Northeast Fisheries Science Center Reference Document 98-15

A Report of the 27th Northeast Regional Stock Assessment Workshop

27th Northeast Regional Stock Assessment Workshop (27th SAW)

Stock Assessment Review Committee (SARC) Consensus Summary of Assessments

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

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MEETING OVERVIEW

The Stock Assessment Review Committee (SARC) meeting of the 27th Northeast Regional Stock Assessment Workshop (27th SAW) was held at the Quality Inn, Falmouth, MA June 22-26, 1998. The SARC Chairman was Dr. Emory Anderson of the Northeast Fisheries Science Center (NEFSC). Members of the SARC included scientists from the NMFS Northeast and Alaska Fisheries Science Centers (NEFSC and AFSC), the Mid-Atlantic and New England Fishery Management Councils (MAFMC and NEFMC), the Commonwealth of Massachusetts, Canada, Rutgers State University, and the International Pacific Halibut Commission (Table 1). In addition, nearly 50 other persons, including industry representatives, attended some or all of the meeting. Many of the attendees, including industry representatives, contributed to the discussion (Table 2). The meeting agenda is presented in Table 3.

Table 1. SAW-27 SARC Composition.

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

Four *ad hoc* experts chosen by the Chair:
Stephen Clark, NMFS/NEFSC
Wendy Gabriel, NMFS/NEFSC
Gordon Waring, NMFS/NEFSC
Susan Wigley, NMFS/NEFSC

One person from each regional Fishery Management Council:
Andrew Applegate, NEFMC
Tom Hoff, MAFMC

Atlantic States Marine Fisheries Commission/State personnel:
Michael Armstrong, MA DMF
Steven Correia, MA DMF
Joseph Desfosse, ASMFC

One or more scientists from:
Canada - **Robert O'Boyle, DFO**
- **Jean-Jacques Maguire**
Academia - **Judy Grassle, Rutgers State University**
Other Regions - **Martin Dorn, NMFS/AFSC**
External Organization - **Ana Parma, IPHC**

Opening

Dr. Emory Anderson welcomed the participants and introduced the SARC members and Dr. Steven Murawski, Chief of the NEFSC Population Dynamics Branch. He described the SAW process, including the responsibilities of the SAW-27 participants, and announced the upcoming meetings.

Table 2. List of participants.

National Marine Fisheries Service
Northeast Fisheries Science Center
Tom Azarovitz
George Bolz
Russell Brown
Jay Burnett
Steve Cadrin
Kevin Friedland
Lisa Hendrickson
Charles Keith
Han-Lin Lai
Jason Link
Phil Logan
Ralph Mayo
Kim Morgan
Steve Murawski
Helen Mustafa
Paul Nitschke
Vic Nordahl
Loretta O'Brien
Brian O'Gorman
Bill Overholtz
Marjorie Rossman
Fred Serchuk
Gary Shepherd
Michael Sissenwine
Katherine Sosebee
Lynette Suslowicz
Mark Terceiro
Nicole Wallace
Northeast Regional Office
Tom Warren
Massachusetts Institute of Technology-Sea Grant
Judith Pederson
Atlantic State Marine Fisheries Commission
Bob Beal
Najih Lazar
Maine Department of Marine Resources
Chris Finlayson
David Stevenson
Massachusetts Division of Marine Fisheries
David Pierce
New York Division of Marine Resources
John Mason
Rhode Island Division of Fish and Wildlife
Mark Gibson
Richard Sisson
Department of Fisheries and Oceans
Gary Melvin
John Neilson
University of Massachusetts, Dartmouth
Deqin Cai
Rutgers University
Eric Powell
Atlantic Shellfish
Warren Alexander
Sea Watch International
Tom Alspach
South Coast Fisheries
Norman Pennypacker
Wallace and Associates
David Wallace
United Fisherman's Association
James Fletcher

Table 3. Agenda of the 27th Northeast Regional Stock Assessment Workshop (SAW-27) Stock Assessment Review Committee (SARC) meeting.

Quality Inn
291 Jones Road, Falmouth, MA

22 (1:00 PM) - 26 June (6:00 PM) 1998

AGENDA

TOPIC	WORKING GROUP & PRESENTER(S)	SARC LEADER	RAPPORTEUR(S)
MONDAY, 22 June (1:00 PM - 6:00 PM)			
Opening Welcome Agenda Conduct of meeting	**E. Anderson**, Chairman		**H. Mustafa**
SFA requirements: revised overfishing definitions	**S. Murawski**		**H. Mustafa**
Georges Bank cod (A)	Transboundary Assessment Working Group **L. O'Brien**	**None**	**R. Mayo**
Georges Bank haddock (B)	Transboundary Assessment Working Group **R. Brown**	**None**	**K. Sosebee**
Georges Bank yellowtail flounder (C)	Transboundary Assessment Working Group **S. Cadrin**	**None**	**J. Neilson**
TUESDAY, 23 June (9:00 AM - 6:00 PM)			
Black sea bass (H)	Pelagic/Coastal Working Group **G. Shepherd**	**S. Correia**	**P. Nitschke**
Scup (D)	Pelagic/Coastal Working Group **M. Terceiro**	**W. Gabriel**	**N. Lazar**
WEDNESDAY, 24 June (9:00 AM - 5:00 PM)			
Gulf of Maine cod (F)	Northern/Southern Demersal Working Group **R. Mayo**	**A. Parma**	**L. O'Brien**
Atlantic herring (G)	Pelagic/Coastal Working Group **D. Stevenson, K. Friedland** **W. Overholtz**	**M. Dorn**	**G. Melvin**
SOCIAL at the Andersons' (7:00 PM)			
THURSDAY, 25 June (9:00 AM - 6:00 PM)			
Southern New England yellowtail flounder (I)	Northern/Southern Demersal Working Group **W. Overholtz**	**R. O'Boyle**	**R. Brown**
Ocean quahogs (E)	Invertebrate Working Group **J. Weinberg, P. Rago**	**J. Grassle**	**P. Rago, J. Weinberg**
FRIDAY, 26 June (9:00 AM - 6:00 PM)			
SARC comments, research recommendations, and 2nd drafts of Advisory Reports			
Other business			**H. Mustafa**

The Process

The SAW Steering Committee, which guides the process, is composed of the executives of the five partner organizations (NMFS/NEFSC, NMFS/NER, MAFMC, NEFMC, and ASMFC). Working groups assemble the data for assessments, decide on the methodology, and prepare documents for SARC review. The SARC's task is to peer review the information provided by the working groups, make research recommendations, and prepare management advice. This time, as three transboundary species had already been reviewed by the Transboundary Resources Assessment Committee (TRAC), which met in April 1998, the SARC will prepare only the management advice for these species. Information from the SARC is presented to the public as part of planned meetings of the two Regional Councils and sometimes of the ASMFC, usually about six weeks after a SARC meeting, in two to three sessions of the SAW Public Review Workshop. The two sessions of the SAW-27 Public Review Workshop will be held during the NEFMC meeting, 10-11 August 1998 in Peabody, MA, and during the MAFMC meeting, 17-20 August in Philadelphia, PA.

SARC Documentation

SARC documentation includes two reports, one containing the assessments, SARC comments, and research recommendations, and another produced in a standard format which includes management advice. Although draft SARC reports are normally not made available until the Public Review Workshop, beginning with this SAW, the reports will be made available in advice for use by Council committees. After the Workshop sessions, the documents are published in the NEFSC Reference Document series as reports of the *SARC Consensus Summary of Assessments* and *SAW Public Review Workshop*.

SAW documentation occasionally includes special advisories, as was done in 1994 relative to the New England groundfish stocks.

Responsibilities of SARC Participants

Presenters at SARC meetings are either working group chairs or the lead assessment persons. Presentations include the results of assessments and will, at this meeting, be limited to no more than 1 or 1½ hours. SARC leaders take the lead in the discussion of an assessment, provide critical comments, and ensure that research recommendations are correctly reported. The rapporteurs, not members of the SARC, keep notes of discussions and record major comments and recommendations, making sure that these are incorporated in the documentation. Together, the presenters, SARC leaders, and rapporteurs make sure that the SARC documentation is in good shape.

Agenda and Reports

The SAW-27 SARC agenda (Table 3) included a presentation on the requirements of the Sustainable Fisheries Act (SFA), Georges Bank cod, Georges Bank haddock, Georges Bank yellowtail flounder, black sea bass, scup, Gulf of Maine cod, Atlantic herring, Southern New England yellowtail flounder, and ocean quahogs. Working papers for SARC review were prepared at the meetings listed in Table 4.

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

Highlights of Presentations and Discussion

SFA Requirements: Revised Overfishing Definitions

Dr. Steven Murawski indicated that a report had been prepared (*Evaluation of Existing Overfishing Definitions and Recommendations for New Overfishing Definitions to Comply with the Sustainable Fisheries Act*) by the NEFMC Overfishing Definition Review Panel (Andrew Applegate, Steven Cadrin, John Hoenig, Chris Moore, Steven Murawski, and Ellen Pikitch) which had reviewed existing biological reference points, provided advice on how overfishing definitions meet new SFA requirements, and recommended new overfishing definitions where requirements could not be met. As a result of the SFA implications, a paragraph on "SFA Considerations" was added to each species section of the SARC advisory document.

Table 4. SAW-27 Working Group meetings and participants.

Working Group and Participants		Meeting Date and Place	Stock/Species
Joint US/Canada Transboundary Assessment Working Group		31 March - 2 April 1998 NEFSC, Woods Hole	Georges Bank cod Georges Bank haddock Georges Bank yellowtail flounder
E. Anderson, NEFSC	J. Neilson, DFO		
M.-I. Buzeta, DFO	Nitschke, NEFSC		
G. Bolz, NEFSC	P. Perley, DFO		
S. Cadrin	L. O'Brien, NEFSC (Chair)		
R. Brown, NEFSC	K. Sosebee, NEFSC		
S. Correia, MA DMF	M. Terceiro, NEFSC		
S. Gavaris, DFO	L. Van Eeckhaute, DFO		
J. Hunt, DFO	S. Wigley, NEFSC		
SAW Joint Northern/Southern Demersal Working Group		18-20 May 1998	Gulf of Maine cod Southern New England yellowtail flounder
R. Brown, NEFSC	L. O'Brien, NEFSC (Chair)		
S. Cadrin, NEFSC	W. Overholtz, NEFSC		
R. Mayo, NEFSC	S. Wigley, NEFSC		
SAW Pelagic/Coastal Working Group		18-22 May 1998	Atlantic herring Scup Black sea bass
M. Armstrong, MA DMF	P. Nitschke, NEFSC		
K. Friedland, NEFSC	W. Overholtz, NEFSC (Co-Chair)		
D. Libby, ME DMR	G. Shepherd, NEFSC (Co-Chair)		
G. Melvin, DFO	D. Stevenson, ME DMR		
C. Moore, MAFMC	M. Terceiro, NEFSC (Co-Chair)		
SAW Invertebrate Working Group		7-8 May 1998 28-29 May 1998	Ocean quahogs
W. Alexander, Atl. Shellfish	N. Moore, NFI		
T. Alspach, Sea Watch Int.	S. Murawski, NEFSC		
T. Azarovitz, NEFSC	E. Powell, Rutgers Univ.		
G. Begg, NEFSC	P. Rago, NEFSC (Chair)		
L. Hendrickson, NEFSC	E. Wade, DFO		
T. Hoff, MAFMC	D. Wallace, Wallace and Assoc.		
C. Keith, NEFSC	C. Weidman, NEFSC/WHOI		
H.-L. Lai, NEFSC	J. Weinberg, NEFSC		
R. Mann, VIMS	J. Womack, Wallace and Assoc.		

Dr. Murawski discussed some considerations in defining overfishing reference points under the Magnuson-Stevens Act. His presentation included the following salient points:

- The Act stipulates that management measures shall prevent overfishing while achieving on a continuing basis, optimum yield (OY).
- OY is defined as Maximum Sustainable Yield (MSY), as *reduced* by relevant social, economic, or ecological factors.
- MSY is defined as: "the largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological and environmental conditions." The Act specifically states that MSY is the maximum catch that can be taken from a given level of recruitment, meaning over the range of potential exploitation patterns of the fishery.
- The Act specifies that a "control rule", relating annual harvest rate to stock size, be determined, with the objective of preventing overfishing at all ranges of stock size, while optimizing yield. Although there are many types of control rules that can be specified, one important consideration is to reduce fishing mortality on the stock when population size is low, and allow higher fishing rates when the stock is capable of producing OY (see below). The MSY control rule is defined as "a harvest strategy, which, if implemented, would be expected to result in a long-term average catch approximating MSY."
- Some options for the control rule include: (1) constant catch strategy (when stock size exceeds an appropriate lower bound), (2) constant harvest rate (fraction of biomass re-

moved), chosen to maximize lang-term yield, (3) constant spawning escapement, and (4) variable harvest rates as a continuous function of stock size. In any MSY control rule, a given stock size is associated with a given level of fishing mortality resulting in a potential harvest. The long-term average of these potential harvests should be MSY.

- For mixed-stock fisheries where MSY cannot be specified on a stock-by-stock basis, one or more species may be chosen as indicators, but stringent conditions must be met to allow overfishing of any stock in the complex.

- The control rule must specify a maximum harvest rate threshold that cannot be exceeded. Exceeding this rate for 1 year or more constitutes overfishing. Also, the control rule must specify a minimum stock size threshold (MSST), which is ½ the stock size associated with MSY, or the minimum stock size at which rebuilding to the MSY stock size could occur within 10 years, which ever is greater. Below the MSST, the stock is considered overfished and a rebuilding plan (reduced F) is needed.

- When data are insufficient to estimate MSY, proxies for minimum stock size and maximum fishing mortality rates that result in MSY can be specified. Several reasonable proxies for the F_{MSY} fishing rate are 30-40% of maximum spawning biomass per recruit and F equal to the natural mortality rate (M). Proxies for stock size can include 40% of the average stock size that would be expected in the absence of fishing, relative survey indices of abundance, as long as they are associated with fishing mortality rates or suitable proxies, and others.

- Uncertainty and risk of exceeding the harvest rate appropriate to a particular stock size must be incorporated explicitly into the control rule. Target catch levels should be explicitly risk-averse, so that greater uncertainty regarding the status of the stock corresponds to greater caution in setting target catch levels. In the absence of uncertainty measures for F, the target fishing mortality should be reduced at least 25% below the F_{limit} (F_{MSY}), in order to assure that the limit is not exceeded with any appreciable degree of frequency. For example, in the NW groundfish plan, the relationship between target F values and F_{MSY} is explicitly related to the certainty to which current F is known, viz:

High certainty	$F_{target} = 90\% \ F_{MSY}$
Moderate certainty	$F_{target} = 75\% \ F_{MSY}$
Low certainty	$F_{target} = 60\% \ F_{MSY}$
Extremely low certainty	$F_{target} = 50\% \ F_{MSY}$

- If the stock size falls below $½B_{MSY}$, the rebuilding time frame is set to 10 years, if the stock is capable of being rebuilt by B_{MSY} in that time frame, *even if this requires the fishery to be closed*. If the life history of the animal is such that it cannot be rebuilt in 10 years, even if F = 0, the rebuilding time frame is ≤10 years plus one generation time for the animal.

Transboundary Stocks

Georges Bank cod, Georges Bank haddock, and Georges Bank yellowtail flounder were last addressed within the SAW process in 1997 at SAW-24. Subsequently, the stocks were assessed by the Joint US/Canada Transboundary Assessment Working Group (TAWG) which met in Woods Hole, 31 March - 3 April. The assessments were then peer reviewed by the Joint US/Canada Transboundary Resources Assessment Committee (TRAC) at a meeting in St. Andrews, NB, April 20-24, 1998.

Because assessments for the transboundary stocks have been previously peer reviewed, they were not subjected to further review by the SARC. Instead, the SARC was presented relatively brief overviews of the status of each of these three stocks before focussing attention on (a) reviewing existing biological reference points and advising on new reference points to meet SFA requirements, and (b) preparing the management advice.

Much discussion relative to the three stocks concerned estimates of recruitment and discards, rebuilding stock biomass, and meeting SFA requirements. The SARC, in fact, tended to re-review the assessments, perhaps to develop needed background for crafting the management advice. The Committee's research recommendations for the three stocks reflect the need for additional or improved sampling, additional information, and new methodology, as well as a look at rebuilding scenarios.

Black Sea Bass

Black sea bass (*Centropristis striata*) was last addressed in 1997 at SAW-25. Although a VPA analysis was attempted during SAW-25, the data were viewed as inadequate to provide a basis for catch and stock projections. The VPA was thus considered to be exploratory with a high level of uncertainty.

The stock represented in the current analysis resides north of Cape Hatteras, NC. The data in the analysis were equally poor, again posing a source of concern for the SARC, including concern for the results of the general surplus production model for black sea bass. In this regard, there was discussion on artificial reefs as additional habitat and increasing fishing pressure due to these reefs, in addition to technological improvements. The implications of survey indices, which suggest that the stock is overexploited, and meeting SFA requirements on the basis of uncertainty in the assessment were also discussed.

Recommendations concerned the examination of methods for estimating fishing mortality rates, reevaluation of exploitation rates, and the examination of data for sex ratio changes.

Scup

Scup (*Stenotomus chrysops*) was last addressed in 1997 at SAW-25. At that time, the SARC declared the VPA to be exploratory.

At the present review, much discussion again centered around data quality and the precision of discard estimates, as well as the use of the VPA and ASPIC models in making management decisions, given the uncertainties associated with data in the assessment. It was recommended that there should be more representative sea and port sampling data, a pilot study to develop a sampling program to estimate discards, studies to better characterize the mortality of scup in different gear types, more age sampling, and additional biological studies.

Gulf of Maine Cod

Gulf of Maine cod (*Gadus morhua*) was last addressed in 1997 at SAW-24. The current assessment represents an update with an additional year of data. Points of discussion included an alternative model to confirm results, projections and estimates of recruitment, management measures, and the relationship between the Gulf of Maine and Georges Bank cod fisheries. The analysis was accepted without suggested changes.

Atlantic Herring

Atlantic herring (*Clupea harengus*) was last addressed in 1995 at SAW-21. The current assessment constitutes a revision of the assessment of the same stock complex with no major changes in methodology. The range of the Atlantic herring coastal stock complex includes the US Atlantic coast, as well as areas in Canadian waters on Georges Bank and on the western shore of the Bay of Fundy. Points of discussion included the robustness of the stock complex, possible reasons for its being and its vulnerability, partitioning abundance among herring management units, management by the individual stocks, as well as the models used in the analysis. Collaborative work between US agencies and the Canadian Department of Fisheries and Oceans on acoustic surveys was encouraged. It was recommended that the Atlantic herring should be assessed and reviewed next in the year 2000 within the Joint US/Canada Transboundary Resources Assessment Process.

Southern New England Yellowtail Flounder

Southern New England yellowtail flounder (*Limanda ferruginea*) was last addressed in 1997 at SAW-24. At that time, sea sampling data were used to estimate discards. In the current assessment, vessel trip record (VTR) information instead of sea sample data were used for discard estimation.

Reporting practices of fishermen, including the consistency of information, and the cause of the sharp drop in the bottom trawl survey indices in the 1972-1974 period were discussed. Spacial distribution of yellowtail flounder east and west of the stock area boundaries were examined, and the importance of re-examining the stock definition for the yellowtail flounder resource south and west of Georges Bank was emphasized. The use of the VPA and ASPIC analyses, including their use in establishing harvest reference points and assessing the stock status was a point of discussion, as was the methodology for estimating uncertainty in the projections. Sea samples were a central issues of several recommendations. It was also recommended to re-examine the stock boundaries.

Ocean Quahogs

Ocean quahogs (*Arctica islandica*) from the Canadian border to Cape Hatteras were last addressed within the SAW process in 1994 at SAW-19. At that time, the catch per survey tow in the 1994 survey was found to be unusually high, suggesting that the gear efficiency had changed. Thus, 1994 survey data were not used during that assessment.

The current assessment relies heavily on data collected in 1997 and 1998. Depletion studies of dredge efficiency that were carried out in a cooperative program between NMFS, the clam industry and academia and the use of historical survey time series as an indicator of relative abundance were discussed. The possibility of adding sensors on the survey dredge and additional studies to determine dredge efficiency and building a reliable time series beginning with the 1997 survey were discussed. Underlying causes of the northeastward expansion of the ocean quahog fishery, the concern over the considerable uncertainty about the impact of harvesting on ocean quahog populations, as well as the effect of reduced clam density on fertilization rate and the effect of dredging on recruitment, reflected in the research recommendations, were discussed. Recommendations also addressed modification of dredging equipment, calibration of dredge efficiency, fixed survey stations, dredge performance sensors, the need for additional sampling, and the contribution of each region to recruitment across geographical regions.

Documentation Due Date

The Chairman noted that committee meetings of the MAFMC were scheduled for the third week of July, which left only three weeks to complete the documentation of this meeting. Reports for scup, ocean quahogs, and black sea bass must reach the MAFMC by July 20. Relevant reports must also be provided to the NEFMC Groundfish Committee scheduled to meet July 16.

Any comments by SARC members on the last distributed versions of draft advisory reports and SARC comments must be submitted to the Chairman by no later than 3 July.

Other Business

Concern was expressed over the number of assessments the SARC was tasked to review at the meeting. Reviewing nine assessments, the majority of which were benchmarks, at a 4½-day meeting was viewed as too much. Ideally, the SARC should peer review and write advice for no more than five stocks during a meeting of this duration. Since the SARC was faced with the possibility of seven benchmark assessments on the SAW-28 agenda, the Chairman had already expressed concern with members of the SAW Steering Committee.

It was also noted that it was not practical to proceed immediately from a presentation to the writing of advice, as time for thought was needed after a presentation. In addition, it was indicated that the crafting of advice cannot be decoupled from the discussion of details, as was attempted this time in the case of the three Georges Bank stocks. Knowing the details of an assessment was considered important to writing the management advice.

To save time in reviewing stocks, it was suggested that the SARC not get involved in examining all the assessment details. Although, in the opinion of some, a brief presentation on stock status and how the assessment was done, without the benefit of hearing as many details as was done this time, should suffice, others felt that this cannot be done in the case of new or benchmark assessments.

The possibility of more or longer SARC meetings was briefly entertained and disregarded as being unrealistic, given the already heavy workloads of most assessment scientists and the heavy meeting schedules for both Councils. It was concluded that the SARC needs one day per stock (one-half day for presentation and discussion and one-half day for crafting the advice) to do benchmark assessments. West coast and ASMFC peer-review models were briefly summarized as examples of other review processes, and it was noted that the Canadian peer-review process does not include updates.

Regarding the review of updates, the Chairman indicated that the Steering Committee was continuing to consider the possibility of using Council Scientific and Statistical Committees.

The need to involve external experts at the working group level was noted, and the status of the national pool of experts pilot program headed by Victor Restrepo was reviewed. The purpose of this program was to create a national pool of experts who would be funded and available to participate in SARC and working group meetings.

It was noted that it is impossible or unrealistic to attempt assessments when adequate data are lacking, as in the case of scup and black sea bass. It was recommended that a strong message be sent to managers that doing assessments on stocks without adequate data is "not a good use of the scientists' time and is not productive."

The Chairman indicated that although there was no immediate solution to the problems currently facing the SARC, he would raise and discuss these issues with the NEFSC Science and Research Director and the SAW Steering Committee which would meet later in the summer.

Closing

The Chairman thanked the Committee for enduring this meeting with such a packed agenda. The group acknowledged Dr. Anderson's leadership and hospitality before the meeting adjourned.

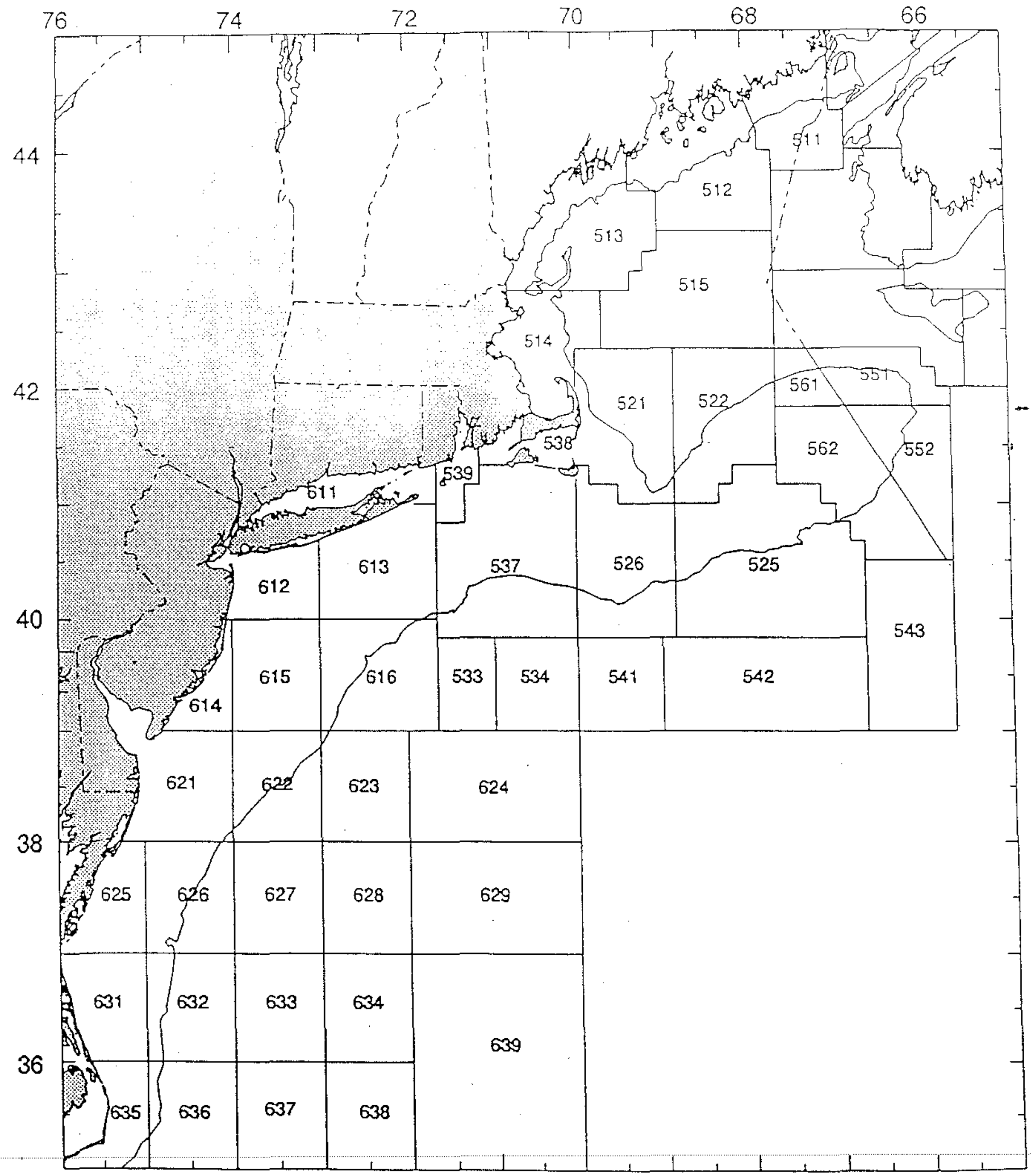

Figure 1. Statistical areas used for catch monitoring in offshore fisheries in the Northeast United States.

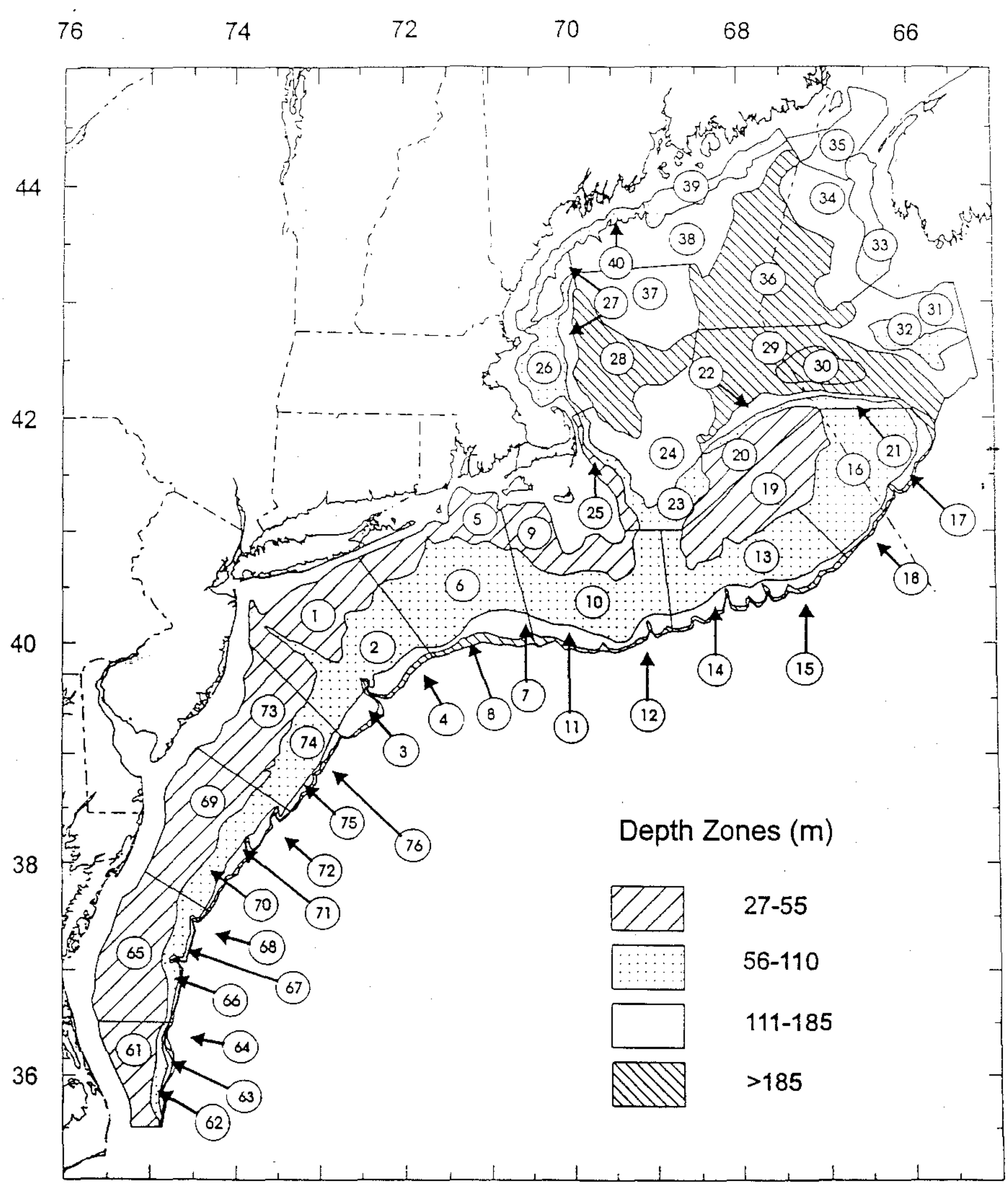

Figure 2. Offshore sampling strata used in NEFSC bottom trawl surveys.

A. GEORGES BANK COD

Terms of Reference

a. Update the status of Georges Bank cod through 1997 and characterize the variability of estimates of stock size and fishing mortality rates.

b. Provide projected estimates of catch for 1998-1999 and spawning stock biomass for 1999-2000 at various levels of F.

c. Review existing biological reference points and advise on new reference points for Georges Bank cod to meet SFA requirements.

Introduction

This report presents an updated and revised analytical assessment of the Georges Bank cod stock (NAFO Division 5Z and Statistical Area 6) for the period 1978-1997 based on analysis of commercial landings and effort data and research vessel survey data through 1997. The life history of Georges Bank cod and the commercial fishery are described in the previous assessment (O'Brien 1997, NEFSC 1997).

The Fishery

Commercial Landings

The methodology for proration of the commercial fishery landings data since 1994 is described in Wigley *et al.* 1998. The 1997 data were prorated using the same methodology, however, the criteria for matching the data were changed and resulted in a larger data set from which to prorate.

Total commercial landings of Georges Bank cod in 1997 were estimated at 10,435 mt, 17% higher than in 1996 (Table A1, Figure A1). The US fleet landed 72% (7,500 mt) of the total landings, and the Canadian fleet landed the remaining 28% (2,900 mt).

Otter trawl landings from the US and Canada accounted for about 54% of the total 1997 landings. US otter trawl landings accounted for the majority (61%) of the US landings (Table A2). In the Canadian fishery, the otter trawl and longline fisheries accounted for 36% and 43%, respectively, of the cod landings (Hunt and Buzeta 1998). During 1978-1997, otter trawl gear accounted for 83% of the US landings and 57% of the Canadian landings. The US cod landings from Georges Bank continue to be dominated by 'market' cod in both weight (55%) and number (51%) in 1997 (Table A3). Historically, 'market' cod have accounted for 40-60% of the landings.

Commercial Discards

Preliminary estimates of discards on otter trawl and gillnet trips were derived for 1989-1997 using the Sea Sampling Data Base. Discard ratios were estimated as the amount of cod discarded to the amount kept. Discard ratios are presented in Table A4 for each quarter for catch taken in the western part (Statistical Areas 521, 522, 525, 526) and the eastern part (Statistical Areas 561, 562) of Georges Bank. In the otter trawl fishery, ratios ranged from 0 to 0.10, with less discarding occurring in the eastern part. In the gillnet fishery, discard ratios ranged from 0 to 0.19, but were predominantly less than 0.10. Discard estimates were not included in the assessment, however, due primarily to the lack of data for 1978-1988.

Recreational Catches

The total cod caught during 1979-1997 by recreational fisherman ranged from 500 mt to 9,000 mt, accounting for 1-19% of the total landings (Table A5). Recreational landings increased by 28% in 1997 to an estimated 770 mt, which represents 6.9% of the total cod landings.

In the previous assessment (O'Brien 1996), an analysis that incorporated recreational catches resulted in slightly elevated stock sizes with little change in fishing mortality or the spawning stock biomass. Recreational catches were not included in the final assessment analysis, however, since a number of problems exist in estimating the quantity and size/age composition of the recreational catch by stock (Recreational Fisheries Statistics Working Group 1992). Among these are: 1) lack of recreational catch estimates in January and February when some party boats in Massachusetts, Rhode Island, and New York land cod; 2) inability to properly categorize catches of long-range trips (e.g., to Georges Bank) that are being made in increasing numbers by party boats from Maine to New York; 3) catch estimates for the Georges Bank stock are imprecise (i.e., relatively large CVs), and 4) length frequency sampling intensity, particularly for the Georges Bank stock, is low and is probably insufficient to accurately characterize the size composition of the catch. Moreover, length frequency sampling is opportunistic and thus samples are not distributed in proportion to the catch by time, fishing mode, or state of landing.

Sampling Intensity

Commercial landings

The numbers of samples taken for the length and age composition of the US and Canadian commercial cod fishery for the Georges Bank region are summarized in Table A6. The average number of fish in each length sample is about 80 for the US and about 270 for Canada.

Sampling intensity was high in 1997 with 1 sample per 94 mt for the US (Table A7) and 1 sample per 24 mt for the Canadian fishery. The spatial and temporal pattern of sampling for landings from the eastern part of Georges Bank for the US was minimal in 1997. There were only 2 samples taken in the 'market' category for quarters 2 and 3 in Statistical Areas 561 and 562. The distribution of sampling by market category (scrod: 34%, market: 49%, large: 18%) approximates the distribution of the 1997 landings in number by market category (Table A3).

Recreational catch

Recreational landings are sampled only for length frequency. Since 1981, the number of fish sampled represent less than 0.1% of the total number of fish landed. During 1981-1997, the number of fish measured ranged from 0.01 to 0.06% of the total number landed. In 1997, 0.01% of the fish landed were sampled.

Commercial Catch at Age

The age composition of the 1978-1993 US landings was estimated by market category from monthly length frequency and age samples and pooled by calendar quarter. Landed mean weights were estimated by applying the cod length-weight equation:

$$\ln \text{Weight}_{(kg,live)} = -11.7231 + 3.0521 \ln \text{Length}_{(cm)}$$

to the quarterly length frequency samples by market category. Numbers landed by quarter were estimated by dividing the mean weight values into the quarterly landings by market category and prorating the total numbers by the corresponding market category sample length frequency. Quarterly age-length keys were then applied to the numbers at length to estimate numbers at age. Annual estimates of catch at age were obtained by summing values over market category and quarter (Table A8). Derivation of catch by quarter, rather than by month, was performed since not all months had at least two length frequency samples per market category (i.e., minimum desired for monthly catch estimates).

The age composition of the 1994-1996 US landings was also estimated by market category from monthly length frequency and age samples, but were pooled semi-annually due to insufficient samples within a quarter. The consistency in the estimation of the catch at age during 1978-1993 was maintained by disaggregating the landings into eastern (SA 561-562) and western components (SA 521, 522, 525, 526) to estimate the age composition. The age composition of the US landings from the eastern component was estimated by applying US length frequency and combined US and Canadian age samples, while the age composition of the US landings from the western component was estimated by applying only US length frequency and age samples.

The age composition of the 1997 US landings was estimated in a similar manner. However, due to the lack of length samples in the eastern component, the assumption was made that eastern and western length frequencies would be similar. Accordingly, western length frequencies were used to characterize eastern component landings. The 1997 catch at age was then derived as described above for the 1978-1993 landings. The eastern and western components were pooled to obtain the age composition for US Georges Bank cod landings for 1997. The US eastern component was used in the Canadian assessment of cod in area 5Zjm (Hunt and Buzeta 1998).

Canadian landings-at-age data (Table A9) from the eastern component (5Zjm) for 1997 were provided by Hunt (pers. comm.). Canadian and US data were combined to produce a total landings-at-age matrix for 1978-1997 (Table A10). The proportions of the total landings accounted for by the US and Canada are also indicated in Table A10. Total commercial landings in 1997 were dominated by age 4 and 5 fish from the 1992 and 1993 year classes, respectively (Table A11). These two cohorts combined accounted for 55% of the landings by number and 61% by weight.

Commercial Mean Weights at Age

Mean weights at age for ages 1-10+ are summarized for US, Canadian, and total landings in Tables A8-A10. There does not appear to be any consistent trend in the mean weight by age during the 20-year time series. Anomalous weights in the older fish in recent years may be due to poorer sampling in recent years. Stock mean weights at age at the beginning of the year derived from catch mean weights at age (Rivard 1980) are presented in Table A12.

Stock Abundance and Biomass Indices

Commercial Catch Rates

US commercial landings per unit effort (LPUE) and standardized fishing effort and LPUE were derived for all interviewed otter trawl trips landing cod from Georges Bank and south as described in O'Brien (1997) and Mayo *et al.* 1994 (Table A13). Total standardized (raised) effort was then derived by dividing total US landings by the standardized LPUE (Table A14).

Nominal LPUE and standardized LPUE exhibit similar trends and, since 1985, are almost equivalent (Table A14, Figure A2). Standardized LPUE peaked in 1980 at 2.9 mt/day fished and declined steadily from 1982 to 1986. LPUE then remained stable, increasing slightly, until 1990 when another sharp decline occurred from 1990 to 1995. LPUE increased in 1996 and 1997 and is estimated to be about 0.6 mt/day fished in 1997. Standardized or raised effort and nominal effort have similar trends in general, although effort trends did diverge in both 1991 and 1995 (Figure A3). Raised effort more than doubled from 1978 to 1985, declined in 1986, and then increased to historic high levels until 1993. Standardized effort in 1997 has declined to about 45% of the 1996 estimate.

Under the current management restrictions of closed areas imposed in December of 1994 and with the use of mandatory logbooks to collect effort data implemented in May 1994, the 1994-1997 effort data may no longer be equivalent to the historic 1978-1993 effort series. Additionally, the effort estimates for 1994-1997 were derived from unaudited data. The LPUE series was, therefore, not used as an index of abundance in the subsequent calibration of the VPA.

Research Vessel Survey Indices

US surveys

NEFSC spring and autumn research bottom trawl surveys have been conducted off the Northeast coast of the US since 1968, and 1963, respectively (Azarovitz 1981). Indices of abundance (stratified mean number per tow) and biomass (stratified mean weight per tow) were estimated from both the spring and autumn bottom trawl surveys for Georges Bank cod during 1963-1997 (Table A15). Standardized catch per tow at age in number for NEFSC spring and autumn surveys are presented in Appendix A1: Table 1.

NEFSC spring and autumn catch per tow indices for both biomass and abundance show similar trends throughout the time series (Table A15, Figures A4-A5). Survey biomass indices were stable between 1963-1971, then increased to a record high in 1973. Georges Bank cod biomass generally declined over the next two decades, reaching record low biomass levels between 1991 and 1994, increased in 1995, but declined in both 1996 and 1997. The autumn estimate of stratified number per tow in 1997 was the lowest in the time series. Survey abundance indices for ages 1 and 2 indicate above-average recruitment for the 1966, 1971, 1975, 1980, 1983, 1985, 1988, and 1993 year classes (Figure A6). The magnitude of an above-average year class, however, has been declining over time, particularly noticeable in the recruits at age 1.

Canadian surveys

Canadian research vessel bottom trawl surveys have been conducted on Georges Bank during the spring since 1986. Indices of abundance for Canadian surveys are summarized as stratified mean number per tow during 1986-1998 (Appendix A1: Table 2). In 1993 and 1994, the Canadian survey did not sample the western part of Georges Bank (Canadian strata 5Z5 - 5Z7) and, therefore, were not used in the calibration of the VPA. Survey abundance indices indicated a steady decline in total numbers of cod from 1990 to 1995, then an increase in 1996 dominated by the 1994 year class at age 4. The 1998 index increased slightly from the 1997 value and is dominated by the 1995 year class.

Mortality

Total Mortality

Pooled estimates of instantaneous total mortality (Z) were estimated for eight time periods from both spring and autumn survey catch per tow indices (Table A16, Appendix A2: Table 2). Estimates in the spring are less than in the autumn in all time periods except 1973-1976.

Total mortality decreased from a high of 0.73 during 1964-1967 to a record low of 0.34 during 1968-1972, then increased and remained stable between 0.56 and 0.68 during 1973-1984. Total mortality then reached a record high of 1.10 during 1985-1987, declined to 0.6 during 1988-1990, and then increased to 1.45 during 1991-1993 before declining to 0.87 during 1994-1996.

Estimates of Stock Size and Fishing Mortality

Virtual Population Analysis Calibration

The ADAPT calibration method (Parrack 1986, Gavaris 1988, Conser and Powers 1990) was used to derive estimates of fishing mortality in 1997 and beginning-year stock sizes in 1998. The catch at age used in the VPA consisted of combined US and Canadian commercial landings from 1978-1997 for ages 1-9 with a 10+ age group. The indices of abundance used to calibrate the VPA included both the NEFSC 1978-1997 spring research survey abundance indices for ages 1-8 and the Canadian 1986-1998 spring research survey abundance indices for ages 1-8, and the NEFSC 1977-1997 autumn research survey catch at ages 0-6. The NEFSC spring survey was separated into two series based on the use of the Yankee 36 trawl or the 41 trawl. The NEFSC employed the 41 trawl during 1973-1981. The spring indices were split into a index series from 1978-1981 for the 41 trawl and a series from 1982-1997 for the 36 trawl. The autumn survey indices were lagged forward one age and one year to match cohorts in the subsequent year.

Several trial ADAPT calibrations were performed and results are presented in Table A17. The final ADAPT formulation provided stock size estimates for ages 1-8 in 1998 and corresponding F estimates for ages 1-7 in 1997. Assuming full recruitment at age 4, the F on ages 8 and 9 in the terminal year was estimated as the average of the F on ages 4-8. The F on age 9 in all years prior to the terminal year was derived from weighted estimates of Z for ages 4-9. For all years, the F on age 9 was applied to the 10+ age group. Spawning stock estimates were derived by applying pooled maturity ogives for 1978-1981, 1982-1985, 1986-1989, 1990-1993, and 1994-1997 (Table A18) derived from NEFSC spring research survey data using methodology described in O'Brien (1990). The new pooled ogives, estimated with current data, are more representative of the current population than the previous 1986-1996 pooled ogive (NEFSC 1997).

The final ADAPT calibration results are presented in Appendix A2 for estimates of F, stock size, and SSB at age and summarized in Table A18. Estimates of stock size were more precise for ages 2-8, with

CVs ranging from 0.26 to 0.33, than for age 1 (CV = 0.51). The residual patterns of the indices did not show any strong trends for the four surveys (Figure A7). The natural log of the observed survey indices, standardized to the mean, are presented in Figure A8.

Average fishing mortality (ages 4-8) in 1997 was estimated to be 0.26, an increase of 30% from the 1996 estimate (Table A18, Figure A9). The 1997 estimate of SSB was 36,000 mt, only a 5% increase from the 1996 estimate (Table A18, Figure A10).

Since 1978, recruitment has ranged from 4 million fish at age 1 (1994 year class) to 43 million (1985 year class); in 1998, the 1997 year class is estimated to be less than a million fish (424,000). With the exception of the slightly above-average 1990 year class, recruitment since 1989 has been at record low values. The 1994 and 1997 year classes are the poorest of the 20-year time series (Table A18, Figure A10).

Precision Estimates of F and SSB

A bootstrap procedure (Efron 1982) was used to evaluate the uncertainty associated with the estimates of fishing mortality and spawning stock biomass from the final VPA. One thousand bootstrap iterations were performed to estimate standard errors, coefficients of variation (CVs), and bias estimates for the age 1-8 stock size estimates at the start of 1998, the catchability estimates (q) for each index of abundance used in calibrating the VPA, and Fs at ages 1-7 in 1997 (Appendix A3).

The bootstrap results indicate that stock sizes were well estimated for ages 1-8, with CVs varying between 0.19 and 0.43. The CVs for the catchability coefficients for all indices ranged between 0.11 and 0.28. The fully-recruited F for ages 4+ was well estimated with a CV = 0.11. The bootstrap estimate of 0.27 was only slightly higher than the NLLS estimate (Appendix A3). The distribution of the 1997 F estimates, derived from the 1,000 bootstrap iterations, ranged from 0.20 to 0.46 (Figure A11). There is an 80% probability that the F in 1997 is between 0.25 and 0.31 (Figure A11).

The spawning stock biomass was reasonably well estimated (CV = 0.08) and slightly higher than the NLLS estimate of 36,600 mt (Appendix A3). The distribution of the 1997 spawning stock biomass estimates, derived from the 1,000 bootstrap iterations, ranged from 28,000 mt to 50,000 mt (Figure A12). There is an 80% probability that the 1997 SSB is between 33,000 mt and 39,000 mt (Figure A12). There is 100% probability that the SSB in 1997 is less than 70,000 mt, the SSB threshold for re-building.

Retrospective Analysis

A retrospective analysis was performed to evaluate how well the current ADAPT calibration would estimate spawning stock biomass, fishing mortality, and recruits at age 1 for the five years prior to the current assessment (1992-1996). Convergence of the estimates generally occurs after about three years (Figures A13-A15). With the exception of 1996, the retrospective analysis indicates a pattern of closely estimating or underestimating the recruits at age 1 (Figure A13). Estimates of spawning stock biomass appear to be overestimated, but then converge after about three years (Figure A14). Estimates of fishing mortality do not show a consistent trend over the 5-year period (Figure A15). Fishing mortality in 1996, 1995, and 1994 was underestimated, and the F was overestimated in 1993 and 1992. The very high overestimation of F in 1993 and the underestimation of F in 1994 may be influenced by the lack of 1993-1994 Canadian survey indices in the current calibration. The actual ADAPT formulation employed for the 1994 assessment had Canadian survey (5Zjm) indices for all years, derived for only the eastern portion of the survey (Serchuk *et al.* 1994). The fishing mortality in the 1994 assessment was estimated to be 0.91 for 1994 (Serchuk *et al.* 1994).

Biological Reference Points

Yield and Spawning Stock Biomass per Recruit

Yield per recruit, total stock biomass per recruit, and spawning stock biomass per recruit were estimated using the methodology of Thompson and Bell (1934). The estimates were derived based on arithmetic means of the 1995-1997 catch mean weights at age and stock mean weights at age (Tables A10 and A12) and the 1994-1997 maturity ogive. A partial recruitment (PR) vector was calculated as the geometric mean of the 1994-1997 F estimates from the final VPA (Table A18) based on the change in mesh regulations in 1994. The final exploitation pattern was derived by dividing the PR by the geometric mean of the unweighted F for ages 4-8 and smoothed by applying full exploitation at ages 4 and older. The exploitation pattern of:

Age 1	0.00
Age 2	0.17
Age 3	0.66
Ages 4+	1.00

reflects an increase in the exploitation at ages 2 and 3 compared to the previous assessment (NEFSC 1997). Input values for the yield-per-recruit analysis are provided in Table A19, and results of the analysis are provided in Table A19 and Figure A16. The resulting biological reference points were $F_{0.1} = 0.18$ and $F_{20\%} = 0.41$. The yield and spawning stock biomass per recruit was re-estimated to account for the updated maturity ogive. The values remained very near the previous analysis ($F_{0.1} = 0.17$, $F_{20\%} = 0.43$).

Stock Production Model - ASPIC

The ASPIC model (Prager 1994, 1995), a non-equilibrium stock production model incorporating covariates, was employed to estimate F_{msy} and B_{msy} for the Georges Bank cod stock. Results of a bootstrapped analysis are presented in Appendix A4. The NEFSC autumn indices were employed as a series of observed effort, and the NEFSC spring survey, split by gear type, and the Canadian spring survey were used as independent biomass indices.

The model fit the NEFSC autumn and spring 36 trawl well ($R^2 = 0.44$ and 0.45, respectively), but fit the Canadian spring and NEFSC 41 trawl surveys poorly ($R^2 = -0.06$ and -0.18, respectively). The residuals showed no pattern or trend; however, there was a large negative residual for NEFSC spring 1994 (Appendix A4).

The average biomass was estimated with a similar trend, but higher than the VPA estimates from 1978-1988, and less than the VPA until 1996 (Figure A17). The model estimated an MSY of 33,000 mt and a B_{msy} of 136,000 mt (Appendix A4). F_{msy} was estimated as 0.24, which is about equivalent to a fully-recruited $F_{4-8} = 0.36$. The MSY was well estimated (IQ range = 0.13), but B_{msy} and F_{msy} were not as well estimated (IQ range = 0.62 and 0.67, respectively).

A similar analysis was also recently conducted for several groundfish species, including cod, by Cadrin *et al.* (1998). Comparison of the ASPIC analysis in this assessment with the ASPIC analysis conducted by Cadrin *et al.* (1998), which employed a constrained model, indicates that the latter analysis provides more precise estimates. Based on the results of Cadrin *et al.* (1998) and the proposed rule for the Sustainable Fisheries Act (SFA) requirements, the target F_{SFA} should be 0.14, given the current biomass levels.

Stock-Recruitment Analysis

A Beverton-Holt stock-recruitment relationship was employed as an alternative model to estimate the biological reference points B_{msy} and F_{msy}. Yield per recruit and the Beverton-Holt stock-recruitment curve were both used to estimate equilibrium yield, spawning stock biomass, and recruitment (Sissenwine and Shepherd 1987, Sinclair 1997). Beverton-Holt spawner-recruit parameters were estimated using non-linear regression (Hilborn and Walters 1992) and fitted with a Gauss-Newton iterative search algorithm (SAS 1990) using the 1978-1997 spawner and recruit data from this assessment. B_{msy} was estimated to be about 257,000 mt, with an MSY of 37,000 mt and an F_{msy} of 0.15 (Figure A18). On the recommendation of the Joint US/Canada Transboundary Resources Assessment Committee (TRAC), additional analyzes were performed backcasting spawning stock biomass and recruits during 1963-1977; these results are presented in O'Brien and Cadrin (1998).

Projections

Short-term, 3-year stochastic projections were performed to estimate landings and SSB during

1998-2000 under the F scenarios of *status quo* F_{98} = 0.26 and $F_{0.1}$ = 0.18 and F_{SFA} = 0.14. Data input are the same as described in the yield-per-recruit analysis (Table A20). In addition, recruitment in 1998 was set at 424,000 fish, as estimated by the ADAPT formulation, and the recruitment for 1999 and 2000 was estimated by randomly drawing from the observed 1992-1998 recruitment at age 1 (Table A18). These most recent years of recruitment were chosen based on having been produced from similar levels of SSB.

Under a *status quo* F of 0.26, landings are projected to be about 9,800 mt in 1999, and then decline to 9,000 mt in 2000 (Table A20, Figure A19). SSB increases to about 39,400 in 1999, but declines to 35,300 mt in 2000. Fishing at $F_{0.1}$ = 0.18, landings will decline to 7,050 mt in 1999 and remain at about 6,900 mt in 2000. SSB at F = 0.18 will remain relatively stable, increasing in 1999 (39,900 mt) and declining in 2000 (38,500 mt). If fishing mortality is reduced to F_{SFA} = 0.14, landings will decline in 1999 to 5,600 mt and then increase in 2000 to 5,700 mt. SSB will increase in 1999 (40,200) mt and remain stable in 2000.

Conclusions

The Georges Bank cod stock is at a low biomass level and is over exploited relative to the Amendment 7 rebuilding target. Biomass indices derived from research surveys indicate that the stock remains near the 30-year record low value. Fishing mortality declined from record high levels in 1993 (1.1) and 1994 (1.2) to an F in 1997 of 0.26, which is about 45% higher than $F_{0.1}$ = 0.18. Spawning stock biomass declined from about 90,000 mt in the early 1980s, reached a record low (25,000 mt) in 1994, and remains near record low size (36,000 mt) in 1997. Recruiting year classes continue to decline in size, with the four most recent year classes (1994, 1995, 1996, 1997) being the lowest on record.

Accounting for the estimation uncertainty associated with the 1997 SSB (36,000 mt) and F (0.26) estimates, there is an 80% probability that the 1997 SSB is between 33,000 mt and 39,000 mt and an 80% probability that the F in 1997 is between 0.25 and 0.31.

At the present rate of exploitation (21%), given the probable level of recruitment, the SSB is expected to increase in 1999, but again decline just below the current value (36,000 mt) in 2000.

SARC Comments

On the strength of the poor 1997 year class, it was noted that provisional data from the 1998 NEFSC spring bottom trawl survey, as well as final results from the 1998 Canadian DFO spring survey on Georges Bank, suggest that the 1997 year class is indeed poor.

To extend the VPA-derived SSB and recruitment estimates to an earlier period, an SSB and a recruitment index derived from the NEFSC spring and autumn surveys were used as proxies. The SSB index derived from the surveys was taken from a report in which results were given through 1994. Thus, the VPA results available at the time of analysis were used in conjunction with the available survey indices through 1994 to derive the conversion from survey index to VPA-derived estimates.

It may be useful to employ the ADAPT calibration coefficients (q) in conjunction with survey indices to backcast estimates of recruitment and SSB for the period prior to the VPA. However, this approach still does not solve the inherent variability in recruitment indices in the surveys, and it was noted that an investigation into methods which employ additional information from the lifespan of the cohort to derive a more accurate survey-based recruitment index are ongoing.

Results from the Beverton-Holt stock-recruitment relationship for Georges Bank cod were discussed in the context of SFA reference points. This relationship is employed in the Sissenwine-Shepherd age-based approach to deriving estimates of MSY and B_{msy}. Large outliers may have affected the parameter estimates of the relationship and it was suggested that some iterative re-weighting may minimize the impact of the large year classes.

Differences in the results from the ASPIC and Sissenwine-Shepherd approaches may be due in part to the partial recruitment information employed in each. ASPIC accounts for partial recruitment implicitly by integrating catch and biomass information over the long-term, while the Sissenwine-Shepherd age-based approach allows for an explicit partial recruitment to be specified in the yield-per-recruit calculations. The partial recruitment employed in the Georges Bank cod analysis used a recent partial recruitment pattern.

The question of whether ASPIC estimates total or exploitable stock biomass was not resolved.

With respect to the Georges Bank cod advisory, it was noted that the stock is close to the SFA threshold biomass level and is, therefore, technically on the verge of being over exploited. In the longer term, the stock still remains in an over-exploited state.

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Table A1. Commercial landings (metric tons, live) of Atlantic cod from Georges Bank and South (Division 5Z and Subarea 6), 1960-1997.

	Country						
Year	USA	Canada	USSR	Spain	Poland	Other	Total
1960	10834	19	-	-	-	-	10853
1961	14453	223	55	-	-	-	14731
1962	15637	2404	5302	-	143	-	23486
1963	14139	7832	5217	-	-	1	27189
1964	12325	7108	5428	18	48	238	25165
1965	11410	10598	14415	59	1851	-	38333
1966	11990	15601	16830	8375	269	69	53134
1967	13157	8232	511	14730	-	122	36752
1968	15279	9127	1459	14622	2611	38	43136
1969	16782	5997	646	13597	798	119	37939
1970	14899	2583	364	6874	784	148	25652
1971	16178	2979	1270	7460	256	36	28179
1972	13406	2545	1878	6704	271	255	25059
1973	16202	3220	2977	5980	430	114	28923
1974	18377	1374	476	6370	566	168	27331
1975	16017	1847	2403	4044	481	216	25008
1976	14906	2328	933	1633	90	36	19926
1977	21138	6173	54	2	-	-	27367
1978	26579	8778	-	-	-	-	35357
1979	32645	5978	-	-	-	-	38623
1980	40053	8063	-	-	-	-	48116
1981	33849	8499	-	-	-	-	42348
1982	39333	17824	-	-	-	-	57157
1983	36756	12130	-	-	-	-	48886
1984	32915	5763	-	-	-	-	38678
1985	26828	10443	-	-	-	-	37271
1986	17490	8411	-	-	-	-	25901
1987	19035	11845	-	-	-	-	30880
1988	26310	12932	-	-	-	-	39242
1989	25097	8001	-	-	-	-	33098
1990	28193	14310	-	-	-	-	42503
1991	24175	13455	-	-	-	-	37630
1992	16855	11712	-	-	-	-	28567
1993	14594	8519	-	-	-	-	23113
1994	9893	5276	-	-	-	-	15169
1995	6759	1100	-	-	-	-	7859
1996	7020	1885	-	-	-	-	8905
1997	7537	2898	-	-	-	-	10435

Table A2. Distribution of USA commercial landings (metric tons, live) of Atlantic cod from Georges Bank (Area 5Ze), by gear type, 1965-1997. The percentage of total USA commercial landings of Atlantic cod from Georges Bank, by gear type, is also presented for each year. Data only reflect Georges Bank 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	10251	0	582	505	9	11347	90.3	-	5.1	4.5	0.1	100.0
1966	10206	0	787	757	19	11769	86.7	-	6.7	6.4	0.2	100.0
1967	10915	0	894	704	9	12522	87.2	-	7.1	5.6	0.1	100.0
1968	12084	0	936	524	<1	13544	89.2	-	6.9	3.9	-	100.0
1969	13194	0	1371	387	<1	14952	88.2	-	9.2	2.6	-	100.0
1970	11270	0	1676	404	<1	13350	84.4	-	12.6	3.0	-	100.0
1971	12436	0	2334	230	2	15002	82.9	-	15.6	1.5	-	100.0
1972	10179	0	2071	217	10	12477	81.6	-	16.6	1.7	0.1	100.0
1973	12431	3	2185	206	21	14846	83.7	-	14.7	1.4	0.2	100.0
1974	14078	3	2548	11	9	16649	84.6	-	15.3	0.1	-	100.0
1975	12069	0	2435	84	4	14592	82.7	-	16.7	0.6	-	100.0
1976	12257	4	1519	153	5	13938	88.0	-	10.9	1.1	-	100.0
1977	18529	30	912	83	22	19576	94.7	0.2	4.7	0.4	0.1	100.0
1978	20862	81	1569	1180	59	23751	87.8	0.3	6.6	5.0	0.3	100.0
1979	26562	620	2707	860	159	30908	85.9	2.0	8.8	2.8	0.5	100.0
1980	32479	4491	1102	0	273	38345	84.7	11.7	2.9	-	0.7	100.0
1981	27694	3515	120	584	197	32110	86.2	10.9	0.4	1.8	0.6	100.0
1982	33371	2935	385	624	210	37525	88.9	7.8	1.0	1.7	0.6	100.0
1983	30981	1812	831	441	81	34146	90.7	5.3	2.4	1.3	0.3	100.0
1984	26161	2573	366	753	197	30050	87.1	8.6	1.2	2.5	0.6	100.0
1985	21444	2482	436	284	163	24809	86.4	10.0	1.8	1.1	0.7	100.0
1986	13576	1679	692	305	95	16347	83.0	10.3	4.2	1.9	0.6	100.0
1987	13711	1522	1636	222	71	17162	79.9	8.9	9.5	1.3	0.4	100.0
1988	20296	1864	1950	232	116	24458	83.0	7.6	8.0	0.9	0.5	100.0
1989	17946	3150	1583	119	91	22889	78.4	13.8	6.9	0.5	0.4	100.0
1990	21707[1]	2316	1252	395	133	25803	84.1	9.0	4.9	1.5	0.5	100.0
1991	17892[2]	2171	1919	286	180	22448	79.7	9.7	8.5	1.3	0.8	100.0
1992	11696[3]	1747	1709	186	114	15452	75.7	11.3	11.1	1.2	0.7	100.0
1993	10893[4]	1321	1316	62	78	13670	79.7	9.7	9.6	0.4	0.6	100.0
1994	7139	1318	1372	-[5]	21	9850	72.5	13.4	13.9	-	0.2	100.0
1995	3780	1300	1660	-[5]	18	6758	55.9	19.2	24.6	-	0.3	100.0
1996	4047	1552	1413	-[5]	6	7018	57.7	22.1	20.1	-	0.1	100.0
1997	4583	1595	1331	-[5]	28	7537	60.8	21.2	17.7	-	0.3	100.0

[1]Includes 849 tons taken by pair-trawl (Note: 1990 was the first year that pair-trawl landings exceeded a few tons). [2]Includes 1068 tons taken by pair-trawl. [3]Includes 1149 tons taken by pair-trawl. [4]Includes 1352 tons taken by pair-trawl. [5]Handline included with line trawl.

Table A3. Percentage, by weight and number of fish landed, of USA commercial Atlantic cod landings from Georges Bank and South (NAFO Division 5Z and Subarea 6), by market category, 1964-1997. Percent values, by number, are only available from 1978 onwards.

	Percentage by Weight				Percentage by Number			
Year	Large	Market	Scrod	Total [a]	Large	Market	Scrod	Total [a]
1964	45	47	8	100	-	-	-	-
1965	56	40	3	100	-	-	-	-
1966	53	37	10	100	-	-	-	-
1967	41	42	16	100	-	-	-	-
1968	34	46	19	100	-	-	-	-
1969	27	57	16	100	-	-	-	-
1970	30	62	8	100	-	-	-	-
1971	40	51	9	100	-	-	-	-
1972	37	53	10	100	-	-	-	-
1973	24	40	36	100	-	-	-	-
1974	24	59	17	100	-	-	-	-
1975	28	62	10	100	-	-	-	-
1976	34	48	18	100	-	-	-	-
1977	26	39	34	100	-	-	-	-
1978	29	60	11	100	14	64	22	100
1979	37	55	8	100	20	57	23	100
1980	42	47	11	100	20	53	27	100
1981	37	51	12	100	13	56	31	100
1982	31	47	22	100	10	42	48	100
1983	25	53	22	100	9	48	43	100
1984	32	56	12	100	13	60	27	100
1985	28	47	25	100	10	35	55	100
1986	31	48	21	100	11	46	43	100
1987	25	38	37	100	8	27	65	100
1988	24	48	28	100	9	43	48	100
1989	24	54	22	100	10	49	41	100
1990	23	45	32	100	9	36	55	100
1991	31	50	19	100	14	49	37	100
1992	31	42	27	100	12	37	51	100
1993	28	43	29	100	10	39	51	100
1994	27	52	21	100	11	49	40	100
1995	26	49	25	100	11	40	49	100
1996	23	57	20	100	12	54	34	100
1997	27	55	18	100	13	51	36	100

[a] Includes landings of 'mixed' cod.

Table A4. Estimates of the discard ratios of Georges Bank Atlantic cod in the otter trawl and gillnet fisheries, by quarter, in the western part (Statistical Area 521, 522, 525, 526) and the eastern part (Statistical Area 561, 562) of Georges Bank, 1989-1997. Number of tows in parentheses.

Otter trawl								
Year	West	East	West	East	West	East	West	East
1989	0.029 (126)	0.018 (16)	0.054 (239)	0.027 (100)	0.073 (222)	0.043 (16)	0.057 (151)	0.030 (27)
1990	0.100 (175)	0.012 (63)	0.074 (130)	0.008 (20)	0.027 (116)	0.002 (14)	0.020 (172)	0.026 (35)
1991	0.005 (187)	0.016 (81)	0.032 (173)	0.027 (1)	0.020 (167)	-	0.075 (220)	-
1992	0.012 (121)	0.022 (120)	0.009 (108)	0.001 (21)	0.053 (67)	-	0.018 (90)	0.061 (31)
1993	0.053 (41)	0.017 (18)	0.023 (38)	0.018 (203)	0.088 (74)	-	0.030 (123)	0.015 (15)
1994	0.008 (172)	0.003 (114)	0.043 (36)	0.005 (172)	0.000 (13)	0.003 (43)	0.004 (49)	0.000 (10)
1995	0.004 (227)	0.002 (38)	0.032 (217)	0.001 (38)	0.010 (114)	0.000 (8)	0.012 (103)	0.001 (28)
1996	0.012 (99)	0.007 (30)	0.001 (165)	0.000 (124)	-	-	0.009 (58)	-
1997	0.008 (152)	-	0.000 (1)	-	0.004 (156)		0.022 (77)	

Gillnet								
Year	West	East	West	East	West	East	West	East
1989	-	-	0.001 (3)	-	0.011 (58)	-	0.067 (36)	-
1990	0.017 (8)	-	0.017 (37)	-	0.072 (15)	-	0.142 (21)	-
1991	0.115 (4)	-	0.011 (220)	0.001 (14)	0.033 (508)	-	0.102 (128)	-
1992	0.033 (29)	-	0.046 (340)	0.030 (18)	0.028 (257)	-	0.040 (188)	-
1993	0.060 (83)	-	0.074 (140)	0.064 (5)	0.007 (9)	0.003 (5)	0.056 (197)	-
1994	0.124 (88)	-	-	-	0.043 (18)	-	0.070 (70)	-
1995	0.193 (32)	-	0.028 (40)	-	0.029 (35)	-	0.081 (44)	-
1996	0.017 (32)	-	0.080 (18)	-	0.146 (6)	-	0.050 (50)	-
1997	0.068 (28)	-	0.049 (23)	-	0.020 (22)		0.180 (6)	

Table A5. Estimated number (000's) and weight (metric tons, live) of Atlantic cod caught by marine recreational fishermen from the Georges Bank stock in 1960, 1965, 1970, 1974, and 1979 - 1997.[1]

Year	Total Cod Caught		Total Cod Retained (excluding those caught and released)			
	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	Not Estimated		Not Estimated		-----	-----
1965	Not Estimated		Not Estimated		-----	-----
1970	Not Estimated		Not Estimated		-----	-----
1974	Not Estimated		Not Estimated		-----	-----
1979	393	580	393	580	1.476	1.5
1980	186	471	133	270	2.523	1.0
1981	1749	6265	1695	6074	3.161	12.5
1982	1650	4582	1600	4444	1.022	7.2
1983	1885	5994	1709	5435	2.860	10.0
1984	499	1385	464	1289	2.603	3.2
1985	2144	9075	2054	8693	3.619	18.9
1986	354	1060	291	872	2.311	3.3
1987	472	797	434	734	2.539	2.3
1988	1321	4368	1102	3643	3.096	8.5
1989	567	1979	404	1411	3.517	4.1
1990	586	989	463	782	2.728	1.8
1991	485	1908	333	1308	3.356	3.4
1992	265	556	193	405	2.046	1.4
1993	1106	2856	755	1948	1.864	7.8
1994	437	1458	303	1010	2.140	6.2
1995	742	2080	471	1320	2.272	14.4
1996	235	817	174	603	3.059	6.3
1997	392	1220	247	769	2.591	6.9

[1]From 1979-1993 Marine Recreational Fishery Statistics Survey expanded catch estimates. 1981 to present estimated from new MRFSS methodology (1 January 1997).

Table A6. USA and Canadian sampling of commercial Atlantic cod landings from the Georges Bank and South cod stock (NAFO Division 5Z and Subarea 6), 1978-1997.

	USA			3	Canada			
	Length Samples		Age Samples		Length Samples		Age Samples	
Year	No.	# Fish Measured	No.	# Fish Aged	No.	# Fish Measured	No.	# Fish Aged
1978	88	6841	76	1463	29	7684	29	1308
1979	80	6973	79	1647	13	3991	12	656
1980	69	4990	67	1119	10	2784	10	536
1981	57	4304	57	1231	17	4147	16	842
1982	151	11970	147	2579	17	4756	8	858
1983	146	12544	138	2945	15	3822	14	604
1984	100	8721	100	2431	7	1889	7	385
1985	100	8366	100	2321	29	7644	20	1062
1986	94	7515	94	2222	19	5745	19	888
1987	80	6395	79	1704	33	9477	33	1288
1988	76	6483	76	1576	40	11709	40	1984
1989	66	5547	66	1350	32	8716	32	1561
1990	83	7158	83	1700	40	9901	40	2012
1991	88	7708	88	1865	45	10873	45	1782
1992	77	6549	77	1631	48	10878	48	1906
1993	82	6636	82	1598	51	12158	51	2146
1994	58	4688	54	1064	104	25845	101	1268
1995	40	2879	40	778	36	11598	36	548
1996	55	4600	54	1080	129	26663	129	879
1997	80	6638	80	1581	118	31882	38	1244

Table A7. USA sampling of commercial Atlantic cod landings, by market category, for the Georges Bank and South cod stock (NAFO Division 5Z and Subarea 6), 1978-1997.

	Number of Samples, by Market Category & Quarter															Annual Sampling Intensity			
	Scrod					Market					Large					No. of Tons Landed/Sample			
Year	Q1	Q2	Q3	Q4	Σ	Q1	Q2	Q3	Q4	Σ	Q1	Q2	Q3	Q4	Σ	Scrd	Mkt	Lge	Σ
1978	17	15	6	3	**41**	9	12	13	9	**43**	1	0	1	2	**4**	69	374	1922	302
1979	2	5	14	8	**29**	6	19	11	8	**44**	2	0	4	1	**7**	88	407	1742	408
1980	7	10	13	4	**34**	12	14	5	1	**32**	3	0	0	0	**3**	136	588	5546	580
1981	4	10	11	3	**28**	6	9	10	2	**27**	2	0	0	0	**2**	149	634	6283	594
1982	5	9	32	9	**55**	6	20	27	13	**66**	8	8	9	5	**30**	156	279	410	260
1983	4	12	17	10	**43**	12	19	22	14	**67**	2	15	16	3	**36**	185	291	259	252
1984	6	8	8	7	**29**	8	15	8	11	**42**	18	5	3	3	**29**	138	441	358	329
1985	6	7	16	5	**34**	11	11	12	8	**42**	4	8	7	5	**24**	201	299	310	268
1986	6	7	7	6	**26**	8	10	10	11	**39**	6	5	10	8	**29**	142	215	186	186
1987	7	8	6	8	**29**	6	8	9	10	**33**	6	6	4	2	**18**	240	220	267	238
1988	8	6	7	5	**26**	13	7	9	9	**38**	4	4	3	1	**12**	283	331	532	346
1989	2	7	9	9	**27**	7	8	8	7	**30**	3	4	1	1	**9**	210	450	660	380
1990	8	9	10	4	**31**	10	13	9	8	**40**	4	4	4	0	**12**	295	315	538	340
1991	6	11	7	5	**29**	12	13	8	8	**41**	4	6	3	5	**18**	158	293	423	275
1992	6	7	7	10	**30**	8	10	6	9	**33**	5	5	3	1	**14**	149	215	377	219
1993	5	16	7	6	**34**	10	10	7	9	**36**	6	1	3	2	**12**	126	173	339	178
1994	3	9	8	2	**22**	5	11	7	4	**27**	1	4	3	1	**9**	92	187	290	167
1995	2	3	13	2	**20**	2	4	10	2	**18**	0	1	0	1	**2**	83	181	880	167
1996	6	2	12	3	**23**	5	6	11	6	**28**	0	2	1	1	**4**	59	143	400	127
1997	3	11	3	10	**27**	5	16	9	9	**39**	3	6	0	5	**14**	50	105	148	94

Table A8. Landings at age (thousands of fish; metric tons) and mean weight (kg) and mean length (cm) at age of USA commercial landings of Atlantic cod from the Georges Bank and South cod stock (NAFO Division 5Z and Subarea 6), 1978-1997.

	Age										
Year	1	2	3	4	5	6	7	8	9	10+	Total
USA Commercial Landings in Numbers (000's) at Age											
1978	-	331	5731	1636	625	53	288	35	28	8	8735
1979	34	1618	572	4107	910	403	59	244	-	45	7992
1980	88	3002	4707	286	1888	951	413	76	153	-	11564
1981	25	3060	3613	1960	101	1026	330	72	109	46	10342
1982	325	7855	2466	1682	1258	117	452	116	50	57	14378
1983	81	3542	5557	1244	854	722	85	218	88	62	12453
1984	81	1281	3305	2961	500	393	386	25	153	82	9167
1985	130	4280	1539	985	1388	273	173	165	12	86	9031
1986	137	1091	3290	432	337	412	58	53	38	26	5874
1987	12	4878	804	1380	188	173	153	41	23	18	7670
1988	-	1345	5662	688	1076	175	100	86	21	18	9171
1989	-	1770	2638	3237	207	362	51	20	13	-	8298
1990	-	4603	3273	1265	1465	134	143	28	3	8	10922
1991	41	1032	2731	2040	873	572	52	23	8	3	7375
1992	-	2387	1268	746	936	217	133	9	12	3	5711
1993	-	781	3178	521	269	228	68	74	15	2	5136
1994	0.1	258	1186	1232	181	62	90	24	22	4	3059
1995	-	354	895	629	237	35	24	14	1	1	2190
1996	0.1	183	744	971	190	88	6	0.4	3	-	2185
1997	-	427	511	633	565	72	58	8	6	3	2283
USA Commercial Landings in Weight (Tons) at Age											
1978	-	430	14159	6041	2794	276	2168	274	356	81	26579
1979	30	2462	1411	17662	4525	2943	541	2507	-	564	32645
1980	74	4475	11663	1141	10937	6375	3504	657	1227	-	40053
1981	22	4592	8528	6644	524	7532	2773	716	1628	890	33849
1982	249	10960	7032	6465	6856	755	4281	1200	624	911	39333
1983	80	5303	13647	4271	4015	4628	679	2244	975	914	36756
1984	85	2099	8096	10650	2655	2655	3456	246	1739	1234	32915
1985	118	6094	3320	3930	7219	1746	1397	1707	148	1149	26828
1986	131	1586	7498	1475	1892	2964	528	537	507	372	17490
1987	10	6888	1953	5581	1063	1349	1306	392	242	251	19035
1988	-	2098	12981	2288	5677	1157	848	776	226	259	26310
1989	-	2958	5964	11861	1106	2403	439	209	157	-	25097
1990	-	7094	7411	4346	6902	817	1193	297	35	98	28193
1991	47	1615	6840	6943	4362	3526	406	285	96	55	24175
1992	-	3663	3040	2949	4470	1379	1070	93	137	54	16855
1993	-	1192	7081	1865	1417	1581	560	692	166	40	14594
1994	-	378	2491	4407	868	473	726	234	236	79	9893
1995	-	515	1810	2412	1314	267	253	161	9	20	6759
1996	-	275	1823	3303	915	593	64	3	45	-	7020
1997	-	678	1192	2301	2284	441	461	73	69	37	7537
USA Commercial Landings Mean Weight (kg) at Age											Mean
1978	-	1.298	2.470	3.692	4.473	5.199	7.522	7.924	12.794	10.125	3.043
1979	0.889	1.522	2.464	4.301	4.974	7.309	9.127	10.264	-	12.533	4.085
1980	0.839	1.490	2.478	3.992	5.792	6.703	8.489	8.648	8.046	-	3.464
1981	0.885	1.501	2.360	3.389	5.209	7.339	8.397	9.988	14.884	19.348	3.274
1982	0.767	1.395	2.852	3.845	5.449	6.457	9.473	10.297	12.434	15.982	2.736
1983	0.993	1.497	2.456	3.434	4.703	6.407	7.955	10.280	11.091	14.742	2.952
1984	1.053	1.638	2.450	3.597	5.308	6.751	8.960	9.710	11.361	15.049	3.590
1985	0.914	1.424	2.157	3.989	5.201	6.398	8.075	10.355	12.107	13.360	2.971
1986	0.957	1.454	2.279	3.414	5.608	7.198	9.066	10.135	13.339	14.308	2.978
1987	0.801	1.412	2.429	4.043	5.657	7.811	8.520	9.466	10.621	13.944	2.482
1988	-	1.559	2.293	3.326	5.278	6.629	8.487	9.067	10.606	14.389	2.869
1989	-	1.672	2.260	3.664	5.351	6.632	8.686	10.673	11.622	-	3.025
1990	-	1.541	2.264	3.436	4.712	6.103	8.366	10.482	10.246	12.250	2.581
1991	1.131	1.566	2.504	3.403	4.955	6.161	7.829	12.392	11.991	20.861	3.278
1992	-	1.535	2.397	3.951	4.775	6.359	8.035	10.457	11.107	17.418	2.951
1993	-	1.526	2.228	3.580	5.271	6.936	8.185	9.386	10.520	21.211	2.841
1994	0.900	1.463	2.101	3.577	4.804	7.591	8.089	9.786	10.980	19.055	3.234
1995	-	1.453	2.022	3.837	5.535	7.679	10.701	11.761	10.678	14.953	3.088
1996	-	1.503	2.451	3.400	4.825	6.727	10.497	8.346	13.836	-	3.212
1997	-	1.586	2.335	3.635	4.041	6.156	7.987	8.705	11.898	12.843	3.302

Table A8 continued. Landings at age (thousands of fish; metric tons) and mean weight (kg) and mean length (cm) at age of USA commercial landings of Atlantic cod from the Georges Bank and South cod stock (NAFO Division 5Z and Subarea 6), 1978-1997.

	Age										
Year	1	2	3	4	5	6	7	8	9	10+	Mean
				USA Commercial Landings Mean Length (cm) at Age							
1978	-	50.2	61.5	69.8	73.7	79.3	89.3	91.3	107.1	101.0	64.9
1979	44.7	52.9	61.0	73.9	77.5	88.2	95.3	99.4	-	106.1	70.9
1980	43.9	52.6	61.6	72.4	81.9	86.3	92.9	92.2	91.2	-	66.5
1981	44.6	52.3	60.4	68.5	78.4	88.7	93.1	98.2	112.8	123.2	64.6
1982	42.3	51.4	64.4	70.8	79.9	84.1	96.5	99.2	105.5	114.9	60.7
1983	46.3	52.7	61.5	68.1	75.9	84.5	90.7	99.1	101.5	111.7	63.3
1984	47.2	54.1	61.5	69.8	79.3	86.5	94.8	97.5	102.5	112.0	67.7
1985	45.1	51.8	58.6	72.4	79.0	84.5	91.4	99.4	104.7	107.9	62.5
1986	45.8	52.0	60.1	67.6	81.1	88.2	95.2	98.7	108.2	109.8	63.2
1987	43.3	51.7	61.3	72.7	81.6	90.9	93.2	96.6	100.1	110.1	59.4
1988	-	53.6	60.3	67.6	79.2	85.5	92.7	94.8	100.1	109.6	63.4
1989	-	54.7	60.1	70.0	79.3	85.3	94.2	100.4	103.6	-	64.8
1990	-	53.4	59.8	68.6	76.1	82.7	92.2	99.7	99.3	106.0	61.1
1991	48.4	53.5	62.1	68.0	77.5	82.8	90.0	106.1	105.7	125.8	66.3
1992	-	53.1	61.0	71.7	75.9	83.5	91.1	99.3	101.8	118.2	63.3
1993	-	53.1	59.8	69.4	78.4	87.0	91.7	96.1	99.8	126.0	63.0
1994	45.0	52.4	58.7	69.5	76.4	89.4	91.3	97.4	101.4	122.1	65.7
1995	-	52.4	57.8	71.0	81.0	89.9	100.9	104.3	100.9	113.0	64.6
1996	46.0	53.0	61.6	68.4	76.7	86.4	99.4	92.1	109.8	-	66.4
1997	-	53.8	60.6	69.9	71.9	83.5	91.1	93.7	104.4	107.0	66.5

Table A9. Landings at age (thousands of fish; metric tons) and mean weight (kg) and mean length (cm) at age of Canadian commercial landings of Atlantic cod from the Georges Bank and South cod stock (NAFO Division 5Z and Subarea 6), 1978 - 1997.

	Age										
Year	1	2	3	4	5	6	7	8	9	10+	Total
				CAN Commercial Landings in Numbers (000's) at Age							
1978	2	62	2017	667	205	78	57	12	12	7	3119
1979	-	371	328	763	302	55	18	9	4	3	1853
1980	1	775	1121	214	420	125	32	11	14	10	2723
1981	2	145	608	504	134	380	87	51	21	16	1948
1982	6	1283	1358	1105	742	164	221	97	21	26	5023
1983	27	744	2506	1212	201	54	10	17	12	3	4786
1984	-	26	118	375	340	123	72	19	18	39	1130
1985	4	2146	904	383	497	139	45	38	9	11	4176
1986	19	235	1283	365	143	215	29	19	9	3	2320
1987	14	2595	602	741	91	79	117	22	15	6	4282
1988	10	232	2360	324	421	69	61	111	29	29	3646
1989	-	318	284	918	124	179	31	23	37	18	1932
1990	7	339	1769	617	799	95	102	8	14	30	3780
1991	11	493	512	1241	585	516	74	47	15	20	3514
1992	70	1790	902	292	546	187	176	25	21	7	4016
1993	4	252	1068	594	171	244	91	69	17	15	2525
1994	2	140	340	593	213	34	47	22	16	2	1409
1995	0.1	38	162	63	53	10	2	1	1	-	331
1996	0.6	24	159	262	51	35	9	2	1	0.2	545
1997	3	89	128	249	228	60	26	7	4	1	795
				CAN Commercial Landings in Weight (Tons) at Age							
1978	1	85	4913	1949	803	483	378	122	113	107	8778
1979	-	509	525	2842	1398	342	169	105	47	42	5978
1980	1	1041	2720	692	2099	809	228	133	177	157	8063
1981	2	197	1426	1772	699	2624	801	497	220	224	8499
1982	4	1853	3156	4217	3849	1074	2019	914	266	418	17824
1983	24	1084	5521	3854	876	335	80	176	147	37	12130
1984	-	38	292	1423	1615	743	622	202	195	620	5763
1985	3	3017	1775	1388	2370	895	368	369	94	160	10443
1986	14	369	3691	1442	800	1543	250	180	89	28	8411
1987	9	4183	1556	3302	557	596	1113	243	189	93	11845
1988	8	300	5942	1265	2406	462	564	1188	334	437	12932
1989	-	417	669	3812	678	1221	231	247	432	276	8011
1990	5	615	5001	2283	4173	631	876	85	187	454	14310
1991	12	866	1425	4278	2593	2885	527	451	127	291	13455
1992	80	2778	2308	1042	2501	1107	1252	241	265	138	11712
1993	3	393	2485	1852	767	1431	635	623	150	180	8519
1994	2	203	817	2266	1023	243	370	196	128	23	5272
1995	0.1	56	405	237	281	60	20	14	12	-	1085
1996	1	37	376	875	268	224	62	18	14	2	1877
1997	3	138	290	813	972	348	213	62	43	16	2898
				CAN Commercial Landings Mean Weight (kg) at Age							
1978	0.707	1.376	2.436	2.922	3.918	6.187	6.625	10.148	9.429	15.262	2.814
1979	-	1.371	1.601	3.725	4.630	6.222	9.365	11.638	11.699	14.064	3.226
1980	0.567	1.343	2.426	3.235	4.997	6.468	7.119	12.135	12.652	15.721	2.961
1981	0.839	1.362	2.345	3.516	5.216	6.905	9.204	9.747	10.465	13.993	4.363
1982	0.652	1.444	2.324	3.816	5.188	6.550	9.137	9.418	12.667	16.092	3.548
1983	0.904	1.457	2.203	3.180	4.357	6.203	8.042	10.368	12.222	12.270	2.534
1984	-	1.477	2.473	3.794	4.751	6.043	8.633	10.622	10.807	15.897	5.100
1985	0.686	1.406	1.964	3.625	4.768	6.440	8.181	9.718	10.499	14.537	2.501
1986	0.723	1.572	2.877	3.952	5.592	7.179	8.612	9.453	9.934	9.437	3.625
1987	0.661	1.612	2.584	4.456	6.125	7.540	9.510	11.031	12.629	15.444	2.766
1988	0.786	1.294	2.518	3.904	5.716	6.694	9.251	10.700	11.531	15.065	3.547
1989	-	1.310	2.356	4.153	5.471	6.820	7.459	10.757	11.680	15.356	4.141
1990	0.831	1.812	2.827	3.699	5.221	6.657	8.582	11.227	13.080	14.821	3.786
1991	1.051	1.756	2.783	3.447	4.432	5.591	7.116	9.604	8.457	14.550	3.829
1992	1.148	1.552	2.559	3.568	4.581	5.921	7.112	9.626	12.603	19.714	2.916
1993	0.872	1.557	2.327	3.116	4.489	5.858	7.006	9.035	8.974	12.173	3.374
1994	0.906	1.453	2.404	3.822	4.805	7.141	7.869	8.914	7.970	11.637	3.742
1995	0.906	1.472	2.495	3.759	5.298	6.313	10.903	10.181	10.175	-	3.284
1996	1.034	1.538	2.358	3.337	5.237	6.358	6.916	8.455	10.594	12.002	3.443
1997	0.954	1.536	2.264	3.269	4.257	5.855	8.190	8.546	11.825	12.688	3.644

Table A9 continued. Landings at age (thousands of fish; metric tons) and mean weight (kg) and mean length (cm) at age of Canadian commercial landings of Atlantic cod from the Georges Bank and South cod stock (NAFO Division 5Z and Subarea 6), 1978-1997.

Year	Age 1	2	3	4	5	6	7	8	9	10+	Total
					CAN Commercial Landings Mean Length (cm) at Age						
1978	39.5	48.9	59.0	63.3	69.6	81.2	82.5	98.3	94.7	112.8	61.8
1979	-	49.3	51.9	69.3	74.8	82.2	95.2	103.2	103.4	110.4	64.1
1980	36.6	48.9	59.5	66.2	76.4	83.6	86.6	104.7	105.7	114.6	61.7
1981	41.8	49.1	59.1	68.1	78.0	86.1	94.8	96.6	97.5	108.9	70.6
1982	38.3	50.1	58.9	70.0	77.8	84.4	94.9	95.2	106.4	115.3	65.5
1983	42.9	50.4	57.9	65.8	73.0	82.9	90.9	99.0	105.1	105.0	59.9
1984	-	50.7	60.4	70.0	75.7	82.3	92.3	100.1	100.8	114.5	75.6
1985	39.0	49.8	55.7	68.7	75.3	83.8	91.1	96.3	99.0	110.8	58.1
1986	39.6	51.7	63.5	71.0	79.6	86.8	92.8	95.9	96.3	96.1	67.2
1987	38.5	52.1	61.0	73.6	82.3	88.4	96.1	101.2	106.3	114.4	60.1
1988	40.8	48.3	60.5	70.4	80.2	84.8	95.2	99.9	102.5	112.2	65.8
1989	-	48.6	59.1	71.9	79.0	85.1	87.7	100.3	103.1	113.3	69.4
1990	41.7	54.3	63.1	69.0	77.6	84.0	92.0	102.0	107.4	112.1	68.2
1991	45.1	53.7	62.6	67.2	73.3	78.8	86.2	96.1	90.6	112.1	68.4
1992	46.2	51.4	60.6	67.7	73.8	80.6	85.4	94.8	105.8	115.1	61.1
1993	42.2	51.4	58.9	64.9	72.9	80.4	85.5	94.1	92.4	104.5	65.0
1994	43.0	50.3	59.6	69.8	75.3	85.9	89.4	93.0	88.6	102.6	67.9
1995	43.0	50.6	60.4	69.5	78.3	83.1	100.9	98.4	97.8	-	65.0
1996	44.9	51.3	59.3	66.6	77.7	83.3	84.7	90.8	99.9	104.6	66.4
1997	43.7	51.3	58.6	66.1	72.4	80.9	91.3	92.5	103.9	105.5	67.4

Table A10. 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 Georges Bank and South cod stock (NAFO Division 5Z and Subarea 6), 1978-1997.

	Age											% of Total Landings	
Year	1	2	3	4	5	6	7	8	9	10+	Total	USA	Canada
				Total Commercial Landings in Numbers (000's) at Age									
1978	2	393	7748	2303	830	131	345	47	40	15	11854	73.7	26.3
1979	34	1989	900	4870	1212	458	77	253	4	48	9845	81.2	18.8
1980	89	3777	5828	500	2308	1076	445	87	167	10	14287	80.9	19.1
1981	27	3205	4221	2464	235	1406	417	123	130	62	12290	84.1	15.9
1982	331	9138	3824	2787	2000	281	673	213	71	83	19401	74.1	25.9
1983	108	4286	8063	2456	1055	776	95	235	100	65	17239	72.2	27.8
1984	81	1307	3423	3336	840	516	458	44	171	121	10297	89.0	11.0
1985	134	6426	2443	1368	1885	412	218	203	21	97	13207	68.4	31.6
1986	156	1326	4573	797	480	627	87	72	47	29	8194	71.7	28.3
1987	26	7473	1406	2121	279	252	270	63	38	24	11952	64.2	35.8
1988	10	1577	8022	1012	1497	244	161	197	50	47	12817	71.6	28.4
1989	-	2088	2922	4155	331	541	82	43	50	18	10230	81.1	18.9
1990	7	4942	5042	1882	2264	229	245	36	17	38	14702	74.3	25.7
1991	52	1525	3243	3281	1458	1088	126	70	23	23	10889	67.7	32.3
1992	70	4177	2170	1038	1482	404	309	34	33	10	9727	58.7	41.3
1993	4	1033	4246	1115	440	472	159	143	32	17	7661	67.0	33.0
1994	2	398	1526	1825	394	96	137	46	38	6	4468	68.5	31.5
1995	0.1	392	1058	692	290	44	26	15	2	1	2520	86.9	13.1
1996	0.7	207	903	1234	241	123	15	3	5	0.2	2731	80.0	20.0
1997	3	517	639	881	794	131	84	16	9	4	3078	74.2	25.8
				Total Commercial Landings in Weight (Tons) at Age									
1978	1	515	18890	7990	3597	757	2549	395	465	198	35357	75.2	24.8
1979	30	2970	1936	20504	5923	3288	711	2611	44	606	38623	84.5	15.5
1980	75	5516	14382	1833	13036	7184	3735	793	1408	154	48116	83.2	16.8
1981	24	4789	9953	8416	1224	10156	3575	1212	1848	1151	42348	79.9	20.1
1982	253	12812	10187	10681	10705	1827	6303	2110	891	1388	57157	68.8	31.2
1983	105	6387	19167	8126	4891	4963	763	2418	1120	946	48886	75.2	24.8
1984	85	2137	8389	12074	4271	3401	4078	447	1938	1858	38678	85.1	14.9
1985	121	9111	5095	5319	9588	2644	1765	2073	246	1309	37271	72.0	28.0
1986	145	1955	11189	2917	2692	4505	776	717	596	409	25901	67.5	32.5
1987	19	11071	3509	8882	1619	1945	2416	633	426	360	30880	61.6	38.4
1988	8	2399	18923	3552	8085	1618	1412	1960	566	719	39242	67.0	33.0
1989	-	3375	6633	15673	1783	3625	669	455	588	298	33098	75.8	24.2
1990	5	7709	12412	6629	11075	1448	2069	382	222	552	42503	66.3	33.7
1991	59	2481	8265	11221	6955	6411	933	736	223	346	37630	64.2	35.8
1992	80	6441	5348	3991	6971	2486	2322	334	402	192	28567	59.0	41.0
1993	3	1585	9566	3717	2184	3012	1195	1315	316	220	23113	63.1	36.9
1994	2	581	3308	6673	1892	716	1095	430	364	103	15165	65.2	34.8
1995	0.1	577	2215	2649	1595	327	273	174	20	20	7851	86.1	13.9
1996	0.6	311	2199	4178	1183	817	127	21	59	2	8898	78.9	21.1
1997	3	816	1483	3114	3256	790	674	135	111	53	10435	72.2	27.8
				Total Commercial Landings Mean Weight (kg) at Age							Mean		
1978	0.707	1.310	2.461	3.469	4.336	5.787	7.374	8.492	11.785	13.200	2.983		
1979	0.889	1.494	2.149	4.211	4.888	7.178	9.183	10.313	11.699	12.625	3.923		
1980	0.836	1.460	2.468	3.668	5.647	6.676	8.390	9.089	8.432	15.400	3.368		
1981	0.882	1.495	2.358	3.415	5.213	7.222	8.565	9.888	14.170	18.565	3.446		
1982	0.765	1.402	2.664	3.834	5.352	6.511	9.363	9.897	12.503	16.723	2.946		
1983	0.971	1.490	2.377	3.309	4.637	6.393	7.964	10.286	11.227	14.554	2.836		
1984	1.053	1.635	2.451	3.619	5.083	6.582	8.909	10.104	11.303	15.356	3.756		
1985	0.907	1.418	2.086	3.887	5.087	6.412	8.097	10.236	11.418	13.494	2.822		
1986	0.929	1.475	2.447	3.660	5.603	7.191	8.915	9.955	12.687	14.104	3.161		
1987	0.726	1.481	2.495	4.187	5.810	7.726	8.949	10.013	11.414	15.000	2.584		
1988	0.786	1.520	2.359	3.511	5.401	6.647	8.776	9.987	11.143	15.298	3.062		
1989	-	1.617	2.269	3.772	5.396	6.694	8.222	10.718	11.665	17.111	3.235		
1990	0.831	1.560	2.462	3.522	4.892	6.333	8.456	10.648	12.580	14.526	2.891		
1991	1.114	1.627	2.548	3.420	4.769	5.891	7.410	10.520	9.686	15.373	3.456		
1992	1.148	1.542	2.464	3.843	4.704	6.156	7.509	9.846	12.059	19.025	2.937		
1993	0.872	1.534	2.253	3.333	4.967	6.379	7.510	9.217	9.699	13.236	3.017		
1994	0.906	1.459	2.168	3.657	4.804	7.432	8.013	9.368	9.698	16.659	3.394		
1995	0.906	1.471	2.095	3.830	5.492	7.384	10.715	11.617	10.383	14.953	3.087		
1996	0.882	1.507	2.435	3.387	4.912	6.622	8.369	8.438	12.883	12.002	3.212		
1997	0.954	1.577	2.321	3.532	4.103	6.019	8.050	8.631	11.870	12.795	3.390		

Table A10 continued. 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 Georges Bank and South cod stock (NAFO Division 5Z and Subarea 6), 1978-1997.

Total Commercial Landings Mean Length (cm) at Age

Year	Age 1	2	3	4	5	6	7	8	9	10+	Mean
1978	39.5	50.0	60.8	67.9	72.7	80.4	80.2	93.1	103.4	106.5	64.1
1979	44.7	52.2	57.7	73.2	76.8	87.5	95.3	99.5	103.4	106.4	69.6
1980	43.8	51.8	61.2	69.7	80.9	86.0	92.4	93.8	92.4	114.6	65.6
1981	44.4	52.2	60.2	68.4	78.2	88.0	93.5	97.5	110.3	119.5	65.6
1982	42.2	51.2	62.4	70.5	79.1	84.3	96.0	97.4	105.8	115.0	61.9
1983	45.5	52.3	60.4	67.0	75.3	84.4	90.7	99.1	101.9	111.4	62.4
1984	47.2	54.0	61.5	69.8	77.8	85.5	94.4	98.6	102.3	112.8	68.6
1985	44.9	51.1	57.5	71.4	78.0	84.3	91.3	98.8	102.3	108.2	61.1
1986	45.0	51.9	61.1	69.2	80.7	87.7	94.4	98.0	105.9	108.4	64.3
1987	40.7	51.8	61.2	73.0	81.8	90.1	94.5	98.2	102.5	111.2	59.7
1988	40.8	52.8	60.4	68.5	79.5	85.3	93.6	97.7	101.5	111.2	64.1
1989	-	53.8	60.0	70.4	79.2	85.2	91.7	100.3	103.2	113.3	65.7
1990	41.7	53.5	61.0	68.7	76.6	83.2	92.1	100.2	106.0	110.8	62.9
1991	47.7	53.6	62.2	67.7	75.8	80.9	87.8	99.4	95.9	113.9	67.0
1992	46.2	52.4	60.8	70.6	75.1	82.2	87.9	96.0	104.3	116.0	62.4
1993	42.2	52.7	59.6	67.0	76.3	83.6	88.2	95.1	95.9	107.0	63.0
1994	43.1	51.7	58.9	69.6	75.8	88.2	90.7	95.3	95.9	115.8	65.8
1995	43.0	50.6	58.2	70.9	80.5	88.5	100.9	103.8	99.1	113.0	64.6
1996	45.1	52.7	61.2	68.0	76.9	85.5	90.7	91.0	106.9	104.6	66.4
1997	43.7	53.4	60.2	68.8	72.1	82.3	91.2	93.1	104.2	106.5	66.7

Table A11. Summary of USA and Canadian 1997 commercial landings of Atlantic cod from the Georges Bank and South cod stock (NAFO Division 5Z and Subarea 6).

Age	USA Catch at Age: Catch in Numbers (000's)	% of USA Total	Catch in Weight (mt)	% of USA Total	Canadian Catch at Age: Catch in Numbers (000's)	% of CAN Total	Catch in Weight (mt)	% of CAN Total	Total 1997 Catch at Age: Catch in Numbers (000's)	% of Total	Catch in Weight (mt)	% of Total
1	-	-	-	-	3	0.3	3	0.1	3	0.1	3	0.03
2	427	18.7	678	9.0	89	11.3	138	4.8	517	16.8	816	7.8
3	511	22.4	1192	15.8	128	16.1	390	10.0	639	20.8	1483	14.2
4	633	27.7	2301	30.5	249	31.3	813	28.0	881	28.6	3114	29.8
5	565	24.8	2284	30.3	228	28.7	972	33.6	794	25.8	3256	31.2
6	72	3.1	441	5.9	60	7.5	348	12.0	131	4.3	790	7.6
7	58	2.5	461	6.1	26	3.3	213	7.4	84	2.7	674	6.5
8	8	0.4	73	1.0	7	0.9	62	2.1	16	0.5	135	1.3
9	6	0.3	69	0.9	4	0.5	43	1.5	9	0.3	111	1.1
10+	3	0.1	37	0.5	1	0.2	16	0.6	4	0.1	53	0.5
Total	2283	100.0	7537	100.0	795	100.0	2898	100.0	3078	100.0	10435	100.0
	Mean Weight Per Fish (kg)		3.302		Mean Weight Per Fish (kg)		3.644		Mean Weight Per Fish (kg)		3.390	

Table A12. Mean weight at age (kg) at the beginning of the year (January 1) for Georges Bank and South cod stock (NAFO Division 5Z and Subarea 6), 1978 - 1998. Values derived from landings mean weights-at-age using the procedures described by Rivard (1980).

Age	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1	0.486	0.694	0.625	0.700	0.548	0.748	0.907	0.711	0.736	0.502	0.548	0.583	0.594	0.947	0.993	0.674	0.711	0.702	0.666	0.772	0.680
2	1.023	1.028	1.139	1.118	1.112	1.068	1.260	1.222	1.157	1.173	1.050	1.127	1.123	1.163	1.311	1.327	1.128	1.154	1.168	1.179	1.179
3	1.881	1.678	1.920	1.855	1.996	1.826	1.911	1.847	1.863	1.918	1.869	1.857	1.995	1.994	2.002	1.864	1.824	1.748	1.893	1.870	2.109
4	2.922	3.219	2.808	2.903	3.007	2.969	2.933	3.087	2.763	3.201	2.960	2.983	2.827	2.902	3.129	2.866	2.870	2.882	2.664	2.933	2.880
5	3.370	4.118	4.876	4.373	4.275	4.216	4.101	4.291	4.667	4.611	4.755	4.353	4.296	4.098	4.011	4.369	4.001	4.482	4.337	3.728	4.254
6	4.594	5.579	5.712	6.386	5.826	5.849	5.525	5.709	6.048	6.579	6.214	6.013	5.846	5.368	5.418	5.478	6.076	5.956	6.031	5.437	4.516
7	6.235	7.290	7.760	7.562	8.223	7.201	7.547	7.300	7.561	8.022	8.234	7.393	7.524	6.850	6.651	6.799	7.149	8.924	7.861	7.301	6.663
8	7.235	8.721	9.136	9.108	9.207	9.814	8.970	9.549	8.978	9.448	9.454	9.699	9.357	9.432	8.542	8.319	8.388	9.648	9.509	8.499	8.876
9	10.004	9.967	9.325	11.349	11.119	10.541	10.783	10.741	11.396	10.660	10.563	10.793	11.612	10.156	11.263	9.772	9.454	9.862	12.234	10.008	8.765
10+	13.200	12.625	15.400	18.565	16.723	14.554	15.356	13.494	14.104	15.000	15.298	17.111	14.526	15.373	19.025	13.236	16.659	14.953	12.002	12.795	12.795

Table A13. General linear model (GLM) analysis of LPUE of Georges Bank cod for interviewed trips landing cod during 1978-1993 as a function of year, area, quarter, tonnage class, and depth with no interaction.

General Linear Models Procedure

Dependent Variable: LNCPUEDF

Source	DF	Sum of Squares	Mean Square	F Value	> F
Model	28	31732.79388553	1133.31406734	735.46	0.0001
Error	54356	83760.33125977	1.54095834		
Corrected Total	54384	115493.12514529			

R-Square	C.V.	Root MSE	LNCPUEDF Mean
0.274759	-549.0211	1.24135343	-0.22610303

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	15	12685.54117665	845.70274511	548.82	0.0001
AREA	5	5241.16957276	1048.23391455	680.25	0.0001
QTR	3	4097.78364005	1365.92788002	886.41	0.0001
TC2	3	6023.47684536	2007.82561512	1302.97	0.0001
DEPTH	2	3684.82265071	1842.41132535	1195.63	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	15	15953.77293165	1063.58486211	690.21	0.0001
AREA	5	7615.39757423	1523.07951485	988.40	0.0001
QTR	3	3159.27477519	1053.09159173	683.40	0.0001
TC2	3	6322.64153966	2107.54717989	1367.69	0.0001
DEPTH	2	3684.82265071	1842.41132535	1195.63	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate	Retransformed Estimate
INTERCEPT		0.760997649 B	26.75	0.0001	0.02844571	
AREA	522	-0.444577000 B	-29.48	0.0001	0.01507858	0.641168
	523	-0.010785910 B	-0.53	0.5968	0.02038704	0.989478
	524	-0.735978983 B	-41.37	0.0001	0.01778914	0.479112
	525	-0.843403568 B	-36.88	0.0001	0.02286656	0.430356
	526	-1.194326116 B	-60.80	0.0001	0.01964379	0.302966
	521	0.000000000 B	.	.	.	1.000000
QTR	1	-0.057274522 B	-3.86	0.0001	0.01482597	0.944439
	3	-0.621223632 B	-41.41	0.0001	0.01500215	0.537347
	4	-0.417172723 B	-26.54	0.0001	0.01571823	0.658989
	2	0.000000000 B	.	.	.	1.000000
Tonclass	31	-0.793757151 B	-32.66	0.0001	0.02430028	0.452276
	32	-0.540370836 B	-33.92	0.0001	0.01593153	0.582606
	41	0.433927651 B	33.67	0.0001	0.01288832	1.543435
	33	0.000000000 B	.	.	.	1.000000
DEPTHCD	1	0.731465629 B	48.11	0.0001	0.01520442	2.078364
	2	0.373888353 B	24.87	0.0001	0.01503558	1.453539
	3	0.000000000 B	.	.	.	1.000000

Table A14. Georges Bank cod landings (mt), nominal and standardized effort (days fished) and landings per day fished (LPUE), USA only.

Year	USA Landings Used in GLM (mt)	Nominal Effort	Nominal LPUE	Standardized Effort	Standardized LPUE	Standardized Raised Effort[1]
1978	15776	7980	1.977	5937	2.657	10003
1979	20584	9406	2.188	7720	2.666	12244
1980	25213	10080	2.501	8525	2.958	13543
1981	18339	9089	2.018	8130	2.256	15005
1982	23289	10045	2.319	8833	2.607	15087
1983	22072	11668	1.892	10561	2.090	17587
1984	19669	14641	1.343	12632	1.557	21140
1985	18012	16447	1.095	15045	1.197	22408
1986	11572	12520	0.924	11956	0.968	18072
1987	12731	14945	0.852	13942	0.913	20846
1988	19010	17769	1.070	17099	1.112	23666
1989	15557	15834	0.983	15581	0.998	25136
1990	18358	15882	1.156	15007	1.223	23047
1991	14173	14857	0.954	15085	0.940	25730
1992	8786	13606	0.646	12989	0.676	24919
1993	7749	12958	0.598	12883	0.602	24262
1994	3939	7397	0.532	6834	0.576	17166
1995	1951	6564	0.297	6166	0.316	21365
1996	2242	6200	0.362	5687	0.394	17806
1997	2683	5173	0.519	4782	0.561	13433

[1]Derived as total landings/ standardized LPUE.

Table A15. Standardized stratified mean catch per tow in numbers and weight (kg) for Atlantic cod in NEFSC offshore spring and autumn research vessel bottom trawl surveys on Georges Bank (Strata 13-25), 1963-1997. [a,b,c]

	Spring		Autumn	
Year	No/Tow	Wt/Tow	No/Tow	Wt/Tow
1963	-	-	4.37	17.8
1964	-	-	2.98	11.6
1965	-	-	4.25	11.7
1966	-	-	4.81	8.1
1967	-	-	10.38	13.6
1968	4.72	12.6	3.30	8.6
1969	4.64	17.8	2.20	8.0
1970	4.34	15.6	5.07	12.5
1971	3.39	14.2	3.19	9.9
1972	8.97	19.0	13.09	23.0
1973	18.68 [d]	39.7 [d]	12.28	30.8
1974	14.75	36.4	3.49	8.2
1975	6.89	26.0	6.41	14.1
1976	7.06	18.6	10.44	17.7
1977	6.30	15.4	5.45	12.5
1978	12.31	31.2	8.59	23.3
1979	5.16	16.9	5.95	16.5
1980	6.12	16.7	2.91	6.7
1981	10.44	26.1	9.04	19.0
1982	8.20 [e]	15.4 [e]	3.71	6.9
1983	7.70	24.0	3.64	6.5
1984	4.08	15.4	4.75	10.3
1985	6.94	21.5	2.43	3.5
1986	5.04	16.7	3.12	4.7
1987	3.26	10.3	2.33	4.4
1988	5.86	13.5	3.11	5.8
1989	4.80	10.8	4.78	4.6
1990	4.74	11.6	3.62 [f]	7.1 [f]
1991	4.39	9.0	0.96	1.4
1992	2.67	7.5	1.84	3.1
1993	2.48	7.3	2.15	2.2
1994	0.94	1.2	1.82	3.3
1995	3.29	8.4	3.62	5.6
1996	2.70	7.5	1.10	2.7
1997	2.32	5.2	0.87	1.9

[a] During 1963-1984, BMV oval doors were used in spring and autumn surveys: since 1985, Portuguese 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 1980-1982, 1989-1991 and 1994 and autumn surveys during 1977-1981, 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 Albatross IV* equivalents. Conversion coefficients of 0.79 (numbers) and 0.67 (weight) were used in this standardization (NEFC 1991).

[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 gear differences.

[d] Excludes unusually high catch of 1894 cod (2558 kg) at Station 230 (Strata tow 20-4).
[e] Excludes unusually high catch of 1032 cod (4096 kg) at Station 323 (Strata tow 16-7).
[f] Excludes unusually high catch of 111 cod (504 kg) at Station 205 (Strata tow 23-4).

Table A16. Estimates of instantaneous total mortality (Z) and fishing mortality (F)[1] for the Georges Bank cod stock for ten time periods, 1964-1996, derived from NEFSC offshore spring and autumn bottom trawl survey data.[2]

Time Period	Spring		Autumn		Geometric Mean	
	Z	F	Z	F	Z	F
1964-1967	-	-	0.73	0.53	0.73	0.53
1968-1972	0.34	0.14	0.35	0.15	0.34	0.14
1973-1976	0.70	0.50	0.56	0.36	0.63	0.43
1977-1981	0.47	0.27	0.67	0.47	0.56	0.36
1982-1984	0.42	0.22	1.12	0.92	0.68	0.48
1985-1987	0.84	0.64	1.45	1.25	1.10	0.90
1988-1990	0.60	0.40	0.60	0.40	0.60	0.40
1991-1993	1.04	0.84	2.02	1.82	1.45	1.25
1994-1996	0.54	0.34	1.39	1.19	0.87	0.67

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

[2]Estimates derived from:

Georges Bank spring: ln (Σ age 4+ for years i to j/ Σ age 5+ for years i+1 to j+1).
Georges Bank autumn: ln (Σ age 3+ for years i-1 to j-1/ Σ age 4+ for years i to j).

Table A17. Parameter estimates of stock size, with CVs, fishing mortality, and partial variance of the indices for the trial ADAPT calibrations for Georges Bank cod, 1997.

	BASE	Split 36/41	No #41
Run #	6	9	10
# of surveys	3	4	3
N1	421	424	424
N2	5292	5283	5283
N3	3698	3718	3718
N4	1178	1202	1202
N5	2535	2841	2841
N6	1345	1516	1516
N7	420	479	479
N8	266	349	349
CV1	0.51	0.51	0.5
CV2	0.32	0.32	0.32
CV3	0.28	0.28	0.27
CV4	0.31	0.3	0.3
CV5	0.27	0.26	0.26
CV6	0.32	0.3	0.3
CV7	0.34	0.32	0.32
CV8	0.36	0.33	0.33
F4-8	0.3	0.26	0.26
pV usspr 1	1.12	0.955	0.961
pV usspr 2	0.14	0.144	0.145
pV usspr 3	0.132	0.109	0.11
pV usspr 4	0.172	0.197	0.199
pV usspr 5	0.334	0.368	0.371
pV usspr 6	0.704	0.873	0.879
pV usspr 7	0.52	0.541	0.545
pV usspr 8	0.603	0.398	0.401
pVcansp 1	0.53	0.526	0.532
pVcansp 2	0.238	0.241	0.243
pVcansp 3	0.079	0.072	0.073
pVcansp 4	0.209	0.194	0.196
pVcansp 5	0.276	0.142	0.144
pVcansp 6	0.47	0.363	0.367
pVcansp 7	1.018	0.939	0.949
pVcansp 8	0.991	0.632	0.638
pV autsp1	0.639	0.64	0.644
pV autsp2	0.251	0.25	0.251
pV autsp3	0.471	0.457	0.459
pV autsp4	0.419	0.41	0.412
pV autsp5	0.796	0.79	0.793
pV autsp6	0.477	0.472	0.474
pV 41sp1		2.475	
pV 41sp2		0.213	
pV 41sp3		0.195	
pV 41sp4		0.104	
pV 41sp5		0.202	
pV 41sp6		0.086	
pV 41sp7		0.456	
pV 41sp8		1.74	

Table A18. Estimates of beginning year stock size (thousands of fish), instantaneous fishing mortality (F), and spawning stock biomass (mt) of Georges Bank cod, estimated from virtual population analysis (VPA), calibrated using the commercial catch-at-age ADAPT formulation, 1978-1997.

Stock numbers (Jan 1) in thousands

Age	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1	27714	23514	20105	41394	17471	9616	27397	8682	42813	16389	23486	15800	9355	19176	7957	10844	10116	3523	6246	6456	424
2	4268	22688	19221	16380	33867	14005	7775	22358	6987	34912	13395	19220	12936	7653	15653	6451	8874	8280	2884	5113	5283
3	25526	3139	16776	12319	10511	19459	7588	5183	12490	4521	21821	9540	13846	6120	4886	9036	4347	6906	6425	2174	3718
5	2878	4422	6964	985	4698	2609	1991	4052	1313	943	3066	1073	4925	2527	2578	760	659	1260	1157	2729	2841
6	1124	1605	2524	3614	594	2037	1181	870	1612	640	520	1155	579	1984	750	769	224	183	769	730	1516
7	1434	802	900	1093	1686	232	965	500	339	752	296	205	456	267	640	248	203	97	110	519	479
8	67	862	587	334	518	772	104	376	212	199	372	97	94	152	104	244	59	42	56	76	349
9	146	12	477	402	162	231	419	45	124	109	106	126	40	44	61	55	70	7	21	43	48
10+	54	148	28	190	187	148	293	206	76	68	98	45	89	43	18	29	11	3	1	19	39
1 +	71158	71081	69337	85172	75960	54254	56350	45387	68000	64622	65589	57868	47488	44740	34723	30473	28120	22479	22365	22301	15898

Fishing mortality

Age	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1	0	0	0	0	0.02	0.01	0	0.02	0	0	0	0	0	0	0.01	0	0	0	0	0
2	0.11	0.1	0.24	0.24	0.35	0.41	0.21	0.38	0.24	0.27	0.14	0.13	0.55	0.25	0.35	0.19	0.05	0.05	0.08	0.12
3	0.41	0.38	0.48	0.48	0.51	0.61	0.69	0.74	0.52	0.42	0.52	0.41	0.51	0.88	0.67	0.73	0.49	0.19	0.17	0.39
4	0.39	0.49	0.38	0.39	0.68	0.75	0.56	0.66	0.57	0.49	0.62	0.57	0.52	0.77	0.8	0.93	0.84	0.43	0.34	0.25
5	0.38	0.36	0.46	0.31	0.64	0.59	0.63	0.72	0.52	0.4	0.78	0.42	0.71	1.02	1.01	1.02	1.08	0.29	0.26	0.39
6	0.14	0.38	0.64	0.56	0.74	0.55	0.66	0.74	0.56	0.57	0.73	0.73	0.57	0.93	0.91	1.13	0.64	0.31	0.19	0.22
7	0.31	0.11	0.79	0.55	0.58	0.6	0.74	0.66	0.33	0.51	0.92	0.58	0.9	0.74	0.76	1.23	1.37	0.35	0.16	0.2
8	1.48	0.39	0.18	0.52	0.61	0.41	0.63	0.91	0.47	0.43	0.88	0.67	0.55	0.71	0.45	1.04	1.94	0.5	0.06	0.26
9	0.36	0.44	0.49	0.44	0.66	0.65	0.6	0.72	0.54	0.49	0.74	0.58	0.62	0.86	0.91	1.04	0.91	0.38	0.31	0.26
10+	0.36	0.44	0.49	0.44	0.66	0.65	0.6	0.72	0.54	0.49	0.74	0.58	0.62	0.86	0.91	1.04	0.91	0.38	0.31	0.26
4-8,u	0.54	0.35	0.49	0.47	0.65	0.58	0.64	0.74	0.49	0.48	0.79	0.59	0.65	0.83	0.79	1.07	1.17	0.38	0.20	0.26
3-6,w	0.40	0.44	0.48	0.45	0.59	0.63	0.62	0.72	0.53	0.46	0.58	0.50	0.55	0.86	0.80	0.80	0.68	0.25	0.24	0.32

SSB at the start of the spawning season - males and females (mt)

Age	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1	913	1104	850	1960	1200	903	3124	774	8525	2226	3485	2493	645	2106	916	848	278	96	159	193
2	1410	7539	6913	5782	16138	6345	4303	11653	5036	25369	8909	13745	6670	4294	9734	4168	4224	4032	1414	2516
3	33845	3729	22417	15929	15642	26060	10501	6879	18782	7116	32911	14555	22071	9170	7610	12976	6571	10529	10634	3425
4	20219	38256	4297	21379	15793	12649	21658	8076	4844	17034	6148	27285	12834	16565	5439	4787	8587	5649	11428	12094
5	8798	16585	30442	3958	17473	9639	7111	14910	5436	3939	12390	4214	18179	8458	8451	2710	2129	5202	4648	9222
6	4882	8130	12541	20323	2957	10520	5656	4244	8587	3706	2766	5950	2975	8817	3379	3374	1185	1000	4345	3698
7	8215	5550	5918	7296	12172	1460	6227	3166	2347	5367	2026	1329	2859	1563	3622	1330	1115	788	813	3544
8	367	6810	5034	2696	4165	6840	811	2986	1705	1693	2935	813	772	1231	801	1650	349	361	508	601
9	1331	112	3963	4097	1561	2113	3956	416	1251	1033	957	1196	410	374	572	435	553	63	235	398
10+	653	1681	388	3168	2710	1873	3940	2384	945	910	1285	675	1132	558	288	308	151	47	9	225
Total	80633	89496	92765	86590	89813	78403	67287	55488	57457	68393	73812	72255	68547	53137	40812	32587	25142	27767	34193	35915

Percent mature (females)

Age	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1	7	7	7	7	13	13	13	13	28	28	28	28	12	12	12	12	4	4	4	4
2	34	34	34	34	47	47	47	47	67	67	67	67	52	52	52	52	44	44	44	44
3	78	78	78	78	84	84	84	84	91	91	91	91	90	90	90	90	93	93	93	93
4	96	96	96	96	97	97	97	97	98	98	98	98	99	99	99	99	100	100	100	100
5-10+	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table A19. Yield and SSB per recruit results for Georges Bank cod.

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: 7- 4-1998; Time: 17:28:09.47 Cod Georges Bank - 1998

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: ==> GBYPR10P.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	.0001	1.0000	.0400	.914	.711
2	.1700	1.0000	.4400	1.518	1.167
3	.6600	1.0000	.9300	2.283	1.837
4	1.0000	1.0000	1.0000	3.583	2.826
5	1.0000	1.0000	1.0000	4.835	4.182
6	1.0000	1.0000	1.0000	6.675	5.808
7	1.0000	1.0000	1.0000	9.044	8.028
8	1.0000	1.0000	1.0000	9.562	9.218
9	1.0000	1.0000	1.0000	11.712	10.700
10+	1.0000	1.0000	1.0000	13.250	13.250

Summary of Yield per Recruit Analysis for: Cod Georges Bank - 1998

Slope of the Yield/Recruit Curve at F=0.00: --> 24.7823
F level at slope=1/10 of the above slope (F0.1): -----> .175
Yield/Recruit corresponding to F0.1: -----> 1.6614
F level to produce Maximum Yield/Recruit (Fmax): -----> .340
Yield/Recruit corresponding to Fmax: -----> 1.8051
F level at 20 % of Max Spawning Potential (F20): -----> .406
SSB/Recruit corresponding to F20: --------> 5.0472

Listing of Yield per Recruit Results for:
Cod Georges Bank - 1998

	FMORT	TOTCTHN	TOTCTHW	TOTSTKN	TOTSTKW	SPNSTKN	SPNSTKW	% MSP
	.000	.00000	.00000	5.5167	27.3986	3.9184	25.2391	100.00
	.050	.13115	.89059	4.8636	20.3778	3.2642	18.3023	72.52
	.100	.21908	1.34762	4.4265	16.0044	2.8262	13.9970	55.46
	.150	.28229	1.58847	4.1130	13.0878	2.5116	11.1361	44.12
F0.1	.175	.30759	1.66141	3.9877	11.9857	2.3858	10.0580	39.85
	.200	.33004	1.71408	3.8766	11.0438	2.2743	9.1382	36.21
	.250	.36748	1.77563	3.6918	9.5555	2.0886	7.6881	30.46
	.300	.39770	1.80069	3.5430	8.4381	1.9389	6.6026	26.16
Fmax	.340	.41785	1.80513	3.4440	7.7381	1.8392	5.9243	23.47
	.350	.42265	1.80475	3.4205	7.5772	1.8155	5.7687	22.86
	.400	.44364	1.79678	3.3176	6.8995	1.7119	5.1139	20.26
F20%	.406	.44587	1.79535	3.3068	6.8304	1.7009	5.0472	20.00
	.450	.46159	1.78208	3.2299	6.3559	1.6234	4.5898	18.19
	.500	.47715	1.76384	3.1542	5.9126	1.5469	4.1633	16.50
	.550	.49077	1.74397	3.0880	5.5458	1.4800	3.8111	15.10
	.600	.50284	1.72364	3.0296	5.2382	1.4209	3.5163	13.93
	.650	.51360	1.70352	2.9776	4.9774	1.3683	3.2667	12.94
	.700	.52329	1.68402	2.9310	4.7539	1.3210	3.0531	12.10
	.750	.53206	1.66535	2.8889	4.5605	1.2783	2.8684	11.36
	.800	.54006	1.64762	2.8506	4.3918	1.2395	2.7074	10.73
	.850	.54738	1.63085	2.8156	4.2433	1.2040	2.5660	10.17
	.900	.55412	1.61504	2.7835	4.1118	1.1713	2.4408	9.67
	.950	.56036	1.60016	2.7539	3.9945	1.1412	2.3292	9.23
	1.000	.56615	1.58616	2.7265	3.8892	1.1133	2.2291	8.83

Table A20. Summary of **stochastic projections** for Georges Bank cod for 1999-2000 fishing mortalities of $F_{0.1} = 0.18$, $F_{98} = 0.26$, and $F_{SFA} = 0.14$.

Input for Projections:

Number of Years: 3: Initial Year: 1998: Final Year: 2000
Number of Ages : 10: Age at Recruitment: 1: Last Age: 10
Natural Mortality is assumed Constant over time at: .20
Proportion of F before spawning: .1667
Proportion of M before spawning: .1667
Last age is a PLUS group.

Age	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Weights Catch	Average Weights Stock
1	.0001	1.0000	.0400	.914	.711
2	.1700	1.0000	.4400	1.518	1.167
3	.6600	1.0000	.9300	2.283	1.837
4	1.0000	1.0000	1.0000	3.583	2.826
5	1.0000	1.0000	1.0000	4.835	4.182
6	1.0000	1.0000	1.0000	6.675	5.808
7	1.0000	1.0000	1.0000	9.044	8.028
8	1.0000	1.0000	1.0000	9.562	9.218
9	1.0000	1.0000	1.0000	11.712	10.700
10+	1.0000	1.0000	1.0000	13.250	13.250

Projection results:

Year	Recruitment	F	Median Landings	Median SSB
1998	424	0.26	9390	39100
1999	6460	0.26	9830	39400
2000	6460	0.26	8990	35300
1998	424	0.26	9390	39100
1999	6460	0.18	7050	39900
2000	6460	0.18	6940	38500
1998	424	0.26	9390	39100
1999	6460	0.14	5580	40200
2000	6460	0.14	5710	40200

Appendix 1: Table 1. Standardized (for vessel and door changes) stratified mean catch per tow at age (numbers) of Atlantic cod in NEFSC offshore spring and autumn bottom trawl surveys on Georges Bank (Strata 13-25), 1963-1997. [a,b,c]

	Age											Totals						
Year	0	1	2	3	4	5	6	7	8	9	10+	0+	1+	2+	3+	4+	5+
Spring																	
1968	0.513	0.136	1.615	0.825	0.665	0.385	0.246	0.140	0.083	0.056	0.058	4.722	4.209	4.073	2.459	1.633	0.969
1969	0.000	0.123	0.546	1.780	0.888	0.451	0.326	0.215	0.128	0.072	0.112	4.641	4.641	4.518	3.972	2.192	1.304
1970	0.000	0.381	0.814	0.480	1.295	0.162	0.655	0.275	0.061	0.136	0.083	4.341	4.341	3.961	3.147	2.666	1.371
1971	0.000	0.207	0.819	0.502	0.223	0.585	0.142	0.351	0.304	0.080	0.175	3.388	3.388	3.181	2.362	1.860	1.636
1972	0.056	2.902	1.833	2.641	0.510	0.119	0.324	0.122	0.220	0.115	0.125	8.967	8.911	6.009	4.176	1.535	1.025
1973	0.056	0.521	11.644	2.189	2.540	0.426	0.314	0.354	0.050	0.203	0.388	18.684	18.628	18.107	6.463	4.274	1.735
1974	0.000	0.446	4.557	5.972	0.761	2.003	0.440	0.101	0.257	0.034	0.175	14.747	14.747	14.301	9.744	3.772	3.011
1975	0.000	0.064	0.378	2.042	3.092	0.261	0.686	0.129	0.094	0.108	0.039	6.892	6.892	6.828	6.451	4.409	1.317
1976	0.111	1.301	1.922	0.944	0.691	1.572	0.164	0.262	0.036	0.000	0.055	7.057	6.947	5.646	3.724	2.780	2.089
1977	0.000	0.028	3.527	1.080	0.523	0.279	0.727	0.051	0.066	0.000	0.020	6.301	6.301	6.273	2.746	1.666	1.143
1978	3.312	0.376	0.187	5.530	0.969	0.778	0.144	0.713	0.051	0.142	0.109	12.312	9.000	8.624	8.436	2.906	1.938
1979	0.109	0.435	1.359	0.298	1.913	0.541	0.234	0.087	0.145	0.012	0.022	5.156	5.047	4.611	3.253	2.955	1.042
1980	0.083	0.031	1.790	2.124	0.165	1.171	0.472	0.152	0.025	0.024	0.088	6.122	6.039	6.008	4.219	2.095	1.930
1981	0.301	2.303	1.916	2.779	1.667	0.100	0.870	0.269	0.144	0.000	0.085	10.435	10.134	7.831	5.914	3.135	1.468
1982	0.148	0.488	3.395	1.406	1.295	1.039	0.016	0.298	0.064	0.016	0.035	8.200	8.053	7.564	4.169	2.763	1.468
1983	0.081	0.329	1.967	3.048	0.766	0.697	0.431	0.055	0.192	0.000	0.136	7.702	7.621	7.291	5.324	2.276	1.510
1984	0.000	0.402	0.462	0.797	1.161	0.446	0.424	0.223	0.000	0.156	0.008	4.079	4.079	3.677	3.215	2.418	1.257
1985	0.244	0.098	2.633	0.757	1.058	1.328	0.270	0.203	0.172	0.025	0.150	6.938	6.694	6.596	3.963	3.206	2.148
1986	0.092	0.871	0.423	1.824	0.360	0.545	0.633	0.063	0.119	0.095	0.015	5.040	4.948	4.077	3.654	1.830	1.470
1987	0.000	0.034	1.612	0.403	0.752	0.060	0.179	0.147	0.016	0.027	0.025	3.255	3.255	3.221	1.609	1.206	0.454
1988	0.180	0.700	0.684	3.115	0.413	0.645	0.045	0.020	0.052	0.000	0.007	5.861	5.681	4.981	4.297	1.182	0.769
1989	0.000	0.380	1.334	0.743	1.532	0.228	0.344	0.051	0.040	0.081	0.067	4.798	4.798	4.418	3.084	2.342	0.810
1990	0.041	0.194	0.926	1.707	0.653	0.896	0.125	0.139	0.013	0.016	0.027	4.736	4.695	4.501	3.575	1.868	1.215
1991	0.195	1.068	0.511	0.807	0.883	0.464	0.336	0.039	0.041	0.000	0.045	4.389	4.194	3.126	2.615	1.808	0.925
1992	0.000	0.123	1.255	0.470	0.163	0.270	0.144	0.161	0.020	0.037	0.028	2.671	2.671	2.548	1.293	0.823	0.660
1993	0.115	0.017	0.398	1.347	0.222	0.107	0.120	0.037	0.037	0.021	0.055	2.476	2.361	2.344	1.946	0.599	0.377
1994	0.029	0.123	0.273	0.199	0.216	0.033	0.005	0.044	0.000	0.019	0.000	0.943	0.914	0.791	0.518	0.318	0.102
1995	0.482	0.050	0.382	0.854	0.534	0.599	0.107	0.234	0.028	0.022	0.000	3.292	2.810	2.760	2.378	1.524	0.990
1996	0.000	0.073	0.214	0.736	1.247	0.174	0.209	0.028	0.018	0.000	0.000	2.699	2.699	2.626	2.412	1.676	0.429
1997	0.302	0.291	0.437	0.170	0.489	0.422	0.050	0.134	0.020	0.000	0.000	2.315	2.013	1.722	1.285	1.115	0.626

[a] 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 gear differences.
[b] During 1963-1984, BMV oval doors were used in spring and autumn surveys; since 1985, Portuguese 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 (NEFSC 1991).
[c] Spring surveys during 1980-1982, 1989-1991 and 1994, and autumn surveys during 1977-1981, 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 Albatross IV* equivalents. Conversion coefficients of 0.79 (numbers) and 0.67 (weight) were used in this standardization (NEFSC 1991).
[d] Excludes unusually high catch of 1894 cod (2558 kg) at Station 230 (Strata tow 20-4).
[e] Excludes unusually high catch of 1032 cod (4096 kg) at Station 323 (Strata tow 16-7).

Appendix 1: Table 1 (Continued). Standardized (for vessel and door changes) stratified mean catch per tow at age (numbers) of Atlantic cod in NEFSC offshore spring and autumn bottom trawl surveys on Georges Bank (Strata 13-25), 1963-1997. [b,c]

	Age											Totals					
Year	0	1	2	3	4	5	6	7	8	9	10+	0+	1+	2+	3+	4+	5+
Autumn																	
1963	0.019	0.719	0.778	0.920	0.897	0.354	0.326	0.175	0.103	0.014	0.069	4.374	4.356	3.636	2.858	1.938	1.041
1964	0.009	0.640	0.699	0.588	0.538	0.145	0.136	0.062	0.050	0.030	0.083	2.980	2.970	2.331	1.632	1.044	0.505
1965	0.173	1.299	0.998	0.707	0.484	0.167	0.179	0.112	0.081	0.023	0.023	4.248	4.075	2.775	1.777	1.070	0.587
1966	1.025	1.693	1.000	0.515	0.264	0.100	0.095	0.062	0.039	0.002	0.017	4.811	3.786	2.094	1.094	0.579	0.315
1967	0.072	7.596	1.334	0.523	0.406	0.133	0.133	0.055	0.051	0.012	0.070	10.383	10.312	2.716	1.382	0.860	0.454
1968	0.070	0.314	1.611	0.783	0.271	0.073	0.067	0.027	0.023	0.008	0.048	3.296	3.226	2.913	1.301	0.518	0.246
1969	0.000	0.343	0.622	0.626	0.331	0.094	0.061	0.019	0.023	0.022	0.059	2.200	2.200	1.856	1.234	0.608	0.278
1970	0.413	1.688	1.353	0.524	0.694	0.153	0.000	0.033	0.055	0.055	0.098	5.065	4.652	2.964	1.611	1.087	0.393
1971	0.399	0.602	0.632	0.390	0.301	0.476	0.183	0.042	0.089	0.000	0.075	3.189	2.789	2.187	1.555	1.165	0.864
1972	0.947	7.443	1.295	1.771	0.399	0.243	0.571	0.109	0.204	0.022	0.083	13.087	12.140	4.697	3.402	1.632	1.232
1973	0.203	1.749	6.070	1.182	2.012	0.211	0.226	0.175	0.062	0.139	0.251	12.280	12.078	10.329	4.259	3.076	1.064
1974	0.462	0.409	0.654	1.521	0.164	0.114	0.103	0.000	0.069	0.000	0.000	3.494	3.033	2.624	1.970	0.449	0.285
1975	2.377	0.994	0.421	0.624	1.685	0.112	0.156	0.000	0.000	0.000	0.037	6.407	4.029	3.036	2.615	1.991	0.306
1976	0.000	6.148	2.072	0.763	0.278	0.739	0.055	0.270	0.039	0.053	0.020	10.436	10.436	4.288	2.217	1.454	1.176
1977	0.152	0.237	3.424	0.702	0.251	0.174	0.396	0.007	0.027	0.000	0.078	5.447	5.296	5.059	1.635	0.933	0.682
1978	0.396	1.855	0.255	4.180	0.964	0.335	0.165	0.344	0.051	0.030	0.014	8.587	8.192	6.337	6.082	1.902	0.938
1979	0.118	1.619	1.717	0.224	1.613	0.296	0.180	0.036	0.115	0.007	0.022	5.948	5.829	4.210	2.493	2.269	0.656
1980	0.280	0.818	0.564	0.774	0.076	0.251	0.053	0.067	0.025	0.000	0.000	2.908	2.629	1.810	1.246	0.472	0.396
1981	0.261	3.525	2.250	1.559	0.589	0.054	0.579	0.057	0.064	0.018	0.083	9.040	8.778	5.254	3.003	1.444	0.855
1982	0.320	0.875	2.094	0.220	0.069	0.097	0.000	0.016	0.000	0.000	0.022	3.711	3.391	2.516	0.423	0.203	0.134
1983	1.031	0.647	1.022	0.796	0.055	0.047	0.003	0.000	0.012	0.000	0.023	3.636	2.605	1.958	0.936	0.140	0.086
1984	0.186	2.496	0.101	0.886	0.870	0.017	0.062	0.039	0.006	0.039	0.044	4.747	4.561	2.065	1.964	1.078	0.207
1985	1.084	0.220	0.803	0.103	0.115	0.101	0.000	0.000	0.004	0.000	0.000	2.430	1.346	1.126	0.323	0.220	0.105
1986	0.096	2.280	0.153	0.382	0.010	0.061	0.090	0.016	0.000	0.008	0.028	3.124	3.028	0.748	0.595	0.213	0.203
1987	0.204	0.414	1.353	0.112	0.195	0.028	0.012	0.000	0.000	0.007	0.000	2.325	2.121	1.707	0.354	0.242	0.047
1988	0.549	0.903	0.433	0.909	0.091	0.178	0.000	0.011	0.039	0.000	0.000	3.113	2.564	1.661	1.228	0.319	0.228
1989	0.262	2.738	1.030	0.183	0.499	0.055	0.008	0.004	0.000	0.000	0.000	4.780	4.518	1.780	0.750	0.566	0.067
1990 [f]	0.156	0.362	1.534	1.164	0.209	0.145	0.012	0.013	0.000	0.000	0.022	3.617	3.460	3.098	1.564	0.401	0.192
1991	0.040	0.415	0.168	0.277	0.028	0.029	0.000	0.000	0.000	0.000	0.000	0.957	0.917	0.502	0.334	0.057	0.029
1992	0.033	0.454	1.024	0.180	0.112	0.030	0.010	0.000	0.000	0.000	0.000	1.843	1.810	1.356	0.332	0.152	0.040
1993	0.179	0.970	0.532	0.382	0.017	0.025	0.022	0.000	0.000	0.022	0.000	2.149	1.970	1.000	0.468	0.086	0.070
1994	0.067	0.406	0.664	0.433	0.153	0.068	0.021	0.000	0.006	0.000	0.000	1.818	1.751	1.345	0.681	0.248	0.095
1995	0.160	0.245	1.811	1.249	0.087	0.054	0.011	0.000	0.000	0.000	0.000	3.617	3.457	3.212	1.401	0.152	0.065
1996	0.022	0.240	0.196	0.414	0.143	0.060	0.027	0.000	0.000	0.000	0.000	1.102	1.080	0.840	0.644	0.230	0.087
1997	0.006	0.236	0.321	0.109	0.129	0.049	0.009	0.007	0.000	0.000	0.000	0.867	0.860	0.624	0.303	0.194	0.065

[b] During 1963-1984, BMV oval doors were used in spring and autumn surveys; since 1985, Portuguese 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 (NEFSC 1991).

[c] Spring surveys during 1980-1982, 1989-1991 and 1994, and autumn surveys during 1977-1981, 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 Albatross IV* equivalents. Conversion coefficients of 0.79 (numbers) and 0.67 (weight) were used in this standardization (NEFSC 1991).

[f] Excludes unusually high catch of 111 cod (504 kg) at Station 205 (Strata tow 23-4).

Appendix 1: Table 2. Stratified mean catch per tow at age (numbers) of Atlantic cod in Canadian spring bottom trawl surveys on Eastern Georges Bank, 1986-1998.

	Age										Totals				
Year	1	2	3	4	5	6	7	8	9	10+	1+	2+	3+	4+	5+
1986	0.60	2.27	2.81	0.37	0.65	0.44	0.26	0.04	0.07	0.03	7.54	6.94	4.67	1.86	1.49
1987	0.25	2.13	0.93	1.09	0.34	0.12	0.22	0.08	0.03	0.07	5.26	5.01	2.88	1.95	0.86
1988	0.28	1.01	4.66	0.58	1.02	0.13	0.08	0.17	0.04	0.07	8.04	7.76	6.75	2.09	1.51
1989	1.63	2.78	1.38	2.85	0.36	0.42	0.05	0.10	0.12	0.06	9.75	8.12	5.34	3.96	1.11
1990	0.42	2.44	3.78	2.08	3.87	0.42	0.93	0.12	0.12	0.35	14.55	14.11	11.67	7.89	5.81
1991	1.18	1.16	1.84	2.15	1.05	1.31	0.16	0.22	0.03	0.09	9.19	8.01	6.85	5.01	2.86
1992	0.11	2.86	1.77	0.80	0.98	0.60	0.43	0.12	0.07	0.02	7.76	7.65	4.79	3.02	2.22
1993	0.05	0.60	2.83	1.04	0.62	1.23	0.44	0.42	0.07	0.12	7.42	7.37	6.77	3.94	2.90
1994	0.02	0.80	0.89	1.65	0.60	0.23	0.45	0.11	0.15	0.04	4.94	4.92	4.12	3.23	1.58
1995	0.07	0.67	1.50	0.86	0.60	0.19	0.04	0.05	0.02	0.02	4.02	3.95	3.28	1.78	0.92
1996	0.14	0.49	2.31	4.02	1.09	0.79	0.33	0.08	0.11	0.03	9.39	9.25	8.76	6.45	2.43
1997	0.32	0.53	0.55	1.25	1.23	0.27	0.06	0.03	0.02	0.01	4.27	3.95	3.42	2.87	1.62
1998	0.01	1.42	2.04	0.79	0.77	0.58	0.14	0.07	0.02	0.04	5.88	5.87	4.45	2.41	1.62

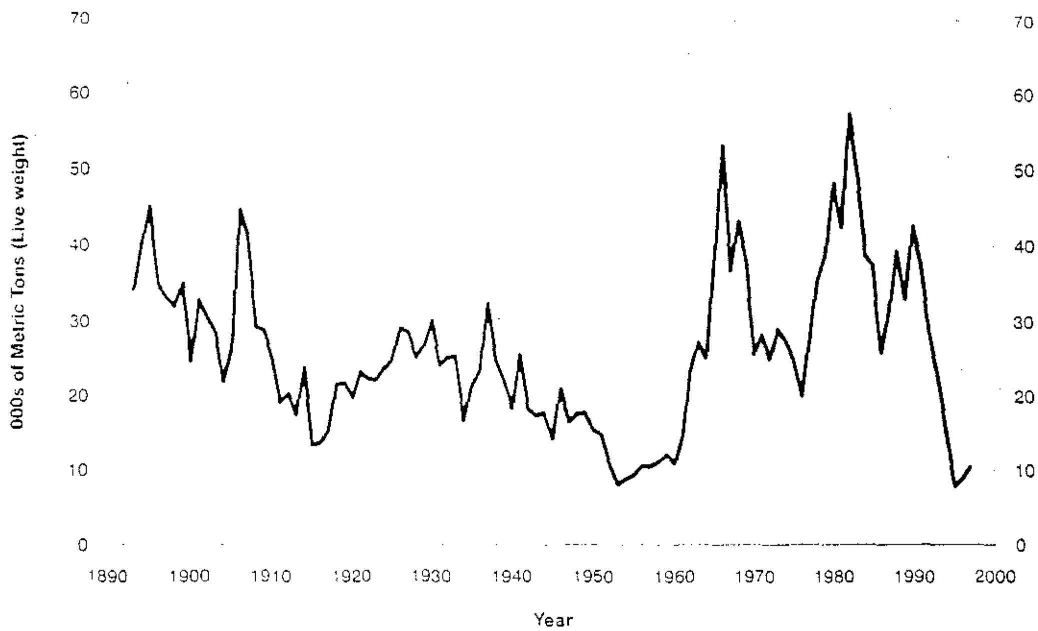

Figure A1. Total commercial landings of Georges Bank cod (Division 5Z and 6), 1893-1997.

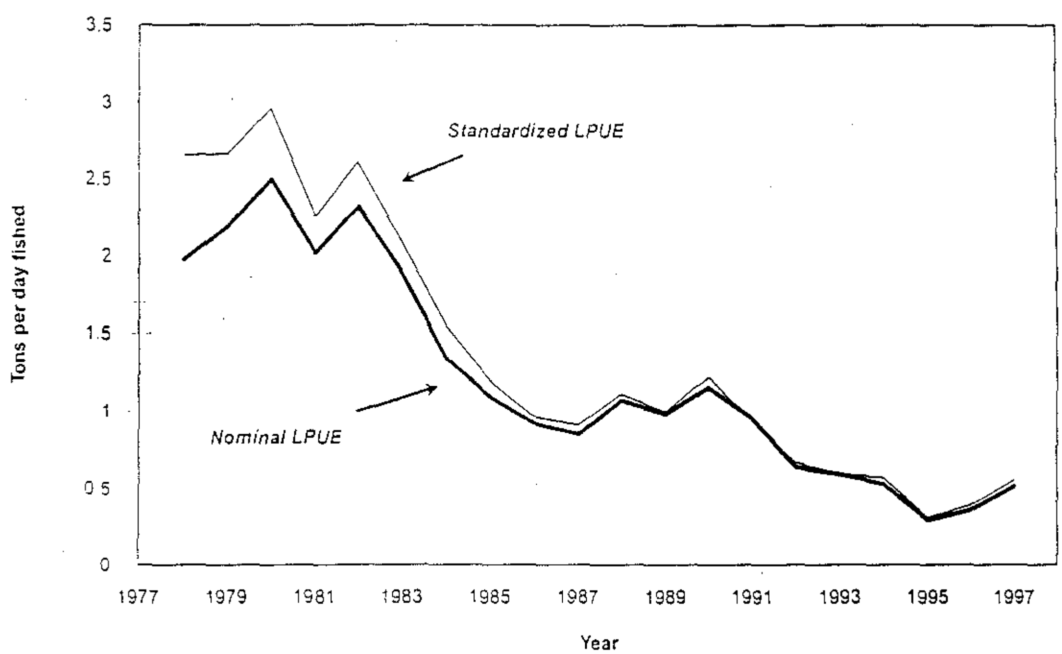

Figure A2. Trends in USA LPUE (landings per day fished) of Georges Bank cod, 1978-1997. Nominal LPUE is based on all otter trawl trips landing cod. Standardized LPUE is derived from a GLM incorporating year, tonnage class, area, quarter, and depth.

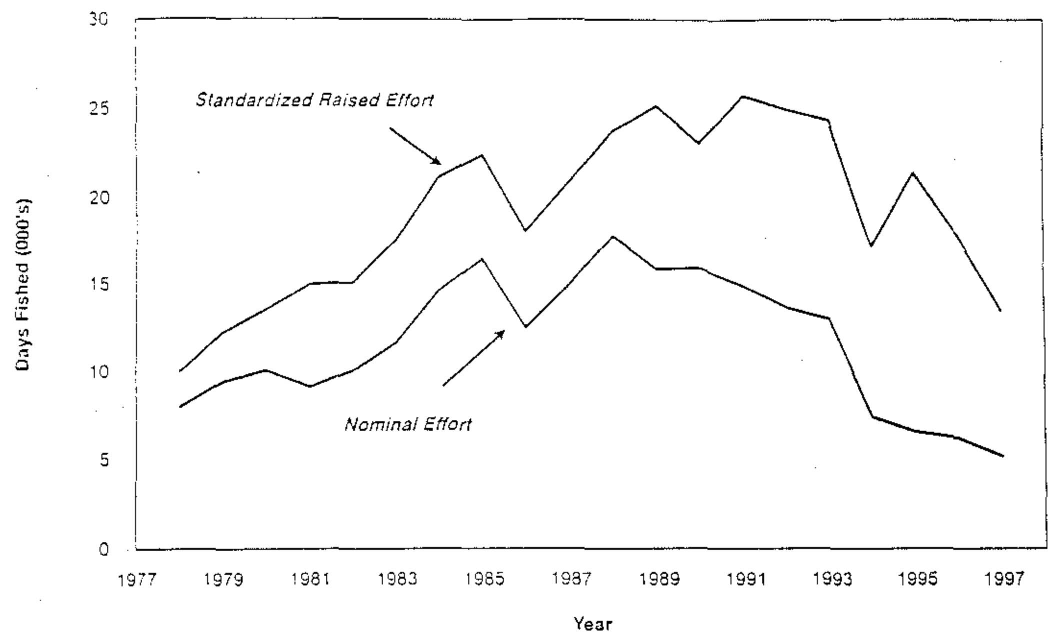

Figure A3. Trends in USA fishing effort (days fished) on Georges Bank, 1978-1997. Nominal effort based on all otter trawl trips landing cod. Standardized-raised effort derived from a GLM incorporating year, tonnage class, area, quarter, and depth.

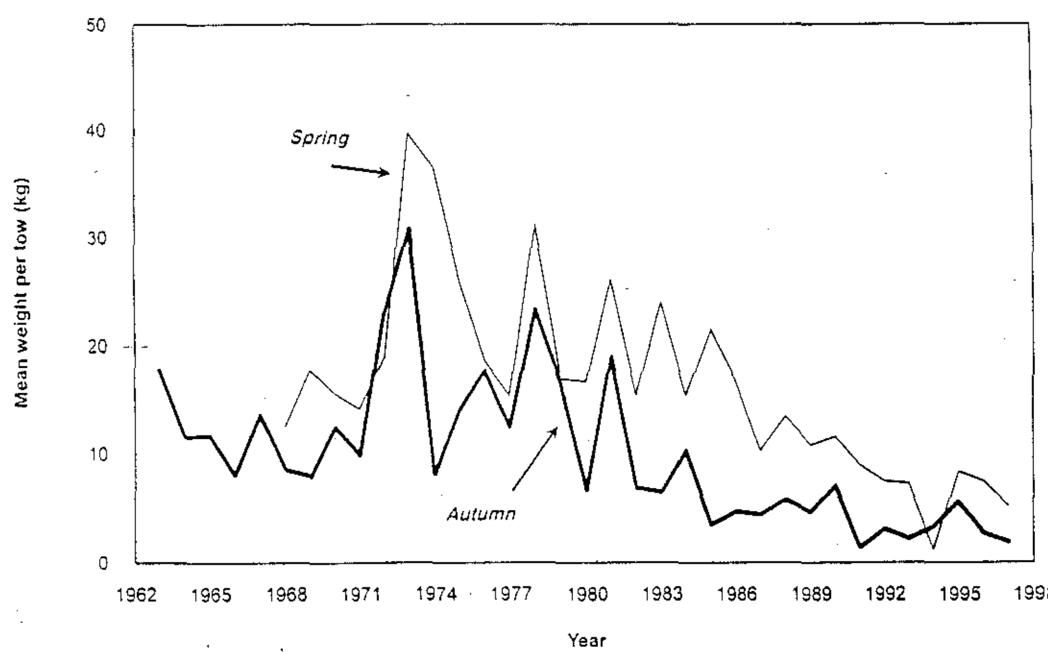

Figure A4. Standardized stratified mean catch per tow (kg) of Atlantic cod in NEFSC spring and autumn research vessel bottom trawl surveys on Georges Bank, 1963-1997.

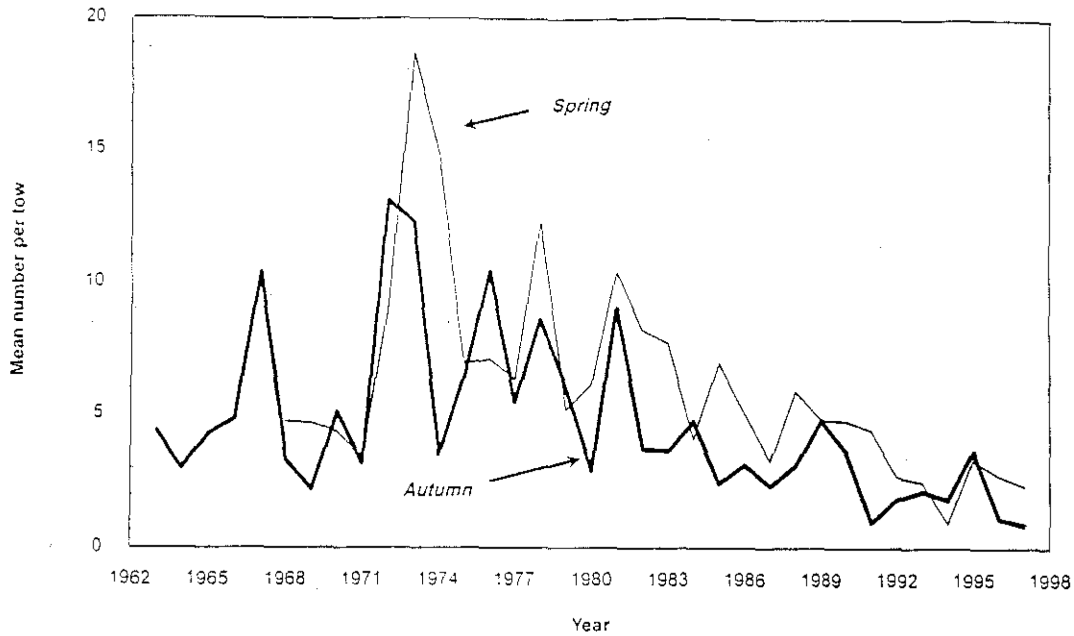

Figure A5. Standardized stratified man number per tow of Atlantic cod in NEFSC spring and autumn research vessel bottom trawl surveys on Georges Bank, 1963-1997.

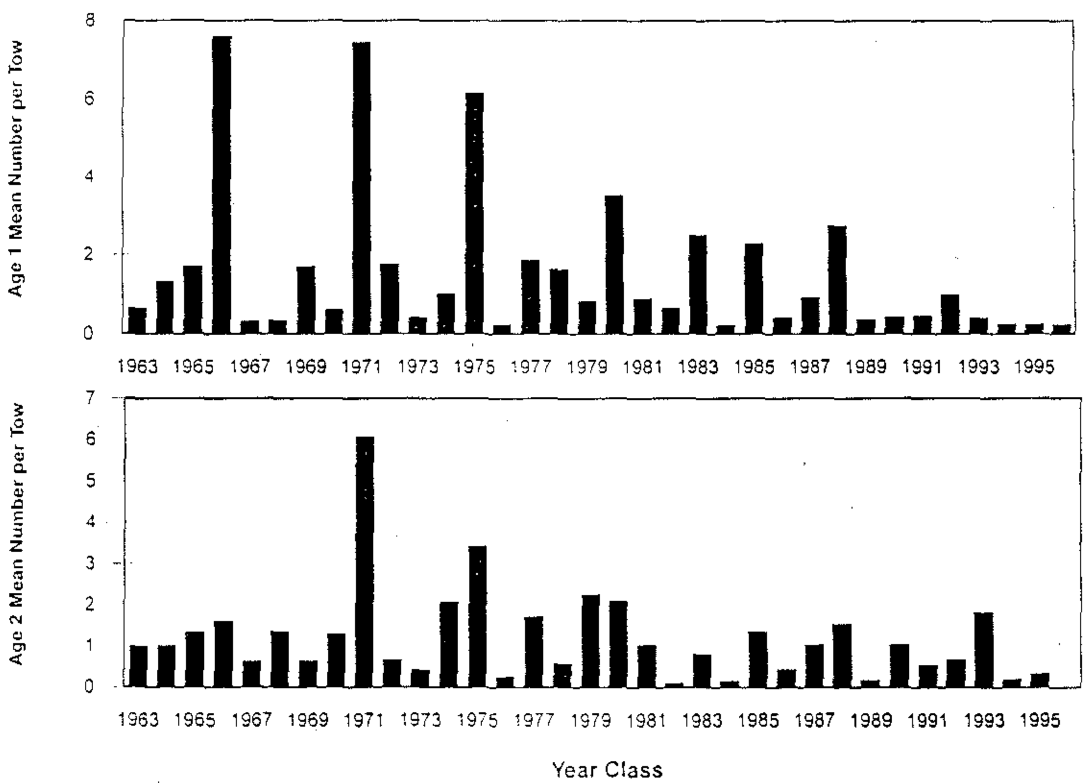

Figure A6. Relative year class strengths of Georges Bank cod age 1 and age 2 based on standardized catch (number) per tow indices from NEFSC autumn research vessel bottom trawl surveys, 1963-1997.

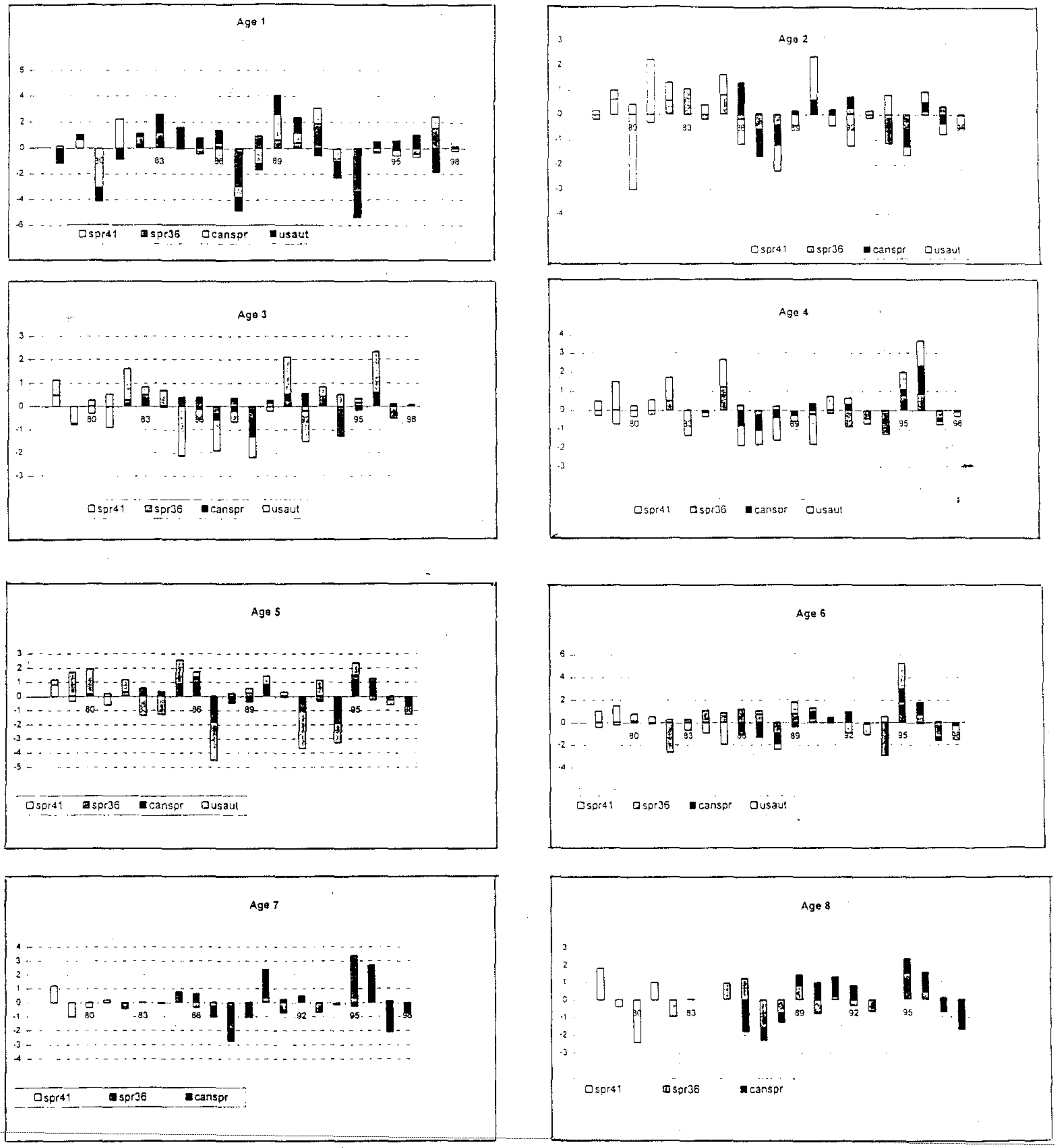

Figure A7. Residual plots (expected-observed) for ages 1-8 for the USA spring and Canadian spring abundance indices, and ages 1-6 for the USA autumn research survey indices.

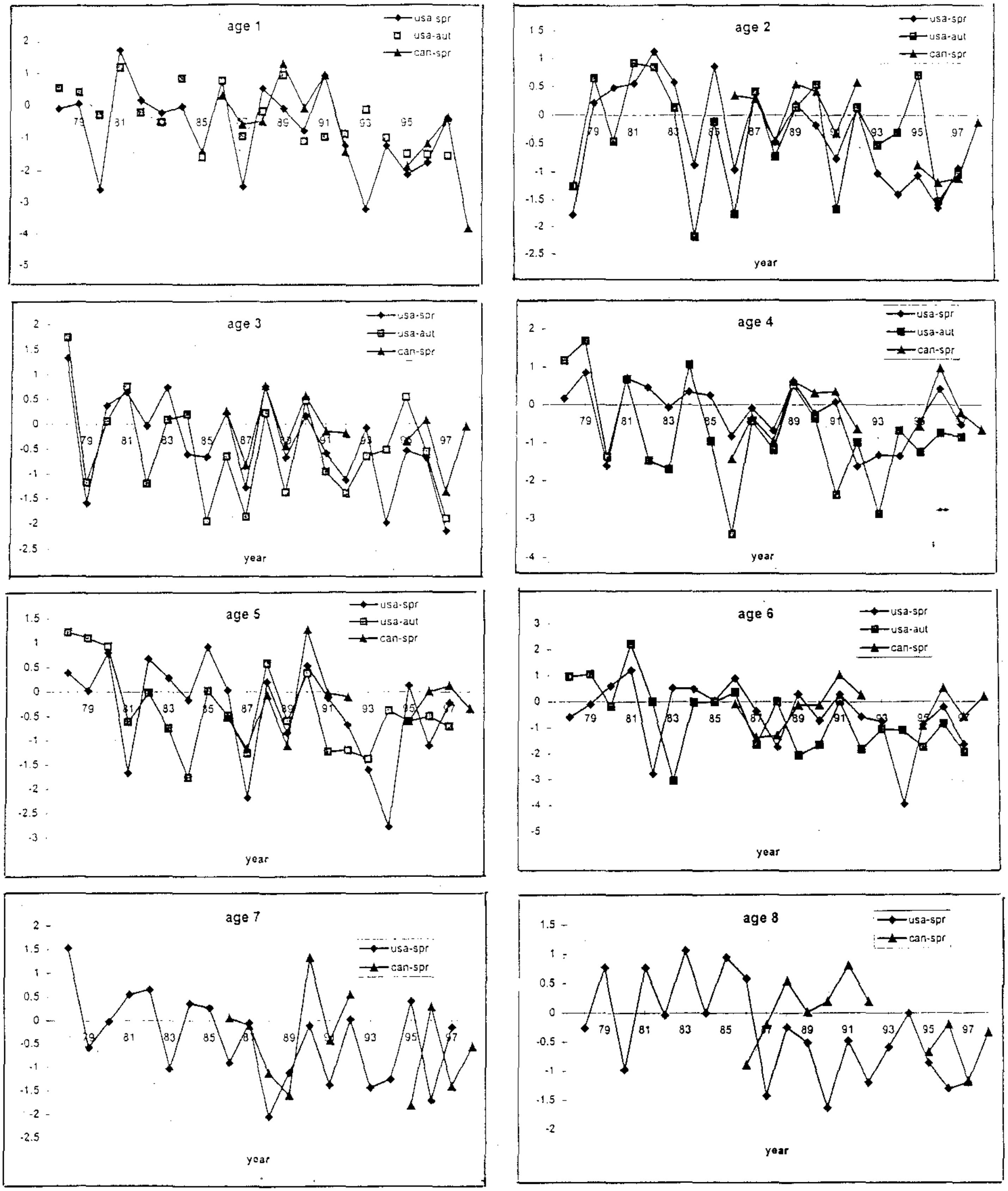

Figure A8. Natural log of the observed survey indices, standardized to the mean, for the USA spring and autumn survey and the Canadian spring survey.

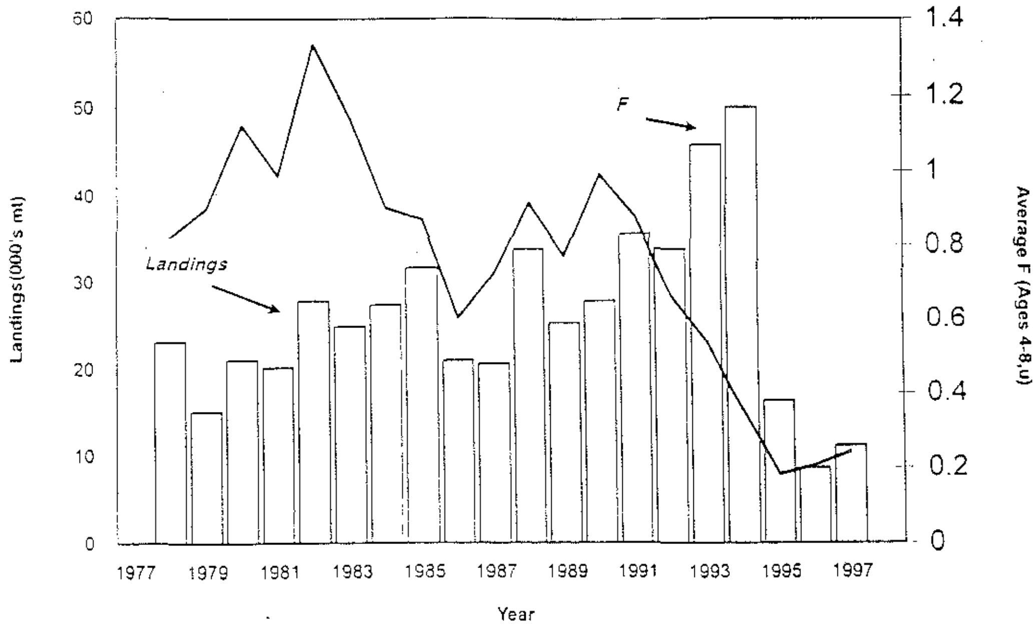

Figure A9. Trends in total commercial landings and fishing mortality for Georges Bank cod, 1978-1997.

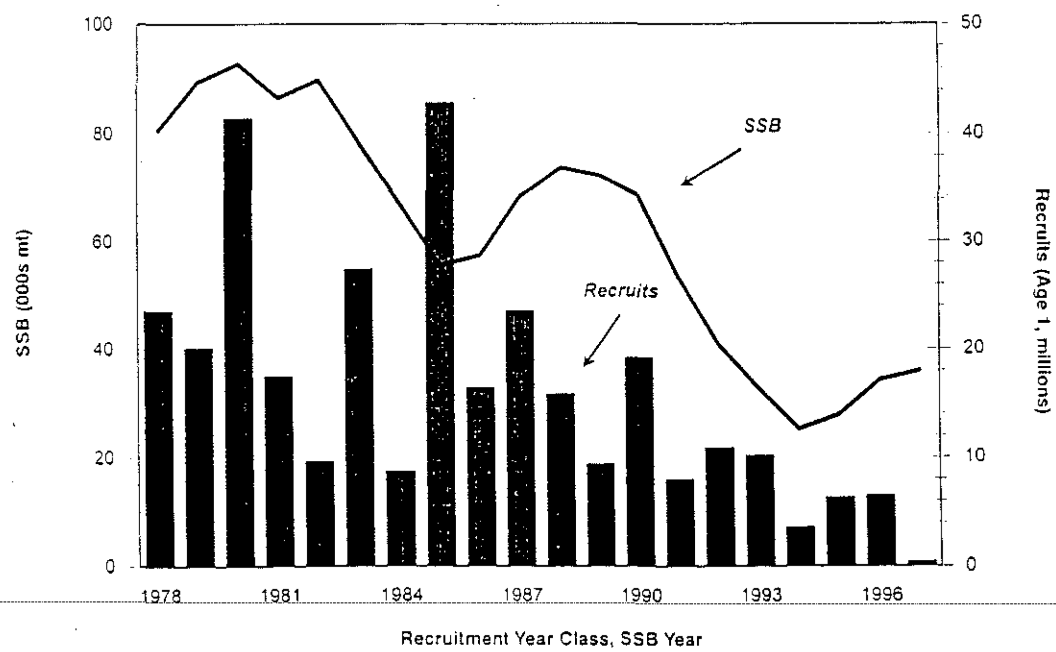

Figure A10. Trends in spawning stack biomass and recruitment for Georges Bank cod, 1978-1997.

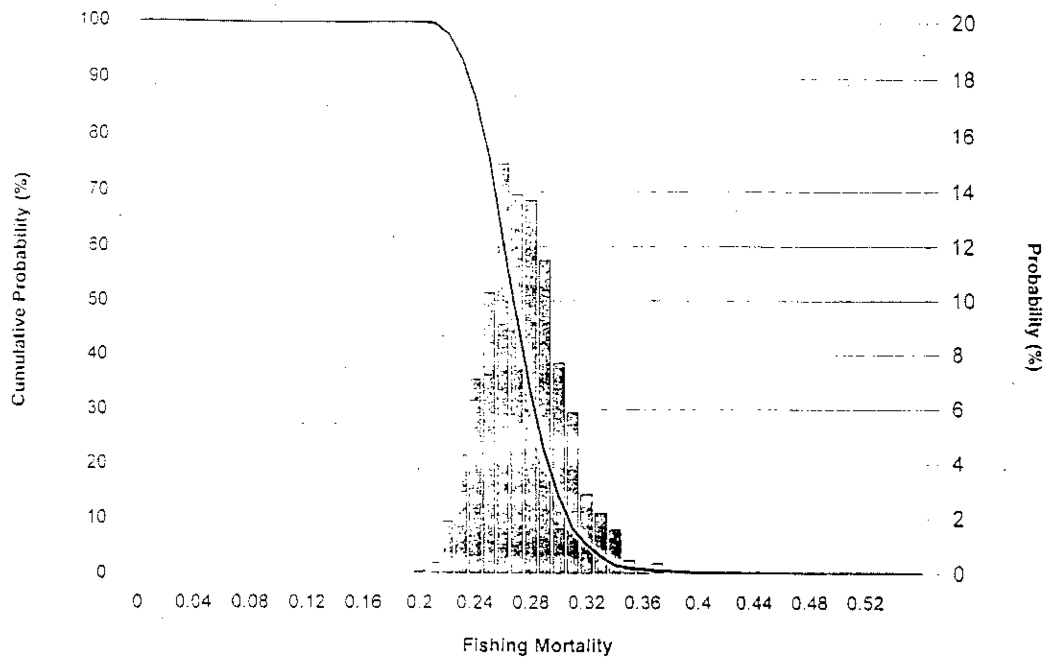

Figure A11. Precision of the estimates of the instantaneous rate of fishing (F) on the fully recruited ages (4+) in 1997 for Georges Bank cod. The bar height indicates the probability of values within the range. The solid line gives the probability that F is greater than any selected value on the X-axis.

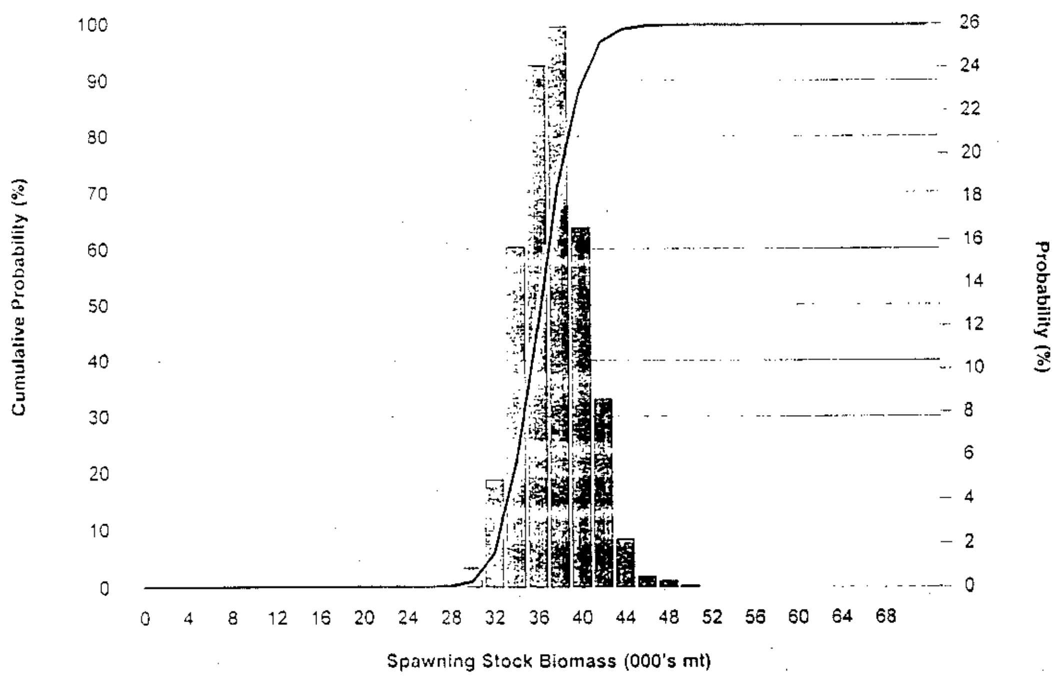

Figure A12. Precision of the estimates of spawning stock biomass (SSB) at the beginning of the spawning season for Georges Bank cod, 1997. The bar height indicates the probability of values within that range. The solid line gives the probability that SSB is less than any selected value on the X-axis.

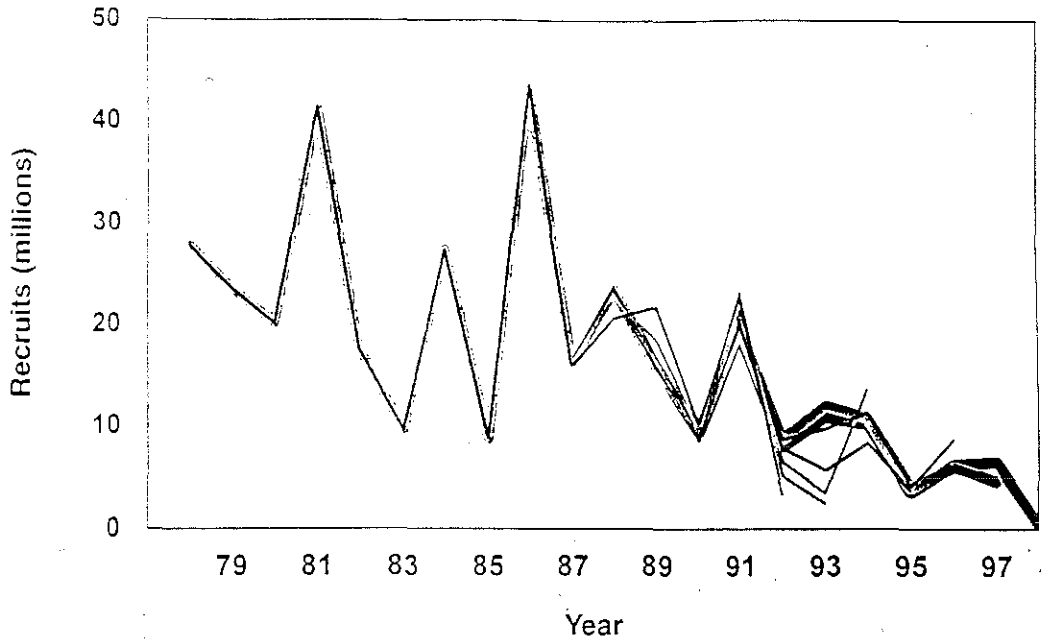

Figure A13. Retrospective analysis of Georges Bank cod-recruits at age 1 based on the final ADAPT-VPA formulation, 1997-1989.

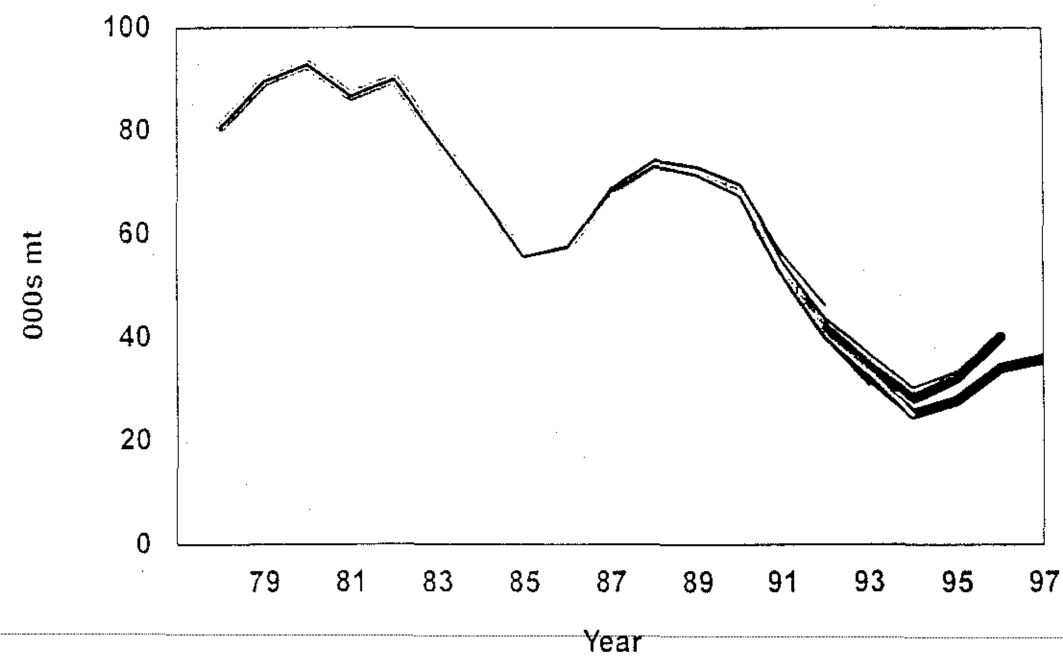

Figure A14. Retrospective analysis of Georges Bank cod spawning stock biomass based on the final ADAPT VPA formulation, 1997-1989.

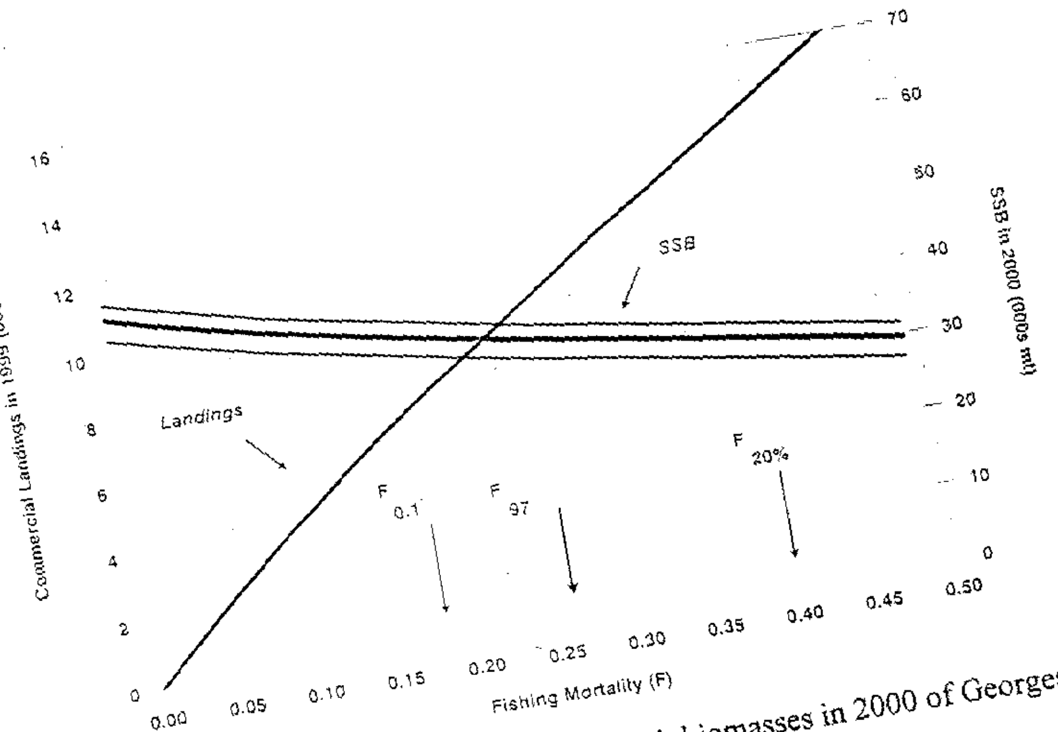

Figure A19. Predicted landings in 1999 and spawning stock biomasses in 2000 of Georges Bank cod over a range of fishing mortalities in 2000 from F=0.0 to F=0.45.

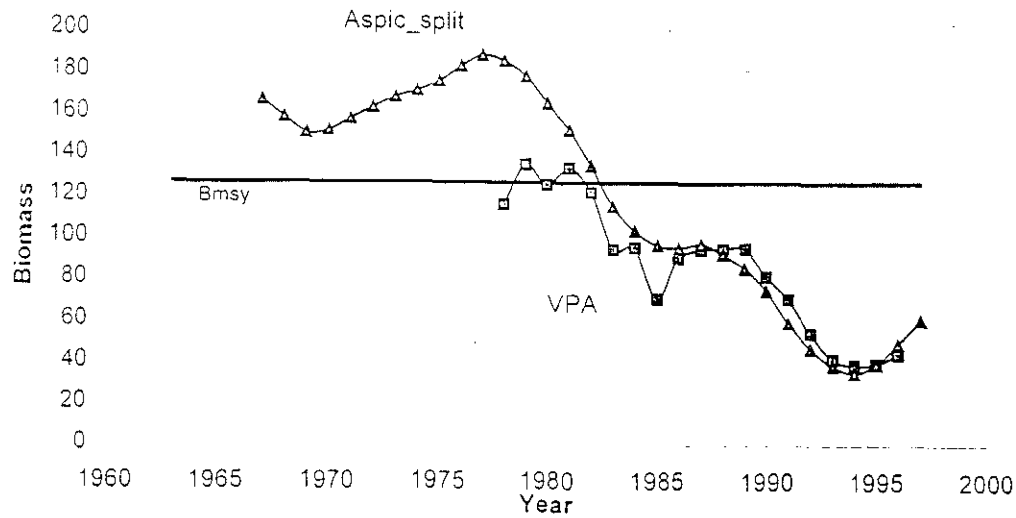

Figure A17. Mean biomass estimates from the ADAPT calibration and ASPIC using four indices.

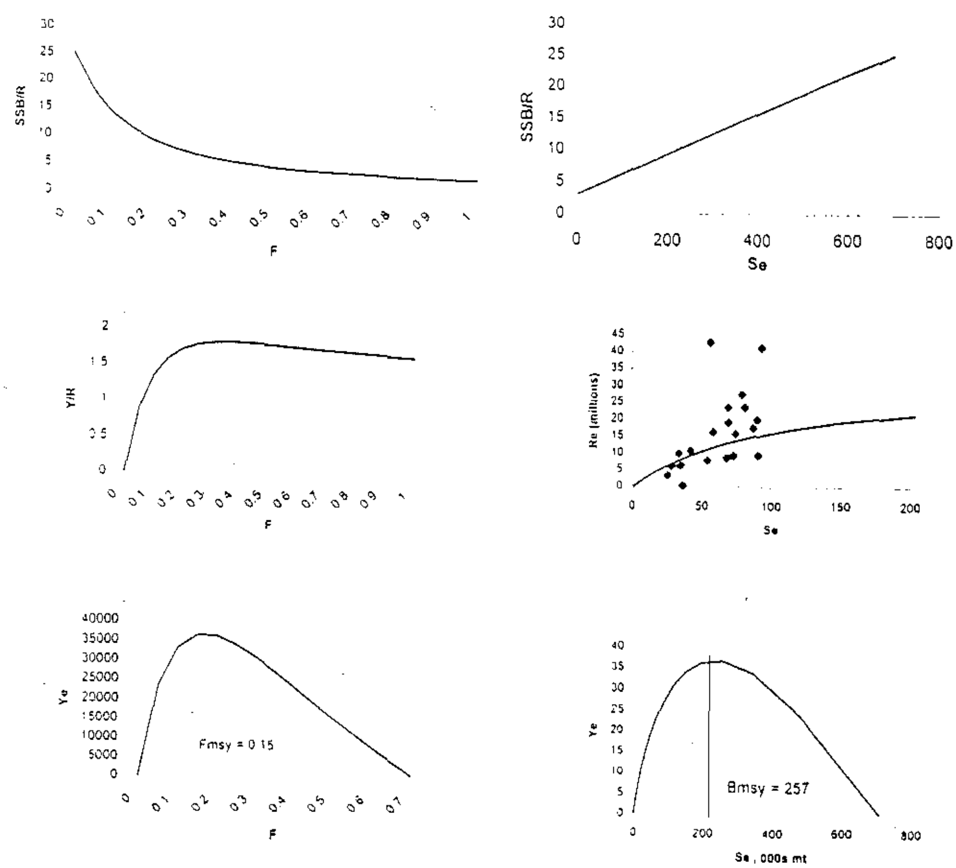

Figure A18. Equilibrium yield per recruit (Ye) and spawning stock biomass per recruit (Se) based on a Beverton-Holt model (estimated from 1978-1997 data) with estimates of Bmsy and Fmsy.

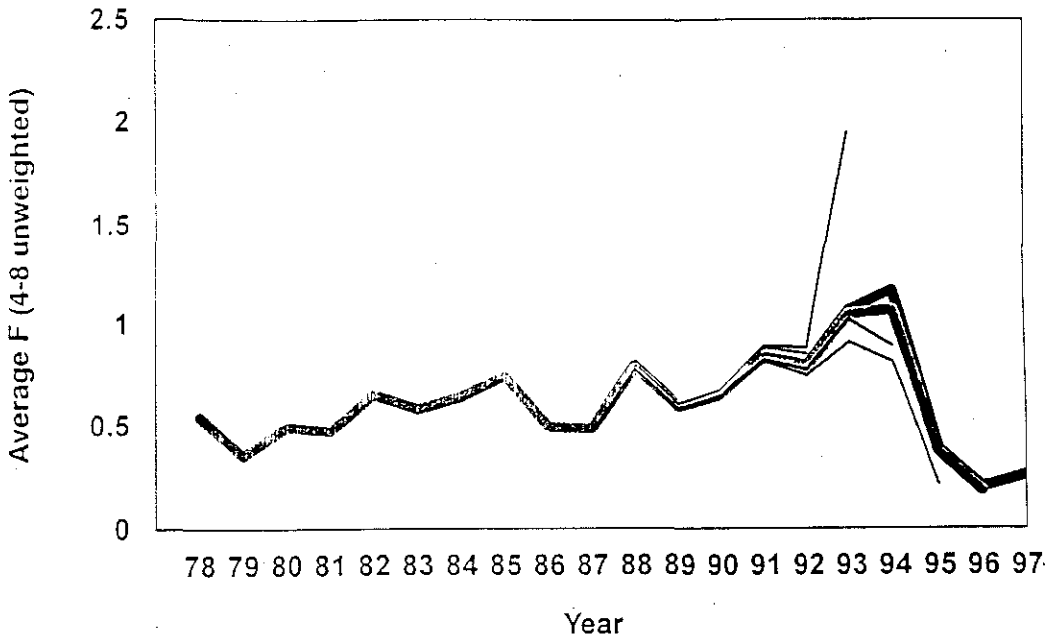

Figure A15. Retrospective analysis of Georges Bank cod fishing mortality (average F, ages 4-8, unweighted) base on the final ADAPT VPA formulation, 1997-1989.

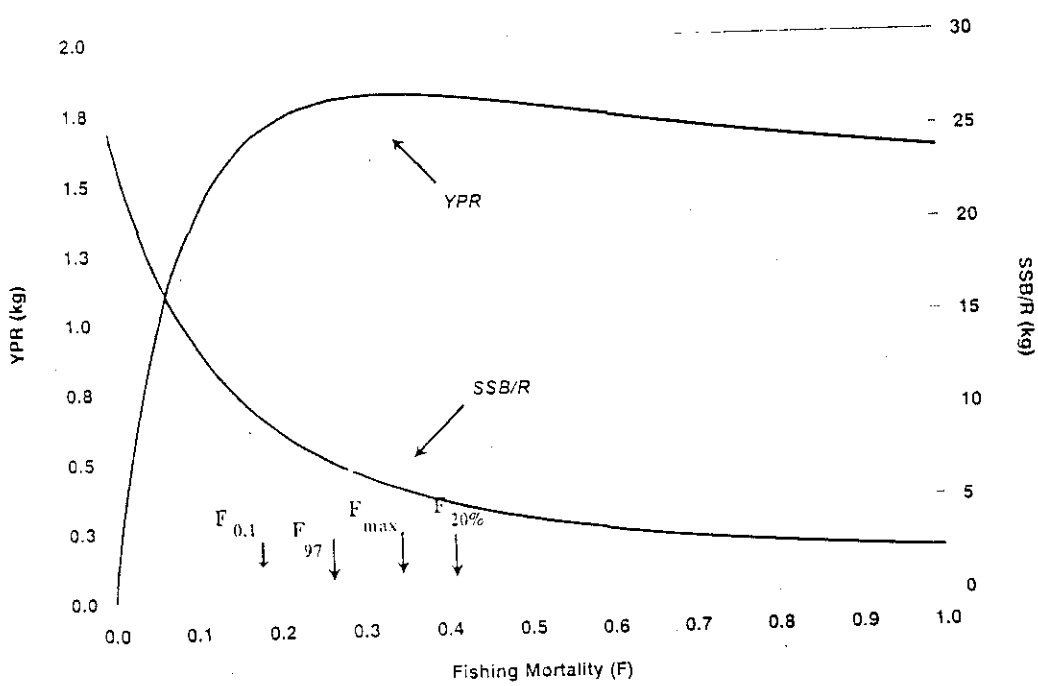

Figure A16. Yield per recruit (YPR) and spawning stock per recruit (SSB/R) for Georges Bank cod.

B. GEORGES BANK HADDOCK

Terms of Reference

a. Update the status of Georges Bank haddock through 1997 and characterize the variability of estimates of stock size and fishing mortality rates.

b. Provide projected estimates of catch for 1998-1999 and spawning stock biomass for 1999-2000 at various levels of F.

c. Review existing biological reference points and advise on new reference points for Georges Bank haddock to meet SFA requirements.

Introduction

Haddock (*Melanogrammus aeglefinus*) resources within US waters are assessed and managed as two separate stocks, one on Georges Bank and south (NAFO Division 5Z and Subarea 6), and a second in the Gulf of Maine (NAFO Division 5Y; Figure B1). These stock definitions are based on tagging studies, meristic data, age compositions, and growth data (see Clark *et al.* 1982). Haddock landed from Division 5Z and Subarea 6 comprise the Georges Bank stock (Figure B1), while haddock from Division 5Y represent the Gulf of Maine Stock. The Georges Bank stock area (5Ze) represents a transboundary resource which is exploited by both US and Canadian fisheries. The Canadian Department of Fisheries and Oceans (DFO) produces a separate stock assessment for the transboundary haddock resource on the Northeast Peak of Georges Bank. The Canadian assessment covers a subset of the US Georges Bank assessment area, including area 5Zjm, which approximately corresponds to US Statistical Areas 551, 552, 561, and 562 (Figure B1).

Commercial fisheries for haddock on Georges Bank developed during the mid-1800s as a bycatch in the cod handline fishery (Jensen 1967). After an initial development period, yields from the fishery stabilized, averaging approximately 46,000 mt annually from 1935 to 1960 (Clark *et al.* 1982; Figure B2). During the early 1960s, distant water fleets from the former Soviet Union, Spain, and other countries began to direct fishing effort toward haddock on Georges Bank. Increased fishing effort corresponded with a large 1962 year class and an exceptionally large 1963 year class and resulted in yields in excess of 100,000 mt in 1965 and 1966 (Figure B2). By 1969, landings declined well below the 1935-1960 average, and continued to decline throughout the mid-1970s (Figure B2). During the late 1970s and early 1980s, large 1975 and 1978 year classes resulting in a temporary increase in landings. During the 1980s, landings declined steadily from 27,000 mt to approximately 4,500 mt in 1989. With restrictive management measures implemented during the 1990s (Table B1), commercial landings reached a record low level of 2,300 mt in 1995, and have risen to approximately 3,600 mt 1997 (Table B2).

The US haddock fishery is currently managed under the Northeast Multispecies Fishery Management Plan administered by the New England Fishery Management Council. Commercial landings are the most significant form of fishery removals from this stock. Significant levels of regulatory discarding have been caused by US management regulations (minimum size and trip limits) during several years analyzed for this assessment, including the period since 1994. Recreational landings are generally insignificant relative to commercial landings and discards.

Management regulations have attempted to address the decline of the Georges Bank haddock resource since the early 1970s (Table B1). Seasonal area closures were first established in 1970. Although the spatial and temporal configurations for these closures have changed numerous times over the past 25 years, a general pattern of spatial and temporal expansion of closures has occurred.

Recently, a series of significant management measures have been implemented by US and Canadian management agencies resulting in significant changes in the haddock resource and it's associated fisheries. The US Department of Commerce closed two large areas on Georges Bank on a year-round basis in December 1994, and these areas have remained closed to fishing through 1997. The Canadian DFO currently closes the Canadian waters of Georges Bank to directed ground fishing from January to mid-

June. Both countries have increased the regulated mesh size in their respective fisheries. In January 1994, NMFS implemented a 500-lb/trip landings limit to discourage targeting of haddock by the commercial fishery. This trip limit was raised to 1,000 lb/trip in July 1996, and further liberalized on September 1, 1997 to 1,000 lb/day fished with a maximum of 10,000 lb/trip. In addition, days-at-sea reductions have been implemented in the US fishery to reduce overall groundfish effort. Canada has been managing Georges Bank haddock resources under an individual quota system since 1992. In addition, prohibitions on discarding of haddock, high levels of sea sampling coverage, and mandatory dockside monitoring have increased the precision of estimates of Canadian fishery removals from this stock. The combined effect of US and Canadian management measures has reduced the total fishery removals from the stock since the early 1990s.

The Fishery

US Commercial Landings

The 1997 US landings of haddock were prorated into stock areas using dealer and vessel trip report (VTR) data available at the time of assessment preparation (through March 2, 1998). Some state dealer data, including landings from the states of Connecticut and New York, were unavailable at the time that prorations were completed. Haddock landings from these states are normally insignificant relative to total landings from the stock. Since auditing and proration methodology development continue to evolve, US landings data from 1994 to 1997 are considered preliminary and subject to revision.

The 1997 proration stratification design, which included species/market category, port group, gear group, and quarter, was the same design employed to prorate 1994-1996 dealer data (Wigley *et al.* 1998). The 1997 port and gear groups are the same as used in the 1994-1996 prorations (see Wigley *et al.* 1998).

The major difference in the 1997 proration verses the 1994-1996 proration is in the identification and matching of unique trips with dealer transactions during the creation of the matched subset used in proration. During the proration of the 1994-1996 data, permit, month, day, and port were the fields used to establish an indirect link between the dealer and VTR data sets. Since then, an additional field, dealer permit number, has become available in both data sets. This information was used in the 1997 indirect link which consisted of permit, month, day, and dealer number.

Commercial landings of haddock by the US fleet were traditionally dominated by trawl gear, although other gears including hook gear, gillnets, scallop dredges, and other nets have also landed haddock historically (Table B3). US landings increased from 314 mt in 1996 to 888 mt in 1997, and total catch (landings and discards) increased from 641 mt in 1996 to 1,514 mt in 1997. Sharp increases in the total catch of haddock following liberalization of the haddock trip limit on September 1, 1997 may indicate that the US fishery is increasingly targeting haddock.

Canadian Landings

The Canadian fleet has accounted for approximately 87% of the commercial landings and 77% of the total fishery removals from the Georges Bank stock since 1993. Canadian landings are collected though a mandatory dockside monitoring program. Landings from Georges Bank are monitored by an independent observer who verifies both the landings totals for each species. Increased at-sea monitoring and mandatory dockside monitoring of landings has resulted in relatively precise data on Canadian fishery effort and landings. The majority of Canadian landings are taken by otter trawlers and longliners which are less than 65 feet. Landings shares in the Canadian fishery remain relatively constant between gears recently because quota allocations have remained stable among gear sectors.

Since 1995, restrictive quotas on Georges Bank cod have limited the ability of Canadian fishermen to catch their allocated quota of haddock. Canadian vessels are not permitted to depart on a Georges Bank trip unless they have a minimum level of both cod and haddock quota remaining. In recent years, operators have exhausted their cod quota before catching their entire haddock quota.

Commercial Discards

Through most of the assessment time period (1963-1998), discarding by the US commercial fishery is believed to have occurred at a relatively low and constant level. Observations from commercial operators and recent sea sampling (1989-1993) appear to indicate that discarding is insignificant relative to commercial landings. Discard estimates have been added to the catch at age periodically during the assessment time series when resource conditions and management actions have resulted in the generation of levels of regulatory discard significantly higher than chronic background levels. In 1974, 1977, 1978, and 1980, discarding increased sharply as three large year classes (1972, 1975, 1978) recruited to the fishery (Overholtz *et al.* 1983). The catch at age in each of these years was augmented by estimates of associated discard. More recently, the catch at age was also augmented with estimates of discards from 1994 to 1997 to account for discard mortality generated in response to trip limit regulations in the US fishery.

Discard sampling by the US sea sampling program was insufficient to estimate the quantity of discards in the Georges Bank trawl fishery (Table B4). Only 10 trips catching haddock in western Georges Bank were sampled at sea, and no trips catching haddock on eastern Georges Bank were sampled.

Information in the US vessel trip report (VTR) database on reported landings and discards was used to estimate discard weight in the US fishery in 1997 using the discard ratio method employed in the most recent US haddock assessment (Brown 1998). Briefly, this method uses the ratio of discards to landings by area and time period from the US VTR database to estimate discards for area/time period combinations. Because many operators fail to report discards, it is clear that discard reporting is incomplete in the VTR database. Only VTR records that report at least 1 lb of discards for any species are included in the discard ratio calculation. Thus, both trips with haddock landings or discards were included in the ratio calculation, unless the trip reported no discards for any species. In 1997, approximately 52% of all Georges Bank trawl trips landing haddock also reported discards for some species.

The number of VTR trips used in the estimation procedure, the number of trips exceeding the trip limit in place at the time (1,000 lb/trip from January to August 31, 1997; 1,000 lb/day up to 10,000 lb/trip from September 1 to December 31, 1997), and discard ratios for each time period and area (eastern and western Georges Bank) are summarized in Table B5. Third quarter discard ratios were estimated separately for July/August and September because the liberalization of the haddock trip limit on September 1, 1997 resulted in a significant shift in discard behavior. Between January 1 and August 31, 1997, discard rates were elevated, ranging from 43 to 452% of landings. These rates are similar to levels observed during 1994-1996 (Brown 1998). Following liberalization of the haddock trip limit on September 1, 1997, discard rates declined dramatically, ranging from 4 to 14% of landings.

There was a relatively low level of correspondence in the discard ratios estimated from limited sea sampling and the VTR database (see Tables B4 and B5). Discard ratios were higher for the Quarter 1 and July-August time period in the VTR database. The distribution of discard ratios from individual trips indicates that a large proportion of trips have relatively low discard ratios (Figure B3), and that the haddock trips with high catch rates are largely responsible for discarding behavior that elevates the overall discard ratio estimated for the fleet. The limited level of available sea sampling produced a distribution of discard ratios similar to the larger distribution observed in the VTR database (Figure B3). However, limited sea sampling failed to sample high discard trips which produce the majority of landings and discards that contribute to higher discard ratios in the VTR database.

Discarding and misreporting in the Canadian fishery are considered to be limited after 1992 with the implementation of dockside and at-sea monitoring, increased mesh size regulations, and restrictions on licensing conditions.

Total Fishery Removals

US and Canadian landings, discards, and total catch for 1996 and 1997 are summarized in Table B6. Discarding has been a significant source of fishery removals by the US fishery since 1994. The trip limit regulations have been gradually liberalized since 1994, resulting in a decline in the proportion of discards in the total US haddock catch. In 1994, discards accounted for 70% of the US fishery-induced mortality. The percentage of fishery-induced mortality accounted for by discarding declined to 51% in 1996, and 41% in 1997. Although discarding has been a significant source of mortality in the US fishery, discards represent a minor component of the total fishery removals from the stock. With inclusion of the Canadian landings, US discards accounted for 16.1% of fishery removals in 1994 and 14.7 % in 1997 (Table B6). From 1994 to 1996, approximately 75% of the discards by number and greater than 90% of the discards by weight were legal sized fish, presumably discarded in response to trip limit regulations. In 1997, the proportion of sublegal discards rose, both in response to more liberalized US trip limit regulations and the partial recruitment of the 1996 year class to the US fishery.

Recreational Fishery

Offshore charter and party boats targeting cod on Georges Bank produce some bycatch landings of haddock. However, recreational fishery landings and discards generally account for an insignificant portion of the total fishery removals from this stock. Since reliable estimates of recreational landings were not available for this stock, no estimates of recreational landings or discard were included in the catch-at-age matrix analyzed in this assessment.

US Length Frequency Sampling

Historically, length and age samples from US commercial landings were collected through the port sampling program. US commercial landings of haddock are sold and reported under market category determinations based primarily on size. Although haddock have been landed under as many as six different market categories historically, two market categories (large and scrod) account for greater than 95% of landings in recent years (Figure B4). Sampling and stratification of catch-at-age calculations by market category provides a powerful statistical stratification, reducing the sample sizes required to adequately characterize the size and age composition of landings.

Traditionally, the port sampling program produced length and age samples used to partition landings into a numerical catch at age. As landings in the US fishery have declined, the availability of fish to port samplers also declined. The implementation of trip limit regulations in 1994 resulted in a further reduction in landings, and resulting landings entered ports in small quantities that were quickly processed, making it difficult to obtain samples. Although sampling intensity (samples/landings) remained within acceptable ranges, landings declined to below the point where accepted levels of sampling intensity would produce the minimum threshold levels of sampling needed to complete catch-at-age calculations (Table B7). Only 17 haddock samples were collected from Georges Bank landings by the port sampling program from 1994 to 1996.

Sampling of the US landings remained poor for the first half of 1997, but improved markedly beginning in September 1997 with the liberalization of haddock trip limits. The number of haddock length and age samples collected during the last six months of 1997 exceeded the total number of haddock samples collected from the US fishery for the preceding three and one-half year period (Table B7). Both landings and port sampling of landings from eastern Georges Bank (Statistical Areas 561 and 562) remained poor in 1997, primarily due to low levels of fishing effort in this area.

US Port Sampling and Estimation of US Landings at Age

When sampling intensity permits, it is desirable to estimate landings at age separately for landings from eastern Georges and western Georges Bank and south (primarily Areas 521, 522, 525, and 526) to account for differences in growth rates between these two areas. Pooling of samples from eastern and western Georges Bank has been necessary during the 1990s due to limited sampling of the US landings.

The landings at age for US landings from western Georges Bank and south were estimated using US port sampling data. Landings and sampling were pooled for Quarters 1 and 2 and estimated separately for Quarters 3 and 4 (three time periods). Sampling was relatively poor during Quarters 1 and 2, but fairly robust during Quarters 3 and 4 when the majority of US landings occurred in 1997 (Table B8).

Port samples (one Quarter 2 large sample) were insufficient to characterize US landings from eastern Georges Bank (Table B7). However, proration of landings from this area estimates landings by market category, providing information on the relative size distribution of the landings from eastern Georges Bank. Two options were considered for estimating the size and age distribution of the US landings from eastern Georges Bank: 1) use Canadian length and age sampling to characterize the length and age characteristics of the US fishery; or 2) use US length frequency distributions by market category from western Georges Bank to characterize the length distribution of the eastern Georges Bank landings, and Canadian commercial age distributions to partition the landings at length into landings at age.

The use of both Canadian length and age samples was problematic because the selectivity pattern of the US and Canadian fisheries is different due to different mesh size regulations and seasonal timing of the fisheries. The US landings from eastern Georges Bank were partitioned using US length samples by market category from western Georges Bank and Canadian survey ages (Quarter 1) and Canadian commercial ages (Quarters 2, 3, and 4). Samples and landings were pooled identically to the analysis for western Georges Bank (Quarters 1 and 2 pooled, Quarters 3 and 4 separate).

Table 8 summarizes the landings (mt) by quarter and market category, and the corresponding number of lengths used to estimate the catch at length from these landings. Sampling of the scrod market category during the first half of 1997 (Quarters 1 and 2) was extremely limited resulting in a single sample of 50 lengths being used to estimate the numbers at length for 55.7 mt of scrod landings from western Georges and 7.0 mt of scrod landings from eastern Georges Bank.

US Discard Sampling and Estimation of US Discards at Age

Discard length samples were obtained from trips sampled by the US sea sampling program, although the number of trips and number of discarded haddock measured was extremely limited (Table B9). Because estimates of US discards were based primarily on discarding occurring from the trawl fleet sector, only length samples collected on trawl trips were used to estimate discard numbers at length.

Sea sampling lengths were applied to estimated US discards in all cases because no surrogate information on US discards was available. Length and discard weight data were pooled as follows: January-June, July-August, September-December) to estimate discard numbers at length. Separate estimation of the July-August and September-December periods was necessitated by the liberalization of the US haddock trip limit on September 1, 1997 resulting in a significant shift in discarding behavior. Before September 1, 1997, US discards were high relative to landings (Tables B4 and B5) and dominated by legal and marketable size fish that were discarded due to trip limit regulations (Figure B5). After September 1, 1997, the rate of US discarding declined sharply (Tables B4 and B5) and were dominated by sublegal fish that were generally smaller than either the legal or marketable size (Figure B5).

Discard age data were also insufficient to estimate discards at age. Sea sampling age data were augmented with both US spring (Quarters 1 and 2) and autumn (Quarters 3 and 4) survey and commercial age data. The use of survey ages was necessary because a significant portion of the discards occurred at lengths less than the commercial legal size and, therefore, were not represented in the commercial age sampling.

Length-Weight Relationships

US research vessel bottom trawl surveys initiated collection of individual length-weight data necessary to calculate recent length-weight relationships in 1992. Length-weight regressions were calculated using individual length and weight data collected from 1992-1996 NEFSC surveys. Spring survey data were combined to calculate regression equations for the first two calendar quarters, while autumn survey data were used to calculate regressions for the last two calendar quarters. Data were included from NEFSC survey strata consistent with those used to characterize the Georges Bank haddock stock. All regression equations were calculated from natural log transformed fork length (cm) and natural log transformed live weight (kg) using least squares linear regression. Separate regression equations were calculated for each survey for use during the appropriate half year. The resulting regression equations were:

Spring: $\text{Live wt (kg)} = 0.0000078767 * \text{length (cm)}^{3.064514}$
$R^2 = 0.993$, N = 1,159

Autumn: $\text{Live wt (kg)} = 0.0000081036 * \text{length (cm)}^{3.065053}$
$R^2 = 0.994$, N = 1,081

Catch at Age

The US catch-at-age time series from 1982 to 1997 is summarized in Table B10. Estimates of 1997 US landings and discards at age were combined with estimates of 1997 Canadian landings at age (S. Gavaris, pers. comm.) to estimate an overall 1997 catch at age for the Georges Bank (5Z & 6) assessment. In addition, minor revisions to the Canadian catch at age for 1996 were also incorporated into the assessment. The Canadian catch-at-age time series from 1982 to 1997 is summarized in Table B11. No revisions to the 1994-1996 US catch at age were attempted in this assessment, and the 1994-1997 estimates of the US catch at age are considered provisional. Catch at age for the years 1963-1993 were taken from previous assessments of the Georges Bank haddock stock (Clark *et al.* 1982; Overholtz *et al.* 1983; Hayes and Buxton 1992; O'Brien and Brown 1996; Brown 1998).

The total catch at age for the Georges Bank stock including catch from all countries for the period 1963-1996 is summarized in Table B12. Several historically large year classes including the 1963, 1975, and 1978 year classes appear to track well through the catch-at-age matrix. Catch at age during 1982-1997 has been dominated by the 1978, 1983, 1985, 1987, and 1992 year classes (Table B12), although recent year classes are contributing to the catch over several years due to lower fishing mortality rates on the stock.

Mean Weights at Age

Mean lengths and weights at age at capture were calculated for the US fishery for 1982-1997 (Table B10). Mean weights at age from the US fishery for previous years were taken from previous assessments (Clark *et al.* 1982; Overholtz *et al.* 1983; Hayes and Buxton 1992; O'Brien and Brown 1996; Brown 1998).

Mean weights of the US catch have shown several interesting trends since the early 1990s (Figure B6). The mean weight of partially-recruited year classes (primarily age 2 fish) has declined since 1992. At the same time, the mean weight of fully-recruited age classes (age 3+) appears to be increasing. These trends are evident in the commercial weights-at-age data, but are not apparent in either the US spring or autumn survey mean lengths at age (Figure B7).

Two important factors have influenced trends in the US fishery mean weights since 1994. First, mean weights of the US catch estimated since 1994 include discards, which tend to reduce the mean weight of partially-recruited ages. Second, there has been a significant temporal and spatial shift in the US fishery in response to US management actions. The US fishery has shifted from a fishery dominated by eastern Georges to western Georges Bank haddock landings (Figure B8). Growth rates of western Georges Bank haddock are slightly higher than haddock on eastern Georges Bank, resulting in a higher mean weight at age during recent years. In addition, the timing of the fishery has shifted from a fishery dominated by 1st and 2nd quarter landings, to one dominated by 3rd and 4th quarter landings (Figure B9). Fish caught later in the calendar year are heavier at age, contributing to the recent trend of larger mean weights at age.

Mean weight-at-age data for the Canadian fishery (Table B11) were taken from previous and current assessments (Gavaris and Van Eeckhaute 1998). Mean weights for the total catch at age are summarized in Table B12. Mean weights at age for the total catch at age for 1994-1996 are largely reflective of Canadian mean weights due the dominance of Canadian landings in the total catch.

Historically, fishery mean weights have been used in the Georges Bank (5Z & 6) assessment to estimate spawning stock biomass. Since fishery mean weights are normally higher than stock mean weights, this approach tends to overestimate spawning stock biomass levels. Recent shifts in fishery mean weights due to spatial and temporal shifts in the US fishery also provide motivation for using more representative values to estimate spawning stock biomass.

Stock Abundance and Biomass Indices

US Research Vessel Survey Abundance and Biomass Indices

US research vessel survey indices of abundance (stratified mean number per tow) and biomass (stratified mean kg per tow) were estimated from both the NEFSC spring and autumn bottom trawl surveys during 1963-1997 (Table B13; Figure B10). Survey indices included catch data from stations occupied within NEFSC offshore strata 01130-01250 and 01290-01300 and having suitable station (=1), haul (≤3), and gear (≤6) values. The survey indices were adjusted for differences in fishing power of the *Albatross IV* and *Delaware II*, and for differences in the catchability of BMV doors (used before 1985) and the polyvalent doors introduced in 1985 (Forrester *et al.* 1998). Table B14 summarizes the factors applied to each survey. In the US spring survey, a different net (Yankee 41 trawl) was used in the 1973-1981 surveys than in other years (Yankee 36 trawl). No adjustment factors were estimated for this gear adjustment (Sissenwine and Bowman 1978).

Spring and autumn indices of abundance and biomass exhibit similar trends throughout the time period (Figure B10). Indices declined from record high levels in the early 1960s to low levels in the early 1970s. Relatively strong 1975 and 1978 year classes are reflected by temporary increases in survey indices. Survey indices declined again in the early 1980s and remained at low levels until the early 1990s. Recent indices since 1994 appear to indicate some increase in haddock abundance, although indices have yet to demonstrate a consistent upward trend.

Age-disaggregated survey abundance indices (stratified mean number per tow) for ages 1-8 from the spring survey and ages 0-8 from the autumn survey were available as tuning inputs in the stock assessment. The adjusted stratified mean catch/tow (numbers) are presented for the US spring and autumn surveys in Tables B15 and B16, respectively. Age 0 and 1 indices from the autumn survey and age 1 indices from the spring survey provide an indication of strong year classes of haddock (Figure B11). The strong 1963, 1975, and 1978 year classes are readily apparent in age 0+ and age 1 indices (Figure B11), and track strongly through the age-disaggregated matrix of survey abundance (Tables B15 and B16).

Canadian Research Vessel Survey Abundance Indices

DFO Canada initiated a bottom trawl survey on Georges Bank in 1986. Indices of abundance for the Canadian spring research vessel survey from 1986 to 1997 are summarized in Table B17. Recent dominate year classes (1985, 1987, 1992) appear to track strongly through the age-disaggregated matrix of Canadian spring survey abundance (Table B17). Additional details of this survey are provided in Gavaris and Van Eeckhaute (1998).

Correspondence between Surveys

Normalized (ln obs/mean) survey indices of abundance at age were plotted for the four survey series at each age (ages 1-8) to be estimated in the VPA (Figures B12a and b). There was a close correspondence in the trends of normalized survey indices at age for younger ages, but relationships were less clear for older ages.

Natural Mortality and Maturity

Natural Mortality

As in previous assessments of this stock (O'Brien and Brown 1996, Brown 1998, Gavaris and Van Eeckhaute 1997), the natural mortality rate was assumed to be 0.2. The presence of haddock in excess of 15 years of age in both the US and Canadian research vessel surveys is consistent with this assumption for natural mortality.

Maturity Ogives

A logistic regression approach (O'Brien *et al.* 1993) was used to calculate maturity-at-age relationships for each year from 1985 to 1997. Maturity data from adjacent years with similar relationships were pooled, and subsequent logistic regression relationships were calculated for pooled time periods. Based on this approach, maturity relationships were calculated for four time periods: 1985-1989, 1990-1992, 1993-1994, and 1995-1997. Table B18 summarizes the percent maturity of female haddock at age for the entire time period used to estimate spawning stock biomass (SSB) in this assessment.

Estimates of Stock Size and Fishing Mortality

Virtual Population Analysis Tuning

The ADAPT virtual population analysis (VPA) calibration method (Parrack 1986; Gavaris 1988; Conser and Powers 1990) was used to estimate terminal stock abundance for ages 1-9+ and derive age-specific estimates of fishing mortality in 1997 and beginning year stock sizes in 1998. The catch at age in the VPA consisted of combined US, Canadian, and distant water fleet landings for 1963-1997 for ages 1-8 with a 9+ age group. The indices used to calibrate the VPA included both the US and Canadian spring research vessel survey catch (numbers) at ages 1-8 and the US autumn survey catch (numbers) at ages 0-8 lagged forward one age and one year. Final assessments runs were made incorporating catch at age information from the 1931-1962 period (from Clark *et al.* 1983) to estimate stock numbers, spawning stock biomass, and fishing mortality for 1931-1997. No tuning indices are available before 1963.

Three principal VPA calibrations were produced in preparation for and during the Transboundary Assessment Working Group (TAWG) meeting (Table B19). The first (Run 14) was a run based on the accepted run from the 1997 US assessment of Georges Bank haddock (Brown 1998) which included the following tuning indices: US spring 1-8 (all years 1963-1997), Canada spring 1-8, US autumn 0-8 (lagged forward one year and one age). Diagnostics for this run were similar to the 1997 US assessment with relatively high CVs on age 1 (0.62) and age 2 (0.39), and CVs ranging from 0.25 to 0.31 for the remaining ages. Summaries of other key diagnostics including sums of squares, mean squared residuals, CVs on *q*s, standardized residuals >2, and maximum partial variance are given in Table B19. The inclusion of US autumn indices for ages 6-8 (lagged forward to ages 7-9) was questioned during the evaluation of the 1997 assessment, given the large numbers of zero observations for these ages in the time series.

A second VPA run (Run 15) was produced that removed the US autumn indices for ages 6-8 (lagged forward to ages 7-9) as tuning indices. The diagnostics for this run were analogous to the first run, with the exception of lower total sums of squares and slightly lower mean squared residual values. Terminal year results for this run were largely unaffected by the exclusion of older age indices from the US autumn survey.

In the Canadian assessment of Georges Bank haddock, the assessment detected a significant difference in the *q*s in the US spring survey at all ages between a time series containing the years 1968-1972 and 1982-1997, and the period 1973-1981. A similar pattern of higher survey *q*s was noted for the US assessment (Figure B13). The period 1973-1981 is of interest because, during these nine years, a Yankee 41 trawl net was substituted for the Yankee 36 trawl net that was used during the years prior to and after the 1973-1981 time period. Although some experimental studies were conducted to assess the relative catchability between the two nets (Sissenwine and

Bowman, 1978), data were insufficient to assess the relative catchability of haddock in the two nets (as was previously assessed for changes in vessels and doors). Relatively catchabilities in the US assessment were consistently higher at age, consistent with the observation that the Yankee 41 trawl was both wider and higher rising than the Yankee 36 trawl.

To address concerns about the relative catchability in the US spring survey between these two time periods, a third VPA calibration was conducted treating the times periods employing different trawl gear as separate surveys (Run 17). The third calibration was tuned with 30 indices at age: US spring ages 1-8, 1968-1972, 1982-1997 (Yankee 36 trawl years); US spring ages 1-8, 1973-1981 (Yankee 41 trawl years); US autumn ages 0-5 (lagged forward one age and one year), and Canada spring ages 1-8. The diagnostics for this run were similar to the first two calibrations with slightly lower sums of squares and mean squared residuals (Table B19). The relative impact of the changes on the terminal year results was negligible, but some improvement in the residual patterns for the affected years was noted. The TAWG selected this VPA calibration (Run 17) as the preferred assessment formulation.

At the TRAC meeting, concern was expressed about the reliability of discard estimates at age for both the most recent time period (1994-1997) and earlier time periods (1974-1980). To address these concerns, two sensitivity VPA runs were completed: the first excluded discards from the most recent time period (1994-1997), while the second excluded discards from the 1974-1980 and the current (1994-1997) time periods. The diagnostics for these sensitivity runs were similar to the accepted run (Run 17), and the exclusion of discards had a negligible effect on the terminal year results. Since discards were known to have occurred at significant levels during these two periods, the VPA calibration that included discards (Run 17) was accepted as the preferred assessment formulation.

VPA Diagnostics

The diagnostics from the accepted VPA (Run 17) were similar to those from the accepted 1997 assessment for this stock. The CVs on ages 1 and 2 are relatively high (0.61 and 0.39, respectively), but range from 0.25 to 0.31 for older age classes (Table B19). The maximum partial variance (2.433) occurs on the US spring Yankee 41 age 1 index (years 1973-1981). The CVs on estimates of survey *q*s ranged from 0.15-0.34 and were generally inversely related to the length of the time series for each survey.

There were 25 residuals with values greater than 2.0 in the accepted assessment. Standardized residuals for all four survey series were plotted in Figures B14a and b. Residual patterns were generally random, although year effects across ages were apparent in some instances (e.g., 1996 US spring survey at all ages).

VPA Results

The assessment results indicate that stock numbers ranged between 350 and 725 million fish during the early 1960s and declined rapidly to 16 million fish by 1971 (Table B20). Improved recruitment from three strong year classes (1972, 1975, 1978) resulted in a temporary increase in stock numbers to 133 million fish in 1979, but stock numbers declined to less than 25 million by 1983. Stock numbers remained stable during the mid 1980s, but declined to a record low of 15 million fish in 1991. Stock number increased again in the early 1990s and, with the exception of 1997 (large numbers of age 1 haddock), appear to have stabilized at approximately 37 to 40 million fish.

Spawning stock biomass (SSB) was estimated to be approximately 150,000 mt in the early-to-mid 1960s, but declined sharply reaching a low of 12,000 mt in 1973 (Table B21; Figure B15). SSB increased with improved recruitment in the 1970s reaching 69,000 mt in 1978, but declined to approximately 20,000 mt by the mid 1980s. SSB remained stable at this level until it began to decline in the early 1990s reaching record low levels of 12,000 mt in 1993. Since 1993, SSB has increased steadily reaching 40,500 mt in 1997.

Increases in spawning stock biomass since 1994 have occurred primarily as a result of broadening the age distribution of the adult stock. Stock numbers have remained relatively constant since 1993, but the age distribution of the adult stock has broadened by roughly one age per year since 1993 (Figure B16). Low total mortality rates are largely responsible for the higher numbers of haddock at older ages.

Age 1+ mean biomass was estimated to exceed 200,000 mt in the mid-1960s, but declined rapidly to 25,000 mt by 1973 (Table B22). Mean biomass increased in the mid-1970s reaching 104,000 mt in 1977, but declined below 50,000 mt by 1983. During the mid-1980s to early 1990s, mean biomass declined gradually reaching an assessment low level of 19,500 mt in 1992. Biomass has increased steadily since 1992 and was estimated at almost 53,000 mt in 1997.

Fishing mortality ranged between 0.32 and 0.61 during the 1960s and 1970s before declining below 0.20 in the mid 1970s (Table B23; Figure B17). Fishing mortality increased in the late 1970s and ranged between 0.32 and 0.45 from 1979 to 1991. In 1992 and 1993, fishing mortality increased sharply exceeding 0.50. Since 1993, fishing mortality has declined below the target fishing mortality rate ($F_{0.1}$ = 0.24 - 0.28) for this stock. The terminal year (1997) estimate is the lowest average fishing mortality rate estimated for this stock since 1974.

Precision of F and SSB Estimates

Uncertainty and potential bias of estimates were assessed using bootstrap analysis of the VPA calibration. One thousand bootstrap realizations were produced by randomly resampling survey residuals produced by the original calibration. Bootstrapped abundance estimates had slightly larger CVs than the least squares estimates produced by the original calibration. Estimates of bias were large on ages 1 (24.88%) and 2 (12.44%), but were less than 4% for older ages. Estimates of survey *q*s were comparable with those produced in the original VPA calibration. Bias corrected estimates of stock size for ages 2-8 were well estimated, with CVs ranging from 0.15 to 0.42; however, the CV for age 1 was relatively high (0.71). SSB was also well estimated with a CV of 0.15.

The distribution of bootstrap realizations of SSB suggests that there is an 80% chance that the 1997 SSB was between 34,200 mt and 48,100 mt (Figure B18a). There is a 0% chance that SSB has exceeded the US management threshold biomass level of 80,000 mt. The distribution of bootstrap realizations of fishing mortality suggests that there is an 80% chance that F_{97} was between 0.098 and 0.122 (Figure B18b). There is a 0% chance that F_{97} exceeded the management target of $F_{0.1}$ (0.26 as estimated by Brown 1998).

Retrospective Analysis

Retrospective analyses of the Georges Bank haddock VPA were performed from 1997 back to 1991. Given the short time period of the tuning indices from the Canadian survey, no analysis was attempted prior to 1991 to provide a minimum 5-year time series of Canadian survey indices. The ADAPT procedure was formulated to estimated ages 1-8 in the terminal year, and unweighted mean fishing mortality was estimated for ages 4-7.

Retrospective patterns for fishing mortality (Figure B19) were similar to those observed in the last assessment of this stock (Brown 1998) with fishing mortality consistently overestimated in the terminal year of the assessment during the early 1990s. This pattern began to shift in 1994, and by 1995, it appears that fishing mortality was relatively well estimated in the terminal year. The retrospective pattern indicates that spawning stock biomass was slightly, but consistently underestimated for terminal years from 1991 through 1994 (Figure B19). Consistent with the trend observed for fishing mortality, there was a shift in the retrospective pattern in 1995, with spawning stock biomass being relatively well estimated in the terminal year. The shifts in the retrospective patterns for fishing mortality and spawning stock biomass correspond with reduced catch and corresponding exploitation rates occurring between 1994 and 1995.

Retrospective patterns were analyzed further by examining patterns in the estimate of age 1 stock abundance for year classes from 1983 to 1996 (Figure B20). The 1983-1991 year classes tend to produce stable terminal year estimates due to the convergent properties of the VPA. Patterns for the 1992 to 1996 year classes were less stable. Retrospective patterns for these year classes were highly correlated with one another, with higher estimates in the 1994 and 1996 assessment years (1993 and 1995 indices), and lower values occurring in the 1995 and 1997 assessment years (1994 and 1996 indices). This pattern would be consistent with interannual shifts in catchability of research vessel surveys used as tuning indices in the VPA calibration. Age 1 estimates of the 1995 year class dropped more than 60% from 23 million fish (1995 terminal year) to less than 9 million fish in the 1996 terminal year assessment.

Biological Reference Points

Yield per Recruit

A yield-per-recruit analysis (Thompson and Bell 1934) was performed during the 1997 assessment and has not been revised in the current assessment. Results of these analyses indicate that $F_{0.1} = 0.26$ and the overfishing definition currently defined by the Northeast Multispecies Fishery Management Plan ($F_{30\%}$) is 0.45 (Table B24; Figure B21). Estimates of F_{max} are considered to be unreliable because of the asymptotic nature of the yield-per-recruit curve at high F levels.

Sustainable Fisheries Act Reference Points

One of the current challenges for the management of marine fish and shellfish species is the determination of maximum sustainable yield (MSY) reference points, as outlined in the reauthorization of the Sustainable Fisheries Act (SFA). To comply with the SFA and the proposed National Standard 1 guidelines, overfishing definitions must contain, at a minimum, the following six elements that define management targets and thresholds:

1. *Status determination criteria*: Objective and measurable means of determining the condition of the stock and the amount of fishing mortality should be specified in the overfishing definition.

2. *Maximum fishing mortality threshold*: A maximum fishing mortality threshold ($F_{threshold}$) may be expressed either as a single number or as a function of spawning biomass or other measure of productive capacity.

3. *Minimum biomass threshold*: A minimum biomass threshold ($B_{threshold}$) is required to determine when a stock is in an overfished condition.

4. *Biomass target*: A biomass target (B_{target}) should be specified that would allow the fishery to achieve MSY on a continuing basis.

5. *Optimum yield (OY)*: OY may be expressed in numbers of fish, weight of fish, or as a formula that converts periodic stock assessments into target harvest levels. Applying the precautionary principal for fisheries management, OY should always be less than MSY.

6. *Maximum rebuilding time period*: If a stock is overfished, management must specify a time period for rebuilding that is as short as possible, taking into account the biology of the stock. In no case, should the time frame for rebuilding exceed 10 years.

A dynamic shift in productivity of Georges Bank haddock is problematic for estimation of overfishing reference points based on maximum sustainable yield. Despite the availability of a long time series of relatively precise stock assessment information, conventional methods have been largely unsuccessful in providing reliable estimates of overfishing reference points. Results from several approaches are summarized to provide advice on new reference points to meet SFA requirements.

Landings, stock biomass, spawning biomass, and recruitment of Georges Bank haddock were relatively stable at high levels from 1930s to the 1950s (Figures B2, B15, and B17). Two extremely abundant year classes (1962, 1963) led to increased catch and biomass in the early 1960s. Following this productive period, recruitment, stock biomass, and catch declined significantly and have remained at low levels for the past three decades.

Stock-Recruit Methods

Spawning stock and recruitment data are discontinuously distributed into two periods: high SSB and

R (1931-1967) and low SSB and R (1968-1995). A bivariate cluster analysis discriminated the two distinct regions, with 75% confidence regions of 70,000-110,000 mt for the high SSB period and less than 70,000 mt for the low SSB period (Figure B22). Overholtz *et al.* (1998) used the latter period to fit a SSB-R relationship because attempts to fit a single relationship to the entire time series had problems with significant parameters, convergence, and unreasonable results. Stochastic projection of the short-term SSB-R relationship suggest that biomass can slowly rebuild at $F_{0.1}$ (currently estimated at 0.26).

Using the short-term SSB-R relationship and the yield- and SSB-per-recruit estimates in NEFSC (1997), age-based production calculations (described in Mace 1994), suggests that MSY = 10,000 mt, SSB_{msy} = 80,000 mt, and F_{msy} = 0.38 (Table B25). However, F_{max} was not well defined and F_{crash} approaches infinity. Furthermore, this result is inconsistent with assessment results that suggest that the stock sustained yields of 20,000-60,000 mt at SSB levels of 70,000-100,000 mt for three decades (1931-1960).

Cook (1998) analyzed the recent SSB-R data from the eastern portion of Georges Bank (1963-1996) and found no obvious SSB-R relationship. A fitted LOWESS smoother failed to demonstrate a relationship and resulted in a flat-topped production curve, similar to the analysis described above. In contrast to the projections by Overholtz *et al.* (1998), simulations by Cook (1998) indicate that SSB will fluctuate at approximately 25,000 mt even at low F (0.2), and there is low probability that SSB will increase to 80,000 mt at $F_{0.1}$. These analyses indicate that $F_{0.1}$ may be an adequate long-term target for management, but may not be an appropriate target to promote rebuilding.

Biomass Dynamics Methods

Fitting a logistic Schaefer model to the Georges Bank haddock data is also difficult. Spencer and Collie (1997) obtained plausible parameter estimates with a highly constrained model applied only to recent data (1976-1993; Figure B23). Similar to the age-based results, estimates of MSY and B_{msy} were well below historically sustainable levels (Table B25).

Spencer and Collie (1997) could only fit a linear biomass-yield relationship to the entire time series of biomass and landings. The MSY and B_{msy} estimates were unrealistically high. Fitting just the historical data (1931-1963) to a Schaefer model produces similar results (Figure B23, Table B25).

Spencer and Collie (1997) fit a production model with a nonlinear predation rate to the entire time series. The model fit the data reasonably well (Figure B23), but produced estimates of MSY and B_{msy} that were rarely observed (Table B25). The estimate of MSY (70,000 mt) was only exceeded in two years, and the estimate of B_{msy} (250,000 mt) was only exceeded in five years. An overfishing definition based on the nonlinear predation rate model would be problematic because there are multiple equilibrium yields at F_{msy} that range from 5,000 to 70,000 mt.

Dynamic Pool Methods

The TRAC recommended that proxies may have to be used to meet SFA guidelines (DFO 1998). One suggested proxy was applying an average recruitment from a specified period to yield-per-recruit and biomass-per-recruit estimates. Under the assumptions that $F_{0.1}$ is sustainable (as indicated by ICES 1997, Overholtz *et al.* 1998, and Cook 1998), and mean recruitment from 1931 to 1961 represents the level which produces MSY, MSY = 60,000 mt, B_{msy} = 375,000 mt, SSB_{msy} = 290,000 mt, and F_{msy} = 0.26 (Table B25). Estimates of biomass and SSB which can produce MSY are much greater than the levels observed in the same period (1931-1961) because the current exploitation pattern is substantially delayed compared to historical patterns.

Descriptive Methods

The TRAC also recommended that MSY proxies may be based on historical estimates of biomass and yield (DFO 1998). Assuming that mean 1931-1961 levels of observed yield and estimated stock size approximate MSY conditions, MSY = 46,000 mt, B_{msy} = 160,000 mt, and SSB_{msy} = 105,000 mt. Implicitly, F on total biomass during this period was 0.29, which may not apply to the current exploitation pattern. Therefore, historical levels of F may not be an appropriate proxy for F_{msy} because selectivity patterns were much different than the current fishing patterns.

Reference Points and Control Rule

Estimating MSY reference points may not be possible for this stock because of the apparent shift in productivity (DFO 1998). However, attempts to derive MSY proxies from historical data are hampered by a change in exploitation pattern from the historical period to current conditions.

The following MSY-based reference point proxies are proposed. Based on the historic period of sustainability, SSB_{msy} may be approximately 105,000 mt. It appears from age-based simulations (ICES 1997, Overholtz *et al.* 1998, Cook 1998) that $F_{0.1}$ may be an appropriate proxy for F_{msy}, but lower levels are required to rebuild the stock. The discontinuity in paired SSB-R observations suggests that it is desirable to maintain SSB levels greater than 68,000 mt. By analogy to other stocks with F_{msy} of approximately 0.26, Georges Bank haddock is expected to have the capacity to rebuild from ½B_{msy} in 10 years or less.

A control rule based on proxies to MSY-based reference points can be derived from these analyses (Figure B24). When SSB is greater than 105,000 mt (1931-1961 historical average), the overfishing limit is $F_{0.1}$ (0.26), and the target F is 75% of the F_{msy} proxy (0.20; as proposed by Restrepo *et al.* 1998). To avoid low levels of recruitment, the limit F decreases linearly from 0.26 at 105,000 mt SSB to zero at 52,500 mt SSB (½SSB_{msy}), and the target F decreases linearly from 0.20 at 105,000 mt SSB to zero at 68,000 mt SSB. The most current estimates of SSB and F_{97} indicate that F exceeds the rebuilding limit, indicating that the stock is overfished.

Short-Term Projections

Short-term stochastic projections were performed for 1999 and 2000 projecting for three scenarios of fishing mortality in 1998 (F = 0.00, *status quo* F_{97} = 0.11, $F_{0.1}$ = 0.26; Table B26). Terminal stock size estimates for the terminal year of the assessment were assumed, and fishing mortality in 1998 was assumed to remain constant at F_{97} = 0.11. Projections were based on a partial recruitment vector estimated as the geometric mean of the 1995-1997 Fs from the final VPA calibration, arithmetic mean of 1994-1996 stock and catch weights, and pooled median maturity at age estimates for 1995-1997. Discard proportions at age were estimated at the geometric mean of discard proportions from 1995-1997, and mean weights were estimated as the arithmetic mean of mean discard proportions for 1995-1997. Age 1 recruitment for the 1997-1999 year classes was estimated by resampling of observed age 1 recruitment from the 1979-1996 year classes.

Projection results indicate that, in the absence of fishery removals for 1999 (i.e., F_{99} = 0.00), SSB would increase to 58,700 mt in 1999 and 63,400 mt in 2000 (Table B26; Figure B25). Under this scenario, there would be an 80% probability that the SSB in 2000 would range from 51,800 to 77,600 mt, and approximately a 7% chance that SSB would exceed the US management threshold of 80,000 mt.

Projection results indicate that, under the *status quo* F_{97} = 0.11 scenario, SSB would increase to 57,400 mt in 1999 and decline to 56,900 mt in 2000 (Table B26; Figure B25). There is an 80% probability that SSB in 2000 would range from 46,300 to 70,000 mt, and less than a 2% chance that SSB would exceed the US management threshold of 80,000 mt. At *status quo* F, US and Canadian landings are projected to rise to 4,600 mt in 1999. There is an 80% probability that landings would range between 3,800 and 5,300 mt in 1999. Under the *status quo* F_{97} scenario, median discard levels from the US fishery in 1999 would be approximately 600 mt.

Projections results indicate that under an $F_{0.1}$ = 0.26 scenario, spawning stock biomass will rise to 55,600 mt in 1999 and decline to 49,200 mt in 2000 (Table B26; Figure B25). There is an 80% probability that SSB in 2000 would range from 39,800 to 61,000 mt, and a 0% chance that SSB would exceed the US management threshold of 80,000 mt. The median value of the projected 1999 landings is 10,100 mt, and there is an 80% probability that 1999 landings would range between 8,500 and 11,800 mt. Under the $F_{0.1}$ scenario, median discard levels from the US fishery in 1999 would be approximately 1,400 mt.

The decline in SSB at relatively low fishing mortality rates occurs because of relatively poor recruitment in recent years relative to recruitment of previously-conserved year classes that currently comprise the majority of the spawning stock biomass. Much of the rebuilding in SSB since 1993 has been due to somatic growth of conserved year classes rather than any significant improvement in recruitment. Further increases due to growth of conserved year classes is unlikely because production is likely to level off as losses of SSB from natural mortality and low rates of fishing offset any gain in biomass due to somatic growth as fish grow older. SSB levels can be stabilized or slightly increased between 1999 and 2000 only if fishing mortality is maintained at very low levels (less than 0.11).

Comparison of the US Assessment of 5Z with the Canadian Assessment of 5Zjm

Georges Bank haddock is a transboundary resource that is currently managed by both the United States and Canada. Each country defines the different fishery management units for which stock assessments are prepared. The US assesses and manages the Georges Bank haddock resource as a unit area, where the primary area of concentration includes all of NAFO Division 5Z (US Statistical Areas 521, 522, 525, 526, 551, 552, 561, and 562. For management purposes, Canada defines a management area that encompasses the Northeast Peak concentration of haddock in NAFO Subdivision 5Zjm (US Statistical Areas 551, 552, 561, and 562). Thus, the Canadian management unit is a subset of the larger US management unit. Both the US and Canadian management units include waters within the other country's jurisdiction.

Recent management measures including Canadian TACs, US area closures, and increases in regulated mesh size and effort control strategies in conjunction with improved recruitment have resulted in improved biomass and reduced F on both components of the resource. Discard rates associated with restrictive US trip limits have increased, but overall US catch has declined substantially. Surveys and special sampling of Closed Area 1 in US waters indicate some increase in haddock resources in the Great South Channel area.

To place assessment results of US and Canadian assessments on a comparable basis, the VPA results from the US survey were bias corrected and a deterministic VPA was run using bias-corrected, terminal-year stock sizes. Stock numbers and SSB estimates were calculated using ages 1-8 (excluding the age 9 plus group) to be consistent with Canadian assessment results. SSB estimates were calculated using Canadian survey mean weights to scale biomass estimates to the Canadian assessment.

A comparison of catch from the two management jurisdictions indicates that the majority of the Bank-wide catch has come from eastern Georges Bank (5Zjm) in the management area common to both assessments (Figure B26). This result is consistent with both US and Canadian survey results which indicate that the majority of the haddock resource has been concentrated in this area since the mid 1980s. Long-term trends in fishing mortality are consistent between the assessments (Figure B27). Both assessments show initial high levels of fishing mortality declining to low levels in 1974, and then gradually increasing through the 1980s. Fishing mortality increased sharply in the early 1990s, and then declined below 0.20 in 1995, 1996, and 1997 in both assessments.

Recruitment patterns are also consistent between the assessments, with both indicating large 1975 and 1978 year classes and moderately-sized 1983, 1985, 1987, and 1992 year classes (Figure B28). Estimated age 1 recruitment in both assessments indicates that year classes after 1992 are relatively weak, except that both assessments estimate that the 1996 year class is approximately 13 million fish at age 1.

A comparison of total age 1+ biomass trends shows a consistent overall pattern between the assessments (Figure B29). Both assessments indicate a decline in stock biomass in the late 1970s, some resurgence in the mid 1970s, a gradual decline through the early 1990s, and an increase since 1992. The US assessment consistently estimates a larger stock biomass because it includes a larger management area. Biomass in the two assessments converges following the mid 1970s as haddock resources on western Georges Bank (included only in the US assessment) declined to very low levels. The slight divergence in biomass between the two assessments in the most recent years may be interpreted as an indication of some stock rebuilding in the western part of Georges Bank. This observation is consistent with both US and Canadian survey results indicating high densities of haddock inside Closed Area 1.

If stock rebuilding is occurring in the Great South Channel area in the western part of Georges Bank, US and Canadian assessment results would be expected to diverge in the future. Both countries have adopted a management objective to fish the Georges Bank haddock resource at a level at or below $F_{0.1}$. Current assessment results are similar, and resulting short-term management advice can be expected to be consistent between countries in the near future.

SARC Comments

It was suggested that the stock may be exhibiting a lower biomass equilibrium than occurred during the 1931-1960 period. If this is true, it may not be possible to achieve significantly improved recruitment needed to rebuild stock biomass to Amendment 7 or MSY-based targets. However, if stock rebuilding is not attempted, it will never be known if biomass targets are attainable. In the 1931-1960 period and in the period of biomass increase in the late 1970s, the proportion of stock biomass and recruitment contribution of the western component (Nantucket Shoals) was significantly higher than during the current period. Some evidence of rebuilding of the western component is apparent, and this will likely contribute to improved future recruitment.

A question was asked about how $F_{0.1}$ compares to F_{med} in the last ten years. F_{med} from the 1980s was probably around 0.05; however, recent survivorship based on log (R/SSB) has improved and is now equal to that found during the 1931-1960 period.

The SARC discussed the use of age 1 vs age 2 stock numbers as a measure of recruitment. Relatively poor estimates of discarding may have led to proportionally higher numbers at age 1. It was noted that the age composition of discards is fundamentally different between discards occurring in the 1970s and in the 1990s. In the 1970s, discards were comprised primarily of age 1 and 2 fish discarded in response to minimum size limits and market acceptance. In the 1990s, discards occur across the age structure in response to trip limit regulations.

The SARC questioned the confidence in SSB estimates for the period prior to research vessel surveys (1931-1963). A conclusion was reached that, although fishery-independent surveys were unavailable to tune the assessment before 1964, sampling of commercial landings was extremely robust and the resulting estimates of stock size are reliable.

Research Recommendations

- Improve the spatial and temporal coverage of biological sampling of commercial landings and discards. An increase in sea sampling coverage is needed to better characterize the discard portion of the catch. Alternative sampling designs for gathering biological information should be investigated.
- Estimate and use fishery-independent weights (vs fishery catch weights) to estimate population parameters including spawning stock biomass.
- Further investigate trends in survey catchability associated with gear changes in the US spring research vessel survey.
- Examine the effects of treating zero values in the survey data as missing values and develop methods that include these data.
- Explore the use of multinomial error structure in the catch-at-age matrix.
- Investigate the impact of fixing the F on terminal ages.

- Investigate the use of alternative ratio estimators to estimate the magnitude of haddock discards occurring in the US fishery.

Conclusions

The Georges Bank haddock stock remains in an over-exploited condition based on the current low level of biomass in relation to management rebuilding thresholds and pre-collapse stock levels. Fishing mortality has been reduced, and F_{97} (0.11 or 9% exploitation) is below the $F_{0.1}$ rebuilding target established in US rebuilding plans and is approximately equal to the $½F_{0.1}$ rebuilding target proposed by Canadian management interests. The age structure of the population is continuing to expand, and the age 4+ biomass is at its highest levels since 1983. Spawning stock biomass in 1997 was estimated to be 40,500 mt, approximately half of the 80,000 mt stock rebuilding threshold. Although the 1994-1996 year classes appear to be moderate relative to recruitment observed in the past decade, this recruitment level is far below average levels when the stock was in a healthy condition. The 1996 year class, currently estimated at 13.8 million fish at age 1, will result in continued increases in SSB through 1999. Increases in SSB after 1999 will only occur if recruitment levels are singificantly higher than have been observed over the past decade.

Observed increases in spawning stock biomass of Georges Bank haddock have resulted from conservation of a series of relatively weak year classes. This is a necessary first step in the stock rebuilding process. Significant rebuilding beyond projected 1999 stock levels will require improved recruitment significantly higher than levels observed in the past decade. To date, there are no indications in the survey data to suggest that incoming recruitment has improved significantly. The expanded age distribution of the current spawning population may enhance future recruitment prospects if paired with favorable environmental conditions. Significant stock rebuilding will only be achieved when significant and consistent improvement in recruitment is realized. Until this occurs, restrictive management practices will continue to be necessary to maintain fishing mortality rates on this stock at very low levels.

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Table B1. Significant changes in management regulations governing the US commercial fishery for haddock.

1953-1977		ICNAF Era
1953		Minimum mesh in body and codend - 4 1/2".
1970		Areas 1(A) and 2(B) closed during haddock spawning season; from March through April.
1972-1974		Areas 1(A) and 2(B) closure extended to March through May.
		Total Allowable Catch (TAC) regulations implemented for Subarea 5 haddock on an annual basis beginning in 1972; set at 6,000 t per year.
1975		Areas 1(A) and 2(B) closure extended to February through May; haddock TAC declared for incidental catches only
1977-Present		Extended Jurisdiction and National Management
1977		USA Fishery Conservation and Management Act of 1976 (FCMA) effective.
1977-1982		Fishery Management Plan (FMP) for Atlantic groundfish (cod, haddock and yellowtail fl.); mesh size of 5 1/8", seasonal spawning closure (areas 1 and 2), quotas established on annual, quarterly and vessel class basis, eventually leading to trip limits.
1982-1985		The "Interim Plan" for Atlantic groundfish; eliminated all catch controls, retained closed area and mesh size regulations, implemented minimum landings sizes.
1983		mesh size increased to 5 1/2 " minimum landing size - 17" commercial, 15" recreational.
1984	October	Implementation of the 'Hague' line establishing separate fishing zones for USA and Canada in the Gulf of Maine and on Georges Bank.
1985		Fishery Management Plan for the Northeast Multispecies Fishery.
		5 1/2" mesh size, areas 1 and 2 closed during February-May.
1991		Amendment 4 established overfishing definitions for haddock in terms of Fmed (F20%) replacement levels.
1993		Area 2 closure in effect from Jan 1-June 30.
1994	January	Amendment 5 implemented - expanded Area 2, Area 1 closure not in effect.
	January 3	500 pound trip limit regulation implemented.
	May December 8	6 inch mesh restriction implemented (delayed from March 1). Both Area 1,2 and Nantucket Lightship Area closed year-round.
1996	July 1	Amendment 7 implemented: additional Days-at-Sea restrictions, trip limit raised to 1000 pounds.
1997	May 1	Additional scheduled Days-at-Sea restrictions from Amendment 7.
	September 1	Trip limit raised to 1000 pounds/day, maximum of 10,000 pounds/trip.
1998	September 1	Proposed: Trip limit raised to 3000 pounds/day, maximum of 30,000 pounds/trip.

Table B2. Commercial landings (metric tons, live) of haddock from Georges Bank and South (NAFO Division 5Z and Subarea 6), 1960-1996[1].

Year	USA	Canada	USSR	Spain	Other	Total
1960	40800	77	0	0	0	40877
1961	46384	266	0	0	0	46650
1962	49409	3461	1134	0	0	54004
1963	44150	8379	2317	0	0	54846
1964	46512	11625	5483	2	464	64086
1965	52823	14889	81882	10	758	150362
1966	52918	18292	48409	1111	544	121274
1967	34728	13040	2316	1355	30	51469
1968	25469	9323	1397	3014	1720	40923
1969	16456	3990	65	1201	540	22252
1970	8415	1978	103	782	22	11300
1971	7306	1630	374	1310	242	10862
1972	3869	609	137	1098	20	5733
1973	2777	1563	602	386	3	5331
1974	2396	462	109	764	559	4290
1975	3989	1358	8	61	4	5420
1976	2904	1361	4	46	9	4324
1977	7934	2909	0	0	0	10843
1978	12160	10179	0	0	0	22339
1979	14279	5182	0	0	0	19461
1980	17470	10017	0	0	0	27487
1981	19176	5658	0	0	0	24834
1982	12625	4872	0	0	0	17497
1983	8682	3208	0	0	0	11890
1984	8807	1463	0	0	0	10270
1985	4273	3484	0	0	0	7757
1986	3339	3415	0	0	0	6754
1987	2156	4703	0	0	0	6859
1988	2492	4046[2]	0	0	0	6538
1989	1430	3059	0	0	0	4489
1990	2001	3340	0	0	0	5284
1991	1395	5446	0	0	0	6841
1992	2005	4058	0	0	0	6063
1993	687	3727	0	0	0	4414
1994	218	2411	0	0	0	2629
1995	218	2064	0	0	0	2282
1996	313	3643	0	0	0	3956
1997	888	2739	0	0	0	3627

[1]All landings 1960-1979 are from Clark *et al.* (1982); USA landings 1980-1981 are from Overholtz *et al.* (1983); USA landings 1982-1993 are from NMFS, NEFC Detailed Weighout Files and Canvass data; Canadian landings 1980-1994 from Gavaris and Van Eeckhaute (1996); Canadian landings 1995-1996 from S. Gavaris (personal communication).

[2]1895 tons were excluded because of suspected misreporting (Gavaris and Van Eeckhaute 1995).

Table B3. US and Canadian commercial landings (mt, live) of haddock from Georges Bank and South (NAFO Division 5Z and Subarea 6) by major gear type, 1965-1996.

	United States				Canada			
	Otter Trawl	Long line	Other	Total	Otter Trawl	Long line	Other	Total
1964	45617	742	153	46512	11624	1	0	11625
1965	52034	716	73	52823	14862	22	5	14889
1966	51686	1127	105	52918	17905	63	324	18292
1967	33825	814	89	34728	12923	96	21	13040
1968	24930	495	44	25469	9201	111	11	9323
1969	15494	950	12	16456	3955	22	13	3990
1970	7979	430	6	8415	1900	76	2	1978
1971	7004	300	2	7306	1475	154	1	1630
1972	3674	190	5	3869	411	198	0	609
1973	2675	100	2	2777	1461	102	0	1358
1974	2308	80	8	2396	374	87	1	462
1975	3839	143	7	3989	1247	111	0	1358
1976	2840	51	13	2904	1192	154	15	1361
1977	7842	36	56	7934	2814	94	1	2909
1978	11962	63	135	12160	9716	171	292	10179
1979	14138	30	111	14279	4907	274	1	5182
1980	17170	30	270	17470	9510	590	1	10101
1981	19031	3	142	19176	4644	1015	0	5659
1982	12484	2	139	12625	4222	709	0	4931
1983	8588	35	59	8682	2396	813	3	3212
1984	8661	79	67	8807	624	838	1	1463
1985	4194	43	36	4273	2745	626	41	3484
1986	3298	24	17	3339	2734	594	35	3415
1987	2124	21	11	2156	3521	1046	89	4703
1988	2408	32	52	2492	3183	695	97	4046
1989	1356	24	50	1430	1976	977	106	3059
1990	1949	15	37	2001	2411	853	76	3340
1991	1340	28	27	1395	4018	1309	119	5446
1992	1974	17	14	2005	2583	1384	90	4058
1993	659	16	12	687	2490	1144	94	3727
1994	175	33	10	218	1597	714	100	2411
1995	144	59	15	218	1647	389	28	2064
1996	210	63	40	313	2691	932	21	3643
1997	754	76	58	888	1991	713	36	2739

Other includes: scallop dredge, handline, gillnet, midwater trawl, Danish seine.

Table B4. Number of trips, total discard, and total kept weight (pounds) of sea sampled trawl trips catching haddock in the Georges Bank stock area in 1997. Many sea sampled trips fish in multiple stock areas. Determinations of trips exceeding the trip limit were made based on the total catch (kept + discards) from the entire trip. Discard, kept, and discard ratios are reported based on fishing activity occurring within the Georges Bank stock area.

Year	Area		Qtr 1	Qtr 2	July, Aug	September	Qtr 4
1997	Eastern	Trips	0	0	0	0	0
		Trips exceeding Trip Limit	0	0	0	0	0
		Discard (pounds)	0	0	0	0	0
		Kept (pounds)	0	0	0	0	0
		Discard Ratio	---	---	---	---	---
	Western	Trips	5	0	4	0	1
		Trips exceeding Trip Limit	1	0	4	0	0
		Discard (pounds)	1696.2	0	4202.5	0	13.5
		Kept (pounds)	2151.6	0	5249.0	0	2498.0
		Discard Ratio	0.788	---	0.801	---	0.005

Table B5. Number of trips, number of trips exceeding the trip limit, total discard weight (pounds), total kept weight (pounds), and discard ratio (discarded/kept) for Georges Bank haddock reported for trawl trips in the Vessel Trip Record database. Only trawl trips reporting discards for some species (haddock or any other species) were included in estimates of discard ratio.

Year	Area		Qtr 1	Qtr 2	July, Aug	September	Qtr 4
1997	Eastern	Trips	9	15	3	3	4
		Trips exceeding Trip Limit	8	4	1	0	0
		Discard (pounds)	32500	11415	800	60	500
		Kept (pounds)	7185	9386	1870	1550	3930
		Discard Ratio	4.523	1.216	0.428	0.039	0.127
	Western	Trips	71	90	57	37	32
		Trips exceeding Trip Limit	19	19	24	5	6
		Discard (pounds)	54255	29063	84947	6230	16567
		Kept (pounds)	33680	39567	35220	142109	118495
		Discard Ratio	1.611	0.735	2.412	0.044	0.140

Table B6. Commercial catch (landings and discards) of haddock from Georges Bank and subareas for the period 1996-1997. 1996 Canadian landings were revised from 1997 estimates; US landings for 1996-1997 are provisional and subject to revision.

			Landings					Discards					Catch
		Country	Qtr 1	Qtr 2	Qtr 3	Qtr 4	**Total**	Qtr 1	Qtr 2	Qtr 3	Qtr 4	**Total**	**Total**
1996	Eastern	Canada	—	1066.5	1717.3	859.2	**3643.0**	---	---	---	---	---	**3643.0**
1996	Eastern	USA	9.0	14.1	6.1	6.3	**35.5**	10.1	15.9	7.2	7.4	**40.6**	**76.1**
1996	Western	USA	43.6	46.5	111.7	76.8	**278.6**	67.3	29.1	138.5	52.7	**287.6**	**565.2**
1996	All	**Both**	**52.6**	**1127.1**	**1835.1**	**942.3**	**3957.1**	**77.4**	**45.0**	**145.7**	**60.1**	**328.2**	**4284.3**
1997	Eastern	Canada	---	328.0	1939.6	471.8	**2739.4**	---	---	---	---	---	**2739.4**
1997	Eastern	USA	7.4	18.3	14.3	8.3	**48.3**	33.5	22.3	5.7	1.1	**62.6**	**110.9**
1997	Western	USA	93.3	120.1	295.1	331.0	**839.5**	150.3	88.3	278.9	46.3	**563.8**	**1403.3**
1997	All	**Both**	**100.7**	**466.4**	**2249.0**	**811.1**	**3627.2**	**183.8**	**110.6**	**284.6**	**47.4**	**626.4**	**4253.6**

Table B7. USA sampling of commercial haddock landings for length composition from Georges Bank and South (NAFO Division 5Z and Subarea 6), 1982-1993. Eastern Georges (areas 561, 562, 523 and 524), Western Georges (521, 522, 525, 526, 541, 542, 537, 538, 539 and Statistical Area 6). Q1, Q2, Q3, Q4, denote quarters 1, 2, 3, and 4, respectively.

Number of Samples				Number of Samples by Market Category, Area, and Quarter																				Annual Sampling Intensity			
				Scrod										Large										No. of Tons Landed/Sample			
				Eastern Georges					Western Georges					Eastern Georges					Western Georges					East	West	East	West
Year	No.	# Fish Meas.	# Fish Aged	Q1	Q2	Q3	Q4	∑	Q1	Q2	Q3	Q4	∑	Q1	Q2	Q3	Q4	∑	Q1	Q2	Q3	Q4	∑	Scrod		Large	
1982	89	7851	1788	6	7	6	3	**22**	1	4	15	4	**24**	3	9	8	4	**24**	1	4	7	7	**19**	96	54	172	264
1983	104	8955	2000	3	9	4	4	**20**	2	5	8	2	**17**	7	9	6	5	**27**	2	12	17	5	**38**	54	35	139	95
1984	57	4762	1142	11	4	2	1	**18**	0	1	2	3	**6**	9	7	1	5	**22**	3	3	2	3	**11**	56	65	122	299
1985	32	2528	627	7	4	2	0	**13**	0	1	2	1	**4**	7	1	1	0	**9**	1	0	4	1	**6**	18	136	161	338
1986	30	2276	571	2	3	1	0	**6**	0	1	2	1	**4**	4	2	3	2	**11**	1	2	3	3	**9**	186	77	98	92
1987	36	2573	837	2	7	0	1	**10**	0	0	3	1	**4**	3	4	1	3	**11**	2	1	6	2	**11**	51	41	168	52
1988	34	2542	1096	2	4	2	4	**12**	1	2	2	0	**5**	5	4	1	4	**14**	1	1	1	0	**3**	61	47	69	186
1989	23	1548	856	4	1	1	1	**7**	0	1	7	1	**9**	2	2	0	1	**5**	1	1	0	0	**2**	50	29	87	189
1990	27	2001	945	5	5	1	2	**13**	1	1	1	1	**4**	1	5	0	1	**7**	2	0	1	0	**3**	46	77	84	167
1991	32	1065	439	3	3	0	3	**9**	0	0	7	0	**7**	0	9	0	3	**12**	4	0	0	0	**4**	56	48	35	31
1992	54	2456	922	7	10	5	0	**22**	3	4	0	0	**7**	3	8	2	0	**11**	3	4	5	0	**12**	46	38	56	9
1993	31	1140	533	3	3	0	0	**6**	2	3	3	2	**10**	0	11	0	0	**11**	0	0	2	2	**4**	30	27	13	20
1994	8	546	212	0	0	1	0	**1**	0	1	0	1	**2**	0	0	1	0	**1**	2	1	0	1	**4**	11	46	22	23
1995	3	198	58	0	0	0	0	**0**	2	1	0	0	**3**	0	0	0	0	**0**	0	0	0	0	**0**	--	25	--	--
1996	6	524	191	0	0	1	0	**1**	0	0	0	1	**1**	0	0	0	0	**0**	0	0	1	3	**4**	6	30	--	50
1997	34	3203	848	0	0	0	0	**0**	0	1	7	3	**10**	0	1	0	0	**1**	1	1	7	13	**22**	–	22	33	10

Table B8. Data sources and sample sizes of length used to partition 1997 US landings and discards from Western Georges Bank into numerical catch at age. Both port samples of landings and sea sampled length frequencies were used to partition landings into numbers at length.

	Market Category:	Large (1470)			Scrod (1475)			Discards All		
Area	Data Source	Qtrs 1&2	Qtr 3	Qtr 4	Qtrs 1&2	Qtr 3	Qtr 4	Qtrs 1&2	July/August	Sept - Dec
West	Port Sampling	308	768	1253	50	558	235	not used	not used	not used
West	Sea Sampling	not used	not used	not used	not used	not used	not used	39	127	96
West	Catch (mt)	157.7	208.7	249.7	55.7	86.4	81.2	238.6	267.7	57.5
East	Port Sampling	Used Western Georges Port Samples to Calculate Landings at Length						Used Western Georges Port Samples to Calculate Landings at Length		
East	Sea Sampling	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
East	Catch	18.8	12.1	7.1	7.0	2.2	1.2	55.8	5.2	1.6

Table B9. Summary of at-sea sampling of commercial trips and hauls from Georges Bank and South where haddock were sampled in 1997.

			Quarter 1	Quarter 2	July, August	September	Quarter 4	Total
Trawl	Kept	Trips	5	0	2	0	2	9
		Hauls	13	0	9	0	4	25
		Lengths	64	0	230	0	170	464
	Discard	Trips	3	1	3	0	2	9
		Hauls	8	1	8	0	8	25
		Lengths	36	3	127	0	96	262
Gillnet	Kept	Trips	2	0	1	2	1	6
		Hauls	6	0	2	2	1	11
		Lengths	63	0	2	2	1	68
	Discard	Trips	0	0	0	0	1	1
		Hauls	0	0	0	0	2	2
		Lengths	0	0	0	0	2	2
Scallop Dredge	Kept	Trips	0	0	0	0	0	0
		Hauls	0	0	0	0	0	0
		Lengths	0	0	0	0	0	0
	Discard	Trips	0	1	0	0	0	1
		Hauls	0	3	0	0	0	3
		Lengths	0	3	0	0	0	3

Table B10. Catch at age (000's), mean weight (kg) and mean length (cm) at age of US commercial catch of haddock from Georges Bank and South (NAFO Division 5Z and Subarea 6), 1982-1996. Catch at age from 1982-1993 includes only landings (discards assumed insignificant), while catch at age from 1994-1996 includes both landings and discards.

Year	1	2	3	4	5	6	7	8	9+	TOTAL
					USA Commercial Catch in Numbers (000's) at Age					
1982	1	852	1164	2333	298	463	924	97	105	6237
1983	0	53	454	432	1560	196	152	711	72	3630
1984	0	81	259	664	345	1310	173	234	439	3506
1985	0	384	245	80	372	173	439	56	90	1839
1986	0	16	1109	137	76	121	121	226	39	1845
1987	0	9	39	525	63	41	59	78	67	881
1988	0	1	506	53	541	96	48	48	20	1313
1989	0	131	18	254	79	156	33	20	8	699
1990	0	5	375	117	367	84	55	17	10	1030
1991	0	19	30	340	52	113	45	31	15	644
1992	0	17	83	70	507	97	111	24	8	917
1993	0	44	31	54	35	108	31	16	7	324
1994	1	59	107	33	17	36	44	30	6	334
1995	8	34	84	52	8	7	6	6	4	209
1996	5.0	26.7	97.6	95.4	52.1	9.1	4.7	2.8	8.5	301.8
1997	28.8	105.2	219.6	252.1	96.9	33.6	7.7	9.1	14.9	767.8
					Commercial Catch in Weight (tons) at Age					
1982	0	794	1641	4325	708	1275	3063	389	430	12625
1983	0	53	611	794	3452	527	508	2423	308	8676
1984	0	75	338	1203	756	3483	515	801	1632	8803
1985	0	458	380	149	942	458	1323	219	342	4271
1986	0	14	1352	227	169	340	339	751	147	3339
1987	0	11	59	965	141	109	181	298	287	2051
1988	0	1	727	80	1043	244	143	175	79	2492
1989	0	154	29	459	174	393	113	76	31	1429
1990	0	5	571	212	719	218	163	68	42	1998
1991	0	21	44	579	121	304	143	114	63	1390
1992	0	23	125	128	1029	250	328	82	36	2000
1993	0	53	46	101	74	257	78	50	26	685
1994	1	55	164	70	43	109	135	119	26	722
1995	3	28	113	101	21	22	21	22	13	343
1996	2	31	174	213	135	26	17	11	32	641
1997	12	89	396	552	258	99	25	31	53	1515
					USA Commercial Catch Mean Weight (kg) at Age					
1982	0.225	0.932	1.410	1.854	2.375	2.753	3.315	4.015	4.091	
1983	-	0.996	1.345	1.839	2.213	2.691	3.345	3.408	4.275	
1984	-	0.924	1.305	1.812	2.191	2.659	2.979	3.425	3.718	
1985	-	1.194	1.553	1.861	2.532	2.649	3.013	3.909	3.798	
1986	-	0.846	1.219	1.656	2.230	2.807	2.798	3.325	3.781	
1987	-	1.182	1.515	1.838	2.239	2.662	3.074	3.817	4.287	
1988	-	1.065	1.436	1.510	1.927	2.545	2.972	3.643	3.963	
1989	-	1.174	1.603	1.806	2.200	2.519	3.415	3.783	3.818	
1990	-	0.981	1.523	1.809	1.959	2.597	2.960	4.005	4.164	
1991	-	1.143	1.505	1.704	2.338	2.685	3.169	3.669	4.337	
1992	-	1.336	1.503	1.833	2.030	2.584	2.947	3.458	4.267	
1993	-	1.220	1.496	1.877	2.132	2.376	2.251	3.037	4.014	
1994	0.447	0.942	1.529	2.103	2.595	3.007	3.075	3.924	4.546	
1995	0.369	0.836	1.340	1.952	2.490	3.027	3.406	3.400	3.981	
1996	0.453	1.175	1.778	2.223	2.574	2.924	3.799	3.964	3.807	
1997	0.408	0.847	1.801	2.191	2.658	2.939	3.209	3.390	3.561	
					USA Commercial Catch Mean Length (cm) at Age					
1982	27.0	44.4	51.5	56.8	61.9	65.3	69.7	74.8	74.8	
1983	-	45.5	50.7	56.6	60.7	64.6	69.5	70.4	75.7	
1984	-	44.7	50.3	56.1	60.4	64.4	67.7	70.5	72.7	
1985	-	48.7	53.4	57.1	63.8	65.1	67.6	73.9	73.4	
1986	-	43.5	49.3	54.5	60.5	65.7	66.1	70.2	73.1	
1987	-	48.6	53.3	57.1	60.7	65.1	68.5	74.0	76.8	
1988	-	46.8	51.9	53.3	58.3	64.2	67.9	72.5	74.3	
1989	-	48.4	53.6	56.6	60.7	64.0	71.1	74.4	74.9	
1990	-	44.9	52.4	56.9	58.6	64.7	67.8	75.4	76.4	
1991	-	47.9	52.9	55.5	61.9	65.2	69.8	73.6	78.4	
1992	-	49.6	53.1	57.1	59.1	64.8	68.0	72.3	77.6	
1993	-	48.1	53.5	57.7	60.0	62.9	64.1	68.8	75.0	
1994	34.6	44.7	52.4	58.2	62.6	65.4	66.1	71.4	75.0	
1995	32.6	42.2	50.1	56.7	61.5	65.9	68.1	68.2	72.2	
1996	35.0	47.5	54.6	59.0	62.2	65.2	71.1	72.1	71.1	
1997	32.6	42.9	54.7	58.5	62.8	65.0	67.1	68.4	71.4	

Table B11. Landings at age, mean weight (kg) of haddock landed in the Canadian fishery from Georges Bank and South (NAFO Division 5Z and Subarea 6), 1982-1996.

Year	1	2	3	4	5	6	7	8	9+	TOTAL
			Canadian Commercial Landings in Numbers (000's) at Age							
1982	0	313	469	1400	93	106	195	9	5	2590
1983	0	161	359	258	679	76	34	89	4	1660
1984	0	12	38	63	52	172	61	33	104	535
1985	0	2022	305	114	89	55	87	22	62	2756
1986	6	38	1701	86	70	52	29	40	21	2043
1987	0	1986	90	1088	59	32	30	28	68	3381
1988	4	51	1878	81	390	53	7	16	86	2566
1989	0	1132	68	623	64	202	13	8	37	2147
1990	2	6	1070	55	501	14	122	29	34	1833
1991	6	429	62	1809	50	297	28	123	57	2861
1992	7	230	237	62	1020	14	212	3	86	1871
1993	7	246	319	245	69	551	7	143	69	1656
1994	0	210	703	137	49	33	107	13	37	1289
1995	1	56	512	405	52	24	2	50	15	1119
1996	0.1	27.0	472.0	850.5	411.5	59.2	17.3	2.6	70.6	1910.8
1997	0.0	72.7	68.6	525.4	469.9	186.6	11.6	7.0	61.5	1374.2
			Canadian Commercial Landings in Weight (mt) at Age							
1982	0	331	730	2681	218	297	567	31		
1983	0	166	503	470	1494	193	96	268		
1984	0	11	53	127	117	476	178	110		
1985	0	1917	386	236	193	162	286	71		
1986	3	37	2480	181	204	151	106	170		
1987	0	1652	125	2255	133	83	87	101		
1988	2	50	2470	145	871	120	21	49		
1989	0	975	99	1115	142	526	36	24		
1990	1	6	1563	94	1118	32	334	69		
1991	3	517	76	3325	101	781	66	356		
1992	4	267	400	105	2309	29	631	8		
1993	5	285	558	548	146	1475	21	448		
1994	0	240	1173	308	131	80	303	42		
1995	1	59	774	823	133	66	6	151		
1996	0	28	679	1527	944	147	57	8		
1997	1	88	92	918	997	462	35	24		
			Canadian Commercial Landings Mean Weight (kg) at Age							
1982	-	1.056	1.556	1.915	2.348	2.801	2.909	3.414		
1983	-	1.031	1.401	1.822	2.200	2.543	2.821	3.007		
1984	-	0.883	1.401	2.010	2.257	2.770	2.918	3.326		
1985	-	0.948	1.264	2.068	2.169	2.942	3.289	3.238		
1986	0.452	0.981	1.458	2.104	2.913	2.899	3.646	4.248		
1987	-	0.832	1.391	2.073	2.253	2.598	2.906	3.623		
1988	0.421	0.974	1.315	1.787	2.234	2.264	2.978	3.036		
1989	-	0.861	1.449	1.789	2.215	2.604	2.795	3.014		
1990	0.639	0.956	1.461	1.711	2.232	2.281	2.736	2.396		
1991	0.581	1.204	1.220	1.838	2.023	2.63	2.341	2.891		
1992	0.538	1.163	1.687	1.694	2.264	2.073	2.977	2.633		
1993	0.659	1.160	1.750	2.236	2.113	2.677	2.987	3.133		
1994	0.405	1.135	1.669	2.246	2.664	2.439	2.835	3.240		
1995	0.797	1.055	1.511	2.033	2.550	2.755	2.908	3.010		
1996	0.576	1.022	1.439	1.795	2.294	2.485	3.322	3.032		
1997	0.685	1.216	1.336	1.747	2.121	2.476	3.034	3.367		

[1]Data from Gavaris and Van Eeckhaute (1997) and S. Gavaris (pers. comm.).

Table B12. Total catch at age (000's)and mean weight (kg) and mean length (cm) at age of commercial landings and discards of haddock from Georges Bank and South (NAFO Division 5Z and Subarea 6), 1982-1996.

Year	1	2	3	4	5	6	7	8	9+	TOTAL
				Total Commercial Catch in Numbers (000's) at Age						
1963	2910	4047	7418	11152	8198	2205	1405	721	1096	39152
1964	10101	15935	4554	4776	8722	5794	2082	1028	1332	54324
1965	9601	125818	44496	5356	4391	6690	3772	1094	1366	202584
1966	114	6843	100810	19167	2768	2591	2332	1268	867	136760
1967	1150	168	2891	20667	10338	1209	993	917	698	39031
1968	8	2994	709	1921	14519	3499	667	453	842	25612
1969	2	11	1698	448	654	5954	1574	225	570	11136
1970	46	158	16	570	186	214	2308	746	464	4708
1971	1	1375	223	40	289	246	285	1469	928	4856
1972	156	2	450	81	32	120	78	66	1236	2221
1973	2560	2075	3	386	53	30	77	15	447	5646
1974	46	4320[2]	657	2	70	2	2	53	249	5401
1975	192	1034	1864	375	4	42	4	4	88	3607
1976	144	473	550	880	216	0	23	4	112	2402
1977	1	19585[3]	187	680	515	357	4	39	111	21479
1978	1	761	14395[4]	305	567	517	139	14	67	16766
1979	1	26	1726	7169	525	410	315	96	46	10314
1980	8	31000[5]	347	975	6054	594	546	153	81	39758
1981	1	1743	10998	831	937	2572	331	158	94	17665
1982	1	1165	1633	3733	391	569	1119	106	110	8827
1983	0	214	813	690	2239	272	186	800	76	5290
1984	0	93	297	727	397	1482	234	267	543	4041
1985	0	2406	550	194	461	228	526	78	152	4596
1986	6	54	2810	223	146	173	150	266	60	3888
1987	0	1995	129	1613	122	73	89	106	135	4262
1988	4	52	2384	134	931	149	55	64	106	3879
1989	0	1263	86	877	143	358	46	28	45	2846
1990	2	11	1445	172	868	98	177	46	44	2863
1991	6	448	91	2149	102	410	73	154	72	3505
1992	7	247	320	132	1527	111	323	27	94	2788
1993	7	290	350	299	104	659	38	159	76	1980
1994[6]	1.2	268.9	810.4	170.3	65.6	69.3	150.8	43.4	42.7	1622.6
1995[6]	9.2	89.4	596.5	457.2	59.9	31.5	8.2	56.6	18.0	1326.5
1996[6]	5.1	53.6	569.6	946.0	463.6	68.2	21.9	5.4	7.9	2141.3
1997[6]	29.7	177.8	288.2	777.4	566.8	220.2	19.3	16.1	46.4	2141.9

Table B12. (continued)

Year	1	2	3	4	5	6	7	8	9+
				Total Commercial Landings Mean Weight[1](kg) at Age					
1963	0.57	0.87	1.18	1.47	1.68	2.15	2.35	3.04	3.10
1964	0.50	0.83	1.12	1.43	1.64	2.01	2.40	2.64	2.97
1965	0.58	0.69	1.03	1.35	1.67	1.99	2.26	2.66	3.11
1966	0.58	0.73	0.89	1.26	1.70	2.07	2.28	2.87	3.18
1967	0.66	0.70	0.95	1.18	1.42	2.05	2.31	2.66	3.10
1968	0.59	0.81	1.05	1.32	1.57	2.10	2.32	2.62	2.86
1969	0.52	0.78	1.10	1.69	1.75	1.99	2.52	2.99	3.63
1970	0.71	1.27	1.22	1.93	2.19	2.39	2.58	3.23	3.75
1971	(0.67)	1.03	1.31	1.74	2.39	2.81	2.92	3.10	3.72
1972	0.62	1.03	1.74	2.04	2.42	2.92	3.06	3.44	3.66
1973	0.60	1.03	1.58	2.13	2.41	3.29	3.42	3.86	3.94
1974	0.72	1.06	1.82	2.32	2.83	3.76	4.05	3.92	4.26
1975	0.62	0.98	1.63	2.21	2.20	2.94	4.00	4.05	4.33
1976	0.50	0.99	1.39	1.99	2.66	(3.08)	3.69	4.67	4.94
1977	(0.53)	1.07	1.44	2.17	2.73	3.21	4.15	4.00	4.99
1978	(0.53)	0.94	1.50	2.04	2.79	3.19	3.37	3.61	5.11
1979	(0.53)	1.00	1.28	2.02	2.51	3.14	3.78	3.79	4.87
1980	0.55	0.94	1.21	1.73	2.17	2.82	3.60	3.56	3.87
1981	0.39	0.87	1.24	1.83	2.30	2.72	3.71	4.04	4.44
1982	0.22	0.97	1.45	1.88	2.37	2.76	3.24	3.96	4.09
1983	(0.33)	1.02	1.37	1.83	2.21	2.65	3.25	3.36	4.27
1984	(0.33)	0.92	1.32	1.83	2.20	2.67	2.96	3.41	3.72
1985	(0.33)	0.99	1.39	1.98	2.46	2.72	3.06	3.72	3.80
1986	0.45	0.94	1.36	1.83	2.56	2.83	2.96	3.46	3.78
1987	(0.43)	0.83	1.43	2.00	2.25	2.63	3.02	3.77	4.29
1988	0.42	0.98	1.34	1.68	2.06	2.45	2.97	3.49	3.96
1989	(0.53)	0.89	1.48	1.79	2.21	2.57	3.24	3.56	3.82
1990	0.64	0.97	1.48	1.78	2.12	2.55	2.81	2.99	4.16
1991	0.581	1.201	1.311	1.817	2.183	2.645	2.852	3.048	4.337
1992	0.538	1.175	1.639	1.768	2.186	2.519	2.967	3.365	4.267
1993	0.659	1.169	1.728	2.171	2.119	2.628	2.649	3.123	4.014
1994	0.447	1.093	1.643	2.209	2.628	2.728	2.902	3.783	4.546
1995	0.429	0.967	1.489	2.025	2.542	2.815	3.275	3.091	3.981
1996	0.456	1.098	1.497	1.838	2.325	2.543	3.423	3.516	3.712
1997	0.416	0.998	1.690	1.891	2.213	2.547	3.1.4	3.380	3.655

[1]Data 1963-1979 from Clark *et al.* (1982); Data 1980-1981 from Overholtz *et al.* (1983); Data 1982-1990 current assessment and Gavaris and Van Eekhaute (1991).
[2]Of this total, approximately 1.0 million fish were added to the catch at age to account for high discards in 1974.
[3]Of this total, approximately 12.8 million fish were added to the catch at age to account for high discards in 1977.
[4]Of this total, approximately 5.0 million fish were added to the catch at age to account for high discards in 1978.
[5]Of this total, approximately 20.0 million fish were added to the catch at age to account for high discards in 1980.
[6]Total includes discards resulting from trip limit regulations for most year classes. See Brown 1998 for details.

Table B13. Mean number and mean weight (kg) per tow of haddock caught in NEFSC spring and autumn bottom trawl surveys from 1963-1996.

	Spring Survey		Autumn Survey	
Year	Number/Tow	Weight (kg)/tow	Number/tow	Weight (kg)/tow
1963	-----	-----	145.01	79.77
1964	-----	-----	193.24	96.75
1965	-----	-----	101.69	72.78
1966	-----	-----	33.26	29.87
1967	-----	-----	17.70	25.47
1968	13.84	20.55	7.51	15.40
1969	7.33	16.93	3.38	8.44
1970	6.00	17.12	7.70	13.50
1971	2.79	5.00	4.20	5.59
1972	6.38	7.37	11.35	8.47
1973	37.62	15.37	14.89	9.78
1974	19.01	17.70	4.05	3.99
1975	6.24	8.21	30.95	15.10
1976	83.19	15.72	71.07	35.76
1977	36.86	26.58	23.25	27.52
1978	19.41	31.27	25.29	18.06
1979	45.50	19.77	52.24	31.98
1980	60.06	53.92	30.54	21.98
1981	31.21	38.02	13.45	14.01
1982	8.60	13.11	4.96	7.34
1983	5.60	13.21	7.99	5.75
1984	6.24	7.45	5.38	4.48
1985	8.85	11.14	14.19	3.86
1986	5.85	5.86	6.81	5.10
1987	4.95	5.60	3.62	2.56
1988	3.38	3.43	5.35	5.57
1989	5.35	4.70	4.34	4.70
1990	7.68	7.57	2.92	2.62
1991	3.97	4.38	2.92	0.94
1992	1.18	1.41	6.06	3.17
1993	2.79	2.48	8.09	4.33
1994	4.99	3.63	3.58	2.93
1995	5.61	5.72	17.11	10.66
1996	23.40	25.73	4.47	4.11
1997	12.95	18.50	6.16	6.51

Table B14. Conversion factors used to account for differences in fishing power between research vessels and changes in doors used to conduct the US research vessel bottom trawl surveys. Coefficients of 0.82 (*Delaware II*) and 1.49 (BMV door) were applied to numerical abundance indices, and 0.79 (*Delaware II*) and 1.51 (BMV door) were applied to biomass indices.

		Spring		Autumn	
Years	Door	Vessel	Conversion	Vessel	Door
1963-1967	BMV	---	---	Albatross IV	1.49
1968-1976	BMV	Albatross IV	1.49	Albatross IV	1.49
1977-1980	BMV	Albatross IV	1.49	Delaware II	1.222
1981	BMV	Delaware II	1.222	Delaware II	1.222
1982	BMV	Delaware II	1.222	Albatross IV	1.49
1983-1984	BMV	Albatross IV	1.49	Albatross IV	1.49
1985-1988	Polyvalent	Albatross IV	1.00	Albatross IV	1.00
1989-1991	Polyvalent	Delaware II	0.82	Delaware II	0.82
1992	Polyvalent	Albatross IV	1.00	Albatross IV	1.00
1993	Polyvalent	Albatross IV	1.00	Delaware II	0.82
1994	Polyvalent	Delaware II	0.82	Albatross IV	1.00
1995-1997	Polyvalent	Albatross IV	1.00	Albatross IV	1.00

Table B15. Stratified mean catch per tow (numbers) for haddock in NEFSC offshore spring research vessel bottom trawl surveys on Georges Bank (Strata 01130-01250, 01290-01300), 1968-1996. Indices have been corrected to account for changes in catchability due to changes in research vessels and doors.

	Age group											
Year	0	1	2	3	4	5	6	7	8	9+	Total	Total 1+
1968	0.00	0.40	2.83	0.46	0.70	6.72	1.68	0.25	0.45	0.34	13.84	13.84
1969	0.00	0.00	0.07	0.58	0.25	0.42	4.23	1.03	0.28	0.46	7.33	7.33
1970	0.00	0.67	0.25	0.00	0.33	0.46	0.46	2.00	0.98	0.85	6.00	6.00
1971	0.00	0.00	1.16	0.25	0.00	0.12	0.12	0.09	0.82	0.22	2.79	2.79
1972	0.00	4.02	0.09	0.61	0.12	0.03	0.04	0.13	0.03	1.30	6.38	6.38
1973	0.00	30.68	4.84	0.00	0.54	0.09	0.00	0.18	0.01	1.28	37.62	37.62
1974	0.00	2.13	13.29	2.86	0.00	0.24	0.00	0.01	0.10	0.37	19.01	19.01
1975	0.00	0.94	0.97	3.32	0.63	0.00	0.13	0.09	0.01	0.15	6.24	6.24
1976	0.00	80.79	0.30	0.60	0.92	0.43	0.00	0.04	0.00	0.10	83.19	83.19
1977	0.00	0.61	33.41	0.42	1.22	0.60	0.45	0.00	0.04	0.12	36.86	36.86
1978	0.00	0.07	0.97	15.93	0.36	0.94	0.82	0.16	0.06	0.10	19.41	19.41
1979	0.00	36.12	1.58	1.13	5.71	0.33	0.16	0.37	0.06	0.04	45.50	45.50
1980	0.00	5.20	46.70	0.51	1.04	4.87	0.67	0.37	0.46	0.24	60.06	60.06
1981	0.00	3.30	3.29	19.49	2.19	0.76	1.78	0.24	0.11	0.05	31.21	31.21
1982	0.00	0.76	1.53	0.94	4.07	0.42	0.28	0.61	0.00	0.00	8.60	8.60
1983	0.00	0.43	0.55	0.58	0.22	2.41	0.01	0.04	1.16	0.18	5.60	5.60
1984	0.00	2.09	1.18	0.64	0.63	0.58	0.72	0.07	0.04	0.30	6.24	6.24
1985	0.00	0.00	4.96	0.76	0.40	0.87	0.34	1.17	0.10	0.25	8.85	8.85
1986	0.00	2.49	0.18	2.06	0.24	0.11	0.21	0.12	0.33	0.11	5.85	5.85
1987	0.00	0.00	3.62	0.06	0.81	0.08	0.10	0.05	0.22	0.01	4.95	4.95
1988	0.00	1.55	0.04	0.99	0.13	0.32	0.12	0.11	0.12	0.00	3.38	3.38
1989	0.00	0.02	3.49	0.45	0.71	0.14	0.41	0.06	0.05	0.01	5.35	5.35
1990	0.00	0.86	0.00	5.72	0.33	0.58	0.06	0.13	0.00	0.01	7.68	7.68
1991	0.00	0.54	1.07	0.24	1.85	0.09	0.10	0.02	0.04	0.02	3.97	3.97
1992	0.00	0.40	0.18	0.11	0.07	0.33	0.03	0.03	0.03	0.00	1.18	1.18
1993	0.00	1.17	0.65	0.18	0.14	0.12	0.37	0.06	0.02	0.02	2.73	2.73
1994	0.08	0.70	2.68	1.00	0.15	0.10	0.07	0.16	0.02	0.05	4.99	4.99
1995	0.00	0.50	1.29	2.32	0.91	0.17	0.11	0.03	0.18	0.09	5.61	5.61
1996	0.00	1.09	4.59	8.86	5.21	2.62	0.35	0.07	0.08	0.54	23.40	23.40
1997	0.00	1.79	1.02	3.35	3.66	2.01	0.89	0.13	0.07	0.02	12.95	12.95

Table B16. Stratified mean catch per tow (numbers) for haddock in NEFC offshore autumn research vessel bottom trawl surveys on Georges Bank (Strata 01130-01250, 01290-01300), 1963-1996. Indices have been corrected to account for changes in catchability due to changes in research vessels and doors.

	Age group										
Year	0	1	2	3	4	5	6	7	8	9+	Total	Total 1+
1963	83.93	25.39	9.22	6.81	8.34	5.95	2.04	1.68	1.18	0.46	145.01	61.08
1964	2.37	112.87	63.74	5.83	1.79	3.81	1.56	0.69	0.25	0.33	193.24	190.87
1965	0.33	10.16	77.39	9.70	1.07	0.80	0.91	0.80	0.25	0.27	101.69	101.36
1966	6.14	0.95	2.89	18.39	3.35	0.52	0.49	0.33	0.12	0.07	33.26	27.12
1967	0.03	6.72	0.36	0.99	6.76	1.62	0.49	0.21	0.33	0.18	17.70	17.67
1968	0.09	0.06	0.95	0.13	0.33	3.86	1.27	0.27	0.16	0.39	7.51	7.42
1969	0.39	0.03	0.00	0.28	0.13	0.16	1.52	0.51	0.09	0.27	3.38	2.99
1970	0.04	4.13	0.21	0.01	0.28	0.27	0.51	1.37	0.48	0.40	7.70	7.66
1971	2.43	0.00	0.31	0.07	0.01	0.22	0.03	0.09	0.75	0.28	4.20	1.77
1972	6.75	2.52	0.00	0.52	0.09	0.00	0.09	0.06	0.03	1.30	11.35	4.60
1973	3.23	9.00	1.61	0.00	0.19	0.04	0.00	0.07	0.01	0.72	14.89	11.65
1974	0.75	1.77	0.98	0.31	0.00	0.01	0.00	0.00	0.00	0.22	4.05	3.31
1975	23.48	0.63	0.72	4.86	0.92	0.00	0.03	0.00	0.01	0.30	30.95	7.46
1976	4.32	64.17	0.52	0.54	0.82	0.30	0.00	0.04	0.10	0.25	71.07	66.75
1977	0.13	2.14	18.73	0.56	0.57	0.64	0.34	0.04	0.01	0.09	23.25	23.12
1978	13.22	0.84	1.04	9.27	0.18	0.26	0.45	0.01	0.00	0.01	25.30	12.07
1979	1.32	45.57	0.04	0.90	3.81	0.26	0.28	0.05	0.01	0.00	52.24	50.92
1980	11.68	2.71	12.72	0.45	0.18	1.70	0.48	0.46	0.09	0.06	30.54	18.86
1981	0.38	6.13	2.08	3.70	0.21	0.42	0.53	0.00	0.00	0.01	13.45	13.07
1982	1.37	0.00	1.33	0.34	1.40	0.13	0.07	0.21	0.01	0.10	4.96	3.61
1983	5.80	0.24	0.21	0.27	0.30	0.94	0.12	0.00	0.10	0.02	7.99	2.19
1984	0.03	3.32	0.88	0.24	0.28	0.06	0.45	0.00	0.00	0.12	5.38	5.35
1985	11.35	0.65	1.53	0.22	0.05	0.10	0.07	0.17	0.00	0.05	14.19	2.84
1986	0.00	5.11	0.09	1.21	0.06	0.13	0.13	0.02	0.03	0.03	6.81	6.81
1987	1.80	0.00	0.79	0.10	0.77	0.06	0.06	0.02	0.02	0.00	3.62	1.82
1988	0.07	3.02	0.18	1.30	0.12	0.40	0.12	0.11	0.00	0.03	5.35	5.28
1989	0.47	0.05	2.71	0.20	0.66	0.09	0.13	0.02	0.02	0.00	4.33	3.87
1990	0.78	0.67	0.03	1.19	0.05	0.17	0.04	0.00	0.00	0.00	2.92	2.15
1991	2.16	0.21	0.24	0.05	0.22	0.02	0.02	0.00	0.00	0.02	2.92	0.76
1992	2.85	2.08	0.23	0.24	0.00	0.47	0.02	0.08	0.03	0.06	6.06	3.21
1993	1.52	4.04	2.01	0.30	0.00	0.06	0.15	0.02	0.00	0.00	8.09	6.58
1994	0.91	0.77	0.81	0.67	0.12	0.05	0.02	0.17	0.06	0.00	3.58	2.67
1995	2.27	7.14	4.90	2.32	0.38	0.01	0.00	0.07	0.02	0.00	17.11	14.84
1996	1.31	0.54	0.93	1.04	0.49	0.14	0.01	0.01	0.00	0.01	4.47	3.16
1997	0.32	2.47	1.47	0.75	0.55	0.33	0.13	0.00	0.07	0.08	6.16	5.84

Table B17. Stratified mean catch per tow (numbers) for haddock in Canadian offshore research vessel bottom trawl surveys on Georges Bank, 1986-1998[1]. The Georges Bank strata set includes strata 5Z1-5Z8. Indices at age for 1997 were slightly revised based on complete ageing of available samples. The 1998 indices are based on ageing a subset of available ageing material and will be revised in 1999.

	Age group										
Year	0	1	2	3	4	5	6	7	8	9+	Total
1986	0.00	4.06	0.22	6.05	1.07	0.19	0.29	0.34	0.37	0.42	13.01
1987	0.00	0.03	3.04	0.69	2.51	0.67	0.08	0.30	0.10	0.86	8.28
1988	0.00	1.47	0.05	8.53	0.17	2.85	0.18	0.17	0.11	0.50	14.03
1989	0.00	0.03	5.34	0.72	2.12	0.19	0.42	0.03	0.03	0.23	9.11
1990	0.00	0.93	0.11	9.87	0.13	3.36	0.23	1.09	0.13	0.34	16.19
1991	0.00	0.75	1.67	0.14	8.99	0.11	1.60	0.09	0.44	0.21	14.00
1992	0.00	3.30	2.95	1.13	0.17	3.82	0.03	1.06	0.04	0.58	13.08
1993	0.00	3.96	2.16	0.55	0.45	0.04	1.28	0.02	0.32	0.16	8.94
1994	0.00	3.32	11.52	4.08	0.42	0.24	0.02	0.70	0.01	0.27	20.59
1995	0.00	1.94	2.62	4.30	2.22	0.56	0.28	0.00	0.48	0.66	13.06
1996	0.00	5.37	2.54	4.25	4.43	2.57	0.23	0.21	0.03	0.50	20.14
1997	0.00	1.74	1.15	0.81	2.36	2.47	1.77	0.24	0.09	0.59	11.22
1998	0.00	2.41	8.18	3.08	2.57	3.76	3.67	1.98	0.24	0.48	26.37

[1]S. Gavaris, personal communication.

Table B18. Percentage maturity of female Georges Bank haddock at age, 1963-1997.

	Age				
Year	1	2	3	4	Source
1963-1967	0	0	78	100	Clark (1959)
1968 - 1972	0	28	76	100	Livingstone (pers. comm., March 1980) as cited in Clark *et al.* (1982)
1973 - 1976	0	34	92	100	Livingstone (pers. comm., March 1980) as cited in Clark *et al.* (1982)
1977	0	61	100	100	Overholtz (1987)
1978	0	26	99	100	Overholtz (1987)
1979	0	8	71	100	Overholtz (1987)
1980	0	41	100	100	Overholtz (1987)
1981	0	52	94	100	Overholtz (1987)
1982	0	31	67	100	Overholtz (1987)
1983	0	11	39	100	Overholtz (1987)
1984	12	33	94	100	O'Brien (pers. comm.)
1985 - 1989	24	65	92	98	Brown (1998)
1990 - 1992	10	56	94	99	Brown (1998)
1993 - 1994	7	30	71	94	Brown (1998)
1995 - 1997	2	34	94	100	Current assessment

Table B19. VPA run descriptions including a summary of diagnostics and results.

VPA Run #	Run 14	Run 15	Run 36	Run 37	Run 17 (Accepted)
Tuning Indices					
US Spring 1-8	Yes	Yes	Yes	Yes	Yes
US Spring 1973-1981			Yes	Yes	
(Yankee 41 years) separate index	No	No			Yes
Canada Spring 1-8	Yes	Yes	Yes	Yes	Yes
US Autumn 0-5 Lagged	Yes	Yes	Yes	Yes	Yes
US Autumn 2-5 Lagged	Yes	Yes	No	Yes	Yes
US Autumn 6-8 Lagged	Yes	No	No	No	No
Discards					
1974-1980 Estimates Included	Yes	Yes	Yes	No	Yes
1994-1997 Estimates Included	Yes	Yes	No	No	Yes
Diagnostics					
Sum of squares	410.564	343.739	320.661	326.117	338.164
Mean squared residuals	0.71527	0.69583	0.65980	0.67102	0.69581
CV n1	0.62	0.61	0.59	0.60	0.61
CV n2	0.39	0.39	0.38	0.38	0.39
CV n3	0.32	0.31	0.30	0.30	0.31
CV n4	0.28	0.27	0.25	0.26	0.27
CV n5	0.27	0.27	0.25	0.26	0.27
CV n6	0.24	0.25	0.23	0.24	0.25
CV n7	0.25	0.28	0.25	0.25	0.27
CV n8	0.32	0.31	0.28	0.29	0.31
Min/Max CV q (US Spring)	0.16 - 0.17	0.16 - 0.17	N/A	N/A	N/A
Min/Max CV q (US Spring w/o Yankee 41 1973-1981)	N/A	N/A	0.18 - 0.20	0.18 - 0.20	0.19 - 0.21
Min/Max CV q (US Spring - Yankee 41)	N/A	N/A	0.27 - 0.33	0.27 - 0.34	0.28 - 0.34
Min/Max CV q (Can Spring)	0.24 - 0.25	0.24 - 0.25	0.23 - 0.24	0.23 - 0.25	0.24 - 0.25
Min/Max CV q (US Autumn)	0.15 - 0.17	0.15 - 0.15	0.14 - 0.15	0.14 - 0.15	0.15 - 0.15
Standardized Residuals > 2	23	27	31	30	25
Max Partial Variance	1.444 (US Spr 1)	1.436 (US Spr 1)	2.432(US Spr 41 - Age 1)	2.646 (US Spr 41 - Age 1)	2.433 (US Spr 41 - Age 1)
Results					
Stock Numbers					
1998 n1	5323	5314	5350	5276	5424
1998 n2	10625	10607	11129	10999	11247
1998 n3	5501	5494	5793	5744	5805
1998 n4	5025	5021	5267	5232	5259
1998 n5	4457	4574	5092	5063	4823
1998 n6	5229	4511	5108	5083	4786
1998 n7	1558	1539	1881	1872	1679
1998 n8	160	199	258	257	215
1998 n9+	459	466	513	511	499
Fishing Mortality					
1997 F_3	0.05	0.05	0.03	0.03	0.05
1997 F_4	0.15	0.14	0.11	0.11	0.14
1997 F_5	0.09	0.11	0.09	0.09	0.10
1997 F_6	0.12	0.12	0.09	0.09	0.11
1997 F_7	0.10	0.08	0.05	0.06	0.08
1997 F_{4-7}	0.12	0.11	0.09	0.09	0.11
Biomass					
1997 Mean Biomass	51436	50002	54381	53687	52869
1997 SSB	39669	38306	42138	41914	40472

Table B20. Beginning year stock size of Georges Bank haddock estimated from VPA calibration (Run 17).

STOCK NUMBERS (Jan 1) in thousands

	1963	1964	1965	1966	1967	1968	1969
1	190707	471887	33154	4137	12954	422	988
2	32266	153505	377209	18457	3284	9565	338
3	32743	22756	111260	194987	8920	2536	5122
4	45821	20096	14510	50831	68426	4687	1435
5	29031	27424	12131	7034	24274	37322	2099
6	9186	16351	14561	5959	3254	10519	17419
7	5595	5526	8144	5868	2535	1570	5446
8	2795	3309	2640	3255	2694	1177	682
9	4217	4251	3258	2201	2031	2163	1712
1+	352361	725104	576869	292729	128371	69962	35243

	1970	1971	1972	1973	1974	1975	1976
1	4661	369	8517	19419	10549	7663	103326
2	807	3774	301	6832	13583	8595	6100
3	267	518	1846	245	3716	7212	6101
4	2657	204	222	1104	198	2448	4218
5	770	1660	131	109	555	160	1665
6	1127	462	1098	78	41	391	128
7	8874	729	156	790	37	32	282
8	3035	5177	339	57	577	28	22
9	1875	3245	6311	1679	2702	622	623
1+	24073	16138	18921	30313	31958	27151	122465

	1977	1978	1979	1980	1981	1982	1983
1	13817	6077	84012	10145	7233	2487	3125
2	84466	11312	4975	68782	8299	5921	2035
3	4566	51433	8573	4049	28264	5218	3793
4	4498	3569	29085	5457	3001	13189	2794
5	2657	3067	2646	17326	3586	1705	7421
6	1168	1709	1998	1692	8707	2088	1042
7	104	633	932	1265	847	4802	1194
8	210	82	393	478	542	394	2919
9	595	390	187	251	320	406	275
1+	112081	78273	132800	109445	60799	36210	24599

	1984	1985	1986	1987	1988	1989	1990
1	17313	1770	14862	2195	16979	1113	2784
2	2558	14175	1449	12163	1797	13898	911
3	1473	2010	9428	1138	8153	1424	10236
4	2370	937	1148	5177	815	4518	1088
5	1663	1283	592	738	2779	546	2905
6	4050	1003	633	352	494	1433	318
7	607	1975	615	362	222	270	849
8	810	286	1141	367	216	132	179
9	1632	552	256	464	354	211	170
1+	32475	23990	30123	22956	31808	23544	19440

	1991	1992	1993	1994	1995	1996	1997	1998
1	2557	10034	17663	13359	10141	8905	13770	5424
2	2278	2088	8209	14455	10937	8294	7286	11247
3	736	1459	1486	6458	11591	8873	6742	5805
4	7073	520	905	900	4554	8950	6749	5259
5	735	3846	306	471	583	3315	6472	4823
6	1593	510	1767	157	326	423	2295	4786
7	171	933	317	851	66	238	284	1679
8	535	74	472	225	560	46	175	215
9	248	256	224	220	177	68	504	499
1+	15926	19720	31349	37096	38935	39113	44278	39738

Table B21. Spawning stock biomass (mt) of Georges Bank haddock estimated from the VPA calibration (Run 17).

SSB AT THE START OF THE SPAWNING SEASON -MALES AND FEMALES (MT)

	1963	1964	1965	1966	1967	1968	1969
1	00	00	00	00	00	00	00
2	00	00	00	00	00	1675	61
3	24231	15657	65969	91733	4933	1433	3119
4	56090	23010	14888	48137	60262	4294	1636
5	38627	36348	15695	8788	26344	41988	2731
6	16463	25241	20959	8948	5063	15409	26012
7	10878	10437	13801	10289	4575	2780	10825
8	6533	7058	5446	6850	5609	2397	1526
9	11435	10811	8271	5784	5324	5124	5278
1+	164257	128561	145028	180528	112109	75100	51188

	1970	1971	1972	1973	1974	1975	1976
1	00	00	00	00	00	00	00
2	164	756	67	1594	3144	2253	1511
3	185	411	1652	273	4217	7627	6071
4	3442	266	304	1790	359	4459	6768
5	1303	3215	236	189	1248	342	3694
6	2067	873	2671	183	116	1039	316
7	17574	1590	354	2308	126	113	863
8	7609	12677	962	170	1957	105	87
9	6178	10451	20681	5771	10661	2456	2771
1+	38522	30239	26926	12277	21828	18393	22081

	1977	1978	1979	1980	1981	1982	1983
1	00	00	00	00	00	00	00
2	18010	2458	1135	12827	1687	1075	293
3	4152	45769	6803	3348	20429	4061	3149
4	7099	5677	44478	7311	3877	17441	3998
5	5547	6780	5354	30542	6248	3140	13001
6	2928	4335	5275	3786	18230	4575	2282
7	351	1848	2738	3440	2264	12587	3246
8	725	286	1233	1495	1783	1317	8371
9	2665	1798	800	828	1225	1447	1021
1+	41476	68950	67818	63577	55742	45642	35362

	1984	1985	1986	1987	1988	1989	1990
1	377	79	1124	143	1118	100	124
2	438	4756	494	4372	715	5116	347
3	1434	1798	8570	1104	6751	1459	10068
4	3219	1323	1607	7161	1120	6140	1584
5	2941	2281	1170	1355	4779	919	4867
6	8220	2170	1452	815	997	2892	646
7	1408	4921	1533	929	546	686	2031
8	2289	824	3277	1061	603	383	488
9	5155	1824	853	1721	1208	718	620
1+	25481	19977	20081	18661	17837	18413	20775

	1991	1992	1993	1994	1995	1996	1997
1	99	348	602	270	52	52	67
2	1000	887	1839	3483	2320	1838	1579
3	715	1708	1326	5823	13030	9372	8114
4	9860	687	1363	1482	7673	13654	10441
5	1322	6311	502	1026	1274	6561	12104
6	3298	1061	3528	303	820	974	5165
7	375	2205	751	2116	180	685	746
8	1352	192	1216	638	1549	145	552
9	930	913	760	897	652	230	1705
1+	18953	14313	11888	16039	27550	33511	40472

Table B22. Mean biomass (mt) of Georges Bank haddock estimated from the VPA calibration (Run 17).

	1963	1964	1965	1966	1967	1968	1969
1	97717	211391	14554	2142	7375	223	465
2	23694	108939	190544	9574	2026	5762	235
3	30570	20524	79455	107564	6249	2031	4132
4	52683	22565	13938	45273	60548	4253	1805
5	37107	33322	14500	8336	23358	41007	2735
6	15484	23667	19034	8292	4737	16184	25214
7	10228	9378	12048	9296	4088	2471	10392
8	6577	6509	4809	6534	5219	2165	1497
9	10122	9407	6938	4896	4586	4345	4563
1+	284183	445701	355820	201909	118185	78440	51038

	1970	1971	1972	1973	1974	1975	1976
1	2983	224	4739	9797	6868	4248	46790
2	828	2777	280	5271	10667	7132	5243
3	286	458	2512	349	5530	9098	7310
4	4091	287	324	1700	414	4490	6721
5	1320	3249	248	167	1325	315	3729
6	2183	791	2731	181	136	980	356
7	17700	1487	300	2319	132	107	901
8	7655	12199	942	169	1948	96	85
9	5489	9175	18667	5098	9912	2252	2514
1+	42535	30646	30743	25050	36930	28718	73649

	1977	1978	1979	1980	1981	1982	1983
1	6637	2919	40356	5055	2556	496	935
2	71251	9286	4496	42826	5777	4635	1774
3	5828	58805	8829	4234	24525	5627	4146
4	8109	6293	45854	7709	4195	18857	3990
5	5866	6960	5355	27182	6370	3192	12301
6	2803	4088	5036	3444	17849	4415	2134
7	385	1696	2569	3070	2197	12255	3216
8	683	242	1163	1258	1654	1200	7507
9	2412	1634	711	718	1072	1276	899
1+	103974	91923	114369	95496	66195	51953	36901

	1984	1985	1986	1987	1988	1989	1990
1	5178	530	6060	855	6463	535	1614
2	2091	11524	1210	8320	1571	10656	796
3	1564	2140	9644	1383	8251	1848	12664
4	3241	1487	1699	7708	1128	6538	1601
5	2872	2263	1182	1368	4186	931	4624
6	7714	2157	1372	742	908	2867	605
7	1262	4651	1422	853	515	717	1908
8	2027	814	3109	1049	566	376	415
9	4456	1607	761	1509	1056	645	549
1+	30405	27171	26459	23788	24644	25113	24775

	1991	1992	1993	1994	1995	1996	1997
1	1345	4891	10547	5412	3941	3679	5186
2	2208	2080	8532	14177	9543	8226	6505
3	815	1902	2019	8956	15209	11621	10090
4	9624	714	1443	1612	7902	14050	10839
5	1344	5844	473	1035	1267	6449	12363
6	3264	1022	3294	286	788	888	5020
7	331	2008	711	2017	182	703	771
8	1236	178	1076	689	1482	138	510
9	815	780	655	810	605	213	1585
1+	20982	19418	28751	34994	40918	45967	52869

Table B23. Estimated fishing mortality (F) for the Georges Bank haddock estimated from VPA calibration (Run 17).

	1963	1964	1965	1966	1967	1968	1969
1	0.02	0.02	0.39	0.03	0.10	0.02	0.00
2	0.15	0.12	0.46	0.53	0.06	0.42	0.04
3	0.29	0.25	0.58	0.85	0.44	0.37	0.46
4	0.31	0.30	0.52	0.54	0.41	0.60	0.42
5	0.37	0.43	0.51	0.57	0.64	0.56	0.42
6	0.31	0.50	0.71	0.65	0.53	0.46	0.47
7	0.33	0.54	0.72	0.58	0.57	0.63	0.38
8	0.34	0.42	0.61	0.56	0.47	0.55	0.45
9	0.34	0.42	0.61	0.56	0.47	0.55	0.45

	1970	1971	1972	1973	1974	1975	1976
1	0.01	0.00	0.02	0.16	0.00	0.03	0.00
2	0.24	0.52	0.01	0.41	0.43	0.14	0.09
3	0.07	0.65	0.31	0.01	0.22	0.34	0.10
4	0.27	0.24	0.52	0.49	0.01	0.19	0.26
5	0.31	0.21	0.31	0.77	0.15	0.03	0.15
6	0.24	0.89	0.13	0.55	0.06	0.13	0.00
7	0.34	0.57	0.81	0.11	0.06	0.15	0.09
8	0.32	0.38	0.24	0.35	0.11	0.17	0.22
9	0.32	0.38	0.24	0.35	0.11	0.17	0.22

	1977	1978	1979	1980	1981	1982	1983
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.30	0.08	0.01	0.69	0.26	0.25	0.12
3	0.05	0.37	0.25	0.10	0.56	0.42	0.27
4	0.18	0.10	0.32	0.22	0.37	0.38	0.32
5	0.24	0.23	0.25	0.49	0.34	0.29	0.41
6	0.41	0.41	0.26	0.49	0.40	0.36	0.34
7	0.04	0.28	0.47	0.65	0.57	0.30	0.19
8	0.23	0.21	0.32	0.44	0.39	0.35	0.36
9	0.23	0.21	0.32	0.44	0.39	0.35	0.36

	1984	1985	1986	1987	1988	1989	1990
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.04	0.21	0.04	0.20	0.03	0.11	0.01
3	0.25	0.36	0.40	0.13	0.39	0.07	0.17
4	0.41	0.26	0.24	0.42	0.20	0.24	0.19
5	0.31	0.51	0.32	0.20	0.46	0.34	0.40
6	0.52	0.29	0.36	0.26	0.41	0.32	0.42
7	0.55	0.35	0.31	0.32	0.32	0.21	0.26
8	0.45	0.36	0.30	0.38	0.40	0.27	0.33
9	0.45	0.36	0.30	0.38	0.40	0.27	0.33

	1991	1992	1993	1994	1995	1996	1997
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.25	0.14	0.04	0.02	0.01	0.01	0.03
3	0.15	0.28	0.30	0.15	0.06	0.07	0.05
4	0.41	0.33	0.45	0.23	0.12	0.12	0.14
5	0.17	0.58	0.47	0.17	0.12	0.17	0.10
6	0.33	0.28	0.53	0.67	0.11	0.20	0.11
7	0.64	0.48	0.14	0.22	0.15	0.11	0.08
8	0.38	0.51	0.47	0.24	0.12	0.14	0.11
9	0.38	0.51	0.47	0.24	0.12	0.14	0.11

Table B24. Yield-per-recruit analysis for Georges Bank haddock (from Brown 1998).

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

GEORGE BANK HADDOCK - 1997 AVE WTS, FPAT AND MAT VECTORS

Proportion of F before spawning: .2500
Proportion of M before spawning: .2500
Natural Mortality is Constant at: .200
Initial age is: 1; Last age is: 15
Last age is a PLUS group:
Original age-specific PRs, Mats, and Mean Wts from file:
==> GBHAD97.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	.0200	.447	.291
2	.0400	1.0000	.3400	1.053	.731
3	.3800	1.0000	.9400	1.547	1.290
4	.7200	1.0000	1.0000	2.030	1.812
5	1.0000	1.0000	1.0000	2.497	2.310
6	1.0000	1.0000	1.0000	2.693	2.554
7	1.0000	1.0000	1.0000	3.197	2.952
8	1.0000	1.0000	1.0000	3.270	3.087
9	1.0000	1.0000	1.0000	3.431	3.298
10	1.0000	1.0000	1.0000	3.609	3.513
11	1.0000	1.0000	1.0000	3.981	3.724
12	1.0000	1.0000	1.0000	4.116	3.914
13	1.0000	1.0000	1.0000	4.264	4.139
14	1.0000	1.0000	1.0000	4.492	4.294
15+	1.0000	1.0000	1.0000	4.841	4.638

Summary of Yield per Recruit Analysis for:
GEORGE BANK HADDOCK - 1997 AVE WTS, FPAT AND MAT VECTORS

Slope of the Yield/Recruit Curve at F=0.00: --> 8.8284
F level at slope=1/10 of the above slope (F0.1): -----> .264
Yield/Recruit corresponding to F0.1: -----> .8086
F level to produce Maximum Yield/Recruit (Fmax): -----> 1.485
Yield/Recruit corresponding to Fmax: -----> .9781
F level at 30 % of Max Spawning Potential (F30): -----> .454
SSB/Recruit corresponding to F30: --------> 2.8760

Table B25. Alternative estimates of MSY biological reference points for Georges Bank haddock.

Method	Period	MSY (k mt)	B_{msy} (k mt)	F_{msy}	Source
Beverton Holt S-R	1968-1995	10	[1]80	[2]0.38	ODRP 1998
Schaefer	1931-1993	143	896	0.16	Spencer & Collie
Schaefer	1976-1993	13	65	0.20	Spencer & Collie
Steele & Henderson	1931-1993	70	250	0.28	Spencer & Collie
Schaefer	1931-1963	68	323	0.21	ODRP 1998
YPR & mean R	1931-1961	60	375 ([1]290)	[2]0.26	ODRP 1998
Descriptive	1931-1961	46	160 ([1]105)	0.29	ODRP 1998

[1]SSB_{msy}. [2]Fully-recruited F.

Table B26. Stochastic short-term (3-year) projections of spawning stock biomass (mt), landings (mt), and discards (mt) for Georges Bank haddock at fishing mortality levels of 0.00, *status quo* $F_{97} = 0.11$, $F_{0.10} = 0.26$, and $F_{30\%} = 0.45$. Probability of SSB exceeds the US management threshold for spawning stock biomass level (80,000 mt) is also given, along with the 10th and 90th percentiles for each estimate.

	2000 Spawning biomass				1999 Landings			1999 Discards		
Fishing mortality F	10th percentile	Median	90th percentile	Probability of exceeding 80,000 mt threshold	10th percentile	Median	90th percentile	10th percentile	Median	90th percentile
0.00	51,802	63,377	77,598	7 %	0	0	0	0	0	0
0.11	46,303	56,877	69,978	2 %	3,820	4,566	5,343	485	609	776
0.26	39,823	49,207	61,030	0 %	8,451	10,110	11,843	1,083	1,362	1,741
0.45	33,062	41,210	51,598	0 %	13,498	16,150	18,926	1,749	2,204	2,828

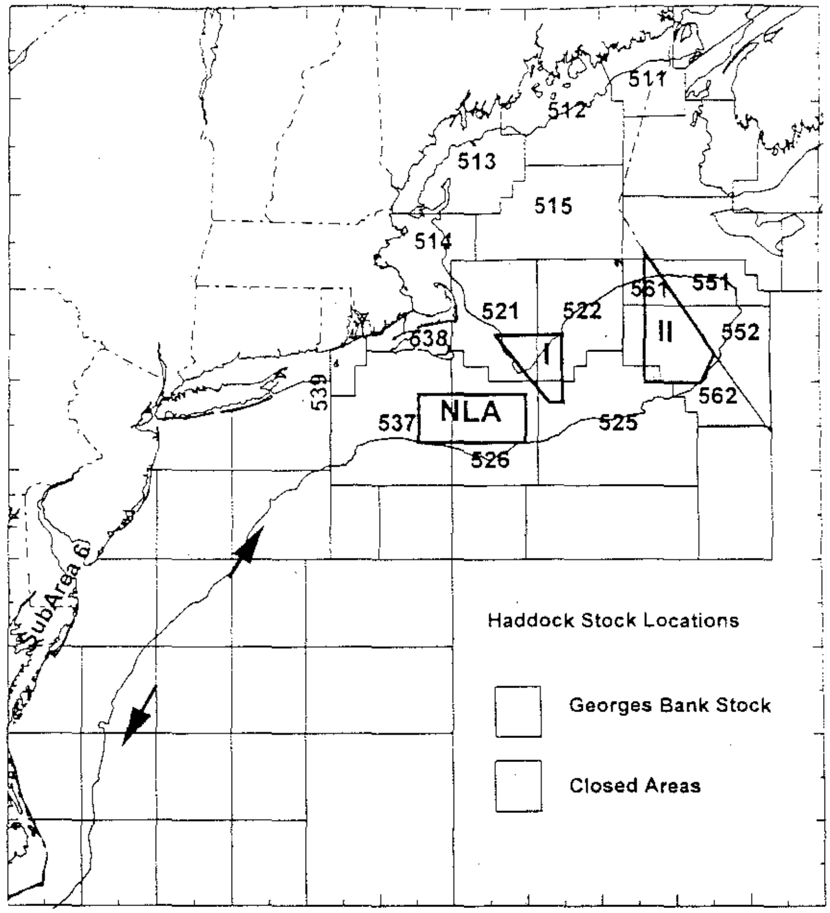

Figure B1. NEFSC statistical areas included in the Georges Bank haddock assessment. Shading indicates the area where 99% of catch occurs, although landings from areas 5 and 6 south of the primary area of concentration are also included in the assessment.

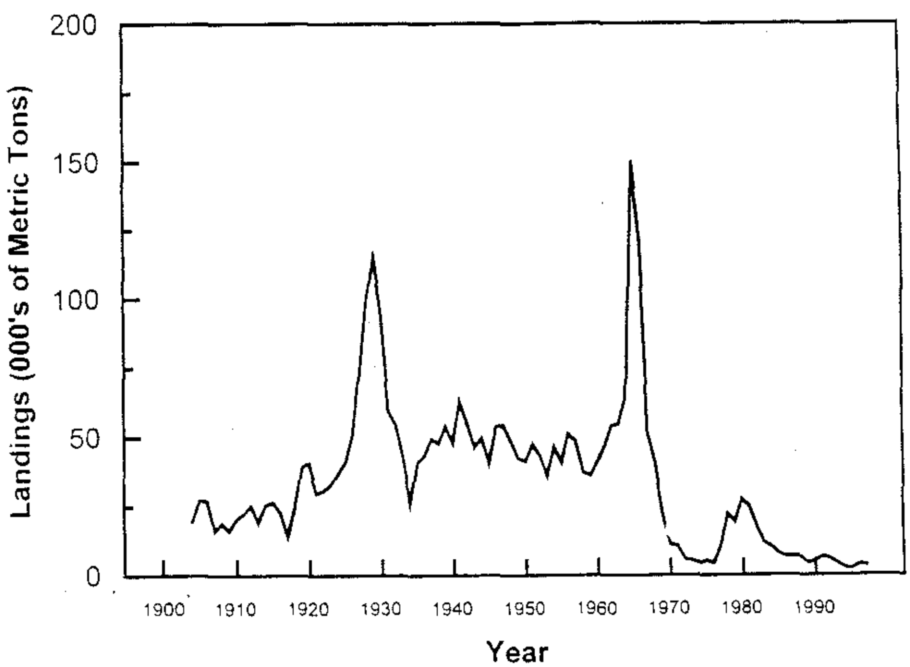

Figure B2. Total commercial landings of haddock from Georges Bank and South, 1904-1997.

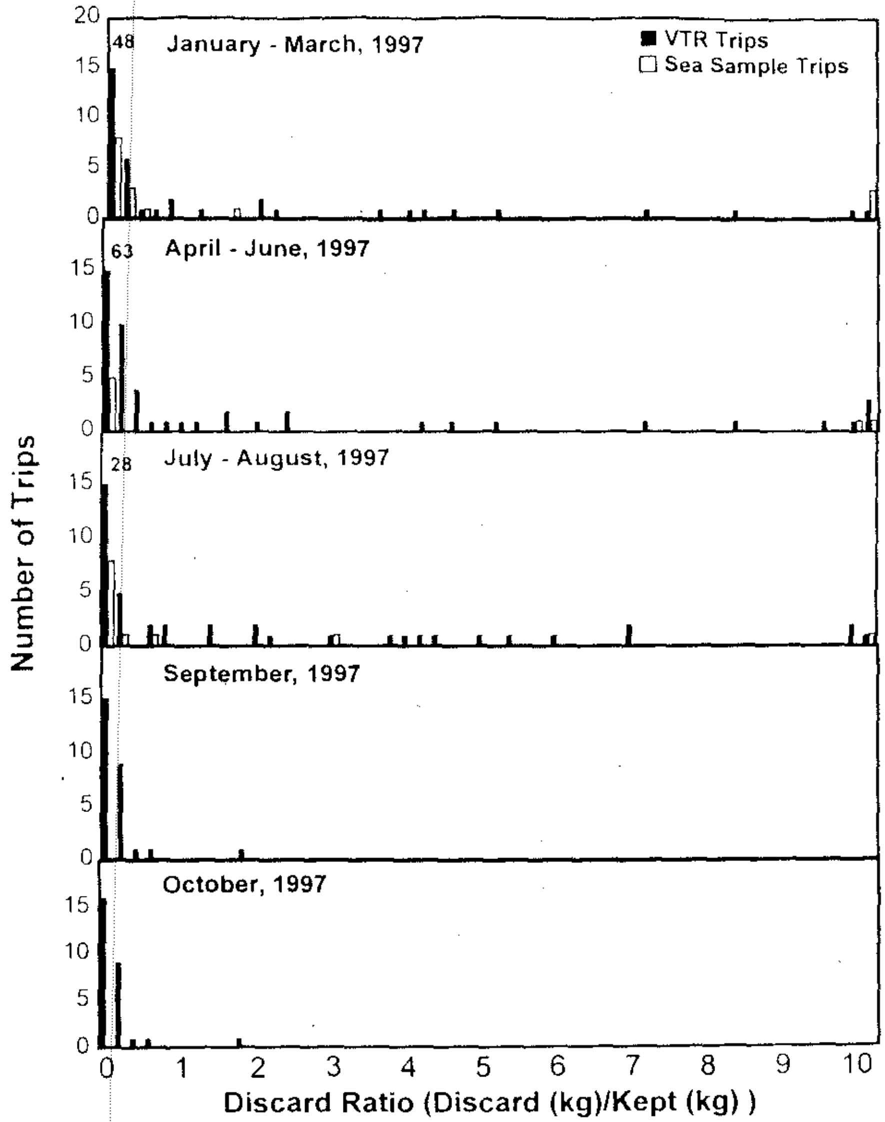

Figure B3. Distribution of discard ratios (discarded weight/kept weight) for Georges Bank haddock trips reported in the Vessel Trip Report (VTR) and Sea Sample databases in 1997. The last two bars report trips where the entire haddock catch was discarded.

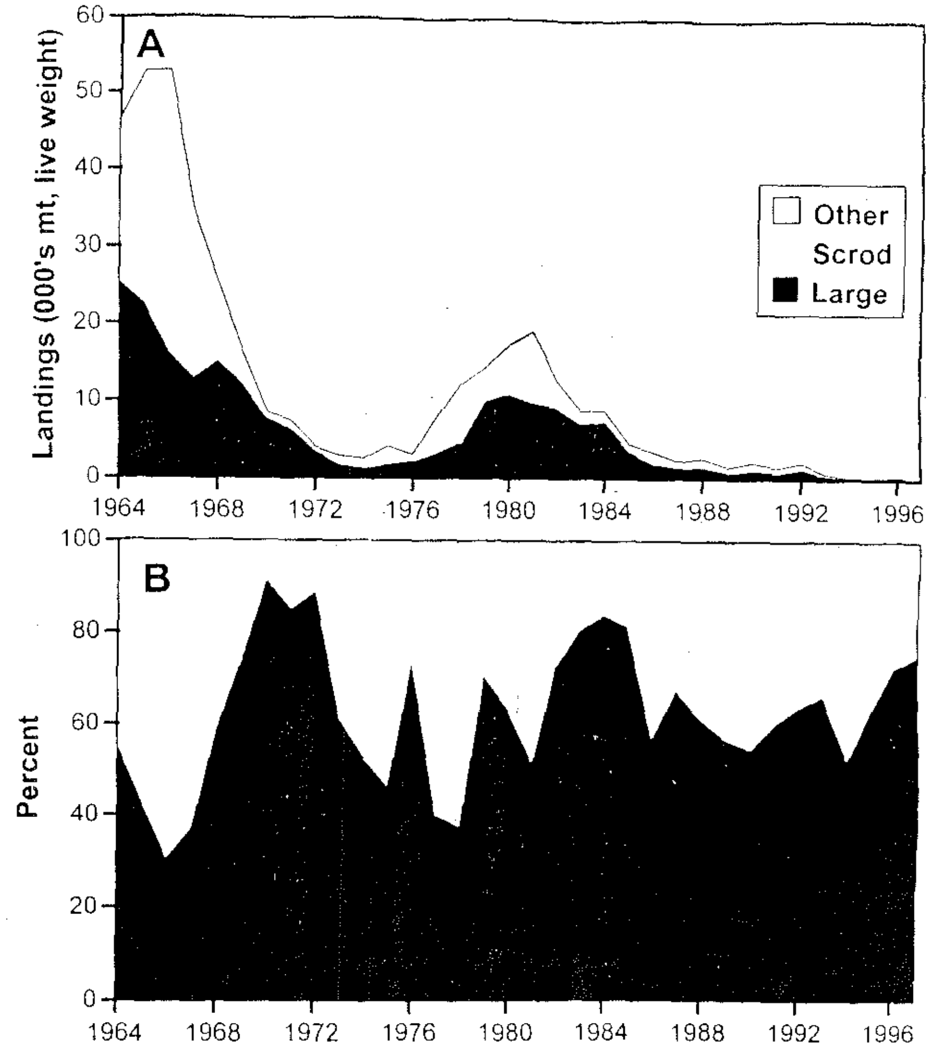

Figure B4. USA Georges Bank haddock landings by market category (Panel A) and percent distribution of landings by market category (Panel B).

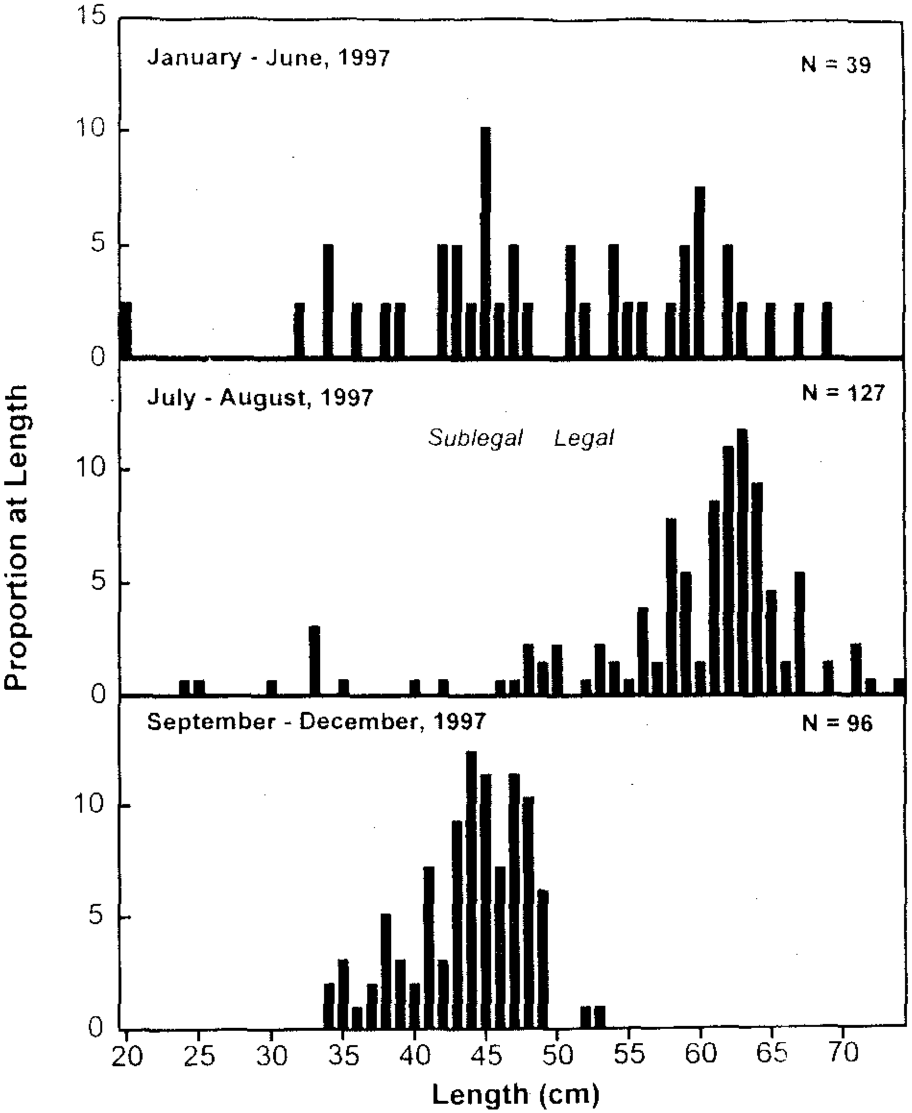

Figure B5. Length frequency distributions of discarded haddock sampled at sea for three time periods in 1997. The haddock trip limit was liberalized on September 1, 1997, resulting in a shift in the size distribution of discarded haddock from predominantly sublegal size fish.

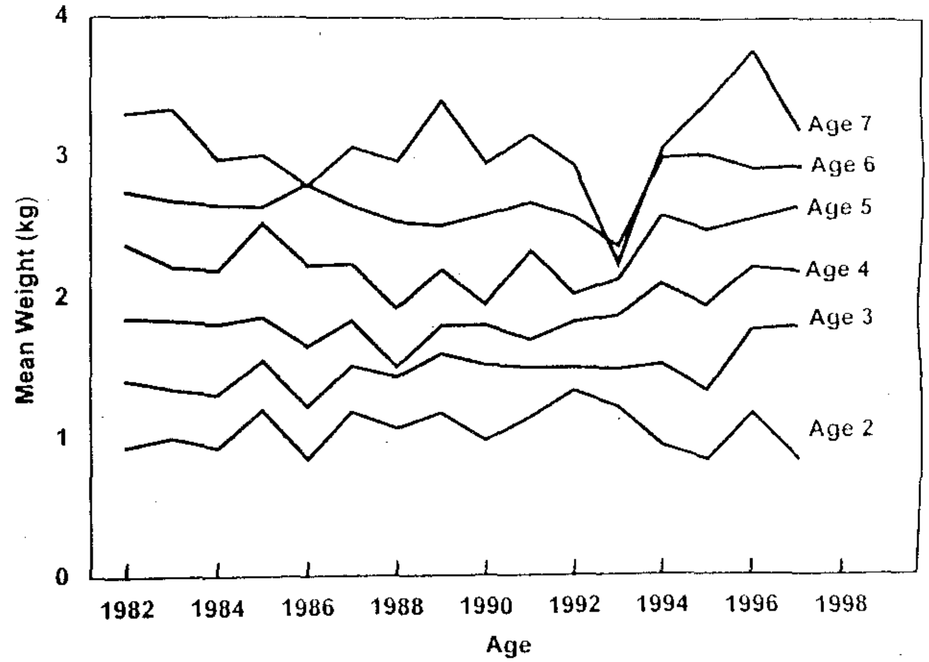

Figure B6. Mean weights at age in the U.S. commercial catch of Georges Bank haddock (5Z & 6) from 1982-1997 Mean weights of fully recruited ages (3+) have systematically increased since 1994.

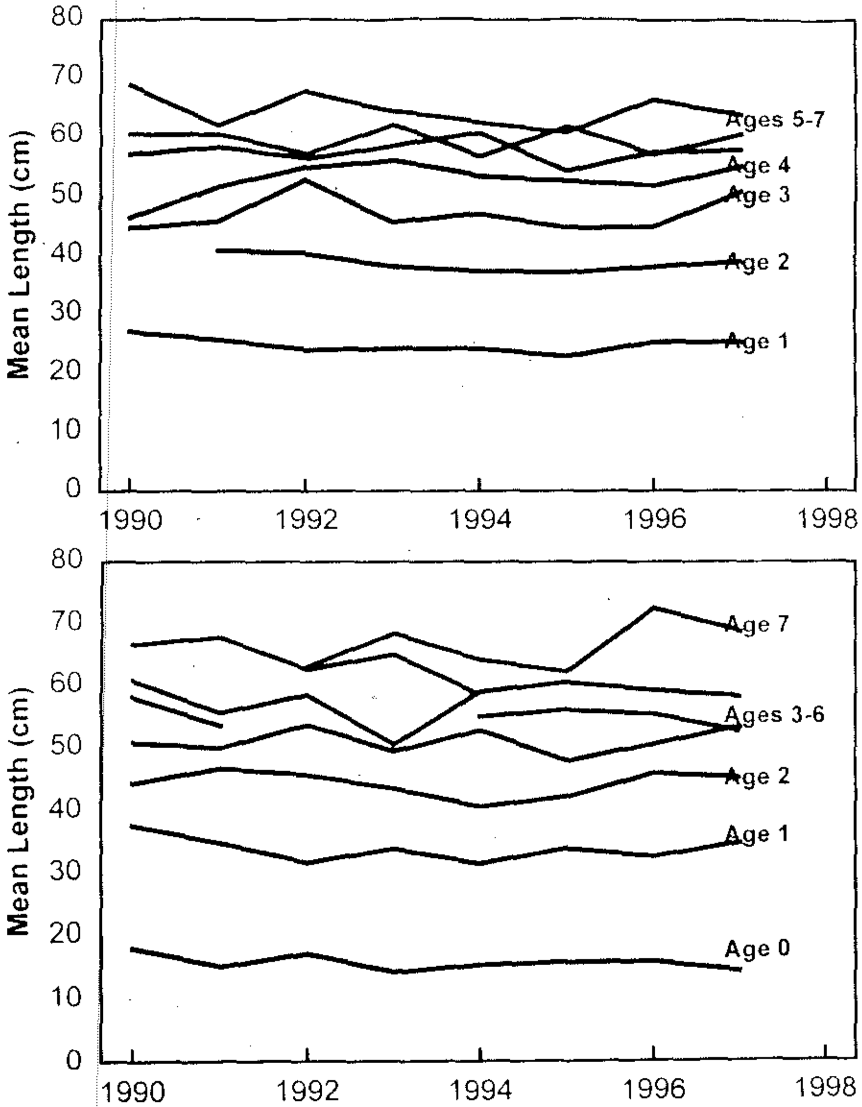

Figure B7. Mean length at age in the U.S. Spring (Panel A) and Autumn (Panel B) surveys for Georges Bank haddock (5Z & 6) from 1990-1997. Mean lengths at age have remained relatively stable since 1990.

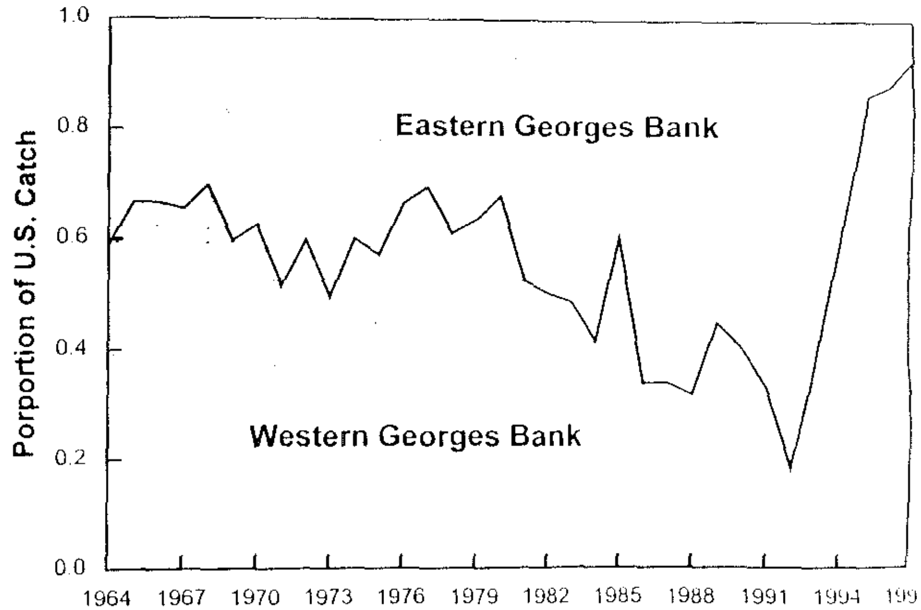

Figure B8. The proportion of U.S. catch occurring in Eastern Georges Bank (U.S. statistical areas 551, 552, 561, 562) and Western Georges Bank (U.S. statistical areas 521, 522, 525, 526, 537, 538, 539, and south). U.S. landings have shifted from eastern to Western Georges Bank in response to U.S. management actions including Closed Areas and Days at Sea restrictions.

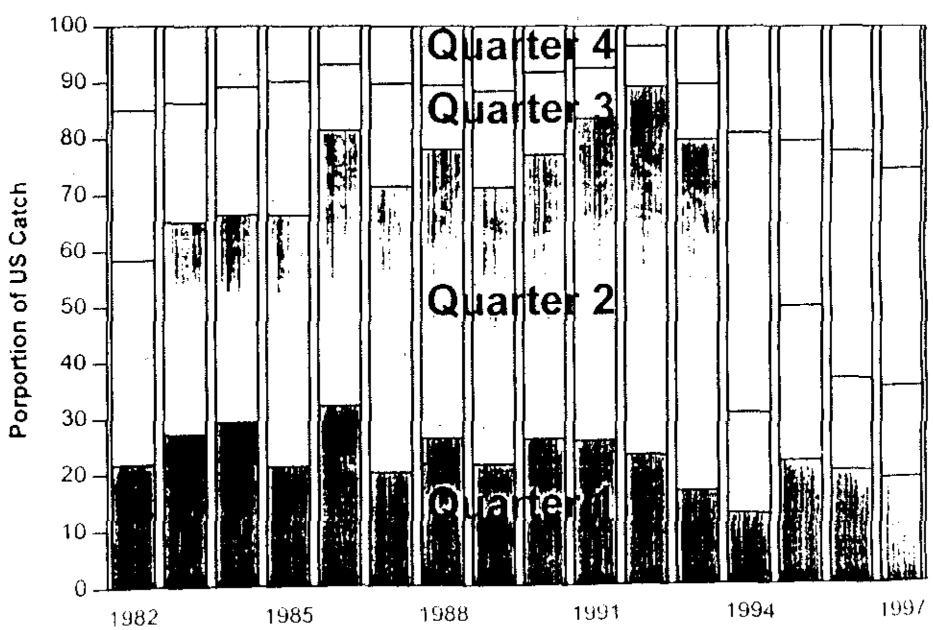

Figure B9. The proportion of U.S. catch by three month periods during the calendar year. Since 1994, the proportion of U.S. catch occurring in the third and fourth quarters has increased relative to the first half of the year.

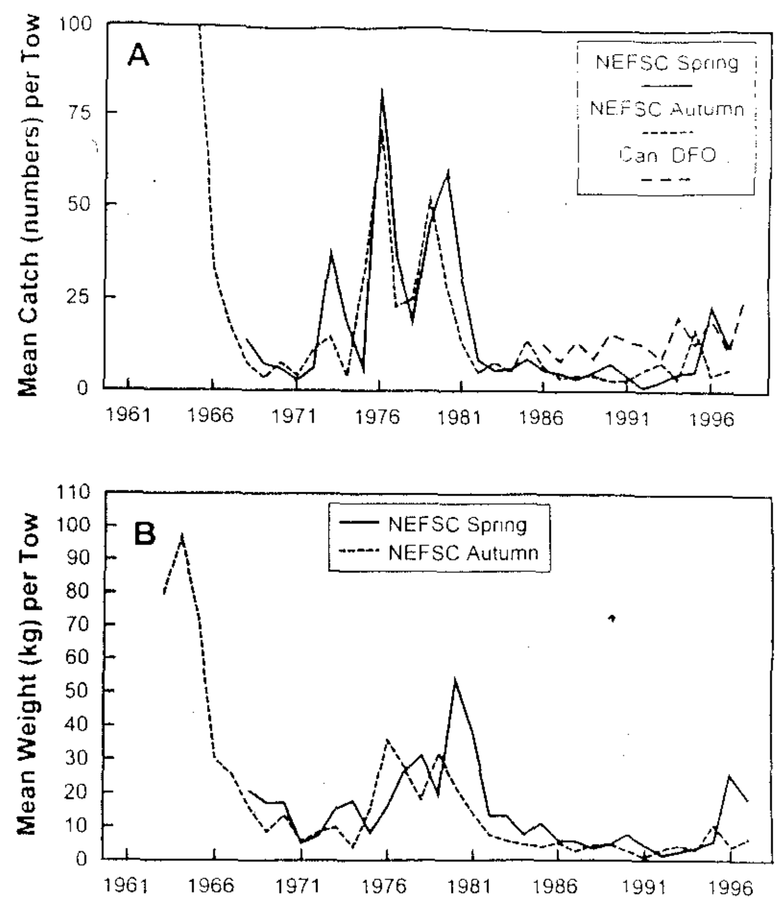

Figure B10. NEFSC and Canadian DFO bottom trawl survey abundance (number per tow; Panel A) and biomass (kg per tow; Panel B) for Georges Bank haddock, 1963-1996. Surveys have not been adjusted for catchabilities.

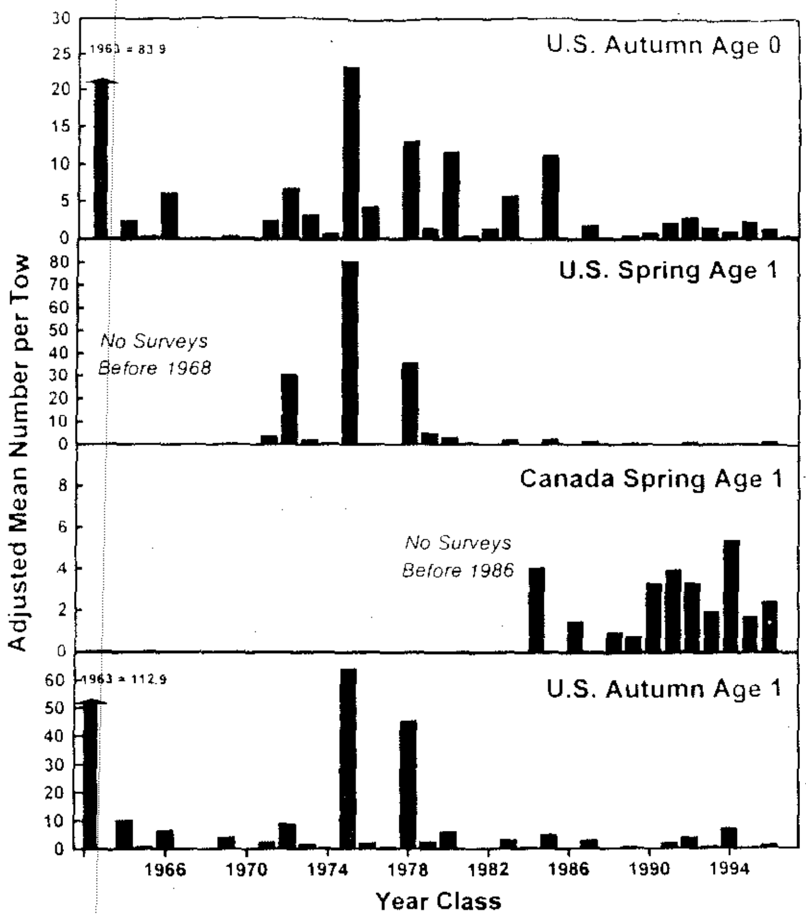

Figure B11. Stratified mean number per tow of age 0 and 1 haddock sampled during the U.S. Spring and Autumn, and Canadian Spring Research Vessel Surveys from Georges Bank and South.

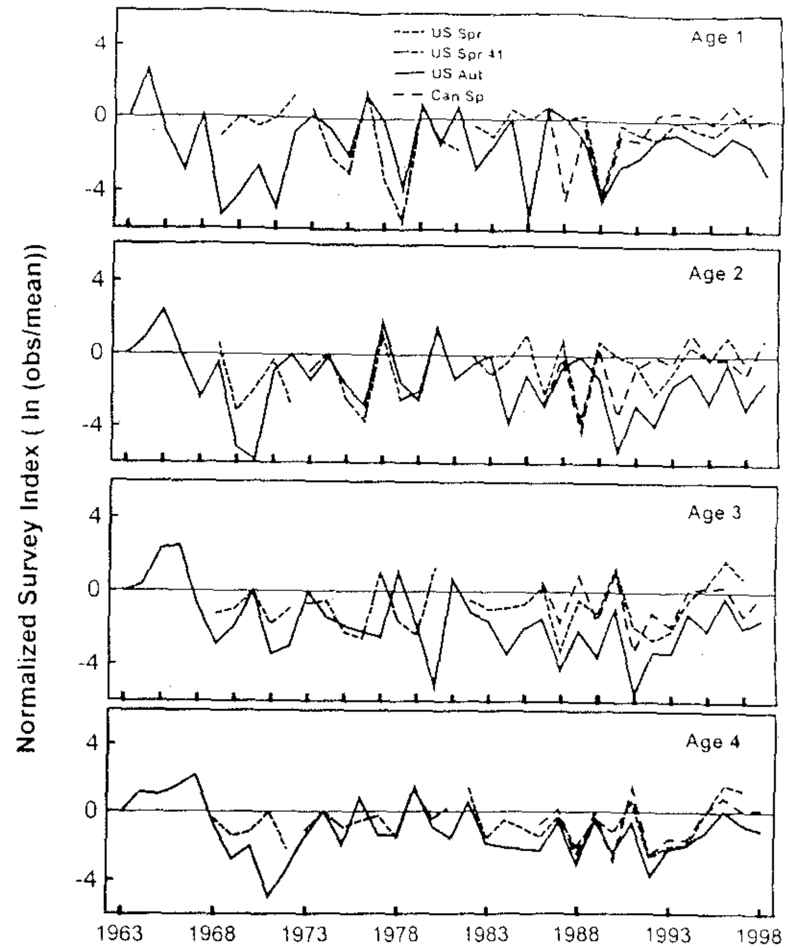

Figure B12a. Normalized indices of abundance at age (ages 1-4) for Georges Bank haddock (5Z & 6). Indices included the U.S. spring (1968-1972, 1982-1996), the U.S. spring Yankee 41 (1973-1981), the U.S. autumn (lagged forward to 1964-1998), and the Canada spring (1986-1998).

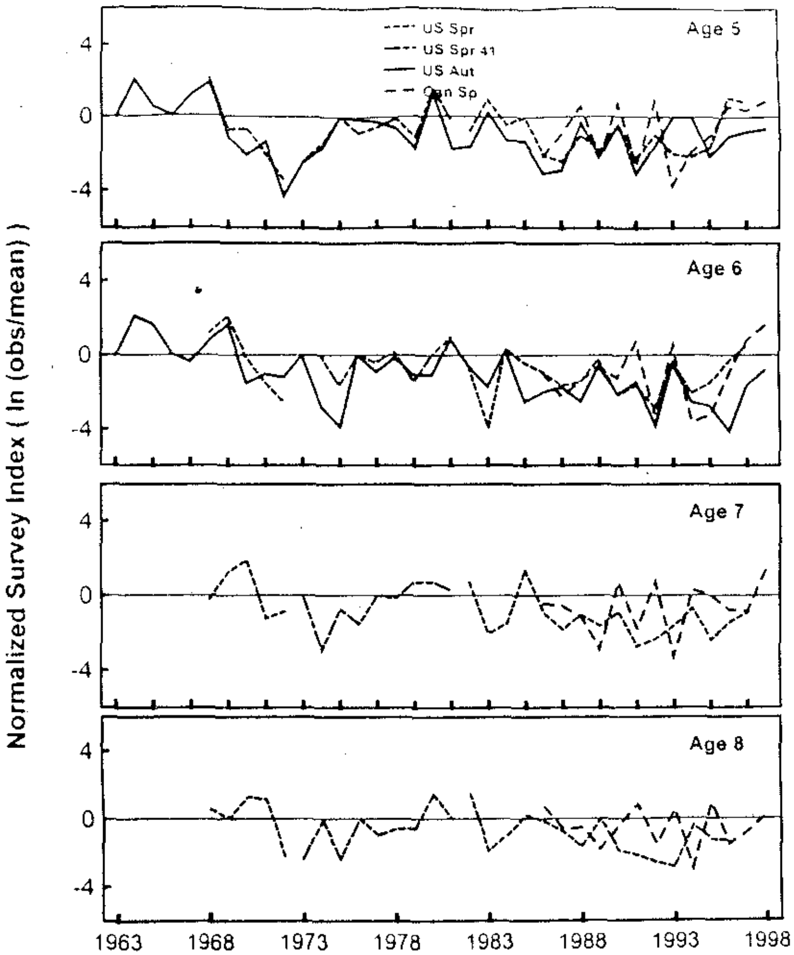

Figure B12b. Normalized indices of abundance at age (ages 5-8) for Georges Bank haddock (5Z & 6). Indices included the U.S. spring (1968-1972, 1982-1996), the U.S. spring Yankee 41 (1973-1981), the U.S. autumn (lagged forward to 1964-1998), and the Canada spring (1986-1998).

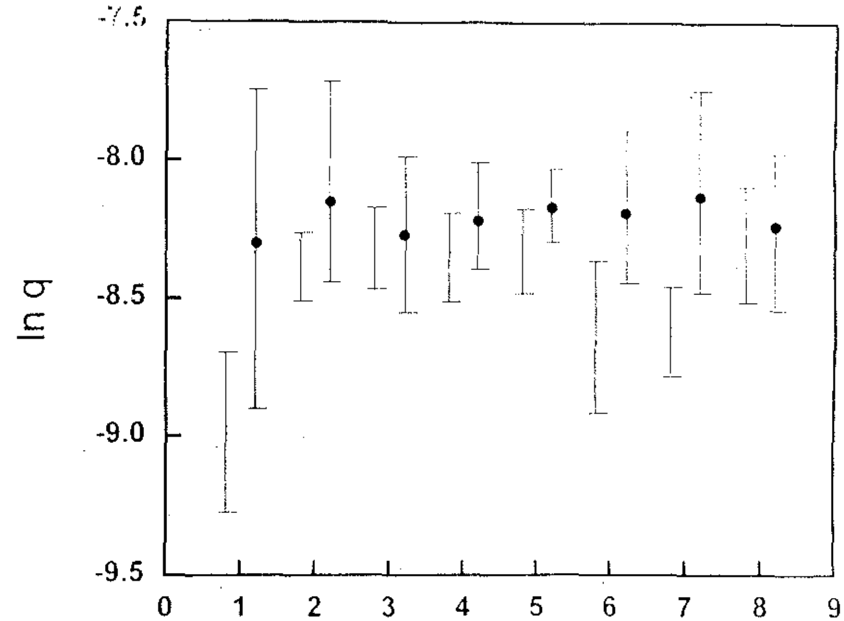

Figure B13. Comparison of log catchability estimates derived from a Virtual Population Analysis for two trawls (Yankee 36 and Yankee 41 trawls). Results show a pattern of high catchability estimates at age for the Yankee 41 trawl, providing some evidence that the catchability of haddock was not equivalent between the gears.

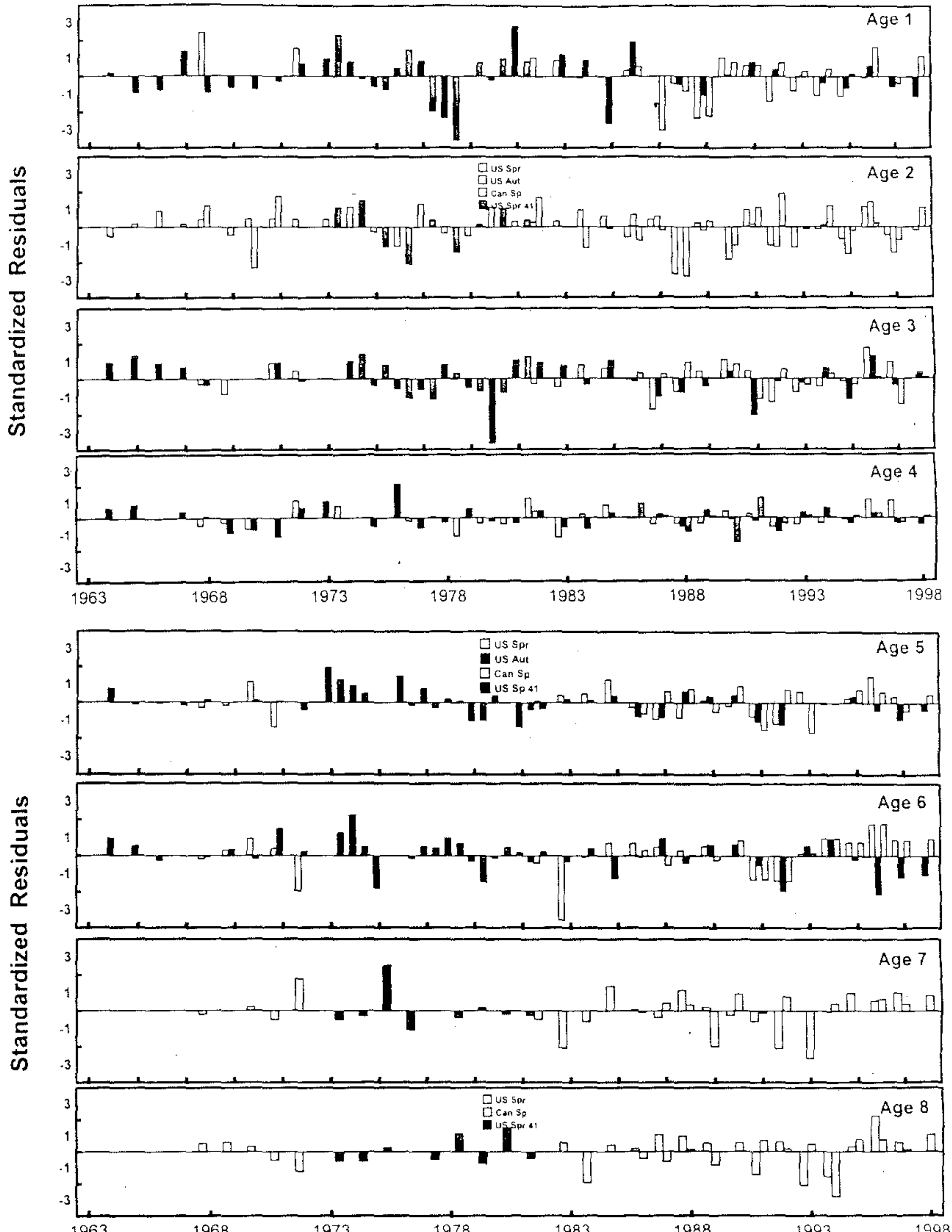

Figure B14. Standardized residuals for the age 1-4 U.S. and Canadian Research Vessel survey indices used to tune the Virtual Population Analysis for Georges Bank haddock.

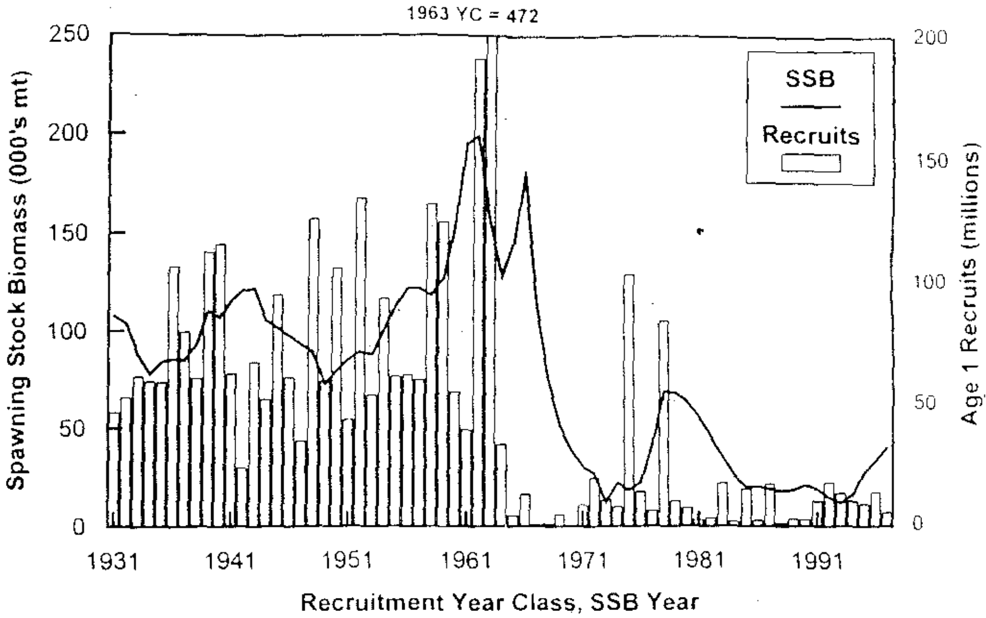

Figure B15. Trends in spawning stock biomass (line) and age 1 recruitment (bars) for Georges Bank (5Z & 6) haddock, 1931-1997.

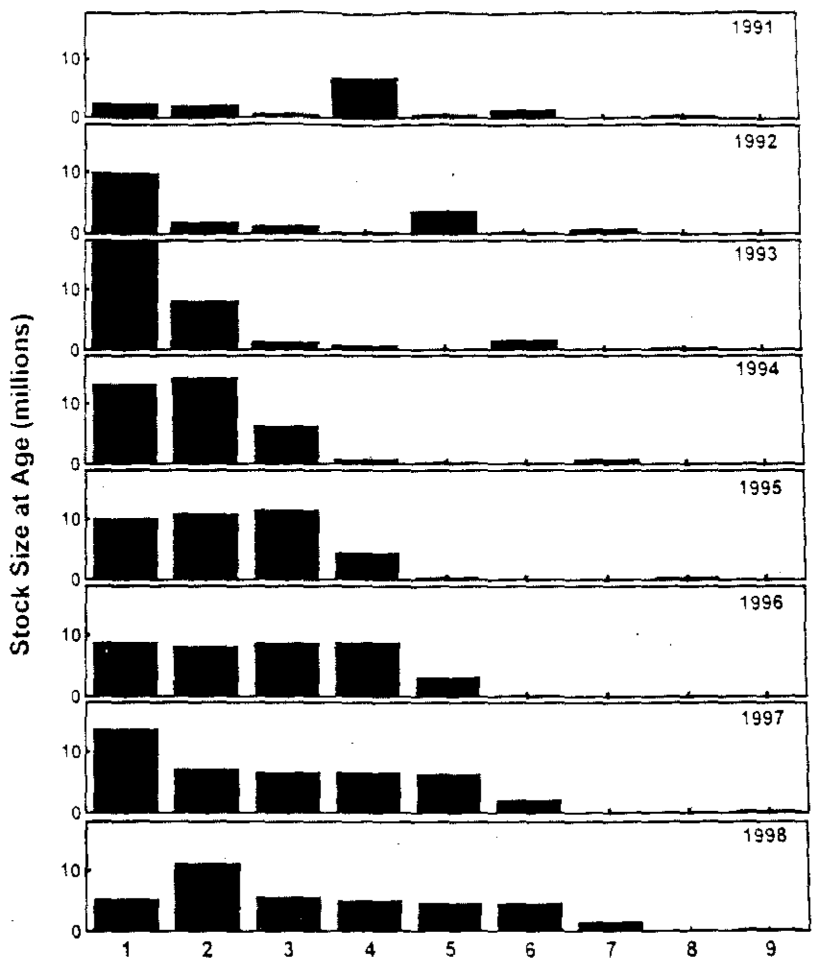

Figure B16. Stock numbers at age (millions) from the ADAPT calibration of Run 17 of the Georges Bank (5Z & 6) assessment.

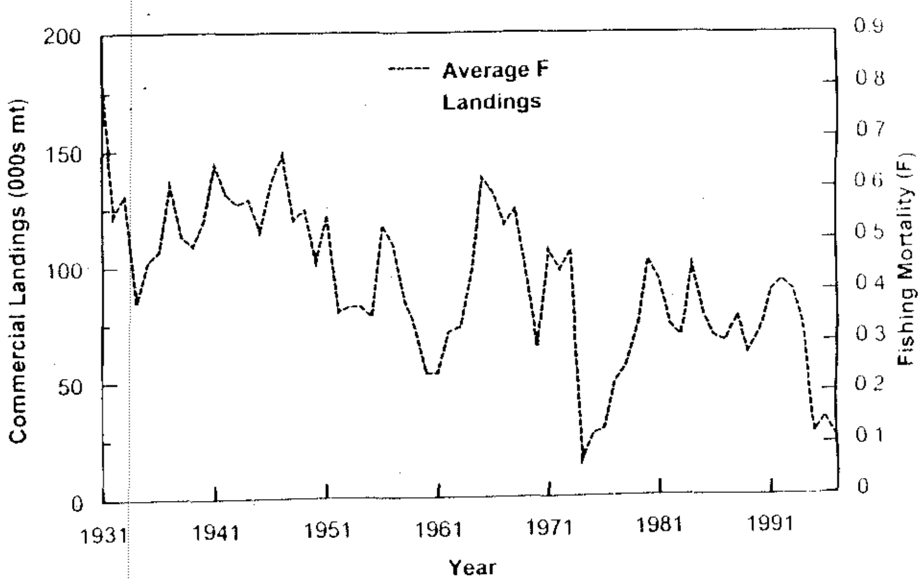

Figure B17. Trends in commercial landings (metric tons, live weight) and fully recruited fishing mortality (mean F, 4-7, unweighted) for Georges Bank haddock, 1963-1997.

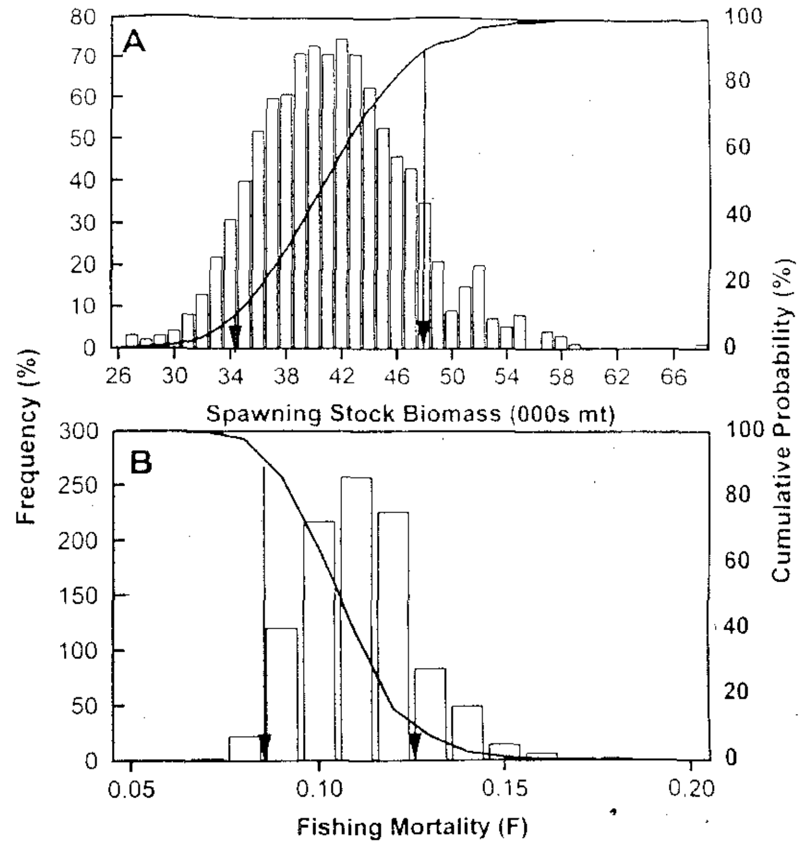

Figure B18. Precision of the estimates of spawning stock biomass (Panel A) at the beginning of the spawning season (April 1) and instantaneous rate of fishing mortality (Panel B) on fully recruited ages (ages 4+) in 1996 for Georges Bank haddock. The vertical bars display both the range of the estimator and the probability of individual values within the range. The solid line gives the probability of individual values within the range. The solid line gives the probability that F is greater than or SSB is less than the corresponding value on the X-axis. The solid arrows indicate the approximate 90% and 10% confidence levels for F and SSB. The precision estimates were derived from 1000 bootstrap replications of the final ADAPT VPA formulation (Run 17).

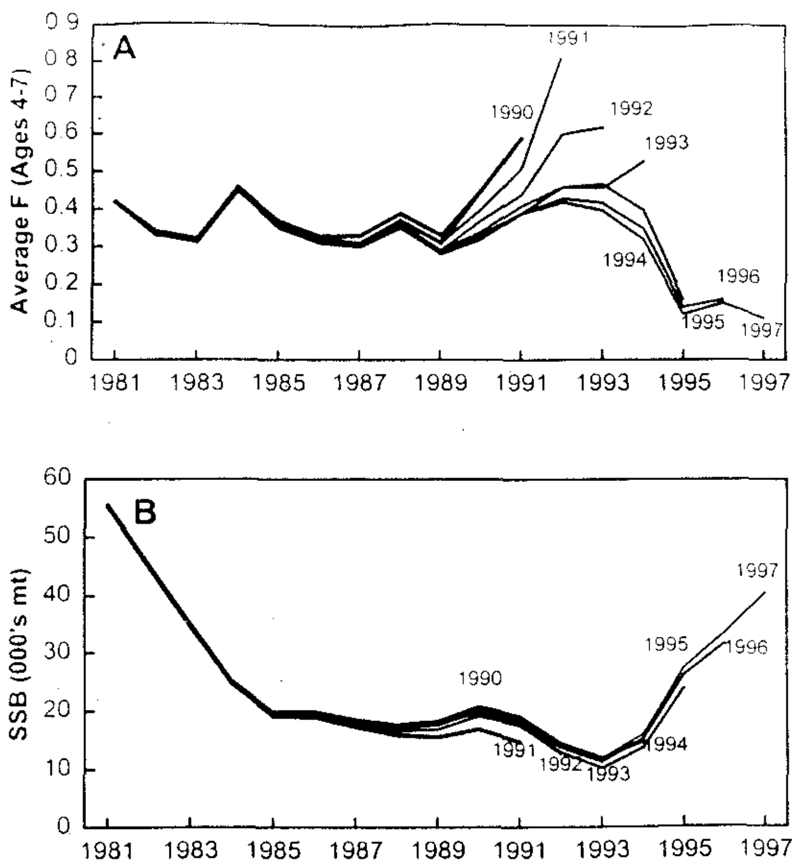

Figure B19. Retrospective analysis results of fishing mortality (Panel A) and spawning stock biomass (Panel B) for the USA Georges Bank haddock assessment, 1996 to 1991.

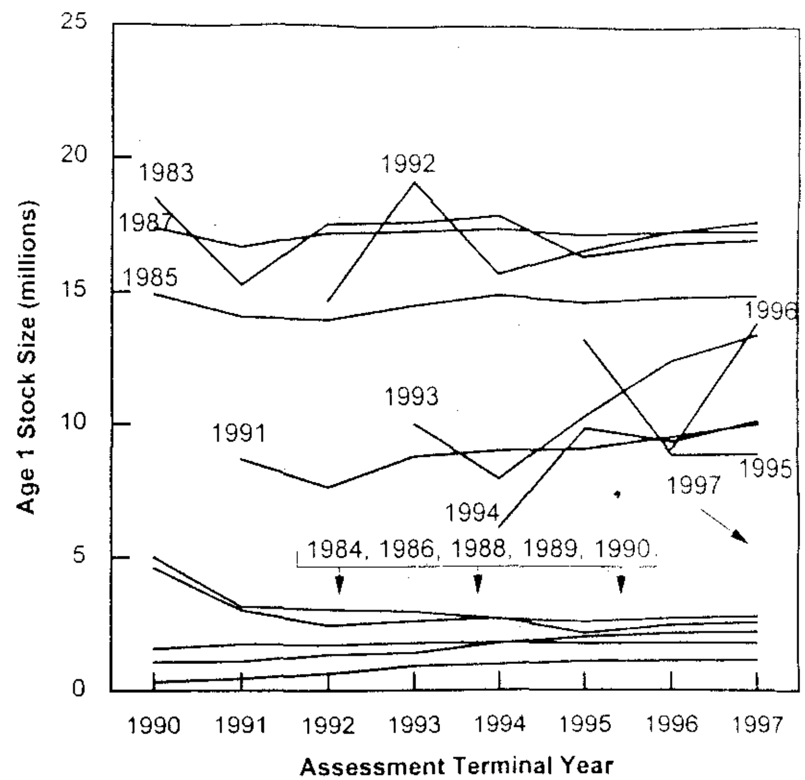

Figure B20. Retrospective analysis results showing successive estimates of year class abundance as additional years of data were included in the assessment. The estimated size of the 1997 year class is indicated by the star.

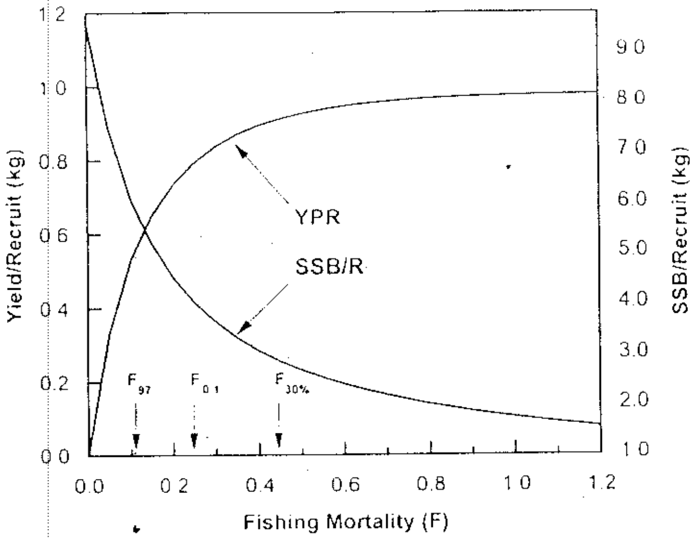

Figure B21. Yield (YPR) and spawning stock biomass (SSB/R) per recruit for Georges Bank haddock from Brown (1998).

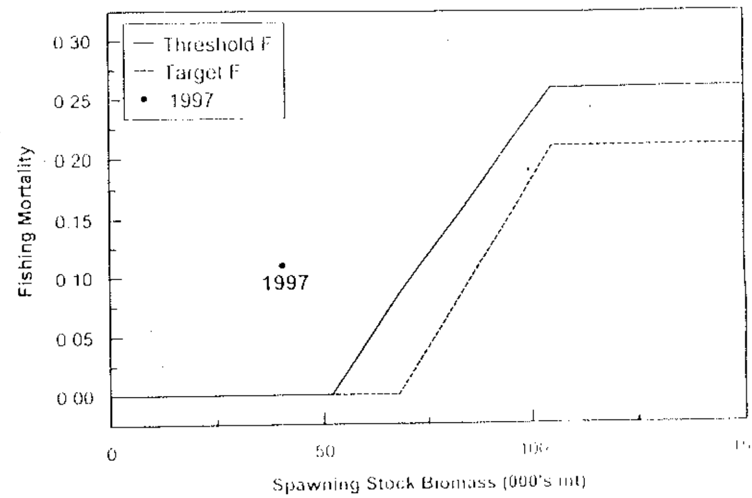

Figure B23. Proposed control rule for Georges Bank haddock based on proxies of MSY-based reference points and minimum biomass thresholds (as proposed by the Overfishing Definition Review Panel (ODRP 1998).

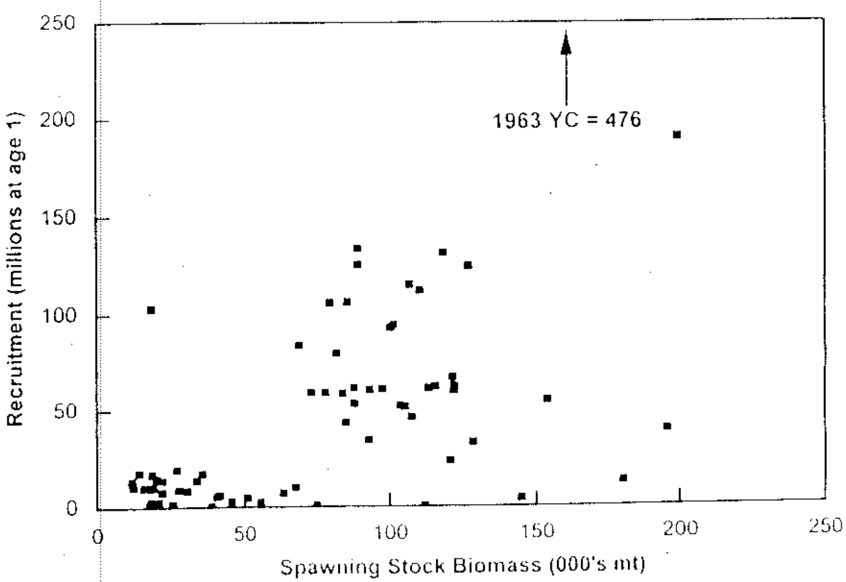

Figure B22. Spawning stock biomass and recruitment of Georges Bank haddock from 1931-1997.

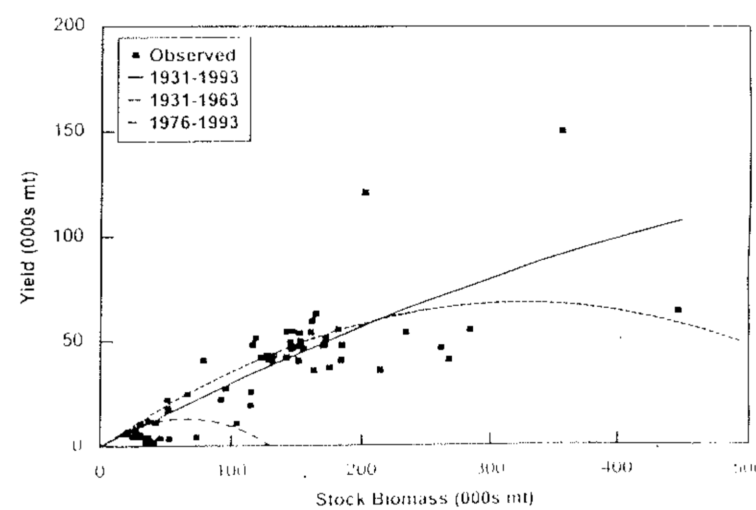

Figure B24. Equilibrium yield from surplus production analyses by Spencer and Collie (1997) of Georges Bank haddock using three alternative time periods.

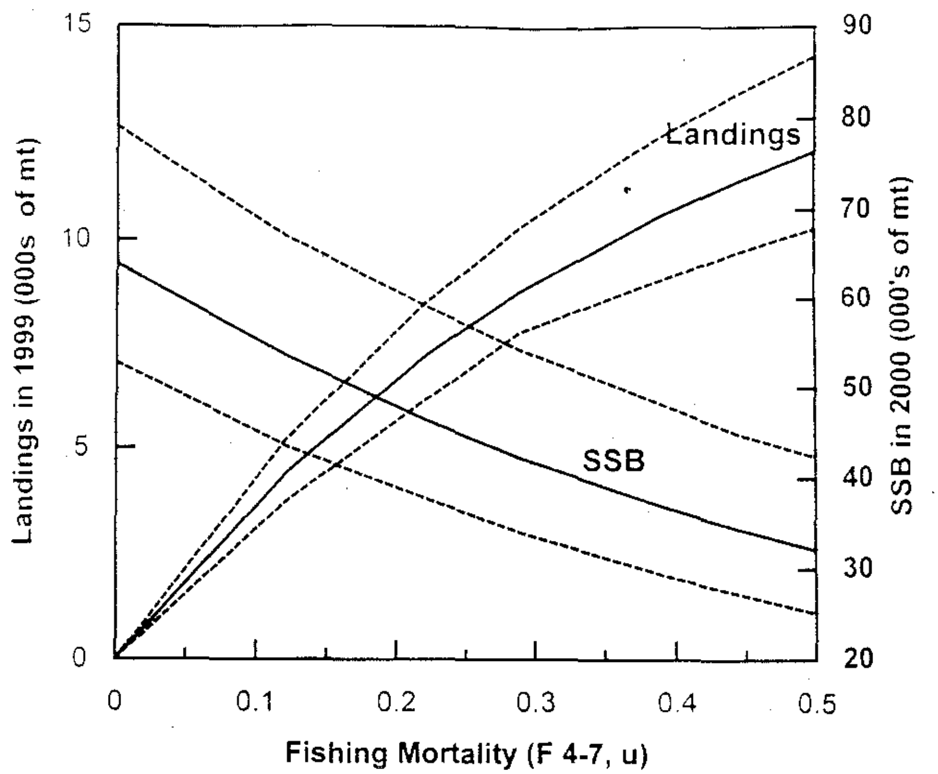

Figure B25. Results of short-term stochastic projections for the Georges Bank stock of haddock. Solid lines indicate the 50% (median) outcome. The dashed lines indicate the 80% confidence limits around the estimates of landings and SSB.

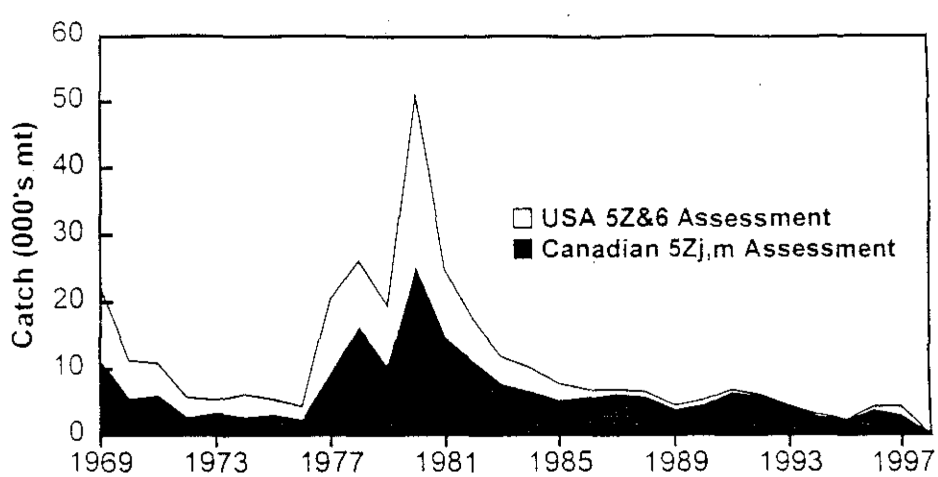

Figure B26. Comparison of total catch (mt) incorporated in the USA and Canadian assessments of Georges Bank haddock.

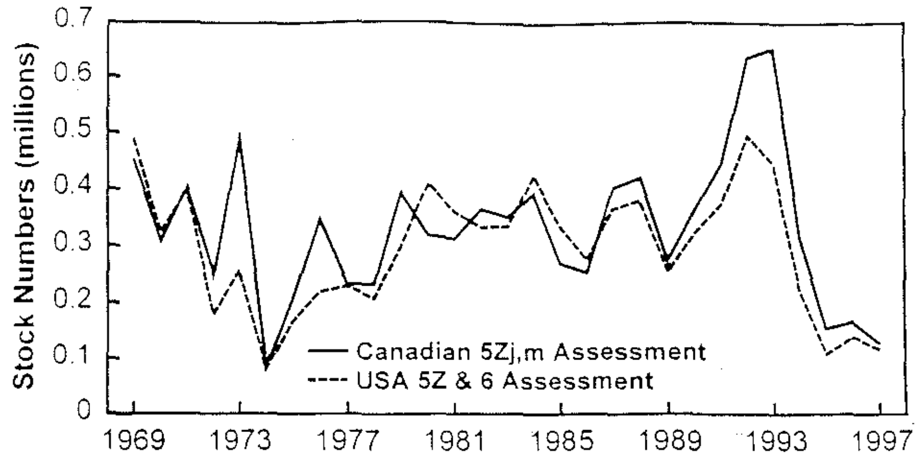

Figure B27. Comparison of fishing mortality (ages 4-7) estimated by the USA and Canadian assessments of Georges Bank haddock. For comparison purposes, USA assessment results have been bias corrected.

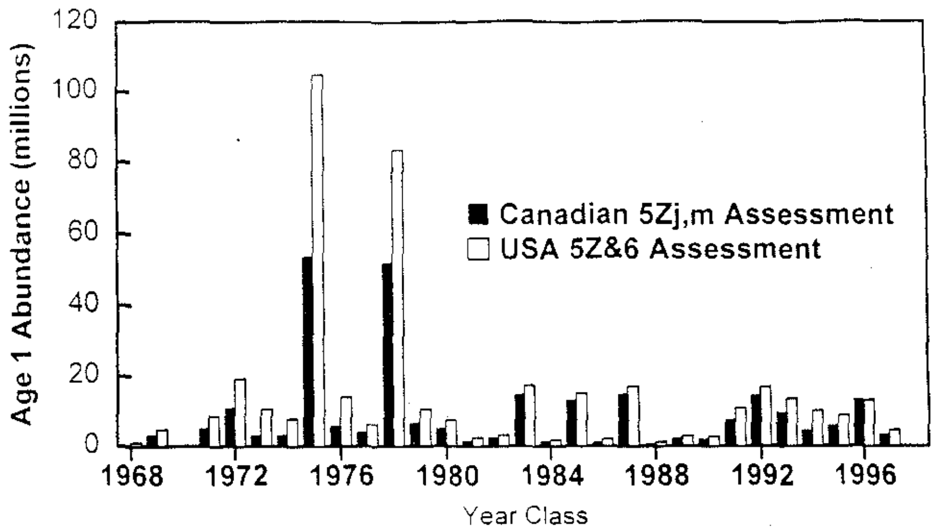

Figure B28. Comparison of age 1 recruites estimated by the USA and Canadian assessments of Georges Bank haddock. For comparison purposes, USA assessment results have been bias corrected.

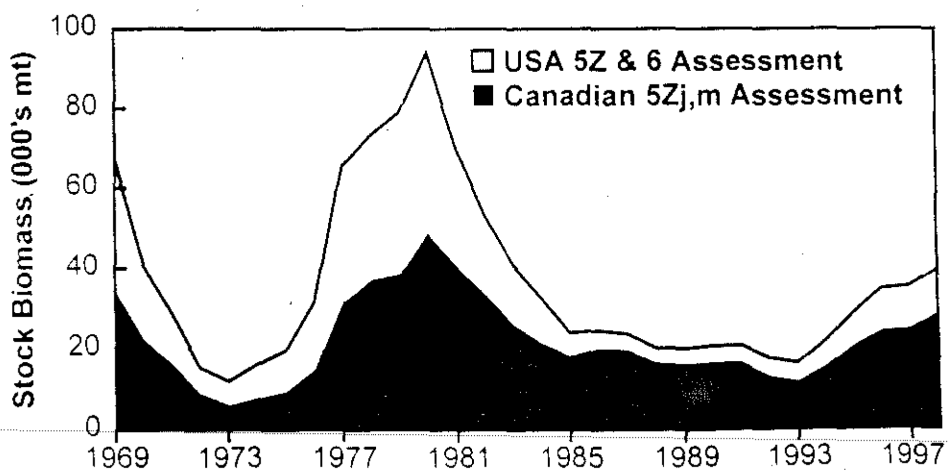

Figure B29. Comparison of beginning year stock numbers estimated by the USA and Canadian assessments of Georges Bank haddock. Form comparison purposes, USA Assessment results have been bias corrected and USA assessment biomass was calculated using Canadian survey mean weights.

C. GEORGES BANK YELLOWTAIL FLOUNDER

Terms of Reference

a. Update the status of Georges Bank yellowtail flounder through 1997 and characterize the variability of estimates of stock size and fishing mortality rates.

b. Provide projected estimates of catch for 1998-1999 and spawning stock biomass for 1999-2000 at various levels of F.

c. Review existing biological reference points and advise on new reference points for Georges Bank yellowtail flounder to meet SFA requirements.

Introduction

Yellowtail flounder (*Limanda ferruginea*) range from Labrador to Chesapeake Bay. These flatfish are typically caught at depths between 37 and 73 m, and a major concentration occurs on Georges Bank to the east of the Great South Channel. Yellowtail flounder appear to be relatively sedentary, although seasonal movements have been reported (Royce *et al.* 1959). Spawning occurs during spring and summer, peaking in May. Larvae are pelagic for a month or more, then develop demersal form and settle to benthic habitats. Growth is sexually dimorphic, with females growing at a faster rate than males (Moseley 1986). Based on tagging investigations (Royce *et al.* 1959; Lux 1963), the management unit is considered to include Georges Bank encompassing statistical areas 5Zj, 5Zm, 5Zn, and 5Zh (Figure C1). Thus, the management unit is transboundary in nature. Both the US and Canada employ the same convention for the management unit.

Over the past 25 years, the US fishery for yellowtail flounder has been managed using several strategies. During 1971-1976, national quotas were allocated by the International Commission for the Northwest Atlantic Fisheries. Minimum mesh size, area closures, and trip limits were imposed through the New England Fishery Management Council's Atlantic Groundfish Fishery Management Plan from 1977 to 1982. In 1982, the Council adopted an Interim Groundfish Plan, which established a minimum size limit of 28 cm (11 in). In 1986, the Council's Multispecies Fishery Management Plan increased the minimum legal size to 30 cm (12 in), increased minimum mesh size to 140 mm (5.5 in), and imposed seasonal closures. Amendment 4 to the Plan further increased the minimum legal size to 33 cm (13 in) in 1989. Amendments 5 and 7 in 1995 and 1996, respectively, limited days at sea, closed areas year-round, further increased minimum mesh size to 142 mm (6 in diamond or square), and imposed trip limits for groundfish bycatch in the sea scallop fishery.

The Georges Bank yellowtail stock has been assessed for the last four decades using yield-per-recruit analyses and various models for estimating abundance and mortality from catch and survey data. Results have shown that the instantaneous rate of fishing mortality (F) has exceeded the level of maximum yield-per-recruit (F_{max}) since the late 1950s (Brown and Hennemuth 1971, Pentilla and Brown 1973, Sissenwine *et al.* 1978, Clark *et al.* 1981; Collie and Sissenwine 1983, McBride and Clark 1983, McBride 1989). Virtual population analysis (VPA) calibrated with survey indices of cohort abundance (Conser *et al.* 1991, Rago *et al.* 1994) confirmed that F greatly exceeded overfishing reference points. The 1994 assessment showed that the stock had collapsed and F needed to be substantially reduced to rebuild spawning stock biomass (SSB) (NEFSC 1994a). An updated analysis of combined US and Canadian catch and survey indices confirmed historical patterns of stock abundance and F, but indicated that F decreased in 1995 (Gavaris *et al.* 1996). Projections based on updated landings and survey information suggested that F decreased and SSB was increasing (NEFMC 1996). Recently, an assessment based on VPA and biomass dynamics modeling confirmed that biomass was increasing and recent F levels were comparatively low (Neilson *et al.* 1997). This is an updated stock assessment with data through 1997. For further details on assessment methodology and results, see Neilson and Cadrin (1998).

The Fishery

Figure C2 shows the landings of Georges Bank yellowtail flounder from 1935 to the present. Landings, which have been predominantly taken by the US fleet, gradually increased to 7,300 mt in 1949, decreased in the early 1950s to 1,600 mt in 1956, and increased again in the late 1950s. Annual landings averaged 16,300 mt during 1962-1976, with some taken by distant water fleets. No foreign landings of yellowtail have occurred since 1975. US landings declined to approximately 6,000 mt between 1978 and 1981. Strong recruitment and intense fishing effort produced landings greater than 10,500 mt in 1982 and 1983. In every year since 1985, landings have been 3,000 mt or less. US landings fell to 1,100 mt in 1989, averaged 2,200 mt from 1990 to 1994, dropped to a record low of 200 mt in 1995, then increased to 1,000 mt in 1997.

The principle fishing gear used in the US fishery for yellowtail flounder is the otter trawl, but scallop dredges and sink gillnets contribute some landings. In recent years, otter trawls caught greater than 95% of the total landings from the Georges Bank stock, dredges caught 2-5% of the annual totals, and gillnet landings were less than 0.1%. US trawlers that land yellowtail flounder generally target multiple species on the Southwest Part of the Bank, on the Northern Edge, and just east of the closed area adjacent to the international boundary. Current levels of recreational and foreign fishing are negligible.

Discarding of small yellowtail is an important source of mortality due to intense fishing pressure, discrepancies between minimum size limits and gear selectivity, and recently imposed trip limits for the scallop dredge fishery. Methods of estimating US discards described in NEFSC (1997) indicate that 1997 discards were approximately 100 mt.

The directed Canadian fishery for yellowtail flounder has had a shorter history than its US counterpart and began in 1993. Prior to 1993, Canadian landings were small, typically less than 100 mt (Table C1, Figure C2). Peak landings of 1,328 mt occurred in 1994 in an unrestricted fishery and after a TAC of 400 mt was established, yellowtail landings dropped to 397 mt in 1995. In 1997, landings of yellowtail flounder were 809 mt against a quota of 800 t (Table C2).

"Unspecified" flatfish landings in the Canadian fishery have been significant in previous years and generally consist of yellowtail on Georges Bank. To estimate the proportion of unspecified flatfish in 1997 that were actually yellowtail, the ratio of known yellowtail to the sum of known winter flounder, American plaice, and yellowtail flounder caught by month and unit area was calculated. For otter trawl landings, the ratio was relatively constant over the months of the fishery, and the values of 0.31 and 0.92 were used for areas 5Zj and 5Zm, respectively. The unspecified flounder problem has been considerably reduced over time due to improved monitoring of the landings. In 1997, only 32 mt of unspecified flounder were landed. Table C1 shows the total Canadian yellowtail landings, which includes both the specified yellowtail flounder plus the assumed yellowtail flounder, calculated as described above.

The majority of Canadian landings of yellowtail flounder are made by otter trawl from vessels less than 65 ft (tonnage classes 2 and 3). The fishery takes place from June to December, with the peak months of activity in 1997 occurring during July-October. The number of vessels participating in the fishery was about 55 in 1994 and dropped to about 40 in 1995 because of a requirement for participants to have a catch history of greater than 5 mt of yellowtail flounder. About 45 vessels participated in the fishery in 1996 and 1997. Industry representatives indicated that about half the fleet fished 140 mm square mesh gear in 1994, with one-fourth fishing 130 mm square mesh and one-fourth fishing 155 square mesh. By agreement among those participating in the Canadian fishery, only 155 mm square mesh gear was used from 1995 to 1997. The same rigging of the foot gear was used from 1994 to 1997.

There was also a trip limit of 17,000 lb. imposed by industry in 1995 to equitably share the reduced quota among eligible participants. In 1996 and 1997, no trip limit was in place, and the quota was allocated based on previous catch history.

Canadian yellowtail directed fishing activity was concentrated in the southern half of the Canadian fishing zone, in the portion of area 5Zm referred to as the "Yellowtail Hole". Comments from industry have indicated that the area where good rates are encountered has expanded slightly from 1996 to 1997. The distribution of the fishery appears to have spread to the west relative to 1995 and 1996.

In previous years, there have been some landings of yellowtail flounder in the Canadian scallop fishery on Georges Bank. Management measures established in 1996 prohibit the landing of yellowtail flounder by this fleet, and no records of discarded quantities are available for 1997. This represents a source of mortality for this resource of unknown magnitude, and efforts are required to quantify discarded catches. In 1996, at-sea observer records estimated the amount of discarded yellowtail flounder as 11 mt.

Age and Length Composition

Sampling information for 1997 is summarized on Table C2. In general, sampling of the fishery by both countries has been inadequate. For the US, very few length measurements are available to characterize the fishery during the third and fourth quarters of 1997. Canada has more length measurements available through that period, but no age determinations have been made (Canada collects age determination material, but the age determination program is not yet operational). The low number of age determinations available has hampered the development of reliable age/length keys. This problem has also been noted in the most recent assessment of this resource.

A difficulty with the Canadian sea samples was detected in 1997. When the length composition information from the sea samples was compared with those obtained from the port sampling program, discrepancies were apparent. These differences are attributed to problems of flatfish species and sex identifications within the at-sea observer program. Given such potential errors, it was decided to characterize the Canadian landings using the length measurements obtained from the port sampling program.

The average size of the commercial landings has increased in the Canadian fishery from 1994 to 1997. However, such trends in average size are less apparent in the US fishery. The modal age in 1997 was 4, compared with 3 years in 1996. The US age composition also demonstrated a trend of increasing age in the catch.

The combined catch-at-age and weight-at-age information for both countries is shown on Tables C3 and C4, respectively.

Stock Abundance and Biomass Indices

Commercial Fishery Catch Rates

Catch (mt) and effort (hr) for Canadian otter trawlers less than 65 ft in length fishing for yellowtail flounder in 1993-1997 were summarized on a trip basis. Initial examination of the trip records showed a large proportion of trips with very small amounts of yellowtail in the total catch. These trips were not considered to be representative of yellowtail directed effort and, therefore, only trips with reported landings of more than 500 kg (1,100 lb.) were considered. As well, only vessels with reported landings in two or more years in 1993-1997 were included in the analysis. Examination of the spatial distribution of effort showed highest concentrations in the area described by fishermen as the "Yellowtail Hole" located in the southeast part of the bank and adjacent to the Canada-US boundary. Therefore, only landings and effort from the Yellowtail Hole were included in the analysis.

Yellowtail landings and effort for trips were aggregated by month and year and monthly catch rates (mt/hr). The catch rate decreased between 1993 and 1994, but increased by a factor of over 2 between 1994 and 1995 and increased further in 1996 and 1997. This is consistent with industry observations of increasing catch rates in the last three years. The increase from 1996 to 1997 appears to be smaller than that which occurred in the preceding year.

Substantial gear changes occurred in the fishery between 1993 and 1994 with the introduction of 'flounder gear' which uses small diameter footgear. Changes in mesh size also occurred, as described earlier. However, fishing practices have been relatively constant since 1994. While catch rates may prove to be useful as an index of abundance for this resource, the time series is too short to be included directly in the assessment at present.

Research Vessel Surveys

Annual bottom trawl surveys are conducted on Georges Bank by the Canadian Department of Fisheries and Oceans (DFO) in the spring and by the NMFS in the spring and fall. Both agencies use a stratified random design, but with different strata boundaries. US spring and autumn bottom trawl survey catches (strata 13-21), US scallop survey catches (strata 54-74), and Canadian bottom trawl survey catches (strata 5Z1-5Z4) were used to estimate relative stock biomass and relative abundance at age for Georges Bank yellowtail. Standardization coefficients, which compensate for survey door, vessel, and net changes in US surveys (1.22 for old doors, 0.85 for the *Delaware II*, and 1.76 for the 'Yankee 41' net; Rago *et al.* 1994) were applied to the catch of each tow.

Aging of DFO survey samples has not been done and, therefore, age sampling from the corresponding NMFS spring survey was used to obtain abundance indices by age. Males and females were treated separately and then combined for the index at age. However, the small number of fish aged in some years and the further partitioning of the age/length key by sex resulted in low precision for the estimates.

Results from the Canadian and US spring surveys are shown on Figure C3 and Tables C5-C6. The US and Canadian survey series show good concurrence. The surveys indicated low abundance in the late 1980s, but have been following an increasing trend since then. US age sampling was not available to apply against the 1998 DFO results. In 1997, the Canadian survey index was the highest value recorded in the series. The 1998 survey index was down somewhat, but still follows an increasing trend since 1995.

The fall survey series is the longest available for this resource. In general, the series follows the same trends indicated by the spring series (Table C7, Figure C4), but the indication of the start of resource rebuilding was not apparent until 1996.

The Canadian survey results suggest that the resource has expanded beyond the area associated with the highest catch rates in the past, consistent with observations from the fishery. The spring US survey encountered the largest catches of yellowtail flounder in the Yellowtail Hole of area 5Zm. The US fall 1997 survey had a similar distribution of catches, but the set density in areas of key yellowtail flounder habitat was low. Consistent with the indications from the commercial fishery, the average size of the fish in the research survey catches has been increasing.

US scallop survey indices of yellowtail abundance at age were also evaluated. The survey indices were delta transformed (Pennington 1986) because there is a high proportion of tows with no yellowtail caught. The age 1 index from the NEFSC scallop survey was revised to address concerns about catchability estimates. Previous assessments, which used age data from the fall survey to characterize catches from the scallop survey, had a problematic pattern to catchability estimates (NEFSC 1997). Inspection of catch at length from the scallop survey and the range of length at age 1 from the fall survey suggests that age 1 yellowtail grow substantially between the time of the scallop and autumn surveys. Using the fall age data appears to classify many age 2 fish as age 1, thus inflating the age 1 index and reducing the age 2 index. The age 1 index was revised to reflect the total catch of yellowtail in the smallest length mode, which was fairly well defined and stable (generally 9-23 cm). The revised scallop age 1 index has generally increased since the early 1990s (Table C8).

Fishing Mortality and Stock Size

Low levels of sampling and contradictions among sources of information on relative year-class strength indicate that there is a great deal of uncertainty in estimates of catch at age in recent years. Therefore, two methods of analysis were updated from the previous assessment, the traditional age-structured virtual population analysis (VPA) and the surplus production model as a confirmatory analysis that does not rely on age structure information.

Virtual Population Analysis

The adaptive framework ADAPT (Gavaris 1988) was used to calibrate the VPA with the research survey abundance trend results. The model formulation employed assumed that the error in the catch at age was negligible. The error in the survey abundance indices was assumed to be independent and identically distributed after taking natural logarithms of the values. The annual natural mortality rate (M) was assumed constant and equal to 0.2. A model formulation using as parameters the ln population abundance at the beginning of the year following the terminal year for which catch at age is available was considered (Gavaris 1993). ADAPT was used to solve for parameters by minimizing the sum of squared differences between the ln observed abundance indices and the ln population abundance adjusted for catchability by the calibration constants. The population abundance for ages 6+ was calculated assuming that the fishing mortality for these was equal to the average fishing mortality on ages 4 and 5. The population abundance was computed using the virtual population analysis algorithm which incorporates the exponential decay model. Year was used as the unit of time; therefore, ages were expressed as years and the fishing and natural mortality rates were annual instantaneous rates. The fishing mortality rate exerted during the time interval was obtained by solving the catch equation. The fishing mortality rate for age 6+ in the last time interval of each year was assumed equal to the fishing mortality at age 5. The data used were annual catch at age for ages a = 1, 2...6+ and for t = 1973-1997 (before 1973, catches from distant water fleets and US discards comprised a large portion of the total catch and were not well sampled) and bottom trawl survey abundance indices.

Choice of survey indices was based on correlations among indices and reliability of age data. Correlations were moderate to strong for ages 3-6, but the Canadian and NEFSC fall surveys were not positively correlated at ages 1 and 2 (Table C9). Figure C5 shows correspondence among normalized indices. The Canadian age 1 index is based on many lengths that have no corresponding age sample from the NMFS spring survey and is not considered to be a reliable index. Alternative ADAPT configurations were performed to assess the sensitivity of results to the choice of indices used.

Approximate coefficients of variation (CVs) for abundance estimates ranged from 20 to 50% and improved with age. Estimates of q for each index were well estimated (CV = 17-26%). Although the model generally fit the data well, there were some slight trends in residuals (e.g., fall age 2; Figure C6), and there were three statistical outliers (e.g., spring 36 age 1 in 1981; fall age 1 in 1988; and fall age 2 in 1995).

Variance and model bias of estimates were assessed using bootstrap analysis of the VPA calibration. One thousand bootstrap estimations were performed by randomly resampling survey residuals. Bootstrapped abundance estimates had only slightly greater CVs than the least squares approximations reported above. Bootstrapped Fs were estimated with similar precision to abundance estimates. CVs were high at age 2 (CV = 50%), but decreased with age (CV = 18% for ages 4-6). Bootstrap analysis indicates that SSB in 1997 was well estimated (CV = 15%). Bootstrap estimates of bias were relatively low for older ages (1-10% for age 3+ abundance estimates, 2% for F_{4+}, and 4% for SSB), but was substantial for the age 2 abundance estimate (15%). However, there are several difficulties in completely correcting for bias (NEFSC 1997). Therefore, bias correction was not incorporated into stochastic projections.

Consistency of VPA estimates was assessed using retrospective analysis (Sinclair *et al.* 1990). Unfortunately, the length of the Canadian survey time series limited the number of retrospective comparisons. Retrospective ADAPT runs were made by iteratively truncating the terminal year of catch and survey data back to a terminal year of 1991 (when the Canadian survey had five years of data).

Short-term projections of landings and SSB incorporated uncertainty in VPA estimates using the 1,000 bootstrap estimates of age 2-6+ 1998 abundance. Projections through 1999 were simulated for each of the 1,000 abundance estimates by randomly sampling point estimates of 1973-1997 age 1 abundance 100 times (totaling 100,000 simulated trajectories). Projections assumed geometric mean partial recruitment in 1994-1997, mean discard ratios at age in 1994-1997, mean weight of landings at age in 1994-1997, and proportion mature at age from 1992-1997 survey observations.

Surplus Production Model

The non-equilibrium surplus production model ASPIC (A Stock-Production model Incorporating Covariates) (Prager 1994, 1995) was also used to assess stock status and biological reference points. The method requires total catch along with one or more abundance indices (including CPUE or survey indices) as input. In this case, the DFO spring survey (1987-1998) was an index of biomass at the end of the previous year, the NMFS spring survey (1968-1997) was considered a beginning-of-year biomass index, and the NMFS fall survey (1963-1997) was treated as a mid-year index. The error in the survey abundance indices was assumed to be independent and identically distributed after taking natural logarithms of the values. ASPIC was used to solve for the parameters by minimizing the sum of squared differences between the ln observed survey catch rate and the ln predicted survey catch rate. The analysis from the previous assessment (Neilson *et al.* 1997) was revised to include discard estimates (Table C1).

Correlations among survey biomass indices were moderate to strong ($r = 0.5$-0.8). Most of the variance in the NMFS spring 36, Canada, and NMFS fall surveys was explained by the model ($R^2 = 0.75$, 0.58, and 0.56), but none of the variance in the NMFS spring 41 series was explained. Biomass estimates for the first 2-5 years of the analysis (1963 to 1964-1966) are imprecise and are not considered reliable (Prager 1994, 1995).

Survey residuals were randomly resampled 1,000 times to estimate precision and model bias. Bootstrap estimates from ASPIC suggest that there is 80% confidence that current biomass is 54-86% of B_{msy} (44,000 mt). The 1997 F estimate from ASPIC was low (0.08), and bootstrap estimates of F_{97} indicate that there is negligible probability that F exceeded F_{msy}. The bootstrap analyses indicates that MSY, K, r, B_{msy}, and F_{msy} were well estimated (interquartile ranges <19%), but q and the ratios of current year B and F relative to B_{msy} and F_{msy} were generally more variable (IQR = 14-28%). Also, biomass in 1963 was poorly estimated (IQR > 150%). As suggested by Prager (1994,1995), biomass estimates in the first several years are unreliable. Alternative configurations were explored to examine sensitivity of estimates to including discards and treating the NMFS spring survey as a single index.

Results

The VPA indicates that the stock continued to rebuild from the collapsed state of the early 1990s (Table C19). Growth in stock biomass was the product of high survival and moderate recruitment. Fully-recruited F ($F_{4\text{-}5}$) remained low in 1997 (0.13, Figure C7, Table C11). Recruitment has been relatively stable for the last several years (age 1 abundance averaged 20 million from 1991 to 1996), but only the 1993 cohort exceeded the 1972-1996 average (Figure C8). SSB increased to 15,700 mt in 1997 (Figure C8, Table C12).

Bootstrap distributions suggest that there is nearly 100% probability that SSB in 1997 exceeded the current rebuilding target of 10,000 mt (80% confidence interval = 13,500-19,200 mt) and nearly 100% probability that F in 1997 was less than $F_{0.1}$ (80% CI = 0.11-0.17) (Figure C9). Estimates of bias were low for $F_{4\text{-}5}$ (2%) and SSB (4%). Given the substantial uncertainty in estimates of catch at age, statistical bias was considered negligible for $F_{4\text{-}5}$ and SSB and abundance of older cohorts. Bias of the estimate of age 2 abundance (N_2) was greater (15%), and decreases the reliability of the estimate. However, bias of the N_2 estimate is low relative to the associated uncertainty (CV = 75%), and 1998 projections will be minimally affected by the bias because age 2 fish are only 10% recruited to the fishery.

Three alternative ADAPT configurations were explored which 1) included the Canadian age 1 index,

2) included preliminary 1998 indices from the Canadian survey (based on cohort slicing), and 3) excluded the scallop survey index. All three sensitivity runs estimated age 2 abundance in 1998 to be approximately 50% lower than reported in Table C10. However, the Canadian age 1 index is composed of many lengths with no corresponding age sample from the NMFS spring survey, there is considerable subjectivity involved in cohort slicing samples from the 1998 Canadian survey, and there is no *a priori* evidence for excluding the NMFS scallop survey. A fourth sensitivity analysis that combined the NMFS spring survey into a single tuning index (using the conversion factor for the Yankee 41 net reported by Sissenwine and Bowman 1978) estimated very similar parameters to those reported in Table C10, but had large negative residuals for the surveys that used the Yankee 41 net.

Although some retrospective differences were substantial, there were no patterns of positive or negative inconsistency. Initial estimates of abundance of the 1990 and 1993 cohorts were much greater than the revised estimates, presumably resulting from imprecise discard estimates. Abundance estimates in penultimate years were relatively consistent. Fully-recruited F estimates were more consistent than retrospective recruitment estimates, and SSB estimates were very consistent (Figure C10).

The magnitude and recent decrease in mortality indicated by the VPA was confirmed by a modified catch-curve analysis which incorporates multiple surveys (A. Sinclair, Marine Fish Division, Gulf Fisheries Centre, pers. comm.) Results indicated that total mortality exceeded 1.0 in most years, but decreased to 0.4 in the last three years.

Patterns and magnitude of F and biomass estimates from the surplus production model generally confirm age-based estimates (Figure C11). However, the 1997 mean biomass estimate of 24,000 mt from ASPIC was substantially greater than the biomass estimate from ADAPT (18,000 mt). The sensitivity analysis that excluded discards had lower estimates of MSY by 15% and B_{msy} by 5%, but a similar estimate of F_{msy}. Combining the NMFS spring 36 and 41 series had negligible effects on parameter estimates.

ASPIC results indicate that a maximum sustainable yield of 13,700 mt can be produced when stock biomass is approximately 44,000 mt (B_{msy}, Figure C12) and F is 0.31 (F_{msy}). Assuming equilibrium age structures, current partial recruitment and mean weight at age, a biomass-weighted F of 0.31 is equivalent to a fully-recruited F of 0.39. The MSY and B_{msy} estimates are slightly greater, and *r* was slightly lower, than the estimates in the last assessment (Neilson *et al.* 1997) because discards were not included in the previous assessment. MSY reference points estimated from stock-recruit data are similar: MSY = 13,200 mt, SSB_{msy} = 33,800 mt, and fully-recruited F_{msy} = 0.37 (Overholtz 1998).

Results from VPA indicate that all cohorts were less than 30 million in age 1 abundance, except four year classes that exceeded 50 million in age 1 abundance (1973, 1974, 1977, and 1981). The relationship between SSB and recruitment suggests that strong recruitment is more likely at high levels of SSB (Figure C8). For example, three of the four dominant cohorts in the VPA time series (1973-1997) were produced when SSB exceeded 10,000 mt, and three of the six cohorts produced when SSB exceeded 10,000 mt were greater than 50 million in age 1 abundance. Extending the stock and recruitment series using survey estimates of age 1 abundance (scaled with the ADAPT estimate of catchability) and total biomass estimates from the production model (1968-1997) supports the conclusion that much greater levels of recruitment can be produced at greater levels of stock biomass (Figure C13).

Yield and Spawning Biomass per Recruit

Yield- and spawning-biomass-per-recruit reference points were revised by incorporating updated estimates of partial recruitment (1994-1997), mean weights (1994-1997), and maturity (1997). F_{max} is calculated as 0.82 (but the maximum yield per recruit is not well defined), $F_{0.1}$ as 0.25, and $F_{20\%}$ as 0.69 (Table C13, Figure C14). An alternative analysis with ages 1-14 (the oldest observed age in surveys) had a similar estimate of F_{max} (0.83), slightly greater estimate of $F_{0.1}$ (0.28), and a substantially greater estimate of $F_{20\%}$ (0.62).

Short-Term Projections

Projections are presented in accordance with US and Canada management requirements. For Canada, projections of landings in 1998 and beginning-year biomass for 1998 and 1999 are required. For the US, projections of landings in 1999 and spawning stock biomass during the 1999 and 2000 spawning seasons are required and assume *status quo* fishing mortality in 1998. Age-based projection inputs included average 1994-1997 partial recruitment, weights at age, and maturity at age (Table C11 illustrates F_{97} results). Projections of ASPIC parameters were obtained assuming a *status quo* F (0.08) and a biomass-weighted approximation to $F_{0.1}$. Results from a *status quo* projection, which is a similar scenario for US and Canadian requirements, are presented in Table C14.

Canada

Projection results for 1998 are documented below for two scenarios of fishing mortality:

F_{98}	Method	1998 Landings	1998 Biomass[1]	1999 Biomass[1]
F_{97}	Age-based (VPA)	1.8	16.1	21.3
	Biomass-based (Surplus production)	2.6	26.2	36.3
$F_{0.1}$	Age-based (VPA)	3.2	16.1	19.7
	Biomass-based (Surplus production)	5.5	26.2	33.3

[1]Total biomass at beginning of year.

The risk of not achieving fishery targets for population growth and exploitation rate from 1998 to 1999 was explored using VPA projections at various levels of yield (Figure C15). A fishery yield in 1998 equal to that of 1997 (1,788 t) is associated with negligible risk of exceeding the $F_{0.1}$ fishing mortality target and has a low risk of not achieving growth in spawning stock biomass. A fishery yield associated with $F_{0.1}$ (3,244 t), however, has a greater than 60% risk that a 20% growth in biomass will not occur.

Age-based (F values are for ages 4+ and are unweighted)

F	1998 Landings	1998 SSB	$F_{1999-2000}$	1999 Landings	1999 SSB	2000 SSB	Consequences/Implications
0.13	1.8	17.8	0.13 (F_{98})	2.2	21.5	24.1	SSB increases to about 70% SSB_{msy} in 2000; landings in 1999 increase slightly.
			0.25 ($F_{0.1}$)	4.0	20.6	21.4	SSB increases to about 60% SSB_{msy} in 2000; landings in 1999 increase to twice the 1997 level.

Biomass-based (F values are for ages 1+ and are weighted by biomass)

F	1998 Landings	1998 B	$F_{1999-2000}$	1999 Landings	1999 B	2000 B	Consequences/Implications
0.08	2.6	26.2	0.08 (F_{98})	3.4	36.3	46.4	Biomass (B) surpasses B_{msy} in 2000; landings in 1999 increase to almost twice the 1997 level.
			0.17 ($F_{0.1}$)	7.3	36.3	42.5	Biomass increases to about 97% B_{msy} in 2000; landings in 1999 increase to four times the 1997 level.

USA

Age-based projections suggest that landings and SSB increase in 1999 and 2000 at fishing mortality rates equivalent to the 1997 *status quo* level or $F_{0.1}$. However, at greater levels of F, there is substantial risk of decreasing SSB (Figure C16).

As indicated in the projections for both Canada and the US, biomass-based estimates are more optimistic than those obtained using the age-based (VPA) approach. For the VPA approach, such differences may be attributed to poor sampling and the absence of age determinations from the Canadian fishery. The surplus production model attempts to describe long-term average dynamics which may not apply if recent recruitment has been weak.

Conclusions

Although there are some differences in results from the two analytical models, information on current stock status is relatively clear. The stock is still rebuilding. SSB in 1997 (from ADAPT) was approximately half of the SSB_{msy} (from stock-recruit analysis), and total biomass in 1997 (from ASPIC) was also approximately half of the B_{msy} (from ASPIC). Fishing mortality in 1997 remained at levels which should allow continued rebuilding. Fully-recruited F (from ADAPT) was well below $F_{0.1}$ and was approximately one-third the level of fully-recruited F_{msy} (from stock-recruit analysis), and F on total biomass (from ASPIC) was also approximately one-third of the F_{msy} (from ASPIC).

Despite the congruence in results on stock status, forecasting yield, SSB, and risk is difficult. Age-based projections are generally more informative, but are currently hampered by poor sampling and the absence of age determinations from the Canadian fishery. Conversely, projections based on biomass dynamics imply high levels of recruitment at the current biomass level. While there are suggestions of good recruitment evident from examination of the 1997 spring survey length distributions, they were not confirmed in the age-based estimates of abundance. Given the uncertainties in both the VPA and the biomass dynamics model, the more conservative age-based projections and risk analyses from the VPA are considered to be more risk averse.

SARC Comments

A question was raised concerning which survey was used for back-calculated estimates of recruitment. The fall survey was used for this purpose because it constituted the longest time series. A possible inconsistency between the estimate of B_{msy} and historical levels of biomass and recruitment was noted. Survey recruitment estimates were greater when biomass exceeded B_{msy}. The reason for this discrepancy was not resolved at the SARC meeting.

It was noted that the environment on Georges Bank during the 1960s was considerably different than in more recent decades.

The Overfishing Definition Review Panel used slightly different ASPIC analyses and obtained an estimate of B_{msy} of 49,000 mt vs 44,000 mt in the current assessment. The latter was viewed as the latest analysis.

There was discussion of the rather optimistic nature of the surplus production model relative to the VPA. It was felt that the average recruitment implicit in the ASPIC calculations may not be realistic in recent years. It was noted that age-based projections were generally viewed as more reliable than biomass-based projections from ASPIC, but that the latter, nevertheless, were useful and informative.

The point made that the life cycle of yellowtail flounder is about 14 years. Restrictive management measures may be required for some time to attain equilibrium age-structure and attain the expected levels of recruitment.

There was discussion of whether the right metric (i.e., mt) was being used for SSB. It was suggested that perhaps the number of viable eggs, for example, may be a better measure of reproductive potential.

Research Recommendations

- More complete sampling of spatial and temporal aspects of the US fishery and dedicated age/

length keys for the Canadian fishery are needed for more reliable age-based estimates.

- Stochastic age-based simulation of rebuilding scenarios is needed to confirm the expected growth rates from the production model.
- Consistent sampling of Georges Bank strata during NMFS winter surveys may substantially improve the assessment.
- Extended VPA of historical catch and survey information would help to assess historical stock conditions and MSY reference points.

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Table C1. Commercial catch (000s t) of Georges Bank yellowtail flounder.

Year	USA Landings	USA Discards	Canada Landings	Foreign Landings	Total
1963	10.990	6.368	0.000	0.100	17.458
1964	14.914	4.855	0.000	0.000	19.769
1965	14.248	4.266	0.000	0.800	19.314
1966	11.341	2.545	0.000	0.300	14.186
1967	8.407	4.389	0.000	1.400	14.196
1968	12.799	3.722	0.000	1.800	18.321
1969	15.944	3.105	0.000	2.400	21.449
1970	15.506	6.037	0.000	0.250	21.793
1971	11.878	2.824	0.000	0.503	15.205
1972	14.157	1.330	0.000	2.243	17.730
1973	15.899	0.364	0.000	0.260	16.523
1974	14.607	0.980	0.000	1.000	16.587
1975	13.205	2.715	0.000	0.091	16.011
1976	11.336	3.021	0.000	0.000	14.357
1977	9.444	0.567	0.000	0.000	10.011
1978	4.519	1.669	0.000	0.000	6.188
1979	5.475	0.720	0.000	0.000	6.195
1980	6.481	0.382	0.000	0.000	6.863
1981	6.182	0.095	0.000	0.000	6.277
1982	10.621	1.376	0.000	0.000	11.997
1983	11.350	0.072	0.000	0.000	11.422
1984	5.763	0.028	0.000	0.000	5.791
1985	2.477	0.043	0.000	0.000	2.520
1986	3.041	0.019	0.000	0.000	3.060
1987	2.742	0.233	0.000	0.000	2.975
1988	1.866	0.252	0.000	0.000	2.118
1989	1.134	0.073	0.000	0.000	1.207
1990	2.751	0.818	0.000	0.000	3.569
1991	1.784	0.246	0.000	0.000	2.030
1992	2.859	1.873	0.000	0.000	4.732
1993	2.089	1.089	0.696	0.000	3.874
1994	1.589	0.141	2.142	0.000	3.871
1995	0.292	0.024	0.495	0.000	0.811
1996	0.751	0.039	0.483	0.000	1.273
1997	0.966	0.058	0.810	0.000	1.834
Average	7.697	1.610	0.132	0.318	9.758

Table C2. Sampling intensity for estimation of landings at age for Georges Bank yellowtail flounder.

US		Port Samples			Sea Samples			Landings (mt)
Quarter	*Size*	*Trips*	*Lengths*	*Ages*	*Trips*	*Lengths*	*Ages*	
1	small	6	366					81.11
	large	3	467					296.45
	all	6	833	236	3	149	109	377.56
2	small	5	591					107.76
	large	3	259					168.55
	all	5	850	280	2	27	107	276.31
3	small							51.09
	large							55.64
	all	1	103	63	2	7	59	106.73
4	small							62.98
	large							142.39
	all	0	0	0	1	41	0	205.37
Canada								
2	all	3	600	0				100.29
3	all	6	1347	0	3	1452	0	524.00
4	all	4	961	0	6	2010		185.44

Table C3. Total catch at age of Georges Bank yellowtail flounder (thousands).

Year	Age 1	2	3	4	5	6	7	8+	Total
1973	347	4,890	13,243	9,276	3,743	1,259	278	81	33117
1974	2,143	8,971	7,904	7,398	3,544	852	452	173	31437
1975	4,372	25,284	7,057	3,392	2,084	671	313	164	43337
1976	615	31,012	5,146	1,347	532	434	287	147	39520
1977	330	8,580	9,917	1,721	394	221	129	124	21416
1978	9,659	3,105	4,034	1,660	459	102	37	35	19091
1979	233	9,505	3,445	1,242	550	141	79	52	15247
1980	309	3,572	8,821	1,419	321	85	4	10	14541
1981	55	729	5,351	4,556	796	122	4	-	11613
1982	2,063	17,491	7,122	3,246	1,031	62	19	3	31037
1983	696	7,689	16,016	2,316	625	109	10	8	27469
1984	428	1,917	4,266	4,734	1,592	257	47	17	13258
1985	650	3,345	816	652	410	60	5	-	5938
1986	158	5,771	978	347	161	52	16	8	7491
1987	140	2,653	2,751	761	132	39	32	41	6549
1988	483	2,367	1,191	624	165	15	20	3	4868
1989	185	1,516	668	262	68	11	8	-	2718
1990	219	1,931	6,123	800	107	17	3	-	9200
1991	412	54	1,222	2,430	293	56	4	-	4471
1992	2,389	8,359	2,527	1,269	510	20	7	-	15081
1993	5,194	1,009	2,777	2,392	318	65	9	1	11765
1994	71	861	5,742	2,571	910	99	37	1	10291
1995	14	157	895	715	137	13	11	4	1944
1996	50	383	1,509	716	167	9	5	1	2841
1997	16	595	1,258	1,502	341	26	45	19	3802
Mean	1,249	6,070	4,831	2,294	776	192	74	36	15522

Table C4. Mean weight at age for the total catch of Georges Bank yellowtail flounder (kg).

Year	Age 1	2	3	4	5	6	7	8+
1973	0.010	0.347	0.462	0.527	0.603	0.689	1.067	1.136
1974	0.010	0.339	0.498	0.609	0.680	0.725	0.906	1.249
1975	0.010	0.309	0.489	0.554	0.618	0.687	0.688	0.649
1976	0.010	0.304	0.542	0.636	0.741	0.814	0.852	0.866
1977	0.010	0.337	0.524	0.634	0.782	0.865	1.036	1.013
1978	0.010	0.309	0.510	0.684	0.793	0.899	0.930	0.948
1979	0.010	0.325	0.460	0.649	0.728	0.835	1.003	0.882
1980	0.010	0.318	0.492	0.656	0.813	1.054	1.256	1.214
1981	0.010	0.340	0.490	0.603	0.707	0.798	0.832	1.042
1982	0.010	0.297	0.485	0.650	0.748	1.052	1.024	1.311
1983	0.010	0.296	0.440	0.604	0.736	0.952	1.018	0.987
1984	0.010	0.240	0.378	0.500	0.642	0.738	0.944	1.047
1985	0.010	0.363	0.497	0.647	0.733	0.819	0.732	1.042
1986	0.010	0.342	0.540	0.664	0.823	0.864	0.956	1.140
1987	0.010	0.309	0.521	0.666	0.680	0.938	0.793	0.788
1988	0.010	0.319	0.555	0.688	0.855	1.054	0.873	1.385
1989	0.010	0.342	0.542	0.725	0.883	1.026	1.254	1.042
1990	0.010	0.281	0.389	0.574	0.696	0.807	1.230	1.042
1991	0.010	0.258	0.359	0.479	0.725	0.820	1.306	1.042
1992	0.010	0.283	0.360	0.519	0.646	1.203	1.125	1.042
1993	0.010	0.275	0.367	0.503	0.561	0.858	1.263	1.044
1994	0.010	0.262	0.351	0.471	0.628	0.786	0.896	1.166
1995	0.010	0.260	0.367	0.463	0.582	0.777	0.785	0.540
1996	0.010	0.309	0.409	0.523	0.667	0.866	0.916	1.215
1997	0.010	0.309	0.458	0.592	0.712	0.874	0.989	1.042
Mean	0.010	0.307	0.459	0.593	0.711	0.872	0.987	1.035

Table C5. Canadian DFO spring survey indices of Georges bank yellowtail flounder abundance at age (no./tow) and stratified total biomass.

Year	Age 1	2	3	4	5	6	Total	Wt (000s t)
1987	0.12	0.68	2.00	1.09	0.06	0.00	3.95	1.264
1988	0.00	0.66	1.89	0.80	0.59	0.01	3.96	1.235
1989	0.11	0.78	0.80	0.32	0.10	0.02	2.13	0.471
1990	0.00	1.27	4.62	1.12	0.43	0.01	7.45	1.578
1991	0.02	0.59	1.72	2.91	0.99	0.00	6.24	1.759
1992	0.22	10.04	4.52	1.21	0.16	0.00	16.14	2.475
1993	0.33	2.16	5.04	3.47	0.62	0.00	11.63	2.642
1994	0.00	6.03	3.33	3.08	0.75	0.33	13.51	2.753
1995	0.21	1.31	4.07	2.22	1.14	0.11	9.07	2.027
1996	0.45	5.54	8.44	7.49	1.37	0.16	23.45	5.304
1997	0.10	9.48	15.16	19.09	3.11	0.54	47.49	13.292
1998	0.89*	0.29*	3.31*				16.04	4.292
Mean	0.20	3.50	4.69	3.89	0.85	0.11	13.19	3.258

*Preliminary: Based on cohort slicing (visual inspection).

Table C6. NEFSC spring survey indices of Georges bank yellowtail flounder abundance at age (no./tow) and total biomass (kg/tow).

	Age									Biomass
Year	1	2	3	4	5	6	7	8+	Total	(kg)
1968	0.149	3.364	3.579	0.316	0.084	0.160	0.127	0.000	7.779	2.813
1969	1.015	9.406	11.119	3.096	1.423	0.454	0.188	0.057	26.758	11.170
1970	0.093	4.485	6.030	2.422	0.570	0.121	0.190	0.000	13.911	5.312
1971	0.791	3.335	4.620	3.754	0.759	0.227	0.050	0.029	13.564	4.607
1972	0.138	7.136	7.198	3.514	1.094	0.046	0.122	0.000	19.247	6.450
1973	1.931	3.266	2.368	1.063	0.410	0.173	0.023	0.020	9.254	2.938
1974	0.316	2.224	1.842	1.256	0.346	0.187	0.085	0.009	6.265	2.719
1975	0.420	2.939	0.860	0.298	0.208	0.068	0.000	0.013	4.806	1.676
1976	1.034	4.368	1.247	0.311	0.196	0.026	0.048	0.037	7.268	2.273
1977	0.000	0.671	1.125	0.384	0.074	0.013	0.000	0.000	2.267	0.999
1978	0.936	0.798	0.507	0.219	0.026	0.000	0.008	0.000	2.494	0.742
1979	0.279	1.933	0.385	0.328	0.059	0.046	0.041	0.000	3.072	1.227
1980	0.057	4.644	5.761	0.473	0.057	0.037	0.000	0.000	11.030	4.456
1981	0.012	1.027	1.779	0.721	0.205	0.061	0.000	0.026	3.830	1.960
1982	0.045	3.742	1.122	1.016	0.455	0.065	0.000	0.026	6.472	2.500
1983	0.000	1.865	2.728	0.531	0.123	0.092	0.061	0.092	5.492	2.642
1984	0.000	0.093	0.809	0.885	0.834	0.244	0.000	0.000	2.865	1.646
1985	0.110	2.198	0.262	0.282	0.148	0.000	0.000	0.000	3.000	0.988
1986	0.027	1.806	0.291	0.056	0.137	0.055	0.000	0.000	2.372	0.847
1987	0.000	0.128	0.112	0.133	0.053	0.055	0.000	0.000	0.480	0.329
1988	0.078	0.275	0.366	0.242	0.199	0.027	0.000	0.000	1.187	0.566
1989	0.047	0.424	0.740	0.290	0.061	0.022	0.022	0.000	1.605	0.729
1990	0.000	0.065	1.108	0.393	0.139	0.012	0.045	0.000	1.762	0.699
1991	0.435	0.000	0.254	0.675	0.274	0.020	0.000	0.000	1.659	0.631
1992	0.000	2.010	1.945	0.598	0.189	0.000	0.000	0.000	4.742	1.566
1993	0.046	0.290	0.500	0.317	0.027	0.000	0.000	0.000	1.180	0.482
1994	0.000	0.621	0.638	0.357	0.145	0.043	0.000	0.000	1.804	0.660
1995	0.040	1.180	4.810	1.490	0.640	0.010	0.000	0.000	8.170	2.579
1996	0.030	0.990	2.630	2.700	0.610	0.060	0.000	0.000	7.020	2.853
1997	0.019	1.169	3.733	4.081	0.703	0.134	0.000	0.000	9.837	4.359
Mean	0.268	2.215	2.349	1.073	0.342	0.082	0.034	0.010	6.373	2.447

Table C7. NEFSC fall survey indices of Georges bank yellowtail flounder abundance at age (no./tow) and total biomass (kg/tow).

	Age										Biomass
Year	0	1	2	3	4	5	6	7	8+	Total	(kg)
1963	0.000	14.722	7.896	11.226	1.858	0.495	0.281	0.034	0.233	36.746	12.788
1964	0.000	1.721	9.723	7.370	5.998	2.690	0.383	0.095	0.028	28.007	13.623
1965	0.014	1.138	5.579	5.466	3.860	1.803	0.162	0.284	0.038	18.345	9.104
1966	1.177	8.772	4.776	2.070	0.837	0.092	0.051	0.000	0.000	17.775	3.988
1967	0.106	9.137	9.313	2.699	1.007	0.309	0.076	0.061	0.000	22.708	7.575
1968	0.000	11.782	11.946	5.758	0.766	0.944	0.059	0.000	0.000	31.254	10.536
1969	0.135	8.106	10.381	5.855	1.662	0.553	0.149	0.182	0.000	27.023	9.279
1970	1.048	4.610	5.133	3.144	1.952	0.451	0.063	0.017	0.000	16.417	4.979
1971	0.025	3.627	6.949	4.904	2.248	0.551	0.234	0.024	0.024	18.586	6.365
1972	0.785	2.424	6.525	4.824	2.095	0.672	0.279	0.000	0.000	17.604	6.328
1973	0.094	2.494	5.497	5.104	2.944	1.216	0.416	0.171	0.031	17.996	6.602
1974	1.030	4.623	2.854	1.524	1.060	0.460	0.249	0.131	0.000	12.133	3.733
1975	0.361	4.625	2.511	0.877	0.572	0.334	0.033	0.000	0.031	9.420	2.365
1976	0.000	0.336	1.929	0.475	0.117	0.122	0.033	0.000	0.067	3.078	1.533
1977	0.000	0.928	2.161	1.649	0.618	0.113	0.056	0.036	0.016	5.614	2.829
1978	0.037	4.729	1.272	0.773	0.406	0.139	0.011	0.000	0.024	7.443	2.383
1979	0.018	1.312	1.999	0.316	0.122	0.138	0.038	0.064	0.007	4.041	1.520
1980	0.078	0.761	5.086	6.050	0.678	0.217	0.162	0.006	0.033	13.217	6.722
1981	0.000	1.584	2.333	1.630	0.500	0.121	0.083	0.013	0.000	6.345	2.621
1982	0.000	2.424	2.185	1.590	0.423	0.089	0.000	0.000	0.000	6.711	2.270
1983	0.000	0.109	2.284	1.914	0.473	0.068	0.012	0.000	0.038	4.898	2.131
1984	0.012	0.661	0.400	0.306	2.428	0.090	0.029	0.000	0.018	3.944	0.593
1985	0.010	1.350	0.560	0.160	0.040	0.080	0.000	0.000	0.000	2.200	0.709
1986	0.000	0.280	1.110	0.350	0.070	0.000	0.000	0.000	0.000	1.810	0.820
1987	0.000	0.113	0.390	0.396	0.053	0.079	0.000	0.000	0.000	1.031	0.509
1988	0.011	0.019	0.213	0.102	0.031	0.000	0.000	0.000	0.000	0.376	0.171
1989	0.027	0.248	1.992	0.774	0.069	0.066	0.000	0.000	0.000	3.176	0.977
1990	0.147	0.000	0.326	1.517	0.280	0.014	0.000	0.000	0.000	2.284	0.725
1991	0.000	2.100	0.275	0.439	0.358	0.000	0.000	0.000	0.000	3.172	0.730
1992	0.000	0.151	0.396	0.712	0.162	0.144	0.027	0.000	0.000	1.592	0.576
1993	0.000	0.842	0.136	0.587	0.536	0.000	0.000	0.000	0.000	2.101	0.545
1994	0.010	1.200	0.220	0.980	0.710	0.260	0.030	0.030	0.000	3.440	0.897
1995	0.070	0.280	0.120	0.350	0.280	0.050	0.010	0.000	0.000	1.160	0.354
1996	0.000	0.140	0.350	1.870	0.450	0.070	0.000	0.000	0.000	2.880	1.303
1997	0.000	1.392	0.533	3.442	2.090	1.071	0.082	0.000	0.000	8.611	3.781
Mean	0.148	2.821	3.296	2.492	1.079	0.386	0.086	0.033	0.017	10.375	3.770

Table C8. NEFSC scallop survey index of Georges bank yellowtail flounder age 1 abundance.

Year	No./tow
1982	0.313
1983	0.140
1984	0.233
1985	0.549
1986	0.103
1987	0.047
1988	0.116
1989	0.195
1990	0.100
1991	2.117
1992	0.167
1993	1.129
1994	1.503
1995	0.609
1996	0.508
1997	1.062
Mean	0.556

Table C9. Correlations among normalized indices of abundance at age for Georges Bank yellowtail flounder.

Age 1

	Spring	*Fall*	*Canada*	*Scallop*
Spring	1.00			
Fall	0.40	1.00		
Canada	0.18	-0.01	1.00	
Scallop	0.36	0.70	0.22	1.00

Age 2

	Spring	*Fall*	*Canada*
Spring	1.00		
Fall	0.60	1.00	
Canada	0.63	-0.06	1.00

Age 3

	Spring	*Fall*	*Canada*
Spring	1.00		
Fall	0.70	1.00	
Canada	0.76	0.61	1.00

Age 4

	Spring	*Fall*	*Canada*
Spring	1.00		
Fall	0.65	1.00	
Canada	0.70	0.75	1.00

Age 5

	Spring	*Fall*	*Canada*
Spring	1.00		
Fall	0.21	1.00	
Canada	0.74	0.46	1.00

Age 6

	Spring	*Fall*	*Canada*
Spring	1.00		
Fall	0.44	1.00	
Canada	0.64	1.00	1.00

Table C10. Estimates of Georges Bank yellowtail flounder abundance at age (millions).

	Age						
Year	1	2	3	4	5	6	Sum
1973	28.290	23.279	28.937	16.960	6.729	2.859	107.054
1974	50.265	22.848	14.635	11.709	5.492	2.240	107.189
1975	68.516	39.214	10.589	4.830	2.893	1.551	127.593
1976	22.919	52.140	9.228	2.284	0.885	1.417	88.873
1977	15.760	18.208	14.628	2.899	0.651	0.768	52.914
1978	50.823	12.605	7.144	3.003	0.816	0.304	74.695
1979	23.375	32.871	7.510	2.199	0.957	0.465	67.377
1980	22.099	18.927	18.312	3.032	0.677	0.206	63.253
1981	61.066	17.814	12.264	7.011	1.198	0.185	99.538
1982	21.627	49.947	13.925	5.199	1.618	0.129	92.445
1983	5.818	15.840	25.067	4.957	1.319	0.264	53.265
1984	8.620	4.134	6.011	6.031	1.962	0.382	27.140
1985	14.594	6.670	1.650	1.062	0.654	0.102	24.732
1986	6.660	11.361	2.434	0.613	0.279	0.129	21.476
1987	7.025	5.310	4.080	1.108	0.188	0.155	17.866
1988	19.361	5.625	1.947	0.851	0.219	0.049	28.052
1989	8.552	15.414	2.463	0.516	0.132	0.036	27.113
1990	11.831	6.834	11.248	1.412	0.186	0.034	31.545
1991	22.365	9.488	3.848	3.669	0.432	0.086	39.888
1992	17.223	17.938	7.719	2.045	0.805	0.042	45.772
1993	16.539	11.939	7.123	4.033	0.526	0.122	40.282
1994	27.010	8.842	8.862	3.319	1.138	0.165	49.336
1995	20.934	22.050	6.460	2.060	0.391	0.078	51.973
1996	14.801	17.127	17.911	4.479	1.040	0.095	55.453
1997	21.069	12.072	13.676	13.299	3.019	0.791	63.926
1998	--	17.235	9.346	10.059	9.529	2.730	48.899
Mean	23.486	18.297	10.270	4.563	1.682	0.592	57.987

Table C11. Estimates of Georges Bank yellowtail flounder fishing mortality at age.

Year	Age 1	2	3	4	5	6	Mean 4-5
1973	0.01	0.26	0.70	0.93	0.95	0.95	0.94
1974	0.05	0.57	0.91	1.20	1.25	1.25	1.23
1975	0.07	1.25	1.33	1.50	1.59	1.59	1.55
1976	0.03	1.07	0.96	1.05	1.09	1.09	1.07
1977	0.02	0.74	1.38	1.07	1.10	1.10	1.09
1978	0.24	0.32	0.98	0.94	0.97	0.97	0.96
1979	0.01	0.39	0.71	0.98	1.01	1.01	1.00
1980	0.02	0.23	0.76	0.73	0.74	0.74	0.74
1981	0.00	0.05	0.66	1.27	1.33	1.33	1.30
1982	0.11	0.49	0.83	1.17	1.22	1.22	1.20
1983	0.14	0.77	1.22	0.73	0.74	0.74	0.74
1984	0.06	0.72	1.53	2.02	2.27	2.27	2.15
1985	0.05	0.81	0.79	1.14	1.18	1.18	1.16
1986	0.03	0.82	0.59	0.98	1.01	1.01	1.00
1987	0.02	0.80	1.37	1.42	1.50	1.50	1.46
1988	0.03	0.63	1.13	1.66	1.79	1.79	1.73
1989	0.02	0.12	0.36	0.82	0.84	0.84	0.83
1990	0.02	0.37	0.92	0.98	1.01	1.01	1.00
1991	0.02	0.01	0.43	1.32	1.38	1.38	1.35
1992	0.17	0.72	0.45	1.16	1.20	1.20	1.18
1993	0.43	0.10	0.56	1.07	1.10	1.10	1.09
1994	0.00	0.11	1.26	1.94	2.15	2.15	2.05
1995	0.00	0.01	0.17	0.48	0.49	0.49	0.49
1996	0.00	0.03	0.10	0.19	0.20	0.20	0.20
1997	0.00	0.06	0.11	0.13	0.13	0.13	0.13
Mean	0.06	0.46	0.81	1.08	1.13	1.13	1.10

Table C12. Estimates of Georges Bank yellowtail flounder spawning stock biomass (mt).

Year	Age 2	3	4	5	6	Sum
1973	2,796	8,895	5,531	2,509	1,372	21,103
1974	2,530	4,500	3,982	2,042	1,031	14,085
1975	2,984	2,678	1,319	848	502	8,331
1976	4,200	3,026	861	383	691	9,161
1977	1,870	3,883	1,084	296	424	7,557
1978	1,413	2,185	1,275	397	171	5,441
1979	3,767	2,320	873	421	251	7,632
1980	2,260	5,918	1,351	371	150	10,050
1981	2,678	4,161	2,295	449	78	9,661
1982	5,454	4,347	1,908	670	75	12,454
1983	1,534	6,031	2,035	656	171	10,427
1984	629	1,103	1,195	450	107	3,484
1985	1,480	543	394	270	46	2,733
1986	2,358	947	248	139	71	3,763
1987	1,004	1,106	375	63	64	2,612
1988	1,183	621	269	82	21	2,176
1989	4,299	1,059	244	75	26	5,703
1990	1,406	2,744	495	78	18	4,741
1991	2,089	1,062	934	162	38	4,285
1992	1,796	2,120	603	290	28	4,837
1993	1,508	1,635	1,197	172	64	4,576
1994	1,057	1,456	628	268	51	3,460
1995	2,734	1,750	703	171	44	5,402
1996	2,506	5,565	1,948	588	74	10,681
1997	1,744	4,739	6,715	1,871	666	15,735
Mean	2,291	2,976	1,538	549	249	7,604

Table C13. Yield and spawning stock per recruit analyses for Georges Bank yellowtail flounder.

```
   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: 27- 3-1998:  Time: 10:31:09.91
GEORGES BANK YELLOWTAIL FLOUNDER - TRAC 1998

Proportion of F before spawning:  .4167
Proportion of M before spawning:  .4167
Natural Mortality is Constant at:  .200
Initial age is:  1: Last age is:  8
Last age is a PLUS group:
Original age-specific PRs, Mats, and Mean Wts from file:
==> GBYT8.DAT
----------------------------------------------------------
Age-specific Input data for Yield per Recruit Analysis
----------------------------------------------------------
 Age | Fish Mort  Nat Mort | Proportion | Average Weights
     |  Pattern    Pattern |   Mature   |  Catch    Stock
----------------------------------------------------------
  1  |   .0100    1.0000   |    .0000   |   .100    .100
  2  |   .1600    1.0000   |    .5400   |   .285    .119
  3  |   .6200    1.0000   |    .9100   |   .396    .216
  4  |  1.0000    1.0000   |    .9700   |   .512    .512
  5  |  1.0000    1.0000   |   1.0000   |   .647    .647
  6  |  1.0000    1.0000   |   1.0000   |   .826    .826
  7  |  1.0000    1.0000   |   1.0000   |   .897    .897
  8+ |  1.0000    1.0000   |   1.0000   |  1.041   1.041

----------------------------------------------------------
Summary of Yield per Recruit Analysis for:
GEORGES BANK YELLOWTAIL FLOUNDER - TRAC 1998

 Slope of the Yield/Recruit Curve at F=0.00: -->    2.5057
   F level at slope=1/10 of the above slope (F0.1): ----->      .241
     Yield/Recruit corresponding to F0.1: ----->     .2179
   F level to produce Maximum Yield/Recruit (Fmax): ----->      .687
     Yield/Recruit corresponding to Fmax: ----->     .2473
   F level at 20 % of Max Spawning Potential (F20): ----->      .487
     SSB/Recruit corresponding to F20: -------->     .5037
```

Table C14. Age-based projection of the Georges Bank yellowtail flounder stock at status quo F.

PROJECTION RUN: Georges Bank yellowtail - status quo projection
INPUT FILE: gbytsq.in
OUTPUT FILE: gbytsq.out
RECRUITMENT MODEL: 3
NUMBER OF SIMULATIONS: 100

F-BASED PROJECTIONS
CONSTANT F:0.130

SPAWNING STOCK BIOMASS (THOUSAND MT)

YEAR	AVG SSB (000 MT)	STD
1998	18.044	2.854
1999	22.053	4.064
2000	24.947	5.283

PERCENTILES OF SPAWNING STOCK BIOMASS (000 MT)

YEAR	1%	5%	10%	25%	50%	75%	90%	95%	99%
1998	11.743	13.621	14.537	16.131	17.799	19.761	21.786	22.976	25.820
1999	13.867	16.270	17.418	19.197	21.545	24.463	27.535	29.636	33.053
2000	15.379	17.668	18.873	21.068	24.162	28.006	32.541	34.937	38.926

ANNUAL PROBABILITY THAT SSB EXCEEDS THRESHOLD: 10.00000 THOUSAND MT

YEAR	Pr(SSB > Threshold Value)
1998	1.000
1999	1.000
2000	1.000

RECRUITMENT UNITS ARE: 1000.000 FISH

BIRTH YEAR	AVG RECRUITMENT	STD
1998	23123.139	16356.631
1999	23138.766	16356.953
2000	23072.730	16295.333

PERCENTILES OF RECRUITMENT UNITS ARE: 1000.000 FISH

BIRTH YEAR	1%	5%	10%	25%	50%	75%	90%	95%	99%
1998	5822.000	6714.000	6892.000	13738.000	19303.000	22773.000	50272.000	60926.000	68014.000
1999	5822.000	6714.000	6892.000	13738.000	19303.000	22773.000	50272.000	60926.000	68014.000
2000	5822.000	6714.000	6892.000	13738.000	19303.000	22773.000	50272.000	60926.000	68014.000

LANDINGS FOR F-BASED PROJECTIONS

YEAR	AVG LANDINGS (000 MT)	STD
1998	1.816	0.272
1999	2.249	0.364
2000	2.621	0.524

PERCENTILES OF LANDINGS (000 MT)

YEAR	1%	5%	10%	25%	50%	75%	90%	95%	99%
1998	1.208	1.397	1.484	1.634	1.788	1.977	2.172	2.310	2.528
1999	1.471	1.695	1.817	2.000	2.220	2.462	2.721	2.893	3.235
2000	1.621	1.886	2.032	2.240	2.555	2.922	3.315	3.617	4.097

DISCARDS FOR F-BASED PROJECTIONS

YEAR	AVG DISCARDS (000 MT)	STD
1998	0.030	0.010
1999	0.033	0.013
2000	0.034	0.015

PERCENTILES OF DISCARDS (000 MT)

YEAR	1%	5%	10%	25%	50%	75%	90%	95%	99%
1998	0.014	0.017	0.019	0.023	0.028	0.035	0.042	0.047	0.062
1999	0.012	0.016	0.019	0.024	0.030	0.040	0.054	0.060	0.070
2000	0.012	0.016	0.019	0.024	0.030	0.045	0.056	0.061	0.079

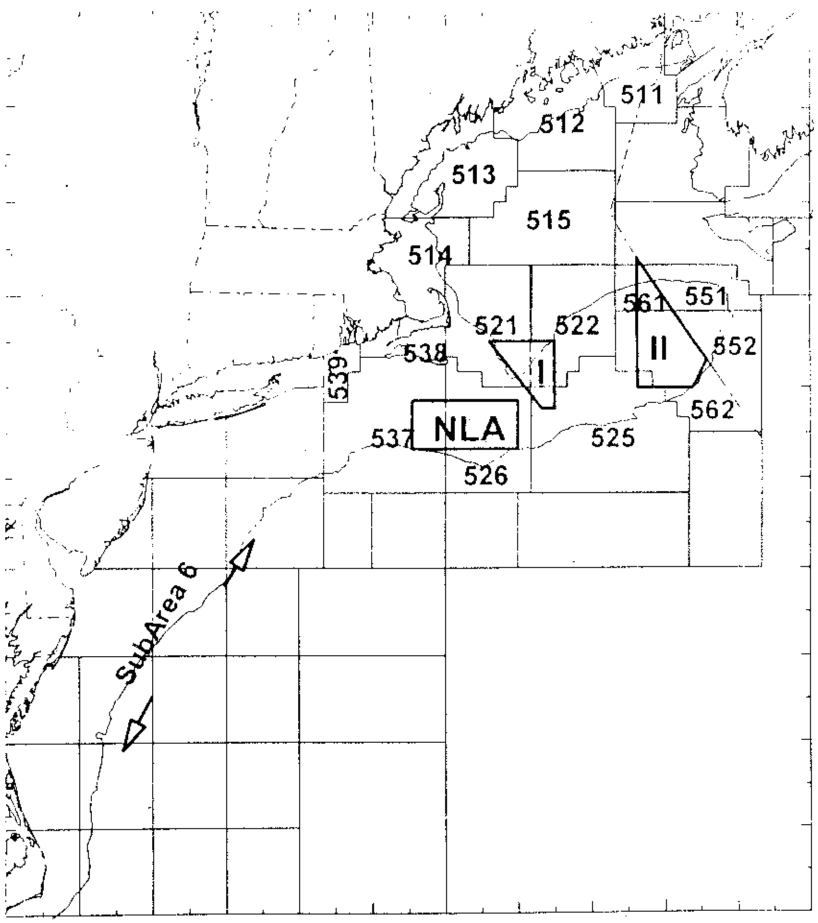

Figure C1. Statistical reporting areas for Georges Bank yellowtail flounder. Catches from shaded areas are included in the analyses. Areas I, II, and the Nantucket lightship area are closed to fishing.

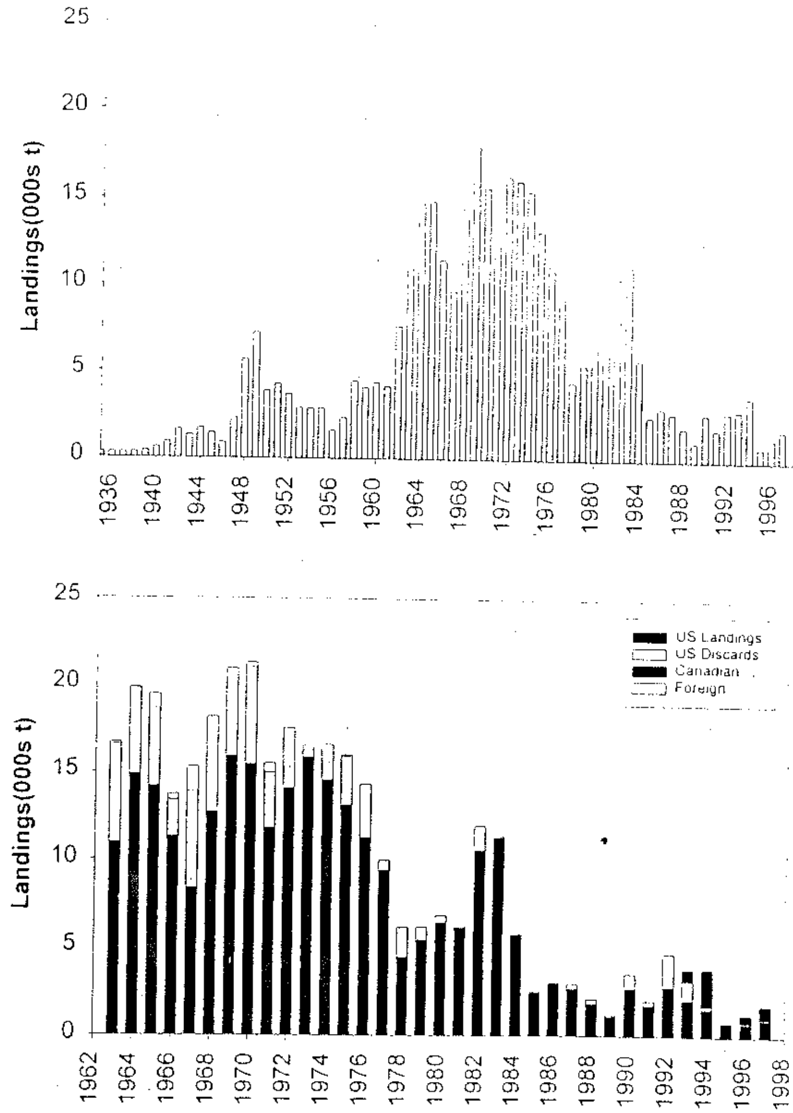

Figure C2. Landings of Georges Bank yellowtail flounder by Canada and the United States. The top panel shows landings from 1935-1997, and the bottom panel shows the national composition of landings from 1963-1997.

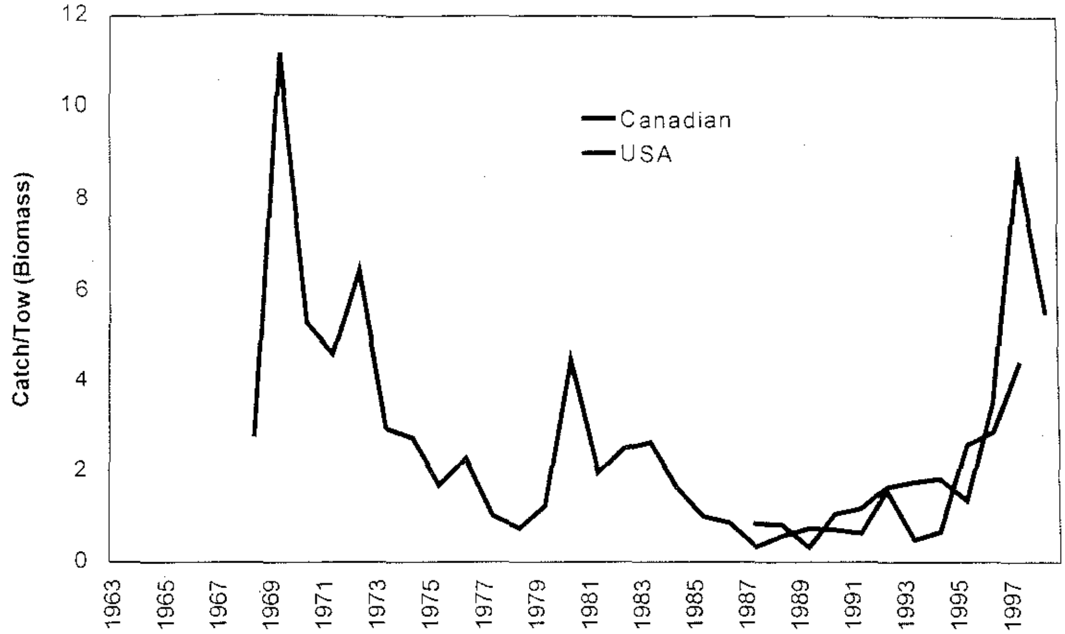

Figure C3. USA and Canadian spring survey results for yellowtail flounder (Strata 5Z1-4), 1987-1997 (the series includes 1998 for the Canadian survey).

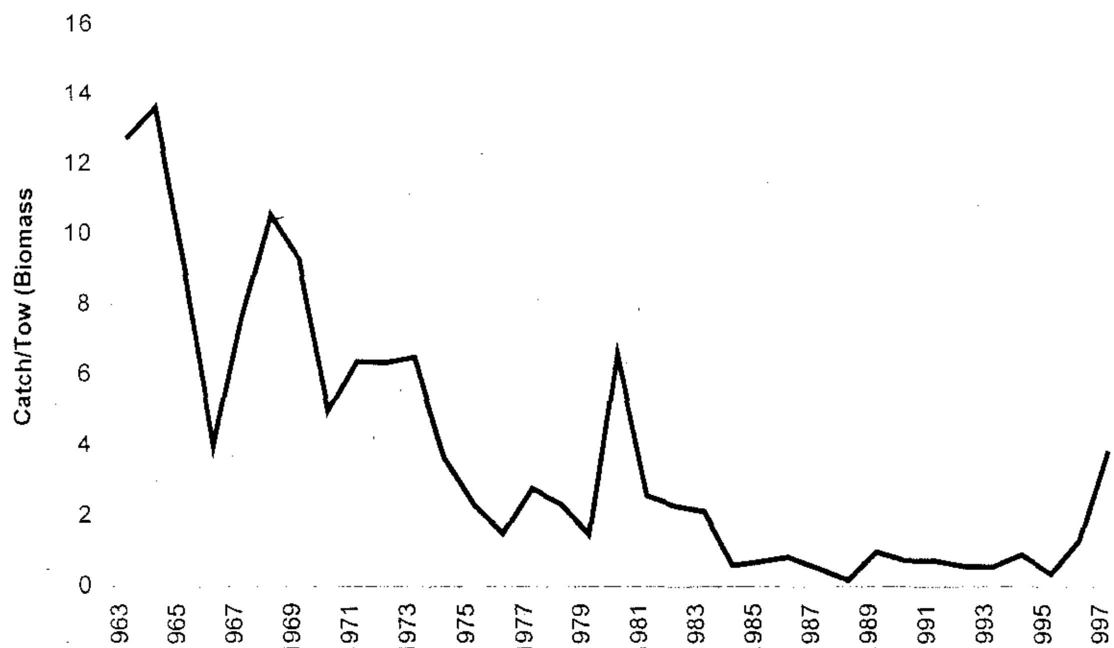

Figure C4. USA fall survey results for yellowtail flounder on Georges Bank, 1963-1997.

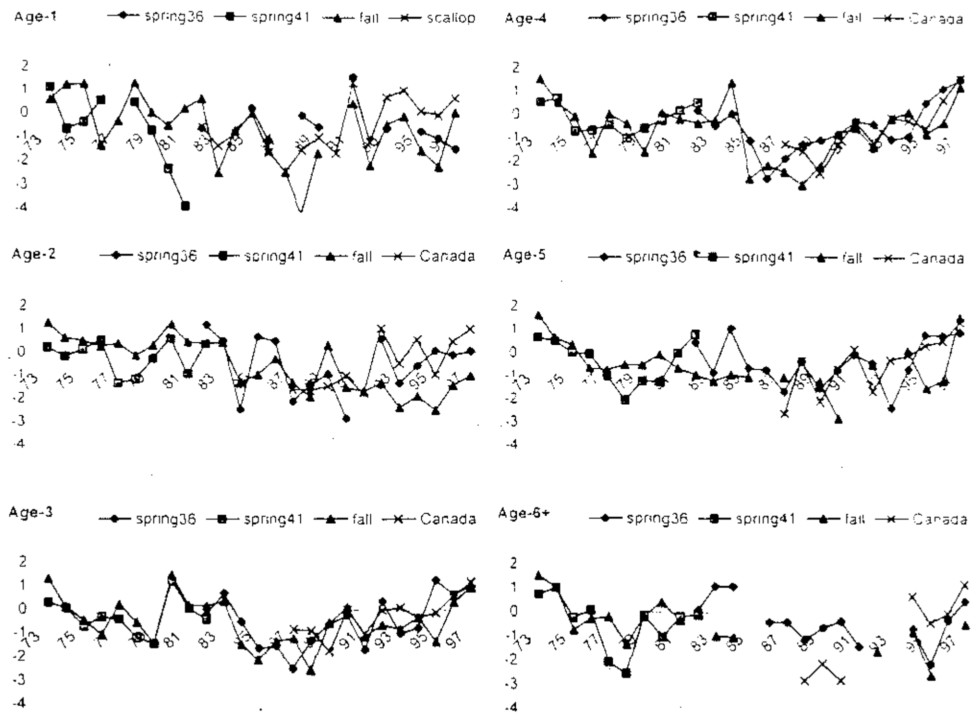

Figure C5. Normalized indices of abundance at age [Ln (x/mean)] for Georges Bank yellowtail flounder.

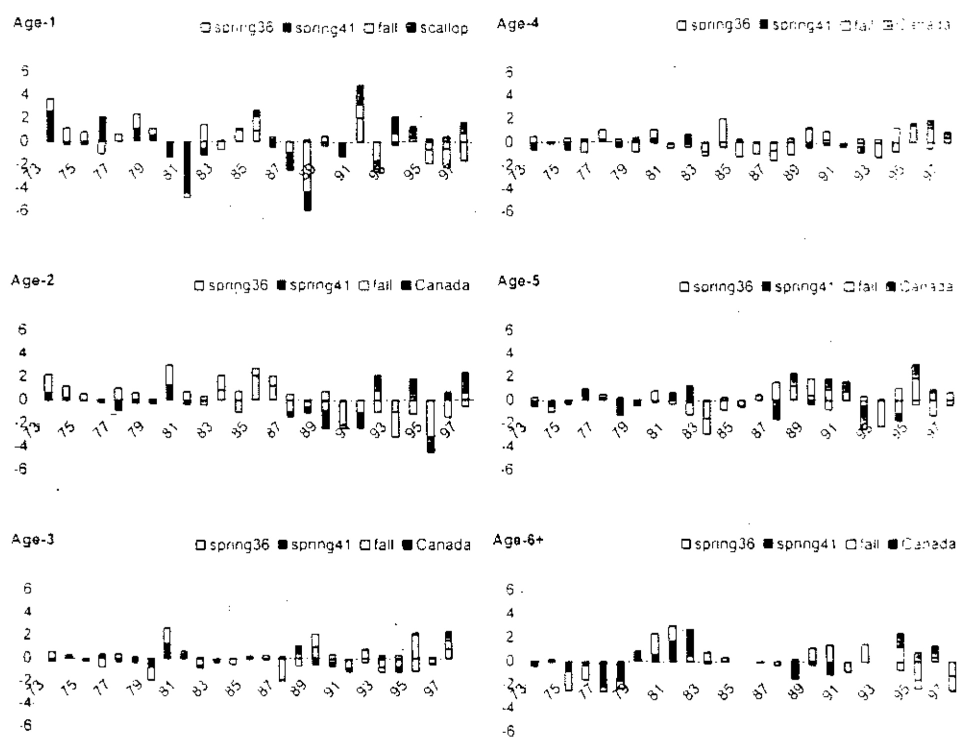

Figure C6. Standardized residuals from ADAPT calibration of the Georges Bank yellowtail flounder VPA.

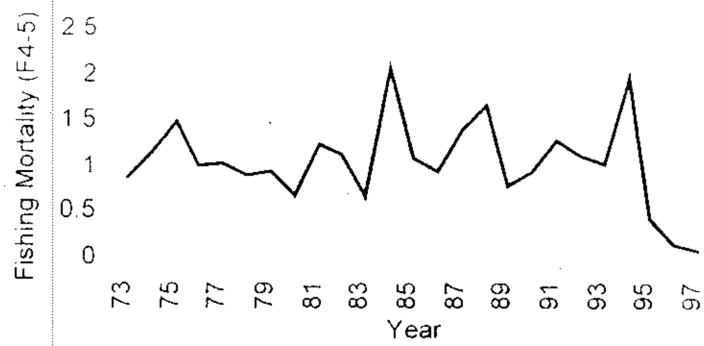

Figure C7. Instantaneous rate of fishing mortality (F4-5) of Georges Bank yellowtail flounder.

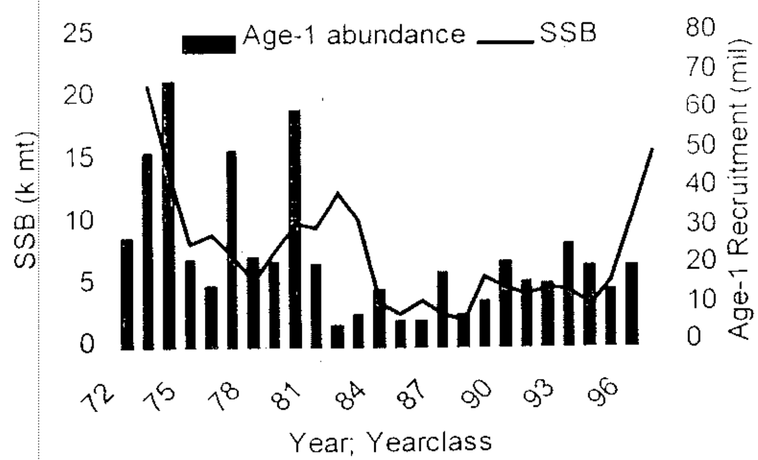

Figure C8. Spawning stock biomass and age-1 recruitment of Georges Bank yellowtail flounder.

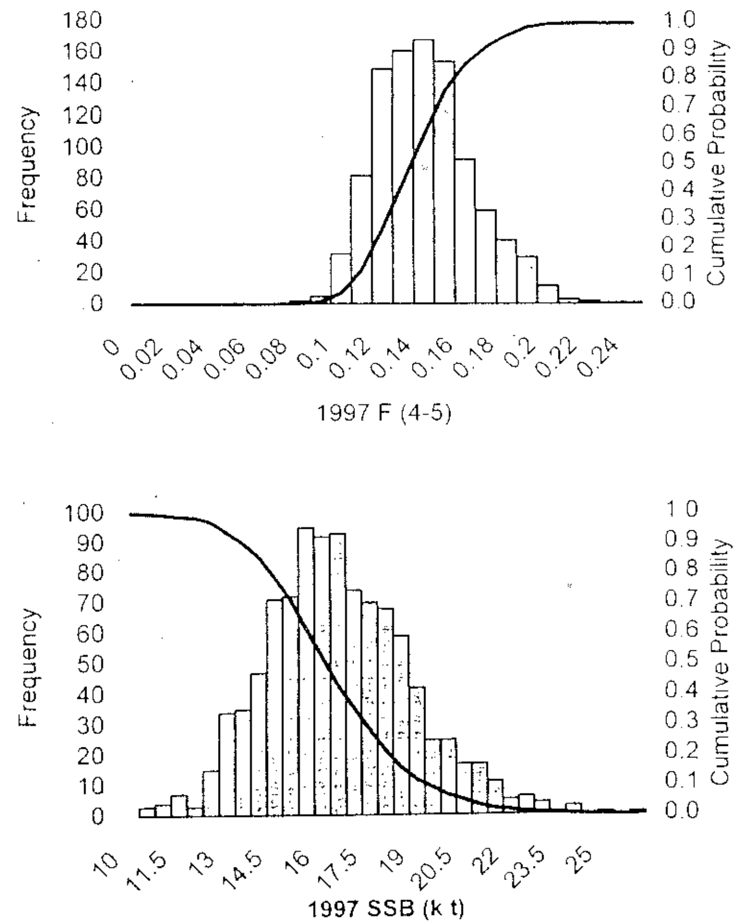

Figure C9. Bootstrap distributions of fully-recruited fishing mortality (above) and spawning stock biomass (below) of Georges Bank yellowtail flounder in 1997.

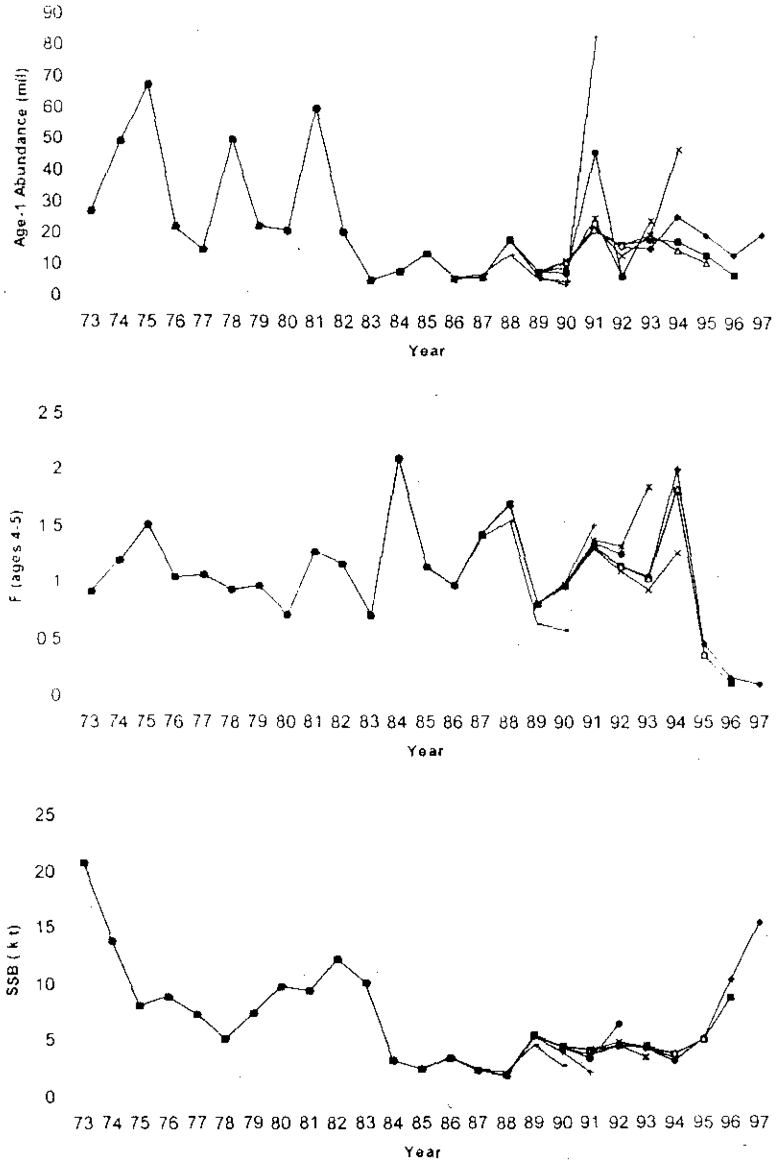

Figure C10. Retrospective analyses of Georges Bank yellowtail flounder, showing the impacts of additional year's of data on estimates of spawning stock biomass (bottom panel), fishing mortality (middle panel) and recruitment (top panel).

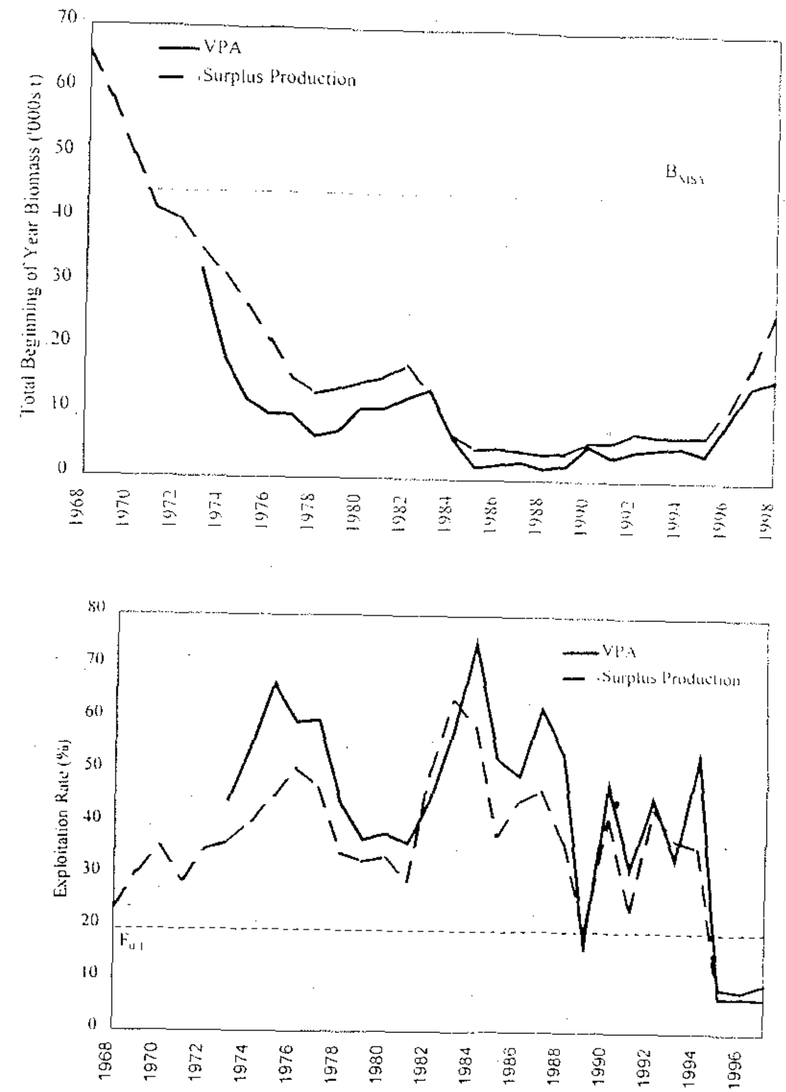

Figure C11. Comparison of results from VPA and surplus production modeling of Georges Bank.

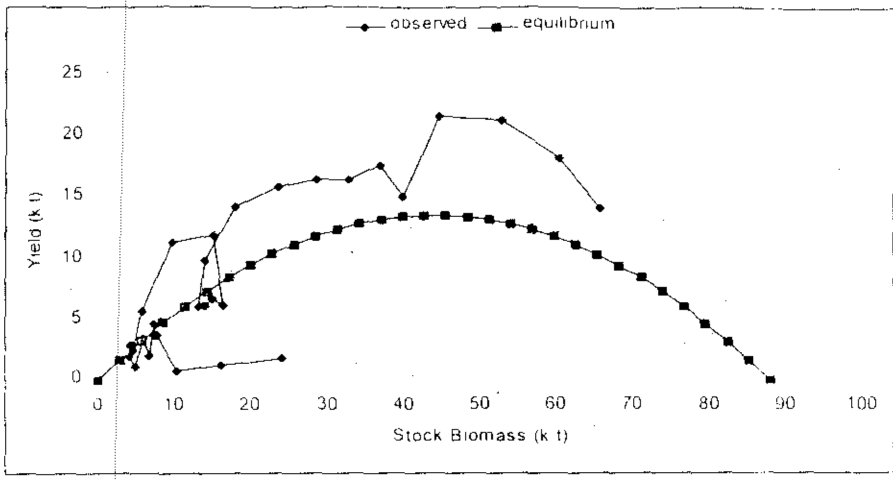

Figure C12. Observed yield and fitted biomass of Georges Bank yellowtail flounder from ASPIC results.

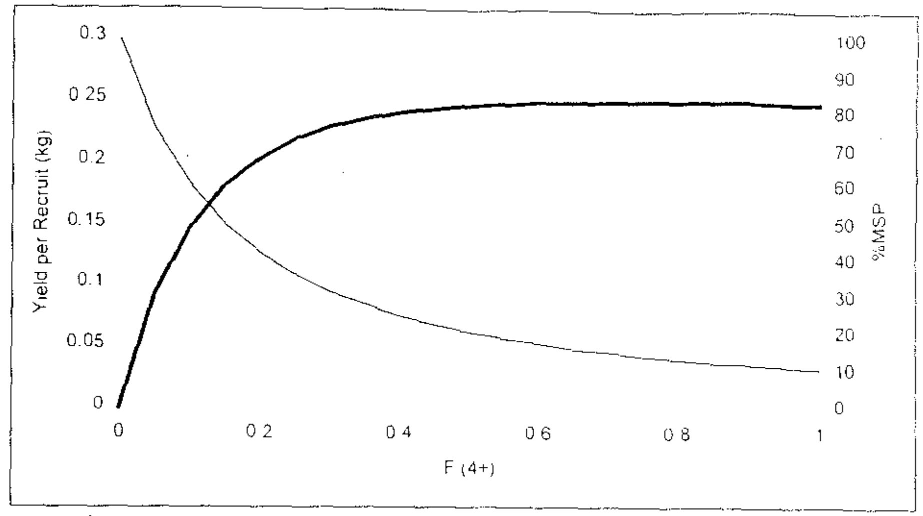

Figure C14. Yield per recruit and percent maximum spawning potential (SSB/R) of Georges Bank yellowtail flounder.

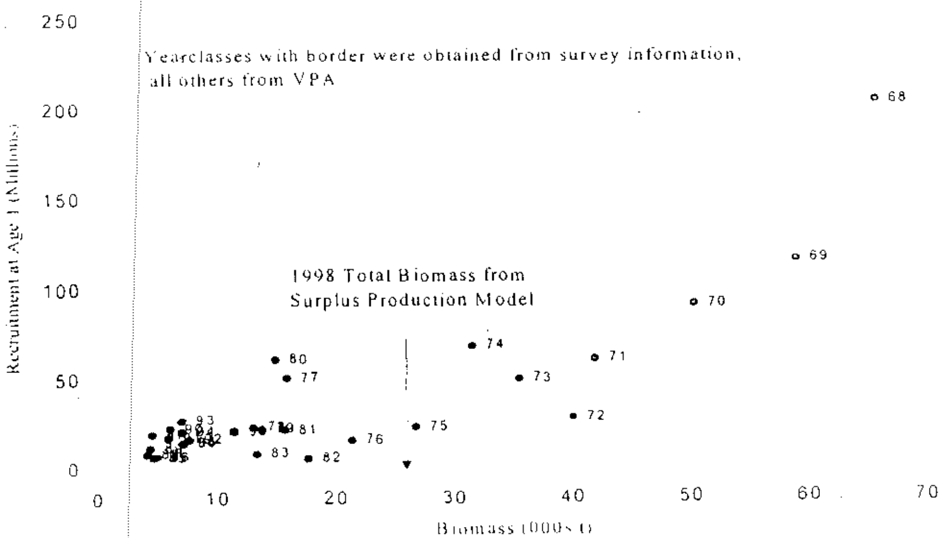

Figure C13. Relationship between total stock biomass from surplus production modeling and age-1 recruitment from the VPA (1972 to 1996 year-classes) or recruitment from the USA fall surveys (1969 to 1971 year-classes), Georges Bank yellowtail flounder.

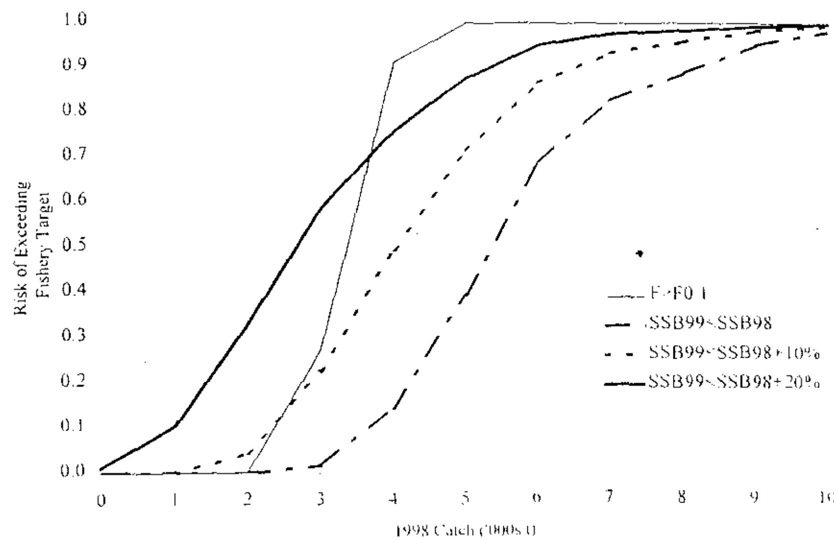

Figure C15. Risk of exceeding various fishery targets ($F_{0.1}$, spawning stock biomass in 1999 being less than 1998, or not having a 10 or 20% increase in biomass in 1999.

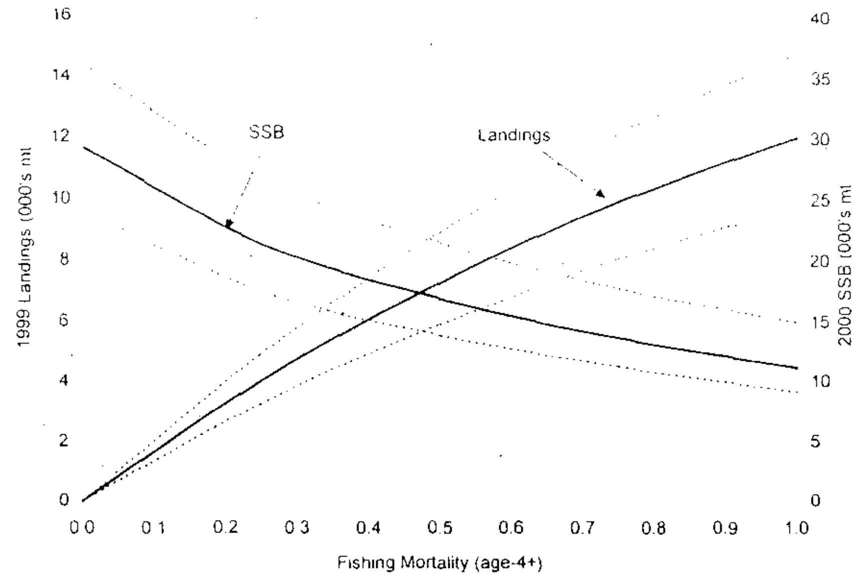

Figure C16. ASPIC projections (median and interquartile range) of Georges Bank yellowtail founder catch (above) and total stock biomass (below) at status quo F.

D. SCUP

Terms of Reference

a. Update commercial and recreational landings and discard estimates for scup through 1997.

b. Evaluate quantitative indicators of exploitation rate, stock abundance, and recruitment from state and Federal research surveys, commercial and recreational fisheries, sea sampling data, and other sources.

c. If possible, use alternative models such as ASPIC to assess the status of scup.

d. Provide total allowable catch recommendations for scup to meet the target exploitation rate for 1999.

e. Review existing biological reference points and advise on new reference points for scup to meet SFA requirements.

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 in offshore waters in the winter. Sexual maturity occurs at age 2, with spawning occurring from May to August. Scup reach a maximum length of about 40 cm and a maximum age of about 20 years (Dery and Rearden 1979). Tagging studies (e.g., Neville and Talbot 1964; Cogswell 1960, 1961; Hamer 1970, 1979) have indicated the possibility of two stocks of scup, one in Southern New England and another extending south from New Jersey. However, a lack of definitive tag return data coupled with distributional data from the NEFSC bottom trawl surveys support the concept of a single unit stock extending from Cape Hatteras north to New England (Mayo 1982).

The Mid-Atlantic Fishery Management Council (MAFMC) and the Atlantic States Marine Fisheries Commission (ASMFC) manage scup under Amendment 8 to the Summer Flounder FMP. In 1996, the FMP implemented minimum size requirements of 9 in (23 cm) for commercially landed scup and 7 in (18 cm) size limits for recreationally landed scup, and a minimum mesh size of 4.0 in for commercial vessels retaining more than 4,000 lb of scup. In 1997, the minimum mesh size was increased to 4.5 in and the level of catch triggering the mesh requirement changed to seasonal thresholds of 4,000 lb from November through April and 1,000 lb from May through October. Exploitation rates are to be reduced to 47% (F = 0.72) during 1997-1999, to 33% (F = 0.45) during 2000-2001, and to 19% (F = 0.24) in 2002, through coastwide commercial quotas and season and possession limits in the recreational fishery. The total allowable catch (TAC) established for 1997 of 9.11 million lb (4,132 mt) included a commercial fishery quota of 6.00 million lb (2,722 mt), a recreational fishery harvest limit of 1.95 million lb (885 mt), and projected total discards of 1.16 million lb (528 mt). For 1998, the TAC of 7.28 million lb (3,300 mt) includes a commercial fishery quota of 4.57 million lb (2,074 mt), a recreational fishery harvest limit of 1.55 million lb (704 mt), and projected total discards of 1.15 million lb (522 mt). Overfishing for scup is currently defined as fishing in excess of F_{max}. The 19% exploitation rate corresponds to the current estimate of F_{max} = 0.24. The FMP has as a management unit all scup from Cape Hatteras northward to the US-Canadian border.

The Fishery

Commercial Landings

US commercial landings averaged less than 10,000 mt annually during 1930-1947 (Figure D1), averaged over 19,000 mt per year during 1953-1964 (peaking at over 22,000 mt in 1960), and declined to around 4,000 mt per year in the early 1970s. From 1974 to 1986, landings fluctuated between 7,000 and 10,000 mt, and have since declined to less than 3,000 mt. Under TAC and other restrictions, landings in 1997 were about 2,200 mt (4.8 million lb), the lowest observed in the time series beginning in 1930 (Table D1). The reported commercial landings fell short of the available quota (2,700 mt or 6.0 million lb) by

20%. During the 1995-1997 period, the proportion of landings from the winter periods (January-April, November-December) has declined, and the proportion landed during the summer period (May-October) has increased (Figure D2).

Commercial landings in 1994-1997 were reported by dealers by market category, but not by area of catch. Procedures developed by Wigley *et al.* (1998) were used to allocate those landings by market category to statistical area based on information collected under the Vessel Trip Report (VTR) system. In those procedures, a monthly set of landings which are reported in both dealer and VTR databases are used to characterize the distribution of dealer-reported landings by statistical area. This proration procedure contributes to uncertainty in the attribution of market category landings by area, especially if vessels which are not participating in any fishery with mandatory VTR requirements land scup from different areas than those which produce landings for participating vessels. Other sources of uncertainty include unreported landings by dealers.

Distant-water fleet landings (principally from the Southern New England area) were reported during 1963-1981 (Figure D1). Landings peaked at about 5,900 mt in 1963, averaged only about 1,100 mt per year during 1964-1975, and were only a few mt annually during 1976-1981.

Landings of scup in Rhode Island and New Jersey have accounted for about two-thirds of the total during 1979-1997 (Table D2), with Rhode Island averaging about 38% of the total and New Jersey about 28% of the total. New York landings comprised an average of 15% of the total.

Scup landings reported for Massachusetts increased substantially from 176 mt (388,000 lb) in 1996 to 677 mt (1,492,530 lb) in 1997, in contrast to the pattern observed in all other states. Most of this increase was from the handline gear category, generally employed from vessels of displacement less than 5 gross registered tons, suggesting a change in reporting accuracy for scup landings in Massachusetts. Staff from MADMF noted that they had obtained affidavits from several major scup dealers detailing previously unreported landings of scup in Massachusetts for the years 1992-1997. These landings ranged from 1,249,611 lb (567 mt) in 1996 to 1,795,100 lb (814 mt) in 1993. At the time of its June 1998 meeting, the SARC was not in consensus about how to account for these landings in the assessment because of the following uncertainties: 1) should the level of unreported landings be considered constant back in time (i.e., raise Massachusetts landings by a constant proportion for years prior to 1992), 2) what were the biological characteristics of the landings, 3) to what degree have landings for other states been under-reported? Pending inspection and inclusion of these previously unreported landings records in the NMFS NER dealer landings database, the SARC decided not to revise the reported commercial fishery landings used in the scup assessment at this time.

The principal commercial fishing gear is the otter trawl, accounting for an average of 76% of the total catch during 1979-1997 (Table D3). The remainder of the commercial landings are taken by floating trap (12%), with paired trawl, pound net, pots and traps, and handlines 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.

The intensity of NER commercial fishery biological sampling during 1979-1997 is summarized in Table D4. Annual sampling intensity varied from 41 to 640 mt per 100 lengths. In 14 of the 19 years, the overall sampling exceeded the informal criterion of 100 lengths sampled per 200 mt. This alone does not indicate adequate sampling, however, because scup are landed in seven commercial market categories from over 20 statistical areas, and many of these strata with substantial landings lack samples.

The distribution and pooling of NER commercial fishery samples used in developing the estimates of landings at age for 1997 are presented in Table D5. In 1997, 22% of the landings were in the unclassified market category, for which only one length sample was collected. Based on comparison of this length frequency and the time/space landings pattern of the unclassified landings with those of other 1997 market categories, the unclassified sample and landings were pooled with the large/mix category on a quarter 1, quarter 2-4 basis (Table D5). Numbers at length were converted to numbers at age by applying age-length keys derived from NEFSC survey catches of scup and commercial samples. Age-length keys from spring surveys and first and second quarter commercial samples were applied to numbers at length from the first half of the year, while age-length keys from autumn surveys and third and fourth quarter commercial samples were applied to numbers at length from the second half of the year. Note that for all 1997 market categories, corresponding age-length keys from 1996 were used in developing these estimates since 1997 age data were not available. Therefore, all 1997 commercial landings-at-age estimates (as well as commercial discard-at-age and recreational catch-at-age estimates) are considered preliminary.

Numbers and mean weights at age for the commercial landings are presented in Tables D10 and D14. For 1997, 57% of the commercial landings at age were age 3, possibly reflecting both the implementation on September 26, 1996 of the 9 in (23 cm) commercial fishery minimum size limit and the influence of a strong 1994 year class, which also accounted for a large (66%) proportion of the commercial landings in 1996 at age 2 (Table D10, Figure D3).

Commercial Discards

The NEFSC sea sampling program has collected information on landings and discards in the commercial fishery during 1989-1997. For VPA time series years in which no discard data were collected (1984-1988), commercial landings at age were raised by the geometric mean of the ratios of discards to landings at age during 1989-1993. NER discard estimates were raised to account for North Carolina landings. In the absence of any published estimates of discard mortality rates for this species, a discard mortality rate of 100% was assumed. The number of trips in which scup were landed and/or discarded is tabulated in Table D6. Between 7 and 91 otter trawl trips per year were sampled in which scup were landed or discarded. The number of sampled trips was especially low in 1994-1996, with between 7 and 27 otter trawl trips sampled per year. Sampling increased from 1996 to 1997, from 27 to 45 otter trawl trips with observed landings or discards.

The scup assessment review by the SARC during SAW-25 (NEFSC 1997b) indicated that the NEFSC sea sampling data were inadequate to develop reliable estimates of scup discard at age in the commercial fishery for use in analytical models. However, as in the previous assessment, ratios of discards to landings by landings level (for trip landings <300 kg (661 lb) or ≥300 kg) and half-year were calculated (uncorrected geometric mean by cell) and multiplied by corresponding observed landings levels from the weighout database to provide estimates of discards for 1997 for use as guidance in setting TAC levels for management. Geometric mean rates are used because the distributions of landings, discards, and the ratio of discards to landings on a per-trip basis in the scup fishery are highly variable and positively skewed (e.g., see 1997, Figure D4).

In 1995 and 1996, no sea-sampled observations were available for trips landing ≥300 kg per trip in the first half of 1995 and the second half of 1996, one observation was available for trips landing ≥300 kg per trip in the second half of 1995 and two observations at that landings level were available for the first half of 1996. Consequently, the 1989-1994 average rate for trips with landings ≥300 kg (from both half years) was used for the 1995-1996 rates in both half years.

For 1997, sea sample data were available though October. Observations from 17 trips (with both non-zero landings and discards) were available for trips <300 kg, and 4 trips were available for trips ≥300 kg in the first half of the year. No sea sample observations were available for the second half of 1997 for trip landings in either category. Three alternative calculations for the 1997 commercial fishery discard estimates were performed. For the first alternative (Table D7a), the first half-year geometric mean discard ratio for trips <300 kg was used for the second half of 1997, and the long-term (1989-1994) geometric mean discard rate for trips with landings ≥300 kg was used for both half-years of 1997, providing an annual discard estimate of 1,060 mt. For the second alternative (Table D7B), the first half-year geometric mean rates from the trips sampled in 1997 were used for both half-years for both trip landings levels, providing an annual discard estimate of 1,793 mt. For the third alternative, arithmetic discard to landed ratios were calculated, as in the black sea bass (NEFSC 1997b) and New England groundfish assessments (e.g., Georges Bank yellowtail flounder, NEFSC 1997a), which use vessel trip report (VTR) data as the basis for discard ratios. Discard ratios calculated from VTR data are used in the black sea bass and groundfish assessments because the VTR ratios are comparable to sea sample data ratios, but the sample size from VTR is larger (NEFSC 1997a, 1997b). The arithmetic discard ratios for scup from sea sample data provided an annual discard estimate of 2,101 mt (Table D7c).

The VTR discard data for scup were also explored and compared with sea sample data. In contrast to black sea bass and New England groundfish discard data, geometric mean discards-to-landings ratios for scup for 1994-1997 sea sample data are 2-12 times higher than those from VTR data, with a single exception in 1996 for trips landing ≥300 kg (Table D8, Figure D5). The pattern persists when trips are disaggregated by mesh size, although sea sample data are very limited in this comparison (Table D9).

The calculation presented in Table D7b (1997 sea sample geometric mean first half-year rates used for both half-years) was used to estimate discards in the NER commercial fishery, raised to account for North Carolina landings, and carried forward in the assessment (1,793 mt). For 1989-1997, the total weight (mt) of discards was estimated from the observed ratios of discards to landings (as described above), and an aggregate length frequency distribution was developed by half-year (where component length frequency samples were weighted by the weight of the discards in the tow sampled). The intensity of length frequency sampling of discarded scup from sea sampling has declined in 1992-1997 relative to 1989-1991. Sampling intensity has ranged from 100 to 500 mt per 100 lengths sampled during 1992-1997, meeting the informal criterion of 200 mt per 100 lengths sampled only for 1996 (Table D6). 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. No age data are available from sea samples. 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. Estimated discard at age and mean weight at age are displayed in Tables D10 and D14.

For 1984-1993, no clear pattern of age- or cohort-specific trends emerged from examination of the example calculation of discards at age (Table D10). Discards were dominated by fish at ages 0, 1, or 2, depending on the year under consideration. There is some evidence for discarding of a strong 1994 year class based on the changes in age composition of discards between 1994 and 1996, but tempered by uncertainty due to poor sampling in those years (Table D10, Figure D6). The 1997 discard estimate is dominated by age 2 fish from the 1995 year class, probably as a result of minimum size and mesh regulations implemented during late 1996 and early 1997 (Table D10, Figure D6). The 1997 commercial fishery discard estimate of about 1,800 mt (4.0 million lb) is 3.6 times higher than the projected commercial fishery discard of about 500 mt (1.1 million lb) used to establish the 1997 TAC.

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 1979-1997. 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 estimated recreational landings (types A and B1) in weight during 1979-1997 averaged about 2,150 mt per year (Table D1). Since 1979, the MRFSS data indicate that the recreational landings have comprised approximately ¼ of the commercial and recreational total. The 1997 estimate of 479 mt is the lowest of the 1979-1997 time series, and about 54% of the available 1997 harvest limit.

The estimated recreational discards in weight during 1984-1997 ranged from 25 mt in 1997 to a high of 87 mt in 1986, while averaging about 44 mt per year (Table D18), based on the assumption that 15% of the discards (type B2) die. Mortality due to discarding in the recreational fishery has been reported to range from 0 to 15% (Howell and Simpson 1985) and from 0 to 13.8% (Williams, pers. comm.). Howell and Simpson found mortality rates positively correlated with size, due largely to the tendency for larger fish to take the hook deep in the esophagus or gills. Williams more clearly demonstrated increased mortality with depth of hook location, as well as handling time, but found no association with fish size. Based on these studies, discard mortality in the recreational fishery between 5 and 15% appears reasonable. In this and previous assessments, a recreational fishery discard mortality rate of 15% was assumed (NEFSC 1997b).

In the recreational fishery, sampling intensity varied from 48 to 443 mt per 100 lengths. Sampling in all years except one during 1979-1987 failed to satisfy the above informal criterion, but since 1987 the criterion has been met (Table D4). Numbers at length for recreational landings were determined based on available recreational fishery length frequency samples pooled by half-years over all regions and fishing modes, and were converted to numbers at age by applying age-length keys derived from NEFSC survey catches of scup and commercial samples. Age-length keys from spring surveys and first and second quarter commercial samples were applied to numbers at length from the first half of the year, while age-length keys from autumn surveys and third and fourth quarter commercial samples were applied to numbers at length from the second half of the year. Note that for 1997 recreational landings at age, corresponding age-length keys from 1996 were used in developing the estimates since 1997 age data were not available. As a result, 1997 recreational landings-at-age estimates are considered preliminary.

Numbers and mean weights at age for the recreational landings are presented in Tables D11 and D15. No length frequency distribution data on scup discards are collected under the MRFSS program, so recreational discards were assumed to be fish at ages 0 and 1, in the same relative proportions as in the landed catch, consistent with regulated minimum fish sizes and informal inspection of samples collected from the New York recreational fishery (Table D11). For 1997, 46% of the recreational landings-at-age are estimated to be age 2 scup. Virtually all of the recreational catch is estimated to be above the 7 in (18 cm) recreational fishery minimum size limit (Table D11, Figure D7).

Total Catch and Age Composition

Estimates of the total catch of scup during 1984-1997 include commercial and recreational landings and discards. The total catch during this period varied from a high of nearly 14,300 mt in 1986 to a low of about 4,500 mt in 1997. The total catch decreased by two-thirds from 1991 (14,100 mt) to 1997. During this 14-year period, commercial landings averaged about 50% of the total catch, with total discards and recreational landings each accounting for about 25%.

Numbers at age were estimated for 1984-1997 for the commercial landings (separately for Maine-Virginia, i.e., NEFSC weighout landings; and North Carolina), commercial discards, recreational landings, and recreational discards (Tables D10-D12, and summed over all sources in Table D13). Mean weights at age for the commercial landings, commercial discards, recreational landings, and recreational discards for 1984-1997 are given in Tables D14-D16, and estimates of mean weight at age of removals from all sources are given in Table D17. Variability in mean weights at age in the catch are partially a function of the relative magnitude of the discards in any particular year, e.g., the 1994 year class at age 1 in 1995.

Stock Abundance and Biomass Indices

Research Vessel Survey Indices

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

Department of Environmental Conservation, New Jersey Bureau of Marine Fisheries, and the Virginia Institute of Marine Science.

NEFSC

Abundance indices for scup were determined from autumn (1963-1997), spring (1968-1998), and winter (1992-1998) NEFSC bottom trawl surveys. Mean number- and weight-per-tow indices for the spring and autumn survey time series are presented in Table D19, which include only offshore strata for consistency over the early part of the time series. Although the indices exhibit considerable year-to-year variability, both surveys indicate that current levels of biomass are much lower than in years prior to about 1980. The spring indices show a high level from the late 1960s to the late 1970s followed by a sharp, almost continuous, decline through 1996. The autumn indices, although much more variable, may indicate an increase in biomass from the early 1960s to the mid-1970s, dropping thereafter, and declined to the lowest observed levels in the time series during 1993-1996. The winter survey indices exhibited a downward trend through 1997 (Table D22).

Mean number-per-tow-at-length and number-per-tow-at-age indices from the spring and autumn surveys were based on tows in offshore strata 1-12, 23, 25, and 61-76 and inshore strata 1-61 (Tables D20-D21, Figures D8 and D10). The indices from the relatively short winter survey series were based on tows in only the above-indicated offshore strata (Table D22, Figure D9). Note that NEFSC 1998 spring indices are based on preliminary, unaudited trawl log data.

The 1998 winter and 1998 spring surveys indicate that a potentially strong 1997 year class is recruiting to the stock. This year class can be tracked beginning with the 1997 autumn survey index at age 0 (11-cm mode), in which it appears to be about the same magnitude as the 1994 year class, progressing through the 1998 winter and spring surveys at age 1 (mode still at about 10 cm; Figures D8-D10). This incoming year class has contributed to overall increases in weight-per-tow indices for the 1997 autumn and 1998 winter and spring surveys (Tables D19 and D22).

During the SAW-27 SARC, indices of scup spawning stock biomass per tow (SSB kg/tow) were developed from the NEFSC spring and autumn offshore strata series for use as minimum biomass indices for stock rebuilding in response to Sustainable Fisheries Act (SFA) considerations. The SARC selected a 3-year moving average of the NEFSC spring SSB index as a representative measure of scup SSB, due to the characteristics of the survey age structure and the magnitude of the survey catch when compared with the autumn series. Current NEFSC spring indices of SSB are at record lows (1996-1998 average = 0.06 SSB kg/tow), and less than one-tenth of the maximum observed during 1977-1979 of 2.77 SSB kg/tow (Table D19, Figure D11).

Massachusetts

The Massachusetts Division of Marine Fisheries (MADMF) has conducted a semi-annual bottom trawl survey of Massachusetts territorial waters in May and September since 1978. Survey coverage extends from the New Hampshire to Rhode Island boundaries and seaward to three nautical miles including Cape Cod Bay and Nantucket Sound. The study area is stratified into geographic zones based on depth and area. Pre-determined trawl sites are allocated in proportion to stratum area and are chosen randomly within each sampling stratum. A 20-minute tow at 2.5 knots is made at each station with a 3/4-size North Atlantic two-seam otter trawl (11.9 m headrope, 15.5 m footrope) rigged with a 19.2 m chain sweep with 7.6 cm rubber discs. The net contains a 6.4 mm mesh codend liner to retain small fish. Approximately 95 stations are sampled during each survey. Standard bottom trawl survey techniques are used to process the catch of each species. Generally, the total weight (nearest 0.1 kg) and length frequency (nearest cm) are recorded for each species on standard trawl logs. Collections of age and growth structures, maturity observations, and pathology observations are taken.

The MADMF spring indices dropped sharply from a high in 1980 to remain at fairly low levels until increasing briefly in 1989 and 1990 (Figure D12). Indices in 1996 and 1997 have been low. The catch per tow in numbers at age for the spring and autumn surveys are given in Table D23. There is no indication of a strong 1997 year class from the MADMF autumn index at age 0.

Rhode Island

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

Analysis of length frequency data indicates seasonal variability in mean length, with a spring mean of 23 cm and an autumn mean of 10 cm. Further examination indicates that about 99% of the scup caught in the autumn survey are ages 0 and 1. Because the index is dominated by the autumn component of the survey, that portion of the index was used as the index of abundance for VPA tuning.

RIDFW autumn survey number/tow indices increased in the early 1990s, but declined through 1996, until increasing in 1997 (Table D24, Figure D12). The 1996 age 0 index was the second lowest of the time series, while the 1997 year class appears to be the strongest since 1993 (Figure D13).

Connecticut

The Connecticut Department of Environmental Protection (CTDEP) trawl survey program was initiated in May 1984 and encompasses both New York and Connecticut waters of Long Island Sound. The stratified random design survey is currently conducted in the spring (April-June) and autumn (September-October). Each survey consists of three cruises, each with 40 stations sampled, providing a sampling density of one station per 20 square nautical miles per cruise. Prior to 1990, the survey was conducted monthly from April to November.

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

The mean weight/tow index remained relatively stable during 1984-1989, increased to a peak in 1991, and declined since. Number-per-tow indices (Table D25, Figure D12) indicate potential increases during 1984-1991, but abundance has been stable or declining thereafter. As with the MADMF autumn index, there is no indication of a strong 1997 index from the CTDEP autumn survey (Table D25, Figure D13).

Virginia Institute of Marine Science

The Virginia Institute of Marine Science (VIMS) has conducted a juvenile scup survey in lower Chesapeake Bay during June-September since 1988. Age 0 geometric mean indices based on an average of 104 samples per survey are presented in Table D26. The 1989 index is about 6 times higher than the mean level in the other six years. The VIMS age 0 index fell to the lowest value in the time series in 1997 (Table D26, Figure D13).

New York

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

For this analysis, a young-of-the-year index was provided based on slicing at length. Fish were categorized as young of the year if ≤75 mm in the July survey, 100 mm in August, and 125 mm in September. The time series extended from 1987 to 1996. The young-of-the-year index peaked in 1991-1992 and declined thereafter. The geometric mean catch per station in numbers at length pooled over the survey season is presented in Table D26 and Figure D13.

New Jersey

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

Catch per tow at length was reported by survey, pooled, and aged using NEFSC survey age-length keys (augmented with commercial age-length keys when available and necessary). Results are reported in Table D27. The index increased overall from 1989 to 1993, then declined to the lowest levels in the 1989-1996 series in 1997 (Figure D12). As with the MADMF, CTDEP, and VIMS recruitment indices, there is no indication in the NJDMF that the 1997 year class is strong (Figure D13).

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. Various indices were likely measuring different components of the stock distributed differentially in time and space. In light of this, all relevant tuning indices were included in the ADAPT tuning model for estimating stock size and fishing mortality.

Overall, stock sizes (as indexed by mean weight per tow) appear to have dropped during the late 1970s (NEFSC spring survey) to the early 1980s (MADMF spring survey). Since then, biomass has continued to trend downward to the lowest observed levels during 1993-1997 (NEFSC and MADMF spring surveys). Intermittent increases in biomass were not sustained for more than three years in either index. In recent years, the fluctuating NEFSC autumn survey index has included several of the lowest observations in the 34-year time series. Other indices of abundance, based on number per tow, are much shorter, beginning in 1984. While several of those indices show increasing trends from 1985 to 1993, indices in 1996 are at or near the lowest values in the survey series. Recruitment indices (age 0 scup) from the 1984-1997 autumn surveys generally show the highest values during 1988-1992, and lower values thereafter. Of the state recruitment indices at age 0, only the RIDFW surveys indicate a strong 1997 year class (Figure D13). NEFSC 1998 winter and spring surveys also suggest that the 1997 year class may be strong (Figures D9-D10).

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).

Exploratory Virtual Population Analysis

Tuning

Numbers at age on 1 January 1998 and corresponding fishing mortality (F) rates in 1997 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 1998 were directly estimated for ages 1-4, with abundance at age 5 and 6+ calculated from F estimated for age 4 in 1997. Stock size at age 0 in 1998 could not be estimated because no 1998 survey indices of age 0 abundance were available. Fishing mortality 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.

The following research trawl survey indices were inspected for use in VPA tuning:

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

Spring and NEFSC winter survey indices at age were compared to stock sizes at age 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. Residual patterns and partial variances contributed by individual indices lead to the elimination of the MADMF spring age 1, NEFSC spring age 4, RIDFW ages 2-4, and VIMS age 0 based on high partial variances, and CTDEP age 0 based on trend in residual patterns. Because 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 1-4 ranged from 32 to 56%. Approximate coefficients of variation for survey catchability coefficients ranged from 26 to 47%. Absolute values of correlation coefficients between estimated parameters were all less than 0.25, with nearly all below 0.15. No trends in standardized residuals were observed.

Exploitation pattern

The exploitation pattern has been variable from year to year, but full recruitment has occurred between ages 2-4 during 1989-1997, influenced by the magnitude of uncertain annual commercial discard-at-age patterns. An average exploitation pattern was calculated as the ratio of the geometric means (1996-1997) of the fishing mortality rates at ages 0-2 to the means at ages 3-5. The resulting 1996-1997 pattern indicates less than 1% recruitment at age 0, 10% at age 1, and 100% at age 2 and older. In previous yield-per-recruit calculations, full (100%) recruitment was assumed at ages 2 and older, consistent with these observations.

Evaluation of VPA adequacy

The SARC believes that an exploratory VPA integrates existing data to produce estimated trends in fishing mortality rates and biomass that are generally indicative of actual trends, but due to gross inadequacies in the input data, the SARC rejects the exploratory VPA as a basis for assessing current stock status or as the basis for projections. Similar to other assessments in the region, the amount of variance in each component of the catch-at-age matrix has not been estimated. In the case of scup, this amount of variance is believed by the SARC to be unreasonably large. In the case of the 1993-1994 commercial landings reported through the NEFSC system, 37-46% of the total tonnage was not sampled at the resolution of market category, quarter, and two-digit statistical area and consequently was characterized by the size composition of landings of market categories from different statistical areas or quarters, or from a combination of market categories. While market category is more likely to be related to size composition rather than statistical area of catch, the SARC felt that, overall, under-sampling produced a significant source of uncertainty in the development of the NEFSC commercial landings-at-age component.

In the case of commercial discard-at-age estimates, sampling was not adequate to cover all cells in the stratification scheme (landings level and half-year) in the past three years, requiring substitution of long-term average cell means or first half-year ratios for the entire year. For years before the implementation of the sea sampling program, the discard-at-age matrix was estimated using average observed ratios of discard to landings from later years. Accordingly, early estimates of discard do not include any direct observations. Because discard levels appear to be highly variable even between tows on the same sea-sampled trip, typical estimators such as ratios of discards to landings or discards per day fished are highly variable and can range over three orders of magnitude, simply depending on the form of the mean used, based on comparisons in the previous assessment. Identification of specific mechanisms or factors which lead to differences in discard rates is complicated by the wide spatial and temporal range of the component fisheries as well as operational characteristics of fisheries, e.g., target species and gear type. This combination of variable discard rates within trip and the range of temporal, spatial, and operational characteristics of component fisheries will continue to make accurate characterization of discard levels difficult, even if sampling levels were to increase. The VTR data appear to offer little improvement, as reported discard ratios appear unreasonably low.

Performance of tuning indices in the VPA was generally poor: year classes are poorly tracked over time by individual surveys, and indices may reflect local patterns in availability or recruitment rather than abundance of the stock. Even surveys which cover the entire range of the stock (NEFSC winter, spring, and autumn surveys) exhibit large interannual fluctuations, in part due to domination of indices by incoming year classes which are rarely abundant in surveys in following years, and in part due to availability. The coefficients of variation for parameter estimates obtained from this VPA were comparable to those obtained in the previous assessment (SAW-25; NEFSC 1997b). The SARC concluded that the precision of the estimates of fishing mortality and stock size was unacceptably low and would provide an unreliable basis for any estimates of stock size and fishing mortality rates.

Exploratory ASPIC Model Analysis

Surplus production models can be useful in assessing the status of fish stocks when information on age structure is unavailable or unreliable, or simply to provide an alternative method to VPA in estimating trends in fishing mortality and abundance. Production models can also provide guidance on biological reference points such as maximum sustainable yield (MSY), the biomass which would support MSY (B_{msy}), and the total stock biomass fishing mortality rate at MSY (F_{msy}).

A non-equilibrium surplus production model incorporating covariates (ASPIC; Prager 1994) was applied to estimates of scup catch and NEFSC and state agency survey indices of scup biomass. Indirect estimates (by ratio to commercial landings) of recreational catch and commercial fishery discards were made to extend the catch series back to 1960. The earliest catches in the 1960-1997 time series are the least reliable due to uncertainty about the level of DWF catch, recreational catch (50% reduction from interpolations made in Mayo 1982), and commercial fishery discard (average discard-to-landings ratio from 1984-1997 applied to all earlier years). Various combinations and time series of NEFSC spring (1968-1997), autumn (1963-1997), and winter (1992-1997) biomass indices, both arithmetic stratified mean and fitted mean (ARIMA model with theta = 0.4; Pennington 1985), and CTDEP autumn (1984-1997), MADMF spring (1978-1997), and combined RIDFW trawl survey (1960-1997) biomass indices, were included as input in an attempt to develop a reliable analysis.

The SARC noted that the inability to directly estimate historical commercial fishery discards (1968-1988) and recreational catch (1968-1978) casts uncertainty on the validity of the ASPIC absolute estimates of stock biomass, fishing mortality rates, and biological reference points. Since the exploratory ASPIC analysis suffered from many of the same input data inadequacies as the exploratory VPA, the SARC rejected the ASPIC analysis as a basis for current status, projections, or reference points.

Biological Reference Points

Yield and Spawning Stock Biomass per Recruit

The MAFMC and ASMFC have jointly adopted an F_{max} overfishing definition. Analysis from the SAW-19 assessment indicated that $F_{0.1}$ = 0.141 and F_{max} = 0.236, with yield including both landings and discards. At F_{max}, about 24% of the maximum spawning potential (%MSP) is obtained.

Because of recent changes in commercial fishery minimum fish sizes and commercial trawl fishery mesh requirements, the yield- and spawning-stock-biomass-per-recruit analysis was re-evaluated in this assessment. The partial recruitment of ages 0-1 scup and the mean weights of scup at ages 0-6 were revised to reflect the patterns estimated in the exploratory VPA for 1996-1997. Relative to the SAW-19 assessment, the partial recruitment of age 0 scup was reduced from 4% to 1%, and of age 1 scup from 22% to 10%. The current yield-per-recruit analysis (Table D28) provides estimates of $F_{0.1}$ = 0.147 (15% exploitation; 39% MSP) and F_{max} = 0.261 (21% exploitation; 23% MSP). The SARC noted that reference points from the current yield- and spawning-stock-biomass-per-recruit analysis are subject to uncertainty due to effects of discarding on the fishery exploitation pattern estimated by the exploratory VPA.

Threshold Biomass for SFA Considerations

The Sustainable Fisheries Act emphasizes the need to conserve US fishery resources for long-term maximum sustainable yield (MSY) through precautionary management. Proposed guidelines on managing sustainable fisheries include several components: 1) preventing overfishing while producing MSY on a continuing basis, 2) defining overfishing as a rate of fishing mortality (F) that exceeds the threshold rate associated with producing MSY (F_{msy}), 3) defining an overfished stock as a stock size that is less than a minimum stock size threshold, which is the stock biomass that will allow rebuilding to the MSY level in 10 years, and 4) adopting control rules that incorporate uncertainty of MSY reference point estimates so that fishing targets are risk averse (DOC 1997).

The SARC noted that estimates of B_{msy} using scup landings and survey time series may be too low, given the very high commercial fishery catch removed from the stock prior to the initiation of the NEFSC spring and autumn surveys (e.g., 1950s and early 1960s). However, the SARC defined a minimum threshold biomass index for stock rebuilding as the maximum value of a 3-year moving average of the NEFSC spring survey catch per tow of spawning stock biomass (1977-1979 = 2.77 SSB kg/tow). Similarly, F_{msy} cannot be estimated, and $F_{0.1}$ (0.15) is suggested as a proxy for F_{msy}, although that estimate is also subject to considerable uncertainty about the effect of discarding on exploitation patterns, as noted above. The SARC believes greater caution is necessary in setting a fishing mortality threshold to accommodate the greater uncertainty in the assessment of scup compared to other species where F_{max} has been acceptable (i.e., summer flounder). If fishing mortality rates are obtained which are at or below the current management schedule for reductions in F, there is minimal probability that the stock would rebuild to the minimum biomass index within 10 years, conditional on incoming recruitment.

Projections of Catch and Stock Biomass

In the absence of any quantitative estimates of current stock size, a forecast of future stock and catch was not possible. However, the SARC recommends that the 1999 TAC should be less than that in 1998 to at least remain on the current fishing mortality reduction schedule.

Conclusions

The scup stock is over exploited and at a low biomass level. This conclusion is based on the truncated age structure of fishery catches and current record low research survey indices of spawning stock biomass, which both indicate that the stock has been subject to prolonged high fishing mortality. Indices of recruitment have trended downward in recent years, except for a moderate 1994 year class and what may be a strong 1997 year class. Although discard estimates are uncertain, the majority of fishing mortality in recent years is clearly attributable to discards, particularly when incoming recruitment is strong.

Fishing mortality should be reduced substantially and immediately. Reduction in fishing mortality from discards will have the most impact on the stock, particularly considering the importance of the 1997 year class. This could be most effectively accomplished by reducing discards from small-mesh fisheries.

SARC Comments

The uncertainties associated with the catch data and lack of confidence in model results led the SARC to conclude that an analytical assessment (using the current VPA or ASPIC models) would be inappropriate as the basis for management decisions for scup. The current qualitative advice on stock status is based on a truncated age structure of the fishery catches and the record low level of research survey biomass indices. The SARC concluded that efforts should be made to increase the level of commercial fishery sampling to better characterize commercial catch at age due to the large number of market categories, wide geographical range, and many types of fisheries that prosecute this species. Commercial fishery discards of ages 0-3 from directed and non-directed fisheries are a significant component of the current estimates of catch at age. However, discards are poorly estimated because sea sampling is not adequate to characterize discards in various components of this fishery, and VTR data do not accurately reflect the level of scup discards expected for commercial trawl fisheries. A VPA or other analytical model formulation for scup will not be feasible until the quality of the input data, particularly the precision of discard estimates, is significantly improved.

Research Recommendations

- Increased and more representative sea and port sampling data of the various commercial fisheries in which scup are landed and discarded is critical to characterize adequately the length composition of both landings and discards. The current level of sampling, particularly of commercial fishery discards, seriously impedes the development of analytic assessment and forecasts of catch and stock biomass. A pilot study to develop a sampling program to estimate discards should be implemented. This would quantify the advantages of obtaining sea samples from freezer trawlers and other small-mesh fleets from which few samples have been collected, and would provide an opportunity for joint industry research programs.
- Additional information on compliance with regulations (e.g., length limits) and hooking mortality is needed to interpret recreational discard data.
- Commercial discard mortality was assumed to be 100%. It is recommended that studies to better characterize the mortality of scup in different gear types be conducted to more accurately assess discard mortality.
- Expanded age sampling of scup from commercial and recreational catches is required, with special emphasis on the acquisition of large specimens.
- Further biological studies are needed to look at factors affecting annual availability of scup to research surveys and maturity schedules.

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Table D1. Landings (mt) of scup from Maine through North Carolina.

Year	Commercial	Recreational	Total
1979	8,584	1,198	9,782
1980	8,424	3,109	11,533
1981	9,856	2,636	12,492
1982	8,703	2,361	11,064
1983	7,794	2,836	10,630
1984	7,769	1,096	8,865
1985	6,726	2,764	9,490
1986	6,918	5,264	12,182
1987	6,069	2,806	8,875
1988	5,728	1,936	7,664
1989	3,716	2,521	6,237
1990	4,318	1,878	6,196
1991	6,867	3,668	10,535
1992	6,002	2,001	8,003
1993	4,463	1,450	5,913
1994	4,151	1,192	5,343
1995	2,894	596	3,490
1996	2,688	1,015	3,703
1997	2,179	479	2,658
Mean	5,992	2,148	8,140

Table D2. Commercial landings (mt) of scup by state. One mt was landed in DE in 1995.

Year	ME	MA	RI	CT	NY	NJ	MD	VA	NC	Total
1979		782	3,123	91	1,422	2,159	21	397	589	8,584
1980	1	706	2,934	17	1,294	2,310	32	531	599	8,424
1981		523	2,959	44	1,595	2,990	9	1,054	682	9,856
1982		545	3,202	25	1,473	1,746	2	1,042	668	8,703
1983		672	2,583	49	1,103	2,536	13	536	302	7,794
1984		540	2,919	32	904	2,217	6	673	478	7,769
1985		387	3,583	41	861	1,492	17	74	271	6,726
1986		619	2,987	67	893	1,894	14	272	172	6,918
1987	5	529	2,162	301	911	1,816		232	113	6,069
1988	9	320	2,833	359	687	1,334	1	127	58	5,728
1989	31	311	1,402	89	603	1,219	1	45	15	3,716
1990	4	443	1,786	165	755	1,005	4	75	81	4,318
1991	15	340	2,902	287	1,223	1,960	15	56	69	6,867
1992		398	2,676	193	1,043	1,475	17	73	127	6,002
1993		296	1,332	148	729	1,822	10	73	53	4,463
1994		112	1,514	142	688	1,456	7	93	139	4,151
1995		128	1,048	89	511	1,086	1	20	11	2,894
1996		176	776	99	377	1,141	20	72	27	2,688
1997		677	491	50	361	596	1	2	1	2,179
Mean	11	448	2,274	120	918	1,698	11	287	234	5,992

Table D3. Commercial landings (mt) of scup by major gear types. All North Carolina landings in 1990-1997 are assumed to be taken by otter trawls. Midwater paired trawl landings are combined with other gears during 1994 and later.

Year	Otter trawl	Paired trawl	Floating trap	Pound net	Pots and traps	Handlines	Other gear	Total mt
1979	6,387	146	1,305	429	26	215	76	8,584
1980	6,192	160	1,559	194	8	303	8	8,424
1981	7,836	79	1,291	246	49	306	49	9,856
1982	6,563	104	1,514	244	9	226	43	8,703
1983	5,861	398	850	390	8	265	22	7,794
1984	5,617	272	1,266	295	8	287	24	7,769
1985	4,856	417	1,022	229	5	182	15	6,726
1986	5,189	540	630	332	7	208	12	6,918
1987	4,607	237	589	194	237	188	17	6,069
1988	4,142	166	1,054	52	115	155	44	5,728
1989	3,174	89	193	74	104	67	15	3,716
1990	3,205	200	505	60	239	87	21	4,317
1991	5,217	152	988	40	258	182	30	6,867
1992	4,371	94	934	67	303	190	42	6,001
1993	3,865	46	166	24	202	85	74	4,462
1994	3,416		331	79	76	97	152	4,151
1995	2,208		331	41	146	26	142	2,894
1996	2,231		229	6	111	101	10	2,688
1997	1,482		87	12	99	497	2	2,179
Mean	4,548	207	781	158	106	193	42	5,992

Table D4. Summary of the sampling intensity for scup in the NER (ME-VA) commercial and coastal recreational fisheries.

	NER Commercial fishery				Coastal Recreational fishery		
Year	No. of samples	No. of lengths	NER landings (mt)	Sampling intensity (mt/100 lengths)	No. of lengths	Estimated landings (A + B1) (mt)	Sampling intensity (mt/100 lengths)
1979	10	1,250	7,995	640	322	1,198	372
1980	26	3,478	7,825	225	1,263	3,109	246
1981	16	2,005	9,174	458	642	2,068	322
1982	81	9,896	8,035	81	1,057	3,100	293
1983	72	7,860	7,492	95	1,384	3,432	248
1984	60	6,303	7,291	116	943	1,434	152
1985	31	3,058	6,455	211	741	3,282	443
1986	54	5,467	6,746	123	2,580	5,908	229
1987	61	6,491	5,956	92	777	2,980	384
1988	85	8,691	5,670	65	2,156	2,414	112
1989	46	4,806	3,701	77	4,111	3,248	79
1990	46	4,736	4,237	89	2,698	2,007	74
1991	31	3,150	6,798	216	4,230	3,634	86
1992	33	3,260	5,875	180	4,419	2,110	48
1993	23	2,287	4,410	193	2,206	1,341	61
1994	22	2,163	4,012	185	1,374	1,188	86
1995	22	2,487	2,883	116	822	595	72
1996	61	6,544	2,661	41	526	1,015	193
1997	36	3,632	2,178	60	399	479	120

Table D5. Distribution of 1997 NER commercial fishery length frequency samples. Sample areas defined (AREA) defined as: 5 = 511 to 539, 6 = 611 to 639. MC = landings market category defined as: 3290 = Large, 3291 = Large/Mix, 3292 = Medium, 3292 = Small, 3296 = Jumbo, 3295 = Unclassified. Top entry in each table cell is the number of samples, middle entry is the number of fish measured, bottom entry is landings in metric tons. Double lines indicate Area by Quarter pooling design for allocation of length frequency samples (BIOSTAT). For 1997, unclassified landings and sample (3295) were pooled with the Large/Mix category (3291) based on similar time/space landings pattern and length frequency characteristics.

MC = Large, 3290; Landings = 548 mt; 26% of NER Commercial Total

	Quarter				
Area	1	2	3	4	Total
5		4 489 162 mt		2 207 69 mt	6 696 329 mt
	4 mt		94 mt		
6	6 609 92 mt	2 177 93 mt	10 mt	24 mt	8 786 219 mt
Total	6 609 96 mt	6 666 256 mt	104 mt	2 207 93 mt	14 1482 548 mt

MC = Large/Mix, 3291; Landings = 472 mt; 22% of NER Commercial Total

	Quarter				
Area	1	2	3	4	Total
5	6 mt	2 mt	1 mt	4 mt	13 mt
6	7 700 229 mt	3 312 228 mt	1 mt	1 mt	10 1012 459 mt
Total	7 700 235 mt	3 312 230 mt	2 mt	5 mt	10 1012 472 mt

MC = Medium, 3292; Landings = 542 mt; 25% of NER Commercial Total

	Quarter				
Area	1	2	3	4	Total
5	16 mt	2 205 94 mt	29 mt	2 215 108 mt	4 420 247 mt
6	2 209 133 mt	1 85 113 mt	6 mt	43 mt	3 294 295 mt
Total	2 209 149 mt	3 290 207 mt	35 mt	2 215 151 mt	7 714 542 mt

Table D5. (Continued).

MC = Small, 3293; Landings = 46 mt; 2% of NER Commercial Total

Area	Quarter 1	2	3	4	Total
5	1 mt	7 mt	1 mt	4 mt	13 mt
6	2 203 23 mt	6 mt	1 mt	3 mt	2 203 33 mt
Total	2 203 23 mt	13 mt	2 mt	7 mt	2 203 46 mt

MC = Jumbo, 3296; Landings = 100 mt; 5% of NER Commercial Total

Area	Quarter 1	2	3	4	Total
5	0 mt	1 4 23 mt	28 mt	23 mt	1 4 74 mt
6	1 100 6 mt	18 mt	1 mt	1 mt	1 100 26 mt
Total	1 100 6 mt	1 4 41 mt	29 mt	24 mt	2 104 100 mt

MC = Unclassified, 3295; Landings = 469 mt; 22% of NER Commercial Total

Area	Quarter 1	2	3	4	Total
5	0 mt	1 117 186 mt	136 mt	35 mt	1 117 357 mt
6	26 mt	58 mt	17 mt	11 mt	112 mt
Total	26 mt	1 117 244 mt	153 mt	46 mt	1 117 469 mt

Table D6. Summary of sampling in the Northeast Region sea sampling program, 1989-1997. 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 (<300 kg per trip, ≥300 kg per trip) to reported weighout landings. Estimates of tonnage reflecting potential discard in the entire fishery are reported in Table D18. Eleven length measurements from scallop dredges were not used in 1995. NOTE THAT SEA SAMPLE DATA WERE AVAILABLE ONLY THROUGH OCTOBER 1997.

Year	Trips		Lengths			SS Discard	Intensity
	All	OT	H1	H2	Total	(mt)	(mt/100 lengths)
1989	63	61	4,449	2,910	7,359	2,173	30
1990	52	52	2,582	781	3,363	3,877	115
1991	104	91	1,237	1,780	3,017	3,535	117
1992	106	53	1,158	0	1,158	5,749	496
1993	64	29	275	154	429	1,434	334
1994	7	7	99	119	218	773	355
1995	20	18	162	383	556	2,046	368
1996	32	27	1,093	435	1,528	1,522	100
1997	58	45	750	1	751	1,793	239

Table D7. Alternative calculations of Northeast Region commercial fishery discard estimate for 1997. Data are from NEFSC Domestic Sea Sampling program and dealer reporting (weighout) system. Calculation is stratified by half-year period (HY1, HY2) and trip landings level (<300 kg, ≥300 kg). N is number of sea sample trips used to calculate the discard ratios. In all Parts A to C, first half-year ratios are used to characterize second half rates. NOTE THAT SEA SAMPLE DATA WERE AVAILABLE ONLY THROUGH OCTOBER 1997. In Part A, the long-term (1989-93) ratio (GM D/L) is used for both half-year periods for trips ≥300 kg. In Part B, the 1997 first half-year GM D/L ratio for trips ≥300 kg is used for the second half-year period. This calculation in Table B is carried forward in the assessment. In Part C, a stratum aggregate arithmetic discard-to-landings ratio is used as in the black sea bass and New England groundfish assessments. First half-year ratios are used for second half-year periods.

Part A. 1997 discard estimate using long-term (1989-93) second half-year ratio (GM D/L = 0.4832) for trips ≥300 kg.

	Trips <300 kg				Trips ≥300 kg			
Period	GM D/L	N	Dealer landings (kg)	Estimated discard (kg)	GM D/L	N	Dealer landings (kg)	Estimated discard (kg)
HY 1	0.8957	17	8,876	7,950	0.4832	n/a	1,517,875	733,437
HY 2	0.8957	0	8,872	7,947	0.4832	n/a	643,482	310,931
Total				15,797				1,044,368

Part B. 1997 discard estimate using 1997 first half-year ratio for second half-year GM D/L for trips ≥300 kg.

	Trips <300 kg				Trips ≥300 kg			
Period	GM D/L	N	Dealer landings (kg)	Estimated discard (kg)	GM D/L	N	Dealer landings (kg)	Estimated discard (kg)
HY 1	0.8957	17	8,876	7,950	0.8221	4	1,517,875	1,247,845
HY 2	0.8957	0	8,872	7,947	0.8221	0	643,482	529,007
Total				15,797				1,776,852

Part C. 1997 discard estimate using 1997 aggregate arithmetic discard ratio (total discard to total landings). First half-year ratio used for second half-year for trips ≥300 kg. Number of trips is larger than in Tables A and B because trips with zero landings or zero discard may be included.

	Trips <300 kg				Trips ≥300 kg			
Period	D/L	N	Dealer landings (kg)	Estimated discard (kg)	D/L	N	Dealer landings (kg)	Estimated discard (kg)
HY 1	6.4453	41	8,876	57,208	0.9194	4	1,517,875	1,395,534
HY 2	6.4453	0	8,872	57,183	0.9194	0	643,482	591,617
Total				114,391				1,987,152

Table D8. Comparison of Sea Sampled (SS) and Vessel Trip Report (VTR) trawl gear geometric mean discard ratios for scup (Re-transformed mean of the natural log of discard-to-landed ratio on trips catching scup. In VTR, data was subset to include only trawl trips that reported some discard of any species). Values in bold are substituted for inadequate data (i.e., missing or unrepresentative SS trips; see report text). NOTE SEA SAMPLE DATA WERE AVAILABLE ONLY THROUGH OCTOBER 1997.

		Trip landings <300 kg		Trip landings ≥300 kg	
Year	Reporting system	Half-year 1	Half-year 2	Half-year 1	Half-year 2
1994	SS	0.81	0.74	0.11	0.18
	VTR	0.11	0.10	0.05	0.03
1995	SS	1.62	1.77	**0.48**	**0.48**
	VTR	0.14	0.23	0.05	0.04
1996	SS	0.74	0.91	**0.48**	**0.48**
	VTR	0.44	0.23	0.89	0.05
1997	SS	0.90	**0.90**	0.82	**0.82**
	VTR	0.14	0.37	0.04	0.05

Table D9. Detail of Sea Sampled (SS) and Vessel Trip Report (VTR) trawl gear geometric mean discard-to-landings ratios (GM D/L) for scup in 1997. Ratios stratified by half year (HY 1: January-June, HY 2: July-December), trip landings level (<300 kg, ≥300 kg), and codend mesh size category (small: <4 in ; large ≥4 in). Trips are split by mesh and all data elements (kept, discard, mesh size) must be reported, so totals (i.e., HY 1 trips ≥300 kg) do not match Table D7. NOTE SEA SAMPLE DATA WERE AVAILABLE ONLY THROUGH OCTOBER 1997.

	Trips <300 kg				Trips ≥300 kg			
	HY 1		HY 2		HY 1		HY 2	
	Large mesh	Small mesh	Large mesh	Small mesh	Large mesh	Small mesh	Large mesh	Small mesh
VTR Ratio	0.14	0.14	0.35	0.40	0.03	0.08	0.04	0.05
VTR trips	26	88	28	77	23	18	11	27
SS Ratio	0.29	1.06	n/a	n/a	n/a	1.08	n/a	n/a
SS trips	4	13	0	0	0	6	0	0

Table D10. Commercial landings and discard at age of scup, ME-VA ('000). Assumes landings not sampled by NEFSC weighout have same biological characteristics as weighout landings. NOTE THAT 1997 LENGTHS AGED WITH 1996 AGE-LENGTH KEYS.

Landings					Age							
Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	0	2679	5291	6560	5437	1340	490	213	1	0	0	22011
1985	69	3239	5439	7542	2594	343	516	157	0	0	0	19899
1986	0	297	11899	4361	767	75	84	254	5	0	0	17742
1987	0	1662	9890	10256	1666	161	102	14	17	0	0	23768
1988	2	416	7623	9437	2406	58	122	34	0	0	0	20098
1989	0	1483	4887	7053	683	22	69	24	0	0	0	14221
1990	0	245	10079	6609	1002	349	144	0	0	0	0	18427
1991	0	2405	12831	10124	2149	409	193	0	0	0	0	28112
1992	0	1485	10409	3686	3772	1214	136	0	0	0	0	20703
1993	0	226	6347	6826	1486	1141	123	0	0	0	0	16149
1994	0	1051	13399	6211	752	64	23	0	0	0	0	21499
1995	0	2198	8329	2873	883	245	31	7	0	0	0	14565
1996	0	346	6343	1627	747	454	59	0	0	0	0	9576
1997	0	131	2080	4089	732	84	97	0	0	0	0	7213
Discard												
Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	78	10847	6367	924	21	0	0	0	0	0	0	18237
1985	52773	13093	6534	1060	10	0	0	0	0	0	0	73470
1986	78	1180	14040	602	3	0	0	0	0	0	0	15903
1987	78	6814	12215	1366	5	0	0	0	0	0	0	20478
1988	1552	1698	9242	1339	10	0	0	0	0	0	0	13841
1989	387	8943	13603	813	28	0	0	0	0	0	0	23774
1990	822	8269	17249	2801	0	0	0	0	0	0	0	29141
1991	1794	17231	5397	1733	5	0	0	0	0	0	0	26160
1992	38804	10023	26380	72	0	0	0	0	0	0	0	75279
1993	5386	1549	6960	224	0	0	0	0	0	0	0	14119
1994	6858	3099	3422	74	0	0	0	0	0	0	0	13486
1995	1855	50174	335	108	14	0	0	0	0	0	0	52486
1996	199	3009	5990	691	21	1	0	0	0	0	0	9911
1997	1	1178	11374	214	8	0	0	0	0	0	0	12775

Table D11. Recreational landings and discard at age of scup, Cape Cod to North Carolina ('000). NOTE THAT 1997 LENGTHS AGED WITH 1996 AGE-LENGTH KEYS.

Landings						Age						
Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	23	3036	1353	570	182	219	442	86	51	30	66	6057
1985	431	4478	3054	1330	788	441	137	33	0	0	115	10810
1986	538	4353	15570	2617	845	431	87	5	4	57	315	24823
1987	77	2299	4686	1261	824	598	112	0	0	11	46	9914
1988	9	1001	2229	1824	460	216	123	92	20	0	86	6061
1989	311	3978	3371	823	86	235	154	13	0	50	148	9168
1990	169	1352	5091	1102	147	112	36	7	2	3	22	8043
1991	299	4838	3797	3319	700	210	19	0	2	20	68	13272
1992	99	1850	4457	530	672	84	12	6	8	7	30	7755
1993	46	1245	3051	908	254	133	2	2	0	2	7	5651
1994	31	1473	1840	691	95	88	21	6	0	0	0	4245
1995	16	803	1193	200	106	37	3	6	0	0	0	2362
1996	9	580	1735	422	200	117	11	0	0	0	5	3080
1997	13	323	806	396	89	67	32	6	0	0	4	1736
Discard												
Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	2	255	0	0	0	0	0	0	0	0	0	257
1985	40	417	0	0	0	0	0	0	0	0	0	458
1986	100	807	0	0	0	0	0	0	0	0	0	907
1987	12	357	0	0	0	0	0	0	0	0	0	369
1988	2	219	0	0	0	0	0	0	0	0	0	222
1989	24	308	0	0	0	0	0	0	0	0	0	333
1990	36	284	0	0	0	0	0	0	0	0	0	319
1991	31	505	0	0	0	0	0	0	0	0	0	536
1992	17	325	0	0	0	0	0	0	0	0	0	343
1993	8	204	0	0	0	0	0	0	0	0	0	212
1994	4	203	0	0	0	0	0	0	0	0	0	207
1995	4	192	0	0	0	0	0	0	0	0	0	196
1996	4	262	0	0	0	0	0	0	0	0	0	266
1997	6	150	0	0	0	0	0	0	0	0	0	156

Table D12. North Carolina landings at age of scup ('000).

	Age											
Year	0	1	2	3	4	5	6	7	8	9	10+	Total
1984	1	12	823	530	356	78	46	38	0	0	0	1884
1985	10	6	1328	154	46	3	4	2	0	0	0	1553
1986	9	4	422	412	237	0	22	83	0	0	0	1189
1987	2	17	62	143	59	16	22	7	1	0	1	330
1988	15	7	86	89	18	0	5	5	0	0	0	225
1989	17	0.5	56	18	2	0	0.2	0	0	0	0	94
1990	0	2	124	172	20	6	5	2	0	0.2	0	331
1991	0	7	125	78	12	0.3	0.4	0	0	0	0	223
1992	21	92	474	51	25	29	2	0	0	0.1	0	694
1993	0.8	4	211	51	14	2	0.7	0	0	0	0	284
1994	0	1	145	147	84	18	16	0	0	0	0	411
1995	0	0	16	5	8	3	0.4	0	0	0	0	32
1996	0	0	0	13	23	15	3	0	0	0	0	54
1997												

Table D13. Total catch at age of scup, Maine to North Carolina. ('000). NOTE THAT 1997 LENGTHS AGED WITH 1996 AGE-LENGTH KEYS.

	Age											
Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	103	16830	13834	8584	5996	1637	978	337	52	30	66	48446
1985	53324	21234	16355	10086	3438	787	657	192	0	0	115	106190
1986	725	6641	41931	7992	1852	506	193	342	9	57	315	60564
1987	169	11149	26853	13026	2554	775	236	21	18	11	47	54859
1988	1580	3342	19180	12689	2894	274	250	131	20	0	86	40447
1989	739	14713	21917	8707	799	257	223	37	0	50	148	47589
1990	1027	10151	32543	10684	1168	467	185	9	2	3	22	56262
1991	2124	24986	22150	15254	2867	620	212	0	2	20	68	68302
1992	38942	13776	41720	4339	4469	1327	150	6	8	7	30	104774
1993	5441	3228	16569	8008	1754	1277	126	2	0	2	7	36415
1994	6893	5826	18806	7123	931	170	59	6	0	0	0	39815
1995	1875	53368	9872	3186	1010	284	34	13	0	0	0	69642
1996	213	4196	14068	2754	990	588	73	0	0	0	5	22887
1997	21	1800	14260	4699	829	151	129	6	0	0	4	21899

Table D14. Mean weight at age of scup landed and discarded in the commercial fishery, ME-VA (kg).

Landings					Age						
Year	0	1	2	3	4	5	6	7	8	9	10
1984	0.000	0.156	0.199	0.296	0.344	0.400	0.766	1.040	1.545	0.000	0.000
1985	0.045	0.134	0.213	0.294	0.410	0.517	0.739	1.042	0.000	0.000	0.000
1986	0.075	0.141	0.220	0.352	0.672	0.670	1.012	1.123	1.616	0.000	0.000
1987	0.000	0.137	0.203	0.244	0.406	0.540	0.754	1.220	1.072	0.000	0.000
1988	0.028	0.124	0.201	0.263	0.441	0.636	0.713	0.949	1.545	0.000	0.000
1989	0.070	0.144	0.189	0.275	0.367	0.651	0.721	1.036	0.000	0.000	0.000
1990	0.000	0.140	0.189	0.246	0.366	0.517	0.849	0.000	0.000	0.000	0.000
1991	0.000	0.187	0.195	0.263	0.389	0.511	0.729	0.000	0.000	0.000	0.000
1992	0.000	0.179	0.201	0.325	0.419	0.506	0.860	0.000	0.000	0.000	0.000
1993	0.000	0.142	0.199	0.261	0.442	0.510	0.782	0.000	0.000	0.000	0.000
1994	0.000	0.203	0.193	0.257	0.425	0.645	0.717	0.000	0.000	0.000	0.000
1995	0.000	0.161	0.209	0.295	0.395	0.479	0.724	0.000	0.000	0.000	0.000
1996	0.000	0.206	0.200	0.324	0.468	0.554	0.792	0.000	0.000	0.000	0.000
1997	0.000	0.227	0.253	0.300	0.386	0.529	0.749	0.000	0.000	0.000	0.000
Discards											
Year	0	1	2	3	4	5	6	7	8	9	10
1984	0.033	0.108	0.125	0.198	0.222	0.000	0.000	0.000	0.000	0.000	0.000
1985	0.033	0.108	0.125	0.198	0.222	0.000	0.000	0.000	0.000	0.000	0.000
1986	0.033	0.108	0.125	0.198	0.222	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.033	0.108	0.125	0.198	0.222	0.000	0.000	0.000	0.000	0.000	0.000
1988	0.033	0.108	0.125	0.198	0.222	0.000	0.000	0.000	0.000	0.000	0.000
1989	0.039	0.060	0.111	0.198	0.217	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.026	0.121	0.137	0.187	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1991	0.057	0.127	0.163	0.207	0.252	0.000	0.000	0.000	0.000	0.000	0.000
1992	0.033	0.078	0.136	0.243	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	0.026	0.106	0.154	0.269	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1994	0.024	0.068	0.122	0.198	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1995	0.038	0.037	0.229	0.310	0.331	0.000	0.000	0.000	0.000	0.000	0.000
1996	0.033	0.110	0.169	0.240	0.268	0.532	0.000	0.000	0.000	0.000	0.000
1997	0.010	0.090	0.144	0.240	0.257	0.423	0.000	0.000	0.000	0.000	0.000

Table D15. Mean weight at age of scup landed and discarded in the recreational fishery, Cape Cod to North Carolina (kg).

Landings					Age						
Year	0	1	2	3	4	5	6	7	8	9	10
1984	0.044	0.117	0.266	0.373	0.472	0.557	0.678	0.825	0.912	1.002	1.145
1985	0.038	0.125	0.253	0.340	0.573	0.718	0.913	1.087	0.000	0.000	1.673
1986	0.052	0.101	0.234	0.374	0.534	0.654	0.801	0.912	1.003	1.003	1.638
1987	0.029	0.105	0.242	0.381	0.548	0.698	0.737	0.000	0.000	1.003	3.808
1988	0.026	0.142	0.240	0.325	0.497	0.663	0.794	1.144	1.099	0.000	1.532
1989	0.035	0.123	0.234	0.376	0.433	0.653	0.696	0.657	0.000	1.003	1.332
1990	0.057	0.128	0.208	0.325	0.461	0.567	0.761	0.939	1.088	1.202	1.947
1991	0.064	0.150	0.275	0.361	0.474	0.714	0.675	0.000	1.003	1.003	1.305
1992	0.092	0.140	0.240	0.373	0.454	0.598	0.804	0.859	1.311	1.003	2.117
1993	0.087	0.135	0.226	0.336	0.460	0.524	0.912	0.827	0.000	1.026	1.100
1994	0.054	0.180	0.281	0.357	0.467	0.674	0.905	1.430	0.000	0.000	0.000
1995	0.065	0.169	0.291	0.456	0.529	0.532	0.912	1.205	0.000	0.000	0.000
1996	0.095	0.178	0.274	0.419	0.529	0.643	0.881	0.000	0.000	0.000	1.311
1997	0.061	0.166	0.273	0.346	0.469	0.656	0.827	1.202	0.000	0.000	2.613
Discards											
Year	0	1	2	3	4	5	6	7	8	9	10
1984	0.044	0.117	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1985	0.038	0.125	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1986	0.052	0.101	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.029	0.105	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1988	0.026	0.142	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1989	0.035	0.123	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.057	0.128	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1991	0.064	0.150	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1992	0.092	0.140	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	0.087	0.135	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1994	0.054	0.180	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1995	0.065	0.169	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	0.095	0.178	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1997	0.061	0.166	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table D16. Mean weight at age of scup landed in the North Carolina commercial fishery (kg).

	Age										
Year	0	1	2	3	4	5	6	7	8	9	10
1984	0.033	0.033	0.132	0.258	0.349	0.368	0.778	1.066	0.000	0.000	0.000
1985	0.029	0.370	0.133	0.248	0.366	0.481	0.772	1.051	0.000	0.000	0.000
1986	0.036	0.055	0.201	0.410	0.691	0.000	1.000	1.623	0.000	0.000	0.000
1987	0.034	0.077	0.152	0.263	0.431	0.579	0.713	1.141	1.000	0.000	0.000
1988	0.046	0.069	0.170	0.242	0.488	0.000	0.766	1.207	0.000	0.000	0.000
1989	0.025	0.037	0.122	0.232	0.269	0.000	0.843	0.962	0.000	0.000	0.000
1990	0.000	0.155	0.190	0.244	0.408	0.599	0.650	0.846	0.000	1.096	0.000
1991	0.158	0.049	0.142	0.246	0.323	0.685	0.672	0.632	0.000	0.000	0.000
1992	0.039	0.078	0.162	0.322	0.395	0.385	0.778	1.236	0.000	1.096	0.000
1993	0.031	0.043	0.140	0.291	0.471	0.661	0.798	1.159	0.000	1.096	0.000
1994	0.000	0.154	0.171	0.325	0.475	0.728	0.777	1.200	1.264	0.000	0.000
1995	0.000	0.000	0.195	0.343	0.485	0.598	0.746	0.000	0.000	0.000	0.000
1996	0.000	0.000	0.206	0.418	0.483	0.562	0.618	0.000	0.000	0.000	0.000
1997											

Table D17. Mean weight at age of scup caught in commercial and recreational fisheries, ME-NC (kg).

	Age										
Year	0	1	2	3	4	5	6	7	8	9	10
1984	0.036	0.117	0.168	0.288	0.348	0.419	0.727	0.988	0.924	1.002	1.145
1985	0.033	0.116	0.179	0.289	0.446	0.630	0.776	1.050	0.000	0.000	1.673
1986	0.050	0.104	0.193	0.351	0.611	0.656	0.915	1.241	1.341	1.003	1.638
1987	0.031	0.112	0.174	0.253	0.452	0.662	0.742	1.194	1.068	1.003	3.727
1988	0.033	0.122	0.169	0.265	0.449	0.658	0.754	1.096	1.099	0.000	1.532
1989	0.037	0.087	0.147	0.277	0.369	0.653	0.704	0.903	0.000	1.003	1.332
1990	0.032	0.123	0.164	0.239	0.379	0.530	0.827	0.917	1.088	1.195	1.947
1991	0.058	0.138	0.201	0.278	0.409	0.580	0.724	0.000	1.003	1.003	1.305
1992	0.033	0.099	0.164	0.329	0.424	0.509	0.854	0.859	1.311	1.004	2.117
1993	0.027	0.121	0.184	0.270	0.445	0.512	0.785	0.827	0.000	1.026	1.100
1994	0.024	0.124	0.188	0.267	0.434	0.669	0.799	1.430	0.000	0.000	0.000
1995	0.038	0.045	0.220	0.306	0.409	0.487	0.740	0.528	0.000	0.000	0.000
1996	0.037	0.132	0.197	0.319	0.477	0.572	0.798	0.000	0.000	0.000	1.311
1997	0.059	0.122	0.168	0.302	0.395	0.589	0.770	1.202	0.000	0.000	2.613

Table D18. Total catch (mt) of scup from Maine through North Carolina.

Year	Commercial landings	Commercial discards[1]	Recreational landings	Recreational discards[2]	Total catch
1984	7,767	[3] 2,158	1,096	30	11,051
1985	6,723	[3] 4,184	2,764	54	13,725
1986	6,918	[3] 2,005	5,264	87	14,274
1987	6,070	[3] 2,537	2,806	38	11,451
1988	5,726	1,657	1,936	31	9,350
1989	3,711	2,229	2,521	39	8,499
1990	4,318	3,909	1,878	38	10,143
1991	6,868	3,530	3,668	78	14,144
1992	6,001	5,668	2,001	47	13,717
1993	4,463	1,436	1,450	28	7,378
1994	4,150	807	1,192	37	6,186
1995	2,893	2,057	596	33	5,579
1996	2,688	1,522	1,015	47	5,272
1997	2,179	1,793	479	25	4,476
Mean	5,034	2,535	2,048	44	9,660

[1]Based on the assumption of 100% mortality of all scup discards from commercial fishing.
[2]Based on the assumption of 15% mortality of all scup discards from recreational fishing.
[3]Estimated using geometric mean ratio of discards to landings at age (numbers), 1989-1993.

Table D19. NEFSC spring and autumn trawl survey indices for scup. Strata set includes only offshore strata 1-12, 23, 25, and 61-76 for consistency over entire time series. Strata set excludes inshore strata 1-61 that are included in the 1984 and later indices at age in later tables. NOTE THAT 1998 SPRING INDICES ARE FROM PRELIMINARY, UNAUDITED DATA.

Year	Spring no./tow	Spring kg/tow	Spring SSB kg/tow	Spring SSB 3-yr avg	Autumn no./tow	Autumn kg/tow
1963					2.12	1.21
1964					118.70	2.23
1965					3.84	0.62
1966					2.00	0.41
1967					29.38	1.46
1968	59.21	2.25	0.940		14.35	0.54
1969	2.26	0.40	0.390	0.880	99.41	4.48
1970	78.50	3.01	1.300	1.090	10.34	0.22
1971	70.91	2.41	1.570	1.280	7.73	0.25
1972	49.80	2.30	0.980	1.210	40.56	2.34
1973	3.62	1.19	1.090	1.000	22.82	0.93
1974	30.28	3.24	0.940	0.680	9.94	1.01
1975	14.01	3.12	0.000	0.310	52.21	3.40
1976	4.09	0.63	0.000	1.450	161.14	7.35
1977	42.46	4.48	4.350	2.310	32.64	1.71
1978	48.23	4.56	2.590	2.770	12.17	1.32
1979	22.42	1.95	1.380	1.690	15.77	0.61
1980	9.31	1.31	1.090	1.120	11.05	0.92
1981	14.72	1.16	0.900	1.000	67.14	3.01
1982	7.88	1.16	1.020	0.650	25.47	1.17
1983	0.80	0.29	0.030	0.460	4.59	0.34
1984	8.52	0.51	0.330	0.240	24.03	1.22
1985	14.67	0.80	0.370	0.680	68.30	3.56
1986	11.74	1.30	1.330	0.980	46.19	1.66
1987	10.82	1.21	1.240	1.100	5.76	0.15
1988	25.41	1.26	0.730	0.660	5.75	0.09
1989	1.63	0.12	0.000	0.350	5.70	0.30
1990	1.17	0.39	0.310	0.260	16.53	0.83
1991	12.61	0.75	0.450	0.320	9.52	0.43
1992	6.79	0.40	0.210	0.320	16.19	1.12
1993	2.93	0.33	0.310	0.180	0.43	0.04
1994	1.54	0.09	0.030	0.150	3.59	0.11
1995	2.90	0.22	0.120	0.060	24.72	0.91
1996	0.53	0.03	0.020	0.080	4.46	0.23
1997	0.91	0.11	0.110	0.060	16.92	0.88
1998	40.61	0.90	0.060			

Table D20. NEFSC spring trawl survey stratified mean number of scup per tow at age. Strata set includes offshore strata 1-12, 23, 25, 61-76, and inshore strata 1-61. NOTE THAT 1998 SPRING INDICES ARE FROM PRELIMINARY, UNAUDITED DATA, AND THAT 1998 SPRING LENGTHS ARE AGED WITH 1997 SPRING AGE-LENGTH KEY.

Spring																
Year	0	1	2	3	4	5	6	7	8	9	10	11	Total	Age 2+	Age 3+	F
1984	0.00	4.95	1.55	0.18	0.10	0.02	0.00	0.00	0.00	0.00	0.00	0.00	6.88	1.85	0.30	2.13
1985	0.00	9.84	1.65	0.17	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.98	1.83	0.18	2.07
1986	0.00	0.84	8.06	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.47	8.25	0.19	1.13
1987	0.00	3.76	2.96	1.49	0.61	0.03	0.02	0.02	0.01	0.00	0.00	0.01	8.90	5.15	2.19	2.91
1988	0.00	13.66	6.90	0.14	0.02	0.00	0.02	0.05	0.00	0.00	0.00	0.00	20.98	7.13	0.23	4.17
1989	0.00	0.66	0.42	0.08	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.36	0.51	0.09	-0.40
1990	0.00	0.14	0.24	0.25	0.15	0.08	0.11	0.03	0.00	0.00	0.00	0.00	1.01	0.86	0.62	-0.40
1991	0.00	8.26	0.42	0.89	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.17	1.47	1.05	1.57
1992	0.00	4.60	0.71	0.06	0.04	0.05	0.10	0.00	0.00	0.00	0.00	0.00	5.46	0.96	0.25	1.15
1993	0.00	0.50	1.62	0.14	0.09	0.02	0.00	0.00	0.00	0.00	0.00	0.00	2.37	1.87	0.25	3.93
1994	0.00	1.07	0.08	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.24	0.11	0.03	-0.29
1995	0.00	1.84	0.36	0.08	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.35	0.48	0.12	2.57
1996	0.00	0.35	0.04	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.07	0.03	-0.33
1997	0.00	0.27	0.52	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.87	0.60	0.08	3.89
1998	0.00	32.88	0.18	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.07	0.19	0.01	

Table D21. NEFSC autumn trawl survey stratified mean number of scup per tow at age. Strata set includes offshore strata 1-12, 23, 25, 61-76, and inshore strata 1-61. NOTE THAT 1997 AUTUMN LENGTHS ARE AGED WITH 1996 AUTUMN AGE-LENGTH KEY.

Autumn																
Year	0	1	2	3	4	5	6	7	8	9	10	11	Total	Age 2+	Age 3+	F
1984	47.64	9.2	0.34	0.03	0.01	0	0.01	0	0	0	0	0	59.96	0.39	0.05	-0.15
1985	61.22	11.53	1.1	0.26	0.06	0.05	0	0	0	0	0	0	74.71	1.47	0.37	4.79
1986	70.19	6.58	0.57	0	0.01	0	0	0	0	0	0	0	77.36	0.58	0.01	3.86
1987	49.93	29.85	0.46	0.01	0	0	0	0	0	0	0	0	80.45	0.47	0.01	1.35
1988	47.44	15.95	0.67	0.1	0	0	0	0	0	0	0	0	64.22	0.77	0.10	3.05
1989	176.4	25.92	0.66	0.03	0	0	0	0	0	0	0	0	203	0.69	0.03	2.65
1990	77.45	9.21	0.75	0.04	0	0	0	0	0	0	0	0	87.46	0.79	0.04	3.48
1991	151.6	12.51	0.07	0.02	0	0	0	0	0	0	0	0	164.2	0.09	0.02	0.21
1992	25.92	14.51	1.66	0.04	0.02	0	0	0	0	0	0	0	42.15	1.72	0.06	??
1993	46.78	9.76	0.32	0	0	0	0	0	0	0	0	0	56.86	0.32	0.00	3.27
1994	39.54	3.92	0.04	0.01	0	0	0	0	0	0	0	0	43.52	0.05	0.01	1.41
1995	33.04	2.61	0.08	0.01	0	0	0	0	0	0	0	0	35.74	0.09	0.01	2.00
1996	24.42	2.86	0.43	0.01	0	0	0	0	0	0	0	0	27.73	0.44	0.01	3.58
1997	36.99	10.63	0.02	0	0.01	0	0	0	0	0	0	0	47.66	0.03	0.01	

Table D22. NEFSC Winter trawl survey indices of abundance for scup. THE 1992, 1993, AND 1996 LENGTHS ARE AGED WITH THE CORRESPONDING ANNUAL SPRING SURVEY AGE-LENGTH KEY. NOTE THAT 1998 WINTER LENGTHS ARE AGED WITH 1997 SPRING AGE-LENGTH KEY.

Year	Mean no. per tow	Mean kg per tow
1992	63.18	2.76
1993	25.71	2.73
1994	17.09	0.66
1995	67.01	2.18
1996	18.29	1.19
1997	13.90	0.32
1998	46.92	1.20

Winter	Age												
Year	0	1	2	3	4	5	6	7	8	Total	Age 2+	Age 3+	F
1992	0.00	57.61	4.75	0.19	0.09	0.10	0.45	0.00	0.00	63.18	5.57	0.82	1.38
1993	0.00	2.51	22.05	0.56	0.57	0.02	0.00	0.00	0.00	25.71	23.19	1.15	5.76
1994	0.00	16.31	0.73	0.02	0.02	0.01	0.00	0.00	0.00	17.09	0.79	0.06	1.17
1995	0.00	64.94	1.87	0.15	0.01	0.01	0.02	0.01	0.00	67.01	2.07	0.20	3.75
1996	0.00	12.95	5.31	0.03	0.01	0.00	0.00	0.00	0.00	18.29	5.34	0.04	3.68
1997	0.00	13.27	0.52	0.11	0.00	0.00	0.00	0.00	0.00	13.90	0.64	0.11	-0.01
1998	0.00	45.61	0.78	0.35	0.14	0.03	0.01	0.00	0.00	46.92	1.31	0.53	

Table D23. MADMF spring (survey regions 1-3) and autumn (all survey regions) trawl survey mean number of scup per tow at age. NOTE THAT 1997 SPRING SURVEY LENGTHS AGED WITH NEFSC 1997 SPRING AGE-LENGTH KEY.

Spring	Age					
Year	0	1	2	3	4	Total
1984	0.00	0.07	4.18	1.95	2.14	8.34
1985	0.00	55.75	8.08	0.83	0.20	64.86
1986	0.00	0.15	38.48	3.07	0.20	41.90
1987	0.00	0.33	2.20	2.61	0.45	5.59
1988	0.00	0.00	10.75	2.33	0.30	13.38
1989	0.00	0.08	125.62	16.40	0.43	142.53
1990	0.00	3.71	107.96	24.33	2.26	138.26
1991	0.00	0.58	7.80	17.65	1.82	27.85
1992	0.00	0.05	12.50	0.84	0.40	13.79
1993	0.00	0.05	10.01	6.77	0.92	17.75
1994	0.00	0.24	2.52	2.61	0.00	5.37
1995	0.00	42.60	4.58	0.72	0.33	48.23
1996	0.00	0.38	4.50	0.12	0.04	5.04
1997	0.00	0.48	0.85	1.88	0.00	3.21

Autumn	Age			
Year	0	1	2+	Total
1984	881.8	24.3	1.1	907.2
1985	544.6	33.4	15.4	593.4
1986	692.3	27.9	7.2	727.4
1987	518.8	7.8	2.3	528.9
1988	1255.2	13.3	1.2	1269.7
1989	487.8	39.6	1.2	528.6
1990	1039.0	9.8	3.1	1051.9
1991	1076.7	10.5	0.6	1087.8
1992	2258.6	12.7	1.2	2272.5
1993	947.3	1.6	1.0	949.9
1994	778.4	2.0	0.7	781.1
1995	472.9	8.5	0.4	481.8
1996	958.2	5.6	1.2	965.0
1997	867.4	6.0	0.7	874.1

Table D24. RIDFW autumn trawl survey mean number of scup per tow at age. Note that 1997 lengths aged with 1996 NEFSC key.

Autumn	Age							
Year	0	1	2	3	4	5	6	Total
1984	539.56	45.58	3.23	0.92	0.32	0.05	0.00	589.67
1985	71.42	2.62	0.17	0.04	0.00	0.02		74.27
1986	262.97	54.40	9.25	18.63	1.22			346.47
1987	289.99	23.52	1.39					314.90
1988	759.01	44.68	0.00	0.31				804.00
1989	263.55	61.77	1.53					326.85
1990	512.39	14.01	0.91					527.31
1991	557.85	97.81						655.66
1992	976.65	12.05	0.55	2.88				992.13
1993	1234.70	11.03	0.63					1246.35
1994	227.63	8.47	0.02	0.00				236.12
1995	400.77	22.09	0.16					423.02
1996	170.10	13.95	0.65	0.01				184.71
1997	592.11	5.76	0.03					597.90

Table D25. CTDEP autumn trawl survey, mean number of scup per tow at age.

Autumn	Age							
Year	0	1	2	3	4	5	6	Total
1984	7.47	0.97	0.73	0.49	0.26	0.08	0.02	10.02
1985	23.96	4.65	0.39	0.53	0.19	0.04	0.03	29.80
1986	12.88	9.89	2.68	0.26	0.01	0.01	0.01	25.74
1987	12.57	3.97	1.27	0.61	0.08	0.01	0.02	18.52
1988	31.70	5.88	1.81	0.24	0.05			39.68
1989	38.71	24.67	1.53	0.11	0.03	0.00		65.05
1990	54.19	6.83	7.57	0.84	0.03	0.00	0.02	69.47
1991	291.25	17.32	1.67	1.21	0.11	0.02		311.57
1992	47.04	29.45	6.39	0.52	0.29	0.04	0.00	83.72
1993	73.91	1.74	1.09	0.16	0.01	0.01	0.00	76.92
1994	90.64	1.08	0.52	0.22	0.01	0.00		92.47
1995	32.39	26.60	0.15	0.01				59.14
1996	51.50	8.39	1.53	0.03		0.01		61.46
1997	31.78	8.60	0.65	0.25	0.01			41.29

Table D26. New York State Department of Environmental Conservation young-of-year index, geometric mean catch per station (August-September); and Virginia Institute of Marine Science juvenile fish survey, Chesapeake Bay and Rivers (strata 1-8), June-September, arithmetic mean number of scup per tow at age 0.

	NY	VIMS
Year	0	0
1984		
1985		
1986		
1987	0.12	
1988	0.24	12.62
1989	0.22	14.83
1990	0.70	28.95
1991	1.47	9.59
1992	1.26	1.81
1993	0.09	12.01
1994	0.69	3.38
1995	0.18	3.85
1996	0.13	1.92
1997		0.48

Table D27. New Jersey Division of Fish, Game, and Wildlife bottom trawl survey index.

	Age					
Year	0	1	2	3	4	Total
1989	198.97	146.30	6.82	0.05	0.00	352.14
1990	190.53	153.24	20.82	0.87	0.00	365.45
1991	681.32	273.69	0.25	0.06	0.01	955.33
1992	643.83	413.83	11.74	0.04	0.02	1069.46
1993	987.49	211.95	8.31	0.01	0.00	1207.75
1994	305.69	101.34	0.15	0.00	0.00	407.17
1995	40.77	86.97	0.58	0.02	0.00	128.34
1996	15.06	127.95	2.22	0.10	0.00	145.33
1997	35.69	34.18	1.01	0.12	12.08	87.09

Table D28. Results of yield and spawning stock biomass per recruit analysis for 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	.0100	1.0000	.0000	.048	.048
1	.1000	1.0000	.1300	.127	.127
2	1.0000	1.0000	.7500	.183	.183
3	1.0000	1.0000	.9900	.311	.311
4	1.0000	1.0000	1.0000	.436	.436
5	1.0000	1.0000	1.0000	.575	.575
6	1.0000	1.0000	1.0000	.749	.749
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: --> 2.5859
F level at slope=1/10 of the above slope (F0.1): -----> .147
Yield/Recruit corresponding to F0.1: -----> .1492
F level to produce Maximum Yield/Recruit (Fmax): -----> .261
Yield/Recruit corresponding to Fmax: -----> .1604
F level at 20 % of Max Spawning Potential (F20): -----> .304
SSB/Recruit corresponding to F20: --------> .5194

Listing of results by fishing mortlaity 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	2.9944	3.3407	2.5977	100.00
	.100	.22928	.13094	4.3759	1.6561	2.2040	1.3116	50.49
F0.1	.147	.29133	.14922	4.0683	1.3432	1.8981	1.0159	39.11
	.200	.34435	.15803	3.8061	1.0986	1.6379	.7872	30.30
Fmax	.261	.39016	.16043	3.5803	.9069	1.4142	.6098	23.47
	.300	.41373	.15981	3.4646	.8163	1.2997	.5267	20.28
F20%	.304	.41588	.15969	3.4540	.8083	1.2893	.5194	19.99
	.400	.46026	.15515	3.2372	.6545	1.0753	.3801	14.63
	.500	.49374	.14934	3.0749	.5534	.9158	.2899	11.16
	.600	.51905	.14390	2.9534	.4859	.7968	.2305	8.87
	.700	.53892	.13919	2.8589	.4384	.7047	.1893	7.29
	.800	.55498	.13519	2.7833	.4036	.6313	.1593	6.13
	.900	.56826	.13183	2.7215	.3771	.5715	.1368	5.27
	1.000	.57946	.12898	2.6699	.3564	.5219	.1194	4.60
	1.100	.58906	.12656	2.6262	.3399	.4800	.1056	4.06
	1.200	.59740	.12448	2.5887	.3264	.4442	.0944	3.63
	1.300	.60473	.12269	2.5560	.3151	.4133	.0852	3.28
	1.400	.61124	.12113	2.5274	.3057	.3862	.0775	2.98
	1.500	.61707	.11976	2.5019	.2976	.3624	.0710	2.73
	1.600	.62234	.11856	2.4792	.2907	.3413	.0654	2.52
	1.700	.62713	.11750	2.4587	.2846	.3224	.0606	2.33
	1.800	.63151	.11655	2.4401	.2792	.3054	.0564	2.17
	1.900	.63555	.11571	2.4231	.2745	.2900	.0527	2.03
	2.000	.63928	.11495	2.4075	.2703	.2760	.0494	1.90

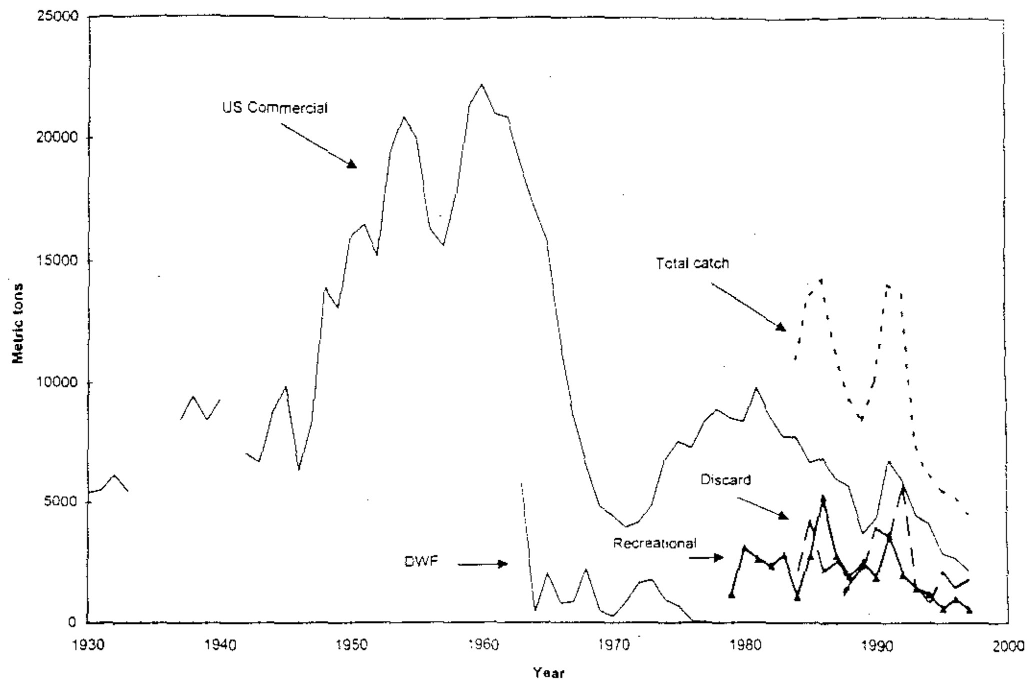

Figure D1. Total catch of scup from Maine through North Carolina, 1930-1997, including US commercial landings (does not include North Carolina prior to 1979), distant water fleet (DWF) landings, recreational landings, and commercial and recreational discards combined.

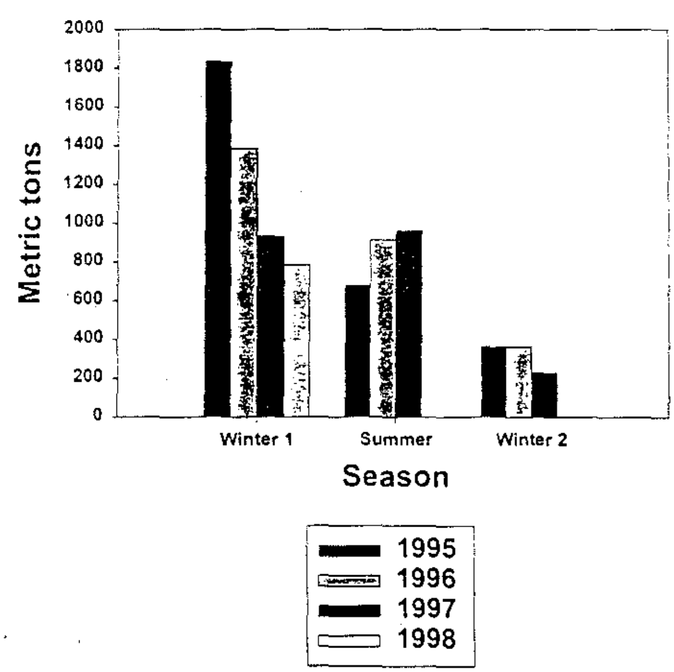

Figure D2. Seasonal pattern of commercial scup landings during 1995-1998.

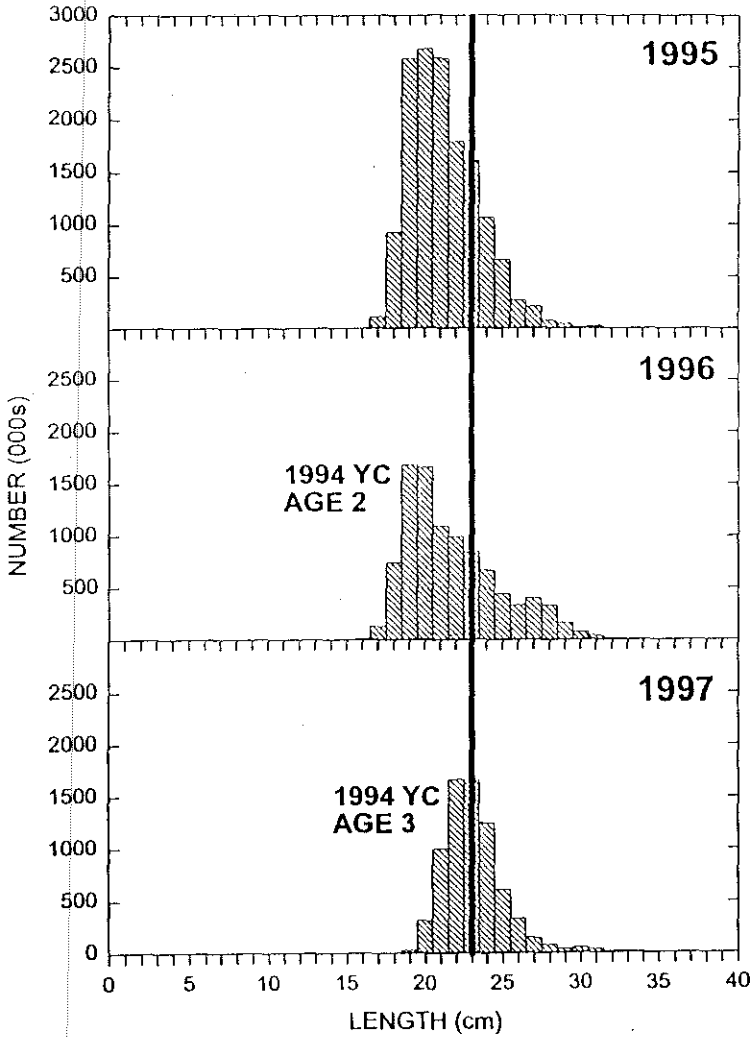

Figure D3. Northeast Region (NER; ME to VA) commercial fishery estimates of scup landings at length. Vertical line is at the current minimum size of 23 cm (9 in).

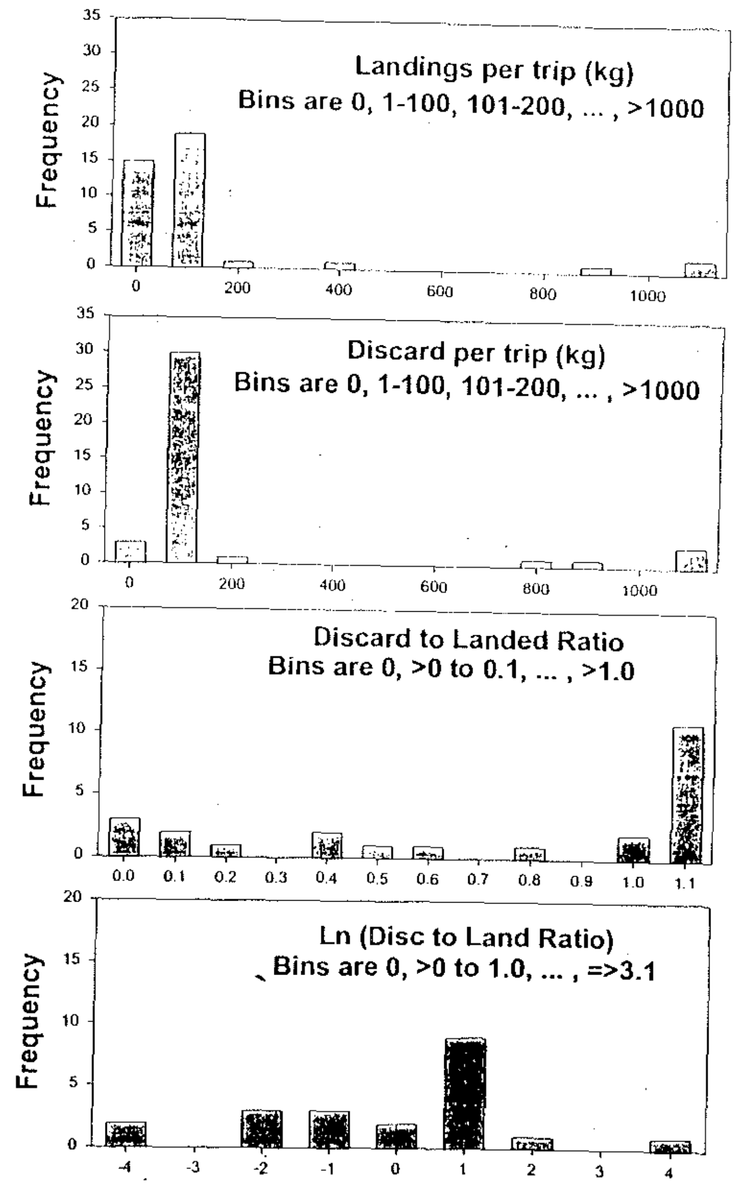

Figure D4. Distribution of 1997 sea sample (domestic observer) trawl data for scup: landings (kg) per trip, discards (kg) per trip, discard to landed ratio, and ln-transformed discard to landed ratio.

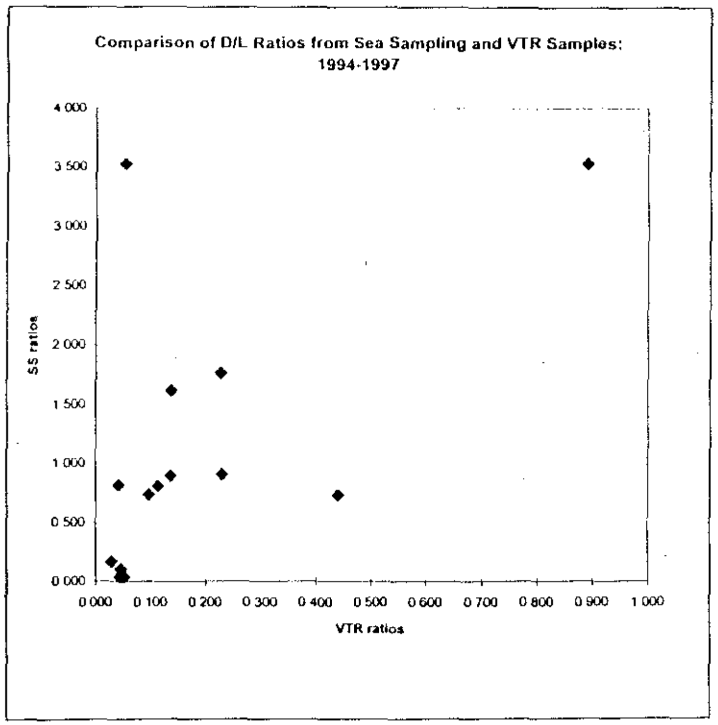

Figure D5. Comparison of discard to landed ratios for scup derived from sea sample and vessel trip report (VTR) data: 1994-1997.

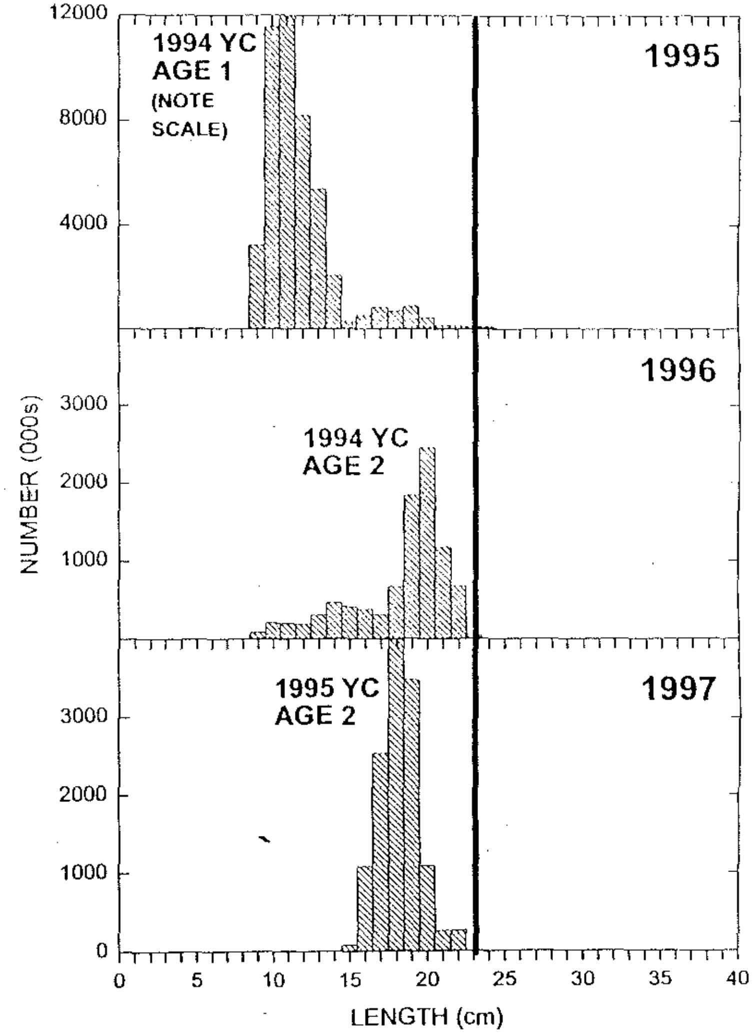

Figure D6. Northeast Region (NER; ME to VA) commercial fishery estimates of scup discards at length. Vertical line is at the current minimum size of 23 cm (9 in).

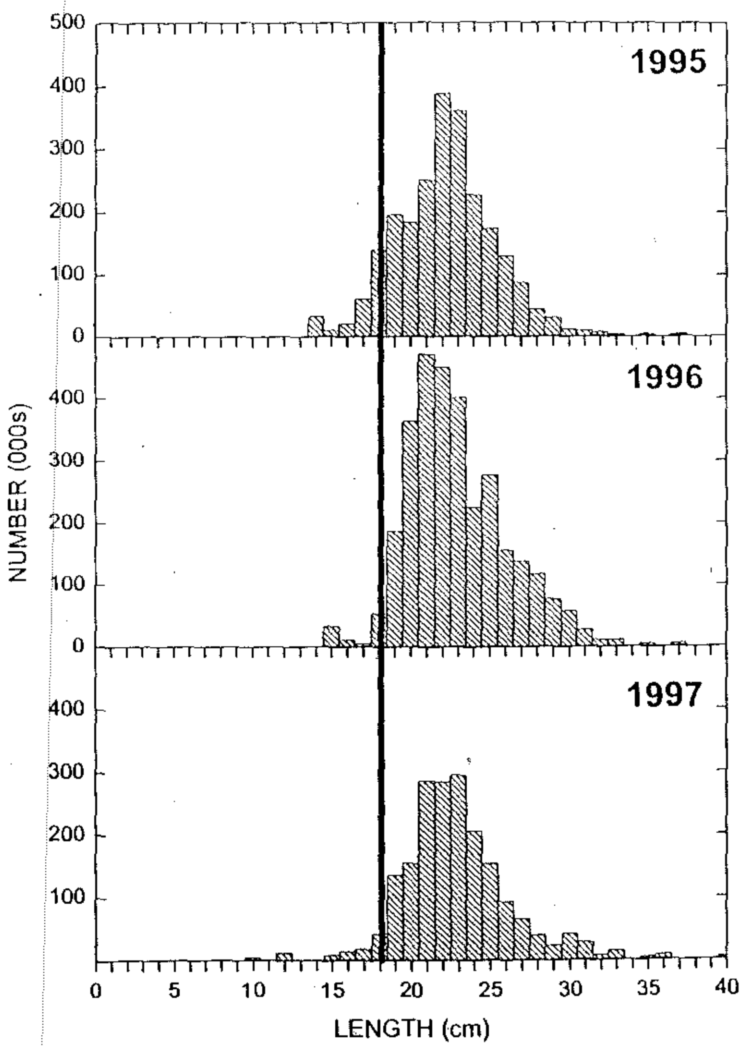

Figure D7. Coastal (ME to NC) recreational fishery estimates of scup catch at length. Vertical line is at the current minimum size of 23 cm (9 in).

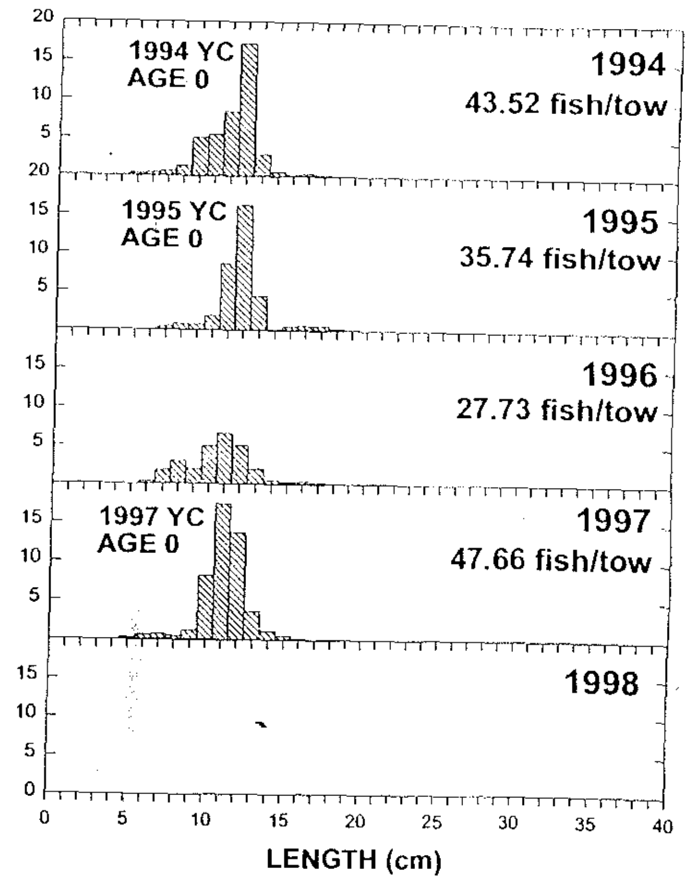

Figure D8. Abundance in indices for scup from NEFSC autumn research vessel surveys, offshore strata 1-12, 23, 25, 61-76, inshore strata 1-61: stratified mean number/tow at length.

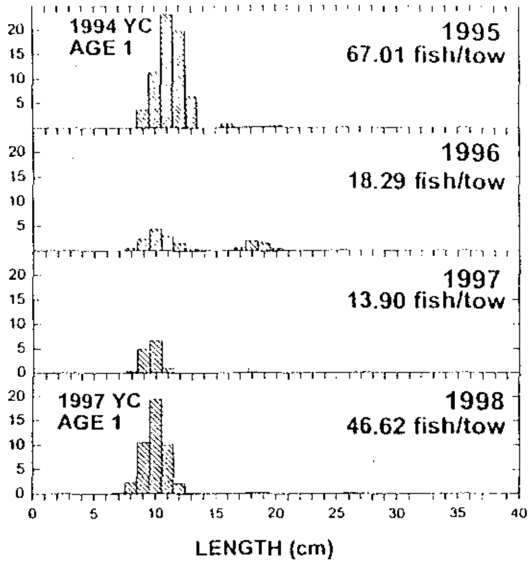

Figure D9. Abundance indices for scup from NEFSC winter research vessel surveys, offshore strata 1-12, 23, 25, 61-76: stratified mean number/tow at length.

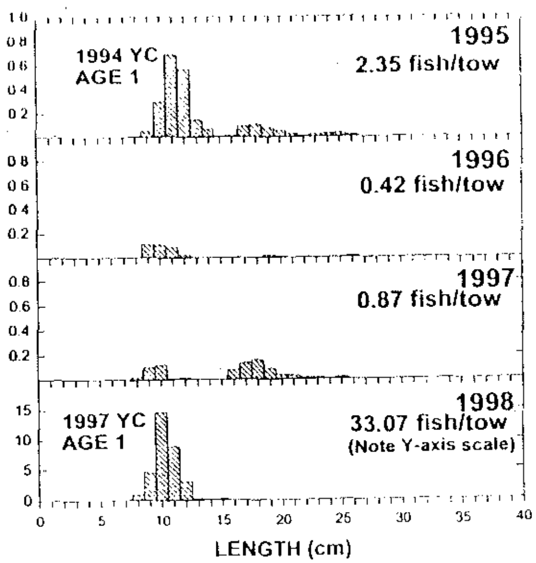

Figure D10. Abundance indices for scup from NEFSC spring research vessel surveys, offshore strata 1-12, 23, 25, 61-76, inshore strata 1-61: stratified mean number/tow at length. Note Y-axis scale difference for 1998.

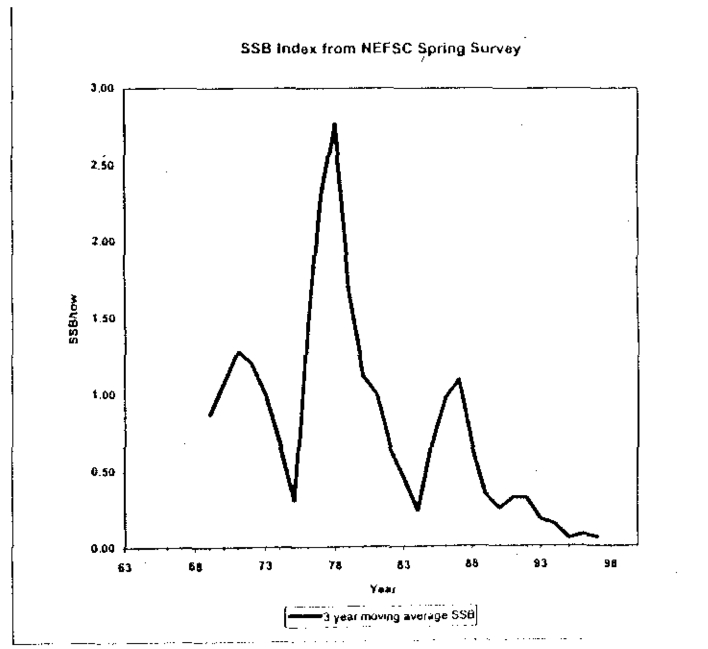

Figure D11. Spawning stock biomass indices (SSB kg/tow) for scup from NEFSC spring research surveys, offshore strata 1-12, 23, 25, 61-76. Indices are 3-year moving averages (e.g., 1978 point is average of 1977, 1978, and 1979 annual indices).

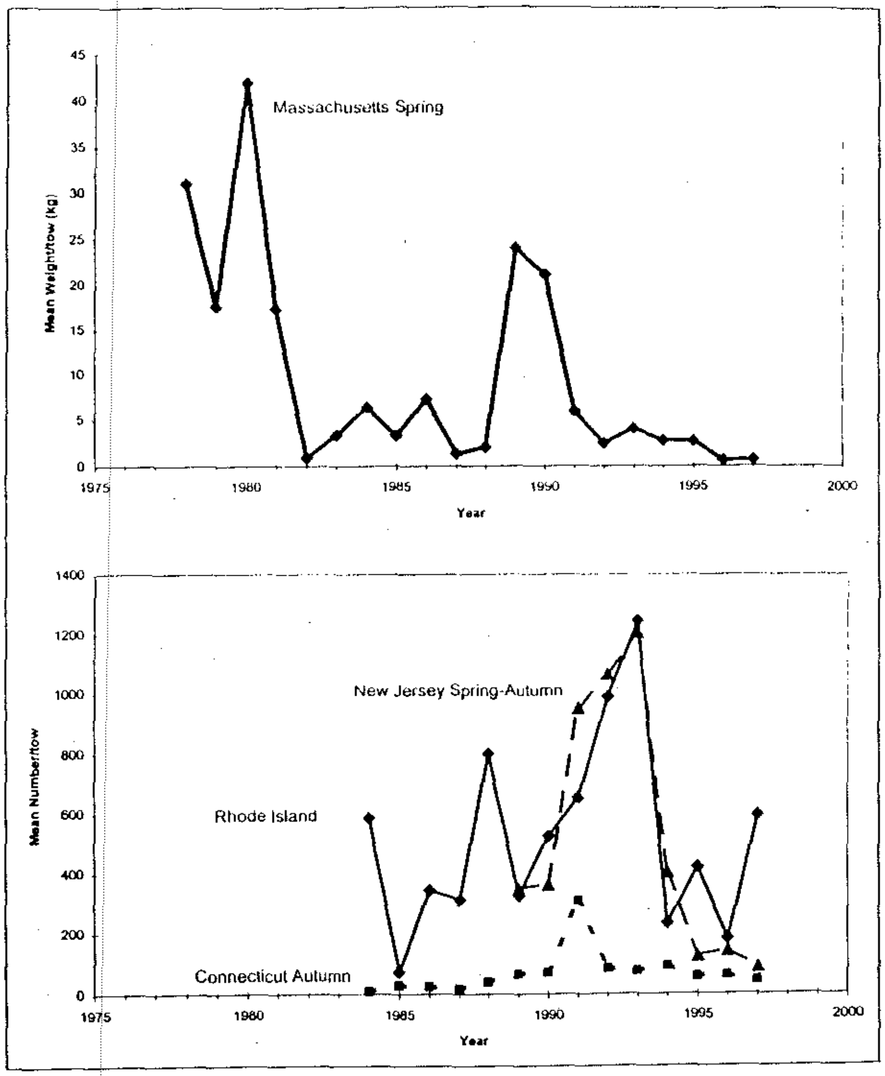

Figure D12. Mean catch-per-tow indices for scup. Top: MADMF spring research vessel survey, stratified mean kg/tow; Bottom: RIDFW autumn, CTDEP autumn, and NJBMF spring-autumn research vessel surveys, stratified mean number/tow.

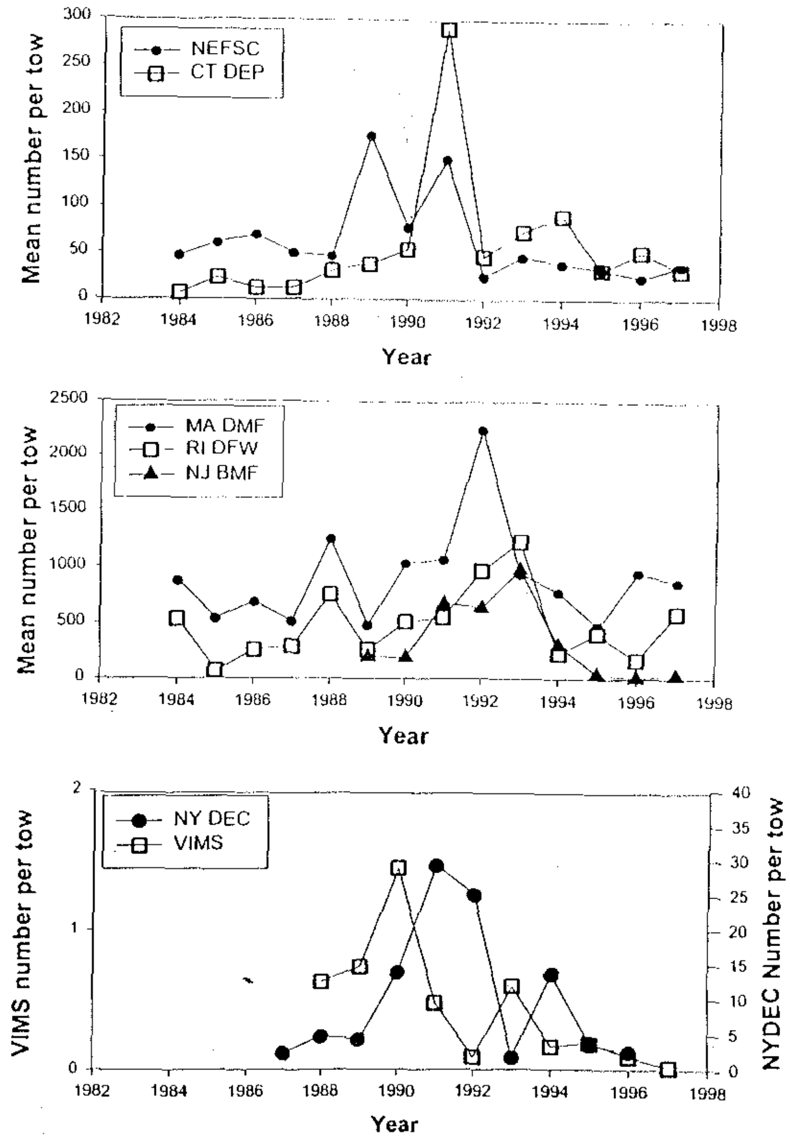

Figure D13. Scup recruitment at age 0 indices from NEFSC autumn, CTDEP autumn, MADMF autumn, RIDMF autumn, NJBMF annual, NYDEC August-September, and VIMS June-September surveys.

E. OCEAN QUAHOGS

Terms of Reference

a. Develop, test, and implement models to estimate ocean quahog abundance and mortality rates, using appropriate indices of abundance and total catch.

b. Review existing biological reference points and advise on new reference points for both ocean quahogs and surfclams to meet SFA requirements.

c. Assess the status of EEZ ocean quahog populations under management, and provide quota options consistent with biological reference points.

d. Consider the importance of refugia to new recruitment by examining biological and economic aspects for three scenarios: 1) no refugia, 2) Georges Bank only, and 3) Georges Bank and deep offshore unfished areas.

Introduction

The ocean quahog has a broad distribution in cold waters of the northern hemisphere. It is the sole extant species of an ancient genus which dates to the early Cretaceous. Ocean quahogs are common around Iceland, in the eastern Atlantic as far south as Spain, and in the western Atlantic as far south as Cape Hatteras (Theroux and Wigley 1983). The depth range is between 10 m and 200-400 m, depending on the reference (Theroux and Wigley 1983; Thompson *et al.* 1980a). This bivalve is slow-growing, and some individuals have been aged at over 200 years (Jones 1983; Steingrimsson and Thorarinsdottir 1995). Early studies of populations off New Jersey and Long Island (Thompson *et al.* 1980a; Murawski *et al.* 1982) demonstrated that clams ranging in age from 50-100 years were common. Although they can grow to approximately 100 mm in shell length, the growth rate of fully-recruited ocean quahogs (0.51-0.77% in meat weight per year and < 1 mm in shell length per year) is an order of magnitude slower than for surfclams (SAW-22, NEFSC 1996).

Females are more common than males among the oldest, largest individuals in the population (Ropes *et al.* 1984; Fritz 1991; Thorarinsdottir and Einarsson 1994). Size and age at maturity are variable. Off Long Island, the smallest mature quahog found was a male 36 mm long and 6 years old; the smallest and youngest mature female found was 41 mm long and 6 years old (Ropes *et al.* 1984). Some clams in this region are still sexually immature at ages 8-14 years (Thompson *et al.* 1980b; Ropes *et al.* 1984).

The history of surfclam and ocean quahog management along the Atlantic coast of the United States is summarized, through 1986, in Murawski and Serchuk (1989). Ocean quahogs were assessed in 1992 and 1994 (NEFSC 1993, 1995) for SAW-15 and SAW-19, respectively. Those assessments reported historical trends in commercial landings and effort by region, size composition of the landings, trends in survey abundance indices, and population size structure. Estimates of exploitable ocean quahog biomass and fishing mortality rate were derived for SAW-19 from a modified Leslie-DeLury model, based on a time series of commercial CPUE and catch in numbers from 1988 to 1994. It was noted that the estimates only applied to the fished portions of the resource. The survey time series was not incorporated into the model because the catch per survey tow for surfclam and ocean quahog was unusually high in the 1994 survey, suggesting that the gear efficiency had changed. Likewise, the survey data from 1994 were not used to obtain an estimate of minimum swept-area biomass because of uncertainty regarding survey gear performance and efficiency at that time. Because of the uncertainty about the 1994 survey data, SAW-22 concluded that current abundance of surfclams was uncertain (NEFSC 1996). An extensive list of terms of reference were drafted for the recent SAW-26 surfclam assessment (NEFSC 1998a and 1998b) and the current ocean quahog assessment. The report from SAW-26 describes studies carried out in 1997 which estimated the efficiency of the clam dredge used by the R/V *Delaware II*, as well as those used by commercial vessels.

The current assessment builds on the SAW-26 report (NEFSC 1998a and 1998b) and also relies heavily on data collected in 1997 and 1998. The data include a stratified random survey of the EEZ stock, as well as experiments conducted to understand the behavior and efficiency of the NEFSC clam dredge. Continuous data on ship speed, position, and dredge angle were recorded for every tow during the 1997 survey. For the first time, these data allowed for a direct estimate of the distance sampled per tow by the dredge. Depletion studies of dredge efficiency were also conducted, and these were carried out in a cooperative program between NMFS, the clam industry and academia (see **Acknowledgments**). Stock biomass and net annual production were estimated for each region along the east coast of the United States. Confidence intervals on stock size were obtained via a bootstrap procedure taking into account the stratified random sampling design. Estimates of biomass were also made using kriging, a geostatistical method. The distribution of this species extends into deeper, unsurveyed waters. Therefore, the survey estimates do not include the entire range. They do, however, include the majority of the historically-fished region. One section of the report discusses the importance of refugia, in the form of closed areas on Georges Bank as well as deep offshore populations, to recruitment. Because this fishery has migrated from south to north in the last decade, considerable attention was also given to temporal and spatial trends in the commercial data, as well as to the economic reasons underlying the migration. Detailed analyses of vessel logbook information included evaluating changes in the spatial distribution of fishing in relation to resource abundance and the adequacy of LPUE as a measure of relative abundance.

This report also includes revised biological reference points using shell length and weight data collected during the 1997 survey. These reference points are used for comparison with observed fishing mortality rates. New research recommendations and sources of uncertainty are also listed.

Executive Summary

<u>(TOR a) Develop, test, and implement models to estimate ocean quahog abundance and mortality rates, using appropriate indices of abundance and total catch</u>

- It is difficult to draw conclusions about changes in stock biomass from the historical survey data owing to likely changes in dredge efficiency between surveys, difficulties standardizing the catch data for distance sampled per tow, and high levels of within-year sampling variance. Recognizing these uncertainties, there is a declining trend in survey biomass in the Delmarva region.

- Analyses of survey length compositions over time failed to show significant trends that would be indicative of cumulative effects of fishing mortality.

- The NMFS clam survey estimates biomass from Delmarva to Southern New England out to 80 m (40 fathoms). Ocean quahogs inhabit depths beyond 80 m. The fraction of the resource in deeper water is currently unknown, although the depth range of this species is centered at 50-99 m, and frequency of occurrence declines at both shallower and deeper depths (Theroux and Wigley 1983). On Georges Bank, attempts have been made to sample two deeper strata at the maximum working depth for the power cable and pump (80+ m), and ocean quahogs were abundant at those locations. In Southern New England, the industry has recently started harvesting ocean quahogs from waters beyond those surveyed by NMFS.

- The 1997 clam survey and associated field studies should provide the best estimate of current biomass, for the areas sampled, because the ocean quahog catch-per-tow data can be properly standardized for tow distance and adjusted for dredge efficiency. Performance of the dredge in the 1997 survey was monitored with additional new technology including bottom contact sensors, an angle indicator (which was the main method to determine when the dredge was and was not fishing), pressure/depth sensors, amperage gauge, P-code GPS to determine the ship's position and velocity, and some video monitoring of dredge performance.

- From the information available on each tow, it was possible to estimate the path length by multiplying the velocity of the ship in each 1-second interval of the tow by a 0/1 indicator of bottom contact, based on information from the angle indicator, and summing over the duration of the tow. In the 1997 survey, the average tow path length was significantly longer than in previous years, owing to the slower winch pay out and retrieval speeds. Survey catches were standardized to a path length of 0.15 nm by multiplying the nominal catch by the ratio of 0.15/imputed path length, using the procedure noted above. Based on this procedure and associated monitoring, confidence in the estimation of path length has increased.

- Based on a bootstrap procedure applied to the 1997 survey data on ocean quahogs and length-weight equations from NEFSC (1996a), minimum swept-area biomass estimates ('000 mt) and 95% CIs for the surveyed areas are:

Region	Lower	Mean	Upper
GBK	114	177	238
SNE	45	113	207
LI	107	172	232
NJ	74	103	131
DMV	15	24	36
SVA	0	0	0
All	488	599	723

- A minimum swept-area biomass estimate ('000 mt) from the 1997 survey based on geostatistical kriging and using length-weight equations from NEFSC (1996a) is:

Region	Lower	Mean	Upper
All	534	612	690

- No estimates of efficiency of the NMFS clam dredge were made in ocean quahog habitat. The efficiency of the NMFS clam dredge for ocean quahogs was inferred by assuming that it would be roughly comparable to the performance of commercial dredges. The median efficiency of five experimental studies with commercial dredges was 0.43. The minimum swept-area biomass estimates (above) can be divided by this factor to obtain estimates of biomass in the surveyed area.

- Based on the biomass point estimates from the surveyed areas (above), current F estimates are:

Region	Bootstrap	Kriging
GBK	0	-
SNE	0.035	-
LI	0.013	-
NJ	0.018	-
DMV	0.019	-
SVA	0	-
DMV to SNE	0.021	-
All	0.014	0.014

- Regions in the south (Delmarva, New Jersey) have been exploited since the late 1970s. The fishery moved northeastward to the Long Island region in 1992 and expanded to Southern New England in 1995.

- Commercial catch per unit effort (CPUE) has declined off Delmarva from about 700 kg meat/hr fished during 1983-1987 to its current value of about 300-400 kg/hr. CPUE has declined off New Jersey from about 600 kg meat/hr fished during 1982-1987 to 300-400 kg/hr during 1992-1995. In the last two years, CPUE off New Jersey increased to about 500 kg/hr as a result of harvests being taken from deeper water, further offshore. The highest CPUE in 1997 was off Southern New England (690 kg meat/hr), followed by Long Island (638 kg meat/hr fished).

- Detailed analyses of subareas (i.e., 10-minute squares) suggest that the fishery in any suitable location can be characterized by three phases. Landings in the first 4 years tend to be high but variable as harvesters locate and exploit high density clam beds. Median CPUE in this phase typically exceeds 600 kg meat/hr fished. In years 5-10 of the fishery, median CPUE drops slightly and the variance is reduced. After 11 years or more, CPUE drops to median levels of 430 kg/hr and fishing effort is often curtailed. Independent information from industry sources supports these observations and adds that the decision to curtail effort is determined by economic factors.

(TOR b) Review existing biological reference points and advise on new reference points for both surfclams and ocean quahogs to meet SFA requirements

- The current overfishing definition for surfclams is $F_{20\%}$. Current biological reference points for surfclams are:

Region	F_{max}	$F_{0.1}$	$F_{20\%}$	F_{PO}
NNJ	0.21	0.07	0.18	0.05
DMV	0.21	0.07	0.18	0.05
GBK	0.09	0.07	0.17	0.12

- The recommended reference point for surfclams is from the New Jersey region, where nearly all of the catch is taken. F_{P0} is the fishing mortality that would occur if the catch were equivalent to the annual production of biomass. No new information is available since SAW-26.

- The current overfishing definition for ocean quahogs is $F_{25\%}$. Current biological reference points for ocean quahogs based on a revised length-weight equation are:

Region	F_{max}	$F_{0.1}$	$F_{20\%}$	F_{PO}
LI	0.065	0.022	0.042	0

  The revised reference points are very similar to those computed earlier (NEFSC 1995).

- F levels resulting in zero net production, F_{P0}, are difficult to assess for ocean quahogs owing to uncertainty in the annual estimates of recruitment, natural mortality rate, and average instantaneous growth. The magnitude of each process is small, ranging between 1 and 2%, and is near the limitations of existing data to estimate. This fishery did not develop until the late 1970s. Given the cumulative landings of 388,000 mt and the estimated biomass of 1,423,000 mt in 1997, the stock is more likely to be closer in biomass to its pristine state than the MSY stock level. Hence, production is expected to be low.

- For ocean quahogs in the regions that have been historically fished, the production model indicates that production is close to zero and net production (i.e., production minus removals) is negative. This result holds for both the traditional and revised length-weight equations. A major source of uncertainty in the model, however, is the abundance of small ocean quahogs (40-70 mm in length) in the population. Clams of this size can pass through spaces in the survey dredge. Loss of these clams results in an underestimate of production. In contrast with the results for ocean quahogs, the same model indicated that, with surfclams, there is adequate production and stock biomass to sustain the surfclam fishery at current removal rates for the NNJ area, where the bulk of the surfclam fishery is concentrated (NEFSC 1998).

- The current biomass is less than the likely carrying capacity of the resource, but well above K/2. The 1997 surveyed biomass estimate (1.4 million mt) is at about 80% of the virgin biomass (1.8 million mt). The current fishing mortality rates are well below common fishing mortality rate thresholds. For example, exploitation rates are below F_{max}, often used as a proxy for F_{msy}. Fishing mortality rates are below two other alternative action levels, and overall population biomass exceeds levels which would require rebuilding. Nonetheless, 22 years of harvesting appear to have reduced the population in some areas. It is not yet possible to characterize the dynamic response of the population to these decreases in density. In many instances, the recruits that might have been produced as a result of prior reductions are only now becoming vulnerable to the survey dredge. Thus, some caution is necessary.

(TOR c) Assess the status of EEZ ocean quahog populations under management, and provide quota options consistent with biological reference points

- Analysis of data from the 1997 survey, coupled with an estimate of dredge efficiency, led to revised estimates of ocean quahog biomass by region. These estimates are greater than those reported at SAW-19 (NEFSC 1995), which were derived from trends in commercial CPUE only from fished areas. Current harvests represent approximately 2% per year of the total surveyed biomass in exploited Mid-Atlantic regions (SNE to DMV). Additional resource is in deeper water, but a survey has not been conducted to estimate its magnitude. Therefore, the current biomass estimates are conservative. Using the conservative biomass estimates, current F in the exploited regions (0.021) is below the current overfishing definition ($F_{25\%}$ = 0.042) as well as below F_{max}= 0.065.

- Recent annual quotas have been decreasing, but ranged from 18,000 to 22, 000 mt (about 4.0 - 4.9 million bushels). Quotas in this range were intended to satisfy a 30-year supply policy, which was considered to represent conservative management because it is reevaluated annually. Given the revised biomass estimate for 1997, these quotas are consistent with a supply policy of 55 to 75 years, which is even more conservative. If quotas in this range were taken for the next decade and assuming that recruitment is roughly balanced by natural mortality, the estimated stock biomass would decline by approximately 13-16% (see section on Supply-Year Calculations for specific cases with more detail). However, greater reductions in stock size could occur in certain locations if the harvest were taken from a small area. Given the past performance of this fishery, effort is directed away from areas as soon as CPUE declines by 30-40%. Therefore, the number of areas that are profitable for harvesting may become limiting years before the overall stock undergoes a major decline in biomass.

- The ocean quahog resource in surveyed EEZ waters from Southern New England (SNE) to Delmarva (DMV) is at a medium-high level of biomass and, according to the existing overfishing definition, would be considered under-exploited at the scale of the management unit. CPUE, however, has continued to decline substantially in localized areas. Annual recruitment is approximately 1% of the stock biomass, and this is roughly equal to the rate of natural mortality. Thus, the population should be at equilibrium in the absence of significant exploitation. Harvesting should cause a decline in biomass over time, and there is evidence of this in long-term commercial CPUE data from the DMV and NJ regions. Since 1992, the Mid-Atlantic fishery has moved northeastward to Long Island (LI) and more recently to SNE, where CPUE is much higher. In 1997, 47% of the landings were taken from SNE. Significant biomass may exist in deeper water, especially off LI and SNE, but a survey has not yet been conducted to determine its magnitude. About 30% of the total stock biomass is on Georges Bank (GBK), and this region continues to be closed to harvesting due to previous contamination by PSP. The overall fishing mortality rate (F) in the surveyed Mid-Atlantic regions being fished (SNE to DMV) was 0.021 in 1997, which is below the current overfishing definition ($F_{25\%}$ = 0.042). The stock in the EEZ off the coast of Maine continues to be harvested and, to date, neither NMFS nor the State of Maine has conducted a quantitative survey in this region.

(TOR d) Consider the importance of refugia to new recruitment by examining biological and economic aspects of three scenarios: 1) no refugia, 2) Georges Bank only, and 3) Georges Bank and deep unfished offshore areas

- As opposed to the restricted fisheries definition of "pre-recruits", "recruitment" is used in the broader sense here and includes juveniles and larvae.

- The deep bathymetric limit of *Arctica islandica* has yet to be determined, although limited data suggest that populations extend at least as deep as 50 fathoms (100 m). Significant areas of bottom in the 45-50+ fathom range exist throughout the Mid-Atlantic Bight which may provide suitable habitat for as yet unsurveyed *A. islandica* populations. Therefore, the current estimates of standing stock for this species in the region should be viewed as conservative.

- The gyre-like circulation on Georges Bank has been implicated in the retention of larval forms.

That region may export larvae to the southwest, but only at certain restricted times of the year and only as far as between Nantucket and the eastern end of Long Island. Populations "downstream" of this spatial window must be maintained from spawning of populations resident in the Mid-Atlantic Bight.

- If deep-water populations are significant in number and distribution, they might contribute to the maintenance of inshore populations of *A. islandica* in the Mid-Atlantic Bight.

Commercial Data

Commercial landings and effort data from 1980 to 1997 are from mandatory vessel logbooks. It is assumed throughout this assessment that one bushel of surfclams = 10 lbs = 4.5359 kg of usable meats. Parameters relating shell length to meat weight are from Murawski and Serchuk (1979), are region specific, and were based on samples obtained in winter. Revised length-weight information was collected during the summer 1997 resource survey aboard the R/V *Delaware II*. 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 were estimated by region from port agent sampling.

Landings

The ocean quahog fishery was in its early stage between 1967 and 1975 when total landings were <1,000 mt of meats per year (Table E1, Figure E1). The period from 1976 to 1984 was a transition from low to high catches. Since 1985, 20,000-24,000 mt of meats have been harvested annually, with 90-100% of those landings from the EEZ.

Annual EEZ quotas have been set since 1978. Between 1986 and 1994, the quota was well above the annual catch. The EEZ quota was reduced each year from 1995 to 1997, and in 1997 the entire quota was taken (Table E1).

Through time, the fishery has moved from south to north (Figures E2-E4). There were multiple reasons for the movement. One set of reasons is related to cost and efficiency of operating a processing plant. These include relocation of plants to sites with deep-water piers, cheaper freight, and fewer problems with disposal of waste water. Another set of reasons is related to the relative abundance of clams in the south and north and the proximity of those clam beds to shore.

The movement of the fishery over time is reflected in the pattern of landings. Regions with the most landings by period include New Jersey during 1978-1986, Delmarva 1987-1988, New Jersey 1989-1991, Long Island 1992-1995, and Southern New England 1996-1997 (Table E2, Figure E3). Maps of cumulative ocean quahog catch during 1980-1985, 1980-1989, 1980-1993, and 1980-1997 show the northeastward migration of the fishery through time (Figure E4). No landings have been reported from east of 69°N latitude because Georges Bank has been closed since 1990 due to the risk of paralytic shellfish poisoning (PSP).

Catch per Unit Effort (CPUE)

Effort trends

In general, the regional trends in fishing effort (i.e., hours fished) over time (Figure E5) are similar to trends in landings over time (Figure E3). In 1996-1997, total fishing time in Southern New England was greater than in any other region. Before 1995, there was very little fishing effort in Southern New England. In 1995, maximum hours fishing took place in the Long Island region. Before 1995, fishing effort was always greatest in the New Jersey and Delmarva regions.

From 1994 to 1997, there has been a decline in total fishing effort (Southern New England to Southern Virginia/North Carolina). This is at least partially explained by recent reductions in the quota (Table E2). It is probably also explained by the high catch rates off Southern New England where most of the harvesting now occurs.

CPUE

Nominal trends by region: From Southern New England to Southern Virginia/North Carolina, typically >80% of the annual catch is taken by large (105+ GRT) vessels (Table E2). For New Jersey and Delmarva, the regions that have been fished the longest, CPUE of large vessels has declined over time. For example, CPUE in Delmarva was 600-650 kg/hr during 1980-1982, 660-760 kg/hr during 1983-1987, and 300-460 kg/hr during 1990-1997 (Table E2, Figure E5). The same pattern is seen for New Jersey, although CPUE did increase in 1996-1997. A detailed spatial analysis of landings revealed that this increase resulted from movement by a few fishermen to deeper areas further offshore which were not exploited previously.

The Long Island and Southern New England regions have been harvested for relatively short periods of time. Since 1992, when effort increased dramatically in the Long Island region, CPUE peaked at 870 kg/hr and then declined to 600-650 kg/hr during 1993-1997. Southern New England has only been fished intensively since 1995, and CPUE has been high at 650-710 kg/hr.

Changes in CPUE over time for all regions south and west of Georges Bank are shown in Figure E7. This demonstrates a decline over time in CPUE in the Delmarva and New Jersey regions. It also shows the movement of the fishery to Long Island and Southern New England, where current catch rates are higher than in more southern regions.

General linear models (GLM) by region: A separate GLM was carried out for each region (Tables E3-E6) on the natural log of CPUE to obtain a standardized abundance index from the commercial data. Year, vessel ton class, and subregions were included as explanatory variables. "Subregions" were created by partitioning each region into approximate halves.

Estimates of the coefficients for the year parameter are indicative of CPUE over time for that region (1997 was set as the standard year in the model and is listed as 9999). The bias-corrected, back-transformed coefficients are plotted in Figure E6 for three regions. There appears to be a strong correlation between nominal CPUE from large vessels and the GLM standardized CPUE, which includes all vessels. This is not surprising given that large vessels dominate the fishery (see above).

Declines in CPUE off New Jersey and Delmarva probably represent changes in the abundance of the stock in the areas that have been historically fished. CPUE is not likely to increase in these two regions in the future unless dense clam beds are discovered in deeper waters. There is already evidence of such movement to deeper water off New Jersey. New beds are less likely to be found off the Delmarva region because the continental slope is steep beyond 90 m (45 fathoms). In contrast, there are broad regions of continental shelf in the 80-120 m (40-60 fathom) range off the coasts of New Jersey, Long Island, and Southern New England. Depths greater than 80 m (40 fathoms) have not been included on a regular basis as part of the NMFS clam surveys.

Nominal trends by 10-minute square (TNMS): CPUE was also examined using a smaller spatial unit, the TNMS. Given that ocean quahogs are sedentary and have a slow rate of growth, each TNMS can be considered to have had its maximum stock biomass before harvesting began. If each year of harvesting reduces the resource in the TNMS, then there should be a negative relationship between CPUE and total years of harvesting ("Fishing Year"). This was examined for nine TNMSs located from east of Long Island to the Delmarva region. The five squares from the south (Figure E8) had a long history of harvesting (Table E7) compared with those from the north. A plot of the data support the model that biomass declines within TNMSs as the years of fishing increase (Figure E9). The data were then partitioning into three groups based on years of fishing: 1-4 ("Early"), 5-10 ("Mid"), and ≥11 ("Late"). Catch per unit effort declines across groups from "Early" to "Mid" to "Late" (Figures E10 and E11).

Size Composition of Landings by Region

Length frequency distributions for ocean quahogs landed between 1982 and 1997 are presented for the Southern New England, Long Island, New Jersey, and Delmarva regions in Figures E12-E15, respectively. Sampling data are summarized in Table E8. Between 1982 and 1997, average length of clams landed from New Jersey (approximately 90-95 mm) was greater than that from other areas (typically 80-90 mm; Table E8). Mean length of clams landed from the Delmarva region has decreased steadily from 92.5 mm in 1994 to 85 mm in 1997. Mean length of clams landed from the New Jersey and Long Island regions has remained relatively steady. Although mean shell size from the Southern New England landings declined in 1997, this was due to targeting of specific beds with high meat yield and does not represent a shift in mean shell size of the exploited stock throughout that region.

Research Surveys

Uncertainty in dredge performance confounded the interpretation of survey indices (e.g., 1994) and led to low confidence in swept-area population estimates. To address this shortcoming, changes to some operational procedures were implemented in 1997.

Sensor Data

Better monitoring of dredge performance in 1997 was achieved via the Shipboard Computing System (SCS) on *Delaware II* which permits continuous monitoring of variables that are critical to operations. In addition to the SCS sensors, other sensors were attached to the clam dredge. During most tows, these sensors collected data on ship speed, ship position, dredge angle, power to the hydraulic pump, and water pressure from the pump at depth. Depending on the sensor, the sampling interval varied from once per second to once per 10 seconds. The smallest time unit for analysis was 1 second. In cases where data were not collected every second, empty cells were filled with the previous measurement. The data were then smoothed using a 7-second moving average, centered on the time being calculated. This time window was considered appropriate for smoothing the data and conserving patterns in the data.

Estimation of Distance Towed and Station Depth

Contact time of the dredge with the bottom was computed for the 1997 survey from data on ship speed and dredge angle, each measured continuously during a tow. Ship speed was measured in knots with PCODE GPS. Dredge angle was determined from inclinometer data collected from a sensor mounted on the outside of the dredge at an angle of 25° (this angle was determined from field measurements and blueprints of the dredge). For data analysis, the dredge was considered to be in contact with the substrate whenever its angle was 2.3° or less during a tow. The maximum possible depth of the blade is 8 inches, and 2.3° corresponds to a blade depth of 4 inches into the bottom. This was selected as a reasonable critical fishing angle for the dredge 1) based on videos of the dredge while being towed, 2) because the action of the hydraulic jets turns the bottom into a fluid and causes the clams to be at or near the surface, 3) ocean quahogs have relatively short siphons, and 4) 4 inches is the midpoint between the maximum and minimum possible values of possible blade penetration.

Area sampled while towing was computed as the product of ship speed, dredge width, and an indicator variable for whether the dredge was "fishing" at that second summed over time.

Sensors were used to measure when and for how long the dredge was in contact with the bottom during each tow in the 1997 surfclam and ocean quahog survey. Acceptable tows were collected at 402 stations. The median station depth (and 5th and 95th percentiles) was 37.25 m (17 and 70 m). Based on sensors, the median tow distance (and 5th and 95th percentiles) was 0.247 n.mi (0.171 and 0.333 n.mi.). This estimate of tow distance can be contrasted with the doppler distance during the timed, 5-minute tow (which was used in previous surveys). For the same set of stations, the median tow distance based on the doppler (and 5th and 95th percentiles) was 0.13 n.mi (0.11 and 0.14 n.mi.). Thus, the actual distance sampled in 1997 was approximately twice that estimated from the doppler. The difference between the two estimates increases with depth because additional time is required in deeper water to set out and haul back the hydraulic clam dredge, operations not considered as part of the 5-minute timed tow. This would affect ocean quahog tows more than surfclam tows because the former live in deeper water. It should be noted, however, that since a slower winch was used in 1997, the difference between the doppler distance and the actual distance sampled (based on sensors) would be greater in 1997 than for previous surveys.

Depletion Experiments to Estimate Dredge Efficiency

Although studies of clam dredge efficiency have been conducted (Myer *et al.* 1981; Smolovitz and Nulk 1982), they did not obtain reliable estimates of dredge efficiency for the dredge currently in use and/or in the habitat where the EEZ stock is located. Thus, it was necessary to carry out new studies.

Model

The underlying methodology for the efficiency estimates is known as a depletion experiment. At the most basic level, a closed population is sampled without replacement two or more times, and the rate of decline in catch per unit effort is a measure of the remaining population. The total population is derived as a function of the rate of decline in catch over successive samples and the total quantity removed. The theory for this type of experiment and its analyses was originally proposed by Leslie and Davis (1939). Later, DeLury (1947, 1951) considered a similar model in which cumulative effort (e.g., number of samples) rather than cumulative catch was employed as a predictor in a regression model. The models are closely related, as discussed in Seber (1973) and more recently by Gould and Pollock (1997). For the purposes of this study, estimates of population size were based on the model of Leslie and Davis (1939) in which catch per tow is written as:

$$C_i = p\,(N-T_{i-1}) \qquad (1)$$

where T_{i-1} represents the cumulative catch through the I-th minus one tow. The parameter N denotes the population size and p represents the catchability coefficient.

The apparent simplicity of the model belies the complexity of fitting observations to real data. If sampling is random within a defined area in which the population is found, then the expected value of C_i is based on a binomial model with parameters p and $(N-T_{i-1})$. As each catch is removed, the value $(N-T_{i-1})$ decreases and thus the quantity $p\,(N-T_{i-1})$ also decreases. As a result, the statistical error structure (i.e., the pattern of differences between observed and predicted values) is neither independent nor identical. Both of these conditions are required for linear regression models. Instead, the likelihood model for the experiment can be constructed as a product of linked binomial models in which the $(N-T_{i-1})$ term reflects the history of removals up to the I-th observation. This model is known as chain binomial process or more commonly as a multinomial model. Recently, Gould and Pollock (1997) advanced the theory of estimation for the Leslie-Davis model and proposed some model extensions. Their methodology was used to analyze each of the depletion experiments. The multinomial model was coded in Excel and tested using the original rat population data of Leslie and Davis. Confidence intervals for model parameters were estimated using profile likelihood (Venzon and Moolgavkor 1988).

Six surfclam depletion experiments were carried out off the coast of New Jersey in spring/summer of 1997, and those results were described at SAW-26 (NEFSC 1998). Five ocean quahog depletion experiments were carried out using commercial vessels. The primary goal was to determine the efficiency of commercial clam dredges and to assume that the efficiency of the dredge used by the *Delaware II* would be approximately equal to or less than those estimates.

Ocean Quahog Experiments

Five separate depletion experiments of ocean quahogs were conducted aboard three commercial fishing vessels during between July 15, 1997 and April 26, 1998. Study locations are presented in Figures E16-E17.

Each experiment consisted of making repeated passes with the dredge over an area approximately 2.0 microseconds long, as close to a repeated path as possible. The width of the area depleted was 0.3-0.4 microseconds depending upon the experiment. Each tow was about 5 minutes in duration, and LORAN bearings were recorded each minute. The catch from each dredge haul was sorted and measured into US standard level bushels. Subsamples for length frequency (one bushel) and numbers per bushel (one additional bushel sample) were obtained every fifth haul. Data were recorded on standard log sheets (see Appendix A for additional details on these experiments).

The ocean quahog depletion sites were at or near 1997 survey sites. However, unlike the surfclam depletion experiments, the *Delaware II* did not perform replicate setup tows immediately before each depletion experiment. Cruise tracks for the commercial tows are shown in Figures E18-E22. Line widths in the figures are proportional to the dimensions of the dredge.

The catchability coefficient in the Leslie-Davis model is related to gear efficiency *e* by the relationship $e = (A/a)p$ where *A* is the total area swept at least once by the dredge and *a* is average area swept by an individual tow. The total area *A* represents the sum of all non-overlapping areas swept by the dredge. ARCINFO was used to estimate this quantity based for each experiment. Computations of average area swept were based on analyses of the vessel track coordinates for each tow. Results of these computations are presented in Table E9.

To determine area depleted, the tows were plotted using ARCINFO and SYSTAT. Tows were excluded if a significant portion of the tow (typically >½) was made outside of the region covered by most of the other tows. This process was made more objective by considering tow locations relative to the 90% confidence contour of tow locations, based on the Epanechnikov-kernel function (Cressie 1988, implemented in SYSTAT). The decision was made to remove 4 tows from the SH-1 experiment and 4 tows from the WW-1 experiment. Area depleted was then computed as the intersection of the remaining tows.

Parameter estimates and profile-likelihood confidence intervals of gear efficiency (defined as the probability of capture given encounter) and clam density (numbers/square meter) are summarized in Table E9. The derived efficiency estimates are influenced by sea state and bottom type. Moreover, the size of the area depleted is also important. Experimental dredge efficiencies ranged from 1.1 to 0.29. Estimated efficiencies greater than 1 are likely to be due to a narrow dredge path, which violates the assumption of independent observations in the Leslie-Davis model.

No estimates of efficiency of the NMFS clam dredge were made in ocean quahog habitat. The efficiency of the NMFS clam dredge for ocean quahogs was inferred by assuming that it would be roughly comparable to the performance of the commercial dredges. The median efficiency of 5 experimental studies with commercial dredges was 0.43. The minimum swept-area biomass estimates (above) can be divided by this factor to obtain estimates of biomass in the surveyed area.

Survey Results

Description of surveys

A series of 21 research vessel survey cruises were conducted between 1965 and 1997 to evaluate the distribution, relative abundance, and size composition of surfclam and ocean quahog populations in the Mid-Atlantic, Southern New England, and Georges Bank (Figure E2). Since survey methods changed significantly before and after 1980 (NEFSC 1996), the period 1980-1997 is examined here. Even within this period, some methods have changed, making it difficult to detect temporal trends in stock size if they exist. The changes are discussed in more detail below, but involve gear efficiency and the method used to estimate distance sampled per tow.

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 (once the dredge is on the "poly" line) 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 the area of each stratum within the region as a weighting factor.

In years prior to 1997, doppler distance during the timed 5-minute tow was used to standardize the catch of every tow to a common distance (0.15 n. mi). This did not consider that the dredge could be sampling during set out and haul back, or that the blade may not always be in contact with the substrate during the tow. As described in previous sections, tow distance in the 1997 survey was standardized by imputing tow distance from ship velocity (measured by GPS) and contact by the dredge on the bottom as indicated by the inclinometer. Catches were then standardized by multiplying nominal catch at each station by the ratio of 0.15/imputed path length.

Survey catch per tow of both surfclams and ocean quahogs was much higher in 1994 than in previous surveys. It is felt that gear efficiency increased significantly during that survey, although the cause has not been identified (NEFSC 1996a,b, NEFSC 1998.

Confidence intervals on catch-per-tow indices were computed by two methods. Smith's (1997) bootstrapping procedure for complex survey designs was applied. This approach allows for asymmetric confidence intervals, which eliminates the difficulty associated with negative estimates at the lower bound of the interval. Kriging (Cressie 1993) was also applied. This method utilizes the spatial autocorrelation to interpolate between sampled points. When spatial autocorrelation is strong and the precision is high, kriging can reduce the confidence intervals on total biomass and improve the accuracy related to spatial distribution.

Abundance indices

Calculated abundance indices and associated statistics from a bootstrap estimation method are given in Tables E10-E12 for surveys conducted in 1997, 1994, 1992, 1989, 1986, 1984, 1983, 1982, 1981, and 1980. Statistics are computed for total number per standardized tow and total catch weight (kg meats). Estimates are based on traditional length-weight equations (Serchuk and Murawski 1980; NEFSC 1996a). These estimates are expanded to minimum swept-area population estimates (e.g., assuming 100% dredge efficiency) by determining the number of possible standard tow paths in each stratum and multiplying by the average and upper/lower 95th percentiles. The regional biomass estimates are only for the surveyed portion of the resource; ocean quahogs are known to inhabit depths beyond what was surveyed.

Total minimum swept-area biomass was 599 kmt of meats in 1997 (all sizes). The majority of the resource in 1997 is on Georges Bank, Long Island, and Southern New England (Tables E10-E12; Figures E23-E26). Computations of relative abundance of the stock for previous years gave approximately the same relative resource distributions among areas, with minimum population sizes greater in 1994 than the other years evaluated.

Temporal estimates of minimum swept-area biomass for each region are given in Figures E23-E25. With the exception of a decline in the Delmarva region, these figures do not suggest any obvious monotonic trends in regional biomass over time. However, trends that possibly do exist might not appear in the graphs because of the suspected changes in dredge efficiency between surveys, particularly in 1994, and because the method for standardizing tow distance was not improved until 1997.

Biomass estimates based on doppler distances (i.e., applies to all surveys before 1997) are overestimated because doppler distances underestimated distance sampled by the dredge. For 1997, the estimate of biomass was made using the two methods for estimating tow distance. The difference between the means labeled "d" (for doppler) and "4 in" (for sensors used, assuming a 4 inch critical blade depth for sampling) demonstrates the magnitude of bias in the biomass estimate for that survey when the doppler reading is used to estimate tow distance (Figures E23-E25).

Geostatistical estimation procedures were applied to the 1997 survey data and gave similar results (Table E13). The confidence intervals were smaller than those computed for either the bootstrap analyses or simple random sampling designs. A map of biomass, based on kriging, is given in the section on **Co-Distribution of the Fishery with the Resource**.

Spatial distribution of clams from the 1997 survey

The distribution of sampled survey stations in 1997 is given in Figure E27. Station intensity was greater in 1997 in some areas (e.g., NJ) because the estimation of surfclam population abundance via swept-area methods was anticipated. Ocean quahog abundance-per-tow data from the 1997 survey were partitioned into two size classes based on shell length: small (1-69 mm) and large (≥70 mm). Detailed distribution data by size class are plotted in Figures E28-E31. Clams in the "large" class were most abundant from Georges Bank to Long Island. The largest concentrations of "small" clams were on Georges Bank and in Southern New England.

Size frequency distributions

Size frequency distributions from surveys conducted between 1980 and 1997 are plotted by region in Figures E32-E36. Mean number of ocean quahogs per standardized tow was typically lower in 1997 due in part to the switch to a more accurate method of standardizing the catch to a common tow distance. The method used previously overestimated the number of clams per area.

The modal size in the New Jersey and Delmarva regions (90-100 mm shell length) is greater than that from the more northern regions of Georges Bank, Southern New England, and Long Island (70-90 mm). In all cases, the size structure of clams within a region changed little over time. This could be partially due to partial selectivity of small individuals by the clam dredge, particularly those below 70 mm in length (Table E14).

Out of all the strata that were sampled, most had a unimodal frequency distribution of shell lengths. Ocean quahogs <50 mm in length were common in only a few of the tows taken in 1997. These tows with small individuals were collected from Strata 55 and 59 (Figure E2) in the Georges Bank region. Previous ocean quahog surveys found a similar pattern, with small (<50 mm) clams present in tows from Strata 55, 57, 59, and 61 on Georges Bank (Lewis 1997).

Recruitment to the fishery

In this section, "recruits" (also known as "pre-recruits") are defined as those individuals that will become fully recruited or vulnerable to the fishery given one year of growth. To run the Stock Size models (see below), it was necessary to estimate the magnitude of annual recruitment to the population. Based on the commercial length frequency distributions, size of fully-recruited clams was set at 80 mm in length. The age/length curve for ocean quahogs from off Long Island (NEFSC 1990) gives a 1-year growth interval of 0.539 mm (from 79.676 mm at age 40 to 80.215 mm at age 41) at the size of full recruitment.

The fraction of biomass in this interval was determined from the survey size frequency distributions, using a 1-mm size interval. Since the survey gear retains clams greater than 77 mm in shell length (Table E14), the survey size frequency data were suitable for estimating the fraction by weight of "recruits" in the population. An estimate was derived from each survey from 1984 to 1997 for each of the currently exploited regions (DMV, NJ, LI, SNE). Instead of estimating the fraction in the small 0.539 mm interval, it was estimated as the fraction in a larger 4-mm interval (78-82 mm) multiplied by (0.539/4). Estimates of the pre-recruit weight in the population range from 0.46% to 2.31% (Figure E37).

To obtain a single estimate of the pre-recruit component, a mean was computed by region from the six survey estimates. Using the fraction of biomass in each region (Figure E26) as a weighting factor, the weighted average recruitment over all regions was 1.126%.

Refugia and recruitment

Term of reference *d* called for information on the importance of refugia to new recruitment, considering three scenarios: 1) no refugia, 2) Georges Bank only, and 3) Georges Bank and deep offshore unfished areas. As opposed to the fisheries definition of "pre-recruits" used in the previous section, "recruitment" is used in the broader sense here and includes juveniles and larvae.

Bathymetric distribution of Arctica islandica populations: possible deep water resources: Current surveys occupy stations to approximately 42 fathoms (84 m), a limit dictated by pump design on the survey vessel. At least on the Southern New England shelf, current commercial activity extends to 47 fathoms with regularity. This prompts the question: what is the bathymetric limit of *A. islandica* resources (populations) in regions of the Mid-Atlantic Bight open to commercial exploitation? The inshore, shallow bathymetric distribution is marked by the 16°C bottom isotherm in the fall, which is the lethal temperature of the species at the warmest period of the year for their bathymetric range. This is amply illustrated by the concordance of the data of Bigelow (1933) for tem perature with distribution data in Merrill and Ropes (1969), Theroux and Wigley (1983), and serial stock assessment surveys by NMFS. These distribution data clearly map the inshore limit, but not the offshore limit, by including a series of deep stations with no *A. islandica* present. For some regions, the 1997 survey data indicate increasing numbers per station with depth, followed by only a marginal decrease at the deepest stations. The deep bathymetric limit has yet to be determined, although limited data suggest that populations extend at least as deep as 50 fathoms (100 m). Franz and Worley (1982) examined stomach contents of the starfish *Astropecten americanus* from 50 fathoms on the Southern New England Shelf and noted a strong dietary preference for juvenile *A. islandica*. Significant areas of bottom in the 45-50+ fathom range exist throughout the Mid-Atlantic Bight which may provide suitable habitat for as-yet-unsurveyed *A. islandica* populations. Therefore, the current estimates of standing stock for this species in the region should be viewed as conservative.

Possible deep water populations and Georges Bank populations of *Arctica islandica*: what role do they play in recruitment to commercially exploited resources? Long-term recruitment success is dependent on a stable source of progeny from actively breeding parent populations. While there is little doubt that individuals resident within the commercially fished region spawn there is interest in the role of specific regions as major sources of larvae with the commercially-fished region possibly serving as a sink region. Consideration is given here to the role of the Georges Bank populations of *A. islandica*, unavailable to commercial harvest currently and for the foreseeable future, and possible deep water populations (see previous section) as source populations.

Georges Bank differs considerably from the Mid-Atlantic Bight in major features of its physical oceanography on an annual basis. Where Georges Bank has strong vertical mixing for the majority of the year with gyre-like circulation and spillage of water across the Great South Channel into the Mid-Atlantic Bight (Backus and Bourne 1987), the latter body of water is marked by very strong seasonal stratification in late spring - early fall, strong vertical mixing in the winter, and a general southwesterly flow of water along the inner shelf over the bathymetric range of concern for *A. islandica* (Bigelow 1933, Beardsley and Boicourt 1980) The gyre-like circulation on Georges Bank has been implicated in retention of larval forms of commercially-important shellfish and the spatial patterns as well as frequency of recruitment of post-metamorphic forms (see Tremblay *et al.* 1994 for examples with the sea scallop *Placopecten magellanicus*). The same argument can be made for the higher-than-mean frequency of observation of small size classes of *A. islandica* in serial NMFS stock assessment surveys on the southwestern corner of Georges Bank. Given the suggestion of frequent spawning and recruitment to the benthos of *A. islandica* on Georges Bank, can that same population serve to export larvae to the Mid-Atlantic Bight? The answer is a strongly qualified yes, with the qualifications as follows:

1) Despite a probable extended period of possible spawning of *A. islandica* on Georges Bank [by logical extension of the data of Mann (1982) on spawning in the Mid-Atlantic Bight to a period of similar bottom temperatures on Georges Bank], export will only be successful in a relatively narrow time window when absolute temperature and vertical stratification (mostly lack thereof) in the Mid-Atlantic Bight is conducive to larval survival and growth.

This window is probably limited to the September - early November period, as suggested by the larval tolerances and behavior described in Lutz *et al.* (1982) and Mann and Wolf (1983) and direct observation of larval occurrence (Mann 1985).

2) The spatial region of influence is limited by surface drift and larval developmental rate at the prevailing temperature. Surface drift in a southwesterly direction in early fall is typically in the range of 2-8 cm/sec (Beardsley and Boicourt 1980, Beardsley and Haidvogel 1981) Developmental period at 13°C is 32 days, decreasing to 55 days at 8.5-10.0°C (Lutz *et al.* 1982). At the lowest temperature and mean surface drift rate (5 cm/sec), a possible dispersal range of 237 km is estimated, decreasing to 138 km at optimal temperature for development. These data suggest that larvae spawned on the southwest corner of Georges Bank recruit no further west than approximately midway between Nantucket and the eastern end of Long Island. Clearly, populations downstream of this spatial window must be maintained by spawning of populations resident in the Mid-Atlantic Bight.

The earlier discussion of populations in depths beyond current survey and fishing activity prompts the question as to the capability of such possible populations contributing to recruitment in shallower depths. Cox and Wiebe (1979) examine the origins of oceanic plankton in the Mid-Atlantic Bight and note them to be numerous. In addition to the previous description whereby *"Arctic-Boreal species are brought in from the northeast largely by over-shelf transport"*, they also note that *"Transition zone species are brought in by slope water penetration, at the surface when horizontal density gradients are minimal and at mid-depth in response to physical processes such as estuarine-type circulation, wind-driven upwelling, cold-shelf water 'bubble' formation and movement out into slope waters, or shelf-slope water interactions associated with warm core eddies or rings."* While *A. islandica* is generally considered to be Arctic-Boreal, the mechanism proposed for transition-zone species would successfully transport larvae from deeper water populations into shallower locations during the fall months of the year. Thus, if deep water populations are significant in number and distribution, they might contribute to the maintenance of inshore populations of *A. islandica* in the Mid-Atlantic Bight.

Co-Distribution of the Fishery with the Resource

This section integrates geographical information on catch locations by the fishery with research vessel survey information on the distribution and abundance of the resource. In the section on **Commercial Data**, it was shown that this fishery moved from DMV and the southern NJ area in the early 1980s to LI and SNE in the 1990s (Figure E4). CPUE declined in DMV and NJ after the 1980s (Figure E7). Cumulative landings through 1997 (Figures E4 and E38) are greatest off DMV, northern NJ, and LI. One small area south of Nantucket has been harvested intensively in the last two years, a site with very high CPUE (Figure E7). The survey data can be used to identify whether there are additional areas of high biomass that, to date, have not been exploited heavily.

Figure E39 is a map of the resource generated by kriging the 1997 survey data. Areas of relatively high biomass (darker shade) are off the coast of LI, SNE, and on GBK. Off the coast of NJ, there is evidence of resource in deeper water, extending to at least the outer depth limit of the survey. The same is true for the concentration in the Great South Channel just west of GBK.

GBK is closed to harvesting, but does have a high concentration of ocean quahog biomass. Based on the survey data from the remaining areas, it appears that the fishery either is currently exploiting, or has traditionally exploited, the major areas of high biomass within the surveyed area (as deep as 40 fathoms, 80 m). There is some evidence in Figure E39 of additional resource in deeper water, but its magnitude is not known at this time. The variance associated with the biomass estimate from kriging was high for the deeper areas off LI and SNE, possibly due to low replication in the outer strata. Without further studies it is not possible to quantify the extent of the unsampled, offshore resource; however, data in Theroux and Wigley (1983) are especially relevant. Based on thousands of benthic samples (Figure E40, left panel) collected between 1903 and 1971, they found that 57% of the samples which had *A. islandica* were collected between 50 and 99 m depth (Figure E40, right panel), 14.9% were from 100 to 199 m, and only 3.5% were from ≥200m. Maximum depth along the Atlantic coast for *A. islandica* was 400 m. From these data, it appears that *A. islandica* abundance should decline rapidly beyond 100 m (i.e., about 50 fathoms). Additional work in 1999 will be conducted to test this hypothesis.

Stock Size Models and Biological Reference Points

This section contains results pertaining to stock size, fishing mortality and exploitation rates, and biological reference points. A number of biological reference points and harvest policies have been proposed for management of EEZ populations of surfclams and ocean quahogs. The Mid-Atlantic Fishery Management Council's harvest policy has been erroneously called a mining policy in which the resource is fished to extinction over some finite planning horizon. In reality, the policy is a risk-averse adaptive strategy that computes a harvest rate based on current estimates of population biomass and an assumed level of recruitment to the population. The most conservative assumption, that recruitment is zero, implies the lowest harvest rate. Harvest levels are recomputed each year using the predicted population size as the measure of abundance. Periodic surveys of the resource are used to update abundance levels, thereby allowing revision of harvest levels in response to actual resource conditions. Other biological reference points have been utilized for management of ocean quahogs and surfclams. At SAW-26, surfclam harvest levels were set so as to maintain current population biomass. This policy seeks to preserve current resource levels by allowing harvest of projected biological production.

Another general class of rate-based biological reference points are those derived from yield-per-recruit (YPR) and spawning-stock-biomass-per-recruit (SSB/R) models. This class of reference points has been used extensively in the fisheries literature and management plans. Biological reference points based on YPR usually rely on the general assertion that the fishing mortality that maximizes YPR will also maximize sustainable yield. Reference points based on SSB/R rely on a similar, but weaker analogy, that recruitment overfishing can be avoided by reducing F below a level that produces some prescribed fraction of maximum spawning potential. Maximum spawning potential is a conceptual device specifying the expected lifetime egg production of a recruit. The lifetime production is computed as a discounted sum of age-specific egg production adjusted for the probability of surviving to a given age. Variables are defined as:

B_t = biomass of population at time t (biomass)
C_t = total landings at time t (biomass)
G = average instantaneous rate of growth for population
M = average instantaneous rate of natural mortality
R_t = recruitment to exploitable stock at time t. (biomass)
T = planning horizon in years
P_t = total production elaborated between t and t+1
Np_t = net production between t and t+1
$N_{L(t)}$ = number at length L alive at time t
L_t = length in mm at time t
L_∞ = maximum size in mm
K = von Bertalanffy growth rate
W_L = average weight of individual of length L (kg)

All of the harvest policies can be thought of as simple mass balance expressions in which the population biomass at some time step is equal to what was present in the previous time step plus its growth and recruitment and minus natural mortality and harvest. The most basic equation can be expressed as:

$$B_{t+1} = (B_t - C_t + R_t)\, e^{(G-M)} \qquad (2)$$

Equation 2 assumes that catch and recruitment occur at the beginning of the time period and that the residual population is modified by the process of growth (G) and natural mortality (M) over the remainder of the time period. Note that a unit time step of 1 year is implied. Equation 2 can be further modified to allow for catch or recruitment at some intermediate point within the year.

Supply-Year Calculations

The current harvest policy of the MAFMC is guided by the principle that the annual harvest should be set no higher than that which would allow a 30-year supply of constant catches, with an infinite time horizon, given input data on standing stock, growth, recruitment, and natural mortality. The boundary conditions are:

$$B(t) = B_o$$
$$B(t+T) = 0 \quad (3)$$

where B is biomass and T is the duration of the planning horizon. The catch level is given by:

$$C(t) = \frac{B_t}{\sum_{i=0}^{T-1} e^{(M-G)\,i}} + R_t \qquad t=1, \ldots, \infty \quad (4)$$

where C is the annual catch, M is natural mortality, G is instantaneous growth, and R is recruitment. This policy implies simultaneous downward trends in biomass and catch and a gradual increase in exploitation rate.

A series of spreadsheet calculations of harvests under various catch and fishing mortality rate policies, using traditional length-weight equations, was undertaken for the regions that are exploited south and west of Georges Bank (Tables E15-E18; Figures E41-E42). Georges Bank biomass was modeled as being unexploited in simulation because that region has been closed for an extended period, and it is unknown when it will be reopened. This makes the spreadsheet calculation of the quota more conservative, but reasonable given the uncertainty over availability of that resource.

30-year supply policy

The initial supply-year calculation, based on the 30-year policy, was undertaken with a natural mortality rate of 0.02 (NEFSC 1995). Initial population sizes were minimum swept-area biomasses from surveyed strata (Survey Results section) divided by a dredge efficiency of 0.43, calculated from the depletion experiments using commercial vessels. Annual recruitment was based on the fraction of the survey catch biomass, from the average of surveys conducted between 1984 and 1997, that would recruit to harvestable size in 1 year. An assumption of the current version of the model is that annual recruitment is constant (i.e., independent of stock size). This is known to be somewhat unrealistic and was discussed by the SARC at SAW-22. There are various options for modeling recruitment, however, given the available data, no single option was recommended at this time. Growth rates of the biomass were based on calculations from SAW-22. Exploitation rates were calculated as the fraction of initial exploited biomass removed by the fishery each year.

The method re-calculates the harvest level which would result in a 30-year supply of constant catches each year in the simulation (e.g., simulates a re-evaluation of the resource in terms of 30-year supply implications each year).

The 30-year supply policy for M = 0.02 results in catches increasing from about 18,140 mt in 1998 to 36,249 mt in 1999, and declining thereafter to about 30,000 mt in the ninth year of the simulation (Table E15, Figure E41). The initial exploitation rate (i.e., for 1998 using the 1998 EEZ quota) is 1.9% in the exploited regions, but this increases in 1999 to about 4%, and would exceed the overfishing definition by the eighth year ($F_{25\%}$ = 0.0437; equivalent to a 4.2% exploitation rate). The catch computed for 1999 under this policy is approximately twice the 1998 quota. The increase is the result of using the revised minimum swept-area biomass estimates from the 1997 survey and, for the first time, applying a dredge efficiency to those estimates.

A sensitivity analysis was carried out, varying three input variables: M, dredge efficiency, and annual recruitment. As M is increased from 0.015 to 0.25, the catches computed for 1999, associated with the 30-year policy, decline. As dredge efficiency is increased, the 1999 catch declines. As recruitment decreases, the catch for 1999 declines (Table E16). Under the 30-year policy and across a reasonable range of parameter values, the resulting 1999 catch is in the range from 26,000 to 49,000 mt.

Other supply-year policies

Given the new biomass and dredge efficiency estimates, the 30-year policy resulted in a catch for 1999 much greater than the current quota (i.e., 18,140 mt). Calculations were, therefore, made to determine what policy would be consistent with the current quota and values near it (Table E17). The range of quotas examined, 18,144 mt, 20,412 mt and 22,680 mt (i.e., 4, 4.5, and 5 million bushels, respectively), were found to represent supply-year policies of 76, 63, and 54 years, respectively.

The 63-year supply policy (corresponding to a catch in 1999 of 20,412 mt (4.5 million bushels) was examined in more detail by projection to see how exploitation rates, stock biomass, and harvests would change over time. Under this policy, exploitation rates would remain below 2.5% for the first 10 years of exploitation (Table E18, Figure E42) and not exceed the current overfishing definition for more than 28 years. Stock biomass in the exploited (and surveyed) regions would decline from 958,000 mt in 1997 to about 750,000 mt in 2008. During this period, annual harvests from the exploited region would be close to their current values, ranging from about 20,400 to 18,500 mt.

The supply-year policy assures relative continuity of catches from year to year. This policy is less risk-prone than constant-harvest policies because the catch and harvest rates are updated annually. Annual landings under this policy are consistently lower than those obtained under a constant exploitation rate. However, the policy does result in continuously declining stock sizes because it does not explicitly require that removals be balanced by growth and recruitment.

Production Forecast

If the resource is considered to be at appropriate levels of stock size now, then it may also be appropriate to establish explicit targets which result in catch and unaccounted fishing mortalities balancing growth and recruitment (e.g., no net change in resource abundance). Such a policy would imply stable catch rates if fishing were distributed equally over the stock.

This policy seeks to preserve the current population biomass by harvesting only the production that would be available from the current level and size structure of the population biomass. The boundary conditions for this problem can be written as:

$$\begin{aligned} B(t) &= B_o \\ B(t+1) &= B(t) \end{aligned} \qquad (5)$$

The catch policy for these boundary conditions is found by setting $B_{t+1} = B_t$ in Equation 2 and solving for C_t:

$$C(t) = B(t)\left(1 - e^{(M-G)}\right) + R(t) \qquad (6)$$

An important assumption of this approach is that the *status quo* population size B_o has desirable properties worth preserving. If a population is declining, a *status quo* harvest policy would arrest the decline. Similarly, if the population is at some optimal production level, say B_{max}, then a *status quo* policy would be appropriate. However, if the population is below some target threshold, then the computed quota may be too high. By the same measure, C_t could be too low if average growth rate of the population could increase under a higher level of F. For example, a population dominated by older, slower-growing individuals could have improved productivity if the population were dominated by smaller, faster-growing individuals.

To calculate the effects of various harvests on production of the stock, swept-area biomass calculations from the 1997 survey, size compositions, and various other population dynamics assumptions described below were used. A model was developed for ocean quahogs to determine whether annual production could balance the direct and indirect losses in biomass due to fishing. The model is used for short-term projection and was implemented as follows.

The equation relating numbers at length (N_L) over the 1-year time step is:

$$\hat{N}_L' = N_L\, e^{-M} \qquad (7)$$

The vector of numbers at length was computed from 1997 research survey data. Natural mortality (M) is in the range from 0.01 to 0.03 (NEFSC 1995) and was set at 0.015. Production in region *I*, P_i, is the difference in biomass (*B*) at the beginning and end of 1 year:

$$P_i = B_i - B_i' \qquad (8)$$

where B is the sum product of the observed numbers at length and the predicted average weight at length.

This is rewritten as:

$$P_i = (\sum_L a\, \hat{L}^{/b} \hat{N}_L - \sum_L a\, L_t^b\, N_L) \cdot (^1/E) \cdot (T) \quad (9)$$

where a and b are the parameters of the equation relating shell length (L) to meat weight, E is the efficiency of the dredge, and T is the number of tows in region I. The change in shell length over one time step is computed from:

$$L'_{t+1} = L_t + \Delta L_{t-(t+1)} \quad (10)$$

where

$$\Delta L_{t-(t+1)} = (L_\infty - L_t) \cdot (1 - e^{-k}) \quad (11)$$

Parameters in the length-weight equations were revised for LI and GBK using data collected in 1997. Compared to the older equations, the revised equations indicate greater meat weight for a given shell length. The revised parameters from LI were applied to other regions including SNE, NJ, DMV, and SVA. Net production (NP_i) in region I is equal to production (P) minus removals (R),

$$NP_i = (P_i - R_i) \quad (12)$$

where

$$R_i = (C_i + IC_i) \quad (13)$$

C and IC represent the landed and indirect catches, respectively. Indirect catch refers to all mortality on ocean quahogs caused by dredging other than that landed. Based on descriptions (Myer *et al.* 1981) of damage to surfclams on the bottom as well as the increased number of predators shortly after a dredge passes an area, IC was set at 20% of C in the surfclam assessment. For ocean quahogs, IC was set at 5%.

In considering the results from the production model, note that the values chosen for input variables, M (0.015), non-catch mortality (5%), and revised length-weight equations, err in the direction that results in higher production. However, partial selectivity by the survey dredge for individuals <70 mm would tend to underestimate abundance in productive size classes in the population and result in an underestimate of production. The selectivity issue was examined by inferring what individuals may have been lost from the sample [following a modification of work by Barry and Tenner (1989)], adding them in (Figure E43), and re-running the model (see below). This method estimates the expected size frequency distribution under a generalized growth model and size-dependent fishing mortality.

Results

Tables E19-E20 show inputs and results from runs of the ocean quahog production model, described above, using the observed and augmented size frequency distribution. The model results suggest that there is negligible annual production in DMV, NJ, and LI. The model suggests that SNE has a small amount of positive production (142 mt/yr), while the greatest amount of production is associated with GBK (about 7,500 mt/yr). The total production estimates represented only 0.2-0.5% of the stock biomass. Changes of this magnitude are of the same small order as annual estimates of recruitment, natural mortality, and average instantaneous growth. The magnitude of each process is small, ranging between 1 and 2%, and is near the limitations of existing data to estimate.

The stock is more likely to be closer in biomass to its pristine state than the MSY stock level given the cumulative landings of 388,000 mt and the biomass of 1,423,000 mt in 1997. Hence, production is expected to be low.

Other improved methods could be developed to adjust the observed size frequency distribution, taking gear selectivity into account. The method that was used thus far did not cause a major change in the results regarding ocean quahog production.

Biological Reference Points

The underlying premise of rate-based policies is to specify a fishing mortality rate which is independent of population size and achieves some desirable outcome with respect to yield or reproduction. Rate-based policies assume invariant life history parameters (e.g., growth, maturity, mortality, and reproduction). Feedback effects of fishing mortality on growth rates or the magnitude of recruitment are not considered. If rate-based policies are used to define specific biomass thresholds or targets, then it is also necessary to assume the level of recruitment or the dynamic relationship between spawner biomass and recruits.

Per-recruit calculations

Given new information on the length-weight relationship for ocean quahogs from 1997, the analysis of yield-per-recruit and spawning-biomass-per-recruit reference points for LI (Table E21, Figure E44) were recomputed. Specifically, revised estimates of F_{max}, $F_{0.1}$, and $F_{20\%}$ were generated. Estimates were similar to those reported previously. Note that these estimates were produced with a nominal M of 0.02, recruitment to the fishery at age 17 years, maturity between 5 and 11 years, and a plus group for individuals > 99 years old.

Similar analyses were recently carried out for surfclams (NEFSC 1998). Those results are also summarized in Table E21.

Current mortality rates

Current (e.g., 1997) exploitation (U) and instantaneous fishing mortality rates (F) were estimated by calculating the proportion of the stock biomass removed (an estimate of the utilization rate) and iterating the catch equation to solve for F:

$$U = F/Z*\{1 - \exp(-[F+M])\} \qquad (14)$$

The stock biomass only includes the strata that were surveyed, and the traditional length-weight equations were used. The entire catch is assumed to have come from the surveyed strata, an assumption that was true until 1997. In 1997, some of the landings have been taken from waters deeper than those surveyed. These analyses incorporate uncertainty in minimum swept-area population estimates and provide results for each assessment area separately (Table E22, Figure E44).

Two major components of uncertainty in estimates of F are 1) variation in survey abundance estimates and 2) variation in gear efficiency over sampled strata. The two factors are not mutually exclusive. For example, variation in efficiency over depth or substrate contributes to the survey variability estimates by the bootstrapping approach. Analyses of the effects of sampling variation (i.e., bootstrap CI) on estimates of F were assessed as follows. The point estimate of dredge efficiency (0.43) was divided into the mean and bootstrap 95% CI to give three estimates of stock biomass in 1997 for each area. The 1997 catch (mt) was divided by these three estimates to derive exploitation rates associated with the CI of stock biomass, which were then solved for F (Table E22). No analyses of the effects of variation in dredge efficiency were conducted.

For the exploited regions (SNE, LI, NJ, DMV) taken together, current Fs associated with the lower CI, the mean biomass, and the upper CI were 0.035, 0.021, and 0.014, respectively. For SNE, where 47% of the EEZ landings were taken in 1997, current Fs associated with the lower CI, the mean biomass, and the upper CI were 0.090, 0.035, and 0.019, respectively. Other areas show current exploitation rates lower than those of SNE. For the entire surveyed stock including GBK, the set of Fs is 0.017, 0.014, and 0.012. Fs based on the geostatistical estimate of biomass were similar (Table E22).

Estimation of pristine biomass

Although the biomass dynamics model was not estimated, the general principles of the surplus production model were considered. In particular, it was assumed that the population size at the start of the fishery in 1976 was representative of the pristine biomass for the resource. In view of the great longevity of ocean quahogs (over 200 years) and absence of prior exploitation, the population size in 1976 was probably near the carrying capacity K.

Population reconstruction techniques or VPA was used to estimate pristine stock size. Instantaneous growth and mortality rates were assumed to exactly offset each other (M - G = 0) and recruitment was assumed to be zero. Under these assumptions, population biomass was reconstructed using the following equation:

$$B_t = B_{t+1}\, e^{(M-G)} + C_t \qquad (15)$$

An initial application of this approach is shown in Figure E45. The 1997 biomass estimate, derived from kriging, was considered the most reliable value in the survey time series and, therefore, was used as the starting value. For comparison, the backward projection of the 1983 estimate, using 1997 as a starting point, was plotted with the actual 95% confidence interval from the 1983 survey. These results should be viewed as preliminary and subject to further refinement. Nonetheless, the results suggest that the current stock size is about 80% of the pristine biomass present in 1976.

SFA considerations

The current biomass is less than the likely carrying capacity of the resource, but well above K/2. Moreover, the current fishing mortality rates are well below existing fishing mortality rate thresholds. Current status of the ocean quahog resource is schematically depicted in Figure E46. The 1997 surveyed biomass estimate (1.4 million mt) is at about 80% of the virgin biomass (1.8 million mt). This figure suggests that fishing mortality rates are below two alternative action levels and that overall population biomass exceeds levels which would require rebuilding. Nonetheless, 22 years of harvesting appear to have reduced the population in some areas. It is not yet possible to characterize the dynamic response of the population to these decreases in density. In many instances, the recruits that might have been produced as a result of prior reductions are only now becoming vulnerable to the survey dredge. Thus, some caution is necessary in the interpretation of Figure E46.

SARC Comments

The fraction of resource in water beyond that traditionally sampled is unknown. This is critical to determine.

Conversion of minimum swept-area biomass to total biomass relies on the estimate of dredge efficiency. Much work remains to be done, not only to obtain an overall estimate of efficiency for each clam species, but to understand, on a finer scale, its dependence on depth and bottom type.

The SARC discussed whether the historical survey time series should be used as an indicator of relative abundance. Changes in survey methods and apparent changes in gear efficiency make it difficult to interpret the historical survey time series. Much reliance is placed on the most recent survey (i.e., 1997), and additional surveys are necessary to corroborate the findings from the 1997 survey. With the addition of sensors on the survey dredge and additional studies to determine dredge efficiency, it should be possible to establish a reliable time series starting with the 1997 survey.

There is considerable uncertainty about the impact of harvesting on ocean quahog population dynamics. Of particular concern is the effect of reduced clam density on fertilization rate and the effect of dredging on recruitment. The SARC felt that these subjects should take on a high priority for future research.

It is unclear why small individuals are sometimes captured by the dredge. The rate of clogging of the dredge with shells and debris may be an important factor affecting selectivity of small surfclams and ocean quahogs.

The SARC discussed the causes underlying the northeastward expansion of the ocean quahog fishery.

Research Recommendations

- Studies are needed to determine whether reduced clam density, resulting from harvesting, has an impact on fertilization rate. In particular, at what density does the probability of reproductive success decline. Studies are needed to determine if area closures would reduce the risk of reduced fertilization rates in fished areas. The impact of harvesting on larval recruitment and juvenile survival should also be investigated.

- The most important need for the 1999 survey is to expand the area surveyed. New areas requiring surveying are of three types:

  1) Because of the sensitivity of the stock assessment and quota-setting process on the total quahog biomass present, it is essential to include as much of the biomass as possible within the survey. In order to do this, the survey needs to be extended to the 60-fathom contour from Cape Hatteras to Georges Bank. Extending the survey to 50 fathoms would be a distinct improvement.

  2) Some strata in shallower water (42, 43) have not been sampled because they contain mud, but there are data suggesting that ocean quahogs are present and may be exploited in those areas. Stratum 63 on GBK should also be sampled.

  3) Although this report targets ocean quahogs, the Invertebrate Working Group earlier also identified a need to increase the sampling of surfclams off northern New Jersey to obtain a better estimate of density in fished areas.

- In order to sample to 60 fathoms, survey gear will need to be modified. The pump housing will have to be modified to withstand more pressure. The power cable will have to be extended to tow in 60 fathoms, and will require the purchase of a new, longer power cable.

- The rate of deployment and retrieval of the dredge has proven to be a critical variable in calculating abundance because it introduces a bias into the estimate of the area swept by the dredge. In some cases, the present winch has increased the area swept by an estimated factor of 2 because of the slowness of deployment and retrieval. Therefore, a winch capable of a much more rapid rate of deployment and retrieval is essential to minimize the errors associated with the calculation of the area swept by the dredge.

- Calibration of dredge efficiency has proven to be extremely useful for calculating abundance from both the 1997 surfclam and ocean quahog surveys. The 1999 survey must be similarly calibrated. Dredge efficiency was obtained in two ways in 1997. The R/V *Delaware II* conducted one experiment by itself. In addition, in 1997, the *Delaware II* "set-up" a series of industry depletion experiments by making 8 standard tows in an area to characterize abundance; this was followed by an industry vessel conducting a depletion experiment at that site to measure true abundance. The 1999 survey should include both of these steps again.

- There is a need to include some fixed stations in the survey, perhaps 20% of the sites. Fixed stations permit a direct comparison between surveys to provide more confidence in the comparisons required from one survey to the next. These fixed stations should be of two types. On Georges Bank, they should be chosen for repeated sampling from one survey to the next. Elsewhere, a certain number of stations should be chosen from the previous two surveys for re-sampling. This was done in 1997 for comparison with 1992 and 1994 and was very successful.

- The 1997 survey included a number of dredge performance sensors which provided extremely valuable data. However, retrieving the data from each of these individual sensors added a significant complexity to post-deployment processing, and the need to calibrate a number of independent clocks proved to be a difficult process. To the extent possible, the data sensor system should be integrated in such a way as to minimize the number of independent clocks and minimize the time required interrogating sensors after each haul.

- To accomplish these addition tasks, there is a need to expand the 1999 survey time slot. Realistically, recognizing the need for additional sampling, the need to sample the deeper stations last to minimize the chances of dredge pump failure compromising the survey, and the time required for depletion set-ups, expansion of the planned

6-week mission to 8 weeks is strongly recommended.

- Size selectivity of the survey dredge for surfclams and ocean quahogs is uncertain and needs to be estimated. The effect of clogging by shells and debris within the dredge should be considered.

- Additional work is needed to determine the contribution of each region to recruitment across geographical regions.

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

Year	State Water	EEZ	Total	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	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]	1,297	22,133	23,430	94	24,494
1994[2]	76	21,017	21,093	99	24,494
1995[2]	1,060	21,169	22,229	95	22,226
1996	1,575	19,499	21,074	93	20,185
1997[3]	-	19,740	-	-	19,581

[1]Landings through 1993 and for 1996 are from the U.S. Dept. of Commerce series "Fisheries of the United States" (FSUS).
[2]For 1994-95, EEZ landings are from logbooks. The total is from FSUS.
[3]The 1997 EEZ landings were estimated from data available in the logbook database in March, 1998.

Table E2. Annual ocean quahog catch (thousands of metric tons), effort (thousands of hours fished), and CPUE data (kilograms per hour fished) by EEZ region.

	Delmarva[1]				New Jersey				Long Island			
Year	Sum[2]	Catch[3]	Eff[3]	CPUE[3]	Sum	Catch	Eff	CPUE	Sum	Catch	Eff	CPUE
1978[4]	1.29	-	-	-	6.35	-	-	-	0.00	-	-	-
1979	5.45	-	-	-	6.03	-	-	-	0.00	-	-	-
1980[5]	4.23	4.02	6.61	609	7.75	6.41	13.18	486	0.01	-	0.03	183
1981	3.64	3.59	5.78	621	8.40	7.30	13.35	547	0.00	-	-	556
1982	4.60	4.47	6.91	647	8.54	7.86	12.86	611	0.00	-	-	-
1983	5.40	5.19	6.85	758	8.25	7.73	12.57	615	0.02	0.02	0.05	421
1984	7.16	6.45	9.71	665	8.86	7.96	13.63	584	0.00	-	-	-
1985	7.20	6.42	8.61	746	10.68	9.81	16.25	604	0.04	0.04	0.09	462
1986	8.23	6.94	9.80	708	9.06	8.33	13.20	631	0.40	0.37	0.32	1159
1987	10.54	9.53	13.73	694	9.07	8.10	13.69	592	1.18	1.18	0.81	1454
1988	11.72	10.92	18.00	607	7.01	6.71	11.39	589	0.64	0.44	0.46	964
1989	6.44	5.43	10.39	523	14.10	12.15	21.37	568	0.60	0.60	0.80	759
1990	3.69	2.88	6.21	464	15.58	13.46	25.26	533	0.74	0.74	1.28	577
1991	4.84	3.97	9.99	397	14.57	12.64	26.96	469	1.67	0.94	1.15	820
1992	2.38	1.92	4.50	426	6.94	5.38	13.55	397	11.94	10.53	12.1	870
1993	1.98	1.74	4.33	401	10.17	8.03	21.26	377	8.65	7.85	11.94	657
1994	0.99	0.98	2.21	441	6.97	6.04	18.31	330	11.98	10.29	16.73	615
1995	0.70	0.70	1.61	431	5.36	3.90	10.19	382	9.46	7.81	12.57	621
1996	0.74	0.74	2.45	300	4.86	2.96	5.71	519	5.91	5.43	8.98	605
1997	1.06	0.95	2.44	391	4.24	2.71	5.84	464	5.13	4.63	7.25	638

	Southern New England				Total Southern Area				Maine			
Year	Sum	Catch	Eff	CPUE	Sum	Catch	Eff	CPUE	Sum	Catch	Eff	CPUE
1978	0.07	-	-	-	7.72	-	-	-	-	-	-	-
1979	-	-	-	-	11.48	-	-	-	-	-	-	-
1980	-	-	-	-	11.99	10.44	19.82	527	-	-	-	-
1981	-	-	-	-	12.10	10.95	19.22	570	-	-	-	-
1982	-	-	-	-	13.14	12.35	19.79	624	-	-	-	-
1983	0.63	0.62	1.55	401	14.29	13.56	21.02	645	-	-	-	-
1984	0.82	0.82	2.51	327	16.85	15.24	25.87	589	-	-	-	-
1985	0.69	0.69	2.07	335	18.77	17.13	27.22	629	-	-	-	-
1986	0.56	0.56	1.14	494	18.25	16.21	24.46	662	-	-	-	-
1987	0.70	0.67	1.17	573	21.49	19.48	29.40	663	-	-	-	-
1988	0.84	0.68	1.24	553	20.25	18.80	31.15	603	-	-	-	-
1989	1.20	0.91	2.08	438	22.34	19.09	34.65	551	-	-	-	-
1990	0.93	0.91	1.83	498	20.96	18.01	34.61	520	0.004	-	-	-
1991	0.86	0.86	1.43	599	21.95	18.41	39.53	466	0.166	0.075	8.17	9
1992	1.14	1.09	1.52	713	22.40	18.92	31.68	597	0.113	0.051	6.15	8
1993	1.02	0.94	1.32	707	21.82	18.55	38.86	477	0.085	0.032	2.29	14
1994	.95	0.87	1.47	593	20.90	18.18	38.72	469	0.097	0.052	2.32	22
1995	5.44	5.42	8.34	651	20.96	17.82	32.71	545	0.208	0.080	2.53	32
1996	8.32	7.63	10.76	709	19.82	16.76	27.90	601	0.204	0.076	2.53	30
1997	8.96	7.99	11.58	690	19.40	16.28	27.12	601	0.103	0.030	1.01	30

1 Regions correspond to those shown in Figure E2. "Total Southern Area" = Delmarva + New Jersey + Long Island + Southern New England + George's Bank + S. Virginia/N. Carolina. It does not include Maine.

2 "Sum" is the sum of all landings by all vessels.

3 Catch, effort, and CPUE are based on large Class 3 vessels, except for the Maine region where small vessels were used. For Maine 1997, only federal codeQ888 is reported.

4 Sums from 1978-1979 are based on the "WO" database. Sums from 1980-1997 as well as catch, effort and CPUE values are based on the s1032 logbook database.

5 From 1980-1997, trips were assigned to regions based on their ten minute squares.

Table E3. Ocean quahog GLM OF CPUE 1983-1997 for Southern New England. Factors are year, subregion, and tonclass. Standards are: year = 1997, toncl = 3 large, subreg = 1.

General Linear Models Procedure

Dependent Variable: L_LPUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	16	365.5226351	22.84516470	117.71	0.0001
Error	2749	533.52712492	0.19408044		
Corrected Total	2765	899.04976008			

R-Square	C.V.	Root MSE	L_LPUE Mean
0.406566	7.001920	0.44054561	6.29178304

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	14	146.57451220	10.46960801	53.94	0.0001
SUBREG	1	32.06215132	32.06215132	165.20	0.0001
TONCL	1	186.88597163	186.88597163	962.93	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	14	96.66618763	6.90472769	35.58	0.0001
SUBREG	1	33.35205642	33.35205642	171.85	0.0001
TONCL	1	186.88597163	186.88597163	962.93	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		6.709513767 B	317.01	0.0001	0.02116508
YEAR	1983	-0.509545605 B	-8.30	0.0001	0.06140590
	1984	-0.716299584 B	-13.39	0.0001	0.05348451
	1985	-0.654602220 B	-12.11	0.0001	0.05405379
	1986	-0.302001771 B	-4.79	0.0001	0.06299273
	1987	-0.141945355 B	-2.64	0.0083	0.05370031
	1988	-0.098542958 B	-1.99	0.0466	0.04950034
	1989	-0.166560205 B	-3.63	0.0003	0.04588896
	1990	-0.330273620 B	-6.09	0.0001	0.05419805
	1991	-0.332449887 B	-6.63	0.0001	0.0515839
	1992	-0.123892968 B	-3.01	0.0026	0.04113125
	1993	-0.216120524 B	-5.42	0.0001	0.03984774
	1994	-0.436990246 B	-10.61	0.0001	0.04119593
	1995	-0.231305612 B	-8.22	0.0001	0.02814461
	1996	-0.000425465 B	-0.02	0.9871	0.02639467
	9999	0.000000000 B	.	.	.
SUBREG	2	-0.249880673 B	-13.11	0.0001	0.01906173
	99	0.000000000 B	.	.	.
TONCL	2	-0.816430822 B	-31.03	0.0001	0.02631007
	99	0.000000000 B	.	.	.

Table E4. Ocean quahog GLM OF CPUE 1980-1997 for Long Island. Factors are year, subregion, and ton-class. Standards are: year = 1997, toncl = 3 large, subreg = 1.

General Linear Models Procedure

Dependent Variable: L_LPUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	16	201.30887390	12.58180462	89.29	0.0001
Error	4906	691.26666894	0.14090230		
Corrected Total	4922	892.57554284			

R-Square	C.V.	Root MSE	L_LPUE Mean
0.225537	5.756932	0.37536955	6.52030483

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	14	160.78457738	11.48461267	81.51	0.0001
SUBREG	1	40.07099913	40.07099913	284.39	0.0001
TONCL	1	0.45329739	0.45329739	3.22	0.0729

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	14	186.16590286	13.29756449	94.37	0.0001
SUBREG	1	40.00325557	40.00325557	283.9	0.0001
TONCL	1	0.45329739	0.45329739	3.22	0.0729

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		6.450808836 B	338.34	0.0001	0.01906598
YEAR	1980	-1.004928954 B	-2.67	0.0076	0.37603034
	1983	-0.455414802 B	-2.41	0.0158	0.18865070
	1985	0.018212398 B	0.14	0.8924	0.13457082
	1986	0.671580956 B	9.06	0.0001	0.07410779
	1987	1.035408149 B	23.83	0.0001	0.04345520
	1988	0.696086165 B	10.57	0.0001	0.06588271
	1989	0.378126113 B	6.73	0.0001	0.05616984
	1990	0.269925684 B	5.16	0.0001	0.05228420
	1991	0.336039428 B	9.33	0.0001	0.03601241
	1992	0.329090334 B	14.51	0.0001	0.02268169
	1993	0.110394561 B	4.63	0.0001	0.02385286
	1994	0.058862163 B	2.64	0.0083	0.02228945
	1995	0.000355282 B	0.02	0.9875	0.02261351
	1996	-0.041016071 B	-1.69	0.0917	0.02431277
	9999	0.000000000 B	.	.	.
SUBREG	2	-0.235710902 B	-16.85	0.0001	0.01398914
	99	0.000000000 B	.	.	.
TONCL	2	-0.028043592 B	-1.79	0.0729	0.01563511
	99	0.000000000 B	.	.	.

Table E5. Ocean quahog GLM OF CPUE 1980-1997 for New Jersey. Factors are year, subregion, and ton-class. Standards are: year = 1997, toncl = 3 large, subreg = 1.

General Linear Models Procedure

Dependent Variable: L_LPUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	20	567.43338224	28.37166911	184.71	0.0001
Error	18119	2783.09771969	0.15360107		
Corrected Total	18139	3350.53110192			

R-Square	C.V.	Root MSE	L_LPUE Mean
0.169356	6.317715	0.39191972	6.20350427

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	17	439.45539203	25.85031718	168.30	0.0001
SUBREG	1	106.12426650	106.12426650	690.91	0.0001
TONCL	2	21.85372370	10.92686185	71.14	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	17	471.70543370	27.74737845	180.65	0.0001
SUBREG	1	101.32930878	101.32930878	659.69	0.0001
TONCL	2	21.85372370	10.92686185	71.14	0.0001

Parameter		Estimate		T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		6.349928912	B	308.81	0.0001	0.02056241
YEAR	1980	0.047520666	B	2.15	0.0314	0.02208144
	1981	0.097510216	B	4.43	0.0001	0.02202858
	1982	0.188675463	B	8.42	0.0001	0.02239830
	1983	0.227729633	B	10.11	0.0001	0.02252535
	1984	0.172689720	B	7.78	0.0001	0.02220655
	1985	0.187070644	B	8.65	0.0001	0.02161496
	1986	0.215412555	B	9.59	0.0001	0.02246857
	1987	0.185913710	B	8.15	0.0001	0.02281871
	1988	0.159785782	B	6.73	0.0001	0.02375192
	1989	0.153184055	B	7.11	0.0001	0.02153922
	1990	0.073427307	B	3.44	0.0006	0.02136018
	1991	-0.055037115	B	-2.55	0.0109	0.02162239
	1992	-0.111657074	B	-4.71	0.0001	0.02371701
	1993	-0.204658175	B	-9.30	0.0001	0.02200375
	1994	-0.382006811	B	-16.58	0.0001	0.02304166
	1995	-0.181260358	B	-7.48	0.0001	0.02422772
	1996	0.127770174	B	4.98	0.0001	0.02563098
	9999	0.000000000	B	.	.	.
SUBREG	2	-0.226305531	B	-25.68	0.0001	0.00881099
	99	0.000000000	B	.	.	.
TONCL	1	-0.888597229	B	-8.16	0.0001	0.10891269
	2	-0.073266450	B	-8.80	0.0001	0.00832614
	99	0.000000000	B	.	.	.

Table E6. Ocean quahog GLM OF CPUE 1980-1997 for Delmarva. Factors are year, subregion, and tonclass. Standards are: year = 1997, toncl = 3 large, subreg = 1.

General Linear Models Procedure

Dependent Variable: L_LPUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	20	403.65303207	20.18265160	130.47	0.0001
Error	9107	1408.79533409	0.15469368		
Corrected Total	9127	1812.44836616			

R-Square	C.V.	Root MSE	L_LPUE Mean
0.222711	6.189894	0.39331117	6.35408601

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	17	277.64035793	16.33178576	105.58	0.0001
SUBREG	1	31.46223870	31.46223870	203.38	0.0001
TONCL	2	94.55043544	47.27521772	305.61	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	17	198.71338255	11.68902250	75.56	0.0001
SUBREG	1	36.37871962	36.37871962	235.17	0.0001
TONCL	2	94.55043544	47.27521772	305.61	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		5.835200567 B	148.30	0.0001	0.03934600
YEAR	1980	0.450083016 B	10.56	0.0001	0.04261477
	1981	0.440549280 B	10.17	0.0001	0.04331450
	1982	0.504554490 B	11.96	0.0001	0.04217140
	1983	0.611165177 B	14.70	0.0001	0.04158467
	1984	0.500700890 B	12.22	0.0001	0.04098113
	1985	0.596269791 B	14.55	0.0001	0.04097907
	1986	0.565683145 B	13.95	0.0001	0.04056260
	1987	0.548428980 B	13.66	0.0001	0.04015449
	1988	0.470507030 B	11.74	0.0001	0.04008497
	1989	0.354442228 B	8.48	0.0001	0.04179651
	1990	0.250935570 B	5.82	0.0001	0.04312925
	1991	0.128928303 B	3.07	0.0021	0.04194391
	1992	0.216772240 B	4.66	0.0001	0.04652622
	1993	0.224586549 B	4.80	0.0001	0.04679121
	1994	0.176817182 B	3.24	0.0012	0.05455269
	1995	0.102523086 B	1.77	0.0771	0.05797991
	1996	0.143038816 B	2.45	0.0143	0.05837523
	9999	0.000000000 B	.	.	.
SUBREG	2	0.154972025 B	15.34	0.0001	0.01010569
	99	0.000000000 B	.	.	.
TONCL	1	-1.035842551 B	-5.25	0.0001	0.19725878
	2	-0.298392733 B	-24.21	0.0001	0.01232442
	99	0.000000000 B	.	.	.

Table E7. Cumulative annual ocean quahog catch and CPUE data for nine ten-minute squares in the EEZ from Delmarva to Southern New England from 1980-1997.

	Ten Minute Square																	
	377422		377431		377441		387462		387463		407346		407356		407223		407131	
Year	CUM[1]	CPUE[2]	CUM	CPUE	CUM	CPUE	CUM	CPUE	CUM	CPUE	CUM	CPUE	CUM	CPUE	CUM	CPUE	CUM	CPUE
1980	.04	687	1.54	710	.48	651	.66	480	.00	387	-	-	-	-	-	-	-	-
1981	.18	808	2.71	580	.75	571	1.13	618	.15	681	-	-	-	-	-	-	-	-
1982	.38	896	4.73	684	1.25	701	1.77	571	.69	629	-	-	-	-	-	-	-	-
1983	2.05	728	6.62	804	1.30	862	2.15	619	2.12	740	-	-	-	-	-	-	-	-
1984	3.09	627	8.40	647	2.26	799	3.20	633	4.13	668	-	-	-	-	-	-	-	-
1985	4.10	768	10.00	735	4.62	852	5.67	604	5.42	644	.13	841	-	-	-	-	.21	301
1986	5.69	674	11.97	735	5.67	732	6.84	593	5.99	642	.94	999	.05	859	-	-	.46	561
1987	7.03	750	14.52	718	7.73	637	8.10	607	6.60	597	1.59	624	-	-	-	-	.73	552
1988	8.75	610	17.14	664	10.09	578	8.99	539	7.63	536	2.79	806	-	-	-	-	-	-
1989	8.99	411	17.53	514	10.96	497	10.94	514	8.77	545	3.88	728	.54	808	-	-	-	-
1990	9.19	399	18.08	451	11.50	562	12.45	479	10.15	522	4.77	676	1.00	936	.16	366	-	-
1991	9.34	259	18.80	362	12.07	404	13.35	396	10.91	434	6.27	672	1.16	648	.70	971	-	-
1992	9.54	404	18.92	289	12.12	365	14.34	372	11.52	408	6.86	597	1.28	656	6.96	911	.99	712
1993	-	-	18.98	347	12.21	185	14.83	295	12.03	340	7.34	547	1.38	516	9.39	685	1.04	642
1994	9.76	493	19.23	496	12.26	110	15.07	296	12.16	287	8.23	477	2.49	536	11.45	658	1.08	541
1995	10.20	431	19.25	440	-	-	15.11	356	12.24	379	8.57	426	2.76	411	11.95	551	1.30	532
1996	10.23	331	19.33	70	12.39	216	-	-	-	-	8.71	419	2.87	463	12.22	589	1.55	576
1997	10.28	408	19.49	396	12.64	611	-	-	12.30	286	8.75	392	2.98	458	12.39	584	2.13	508

[1]Cumulative catch data (CUM) are thousands of metric tons of shucked meats collected by vessels of all sizes from 1980-1997.
[2]Catch per unit effort data (CPUE) are kg/hour fishing by class 3 (large) vessels.

Table E8. 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
1995	84.8	65	105	420
1996	84.0	65	115	635
1997	84.6	55	105	570
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
1995	-	-	-	-
1996	92.0	75	105	60
1997	93.9	65	115	540
Long Island				
1992	87.3	70	98	30
1993	-	-	-	-
1994	89.7	75	105	30
1995	-	-	-	0
1996	83.1	65	105	79
1997	89.0	55	135	840
Southern 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	-	-	-	-
1995	-	-	-	-
1996	86.7	65	115	356
1997	78.7	55	105	310

[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]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 LDR 83-25. Values from 1985-1990 and 1994 are from subsamples of the data. Subsamples contain data from 30 randomly selected trips, when available.

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

Table E9. Summary of depletion experiments for ocean quahog by site. Estimates of area swept are derived using GIS techniques. Tows included in the analysis are denoted by a 1. Density and efficiency estimates are derived using maximum likelihood estimation. Confidence intervals on efficiency derived using profile likelihood.

	Depletion Site Name				
Tow Number	Shinnecock #1 (bushels)	Shinnecock #2 (bushels)	Shinnecock #3 (bushels)	Nantucket Shoals (bushels)	Wildwood (bushels)
1	6*	9	6.25	41.5	0.5*
2	14.5*	4.75	11.75	72	1.75
3	16.33	9.9	6.1	58	1.9
4	16	4.6	5.5	40	3.9
5	14.9	4.5	4.6	64.5	2
6	9.25	6	3.5	38	1.9
7	16	5	2.75	56	1.25
8	12.75	8.1	3	56	2.9
9	14.25	5.5	1.5	50	1.8
10	10.66	3	3.25	24	2.1
11	12.25	6	4.3	95	0.9
12	12.9*	3.75	2	26	2
13	12.4	3.6	1.6	46	0.9
14	9.4	3.25	1.2	19	4
15	10.25	4.1		64	0.4
16	11.4	2.75		27	1.8
17	7.2	4		58	2.7
18	9.5*	1.25		29	1.8
19	6.2	4.1		52	8.25*
20	7.9	2.3		28	2.5
21	6.1	2.5		18	3.1
22	4.7	4		29	1.8
23	8	2.9		22	5.1*
24	7			33	3
25	6.5				0.5
26	6.8				1.8
27	6.1				6.4*
28	9.2				1.2
29	3.5				2
30	5.4				2.8
31	5				0.4
32	2.4				0.3

Summary Statistics

	Shinnecock #1	Shinnecock #2	Shinnecock #3	Nantucket Shoals	Wildwood
Total Area Swept (m^2)	28364	21874	12459	44028	45495
Ave Area Swept/Tow [a] (m^2)	1554	951	890	1835	1625
Area Swept at least once [A] (m^2)	13619	10479	7867	34011	32017
Number/Bushel	240.4	169.4	169.4	208.0	152.7
Population Size [N] (bushels)	349.7	154.3	67.8	2722.4	155.6
Population Size (numbers)	84,051	26,143	11,479	566,259	23,762
Density (#/m^2)	6.17	2.49	1.46	16.65	0.74
Catchability Parameter [p]	0.0466	0.0483	0.1249	0.0200	0.0149
Estimated Efficiency [e]	0.4088	0.5317	1.1045	0.3708	0.2936
Lower Bound Efficiency	0.3287	0.2204	0.5658	0.3152	undefined
Upper Bound Efficiency	0.5040	0.8374	1.6399	0.7787	0.9261

/* Tows denoted with an asterisk were considered outliers and not included in the Leslie-Davis depletion model estimates of density and efficiency

Table E10. Survey stock size estimates for ocean quahogs in number and meat weight per tow and by region for 1997. Estimates are based on 5 mm size intervals. Catch was not adjusted for dredge efficiency. Catch per tow was standardized to a distance of 0.15 nmi based on either sensors on the dredge (assuming a critical blade depth for sampling of 2, 4, 6, or 8 inches) or just on doppler distance during the timed 5 minute tow.

Bootstrap

1997		Number/Tow						Total Weight					
		per tow (#)			per region (#)			per tow (Kg)			per region (mt)		
Region	Tows/Region	lower	mean	upper	lower	mean	upper	lower	mean	upper	lower	mean	upper
2 in													
GBK	58,679,132	88.69	128.50	169.10	5,204,252	7,540,268	9,922,641	1.88	2.80	3.67	110,551	164,008	215,587
SNE	43,505,031	37.89	113.40	222.03	1,648,406	4,933,471	9,659,422	1.08	2.43	4.49	46,898	105,891	195,164
LI	36,278,497	122.30	179.90	240.70	4,436,860	6,526,502	8,732,234	3.15	4.57	6.23	114,386	165,902	226,088
NJ	55,543,853	36.04	50.90	65.21	2,001,800	2,827,182	3,622,015	1.31	1.79	2.28	72,485	99,590	126,751
DMV	34,771,619	10.31	18.95	26.66	358,495	658,922	927,011	0.41	0.67	0.96	14,211	23,377	33,447
SVA	4,172,270	0.12	0.23	0.24	502	944	1,005	0.00	0.00	0.00	0	0	0
ALL	232,950,403	74.15	95.50	119.41	17,273,272	22,246,763	27,816,608	1.93	2.40	2.92	450,293	559,314	679,050
4 in													
GBK	58,679,132	100.30	143.40	187.50	5,885,517	8,414,588	11,002,337	1.95	3.03	4.06	114,366	177,563	238,355
SNE	43,505,031	35.99	121.70	261.86	1,565,746	5,294,562	11,392,227	1.04	2.59	4.77	45,028	112,678	207,301
LI	36,278,497	125.70	186.40	252.60	4,560,207	6,762,312	9,163,948	2.95	4.74	6.40	107,022	171,779	232,219
NJ	55,543,853	37.60	52.30	67.88	2,088,449	2,904,944	3,770,317	1.33	1.86	2.35	73,929	103,423	130,639
DMV	34,771,619	11.63	19.97	28.49	404,394	694,389	990,643	0.43	0.70	1.04	15,060	24,479	36,176
SVA	4,172,270	0.12	0.18	0.24	502	746	1,005	0.00	0.00	0.00	0	0	0
ALL	232,950,403	81.41	104.20	131.96	18,964,492	24,273,432	30,740,135	2.09	2.57	3.10	487,798	599,381	722,612
6 in													
GBK	58,679,132	131.80	187.20	239.40	7,733,910	10,984,734	14,047,784	2.77	4.01	5.21	162,776	235,127	305,953
SNE	43,505,031	41.68	148.00	292.34	1,813,290	6,438,745	12,718,261	1.20	3.20	5.86	52,163	139,216	254,852
LI	36,278,497	135.30	205.60	276.80	4,908,481	7,458,859	10,041,888	3.59	5.27	7.37	130,167	191,224	267,336
NJ	55,543,853	40.99	58.64	77.35	2,276,743	3,257,092	4,296,317	1.43	2.05	2.66	79,483	113,976	147,469
DMV	34,771,619	12.79	22.81	32.69	444,729	793,141	1,136,684	0.49	0.79	1.16	40,335	16,965	27,518
SVA	4,172,270	0.12	0.19	0.30	502	784	1,268	0.00	0.00	0.00	0	0	0
ALL	232,950,403	95.53	124.60	160.97	22,253,752	29,025,620	37,498,026	2.42	3.05	3.71	564,439	709,567	863,081
8 in													
GBK	58,679,132	288.40	436.10	567.90	16,923,062	25,589,970	33,323,879	6.66	9.63	13.00	390,920	565,080	762,946
SNE	43,505,031	70.62	214.00	431.99	3,072,325	9,310,077	18,793,738	1.75	4.53	8.39	76,177	196,904	365,051
LI	36,278,497	157.40	237.40	324.10	5,710,235	8,612,515	11,757,861	3.94	6.02	8.54	142,901	218,505	309,927
NJ	55,543,853	48.39	70.09	92.19	2,687,767	3,893,069	5,120,588	1.72	2.44	3.10	95,647	135,527	172,297
*DMV	34,771,619	16.88	29.99	43.55	586,945	1,042,801	1,514,304	0.60	1.04	1.53	20,773	36,093	53,350
SVA	4,172,270	0.12	0.22	0.36	502	906	1,507	0.00	0.00	0.00	0	0	0
ALL	232,950,403	156.80	206.40	261.40	36,526,623	48,080,963	60,893,235	3.83	4.96	6.14	892,200	1,156,133	1,429,384
Doppler													
GBK	58,679,132	190.30	299.90	408.60	11,166,639	17,597,872	23,976,293	4.15	6.46	8.95	243,694	378,891	525,296
SNE	43,505,031	83.75	280.30	570.32	3,643,546	12,194,460	24,811,789	2.22	5.79	11.35	96,494	251,677	493,913
LI	36,278,497	278.40	402.60	539.50	10,099,934	14,605,723	19,572,249	7.26	10.11	13.44	263,346	366,776	487,510
NJ	55,543,853	82.70	117.30	149.70	4,593,477	6,515,294	8,314,915	3.01	4.12	5.24	166,909	228,785	291,105
DMV	34,771,619	24.02	45.30	63.29	835,214	1,575,154	2,200,696	0.98	1.59	2.23	33,944	55,217	77,520
SVA	4,172,270	0.12	0.37	0.60	502	1,533	2,511	0.00	0.00	0.00	0	0	0
ALL	232,950,403	168.20	222.30	287.60	39,182,258	51,784,875	66,996,536	4.37	5.50	6.77	1,018,226	1,280,295	1,578,006

Table E11. Survey stock size estimates for ocean quahogs in number and meat weight per tow and by region for 1984, 1986, 1989, 1992, and 1994. Estimates are based on 5 mm size intervals. Catch was not adjusted for dredge efficiency. Catch per tow was standardized to a distance of 0.15 nmi based on doppler distance during the timed 5 minute tow. "ns": region not sampled. "*": some strata in this region were not sampled.

Bootstrap

		Number/Tow						Total Weight					
		per tow (#)			per region (#)			per tow (Kg)			per region (mt)		
Region	Tows/Region	lower	mean	upper	lower	mean	upper	lower	mean	upper	lower	mean	upper
1994													
GBK	58,679,132	276.50	423.80	578.00	16,224,780	24,868,216	33,916,538	6.36	9.86	13.93	373,199	578,283	817,400
SNE	43,505,031	247.90	462.40	717.40	10,784,897	20,116,726	31,210,509	6.80	11.60	16.90	295,834	504,658	735,235
LI	36,278,497	411.40	592.60	796.70	14,924,974	21,498,637	28,903,079	9.75	13.95	18.74	353,643	506,085	679,823
NJ	55,543,853	141.30	231.30	330.30	7,848,346	12,847,293	18,346,135	4.83	7.58	10.48	268,443	420,856	581,988
DMV	34,771,619	21.16	38.25	61.15	735,767	1,330,014	2,126,284	0.81	1.27	1.86	28,321	44,056	64,567
SVA	4,172,270	0.24	4.67	10.90	1,005	19,464	45,485	0.12	0.30	0.61	502	1,249	2,552
ALL	232,950,403	272.30	341.70	419.70	63,432,395	79,599,153	97,769,284	7.10	8.84	10.47	1,652,783	2,059,282	2,438,059
1992													
*GBK	46,389,163	204.70	365.60	541.70	9,495,862	16,959,878	25,129,010	4.89	8.44	12.45	226,843	391,478	577,545
SNE	43,505,031	216.70	326.60	426.20	9,427,540	14,208,743	18,541,844	5.83	8.57	11.65	253,808	372,708	506,877
LI	36,278,497	209.20	315.80	427.30	7,589,462	11,456,749	15,501,802	5.51	7.61	10.20	199,931	276,043	369,896
NJ	55,543,853	59.08	87.11	119.51	3,281,531	4,838,425	6,638,046	2.01	2.98	4.01	111,365	165,632	222,897
DMV	34,771,619	26.80	68.98	126.80	931,879	2,398,546	4,409,041	1.06	2.21	3.63	36,719	76,776	126,291
SVA	4,172,270	0.00	0.00	0.00	0	0	0	0.00	0.00	0.00	0	0	0
ALL	220,950,403	182.60	228.00	275.90	40,345,544	50,376,692	60,960,216	4.76	5.79	7.08	1,052,608	1,279,524	1,563,666
1989													
GBK	ns	-	-	-	-	-	-	-	-	-	-	-	-
*SNE	36,205,584	134.10	233.50	333.60	4,855,169	8,454,004	12,078,183	3.60	5.91	8.07	130,413	214,011	291,998
LI	36,278,497	110.00	224.80	398.50	3,990,635	8,155,406	14,456,981	2.49	4.53	7.27	90,333	164,305	263,890
NJ	55,543,853	40.43	67.05	99.12	2,245,638	3,724,215	5,505,507	1.27	2.05	3.04	70,763	113,809	168,576
DMV	34,771,619	15.99	62.37	132.08	555,998	2,168,706	4,592,635	0.58	1.71	3.37	20,168	59,599	117,180
SVA	4,172,270	0.12	0.81	1.57	502	3,370	6,530	0.00	0.00	0.00	0	0	0
ALL	ns	-	-	-	-	-	-	-	-	-	-	-	-
1986													
GBK	58,679,132	67.73	212.90	341.54	3,974,338	12,492,787	20,041,271	1.77	4.24	6.76	103,627	248,917	396,671
*SNE	41,649,789	143.90	288.90	423.30	5,993,405	12,032,624	17,630,355	3.60	6.96	10.60	150,023	290,007	441,654
LI	36,278,497	182.50	308.30	457.40	6,620,826	11,184,661	16,593,785	4.70	7.65	11.13	170,436	277,567	403,635
NJ	55,543,853	78.63	135.70	200.54	4,367,413	7,537,301	11,138,764	2.73	4.66	6.89	151,801	259,001	382,419
DMV	34,771,619	47.14	74.85	112.34	1,639,134	2,602,656	3,906,244	1.60	2.47	3.55	55,774	85,886	123,265
SVA	4,172,270	0.12	0.62	1.08	502	2,579	4,521	0.12	0.12	0.12	501	501	501
ALL	231,095,160	144.60	196.10	251.10	33,416,360	45,317,761	58,027,995	3.91	5.05	6.24	904,506	1,166,568	1,441,341
1984													
GBK	ns	-	-	-	-	-	-	-	-	-	-	-	-
SNE	ns	-	-	-	-	-	-	-	-	-	-	-	-
LI	ns	-	-	-	-	-	-	-	-	-	-	-	-
*NJ	37,817,781	43.58	119.80	214.80	1,648,099	4,530,570	8,123,259	1.75	3.93	6.83	66,143	148,737	258,182
*DMV	29,724,387	8.82	38.50	79.75	262,110	1,144,389	2,370,579	0.35	1.31	2.64	10,448	39,058	78,615
SVA	4,172,270	0.12	0.25	0.59	502	1,040	2,466	0.12	0.13	0.15	502	536	608
ALL	ns	-	-	-	-	-	-	-	-	-	-	-	-

Table E12. Survey stock size estimates for ocean quahogs in number and meat weight per tow and by region for 1980-1983. Estimates are based on 5 mm size intervals. Catch was not adjusted for dredge efficiency. Catch per tow was standardized to a distance of 0.15 nmi based on doppler distance during the timed 5 minute tow. "ns": region not sampled. "*": some strata in this region were not sampled.

Bootstrap

		Number/Tow						Total Weight					
		per tow (#)			*per region* (#)			*per tow* (Kg)			*per region* (mt)		
Region	Tows/Region	lower	mean	upper	lower	mean	upper	lower	mean	upper	lower	mean	upper
1983													
GBK	ns	-	-	-	-	-	-	-	-	-	-	-	-
SNE	43,505,031	83.10	172.60	260.10	3,615,268	7,508,968	11,315,659	2.10	4.21	6.48	91,317	182,982	281,695
LI	36,278,497	113.20	178.50	263.40	4,106,726	6,475,712	9,555,756	2.84	4.64	6.77	103,031	168,405	245,678
NJ	55,543,853	47.86	82.59	120.66	2,658,329	4,587,367	6,701,921	1.69	2.75	3.80	93,591	152,968	210,956
DMV	34,771,619	25.84	86.27	151.55	898,499	2,999,748	5,269,639	0.87	2.53	4.28	30,251	88,077	148,767
SVA	4,172,270	0.36	2.17	4.57	1,507	9,071	19,076	0.12	0.19	0.31	502	809	1,302
ALL	ns	-	-	-	-	-	-	-	-	-	-	-	-
1982													
GBK	ns	-	-	-	-	-	-	-	-	-	-	-	-
*SNE	39,494,791	142.00	282.20	435.20	5,608,260	11,145,430	17,188,133	3.94	7.34	10.96	155,530	289,931	432,863
LI	36,278,497	185.30	263.80	357.80	6,722,405	9,570,268	12,980,446	3.95	6.03	8.22	143,300	218,651	298,064
NJ	55,543,853	70.76	107.50	151.20	3,930,283	5,970,964	8,398,231	2.21	3.48	5.05	122,585	193,459	280,552
DMV	34,771,619	33.44	75.88	126.65	1,162,763	2,638,470	4,403,826	1.20	2.91	4.78	41,761	101,220	166,034
SVA	4,172,270	0.12	0.15	0.24	502	609	1,005	0.00	0.00	0.00	0	0	0
ALL	ns	-	-	-	-	-	-	-	-	-	-	-	-
1981													
GBK	ns	-	-	-	-	-	-	-	-	-	-	-	-
SNE	ns	-	-	-	-	-	-	-	-	-	-	-	-
LI	36,278,497	152.90	367.10	712.30	5,546,982	13,317,836	25,841,173	3.31	6.66	12.39	119,937	241,470	449,382
NJ	55,543,853	90.77	170.50	258.59	5,041,716	9,470,227	14,363,085	2.94	5.49	8.21	163,077	305,047	455,904
DMV	34,771,619	63.49	137.90	222.28	2,207,650	4,795,006	7,729,035	1.55	4.00	1.16	40,335	53,966	139,052
SVA	4,172,270	0.16	1.80	3.45	683	7,506	14,386	0.00	0.00	0.00	0	0	0
ALL	ns	-	-	-	-	-	-	-	-	-	-	-	-
1980													
GBK	ns	-	-	-	-	-	-	-	-	-	-	-	-
SNE	ns	-	-	-	-	-	-	-	-	-	-	-	-
LI	ns	-	-	-	-	-	-	-	-	-	-	-	-
NJ	55,543,853	66.25	105.30	151.12	3,679,780	5,848,768	8,393,787	2.02	3.23	4.61	112,087	179,184	255,891
*DMV	32,916,376	7.90	52.07	137.41	260,072	1,713,956	4,523,039	0.41	1.90	4.20	13,473	62,508	138,338
SVA	ns	-	-	-	-	-	-	-	-	-	-	-	-
ALL	ns	-	-	-	-	-	-	-	-	-	-	-	-

Table E13. Comparison of bias-corrected bootstrap estimate of stratified random sample population size with kriged estimate for ocean quahogs in 1997. Estimated weights (kg) meat) per tow are standardized to 0.15 nmi.

Parameter	Estimation Method		
	Kriging	Bootstrap	Simple Random Sample
Mean Meat Weight per tow (kg)	2.6	2.57	1.91
Total Population Biomass (mt)	612,218	599,381	448,818
2 x Standard Deviation of Estimate (%)	12.73	—/a	21.98
Lower Limit of Population Biomass	534,466	487,798	350,168
Upper Limit of Population Biomass	689,969	722,612	547,468

—/a Bootstrap Confidence intervals are asymmetric and computed via the percentile method.
Approximate % error bound for total is approximately 0.5*(722,612 - 487,798) / 599,381 = 19.59%

Table E14. Selectivity of the clam dredge used by the *Delaware II* for clam surveys. Ocean quahogs were held at different places on the dredge to see if they could pass through the bars and mesh. Data are from deep stations off Long Island during the 1997 clam survey.

A: The most forward floor grate, attached to the blade.
B: The vertical rectangle between the front grate and main floor rear compartment. Moving aft, height of floor changes, creates gap and it is back a little.
C: Mesh lining the main cage.

					Can OQs pass this space in the dredge?				
Count	Species	Length	Girth	Height	A	B	C	station	date
1	Arctica	50	25	43	yes	yes	yes	318	29-Jun-97
2	Arctica	51	25	45	yes	yes	yes	318	29-Jun-97
3	Arctica	53	30	48	yes	n	yes	318	29-Jun-97
4	Arctica	58	30	50	yes	n	yes	318	29-Jun-97
5	Arctica	59	30	50	yes	n	yes	318	29-Jun-97
6	Arctica	63			yes	yes	yes (diag only)	309	28-Jun-97
7	Arctica	65	31	52	yes	n	yes (diag only)	318	29-Jun-97
8	Arctica	66	34	60	yes	n	n	318	29-Jun-97
9	Arctica	68	34	60	yes	n	yes (diag only)	318	29-Jun-97
10	Arctica	70	38		n	n	n	310	28-Jun-97
11	Arctica	70	38		yes	n	n	310	28-Jun-97
12	Arctica	70	38		yes	yes	n	310	28-Jun-97
13	Arctica	73	38		n	n	n	310	28-Jun-97
14	Arctica	73	40		n	n	n	310	28-Jun-97
15	Arctica	73	36	63	yes	n	n	318	29-Jun-97
16	Arctica	75	38		n	n	n	310	28-Jun-97
17	Arctica	75	41		n	n	n	310	28-Jun-97
18	Arctica	75	37	65	yes	n	n	318	29-Jun-97
19	Arctica	76	43		n	n	n	310	28-Jun-97
20	Arctica	77	42		n	n	n	310	28-Jun-97
21	Arctica	77	37	63	yes	n	n	318	29-Jun-97
22	Arctica	78			n	n	n	309	28-Jun-97
23	Arctica	79			n	n	n	309	28-Jun-97
24	Arctica	80			n	n	n	310	28-Jun-97
25	Arctica	82			n	n	n	309	28-Jun-97
26	Arctica	83			n	n	n	309	28-Jun-97
27	Arctica	83			n	n	n	309	28-Jun-97
28	Arctica	84			n	n	n	309	28-Jun-97
29	Arctica	86			n	n	n	309	28-Jun-97
30	Arctica	86	47		n	n	n	305	28-Jun-97
31	Arctica	90			n	n	n	309	28-Jun-97
32	Arctica	90	48		n	n	n	305	28-Jun-97
33	Arctica	111	57		n	n	n	305	28-Jun-97

Table E15. Ocean quahog supply-year calculations: 30-year harvesting horizon policy (with option to harvest unexploited stock). SNE-SVA run, M = 0.02, R = 1.126% initial biomass, supply-year policy = 30 years.

ASSUMPTIONS / INPUTS:

Full-Recruit Biomass estimate for 1997: (from S. Smith software, bootstrap)
(Exploited Regions Only)

Region	Minimum Biomass
GBK	mt
SNE	112,678
LI	171,779
NJ	103,423
DMV	24,479
SVA	0
Sum Regions:	412,359 mt

Dredge Efficiency: 0.43

Sum (Adj. for Effic.): 958,974 mt
Total Stock Biomass (1997, Exploited Area only)

Do not edit. (used in harvest calc.)
1+exp(M)+exp(2M)+ . +exp(29M) = 36.13
(note: M = m-g)
In parts: 22.56 13.57
(Note: M = m-g, as defined below)

Commercial Catch Estimate from Exploited Area (units: mt):

Year	Catch (mt)	Source
1997	19,581	1997 quota
1998	18,140	1998 quota

Conversion Fac: 10 lbs/bu

Policy: Harvest calculated for 30-yr horizon

Natural Mortality Rate, m: 0.020

Overfishing Def: F_ref 0.0437 = Label F_25% MSP

Portion of total biomass that is unexploited in 1998: 30%

Annual Recruitment: (Pre-recruits grow to Full-Recruits)
Assumed to be a fixed % of Total Stock Biomass = 1.126%
10,798 mt. This is applied to "Actual" Stock Biomass, 1998 +
4,628 mt, annual recruitment in unexploited areas (initially)

Want to exploit part of unexploited stock ?
Enter fraction of unexpl. biomass to make available (exploitable): 1.00
Starting in Year (>=1999): 2011

Annual Growth of Full-Recruits:
(enter fractional increase in meat weight/ clam): 0.0076
(e.g., 0.08 represents 8% / yr)

Instant. Growth Rate (g): 0.0076 (do not type this value.) (computed by spreadsheet)

SIMULATION RESULTS:

Marker		Year	Biomass (Expl), mt	Biomass (Unexpl), mt	Tot Biomass	Harvest from Expl. Area: mt	bushels	Realized Exploitation Rate: Expl Areas	All Areas	Overfishing Ref. Point: Inst. Rate (F_ref) = F_25% MSP	Exploit. Rate = (F_ref / Z) * (1-exp(-Z))
0	1	1998	938,455	410,463	1,348,938	18,140	3,999,185.40	1.9%	1.3%	0.0437	4.2%
0	2	1999	919,612	409,984	1,329,596	36,249	7,991,566	3.9%	2.7%	0.0437	4.2%
0	3	2000	883,116	409,490	1,292,606	35,239	7,768,888	4.0%	2.7%	0.0437	4.2%
0	4	2001	848,069	409,003	1,257,072	34,269	7,555,048	4.0%	2.7%	0.0437	4.2%
0	5	2002	814,413	408,521	1,222,934	33,338	7,349,694	4.1%	2.7%	0.0437	4.2%
0	6	2003	782,092	408,046	1,190,138	32,443	7,152,490	4.1%	2.7%	0.0437	4.2%
0	7	2004	751,054	407,576	1,158,631	31,584	6,963,112	4.2%	2.7%	0.0437	4.2%
0	8	2005	721,248	407,113	1,128,361	30,759	6,781,249	4.3%	2.7%	0.0437	4.2%
0	9	2006	692,625	406,655	1,099,279	29,967	6,606,604	4.3%	2.7%	0.0437	4.2%
0	10	2007	665,137	406,202	1,071,339	29,206	6,438,890	4.4%	2.7%	0.0437	4.2%
0	11	2008	638,741	405,756	1,044,496	28,476	6,277,832	4.5%	2.7%	0.0437	4.2%

Table E16. 30-year supply policy sensitivity analysis. Tables gives 1999 ocean quahog catch (mt).

M = 0.015		DII Dredge Efficiency					
		0.3	0.35	0.43	0.5	0.6	0.7
	0.0000	39,334	33,556	27,106	23,155	19,110	16,221
	0.0025	42,974	36,676	29,645	25,339	20,930	17,781
	0.0050	46,613	39,795	32,184	27,522	22,750	19,340
	0.0075	50,252	42,914	34,723	29,706	24,569	20,900
Rec (Fract)	0.0113	55,726	47,606	38,542	32,990	27,306	23,246
	0.0125	57,531	49,153	39,801	34,073	28,209	24,020
	0.0150	61,170	52,273	42,340	36,257	30,028	25,579
	0.0175	64,810	55,392	44,879	38,440	31,848	27,139
	0.0200	68,449	58,511	47,418	40,624	33,668	28,699

M = 0.02		DII Dredge Efficiency					
		0.3	0.35	0.43	0.5	0.6	0.7
	0.0000	36,083	30,782	24,864	21,240	17,529	14,879
	0.0025	39,706	33,887	27,392	23,414	19,341	16,431
	0.0050	43,329	36,993	29,920	25,588	21,152	17,984
	0.0075	46,952	40,098	32,447	27,761	22,964	19,537
Rec (Fract)	0.0113	52,401	44,769	36,249	31,031	25,688	21,872
	0.0125	54,198	46,309	37,503	32,109	26,587	22,642
	0.0150	57,821	49,415	40,031	34,283	28,398	24,195
	0.0175	61,444	52,520	42,558	36,457	30,210	25,748
	0.0200	65,067	55,625	45,086	38,630	32,021	27,300

M = 0.025		DII Dredge Efficiency					
		0.3	0.35	0.43	0.5	0.6	0.7
	0.0000	33,039	28,185	22,766	19,447	16,049	13,622
	0.0025	36,646	31,277	25,283	21,612	17,853	15,168
	0.0050	40,254	34,369	27,800	23,776	19,657	16,714
	0.0075	43,862	37,461	30,317	25,941	21,461	18,261
Rec (Fract)	0.0113	49,288	42,112	34,103	29,197	24,174	20,586
	0.0125	51,077	43,646	35,351	30,270	25,068	21,353
	0.0150	54,685	46,738	37,868	32,435	26,872	22,899
	0.0175	58,293	49,831	40,385	34,599	28,676	24,445
	0.0200	61,900	52,923	42,902	36,764	30,480	25,991

Notes:
Exploited region is SNE - SVA (not GBK)
m = 0.01-0.03 (SARC 19)
g = 0.0076 (SARC 22)

oq_sup_27.xls 8-Jun-98

Table E17. Ocean quahog supply-year calculations: calculation of supply years implied by various 1999 catch levels. SNE-SVA run, M = 0.02, R = 1.126% initial biomass.

ASSUMPTIONS / INPUTS:

Full-Recruit Biomass estimate for 1997: (from S. Smith software, bootstrap)

Region	Minimum Biomass	
GBK		mt
SNE	112,678	
LI	171,779	
NJ	103,423	
DMV	24,479	
SVA	0	
Sum Regions:	412,359	mt

Dredge Efficiency: 0.43

Sum (Adj. for Effic.): 958,974 mt
Total Stock Biomass (1997, Exploited Area only)

Do not (used in harvest calc:)
1+exp(M)+exp(2M)+...+exp(29M) = 125.19
(note M = m-g)
In parts: 22.56 13.57
(Note M = m-g, as defined below)

Commercial Catch Estimate from Exploited Area (units: mt):

Year	Catch (mt)	Source
1997	19,581	1997 quota
1998	18,140	1998 quota

Natural Mortality Rate, m : 0.020

Portion of total biomass that is unexploited in 1998: 30%

Want to exploit part of unexploited stock ?
Enter fraction of unexpl. biomass to make available (exploitable): 1.00
Starting in Year (>=1999): 2005

Conversion Fac: 10 lbs/bu

Policy: Harvest calculated for 30-yr horizon

Overfishing Def: F_ref 0.0437 = Label F_25% MSP

Annual Recruitment: Assumed to be a fixed % of Total Stock 1.126%
(Pre-recruits grow to Full-Recruits) 10,798 mt. This is applied to "Actual" Stock Biomass, 1998 +
4,628 mt, annual recruitment in unexploited areas (initially)

Annual Growth of Full-Recruits:
(enter fractional increase in meat weight/ clam): 0.0076
(e.g., 0.08 represents 8% / yr)
Instant. Growth Rate (g): 0.0076 (do not type this value.) (computed by spreadsheet)

RESULTS:

1999 Catch (Bushels)*	1999 Catch (MT)	Expon. Series	Implied Supply Year Policy
7,991,566	36,249	36.13	30
5,000,000	22,680	77.4	54
4,500,000	20,412	95.66	63
4,000,000	18,144	125.19	76

* conversion to MT assumes 10 lbs meats per bushel

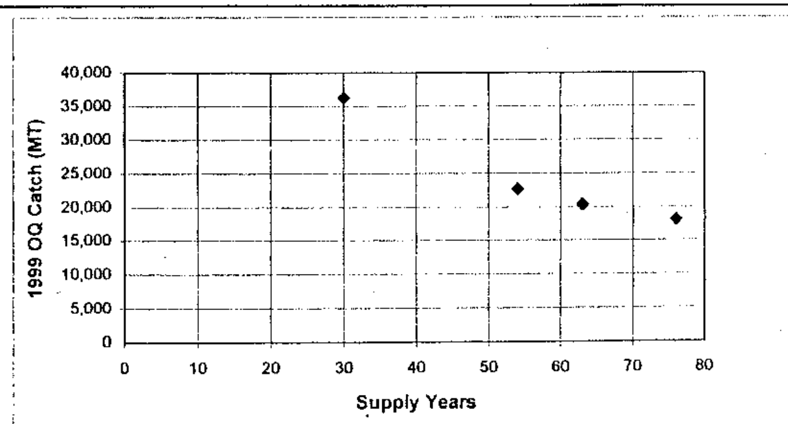


Table E18. Ocean quahog supply-year calculations: 63-year harvesting horizon policy (1999 catch of 20,412 mt, 4.5 million bushels) close to *status quo* quota. SNE-SVA run, M = 0.02, R = 1.126% initial biomass, supply-year policy = 63 years.

ASSUMPTIONS / INPUTS:

Full-Recruit Biomass estimate for 1997: (from S. Smith software, bootstrap)
(Exploited Regions Only)

Region	Minimum Biomass
GBK	mt
SNE	112,678
LI	171,779
NJ	103,423
DMV	24,479
SVA	0
Sum Regions:	412,359 mt

Dredge Efficiency: 0.43

Sum (Adj. for Effic.): 958,974 mt
Total Stock Biomass (1997, Exploited Area only)

Do not edit. (used in harvest calc.)
1+exp(M)+exp(2M)+...+exp(29M) = 95.66
(note: M = m-g)
In parts: 22.56 13.57
(Note: M = m-g, as defined below)

Commercial Catch Estimate from Exploited Area (units: mt):

Year	Catch (mt)	Source
1997	19,581	1997 quota
1998	18,140	1998 quota

Conversion Fac: 10 lbs/bu

Policy: Harvest calculated for 30-yr horizon

Natural Mortality Rate, m: 0.020

Overfishing Def: F_ref 0.0437 = Label F_25% MSP

Portion of total biomass that is unexploited in 1998: 30%

Annual Recruitment: Assumed to be a fixed % of Total Stock Biomass = 1.126%
(Pre-recruits grow to Full-Recruits) 10,798 mt. This is applied to "Actual" Stock Biomass, 1998 +
4,628 mt, annual recruitment in unexploited areas (initially)

Want to exploit part of unexploited stock ?
Enter fraction of unexpl. biomass to make available (exploitable): 1.00
Starting in Year (>=1999): 2011

Annual Growth of Full-Recruits: 0.0076
(enter fractional increase in meat weight/ clam):
(e.g., 0.08 represents 8% / yr)

Instant. Growth Rate (g): 0.0076 (do not type this value.) (computed by spreadsheet)

SIMULATION RESULTS :

Marker		Year	Biomass (Expl), mt	Biomass (Unexpl), mt	Tot Biomass	Harvest from Expl. Area: mt	bushels	Realized Exploitation Rate: Expl Areas	All Areas	Overfishing Ref. Point: Inst. Rate (F_ref) = F_25% MSP	Exploit. Rate = (F_ref / Z) * (1-exp(-Z))
o	1	1998	938,455	410,483	1,348,938	18,140	3,999,185.40	1.9%	1.3%	0.0437	4.2%
o	2	1999	919,612	409,984	1,329,596	20,411	4,499,941	2.2%	1.5%	0.0437	4.2%
o	3	2000	898,759	409,490	1,308,249	20,193	4,451,882	2.2%	1.5%	0.0437	4.2%
o	4	2001	878,378	409,003	1,287,381	19,980	4,404,911	2.3%	1.6%	0.0437	4.2%
o	5	2002	858,459	408,521	1,266,981	19,772	4,359,007	2.3%	1.6%	0.0437	4.2%
o	6	2003	838,993	408,046	1,247,039	19,569	4,314,143	2.3%	1.6%	0.0437	4.2%
o	7	2004	819,967	407,576	1,227,544	19,370	4,270,296	2.4%	1.6%	0.0437	4.2%
o	8	2005	801,374	407,113	1,208,486	19,175	4,227,444	2.4%	1.6%	0.0437	4.2%
o	9	2006	783,201	406,655	1,189,856	18,985	4,185,563	2.4%	1.6%	0.0437	4.2%
o	10	2007	765,441	406,202	1,171,643	18,800	4,144,632	2.5%	1.6%	0.0437	4.2%
o	11	2008	748,084	405,756	1,153,839	18,618	4,104,630	2.5%	1.6%	0.0437	4.2%

Table E19. Original ocean quahog biomass production model.

(1-yr projection)
Time T = 1997

INPUTS :
(Assumptions)

Nat. mortality (m) :	0.015
Dredge Efficiency (0-1):	0.43
Non-catch mortality (0-1	0.05

I.e.,(fraction dying| impac[redacted]

Area / Tow =	
(sq. n.mi)	
	0.000123434

e:/survey/progs/oq97expl.xls
6/4/98

Inputs for Determining Length (t+1):

Region				Source
SVA				LI equation
DMV				LI equation
NJ				LI equation
LI	separate equations for 0-19 yr (<64 mm), and 20+yr (>=64mm)			Muraw.,Ropes,Ser. 198
SNE				LI equation
GBK	power cur	42.4005	0.1981	--- Ropes & Pyoas 1982

Only New Params.

Region	Len/Wt Params	A	B	Source
1	SVA	-9.310191	2.860486	LI data
2	DMV	-9.310191	2.860486	LI data
3	NJ	-9.310191	2.860486	LI data
4	LI	-9.310191	2.860486	1997 Survey (LI data)
5	SNE	-9.310191	2.860486	LI data
6	GBK	-8.833807	2.761124	1997 Survey (GBK data)

Other notes: Catch per tow was adjusted to 0.15 nmi based on sensor data, assuming a critical cutting depth of 4 inches. A 1-mm size interval was used.
Traditional stratum areas used. Strata composing SNE and GBK were revised to follow surfclam habitat more closely. No clams were added in to correct for selectivity.

OUTPUTS :

NOT ADJUSTED FOR DREDGE EFFICIENCY:

Wt per tow by Region (grams)		
Region	Time = T	Time = T + 1
SVA	6.2	6.2
DMV	739.7	734.2
NJ	2,109.1	2,090.4
LI	5,779.0	5,759.7
SNE	3,199.7	3,201.1
GBK	3,819.0	3,874.4

ADJUSTED FOR THE DREDGE EFFICIENCY LISTED ABOV

Wt per tow by Region (grams)			Total Biomass Estimate: Adjusted for eff. Regional Biomass (MT)	Total Biomass Estimate: NOT Adjusted for eff. Regional Biomass (MT)
Region	Time = T	Time = T + 1	Time = T (1997)	Time = T (1997)
SVA	14.3	14.4	60	26
DMV	1,720.1	1,707.4	59,812	25,719
NJ	4,904.8	4,861.4	272,434	117,146
LI	13,439.6	13,394.6	487,570	209,655
SNE	7,441.2	7,444.4	323,728	139,203
GBK	8,881.3	9,010.2	521,149	224,094
			1,664,753	715,844

ADJUSTED FOR DREDGE EFFICIENCY: T ===> T+1 comparisons

ADJUSTED FOR DREDGE EFFICIENCY & INDIRECT FISHING MORT.:

Region	Change in Biomass / Tow (gr)	% change per tow	Region Area (sq n.mi)	Possible Tows/ Region	Production : Regional Change in Biomass (M Tons)	Removals : 1996 Landings (dir + indir)	t Production of Biomass: (Production - Removals) (M. Tons)	Region
1 SVA	0	0.2	515	4,172,270	0.1	0	0.1	SVA
2 DMV	-13	-0.7	4292	34,771,619	-441.9	1,111	-1,552.8	DMV
3 NJ	-43	-0.9	6856	55,543,853	-2,413.4	4,456	-6,869.6	NJ
4 LI	-45	-0.3	4478	36,278,497	-1,635.4	5,387	-7,021.9	LI
5 SNE	3	0.0	5370	43,505,031	141.8	9,406	-9,264.1	SNE
6 GBK	129	1.5	7243	58,679,132	7,560.3	0	7,560.3	GBK
					3,211.5 Annual Total (MT)	20,360	-17,148.0	Sum (MT)

Table E20. Revised ocean quahog biomass production model.

(1-yr projection)
Time T = 1997
Run with curves adjusted for MISSING CLAMS !!

INPUTS :
(Assumptions)

Nat. mortality (m) :	0.015
Dredge Efficiency (0-1):	0.43
Non-catch mortality (0-1	0.05
I.e.,(fraction dying| impac[redacted]	

Area / Tow =	jazz/oqproall.xls
(sq. n.mi)	5/28/98
0.000123434	

Tab:
ALL_adjProd

Inputs for Determining Length (t+1):

Region					Source
SVA					LI equation
DMV					LI equation
NJ					LI equation
LI	separate equations for 0-19 yr (<64 mm), and 20+yr (>=6				Muraw.,Ropes,Ser. 198
SNE					LI equation
GBK	power cur	42.4005	0.1981	---	Ropes & Pyoas 1982

Only New Params.

Region	Len/Wt Params	alpha	beta	Source
1	SVA	-9.310191	2.860486	(LI '97 data)
2	DMV	-9.310191	2.860486	(LI '97 data)
3	NJ	-9.310191	2.860486	(LI '97 data)
4	LI	-9.310191	2.860486	1997 Survey (LI data)
5	SNE	-9.310191	2.860486	(LI '97 data)
6	GBK	-8.833807	2.761124	1997 Survey (GBK data)

Other notes: Catch per tow was adjusted to 0.15 nmi based on sensor data, assuming a critical cutting depth of 4 inches. A 1-mm size interval was used.
Traditional stratum areas used. Strata composing SNE and GBK were revised to follow surfclam habitat more closely. Adjusted obs. Size freq. Curves were used for all regions.

OUTPUTS :

NOT ADJUSTED FOR DREDGE EFFICIENCY:

Region	Wt per tow by Region (grams) Time = T	Time = T + 1
SVA	6.2	6.2
DMV	751.3	746.8
NJ	2,124.1	2,106.7
LI	5,870.8	5,855.7
SNE	3,433.6	3,449.3
GBK	4,017.3	4,092.5

ADJUSTED FOR THE DREDGE EFFICIENCY LISTED ABOV

Region	Wt per tow by Region (grams) Time = T	Time = T + 1	Total Biomass Estimate: Adjusted for eff. Regional Biomass (MT) Time = T (1997)	Total Biomass Estimate: NOT Adjusted for eff. Regional Biomass (MT) Time = T (1997)
SVA	14.3	14.4	60	26
DMV	1,747.2	1,736.7	60,753	26,124
NJ	4,939.9	4,899.3	274,379	117,983
LI	13,653.1	13,617.9	495,312	212,984
SNE	7,985.1	8,021.6	347,391	149,378
GBK	9,342.5	9,517.4	548,207	235,729
			1,726,102	742,224

ADJUSTED FOR DREDGE EFFICIENCY: T ===> T+1 comparisons

ADJUSTED FOR DREDGE EFFICIENCY & INDIRECT FISHING MORT.:

Region		Change in Biomass / Tow (gr)	% change per tow	Region Area (sq n.mi)	Possible Tows/ Region	Production : Regional Change in Biomass (M Tons	Regional Biomass Contributions (%)	Removals : 1996 Landings (dir + indir)	Net Production of Biomass: (Production - Removals) (M. Tons)	Region
1	SVA	0	0.2	515	4,172,270	0.1	0.0	0	0.1	SVA
2	DMV	-11	-0.6	4292	34,771,619	-366.3	-4.6	1,111	-1,477.2	DMV
3	NJ	-41	-0.8	6856	55,543,853	-2,251.8	-28.3	4,456	-6,708.0	NJ
4	LI	-35	-0.3	4478	36,278,497	-1,275.6	-16.0	5,387	-6,662.1	LI
5	SNE	37	0.5	5370	43,505,031	1,588.2	19.9	9,406	-7,817.7	SNE
6	GBK	175	1.9	7243	58,679,132	10,267.9	129.0	0	10,267.9	GBK
						7,962.6	100.0	20,360	-12,396.9	Sum (MT)
						Annual Total (MT)				

Adjusted obs. Size freq. Curves were used for all regions.

Table E21. Biological reference points for ocean quahogs and surfclams.

Ocean quahog (OQ):

	Region	F_{max}	$F_{0.1}$	$F_{25\%MSP}$	F_{P0}
7/95 (old)	LI	0.068	0.023	0.043	
5/98 (revised)	LI	0.065	0.022	0.042	0

OQ Assumptions:
M = 0.02; earliest maturity = 5-11 yrs; Recruit to fishery = 17 yr

Surfclam (SC):

	Region	F_{max}	$F_{0.1}$	$F_{20\%MSP}$	F_{P0}
SAW-26 1998 (revised)	NNJ	0.21	0.07	0.18	0.05
"	DMV	0.21	0.07	0.18	0.05
"	GBK	0.19	0.07	0.17	0.12

SC Assumptions:
M = 0.05; earliest maturity = 1st yr; Recruit to fishery = 5.5 yr

Table E22. Fishing mortality rates (F) on ocean quahogs by region based on the bootstrap or kriging estimation, with 95% CIs of total biomass from the 1997 survey and the landings from 1997. These estimates are based on the 4-in. critical blade depth and the assumption that indirect mortality from clam harvesting = 0, that all landings are reported, and that M = 0.02. In this table, the efficiency is set at the trimmed average of the depletion experiments by commercial vessels = 0.43. Catches = (constant X number of bushels collecdted). This could also be evaluated using commercial length frequency data. *Exploited region includes: SNE-DMV.

Region	Stock Estimate	Estimation Method	Stock Biomass, 1997 (MT)	1997 Catch (MT)	Explotation Rate U	Estimate of F	(U-(FA/Z)) =0 objective function
GBK	Lower CI	Bootstrap	265,967	0	0.0000	0.0000	0.0000
	Mean	Bootstrap	412,937	0	0.0000	0.0000	0.0000
	Upper CI	Bootstrap	554,314	0	0.0000	0.0000	0.0000
SNE	Lower CI	Bootstrap	104,716	8,960	0.0856	0.0904	0.0000
	Mean	Bootstrap	262,042	8,960	0.0342	0.0351	0.0000
	Upper CI	Bootstrap	482,095	8,960	0.0186	0.0190	0.0000
LI	Lower CI	Bootstrap	248,888	5,130	0.0206	0.0210	0.0000
	Mean	Bootstrap	399,486	5,130	0.0128	0.0131	0.0000
	Upper CI	Bootstrap	540,044	5,130	0.0095	0.0096	0.0000
NJ	Lower CI	Bootstrap	171,928	4,240	0.0247	0.0252	0.0000
	Mean	Bootstrap	240,519	4,240	0.0176	0.0180	0.0000
	Upper CI	Bootstrap	303,812	4,240	0.0140	0.0142	0.0000
DMV	Lower CI	Bootstrap	35,023	1,060	0.0303	0.0310	0.0000
	Mean	Bootstrap	56,928	1,060	0.0186	0.0190	0.0000
	Upper CI	Bootstrap	84,130	1,060	0.0126	0.0128	0.0000
SVA/NC	Lower CI	Bootstrap	0	0	0.0000	0.0000	0.0000
	Mean	Bootstrap	0	0	0.0000	0.0000	0.0000
	Upper CI	Bootstrap	0	0	0.0000	0.0000	0.0000
Exploited*	Sum Lo CIs	Bootstrap	560,556	19,400	0.0346	0.0356	0.0000
Regions	Sum Means	Bootstrap	958,974	19,400	0.0202	0.0206	0.0000
Only	Sum Hi CIs	Bootstrap	1,410,081	19,400	0.0138	0.0140	0.0000
ALL	Lower CI	Bootstrap	1,134,414	19,400	0.0171	0.0174	0.0000
	Mean	Bootstrap	1,393,909	19,400	0.0139	0.0142	0.0000
	Upper CI	Bootstrap	1,680,493	19,400	0.0115	0.0117	0.0000
ALL	Lower CI	Kriging	1,242,945	19,400	0.0156	0.0159	0.0000
	Mean	Kriging	1,423,763	19,400	0.0136	0.0139	0.0000
	Upper CI	Kriging	1,604,581	19,400	0.0121	0.0123	0.0000

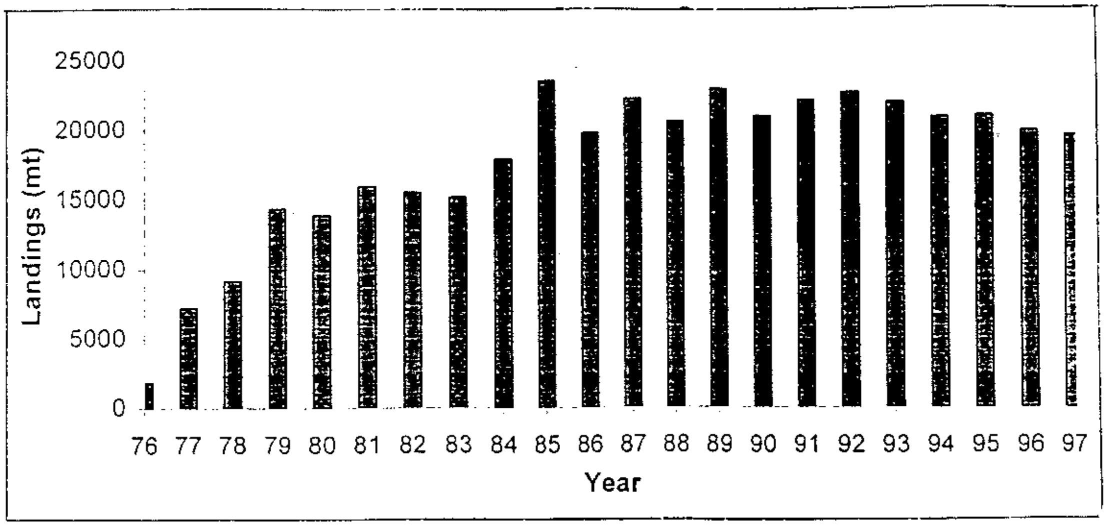


Figure E1. Landings of ocean quahogs from EEZ waters, 1976-1997.

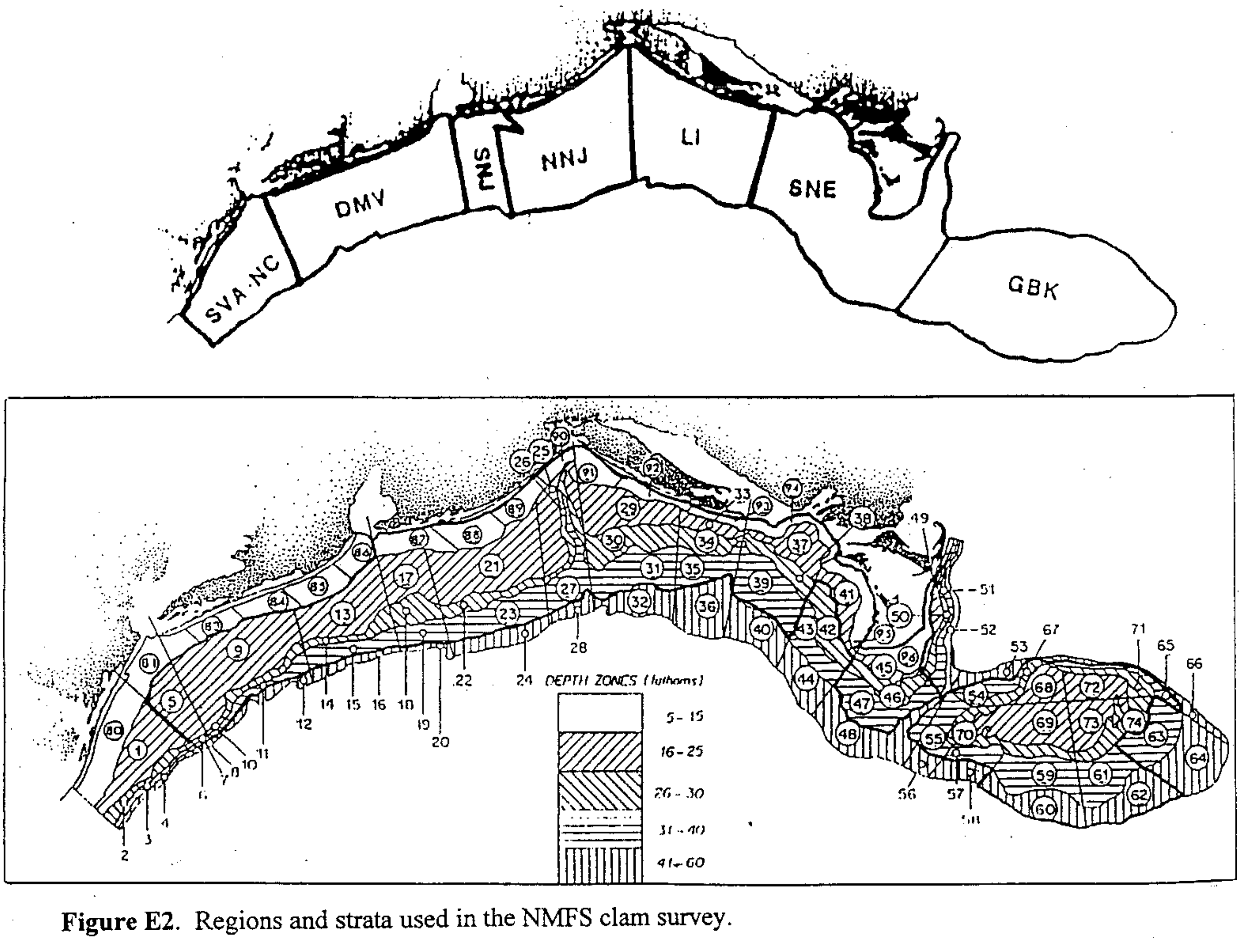


Figure E2. Regions and strata used in the NMFS clam survey.

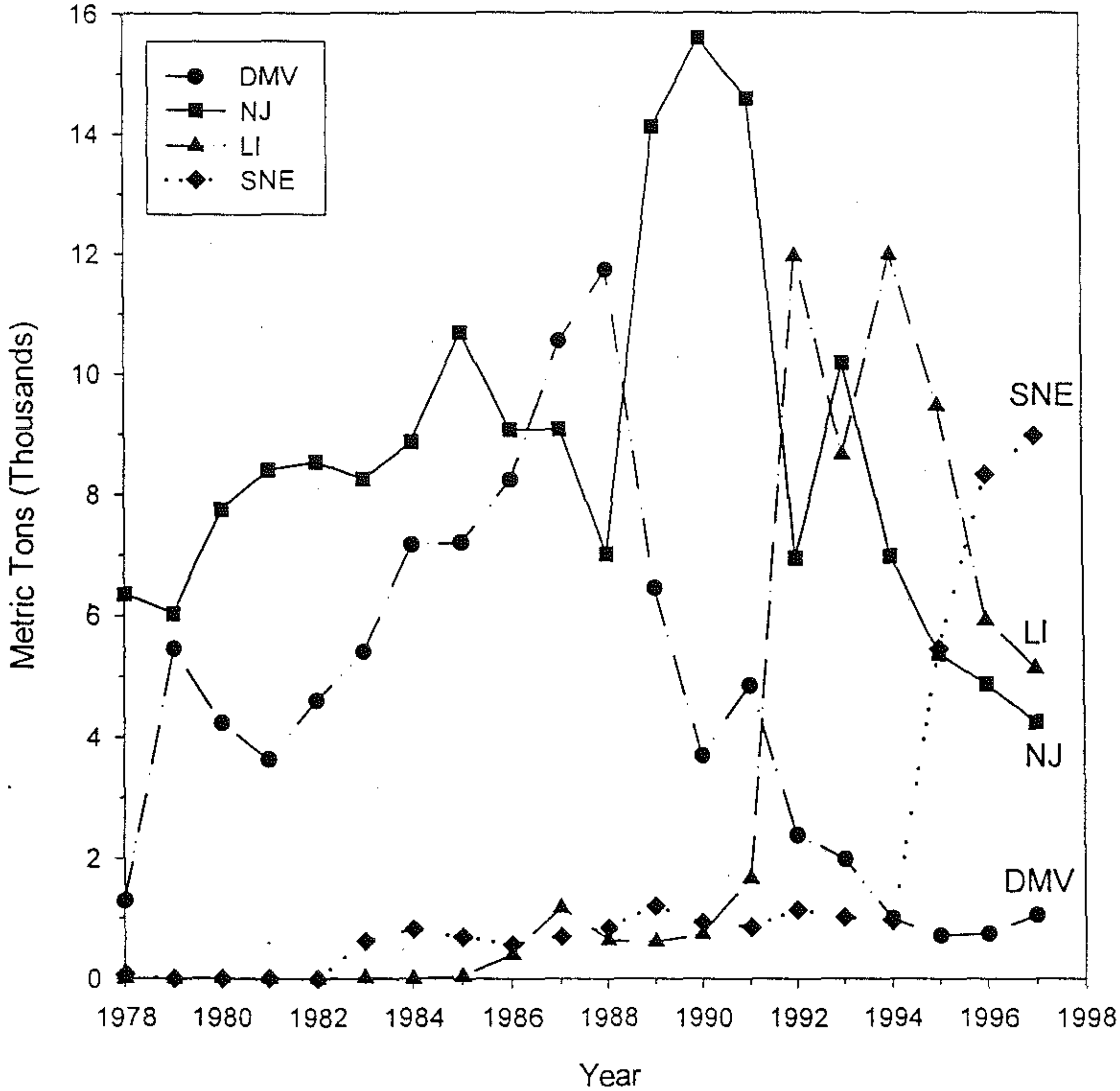


Figure E3. Annual ocean quahog landings (thousands of metric tons of meats) by region, 1978-1997.

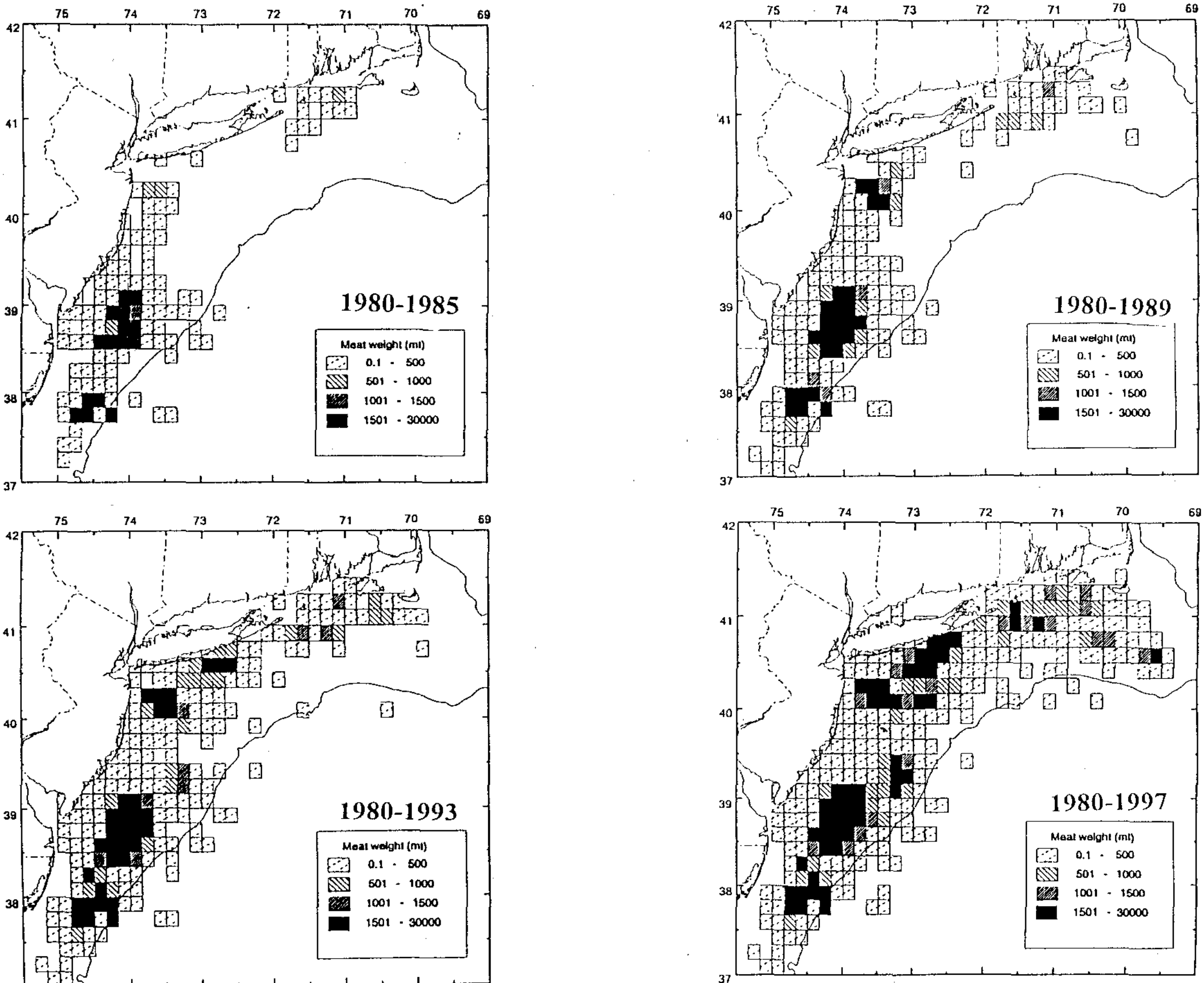


Figure E4. Cumulative landings of ocean quahogs by 10' square for various time periods.

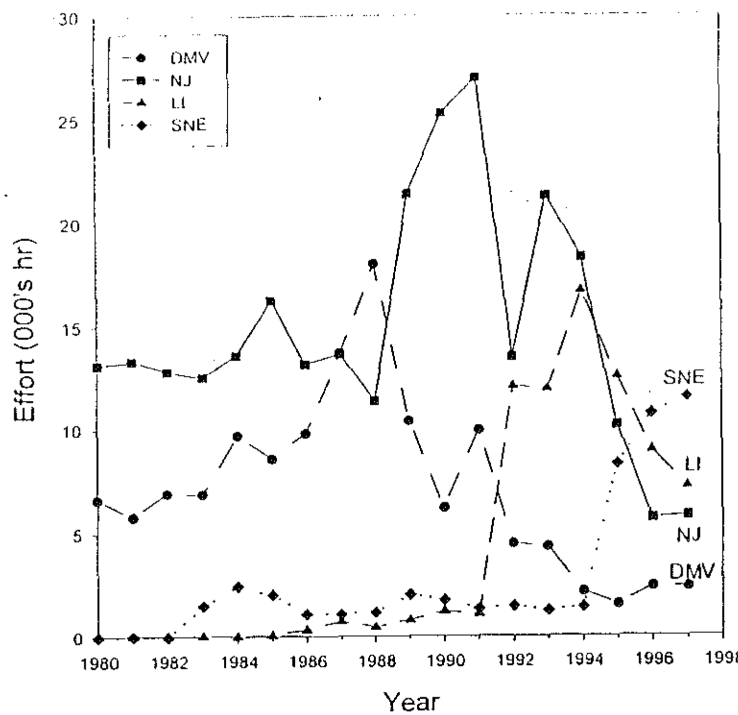


Figure E5. Annual fishing effort (thousands of hours), by class three vessels in the ocean quahog fishery, 1980-1997.

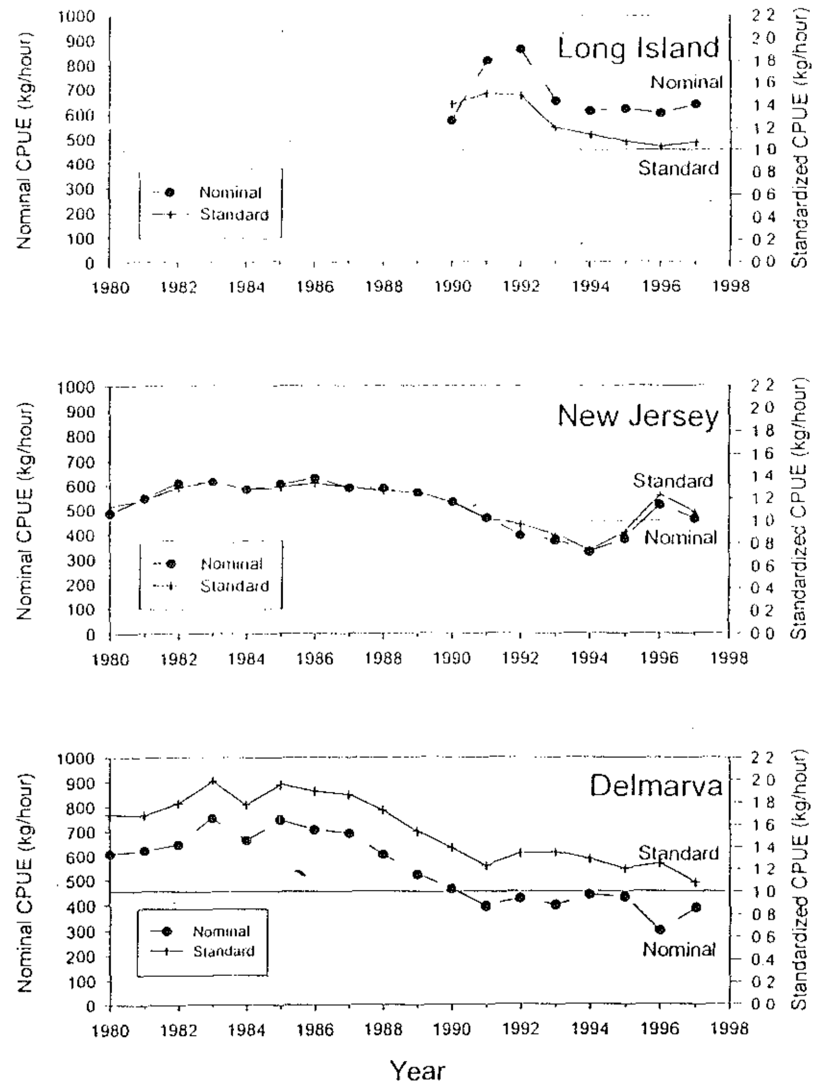


Figure E6. Nominal and standardized catch per unit of effort by class 3 vessels fishing ocean quahogs off Long Island, New Jersey, and Delmarva.

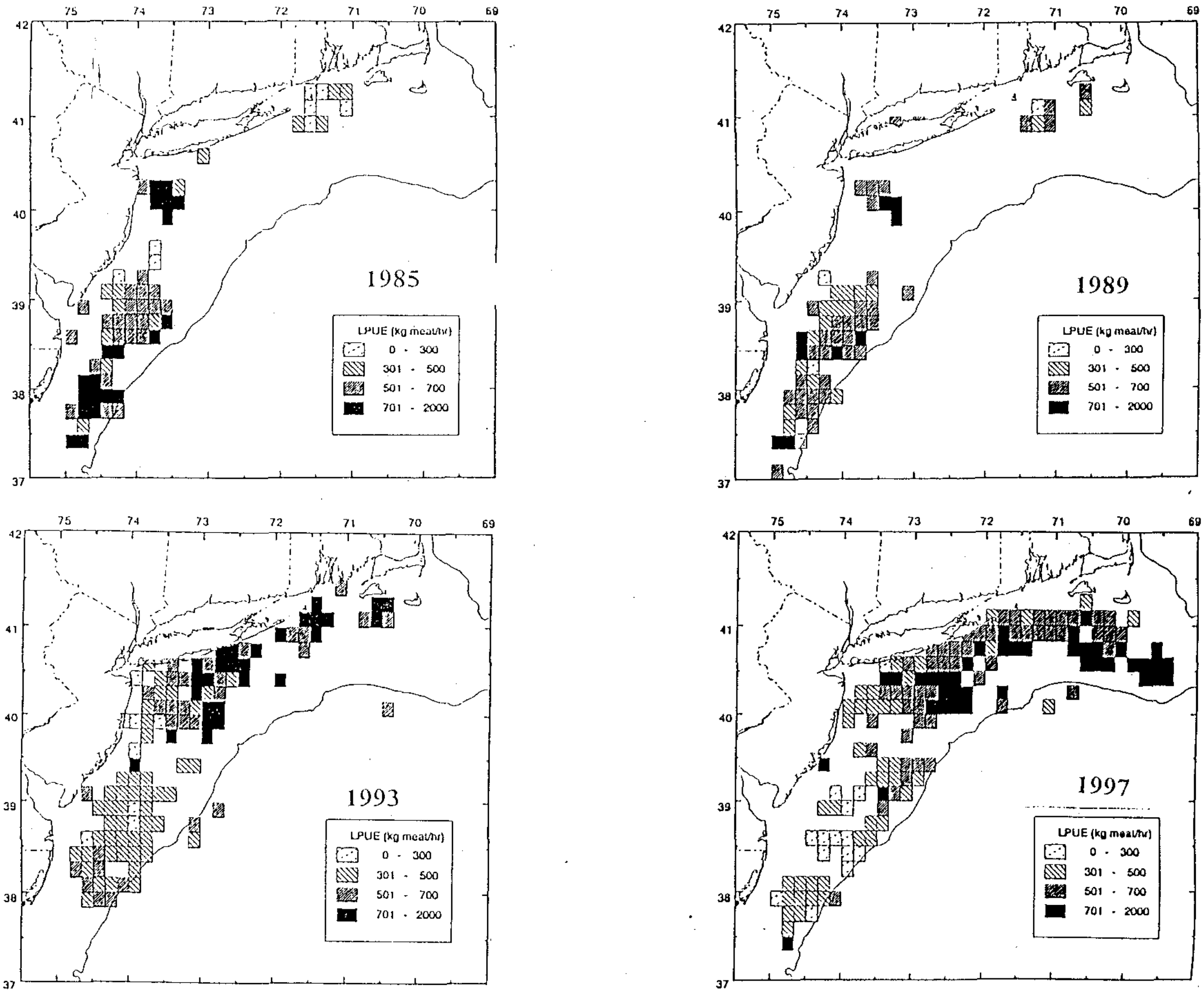


Figure E7. Maps of landings-per-unit effort, LPUE (kg meat/hr fished) of ocean quahogs by 10' square for 1985, 1989, 1993, and 1997.

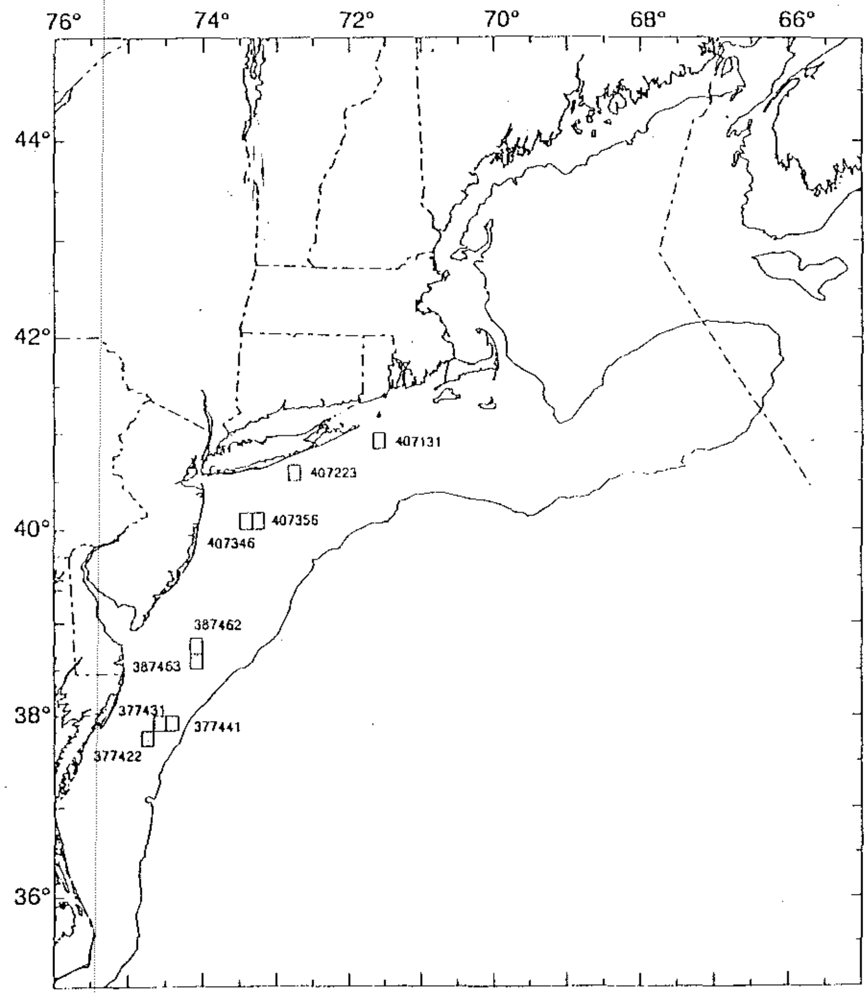


Figure E8. Locations of 10' squares off the coast of the U.S.

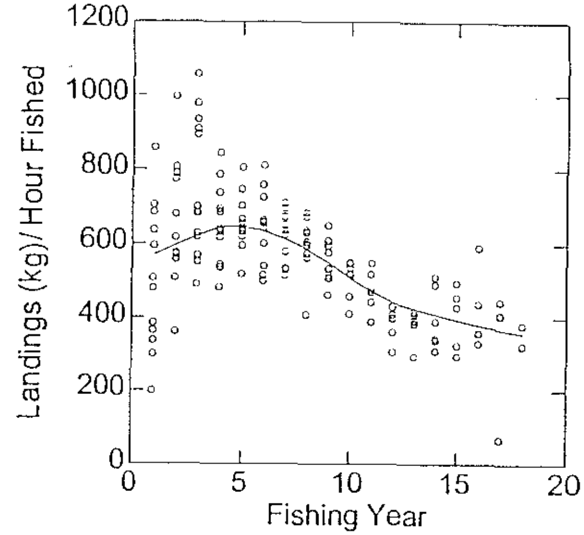


Figure E9. Ocean quahog catch rate within heavily fished 10' squares in relation to years of exploitation.

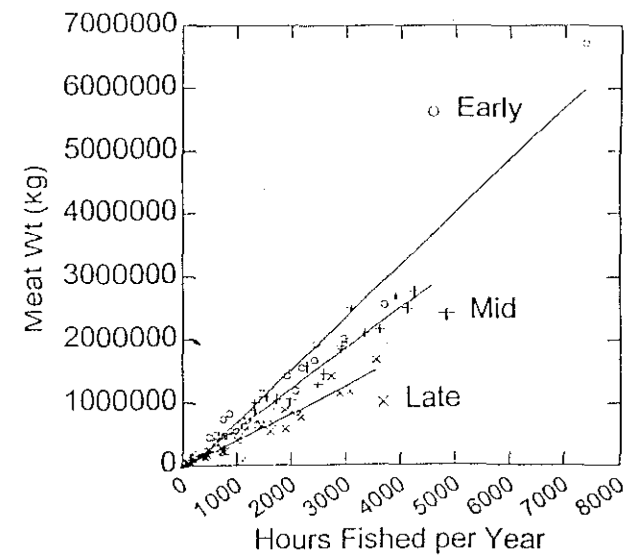


Figure E10. Ocean quahog catch vs. effort per trip. Data were separated into 3 groups based on how long the 10' square had been fished, "Early": 1-4 yr, "Mid": 5-10 yr, "Late":>=11 yr.

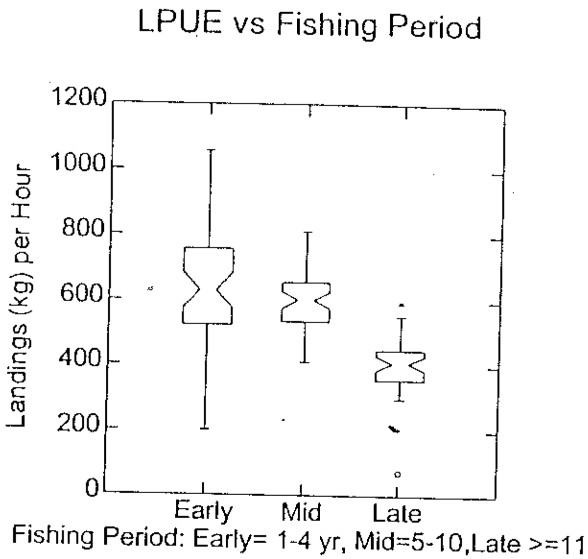


Figure E11. Ocean quahog catch per trip in heavily fished 10' squares as a function of years of exploitation. Shown are the median and box enclosing the 25th and 75th percentiles.

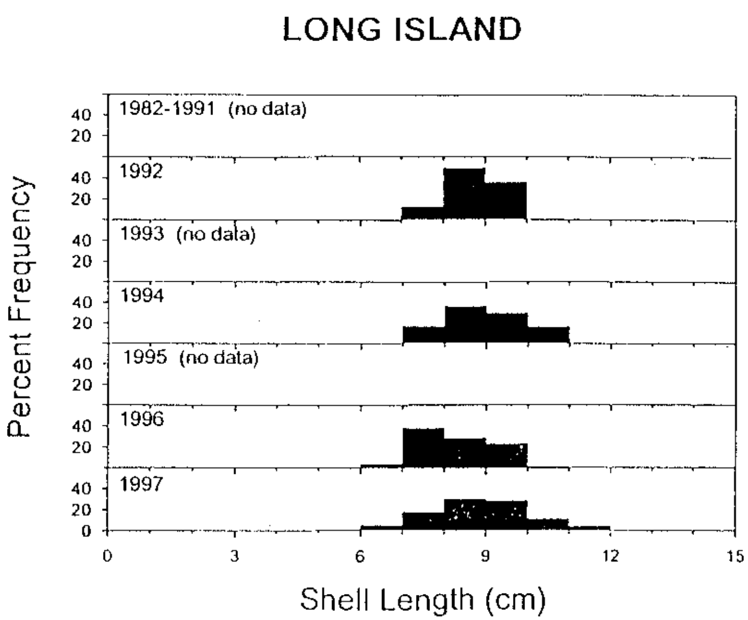


Figure E13. Ocean quahog length frequency distributions derived from port samples. Trips were catch-weighted.

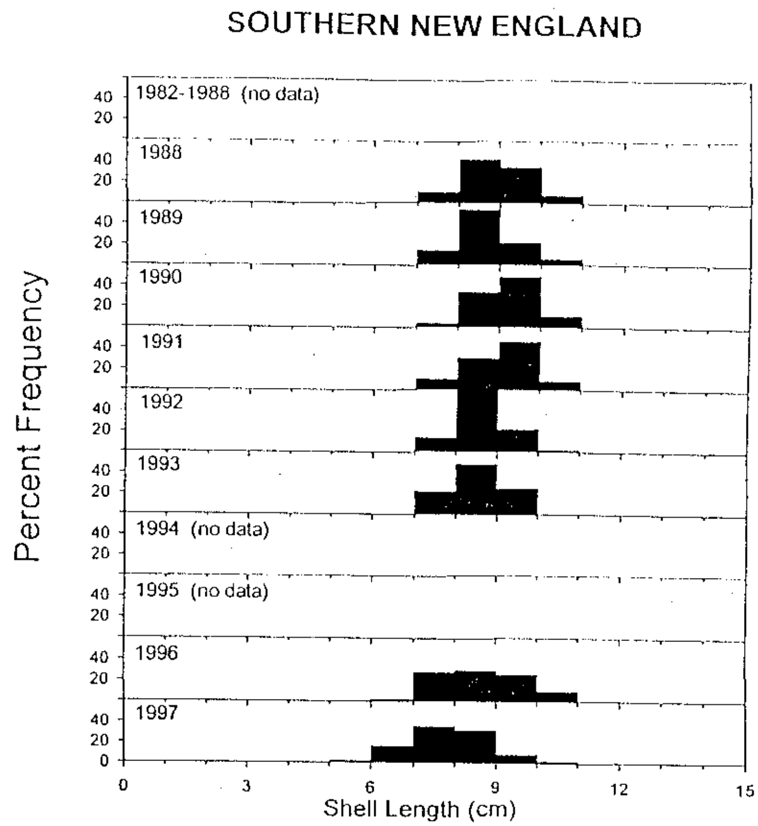


Figure E12. Ocean quahog length frequency distributions derived from port samples. Trips were catch-weighted.

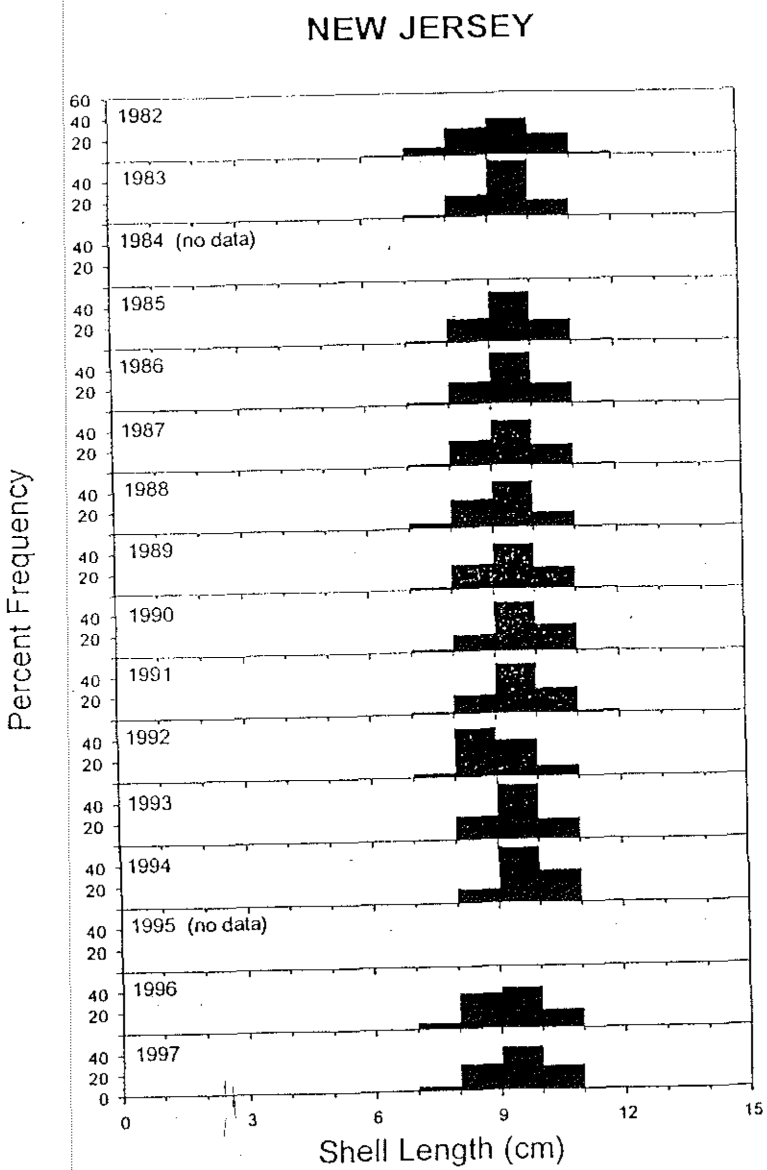


Figure E14. Ocean quahog length frequency distributions derived from port samples. Trips were catch-weighted.

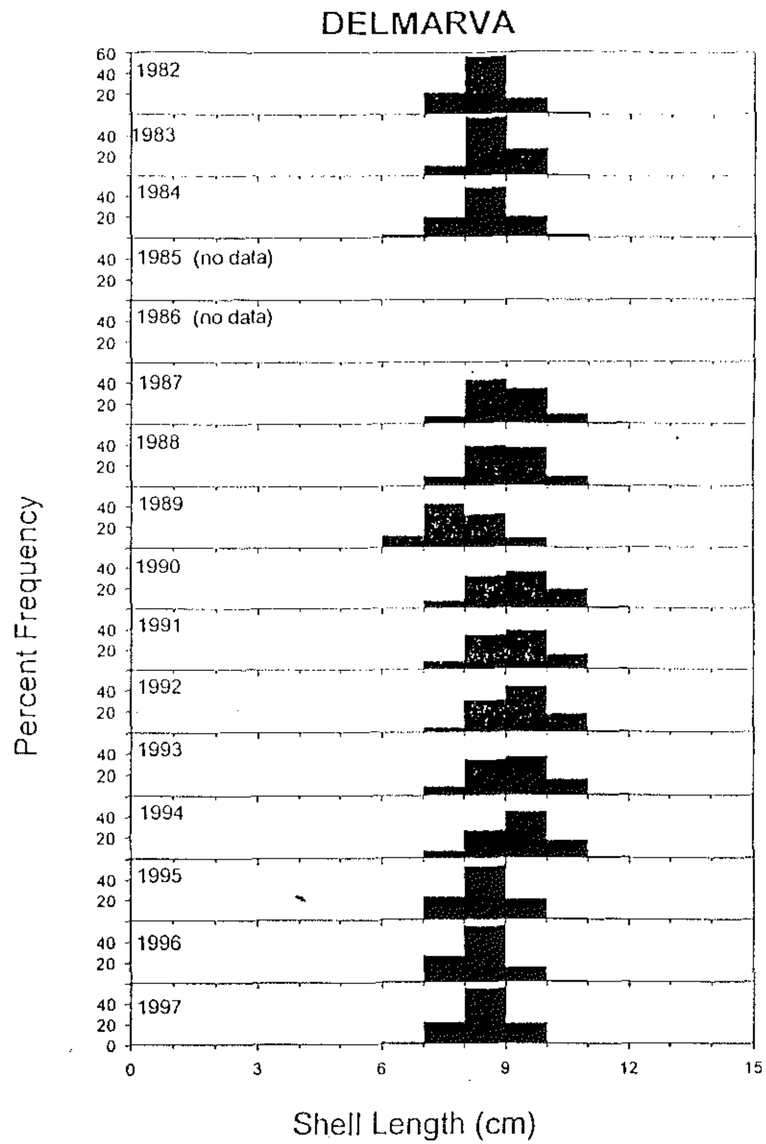


Figure E15. Ocean quahog length frequency distributions derived from port samples. Trips were catch-weighted.

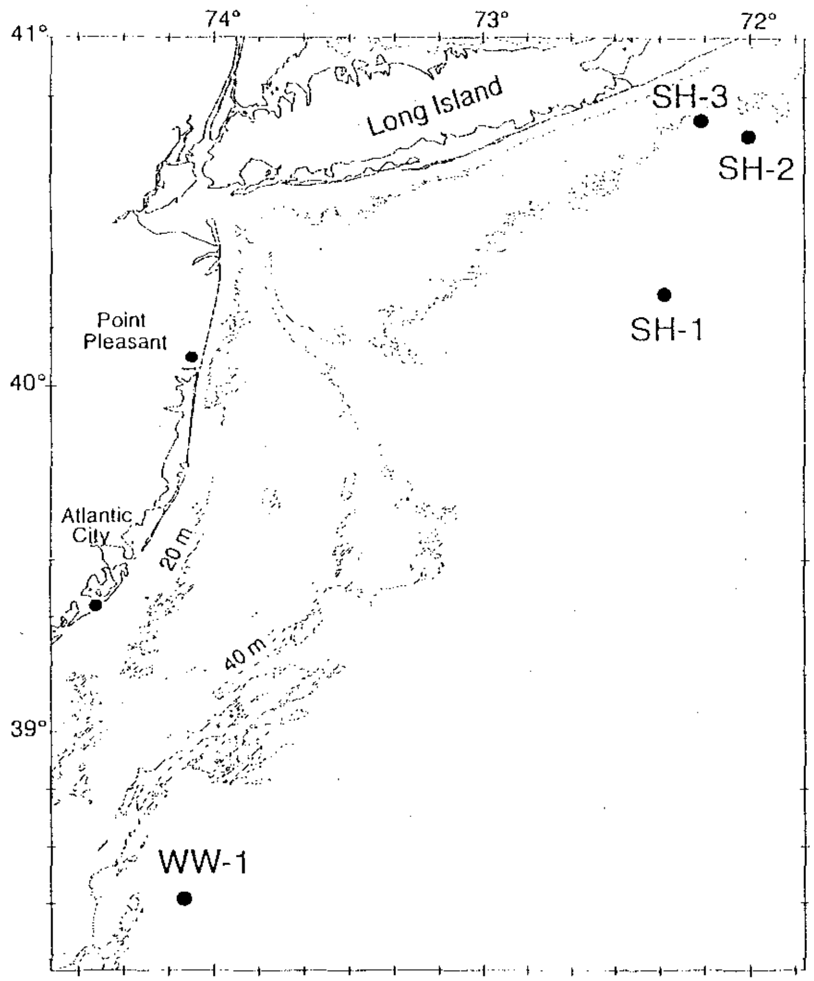


Figure E. 16. Locations of ocean quahog depletion studies. SH-1 (7/15/97), WW-1 (8/28/97), S-H2 and SH-3 (3/6/98).

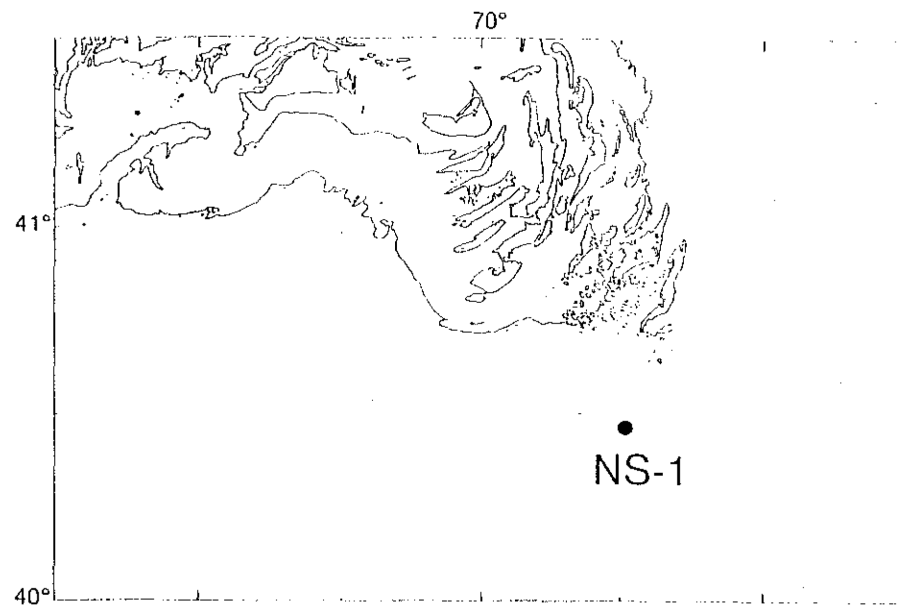


Figure E17. Location of ocean quahog depletion study NS-1, off Nantucket Shoals (4/26/98).

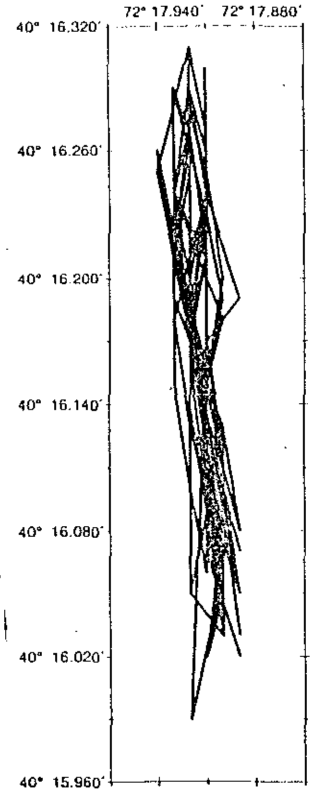


Figure E18. Depletion study SH-1 off the coast of Shinnecock, New York. Tows 1,2,12, and 18 excluded.

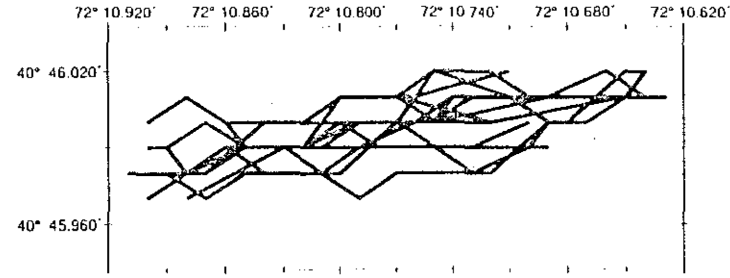


Figure E20. Depletion study SH-3 off the coast of Shinnecock, New York. All 14 tows included.

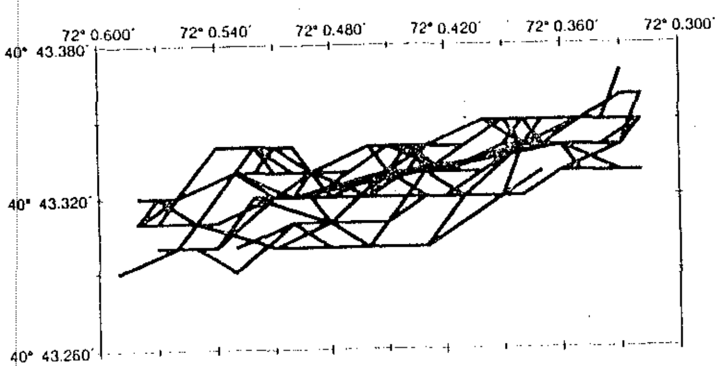


Figure E19. Depletion study SH-2 of the coast of Shinnecock, New York. All 23 tows included.

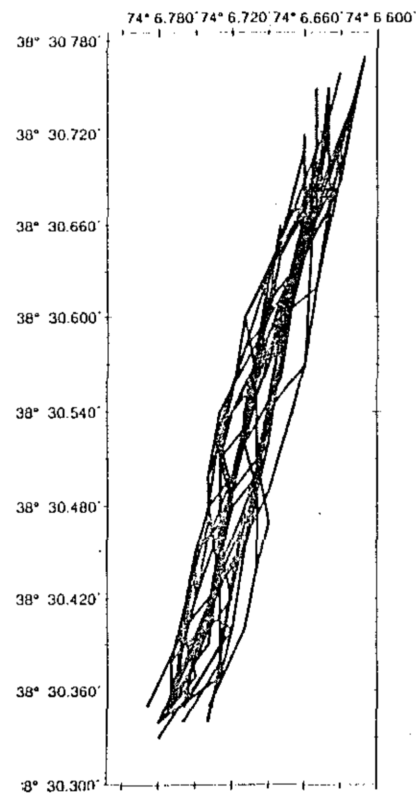


Figure E21. Depletion study WW-1 off the coast of Wildwood, New Jersey. Tows 1,19,23, and 27 excluded.

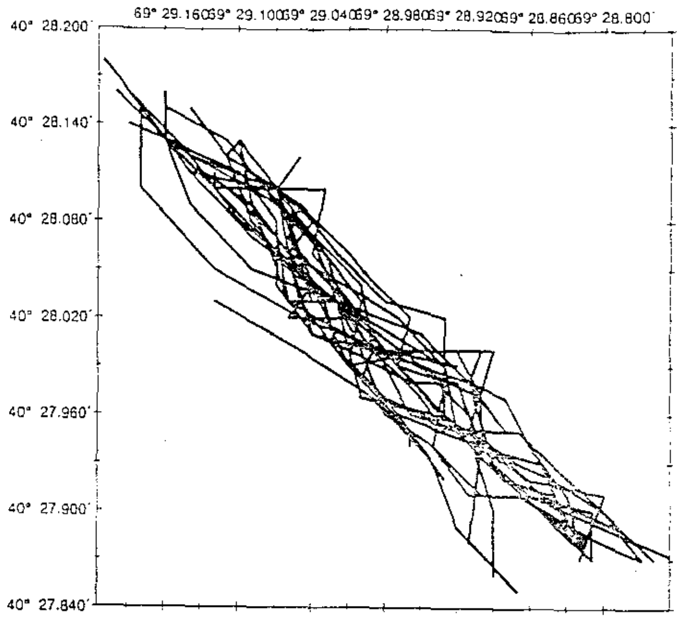


Figure E22. Depletion study NS-1 located off Nantucket Shoals. All 24 tows included.

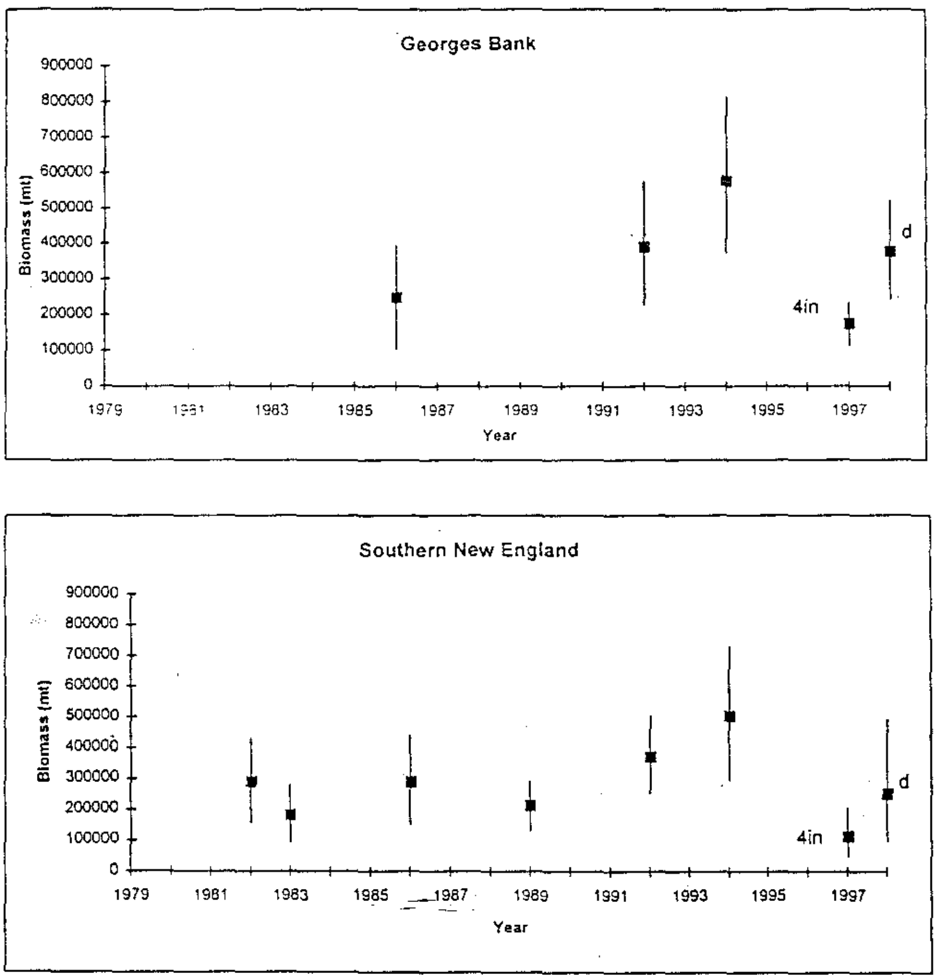


Figure E23. Regional survey of ocean quahog biomass (means with 95% CI), not adjusted for dredge efficiency. 1980-1994 catch per tow was standardized by doppler distance. For 1997 "d" = standardized by doppler distance and "4 in" = standardized for a 4 inch blade depth. On Georges Bank deep strata (60 & 62) were not sampled in 1992.

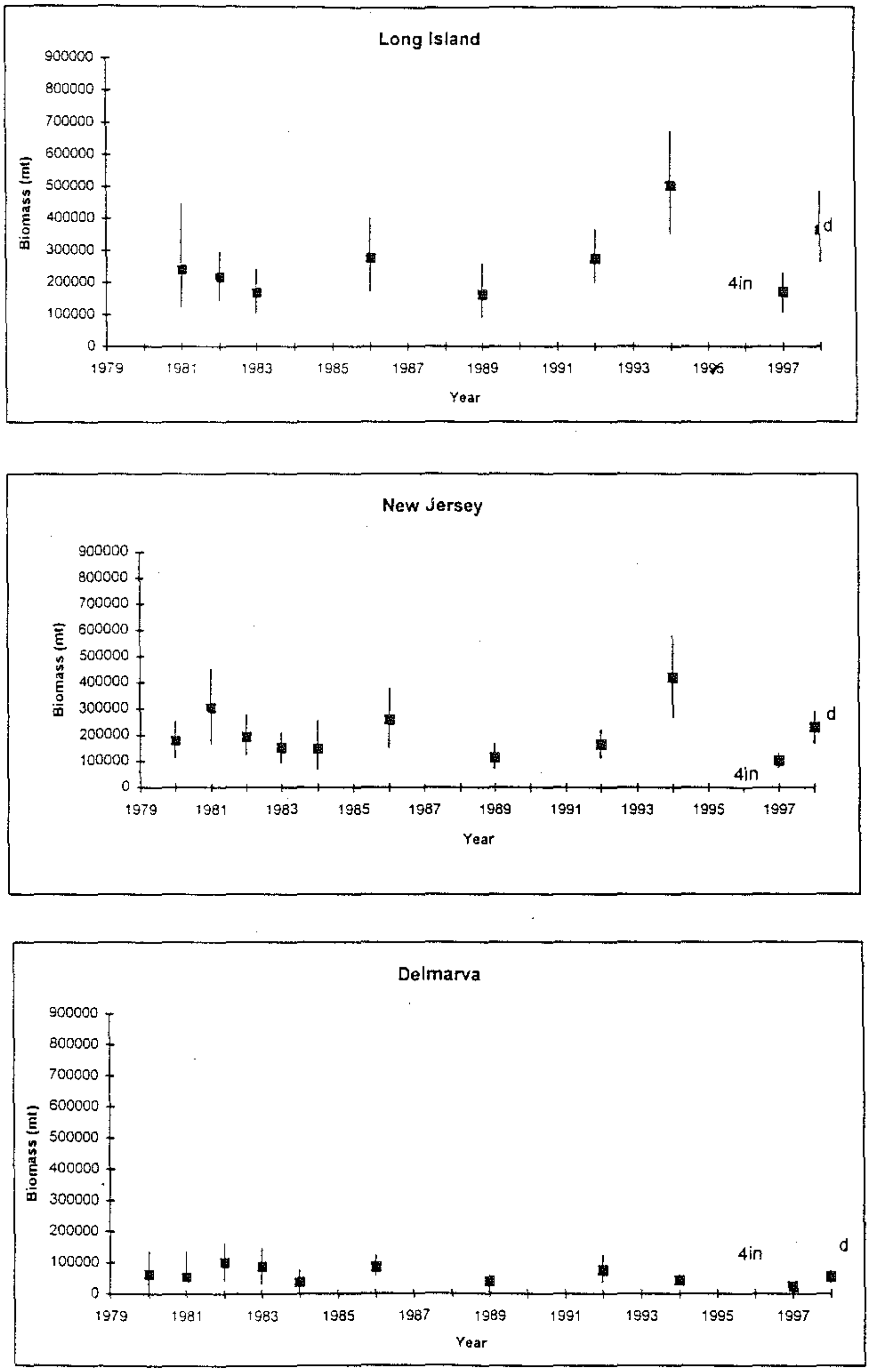
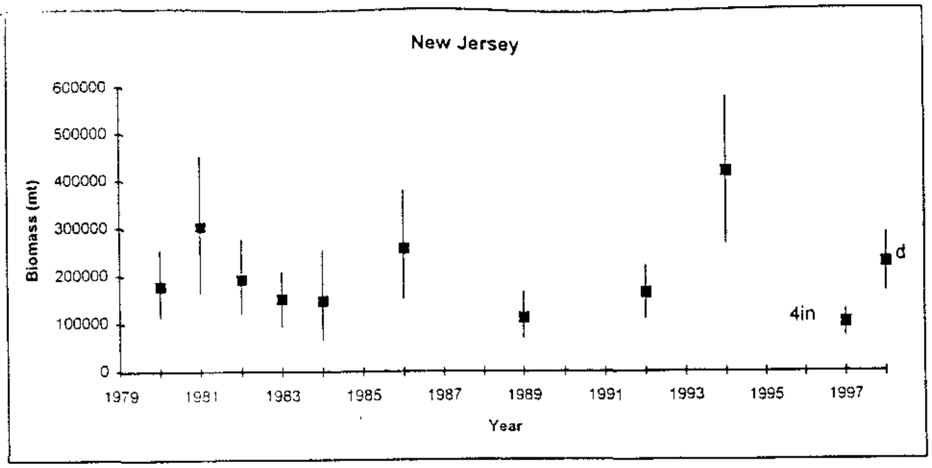


Figure E24. Regional survey of ocean quahog biomass (means with 95% CI), not adjusted for dredge efficiency. 1980-1994 catch per tow was standardized by doppler distance. For 1997 "d" = standardized by doppler distance and "4 in" = standardized for a 4 inch blade depth. For New Jersey in 1984 offshore strata 18,19,22,23,26, and 27 were not sampled. For Delmarva in 1984 offshore strata 11 and 15 were not sampled.



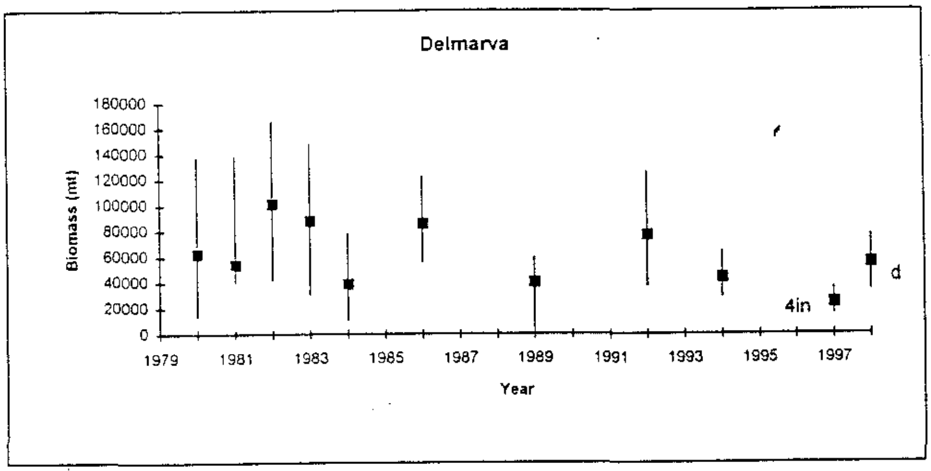


Figure E25. Regional survey of ocean quahog biomass (means with 95% Cl), not adjusted for dredge efficiency. 1980-1994 catch per tow was standardized by doppler distance. For 1997 "d" = standardized by doppler distance and "4 in" = standardized for a 4 inch blade depth. For New Jersey in 1984 offshore strata 18,19,22,23,26, and 27 were not sampled. For Delmarva in 1984 offshore strata 11 and 15 were not sampled. Plots have varied scales.

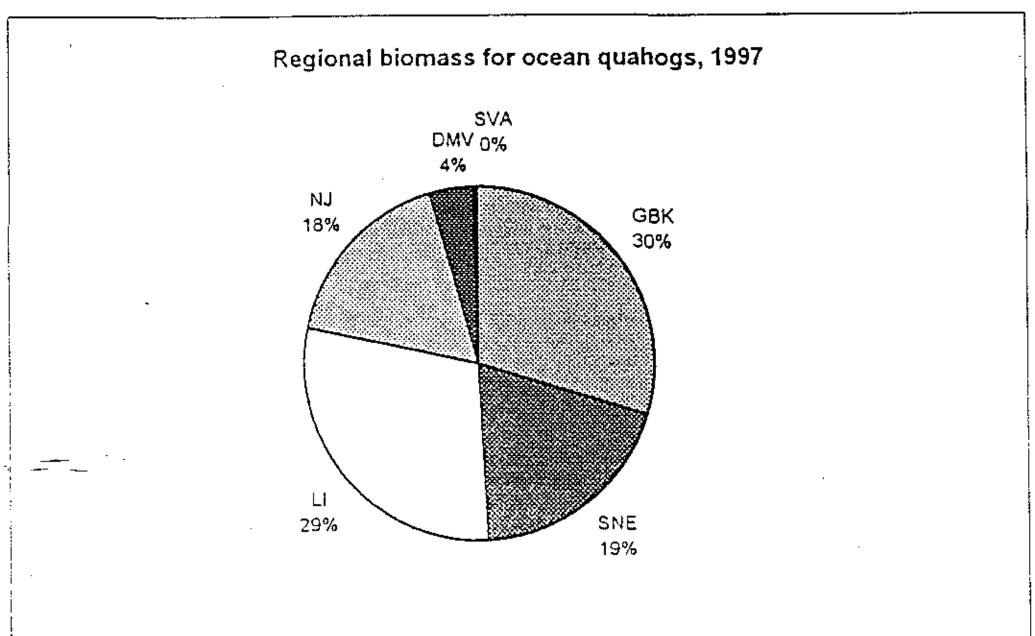


Figure E26. Percent of stock biomass by region based on the NMFS 1997 survey. Tows were standardized to 0.15 nm based on sensors, assuming a 4" critical blade depth.

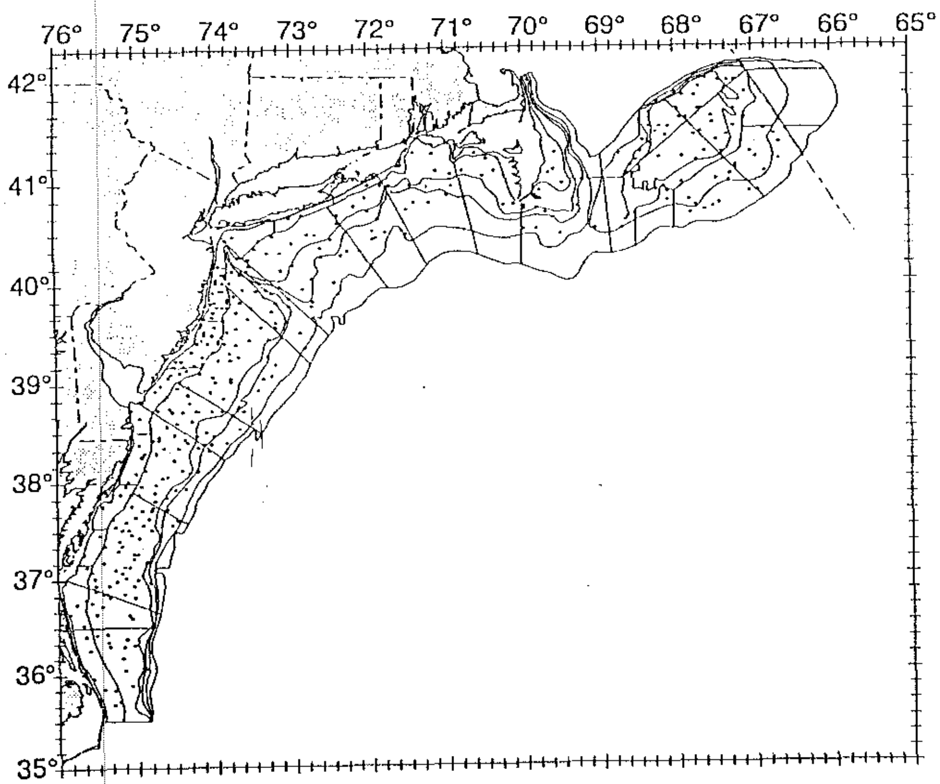


Figure E27. Stations sampled during the 1997 stratified, random clam survey.

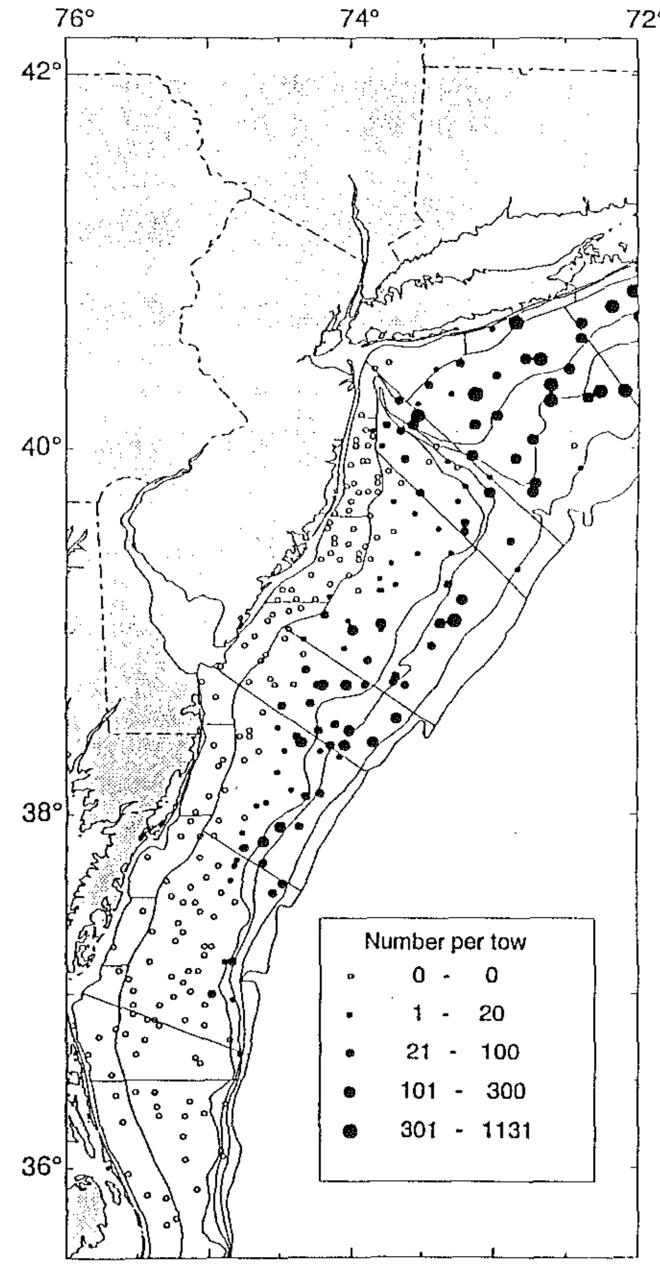


Figure E28. Distribution of ocean quahog abundance per tow (>=70 mm), during the 1997 NEFSC survey, adjusted to 0.15 n. mi. tow distance with sensor data. Blade depth = 4 inches.

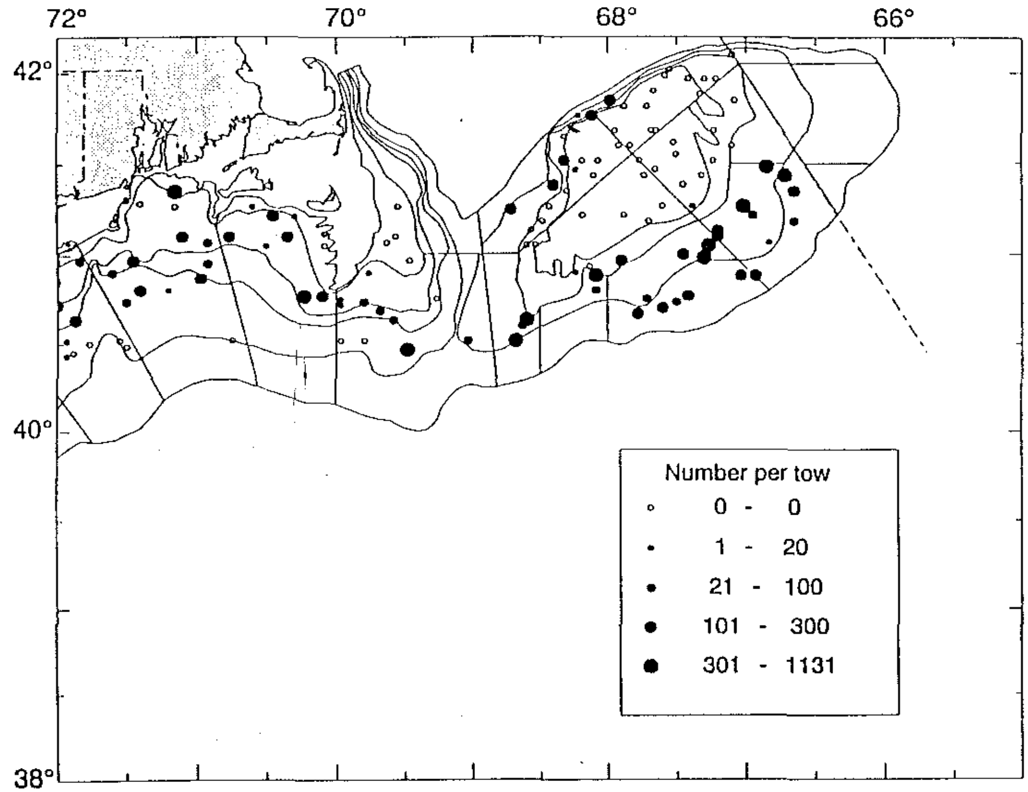


Figure E29. Distribution of ocean quahog abundance per tow (>=70mm), during the 1997 NEFSC survey, adjusted to 0.15 n. mi. tow distance with sensor data. Blade depth = 4 inches.

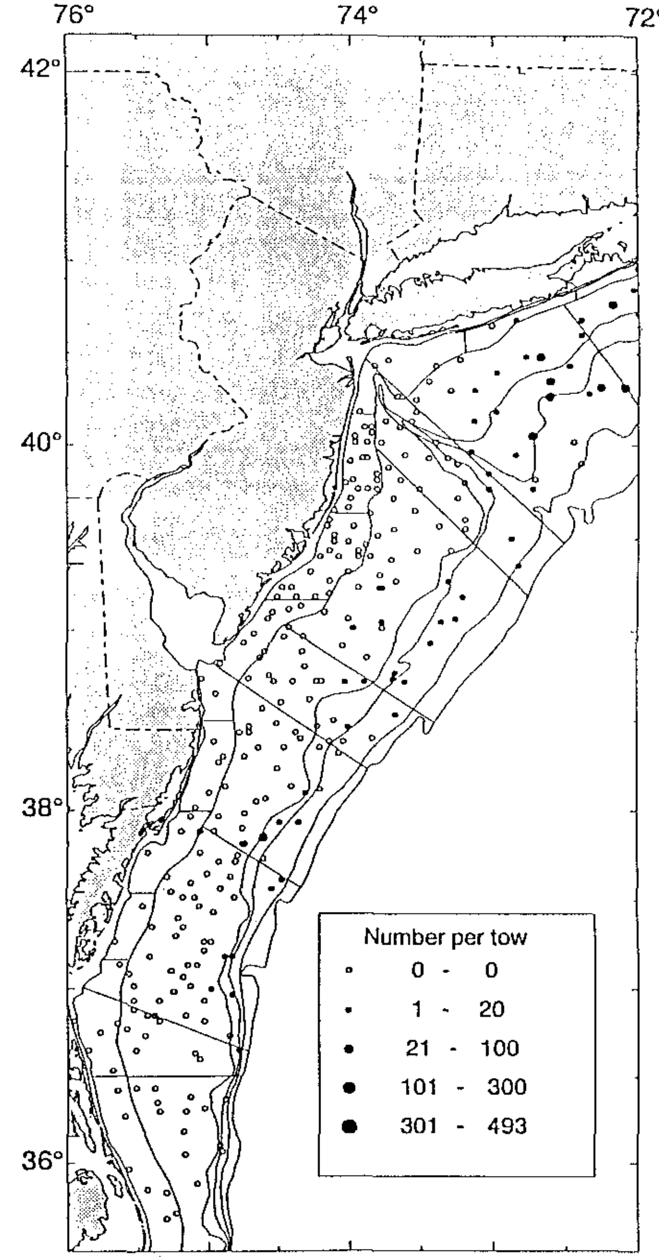


Figure E30. Distribution of ocean quahog abundance per tow (<70mm), during the 1997 NEFSC survey, adjusted to 0.15 n. mi. tow distance with sensor data. Blade depth = 4 inches.

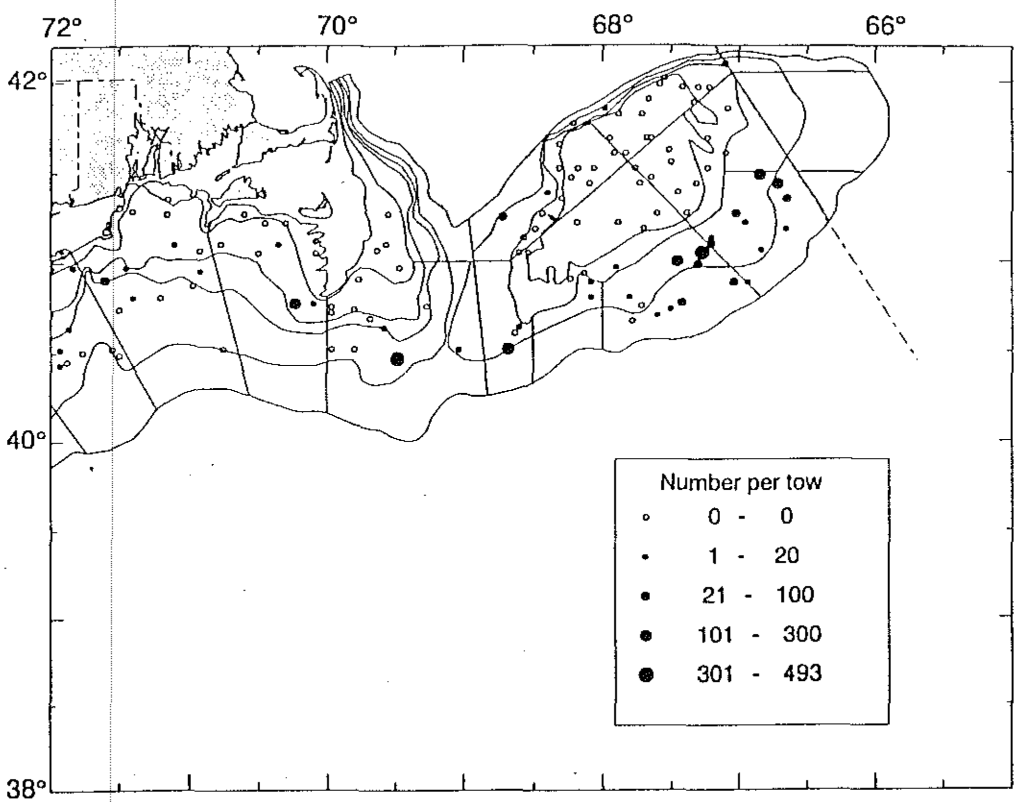


Figure E31. Distribution of ocean quahog abundance per tow (<70 mm), during the 1997 NEFSC survey, adjusted to 0.15 n. mi. tow distance with sensor data. Blade depth = 4 inches.

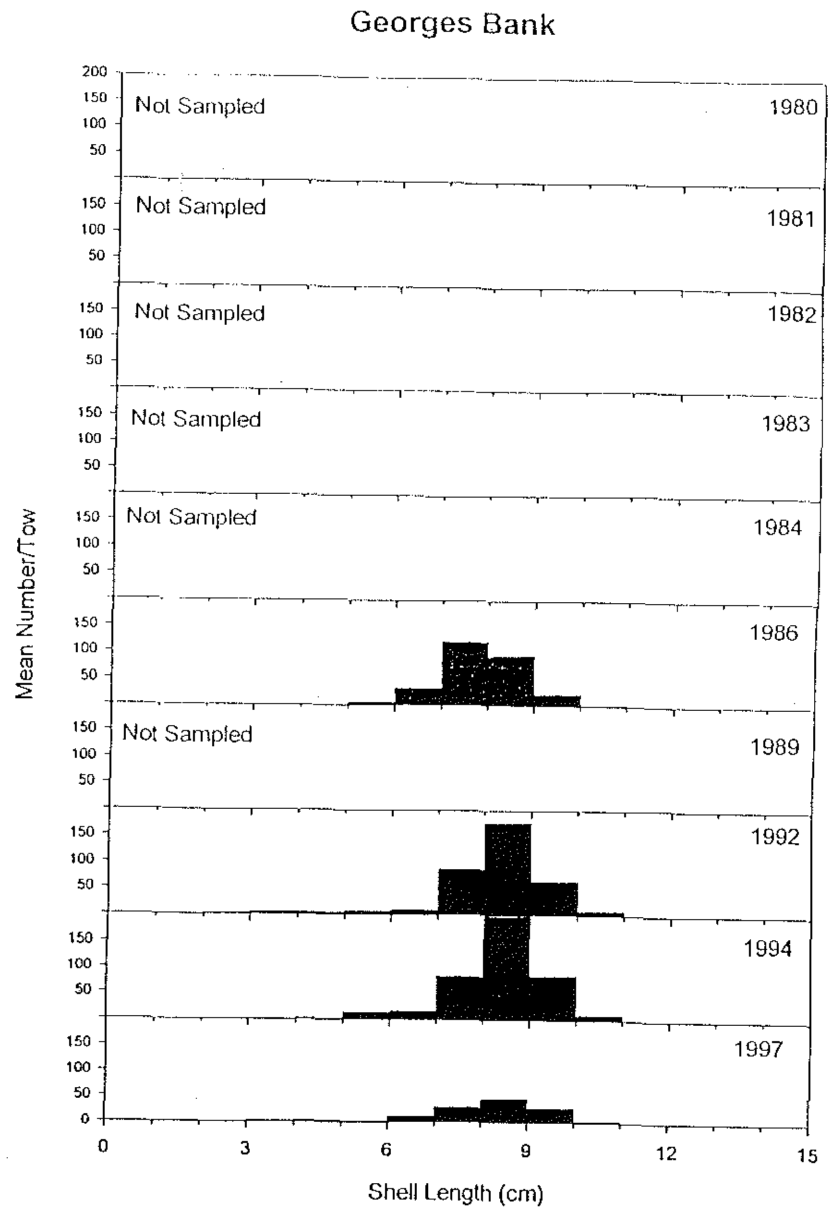


Figure E32. Length frequencies of ocean quahogs taken during hydraulic dredge surveys off Georges Bank, 1980-1997. Data are stratified mean numbers per standardized survey tow (0.15 nm). 1980-1994: data standardized by doppler distance during 5-min timed tow. 1997: data standardized by sensors on hydraulic dredge.

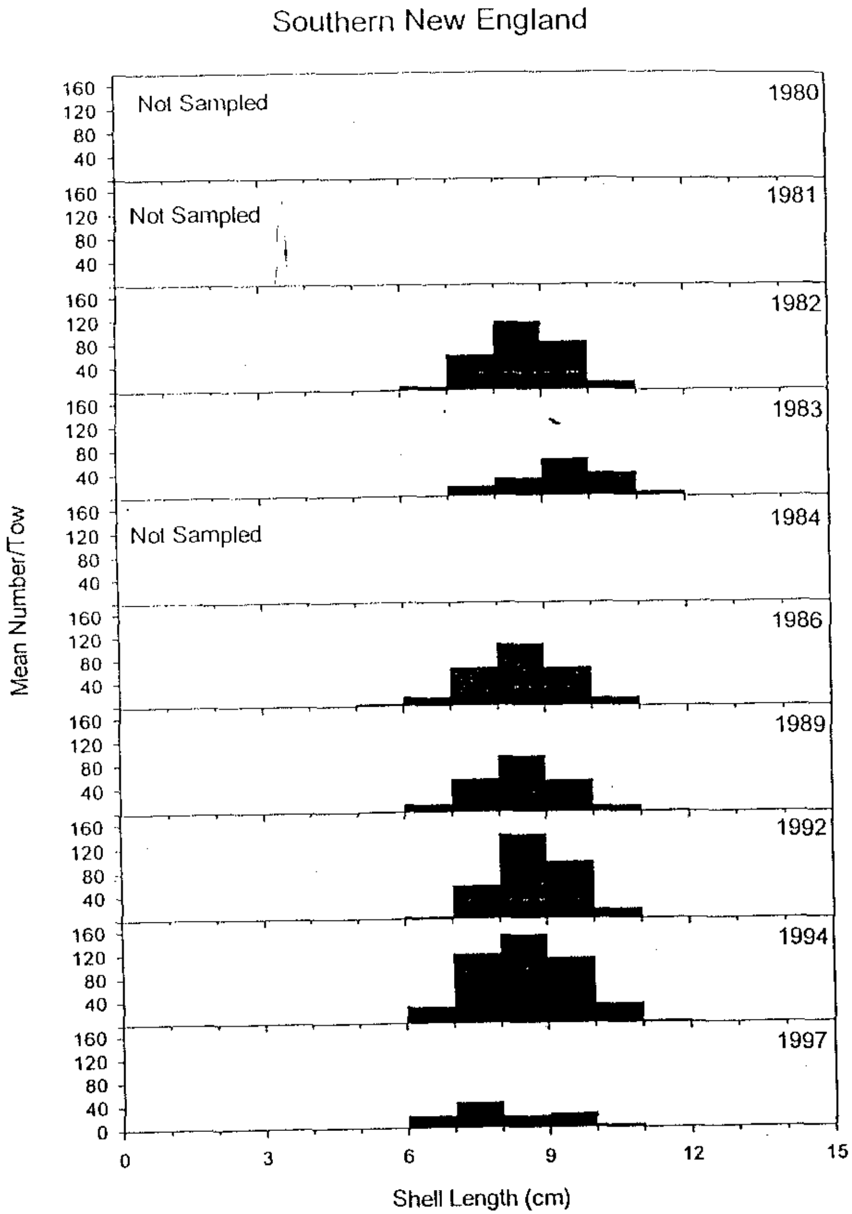


Figure E33. Length frequencies of ocean quahogs taken during hydraulic dredge surveys off Southern New England, 1980-1997. Data are stratified mean numbers per standardized survey tow (0.15 nm). 1980-1994: data standardized by doppler distance during 5-min timed tow. 1997: data standardized by sensors on hydraulic dredge.

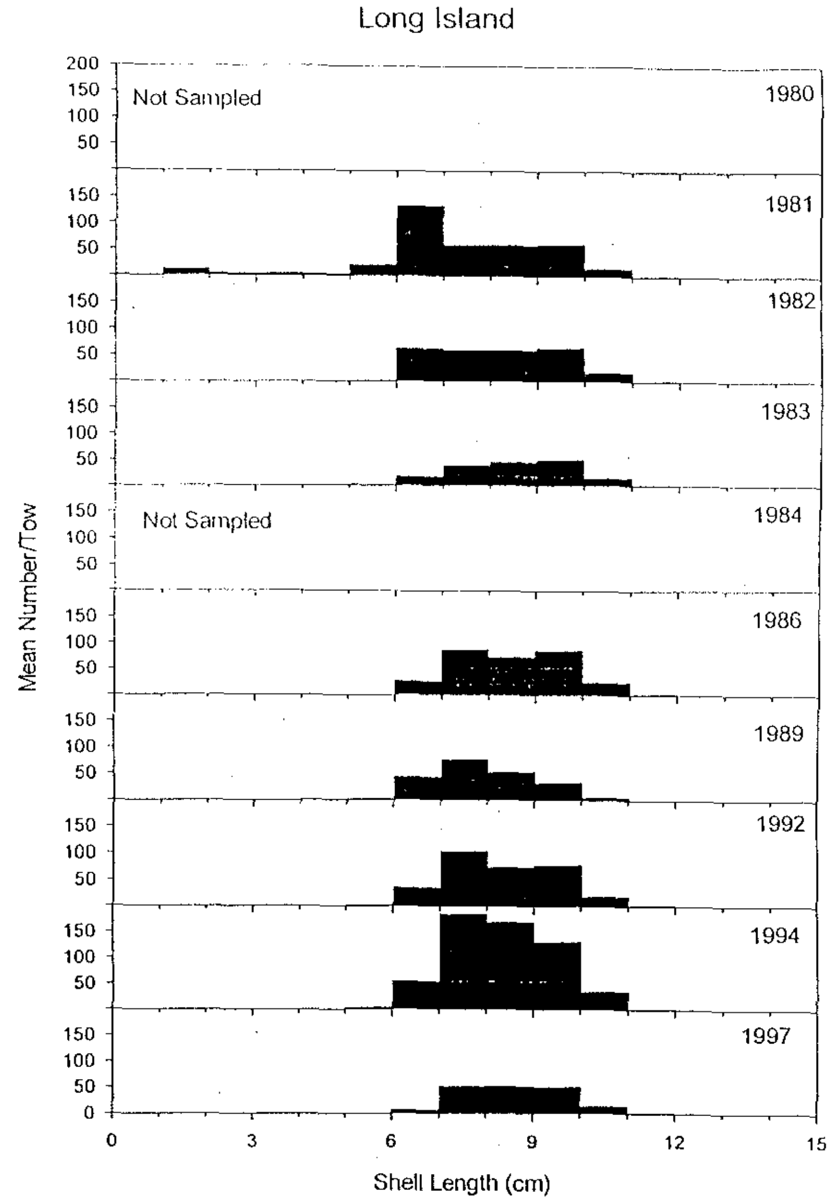


Figure E34. Length frequencies of ocean quahogs taken during hydraulic dredge surveys off Long Island, 1980-1997. Data are stratified mean numbers per standardized survey tow (0.15 nm). 1980-1994: data standardized by doppler distance during 5-min timed tow. 1997: data standardized by sensors on hydraulic dredge.

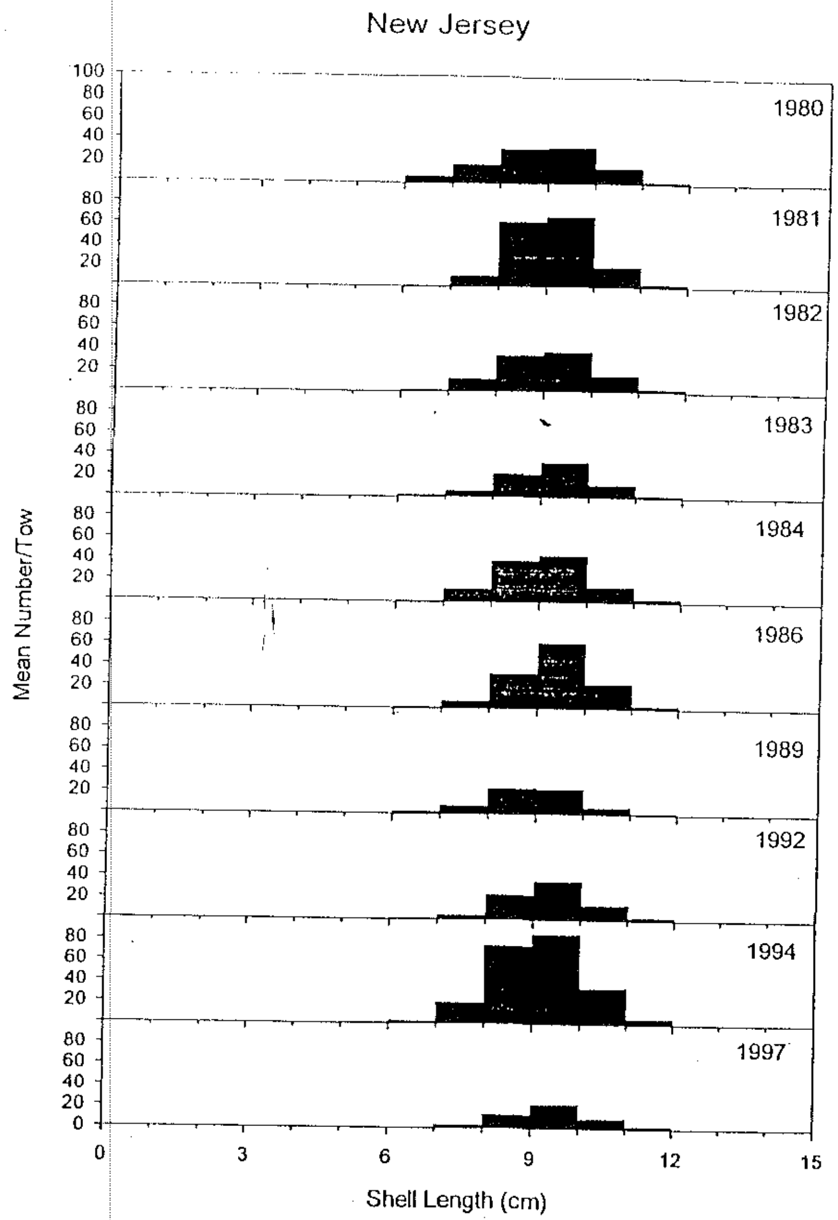


Figure E35. Length frequencies of ocean quahogs taken during hydraulic dredge surveys off New Jersey, 1980-1997. Data are stratified mean numbers per standardized survey tow (0.15 nm). 1980-1994: data standardized by doppler distance during 5-min timed tow. 1997: data standardized by sensors on hydraulic dredge.

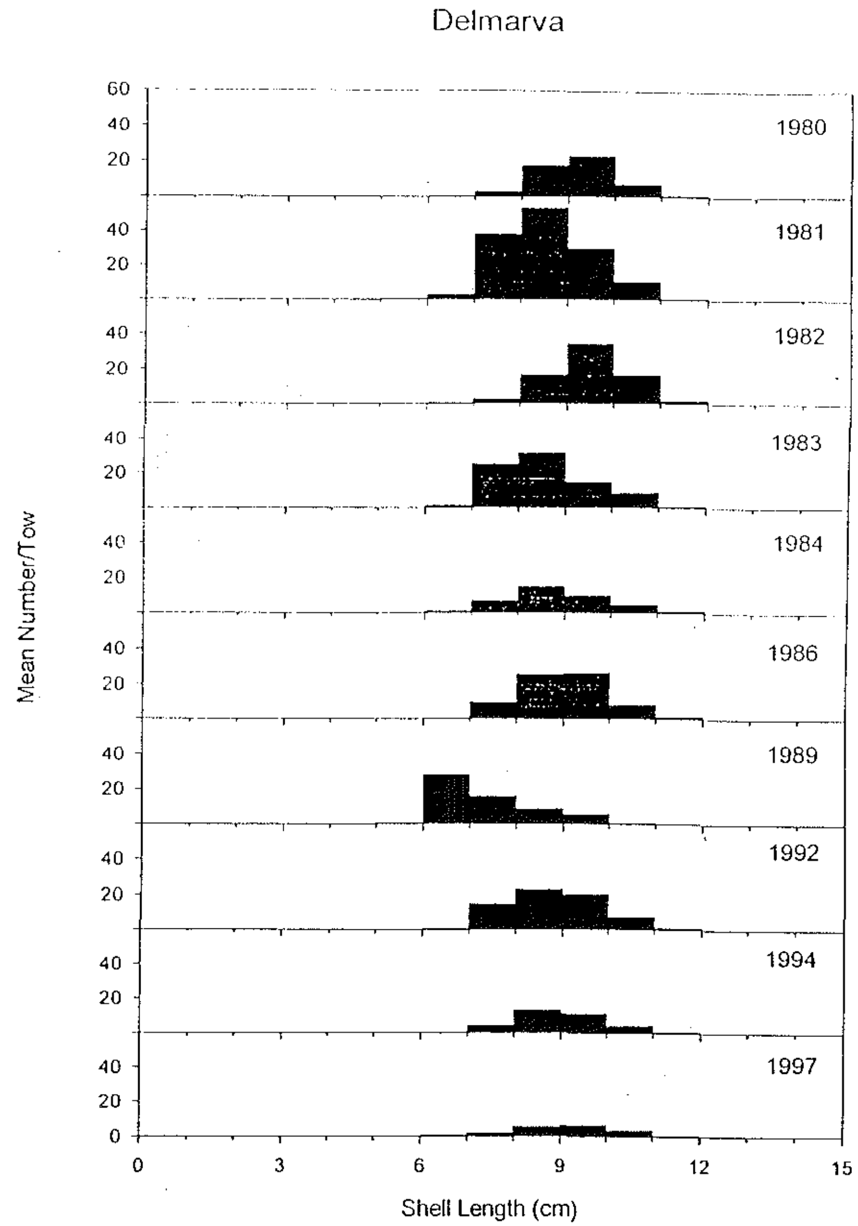


Figure E36. Length frequencies of ocean quahogs taken during hydraulic dredge surveys off Delmarva, 1980-1997. Data are stratified mean numbers per standardized survey tow (0.15 nm). 1980-1994: data standardized by doppler distance during 5-min timed tow. 1997: data standardized by sensors on hydraulic dredge.

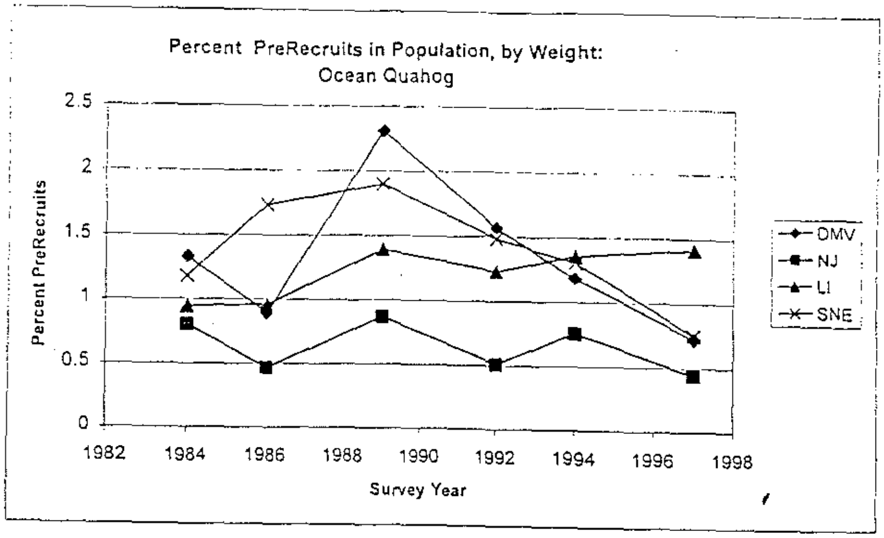


Figure E37. Estimates of PreRecruits, by weight, in ocean quahog populations, based on NMFS survey data, 1-mm intervals.

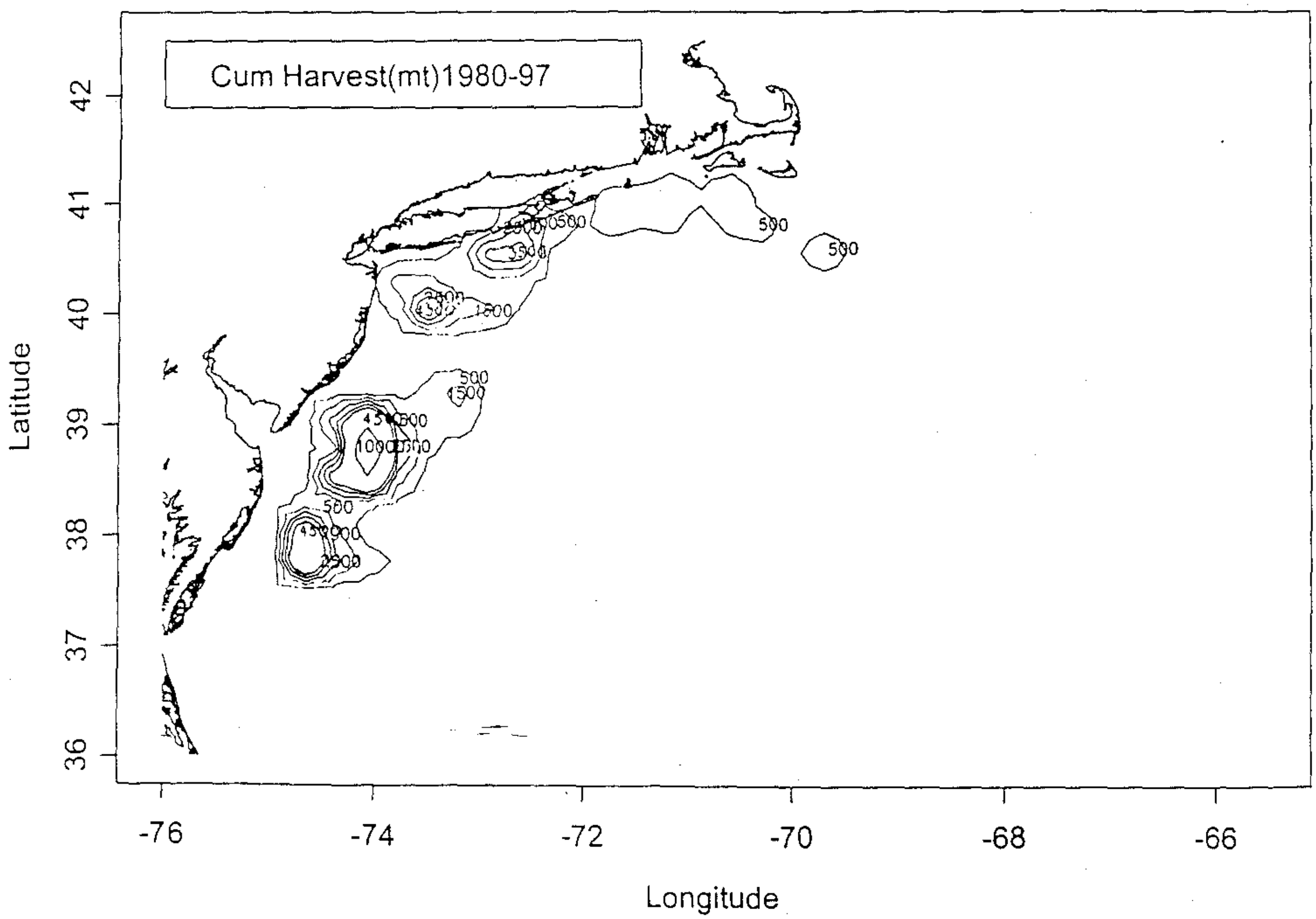


Figure E38. Cumulative harvest of ocean quahogs for years 1980-1997.

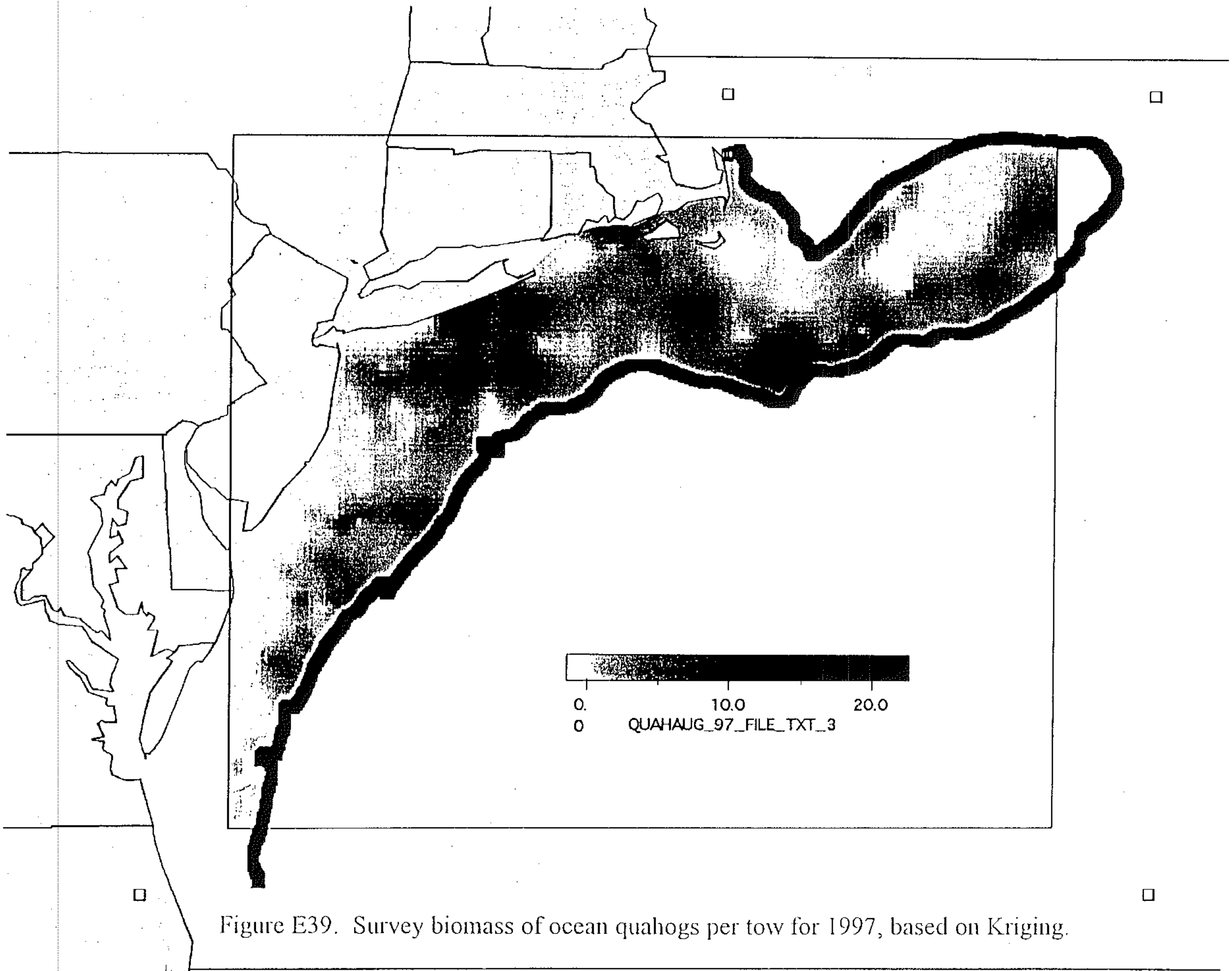


Figure E39. Survey biomass of ocean quahogs per tow for 1997, based on Kriging.

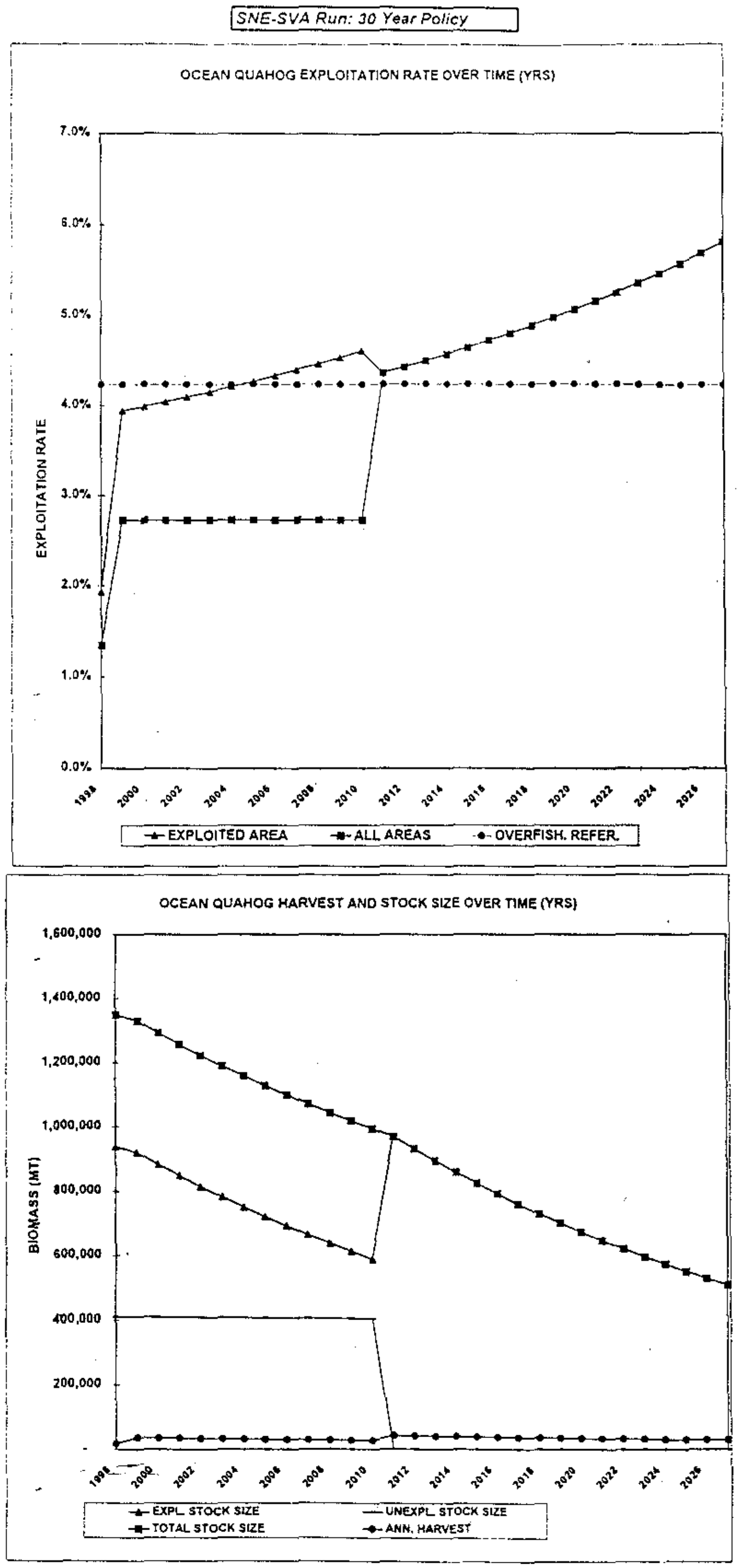


Figure E41. Ocean quahog 30-year supply model. In each year, the catch is set at that which could be taken for 30-years. The model assumes constant recruitment, and accounts for growth and natural mortality. This model does not consider "indirect" mortality from clam harvesting.

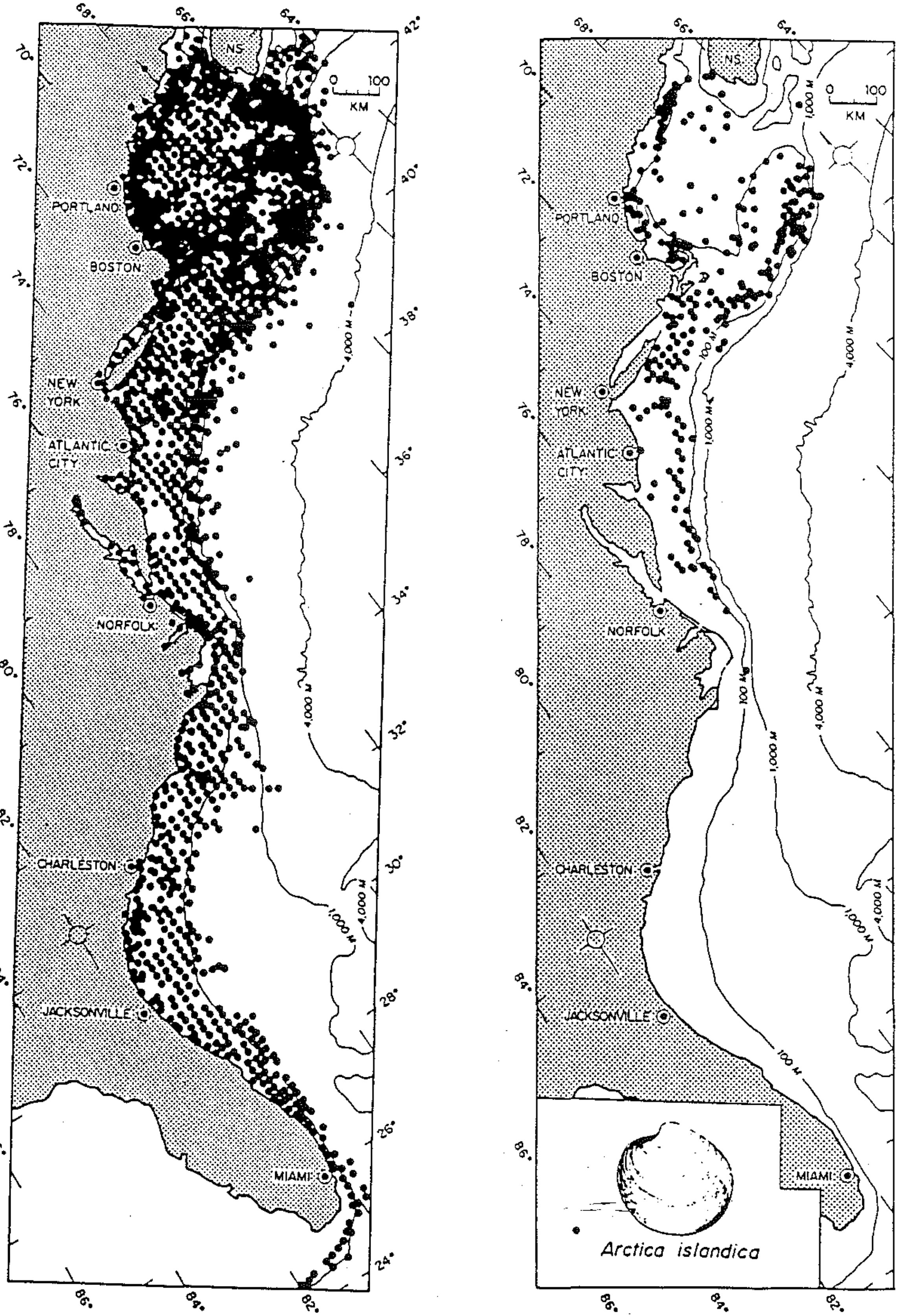


Figure E40. NOAA Technical Report NMFS SSRF-768, Roger B. Theroux and Roland L. Wigley (June 1983).

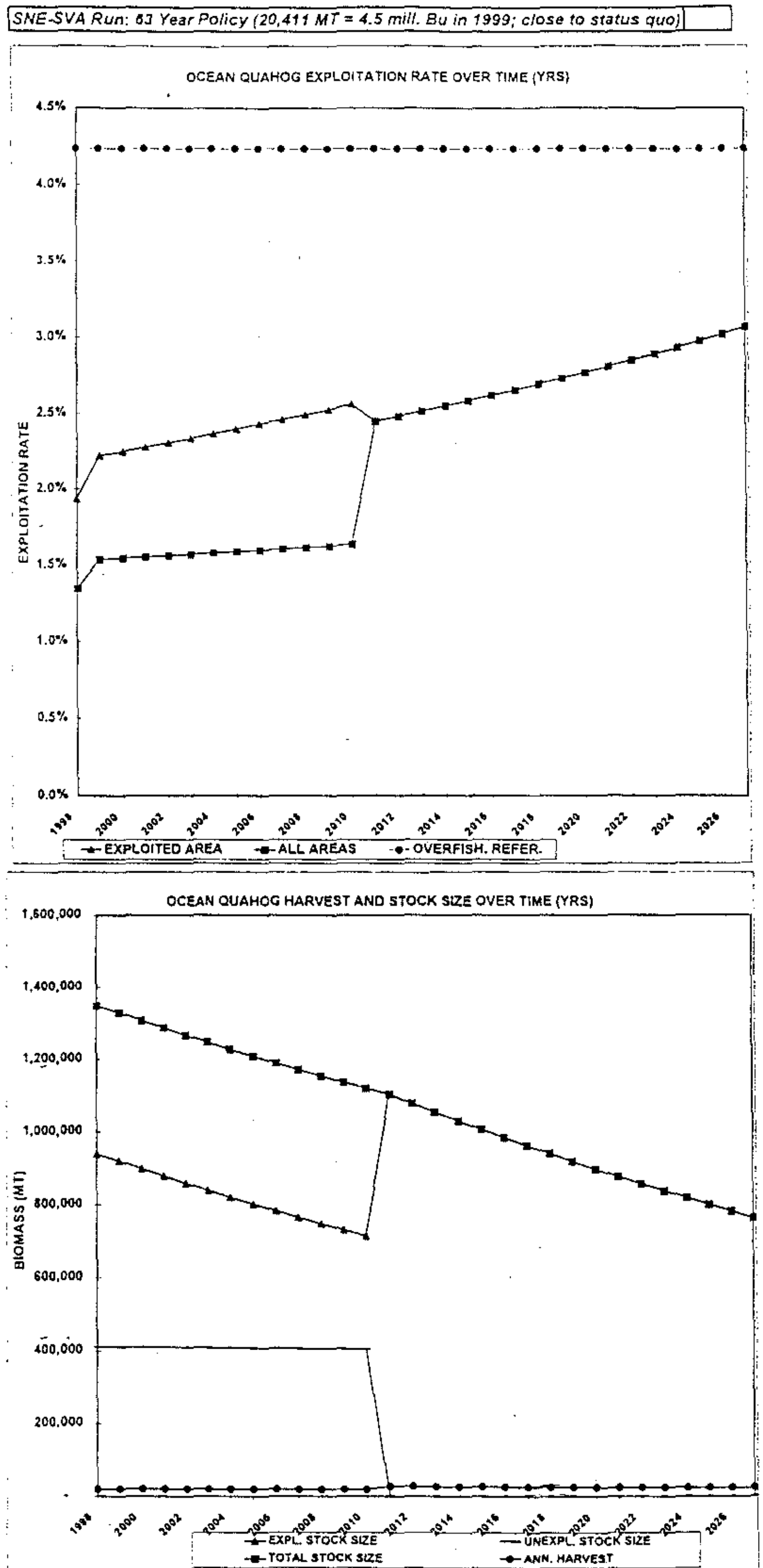


Figure E42. Ocean quahog 63-year supply model. In each year, the catch is set at that which could be taken for 63-years. The model assumes constant recruitment, and accounts for growth and natural mortality. This model does not consider "indirect" mortality from clam harvesting.

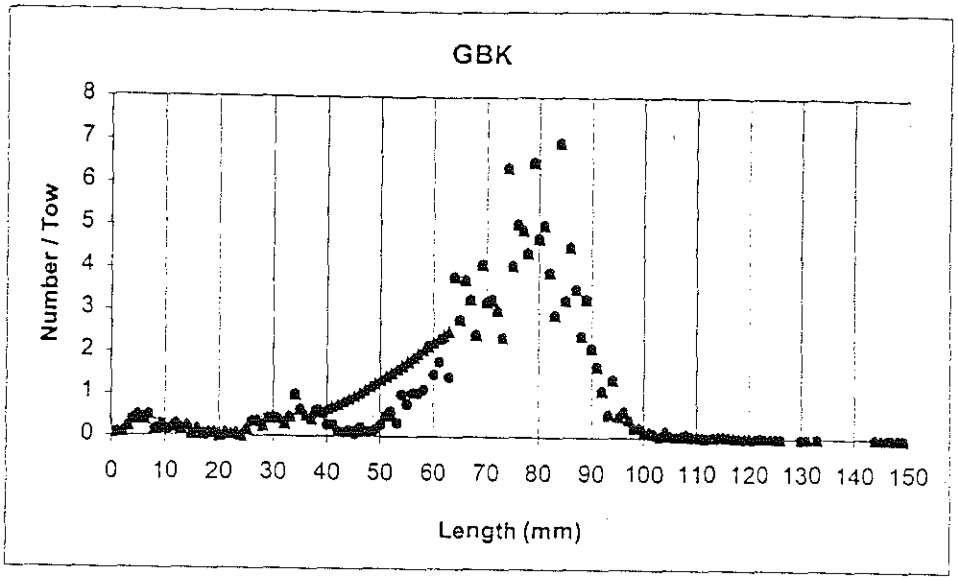


Figure E43. Observed and revised length frequency distributions for ocean quahogs. Revised curve adds clams to the small sizes to account for gear selectivity.

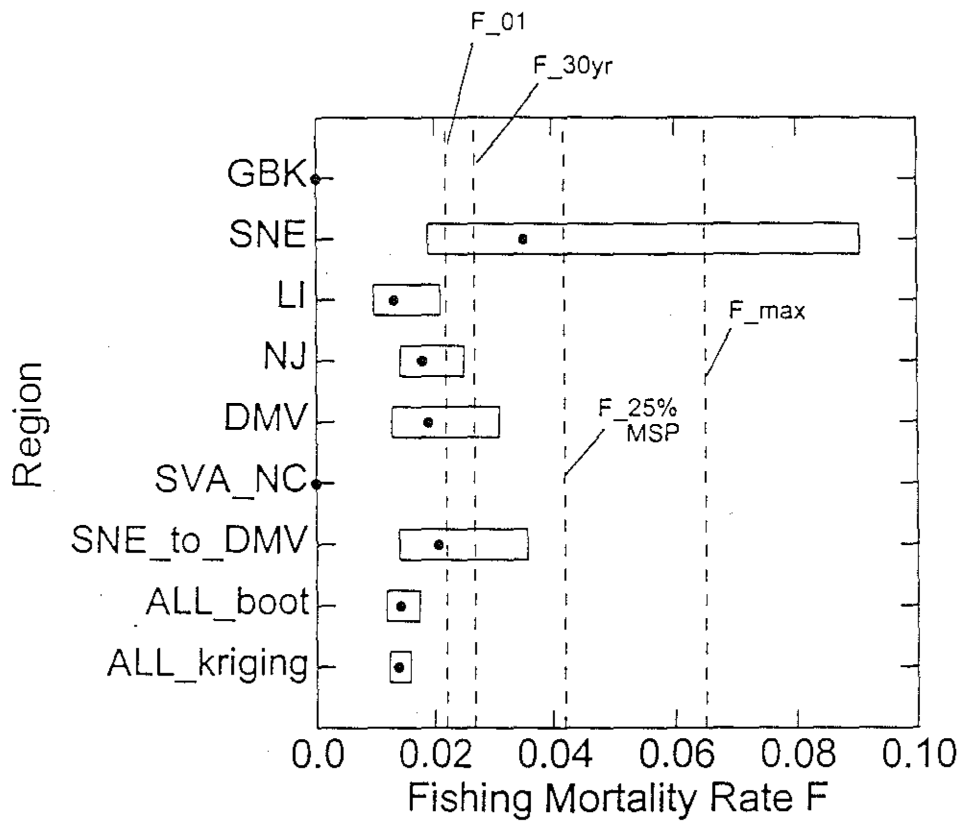


Figure E44. Comparison of estimated fishing mortality rates by region for ocean quahog with alternative biological reference points. Dots represent mean estimates, bars represent the lower and upper percentiles of 95% confidence intervals on F derived from bootstrap estimates of population biomass. For F estimates derived from kriging, the bars represent +/-2SD. Dashed lines represent alternative biological reference points.

Backward Projection

Year	Landings (mt)	Population Size (mt)	End of Yr Population Size	
1976	2,510	1,846,144	1,843,634	
1977	8,411	1,843,634	1,835,223	
1978	10,415	1,835,223	1,824,808	
1979	15,748	1,824,808	1,809,060	
1980	15,343	1,809,060	1,793,717	
1981	16,375	1,793,717	1,777,342	
1982	15,779	1,777,342	1,761,563	
1983	15,978	1,761,563	1,745,585	2,110,549 Observed '83
1984	17,602	1,745,585	1,727,983	
1985	23,755	1,727,983	1,704,228	
1986	20,585	1,704,228	1,683,643	
1987	22,795	1,683,643	1,660,848	
1988	21,006	1,660,848	1,639,842	
1989	23,145	1,639,842	1,616,697	
1990	21,195	1,616,697	1,595,502	
1991	22,287	1,595,502	1,573,215	
1992	22,882	1,573,215	1,550,333	
1993	23,430	1,550,333	1,526,903	
1994	21,093	1,526,903	1,505,810	
1995	22,229	1,505,810	1,483,581	
1996	21,074	1,483,581	1,462,507	
1997	19,740	1,462,507	1,442,767	
TOTAL	403,377	Fract of Initial Pop	0.782	

Ocean Quahogs: 1983-1997: Backward VPA

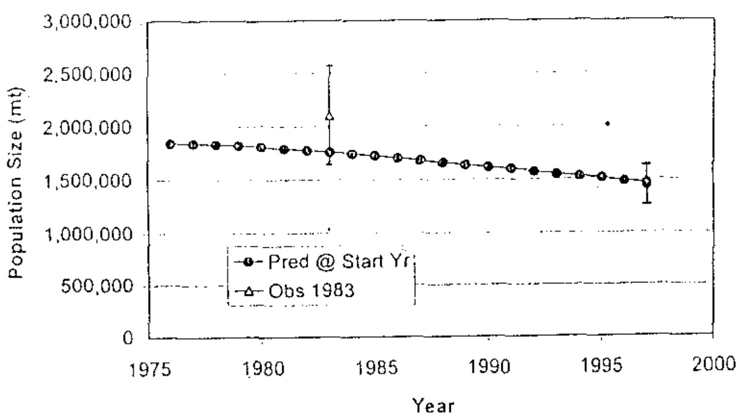


Figure E45. Estimation of virgin population biomass for ocean quahogs using VPA techniques. Starting point was 1997. The 1983 abundance estimate may be overestimated since area swept per tow were based on Doppler distances. Instantaneous rates of growth and mortality were assumed to be equal such that M-G=0. Recruitment was also assumed to be zero.

SFA Harvest Control Plot for Ocean Quahogs

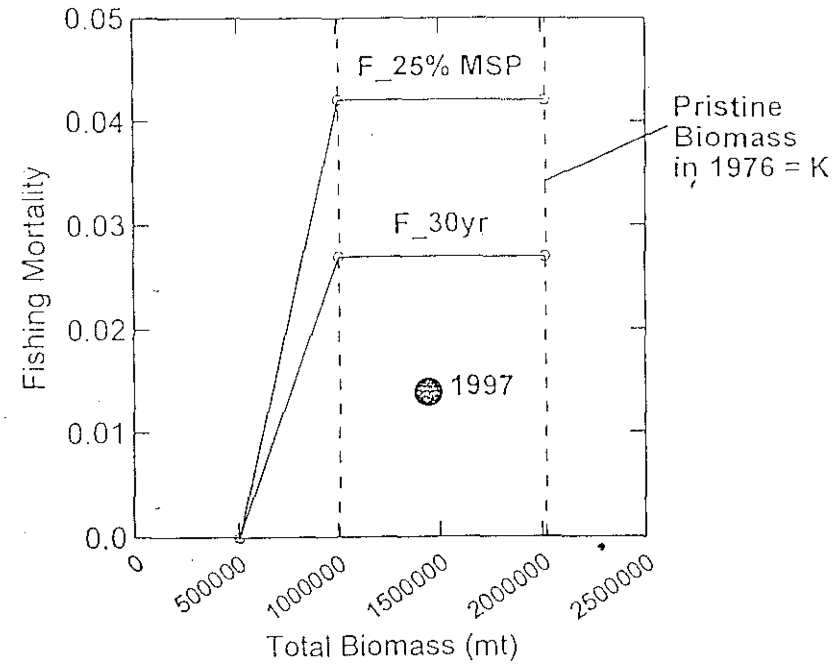


Figure E46. Estimated fishing mortality rate and total biomass of ocean quahogs in 1997 (filled circle) in relation to fishing mortality biomass thresholds and targets. Pristine biomass (K) in 1976 (right dashed line) is estimated via back-calculation method using 1997 population estimate and cumulative harvests. B_{msy} (left dashed line) is estimated as 1/2K. Horizontal lines represent two alternative fishing mortality thresholds. Sloped lines represent implied fishing mortality rates for population biomass levels between 1/4K and 1/2K.

APPENDIX A

Cruise Results, Ocean Quahog Depletion Studies
July 15, 1997 - April 26, 1998

Depletion Experiment #1

Location: Shinnecock #1, New York
F/V *Laura Ann*

Date, Time: 7/15/97, 0200-1215 hrs.

Seas 1-3 feet, wind NE-NW approx. 10-15 kn, skies sunny

Captain: Mike McVey

Owner: Thomas McNulty

Scientific personnel:	E. Powell	Rutgers
	M. Ellis	Rutgers
	P. Rago	NMFS
	J. Weinberg	NMFS

Location of experiment:
LAT: 40° 16.17'
LONG: 72° 17.91'
LORAN C x ~26150
LORAN C y ~43490

Water depth: 31-32 fathoms

Knife blade width: 93 inches

Operations:

Approximately 345 feet of towing hawser. Thirty two dredge tows completed. A total of 7 length frequency samples were obtained.

Depletion Experiment #2

Location: Wildwood, New Jersey
F/V *Agitator*

Date, Time: 8/28/97, 0600-1435 hrs.

Seas 3-5 feet, wind NE-NW approx. 10-15 kn, skies sunny

Captain: Dan

Owner: Carl Carlson

Scientific personnel:	M. Chintalla	Rutgers
	E. Powell	Rutgers
	M. Ellis	Rutgers
	K. Hubbard	Rutgers

Location of experiment:
LAT: 38°30.57'
LONG: 74°06.69'
LORAN C x~26800
LORAN C y~42700

Water depth: 26-27 fathoms

Knife blade width: 120 inches

Operations:

A total of 32 dredge tows were completed. A total of six length frequency samples were obtained.

Depletion Experiment #3

Location: Shinnecock #3, New York
F/V *Cape Fear*

Date, Time: 3/06/98, 0930-1230 hrs.

Seas 1-2 feet, wind calm, skies sunny

Captain: Steve Novack

Owner: Warren Alexander

Scientific personnel:	E. Powell	Rutgers
	R. Mann	VIMS
	M. Ellis	Rutgers
	K. Hubbard	Rutgers

Location of experiment:
LAT: 40° 45.99'
LONG: 72° 10.77'
LORAN C x ~26140
LORAN C y ~43755

Water depth: 22-23 fathoms

Knife blade width: 120 inches

Operations:

A total of 14 dredge tows were completed at this site. A total of two length frequency samples were obtained.

Depletion Experiment #4

Location: Shinnecock #2, New York
F/V *Cape Fear*

Date, Time: 3/06/98, 1330-1800 hrs.

Seas 1-3 feet, wind calm, skies sunny

Captain: Steve Novack

Owner: Warren Alexander

Scientific personnel:	E. Powell	Rutgers
	R. Mann	VIMS
	M. Ellis	Rutgers
	K. Parsons	

Location of experiment:
LAT: 40° 43.32'
LONG: 72° 00.45'
LORAN C x ~26040
LORAN C y ~43715

Water depth: 24-25 fathoms

Knife blade width: 120 inches

Operations:

A total of 23 dredge tows were completed at this site. A total of three length frequency samples were obtained.

Depletion Experiment #5

Location: Nantucket Shoals #1
F/V *Cape Fear*

Date, Time: 4/26/98, 1440-2300 hrs.

Seas 1-4 feet, wind NE approx. 10-15 kn, changing to SE later in the day, skies overcast and raining

Captain: Steve Novack

Owner: Warren Alexander

Scientific personnel:	E. Powell	Rutgers
	R. Mann	VIMS
	K. Parsons	Rutgers
	M. Ellis	Rutgers

Location of experiment:
LAT: 40° 28.02'
LONG: 69°28.98'
LORAN C x ~25050
LORAN C y ~43835

Water depth: 34.5 fathoms

Knife blade width: 120 inches

Operations:

A total of 24 dredge tows were completed at this site. A total of five length frequency samples were obtained.

F. GULF OF MAINE COD

Terms of Reference

a. Update the status of Gulf of Maine cod through 1997 and characterize the variability of estimates of stock size and fishing mortality rates.

b. Provide projected estimates of catch for 1998-1999 and spawning stock biomass for 1999-2000 at various levels of F.

c. Review existing biological reference points and advise on new reference points for Gulf of Maine cod to meet SFA requirements.

Introduction

This report presents an updated and revised analytical assessment of the Gulf of Maine cod stock (NAFO Division 5Y) for the period 1982-1997 based on analyses of commercial and research vessel survey data through 1997. A more complete presentation of assessment results, including full VPA output and bootstrap diagnostics and more detailed methodology may be found in Mayo *et al.* (1998).

From the early 1960s through 1993, information on the catch quantity by market category was derived from reports of landings transactions submitted voluntarily by processors and dealers. More detailed data on fishing effort and location of fishing activity were obtained for a subset of trips from personal interviews of fishing captains conducted by port agents in the major ports of the Northeast. Information acquired during the course of these interviews was used to augment the total catch information obtained from the dealer. After 1993, however, procedures for collecting and processing commercial fishery data in the Northeast were substantially revised. A full description of the proration methodology and an evaluation of the 1994-1996 logbook data is given in Wigley *et al.* (1998) and DeLong *et al.* (1997), and a description of data entry and auditing procedures is provided by Power *et al.* (1997).

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 12th, 15th, 19th, and 24th Northeast Regional Stock Assessment Workshops in June 1991, December 1992, December 1994, and June 1997 (NEFSC 1991, 1993, 1995, 1997; Mayo *et al.* 1993; Mayo 1995, 1998).

The Fishery

Commercial Fishery Landings

Annual commercial landings data for Gulf of Maine cod in years prior to 1994 were obtained from trip-level detailed landings records contained in master data files maintained by the Northeast Fisheries Science Center, Woods Hole, MA (1963-1993) and from summary reports of the Bureau of Commercial Fisheries and its predecessor the US Fish Commission (1895-1962). Beginning in 1994, landings estimates were derived from dealer reports prorated to stock based on the distribution of reported landed catch contained in fishing vessel logbooks as described above.

Total commercial landings in 1997 were 5,421 mt, 25% less than in 1996, and 70% less than the 1991 peak (Table F1, Figure F1). Since 1977, the US 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 account for most of the landings (52% by weight in 1997), the quantity taken by gillnets increased to 38-44% during 1993-1997 from a low of 23% in 1991; the 1997 gillnet percentage was similar to 1987-1989 (Table F2).

Commercial Fishery Discards

Discard rates were calculated by quarter and gear from NEFSC sea sampling data collected between 1989 and 1997 (Table F3). Discard and kept components of the catch were summed for all observed tows, within each gear type, occurring in Division 5Y, and the ratio of the discarded to kept quantity was applied to landings for the corresponding quarter and gear type within each year. Data were available for otter trawls, shrimp trawls and sink gillnets. Calculations and sample sizes are given in Mayo *et al.* (1998: Appendix 1: Tables 1-3 and Figures 1-3).

Discard-to-kept ratios and absolute quantities were highest in 1989 and 1990 for the otter trawl and shrimp trawl gear. Ratios in the otter trawl fishery declined from 0.30-0.60 in 1989 and 1990 and remained low through 1997, fluctuating between 0.002 and 0.155. In the shrimp trawl fishery, ratios remained high throughout 1989-1991, but declined substantially in 1992 and remained negligible in 1993. Sea sampling data for 1994-1997 were minimal; therefore, landings by this gear component were not distinguished from all other otter trawls in the proration scheme employed to derive the landings by stock for the present assessment. Consequently, discard estimates from both otter trawl and shrimp trawl gear were combined for the 1994-1997 period.

Discards of Gulf of Maine cod ranged from 190 mt in 1997 to 3,598 mt in 1990 (Table F3). Discards exceeded 1,000 mt in each year between 1989 and 1991 before declining steadily since 1992. The relatively high discard rates calculated for otter trawl and shrimp trawl gear during 1989-1991 coincide with recruitment of the strong 1987 year class to the small-mesh shrimp trawl gear and then the large-mesh general otter trawl gear. Available length composition data for these gear types suggest that most of the discarded cod were about 30-50 cm with a mode around 40 cm. Discards emanating from these two gears are the likely result of minimum size regulations. In contrast, the relatively low, but persistent, discards of cod in the gillnet fishery comprised fish of all sizes, up to 125 cm. The larger size range reflects discarding resulting from minimum size regulations as well as poor fish quality (in the case of the larger, marketable cod).

Recreational Fishery Catches

Estimates of the recreational cod catch were derived from the Marine Recreational Fishery Statistics Survey (MRFSS) conducted annually since 1979. The Gulf of Maine cod catch was estimated assuming that catches of cod recorded by that portion of the intercept survey were removed from the ocean in statistical areas adjacent to the state or county of landing. The MRFSS database has been recently revised, resulting in adjusted catch estimates for the years 1981- 1997. Revised estimates of the total Gulf of Maine cod recreational catch as well as the portion of the catch excluding those caught and released are provided in Table F4. Information on the catch prior to 1981, which has not been revised, is included in Table F4 to provide a longer-term perspective. Further information on the details of the allocation scheme and sampling intensity are given in NEFSC (1992).

The quantity of cod retained generally exceeded 75% of the total recreational catch during 1979-1991, but has averaged less than 50% since 1993. The estimated total cod catch (including those caught and released) declined from over 5,000 mt in 1980 and 1981 to less than 2,000 mt between 1983 and 1986, increased to over 3,500 mt in 1990 and 1991, then fluctuated between 1,100 and 2,600 mt between 1992 and 1996 before declining sharply to 671 mt in 1997.

Commercial Fishery Sampling Intensity

A summary of US length frequency and age sampling of Gulf of Maine cod landings during 1982-1997 is presented in Table F5. Length frequency sampling averaged one sample per 155-200 mt landed during 1983-1987, but the sampling intensity was reduced in 1990 (1 sample per 387 mt) and 1993 (1 sample per 360 mt), and the absolute level of sampling was extremely low in 1993. Overall sampling improved slightly in 1994 and 1995, but the seasonal distribution was uneven and poorly matched to the landings. Sampling improved substantially in 1996 and remained equally high in 1997, reaching all-time highs in terms of both absolute number of samples and samples per ton landed in both years.

Virtually all of the US samples have been taken from otter trawl landings, but sampling and the estimation of length composition is stratified by market category (scrod, market, and large). Although the length composition of cod differs among gear types (primarily between otter trawl and gillnet), the length composition of cod landings within each market category is virtually identical among gear types. Of the 78 samples collected in 1997, 29 were scrod samples (37%), 36 were market (46%), and 13 were large

(17%). Compared with the 1997 market category landings distribution by weight (scrod: 20%; market: 60%; large: 17%), sampling in 1997 reasonably approximated the market category distribution of the landings.

Commercial Landings Age Composition

The 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 NEFSC research vessel survey length-weight equation for cod:

$$\ln \text{Weight}_{(kg,live)} = -11.7231 + 3.0521 \ln \text{Length}_{(cm)}$$

to the quarterly market category sample length frequencies. Computed mean weights were then divided into quarterly market category landed weight to derive estimated numbers landed by quarter, by market category. Quarterly age/length keys were applied to the quarterly market category numbers at length distributions to provide numbers at age. These results were summed over market categories and quarters to derive the annual landings-at-age matrix (Table F6).

Age composition of landings from 1994 through 1997 were estimated in a manner similar to that employed for the 1982-1993 estimates except that samples and landings were, on occasion, pooled to the semi-annual level because of the uneven distribution of length and age samples by quarter (Table F5). Semi-annual pooling was required for the first and second quarters of 1994 because of incomplete sampling coverage of scrod and large cod landings. In 1995, samples were pooled in both semi-annual periods due to the absence of large cod samples and the sparse coverage of market cod in quarters 1 and 3. Quarterly allocation of samples to landings was achieved for all market categories in 1996 and 1997.

Gulf of Maine cod landings are generally dominated by age 3 and 4 fish in numbers and ages 3, 4, and 5 by weight. Cod from the strong 1987 year class predominated from 1990 through 1992, but, by 1993, fish from the 1990 year class accounted for the greatest proportion of the total number landed (Table F6). 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. From 1994 through 1996, landings were dominated by age 4 cod in both number and weight. In 1997, age 5 fish were dominant in terms of both number and weight, reflecting the higher abundance of the 1992 year class. Although traditionally low in terms of their contribution to the total landings, age 10 and 11+ fish were completely absent in 1993 and 1996, and numbers of age 8 and 9 fish have also been unusually low (Table F6). Although this pattern may be partly a result of the poor sampling of 'large' category cod, a trend towards fewer older fish in the landings has been apparent since 1991. As well, the contribution of age 2 fish to the landings has decreased in recent years.

Commercial Landings Mean Weights at Age

Mean weights at age in the catch for ages 1-11+ during 1982-1997 are given in Table F7 and, based on landings patterns, are considered mid-year values. Mean weights of age 2 and 3 cod have risen since about 1992, reflecting decreased partial recruitment of younger fish to the fishery, while those for intermediate-aged fish have fluctuated without any particular trend. Mean weights for ages 9 and older fluctuate considerably and are particularly sensitive to sampling variability. Thus, it is unlikely that the apparent increases in mean weights at ages 10 and 11+ since the late 1980s would indicate a shift in growth or an increase in older fish in the plus group.

In 1990, mean weights at ages 2 and 4 were the lowest in the 9-year time series, while mean weights for ages 6, 7, and 9 were among the highest. These changes, however, may be artifacts of low sampling levels in 1990. Mean weights at ages 8 and 9 in 1993 and at ages 5 and 6 in 1995 were the highest in the series, but these anomalies are also the likely result of poor sampling. However, the increase in mean weight at age 2 in 1995 and 1996 may be related to the use of 152 mm (6 in) mesh in the otter trawl fishery. Mean weights at age for calculating stock biomass at the beginning of the year are provided in Table F8. These values were derived from the catch mean weight-at-age data (Table F7) using the procedures described by Rivard (1980).

Recreational Fishery Sampling Intensity

Information on the length frequency sampling levels of Gulf of Maine cod taken in the recreational fishery is provided in Table F4. An examination of the available length frequency sampling coverage was conducted to evaluate the potential utility of these data in estimating the overall length composition of the removals from the stock which could be attributed to this gear type. Overall, sampling for cod taken by recreational gear is poor, averaging less than 1 sample per 1,000 mt removed (Table F4). Sampling of the recreational fishery has improved in recent years. However, given the highly variable sampling over the past 15 years, these data were not formally included in the VPA conducted in 1997 (NEFSC 1997; Mayo 1998). Therefore, no further treatment of the 1997 recreational data was performed in this assessment.

Stock Abundance and Biomass Indices

Commercial Catch Rates

Trends in commercial LPUE and fishing effort for the period 1965-1993 and 1994-1996 have been recently described by Mayo (1998) and are illustrated in Figures F2 and F3. Given the uncertainty in reported fishing effort since 1994, these data were not formally included in the previous VPA conducted in 1997 (NEFSC 1997; Mayo 1998). Until effort units are resolved in the commercial fishery database, no further treatment of the LPUE series after 1993 will be performed. Further details regarding data selection, preparation, and LPUE 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 kg), developed from Northeast Fisheries Science Center (NEFSC) and Commonwealth of Massachusetts research vessel bottom trawl survey data, have been used to monitor changes and assess trends in population size and recruitment of cod populations off New England. Offshore (>27 m) stratified random NEFSC surveys have been conducted annually in the Gulf of Maine in autumn since 1963 and in spring since 1968. Inshore areas of the Gulf of Maine (<27 m) have been sampled during spring and autumn NEFSC and Commonwealth of Massachusetts inshore bottom trawl surveys since 1978. For the NEFSC surveys, a "36 Yankee" trawl has been the standard sampling gear, except for spring 1973-1981 when a modified "41 Yankee" trawl was used.

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 Commonwealth 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 trawl differences, but vessel and door coefficients have been applied to adjust the stratified means (number and weight per tow) as described in Table F9. Unadjusted catch-per-tow-at-age (number) indices from NEFSC spring and autumn surveys are given in Mayo *et al.* (1998: Appendix 2: Table 1), and standardized catch-per-tow-at-age (number) indices are listed in Table F10. Catch-per-tow-at-age (number) indices from Massachusetts spring and autumn surveys are listed in Table F11.

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 F9, Figure F4). Abundance indices (stratified mean number per tow) declined during the mid- and late 1960s but since 1972-1973 have fluctuated as a result of a series of recruitment pulses. Sharp increases in the abundance indices reflect above-average recruitment of the 1971, 1973, 1977-1980, 1983, and 1985-1987 year classes at ages 1 and 2 (Table F9, Figure F5). 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. The recent increases in the autumn 1995 and spring 1996 abundance indices may be attributed to the 1992 year class which was the largest within the recent series of poor year classes (Figure F5).

Spring NEFSC abundance indices have remained relatively low since 1985 at a level below the 1981-1984 average (Table F9); spring biomass indices (stratified mean weight per tow) 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 F9). The index declined markedly in 1994, remained low in 1995, increased moderately in 1996, and remained essentially unchanged in 1997.

Autumn abundance and biomass indices declined sharply in 1991 to unprecedented low levels. Biomass indices continued to decline to record low levels through 1993 and have remained extremely low through 1996 (Figure F4). Increased abundance levels in 1988 and 1989, resulting from recruitment of the strong 1986 and 1987 year classes, were depleted by 1991, resulting in the sharp declines in the overall index. This reduction, combined with a general paucity of large fish in the surveys in recent years (Table F10), has resulted in the decline and subsequent continuation of low biomass indices since 1991. Although the recent increase in the autumn abundance and biomass indices in 1994 and 1995 reflected recruitment of the 1992 year class, these indices declined again in 1996 and remained low in 1997.

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 F10 and F11). Based on Massachusetts DMF and NEFSC survey-catch-per-tow indices during 1989-1996, only the 1992 year class appears to be of moderate strength. The remaining year classes appear to be below average, and the 1994, 1995, and 1996 year classes are likely to be record lows.

Mortality

Total Mortality Estimates

Pooled estimates of instantaneous total mortality (Z) were calculated for six time periods encompassed by the NEFSC spring and autumn offshore surveys: 1964-1967, 1968-1976, 1977-1982, 1983-1987, 1988-1990, and 1991-1994 (Table F12). Total mortality was calculated from survey catch-per-tow-at-age data (Table F10) 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:

Spring: ln (Σ age 4+ for 1982-84/ Σ age 5+ for 1983-1985)

Autumn: ln (Σ age 3+ for 1981-83/ Σ age 4+ for 1982-1984)

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

Values of Z derived from the spring surveys are generally comparable to 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 ($Z \leq 0.50$) between 1964 and 1982, but increased significantly thereafter to approximately 1.0 during 1982-1994, with an indication of a slight decline after 1994.

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).

Estimation of Fishing Mortality Rates and Stock Size

Virtual Population Analysis Calibration

The ADAPT calibration method (Parrack 1986, Gavaris 1988, Conser and Powers 1990) was used to derive estimates of terminal fishing mortality (F) in 1997. As in previous assessments, age-disaggregated analyses were performed. Several exploratory ADAPT formulations were performed using NEFSC spring and autumn (ages 2-6), and Massachusetts DMF spring (ages 2-4) and autumn (ages 1-3) survey series. Due to uncertainty in the interpretation of effort units in the 1994-1997 VTR data, US commercial LPUE abundance indices for ages 3-6 were included only through 1993. This change effectively removed the influence of the LPUE indices on the terminal year outcome of the calibration, while preserving the historic relationship employed in the previous assessment. As in the previous assessment (Mayo 1998), the US commercial LPUE indices from 1982 through 1993 were derived from the catch at age corresponding to the effort sub-fleet used in the estimation of standardized fishing effort as described by Mayo *et al.* (1994). The NEFSC and Massachusetts DMF autumn indices were lagged forward by one age and one year, whereby age 1-6 indices were related to age 2-7 stock sizes in the subsequent year for corresponding cohorts. All NEFSC and Massachusetts DMF indices were related to January 1 stock sizes, and US commercial LPUE indices were related to mid-year stock sizes.

The 1982-1997 commercial landings at age, as provided in Table F6, include true ages 2-10 as well as the 11+ group. In recent years, however, older fish beyond age 7 have been poorly represented. As reported by Mayo (1995), a previous calibration run employing an extended 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, as in previous assessments of this stock (NEFSC 1993, 1995, 1997) all trial formulations employed a reduced age range (ages 2-6 and 7+).

As in the past, Massachusetts DMF survey data were included in the VPA calibration primarily to improve the estimates of recruiting year class size. In exploratory analyses, the DMF autumn age 1 and 3 (age 2 before lagging) indices often accounted for up to 40% of the total sum of squares. These indices were again, as in previous assessments, excluded from the final calibration because of their high variability. The series of trial formulations is summarized in Table F13. All of the trial calibrations employed equal weighting among indices in all years. The formulation identical to that employed in the previous assessment (NEFSC 1997; Mayo 1998) is presented first. This formulation and the second one listed in Table F12 employed commercial landings-at-age data as in the previous assessment. Two additional trial calibration runs were performed as sensitivity analyses. The first of these eliminated all of the LPUE indices, and the second excluded the Massachusetts DMF autumn age 2 index. These formulations employed the same age range in the direct estimation of terminal populations.

In all trials, the F pattern in 1997 was somewhat inconsistent, with relatively high Fs estimated for age 3 relative to age 4. However, CVs among all trials were generally similar, ranging from 30-38% on age 3 to 46-57% on age 6. None of the variations on the initial formulation produced noticeably different results in terms of terminal Fs, population numbers, or CVs. Residuals of the observed and predicted indices derived from the final VPA formulation (Figure F6) do not indicate any consistent trends over the period of the VPA, except for the Massachusetts DMF age 2 autumn index. Exclusion of this index, however, results in the highest CV on the age 2 stock size estimate, although the magnitude of the estimate is similar. Incorporation of the age 1 and 3 indices from the Massachusetts DMF survey adds additional noise to the calibration analysis, resulting in higher CVs on the estimates of older ages, higher total sums of squares, and mean square residuals compared to the other trial formulations.

The ADAPT formulation employed in the final VPA calibration was the same as that used in the previous assessment (NEFSC 1997; Mayo 1998). This analysis provided direct stock size estimates for ages 2-6 in 1998 and corresponding estimates of F on ages 1-5 in 1997. 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 4-6. 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. The present analysis uses an updated maturity schedule which reflected earlier maturation beginning in 1994.

Virtual Population Analysis Results

Full results from the final VPA calibration are given in Mayo *et al.* (1998: Appendix 3), and estimates of F, stock size, and spawning stock biomass are presented in Table F14. All parameter estimates were significant. Coefficients of variation on the stock size estimates ranged from 0.32 (age 3) to 0.52 (age 6), while CVs on the estimates of slopes were between 0.16 and 0.19. Slopes of the abundance index-stock size relationships (Mayo *et al.* 1998: Appendix 3, page 10) increased with age generally up to age 4 for the NEFSC spring and autumn surveys and the US commercial LPUE indices. The Massachusetts DMF spring indices exhibited a decreasing trend in q between ages 2 and 4, possibly reflecting the inshore nature of the survey relative to the distribution of the adult stock.

Average (ages 4-5, unweighted) fishing mortality in 1997 was estimated at 0.75 (Table F14, Figure F7), a 21% decrease from 1996. The spawning stock biomass of age 2 and older cod declined from about 22,500 mt in 1982 to about 14,100 mt in 1987. Following the recruitment and maturation of the strong 1987 year class, SSB increased sharply in 1989 to a maximum of about 26,100 mt, but declined to about 10,100 mt in 1993, a 4-year reduction of 61% (Table F14, Figure F8). SSB increased to about 14,300 mt in 1995 due to growth and maturation of the 1992 year class, but declined again in 1996 and reached a record low of about 8,600 mt in 1997. SSB estimates for the 1994-1996 period are higher than those reported in the 1997 assessment primarily as a result of the revision to the maturation schedule employed in the present assessment. Total stock size (ages 2+) has also declined sharply in recent years from 28 million fish in 1989 to 2.6 million in 1998, a decrease of 91% (Table F14).

Since 1982, recruitment at age 2 has ranged from less than 1.5 million fish (1994, 1995, and 1996 year classes) to 17.7 million fish (1987 year class). Over the 1982-1996 period, geometric mean recruitment for the 1980-1994 year classes was 4.4 million fish. The 1987 year class is the highest in the 1982-1996 series and about twice the size of the above-average 1980 and 1986 year classes. Except for the moderate 1992 year class, recent recruitment has been poor as the 1988-1989 and the 1993-1996 year classes (all < 3 million at age 2) are estimated to be among the poorest in the series (Table F14, Figure F8). In particular, the 1994, 1995, and 1996 year classes average less than 1 million fish. The 1993-1996 year classes are each about 1/2 the size of their immediate predecessor; the 1996 year class being about 1/16th the size of the 1992 year class.

Precision of F and SSB

A bootstrap procedure (Efron 1982) was used to evaluate the precision of the final estimates by generating 1,000 estimates of the 1997 fishing mortality rate and spawning stock biomass. The distributions of the bootstrap estimates and the corresponding cumulative probability curves are shown in Figures F9 and F10. The cumulative probability expresses the likelihood that the fishing mortality rate was greater than a given level (Figure F9) or the likelihood that spawning stock biomass was less than a given level (Figure F10) when measurement error is considered. An evaluation of the precision of the 1998 stock size, 1997 fishing mortality, 1997 spawning stock biomass, and q estimates is presented in Mayo *et al.* (1998: Appendix 4).

Coefficients of variation for the 1997 stock size (numbers) estimates ranged from 0.31 (age 3) to 0.61 (age 2), and CVs for qs among all indices ranged from 0.15 to 0.17. The fully-recruited fishing mortality for ages 4+ was reasonably well estimated (CV = 0.24). The mean bootstrap estimate of F (0.7750) was slightly higher than the point estimate (0.7507) from the VPA and ranged from 0.46 to 2.04. The 80% probability interval ranges from 0.57 to 1.00 (Figure F9). $F_{20\%}$ and F_{max} are much lower than the lowest bootstrap estimate, and F_{97} is higher than the overfishing definition mortality rate and the maximum F allowable to achieve stock rebuilding.

Although the abundance estimates for individual ages in 1998 had wide variances (CV = 0.31-0.61), the estimate of 1997 spawning stock biomass was robust (CV = 0.15). The bootstrap mean (9,200 mt) was slightly higher than the VPA point estimate (8,900) and ranged from 5,700 mt to 15,400 mt. The 80% probability interval ranges from 7,700 to 10,900 mt (Figure F10). Despite this variability, current spawning stock biomass is estimated to be the lowest observed in the series. In general, estimates of stock size and fishing mortality in the present assessment are estimated with about the same precision as in the previous assessment of this stock (Mayo 1998). The VPA results are, therefore, considered sufficient to accurately characterize the overall status of the Gulf of Maine cod stock.

Retrospective Analysis

No new retrospective analyses of the Gulf of Maine cod VPA were carried out in the present assessment because only one year of data was added and the final ADAPT formulation was the same as in the 1997 assessment (NEFSC 1997; Mayo 1998). Results of the previous retrospective analysis were reported in Mayo (1998). Convergence of estimates was generally evident within 3 years, and often within 2 years, prior to any given terminal year. Retrospective patterns with respect to terminal F were evident for Gulf of Maine cod in the most recent years. Mean F (ages 4-5, unweighted) in the terminal year was generally under-estimated in the most recent years by the ADAPT calibration and slightly over-estimated in earlier years. Terminal Fs appear to have been well estimated through 1993. Despite these patterns, the retrospective analysis provides additional evidence to substantiate the current high levels of F. Retrospective patterns for SSB and age 2 recruits are similar, both indicating relatively consistent estimates of terminal year values during 1991-1996. Although subject to some variability, terminal year recruitment and SSB appear to have been estimated with a high degree of reliability in recent years.

Spawning Stock and Recruitment

The relationship between spawning stock biomass and recruitment for Gulf of Maine cod was examined from two perspectives. First, a traditional spawning stock-recruitment scatterplot (Figure F11) was constructed over the period covering the 1982-1996 year classes. In addition, a survival ratio, expressed as recruits per unit of SSB (R/SSB) was calculated for each year class (Figure F12). The stock-recruitment trajectory indicates the position of the most recent levels of SSB and recruitment in the lower left corner of the plot. The 1994, 1995, and 1996 year classes appear as the lowest in the series, and each originated from SSBs of 10,000-14,000 mt. The 1997 SSB (8,600 mt) and the likely 1998 SSB (6,600 mt) are also shown in contrasting symbol. The probability of realizing low recruitment appears to increase at SSB levels below 14,000 mt.

Survival ratios of pre-recruits up to age 2 are highest for the 1987 and 1992 year classes, both of which emerged from about average year classes. Survival ratios were consistently higher during the early-to-mid 1980s prior to the emergence of the large 1987 year class. Survival has been declining since the 1992 year class recruited and is at a record-low level for the 1995 and 1996 year classes.

Biological Reference Points

Yield and Spawning Stock Biomass per Recruit

Analyses of yield, total stock biomass, and spawning stock biomass per recruit were performed using the method of Thompson and Bell (1934). Mean weights at age for application to yield per recruit were computed as a 16-year arithmetic average of catch mean weights at age (Table F7) over the 1982-1997 period. Mean weights at age for application to SSB per recruit were computed as a 16-year arithmetic average of stock mean weights at age (Table F8) over the 1992-1997 period. The maturation ogive was the same as used in computing SSB during the 1994-1997 period in the VPA. To obtain the exploitation pattern for these analyses, a 3-year geometric mean F at age was first computed over the period 1994-1996 from the final converged VPA results. These years were chosen specifically to encompass the period since enactment of the increase in the minimum allowable mesh (152 mm). The 1997 results were excluded because the exploitation pattern at age 3 appeared inconsistent with the previous years. A smoothed exploitation pattern was then obtained by dividing the F at age by the mean unweighted F for ages 4-5, adjusted to the average partial recruitment for ages 4 and 5. The final exploitation pattern is as follows:

Age 1	0.000
Age 2	0.027
Age 3	0.231
Age 4	0.786
Ages 5+	1.000

This pattern is similar to that used in the 1997 assessment (NEFSC 1997; Mayo 1998), but differs from those used in the previous two Gulf of Maine cod assessments (Mayo *et al.* 1993; Mayo 1995) and reflects recent management actions designed to increase mesh selectivity. This partial recruitment pattern 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 F15 and are illustrated in Figure F13. The yield-per-recruit analyses indicate that $F_{0.1} = 0.16$ and $F_{max} = 0.29$, and SSB-per-recruit calculations indicate that $F_{20\%} = 0.39$. The yield-per-recruit reference points are identical to and the SSB-per-recruit reference point ($F_{20\%}$) is slightly higher than those reported in the previous assessment (NEFSC 1997; Mayo 1998).

MSY-Based Reference Points

Estimates of B_{msy} and F_{msy} for Gulf of Maine cod were derived from production model analyses (Prager 1995) integrating landings and relative biomass indices over the period 1963-1996 (Anon. 1998). Results suggest that B_{msy} for Gulf of Maine cod is in the range of 33,000 mt and that the corresponding F_{msy} is 0.31, slightly above the current rebuilding F. The modeling results indicate that biomass was above B_{msy} from the 1960s to the early 1980s (Anon. 1998), but as F exceeded F_{msy} in the early 1980s, biomass declined to low levels in the 1990s. Current biomass is estimated to be only 35% of B_{msy} (Anon. 1998). According to a proposed harvest control rule for this stock based on SFA requirements, fishing mortality should be less than $\frac{1}{2}F_{msy}$ (i.e., less than 0.15), based on the current level of SSB.

Catch and Stock Biomass Projections

Short-term projections of spawning stock biomass, recruitment at age 2, and commercial landings were performed using the VPA-calibrated 1997 fully-recruited mean F (ages 4-5, u) and 1998 stock size estimates from the 1,000 bootstrap replications as starting conditions. The stochastic simulations were repeated 100 times to obtain a series of probability profiles for each projected variable. The exploitation pattern and maturation rates were as described above for the yield- and SSB-per-recruit analyses. Catch and stock mean weights at age were computed as 5-year arithmetic averages over the 1993-1997 period.

Recruitment was generated based on the model 9 formulation of Brodziak and Rago (1994). In this model, age 2 recruitment is estimated two years ahead by re-sampling the distribution of a specified range of empirical recruitment. For the near term, age 2 recruitment in 1998 was fixed at the level estimated in the VPA calibration, and recruitment in 1999 and 2000 was derived by re-sampling the distribution of values observed for the 1993-1995 year classes. This period was chosen based on the expectation that recruitment in the near term is unlikely to improve over the recent past, given the current low level of SSB. Short-term projections are provided over a range of 1999-2000 F levels which includes: F = 0.0, $F_{0.1}$, F_{max}, $F_{20\%}$, and F_{97}). Input and output from the projections are given in Table F16. The assumption of *status quo* F (i.e., F_{97}) in 1998 equal to 0.75 resulted in a 1998 catch of about 3,800 mt and a corresponding SSB of 6,600 mt. Given the potential for further shifts in fishing effort toward coastal Gulf of Maine grounds, the assumption of *status quo* F in 1998 appears reasonable, unless restrictive management actions are initiated early in the 1998-1999 fishing year.

Continued fishing at F = 0.75 in 1999 will result in projected 1999 landings of about 3,000 mt and a continued decline in SSB to 4,400 mt in 2000 from the record low 1998 level of 6,600 mt (Table F16,

Figure F14). Even if fishing mortality is reduced to F_{max} (0.29) in 1999 and 2000, SSB will not increase above the record-low 1998 level (Table F16, Figure F14).

Conclusions

The Gulf of Maine cod stock is presently at a low biomass level and remains over-exploited. Fishing mortality in 1997 (0.75) has decreased from the 1996 level (0.95), but there is a 90% probability that the 1997 F is at least twice the maximum allowable level to achieve stock rebuilding. Spawning stock biomass (SSB) has declined from over 26,000 mt in 1989 to a record low of 6,600 mt in 1998, and is expected to decline further in 1999 to a new record-low 5,700 mt or less. Accounting for the estimation uncertainty associated with the 1997 SSB (8,600 mt) and 1997 F (0.75) estimates, there is an 80% probability that the 1997 SSB lies between 7,700 mt and 10,900 mt, and that the 1997 F lies between 0.57 and 1.00. This further implies a 90% probability that the 1997 F is greater than 0.57, or 1.5 times greater than the overfishing definition ($F_{20\%}$ = 0.41).

At the present level of exploitation and probable levels of recruitment in the near term, the decline in spawning stock biomass is expected to continue. At the current rate of exploitation (F = 0.75), landings are expected to decline to about 3,000 mt in 1998, and spawning stock biomass is projected to decline to about 4,400 mt in 2000. Current SSB is no longer dominated by the 1987 year class, but by a series of very low to average year classes produced from 1988 through 1995. The moderate 1992 year class was the only above-average year class since 1987. Recruitment from the three most recent year classes produced in 1994, 1995, and 1996 is extremely poor, far below any previously observed levels.

An immediate and substantial reduction in fishing mortality, in the order of 50%, is required to halt the continuing decline in SSB. Rebuilding of SSB will require even further reductions over the long term. If fishing mortality is not reduced from the present level, SSB will decline to only 4,400 mt in the near future.

SARC Comments

Alternative model formulations discussed during the SAW-24 SARC meeting (e.g. zero values vs missing values, allowing error in the catch at age, use of all survey data) are still applicable to the current assessment and need to be explored in future assessments. In terms of current stock status, incorporating the survey data prior to 1982 would be beneficial for estimating trends in productivity and reference points related to MSY.

An alternative model would be expected to give confirmatory results, as was shown for the SAW-24 assessment. In addition, it was noted that, given the depleted state of this stock and the consistency of the signals coming from the surveys, any alternative model would give similar results.

Recruitment for the last several years has been estimated to be the lowest in the time series. It was noted that, given that the R/S survivorship has also been declining in recent years, the projections based on these estimates of recruitment may be optimistic.

It was noted that the recent changes in F are difficult to interpret. Management measures (e.g., mandatory logbooks, differential accounting of days at sea by fleet sector, rolling area closures) have been too variable or too recent to attribute a change in F to management restrictions. Possible reallocation of effort between Georges Bank and the Gulf of Maine or the inherent imprecision in the proration of landings to proper stock area may also be influencing F estimates.

It was noted that the high exploitation of Gulf of Maine cod may influence or be influenced by the fishery on Georges Bank cod since the stocks are not completely separate units. Tagging studies have shown eastern-western migration on Georges Bank, although no tagging has concentrated on potential northern-southern movement between Georges Bank and the Gulf of Maine. Also, there is evidence of movement of cod between the Gulf of Maine and the Scotian Shelf.

Research Recommendations

- Investigate the effect of treating zero catches in the survey indices as missing values.
- Calculate mean weights at age applicable to the population from survey size and age composition data.
- Investigate alternative modeling approaches to capture trends in abundance, SSB and recruitment from periods prior to the VPA time series.

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Table F1. Commercial landings (metric tons, live) of Atlantic cod from the Gulf of Maine (NAFO Division 5Y), 1960 - 1997.[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
1994*	7877	-	-	-	7877
1995*	6798	-	-	-	6798
1996*	7194	-	-	-	7194
1997*	5421	-	-	-	5421

* Provisional

[1] USA 1960-1993 landings from NMFS, NEFSC detailed weighout files and canvass data.
[2] USA 1994-1996 landings estimated by prorating NMFS, NEFSC detailed weighout data by Vessel Trip Reports.

Table F2. Distribution of USA commercial landings (metric tons, live) of Atlantic cod from the Gulf of Maine (Area 5Y), by gear type, 1965-1997. 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 Gillnet	Line Trawl	Handline	Other Gear	Total	Otter Trawl	Sink Gillnet	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
1994	4205	3317	338	[i]	17	7877	53.4	42.1	4.3	[i]	0.2	100.0
1995	3450	3050	281	[i]	17	6798	50.8	44.9	4.1	[i]	0.3	100.0
1996	4012	2825	335	[i]	22	7194	55.8	39.3	4.7	[i]	0.3	100.0
1997	2798	2175	426	[i]	22	5421	51.6	40.1	7.9	[I]	0.4	100.0

[a] Of 166 mt landed, 107 mt were by mid-water pair trawl and 42 mt were by drifiting gillnets.
[b] Of 91 mt landed, 56 mt were by Danish seine and 27 mt were by drifting gillnets.
[c] Of 167 mt landed, 199 mt were by drifting gillnets 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.
[i] Handline and line trawl combined.

Table F3. Discard and total catch estimates (metric tons, live) for Gulf of Maine cod by otter trawl, shrimp trawl, and sink gillnet gear, 1989-1997.

Year	Total Landings	Discard Estimates: Included Landings	Discard Estimate	Discard to Landings Ratio	Total Discard	Total Catch
1989	10397	10182	1513	0.1486	1545	11942
1990	15154	14827	3521	0.2375	3598	18752
1991	17781	17374	1025	0.0590	1049	18830
1992	10891	10511	582	0.0554	603	11494
1993	8287	8058	320	0.0397	329	8616
1994	7877	7522	228	0.0303	239	8116
1995	6798	6500	408	0.0627	426	7224
1996	7194	6837	189	0.0277	199	7393
1997	5421	4974	174	0.0351	190	5611

Table F4. Estimated number (000's) and weight (metric tons, live) of Atlantic cod caught by marine recreational fishermen from the Gulf of Maine stock, 1979-1997.[1]

Year	Total Cod Caught		Total Cod Retained (excluding those caught and released)				
	No. of Cod (000's)	Wt. of Cod (mt)	No. of Cod (000's)	Wt. of Cod (mt)	Mean Weight (kg)	Number Sampled	Percent of Total Landings
1979	2698	3466	not estimated		------- not estimated ------		
1980	2254	6860	not estimated		------- not estimated ------		
1981	2933	5944	2738	5549	1.595	380	30.7
1982	1833	2138	1736	2025	1.121	377	13.0
1983	1455	1388	1237	1180	1.323	882	7.8
1984	1098	1705	905	1405	1.520	596	11.5
1985	1671	1964	1471	1729	1.238	295	13.9
1986	1114	967	993	862	1.942	75	8.2
1987	2625	2317	2054	1813	1.738	320	19.4
1988	1487	2114	1300	1848	2.049	407	18.8
1989	1769	2690	1193	1814	1.736	404	14.9
1990	1725	3882	1247	2806	1.964	206	15.6
1991	1770	3635	1419	2914	2.004	370	14.1
1992	585	1154	332	655	2.001	922	5.7
1993	1564	2378	772	1174	1.831	290	12.4
1994	1424	2578	516	934	1.844	750	10.6
1995	1206	1799	517	771	1.716	1028	10.2
1996	812	2112	351	913	2.099	1068	11.3
1997	434	671	161	250	2.692		4.4

[1] 1981-1997 from Revised Marine Recreational Fishery Statistics Survey database expanded catch estimates.

Table F5. USA sampling of commercial Atlantic cod landings from the Gulf of Maine cod stock (NAFO Division 5Y), 1982-1997.

	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
1994	30	2696	33	665	0	2	2	4	**8**	1	4	4	6	**15**	0	2	3	2	**7**	180	284	272	263
1995	31	2568	32	662	4	2	2	4	**12**	2	7	1	2	**12**	0	5	0	2	**7**	133	300	202	219
1996	77	7027	71	1483	6	5	7	9	**27**	7	9	10	12	**38**	1	3	3	5	**12**	62	116	79	93
1997	78	6657	74	1521	7	10	3	9	**29**	11	9	9	7	**36**	1	8	2	2	**13**	37	91	71	69

Source: 1978-1985 from Serchuk and Wigley (Woods Hole Lab. Ref 86-12); 1986-1997 from NEFSC files.

Table F6. Catch at age (thousands of fish; metric tons) of total commercial landings of Atlantic cod from the Gulf of Maine stock (NAFO Division 5Y), 1982-1997.

Year	Age 1	2	3	4	5	6	7	8	9	10	11+	Total
Total Commercial Catch 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
1994	-	29	1016	1135	288	72	54	17	13	1	1	2626
1995	-	218	880	1153	194	12	8	22	3	1	-	2491
1996	-	65	584	1738	347	45	5	2	3	-	-	2789
1997	-	53	438	435	832	68	4	1	1	1	1	1834
Total Commercial Catch 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
1994	-	43	1975	3576	991	442	451	218	156	20	6	7877
1995	-	361	1689	3200	997	96	92	291	45	27	-	6798
1996	-	110	1247	4131	1267	333	49	18	39	-	-	7194
1997	-	92	977	1308	2658	316	36	15	7	10	2	5421

Table F7. 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), 1982-1997.

Year	Age 1	2	3	4	5	6	7	8	9	10	11+	Average
						Total Commercial Catch 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
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
1994	-	1.450	1.943	3.151	3.444	6.132	8.321	12.628	12.052	21.532	19.369	3.000
1995	-	1.652	1.921	2.775	5.142	8.290	10.755	12.914	16.433	21.504	-	2.728
1996	-	1.687	2.136	2.376	3.648	7.376	10.440	11.928	13.471	-	-	2.580
1997	-	1.733	2.233	3.007	3.193	4.649	8.543	13.439	14.787	16.075	21.356	2.958
						Total Commercial Catch 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
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
1994	-	52.4	57.2	66.6	68.1	82.7	92.0	106.4	104.9	127.3	123.0	64.4
1995	-	54.4	56.9	63.4	78.6	92.5	101.1	107.2	116.1	127.2	-	62.3
1996	-	54.6	58.8	60.7	69.3	88.9	99.9	104.8	108.7	-	-	61.8
1997	-	55.0	59.7	65.4	66.4	74.9	93.3	108.7	112.2	115.6	127.0	64.7

Table F8. Mean weight at age at the beginning of the year for Gulf of Maine cod derived from commercial landings mean weight at age using prodedures described by Rivard (1980).

	Age										
Year	1	2	3	4	5	6	7	8	9	10	11+
1982	0.791	0.965	1.364	2.364	4.267	5.670	8.246	9.853	14.071	11.713	18.456
1983	0.793	1.024	1.385	2.029	3.231	5.333	6.256	9.701	10.010	11.867	17.813
1984	0.761	1.021	1.394	2.125	3.017	4.720	6.957	7.465	11.646	11.864	15.028
1985	0.748	1.065	1.423	2.178	3.486	4.507	6.826	9.544	10.468	13.135	14.523
1986	0.745	1.083	1.521	2.259	3.622	5.205	6.509	8.902	11.824	12.141	16.554
1987	0.758	1.087	1.482	2.456	3.758	5.614	7.339	8.767	11.744	13.553	14.596
1988	0.765	1.068	1.572	2.021	4.118	5.718	8.233	9.939	12.245	14.723	20.356
1989	0.825	1.059	1.501	2.373	3.062	5.017	7.919	10.889	12.835	16.499	21.521
1990	0.803	0.982	1.453	2.008	3.573	5.435	7.232	10.438	13.388	14.795	20.295
1991	0.690	1.008	1.296	2.062	3.065	5.583	8.586	11.501	13.520	19.112	21.885
1992	0.751	1.175	1.474	2.063	2.773	4.548	8.362	10.962	12.873	16.080	20.000
1993	0.709	1.079	1.702	2.198	3.438	4.347	7.071	11.518	14.786	14.956	20.000
1994	0.664	1.142	1.585	2.440	2.942	5.168	7.168	11.237	12.929	19.436	19.369
1995	0.657	1.219	1.669	2.322	4.025	5.343	8.113	10.366	14.405	16.099	20.000
1996	0.649	1.232	1.878	2.136	3.182	6.159	9.303	11.316	13.190	18.129	20.000
1997	0.649	1.249	1.941	2.534	2.754	4.118	7.938	11.845	13.281	14.716	21.356
Average											
1993-97	0.666	1.184	1.755	2.326	3.268	5.027	7.919	11.256	13.718	16.667	20.145
1982-97	0.735	1.091	1.540	2.223	3.395	5.155	7.629	10.265	12.701	14.926	18.860

Table F9. 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), 1963-1997 [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	2.14	2.7
1995	1.91	2.4	2.01	3.7
1996	2.46	5.4	1.32	2.4
1997	2.19	5.6	0.87	1.9

[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 DELAWARE II catch per tow data to standardize these to R/V ALBTATROSS IV equivalents. Conversion coefficients 0.79 (number) and 0.67 (weight) were used in this standardization (NEFC 1991).

Table F10. 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, 1963-1997. [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
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	0.016	0.316	0.387	0.213	0.095	0.047	0.126	0.024	0.024	0.018	1.266	1.266	1.251	0.935	0.547	0.334	2.43
1995	0.000	0.050	0.180	1.120	0.370	0.150	0.030	0.000	0.010	0.000	0.000	1.910	1.910	1.860	1.680	0.560	0.190	2.43
1996	0.000	0.060	0.020	0.590	1.330	0.400	0.060	0.000	0.000	0.000	0.000	2.465	2.465	2.405	2.385	1.795	0.465	5.43
1997	0.000	0.158	0.132	0.399	0.264	0.876	0.242	0.120	0.000	0.000	0.000	2.191	2.191	2.033	1.901	1.502	1.238	5.62

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

[b] Autumn 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 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 F10 (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
1994	0.030	0.210	0.880	0.830	0.090	0.050	0.000	0.050	0.000	0.000	0.000	2.140	2.110	1.900	1.020	0.190	0.100	2.74
1995	0.010	0.070	0.280	1.230	0.330	0.080	0.010	0.000	0.000	0.000	0.000	2.010	2.000	1.930	1.650	0.420	0.090	3.67
1996	0.030	0.120	0.380	0.190	0.540	0.060	0.000	0.000	0.000	0.000	0.000	1.320	1.290	1.170	0.790	0.600	0.060	2.35
1997	0.000	0.297	0.086	0.160	0.182	0.149	0.000	0.000	0.000	0.000	0.000	0.872	0.872	0.575	0.490	0.330	0.149	1.87

[a] Strata 26-30 and 36-40.
[b] Autumn 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 F11. 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), 1978-1997. [a]

Year	Age Group 0	1	2	3	4	5	6	7	8	9	10+	Totals 0+	1+	2+	3+	Stratified Mean Weight (kg)
					Gulf of Maine Area (Mass. Regions 4-5)											
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	4.45	5.67	2.46	0.52	0.23	0.03	0.06	0.00	0.03	0.00	17.35	13.45	9.00	3.33	4.83
1995	9.84	6.41	1.36	3.89	1.20	0.09	0.00	0.00	0.00	0.00	0.00	22.79	12.95	6.54	5.18	4.49
1996	6.40	1.29	0.97	2.11	0.81	0.36	0.00	0.00	0.00	0.00	0.00	11.96	5.56	4.27	3.30	4.06
1997	10.40	3.66	1.00	1.34	0.20	0.42	0.00	0.00	0.00	0.00	0.00	17.09	6.69	3.03	2.03	2.97
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
1994	33.49	14.13	6.37	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	54.26	20.77	6.64	0.27	4.47
1995	2.56	0.64	0.54	0.79	0.02	0.00	0.00	0.00	0.00	0.00	0.00	4.55	1.99	1.35	0.81	0.74
1996	7.59	0.15	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	7.78	0.19	0.04	0.03	0.09
1997	2.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.04	0.02	0.00	0.00	0.02

[a] Massachusetts sampling strata 25-36.

Table F12. Estimates of instantaneous total mortality (Z) and fishing mortality (F)[1] for Gulf of Maine Atlantic cod, 1964 - 1996, derived from NEFSC offshore spring and autumn bottom trawl survey data.[2]

Time Period	Gulf of Maine					
	Spring		Autumn		Geometric Mean	
	Z	F	Z	F	Z	F
1964-1967	-	-	0.39	0.19	0.39	0.19
1968-1976	0.36	0.16	0.44	0.24	0.40	0.20[3]
1977-1982	0.56	0.36	0.44	0.37	0.50	0.30[4]
1983-1987	0.93	0.73	1.12	0.92	1.02	0.82
1988-1990	1.24	1.04	0.72	0.61	0.94	0.74
1991-1994	1.06	0.86	1.13	0.93	1.09	0.89[5]
1991-1996	0.69	0.49	1.07	0.75	0.86	0.66

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

[2] Estimates derived from:

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

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

[3] Excludes autumn 1967-1968 data (3+/4+) since these gave large negative Z value.

[4] Excludes autumn 1976-1977 data (3+/4+) since these gave large negative Z value.

[5] Excludes spring 1991-1992 data (4+/5+) since these gave unreasonably low Z value.

Table F13. Summary statistics of the final, base, and alternative, ADAPT VPA calibration for Gulf of Maine cod; terminal year 1997.

Final Run - Same Formulation as 1997 Assessment (Mayo 1998)
RESULTS

Approximate Statistics Assuming Linearity Near Solution
Sum of Squares: 107.044885373016
Mean Square Residuals: 0.42144

1998 Age		PAR. EST.	STD. ERR.	T-STATISTIC	C.V.	1997 Age		
N	2	4.28E+02	2.04E+02	2.10E+00	0.48	F	2	0.07
N	3	6.68E+02	2.13E+02	3.14E+00	0.32	F	3	0.63
N	4	4.56E+02	1.81E+02	2.52E+00	0.40	F	4	0.51
N	5	5.86E+02	2.20E+02	2.67E+00	0.38	F	5	0.99
N	6	4.47E+02	2.33E+02	1.92E+00	0.52	F	6	0.75

Base Run - All Indices
RESULTS

Approximate Statistics Assuming Linearity Near Solution
Sum of Squares: 210.074922109211
Mean Square Residuals: 0.70971

1998 Age		PAR. EST.	STD. ERR.	T-STATISTIC	C.V.	1997 Age		
N	2	9.30E+02	4.70E+02	1.98E+00	0.51	F	2	0.06
N	3	7.45E+02	2.80E+02	2.66E+00	0.38	F	3	0.54
N	4	5.55E+02	2.46E+02	2.26E+00	0.44	F	4	0.36
N	5	9.09E+02	3.62E+02	2.51E+00	0.40	F	5	0.73
N	6	6.98E+02	3.99E+02	1.75E+00	0.57	F	6	0.55

1997 Formulation W/O CPUE indices
RESULTS

Approximate Statistics Assuming Linearity Near Solution
Sum of Squares: 104.430923491212
Mean Square Residuals: 0.49729

1998 Age		PAR. EST.	STD. ERR.	T-STATISTIC	C.V.	1997 Age		
N	2	4.28E+02	2.21E+02	1.93E+00	0.52	F	2	0.07
N	3	6.68E+02	2.31E+02	2.89E+00	0.35	F	3	0.63
N	4	4.56E+02	1.97E+02	2.32E+00	0.43	F	4	0.51
N	5	5.85E+02	2.39E+02	2.45E+00	0.41	F	5	0.99
N	6	4.46E+02	2.53E+02	1.76E+00	0.57	F	6	0.75

1997 Formulation W/O Mass Autumn Age 2 Index
RESULTS

Approximate Statistics Assuming Linearity Near Solution
Sum of Squares: 75.1191873904909
Mean Square Residuals: 0.31563

1998 Age		PAR. EST.	STD. ERR.	T-STATISTIC	C.V.	1997 Age		
N	2	4.24E+03	2.47E+03	1.72E+00	0.58	F	2	0.05
N	3	8.69E+02	2.64E+02	3.29E+00	0.30	F	3	0.63
N	4	4.52E+02	1.63E+02	2.77E+00	0.36	F	4	0.64
N	5	4.35E+02	1.59E+02	2.73E+00	0.37	F	5	1.02
N	6	4.23E+02	1.97E+02	2.15E+00	0.46	F	6	0.83

Table F14. Estimates of stock size (000s of fish) and instantaneous fishing mortality rate (F) for Gulf of Maine cod.

Stock numbers (Jan 1) in thousands

Age	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	6162	5534	7746	4914	7410	9954	21648	3376	3392
2	9108	5018	4530	6339	4023	6067	8148	17724	2764
3	4328	6208	3325	3306	4821	3218	4772	6526	14206
4	2666	2066	2950	1600	1399	1989	2096	2601	3911
5	1661	1149	734	1058	413	410	625	854	814
6	166	787	363	206	296	112	85	145	293
7+	547	284	250	214	156	132	58	98	182
1+	24639	21046	19900	17636	18519	21882	37432	31324	25561

Age	1991	1992	1993	1994	1995	1996	1997	1998
1	5884	5340	8252	3436	1641	1067	523	0
2	2777	4817	4372	6756	2813	1344	874	428
3	2077	1962	3661	3511	5505	2106	1041	668
4	8532	856	1127	1652	1955	3711	1196	456
5	1334	3220	263	343	325	557	1466	586
6	277	323	811	98	20	91	142	447
7+	151	131	63	114	55	20	17	61
1+	21032	16649	18547	15910	12315	8896	5258	2646

Fishing mortality

Age	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	0.01	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	0.09
3	0.54	0.54	0.53	0.66	0.69	0.23	0.41	0.31	0.31
4	0.64	0.83	0.83	1.15	1.03	0.96	0.70	0.96	0.88
5	0.55	0.95	1.07	1.07	1.10	1.37	1.26	0.87	0.88
6	0.61	0.90	0.89	1.16	1.08	1.05	0.82	0.97	0.90
7+	0.61	0.90	0.89	1.16	1.08	1.05	0.82	0.97	0.90
Avg 4-5 u	0.59	0.89	0.95	1.11	1.07	1.17	0.98	0.92	0.88
Avg 4-5 w	0.61	0.88	0.87	1.12	1.05	1.03	0.83	0.94	0.88

Age	1991	1992	1993	1994	1995	1996	1997
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.15	0.07	0.02	0.00	0.09	0.05	0.07
3	0.69	0.35	0.60	0.39	0.19	0.37	0.63
4	0.77	0.98	0.99	1.42	1.05	0.73	0.51
5	1.22	1.18	0.78	2.64	1.08	1.16	0.99
6	0.84	1.18	0.98	1.66	1.09	0.79	0.75
7+	0.84	1.18	0.98	1.66	1.09	0.79	0.75
Avg 4-5 u	1.00	1.08	0.89	2.03	1.07	0.95	0.75
Avg 4-5 w	0.83	1.14	0.95	1.63	1.06	0.79	0.77

Table F14 (Continued). Estimates of spawning stock biomass (000s mt) and sexual maturation for Gulf of Maine cod.

SSB at the start of the spawning season - males and females (mt)

Age	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	330	297	399	142	214	292	641	108	290
2	2144	1247	1141	3096	2015	3041	4025	8683	725
3	3184	4633	2503	3872	6011	4218	6440	8545	10617
4	4820	3105	4650	2781	2575	4029	3647	5085	5317
5	6071	2971	1738	2983	1205	1184	2017	2187	2260
6	823	3496	1429	739	1245	511	409	597	1298
7+	5415	2311	2125	1659	1297	1096	552	987	2079
1+	22786	18061	13984	15272	14561	14371	17732	26192	22586
2+	22456	17764	13585	15130	14347	14079	17091	26084	22296

Age	1991	1992	1993	1994	1995	1996	1997
1	432	427	622	88	42	27	13
2	740	1514	1273	2833	1242	603	397
3	1300	1477	3056	4492	7657	3203	1568
4	12114	1174	1645	3043	3646	6721	2663
5	3002	6599	713	627	1058	1413	3311
6	1275	1143	2839	373	86	474	500
7+	1451	1108	571	839	579	196	176
1+	20314	13441	10719	12296	14309	12637	8628
2+	19882	13014	10097	12208	14267	12610	8615

Percent mature (females)

Age	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	7	7	7	4	4	4	4	4	11
2	26	26	26	48	48	48	48	48	28
3	61	61	61	95	95	95	95	95	56
4	88	88	88	100	100	100	100	100	81
5	97	97	97	100	100	100	100	100	93
6	100	100	100	100	100	100	100	100	98
7+	100	100	100	100	100	100	100	100	100

Age	1991	1992	1993	1994	1995	1996	1997
1	11	11	11	4	4	4	4
2	28	28	28	38	38	38	38
3	56	56	56	89	89	89	89
4	81	81	81	99	99	99	99
5	93	93	93	100	100	100	100
6	98	98	98	100	100	100	100
7+	100	100	100	100	100	100	100

Table F15. 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
           ---------------------------------------
           Run Date:  1- 7-1998;  Time: 16:46:52.65
GULF OF MAINE COD (5Y) -  1998 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:
==> C:\ASSESS\GMCOD98\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	.0400	.900	.735
2	.0272	1.0000	.3800	1.339	1.091
3	.2305	1.0000	.8900	1.826	1.540
4	.7863	1.0000	.9900	2.734	2.233
5	1.0000	1.0000	1.0000	4.151	3.395
6	1.0000	1.0000	1.0000	6.327	5.155
7	1.0000	1.0000	1.0000	9.031	7.629
8	1.0000	1.0000	1.0000	11.606	10.265
9	1.0000	1.0000	1.0000	13.850	12.701
10+	1.0000	1.0000	1.0000	17.771	17.771

```
Summary of Yield per Recruit Analysis for:
GULF OF MAINE COD (5Y) -  1998 UPDATED AVE WTS, FPAT AND MAT VECTORS

 Slope of the Yield/Recruit Curve at F=0.00: -->   27.4315
   F level at slope=1/10 of the above slope (F0.1): ----->     .161
     Yield/Recruit corresponding to F0.1: ----->    1.7305
   F level to produce Maximum Yield/Recruit (Fmax): ----->     .287
     Yield/Recruit corresponding to Fmax: ----->    1.8591
   F level at 20 % of Max Spawning Potential (F20): ----->     .407
     SSB/Recruit corresponding to F20: -------->    5.7104

Listing of Yield per Recruit Results for:
GULF OF MAINE COD (5Y) -  1998 UPDATED AVE WTS, FPAT AND MAT VECTORS
```

	FMORT	TOTCTHN	TOTCTHW	TOTSTKN	TOTSTKW	SPNSTKN	SPNSTKW	% MSP
	.00	.00000	.00000	5.5167	30.9067	3.8396	28.5534	100.00
	.10	.18746	1.45660	4.5839	17.8976	2.9038	15.7285	55.08
F0.1	.16	.25194	1.73046	4.2641	13.9928	2.5822	11.9049	41.69
	.20	.28253	1.80868	4.1127	12.2897	2.4298	10.2435	35.87
Fmax	.29	.33410	1.85915	3.8583	9.6856	2.1729	7.7137	27.01
	.30	.34057	1.85817	3.8265	9.3858	2.1408	7.4234	26.00
	.40	.38006	1.81826	3.6328	7.7003	1.9444	5.7961	20.30
F20%	.41	.38233	1.81429	3.6217	7.6113	1.9332	5.7104	20.00
	.50	.40890	1.75579	3.4920	6.6383	1.8012	4.7755	16.72
	.60	.43106	1.69272	3.3845	5.9253	1.6914	4.0924	14.33
	.70	.44874	1.63582	3.2992	5.4215	1.6039	3.6107	12.65
	.80	.46327	1.58651	3.2295	5.0500	1.5321	3.2558	11.40
	.90	.47548	1.54435	3.1713	4.7662	1.4718	2.9847	10.45
	1.00	.48595	1.50840	3.1216	4.5429	1.4202	2.7713	9.71
	1.10	.49505	1.47765	3.0785	4.3627	1.3753	2.5988	9.10
	1.20	.50308	1.45122	3.0407	4.2140	1.3358	2.4563	8.60
	1.30	.51024	1.42833	3.0072	4.0892	1.3006	2.3365	8.18
	1.40	.51668	1.40838	2.9771	3.9826	1.2690	2.2340	7.82
	1.50	.52253	1.39086	2.9499	3.8904	1.2403	2.1451	7.51
	1.60	.52787	1.37536	2.9252	3.8096	1.2141	2.0671	7.24
	1.70	.53278	1.36157	2.9025	3.7382	1.1900	1.9980	7.00
	1.80	.53732	1.34921	2.8815	3.6744	1.1678	1.9361	6.78
	1.90	.54155	1.33807	2.8621	3.6169	1.1471	1.8803	6.59
	2.00	.54549	1.32797	2.8440	3.5648	1.1278	1.8296	6.41

Table F16. Stochastic stock biomass and catch projections, starting conditions and input data for Gulf of Maine cod, 1998-2000.

Input for Projections:

Number of Years: 3; Initial Year: 1998; Final Year: 2000
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;
Original age-specific PRs, Mats, and Mean Wts from file:
==> c:\ASSESS\GMCOD98\PRCODGMA.DAT

Age-specific Input data for Projection # 1

Age	Stock Size in 1998	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Weights Catch	Average Weights Stock
2	428.	.0272	1.0000	.3800	1.563	1.184
3	668.	.2305	1.0000	.8900	2.024	1.755
4	456.	.7863	1.0000	.9900	2.764	2.326
5	586.	1.0000	1.0000	1.0000	3.957	3.268
6	447.	1.0000	1.0000	1.0000	6.524	5.027
7+	61.	1.0000	1.0000	1.0000	11.635	11.635

Projections for 1998-2000: F(98)=0.75. Basis: Status quo 1997 point estimate.
Recruitment (age 2) of the 1997 and 1998 year classes derived by resampling the distribution of empirical recruitment of the 1993-1995 year classes (median=1.34 million).

SSB was estimated to be 8.615 t in 1997.

1998 F	1998 Landings	1998 SSB	1999 F	1999 Landings	1999 SSB	2000 SSB
0.75	3820	6640	F_0 =0.00	0	5980	8150
0.75	3820	6640	$F_{0.1}$ =0.16	820	5840	7090
0.75	3820	6640	F_{max} =0.29	1400	5730	6350
0.75	3820	6640	$F_{20\%}$ =0.41	1890	5630	5760
0.75	3820	6640	F_{SQ} =0.75	3010	5360	4430

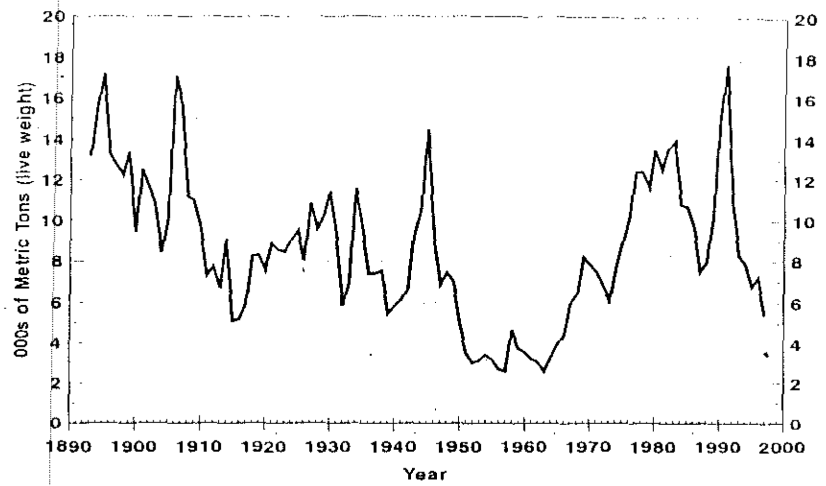

Figure F1. Total commercial landings of Gulf of Maine cod (NAFO Div. 5Y), 1893-1997.

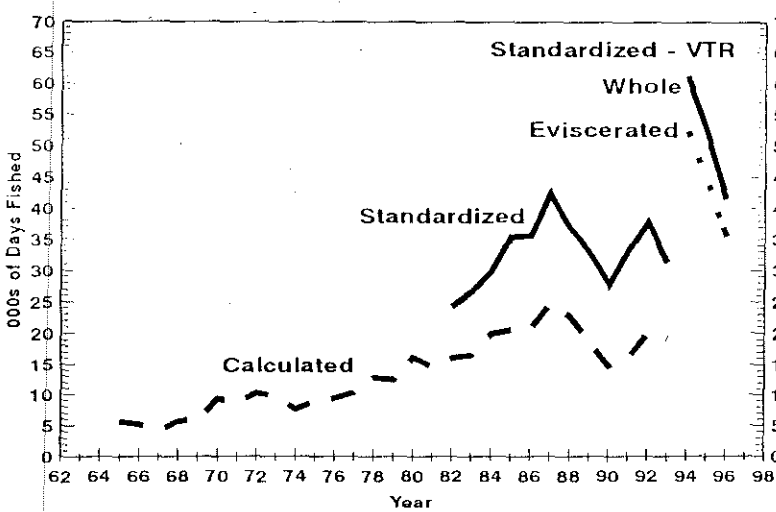

Figure F2. Trends in standardized and calculated USA fishing effort (days fished) on Gulf of Maine cod, 1982-1993 and trips landing cod. Standardized effort series (interviewed) based on GLM incorporating year, tonnage class, area, assuming portion kept represents either whole or eviscerated weight.

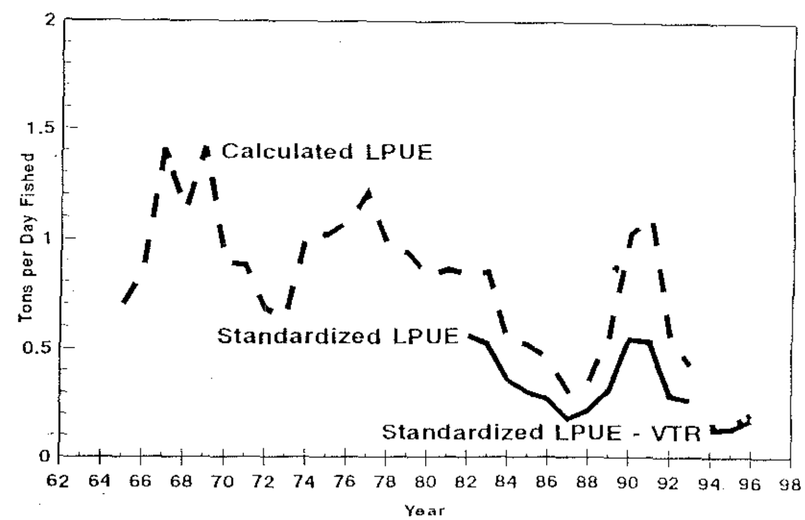

Figure F3. Trends in USA LPUE (landings per day fished) of Gulf of Maine cod. The 1965-1993 indices (dashed line) based on all otter trawl trips landing cod. Standardized LPUE from 1982-1993 (interview data) and 1994-1996 (VTR data) based on GLM incorporating year, tonnage class, area, quarter and depth.

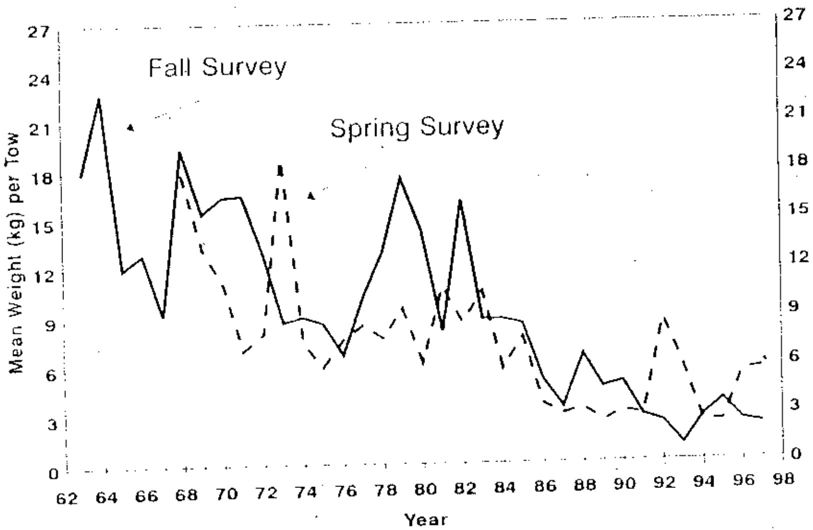

Figure F4. Standardized Stratified mean catch (kg) per tow of Atlantic cod in NEFSC spring and autumn research vessel bottom trawl surveys in the Gulf of Maine, 1963-1997.

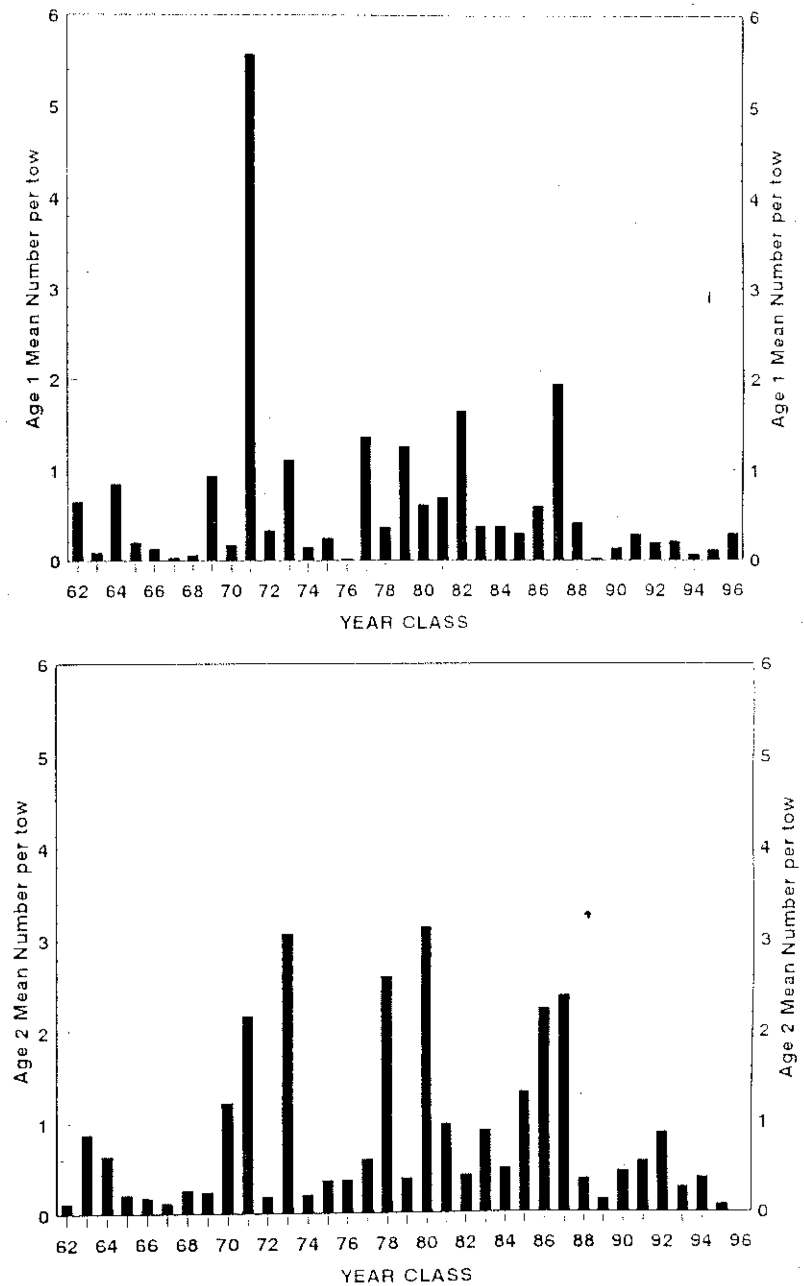

Figure F5. Relative year class strengths of Atlantic cod at age 1 and 2 based on standardized stratified mean catch (number) per tow indices from NEFSC autumn research vessel bottom trawl surveys in the Gulf of Maine, 1963-1997.

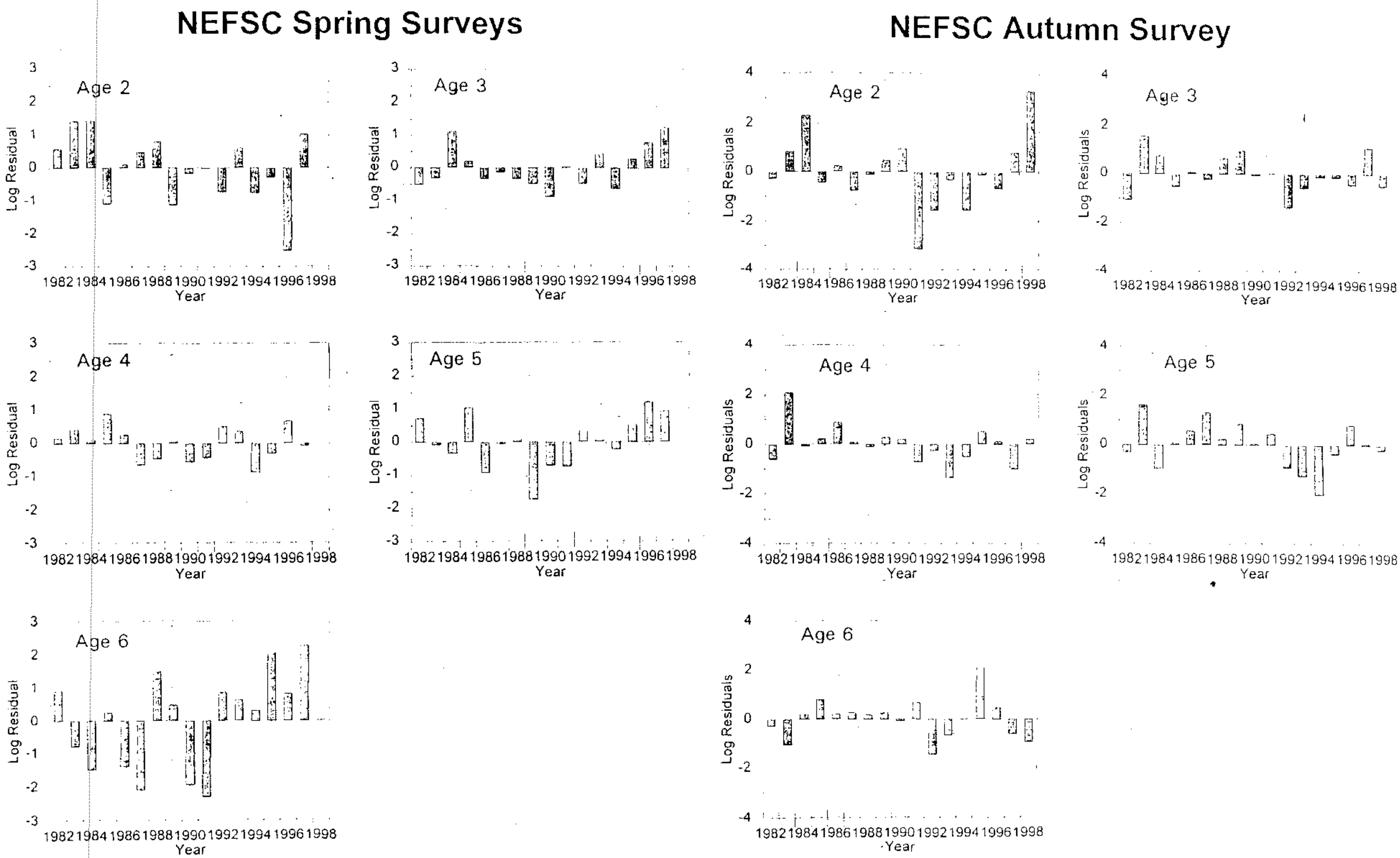

Figure F6. Residual patterns from final ADAPT VPA formulation for Gulf of Maine cod.

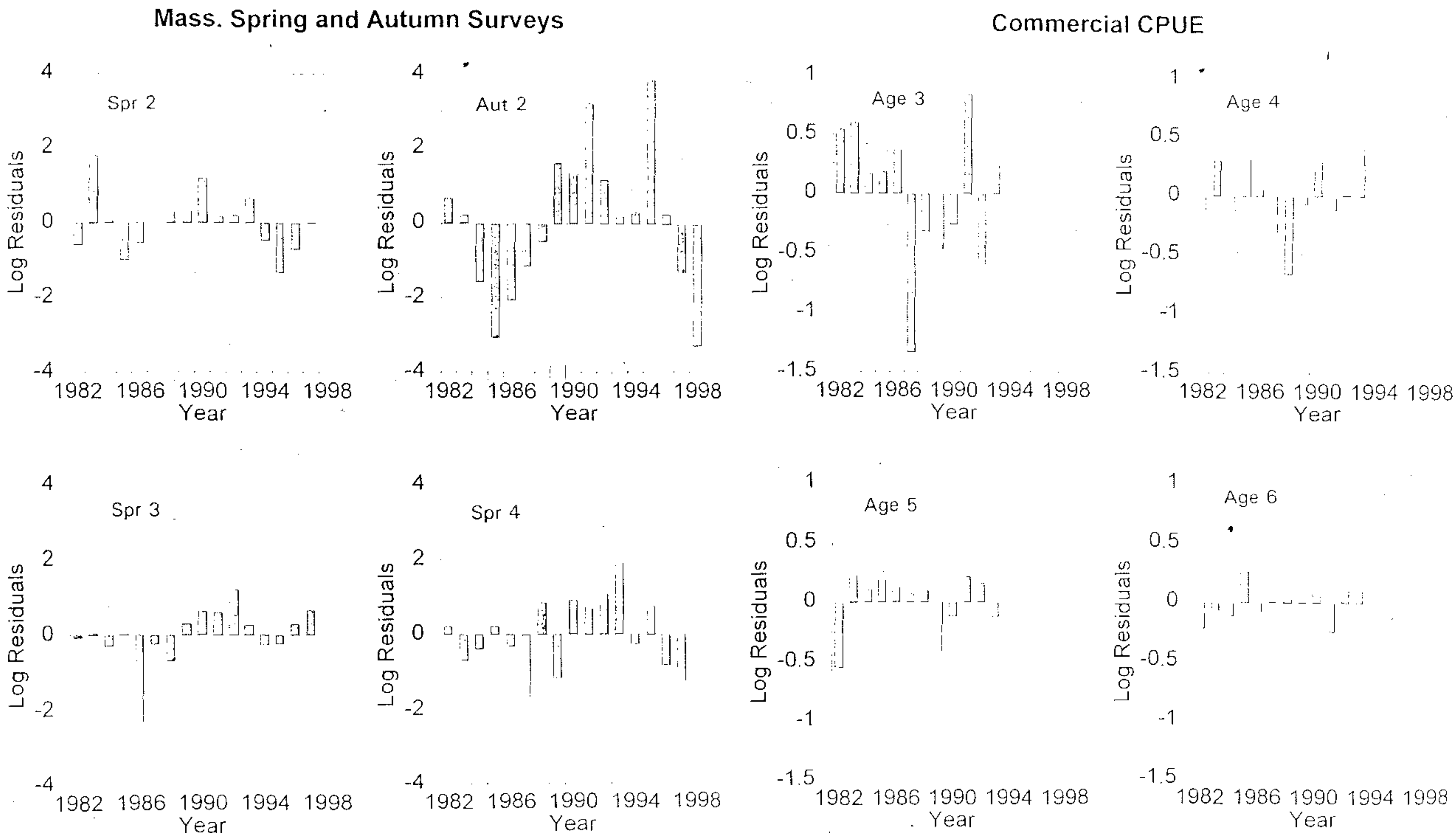

Figure F6. (Continued)

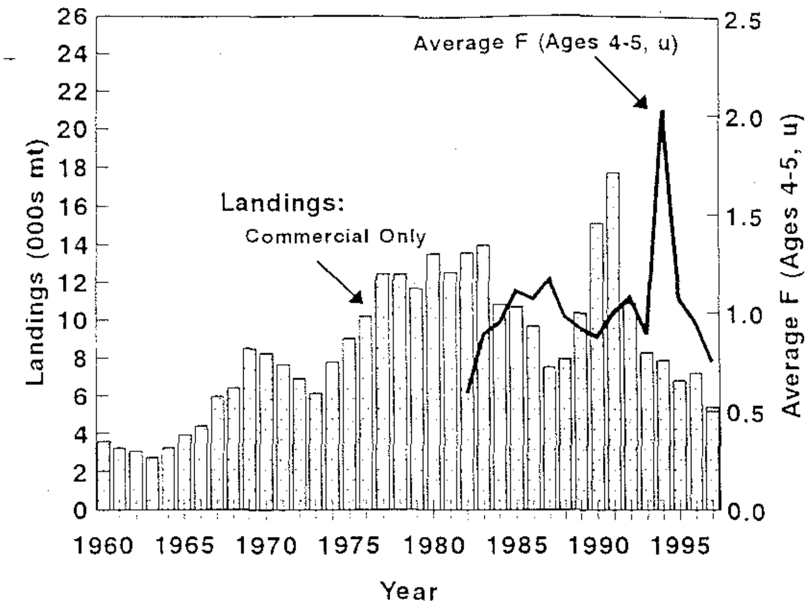

Figure F7. Trends in commercial landings (1960-1997) and fishing mortality (1982-1997) for Gulf of Maine cod.

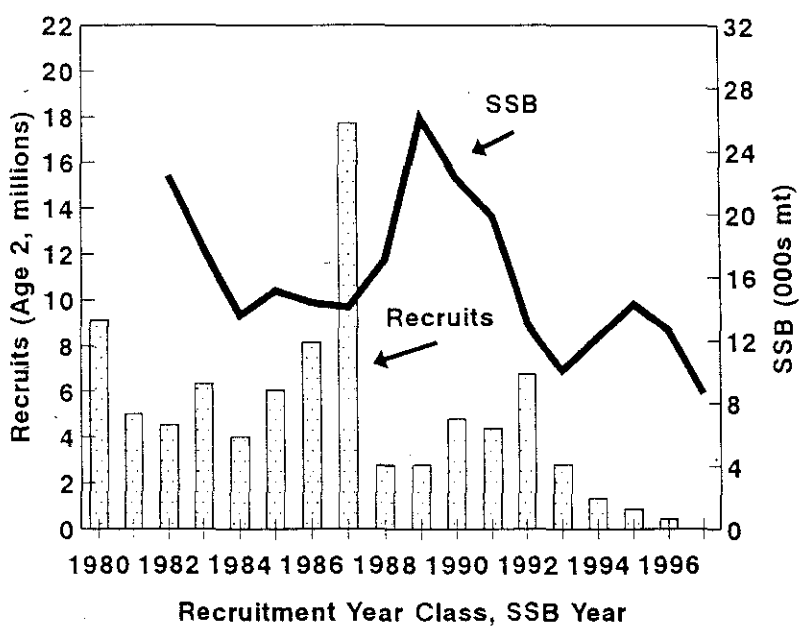

Figure F8. Trends in spawning stock biomass and recruitment for Gulf of Maine cod.

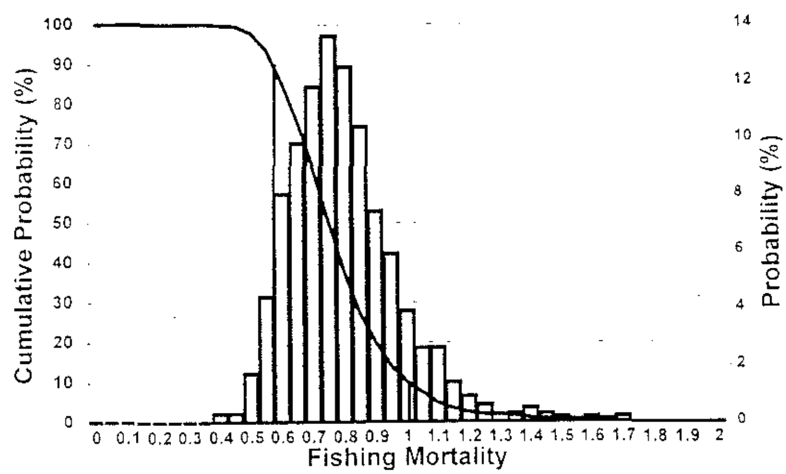

Figure F9. Precision estimates of the instantaneous rate of fishing mortality (F) on the fully recruited (ages 4+) in 1997 for Gulf of Maine cod. The vertical bars display both the range of the estimator and the probability of individual values within the range. The solid line gives probability that F is greater than any selected value on the X-axis. The precision estimates were derived from 1,000 bootstrap replicates of the final ADAPT VPA formulation.

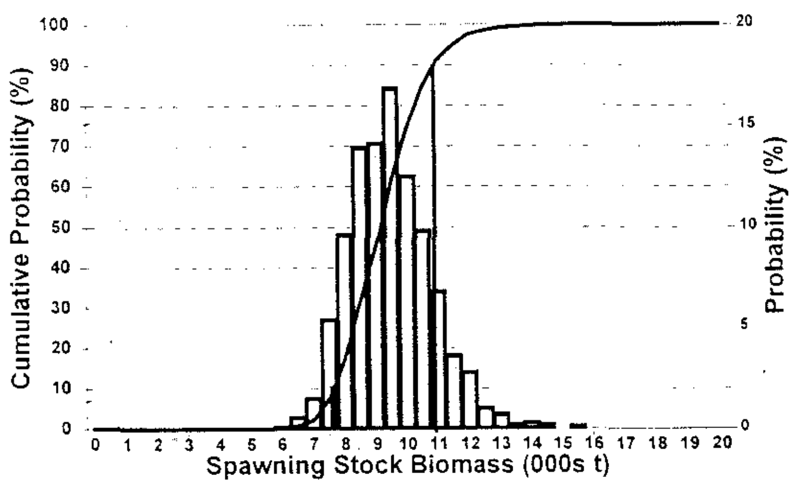

Figure F10. Precision estimates of the instantaneous rate of fishing mortality (F) on the fully recruited (ages 4+) in 1997 Gulf of Maine cod. The vertical bars display both the range of the estimator and the probability of individual values within the range. The solid line gives probability that F is greater than any selected value on the X-axis. the precision estimates were derived from 1,000 bootstrap replicates of the final ADAPT VPA formulation.

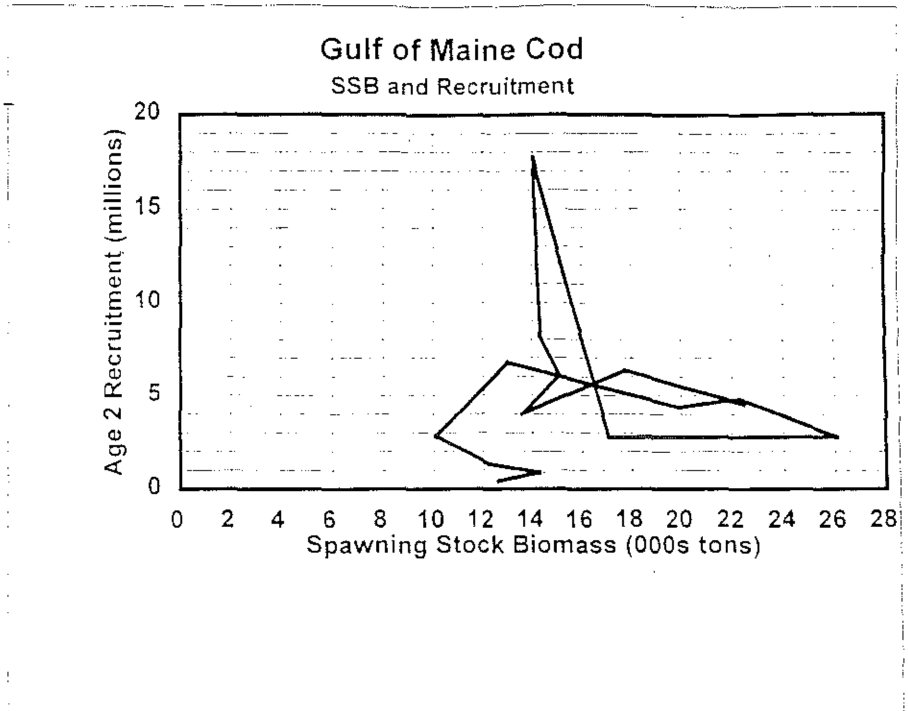

Figure F11. Relationship between spawning stock biomass (000s tons) and recruitment at age 2 (millions of fish) for Gulf of Maine cod as derived from VPA.

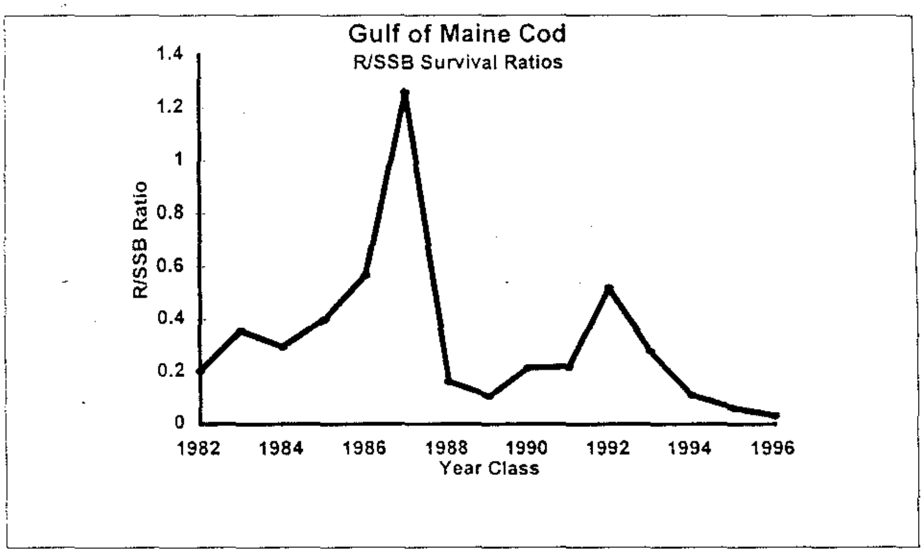

Figure F12. Survival ratios (R/SSB) estimated as the ratio of recruits at age 2 over the spawning stock biomass which produced the recruits. The survival ratios and plotted for each year class from 1982 through 1996.

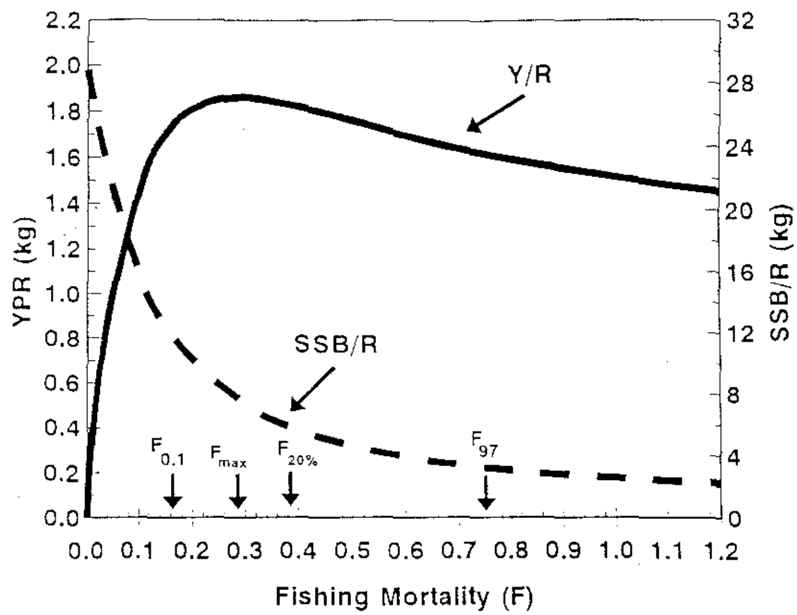

Figure F13. Yield per recruit (Y/R) and spawning stock biomass per recruit (SSB/R) for Gulf of Maine cod.

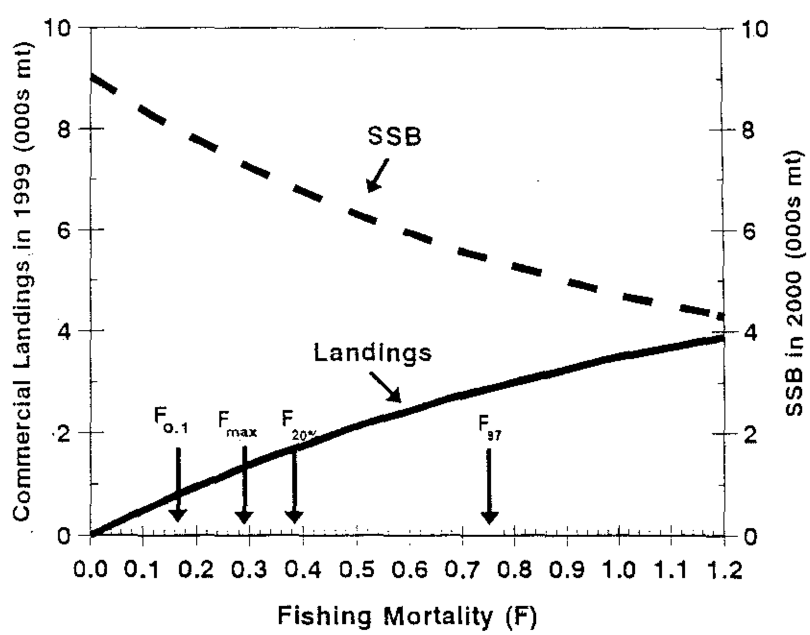

Figure F14. Predicted catches in 1999 and spawning stock biomass in 2000 for Gulf of Maine cod over a range of fishing mortality rates in 1999 from F=0.0 to F=1.2.

G. ATLANTIC HERRING

Terms of Reference

a. Review the results of the December 1997 Herring Stock Assessment & Research Priorities Workshop and incorporate any relevant recommendations in the present assessment.

b. Evaluate scientific information relating to the stock affinity of herring caught in the New Brunswick fixed gear fishery and define the geographical range of the coastal stock complex.

c. Update the status of the coastal stock complex of Atlantic herring through 1997 and characterize the variability of estimates of stock size and fishing mortality rates.

d. Provide, to the extent possible, information regarding the relative status of the various stocks within the coastal stock complex.

e. Review and evaluate methods and results of virtual population analysis of the Gulf of Maine herring stock and acoustic surveys of spawning herring on Jeffreys Ledge in 1995, 1996, and 1997.

f. Provide projected estimates of catch for 1998-1999 and spawning stock biomass for 1999-2000 at various levels of F for the coastal stock complex and, if possible, for the Gulf of Maine stock.

g. Review existing biological reference points and advise on new reference points for Atlantic herring to meet SFA requirements.

Introduction

Results of an analytical assessment of the aggregated coastal stock complex of Atlantic herring (*Clupea harengus*) from the Gulf of Maine to Cape Hatteras are summarized in this report. This assessment constitutes a revision of an assessment of the same stock complex reviewed by the SAW-21 Stock Assessment Review Committee (SARC) in the fall of 1995 (NEFSC 1996). Also included in this report is a summary of available information regarding the relative abundance of the two major components of the stock complex, Georges Bank-Nantucket Shoals and the Gulf of Maine. Available information relating to the stock affinity of juvenile and adult herring caught in the New Brunswick fixed gear fishery was also reviewed as were biological reference points for the Atlantic herring stock complex that have recently been adopted by the New England Fishery Management Council, acting on the recommendations of the NEFMC Overfishing Definition Review Panel.

The methodology used to derive input data for this assessment was basically the same as in previous assessments (NEFSC 1996). A biostatistical program (BIOSTAT) was used to derive the estimated numbers of fish caught at age for individual gear/area categories for each month of the year based on age-length keys, catch data, and estimated mean weight-at-age data. Estimates were summed to produce annual catch-at-age estimates for the years 1995-1997 which were added to the existing time series (1967-1997). These input parameters formed the basis for a virtual population analysis which was performed using the ADAPT formulation of the model in the new Woods Hole Assessment Toolbox (WHAT) software package. The coastal stock complex VPA was tuned using spring and winter NEFSC bottom trawl survey data. Previous assessments of the stock complex have relied solely on spring trawl survey data and, in some cases, a larval survey index. Larval surveys were discontinued in 1994.

Additional analyses of fall and winter NEFSC bottom trawl survey data are also summarized in this report for the purpose of characterizing the age composition of the stock complex over time and comparing the relative abundance of herring in different geographical areas during the spawning season. Additional information on the relative abundance of herring in coastal Gulf of Maine waters (including New Brunswick) is provided by an independent virtual population analysis of catch-at-age data that are specific to this area. In the absence of reliable survey data for this area, terminal fishing mortality rates for this VPA were estimated directly from catch-at-age data on a cohort-by-cohort basis.

The proceedings of a Herring Stock Assessment & Research Priorities Workshop sponsored by the New England Aquarium in December 1997 (NEAQ 1998) were reviewed. A number of important research priorities and recommendations were made at that meeting, but it was concluded that there were no specific assessment recommendations that needed to be incorporated into this review.

Stock Structure

Herring which spawn off southwest Nova Scotia (Divisions 4WX), on Georges Bank and Nantucket Shoals (Division 5Z and Subarea 6), and in coastal waters of the Gulf of Maine (Division 5Y) have historically been recognized as separate stocks. US assessments performed prior to 1991 (Anthony and Waring 1980, Fogarty and Clark 1983, Fogarty *et al.* 1989) were specific to either the Georges Bank-Nantucket Shoals stock or the Gulf of Maine stock. The early Gulf of Maine virtual population analyses were tuned, however, with spring NEFSC bottom trawl survey data, even though it was recognized at the time that herring from both stocks mix in unknown proportions south of Cape Cod in the winter and spring. It was precisely for this reason that a single assessment of the Atlantic coast stock complex was first performed in 1991 (NEFSC 1992). Since then, the coastal stock complex has been defined to include Atlantic herring throughout their range along the US Atlantic coast, including areas in Canadian waters on Georges Bank and on the western (New Brunswick) shore of the Bay of Fundy. The inclusion of fixed gear catches from New Brunswick into the historical catch-at-age matrix is consistent with their exclusion from Canadian assessments of the Division 4WX stock and the view that they are derived from the Gulf of Maine stock (Stephenson *et al.* 1995).

The New Brunswick stock affinity issue was reviewed in light of the current Canadian view that the "*aggregation of large numbers of juvenile herring near shore at the mouth of the Bay of Fundy ... have traditionally been considered to be a mixture [of] juvenile fish dominated by fish originating from subarea 5[Y] spawning components.... Mature fish (ages 4+) taken in this fishery would be considered to be of 4WX origin*" (Stephenson *et al.* 1998). Historical catch-at-age data for the coastal Maine and New Brunswick fisheries and published studies of larval herring distribution and transport in southwest Nova Scotia and the Bay of Fundy were reviewed. In addition, correlation analysis of Gulf of Maine age 1-3 indices with landings of these age groups in the New Brunswick fishery were performed indicating a positive correlation. Additional analyses are required in order to fully resolve this issue. New Brunswick fixed gear catches (all ages) were included in the US coastal stock complex assessment. It was noted that this would not result in the "double counting" of these catches since Canada did not adopt an analytical assessment of the 4WX stock in 1998 which incorporates catch-at-age estimates. This is an important issue since proposed new management measures being considered for the herring stock complex include an annual total allowable catch for the US portion of the Gulf of Maine which is computed after deducting the expected Canadian harvest from the total area TAC.

The Fishery

The commercial fishery for Atlantic herring takes place in the Gulf of Maine, in Southern New England and the Mid-Atlantic region, and, to a small extent, on Georges Bank (Table G1). Landings are made principally in New Brunswick, Maine, Massachusetts, and Rhode Island to supply the canning industry and bait for the lobster fishery. Landings in Rhode Island have increased during the last three years and currently account for 20% of the US harvest. The total catch increased substantially in 1996 and 1997 to almost 120,000 mt. At present, the catch is limited by the domestic demand for canned products and bait. Historically, when foreign fleets were active on Georges Bank, the reported catch exceeded 400,000 mt. The Georges Bank-Nantucket Shoals stock collapsed under heavy fishing pressure in the early 1970s. The Gulf of Maine fishery was exclusively an inshore fixed-gear fishery until the late 1960s when purse seines began accounting for a significant portion of the catch. Now, the US catch is taken almost entirely with purse seines and mid-water trawls, although fixed gear is still common in New Brunswick.

Samples -

Herring samples are obtained from commercial catches landed in Maine and Massachusetts (Gloucester), primarily from May to October, in Rhode Island in the winter and early spring, and aboard foreign processing vessels participating in the IWP fishery. Additional samples were collected by observers placed aboard herring fishing vessels in 1997 and by the Canadian Department of Fisheries and Oceans in St. Andrews, NB. All samples include fish measured for total length (usually either 50 or 100 fish per sample) and a sub-sample which is aged (usually 30 fish). Additional information on sex, state of maturity, and weight is also recorded. These data are used, along with catch data, to estimate the age composition of the catch. Sampling effort increased between 1995 and 1997 (see below) to the point where one sample was taken for approximately every 500 mt of herring caught. The sampling coverage is typically higher during the summer-fall fishery in the Gulf of Maine than during the winter fishery in Southern New England (e.g., one sample per 432 mt in April-November 1997 and one per 1,250 mt January-March and December).

Year	1995	1996	[1]1997
No. samples	90	140	210
No. fish processed	6,202	7,342	9,921
No. fish aged	1,925	1,820	3,289

[1]Through April 1998

Year	No. samples	US catch (mt)	Mt/sample
1995	90	76,135	846
1996	140	103,663	740
1997	210	98,089	467

Sampling effort in the New Brunswick fixed gear fishery, May-November 1997, totalled 642 samples, 72,918 length measurements and 1,177 aged fish (Stephenson *et al.* 1998). The large number of length measurements were primarily made by employees in the sardine canneries, with the data provided to the Department of Fisheries and Oceans.

Age Composition

Catch at age in numbers for 1995, 1996, and 1997 were estimated from US sample and catch data and combined with published New Brunswick catch-at-age estimates for incorporation into the existing time series (Tables G2-G5). US catch-at-age estimates were generated independently for eastern, central, and western Maine (NMFS Statistical Areas 511, 512, and 513), Massachusetts Bay (Area 514), Georges Bank (Areas 521, 522, 525, 526, 561, and 562), Southern New England (Areas 533, 534, 537-539, and 611-616), and the Mid-Atlantic region (Areas 624-639) and summed to produce annual estimates. Catches from Area 515 (offshore Gulf of Maine) were combined with Area 513.

Mean Weights at Age

Mean weights at age in the US portion of the catch (Table G6) were calculated, as in previous assessments, by summing the estimated monthly catches (mt) for each age and dividing by the estimated total numbers of fish caught at the same age. The reduction in US mean weights, first evident in 1987, was still apparent in 1995-1997. Since estimates of stock mean weight at age were not available, they were assumed to be equal to catch mean weights at age.

Percent Maturity at Age

Male and female herring in samples collected from the commercial fishery prior to spawning were examined for state of maturity. The percentages of age 3 and 4 fish that were either mature, in a state of gonad development that leads to maturity, or had spawned (i.e., fish in gonad stages III-VIII) were calculated as a ratio of the total number of age 3 or 4 fish in the samples (Table G7). The percentage of mature age 3 herring in 1995 (30%) was the same as in 1992 and 1993 and increased to 44% in 1996 and to 78% in 1997. The 1997 estimate is the highest in the entire time series and is inconsistent with the hypothesis that fewer age 3 fish mature when the stock is large and growth rates are reduced.

Stock Abundance Indices

Spring Bottom Trawl Survey Indices

NMFS spring bottom trawl survey abundance indices (stratified mean number and kg per tow) were calculated for strata 1-30, 36-40, and 61-76 (Figure G1) for the time period 1968-1997. All trawl survey indices were adjusted to account for different fishing powers of the two survey vessels *Albatross IV* and *Delaware II* (NEFSC 1992). Indices of number and weight per tow were smoothed using a 5-year moving average (Figure G2) for illustration purposes only. Age-disaggregated indices (number) were calculated for ages 1-10 (Figure G3).

Both sets of indices have increased steadily since 1982 and, although variable, have remained above the highest point (1968) in the early period of the survey since 1991 (Figure G3).

Winter Bottom Trawl Survey Indices

Bottom trawl indices were available for offshore strata (1-3, 5-7, 9-11, 13-14, 16, 61-63, 65-67, 69-71, 73-75) for the years 1992-1997 and ages 2-8. Indices for ages 2-6 were fairly high in 1992 and 1993, were low overall in 1994 and 1995, and high in 1996 and 1997 (Figure G5). The high numbers and low precision of the 1996 estimates were associated with the extremely high incidence of age 2 fish (1994 year class) and, in 1997, with good catches of age 6-8 fish (Figure G6). The 1994 year class did not show up at age 3 in 1997 in this survey.

Fall Bottom Trawl Survey Indices

Autumn bottom trawl indices were calculated for the same strata set and age range as the spring survey for the period 1963-1997 (Figures G6-G8). High indices in 1992 and 1995 were associated with older (ages 4-7) fish. Catch rates in 1996 and 1997 were low, as they were in 1993 and 1994, but the overall upward trend since the mid-1980s is consistent with the spring survey data. Abundance indices at the beginning of the time series, however, were lower than in the spring.

Mortality and Stock Size Estimates

Natural Mortality

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

Virtual Population Analysis Calibration

A series of VPA models were evaluated to assess fitting strategies and performance of the available tuning data. In previous assessments, ages 4, 5, and 6, were estimated. Several other ADAPT calibrations with more than three ages were evaluated with respect to estimate of CVs, residual patterns, and partial variances, but none were useful. ADAPT runs using fall bottom trawl survey data were also completed, but in all cases, fall indices produced highly patterned residuals. Residuals in the first half of the time series was mostly negative; whereas, residuals in the second half of the time series tended to be positive. In addition, precision estimates of fall survey *q*s were considered too large in these runs. Another evaluation, using fall data, considered the effect of eliminating the early part of the data time series. In these models, only the last twenty years of data were used with various combinations of tuning indices. These results were in agreement with the full time series models except that they tended to have lower precision.

The final ADAPT run utilized the full time series of age 2-8 spring and age 2-8 winter trawl survey (numbers per tow) as tuning indices; ages 4-6 were estimated. Coefficients of variation for the estimated ages varied between 55 and 70%. Residuals for the spring survey tended to be positive in the second half of the time series, but not strongly so (Figure G9). The winter survey time series was too short to reveal any strong pattern. Overall, the average residuals were heavily influenced by the spring survey.

Fishing Mortality, Recruitment, and Stock Biomass

Estimated average age 3-7 fishing mortality rates exceeded 0.5 from 1971 to 1982, dropped to 0.2-0.45 between 1983 and 1992 and 0.15-0.18 between 1993 and 1995, and then dropped to <0.1 in 1996 and 1997

(Table G11; Figure G10). High F values persisted following the collapse of the Georges Bank-Nantucket Shoals stock (Anthony and Waring 1980) and were associated with large catches of juveniles in the coastal Maine and New Brunswick fixed gear fisheries.

Recruitment appears to be very strong in recent years (Table G11; Figure G11). Estimated numbers from the 1990 and 1991 year classes were roughly equal to the number of juveniles produced by the 1970 year class, the largest year class to have recruited to the stock until the 1990s. The 1992 and 1993 year classes were above average and the 1994 year class appears to be very large, making large contributions to the stock at ages 2, 3, and 4 in the last three years. Estimated numbers in 1997 (1996 cohort) were equally as high (Table G11). However, the actual size of these recent year classes is very uncertain since they have only been represented for several years in the catches. For example, the 1992 year class appeared to be very large when the last assessment was done on catch-at-age data through 1994, but now is estimated to be just above average.

Total biomass and spawning stock biomass increased by a factor of three between 1994 and 1997 (Table G11; Figure G12), reaching 2.9 and 1.8 million mt, respectively. These results indicate that the US Atlantic coastal herring stock complex is large and under-utilized, but there is considerable uncertainty about current stock size which could be overestimated.

Precision of F and SSB Estimates

To evaluate the precision of the final estimates of spawning stock biomass and fishing mortality, a bootstrap approach (Efron 1982) was used to generate probability distributions around fishing mortality rates and SSB. These results indicate that there is an 80% probability that SSB is between 1.35 and 2.05 million mt and fishing mortality (age 3-7) between 0.03 and 0.06 (Figure G13).

Retrospective Analysis

A 5-year retrospective analysis of SSB and F (Figure G10) revealed a considerable positive bias in the estimation of recent-year biomass and negative bias in fishing mortality. Estimated 1992 and 1994 SSB in the most recent VPA, for example, dropped by 50% from the values estimated when catch at age and survey data were available through 1994 at the same time that fishing mortality rates increased by 40-50%. It was discussed whether the retrospective pattern might result from the trawl survey depicting the abundance of the stock complex throughout its range, including a large offshore area not being fished, whereas the catch-at-age data are being produced primarily in inshore Gulf of Maine waters where fishing mortality rates are considerably higher.

Biological Reference Points

Biological reference points were last computed for the herring coastal stock complex during SAW-21 (NEFSC 1996) from a yield-per-recruit analysis. Values determined then were $F_{0.1} = 0.20$, $F_{20\%} = 0.34$, and $F_{max} = 0.40$. These reference points were not updated for this assessment.

The Working Group reviewed and endorsed the MSY-based biological reference points for the Atlantic herring coastal stock complex that were determined by the NEFMC Overfishing Definition Review Panel (ODRP) in early 1998. Estimates of MSY, F_{msy}, and B_{msy} were based on the results of a non-equilibrium surplus production model (ASPIC; Prager 1994) using landings and the spring trawl survey index through 1996. A conditioned run of the model with the B1 ratio fixed at 1.0 produced stable values for all estimated parameters. MSY was estimated at 317,000 mt (80% CI = 312,000-331,000 mt). B_{msy} was estimated indirectly to be 1.066 million mt by applying the annual ratios of B/B_{msy} from the model to January 1 estimates of total biomass for the years 1973-1990 from the 1995 VPA (NEFSC 1996). F_{msy} (0.30) was estimated by dividing MSY by B_{msy}. F_{msy} will be the maximum fishing mortality rate when biomass is at or greater than B_{msy}. The ODRP selected a target fishing mortality of 0.28 based on the ratio (0.91) of the lower limit of the 80% confidence interval to the point estimate of F_{msy} coming directly from the model applied to the calculated F_{msy} (0.30 * 0.91 = 0.28). Minimum biomass for the stock complex was set at $\frac{1}{2}B_{msy}$ (535,000 mt).

These reference points are based on the entire stock complex including catches taken by Canada in the New Brunswick weir fishery and on Georges Bank east of the Hague line. When considering harvest policy, management should be careful that fishing mortality does not exceed sustainable levels for individual spawning components of the coastal stock complex.

The SARC, in reviewing the application of the surplus production model (ASPIC) to a multi-stock complex, expressed reservations about the validity of the use of such a model on multiple stocks. The concern was based primarily on the fact that multiple stocks are likely to possess differences in productivity and hence in their responses to exploitation. Furthermore, the MSY estimate of 317,000 mt derived from the ASPIC model was considered to be somewhat unrealistic since the stock complex had only briefly (1968-1971) supported total landings of this level and higher (Table G1), most of which had come from the Georges Bank stock which collapsed shortly thereafter due to excessive exploitation (Anthony and Waring 1980).

As an alternative approach, the SARC applied yield-per-recruit and biomass-per-recruit values at $F_{0.1}$ (0.20) to average recruitment to estimate MSY and B_{msy}. Depending on the range of years used in the analysis, the MSY values based on geometric mean recruitment ranged from 108,000 to 290,000 mt. Without a firm basis to select within this range, the SARC felt that it would not be prudent to consider MSY to be above 200,000 mt or B_{msy} to be above 1.5 million mt until the sizes of recent, apparently large, year classes were better estimated.

Projections of Stock Biomass

Forecasts of stock status were completed for Atlantic herring for 1998-2000. A stochastic approach was utilized to project spawning stock biomass and fishing mortality over the 3-year period. Catch scenarios used in the projections were the catch in 1997 (119,000 mt), the MSY estimate of 200,000 mt advocated by the SARC, and the MSY estimate determined by the ODRP (317,000 mt). Recruitment estimates were resampled from the estimated age 1 recruitment for the 1986-1993 year classes from the final ADAPT run.

Spawning stock biomass would increase steadily from 1998-2000 under all three catch scenarios. If landings were 317,000 mt in 1999-2000, SSB (median estimate) would increase from 2.4 to 3.4 million mt from 1998-2000, and fishing mortality would be about 0.08 (Table G12). The 80% CI on SSB in 2000 would be 2.4-4.2 million mt. If catches remain at the 1997 level (119,000 mt) over the 1998-2000 period, SSB would increase from 2.4 to 3.7 million mt, and F would be very low at roughly 0.03 (Table G12). The 80% CI on SSB in 2000 would be 2.8-4.5 million mt. The landings scenario of 200,000 mt would produce SSB and F levels intermediate between those of the other two scenarios (Table G12).

Status of Stock Components

NEFSC fall trawl survey data were examined in order to determine the relative abundance of herring in three different areas during the spawning season when the spawning components of the stock complex occupy their respective spawning grounds. Swept-area estimates of minimum population size were generated for three strata sets (coastal Maine: 26-28, 37-40; Nantucket Shoals: 9-11, 23-25; Georges Bank: 13-14, 16-17, 19-22, 29-30) in terms of numbers and weight for the years 1963-1997. These three areas correspond closely to the three management areas which have been identified for herring resource allocation and management purposes (ASMFC 1995). Annual ratios of population size in each area to total population size in all three areas were computed and averaged for the most recent 5- and 10-year periods. The coastal Maine area accounted for 27% of the total population biomass and 26% of the population numbers between 1988 and 1997, while Nantucket Shoals accounted for 63% (numbers and weight) and Georges Bank for 10% of the numbers and 11% of the weight. For the shorter time period (1993-1997), about the same fraction of the population occupied coastal Maine waters (24-26%), but Georges Bank increased to 17-18% and Nantucket Shoals decreased to 57%. This shift is indicative of the increasing numbers of herring spawning on Georges Bank in the last five years (Figure G14). Minimum population size estimates were high in 1992 and 1995 and low in 1993, 1994, and 1996 in all three areas.

The methodology used to conduct an un-tuned virtual population analysis for the coastal Gulf of Maine and the results produced by the model were reviewed. This analysis was originally developed to utilize catch-at-age estimates that represented as closely as possible herring belonging to the Gulf of Maine stock, i.e., after removing the 1968-1973 Georges Bank catch-at-age data (Table G4) and a percentage of the coastal catch-at-age estimates (Table G2) that approximated the contribution of Georges Bank-Nantucket Shoals herring to the winter catch in Southern New England and to the spring and early summer catch in the Gulf of Maine (Stevenson 1998). This approach was rejected since it requires information on the relative sizes and mixing proportions of the two major stock components in different locations and times of year over the entire 30-year time series. Instead, a cohort-based VPA was performed using US and New Brunswick coastal catch-at-age data, without the historical Georges Bank data and without catch-at-age data from Southern New England (Table G8). Southern New England catch-at-age data were not available prior to 1991, thus any catches made in this area between 1968 and 1990 remained in the database. Southern New England (and Mid-Atlantic) catch was not significant until the last three years when catches increased to 10,000-20,000 mt a year (Table G1).

Given the relative abundance of spawning herring in the Nantucket Shoals and coastal Maine areas in recent years (see Figure G14; also Smith and Morse 1993) and the fact that not all of the adults that spawn in the Gulf of Maine migrate south of Cape Cod, the Southern New England catch is dominated (>95%) by Georges Bank-Nantucket Shoals stock fish. Conversely, the contribution of the Georges Bank-Nantucket Shoals stock to the spring and early summer catches in the Gulf of Maine is thought to be very small (10-15%). Thus, it was concluded that the results of a VPA performed on Gulf of Maine area catch-at-age data should approximate results which would be obtained from a VPA for the Gulf of Maine stock.

The Gulf of Maine VPA was performed using Murphy's (1965) explicit solution of the catch equation as modified by Tomlinson (1970) in the computer program MURPHY. The methodology used was generally identical to that used by Vaughan and Smith (1988) to assess the Atlantic menhaden stock. In the absence of a reliable abundance index specific to the Gulf of Maine (the fall trawl survey was rejected as a tuning index for the coastal stock complex VPA because the precision of the estimated stock numbers was too low), terminal fishing mortality rates were derived using a minimum variance unbiased estimator of total mortality (Chapman and Robson 1960) for individual year classes and a constant natural mortality rate of 0.2. Terminal F values for 23 fully-recruited year classes (1966-1988) were estimated in this fashion (Table G9). For the last year in the time series (1997), terminal MVUE estimates of F at age were derived from averaged catches at age for the time period 1990-1997 and adjusted according to a partial recruitment vector (Table G10) from a separable VPA.

Results of the Gulf of Maine VPA were produced for a 22-year period, 1976-1997. During this time period, population numbers varied between 2.4 and 7.0 billion fish (Figure G15). Population biomass was fairly stable at 130,000-220,000 mt between 1976 and 1984 and tripled in size between 1983 and 1986 (Figure G16). Biomass remained stable at 300,000-350,000 mt for ten years, then increased again in 1996 and 1997, reaching 440,000 mt. Juvenile and adult fishing mortality rates were very high during the early part of the time series and dropped abruptly after 1982 to values between 0.20 and 0.60 (mostly 0.3-0.5) between 1983 and 1997 (Figure G17). The sharp reduction in fishing mortality coincided with the demise of the US inshore fixed gear fishery which had produced large catches of primarily juveniles along the Maine coast during the earlier part of the century. Reduced juvenile fishing mortality rates in 1983 coincided with the recruitment of a strong 1983 year class. The "escapement" of juveniles from this year class into the adult portion of the population stimulated the growth in population size. There is evidence of a second build-up in the population during the last two years, coinciding with the recruitment of the 1994 year class.

Summary and Conclusions

The Atlantic herring coastal stock complex is large and under-utilized. The abundance of herring in continental shelf waters between Cape Hatteras and the Gulf of Maine has been increasing steadily since the mid 1980s, and the Georges Bank-Nantucket Shoals stock component has fully recovered from an over-exploited condition brought about by heavy foreign fishing in the late 1960s and early 1970s. Estimated total biomass in 1997 was 3 million mt, with a spawning stock biomass of 1.8 million mt. Fishing mortality on the entire stock complex was less than F = 0.1. Recent year classes appear to be very large. Projections based on either the current catch (119,000 mt), 200,000 mt, or the preliminary MSY estimate (317,000 mt) and recruitment estimates between 1986 and 1993 indicated that SSB would increase over the next three years and F would remain very low. The precision of the assessment is low, however, with CVs on the estimated numbers of age 4-6 fish between 0.55 and 0.70 and a 80% confidence interval on SSB of 1.4 - 2.2 million mt. Retrospective analysis revealed a strong positive bias in current year estimates of population size. Despite the large size of the stock complex, the results of an exploratory VPA indicate that the Gulf of Maine component, which provides most of the commercial harvest, is fully utilized. Based on swept-area minimum population size estimates generated from fall bottom trawl surveys during the last 5 or 10 years, 25% of the stock complex occupies the interior Gulf of Maine area (exclusive of Georges Bank) during the spawning season, with 65% in the Nantucket Shoals area and only 10% on Georges Bank.

SARC Comments

Survey Indices

Large year classes cannot always be followed through the spring bottom trawl index. The SARC discussed examining lag correlations of cohorts in the indices. A subjective examination of the spring bottom trawl index over the entire time series suggests that catch rates may have been affected by a change in catchability resulting from gear modifications (type of net and trawl doors). Splitting the index into two or more periods may overcome this problem. It was also suggested that other available indices (e.g., Massachusetts and New Jersey nearshore trawl surveys, Canadian trawl surveys on Georges Bank) be examined.

Coastal Stock Complex VPA

Estimates of fishing mortality during the late 1960s, when the Georges Bank fishery peaked, appear relatively low. There is a need to extend the estimates back beyond 1968. It was suggested that pre-1968 catch-at-age estimates be used for this purpose. Given the low Fs in recent years, the VPA may not be extracting any information from the catch-at-age data. The current year over-estimates of population size appear to be heavily influenced by the trawl survey indices. The assessment has a strong positive retrospective pattern. Partitioning the abundance of the stock complex among the three existing herring management areas using the fall bottom trawl survey data may provide an estimate of stock distribution during the spawning season. However, the estimated percentages for each area are also affected by the varying degrees of exploitation in each area and how they change over time. A question was raised regarding the comparability of swept-area population size estimates for different areas due to the availability of herring to capture on hard (e.g., Gulf of Maine) and soft (e.g., Southern New England and Mid-Atlantic) bottom areas.

Reference Points

Use of the surplus production model (ASPIC) to estimate reference points for the stock complex may be inappropriate since individual stock components (e.g., Georges Bank vs Gulf of Maine) have their own characteristic intrinsic growth rates, carrying capacities, etc. The SARC was concerned about the use of the surplus production model to estimate MSY for the stock complex and requested that an estimate be generated from a yield-per-recruit analysis at a $F_{0.1}$ reference point as an alternative.

Gulf of Maine VPA

The SARC noted that the accuracy of an untuned VPA depends on the accuracy of the catch-at-age data that are used. Increases in biomass in recent years seem inconsistent with F values of 0.3-0.5, suggesting that there may be some emigration of older fish out of or younger fish into the Gulf of Maine that is more prevalent when the offshore portion of the stock is large.

Research Recommendations

- Mean catch weights at age should be the subject of further analysis. Do they vary by management unit? Can predicted mean weights be substituted for observed mean weights, particularly for older under-sampled ages? What are the stock mean weights at age?

- Possible effects of density dependence (e.g., reduced growth rates at high population size) on parameter estimates used in assessments should be examined.

- Potential changes in catchability within the spring bottom trawl survey index should be investigated.

- Investigate the validity of the extremely high recruitment in recent years. Can the size of recent year classes be estimated accurately given the retrospective pattern in the VPA? Are there other more direct means for estimating recruitment that could be developed?

- Collaborative work between NMFS, DFO, state agencies, and the herring industry on acoustic surveys for herring is encouraged.

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Table G1. Georges Bank (GB), Gulf of Maine (GOM), Southern New England (SNE), Middle Atlantic (MAT), and New Brunswick, Canada (NB) herring catch, 1960-1997 (includes foreign fishing, internal waters processing operations and at-sea transfers to Canadian carriers in the GOM).

Year	GB[1]	GOM[2]	SNE[3]	MAT[4]	NB[5]	Total
1960	0	60237	261	152	34304	94954
1961	67655	25548	197	101	8054	101555
1962	152242	69980	131	98	20698	243149
1963	97968	67736	195	78	29366	195343
1964	131438	27226	200	148	29432	188444
1965	42882	34104	303	208	33346	110843
1966	142704	29167	3185	176	35805	211037
1967	218743	36384	247	524	30032	285930
1968	373598	62973	245	122	33145	470083
1969	310758	53771	2104	193	26539	393365
1970	247294	42897	1037	189	15840	307257
1971	267347	50989	1318	1151	12660	333465
1972	174190	62416	2310	409	32699	272024
1973	202335	32391	4249	233	19935	259143
1974	149525	37236	2918	200	20602	210481
1975	146096	36841	4119	117	30819	217992
1976	43502	50319	191	57	29206	123275
1977	2157	50654	301	33	23487	76632
1978	2059	48998	1730	46	38842	91675
1979	1270	63764	1341	31	37828	104234
1980	1700	81933	1200	21	13525	98379
1981	672	64324	749	16	19080	84841
1982	1378	32157	1394	20	25963	60912
1983	53	24824	72	21	11383	36353
1984	58	33958	79	10	8698	42803
1985	316	27157	196	13	27863	55545
1986	586	27942	632	20	27883	57063
1987	11	39970	376	87	27320	67764
1988		39568	1307	365	33421	74661
1989		52774	269	39	44112	97194
1990		54192	2761	48	38778	95779
1991		50984	3947	402	24576	79909
1992		55948	716	4564	31968	93196
1993		53929	1829	1347	31572	88677
1994	474	51413	1935	502	22241	76565
1995	64	69969	14630	856	18248	103767
1996	1758	78885	26876	1079	15913	124511
1997	6262	70115	20914	527	20552	118370

[1]1961-1987: foreign catch from areas 5Z and 6, including some US landings (<5,000 mt/yr) 1994-1997: catch from NMFS Statistical Areas 521, 522, 525, 526, 561 and 562. [2]ME, MA & NH landings + foreign catch from Jeffreys Ledge (1967-1978)- GB catch. [3]RI, CT, NY landings; [4]NJ, DE, MD, VA landings; [5]fixed gear catch only.

Table G2. Catch at age (millions) for coastal US Atlantic herring fishery.

Year	1	2	3	4	5	6	7	8	9	10	11+
67	6.83	261.94	166.40	42.60	10.64	15.53	9.05	0.67	0.45	0.39	0.17
68	13.29	695.48	177.37	24.09	32.00	29.87	28.93	19.01	3.24	2.49	0.65
69	10.02	231.06	229.66	18.80	14.41	24.28	22.29	22.85	20.03	5.73	1.03
70	2.02	168.93	55.35	30.74	20.29	25.96	33.00	26.75	21.09	14.70	2.88
71	73.72	55.51	44.23	45.07	44.84	44.01	29.17	17.86	12.18	8.55	3.53
72	0.68	357.84	23.73	45.07	43.79	49.60	25.20	9.49	2.89	2.68	1.65
73	11.36	143.56	96.75	7.64	11.85	13.75	13.09	7.47	1.80	0.55	0.34
74	31.36	181.33	63.52	110.36	8.82	5.46	2.96	2.05	0.94	0.44	0.35
75	28.26	181.47	49.20	25.75	90.98	9.54	3.81	2.27	1.09	0.45	0.27
76	23.59	331.48	137.18	20.55	15.88	57.96	3.70	0.68	0.89	0.18	0.09
77	82.21	454.92	72.68	42.87	12.48	10.79	42.90	2.30	0.56	0.39	0.32
78	56.02	328.01	80.67	20.10	37.80	4.62	7.68	30.85	1.10	0.65	0.22
79	4.16	750.35	170.08	43.40	14.86	15.84	5.67	3.42	6.90	0.34	0.00
80	67.15	224.72	301.08	163.46	20.85	6.03	8.09	0.78	0.62	4.43	0.12
81	8.37	874.47	15.58	57.90	41.52	4.55	1.31	1.17	0.04	0.14	0.81
82	22.49	274.05	36.94	3.52	28.47	17.70	1.98	0.38	0.75	0.12	0.15
83	30.28	132.19	37.42	21:37	0.81	6.22	7.17	0.33	0.19	0.13	0.00
84	4.53	98.45	113.11	32.12	22.00	1.00	3.13	1.35	0.37	0.04	0.00
85	9.90	177.30	36.89	31.60	17.81	8.92	0.25	1.51	0.49	0.00	0.00
86	37.47	111.15	103.49	24.21	27.30	11.52	5.38	0.00	0.34	0.00	0.33
87	15.28	92.12	85.28	124.43	20.67	11.00	3.12	1.71	0.02	0.21	0.01
88	3.23	153.08	64.73	38.69	85.45	18.80	6.58	1.53	0.69	0.00	0.03
89	0.21	129.19	84.62	86.70	58.62	87.67	17.74	5.29	1.39	0.03	0.0
90	0.01	116.25	151.56	58.67	31.64	35.94	67.45	25.11	12.19	3.64	1.09
91	0.01	123.52	135.99	78.08	55.77	30.12	20.67	18.01	8.29	3.08	1.20
92	0.00	171.06	121.89	57.78	77.73	52.05	25.13	15.28	13.25	3.54	0.00
93	0.00	139.82	137.40	64.29	65.33	38.47	29.75	16.34	4.48	1.62	0.33
94	0.00	131.53	112.22	62.74	69.02	62.08	33.44	17.84	5.12	1.39	0.05
95	1.38	205.59	93.44	38.53	36.12	82.00	89.96	56.16	17.32	3.39	0.88
96	0.44	344.50	135.92	60.78	73.16	166.97	96.98	27.66	6.25	2.20	0.15
97	1.91	75.70	422.38	69.52	49.80	76.80	82.09	18.44	2.76	0.04	0.10

Table G3. Catch at age (millions) for New Brunswick Atlantic herring fishery.

Year	1	2	3	4	5	6	7	8	9	10	11+
67	129.72	160.35	55.31	105.56	11.89	4.09	1.11	0.11	0.00	0.00	0.00
68	2.20	694.45	47.71	23.16	29.24	3.65	2.90	0.70	0.07	0.01	0.00
69	61.44	350.73	94.54	4.72	9.22	7.22	6.06	1.90	0.28	0.00	0.00
70	3.97	312.87	9.23	11.63	5.57	3.51	2.18	0.82	0.06	0.01	0.00
71	80.94	164.99	33.70	7.33	3.82	2.03	2.86	1.12	0.31	0.05	0.00
72	7.57	615.19	6.00	10.09	3.94	1.87	0.96	1.08	0.33	0.03	0.00
73	26.06	197.68	178.60	20.37	1.02	0.59	0.09	0.13	0.06	0.00	0.00
74	3.26	246.04	43.48	31.15	1.23	0.05	0.05	0.04	0.04	0.03	0.04
75	16.88	462.98	57.23	9.56	16.38	2.18	1.11	0.92	0.29	0.16	0.17
76	51.79	199.27	104.62	19.99	14.91	10.13	1.60	0.37	0.46	0.19	0.11
77	514.97	124.29	10.35	20.99	7.27	7.46	4.87	0.23	0.01	0.00	0.00
78	213.78	894.37	52.13	3.67	0.81	1.06	0.28	0.13	0.00	0.00	0.00
79	2.40	423.73	247.36	12.24	0.82	0.84	0.48	1.01	0.19	0.00	0.00
80	276.00	5.33	62.09	21.62	0.92	0.13	0.12	0.07	0.06	0.06	0.00
81	53.34	294.72	18.78	10.20	5.37	0.31	0.05	0.03	0.03	0.00	0.00
82	30.21	395.42	73.20	3.20	1.80	1.60	0.20	0.04	0.07	0.00	0.00
83	2.53	135.28	21.68	7.53	0.44	0.40	0.19	0.00	0.00	0.00	0.00
84	14.35	86.59	19.99	8.22	6.48	1.14	1.19	0.37	0.15	0.08	0.04
85	20.30	385.45	47.43	19.47	9.36	4.63	0.93	0.88	0.23	0.00	0.07
86	3.21	136.31	121.66	24.29	10.70	4.73	2.33	0.36	0.12	0.09	0.02
87	35.71	131.66	49.53	56.08	24.19	7.43	2.57	0.64	0.19	0.11	0.00
88	76.05	349.17	46.21	23.43	41.16	16.06	2.56	0.65	0.39	0.10	0.07
89	26.86	331.01	81.41	21.44	22.72	93.02	11.53	3.10	0.81	0.12	0.25
90	12.58	454.80	69.00	30.69	6.36	7.23	15.03	3.42	2.52	0.62	0.31
91	5.53	338.26	44.45	23.62	9.53	3.15	2.62	3.44	1.46	0.27	0.15
92	0.80	375.77	97.68	36.44	10.38	3.99	1.61	1.36	0.56	0.25	0.04
93	1.72	244.08	106.10	37.19	23.22	12.26	4.92	1.12	1.10	0.86	0.18
94	1.97	291.96	63.90	9.97	16.26	9.33	3.89	1.48	1.08	0.54	0.33
95	57.84	259.74	40.12	14.80	1.82	1.57	1.55	0.03	0.00	0.00	0.00
96	5.35	269.43	22.39	9.34	4.30	1.15	1.27	0.43	0.04	0.01	0.00
97	9.31	216.16	113.20	11.33	3.60	0.52	0.21	0.10	0.01	0.00	0.00

Table G4. Catch at age (millions) for Georges Bank Atlantic herring fishery.

Year	1	2	3	4	5	6	7	8	9	10	11
67	0.00	1.80	6.90	60.60	108.00	250.70	379.20	49.40	11.10	10.00	0.00
68	0.00	2.50	52.10	133.30	336.00	233.40	432.90	336.40	21.80	6.60	0.00
69	0.00	0.00	73.40	210.80	277.10	278.10	188.50	190.50	109.70	23.60	0.00
70	0.00	12.60	125.40	450.50	270.30	122.30	92.90	51.60	29.60	17.70	0.00
71	0.00	12.90	332.50	275.50	284.60	175.80	103.90	50.40	13.90	21.80	0.00
72	0.00	28.00	35.00	110.00	214.00	158.00	100.00	45.00	29.00	21.00	0.00
73	0.00	10.00	1026.00	266.00	64.00	33.00	23.00	12.00	3.00	5.00	0.00
74	0.00	1.90	39.90	608.90	68.60	12.90	6.10	3.50	2.10	0.00	0.00
75	0.00	1.40	11.30	76.80	503.00	34.60	12.50	6.20	4.20	0.10	0.00
76	0.00	0.50	7.50	6.80	18.60	140.80	5.10	2.30	1.20	0.30	0.00
77	0.00	0.10	0.30	6.70	1.20	0.20	1.90	0.10	0.10	0.00	0.00
78	0.00	0.10	5.60	2.30	4.30	0.50	0.30	1.20	0.00	0.00	0.00
79	0.00	0.10	5.10	2.10	0.40	0.40	0.00	0.10	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
96	0.00	5.79	2.29	1.02	1.23	2.81	1.63	0.46	0.10	0.04	0.00
97	0.00	2.00	49.00	5.29	1.18	1.50	1.16	0.51	0.09	0.00	0.00

Table G5. Total estimated catch at age (millions) for the coastal stock complex of Atlantic herring, including US and New Brunswick (Canada) shoreside landings, herring processed aboard foreign processing ships or transferred to Canadian carriers, and historical foreign fishing in US waters.

Year	1	2	3	4	5	6	7	8	9	10	11+
67	136.55	424.09	228.61	208.76	130.53	270.32	389.36	50.18	11.55	10.39	0.17
68	15.49	1392.43	277.18	180.55	397.24	266.92	464.73	356.11	25.11	9.1	0.65
69	71.46	581.79	397.6	234.32	300.73	309.6	216.85	215.25	130.01	29.33	1.03
70	5.99	494.4	189.98	492.87	296.16	151.77	128.08	79.17	50.75	32.41	2.88
71	154.66	233.4	410.43	327.9	333.26	221.84	135.93	69.38	26.39	30.4	3.53
72	8.25	1001.03	64.73	165.16	261.73	209.47	126.16	55.57	32.22	23.71	1.65
73	37.42	351.24	1301.35	294.01	76.87	47.34	36.18	19.6	4.86	5.55	0.34
74	34.62	429.27	146.9	750.41	78.65	18.41	9.11	5.59	3.08	0.47	0.39
75	45.14	645.85	117.73	112.11	610.36	46.32	17.42	9.39	5.58	0.71	0.44
76	75.38	531.25	249.3	47.34	49.39	208.89	10.4	3.35	2.55	0.67	0.2
77	597.18	579.31	83.33	70.56	20.95	18.45	49.67	2.63	0.67	0.39	0.32
78	269.8	1222.48	138.4	26.07	42.91	6.18	8.26	32.18	1.1	0.65	0.22
79	6.56	1174.18	422.54	57.74	16.08	17.08	6.15	4.53	7.09	0.34	0
80	343.15	230.05	363.17	185.08	21.77	6.16	8.21	0.85	0.68	4.49	0.12
81	61.71	1169.19	34.36	68.1	46.89	4.86	1.36	1.2	0.07	0.14	0.81
82	52.7	669.47	110.14	6.72	30.27	19.3	2.18	0.42	0.82	0.12	0.15
83	32.81	267.47	59.1	28.9	1.25	6.62	7.36	0.33	0.19	0.13	0
84	18.88	185.04	133.1	40.34	28.48	2.14	4.32	1.72	0.52	0.12	0.04
85	30.2	562.75	84.32	51.07	27.17	13.55	1.18	2.39	0.72	0	0.07
86	40.68	247.46	225.15	48.5	38	16.25	7.71	0.36	0.46	0.09	0.35
87	50.99	223.78	134.81	180.51	44.86	18.43	5.69	2.35	0.21	0.32	0.01
88	79.28	502.25	110.94	62.12	126.61	34.86	9.14	2.18	1.08	0.1	0.1
89	27.07	460.2	166.03	108.14	81.34	180.69	29.27	8.39	2.2	0.15	0.25
90	12.59	571.05	220.56	89.36	38	43.17	82.48	28.53	14.71	4.26	1.4
91	5.54	461.78	180.44	101.7	65.3	33.27	23.29	21.45	9.75	3.35	1.35
92	0.8	546.83	219.57	94.22	88.11	56.04	26.74	16.64	13.81	3.79	0.04
93	1.72	383.9	243.5	101.48	88.55	50.73	34.67	17.46	5.58	2.48	0.51
94	1.97	423.49	176.12	72.71	85.28	71.41	37.33	19.32	6.2	1.93	0.38
95	59.22	465.33	133.56	53.33	37.94	83.57	91.51	56.19	17.32	3.39	0.88
96	5.79	619.72	160.6	71.14	78.69	170.93	99.88	28.55	6.39	2.25	0.15
97	11.22	293.86	584.58	86.14	54.58	78.82	83.46	19.05	2.86	0.04	0.1

Table G6. Catch mean weight at age (kg), US Atlantic herring stock complex, 1976-1997.

Year	1	2	3	4	5	6	7	8	9	10	11+
1967	0.005	0.029	0.078	0.118	0.162	0.257	0.275	0.342	0.288	0.292	0.313
1968	0.007	0.025	0.059	0.142	0.194	0.215	0.245	0.260	0.273	0.292	0.313
1969	0.010	0.039	0.079	0.051	0.252	0.270	0.320	0.296	0.273	0.292	0.313
1970	0.021	0.063	0.106	0.167	0.210	0.240	0.304	0.309	0.311	0.292	0.313
1971	0.019	0.049	0.115	0.180	0.234	0.327	0.294	0.291	0.329	0.331	0.313
1972	0.035	0.051	0.120	0.187	0.234	0.273	0.314	0.357	0.273	0.292	0.313
1973	0.016	0.054	0.108	0.170	0.233	0.257	0.293	0.325	0.338	0.263	0.324
1974	0.017	0.053	0.108	0.169	0.204	0.232	0.247	0.272	0.286	0.293	0.305
1975	0.023	0.051	0.096	0.169	0.192	0.230	0.274	0.274	0.302	0.293	0.314
1976	0.018	0.042	0.114	0.179	0.206	0.211	0.260	0.282	0.319	0.334	0.399
1977	0.016	0.042	0.103	0.161	0.189	0.219	0.228	0.260	0.304	0.294	0.281
1978	0.013	0.040	0.120	0.186	0.226	0.256	0.273	0.285	0.317	0.349	0.345
1979	0.008	0.032	0.089	0.198	0.255	0.281	0.182	0.325	0.332	0.313	0.313
1980	0.015	0.041	0.103	0.169	0.268	0.319	0.344	0.241	0.306	0.391	0.372
1981	0.012	0.045	0.114	0.190	0.232	0.293	0.316	0.342	0.470	0.304	0.373
1982	0.020	0.049	0.130	0.194	0.250	0.267	0.300	0.322	0.342	0.423	0.313
1983	0.022	0.055	0.138	0.216	0.223	0.310	0.348	0.368	0.390	0.397	0.313
1984	0.019	0.051	0.133	0.182	0.227	0.260	0.305	0.343	0.314	0.402	0.528
1985	0.013	0.049	0.139	0.181	0.203	0.229	0.281	0.273	0.289	0.292	0.313
1986	0.021	0.053	0.116	0.166	0.215	0.230	0.251	0.260	0.299	0.292	0.313
1987	0.018	0.044	0.093	0.141	0.178	0.218	0.233	0.227	0.251	0.265	0.320
1988	0.009	0.034	0.090	0.129	0.164	0.187	0.228	0.238	0.254	0.292	0.247
1989	0.005	0.046	0.101	0.136	0.168	0.196	0.235	0.248	0.244	0.313	0.300
1990	0.005	0.044	0.099	0.148	0.183	0.194	0.207	0.229	0.240	0.258	0.300
1991	0.005	0.053	0.087	0.133	0.166	0.193	0.214	0.225	0.229	0.243	0.300
1992	0.005	0.046	0.090	0.128	0.153	0.175	0.201	0.219	0.229	0.256	0.300
1993	0.005	0.044	0.096	0.132	0.158	0.182	0.211	0.238	0.258	0.282	0.300
1994	0.005	0.049	0.086	0.119	0.139	0.159	0.184	0.214	0.243	0.261	0.300
1995	0.026	0.056	0.097	0.123	0.140	0.155	0.170	0.192	0.224	0.256	0.272
1996	0.025	0.054	0.091	0.125	0.152	0.171	0.191	0.206	0.235	0.249	0.332
1997	0.016	0.057	0.090	0.122	0.145	0.170	0.187	0.216	0.264	0.332	0.345

Table G7. Percent maturity at age, US Atlantic herring stock complex.

Year	1	2	3	4	5+
1976	0	0	0.65	0.99	1
1977	0	0	0.36	0.98	1
1978	0	0	0.17	0.95	1
1979	0	0	0.39	0.98	1
1980	0	0	0.13	0.93	1
1981	0	0	0.28	0.97	1
1982	0	0	0.59	0.99	1
1983	0	0	0.58	0.99	1
1984	0	0	0.51	0.99	1
1985	0	0	0.68	0.99	1
1986	0	0	0.34	0.98	1
1987	0	0	0.15	0.94	1
1988	0	0	0.4	1	1
1989	0	0	0.36	0.99	1
1990	0	0	0.12	0.89	1
1991	0	0	0.19	0.96	1
1992	0	0	0.3	0.89	1
1993	0	0	0.3	1	1
1994	0	0	0.15	1	1
1995	0	0	0.3	0.83	1
1996	0	0	0.44	0.95	1
1997	0	0	0.78	1	1

Table G8. Catch at age estimates (millions) used in Gulf of Maine VPA.

Year	1	2	3	4	5	6	7	8	9	10
1967	136.55	422.29	221.71	148.16	22.53	19.62	10.16	0.78	0.45	0.39
1968	15.49	1389.93	225.08	47.25	61.24	33.52	31.83	19.71	3.31	2.5
1969	71.46	581.79	324.2	23.52	23.63	31.5	28.35	24.75	20.31	5.73
1970	5.99	481.8	64.58	42.37	25.86	29.47	35.18	27.57	21.15	14.71
1971	154.66	220.5	77.93	52.4	48.66	46.04	32.03	18.98	12.49	8.6
1972	8.25	973.03	29.73	55.16	47.73	51.47	26.16	10.57	3.22	2.71
1973	37.42	341.24	275.35	28.01	12.87	14.34	13.18	7.6	1.86	0.55
1974	34.62	427.37	107	141.51	10.05	5.51	3.01	2.09	0.98	0.47
1975	45.14	644.45	106.43	35.31	107.36	11.72	4.92	3.19	1.38	0.61
1976	75.38	530.75	241.8	40.54	30.79	68.09	5.3	1.05	1.35	0.37
1977	597.18	579.21	83.03	63.86	19.75	18.25	47.77	2.53	0.57	0.39
1978	269.8	1222.38	132.88	23.77	38.61	5.68	7.96	30.98	1.1	0.65
1979	6.56	1174.08	417.44	55.64	15.68	16.68	6.15	4.43	7.09	0.34
1980	343.15	230.05	363.17	185.08	21.77	6.16	8.21	0.85	0.68	4.49
1981	61.71	1169.19	34.36	68.1	46.89	4.86	1.36	1.2	0.07	0.14
1982	52.7	669.47	110.14	6.72	30.27	19.3	2.18	0.42	0.82	0.12
1983	32.81	267.47	59.1	28.9	1.25	6.62	7.36	0.33	0.19	0.13
1984	18.88	185.04	133.1	40.34	28.48	2.14	4.32	1.72	0.52	0.12
1985	30.2	562.75	84.32	51.07	27.17	13.55	1.18	2.39	0.72	0.001
1986	40.68	247.46	225.15	48.5	38	16.25	7.71	0.36	0.46	0.09
1987	50.99	223.78	134.81	180.51	44.86	18.43	5.69	2.35	0.21	0.32
1988	79.28	502.25	110.94	62.12	126.61	34.86	9.14	2.18	1.08	0.1
1989	27.06	460.21	166.03	108.15	81.34	180.69	29.27	8.38	2.2	0.15
1990	12.59	571.05	220.56	89.36	37.99	43.17	82.48	28.53	14.71	5.69
1991	5.54	460.20	161.54	90.34	61.96	31.54	22.73	21.28	9.69	4.96
1992	0.80	561.02	234.44	95.71	68.59	40.46	21.45	15.14	8.35	2.72
1993	1.72	383.90	237.68	95.16	82.05	48.33	29.93	15.82	5.33	2.48
1994	1.97	423.49	176.11	72.70	85.26	71.40	37.32	19.32	6.20	1.93
1995	59.22	464.77	127.73	45.34	29.31	61.53	66.91	44.11	13.32	3.39
1996	5.79	571.63	134.62	52.44	57.22	108.07	68.47	21.60	5.04	1.97
1997	11.22	291.45	436.15	59.34	38.39	55.15	55.52	13.41	2.13	0.04

Table G9. Gulf of Maine total mortality estimates.

Year class	Age 1	Age N	MVUE Z
1966	6	10	1.34
1967	5	10	1.03
1968	5	8	0.79
1969	6	10	0.81
1970	5	10	0.62
1971	5	10	0.78
1972	5	8	0.90
1973	5	10	0.94
1974	5	10	1.05
1975	6	9	0.86
1976	5	9	1.01
1977	5	10	0.96
1978	6	10	0.64
1979	5	9	0.82
1980	5	9	0.79
1981	5	10	0.49
1982	6	10	0.60
1983	6	10	1.04
1984	5	10	0.70
1985	6	10	0.64
1986	5	10	0.54
1987	5	9	0.55
1988	5	9	0.59
1990-97	6	10	0.75

Table G10. Terminal fishing mortality rates (F_t) at age in 1997 derived as products of the terminal fishing mortality rate for the 1990-1997 time period (see Table G1) times partial recruitment values.

Age	F_t (1990-97)	PR	F_t at age in 1997
1	0.55	0.008	0.004
2	0.55	0.607	0.33
3	0.55	0.451	0.25
4	0.55	0.385	0.21
5	0.55	0.564	0.31
6	0.55	0.773	0.42
7	0.55	1.0	0.55
8	0.55	1.0	0.55

Table G11. Summary of results for the coastal stock complex of Atlantic herring from SAW-27 VPA.

STOCK NUMBERS (Jan 1) in thousands

	1967	1968	1969	1970	1971	1972	1973
1	5323	2657	2090	1413	7717	1184	1008
2	2842	4235	2161	1647	1151	6178	962
3	1822	1943	2207	1243	901	731	4152
4	1835	1284	1340	1447	846	366	540
5	1177	1314	888	885	739	396	150
6	1522	846	716	455	457	304	87
7	1287	1001	451	306	235	173	59
8	189	701	399	173	135	70	28
9	42	109	252	132	70	48	07
10	51	24	67	89	62	33	10
11	01	02	02	08	07	02	01
1+	16091	14116	10575	7798	12320	9485	7005

	1974	1975	1976	1977	1978	1979	1980
1	1662	1025	1290	3594	2754	408	2355
2	792	1330	798	988	2402	2011	328
3	470	260	504	173	285	860	584
4	2222	252	106	187	66	108	322
5	176	1140	105	44	89	30	36
6	54	73	381	41	17	34	10
7	29	27	18	123	17	08	13
8	16	15	07	05	56	06	01
9	05	08	04	02	02	17	01
10	01	01	01	01	01	01	07
11	01	01	00	01	00	00	00
1+	5427	4131	3215	5160	5690	3484	3658

	1981	1982	1983	1984	1985	1986	1987
1	1403	1147	1124	2925	1337	1486	2038
2	1618	1093	892	890	2378	1067	1179
3	60	267	289	488	561	1437	650
4	149	18	119	183	279	383	973
5	96	61	09	71	113	182	270
6	10	36	22	06	32	68	115
7	03	04	12	12	03	14	41
8	03	01	01	03	06	01	05
9	00	01	01	01	01	03	01
10	00	00	00	00	00	00	02
11	02	00	00	00	00	01	00
1+	3345	2629	2468	4580	4711	4644	5274

	1988	1989	1990	1991	1992	1993	1994
1	2076	2536	3951	8786	6436	3588	4464
2	1622	1628	2052	3223	7189	5268	2936
3	763	874	917	1163	2221	5391	3966
4	410	524	565	551	789	1620	4193
5	633	279	332	382	359	561	1234
6	180	404	155	237	254	214	379
7	77	116	167	88	164	157	129
8	29	55	69	62	51	110	97
9	02	21	38	30	32	27	74
10	01	00	16	17	16	13	17
11	01	01	05	07	00	03	03
1+	5794	6440	8265	14548	17510	16952	17494

Table G11. (Continued)

	1995	1996	1997	1998
1	29198	8927	24790	00
2	3653	23851	7304	20287
3	2021	2570	18967	5714
4	3088	1533	1959	15000
5	3367	2480	1191	1526
6	934	2723	1959	926
7	246	689	2074	1533
8	72	118	473	1623
9	62	08	71	370
10	55	35	01	56
11	14	02	02	03
1+	42709	42937	58793	47036

FISHING MORTALITY

	1967	1968	1969	1970	1971	1972	1973
1	0.03	0.01	0.04	0.00	0.02	0.01	0.04
2	0.18	0.45	0.35	0.40	0.25	0.20	0.52
3	0.15	0.17	0.22	0.19	0.70	0.10	0.43
4	0.13	0.17	0.21	0.47	0.56	0.69	0.92
5	0.13	0.41	0.47	0.46	0.69	1.31	0.83
6	0.22	0.43	0.65	0.46	0.77	1.44	0.92
7	0.41	0.72	0.76	0.62	1.02	1.63	1.13
8	0.35	0.82	0.91	0.70	0.84	2.13	1.52
9	0.37	0.29	0.84	0.55	0.54	1.38	1.59
10	0.25	0.55	0.66	0.52	0.77	1.53	0.99
11	0.25	0.55	0.66	0.52	0.77	1.53	0.99
Ave.3,7	0.21	0.38	0.46	0.44	0.75	1.04	0.85

	1974	1975	1976	1977	1978	1979	1980
1	0.02	0.05	0.07	0.20	0.11	0.02	0.18
2	0.91	0.77	1.33	1.04	0.83	1.04	1.49
3	0.42	0.69	0.79	0.76	0.77	0.78	1.16
4	0.47	0.68	0.68	0.54	0.57	0.89	1.01
5	0.68	0.90	0.74	0.74	0.76	0.88	1.09
6	0.48	1.20	0.93	0.69	0.51	0.80	1.07
7	0.43	1.23	1.02	0.59	0.78	1.62	1.25
8	0.51	1.15	0.84	0.79	1.01	1.55	1.15
9	1.16	1.63	1.27	0.39	0.94	0.64	1.15
10	0.62	0.95	0.92	0.65	0.82	0.90	1.16
11	0.62	0.95	0.92	0.65	0.82	0.90	1.16
Ave.3,7	0.50	0.94	0.83	0.66	0.68	0.99	1.12

	1981	1982	1983	1984	1985	1986	1987
1	0.05	0.05	0.03	0.01	0.03	0.03	0.03
2	1.60	1.13	0.40	0.26	0.30	0.30	0.24
3	0.99	0.61	0.26	0.36	0.18	0.19	0.26
4	0.70	0.52	0.31	0.28	0.23	0.15	0.23
5	0.77	0.80	0.17	0.59	0.31	0.26	0.20
6	0.78	0.88	0.40	0.49	0.62	0.31	0.20
7	0.72	1.04	1.08	0.49	0.55	0.91	0.17
8	0.59	0.51	0.42	0.80	0.56	0.32	0.80
9	0.24	1.10	0.46	4.92	0.99	0.20	0.31
10	0.78	0.86	0.49	0.59	0.39	0.30	0.20
11	0.78	0.86	0.49	0.59	0.39	0.30	0.20
Ave.3,7	0.79	0.77	0.44	0.44	0.38	0.36	0.21

Table G11. (Continued)

	1988	1989	1990	1991	1992	1993	1994
1	0.04	0.01	0.00	0.00	0.00	0.00	0.00
2	0.42	0.37	0.37	0.17	0.09	0.08	0.17
3	0.18	0.24	0.31	0.19	0.12	0.05	0.05
4	0.18	0.26	0.19	0.23	0.14	0.07	0.02
5	0.25	0.39	0.14	0.21	0.32	0.19	0.08
6	0.24	0.68	0.37	0.17	0.28	0.30	0.23
7	0.14	0.33	0.79	0.35	0.20	0.28	0.38
8	0.09	0.18	0.61	0.48	0.45	0.19	0.25
9	1.18	0.12	0.57	0.44	0.66	0.26	0.10
10	0.24	0.49	0.36	0.24	0.30	0.23	0.14
11	0.24	0.49	0.36	0.24	0.30	0.23	0.14
Ave.3.7	0.20	0.38	0.36	0.23	0.21	0.18	0.15

	1995	1996	1997
1	0.00	0.00	0.00
2	0.15	0.03	0.05
3	0.08	0.07	0.03
4	0.02	0.05	0.05
5	0.01	0.04	0.05
6	0.10	0.07	0.05
7	0.53	0.17	0.05
8	1.97	0.31	0.05
9	0.37	1.92	0.05
10	0.07	0.07	0.05
11	0.07	0.07	0.05
Ave.3.7	0.15	0.08	0.05

SSB AT THE START OF THE SPAWNING SEASON - MALES AND FEMALES (MT) (using SSB mean weights)

	1967	1968	1969	1970	1971	1972	1973
1	00	00	00	00	00	00	00
2	00	00	00	00	00	00	00
3	02	04	25	28	16	14	94
4	91	90	53	100	65	27	33
5	130	126	102	56	75	26	14
6	292	99	87	68	58	22	09
7	231	126	58	47	25	14	06
8	48	87	47	28	18	04	02
9	08	23	31	23	13	04	01
10	11	04	10	15	10	03	01
11	00	00	00	01	01	00	00
1+	812	559	411	365	282	115	161

	1974	1975	1976	1977	1978	1979	1980
1	00	00	00	00	00	00	00
2	00	00	00	00	00	00	00
3	14	06	12	02	02	10	02
4	180	17	07	14	05	07	15
5	17	90	10	04	08	03	03
6	07	06	33	04	02	04	01
7	04	02	02	15	02	00	01
8	03	01	01	01	06	01	00
9	01	01	00	00	00	03	00
10	00	00	00	00	00	00	01
11	00	00	00	00	00	00	00
1+	227	124	65	41	25	28	23

Table G11. (Continued)

	1981	1982	1983	1984	1985	1986	1987
1	00	00	00	00	00	00	00
2	00	00	00	00	00	00	00
3	00	07	10	14	24	27	05
4	10	02	13	20	31	44	85
5	09	06	01	09	15	25	34
6	01	04	04	01	04	10	18
7	00	00	01	02	00	01	07
8	01	00	00	01	01	00	01
9	00	00	00	00	00	01	00
10	00	00	00	00	00	00	00
11	00	00	00	00	00	00	00
1+	23	19	30	47	76	110	151

	1988	1989	1990	1991	1992	1993	1994
1	00	00	00	00	00	00	00
2	00	00	00	00	00	00	00
3	15	13	05	10	36	88	31
4	34	41	46	44	58	144	381
5	69	26	41	44	35	59	135
6	24	37	18	34	30	25	43
7	13	16	16	12	24	21	15
8	05	10	09	08	07	18	15
9	00	04	05	04	04	04	14
10	00	00	03	03	03	02	03
11	00	00	01	02	00	01	01
1+	160	149	143	161	196	363	638

	1995	1996	1997
1	00	00	00
2	00	00	00
3	34	65	868
4	224	133	171
5	370	285	133
6	109	344	262
7	23	89	309
8	03	15	80
9	09	00	14
10	11	07	00
11	03	01	01
1+	787	939	1838

Table G12. Projections for the coastal stock complex of Atlantic herring. Basis: *Status quo* landings equivalent to 1997 landings of 119,000 mt: landings of 200,000 mt correspond to SARC estimate of MSY; landings of 317,000 mt correspond to Overfishing Definition Review Panel estimate of MSY from calibrated ASPIC analysis; SSB estimated to be 2,444,000 mt in 1998 (weights in '000 mt).

1998			1999			2000			
F	Landings	SSB	F	Landings	SSB	F	Landings	SSB	Consequences/Implications
0.031	119	2,444	0.029	119	3,170	0.028	119	3,715	SSB increases about 52% from 1998 to 2000
			0.049	200	3,121	0.048	200	3,589	SSB increases about 47% from 1998 to 2000
			0.078	317	3,051	0.080	317	3,405	SSB increases about 39% from 1998 to 2000

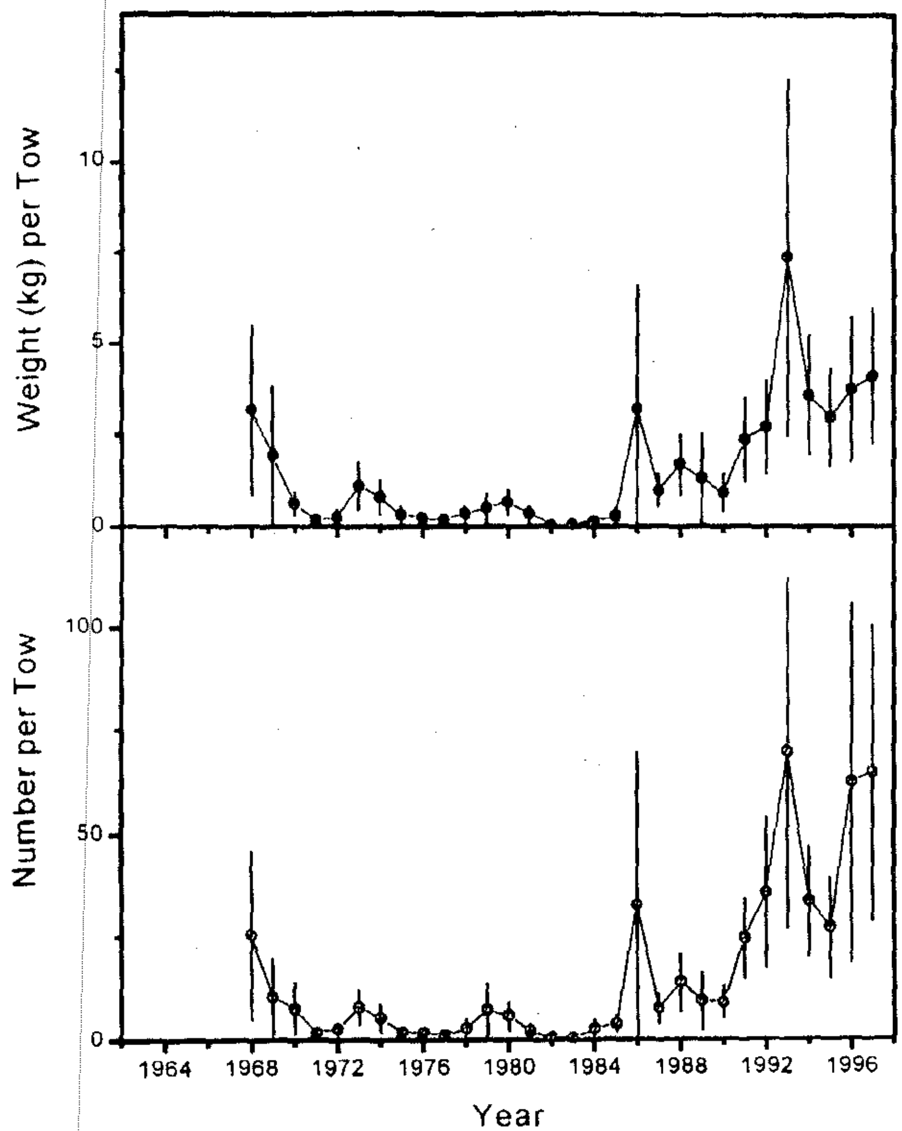

Figure G1. Spring bottom trawl survey index.

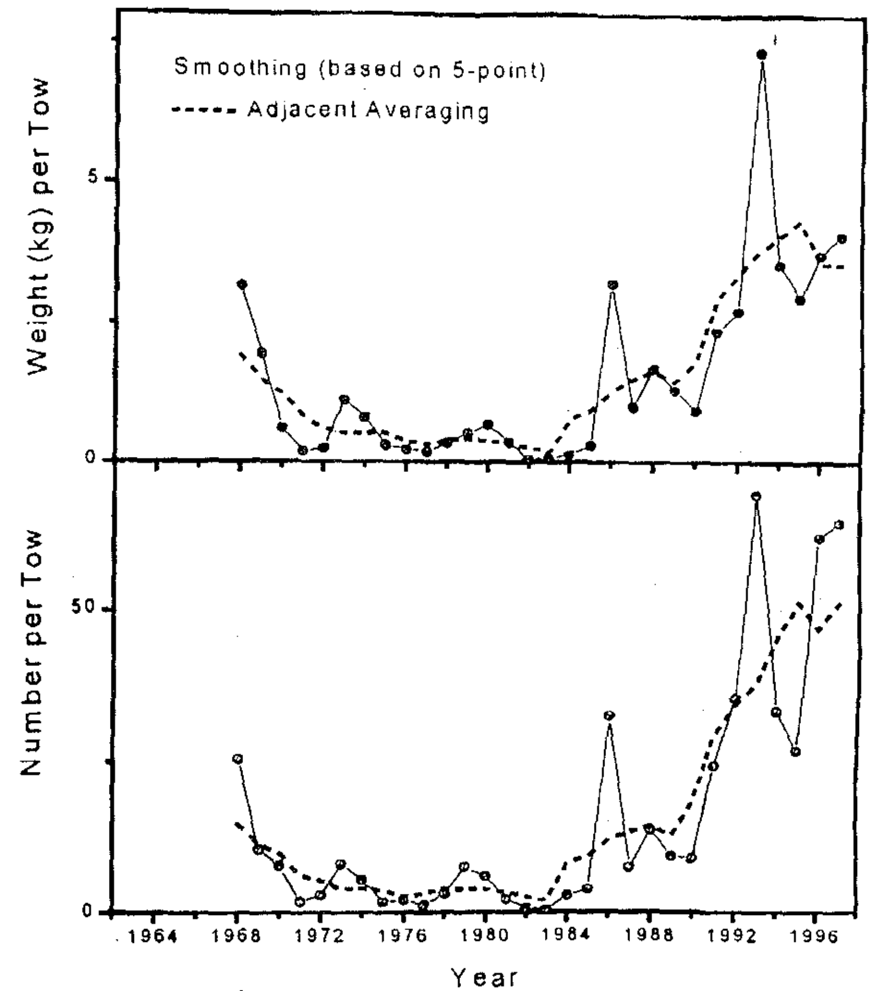

Figure G2. Spring bottom trawl survey index smoothed with 5 year adjacent averaging.

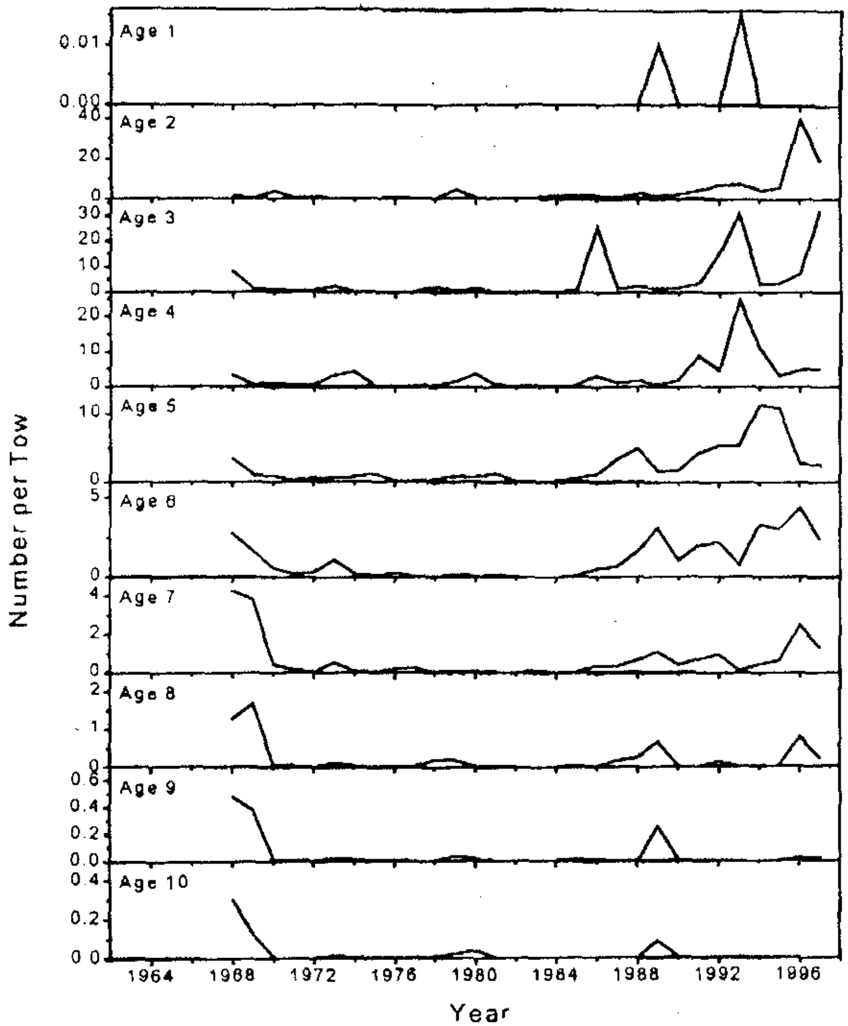

Figure G3. Spring bottom trawl survey index by age.

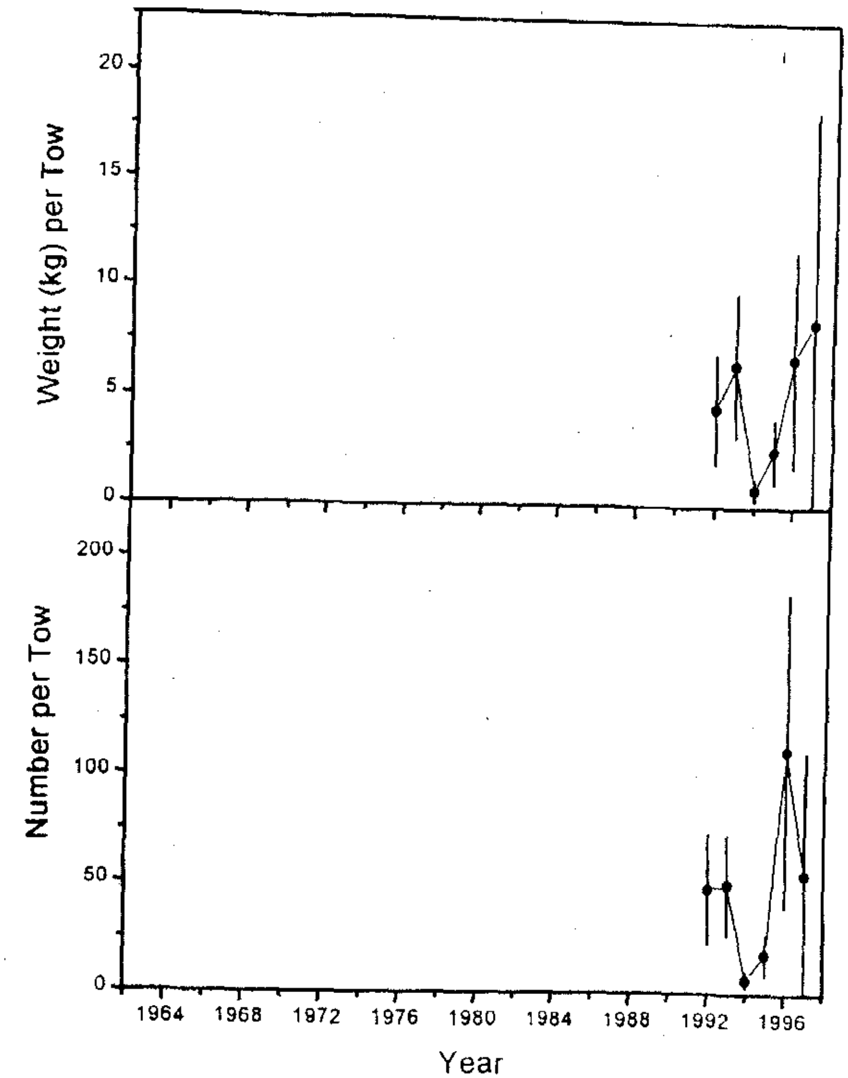

Figure G4. Winter bottom trawl survey index.

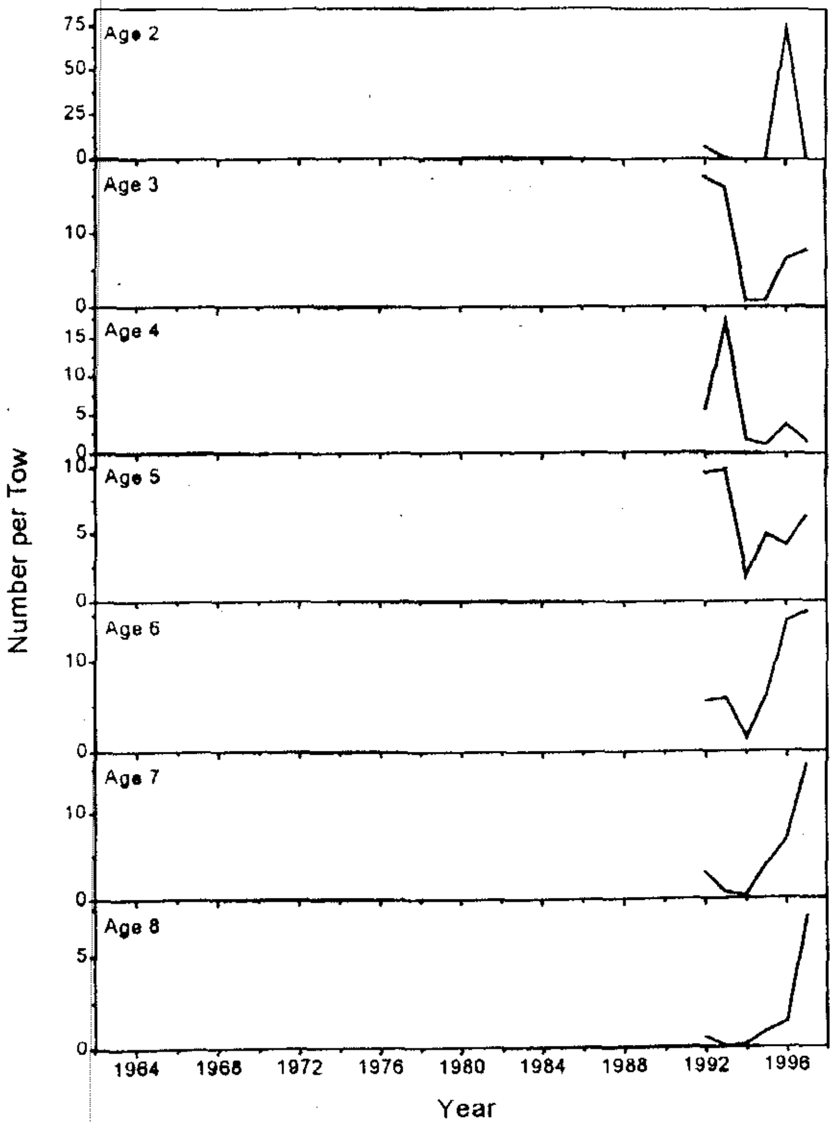

Figure G5. Winter bottom trawl survey index by age.

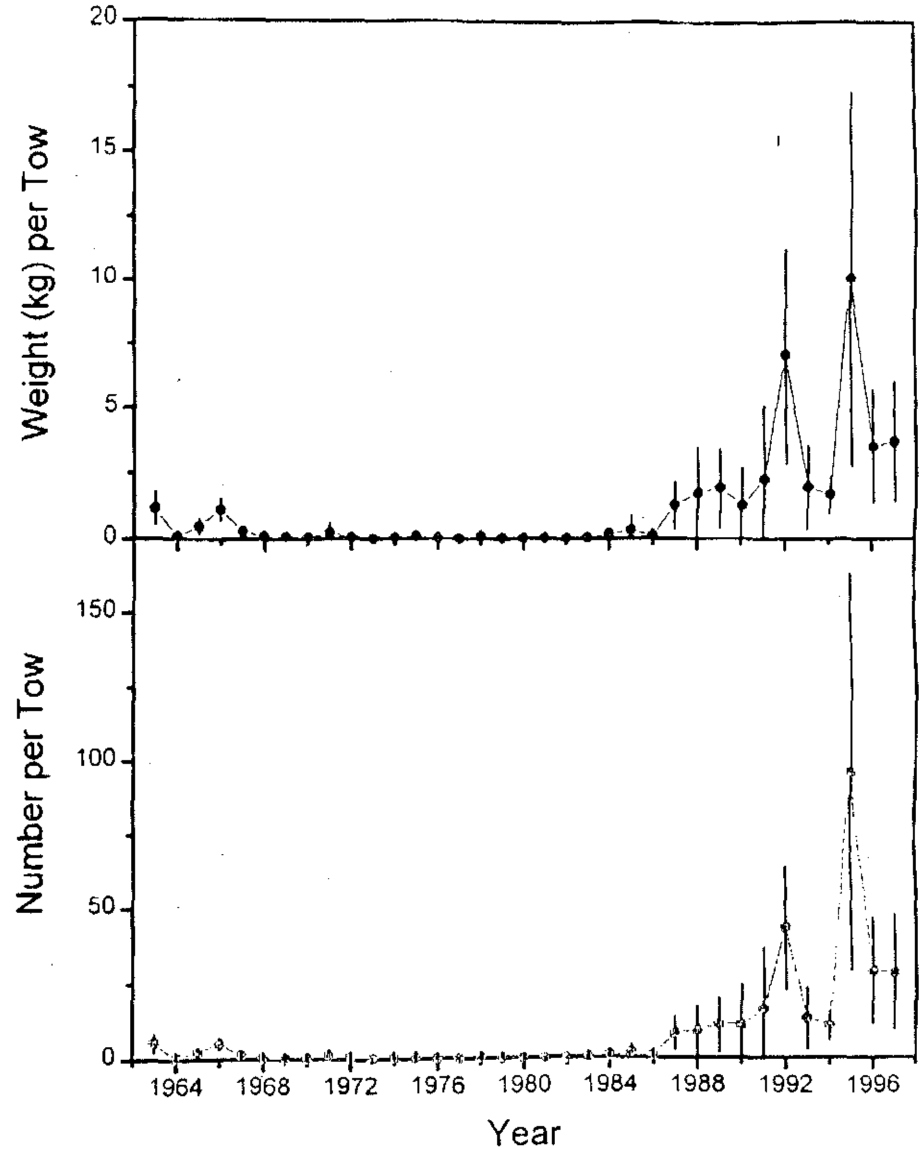

Figure G6. Fall bottom trawl survey index.

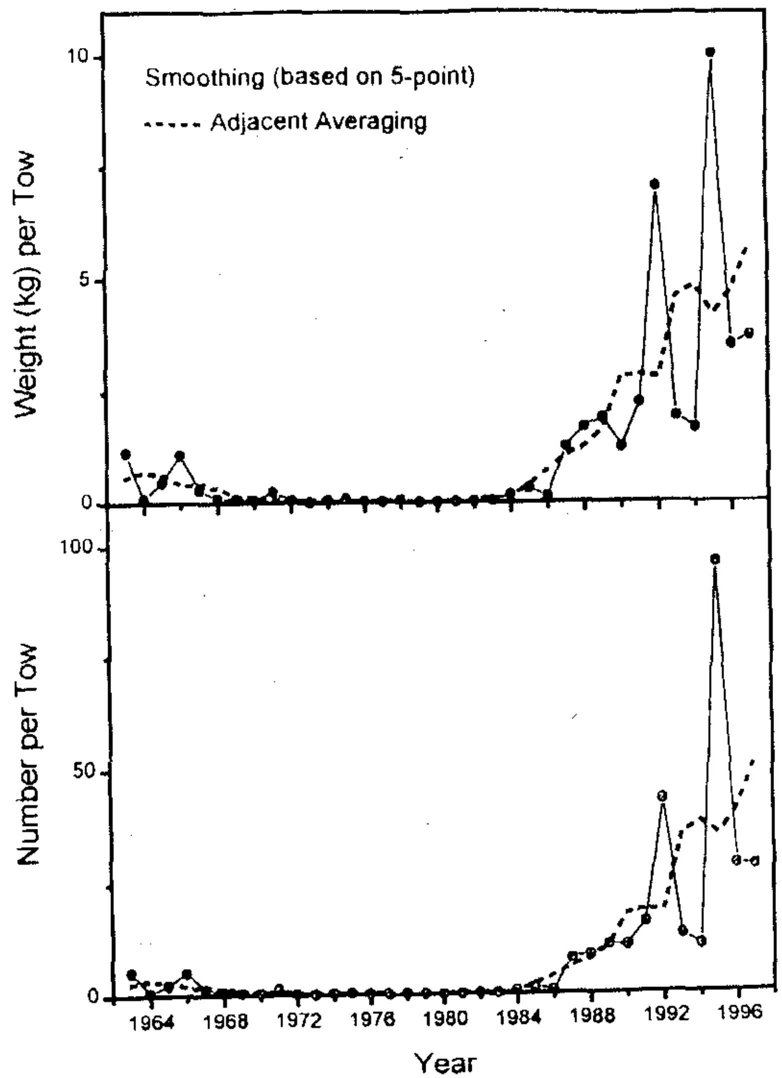

Figure G7. Fall bottom trawl survey index smoothed with 5 year adjacent averaging.

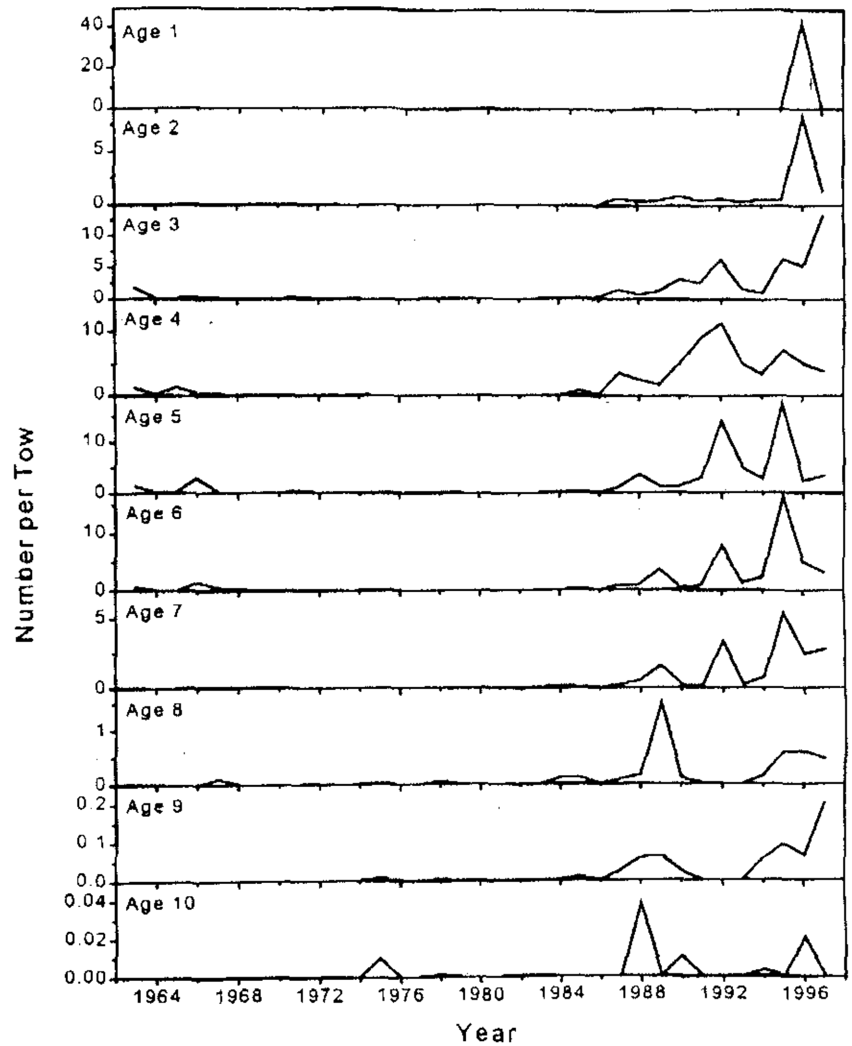

Figure G8. Fall bottom trawl survey index by age.

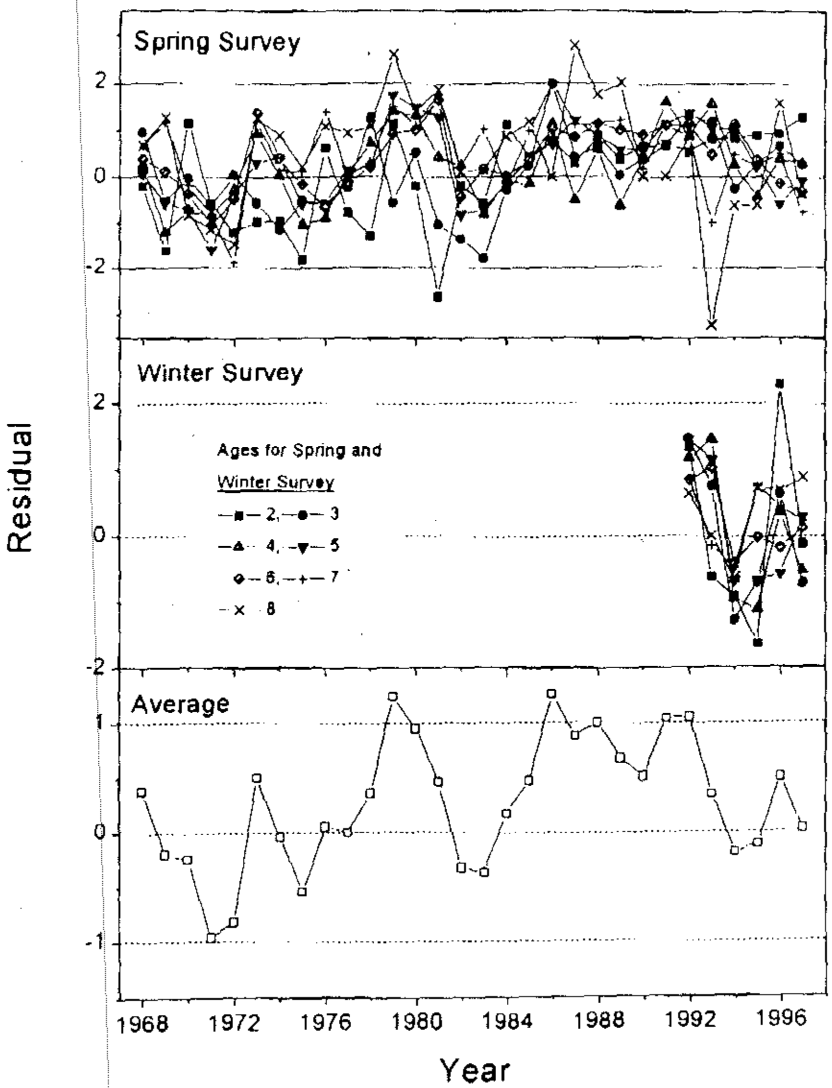

Figure G9. Residuals, final adapt run coastal stock complex.

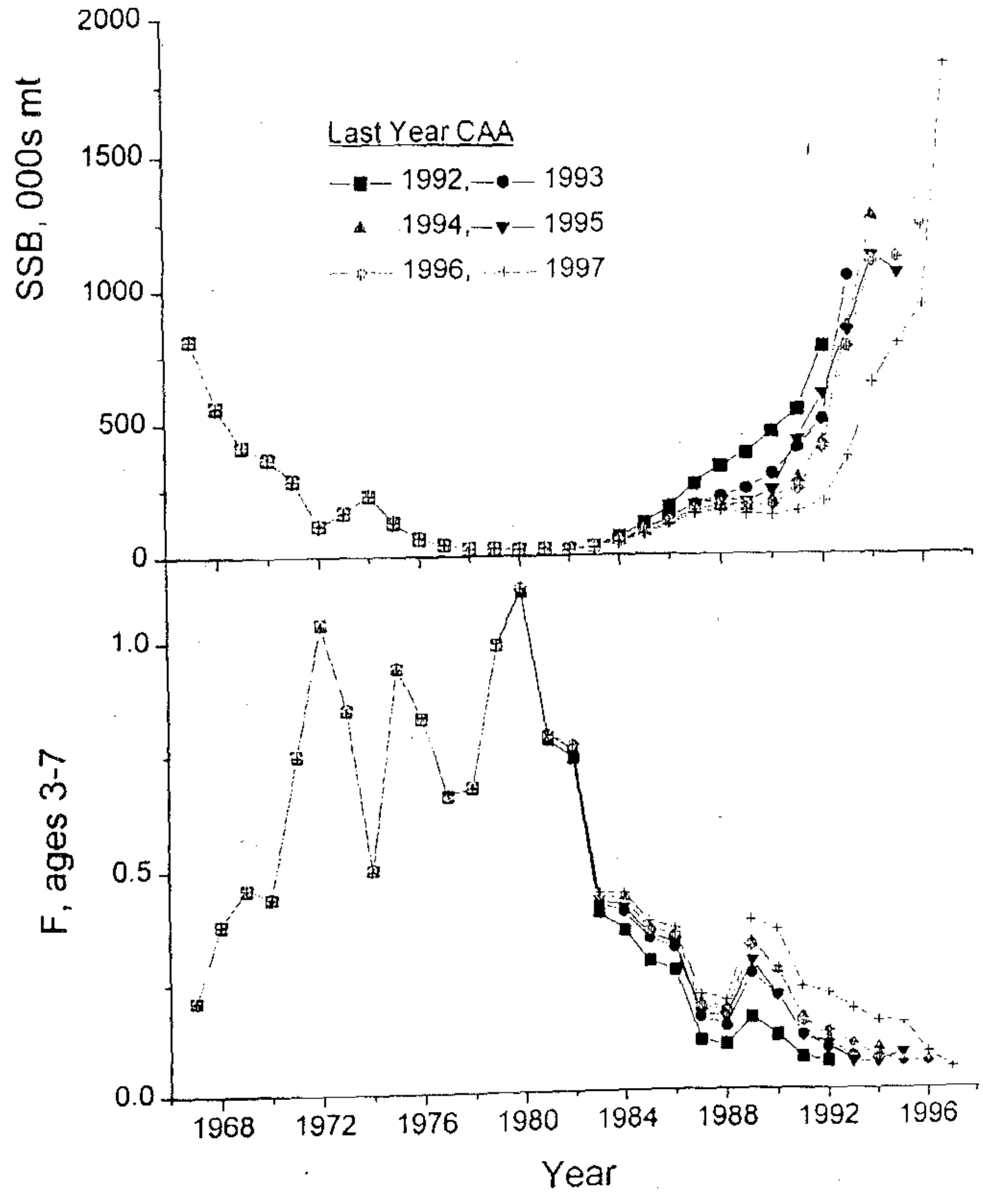

Figure G10. Retrospective analysis of SSB and F.

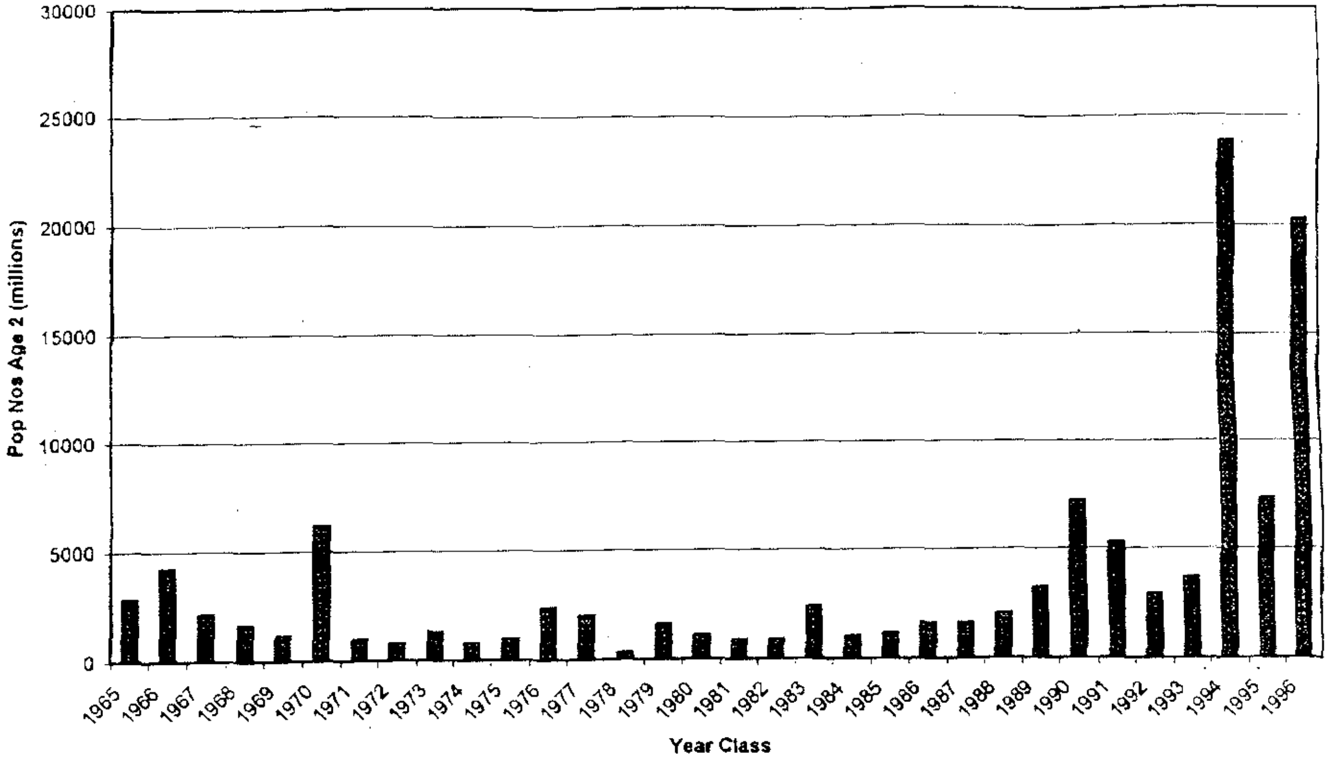

Figure G11. Recruitment, coastal stock complex.

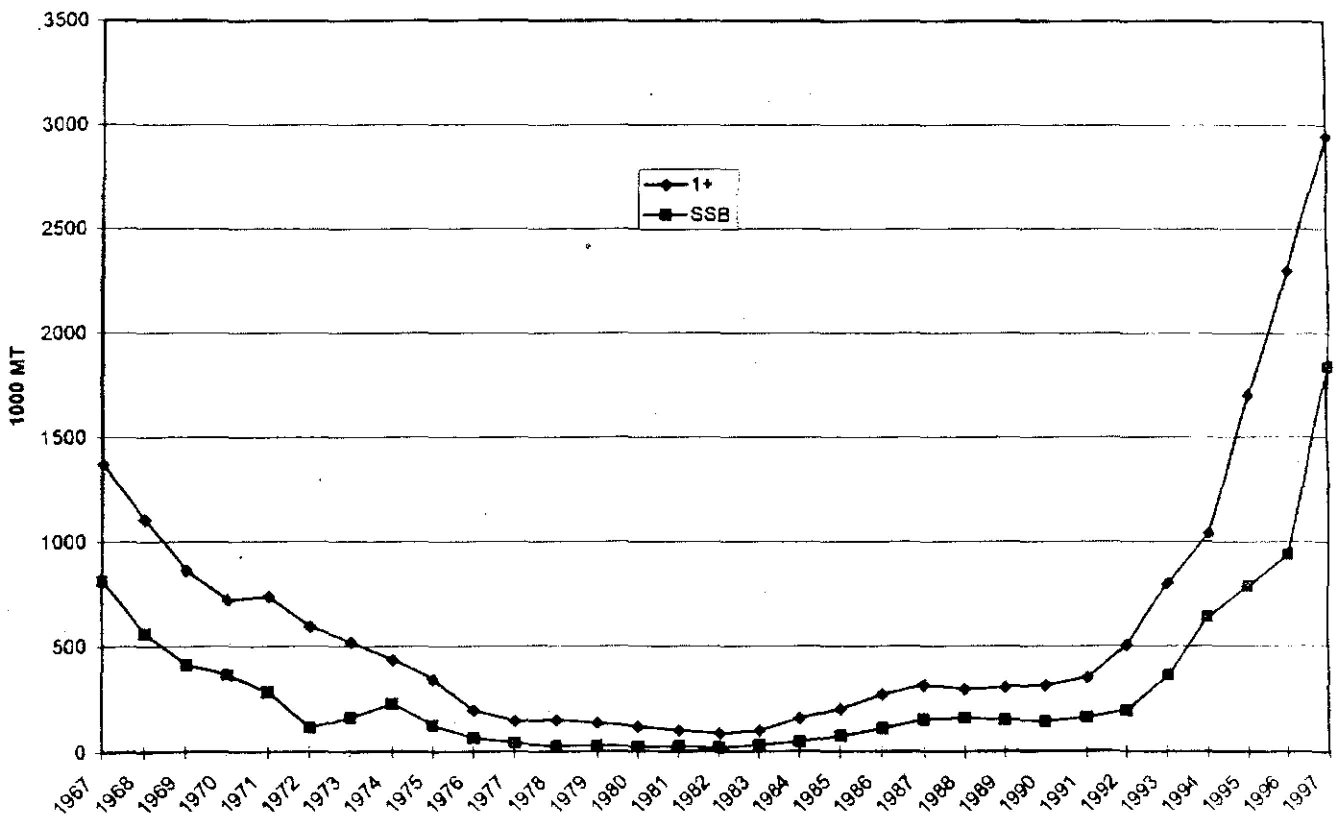

Figure G12. Stock biomass, coastal stock complex.

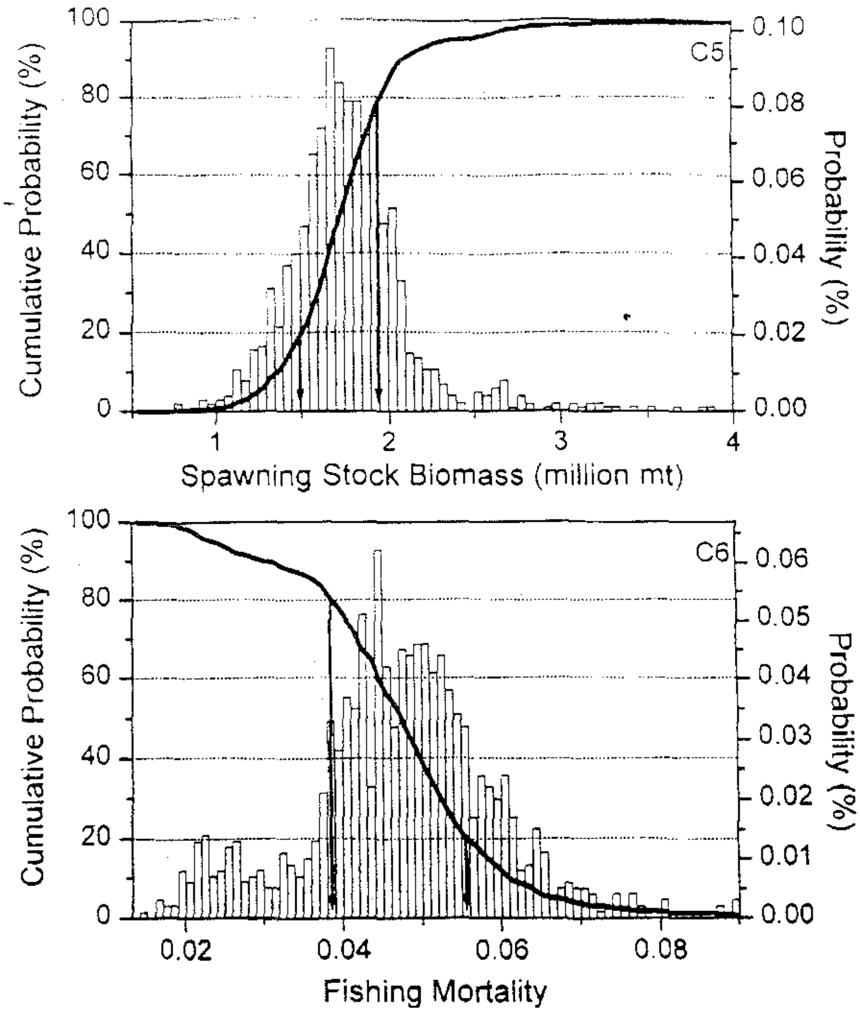

Figure G13. Precision of SSB, F.

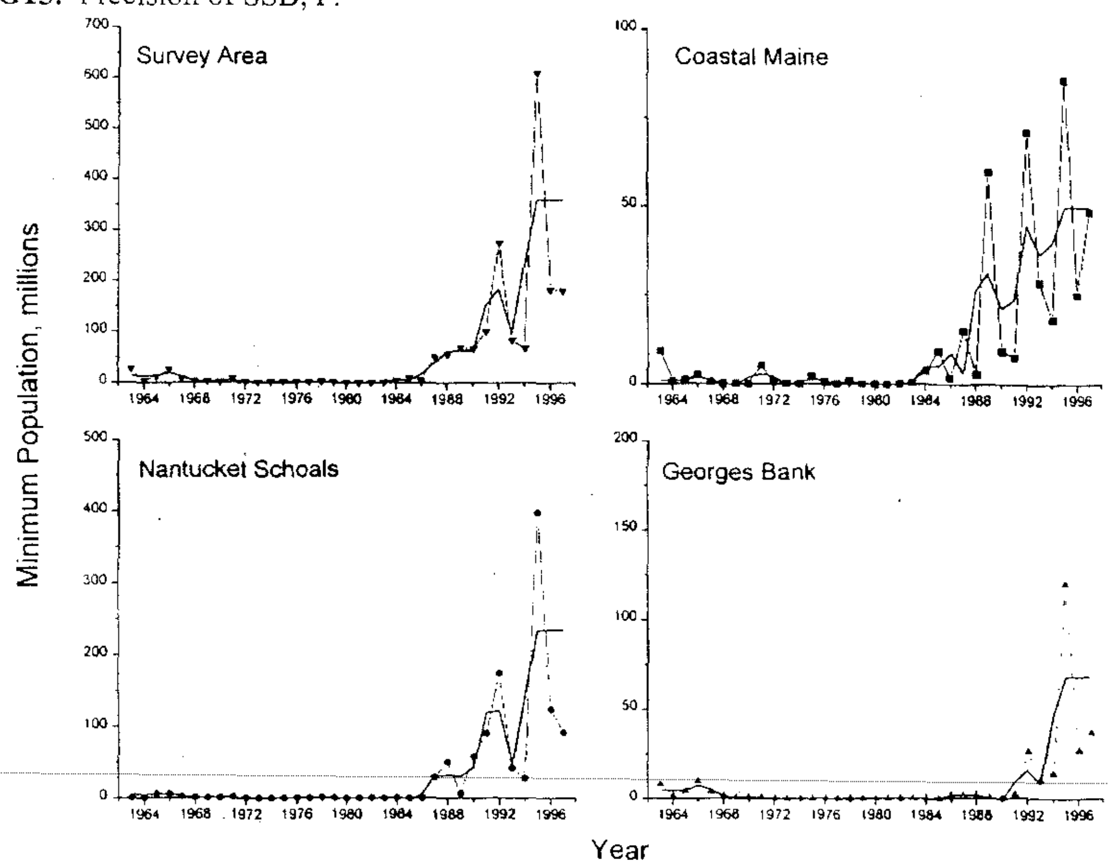

Figure G14a. Minimum population estimates (numbers), fall bottom trawl survey index by area.

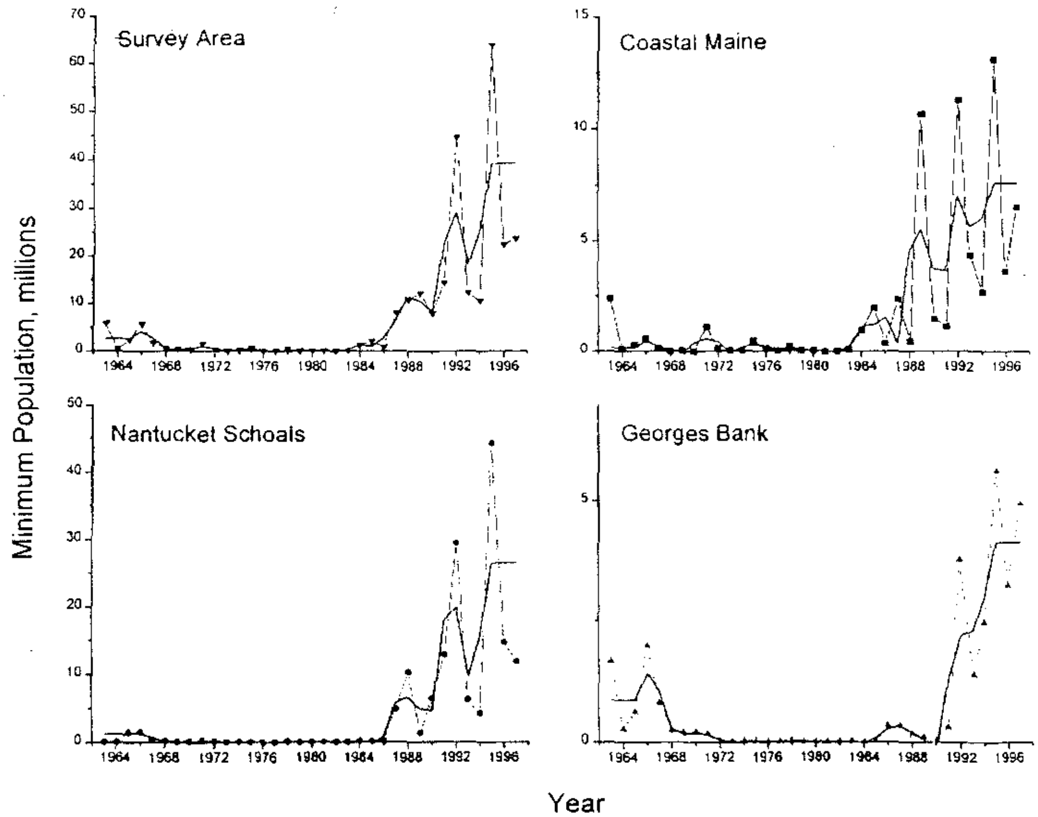

Figure G14b. Minimum population estimates (biomass), fall bottom trawl survey index by area.

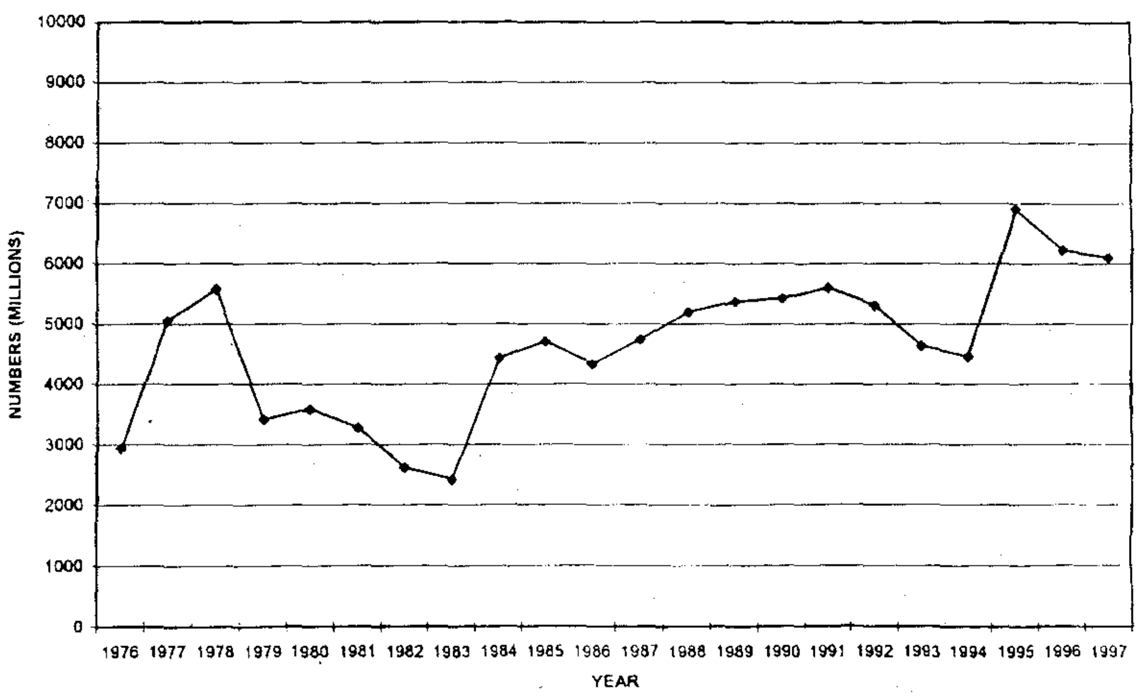

Figure G15. Area 1 population size in numbers.

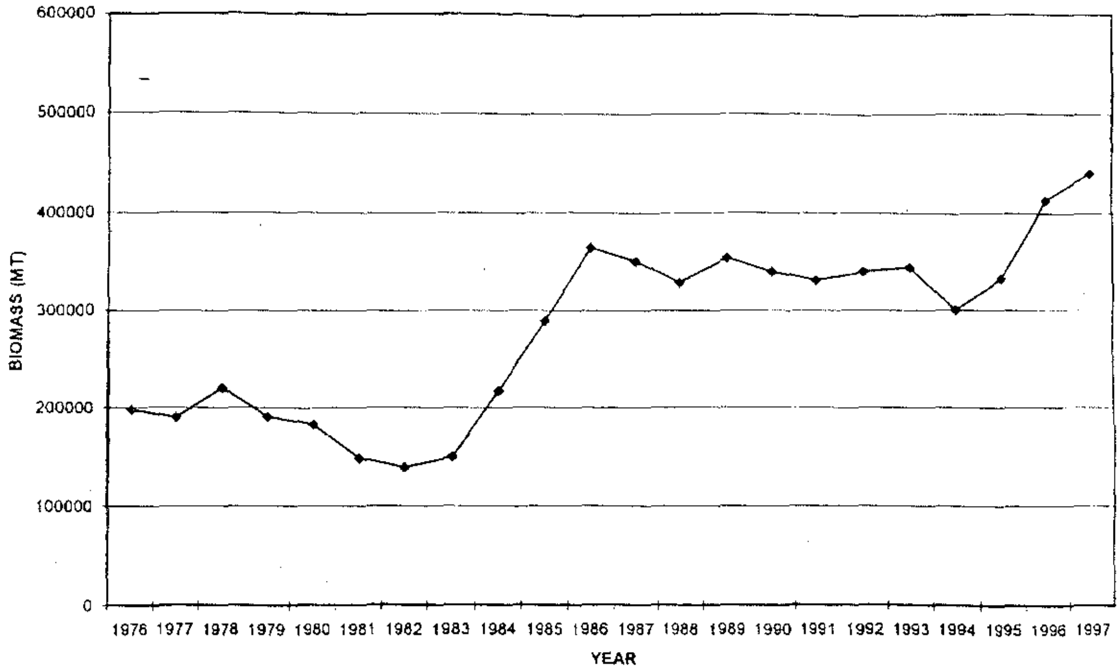

Figure G16. Area 1 population biomass.

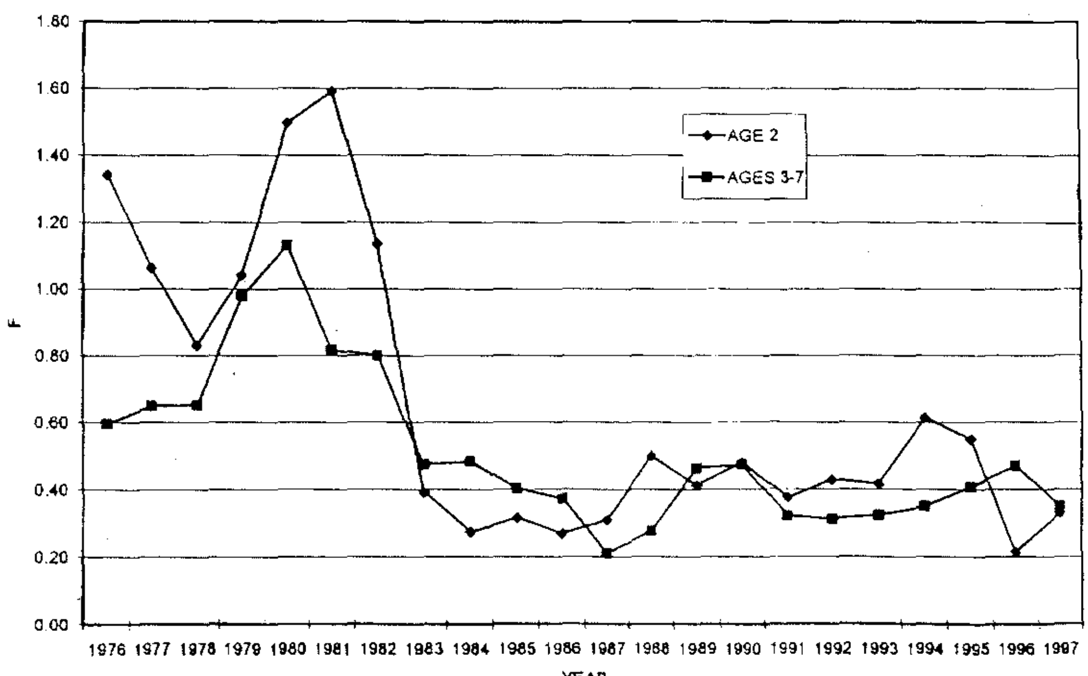

Figure G17. Area 1 fishing mortality.

H. BLACK SEA BASS

Terms of Reference

a. Update commercial and recreational landings and discard estimates for black sea bass through 1997.

b. Evaluate quantitative indicators of exploitation rate, stock abundance, and recruitment from state and Federal research surveys, commercial and recreational fisheries, sea sampling data, and other sources.

c. If possible, use alternative models such as ASPIC to assess the status of black sea bass.

d. Provide total allowable landings recommendations for black sea bass to meet the target exploitation rate for 1999.

e. Review existing biological reference points and advise on new reference points for black sea bass to meet SFA requirements.

Introduction

Black sea bass considered in this assessment update is the stock north of Cape Hatteras, NC. Management is based on an FMP developed by the Mid-Atlantic Fisheries Management Council and implemented in 1996 (MAFMC 1996). In 1998, year 3 of the Plan, quota restrictions were implemented with the objective of reaching a target exploitation rate of 48%. The commercial quota was 1,372 mt and the recreational quota 1,428 mt for a total quota of 2,800 mt.

Black sea bass was reviewed by the SARC in 1995 (SAW-20) at which time an analytical assessment was completed and accepted. The assessment was updated in 1997 (SAW-25), but the VPA was rejected due to inadequate commercial and recreational samples and uncertainty in estimation of discards. The SARC, in 1997, concluded that future development of an age-based assessment could not be done without improved sampling of landings and discards in both commercial and recreational fisheries and would require at least several years to correct the shortcomings in the current database. The present update is an attempt to examine the current status of the stock through survey indices, landing and discard estimates, and alternative non-age based models.

The Fishery

Commercial Landings

Total commercial landings in 1997 were 1,115 mt, a slight decrease from 1,472 mt in 1996 and less than the 10-year average of 1,402 mt (Table H1). The major gear types were fish pots, with 47% of the landings, otter trawls with 36%, and handlines with 11% (Table H2). The largest commercial landings were in New Jersey, Maryland, and Virginia. The fish pot landings were primarily from New Jersey and Maryland, while the majority of trawl landings were in Virginia.

Commercial Discards

Estimates of commercial discards were available from two sources. Vessels fishing in the EEZ for permitted species are required to maintain a logbook for each trip. The vessel logbook (or VTR data) contains information by species of the total pounds landed and total pounds discarded per trip. The VTR database contains 76.8% of the total black sea bass landings reported in the dealer (weighout) database (Table H3). The total VTR data (118,873 trips) was subset to include only those vessels which reported some level of discards (40.6% or 48,211 trips). The subset was further reduced to trips which recorded black sea bass (1.5% or 1,730 trips) in either the landed or discarded category. Reported discarded metric tons by gear type was comprised of fish pots (58%), lobster pots (18%), trawl gear (12%), and handlines (12%). A ratio of discards to landed pounds was calculated as the sum of discarded pounds divided by the sum of landed pounds on a half-year basis. The frequency distributions of the total discard ratios are presented in Figure H1.

Total discard weight based on the sum of all black sea bass trips was 126.3 mt (Table H4). The total discard loss, accounting for gear-specific mortality and adjusting to total landings from all gear types, was 72.7 mt. The sum discard ratio for trawl gear (0.06 first half-year and 0.05 second half-year) was lower than the ratios calculated using the geometric mean (0.11 first-half and 0.8 second-half). The discard ratio for pots (0.14) was higher than for trawl gear (0.06). The total discard estimate was 23.1 mt for trawl gear, 78.5 mt for pots, and 31.3 mt for handlines. Assuming a discard mortality rate of 100% for trawl discards, 50% for pot discards, and 25% for handline discards, discard losses equated to 23.1 mt for trawls, 39.2 mt for pots, and 5.3 mt for handlines.

Alternative discard rates were estimated using observer data (sea samples) (Table H5). Black sea bass were caught on 47 sea sampling trips. Most of the observer trips (34 trips) were done using trawl gear. No pot, handline, or lobster trips were sampled. The ratio of landings to discards was calculated as the sum of discarded weight over the sum of landed weight in half-year periods. The total frequency distribution of discard ratios is presented in Figure H2. The estimate of total discard losses was 139.0 mt for trawl gear (Table H6). The final discard estimate was based on the VTR data which covered a greater variety of gear types.

Recreational Landings

Recreational landings north of Cape Hatteras, NC decreased in 1997 to 1,430 mt from 2,680 mt in 1996 (Table H1). Total number of black sea bass landed was 3.41 million fish (Table H7). The majority of the landings (51%) occurred in wave 5. New Jersey accounted for 71% of the recreational landings followed by Virginia with 11%.

Recreational Discards

Total number of black sea bass released (B2) in 1997 was 5.25 million fish (Table H7). New Jersey accounted for the largest percentage of the discards (46.8%) followed by Virginia (22.7%). Application of a 25% discard mortality rate, as used in SAW-25, results in a total loss of 1.31 million fish.

Recreational Catch per Effort

Recreational catch per angler was calculated from the effort (# trips per angler) where black sea bass were caught or targeted. Catch per angler (CPA) was not standardized using a general linear model.

The CPA since 1981 ranged from 4.1 to 7.1 fish per trip (Table H8). Although the CPA has shown considerable annual variation, there has been a slight upward trend (slope = 0.08, $r^2 = 0.23$) (Figure H3).

Commercial Sampling

Landings

A total of 42 biological samples of black sea bass were collected by NMFS in 1997, an increase from 35 samples in 1996 (Table H9). Eighteen samples were collected from the trawl fishery (2,088 length measurements) and 23 from fish pots (2,301 length measurements). Trawl samples were primarily from the 1st quarter (11 of 18), while the trap samples were from the 2nd and 3rd quarters (16 and 7, respectively). One sample from lobster traps was also collected. Trawl samples were collected in New Jersey, Maryland, and Rhode Island, while pot samples were from Massachusetts, New Jersey, and Maryland.

Discards

Length samples where collected on sea sampling trips. A total of 631 black sea bass were measured: 293 lengths from discarded fish and 338 lengths from landed fish. The breakdown by time and area is shown in Table H10.

Recreational Sampling

Landings

A total of 1,466 black sea bass were measured during the 1997 MRFSS dockside interviews. The level of sampling was equivalent to 1.0 lengths per mt landed.

Discards

No length data were available to characterize the length composition of recreational discards.

Age Data

No age data were available for 1997 samples.

Stock Abundance and Biomass Indices

Research Vessel Indices

NEFSC spring

Long-term trends in abundance were examined using the NEFSC spring offshore bottom trawl survey index for black sea bass. Only the offshore strata were included since black sea bass congregate in offshore waters during the winter-early spring. The strata area defined for black sea bass extends from Cape Cod, MA to Cape Hatteras, NC. The survey time series for offshore strata in the Mid-Atlantic began in 1968.

The mean number per tow rose to 3.16 in 1977, peaked in 1978 at 8.21, then declined to 3.00 in 1980. The index has remained below 3 since. Recent indices increased from 0.45 in 1996 to 2.04 in 1997. The 1997 index is the highest since 1988, although only slightly higher than the 1968-1996 average of 1.72 (Table H11). However, high variance around the indices leads to the conclusion that the indices have fluctuated without trend since 1980 (Figure H4). A similar pattern exists in the mean weight per tow (Figure H5).

The length distributions show a distinctive mode for age 1 fish less than 12 cm in length (Figure H6). The index for fish greater than age 1 shows a similar pattern as the total mean number per tow, with an increase in 1997 to 2.01 from the 1996 adult index of 0.38 (Table H10). Recruitment indices suggest a series of good year classes from 1988 to 1992 (0.20 to 0.76 fish per tow). A moderate year class appeared in 1995 (0.16 fish per tow). The index of recruitment in 1997 was 0.03 fish per tow compared to the 1968-1996 average of 0.20 (Table H11).

NEFSC autumn

The NEFSC autumn survey included the inshore and offshore strata to account for areas inhabited by black sea bass prior to their offshore migration. The time series for the Mid-Atlantic began in 1972. Mean number per tow peaked in 1977 at 8.87 fish per tow, but has since been above 3 fish per tow only once. The average index for 1972-1996 was 1.93, and the 1997 index was 1.73 (Table H12).

The length frequency shows a distinctive mode of young-of-the-year fish less than 12 cm. This age group is a significant percentage of the total index in some years. The mean number per tow of fish greater than 12 cm has fluctuated without trend throughout the entire time series (Table H12). The young-of-the-year indices show a strong year class in 1977, but the dominance of this year class is not evident in the spring of the following year. The average index of recruitment (1972-1996) was 1.14, while the 1997 index was 0.59 (Table H12). There is little correlation between indices of recruitment in the autumn and spring surveys.

Massachusetts Division of Marine Fisheries spring

The Massachusetts spring bottom trawl survey has fluctuated without trend at a low level for the past decade. From the beginning of the survey in 1979 to the early to mid-1980s, the mean number per tow ranged from 0.71 to 4.29. Since the late 1980s, the index has generally been less than 1.0. The 1997 index continued at a similar low level with a mean number per tow of 0.45 (Table H13). This represented a slight increase from the 1996 index of 0.15, but was not significantly different.

Massachusetts Division of Marine Fisheries autumn

The autumn survey, begun in 1978, has traditionally had higher catches of black sea bass than the spring survey. The mean number per tow is dominated by young of the year less than 12 cm. The overall index in number ranged from 34.83 to 398.25 between 1978 and 1988. From 1989 to 1993, the index dropped significantly, ranging from 1.07 to 10.90. There was a slight increase between 1994 and 1996 when the index rose as high as 45.07, but the 1997 index was back down to 5.77 (Table H13).

The index of recruits showed a similar pattern with peak values between 1982 and 1986, a significant drop between 1989 and 1993, and a slight resurgence between 1994 and 1996. However, the 1997 index of 2.9 was the third lowest in the time series (Table H13).

Comparison of Length Frequencies

The length frequencies from the commercial and recreational fisheries and the NEFSC spring offshore survey are presented in Figures H6-H8. The figures show that the three sources are generally sampling the same sizes of fish from the population. The recreational fishery tends to have higher proportions of larger fish, but is still dominated by fish 20-35 cm. The adult fish in the survey also fall within the 20-35 cm range, although the modes are less well defined due to sample sizes. The survey includes significant numbers of smaller fish due to the selectivity of the gear.

Production Model Analysis

The SAW-25 SARC concluded that there was inadequate information to pursue an age-based assessment at least for several years. That conclusion, coupled with a lack of age data for 1997, precluded any attempts at an updated VPA. Attempts were made to evaluate the current status of black sea bass using the non-equilibrium surplus production model ASPIC. This analysis was unsuccessful due to the lack of contrasting catches in the short time series compared to historic landings, and the poor relationship between indices of abundance and recreational landings in 1982 and 1986.

Relative Exploitable Biomass

A measure of relative exploitable biomass since 1968 was calculated using NEFSC spring survey mean weight per tow indices of fish greater than 22 cm, which is the size of full recruitment in the commercial length frequencies (Table H14). The index reached a peak in 1977 at 1.036 and then dropped sharply during the early 1980s. The index has been less than 0.15 since 1982. The mean value in the time series was 0.26 (Figure H9).

The relationship between commercial landings and NEFSC spring survey mean number per tow was evaluated with a linear regression (r^2 of 0.423 and slope of 0.0027) (Figure H10). Based on this relationship, the survey indices were predicted using the commercial landings back to 1950. The index peaked at a value of 24.30 in 1952 (Figure H11) compared to the 1977 value of 4.4. The implication is that the time series of survey indices since 1979 may be an underestimation of the potential stock biomass.

Fishing Mortality

Fishing mortality during 1984-1997 was estimated using length-based methods. The Beverton-Holt (1956) method and the Hoenig (1987) method were both applied to length frequencies of the combined commercial and recreational landings and of the spring NEFSC survey. An $L_\infty = 66.3$, $K = 0.168$, and length at full recruitment of 24 cm were used in the estimations. The estimate of fishing mortality for 1997 based on the commercial/recreational length data was 0.51 using the Hoenig method and 0.92 using the Beverton-Holt approach (Table H15). The F estimates for 1997 based on the spring survey length data were 0.52 and 0.96 for the Hoenig and Beverton-Holt methods, respectively (Table H15).

Sensitivity to variations in L_∞ were examined for both methods. Reduction in L_∞ results in a linear reduction in F. In example, a reduction of L_∞ to 50 cm results in an F estimate of 0.26 with the Hoenig model and 0.43 for the Beverton-Holt model (Table H15).

Estimates of F for 1984-1997 from both methods based on spring survey length data are shown in the following text table:

Year	Hoenig	Beverton-Holt	Average
1984	0.41	0.70	0.56
1985	0.49	0.89	0.69
1986	0.56	1.03	0.79
1987	0.47	0.83	0.65
1988	0.43	0.76	0.59
1989	0.55	1.01	0.78
1990	0.46	0.82	0.64
1991	0.49	0.89	0.69
1992	0.50	0.91	0.71
1993	0.52	0.94	0.73
1994	0.46	0.82	0.64
1995	0.47	0.84	0.66
1996	0.47	0.84	0.66
1997	0.52	0.94	0.73

Biological Reference Points

The yield-per-recruit model presented at SAW-25 provided estimates of F_{max} (0.324) and $F_{0.1}$ (0.178). Since model-based estimates of F_{msy} were not available, the SARC chose $F_{0.1}$ as a proxy for F_{msy}.

Conclusions

The SARC concluded that commercial discards were best estimated using vessel logbook data. The sea sampling data were limited to only otter trawls and required extrapolation to other gear types, which constituted the majority of the landings. There was some concern that the VTR data may provide an under-estimate of total discards. The need for increased at-sea sampling, particularly in the fish pot fishery, was reiterated.

The available information on black sea bass suggests that the population has remained relatively stable over the past decade, although at low levels. Length-based estimates of fishing mortality were in excess of all available biological reference points. The survey indices have fluctuated without trend and the recreational catch per angler has fluctuated annually, although it has exhibited a slight increase since 1981. Recruitment of good year classes, as indicated by the survey indices, has been sporadic. There is no indication of a strong year class since 1992.

The analysis of black sea bass using the general production model ASPIC did not provide satisfactory results with the available data. Analysis of relative exploitable biomass from NEFSC spring survey data indicates the population is significantly reduced since the early 1980s.

Sources of Uncertainty

There was some concern expressed by the SARC that the survey indices may not accurately reflect the relative abundance of black sea bass. As the abundance of suitable habitat for this species has changed over time, the survey *q* may be changing as well. The same changes in habitat may effect *q* in the recreational CPA, creating the appearance of an upward trend.

Alternative methods for evaluating black sea bass populations should be considered. One possible method would be a coastwide tagging program over several years. If states agencies coordinated the tagging and release of black sea bass over a limited time period, tag returns could be used to generate survival estimates. In addition, important information about migrations could be determined.

SARC Comments

The SARC reviewed the results of a general surplus production model (ASPIC) for black sea bass and concluded that the input data were inadequate. Concerns were raised about the adjustments to anomalous recreational catches in 1982 and 1986 which were required to run the ASPIC model and the use of the recreational catch per angler as a tuning index.

Discussion centered around the possibility that catch per angler (CPA) was increasing over time because of increases in black sea bass habitat in the form of artificial reefs. The reefs may attract fish, and consequently fishing pressure may truly be improving productivity of black sea bass. Fishing pressure could also be increasing due to technological improvements.

The catch time series fit to the model also had little contrast, which was reflected in the diagnostics of the output. High imprecision around annual survey estimates may reflect the structural orientation and seasonal movement of the species. However, it was felt that the fall survey may provide an index of recruit abundance and the spring survey an index of adult abundance since the spring survey occurs in similar habitat as the offshore winter trawl fishery. It was noted that survey indices and landings appeared to be relatively stable over the past twenty years.

A truncated size/age structure, low landings relative to historic levels, and low survey indices strongly suggest that the stock is over-exploited. It was felt that yield could be greater than current levels.

A re-evaluation of relative exploitation rates using only adults was conducted during the SARC meeting. There was extensive discussion on how to meet SFA requirements for a stock possessing such uncertainty in the assessment. The unusual life history of black sea bass (protogynous hermaphrodite) raised concerns that traditional MSY calculations would not be appropriate for this species. The SARC recommended examining existing data for sex-ratio changes and length-based methods of estimating fishing mortality rates.

Research Recommendations

- Increase sea sampling, particularly in the fish pot fishery of the Mid-Atlantic.
- Obtain commercial length frequency data, by market category, from North Carolina from 1984-1993 and 1997.
- A tagging program should be initiated through state fisheries agencies. The objective would be to tag several thousand black sea bass per state each year for several years. The information from tag returns would allow calculation of survival estimates independent of survey data. Use of several high-reward tags or a lottery-type system may be considered to evaluate tag reporting rate.
- Ageing should be updated to include the most recent biological samples.
- A study further investigating the size/age and density effects on sex changes in black sea bass would be valuable in stock assessments. Studies on sex-specific mortality rates and growth are also needed.
- A study determining the value of artificial reefs for increased production of black sea bass would be valuable in estimating potential yield.
- Consideration should be given to a pot survey for an index of abundance because of the catchability problems in the trawl survey for a species such as black sea bass that is structure-oriented.

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Table H1. Landings (mt) of black sea bass from Maine to Cape Hatteras, NC.

Year	Commercial	Recreational	Foreign	Total
1950	5736			5736
1951	8361			8361
1952	9883			9883
1953	6521			6521
1954	5141			5141
1955	5131			5131
1956	5251			5251
1957	4320			4320
1958	5242			5242
1959	3655			3655
1960	3102			3102
1961	2483			2483
1962	3692			3692
1963	3798			3798
1964	3199			3199
1965	3604			3604
1966	1652			1652
1967	1302			1302
1968	1201			1201
1969	1199			1199
1970	1100			1100
1971	614			614
1972	760			760
1973	1161			1161
1974	1069			1069
1975	1885			1885
1976	1690			1690
1977	2424			2424
1978	2115		5	2120
1979	1875	560	41	2475
1980	1252	1002	14	2267
1981	1129	1062	39	2230
1982	1177	4499	21	5697
1983	1513	1967	14	3494
1984	1965	667	18	2650
1985	1551	1052	33	2636
1986	1901	5622	10	7533
1987	1890	901	4	2795
1988	1879	1241		3120
1989	1324	1509		2833
1990	1588	1268		2856
1991	1272	1887		3159
1992	1364	1199		2563
1993	1412	2031		3443
1994	896	1350		2246
1995	925	2592		3517
1996	1472	2680		4152
1997	1115	1430		2545

Table H2. 1997 black sea bass commercial landings by gear.

Gear	Mt	%
Fish pot	525.5	47.1%
Otter trawl	405.7	36.4%
Handline	119.4	10.7%
Lobster trap, inshore	25.4	2.3%
Gillnet	12.2	1.1%
Lobster trap, offshore	7.2	0.6%
Floating trap	3.2	0.3%
Pound net	2.1	0.2%
Other	14.2	1.3%

Table H3. Commercial logbook data for 1997, all gears.

Grouping	No. trips	Percent of total
Total reported trips, all species	118,873	
Total trips recording discard of any species	48,211	40.56%
Total trips reporting black sea bass	6,474	5.45%
Sea bass trips reporting discard of any species	1,730	1.46%
Sea bass trips reporting discard of any species and sea bass landings > 0	1,628	1.37%
Sea bass trips reporting discard of any species and sea bass landings > 0 and discards > 0	780	0.66%

Table H4. Discard estimates (mt) of black sea bass from 1997 VTR logbook data using sum discard/sum landed.

Gear	Period	# Trips	Discard (kg)	Landed (kg)	Ratio	Total mt landed	Total mt discarded	Total discard losses (mt) *
Otter trawl	1	439	1697	29000	0.059	345.3	20.2	20.2
	2	203	280	6035	0.046	62.6	2.9	2.9
							23.1	23.1
Handline	1	61	185	1179	0.157	51.2	8.1	2.0
	2	328	1711	9283	0.184	71.8	13.2	3.3
							21.3	5.3
Fish pots	1	132	1211	16494	0.073	206.5	15.2	7.6
	2	259	8374	42232	0.198	319.2	63.3	31.6
							78.5	39.2
Lobster pots	1	85	2707	2733	0.991	3.0	3.0	1.5
	2	128	327	3309	0.099	4.9	0.5	0.2
Sub-total		1635	16492	110265		1064.5	126.3	69.4
Total						1114.8	132.3	72.7

* Assumed mortality rates: trawl = 100%, handline = 25%, pots = 50%, lobster pots = 50%

Table H5. Number of sea sample trips by year, quarter,division which caught black sea bass.

1989

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

1993

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

1990

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

1994

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

1991

Division	Quarter 1	2	3	4	
51				1	1
52					
53	4	5		3	12
61	4	3		14	21
62	5	3	3	4	15
63				4	4
	13	11	3	26	53

1995

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

1992

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

1996

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

1997

Division	Quarter 1	2	3	4	
51					
52					
53	5	6		1	12
61	14	3	4		21
62	5	5	1		11
63	3				3
	27	14	5	1	47

Table H6. Discard estimates (mt) of black sea bass from 1997 observer data using sum discard/sum landed. Trawl data only.

Period	No. trips	Discard (kg)	Landed (kg)	Ratio	Total landed (mt)	Total discard (mt)	Discard losses *
1	29	4133	10792	0.383	345	132	132
2	4	84	779	0.108	63	7	7
Total	33	4217	11571		408	139	139

* Assumed mortality rates: trawl = 100%, no observer data for handline, pots, or lobster pots exist.

Table H7. MRFSS black sea bass landed (A+B1 in 000's), release (B2 in 000's) estimates, and discard losses from Maine to Cape Hatteras, NC. Losses assume 25% mortality.

Year	A+B1	B2	%B2	Discard losses
1984	1880.6	1588.7	45.7	397.2
1985	3770.6	2701.3	41.7	675.3
1986	21747.2	7114.4	24.6	1778.6
1987	2935.7	2134.2	42.1	533.6
1988	2949.3	4965.7	62.7	1241.4
1989	4285.5	2174.7	33.6	543.7
1990	3919.9	5196.4	57.0	1299.1
1991	5237.4	5529.0	51.3	1382.3
1992	3556.6	4112.8	53.6	1028.2
1993	5539.9	2753.6	33.2	688.4
1994	3410.6	3963.9	53.8	991.0
1995	6705.3	7694.2	53.4	1923.6
1996	4909.4	5044.8	50.7	1261.2
1997	3414.3	5252.2	60.6	1313.1

Table H8. Recreational catch per unit effort from MRFSS trips with sea bass caught or targeted.

Year	Catch per trip	Catch per hour fished	N
1981	5.66	1.24	899
1982	5.19	1.01	918
1983	4.10	1.06	1667
1984	4.49	1.09	1682
1985	5.09	1.18	2341
1986	5.45	1.43	3894
1987	6.04	1.44	2064
1988	4.92	1.04	2512
1989	4.79	1.12	5120
1990	5.13	1.17	4030
1991	5.92	1.42	4684
1992	5.67	1.46	4474
1993	4.39	1.02	3098
1994	4.82	1.21	3987
1995	6.54	1.62	3607
1996	5.88	1.31	3540
1997	7.11	1.68	3702

Table H9. Number of commercial length samples by month and gear, 1996-1997.

1996	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Otter trawl	1	1	2		2						4	4	14
Fish pot					6	4	2	2	3	3			20
Handline							1						1
Total	1	1	2		8	4	3	2	3	3	4	4	35

1997	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Otter trawl	2	7	2	1	4						1	1	18
Fish pot				2	6	8	3	2	2				23
Lobster pot	1												1
Total	3	7	2	3	10	8	3	2	2		1	1	42

Table H10. Number of length samples collected on 1997 NEFSC sea sampling trips. Trawl gear only.

Division	Quarter 1	2	3	4	
51					
52					
53	9	19			28
61	233	2	164		399
62	134	70			204
63					0
	376	91	164	0	631

Table H11. NEFSC spring bottom trawl survey indices (mean no./tow) from offshore strata, Cape Cod to Cape Hatteras.

Year	Total no./tow	Adult no./tow	Recruit (<12 cm) no./tow
1968	0.70	0.29	0.408
1969	1.25	1.25	0.000
1970	0.12	0.12	0.000
1971	0.26	0.26	0.000
1972	0.82	0.58	0.243
1973	0.97	0.97	0.000
1974	2.40	2.40	0.000
1975	2.15	2.08	0.069
1976	3.16	2.23	0.932
1977	8.21	8.03	0.181
1978	4.59	4.46	0.128
1979	5.26	5.24	0.017
1980	3.00	1.98	1.018
1981	1.08	1.04	0.038
1982	0.28	0.28	0.003
1983	0.72	0.71	0.009
1984	0.28	0.28	0.008
1985	0.54	0.44	0.095
1986	2.35	2.18	0.176
1987	1.42	1.40	0.020
1988	2.36	1.88	0.479
1989	0.76	0.56	0.196
1990	1.00	0.60	0.395
1991	1.13	0.37	0.757
1992	1.99	1.60	0.391
1993	1.73	1.72	0.007
1994	0.31	0.31	0.007
1995	0.74	0.58	0.156
1996	0.45	0.38	0.071
1997	2.04	2.01	0.027

Table H12. NEFSC Autumn bottom trawl survey indices (mean no./tow) from inshore and offshore strata, Cape Cod to Cape Hatteras.

Year	Total no./tow	Adult no./tow	Recruit (<12 cm) no./tow
1972	0.917	0.683	0.234
1973	1.596	0.463	1.133
1974	1.704	1.574	0.130
1975	2.572	0.948	1.624
1976	3.323	1.220	2.103
1977	8.874	0.605	8.269
1978	0.796	0.179	0.617
1979	1.653	0.170	1.483
1980	0.662	0.334	0.328
1981	1.128	1.031	0.097
1982	3.066	0.311	2.755
1983	0.800	0.269	0.531
1984	2.382	2.170	0.212
1985	2.640	0.647	1.993
1986	2.633	1.056	1.577
1987	0.814	0.674	0.140
1988	0.680	0.372	0.308
1989	0.858	0.425	0.433
1990	2.269	1.822	0.447
1991	1.890	1.589	0.301
1992	1.395	0.712	0.683
1993	0.313	0.311	0.002
1994	1.858	0.737	1.121
1995	2.611	0.804	1.807
1996	0.787	0.478	0.309
1997	1.733	1.142	0.591

Table H13. Massachusetts DMF spring and autumn bottom trawl survey, mean number and weight (kg) per tow. Massachusetts strata set 11-21.

	Mean number per tow		Autumn	Mean weight per tow	
	Spring	Autumn	recruits	Spring	Autumn
Year			no./tow <12 cm		
1978		79.635	42.8		0.873
1979	0.988	74.554	40.0	0.728	1.111
1980	0.997	93.509	51.8	0.787	0.979
1981	2.233	63.842	34.3	1.334	0.314
1982	2.158	398.247	216.7	0.903	1.482
1983	4.291	215.300	117.0	1.387	1.180
1984	1.597	202.234	109.9	0.673	1.601
1985	1.208	197.966	107.3	0.573	0.900
1986	1.567	79.558	42.9	0.735	0.851
1987	0.705	34.826	19.2	0.203	0.329
1988	0.420	60.690	33.7	0.200	0.416
1989	1.067	6.610	3.6	0.354	0.054
1990	0.698	4.285	2.3	0.449	0.090
1991	0.381	9.459	5.3	0.428	0.053
1992	0.087	10.899	6.1	0.037	0.081
1993	0.112	1.073	0.6	0.081	0.007
1994	0.219	45.073	24.6	0.190	0.170
1995	0.465	32.657	17.8	0.153	0.198
1996	0.154	23.692	12.9	0.089	0.148
1997	0.452	5.768	2.9	0.179	0.252

Table H14. Relative exploitable biomass from NEFSC spring survey mean weight/tow for fish ≥22 cm.

Year	Mean wt/tow	3-point moving average
1968	0.128	
1969	0.204	0.130
1970	0.057	0.106
1971	0.056	0.083
1972	0.135	0.143
1973	0.239	0.409
1974	0.854	0.611
1975	0.739	0.711
1976	0.540	0.772
1977	1.036	0.749
1978	0.672	0.905
1979	1.006	0.647
1980	0.263	0.509
1981	0.257	0.182
1982	0.025	0.139
1983	0.136	0.088
1984	0.104	0.115
1985	0.104	0.095
1986	0.076	0.092
1987	0.097	0.088
1988	0.091	0.094
1989	0.093	0.092
1990	0.091	0.092
1991	0.093	0.090
1992	0.087	0.087
1993	0.081	0.085
1994	0.086	0.086
1995	0.091	0.095
1996	0.107	0.092
1997	0.079	
Median	0.100	
Mean	0.264	
Mean of		
1st quartile	0.087	
2nd quartile	0.093	
3rd quartile	0.175	
4th quartile	0.701	

Table H15. Length-based estimates of black sea bass.

L_∞	66.3	
K	0.168	
M	0.2	

	Commercial and recreational landings	Spring survey
Lbar	27.8	25.9
L_c	22	20
Z (Hoenig)	0.71	0.72
F (Hoenig)	0.51	0.52
Z (Beverton-Holt)	1.12	1.16
F (Beverton-Holt)	0.92	0.96

Sensitivity to L_∞

L_∞	F (Hoenig)	F(Beverton-Holt)
50	0.26	0.43
51	0.28	0.46
52	0.29	0.50
53	0.31	0.53
54	0.33	0.56
55	0.35	0.59
56	0.36	0.62
57	0.38	0.65
58	0.39	0.68
59	0.41	0.71
60	0.42	0.74
61	0.44	0.77
62	0.45	0.80
63	0.47	0.83
64	0.48	0.87
65	0.50	0.90
66	0.51	0.93
66.3	0.52	0.94

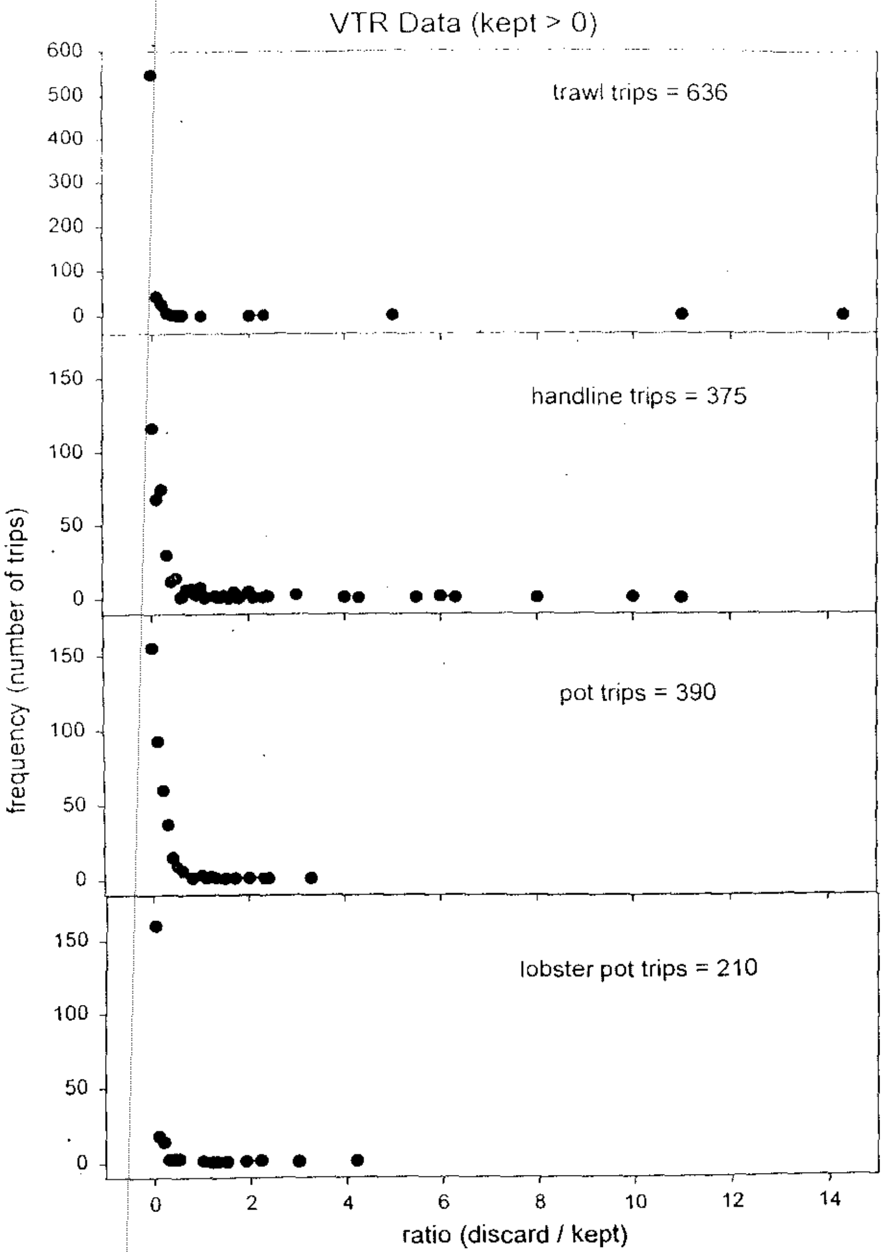

Figure H1. Frequency distribution of black sea bass discard ratios from 1997 vessel logbook data by gear type.

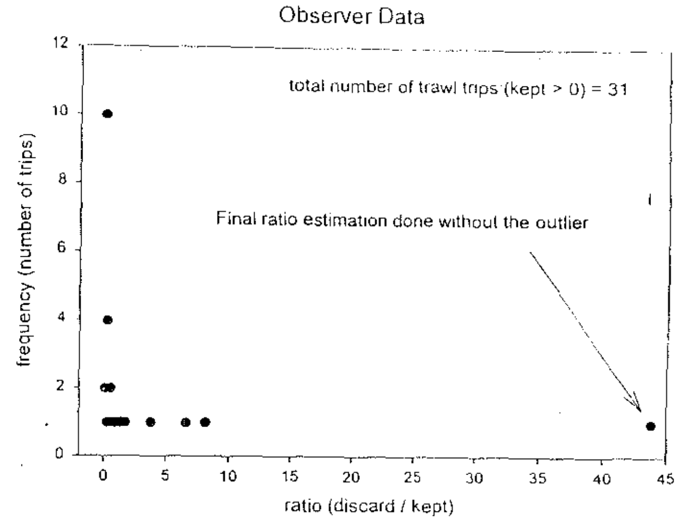

Figure H2. Frequency distribution of black sea bass discard ratios from 1997 sea sample data Otter trawl data only.

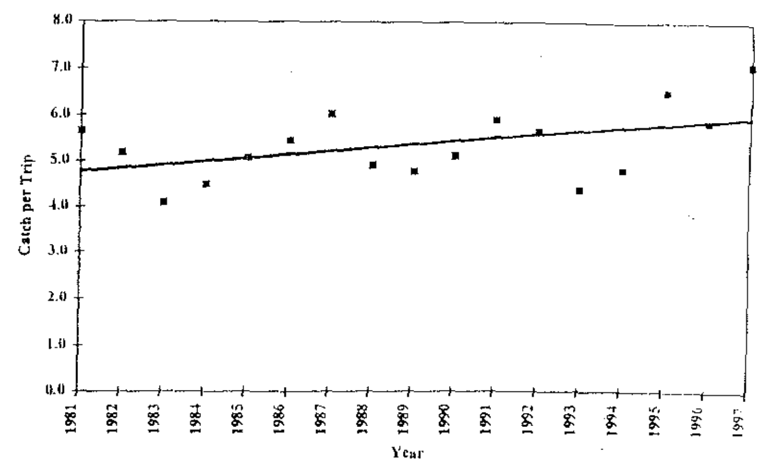

Figure H3. Recreational catch per trip for trips catching or targeting black sea bass.

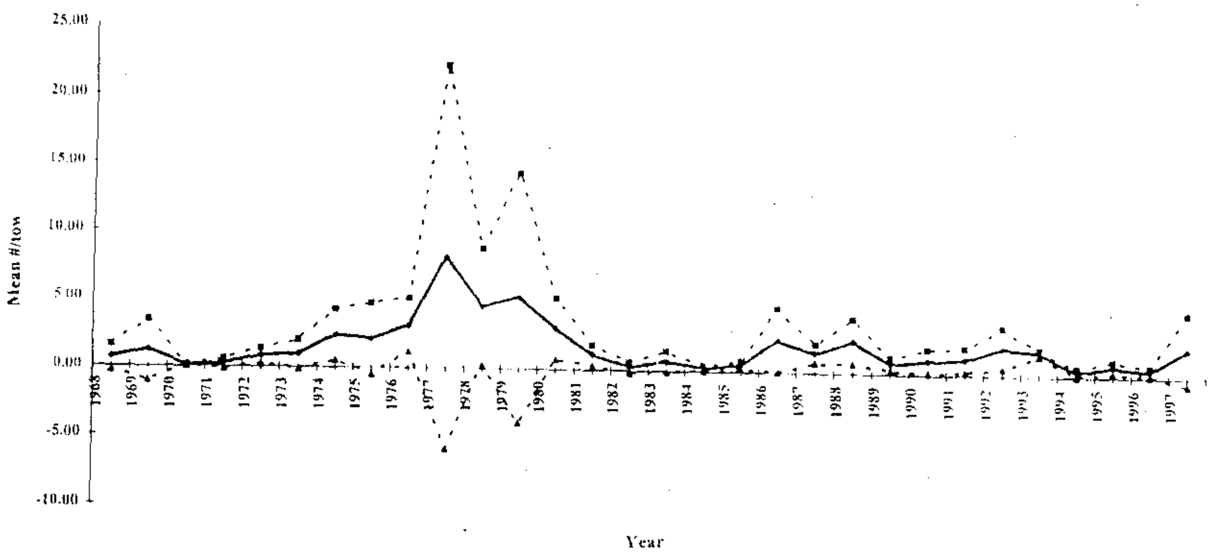

Figure H4. NEFSC spring survey mean number/tow with upper and lower 95% confidence interval.

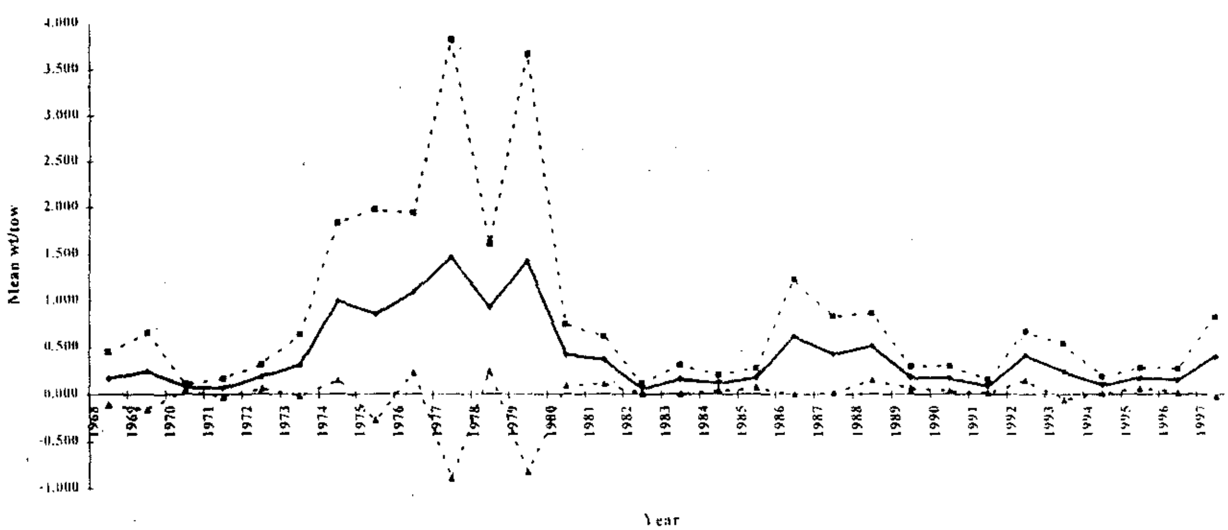

Figure H5. NEFSC spring survey mean weight/tow with upper and lower 95% confidence interval.

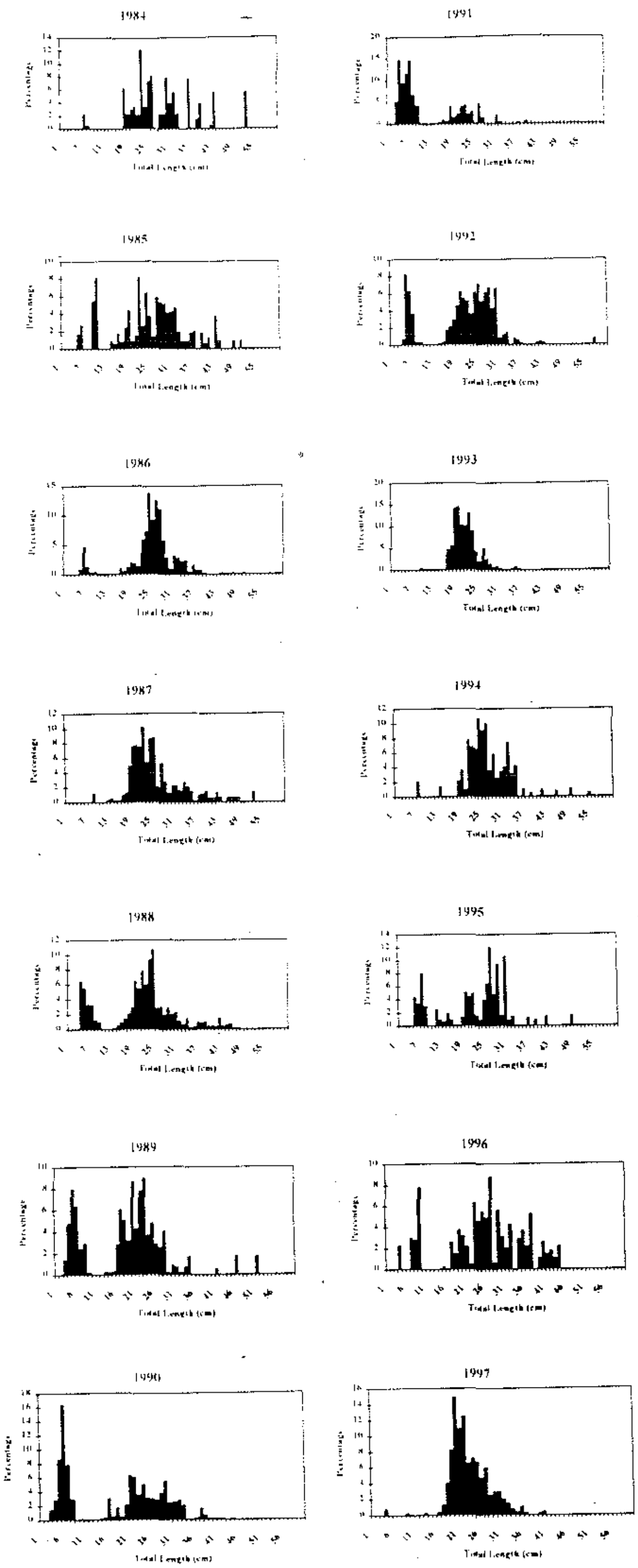

Table H6. Length distribution of black sea bass collected during NEFSC spring survey, 1984-1997.

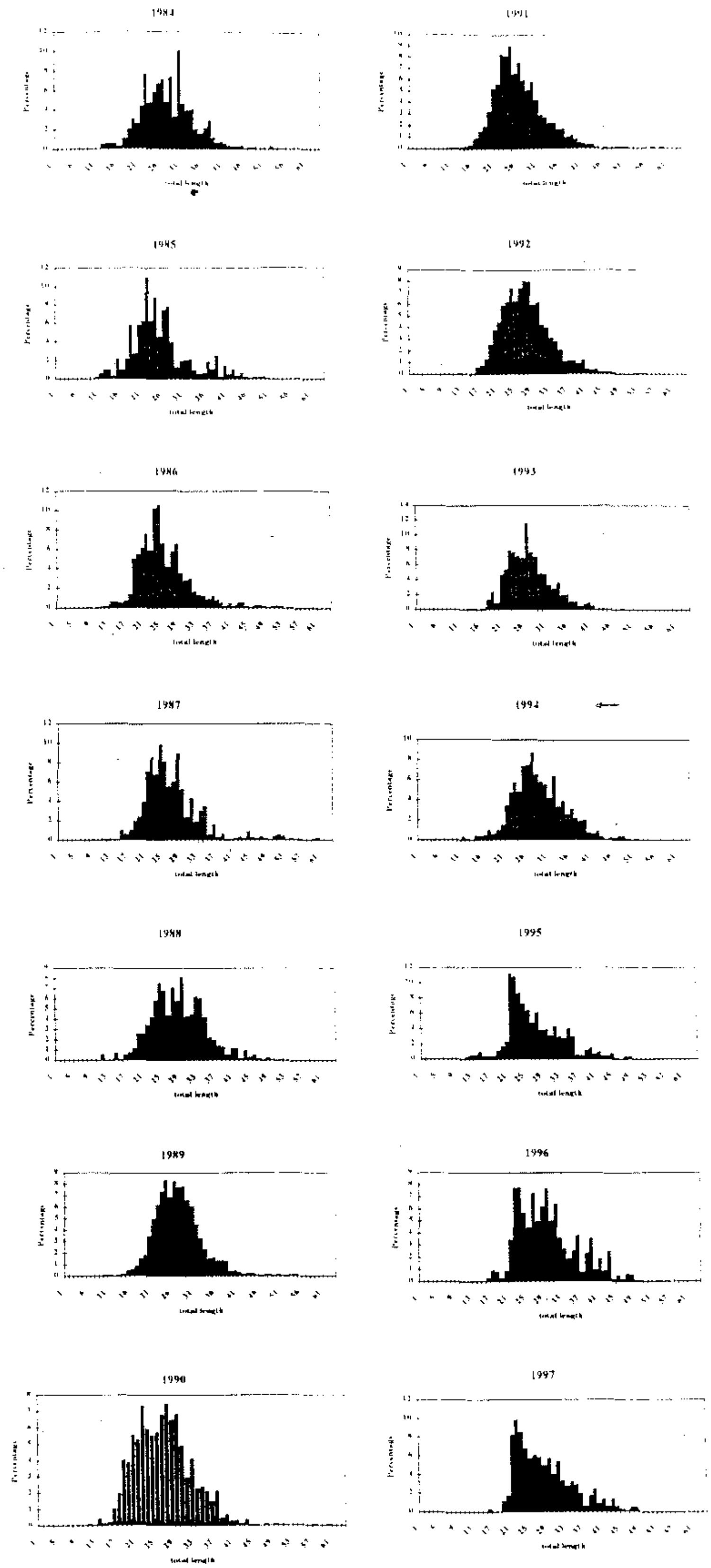

Figure H7. Length distributionnns from black sea bass recreational fishery, 1984-1997.

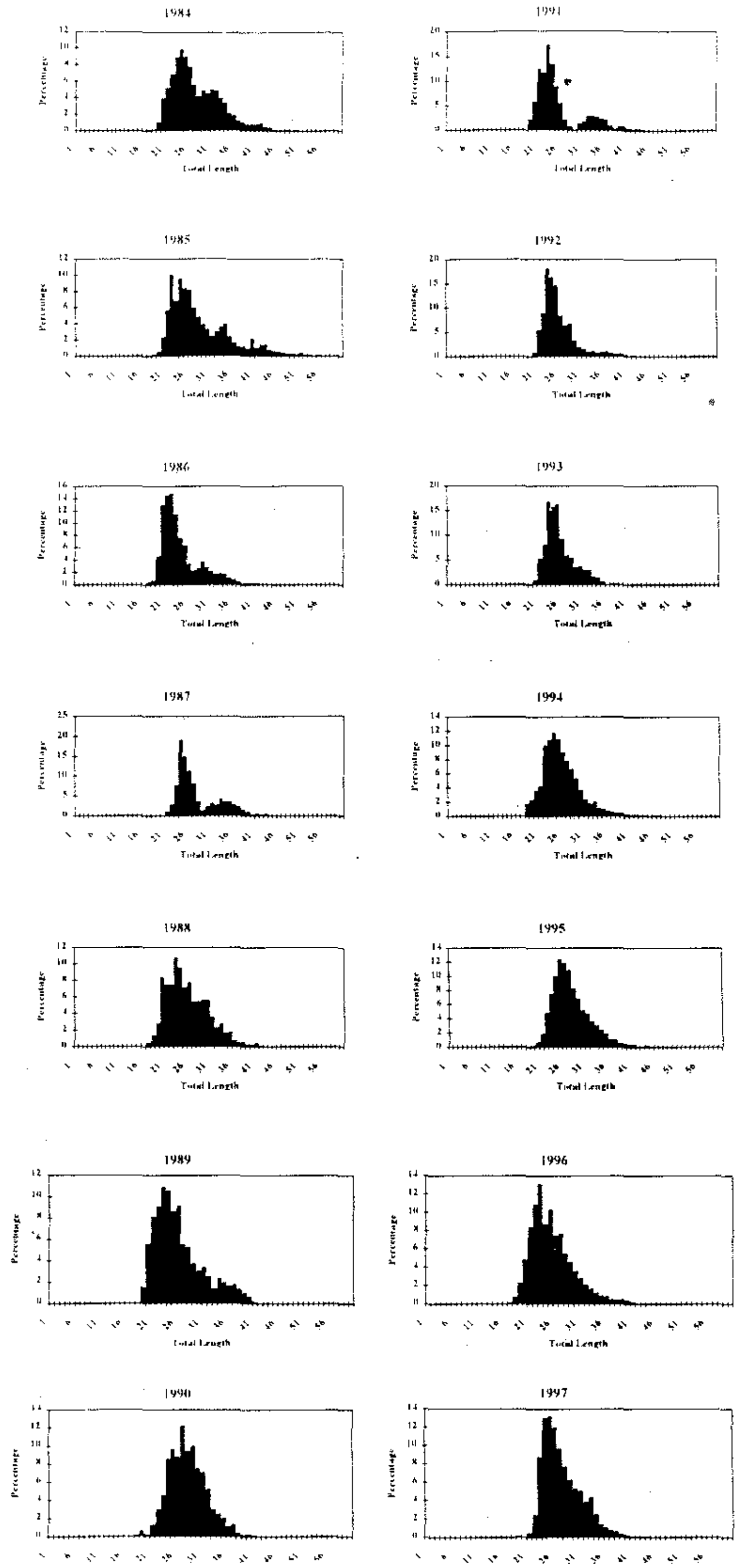

Figure H8. Length distributions from black sea bass commercial landings, 1984-1997.

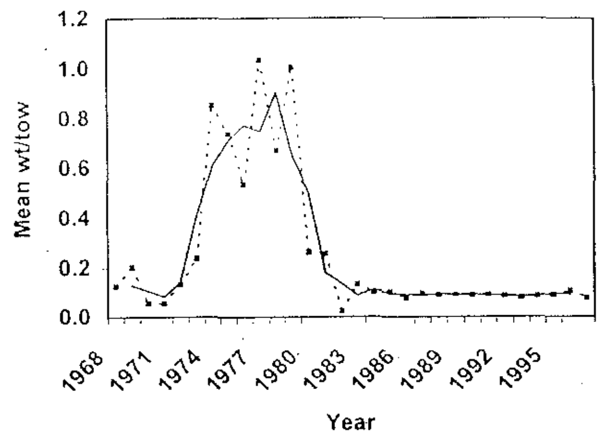

Figure H9. Relative exploitable biomass of black sea bass from NEFSC spring survey mean weight/tow of fish> = 22 cm.

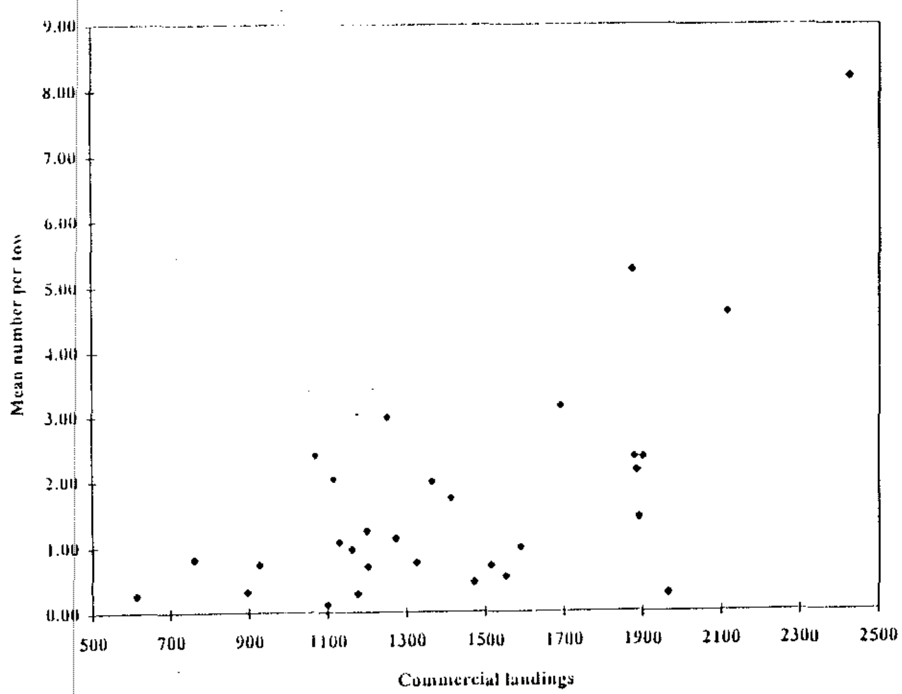

Figure H10. Relationship between black sea bass commercial landings and NEFSC Spring survey mean number per tow.

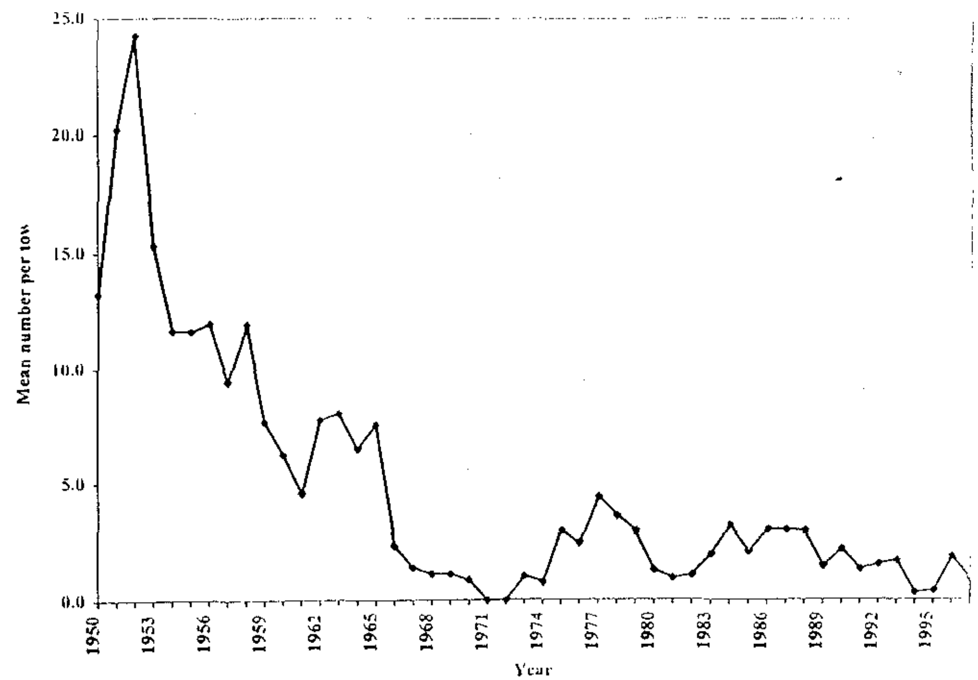

Figure H11. Mean number per tow for NEFSC spring survey extrapolated from relationship between indices and commercial landings.

I. SOUTHERN NEW ENGLAND YELLOWTAIL FLOUNDER

Terms of Reference

a. Update the status of Southern New England yellowtail flounder through 1997 and characterize the variability of estimates of stock size and fishing mortality rates.

b. Provide projected estimates of catch for 1998-1999 and spawning stock biomass for 1999-2000 at various levels of F.

c. Review existing biological reference points and advise on new reference points for Southern New England yellowtail flounder to meet SFA requirements.

Introduction

Yellowtail flounder (*Limanda ferruginea*) became an important component of the domestic demersal fishery in the early 1930s as abundance of winter flounder declined. Total landings rose from about 10,000 mt in 1938 to about 38,000 mt in 1942, but declined in the 1950s, with most landings from the Southern New England stock. Some recovery was observed in the 1960s, and estimated landings from the stock peaked at 33,200 mt in 1969, including a foreign fishery which also harvested the stock between 1965-1974. Landings declined to 1,600 mt by 1976. Although landings rebounded to 17,000 mt in 1983, they dropped the following year to 7,900 mt and steadily declined to 900 mt in 1988. Another increase in landings to 8,000 mt occurred in 1990, but was also short-lived. Total commercial landings declined further from 3,900 mt in 1992 to an historic low of 186 mt in 1995, increased slightly to 285 mt in 1996, and dropped to 231 mt in 1997 (Table I1).

Given the wide variations in yellowtail flounder catch and its importance as a food fish, fishery managers have struggled over the past two decades to develop adequate fishery regulations. Yellowtail flounder were managed under the International Commission for the Northwest Atlantic Fisheries with nationally-allocated catch quotas in 1971-1976. With the implementation of the Magnuson Fisheries and Conservation Act in 1976, yellowtail flounder were managed under the New England Fishery Management Council's (NEFMC) Fishery Management Plan (FMP) for Atlantic Groundfish during 1977-1982. This complex plan regulated minimum codend meshes on trawls, defined spawning area closures, and imposed trip limits and mandatory reporting. These measures were difficult to enforce and were, in aggregate, ineffective.

From September 1982 to September 1986, the species was managed under the Interim Plan which included a minimum possession size of 28 cm (11 in). The Interim Plan made reporting voluntary and defined "large mesh" (5⅛ in stretch mesh) fishing areas. Under the Plan, small-mesh fisheries were permitted within the large-mesh areas. These measures also failed to arrest the decline of yellowtail flounder.

The Multispecies FMP of September 1986 prepared by the NEFMC imposed minimum sizes of 30 cm (12 in), increased the minimum mesh size to 5½ in, and required seasonal area closures west of 69° 40' longitude. Amendment 5 of the Plan later revised the minimum size to 33 cm (13 in) in September 1989. An emergency action in 1994 closed Areas I and II on Georges Bank, and in December 1994, these areas were closed permanently. Amendment 7 of the Multispecies FMP was used to implement an effort reduction program utilizing controls on days at sea (DAS) for groundfish vessels, implement minimum threshold spawning stock biomass targets, and target total allowable catch (TACs) for the major groundfish stocks (NEFMC 1996). In addition, a year-round area closure in the Nantucket Lightship area was imposed for the protection of the Southern New England yellowtail stock.

This report presents an updated and revised analytical assessment of the Southern New England yellowtail flounder stock for the period 1973-1997 based on analyses of commercial and research vessel survey data through 1997. After 1993, however, the methodology for collecting and processing commercial fishery data in the Northeast was substantially changed. Prior to 1994, information on the catch quantity by market category was derived from reports of landings transactions submitted voluntarily by processors and dealers. More detailed data on fishing effort and location of fishing activity were obtained for a subset of trips from personal interviews of fishing captains conducted by port agents in the major ports of the Northeast. Information acquired during these interviews was used to augment the total catch information obtained from the dealer.

Beginning in 1994, information on fishing effort and catch location was no longer obtained from personal interviews of fishing captains. Instead, data on number of hauls, average haul time, and catch locale were obtained from logbooks submitted to NMFS by operators fishing for groundfish in the Northeast under a mandatory reporting program. Estimates of total catch by species and market category were derived from mandatory dealer reports submitted on a trip basis to NMFS. Catches by market category were allocated to stock based on a matched subset of trips between the dealer and logbook databases. Data in both databases were stratified by calender quarter, port group, and gear group to form a pool of observations from which proportions of catch by stock could be allocated to market category within the matched subset. The cross products of the market category x stock proportions derived from the matched subset were employed to compute the total catch by stock, market category, calender quarter, port group, and gear group in the full dealer database. A full description of the proportion methodology and an evaluation of the 1994-1996 logbook data is given in Wigley *et al.* (1998) and DeLong *et al.* (1997). The data for 1997 were prorated in the same fashion.

Fisheries Data

Landings

Commercial landings for 1973-1993 were derived from the NEFSC commercial landings files by stock area (US Statistical Areas 526, 537-539) (Figure 1). Landings for 1994-1997 were obtained by prorating dealer records with data from the vessel trip report system (VTR) (Figure 1) (Wigley *et al.* 1998). A landings-at-age matrix was developed from quarterly length samples and age/length keys from the commercial fishery for 1973-1992, as described in Conser *et al.* (1991). Landings at age for 1993-1997 were obtained by applying commercial length and age data on a semi-annual basis to the available landings (Table I2). For estimation of landings at age, age samples were pooled over market categories within quarter or semi-annual period (Table I3). Consistent with previous assessments, no separation using sex disaggregated age/length keys was attempted. Mean weights at age in the landings from 1973-1997 are summarized in Table I4. For 1997, length samples were applied on a quarterly basis for small (1232) and large (1231), except in the third and fourth quarters where a half-year basis was used for the large market category. Since no ages were available for the fourth quarter, the third quarter commercial sample was applied to the fourth quarter.

Discard Estimation

Discarding of undersized fish by otter trawlers has long been recognized as a problem in the yellowtail flounder fishery (Figure I4). Information on discarding is available from a number of sources, but the quality and quantity of information varies widely. These sources can be categorized as interviewed trips, research surveys, sea sampling, and vessel logbooks. In previous assessments, this information was used to fit logistic models to estimate retention rates by quarter (Conser *et al.*1991; Rago *et al.* 1993). These models were used to estimate retention rates for individual cohorts (Conser *et al.* 1991) or age specific retention (Rago *et al.* 1993). In the current assessment, ratios from vessel trip reports (DeLong *et al.* 1997) and pooled length compositions from sea sampling were used to estimate discards by otter trawlers for 1994-1997 (Table I2; Table I5a). Otter trawl discards at age for 1993 were estimated by using average discard rates from 1994-1996.

The implementation of Amendment 5 to the Multispecies FMP prohibited scallop vessels from retaining more than 500 lb of groundfish per trip. This amount was further reduced to 300 lb when Amendment 7 was put in place on May 1, 1996. Thus, beginning in 1994, scallop vessels began to discard yellowtail flounder in excess of 500 lb. Discards from scallop vessels during 1994-1997 were also estimated from logbook data (DeLong *et al.* 1997) and pooled sea sample lengths (Table I2; Table I5b). Total discards for 1993-1997 are summarized in Table I6.

Catch at Age

Catch at age for 1973-1997 for the Southern New England yellowtail flounder stock composed of landings and discards is summarized in Table I7. Mean weights at age in the catch for 1973-1997 are summarized in Table I8.

Stock Abundance Indices

Indices of mean weight per tow from spring and autumn research vessel surveys indicate that this stock has undergone several major changes in abundance during 1963-1997. Indices throughout the 1960s and early 1970s were relatively high in both surveys (Table I9). Both indices declined in the mid-1970s coincident with the foreign fishery off the eastern seaboard during this period. Some recovery occurred in the early 1980s, with recruitment from several large year classes, but this was short lived and indices dropped dramatically after this to very low levels in the mid-1980s (Table I9). Indices rebounded in 1989 with recruitment of the large 1987 year class, but declined again, this time to historically low levels in 1993 and 1994. The spring and autumn indices have increased slightly since 1994 (Table I9).

Indices of age-specific stratified mean catch per tow (number) were available from NEFSC spring (1968-1997) and autumn (1963-1997) bottom trawl surveys (Tables I10 and I11, respectively) and from NEFSC scallop (1982-1997) surveys (Table I12). Spring and autumn survey indices have been adjusted for the effects of vessel (*Albatross IV* vs *Delaware II*), otter trawl door changes, and, in the case of the spring surveys net changes (Sissenwine and Bowman 1978) over the course of the autumn and spring surveys. The winter survey began in 1992 utilizing a net specifically designed to capture flatfish and producing catch rates that are approximately 10 times higher than the spring and autumn surveys (Table I13). This survey was added as a tuning index for 1992-1997.

Aggregate indices in 1993 were the lowest in the time series for autumn trawl, scallop, and winter surveys. The aggregate index from the 1994 spring survey was the lowest in the time series. Age-specific indices generally indicated relatively weak year classes since 1989, with the exception of the moderate 1993 year class. Although age distributions in trawl survey catches have become truncated since 1983, there is some indication that older age groups are beginning to appear again in the survey age distributions (Tables I10-I13). Indices from the spring, autumn, scallop, and winter surveys were used to tune an ADAPT run for this stock for 1997.

Survey indices (number per tow) for winter and spring 1998 confirm that the 1996 year class that was apparent in the winter and autumn 1997 surveys is likely the strongest observed since 1988 (Figure I2). The modes at 28 cm and 26 cm in the winter and spring surveys, respectively, would be in the correct length range for the 1996 year class at age 2 (Figure I2).

VPA Results

The virtual population analysis (VPA) was tuned using unweighted, non-linear least squares methods (ADAPT; Gavaris 1988; Conser and Powers 1990). Survivors at ages 2-5 in 1997 were estimated as well as catchability coefficients for the spring survey ages 2-4 and 5+, autumn survey ages 2-4 and 5+, and winter survey ages 2-4 and 5+ abundance. The survey indices used in the objective function were unweighted, and the catch at ages 7 and 8 were combined in a plus group. Fishing mortality at age 7 was assumed equal to F at age 6. Natural mortality (M), as in previous assessments, was assumed to equal 0.2.

Several ADAPT runs were completed with different sets of survey indices (Table I14). Diagnostics were examined, and Run 46 was judged to be the most useful based on goodness of fit, residual patterns, partial variances, and other factors. Residuals from the scallop survey were patterned and large in magnitude. Also, a close examination of the scallop indices used to tune Run 42 indicated that the catchability at age 1 was larger than at age 2. It was determined that this problem was caused by the application of an autumn age/length key over a period of growth that incorrectly assigned catch per tow at length to ages 1 and 2. To still utilize data from the scallop survey and to better estimate the age 1 index, the length distribution was sliced and only the age 1 index from the scallop survey was used in the ADAPT run (Run 46).

Other preliminary runs were made to assess whether different approaches might be useful in enhancing the information content produced by ADAPT. One run examined an estimation of ages 1-5, but as in previous attempts, the CV on age 1 was so high (> 1.0) that it precluded the use of a direct estimation on this age group. Another run examined the effect of lagging the autumn index to gain an extra degree of freedom in the fitting. This approach was also rejected because it produced CVs that were higher than the current runs that use the autumn survey as a mid-year index.

Fishing Mortality

Fishing rates have historically been very high and always in excess of any biological reference points for this stock (Conser *et al.* 1991; Rago *et al.* 1993). However, fishing mortality in 1995 dropped to 0.7, was reduced even further to 0.4 in 1996, and to 0.07 in 1997 (Table I15). The fishing mortality rate in 1997 was below the $F_{0.1}$ reference point of 0.27 and below the $F_{20\%}$ overfishing definition reference point of 0.94.

Stock Size

Stock size at age 2 was imprecisely estimated and the CV on ages 3-5+ averaged about 0.34 (Table I15). Stock size reached a series high of 182 million fish in 1982, declined to much lower levels in the mid-1980s, and then rebounded to 134 million fish in 1988. Thereafter, stock size declined sharply, reaching a 1973-1996 low of 4 million fish in 1993. Since then, stock size gradually increased from 4 million in 1993 to 25 million fish in 1997.

Spawning Stock Biomass

Spawning stock biomass declined from 14,000 mt in 1973 to about 4,000 mt in 1975 and then increased to a series (1973-1996) high of 22,000 mt in 1982 (Table I15; Figure I3). This increase in 1982 resulted primarily from recruitment of the large 1980 year class. The stock was fished heavily, and SSB declined again to only 1,700 mt in 1987. Another large cohort (1987) recruited in 1989, and the SSB again increased to about 22,000 mt. This year class attracted increased fishing effort resulting in large numbers of discarded fish because of a minimum size regulation. The spawning stock was quickly reduced because of this, falling to a series low of only about 600 mt in 1994. SSB increased gradually during 1995-1996 reaching 4,200 mt in 1997. The current SSB is still well below the minimum threshold of 10,000 mt established in Amendment 7 of the Multispecies FMP.

Recruitment

Recruitment (age 1) in the early years of the time series (1973-1982) was comprised generally of moderate-to-large year classes and the dominant 1980 cohort of 127 million fish (Table I15; Figure I4). Fishing effort on this stock increased following recruitment of the large 1980 and 1981 cohorts in 1983 and 1984 (Conser *et al.* 1991; Rago *et al.* 1993). Recruitment was generally lower during 1984-1987, ranging from 7 million to 19.8 million fish and averaging about 14 million fish. Another large year class (1987) recruited in 1988 (122 million fish), and additional fishing effort resulted in a quick reduction of this cohort to low levels by 1991 (Conser *et al.* 1991; Rago *et al.* 1993). Year classes during 1990-1996 ranged from 1.3 million to 7.0 million fish and averaged only about 5 million fish. The 1996 cohort may be the largest in the 1990s.

Bootstrap Estimates

ADAPT results were re-sampled to provide estimates of approximate bias and to produce probability distributions of spawning stock biomass and fishing mortality rate. Coefficients of variation of estimates of stock size for Southern New England yellowtail flounder range from 0.24 to 0.40 for ages 2-5, respectively. Approximate bias was about 6% on age 2 and substantially lower on the other ages.

Cumulative frequency distributions of SSB and fishing mortality are presented in Figures I5 and I6.

Spawning stock biomass ranged from roughly 3,500 mt to 6,500 mt, with an 80% CI of 3,500-5,000 mt (Figure I5). Fishing mortality rates ranged from 0.05 to 0.13, with an 80% CI of 0.065-0.09 (Figure I6).

Biological Reference Points

Yield per Recruit

Since the selection pattern in 1997 for this stock was very similar to the pattern for 1994-1996, biological reference points were not recalculated. Based on the previous analysis, $F_{0.1} = 0.27$ and $F_{20\%} = 0.94$.

F_{msy} and B_{msy}

The ASPIC model (Prager 1994) was used to estimate F_{msy} and B_{msy} for the Southern New England yellowtail flounder stock during 1963-1997. Values for discards (mt) during 1963-1972 were obtained from McBride and Clark (1983) and for 1973-1997 were estimated from mean weights and discard estimates (numbers) from recent assessments. Discard estimates were combined with landings to produce total catch (mt) for 1963-1997. Spring (1968-1997) and autumn (1963-1997) survey indices (kg/tow) were used to tune the ASPIC run.

F_{msy} was estimated to be 0.23 ($F_{4+} = 0.37$), B_{msy} at 61,500 mt, and MSY at 14,200 mt. An examination of diagnostics from the run indicated that the R^2 values for both surveys were relatively high and there was relatively good agreement between the surveys. Other factors such as B ratios and ranges on parameters indicated a relatively good fit.

Projections

Forecasts of stock status during 1999-2000 for the Southern New England yellowtail flounder stock were completed. A stochastic approach, utilizing 1,000 bootstrap starting stock size estimates from ADAPT results, were utilized to project landings, discards, and spawning stock biomass over the 3-year period. Fishing mortality rates used in the projections were $F_{0.1}$ (0.27) and F_{97} (0.07). Recruitment estimates were drawn from estimates for the 1991-1996 year classes (six values, range = 1.3-12.5 million fish). Spawning stock size has been low over the last several years, producing many of the poorest year classes in the 1973-1997 series.

Landings and SSB (median values) would continue to increase slowly through 2000 under either the $F_{0.1}$ or the F_{97} fishing rates used in the projections. Under the $F_{0.1}$ option, landings would increase from about 1,100 mt in 1999 to about 1,400 mt in 2000 (Table I16). Spawning stock biomass would also continue to increase from about 6,600 mt in 1998 to about 7,800 mt in 2000. Assuming the fishing mortality rate in 1997 was applied over the 1998-2000 period, landings would increase from about 310 mt in 1999 to about 340 mt in 2000. The spawning stock would increase from 6,600 mt in 1998 to about 9,200 mt in 2000.

Summary

Results from virtual population analysis and bottom trawl surveys indicate that stock abundance was still very low in 1997, although there appears to be an increasing trend.

Fishing mortality declined to 0.42 in 1996 and was well below the $F_{0.1}$ reference point of 0.27 in 1997 (0.07).

Recruitment still remains poor, with all recent year classes well below the historic average. Research surveys indicate that all incoming year classes are relatively poor. The 1993, 1994, 1995, and possibly the 1996 cohorts are moderately larger than cohorts during 1988-1992, but these are all small when compared to the year classes during 1973-1987.

Age structure in this stock was severely truncated during the period 1970-1994. There is some indication that this trend may have been reversed and that stock age structure may be expanding.

Forecasts indicate that the spawning stock will continue to improve slowly during 1999-2000 if fishing mortality is kept at or below the $F_{0.1}$ level.

SARC Comments

The SARC noted the switch from the use of sea sample data to vessel trip record (VTR) information to estimate discards for 1994-1997. Questions were raised concerning the reporting practices of fishermen and the consistency of discard reports in logbooks compared to sea sample data. It was noted that changes in the selection pattern due to mesh regulations and spatial shifts in the fishery due to the Nantucket Lightship Closed Area both minimized discards relative to historical levels and obviates previously-used methods (logistic models) to estimate discards.

The SARC discussed the cause of the sharp drop in the bottom trawl survey indices from 1972 to 1974. It was noted that there had been a large foreign catch (primarily USSR) in the late 1960s, but this was mismatched with the sharp drop in the survey indices. It was suggested that under- or mis-reporting of foreign landings may have occurred during the 1970s.

The SARC examined spatial distribution maps from research vessel surveys and noted high concentrations of yellowtail flounder both the east and west of the stock area boundaries. Concentrations of fish west of the stock area were particularly noteworthy, raising questions concerning the stock boundaries and basis for stock definitions. The SARC emphasized the importance of re-examining the stock definition for the yellowtail flounder resource south and west of Georges Bank.

The SARC noted the potential impact of the 1996 year-class estimate on the projections. The SARC discussed the temporal pattern in the residuals from the scallop survey (the index that produced the higher estimate of the 1996 year class), noting the significantly lower estimate of the 1996 year class that resulted when this survey was removed from the ADAPT tuning. Examination of the length frequency distribution in both the 1998 winter and spring surveys, from which age data were not yet available, confirmed the presence of significant numbers of age 2 fish.

The SARC noted the good correspondence between the VPA and ASPIC assessments of this stock, indicating that the scaling of MSY-based reference points from surplus production modeling is consistent with the VPA assessment. The SARC recommended caution concerning the use of ASPIC to determine MSY-based reference points. It was noted that it would be preferable to use the same modeling framework to both establish harvest reference points and to assess stock status relative to these reference points.

The methodology for estimating uncertainty in the projections was discussed. It was noted that a static F level was applied in the projections, and that resampling of the bootstrapped Fs may represent a preferred approach to incorporating additional sources of uncertainty into the projections.

Research Recommendations

- Improve sea sampling coverage for otter-trawl and scallop vessels to allow for better estimation of discards.
- Increase sampling frequency of yellowtail flounder for this stock in the bottom trawl surveys where needed.
- Collect adequate numbers of quarterly commercial samples for length and age composition.
- Evaluate changes in the maturation schedule in recent years and sample yellowtail flounder maturity during the summer scallop survey if possible.
- Re-examine stock boundaries and, if needed, consider different assessment and management units, especially with respect to the Southern New England and Mid-Atlantic stocks. Based on the results of the stock area examination, either independently assess or incorporate into the existing Mid-Atlantic stock area to produce a comprehensive assessment of the status of yellowtail flounder resources west and south of Georges Bank.

- Examine research vessel lengths and weights at age to determine if there have been long term changes in size at age or growth characteristics.

- Examine q from the VPA before, during, and after gear changes in the NEFSC spring bottom trawl survey to confirm that gear conversion factors are appropriate.

- Examine a suite of survey data diagnostics including cohort continuity, z, and recruitment trends (e.g., application of a multiplicative model).

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Table I1. Commercial landings of yellowtail flounder (thousands of metric tons) from Southern New England for 1960-1997 (US Statistical Reporting Areas 526, 537-539) as reported by NEFSC weighout, state bulletin, and canvas data (US) and by ICNAF/NAFO or estimated by Brown and Hennemuth 1971 (foreign).

Year	U.S.	Foreign	Total
1960	8.3	-	8.3
1961	12.3	-	12.3
1962	13.3	-	13.3
1963	22.3	0.2	22.5
1964	19.5	-	19.5
1965	19.4	1.4	20.8
1966	17.6	0.7	18.3
1967	15.3	2.8	18.1
1968	18.2	3.5	21.7
1969	15.6	17.6	33.2
1970	15.2	2.5	17.7
1971	8.6	0.3	8.9
1972	8.5	3.0	11.5
1973	7.2	0.2	7.4
1974	6.4	0.1	6.5
1975	3.2	-	3.2
1976	1.6	<0.1	1.6
1977	2.8	<0.1	2.8
1978	2.3	-	2.3
1979	5.3	-	5.3
1980	6.0	-	6.0
1981	4.7	-	4.7
1982	10.3	-	10.3
1983	17.0	-	17.0
1984	7.9	-	7.9
1985	2.7	-	2.7
1986	3.3	-	3.3
1987	1.6	-	1.6
1988	0.9	-	0.9
1989	2.5	-	2.5
1990	8.0	-	8.0
1991	3.9	-	3.9
1992	1.4	-	1.4
1993	0.5	-	0.5
1994	0.2	-	0.2
1995	0.2	-	0.2
1996	0.3	-	0.3
1997	0.2	-	0.2

Table I2. Samples available for 1998 SNE yellowtail flounder assessment.

Commercial													Discard					
	Lengths								Ages				Lengths-sea sampling		VTR Trips		Sea Sampled Trips	
	Market Category												Gear					
	1231				1232								050	132	050	132	050	132
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1-Q4	Q1-Q4	Q1-Q4		Q1-Q4	
97	437	376	328	0	459	344	548	131	144	173	133	0	148	119	186	10	10	1

Table I3. Commercial landings at age of yellowtail flounder (numbers in thousands), Southern New England (U.S. Statistical Reporting Areas 526, 537-539), 1973-1997.

	Age								
Year	1	2	3	4	5	6	7	8	Total
1973	28	2570	7169	4630	1716	1517	257	55	17942
1974	130	1766	3922	5053	2500	950	1021	196	15538
1975	170	2352	1496	973	1257	549	308	163	7268
1976	0	1396	898	245	337	391	167	188	3622
1977	66	2039	3931	392	205	253	123	160	7169
1978	21	3209	1488	1025	165	34	44	28	6014
1978	19	4972	8252	1033	428	96	24	0	14824
1980	119	4557	6324	3619	472	117	19	12	15239
1981	0	2732	6418	2449	884	128	14	0	12625
1982	56	17414	12788	1741	404	78	7	0	32488
1983	57	13823	33242	3347	376	129	35	7	51016
1984	45	2624	13902	6587	740	244	7	14	24163
1985	166	3984	1496	1312	774	135	27	4	7898
1986	39	5926	2882	561	324	119	21	1	9873
1987	72	1370	2014	803	139	47	8	1	4454
1988	0	1154	504	407	101	17	6	0	2189
1989	0	5213	1269	280	41	3	0	0	6806
1990	0	415	18476	1352	68	5	0	0	20316
1991	0	253	2230	6606	81	1	17	0	9188
1992	0	301	896	1687	246	10	3	0	3143
1993	0	211	361	417	124	4	0	0	1117
1994	0	15	187	136	120	48	1	0	507
1995	0	154	125	182	18	1	3	0	483
1996	0	224	439	122	15	10	5	1	817
1997	0	33	319	146	14	2	2	1	518

Table I4. Mean weight (kilograms) at age of Southern New England yellowtail flounder in landings, 1973-1997.

	Age						
Year	1	2	3	4	5	6	7+
1973	0.210	0.298	0.381	0.420	0.430	0.506	0.611
1974	0.203	0.308	0.359	0.429	0.477	0.476	0.518
1975	0.218	0.290	0.385	0.439	0.436	0.469	0.515
1976	-	0.303	0.427	0.528	0.533	0.568	0.603
1977	0.215	0.284	0.385	0.521	0.529	0.484	0.612
1978	0.234	0.296	0.402	0.543	0.710	0.791	0.677
1979	0.189	0.301	0.366	0.476	0.590	0.684	0.679
1980	0.206	0.281	0.384	0.499	0.690	0.891	1.182
1981	0.140	0.262	0.343	0.484	0.619	0.664	0.476
1982	0.226	0.263	0.354	0.502	0.661	0.821	0.956
1983	0.175	0.262	0.341	0.499	0.671	0.829	0.838
1984	0.182	0.239	0.298	0.388	0.497	0.652	0.724
1985	0.183	0.264	0.370	0.428	0.541	0.620	0.867
1986	0.186	0.285	0.335	0.470	0.598	0.617	0.804
1987	0.247	0.268	0.361	0.412	0.542	0.595	0.905
1988	-	0.293	0.398	0.501	0.664	0.936	0.937
1989	-	0.337	0.389	0.546	0.736	0.959	1.278
1990	-	0.327	0.378	0.461	0.800	0.884	0.781
1991	-	0.336	0.379	0.426	0.715	1.530	0.599
1992	-	0.347	0.386	0.460	0.631	0.802	1.432
1993	-	0.358	0.430	0.471	0.645	1.040	1.040
1994	-	0.319	0.349	0.416	0.556	0.717	0.876
1995	-	0.317	0.410	0.460	0.668	0.883	0.863
1996	-	0.363	0.399	0.476	0.602	0.680	0.780
1997	-	0.347	0.435	0.494	0.677	0.847	0.926

Table I5a. Discards of Southern New England yellowtail flounder by otter trawls during 1997.

		Age					
		1	2	3	4	5	6
	half						
1997	1		17106	18414	616		
	2	1402	4964	6920			
Total		1402	22070	25334	616		

Table I5b. Discards of southern New England yellowtail flounder by scallop dredges during 1997.

		Age						
		1	2	3	4	5	6	7
	half							
1997	1		69	761	658	292	73	73
	2		699	5447	2705	840	413	129
Total			768	6208	3363	1132	486	202

Table I6. Estimated discard at age of yellowtail flounder (numbers in thousands), Southern New England, 1973-1997.

	Age								
Year	1	2	3	4	5	6	7	8	Total
1973	160	2486	1130	43	0	0	0	0	3819
1974	728	26568	793	45	0	0	0	0	28134
1975	8670	1427	1	10	0	0	0	0	10108
1976	214	5203	14	0	0	0	0	0	5431
1977	5376	2732	42	0	0	0	0	0	8150
1978	8677	10102	7	0	0	0	0	0	18786
1979	185	14253	119	0	0	0	0	0	14557
1980	869	5441	18	0	0	0	0	0	6328
1981	38	4013	319	0	0	0	0	0	4370
1982	113	17716	905	3	0	0	0	0	18737
1983	2469	4607	5373	17	0	0	0	0	12466
1984	465	3107	941	74	0	0	0	0	4587
1985	2064	3031	20	0	0	0	0	0	5115
1986	423	3754	39	0	0	0	0	0	4216
1987	1518	2034	19	0	0	0	0	0	3572
1988	5899	896	4	0	0	0	0	0	6798
1989	24	14002	1834	131	6	0	0	0	15996
1990	192	1633	23709	673	11	0	0	0	26217
1991	445	1354	2820	2883	12	0	0	0	7514
1992	477	1152	1086	659	33	0	0	0	3408
1993	13	212	15	9	0	0	0	0	249
1994	9	134	35	29	12	2	0	0	221
1995	7	94	38	27	12	3	0	0	182
1996	21	81	56	29	13	2	0	0	202
1997	1	23	32	4	1	0	0	0	61

Table 17. Total catch at age of yellowtail flounder (numbers in thousands), Southern New England, 1973-1997.

	Age								
Year	1	2	3	4	5	6	7	8	Total
1973	188	5056	8299	4673	1716	1517	257	55	21761
1974	858	28334	4715	5098	2500	950	1021	196	43672
1975	8840	3779	1497	983	1257	549	308	163	17376
1976	214	6599	912	245	337	391	167	188	9053
1977	5442	4771	3973	392	205	253	123	160	15319
1978	8698	13311	1495	1025	165	34	44	28	24800
1979	204	19225	8371	1033	428	96	24	0	29381
1980	988	9998	6342	3619	472	117	19	12	21567
1981	38	6745	6737	2449	884	128	14	0	16995
1982	169	35130	13693	1744	404	78	7	0	51225
1983	2526	18430	38615	3364	376	129	35	7	63482
1984	510	5731	14843	6661	740	244	7	14	28750
1985	2230	7015	1516	1312	774	135	27	4	13013
1986	462	9680	2921	561	324	119	21	1	14089
1987	1590	3404	2033	803	139	47	8	1	8026
1988	5899	2050	508	407	101	17	6	0	8987
1989	24	19215	3103	411	47	3	0	0	22802
1990	192	2048	42185	2025	79	5	0	0	46533
1991	445	1607	5050	9489	93	1	17	0	16702
1992	477	1453	1982	2347	279	11	3	0	6551
1993	13	423	376	426	124	40	0	0	1366
1994	9	150	222	165	132	49	1	0	728
1995	7	248	163	210	30	4	3	0	666
1996	21	305	496	151	29	13	5	1	1019
1997	1	56	351	150	15	2	2	1	578

Table 18. Mean weight (kilograms) at age of Southern New England yellowtail flounder in catch, 1973-1997.

	Age						
Year	1	2	3	4	5	6	7+
1973	0.210	0.298	0.381	0.420	0.430	0.506	0.611
1974	0.203	0.308	0.359	0.429	0.477	0.476	0.518
1975	0.218	0.290	0.385	0.439	0.436	0.469	0.515
1976	0.228	0.303	0.427	0.528	0.533	0.568	0.603
1977	0.215	0.284	0.385	0.521	0.529	0.484	0.612
1978	0.234	0.296	0.402	0.543	0.710	0.791	0.677
1979	0.189	0.301	0.366	0.476	0.590	0.684	0.679
1980	0.206	0.281	0.384	0.499	0.690	0.891	1.182
1981	0.140	0.262	0.343	0.484	0.619	0.664	0.476
1982	0.226	0.263	0.354	0.502	0.661	0.821	0.956
1983	0.175	0.262	0.341	0.499	0.671	0.829	0.838
1984	0.182	0.239	0.298	0.388	0.497	0.652	0.724
1985	0.183	0.264	0.370	0.428	0.541	0.620	0.867
1986	0.186	0.285	0.335	0.470	0.598	0.617	0.804
1987	0.247	0.268	0.361	0.412	0.542	0.595	0.905
1988	0.270	0.293	0.398	0.501	0.664	0.936	0.937
1989	0.311	0.337	0.389	0.546	0.736	0.959	1.046
1990	0.301	0.327	0.378	0.461	0.800	0.884	0.781
1991	0.206	0.262	0.336	0.414	0.676	0.874	0.594
1992	0.167	0.316	0.367	0.430	0.597	0.779	1.409
1993	0.122	0.272	0.424	0.467	0.645	1.040	1.040
1994	0.108	0.211	0.346	0.412	0.546	0.712	0.951
1995	0.123	0.272	0.387	0.447	0.579	0.656	0.876
1996	0.147	0.328	0.360	0.454	0.522	0.652	0.821
1997	0.143	0.295	0.425	0.495	0.68	0.871	0.926

Table I9. Mean weight per tow (kg) from research vessel surveys during 1963-1998 for Southern New England yellowtail flounder during winter, spring, and autumn (Strata 5,6,9,10).

	Winter	Spring	Autumn
1963			16.842
1964			19.030
1965			12.675
1966			9.431
1967			14.057
1968		18.624	10.062
1969		13.340	14.401
1970		11.721	10.965
1971		10.693	11.632
1972		10.728	20.114
1973		14.678	2.264
1974		5.040	2.141
1975		1.984	0.715
1976		2.452	2.962
1977		1.993	1.501
1978		5.146	3.057
1979		2.147	2.565
1980		5.949	1.957
1981		6.846	3.789
1982		6.001	8.126
1983		4.641	6.515
1984		1.625	1.365
1985		0.666	0.438
1986		1.605	0.883
1987		0.402	0.607
1988		0.399	0.496
1989		2.433	2.359
1990		7.828	0.974
1991		2.786	1.013
1992	4.402	0.653	0.229
1993	1.968	0.506	0.053
1994	6.809	0.219	0.374
1995	4.059	0.360	0.432
1996	5.159	1.054	0.266
1997	5.831	1.183	1.041
1998	1.281		

Table I10. NEFSC spring trawl survey mean number of Southern New England yellowtail flounder per tow at age during 1968-1997 (NEFSC offshore strata 5, 6, 9 and 10) (corrected for net, door, and vessel).

	Age								
	1	2	3	4	5	6	7	8	total
1968	1.662	31.719	31.913	19.002	0.886	0.168	0.067	0.000	85.416
1969	5.102	19.866	27.261	14.675	2.540	0.285	0.000	0.000	69.730
1970	1.486	10.669	19.964	14.136	4.066	1.096	0.235	0.096	51.749
1971	1.066	11.323	8.519	23.664	6.065	0.967	0.011	0.011	51.627
1972	0.492	21.844	14.735	4.596	8.813	1.360	0.257	0.000	52.098
1973	1.301	7.270	12.713	6.276	4.261	6.595	0.820	0.456	39.693
1974	0.742	2.972	2.326	2.530	1.647	0.593	0.964	0.193	11.967
1975	0.561	1.556	0.500	0.769	0.810	0.471	0.033	0.146	4.845
1976	0.026	3.259	0.528	0.250	0.302	0.250	0.157	0.051	4.823
1977	0.205	1.251	1.556	0.166	0.173	0.080	0.024	0.103	3.557
1978	2.963	9.783	2.027	0.715	0.187	0.036	0.047	0.138	15.897
1979	1.542	3.357	1.741	0.354	0.110	0.000	0.000	0.008	7.112
1980	0.370	4.303	3.278	2.711	0.291	0.116	0.006	0.039	11.115
1981	0.203	8.622	3.089	1.279	0.464	0.047	0.000	0.000	13.704
1982	0.333	14.049	7.459	1.860	0.605	0.186	0.020	0.000	24.512
1983	0.090	3.900	12.916	1.059	0.312	0.000	0.000	0.000	18.278
1984	0.000	0.500	1.648	2.612	0.665	0.223	0.000	0.000	5.649
1985	0.561	0.744	0.417	0.201	0.454	0.093	0.000	0.000	2.470
1986	0.037	4.083	1.492	0.308	0.073	0.036	0.000	0.000	6.029
1987	0.000	0.198	0.919	0.144	0.000	0.000	0.000	0.000	1.261
1988	0.327	0.692	0.177	0.245	0.127	0.000	0.000	0.000	1.568
1989	0.151	10.308	0.604	0.066	0.000	0.000	0.000	0.000	11.129
1990	0.091	0.368	18.994	3.794	0.031	0.000	0.000	0.000	23.278
1991	0.438	0.340	1.573	4.484	0.510	0.111	0.000	0.000	7.455
1992	0.081	0.269	0.275	1.196	0.112	0.000	0.000	0.000	1.933
1993	0.037	0.533	0.221	0.517	0.097	0.000	0.000	0.000	1.405
1994	0.031	0.494	0.040	0.019	0.045	0.015	0.000	0.000	0.643
1995	0.054	0.944	0.284	0.072	0.030	0.011	0.018	0.000	1.413
1996	0.000	0.528	2.442	0.314	0.063	0.000	0.000	0.000	3.347
1997	0.119	1.816	1.735	0.274	0.081	0.000	0.000	0.000	4.025

Table I11. NEFSC autumn trawl survey mean number of Southern New England yellowtail flounder per tow at age during 1963-1997 (NEFSC offshore strata 5, 6, 9, and 10) (corrected for door and vessel).

	Age								
	1	2	3	4	5	6	7	8	total
1963	19.798	20.168	14.960	5.830	0.660	0.151	0.000	0.100	61.667
1964	22.529	31.952	5.861	8.701	3.983	1.108	0.000	0.000	74.133
1965	13.231	21.390	7.771	2.140	2.167	0.155	0.000	0.090	46.944
1966	43.305	13.066	2.375	1.247	0.231	0.000	0.000	0.000	60.224
1967	22.497	31.159	13.716	1.936	0.472	0.079	0.160	0.000	70.019
1968	11.285	13.352	22.860	1.443	0.115	0.000	0.000	0.000	49.055
1969	14.481	11.884	33.861	6.351	0.113	0.050	0.050	0.000	66.791
1970	5.157	6.736	19.936	12.961	3.067	0.520	0.089	0.000	48.466
1971	7.748	13.298	7.618	18.468	3.287	0.264	0.196	0.000	50.879
1972	5.135	20.125	24.054	22.993	14.991	2.050	0.054	0.000	89.402
1973	1.726	1.590	2.224	1.640	1.241	1.057	0.212	0.000	9.689
1974	1.216	2.047	0.676	2.776	1.166	0.489	0.238	0.093	8.701
1975	1.981	0.516	0.266	0.329	0.334	0.000	0.104	0.000	3.531
1976	3.632	7.331	0.877	0.088	0.139	0.361	0.423	0.189	13.041
1977	1.759	2.275	0.828	0.053	0.046	0.113	0.078	0.000	5.151
1978	3.247	7.599	0.450	0.392	0.043	0.009	0.079	0.032	11.851
1979	1.794	4.533	2.537	0.388	0.043	0.041	0.000	0.000	9.335
1980	1.463	4.506	1.202	0.426	0.000	0.000	0.000	0.000	7.597
1981	4.704	8.944	1.404	0.334	0.080	0.061	0.000	0.000	15.527
1982	2.610	29.372	8.673	1.025	0.409	0.000	0.000	0.000	42.088
1983	4.582	17.956	10.078	0.876	0.073	0.000	0.050	0.000	33.616
1984	0.719	2.217	2.400	0.659	0.000	0.000	0.000	0.000	5.994
1985	1.018	0.447	0.161	0.122	0.000	0.000	0.000	0.000	1.748
1986	0.826	1.685	0.365	0.088	0.000	0.000	0.000	0.000	2.963
1987	1.515	0.674	0.558	0.047	0.037	0.000	0.037	0.000	2.868
1988	1.261	0.388	0.173	0.195	0.048	0.000	0.000	0.000	2.065
1989	0.000	8.004	1.400	0.065	0.000	0.000	0.000	0.000	9.469
1990	0.000	0.097	2.395	0.270	0.000	0.000	0.000	0.000	2.763
1991	0.865	0.219	1.709	0.453	0.000	0.000	0.000	0.000	3.247
1992	0.261	0.062	0.180	0.337	0.012	0.000	0.000	0.000	0.852
1993	0.070	0.015	0.028	0.020	0.000	0.000	0.000	0.000	0.133
1994	0.754	0.553	0.198	0.192	0.085	0.011	0.000	0.000	1.793
1995	0.180	1.306	0.171	0.095	0.000	0.000	0.000	0.000	1.752
1996	0.653	0.290	0.258	0.025	0.000	0.000	0.000	0.000	1.226
1997	0.889	0.716	1.687	0.373	0.037	0.000	0.000	0.000	3.702

Table I12. NESFC scallop survey mean number of Southern New England yellowtail flounder per tow at age during 1982-1997.

	Age								
Year	1	2	3	4	5	6	7	8	Total
1982	0.584	2.404	0.559	0.054	0.013	0	0	0	3.614
1983	0.891	0.652	0.417	0.038	0	0	0	0	1.998
1984	0.205	0.130	0.127	0.033	0.031	0	0	0	0.526
1985	0.647	0.180	0.027	0.023	0.010	0	0	0	0.887
1986	0.282	0.395	0.051	0.028	0	0	0	0	0.756
1987	0.601	0.086	0.075	0.011	0.006	0	0.004	0	0.783
1988	1.343	0.047	0.054	0.008	0.001	0	0	0	1.453
1989	0.169	3.878	0.576	0.039	0.014	0	0	0	4.676
1990	0.026	0.180	0.592	0.038	0	0	0	0	0.836
1991	1.060	0.007	0.295	0.040	0	0	0	0	1.402
1992	0.411	0	0.012	0.086	0	0	0	0	0.509
1993	0.419	0.002	0.004	0	0	0	0	0	0.484
1994	1.265	0.192	0.118	0.051	0.039	0	0	0	1.665
1995	0.551	0.926	0.604	0.181	0	0.015	0	0	2.276
1996	0.608	0.119	0.249	0.014	0.002	0	0.028	0	1.019
1997	2.744	0.154	0.258	0.083	0.011	0	0	0	3.250

Table I13. NESFC winter survey mean number of Southern New England yellowtail flounder per tow at age during 1992-1997.

	Age								
Year	1	2	3	4	5	6	7	8	Total
1992	0	2.884	1.881	6.418	1.295	0	0	0	12.502
1993	1.349	3.853	0.711	1.841	0.306	0	0	0	8.070
1994	0.586	17.778	1.363	2.917	1.258	0.199	0	0	24.102
1995	0.368	7.615	4.474	1.317	0.493	0.123	0.036	0	14.131
1996	0.092	2.304	11.703	1.552	0.207	0.109	0.033	0	16.001
1997	0.301	3.976	9.141	2.625	0.508	0.000	0	0	16.551

Table I14. Parameter estimates for stock size with standard error, T-statistic, and CV and estimates of terminal year (1997) fishing mortality (F) from trial ADAPT runs for Southern New England yellowtail flounder.

Age	Stock size estimate	Standard error	T-statistic	CV	F in 1997
Run 42: Spring, Scallop, and Autumn indices					
2	16.3	9.5	1.71	0.58	0.01
3	7.2	3.3	2.20	0.45	0.07
4	4.6	1.5	3.13	0.32	0.04
5	3.2	1.0	3.28	0.30	0.05
Run 45: Spring, Winter, and Autumn indices					
2	5.8	3.1	1.85	0.54	0.02
3	3.1	1.3	2.34	0.43	0.11
4	2.8	0.9	3.08	0.32	0.07
5	1.9	0.6	3.21	0.31	0.09
Run 46: Spring, Winter, Scallop (age 1), and Autumn indices					
2	10.2	4.9	2.07	0.48	0.01
3	3.7	1.5	2.49	0.40	0.09
4	3.3	1.0	3.19	0.31	0.06
5	2.3	0.7	3.31	0.30	0.08

Table I15. Summary of results for Southern New England yellowtail flounder from SAW-27 VPA.

STOCK NUMBERS (Jan 1) in thousands

	1973	1974	1975	1976	1977	1978	1979
1	42144	9234	28866	12910	47571	52422	30090
2	15230	34335	6784	15635	10376	34024	35049
3	19877	7894	2473	2135	6829	4179	15812
4	10100	8765	2197	670	922	1997	2068
5	3810	4041	2563	909	327	400	707
6	3446	1567	1046	961	439	82	179
7	577	1651	578	406	210	105	44
1+	95184	67486	44506	33626	66676	93209	83950

	1980	1981	1982	1983	1984	1985	1986
1	41943	126925	53147	14583	16730	19837	6969
2	24451	33446	103883	43360	9654	13236	14223
3	11300	10973	21280	53266	18824	2719	4489
4	5371	3513	2888	5033	8670	1982	854
5	759	1123	661	786	1077	1071	435
6	192	194	120	175	303	212	177
7	31	21	11	46	08	41	30
1+	84047	176195	181989	117250	55267	39098	27178

Table I15. (Continued)

	1987	1988	1989	1990	1991	1992	1993
1	13987	122009	16439	6863	3720	2041	1298
2	5287	10013	94555	13437	5445	2643	1240
3	2886	1249	6343	60029	9148	3004	849
4	1032	524	563	2385	10977	2921	666
5	192	119	60	89	121	401	268
6	63	31	06	07	01	15	76
7	10	11	00	00	22	04	00
1+	23458	133955	117966	82811	29435	11029	4397

	1994	1995	1996	1997	1998
1	6490	6982	5629	12497	00
2	1051	5305	5710	4589	10231
3	632	725	4119	4399	3707
4	355	317	446	2924	3284
5	160	142	69	228	2258
6	107	12	89	30	173
7	02	09	34	30	46
1+	8797	13490	16095	24698	19699

FISHING MORTALITY

	1973	1974	1975	1976	1977	1978	1979
1	0.00	0.11	0.41	0.02	0.14	0.20	0.01
2	0.46	2.43	0.96	0.63	0.71	0.57	0.93
3	0.62	1.08	1.11	0.64	1.03	0.50	0.88
4	0.72	1.03	0.68	0.52	0.63	0.84	0.80
5	0.69	1.15	0.78	0.53	1.18	0.61	1.11
6	0.67	1.11	0.87	0.60	1.01	0.61	0.90
7	0.67	1.11	0.87	0.60	1.01	0.61	0.90

	1980	1981	1982	1983	1984	1985	1986
1	0.03	0.00	0.00	0.21	0.03	0.13	0.08
2	0.60	0.25	0.47	0.63	1.07	0.88	1.39
3	0.97	1.13	1.24	1.62	2.05	0.96	1.27
4	1.36	1.47	1.10	1.34	1.89	1.32	1.29
5	1.16	2.04	1.13	0.75	1.43	1.60	1.73
6	1.12	1.30	1.27	1.68	2.19	1.22	1.36
7	1.12	1.30	1.27	1.68	2.19	1.22	1.36

	1987	1988	1989	1990	1991	1992	1993
1	0.13	0.05	0.00	0.03	0.14	0.30	0.01
2	1.24	0.26	0.25	0.18	0.39	0.94	0.47
3	1.51	0.60	0.78	1.50	0.94	1.31	0.67
4	1.96	1.96	1.64	2.78	3.11	2.19	1.23
5	1.62	2.82	1.97	3.99	1.91	1.47	0.72
6	1.73	0.93	0.85	1.63	1.72	1.76	0.87
7	1.73	0.93	0.85	1.63	1.72	1.76	0.87

	1994	1995	1996	1997
1	0.00	0.00	0.00	0.00
2	0.17	0.05	0.06	0.01
3	0.49	0.29	0.14	0.09
4	0.72	1.32	0.47	0.06
5	2.42	0.27	0.62	0.08
6	0.71	0.48	0.18	0.08
7	0.71	0.48	0.18	0.08

Table I15. (Continued)

SSB AT THE START OF THE SPAWNING SEASON -MALES AND FEMALES (MT)

	1973	1974	1975	1976	1977	1978	1979
1	1056	214	632	349	1155	1347	678
2	2548	2592	896	2476	1488	5402	4853
3	5262	1623	539	628	1537	1225	3604
4	2887	2243	666	262	339	701	646
5	1128	1093	740	357	97	203	241
6	1212	430	313	391	128	46	77
7	245	494	190	175	77	51	19
1+	14338	8689	3977	4637	4821	8974	10117

	1980	1981	1982	1983	1984	1985	1986
1	1021	2124	1434	279	359	410	150
2	3631	5363	15272	5921	1003	1642	1535
3	2603	2105	4029	8304	2136	606	795
4	1389	843	839	1314	1398	449	214
5	295	271	250	354	270	272	116
6	98	69	53	66	72	72	56
7	21	05	05	18	02	20	13
1+	9059	10780	21882	16256	5240	3471	2879

	1987	1988	1989	1990	1991	1992	1993
1	390	3848	611	244	86	36	19
2	572	1792	19484	2767	822	384	188
3	499	349	1604	10893	1865	574	245
4	171	106	142	314	1132	460	171
5	48	22	18	12	34	119	117
6	17	18	04	03	01	05	50
7	04	06	00	00	06	02	00
1+	1702	6141	21861	14233	3946	1580	790

	1994	1995	1996	1997
1	84	103	99	214
2	140	960	1242	916
3	160	224	1258	1620
4	99	75	153	1298
5	29	67	26	138
6	52	06	49	24
7	01	06	24	25
1+	566	1440	2851	4235

Table I16. Projections of landings (mt), discards (mt), and SSB (mt), for Southern New England yellowtail flounder during 1998-2000 at $F_{0.1}$ and F97.

1998					1999			2000	
F	L	D	SSB	$F_{1999\text{-}2000}$	L	D	SSB	SSB	Consequences/Implications
0.07	226	17	6,574	0.27 ($F_{0.1}$)	1,112	103	7,855	7,828	SSB increases about 20% from 1998 to 2000, landings increase slowly
				0.07 (F_{98})	314	29	8,239	9,187	SSB increases about 40% from 1998 to 2000, landings increase slowly

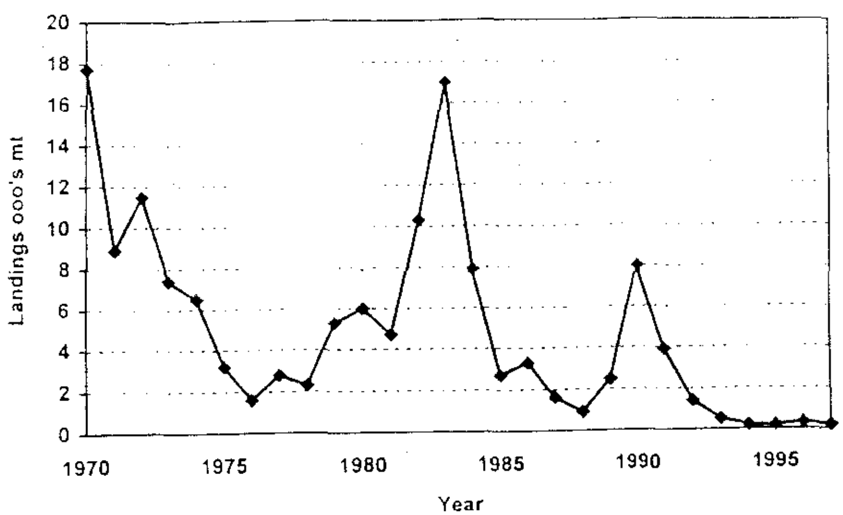

Figure I1. Landings of Southern New England yellowtail flounder during 1970-1997.

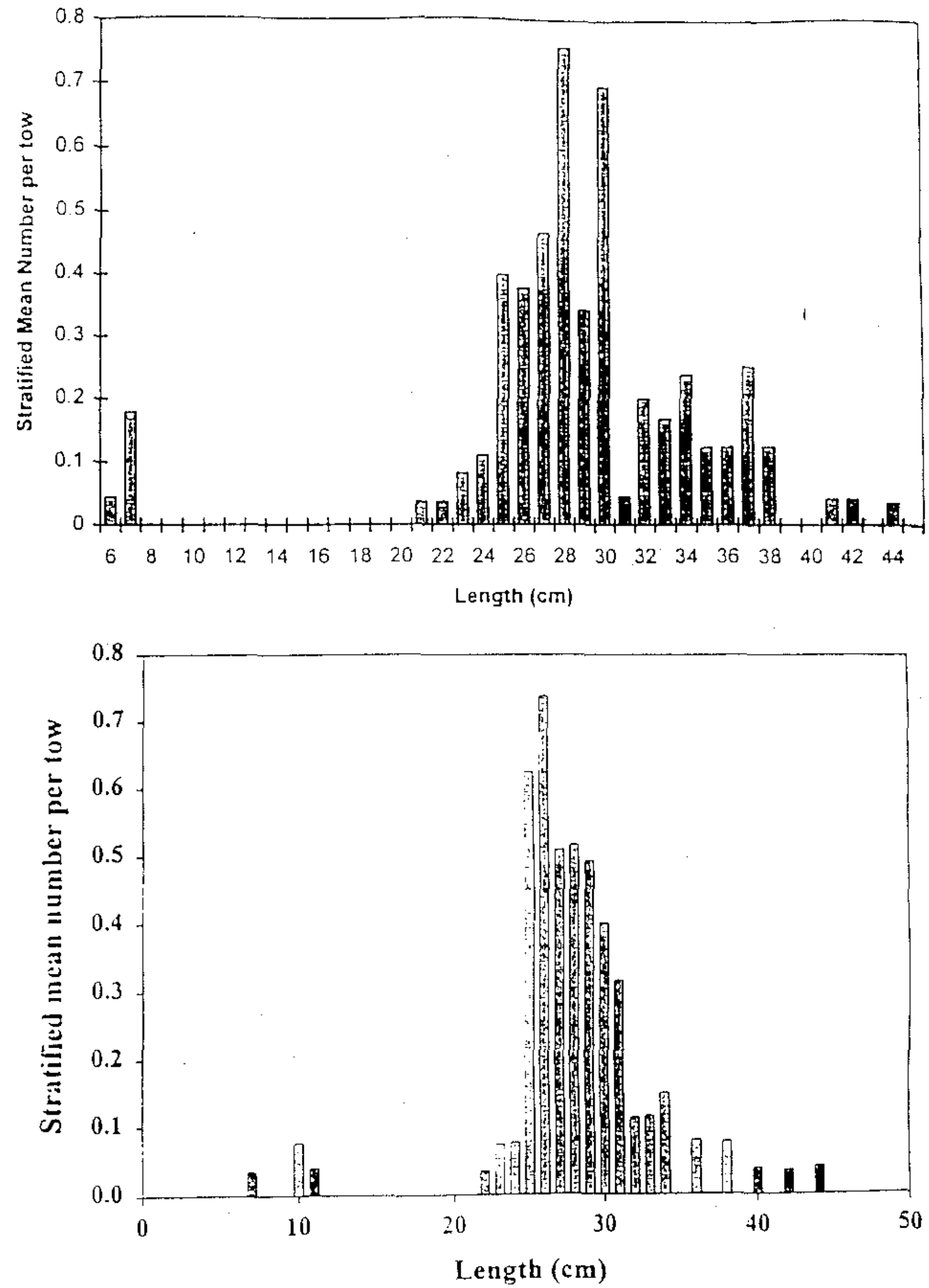

Figure I2. Winter and spring survey catch per tow at length for 1998.

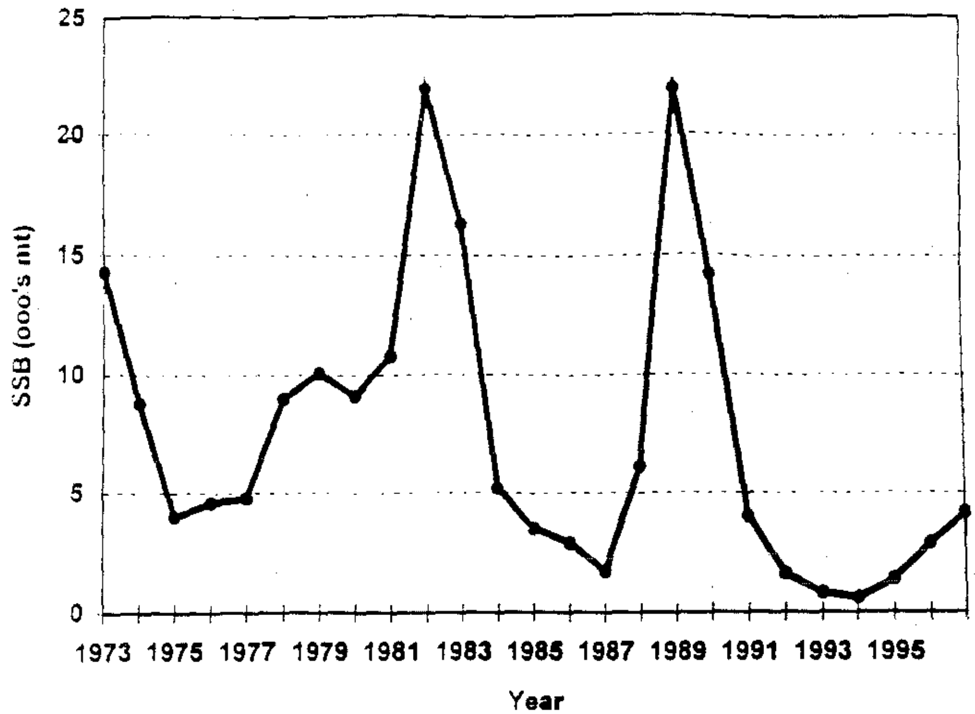

Figure I3. Spawning stock biomass of Southern New England yellowtail flounder during 1973-1997.

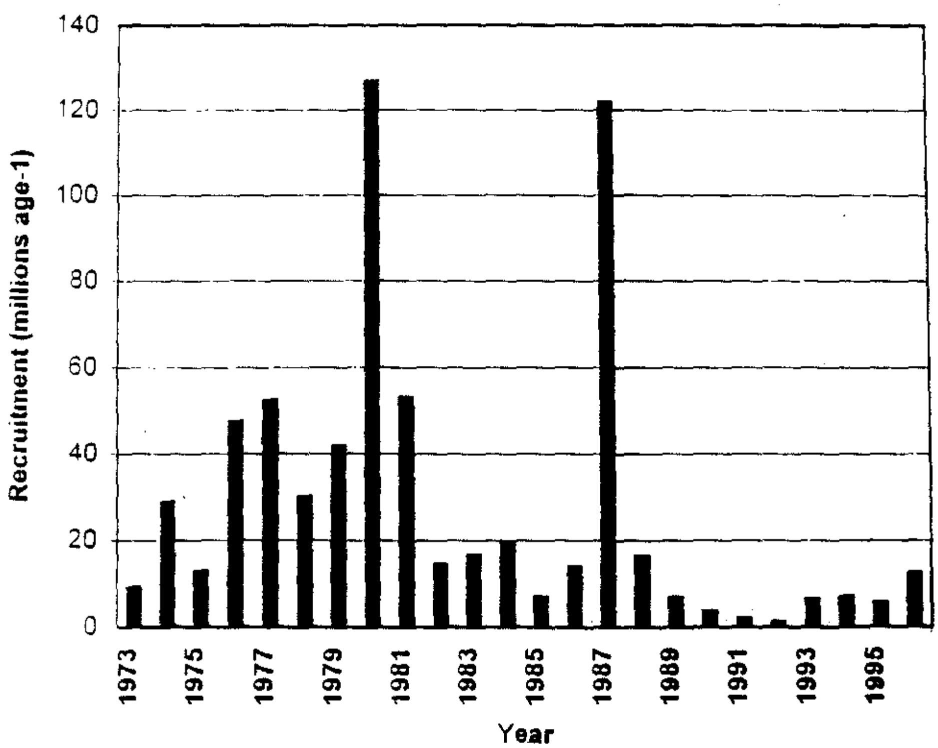

Figure I4. Recruitment of Southern New England yellowtail flounder during 1973-1996.

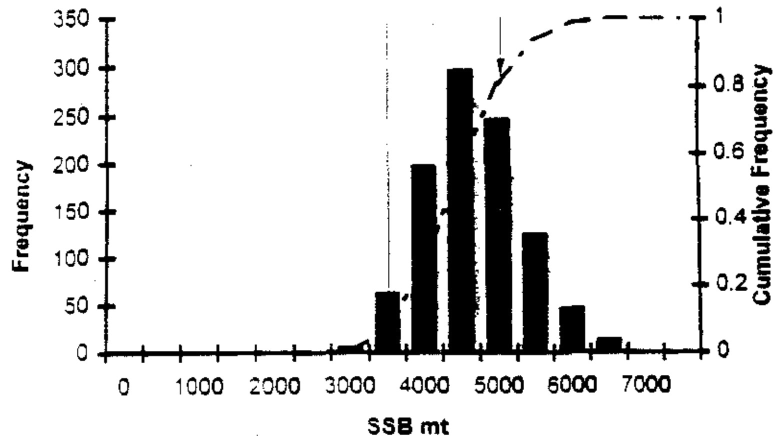

Figure I5. Precision of estimates of spawning stock biomass for Southern New England yellowtail flounder.

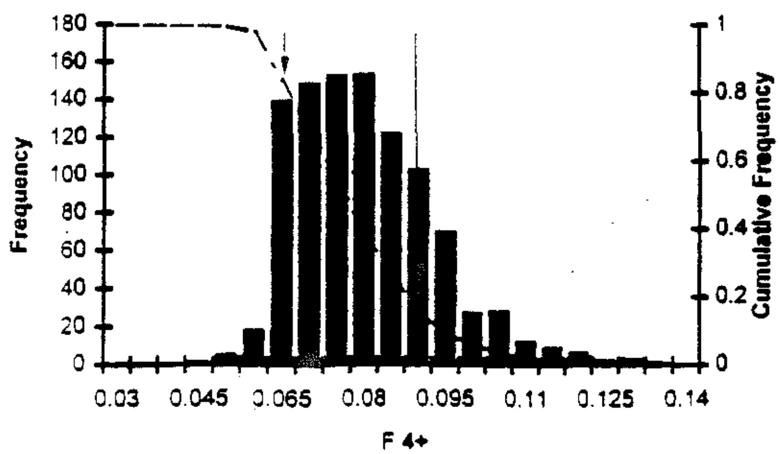

Figure I6. Precision of estimates of Fishing Mortality for Southern New England yellowtail flounder.