Northeast Fisheries Science Center Reference Document 97-12

24th Northeast Regional Stock Assessment Workshop (24th SAW)

Stock Assessment Review Committee (SARC) Consensus Summary of Assessments

October 1997

Northeast Fisheries Science Center Reference Document 97-12

A Report of the 24th Northeast Regional Stock Assessment Workshop

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Stock Assessment Review Committee (SARC) Consensus Summary of Assessments

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

October 1997

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This report may be cited as: Northeast Fisheries Science Center. 1997. Report of the 24th Northeast Regional Stock Assessment Workshop (24th SAW): Stock Assessment Review Committee (SARC) consensus summary of assessments. *Northeast Fish. Sci. Cent. Ref. Doc.* 97-12; 291 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026.

This report is a product of the 24th Northeast Regional Stock Assessment Workshop (24th SAW). Proceedings and products of the 24th SAW are scheduled to be documented and released as issues of the *Northeast Fisheries Science Center Reference Document* series. Tentative titles for the 24th SAW are:

An alternative stock assessment analysis for Gulf of Maine Atlantic cod

Assessment of the Georges Bank Atlantic cod stock for 1997

Assessment of the Gulf of Maine Atlantic cod stock for 1997

Assessment of the Southern New England yellowtail flounder stock for 1997

Evaluation of vessel logbook data for discard and catch-per-unit-of-effort (CPUE) estimates

Proration of 1994-96 commercial landings of Atlantic cod, haddock, and yellowtail flounder

Report of the 24th Northeast Regional Stock Assessment Workshop (24th SAW): Public Review Workshop

Report of the 24th Northeast Regional Stock Assessment Workshop (24th SAW): Stock Assessment Review Committee (SARC) consensus summary of assessments

Stock assessment of Georges Bank yellowtail flounder for 1997

Ten-year projections of landings, spawning stock biomass, and recruitment for the five groundfish stocks considered at the 24th Northeast Regional Stock Assessment Workshop (24th SAW)

U.S. assessment of the Georges Bank haddock stock, 1997

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MEETING OVERVIEW

The Stock Assessment Review Committee (SARC) meeting of the 24th Northeast Regional Stock Assessment Workshop (24th SAW) was held at the Northeast Fisheries Science Center (NEFSC), Woods Hole, MA during 19-23 May 1997. The SARC Chairman was Dr. Emory Anderson (NEFSC). Members of the SARC included scientists from the NMFS Northeast and Southeast Fisheries Science Centers (NEFSC and SEFSC) and Office of Science and Technology (S & T), New England Fishery Management Council (NEFMC), Atlantic States Marine Fisheries Commission (ASMFC), the States of Connecticut and Massachusetts, the Canadian Department of Fisheries and Oceans, the International Pacific Halibut Commission (IPHC), and the University of Rhode Island (Table 1). In addition, 20 other persons attended some or all of the meeting (Table 2). The meeting agenda is presented in Table 3.

Table 1. Composition of the SARC.

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

Four *ad hoc* experts chosen by the Chair:
Wendy Gabriel, NMFS/NEFSC
Han-Lin Lai, NMFS/NEFSC
Pamela Mace, NMFS/SEFSC
Mark Terceiro, NMFS/NEFSC

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

Atlantic States Marine Fisheries Commission/State personnel:
Najih Lazar, ASMFC
Michael Armstrong, MA DMF
David Simpson, CT DEP

One or more scientists from:
Canada - **Robert O'Boyle, DFO**
Academia - **Jeremy Collie, Univ. Rhode Island**
Other Regions - **Clay Porch, NMFS/SEFSC**
Victor Restrepo, NMFS/S&T
External Organization - **Pat Sullivan, IPHC**

Opening

Dr. Emory Anderson introduced the SARC members, Dr. Steven Murawski, Chief of the NEFSC Population Dynamics Branch, and Dr. Michael Sissenwine, NEFSC Science and Research Director.

Dr. Sissenwine welcomed the participants and noted the demands for more advice and higher quality of the science. He thanked the members of the SARC for agreeing to serve and indicated that he was proud of the process and the people who prepared the documents for this review.

Table 2. List of participants.

National Marine Fisheries Service
Northeast Fisheries Science Center
Frank Almeida
Russell Brown
Steve Cadrin
Jeffrey Cross
Lisa Hendrickson
Josef Idoine
Steve Murawski
Helen Mustafa
Loretta O'Brien
William Overholtz
Fredric Serchuk
Gary Shepherd
Michael Sissenwine
Katherine Sosebee
Susan Wigley
Northeast Region
Andrew Rosenberg
Conservation Law Foundation
Eleanor Dorsey
University of Rhode Island
Tim Hennesy
M'Hamed Idrissi
Heather Mooney

The Process

The Chairman reviewed the SAW process, including its working components (Steering Committee, Working Groups, SARC, and Public Review Workshop) and their responsibilities. The SARC considers the reports of the Working Groups, peer reviews the assessments, develops the management advice, and agrees on the working papers to be published. The SARC advice is presented at meetings of the regional Fishery Management Councils, the two major management fora in the Northeast Region.

Table 3. Agenda of the 24th Northeast Regional Stock Assessment Workshop (SAW-24) Stock Assessment Review Committee (SARC) meeting.

NEFSC Aquarium Conference Room
166 Water Street
Woods Hole, Massachusetts

19 (1:00 PM) - 23 (6:00 PM) May 1997

AGENDA

TOPIC	WORKING GROUP & PRESENTER	SARC LEADER	RAPPORTEUR
MONDAY, 19 May (1:00 PM - 6:00 PM)			
Opening Welcome Agenda Conduct of Meeting		E. Anderson, Chairman	H. Mustafa
Data Issues	R. Mayo		S.Wigley
Gulf of Maine Cod (A)	Northern Demersal R. Mayo	V. Restrepo	K. Sosebee
TUESDAY, 20 May (9:00 AM - 6:00 PM)			
Georges Bank Cod (B)	Northern Demersal R. Mayo	J. Collie	L. O'Brien
Georges Bank Haddock (C)	Northern Demersal R. Mayo	P. Mace	R. Brown
WEDNESDAY, 21 May (9:00 AM - 6:00 PM)			
Georges Bank Yellowtail Flounder (D)	Southern Demersal W. Overholtz	W. Gabriel	S. Cadrin
Southern New England Yellowtail Flounder (E)	Southern Demersal W. Overholtz	M. Terceiro	S. Wigley
THURSDAY, 22 May (9:00 AM - 6:00 PM)			
Review Available Advisory Report Sections Review Available SARC Report Sections			
FRIDAY, 23 May (9:00 AM - 6:00 PM)			
Complete Advisory Report Sections Review Research Recommendations Complete SARC Report Sections Review List of Publications for the SAW-24 Series Other Business			H. Mustafa

SARC documentation includes a "Consensus Summary of Assessments", with research recommendations, and a shorter, stylized advisory document, both of which are distributed at the two sessions of the Public Review Workshop. From time to time, the SARC also produces special advisories such as the "Special Advisory on Groundfish Status on Georges Bank" developed in 1994 as part of the SAW-18 documentation.

The Working Group Chairmen are Ralph Mayo (Northern Demersal), Dr. Wendy Gabriel (Southern Demersal), Dr. William Overholtz (Coastal/Pelagic), and Dr. Paul Rago (Invertebrate). The Chair of the Assessment Methods Working Group is currently vacant. Only the Northern Demersal and Southern Demersal Working Groups were involved in the SAW-24 assessments and they met jointly in Woods Hole April 3-11 (Table 4).

Since three of the five stocks on the agenda were transboundary, five Canadian scientists participated in the Working Group meeting, and assessments for those three species were later reviewed by the Canadian Maritimes Regional Advisory Process (RAP) Marine Fisheries Subcommittee. Four NEFSC scientists participated in the RAP meeting held April 21-24 in Moncton, New Brunswick. The "Stock Status" reports on Georges Bank cod, Eastern Georges Bank haddock, and Georges Bank yellowtail flounder from the RAP meeting were available at the SARC meeting. Although US and Canadian scientists participate in the other country's assessment forum, it was noted that there is a need for additional and expanded interaction. Merging the US and Canadian peer-review processes for transboundary stocks would eliminate a considerable amount of redundancy that currently exists relative to the stock assessments and their peer reviews.

Table 4. SAW-24 Working Group meeting.

Working Group Participants	Meeting Date and Place	Stocks
Joint Northern and Southern Demersal Working Group	3-11 April 1997	Gulf of Maine cod
E. Anderson, NMFS/NEFSC (part time)	Woods Hole, MA	Georges Bank cod
A. Applegate, NEFMC (part time)		Georges Bank haddock
R. Brown, NMFS/NEFSC		Georges Bank yellowtail flounder
M.I. Buzeta, DFO, St. Andrews		Southern New England yellowtail flounder
S. Cadrin, NMFS/NEFSC		
S. Correia, MA DFM		
A. DeLong, NMFS/NERO		
J. Forrester, NMFS/NEFSC (part time)		
W. Gabriel, NMFS/NEFSC (Chair SDWG)		
S. Gavaris, DFO, St. Andrews		
T. Helser, NMFS/NEFSC		
J. Hunt, DFO, St. Andrews		
J. Ianelli, NMFS/AFSC		
J. King, MA DMF		
R. Mayo, NMFS/NEFSC (Chair, NDWG)		
S. Murawski, NMFS/NEFSC		
J. Neilson, DFO, St. Andrews		
L. O'Brien, NMFS/NEFSC		
W. Overholtz, NMFS/NEFSC		
G. Power, NMFS/NERO (part time)		
K. Sosebee, NMFS/NEFSC		
M. Terceiro, NMFS/NEFSC		
L. VanEeckhaute, DFO, St. Andrews		
S. Wigley, NMFS/NEFSC		
J. Witzig, NMFS/HQ (part time)		

Dr. Anderson reviewed the procedure for the production of documentation at the meeting, including the responsibilities of the presenters, SARC leaders, and rapporteurs, and asked members of the SARC to look critically at the assessments and ask questions. In spite of the fact that three stocks had already undergone a RAP review, the analyses should not be 'rubber stamped' by the SARC.

It was noted that the five groundfish stocks that were being reviewed by the SARC would undergo a subsequent critique by a Congressionally mandated National Research Council (NRC) review panel in July. Because of the NRC review, the SARC meeting was scheduled one month earlier than usual and an additional third 1997 SARC was scheduled for July to deal with other stocks primarily of interest to the Mid-Atlantic Fishery Management Council. Due to these unusual circumstances, a rigorous schedule of work and deadlines beginning early in the year had been developed. Background documentation and working papers had already been provided to the NRC, and the SARC's draft reports would be forwarded two weeks after the meeting.

It was also noted that the Northeast Region is considering ways to strengthen its stock assessment peer-review process. A coastwide SAW process is also being considered. To meet the increasing demands, there are also plans to involve more experts from academia and outside the Region.

Agenda and Reports

Because of the NRC review, the SAW-24 agenda was devoted exclusively to the review of Northeast groundfish stocks (Gulf of Maine cod, Georges Bank cod, Georges Bank haddock, Georges Bank yellowtail flounder, and Southern New England yellowtail flounder) (Table 3). A chart of US commercial statistical areas used to report landings in the Northwest Atlantic is presented in Figure 1. A chart showing the sampling strata used in NEFSC bottom trawl surveys is presented in Figure 2.

The SARC reviewed 13 working papers. Six of the papers were generic in nature, pertaining to some or all of the stocks and were summarized in the report of the Northern Demersal and Southern Demersal Working Groups. Nine papers were recommended for publication in the NEFSC Reference Document series (Table 5).

Table 5. SAW-24 documents recommended for publication in the NEFSC Reference Documents series.

Assessment of the Gulf of Maine cod for 1997
by R. Mayo

An alternative stock assessment analysis for Gulf of Maine cod
by J. Ianelli

Assessment of the Georges Bank cod stock for 1997
by L. O'Brien

U.S. assessment of the Georges Bank haddock stock, 1997
by R. Brown

Stock assessment of Georges Bank yellowtail flounder for 1977
by S.X. Cadrin, W.J. Overholtz, J.D. Neilson, S. Gavaris, and S.E. Wigley

Assessment of the Southern New England yellowtailflounder stock for 1997
by W. Overholtz, S. Cadrin, and S. Wigley

Ten-year projections of landings, spawning stock biomass, and recruitment for the five groundfish stocks considered at SAW-24
by W.J. Overholtz, S.A. Murawski, P.J. Rago, W.L. Gabriel, and M. Terceiro

Proration of 1994-1996 commercial landings of cod, haddock, and yellowtail flounder
by S. Wigley, M. Terceiro, A. DeLong, and K. Sosebee

Evaluation of vessel logbook data for discard and CPUE estimates
by A. DeLong, K. Sosebee, and S. Cadrin

Draft sections of this report, as well as the advisory document, were reviewed before the SARC adjourned and were assembled into a draft *Report of the 24th Northeast Regional Stock Assessment Workshop (24th SAW) Stock Assessment Review Committee (SARC) Consensus Summary of Assessments* and the *Advisory Report on Stock Status* for distribution to the NRC and the SAW Steering Committee on 6 June, 1997 and subsequently to the participants of the SAW-24 Public Review Workshop.

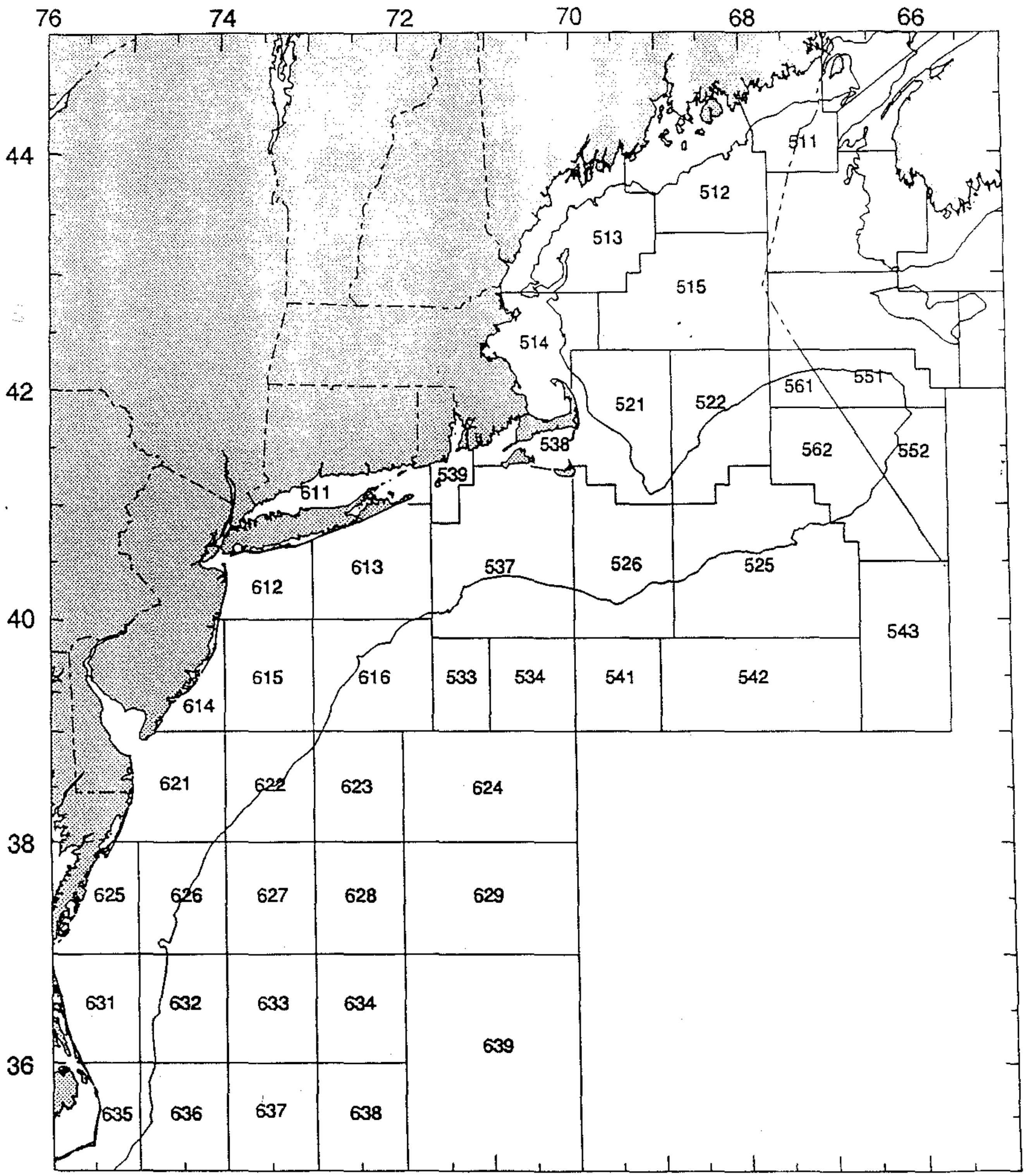

Figure 1. Statistical areas used for catch monitoring offshore fisheries in the Northeast United States.

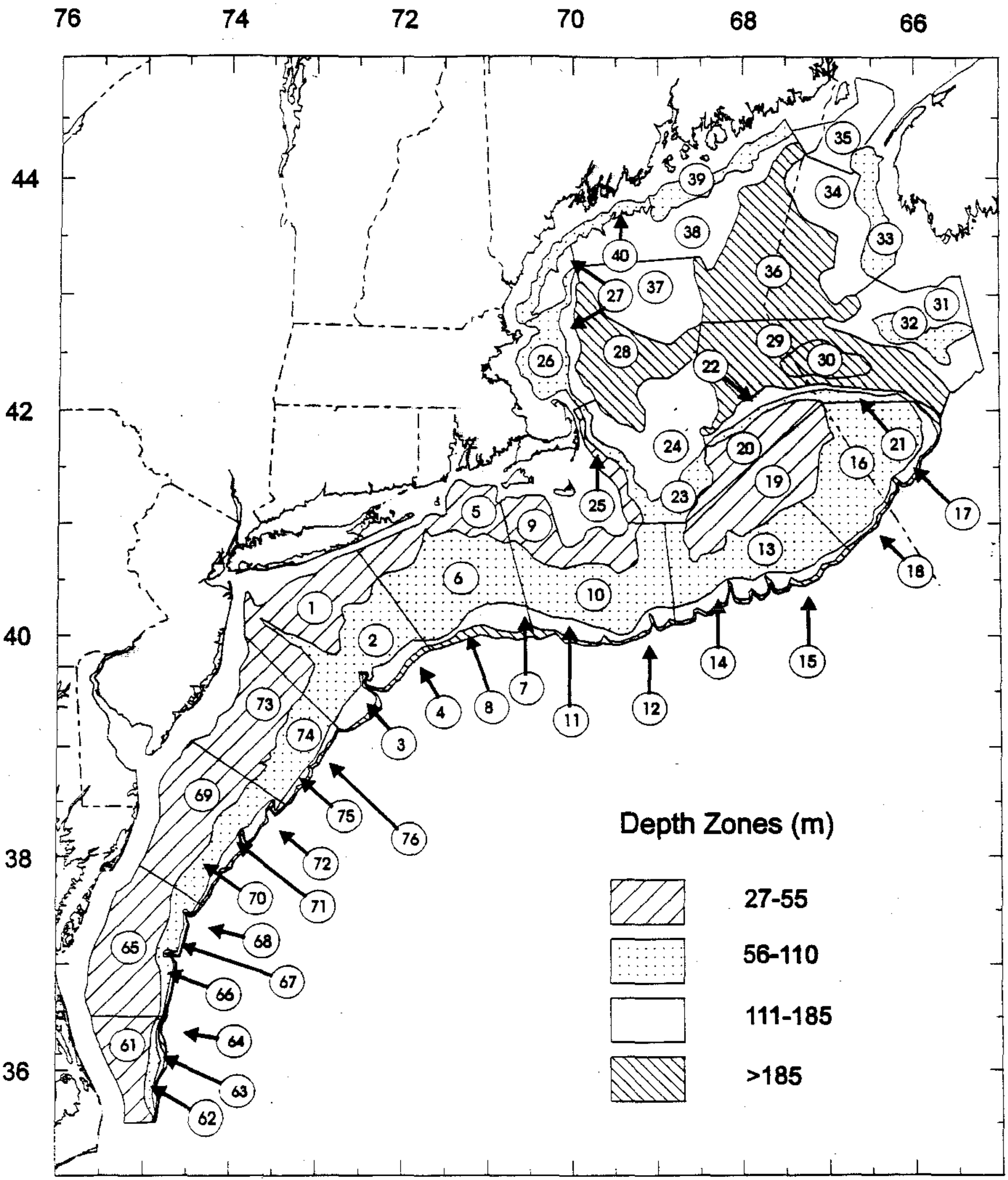

Figure 2. Offshore sampling strata used in NEFSC bottom trawl surveys.

DATA AND METHODOLOGY ISSUES

Background

Terms of reference for SAW-24 required up-to-date assessment information for five stocks of groundfish. Three of these stocks were formally assessed and reviewed in 1994, one in 1993, and one in 1995. The updated assessments presented herein are part of the first attempts to use, for assessment purposes, commercial fisheries data collected under a new system of mandatory dealer and vessel trip reporting. Because that database system is still evolving in content and structure, a substantial amount of the work presented to the SARC was devoted to the analysis of *ad hoc* data handling and summary procedures newly implemented for these assessments.

Several other generic data issues were addressed by the Northern Demersal and Southern Demersal Working Groups and the SARC. These include 1) effects of research vessel survey door conversion factors applied to the US bottom trawl survey indices prior to 1985; 2) incorporation of sexually dimorphic growth information in the derivation of yellowtail flounder catch at age; and 3) estimation of bias in results of virtual population analysis.

The stock assessment results summarized in the accompanying sections of this report reflect the consensus of the SARC and, for the three transboundary stocks on Georges Bank, the Canadian Department of Fisheries and Oceans RAP (Regional Advisory Process) Marine Fisheries Subcommittee review.

The SARC reviewed the input data, model assumptions, and analytical methods employed by the joint Northern Demersal and Southern Demersal Working Group in performing these assessments and had numerous suggestions and recommendations for improvements (which it usually does when reviewing any stock assessments). These are discussed throughout this report. These suggestions and recommendations would undoubtedly have resulted in some quantitative changes in the assessment results. But since it was not practical to implement these suggestions and recommendations in a timely manner given the schedule for completing and reviewing the assessments, it was necessary for the SARC to judge the adequacy of the existing assessment outputs for the purpose of providing management advice. **The SARC concluded that the assessments generally give a realistic indication of the status of the stocks and that the advice based on these assessments is robust (i.e., it is unlikely to have been different if the SARC's suggestions and recommendations for improving the assessments could have been implemented).**

Proration Methodology for US Landings

Introduction

Beginning in June 1994, the NMFS Northeast Region data collection system changed from voluntary collection to mandatory reporting for fishermen and dealers who catch and buy groundfish species regulated by the Northeast Multispecies Fisheries Management Plan. The mandatory reporting system consists of two components: 1) dealer reporting and 2) vessel trip reporting. Each component of the mandatory system contains information needed for stock assessment analyses. The dealer report contains total landings and market category information, while the vessel trip report contains information on area fished, kept and discarded portions of the catch, and effort information (see Power *et al.* 1997 MS for information on the voluntary and mandatory reporting systems of the Northeast US).

In order to conduct 1997 stock assessments, it was necessary to partition total species landings for 1994-1996, the period encompassed by the mandatory data collection system, into stock area of landings. Furthermore, the derivation of catch-at-age matrices for each assessment required that these stock area landings be allocated to market categories. To attain this necessary information, the two components of the mandatory reporting system had to be linked.

Data Sources

Dealer data

Species landings information is collected in both components of the mandatory reporting system: 'kept' pounds are recorded in the vessel trip report and 'landed' pounds are recorded in the dealer report. The vessel trip report data represent about 79% of the cod, haddock, and yellowtail flounder landed weight recorded in the dealer database over the 1994-1996 period (Table 6). Therefore, for these analyses, it was assumed that the dealer data contain the most complete record of total landings, and that the vessel trip report data would serve as a subset of the dealer data. The dealer reports contain, in addition to species landed and live pounds, information on market category, date landed, vessel permit, gear type, and port landed along with other information. Since mandatory reporting of regulated groundfish began in June 1994, data prior to June were collected under the voluntary system and, therefore, did not need to be handled in the same fashion (i.e., no proration was needed) since area fished was recorded with the dealer reports by the NMFS staff which conducted interviews.

Vessel trip report data

The vessel trip report data are still undergoing final auditing procedures at various levels of detail (Power *et al.* 1997 MS). For this analysis, data sets were made available for 1994, 1995, and 1996 which contained the most complete available data to date. All the vessel trip report data and all stock area landings resulting from analyses using the vessel trip report data should be considered provisional. The vessel trip report data contain information on area fished, kept and discarded portions of the catch, and effort information. It is uncertain whether 'kept' weight in the vessel trip report data was recorded in live or landed pounds.

Matched data set

Joining the dealer report data with the vessel trip report data was necessary to simultaneously combine market category information reported by the dealers and the area fished reported by the vessels. However, due to the lack of a unique linking criteria on each data component of the mandatory system (an oversight in the design of the data collection system), there was no direct link of a dealer's 'transaction' to a vessel's trip. Using fields common to both components and fields which contain usable data (i.e., data values not null), an indirect link was established to join the two data sets which would best identify and match a unique dealer's transaction and a vessel's trip. The indirect link consisted of the following fields: species, port landed, vessel permit, month, and day landed. Thus, the needed information (market category landings and area fished) could be attained for assessment purposes.

Annual dealer report sets and annual vessel trip report sets were reduced to eliminate data observations which had either month landed, day landed, port landed, vessel permit, or area fished equal to zero, since missing information in these fields would result in erroneous matches. These observations were eliminated from the annual sets, and matched subsets were created which would be used for prorating dealer report data. Due to the uncertainty of whether live weight or landed weight was recorded in the vessel trip report, the matched set contains both the weight recorded from the dealer report set as well as the 'kept' weight from the vessel trip report. Figure 2 summarizes the data sets and the sequences of steps used to construct the match sets.

Methods

Exploratory analysis of vessel trip report data revealed that grouping of data was necessary to obtain a sufficient number of observations for the proration to be representative of annual landings patterns. The following factors were grouped: market category, port, and gear groups; and a quarterly time block was selected which corresponded to the derivation of catch-at-age matrices in each assessment (Table 7).

For each year and species, comparisons of the dealer report sets with the vessel trip report data sets and with the matched sets were conducted to validate the matched set with respect to the landings patterns observed in the 'parent' sets. The comparisons were performed at the same level of resolution in which the proration would be conducted, i.e., quarter, port group, gear group, stock areas, and market category. These comparisons were qualitatively evaluated based upon the percentage of landings within the groups. Figure 2 identifies the comparisons used to validate the matched set with the dealer report set, the vessel trip report set, and the proration procedure.

For each year, species, and trip in the matched set, the cross products of the market category proportions from the dealer reports and the stock area proportions from the vessel trip report data were calculated and applied to the trip's landed weight to apportion the trip's catch by market category and stock area. Trip landed weights were then summed over the stratification level (i.e., market category, port group, gear group, and quarter) and stock area proportions were derived. The stock area proportions in the matched set were based on the weight obtained from the dealer report set due to the uncertainty as to whether the landings reported in the vessel trip record set were expressed in live or landed weight. These stock area proportions were then applied to the dealer report data to compute total landings by stock area, market category, port group, gear group, and quarter. Figure 2 illustrates the two data sets used in the proration procedure.

Dealer report landings were classified into an unknown stock area if there were no corresponding matched set data with which to prorate them. Prorated landings from unknown areas were subsequently re-distributed among known stock areas based upon the proportions of known stock area landings.

Results

Total US cod landings in 1994 were 17,791 mt, with 10,717 mt reported under the mandatory reporting system which required proration. Total cod landings in 1995 and 1996 were 13,671 mt and 14,221 mt, respectively (Table 6). The 1996 landings are provisional until state/canvas data are available, but are unlikely to change substantially. The annual cod landings reported in the vessel trip report set were approximately 74-79% of the landings reported in the dealer report set (Table 6). Annual cod landings in the matched set ranged between 49% and 53% of the landings in the vessel trip report set and were approximately 47% of the annual cod landings in the dealer report set (Table 6). The 1994-1996 cod landings patterns by quarter, gear, port, stock area, and market category in the matched set generally reflected those patterns observed in the vessel trip report and dealer report sets (e.g., Figures 3 and 4). Detailed comparisons of the cod landings by quarter, gear, port, stock area, and market category are presented in Wigley *et al.* (1997).

Total US haddock landings in 1994 were 330 mt, with 223 mt reported under the mandatory reporting system which required proration. Total haddock landings in 1995 and 1996 were 410 mt and 570 mt, respectively (Table 6). The 1996 landings are provisional until state/canvas data are available, but are unlikely to change substantially. The annual haddock landings reported in the vessel trip report set ranged between 77% and 87% of the landings reported in the dealer report set (Table 6). Annual haddock landings in the matched set ranged between 44% and 53% of the landings in the vessel trip report set and were approximately 44% of the annual haddock landings in the dealer report set (Table 6). The 1994-1996 haddock landings patterns by quarter, gear, port, stock area, and market category in the matched set generally reflected those patterns observed in the vessel trip report and dealer report sets (e.g., Figures 5 and 6). Detailed comparisons of the haddock landings by quarter, gear, port, stock area, and market category are presented in Wigley *et al.* (1997).

Total US yellowtail flounder landings in 1994 were 3,099 mt, with 2,495 mt reported under the mandatory reporting system which required proration. Total yellowtail flounder landings in 1995 and 1996 were 1,929 mt and 2,343 mt, respectively (Table 6). The 1996 landings are provisional until state/canvas data are available, but are unlikely to change substantially. The annual yellowtail flounder landings reported in the vessel trip report set ranged between 87% and 97% of the landings reported in the dealer report set (Table 6). Annual yellowtail flounder landings in the matched set ranged between 39% and 45% of the landings in the vessel trip report set and were approximately 39% of the annual yellowtail flounder landings in the dealer report set (Table 6). The 1994-1996 yellowtail flounder landings patterns by quarter, gear, port, stock area, and market category in the matched set generally reflected those patterns observed in the vessel trip report and dealer report sets (e.g., Figures 7 and 8). Detailed comparisons of the yellowtail flounder landings by quarter, gear, port, stock area, and market category are presented in Wigley *et al.* (1997).

Based on the comparisons, the matched sets for cod, haddock, and yellowtail flounder were judged to be representative of the landings patterns contained in the 'parent' sets, and were used for the proration. Prorated landings by stock area for cod, haddock, and yellowtail flounder during 1994-1996 are presented in Table 8. Stock area landings in 1994, 1995, and 1996 are as follows: Gulf of Maine cod landings were 7,877 mt, 6,798 mt, and 7,194 mt, respectively; Georges Bank cod landings were 9,893 mt, 6,759 mt, and 7,020 mt, respectively; Georges Bank haddock landings were 218 mt, 218 mt, and 313 mt, respectively; Georges Bank yellowtail flounder landings were 1,588 mt, 292 mt, and 751 mt, respectively; and Southern New England yellowtail flounder landings were 225 mt, 187 mt, and 285 mt, respectively.

Conclusions

Using the data sets and methods outlined in this proration method, approximately 46% of the landings reported in the vessel trip report data were utilized in the proration of cod, haddock, and yellowtail flounder landings. When re-design of the mandatory reporting system is completed, including establishing unambiguous linking criteria and providing clear instructions for recording data, and as compliance of vessel reporting increases, it is anticipated that nearly all of the vessel trip report data could be directly linked with the dealer report data, and the need to prorate dealer reported landings will diminish.

SARC Comments: Proration Methodology

The SARC noted the 'growing pains' associated with a new data collection system and raised concerns regarding the quality of the data being collected and the confidence in its accuracy. Although previous analyses (SAW-22) revealed that the data collected under the mandatory system appear to be as representative/accurate as the data collected under the voluntary system, the SARC recognized the need for system design improvements to establish unique links between the data components, and that auditing procedures were still ongoing. The SARC suggested future examination of fields, such as quantity kept, to resolve how the quantity kept portion of the catch is recorded in the VTR database (i.e., weight recorded in live or landed pounds). Since there is less than 100% vessel trip reporting compliance, the proration methodology for partitioning total landings into stock area landings assumed that there was no fleet reporting bias, and that the vessel trip reports submitted represented a random sample. Future examination of the VTR data for potential systematic biases is warranted. The SARC accepted the methodology for prorating total landings to stock area landings for the five stock assessments conducted during SAW-24.

Discard and Effort Analyses from VTR Data

Introduction

In June 1994, NMFS initiated a program requiring all fishing vessel operators with multispecies fishing permits to submit to NMFS a vessel trip report (VTR = logbook) for each fishing trip. These logbooks contain information on many aspects of the fishing trip, including catch and effort information. Discard and CPUE data were historically provided by NMFS port agents who were tasked to perform routine interviews of individual vessel operators to obtain direct information about fishing trips. When the vessel logbook system began, the port agents stopped these interviews. As a result, since the initiation of the logbook reporting system, logbook data have been used to determine information on catch locale and fishing effort. Independent estimates of catch, discards, catch location, etc. are available from a scientific observer program. The observer data, collected by individuals trained in sea sampling procedures and placed aboard vessels during fishing trips, contain precise information on fishing trips. If deemed suitable for use, the vessel logbook data contain information on a much larger number of fishing trips than the observer data. Moreover, there is an insufficient number of observed trips over the years 1994-1996 and covering seasons and gears to estimate discards for the Southern New

England yellowtail stock for these years (Overholtz *et al.* 1997).

The SAW-22 SARC dedicated considerable time to the evaluation of the vessel logbook data and found that it contained some promising information, but needed to be thoroughly audited. Since that time, these data have been audited to the degree and by the methods outlined in Power *et al.* (1997 MS). In an effort to utilize the best available data for the 1997 cod, haddock, and yellowtail flounder stock assessments, the logbook data were evaluated for discard and effort information and the results were compared with those obtained from corresponding observer data.

Discard Evaluation

The vessel logbooks include, but are not restricted to, the date of the fishing trip, the area fished, the gear used, and the approximate weight of all species caught subdivided into discarded and kept portions. The information in these fields can be used to approximate the ratio of discarded catch to kept catch by season, stock area, and gear as needed in the stock assessments. To evaluate the discard-related fields in the 1994-1996 vessel logbook data, a subset was first created of the full vessel logbook data set for each of the years 1994-1996 that consisted of trip reports with valid species, pounds kept, and pounds discarded fields. The logbook subset was then compared to the full logbook data set and the full dealer data set. Since data collected by the observer program provide a good check of the validity and bias of the discard estimates in the logbook discard subset, ratios of discarded catch to kept catch and discard estimates generated from the logbook subset and observer data were calculated and compared.

Vessel Logbook Discard Subset

To create what can be considered the most reliable and least biased subset of the 1994-1996 full vessel logbook data set, those trip reports that did not include any discard information were first removed. More precisely, all trip reports from the full logbook data set that did not include information on the discard of any species were removed. This first reduction resulted in a data set that contained about 30-40% of the landings of cod, haddock, and yellowtail flounder as recorded in the full vessel logbook data set. To ensure the subset was representative of the entire logbook and dealer data sets, the cod, haddock, and yellowtail flounder landings in all three sets were summed by each of the following categories: year, quarter, stock area, gear, and port landed (DeLong *et al.* 1997). Comparison of the distribution of the percent landings over these strata in the dealer and full vessel logbook data sets with the logbook subset can provide insight into the comparability of the logbook subset. Area fished, gear used, and port landed were grouped according to the methods outlined in Wigley *et al.* (1997): Details pertaining to the stock area, gear, and port groupings can be found in Table 7.

Close examination of the distribution of the landings percentages in the three data sets, the dealer, the full vessel logbook, and the vessel logbook subset reveals an observable similarity among the sets. When the landings are aggregated by quarter and gear, the percentage rankings remain the same from one set to another. The cod, haddock, and yellowtail flounder landings by port group and stock area deviate slightly from the full logbook data set and the subset created to evaluate discard rates.

Comparison of Vessel Logbook Discard Subset and Observer Data

The ratio of discarded pounds to kept pounds is expected to vary from trip to trip, regardless whether the trips occurred over the same strata (i.e., gear, stock area, year, quarter, and port). To understand the distribution of this ratio, the ratio of discarded to kept pounds of the 1989-1996 observed trips that landed cod from the Gulf of Maine and utilized gillnet or otter trawl gear was summarized (Figures 9 and 10). The results depicted in these figures indicate a decrease in the number of trips as the ratio increases. The bin farthest to the right includes trips in which the discard/kept ratio was >1.0. In the Gulf of Maine, there were more than 40 otter trawl cod trips with discard to kept ratios greater than 1. If the landings accrued on these trips are large and if the discard ratio is determined by dividing the sum of total discarded pounds by the sum of total kept pounds of the strata, then these trips could skew the discard ratio. The individual Gulf of Maine otter trawl and gillnet cod trip ratios were transformed. The transformation was $R = \ln[(d+1)/(k+1)]$, where d was the total pounds of cod discarded on the trip, k was the total pounds of cod kept on the trip, and R is the transformed discard ratio. Figures 11 and 12 show the distribution of the transformed ratios for the Gulf of Maine otter trawl and gillnet observed trips, respectively. This transformation creates a distribution resembling a normal probability curve.

To compare the discard ratios from the vessel logbook subset with the 1994-1996 observer data set, the transformed ratio of discarded to kept pounds was calculated for each of the gillnet and otter trawl trips in these data sets. The average transformed discard ratio was then computed over year, quarter, gear group, and stock area. Figure 13 provides the results of a comparison of the ratios over these strata. Each point on the graph represents the relationship between the average transformed discard ratios in the logbook subset and the observer data over one stratum. Those points laying upon the axes represent strata that had data in only one of the data sets. The correlation between these data sets is $r = 0.28$ for all data and $r = 0.57$ when zero values are removed.

Georges Bank Yellowtail Flounder Case Study

In the 1997 Georges Bank yellowtail flounder stock assessment, Cadrin *et al.* (1997) compared the total yearly discard estimates for 1994-1996 obtained from the observer data with the total yearly discard estimates for 1994-1996 obtained from the logbook subset. In this analysis, the sea sampling data provided a total of 22, 16, and 18 trips in the years 1994, 1995, and 1996, respectively. Over these same three years, the vessel logbook subset contained 232, 122, and 225 trips, respectively. Cadrin *et al.* (1997) estimated and constructed 95% confidence intervals about the total metric tons of yellowtail flounder expected to have been discarded from this stock for these three years (Figure 14). As there is a significantly larger number of trips in the logbook data than in the observer data, the confidence intervals about the discard estimates are much narrower with the logbook data. For 1994 and 1996, the discard estimates calculated using the logbook subset are not significantly different from the discard estimates calculated from the observer data.

Analysis of Days Absent, CPUE, and Main Species Sought from Weighout and Logbook Data

Methods

Frequency distributions of days absent and catch per unit effort (total pounds landed per day absent) were developed from the Commercial Fisheries Database (weighout from 1991-1996 and logbook data from 1994-1996). Data were analyzed from all trips on which scallop dredges, sink gillnets, and otter trawls were used, and from the subset of those trips that landed cod, haddock, or yellowtail flounder. From 1991-1993, all data were obtained from the weighout database. From 1994-1996, data were obtained from logbooks for participants in the multispecies, scallop, or summer flounder fisheries; otherwise, data were obtained from the weighout database.

The calculation of days absent from weighout data depends on the number of trips contained on the trip record. Weighout data contain information about trips in three formats. A trip record may consist of one trip (ntrips = 1), be a summary of multiple trips (ntrips > 1), or be a part of a trip (ntrips < 1). For weighout data with ntrips = 1, a simple frequency of days absent was calculated. For ntrips greater than 1, the days absent were divided by the number of trips and the number of trips summed. Records with ntrips < 1 were combined to whole trips using month, day, and permit as a link and summing days absent and pounds landed. For CPUE, total trip pounds landed were divided by the days absent.

Logbook data do not contain an explicit days absent field. Therefore, days absent were calculated by subtracting date sailed from date landed and adding 1 to account for day trips. Values ranged from negative to greater than 25 days absent. CPUE was calculated as the sum of pounds landed from the trip divided by days absent (excluding negative observations for days absent).

An analysis of otter trawl cod catch per unit effort was undertaken to see if the data set used in the general linear model of the assessment (O'Brien 1997; Mayo 1997) was consistent over the time series. This involved subsetting the data and deleting records which did not contain information on effects evaluated in the GLM, such as depth, vessel tonnage class, area, and month. Effort was calculated as days absent and as number of hauls times the average tow duration to estimate days fished. Frequency distributions of days absent and CPUE were derived for all cod trips and trips by cod stock area. For Gulf of Maine cod, trips with days absent = 1 were deleted because it appeared that more day boats were reporting under the logbook system. The GLM for Georges Bank cod included an open/closed area effect which required latitude and longitude data. For 1994, all trips with missing location information were deleted. The data for 1995 and 1996 were all assumed to come from the open area.

Results

The frequency distribution of days absent for all trips using otter trawls and sink gillnets appears fairly consistent over the time period (Figure 15). For scallop dredges, the total number of trips declines dramatically in 1994 (Table 9) and the entire frequency distribution becomes flattened, with a possible rightward shift to higher average days fished. The reason for this is unclear.

For otter trawls and sink gillnets that landed cod, haddock, or yellowtail flounder, the overall pattern is similar to the distribution of days absent for all trips, but the number of trips included in the frequency distribution is reduced (Figure 16). This is most likely due to the Amendment 5 regulations which limit bycatch of these species. Distribution of days absent on scallop dredge trips again changes markedly in 1994-1996. The large number of day boats in 1995 is a result of one or two records which included 1,391 trips, some of which must have landed one of the three species. These cannot be disaggregated and probably all trips did not catch cod, haddock, or yellowtail flounder. There are even fewer trips in the scallop data also due to limits on bycatch of groundfish.

Distributions of catch per unit effort by all sink gillnets appear stable from 1991-1996 (Figure 17). Otter trawl trips show a decline in CPUE starting in 1993, which is to be expected with declining stock abundance. Scallop dredge trips show a decline in the right (second) peak of CPUE which may be an artifact of the calculation method of adding 1 for days absent.

Sink gillnet trips that landed cod, haddock, or yellowtail flounder exhibit a slight decline in CPUE, with the height of the mode at 1,000-1,500 pounds per day absent declining, while the rest of the distribution is fairly stable (Figure 18). Otter trawls trips again show a decline in CPUE beginning in 1993. The decline in scallop dredge CPUE also begins in 1993, and the number of trips is low for the rest of the time period. The large value in 1995 is again due to the records mentioned above.

For otter trawl trips landing cod, the decline in CPUE begins a year earlier than for trips landing all species (Figure 19). The decline stabilizes in 1995 and 1996. The number of day trips, however, increases in 1995 and 1996, either due to shorter trips to avoid the closed areas, or better reporting under the logbook system.

When these data are disaggregated by stock area, the pattern is slightly different (Figures 20 and 21). For Gulf of Maine cod, the shift in CPUE to lower values is very distinct, particularly between 1993 and 1994 (Figure 20), but CPUE increases slightly thereafter. Removing days absent = 1 from the distribution does not change the distribution except to lower the number of trips over the range of CPUE values. The decline in Georges Bank cod CPUE does not occur until 1995, which is the first full year of the area closures (Figure 21). Again, the number of day trips increases in 1994-1996. Removing missing location information in 1994 does not change the distribution.

Conclusions

Although this analysis provides only a cursory understanding of the discard data in the vessel logbook data set, the 1994-1996 vessel logbook data appear to contain useful information for estimating discard rates and total discards to be used in the cod, haddock, and yellowtail flounder stock assessments. At the very least, these data serve as a check of the estimates calculated using the observer data. In the event that there is an insufficient number of observed trips, the vessel logbook data are the only alternative consistent data source for these estimates.

Caution must be taken in using any CPUE estimates based on logbook data. Until a better understanding of the effort field is reached, CPUE in recent years cannot be considered a smooth, continuous extension of the previous time series.

SARC Comments: Discard and Effort Analyses from VTR Data

The SARC noted the potential bias associated with using a discard ratio derived from only VTR data reporting discards. Approximately 30-40% of the VTR data include reports of any discards, and it appeared unlikely that 60-70% of the trips were retaining all fish that were caught. However, the SARC agreed that the discard ratio derived from VTR data seemed to correspond (similar in magnitude) to observed discard rates in the Domestic Sea Sampling Program. The SARC noted the possibility of a relationship between discard ratio and catch size and recommended that catch size or a running average of catch size could be included as a covariate in future analyses.

Due to several changes in management regulations that went into effect during 1993-1996, including mesh size changes, closed areas, and trip limits, the observed changes in cod CPUE patterns could not necessarily be attributed to any particular regulatory change. The SARC discussed the recording of effort data in the vessel trip reports, i.e., was effort recorded by fishermen similar to effort recorded by port agents during an interview under the voluntary system? Further investigation of how effort is recorded in the VTR may be warranted.

Research Vessel Door Conversion Factors

The NEFSC has conducted bottom trawl surveys since the early 1960s to collect information on groundfish populations. During this time period, equipment (e.g., ships, types of trawls) has changed. Two research vessels, *Albatross IV* and *Delaware II*, have conducted all the spring and autumn surveys, the choice depending on the availability of the two ships (Byrne and Forrester 1991a). During 1973-1981, spring surveys used a larger and higher opening trawl in an attempt to better sample pelagic resources (Sissenwine and Bowman 1978). Beginning in 1985, the otter trawl doors, used to spread the trawl when fishing, were switched from a wood and steel 'BMV' door of Norwegian manufacture, to an all steel 'polyvalent' door of Portuguese manufacture (Byrne and Forrester 1991b). Analyses were conducted to determine whether catchability of the doors was different and, if differences were found, to determine the magnitude of the differences. Standard analysis of variance (ANOVA; Byrne and Forrester 1991b; Forrester 1997 MS) was used to test for differences between doors. The results from these analyses were used to calculate conversion coefficients. These conversion coefficients were used to adjust the catches obtained using the BMV door to make them comparable to catches using the polyvalent door.

The effect of door type is larger generally than the effect of vessel type (Table 10). Vessels have been substituted or used in tandem for various surveys, and this practice continues. The vessel effect thus becomes an intermittent factor in the survey time series. The larger net was used for a brief part of the series, but only in spring surveys; net effects were only estimated for yellowtail flounder. Therefore, the effect of vessel and trawl net differences is expected to have a smaller overall effect on the assessments. The doors, however, represent an intervention in the most recent years in the time series, and the estimated relative catchabilities (for catches in numbers) are significantly different among the door types for cod, haddock, and yellowtail flounder, among other species.

Forrester (1997 MS) describes the estimator used for calculating vessel and door calibration coefficients. Survey catches are assumed lognormal; $\log_e$ catches in numbers were used in a general linear model to estimate the calibration coefficient. A bias correction was used in back-transforming the estimated calibration coefficient to the linear scale. A similar calibration coefficient was estimated for vessels. Pairwise data from directed experiments and parallel surveys were used to estimate the calibrations. Only pairs where positive catches were obtained by both doors or vessels were used in fitting linear models to estimate parameters.

ANOVA assumes a linear relationship among fixed gear effects and the natural log of number of individuals captured; an additional assumption is that the data have a log normal distribution. Only paired samples with non-zero results for individual species were used in the analysis. All data were log transformed. The ANOVA approach is reasonable to test hypotheses concerning the comparability of gear. However, if the transformed data are not normally distributed, results may not be reliable. In the present case, residual analysis did not reveal any substantial problems with the data.

The elimination of data for paired tows in which one or the other (but not both) of the door (or vessel) catches was zero raises the question whether the procedure results in a systematic bias in the estimated coefficients. All data from the door experiments where at least one of the catches was non-zero are given for haddock, cod, and yellowtail flounder in Figures 22-24. Data points along the axes are interpreted as: (0,y) representing zero catches by BMV doors and positive catches by the polyvalent doors, or (x,0) representing zero catches by polyvalent doors and positive BMV catches. For all three species, zero points along the y-axis outnumber x-axis zeros, and the average polyvalent catch when BMV catch is zero exceeds the average BMV catch when polyvalent catch is zero. This observation is consistent with the direction of the estimated calibration coefficients, indicating greater catch rates for polyvalent doors.

The SARC considered additional analyses of the robustness of the estimated door calibration coefficients to the inclusion of data in which one member of the data pair was zero. The estimated median line through all data points and summary statistics for polyvalent and BMV door catches are given in Figures 22-24. For all three species, the slopes of the median lines through the data (i.e., median value of polyvalent catches ÷ BMV catches) are close to the calibration coefficients calculated from only positive pairs of data. These additional analyses suggest that the estimated calibration coefficients are not substantially biased by the exclusion of data when one of the pairs was a zero catch.

SARC Comments: Door Conversion Factors

The SARC discussion of the door conversion factors centered on the use of zero values in the analyses. The secondary issue of an appropriate transformation hinged on whether zero values should be included in the analyses. The SARC reviewed additional exploratory analyses of the gear comparison data conducted after the Working Group meeting. Scatter plots of all data, including non-zero:zero pairs with a median slope through all data points, were presented. Original analyses of gear conversion factors had excluded non-zero:zero paired data. The SARC concluded that there was no major effect by excluding the zero values in the original analysis, that the polyvalent doors had a higher catchability, and that other methods could be explored to fine-tune the magnitude of the door conversion coefficient. A joint group of US and Canadian scientists had previously agreed to investigate other methods of estimating door conversion factors.

The SARC recommended that additional analyses on the gear (door, vessel, net) conversion coefficients for the trawl surveys be conducted to examine the robustness of the estimates. In particular, the paired tows with zero catches should be incorporated into the analyses. As well, consideration could be given to explicitly incorporating conversion coefficients as parameters in the calibration procedure. Sensitivity analyses presented at the meeting indicated that the inclusion of zero tow data had no significant effect on the calibration coefficients used to adjust for door effects.

Estimation of Bias in Results of Virtual Population Analysis

Estimation of bias in results of virtual population analysis (VPA) from ADAPT formulations has been commonly done using bootstrap methods; or the method of Box (1971), as described in Gavaris (1993). Implementation of the bootstrap method for these assessment is based on re-sampling residuals from predicted survey indices, and re-estimating results of the VPA. The bias is calculated as the difference between the mean of the bootstrapped results and the original point estimate. Bias correction can be described as an analogy: the mean of the bootstrapped estimates is to the original point estimate as the original point estimate is to a bias-corrected point estimate. Thus, if the mean of the bootstrapped estimates is larger than the original point estimate, it would be assumed that the original point estimate would be an overestimate of the true unbiased point estimate.

The SARC identified several difficulties in completely implementing bias correction of assessment results. At the most basic level, the quality of the estimate of bias must be established. In the case of bootstrap results, bias estimates may be sensitive to the number of bootstrap iterations given a particular bootstrap framework and would also be sensitive to the details of the bootstrapping application (e.g., if additional or different sources of uncertainty were included in the design of the bootstrap). For the Box (1971) method, assumptions of, for example, normally-distributed error terms must be reasonable.

Some of the operational questions arising in the process of bias correction have included:

1) If estimates of stock numbers (N) are bias-corrected, how should corresponding estimates of fishing mortality (F) be adjusted? Currently, it is possible for estimates of both N and F to appear to require, say, downward bias correction. Since F is a derived quantity from the estimated N and the fixed catch (C), decreases in N should always yield increases in F. While the magnitude of the increase in F will vary non-linearly with N, the direction of change should be internally consistent with the structural equations of the VPA. (Large bootstrapped values of N have corresponding small values of F for an observed value of catch: realizations of N-F pairs map onto different sides of the medians of distributions which are generally skewed to the right.)

2) If distributions of bootstrapped realizations serve as the basis for stochastic projections, how should individual realizations be bias-corrected?

3) If distributions of bootstrapped realizations serve as the basis for confidence intervals around point estimates, how [or] should the distribution be adjusted? The empirical distribution of bootstrap realizations provides a means of characterizing the variability of the estimates and a means of estimating the bias. It is not clear that a simple recentering of the empirical distribution at the bias-corrected point estimate is equivalent to the sampling distribution of the bias-corrected estimator. Thus, the inferential properties of the original bootstrap values may not apply to the construction of confidence intervals for the bias-corrected values.

4) If point estimates of N are bias corrected, how should that effect be reflected in the results of the revised VPA, e.g., in the case of bias-corrected plus groups which in some cases would have been originally estimated with a forward-projection algorithm?

It is important to note that the bias estimate from a bootstrapping procedure is a statistical property of the estimator and not necessarily an indicator of factors which give rise to retrospective patterns in VPAs. In general, processes that generate retrospective patterns (such as underestimation of catch) are likely to result in much larger deviations between the estimate and the "true" state of nature than the bias adjustment. Hence, it seems prudent not to change current procedures until future theoretical work is conducted.

SARC Comments: Estimation of Bias in Results of Virtual Population Analysis

The SARC supported the Working Group's conclusion not to bias-correct projections until a full understanding of the underlying processes in ADAPT was obtained. The SARC noted that there were different ways to perform a bias correction, and each method yields different answers. The SARC consensus was that bias correction was an unsolved issue and a technical area for future research.

Several discussions took place relative to bias-correction of the assessment estimates. Bias correction is routinely done in some assessments in Atlantic Canada. However, the SARC recommended that bias corrections not be routinely performed. There are several ways of estimating bias and several ways of 'correcting' for it. The SARC recommended that the following steps be taken in sequence: a) use bias estimates as another assessment diagnostic; b) if a bias is present, attempt to find out what causes it, perhaps through simulation; c) accordingly, attempt to modify the model in order to eliminate or reduce the bias; d) when it seems prudent to do so, apply a bias correction.

Medium-Term Projection Methodology

Amendment 7 to the Multispecies FMP included a series of 10-year stochastic projections of spawning biomass, recruitment, and catch for Georges Bank cod, Georges Bank haddock, Georges Bank yellowtail flounder, Gulf of Maine cod, and Southern New England yellowtail flounder. These projections were undertaken to assess the probabilities of rebuilding spawning stock biomass to minimum threshold levels established by the New England Fishery Management Council (NEFMC) and as a basis for economic evaluations of the consequences of alternative rebuilding strategies. Biomass threshold values (Georges Bank haddock = 80,000 mt, Georges Bank cod = 70,000 mt, Georges Bank and Southern New England yellowtail flounder = 10,000 mt) were based on historic stock/recruitment data for these stocks and were defined as minimum biological thresholds above which the probability of good recruitment would improve. They were not intended to be management target levels (NEFMC 1996). No threshold value for the Gulf of Maine cod stock was established due to the shortness of the spawning stock biomass and recruitment time series.

Results from the revised assessments contained herein indicate that, with the exception of Gulf of Maine cod, fishing mortality rates have declined substantially to, or below, $F_{0.1}$ levels, and spawning stock biomass levels have stabilized or increased modestly. New sets of 10-year projections were completed to re-assess the medium-term prognoses for these five stocks. Specific projection results are presented in the individual stock sections of this report

The medium-term forecasts assumed a time horizon of ten years, beginning on January 1, 1997 (1997-2006). Starting (1997) stock sizes for each 10-year projection were obtained from 1997 ADAPT results. Bootstrap re-sampling of the ADAPT results for each stock produced an input matrix of 200 realizations of starting population numbers at age. Natural mortality rates, mean weight at age, partial recruitment (PR) patterns, and maturity schedules were the same as used in the new assessments (mean weights, PRs and maturities were averages of 1994-1996 values). For Southern New England and Georges Bank yellowtail flounder, discard fractions at age were estimated from ratios of discards to catches for 1994-1996 and used to estimate discards in the 10-year scenarios, assuming a constant fraction of the catch.

Time series of spawning stock biomass (SSB) and recruitment (R, age 1) for each of the five stocks were used to fit Beverton and Holt stock/recruitment relationships. Variability in recruitment was assumed lognormal (Hilborn and Walters 1992); nonlinear regression was used to estimate the parameters of the Beverton and Holt model:

$$R = \frac{a * SSB}{b + SSB} * e^{w}$$

where w is a random variable ~ $N(0,s^2)$.

The estimated parameters for stock recruitment model fits are presented in Table 11. Maximum recruitment values estimated by the models are given in Table 12. Estimated a and b parameters are in general agreement with previous results used in Amendment 7 (NEFMC 1996; Brodziak 1994). Any differences are due to the addition of several years of new data to each series and some slight changes in stock and recruitment estimates for some years from the ADAPT tuning process.

Residuals from the nonlinear estimations were tested for time trends in differences between observed and predicted recruitment for the five stocks. With the exception of a 1-year lag for Southern New England yellowtail flounder, no significant autocorrelations were found for any of the stocks in an examination of first- to sixth-order autocorrelations. The residuals from the model fits were tested for the assumption of lognormality. In all cases, the assumption of lognormal residual patterns for the five groundfish stock could not be rejected at the 0.05 level.

Stochastic projections using the fitted Beverton-Holt stock-recruitment relationships were accomplished in the following manner:

1) Each of the bootstrap realizations of initial (1997) stock size from ADAPT were used separately as the starting point for a 10-year projection sequence.

2) Recruitment for each year of the projection was computed using the fitted S/R relationship and the projected SSB. Calculated recruitment incorporated multiplicative lognormal error. A total of 100 10-year projections were made for each initial vector of stock size.

3) Several different fishing mortality rate scenarios were evaluated ($F_{0.1}$ and F_{96} for each stock, and F = 0.0 for Gulf of Maine cod and F = 0.10 for Georges Bank haddock). The AGEPRO projection software (Brodziak and Rago 1996) was used for these analyses.

The Beverton-Holt equation with multiplicative lognormal error has the potential to generate recruitment values that are much larger than and possibly far out of the range of the available empirical data series (Brodziak 1994 MS). Therefore, as in the previous 10-year projection analyses, recruitment was constrained by values within the observed time series for each stock. This was accomplished by using a threshold SSB corresponding to the lowest observed level, below which only R/SSB values that were within the 80% CI of the empirical distribution were allowed. If the SSB level was greater than the observed minimum SSB, the R/SSB value was allowed within the range R/SSB_{min} to R/SSB_{max} for the empirical R/SSB distribution. Values for these constraints from the empirical stock-recruitment series are presented in Table 12.

In the case of Gulf of Maine cod, recent R/SSB and spawning stock biomass levels are low and declining, and the fishing mortality rate in 1996 was far above biological reference points. Projections at low spawning stock sizes may be overly optimistic if survival rates (measured as R/SSB) are non-stationary (e.g., declining with stock size or in recent time), and short-term prospects for resource recovery are low due to declining SSB and high fishing rates. In this case, the SARC concluded that a more conservative medium-term projection should set the upper R/SSB constraint equal to the long-term median of the series (0.3 recruits/kg SSB), and the lower R/SSB to 0.0, when SSB was below the observed minimum in 1994. These revised constraints were used for three medium-term projections for Gulf of Maine cod: F_{96} = 1.04, F_{max} = 0.29, and F = 0.00.

Medium- and long-term projections utilizing stock-recruitment models are intended to provide strategic advice on optimal harvest policies, stock recovery strategies, and economic benefits for fish stocks (Hilborn and Walters 1992). Results from these approaches are most useful for comparisons among management scenarios and are not intended to provide point estimates relative to management reference values or targets (Overholtz *et al.* 1995). Results of medium-term projections are, therefore, presented as the median and inter-quartile ranges of annual spawning stock biomass, recruitment, and landings. The short-term (2-year) projections included in each stock section of this report should be considered the more robust result for near-term stock status.

SARC Comments: Projections

When assessments are conducted, a variety of models should be used to explore stock trends while encapsulating uncertainty. Similarly, when stock projections are conducted, it may be necessary to explore a variety of scenarios to adequately represent the gains and risks associated with management actions.

The SARC recommended that projections of stock trends, recruitment, and landings be examined under a variety of harvesting strategies and, when necessary, a variety of model projection forms that encapsulate the uncertainty in the predictions.

The SARC recognized that, while stock assessment scientists are not responsible for determining harvesting guidelines, they should provide a full range of harvest strategies with predicted results to establish the likely outcomes of management actions. Predictions should be summarized in such a manner that they convey expected trends, their uncertainty, and the likelihood of achieving or exceeding biological reference points.

Generic SARC Comments

Overview

The SARC agreed that while the signals emerging from the assessments on stock, recruitment, and fishing mortality trends appear decisive, it also seems clear that a number of steps can be taken to strengthen these analyses in terms of data utilization, modeling, and prediction methodology. It was noted that the SARC Assessment Methods Working Group has been inactive for several years. It was suggested that this Working Group, with outside participation, convene in the near future to consider and prioritize the recommendations herein (and other relevant ones) and establish a timetable for actions.

Fishery Statistics

Fishery statistics play an important role in the assessments. The coverage of valuable statistics such as age-length keys and length-frequency samples over time and space is uneven for the various fishery components (directed gears, bycatch, discards). A robust protocol for assigning catches to statistical areas is needed, and efforts should be made to substantially increase the intensity of sea and port sampling. Furthermore, the recent VTR data should be audited exhaustively. Recreational catches are becoming increasingly more important for various stocks and should be monitored more directly.

Commercial CPUE data have been analyzed by general linear models for estimation of standardized effort and for possible inclusion in the calibrated VPA. The SARC agreed with the recent practice to not include such CPUE data in tuning unless they are found to be adequate in terms of quality and coverage. Consideration should be given to initiating joint projects with the fishing industry which could provide consistent CPUE time series. Nevertheless, it was noted that existing CPUE data can be useful by themselves in exploring the spatio-temporal dynamics of stocks and fleets, and, potentially, the effect of regulations. As such, further analyses incorporating interaction terms (e.g., area x quarter) would be useful.

Research Vessel Surveys

The fishery-independent survey data collected by the NEFSC since 1963 is perhaps the single most important type of information available for the Region from the point of view of stock assessment. It provides an independent means of monitoring stock trends and is also the basis for calibrating the quantitative assessments. Further analyses of these data are desirable.

Nature of the survey data

The survey data are sometimes indicative of very clumped fish distributions, and a single tow can be very influential on the calculated indices for use in tuning (e.g., Georges Bank haddock). The SARC considered it important to conduct more analyses of these data separately from the calibration to ultimately have a better basis for deciding how the indices should be modeled in the objective function.

Several types of exploratory analyses were identified as potentially useful. Bootstrapping sample distributions or incorporating all of the survey data into the assessment algorithm might better represent the distributional properties of the estimated indices of abundance, in contrast to including simple means alone. In the case of influential tows, detailed spatial analyses (e.g., kriging, re-stratification) could provide alternative estimators of relative abundance that better account for heterogeneity among observations. Generalized linear models with non-Gaussian error distributions could be explored for the purpose of obtaining more robust estimates of abundance, but such an analysis might be better included directly in the full stock assessment algorithm.

The assumed error distribution for the indices in the objective function of the tuned assessment should be revisited after conducting the exploratory analyses. Currently, the assessments reviewed assume that the indices (stratified mean numbers per tow) are lognormally-distributed, and the indices are given equal weight. Other weighting methods and error distributions may be more appropriate, depending on the data and the estimators. This should be examined carefully by the exploratory analyses, by simulation, and based on available biological information. How individual index values are (or are not) weighted should be considered carefully. Weighted Gaussian, over-dispersed Poisson, or a multinomial distribution are possibilities which could reduce the influence of influential tows.

Treatment of zero indices in VPA calibration

The age-specific survey indices are assumed to be lognormally distributed for calibration with ADAPT. This constitutes a problem for index values equal to zero, which are treated as missing observations. However, the zeros are an indication of low densities which should be considered in the analyses. As the stocks decline in abundance, the occurrence of zeros will increase, perhaps biasing results if ignored. The SARC recommended that the objective function in the calibration routine be modified so that it can more naturally account for zero values, e.g., by assuming a normal, Poisson, or other suitable distribution. The SARC also recommended against adding arbitrary constants to the survey indices before logarithmic transformation as this practice can uncontrollably influence the results.

<u>Assessments</u>

The SARC felt that the assessments could be strengthened in several ways, as discussed below. The role of the assessment scientist with respect to uncertainty in stock status and prediction can be viewed as a two-step process: minimizing uncertainty or accounting for it, and then describing the remaining uncertainty. The ADAPT assessments reviewed use a conditional non-parametric bootstrap to describe uncertainty. The SARC did not discuss the pros and cons of this approach in any detail. Instead, the discussions focused on alternative analyses which may account for the various sources of information available in different ways.

Sources of mortality

The analyses reviewed included various sources of mortality (commercial and recreational catches and discards) to different degrees. While the overall management advice may be robust to ignoring some sources, it could be improved by including all sources of mortality more explicitly. The SARC recommended that efforts be devoted to estimating sources of mortality (and their variability) in time for possible inclusion in future assessments. These include commercial catches by fleet, recreational catches (and survival of released fish), discards (and their survival), and indicators of fluctuations in natural mortality (e.g., from the Food Habits Investigation). Once compiled, such statistics should be included into the assessments with weightings that represent the reliability of the information they contain.

ADAPT

ADAPT is used with a rather uniform model structure across stocks in the Northeast. However, it is evident that relatively minor modifications to the software would allow for more flexible modeling of each stock, depending on the circumstances. It was recommended that the software be made more adaptable in the near future and that it include built-in graphic presentation capabilities.

Other age-structured methods

Existing methods used elsewhere, which integrate the various inputs in a more comprehensive manner and allow for process error in the catch, should be considered. For example, certain integrated approaches (e.g., Stock Synthesis and similar variants) allow for weighting (sampling variance and/or 'credibility') of the various catch, length frequency and age samples, and relative abundance inputs. These approaches could bring several benefits, including the possibility of extending the assessment time series back in time to years where less intensive sampling was in place.

It was also noted that an age-structured version of the modified DeLury model of Collie and Sissenwine (1983) would be a useful assessment tool which also includes process error, the results of which could be used for comparison with other assessment techniques.

More aggregated models

Other types of models are useful for examining long-term dynamics, as evidenced by the dynamic production model applied to Georges Bank yellowtail flounder data. The SARC recommended that more of these methods be considered for alternative analyses, including the simple modified DeLury model, age-structured production models, and delay-difference models.

Research Recommendations

Fishery Statistics

- Investigate the use of general linear models (GLM) to evaluate factors associated with discard ratios and to quantify the relationship among factors.

- Biological sampling to determine the length and age composition of commercial landings, discards, and recreational catches must be of sufficient intensity to support assessment needs. The recreational fishery should be monitored more closely to improve estimates of total catch.

- Full auditing of all vessel trip report records must be completed, and design changes required to allow integration of all commercial fishery databases, including biological sampling, should be implemented as soon as possible.

- Examine the effect of shrimp trawls separately from otter trawls, in discard analyses.

- Investigate the use of a species composition index (e.g., PCA, cluster analysis) instead of gear type to determine the fishery stratification used in the discard estimation from VTR data.

Research Vessel Surveys

- Additional statistical analyses associated with calibration of vessel, door, and trawl effects should be undertaken, including: a) the effect of the log transformation in the analysis, b) the potential for non-linear differences in catchability between door types with abundance, c) the effect of combined vessel-door effects vs. the separate multiplicative effect of the vessel and door effects, d) the influence of outliers on the estimates of door conversion factors, e) effects of changes in vessel speed and bottom type on door performance, f) effects of excluding the zero catches from the analyses, g) use of distribution-free analysis methods, h) the impacts of patchiness in fish distributions on the analyses of conversion factors, and I) the effects of size and/or age on survey door catchability, if possible.

- Examination of the effects of potential misreporting of historical catches on the residual patterns observed in VPAs should be conducted.

- Means of explicitly incorporating conversion coefficients as parameters in the VPA calibration procedure should be investigated.

- Alternate approaches for treating survey data should be examined, including: a) inverse variance weighting, b) spatial weighting, c) distribution-free models (e.g., kriging, GAMS), and d) alternate distribution models to deal with zeros (e.g., Poisson).

Assessments

- The objective function in the calibration routine could be modified so that it can more naturally account for zero values, e.g., by assuming a normal, Poisson, or other suitable distribution. Arbitrary constants should not be added to the survey indices before logarithmic transformation, as this practice can uncontrollably influence the results.

- Bias corrections need not be routinely performed, but bias should instead be first estimated as a diagnostic, and modifications of the calibration formulation should be investigated to try eliminating or reducing the bias. Operational procedures for implementing bias correction in forward and back calculations should be developed.

Medium-Term Projections

- A variety of projection models should be investigated.
- A full range of potential harvesting strategies should be presented to managers.
- Uncertainty, i.e., the likelihood of achieving targets/thresholds, should be incorporated into medium-term management advice.

Model Development

- Other model formulations of the stock analysis (allowing for error in the catch-at age component, for example) should be explored to address the incorporation of information and uncertainty as it pertains to each specific stock.
- Models which address long-term stock dynamics should be considered for alternative analyses, including the simple modified DeLury model, age-structured production models, and delay-difference models.

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Table 6. Cod, haddock and yellowtail flounder landings (mt, live wt) from the dealer report data, the vessel trip report data and the matched set data, 1994-1996.

		Dealer Report Sets		Vessel Trip Report Sets		Matched Set[3]	
Species	Year[1]	All	Reduced[2]	All	Reduced[2]	Vtr	Dealer
Cod	1994	10717.4	10694.5	7960.8	7751.6	4128.8	5027.9
	1995	13670.9	13576.8	10378.9	10092.7	5542.6	6659.3
	1996	14221.1	14196.8	11236.4	10975.8	5478.8	6652.6
Haddock	1994	222.9	222.2	170.6	164.4	88.0	99.8
	1995	410.4	409.2	314.0	301.8	165.9	185.6
	1996	570.3	569.6	497.2	485.5	217.7	240.6
Yellowtail Flounder	1994	2495.1	2490.8	2171.4	1925.7	892.1	952.2
	1995	1928.6	1916.5	1753.2	1716.6	789.9	789.8
	1996	2342.8	2339.1	2265.8	2221.0	900.4	906.6

[1] Values for 1994 represent the portion of landings which needed to be prorated (total 1994 cod landings were 17790.5 mt, haddock landings were 329.7 mt, and yellowtail flounder landings were 3098.7 mt). 1996 Landings are provisional.

[2] Data sets were reduced by eliminating observations where port, vessel permit, month landed, day landed, or area equaled zero.

[3] Matched set is the joined set from the reduced dealer report set and the reduced vessel trip report set. This set contains both the dealer report recorded weight, and the 'kept' weight from the vessel trip report.

Table 7. Stock areas, port groups, gear groups and market category groups used in the proration of cod, haddock and yellowtail flounder landings.

Statistical areas associated with species stock areas:

Cod:	
Gulf of Maine:	Areas 510-515.
Georges Bank, west:	Area 520-526, 530, 537-539, 600-639.
Georges Bank, east:	Areas 560, 561, 562, 551, 552.
Area 500:	Area 500.
Other:	All other areas not listed above.
Unknown:	no vessel trip report data in cell to prorate dealer landings.
Haddock:	
Georges Bank, west:	Area 520-526, 530, 537-539, 600-639
Georges Bank, east:	Area 560, 561, 562, 551, 552.
Area 500:	Area 500.
Other:.	All other areas not listed above.
Unknown:	no vessel trip report data in cell to prorate dealer landings.
Yellowtail flounder:	
Georges Bank:	Areas 522, 525, 560, 561, 562, 551, 552.
Southern New England:	Areas 526, 530, 537-539.
Area 500:	Area 500.
Area 520:	Area 520.
Other:	All other areas not listed above.
Unknown:	no vessel trip report data in cell to prorate dealer landings.

Port groups:

Cod and Haddock
Portland and Gloucester
All other Maine, all NH, Sandwich, Provincetown and MA counties = 07,11,13,15
Boston
Chatham and Harwichport
New Bedford and Nantucket
All other ports south and west.

Yellowtail flounder
All Maine, All NH, Sandwich, Provincetown, and MA counties = 07,11,13,15
Boston, Gloucester and Fairhaven
New Bedford
Other MA counties = 01,03,05
Newport, RI and CT
Point Judith and all other Rhode Island ports
All other ports south and west.

Gear groups:

Cod and Haddock
hook gear
otter trawl gear
gillnet gear
unknown gear
all other gears

Yellowtail flounder
otter trawl gear
gillnet gear
dredge gear
unknown gear
all other gears

Market Category groups:

Cod:
Large ('whale', 'steaker' and 'large')
Market
Scrod ('snapper' and 'scrod')
Unclassified ('unclass. round' and 'unclassified')

Haddock:
Large
Scrod ('snapper' and 'scrod')
Unclassified ('unclass. round' and 'unclassified')

Yellowtail flounder:
Large
Small ('medium' and 'small')
Unclassified

Table 8. Prorated commercial landings (mt-live weight) by species and stock area for cod, haddock and yellowtail flounder during 1994-1996. Bold-faced entries were derived by re-distributing landings from unknown areas and Area 500/Area 520. Georges Bank stock area landings are the sum of values for Georges Bank, east and Georges Bank west. Bold-faced entries were derived by individual stock assessment scientists (cod: R. Mayo; haddock: R. Brown; and yellowtail flounder: S. Cadrin; personal communication)

Species	Stock Area[1]	YEAR 1994	1995	1996
Cod	Gulf of Maine	7865.7	6764.6	7173.9
	Georges Bank, west	8651.5	6064.0	6229.3
	Georges Bank, east	1226.9	662.0	771.4
	Area 500	8.7	6.2	24.8
	Other	20.8	113.8	7.5
	Unknown	17.0	60.4	14.3
	Total	17790.5	13670.9	14221.1
	Gulf of Maine	**7877.0**	**6797.7**	**7193.6**
	Georges Bank	**9892.6**	**6758.9**	**7019.9**
Haddock	Georges Bank, west	184.2	194.0	275.4
	Georges Bank, east	32.6	21.2	35.3
	Area 500	0.7	.	3.2
	Other	110.8	189.8	255.1
	Unknown	1.4	5.4	1.3
	Total	329.7	410.4	570.3
	Georges Bank	**218.2**	**218.1**	**313.1**
Yellowtail Flounder	Georges Bank	1576.9	289.6	744.3
	Southern New England	223.5	185.2	283.2
	Area 500	.	0.0	.
	Area 520	13.2	0.6	8.6
	Other	1278.7	1438.0	1296.4
	Unknown	6.4	15.3	10.2
	Total	3098.7	1928.6	2342.8
	Georges Bank	**1588.5**	**292.1**	**751.3**
	Southern New England	**224.6**	**186.5**	**285.2**

[1] See Table 7 for statistical areas associated with stock areas. 1996 landing are provisional.

Table 9. Total number of trips in three gear categories from 1991-1996 using the weighout and the vessel logbook data. The data are given for all trips and for trips landing cod, haddock, or yellowtail.

	All Trips			Cod, Haddock, and Yellowtail Trips		
	Scallop Dredge	Sink Gill Net	Otter Trawl	Scallop Dredge	Sink Gill Net	Otter Trawl
1991	17024	16656	36310	2396	13899	24445
1992	16920	16931	36175	2397	13669	23821
1993	17661	17255	35120	2012	13906	20430
1994	9585	14113	37610	596	9779	15777
1995	5635	17214	40368	1747	11169	13742
1996	8572	15285	38842	490	8924	13682

Table 10. Estimated survey calibration coefficients used to adjust standardized trawl survey data time series.

Species	*Vessel Coefficient*[1]	*Net Coefficient*[2]	*Door Coefficient*[3]
Haddock	0.79 (0.69-0.94)	not estimated	1.49 (1.18-1.82)
Cod	0.82 (0.69-0.95)	not estimated	1.56 (1.33-1.88)
Yellowtail Flounder	0.85 (0.77-0.96)	1.76 (1.31-2.41)	1.22 (1.02-1.39)

[1] Ratio of catch of ALBATROSS IV to DELAWARE II (includes 95% CI)
[2] Ratio of catch of Yankee 41 to Yankee 36 trawls (includes 95% CI)
[3] Ratio of catch of Polyvalent to BMV trawl doors (includes 95% CI)

Table 11. Estimated parameters[1], variance (S^2), and series duration for Beverton and Holt stock/recruitment relationships fit with nonlinear regression for five groundfish stocks.

Stock	a	b	S^2	Time series
Georges Bank cod	37745.13477	95826.72456	0.239801	1978-1995
Georges Bank haddock	17105.55857	39738.40459	1.8728415	1968-1995
Georges Bank yellowtail	50089.70202	10737.07716	0.4203756	1973-1995
Gulf of Maine cod	5593.837237	2542.61787	0.6822985	1982-1995
Southern New England yellowtail	21851.34499	1421.76952	1.1776888	1973-1995

[1] $R = [a*SSB/b+SSB]*e^w$, where $w \sim N(0,S^2)$.

Table 12. Values for observed minimum spawning stock biomass (SSB_{min}), minimum recruitment per spawning stock biomass (R/SSB_{min}), lower limit of the 80% confidence limit on recruitment per spawning stock biomass (R/SSB_{10}), upper limit of the 80% confidence limit on recruitment per spawning stock biomass (R/SSB_{90}), and maximum observed recruitment per spawning stock biomass (R/SSB_{max}) for the five groundfish stocks.

Stock	SSB_{min}[1]	R/SSB_{min}	R/SSB_{10}	R/SSB_{90}	R/SSB_{max}
Georges Bank cod	31,317	0.1070	0.1265	0.4462	0.7722
Georges Bank haddock	10,938	0.0096	0.0445	1.2184	5.6173
Georges Bank yellowtail	2,299	0.4558	1.0318	5.9047	7.1427
Gulf of Maine cod	8,810	0.0900	0.1295	0.6838	1.5055
Southern New England yellowtail	1,057	0.2677	0.6326	10.6236	71.3602

[1] Metric tons.

[2] Note that the Gulf of Maine cod projections used $R/SSB_{90} = 0.3$ and $R/SSB_{10} = 0.0$ when $SSB < SSB_{min}$.

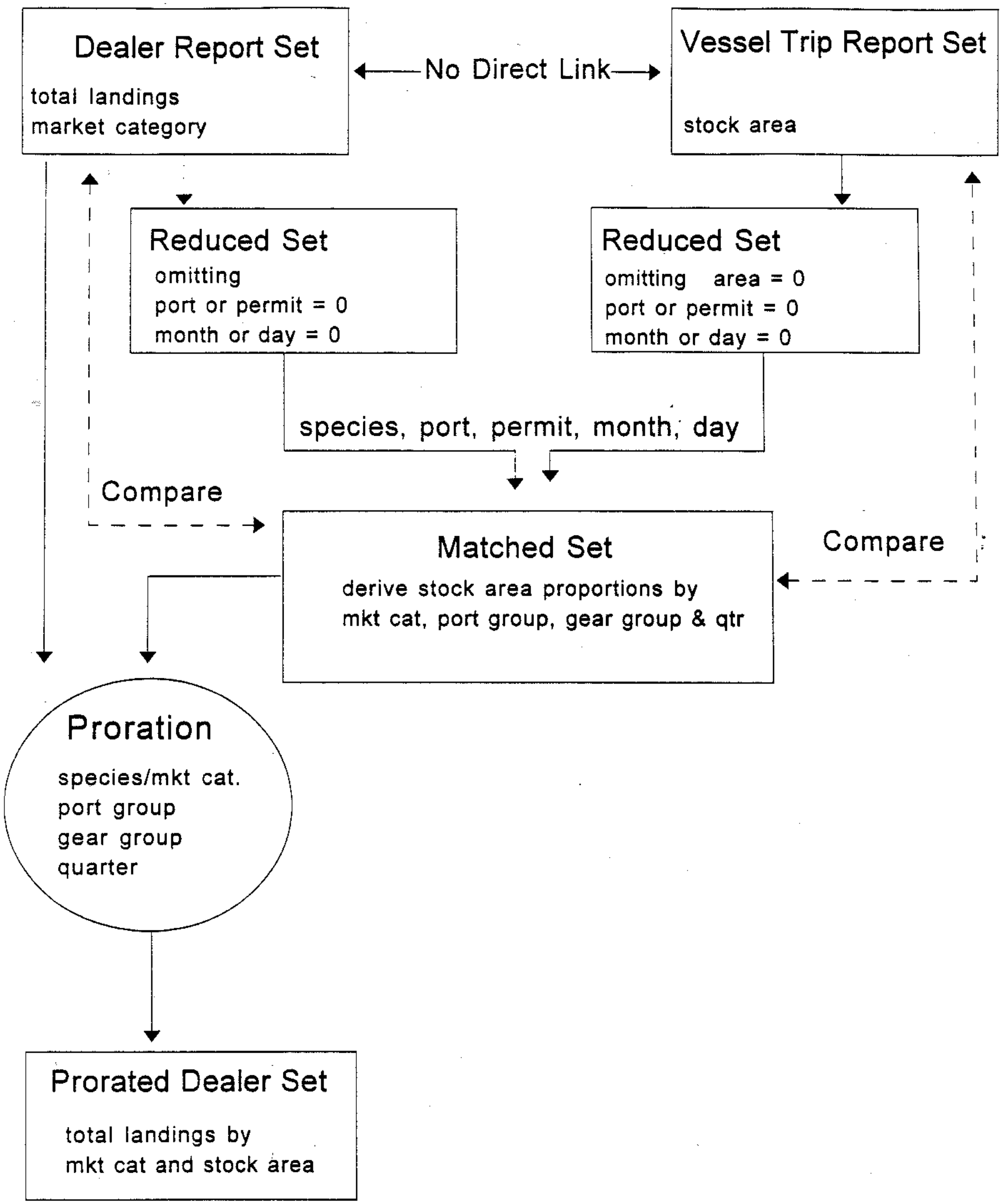


Figure 2. Diagram identifying data sets used in the proration of commercial landings for cod, haddock and yellowtail flounder during 1994-1996.

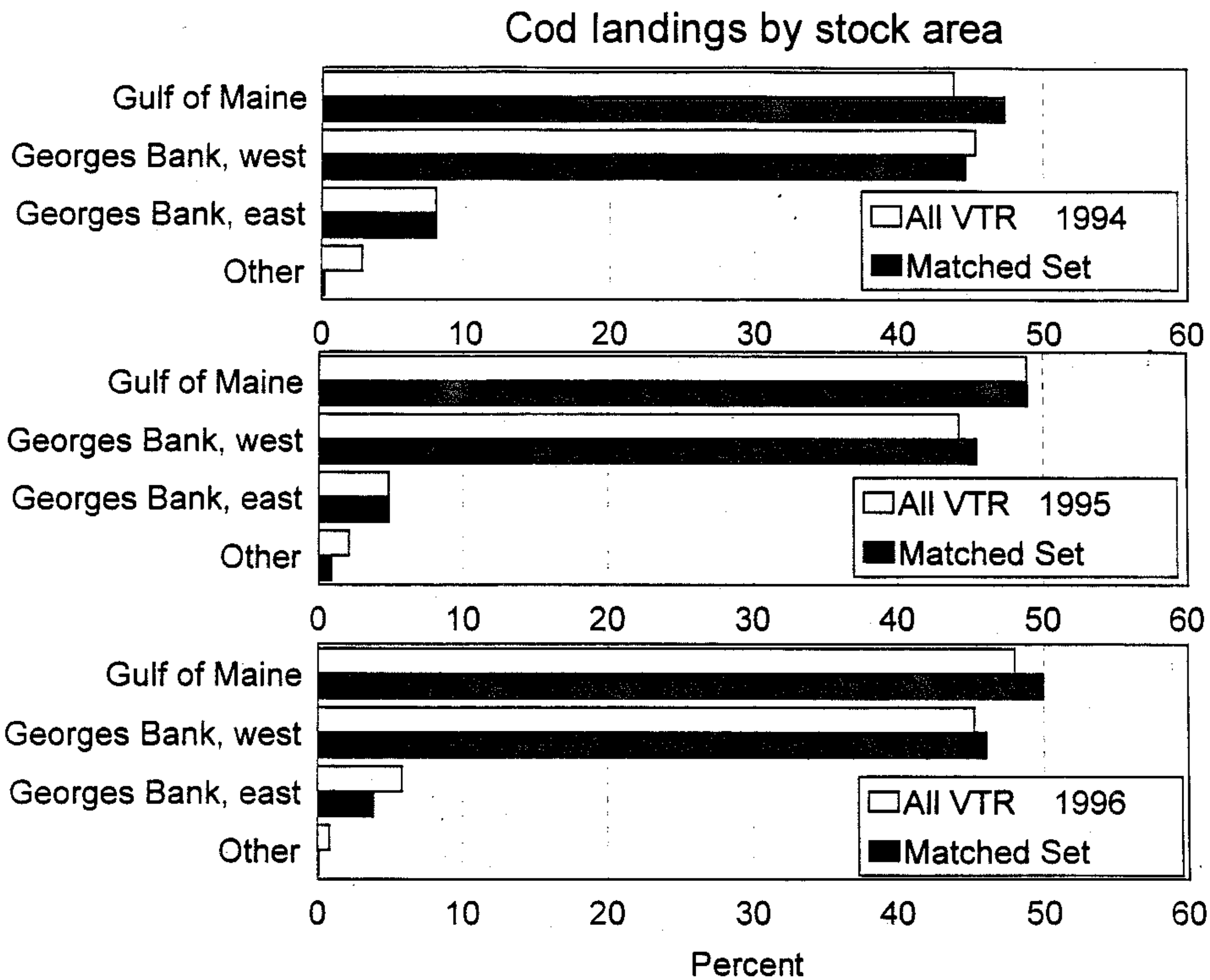


Figure 3. Comparison of cod landings by stock areas (percent) between the vessel trip report data and the matched set data for 1994-1996.

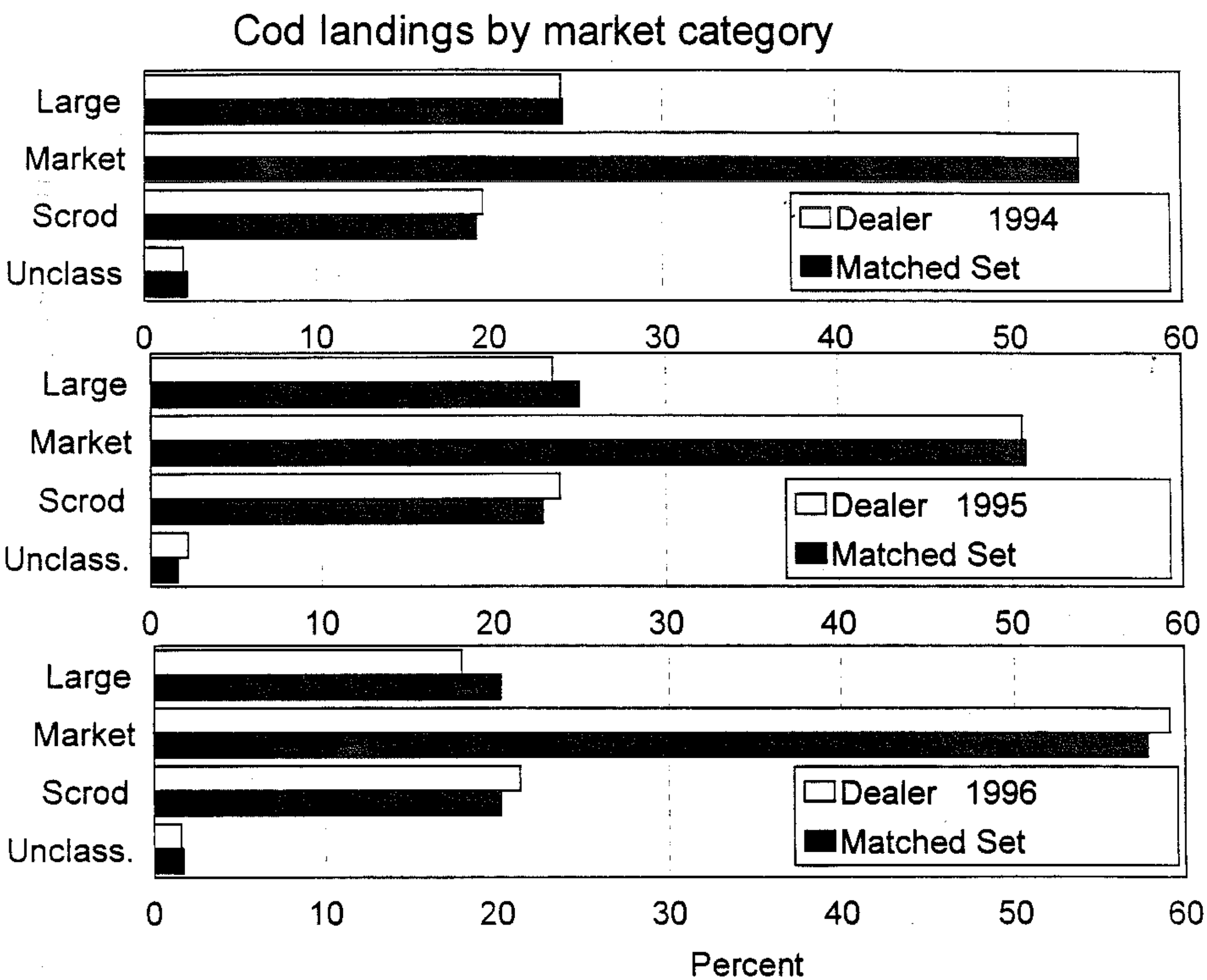


Figure 4. Comparison of cod landings by market category (percent) between the dealer report data and the matched set data for 1994-1996.

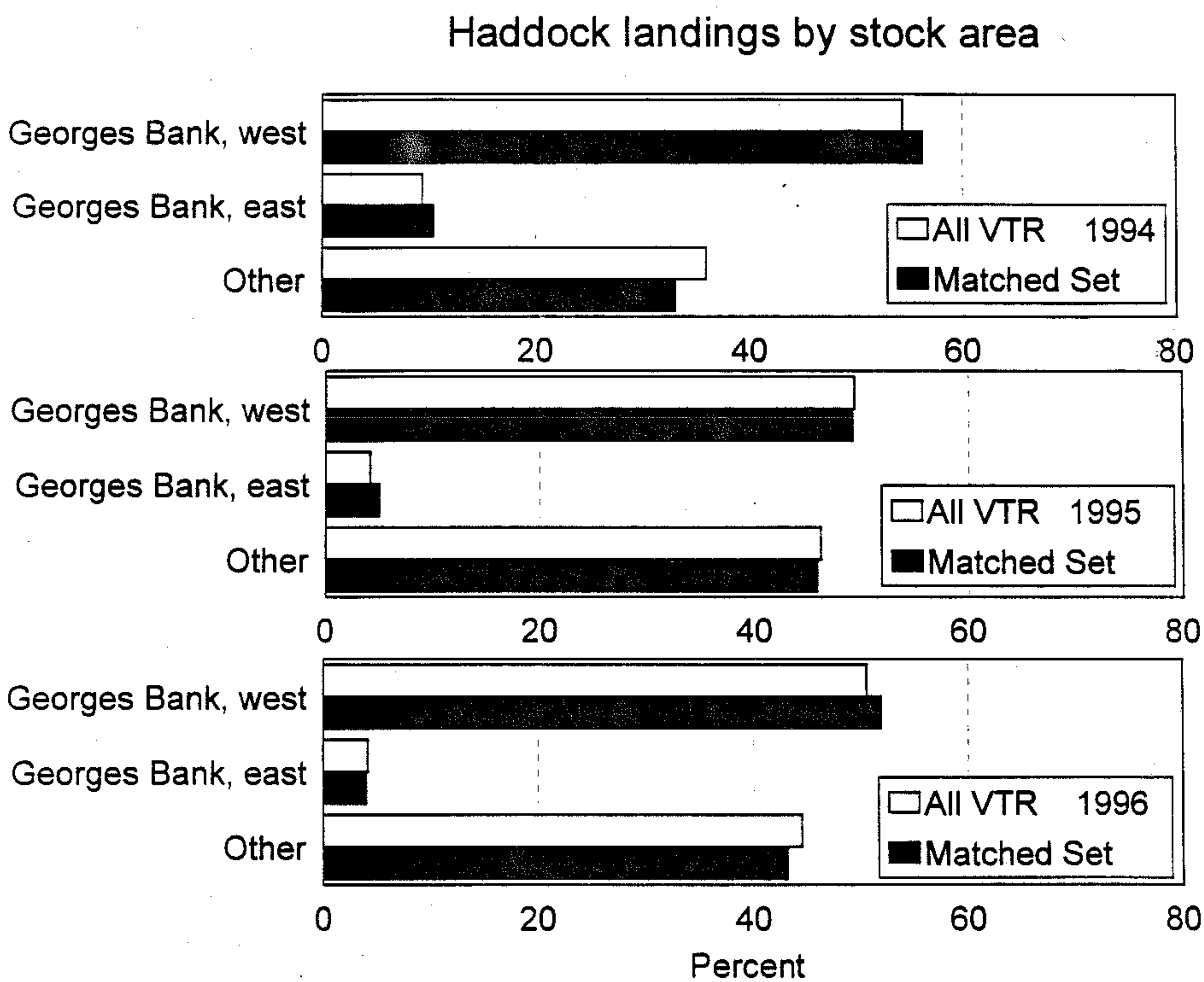


Figure 5. Comparison of haddock landings by stock areas (percent) between the vessel trip report data and the matched set data for 1994-1996.

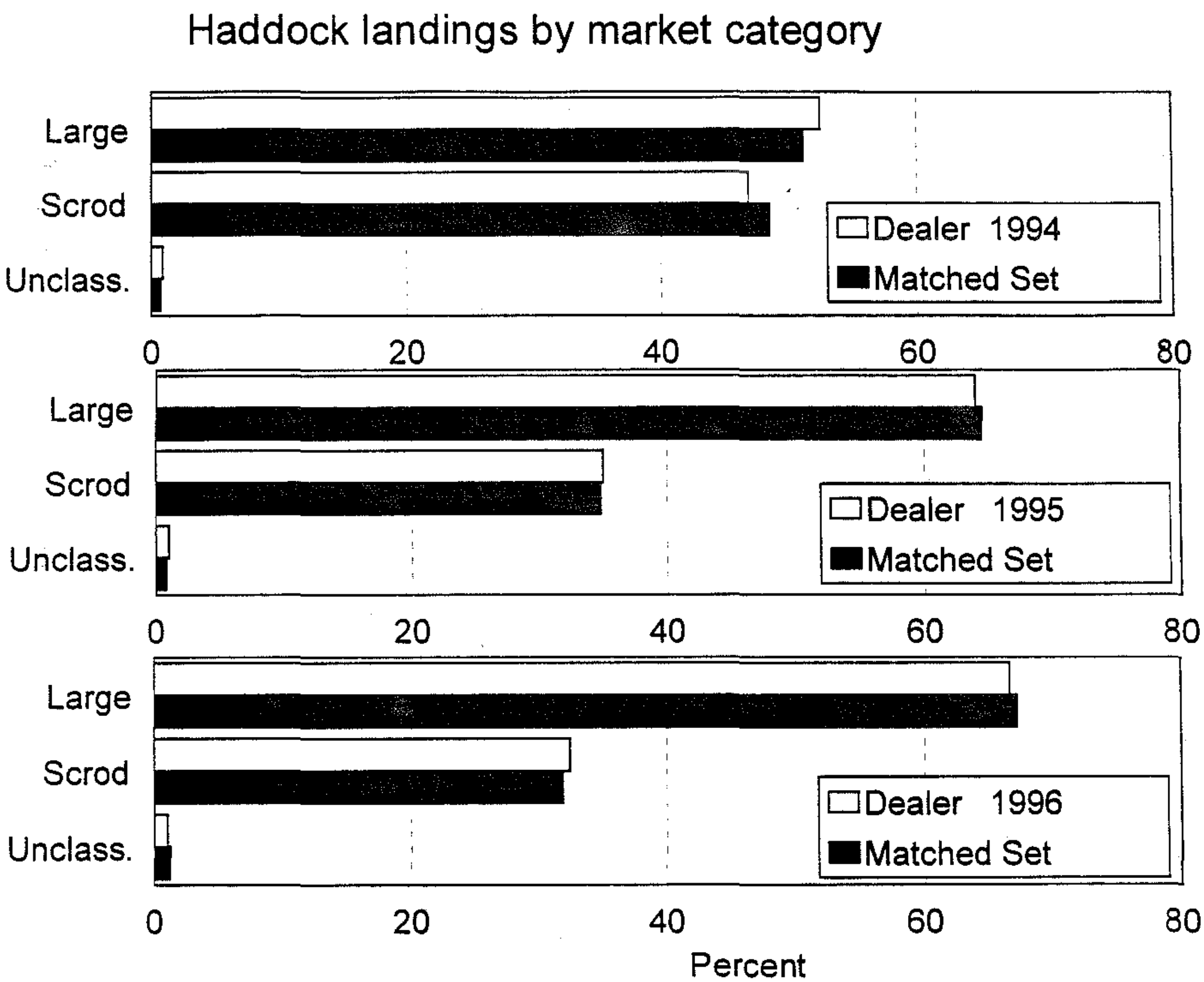


Figure 6. Comparison of haddock landings by market category (percent) between the dealer report data and the matched set data for 1994-1996.

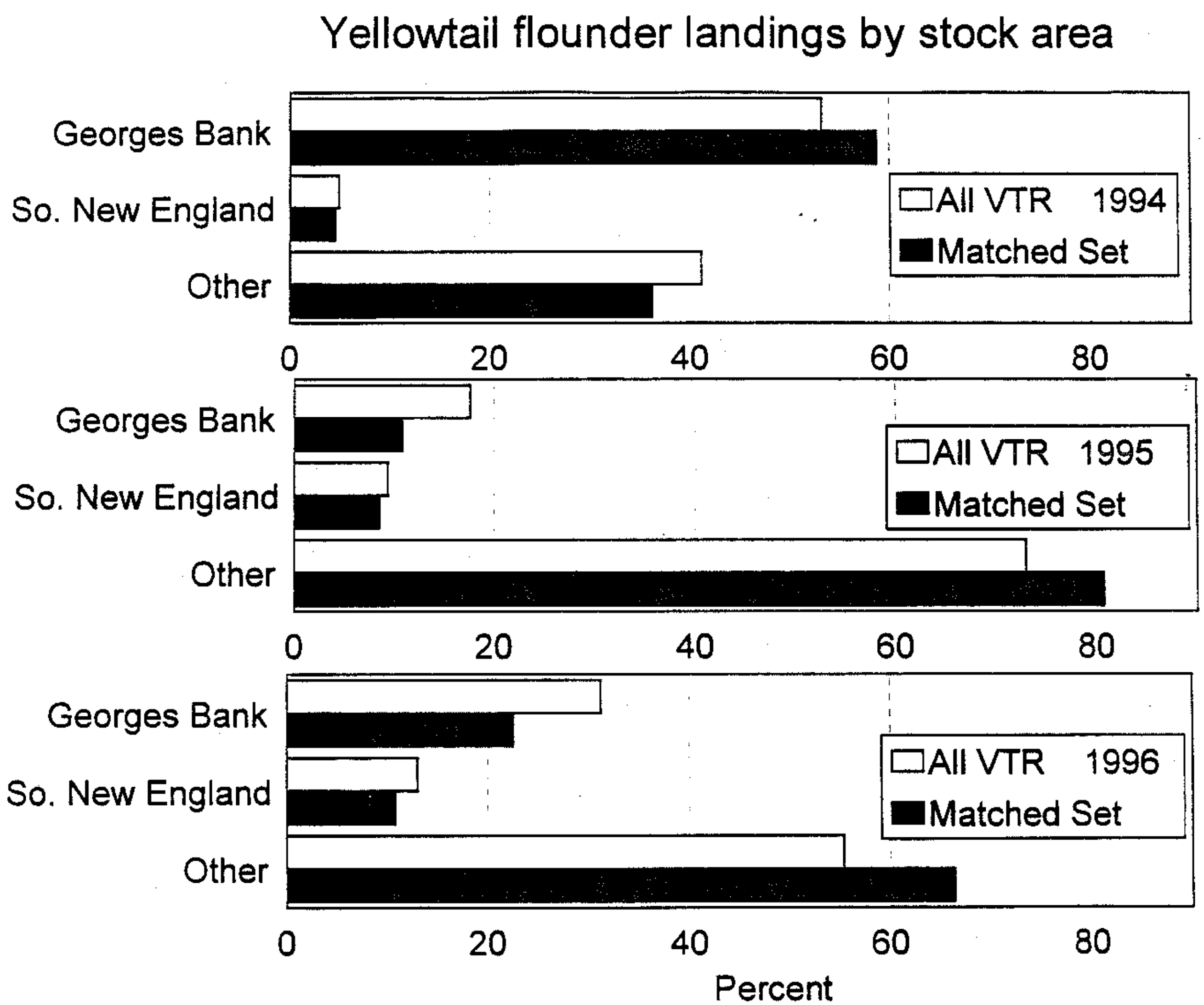


Figure 7. Comparison of yellowtail flounder landings by stock areas (percent) between the vessel trip report data and the matched set data for 1994-1996.

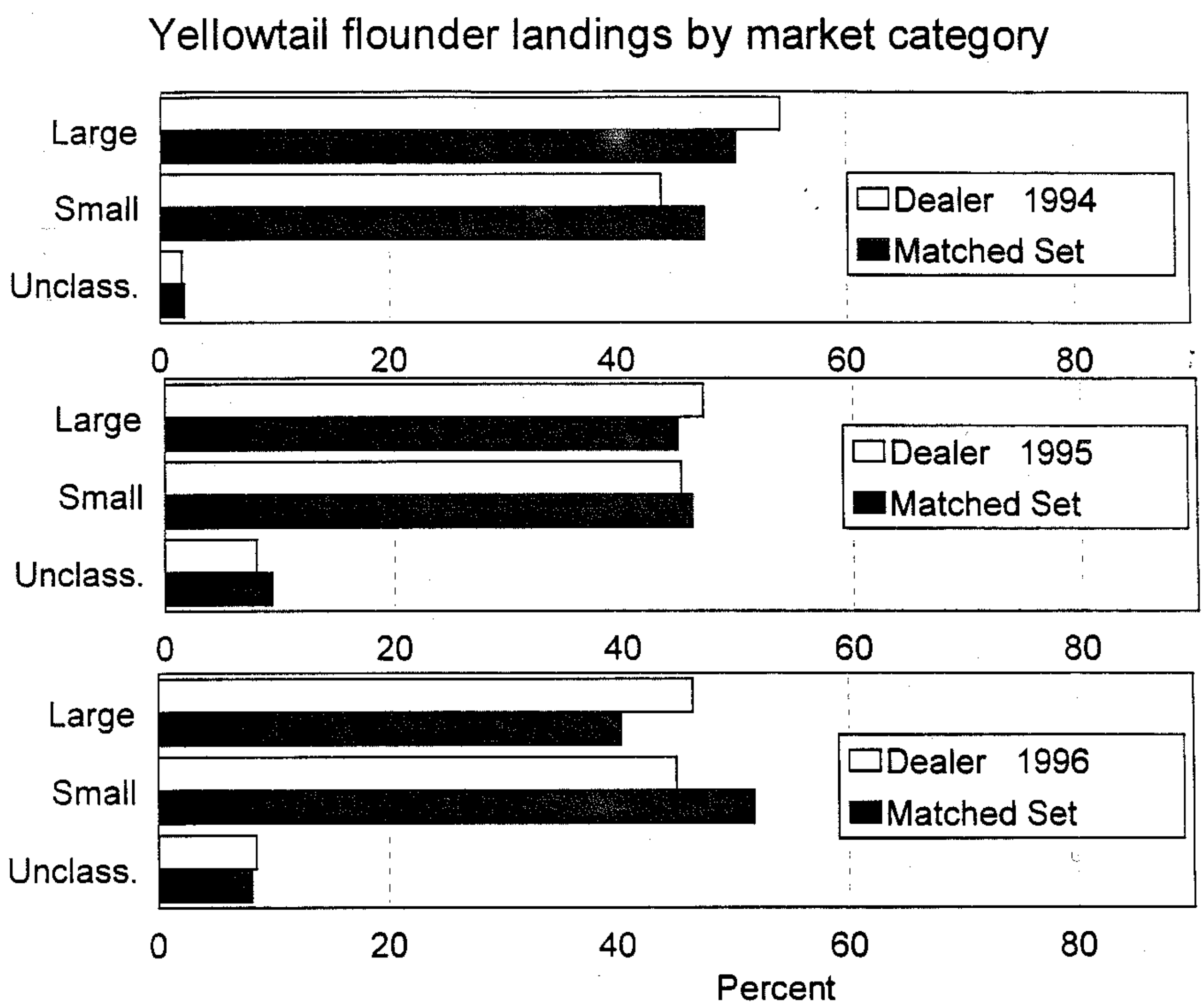


Figure 8. Comparison of yellowtail flounder landings by market category (percent) between the dealer report data and the matched set for 1994-1996.

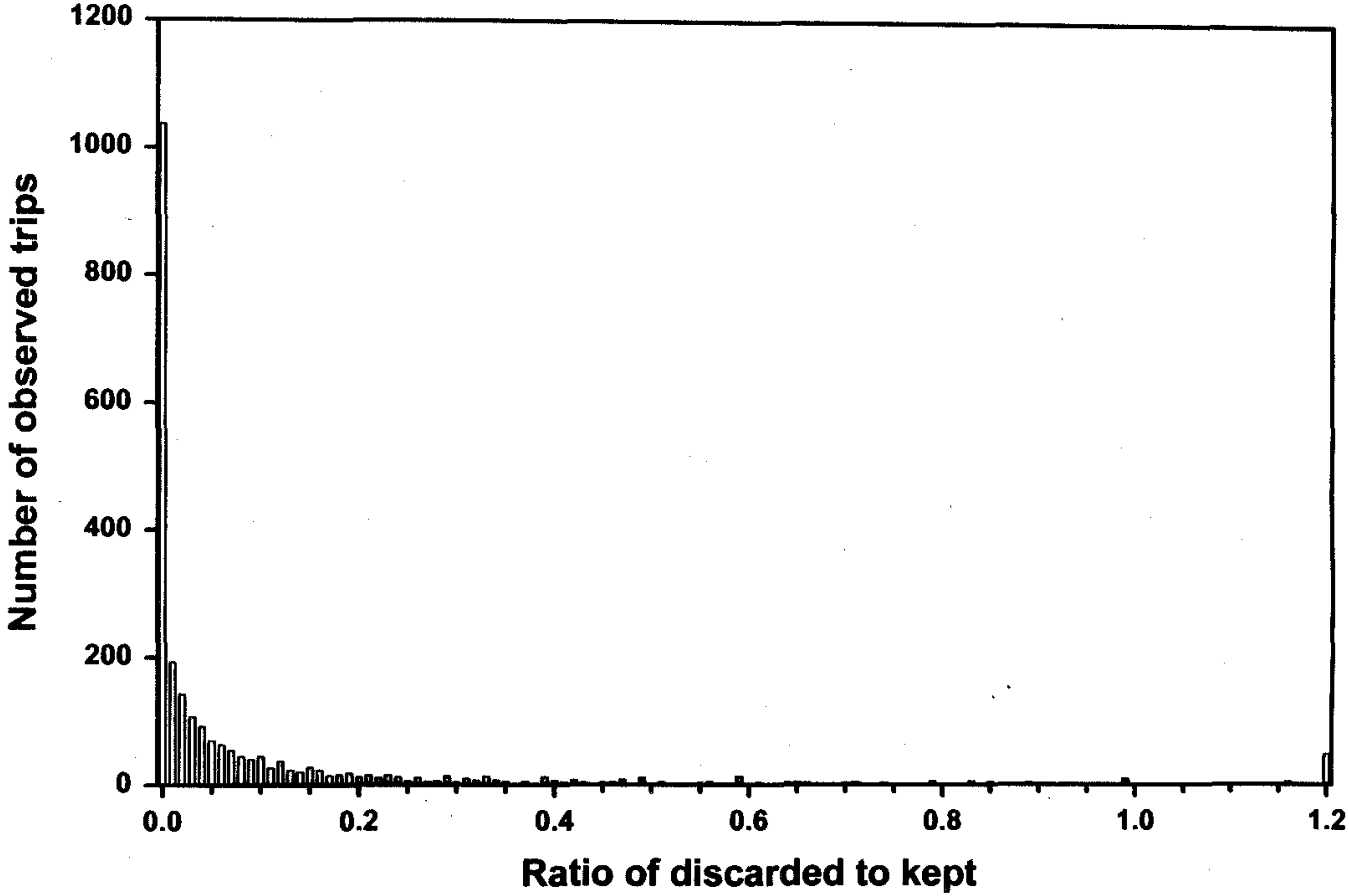


Figure 9. The ratio of discarded pounds to kept pounds versus the number of trips from observed trips (1989-1996) that landed cod, fished in the Gulf of Maine and used gillnet gear. The stock area and gear were defined according to the groupings in Table 7.

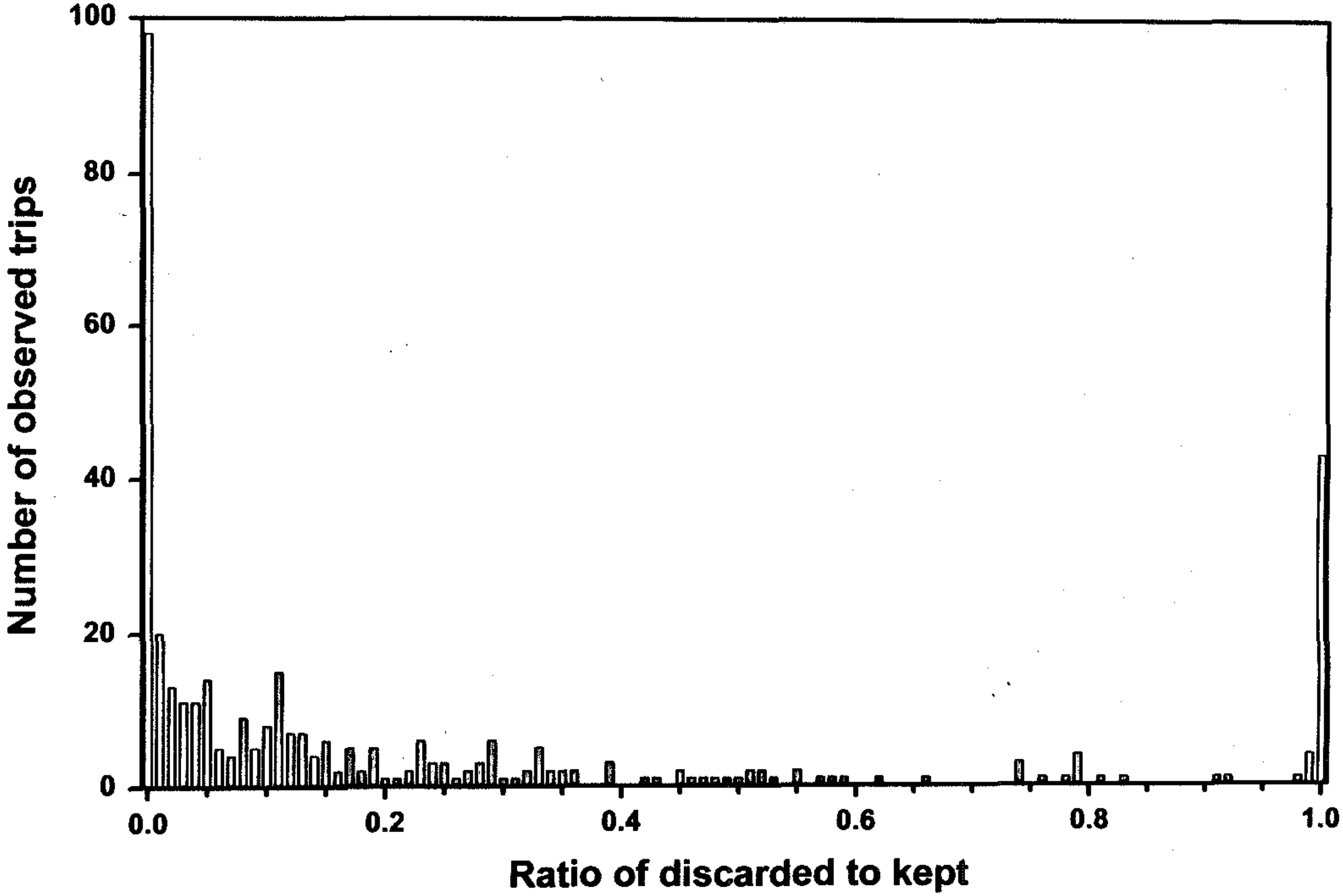


Figure 10. The ratio of discarded pounds to kept pounds versus the number of trips from observed trips (1989-1996) that landed cod, fished in the Gulf of Maine and used otter trawl gear. The stock area and gear were defined according to the groupings in Table 7.

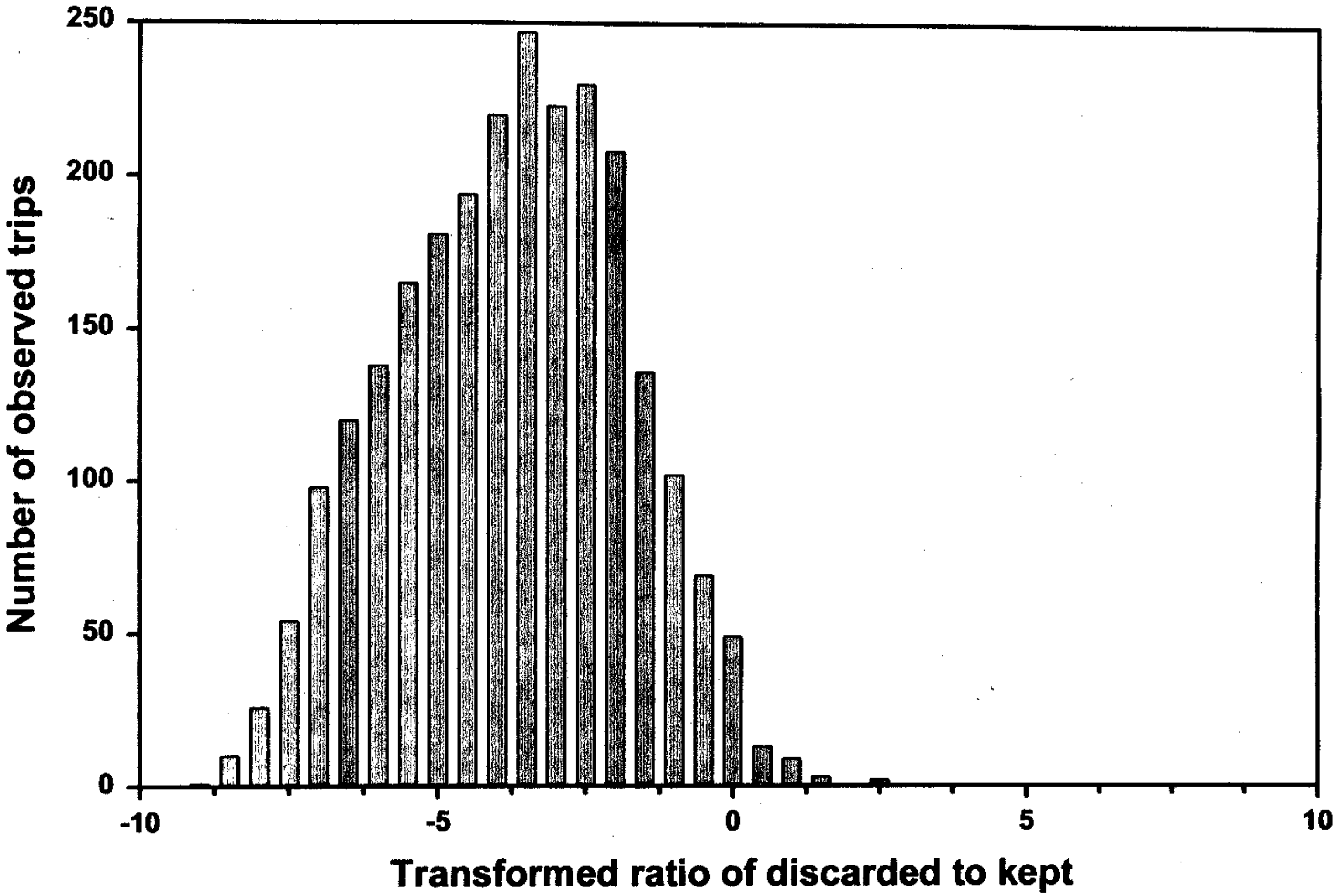


Figure 11. The transformed discard ratio versus the number of trips from observed trips (1989-1996) that landed cod, fished in the Gulf of Maine and used gill net gear. The stock area and gear were defined according to the groupings in Table 7.

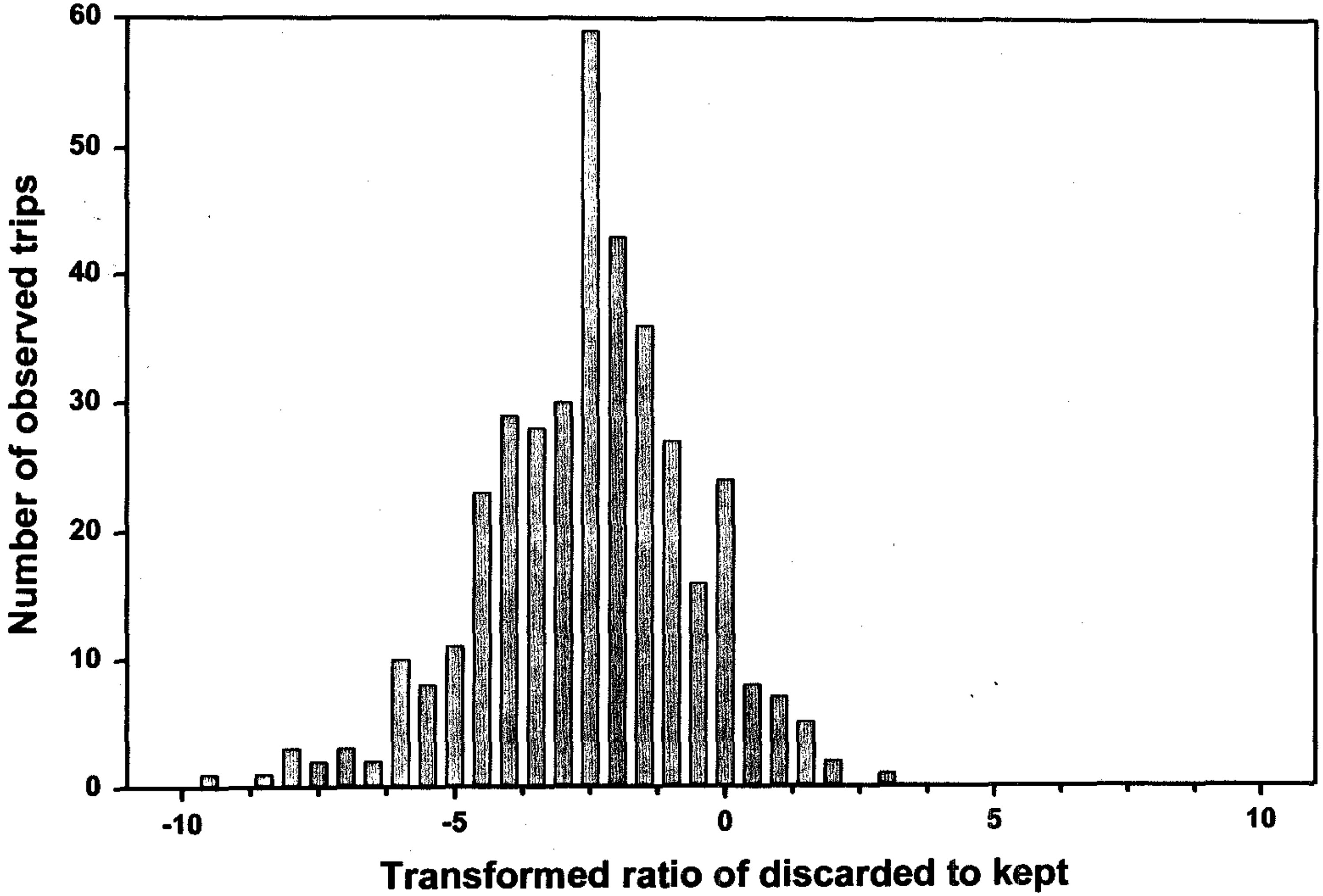


Figure 12. The transformed discard ratio versus the number of trips from observed trips (1989-1996) that landed cod, fished in the Gulf of Maine and used otter trawl gear. The stock area and gear were defined according to the groupings in Table 7.

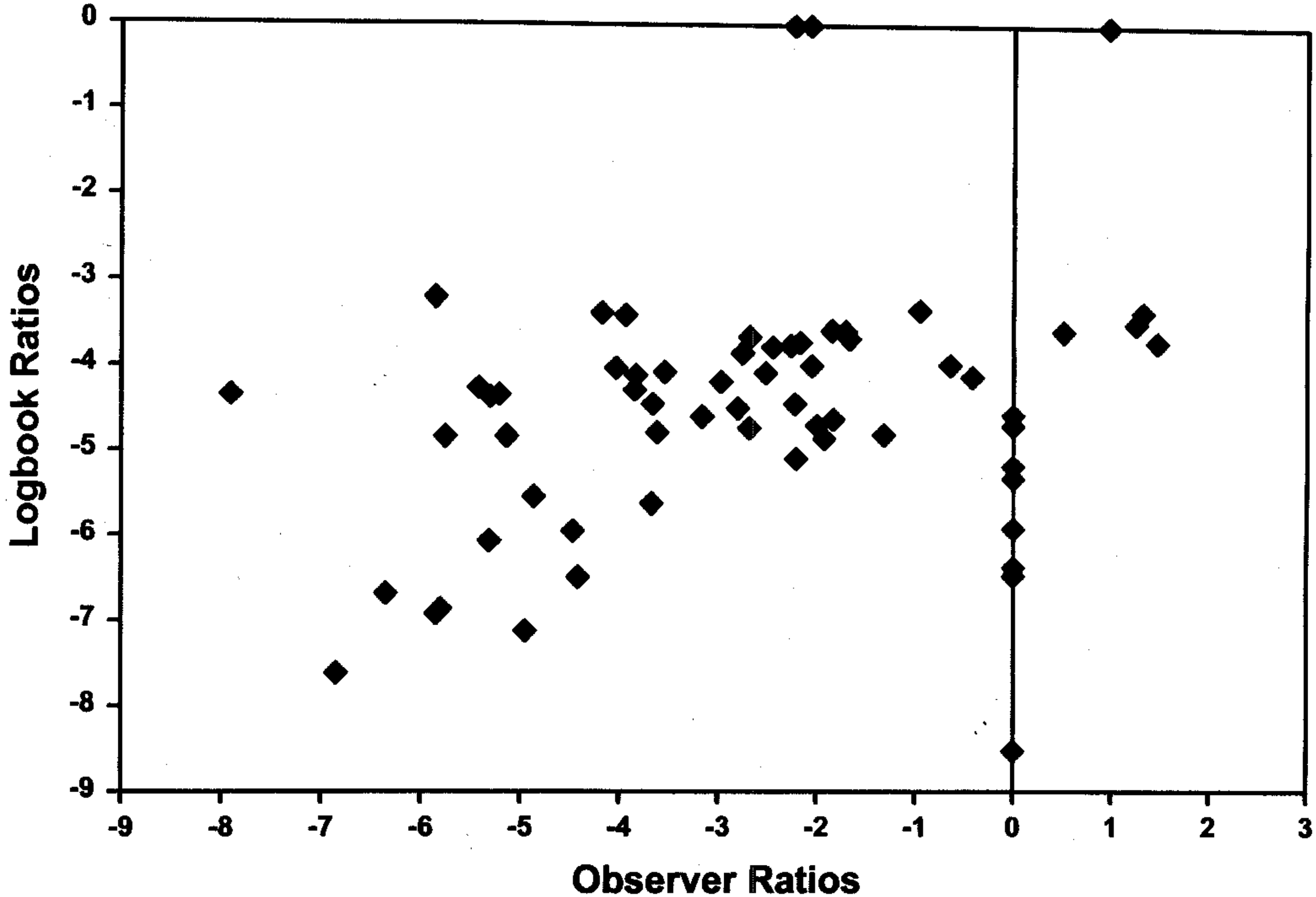


Figure 13. Comparison of average transformed discard/kept ratios from the vessel logbook discard subset with the average transformed ratios from the observer data sets. Only otter trawl and gillnet trips are included.

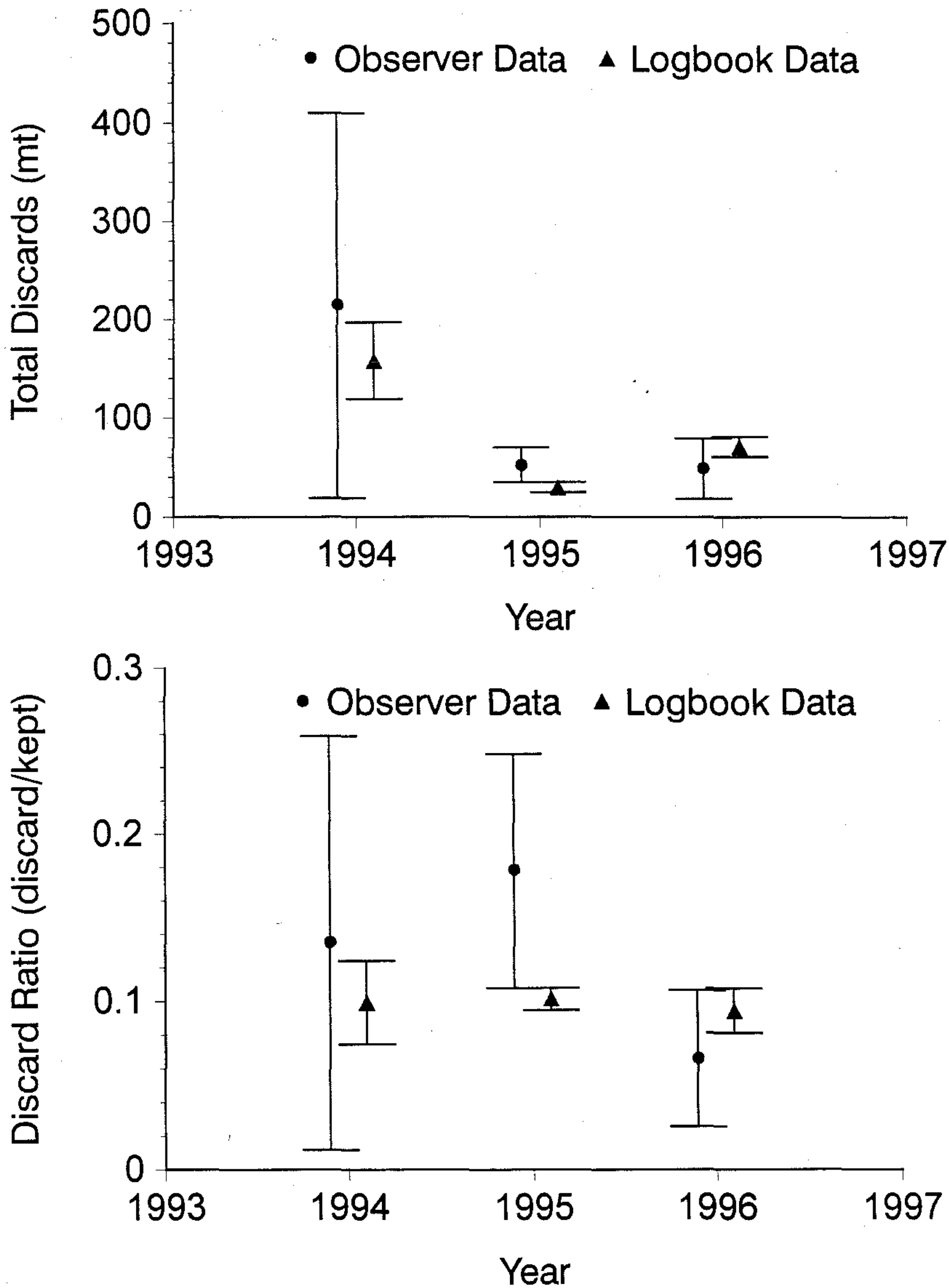


Figure 14. Estimates of total discards (above) and discard ratios (below) for Georges Bank yellowtail flounder with 95% confidence intervals.

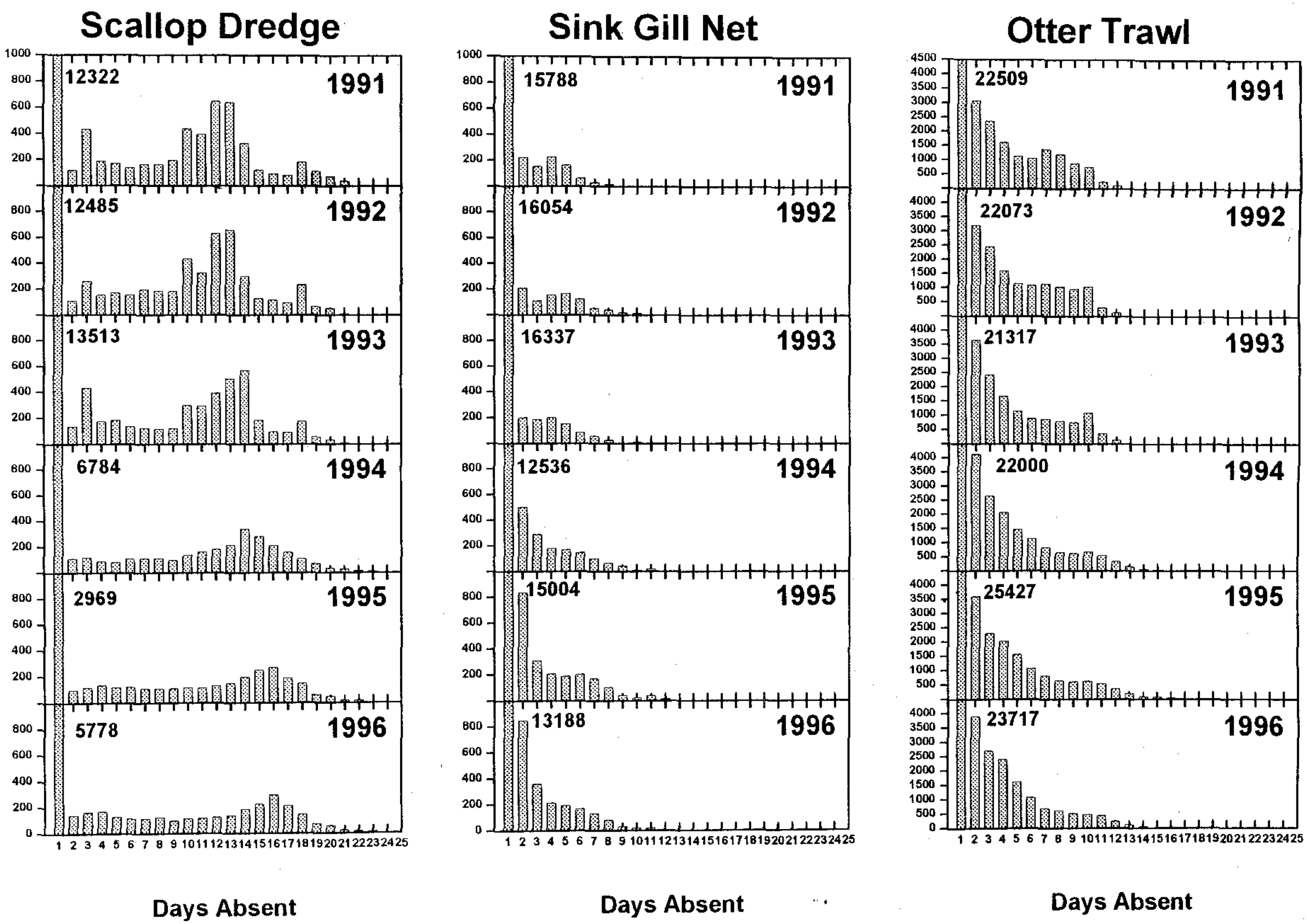


Figure 15. Frequency distribution ofeffort (days absent) from 1991 to 1996 for scallop dredge (132), sink gill net (100), and otter trawl (050) (sources: weighout and logbook data).

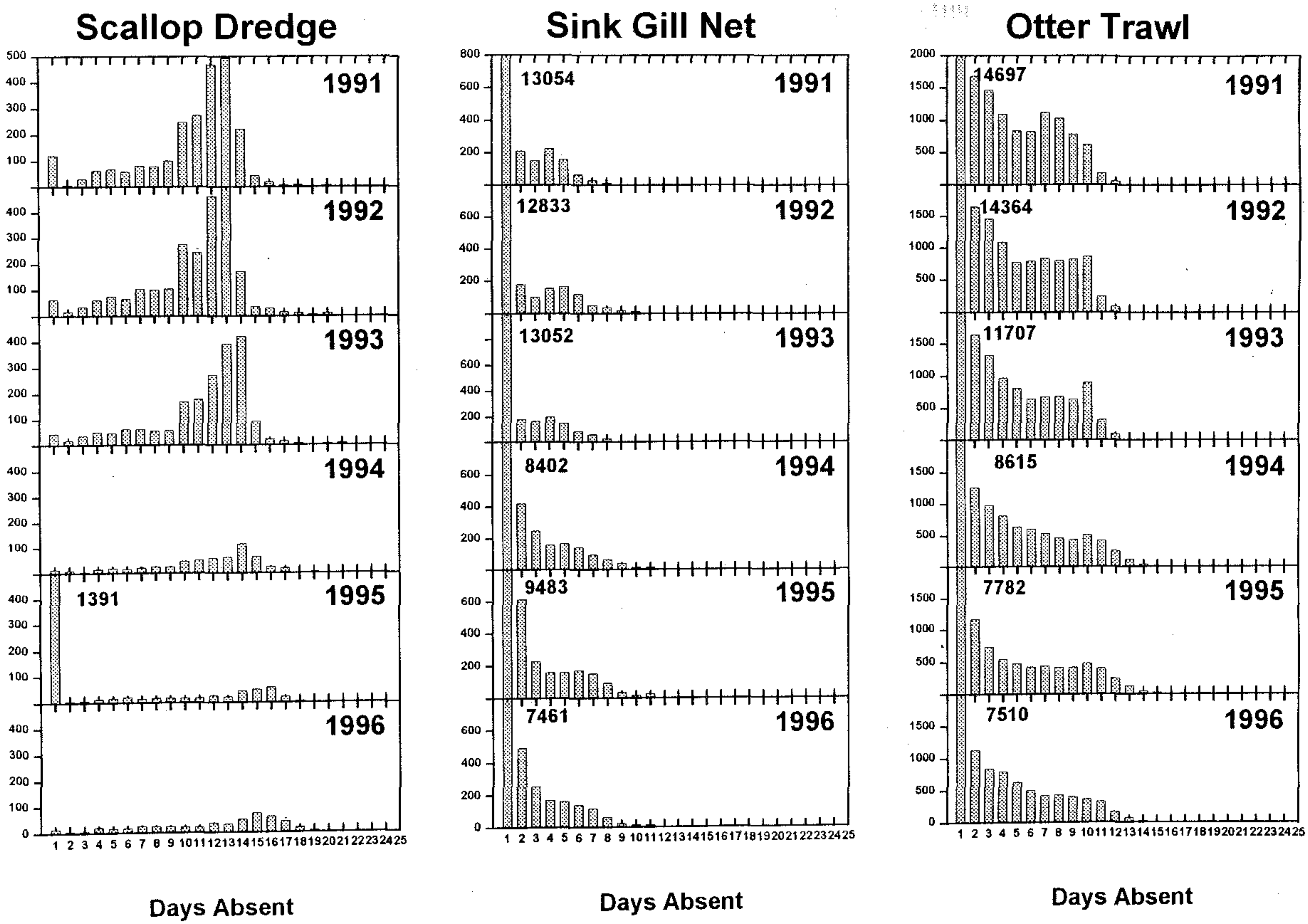


Figure 16. Frequency distribution of effort (days absent) from 1991 to 1996 for scallop dredge, sink gill net, and otter trawl landing any cod, haddock, or yellowtail flounder (sources: weighout and logbook data).

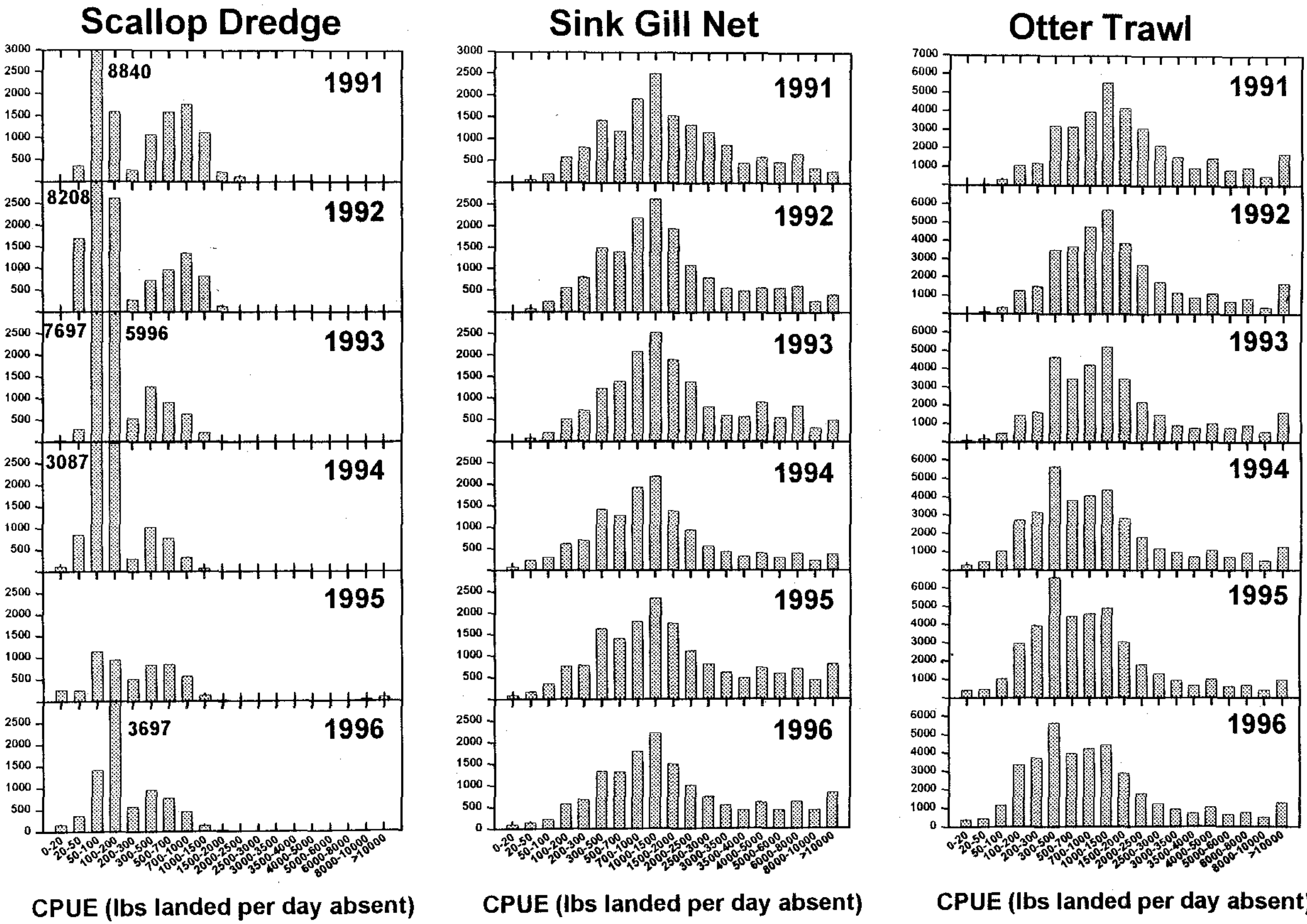


Figure 17. Frequency distribution of CPUE (in total lbs landed per day absent) for scallop dredge, sink gill net, and otter trawl from 1991 to 1996 (sources: weighout and logbook data).

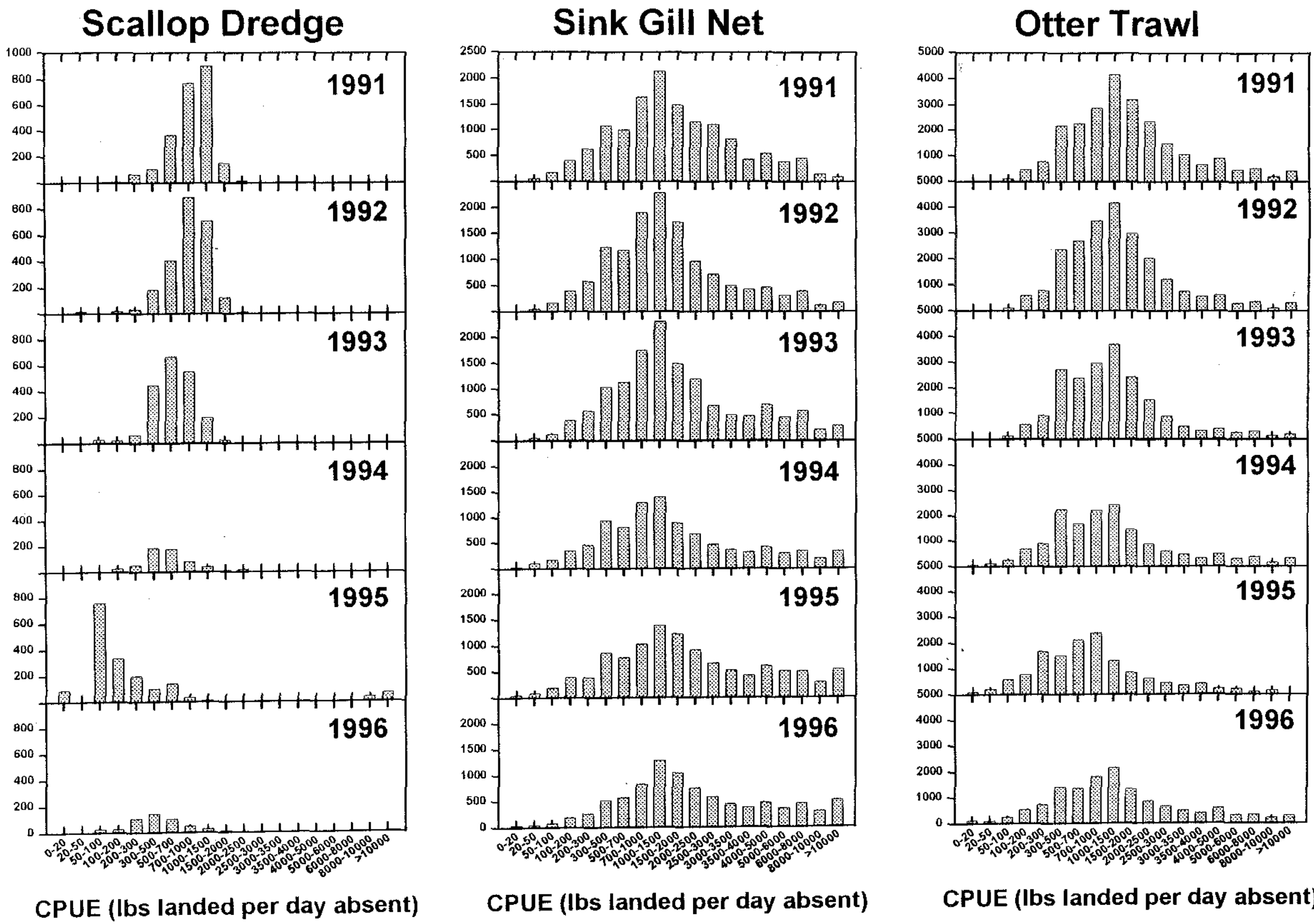


Figure 18. Frequency distribution of CPUE (in total lbs landed per day absent) for scallop dredge, sink gill net, and otter trawl trips that landed cod, haddock, or yellowtail flounder from 1991 to 1996 (sources: weighout and logbook data).

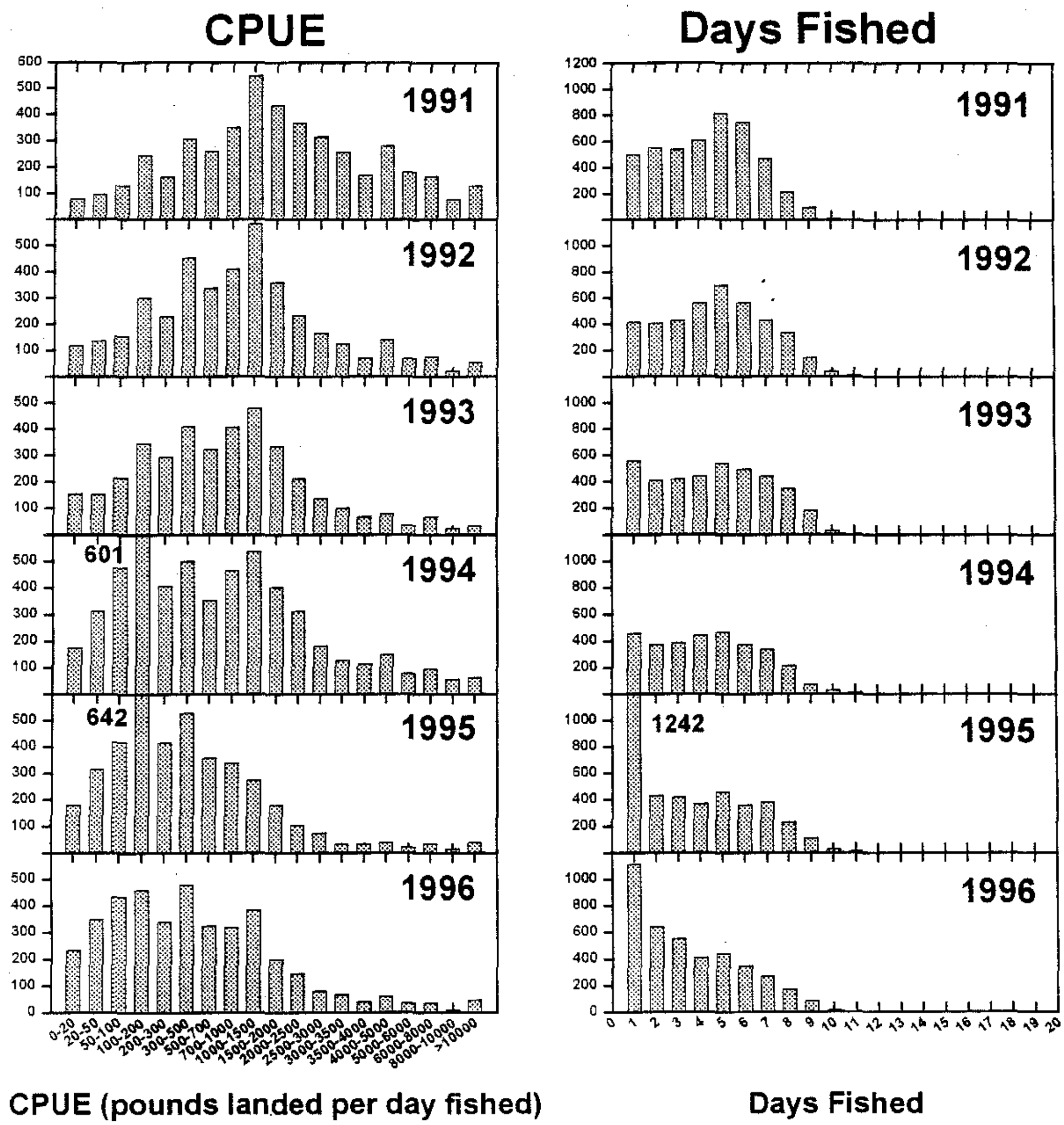


Figure 19. Frequency distribution of CPUE (in lbs of cod landed per day fished) and days fished for otter trawl trips from 1991 to 1996 (sources: weighout and logbook data).

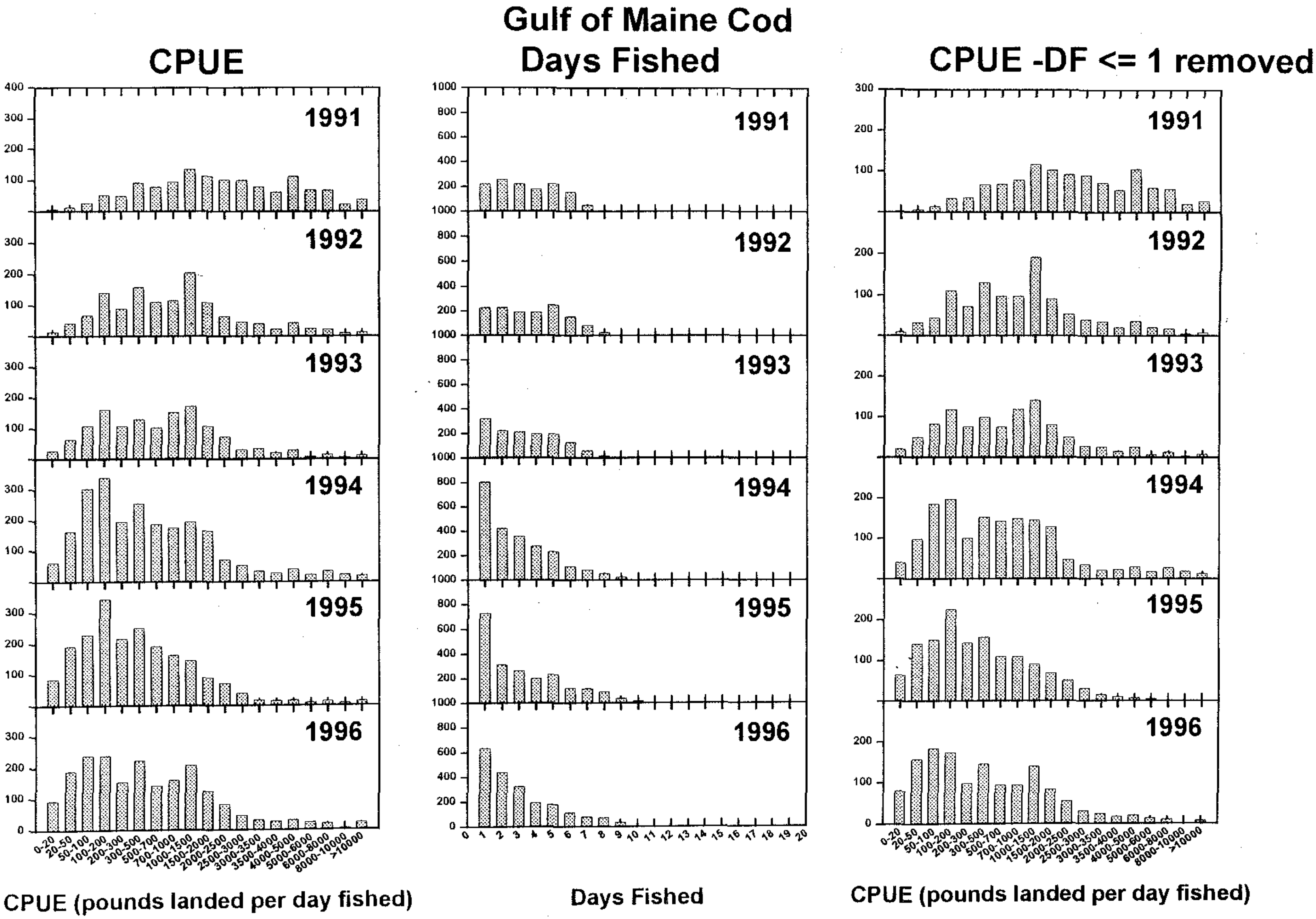


Figure 20. Frequency distribution of CPUE (in lbs of cod landed per day fished), days absent, and CPUE with days absent = 1 removed for otter trawl trips in the Gulf of Maine from 1991 to 1996 (sources: weighout and logbook data).

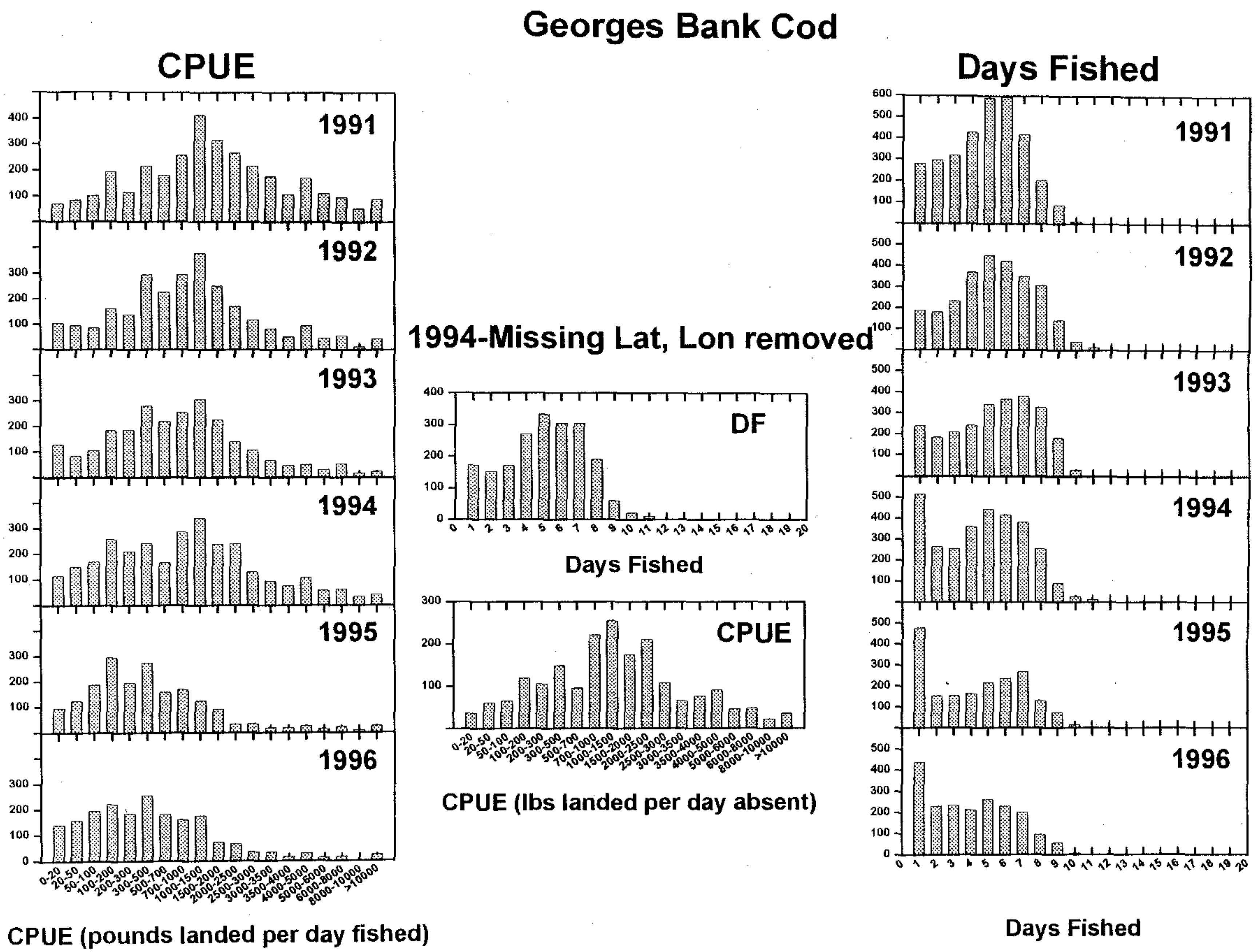
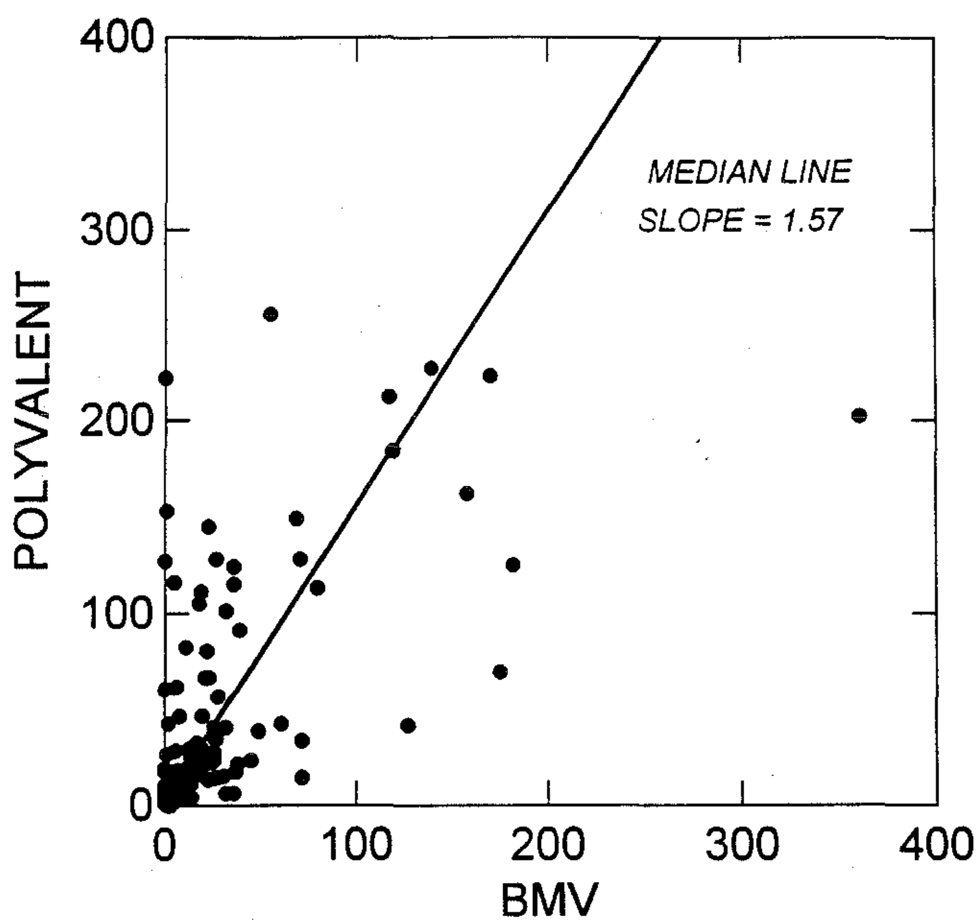


Figure 21. Frequency distribution of CPUE (in lbs of cod landed per day fished), days absent for all otter trawl trips on Georges Bank from 1991 to 1996 and for trips in 1994 where latitude and longitude were missing (sources: weighout and logbook data).

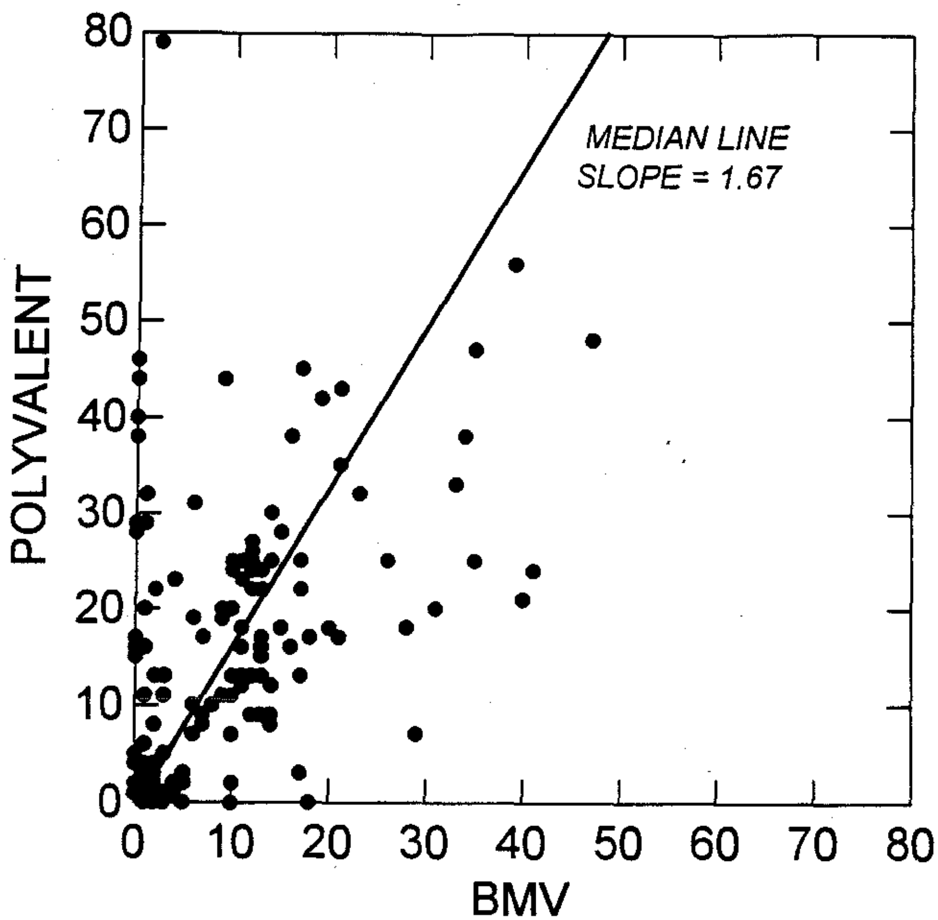
HADDOCK DOOR EXPERIMENTS



	POLYVALENT	*BMV*	*SLOPE*
N of cases	141	141	141
Minimum	0.0	0.0	0.00
Maximum	255	361	153.00
Median	14	7	**1.571**
Mean	38.043	23.376	
Standard Dev	56.970	46.172	
Variance	3245.570	2131.865	
C.V.	1.498	1.975	

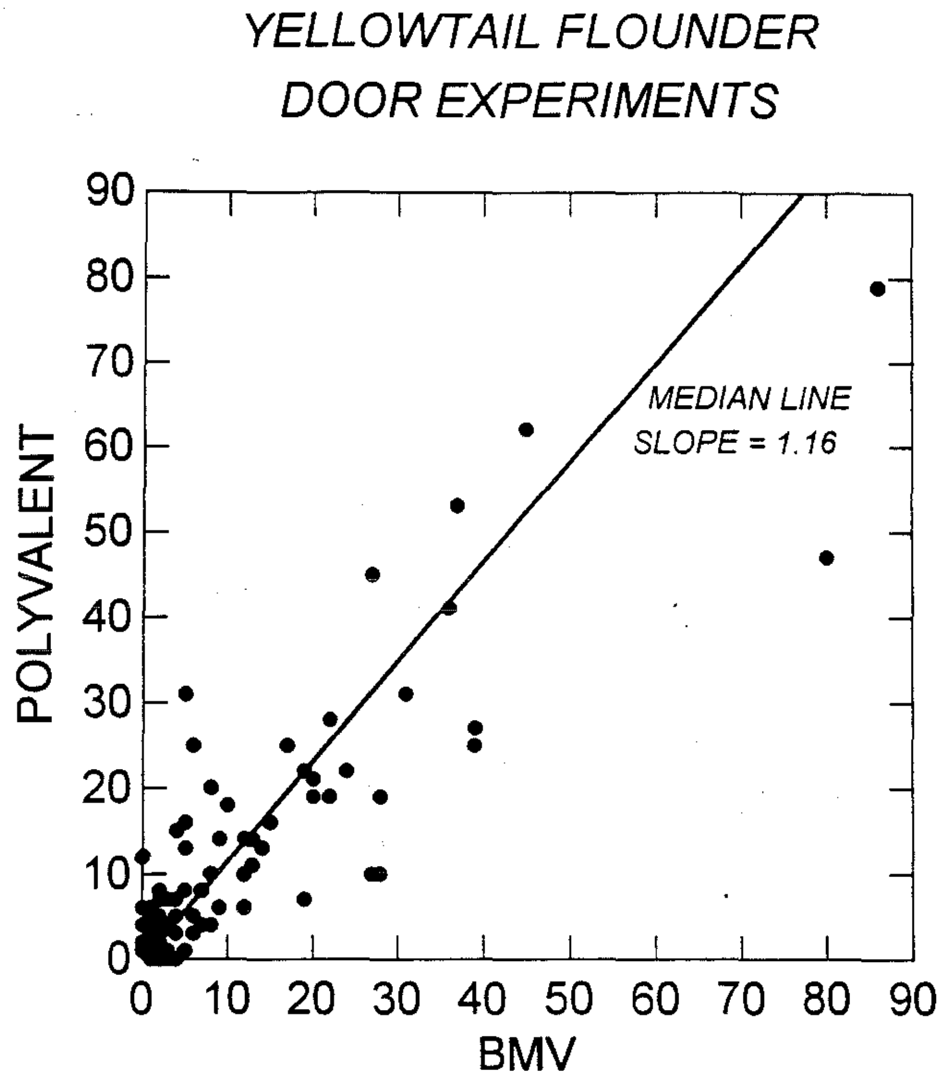
Figure 22. Numbers of haddock obtained in pair-wise sampling between BMV and polyvalent trawl doors. All data, including zero observations are included. The slope of the median line through the data (1.57) is similar to the estimated calibration coefficient (1.49, 95% CI=1.18-1.82) derived only using data when both elements of the pair were non-zero.

COD DOOR EXPERIMENTS



	POLYVALENT	*BMV*	*SLOPE*
N of cases	162	162	162
Minimum	0	0	0.00
Maximum	79	47	39.500
Median	11	4	**1.667**
Mean	13.784	8.191	
Standard Dev	14.185	9.877	
Variance	201.214	97.559	
C.V.	1.029	1.206	

Figure 23. Numbers of cod obtained in pair-wise sampling between BMV and polyvalent trawl doors. All data, including zero observations are included. The slope of the median line through the data (1.67) is similar to the estimated calibration coefficient (1.56, 95% CI=1.33-1.88) derived only using data when both elements of the pair were non-zero.



	POLYVALENT	*BMV*	*SLOPE*
N of cases	112	112	112
Minimum	0	0	0.0
Maximum	79	86	6.200
Median	4	2	**1.162**
Mean	9.518	8.643	
Standard Dev	13.591	14.313	
Variance	184.720	204.862	
C.V.	1.428	1.656	

Figure 24. Numbers of yellowtail flounder obtained in pair-wise sampling between BMV and polyvalent trawl doors. All data, including zero observations are included. The slope of the median line through the data (1.16) is similar to the estimated calibration coefficient (1.22, 95% CI=1.02-1.39) derived only using data when both elements of the pair were non-zero.

A. GULF OF MAINE COD

Terms of Reference

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

b. Provide projected estimates of catch for 1997-1998 and SSB for 1998-1999 at various levels of F, including all relevant biological reference points.

c. Advise on the assessment and management implications of incorporating recreational catch and commercial discard data in the assessment.

Introduction

This report presents an updated and revised analytical assessment of the Gulf of Maine cod stock (NAFO Division 5Y) for the period 1982-1996 based on analyses of commercial and research vessel survey data through 1996. After 1993, however, the methodology for collecting and processing commercial fishery data in the Northeast was substantially revised. 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 the course of 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 calendar 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 by stock proportions derived from the matched subset were employed to compute the total catch by stock, market category, calendar quarter, port group, and gear group in the full dealer database. A full description of the proration methodology and an evaluation of the 1994-1996 logbook data is given in Wigley *et al.* (1997) 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 SAW-7 in November 1988 (NEFC 1989), and subsequent revisions were presented at SAW-12, SAW-15, and SAW-19 in June 1991, December 1992, and December 1994, respectively (NEFSC 1991, 1993, 1995; Mayo *et al.* 1993; Mayo 1995).

This assessment extends and expands the analyses presented in the previous assessment of the Gulf of Maine cod stock (Mayo 1995). The major revisions are:

1) Commercial landings during 1994-1996 were derived from mandatory dealer reports prorated to stock using mandatory vessel trip report (VTR) data.

2) Discards of Gulf of Maine cod during 1989-1996 were estimated using NEFSC sea sampling data for otter trawl, shrimp trawl and gillnet gear.

3) Catch at age of Gulf of Maine cod taken in the recreational fishery during 1982-1996 were estimated using MRFSS catch and biological sampling data.

4) Commercial landings per unit effort (LPUE) indices and standardized fishing effort were re-estimated for 1982-1993 using commercial interview data.

5) Commercial landings per unit effort (LPUE) indices and standardized fishing effort were estimated for 1994-1996 using commercial vessel trip report data.

6) The influence of the commercial LPUE-at-age index was removed from the VPA calibration because the VTR-based effort estimates were considered uncertain.

The Fishery

Commercial Fishery Landings

Atlantic cod (*Gadus morhua*) in the Gulf of Maine region have been commercially exploited since the 17th century, and reliable landings statistics are available since 1893. Historically, the Gulf of Maine fishery can be separated into four periods (Figure A1): 1) an early era from 1893-1915 in which record-high landings (>17,000 mt) in 1895 and 1906 were followed by about 10 years of sharply-reduced catches; 2) a later period from 1916-1940 in which annual landings were relatively stable, fluctuating between 5,000 and 11,500 mt and averaging 8,300 mt per year; 3) a period from 1941-1963 when landings sharply increased (1945: 14,500 mt) and then rapidly decreased to a record-low of 2,600 mt in 1957; and 4) the most recent period from 1964 onward during which Gulf of Maine landings have generally increased. Total landings doubled between 1964 and 1968, doubled again between 1968 and 1977, and averaged 12,200 mt per year during 1976-1985 (Table A1). Although Gulf of Maine landings declined between 1984 and 1987, landings subsequently increased, reaching 17,800 mt in 1991, the highest level since the early 1900s. Total landings declined sharply in 1992 to 10,892 mt, decreased further in 1993 to 8,287 mt, and have remained within the 7,000-8,000 mt range during 1994-1996.

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, Massachusetts (1963-1993) and from summary reports of the Bureau of Commercial Fisheries and its predecessor the U.S. Fish Commission (1895-1962). Beginning in 1994, landings estimates were derived from dealer data prorated to stock based on the distribution of reported landed catch contained in logbooks.

Total commercial landings in 1996 were 7,194 mt, 6% greater than in 1995, but 60% less than the 1991 peak (Table A1). 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 (59% by weight in 1996), the quantity taken by gillnets increased to over 40% in 1994 and 1995 from a low of 23% in 1991; the 1996 gillnet catches were at a percentage comparable to the 1987-1989 period (Table A2).

Commercial Fishery Discards

Discard rates were calculated by quarter and gear from NEFSC sea sampling data collected between 1989 and 1996. 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. Detailed calculations and sample sizes are presented in Mayo (1997) and summary results are given in Table A3.

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 to 0.60 in 1989 and 1990 and remained low through 1996, fluctuating between 0.002 and 0.005. 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 1994-1996 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 1994-1996 period.

Discards of Gulf of Maine cod ranged from a high of 3,599 mt in 1990 to 176 mt in 1996 (Table A3). Discards exceeded 1,000 mt in each year between 1989 and 1991 before declining steadily from 1992 to present. The relatively high discard rates calculated for 1989-1991 for otter trawl and shrimp trawl gear coincide with the recruitment of the strong 1987 year class to the small-mesh shrimp trawl gear and the large-mesh general otter trawl gear. Available length composition data for these years and gear types suggest that most of the discarded cod were in the 30-50 cm range, 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 since 1979. The Gulf of Maine cod catch was estimated on the assumption that the catches of cod recorded by the intercept survey were removed from the ocean in statistical areas adjacent to the state or county of landing. The MRFSS database has been recently revised, resulting in adjusted catch estimates for the years 1981-1996. 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 A4. Information on the catch prior to 1981 which has not been revised is included in Table A4 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 retained generally exceeded 75% of the total catch during 1979-1991, but has averaged less than 50% since 1992. The estimated catch 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, and has fluctuated between 1,200 and 2,500 mt since 1992.

Commercial Fishery Sampling Intensity

A summary of US length frequency and age sampling of Gulf of Maine cod landings during 1982-1993 is presented in Table A5. US length frequency sampling averaged one sample per 155-200 mt landed during 1983-1987, but the sampling intensity declined in 1990 (1 sample per 387 mt) and 1993 (1 sample per 360 mt). Only 23 samples were taken in 1993. Despite slight overall increases in sampling intensity in 1994 and 1995, the seasonal distribution of sampling was uneven and poorly matched to the landings. Sampling improved substantially in 1996, reaching an all-time high in terms of both absolute and relative measures.

Virtually all of the US samples have been taken from otter trawl landings, but sampling and the estimation of length composition are 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 77 samples collected in 1996, 27 were scrod samples (35%), 38 were market (49%), and 12 were large (16%). Compared with the 1996 market category landings distribution (by weight - scrod: 23%; market: 61%; large: 13%) (Table A6), sampling in 1996 reasonably approximated the market category distribution of the landings.

Commercial Landings Age Composition

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 cod length-weight equation:

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

to the quarterly market category sample length frequencies. Mean weight values were divided into quarterly market category landings 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 values were summed over market categories and quarters to derive the annual landings-at-age matrix (Table A7a).

Age composition of landings for 1994-1996 was 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 A5). 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.

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 during 1990-1992, but by 1993, fish from the 1990 year class accounted for the greatest proportion of the total number landed (Table A7a). 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. During 1994-1996, landings were dominated by age 4 cod in both number and weight. 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 A7a). 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 1982-1996 are given in Table A7b and, based on landings patterns, are considered mid-year values. Mean weights of age 2 and 3 cod have risen since about 1992, 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 weight at age for 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 age for ages 2-4 were the lowest in the 9-year time series, while mean weights for ages 6 and 7 were the highest. These changes, however, may be artifacts of the reduced sampling intensity of the landings 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 weights at age 2 in 1995 and 1996 may be related to the use of 152 mm (6 in.) mesh in the otter trawl fishery. Catch at age and recalculated mean weights at age for the 7+ group used in the VPA are given in Tables A8a and A8b. Mean weights at age for calculating stock biomass at the beginning of the year are provided in Table A9. These values were derived from the catch mean weight-at-age data (Table A7b) 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 A4. An examination of the available length frequency sampling coverage was conducted to evaluate the potential of these data for use in estimating the overall length composition of the removals from the stock 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 A4). The length composition data, however, provide a general indication of the size composition of the catch. Length frequency sample data, summarized by wave and fishing mode over the 16-year period from 1981-1996, display only minor variation among seasons and fishing mode. Most cod caught are in the 40-70 cm range, with few fish larger than 100 cm. Length frequency data are available only for fishing modes 6 and 7 and waves 2-6 (March-December). These data, in conjunction with estimates of mean weight of the catch, indicate that cod taken in the recreational fishery are generally smaller, on average, than those taken by the commercial sector. The mean weights of cod taken in the recreational fishery (1.5-2.0 kg; Table A4) are comparable to those of age 2-3 cod in the commercial landings, or approximately equal to the mean weight of the scrod market category.

Recreational Landings Age Composition

Given the limited sampling coverage in this sector of the fishery, estimation of numbers caught by length and age required samples to be pooled on an annual basis. The low inter-seasonal variability displayed by the sample length composition data supports this approach. Differences between fishing modes 6 and 7 are also minimal. Therefore, estimates of the age composition of recreationally caught cod were derived from the length composition data applied to the retained numbers of cod based on pooled annual length frequency samples from Gulf of Maine trips. Only the retained numbers of cod were included because the intercept sampling may not accurately reflect the size composition of the released cod. Age-length keys obtained from sampling the commercial landings, augmented by age samples from NEFSC bottom trawl surveys for cod less than 40 cm, were applied to the numbers retained at length on an annual basis to derive the numbers retained at age (Table A10a).

The Gulf of Maine cod recreational catch in numbers is dominated by age 3 fish, with age 2 fish next in importance. The strong 1987 year class dominated the age 3, 4, and 5 catch in 1990, 1991 and 1992, respectively. Age 3 and 4 cod generally predominate in terms of weight caught, although the 1987 year class predominated in 1992 at age 5. This pattern represents a downward shift of one age compared to the commercial landings at age. The contribution of age 1 cod has become negligible in recent years.

Recreational Landings Mean Weights at Age

Mean lengths and weights at age of recreationally-caught cod (Table A10b) are consistently lower than those taken in the commercial fishery. This pattern persists through age 5, but mean weights for ages 6 and older are highly variable due to the relatively poor sampling of fish at the larger sizes combined with the lack of market category stratification. Despite this variability, patterns present in the commercial landings mean weights are also evident in the recreational landings, i.e., low mean weights in 1990 and higher mean weights at age 2 in 1995 and 1996.

Stock Abundance and Biomass Indices

Commercial Catch Rates

US commercial LPUE indices (landings per unit effort, expressed in metric tons landed per day fished) were calculated from otter trawl trips landing cod from the Gulf of Maine (Division 5Y) between 1982 and 1996. Due to the change in data collection procedures implemented in 1994, methods employed to compute LPUE for the 1994-1996 period differed from those used to compute indices for 1982-1993.

The 1982-1993 series

Standardized effort and LPUE series for Gulf of Maine cod for the period prior to 1994 were developed for a sub-fleet by applying a five-factor (year, area, quarter, tonnage class, and depth) general linear model (GLM) to log LPUE data derived for all interviewed otter trawl trips taking cod during 1982-1993 (Table A11). Details regarding data selection and preparation and model formulation are provided by Mayo *et al.* (1994).

The effort standardization factors employed in the previous Gulf of Maine cod assessment were based on a GLM using data for 1982-1992. Standardized effort for the 1982-1992 period and for 1993 were derived from the cross products of year, area, quarter, tonnage class, and depth cell coefficients corresponding to the 1982-1992 period. For the present assessment, cell coefficients were re-computed using the same GLM formulation based on data for 1982-1993 inclusive. During the course of this analysis, it was discovered that a coefficient for one level of one factor (tonnage class 32) was mis-specified in the effort standardization software. The class 32 coefficient of 2.35 (Mayo 1995, Table 11) was erroneously entered as 0.55. When the previous effort analysis was re-run with the correct entry, the resulting effort series increased by about 22% across all years, i.e., standardized effort was re-scaled up by 22%. The impact of this change on the VPA outcome was minimal; terminal F in 1993 increased from 0.93 to 0.94 (1%), terminal population estimates decreased by a corresponding amount, and coefficients of variation of the population estimates remained unchanged.

The updated 1982-1993 model again accounted for just under 25% of the total sum of squares, and all five factors were again highly significant. For each year between 1982 and 1993, standardized effort in each area-quarter-tonnage class-depth category was estimated by multiplying the sum of the nominal effort for that cell by the product of the re-transformed GLM coefficients for each factor. The estimated standardized sub-fleet effort was then accumulated over all categories to provide annual estimates as given in Table A12. Total standardized effort was then calculated by raising the sub-fleet effort to account for all cod landings.

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

The 1994-1996 series

Beginning in 1994, information on fishing effort was no longer obtained from personal interviews of fishing captains. Instead, effort data for the 1994-1996 period were obtained from NMFS Northeast Region Vessel Trip Report (VTR) databases which were subjected to preliminary audits on selected fields (Power *et al.* 1997). These logbook data were extracted from the same database used to prorate total landings by stock. Fishing effort from otter trawl trips landing Gulf of Maine cod was computed from logbook records in which cod were reported from locations within Division 5Y. Effort in terms of days fished was computed as the product of the reported average haul time and the total number of hauls, converted to 24-hour days. Filtering of suspected outliers was performed. Trip data were aggregated in the same manner as the 1982-1993 interview records, i.e., by year, area, quarter, tonnage class, and depth categories. Nominal effort for 1994-1996 was then adjusted by the cell cross products derived from the 1982-1993 GLM results to produce the standardized effort and LPUE series for this period.

Trends in LPUE and Fishing Effort

The LPUE analysis presented in previous assessments using 'calculated effort' from cod trips weighted by catch within tonnage class was discontinued in the present assessment. Trends in the proportion of 'directed' cod trips, in which cod comprised 50% or more of the total trip catch by weight, and the historic 1965-1993 catch-weighted LPUE and effort series based on all cod trips can be obtained from Mayo (1995).

Calculated LPUE values based on catch-weighted effort by tonnage class increased during the late

1960s, declined during the early 1970s, sharply increased in 1974, and then stabilized during 1975-1983 at a relatively high level. After 1983, LPUE indices trended downward, reaching record-low levels in 1987. The LPUE index increased between 1988 and 1991, attaining its maximum value since 1977 (and among the highest in the time-series). In 1992 and 1993, LPUE declined sharply, approaching the lowest on record in 1993. In terms of calculated effort (total landings/LPUE index), total fishing effort reached a record-high level in 1987, declined from 1988 to 1990, and increased well above the 1990 level in 1993. Total calculated effort on Gulf of Maine cod since 1984 appears to have remained at a consistently high level relative to the 1960s and 1970s.

Standardized fishing effort increased during the 1980s, with peak effort occurring in 1987. Effort declined thereafter and remained rather variable between 1991 and 1993 (Table A12, Figure A2). As well, standardized LPUE declined gradually between 1982 and 1987, increased steadily until 1990, and then declined sharply by about 50-60% between 1991 and 1993 (Table A12, Figure A3). Over the 1982-1993 period when both series were available, standardized LPUE and the weighted average LPUE based on all cod trips were quite consistent in both scale and trend (Figure A3).

Estimated standardized effort increased sharply in 1994, but declined thereafter, returning to pre-1994 levels by 1996. The abrupt increase in 1994 raised effort (Figure A2) reflected a corresponding increase in the observed nominal and estimated standardized effort in the otter trawl sub-fleet (Table A12). The reported landings for the corresponding VTR trips declined sharply in 1994, however, resulting in a substantial decrease in the ratio landings to nominal effort and the consequent standardized LPUE index. The sharp increase in raised effort occurred when this low sub-fleet LPUE index was raised to total landings. Estimates of standardized LPUE gradually increased over the 1994-1996 period, but remained substantially below the 1993 LPUE (Figure A3).

The reasons for this dramatic 1-year increase in estimated effort in 1994, followed by a more gradual decline in 1995 and 1996, may be related to changes in reporting methods, use of unaudited effort fields in the VTR data sets, or a change in the relationship between otter trawl LPUE and fixed gear LPUE. In the VTR data, effort is recorded in two fields: number of hauls and average haul duration. Trip effort must then be computed as the product of these factors. If either field is misinterpreted or entered incorrectly, the resulting effort estimate for the trip may be in error. A preliminary scan of the effort fields revealed some very large outliers. Consequently, data included in the effort calculations were restricted to computed effort per trip of 12 days fished or less. Analyses of the 1994-1996 computed effort per trip by DeLong *et al.* (1997) indicated an abrupt shift in the distribution of 1994-1996 LPUE towards a higher frequency of low LPUE and low effort trips compared to the 1991-1993 period.

As well, it is not known whether the landings reported in the VTR data reflect whole or eviscerated weight estimates. Estimates of standardized effort and LPUE for 1994-1996 given in Figures A2 and A3 were derived to consider either assumption; i.e., the higher LPUE and lower estimates of effort correspond to the assumption that the kept portion of the catch reported on VTR records reflected fish in eviscerated condition. Given the uncertainty about the effort data in the VTR data sets, estimates of effort and LPUE for 1994-1996 must be considered provisional, and further analyses of the VTR-based estimates of LPUE in relation to the interview-based estimates are required.

<u>Research Vessel Survey Indices</u>

Indices of cod abundance (stratified mean catch per tow in numbers) and biomass (stratified mean weight per tow in kg), developed from NEFSC and Commonwealth of Massachusetts research vessel bottom trawl surveys, have been used to monitor changes and assess trends in population size and recruitment of US cod populations since 1963. Offshore (>27 m) stratified random NEFSC surveys have been conducted annually in the Gulf of Maine in the autumn since 1963 and in the spring since 1968. Inshore areas (<27 m) have been sampled since 1978 during spring and autumn NEFSC and Commonwealth of Massachusetts inshore bottom trawl surveys. 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 A13. Standardized catch-per-tow-at-age indices (number) from NEFSC spring and autumn surveys are listed in Table A14. Catch-per-tow-at-age indices (number) from Massachusetts spring and autumn surveys are listed in Table A15.

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 A13, Figure A4). Number-per-tow indices 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 number-per-tow indices reflect above-average recruitment of the 1971, 1973, 1977-1980, 1983, and 1985-1987 year classes at ages 1 and 2 (Table A14, Figure A5). The sequential dominance of these cohorts at older ages can be discerned from number-per-tow-at-age values in both spring and autumn NEFSC surveys (Table A14).

Spring NEFSC number-per-tow indices have remained relatively stable since 1985 at a level below the 1981-1984 period (Table A13); spring weight-per-tow indices have also remained relatively low through 1991, but the index increased substantially in 1992 and remained relatively high in 1993 due to a large contribution from the 1987 year class (Table A14). The index declined markedly in 1994, remained low in 1995, and increased moderately in 1996. Autumn number- and weight-per-tow indices declined sharply in 1991 to unprecedented low levels; weight per tow continued to decline to record-low levels through 1993 and has remained extremely low through 1996 (Figure A4). The increased abundance in 1988 and 1989, resulting from recruitment of the strong 1986 and 1987 year classes, was depleted by 1991, resulting in the sharp declines in the overall index. This reduction, combined with a general paucity of large fish in the survey indices (Table A14) in recent years, has resulted in the sharp decline and subsequent low values of the weight-per-tow indices since 1991 as well. Overall, the 1987 year class appears to have been one of the strongest ever produced; catch-per-tow indices of this cohort at ages 1-3 in the NEFSC autumn surveys and at ages 0 and 1 in the Massachusetts DMF autumn inshore surveys were nearly all record-high values (Tables A14 and A15). 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 of Gulf of Maine cod appear to be below average, and the 1994 and 1995 year classes are likely to be record lows.

Mortality

Total Mortality Estimates

Pooled estimates of instantaneous total mortality (Z) were calculated for eight time periods encompassed by the NEFSC spring and autumn offshore surveys: 1964-1967, 1968-1972, 1973-1976, 1977-1981, 1982-1984, 1985-1987, 1988-1990, 1991-1993, and 1994-1996 (Table A16). Total mortality was calculated from survey catch-per-tow-at-age data (Table A14) 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: $\ln(\Sigma$ age 4+ for 1982-1984/ Σ age 5+ for 1983-1985)

Autumn: ln (Σ age 3+ for 19811983/ Σ age 4+ for 1982-1984)

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

Except for the 1988-1990 and 1994-1996 periods, values of Z derived from the spring surveys are slightly lower than those calculated from the autumn data. Rather than selecting one survey series over the other, total mortality was calculated by taking a geometric mean of the spring and autumn estimates in each time period. The pooled estimates indicate that total mortality was relatively low (Z = 0.40) between 1964 and 1976, but significantly increased afterward to 0.75-0.78 during 1982-1987. Total mortality increased further to 0.94 during 1988-1990 and to 1.10 during 1991-1993 and remained high (1.11) during 1994-1996.

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 F values in 1993. As in previous assessments, age-disaggregated analyses were performed. Several exploratory ADAPT formulations were performed using NEFSC spring and autumn (ages 2-6) and Massachusetts DMF spring (ages 2-4) and autumn (ages 2 and 3) catch-per-tow-at-age indices. Due to uncertainty in the interpretation of effort units in the 1994-1996 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 1995), the US commercial LPUE indices for 1982-1993 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 by one age and one year, whereby age 1-6 indices were related to age 2-6 stock sizes in the subsequent year for corresponding cohorts. All NEFSC and Massachusetts DMF indices were related to January 1 stock sizes, and US commercial LPUE indices were related to mid-year stock sizes.

The 1982-1996 commercial landings at age provided in Table A7a include true ages 2-10 as well as 11+. 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 (Mayo *et al.* 1993; Mayo 1995), all trial formulations employed a reduced age range (2-6, 7+).

As in the past, Massachusetts DMF survey data were included in the VPA calibration primarily to improve the estimates of recruiting year class strength. In exploratory analyses, the DMF autumn age 3 (age 2 before lagging) index often accounted for up to 40% of the total sum of squares; this index was again, as in previous assessments, excluded from the final calibration. A summary of a series of trial formulations is provided in Table A17. All of the trial calibrations employed equal weighting among indices and in all years. The formulation identical to that employed in the previous assessment is presented first. This formulation and the second one listed in Table A17 employed commercial landings-at-age data only as in all previous assessments. The second trial calibration included an extended age range in the landings data, but included direct estimates of age 2-6 stock sizes as in the previous trial. Two additional trial calibration runs were performed incorporating estimates of recreational landings at age. The first of these employed the same age range in the direct estimation of terminal populations and the same calibration block as the previous trials, while the second of the two trials incorporating recreational data included a direct estimate of age 1 numbers and two age 1 calibration indices from the Massachusetts DMF spring and autumn surveys.

In all trials, a rather sharp increase in the 1996 F is evident between ages 4 and 5, although the CVs are similar among trials. The F pattern in 1994 was also rather unstable in all formulations, with unusually high Fs on ages 4 and 5, particularly on age 5. None of the variation on the initial formulation produced noticeably different results in terms of terminal Fs, population numbers, or CVs. The impact of including the recreational landings in the VPA was an increase in the 1997 terminal population numbers; changes in the 1996 terminal F estimates were minimal. Incorporation of age 1 in the formulation resulted in improved precision on the estimate of age 2 population numbers (CV = 0.37) and a less precise estimate of the age 6 numbers (CV = 0.65). As well, age 1 numbers were poorly estimated (CV = 0.74). Prior to the terminal year, estimates of F at younger ages were generally higher, and stock size estimates at all ages increased over those obtained from the trial employing only commercial landings at age. Noting the low precision on ages 1 and 6, taking into account the poor length sampling for cod in the recreational fishery, and recognizing the rather uncertain estimates of the recreational catch allocation between the Gulf of Maine and Georges Bank stocks, recreational landings were excluded from the final VPA.

The ADAPT formulation employed in the final VPA calibration, based on commercial landings only, provided direct stock size estimates for ages 2-6 in 1997 and corresponding estimates of F on ages 1-5 in 1996. 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 Fs at ages 4 and 5; 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 provided by O'Brien (pers. comm.).

Virtual Population Analysis Results

Full results from the final VPA calibration are presented in Mayo (1997, Appendix 3) and estimates of F, stock size, and spawning stock biomass are given in Table A18. Summary results from a secondary calibration run which included recreational catch at age are presented in Table A18a. Results are similar to those obtained from the primary VPA based on commercial landings only: estimates of stock size and biomass are higher (roughly in proportion to the difference between the commercial landings and the commercial plus recreational landings) and fully recruited fishing mortality follows the same pattern as in the primary VPA run.

Except for a few cases, the final calibration yielded low correlations (<0.10) among estimates of slope (q) and moderately low correlations (<0.20) between stock size and q. The highest correlations were noted between stock size estimates and the NEFSC spring and autumn abundance index for the corresponding age (Mayo 1997, Appendix 3, page 11). All parameter estimates were significant. Coefficients of variation on the stock size estimates ranged from 0.31 (age 3) to 0.57 (age 6), while CVs on the estimates of slope were between 0.16 and 0.18. Slopes of the abundance index-stock size relationships (Mayo 1997, 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. Slopes from the Massachusetts DMF indices also exhibited an increasing trend in q between ages 2 and 4.

Average (ages 4-5, unweighted) fishing mortality in 1996 was estimated to be 1.04 (Table A18, Figure A6), a 17% increase from 1993. This increase in mean fully recruited F is consistent with estimates of continued high fishing effort indicated by the general linear model (Figure A3). The spawning stock biomass of age 2 and older cod declined from 22,400 mt in 1982 to 14,300 mt in 1987. Following the recruitment and maturation of the strong 1987 year class, SSB increased sharply in 1989 to a maximum of 26,100 mt, but declined to 8,600 mt in 1994 (Figure A7). Total (ages 2+) stock size has also declined sharply in recent years from 28 million fish in 1989 to 4.2 million in 1997 (Table A18).

Since 1982, recruitment at age 2 has ranged from approximately 1 million fish (1994 year class) to 17.7 million fish (1987 year class). Over the 1982-1996 period, geometric mean recruitment for the 1980-1994 year classes equaled 4.7 million fish. The 1987 year class is the strongest 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 1988-1991 and the 1993-1995 year classes (all ≤4.7 million at age 2) are estimated to be among the poorest in the series (Table A18, Figure A7). In particular, the 1994 and the 1995 year classes are each estimated to be less than 1 million fish.

Precision of F and SSB

To evaluate the precision of the final estimates, a bootstrap procedure (Efron 1982) was used to generate 1,000 distributions of the 1996 fishing mortality rate and spawning stock biomass. Figures A8 and A9 show the distribution of the bootstrap estimates and a cumulative probability curve. The cumulative probability expresses the likelihood that the fishing mortality rate was greater than a given level (Figure A8) or the likelihood that spawning stock biomass was less than a given level (Figure A9) when measurement error is considered. An evaluation of the precision of the 1997 stock size, q, 1996 fishing mortality, and 1996 spawning stock biomass estimates is presented in Mayo (1997, Appendix 4).

Coefficients of variation (CV) for the 1997 stock size estimates ranged from 0.31 (age 3) to 0.70 (age 6), and CVs for qs among all indices ranged from 0.15 to 0.19 (Mayo 1997, Appendix 4, Table 1). The fully recruited fishing mortality for ages 4+ was reasonably well estimated (CV = 0.25). The mean bootstrap estimate of F (1.08) was slightly higher than the point estimate (1.04) from the VPA (Mayo 1997, Appendix 4, Table 5) and ranged from 0.46 to 2.04 (Figure A8). $F_{20\%}$ and F_{max} are much lower than the lowest bootstrap estimate, and F_{96} is almost certainly above the overfishing definition mortality rate and the maximum F allowable to achieve stock rebuilding.

Although the abundance estimates of individual ages in 1997 had wider variances (CV = 0.31 to 0.70), the estimate of the 1996 spawning stock biomass was robust (CV = 0.15). The bootstrap mean (9,600 mt) was slightly higher than the VPA point estimate (9,300 mt) (Mayo 1997, Appendix 4, Table 6) and ranged from 6,000 mt to 14,700 mt (Figure A9). Current spawning stock biomass is the lowest observed in the series.

In general, the precision of the estimates of stock size and fishing mortality in the present assessment is less than in the previous assessment of this stock (Mayo 1995). This may be due to greater variability in the estimates of landings at age resulting from lower sampling in recent years, or the exclusion of commercial LPUE indices in the most recent years of the VPA calibration. Despite this lower precision, the VPA results are sufficient to accurately characterize the overall status of the Gulf of Maine cod stock.

Retrospective Analysis

Retrospective analyses of the Gulf of Maine cod VPA were carried out using the final ADAPT formulation with the terminal year ranging from 1996 back to 1991. Results are given in Table A19 and Figure A10. Convergence of estimates is generally evident within 3 years, and often within 2 years, prior to any given terminal year. Retrospective patterns are evident for Gulf of Maine cod, particularly with respect to terminal F. Mean (ages 4-5, unweighted) F in the terminal year was generally under-estimated by the ADAPT calibration in the most recent years and slightly over-estimated in earlier years; age 2 recruits and SSB did not exhibit any persistent retrospective pattern. 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 for 1991-1996. Although subject to some variability, terminal year recruitment and SSB appear to have been estimated recently with a high degree of reliability.

Yield and Spawning Stock Biomass per Recruit

Yield-per-recruit, total stock biomass-per-recruit, and spawning stock biomass-per-recruit analyses were performed using the Thompson and Bell (1934) method. Mean weights at age for application to yield per recruit were computed as a 15-year arithmetic average of catch mean weights at age (Table A7b) over the 1982-1996 period. Mean weights at age for application to SSB per recruit were computed as a 15-year arithmetic average of stock mean weights at age (Table A9) over the 1992-1996 period. The maturation ogive was the same as used in computing SSB during the 1990-1996 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). A smoothed exploitation pattern was then obtained by dividing the F at age by the mean unweighted F for ages 4-5. The final exploitation pattern is as follows:

Age 1 = 0.000	Age 4 = 0.768
Age 2 = 0.028	Age 5+ = 1.000
Age 3 = 0.211	

This pattern 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 given in Table A20 and illustrated in Figure A11. The yield-per-recruit analyses indicate that $F_{0.1} = 0.16$, $F_{max} = 0.29$, and SSB-per-recruit calculations indicate that $F_{20\%} = 0.37$. These reference points are either identical to or slightly higher than those reported in the previous assessment (Mayo 1995).

Short-Term Projections

Recruitment

Short- and medium-term projections of spawning stock biomass, recruitment, and commercial landings were performed using the VPA-calibrated 1996 fully recruited mean F (ages 4-5, u) and 1997 stock size estimates from the 1,000 bootstrap replications as starting conditions. Recruitment was generated based on the model 9 formulation of Brodziak and Rago (MS 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 these short-term projections, age 2 recruitment in 1997 was fixed at the level estimated in the VPA calibration, and recruitment in 1998 and 1999 was derived by re-sampling the distribution of observed values of the 1988-1994 year classes. The stochastic simulations were repeated 50 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 a 5-year arithmetic average over the 1992-1996 period.

Short-Term Projection Results

Short-term projections are provided over a range of F levels including $F = 0$, $F_{0.1}$, F_{max}, $F_{20\%}$, and F_{96}. Input and output from the projections are given in Table A21. The assumption of $F_{96} = 1.04$ in 1997 resulted in a 1997 catch of approximately 5,800 mt and a corresponding SSB of 6,900 mt. Given the delayed implementation of Amendment 7 effort restrictions in 1997 and the potential for further shifts in fishing effort toward coastal Gulf of Maine grounds, the assumption of F_{96} in 1997 appears reasonable.

Continued fishing at $F = 1.04$ in 1998 will result in projected 1998 landings of about 3,900 mt and in a continued decline in SSB to 4,300 mt in 1999 from the record-low 1997 level of 6,900 mt (Table A21,

Figure A12). SSB is projected to decline even further in 1999 if F remains at the current level in 1998. Even if fishing mortality is reduced to $F_{20\%}$ (0.37) in 1998 and 1999, SSB will not increase above the record-low 1997 level (Table A21, Figure A12).

Medium-Term Projections

The methodology for conducting medium-term (e.g., 10-year) projections is described in the **Data and Methodology Issues** section of this report. Stock-recruitment data and the fitted Beverton-Holt equation are presented in Figure A13. Trends in pre-recruit survival (measured as the R/SSB ratio) are presented in Figure A14. The median, lower 25th, and upper 75th percentiles of projected spawning stock biomass, recruitment (age 1), and landings are given in Tables A22, A23, and A24 and Figure A15 for fishing mortality rate scenarios of F = 0.00, 0.29, and 1.04.

Recent recruitment, R/SSB, and spawning stock biomass are low and declining, and fishing mortality in 1996 was far above biological reference points. Accordingly, the SARC concluded that the most realistic medium-term projection for this stock should constrain R/SSB values to no more than the median of the time series when SSB is below the time-series minimum (particularly since very recent recruit survival values are about one-third of the time-series median). For F = 0.29 and F = 0.00, this constraint had little influence on the projected SSB, recruitment, and landings since the stock rebounds to above the time-series minimum SSB (8,800 mt in 1994) rather quickly. However, for F = 1.04, the maximum R/SSB constraint results in declining trends throughout the 10-year time period.

Projected landings under F_{96} = 1.04 decline steadily from about 4,000 mt in 1998 to about 2,100 mt in 2006. Spawning stock biomass declines from 5,200 mt in 1998 to 2,000 mt in 2006, while recruitment declines from 1.4 to 0.5 million fish over the same period (Table A23). Under the F_{max} = 0.29 scenario, landings rise steadily from 2,600 mt in 1998 to 11,100 mt in 2006, while spawning stock biomass improves from 9.600 mt to 44,000 mt and recruitment from 1.6 to 7.4 million during 1998-2006 (Table A22). For F = 0.00, spawning stock biomass increases 10-fold from 12,400 mt in 1998 to 120,700 mt in 2006, while median recruitment improves from 1.7 to 14.0 million fish.

Alternative Assessment Results

An alternative assessment of this stock was also reviewed by the SARC (Ianelli 1997). The model employed follows the basic concepts outlined by Fournier and Archibald (1982) and expanded upon by Haist *et al.* (1993) and Ianelli and Fournier (1996). The model employed in this analysis of Gulf of Maine cod differs from a VPA specifically because estimates of catch in numbers at age are treated as observations with error. The model, as formulated for the present analysis, also differs from CAGEAN (Deriso *et al.* 1985) and Stock Synthesis (Methot 1990) because it allows greater flexibility in the treatment of gear selectivity and the type of errors that can be modeled. Depending on the assumptions and options employed, the model can be configured to behave as a fully separable model or as a VPA with no separability.

Selectivity formulations in the present analysis assume that large differences between a selectivity coefficient in a given year for a given age should not vary much from adjacent years and ages. The magnitude of these changes is determined by prior variances. Sensitivity of model results with different prior variances was investigated by bracketing a baseline model with low and high variance versions for comparison. This allows explicit consideration of how selectivity may vary between ages over time.

Results from this assessment (Ianelli 1997) were similar to those obtained from the VPA (Figure A16). The model also detected rather abrupt changes in selectivity over time, specifically between the late 1980s and early 1990s. Overall, average fishing mortality (ages 4 and 5) was found to increase steadily from about 0.8 in 1982 to over 1.0 after 1983. Fishing mortality increased abruptly in 1994 to about 1.4 before declining to 0.8-1.0 in 1995-1996. Spawning stock biomass declined steadily between 1982 and 1987, increased in 1989, but has declined sharply during the 1990s to the lowest on record. Recruitment (age 2) trends also follow those obtained from the VPA, with the strong 1987 year class dominant, followed by weak to average year classes between 1988 and 1993. The two most recent year classes produced in 1994 and 1995 are by far the poorest on record.

Conclusions

The Gulf of Maine cod stock is presently at a low biomass level and remains over-exploited. Fishing mortality in 1996 (1.04) has increased from the 1993 level (0.93), while spawning stock biomass (SSB) has declined from over 26,000 mt in 1989 to record-low levels of 8,600 mt in 1994 and is expected to decline further in 1997 to a new record-low of 6,900 mt. Accounting for the estimation uncertainty associated with the 1996 SSB (9,200 mt) and 1996 F (1.04) estimates, there is an 80% probability that the 1996 SSB lies between 7,800 mt and 11,300 mt, and that the 1996 F lies between 0.79 and 1.41. This further implies a 90% probability that the 1996 F is greater than 0.79, or more than two times greater than the overfishing definition ($F_{20\%} = 0.37$).

At the present level of exploitation and probable levels of recruitment in the near term, the decline in spawning stock biomass is expected to accelerate. If the current level of exploitation continues, landings are expected to decline to less than 4,000 mt in 1998 and spawning stock biomass is projected to decline to about 4,300 mt in 1999. Current SSB is no longer dominated by the 1987 year class, but by a series of very low to average year classes produced during 1988-1995. The moderate 1992 year class was the only above-average year class since 1987. Recruitment from the two most recent year classes produced in 1994 and 1995 is expected to be extremely poor, well below previously observed levels.

An immediate and substantial reduction in fishing mortality, in the order of 70%, 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 less than 5,000 mt in the near future.

SARC Comments

The SARC discussed whether discard mortality in both the recreational and commercial fisheries was 100%. Since no hooking mortality studies have been done on cod, recreational discard mortality was assumed to be zero. The amount of cod caught by the recreational fishery has been stable over the time period, but the number landed has declined. Commercial discard mortality was assumed to be 100%.

A question arose as to the age-length key used for the recreational landings and the differences in mean weight at age between the commercial and the recreational landings. A difference was noted between the estimated landings in weight from the MRFSS and the estimated weight from the length-weight relationship. The differences were very marked in some years. The differences were attributed to several factors. The length-weight relationship is that used in the survey audit and needs to be reevaluated. The weight from the MRFSS is derived from very few samples, with substitutions for missing cells.

The significance of the interactions in the GLM model were discussed. All interaction terms were significant because of the large number of degrees of freedom. Not accounting for real interactions may give misleading trends. However, *a priori* knowledge of which interactions have biological meaning is needed prior to running the GLM. There may be an age distribution effect, but the location information on trips is not sufficiently detailed since a single trip will fish in many different areas. An interaction between area and depth, as well as area and season, was considered to be real.

The calculation of days fished in the two data collection series was evaluated. It was determined that the calculation was the same (number of sets x average tow duration) in the logbook as in the interview system. However, the subset of vessel captains submitting the information is probably very different. This may account for the increase in standardized effort or the decrease in LPUE. Other reasons for increased effort (decreased LPUE) were explored. An increase in smaller trips of groundfish is probably due to the 500-lb trip limit of exempted vessels. The haddock trip limit implemented in January 1994 may have driven effort from Georges Bank. The relationship between stock size and LPUE may not be linear at low stock sizes and may decrease at a faster rate. This method of standardizing LPUE does not take into account changes in technology.

The SARC discussed the exclusion of both recreational landings and commercial discards in the catch-at-age data used in the ADAPT formulation. Commercial discards were not included for several reasons. The time series only extends back to 1989, and the age and length composition of the discards was not derived at that time. The recreational landings at age were derived, but were considered to be very uncertain due to many of the reasons given above. The sampling of party/charter vessels is very poor, the length frequency data are poor, and pooling was done on an annual basis. Including the recreational series does not change the interpretation of stock status. The SARC concluded that the estimates of stock biomass are increased by the proportion of recreational catch included. Fishing mortality estimates changed very slightly in the terminal year. The question whether management is ready for a quota that includes recreational landings was discussed.

A difference in survey qs was noted between Gulf of Maine and Georges Bank cod. Adding recreational catch to the catch-at-age data seemed to bring the estimates more in line. However, adding the recreational catch to the Georges Bank catch-at-age data would lower those as well.

The number of missing values in the survey indices at age was noted, and a suggestion was made to use a different error structure to allow inclusion of those values instead of designating them as missing. Weighting of survey indices by the inverse of their variance was discussed. Estimates of variance by age are currently not available.

The high value of F in 1994 was discussed. This matches the pattern in effort derived from the GLM. It could be due, however, to the unweighted average of terminal F for age 6. The large increase in weight at age from ages 4 and 5 in 1994 to ages 5 and 6 in 1995 may have influenced the low numbers. Since sampling has been poor, these may not be well estimated. Effort may also have increased due to the reasons noted above.

Initial medium-term projections at current F levels were thought to be overly optimistic, particularly at F_{96}. It was noted that previous medium-term projections (1994) for this stock were optimistic. The stock-recruitment curve used in the projections is very steep near the origin (Figure A13). The most recent estimates of recruitment are substantially below the predicted stock-recruitment curve. Revised medium-term projections constrained upper estimates of R/SSB to the median of the time series when SSB was below the time-series minimum (1994). The SARC concluded that these revised projections were the most realistic, given current conditions in the stock and fishery.

Research Recommendations

- Further investigation of the changes in effort and LPUE in the VTR data set is required before LPUE can be used to calibrate the VPA.
- Recreational landings and discards and commercial discards should be included in VPA. However, the SARC noted that further investigation of the basis for deriving the recreational component of the cod catch, specifically the effect of sampling levels in the party and charter categories, is required before the recreational landings at age can be used to augment the commercial landings at age in the VPA.
- The SARC recommended that a study on hooking mortality of cod in the recreational fishery be initiated to determine what fraction of the total catch should be used in the catch at age.
- Further examination of discard rates in years prior to 1989 is required before discard data can be incorporated into the catch at age
- Other model formulations of the VPA allowing for error in the catch at age with the appropriate

error structures for each component of the catch at age should be investigated.

- Information on the magnitude of spawning biomass prior to 1982 should be provided to gain a longer-term perspective on stock dynamics.

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Table A1. Commercial landings (metric tons, live) of Atlantic cod the Gulf of Maine (NAFO Division 5Y), 1960 - 1996.[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

* 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 A2. Distribution of USA commercial landings (metric tons, live) of Atlantic cod from the Gulf of Maine (Area 5Y), by gear type, 1965 - 1996. The percentage of total USA commercial landings of Atlantic cod from the Gulf of Maine, by gear type, is also presented for each year. Data only reflect Gulf of Maine cod landings that could be identified by gear type.

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

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

Table A3. Discard and total catch estimates (metric tons, live) for Gulf of Maine cod by otter trawl, shrimp trawl, and sink gillnet gear.

Year	Total Landings	Discard Estimates: Included Landings	Discard Estimate	Discard to Landings Ratio	Total Discard
1989	10397	10182	1513	0.1486	1545
1990	15154	14827	3521	0.2375	3599
1991	17781	17374	1032	0.0594	1056
1992	10891	10511	582	0.0554	603
1993	8287	8058	320	0.0397	329
1994	7877	7522	228	0.0303	239
1995	6798	6500	393	0.0605	411
1996	7194	6837	167	0.0244	176

Table 4. Estimated number (000's) and weight (metric tons, live) of Atlantic cod caught by marine recreational fishermen from the Gulf of Maine stock, 1979 - 1996.[1]

Year	Total Cod Caught: No. of Cod (000's)	Total Cod Caught: Wt. of Cod (mt)	Total Cod Retained (excluding those caught and released): 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

[1] 1981-1996 from Revised Marine Recreational Fishery Statistics Survey database expanded catch estimates.

Table A5. USA sampling of commercial Atlantic cod landings from the Gulf of Maine cod stock (NAFO Division 5Y), 1982 - 1996.

	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

Source: 1978-1985 from Serchuk and Wigley (Woods Hole Lab. Ref 86-12); 1986-1996 from NEFSC files.

Table A6. Percentage (by weight) of USA commercial Atlantic cod landings from the Gulf of Maine (NAFO Division 5Y), by market category, 1964 - 1996.

	Gulf of Maine			
Year	Large	Market	Scrod	Total [a]
1964	29	59	12	100
1965	39	54	7	100
1966	42	48	10	100
1967	41	41	17	100
1968	47	43	9	100
1969	35	55	9	100
1970	43	52	6	100
1971	52	42	6	100
1972	58	35	7	100
1973	52	36	11	100
1974	39	33	28	100
1975	32	42	26	100
1976	29	45	20	100
1977	33	42	22	100
1978	38	44	17	100
1979	37	49	14	100
1980	36	45	19	100
1981	29	45	22	100
1982	29	45	24	100
1983	25	45	28	100
1984	26	51	19	100
1985	25	51	20	100
1986	22	51	23	100
1987	29	52	16	100
1988	26	45	23	100
1989	17	55	23	100
1990	34	43	19	100
1991	26	51	20	100
1992	31	49	18	100
1993	32	44	21	100
1994	24	54	18	100
1995	21	53	23	100
1996	13	61	23	100

[a] Includes landings of 'mixed' cod.

Table A7a. 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 - 1996.

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
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

Table A7b. 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 - 1996.

	Age											
Year	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
					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

Table A8a. 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 - 1996. (Input data for Virtual Population Analysis).

Year	Age 1	2	3	4	5	6	7+	Total
Total Commercial Catch in Numbers (000's) at Age								
1982	30	1380	1633	1143	633	69	230	5118
1983	-	866	2357	1058	638	422	155	5496
1984	4	446	1240	1500	437	194	136	3957
1985	-	407	1445	991	630	128	136	3737
1986	-	84	2164	813	250	177	95	3583
1987	2	216	595	1109	277	66	79	2344
1988	-	160	1443	953	406	43	30	3035
1989	-	337	1583	1454	449	81	56	3960
1990	-	205	3425	2064	430	157	99	6380
1991	-	344	934	4161	851	143	79	6512
1992	-	313	530	484	2018	202	84	3631
1993	-	76	1487	641	129	457	36	2825
1994	-	29	1016	1135	288	72	86	2626
1995	-	218	880	1153	194	12	34	2491
1996	-	65	584	1738	347	45	10	2789
Total Commercial Catch in Weight (Tons) at Age								
1982	24	1595	2717	3160	3019	461	2606	13582
1983	-	1009	3913	2619	2410	2518	1512	13981
1984	3	516	2071	4080	1607	1145	1384	10816
1985	-	513	2523	2816	2814	705	1322	10693
1986	-	110	3976	2375	1153	1072	978	9664
1987	2	283	1001	3641	1340	451	809	7527
1988	-	203	2715	2311	2097	295	337	7958
1989	-	420	2811	4351	1737	325	683	10397
1990	-	219	5794	4687	1834	1200	1361	15095
1991	-	388	1463	10455	3520	1045	910	17781
1992	-	480	1019	1313	6175	1011	892	10891
1993	-	99	2809	1611	561	2819	387	8286
1994	-	43	1975	3576	991	442	851	7877
1995	-	361	1689	3200	997	96	455	6798
1996	-	110	1247	4131	1267	333	106	7194

Table A8b. 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 - 1996. (Input data for Virtual Population Analysis)

Year	Age 1	2	3	4	5	6	7+	Average
Total Commercial Catch Mean Weight (kg) at Age								
1982	0.801	1.156	1.664	2.764	4.770	6.739	11.330	2.654
1983	-	1.164	1.660	2.475	3.778	5.962	9.755	2.544
1984	0.589	1.159	1.670	2.721	3.677	5.898	10.176	2.731
1985	-	1.260	1.746	2.840	4.466	5.525	9.721	2.861
1986	-	1.304	1.837	2.923	4.619	6.067	10.295	2.698
1987	1.028	1.313	1.684	3.283	4.831	6.824	10.241	3.212
1988	-	1.268	1.881	2.426	5.166	6.767	11.233	2.622
1989	-	1.247	1.776	2.993	3.864	4.872	12.200	2.626
1990	-	1.071	1.692	2.271	4.265	7.645	13.747	2.366
1991	-	1.130	1.568	2.512	4.136	7.309	11.449	2.731
1992	-	1.533	1.922	2.714	3.061	5.000	10.614	2.999
1993	-	1.293	1.889	2.513	4.353	6.174	11.063	2.933
1994	-	1.450	1.943	3.151	3.444	6.132	10.018	3.000
1995	-	1.652	1.921	2.775	5.142	8.290	12.969	2.728
1996	-	1.687	2.136	2.376	3.648	7.376	11.647	2.580
Total Commercial Catch Mean Length (cm) at Age								
1982	43.2	48.3	53.8	63.4	76.8	86.1	101.6	59.9
1983	-	48.6	53.8	61.4	70.8	82.4	95.1	59.8
1984	39.0	48.4	54.1	63.4	69.7	81.8	98.0	61.6
1985	-	49.8	55.1	64.6	74.9	80.3	96.7	62.8
1986	-	50.3	55.9	65.0	75.4	82.6	98.4	61.6
1987	47.0	50.4	54.4	67.8	76.9	86.5	98.4	65.4
1988	-	50.1	56.4	61.1	78.7	86.4	103.1	61.4
1989	-	49.8	55.5	65.7	71.5	76.7	103.6	61.7
1990	-	47.5	54.8	60.0	73.7	90.0	108.8	59.2
1991	-	47.7	52.6	61.8	72.6	88.6	102.2	62.2
1992	-	53.1	56.6	62.9	65.6	77.0	100.4	64.3
1993	-	50.5	56.8	61.7	74.2	83.7	101.6	63.5
1994	-	52.4	57.2	66.6	68.1	82.7	97.6	64.4
1995	-	54.4	56.9	63.4	78.6	92.5	107.1	62.3
1996	-	54.6	58.8	60.7	69.3	88.9	103.5	61.8

Table A9. Mean weight at age (kg) at the beginning of the year (January 1) for Atlantic cod from the Gulf of Maine stock (NAFO Division 5Y), 1982 - 1996. Values derived from commercial landings mean weight-at-data (mid-year) using procedures described by Rivard (1980).

	Age									
Year	1	2	3	4	5	6	7	8	9	10+ [a]
1982	0.791	0.965	1.364	2.364	(3.750)	(5.600)	(7.400)	9.853	(11.650)	17.771
1983	0.793	1.024	1.385	2.029	3.231	5.333	6.256	9.701	10.010	17.771
1984	0.761	1.021	1.394	2.125	3.017	4.720	6.957	(9.670)	11.646	17.771
1985	0.748	1.065	1.423	2.178	3.486	4.507	6.826	9.544	10.468	17.771
1986	0.745	1.083	1.521	2.259	3.622	5.205	6.509	8.902	11.824	17.771
1987	0.758	1.087	1.482	2.456	3.758	5.614	7.339	8.767	11.744	17.771
1988	0.765	1.068	1.572	2.021	4.118	5.718	8.233	9.939	12.245	17.771
1989	0.825	1.059	1.501	2.373	3.062	5.017	7.919	10.889	12.835	17.771
1990	0.803	0.982	1.453	2.008	3.573	5.435	7.232	10.438	13.388	17.771
1991	0.690	1.008	1.296	2.062	3.065	5.583	8.586	11.501	13.520	17.771
1992	0.751	1.175	1.474	2.063	2.773	4.548	8.362	10.962	12.873	17.771
1993	0.709	1.079	1.702	2.198	3.438	4.347	7.071	11.518	14.786	17.771
1994	0.664	1.142	1.585	2.440	2.942	5.168	7.168	11.237	12.929	17.771
1995	0.657	1.219	1.669	2.322	4.025	5.343	8.113	10.366	14.405	17.771
1996	0.657	1.232	1.878	2.136	3.182	6.159	9.303	11.316	13.190	17.771
Mean Values										
1992-96	0.751	1.110	1.605	2.227	3.360	5.141	7.807	10.546	12.829	17.771
1982-96	0.741	1.081	1.513	2.202	3.437	5.330	7.608	10.160	12.479	17.771

[a] Mean weight-at-age values for 10+ set equal to mean (1982-1996) catch (mid-year) weight at age value for 10+.

( ) Values in parentheses are modified from calculated values.

Table A10a. Catch at age (thousands of fish; metric tons) of total recreational landings of Atlantic cod from the Gulf of Maine stock (NAFO Division 5Y), 1982 - 1996. (Input data for Virtual Population Analysis).

	Age							
Year	1	2	3	4	5	6	7+	Total
	Total Recreational Catch in Numbers (000's) at Age							
1982	58	615	717	243	84	6	12	1735
1983	14	471	539	126	47	26	14	1237
1984	20	367	332	136	32	11	6	904
1985	49	582	666	131	35	5	1	1469
1986	26	124	586	116	25	20	95	992
1987	39	691	823	416	53	13	18	2053
1988	6	360	697	196	28	8	4	1299
1989	5	193	701	244	36	10	5	1194
1990	7	89	770	309	58	10	6	1249
1991	5	103	415	787	95	8	6	1419
1992	-	37	70	42	166	14	2	331
1993	1	76	511	146	11	24	3	772
1994	1	28	364	93	27	2	2	517
1995	-	61	272	171	10	2	-	516
1996	-	21	104	205	21	1	-	352
	Total Recreational Catch in Weight (Tons) at Age							
1982	26	556	1018	559	373	33	132	2697
1983	6	412	751	272	158	173	168	1940
1984	9	304	480	332	103	47	78	1353
1985	18	494	899	305	115	20	5	1856
1986	11	103	970	304	99	114	1247	2848
1987	11	634	1184	1111	224	96	189	3449
1988	1	310	1049	425	107	26	26	1944
1989	3	208	1111	628	124	61	43	2178
1990	1	80	1147	727	212	66	63	2296
1991	1	119	582	1749	287	48	34	2820
1992	-	56	130	119	509	69	19	902
1993	1	73	841	292	33	108	41	1389
1994	-	35	593	214	56	7	17	922
1995	-	91	443	331	36	4	-	905
1996	-	32	193	406	54	7	3	695

Table A10b. Mean weight (kg) and mean length (cm) at age of total recreational landings of Atlantic cod from the Gulf of Maine stock (NAFO Division 5Y), 1982 - 1996. (Input data for Virtual Population Analysis)

	Age							
Year	1	2	3	4	5	6	7+	Average
				Total Recreational Catch Mean Weight (kg) at Age				
1982	0.452	0.904	1.420	2.297	4.417	5.542	10.872	1.554
1983	0.410	0.874	1.394	2.159	3.350	6.635	12.136	1.568
1984	0.450	0.827	1.447	2.432	3.236	4.215	11.892	1.497
1985	0.371	0.848	1.349	2.330	3.298	3.780	5.2091	1.263
1986	0.413	0.832	1.655	2.630	3.884	5.600	12.995	2.871
1987	0.269	0.918	1.439	2.672	4.252	7.134	10.283	1.680
1988	0.184	0.860	1.504	2.165	3.816	3.443	6.067	1.497
1989	0.615	1.081	1.586	2.575	3.498	6.285	7.851	1.824
1990	0.148	0.900	1.489	2.354	3.640	6.587	13.783	1.838
1991	0.171	1.156	1.403	2.223	3.013	5.696	5.696	1.987
1992	0.456	1.495	1.858	2.832	3.074	4.820	7.221	2.725
1993	0.582	0.959	1.645	2.001	3.131	4.566	11.797	1.799
1994	0.183	1.240	1.632	2.302	2.046	4.613	8.947	1.783
1995	-	1.501	1.627	1.931	3.404	1.871	6.062	1.754
1996	0.582	1.541	1.853	1.979	2.706	7.829	12.378	1.974
				Total Recreational Catch Mean Length (cm) at Age				
1982	33.9	42.9	50.2	59.0	74.1	79.9	98.4	59.9
1983	33.5	42.9	50.1	57.9	67.1	84.5	101.2	59.8
1984	34.2	42.0	50.5	60.1	66.1	71.0	100.1	61.6
1985	32.0	42.4	49.3	60.0	67.0	70.1	78.9	62.8
1986	33.7	41.6	53.3	62.0	70.8	80.4	113.4	61.6
1987	27.8	43.4	50.5	62.5	72.3	86.0	98.6	65.4
1988	26.2	42.8	51.3	58.2	69.9	66.2	81.3	61.4
1989	38.4	46.2	52.5	61.6	67.8	83.9	97.5	61.7
1990	23.7	43.1	51.1	59.8	69.7	84.4	110.0	59.2
1991	24.9	47.0	50.4	58.5	64.5	80.0	80.9	62.2
1992	35.0	51.3	54.7	63.1	64.9	75.4	86.6	64.3
1993	38.0	44.3	53.2	56.6	64.9	72.8	103.1	63.5
1994	26.3	48.2	53.2	59.1	57.2	71.7	95.1	64.4
1995	-	51.8	53.2	55.9	67.1	55.1	83.0	62.3
1996	38.0	52.3	55.4	56.6	62.0	90.1	106.3	61.8

Table A11. Results of fishing effort standardization for Gulf of Maine cod using SAS General Linear Models Procedure on landings and effort data from 1982 through 1993.

General Linear Models Procedure

Dependent Variable: LNCPUEDF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	25	11590.71659123	463.62866365	297.95	0.000
Error	24312	37830.50628931	1.55604254		
Corrected Total	24337	49421.22288055			

R-Square	C.V.	Root MSE	LNCPUEDF Mea
0.234529	-112.2323	1.24741434	-1.1114573

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	11	4833.96208197	439.45109836	282.42	0.000
AREA	4	164.54673741	41.13668435	26.44	0.000
QTR	3	1191.97998989	397.32666330	255.34	0.000
TONCLASS	4	3340.33653032	835.08413258	536.67	0.000
DEPTHCD	3	2059.89125164	686.63041721	441.27	0.000

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	11	4372.73212998	397.52110273	255.47	0.000
AREA	4	302.41968487	75.60492122	48.59	0.000
QTR	3	1241.37073929	413.79024643	265.92	0.000
TONCLASS	4	4005.54777969	1001.38694492	643.55	0.000
DEPTHCD	3	2059.89125164	686.63041721	441.27	0.000

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate	Retransformed Estimate
INTERCEPT		-0.975002369 B	-23.16	0.0001	0.04210412	
AREA	511	0.314761808 B	5.46	0.0001	0.05768044	1.372214
	512	0.076641989 B	2.22	0.0262	0.03448159	1.080298
	513	0.259103053 B	10.62	0.0001	0.02440657	1.296153
	515	-0.021602360 B	-0.71	0.4778	0.03043501	0.979083
	514	0.000000000 B	.	.	.	1.000000
QTR	1	-0.443624023 B	-18.41	0.0001	0.02409136	0.641893
	3	-0.572620753 B	-25.38	0.0001	0.02255770	0.564189
	4	-0.496972511 B	-22.60	0.0001	0.02199250	0.608517
	2	0.000000000 B	.	.	.	1.000000
TONCLASS	31	0.452176751 B	18.79	0.0001	0.02406528	1.572185
	32	0.867362374 B	35.22	0.0001	0.02462967	2.381346
	33	0.928431872 B	34.51	0.0001	0.02690090	2.531454
	41	1.357558269 B	46.92	0.0001	0.02893149	3.888318
	25	0.000000000 B	.	.	.	1.000000
DEPTHCD	1	0.631312591 B	20.09	0.0001	0.03142483	1.881005
	2	0.360688553 B	14.82	0.0001	0.02433859	1.434742
	4	-0.647192169 B	-25.11	0.0001	0.02576926	0.523688
	3	0.000000000 B	.	.	.	1.000000

Table A12. Nominal and standardized (GLM) Gulf of Maine cod landings (mt), effort (days fished) and landings per day fished (LPUE) for the otter trawl effort standardization fleet, 1982-1996.

	Effort Standardization Subfleet Summary Results					Total	Raised
	Landings	Nominal		Standardized		Landings	Effort
Year	(mt)	Effort	LPUE	Effort	LPUE	(mt)	
1982	3395	3158	1.075	6042	0.562	13582	24167
1983	3698	3791	0.975	7069	0.523	13981	26730
1984	2423	3798	0.638	6700	0.362	10806	29881
1985	3012	5294	0.569	9985	0.302	10693	35446
1986	2794	5568	0.502	10280	0.272	9664	35558
1987	1708	5100	0.335	9618	0.178	7527	42392
1988	2060	4753	0.433	9552	0.216	7958	36898
1989	2316	3524	0.657	7363	0.314	10397	33061
1990	4916	4053	1.213	9020	0.545	15154	27807
1991	5432	4737	1.147	10139	0.536	17781	33188
1992	2777	4978	0.558	9637	0.288	10891	37795
1993	2284	4727	0.483	8605	0.265	8287	31219
1994*	1160	5005	0.232	9034	0.128	7877	61357
1995*	1829	7215	0.254	14002	0.131	6798	52031
1996*	2065	6695	0.308	11930	0.173	7194	41558

* 1982-1993 data from interviews; 1994-1996 data from Vessel Trip Reports

Table A13. 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 - 1996 [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

[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 A14. 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, 1963-1996. **[a,b]**

	Age Group											Totals						Standardized Mean Wt
Year	0	1	2	3	4	5	6	7	8	9	10+	0+	1+	2+	3+	4+	5+	(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	2.100	2.100	2.040	2.020	1.430	0.100	5.43

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

Table A14 (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

[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 A15. 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 - 1996. [a]

Gulf of Maine Area (Mass. Regions 4-5)

Year	Age Group 0	1	2	3	4	5	6	7	8	9	10+	Totals 0+	1+	2+	3+	Stratified Mean Weight (kg)
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
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

[a] Massachusetts sampling strata 25-36.

Table A16. Estimates of instantaneous total mortality (Z) and fishing mortality (F)[1] for Gulf of Maine Atlantic cod for eight time periods, 1964 - 1993, derived from NEFSC offshore spring and autumn bottom trawl survey data.[2]

Time Period	Gulf of Maine Spring Z	Spring F	Autumn Z	Autumn F	Geometric Mean Z	Geometric Mean F
1964-1967	-	-	0.39	0.19	0.39	0.19
1968-1972	0.37[3]	0.17	0.43[7]	0.23	0.40	0.20
1973-1976	0.35[4]	0.15	0.45	0.25	0.40	0.20
1977-1981	0.52	0.32	0.57[8]	0.37	0.54	0.34
1982-1984	0.73	0.53	0.78	0.58	0.75	0.55
1985-1987	0.58[5]	0.38	1.05	0.85	0.78	0.58
1988-1990	1.24	1.04	0.72	0.61	0.94	0.74
1991-1993	1.02[6]	0.82	1.18	0.98	1.10	0.90
1994-1996	1.31	1.11	0.94	0.74	1.11	0.91

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 spring 1972-1973 data (4+/5+) since these gave large negative Z value.

4 Excludes spring 1973-1974 data (4+/5+) since these gave unreasonably high Z value.

5 Excludes spring 1985-1986 data (4+/5+) since these gave unreasonably high Z value.

6 Excludes spring 1991-1992 data (4+/5+) since these gave unreasonably low Z value.

7 Excludes autumn 1967-1968 data (3+/4+) since these gave large negative Z value.

8 Excludes autumn 1976-1977 data (3+/4+) since these gave large negative Z value.

Table A17. Summary statistics of the base, alternative, and final ADAPT VPA calibration for Gulf of Maine cod; terminal year 1996.

ADAPT Run Number 361 1997 4 16 9 8 15

COD: GULF OF MAINE STOCK - COMMERCIAL LANDINGS ONLY FINAL CALIBRATION RUN
ALL INDICES UNWEIGHTED;
NO TIME TAPERED WEIGHTING APPLIED
7+CAA

	PAR. EST.	STD. ERR.	T-STATISTIC	C.V.	1996 F Estimate	
N 2	7.21262E2	3.29056E2	2.19191E0	0.46	F 2	0.08
N 3	7.30254E2	2.24368E2	3.25471E0	0.31	F 3	0.33
N 4	1.36997E3	4.25191E2	3.22201E0	0.31	F 4	0.82
N 5	1.24398E3	5.05247E2	2.46212E0	0.41	F 5	1.25
N 6	1.25367E2	7.18052E1	1.74593E0	0.57	F 6	1.04
					F 7+	1.04

ADAPT Run Number 358 1997 4 17 14 1 58

COD: GULF OF MAINE STOCK - COMERCIAL LANDINGS ONLY
ALL INDICES UNWEIGHTED;
NO TIME TAPERED WEIGHTING APPLIED
FULL CAA 2-10+

	PAR. EST.	STD. ERR.	T-STATISTIC	C.V.	1996 F Estimate	
N 2	7.24209E2	3.29251E2	2.19956E0	0.45	F 2	0.08
N 3	7.33445E2	2.24515E2	3.26680E0	0.31	F 3	0.32
N 4	1.38003E3	4.26110E2	3.23868E0	0.31	F 4	0.77
N 5	1.34525E3	5.28603E2	2.54492E0	0.39	F 5	1.20
N 6	1.34433E2	7.58129E1	1.77322E0	0.56	F 6	0.99
					F 7	0.99
					F 8	0.99
					F 9	0.99
					F 10+	0.99

ADAPT Run Number 356 1997 4 8 11 10 48

COD: GULF OF MAINE STOCK - COMMERCIAL AND RECREATIONAL LANDINGS
ALL INDICES UNWEIGHTED;
NO TIME TAPERED WEIGHTING APPLIED
7+CAA

	PAR. EST.	STD. ERR.	T-STATISTIC	C.V.	1996 F Estimate	
N 2	9.05232E2	4.16297E2	2.17449E0	0.46	F 2	0.07
N 3	9.14172E2	2.82058E2	3.24108E0	0.31	F 3	0.29
N 4	1.73550E3	5.27683E2	3.28890E0	0.30	F 4	0.73
N 5	1.54337E3	6.06747E2	2.54368E0	0.39	F 5	1.20
N 6	1.40041E2	7.99724E1	1.75112E0	0.57	F 6	0.97
					F 7+	0.97

ADAPT Run Number 360 1997 4 9 12 6 32

COD: GULF OF MAINE STOCK - COMMERCIAL AND RECREATIONAL
ALL INDICES UNWEIGHTED;
NO TIME TAPERED WEIGHTING APPLIED
ESTIMATING AGE 1; ADDED AGE 1
INDICES FROM MASS SURVEYS
7+CAA

	PAR. EST.	STD. ERR.	T-STATISTIC	C.V.	1996 F Estimate	
N 1	6.45573E3	4.79997E3	1.34495E0	0.74	F 1	0.00
N 2	1.14175E3	4.25627E2	2.68251E0	0.37	F 2	0.04
N 3	1.83336E3	5.33715E2	3.43509E0	0.29	F 3	0.22
N 4	2.40028E3	7.09920E2	3.38106E0	0.30	F 4	0.72
N 5	1.57653E3	6.69826E2	2.35364E0	0.42	F 5	1.20
N 6	1.39938E2	9.11111E1	1.53591E0	0.65	F 6	0.96
					F 7+	0.96

Table A18. Estimates of beginning year stock size (thousands of fish), instantaneous fishing mortality (F) and spawning stock biomass (tons) for Gulf of Maine cod derived from virtual population analysis (VPA) calibrated using the ADAPT procedure, 1982-1996.
Primary Run: Commercial Landings Only.

STOCK NUMBERS (Jan 1) in thousands - GMCOD97

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1	6162	5534	7746	4913	7410	9954	21645	3373	3391	5847	5294	7758	3753	1177	881	---
2	9108	5018	4530	6339	4023	6067	8148	17721	2761	2776	4787	4334	6352	3073	964	721
3	4328	6208	3325	3306	4821	3218	4772	6526	14204	2075	1961	3636	3480	5174	2319	730
4	2666	2066	2950	1600	1399	1989	2096	2601	3911	8530	854	1126	1631	1930	3440	1370
5	1661	1149	734	1058	413	410	625	854	814	1334	3219	261	342	309	537	1244
6	166	787	363	206	296	112	85	145	293	277	322	810	97	20	77	125
7	547	284	250	214	156	132	58	98	182	151	131	63	113	54	17	27
1+	24639	21046	19900	17636	18518	21881	37428	31318	25555	20990	16569	17988	15769	11737	8234	----
2+	18477	15512	12154	12723	11108	11927	15783	27945	22164	15143	11275	10230	12016	10560	7353	4218

FISHING MORTALITY - GMCOD97

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.18	0.21	0.12	0.07	0.02	0.04	0.02	0.02	0.09	0.15	0.08	0.02	0.01	0.08	0.08
3	0.54	0.54	0.53	0.66	0.69	0.23	0.41	0.31	0.31	0.69	0.35	0.60	0.39	0.21	0.33
4	0.64	0.83	0.83	1.15	1.03	0.96	0.70	0.96	0.88	0.77	0.98	0.99	1.47	1.08	0.82
5	0.55	0.95	1.07	1.07	1.10	1.37	1.26	0.87	0.88	1.22	1.18	0.79	2.66	1.19	1.25
6	0.61	0.90	0.89	1.16	1.08	1.05	0.82	0.97	0.90	0.84	1.18	0.98	1.71	1.13	1.04
7	0.61	0.90	0.89	1.16	1.08	1.05	0.82	0.97	0.90	0.84	1.18	0.98	1.71	1.13	1.04
4-5	0.59	0.89	0.95	1.11	1.07	1.17	0.98	0.92	0.88	1.00	1.08	0.89	2.06	1.14	1.04

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

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	330	297	399	142	214	292	640	108	237	351	346	479	217	67	50
2	2143	1247	1141	3096	2015	3041	4026	8685	620	634	1289	1082	1683	858	272
3	3185	4634	2503	3871	6012	4217	6438	8542	10234	1252	1423	2923	2700	4357	2155
4	4820	3105	4650	2781	2575	4028	3647	5085	5317	12109	1171	1644	2442	2932	5025
5	6070	2972	1738	2983	1204	1184	2017	2187	2284	3033	6666	716	587	927	1259
6	823	3496	1429	739	1245	511	409	597	1298	1274	1141	2834	358	82	379
7	5405	2311	2127	1666	1290	1103	566	985	2076	1451	1107	570	822	564	159
1+	22775	18062	13988	15277	14557	14377	17744	26188	22067	20104	13144	10248	8810	9786	9299
2+	22445	17765	13589	15135	14343	14085	17104	26080	21830	19753	12798	9769	8593	9719	9249

PERCENT MATURE (females) - GMCOD97

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	7	7	7	4	4	4	4	4	9	9	9	9	9	9	9
2	26	26	26	48	48	48	48	48	24	24	24	24	24	24	24
3	61	61	61	95	95	95	95	95	54	54	54	54	54	54	54
4	88	88	88	100	100	100	100	100	81	81	81	81	81	81	81
5	97	97	97	100	100	100	100	100	94	94	94	94	94	94	94
6	100	100	100	100	100	100	100	100	98	98	98	98	98	98	98
7	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table A18a. Estimates of beginning year stock size (thousands of fish), instantaneous fishing mortality (F) and spawning stock biomass (tons) for Gulf of Maine cod derived from virtual population analysis (VPA) calibrated using the ADAPT procedure, 1982-1996.
Secondary Run: Commercial and Recreational Landings.

STOCK NUMBERS (Jan 1) in thousands - GMCOD97

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1	7769	7539	10464	7004	10161	12537	25196	4300	4019	6970	6408	9130	4592	1466	1106	0
2	10891	6281	6160	8545	5690	8296	10228	20624	3516	3285	5702	5246	7474	3759	1201	905
3	5359	7112	3933	4307	6101	4471	5971	7903	16406	2613	2285	4352	4158	6067	2825	914
4	3026	2262	3202	1797	1616	2507	2377	2953	4404	9636	919	1328	1755	2155	3925	1735
5	1796	1223	780	1142	456	483	673	907	881	1458	3412	276	375	326	567	1543
6	170	822	382	214	333	125	97	158	303	280	338	817	99	22	82	140
7	541	305	260	216	315	150	63	104	188	155	132	65	115	53	18	31
1+	29552	25543	25180	23227	24674	28568	44605	36948	29717	24397	19196	21214	18568	13849	9723	----
2+	21073	16878	14075	15791	13864	15756	19249	32386	25207	16993	12318	11202	13762	12307	8517	5098

FISHING MORTALITY - GMCOD97

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.23	0.27	0.16	0.14	0.04	0.13	0.06	0.03	0.10	0.16	0.07	0.03	0.01	0.09	0.07
3	0.66	0.60	0.58	0.78	0.69	0.43	0.50	0.38	0.33	0.85	0.34	0.71	0.46	0.24	0.29
4	0.71	0.86	0.83	1.17	1.01	1.12	0.76	1.01	0.91	0.84	1.00	1.06	1.48	1.14	0.73
5	0.58	0.96	1.09	1.03	1.10	1.41	1.25	0.89	0.95	1.26	1.23	0.82	2.62	1.18	1.20
6	0.67	0.92	0.90	1.16	1.06	1.20	0.87	1.01	0.94	0.91	1.22	1.05	1.73	1.19	0.97
7	0.67	0.92	0.90	1.16	1.06	1.20	0.87	1.01	0.94	0.91	1.22	1.05	1.73	1.19	0.97
4-5	0.64	0.91	0.96	1.10	1.05	1.26	1.01	0.95	0.93	1.05	1.12	0.94	2.05	1.16	0.97

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

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	415	405	539	202	293	368	745	137	281	418	419	563	266	84	63
2	2544	1546	1541	4129	2842	4098	5024	10095	789	748	1537	1307	1979	1049	339
3	3863	5261	2935	4944	7603	5665	7927	10220	11776	1536	1661	3437	3190	5085	2642
4	5413	3382	5043	3115	2986	4944	4092	5726	5959	13534	1256	1915	2619	3245	5814
5	6525	3158	1841	3241	1331	1388	2176	2313	2444	3293	7009	753	648	979	1343
6	833	3634	1500	771	1405	554	462	648	1337	1272	1188	2827	365	93	408
7	5336	2494	2217	1683	3220	1214	605	1015	2129	1496	1100	580	831	545	168
1+	24930	19880	15615	18085	19680	18231	21031	30155	24713	22298	14171	11382	9898	11080	10777
2+	24515	19475	15076	17883	19387	17863	20286	30018	24432	21880	13752	10819	9632	10996	10714

PERCENT MATURE (females) - GMCOD97

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	7	7	7	4	4	4	4	4	9	9	9	9	9	9	9
2	26	26	26	48	48	48	48	48	24	24	24	24	24	24	24
3	61	61	61	95	95	95	95	95	54	54	54	54	54	54	54
4	88	88	88	100	100	100	100	100	81	81	81	81	81	81	81
5	97	97	97	100	100	100	100	100	94	94	94	94	94	94	94
6	100	100	100	100	100	100	100	100	98	98	98	98	98	98	98
7	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table A19. Results of retrospective analysis of Gulf of Maine cod VPA based on final ADAPT formulation.
Primary Run: Commercial Landings Only.

A: Recruitment at age 2

STOCK NUMBERS (Jan 1) in thousands - GMCOD97_RETRO

Term Yr	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1991	9107	5017	4530	6333	4011	5984	8086	16868	3555	2680	4024					
1992	9108	5018	4531	6339	4027	6069	8189	17742	2783	2741	4473	5090				
1993	9108	5018	4531	6339	4024	6067	8156	17728	2827	2553	4213	4329	4221			
1994	9108	5018	4531	6339	4025	6072	8162	17843	2776	2900	4821	4683	5345	3910		
1995	9108	5018	4530	6339	4023	6067	8151	17738	2776	2782	4977	4370	5776	3623	723	
1996	9108	5018	4530	6339	4023	6067	8148	17721	2761	2776	4787	4333	6350	3071	964	721

B: Average (ages 4-5) unweighted F

FISHING MORTALITY - GMCOD97_RETRO

Term Yr	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1991	0.59	0.89	0.95	1.11	1.07	1.17	0.99	0.94	0.93	1.07					
1992	0.59	0.89	0.95	1.11	1.07	1.17	0.98	0.91	0.87	0.98	1.06				
1993	0.59	0.89	0.95	1.11	1.07	1.17	0.98	0.92	0.87	0.99	1.04	0.97			
1994	0.59	0.89	0.95	1.11	1.07	1.17	0.98	0.91	0.87	0.99	1.05	0.82	1.46		
1995	0.59	0.89	0.95	1.11	1.07	1.17	0.98	0.92	0.88	1.00	1.07	0.87	1.89	0.89	
1996	0.59	0.89	0.95	1.11	1.07	1.17	0.98	0.92	0.88	1.00	1.08	0.89	2.06	1.13	1.04

C: Spawning Stock Biomass

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

Term Yr	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1991	22775	18061	13986	15271	14537	14304	17547	25532	21397	18983					
1992	22776	18062	13988	15278	14560	14386	17776	26259	22158	20192	13296				
1993	22775	18062	13988	15277	14558	14379	17751	26207	22083	20073	12968	9516			
1994	22775	18062	13988	15278	14559	14384	17767	26280	22194	20338	13527	10757	9318		
1995	22775	18062	13988	15277	14557	14379	17749	26204	22089	20158	13262	10431	9168	10099	
1996	22775	18062	13988	15277	14557	14377	17744	26188	22067	20104	13143	10247	8808	9782	9292

Table A20. 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: 17- 4-1997; Time: 15:07:56.86
GULF OF MAINE COD (5Y) - 1997 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:
==> YRCODGMA.DAT

Age-specific Input data for Yield per Recruit Analysis

Age	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Weights Catch	Average Weights Stock
1	.0000	1.0000	.0900	.500	.741
2	.0281	1.0000	.2400	1.312	1.081
3	.2110	1.0000	.5400	1.799	1.513
4	.7680	1.0000	.8100	2.716	2.202
5	1.0000	1.0000	.9400	4.215	3.437
6	1.0000	1.0000	1.0000	6.439	5.330
7	1.0000	1.0000	1.0000	9.064	7.608
8	1.0000	1.0000	1.0000	11.484	10.160
9	1.0000	1.0000	1.0000	13.787	12.479
10+	1.0000	1.0000	1.0000	17.771	17.771

Summary of Yield per Recruit Analysis for:
GULF OF MAINE COD (5Y) - 1997 UPDATED AVE WTS, FPAT AND MAT VECTORS

Slope of the Yield/Recruit Curve at F=0.00: --> 27.4085
F level at slope=1/10 of the above slope (F0.1): -----> .163
Yield/Recruit corresponding to F0.1: -----> 1.7404
F level to produce Maximum Yield/Recruit (Fmax): -----> .289
Yield/Recruit corresponding to Fmax: -----> 1.8713
F level at 20 % of Max Spawning Potential (F20): -----> .373
SSB/Recruit corresponding to F20: --------> 5.5590

Listing of Yield per Recruit Results for:
GULF OF MAINE COD (5Y) - 1997 UPDATED AVE WTS, FPAT AND MAT VECTORS

	FMORT	TOTCTHN	TOTCTHW	TOTSTKN	TOTSTKW	SPNSTKN	SPNSTKW	% MSP
	.00	.00000	.00000	5.5167	30.8756	3.4286	27.7974	100.00
	.10	.18611	1.45976	4.5906	17.9353	2.5073	15.0585	54.17
F0.1	.16	.25119	1.74042	4.2678	13.9846	2.1874	11.2009	40.29
	.20	.28051	1.81725	4.1228	12.3471	2.0439	9.6100	34.57
Fmax	.29	.33293	1.87129	3.8642	9.6907	1.7891	7.0440	25.34
	.30	.33816	1.87072	3.8384	9.4471	1.7638	6.8099	24.50
F20%	.37	.36799	1.84735	3.6920	8.1405	1.6203	5.5590	20.00
	.40	.37739	1.83317	3.6460	7.7596	1.5753	5.1961	18.69
	.50	.40605	1.77175	3.5061	6.6935	1.4392	4.1860	15.06
	.60	.42809	1.70884	3.3992	5.9758	1.3359	3.5123	12.64
	.70	.44568	1.65149	3.3144	5.4673	1.2545	3.0392	10.93
	.80	.46013	1.60133	3.2450	5.0916	1.1884	2.6927	9.69
	.90	.47229	1.55810	3.1870	4.8040	1.1334	2.4297	8.74
	1.00	.48271	1.52096	3.1374	4.5773	1.0869	2.2242	8.00
	1.10	.49179	1.48898	3.0945	4.3941	1.0469	2.0595	7.41
	1.20	.49979	1.46130	3.0569	4.2428	1.0120	1.9247	6.92
	1.30	.50694	1.43721	3.0234	4.1157	.9811	1.8123	6.52
	1.40	.51337	1.41609	2.9933	4.0072	.9537	1.7170	6.18
	1.50	.51920	1.39747	2.9662	3.9133	.9290	1.6352	5.88
	1.60	.52454	1.38094	2.9414	3.8311	.9066	1.5642	5.63
	1.70	.52946	1.36618	2.9187	3.7584	.8863	1.5017	5.40
	1.80	.53400	1.35292	2.8977	3.6934	.8676	1.4464	5.20
	1.90	.53823	1.34094	2.8782	3.6350	.8503	1.3969	5.03
	2.00	.54217	1.33006	2.8600	3.5820	.8344	1.3524	4.87

Table A21. Stock biomass and catch projections, starting conditions and input data for Gulf of Maine cod.

Input for Projections:

Number of Years: 4; Initial Year: 1994; Final Year: 1997
Number of Ages : 6; Age at Recruitment: 2; Last Age: 7
Natural Mortality is assumed Constant over time at: .200
Proportion of F before spawning: .1667
Proportion of M before spawning: .1667
Last age is a PLUS group;

Age-specific Input data for Projection # 1

Age	Stock Size in 1997	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Weights Catch	Average Weights Stock
2	721.	.0281	1.0000	.2400	1.523	1.169
3	730.	.2111	1.0000	.5400	1.962	1.662
4	1370.	.7680	1.0000	.8100	2.706	2.232
5	1224.	1.0000	1.0000	.9400	3.930	3.272
6	125.	1.0000	1.0000	1.0000	6.594	5.113
7+	27.	1.0000	1.0000	1.0000	11.262	11.262

Projections for 1997-1999; F(97)=1.04, Basis: Status quo 1996 point estimate. Recruitment (age 2) of the 1996 and 1997 year classes derived by resampling the distribution of empirical recruitment of the 1988-1994 year classes (median=3.1 million).

SSB was estimated to be 9,200 t in 1996.

1997 F	1997 Landings	1997 SSB	1998 F	1998 Landings	1998 SSB	1999 SSB
1.04	5838	6861	F_0 =0.00	0	5335	9456
1.04	5838	6861	$F_{0.1}$ =0.16	842	5411	8264
1.04	5838	6861	F_{max} =0.29	1437	5313	7419
1.04	5838	6861	$F_{20\%}$=0.37	1789	5250	6926
1.04	5838	6861	F_{SQ} =1.04	3857	4781	4296

Table A22. Stochastic medium-term projections of spawning stock biomass (mt), recruitment (age 1, thousands) and landings (mt) for Gulf of Maine cod, assuming F=0.29. The lower and upper quartiles and the median of bootstrap simulations are given.

	- Spawning Biomass -			- Recruitment -			- Landings -		
Year	L-25	Median	U-75	L-25	Median	U-75	L-25	Median	U-75
1997	6,583	7,579	9,015	1,483	2,150	4,556	1,833	2,178	2,602
1998	8,065	9,581	11,673	1,164	1,623	2,303	2,256	2,615	3,098
1999	10,108	12,334	16,592	1,580	2,448	5,408	2,570	3,095	3,785
2000	10,904	14,074	19,635	2,452	4,353	7,406	2,713	3,336	4,622
2001	11,626	15,924	22,662	2,815	4,730	7,940	2,737	3,594	5,364
2002	14,003	19,721	27,745	2,974	4,937	8,258	3,132	4,576	6,885
2003	18,270	25,666	35,713	3,381	5,469	9,005	4,205	6,219	8,903
2004	22,562	30,666	41,574	4,013	6,202	10,003	5,515	7,757	10,555
2005	27,577	37,251	49,099	4,553	6,842	10,837	6,914	9,414	12,455
2006	33,517	44,046	57,008	5,049	7,430	11,562	8,325	11,078	14,386

Table A23. Stochastic medium-term projections of spawning stock biomass (mt), recruitment (age 1, thousands) and landings (mt) for Gulf of Maine cod, assuming F=1.04. The lower and upper quartiles and the median of bootstrap simulations are given.

	- Spawning Biomass -			- Recruitment -			- Landings -		
Year	L-25	Median	U-75	L-25	Median	U-75	L-25	Median	U-75
1997	5,953	6,861	8,091	1,494	2,147	4,609	4,969	5,838	6,950
1998	4,440	5,299	6,540	1,051	1,435	1,896	3,413	3,964	4,643
1999	3,842	4,777	7,139	821	1,102	1,424	2,603	3,195	4,183
2000	3,473	4,390	7,255	752	1,032	1,498	2,469	3,141	5,357
2001	3,015	3,800	5,924	695	964	1,504	2,231	2,849	4,648
2002	2,599	3,277	4,831	605	835	1,253	1,928	2,435	3,629
2003	2,305	2,936	4,403	531	726	1,056	1,682	2,136	3,153
2004	2,020	2,567	3,807	478	652	976	1,472	1,875	2,779
2005	1,772	2,251	3,320	424	578	862	1,294	1,647	2,439
2006	1,564	1,989	2,914	372	505	750	1,141	1,454	2,138

Table A24. Stochastic medium-term projections of spawning stock biomass (mt), and recruitment (age 1, thousands) for Gulf of Maine cod, assuming F=0.0. The lower and upper quartiles and the median of bootstrap simulations are given.

	- Spawning Biomass -			- Recruitment -		
Year	L-25	Median	U-75	L-25	Median	U-75
1997	6,846	7,889	9,409	1,487	2,148	4,540
1998	10,467	12,393	14,993	1,228	1,736	2,864
1999	16,250	19,805	25,872	2,417	4,303	7,358
2000	21,767	26,226	34,376	3,572	5,588	9,143
2001	26,112	31,958	41,893	4,155	6,317	10,110
2002	32,634	41,086	53,471	4,695	6,946	10,991
2003	42,946	55,557	74,333	5,498	7,946	12,116
2004	55,299	71,729	94,313	6,795	9,710	14,517
2005	73,722	95,393	121,600	8,207	11,502	16,622
2006	95,014	120,719	152,506	10,300	13,993	19,870

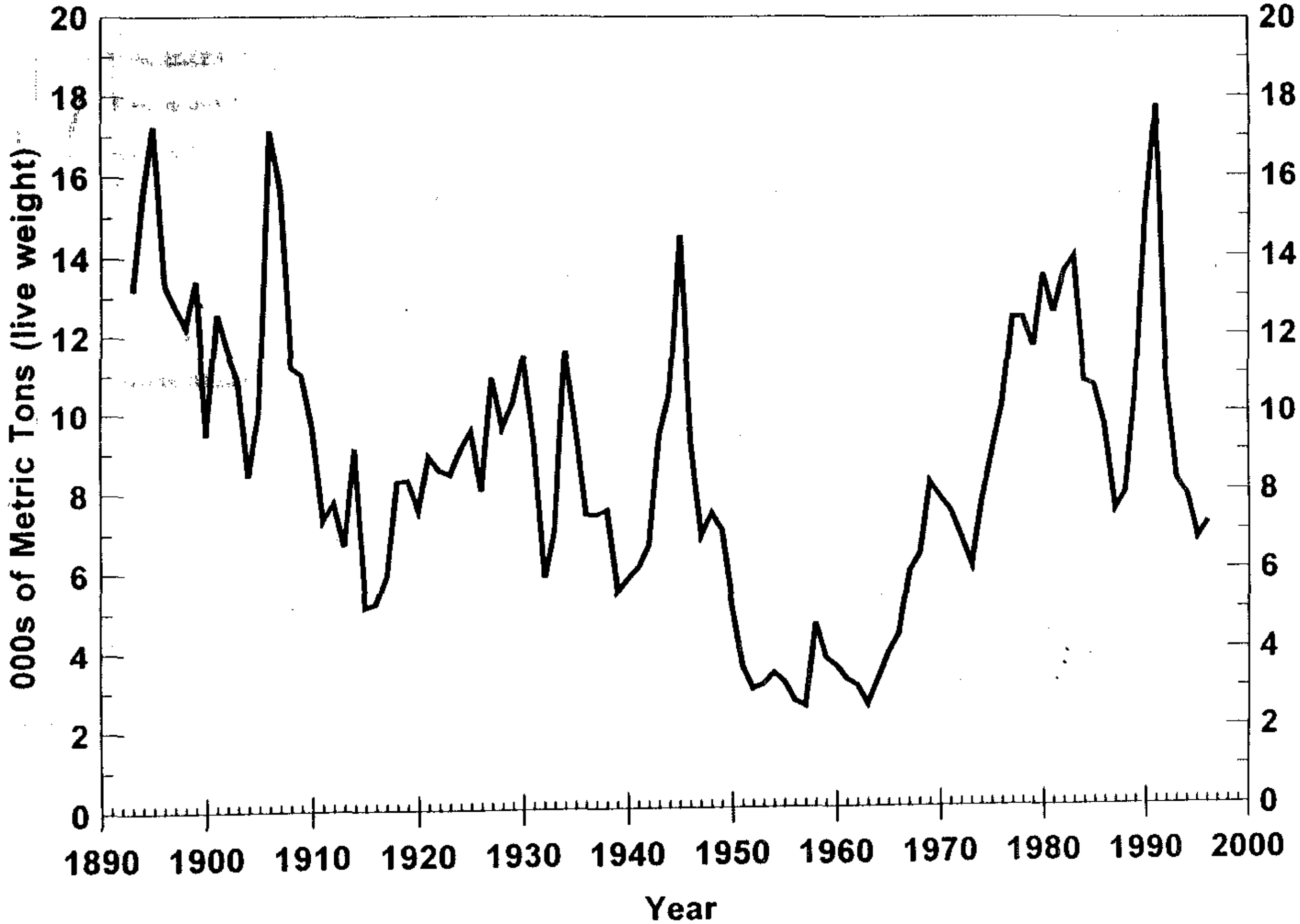


Figure A1. Total commercial landings of Gulf of Maine cod (Division 5Y), 1893-1996.

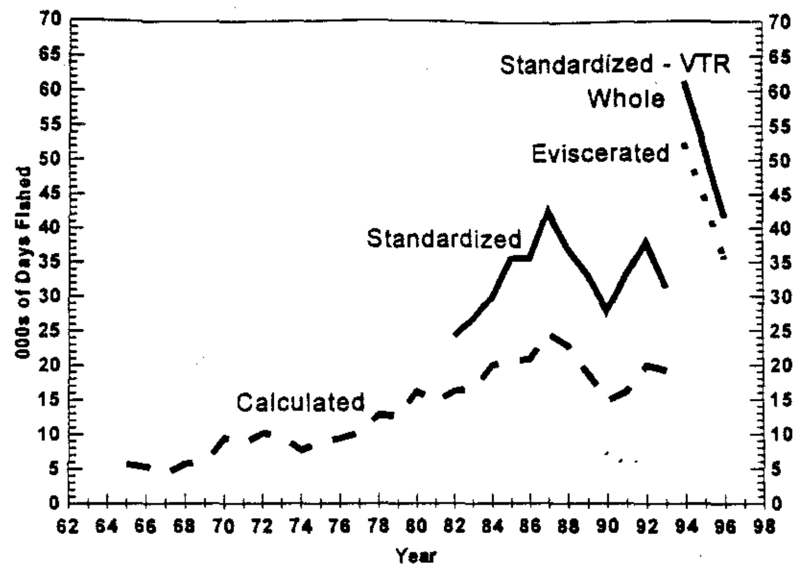


Figure A2. Trends in standardized and 'calculated' USA fishing effort (days fished) on Gulf of Maine cod. The 1965-1993 'calculated' series (dashed line) is based on all otter trawl trips landing cod. Standardized effort from 1982-1993 (Interview data) and 1994-1996 (VTR data) is based on a GLM incorporating year, tonnage class, area, quarter and depth. Results from 1994-1996 from VTR data assuming portion kept represents whole or eviscerated weight.

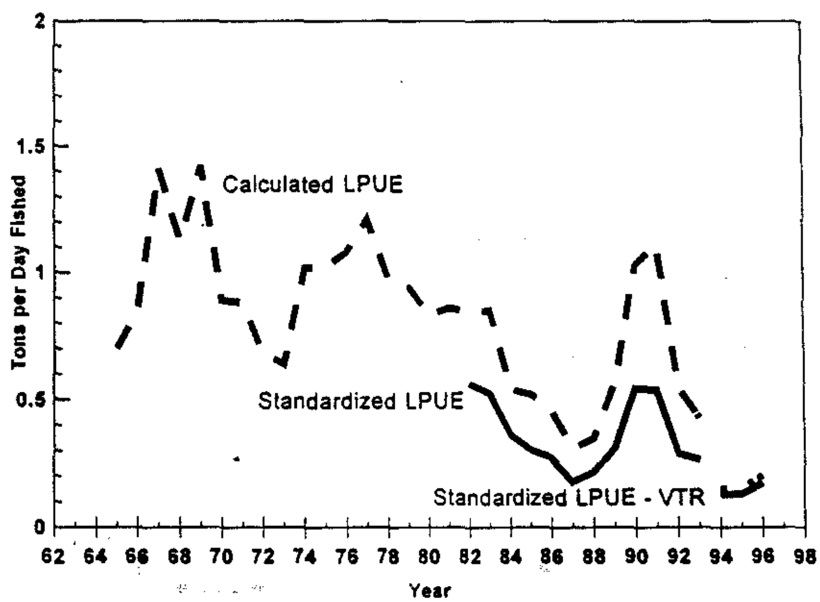


Figure A3. Trends in USA LPUE (landings per day fished) of Gulf of Maine cod. The 1965-1993 indices (dashed line) are based on all otter trawl trips landing cod. Standardized LPUE from 1982-1993 (Interview data) and 1994-1996 (VTR data) are based on a GLM incorporating year, tonnage class, area, quarter and depth.

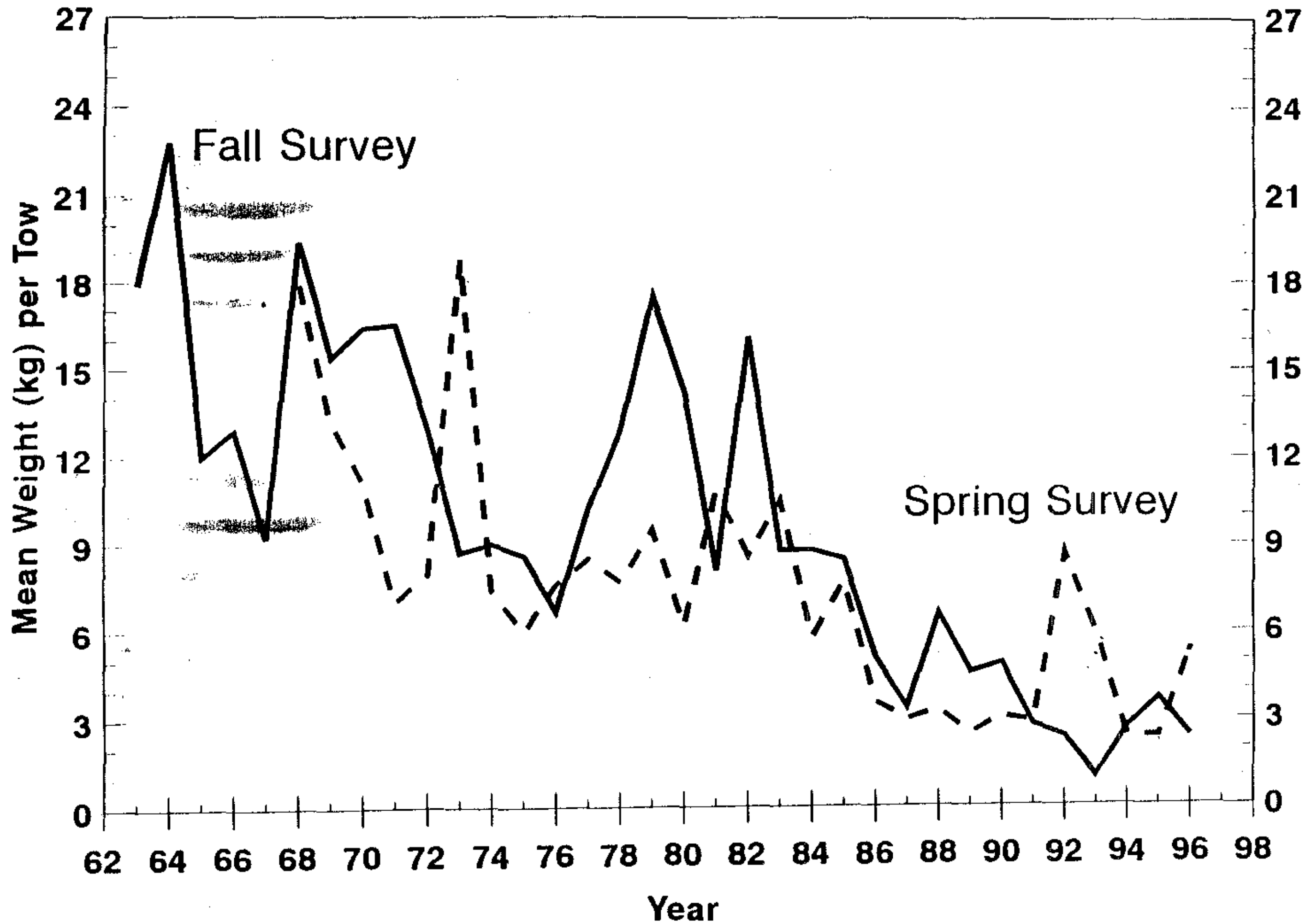
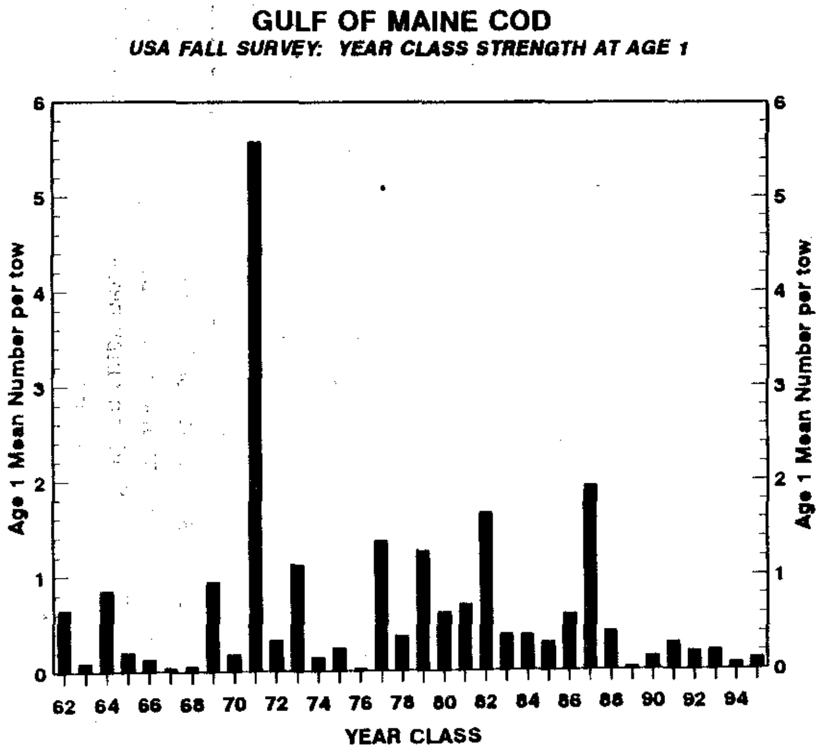


Figure A4. Standardized stratified mean catch (kg) per tow of Atlantic cod in NEFSC spring and autumn research vessel bottom trawl surveys in the Gulf of Maine, 1963-1996.



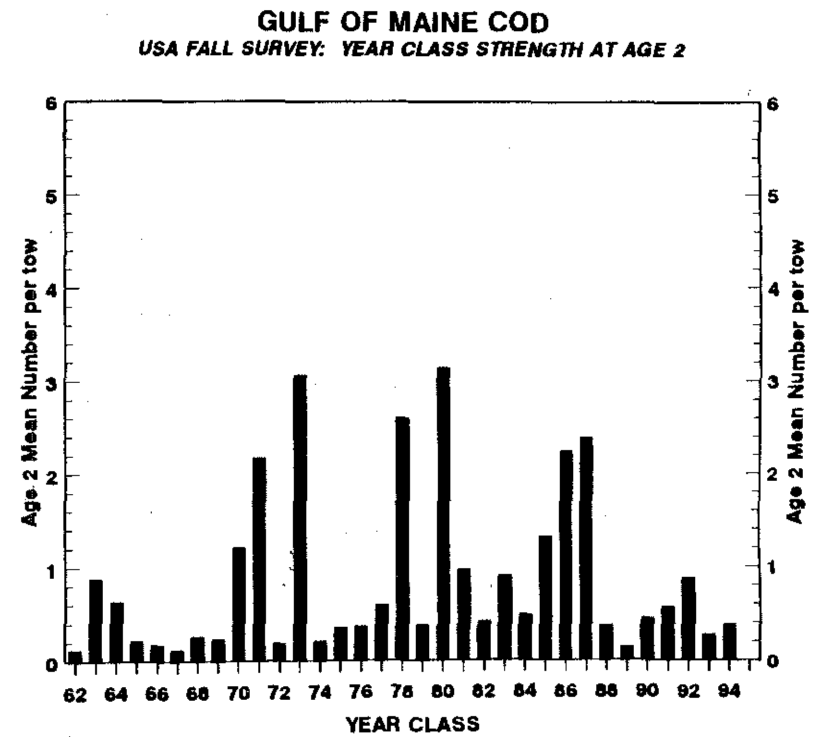


Figure A5. Relative year class strengths of Gulf of Maine cod at age 1 and age 2 based on standardized catch (number) per tow indices from NEFSC autumn research vessel bottom trawl surveys, 1963-1996.

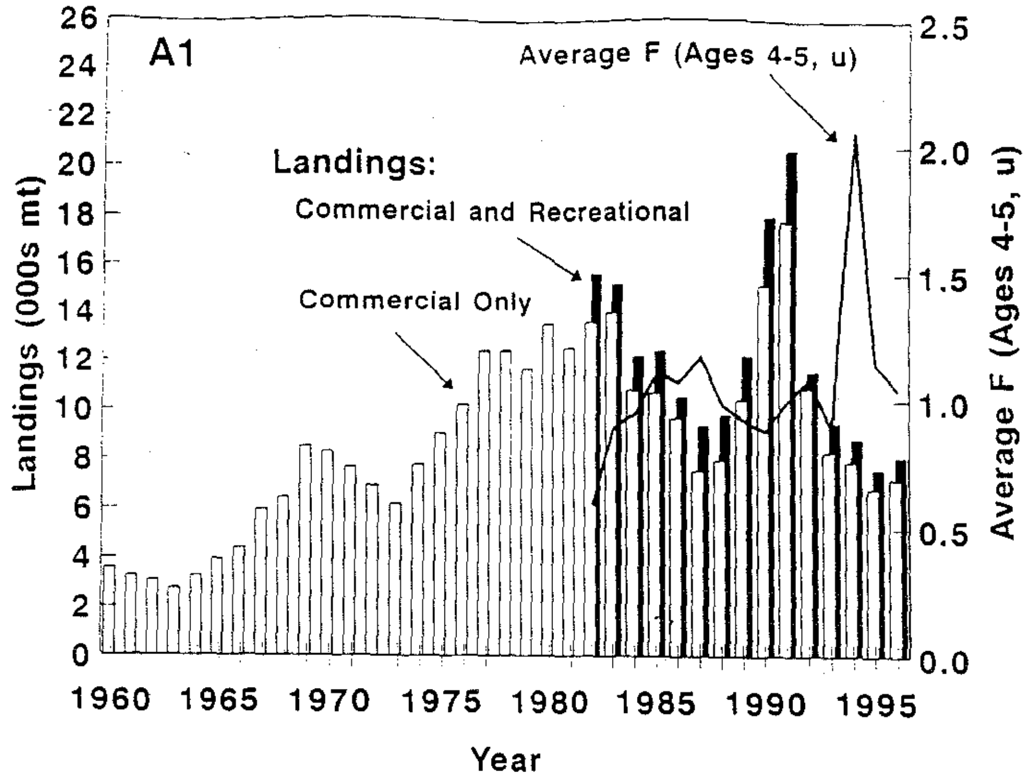


Figure A6. Trends in commercial and recreational landings and fishing mortality for Gulf of Maine cod, 1982-1996.

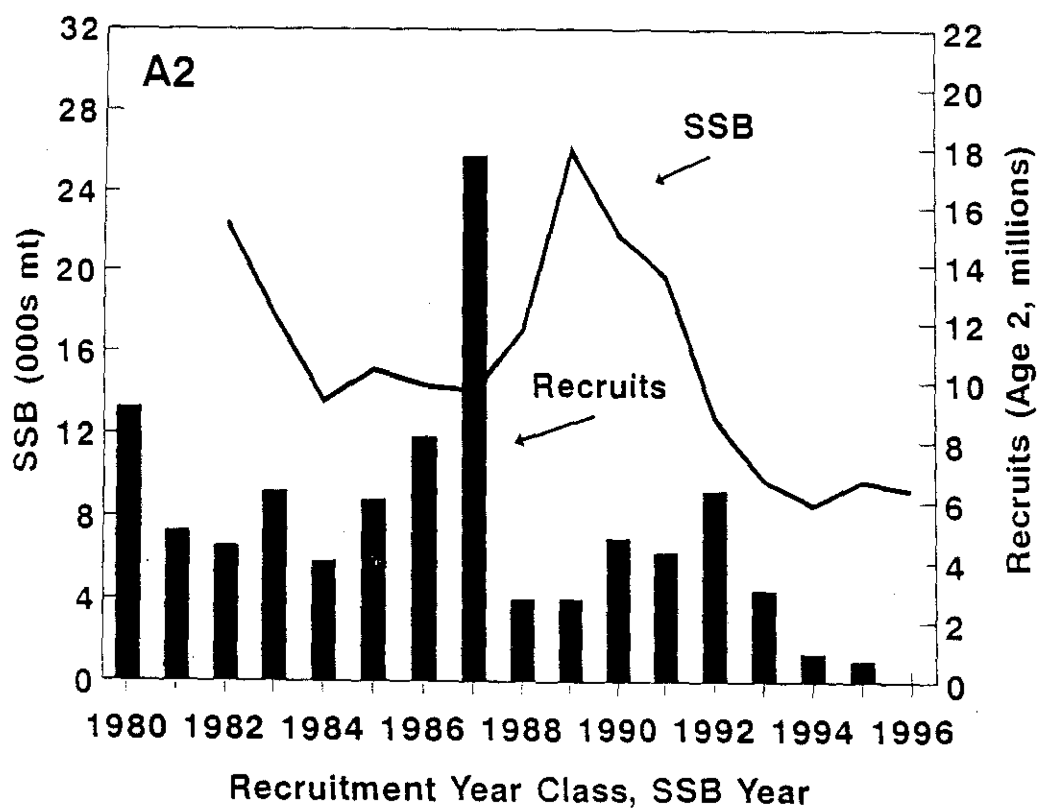


Figure A7. Trends in spawning stock biomass and recruitment for Gulf of Maine cod.

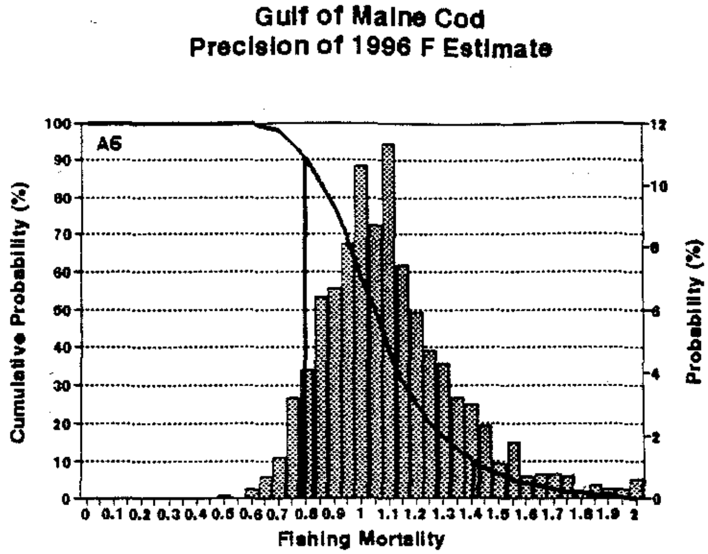


Figure A8. Precision of the estimates of the instantaneous rate of fishing mortality (F) on the fully recruited ages (ages 4+) in 1996 for Gulf of Maine cod. The vertical bars display both the range of the estimator and the probability of individual values within the range. The solid line gives the probability that F is greater than any selected value on the X-axis. The precision estimates were derived from 1000 bootstrap replicates of the final ADAPT VPA formulation.

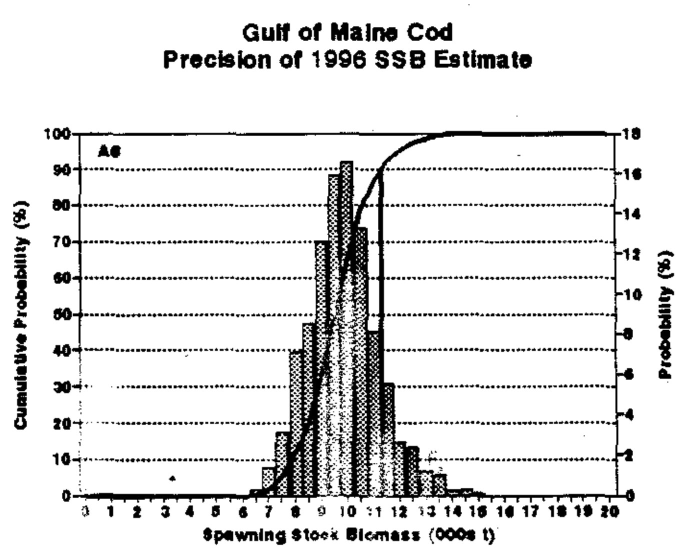
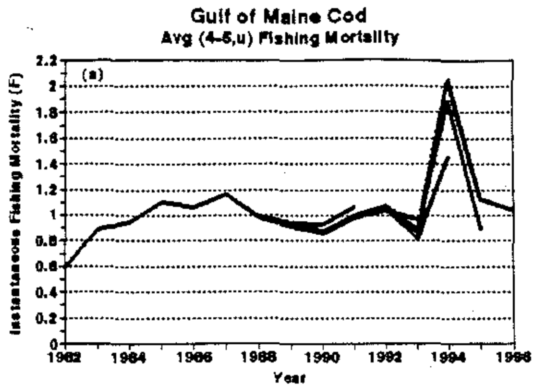
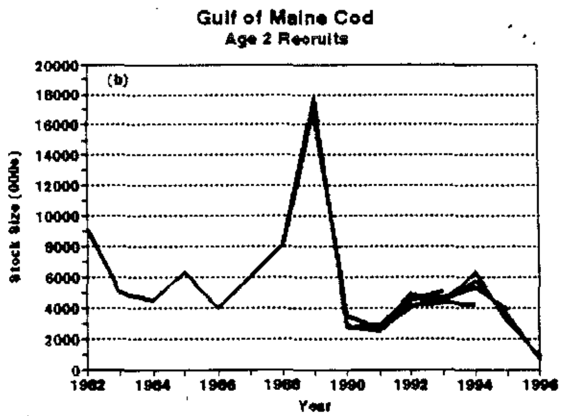


Figure A9. Precision of the estimates of spawning stock biomass (SSB) at the beginning of the spawning season (March 1) for Gulf of Maine cod, 1996. The vertical bars display both the range of the estimator and the probability of individual values within the range. The solid line gives the probability that SSB is less than any selected value on the X-axis. The precision estimates were derived from 1000 bootstrap replicates of the final ADAPT VPA formulation.





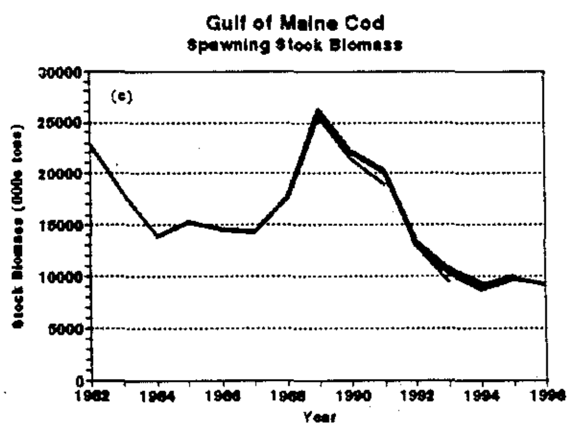


Figure A10. Retrospective analysis of Gulf of Maine cod VPA based on final ADAPT formulation.
a) Average (4-5,unweighted) fishing mortality
b) Recruits (age 2)
c) Spawning stock biomass

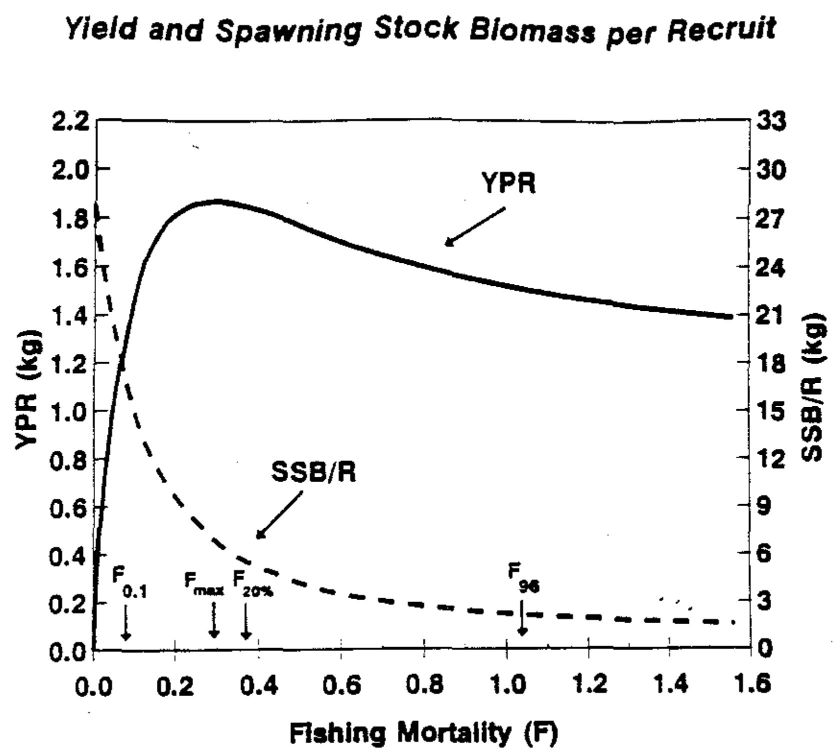


Figure A11. Yield per recruit (YPR) and spawning stock biomass per recruit (SSB/R) for Gulf of Maine cod.

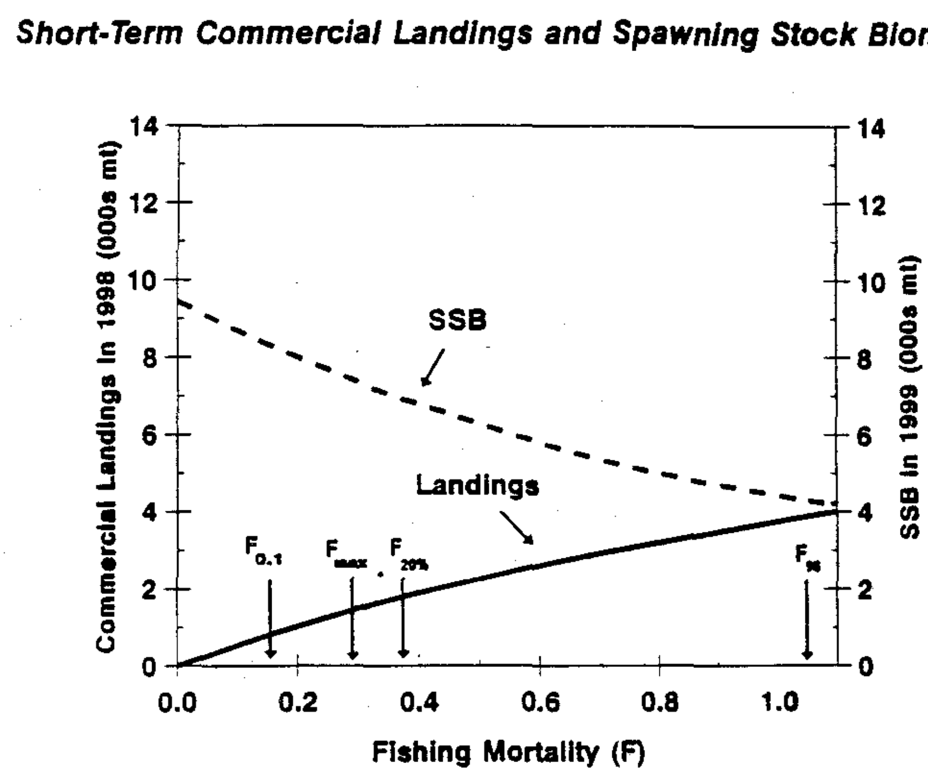


Figure A12. Predicted catches in 1998 and spawning stock biomasses in 1999 of Gulf of Maine cod over a range of fishing mortalities in 1998, from F=0.0 to F=1.1.

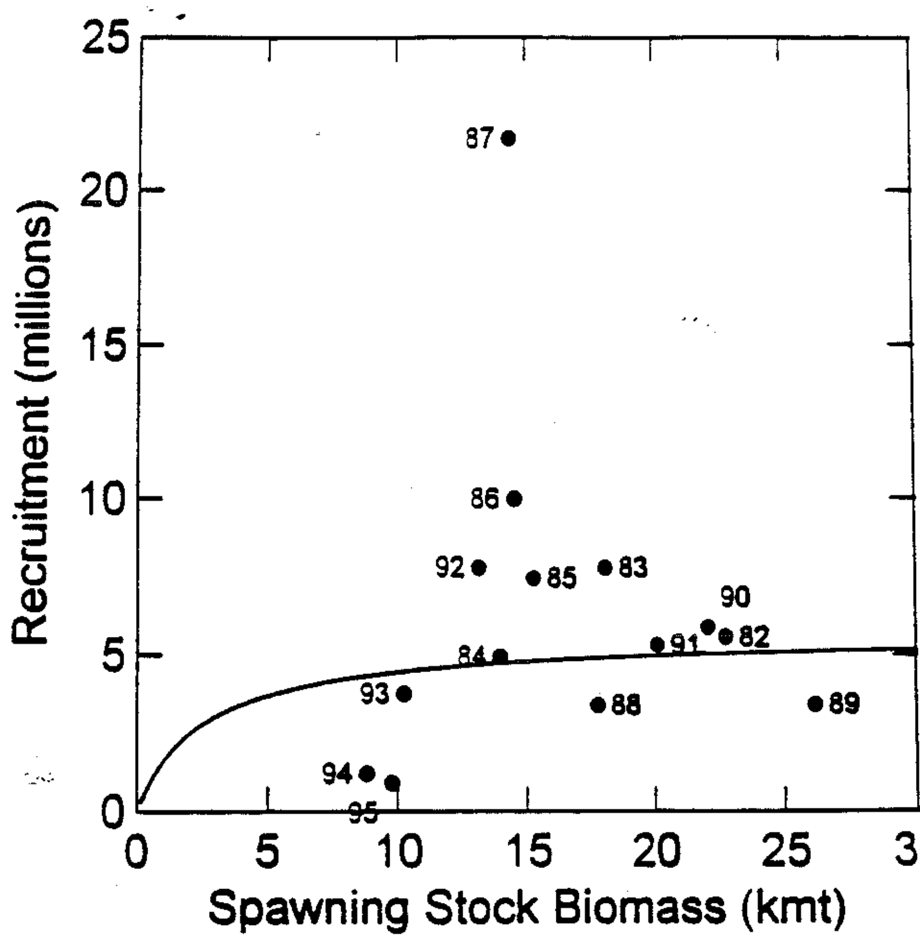


Figure A13. Spawning stock-recruitment information for Gulf of Maine cod. Data are from the final ADAPT run for the 1997 assessment. Recruitment is expressed as age 1. A plot of the fitted Beverton-Holt s/r relationship is given (R=[5593.84·SSB÷2542.62+SSB]).

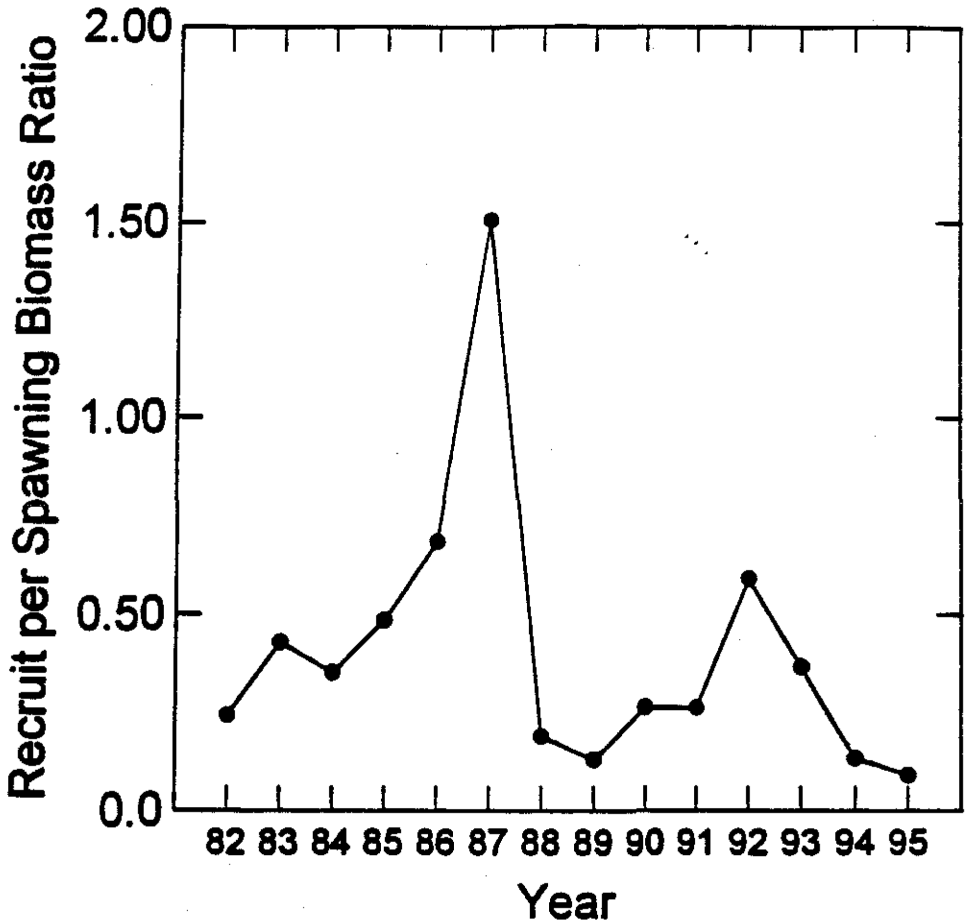


Figure A14. Calculated numbers of age 1 recruits per kilogram of spawning stock biomass for Gulf of Maine cod. The median R/SSB ratio for the entire time series is 0.308, and for the last 5 years is 0.263.

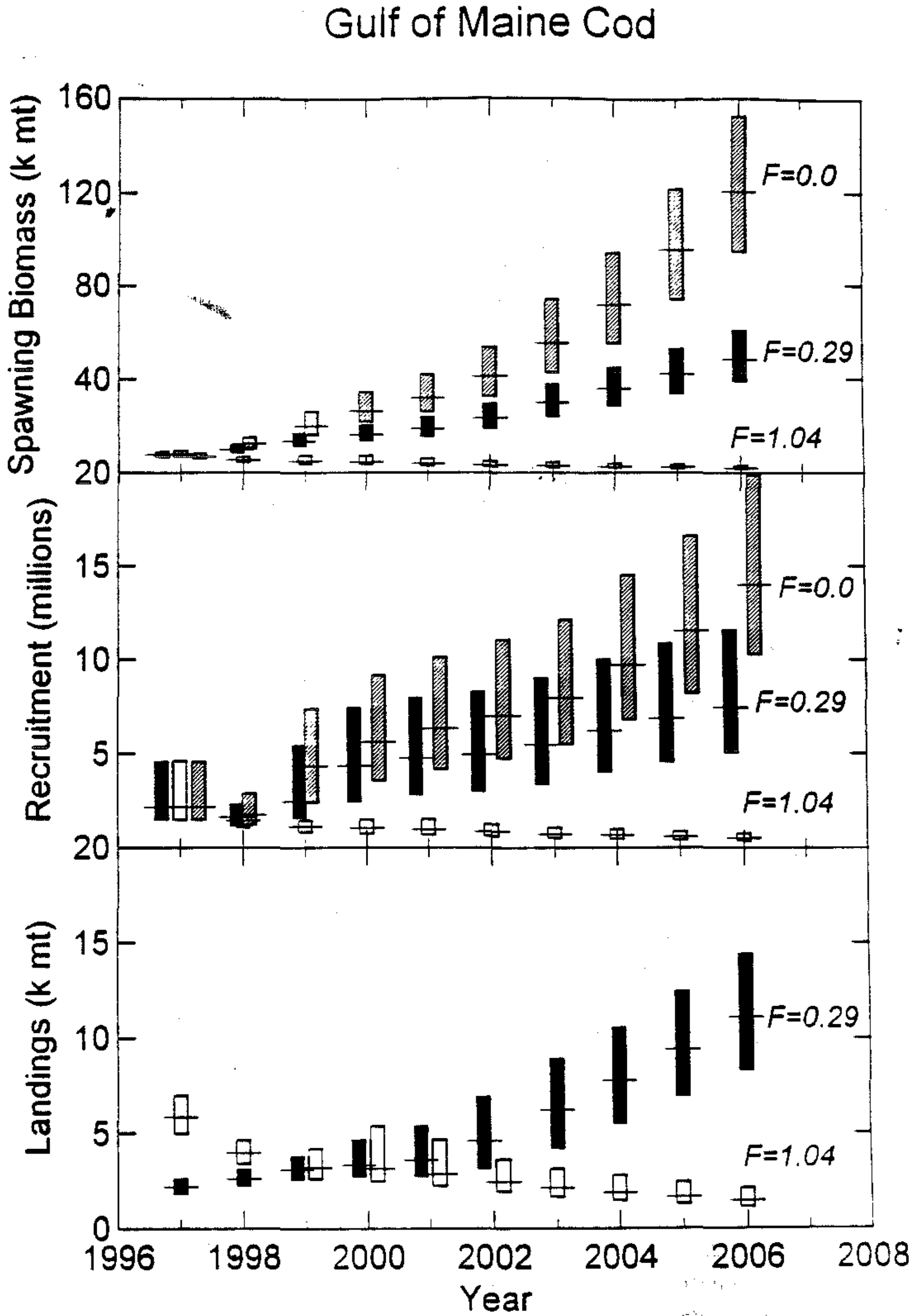


Figure A15. Results of medium-term projections for Gulf of Maine cod, under three different fishing mortality rate scenarios (F=1.04, 0.29, 0.00). Annual spawning stock biomass, recruitment, and landings data are given. Horizontal bars are the median values from bootstrap results, vertical bars are the inter-quartile range (lower 25th percentile to the upper 75th percentile).

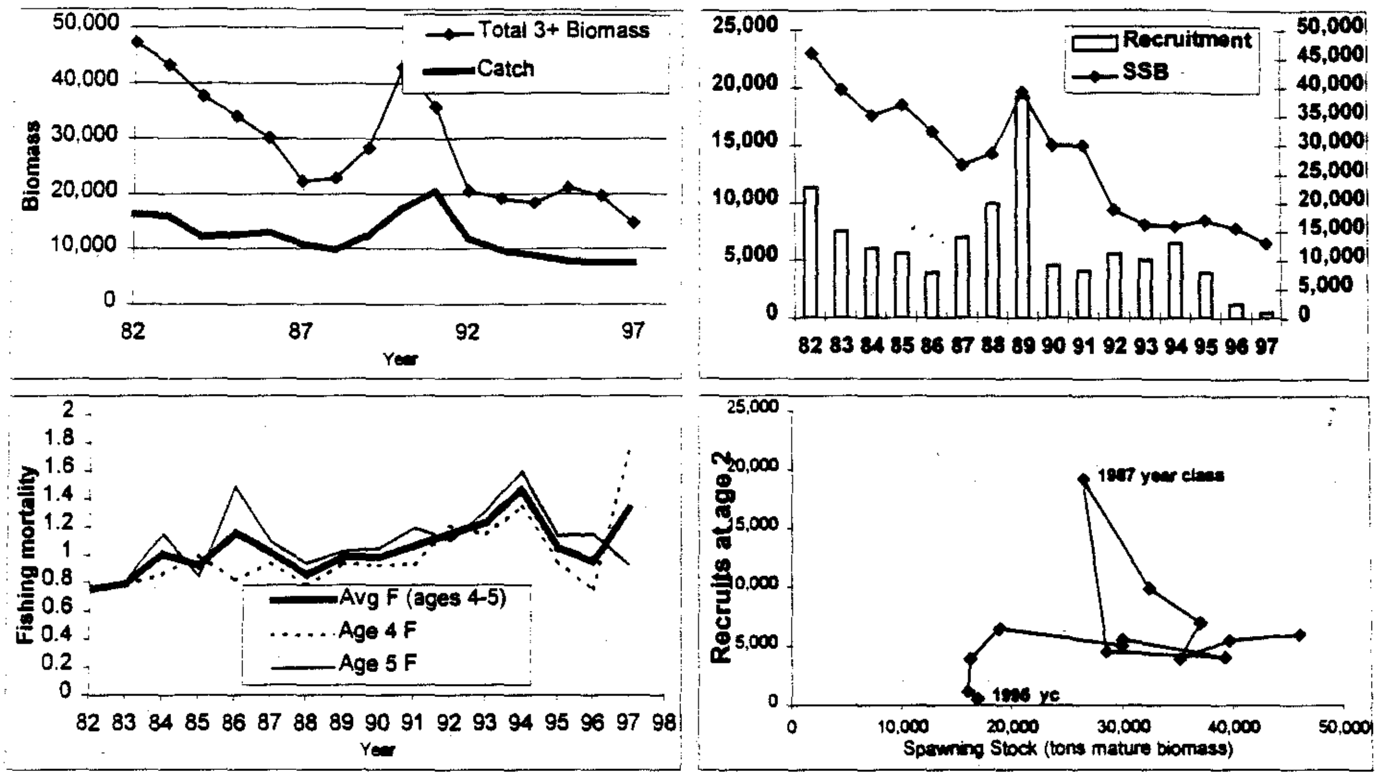


Figure A16. Results of alternative analyses of Gulf of Maine cod stock dynamics, taking into account potential error in the catch at age.

B. GEORGES BANK COD

Terms of Reference

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

b. Provide projected estimates of catch for 1997-1998 and SSB for 1998-1999 at various levels of F, including all relevant biological reference points.

c. Advise on the assessment and management implications of incorporating recreational catch and commercial discard data in the assessment.

Introduction

Atlantic cod (*Gadus morhua*) are distributed in the Northwest Atlantic from West Greenland south, nearly to Cape Hatteras, North Carolina (Bigelow and Schroeder 1953). Within the New England area, four distinct stocks are recognized (Wise 1963): Georges Bank, Gulf of Maine, Southern New England and the South Channel, and the New Jersey coastal cod. Atlantic cod commonly attain lengths up to 130 cm and weights up to 25-35 kg. Maximum ages are in excess of 20 years, although fish at ages 2-5 are most commonly caught by the commercial fishery. Sexual maturity is attained between ages 2 and 4 (O'Brien 1990). The spawning season for Atlantic cod, an iteroparous spawner, is from November to May, with peak spawning on Georges Bank occurring during February and March (Smith 1983).

Atlantic cod in the Georges Bank area have been commercially exploited since the 17th century. Reliable landings statistics are available since 1893. Historically, the Georges Bank fishery (NAFO Division 5Z and Subarea 6) can be separated into five periods (Serchuk and Wigley 1992) (Figure B1): 1) 1893-1914, when high landings (>40,000 mt) in 1895 and 1906-1907 were followed by about 10 years of sharply-reduced landings; 2) 1915-1940, when annual landings fluctuated between 20,000 and 30,000 mt, and when cod was generally taken as a bycatch in the Georges Bank haddock fishery; 3) 1940-1960, when landings declined, reaching a record-low of 8,100 mt in 1953. Declines in this period reflect a reduction in fishing activity during World War II and redirection of remaining fleet effort towards the more abundant haddock resource; 4) 1960-1976, when Canadian and distant-water fleet fisheries for Georges Bank cod developed. Large increases in fishing effort for cod during this period resulted in a five-fold increase in annual landings between 1960 and 1966 (11,000-53,000 mt), but landings sharply declined afterward reaching only 20,000 mt in 1976; and 5) 1977 onward, after the implementation of extended fisheries jurisdiction by both the US and Canada. Total landings of Georges Bank cod doubled between 1977 and 1982 (27,000-57,000 mt), declined to 26,000 mt in 1986, but increased to 42,500 mt in 1990 (Table B1). Commercial landings declined to 15,200 mt in 1994, and declined further in 1995 (7,800 mt) and 1996 (8,900 mt) after a year-round closure of Georges Bank was implemented in December 1994. Since October 1984, when the International Court of Justice delimited a maritime boundary between the US and Canada in the Gulf of Maine/Georges Bank region, fishing activity by each country has been restricted to its own waters on Georges Bank.

This report presents an updated and revised analytical assessment of the Georges Bank cod stock for the period 1978-1996 based on analysis of commercial landings and effort data and research vessel survey data through 1996. An analytical assessment of this stock was first conducted by the US in 1986 by Serchuk and Wigley (1986) and most recently in 1994 by Serchuk *et al.* (1994). Analytical assessments of the component of the Georges Bank cod stock in Canadian waters (Unit Areas 5Zj and 5Zm) were first conducted by CAFSAC (Canadian Atlantic Fisheries Scientific Advisory Committee) in 1990 (Hunt 1990) and now are currently conducted by the Canadian Regional Advisory Process (Hunt and Buzeta 1996, 1997).

The Fishery

Commercial Landings

The methodology for collecting and processing the commercial fishery and landings data has been revised since the last assessment. 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 from the interview was used to augment the total catch information obtained from the dealer.

In 1994, a mandatory reporting system was put into effect requiring anyone fishing for or purchasing regulated groundfish in the Northeast to submit either logbooks or dealer reports, respectively (Power *et al.* 1997 WP). Information on fishing effort (number of hauls and average haul time) and catch location were now obtained from logbooks submitted to NMFS by vessel captains instead of personal interviews. 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. Both databases were stratified by calendar quarter, port group, and gear group to form a pool of observations from which proportion of catch by stock could be allocated to market category with the matched subset. The cross products of the market category by stock proportions derived from the matched subset were employed to compute the total catch by stock, market category, calendar quarter, port group, and gear group in the full dealer database. The US landings for Atlantic cod for 1994-1996 were derived for Eastern Georges Bank (Statistical Areas 560, 561, 562, 551, 552) and Western Georges Bank (Statistical Areas 520-526, 530, 537-539, 600-639) using the proration methodology described above (Wigley *et al.* 1997, DeLong *et al.* 1997).

Total commercial landings of Georges Bank cod in 1996 were estimated at 8,900 mt, 13% higher than in 1995 (Table B1, Figure B1). The US fleet landed 79% (7,000 mt) of the total landings, and the Canadian fleet landed the remaining 21% (1,900 mt). The 1996 US landings were 4% higher than the 1995 landings, and the 1996 Canadian landings were 71% higher than in 1995.

Otter trawl landings accounted for a little more than half (53%) of the total 1996 landings. Although US otter trawl landings declined in 1996, they still continued to account for the majority (58%) of the landings (Table B2). In the Canadian fishery, the otter trawl and longline fisheries accounted for 35% and 52%, respectively, of the cod landings (Hunt and Buzeta 1997).

During 1978-1994, otter trawl gear accounted for 84% of the US landings and 58% of the Canadian landings. US cod landings from Georges Bank continue to be dominated by 'market' cod in both weight (57%) and number 54% in 1996 (Table B3). Historically, 'market' cod have accounted for 40-60% of the landings. The percentage of 'scrod' cod landed, by number, declined by about half from 1995 to 1996.

Commercial Discards

Preliminary estimates of discards on otter trawl and gillnet trips were derived for 1989-1996 using the sea sampling database. Discard ratios were estimated as the amount of cod discarded to the amount kept. Discard ratios are presented in Table B4 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, the discard ratio ranged from 0 to 0.19, but was predominantly less than 0.10. The highest discard ratio was during quarter 1, but this was also associated with a smaller number of sampled tows. Discard estimates were not included in the assessment, however, primarily due to a lack of data for 1978-1988. Further analysis of the sea sampling data will be undertaken to determine how well the samples represent the fishery, and to examine discarding by other gear.

Recreational Catches

Methods for estimating recreational catch surveyed in the Marine Recreational Fishery Statistics Surveys (MRFSS) have recently been revised for 1981-1995 (Gray *et al.* 1994). Catch estimates for Georges Bank cod (Table B5) are now slightly lower than reported in the previous assessment (Serchuk *et al.* 1994). An evaluation of the national saltwater angling surveys and the MRFSS and a description of historic trends in recreational cod catches are provided by Serchuk *et al.* (1993). The total cod catch during 1979-1996 by recreational fisherman ranged from 500 mt to 9,000 mt, accounting for 1-19% of the total landings. Recreational landings in 1996 were 800 mt, representing 6.3% of the total cod landings.

Recreational catches have not been included in the final assessment analysis since a number of problems still remain 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 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 B6. The average number of fish in each length sample is about 80 for the US and about 250 for Canada. The US length frequency sampling averaged 1 sample per 471 mt from 1978-1981 and improved to 1 sample per 281 mt from 1982-1992. Sampling intensity during 1993-1996 was high, with an average of 1 sample per 160 mt. During 1978-1985, Canadian sampling intensity averaged 1 sample per 615 mt and improved to 1 sample per 310 mt during 1986-1992. Sampling intensity improved markedly during 1993-1996 to 1 sample per 52 mt. The high sampling intensity for both the US and Canadian fisheries is attributed to the decrease in landings rather than an increase in sampling.

US sampling intensity in 1995 and 1996 (1 sample per 167 mt and 1 sample per 127 mt, respectively) was the greatest since 1978. However, the number of samples for each market category, per quarter, was the poorest since 1981, particularly for the large market category (Table B7). The distribution of sampling by market category (scrod: 42%, market: 51%, large: 7%) approximated the distribution of the 1996 landings in number, by market category.

Recreational catch

Recreational landings are sampled for length frequency only. Since 1981, the number of fish sampled represents less than 0.1% of the total number of fish landed (Table B8). During 1981-1996, the number of fish measured ranged from 0.01% to 0.06% of the total number landed. In 1996, 0.04% 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 B9). 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 was 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 an eastern component (SA 561-562) and western component (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 age samples and Canadian age samples, while the age composition of the US landings from the western component was estimated by applying US length frequency and age samples only. In 1995 and 1996, the age composition of the large market category was done on an annual basis due to insufficient samples. The catch at age was then derived as described above for the 1978-1993 landings. The eastern and western components were then pooled to obtain the age composition for US Georges Bank cod landings for 1993-1996. The US eastern component was used as part of the Canadian assessment of 5Zj,m (Hunt and Buzeta 1997).

Canadian landings-at-age data (Table B10) from the eastern component (5Zj,m) for 1978-1993 were taken from Hunt and Buzeta (1994), and data for 1994-1996 were provided by Hunt (pers. comm.). Canadian and US data were combined to produce a total landings-at-age matrix for 1978-1996 (Table B11). The proportions of the total landings accounted for by the US and Canada are also indicated in Table B11.

Total commercial landings in 1996 were dominated by the 1992 and 1993 year classes (Table B12). These two cohorts combined accounted for 78% of the landings by number and 72% by weight. The 1992 year class dominated both the US landings (44% by number; 47% by weight) and the Canadian landings (48% by number; 47% by weight) in 1996. The 1993 cohort accounted for the second highest landings in number and weight in both the US fishery (34% and 26%, respectively) and the Canadian fishery (29% and 20%, respectively).

Commercial Mean Weights at Age

Mean weights at age for ages 1-10+ are summarized for US, Canadian, and total landings in Tables B9-B11. There does not appear to be any consistent trend in the mean weight by age during the 19-year time series. In the US landings, age 3 fish in 1994 and 1995 had the lowest mean weight at age on record, but were about average in 1996. The mean weight of age 7 fish was at a record high in 1995 and 1996. The same patterns were not seen in the Canadian landings. However, the age 8 fish in 1996 and the age 9 fish in 1994 had the lowest mean weight on record. These anomalous weights in the older fish in recent years may be due to poorer sampling. Stock mean weights at age at the beginning of the year, derived from catch mean weights at age (Rivard 1980), are presented in Table B13.

Recreational Catch at Age

A landings-at-age matrix for 1981-1996 was derived for recreational landings using methodology similar to that used for the commercial catch-at-age matrix. Preliminary investigation of the pooled 1981-1996 data indicated that length frequencies were similar between modes (i.e., party boat, charter boat) and that, on a semi-annual basis, more larger fish were caught in the latter half of the year. However, since sampling data was insufficient by mode and wave (2-month intervals), the data were pooled on an annual basis.

The age composition of the 1981-1996 recreational landings was estimated from annual recreational length frequency data and commercial age-length data augmented by research survey age-length data for fish <40 cm. The total number of fish landed were prorated by the annual length frequency to estimate number of fish landed at length. The augmented age-length keys were applied to estimate numbers at age (Table B14). Mean weights were estimated by applying the cod length-weight equation, described above, to the estimated number at length (Table B14). The data are not stratified by market category.

Throughout the 1981-1996 time series, recreational landings at age have been dominated by fish at age 2 and 3, which is similar to the US commercial landings at age where ages 2, 3, and 4 are dominant. The strong 1980, 1983, and 1985 year classes are represented in the catch at age up to ages 4 and 5. The 1988 year class, however, is only well represented at ages 2 and 3, similar to the weaker 1992 year class.

Recreational Mean Weights at Age

The mean weight at age for the recreational landings for ages 1-10+ are summarized in Table B14 for 1981-1996. There are no specific trends over the 16-year time series, and the mean weights at age have a range of values similar to the US commercial mean weights at age. In 1994 and 1995, age 3 fish had a record-low mean weight, which was also noted in the US commercial mean weight at age 3. The variability in the mean weight of older fish, with an anomalous low mean weight for age 9 in 1996, is most likely due to the poor sampling of the older fish.

Stock Abundance and Biomass Indices

Commercial Catch Rates

US commercial landings per unit effort (LPUE) were derived for all interviewed otter trawl trips landing cod from Georges Bank and South. Indices were estimated for all tonnage class 2-4 vessels during 1964-1996 that landed any amount of cod. Standardized fishing effort and LPUE were also estimated based on a 5-factor general linear main effects model that included year, area, tonnage class, quarter, and depth (Table B15) using methodology similar to Mayo *et al.* (1994). Standards chosen for the analysis were year 1978, area 521, quarter 2, depth 3, and tonnage class 33. Model coefficients were re-transformed to the linear scale after correcting for bias (Granger and Newbold 1977). Standardized effort was calculated by multiplying nominal effort by the re-transformed coefficients for area, quarter, tonnage class, and depth. Total standardized (raised) effort was then derived by dividing total US landings by the standardized LPUE (Table B16).

Nominal LPUE and standardized LPUE exhibit similar trends, and since 1985 are almost equivalent (Table B16, Figure B2). 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 was estimated to be about 0.4 mt/day fished in 1996. Standardized or raised effort and nominal effort have similar trends in general, although effort trends did diverge in both 1991 and 1994 (Figure B3). Raised effort more than doubled from 1978 to 1985, declined in 1986, and then increased to historic high levels until 1993. Average standardized effort declined during 1994-1996 by about 23% from 1993.

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 1994-1996 effort data may no longer be equivalent to the historic 1978-1993 effort series. Additionally, the effort estimates for 1994-1996 were derived from unaudited data. The LPUE series was, therefore, not used as an index of abundance in the subsequent calibration of the VPA. Analyzes to explore the effect of the closed areas on estimation of LPUE were undertaken and are presented in O'Brien (1997).

Hunt and Buzeta (1997) reported a 50% decline in total effort in all fleet sectors in 1995, and consider the current catch rates to be biased due to the reduced total allowable catch (TAC) and bycatch limitations imposed since 1995.

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 kg per tow) were estimated from both the spring and autumn bottom trawl surveys for Georges Bank cod during 1963-1996 (Table B17a). The indices were adjusted for differences in fishing power of the *Albatross IV* and *Delaware II*, and for differences between catchability of BMV and polyvalent doors introduced in 1985. Fishing power coefficients of 0.79 and 0.67 and door conversion coefficients of 1.56 and 1.62 were applied to abundance and biomass indices, respectively (NEFSC 1991). Standardized catch per tow at age, in number, for NEFSC spring and autumn surveys are presented in Table B17b.

NEFSC spring and autumn catch-per-tow indices for both biomass and abundance show similar trends throughout the time series (Table B17a, Figures B4-B5). Survey biomass indices were stable between 1963 and 1971, then increased to a record high in 1973. Georges Bank cod biomass then generally declined over the next two decades, reaching record-low biomass levels during 1991-1994, increasing in 1995, but again declining in 1996. Survey abundance indices for ages 1 and 2 indicate above-average recruitment for the 1966, 1971, 1975, 1977, 1979, 1980, 1983, 1985, 1988, and 1993 year classes (Figure B6). 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 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 1986-1997 (Table 17c). In 1993 and 1994, the Canadian research 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, followed by a decline in 1997.

Mortality

Natural Mortality

Instantaneous natural mortality (M) of Georges Bank cod is assumed to be 0.2, the conventional value of M used for all Northwest Atlantic cod stocks (Paloheimo and Koehler 1968; Pinhorn 1975; Minet 1978).

Total Mortality

Pooled estimates of instantaneous total mortality (Z) were estimated for eight time periods from both spring and autumn catch-per-tow indices (Table B18). Estimates were derived as the ln ratio of 3+/4+ indices in the autumn and 4+/5+ indices in the spring (Table B17b). Different age groups were used so that Z values for identical year classes could be derived over the same time periods. 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 1.04 during 1991-1995.

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 1996 and stock sizes at the beginning of 1997. The catch at age used in the VPA consisted of combined US and Canadian commercial landings during 1978-1996 for ages 1-9 with a 10+ age group. The indices of abundance used to calibrate the VPA included the NEFSC 1978-1996 spring research survey abundance indices for ages 1-8, the Canadian 1986-1997 spring research survey abundance indices for ages 1-8, and the NEFSC 1977-1996 autumn research survey catch at ages 0-6. The autumn survey indices were lagged one age and one year to match cohorts in the subsequent year.

The final ADAPT formulation provided stock size estimates for ages 1-8 in 1997 and corresponding F estimates for ages 1-7 in 1996. 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, 1986-1996 (Table B19) derived from O'Brien (1990).

The final ADAPT calibration results are presented in Table 19 for estimates of F, stock size, and SSB at age. Estimates of stock size were more precise for ages 2-8, with CVs ranging from 0.27 (ages 3, 4) to 0.33 (ages 2, 8) than for age 1 (CV = 0.52). The residual patterns of the indices did not show any strong trends for the three surveys, although US spring age 3 and Canadian spring age 4 did exhibit a possible trend over time (Figure B7). The observed survey indices, transformed to natural log and standardized to the mean, are presented in Figure B8.

Average fishing mortality (ages 4-8) in 1996 was estimated at 0.18, a decline of 51% from 1995 (Table B19, Figure B9). The 1996 estimate of SSB was 41,200 mt, a 20% increase from the 1995 estimate (34,000 mt) which was the second lowest in the time series (Table B19, Figure B10).

Since 1978, recruitment has ranged from 4 million (1994 year class) to 43 million (1985 year class). With the exception of the slightly above-average 1990 year class, recruitment since 1989 has been at record-low values. The 1994, 1995, and 1996 year classes are the poorest of the 20-year time series (Table B19, Figure B10).

In addition to the final ADAPT calibration, two other ADAPT formulations were performed 1) to evaluate the effect of adding recreational landings to the total catch-at-age matrix and 2) to evaluate the effect of including the commercial indices of abundance (LPUE) as a calibration index.

A base ADAPT run was made with the same formulation as the final ADAPT described above, except that 1978-1980 were eliminated from the catch at age and a second calibration was performed that included the recreational catch at age for 1981-1996. Differences between the two calibrations (Run 28 vs. Run 24) were minimal (Table B20, Figure B11). Stock sizes were slightly higher with the addition of the recreational landings (Figure B11) and the CV's were similar for each age compared to the base run. Fishing mortality and spawning stock biomass estimates were essentially the same from the two calibrations (Figure B11). Estimates of stock size, fishing mortality, and SSB from ADAPT Run 24 with the commercial plus recreational catch at age is presented in Table B21.

The effect of including the LPUE series as a calibration index was lower estimated stock sizes in 1997, and higher fishing mortality in 1996 (Table B20: Run 34) when compared to the final ADAPT formulation (Table B20: Run 29). Stock sizes are estimated more precisely, with lower CVs, in the ADAPT formulation with the LPUE series. Uncertainty associated with the 1994-1996 LPUE indices, however, precludes the acceptance of this ADAPT formulation.

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. A total of 1,000 bootstrap iterations were performed to estimate standard errors, coefficients of variation (CVs), bias estimates for age 1-8 stock size estimates at the beginning of 1997, catchability estimates (q) for each index of abundance used in calibrating the VPA, and the Fs at age 1-7 in 1996.

The bootstrap results indicate that stock sizes were well estimated for ages 2-8, with CVs varying between 0.28 and 0.36. Age 1 was not well estimated (CV = 0.77). The CVs for the catchability coefficients for all indices ranged between 0.15 and 0.23. The fully recruited F for ages 4+ was reasonably well estimated (CV = 0.15), with a point estimate of 0.184, slightly higher than the VPA estimate of 0.178. The distribution of the 1996 F estimates derived from the 1,000 bootstrap iterations ranged from 0.12 to 0.30 (Figure B12). The cumulative probability curve shows that there is an 80% probability that the F in 1996 is between 0.16 and 0.23 (Figure B12).

The bootstrap mean for the estimated 1996 spawning stock biomass (42,400 mt) was reasonably well estimated, with a CV of 0.11, and is slightly higher than the VPA estimate (41,100 mt). The distribution of the 1996 SSB estimates, derived from the 1,000 bootstrap iterations, ranged from 30,000 mt to 66,000 mt (Figure B13). The cumulative probability curve shows that there is an 80% probability that the 1996 SSB is between 37,000 mt and 47,000 mt (Figure B13).

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 six years prior to the current assessment, 1990-1995. Convergence of the estimates generally occurs after about three years (Figures B14-B16). With the exception of 1996, the retrospective analysis indicates a pattern of closely estimating or underestimating the recruits at age 1 (Figure B14). Estimates of SSB show no trend over time. SSB was slightly over-estimated and under-estimated in 1995 and 1994, respectively, and the 1993 SSB was under-estimated to a greater extent (Figure B15). The estimates for 1992-1990 were very close to the 1996 estimates.

Estimates of fishing mortality (F) do not show a consistent retrospective trend over the 6-year period (Figure B16). Fishing mortality was under-estimated in 1995, 1994, and 1990 and over-estimated in 1993, 1992, and 1991. The very high over-estimation of F in 1993 and under-estimation in 1994 may be influenced by the lack of 1993-1994 Canadian survey indices in the calibration. The actual ADAPT formulation employed for the 1994 assessment had Canadian survey (5Z j,m) indices derived for the eastern portion of the survey only (Serchuk *et al.* 1994), which contrasts with the indices used in the current formulation that were derived using all the Georges Bank strata. Fishing mortality in the previous assessment was estimated to be 0.91 for 1994 (Serchuk *et al.* 1994) compared to 1.07 in the present assessment..

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 1994-1996 catch mean weight at age and stock mean weight at age (Tables B11 and B13) and the 1986-1996 maturity ogive. A partial recruitment (PR) vector was calculated as the geometric mean of the 1994-1996 F estimates from the final VPA (Table B19). 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 = 0.0003	Age 3 = 0.5316
Age 2 = 0.1318	Ages 4+ = 1.000

reflects a decrease in the exploitation at age compared to the previous assessment (Serchuk *et al.* 1994). Input values for the yield-per-recruit analysis are provided in Table B22, and results of the analysis are provided in Table B22 and Figure B17. The resulting biological reference points were $F_{0.1} = 0.17$ and $F_{20\%} = 0.43$. Spawning stock biomass (ages 1+) and recruitment (age 1) data and the fitted Beverton-Holt equation are presented in Figure B18. The most recent recruits (1992-1995) are in the lower left quadrant of the plot.

Projections

Short Term

Short-term deterministic projections were performed to estimate landings and SSB in 1997, 1998, and 1999 under the scenarios of $F_{96} = 0.18$, $F_{0.1} = 0.17$, and $F_{20\%} = 0.43$. Data input were the same as described in the yield-per-recruit analysis (Table B23). In addition, recruitment in 1997 was set at 4.562 million fish, as estimated by the ADAPT formulation, and the recruitment for 1998 and 1999 was derived as the geometric mean of the 1990-1996 year classes at age 1 (Table B19).

Under an F_{96} of 0.18, landings are projected to be 7,800 mt in 1997, increase 6% to 8,400 mt in 1998, and increase again to 8,900 mt in 1999 (Table B23, Figure B19). SSB also increases in each of the three years to 55,000 mt by 1999, a 35% increase from 1996. Fishing at $F_{20\%} = 0.43$, landings will increase to 18,000 mt in 1998 and then decline in 1999 to 15,600 mt. SSB at $F_{20\%}$ will initially increase 16% from 1996 (41,000 mt) to 1998 (49,000 mt), but then will decline in 1999 (44,600 mt). Projections for $F_{0.1} = 0.17$ give similar results as $F_{96} = 0.18$ (Table B23).

Medium Term

The methodology for conducting medium-term (e.g., 10-year) projections is described in the **Data and Methodology Issues** section of this report. Trends in pre-recruit survival (measured as the R/SSB ratio) are presented in Figure B20. The median, lower 25th, and upper 75th percentiles of projected spawning biomass, recruitment (age 1), and landings are given in Table B24 and Figure B21 for the fishing mortality rate scenario of $F = 0.17$ (separate scenarios were not undertaken for $F_{0.1} = 0.17$ and $F_{96} = 0.18$, since the results are essentially the same). The annual probability that SSB exceeds the threshold value of 70,000 mt is given in Table B24 and Figure B22.

Under the $F_{0.1} = 0.17$ scenario, landings rise steadily from 8,200 mt in 1998 to 29,400 mt in 2006, while spawning stock biomass improves from 53,700 mt to 199,900 mt and median recruitment from 14 million to 34.4 million fish during 1998-2006 (Table B24). The probability that SSB exceeds the 70,000 mt threshold increases steadily from 0.9% in 1998 to >99% by 2002 and beyond (Figure B22).

Conclusions

The Georges Bank cod stock is at a low biomass level and is in an over-exploited state. Biomass indices derived from research surveys indicate that the stock remains near the 30-year record-low level. Fishing mortality declined from record-high levels in 1993 and 1994 (1.05 and 1.07) to a record low in 1996 ($F = 0.18$) that is nearly equal to $F_{0.1} = 0.17$. Spawning stock biomass declined from about 90,000 mt in the early 1980s, reached a record low (31,300 mt) in 1994, and remains near record-low size (41,100 mt) in 1996. Recruiting year classes continue to decline in size, with the most recent year classes (1994, 1995, and 1996) being the lowest on record.

Accounting for the estimation uncertainty associated with the 1996 SSB (41,100 mt) and F (0.18) estimates, there is an 80% probability that the 1996 SSB is between 37,000 mt and 47,000 mt and there is an 80% probability that the F in 1996 is between 0.16 and 0.23.

At the present exploitation rate (15%), given the probable level of recruitment, SSB is expected to increase each year through 1999. Maintaining this level of exploitation, given average recruitment, presents an opportunity for rebuilding the Georges Bank cod stock.

Comparison of Assessment Results in 5Zj,m and 5Z&6 for Georges Bank Cod

Substantial management actions, including area and seasonal closures, increased mesh size regulation, lower quotas, and trip- and days-at-sea limits to reduce effort have been implemented in both the 5Z & 6 (US assessment) and 5Zj,m (Canadian assessment) areas. Stock status evaluation of the 5Zj,m area was recently completed and comparison with results for the 5Z & 6 area is now possible.

Catches in 1978-1996 from 5Zj,m averaged about 44% of the total catches from 5Z, ranging between 59% and 22% (Figure B23a).

The adult biomass in 5Z declined from about 100,000 mt in the late 1970s to 26,000 mt in 1994, but has since increased to 44,000 mt in 1997. Adult biomass in the 5Zj,m area ranged between 43,000 mt and 13,000 mt and was 21,000 mt in 1997. The 5Zj,m area accounts for 40-60% of the total 5Z & 6 adult biomass (Figure B23b).

Recruitment patterns in the two areas have been similar. The 1980 and 1985 year classes were the most abundant, followed by the 1983 and 1987 cohorts. Since 1990, recruitment has been below average in both areas. The 1995 year class appears to be more abundant in 5Zj,m compared to the total 5Z area, but the reverse is true for the 1996 year class (Figure B23c).

Fishing mortality rate showed a similar trend of increase between the late 1970s and was above 1.0 in 1993. Substantial reductions in the Canadian TAC for the 5Zj,m area and reduced effort by the US have lowered exploitation to below the $F_{0.1}$ level in 1996 (Figure B23d).

Population trends in the 5Zj,m and 5Z & 6 areas have remained relatively consistent over the 1978-present time. This implies some measure of stability in the geographic distribution of the stock, and both areas have shown an increase in biomass following the effort reductions implemented in 1994 and later.

SARC Comments

The derivation of the catch at age was discussed. Poor sampling in the last three years necessitated semi-annual and annual pooling of the biological samples. However, the protocol historically has been to pool on a quarterly basis. A systematic protocol can be followed in the future if there is adequate sampling of the landings.

Results of the analysis of the effect of area closure on LPUE were inconclusive. Suggestions to improve the model included examining the time/area interaction and investigating the differences in mean LPUE between the three areas (open area, Area I, Area II). The LPUE indices were not used in the assessment, as had been done in previous assessments, for several reasons: 1) uncertainty of the effect of the closed areas on the 1994-1996 indices, 2) unaudited effort data for 1994-1996, and 3) uncertainty of what the effort data collected under mandatory logbook reporting represents relative to the historic effort series collected by interviews prior to 1994. The SARC noted that the historical LPUE indices may not have been representative due to the implementation of different management schemes throughout the time series. Fishing grounds available to the fleet have never been consistent year to year due to 1) seasonal closures that have varied both temporally and spatially since 1978, 2) the Hague Line since 1985, and 3) the year-round closed areas since late 1994.

The SARC discussed including recreational landings in the catch at age. The recreational catch at age is based on very few length samples and may not fully characterize the recreational landings. Adding the recreational catch at age would require excluding the first three years of the time series, due to a lack of recreational landings data for 1978-1980. Comparable ADAPT formulations for commercial catch at age only vs. commercial plus recreational catch at age (1981-1996) had minimal differences in F and stock sizes, except for age 1, which was poorly estimated. The SARC concluded that the longer time series reflected the best assessment and accepted as the final ADAPT the formulation using the 1978-1996 commercial-only catch at age.

Research Recommendations

- Evaluate further the effect of closed areas on the use of LPUE as an index of abundance. Investigate the effects of changes in fleet distribution (the progressive exclusion from the Canadian zone and then from Closed Area II) on the LPUE index.

- Further investigate the basis for deriving the party and charter boat component of the recreational cod catch. Investigate other sources of data for estimating the recreational size composition of the catch. Biological sampling intensities appear to be insufficient for characterizing recreational catch at age for assessment purposes.

- Further examine discard rates in years prior to 1989 before incorporating discard data into the catch at age.

- Biological sampling of commercial landings of Georges Bank cod should be increased to insure a representative estimation of the catch at age.

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Table B1. Commercial landings (metric tons, live) of Atlantic cod from Georges Bank and South (Division 5Z and Subarea 6), 1960 - 1996.

Year	Country						Total
	USA	Canada	USSR	Spain	Poland	Other	
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

Table B2. Distribution of USA commercial landings (metric tons, live) of Atlantic cod from Georges Bank (Area 5Ze), by gear type, 1965 - 1996. 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

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 B3. Percentage, by weight and number of fish landed, of USA commercial Atlantic cod landings from Georges Bank and South (NAFO Division 5Z and Statistical Area 6), by market category, 1964 - 1996. 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	24	100

[a] Includes landings of 'mixed' cod.

Table B4. Estimates of the discard ratios of Georges Bank Atlantic cod in the otter trawl and gill net fisheries, by quarter, in the western part (Statistical Area 521, 522, 525, 526) and the eastern part (Statistical Area 561, 562) of Georges Bank, 1989-1996. Number of tows are in parentheses.

Otter trawl

Year	West	East	West	East	West	East	West	East
1989	0.029 (127)	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	0.022 (46)	0.017 (18)	0.004 (49)	0.021 (222)	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 (244)	0.002 (38)	0.032 (217)	0.001 (38)	0.010 (114)	0.000 (8)	0.012 (106)	0.001 (28)
1996	0.012 (113)	0.007 (30)	0.001 (180)	0.000 (126)	-	-	-	-

Gill Net

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)	-	0.069 (17)	-	0.142 (21)	-
1991	0.115 (4)	-	0.011 (227)	-	0.033 (509)	-	0.099 (129)	-
1992	0.033 (29)	-	0.046 (340)	0.030 (18)	0.028 (257)	-	0.043 (198)	-
1993	0.059 (84)	-	0.074 (140)	0.064 (5)	0.007 (9)	0.003 (5)	0.056 (197)	-
1994	0.118 (90)	-	-	-	0.043 (24)	-	0.070 (110)	-
1995	0.193 (52)	-	0.028 (67)	-	0.029 (70)	-	0.081 (61)	-
1996	0.017 (32)	-	0.080 (25)	-	0.146 (6)	-	0.034 (24)	-

Table 85. 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 - 1996.[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

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

Table B6. USA and Canadian sampling of commercial Atlantic cod landings from the Georges Bank and South cod stock (NAFO Division 5Z and Statistical Area 6), 1978 - 1996.

	USA				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

Table B7. USA sampling of commercial Atlantic cod landings, by market category, for the Georges Bank and South cod stock (NAFO Division 5Z and Statistical Area 6), 1978 - 1996.

Year	Number of Samples, by Market Category & Quarter															Annual Sampling Intensity			
	Scrod					Market					Large					No. of Tons Landed/Sample			
	Q1	Q2	Q3	Q4	∑	Q1	Q2	Q3	Q4	∑	Q1	Q2	Q3	Q4	∑	Scrd	Mkt	Lge	∑
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

Table B8. Sampling of recreational Atlantic cod landings from the Georges Bank and South cod stock (NAFO Division 5Z and Statistical Area 6), 1981 - 1996, and the number of combined commercial and NEFSC research survey age samples applied to recreational length samples.

Year	Lengths			Ages
	Number Landed (000's)	Number Measured	Percent Measured	Number
1981	1695	341	0.02	1494
1982	1600	111	0.01	3226
1983	1709	337	0.02	3673
1984	464	223	0.05	2778
1985	2054	155	0.01	2628
1986	291	148	0.05	2589
1987	434	259	0.06	2066
1988	1102	183	0.02	2160
1989	404	212	0.05	1750
1990	463	214	0.05	2183
1991	333	142	0.04	2158
1992	193	122	0.06	1871
1993	755	138	0.02	1831
1994	303	176	0.06	1291
1995	471	157	0.03	1018
1996	174	71	0.04	1312

Table B9. 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 Statistical Area 6), 1978 - 1996.

Year	Age 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
	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
	USA Commercial Landings Mean Weight (kg) at Age										
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

Table B9 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 Statistical Area 6), 1978 - 1996.

Year	Age 1	2	3	4	5	6	7	8	9	10+	Total
					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

Table B10. 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 Statistical Area 6), 1978 - 1996.

Year	Age 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
					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
					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

Table B10 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 Statistical Area 6), 1978 - 1996.

	Age										
Year	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

Table B11. 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 Statistical Area 6), 1978 - 1996.

	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
				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
				Total Commercial Landings Mean Weight (kg) at Age									
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		

Table B11 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 Statistical Area 6), 1978 - 1996.

Year	Age 1	2	3	4	5	6	7	8	9	10+	Total
	Total Commercial Landings Mean Length (cm) at Age										
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

Table B12. Summary of USA and Canadian 1996 commercial landings of Atlantic cod from the Georges Bank and South cod stock (NAFO Division 5Z and Statistical Area 6).

Age	USA Catch at Age				Canadian Catch at Age				Total 1996 Catch at Age			
	Catch in Numbers (000's)	% of USA Total	Catch in Weight (mt)	% of USA Total	Catch in Numbers (000's)	% of CAN Total	Catch in Weight (mt)	% of CAN Total	Catch in Numbers (000's)	% of Total	Catch in Weight (mt)	% of Total
1	-	-	-	-	1	0.1	1	0.0	1	0.0	0.6	0.0
2	183	8.4	275	3.9	24	4.4	37	2.0	207	7.6	311	3.5
3	744	34.1	1823	26.0	159	29.2	376	20.0	903	33.1	2199	24.7
4	971	44.4	3303	47.0	262	48.1	875	46.6	1234	45.2	4178	46.9
5	190	8.7	915	13.0	51	9.4	268	14.3	241	8.8	1183	13.3
6	88	4.0	593	8.5	35	6.5	224	12.0	123	4.5	817	9.2
7	6	0.3	64	0.9	9	1.6	62	3.3	15	0.6	127	1.4
8	-	-	3	-	2	0.4	18	0.9	3	0.1	21	0.2
9	3	0.1	45	0.6	1	0.2	14	0.8	5	0.2	59	0.7
10+	-	-	-	-	0.2	0.0	2	0.1	0.2	0.0	2	0.0
Total	2185	100.0	7021	100.0	545	100.0	1876	100.0	2731	100.0	8898	100.0

Mean Weight Per Fish (kg) 3.212   Mean Weight Per Fish (kg) 3.443   Mean Weight Per Fish (kg) 3.258

Table B13. 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 - 1996. Values derived from landings mean weights-at-age using the procedures described by Rivard (1980).

	Year																			
Age	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
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	0.573	0.711	0.702	0.666	0.675
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	1.168
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	1.944
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	3.133
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	4.307
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	5.563
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	7.271
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	8.910
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	7.488
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	16.658	14.953	12.002	12.002

Table B14. Landings at age (thousands of fish;metric tons) and mean weight (kg) at age of total recreational landings of Atlantic cod from the Georges Bank and south cod stock (NAFO Divison 5Z and Statistical Area 6), 1981-1996.

Total Recreational Landings in Numbers (000's) at Age

Year	1	2	3	4	5	6	7	8	9	10+	Total
1981	97	671	574	217	7	77	26	11	10	5	1695
1982	115	982	275	115	77	5	24	5	2	0.2	1600.2
1983	139	409	711	174	144	100	12	14	4	2.31	1709.31
1984	19	92	141	126	27	27	20	1	6	4.81	463.81
1985	70	563	266	305	507	128	94	88	4	29.203	2054.203
1986	21	48	122	18	28	37	7	6	3	1.644	291.644
1987	6	225	72	82	7	11	17	6	5	2.9	433.9
1988	29	190	637	86	115	18	11	12	2	2	1102
1989	11	132	104	117	13	21	3	1	2	0	404
1990	1	165	158	44	68	10	14	2	0.4	1	463.4
1991	2	51	151	74	26	19	4	5	0.3	0.1	332.4
1992	31	97	32	13	13	3	3	0.4	0.1	0	192.5
1993	10	228	441	45	11	15	2	2	1		755
1994	4	85	122	68	11	4	6	1	0.6	2	303.6
1995	1	154	230	67	17	1	1	0	0	0	471
1996	2	27	76	53	8	6	0	2	0.1	0	174.1

Total Recreational Landings in Weight (tons) at Age

Year	1	2	3	4	5	6	7	8	9	10+	Total
1981	38.617	962.48	1235	787.43	35.354	558.3	238.86	136.49	82.274	12	4086.805
1982	73.232	1282.9	723.85	410.39	466.89	33.122	218.36	49.137	16.701	1.951	3276.533
1983	82.325	555.99	2158.8	772.76	769.31	635.95	92.893	132.12	39.129	30.21	5269.487
1984	18.749	136.98	368.44	534.52	154.47	181.36	161.67	11.629	66.868	85.477	1720.163
1985	53.553	652.66	781.06	1426.9	3049.2	969.41	839.5	918.49	52.589	330.057	9073.419
1986	15.249	74.825	315.15	87.807	198.5	300.55	62.551	53.58	29.972	17.876	1156.06
1987	3.153	387.59	196.17	303.49	39.617	98.908	181.1	75.076	55.036	36.378	1376.518
1988	14.292	249.76	1602.5	280.21	582.88	116.49	84.756	125.42	23.931	30.371	3110.61
1989	6.284	194.4	242.39	505.29	75.959	140.04	34.792	14.153	19.822	0	1233.13
1990	0.494	240.07	353.56	166.62	386.2	73.676	123.99	17.86	3.935	11.887	1378.292
1991	1.95	88.352	388.83	237.53	132.39	133.12	50.311	56.408	2.881	0.786	1092.558
1992	9.859	126.15	82.329	48.228	53.047	26.139	26.222	4.306	1.417	0	377.697
1993	2.942	263.17	938.08	134.47	57.993	71.749	14.387	16.222	4.81		1503.823
1994	2.409	107.06	237	252.72	56.52	31.591	43.609	9.04	5.92	10	755.869
1995	0.453	216.06	450.83	226.74	101.85	8.661	10.222	0	0	0	1014.816
1996	1.141	42.939	190.55	185.01	37.987	50.358	0	9	0.448		517.433

Total Recreational Landings Mean Weight at Age

Year	1	2	3	4	5	6	7	8	9	10+	Total
1981	0.397	1.434	2.154	3.625	5.366	7.223	9.039	12.552	13.78	12	67.57
1982	0.637	1.307	2.628	3.574	6.02	7.151	9.112	9.42	9.485	8.255	57.589
1983	0.594	1.359	3.037	4.434	5.355	6.357	7.661	9.547	9.428	13.08064	60.85264
1984	1.002	1.495	2.603	4.258	5.66	6.677	8.137	8.744	10.91	17.77035	67.25635
1985	0.357	1.159	2.937	4.685	6.012	7.581	8.911	10.49	11.907	11.29424	65.33324
1986	0.711	1.574	2.584	4.785	6.984	8.227	9.017	9.639	11.333	10.8684	65.7224
1987	0.515	1.721	2.718	3.719	5.486	9.178	10.701	11.57	11.941	12.70652	70.25552
1988	0.501	1.313	2.514	3.255	5.075	6.527	7.932	10.648	11.15	12.595	61.51
1989	0.568	1.469	2.34	4.322	6.012	6.773	9.932	11.163	9.387	0	51.966
1990	0.819	1.453	2.232	3.798	5.709	7.652	8.825	8.808	9.095	10.301	58.692
1991	0.915	1.719	2.577	3.219	5.042	6.907	11.598	12.227	10.906	9.387	64.497
1992	0.319	1.296	2.584	3.749	3.952	7.65	9.876	11.641	10.301	0	51.368
1993	0.307	1.152	2.126	3.012	5.278	4.789	6.663	7.01	7.499	0	37.836
1994	0.615	1.258	1.941	3.728	5.303	7.381	7.742	7.948	9.185	10	55.101
1995	0.466	1.408	1.962	3.376	5.973	6.88	8.001	0	0	0	28.066
1996	0.582	1.602	2.504	3.509	4.865	8.335	0	9	5.213	0	35.61

Table B15. 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 B16. 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	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

[1] Derived as total landings/ standardized LPUE.

Table B17a. 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 - 1996. [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

[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 (50[illegible] kg) at Station 205 (Strata tow 23-4).

Table B17b. 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 - 1996. [a,b,c]

	Age Group											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 [d]	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 [e]	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

[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).

Table B17b (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 - 1996. [b,c]

	Age Group											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

[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).

Table B17c. Stratified mean catch per tow at age (numbers) of Atlantic cod in Canadian spring bottom trawl surveys on Eastern Georges Bank, 1986 - 1996.

	Age Group										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[1]	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[1]	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

[1] Only the 5Zj,m strata were sampled due to weather and gear difficulties.; These indices were not used in the ADAPT calibration.

Table B18. Estimates of instantaneous total mortality (Z) and fishing mortality (F)[1] for the Georges Bank cod stock for eight time-periods, 1964 - 1995, 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
1991-1995	0.68	0.44	1.58	1.38	1.04	0.84

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 B19. 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, 1978-1996.

Stock Numbers (Jan 1) in thousands

Age	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
1	27713.8	23513.7	20105.8	41395.7	17471.8	9616.91	27395.4	8694	42850.9	16396.5
2	4268.13	22688.4	19220.7	16380.7	33867.5	14005.2	7775.94	22356.2	6996.8	34942.2
3	25526.3	3138.85	16775.9	12319	10511.4	19460	7588.36	5183.78	12489.2	4528.68
4	7946.75	13888.5	1755.52	8461.58	6266.61	5145.92	8636.78	3115.57	2033.6	6087.47
5	2877.64	4422.41	6964.36	984.879	4698.24	2608.88	1990.84	4052.66	1312.99	943.814
6	1124.37	1605	2524.1	3613.57	593.714	2036.92	1181.37	869.898	1612.42	640.665
7	1434.1	802.022	899.648	1092.95	1686.34	231.832	965.532	500.325	339.42	752.805
8	67.154	861.974	586.968	333.917	517.516	771.702	103.849	376.095	212.377	199.172
9	146.042	12.454	476.801	401.848	162.093	230.976	419.179	45.211	124.239	108.731
10	54.349	148.119	28.273	189.934	187.121	148.284	293.203	206.029	75.848	68.007
1 +	71158.7	71081.4	69338.1	85174.1	75962.4	54256.6	56350.5	45399.7	68047.8	64668.1

Age	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1	23550.2	15656.5	9725.48	19832.5	8717.45	12014.5	10652.2	3961.61	6072.17	4562.38
2	13400.8	19272.2	12818.4	7956.22	16190.4	7073.91	9833.04	8719.44	3243.41	4970.84
3	21846.4	9544.73	13889.5	6023.14	5134.12	9476.07	4856.93	7690.49	6784.17	2468.17
4	2435.57	10627.7	5170.63	6809.55	1996.94	2239.97	3916.41	2595.73	5339.12	4737.34
5	3064.84	1078.38	4941.63	2530.45	2606.42	695.738	825.036	1555.16	1499.06	3254.73
6	520.28	1154.74	583.401	1997.31	752.502	792.985	171.494	318.976	1010.85	1009.26
7	296.513	205.189	455.902	270.441	650.8	250.542	222.158	53.543	221.343	716.321
8	372.039	97.086	93.798	151.576	107.409	253.235	61.257	57.925	20.311	167.648
9	106.064	126.347	40.579	44.221	60.761	57.174	77.939	8.531	33.852	13.915
10	98.336	44.98	89.631	43.533	18.108	29.85	12.131	4.237	1.348	24.115
1 +	65691.1	57807.9	47809	45658.9	36234.9	32884	30628.5	24965.6	24225.6	21924.7

Fishing Mortality

Age	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
1	0.0001	0.0016	0.0049	0.0007	0.0212	0.0125	0.0033	0.0172	0.004	0.0018
2	0.1073	0.1019	0.2448	0.2436	0.3541	0.4128	0.2055	0.3822	0.235	0.2697
3	0.4086	0.3811	0.4844	0.4759	0.5143	0.6123	0.6902	0.7357	0.5186	0.4203
4	0.3861	0.4903	0.378	0.3883	0.6763	0.7496	0.5567	0.6641	0.5676	0.4862
5	0.3838	0.3608	0.4561	0.3061	0.6358	0.5922	0.6279	0.7216	0.5176	0.3956
6	0.1378	0.3789	0.637	0.5621	0.7404	0.5465	0.6592	0.7411	0.5617	0.5704
7	0.3091	0.1122	0.7911	0.5476	0.5817	0.6031	0.7428	0.6569	0.3331	0.5048
8	1.485	0.3921	0.1789	0.5227	0.6067	0.4103	0.6316	0.9076	0.4695	0.4301
9	0.3605	0.4384	0.4895	0.4424	0.6618	0.651	0.5994	0.7202	0.5414	0.4882
10	0.3605	0.4384	0.4895	0.4424	0.6618	0.651	0.5994	0.7202	0.5414	0.4882
mn4-8	0.54036	0.34686	0.48822	0.46536	0.64818	0.58034	0.64364	0.73826	0.4899	0.47742

Age	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	0.0005	0	0.0008	0.0029	0.0089	0.0004	0.0002	0	0.0001
2	0.1393	0.1275	0.5553	0.238	0.3356	0.176	0.0458	0.051	0.0731
3	0.5206	0.413	0.5128	0.904	0.6294	0.6836	0.4265	0.1649	0.1591
4	0.6147	0.5658	0.5146	0.7603	0.8544	0.7988	0.7236	0.349	0.295
5	0.7761	0.4143	0.7059	1.0127	0.9899	1.2004	0.7503	0.2308	0.1956
6	0.7304	0.7294	0.5688	0.9214	0.8998	1.0724	0.9641	0.1654	0.1444
7	0.9165	0.5828	0.9012	0.7234	0.7439	1.2085	1.1442	0.7693	0.0778
8	0.88	0.6723	0.5519	0.7141	0.4305	0.9784	1.7714	0.3371	0.1782
9	0.736	0.5751	0.6217	0.8552	0.9169	0.9638	0.774	0.2999	0.1782
10	0.736	0.5751	0.6217	0.8552	0.9169	0.9638	0.774	0.2999	0.1782
mn4-8	0.78354	0.59292	0.64848	0.82638	0.7837	1.0517	1.07072	0.37032	0.1782

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

Age	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
1	912.564	1104.08	850.305	1960.43	1199.97	902.953	3123.99	775.273	7009.1	1829.6
2	1410.12	7538.93	6913.04	5782.53	16138.9	6345.2	4303.9	11651.9	4817.09	24255.7
3	33844.8	3728.63	22417.1	15928.8	15642.9	26061.5	10501.3	6880.15	18780.4	7129.19
4	20219.5	38256.2	4296.99	21379.4	15792.8	12650.2	21659.7	8076.61	4845.23	17031.4
5	8798.34	16585.4	30442.6	3958.22	17473.6	9639.23	7112.21	14912.2	5436.64	3940.93
6	4882.46	8130.42	12541	20323.5	2957.09	10520.5	5655.63	4245.12	8589.35	3707.18
7	8214.61	5550.16	5918.37	7296.24	12172.7	1460.24	6226.94	3166.34	2348.02	5369.56
8	366.885	6810.36	5034.24	2696.19	4165.19	6840.64	810.978	2985.99	1705.38	1694.15
9	1330.66	111.601	3963.46	4097.27	1561.11	2112.71	3955.93	416.553	1251.19	1033.42
10	653.404	1681.21	388.132	3168.02	2710.47	1872.69	3940.71	2384.8	945.388	909.54
Total	80633.4	89497	92765.3	86590.6	89814.8	78406	67291.3	55494.9	55727.8	66900.6

Age	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	2870.7	2029.1	1284.72	4175.43	1923.06	1801.67	1684.83	619.091	899.29
2	8514.03	13166.4	8125.91	5503.87	12420.6	5642.88	6813.36	6178.31	2317.54
3	32953	14563.5	22393.5	9090.78	8146.52	13871.5	7260.83	11513.2	11005.1
4	6167.28	27344.9	12715.9	16499.7	5136.79	5325.94	9444.78	6689.09	12834
5	12385.9	4236.89	18252.2	8472.4	8573.22	2406.81	2817.69	6486.57	6087.03
6	2768.71	5946.77	3000.18	8894.09	3394.3	3513.63	858.171	1787.52	5755.89
7	2026.93	1331.32	2854.79	1588.31	3698.27	1347.03	1269.46	406.515	1661.24
8	2937.69	814.152	774.243	1227.55	825.904	1731	369.895	511.004	181.333
9	958.482	1198.42	410.872	376.651	568.108	460.193	626.439	77.404	388.834
10	1287.01	676.358	1135.3	561.282	285.984	325.421	171.786	58.292	15.188
Total	72869.8	71307.7	70947.6	56390	44972.8	36426.1	31317.2	34327	41145.5

Percent Mature (females)

Age	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	7	7	7	7	13	13	13	13	23	23	23	23	23	23	23	23	23	23	23
2	34	34	34	34	47	47	47	47	64	64	64	64	64	64	64	64	64	64	64
3	78	78	78	78	84	84	84	84	91	91	91	91	91	91	91	91	91	91	91
4	96	96	96	96	97	97	97	97	98	98	98	98	98	98	98	98	98	98	98
5	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
6	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
7	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
8	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
9	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
10	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table B20 Parameter estimates of stock size, with standard error, t-statistic, and CV, and estimates of terminal year fishing mortality (F) in 1996 from trial ADAPT calibrations for Georges Bank cod (CAA = catch at age).

Run 28: Commercial CAA only with Survey indices,1981-1996

Age	Stock size Estimate	Standard Error	T-Statistic	CV		F in 1996
1	1583.23	1120.09	1.41348	0.71	1	0.0001
2	5137.87	1835.88	2.79859	0.36	2	0.0725
3	2492.37	717.158	3.47535	0.29	3	0.1555
4	4855.03	1358.44	3.57398	0.28	4	0.2823
5	3423.14	1001.33	3.4186	0.29	5	0.1703
6	1174.21	360.193	3.25994	0.31	6	0.0955
7	1110.44	355.228	3.12599	0.32	7	0.0576
8	228.835	77.9414	2.93599	0.34	8	0.1514

Run 24: Commercial CAA plus Recreational CAA with Survey indices,1981-1996

Age	Stock size Estimate	Standard Error	T-Statistic	CV	F in 1996
1	1678.74	1166.5	1.43913	0.69	0.0004
2	5431.83	1906.7	2.84882	0.35	0.0777
3	2621.37	744.08	3.52297	0.28	0.161
4	5070.64	1411.03	3.59357	0.28	0.2892
5	3472.65	1012.76	3.4289	0.29	0.1724
6	1197.45	365.311	3.2779	0.31	0.096
7	1158.25	364.67	3.17615	0.31	0.0541
8	244.341	81.0993	3.01287	0.33	0.1529

Run 34: Commercial CAA with Survey and LPUE indices, 1978-1996

Age	Stock size Estimate	Standard Error	T-Statistic	CV	F in 1996
1	4417.72	2161.05	2.04424	0.49	0.0001
2	4799.7	1483.78	3.23477	0.31	0.0843
3	2128.3	519.951	4.09326	0.24	0.2058
4	3576.52	852.665	4.19453	0.24	0.3743
5	2459.7	629.914	3.90481	0.26	0.231
6	839.019	218.623	3.83775	0.26	0.184
7	551.039	153.492	3.59001	0.28	0.0938
8	137.995	40.3922	3.41636	0.29	0.2208

Run 29: Final ADAPT, Commercial CAA with Survey indices only, 1978-1996

Age	Stock size Estimate	Standard Error	T-Statistic	CV	F in 1996
1	4562.38	2361.03	1.93237	0.52	0.0001
2	4970.84	1626.21	3.05671	0.33	0.0731
3	2468.17	673.624	3.66402	0.27	0.1591
4	4737.34	1264.46	3.74652	0.27	0.295
5	3254.73	918.155	3.54486	0.28	0.1956
6	1009.26	300.895	3.35419	0.3	0.1444
7	716.321	232.355	3.08288	0.32	0.0778
8	167.648	55.5617	3.01732	0.33	0.1782

Table B21. 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 anal commercial plus recreational catch at age ADAPT formulation, 1981-1996.

Stock Numbers (Jan 1) in thousands

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1	45754.63	19148.47	10464	28969.36	9230.145	44783.04	17011.6	24298.23	16284.9	10279.88	22356.72	9926.776	13111.23	11597.07	4227.711	6637.433	1678.744
2	18202.61	37348.53	15273.89	8343.701	23627.62	7372.416	36505.09	13898.96	19858.42	13323	8409.212	18255.27	8035.968	10721.9	9489.445	3460.362	5431.828
3	13701.43	11395.88	21421.43	8256.988	5565.377	13020.75	4792.777	22922.4	9780.66	14249.96	6286.941	5458.856	11078.88	5438.294	8341.313	7275.259	2621.373
4	9249.838	6879.088	5621.231	9599.341	3535.41	2105.341	6412.277	2586.645	10932.29	5269.689	6961.725	2076.293	2476.882	4829.643	2961.327	5663.859	5070.643
5	1030.184	5147.258	3006.283	2222.552	4726.728	1380.756	986.265	3256.572	1124.254	5085.136	2571.74	2664.049	748.941	978.288	2241.32	1737.758	3472.65
6	3843.824	624.473	2334.871	1376.436	1035.178	1705.547	670.81	548.702	1207.658	609.197	2053.277	762.784	828.407	205.1	434.495	1557.253	1197.451
7	1149.246	1805.183	252.491	1118.993	635.604	358.92	795.572	311.24	212.172	480.228	282.512	679.426	256.246	237.586	77.438	315.017	1158.247
8	361.934	540.08	847.287	109.905	483.642	238.079	208.804	391.671	99.19	96.8	158.824	113.673	273.957	64.117	65.127	38.97	244.341
9	435.399	175.078	244.926	468.395	49.265	132.665	124.345	108.52	131.562	41.397	44.87	62.172	61.941	93.096	9.967	39.749	27.382
10	206.515	197.189	156.61	329.42	244.952	80.452	77.042	100.832	45.036	91.682	43.794	18.481	31.396	19.069	4.955	1.552	29.02
1 +	93935.61	83261.23	59623.01	60795.09	49133.92	71177.96	67584.58	68423.78	59676.14	49526.96	49169.61	40017.78	36903.84	34184.16	27853.1	26727.21	20931.68

Fishing Mortality

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	0.003	0.0261	0.0264	0.0038	0.0247	0.0044	0.0021	0.0018	0.0007	0.0009	0.0027	0.0113	0.0012	0.0006	0.0003	0.0004
2	0.2683	0.3559	0.4151	0.2049	0.3959	0.2306	0.2653	0.1514	0.1319	0.551	0.2321	0.2994	0.1905	0.0511	0.0657	0.0777
3	0.489	0.5067	0.6027	0.6482	0.7721	0.5083	0.4167	0.5404	0.4184	0.5163	0.9079	0.5902	0.6303	0.4078	0.1871	0.161
4	0.3861	0.6278	0.7279	0.5085	0.7402	0.5583	0.4775	0.6332	0.5654	0.5174	0.7606	0.8197	0.729	0.5677	0.333	0.2892
5	0.3006	0.5905	0.5812	0.5641	0.8193	0.5219	0.3864	0.792	0.4127	0.7069	1.0154	0.9681	1.0952	0.6116	0.1641	0.1724
6	0.5558	0.7055	0.5355	0.5727	0.8592	0.5626	0.5679	0.7502	0.7222	0.5684	0.9059	0.8908	1.049	0.774	0.1216	0.096
7	0.5551	0.5564	0.6318	0.6388	0.782	0.3417	0.5086	0.9435	0.5847	0.9065	0.7104	0.7083	1.1854	1.0942	0.4867	0.0541
8	0.5262	0.5908	0.3927	0.6024	1.0935	0.4495	0.4545	0.8909	0.6738	0.5689	0.7379	0.4071	0.8793	1.6614	0.2938	0.1529
9	0.4391	0.6177	0.6335	0.5406	0.8229	0.5388	0.4816	0.7541	0.5742	0.6246	0.8531	0.8877	0.8887	0.6129	0.2507	0.1529
10	0.4391	0.6177	0.6335	0.5406	0.8229	0.5388	0.4816	0.7541	0.5742	0.6246	0.8531	0.8877	0.8887	0.6129	0.2507	0.1529
mn4-8	0.4648	0.6142	0.5738	0.5773	0.8589	0.4868	0.479	0.802	0.5918	0.6536	0.826	0.7588	0.9876	0.9418	0.2798	0.1529

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

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	934.835	1234.665	679.113	3281.911	578.646	7004.399	1758.028	1853.445	1242.858	1353.031	4668.871	1538.193	783.562	1285.606	274.744	733.341
2	6345.734	13386.92	6740.545	4071.444	12139.61	4525.462	25062.51	8506.297	11554.55	7074.003	5823.075	14017.42	5513.394	5373.968	5910.064	1853.123
3	17368.82	16912.81	28960.28	11476.75	7466.488	19482.68	7574.627	34626.93	14808.32	22866.09	9474.649	8729.652	16289.53	7938.67	12219.81	11739.45
4	22081.59	17363.08	14017.65	24618.09	9228.561	5140.969	17941.78	6525.13	28254.46	12972.03	16832.87	5372.45	5949.177	11926.18	7581.881	13560.28
5	4422.437	19381.15	11215.9	8129.048	17494.08	5858.415	4135.646	13070.43	4415.165	18862.37	8618.921	8782.911	2638.334	3417.637	9479.182	7045.409
6	21504.5	3132.425	12105.6	6749.49	5068.041	9294.561	3924.843	2906.582	6214.693	3153.453	9202.694	3450.618	3668.227	1060.035	2454.339	9014.382
7	8117.735	13079.74	1580.751	7327.172	4000.1	2533.431	5726.613	2119.796	1380.366	3008.678	1684.493	3895.562	1383.277	1362.757	613.311	2371.885
8	2923.475	4363.037	7513.983	859.328	3729.847	1944.589	1781.567	3110.799	829.422	796.046	1289.599	886.02	1903.56	393.418	578.301	352.337
9	4679.329	1711.611	2238.678	4452.225	447.052	1337.347	1184.836	984.334	1245.746	417.816	380.879	587.154	503.636	767.037	91.037	455.811
10	3355.567	2873.89	1976.722	4497.896	2682.054	990.874	1014.511	1306.213	677.306	1152.079	563.896	293.299	346.587	249.67	68.726	17.566
Total	91734.03	93439.33	87029.22	75463.35	62834.48	58112.72	70104.96	75009.95	70622.89	71655.61	58539.94	47553.27	38979.29	33774.97	39271.39	47143.58

Percent Mature (females)

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	7	13	13	13	13	23	23	23	23	23	23	23	23	23	23	23
2	34	47	47	47	47	64	64	64	64	64	64	64	64	64	64	64
3	76	84	84	84	84	91	91	91	91	91	91	91	91	91	91	91
4	96	97	97	97	97	98	98	98	98	98	98	98	98	98	98	98
5	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
6	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
7	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
8	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
9	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
10	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table B22. 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: 15- 4-1997; Time: 14:13:47.46
Cod Georges Bank - 1997

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: ==> GBYPR.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	.0003	1.0000	.2300	.942	.749
2	.1318	1.0000	.6400	1.502	1.217
3	.5316	1.0000	.9100	2.283	1.866
4	1.0000	1.0000	.9800	3.609	2.882
5	1.0000	1.0000	1.0000	4.975	4.240
6	1.0000	1.0000	1.0000	6.794	5.791
7	1.0000	1.0000	1.0000	8.423	7.476
8	1.0000	1.0000	1.0000	9.697	8.881
9	1.0000	1.0000	1.0000	10.944	10.510
10+	1.0000	1.0000	1.0000	15.174	15.170

Summary of Yield per Recruit Analysis for: Cod Georges Bank - 1997

Slope of the Yield/Recruit Curve at F=0.00: --> 25.9796
F level at slope=1/10 of the above slope (F0.1): -----> .171
Yield/Recruit corresponding to F0.1: -----> 1.6986
F level to produce Maximum Yield/Recruit (Fmax): -----> .338
Yield/Recruit corresponding to Fmax: -----> 1.8521
F level at 20 % of Max Spawning Potential (F20): -----> .430
SSB/Recruit corresponding to F20: --------> 5.4030

Listing of Yield per Recruit Results for:
Cod Georges Bank - 1997

	FMORT	TOTCTHN	TOTCTHW	TOTSTKN	TOTSTKW	SPNSTKN	SPNSTKW	% MSP
	.000	.00000	.00000	5.5167	29.0106	4.2370	27.0151	100.00
	.050	.12691	.92642	4.8847	21.4678	3.6042	19.5677	72.43
	.100	.21200	1.39391	4.4617	16.8132	3.1803	14.9893	55.49
	.150	.27320	1.63661	4.1582	13.7367	2.8759	11.9744	44.32
F0.1	.171	.29372	1.69856	4.0565	12.7662	2.7740	11.0257	40.81
	.200	.31945	1.76168	3.9293	11.5986	2.6462	9.8862	36.60
	.250	.35572	1.82252	3.7502	10.0533	2.4664	8.3818	31.03
	.300	.38501	1.84738	3.6059	8.9003	2.3214	7.2625	26.88
Fmax	.338	.40400	1.85208	3.5126	8.2015	2.2275	6.5859	24.38
	.350	.40921	1.85184	3.4870	8.0167	2.2018	6.4071	23.72
	.400	.42959	1.84472	3.3872	7.3239	2.1013	5.7380	21.24
F20%	.430	.44039	1.83711	3.3344	6.9764	2.0481	5.4030	20.00
	.450	.44702	1.83118	3.3020	6.7699	2.0154	5.2040	19.26
	.500	.46214	1.81423	3.2284	6.3189	1.9411	4.7703	17.66
	.550	.47539	1.79568	3.1640	5.9461	1.8761	4.4123	16.33
	.600	.48714	1.77660	3.1071	5.6337	1.8186	4.1127	15.22
	.650	.49763	1.75762	3.0564	5.3686	1.7673	3.8589	14.28
	.700	.50708	1.73910	3.0108	5.1411	1.7212	3.6414	13.48
	.750	.51565	1.72125	2.9696	4.9440	1.6795	3.4531	12.78
	.800	.52346	1.70417	2.9322	4.7716	1.6415	3.2886	12.17
	.850	.53063	1.68789	2.8979	4.6196	1.6067	3.1438	11.64
	.900	.53723	1.67243	2.8664	4.4846	1.5747	3.0152	11.16
	.950	.54335	1.65775	2.8373	4.3639	1.5451	2.9004	10.74
	1.000	.54903	1.64384	2.8103	4.2553	1.5177	2.7971	10.35

Table B23. Summary of short-term deterministic projections for Georges Bank cod. Recruitment was based on the geometric mean of the 1990-1996 year classes at age 1.

Input for Projections:

Number of Years: 3; Initial Year: 1997; Final Year: 1999
Number of Ages : 10; Age at Recruitment: 1; Last Age: 10
Natural Mortality is assumed Constant over time at: .200
Proportion of F before spawning: .1667
Proportion of M before spawning: .1667
Last age is a PLUS group.

Age	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Weights Catch	Average Weights Stock
1	.0003	1.0000	.2300	.942	.749
2	.1318	1.0000	.6400	1.502	1.217
3	.5316	1.0000	.9100	2.283	1.866
4	1.0000	1.0000	.9800	3.609	2.882
5	1.0000	1.0000	1.0000	4.975	4.240
6	1.0000	1.0000	1.0000	6.794	5.791
7	1.0000	1.0000	1.0000	8.423	7.476
8	1.0000	1.0000	1.0000	9.697	8.881
9	1.0000	1.0000	1.0000	10.944	10.510
10+	1.0000	1.0000	1.0000	15.174	15.170

SSB in 1996 was estimated at 41145 mt
Landings in 1996 were estimated at 8,896 t
F(4-9, unweighted) in 1996 was estimated at 0.18

Projection results:

Year	F	Lndngs	SSB	F	Lndngs	SSB	F	Lndngs	SSB
1997	0.18	7862	46380	0.18	7862	46380	0.18	7862	46380
1998	0.18	8370	50874	0.43	17944	49074	0.17	7941	50948
1999	0.18	8939	55375	0.43	15598	44642	0.17	8552	55868

Table B24. Stochastic medium-term projections of spawning stock biomass (mt), recruitment (age 1, thousands) and landings (mt) for Georges Bank cod, assuming F=0.17. Probability of SSB> the 70,000 mt threshold is given, along with the lower and upper quartiles and the median of bootstrap simulations.

	- Spawning Biomass -				- Recruitment -			- Landings -		
Year	L-25	Median	U-75	Probability	L-25	Median	U-75	L-25	Median	U-75
1997	43,826	47,460	51,253	0.000	9,053	12,708	17,986	6,982	7,679	8,283
1998	49,655	53,660	58,245	0.009	10,031	13,998	19,545	7,565	8,160	8,873
1999	57,116	62,400	68,454	0.200	11,113	15,418	21,896	8,296	8,962	9,738
2000	67,320	74,885	83,495	0.666	12,750	17,518	24,548	9,287	10,208	11,314
2001	79,861	90,054	101,804	0.925	14,671	19,928	27,936	11,165	12,627	14,381
2002	95,378	108,905	124,278	0.991	16,781	22,480	31,219	13,534	15,502	17,783
2003	112,311	129,154	148,598	0.999	19,054	25,276	34,851	16,136	18,624	21,554
2004	130,335	150,290	174,047	1.000	21,606	28,056	37,986	18,821	21,912	25,465
2005	150,436	174,092	202,207	1.000	23,953	30,893	41,187	21,917	25,508	29,733
2006	172,172	199,878	232,636	1.000	26,853	34,428	45,651	25,222	29,387	34,366

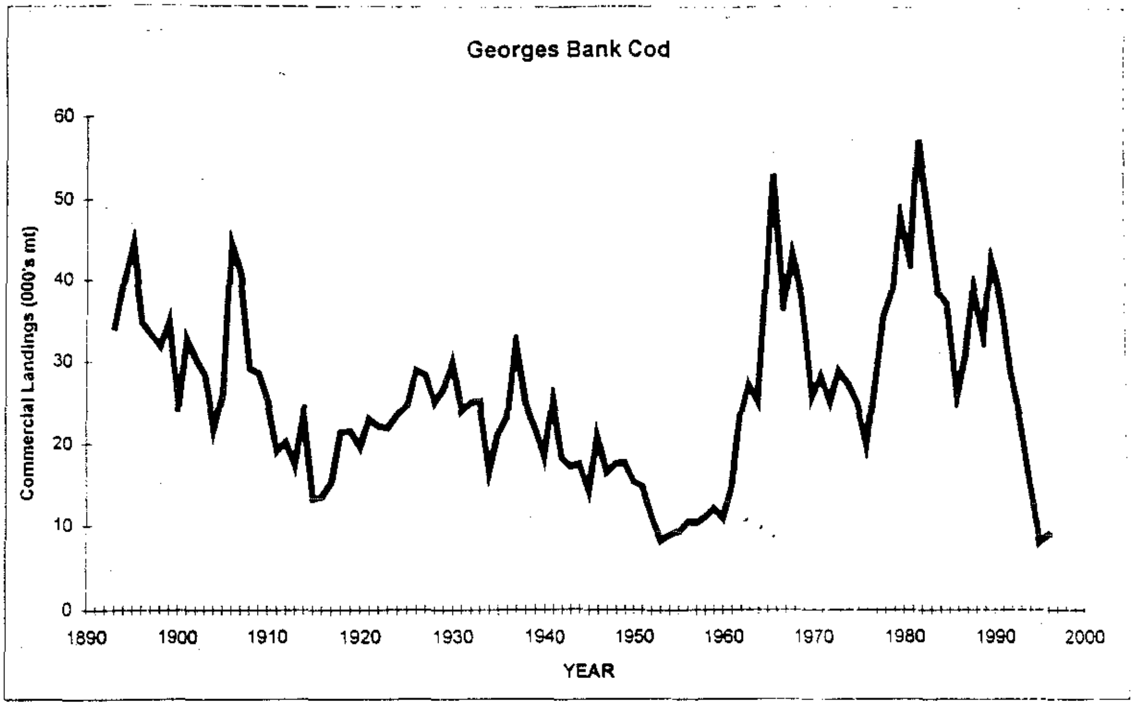


Figure B1. Total commercial landings of Georges Bank cod (Division 5Z and 6), 1893-1996.

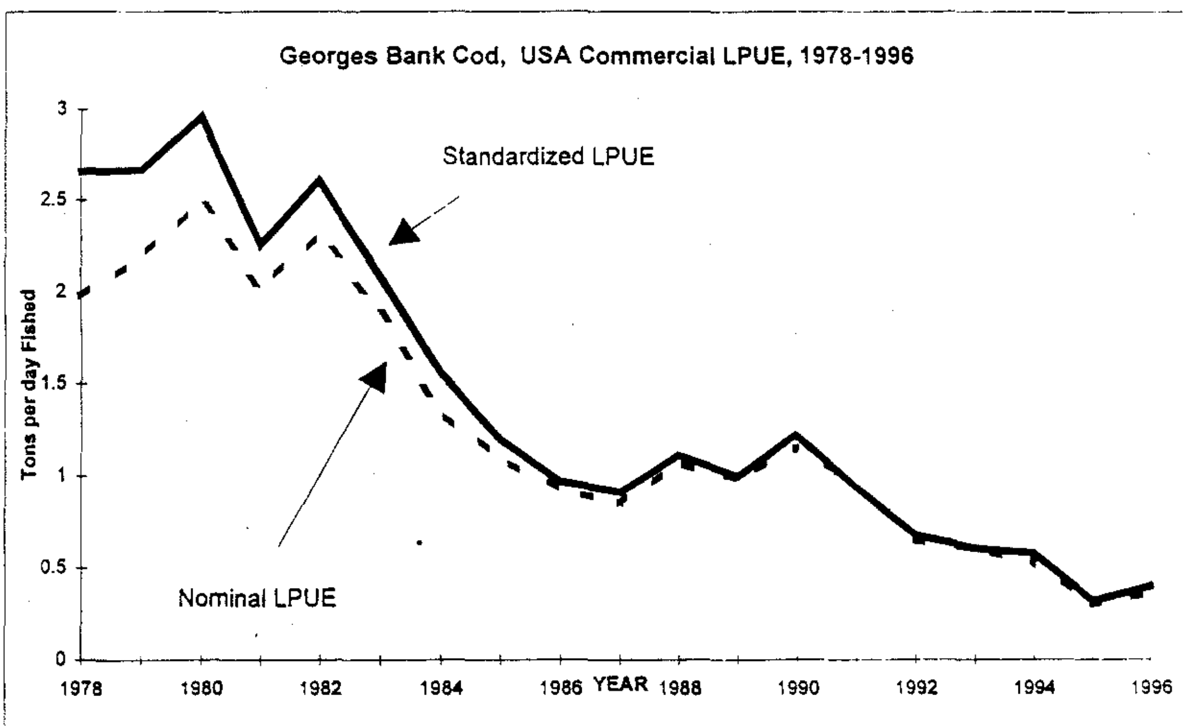


Figure B2. Trends in USA LPUE (landings per day fished) of Georges Bank cod, 1978-1996. Nominal LPUE is based on all otter trawl trips landing cod. Standardized LPUE is derived from a GLM incorporating year, tonnage class, area, quarter, and depth.

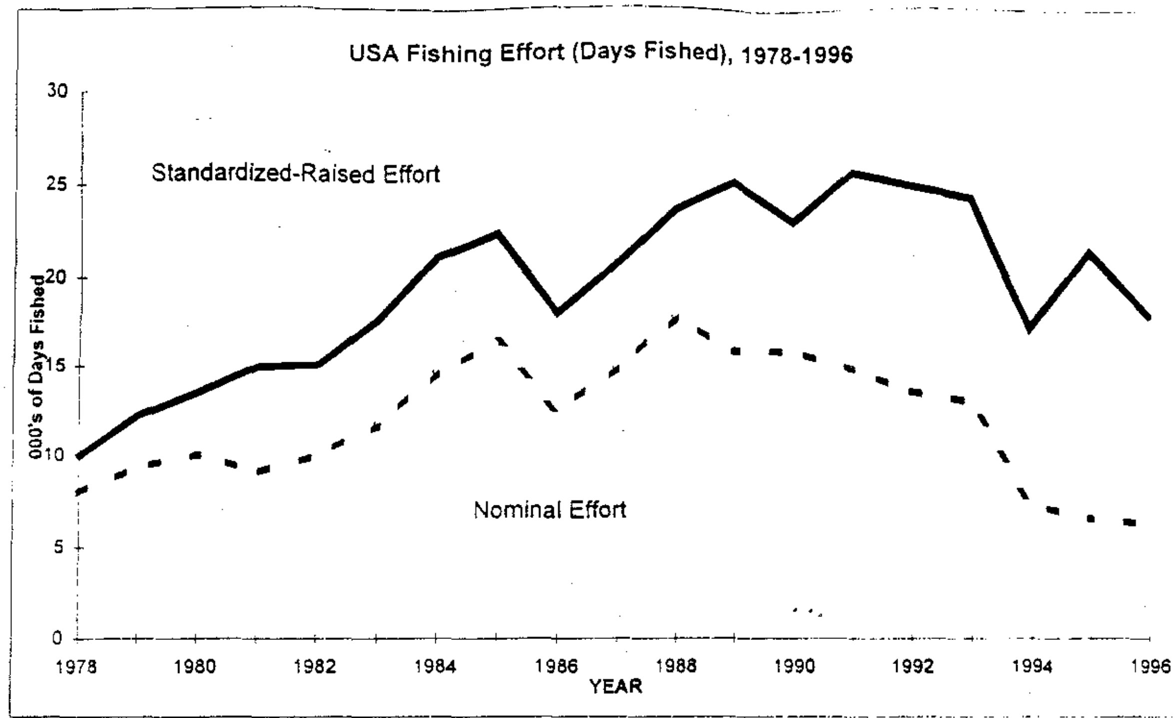


Figure B3. Trends in USA fishing effort (days fished) on Georges Bank, 1978-1996. Nominal effort based on all otter trawl trips landing cod. Standardized-Rasied effort derived from GLM incorporating year, tonnage class, area, quarter, and depth.

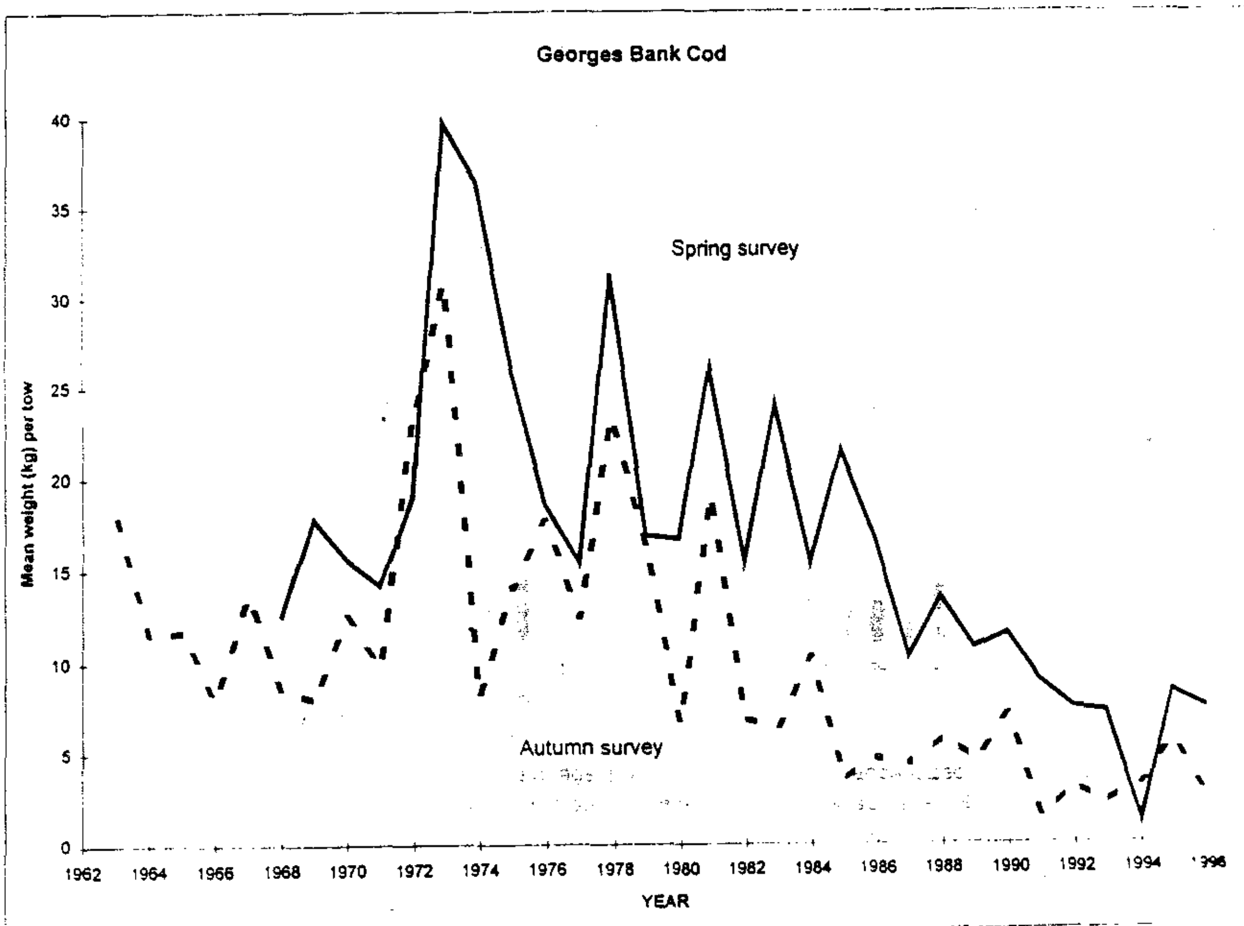


Figure B4. Standardized stratified mean catch per tow (kg) of Atlantic cod in NEFSC spring and autumn research vessel bottom trawl surveys on Georges Bank, 1963-1996.

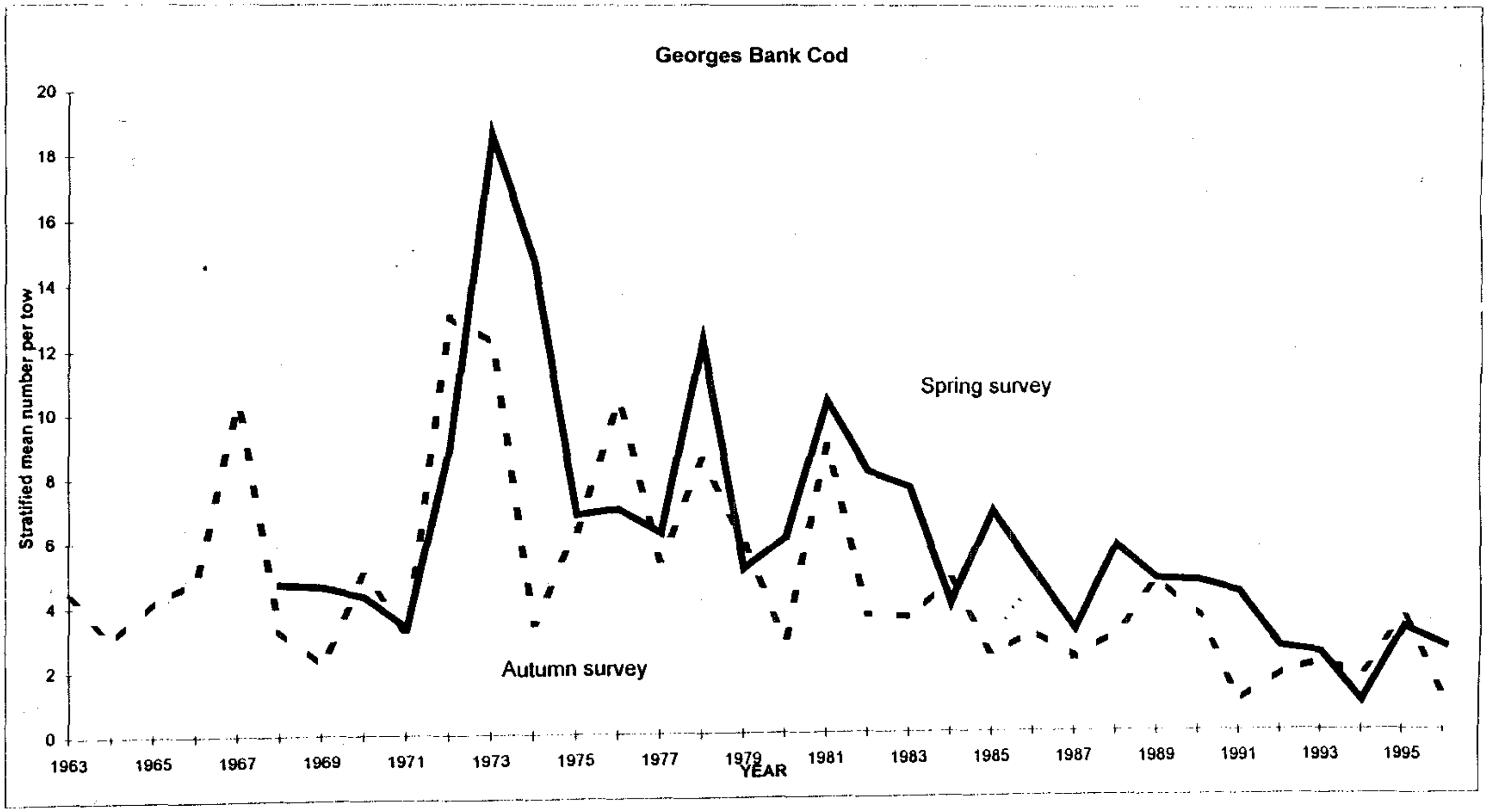
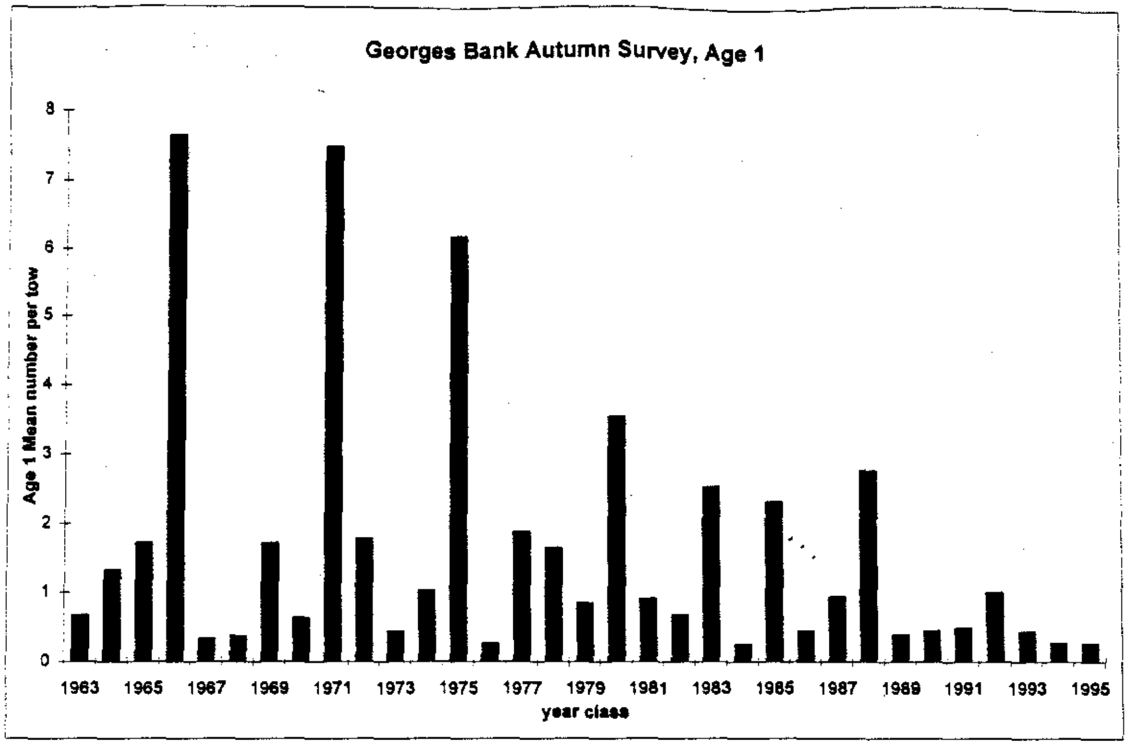


Figure B5. Standardized stratifed mean number per tow of Atlantic cod in NEFSC spring and autumn research vessel bottom trawl surveys on Georges Bank, 1963-1996.



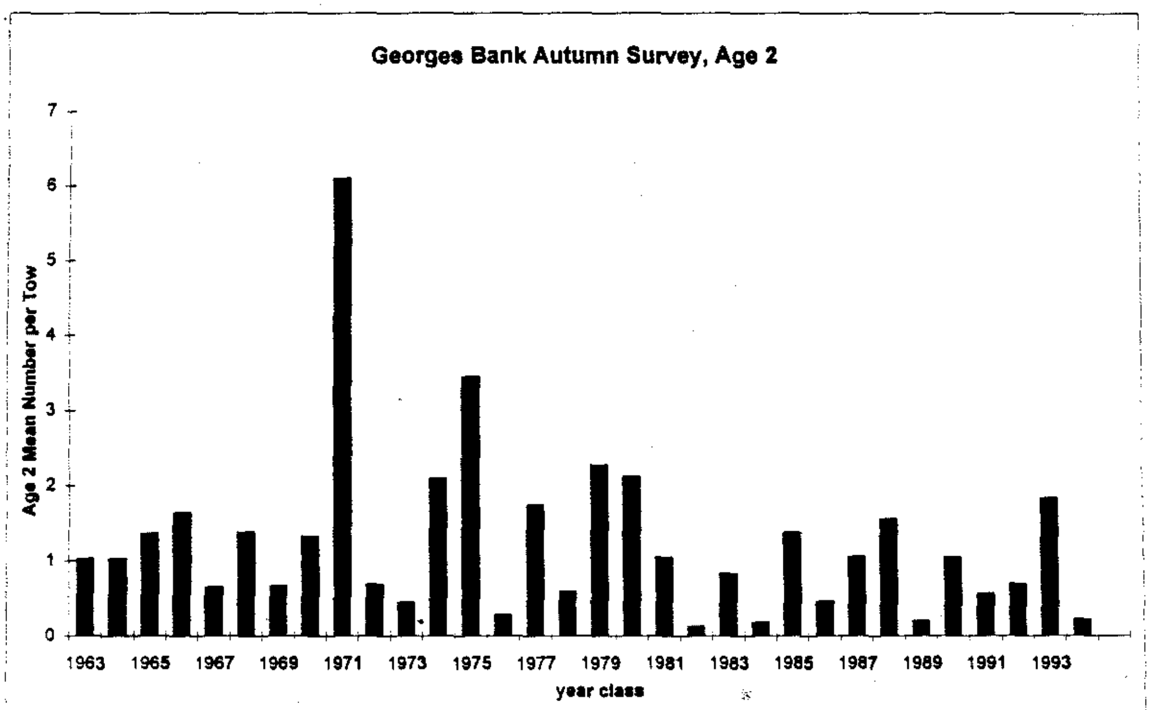


Figure B6. Relative year class strengths of Georges Bank cod at age 1 and age 2 based on standardized catch (number) per tow indices from NEFSC autumn research vessel bottom trawl surveys, 1963-1996.

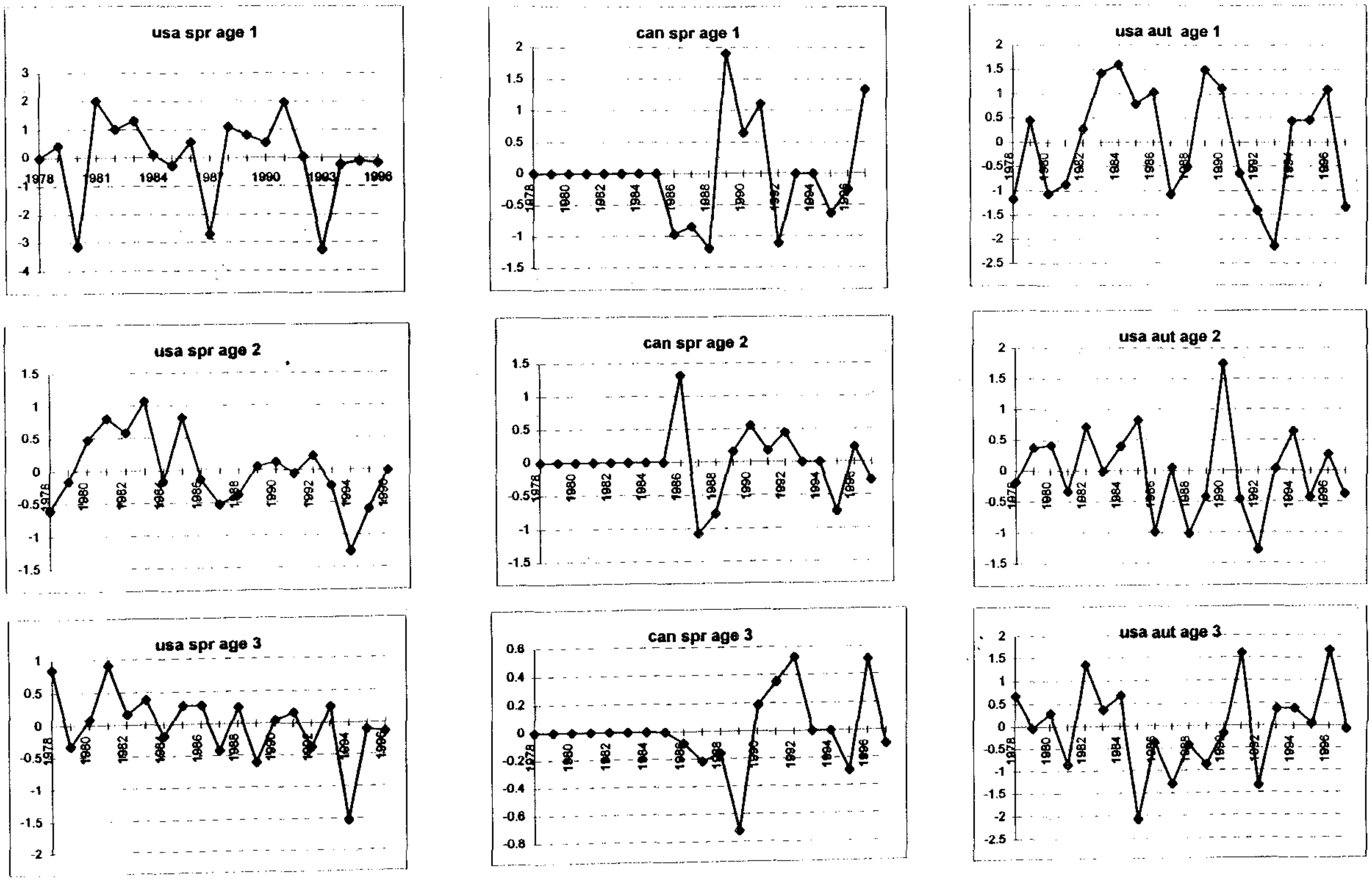


Figure B7. Residual plots (expected -observed) for ages 1-8 for the USA spring and Canadian spring abundance indicies, and ages 1-6 for the USA autumn research survey indices.

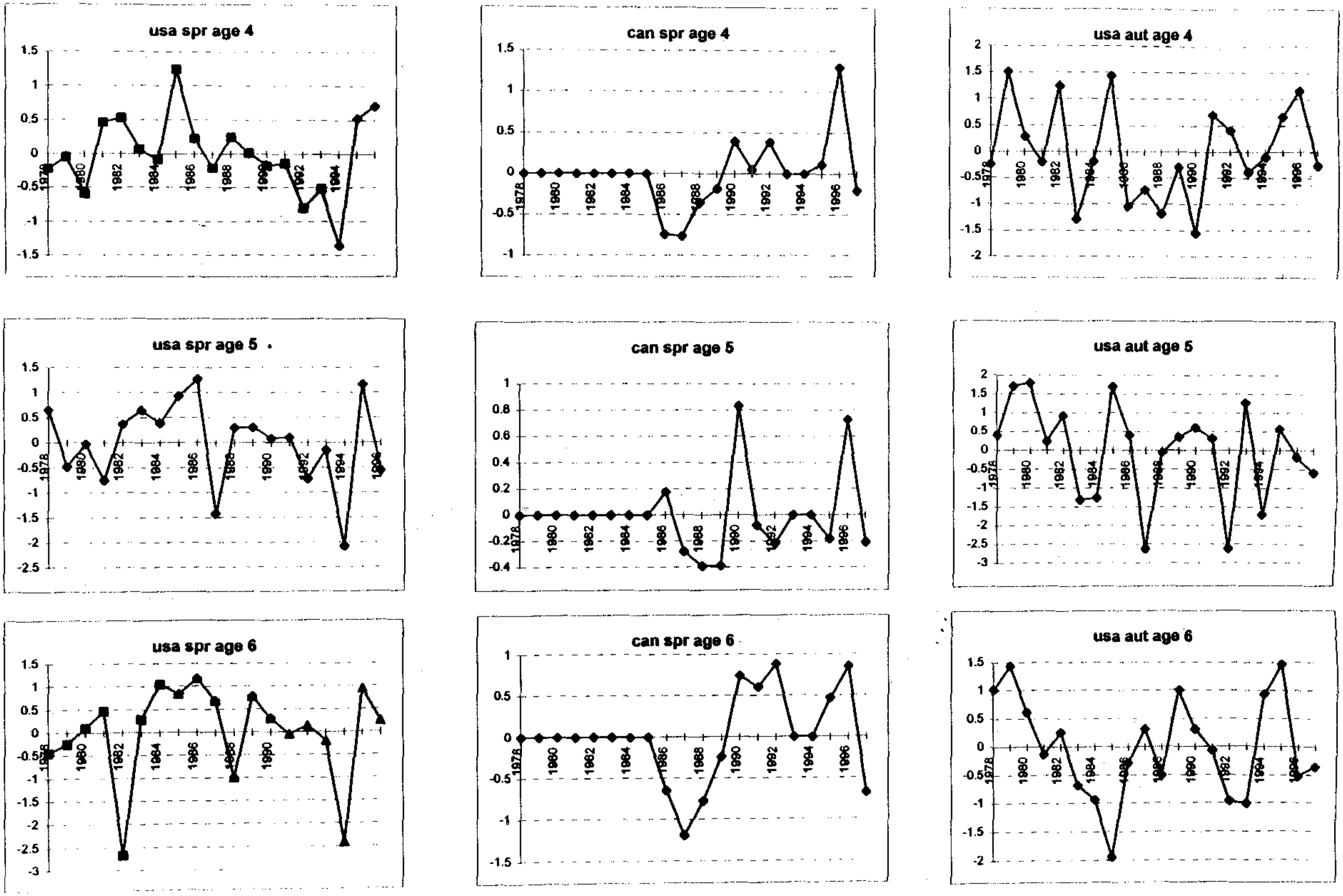


Figure B7 continued. Residual plots (expected -observed) for ages 1-8 for the USA spring and Canadian spring abundance indicies, and ages 1-6 for the USA autumn research survey indices.

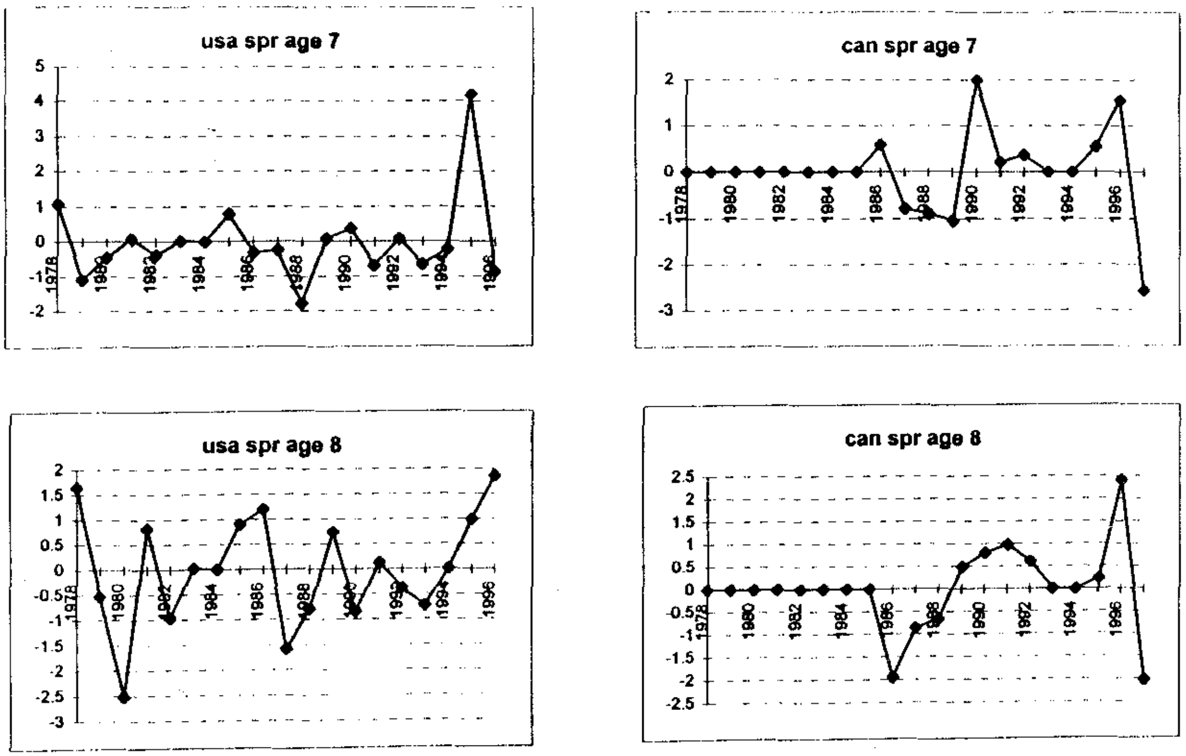


Figure B7 continued. Residual plots (expected -observed) for ages 1-8 for the USA spring and Canadian spring abundance indicies, and ages 1-6 for the USA autumn research survey indices.

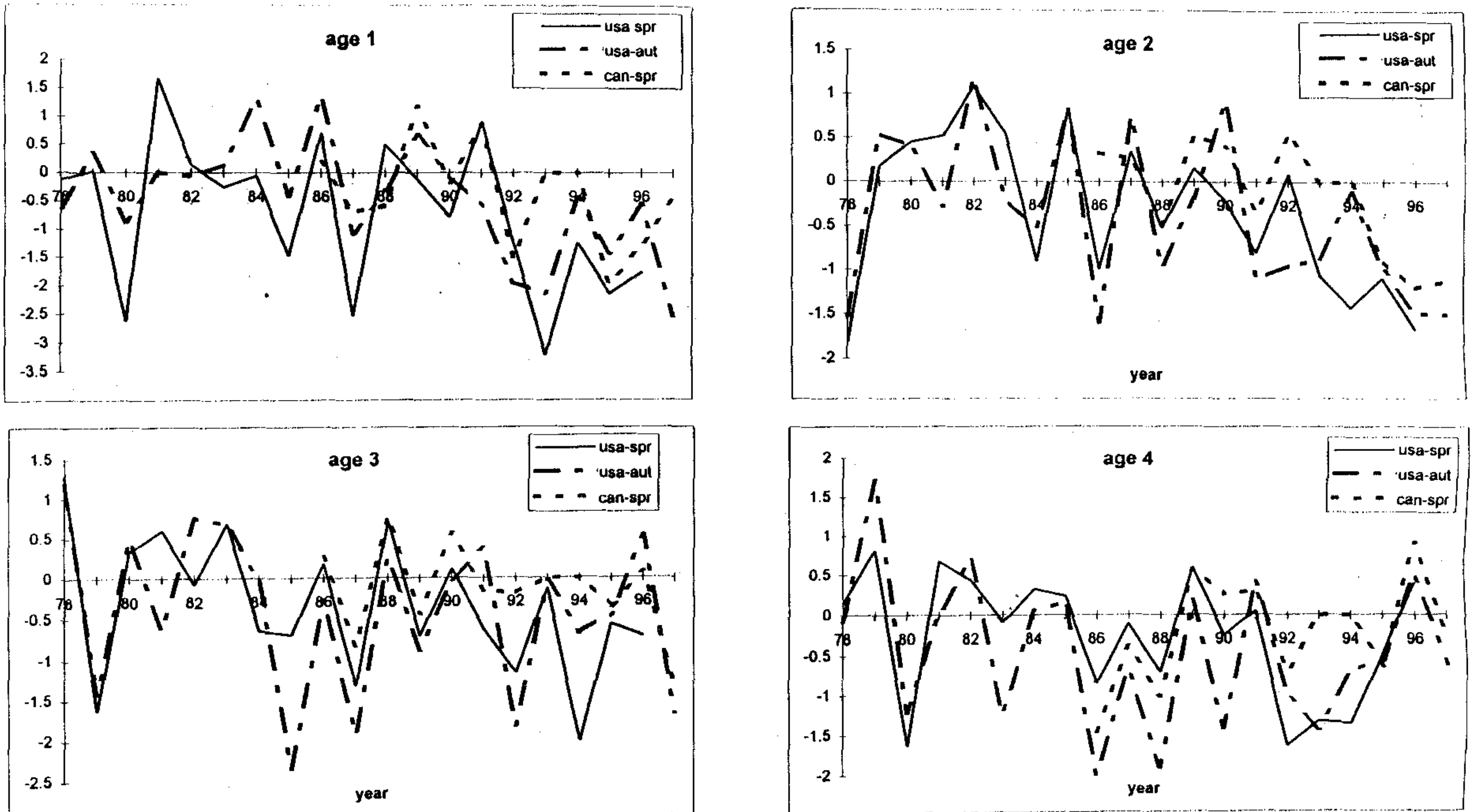


Figure B8. Natural log of the observed survey indices, standardized to the mean, for the USA spring and autumn survey and the Canadian spring survey.

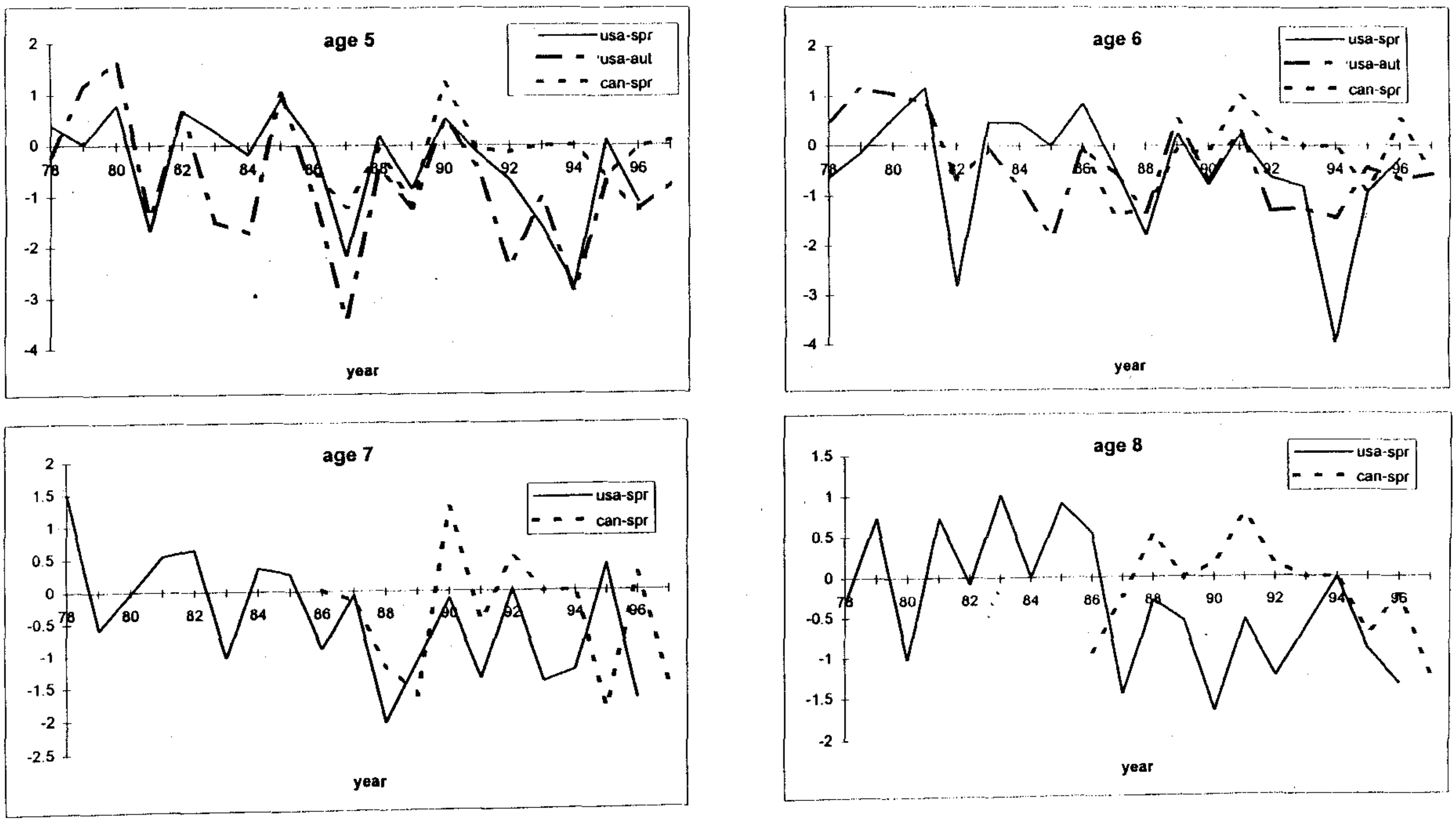


Figure B8 continued. Natural log of the observed survey indices, standardized to the mean, for the USA spring and autumn survey and the Canadian spring survey

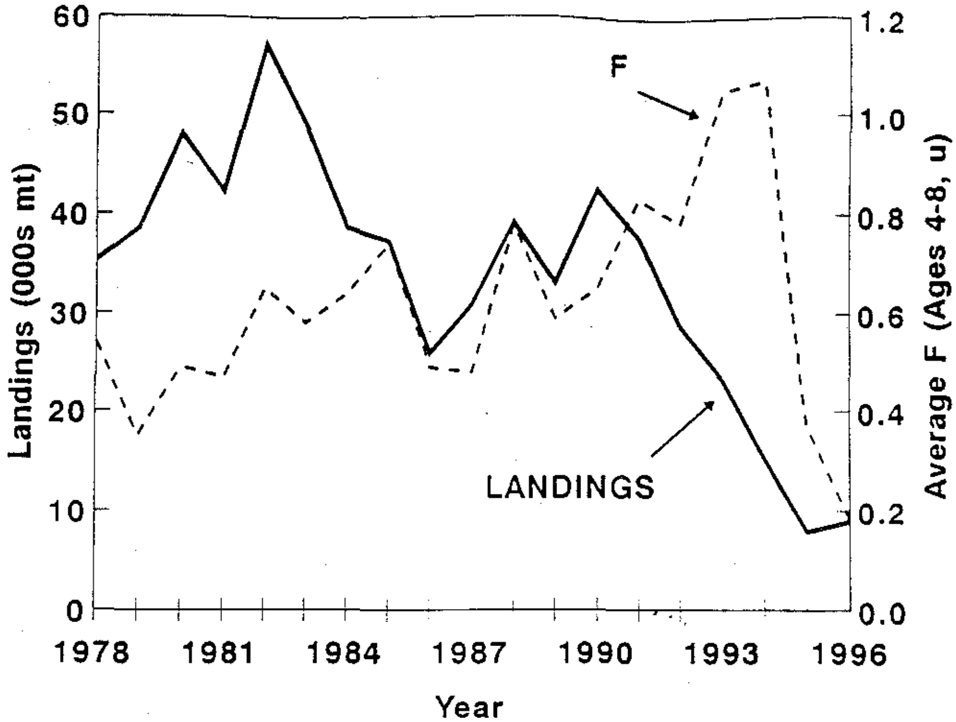


Figure B9. Trends in total commercial landings and fishing mortality for Georges Bank cod, 1978-1996.

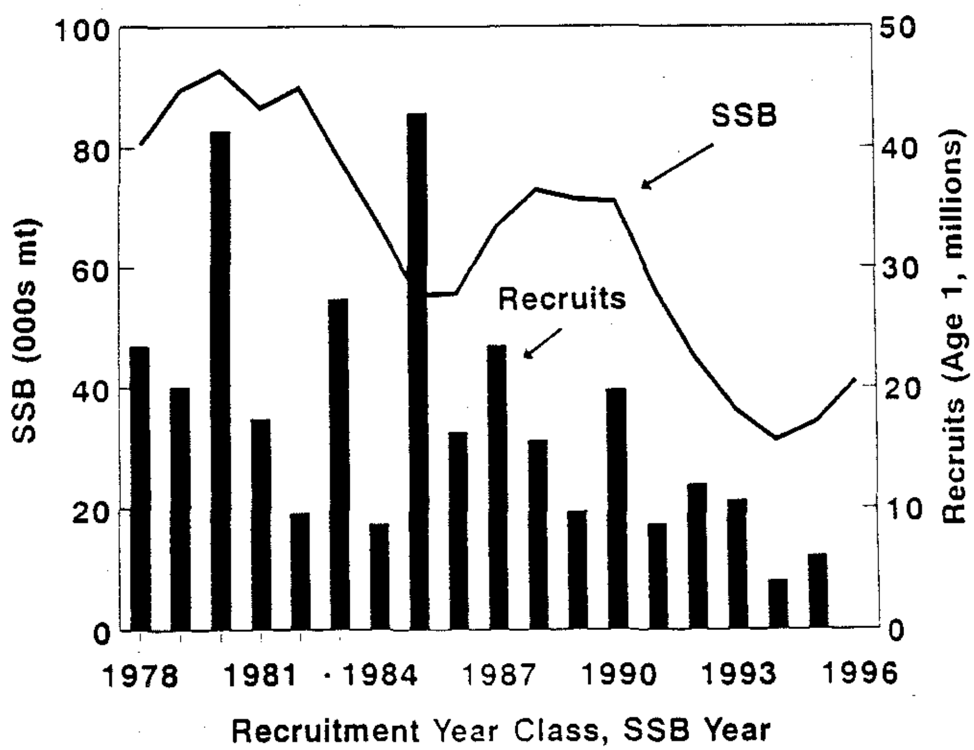


Figure B10. Trends in spawning stock biomass and recruitment for Georges Bank cod, 1978-1996.

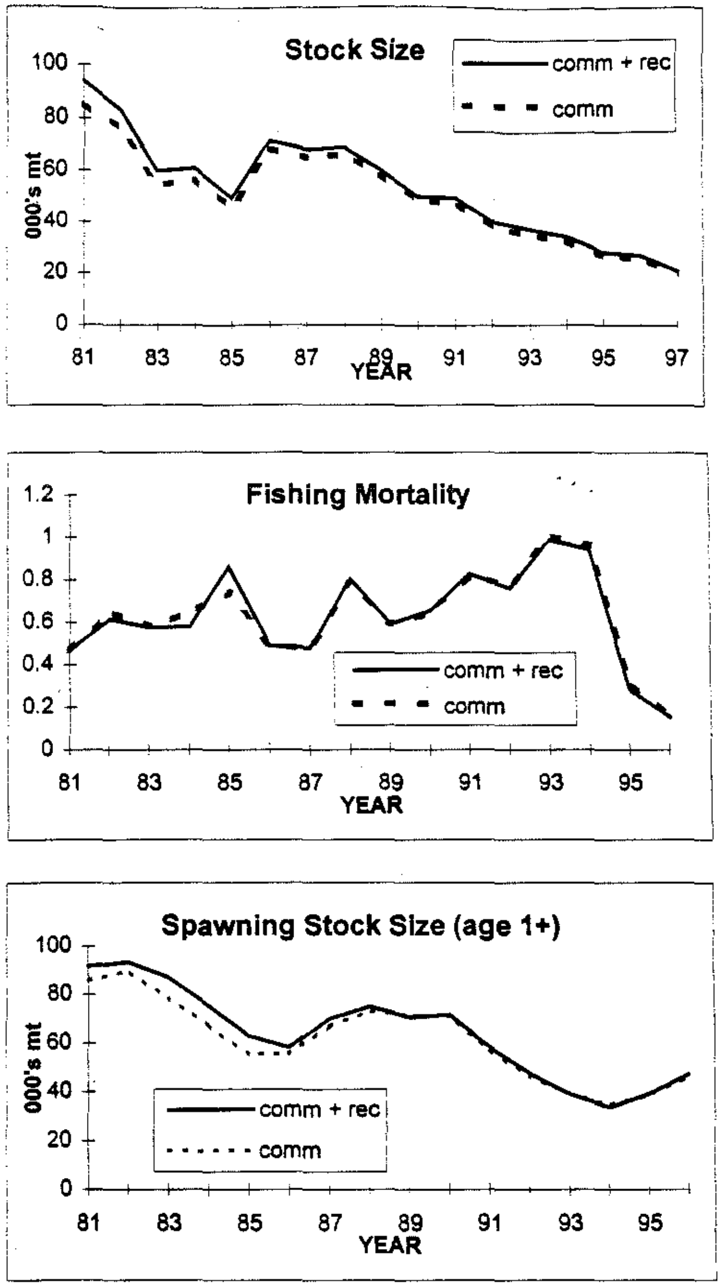


Figure B11. Estimates of stock size at age 1, fishing mortality and spawning stock stock size (age 1+) for ADAPT runs with commercial plus recreational catch at age (Run 24) and a commercial only catch at age (Run 28

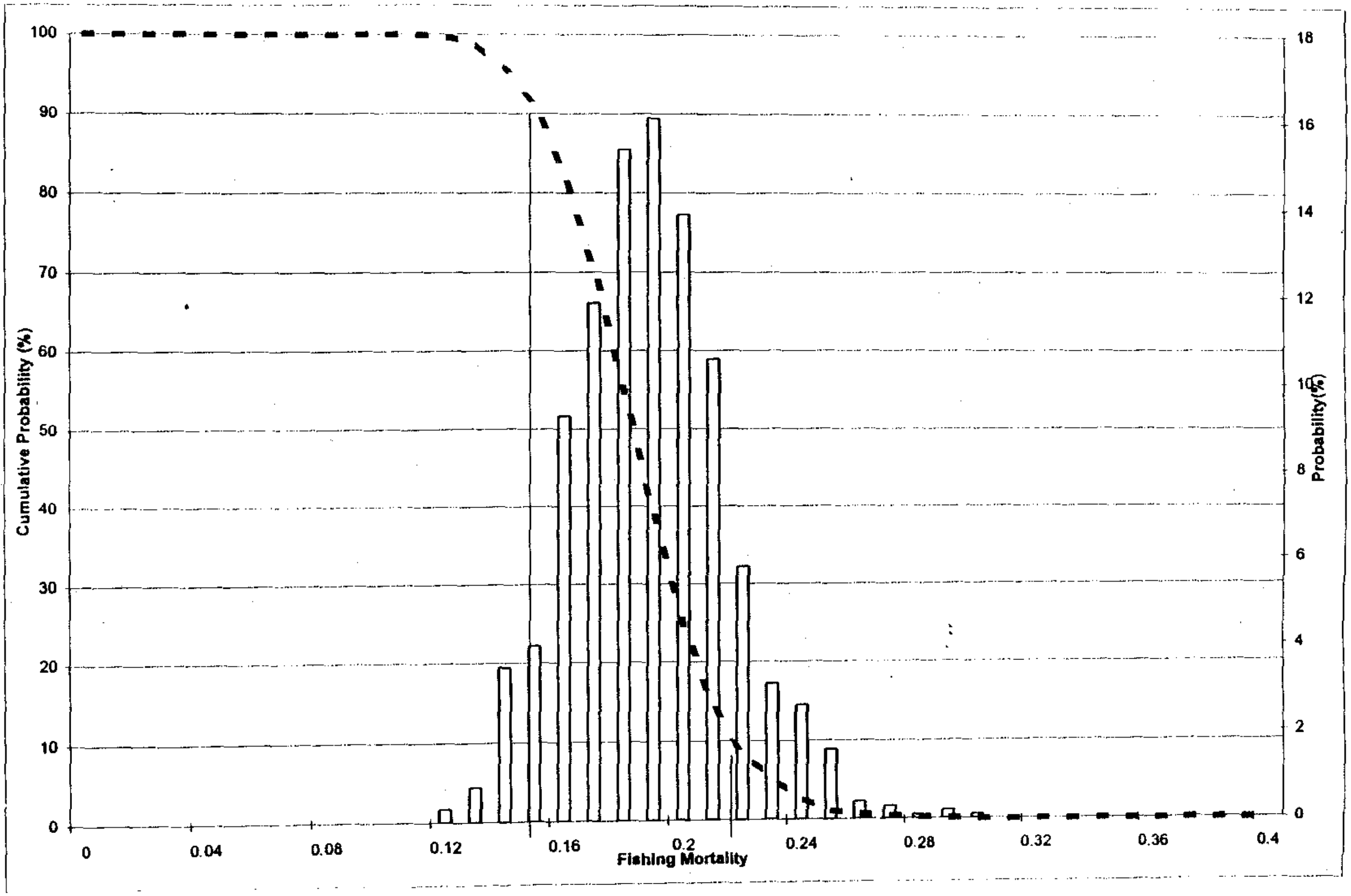


Figure B12 Precision of the estimates of the instantaneous rate of fishing (F) on the fully recruited (ages 4+) in 1996 for Georges Bank cod. The bar height indicates the probability of values within that range. The dashed line give the probability that F is greater than any selected value on the X-axis.

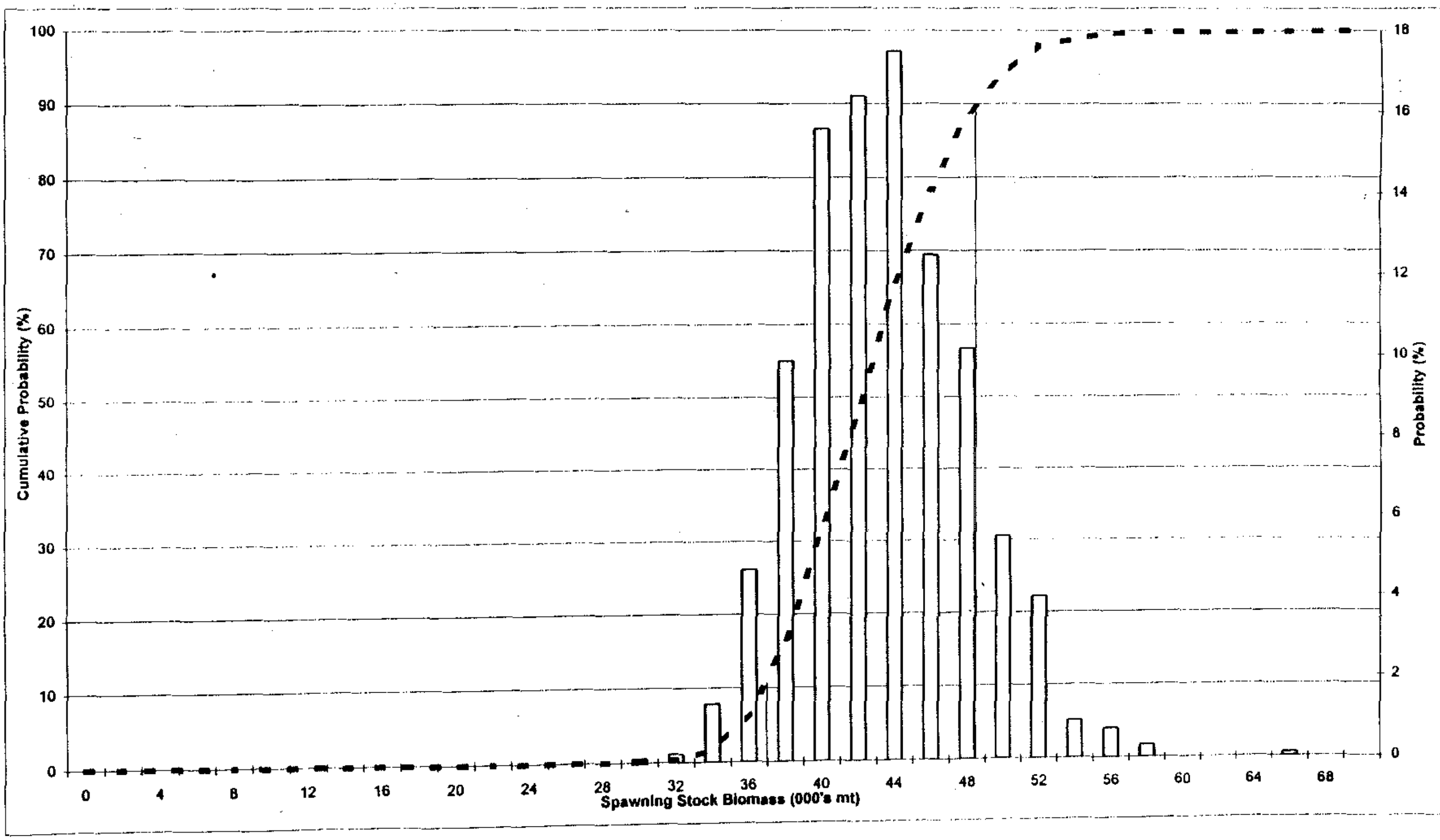


Figure B13. Precision of the estimates of spawning stock biomass (SSB) at the beginning of the spawning season for Georges Bank cod, 1996. The bar height indicates the probability of values within that range. The dashed line give the probability that SSB is less than any selected value on the X-axis.

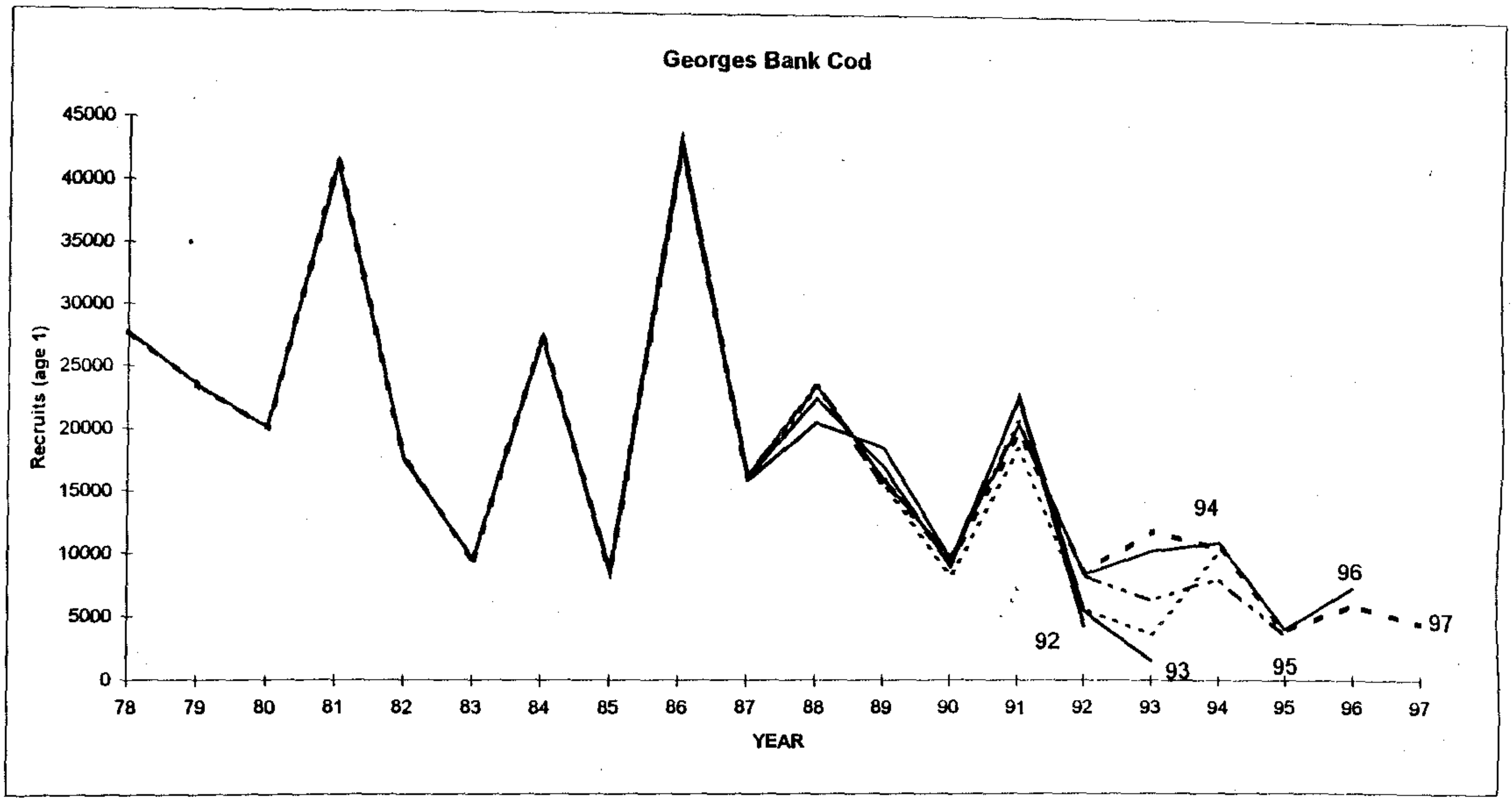


Figure B14. Retrospective analysis of Georges Bank cod VPA based on the final ADAPT formulation for recruits at age 1, 1996-1990

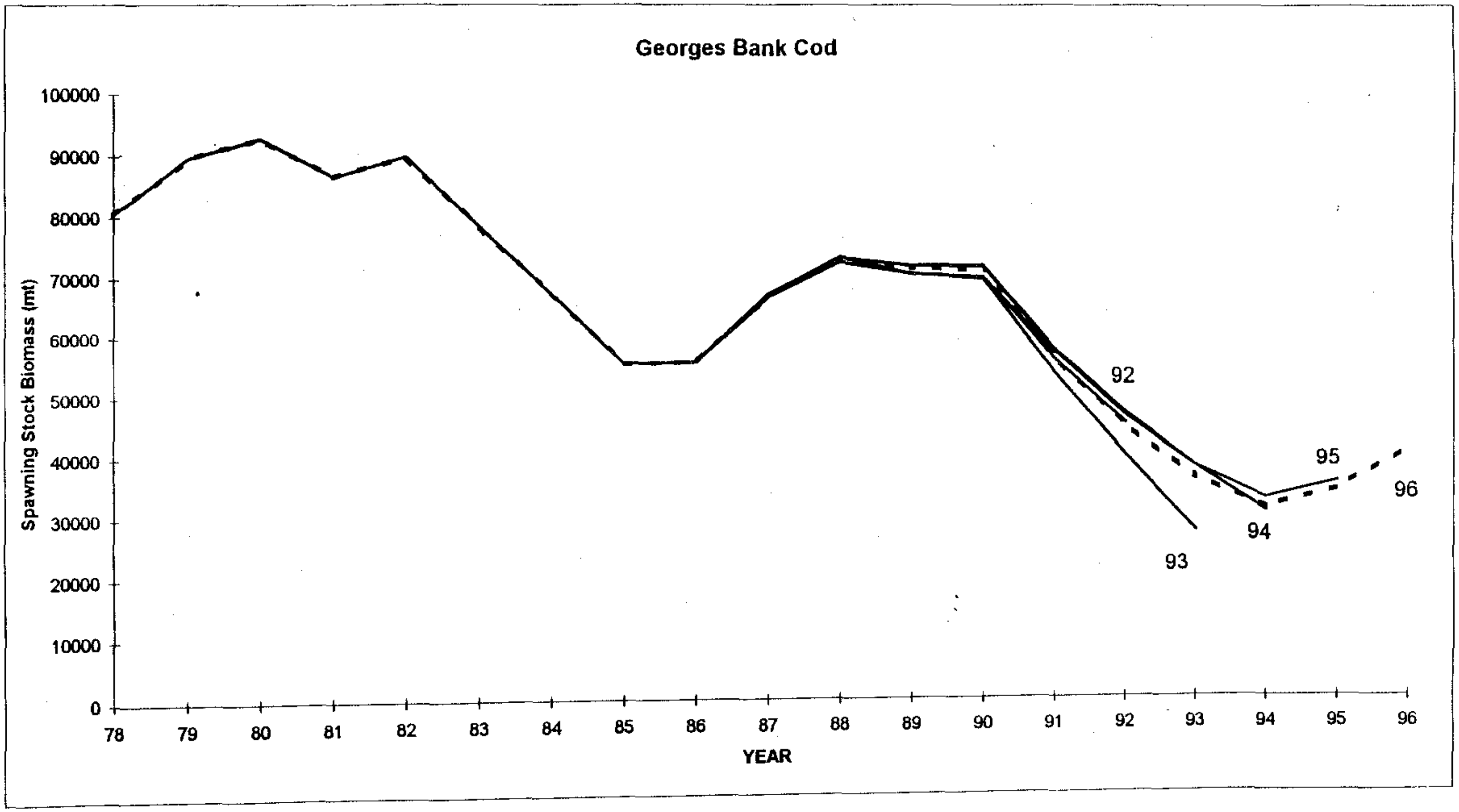


Figure B15. Retrospective analysis of Georges Bank cod VPA based on the final ADAPT formulation for spawning stock biomass, 1996-1990

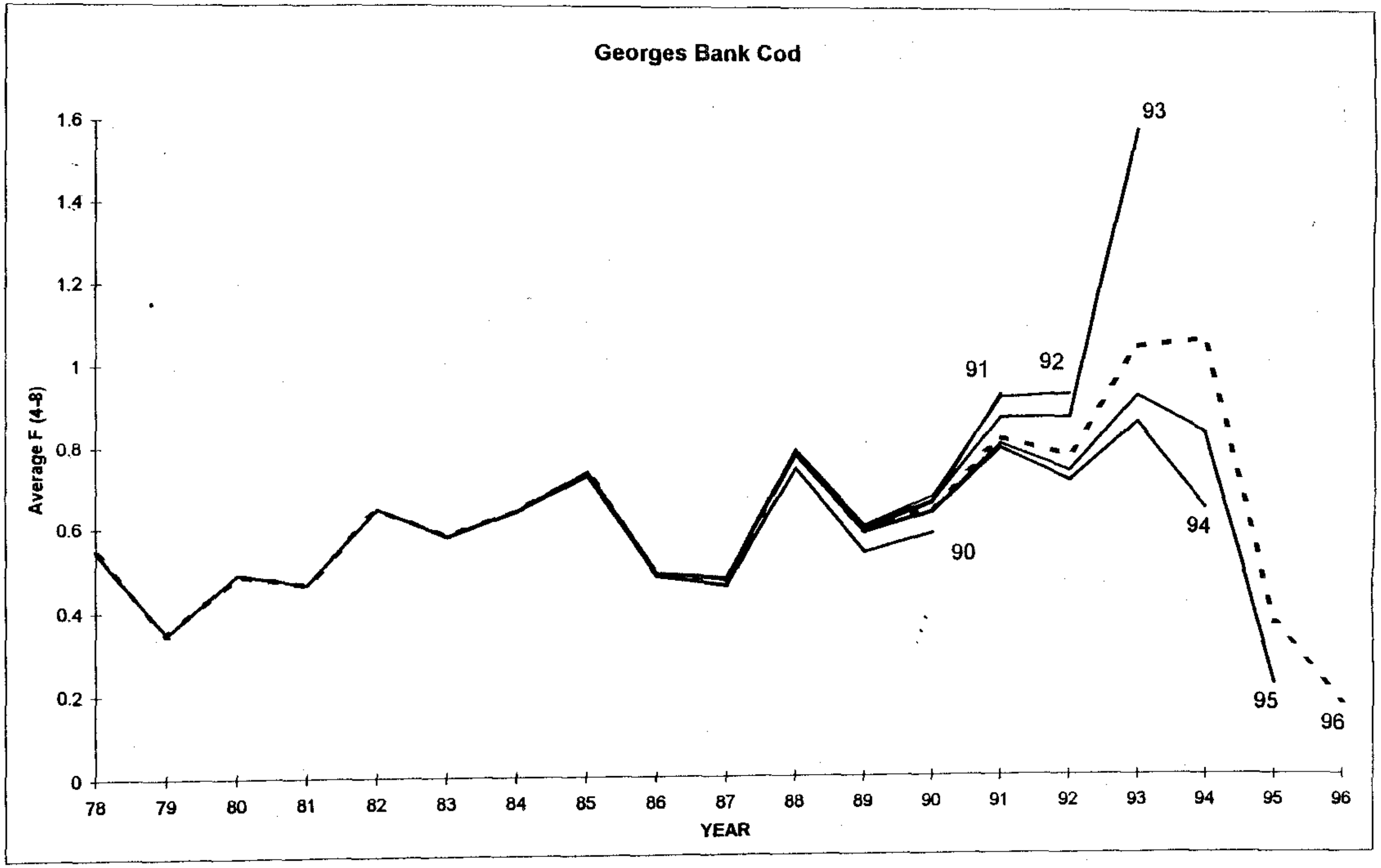


Figure B16. Retrospective analysis of Georges Bank cod VPA based on the final ADAPT formulation for fishing mortality (average F, ages 4-8, unweighted), 1996-1990.

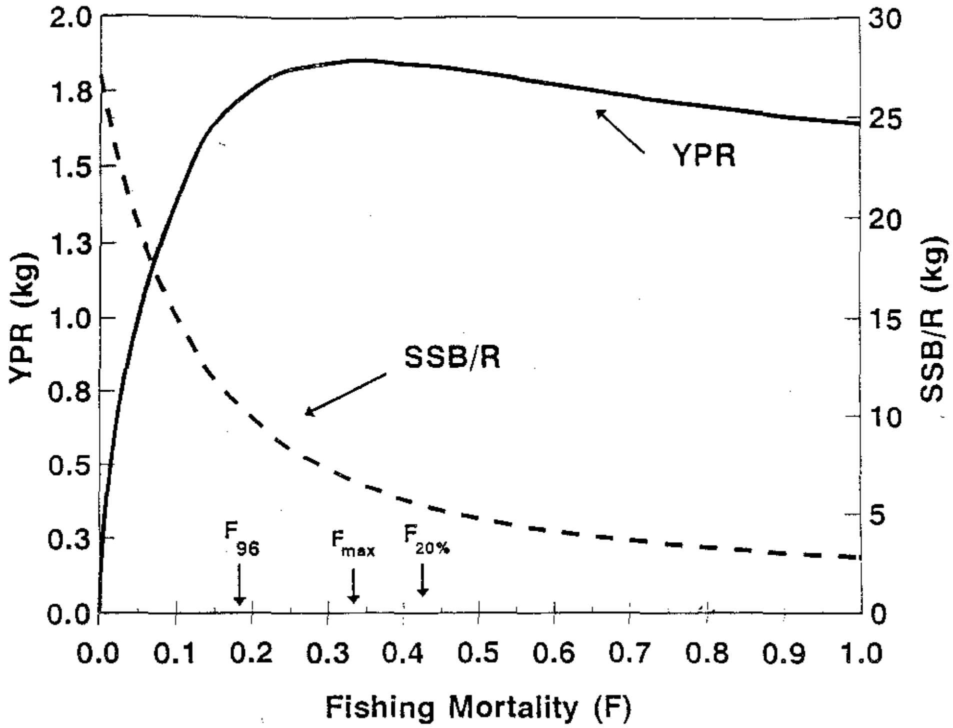


Figure B17. Yield per recruit (YPR) and spawning stock per recruit (SSB / R) for Georges Bank cod.

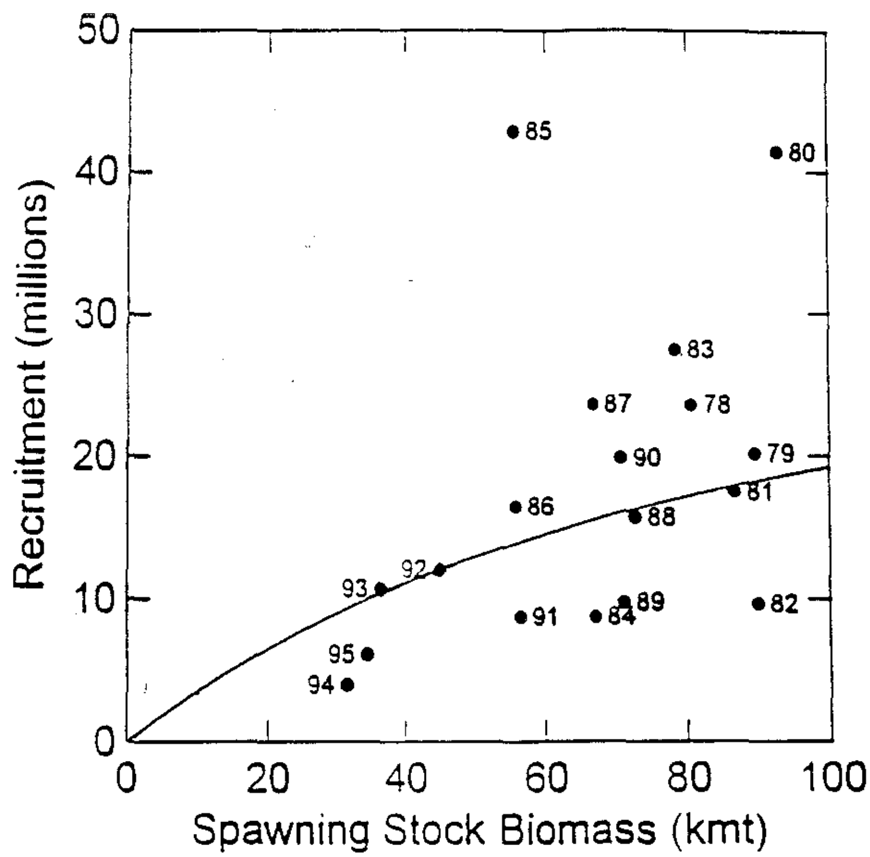


Figure B18. Spawning stock biomass (age 1+, thousands mt) - recruitment (age 1, millions) information for Georges Bank cod. Data are from the final ADAPT run for the 1997 assessment. A plot of the fitted Beverton-Holt s/r relationship is given (R=[37745.13·SSB÷95826.72+SSB]).

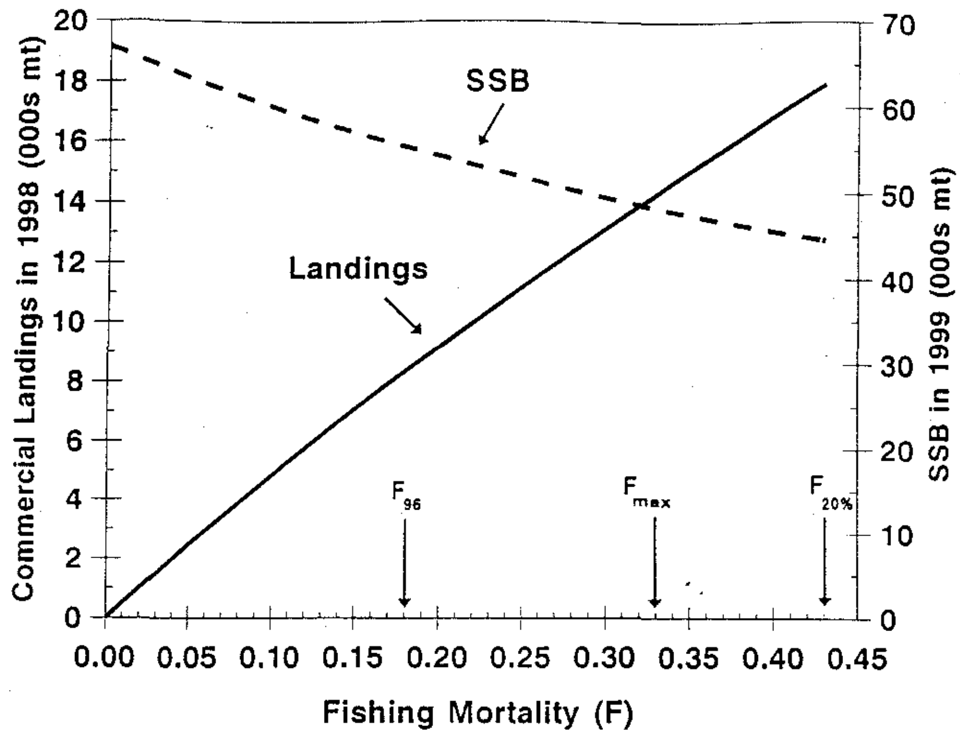


Figure B19. Predicted landings in 1998 and spawning stock biomasss in 1999 of Georges Bank cod over a range of fishing mortalities in 1998 from F=0 to F=0.36.

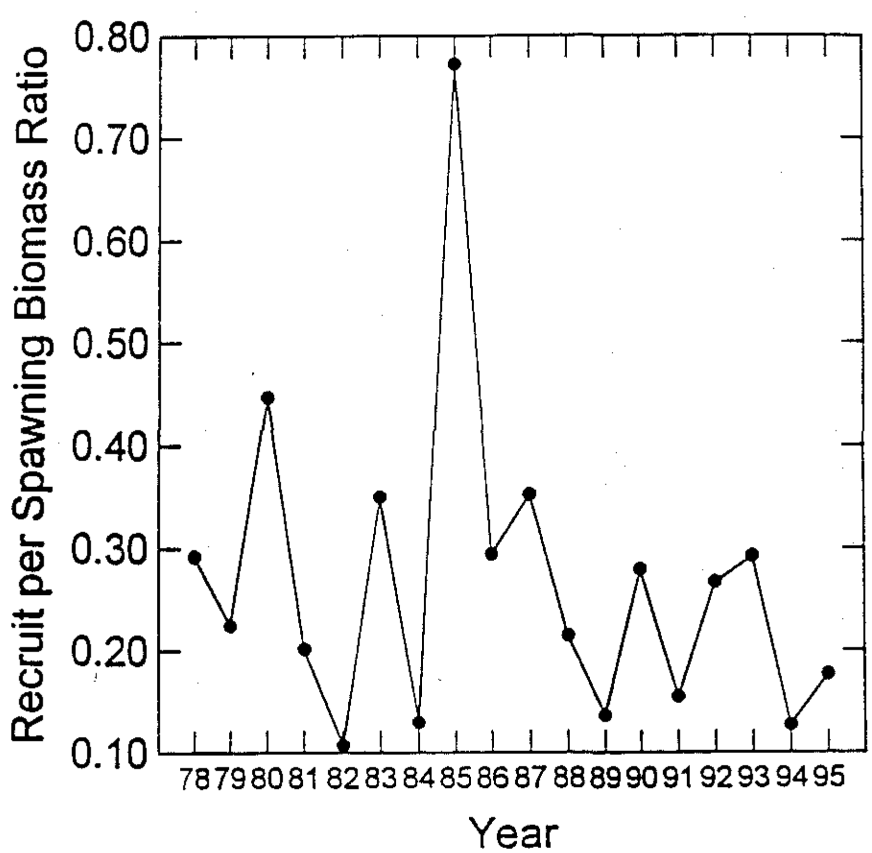


Figure B20. Calculated numbers of age 1 recruits per kilogram of spawning stock biomass for Georges Bank cod. The median R/SSB ratio for the entire time series is 0.246, and for the last 5 years is 0.177.

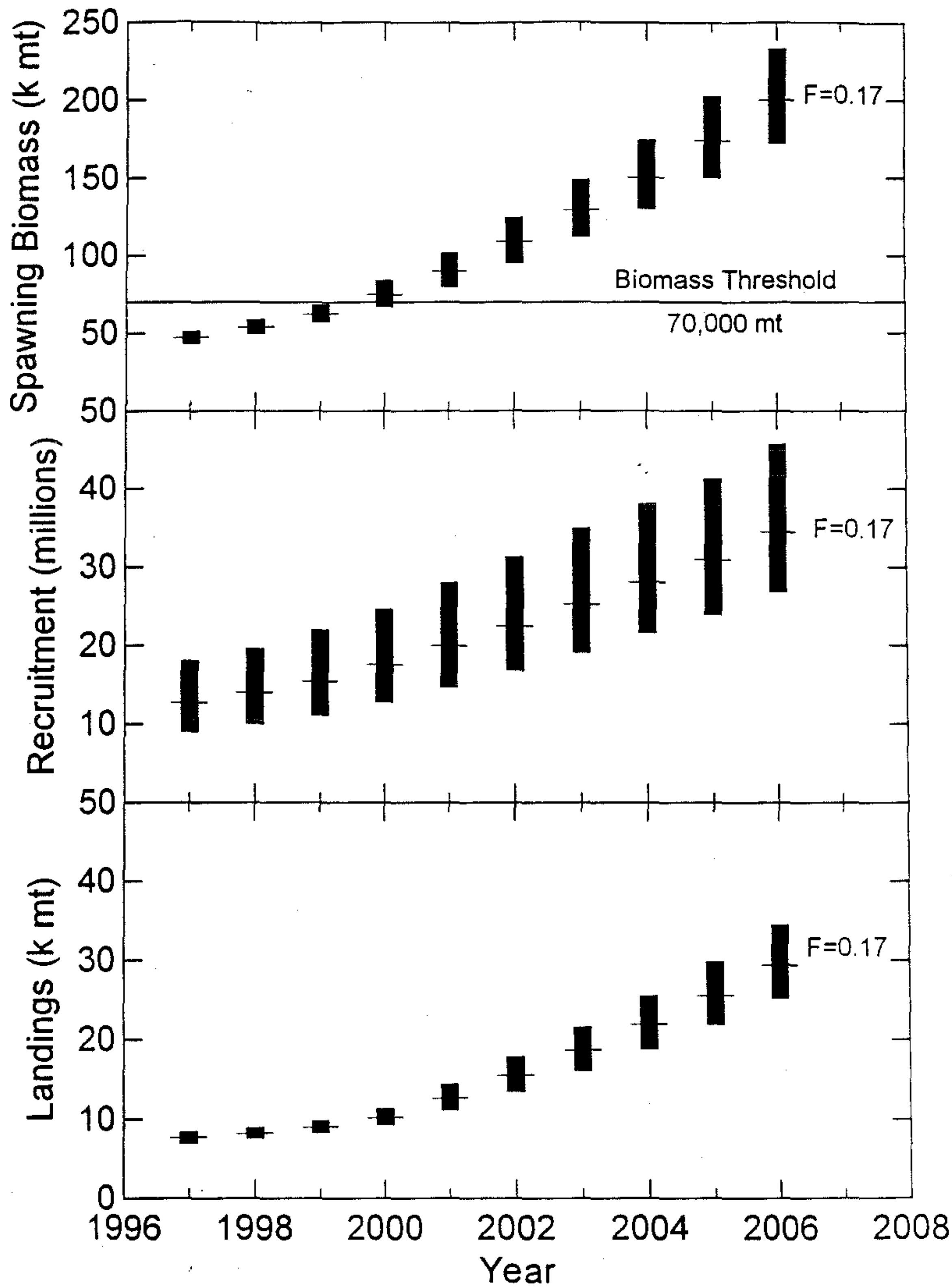


Figure B21. Results of medium-term projections for Georges Bank cod, under a fishing mortality rate scenario of F=0.17. Annual spawning stock biomass, recruitment, and landings data are given. Horizontal bars are the median values from bootstrap results, vertical bars are the inter-quartile range (lower 25th percentile to the upper 75th percentile).

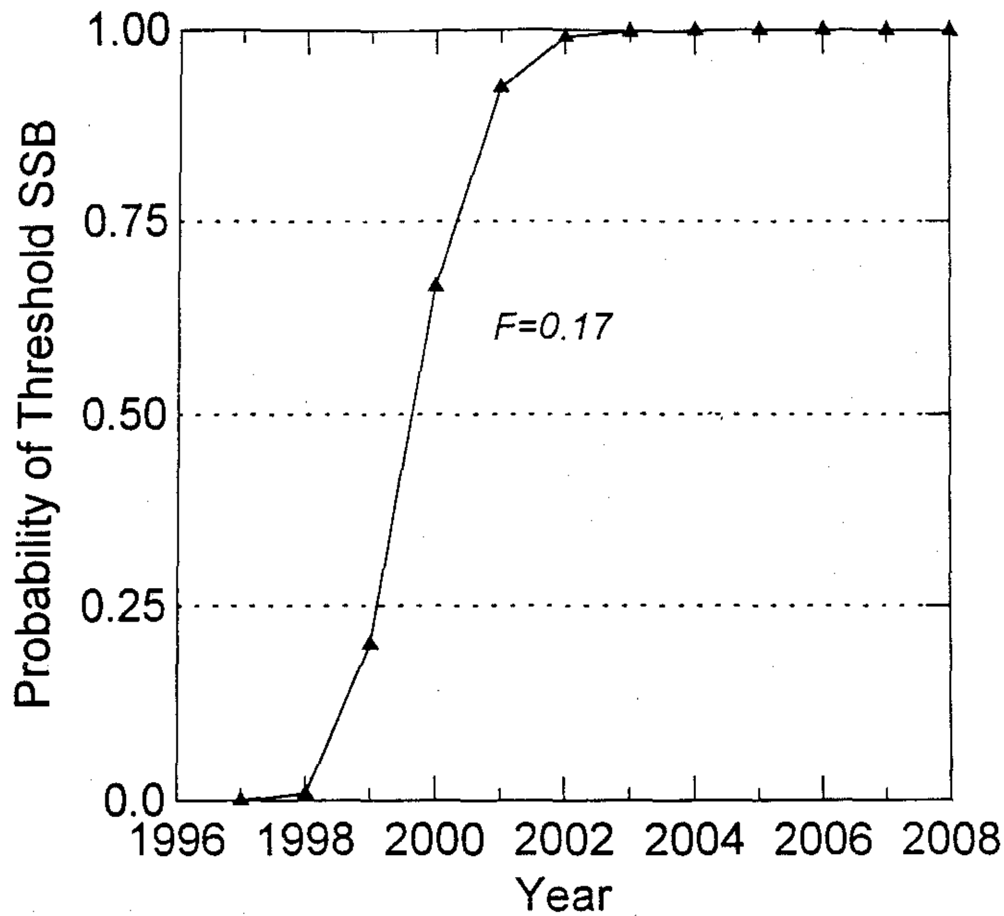


Figure B22. Annual probabilities of Georges Bank cod spawning biomass at or above 70,000 mt. Results are from medium-term stochastic projections.

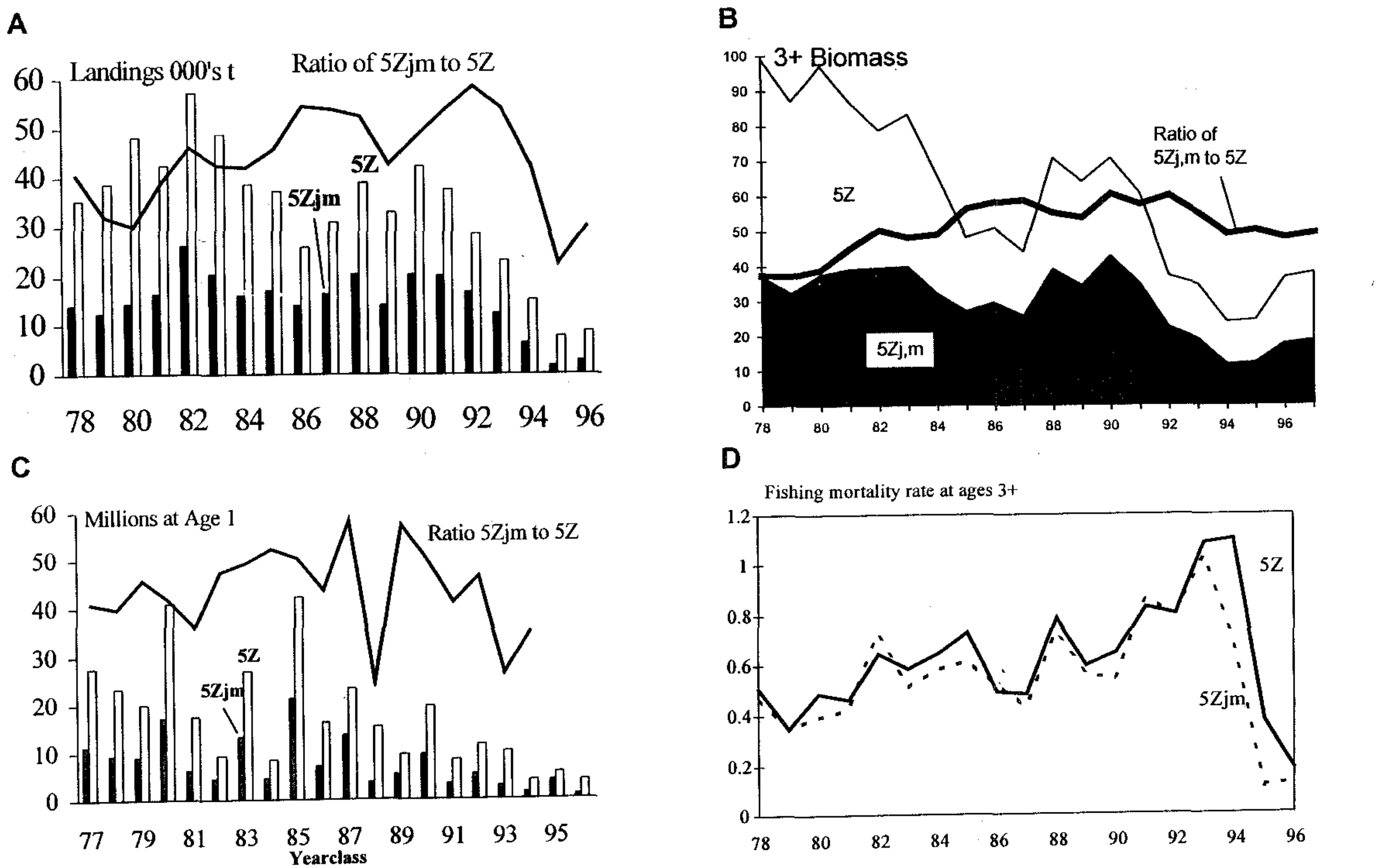


Figure B23. Comparison of total landings (panel a), biomass (panel b), recuitment at age 1 (panel c), and fishing mortality (panel d) estimated by the USA (5Z) and Canadian (5Zjm) assessments of Georges Bank cod.

C. GEORGES BANK HADDOCK

Terms of Reference

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

b. Provide projected estimates of catch for 1997-1998 and SSB for 1998-1999 at various levels of F, including all relevant biological reference points.

c. Advise on the assessment and management implications of incorporating commercial discard data in the assessment.

Introduction

Haddock (*Melanogrammus aeglefinus*) resources within US waters are assessed and managed as two separate stocks, one on Georges Bank and south, and a second in the Gulf of Maine (Figure C1). These stock definitions are based on tagging studies, meristic data, age composition, and growth data (see Clark *et al.* 1982). Haddock landed from NAFO Division 5Z and Subarea 6 comprise the Georges Bank stock (Figure C1), 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 resources on the Northeast Peak of Georges Bank. The Canadian assessment covers a subset of the US Georges Bank assessment area, including NAFO area 5Zj,m, which roughly corresponds to US Statistical Areas 551, 552, 561, and 562 (Figure C1).

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 from 1935 to 1960 (Clark *et al.* 1982; Figure C2). 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 exceptionally large 1963 year class, resulting in yields in excess of 100,000 mt in 1965 and 1966 (Figure C2). By 1969, landings declined well below the 1935-1960 average landings, and continued to decline throughout the mid-1970s (Figure C2). During the late 1970s and early 1980s, large 1975 and 1978 year classes resulted in a temporary increase in landings. Since 1980, landings declined steadily from 27,000 mt to approximately 4,500 mt in 1989. With restrictive management measures implemented during the 1990s (Table C1), commercial landings reached a record-low level of 2,300 mt in 1995, and rose slightly to approximately 4,000 mt in 1996 (Table C2).

Haddock are currently managed under the Northeast Multispecies Fishery Management Plan (FMP) administered by the New England Fishery Management Council (NEFMC). Commercial landings are the most significant form of fishery removals from this stock. Significant levels of regulatory discarding have been produced by management regulations (minimum size and trip limits) during several years analyzed for this assessment. Recreational landings are generally insignificant relative to commercial landings and discards.

Management regulations have attempted to address the decline of Georges Bank haddock resources since the early 1970s (Table C1). 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 authorities resulting in significant changes in the haddock resource and fisheries. The US Department of Commerce (DOC) closed two large areas on Georges Bank on a year-round basis in December 1994, and these areas remained closed to fishing through 1996. The Canadian Department of Fisheries and Oceans currently closes the Canadian waters of Georges Bank to directed groundfishing 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 limit to discourage targeting of haddock by the commercial fishery. This trip limit was raised to 1,000 lb in July 1996. 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. These management measures have resulted in a decline in total fishery removals and fishing mortality on the stock.

The Fishery

Commercial Landings

Significant changes were made in the methodology employed to collect and process US commercial fishery data in the Northeast Region. Before 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 via personal interviews of fishing captains conducted by port agents in the major ports in the Northeast Region. Information obtained during these interviews was used to augment the total catch information obtained from the dealer and assign landings and fishing effort to specific areas.

Beginning in May 1994, the previous interview system was replaced by a mandatory reporting system in which both dealers and operators were required to submit reports when fishing for or purchasing fish species in a regulated fishery (Power *et al.*, 1997). Information on fishing effort and catch location was no longer obtained from personal interviews of fishing captains. Instead, operators reported measures of catch including landings and discard, effort, and catch locations in logbooks that were submitted to NMFS under mandatory reporting regulations. 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 calendar quarter, port group, and gear group to form a pool of observations from which prorations 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 total catch by stock, market category, calendar quarter, port group, and gear group in the full dealer database. For haddock, stock area designations used were eastern Georges Bank (Statistical Areas 561 and 562), western Georges Bank (Areas 521, 522, 525, 526, 533, 534, 537, 538, 539, 541, 542, 543, and areas south), and Gulf of Maine (Areas 464, 465, 511-515). A full description of the proration methodology and an evaluation of the 1994 to 1996 vessel trip report (VTR) data is given in Wigley *et al.* (1997) and DeLong *et al.* (1997).

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 C3). Landings by US trawlers declined since 1992 as a result of restrictive management measures, but trawl gear still accounted for two-thirds of the landings in 1996. US haddock landings declined from 659 mt in 1993 to 218 mt in 1994, remained stable in 1995, and increased to 313 mt in 1996 (Table C2). Since 1994, the US fleet has accounted for approximately 8% of the commercial landings from the Georges Bank haddock stock.

Commercial landings of haddock by the Canadian fleet were also dominated by trawl gear, although longline landings are relatively more important in the Canadian fishery than in the US fishery. Landings shares in the Canadian fishery remain relatively constant between gears recently because quota allocations have remained stable by gear sector. The number of vessels participating in the Canadian Georges Bank fishery and the number of trips made have declined since 1992 (Gavaris and Van Eeckhaute 1997).

Increased at-sea monitoring and mandatory dockside monitoring of landings has resulted in relatively precise data on Canadian fishery effort and landings. Since 1994, the Canadian fleet has accounted for approximately 92% of commercial landings from the Georges Bank stock.

Commercial Discards

Through most of the assessment time period, 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) suggest 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 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, and 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.

Beginning in 1994, trip limit regulations for haddock were implemented under the US Northeast Multispecies Fishery Management Plan (Table C1). In January 1994, a 500-lb haddock trip limit was implemented for commercial fishing trips in US waters. Because haddock are often caught with other species, the regulation resulted in significant levels of discard. Four sources of information indicated that haddock discard increased following implementation of the trip limit: 1) operator reported discarding in vessel trip reports, 2) discard estimates collected by observers through the sea sampling program, 3) US Coast Guard observations during enforcement boardings summarized at the request of the NEFMC, and 4) oral testimony by fishery operators at public fishery-related meetings.

Based on an analysis of these data, discarding appears to have peaked in 1994 and declined substantially in 1995. Evidence of discarding from both the sea sampling and VTR databases was spatially and temporally concentrated. Large estimates of discarding were reported from the Great South Channel area (Statistical Areas 521 and 522) during April, May, June, and July of 1994. In the decade prior to 1994, this area was closed during this period to provide a seasonal spawning closure for haddock. The area was open to fishing during the 1994 spawning season exposing high concentrations of haddock to the fishery just after implementation of the restrictive trip limit. A second and more significant discarding event occurred during May-August 1994 in Statistical Areas 561 and 562 (Northeast Peak area). High catch rates for haddock occurred in this area due to interactions between the commercial fishery and dense concentrations of spawning haddock. A significant portion of the two statistical areas was closed to fishing during January-June 1994 to protect spawning haddock. In the five years before 1994, the opening of this area had resulted in an intensified level of fishing effort producing some of the highest catch rates of cod and haddock annually. This intensified fishery also occurred in 1994. However, due to the 500-lb trip limit in effect at the time, large quantities of haddock were discarded as operators fished through schools of haddock to retain cod and other species. Discard ratio estimates from this period ranged from 4.424 discarded/kept lb (2nd quarter from the VTR database, N = 39 trips) to 35.324 lb discarded/kept pounds (2nd quarter from the sea sampling database, N = 4 trips). Individual trips discarding 5,000-25,000 lb of haddock were common in both databases. The spatial and temporal pattern of high discard trips in 1994 was consistent with the pattern of trips with high landings occurring during 1991-1993 before trip-limit regulations were established.

In December 1994, two large areas (Closed Areas I and II; see Figure C1) of Georges Bank corresponding approximately to previous seasonal haddock spawning closures were closed on a year-round basis to conserve groundfish stocks on Georges Bank. These areas encompassed both of the regions where high levels of discarding were reported in 1994. Discard reporting and resulting estimates declined substantially in 1995.

Based on vessel trip reports (Figure C3) and Coast Guard boarding reports, trip-limit discarding has been limited to a small proportion of the total groundfish trips occurring since implementation of the regulation. Most Georges Bank groundfish trips either failed to catch haddock or had catches that were well below the trip-limit thresholds. However, the small percentage of trips that had catches exceeding the trip-limit thresholds generated large amounts of discard (up to 50 times their retained landings). In 1994, operators reported haddock discards that exceeded haddock landings in vessel trip reports, even though discards are less consistently reported than landings in these logbooks. The low frequency and unpredictability of trips with large haddock catches make it difficult to design an adequate sampling program to estimate this type of discard. The current sea sampling program was not designed to estimate this "pulse" type of discarding and will likely perform poorly if used to estimate "pulse" discarding generated by trip-limit regulations in the future.

Although three sources of quantitative discard information were available for estimating discards, only the VTR database was adequate for generating discard estimates. The sea sampling database, although inherently more reliable as a data source due to data collection by trained and independent observers, did not have adequate sample sizes to produce reliable estimates of discard (Table C4). Data collected by the US Coast Guard during routine boardings was also insufficient due to sample size and the fact that sampled trips were still in progress.

Discard estimates were generated by calculating a discard ratio (discarded weight vs kept weight) from groundfish trips occurring on Georges Bank and from the reported VTR database. In using the VTR data, two important features of the data source were recognized. First, vessel trip reports represent a subset of all groundfish trips and landings because not all operators in the fishery submit required logbooks. For haddock, logbook landings represented approximately 75-87% of the dealer reported landings during the first three years of the mandatory reporting program (Wigley *et al.* 1997). Second, estimates of discards in the logbooks are a subset of the total discards because some operators fail to submit logbooks, while others who do submit them fail to report discards. To estimate discard ratios, a subset of logbook records was used that reported at least 1 lb of discards for any species being reported as caught on the trip (DeLong *et al.* 1997). It was considered highly unlikely that a groundfish trip could operate on Georges Bank for any period of time without generating some form of discard (skates, dogfish, etc). Thus, the subset used to calculate discard ratios included 1) trips reporting only kept haddock, but reporting discard for some other species, 2) trips reporting discarded, but no landed haddock, and 3) trips reporting a combination of kept and discarded haddock.

Initially, VTR data were stratified annually (three years), by calendar quarter (four quarters), by area [eastern Georges Bank (561 and 562), and western Georges Bank (521, 522, 525, 526, 537, 538, 539)], and by principal gears (trawls, longline, and gillnet). Both longlines and gillnets had relatively low levels of discards, and discard ratios were relatively constant seasonally. Therefore, constant discard ratios were calculated annually for all quarters. Discarding by trawls was significantly higher than by longlines or gillnets and varied across both areas and seasons. Discard ratios for trawls were estimated by year, quarter, and area, except that data were pooled to half-years in 1995 and 1996 for eastern Georges Bank, when both effort and available data were limited (Table C5). Discard ratios were multiplied by the prorated dealer landings by gear, quarter, and area to produce overall estimates of discard.

Fishery regulations governing the Canadian commercial fishery on Georges Bank prohibit discarding of haddock and require that haddock caught be landed and counted against individual quotas. Canadian sea sampling indicates that discarding is insignificant in all sectors of the Canadian fishery.

US and Canadian landings, discards, and total catch are summarized in Table C6. Discarding has been a significant source of fishery removals by the US fishery since 1994. In 1994, discards accounted for 70% of the US fishery-induced mortality. The percentage of fishery-induced mortality accounted for by discarding declined to 36% in 1995, but increased to 51% in 1996. Although discarding has been a significant source of mortality in the US fishery, it represents a minor component of the total fishery removals from the stock. With inclusion of Canadian landings, US discards accounted for 16% of the fishery removals in 1994, 5% in 1995 and 8% in 1996 (Table C6).

After discard-at-length calculations were performed (see later sections for details), it was possible to partition discards into the proportions representing sub-legal fish (assumed discarded due to minimum size-limit regulations or unacceptable market size) and legal-sized fish (assumed discarded due to trip-limit regulations). Since 1994, 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.

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 matrix analyzed in this assessment.

Length Frequency Sampling

Historically, length and age samples of 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 the landings in most years (Figure C4). Sampling and stratification of catch-at-age calculations by market category provide a powerful stratification level, 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 C7). Only 17 haddock samples were collected from Georges Bank landings by the port sampling program during 1994-1996.

Port sampling length frequency samples were augmented by using length samples from the sea sampling program with catch dispositions coded as "kept". Two problems with using sea sample lengths are that there is no associated market category code and many trips fished in both the Georges Bank and Gulf of Maine stock areas. Sea sampled trips with at least 90% of their landings from the Georges Bank area were classified as Georges Bank trips, while those with lower proportions of landings from Georges Bank were not used to augment port sampled data. Sea sampled trips with significant length samples were matched to corresponding dealer records to determine the market category under which the landings from the sampled trip were sold. Samples from trips sold under a single market category were assigned to market category and pooled with length samples collected from port sampling. This approach produced a minimum number of length frequency samples necessary to partition US landings into numbers at length. Sample sizes of port and sea sampled length data are summarized in Table C8.

Discard length samples were obtained from trips sampled by the sea sampling program. Because area and catch disposition are determined on a tow-by-tow basis, length samples collected from trips that fished multiple haddock stock areas could be assigned to a specific stock area. Considering the large length range encompassed by discards and the lack of market category stratification, available length samples were considered marginally adequate to partition discard weight estimates into numbers at age.

Length-Weight Regression Relationships

Prior to this assessment, length-weight regression equations by statistical area, month, and market category from samples collected from the 1940s and 1950s were applied to calculate numbers at length. Because of considerable differences in stock sizes and a potential for morphometric changes in the stock over time, there was a strong likelihood that condition factors of haddock have changed since the 1950s. Use of these relationships also resulted in approximately 20 different equations being applied to the landings data annually. In addition, the size distribution of the scrod market category has shifted significantly with the implementation of higher minimum size limits. These relationships were also problematic because it was unlikely that the equations would accurately estimate the weight of sub-legal discards included in this assessment.

US research vessel 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 during 1992-1996 NEFSC research vessel 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 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 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: Live wt (kg) = 0.0000078767 * length (cm)$^{3.064514}$
$R^2 = 0.993$ N = 1,159

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

Age Sampling and Age-Length Keys

The low levels of length sampling by the port sampling program also resulted in an inadequate number of ages needed to characterize the age composition of both landings and discards. In previous assessments, age data collected from research vessel surveys have been used to augment port sampled age data (Table C9). Previous statistical analyses of these data indicate no significant differences in the age compositions of these two sources (Hayes 1993, Hayes and Buxton 1992, O'Brien and Brown 1996). For 1994-1996, age data were also supplemented using data from both kept and discarded portions of the sea sampling database. Sea sampled ages from discarded fish contained considerable numbers of age determinations at lengths that would normally be retained in the absence of trip limit regulations. A complete accounting of the age data by source applied to the numbers at length for both the landings at age and discard at age estimates are summarized in Table C9. Pooled age-length keys were applied to both landings and discard numbers at length. However, different numbers of ages from difference sources were applied to each type of catch (landings vs. discards) due to differences in the lengths represented in each catch type (see Table C9 for details).

Catch at Age

Prorated US landings were estimated quarterly by market category and division (western Georges, eastern Georges) by Wigley *et al.* (1997). Although catch-at-age calculations have applied length and age samples separately by quarter, market category, and division, inadequate sampling of US landings and discards precluded this level of analysis. Length samples and age-length keys were pooled and applied for both divisions (eastern and western Georges combined) and half-years (quarters 1-2 and 3-4), as was done in the previous assessment of this stock for the 1991-1993 landings at age (O'Brien and Brown 1996). A similar semi-annual pooling approach was used to estimate discards at age, except that there was no stratification on market category. Catch at age for 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). The US catch-at-age time series for 1982-1996 is summarized in Table C10.

Catch at age for the Canadian fishery for 1994-1996 was reported by Gavaris and Van Eeckhaute (1997). The Canadian catch at age was computed following the procedures outlined in Quinn *et al.* (1983). The Canadian catch-at-age time series for 1982-1996 is summarized in Table C11.

The total catch at age for the Georges Bank stock, including catches from all countries, for 1963-1996 is summarized in Table C12. 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 1982-1996 has been dominated by the 1978, 1983, 1985, 1987, and 1992 year classes (Table C12).

Mean Weights at Age

Mean lengths and weights at age at capture were calculated for the US fishery for 1982-1996 (Table C10). 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). US fishery mean weights at age have increased for the youngest ages in the fishery (ages 2-4) and appear to be consistent with regulated increases in mesh size. Mean weight-at-age data for the Canadian fishery (Table C11) were taken from previous and current assessments (Gavaris and Van Eeckhaute 1997). Mean weights for the total catch at age are summarized in Table C12. Mean weights at age for the total catch at age for 1994-1996 are largely reflective of Canadian mean weights due to the dominance of Canadian landings in the total catch. Mean weights at age for stock biomass computations were calculated following Rivard (1980) and are provided in Table C13.

Stock Abundance and Biomass Indices

US Research Vessel Survey Abundance and Biomass Indices

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 from 1963 to 1996 (Table C14; Figure C5). Survey indices included catch data from stations occupied within NEFSC Offshore Strata 01130-01250 and 01290-01300 and having suitable station, haul, and gear 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 polyvalent doors introduced in 1985 (see **Data and Methodology Issues** section of this report). Table C15 summarizes the factors applied to each survey.

Spring and autumn indices of abundance and biomass exhibit similar trends throughout the time period (Figure C5). 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. The three most recent spring surveys have each been dominated by a single tow that, in each case, has accounted for more than 60% of the total haddock caught in the survey. In the 1995 and 1996 spring surveys, these tows both occurred inside Closed Area I. Aggregation of fish inside this closed area during the spring survey may confound the usefulness of this survey in characterizing the stock abundance of haddock.

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 used as inputs in the stock assessment. The adjusted stratified mean catch/tow (numbers) values are presented in Tables C16 and C17. Age 0 and 1 indices from the fall survey and age 1 indices from the spring survey provide an indication of year-class strength of haddock (Figure C6). The strong 1963, 1975, and 1978 year classes are readily apparent in age 0+ and age 1 indices (Figure C6) and track strongly through the age-disaggregated matrix of survey abundance (Tables C16 and C17).

Canadian Research Vessel Survey Abundance Indices

In 1986, DFO Canada initiated a spring bottom trawl survey on Georges Bank (Table C16). Indices of abundance from this survey for 1986-1997 are summarized in Table C18. Recent strong year classes (1985, 1987, and 1992) are readily noticeable as they progress through the age-disaggregated matrix of Canadian spring survey abundance indices (Table C18). Additional details of this survey are provided in Gavaris and Van Eeckhaute (1997).

Mortality and Maturity

Natural Mortality

As in previous assessments of this stock (O'Brien and Brown 1996, Gavaris and Van Eeckhaute 1996), the natural mortality rate (M) 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 survey catches is consistent with the assumption for natural mortality.

Maturity Ogives

Haddock maturation rates are temporally variable and appear to be related to stock size and year-class strength. Maturation observations are routinely recorded during both the US and Canadian spring surveys. In previous assessments, only US data were used to calculate maturity ogives. Estimates of maturity at age were tenuous because of small sample sizes of observations in the age range (ages 2-3) where the relationship is generally defined (Table C19). Based on a research recommendation from the last Georges Bank haddock assessment (O'Brien and Brown 1996), US and Canadian maturity data were compared. A chi-square analysis indicated no differences between the two data sets when the US survey has a sample size sufficiently large to characterize the maturation pattern. Based on these results, US and Canadian data were pooled and analyzed to produce 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 1996. 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 1995-1996 (Table C20). Table C21 summarizes percent maturity of female haddock at age for the full time period used to calculate 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 at ages 1-9+ and derive age-specific estimates of fishing mortality in 1996 and stock sizes at the beginning of 1997. The catch at age in the VPA consisted of combined US, Canadian, and distant-water-fleet landings during 1963-1996 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 age (ages 1-8) and the US autumn survey catch (numbers) at age (0-8) lagged forward one age and one year.

In the final ADAPT calibration, the coefficients of variation (CV) on ages 1 (0.62) and 2 (0.40) were relatively high, but CVs on older ages ranged from 0.26 to 0.34. Catchability (q) estimates for each index were well estimated for the US indices (CV = 0.15-0.18), but were marginally higher for the Canadian indices (CV = 0.25-0.26) due to the shorter time series. There were no substantial correlations among parameter estimates.

Examination of diagnostic parameters indicated a significant pattern in the standardized residuals which warranted further examination. A strong residual pattern was noted for the US 1996 spring survey, with large positive residuals noted for most age classes (Figure C7). These residual patterns were attributed to a single large tow in the survey which occurred within US Closed Area I in the Great South Channel.

This single tow accounted for more than 70% of all the haddock caught on Georges Bank during the survey and resulted in a 4-fold increase in the age-aggregated survey index. The tow contained multiple age group dominated primarily by fish at ages 2-6 rather than a single age group (Figure C8). Based on concerns about the influence of this single large tow on the assessment results, a sensitivity VPA run was conducted. The input data for this run were identical to the base run except that the US 1996 spring survey indices were recalculated excluding the large tow. Elimination of the tow produced a better residual pattern for the 1996 survey indices and eliminated the large block of positive residuals in the terminal year of the assessment (Figure C9).

Large tows have occurred periodically in the survey time series for Georges Bank haddock. While these tows have a temporary destabilizing effect on assessment results (especially when they occur in the terminal year), additional information from surveys and the catch at age in subsequent years usually dampens the effect of such tows on the long-term assessment results. It was determined that elimination of the single large tow from the 1996 US spring survey would not be a valid or defendable assessment approach. Elimination of all the US spring survey indices from the ADAPT tuning produced unstable assessment results. A base run including all US spring, Canada spring, and US autumn tows was accepted as the final run for the assessment. However, results are presented for the sensitivity run to examine the effects of the large tow in the terminal year of the VPA.

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. Improved recruitment from three strong year classes (1972, 1975, and 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 (Figure C10; Table C22). Stock numbers remained stable during the mid-1980s, but declined to a record low of 15 million fish in 1991. Stock numbers increased again in the early 1990s and appear to have stabilized at about 35-36 million fish. The 1983, 1985, 1987, and 1992 year classes, ranging in size from 14 to 17 million fish at age 1, are the strongest in the recent time period (Table C22) and are about one-third the size of the 1975 year class.

Spawning stock biomass (SSB) was estimated to be about 150,000 mt in the early-to-mid-1960s, but declined sharply to a low of 12,000 mt in 1973 (Figure C11; Table C23). SSB increased with improved recruitment in the 1970s reaching 69,000 mt in 1978, but declined to about 20,000 mt by the mid-1980s. SSB remained stable at this level until it began declining in the early 1990s reaching record-low levels of 11,000 mt in 1993. Since 1993, SSB has increased sharply following recruitment of the 1992 year class.

The relative contribution of the 1992 year class to SSB has been larger than for similar year classes due to reductions in fishing mortality. The 1983, 1985, 1987, and 1992 year classes were estimated to be of similar size (15-17 million fish) at age 1 (Figure C12). However, the 1992 year class has decreased in size at a lower rate than the other three year classes due to reductions in fishing mortality. The size of the 1992 year class at age 5 is 70-120% larger than the other three year classes at that age.

Fishing mortality (F) ranged between 0.32 and 0.61 during the 1960s and 1970s before declining below 0.20 in the mid-1970s (Figure C13; Table C24). F increased in the late 1970s and ranged between 0.32 and 0.45 from 1979 to 1991. In 1992 and 1993, F increased sharply to 0.47, but subsequently decreased and was less than 0.20 in 1995 and 1996.

Comparison of the Base and Sensitivity Runs

Comparisons of assessment results were made between the accepted base run and the sensitivity run to determine the effect of the large tow of haddock in the 1996 US spring survey. Results of the two assessments were generally identical in the converged portion before 1990. Exclusion of the large tow produced a similar pattern in the trajectory of stock size. In both assessments, stock size increased from the early 1990s and stabilized in the 1994-1996 time period

(Figure C14). SSB continued to increase through the terminal year of both assessments due to somatic growth of recruited spawners, dominated primarily by the 1992 year class. The primary difference between the base and sensitivity runs was that the population stabilized at a lower size and produced a lower estimate of SSB in the terminal year (Figure C14). The 1992-1996 year classes were uniformly estimated at larger sizes in the sensitivity run.

Exclusion of the large tow in the sensitivity run had little effect on the estimates of fishing mortality (Figure C14). Fishing mortality was estimated to be 0.18 for the terminal year in the base run, compared to 0.21 in the sensitivity run.

Precision of F and SSB Estimates

Uncertainty and potential bias of estimates were assessed using bootstrap analysis of the VPA calibration. Two hundred bootstrap realizations were produced by randomly re-sampling 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 (21%) and 2 (13%), but were less than 8% for older ages. Estimates of survey qs 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 1996 estimate of SSB is between 27,700 mt and 39,500 mt (Figure C15). There is a 0% chance that SSB has exceeded the minimum threshold level of 80,000 mt. The distribution of bootstrap realizations of fishing mortality suggests that there is an 80% chance that F_{96} was between 0.16 and 0.23 (Figure C15). There is approximately a 9% chance that F_{96} exceeded the management target of $F_{0.1} = 0.24$, as estimated by O'Brien and Brown (1994). A revised estimate of $F_{0.1}$ based on the current partial recruitment pattern and maturity ogives is presented in the **Yield per Recruit** section.

Retrospective Analysis

Retrospective analyses of the Georges Bank haddock VPA were performed from 1996 to 1991. Given the short time period of the tuning indices from the Canadian survey, no analysis was attempted prior to 1991. The ADAPT procedure was formulated to estimated ages 1-8 in the terminal year, and mean fishing mortality was estimated for ages 4-7.

Retrospective patterns for fishing mortality (Figure C16) were similar to those observed in the last assessment (O'Brien and Brown 1996), with fishing mortality consistently overestimated in the terminal year of the assessment. This pattern began to shift in 1994, and by 1995, it appears that fishing mortality was slightly underestimated 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 C16). Consistent with the trend observed for fishing mortality, there was a shift in the retrospective pattern in 1995, with spawning stock biomass slightly overestimated 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 C17). The 1983-1991 year classes tend to produce stable terminal-year estimates due to convergence of the VPA. Patterns for the 1992-1996 cohorts 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 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

50% from 15.8 million fish (1995 terminal year) to less than 8.4 million fish in the 1996 terminal year assessment.

Historical Perspective on Stock Size and Stock- Recruitment Relationships

The current assessment of Georges Bank haddock employs the ADAPT VPA calibration method for the 1963-1996 time series. The time series has been truncated because of the unavailability of survey indices prior to 1963. However, Georges Bank haddock has been a central focus of study at the Woods Hole Laboratory, and a catch at age has been estimated for this stock continuously since 1931 (see Clark *et al.* 1982 for a description of the 1931-1979 time series).

The current assessment of Georges Bank haddock is limited by not covering any time period where the stock produced sustained yields. To provide an historical perspective on relative stock size and stock-recruitment relationships, an untuned VPA was performed using terminal stock sizes from the assessment VPA to initiate calculations. Natural mortality was assumed to be 0.2, and the catch-at-age matrix for 1931-1996 was used to estimate stock numbers at age. Mean weights at age, available from Clark *et al.* (1982) and the current assessment, were used to calculate stock biomass. To estimate spawning stock biomass, a constant maturity ogive was assumed where 50% of age 2, 80% of age 3, and 100% of age 4 and older females were mature.

This analysis indicates that spawning stock biomass was at significantly higher levels historically than has been observed during the current assessment period (Figure C18). During the 1935-1960 time period, SSB ranged between 100,000 and 150,000 mt. However, since the collapse of the stock in the late 1960s, spawning stock biomass has been depressed at levels less than half of the historical levels. In fact, historical average landings exceed both SSB and total biomass estimates for the stock in most years since 1968.

To provide an historical perspective of the recruitment potential of Georges Bank haddock, the relationship between SSB and age 1 recruitment was investigated (Figure C19). For spawning stock biomass levels less than the management rebuilding target of 80,000 mt, only 2 of 25 year classes (1975 and 1978) have exceeded 40 million fish at age 1. For SSB levels greater than the management rebuilding target, only 7 of 37 year classes were smaller than 40 million fish at age 1. Four of these seven weaker year classes were produced immediately following recruitment of the extremely large 1963 year class and during a time when distant water fleets were intensively exploiting the haddock resource. In the current population, the dominate 1992 year class, representing more than half of the current landings and spawning stock biomass, is estimated at 17 million fish at age 1.

Yield per Recruit

A yield-per-recruit analysis (Thompson and Bell 1934) was conducted using the partial recruitment vector estimated from the calibrated VPA. Because of changes in regulatory measures imposed by management agencies since 1994, and since the maturity schedule and mean weights at age have shown strong shifts over time for this stock, averages for these parameters from the 1994-1996 time period were used. Results indicate that $F_{0.1}$ = 0.26 and the overfishing definition defined in the Multispecies FMP ($F_{30\%}$) is 0.45 (Table C25; Figure C24). Estimates of F_{max} are considered to be unreliable because of the asymptotic nature of the yield-per-recruit curve at high F levels.

Projections

Short-Term Projections

Short-term deterministic projections were performed for 1997, 1998, and 1999 assuming that fishing mortality in 1997 remained at the 1996 level of 0.18. Three different scenarios of fishing mortality in 1998 (F_{96} = 0.18, $F_{0.1}$ = 0.26, and $F_{30\%}$ = 0.45) were projected. The projections were based on a partial recruitment vector estimated as the geometric mean of the 1994-1996 Fs at age from the final VPA calibration, 1994-1996 arithmetic mean stock and catch weights, and pooled median maturity-at-age estimates for 1995-1996. Discard proportions at age were estimated as the geometric mean discard proportions from 1995-1996, and discard mean weights at age were estimated as the arithmetic mean discard weights at age for 1994-1996. Age 1 recruitment in 1997 was estimated from the terminal year of the VPA (8.9 million age 1 recruits) and recruitment in 1998 was estimated as the median of observed age 1 recruitment from the 1979-1996 year classes.

Projection results indicate that under the F_{96} = 0.18 scenario, SSB will increase to 39,800 mt in 1998 and increase slightly (+6%) in 1999 (Figure C25). Catches (US and Canadian landings and discards) are projected to rise to 5,800 mt in 1998 (+7%). If fishing mortality were increased to $F_{0.1}$ = 0.26, SSB is projected to increase to 39,200 mt in 1998 and decline slightly (-1%) to 38,000 mt in 1999 (Figure C25). Catches (US and Canadian landings and discards) would increase by 49% to 8,100 mt in 1998.

If fishing mortality were increased to $F_{30\%}$ = 0.45, SSB is projected to increase to 37,700 mt in 1998 and then decline significantly (-15%) to 32,600 mt in 1999 (Figure C25). Catches (US and Canadian landings and discards) would increase sharply (+240%) to 13,100 mt in 1998. Fishing at $F_{30\%}$ = 0.45 is clearly inconsistent with rebuilding objectives.

Medium-Term Projections

The methodology for conducting medium-term (e.g., 10-year) projections is described in the **Data and Methodology Issues** section of this report. These analyses used the stock-recruitment relationship fitted to data for 1968-1995. The data and the fitted Beverton-Holt equation are presented in Figure C26. Exploratory analyses were also performed with the full time series (1931-1995) since the latter includes more data obtained when the stock was producing significantly higher recruitment and spawning stock biomass was, on average, much larger than in the 1968-1995 period. The full time series is problematic for fitting to a parametric stock-recruitment relationship. Also, the full series may not adequately represent current conditions of expected recruitment from a given SSB level. Thus, it was decided to model only the recent data, recognizing that a long-term perspective of MSY and B_{MSY} would require a different modeling approach.

Recent trends in pre-recruit survival (measured as the R/SSB ratio) are presented in Figure C27. The median, lower 25th, and upper 75th percentiles of projected spawning stock biomass, recruitment (age 1), and landings are given in Tables C26, C27, and C28 and Figure C28 for fishing mortality rate scenarios of F = 0.26, 0.18, and 0.10, respectively. The annual probability that SSB exceeds the 80,000 mt threshold is plotted for the various F scenarios in Figure C29.

Under the $F_{0.1}$ = 0.26 scenario, landings increase from 8,000 mt in 1998 to 12,900 mt in 2006, while spawning stock biomass improves from 39,600 mt to 65,400 mt and recruitment from 8.5 to 10.7 million fish (Table C26). For F = 0.18, landings increase from 6,100 mt in 1998 to 11,600 mt, while spawning stock biomass increases from 42,200 mt in 1998 to 82,000 mt in 2006, and median recruitment improves from 8.8 to 11.7 million fish (Table C27). With F = 0.10, landings rise from 3,700 mt in 1998 to 8,600 in 2006, spawning stock biomass increases from 45,000 mt to 104,600 mt, and recruitment improves from 9.1 to 13.2 million (Table C28). Under the F = 0.26 scenario, the probability of exceeding the biomass threshold of 80,000 mt increases from zero in 1998 to 38% by 2006. For F = 0.18, the annual probability of SSB exceeding the threshold increases from zero in 1998 to 52% by 2006. If F is reduced to 0.10, the annual probability of SSB exceeding the threshold increases from zero in 1998 to 68% by 2006 (Figure C29).

Conclusions

The Georges Bank haddock stock is at a low biomass level and is in an over-exploited state. Fishing mortality has been reduced and the 1996 estimate is below $F_{0.1}$. Although spawning stock biomass has increased from record-low levels due to growth of conserved year classes, stock numbers have not increased since 1994. Spawning stock biomass in 1996 may be over-estimated by as much as 14% due to the influence of a single large tow in the 1996 US spring research vessel survey. The 1992 year class, though it appears large relative to recent recruitment, is only one-third of the average recruitment observed during a period of sustained landings during 1935-1960. The 1992 year class at age 5 is 70-120% larger in number than the similar-sized 1983, 1985, and 1987 year classes at the same age due to lower total mortality rates. Although the 1994-1996 year classes appear to be moderate relative to others in the assessment time series, they are far below historical average levels when the stock was in a healthy condition.

Short-term projections indicate that spawning stock biomass will increase slightly (6%) by 1999 if the stock is fished at the current fishing mortality rate ($F_{96} = 0.18$) in 1998. If fishing mortality is increased to $F_{0.1} = 0.26$ in 1998, spawning stock biomass will decrease slightly (-1%) by 1999. If fishing mortality is increased to the overfishing definition ($F_{30\%} = 0.45$), SSB will decrease sharply (-15%) between 1998 and 1999. Medium-term projections suggest that fishing at the current fishing mortality rate ($F_{96} = 0.18$) would result in a 52% chance of reaching or exceeding the spawning stock biomass threshold (80,000 mt) by 2006. This probability increases to 68% if fishing mortality is reduced to 0.10 and declines to 38% if fishing mortality is allowed to rise to $F_{0.1} = 0.26$.

Observed increases in spawning stock biomass of Georges Bank haddock have resulted from conservation of existing recruitment. This is a necessary first step in the stock rebuilding process. Significant rebuilding beyond current stock levels will require improved recruitment above levels observed in the past decade. To date, there are no indications in the survey data to suggest that incoming recruitment has improved above these levels. 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.

Comparison of the US Assessment of 5Z with the Canadian Assessment of 5Zj,m

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 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 area 5Zj,m (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, year-round US closed areas, 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 I in US waters indicate some increase of haddock resources in the Great South Channel area.

To place 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 age groups 1-8 (excluding the age 9+ 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 (5Zj,m) in the management area common to both assessments (Figure C20). 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 C21). 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 and 1996 in both assessments.

Recruitment patterns are also consistent between the assessments, with both assessments indicating large 1975 and 1978 year classes and moderately-sized 1983, 1985, 1987, and 1992 year classes (Figure C22). Estimated age 1 recruitment in both assessments indicates that year classes after 1992 are relatively weak. The US assessment provides a more optimistic estimate for these year classes; however, they may be overestimated due to high survey tows inside US Closed Area I.

A comparison of total age 1+ biomass trends shows a consistent overall pattern between the assessments (Figure C23). 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 US Closed Area I.

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 in the two countries can be expected to be consistent in the near future.

SARC Comments

Discards were included in the assessment in the 1970s and again during the most recent time period (1994-1996) to account for high discarding events associated with management regulations. Chronic levels of discard are known to have occurred throughout the assessment time period, but were not estimated due to data limitations. The SARC suggested that estimation of chronic discarding throughout the time series be pursued as a long-term research recommendation. The SARC noted that insufficient sampling of commercial landings and inadequate sampling designs for sampling "pulse" type discards occurring in response to trip-limit regulations contributed to uncertainty in the estimation of the US catch at age.

Several strategies were suggested for dealing with large single tows occurring in research vessel survey data, including use of appropriate transformations (log, Poisson), post-stratification of the survey to account for existing closed areas, inverse variance weighting of survey indices in ADAPT, kriging survey results, and the use of information statistics to weight survey indices based on their relative information content. Inverse variance weighting is problematic because large means may be disproportionately downweighted since means and variances are usually positively correlated. The SARC noted that problems with isolated large tows would continue in 1997, based on preliminary results from the NEFSC 1997 spring survey.

The ability of the VPA approach to accurately reflect stock abundance, considering that a significant portion of the resource was inaccessible to the fishery (inside Closed Area I), was also discussed. The SARC examined the base and sensitivity VPA runs and concluded that these runs most likely bracketed the true abundance of the Georges Bank haddock stock.

The SARC noted a retrospective pattern in the assessment for the 1991-1994 time period, with a strong tendency to overestimate fishing mortality and underestimate SSB. This pattern appeared to be reduced in 1995, corresponding to a significant reduction in fishing mortality. The SARC emphasized the importance of examining trends in the retrospective pattern as additional years of data are incorporated into this assessment.

Research Recommendations

- Improve biological sampling of commercial landings and discards.
- Examine effects of large tows on overall and age-specific abundance indices for haddock, specifically with reference to closed areas.
- Examine effects of abrupt changes in mean weights at age during the 1990s, specifically with respect to the 1989-1991 year classes in the eastern part of Georges Bank.
- Investigate factors associated with apparent recent improvements in survival ratios (R/SSB).

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Table C1. Significant changes in management regulations governing the USA 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	6 inch mesh restriction implemented (delayed from March 1).
	December 8	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	Proposed: trip limit raised to 1000 pounds/day, maximum of 10,000 pounds/trip.

Table C2. Commercial landings (metric tons, live) of haddock from Georges Bank and South (NAFO Division 5Z and Statistical Area 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	3656	0	0	0	3969

[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 C3. USA and Canadian commercial landings (Metric tons, live) of haddock from Georges Bank and South (NAFO Division 5Z and Statistical Area 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	2689	944	21	3656

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

Table C4. Number of trips, total discard, and total kept weight (pounds) of sea sampled trips catching haddock in the Georges Bank Stock area. Many sea sampled trips fished 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 activity occurring within the specific area.

Year	Area		Qtr 1	Qtr 2	Qtr 3	Qtr 4
1994	Eastern	Trips	3	4	2	1
		Trips exceeding Trip Limit	1	4	1	0
		Discard (pounds)	1760	44476	14860	0
		Kept (pounds)	269	1252	522	28
		Discard Ratio	6.5428	35.5240	28.4674	0.0000
	Western	Trips	9	3	1	3
		Trips exceeding Trip Limit	5	3	1	0
		Discard (pounds)	10219	825	316	28
		Kept (pounds)	2956	1018	418	171
		Discard Ratio	3.4570	0.8104	0.7560	0.1637
1995	Eastern	Trips	5	2	0	0
		Trips exceeding Trip Limit	0	0	0	0
		Discard (pounds)	47.2	28.5	---	---
		Kept (pounds)	781	742	---	---
		Discard Ratio	0.0604	0.0384	---	---
	Western	Trips	15	11	5	5
		Trips exceeding Trip Limit	0	2	0	0
		Discard (pounds)	302	797	15	12
		Kept (pounds)	1746	1580	894	662
		Discard Ratio	0.1730	0.5044	0.0168	0.0181
1996	Eastern	Trips	0	6	0	0
		Trips exceeding Trip Limit	0	1	0	0
		Discard (pounds)	---	119	---	---
		Kept (pounds)	---	1216	---	---
		Discard Ratio	---	0.0979	---	---
	Western	Trips	7	7	0	1
		Trips exceeding Trip Limit	1	1	0	0
		Discard (pounds)	227	949	---	0
		Kept (pounds)	1370	809	---	0
		Discards Ratio	0.1657	1.173	---	0.0000

Table C5. 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.

<table>
<tr><th>Year</th><th>Area</th><th></th><th>Qtr 1</th><th>Qtr 2</th><th>Qtr 3</th><th>Qtr 4</th></tr>
<tr><td rowspan="10">1994</td><td rowspan="5">Eastern</td><td>Trips</td><td>---</td><td>39</td><td>50</td><td>11</td></tr>
<tr><td>Trips exceeding Trip Limit</td><td>---</td><td>13</td><td>27</td><td>4</td></tr>
<tr><td>Discard (pounds)</td><td>---</td><td>33310</td><td>164815</td><td>14322</td></tr>
<tr><td>Kept (pounds)</td><td>---</td><td>7530</td><td>13800</td><td>4215</td></tr>
<tr><td>Discard Ratio</td><td>4.0000</td><td>4.4236</td><td>11.9431</td><td>3.3979</td></tr>
<tr><td rowspan="5">Western</td><td>Trips</td><td>---</td><td>121</td><td>101</td><td>77</td></tr>
<tr><td>Trips exceeding Trip Limit</td><td>---</td><td>22</td><td>41</td><td>26</td></tr>
<tr><td>Discard (pounds)</td><td></td><td>27405</td><td>92576</td><td>42769</td></tr>
<tr><td>Kept (pounds)</td><td></td><td>25380</td><td>28019</td><td>26055</td></tr>
<tr><td>Discard Ratio</td><td>1.0000</td><td>1.0797</td><td>3.3040</td><td>1.6415</td></tr>
<tr><td rowspan="10">1995</td><td rowspan="5">Eastern</td><td>Trips</td><td>0</td><td>6</td><td>5</td><td>4</td></tr>
<tr><td>Trips exceeding Trip Limit</td><td>---</td><td>2</td><td>0</td><td>1</td></tr>
<tr><td>Discard (pounds)</td><td colspan="2">3000</td><td colspan="2">1020</td></tr>
<tr><td>Kept (pounds)</td><td colspan="2">2450</td><td colspan="2">2152</td></tr>
<tr><td>Discard Ratio</td><td colspan="2">1.2245</td><td colspan="2">0.4740</td></tr>
<tr><td rowspan="5">Western</td><td>Trips</td><td>5</td><td>23</td><td>62</td><td>36</td></tr>
<tr><td>Trips exceeding Trip Limit</td><td>0</td><td>1</td><td>19</td><td>8</td></tr>
<tr><td>Discard (pounds)</td><td>500</td><td>3130</td><td>45036</td><td>6535</td></tr>
<tr><td>Kept (pounds)</td><td>790</td><td>3878</td><td>24578</td><td>8355</td></tr>
<tr><td>Discard Ratio</td><td>0.6329</td><td>0.8071</td><td>1.8324</td><td>0.7822</td></tr>
<tr><td rowspan="10">1996</td><td rowspan="5">Eastern</td><td>Trips</td><td>11</td><td>16</td><td>5</td><td>1</td></tr>
<tr><td>Trips exceeding Trip Limit</td><td>5</td><td>3</td><td>1</td><td>0</td></tr>
<tr><td>Discard (pounds)</td><td colspan="2">10090</td><td colspan="2">5000</td></tr>
<tr><td>Kept (pounds)</td><td colspan="2">8969</td><td colspan="2">2835</td></tr>
<tr><td>Discard Ratio</td><td colspan="2">1.1250</td><td colspan="2">1.1737</td></tr>
<tr><td rowspan="5">Western</td><td>Trips</td><td>56</td><td>79</td><td>74</td><td>40</td></tr>
<tr><td>Trips exceeding Trip Limit</td><td>15</td><td>16</td><td>25</td><td>10</td></tr>
<tr><td>Discard (pounds)</td><td>45770</td><td>16650</td><td>85536</td><td>19575</td></tr>
<tr><td>Kept (pounds)</td><td>18565</td><td>18151</td><td>43716</td><td>18754</td></tr>
<tr><td>Discard Ratio</td><td>2.4654</td><td>0.9173</td><td>1.9566</td><td>1.0438</td></tr>
</table>

Table C6. Commercial catch (landings and discards) of haddock from Georges Bank and subareas for the period 1994-1996.

			Landings					Discards					Catch
		Country	Qtr 1	Qtr 2	Qtr 3	Qtr 4	**Total**	Qtr 1	Qtr 2	Qtr 3	Qtr 4	**Total**	**Total**
1994	Eastern	USA	1.8	8.3	16.2	6.5	**32.8**	7.1	36.7	193.4	21.2	**258.3**	**291.1**
1994	Eastern	Canada	5.0	400.0	1441.0	565.0	**2411.0**	0.0	0.0	0.0	0.0	**0.0**	**2411.0**
1994	Western	USA	42.8	42.5	47.3	52.8	**185.4**	38.6	42.6	107.1	57.5	**245.8**	**431.2**
1994	All	**Total**	**49.6**	**450.8**	**1504.5**	**624.3**	**2629.2**	**45.7**	**79.3**	**300.5**	**78.7**	**504.2**	**3133.3**
1995	Eastern	USA	5.9	13.2	0.7	1.7	**21.5**	7.5	16.8	0.3	0.8	**25.4**	**46.9**
1995	Eastern	Canada	3.0	763.0	896.0	402.0	**2064.0**	0.0	0.0	0.0	0.0	**0.0**	**2064.0**
1995	Western	USA	44.2	40.8	65.5	46.1	**196.6**	18.1	24.6	35.5	21.7	**99.9**	**296.5**
1995	All	**Total**	**51.3**	**817.0**	**963.2**	**449.8**	**2282.1**	**25.6**	**41.4**	**35.8**	**22.5**	**125.3**	**2407.4**
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	Eastern	Canada	0.0	1066.5	1729.8	859.2	**3655.5**	0.0	0.0	0.0	0.0	**0.0**	**3655.5**
1996	Western	USA	43.6	46.5	111.7	76.8	**277.6**	67.3	29.1	138.5	52.7	**287.6**	**565.2**
1996	All	**Total**	**52.6**	**1127.1**	**1847.6**	**942.3**	**3968.6**	**77.4**	**45.0**	**145.7**	**60.1**	**328.2**	**4296.8**

Table C7. USA sampling of commercial haddock landings for length composition from Georges Bank and South (NAFO Division 5Z and Statistical Area 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	Σ	Q1	Q2	Q3	Q4	Σ	Q1	Q2	Q3	Q4	Σ	Q1	Q2	Q3	Q4	Σ	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

Table C8. Data sources and sample sizes of length and age data used to partition 1994-1996 USA landings into numerical catch at age. Both port samples of landings and sea sampled length frequencies were used to partition landings into numbers at length. Sea sampled length frequencies for the kept portion of the catch from Georges Bank sea sampled trips were matched to corresponding dealer records to determine market category. Sea sampled length frequencies were not included in the analysis unless the trip was sold under a single market category.

		Landings				Discards	
	Market Category:	Large (1470)		Scrod (1475)		All	
Year	Data Source	Qtrs 1&2	Qtrs 3&4	Qtrs 1&2	Qtrs 3&4	Qtrs 1&2	Qtrs 3&4
1994	Port Sampling	170	148	66	162	----	----
1994	Sea Sampling	248	0	203	0	469	428
1994	Total	418	148	269	162	469	428
1995	Port Sampling	0	0	198	0	----	----
1995	Sea Sampling	363	93	100	168	177	188
1995	Total	363	93	298	168	177	188
1996	Port Sampling	0	427	0	147	----	----
1996	Sea Sampling	140	0	207	0	267	276
1996	Total	140	427	207	0	267	276

Table C9. Data sources of age samples used in age keys to calculate numerical catch at age for USA landings and discards of haddock from Georges Bank and South (NAFO Division 5Z and Statistical Area 6), 1991-1996. Age-length keys from 1991-1996 were formed semiannually by pooling quarter 1 and 2, and quarters 3 and 4.

		Available Age Samples			Sample Size used
Year		Commercial	Survey	Sea Sampling	in Age Keys
1991	Landings	439	104	-----	599
1992	Landings	922	212	-----	1150
1993	Landings	533	81	-----	649
1994	Landings	211	116	209	536
1994	Discards	211	288	224	723
1995	Landings	58	250	230	528
1995	Discards	55	398	253	706
1996	Landings	191	384	120	695
1996	Discards	191	625	125	941

Table C10. Catch at age (000's), mean weight (kg) and mean length (cm) at age of USA commercial catch of haddock from Georges Bank and South (NAFO Division 5Z and Statistical Area 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	27	98	95	52	9	5	3	8	302
					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
					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	
					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	

Table C11. Landings at age, mean weight (kg) of haddock landed in the Canadian fishery from Georges Bank and South (NAFO Division 5Z and Statistical Area 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	25	459	852	419	60	17	3	71	1907
			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										
1996										
			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										
1996										
			Canadian Commercial Landings Mean Length (cm) at Age							
1982	-	44.92	51.26	55.14	59.16	62.62	63.53	67.37		
1983	-	44.52	49.45	54.11	57.77	60.69	62.94	64.32		
1984	-	44.19	51.13	57.09	59.64	64.26	65.04	68.22		
1985	-	43.24	47.58	56.13	56.79	63.57	66.34	65.78		
1986	33.65	43.81	50.11	56.24	63.43	62.75	68.67	72.33		
1987	-	41.38	49.25	56.58	57.51	60.23	62.87	68.24		
1988	32.84	43.67	48.45	53.69	58.11	58.06	64.10	64.07		
1989	-	41.81	49.66	53.79	57.77	61.23	62.29	64.14		
1990	37.89	43.47	50.15	52.86	57.95	57.79	62.04	59.30		
1991	36.22	47.03	47.05	54.21	55.99	61.45	59.91	63.23		
1992	35.70	46.41	52.66	52.63	58.14	56.31	63.98	61.20		
1993	38.31	46.38	53.36	58.11	56.89	61.60	64.01	65.10		
1994	32.50	46.45	52.59	56.49	57.79	55.72	58.59	70.07		
1995										
1996										

[1] Data from Gavaris and Van Eeckhaute (1995).

Table C12. 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 Statistical Area 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	1	269	810	170	66	69	151	43	43	1625
1995	9	89	596	457	60	31	8	57	18	1328
1996	5	51	557	947	471	69	22	6	79	2209

Table C12. (continued)

Year	1	2	3	4	5	6	7	8	9+	TOTAL
					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	0.58	1.20	1.31	1.82	2.18	2.65	2.85	3.05	4.34	
1992	0.54	1.18	1.64	1.77	2.19	2.52	2.97	3.37	4.27	
1993	0.66	1.17	1.73	2.17	2.12	2.63	2.65	3.12	4.01	
1994	0.45	1.09	1.64	2.21	2.62	2.73	2.90	3.78		
1995	0.43	0.97	1.49	2.03	2.54	2.82	3.27	3.09		
1996	0.46	1.10	1.51	1.85	2.33	2.53	3.42	2.94		

[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)

Table C13. Mean weight at age at January 1 for Georges Bank haddock, calculated from mean weight at capture in the commercial catch using the procedures described by Rivard (1980).

Year	Age 1	2	3	4	5	6	7	8	9+
1963	0.472	0.767	1.072	1.392	1.536	2.035	2.217	2.673	3.100
1964	0.426	0.688	0.987	1.299	1.553	1.838	2.272	2.491	2.970
1965	0.517	0.587	0.925	1.230	1.545	1.807	2.131	2.527	3.110
1966	0.528	0.651	0.784	1.139	1.515	1.859	2.130	2.547	3.180
1967	0.596	0.637	0.833	1.025	1.338	1.867	2.187	2.463	3.100
1968	0.513	0.731	0.857	1.120	1.361	1.727	2.181	2.460	2.860
1969	0.333	0.678	0.944	1.332	1.520	1.768	2.300	2.634	3.630
1970	0.589	0.813	0.975	1.457	1.924	2.045	2.266	2.853	3.750
1971	0.540	0.855	1.290	1.457	2.148	2.481	2.642	2.828	3.720
1972	0.481	0.831	1.339	1.635	2.052	2.642	2.932	3.169	3.660
1973	0.451	0.799	1.276	1.925	2.217	2.822	3.160	3.437	3.940
1974	0.617	0.797	1.369	1.915	2.455	3.010	3.650	3.661	4.260
1975	0.491	0.840	1.314	2.006	2.259	2.884	3.878	4.050	4.330
1976	0.342	0.783	1.167	1.801	2.425	2.603	3.294	4.322	4.940
1977	0.398	0.731	1.194	1.737	2.331	2.922	3.575	3.842	4.990
1978	0.386	0.706	1.267	1.714	2.461	2.951	3.289	3.871	5.110
1979	0.398	0.728	1.097	1.741	2.263	2.960	3.472	3.574	4.870
1980	0.437	0.706	1.100	1.488	2.094	2.660	3.362	3.668	3.870
1981	0.247	0.692	1.080	1.488	1.995	2.429	3.235	3.814	4.440
1982	0.102	0.615	1.123	1.527	2.083	2.520	2.969	3.833	4.090
1983	0.198	0.474	1.153	1.629	2.038	2.506	2.995	3.299	4.270
1984	0.191	0.551	1.160	1.583	2.006	2.429	2.801	3.329	3.720
1985	0.196	0.572	1.131	1.617	2.122	2.446	2.858	3.318	3.800
1986	0.331	0.557	1.160	1.595	2.251	2.639	2.837	3.254	3.780
1987	0.285	0.611	1.159	1.649	2.029	2.595	2.923	3.341	4.290
1988	0.289	0.649	1.055	1.550	2.030	2.348	2.795	3.247	3.960
1989	0.392	0.611	1.204	1.549	1.927	2.301	2.817	3.252	3.820
1990	0.467	0.717	1.148	1.622	1.947	2.375	2.685	3.113	4.160
1991	0.409	0.877	1.128	1.640	1.970	2.366	2.698	2.924	4.337
1992	0.365	0.826	1.403	1.522	1.993	2.345	2.801	3.098	4.267
1993	0.512	0.793	1.425	1.886	1.936	2.397	2.583	3.044	4.014
1994	0.304	0.849	1.386	1.954	2.389	2.404	2.762	3.166	4.546
1995	0.267	0.657	1.276	1.824	2.370	2.720	2.989	2.995	3.981
1996	0.302	0.688	1.207	1.659	2.170	2.537	3.104	3.101	3.807

Table C14. 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

Table C15. Conversion factors used to account for differences in fishing power between research vessels and changes in doors used to conduct the USA Research Vessel bottom trawl surveys. Coefficients of 0.82 (Delaware) and 1.49 (BMV door) were applied to numerical abundance indices, and 0.79 (Delaware) 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
1995-1996	Polyvalent	Albatross IV	1.00	Albatross IV	1.00

Table C16. 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

Table C17. 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

Table C18. Stratified mean catch per tow (numbers) for haddock in Canadian offshore research vessel bottom trawl surveys on Georges Bank, 1986-1990.[1] The Georges Bank strata set includes strata 5Z1-5Z8.

	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

[1] S. Gavaris, personal communication.

Table C19. Sample sizes for calculating maturity ogives for Georges Bank haddock, 1987-1996. Maturity observations were collected during the USA and Canada Spring Research Vessel surveys in the corresponding Georges Bank strata sets.

Year	USA Ages 2-3	Canada Ages 2-3	Total Ages 2-3	USA All Ages	Canada All Ages	Total All Ages
1985	84	---	84	172	---	172
1986	74	---	74	128	---	128
1987	24	55	79	58	165	223
1988	28	134	162	77	338	415
1989	76	128	204	129	372	501
1990	106	322	428	139	574	719
1991	28	102	130	98	574	672
1992	14	92	106	38	405	443
1993	36	134	170	71	369	440
1994	37	128	165	69	704	773
1995	45	83	128	92	230	332
1996	92	163	255	165	577	742

Table C20. Logistic regression equations for haddock maturity ogives calculated from USA and Canadian Spring Research Vessel survey data, 1985-1996.

Years	Alpha	SE	Beta	SE	Sample Ages 2-3	Size All Ages
1985-1989	-2.89895	0.28207	1.74915	0.11985	603	1439
1990-1992	-4.68553	0.32838	2.45480	0.14149	664	1834
1993-1994	-4.36443	0.29225	1.76034	0.11019	335	1074
1995-1996	-7.56224	0.57961	3.45290	0.25240	383	1074

Table C21. Percentage maturity of female Georges Bank haddock at age, 1963-1996.

	Age				
Year	1	2	3	4	Source
1963	0	0	78	100	Clark (1959)
1964	0	0	78	100	Clark (1959)
1965	0	0	78	100	Clark (1959)
1966	0	0	78	100	Clark (1959)
1967	0	0	78	100	Clark (1959)
1968	0	28	76	100	Clark et al. (1982)
1969	0	28	76	100	Clark et al. (1982)
1970	0	28	76	100	Clark et al. (1982)
1971	0	28	76	100	Clark et al. (1982)
1972	0	28	76	100	Clark et al. (1982)
1973	0	34	92	100	Clark et al. (1982)
1974	0	34	92	100	Clark et al. (1982)
1975	0	34	92	100	Clark et al. (1982)
1976	0	34	92	100	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	24	65	92	98	Current Assessment
1986	24	65	92	98	Current Assessment
1987	24	65	92	98	Current Assessment
1988	24	65	92	98	Current Assessment
1989	24	65	92	98	Current Assessment
1990	10	56	94	99	Current Assessment
1991	10	56	94	99	Current Assessment
1992	10	56	94	99	Current Assessment
1993	7	30	71	94	Current Assessment
1994	7	30	71	94	Current Assessment
1995	2	34	94	100	Current Assessment
1996	2	34	94	100	Current Assessment

Table C22. Beginning year stock size of Georges Bank haddock estimated from the final ADAPT VPA run.

STOCK NUMBERS (Jan 1) in thousands - GBHADD97

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
1	190706	471885	33154	4137	12954	422	988	4661	369	8517
2	32266	153504	377207	18457	3284	9565	338	807	3774	301
3	32743	22756	111260	194986	8920	2536	5122	267	518	1846
4	45821	20096	14510	50830	68425	4687	1435	2657	204	222
5	29031	27424	12131	7034	24273	37321	2099	770	1660	131
6	9186	16351	14561	5959	3254	10519	17419	1127	462	1097
7	5595	5526	8144	5868	2535	1570	5446	8874	729	156
8	2795	3309	2640	3255	2694	1177	682	3035	5177	339
9	4217	4251	3258	2201	2031	2163	1712	1875	3245	6311
1+	352360	725101	576866	292727	128369	69960	35241	24071	16137	18919

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
1	19418	10547	7660	103302	13809	6072	83979	10136	7225	2478
2	6832	13582	8593	6098	84446	11305	4971	68755	8291	5914
3	245	3716	7211	6100	4565	51418	8567	4046	28242	5211
4	1104	198	2448	4217	4497	3568	29072	5452	2999	13171
5	109	555	160	1665	2657	3066	2645	17315	3582	1703
6	78	41	391	127	1168	1709	1997	1691	8699	2085
7	790	37	32	282	104	633	931	1264	847	4795
8	57	577	28	22	210	82	392	478	541	394
9	1679	2702	622	623	594	390	187	251	319	406
1+	30311	31953	27145	122437	112049	78242	132742	109388	60744	36157

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
1	3103	17264	1760	14719	2069	16795	1074	2564	2271	9621
2	2028	2541	14135	1441	12046	1694	13747	879	2097	1854
3	3788	1467	1996	9396	1131	8057	1340	10112	710	1312
4	2789	2366	932	1136	5150	809	4439	1019	6971	499
5	7406	1659	1279	588	729	2757	541	2841	679	3763
6	1041	4038	999	630	349	486	1415	314	1541	464
7	1192	606	1965	612	359	220	263	834	168	890
8	2913	808	284	1133	365	214	130	174	523	72
9	275	1627	550	254	461	351	208	165	242	247
1+	24534	32375	23900	29908	22659	31382	23157	18903	15203	18721

	1993	1994	1995	1996	1997
1	17013	11875	8673	8348	8913
2	7871	13923	9721	7092	6830
3	1294	6182	11155	7878	5760
4	784	743	4328	8594	5946
5	289	372	454	3130	6179
6	1699	143	245	318	2136
7	279	795	54	172	198
8	437	194	515	37	121
9	207	190	163	518	378
1+	29873	34415	35307	36085	36461

Table C23. Beginning year spawning stock biomass estimates of Georges Bank haddock from the final ADAPT VPA run.

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

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	1675	61	164	756	67
3	24231	15657	65968	91732	4933	1433	3118	185	411	1652
4	56090	23010	14888	48137	60261	4294	1636	3442	266	304
5	38627	36347	15695	8788	26343	41986	2731	1303	3214	236
6	16463	25241	20959	8948	5063	15408	26011	2067	873	2670
7	10878	10437	13801	10289	4575	2780	10825	17572	1590	354
8	6533	7058	5445	6849	5609	2397	1526	7608	12676	962
9	11435	10811	8271	5784	5324	5124	5278	6177	10450	20678
1+	164257	128561	145027	180526	112107	75098	51185	38519	30236	26923

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
1	0	0	0	0	0	0	0	0	0	0
2	1594	3144	2253	1511	18005	2457	1134	12821	1685	1074
3	272	4217	7626	6069	4151	45754	6799	3345	20410	4055
4	1789	359	4458	6767	7097	5675	44457	7304	3874	17414
5	189	1248	342	3694	5545	6778	5352	30521	6240	3136
6	183	116	1039	316	2927	4333	5273	3784	18210	4567
7	2308	126	113	863	351	1847	2737	3438	2262	12567
8	170	1957	105	87	725	286	1233	1494	1781	1314
9	5770	10658	2455	2771	2664	1797	799	827	1223	1445
1+	12276	21824	18390	22077	41466	68926	67784	63534	55685	45572

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
1	0	375	79	1113	135	1106	96	114	88	334
2	292	435	4742	491	4327	674	5059	335	916	784
3	3144	1428	1784	8536	1097	6662	1371	9941	689	1521
4	3990	3212	1316	1590	7120	1112	6026	1479	9701	656
5	12971	2933	2274	1162	1336	4736	910	4746	1216	6148
6	2278	8191	2162	1445	807	979	2852	638	3179	957
7	3239	1404	4893	1526	923	539	669	1993	367	2087
8	8352	2282	820	3252	1053	597	376	472	1318	185
9	1019	5139	1816	846	1709	1196	706	599	907	876
1+	35286	25401	19885	19960	18507	17600	18066	20317	18380	13550

	1993	1994	1995	1996
1	580	240	44	48
2	1763	3354	2062	1575
3	1140	5564	12533	8332
4	1154	1206	7279	13130
5	469	800	984	6172
6	3369	269	610	716
7	658	1969	147	489
8	1112	544	1419	104
9	694	764	598	1790
1+	10938	14711	25675	32357

Table C24. Estimated fishing mortality (F) for the Georges Bank haddock estimated from the final ADAPT VPA run.

FISHING MORTALITY - GBHADD97

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
1	0.02	0.02	0.39	0.03	0.10	0.02	0.00	0.01	0.00	0.02	0.16	0.00	0.03	0.00	0.00
2	0.15	0.12	0.46	0.53	0.06	0.42	0.04	0.24	0.52	0.01	0.41	0.43	0.14	0.09	0.30
3	0.29	0.25	0.58	0.85	0.44	0.37	0.46	0.07	0.65	0.31	0.01	0.22	0.34	0.10	0.05
4	0.31	0.30	0.52	0.54	0.41	0.60	0.42	0.27	0.24	0.52	0.49	0.01	0.19	0.26	0.18
5	0.37	0.43	0.51	0.57	0.64	0.56	0.42	0.31	0.21	0.31	0.77	0.15	0.03	0.15	0.24
6	0.31	0.50	0.71	0.65	0.53	0.46	0.47	0.24	0.89	0.13	0.55	0.06	0.13	0.00	0.41
7	0.33	0.54	0.72	0.58	0.57	0.63	0.38	0.34	0.57	0.81	0.11	0.06	0.15	0.09	0.04
8	0.34	0.42	0.61	0.56	0.47	0.55	0.45	0.32	0.38	0.24	0.35	0.11	0.17	0.22	0.23
9	0.34	0.42	0.61	0.56	0.47	0.55	0.45	0.32	0.38	0.24	0.35	0.11	0.17	0.22	0.23

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.08	0.01	0.69	0.26	0.25	0.12	0.04	0.21	0.04	0.20	0.03	0.11	0.01	0.27	0.16
3	0.37	0.25	0.10	0.56	0.43	0.27	0.25	0.36	0.40	0.13	0.40	0.07	0.17	0.15	0.31
4	0.10	0.32	0.22	0.37	0.38	0.32	0.41	0.26	0.24	0.42	0.20	0.25	0.21	0.42	0.35
5	0.23	0.25	0.49	0.34	0.29	0.41	0.31	0.51	0.32	0.20	0.47	0.35	0.41	0.18	0.60
6	0.41	0.26	0.49	0.40	0.36	0.34	0.52	0.29	0.36	0.26	0.41	0.33	0.42	0.35	0.31
7	0.28	0.47	0.65	0.57	0.30	0.19	0.56	0.35	0.32	0.32	0.32	0.21	0.27	0.65	0.51
8	0.21	0.32	0.44	0.39	0.35	0.36	0.45	0.36	0.30	0.39	0.40	0.27	0.35	0.39	0.54
9	0.21	0.32	0.44	0.39	0.35	0.36	0.45	0.36	0.30	0.39	0.40	0.27	0.35	0.39	0.54

	1993	1994	1995	1996
1	0.00	0.00	0.00	0.00
2	0.04	0.02	0.01	0.01
3	0.36	0.16	0.06	0.08
4	0.55	0.29	0.12	0.13
5	0.51	0.22	0.16	0.18
6	0.56	0.77	0.15	0.27
7	0.16	0.24	0.18	0.15
8	0.51	0.28	0.13	0.18
9	0.51	0.28	0.13	0.18

Table C25. Yield per recruit analysis for Georges Bank haddock.

```
 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

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--------------------------------------------------------------
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 C26. Stochastic medium-term projections of spawning stock biomass (mt), recruitment (age 1, thousands) and landings (mt) for Georges Bank haddock, assuming F=0.26. Probability of SSB > the 80,000 mt threshold is given, along with the lower and upper quartiles and the median of bootstrap simulations.

	- Spawning Biomass -				- Recruitment -			- Landings -		
Year	L-25	Median	U-75	Probability	L-25	Median	U-75	L-25	Median	U-75
1997	35,286	39,455	42,623	0.000	3,419	8,475	21,321	7,162	7,912	8,536
1998	35,997	39,583	42,976	0.000	3,444	8,535	20,798	7,290	8,028	8,649
1999	36,047	40,783	45,953	0.003	3,490	8,674	21,328	7,377	8,131	8,894
2000	34,829	42,097	53,840	0.077	3,670	8,948	22,441	7,187	8,320	9,905
2001	34,549	45,565	64,586	0.154	3,775	9,320	23,581	7,020	8,779	11,722
2002	35,273	49,926	75,186	0.219	3,963	9,707	23,942	6,974	9,568	14,078
2003	36,953	54,449	84,037	0.273	4,029	10,128	25,088	7,241	10,508	15,956
2004	38,601	58,724	91,536	0.317	4,084	10,166	25,481	7,610	11,407	17,698
2005	40,536	62,068	96,600	0.353	4,171	10,375	26,271	7,986	12,179	18,946
2006	41,969	65,432	101,639	0.377	4,426	10,724	26,548	8,319	12,859	20,072

Table C27. Stochastic medium-term projections of spawning stock biomass (mt), recruitment (age 1, thousands) and landings (mt) for Georges Bank haddock, assuming F=0.18. Probability of SSB > the 80,000 mt threshold is given, along with the lower and upper quartiles and the median of bootstrap simulations.

	- Spawning Biomass -				- Recruitment -			- Landings -		
Year	L-25	Median	U-75	Probability	L-25	Median	U-75	L-25	Median	U-75
1997	35,835	40,068	43,276	0.000	3,519	8,633	21,354	5,114	5,651	6,098
1998	38,387	42,220	45,616	0.000	3,591	8,813	21,895	5,501	6,099	6,558
1999	40,039	45,064	50,426	0.005	3,718	9,238	22,526	5,834	6,412	7,009
2000	40,273	47,675	59,981	0.101	3,916	9,563	23,709	5,938	6,781	7,963
2001	40,917	52,777	73,418	0.204	4,111	10,166	25,167	5,977	7,327	9,539
2002	42,593	59,018	86,457	0.291	4,220	10,347	26,050	6,060	8,112	11,668
2003	45,156	65,185	98,512	0.365	4,423	10,872	27,034	6,382	9,074	13,476
2004	48,015	70,996	108,689	0.426	4,516	11,188	27,992	6,799	9,959	15,225
2005	51,015	76,800	117,506	0.473	4,747	11,519	28,620	7,250	10,810	16,627
2006	53,634	81,963	125,290	0.517	4,822	11,719	29,077	7,640	11,624	17,812

Table C28. Stochastic medium-term projections of spawning stock biomass (mt), recruitment (age 1, thousands) and landings (mt) for Georges Bank haddock, assuming F=0.10. Probability of SSB > the 80,000 mt threshold is given, along with the lower and upper quartiles and the median of bootstrap simulations.

	- Spawning Biomass -				- Recruitment -			- Landings -		
Year	L-25	Median	U-75	Probability	L-25	Median	U-75	L-25	Median	U-75
1997	36,393	40,692	43,940	0.000	3,587	8,793	21,437	2,937	3,241	3,498
1998	41,024	45,038	48,578	0.000	3,764	9,084	22,417	3,346	3,698	3,995
1999	44,637	50,048	55,634	0.012	3,954	9,701	24,248	3,721	4,108	4,453
2000	46,675	54,650	67,211	0.134	4,112	10,016	25,151	3,950	4,480	5,169
2001	49,119	61,658	82,773	0.272	4,444	10,950	27,194	4,131	4,956	6,272
2002	52,438	70,180	100,041	0.396	4,516	11,178	27,923	4,312	5,576	7,748
2003	56,466	79,206	116,382	0.493	4,892	11,915	29,423	4,633	6,345	9,167
2004	61,444	88,043	131,703	0.568	5,083	12,363	30,107	5,011	7,128	10,589
2005	66,347	96,182	145,190	0.630	5,201	12,759	31,137	5,437	7,861	11,877
2006	71,079	104,666	157,811	0.678	5,521	13,196	31,920	5,857	8,583	12,984

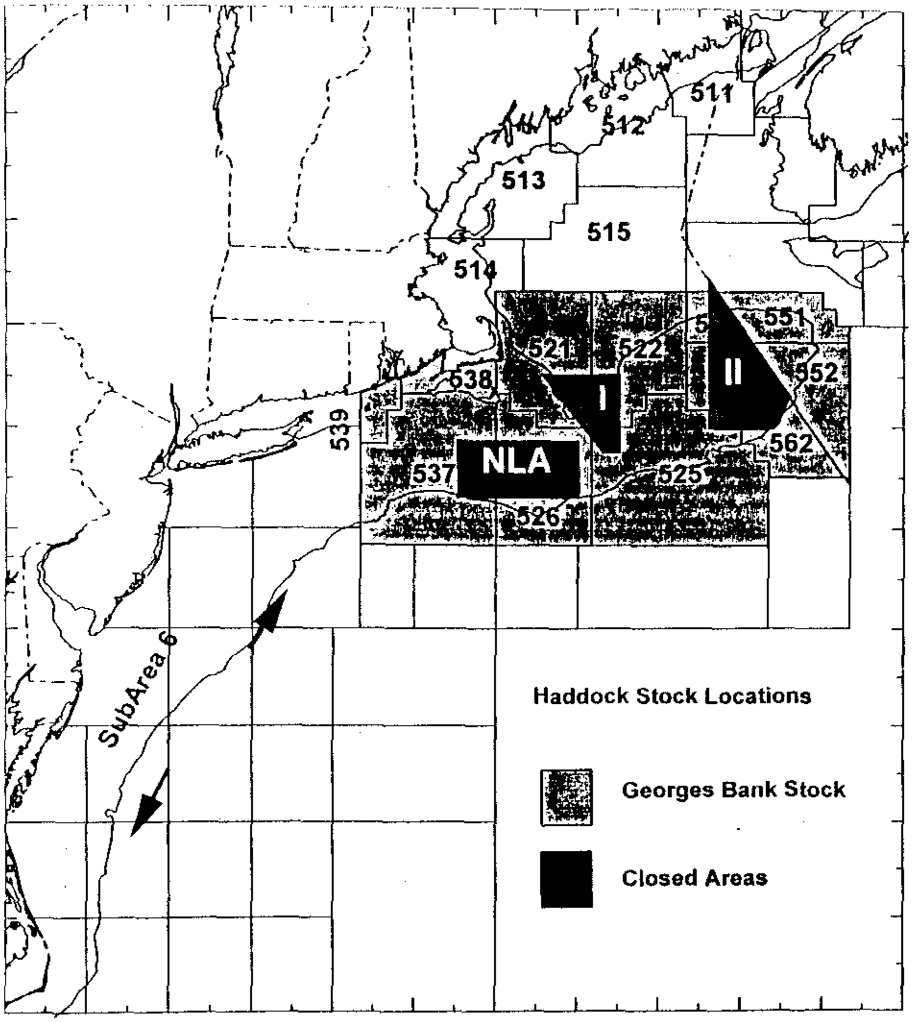

Figure C1. NEFSC statistical areas included in the Georges Bank haddock assessment. Shading indicates the area where 99% of catch occurs, although landings from Subareas 5 and 6 south of the primary area of concentration are also included in the assessment.

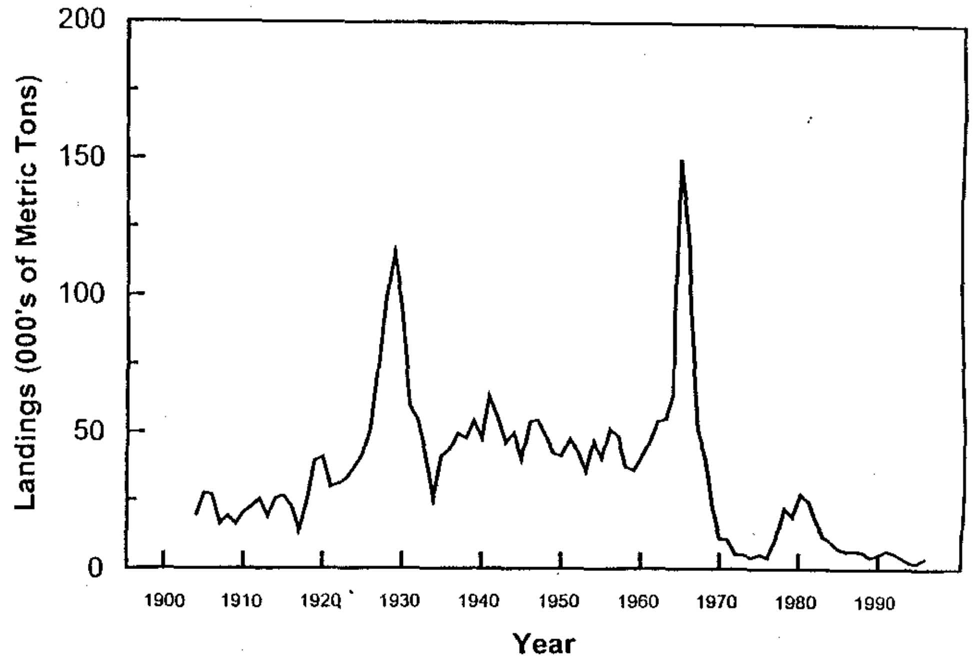

Figure C2. Total commercial landings of haddock from Georges Bank and South, 1904-1996.

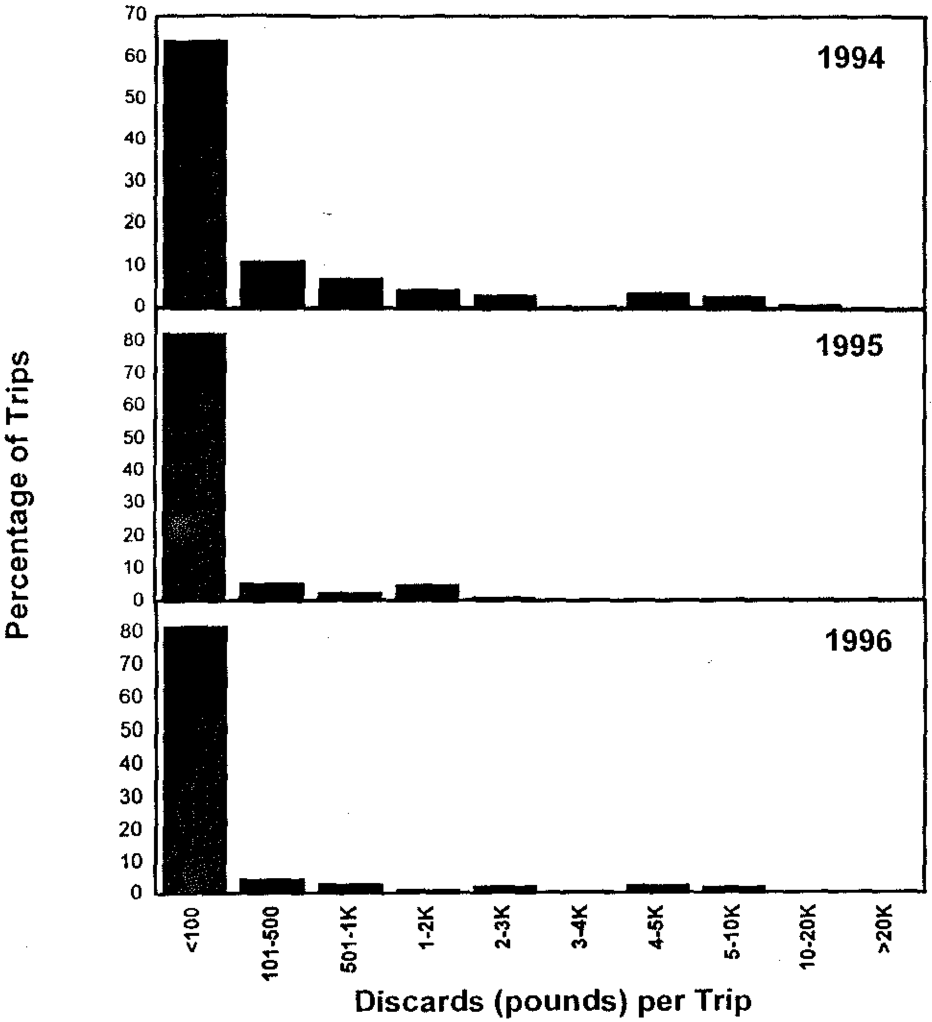

Figure C3. Frequency distribution of haddock discard per trip reported in Vessel Trip Records for Georges Bank groundfish trips from 1994-1996.

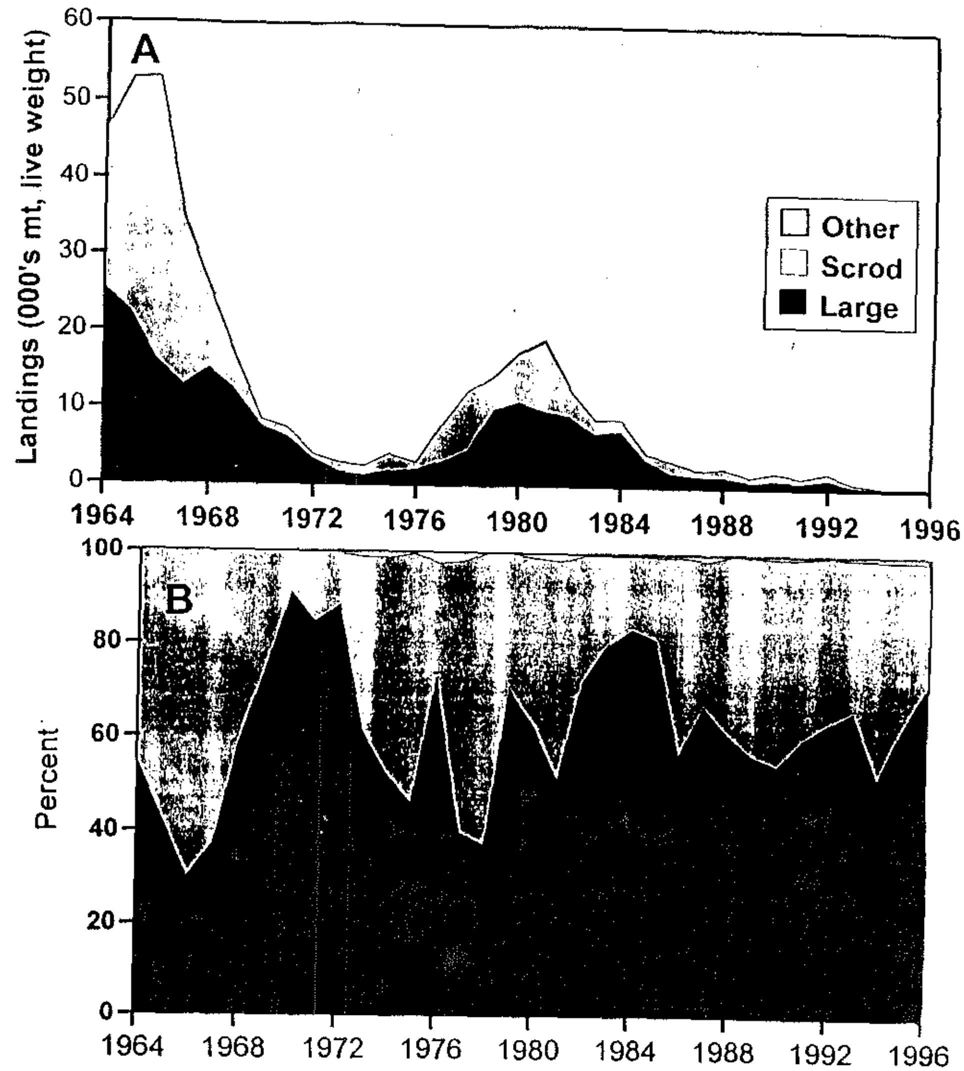

Figure C4. USA Georges Bank haddock landings by market category (Panel A) and percent distribution of landings by market category (Panel B).

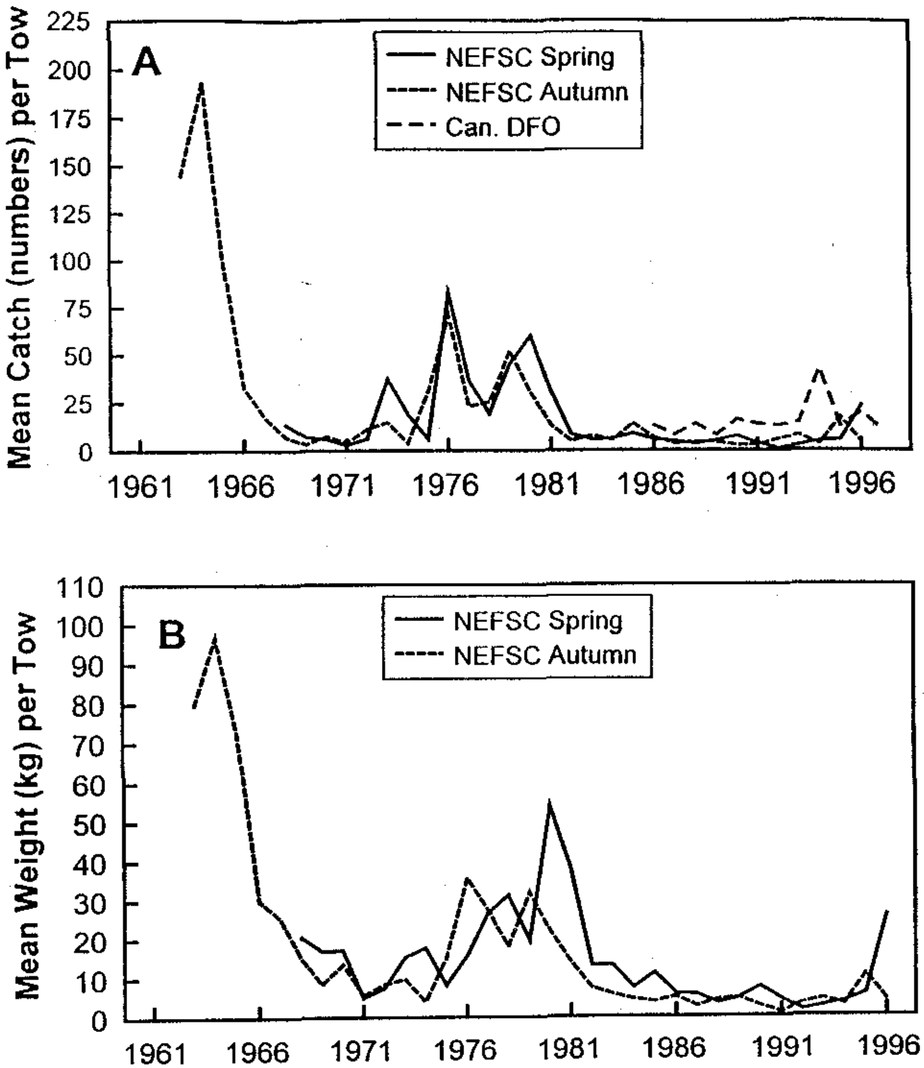

Figure C5. NEFSC and Canadian DFO bottom trawl survey abundance (number per tow; Panel A) and biomass (kg per tow; Panel B) for Georges Bank haddock, 1963-1996.

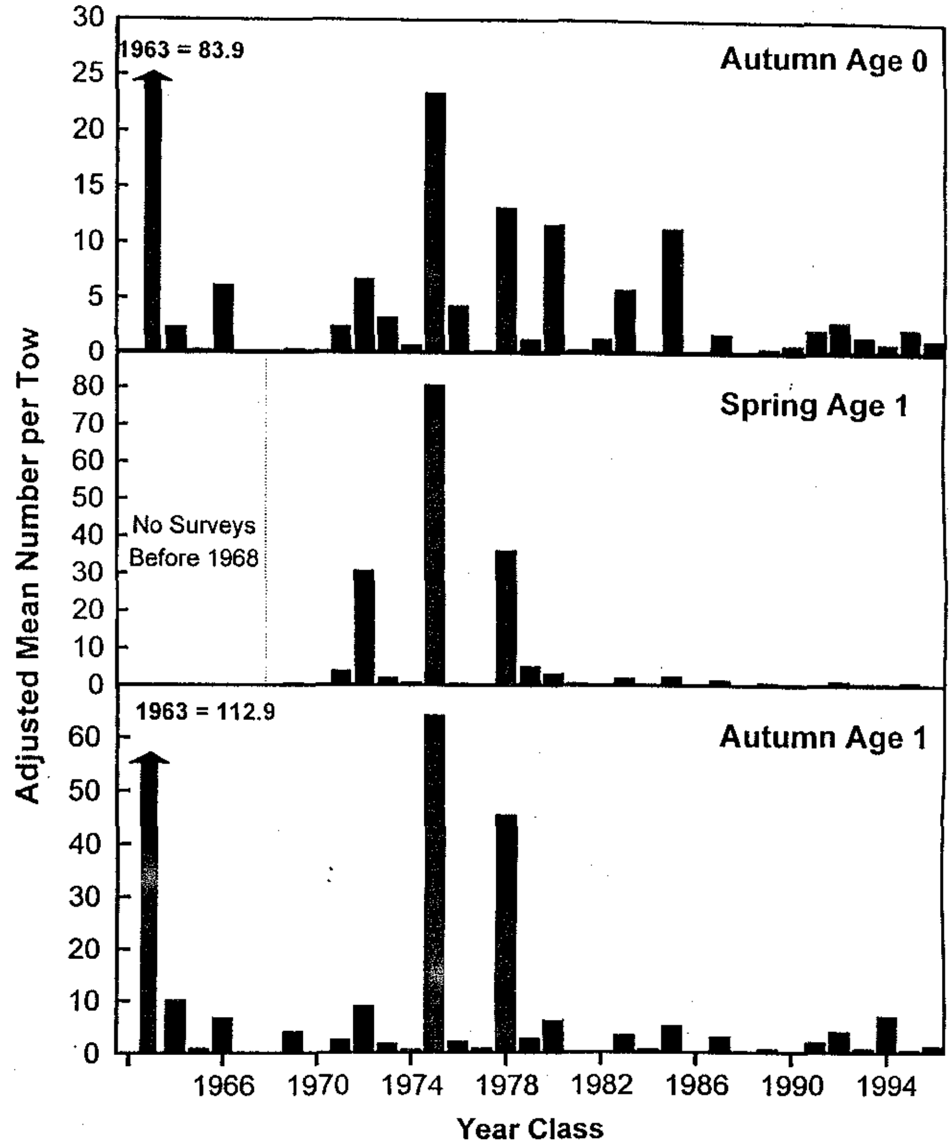

Figure C6. Stratified mean number per tow of age 0 and 1 haddock sampled during the NEFSC Autumn and Spring Research Vessel Surveys from Georges Bank and South.

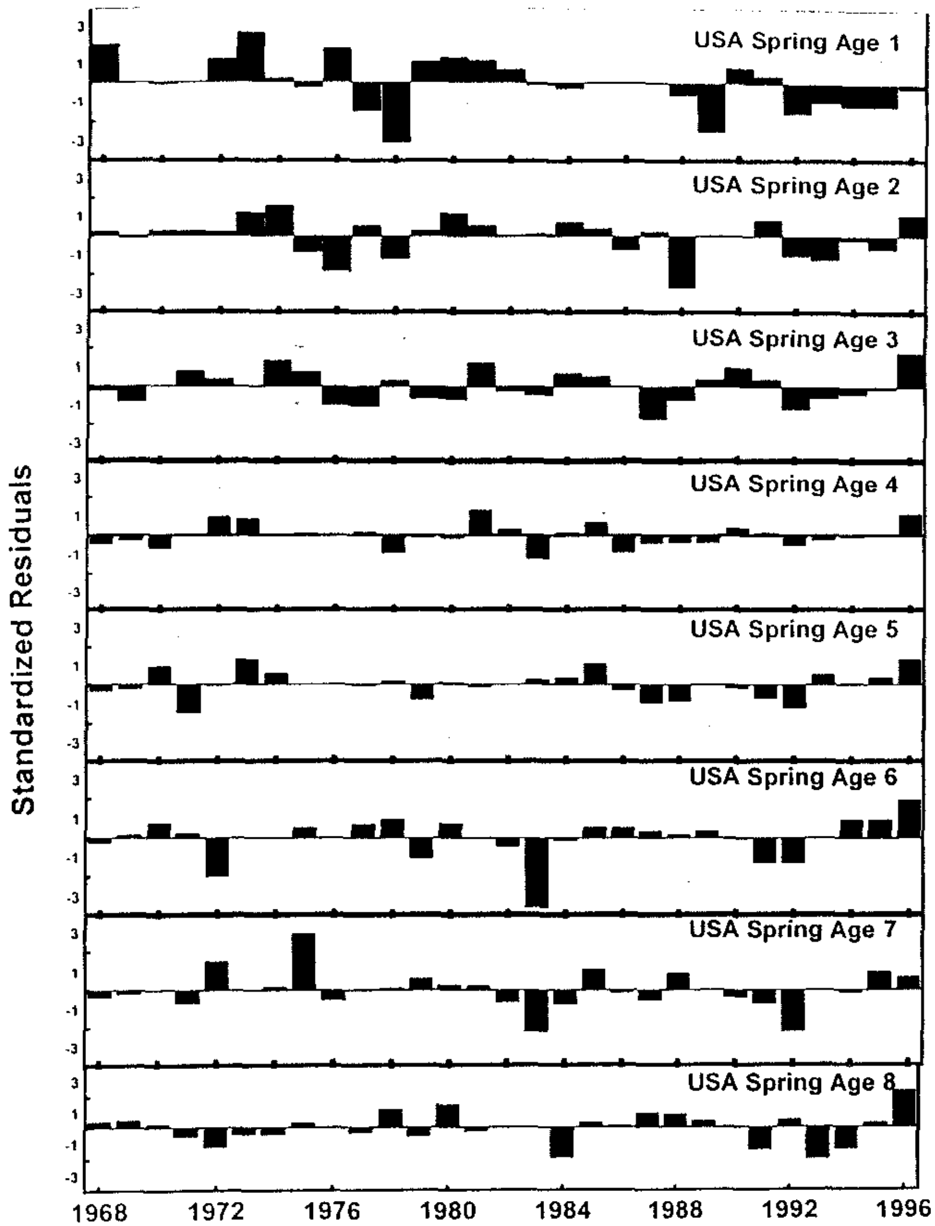

Figure C7 Standardized residuals for the USA Spring Research Vessel Survey from the ADAPT calibration of the base run of the Georges Bank haddock assessment. A pattern of large positive residuals occurred for age classes 2-8 in the terminal year of the assessment.

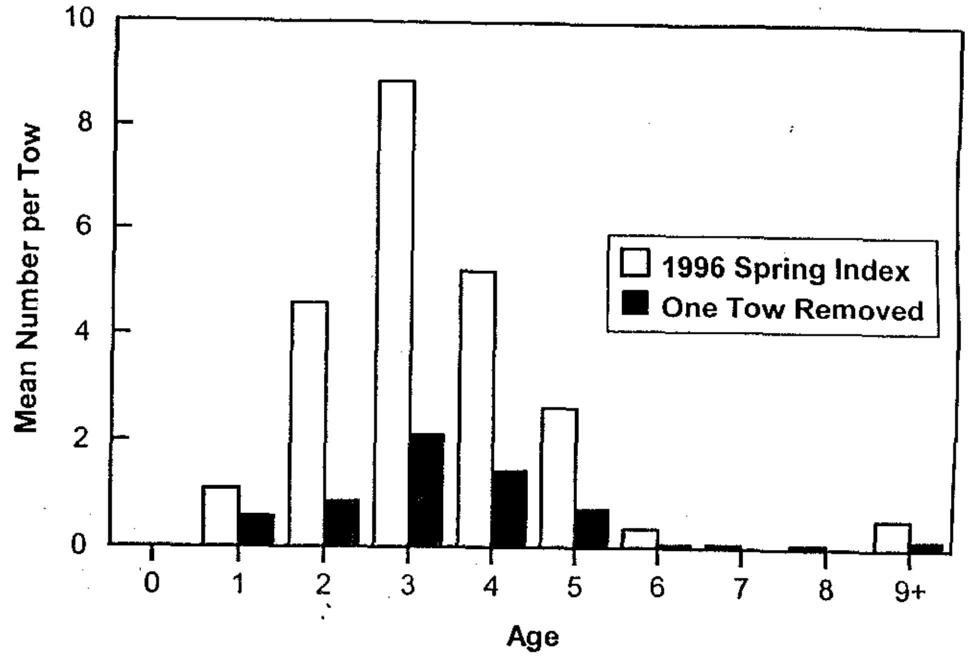

Figure C8. Mean number of haddock per tow at age caught in the Georges Bank strata sets (offshore strata 01130-01250, 01290-01300) during the Spring 1996 Research Vesse; Survey conducted by the Northeast Fisheries Science Center. Results are shown for all tows during the survey, and excluding one tow made inside Closed Area 1 with large catches of haddock.

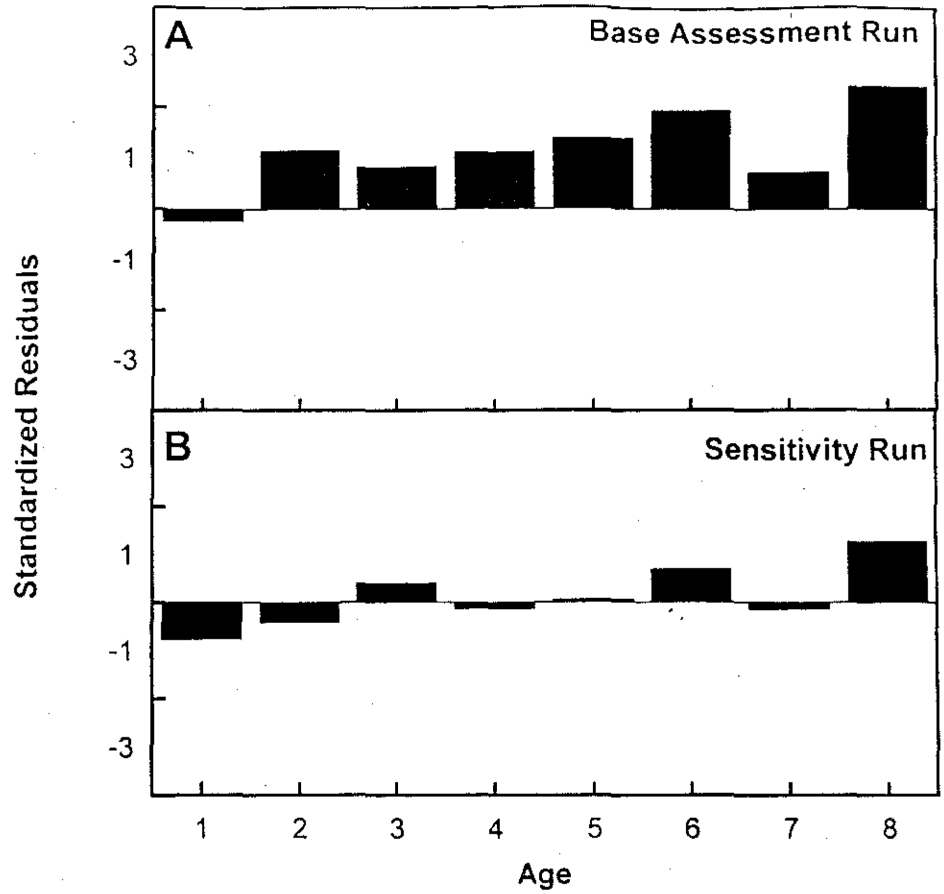

Figure C9. Standardized residual patterns from the final VPA run (Panel A) and the sensitivity run (Panel B) for the 1996 USA Spring age 1-8 indices.

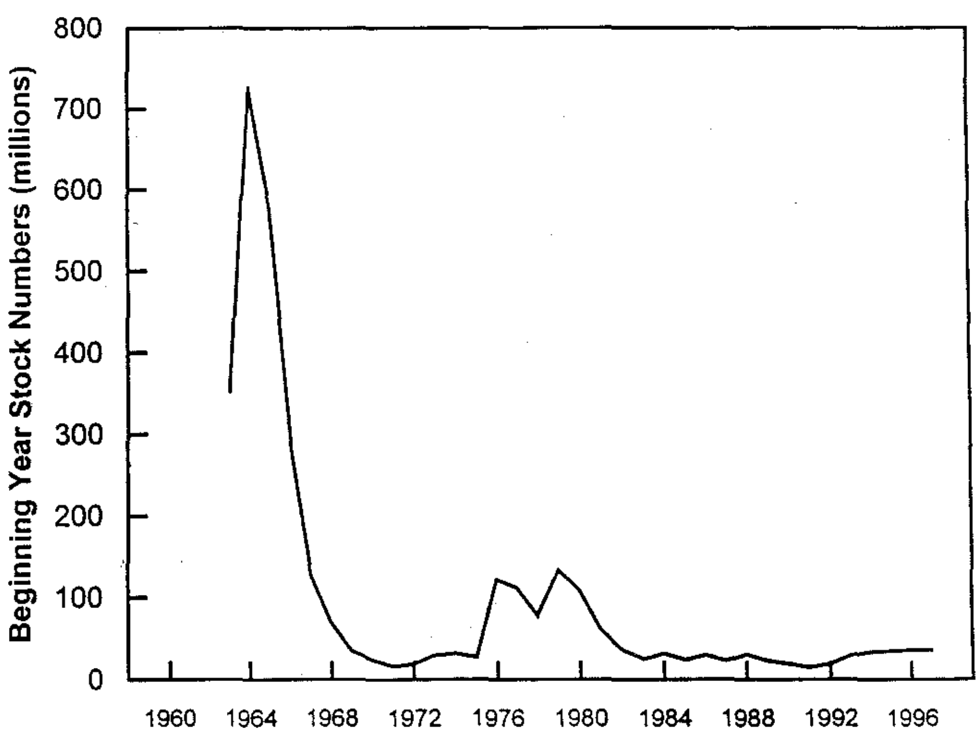

Figure C10. VPA derived estimates of beginning year stock numbers (millions) of Georges Bank haddock from 1963-1997.

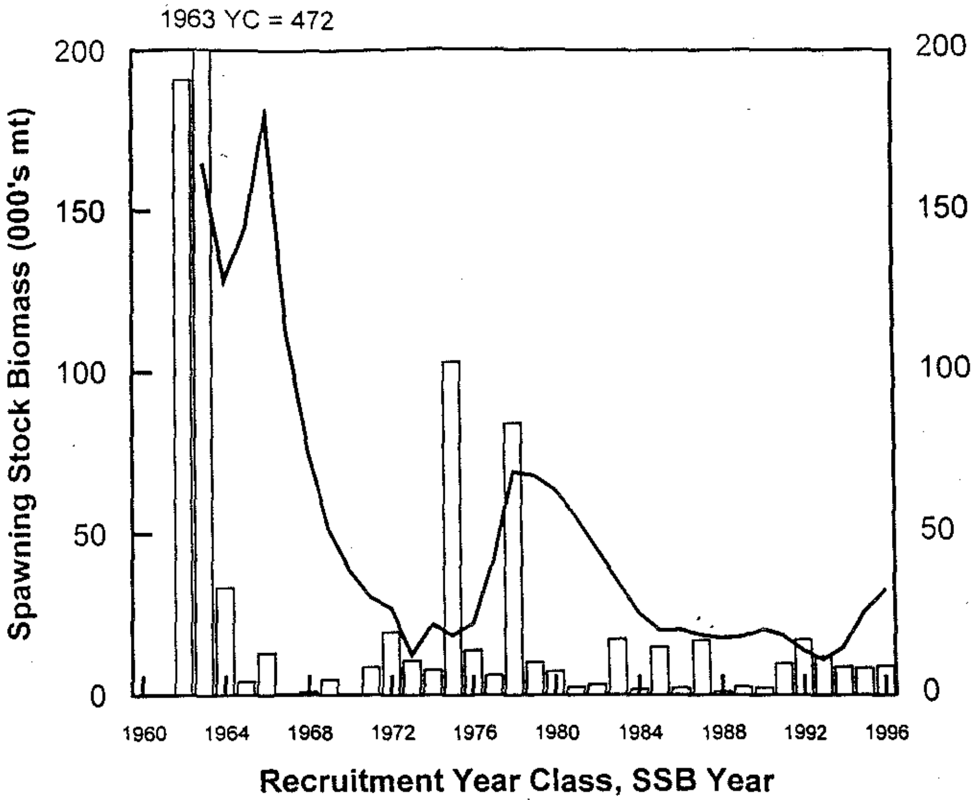

Figure C11. Trends in spawning stock biomass (line) and age 1 recruitment (bars) for Georges Bank haddock, 1963-1996.

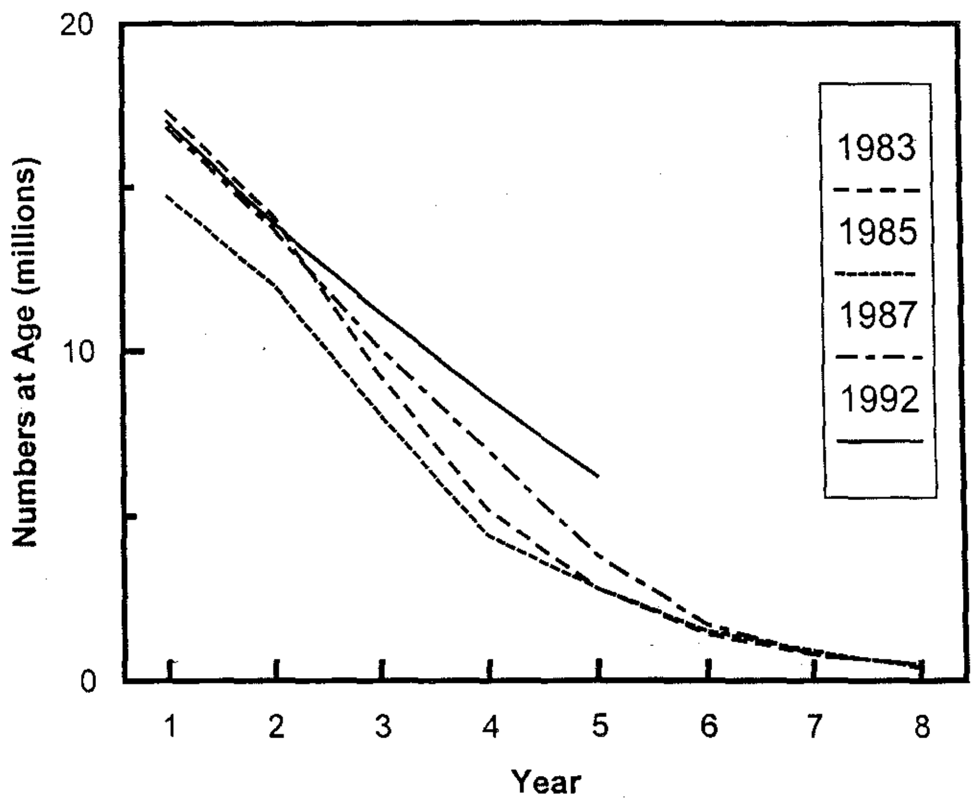

Figure C12. Numbers of haddock at age from four roughly equivalent recent year classes (1983, 1985, 1987, and 1992). Note that the rate of degradation of the 1992 year class is slower than for previous year classes due to lower fishing mortality. Stock numbers at age 5 for the 1992 year class are estimated to be 1.7 to 2.2 times higher than for the other three year classes.

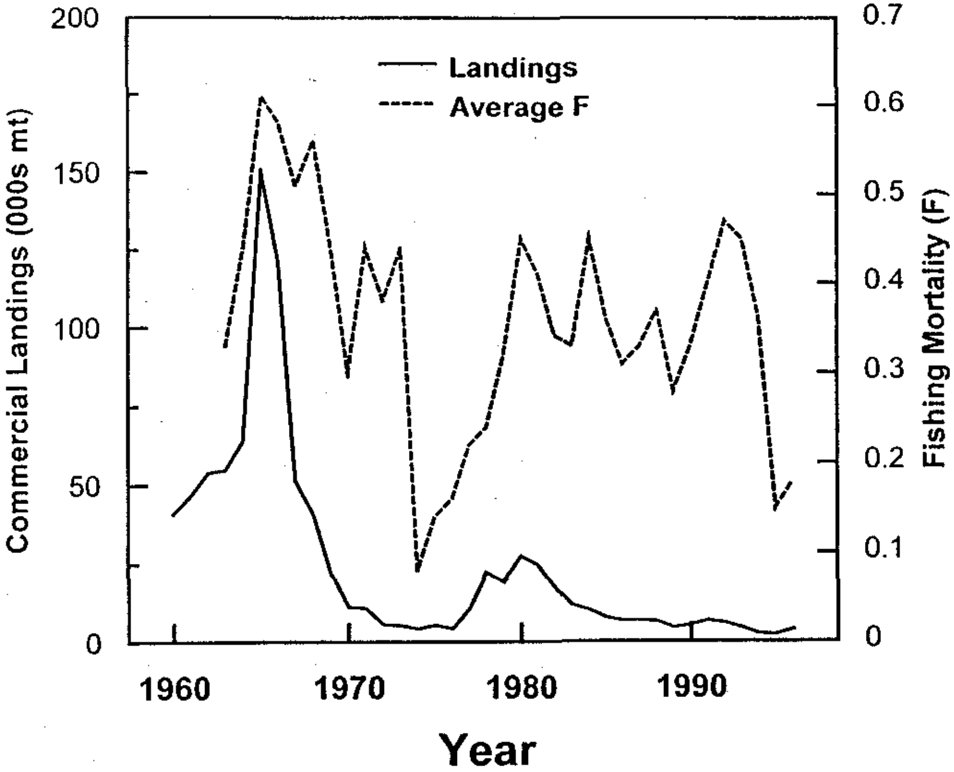

Figure C13. Trends in commercial landings (metric tons, live weight) and fully-recruited fishing mortality (mean F, 4-7, u) for Georges Bank haddock, 1963-1996.

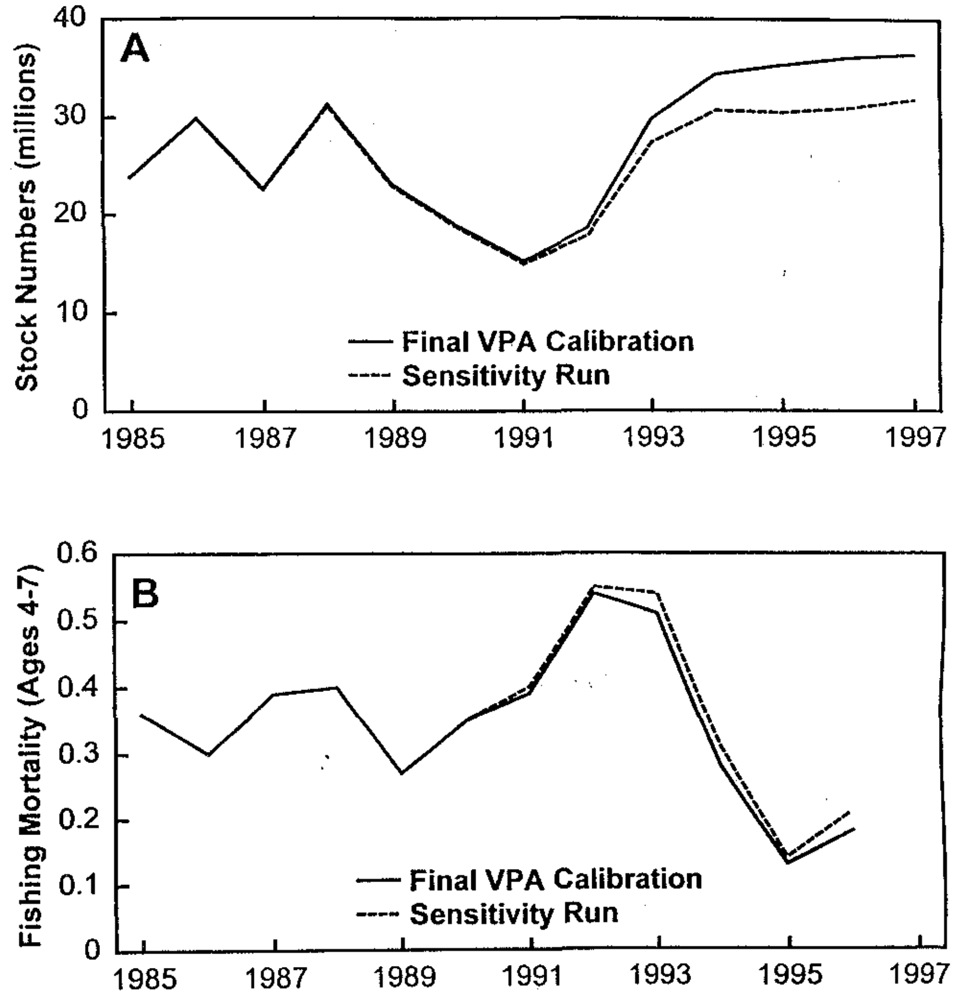

Figure C14. Comparison of VPA results including stock numbers (Panel A) and fishing mortality (Panel B) for the base and sensitivity VPA runs for Georges Bank haddock.

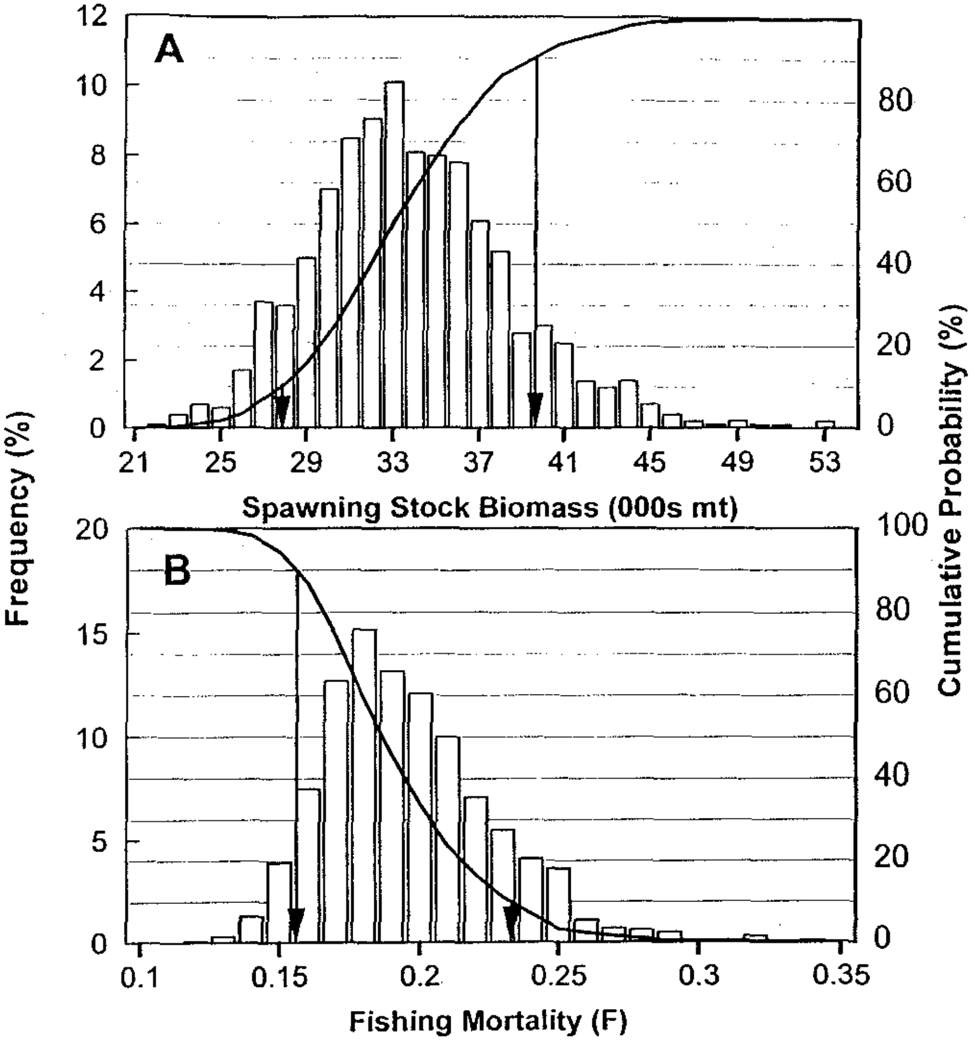

Figure C15. Precision of the estimates of spawning stock biomass (Panel A) at the beginning of the spawning season (April 1) and instantaneous rate of fishing mortality (Panel B) on the fully recruited ages (ages 4+) in 1996 for Georges Bank haddock. The vertical bars display both the range of the estimator 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 200 bootstrap replications of the final ADAPT VPA formulation.

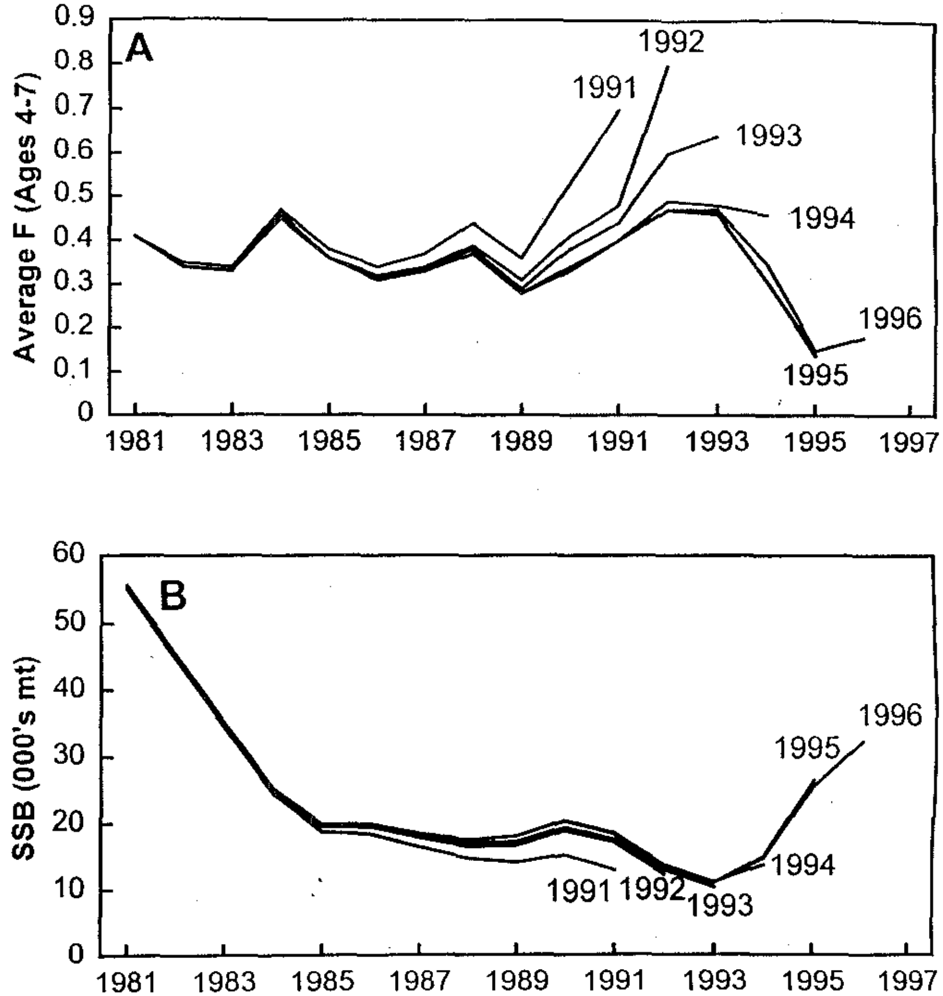

Figure C16. Retrospective analysis results of fishing mortality (Panel A) and spawning stock biomass (Panel B) for the USA Georges Bank haddock assessment, 1996 to 1991.

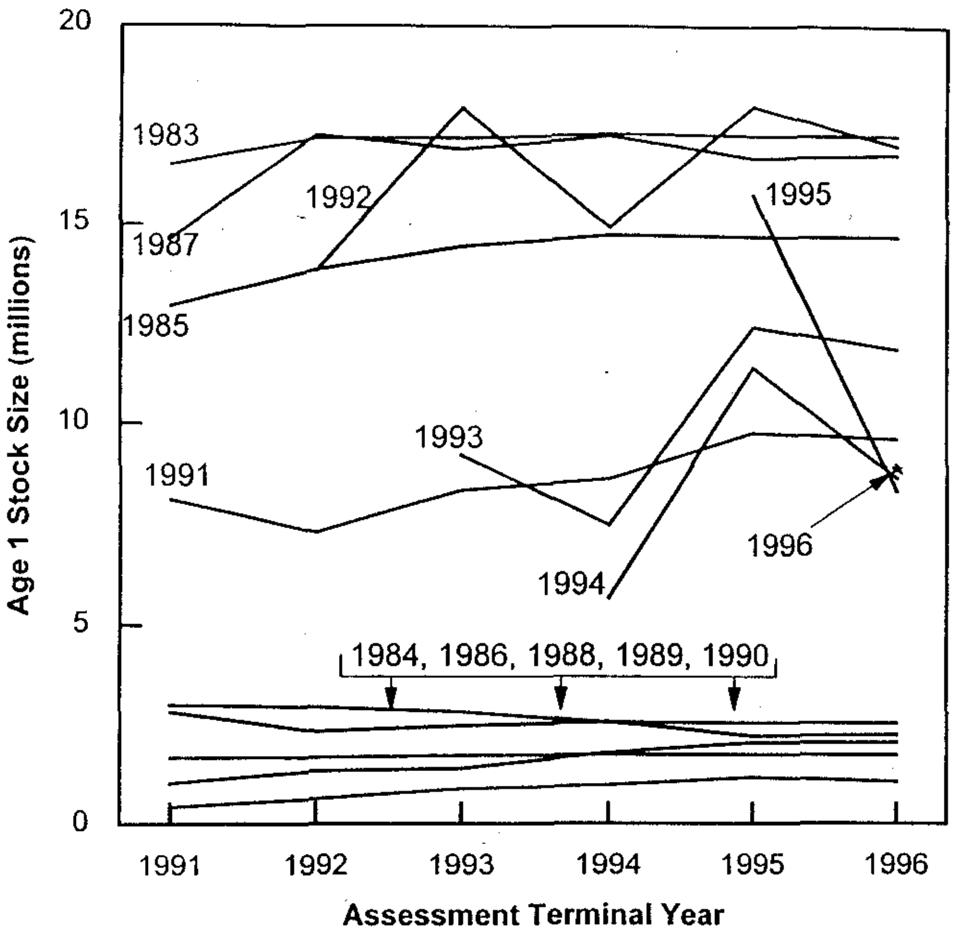

Figure C17. Retrospective analysis results showing successive estimates of year class abundance as additional years of data were included in the assessment. The estimated size of the 1996 year class is indicated by the star.

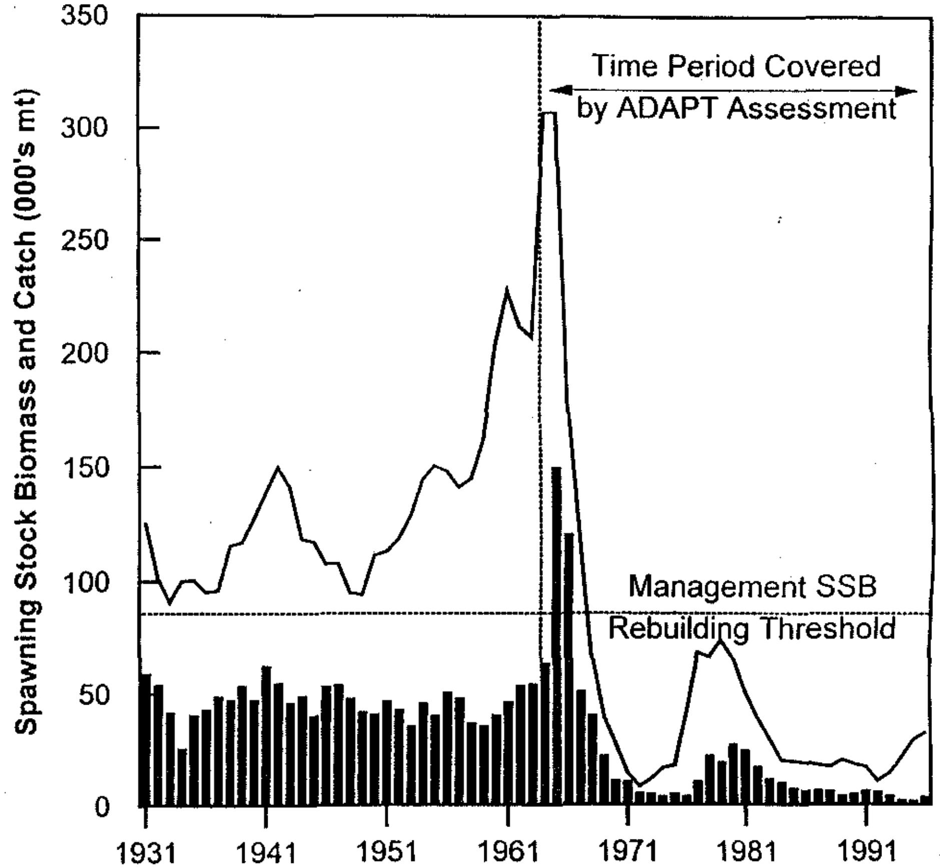

Figure C18. Spawning stock biomass (line) and landings (bars) of Georges Bank haddock, based on a 1931-1996 untuned Virtual Population Analysis. Amendment 7 of the Northeast Multispecies Fishery Management Plan has established 80,000 mt as a rebuilding threshold for Georges Bank haddock.

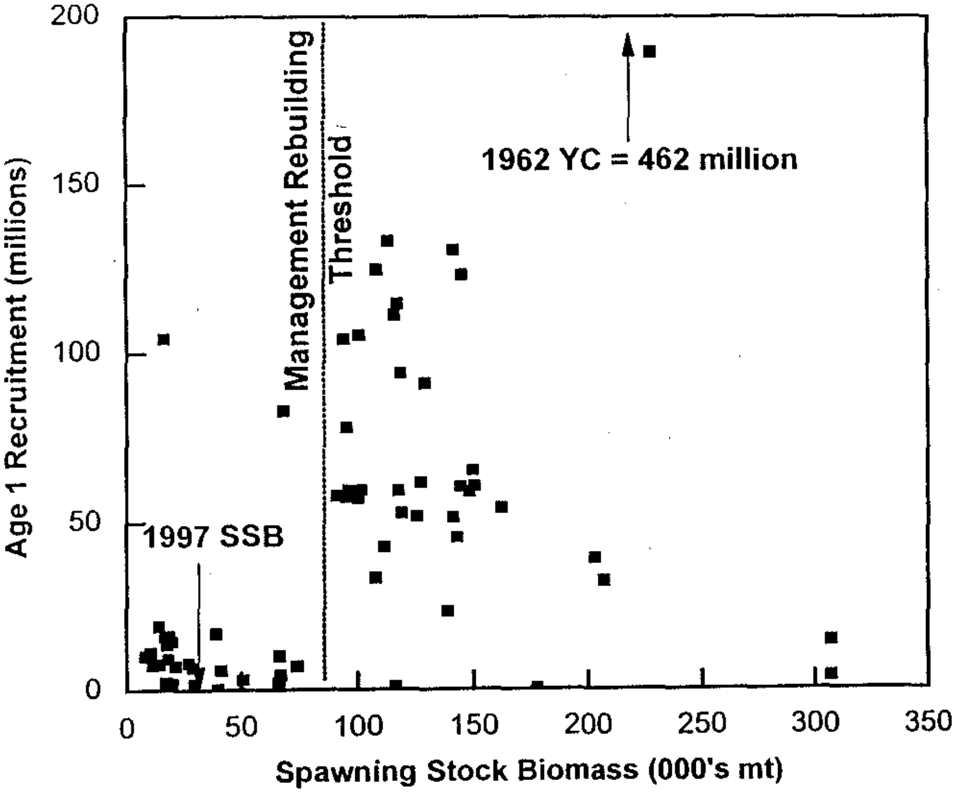

Figure C19. Spawning stock biomass and recruitment relationship for Georges Bank haddock, based on a 1931-1996 untuned Virtual Population Analysis. Amendment 7 of the Northeast Multispecies Fishery Management Plan has established 80,000 mt as a rebuilding threshold for Georges Bank haddock. All of the points to the left of the rebuilding threshold line have occurred since 1967, following the collapse of the stock. The 1997 level of spawning stock biomass is indicated by the arrow.

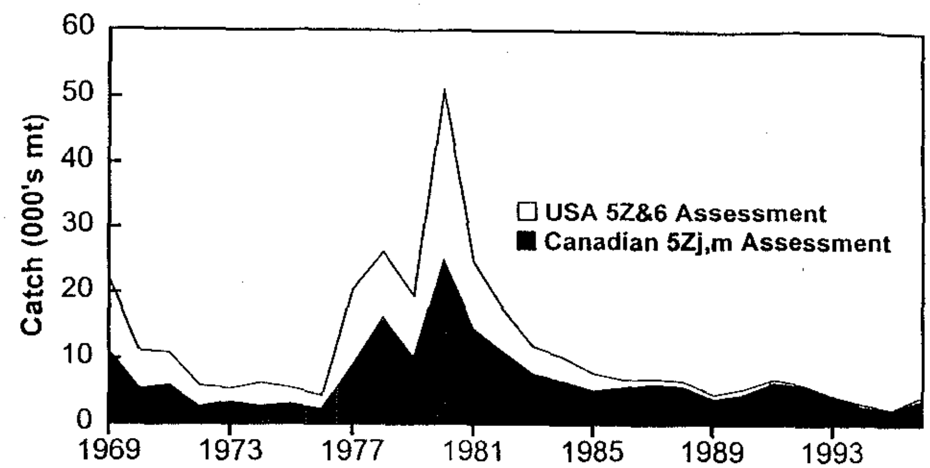

Figure C20. Comparison of total catch (mt) incorporated in the USA and Canadian assessments of Georges Bank haddock.

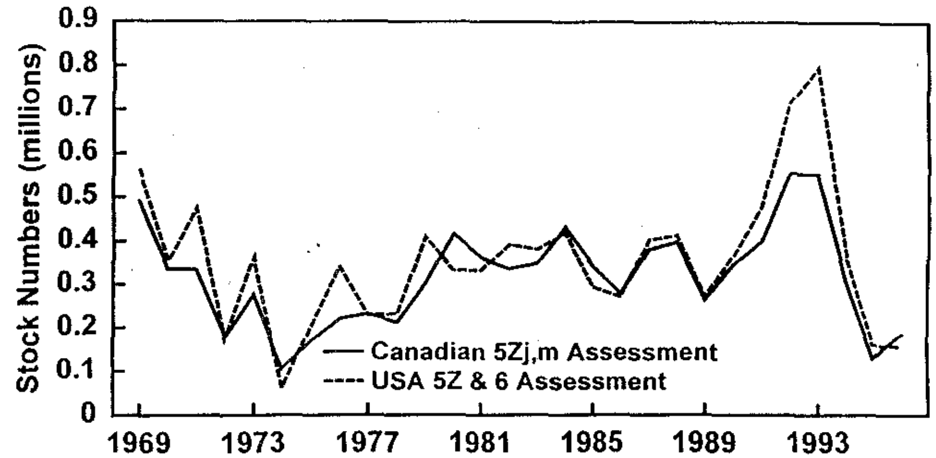

Figure C21. Comparison of fishing mortality (ages 4-7) estimated by the USA and Canadian assessments of Georges Bank haddock. For comparison purposes, USA assessment results have been bias corrected.

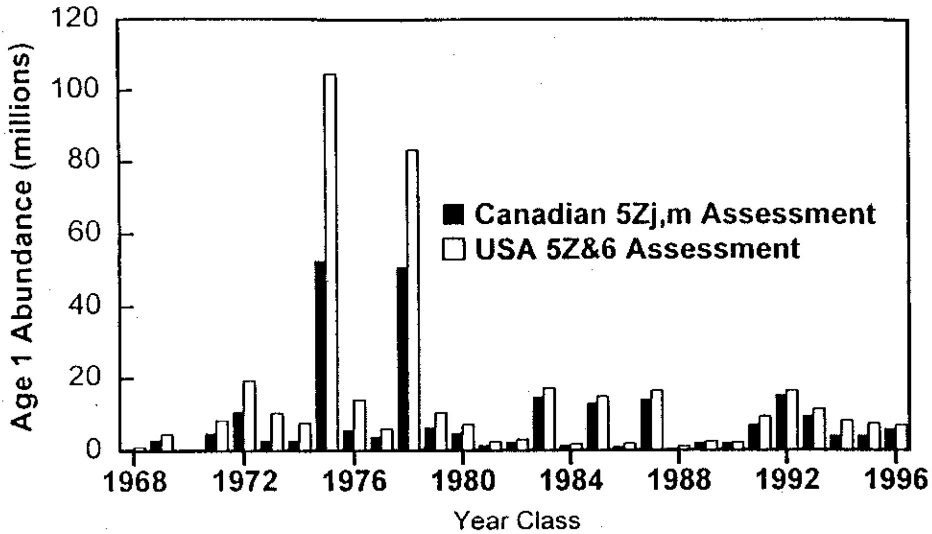

Figure C22. Comparison of age 1 recruitment estimated by the USA and Canadian assessments of Georges Bank haddock. For comparison purposes, USA assessment results have been bias corrected.

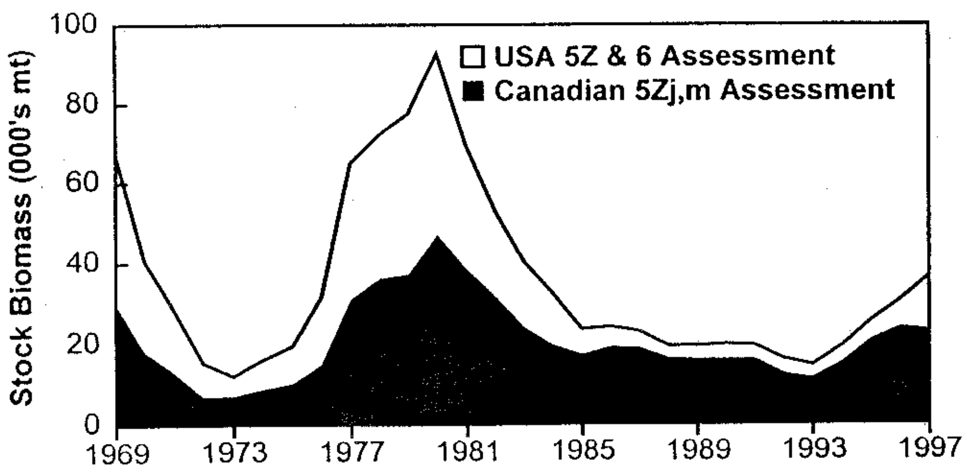

Figure C23. Comparison of beginning year stock numbers estimated by the USA and Canadian assessments of Georges Bank haddock. For comparison purposes, USA assessment results have been bias corrected and USA assessment biomass was calculated using Canadian survey mean weights.

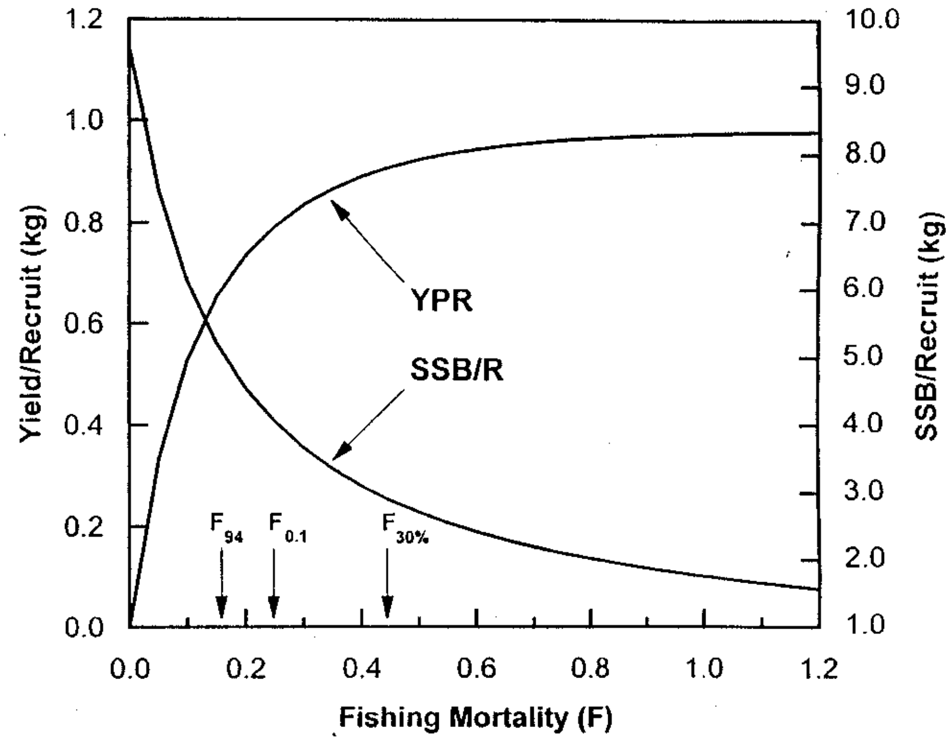

Figure C24. Yield (YPR) and spawning stock biomass (SSB/R) per recruit for Georges Bank haddock.

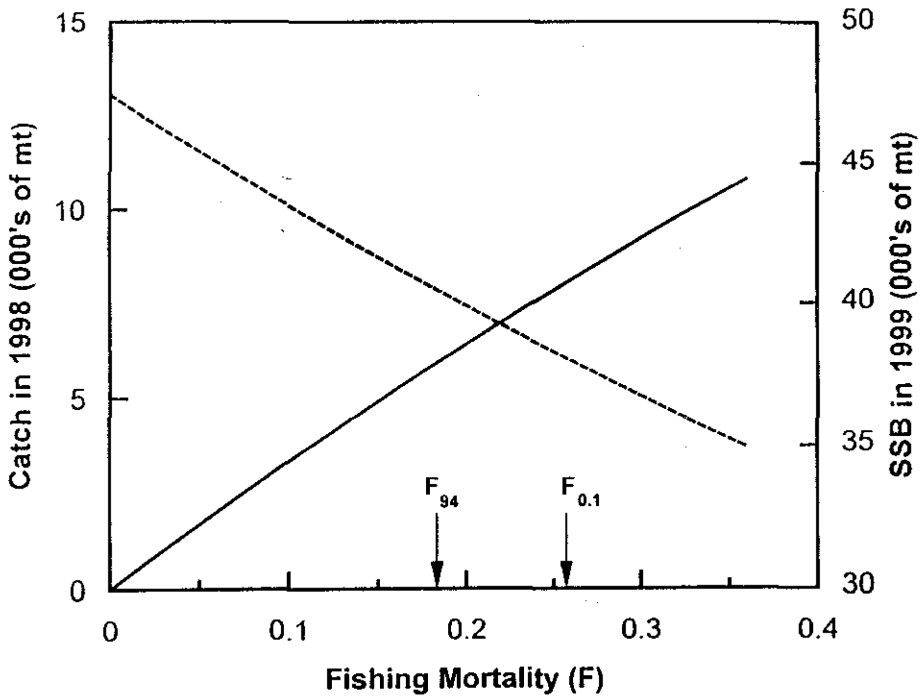

Figure C25. Results of short-term deterministic projections for the Georges Bank haddock stock. Status quo fishing mortality (F=0.18) was assumed in 1997. Haddock catch in 1998 (solid line) and spawning stock biomass at the beginning of 1999 (dotted line) are shown as a function of fishing mortality in 1998.

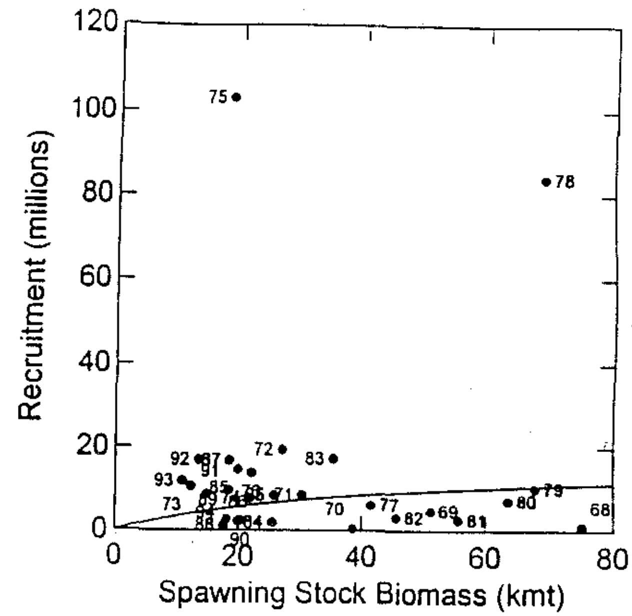

Figure C26. Spawning stock-recruitment information for Georges Bank haddock. Data are from the final ADAPT run for the 1997 assessment. Recruitment is expressed as age 1. A plot of the fitted Beverton-Holt stock/recruitment relationship is given (r=[17105.56*SSB/39738.40+SSB]).

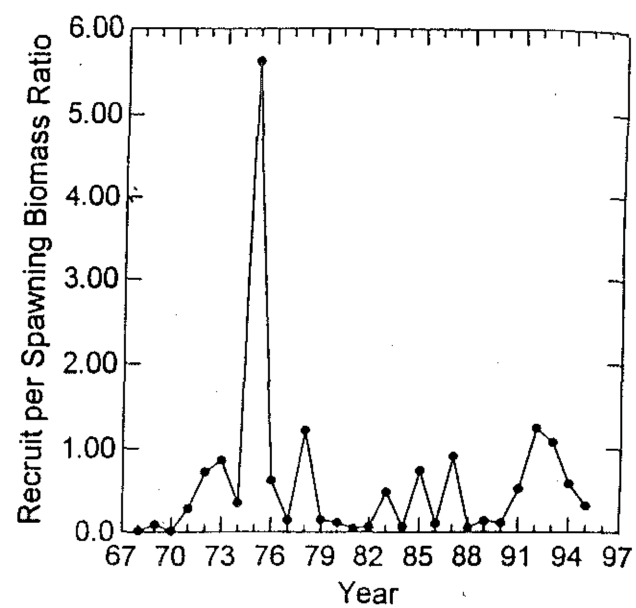

Figure C27. Calculated numbers of age 1 recruits per kilogram of spawning stock biomass for Georges Bank haddock. The median R/SSB ratio for the entire time series is 0.303, and for the last 5 year is 0.590.

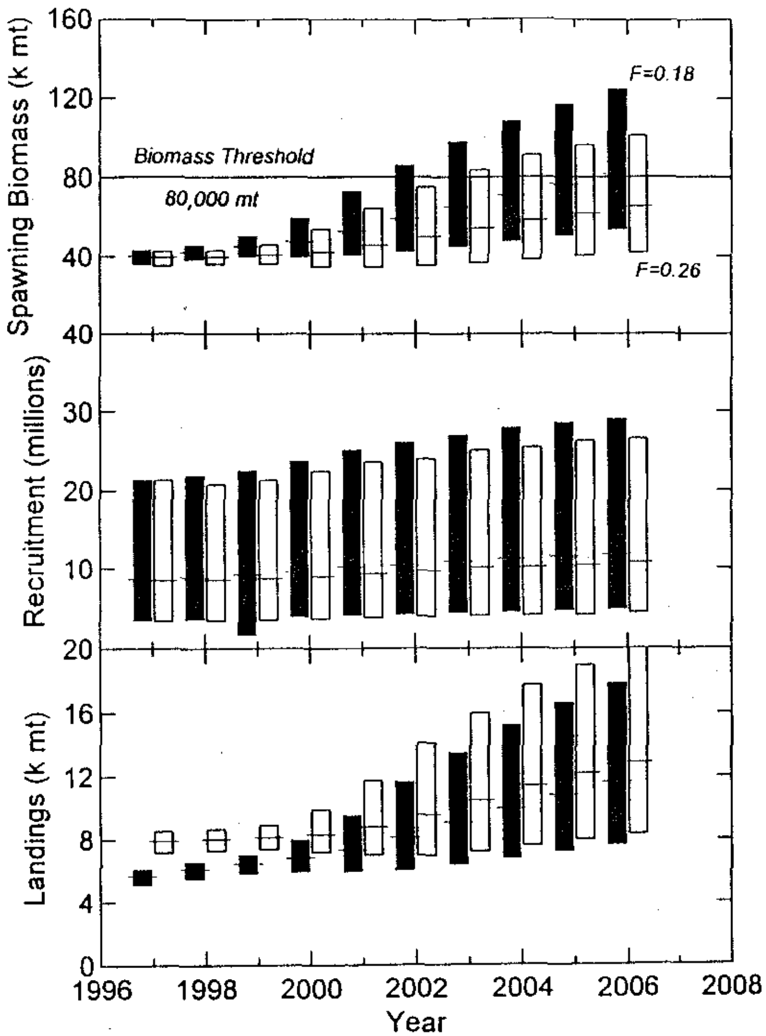

Figure C28. Results of medium-term projections for Georges Bank haddock, under three fishing mortality rate scenarios (F=0.18 [black bars], 0.26 [open bars], 0.10 [shaded bars]). Annual spawning stock biomass, recruitment, and landings are given. Horizontal bars are the median values from the bootstrap results, vertical bars are the inter-quartile range (lower 25th percentile to the upper 75th percentile).

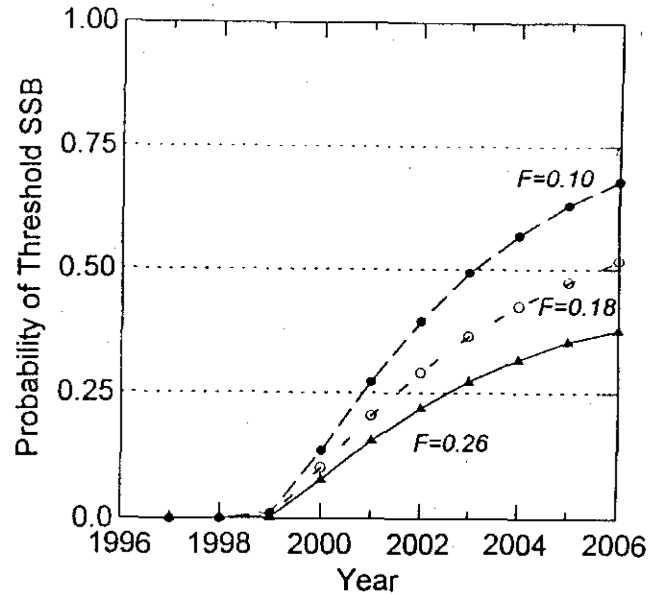

Figure C29. Annual probabilities of Georges Bank haddock spawning biomass at or above 80,000 mt, under three fishing mortality rate scenarios. Results are from medium-term stochastic projections.

D. GEORGES BANK YELLOWTAIL FLOUNDER

Terms of Reference

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

b. Provide projected estimates of catch for 1997-1998 and SSB for 1998-1999 at various rates of fishing mortality, including all relevant biological reference points.

c. Advise on the assessment and management implications of incorporating commercial discard data in the assessment.

This assessment was completed through a joint meeting of the SARC Northern Demersal and Southern Demersal Working Groups and the Canadian Maritimes Regional Advisory Process.

Introduction

Yellowtail flounder (*Pleuronectes ferrugineus* - formerly *Limanda ferruginea*), inhabit the continental shelf of the Northwest Atlantic from Labrador to Chesapeake Bay. Off the US coast, commercially important concentrations are found on Georges Bank, off Southern New England, and off Cape Cod, generally at depths between 37 and 73 m (20-40 fathoms). Yellowtail grow to 55 cm total length (Bigelow and Schroeder 1953), but high rates of fishing mortality have greatly reduced the average size and age of fish in the stocks. Yellowtail 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.

Tagging observations, larval distribution, and geographic patterns of landings and survey data indicate relatively discrete stocks on Georges Bank, in Southern New England waters, and off Cape Cod. Tag returns suggest that stock mixing is rare (Royce *et al.* 1959, Lux 1963). Concentrations of pelagic larvae are discontinuously distributed among the three US stock areas, but larval mixing occurs among stocks in some years (Silverman 1983). Survey catches from Georges Bank are significantly correlated with those from Southern New England waters, but not with those off Cape Cod. The Georges Bank yellowtail stock is defined as the entire Bank, east of the Great South Channel (Statistical Areas 522, 525, 551, 552, 561, and 562; Figure D1).

Over the past 25 years, the fishery for yellowtail flounder has been managed using several strategies. From 1971 to 1976, national quotas were allocated by the International Commission for the Northwest Atlantic Fisheries. Minimum mesh size, spawning area closures, and trip limits were imposed from 1977 to 1982 through the New England Fishery Management Council's (NEFMC) Atlantic Groundfish Fishery Management Plan (FMP). In 1982, the NEFMC adopted an Interim Groundfish Plan which established a minimum size limit of 28 cm (11 in). In 1986, the NEFMC Multispecies FMP 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 FMP 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 consistently 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). The present stock assessment is an updated and revised VPA-based assessment of US and Canadian catch (see Cadrin *et al.* 1997).

Data and Methods

Commercial Landings

US commercial landings of yellowtail flounder were derived from dealer weighout reports. Prior to 1994, landings were allocated to statistical area, month, and gear type according to interview data (Burns *et al.* 1983). From 1994 to 1996, US dealer landings were allocated to stock area using fishing vessel logbook data, by fishing gear, port, and season (Wigley *et al.* 1997). Canadian landings reported in Gavaris *et al.* (1996) were revised and updated from unclassified yellowtail trawl landings and prorated unclassified flounder landings.

The Georges Bank yellowtail stock has been exploited since the late 1930s (Table D1, Figure D2). 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 greater than 10,500 mt in 1982 and 1983. In every year since 1985, landings have been 3,000 mt or less. Landings fell to a low of 1,100 mt in 1989, averaged 2,200 from 1990 to 1994, and dropped to record lows of 200 and 800 mt in 1995 and 1996. For the first time on record, the majority of the Georges Bank yellowtail yield was landed in Canada in 1995. The Canadian fishery for yellowtail was negligible before 1989, landed less than 100 mt during 1989-1992, but increased to yield 2,100 mt in 1994. In 1995 and 1996, Canada set a total allowable catch of 400 mt, and estimated landings were under 500 mt.

The principal fishing gear used to catch 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%. Current levels of recreational and foreign fishing are negligible.

Previous stock assessments of Georges Bank yellowtail used port samples of length and age distribution by market category, quarter, and statistical area to estimate landings at age (Conser *et al.* 1991, 1973-1990; Rago *et al.* 1994, 1991-1993). For the present assessment, 1994-1996 landings by statistical area were not available, and the frequency of port sampling was not adequate for quarterly estimates. Landings at age for 1994-1996 were estimated by half-year for the entire stock. The weighted sum of port samples (by market category) was supplemented with uncategorized sea samples (Table D2). As in previous US assessments, sample length frequencies were expanded to total landings at size using the ratio of landings to sample weight (predicted from length-weight relationships by sex and season, Lux 1969b), and portioned to age using pooled-sex age-length keys. Commercial age-length keys were derived from pooled port samples and sea samples. Age distributions for lengths not represented in commercial samples were derived from survey observations. Estimates of US landings at age and mean weight at age of landed yellowtail are presented in Tables D3 and D4.

Discard Estimates

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. Previous assessments estimated age-specific discard rates using logistic functions fit to observed or approximated portions of catch discarded from trip interviews, trawl selectivity, survey length distributions, and sea sampling information (Conser *et al.* 1991, Rago *et al.* 1994). The 18th Northeast Regional Stock Assessment Review Committee recommended the development of sea sampling coverage to allow direct estimation of discards for all seasons of the fishery (NEFSC 1994b).

Sea sampling coverage has increased since 1993. The number of sampled trips which observed yellowtail catches from Georges Bank was 22 in 1994, 16 in 1995, and 18 in 1996. Ratios of discard per kept weights recorded by observers varied considerably over time and among gear types. Semi-annual estimates of discard per kept ranged from 2-17% for trawl trips and 79-326% for scallop dredge trips. All sampled trawl trips used 152 mm (6 in) mesh. Total discards ($D_{t,g}$) by half-year and gear type were estimated by the product of total landings ($K_{t,g}$) and the ratio ($R_{t,g}$) of mean discards per trip (d_i) to mean landings per trip (k_i) for all sampled trips ($n_{t,g}$) in half-year t using gear type g according to Cochran (1977) (Table D5):

$$R_{t,g} = [(\sum d_{i,t,g})/n_{t,g}] \,/\, [(\sum k_{i,t,g})/n_{t,g})] = (\sum d_{i,t,g}) \,/\, (\sum k_{i,t,g}) \quad (1)$$

$$D_{t,g} = K_{t,g} \mathrm{R}_{t,g} \quad (2)$$

Sample variance of ratio estimates of total discards within half-year and gear types [Var($D_{t,g}$)] was estimated:

$$\mathrm{Var}(D_{t,g}) = \{[N_{t,g}^{\,2}(1\text{-}n_{t,g}/N_{t,g})]/[n_{t,g}(n_{t,g}\text{-}1)]\} \sum (d_{i,t,g} - R_{t,g}k_{i,t,g})^2 \quad (3)$$

where $N_{t,g}$ is the total number of trips in half-year t with gear type g [estimated from landings by half-year and gear and logbook catch per trip for trips which caught yellowtail in the stock area (Table D6)], $d_{i,t,g}$ indicates weight of yellowtail discards from trip i, and $k_{i,t,g}$ indicates weight of landed yellowtail from trip i. Annual discard ratios for 1994-1996 were 14%, 18% and 7% and total discard estimates were 215 mt, 52 mt, and 50 mt, respectively. Unfortunately, there was an insufficient number of trips in many half-year/gear strata (n = 0-14) for precise ratio estimates.

Alternatively, discard ratios were derived from vessel trip reports (Table D6). All trip logs that had a valid statistical area and reported discards of any species were included in the analysis. Landings of the subset of trips which met these criteria had similar spatial-temporal patterns, gear distributions, and target species as landings from all trips in the database with valid statistical area (DeLong *et al.* 1997). Similar to sea sampling indications, discard ratios varied among half-year and gear groups: trawl fishermen reported 4-10% of yellowtail being discarded, and dredge fishermen reported 57-284% discards. The proportion of small mesh trips was 6%, 1%, and 5% in 1994, 1995, and 1996, respectively. Annual discard ratios for 1994-1996 from logbooks were approximately 10% each year, and total discard estimates were 158 mt, 30 mt, and 71 mt, respectively. Total discards from the dredge fishery were comparable in magnitude to those from the trawl fishery because of higher discard ratios. Comparison to discard rates observed during sea sampling suggests that logbook estimates are not significantly underestimated (Figure D3). Estimates of total discards for 1994-1996 were based on logbook data because the larger number of trips are more likely to represent the entire fishery.

Sea sampling length observations were used to characterize the age composition of discards for 1994-1996 by gear and half-year, except for trawl discards in July-December 1996 and first-half dredge discards when there were insufficient samples (Table D7). The length distribution of the 11 mt of trawl discards in the second half of 1996 was approximated using the fall survey length frequency, 1994-1996 retention at size [approximated by the ratios at length of cumulative size distributions from the fishery and surveys (NEFSC 1995)], and 1994-1996 discard ratios at size. Pooled January-June 1994 and 1996 samples were used to characterize the 17, 1, and 8 mt of dredge discards from the first halves of 1994, 1995, and 1996, respectively. The dredge fishery discarded a much wider range of sizes than the trawl fishery resulting from less selective gear and groundfish trip limits. Sea sampled ages were supplemented with age-at-length observations from port samples at larger sizes. Estimated discards at age and mean weight of 1994-1996 discards are presented in Table D8.

A limited number of sea samples suggests that Canadian discarding was relatively small before 1996 (Gavaris *et al.* 1996). In 1996, 11 mt of yellowtail was discarded from the Canadian scallop fishery and is included in estimates of total Canadian catch at age (Table D9). The total catch at age used for virtual population analysis is presented in Table D10. A description of concerns about the reliability of recent estimates of catch at age is included in the **Discussion** section below.

Stock Abundance and Biomass Indices

NEFSC spring and autumn bottom trawl survey catches (Strata 13-21, Figure D4), NEFSC scallop survey catches (Strata 54-74, Figure D5), and Canadian bottom trawl survey catches (Strata 5Z1-5Z4, Figure D6) were used to estimate relative stock biomass and relative abundance at age for Georges Bank yellowtail (Tables D11-D14). Standardization coefficients, which compensate for survey gear changes in NEFSC groundfish surveys (door, vessel, and net; see **Data and Methodology Issues** section of this report), were applied to the catch of each tow. Abundance and biomass indices from NEFSC groundfish surveys have generally declined at a rate of 10% per year since 1963 (Tables D11 and D12, Figure D7). Several large year classes have temporarily interrupted the overall rate of decline, but the general trend has persisted. Between 1963 and 1969, autumn survey indices averaged 26 fish per tow; in the last six years, the average was less than 4 fish per tow. Declines in average weight per tow suggest that current biomass levels are about 10% of the levels observed in the 1960s. However, there are indications of increasing stock levels in the last two years.

Scallop survey indices of yellowtail abundance at age were evaluated in the previous assessment of Georges Bank yellowtail, but were not used to calibrate the VPA because they were not well correlated to population estimates (Rago *et al.* 1994). However, strata near the US/Canada interjurisdictional boundary were inadvertently omitted from previous analyses. The current assessment includes all strata on Georges Bank (54-74, including post-1985 3-digit strata [621, 622, 631, 632, 651, 652, 661, 662]), except for Strata 56, 57, and 73 because they have not been sampled since 1988. Revised scallop survey indices were delta transformed (Pennington 1986) because there is a high proportion of tows with no yellowtail catch. The scallop survey index decreased in the 1980s, but increased to above-average catches in the last four years (Table D13, Figure D8).

The Canadian spring survey has been conducted since 1987. The Canadian yellowtail index generally increased to peak catches in 1996 (Table D14, Figure D9). Preliminary estimates from the 1997 Canadian survey are even greater than those in 1996 (47 fish per tow).

The NEFSC winter survey has superior gear for efficiently sampling a wide size range of flatfishes. Unfortunately, strata on Georges Bank which are important for measuring stock abundance of yellowtail have not been consistently sampled over the survey time series.

Correspondence among survey indices was assessed using log correlations within ages (Rago *et al.* 1994) (Table D15). Normalized indices of catch per tow at age are illustrated in Figure D10. VPA estimates of abundance from Rago *et al.* (1994) and Gavaris *et al.* (1996) were also included in correlation analyses. The strongest correlation among age 2+ indices of abundance was between the NEFSC spring and fall surveys ($r = 0.6$). The Canadian survey and scallop survey age 2+ indices were moderately correlated with spring and fall NEFSC indices ($r = 0.2$-0.6). The strongest correlations among age 1 indices were between the scallop index and the other NEFSC indices ($r = 0.7$ with spring and $r = 0.8$ with fall). The age 1 index from the Canadian survey was not well correlated with other age 1 indices ($r < 0.2$). The NEFSC age 2 spring index was strongly correlated with the NEFSC fall ($r = 0.8$) and the Canadian index ($r = 0.7$). The scallop age 2 index was moderately correlated with other NEFSC indices ($r = 0.5$ with spring and $r = 0.6$ with fall). Spring and fall NEFSC indices of age 3 abundance were strongly correlated ($r = 0.8$), and correlations were moderate to strong among all other age 3 indices. Spring and fall NEFSC indices of age 4 abundance were also strongly correlated ($r = 0.8$), and correlations were moderate to strong among all other age 4 indices. Correlations among age 5+ aggregate indices were considerably lower than those for younger ages. In summary, there is moderate to strong correlation among abundance indices at age (except for the Canadian age 1 index), and the strongest correlations were among age 3 and age 4 indices.

Virtual Population Analysis

VPA of total catch of ages 1-6+, 1973-1996, was calibrated using ADAPT (Gavaris 1988) which estimated age 2-5 survivors in 1997 and survey catchability coefficients (q) according to agreement of relative survey indices with computed abundance using nonlinear least squares. The instantaneous rate of natural mortality (M) was assumed to be 0.2 based on tag returns (Lux 1969a) and relationships of Z to effort (Brown and Hennemuth 1971). Observations of 11-year-old yellowtail from NEFSC surveys corroborate that M is substantially less than 0.3. Yellowtail older than 4 years were assumed to be fully-recruited to estimate F for ages 5 and 6+ for all years in the VPA. Eighteen series of survey indices were used in the VPA calibration (all except age 1 from the Canadian survey):

Tuning Indices for VPA Calibration

Survey	Age 1	Age 2	Age 3	Age 4	Age 5+
NEFSC spring	X	X	X	X	X
Scallop	X	X	X	X (4+)	
NEFSC fall	X	X	X	X	X
Canada		X	X	X	X

The Canadian age 1 index was excluded because it was not well correlated with other indices. An age 4+ index was derived from the scallop survey because the survey gear rarely catches older yellowtail. The NEFSC spring survey and the Canadian survey were used to indicate abundance at the beginning of the year, and the scallop and fall surveys were used as indices of mid-year abundance.

As recommended by the SAW-18, percent mature at age was based on observations from the NEFSC spring survey within continuous periods of similar stock biomass [1973-1991 from Almeida and Burnett (1997); 1992-1996 from spring survey observations]: age 2 were 42-49% mature in years of moderate-to-high stock biomass (1973-1983), increased to 93% at low stock biomass (1984-1991), and decreased to 52% during stock rebuilding (1992-1996).

VPA calibration accounted for 72% of the initial sum of squares and the mean square residual was 0.77. Approximate coefficients of variation (CVs) for abundance estimates ranged from 22% to 53% and improved with age. Estimates of q for each index were well estimated (CV = 18-23%). There were no substantial correlations among parameter estimates ($|r| < 0.15$). Although the model generally fit the data well, there were some patterns in survey residuals (Figures D11a-D11d). Several indices had trended residuals (e.g., NEFSC spring ages 1, 4, and 5+; scallop age 3; fall age 2), there were correlated errors (i.e., all surveys had some years when residuals for all ages were negative or all were positive), and there were two statistical outliers (i.e., the absolute standardized residual was >3).

Variance and model bias of estimates were assessed using bootstrap analysis of the VPA calibration. Two hundred 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 1 (CV = 77%), but decreased with age (CV = 22% for ages 4-6). Bootstrap analysis indicates that the SSB in 1997 was well estimated (CV = 16%). On average, bootstrap analyses indicate that results from the VPA calibration are insensitive to the effects of minor statistical problems (i.e., trended residuals, correlated errors, and outliers). Estimates of bias were relatively low (1-7% for abundance estimates, 4% for

F (ages 4+), and 3% for SSB), which are substantial improvements from the previous assessment.

Consistency of VPA estimates was assessed using retrospective analysis (Sinclair *et al.* 1990). Unfortunately, the number of retrospective comparisons was limited by the length of the Canadian survey. 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 200 bootstrap estimates of age 2-6+ 1997 abundance. Projections through 1999 were simulated for each of the 200 abundance estimates by randomly sampling point estimates of 1973-1996 age 1 abundance 100 times (totaling 20,000 simulated trajectories). Projections assumed geometric mean partial recruitment during 1994-1996, mean discard ratios at age in 1994-1996, mean weight of landings at age in 1994-1996, and proportion mature at age from 1992-1996 survey observations.

Medium-term forecasts (i.e., 10-year) incorporated a Beverton-Holt (1957) spawning stock-recruit relationship with lognormally distributed error to simulate 1997-2006 recruitment (Overholtz *et al.* 1997). Similar to short-term projections, the medium-term forecasts assumed geometric mean partial recruitment for 1994-1996, mean discard ratios at age in 1994-1996, mean weight of landings at age in 1994-1996, and proportion mature at age from the 1992-1996 survey observations.

Surplus Production Model

SAW-18 concluded that age-based assessments of Georges Bank yellowtail flounder have been complicated by the truncated age structure and poor characterization of catch at age, and exploration of alternative assessment methods was recommended (NEFSC 1994b). Therefore, a nonequilibrium surplus production model incorporating covariates (ASPIC; Prager 1994, 1995) was implemented using total catch and survey indices of stock biomass from 1963 to 1996. Estimates of initial biomass (B_1), maximum sustainable yield (MSY), intrinsic rate of increase (r), and catchability of each survey (q) were estimated using nonlinear least squares of survey residuals. The fall survey catch per unit effort (CPUE) contributed to the total sum of squares as a series of observed effort (E = CPUE/C); the NEFSC and Canadian spring surveys contributed as independent biomass indices at the beginning of the year. The NEFSC scallop survey does not measure weights and was not included as a biomass index. Correlations among survey biomass indices were moderate to strong (r = 0.5, 0.7, and 0.8). Residual variance was explored in parameter space to identify areas of local minima. The model was initially constrained to avoid local minima, but removal of constraints produced negligible changes in parameter estimates and slight increases in variance of estimates. Most of the variance in survey indices was explained by the simple biomass dynamics model (R^2 = 0.69, 0.56, and 0.71). There were some runs of either positive or negative survey residuals, but the overall magnitude of the residuals appears small (Figure D12). Effort residuals from the fall survey significantly increased over time indicating that the model was predicting greater biomass than observed from the survey. Biomass estimates for the first two to five years of the analysis (1963 to 1964-1966) are imprecise and not considered reliable (Prager 1994, 1995).

Survey residuals were randomly resampled 500 times to estimate precision and model bias. Bootstrap analysis showed that B_1, MSY, and r were very well estimated (the relative interquartile ranges were <9%), and survey qs were slightly more variable (relative IQS = 7-18%). Bootstrap calculations of K, B_{MSY}, and F_{MSY} were stable (relative IQs = 1-8%), but ratios of current conditions to MSY conditions were less precise (relative IQs = 22-31%). The 1997 yield was projected using the current biomass estimate and the expected rate of change at the current biomass and assumed levels of F. Estimates of bias were less than 7% for all estimates in the production model.

Results

Virtual Population Analysis

VPA indicated that stock abundance of Georges Bank yellowtail was greater than 100 million fish in the early 1970s and was supported by several strong year classes (Table D16). Stock levels rapidly declined in the early 1980s from poor recruitment and extremely high F and remained low through the 1980s. Total stock abundance gradually increased from 18 million fish in 1987 to the current level, which is less than half of the 1973 abundance. F (age 4+) averaged 1.2 during 1973-1994 and was greater than 0.9 each year until 1995 (Figure D13, Table D17). F decreased from 1.7 in 1994 to 0.1 in 1996.

The estimated time series of recruitment is dominated by four strong year classes of greater than 50 million fish at age 1 (1973, 1974, 1977, and 1980 year classes) (Figure D14, Table D16). All other cohorts produced since 1973 were less than 25 million at age 1. The 1990-1994 cohorts were moderately abundant, but the 1995 cohort was the weakest since 1986.

SSB was 21,000 mt in 1973 and declined to less than 4,000 mt during 1984-1988 (Figure D14, Table D18). SSB fluctuated below 6,000 mt from 1989 to 1994 and increased to 11,700 mt in 1996. The relationship between SSB and recruitment is variable, but some general patterns are suggested (Figure D15). The four strong cohorts in the time series were produced when SSB exceeded 7,500 mt. When SSB was greater than 10,000 mt, three of the six cohorts were strong. When SSB was 7,500-10,000 mt, only one of five cohorts was strong, and when SSB was less than 7,500 mt, no strong year classes were produced.

The distribution of bootstrap estimates of fully-recruited F suggests that there is an 80% chance that F_{96} was between 0.08 and 0.14, and there is nearly 0% probability that F_{96} exceeded $F_{0.1}$ (0.25; Conser *et al.* 1991) (Figure D16). The distribution of bootstrap estimates of SSB suggests that there is an 80% probability that the SSB in 1996 was between 9,800 and 14,600 mt, and a 12% chance that it was below the rebuilding threshold of 10,000 mt (NEFMC 1996) (Figure D17).

Retrospective analysis showed that, although some retrospective differences were substantial, there were no patterns of positive or negative inconsistency. Estimates of abundance at ages 1 and 2 were not consistent (Figure D18). For example, initial estimates of abundance of the 1990 and 1993 cohorts were much greater than revised estimates, presumably resulting from imprecise discard estimates. Terminal estimates of abundance for the 1995 year class may also prove to be inconsistent with future assessments. However, abundance estimates in penultimate years were relatively consistent. Fully-recruited F estimates were more consistent, and SSB estimates were very consistent.

Sensitivity analyses were performed to explore two aspects of the VPA calibration. The accuracy of age 1 discards in 1992 and 1993 was suspect because the retention model used to estimate them had no age 1 landings information (Rago *et al.* 1994). Age 1 indices for 1992 and 1993 were removed from the VPA calibration to examine the sensitivity of estimates to discard inaccuracies in those years. The other aspect of VPA tuning which was explored was log transformation of NEFSC groundfish surveys for VPA calibration because survey catches are skewed and indices are sensitive to rare large catches. Results from four permutations of alternative ADAPT runs were very similar (Table D19). All catch data and untransformed survey data were used in the accepted run (Tables D16-D18) because results were not sensitive to log transformation or excluding 1992 and 1993 age 1 from the calibration.

Age-based projections suggest that, at $F_{0.1}$, landings and SSB will continue to increase in the next three years (Figures D19 and D20). At F_{96} = 0.10, landings decrease to approximately 1,200 mt in 1997, then increase to 1,400 mt in 1998 and 1,600 mt in 1999; SSB increases to approximately 13,000 mt in 1997, 16,000 mt in 1998, and 19,000 mt in 1999 (Table D20). Fishing at $F_{0.1}$ = 0.25, landings increase to 2,700 mt in 1997, 2,800 mt in 1998, and 2,900 mt in 1999; SSB increases to 13,000 in 1997, 14,000 mt in 1998 and 15,000 in 1999 (Table D20).

Age-Based Short-Term Projections of Landings and SSB (mt)

F	1997		1998		1999	
	Landings	SSB	Landings	SSB	Landings	SSB
F_{96}	1,200	13,300	1,400	16,000	1,600	18,900
$F_{0.1}$	2,700	12,700	2,800	13,800	2,900	15,200

Medium-term projections included the stock-recruitment data and the fitted Beverton-Holt equation presented in Figure D15. The median, lower 25th, and upper 75th percentiles of projected spawning stock biomass, recruitment (age 1), and landings are given in Tables D21 and D22 and Figure D21 for fishing mortality rate scenarios of F = 0.10 and 0.25.

Under F = 0.10, landings increase from 1,400 mt in 1998 to 5,500 mt in 2006, while spawning stock biomass increases from 17,500 mt in 1998 to 71,600 mt in 2006, and median recruitment improves from 31.1 to 59.8 million fish (Table D21). For the F_{max} = 0.25 scenario, landings rise steadily from 2,800 mt in 1998 to 8,400 mt in 2006, while SSB improves from 14,900 mt to 46,200 mt and recruitment from 29.1 to 47.2 million during 1998-2006 (Table D22). For all years of the medium-term simulations, there is a 100% probability that SSB exceeds the 10,000 mt threshold.

Surplus Production Model

Patterns of stock biomass and F from VPA and the surplus production model were similar (Figure D22, Table D23). The biomass dynamics model indicated that a maximum sustainable yield (MSY) of 12,800 mt can be produced by the Georges Bank yellowtail stock when total stock biomass is approximately 37,500 mt (B_{MSY}) and F (age 1+) is approximately 0.3 (F_{MSY}). Total stock biomass was greater than 45,000 mt in the late 1960s. However, after 1967, F exceeded F_{MSY}, and biomass began to decline. F continued to exceeded F_{MSY} until 1994. By 1971, biomass was reduced to less than B_{MSY} and continued declining to approximately 4,000 mt in the late 1980s. In 1995, F sharply decreased, and biomass began to increase in 1996. However, in 1996, biomass was only 29% of B_{MSY}. Yield, F, and biomass trajectories illustrate that stock biomass and yield have had delayed responses to changes in F (Figure D23).

Projections of 1997 catch from the production model indicate that, at the current level of F, landings will increase to approximately 2,000 mt. Projection results differ between VPA and the surplus production model because age-based projections used estimated abundance at age and assume average 1994-1996 stock conditions (partial recruitment, mean weight, and maturation) and the production model projections assume that population growth is a function of current biomass and assumed F levels (Figure D24). At relatively low biomass and low F, the production model assumes a rapid growth rate in 1997.

Biological Reference Points

Conser *et al.* (1991) estimated biological reference points using yield- and spawning stock biomass-per-recruit models. Analyses were revised with 1994-1996 estimates of mean weight, partial recruitment, and maturity at age. $F_{0.1}$ was estimated as 0.24, F_{max} was 0.61, and $F_{20\%}$ was 0.64. However, as discussed below, there were considerable sources of uncertainty in recent estimates of mean weight and partial recruitment at age, and reference points reported here should be considered provisional. Yield-per-recruit results from the previous analysis ($F_{0.1}$ = 0.25, F_{max} = 0.63; Conser *et al.* 1991) may still be applicable to the current fishery because the assumed conditions (e.g., mean weights, exploitation pattern) appear to be similar to current conditions.

SARC Comments

The adequacy of commercial sampling in recent years and the resulting accuracy of catch-at-age estimates was questioned because mean weight at age substantially increased in 1996 and there was a discrepancy between US age-length keys and patterns in the Canadian catch at length. Fall survey ages may not accurately characterize Canadian landings. Estimation of catch at age is complicated by changing spatial patterns of fishing and low levels of sampling, particularly in 1994 and 1995. Canadian commercial samples show distinct length modes for each sex. However, this pattern is not observed in US samples. US commercial age-length keys do not indicate substantial differences in patterns of length at age by sex. Although Canadian landings are from a relatively restricted segment of the stock's potential range, there was no simple explanation for the different patterns of length composition by sex between the two fisheries. At present, only landings and the Canadian survey can be estimated by sex; discards and other calibration indices can not because US sea sampling data and survey data are not collected by sex.

The SARC concluded that each assessment method (VPA and surplus production) has strengths and weaknesses. For example, the VPA should generate more informative projections, since age structure in the current year is included. The surplus production model is able to employ all survey years, whereas the VPA does not due to problems in reconstructing the fishery catch at age prior to 1973. Results from surplus production modeling strongly suggest that stock biomass is far below the level which would produce MSY (37,500 mt). Therefore, the basis of the 10,000 mt SSB rebuilding threshold should be re-examined.

The SARC suggested that if the stock's age structure continues to rebuild, the number of ages in the VPA should be expanded. An increasing trend in fall survey residuals was observed in the ADAPT calibration and the production model. There was some concern that the scallop survey had large year effects and has different size selectivity. The pattern of catchability estimates for the scallop survey was discussed (0.03, 0.02, 0.04, and 0.05 for ages 1, 2, 3, and 4+, respectively). It was speculated that using age-length keys from the fall survey (which has different size selectivity) may inflate the apparent catchability of age 1 fish in the scallop survey.

Although the ASPIC model fit the data fairly well, the SARC recommended that other models should also be explored (e.g., age-structured production models, modified DeLury analysis). It was noted that MSY, B_{MSY}, and F_{MSY} estimates may be helpful for conforming to the new national standards for overfishing definitions. The SARC recommended that the production model should be extended back to 1935. A revised ASPIC analysis was presented including historical catch and landings per unit effort as an index of biomass for 1943-1966 (Lux 1964, 1969a). The model did not fit the data well using several starting values for biomass and model formulations, but the results suggested that stock biomass exceeded 60,000 mt before 1963 (Figure D25). Estimates of MSY, r, K, and q were not sensitive to extending the time series, including the LPUE series, attempting several starting values of B_1, and changing the model formulation.

Some realizations of the medium-term projections suggest SSBs that are in excess of the carrying capacity (K) estimated from surplus production models. An older 'plus group' and compensatory growth and maturity should be incorporated into the medium-term projections to more realistically model stock rebuilding. The SARC requested a presentation of the time series of recruits per SSB to assess recent patterns in survival. The data showed that survival ratios have fluctuated widely without trend (Figure D26). The median R/SSB ratio for the 1973-1994 time series was 3.5 recruits per kg of spawners, and was 4.2 for 1990-1994. The SARC noted that the SSB threshold should be regarded as a minimum level and not a target.

The SARC concluded that the major issues raised by the Working Group and the RAP (changing maturity schedules, concerns with catch-at-age estimation, and sexually dimorphic growth) were adequately addressed for this assessment. However, changes in survey and sea sampling protocols may be required to address sexually dimorphic growth for a stock with more robust age structure.

Research Recommendations

- The possibility of extending the VPA time series back to the 1960s should be explored to provide a better perspective on historical stock abundance.

- Quarterly port samples and sea samples of length and age from both US and Canadian fisheries are required for better estimates of catch at age.

- Reliability of vessel trip report information should be further assessed and improved. For example, efforts should be made to reduce the proportion of trips that report no discards of any species.

- Changes in maturity should be closely monitored by increasing the number of age and maturity samples from spring surveys.

- The NEFSC winter survey should be modified to ensure coverage of Georges Bank strata, particularly Stratum 16.

- Although bias estimates for this assessment were relatively small and inconsequential to the conclusions, methods to investigate model bias should be continued.

- Yield-per-recruit and percent maximum spawning potential reference points should be revised when more reliable estimates of mean weight and partial recruitment at age are available.

- Evaluate the consistency of sex identification in field sampling programs and the feasibility of sampling protocols required to estimate catch at age and survey indices by sex.

- The number of ages in the VPA and age-based projections should be expanded, if possible.

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Table D1. Georges Bank yellowtail flounder landings (thousand mt) from statistical areas 522, 525, 551, 552, 561, 562.

Year	U.S.	Canada	Foreign	Total
1935	0.3	0.0	0.0	0.3
1936	0.3	0.0	0.0	0.3
1937	0.3	0.0	0.0	0.3
1938	0.3	0.0	0.0	0.3
1939	0.4	0.0	0.0	0.4
1940	0.6	0.0	0.0	0.6
1941	0.9	0.0	0.0	0.9
1942	1.6	0.0	0.0	1.6
1943	1.3	0.0	0.0	1.3
1944	1.7	0.0	0.0	1.7
1945	1.4	0.0	0.0	1.4
1946	0.9	0.0	0.0	0.9
1947	2.3	0.0	0.0	2.3
1948	5.7	0.0	0.0	5.7
1949	7.3	0.0	0.0	7.3
1950	3.9	0.0	0.0	3.9
1951	4.3	0.0	0.0	4.3
1952	3.7	0.0	0.0	3.7
1953	2.9	0.0	0.0	2.9
1954	2.9	0.0	0.0	2.9
1955	2.9	0.0	0.0	2.9
1956	1.6	0.0	0.0	1.6
1957	2.3	0.0	0.0	2.3
1958	4.5	0.0	0.0	4.5
1959	4.1	0.0	0.0	4.1
1960	4.4	0.0	0.0	4.4
1961	4.2	0.0	0.0	4.2
1962	7.7	0.0	0.0	7.7
1963	11.0	0.0	0.1	11.1
1964	14.9	0.0	0.0	14.9
1965	14.2	0.0	0.8	15.0
1966	11.3	0.0	0.3	11.6
1967	8.4	0.0	1.4	9.8
1968	12.8	0.0	1.8	14.6
1969	15.9	0.0	2.4	18.3
1970	15.5	0.0	0.3	15.8
1971	11.9	0.0	0.5	12.4
1972	14.2	0.0	2.2	16.4
1973	15.9	0.0	0.3	16.2
1974	14.6	0.0	1.0	15.6
1975	13.2	0.0	0.1	13.3
1976	11.3	0.0	0.0	11.3
1977	9.4	0.0	0.0	9.4
1978	4.5	0.0	0.0	4.5
1979	5.5	0.0	0.0	5.5
1980	6.5	0.0	0.0	6.5
1981	6.2	0.0	0.0	6.2
1982	10.6	0.0	0.0	10.6
1983	11.3	0.0	0.0	11.3
1984	5.8	0.0	0.0	5.8
1985	2.5	0.0	0.0	2.5
1986	3.0	0.0	0.0	3.0
1987	2.7	0.0	0.0	2.7
1988	1.9	0.0	0.0	1.9
1989	1.1	<0.1	0.0	1.1
1990	2.7	<0.1	0.0	2.7
1991	1.8	<0.1	0.0	1.8
1992	2.8	<0.1	0.0	2.8
1993	2.1	0.8	0.0	2.9
1994	1.6	2.1	0.0	3.7
1995	0.3	0.5	0.0	0.8
1996	0.8	0.5	0.0	1.3

Table D2. Sample sizes for estimates of U.S. landings at age of Georges Bank yellowtail flounder, 1994-1996.

			Port Samples			Sea Samples			Survey	Landings
year	months	size	trips	lengths	ages	trips	lengths	ages	ages	(mt)
1994	Jan-Jun	small	1	95						75.5
		large	1	93						122.4
		all	1	188	53	14	400	0	4	197.9
1994	Jul-Dec	small	7	847						633.1
		large	7	596						757.5
		all	7	1,443	353	8	2,150	73	4	1390.6
1995	Jan-Jun	small	2	235						64.7
		large	4	345						95.9
		all	4	580	166	11	611	43	3	160.6
1995	Jul-Dec	small	0	0						67.7
		large	1	81						63.8
		all	1	81	23	5	89	0	22	131.5
1996	Jan-Jun	small	2	250						158.8
		large	3	254						362.1
		all	3	504	146	15	415	65	2	520.9
1996	Jul-Dec	small	3	382						116.8
		large	3	274						113.6
		all	3	656	173	3	106	9	0	230.4

Table D3. U.S. landings at age (thousands) of Georges Bank yellowtail flounder (1973-1990 from Conser et al. 1991; 1991-1993 from Rago et al. 1994).

	Age								
Year	1	2	3	4	5	6	7	8+	Total
1973	0	3,837	13,076	9,274	3,743	1,259	278	81	31,548
1974	180	6,297	7,818	7,397	3,544	852	452	173	26,713
1975	427	16,851	6,943	3,391	2,084	671	313	164	30,844
1976	43	19,320	5,085	1,347	532	434	287	147	27,195
1977	31	6,616	9,805	1,721	394	221	129	124	19,041
1978	0	2,140	3,970	1,660	459	102	37	35	8,403
1979	17	6,804	3,396	1,242	550	141	79	52	12,281
1980	0	2,371	8,696	1,419	321	85	4	10	12,906
1981	6	479	5,267	4,555	796	122	4	0	11,229
1982	217	13,132	7,061	3,245	1,031	62	19	3	24,770
1983	239	7,667	16,016	2,316	625	109	10	8	26,990
1984	244	1,913	4,266	4,734	1,592	257	47	17	13,070
1985	371	3,335	816	652	410	60	5	0	5,649
1986	90	5,733	978	347	161	52	16	8	7,385
1987	15	1,819	2,730	761	132	39	32	41	5,569
1988	0	1,650	1,181	624	165	15	20	3	3,658
1989	0	1,337	664	262	68	11	8	0	2,350
1990	0	735	4,582	738	105	17	3	0	6,180
1991	0	27	867	2,256	289	56	4	0	3,499
1992	0	3,183	1,891	1,176	502	20	7	0	6,779
1993	0	375	1,538	1,392	287	65	4	1	3,662
1994	0	129	2,614	853	253	40	8	1	3,897
1995	0	12	272	281	70	3	11	3	651
1996	0	161	751	482	144	5	5	1	1,550
mean	78	4,413	4,595	2,172	761	196	74	36	12,326

Table D4. Mean weight (kg) at age of U.S. landings of Georges Bank yellowtail flounder.

	Age								
Year	1	2	3	4	5	6	7	8+	All
1973	0.198	0.375	0.464	0.527	0.603	0.689	1.067	1.136	0.504
1974	0.200	0.378	0.500	0.609	0.680	0.725	0.906	1.249	0.542
1975	0.211	0.340	0.492	0.554	0.618	0.687	0.688	0.649	0.427
1976	0.185	0.339	0.545	0.636	0.741	0.814	0.852	0.866	0.416
1977	0.197	0.364	0.527	0.634	0.782	0.865	1.036	1.013	0.495
1978	0.182	0.337	0.513	0.684	0.793	0.899	0.930	0.948	0.526
1979	0.139	0.356	0.462	0.649	0.728	0.835	1.003	0.882	0.443
1980	0.138	0.354	0.495	0.656	0.813	1.054	1.256	1.214	0.499
1981	0.091	0.389	0.493	0.603	0.707	0.798	0.832	1.044	0.552
1982	0.213	0.313	0.487	0.650	0.748	1.052	1.024	1.311	0.426
1983	0.215	0.296	0.440	0.604	0.736	0.952	1.018	0.987	0.420
1984	0.208	0.240	0.378	0.500	0.642	0.738	0.944	1.047	0.441
1985	0.236	0.363	0.497	0.647	0.733	0.819	0.732	1.044	0.439
1986	0.234	0.343	0.540	0.664	0.823	0.864	0.956	1.140	0.399
1987	0.212	0.338	0.523	0.666	0.680	0.938	0.793	0.788	0.491
1988		0.351	0.557	0.688	0.855	1.054	0.873	1.385	0.504
1989		0.355	0.543	0.725	0.883	1.026	1.254	1.044	0.471
1990		0.337	0.419	0.588	0.699	0.807	1.230	1.044	0.436
1991		0.270	0.383	0.484	0.728	0.820	1.306	1.044	0.484
1992		0.341	0.381	0.528	0.648	1.203	1.125	1.044	0.411
1993		0.316	0.390	0.510	0.562	0.858	1.263	1.044	0.451
1994		0.300	0.355	0.473	0.629	0.787	0.896	1.166	0.403
1995		0.309	0.379	0.465	0.583	0.778	0.785	0.531	0.446
1996		0.321	0.417	0.569	0.726	0.926	1.031	1.209	0.488
mean	0.191	0.334	0.466	0.596	0.714	0.874	0.992	1.035	0.463

Table D5. Estimated discards of Georges Bank yellowtail flounder from sea sampling observations.

	1994					1995					1996				
	Jan-Jun		Jul-Dec		annual	Jan-Jun		Jul-Dec		annual	Jan-Jun		Jul-Dec		annual
	trawl	dredge*	trawl	dredge*	total	trawl	dredge*	trawl	dredge*	total	trawl	dredge	trawl	dredge	total
total landings (mt)	168	0	1,381	40	1,588	160	0	123	9	292	519	3	223	7	751
trips with discard	14	0	4	4	22	11	0	3	2	16	12	3	1	2	18
total kept (mt)	10.71		10.30	0.04		2.06		0.90537 96607	0.03084 45977		12.9892 04391	0.02131 90601	0.04626 68965	0.06373 03819	
total discard (mt)	0.24		0.61	0.12		0.31		0.15558 37794	0.02449 42393		0.60872 72067	0.02630 86274	0.00226 79851	0.10133 35753	
discard/kept	0.02		0.06	3.26		0.15		0.17	0.79		0.05	1.23	0.05	1.59	
Expanded estimates															
total trips	505		587	109	1,201	294		216	86	596	446	34	340	80	899
total discards (mt)	4		82	129	215	24		21	7	52	24	3	11	11	50
sum of squares	0.002					0.013					0.03418 15				
Variance of est.	2.86					9.71					50.23				
Std. Err. of est.	1.69					3.12					7.09				
CV of est.	0.44					0.13					0.29				

* there were no dredge logbooks with discards data for the 1st half of 1994-95; landings from those cells were added to landings for 2nd halves.

Table D6. Estimated discards of Georges Bank yellowtail flounder from logbook data, using all trips with discard of any species. observations.

	1994					1995					1996				
	Jan-Jun		Jul-Dec		annual	Jan-Jun		Jul-Dec		annual	Jan-Jun		Jul-Dec		annual
	trawl	dredge	trawl	dredge	sum	trawl	dredge	trawl	dredge	sum	trawl	dredge	trawl	dredge	sum
total landings (mt)	168.3	29.9	1380.6	9.7	1588.5	159.9	0.6	123.4	8.5	292.3	518.7	2.8	222.8	7.0	751.3
trips with logbooks	134	36	423	61	654	286	5	217	59	567	381	37	292	58	768
total kept (mt)	44.64	4.47	994.22	5.43		155.73	0.56	123.83	6.08		442.65	3.04	191.59	5.12	
kept/trip	0.33	0.12	2.35	0.09		0.54	0.11	0.57	0.10		1.16	0.08	0.66	0.09	
trips with discard	55	16	143	18	232	64	2	34	22	122	93	19	93	20	225
total kept (mt)	19.35	2.73	326.90	1.12		37.79	0.32	9.42	1.39		106.81	1.68	62.69	1.26	
total discard (mt)	1.96	1.55	25.47	1.91		1.40	0.29	0.63	2.47		6.61	4.77	3.22	3.49	
discard/kept	0.10	0.57	0.08	1.70		0.04	0.93	0.07	1.78		0.06	2.84	0.05	2.78	
Expanded estimates															
total trips	505	241	587	109	1,442	294	5	216	83	597	446	34	340	80	899
total discards (mt)	17	17	108	16	141	6	1	8	15	24	32	8	11	20	39
sum of squares	1.18	0.61	41.33	0.66		0.03	0.02	0.03	0.69		2.77	2.32	0.78	1.72	
Variance of est.	90.08	137.60	531.28	21.13		0.55	0.14	1.22	7.54		51.09	3.36	7.58	21.39	
Std. Err. of est.	9.49	11.73	23.05	4.60		0.74	0.38	1.10	2.75		7.15	1.83	2.75	4.63	
CV of est.	0.56	0.69	0.21	0.28		0.13	0.72	0.13	0.18		0.22	0.23	0.24	0.24	

Table D7. Samples sizes for estimation of discards at age of Georges Bank yellowtail flounder, 1994-1996.

year	months	gear	Sea trips	Samples lengths	Commercial ages	Survey ages	Discards (mt)
1994	Jan-Jun	trawl	14	104			17
		dredge	0	0			17
		all	14	104	48	124	34
1994	Jul-Dec	trawl	4	1,421			108
		dredge	4	63			16
		all	8	1,484	402	7	124
1995	Jan-Jun	trawl	11	176			6
		dredge	0	0			1
		all	11	176	179	44	7
1995	Jul-Dec	trawl	3	55			8
		dredge	2	25			15
		all	5	80	15	48	23
1996	Jan-Jun	trawl	12	212			32
		dredge	3	13			8
		all	15	225	189	22	40
1996	Jul-Dec	trawl	1	4			11
		dredge	2	152			20
		all	3	156	174	20	31

Table D8. Discards at age (thousands) of Georges Bank yellowtail flounder (1973-1990 from Conser et al. 1991; 1991-1993 from Rago et al. 1994), and mean weight at age of discards 1994-1996.

Discards

	Age								
Year	1	2	3	4	5	6	7	8+	Total
1973	347	1,053	167	2	0	0	0	0	1,569
1974	1,963	2,674	86	1	0	0	0	0	4,724
1975	3,945	8,433	114	1	0	0	0	0	12,493
1976	572	11,692	61	0	0	0	0	0	12,325
1977	299	1,964	112	0	0	0	0	0	2,375
1978	9,659	965	64	0	0	0	0	0	10,688
1979	216	2,701	49	0	0	0	0	0	2,966
1980	309	1,201	125	0	0	0	0	0	1,635
1981	49	250	84	1	0	0	0	0	384
1982	1,846	4,359	61	1	0	0	0	0	6,267
1983	457	22	0	0	0	0	0	0	479
1984	184	4	0	0	0	0	0	0	188
1985	279	10	0	0	0	0	0	0	289
1986	68	38	0	0	0	0	0	0	106
1987	125	834	21	0	0	0	0	0	980
1988	483	717	10	0	0	0	0	0	1,210
1989	185	179	4	0	0	0	0	0	368
1990	219	1,196	1,541	62	2	0	0	0	3,020
1991	412	27	355	174	4	0	0	0	972
1992	2,389	5,176	636	93	8	0	0	0	8,302
1993	5,189	549	512	99	4	0	0	0	6,353
1994	1	317	238	17	3	0	0	0	577
1995	14	45	47	7	0	0	0	0	136
1996	49	115	103	6	0	0	0	0	273
mean	1,219	1,856	183	19	1	0	0	0	3,278

Mean Weight (kg)

	Age								
Year	1	2	3	4	5	6	7	8+	All
1994	0.130	0.238	0.287	0.417	0.512	0.622			0.265
1995	0.155	0.233	0.283	0.357	0.496	0.593		0.531	0.255
1996	0.137	0.266	0.312	0.418					0.263
mean	0.141	0.247	0.294	0.398	0.513	0.607			0.261

Table D9. Canadian catch at age (thousands) of Georges Bank yellowtail flounder (from Neilson et al. 1997).

	Age								
Year	1	2	3	4	5	6	7	8+	Total
1993	5	85	727	901	27	0	5	0	1,750
1994	70	415	2,890	1,701	654	59	29	0	5,818
1995	0	100	576	427	66	10	0	0	1,179
1996	1	107	655	229	22	4	0	0	1,018
mean	19	177	1,212	815	192	18	9	0	2,441

Table D10. Total catch at age (thousands) of Georges Bank yellowtail flounder (1973-1990 from Conser et al. 1991; 1991-1993 from Rago et al. 1994).

	Age								
Year	1	2	3	4	5	6	7	8+	Total
1973	347	4,890	13,243	9,276	3,743	1,259	278	81	33,117
1974	2,143	8,971	7,904	7,398	3,544	852	452	173	31,437
1975	4,372	25,284	7,057	3,392	2,084	671	313	164	43,337
1976	615	31,012	5,146	1,347	532	434	287	147	39,520
1977	330	8,580	9,917	1,721	394	221	129	124	21,416
1978	9,659	3,105	4,034	1,660	459	102	37	35	19,091
1979	233	9,505	3,445	1,242	550	141	79	52	15,247
1980	309	3,572	8,821	1,419	321	85	4	10	14,541
1981	55	729	5,351	4,556	796	122	4	0	11,613
1982	2,063	17,491	7,122	3,246	1,031	62	19	3	31,037
1983	696	7,689	16,016	2,316	625	109	10	8	27,469
1984	428	1,917	4,266	4,734	1,592	257	47	17	13,258
1985	650	3,345	816	652	410	60	5	0	5,938
1986	158	5,771	978	347	161	52	16	8	7,491
1987	140	2,653	2,751	761	132	39	32	41	6,549
1988	483	2,367	1,191	624	165	15	20	3	4,868
1989	185	1,516	668	262	68	11	8	0	2,718
1990	219	1,931	6,123	800	107	17	3	0	9,200
1991	412	54	1,222	2,430	293	56	4	0	4,471
1992	2,389	8,359	2,527	1,269	510	20	7	0	15,081
1993	5,194	1,009	2,777	2,392	318	65	9	1	11,765
1994	71	861	5,742	2,571	910	99	37	1	10,291
1995	14	157	895	715	137	13	11	4	1,966
1996	50	383	1,509	716	167	9	5	1	2,841
mean	1,301	6,298	4,980	2,327	794	199	76	36	16,011

Table D11. NEFSC spring trawl survey mean catch per tow of Georges Bank yellowtail flounder (strata13-21; standardized for vessel, door, and gear effects).

	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
mean	0.277	2.251	2.301	0.970	0.329	0.080	0.035	0.011	6.254	2.381

Table D12. NEFSC autumn trawl survey mean catch per tow of Georges Bank yellowtail flounder (strata13-21; standardized for vessel, door, and gear effects).

	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
mean	0.153	2.863	3.377	2.464	1.049	0.366	0.086	0.034	0.017	10.427	3.770

Table D13. NEFSC scallop survey mean catch per tow of Georges Bank yellowtail flounder (strata 54, 55, 58-72, 74 including 3-digit strata; delta transformed).

	Age									
Year	0	1	2	3	4	5	6	7	8	Total
1982	0.000	0.509	0.542	0.215	0.085	0.018	0.000	0.000	0.000	1.369
1983	0.000	0.276	0.549	0.464	0.095	0.041	0.010	0.010	0.000	1.446
1984	0.000	0.377	0.125	0.064	0.104	0.011	0.019	0.000	0.000	0.700
1985	0.000	0.662	0.079	0.003	0.015	0.000	0.000	0.000	0.000	0.758
1986	0.000	0.197	0.072	0.006	0.004	0.000	0.000	0.000	0.000	0.279
1987	0.006	0.104	0.151	0.136	0.010	0.014	0.008	0.000	0.000	0.424
1988	0.000	0.118	0.052	0.072	0.022	0.000	0.000	0.000	0.000	0.263
1989	0.000	0.194	0.458	0.233	0.065	0.000	0.000	0.000	0.000	0.951
1990	0.000	0.108	0.063	0.392	0.089	0.000	0.000	0.000	0.000	0.652
1991	0.068	2.434	0.030	0.147	0.146	0.000	0.000	0.000	0.000	2.758
1992	0.008	0.204	0.221	0.126	0.011	0.004	0.000	0.000	0.000	0.566
1993	0.150	1.295	0.100	0.333	0.300	0.027	0.011	0.000	0.000	2.066
1994	0.018	1.606	0.126	0.585	0.334	0.114	0.021	0.001	0.000	2.788
1995	0.021	0.697	0.333	1.008	0.554	0.019	0.046	0.013	0.000	2.670
1996	0.000	0.562	0.563	1.414	0.251	0.104	0.094	0.000	0.000	2.988
mean	0.271	0.623	0.231	0.347	0.139	0.024	0.014	0.002	0.000	1.379

Table D14. Canadian spring trawl survey mean catch per tow of Georges Bank yellowtail flounder.

	Age						
Year	1	2	3	4	5	6	Total
1987	0.08	0.12	0.74	2.58	0.56	0.02	4.02
1988	0.04	0.67	1.81	0.80	0.67	0.01	3.96
1989	0.08	0.76	0.91	0.29	0.04	0.01	2.01
1990	0.05	1.92	4.04	1.07	0.40	0.01	7.44
1991	0.14	0.61	1.86	2.93	0.82	0.00	6.22
1992	0.10	10.06	4.59	1.14	0.29	0.00	16.08
1993	0.32	2.63	6.32	2.45	0.21	0.02	11.63
1994	0.00	6.38	3.46	2.63	0.86	0.19	13.52
1995	0.17	1.17	4.55	2.16	0.95	0.07	8.90
1996	0.53	5.62	8.23	7.16	1.36	0.17	22.54
mean	0.15	2.99	3.65	2.32	0.62	0.05	9.63

Table D15. Log correlations among survey indices of abundance for Georges Bank yellowtail flounder (SAW-18: abundance estimates from Rago et al. 1994; RAP-96: abundance estimates from Gavaris et al. 1996).

Age-2+	SAW-18	RAP-96	Fall	Spring	Canada	Scallop
SAW-18	1.00	0.97	0.73	0.40	0.36	0.24
RAP-96	0.97	1.00	0.72	0.22	0.44	0.27
Fall	0.73	0.72	1.00	0.59	0.26	0.46
Spring	0.40	0.22	0.59	1.00	0.42	0.19
Canada	0.36	0.44	0.26	0.42	1.00	0.53
Scallop	0.24	0.27	0.46	0.19	0.53	1.00

Age-1	SAW-18	RAP-96	Fall	Spring	Canada	Scallop
SAW-18	—	—	—	—	—	—
RAP-96	—	—	—	—	—	—
Fall	—	—	1.00	0.22	0.03	0.69
Spring	—	—	0.22	1.00	-0.04	0.77
Canada	—	—	0.03	-0.04	1.00	0.20
Scallop	—	—	0.69	0.77	0.20	1.00

Age-2	SAW-18	RAP-96	Fall	Spring	Canada	Scallop
SAW-18	1.00	0.98	0.72	0.80	0.49	0.78
RAP-96	0.98	1.00	0.69	0.72	0.30	0.38
Fall	0.72	0.69	1.00	0.79	-0.04	0.63
Spring	0.80	0.72	0.79	1.00	0.73	0.50
Canada	0.49	0.30	-0.04	0.73	1.00	0.24
Scallop	0.78	0.38	0.63	0.50	0.24	1.00

Age-3	SAW-18	RAP-96	Fall	Spring	Canada	Scallop
SAW-18	1.00	0.96	0.71	0.78	0.48	0.47
RAP-96	0.96	1.00	0.67	0.64	0.68	0.36
Fall	0.71	0.67	1.00	0.84	0.52	0.56
Spring	0.78	0.64	0.84	1.00	0.62	0.71
Canada	0.48	0.68	0.52	0.62	1.00	0.67
Scallop	0.47	0.36	0.56	0.71	0.67	1.00

Age-4	SAW-18	RAP-96	Fall	Spring	Canada	Scallop
SAW-18	1.00	0.95	0.80	0.84	0.75	0.33
RAP-96	0.95	1.00	0.80	0.45	0.74	0.37
Fall	0.80	0.80	1.00	0.82	0.73	0.51
Spring	0.84	0.45	0.82	1.00	0.62	0.54
Canada	0.75	0.74	0.73	0.62	1.00	0.47
Scallop	0.33	0.37	0.51	0.54	0.47	1.00

Age-5+	SAW-18	RAP-96	Fall	Spring	Canada	Scallop
SAW-18	1.00	0.81	0.64	0.19	-0.10	-0.11
RAP-96	0.81	1.00	0.38	0.13	0.07	-0.01
Fall	0.64	0.38	1.00	0.69	0.25	0.51
Spring	0.19	0.13	0.69	1.00	0.76	0.32
Canada	-0.10	0.07	0.25	0.76	1.00	0.76
Scallop	-0.11	-0.01	0.51	0.32	0.76	1.00

Table D16. Estimates of beginning year stock size (millions of fish) for Georges Bank yellowtail flounder derived from virtual population analysis (VPA) calibrated using the ADAPT procedure, 1973-1996.

Year	Age 1	2	3	4	5	6+	Total
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	885	1,417	88,873
1977	15,760	18,208	14,628	2,899	651	768	52,914
1978	50,823	12,605	7,144	3,003	816	304	74,695
1979	23,375	32,871	7,510	2,199	957	465	67,377
1980	22,099	18,927	18,312	3,032	677	206	63,253
1981	61,066	17,814	12,264	7,011	1,198	185	99,538
1982	21,627	49,947	13,925	5,199	1,618	129	92,445
1983	5,819	15,840	25,067	4,957	1,319	264	53,266
1984	8,620	4,134	6,011	6,031	1,962	382	27,140
1985	14,595	6,670	1,650	1,062	654	102	24,733
1986	6,661	11,361	2,435	613	279	129	21,478
1987	7,030	5,311	4,080	1,108	188	155	17,872
1988	19,371	5,629	1,947	851	219	49	28,066
1989	8,584	15,423	2,467	517	132	36	27,159
1990	12,026	6,861	11,255	1,415	186	34	31,777
1991	22,800	9,648	3,870	3,675	435	87	40,515
1992	19,085	18,295	7,850	2,063	811	42	48,146
1993	23,038	13,464	7,415	4,141	541	125	48,724
1994	22,130	14,162	10,111	3,558	1,226	179	51,366
1995	16,190	18,054	10,816	3,082	587	119	48,848
1996	7,240	13,243	14,639	8,046	1,877	168	45,213
1997	—	5,882	10,496	10,620	5,939	1,509	—
mean	22,317	18,073	10,291	4,435	1,531	444	53,674
min	5,819	4,134	1,650	517	132	34	17,872
max	68,516	52,140	25,067	11,709	5,939	2,240	127,593

Table D17. Estimates of instantaneous fishing mortality (F) for Georges Bank yellowtail flounder derived from virtual population analysis (VPA) calibrated using the ADAPT procedure, 1973-1996.

Year	Age 1	2	3	4	5	6+	mean age-4+
1973	0.014	0.264	0.705	0.928	0.954	0.954	0.945
1974	0.048	0.569	0.909	1.198	1.249	1.249	1.232
1975	0.073	1.247	1.334	1.497	1.591	1.591	1.559
1976	0.030	1.071	0.958	1.055	1.091	1.091	1.079
1977	0.023	0.736	1.383	1.068	1.105	1.105	1.092
1978	0.236	0.318	0.978	0.944	0.971	0.971	0.962
1979	0.011	0.385	0.707	0.978	1.009	1.009	0.999
1980	0.016	0.234	0.760	0.729	0.743	0.743	0.738
1981	0.001	0.046	0.658	1.266	1.325	1.325	1.305
1982	0.111	0.489	0.833	1.172	1.219	1.219	1.203
1983	0.142	0.769	1.225	0.727	0.741	0.741	0.736
1984	0.056	0.718	1.533	2.022	2.269	2.269	2.186
1985	0.050	0.808	0.790	1.137	1.179	1.179	1.165
1986	0.026	0.824	0.587	0.982	1.014	1.014	1.003
1987	0.022	0.803	1.367	1.421	1.053	1.053	1.176
1988	0.028	0.625	1.126	1.664	1.792	1.792	1.749
1989	0.024	0.115	0.356	0.822	0.842	0.842	0.835
1990	0.020	0.373	0.919	0.980	1.010	1.010	1.000
1991	0.020	0.006	0.429	1.311	1.376	1.376	1.354
1992	0.149	0.703	0.440	1.138	1.183	1.183	1.168
1993	0.287	0.086	0.534	1.017	1.050	1.050	1.039
1994	0.004	0.070	0.988	1.602	1.718	1.718	1.679
1995	0.001	0.010	0.096	0.296	0.299	0.299	0.298
1996	0.008	0.032	0.121	0.104	0.104	0.104	0.104
mean	0.058	0.471	0.822	1.086	1.116	1.120	1.109
min	0.001	0.006	0.096	0.104	0.104	0.104	0.104
max	0.287	1.247	1.533	2.022	2.269	2.269	2.186

Table D18. Estimates of spawning stock biomass (mt) for Georges Bank yellowtail flounder derived from virtual population analysis (VPA) calibrated using the ADAPT procedure, 1973-1996.

	Age						
Year	1	2	3	4	5	6+	Total
1973	0	3,022	8,933	5,531	2,509	1,372	21,368
1974	0	2,821	4,518	3,982	2,042	1,031	14,394
1975	0	3,283	2,694	1,319	848	501	8,646
1976	0	4,684	3,042	861	383	691	9,661
1977	0	2,020	3,906	1,084	296	424	7,729
1978	0	1,541	2,198	1,275	397	171	5,582
1979	0	4,127	2,330	874	421	251	8,001
1980	0	2,516	5,954	1,351	371	150	10,342
1981	0	3,064	4,186	2,295	449	78	10,072
1982	0	5,748	4,366	1,908	670	75	12,767
1983	0	1,534	6,031	2,035	656	171	10,427
1984	0	629	1,103	1,195	450	107	3,485
1985	0	1,480	543	394	270	46	2,732
1986	0	2,365	947	249	139	71	3,770
1987	0	1,099	1,110	376	63	64	2,712
1988	0	1,303	624	269	82	21	2,299
1989	0	4,465	1,063	245	76	26	5,875
1990	0	1,694	2,958	509	79	18	5,257
1991	0	2,223	1,140	948	164	38	4,513
1992	0	2,227	2,291	624	295	28	5,464
1993	0	1,964	1,831	1,272	180	68	5,314
1994	0	1,824	1,868	777	347	66	4,878
1995	0	2,472	3,073	1,139	277	81	7,017
1996	0	1,902	4,518	3,948	1,199	145	11,706
mean	0	2,500	2,968	1,436	528	237	7,667
min	0	629	543	245	63	18	2,299
max	0	5,748	8,933	5,531	2,509	1,372	21,368

Table D19. Summary of results from sensitivity ADAPT runs for Georges Bank yellowtail flounder.

Settings	run 275	run 277	run 279*	run 280
retransformed NEFSC S&F	Y	Y	N	N
92,93 age-1 in tuning	Y	N	Y	N
Diagnostics				
total sum of squares	824.48	816.68	820.57	811.31
residual sum of squares	249.45	245.05	233.70	228.65
~R squared	0.70	0.70	0.72	0.72
mean squared residuals	0.82	0.81	0.77	0.76
CV n2	0.54	0.54	0.53	0.53
CV n3	0.37	0.37	0.35	0.35
CV n4	0.34	0.34	0.32	0.32
CV n5	0.24	0.25	0.23	0.22
min CVq	0.19	0.19	0.18	0.18
max CVq	0.29	0.29	0.28	0.28
parameters correlated	0	0	0	0
residual series trended	Y	Y	Y	Y
standardized residuals >3	3	3	2	2
survey-years with year effect	18	18	18	18
max partial variance (%)	14	14	13	13
Results				
97 n2	5.959	5.667	5.882	5.552
97 n3	9.941	9.728	10.496	10.241
97 n4	9.765	9.678	10.620	10.522
97 n5	5.703	5.893	5.939	6.205
97 n6+	1.449	1.498	1.509	1.577
97 n2+	32.817	32.464	34.446	34.097
96 F1	0.0076	0.0080	0.0077	0.0081
96 F2	0.0343	0.0350	0.0325	0.0333
96 F3	0.1309	0.1320	0.1209	0.1220
96 F4+	0.1076	0.1043	0.1035	0.0993
96 mean Biomass	13.275	13.321	14.049	14.137
96 SSB	11.048	11.131	11.706	11.787

* accepted run.

Table D20. Stochastic short-term projections of spawning stock biomass (mt), recruitment (age 1, thousands) and landings (mt) for Georges Bank yellowtail flounder, assuming F=0.01 and F=0.25. Probability of SSB> the 10,000 mt threshold is given, along with the lower and upper quartiles and the median of bootstrap simulations.

F_{96}=0.10

	- Spawning Biomass -				- Recruitment -			- Landings -		
Year	L-25	Median	U-75	Probability	L-25	Median	U-75	L-25	Median	U-75
1997	12,026	13,344	14,796	1.000	8,620	19,371	23,038	1,038	1,174	1,333
1998	14,663	16,048	17,648	1.000	8,620	21,627	23,375	1,269	1,401	1,564
1999	17,162	18,937	21,206	1.000	8,620	19,371	23,038	1,465	1,595	1,777

$F_{0.1}$=0.25

	- Spawning Biomass -				- Recruitment -			- Landings -		
Year	L-25	Median	U-75	Probability	L-25	Median	U-75	L-25	Median	U-75
1997	11,442	12,665	14,061	1.000	8,620	19,371	23,038	2,339	2,655	3,014
1998	12,577	13,826	15,189	1.000	8,620	21,627	23,375	2,544	2,812	3,132
1999	13,771	15,190	17,136	1.000	8,620	19,371	23,038	2,706	2,939	3,255

Table D21. Stochastic medium-term projections of spawning stock biomass (mt), recruitment (age 1, thousands) and landings (mt) for Georges Bank yellowtail flounder, assuming F=0.10. Probability of SSB> the 10,000 mt threshold is given, along with the lower and upper quartiles and the median of bootstrap simulations.

	- Spawning Biomass -				- Recruitment -			- Landings -		
Year	L-25	Median	U-75	Probability	L-25	Median	U-75	L-25	Median	U-75
1997	13,732	15,383	17,315	1.000	19,074	29,238	44,109	1,000	1,131	1,284
1998	15,926	17,491	19,395	1.000	20,506	31,144	47,332	1,227	1,356	1,513
1999	19,464	21,488	23,872	1.000	22,627	34,497	52,805	1,429	1,559	1,736
2000	23,848	27,212	31,606	1.000	25,170	37,692	57,209	1,739	1,944	2,191
2001	28,896	33,985	40,328	1.000	27,913	40,836	61,704	2,098	2,432	2,862
2002	34,936	41,516	49,632	1.000	31,218	44,559	65,978	2,576	3,041	3,613
2003	41,181	49,263	59,220	1.000	34,652	48,691	71,824	3,092	3,693	4,441
2004	47,258	56,735	68,378	1.000	37,896	52,390	75,554	3,592	4,315	5,202
2005	53,424	64,214	77,259	1.000	41,254	56,125	80,094	4,087	4,919	5,932
2006	59,583	71,637	86,078	1.000	44,489	59,775	84,021	4,595	5,539	6,654

Table D22. Stochastic medium-term projections of spawning stock biomass (mt), recruitment (age 1, thousands) and landings (mt) for Georges Bank yellowtail flounder, assuming F=0.25. Probability of SSB> the 10,000 mt threshold is given, along with the lower and upper quartiles and the median of bootstrap simulations.

	- Spawning Biomass -				- Recruitment -			- Landings -		
Year	L-25	Median	U-75	Probability	L-25	Median	U-75	L-25	Median	U-75
1997	13,016	14,621	16,428	1.000	18,570	28,649	43,613	2,339	2,655	3,014
1998	13,641	14,930	16,616	1.000	18,977	29,069	43,884	2,546	2,815	3,136
1999	15,712	17,362	19,341	1.000	20,460	31,061	47,403	2,730	2,970	3,295
2000	18,452	21,417	25,274	1.000	22,422	34,336	52,408	3,179	3,574	4,097
2001	21,602	25,929	31,188	1.000	24,680	37,033	56,303	3,698	4,385	5,252
2002	25,168	30,260	36,722	1.000	26,562	39,007	59,149	4,373	5,258	6,335
2003	28,588	34,707	42,272	1.000	28,539	41,798	62,702	5,065	6,118	7,445
2004	31,914	38,819	47,409	1.000	29,973	43,315	64,511	5,674	6,910	8,440
2005	34,969	42,746	52,037	1.000	31,966	45,367	67,721	6,295	7,661	9,366
2006	37,915	46,230	56,207	1.000	33,324	47,190	69,570	6,860	8,385	10,206

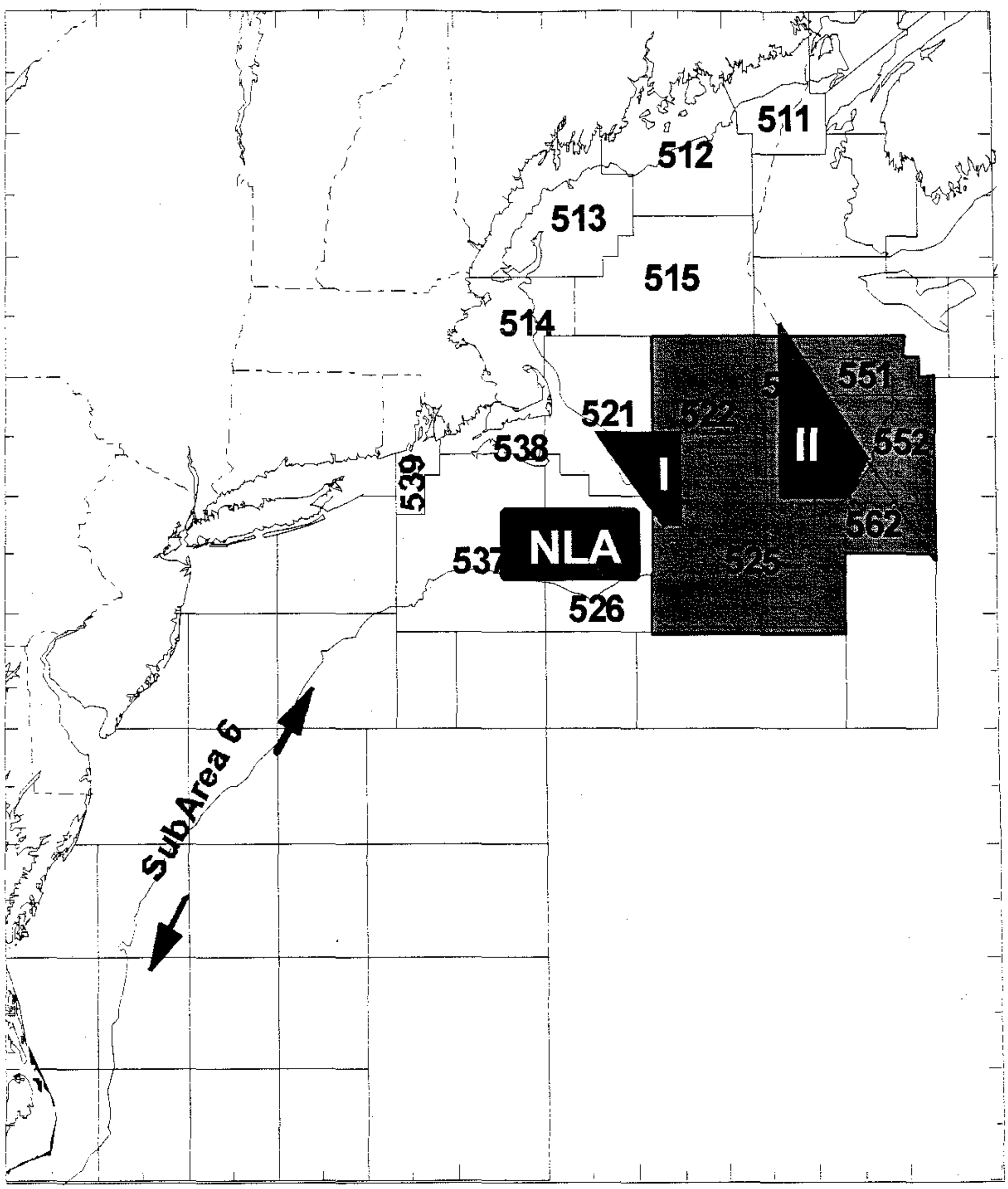

Figure D1. Statistical reporting areas for Georges Bank yellowtail flounder.
Catches from shaded areas are included in the analyses.
Areas I, II, and the Nantucket Lightship Area are closed to fishing.

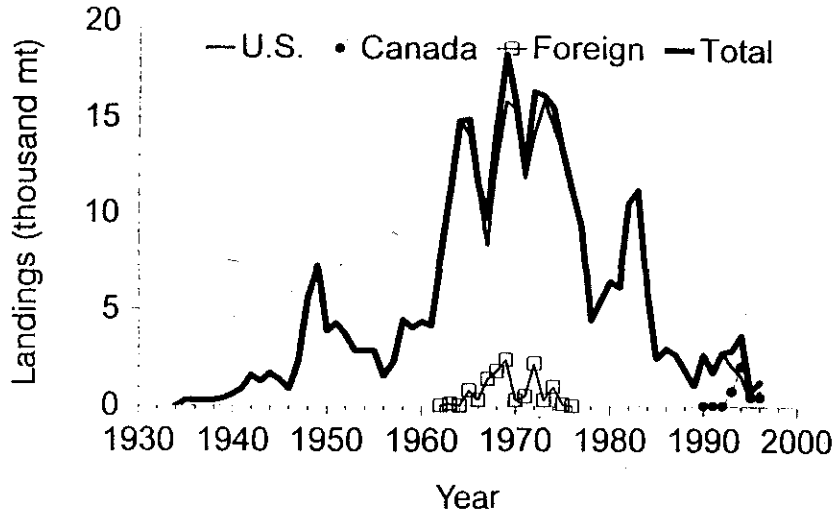

Figure D2. Landings of Georges Bank yellowtail flounder.

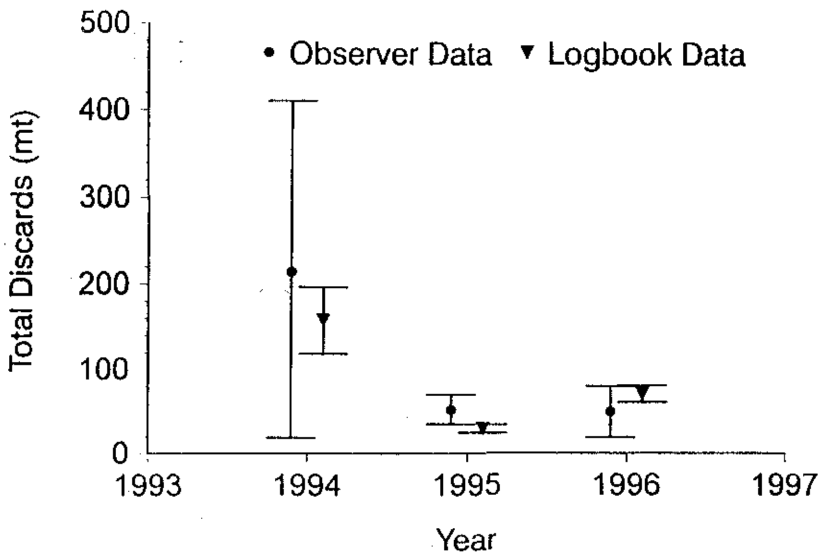

Figure D3. Estimates of total discards (above) and discard ratios (below) for Georges Bank yellowtail flounder with 95% confidence intervals.

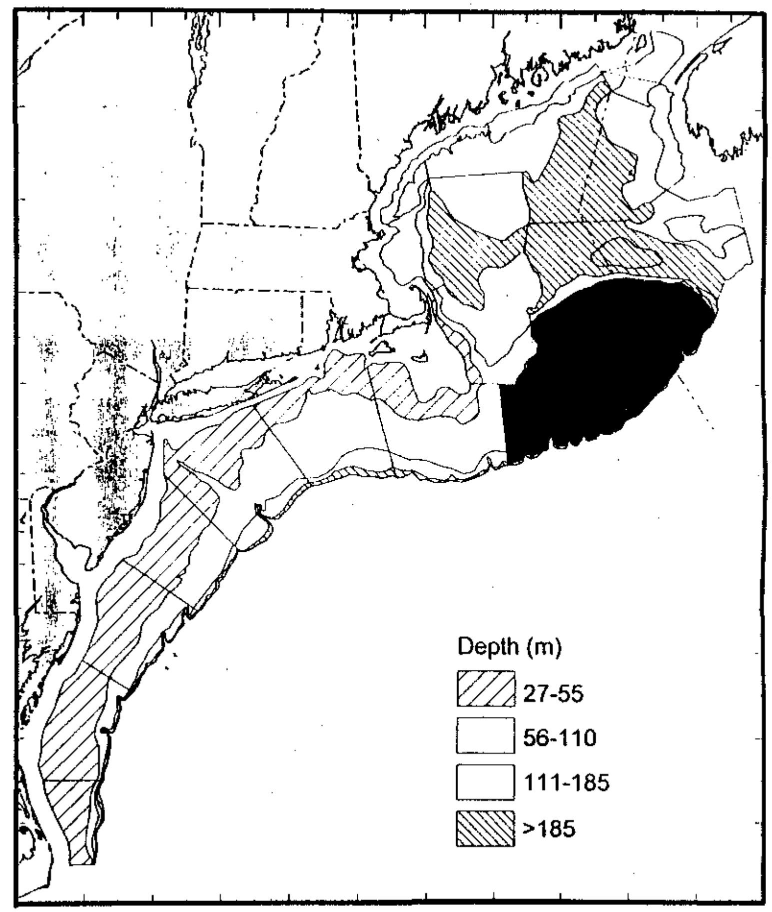

Figure D4. NEFSC groundfish survey strata. Strata 13-21 (shaded) are included in the Georges Bank yellowtail flounder assessment.

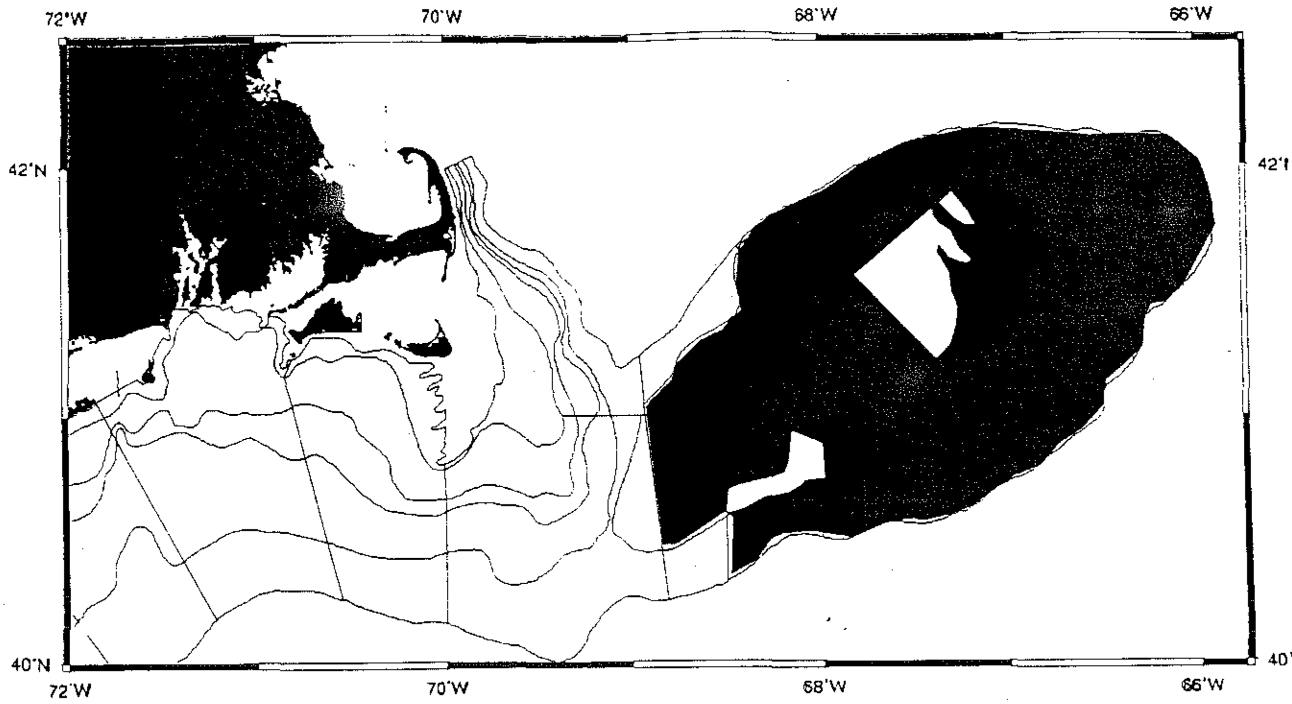

Figure D5. NEFSC scallop survey strata. Strata 54, 55, 58-72, 74 are included in the Georges Bank yellowtail flounder assessment.

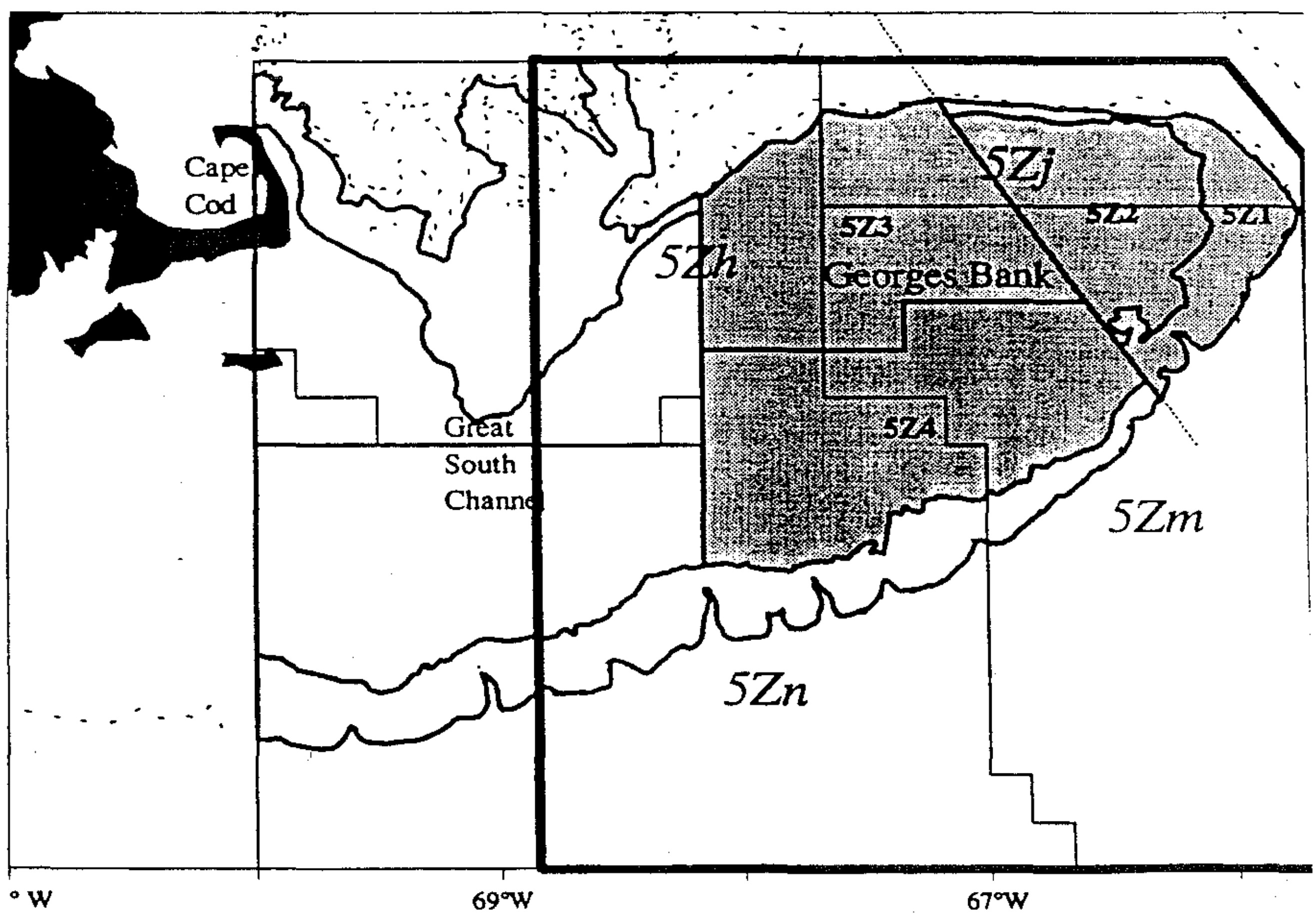

Figure D6. Canada DFO groundfish survey strata. Shaded strata are included in the Georges Bank yellowtail flounder assessment (from Gavaris et al. 1996).

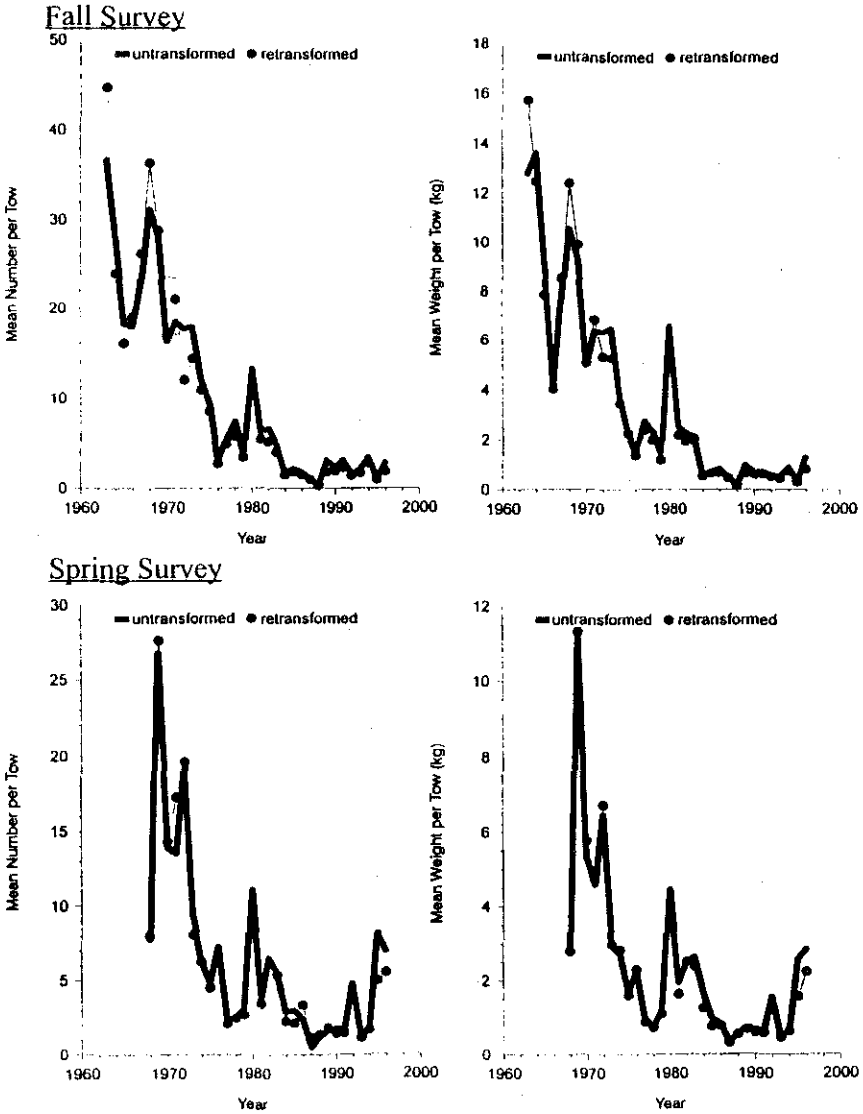

Figure D7. NEFSC spring and fall survey catches of Georges Bank yellowtail flounder.

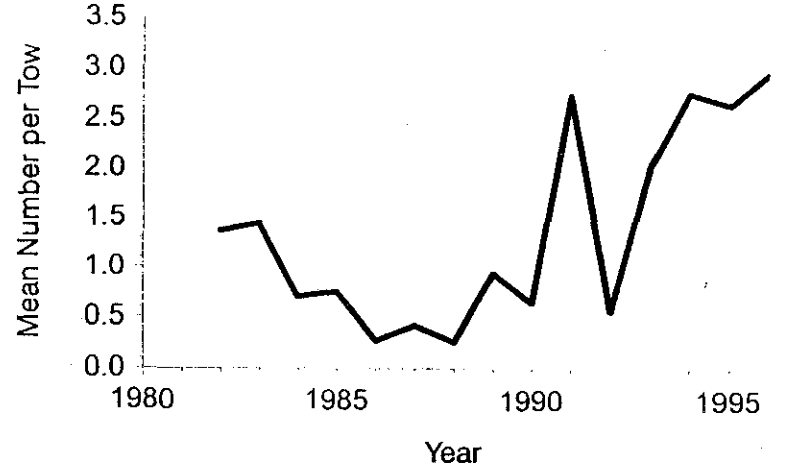

Figure D8. NEFSC scallop survey catches of Georges Bank yellowtail flounder.

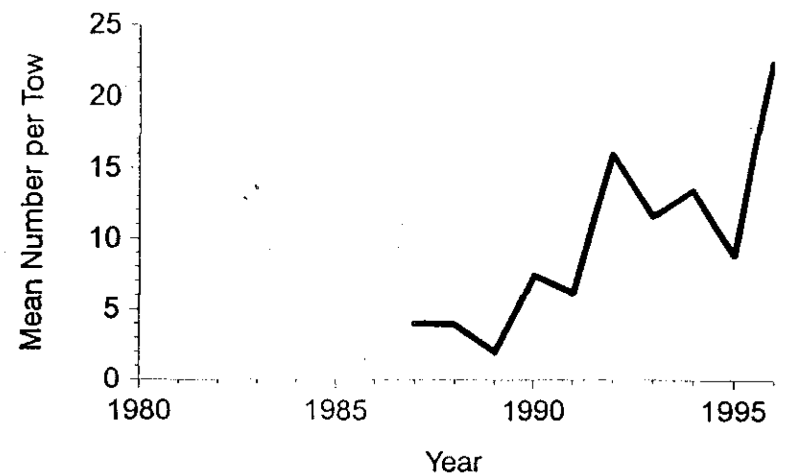

Figure D9. Canadian trawl survey catches of Georges Bank yellowtail flounder.

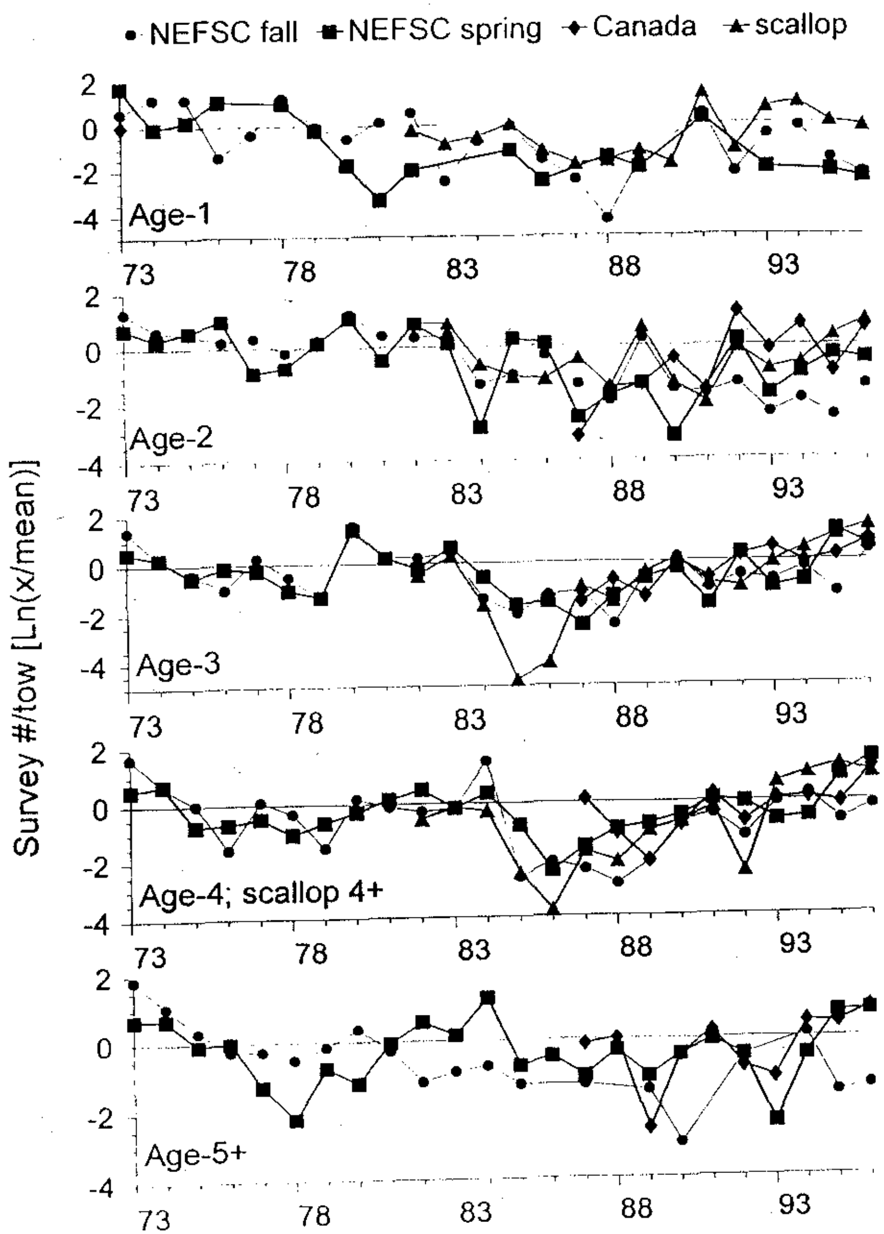

Figure D10. Survey indices of abundance for Georges Bank yellowtail flounder by age.

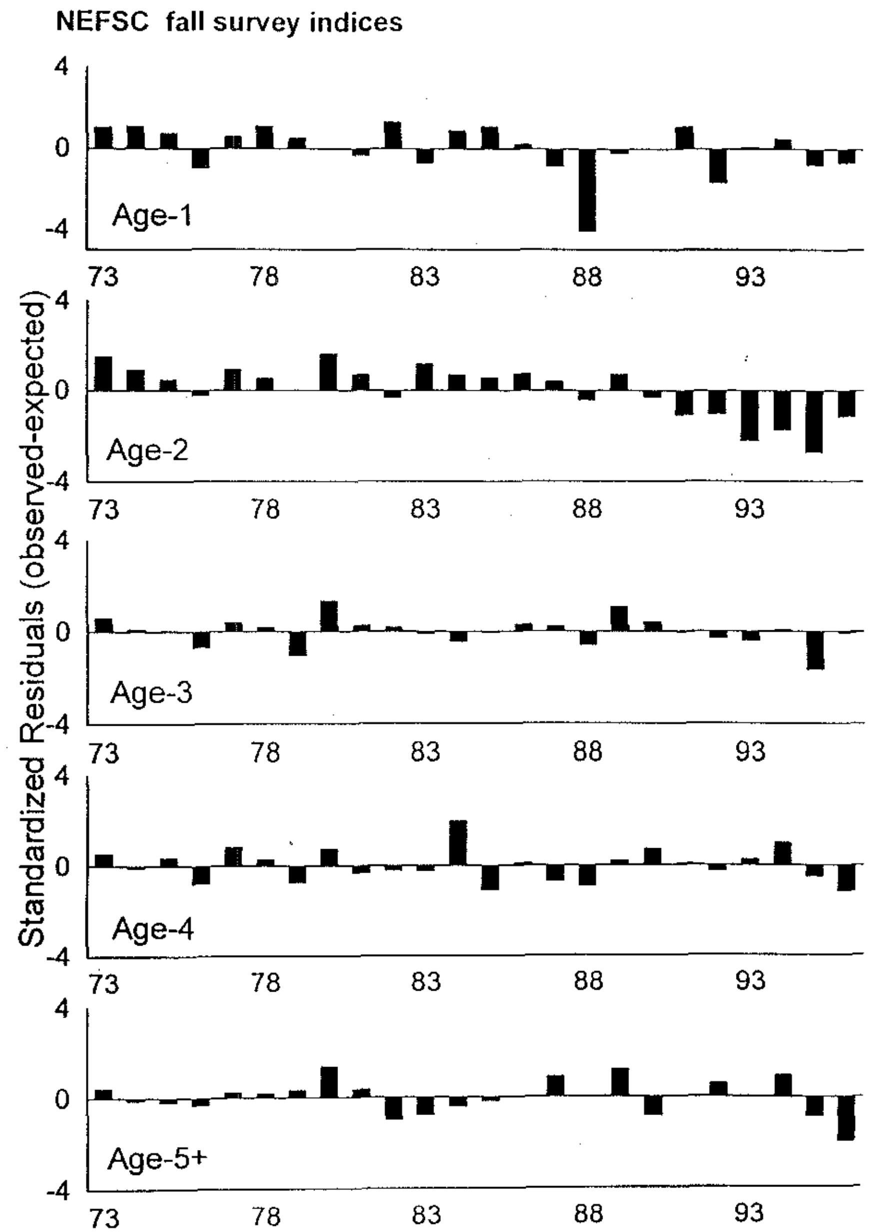

Figure D11a. ADAPT residuals for VPA calibration of Georges Bank yellowtail flounder.

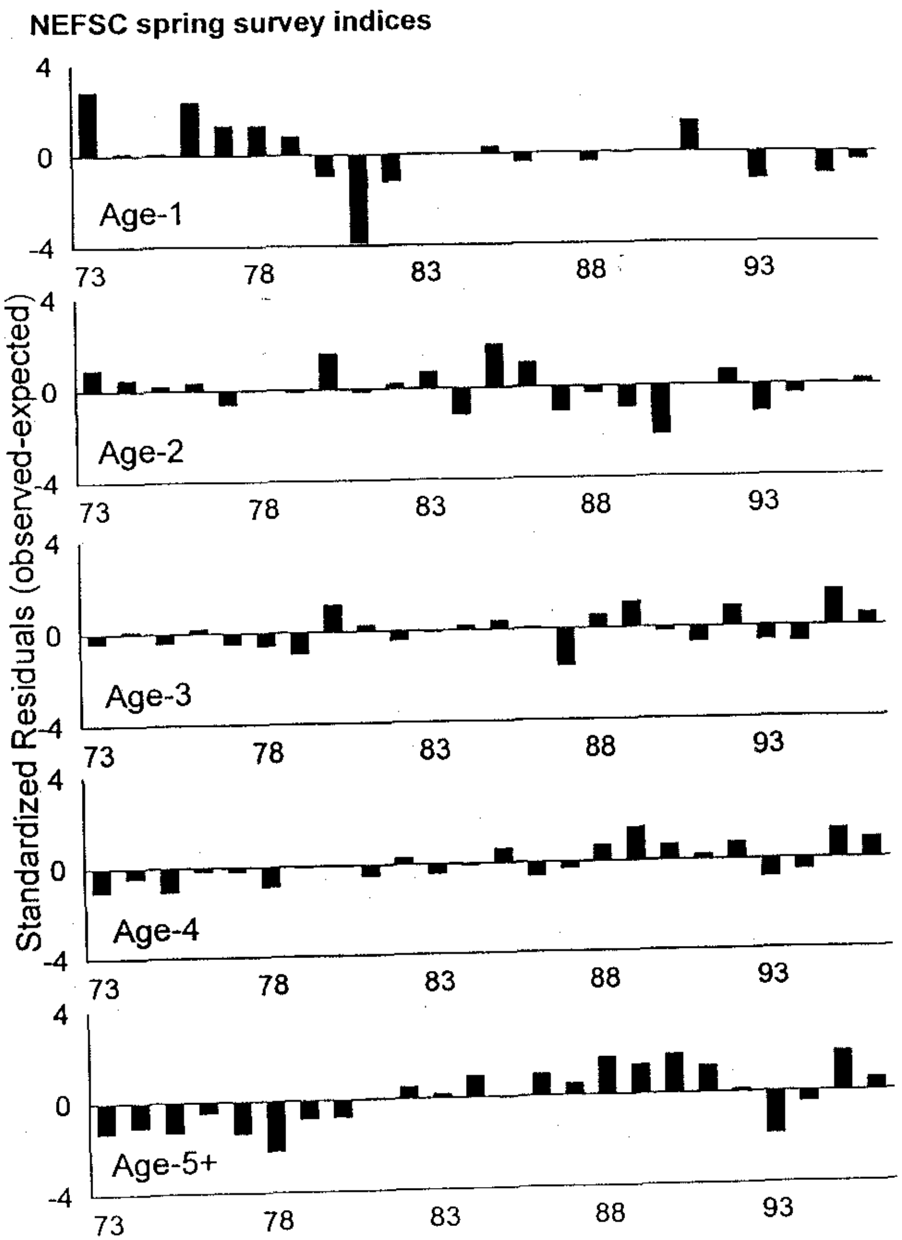

Figure D11b. ADAPT residuals for VPA calibration of Georges Bank yellowtail flounder.

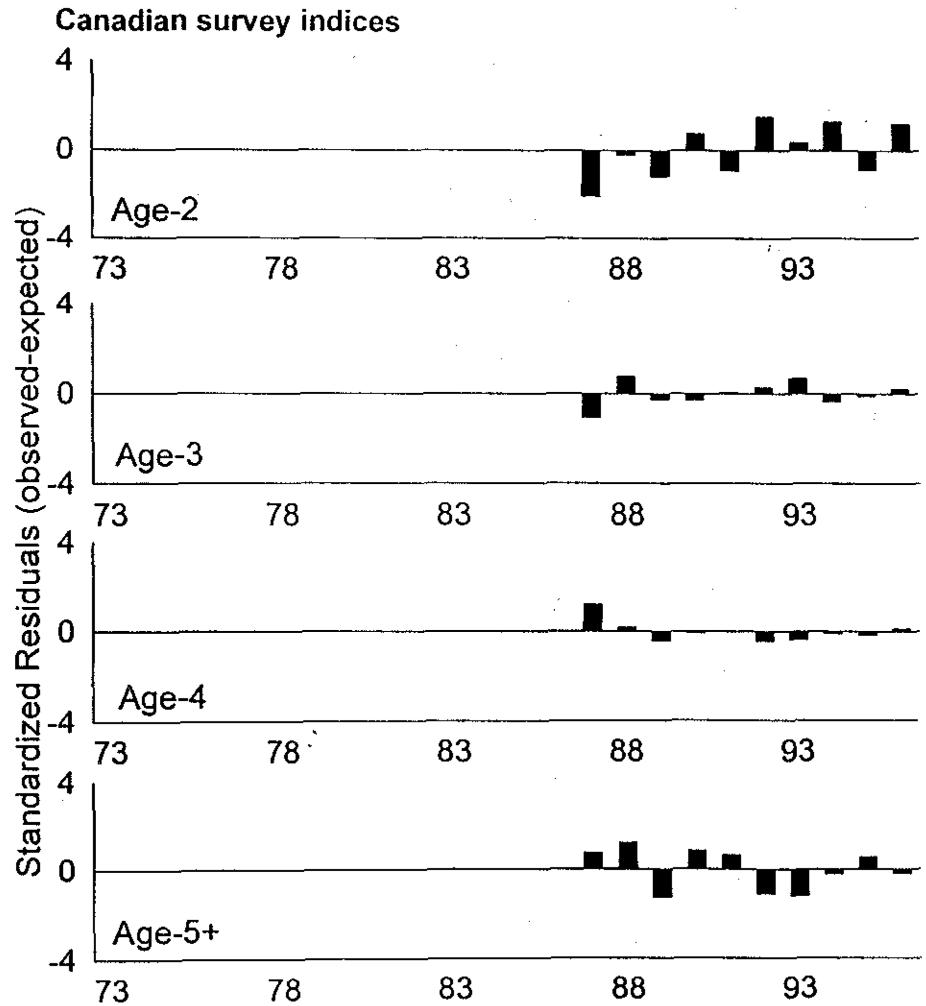

Figure D11c. ADAPT residuals for VPA calibration of Georges Bank yellowtail flounder.

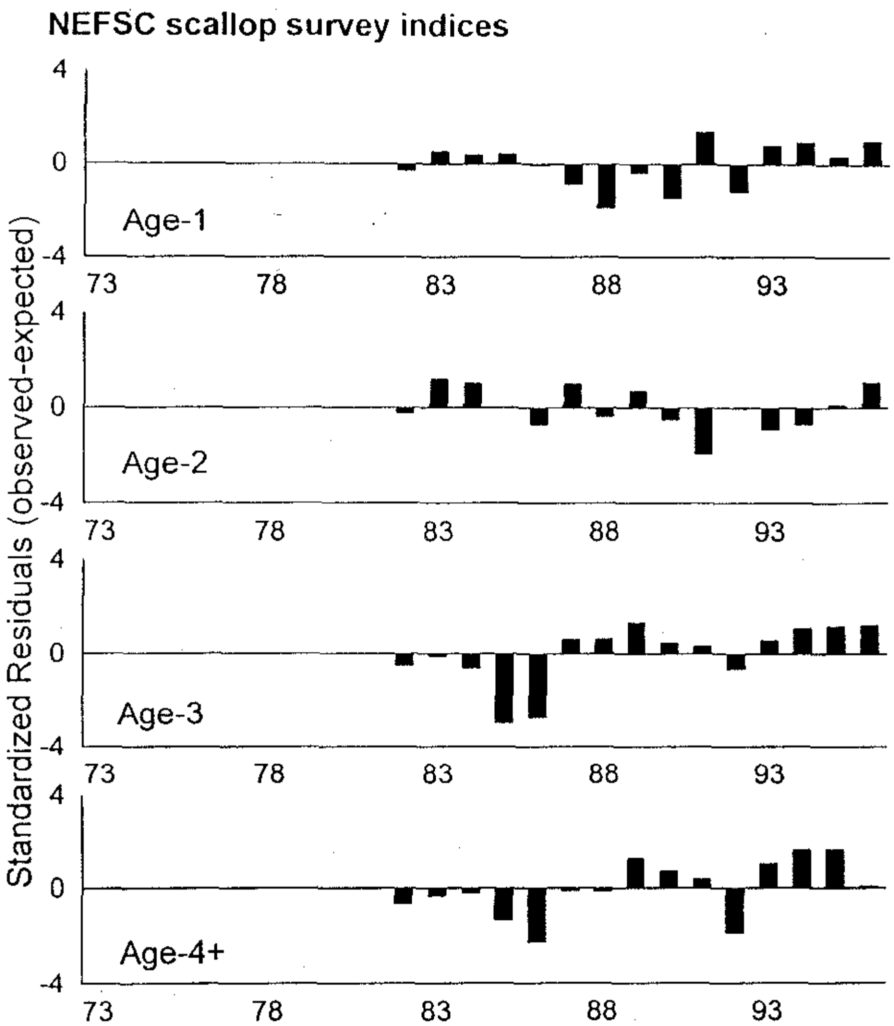

Figure D11d. ADAPT residuals for VPA calibration of Georges Bank yellowtail flounder.

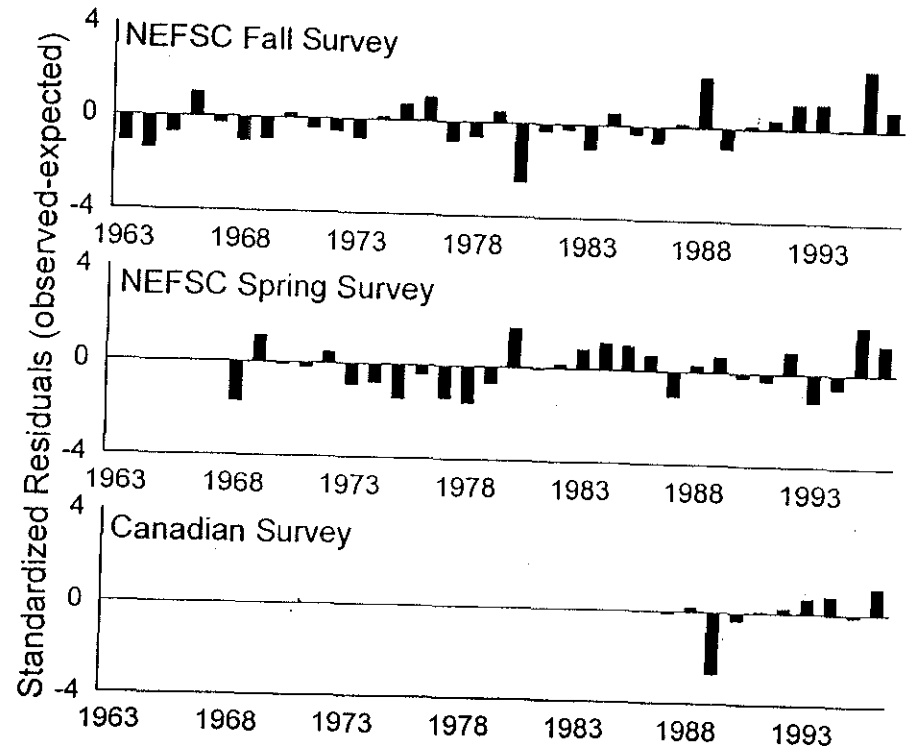

Figure D12. ASPIC residuals for production model calibration of Georges Bank yellowtail flounder.

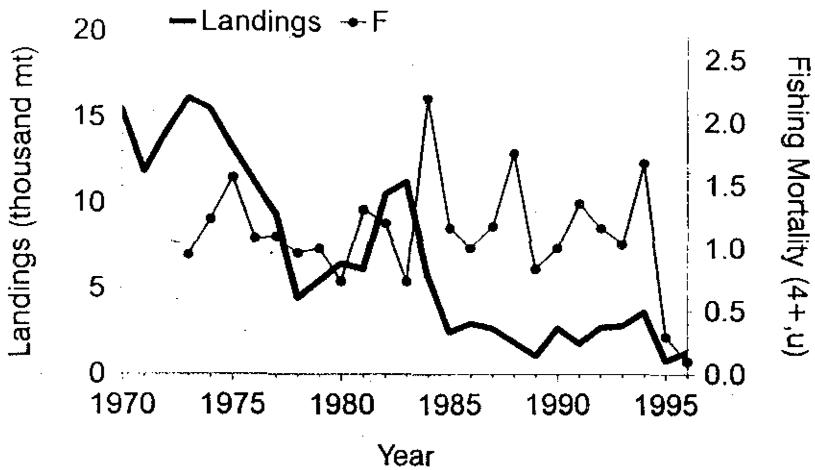

Figure D13. Instantaneous rate of fishing mortality (F[4+,u]) and total landings of Georges Bank yellowtail flounder.

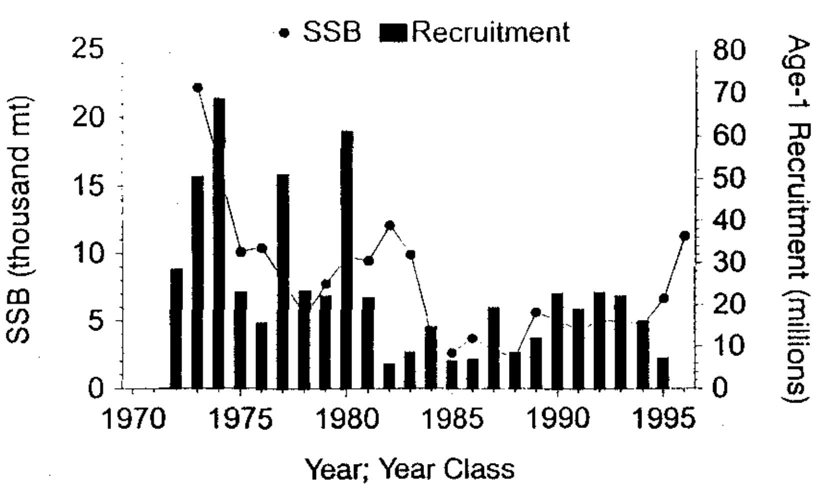

Figure D14. Spawning stock biomass and age-1 recruitment of Georges Bank yellowtail flounder.

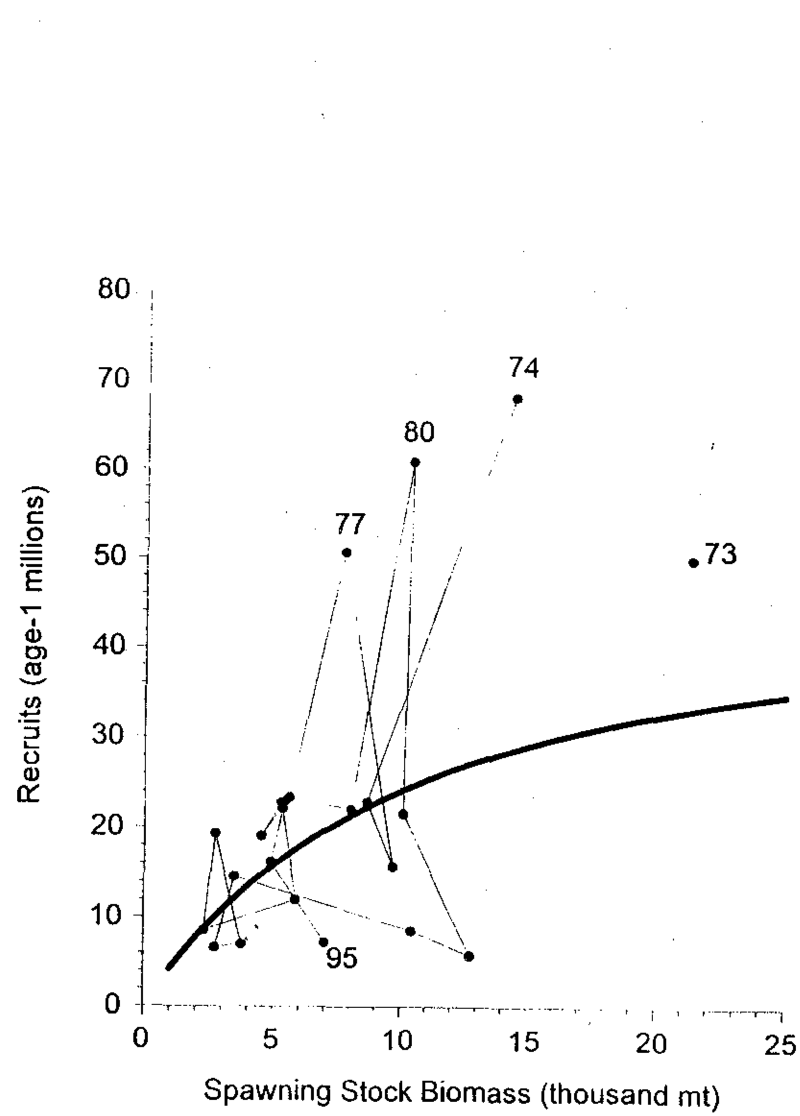

Figure D15. Spawning stock biomass and recruitment relationship for Georges Bank yellowtail flounder. Data labels indicate year-class. Fitted Beverton-Holt relationship from Overholtz et al. 1997: R=50090xSSB/(10737+SSB).

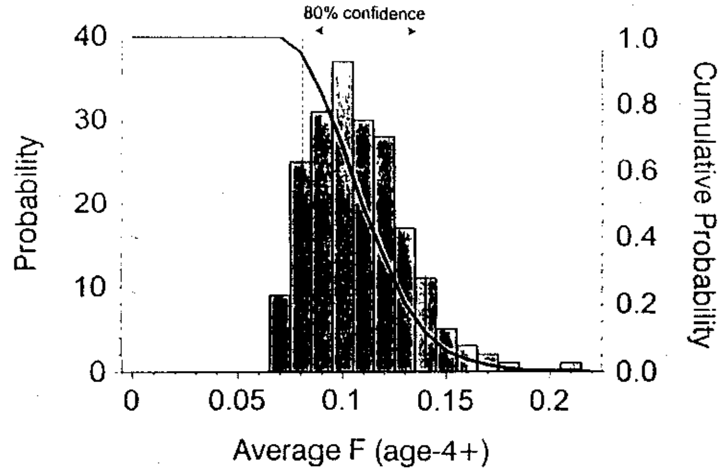

Figure D16. Distribution of bootstrap estimates of instantaneous fishing mortality for Georges Bank yellowtail flounder in 1996.

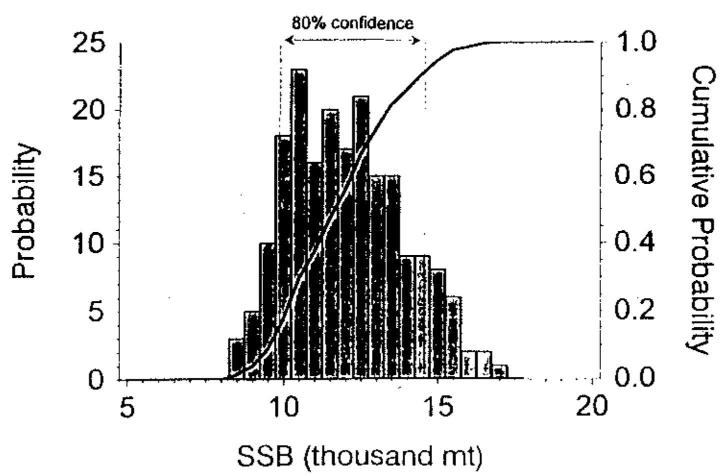

Figure D17. Distribution of bootstrap estimates of spawning stock biomass of Georges Bank yellowtail flounder in 1996.

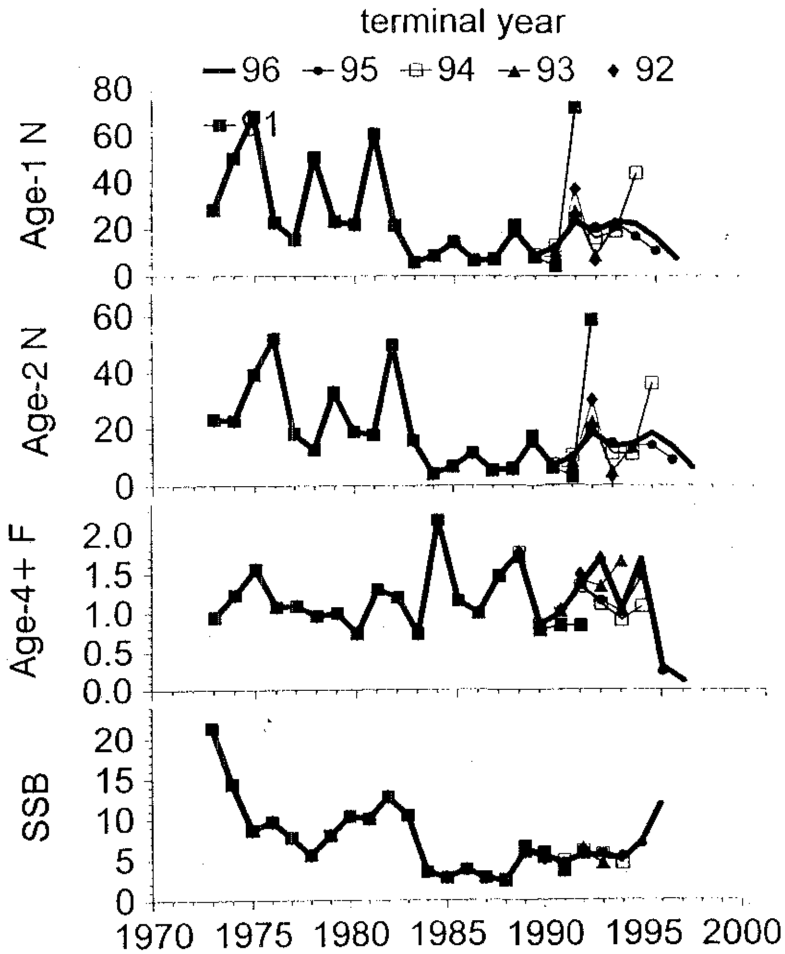

Figure D18. Retrospective analysis of VPA estimates of age-1 abundance, age-2 abundance (millions), fully-recruited F and SSB (thousand mt) of Georges Bank yellowtail flounder.

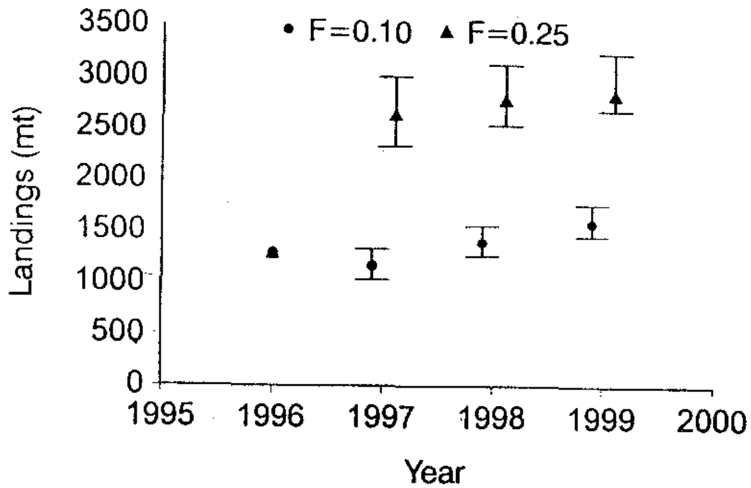

Figure D19. Stochastic short-term projections and interquartile range of Georges Bank yellowtail flounder landings at status quo F (F96) and F0.1.

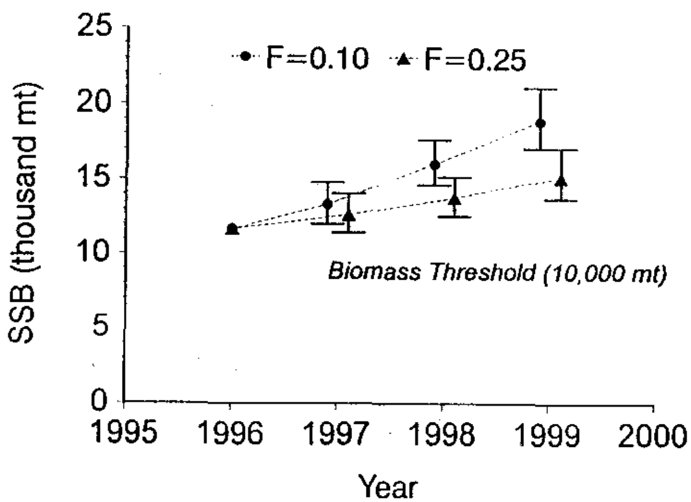

Figure D20. Stochastic short-term projections and interquartile range of Georges Bank yellowtail flounder spawning stock biomass at status quo F (F96=0.10) and F0.1(0.25).

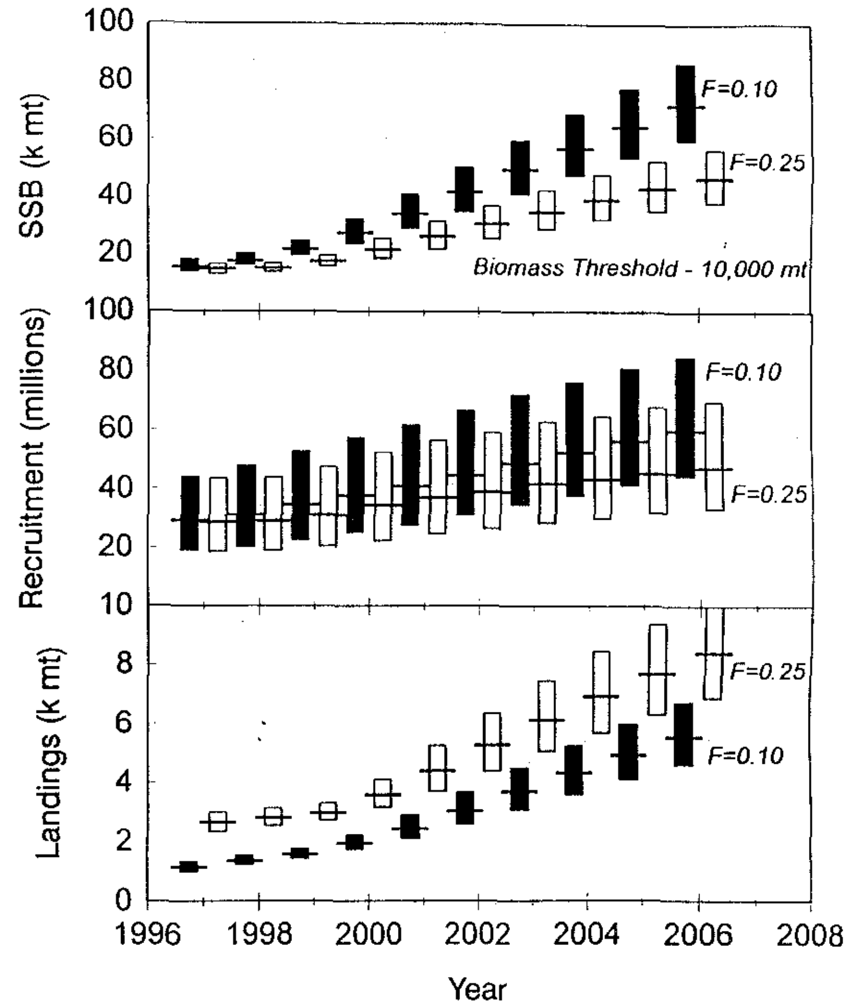

Figure D21. Stochastic medium-term projections and interquartile range of Georges Bank yellowtail flounder spawning stock biomass at status quo F (F96=0.10) and F0.1 (0.25).

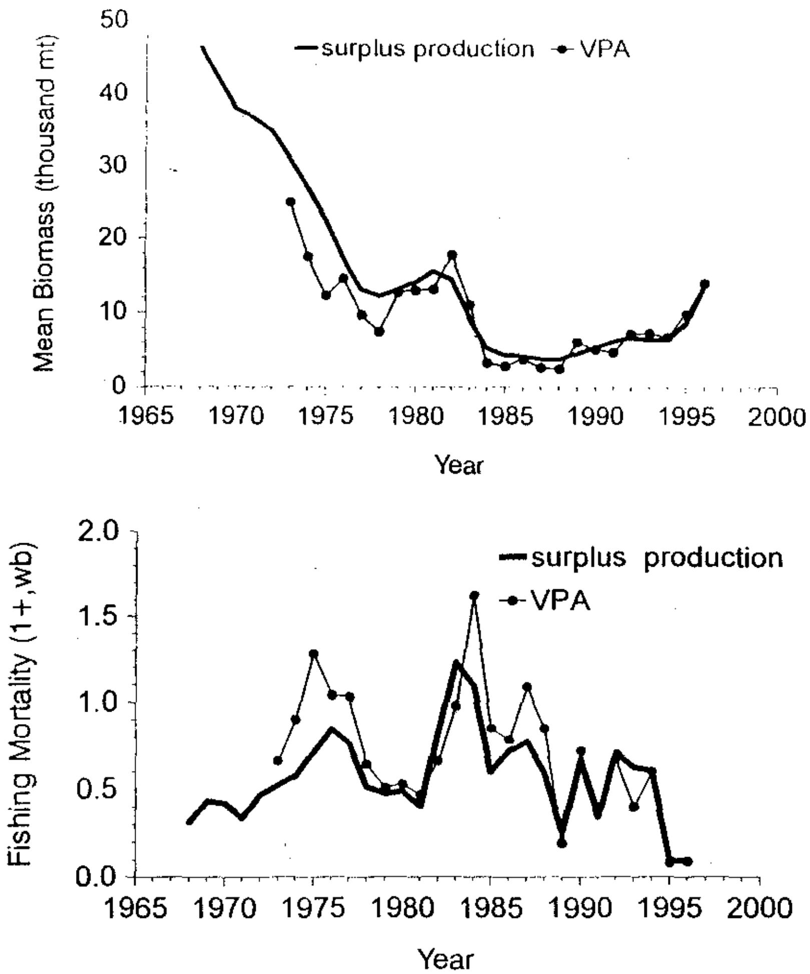

Figure D22. Comparison of results from VPA and surplus production modeling o f Georges Bank yellowtail flounder landings at various levels of fishing mortality.

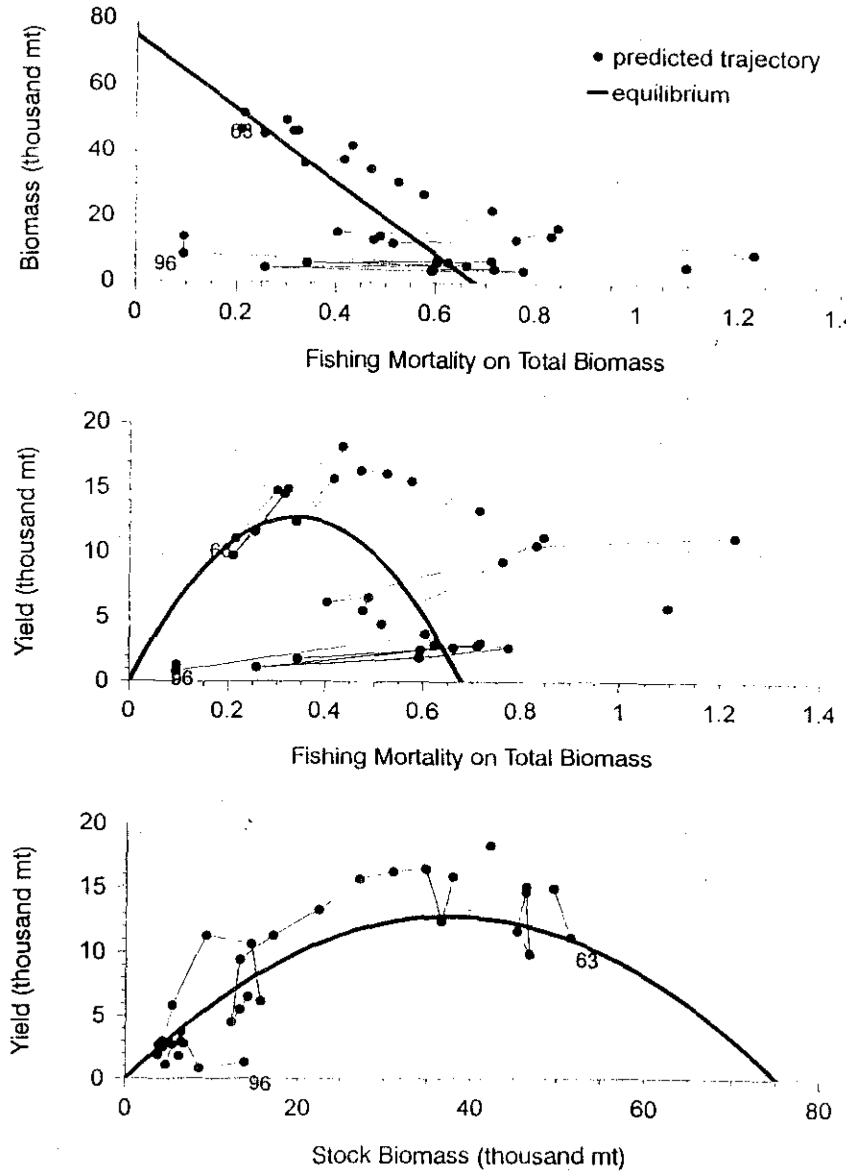

Figure D23. Biomass dynamics of Georges Bank yellowtail flounder.

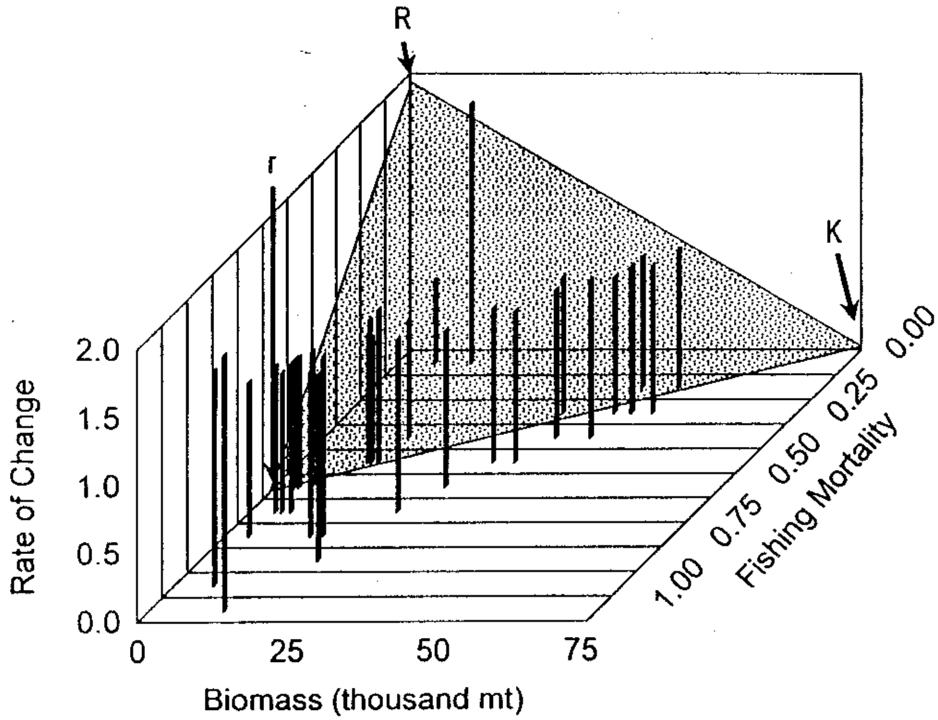

Figure D24. Expected population growth rate of Georges Bank yellowtail flounder as a function of biomass and F.

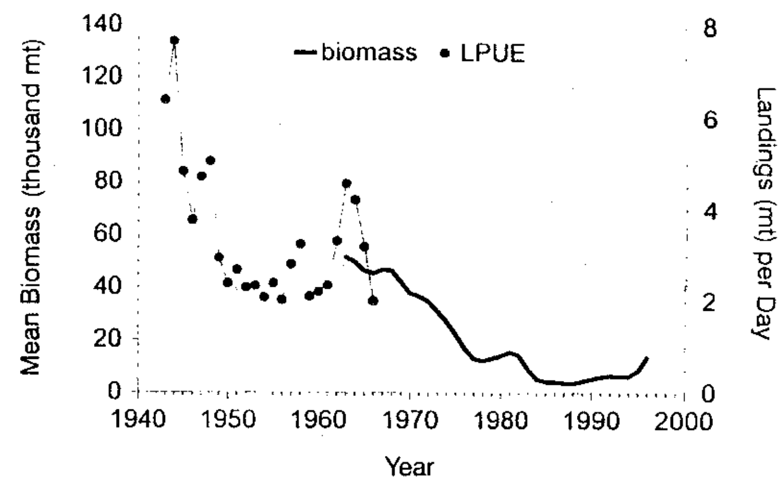

Figure D25. Estimated biomass of Georges Bank yellowtail flounder and historical estimates of landings per unit effort (Lux 1964, 1969a).

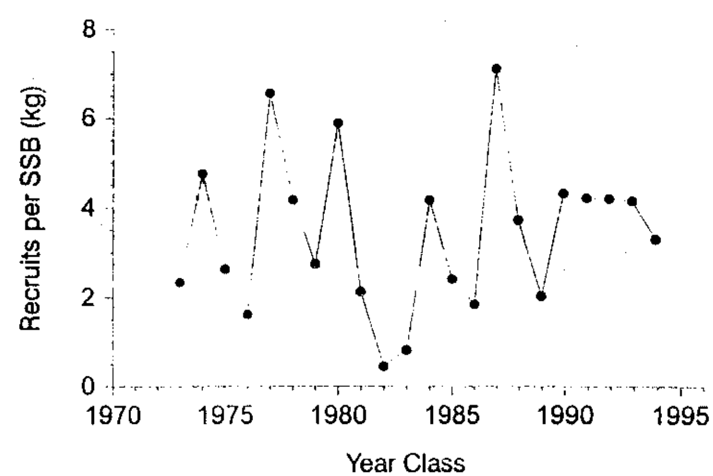

Figure D26. Calculated numbers of age-1 recruits per kilogram of spawning stock for Georges Bank yellowtail flounder, 1973-1994. The median R/SSB ratio for the time series is 3.5 and for the last five years is 4.2.

E. SOUTHERN NEW ENGLAND YELLOWTAIL FLOUNDER

Terms of Reference

a. Assess the status of Southern New England yellowtail flounder through 1996 and characterize the variability of estimates of stock abundance and fishing mortality rates.

b. Provide projected estimates of catch for 1997-1998 and SSB for 1998-1999 at various levels of F, including all relevant biological reference points.

c. Advise on the assessment and management implications of incorporating commercial discard data in the assessment.

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 and 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 and increased slightly to 285 mt in 1996 (Table E1).

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 during 1971-1976. With the implementation of the Magnuson Fishery Conservation and Management Act in 1976, yellowtail flounder was managed under the New England Fishery Management Council's (NEFMC) Fishery Management Plan (FMP) for Atlantic Groundfish from 1977 to 1982. This complex plan regulated minimum cod-end 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 this 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. 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 1973-1996 based on analyses of commercial and research vessel survey data through 1996. 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 the course of 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.* (1997) and DeLong *et al.* (1997).

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). Landings for 1994-1996 were obtained by prorating dealer records with data from the vessel trip report system (VTR) (Wigley *et al.* 1997). 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 1993-1996 were obtained by applying commercial length and age data on a semi-annual basis to the available landings (Table E2). For estimation of landings at age, age samples were pooled over market categories within quarter or semi-annual period (Table E3). Consistent with previous assessments, no separation using sex disaggregated age-length keys was attempted. Mean weights at age in the landings for 1973-1996 are summarized in Table E4.

Discard Estimation

Discarding of undersized fish by otter trawlers has long been recognized as a problem in the yellowtail flounder fishery (Figure E1). 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 1994-1996 (Tables E2 and E5a). 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 for a 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 1994-1996 were also estimated from logbook data (DeLong *et al.* 1997) and pooled sea sample lengths (Tables E2 and E5b). Total discards for 1993-1996 are summarized in Table E6.

Catch at Age

Catch at age for the Southern New England yellowtail flounder stock composed of landings and discards is summarized in Table E7.

Stock Abundance Indices

Indices of mean weight per tow from spring and autumn research vessel surveys indicate that this stock has traversed through several major changes in abundance during 1963-1996. Indices throughout the 1960s and early 1970s were relatively high in both surveys (Table E8). 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 E8). Indices rebounded in 1989 with recruitment from the large 1987 year class, but again declined, this time to historically low levels in 1993 and 1994. The spring and autumn indices have increased slightly since 1994 (Table E8).

Indices of age-specific stratified mean catch per tow (number) were available from NEFSC spring (1968-1996) and autumn (1963-1996) bottom trawl surveys (Table E9a and E10a, respectively) and from NEFSC scallop (1982-1996) surveys (Table E11). Spring and autumn survey indices were adjusted for the effects of vessel (*Albatross IV* vs. *Delaware II*), otter trawl door changes (see **Data and Methodology Issues** section of this report), and, in the case of spring surveys, net changes (Sissenwine and Bowman 1978) over the course of the fall and spring surveys (Tables E9b and E10b).

Aggregate indices in 1993 were the lowest in the time series for autumn trawl and scallop surveys. The aggregate index in 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 E9b, E10b, and E11). Indices from the spring, autumn, and scallop surveys were used to tune an ADAPT run for this stock for 1996.

The winter survey began in 1992 utilizing a net specifically designed to capture flatfish and producing survey catch rates that are approximately 10 times higher than in the spring and autumn surveys (Table E12). This survey time series, although too short to utilize as a tuning index at this time, indicated that the 1992 and 1993 cohorts were relatively stronger that those from 1991, 1994, and 1995.

Area Closure Analysis

Permanent area closures on Georges Bank and Nantucket Shoals have been in place since December 1994. These areas comprise former haddock spawning closure locations, Area I in the Great South Channel, Area II adjacent to the Hague Line, and a rectangular area in Southern New England. Areas I and II were closed to protect groundfish, while the Nantucket Shoals closure was specifically for yellowtail flounder.

NMFS research vessel seasonal data from 1995 and 1996 combined were used to describe the locations of yellowtail flounder relative to the three closed areas. Winter surveys from 1995 and 1996 indicate that a larger proportion of the available fish were found in Area II and also in the Nantucket Shoals closed area. As with the spring surveys, significant numbers of fish were found outside the closed areas on the Northeast Peak and to the east and west of the Nantucket Shoals closed area (Figure E2). Spring surveys indicate that, although some moderate concentrations of yellowtail flounder were found in the Georges Bank areas, most of the catches occurred outside the closures, primarily on the Northeast Peak of Georges Bank and the inshore waters of Massachusetts (Figure E3). Catches in the autumn surveys during 1995 and 1996 were less concentrated and generally lower than in the winter and spring surveys. Although a few concentrations of fish were caught in Areas I and II, much of the available stocks appeared to be located on the Northeast Peak of Georges Bank and along the Massachusetts coast (Figure E4).

In summary, although some concentrations of yellowtail flounder were present in Areas I, II, and in the Nantucket Shoals closure, significant proportions of the available yellowtail flounder resource are currently found outside these closed areas. This seems to be especially true of the Southern New England area where significant numbers of fish were found outside the closed area (Figure E2).

VPA Results

Virtual population analyses were tuned using unweighted non-linear least squares methods (ADAPT; Gavaris 1988; Conser and Powers 1990). Survivors at ages 2-5 in 1996 were estimated as well as catchability coefficients for spring surveys ages 2-4 and 5+, autumn surveys ages 2-3 and 4+ and scallop surveys ages 2-3 and 4+ abundance. The survey indices used in the objective function were unweighted and catches at ages 7 and 8 were combined in a plus group. Fishing mortality at age 7 was assumed to be equal to F at age 6. Natural mortality, as in previous assessments, was assumed to equal 0.2.

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 0.27 and was reduced even further to 0.12 in 1996 (Table E13; Overholtz *et al.* 1997, Appendix A). The fishing rate in 1996 was below the $F_{0.1}$ reference point of 0.27.

Stock Size

Stock size at age 2 was imprecisely estimated and the CV on ages 3-5+ averaged about 0.40 (Table E13; Overholtz *et al.* 1997, Appendix A). 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 6 million fish in 1993. Since then, stock size gradually increased from 14 million in 1994 to 24 million fish in 1996 (Table E13; Overholtz *et al.* 1997, Appendix A).

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 E13, Figure E5; Overholtz *et al.* 1997, Appendix A). This increase in 1982 resulted primarily from recruitment of the large 1980 year class. The stock was fished heavily and SSB declined again to 2,900 mt in 1986 (Figures E5 and E6). Another large cohort (1987) recruited in 1989 and 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 1,057 mt in 1993 (Table E13; Figures E5 and E6; Overholtz *et al.* 1997, Appendix A). SSB increased gradually in 1994-1995, reaching 4,300 mt in 1996. 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 E13; Figure E6; Overholtz *et al.* 1997, Appendix A). 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 (Table E13; Figure E6). 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 1990-1995 ranged from 2.5 million to 9.9 million fish and averaged only about 5 million fish (Table E13; Figure E6;

Overholtz *et al.* 1997, Appendix A). The 1995 cohort may be about equal in magnitude to the 1993.

Bootstrap Estimates

ADAPT results were re-sampled to provide estimates of approximate bias and probability distributions of spawning stock biomass and fishing mortality rates in 1996. Coefficients of variation on estimates of stock size for Southern New England yellowtail flounder range from 0.77 to 0.33 for ages 2-5, respectively (Overholtz *et al.* 1997, Appendix B). Approximate bias was about 26% on age 2 and substantially lower on the other ages (Overholtz *et al.* 1997, Appendix B).

Cumulative frequency distributions of SSB and fishing mortality are presented in Figures E7 and E8. Estimates of spawning stock biomass in 1996 ranged from roughly 2,500 mt to 8,000 mt, with an 80% CI of 2,500-5,000 mt (Figure E7). Fishing mortality rates in 1996 ranged from 0.08 to 0.28, with an 80% CI of 0.10-0.20 (Figure E8).

Yield per Recruit

Since the selection pattern in the fishery for this stock appeared to have changed during 1994-1996, biological reference points were re-estimated. Based on this analysis, $F_{0.1}$ = 0.27 (Table E14).

Short-Term Projections

Forecasts of stock status during 1997-1999 for the Southern New England yellowtail flounder stock were completed. A stochastic approach, utilizing 200 bootstrap starting (1997) stock size estimates from ADAPT results, was utilized to project landings, discards, and spawning stock biomass over the 3-year period. Fishing rates used in the projections were $F_{0.1}$ (F = 0.27) and the 1996 fishing rate (F = 0.12). Recruitment estimates were drawn from the lower 33% (eight values ranging between 2.2 and 9.9 million fish from the 1973-1995 recruitment time series). Spawning stock biomass has been low over the last several years producing many of the poorest year classes in the 1973-1996 series (Figure E9).

Projected landings and SSB (median values) continue to increase slowly through 1999 under either the $F_{0.1}$ or the F_{96} fishing rates that were used in the projections. Under the $F_{0.1}$ scenario, landings would increase from 600 mt in 1997 to 750 mt in 1998 and to 1,000 mt in 1999 (Table E15). Spawning stock biomass would also continue to increase from 5,100 mt in 1997 to 6,800 mt in 1999 (Table E15). Assuming the fishing rate in 1996 was applied over the 1997-1999 period, landings would increase from 300 mt in 1997 to about 600 mt in mt 1999. The spawning stock would increase from 5,300 mt in 1997 to 8,000 mt in 1999 (Table E15). The 80% CI on the estimates is also shown in Table E15.

Medium-Term Projections

The methodology for conducting medium-term (e.g., 10-year) projections is described in the **Data and Methodology Issues** section of this report. Stock-recruitment data and the fitted Beverton-Holt equation are presented in Figure E9. Trends in pre-recruit survival (measured as the R/SSB ratio) are presented in Figure E10. The median, lower 25th, and upper 75th percentiles of projected spawning stock biomass, recruitment (age 1), and landings are given in Tables E16 and E17 and Figure E11 for fishing mortality rate scenarios of F = 0.27 and 0.12, respectively. The annual probability that SSB will exceed the 10,000 mt threshold is plotted in Figure E12.

Under the $F_{0.1}$ = 0.27 scenario, landings increase from 1,000 mt in 1998 to 7,200 mt in 2006, while spawning stock biomass improves from 7,800 mt to 40,700 mt and recruitment from 17.2 to 32.3 million fish during 1998-2006 (Table E16; Figure E11). For F = 0.12, landings increase from 500 mt in 1998 to 4,900 mt, while spawning stock biomass increases from 8,500 mt in 1998 to 57,100 mt in 2006, and median recruitment improves from 17.1 to 37.8 million fish(Table E17; Figure E11). Under the F = 0.27 scenario, the probability of exceeding the biomass threshold increases from 27% in 1998 to >99% by 2004. For F = 0.12, the annual probability of SSB exceeding the 10,000 mt threshold increases from 34% in 1998 to >99% by 2002 (Figure E12).

Summary

Results from virtual population analysis and research vessel surveys indicate that stock abundance was still very low in 1996, although there appears to be an increasing trend.

Fishing mortality declined to F = 0.27 in 1995 and was well below the $F_{0.1}$ reference point of 0.27 in 1996 (F = 0.12).

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 1994 and possibly the 1996 cohorts are moderately larger than the 1990-1993 and 1995 cohorts, but are small in comparison to the average size of a year class during 1973-1988.

Age structure in this stock was severely truncated in the period 1970-1994. There is some indication that this trend may have been reversed and stock age structure may be improving.

Forecasts indicate that spawning stock biomass will continue to improve slowly during 1997-1999 if fishing rates are kept at or below the $F_{0.1}$ level.

SARC Comments

The SARC suggested additional information or analyses which could be included in the assessment of Southern New England yellowtail flounder in the future. It was suggested that a summary of historical fleet capacity (effort) over time would be useful, even in light of the changes in management regulations such as TACs and various time-area closures which have occurred over the assessment period. The SARC agreed that including the historical record of catch as far back as possible would place current conditions in a proper perspective. The SARC commented that there may be different reasons for discarding in the otter trawl fishery and suggested that VTR data be explored further to determine if separate discard ratios could be derived for both small-mesh and large-mesh otter trawl fisheries. The SARC observed that the maturity schedule for Southern New England yellowtail flounder had not changed as much over time as that for Georges Bank yellowtail. The SARC recommended that recent maturity data be evaluated to update the maturity ogive and that the updated maturity vector should be used in any re-calculation of biological reference points.

Pertaining to the virtual population analysis, the SARC commented on the catchability pattern in the scallop survey tuning index. This may be related to a time trend in the residuals. The SARC suggested that the utility of the scallop tuning index be investigated. Also, it was suggested that the high CV associated with age 2 stock numbers be examined further. The SARC recommended that a retrospective analysis be conducted.

General comments were made regarding the decline in Southern New England yellowtail flounder landings and fishing mortality in recent years. Currently, the fishery is primarily a bycatch fishery. This has been attributed to: 1) increases in regulated mesh size; 2) the summer flounder and sea scallop fisheries shifting away from the Southern New England area; and 3) low stock size.

The SARC noted that the SSB threshold should be regarded as a minimum level and not a target, and that absolute biomass thresholds may change as assessment data and methods are updated. The SARC agreed that the 10,000 mt threshold for Southern New England yellowtail flounder was very low relative to historical SSB levels and likely values of B_{MSY}.

Research Recommendations

- Improve sea sampling coverage on otter trawl and scallop vessels to allow for better estimation of discards.
- Increase sampling frequency of yellowtail flounder for this stock in the research surveys.
- Collect adequate numbers of quarterly commercial samples for length and age composition.

- Examine VTR data to determine if otter trawl discard ratios could be derived by mesh size, i.e., small-mesh and large-mesh, if possible.

- Evaluate changes in the maturity ogive in recent years (similar to the Georges Bank yellowtail flounder analysis).

- Perform retrospective analysis on VPA results for this stock.

- Evaluate the overall performance of the scallop survey as an index for tuning the VPA.

- Perform hindcast analyses, using production models (ASPIC) or survey biomass indices. Explore methods to estimate important management reference points such as B_{msy}.

- Evaluate the potential use of the winter NEFSC research survey as a tuning index in the VPA.

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Table E1 Commercial landings of yellowtail flounder (thousands of metric tons) from Southern New England for 1960-1996 (U.S. Statistical Reporting Areas 526, 537-539) as reported by NEFSC weigh out, state bulletin and canvas data (U.S.) 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

Table E2. Samples available for 1996 SNE Yellowtail Flounder Assessment.

	Commercial						Discard					
	Lengths				Ages		Lengths-sea sampling		VTR-trips			
	Market Category						Gear					
	1231		1232				050	132	050		132	
	Q12	Q34	Q12	Q34	Q12	Q34			Q12	Q34	Q12	Q34
93	347	72	625	234	189	73	*	*				
94	102	252	133	254	52	143	*	*	66	169	4	14
95	234	94	240	146	121	50	*	*	182	105	3	18
96	0	469	0	691	0	226	*	*	166	144	9	17

* A total of 173 otter trawl lengths and 212 scallop dredge lengths were available from sea sampling for 1993-1996, no ages were available

Table E3. Commercial landings at age of yellowtail flounder (numbers in thousands), Southern New England (U.S. Statistical Reporting Areas 526, 537-539), 1973-1996.

	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

Table E4. Mean weight (kilograms) at age of Southern New England yellowtail flounder in landings, 1973-1992.

	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

Table E5A. Discards of Southern New England yellowtail flounder by otter trawls during 1993-1996.

		AGE					
		1	2	3	4	5	6
	half						
1993	1		181515	13233	8953		
	2	12824	30432	1730			
total		12824	211947	14963	8953		
1994	1		64527	5377			
	2	7346	29159	2563	2562		
total		7346	93686	7940	2562		
1995	1		45222	11575	1114		
	2	4981	11065	632			
total		4981	56287	12207	1114		
1996	1		25924	24059			
	2	19362	11423	3446			
total		19362	37347	27505			

Table E5B. Discards of southern New England yellowtail flounder by scallop dredges during 1994-1996

		1	2	3	4	5	6
	half						
1994	1		22566	14204	13978	6309	353
	2	1209	18242	12632	12812	5900	1505
total		1209	40808	26836	26790	12209	1858
1995	1		646	409	400	181	10
	2	2452	36995	25618	25982	11966	3053
total		2452	37641	26027	26382	12147	3063
1996	1		22457	14136	13910	6278	351
	2	1412	21301	14751	14960	6890	1758
total		1412	43758	28887	28870	13168	2109

Table E6. Estimated discard at age of yellowtail flounder (numbers in thousands), Southern New England, 1973-1996.

	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

Table E7. Total catch at age of yellowtail flounder (numbers in thousands), Southern New England, 1973-1996.

	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

Table E8. Mean weight per tow (kg) from research vessel surveys during 1963-1996 for Southern New England yellowtail flounder (Strata 5,6,9,10).

	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	0.653	0.229
1993	0.506	0.053
1994	0.219	0.374
1995	0.360	0.432
1996	1.054	0.266

Table E9A. NEFSC spring trawl survey mean number of Southern New England yellowtail flounder per tow at age during 1968-1996 (NEFSC offshore strata 5, 6, 9 and 10) (no correction for net, door, or vessel applied).

	Age								
Year	1	2	3	4	5	6	7	8	Total
1968	1.362	25.999	26.158	15.575	0.726	0.138	0.055	0	70.013
1969	4.182	16.284	22.345	12.029	2.082	0.234	0	0	57.156
1970	1.218	8.745	16.364	11.587	3.333	0.898	0.193	0.079	42.417
1971	0.874	9.281	6.983	19.397	4.971	0.793	0.009	0.009	42.317
1972	0.403	17.905	12.078	3.767	7.224	1.115	0.211	0	42.703
1973	1.877	10.488	18.340	9.053	6.147	9.514	1.183	0.658	57.260
1974	1.070	4.288	3.355	3.650	2.376	0.856	1.390	0.278	17.263
1975	0.809	2.244	0.721	1.110	1.169	0.679	0.047	0.211	6.990
1976	0.037	4.702	0.761	0.361	0.435	0.361	0.227	0.073	6.957
1977	0.296	1.804	2.244	0.239	0.249	0.116	0.035	0.148	5.131
1978	4.275	14.113	2.924	1.032	0.270	0.052	0.068	0.199	22.933
1979	2.224	4.843	2.512	0.510	0.159	0	0	0.012	10.260
1980	0.534	6.208	4.729	3.911	0.420	0.168	0.008	0.056	16.034
1981	0.344	14.634	5.243	2.170	0.788	0.079	0	0	23.258
1982	0.321	13.548	7.193	1.794	0.583	0.179	0.019	0	23.637
1983	0.074	3.197	10.587	0.868	0.256	0	0	0	14.982
1984	0	0.410	1.351	2.141	0.545	0.183	0	0	4.630
1985	0.561	0.744	0.417	0.201	0.454	0.093	0	0	2.470
1986	0.037	4.083	1.492	0.308	0.073	0.036	0	0	6.029
1987	0	0.198	0.919	0.144	0	0	0	0	1.261
1988	0.327	0.692	0.177	0.245	0.127	0	0	0	1.568
1989	0.178	12.127	0.710	0.078	0	0	0	0	13.093
1990	0.107	0.433	22.346	4.464	0.036	0	0	0	27.386
1991	0.515	0.400	1.850	5.275	0.600	0.130	0	0	8.770
1992	0.081	0.269	0.275	1.196	0.112	0	0	0	1.933
1993	0.037	0.533	0.221	0.517	0.097	0	0	0	1.405
1994	0.036	0.581	0.047	0.022	0.053	0.018	0	0	0.757
1995	0.054	0.944	0.284	0.072	0.030	0.011	0.018	0	1.418
1996	0	0.528	2.442	0.314	0.063	0	0	0	3.346

Table E9B NEFSC spring trawl survey mean number of Southern New England yellowtail flounder per tow at age during 1968-1996 (NEFSC offshore strata 5, 6, 9 and 10) (corrected for net, door, and vessel).

	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

Table E10A. NEFSC autumn trawl survey mean number of Southern New England yellowtail flounder per tow at age during 1963-1996 (NEFSC offshore strata 5, 6, 9, and 10) (no correction for net, door, or vessel applied).

	Age								
Year	1	2	3	4	5	6	7	8	Total
1963	16.228	16.531	12.262	4.779	0.541	0.124	0	0.082	50.547
1964	18.466	26.190	4.804	7.132	3.265	0.908	0	0	60.765
1965	10.845	17.533	6.370	1.754	1.776	0.127	0	0.074	38.479
1966	35.496	10.710	1.947	1.022	0.189	0	0	0	49.364
1967	18.440	25.540	11.243	1.587	0.387	0.065	0.131	0	57.393
1968	9.250	10.944	18.738	1.183	0.094	0	0	0	40.209
1969	11.870	9.741	27.755	5.206	0.093	0.041	0.041	0	54.747
1970	4.227	5.521	16.341	10.624	2.514	0.426	0.073	0	39.726
1971	6.351	10.900	6.244	15.138	2.694	0.216	0.161	0	41.704
1972	4.209	16.496	19.716	18.847	12.288	1.680	0.044	0	73.280
1973	1.415	1.303	1.823	1.344	1.017	0.866	0.174	0	7.942
1974	0.997	1.678	0.554	2.275	0.956	0.401	0.195	0.076	7.132
1975	1.624	0.423	0.218	0.27	0.274	0	0.085	0	2.894
1976	2.977	6.009	0.719	0.072	0.114	0.296	0.347	0.155	10.689
1977	1.696	2.194	0.798	0.051	0.044	0.109	0.075	0	4.967
1978	3.131	7.328	0.434	0.378	0.041	0.009	0.076	0.031	11.428
1979	1.730	4.371	2.446	0.374	0.041	0.040	0	0	9.002
1980	1.411	4.345	1.159	0.411	0	0	0	0	7.326
1981	4.536	8.625	1.354	0.322	0.077	0.059	0	0	14.973
1982	2.139	24.075	7.109	0.840	0.335	0	0	0	34.498
1983	3.756	14.718	8.261	0.718	0.060	0	0.041	0	27.554
1984	0.589	1.817	1.967	0.540	0	0	0	0	4.913
1985	1.198	0.526	0.189	0.144	0	0	0	0	2.057
1986	0.972	1.982	0.429	0.103	0	0	0	0	3.486
1987	1.515	0.674	0.558	0.047	0.037	0	0.037	0	2.868
1988	1.484	0.457	0.203	0.229	0.056	0	0	0	2.429
1989	0	9.416	1.647	0.077	0	0	0	0	11.140
1990	0	0.114	2.818	0.318	0	0	0	0	3.250
1991	1.018	0.258	2.011	0.533	0	0	0	0	3.746
1992	0.261	0.062	0.180	0.337	0.012	0	0	0	0.852
1993	0.082	0.018	0.033	0.024	0	0	0	0	0.157
1994	0.754	0.553	0.198	0.192	0.085	0.011	0	0	1.793
1995	0.180	1.306	0.171	0.095	0	0	0	0	1.765
1996	0.653	0.290	0.258	0.025	0	0	0	0	1.226

Table E10B. NEFSC autumn trawl survey mean number of Southern New England yellowtail flounder per tow at age during 1963-1996 (NEFSC offshore strata 5, 6, 9, and 10) (corrected for door and vessel).

	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

Table E11. NESFC scallop survey mean number of Southern New England yellowtail flounder per tow at age during 1982-1996.

	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

Table E12. NESFC winter survey mean number of Southern New England yellowtail flounder per tow at age during 1992-1996.

	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

Table E13. Summary of Results for Southern New England Yellowtail flounder from SAW-24 VPA.

STOCK NUMBERS (Jan 1) in millions - SNE96

	1973	1974	1975	1976	1977	1978	1979	1980	1981
1	42.145	9.228	28.861	12.907	47.568	52.417	30.089	41.941	126.926
2	15.231	34.335	6.779	15.631	10.374	34.021	35.045	24.450	33.445
3	19.879	7.895	2.475	2.132	6.826	4.177	15.811	11.298	10.972
4	10.104	8.765	2.197	0.671	0.922	1.994	2.068	5.370	3.512
5	3.811	4.045	2.564	0.909	0.327	0.400	0.706	0.760	1.123
6	3.443	1.567	1.048	0.961	0.439	0.082	0.178	0.192	0.195
7	0.703	1.968	0.885	0.861	0.484	0.170	0.043	0.049	0.021
1+	95.316	67.803	44.809	34.072	66.939	93.261	83.940	84.060	176.195

	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	53.147	14.584	16.731	19.837	6.969	13.988	122.026	16.544	6.899
2	103.884	43.359	9.654	13.236	14.223	5.287	10.013	94.569	13.524
3	21.280	53.266	18.823	2.719	4.489	2.886	1.249	6.343	60.040
4	2.888	5.032	8.670	1.982	0.854	1.032	0.524	0.563	2.386
5	0.661	0.786	1.077	1.071	0.435	0.192	0.119	0.060	0.089
6	0.119	0.175	0.304	0.212	0.177	0.063	0.031	0.006	0.007
7	0.011	0.056	0.024	0.048	0.032	0.012	0.011	0.000	0.000
1+	181.989	117.258	55.283	39.104	27.179	23.460	133.972	118.086	82.944

	1991	1992	1993	1994	1995	1996	1997
1	3.835	2.536	2.765	9.887	5.165	11.994	0.000
2	5.474	2.737	1.645	2.252	8.086	4.222	9.801
3	9.219	3.028	0.926	0.964	1.708	6.396	3.181
4	10.986	2.979	0.686	0.418	0.588	1.251	4.788
5	0.121	0.409	0.315	0.176	0.193	0.292	0.888
6	0.001	0.015	0.082	0.146	0.025	0.131	0.213
7	0.022	0.004	0.000	0.003	0.018	0.060	0.139
1+	29.659	11.707	6.419	13.845	15.784	24.346	19.009

FISHING MORTALITY - SNE96

	1973	1974	1975	1976	1977	1978	1979	1980	1981
1	0.0049	0.1085	0.4132	0.0185	0.1352	0.2026	0.0075	0.0264	0.0003
2	0.4571	2.4300	0.9566	0.6285	0.7097	0.5663	0.9320	0.6013	0.2522
3	0.6189	1.0791	1.1046	0.6385	1.0304	0.5032	0.8798	0.9683	1.1347
4	0.7155	1.0293	0.6831	0.5185	0.6353	0.8391	0.8011	1.3650	1.4705
5	0.6885	1.1501	0.7809	0.5271	1.1806	0.6069	1.1037	1.1582	2.0441
6	0.6663	1.1086	0.8674	0.5971	1.0122	0.6099	0.9013	1.1219	1.3043
7	0.6663	1.1086	0.8674	0.5971	1.0122	0.6099	0.9013	1.1219	1.3043

	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	0.0035	0.2125	0.0343	0.1327	0.0761	0.1342	0.0549	0.0016	0.0312
2	0.4680	0.6344	1.0673	0.8813	1.3949	1.2430	0.2565	0.2543	0.1832
3	1.2419	1.6154	2.0512	0.9579	1.2698	1.5072	0.5970	0.7779	1.4984
4	1.1012	1.3421	1.8912	1.3157	1.2944	1.9632	1.9605	1.6449	2.7815
5	1.1290	0.7512	1.4254	1.6024	1.7297	1.6175	2.8221	1.9719	3.9864
6	1.2745	1.6800	2.1949	1.2178	1.3648	1.7258	0.9253	0.8525	1.6275
7	1.2745	1.6800	2.1949	1.2178	1.3648	1.7258	0.9253	0.8525	1.6275

	1991	1992	1993	1994	1995	1996
1	0.1373	0.2330	0.0052	0.0010	0.0015	0.0019
2	0.3922	0.8837	0.3343	0.0765	0.0345	0.0832
3	0.9298	1.2852	0.5956	0.2937	0.1114	0.0896
4	3.0917	2.0465	1.1604	0.5733	0.5016	0.1432
5	1.8937	1.4052	0.5709	1.7677	0.1886	0.1164
6	1.6996	1.6894	0.7737	0.4646	0.1982	0.1164
7	1.6996	1.6894	0.7737	0.4646	0.1982	0.1164

Avg F for ages 1 1 2 7 3 7 4 7 5 7

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
1	0.0049	0.1085	0.4132	0.0185	0.1352	0.2026	0.0075	0.0264	0.0003	0.0035
2	0.6354	1.3176	0.8767	0.5845	0.9300	0.6225	0.9199	1.0561	1.2517	1.0815
3	0.6711	1.0951	0.8607	0.5757	0.9741	0.6338	0.9174	1.1471	1.4516	1.2042
4	0.6842	1.0991	0.7997	0.5600	0.9600	0.6665	0.9269	1.1917	1.5308	1.1948
5	0.6737	1.1224	0.8386	0.5738	1.0683	0.6089	0.9688	1.1340	1.5509	1.2260

	1983	1984	1985	1986	1987	1988	1989	1990	1991
1	0.2125	0.0343	0.1327	0.0761	0.1342	0.0549	0.0016	0.0312	0.1373
2	1.2838	1.8042	1.1988	1.4031	1.6304	1.2478	1.0590	1.9508	1.6178
3	1.4137	1.9515	1.2623	1.4047	1.7079	1.4460	1.2199	2.3043	1.8629
4	1.3633	1.9266	1.3384	1.4384	1.7581	1.6583	1.3304	2.5058	2.0961
5	1.3704	1.9384	1.3460	1.4865	1.6897	1.5575	1.2256	2.4138	1.7643

	1992	1993	1994	1995	1996
1	0.2330	0.0052	0.0010	0.0015	0.0019
2	1.4999	0.7014	0.6067	0.2054	0.1108
3	1.6232	0.7749	0.7128	0.2396	0.1164
4	1.7076	0.8197	0.8175	0.2716	0.1231
5	1.5947	0.7061	0.8990	0.1950	0.1164

SSB AT THE START OF THE SPAWNING SEASON - males & females (1000s MT)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
1	1.056	0.214	0.633	0.349	1.156	1.348	0.678	1.022	2.125	1.434
2	2.554	2.616	0.898	2.482	1.492	5.415	4.870	3.641	5.371	15.306
3	5.277	1.630	0.542	0.629	1.542	1.228	3.616	2.613	2.115	4.048
4	2.898	2.253	0.668	0.263	0.339	0.702	0.648	1.396	0.847	0.843
5	1.132	1.099	0.743	0.358	0.097	0.203	0.242	0.298	0.273	0.251
6	1.214	0.432	0.315	0.392	0.128	0.046	0.077	0.098	0.069	0.053
7	0.300	0.591	0.292	0.373	0.179	0.082	0.019	0.034	0.005	0.005
1+	14.431	8.835	4.092	4.845	4.934	9.024	10.151	9.102	10.806	21.941

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
1	0.279	0.359	0.411	0.150	0.391	3.851	0.615	0.245	0.089	0.046
2	5.938	1.007	1.648	1.543	0.575	1.795	19.516	2.790	0.829	0.407
3	8.354	2.151	0.608	0.799	0.501	0.349	1.609	10.960	1.896	0.586
4	1.321	1.407	0.451	0.215	0.173	0.107	0.142	0.318	1.154	0.502
5	0.355	0.272	0.273	0.116	0.049	0.022	0.018	0.012	0.034	0.125
6	0.066	0.073	0.073	0.057	0.017	0.018	0.004	0.003	0.001	0.005
7	0.021	0.006	0.023	0.013	0.005	0.006	0.000	0.000	0.006	0.003
1+	16.334	5.276	3.487	2.894	1.710	6.150	21.904	14.327	4.009	1.675

	1993	1994	1995	1996
1	0.040	0.128	0.076	0.211
2	0.349	0.475	1.720	1.038
3	0.280	0.268	0.603	2.272
4	0.183	0.126	0.202	0.505
5	0.147	0.043	0.110	0.150
6	0.057	0.079	0.018	0.076
7	0.000	0.002	0.013	0.042
1+	1.057	1.122	2.743	4.295

Table E14. Yield per Recruit for Southern New England 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: 30- 4-1997; Time: 13:32:14.95

SNE YT 1996

Proportion of F before spawning: .4170

Proportion of M before spawning: .4170

Natural Mortality is Constant at: .200

Initial age is: 1; Last age is: 7

Last age is a PLUS group;

Original age-specific PRs, Mats, and Mean Wts from file:

==> SNEYPR.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	.0100	1.0000	.1300	.130	.008
2	.1180	1.0000	.7400	.349	.191
3	.2870	1.0000	.9800	.394	.332
4	1.0000	1.0000	1.0000	.448	.454
5	1.0000	1.0000	1.0000	.572	.541
6	1.0000	1.0000	1.0000	.711	.649
7+	1.0000	1.0000	1.0000	.844	.767

Summary of Yield per Recruit Analysis for:

SNE YT 1996

Slope of the Yield/Recruit Curve at F=0.00: --> 2.0642

F level at slope=1/10 of the above slope (F0.1): -----> .273

Yield/Recruit corresponding to F0.1: -----> .1989

F level to produce Maximum Yield/Recruit (Fmax): -----> 6.481

Yield/Recruit corresponding to Fmax: -----> .2458

F level at 20 % of Max Spawning Potential (F20): -----> .936

SSB/Recruit corresponding to F20: --------> .4306

1

Listing of Yield per Recruit Results for:
SNE YT 1996

	FMORT	TOTCTHN	TOTCTHW	TOTSTKN	TOTSTKW	SPNSTKN	SPNSTKW	% MSP
	.000	.00000	.00000	5.5167	2.3924	4.0667	2.1530	100.00
	.075	.16512	.10618	4.6947	1.7878	3.2407	1.5550	72.22
	.150	.26050	.15848	4.2213	1.4481	2.7634	1.2207	56.70
	.225	.32304	.18717	3.9120	1.2321	2.4504	1.0093	46.88
F0.1	.273	.35312	.19891	3.7637	1.1310	2.2998	.9107	42.30
	.300	.36750	.20398	3.6929	1.0835	2.2278	.8645	40.15
	.375	.40094	.21429	3.5287	.9755	2.0604	.7597	35.28
	.450	.42717	.22084	3.4005	.8936	1.9292	.6805	31.61
	.525	.44840	.22512	3.2971	.8294	1.8229	.6187	28.74
	.600	.46604	.22800	3.2115	.7779	1.7347	.5692	26.44
	.675	.48100	.22998	3.1393	.7356	1.6599	.5286	24.55
	.750	.49390	.23140	3.0771	.7001	1.5954	.4947	22.98
	.825	.50520	.23244	3.0229	.6700	1.5390	.4659	21.64
	.900	.51520	.23323	2.9750	.6440	1.4891	.4411	20.49
F20%	.936	.51957	.23355	2.9542	.6329	1.4674	.4306	20.00
	.975	.52417	.23386	2.9323	.6214	1.4445	.4196	19.49
	1.050	.53227	.23438	2.8937	.6014	1.4042	.4006	18.61
	1.125	.53964	.23483	2.8586	.5835	1.3676	.3837	17.82
	1.200	.54641	.23523	2.8265	.5675	1.3340	.3686	17.12
	1.275	.55266	.23560	2.7970	.5531	1.3032	.3550	16.49
	1.350	.55846	.23594	2.7695	.5399	1.2745	.3426	15.91
	1.425	.56387	.23627	2.7440	.5278	1.2479	.3313	15.39
	1.500	.56893	.23658	2.7201	.5166	1.2230	.3208	14.90

Table E15. Projections of landings (mt), discards (mt), and SSB (mt), for Southern New England yellowtail flounder during 1997-1999 at Fo.1 (F=0.27) and F96 (F=0.12).

F97-99		1997 L	1997 D	1997 SSB	1998 L	1998 D	1998 SSB	1999 L	1999 D	1999 SSB
	10%	440	93	3631	566	111	4388	710	120	4948
0.27	50%	601	129	5089	753	148	6227	1032	178	6829
	90%	828	174	6790	978	189	8659	1493	271	9369
	10%	212	45	3753	296	58	4898	405	66	5876
0.12	50%	290	62	5298	395	77	6859	578	96	8024
	90%	399	83	7008	506	99	9438	814	144	10871

Table E16. Stochastic medium-term projections of spawning stock biomass (mt), recruitment (age 1, thousands) and landings (mt) for Southern New England yellowtail flounder, assuming F=0.27. Probability of SSB> the 10,000 mt threshold is given, along with the lower and upper quartiles and the median of bootstrap simulations.

	-Spawning Biomass-				-Recruitment -			- Landings -		
Year	L-25	Median	U-75	Probability	L-25	Median	U-75	L-25	Median	U-75
1997	4,239	5,083	5,791	0.000	7,127	14,737	30,493	608	689	799
1998	6,157	7,837	10,335	0.273	8,352	17,163	35,338	830	983	1,145
1999	8,776	12,016	17,252	0.650	9,641	19,252	38,748	1,267	1,598	2,051
2000	11,871	16,836	24,859	0.846	11,069	21,732	43,713	1,739	2,350	3,348
2001	15,113	21,712	31,735	0.934	12,660	23,751	47,058	2,315	3,241	4,706
2002	18,443	26,268	38,298	0.971	14,248	25,889	49,688	2,944	4,159	6,018
2003	21,534	30,520	44,104	0.988	15,669	28,025	53,609	3,576	5,055	7,315
2004	24,342	34,385	49,097	0.995	16,992	29,611	55,419	4,167	5,841	8,400
2005	26,864	37,676	53,625	0.998	17,966	30,930	56,698	4,688	6,557	9,337
2006	29,093	40,719	57,211	0.999	18,779	32,270	59,501	5,143	7,206	10,214

Table E17. Stochastic medium-term projections of spawning stock biomass (mt), recruitment (age 1, thousands) and landings (mt) for Southern New England yellowtail flounder, assuming F=0.12. Probability of SSB> the 10,000 mt threshold is given, along with the lower and upper quartiles and the median of bootstrap simulations.

	-Spawning Biomass-				-Recruitment -			- Landings -		
Year	L-25	Median	U-75	Probability	L-25	Median	U-75	L-25	Median	U-75
1997	4,425	5,296	6,049	0.000	7,203	14,917	31,099	285	326	377
1998	6,836	8,554	11,171	0.338	8,390	17,104	35,733	426	500	581
1999	10,088	13,505	18,993	0.756	9,837	19,788	40,247	689	852	1,071
2000	14,043	19,523	28,136	0.927	11,506	22,250	44,715	994	1,304	1,809
2001	18,462	25,966	37,242	0.980	13,455	24,709	47,691	1,358	1,858	2,635
2002	23,237	32,556	46,591	0.995	15,407	27,684	51,968	1,796	2,496	3,546
2003	27,880	38,882	55,368	0.999	17,564	30,823	57,375	2,259	3,142	4,471
2004	32,490	45,274	63,840	1.000	19,301	32,763	59,532	2,704	3,763	5,336
2005	37,186	51,525	71,587	1.000	21,351	35,562	63,687	3,150	4,365	6,116
2006	41,279	57,100	79,178	1.000	23,232	37,891	66,939	3,589	4,939	6,914

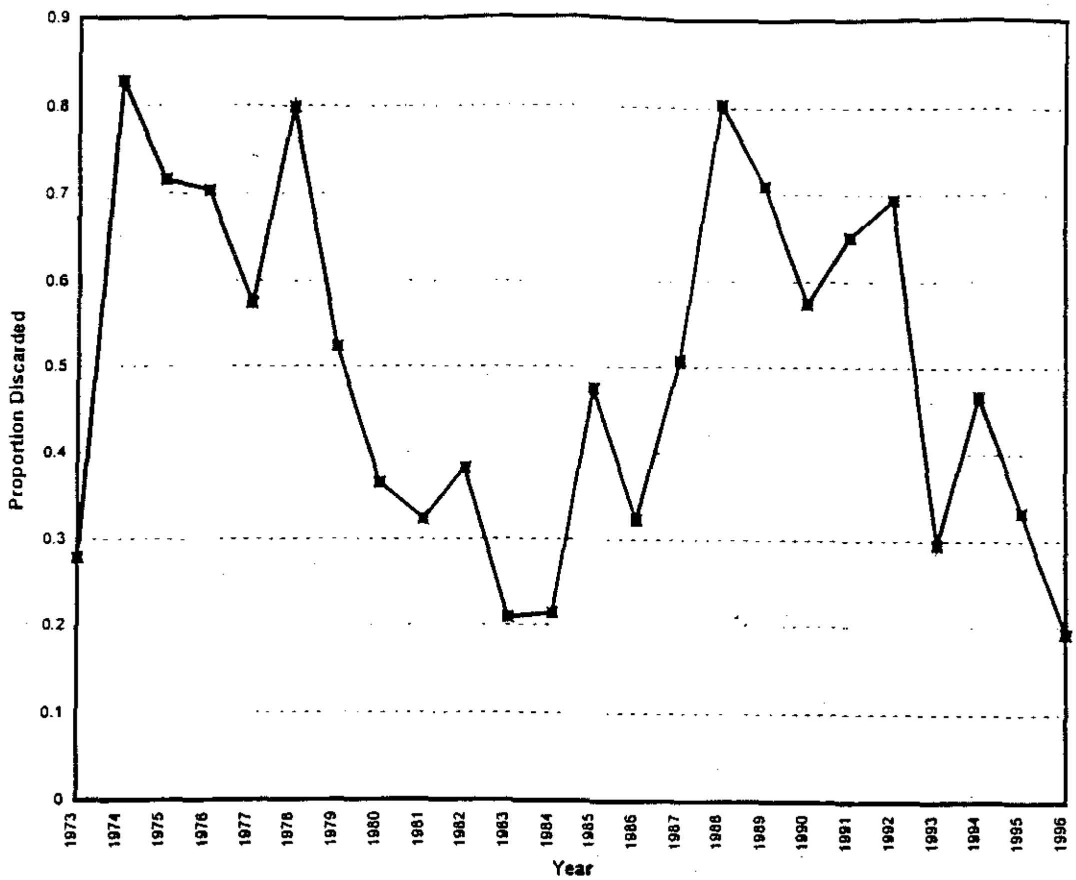

Figure E1. Proportion of total catch discarded in age groups 1-3 of Southern New England Yellowtail flounder during 1973-1996.

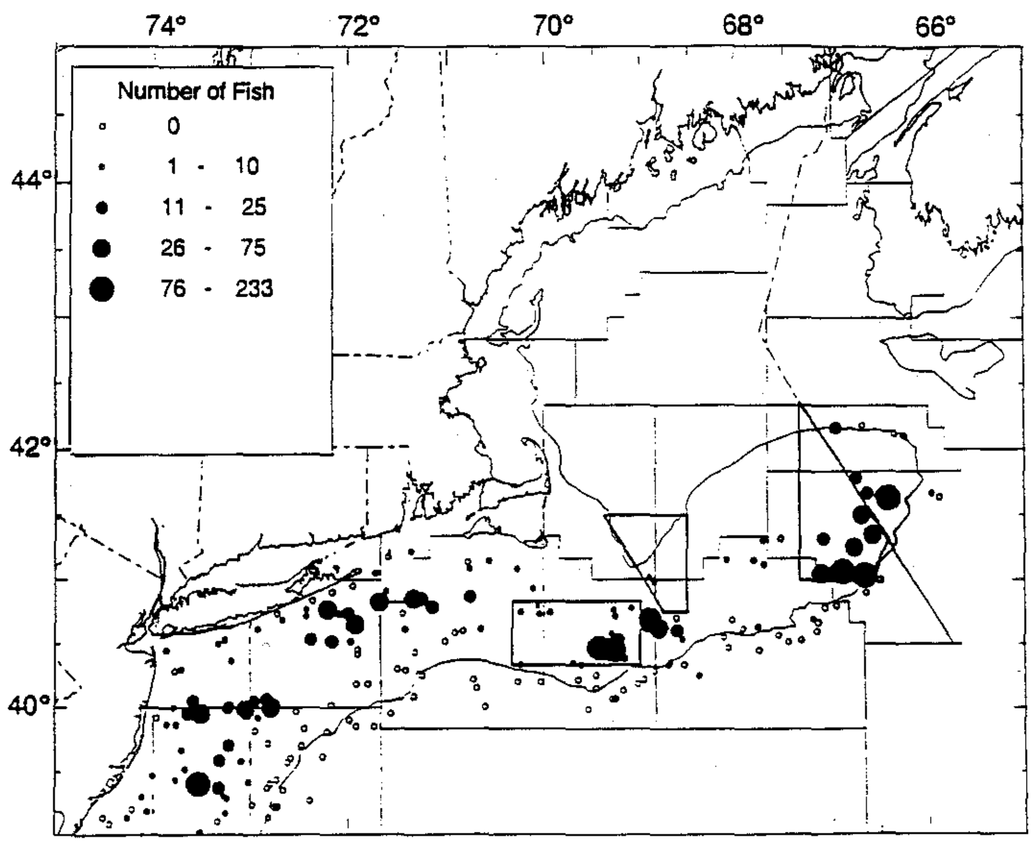

Figure E2. Distribution of yellowtail flounder during 1995-1996 from NEFSC winter bottom trawl surveys.

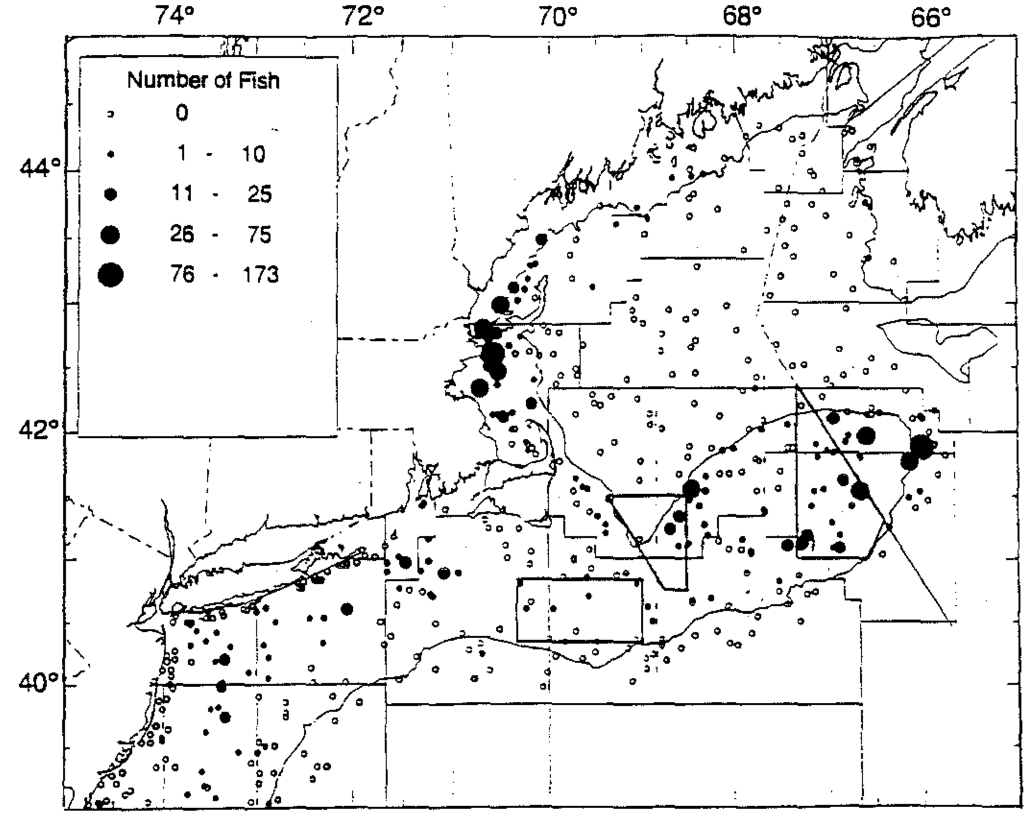

Figure E3. Distribution of yellowtail flounder during 1995-1996 from Spring NEFSC bottom trawl surveys.

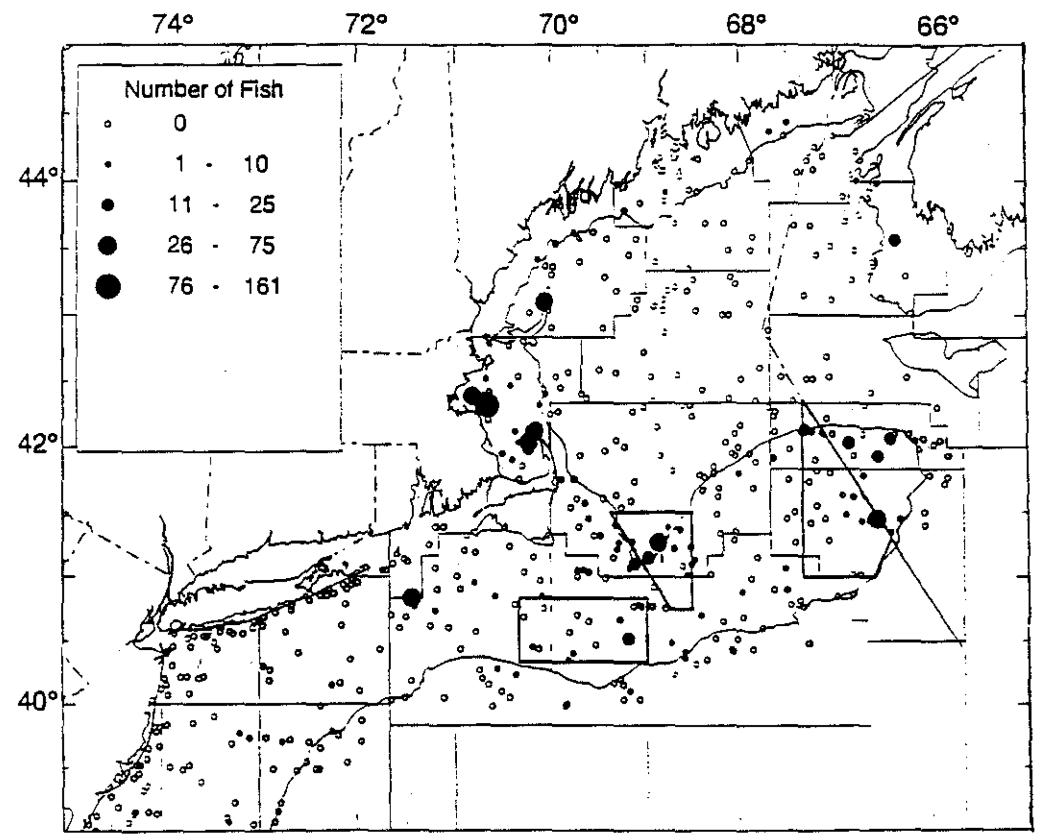

Figure E4. Distribution of yellowtail flounder during 1995-1996 from Autumn NEFSC bottom trawl surveys.

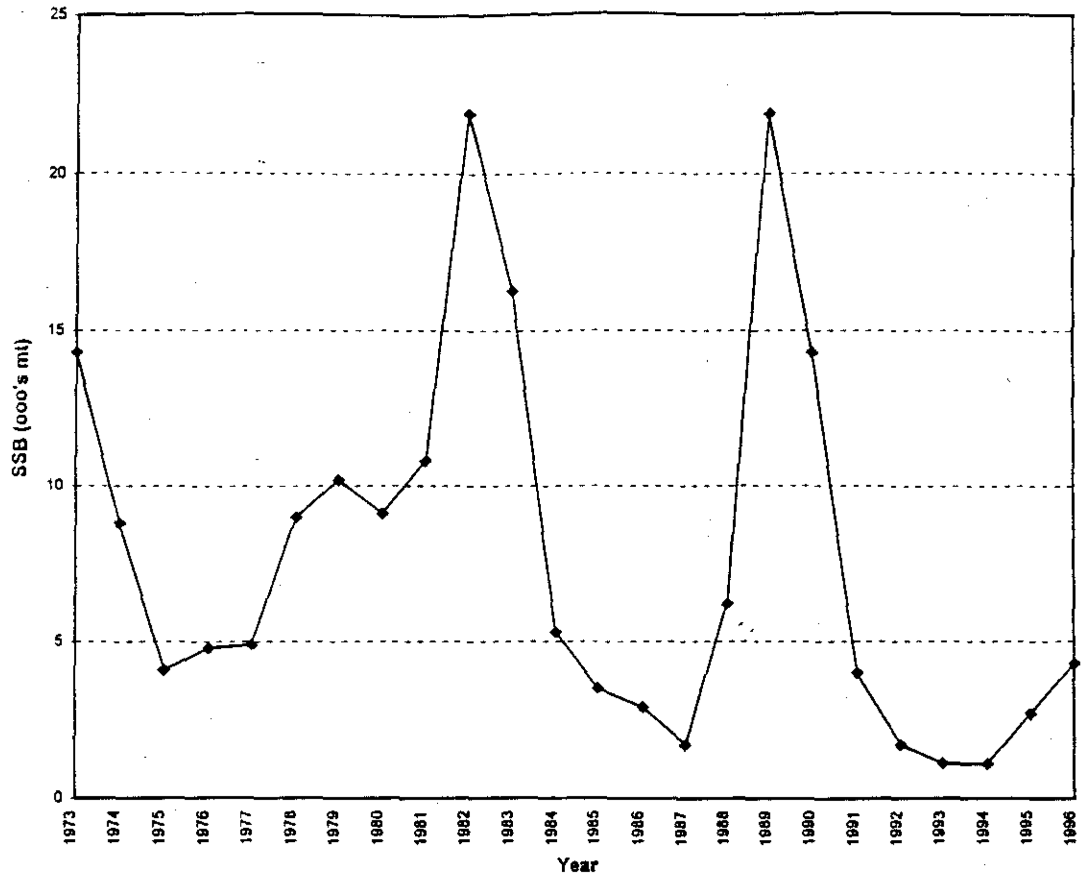

Figure E5. Spawning stock biomass of Southern New England yellowtail flounder during 1973-1995.

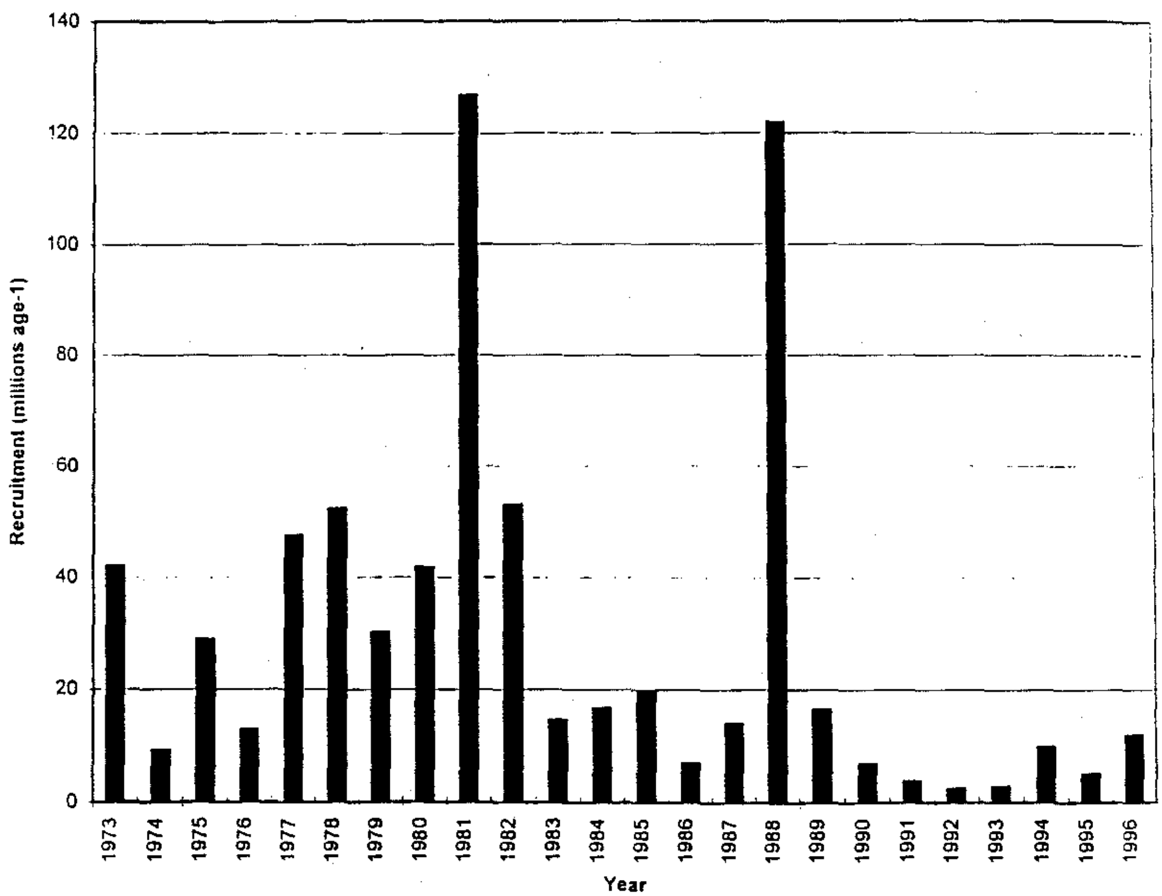

Figure E6. Recruitment of Southern New England yellowtail flounder during 1973-1995.

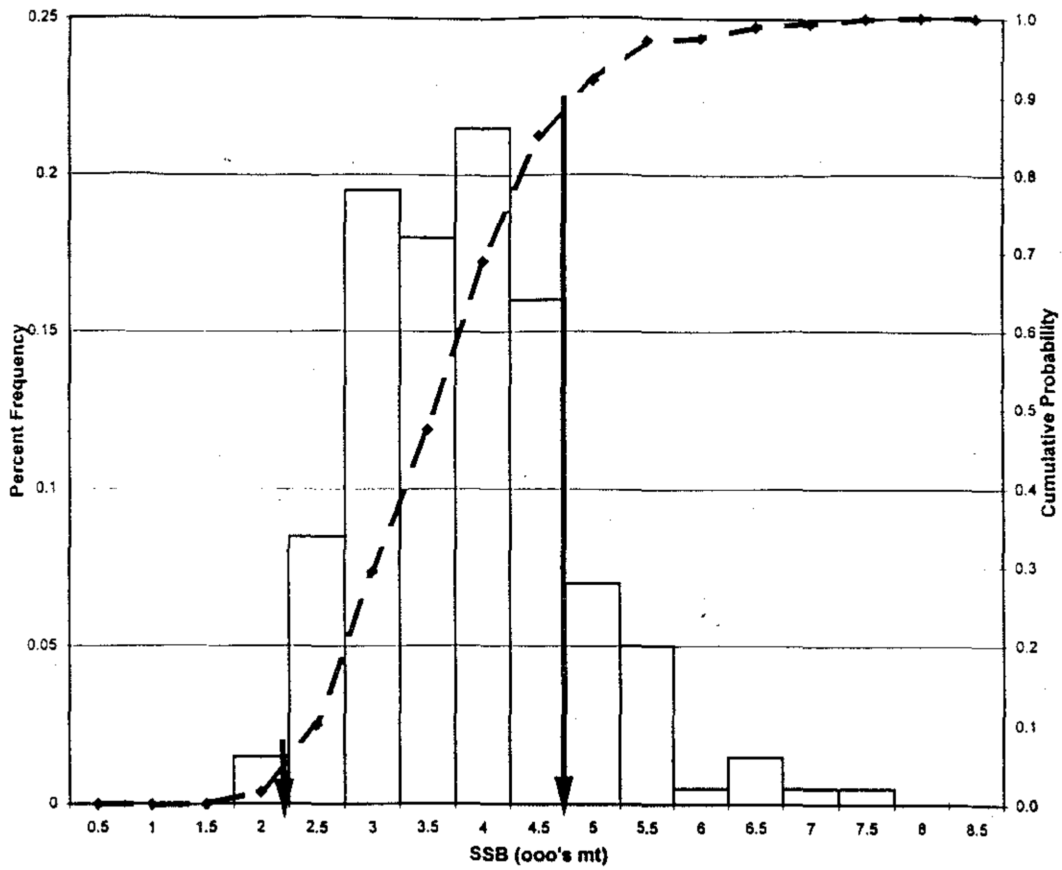

Figure E7. Precision of estimates of spawning stock biomass for Southern New England yellowtail flounder.

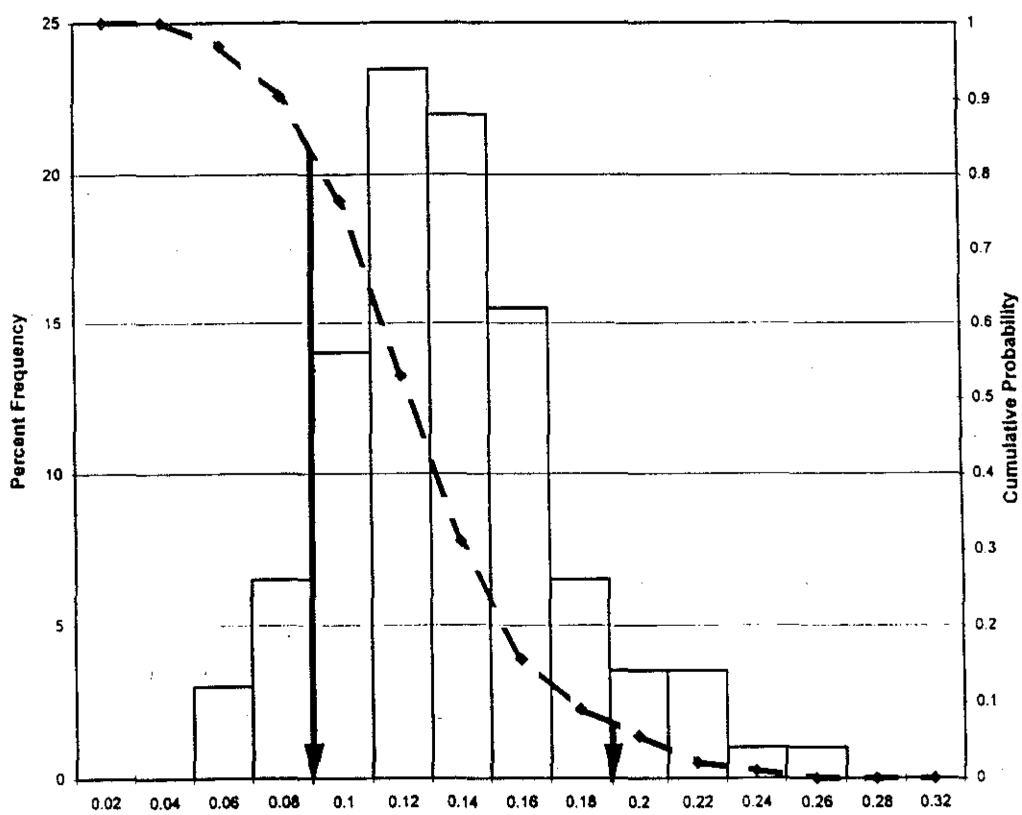

Figure E8. Precision of estimates of Fishing Mortality for Southern New England yellowtail flounder.

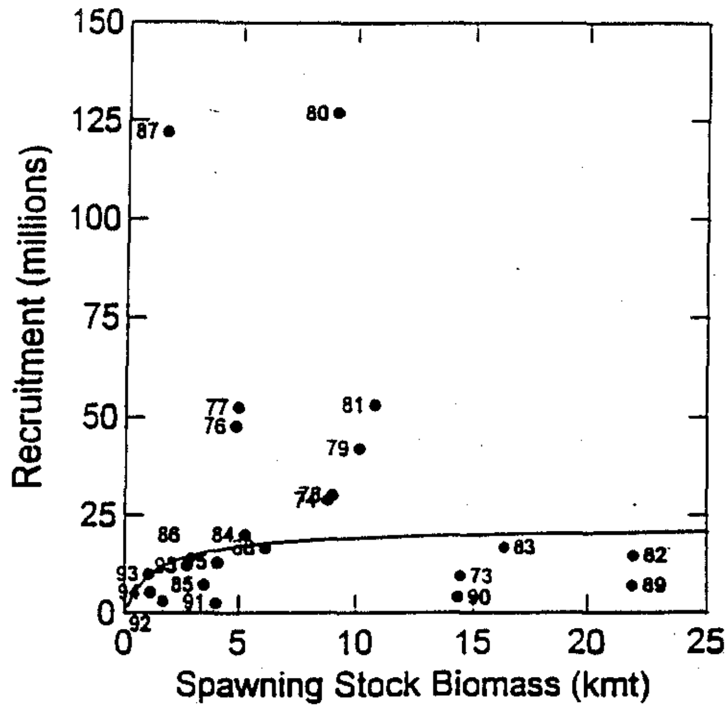

Figure E9. Spawning stock-recruitment information for Southern New England yellowtail flounder. Data are from the final ADAPT run for the 1997 assessment. Recruitment is expressed as age 1. A plot of the fitted Beverton-Holt s/r relationship is given (R=[21851.34*SSB+1421.77+SSB]).

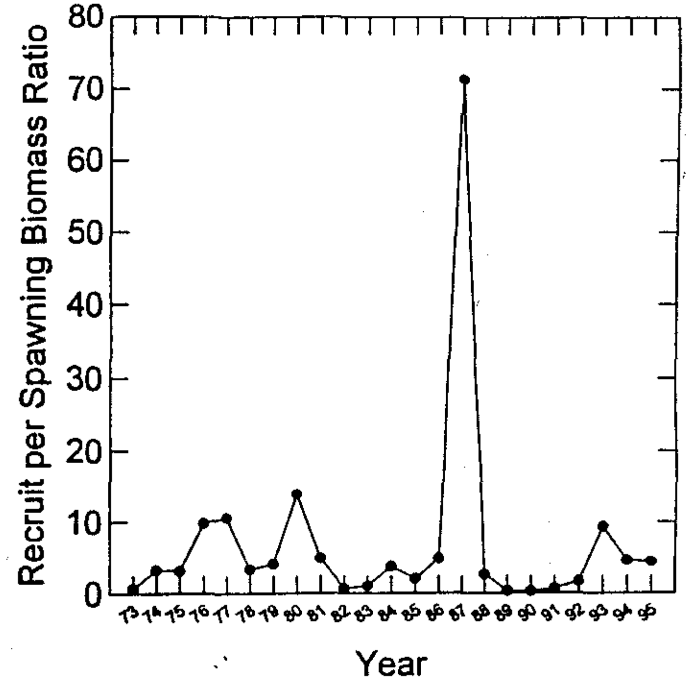

Figure E10. Calculated numbers of age 1 recruits per kilogram of spawning stock biomass for Southern New England yellowtail flounder. The median R/SSB ratio for the entire time series is 3.334, and for the last 5 years is 4.373.

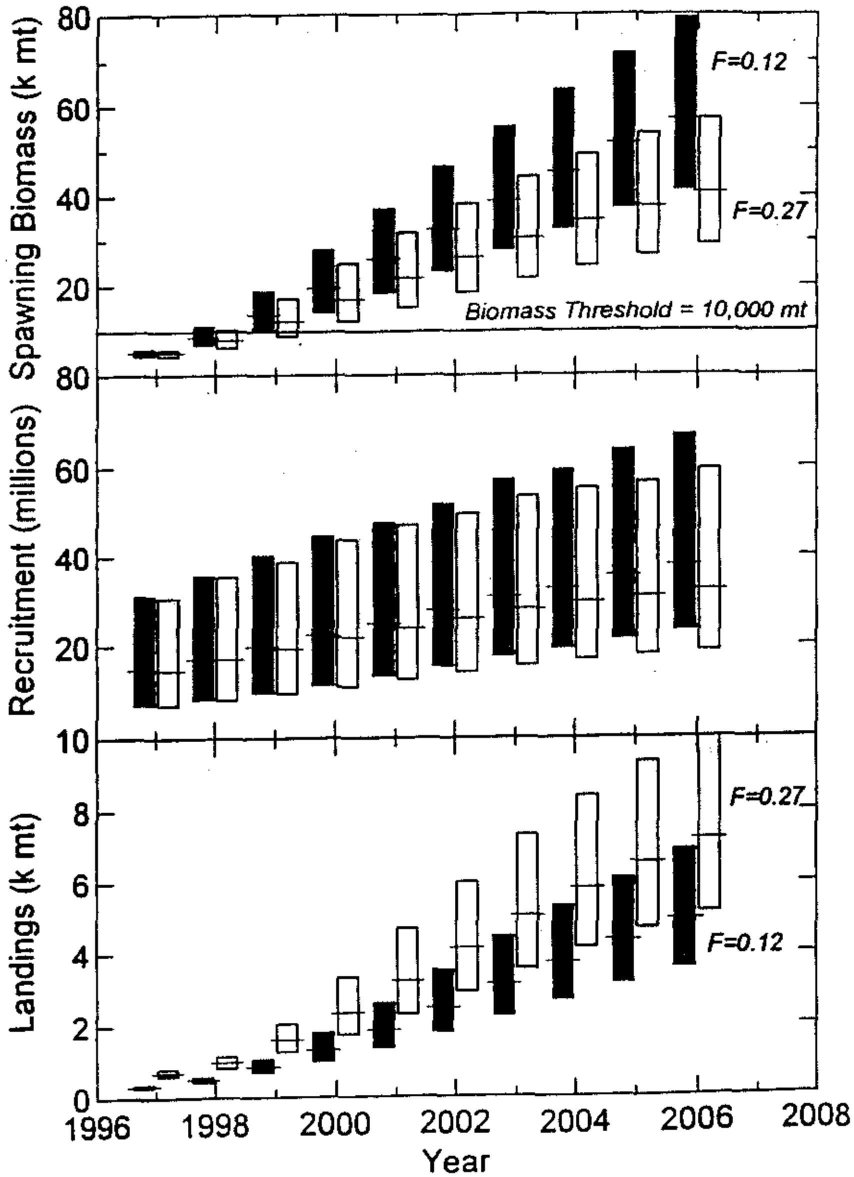

Figure E11. Results of medium-term projections for Southern New England yellowtail flounder, under two fishing mortality rate scenarios (F=0.12 [black bars], 0.27 [open bars]). Annual spawning stock biomass, recruitment, and landings data are given. Horizontal bars are the median values from bootstrap results, vertical bars are the inter-quartile range (lower 25th percentile to the upper 75th percentile).

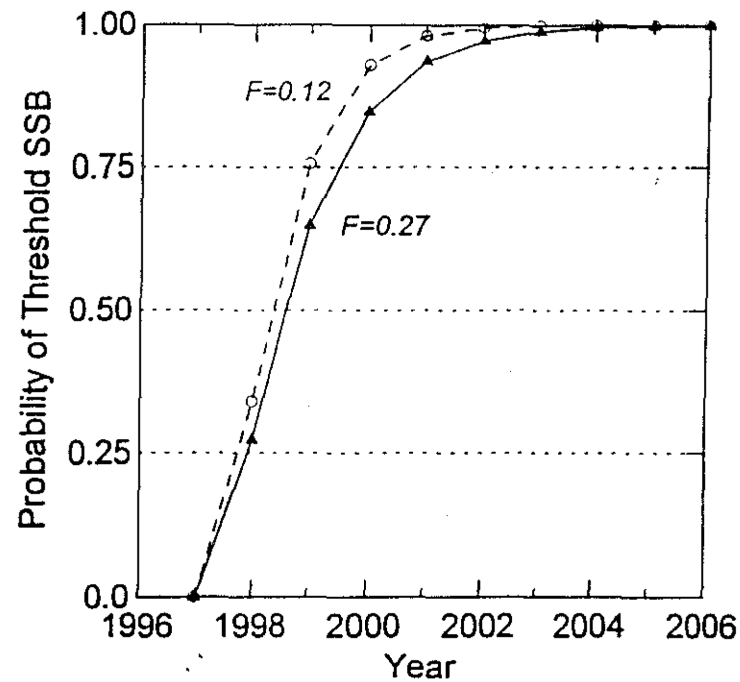

Figure E12. Annual probabilities of Southern New England yellowtail flounder spawning biomass at or above 10,000 mt, under three fishing mortality rate scenarios. Results are from medium-term stochastic projections.