Northeast Fisheries Science Center Reference Document 96-13

A Report of the 22nd Northeast Regional Stock Assessment Workshop

22nd Northeast Regional Stock Assessment Workshop (22nd SAW)

Stock Assessment Review Committee (SARC) Consensus Summary of Assessments

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

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This report is a product of the 22nd Northeast Regional Stock Assessment Workshop (22nd SAW). Proceedings and products of the 22nd SAW are scheduled to be documented and released as issues of the *Northeast Fisheries Science Center Reference Document* series. Tentative titles for the 22nd SAW are:

Estimation of catch and description of sampling programs for American lobster in the U.S. Northwest Atlantic

Length-cohort analyses of U.S. American lobster stocks

Report of the 22nd Northeast Regional Stock Assessment Workshop (22nd SAW): Public Review Workshop

Report of the 22nd Northeast Regional Stock Assessment Workshop (22nd SAW): Stock Assessment Review Committee (SARC) consensus summary of assessments

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MEETING OVERVIEW

The Stock Assessment Review Committee (SARC) meeting of the 22nd Stock Assessment Workshop (22nd SAW) was held at the Northeast Fisheries Science Center (NEFSC), Woods Hole, Massachusetts during 17 - 21 June 1996. The SARC Chairman was Dr. Emory Anderson (NEFSC). Members of the SARC were from the NMFS Northeast and Southwest Fisheries Science Centers and the Northeast Regional Office, the two Regional Fishery Management Councils, the Atlantic States Marine Fisheries Commission, two States, Canada, and a university (Table 1). About 60 others, including industry representatives, attended all or parts of the meeting (Table 2). The meeting agenda is presented in Table 3.

Table 1. Composition of the SARC.

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

Four *ad hoc* experts chosen by the Chair:
Russell Brown, NMFS/NEFSC
Wendy Gabriel, NMFS/NEFSC
Thomas Helser, NMFS/NEFSC
Philip Logan, NMFS/NEFSC

One person from NMFS, Northeast Regional Office:
Peter Colosi, NMFS/NERO

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

Atlantic States Marine Fisheries Commission/State personnel:
Mark Alexander, CTBMF
Joseph Desfosse, ASMFC
David Stevenson, MEDMF

One scientist from:
Canada - **Douglas Pezzack, DFO, Halifax**
Academia - **Nancy Targett, University of Delaware**
Other Region - **Larry Jacobson, NMFS/SWFSC**

Table 2. List of participants.

National Marine Fisheries Service
Northeast Fisheries Science Center
Frank Almeida
Jay Burnett
Darryll Christensen
Stephen Clark
Janessa Cobb
Janet Fields
Kevin Friedland
Richard Greenfield
Lisa Hendrickson
Shih-Wei Ling
Ralph Mayo
Steven Murawski
Helen Mustafa
Bobbie North
Loretta O'Brien
William Overholtz
Joan Palmer
Paul Rago
Anne Richards
Rodney Rountree
Fred Serchuk
Gary Shepherd
Michael Sissenwine
Katherine Sosebee
Mark Terceiro
Eric Thunberg
Jim Weinberg
Susan Wigley
Northeast Regional Office
Walter Anoushian
Allison Delong
Greg Power
Kurt Wilhelm
Mid-Atlantic Fishery Management Council
Tom Hoff
New England Fishery Management Council
William Amaru
Howard Russell
Atlantic States Marine Fisheries Commission
Najih Lazar
Connecticut DMF
Mark Blake
Massachusetts DMF
Steve Cadrin
Steve Correia
Tom Currier
Bruce Estrella
Xi He
Arnold Howe
Jeremy King
David Pierce
New York DEC
John Mason
North Carolina DMF
Rick Monaghan
Rhode Island DFW
Thomas Angell
Mark Gibson
Conservation Law Foundation
Eleanor Dorsey
National Fisheries Institute
Niels Moore
United National Fishermen's Assoc.
James Fletcher
Cape Oceanic
Peter Spalt
Wallace & Assoc.
John Womack
Rutgers University
Eric Powell
U Mass, Dartmouth
Alexei Sharov
IFOP - Chile
Ignacio Paya
Rodolfo Serra

Table 3. Agenda of the 22nd Northeast Regional Stock Assessment Workshop (22nd SAW) Stock Assessment Review Committee (SARC) meeting.

NEFSC Aquarium Conference Room
166 Water Street
Woods Hole , Massachusetts
Telephone: 508-548-5123, x270

17 June (1:00 PM) - 21 June (6:00 PM) 1996

AGENDA

TOPIC	SUBCOMMITTEE & PRESENTER	SARC LEADER	RAPPORTEUR
MONDAY, 17 June (1:00 PM - 6:00 PM)			
Opening Welcome Agenda Conduct of Meeting		E. Anderson, Chairman	H. Mustafa
Surfclam/Ocean Quahog (D)	Invertebrate J. Weinberg	N. Targett	A. Richards L. Hendrickson
TUESDAY, 18 June (9:00 AM - 6:00 PM)			
Summer Flounder (C)	So. Demersal M. Terceiro	C. Moore	M. Gibson N. Lazar
American Lobster (B)	Invertebrate P. Rago	D. Pezzack	S. Cadrin
WEDNESDAY, 19 June (9:00 AM - 6:00 PM)			
American Lobster (B)/Continued Discuss Advisory Report			
Review Surfclam/Ocean Quahog Advisory Report			
Analysis of 1994 Fishing Vessel Logbook Data (A)	No. Demersal R. Mayo Pelagic/Coastal W. Overholtz	P. Colosi	W. Overholtz R. Mayo
Social at the Andersons' (7:00 PM)			

Table 3. (Continued)

<u>**THURSDAY, 20 June**</u> (9:00 AM - 6:00 PM)..

Review Summer Flounder Advisory Report
Review American Lobster Advisory Report
Review Analysis of 1994 Fishing Vessel Logbook Data Advisory Report
Review Available SARC Report Sections

<u>**FRIDAY, 21 June**</u> (9:00 AM - 6:00 PM)..

Review all Research Recommendations
Complete SARC Report Sections — H. Mustafa
Complete Advisory Report Sections — (Coordinator)
Review List of Publications for the SAW-22 Series

Other Business — H. Mustafa

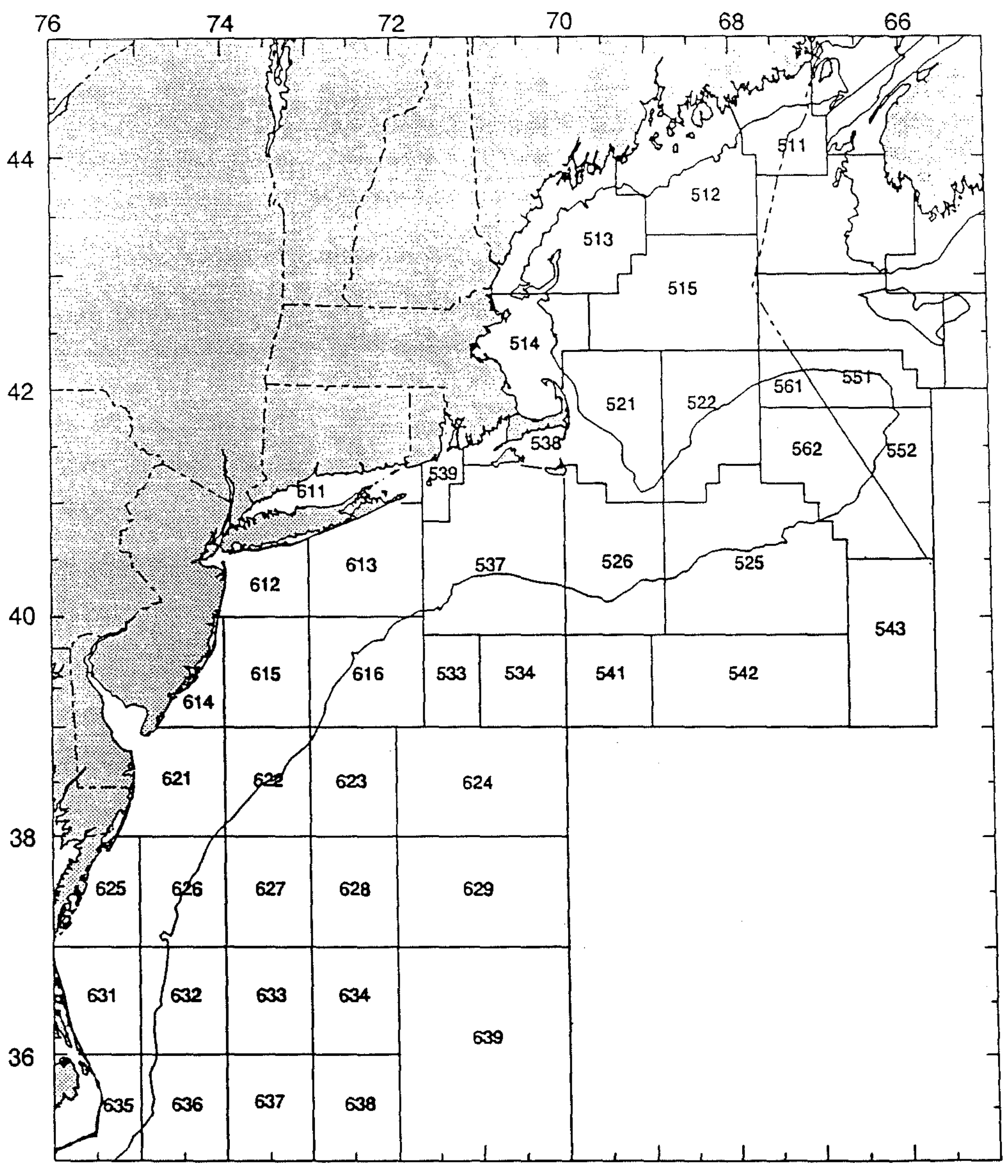

Figure 1. Statistical areas used for catch monitoring in offshore fisheries in the Northeast United States.

Table 4. 22nd SAW Subcommittee meetings.

Subcommittee - Topic Participation		Meeting Date and Place
Northern Demersal and Pelagic/Coastal Subcommittees		28-31 May 1996
- ANALYSIS OF 1994 FISHING VESSEL LOGBOOK DATA		Woods Hole, MA
R. Brown, NMFS/NEFSC	L. O'Brien, NMFS/NEFSC	
P. Hersey, NMFS/NEFSC	W. Overholtz, NMFS/NEFSC (Chair, P/C Subcom)	
L. Hendrickson, NMFS/NEFSC	J. Palmer, NMFS/NEFSC	
A. Kohuth, NMFS/NEFSC	G. Power, NMFS/NERO	
R. Mayo, NMFS/NEFSC (Chair, ND Subcom)		
S. Murawski, NMFS/NEFSC	K. Sosebee, NMFS/NEFSC	
B. North, NMFS/NEFSC	S. Wigley, NMFS/NEFSC	
Invertebrate Subcommittee		13-17 May 1996
- AMERICAN LOBSTER		Woods Hole, MA
T. Angel, RIDEM	N. Lazar, ASMFC	
M. Blake, CTDEP	S. Murawski, NMFS/NEFSC	
P. Briggs, NYDEC	S. Olszewski, RIDEM	
S. Cadrin, MADMF	D. Pezzack, DFO/Canada	
B. Estrella, MADMF	P. Rago, NMFS/NEFSC (Chair)	
M. Fogarty, NMFS/NEFSC	A. Richards, NMFS/NEFSC	
M. Gibson, RIDFW	H. Russell, NEFMC	
J. Idoine, NMFS/NEFSC	K. Sosebee, NMFS/NEFSC	
K. Kelly, MEDMR	D. Stevenson, MEDMR	
Southern Demersal Subcommittee		20-22 May 1996
- SUMMER FLOUNDER		Woods Hole, MA
F. Almeida, NMFS/NEFSC	C. Moore, MAFMC	
S. Cadrin, MADMF	S. Murawski, NMFS/NEFSC	
J. Fletcher, United National Fishermen's Assoc.		
R. Greenfield, NMFS/NEFSC	A. Sharov, U Mass Dartmouth	
M. Gibson, RIDFW	G. Shepherd, NMFS/NEFSC	
N. Lazar, ASMFC	D. Simpson, CTDEP	
R. Monaghan, NCDMF	M. Terceiro, NMFS/NEFSC (Acting Chair)	
J. Mason, NYDEP		
Invertebrate Subcommittee		21-23 May 1996
- SURFCLAM/OCEAN QUAHOG		Woods Hole, MA
L. Hendrickson, NMFS/NEFSC	P. Rago, NMFS/NEFSC (Chair)	
T. Hoff, MAFMC	A. Richards, NMFS/NEFSC	
N. Moore, NFI	F. Serchuk, NMFS/NEFSC	
S. Murawski, NMFS/NEFSC	J. Weinberg, NMFS/NEFSC	
E. Powell, Rutgers University		

Opening

The Chairman welcomed the meeting participants and introduced members of the SARC, Dr. Steven Murawski (Chief of the Population Dynamics Branch), Dr. Frederic Serchuk (Chief of the Conservation and Utilization Division), and Dr. Michael Sissenwine, the new Science and Research Director of the Northeast Fisheries Science Center. The Chairman also acknowledged the presence of participating scientists from a number of organizations, several members of the fishing industry, and two visitors from Chile.

Dr. Sissenwine gave a brief overview of the history of the SAW process. This process of unique meetings and peer reviews has been modified several times. It facilitates debate of scientific issues in an exchange which is as open as possible in the production of peer-reviewed information for fisheries management. The process is becoming a model for the review of stock assessments around the world.

Dr. Emory Anderson briefly reviewed the SAW process, the composition and responsibilities of the SAW Steering Committee, and SAW documentation. He also reviewed the agenda and the responsibilities of the SARC, SARC leaders, Subcommittee chairs, and the rapporteurs.

Agenda and Reports

The SARC agenda included four topics: surfclam/ ocean quahog, summer flounder, American lobster, and analysis of 1994 fishing vessel logbook data. A chart of U.S. commercial statistical areas used to report landings in the Northwest Atlantic is presented in Figure 1. Statistical areas comprising stocks of American lobster are presented in Figure B1 and survey sampling areas of the NMFS/NEFSC Surfclam/ Ocean Quahog Survey are presented in Figure D1.

The SARC reviewed eight submitted working papers on these topics, as well as several data runs and other information prepared during the course of the meeting. The working papers were prepared in a series of formal Subcommittee meetings (Table 4) and form the basis of the topic sections of this report. Several of the working papers will be published in the NEFSC Reference Document series (Table 5).

Table 5. 22nd SAW NEFSC Reference Documents.

Length-cohort analyses of U.S. American lobster stocks
by S. Cadrin and B. Estrella

Estimation of catch and description of sampling programs for American lobster in the U.S. Northwest Atlantic
by P. Rago, J. Idoine, B. Estrella, S. Cadrin, and A. Richards

Report of the 22nd Northeast Regional Stock Assessment Workshop (22nd SAW), Stock Assessment Review Committee (SARC) Consensus Summary of Assessments

Report of the 22nd Northeast Regional Stock Assessment Workshop (22nd SAW), Public Review Workshop

Major products of the SARC are this report, the *Consensus Summary of Assessments*, a compre-hensive technical report containing SARC comments and research recommendations, and the draft "*Advisory Report on Stock Status*," a stylized report whose format was set by the SAW Steering Committee. Both reports will be available at the sessions of the SAW-22 Public Review Workshop in draft form and published later in the NEFSC Reference Document series after review by the SAW Steering Committee. The *Advisory Report* will be contained in the report of the 22nd SAW Public Review Workshop.

Presentations and Discussion

Topic presentations were made by Subcommittee Chairs or their designees as indicated on the agenda.

<u>Surfclam/Ocean Quahog</u>

The harvest policy used for quota setting and the appropriateness of the DeLury model in the analysis of these species was discussed at length. It was suggested that this may be an appropriate time for the MAFMC to revisit the issue of harvest policies and the approach used to calculate annual landings.

The SARC also had several suggestions for the improvement of the presented spreadsheet model developed to aid in simulating changes in stock biomass under the supply years horizon for surfclam and ocean quahog. The Committee considered the spreadsheet model to be a tool for examining various options and assumptions. To improve the model would require additional field studies along with analytical work in the next year.

The SARC's recommendations concerning surfclams and ocean quahogs were prioritized. Higher priority recommendations include extensive field studies and theoretical work, as well as additional examination of the modified DeLury model; determination of appropriate survey frequency relative to the precision of the DeLury model; and experimental sampling with the R/V *Delaware II*, to determine catch size relative to past surveys before attempting another full clam survey. Recommended work should be completed in time for the next surfclam/ocean quahog peer review, tentatively at the SAW-25 SARC in the fall of 1997.

Summer Flounder

Changes since summer flounder was last reviewed at SAW-20, including assumptions regarding logbook data and changes in methodology, were emphasized in this presentation. Much of the discussion centered around the use of and uncertainty concerning age-length keys. Criteria for ageing scales were reviewed by Frank Almeida (NEFSC) with the assistance of Rich Monaghan (NCDMF). The results of a scale exchange between the NEFSC and NCDMF were also reviewed. The SARC suggested that a DeLury model formulation might help to circumvent uncertainty in the age data used in the VPA. One of the issues discussed was the amount of catch underestimation based on survey indices. In spite of the uncertainties, it was concluded that the assessment provided the best estimate of the status of stock and was a useful basis for management advice.

Research recommendations for summer flounder include continuation of cooperative work between the NEFSC and NCDMF to ensure consistent ageing of summer flounder and consultation with the MAFMC Summer Flounder Technical Monitoring and Demersal Committees, as well as industry advisors, concerning the adequacy of NEFSC domestic sea sampling and issues of under-reported and under-sampled landings. The SARC also recommended emphasis for the continued collection of data on summer flounder and a number of technical issues to be addressed by the SAW Assessment Methods and Southern Demersal Subcommittees.

American Lobster

The analysis which was presented constituted a continuation of work begun in the SAW-16 process and incorporated the recommendations of the Lobster Review Panel as expressed in the terms of reference set by the SAW Steering Committee on May 9, 1996.

The Lobster Review Panel had been organized by NMFS and ASMFC under the auspices of the Office of the NMFS Senior Scientist at the request of the SAW Steering Committee. The final report of the Panel will be published jointly by NMFS and ASMFC and should be available later in 1996. The Panel Chairman, Dr. Colin Bannister of the U.K., will make a presentation on the topic at the July 1996 meeting of the ASMFC.

Although the terms of reference for the SAW lobster analysis were not finalized until May, the current assessment process began in January 1996 and culminated in a Subcommittee meeting held during May 13-17, 1996. Due to the nature of the distribution of the species along the Northeast U.S. coast, separate assessments were done for the three recognized stocks: Gulf of Maine, South of Cape Cod to Long Island Sound, and Georges Bank and South, with some analysis also performed for the Central and Western Long Island Sound subarea.

In the attempt to answer the question, "Why are there so many lobster landed?", and to provide the best possible assessment, the SARC engaged in numerous discussions, including various aspects of the DeLury and other models, other technical issues, and assumptions about natural mortality, seasonal timing of growth events, surveys, exploitation, etc. Several additional runs were carried out during the meeting to address SARC concerns about the stability of the analysis. The Committee's concerns and recommendations are reflected in the **Discussion and Consensus Summary**, and **Research Recommendations** sections under American Lobster of this report.

Analysis of 1994 Fishing Vessel Logbook Data

As the quality of data affects all assessments, the Northern Demersal and Pelagic/Coastal Subcommittees were tasked with conducting a comprehensive evaluation of the usefulness of the 1994 vessel logbook data in stock assessments and making recommendations to improve their usefulness. The presenters summarized the background of this task and explained the process for their evaluation. As the system was developed rather quickly to meet the needs of management and lacking a formal design, it has certain obvious shortcomings. Examples of logbook pages, problems concerning their interpretation, and quality assurance procedures, or lack thereof, were discussed. A considerable amount of discussion centered around the difficulty encountered in matching dealer records with corresponding logbook submissions directly related to the absence of a coordinated design for the two data collection systems.

Recommendations include changes in logbook audit procedures, some fine-tuning of data collection forms and procedures, as well as necessary short-term remedies, some of which have already been implemented. In addition, the SARC noted the need to educate fishermen as to the importance of the information in the logbooks. Assuming that the logbook entries are correct, the SARC's recommendations should lead to an improvement in the 1997 logbooks and database and more useful data for scientific purposes. The implementation of the SARC's recommendations, however, must be the decision of the NMFS Regional Director and will need to be carried out by database experts.

Closing

Dr. Anderson reminded the SARC that the draft documentation developed at the meeting would be edited and forwarded to SARC leaders for final review before distribution at the SAW-22 Public Review Workshop sessions. SAW documentation could not be cited until final reports were available after the Steering Committee meeting in August.

Before closing the meeting, Dr. Anderson invited visitors to give their impressions of the SARC process. Dr. Rodolfo Serra and Ignacio Paya of Chile, whose presence as observers had been arranged under a bilateral fisheries agreement, indicated that they had heard about the process a year or so earlier. They expressed their appreciation for the opportunity to observe the SARC meeting and to speak with colleagues. The visitors were impressed with the general dedication to the process, particularly the care taken in writing the advice and recommendations.

A. ANALYSIS OF 1994 FISHING VESSEL LOGBOOK DATA

Terms of Reference

The following terms of reference were addressed:

a. Summarize spatial and temporal trends in vessel logbook entries for major offshore fisheries (e.g., New England large mesh otter trawl, sea scallop dredge).

b. Calculate the proportion of total catch and numbers of trips that are simultaneously represented in dealer and vessel logbook databases and the fraction of permitted vessels accounted for in vessel and dealer logbooks.

c. Characterize the statistical properties of fishing effort and catch from logbooks, compared to information from the previous voluntary interview/weighout program.

d. Evaluate the utility of logbook data for allocating total landings of species to stock areas.

e. Evaluate the consistency of CPUE and effort trends using fishing vessel logbook data.

f. Evaluate the accuracy of vessel logbook information using coincident sea sampling information.

g. Recommend changes to the vessel logbook program to improve the usefulness of data for stock assessment.

Background

In 1993, amendments to the Atlantic Sea Scallop, Northeast Multispecies, and Summer Flounder Fishery Management Plans (FMP) contained requirements for a mandatory reporting system for vessels and dealers in the Northeast. This made the existing dealer reporting system mandatory for firms purchasing species covered under one of these plans. It also required vessels engaged in one of these fisheries to submit logbooks for each trip. These requirements were put into place in April 1994 for the summer flounder fishery and in June 1994 for the multispecies and sea scallop fisheries.

Dealer Reporting

The regulations which resulted from the three FMPs required a dealer to obtain a permit in order to purchase a managed species from a vessel. One requirement of the dealer permit is that the dealer must report, to NMFS, purchases of all species from both permitted and unpermitted vessels. While dealer reporting was mandated under the Summer Flounder FMP in 1992, it was primarily used as a quota monitoring system until 1994. With implementation of the Multispecies and Sea Scallop FMPs, the dealer reporting system was fully mandatory for these three major fisheries in the Northeast.

The new FMP regulations resulted in only minor changes to the methods utilized by dealers to submit data to NMFS. The same data elements are collected under these new regulations as were collected in the past (i.e., dealer identifiers, vessel identifiers, date and port landed, and pounds and price by species and market category). The significant difference for the industry is that submission of the dealer purchase data (weighouts) is now mandatory.

A major consequence of the new regulations was the manner in which NMFS processed the data internally. Under the data collection system which existed prior to 1994, NMFS port agents would collect weighout forms directly from dealers. These same agents would also conduct personal interviews of a sample of vessel operators to obtain additional information. Through these interviews, the port agents would collect data describing the fishing trip. These data elements included: fishing area, effort, a basic description of the gear, and several other elements. Anecdotal information was also noted. These data were then combined with the weighout data collected from dealers for the interviewed trips.

For trips which were not interviewed, port agents would use various methods to estimate the effort, area, and gear-related data elements. Methods used by the agents included using the data-element values from vessels engaged in the same or similar fisheries and past experience and knowledge of the fishing habits of the uninterviewed vessels. The spatial resolution for uninterviewed trips was not as fine as for interviewed trips (i.e., quarter-degree square vs. 10-minute square). The data elements previously obtained through personal interviews are now submitted directly to NMFS by vessel operators through Fishing Vessel Trip Reports.

Vessel Reporting

The new reporting regulations for vessels require that commercial vessels permitted in any of the three FMPs listed above submit a logbook for every trip. This requirement is in effect even if the vessel is not engaged in one of these fisheries for a given trip. A commercial trip is defined as one which is intended to harvest fish or shellfish for a commercial purpose. Party and charter vessels are also included if they are taking passengers for hire. Purely recreational trips are excluded. The only exception to this is if a vessel only has a summer flounder party and charter permit. These vessels are required to submit a logbook only if they land summer flounder.

In April 1994, mandatory reporting requirements for vessels with a summer flounder permit were implemented. Vessels with multispecies and sea scallop permits were included in June 1994. Even though the requirements for the latter two plans were not effective until June 1994, vessels with summer flounder permits were required to report all species.

Vessel Data Processing

When the 1994 vessel logs were initially received at the Regional Office in Gloucester, MA, they were stamped with the date received, indexed, and scanned into the imaging system. No data were keyed other than the fields necessary to uniquely identify the log. Shortly after this commenced, it was realized that this task could not be processed by the limited staff given the required deadlines. A decision was made to use the NMFS standing contract with the Federal Prison Industries (UNICOR) to process these data after they had been scanned and indexed.

Ultimately, all 1994 logs submitted by commercial, party, and charter vessels representing trips landing in the Northeast region were processed by UNICOR. Trips which landed outside the region and negative reports were excluded from this processing flow. A negative report is submitted by a vessel operator when no fishing activity occurs in a calendar month.

Instructions for data entry and output record structures are provided by NMFS to UNICOR. Original logs are submitted for processing in small batches each consisting of approximately 2,000 logs. Once a batch is processed, a diskette containing the output files is returned to NMFS along with the original logs. A total of 55 batches was processed through UNICOR for the 1994 vessel logbook data.

The amount of auditing of the logs by NMFS varied over time before they were sent to UNICOR. As a result, the entry instructions given to UNICOR by NMFS also varied. However, for all batches, the logs were sorted by trip categories, i.e., commercial, party, or charter (TRIPCATG in the output record) and port landed (PORT1, STATE1) and batched accordingly. For each state and trip category within a batch, a unique output file was created by UNICOR. No other sorting of the logs was performed, thus a batch does not represent a particular landing time period.

Pre-Audit and Keying Instructions

The pre-audit involved screening and correction of Vessel Trip Reports by NMFS personnel before shipment to UNICOR for key entry. The specific chronology of pre-audit and keying instructions is provided in Table A1.

Pre-audit instructions - 7/26/94: The first set of pre-audit instructions was designed to standardize the data on the logs to those set out in the database design. This resulted in units of measure being converted to those of the database, incomplete fields being corrected, and missing data being found in existing tables. If entries on the log were not to be entered by UNICOR, they were deleted with a yellow highlighter. Any entries made by NMFS for UNICOR entry were written in red ink.

Pre-audit instructions - 8/9/94: This revision decreased the amount of pre-auditing which was performed. The basic premise of this pre-audit was that if an entry did not meet the database standards, no effort would be made at correction and UNICOR would ignore the problem field. This policy has resulted in many blank fields within the dataset.

Transmittal letter to UNICOR - 8/11/94: The first batch of logs was sent to UNICOR on 8/11/94. This first batch, and possibly some of the following batches, would have contained logs pre-audited using the first pre-audit instructions. It cannot be easily determined at which of the earliest batches the second pre-audit procedures became effective. The first batch contained 658 logs from commercial trips landing in Massachusetts.

Draft pre-audit and keying instructions - 3/10/95: In early March 1995, a decision was made to change the methods used to process the vessel logs. This decision resulted in the suspension of pre-auditing. UNICOR would key the data as submitted by the industry. No deleting of an invalid entry would be done. Other changes resulting from this decision were that the date received would no longer be stamped on the log, and scanning of the 1994 logs would stop. If an entry in a field could not be read, a "?" was entered. However, some fields (IMAGENUM, TRIPCATG, and PORTCODE) would always be legible and must contain data. These changes were implemented on 4/3/95 with batch 14.

Processing of 1995 Logs

All 1995 log data have gone through initial processing within NMFS. This includes scanning and indexing into the imaging system in Gloucester. In order to index a log, certain fields must contain valid entries. These fields include: image number, vessel hull and permit numbers, and date and time sailed. If these fields were not correct, they were edited by NMFS staff to the extent possible. If valid entries could not be determined, they were returned to the vessel operator for correction. Any logs that combined multiple trips were also returned.

The remaining data entry for the logs was accomplished in several stages. Logs with sailing dates from January - May and November - December were completely processed in Gloucester by NMFS personnel. While these were processed with a minimum of auditing, there was limited error checking either prior to or during entry. Coded fields (GEARCODE, SPPCODE) were not checked against a table of valid entries. However, the availability of experienced NMFS personnel, allowed for appropriate entries into these and other fields. Units of measure were converted to the database standards, species and dealer codes were carried through the species records if necessary, and, to a limited extent, coded fields were entered as codes rather than truncated full names.

The same fields in which multiple entries were deleted in 1994 were processed with these methods in 1995. If more than one entry was recorded in fields such as AREA, MESH, and DEPTH, only the first entry was entered. To the extent possible, these are now being coded as MIX during the auditing process. This auditing process commenced in April 1996 and continues.

Logs with sailing dates of June - October are currently being sent to UNICOR for processing. Their instructions have basically been the same as for the 1994 data. No pre-auditing has been performed before the batches are sent other than what was necessary for indexing. The exception to this is that multiple entries in AREA, MESH, and DEPTH are now being coded as MIX, although this change was only initiated recently. For approximately one quarter of the logs processed by UNICOR, only the first value was entered.

Computer Audit and Database Loading Procedures

The computer audit and database loading process was split into four stages to provide for an orderly progression from the keyed ASCII files into a three-tiered database structure (trip, gear, species data tables). An audit program was written to flag errors in the 1994 vessel log data for review and correction and to create the temporary ORACLE tables once the corrections were made. Stage 1 of the audit process checked for the basic information necessary to split the input file into trip and gear-species records. If there were no fatal errors, the tables were created. Stage 2 split the gear-species records into separate gear and species tables. Stage 3 checked for errors in the three resulting tables. Synonym tables were built and used in the third stage to clean up the alpha codes used for gear and species. Stage 4 of the audit process loaded the audited data into the VTR master tables.

Stages 1 and 3 produced fatal and informative error listings. Generally, errors in fields required to build the database or used as linking fields were flagged as fatal errors; all others were flagged as informative errors. Stage 1 fatal errors included unmatched trip or gear-species records, duplicate image numbers (SERIAL_NUM), missing or invalid vessel permits, and invalid record types. Stage 3 fatal errors included missing or invalid errors in the TRIPCATG, PERMIT, HULLNUM, DATESAIL, DATELND1, STATE1, PORT, GEARCODE, MESH, NEMAREA, SPPCODE, DEALNUM, and DATESOLD. Use of the unknown value for a field was not considered a fatal error. More detailed information is provided in Table A2.

Auditors worked on individual batches in temporary ORACLE tables in their own user space and were instructed to correct all fatal errors before going on to the next stage. In an attempt to complete the audits within the time constraints given, auditors were instructed to ignore the informative errors.

As batch audits were completed, the data were loaded into the VTR master tables in ORACLE. As soon as some preliminary analysis was done on the data, it became apparent that the subtrip delineation was being lost in the vessel log data. The 1994 VTR master formats were revised to look like the 1995 VTR data which had additional fields (TRIPID, GEARID, NRPAGES, and PAGENO) for tracking multiple page trips, and the data were reloaded. This still did not solve the subtrip problem since multiple pages were not restricted to changes in effort fields (GEARCODE, MESH, or AREA). Some multiple pages resulted from entries required for more species than could fit on one page, others resulted from misinterpretation of what constituted an area change, etc. Two more fields were added to reflect subtrips (NSUBTRIP, SUBTRIP). The problem was solved by updating the database to generate these values.

As noted earlier, a detailed manual pre-audit of the logbooks was only in effect for two weeks (7/26/94 - 8/9/94). During 8/9/94 - 4/3/95, the pre-audit consisted mainly of deleting (with highlighter pens) data that should not be keyed. All pre-auditing of logbooks was halted on 4/3/95 by management directive. Of the 92,000 logbooks, 39% were pre-audited and 61% were not pre-audited. The keying instructions to UNICOR were also changed as a result of changing management directives. Therefore, for some logbooks, UNICOR was instructed to omit any questionable variables, and for others UNICOR was instructed to key all variables regardless of content. As a result, key fields may be blank or contain unnecessary formatting or unit notation characters. Numeric fields were not restricted to numerics. Fields such as dealer number and date sold were not carried forward to each record even when they obviously applied to a block of species data.

The removal of detailed manual pre-audits at an early stage in the processing of the logbooks negatively affected the quality of the keyed data. The keying instructions also varied greatly over time and led to the omission of critical data. These factors extended the time required to process and audit the data and resulted in labor-intensive computer audits. The audit program had to be revised several times to accommodate and reconstruct poorer quality data. It is recommended that future processing of the logbooks include manual pre-auditing and that the data entry program include more extensive data audits.

Overview of the 1994 Logbook Data

Specific analyses presented in the following sections were based on all logbook records generated by the latest iteration of the data-building software. The database was "frozen" as of April 23, 1996. This provided 64,319 individual trips (approximately 85% of the eventual number audited) for analysis by the SARC. Table A3 provides a general overview of key fields present in the database on the trip, gear, and species records. Key link fields such as DATESAIL and DATELND1, which were verified during the audit process, are within prescribed bounds. The accuracy of these fields, however, has not been determined. The TIMESAIL field is problematic with a large proportion of missing values. Alpha fields such as PORT1, PORT2, and OPERATOR are difficult to interpret due to the large number of possible entries. Data fields such as MESH and DEPTH are generally within expected bounds, but some obvious outliers require further examination. Many of these outliers can be corrected with further scrutiny of the logs.

Proportions of Landings by Gear Type

Catches by gear type were derived from vessel logbooks and mandatory dealer data (Tables A4 and A5). Since gear was not a mandatory field to be included in the dealer data, this data set is incomplete. In several instances, the quantity of catch by gear from vessel logbooks exceeds that in dealer data even though only approximately 85% of the vessel data are included in the data set. Proportional catches by gear type are presented in Figure A1 for six important species: Atlantic cod, haddock, pollock, white hake, summer flounder, and sea scallop. There was a discrepancy between the two data sets in how longline catches were coded. For much of the catch in dealer data, longline catches were coded as coming from pelagic longline, while for most vessel data, these catches were coded as bottom longline. For these comparisons, the two longline categories were thus combined.

In general, the proportional catch by gear was similar between dealer and vessel data sets. Cod dealer data showed a slight under-representation of handline and other minor gears (probably reflecting lumping of catches from small under-tonnage vessels). Likewise, other minor gears were also under-represented in dealer data for haddock, pollock, white hake, summer flounder, and scallop catches. An under-representation of longline catches of white hake in vessel logs is also apparent. Given the general coherence of these two data sets, proration of dealer/vessel data to catch by gear/stock area and time period appears feasible.

Spatial and Temporal Distribution of Logbook Submissions

Fields analyzed from the vessel log gear section included: LAT_DEGREE, LAT_MINUTE, LON_DEGREE, LON_MINUTE, NEMAREA, LORAN1, and LORAN2. Data contained in these fields were examined to determine their quality and in some cases were compared to the same fields contained in the 1993 NEFSC weighout database. A summary of the results is as follows:

Area

Statistical areas are one of the primary fields used by NEFSC scientists to analyze commercial fisheries data since these area codes define geographic stock boundaries. The area field was included in the auditing program as a fatal error. This field was set up in the logbook data entry program with a "not null" constraint, so there are no missing values, but rather zeros to represent missing NEMAREA codes.

Quality of data: The coded area field represents "NEMAREA" which includes subareas of inshore statistical areas and the offshore statistical areas. Approximately 98.4% (65,169) of the area codes contained in the database represented valid NEMAREAs. These valid NEMAREA codes include 90 entries coded as 001-004 which, based on comparison of NEMAREA codes with LAT/LON and/or LORAN pairs (32% of the NEMAREAs coded as 1-4), appeared incorrect. Based on this comparison, it appears that unclear logbook instructions for recording NEMAREAs may have led to this problem. There were no null values since this field was set up with a "not null" constraint. An additional 1,048 of the codes (1.6%) appeared as zeros. In addition, for trips which were split between two NEMAREAs and recorded on the same vessel logbook, only the first NEMAREA was entered. The original logbook entries would have to be reexamined in order to estimate the extent of this problem.

Assignment of missing NEMAREA codes: Valid LORAN1/LORAN2 pairs were converted to LAT/LON pairs, and then used to assign codes to NEMAREAs coded as zeros. Additionally, valid LAT/LON pairs were also used to assign these values. An additional 340 NEMAREAs were determined based on the use of these valid LAT/LON and LORAN pairs. This resulted in valid NEMAREAs for 98.9% of the records in the database.

Validation of NEMAREA codes: Valid LAT/LON pairs can be used to determine the validity of NEMAREA codes. In addition, valid LORAN1 and LORAN2 pairs once edited and converted to valid LAT/LON pairs, using the PC-based software program LORAN/GPS, will then be used to determine the validity of their respective nemarea codes. These NEMAREAs will then be compared to NEMAREAs from a master look-up table of areas.

Latitude/Longitude and Loran Bearings

Quality of data: The fields LAT_DEGREE, LAT_MINUTE, LON_DEGREE, LON_MINUTE, LORAN1, and LORAN2 were audited as informative errors instead of fatal errors, so these errors were not corrected by auditors. As a result, the majority of these fields contained invalid bearings and coordinates.

Approximately 71% of the LORAN1 and LORAN2 fields consisted of nulls for one or both fields; others contained values which could be edited and converted to LAT/LON pairs. Many of the invalid LORAN entries noted above could be easily converted to a LAT/LON coordinate because the time delays are in themselves sufficient for discerning the correct chain required by the LORAN/GPS software.

Only 19% of the LAT/LON pairs contained valid coordinates. This can be compared with the percentages of valid LAT/LON pairs from interviewed trips during 1992 and 1993, which were 28% and 26%, respectively. Approximately 59% of the LAT and LON values were null for one or more of the four fields and another 22% contained values which would require extensive auditing to discern. The latter category, consisting of 14,259 invalid LAT/LON pairs, is primarily a result of no pre-auditing of the LAT/LON and LORAN fields. For example, most of the invalid LAT/LON pairs were actually partial LORAN readings which had been written in the LAT/LON fields on the logbook form, but were truncated when keypunched, since the LAT/LON fields contain fewer digits than are needed for the 12-digit LORAN bearings. The remaining invalid LAT/LON coordinates appeared to be a result of keypunching leading zeros, course heading abbreviations and other alphanumerics, decimal degrees, dashes and zeros which were written on the logbooks or LAT/LON pairs were reversed during data entry. Correction of these LAT/LON coordinates would require reexamining the logbooks for the correct values.

When valid loran pairs exist, they can be subject to the same series of editing and processing programs described in the "Area" section of this report, then converted to valid LAT/LON pairs. However, approximately 97% of the invalid LAT/LON records contained loran fields which were null. Therefore, these invalid LAT/LON pairs would have to be corrected by reexamining the logbooks as well.

Match/Mismatch of VTR and Dealer Data

An analysis of the Multispecies Vessel Trip Report (VTR) data and the dealer data was undertaken to evaluate the correspondence between the two databases. The analysis was divided into three parts: 1) comparison of unique vessel permit numbers, 2) comparison of the frequency of transactions by unique vessel permit, and 3) comparison of each transaction by unique vessel permit. Approximately 85% of the 1994 vessel trip report data were available for analysis. In the subsequent analyses, the preliminary results are based upon subsets of each data set.

To compare vessel permit numbers in the vessel logbook data with the dealer data, it was necessary to subset each data set to eliminate data which did not belong to the multispecies mandatory reporting system. For example, the vessel logbook data contain some logs which represent fishing trips which are not part of the multispecies vessel trip reporting system.

The fishing trips which should be reporting in this system are those with permits for multispecies, summer flounder, and scallops. Fishing trips using the gear types of clam dredge (DRC), drift gillnet (GND), longline pelagic (LLP), midwater pair trawl (PTM), and lobster pot (PTL) were excluded from the comparison because these gear types are predominately used in fisheries which have another reporting system or are not required to report. Recreational and charter fishing trips were also excluded. A summary of the vessel trip reports by gear type for commercial trips is given in Table A6.

In the dealer data, each record represents one transaction by a PERMIT-TRIP-DATESOLD to a dealer. The mandatory dealer data were selected from the entire dealer data set based upon source code (mandatory dealer reporting has source code = 7). A summary of dealer data by source code is presented in Table A7, and the temporal distribution of the dealer data by source code is illustrated in Figures A2a and A2b.

Comparison of Unique Vessel Permit Numbers

The reduced vessel trip report data subset had 36,840 observations with 1,745 unique vessel permit numbers; the reduced dealer subset had 71,412 observations with 2,755 unique vessel permit numbers. When the two subsets were combined, a total of 3,090 unique vessel permit numbers resulted. Of these, 46% (1,410 permits) of the vessel permit numbers occurred in both subsets, 43% of the vessel permit numbers occurred only in the dealer subset, and 11% of the vessel permit numbers occurred only in the vessel trip report subset. The 1,410 matched permits represent 81% of the available permits in the vessel logbook subset and 51% of the available permits in the dealer subset.

Errors in the vessel permit number were detected in the analysis. Since vessel PERMIT number is used along with DATESAIL and TIMESAIL to distinguish a unique trip in the vessel trip report data, it was necessary to first determine the accuracy of this field. Although this field was audited along with vessel hull number (HULLNUM) to ensure that both numbers mapped out to an actual vessel, there was no check to ensure that both numbers mapped out to the same vessel. A cross-check was run to determine the extent of mismatches between the permit and hull numbers. For commercial trips, 1.6% of the trips had permit numbers or hull numbers which did not map out to the same vessel.

Comparison of Frequency of Transactions by Unique Vessel Permit

To compare the frequency of transactions for each vessel permit number between the two data subsets, the vessel trip report data subset was reduced further to exclude any observations in which the dealer number was missing or which indicated that species were retained for home consumption. No further exclusions were made in the dealer set.

In the reduced vessel trip report data subset, there were 1,717 unique vessel permit numbers (42,239 transactions) and 2,755 unique vessel permit numbers (71,412 transactions) in the mandatory dealer subset. In the combined subsets, there were 3,066 unique vessel permit numbers; 46% of the permits occurred in both data subsets, 44% of the permits (21,370 transactions) occurred only in the dealer subset, and 10% of the permits (4,684 transactions) occurred only in the vessel logbook reduced subset. Of the vessel permit numbers which matched, 6% had the same number of transactions in both subsets, 70% of the permits had more dealer transactions than vessel logbook transactions, and 24% of the permits had more vessel logbook transactions than dealer transactions. The 46% matching permits had 37,555 transactions in the vessel logbook data and 50,042 transactions in the dealer data. The frequency of transactions for the vessel trip report subset and the mandatory dealer subset are displayed in Figures A3, A4, and A5.

For the matched permits, the difference between the number of transactions in each set was calculated by subtracting the number of transactions of vessel permits from the number of transactions of dealer permits for each matched permit. The distribution of these differences is presented in Figure A6.

Comparison of Each Transaction by Unique Vessel Permit

In the last segment of this analysis, the direct correspondence of each transaction between the vessel trip report data and the mandatory dealer data was examined; this hinged on finding variables common to both data sets. To match transactions in the dealer and vessel databases, it was necessary to link across a combination of fields present in both data sets that uniquely identify (distinguish) trips in both data sets. The fields PERMIT, PORT, MONTH, DAY, and DEALER_NUMBER are the only fields common to each data set. A match of dealer records with vessel trip report records was attempted using three primary linking fields: permit number, dealer number, and date (month, day),which occurred in both data sets,and in combination had the potential to distinguish unique trips. Problems were encountered with both the dealer and vessel trip report records which limited the ability to match data from these two sources on a trip basis.

Inadequate data in the match fields were encountered in both the dealer and vessel log databases. In the dealer database, an additional 2,331 dealer records (3.8 % of the remaining dealer data set) with missing (null) or zero values for DAY, MONTH, PERMIT, or DEALNUM fields were eliminated. In the vessel log database, 16,216 vessel log records (25% of remaining vessel log data set) where either DATESOLD or DEALNUM was null or zero were eliminated. These records were excluded from the analysis to eliminate the possibility of erroneous matches where data in the matching fields were missing, null, or set to zero by the data entry or auditing processes.

A necessary condition to matching dealer and vessel log records for individual trips was that the PERMIT-DEALER_NUMBER-DATE combination successfully distinguished unique trips in both the dealer and vessel log databases. This was not true for the dealer database. A total of 6,305 dealer records (another 10.2% of the remaining data set) were found where there were multiple month-day trips (with unique document numbers) occurring for the same PERMIT- DEALER_NUMBER-DATE (day-month) combination. The number of trips with the same permit and dealer number sold on the same date ranged from 2 to 20 distinct document numbers. This is problematic because the matching criteria will be unable to distinguish between these trips, resulting in erroneous matches. If this situation is due to incorrect date information on the dealer records, it is also impossible to match these trips correctly to their corresponding vessel logs. Note that the MONTH-DOCUMENT_NUMBER fields are still useful for identifying individual trips within the dealer database. The absence of the DOCUMENT_NUMBER field (which is not present in the vessel log database) during the matching process results in the inability to distinguish individual trips.

This situation occurs for two primary reasons. First, dealers lump the trips from under-tonnage vessels under two permit numbers (190998 and 390998). Of the 3,709 total trips coded with these two permit numbers, 1,074 occurred within unique DEALER_NUMBER-DATE combinations. The remaining 2,635 trips contributed to multiple document numbers occurring in the same PERMIT-DEALER_NUMBER-DATE block, accounting for roughly 43% of these problematic trips. Second, it appears that dealers or port agents are lumping many trips on the same day, no matter when the trip was sold. The frequency of transactions occurring on the 15th, 30th, and 31st day of a month is roughly 50% higher than other days of a month, suggesting that dealer records are being tallied monthly. Approximately 122 dealer numbers have this problem after removing under-tonnage vessels. Of these, 8 dealer numbers accounted for 1,954 of the 3,670 (53%) remaining trips. While DOCUMENT_NUMBER can be used to distinguish among these trips from a dealer perspective, it is impossible to distinguish between trips when linking dealer records with vessel log records to assign dealer trip landings to a specific vessel log.

It was impossible to determine the degree to which the PERMIT-DEALER_NUMBER-DATE combination successfully distinguished unique trips in the vessel log database. However, it is important to reiterate that more than 25% of the relevant, and in theory "matchable", vessel log data would be discarded because of inadequate data in the matching fields.

Conclusions Regarding Direct Trip Match

Given the problems with both the dealer and the vessel log records, it was not possible to make an accurate match between the dealer and vessel log records for individual transactions. Further, many problems encountered could not be rectified, given the existing data collection procedures and database structure. It is clear that the current data collection procedures and database structure were not intended to accommodate the possibility of directly matching dealer and vessel log records for individual transactions. The matching approach outlined in this section is theoretically possible given the current structure. However, it is operationally intractable given the current problems associated with "inappropriate" data in the matching fields and other confounding factors. To directly match the dealer and vessel log records of individual trips-transactions, a data collection system must be designed to satisfy both management and scientific needs. To accomplish this, a comprehensive analysis of fishing operations and dealer transaction procedures must first be performed.

If direct matching of transactions were possible with the present data sets, the following exclusions would be made, and each data set would be reduced to:

VTR trip records: 64,319 records in total, 46,475 records (72%) excluding non-commercial trips.

VTR gear records: 66,217 records in total, 36,840 records excluding non-commercial trips and gear types not required to report in the VTR system.

VTR species-DEALNUM (transaction) records: 215,749 records in total, 150,329 records excluding non-commercial trips and gear types not required to report in the VTR system and species retained from home consumption. This subset would be further reduced by approximately 18% due to 1) zero or missing values for day, month, permit, or dealer number; and 2) zero values for quantity kept.

Dealer trip records: 101,185 records in total, 65,098 records excluding non-mandatory dealer transactions, and non-Federal document numbers. This subset would be further reduced by approximately 15% due to 1) zero or missing values for day, month, permit, or dealer number; 2) multiple month-day dates for the same permit, dealer number; and 3) under-tonnage vessel permits lumped in 190998 or 390998 permit codes.

Distribution of Landings from VTRs

Landings distributed by region, area, month, and port are important components of any assessment work conducted on a fish stock in the Northeast. Prior to 1994, the commercial weighout and interview databases provided detailed information on these and other aspects of the landings of all the important commercial species. Logbook data could provide some useful information to allow for an examination of some of these issues. An analysis comparing landings information from 1993 and the logbooks from 1994 was conducted with the intent of conducting coarse-level comparisons of some of these common aggregation variables for selected species landings. These comparisons were done on a percentage basis because the 1994 data were incomplete.

Cod otter trawl landings by stock area appeared to change little in terms of distribution by region for 1993 and 1994 (Figure A7). Georges Bank provided the bulk of the landings for both years. Landings in the Gulf of Maine were similar on a percentage basis in the two data sets and appeared to be about half of that on Georges Bank. Cod landings by statistical area fluctuated a little more when comparing the percentages for 1993 and 1994 (Figure A8). Landings may have increased in Statistical Areas 511 and 512 while decreasing in Areas 561 and 562. Most of the landings appear to have occurred in Areas 521 and 522 in both years, consistent with historical landings patterns for the Georges Bank stock.

Since the mandatory logbook data system began in May 1994, a comparison of months 5-8 (May - August) was conducted for 1993 and 1994 for cod otter trawl landings. Although there were some differences, the 1993 pattern of landings appeared to be present in 1994 for Boston, Gloucester, and New Bedford landings (Figure A9). This also appeared to be the case for a comparison by region-port, with New Bedford landings dominating in both years and in the Georges Bank region (Figure A10).

Yellowtail flounder otter trawl landings by stock region for 1994 were also comparable to 1993 with Georges Bank dominating the total followed by smaller proportions in the Gulf of Maine and Southern New England (Figure A11). Landings in Statistical Areas 513 and 514 remained relatively constant between 1993 and 1994. Most of the landings appeared to occur in Statistical Area 562 in both 1993 and 1994 and the relative proportions in both areas were similar over these two years (Figure A12). Landings of yellowtail flounder in the other George Bank and Southern New England areas showed slight-to-medium changes over the two years, but no large trends were apparent.

Landings of cod in the sink gillnet fishery were also compared for 1993 and 1994. Most of the landings from this fishery occur in the Gulf of Maine and the remainder occur on Georges Bank (Figure A13). The relative proportions for the two years remained stable in the various stock regions. Landings were highest in Statistical Areas 513, 514, and 521 during 1993 and 1994 (Figure A14). Proportional landings in Area 513 remained stable over the two years, but appeared to change in Areas 514, 515, and 521.

Allocation of Total Landings to Stock

Analyses from the previous section indicated that proration of landings data may be possible for 1994 data as long as the analysts are very careful about prescreening the information before use. This would entail a thorough investigation of all the appropriate sources of information and a careful examination of the data prior to any proration. Data from dealer records and logbooks were examined to determine the percentage coverage of 1994 landings for the ten groundfish species, as well as summer flounder and sea scallops (Table A8). Since the mandatory program began in May 1994, landings of these species had almost no coverage in the first quarter, but were recorded through the previous weighout/interview system. Landings that were under the mandatory system were covered to the greatest extent in the logbooks during the second quarter, but coverage for all quarters is still incomplete.

Since overall logbook coverage of cod was reasonably high (>50%) and only two stocks were involved, the SARC chose cod as a candidate species for an example proration of the 1994 landings data. This analysis was for illustrative purposes only since the data were preliminary, provisional, and incomplete. The steps followed in the proration exercise are illustrated in Figure A15. Since the 1994 data were available from two sources (mandatory and weighout/interview), it was necessary to use both the mandatory and non-mandatory dealer information to produce example landings for the Georges Bank and Gulf of Maine cod stocks. The procedure used was to first obtain the quarterly landings by division from the dealer files for the non-mandatory part of the year (mostly the first and second quarters) (Table A9a). Because the quarterly landings obtained from the mandatory system contained no area designation (Table A9b), landings by area and quarter were obtained from the logbook data to prorate the mandatory dealer information. The logbook landings by region and quarter were converted to percentages and used to prorate the dealer landings data to stock area (Tables A9b - d). The two sources of prorated landings by stock were combined to produce an example set of landings for the Georges Bank and Gulf of Maine cod stocks for 1994 (Table A9e).

In addition, a simpler proration was also attempted with the 1994 logbook data. Cod landings from the logbook data were converted to percent by region for the entire year (Table A10a). These percentages were used to estimate landings by applying them to the total landings from the 1994 dealer database (Table A10b). This procedure produced another example set of landings for the Georges Bank and Gulf of Maine cod stocks (Table A10c).

Consistency of CPUE and Effort Trends including Trip Examination

To investigate the utility of the 1994 logbook system for examining trends in effort for groundfish stocks, a comparison of 1993 and 1994 data for selected stocks was attempted. Since the 1994 logbook data were incomplete, only simple comparisons were possible. Percentages by region and subarea for cod and yellowtail flounder were used as examples to illustrate trends for the two years. Only otter trawl effort was examined since comparisons for other gears were not as feasible at the time. Information for 1993 was obtained from the weighout/interview database. Information for 1994 was obtained from the logbook database. Days fished for 1994 were calculated from information on tow duration and number of trips in the logbook database. Data for both years were converted to percentages by region and area to facilitate comparisons.

Percentages of effort for cod on Georges Bank and the Gulf of Maine changed somewhat in 1994 from those in 1993, but not greatly (Figure A16). This may reflect several factors including area closures on Georges Bank, incomplete logbook data, and many other possibilities. Effort patterns among statistical areas on Georges Bank and in the Gulf of Maine appeared to vary between 1993 and 1994. An increase in Areas 511 and 512 may indicate that these areas were sampled sparingly in the past (Figure A17). The decrease in effort in Area 562 may reflect the Area II closure that went into effect in 1994 on Georges Bank.

Fishing effort for yellowtail flounder apparently decreased on Georges Bank and increased in Southern New England in 1994 (Figure A18). An examination of effort by statistical area suggests that a switch to Southern New England may have occurred in 1994, increasing in Areas 526 and 537 (Figure A19). These trends will need to be examined more closely when the entire audited 1994 database is available.

Fishing vessel operators often find it necessary to fish in several statistical areas. The number of subtrips over the period 1991-1993 from the weighout/interview database and from logbook information in 1994 was compared to investigate if coverage in 1994 had changed. The percentage of split trips by otter trawlers that fished more than 1 day during 1991-1993 averaged 5.5%, while the percentage in 1994 was about 2.4% (Figure A20). This suggests that the logbook database indicates a frequency of split trips about 50% less often as had been recorded by port agents in the previous years. This comparison is preliminary and the conclusion may change when a fully audited and corrected 1994 database is available.

Trip Length Evaluation

An analysis was undertaken to determine if a method could be found of detecting unusually low values in the QTYKEPT field (due to a problem distinguishing between whole pounds and thousands of pounds). A landings-per-unit-effort ratio was calculated by dividing the total number of pounds for a trip by the number of days the vessel was at sea (DATELND1 - DATESAIL). This revealed some very long trips (max 335 days) and some very short trips (min 1). The percentage of trips with days absent less than 1 was very small (0.02%). A slightly larger number (1.1%) were found to be greater than 15. Some of these may be valid, but will require verification.

In the scallop dredge fishery (DRS), the highest frequency of trips were absent for either 1 or 15 days (Figure 21). The sink gillnet fishery (SGN) is mostly comprised of day trips, while the otter trawl fishery (OTF) includes a large number of trip boats as well as day boats. A comparison of the 1994 logbook data with the 1993 weighout data shows similar patterns in each fishery between years (Figure A22). The 1994 data appear to have slightly higher values in general, but appear to be missing a large number of day trips in the scallop fishery. This pattern is reflected in the higher mean days absent for the DRS data in Table A11. Both sets of data also indicate extremely long trips.

Catch-per-unit-effort data (pounds per day absent) also show similar patterns in both years (Figures A23 and A24). The 1994 logbook data indicate slightly lower mean CPUE for the otter trawl and sink gillnet fisheries (Table A11), and the distributions are skewed more towards lower values (Figures A23 and A24). Results for the sea scallop fishery reflect the low frequency of day trips in the 1994 logbook data (Table A11 and Figures A21 and A22). Further review of these results is required when the entire 1994 data set is complete.

VTR-Sea Sample Comparisons

The sea sampled trips were compared with corresponding logbooks for April-December 1994. The sea sampling database is presently being revised, but the 1994 data were available electronically, although in an unaudited form. From April to December 1994, 1,378 trips were sampled by observers and 37,026 tows were recorded, where 50% of these tows were observed.

Only commercial trips were extracted from the logbook database; party and charter boats were specifically excluded. In the sea sample data, all tows, both observed and unobserved, were included in the analysis. The criteria for a successful match of a sea sample trip to a logbook trip were equivalent hull number, date landed, and species code. Of the 1,378 sea sample trips, 27% or 366 trips had matching logbook trips. The reasons for a lack of a match for the other 73% of the trips has yet to be investigated.

Comparison of landed pounds for all species for matched sea sample and logbook trips indicates that agreement is strongest in the sink gillnet vs. the otter trawl (Figure A25 and A26). For gillnets, except for a few notable outliers, agreement between sea sample and logbook catches was good across the range of catches. For otter trawls, however, the best agreement was at lower range of landed pounds.

Cod and all flounders combined (American plaice, yellowtail, summer, witch, fourspot, winter, and windowpane) were chosen as example species for otter trawl and gillnet comparisons (Figures A27-A30). Cod was not well represented in the otter trawl gear (Figure A27), but in sink gillnets, agreement was relatively good, with a slight bias towards higher weights in the logbooks (Figure A28). Flounders were also not well represented in the otter trawl (Figure A29), although the agreement was good. In the sink gillnets, agreement was good across the range of catches, although a few outliers were present (Figure A30).

Histograms of the annual landed pounds by species for otter trawls and gillnets (Figures A31 and A32) indicate that weights from the sea sample records are larger for the majority of the species with the notable exception of species 801 (*Loligo* squid) taken by otter trawls. Further investigation of this is required. Again, agreement was more consistent in the sink gillnet gear than in the otter trawl.

Paired Vessel Considerations

Available logbook records were examined for presence of paired vessel observations. Paired gear types include: pair trawl, bottom (PTB) and pair trawl, midwater (PTM). The initial purpose of this investigation was to determine whether paired vessels reported the entire catch on both logs or split the catch between vessels. Corresponding records from dealers would be scrutinized to determine the total landings from each trip, providing a comparative metric for this gear type.

A total of 22 trips from two vessels (one from Hampton, VA and one from Pamlico, NC) coded as PTB were included in the available database. All of these trips were reported as fishing in Areas 622, 626, or 635. The predominant species were sea scallops and shrimp, with summer flounder as the primary bycatch. Shrimp from this area were reported using the only 3-letter code available (SHR, pandalid), although it is more likely that these shrimp catches comprised penaeid species. It is not likely that these vessels were paired with each other, but rather each fished multiple nets, with the captains reporting the gear as paired.

A total of 86 trips from 9 vessels coded as PTM were included in the available database. Eight of the vessels were reported as fishing in Southern New England (Areas 537-616) for large pelagics and one vessel was reported as fishing in Area 513 for herring. Of the eight vessels reported as pair trawling for large pelagics, only one log recorded another vessel name as its pair.

The majority of trips recorded as PTM were reported for the single vessel fishing for herring in the Gulf of Maine. When all of the actual logs were examined for this vessel, it was noted that the gear used was recorded as midwater trawl. This gear type was interpreted in three ways: PTM, OTM, and OTH. The gear code eventually entered in the database was batch-dependent and thus likely auditor-dependent. Thus, the gear code PTM was incorrect for this vessel. Of greater concern, it was also noted that a very high proportion of the herring catches recorded on the log sheet were entered into the database as "other finfish". This error was associated with trips coded as OTH and was also batch-dependent. Batch numbers higher than 15 were responsible for the erroneous entries. In contrast to lower batch numbers, these logs were designated to be entered in "as is" condition.

Both errors were related to the manner in which the logs were completed and could have been avoided with pre-screening by knowledgeable people. The second error associated with the species coding of the catches casts serious doubt on whether the database accurately reflects the information content in the logs. In order to evaluate the accuracy of the logbook data, the assumption of representation must be met.

Summary

The vessel trip report (VTR) system became effective in April 1994 for vessels landing summer flounder, and in June 1994 for vessels landing multispecies groundfish or sea scallops. The VTR data are important to stock assessments because key information such as location, gear, and effort, previously collected by port agents, are no longer available in the dealer database.

Specific analyses of the available 1994 logbook data were conducted to evaluate the accuracy of the data as specified in the terms of reference. Analyses of the spatial components indicated that the statistical area entry was represented on almost all logbook records, but that analyses of the data at greater spatial resolution was only possible for 19% of the trips because the latitude/longitude or loran fields on the remaining trips could not be interpreted without further scrutiny of the original logbook entries.

In general, the proportional catch by gear was similar between dealer and vessel data sets. Cod dealer data showed a slight under-representation of handline and other minor gears (probably reflecting lumping of catches from small under-tonnage vessels). Likewise, other minor gears were also under-represented in dealer data for haddock, pollock, white hake, summer flounder, and sea scallop catches.

Vessel permit numbers in the 1994 vessel log database were matched with corresponding vessel permit data from the mandatory dealer transaction database. When the two subsets were combined, a total of 3,090 unique vessel permit numbers were detected. Of these, 46% (1,410 permits) of the vessel permit numbers occurred in both subsets, 43% of the vessel permit numbers occurred only in the dealer subset, and 11% of the vessel permit numbers occurred only in the vessel trip report subset. The 1,410 matched permits represent 81% of the available permits in the vessel logbook subset and 51% of the available permits in the dealer subset. About 1.6% of the commercial trips had permit numbers or hull numbers which did not map to the same vessel.

Of those vessel permit numbers which matched, 6% had the same number of transactions in both subsets, 70% of the permits had more dealer transactions than vessel logbook transactions, and 24% of the permits had more vessel logbook transactions than dealer transactions. Further attempts to directly match the data on a trip-by-trip basis were unsuccessful due to the lack of complete linking information in each database. It was necessary to improvise matching criteria from existing fields such as permit number and date, which are required on both dealer transaction records and vessel trip reports. Inaccuracies in the permit field in both data sets contributed to the low probability of direct matching. In addition, various interpretations of the date fields were likely applied by the dealer and the operator on their respective records.

An analysis comparing proportional landings and effort information from 1993 with logbook data from 1994 was conducted for selected species and gear types. Otter trawl landings of cod and yellowtail flounder by stock area appeared to change little in terms of distribution by region for 1993 and 1994. Landings of cod in the sink gillnet fishery were also compared for 1993 and 1994. Most of the landings from this fishery occur in the Gulf of Maine and the remainder occur on Georges Bank. The relative proportions for the two years remained stable between the two stock regions. Percentages of effort for cod on Georges Bank and in the Gulf of Maine changed somewhat in 1994 from those in 1993, but not greatly. This may reflect several factors including area closures on Georges Bank, incomplete logbook data, and many other possibilities. Fishing effort for yellowtail flounder apparently decreased on Georges Bank and increased in Southern New England in 1994. The percentage of split trips by otter trawlers fishing more

than 1 day during 1991-1993 averaged 5.5%, while the percentage derived from the 1994 logbook data was about 2.4%.

Two procedures utilizing different stratification schemes were developed to prorate the recorded landings from the dealer records across stock area. The first scheme included quarter and stock area in the estimation, while the second procedure was based on annual proportions between areas. Different results were obtained from each procedure, although the spatial patterns were similar. The SARC noted that extreme caution must be exercised when attempting such procedures because the results will depend on the stratification scheme employed.

Sea sampled trips were compared with corresponding logbooks for April - December 1994 as a means of determining accuracy of the corresponding logbook data. Of the 1,378 trips comprising 37,026 tows covered by observers, 27% or 366 trips had matching logbook trips. For gillnets, except for a few notable outliers, agreement between sea sample and logbook catches for all species combined was good across the range of catches. For otter trawls, sea sample coverage was sparse, but the best agreement occurred at the lower range of landings.

SARC Comments

The current data collection procedures and database structure of the recently implemented (1994) mandatory vessel and dealer reporting systems were not designed in a coordinated manner to meet multiple scientific and management needs. Most of the vessel trip report logbooks were not screened and verified to standardize the data as set out in the database design. Therefore, a substantial number of serious errors remain in the database, and the database is not likely to accurately reflect the information content of the original logs. Thus, it was not possible to provide a comprehensive evaluation as specified in the terms of reference.

A comprehensive evaluation of the effectiveness of the logbook program depends on the central assumption that the database contains an accurate representation of the information submitted on the logs. Without sufficient quality assurance procedures during the pre-processing, data entry, and audit stages, such accuracy cannot be assured. Such quality assurance procedures initially designed into the pre-audit phase were suspended because of management directives. Thus, many inconsistencies in the observations derived from the logbook database often resulted from erroneous or incomplete entries in the database that were not necessarily present on the original logs. Thus, it was difficult to distinguish between the inaccuracies directly attributable to the logbook information and those introduced as a result of data entry.

Difficulties encountered in attempting to match dealer records with corresponding logbook submissions were due, in part, to the errors introduced to the database during data entry. However, matching of these two data sets was inherently difficult because the design of the two data collection systems was not coordinated. An accurate alignment of the two data sets requires the presence of linking criteria on each component. This has not been achieved under the present system. Thus, trip information which, in theory, exists in the separate data sets to allow a direct match cannot be utilized unless information contained on both vessel and dealer records is linked in the database. To achieve this in the future, a comprehensive mandatory data collection system must be designed which satisfies both management and scientific data needs by taking into account the interrelated effects of the regional database system.

The proration of total landings to stock area, as illustrated by the two examples presented in the section on **Allocation of Total Landings to Stock**, illustrate some potential problems of utilizing unrelated data sets to allocate landings. Many proration schemes may be utilized to produce the same product, but results will vary depending on the degree of resolution or stratification incorporated in the proration scheme. To ensure reproducibility, a master database containing catch allocated by gear, area, mesh, etc., must be constructed from the available data and maintained for the users.

Recommendations

The SARC considers the collection of commercial fishery statistics in a systematic and scientifically sound manner to be of highest priority. However, the large number of discrepancies between the information content of the submitted logbooks and the representation of these data in the database is a matter of serious concern. The SARC, therefore, recommends that immediate attention be given to both short-term problems with the 1994-1996 data and to the development of long-term solutions to problems of sampling design and database management.

To address problems that exist within the current database, the SARC recommends:

1. Verifification and recovery of all information contained on 1994-1996 logbooks be accomplished by screening and performing pre-audits on logbook pages as set out in the database design using software, scanned images, re-entry, or other appropriate procedures.

2. Use of existing data for provisional assessment calculations, such as allocation of catch by stock area, should be done with caution on a case-by-case basis by individuals familiar with the particular fisheries and species. Without additional auditing, all calculations based on these data must be considered preliminary. All calculations should be performed with extreme caution and full awareness of the problems in the database.

To ensure that data collected in the future are usable, the SARC recommends:

3. Analysis and design of the mandatory vessel and dealer reporting system should be completed and implemented in order to accommodate management and scientific data requirements. This analysis must reference the interrelated effect of the Regional database system (e.g., vessel and dealer permitting) on the mandatory reporting system. Such a system should have as its basis at least the following features:

   - unambiguous linking criteria that can be easily implemented for dealer, logbook, sea sampling, and effort monitoring data;
   - pre-audits of all submitted data during the data capture phase with personnel knowledgeable of the fishery, species, regulations, and the database structure and content to eliminate ambiguities in data fields and preserve the original integrity of the logbook information;
   - user-friendly data collection forms which provide clear instructions for recording data in standardized formats.

4. Until the long-term sampling design problems are resolved, immediate steps should be taken to promote cooperation between industry and managers to improve the existing data collection process by adhering to design standards, modifying collection forms and instructions, and by encouraging educational programs.

The SARC advises that experts in sampling design, database management, fishery management, and stock assessment, working in cooperation with industry representatives be directed to implement these recommendations immediately.

Table A1. Pre-audit and keying instructions for 1994 vessel logbook records.

	Pre-Audit and Keying Instructions		
Field	**7/26/94**	**8/9/94**	**3/10/95**
IMAGENUM	← ← ← ← ← ← ← Hyphens not entered → → → → → → →		Not null, no "?" allowed.
HULLNUM			
PERMIT	Check all without zero as third digit	← ← ← ← ← ← ← Do not audit → → → → → → →	
DATESAIL	← ← ← ← ← ← ← ← ← ← ← ← ← ← Format mm/dd/yy → → → → → → → → → → → → → →		
TIMESAIL	Convert AM or PM to 24 hour clock time	Do not convert AM or PM. Delete AM if recorded. If PM recorded, delete entire entry.	Enter as recorded.
TRIPCATG			Not null, no "?" allowed.
CREW			
NANGLERS			
GEARCODE	If three characters do not change. If greater than three, look up correct code.	Delete entries longer than three characters.	Truncate to three characters. If nonvalid code is recorded, the first three characters would be entered.
MESH	If more than one is recorded, enter only first value.	Delete ranges or multiple entries.	Continue to convert to decimal.
GEARQTY			Enter as recorded.
GEARSIZE	If more than one is recorded, enter only first value.	Delete ranges or multiple entries.	Enter as recorded.
AREA	If more than one is recorded, enter only first value.	Delete ranges or multiple entries.	Truncate to three characters. If text recorded, the first three characters would be entered.
DEPTH	If more than one is recorded, enter only first value.	Delete ranges or multiple entries.	Truncate to four characters. Example: "50-60" entered as "50-6".
LAT	← ← ← ← ← ← ← Delete seconds → → → → → → →		Enter as recorded.
LON	← ← ← ← ← ← ← Delete seconds → → → → → → →		Enter as recorded.
LORAN1	Complete entries by inserting station and chain. Right justify time delays.	Delete incomplete entries.	Enter as recorded.
LORAN2	Complete entries by inserting station and chain. Right justify time delays.	Delete incomplete entries.	Enter as recorded.

Table A1. (Continued)

	Pre-Audit and Keying Instructions (Continued)		
Field	**7/26/94**	**8/9/94**	**3/10/95**
NTOWS	If recorded in other than total for trip, calculate based on other information on log	If other than total number for trip, delete.	Truncate to four characters. If something other than total number of tows/hauls per trip recorded, the first four characters would be entered. Example: "10 per day" entered as "10 p"
TOWHRS			
TOWMIN			
SPPCODE	← ← ← ← ← ← ← ← ← ← ← ← ← ← Enter all characters → → → → → → → → → → → → → →		
QTYKEPT	Check units, decimals, etc.		No audit.
QTYDISC	Delete entries other than pounds (percentages, bushels, etc.).		No audit.
DEALNUM	If blank, look-up from dealer table using recorded name. If dealer does not have a permit, or it cannot be determined, enter '00000'. If multiple species entries for one dealer, pass to subsequent records.		No audit.
DEALNAME	If multiple species entries for one dealer, pass to subsequent records.		No pass.
DATESOLD	Format mm/dd/yy. If multiple species entries for one dealer, pass to subsequent records.		No pass.
PORT1			Not null, no "?" allowed.
STATE1			Not null, no "?" allowed.
PORT2			
STATE2			
DATELND1	← ← ← ← ← ← ← ← ← ← ← ← ← ← Format mm/dd/yy → → → → → → → → → → → → → →		
TIMELND1	Convert AM or PM to 24-hour clock time.	Do not convert AM or PM. Delete AM if recorded. If PM recorded, delete entire entry.	Enter as written.
DATELND2	← ← ← ← ← ← ← ← ← ← ← ← ← ← Format mm/dd/yy → → → → → → → → → → → → → →		
TIMELND2	Convert AM or PM to 24-hour clock time.	Do not convert AM or PM. Delete AM if recorded. If PM recorded, delete entire entry.	Enter as written.
OPER_NUM			

Table A2. VESLOG94 computer audits table - description of field audits at each audit stage.

Field Name	Field Type	Stage 1	Stage 3	Stage 4
TRIPID	number(9)	Does not exist	Does not exist	Regional Office
NRPAGES	number(3)	Does not exist	Does not exist	Regional Office
NSUBTRIP	number(3)	Does not exist	Does not exist	Scientific staff
HULLNUM	varchar2(8)	No checks	F Lookup on cfvess94	
PERMIT	number(6)	F No blanks	F Lookup on cfvess94	S used to create subtrip
DATESAIL	date		F Invalid date, > datelnd1,	S used to create subtrip
			> datelnd2	
TIMESAIL	varchar2(4)		Oracle time check	S used to create subtrip
TRIPCATG	number(1)		F Must be 1,2, or 3	
CREW	number(2)		F range 0-99	
NANGLERS	number(3)		F range 0-999	
PORTLND1	varchar2(25)		No checks	
STATE1	varchar2(2)		F Lookup on port	
DATELND1	date		F Invalid, or < datesail	
TIMELND1	varchar2(4)		Oracle time check	
PORTLND2	varchar2(25)		No checks	
STATE2	varchar2(2)		No checks	
DATELND2	date		Invalid, or < datesail	
TIMELND2	varchar2(4)		Oracle time check	
OPERATOR	varchar2(35)		No checks	
OPERNUM	number(8)		No checks	
PORT	varchar2(6)		F Lookup on port	
DATE_SIGNED	date	Does not exist	Does not exist	Regional Office (empty)
DATERECV	date	Does not exist	Does not exist	Regional Office (empty)
GEARID	number(9)	Does not exist	Does not exist	Regional Office
SUBTRIP	number(3)	Does not exist	Does not exist	Scientific staff
PAGENO	number(3)	Does not exist	Does not exist	Regional Office
FILENAME	varchar2(8)	Does not exist	Does not exist	I Regional Office (empty)
SIDEID	varchar2(3)	Does not exist	Does not exist	I Regional Office (empty)
SERIAL_NUM	varchar2(8)	F No blanks, no duplicates,	No checks	
		No unmatched trip/spp		
GEARCODE	varchar2(3)		F Lookup vlgear	S used to create subtrip
MESH	number(31)		F make sure it is numeric	S used to create subtrip
GEARQTY	number(5)		check min-max on vlgear	
GEARSIZE	number(51)		check min-max on vlgear	
NEMAREA	varchar2(3)		F lookup on area	S used to create subtrip

Table A2. (Continued)

LAT_DEGREE	varchar2(3)		No checks	
LAT_MINUTE	varchar2(2)		No checks	
LAT_SECOND	varchar2(2)		No checks	
LAT_DIR	varchar2(1)		No checks	
LON_DEGREE	varchar2(3)		No checks	
LON_MINUTE	varchar2(2)		No checks	
LON_SECOND	varchar2(2)		No checks	
LON_DIR	varchar2(1)		No checks	
LORAN1	varchar2(12)		No checks	
LORAN2	varchar2(12)		No checks	
NHAUL	number(4)		min-max vlgear	
SOAKHRS	number(3)		min-max vlgear	
SOAKMIN	number(2)		range 0-59	
DEPTH	number(4)		range 0-9999	
SPPCODE	varchar2(5)		F lookup on vlspptbl	
QTYKEPT	number(5)		range 0-99999	
QTYDISC	number(5)		range 0-99999	
DEALNUM	number(5)		F lookup if qtykept !=0,	
			qtydisc >=0 and <=99999,	
			dealnum !=00000,00001,	
			00009,99998	
DEALNAME	varchar2(30)		No checks	
DATESOLD	date		F if dealnum != 99998,00001	
RECTYPE	varchar2(1)	F must be 1 or 2		
NOTE: Stage 2 creates the gear and species data tables from the gear-species data; there are no field audits in Stage				
F=Fatal Errors S=Subtrip Information I=Images (once they are scanned)				

Table A3. Overview of vessel trip record database fields.

VIEW: VESLOG94T (approximately 64,000 records, 4/23/96)

1.	TRIPID:	There were not replicated numbers - looks good
2.	NRPAGES:	97.4% of the values are 1, and less than 0.1% are greater than 3 pages (some of these multiple page reports are probably legitimate)
3.	HULLNUM:	This variable was difficult to assess because of the mixture of alphanumeric and numeric numbers - further investigation needed.
4.	PERMIT:	
5.	DATESAIL:	All dates were between January 1 and December 31, 1994, inclusive. 221 dates before April 1, 1994.
6.	TIMESAIL:	There was a significant number of problems in this field including 4856 records with missing values, 29 records with alpha numeric entries (AM, PM, /, A, HR, HB), 68 records missing leading zeros, 20 records with values equal to 2400, 5 records with values exceeding 2400).
7.	TRIPCATG:	All values equalled 1, 2, or 3.
8.	CREW:	This analysis was broken down by trip category:
	TRIPCATG=1:	790 values (1.7%) equal to zero, 45535 values (98%) between 1 and 10, 150 values (0.3%) greater than 10 (maximum = 76)
	TRIPCATG=2:	172 values (1.4%) equal to zero, 12523 values (98.5%) between 1 and 8 inclusive, 17 values (<0.2%) greater than 8
	TRIPCATG=3:	50 values (1.0%) equal to zero, 5076 values (99%) between 1 and 8 inclusive, 3 values exceed 8 (range:21-83)
9.	NANGLERS:	This analysis was broken down by trip category:
	TRIPCATG=1:	44,901 values (96.6%) equal to zero, 1,551 values (3.3%) between 1 and 8 inclusive, 16 values (<0.1%) exceed 10 (range 11-450)
	TRIPCATG=2:	463 values (3.6%) equal to zero, 3,047 values (24.0%) between 1 and 10 inclusive, 3,391 values (26.7%) between 11 and 20 inclusive, 2,717 values (21.4%) between 21 and 30 inclusive, 1,548 values (12.2%) between 31 and 40 inclusive, 1449 values (10.6%) between 41 and 70 inclusive, 197 values (1.5%) between 71 and 138 inclusive.
	TRIPCATG=3:	41 values (0.8%) equal to zero, 4,001 values (78%) between 1 and 10 inclusive, 1,090 values (21.2%) greater than 10 (range 11-131)
10.	PORT1:	Problematic: Some ports are spelled and abbreviated up to 10 different ways; some as street addresses, company names, numeric entries, landing names. Many could be combined and corrected by someone knowledgeable about ports.
11.	STATE1:	All state codes were states between Maine and North Carolina

Table A3. (Continued)

12.	DATELND1:	All dates were between January 1 and December 31, 1994, inclusive. 69 dates before April 1, 1994.
13.	TIMELND1:	99.8 % of values between 0000 and 2359 inclusive; 0.2% of values are problematic as follows: 48 values with alpha numerics (S,AM,PM,P,SAME), 39 with missing leading or trailing zeros, 30 values equal to or exceeding 2400
14.	PORT2:	Problematic with multiple spellings of ports, some numeric codes, company names, fisher names. Small number of total entries. Many could be combined and corrected by someone knowledgible about ports.
15.	STATE2:	All codes for states from Maine to North Carolina inclusive, except one "00" and one "RT"
16.	DATELND2:	All dates were between January 1 and December 31, 1994, inclusive. Three values were earlier than April 1, 1994.
17.	TIMELND2:	Most valid times between 0000 and 2359, 8 outside this range including 03PM, 1289, 1389, 466, 400, 6PM, 8894)
18.	OPERATOR:	How many ways can you spell and abbreviate names
19.	OPERNUM:	Some values appear not to be legitimate, but numbers ranged from 1-8 digits. Further investigation is needed.
20.	PORTCODE:	All port codes were valid with the following exceptions: code 70999 (one record) and code 71011 (181 records) missing leading zeros, does port 490510 (one record) exist?
21.	DATE_:SIGNED	This field appears to be empty for all records.
22.	DATERECV:	This field appears to be empty for all records.
23.	BATCHID:	Appears correct, but not possible for me to assess.

Table A3. (Continued)

VIEW: VESLOG94G

General

1.	SUBTRIP	Mostly Subtrips of 1, 95%, Range 1-5 Subtrips. May be some duplicates, a few records were not split correctly.
2.	MESH	Modes around 2" and 5.5", range 0-10", many zeros, but most are explainable due to gears such as handlines.
3.	NHAUL	Most values are 48 or less, range 0-6970. Many zeros and a small percentage of very large values.
4.	SOAKHRS	Most values are 120 or less, range 0-999. A small percentage of very large values.
5.	SOAKMIN	Most of the values are zeros, range 0-59.
6.	DEPTH	Mostly zeros, range 0-8015. A small percentage of very high values. This variable may be currently unusable.

Gear Type Gillnet: GNS-6,218 records

1.	SUBTRIP	Very small number of subtrips, 99% of records are 1's, range 1-4.
2.	MESH	Median of 6", range 0-10". About 10% are zeros.
3.	NHAUL	95% of values are 8 or less, range 0-361. Some very high values. About 5% are zeros.
4.	SOAKHRS	Median value is 24hrs, range 0-246. About 5% zeros and 5% values greater than 72.
5.	SOAKMIN	Mostly zeros, range 0-50.
6.	DEPTH	50% of values less than 30, range 0-1200. Mostly low values.

Gear Type Otter Trawl, Fish: OTF-20,913 Records

1.	SUBTRIP	95% of values are 1's, range 1-5. Very few split trips, 2% are in the database.
2.	MESH	Modes around 2 and 5.5", range 0-9.9. 1,203 values are zero. 5% of the values are between 6 and 9.9.
3.	NHAUL	95% of the values are 30 or less, range 0-2300. Most of the values are between 1 and 8.
4.	SOAKHRS	99% of values are 8 or less, range 0-504. About 5% are zeros and 1% are greater than 8.
5.	SOAKMIN	955 of values are less than 45, range 0-59. 50% of values are zero.
6.	DEPTH	90% of values are 65 or less, range 0-7280. Many values are zeros, 50% of values are 18 or less, some very high values. This variable may not currently be usuable.

Table A4. Summarary of quantity kept (QTYKEPT) (pounds) of 28 selected species, including all other species (OTX) by 17 selected gear types, including all others (OTX) for the 1994 VTR data, with TRIPCATG = 1.

	GEAR																	
	DRC	DRS	GNS	HND	LLB	LLP	OTC	OTF	OTH	OTM	OTS	OTX	PTF	PTL	PTM	SED	TRP	
	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	
	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	TOTAL
SPPCODE																		
BUT	.	30	3895	920	.	.	158	2376834	11887	2231	2	482	1910	2226	2400	.	41869	2444844
CLSU	6665450	20	.	.	.	.	.	.	.	.	.	102640	.	.	.	.	.	6768110
COD	4585	12316	3202625	334837	777732	22129	349	5905737	262404	.	181	29194	10834	12128	.	.	95	10575146
CRHS	245	0	0	5500	.	.	.	2621791	0	.	.	.	.	.	.	.	.	2627536
DGSP	4635	1730	9621911	141	1351125	.	0	2528519	47252	0	0	85533	.	.	.	.	.	13640846
FLBB	48	30418	44938	191	3100	6	9086	2379698	47789	.	41	1568	205	958	.	.	572	2518618
FLDAB	9665	14629	65994	96	35	905	153	3805117	63373	.	122	9092	13200	8	.	.	.	3982389
FLGS	2983	15210	83369	25478	193	400	264	1683296	26655	.	257	5211	2500	.	.	.	.	1845816
FLSD	.	3265	1415	0	253	.	.	650599	19879	.	10	2803	300	1	.	.	.	678525
FLUKE	994	80409	41876	19820	176	.	10947	5039482	175304	7871	1218	3836	162	1129	.	250	38751	5422225
FLYT	63	40744	56234	2789	338	.	56	2030156	258740	.	84	1693	210	47	.	150	.	2391304
HADD	50	160	13612	1065	32003	1260	.	130707	6601	.	.	1320	.	.	.	.	4000	190778
HERR	.	.	14825	1225	.	5440	190	1323080	464686	6420318	19327	194497	.	52	4837935	.	2840	13284415
LOB	.	1622	10169	617	1141	98042	526	230870	35525	.	248	5874	191039	4646280	.	.	11755	5233708
MACK	.	.	19681	8158	1000	.	.	1889900	9497	94380	.	3093	.	150	.	.	291729	2317588
MEN	.	.	8423	4850	.	.	.	2875949	1676000	240507	.	8450	720	200	.	1587656	60260	6463015
MONK	3088	1150555	1102401	337	2092	1205	17284	3916380	124894	90	2646	56341	2415	1161	.	5800	444	6387133
OFF	1266	59773	39190	33852	47219	872	5096	1002222	3485178	222	4	9149	31030	34191	.	350	37810	4787424
OTX	752540	24532	2498011	680294	482900	362830	22099	9315568	713795	318838	429290	270661	861271	492517	251033	.	352239	17828418
POLL	7054	180	882238	17565	13984	1068	.	884946	41805	.	0	14834	600	0	.	.	54	1864328

Table A4. (Continued).

	GEAR																	
	DRC	DRS	GNS	HND	LLB	LLP	OTC	OTF	OTH	OTM	OTS	OTX	PTF	PTL	PTM	SED	TRP	
	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	QTYKEPT	
	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	TOTAL
SPPCODE																		
RED	100	130	24285	119	459	810	1	246081	11632	.	61	485	100	4	.	.	10	284277
SCAL	23722	7183489	199255	270	.	.	453204	248499	151528	.	162	103690	.	.	.	400	.	8364219
SCUP	11000	8063	4714	41563	501	.	9875	2574843	17834	30046	2555	237	80081	15385	3300	.	420637	3220634
SHAK	35420	50	108204	199	67302	.	256	12927257	92570	3290	21865	67666	2110	1355	.	.	.	13327544
SKATE	645	41953	385954	41302	35599	24	10	5145188	1173123	.	490	5600	2000	92	.	.	6330	6838310
SQI	.	210	4	.	.	.	.	13085096	257636	1378595	.	.	.	.	.	.	.	14721541
SQL	302	5662	11276	1244	.	.	4610	21468653	212671	246106	.	.	5000	30558	.	.	134551	22120633
SQNS	.	230	53699	.	0	.	1090	3951180	221294	7970	120	1703	17000	.	.	.	96	4254382
WHAK	540	1141	481783	18	97582	12600	8	2009892	34725	.	2720	7288	3000	4234	.	.	356	2655887

Table A5. Summary of species landed pounds for 13 selected species, by gear type (99 = unknown) from the CFDETS94 data with source code = 7.

	NEGEAR2																				
	01	02	05	06	08	09	10	11	13	14	16	18	20	21	33	35	36	37	38	40	99	ALL
	SPPLNDLB	SPPLNDLB	SPPLNDLB	SPPLNDLB	SPPLNDLB	SPPLNDLB	SPPLNDLB	SPPLNDLB	SPPLNDLB	SPPLNDLB	SPPLNDLB	SPPLNDLB	SPPLNDLB	SPPLNDLB	SPPLNDLB	SPPLNDLB	SPPLNDLB	SPPLNDLB	SPPLNDLB	SPPLNDLB	SPPLNDLB	SPPLNDLB
	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM	SUM
NESPP3																						
081	1649496	88360	11342391	.	140	.	6295431	.	8935	.	625	1337	2779	6231	.	190	2669	50	.	.	3632	19402266
120	8035	5322	5693777	.	31	605	165913	1	84236	658	153	65	248	220	.	2766	5086	.	43	100	1882	5969141
121	260	66318	4439195	6	23506	.	25057	481	164923	17079	.	2168	7	64	.	4489	147	.	.	.	2722	4746422
122	841	128	3287547	.	.	.	126996	.	34353	.	5997	.	.	.	.	1345	237	.	.	.	396	3457840
123	186	42	5273069	.	.	.	126192	.	73083	.	650	6	.	.	.	16754	7834	.	.	.	1453	5499269
124	1006	120	7774205	.	.	.	103532	.	19349	.	16570	.	.	.	.	1795	431	.	.	.	.	7917008
125	80	22	807763	.	.	.	2546	.	2070	.	.	.	.	.	.	3710	52	.	.	.	75	816318
147	73090	224	297972	.	.	.	56657	.	.	.	15	.	.	.	.	.	15	.	.	.	.	427973
153	1241756	81	3064847	.	.	.	1465547	.	450	.	10	.	2290	17	.	280	518	.	.	.	.	5775796
240	3163	26	527967	.	.	.	50364	.	.	.	.	.	1	6	.	.	1	.	.	.	.	581528
269	118383	1806	1669137	.	50	.	2475866	.	25	.	.	4	7	45	.	20	199	.	.	.	.	4265542
727	.	.	336020	.	.	.	13525	.	727	92	.	19397	2685063	499404	.	181	.	.	26	.	50148	3604583
800	.	.	1354270	.	.	.	9	.	11111980	.	.	.	.	.	4969	1692	.	.	.	1181	13293	12487394

Table A6. Summary of the number of trips in vessel trip report data by gear code for commercial trips

GEAR	Number of Trips	
DIV	46	
DRC	835	clam dredge
DRM	7	
DRO	92	
DRS	1595	
GND	24	drift gillnet
GNR	53	
GNS	6180	
GNT	98	
HND	3596	
HRP	51	
LLB	1206	
LLP	159	long line pelagic
OTB	1	
OTC	96	
OTF	20785	
OTH	788	
OTM	188	
OTS	280	
PTB	23	
PTC	27	
PTF	1034	
PTL	10123	
PTM	103	
PTO	28	
PTS	12	
SED	42	
SES	62	
TRP	551	
Total	48,085	

Table A7. Summary of dealer data by source code.

SOURCE	FREQ
0	19067
1	2185
3	233
5	1796
7	71412
8	6417
9	2
10	73
Total	101,185

SOURCE

0 = weighout only
1 = weightout + interview
2 = weighout + capt log
3 = weighout + sea sampling
4 = weighout + foreign JV
5 = NEMFIS state data
6 = weighout + domestic JV
7 = Mandatory dealer report
8 = calm logbook
9 = tuna logbook
10 = est. general landings
11 = est. mandatory vessel log

Table A8. Comparison of landings from dealer records and vessel logbooks for selected species for 1994 (for mandatory reported data only). These data are preliminary, provisional, and incomplete, and are for illustrative purposes only.

			MTLND				
SPP			QTR				
	1	2	3	4		Total	
Cod							
Logbook	10.56	2254.1	1872.7	659.7		4797.06	
Dealer	3.9	2590.2	3352.3	2854.3		8800.7	
%	270.7692	87.02417	55.86314	23.1125			
Winter fld							
Logbook	2.36	550.9	363.7	225.9		1142.86	
Dealer	0	689.9	847	1170.7		2707.6	
%		79.85215	42.93979	19.29615			
Grey sole							
Logbook	7.41	371	343.9	116.6		838.91	
Dealer	0.1	402.8	622.7	542.9		1568.5	
%		92.10526	55.22724	21.47725			
A. plaice							
Logbook	4.28	728.7	859.4	214		1806.38	
Dealer	0	996.3	1593.7	1001.1		3591.1	
%		73.14062	53.92483	21.37649			
Windowpane							
Logbook	2.05	161.3	116	28.5		307.85	
Dealer	0	140.9	96	133.4		370.3	
%		114.4784	120.8333	21.36432			
Yellowtail fld							
Logbook	0.7	232.1	747.6	104.2		1084.6	
Dealer	0.1	339.5	1290.8	864.1		2494.5	
%		68.36524	57.91757	12.05879			

Table A8. (Continued)

Haddock							
Logbook	1.07	28.3	41.7	15.5		86.57	
Dealer	0	33.3	80.4	80.4		194.1	
%		84.98498	51.86567	19.27861			
Pollock							
Logbook	7.3	344.1	359	135.3		845.7	
Dealer	0	430.4	723.3	781		1934.7	
%		79.94888	49.63362	17.32394			
Redfish							
Logbook	1.1	57.5	55	15.3		128.9	
Dealer	0	93.8	104.4	65.6		263.8	
%		61.30064	52.68199	23.32317			
White hake							
Logbook	2.3	315.2	581	308		1206.5	
Dealer	0	536.1	1378.1	705.7		2619.9	
%		58.795	42.15949	43.64461			
Fluke							
Logbook	21.3	796.3	542.1	1120		2479.7	
Dealer	5.2	577.9	763.9	805.9		2152.9	
%	409.6154	137.792	70.96479	138.9751			
Scallops							
Logbook	36.2	1721	1482.3	563.2		3802.7	
Dealer	0	2090.9	2268.2	1305.1		5664.2	
%		82.30905	65.35138	43.15378			

Table A9. Example of proration of cod landings by stock using 1994 data (all sources by quarter). These data are preliminary, provisional, and incomplete, and are for illustrative purposes only.

A. Data From CFDETS.			Non-Mandatory			
		QTR				
	1	2	3	4	9	
DIV						
51	1401.1	1117	3.2	13.6		
52	2205.7	1238.5	8.4	6.6	33.8	
B. Data From Mandatory Reporting						
		QTR				
	1	2	3	4		
DIV						
0	3.9	2590.4	3352.3	2854.3		
C. Data From Vessel Logbooks (Percentages by stock area).						
		QTR				
	1	2	3	4		
Region						
GB	62.52	67.11	48.89	22.28		
GOM	33.33	31.2	50.21	75.12		
SNE	2.41	0.85	0.38	0.48		
MID	1.74	0.85	0.52	2.12		
D. Example proration of mandatory data (Tables B&C)						
		QTR				
Region	1	2	3	4		
GB	2.60013	1782.454	1669.11	710.1498		
GOM	1.29987	808.2048	1683.19	2144.15		
total	3.9	2590.659	3352.3	2854.3		
E. Example Cod Landings for 1994 by Stock Area						
		QTR				
Region	1	2	3	4	9	Total
GB	2208.3	3020.954	1677.51	716.7498	33.8	7657.314
GOM	1402.4	1925.205	1686.39	2157.75		7171.745
Total	3610.7	4946.159	3363.9	2874.5	33.8	14829.06

Table A10. Example of proration of cod landings by stock using 1994 logbook data. These data are preliminary, provisional, and incomplete, and are for illustrative purposes only.

A. Cod Landings By Region From Logbooks.					
Region					
	mtlnd	%			
GB	2441.84	52.68			
GOM	2118.72	45.71			
SNE	30.76	0.66			
MID	43.54	0.94			
B. Total Landings from CFDETS Data.					
	mtlnd				
1994	14828.8				
C. 1994 Cod Example Landings By Stock Area.					
Region					
GB	8049.073				
GOM	6778.244				
Total	14827.32				

Table A11. Minimum, maximum, and mean values for days absent and CPUE from the 1993 commercial weighout data (June - December) and 1994 commercial logbook data.

Days Absent

	1994 Min	1994 Mean	1994 Max	1993 Min	1993 Mean	1993 Max
OTF	1	2.7	335	1	2.4	34
SGN	1	1.6	26	1	1.2	11
DRS	1	12.2	56	1	3.9	66

CPUE

	1994 Min	1994 Mean	1994 Max	1993 Min	1993 Mean	1993 Max
OTF	0.5	2160.9	200000.0	2.0	2961.3	288126.0
SGN	1.0	2628.9	70845.0	4.0	2925.8	50659.0
DRS	0.1	591.6	13836.0	9.0	263.6	2563.4

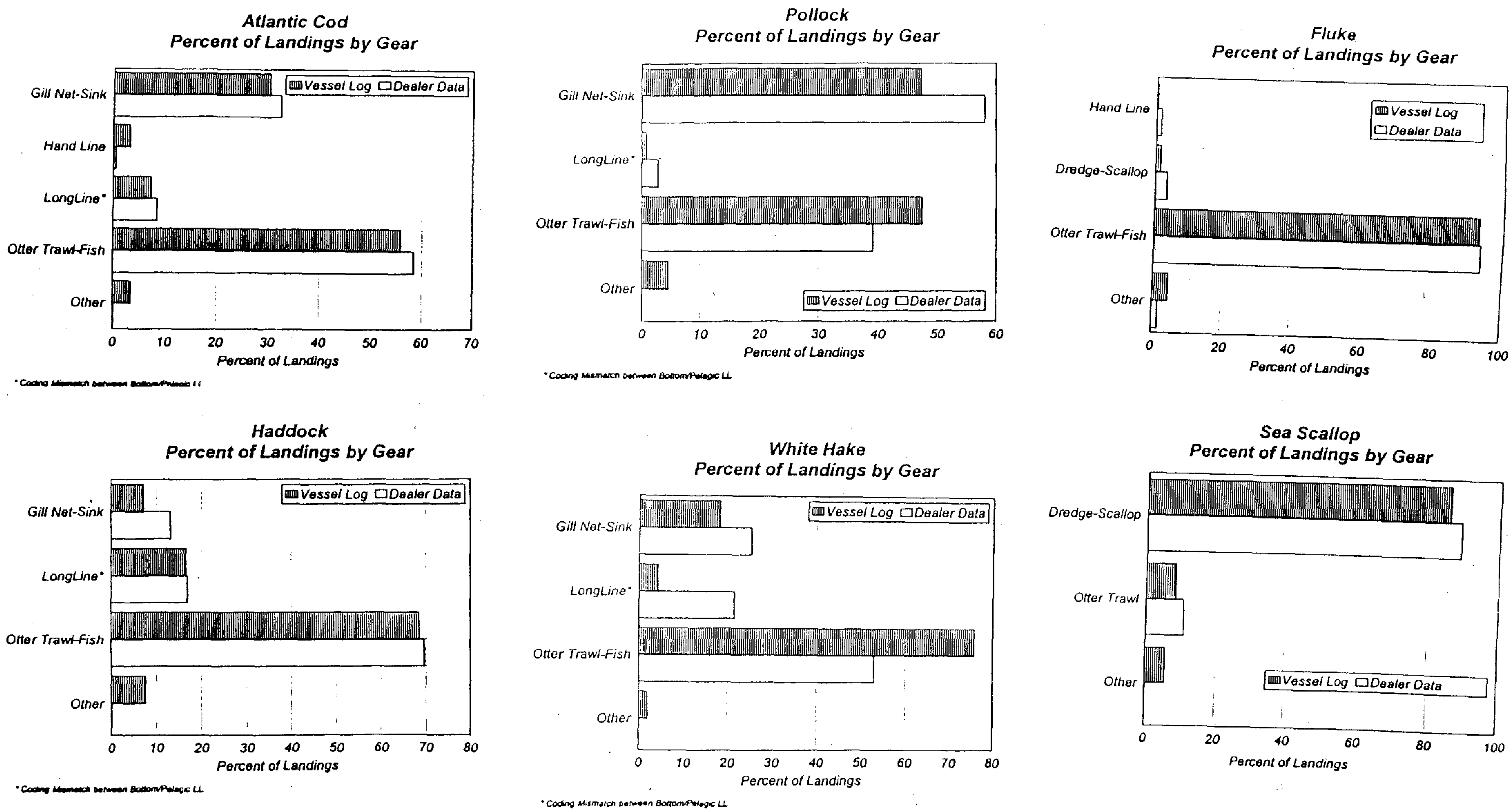

Figure A1. Percentage composition by gear of Atlantic cod, haddock, pollock, white hake, summer flounder, and Atlantic sea scallops in 1994 vessel trip reports and dealer reports.

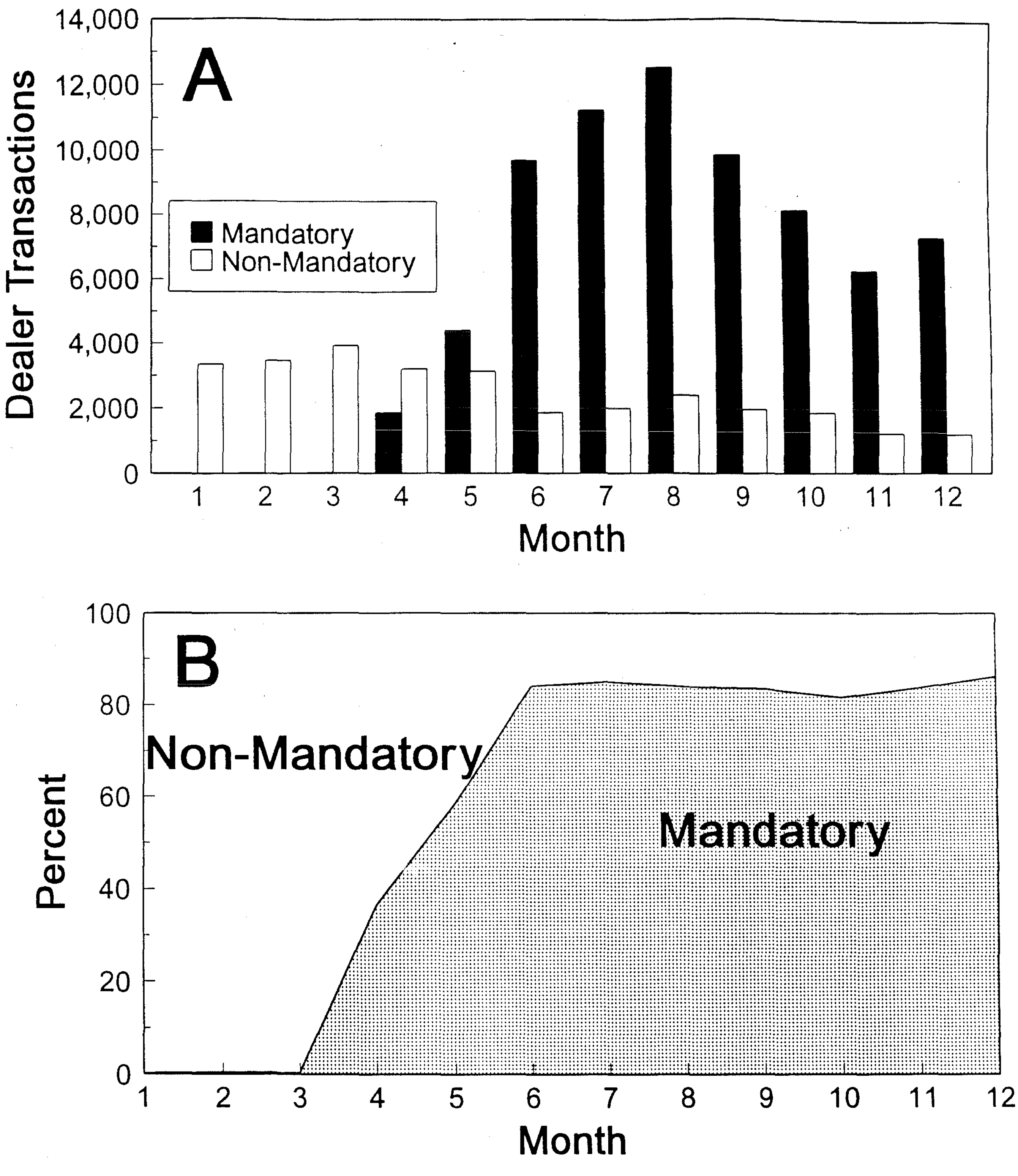

Figure A2. Monthly distribution (Panel A) and monthly percent distribution (Panel B) of dealer transactions reported under the mandatory and non-mandatory reporting systems.

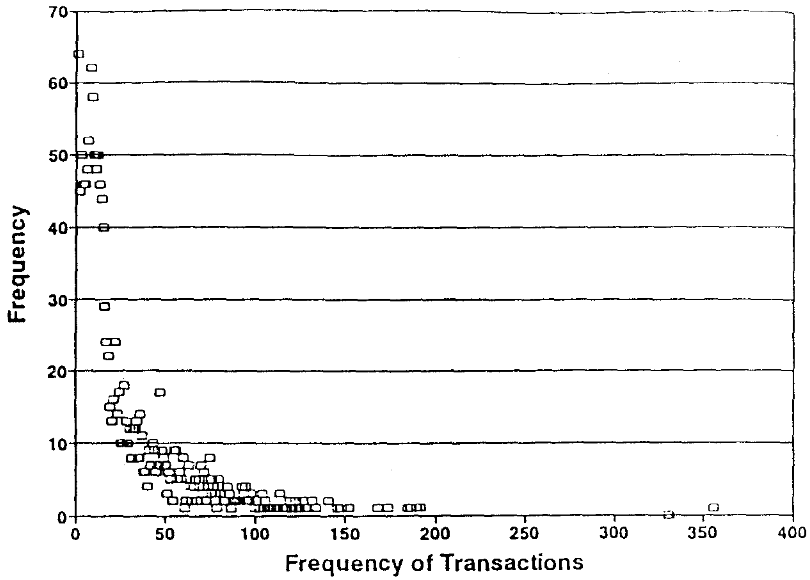

Figure A3. Frequency distribution of the number of transactions for unique vessel permit numbers in the vessel trip report database.

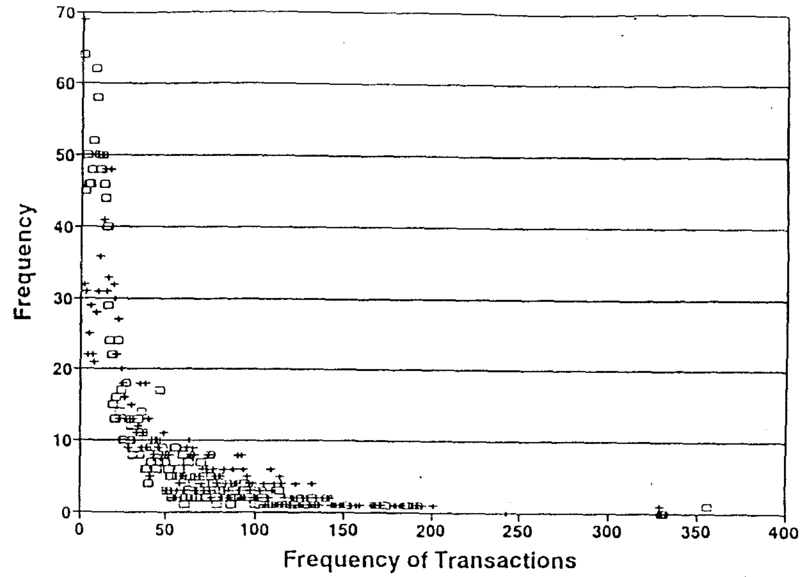

Figure A5. Frequency distribution of the number of transactions for unique vessel permit numbers in the vessel trip report database (open square) and the mandatory dealer database (plus).

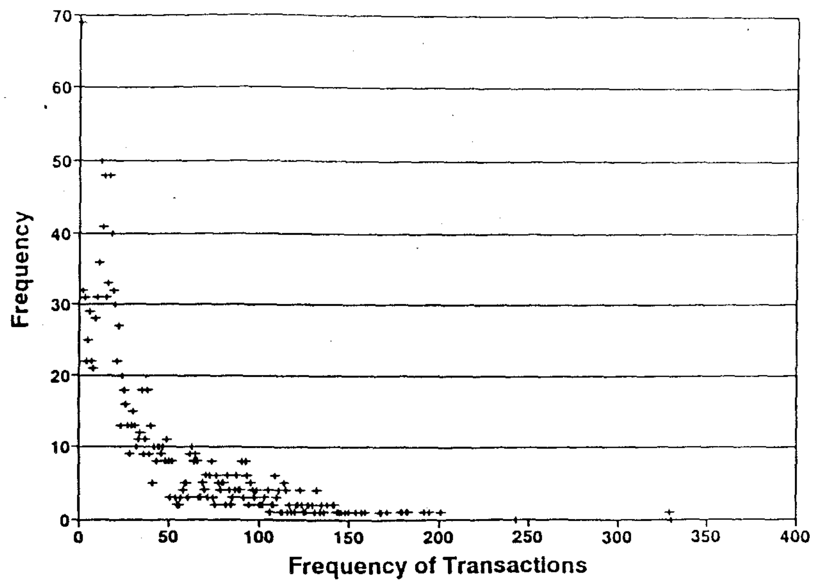

Figure A4. Frequency distribution of the number of transactions for unique vessel permit numbers in the mandatory dealer database.

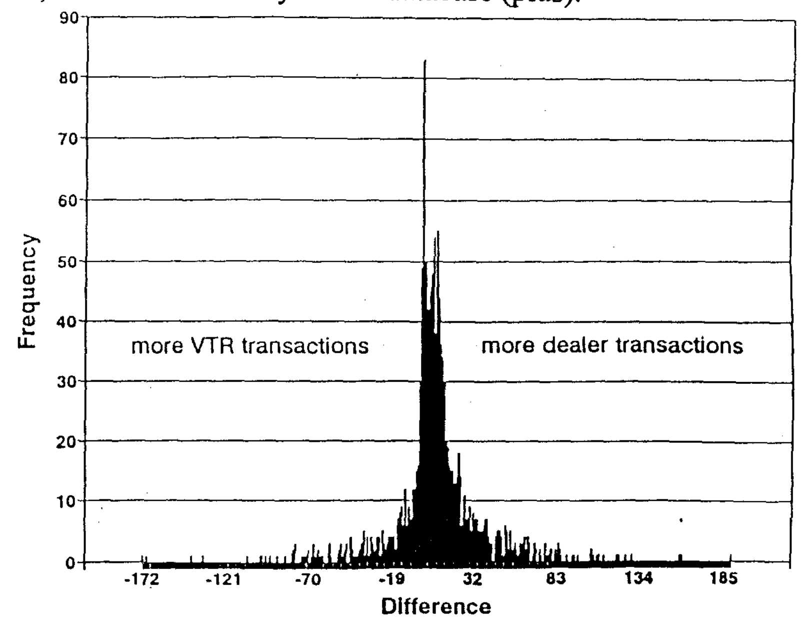

Figure A6. Frequency distribution of the difference between the number of transactions in the mandatory dealer data and the vessel trip report data for unique vessel permit numbers.

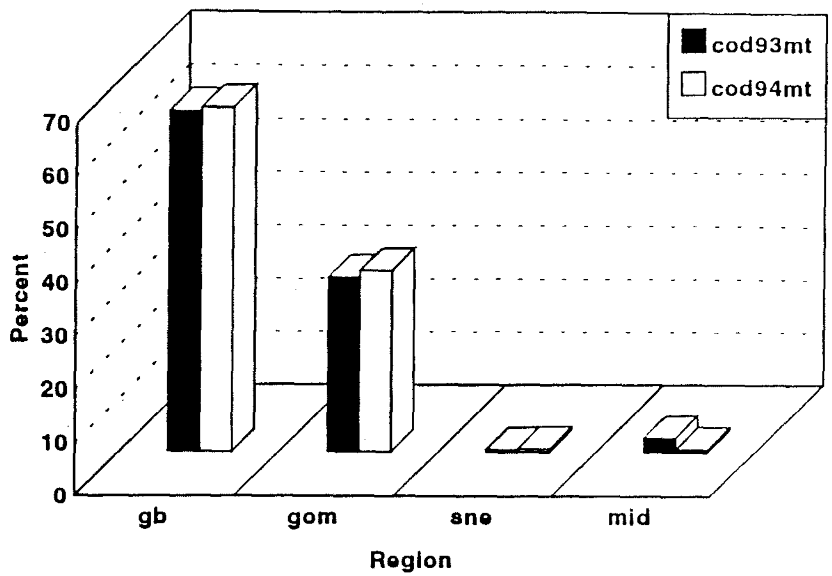

Figure A7. Percentage otter trawl landings of cod by stock area from 1993 commercial weighout data and 1994 logbook records.

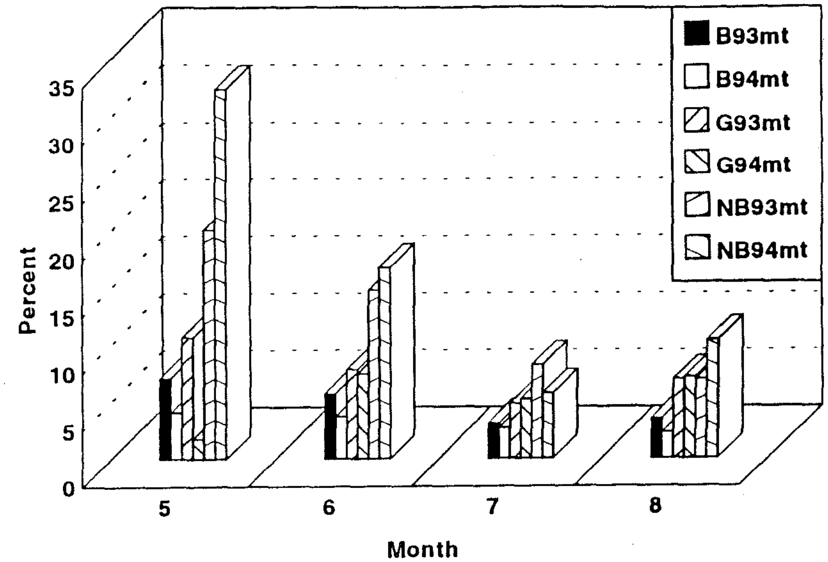

Figure A9. Percentage otter trawl landings of cod by month (May-August) and port (Boston, Gloucester, New Bedford) from 1993 commercial weighout data and 1994 logbook records.

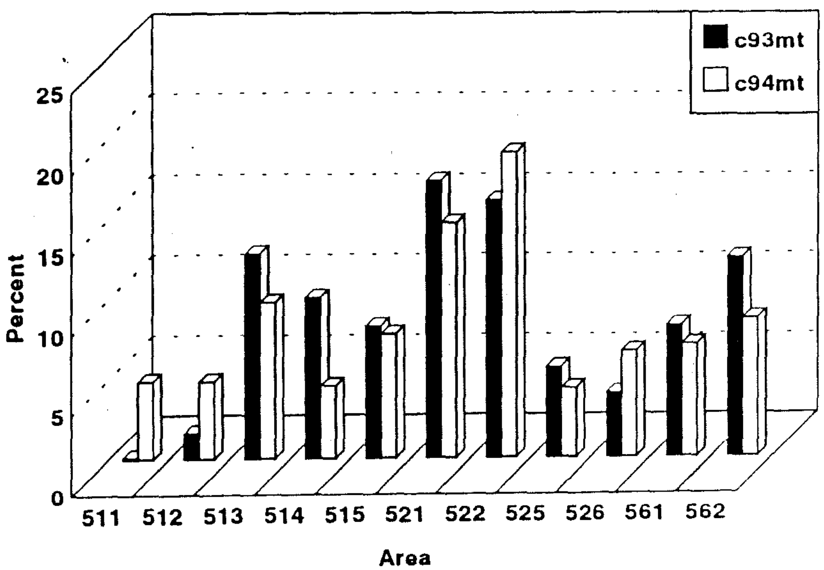

Figure A8. Percentage otter trawl landings of cod by statistical area from 1993 commercial weighout data and 1994 logbook records.

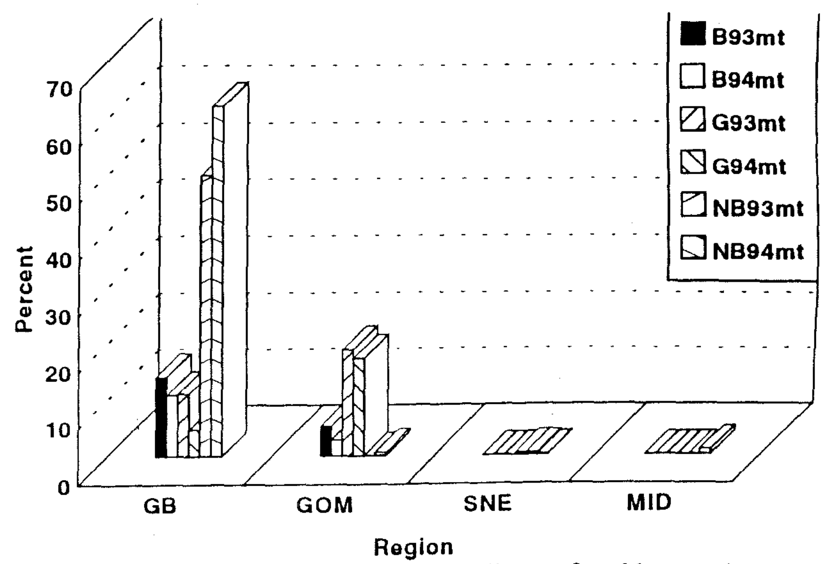

Figure A10. Percentage otter trawl landings of cod by stock area and port (Boston, Gloucester, New Bedford) from 1993 commercial weighout data and 1994 logbook records.

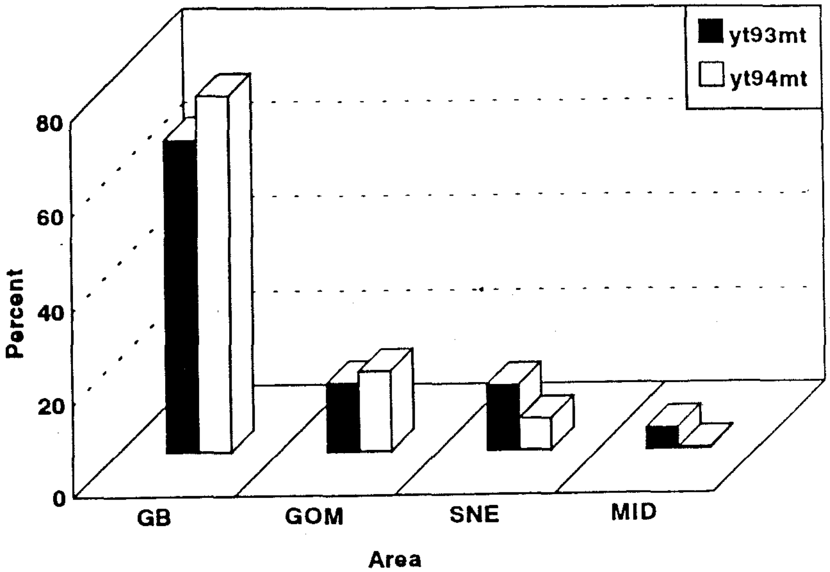

Figure A11. Percentage otter trawl landings of yellowtail flounder by stock area from 1993 commercial weighout data and 1994 logbook records.

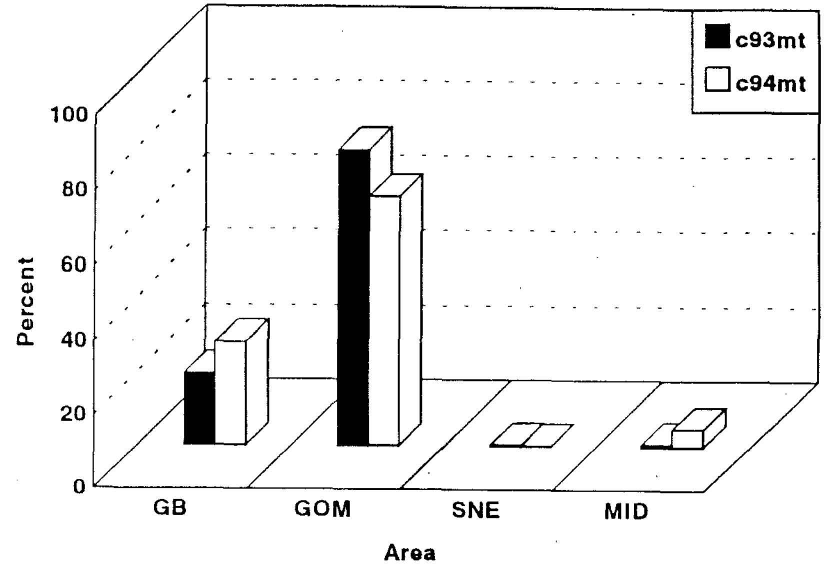

Figure A13. Percentage sink gillnet landings of cod by stock area from 1993 commercial weighout data and 1994 logbook records.

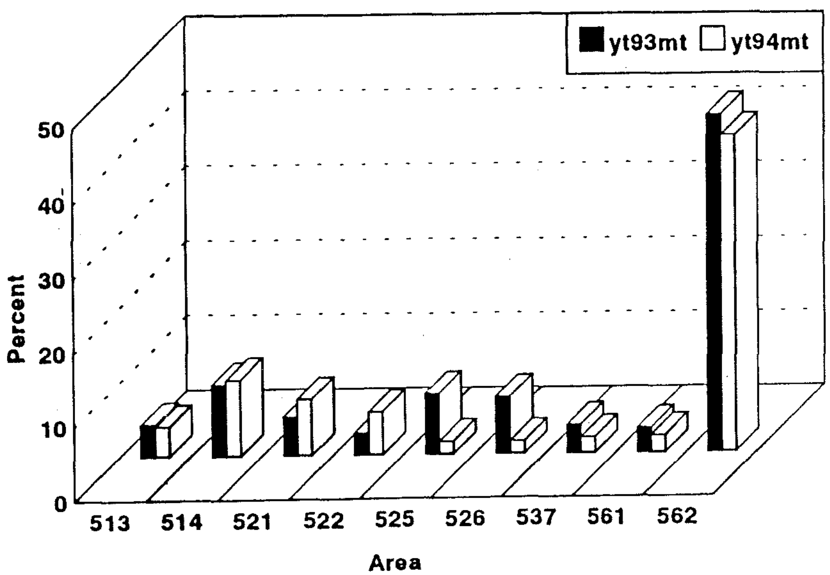

Figure A12. Percentage otter trawl landings of yellowtail flounder by statistical area from 1993 commercial weighout data and 1994 logbook records.

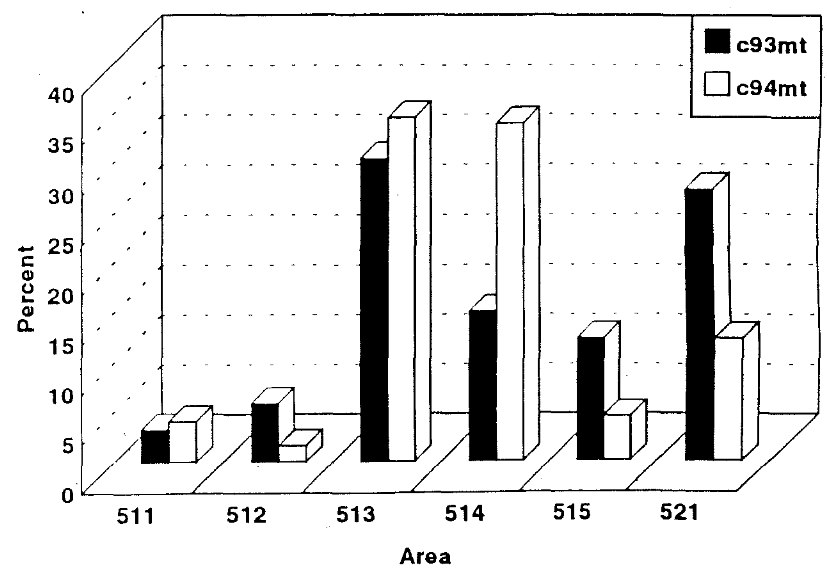

Figure A14. Percentage sink gillnet landings of cod by statistical area from 1993 commercial weighout data and 1994 logbook records.

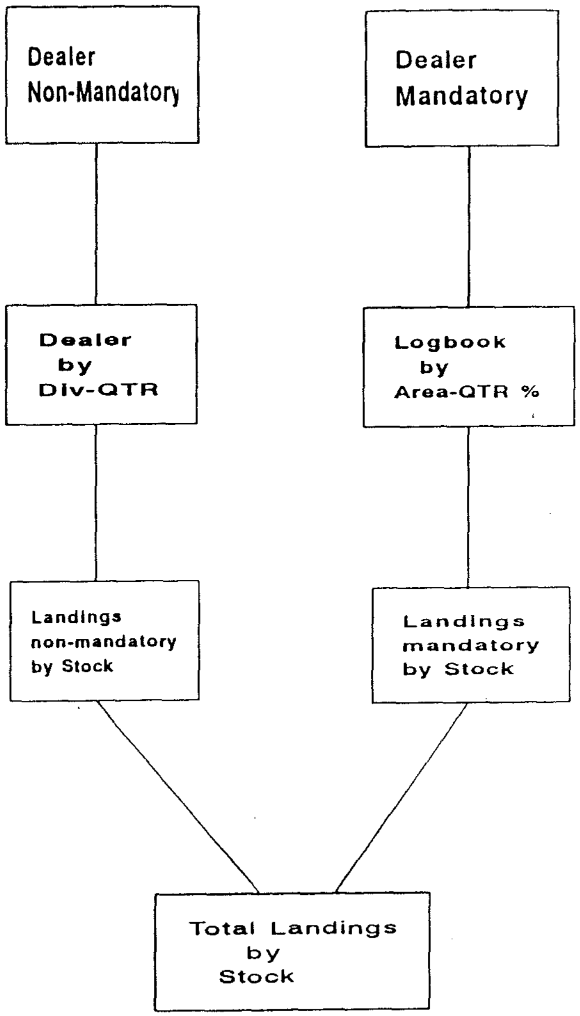

Figure A15. Flow diagram of two-step process followed in the example proration of 1994 cod landings using the 1994 mandatory and non-mandatory dealer records and 1994 logbook records.

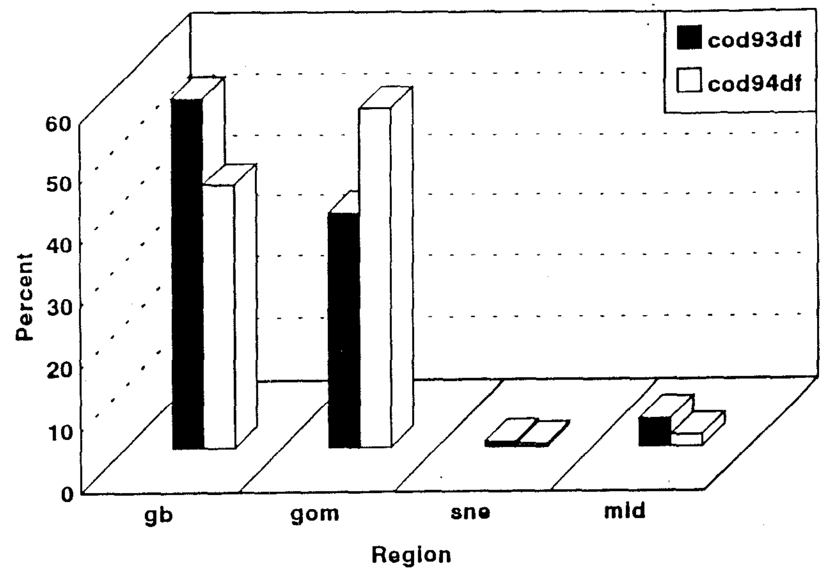

Figure A16. Percentage otter trawl days fished of cod by stock area from 1993 commercial weighout data and 1994 logbook records.

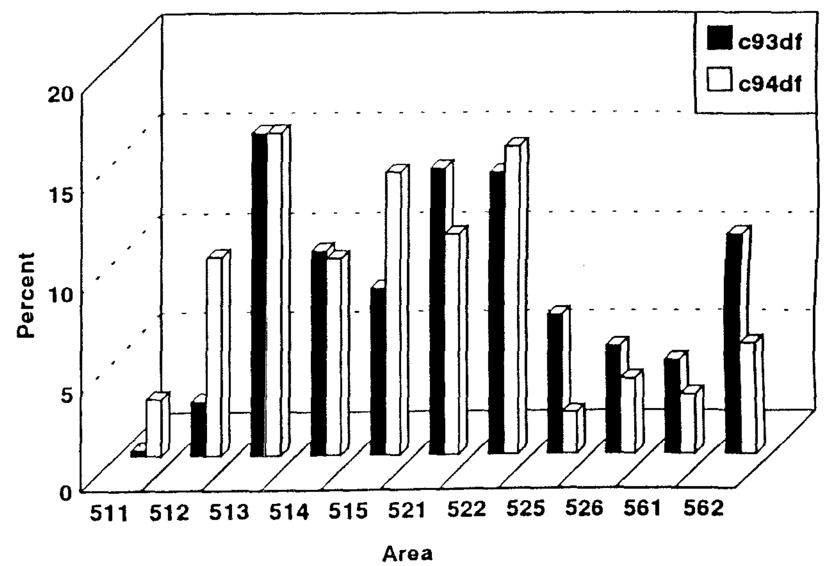

Figure A17. Percentage otter trawl days fished of cod by statistical area from 1993 commercial weighout data and 1994 logbook records.

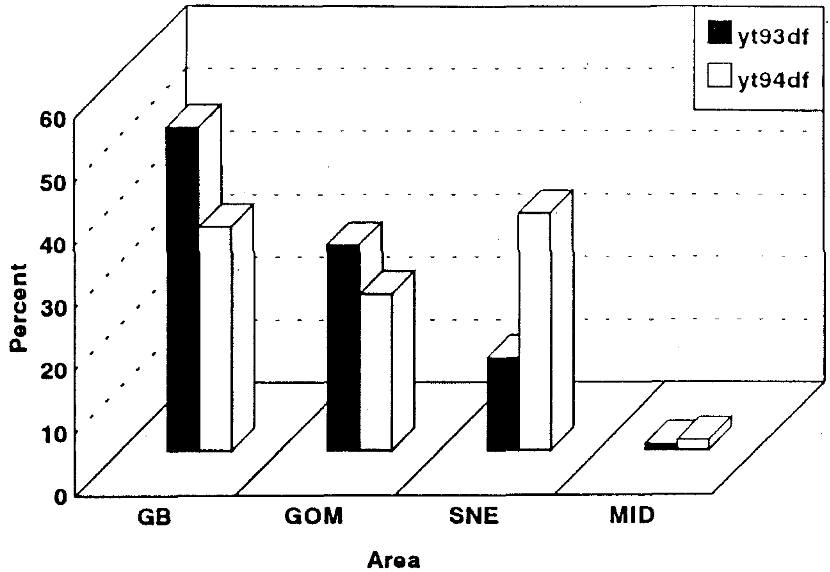

Figure A18. Percentage of otter trawl days fished of yellowtail flounder by stock area from 1993 commercial weighout data and 1994 logbook records.

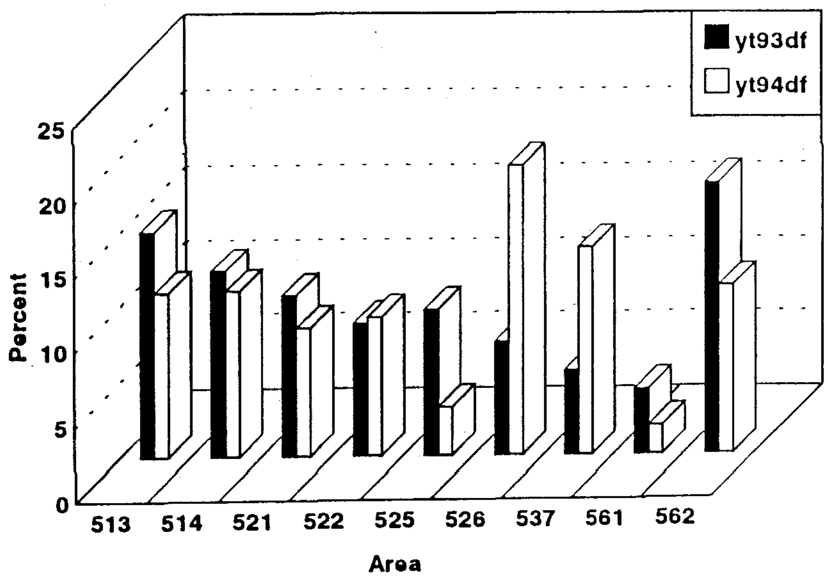

Figure A19. Percentage of otter trawl days fished of yellowtail flounder by statistical area from 1993 commercial weighout data and 1994 logbook records.

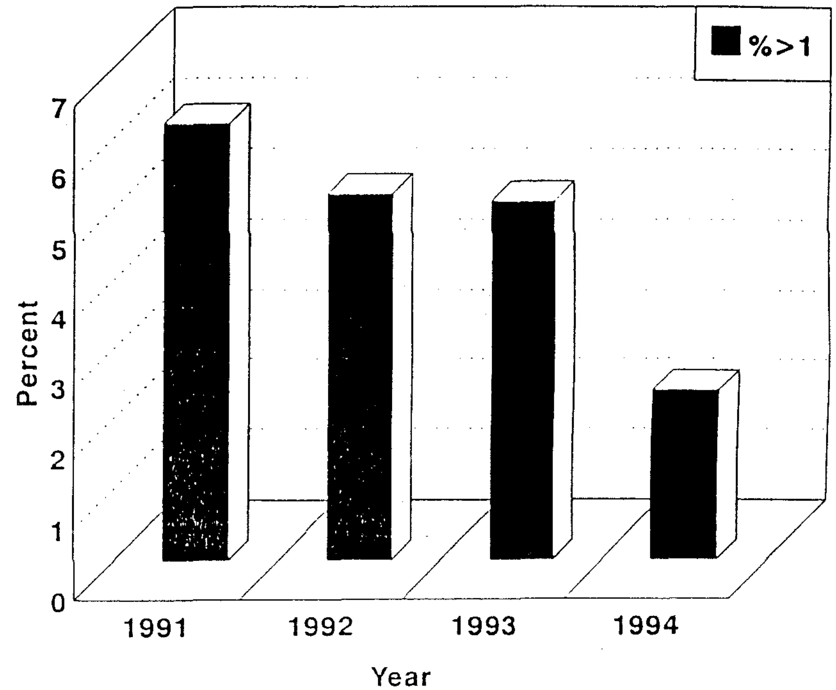

Figure A20. Number of subtrips from interviewed otter trawl trips greater than one day in duration for 1991-1993 and 1994 logbook records.

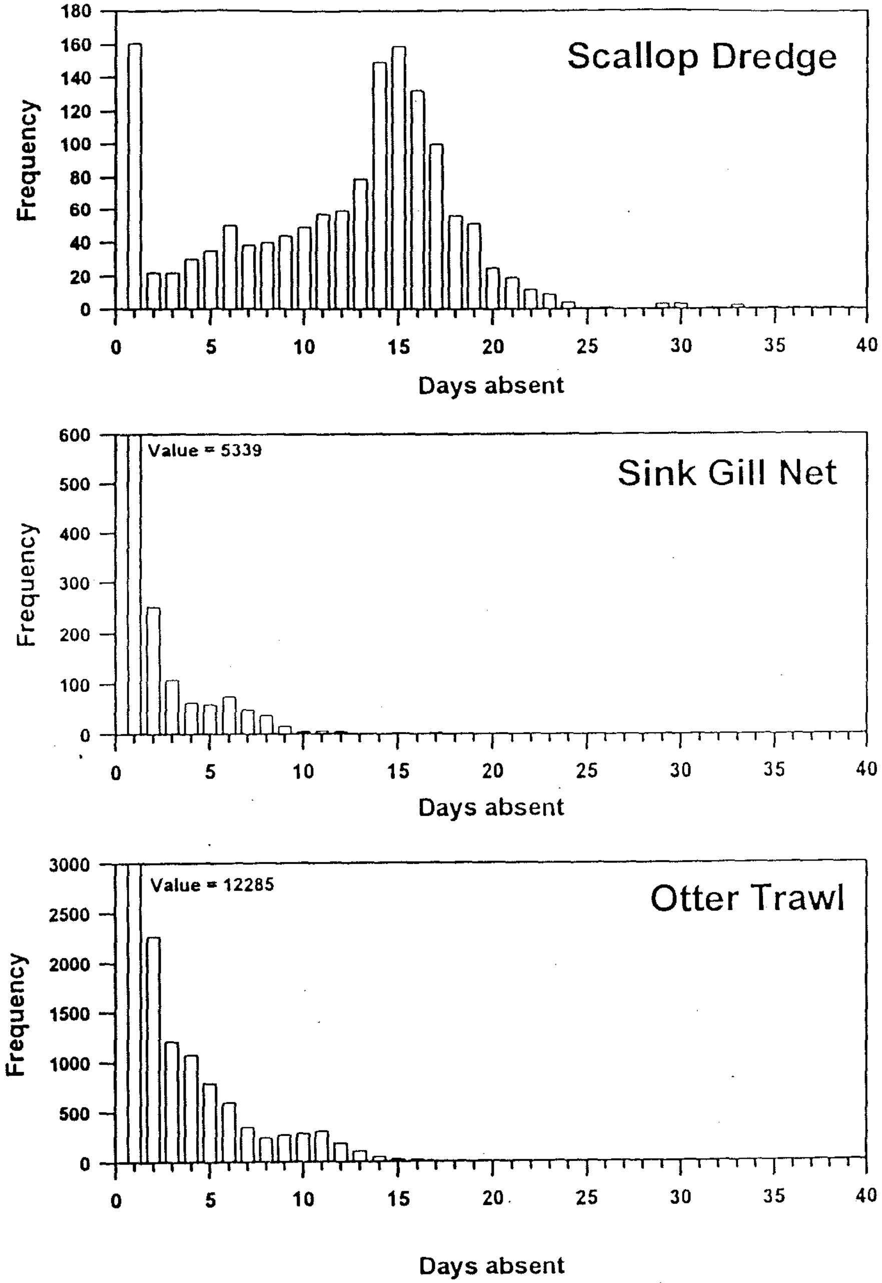

Figure A21. Frequency distribution of days absent from the 1994 logbook data.

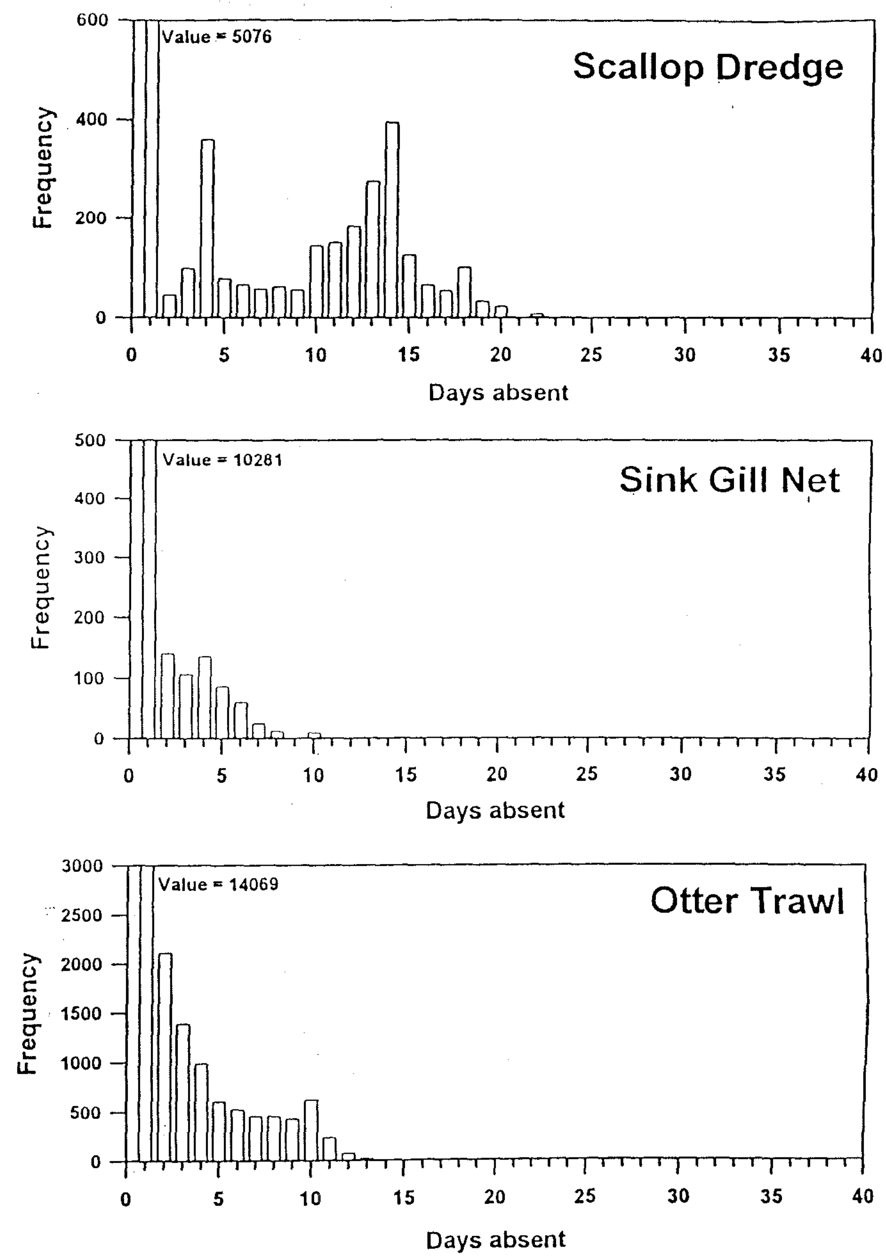

Figure A22. Frequency distribution of days absent from the 1993 weighout data where the number of trips ≥1, from June- December.

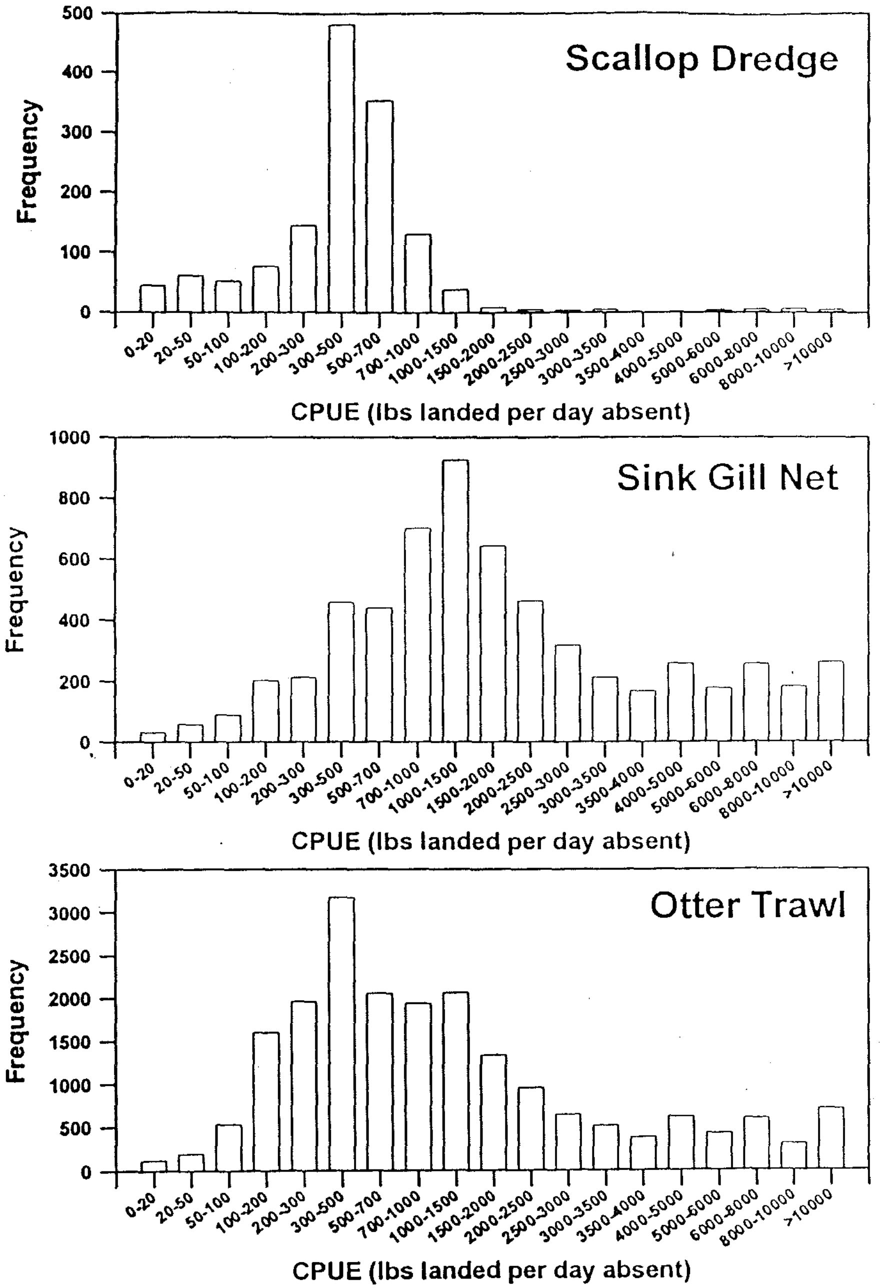

Figure A23. Frequency distribution of CPUE (in lbs per day absent) from the 1994 logbook data.

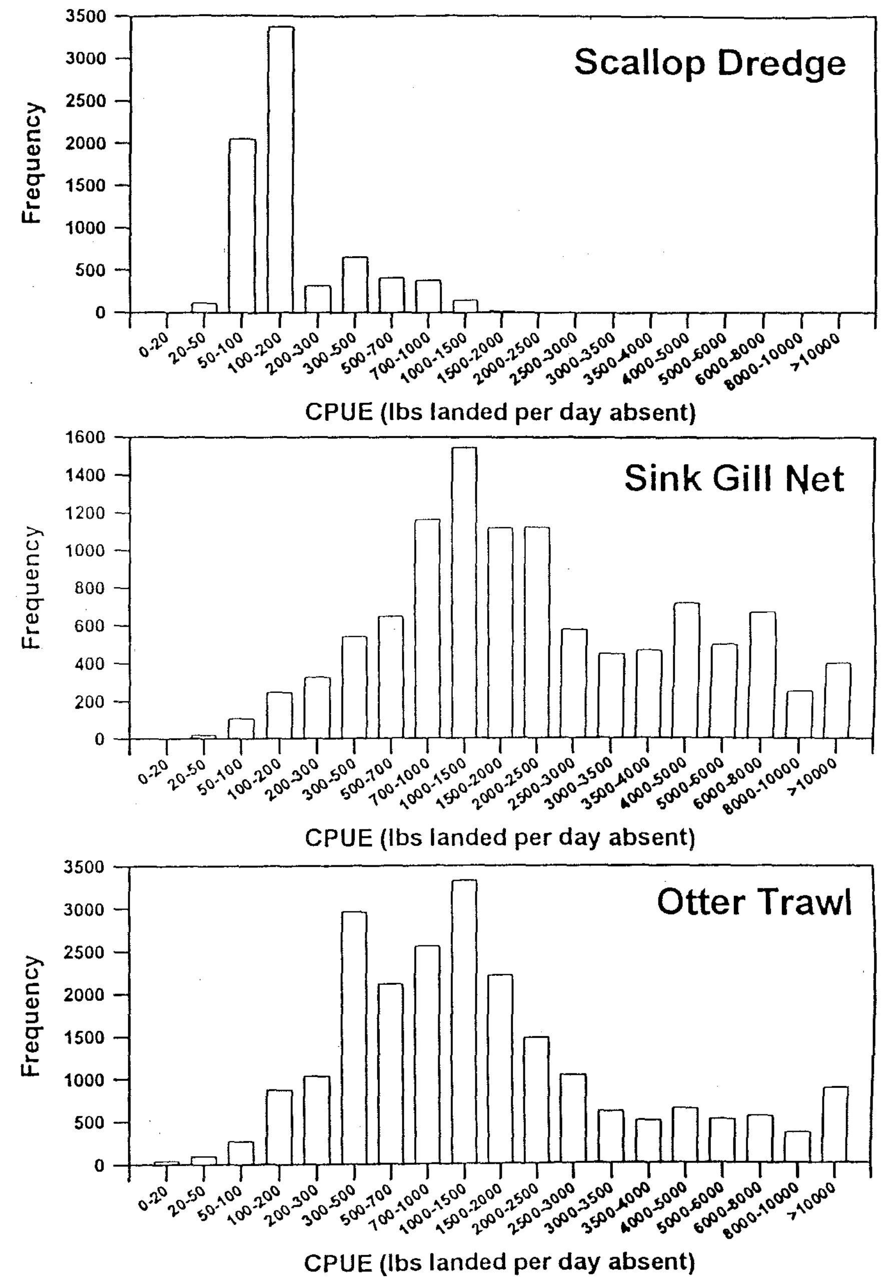

Figure A24. Frequency distribution of CPUE (in lbs per day absent) from the 1993 weighout data, June-December.

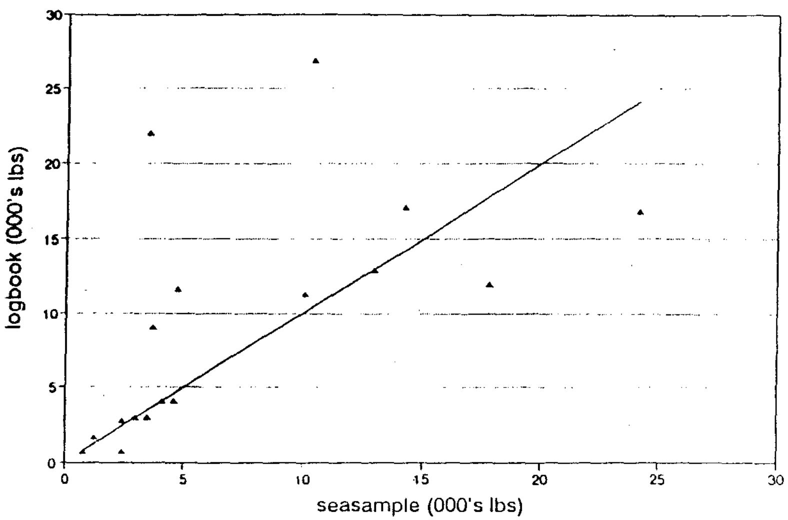

Figure A25. Otter trawl landed pounds of all species from matched sea sample and logbook trips.

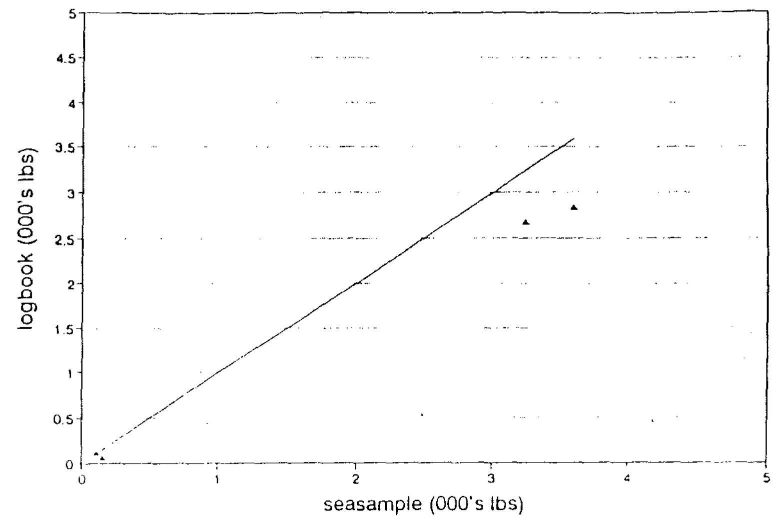

Figure A27. Otter trawl landed pounds of Atlantic cod from matched sea sample and logbook trips.

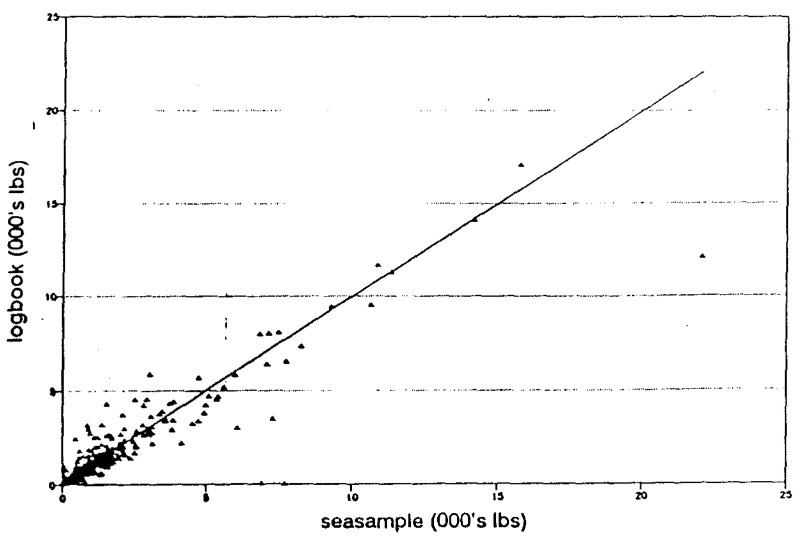

Figure A26. Sink gillnet landed pounds of all species from matched sea sample and logbook trips.

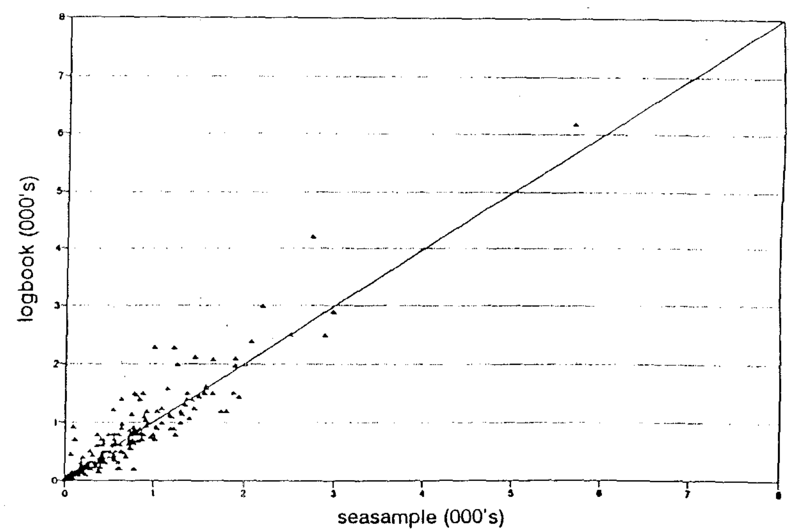

Figure A28. Sink gillnet landed pounds of Atlantic cod from matched sea sample and logbook trips.

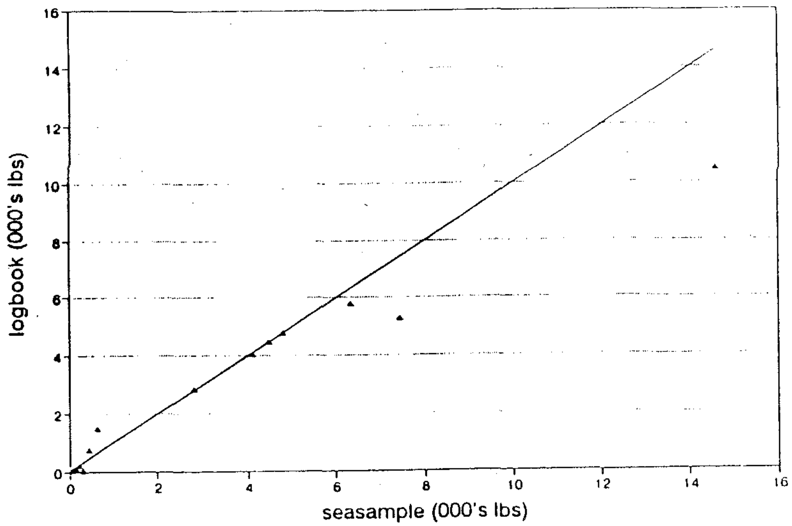

Figure A29. Otter trawl landed pounds of all flounders from matched sea sample and logbook trips.

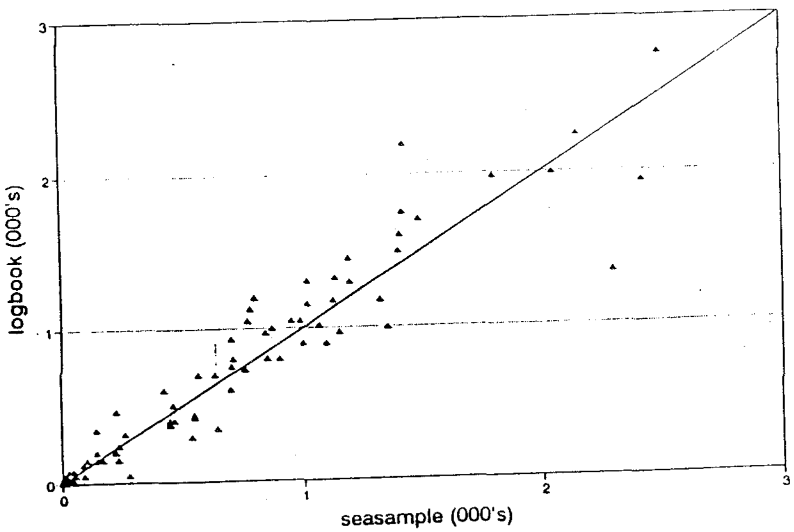

Figure A30. Sink gillnet landed pounds of all flounders from matched sea sample and logbook trips.

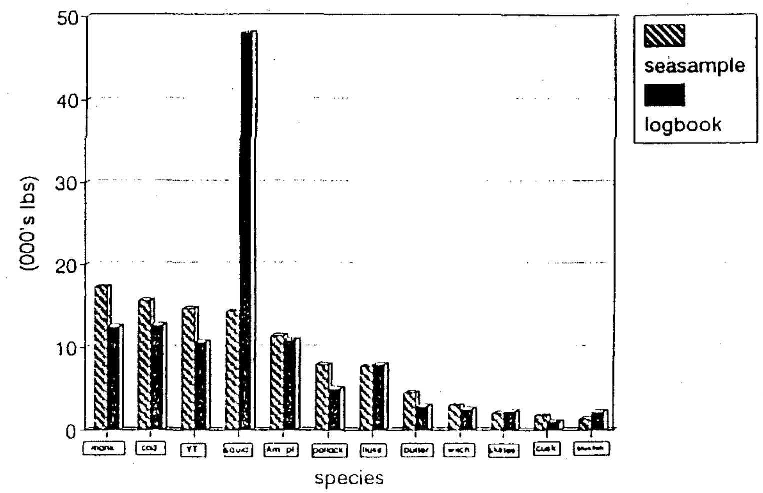

Figure A31. Otter trawl landed pounds for the highest ranked species from matched sea sample and logbook trips.

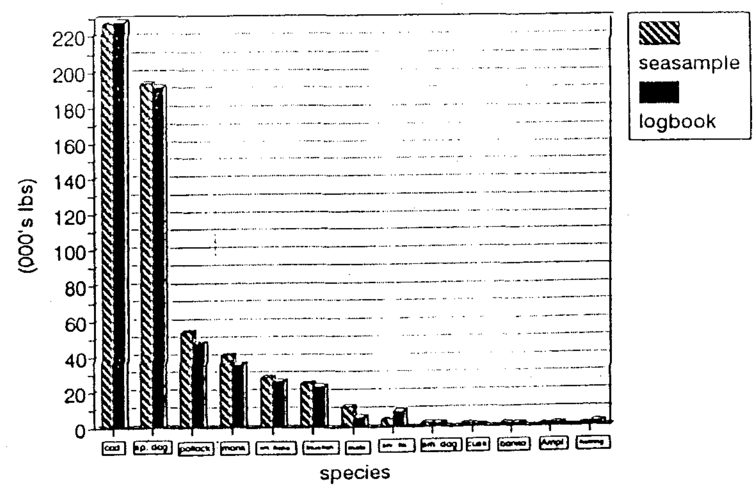

Figure A32. Sink gillnet landed pounds for the highest ranked species from matched sea sample and logbook trips.

B. AMERICAN LOBSTER

Terms of Reference

The following terms of reference were addressed:

a. Review biological bases of stock definitions and define appropriate assessment areas.

b. Estimate abundance and mortality rates by sex and stock and quantify their precision.

c. Evaluate quantitative indicators of exploitation rates and stock status from research survey, commercial fishery and sea sampling databases, and other relevant information.

d. Address the recommendations of the Lobster Review Panel reviewing overfishing definitions for American lobster, and implement if possible.

e. Present the Subcommittee's general views on the Lobster Review Panel draft report, consider and incorporate to the extent possible the Panel's recommendations which pertain to the first three terms of reference particularly with respect to sensitivity analyses, and provide a prioritized research plan for addressing all of the Panel's recommendations.

Introduction

The American lobster (*Homarus americanus*) supports the most valuable single species commercial fishery in the Northeast United States (Current Fisheries Statistics No. 9400). Fishing effort is intense throughout the range of the species and previous stock assessments have warned that the stock is overfished and vulnerable to collapse. The basis for these predictions rests on empirical estimates of high exploitation rates (NEFSC, 1993) using a modified DeLury model and length cohort analysis (Jones 1974), and theoretical analyses of expected lifetime egg production (Fogarty and Idoine 1988). The latter model can be used to define a biological reference point expressed as a fishing mortality rate that results in a fixed percentage of the maximum lifetime egg production (or maximum spawning potential, MSP). Data sufficient to define an exact percentage of MSP for U.S. stocks are sparse, but analogy with other lobster and crustacean species suggests an MSP percentage of 10% as risk averse. The results of SAW-16 initiated the development of management measures to reduce fishing effort. Landings, however, have continued a steady two-decade increase. Maximum recorded landings were attained in 1994, suggesting an apparent contradiction to the warnings of fishery scientists. Early in 1996, a panel (Lobster Review Panel) of internationally-renowned scientists was convened to examine the scientific basis of overfishing definition and review the assessment methodology. A final report was not available at the time of the assessment, although a draft of the report endorsed the general methodologies for assessment and definition of overfishing.

This report represents a continuation of the assessment approaches begun at SAW-16 and complements the report of the Lobster Review Panel. Since 1993, a substantial amount of fishery-dependent and fishery-independent data have been assembled to improve the empirical basis for the assessment. A description of the available data is provided, and a significant fraction of these datasets were synthesized in this assessment. The methodology for estimation of catch in numbers and weight by stock area and sex is thoroughly documented. The integration of state and Federal databases is now sufficiently general to allow redefinition of stock boundaries if desired for future assessments. Moreover, the limitations of the historical databases and, therefore, the types of models that can be applied are defined. Male lobsters are assessed for the first time and the spatial and temporal heterogeneity of the biological characteristics of the landings is addressed. In addition to the DeLury and LCA models for mortality estimation, several indirect measures of fishing mortality trends are analyzed.

An attempt was made to incorporate the recommendations of the Lobster Review Panel to the extent possible. In particular, the EPR model was updated to account for early maturation by sublegal lobsters and improved by reducing the time step to three months. This change allows substantially more biological realism in the timing of population processes and greater fidelity to the seasonal aspects of the commercial fishery by region.

A synopsis of the actions completed on each of the above terms of reference is given in Table B1.

Stock Definitions

The American lobster is distributed in the Northwest Atlantic from Labrador to Cape Hatteras and from coastal regions out to depths of 700 m (Fogarty *et al.* 1982). Lobsters are locally abundant in coastal regions within the Gulf of Maine and off Southern New England and less abundant in more southerly areas. Coastal lobsters are concentrated in rocky areas where shelter is readily available, although occasional high densities occur in mud and other substrates suitable for burrowing. Offshore populations are most abundant in the vicinity of submarine canyons along the continental shelf edge. Tagging experiments in coastal waters suggest that small lobsters undertake rather limited movement with some evidence (Anthony and Caddy 1980) that larger individuals may travel extensively. In contrast, offshore lobsters show well-defined shoalward migrations during the spring, regularly traveling 80 km (50 mi), with a few traveling as much as 300 km (186 mi). Lateral movements along the edge of the Continental Shelf have been demonstrated as well (Uzmann *et al.* 1977).

At SAW-16, the lobster population was stratified into three separate regions corresponding roughly to known differences in biological attributes of the resource. The regional boundaries are depicted in Figure B1. The biological rationale for the stock boundaries is described in the SAW-16 report and is not repeated here. Stocks are, to varying degrees, linked by seasonal migrations of adult lobsters and transport of larvae among regions. The theoretical implications of larval exchange among spatial units for maintenance of population stability has recently been addressed by Fogarty (in press). The practical aspects of assessing the lobster resource as a set of linked populations are imposing, particularly without quantification of larval fluxes among regions.

A general summary of the statistical areas and NMFS trawl survey strata used to define the operational stock boundaries is in Table B2. For this assessment, the boundaries defined in SAW-16 were modified by placing all the landings from Statistical Area 537 into the Georges Bank and South (GBS) stock. This change was predicated by the absence of sufficient biological samples to accurately partition landings in Area 537 at 41° N latitude. The SARC speculated that the population on Cox's Ledge and off Nomans Land was more representative of the South of Cape Cod to Long Island Sound (SCCLIS) stock than the Georges Bank and South stock, but historical information to partition the catches accordingly was considered deficient. The potential consequences of this to the SCCLIS and GBS stocks were considered negligible.

Following the recommendation of the Lobster Review Panel, the dynamics of lobster in Central and Western Long Island Sound were examined. This region is a subset of Statistical Area 611 and excludes Eastern Long Island Sound and Block Island Sound. Catches for this region were summarized by NY and CT state biologists, and biological parameters for this region were derived from published and unpublished data sources.

Description of the Fishery

Management

The lobster fishery is currently managed in EEZ waters under the New England Fishery Management Council's Lobster FMP (NEFMC 1991), and within territorial waters under various states' regulations. The primary regulatory measures used throughout the range are minimum carapace length and ovigerous female protection. Other regulations apply in specific states. Maine does not allow the landing of lobsters with carapace lengths exceeding 5 in (127 mm) or lobsters with clearly defined V-notches.

Catch Estimation

Estimation of the weight and number of lobsters landed requires inclusion of many databases of landings and biological samples. The lobster fisheries are intensive, seasonal and spatially diverse; to realistically model these fisheries, quarterly landings by stock area must be estimated. The purpose of this section is to describe, for the first time, the steps required in the assessment. Necessary assumptions are described in detail and intermediate tables are presented. These details are necessary to ensure repeatability of the assessment in the future and to allow testing of alternative assumptions, if desired. A comprehensive summary of the available databases is found in Rago *et al.* (1996) which describes each sampling program, the status of relevant databases, and duration and frequency of sampling.

Existing data were assembled into an integrated Federal-state database. In view of the multiple data sources and the diverse data collection and sampling procedures, the details of the catch estimation process are described here and in Rago *et al.* (1996). Extensive documentation of the catch estimation process was considered essential for interpretation of the current assessment, repeatability in future assessments, and revisions of the assessment at future SARCs. The general steps for estimation of catch in numbers and weight by sex and survey year are as follows:

1. Use the NMFS general canvass database to estimate total landings (weight) in year Y, state S, and statistical area A, i.e., $L_C(Y,S,A)$. The canvass attempts to record all landings within a state, irrespective of their seasonal timing and 3-digit NAFO statistical area. Estimation procedures differ considerably by state, resulting in widely varying levels of temporal and spatial resolution. Moreover, many state sampling programs have changed and improved over time. The general increase in reliability over time permits the imputation of historical landings patterns in years when sampling programs were less accurate. In some years, a proportion of state landings was not allocated to a specific statistical area. In such instances, unallocated landings were redistributed to statistical areas based on historical landings patterns or advice from state or Federal biologists familiar with the fisheries. Each state was considered separately, and the NMFS canvass data were revised according to the best available information. The details of this reallocation are provided in Rago *et al.* (1996) in a set of three tables for each state. The first table summarizes the general canvass as it exists in the NMFS database. The second table describes the decision rules applied to reallocate the catch, and the third table defines the reallocated landings. Shading was used to highlight the values that were changed. For all states except NY and CT, the total landings by state were unchanged by this reallocation process.

Landings data in NY and CT are recorded in the NMFS database as landings at state ports. Thus CT fishermen can land their catch in NY and vice versa. Both NY and CT, however, record landings by resident fishermen. Thus CT records landings of all CT resident fishermen irrespective of the landing state. A logbook system is mandatory in CT. NY records its landings using an annual recall procedure in which fishermen are required to report their landings from the previous year on their current license applications. The sum of the annual recalls by NY resident fishermen is used to define the total annual catch.

Differences between the state and NMFS general canvass procedures are significant when examined on a state and year basis. In some instances, the differences could be attributed to a lack of updating of the general canvass database over the historical period. Following considerable debate, all of the differences between the collection procedures could not be reconciled. However, the differences are important for the assessment only to the extent in which the landings with the stock assessment area are affected. When the CT and NY landings data were pooled, the discrepancies between the two estimates diminished so that the differences were less than 7%. For the purposes of this assessment, landings reported by NY and CT were used. These data were used for the Central and Western Long Island Sound (CWLIS) and the South of Cape Cod to Long Island Sound (SCC-LIS) assessment areas. The period of coverage for the state-based estimates was 1982-1994. Beginning in 1994, the NMFS general canvass directly incorporated the NY resident recall estimates.

2. Use the NMFS weighout database to estimate the pattern of landings in calendar year Y, month M, and

Statistical Area A, i.e., $L_W(Y,M,A)$. Landings in the weighout database are a subset of the canvass database; the primary difference is the inclusion of detailed temporal (by month) and spatial (10-minute to quarter-degree square resolution). The monthly data were used to compute quarterly proportions by statistical area, $P_W(Y,Q,A)$.

3. Define stock and substock regions R as the set of one or more statistical areas. The substock designations used in this assessment are summarized in Table B2.

4. Compute the total quarterly landings as the product of the canvass totals $L_C(Y,S,A)$ and the monthly proportions from the weighout database $P_W(Y,M,A)$. The regional stock landings $L_R(Y,Q,R)$ were computed as follows:

$$L_R(Y,Q,R) = \sum_{A \in R} \sum_{S} L_C(Y,S,A) \sum_{M \in Q} P_W(Y,M,R) \qquad (1)$$

where the notation A∈R is read as the "Statistical Areas within region R", and M∈Q is read as the "months within quarter Q".

5. The estimation of total landings in numbers by sex requires the inclusion of biological samples from many different sources. For this assessment, biological samples were taken from port samples and sea sampling trips. A complete listing of the available biological samples is summarized in Rago *et al.* (1996). The estimated landings in number by sex were estimated by first dividing the landings by sex based on the total sampled weight of male and female lobsters. To ease readability, the subscripts for year, quarter, and region were dropped from the following equations. Let S_M and S_F denote the total sample weights for males and females, respectively, derived from samples of size n_M and n_F. The sample weights were either estimated directly by weighing the sampled lobsters (e.g., Maine port sampling) or imputed from the carapace length-weight relationship (NMFS port samples). The estimated weights of male and female lobsters were computed as:

$$\begin{aligned} L_M &= L \frac{S_M}{S_M + S_F} \\ L_F &= L \frac{S_F}{S_M + S_F} \end{aligned} \qquad (2)$$

The total numbers of male and female lobsters caught is estimated as the landings divided by the mean weight in the sample. Thus :

$$\begin{aligned} N_M &= \frac{L_M}{\left(\frac{S_M}{n_M}\right)} \\ N_F &= \frac{L_F}{\left(\frac{S_F}{n_F}\right)} \end{aligned} \qquad (3)$$

The number of male and female lobsters at carapace length (cl) is assumed to be proportional to the length frequency in the sample. Thus:

$$\begin{aligned} N_M(cl) &= N_M \left(\frac{n_M(cl)}{n_M}\right) \\ N_F(cl) &= N_F \left(\frac{n_F(cl)}{n_F}\right) \end{aligned} \qquad (4)$$

where n_M(cl) and n_F(cl) are the sample frequencies of male and female lobsters of length (cl), respectively.

6. Landings in number and weight were converted to survey year (i) by defining the fourth calendar quarter in year (i) as quarter 1, and quarters 1, 2, and 3 in calendar year (i+1) as survey quarters 2, 3, and 4, respectively in survey year (i).

7. Examination of average lengths of biological samples suggested a spatial gradient of average size of landed lobsters. Largest lobsters were generally landed on the northern and eastern edges of Georges Bank and gradually diminished in size with statistical areas to the west and south. Regional estimates of catch were based on the sum of estimates for sub-

areas. Subareas were defined on the smallest spatial unit possible given the biological sampling data available.

Overview of Catches

Total landings by state are summarized in Table B3 and Figure B2. Total landings were relatively constant at 14,000 mt through the late 1970s. Since then, landings have doubled, reaching a peak of nearly 32,000 mt in 1994. Landings in Maine constitute about half of the total, with about 25% occurring in Massachusetts. Over the last decade, the relative proportions of landings among states have been relatively constant. New York and Connecticut landings have comprised an increasing share of the total in recent years, but collectively represent about 8% of the total.

Total landings by stock area are summarized in Table B4 and Figure B3. On a relative basis, landings in the SCCLIS assessment area have increased faster than other areas, with increases commencing in about 1982.

Overall, the fishery remains dominated by landings from traps (Table B5). Since 1981, the percentage of total landings from traps has not fallen below 97%.

Fishing Effort

Changes in the fundamental operating characteristics of the lobster fishery have been documented during the last several decades. These changes include dramatic increases in the number of traps being fished, the areal extent of the fishery, a switch from wood to wire traps, increases in trap size, and increases in soak time. Each of these factors affect catch rates and overall levels of catch in the fishery.

Estimates of the total number of traps, the proportion of wire traps, and the proportion of double parlor traps for the period 1967-1995 are presented in the upper panel of Figure B4; the mean number of traps per boat is provided in the lower panel. The number of traps fished more than quadrupled during this period. Within the last two decades, a nearly complete change from wood to wire traps has been documented. Wire traps have been shown to have substantially increased fishing power relative to wood traps (J. Krouse, Maine Dept. Mar. Resources, pers. comm.). A sharp increase in the proportion of double parlor traps to nearly 50% has been noted in the last decade. Double parlor traps reduce saturation effects and exhibit higher overall catch rates. Increases in escape vent openings have also enhanced trap efficiency by increasing the ratio of legal lobsters in the catch and reducing the number of culls.

Catch rates (number per trap haul) in the Maine fishery have increased with increasing proportion of wire traps in the fishery (Figure B5), suggesting that increases in the performance of the fishery can be related to changes in gear type. Time trends in CPUE and the proportion of wire traps must be considered in this analysis and changes in abundance may also underlie changes in CPUE.

The estimated annual number of trap hauls in the Maine fishery has increased slightly during the last three decades (Figure B6). However, the mean soak time has nearly doubled during this period and the estimated fishing effort expressed as trap-haul-set-over-days has increased by a factor of two, indicating a fundamental change in fishing strategies in the recent history of the fishery.

Similar changes in the Massachusetts lobster fishery have also been documented with substantial increases in the number of traps fished since the 1960s (B. Estrella, Massachusetts Div. Mar. Fish,. pers. comm.). Shifts in the proportion of wire gear in the fishery have also been demonstrated for Massachusetts (Figure B7) with a nearly complete change (from less than 5% in 1981 to over 70% in 1994) from wood to wire traps. The proportion of the landings from offshore grounds more than doubled during the period 1980-1994.

Monthly patterns in effort (number of trap hauls) and landings for the Rhode Island fishery are depicted in Figure B8 for both the inshore and offshore components of the fishery since 1991. A general increase in effort in both segments of the fishery is evident. Catch per unit effort increased in the inshore fishery (presumably due, in part, to changes in gear types as in Maine and Massachusetts). However, CPUE in the offshore fishery declined during this period.

Monthly effort statistics for the Connecticut fishery derived from logbook data indicated a sharp increase in the number of traps per individual fisherman, the number of trap hauls for the fishery, average soak time, and total effort expressed as trap-haul-set-over-days (Figure B9). The mean number of traps per fisherman in New York tripled during the period 1982-1994 (Figure B10).

Overall trends in technological changes are difficult to quantify for the fishing industry as a whole. Technological advances in marine electronics (color depth finders, GPS, and LORAN, in particular), hydraulic pot haulers, and larger, faster boats have allowed fishermen not only to expand their fishing areas (now exploiting regions farther from shore which previously received little or no fishing pressure), but to fish more traps and to fish those traps more effectively. Color flashers enable fishermen to locate productive lobster habitat and, if desired, navigational instrumentation such as GPS and LORAN will allow easy relocation of those areas. Unfortunately, synoptic databases for the entire fishery do not exist. Historical state and Federal databases do not include records on a sufficiently fine scale to quantify many of these changes in effort. For example, the finest resolution possible for movement of the fishery to offshore areas would be on the order of 10-minute square at best. It would be worthwhile to quantify historical changes in fishing strategy by interviewing individual or groups of fishermen.

Collectively, these observations on the structural features of the lobster fishery indicate an increase in fishing pressure on the resource mediated through technological changes (gear technology) which have occurred gradually but consistently throughout the last three decades and have important implications for the fishing mortality rates exerted on the resource.

Stock Abundance and Biomass Indices

Research Vessel Trawl Survey Indices

Indices of relative stock abundance were computed from various trawl survey time series developed by NEFSC and the states of Massachusetts, Rhode Island, and Connecticut. These data were used both as relative indices of stock abundance and as tuning indices for the DeLury population models. Indices were developed for two size categories: 1) fully-recruited individuals (≥81 mm carapace prior to 1988, ≥82 mm CL in 1988, and ≥83 mm CL in 1988-1995), and 2) pre-recruits. Pre-recruits were defined as the molt group likely to become legal size during the 12-month period between successive surveys. The following mean growth increments were used to define the size classes for the Gulf of Maine and South of Cape Cod to Long Island Sound stocks:

	Pre-recruits mm below legal size	
Stock area	Males	Females
Gulf of Maine	11 mm	11 mm
S.Cape Cod to LIS	13 mm	10 mm

For the Georges Bank and South stock, growth increment probabilities were used to define the size classes. The distributions for males and females can be summarized as follows:

	Range of assumed molt increment (mm)		
	Max.	Median	Min.
Males	27	17	8
Females	20	14	7

Gulf of Maine assessment area:

Indices of relative abundance for lobsters in the Gulf of Maine assessment area were available from two sources, the NEFSC bottom trawl survey and the State of Massachusetts bottom trawl survey. The NEFSC bottom trawl survey series began in 1963; however, methods used for length determinations were inconsistent prior to 1970, and sex determinations for lobsters were not made prior to 1976. The survey is conducted with a roller-rigged, Yankee 36 bottom trawl. Most stations are located in relatively deep waters, owing to the extremely rough bottom conditions in Gulf of Maine nearshore waters. Additional details on the sampling program are found in Rago *et al.* (1996).

The relative abundance of lobsters of both sexes in the NEFSC series increased substantially during 1983-1994 (Table B6; Figures B11 and B12). In 1995, the relative abundance (numbers per tow) of both sexes declined. Biomass indices (weight per tow) of female lobsters also declined in 1995, while male biomass increased slightly. The size-specific indices (Table B6; Figures B13 - B16) show a greater decline in pre-recruit than recruit indices for both males and females in 1995.

The State of Massachusetts has conducted autumn bottom trawl surveys since 1978. The surveys are conducted with a trawl sweep configured with 3.5-in "cookies"; thus it is likely more efficient in sampling lobsters than the NEFSC sampling gear. However, neither sampling gear is particularly effective in sampling hard bottom lobster habitats. Indices used for the Gulf of Maine analyses were estimated from sampling conducted north of Cape Cod.

Abundance indices for both sexes and size groups have fluctuated widely, possibly with an increasing trend (Table B7; Figures B11 - B16). Very high indices, particularly for pre-recruits, were recorded in 1990, but were not reflected in the subsequent fully-recruited index for 1991. All Massachusetts indices (all sizes, pre-recruits, fully-recruited) for both sexes were down in 1995.

Differences in modal size between the NEFSC and Massachusetts surveys (Figures B15 and B16) are probably due to a combination of differences in gear selection and habitats sampled in the two programs. Comparative tow work in Cape Cod Bay showed that the Massachusetts survey had a significantly greater ratio of recruits to fully-recruited lobsters.

Georges Bank and South assessment area:

The only trawl survey time series available for the Georges Bank and South region is the NEFSC bottom trawl survey. The entire region between Georges Bank and Cape Hatteras (except NEFSC offshore stratum 5 in coastal Rhode Island waters) was included in the strata set for analysis of this assessment area. The inclusion of more southern strata results in lower apparent abundance of pre-recruits relative to fully-recruited animals, and has important implications for assessment results for this area.

The abundance of male and female lobsters varied without trend from the mid-1970s through the late 1980s (Table B8; Figures B17 - B20). However, there appears to be a downward trend during the 1990s for pre-recruits and recruits of both sexes. Pre-recruits of both sexes increased slightly in 1995 to levels near their long-term averages.

South of Cape Cod to Long Island Sound assessment area:

Three sets of trawl survey abundance indices are available for the South of Cape Cod to Long Island Sound assessment area. In addition to the NEFSC trawl survey, the states of Rhode Island and Connecticut conduct inshore trawl surveys each year.

Indices derived from the NEFSC inshore trawl survey for this area fluctuate widely (Table B9; Figures B21 and B22). Indices for females do not show a discernable trend during 1976-1995; indices for males appear to have trended downward during the 1990s. In 1995, indices for both sexes and size classes increased (Table B9; Figures B23 and B24).

Rhode Island has conducted a survey since 1979 in Narragansett Bay, Block Island Sound, and Rhode Island Sound. The survey gear is a 3/4-scale, high-rise, bottom trawl equipped with a "cookie" sweep. Abundance indices for lobsters have increased steadily since the early 1980s (Table B10; Figures B21 - B24, B26, and B28). Aggregate indices for both sexes declined somewhat in 1995; however, pre-recruit indices increased in 1995.

The State of Connecticut has conducted a trawl survey in Long Island Sound since 1986. Abundance indices for females have varied relatively little, while the abundance of males, particularly pre-recruits, has increased substantially (Table B11; Figures B21 - B24, B26, and B28). Connecticut trawl survey data for 1995 are not yet available.

The marked increase in the ratio of males to females in Long Island Sound (LIS) may be related to differential depth preferences and reductions in the trawlable habitat owing to presence of fixed fishing gear (Graulich, pers comm). Graulich's finding of decreasing male-female ratios with depth corroborated previous work by Skud and Perkins (1969), Briggs and Zawacki (1974), and Estrella and McKeirnan (1989). Graulich also noted that the deep holes of LIS are very heavily fished and difficult to sample. Additional examination of such interactions would be instructive for both the Connecticut trawl survey and others.

Although the Massachusetts bottom trawl survey extends west of Nantucket, survey catches are generally very small, and thus a reliable index of stock abundance for lobsters cannot be calculated from those data.

Indices of Stock and Fishery Status

High levels of fishing mortality strongly affect the size composition of the stock and can influence the estimation of critical biological parameters. Maximum sizes are difficult to estimate when few individuals survive above the legal size limits, sex ratios may be distorted by management measures designed to protect spawning females, and inferences about migration patterns may be compromised by intensive fisheries near tag release sites. A number of biological indicators can be examined to investigate the indirect effects of fishing on the population structure. Changes over time can be particularly incisive, especially in situations where long-term assessment data are not available.

Two candidate measures were examined: 1) the predicted fraction of total egg production coming from lobsters less than or equal to one molt increment above the minimum size limit; and 2) the observed proportion of small lobsters in the landings. The first measure indicates the population's reliance upon first- or second-time spawners for total egg production. The second measure can indicate a highly intensive fishery, increased recruitment, or some combination of the two processes. Such measures can provide can tangible evidence of potential risks to the population in terms readily comprehended by specialists and non-specialists alike.

Potential egg production (PEP) was assessed by applying length-specific estimates of molting probabilities [$P_{molt}(L)$], proportion ovigerous $P_{ovig}(L)$, and fecundity-size relationships [Fec(L)] to the observed size composition of population during fishery- independent surveys. The general formulation for potential egg production is expressed as:

$$Potential\ Egg\ Production = \sum_{L=1}^{L_\infty} N(L)\ P_{ovig}(L) \left(\frac{1}{P_{molt}(L)}\right) * Fec(L) \qquad (5)$$

The expected proportion contributed by any size range can be found by altering the limits of summa tion in the above equation. The relative contribution coming from lobsters within one molt of the legal size was considered. The above model was applied to observed survey length frequencies in the NMFS Gulf of Maine and Georges Bank surveys and the Massachusetts, Rhode Island, and Connecticut trawl surveys. In the NMFS Gulf of Maine survey, PEP has increased steadily since 1976. About 60% of the current egg production now comes from lobsters less than 94 mm CL (Figure B29). Comparable values for the Massachusetts trawl survey were in excess of 85% since 1983 (Figure B30). A general increase in PEP can also be observed in the Rhode Island trawl survey (Figure B31). Results for the CT survey suggest that nearly all is coming from lobsters near the legal size limit (Figure B32). Estimates of PEP for Georges Bank are vastly lower, and no trends are apparent (Figure B33).

The percent of landings coming from lobsters within one molt increment of the minimum legal size are shown for various stock assessment areas and regions in Figures B34-B39. Proportions were estimated from the derived annual length frequencies (1-mm intervals) and the region-specific estimates of molt increments. In the inshore Gulf of Maine areas (SA 511-513) (ME) (Figure B34), the upward trend since 1974 is constant with female proportions consistently higher than males. Although egged females are afforded protection from harvesting throughout their range, fishing effort is greatest in the months immediately after eggs have been released. Over the last four years, over 90% of the female landings have come from a narrow 11-mm CL size range. Similar patterns have been observed in SA 514 of MA (Figure B35). In the offshore region (SA 515), lobsters are larger, biological samples are less frequent, and the time series of available data is shorter. Nonetheless, approximately 20% of the landings presently come from one-molt increment compared to about 7% before 1985 (Figure B36). In the Georges Bank and South stock area, the fraction within one molt increment has risen from about 60% in the early 1980s to about 85% in the last four years (Figure B37). Fractions are greater for males than females, a result that may be related to the seasonal distribution of fishing effort. In the SCC-LIS and CWLIS areas, the patterns are consistent for both areas and sexes over the entire time series (Figures B38 and B39). Over 90% of the landings come from lobsters within 10-11 mm CL of the minimum legal size. This characterization is consistent with the high levels of fishing mortality derived for this region via length cohort analysis and the modified DeLury model.

Additional analyses of the biological attributes of the catch and survey data appears warranted. Collectively, the analyses of potential egg production and catch composition imply increasing risk to the population by compression of spawning potential into an increasing narrow size range and, by inference, a narrow age range. Landings trends suggest an increasing reliance on newly molted lobsters to support the fishery. These trends are complementary to the observed trends in fishing mortality. Additional measures that should be examined include the frequency of V-notched and cull lobsters and the sex ratio over time. Change-in-ratio estimator may prove insightful in some areas.

Assessment Models

Length Cohort Analysis

Length cohort analysis (LCA) models were used to estimate abundance and mortality for each sex from size composition of landings. Length cohort models are based on Jones' (1974) modification of Pope's (1972) age-based method of cohort analysis. The size frequency distribution of landings is "sliced" into a series of length-based cohorts using a relationship between size and age. The duration of the resulting age cohorts is variable and depends entirely on the functional relation between length and age. The LCA model can be written succinctly as:

$$N_t = N_{t+\Delta t} \, e^{0.8 \, M \, \Delta t} + C_t \, e^{0.2 \, M \, \Delta t} \qquad (6)$$

where N_t is the number alive at the midpoint of age interval t, M is the natural mortality rate, C_t is the catch of individuals whose imputed average age is t, and Δt is the change in age corresponding to a change in length (ΔL) evaluated at length L (see Cadrin and Estrella 1996 for additional details). The results of the LCA are summarized in Table B12 for the three stock areas as well as a subarea consisting of Central and Western Long Island Sound. According to the LCA results, fishing mortality (F) is higher on males than females in all four areas and exceeds 1.0 for both sexes in most areas in recent years.

Two data sets were tested for estimating size composition of Statistical Area 538 landings in the SCC-LIS assessment area. One set included samples from outer Cape Cod where larger lobsters are seasonally present (presumably these are migrants from offshore); the other used only samples from Buzzards Bay. The percentage difference in F for females averaged 5.2%. As would be expected, inclusion of outer Cape Cod samples resulted in lower F estimates.

Sensitivity analyses have shown that LCA results are strongly influenced by which includes only Δt, the time required to grow from one size class to the next (Cadrin and Estrella 1996). The results for Georges Banks and South females in Table B12 were obtained using revised Δts. Due to time constraints, the remainder of the estimates are based on Δts from the previous assessment. Using the revised Δts resulted in slightly lower F estimates for the Georges Bank and South females (4-12% lower in recent years).

Modified DeLury Model

DeLury model overview:

The stage-based DeLury model utilized in this assessment was based on the model of Collie and Sissenwine (1983) as modified by Conser (1991, 1995). The DeLury population model for American lobster assessments was first introduced at SAW-14 (Conser and Idoine 1992). This method utilizes a two-life-stage model, with the population divided into recruits and fully-recruited sizes. Research vessel bottom trawl survey indices and annual catch in numbers are used to estimate stock sizes and fishing mortality rates. An important feature of the model is that the error distribution of the abundance indices and the underlying process equation are explicitly modeled.

Model and parameter estimation

The modified DeLury model was applied for the estimation of stock sizes in number and fishing mortality rates for the lobster populations in each of the three stock areas as well as Central and Western Long Island Sound. The model is based on a mass balance approach in which the number of fully recruited individuals at time t is equal to the number of full recruits in the previous time step plus the number of new recruits less the number removed by fishing and losses due to natural mortality. These assumptions are incorporated into the following difference equation:

$$N_t = (N_{t-1} + R_{t-1})\exp(-M) - C_{t-1}\exp[(t_c - t_s - 1)M] \qquad \textbf{(7)}$$

where N_t is the fully recruited stock size in number of the population at year t, R_t is the recruited stock size in number of the population at year t, C_t is the catch in number at year t, M is the instantaneous natural mortality rate, t_c is the point during the calendar year when the catch is taken, t_s is the point during the calendar year when the research survey is carried out, for which $0 \leq t_s < t_c \leq 1$.

Population estimates are derived by assuming that the trawl research survey indices are proportional to true abundance:

$$\begin{aligned} n_t &= q_n N_t \\ r_t &= q_r R_t \end{aligned} \qquad \textbf{(8)}$$

where n_t is the survey abundance index of the fully recruited stock at year t, r_t is the survey abundance index of the recruited stock at year t, q_n is the relative catchability coefficient for full recruits, q_r is the relative catchability for recruits.

Substituting Equation 8 into Equation 7 and adding a random process error (ϵ_t) to obtain the relationship of the abundance indices of the fully recruited and recruited stocks gives:

$$n_t = \{(n_{t-1} + s_r r_{t-1})\exp(-M) - q_n C_{t-1}\exp[(t_c - t_s - 1)M]\}\exp(\epsilon_t) \qquad \textbf{(9)}$$

where $s_r = q_n/q_r$. Catchability estimates for full recruits and recruits cannot be estimated separately. The catchability coefficient q in the DeLury model represents a lumped parameter that includes both a gear efficiency term (i.e., probability of capture given encounter $P_{C|E}$) and scaling factor to convert between average area (a) swept by the survey gear and the total area (A). The interrelationship can be expressed as:

$$q = P_{C|E}\left(\frac{a}{A}\right) \qquad \textbf{(10)}$$

The survey abundance indices are measured with error and the model incorporates measurement error. Let n'_t and r'_t be the observations of population abundance indices n_t and r_t, respectively. Then:

$$\begin{aligned} n'_t &= n_t \exp(\eta_t) \\ r'_t &= r_t \exp(\delta_t) \end{aligned} \qquad \textbf{(11)}$$

where δ_t and η_t are the random measurement errors.

The parameters $\underline{\Theta}' = \{(n_t| t=1,...T), (r_t| t=1,...T-1), q_n\}$ are estimated by a method of weighted least squares:

$$SS(\underline{\Theta}) = \lambda_\epsilon \sum_{t=2}^{T} \epsilon_t^2 + \lambda_\eta \sum_{t=1}^{T} \eta_t^2 + \lambda_\delta \sum_{t=1}^{T-1} \delta_t^2 \qquad \textbf{(12)}$$

where λ_ϵ, λ_η and λ_δ are the weighting factors for the process error associated with the system Equation 9 and the measurement errors associated with the observed values (Equation 11). The weighting factors are normalized so that $\lambda_\epsilon + \lambda_\eta + \lambda_\delta = 1$. The coefficient s_r is set equal to 1.0. The catches in number for all years are input to the model without the assumed structure of random error.

Estimation of mortality rates

The recruited and fully recruited stock sizes are estimated as:

$$\hat{N}_t = \hat{n}_t/\hat{q}_n$$
$$\hat{R}_t = s_r\, \hat{r}_t/\hat{q}_n \tag{13}$$

and the total mortality and fishing mortality rates in year t for the entire population are calculated respectively by:

$$Z_{R+N,t} = -\ln\left(\frac{\hat{N}_{t+1}}{\hat{N}_t + \hat{R}_t}\right)$$
$$F_{R+N,t} = Z_{R+N,t} - M \tag{14}$$

The fishing mortality rates for the recruited ($F_{R,t}$) and fully recruited ($F_{N,t}$) stocks are calculated by applying the average partial recruitment ($\overline{p_{R,t}}$) of the recruited stock into the commercial fishery over the course of year t, i.e.,

$$F_{N,t} = \frac{F_{R+N,t}\,(\hat{R}_t+\hat{N}_t)}{\overline{p_{R,t}}\,\hat{R}_t}$$
$$F_{R,t} = \overline{p_{R,t}}\,F_{N,t} \tag{15}$$

The estimation of fishing mortality rates on recruits and full recruits separately is variable owing to the difficulty in estimating the average partial recruitment rate. Equation 15 implies that fishing mortality rates on the full recruits will always exceed the average F_{R+N} and that the estimated rate on recruits will be less than on the full recruits. It should be noted that population estimates in the terminal year are less reliable than earlier years because the implications of the population estimate for the following year cannot been estimated. Similar reservations regarding the terminal estimate of mortality rates are appropriate. These concerns are particularly relevant in fisheries highly dependent on recruitment.

Bootstrap methods were applied to estimate the sampling distribution of the model parameters (abundance measures and catchability) and mortality rates. Details on the methodology are described in Conser (1995). Bootstrapping provides an empirical, nonparametric method of estimating the variability of the estimates.

<u>DeLury model results</u>:

The DeLury model was fit to NMFS survey and landings data for males and females for the three stock areas (Gulf of Maine (GOM), Georges Bank and South (GBS), and the South of Cape Cod to Long Island Sound (SCCLIS). In addition, runs were made for SCCLIS using the Rhode Island Division of Environmental Management trawl survey and for the Central and Western Long Island Sound region using the Connecticut DEP survey. The models were run on a "survey year" basis in which the survey defined the start of the year ($t_s = 0$) and catches were assumed to occur at $t_c = 0.8$. In all runs, natural mortality and relative catchability of recruits were set to 0.15 and 0.5, respectively. Process error residuals were weighted four times as large as the observation error residuals (Equation 12). A summary of the model runs is provided on the next page.

In general, the model fit the data fairly well with no standardized residuals exceeding 2. Coefficients of variation of abundance estimates tended to be high, often exceeding 50%. There is little that can be done about this situation as it probably reflects the true variation of population estimates based on trawl survey indices. Estimates of recruits in year t exhibited strong positive correlations (0.4 - 0.8) with full recruits in the following year. These patterns are expected in heavily fished populations since nearly all of the full recruits are harvested each year. Detailed outputs of the DeLury model runs are not included in this document, but are available upon request. Tables B13 - B22 provide a concise summary of the key model inputs, parameters, and outputs. Data in these tables are sufficient to parameterize a DeLury run.

Gulf of Maine

Model runs for the Gulf of Maine suggest total mortality (Z) rates for males were relatively stable

Stock	Sex	Tuning index (trawl survey)	Survey years	Run no. ID	Tables and figures	
					Deterministic results	Detailed results, *file name*
Gulf of Maine	M	NMFS	1982-93	2	B13	R2.dat
	F	NMFS	1982-93	27	B14	R27.dat
Georges Bank and South	M	NMFS	1981-93	52	B15	R52.dat
	F	NMFS	1981-93	77	B16	R77.dat
South of Cape Cod to Long Island Sound	M	Rhode Island	1982-93	102	B17	R102.dat
	F	Rhode Island	1982-93	127	B18	R127.dat
	M	NMFS	1982-93	111	B19	R111.dat
	F	NMFS	1982-93	137	B20	R137.dat
Central and Western Long Island Sound	M	CT	1984-93	202	B21	R202.dat
	F	CT	1984-93	227	B22	R227.dat

over the entire time period at about 0.7. Slight declines in mortality in recent years are probably due to increases in recruitment. Estimated numbers of full recruits has increased about 2-fold between 1982 and 1994.

Female lobsters in the Gulf of Maine have also increased in recent years with slight declines in mortality rates. Point estimates of total mortality have been relatively stable (range: 0.67-0.97) with the 1992 and 1993 rates being the lowest in the series, 0.73 and 0.67, respectively. Fishing mortality rates (F) on the full recruits have been about 1.0 or greater over the entire time period. Asymptotic estimates of the standard error of the estimates suggested relatively large variances, with CVs of 45% or greater.

Georges Bank and South

Male lobster catches increased steadily from 1981 to 1992, but decreased by 40% between the 1992 and 1993 survey years. Total catch in weight decreased by only 16% during that period. Total population size increased to about 6.8 million lobsters in 1987, but appears to be declining steadily since then (Table B15). In contrast to estimates in the Gulf of Maine, total mortality for males has been increasing in the GBS stock to levels approaching 1.

Female lobster catches peaked in the 1990 survey year with nearly 4.6 million caught. Catches have since declined by nearly 60% in the 1993 survey year. Total population size peaked in 1990 at nearly 9.4 million, but population estimates in 1993 were about 5.3 million. Overall total mortality rates have exceeded 0.5 in every year except 1993. The initial indications of population decline could be due to either high rates of fishing mortality, slight declines in recruitment or decreased numbers of surviving migrants from the inshore areas. The DeLury estimates of total mortality are slightly greater than those reported in SAW-16.

South of Cape Cod to Long Island Sound

Catches of males have nearly doubled from 2 million in 1982 to 3.7 million in 1993. The DeLury model was implemented separately with the Rhode Island and NMFS trawl surveys. Total mortality rates for both index sets were very high, with average fishing mortality rates greater than 1.5 and exceeding 2 in many years. Fishing mortality rates on the fully-recruited males were exceptionally high, exceeding 4.0 in many years. These high rates may be partially attributable to offshore migration of the full recruits.

Average fishing mortality rates on female lobsters were slightly lower than on male lobsters, but were sufficiently high to suggest a similar pattern of emigration to offshore areas. Total population size has been increasing steadily over the past 10 years with most of the change coming from increases in recruits.

Use of the NMFS survey as a tuning index resulted in less precise estimates of abundance than when using the RI trawl survey indices. However, results for the RI tuned model are compromised by an apparent 5-fold difference in the catchability of male and female lobsters (Table B23). Such differences may reflect habitat selectivity or an inability of the survey to cover deeper waters preferred by females. For purposes of estimating recent fishing mortality rates for the entire SCCLIS area, the NMFS data were utilized. The correlations between the catchability coefficient q and recruits r_t were moderate (0.4 - 0.8) to strong (>0.8) for both males and females in the SCCLIS runs. These correlations persisted with both the NMFS and RI trawl indices. The exact causes of this phenomena are unknown, but may be related to spatial heterogeneity in catches and incomplete spatial coverage of the individual trawl surveys in the SCCLIS area. Results suggest that further refinements of the spatial application of the model and/or the use of a multiple-index DeLury model may be appropriate.

Central and Western Long Island Sound

Model results for CWLIS were similar to those observed in SCCLIS as a whole. Total population size appears to have about doubled between the 1984 and 1993 survey years, with most of increase coming from increases in number of recruits. Estimates of total mortality for males and females in CWLIS exceed those estimated for SCCLIS. Fishing mortality rates on full recruits suggest less than 1% of the population remains at the end of the survey year. If fishing mortality rates are as high as the model suggests, the dependency of the fishery on new recruits is extraordinary. If fishing mortality rates are less than the estimates, the results would imply emigration to SCCLIS or offshore areas. The assessment of the CWLIS subarea is clouded further by the apparent 3-fold increase in catchability of males relative to female lobsters in the CT trawl survey. These differences are similar to those observed for the RI trawl survey applied to the SCCLIS stock area.

Bootstrap Results

Bootstrap estimates of average fishing mortality rates for the last three survey years (1991, 1992, and 1993) were computed for female lobsters in all three stock areas and in CWLIS. Following the advice of Collie and Kruse (in press) and the SARC, no adjustment for bias was made in the mortality rate estimates. Bias estimates for composite 1991-1993 rates tended be relatively small, on the order of a few percent, for all areas except the Gulf of Maine stock. For this stock, the bootstrap estimates were 7.1 and 17.6% higher than the nonlinear least squares estimates for females and males, respectively. Bootstrap estimates of fishing mortality rate tended to agree well with point estimates (Table B24). The empirical distribution of mortality estimates were used to compute the relative risk of exceeding the provisional biological reference points. These results are discussed in the section on **Uncertainty Analyses**.

Detailed summaries of the bootstrap estimates from the DeLury model for each stock area by sex are available on request, as is a PC-executable version of the DeLury model with bootstrapping options.

Comparison of DeLury and LCA Results

The length cohort analysis (LCA) and DeLury models are both stage-based models in which the duration between stages is derived from a statistical or functional relationship between length and age. LCA is derived entirely from the length frequency of catch and requires the assumptions of constant recruitment over time and invariant growth. The DeLury model relaxes both of these assumptions, but does not include any information on the size structure of the catch. Both models provide estimates of total mortality and rely on an externally defined estimate of natural mortality to estimate fishing mortality by difference. The general properties of each model are summarized briefly below.

Property	Length cohort analysis	DeLury
Recruitment	Assumed constant	Variable. Defined by length interval corresponding to one molt below legal size limit.
Growth	Constant	Not included explicitly
Catch	Numbers by length Interval	Total numbers only
Indices of abundance	Not included	Included
Error distribution	Not included. Statistical properties of estimate unknown. Catch is assumed to be measured without error.	Residuals assumed to be lognormally distributed. Catch is assumed to be measured without error.

A comparison of the overall rates by each method is provided in Figure B40. Linear regression lines are provided simply as a means of judging the degree of coherence between the two approaches. In general, the agreement was reasonably good for GOM, very good for GBS, but poor for SCCLIS and CWLIS. However, in these regions, the fishing mortality estimates are extraordinarily high and exhibit little contrast using either method.

The SARC and the Lobster Review Panel both felt that the models provided complementary information. More work, most likely based on simulation modeling, is necessary to identify the strengths and weaknesses of the application of these models to lobster populations. As the following sections demonstrate, both models suggest similar rates of mortality, particularly when the underlying rates are moderate. When total mortality rates are high, the agreement between the models tends to diverge.

Biological Reference Points

Biological reference points used in the assessment and management of lobster populations are based on yield- and egg-production-per-recruit analyses. The overfishing definition for American lobster adopted by the New England Fishery Management Council specifies that the resource will be considered overfished when the egg production per recruit is reduced to 10% of the unexploited state throughout the range (NEFMC 1991). The fishing mortality rate associated with this point ($F_{10\%EPR}$) is a measure of recruitment overfishing. Growth overfishing can be measured by yield-per-recruit analyses, and the fishing mortality associated with this is F_{MAX}. Although the overfishing definition applies to a resource-wide state, there is evidence that biological rates (growth, maturity, etc.) and fishing patterns are sufficiently distinct on a regional basis to identify at least three sub-regions: 1) Gulf of Maine; 2) Georges Bank and South, and 3) South of Cape Cod to Long Island Sound (SAW-16). Analyses were, therefore, run separately for these three areas.

Methods and Model Design

Female lobsters exhibit complex life history patterns based on non-continuous growth (in terms of length) and an interrelation between growth and egg production. Since age determination for these animals is generally not possible, conventional growth and associated yield and egg production models are not applicable. The method used in the current assessment is based on the size-structured growth and yield and egg-production-per-recruit model described by Fogarty and Idoine (1988). Basic components of the model include size-specific annual molt probabilities, molt increments, egg bearing proportions, fecundities and weights. Growth is determined by the combination of the annual molt probability and increment and variation around these values. Egg production estimations incorporate the interactions between reproduction and growth (female lobsters suspend molting and thus growth when they are carrying eggs).

In the original form, minimum size restrictions as well as protection for egg bearing lobsters were included. Modifications were made for analyses during SAW-16 to include assessment of additional regulations currently specific to lobster fisheries in the Gulf of Maine and under consideration elsewhere, including the practice of V-notching and the use of maximum legal size limits. V-notching is the practice of making a V-shaped notch in the uropod of an egg-bearing (berried) female lobster. Currently, V-notching is generally practiced only in the State of Maine and it is not mandatory. The landing of V-notched lobsters is currently prohibited in Maine. Implementation of V-notching rates in the model can be further modified by the proportion of the resource that is subjected to this practice (e.g., in the Gulf of Maine approximately 71% of the landings are subject to this measure).

For the current assessment, further modifications were made. The first major change was to include egg production of animals far smaller than the minimum legal size. This was necessitated by the fact that some warm water areas have female lobsters as small as 60 mm carapace length (CL) (i.e., 2+ molts below the current minimum legal size) maturing and producing eggs. The contribution of this portion of the brood stock can now be included in analyses of the effects of fishing.

A second major structural change to the model involves the time step. Former simulations used a one-year interval, relying on approximations for such events as growth, mortality, and egg production. The current version has reduced the time step to a quarter year (three months). While this still requires approximations, it allows some events to be scheduled more realistically in the model The egg-bearing phase, hatching of eggs, V-notching (only of egg bearing animals), fishing effort, molting, and natural mortality all have strong seasonal components. These events and their interactions can be more directly examined with the shorter time steps, thus eliminating some of the error associated with annual approximations.

Other changes include reducing the maximum time a lobster can remain at the same size (i.e., the intermolt period) to 7 years, and quarterly nominal fishing mortality rates which, in combination with molting mortality, result in quarterly total mortality rates (Z). There are several events in a female lobster's life history that "compete". In general, there is the possibility (in a given year) of becoming egg-bearing, molting once, molting more than once, or doing nothing except eat, sleep, and die. At molting, mating may occur leading to internal fertilization and egg extrusion about a year later. The common choice is between molting (one or more times) or egging up from a previous molt and mating[1]. To insure that the sum of the proportions, of the population at a given size, following each choice does not exceed 1.0, the proportions were calculated in order of priority (egging up, double molting, single molting, doing nothing). As the proportion slated for each event was calculated, a running sum was kept to maintain the total at 1.0. The combination of these proportions is shown, by area, in Figure B41.

There are seven states in which a female lobster can reside in this model. These are described in Table B25. Movement between the states occurs on a quarterly/annual basis, with the quarters defined as:

<u>Quarter 1</u> = the major molt (≈ Oct-Dec), animals that do not molt move to the next year at size; also the point at which females will become berried (egg bearing); during this time, berried females that are encountered by the fishery are proportionally V-notched where applicable;

<u>Quarter 2</u> = a period (≈Jan-Mar) when only death takes place (no growth); however, V-notching occurs on the same basis as in Quarter 1;

[1]Although some multiple egg extrusions from a single mating do occur. these are usually at larger sizes, and somewhat infrequent (D. Pezzack, pers. comm.). Additionally, these multiple extrusions may not produce a comparable number of eggs or viability may be reduced. There is also minimal evidence (M. Blake, pers. comm.) of multiple extrusions from a single fertilization with a molt in between. No cases of multiple extrusion were incorporated into these analyses, although they could be included when data are provided relative to their size-specific frequencies.

Quarter 3 = the second molt for the year (of those that are on a twice-a-year molting schedule); no other movement except more animals being V-notched (see Quarter 1);

Quarter 4 = egg are hatched (released); berried protection goes away; no growth or other movement since there are no lobsters to V-notch.

Figure B42 shows the flow between states, time, and size.

Fishing occurs throughout the year, with a seasonal proportionality, based on area-specific estimations of effort (trap hauls), applied to the "nominal fishing mortality rate". This nominal rate is equivalent to the capture rate, removals (resulting in real mortality) are only from those states that are vulnerable (i.e., those between minimum and maximum legal sizes, and that are not egg bearing nor V-notched).

Each model run was based on a cohort of 1,100 female lobsters, initially distributed evenly through 1-mm size groups from 55 to 65 mm CL. It was assumed that V-notching is performed only on females that are berried and that the V-notch mark is no longer legally discernible after two molts.

The model simulates the growth of these animals by size and time within size (intermolt duration), in addition to yield and egg production, over the lifetime of a cohort. Model parameters that can be varied include management measures to reduce vulnerability to fishing mortality under various protections (minimum and maximum size, prohibition of landing berried lobsters, and V-notching), the rates of natural mortality and catch (or nominal fishing mortality), molting probabilities (thus intermolt duration), maturation, and reproduction. In addition, area- and size-specific biological parameters, such as the relationship between length and both fecundity and weight, are incorporated.

Application of the instantaneous rate of natural mortality (M) can be viewed in at least two ways with reference to lobsters: 1) a constant rate throughout its growth, or 2) a higher mortality associated with the act of molting. The structure of the analyses of Fogarty and Idoine (1988) for female lobsters allowed exploration of molting-related mortality and fishing mortality expressed in terms of the nominal fishing mortality rate.

Natural mortality was modeled with a harshell molting mortality of 0.10 and an additional molting mortality of 0.05. In this case, M is not constant through time, since only those members of the cohort who are molting are subject to the higher rate. Figure B43 shows this fluctuating rate through time for a non-fished cohort. Since a significant portion of this resource is protected from exploitation at various points in the individual's life history (including berried and V-notched and minimum and maximum sizes), the vulnerable portion of the population changes, and thus the realized mortality on the population diverges from the nominal rate. One way to view the difference is to consider the nominal rate as that rate which produces the catch and the realized rate as that rate which produces the landings. The realized rates will necessarily be lower than the nominal fishing mortality rates in these simulations. Realized rates were calculated on an annual basis by iteratively solving for F and M based on 1) the deaths due to fishing (landings), 2) deaths due to natural causes, and 3) the population size at the beginning of the period. This procedure was based on Newton's method of solving two non-linear equations in two unknowns (Atkinson and Harley 1983). This was necessary since M not only varies with molting, but also with F, which is not constant (due to the changes in protection, from the fishery, over time and size). Figure B44 show examples of the fluctuation of F and M over a range of nominal rates of F by area. These annual Fs were weighted (by the modelled landings) over the lifetime of the cohort, and the weighted average was considered to be the realized fishing mortality rate. For comparison with fishing mortality rates actually imposed on the population(s) (such as those calculated by the DeLury analyses), it is necessary to express the biological reference points in terms of the realized fishing mortality rates after adjustment for those regulations which temporally remove some females from the fishable population. The reference points $F_{10\%EPR}$ and F_{MAX} were calculated for each of the sub-regions.

Model Parameters

Parameters required are the probability of annual molting, molt increment, fecundity, proportion ovigerous, length-weight relationships (all size specific), and natural mortality rates. The biological parameters used in the model runs for each of the three assessment regions are provided in Table B26. Estimates of molt probability for the Gulf of Maine region are based on tagging studies in the Gulf of Maine and on the Scotian Shelf (D. Pezzack, Dept. Fish. Oceans Canada, Halifax, NS, pers. comm.). Parameter inputs for the Georges Bank and South region are those from Fogarty and Idoine (1988). Molt probability information for the South of Cape Cod to Long Island Sound region were based on unpublished tagging studies conducted by the Rhode Island Dept. of Environmental Management. Information on length-weight relationships and fecundity for the Gulf of Maine and for South of Cape Cod to Long Island Sound was based on studies conducted by the Massachusetts Division of Marine Fisheries. The fraction of V-notched lobsters was modeled at 50% for the Gulf of Maine, and the proportion of this area's resource that was subject to this was 71%, based on Maine's average contribution to the landings from this region. V-notching was set at 0% for the other two areas.

Results

Biological reference points, including the fishing mortality rate resulting in maximum yield per recruit (F_{MAX}) and the level of fishing mortality resulting in reduction to 10% of the maximum egg production per recruit ($F_{10\%\ EPR}$) were calculated for each of the three assessment areas. The relationships between yield and egg production per recruit and fishing mortality rate are provided in Figure B46. Calculated F_{MAX} and $F_{10\%\ EPR}$ values for female lobsters are shown in Table B27. Growth rates, shown as the mean size at time of the cohort under a zero F simulation, are shown in Figure B45. Calculations for YPR for males have not yet been performed.

For all analyses, natural mortality (M) was modelled as a two-stage process: a hardshell rate and a softshell, or molting rate (0.10 and 0.05, respectively). It is assumed that the animals are more vulnerable to predation, fatality due to intraspecific combat, etc. As discussed above, the realized or effective rate of the combination is dependent on the molting frequency and size/temporal specific rates of the fishing mortality (F). Investigations are underway to examine the interactions between these rates and the consequences with regard to egg production and yield.

For the Gulf of Maine, simulations assumed a 50% V-notching rate. This rate is a measure of the proportion of egged females that are encountered (i.e., caught in a trap) and actually V-notched by Maine fishermen. Since V-notching is not mandatory, this was assumed to be a reasonable level for the region. Further work can better define this variable; in fact, the model structure should allow "solving" for this rate based on the predicted number, in the model, that are notched. When viewing the three regions, the Gulf of Maine seems to be intermediate in terms of growth and size at maturity. However it has the lowest reference point. This may be due to the seasonal fishing patterns. Compared to the Georges Bank and South area, this region has twice the proportion of effort in the fourth quarter (model year = July - September). It is during this time that eggs hatch and the females that were berried lose that protection from the fishery. Sensitivity analyses are currently being done to explore the effect of this seasonal pattern of F on the reference points. Yield is between the other two areas and is most likely effected more by the growth rate.

The reference points for the region including Georges Bank and South are similar to those for the Gulf of Maine, but $F_{10\%\ EPR}$ is slightly higher. This can be attributed to the faster growth rate since these animals spend most of the year in near-optimal temperatures and larger size at maturity. Additionally, with maturity occurring at a larger size, the resultant partial recruitment of this portion of the stock is flatter than it would be in the Gulf of Maine. This would also shift F_{MAX} toward a lower value.

The SCCLIS area reference points are the highest of all three. Although the growth of the animals in this area is slower than in the other two areas (Figure B45), the overriding influence is the early maturity and the protection which that creates. The protections due to egg bearing result in a more dome-shaped partial recruitment curve and thus allow for a higher fishing mortality to achieve F_{MAX} than the flatter one exhibited by the other two regions. This protection, however, cannot compensate for the slow growth. Since animals are being removed at smaller sizes, their contribution to total egg production comes from a point when they are (individually) producing a relatively smaller number of eggs.

Simulated landings, by size, are shown (Figures B47 - B49) for the three areas under fishing mortality rates approximately equal to those calculated for the current (1991-1993 average) conditions. These show the compression of the size composition and the strong dependence on newly recruited animals that characterizes this resource.

Uncertainty Analyses

Comparison of the biological reference points with the empirical distribution of fishing mortality rates provides a measure of the risk imposed on the population by fishing mortality and a quantifiable estimate of the degree of overfishing. Percentiles of the distributions of the 3-yr average (1991-1993) F for recruits and full recruits are summarized in Table B24. Results suggest high probabilities of overfishing of females on Georges Bank, in the South of Cape Cod to Long Island Sound area, and in Central and Western Long Island Sound. For the latter two areas, the 10th percentile of the distribution of F is about twice as large as the biological reference point. In the Gulf of Maine, there is a 97% probability that $F_{91\text{-}93}$ exceeded $F_{10\%}$ (Figure B50). For the Georges Bank and South stock, the probability that $F_{91\text{-}93}$ exceeded $F_{10\%}$ is 100% (Figure B51). Equivalent conclusions can be drawn for the SCCLIS stock (Figure B52) and the Central and Western Long Island Sound (CWLIS) area. The biological reference point for the CWLIS area is provisional pending resolution of several modeling and statistical issues. However, under the prevailing fishing mortality rates for 1991-1993, even a biological reference point of $F = 1.6$ would have a 75% chance of being exceeded (Table B24).

Uncertainty in length cohort analyses was addressed by sensitivity analyses. Small variations in the estimated time interval between length groups resulted in significant variation in estimated mortality rates. This is expected because the LCA model maps length directly to age. Changes in the time of catch within the year had a large influence on the weighted average F. Both of these results highlight the need for accurate growth models to define the expected relationship between length and age.

Additional biological sampling of catches in offshore areas, particularly the Georges Bank and South stock area, is needed. Reductions in average size of offshore catches may have important implications for the stability of the entire resource if such areas comprise a large share of the total spawning stock biomass.

The boundaries between stock areas represent compromises between biological realism and availability of data, particularly catch. Existing databases do not allow for historical resolution of catches below the level of statistical area except in few instances. Additional biological sampling, field experimentation, and perhaps modern methods of stock identification could help to refine stock boundaries, particularly in transitional areas such as the Cox's Ledge region between Massachusetts and Rhode Island.

The implications of considering lobster stocks as a series of linked populations deserves further attention. Theoretical analyses suggest that larval subsidies from offshore components are sufficient to maintain an inshore stock subjected to high rates of fishing mortality. If such subsidies are occurring, the current stability of landings may be keyed to maintenance of the offshore stock. While the maintenance of offshore broodstock is critical, it is important to recognize that these populations are supplemented by the survivors of inshore fisheries. Given the longevity of lobsters, it may take many years before reductions in numbers of immigrants to offshore stocks effect reductions in egg production, and ultimately, recruits. As a first step, it will be important to map the spatial pattern of potential egg production (see Equation 5) using the size composition of the research trawl surveys and abundance estimates from the population models.

Within the SCCLIS area, there are several areas known to be transitional zones in which both small and large lobsters are present seasonally. Finer scale analyses of landings patterns in such areas may provide insights into migration. Under current rates of fishing mortality, tagging studies are unlikely to be definitive as most recaptures are expected to occur in the vicinity of the release site shortly after tagging.

Progress on Research Recommendations

A total of eight research recommendations were made at SAW-16 (NEFSC 1993) at the time of the last assessment for American lobster. A status report on each of these recommendations is provided below. The numbering below is keyed to those specific recommendations.

1) The need to resolve issues related to stock identification, particularly as related to inshore-offshore components south of Georges Bank using appropriate genetic techniques was identified. Genetic studies are currently underway examining microsatellite DNA markers for lobsters for use in stock identification studies (Irv Kornfield, UMaine, Orono ME, pers. comm.). Samples of lobster tissue for this purpose have been supplied to Dr. Kornfield from material obtained during NEFSC research surveys. Initial work characterizing the microsatellite markers has been completed (Tam and Kornfield, submitted). This work is not yet ready for application in assessment studies. A morphometric stock discrimination based on size at maturity was developed to classify lobsters to inshore or offshore parts of Southern New England (Cadrin 1995).

An extensive examination of the evidence for a separate stock unit in Long Island Sound was undertaken based on evidence derived from tagging studies and inferences concerning larval dispersal. This issue was also considered by the Lobster Review Panel which concluded that Long Island Sound could be treated as a separate assessment stratum within the SCCLIS area, but not as a separate stock unit.

2) Enhancement of sampling activities for biological characteristics of the catch was recommended, with particular emphasis on the offshore component of the fishery. In the latest assessment, the number of samples for offshore areas in Southern New England was increased though the sea sampling program conducted by the State of Rhode Island and by port sampling by NMFS. Samples derived from the Department of Fisheries and Oceans Canada augmented those derived from U.S. sources. Additional samples from the Domestic Observer Sea Sampling Program were incorporated into the current assessment, and historical data from port samples were put into a computer database for the first time. Enhancement of sampling activities within the Gulf of Maine is still required.

3) The effect of the estimated proportion of V-notched females in the Gulf of Maine on estimated biological reference points was questioned. It was recommended that this issue be addressed in a new study to augment existing survey questionnaire data on this topic. A study is currently underway with Sea Grant funding in Maine, New Hampshire, and Rhode Island to develop a pilot program for an integrated system for monitoring the lobster fishery. This study specifically includes a component to quantify the proportion of V-notched lobsters in the catch (in the Gulf of Maine) based on voluntary logs and sea sampling information. The study is entering its first field season. Information from this study to guide assessment choices is not currently available, however, and it will be necessary to consider this factor in subsequent assessments. Advances in modeling of growth and egg production suggested that the efficacy of the V-notch is dependent on the seasonal nature of the fishery and the maturation rate. The peak landings period for the Maine fishery coincides with the period following hatching and before extrusion of new clutches. Moreover, most of the landings are coming from immature individuals within one molt of the size limit. Hence relatively few lobsters are likely to be V-notched even if all fishermen were voluntarily notching 100% of the egged females encountered.

4) The DeLury model results are sensitive to the relative catchability of pre-recruit and fully recruited lobsters. It was recommended that studies of the selectivity of the trawl gear be undertaken. Direct observations of the selectivity characteristics of the research trawl are not currently available. Comparison of catchability coefficients between males and females was instructive, particularly in the SCCLIS and CW-LIS stock areas using the Rhode Island and Connecticut surveys, respectively. Marked differences in estimated capture efficiencies reflect variations in availability to the trawl. In this context, comparisons between tows in the NMFS and State of Massachusetts surveys in Cape Cod Bay showed that the Massachusetts survey had a significantly greater ratio of recruits to fully-recruited lobsters. Future work in this area is likely to be insightful.

5) The assessment provided in SAW-16 considered only the female component of the population. It was recommended that males be directly considered in subsequent assessments. This has been incorporated in the current assessment.

6) It was recommended that the DeLury model be expanded to allow for multiple survey indices to refine estimates of fishing mortality and population size. A preliminary version of the DeLury model with multiple indices has been developed, but was not available in time for consideration by the SARC.

7) The issue of combining multiple stock areas to provide region-wide assessments and biological reference points was raised with specific reference to inshore-offshore exchange in the Southern New England region. This issue was not specifically addressed in the current assessment because of a lack of quantified exchange rates and weighting factors for these locations. The ability to utilize multiple abundance indices does address a specific issue raised in this recommendation where it was noted that results of a combined inshore-offshore southern region are highly sensitive to whether NMFS survey or State of Rhode Island survey data were used in SAW-16.

8) It was recommended that the length cohort analyses should be extended to the two southern stock areas. The LCA model was extended to include males and females in the three stock areas (GOM, GBS, and SCCLIS) as well as the Central and Western Long Island Sound subarea.

Response to Lobster Review Panel

A draft of the recommendations of the Lobster Review Panel appointed to review approaches to the definition of lobster overfishing definitions and stock assessment methods was made available to the Invertebrate Subcommittee shortly before its scheduled meeting to undertake the assessment. Time did not permit analyses addressing each of the Panel's recommendations. However, substantial progress was made in accounting for important recommendations by the Panel. In particular, with respect to analytical issues, the development of a new egg-production-per-recruit model capable of treating seasonal (quarterly) fishing patterns, egg production by sublegal sized lobsters, and multiple within-year molting was completed as described above. A preliminary version of a multiple-index DeLury model was developed, and sensitivity analyses were undertaken to examine questions raised by the Panel.

The status of attempts to address issues and questions raised by the Review Panel is summarized in Table B28 based on the following general categories: A) stock structure, B) landings/effort/LPUE, C) DeLury analysis, D) length cohort analysis, E) fishing mortality and fishing effort, F) egg production per recruit, G) future assessment methods, and G) benthic ecology. The table provides a brief description/characterization of each Review Panel recommendation, the current status of attempts to address the recommendation, and an indication of future work to be accomplished with respect to the recommendation.

Discussion and Consensus Summary

Exploitation Estimates

The SARC asked why efficiency of the NMFS trawl survey in the Gulf of Maine was so low, as estimated from DeLury model results. It was pointed out that the NMFS survey was limited to soft-bottom habitat, and it was shown that the Gulf of Maine was predominated by gravel, rock, and bedrock bottom, whereas southern areas were mostly clay and silt bottoms. The SARC noted that such low efficiency estimates (0.04-0.05) make DeLury estimates in the Gulf of Maine very sensitive to small changes in gear efficiency in the area which produces the majority of landings. However, it was pointed out that Gulf of Maine female DeLury results from SAW-16 were essentially unchanged after adding 1993 data and revising catch and survey data. Such stability of results suggests that the application is robust to small changes in catchability.

In a related discussion, the SARC questioned the assumption that relative catchability of recruits to fully-recruited lobsters (s_r) was 0.5. In the SAW-16 DeLury analyses, results from two runs (one with s_r=1.0 and one with s_r=0.5) were blended. The catchability ratio was believed to be less than 1 based on the knowledge of changing lobster ecology with growth (i.e., larger lobsters inhabit less protective habitats) and the concern that the NMFS survey avoided hard bottom habitats and areas with concentrations of fixed gear. A comparative tow study between the NMFS survey and the Massachusetts inshore survey (which can tend rougher bottom better) conducted in response to a SAW-16 research recommendation showed that the NMFS survey had a significantly lower ratio of recruits to fully-recruited lobsters. These field observations suggested that the ratio of recruit to fully-recruited catchability is less than 1. The Lobster Review Panel also suggested that differences between DeLury and length cohort analysis should be resolved. It was felt that assuming $s_r > 0.5$ may have been one source of difference between the two methods in SAW-16 results, and $s_r = 0.5$ was assumed for the present analyses.

The SARC noted that the Massachusetts inshore trawl survey in the Gulf of Maine showed similar patterns in recruit and fully-recruited abundance to those from the NMFS survey. It was noted that a DeLury analysis of the Mass. survey data was conducted at SAW-16, but it did not perform as well as the analysis of NMFS survey data. It was also noted that the Mass. survey should be explored in subsequent assessments, perhaps in combination with the NMFS survey.

The SARC discussed derivation of partial recruitment (PR) in DeLury models. It was pointed out that the PR of recruits describes the increasing vulnerability of recruits over the year as they grow into legal size. Mortality of stock components (recruits and fully-recruited lobsters) is largely determined by PR assumptions, but the total mortality of recruits and fully-recruited lobsters was considered robust to the extrinsic determination of PR.

The SARC asked if there were any statistical problems with DeLury runs, such as residual problems. It was noted that, after several alternative runs, there were no excessively large residuals and no significant trends or patterns of residuals. However, there were some large correlations between catchability and abundance estimates in the Central and Western Long Island Sound analyses. Therefore, the CWLIS analyses should be considered preliminary.

The SARC suggested that bias corrections were inappropriate because bias may result from misspecified error structure. It was explained that, without bias correction, F estimates would be greater than reported in the preliminary bootstrap summaries.

The SARC questioned why female F was greater than male F from the Gulf of Maine DeLury analyses because there are more protective measures in place for females. It was explained that the seasonal exploitation pattern in the Gulf of Maine decreased the effectiveness of regulations which protect ovigerous females because effort peaks in summer after the hatching of eggs. It has also been speculated that the large size at maturity in the Gulf of Maine, faster growth of males, and protection of large males and females by the 5-in maximum size in Maine may result in greater F on females than males. In comparison, male F is greater than female F from Georges Bank and South DeLury runs because the seasonal effort pattern is more uniform and there is no maximum size limit.

In a similar discussion, the SARC noted that the proportion of total catch in the first molt size class was also greater for females than males in the Gulf of Maine, but not for other stocks. The SARC agreed that the high or increasing trends in proportion of small lobsters in the catch was cause for concern, and interpreted both indices [1) increase in proportion of egg production from small lobsters and 2) percentage of small lobsters in the catch] as a result of increasing exploitation rate. It was noted that such patterns can also indicate increased recruitment in recent years.

The SARC questioned the realism of the high estimates of F. Supporting evidence was offered for extremely high F in coastal areas. Local fishing patterns suggest that molting events are targeted and new recruits are quickly depleted. Most tagging observations from inshore areas have an average time-at-large of less than 10 days. Canadian catches are generally dominated by the first three weeks of their two- to six-month open seasons.

The SARC discussed the relative strengths of DeLury and length cohort models. It was pointed out that the models complement each other in their assumptions, input data, and disparate sensitivities. However, it was agreed to base management advice on DeLury estimates because of the more comprehensive geographic coverage of trawl surveys and the potential for biases in length cohort analysis due to geographic fishing patterns and poorly estimated growth curves. It was noted that length cohort analyses are useful for confirming high F estimates obtained from the present DeLury analyses.

Overfishing Definitions

The SARC asked how multiple probabilities were estimated for the egg-per-recruit (EPR) models. It was explained that molt probabilities were estimated from logistic regressions of tagging data, the maximum intermolt period was inferred from laboratory studies, the proportion ovigerous was derived from maturity-at-size observations, and the proportion V-notched was deduced by assuming a 50% V-notch rate for 71% of the Gulf of Maine resource. V-notched stages were not included in EPR models for southern stocks. It was reported that the SAW-16 EPR model was not sensitive to assumed V-notching rates.

Sensitivity of the EPR model to maximum intermolt period was discussed. It was noted that, although allowing longer intermolt periods increases over-fishing reference F values, 7 years is considered to be an extreme maximum. Laboratory studies have shown that lobsters 120 mm CL molt every 2 years, and larger lobsters (150-180 mm CL) molt within 4 years, presumably because exoskeletons cannot endure many years of wear, erosion, and epibiotic growth. Limiting intermolt periods to 7 years greatly improved simulated growth trajectories. Earlier models with longer intermolt periods produced growth trajectories which asymptoted at sizes smaller than those observed in the catch. The current model produces growth curves which are similar to tagging observations.

The SARC recommended changes to the EPR model involving the chain of events for internally fertilized females. The current model simulates a molt before oviposition. It was agreed that it was more appropriate to simulate oviposition before growth. Exploratory EPR runs were made without a molt between mating and extruding eggs; although growth rate, yield, and egg production decreased, reference points were very similar.

The SARC discussed the assumption of no discard mortality. Although negligible discard mortality was considered to be a fair assumption, it was noted that there are chronic effects through claw loss and egg loss. Mobile gear fishing also imposes some discard mortality.

The SARC questioned the comparability of realized F from the EPR model and F estimates from DeLury and length cohort analyses. It was pointed out that realized F from the EPR model was comparable to DeLury and LCA estimates because F is catch-weighted, not weighted by abundance in EPR.

There was considerable discussion on assumptions about natural mortality. There was concern that adding greater levels of softshell mortality to lifetime M estimates would overestimate M because published estimates of M encompass all the stages of the life history. However, the resulting estimates of M from EPR model output were within the range of published M values. As F increases, the proportion of smaller lobsters in the population (which molt twice and have greater natural mortality) increases, so the average M also increases as F increases. It was noted that F estimates from preliminary DeLury and length cohort analyses need to be adjusted to incorporate similar values of M, which is 0.15 within the observed range of F (see Figure B44).

There was some discussion concerning the seasonal timing of growth events. The EPR model simulates fall growth for single molters and spring and fall growth for double molters. It was noted that the primary molt is in the spring and the secondary molt is in the fall. It was felt that the timing of growth, reproduction, and fishing should be examined. It was reported that such modification to the EPR model would be a considerable task and could not be addressed at the SARC meeting.

The SARC considered the Central and Western Long Island Sound analyses to be an assessment of a subarea of the South of Cape Cod to Long Island Sound stock. Although there was strong opinion that the subarea analyses should be reported, there was concern that EPR sensitivities were not adequately addressed. Unfortunately, sensitivity analysis of the EPR model to changes in M, maximum intermolt, percent ovigerous at size, and quarterly timing of events was not possible within the time-frame of the SARC. Based on available information, the SARC concluded that the management advice for the SCC-LIS would not be affected by changes in model parameterization for the CWLIS and resulting biological reference points. CWLIS analyses support the results for the entire South of Cape Cod to Long Island Sound stock. The SARC concluded that the CWLIS analyses were not sufficiently complete to provide unique management advice for that segment of the SCCLIS stock due to late documentation of the analyses, lack of review, and outstanding concerns, and concluded that more work is needed on the CWLIS. It was noted that the Lobster Review Panel concluded that the Central and Western Long Island Sound should not be considered a separate management area without careful examination.

The daunting question, "Why are there so many lobsters landed?", was discussed. Explaining increases in recruitment and catch after years of extremely intense fishing mortality is difficult. However, recruitment increased in the late 1980s throughout the range of the lobster, and catch is now decreasing in many areas. Some reasons offered were environmental factors, an ever-expanding fishery (e.g., longer fishing seasons, increased effort, expanded fishing areas), and decreased predation. The stock-recruit relationship is apparently quite flat. As explained in the draft report of the Lobster Review Panel, the implications of such a relationship are that collapse can be sudden and rebuilding a collapsed stock may take many years.

Research Recommendations

- Sensitivity to the assumed ratio of pre-recruit and fully-recruited survey catchability needs to be further investigated. Field studies are needed to support assumptions concerning the trawl selectivity ratio. The best way to estimate s_r would be with *in-situ* observations in surveyed areas.

- Revisions to the structure of the DeLury model should be explored, such as including multiple surveys, CPUE indices, a "sex-linked" run which estimates a single catchability coefficient for both sexes, and using length-cohort results for tuning.

- More accurate information on lobster growth is needed for length cohort analysis and EPR models. Growth information can be improved through stochastic growth models, more powerful statistical analyses of tagging and biological catch samples, and more field observations of molt probability over a broad range of sizes.

- Predictions of EPR models should be validated with respect to data from fishery-dependent and fishery-independent sources including: length frequency distribution of catch, projected growth trajectory, and size-specific sex ratios, fraction egg bearing, fraction soft shell, and fraction V-notched.

- The effects of alternative partitionings of natural mortality (M) between hardshell (HSM) and softshell (SSM), where M = HSM + SSM, should be investigated, and attempts should be made to estimate rates from field or laboratory data.

- Terminologies for lobster life stages need to be defined and standardized for each state's sampling programs in order to ensure comparability and synthesis of available data.

- Methodologies for estimation of size-specific vital rates (e.g., molting, maturation) need to be reviewed in light of known biases induced by high contemporary rates of fishing mortality.

- Review information on maximum intermolt period of large lobsters.

- Explore alternatives to timing of events in the EPR model. Investigate geographic and seasonal patterns of growth, reproductive events, and fishing intensity from catch and sea sampling data. Standardized methods of sampling and statistical analysis are needed to determine these patterns.

- The Massachusetts survey should be investigated for inclusion in the Gulf of Maine DeLury analyses.

- All information on stock identification (biological parameters, stock mixing, correlation of regional catches, etc.) should be reviewed by the ASMFC Lobster Technical Committee to reach consensus on whether or not Central and Western Long Island Sound comprises a distinct and separate stock. Subsequently, consensus is needed on the best scientific information available on biological parameters for each stock.

- The SARC Assessment Methods Subcommittee should determine the appropriate error structure in the DeLury model so that bias corrections can be applied which are not influenced by assumptions about how errors are distributed.

- Additional analyses of biological attributes of the catch and survey data are needed to corroborate patterns and trends in F estimates. Such analyses may provide guidance for assumption of model parameters such as seasonal molting patterns.

- Methods should be developed to derive standardized catch-per-unit-effort indices which include trap attributes, season, soak time, etc. Sea sampling should be modified to include collection of potentially important variables.

- Yield-per-recruit analyses should be conducted for males.

- Discrepancies between annual catch reports and canvass data in Statistical Area 611 need to be resolved.

- Additional research recommendations were submitted in response to draft conclusions of the Lobster Review Panel. These recommendations as well as progress, comments, and suggestions for future work are provided in Table B28.

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Table B1. Terms of reference.

Term of reference	Summary
Review biological bases of stock definitions and define appropriate assessment areas.	No additional biological information on stock definitions was available for Gulf of Maine (GOM) or Georges Bank and South (GBS). Operational definitions of stock boundaries were modified to coincide better with available catch and survey information; boundary between the GBS stock and the South of Cape Cod to Long Island Sound (SCCLIS) stock was modified slightly. A separate analysis of Central and Western Long Island Sound (CWLIS) was conducted.
Estimate abundance and mortality rates by sex and stock and quantify their precision.	DeLury and length cohort analysis (LCA) models were applied by sex to GOM, GBS, and SCCLIS stocks and CWLIS area. Sensitivity analyses were conducted for LCA model; bootstrap analyses were conducted for DeLury model to estimate empirical distributions of population sizes and mortality rates.
Evaluate quantitative indicators of exploitation rates and stock status from research survey, commercial fishery and sea sampling databases, and other relevant information.	Examined two candidate indicators: 1) fraction of potential egg production contributed by females within one molt of legal size and 2) fraction of landings from lobsters within one molt increment of legal size limit.
Address the recommendations of the Lobster Review Panel regarding overfishing definitions and assessment techniques for American lobster, and implement changes if possible.	Developed a new model of eggs per recruit (EPR) that included quarterly time step, greater realism in fishery (seasonality), timing of biological events (molting, reproduction, etc.), and duration of intermolt periods.
Present the Subcommittee's general views on the Lobster Review Panel draft report, consider and incorporate to the extent possible the Panel's recommendations which pertain to the first three terms of reference particularly with respect to sensitivity analyses, and provide a prioritized research plan for addressing all of the Panel's recommendations.	Developed a detailed response to the Panel's research recommendations (Table B28).

Table B2. Allocation of statististical areas and NMFS survey strata to stock areas.

Stock area	Sub-stock	Statistical areas	Sources of biological samples	NMFS survey strata
Gulf of Maine (GOM)	GOM-Inshore West	514	MA samples in Stat. Area 514	1260-1300 1360-1400 3590-3610 3650-3660
	GOM-Inshore East	511 512 513	ME port samples	
	GOM-Offshore	515 464	NMFS sea sampling 91-93	
Georges Bank and South (GBS)	GB-Outer Cape Cod	521	MA samples in Stat. Area 521, 1981-94	1010-1040 1060-1250 1610-1760
	GB-Northeast	522 551 524 552 525 561 562	NMFS port samples 1982-1989, 1990 (Q1) DFO port and sea samples	
	GB-South	526 537 533-534 541-542 612-639	NMFS port? RI sea samples 1990 (Q4)-1994	
South of Cape Cod to Long Island Sound (SCCLIS)	SCCLIS-538	538	MA samples in Buzzards Bay and Outer Cape Cod 1982-93	1050 3450-3550
	SCCLIS-539	539	MA Buzzards Bay 1982-89 RI samples in SA 539, 1990-94	
	Western LIS	Part of 611	CT sea samples 1982-94	None
	Eastern LIS	Part of 611	CT sea samples 1982-94	None
	Central and Western LIS	Part of 611	CT sea samples 1982-94	None

Table B3. Total commercial landings (mt) of American lobster by state, 1962-1994.

Calendar Year	Maine	New Hampshire	Massachusetts	Rhode Island	Connecticut	New York	New Jersey	Delaware, Maryland, Virginia	Total
62	10013	329	1923	261	285	143	395	11	13360
63	10344	339	2020	269	214	172	340	11	13709
64	8586	386	2489	452	132	248	481	14	12788
65	8556	347	2885	816	337	294	462	21	13719
66	9034	366	2190	759	355	331	347	18	13400
67	7479	326	2134	885	409	399	399	98	12129
68	9299	342	2185	1394	402	529	549	53	14755
69	8997	332	2248	1926	423	642	650	94	15313
70	8243	312	2579	2357	305	747	833	114	15489
71	7964	303	2788	2444	237	812	600	132	15281
72	7374	305	3643	1516	245	519	593	421	14617
73	7731	226	2549	1258	247	405	618	115	13149
74	7465	226	2387	1550	294	331	540	153	12947
75	7714	218	3054	1670	269	304	386	80	13696
76	8619	216	2982	1548	217	269	293	130	14275
77	8386	215	3270	1584	290	241	362	54	14400
78	8677	213	4323	1280	362	264	420	91	15630
79	10039	354	4333	1038	366	318	365	97	16912
80	9970	328	4502	1087	374	333	232	54	16880
81	10266	360	5090	849	458	404	269	55	17750
82	10310	366	5965	1440	472	395	384	73	19405
83	9968	594	5635	2320	812	557	349	74	20310
84	8866	712	6669	2386	853	713	421	109	20728
85	9129	538	7391	2332	726	670	490	111	21385
86	8938	515	6830	2571	711	617	509	118	20809
87	8957	570	6857	2412	747	714	634	88	20979
88	9861	227	7198	2159	907	892	706	66	22016
89	10600	649	6997	2597	917	829	934	63	23587
90	12732	752	7736	3292	1053	1230	997	69	27861
91	13965	817	7497	3377	1091	1301	759	40	28848
92	12170	694	7177	3068	1025	1596	550	22	26302
93	13574	768	6503	2825	967	1660	411	33	26742
94	17667	749	7303	2937	978	1794	264	8	31698
Overall Ave. %	53.5	2.3	24.9	9.8	2.9	3.4	2.8	0.4	
Ave % 1985-94	47 0	2.5	28.6	11.0	3.6	4.5	2.5	0.2	

Table B4. Total commercial landings (mt) of American lobster by stock area, 1962-1994.

	Georges Bank			Gulf of Maine		S. Cape Cod & Long Island Sound	
Calendar Year	North & East	Outer Cape Cod	South & West	Inshore East	Inshore West &Offshore	SCCLIS	Total
62	356.6	0.4	964.6	10342.0	1207.1	489.4	13360.1
63	237.1	0.1	1064.7	10682.7	1339.8	384.8	13709.1
64	67.8	0.1	1712.0	8971.3	1667.6	368.9	12787.6
65	1002.0	0.2	1419.3	8902.6	1709.2	685.5	13718.7
66	561.6	0.2	1292.0	9399.7	1458.1	688.3	13399.8
67	569.1	2.2	1625.5	7805.1	1355.6	771.7	12129.2
68	546.3	3.1	1902.5	9642.1	1568.8	1091.8	14754.5
69	538.7	0.8	2743.2	9329.0	1472.6	1229.0	15313.3
70	560.1	0.5	3266.4	8554.8	1776.7	1330.6	15489.0
71	540.3	5.5	2989.2	8267.1	2168.9	1309.7	15280.7
72	480.9	3.3	3000.7	7679.4	2638.7	814.4	14617.3
73	214.9	0.2	2077.3	7956.9	2153.3	746.0	13148.5
74	751.0	1.2	2067.2	7691.2	1541.8	894.3	12946.6
75	755.7	3.1	2033.6	7932.3	2000.5	970.6	13695.8
76	778.7	16.2	1906.8	8835.4	2036.0	701.4	14274.6
77	680.8	20.5	1689.3	8601.7	2603.1	804.8	14400.2
78	1129.2	77.9	1701.2	8891.2	2954.2	876.4	15630.1
79	1004.0	85.9	1482.0	10394.2	3049.5	896.4	16912.1
80	711.8	33.4	1114.6	10299.7	3662.3	1058.5	16880.2
81	728.2	2.2	1388.7	10625.6	4151.7	853.8	17750.2
82	800.5	3.7	1617.5	10676.9	3991.8	2314.5	19405.0
83	1150.4	2.9	1491.5	10563.4	4637.8	2464.5	20310.4
84	804.9	14.1	2255.6	9581.1	4215.7	3857.1	20728.4
85	795.5	9.6	2084.3	9429.5	5124.1	3941.5	21384.5
86	555.7	4.1	2404.6	9201.6	4702.9	3939.8	20808.6
87	573.7	13.2	2496.7	9510.4	4441.6	3943.0	20978.7
88	626.9	10.7	2362.1	10088.2	4327.2	4600.6	22015.6
89	524.6	54.3	2751.3	11254.1	5453.5	3549.2	23587.0
90	575.0	41.3	3576.6	13175.4	6359.2	4133.8	27861.3
91	575.9	14.3	3419.5	14414.1	6117.4	4307.0	28848.3
92	686.6	82.3	3000.2	12865.4	5443.9	4223.9	26302.3
93	656.9	18.0	2807.0	14069.3	5009.5	4181.6	26742.4
94	720.5	43.7	2173.1	18037.2	5751.7	4972.3	31698.4

Table B5. Lobster landings (percent of total) by gear type, 1964-1994, from NMFS weighout and general canvas data.

	Year	Percent Trap	Percent Non-trap
64	1964	87.52%	12.48%
65	1965	81.78%	18.22%
66	1966	86.67%	13.33%
67	1967	83.02%	16.98%
68	1968	83.05%	16.95%
69	1969	79.79%	20.21%
70	1970	79.24%	20.76%
71	1971	83.70%	16.30%
72	1972	92.42%	7.58%
73	1973	94.81%	5.19%
74	1974	92.62%	7.38%
75	1975	94.15%	5.85%
76	1976	95.71%	4.29%
77	1977	96.41%	3.59%
78	1978	96.86%	3.14%
79	1979	97.48%	2.52%
80	1980	97.61%	2.39%
81	1981(2)	98.09%	1.91%
82	1982	98.55%	1.45%
83	1983	98.20%	1.80%
84	1984	97.51%	2.49%
85	1985(3)(4)	98.11%	1.89%
86	1986(3)(4)	97.60%	2.40%
87	1987(4)	97.47%	2.53%
88	1988(3)(4)	97.13%	2.87%
89	1989	97.51%	2.49%
90	1990	97.44%	2.56%
91	1991	97.51%	2.49%
92	1992	96.94%	3.06%
93	1993(5)	97.40%	2.60%
94	1994(5)(6)	98.71%	1.29%

5.74% wt ave for 1964-1994

3.33% wt ave for 1971-1994

2.66% wt ave for 1974-1994

2.33% wt ave for 1984-1994

(1) Other pots include fish pots, conch pots, eel pots, and crab pots.

(2) Unknown gear in RI prorated to gear category using mean of ratios from 1980 and 1982.

(3) Unknown gear in NH prorated to gear category using mean of ratios from 1984, 1987, 1989.

(4) Unknown gear in CT prorated to gear category using mean of ratios from 1984 and 1989.

(5) Preliminary

(6) Based on proportions of known gear type.

Table B6. NMFS autumn survey abundance (number/tow) and biomass (kg/tow) indices for the Gulf of Maine stock of American lobster, by sex, for pre-recruits, recruits, and all sizes combined during 1996-1995.

	FEMALES				MALES			
	Pre-recruits	Recruits	All Sizes		Pre-recruits	Recruits	All Sizes	
	no./tow	no./tow	no./tow	kg/tow	no./tow	no./tow	no./tow	kg/tow
1976	0.00	0.23	0.23	0.22	0.02	0.19	0.22	0.26
1977	0.04	0.55	0.60	0.47	0.05	0.49	0.56	0.61
1978	0.03	0.20	0.26	0.21	0.01	0.17	0.19	0.36
1979	0.02	0.14	0.18	0.13	0.04	0.14	0.21	0.21
1980	0.05	0.47	0.55	0.48	0.10	0.33	0.51	0.46
1981	0.01	0.11	0.12	0.12	0.00	0.10	0.11	0.09
1982	0.13	0.07	0.30	0.11	0.06	0.12	0.22	0.18
1983	0.27	0.38	0.72	0.38	0.22	0.34	0.72	0.33
1984	0.12	0.22	0.38	0.28	0.04	0.11	0.20	0.11
1985	0.30	0.65	1.12	0.76	0.26	0.38	0.94	0.41
1986	0.35	0.35	1.20	0.47	0.23	0.50	1.23	0.69
1987	0.10	0.25	0.43	0.22	0.14	0.36	0.56	0.31
1988	0.43	0.31	0.85	0.38	0.26	0.18	0.63	0.20
1989	0.33	0.36	1.15	0.48	0.46	0.36	1.37	0.49
1990	0.48	0.35	0.97	0.47	0.63	0.55	1.41	0.57
1991	0.52	0.41	1.12	0.51	0.33	0.58	1.13	0.54
1992	0.20	0.19	0.58	0.26	0.29	0.24	0.74	0.37
1993	0.20	0.40	0.70	0.39	0.23	0.39	0.81	0.48
1994	0.76	0.77	2.02	0.92	0.82	0.86	2.25	0.94
1995	0.35	0.60	1.19	0.58	0.60	1.07	1.92	1.11

Table B7. Massachusetts autumn survey abundance (number/tow) and biomass (kg/tow) indices for the Gulf of Maine stock of American lobster, by sex, for pre-recruits, recruits, and all sizes combined, 1978-1995.

	FEMALES				MALES			
	Pre-recruits	Recruits	All Sizes		Pre-recruits	Recruits	All Sizes	
	no./tow	no./tow	no./tow	kg/tow	no./tow	no./tow	no./tow	kg/tow
1978	1.13	0.65						
1979	3.92	1.52						
1980	1.78	0.96						
1981	2.83	1.04						
1982	2.30	1.84	7.29	2.35	1.70	1.59	6.64	4.47
1983	4.35	1.64	14.26	3.77	3.71	1.95	14.06	8.26
1984	2.49	1.49	14.42	3.20	2.51	2.44	17.07	8.19
1985	4.68	2.25	20.81	5.36	4.54	2.17	20.47	10.66
1986	1.98	0.61	5.97	1.59	1.79	1.90	8.08	5.19
1987	0.53	0.37	1.29	0.51	0.57	0.25	1.46	1.02
1988	1.26	0.29	11.46	1.72	0.91	0.66	14.67	4.78
1989	1.64	0.55	12.98	2.50	2.35	0.99	14.33	6.06
1990	7.46	2.30	79.35	11.68	7.68	2.38	88.31	25.92
1991	3.56	0.56	26.77	4.18	4.12	2.61	23.96	11.06
1992	2.69	0.77	17.91	3.26	2.23	1.09	18.55	7.49
1993	1.19	0.23	6.18	1.28	1.86	0.47	7.85	3.95
1994	5.72	1.24	37.66	6.88	6.36	1.73	39.26	15.09
1995	4.22	0.75	30.48	5.72	4.84	1.51	32.30	6.13

Table B8. NMFS autumn survey abundance (number/tow) and biomass (kg/tow) indices for the Georges Bank and South stock of American lobster, by sex, for pre-recruits, recruits, and all sizes combined during 1976-1995.

	FEMALES				MALES			
	Pre-recruits	Recruits	All Sizes		Pre-recruits	Recruits	All Sizes	
	no./tow	no./tow	no./tow	kg/tow	no./tow	no./tow	no./tow	kg/tow
1976	0.11	0.28	0.47	0.39	0.09	0.20	0.38	0.29
1977	0.08	0.56	0.68	0.78	0.11	0.41	0.54	0.78
1978	0.07	0.42	0.52	0.55	0.04	0.23	0.29	0.36
1979	0.10	0.33	0.53	0.49	0.12	0.21	0.43	0.35
1980	0.08	0.32	0.53	0.53	0.10	0.27	0.43	0.64
1981	0.16	0.35	0.63	0.56	0.18	0.20	0.51	0.36
1982	0.12	0.34	0.54	0.48	0.13	0.26	0.46	0.33
1983	0.12	0.27	0.45	0.44	0.19	0.20	0.54	0.37
1984	0.11	0.30	0.48	0.35	0.09	0.24	0.39	0.26
1985	0.16	0.23	0.59	0.40	0.15	0.19	0.50	0.22
1986	0.16	0.29	0.66	0.38	0.20	0.20	0.53	0.31
1987	0.10	0.21	0.43	0.33	0.23	0.21	0.53	0.31
1988	0.09	0.30	0.46	0.44	0.11	0.29	0.48	0.35
1989	0.15	0.30	0.56	0.52	0.19	0.32	0.62	0.52
1990	0.18	0.33	0.69	0.52	0.14	0.23	0.49	0.29
1991	0.09	0.39	0.62	0.58	0.15	0.22	0.47	0.30
1992	0.18	0.32	0.66	0.50	0.17	0.23	0.53	0.31
1993	0.10	0.32	0.51	0.43	0.11	0.14	0.30	0.17
1994	0.02	0.27	0.31	0.38	0.11	0.14	0.34	0.19
1995	0.09	0.25	0.44	0.33	0.15	0.11	0.38	0.19

Table B9. NMFS autumn survey abundance (number/tow) and biomass (kg/tow) indices for the South of Cape Cod to Long Island Sound stock of American lobster, by sex, for pre-recruits, and all sizes combined during 1976-1995.

	FEMALES				MALES			
	Pre-recruits	Recruits	All Sizes		Pre-recruits	Recruits	All Sizes	
	no./tow	no./tow	no./tow	kg/tow	no./tow	no./tow	no./tow	kg/tow
1976	0.00	0.00	0.67	0.18	0.48	0.48	1.28	1.25
1977	0.31	0.22	0.73	0.44	0.00	0.00	0.15	0.03
1978	1.13	0.74	3.01	1.29	0.81	0.34	1.85	0.66
1979	0.21	0.48	0.82	0.42	0.54	0.26	1.08	0.46
1980	0.31	0.44	1.36	0.43	0.46	0.00	1.51	0.34
1981	1.86	0.69	11.31	2.60	2.41	0.39	10.32	2.41
1982	0.89	0.86	2.38	1.18	0.16	0.43	1.31	0.56
1983	0.52	0.51	1.52	0.73	0.50	0.50	1.56	0.68
1984	1.00	1.03	8.88	2.66	1.51	0.36	9.41	2.11
1985	0.68	0.37	1.84	0.62	0.67	0.61	1.70	0.68
1986	0.49	0.17	4.45	1.08	0.99	0.00	5.21	0.89
1987	0.12	1.24	1.36	1.06	0.00	0.22	0.33	0.17
1988	1.29	0.85	4.00	1.54	0.30	0.62	1.97	0.75
1989	2.04	0.24	4.52	1.76	1.73	0.41	4.33	1.27
1990	1.03	0.73	4.13	1.65	0.59	0.16	3.82	1.09
1991	0.57	0.98	1.98	1.13	0.26	0.57	1.62	0.68
1992	1.38	1.39	6.47	1.88	1.49	0.33	3.92	1.03
1993	0.24	0.53	2.22	0.87	0.86	0.36	1.86	0.57
1994	0.14	0.25	0.57	0.30	0.27	0.10	0.51	0.18
1995	1.10	0.65	2.40	1.17	0.41	0.53	1.59	0.67

Table B10. Rhode Island autumn survey abundance (number/tow) and biomass (kg/tow) indices for the South of Cape Cod to Long Island Sound stock of American lobster, by sex, for pre-recruits, recruits, and all sizes combined during 1979-1995.

	FEMALES				MALES			
	Pre-recruits	Recruits	All Sizes		Pre-recruits	Recruits	All Sizes	
	no./tow	no./tow	no./tow	kg/tow	no./tow	no./tow	no./tow	kg/tow
1979	0.10	0.03	0.50	0.08	0.28	0.16	1.08	0.24
1980	0.56	0.07	4.05	0.76	0.70	0.22	3.52	0.65
1981	0.60	0.09	5.84	1.00	1.34	0.20	6.96	1.24
1982	0.19	0.01	0.96	0.19	0.47	0.12	1.79	0.39
1983	0.29	0.09	1.06	0.24	0.24	0.19	1.05	0.29
1984	0.44	0.21	3.74	0.72	1.29	0.16	5.21	1.05
1985	0.49	0.02	3.57	0.62	0.73	0.19	3.62	0.68
1986	0.40	0.04	1.72	0.34	0.88	0.24	3.94	0.89
1987	1.48	0.32	5.25	1.17	1.02	0.19	4.29	0.92
1988	0.83	0.22	3.49	0.87	1.18	0.22	4.50	1.04
1989	1.10	0.29	6.67	1.38	2.78	0.46	9.49	2.15
1990	1.04	0.16	5.16	1.02	1.33	0.45	5.73	1.27
1991	0.68	0.19	5.88	1.07	2.03	0.28	8.55	1.72
1992	1.33	0.25	5.88	1.25	1.33	0.29	7.03	1.39
1993	1.71	0.21	6.32	1.42	2.97	0.49	7.28	1.88
1994	0.85	0.34	8.35	1.47	1.00	0.17	8.03	1.25
1995	1.41	0.11	6.46	1.46	3.09	0.34	11.16	2.42

Table B11. Connecticut autumn survey abundance (number/tow) and biomass (kg/tow) indices for the South of Cape Cod to Long Island Sound stock of American lobster, by sex, for pre recruits, recruits, and all sizes combined during 1984-1994.

	FEMALES				MALES			
	Pre-recruits	Recruits	All Sizes		Pre-recruits	Recruits	All Sizes	
	no./tow	no./tow	no./tow	kg/tow	no./tow	no./tow	no./tow	kg/tow
1984	4.00	2.81	14.37	10.59	4.99	2.61	18.56	13.36
1985	2.73	1.17	7.51	5.80	3.25	1.02	8.63	6.45
1986	3.32	1.53	9.45	7.14	5.08	3.37	16.29	12.75
1987	2.98	1.63	8.74	6.77	5.67	1.97	18.46	13.35
1988	2.75	0.79	6.59	5.07	3.78	1.30	12.53	9.02
1989	1.90	0.61	7.77	5.23	5.63	1.21	15.18	10.84
1990	2.81	1.10	11.55	7.59	6.44	2.29	20.96	14.79
1991	3.58	1.00	19.21	11.04	9.06	1.74	33.42	20.40
1992	2.26	1.26	11.25	7.73	10.72	4.15	48.41	29.62
1993	3.94	1.14	15.26	9.93	11.85	2.08	40.36	25.56
1994	3.54	1.62	13.56	9.43	10.30	3.34	43.23	27.12

Table B12. Estimates of fishing mortality derived from length cohort analyses (Cadrin and Estrella 1996).

Fishing Mortality (F)

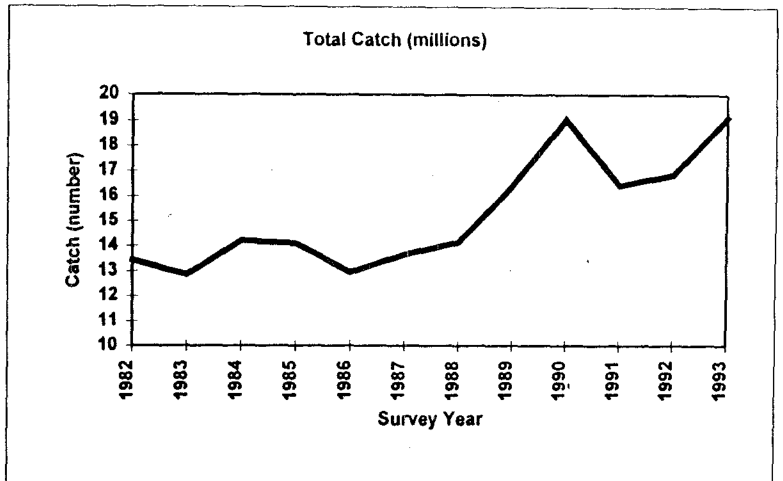
Survey Year	Gulf of Maine females	Gulf of Maine males	Geo Bank/South females	Geo Bank/South males	S Cape Cod/LIS females	S Cape Cod/LIS males	West/Central LIS females	West/Central LIS males
1981	1.10	1.50	0.82	1.35				
1982	1.10	1.51	0.76	1.02	0.97	1.85	0.90	1.52
1983	1.16	1.49	0.70	0.81	1.06	1.86	0.99	1.73
1984	1.22	1.56	1.01	1.31	1.11	1.86	0.94	1.71
1985	1.27	1.52	0.98	1.38	1.28	2.02	1.20	1.95
1986	1.24	1.64	1.16	1.68	1.30	2.14	1.27	2.01
1987	1.34	1.71	1.18	1.27	1.22	1.94	1.17	1.88
1988	1.27	1.65	0.86	1.44	1.09	1.98	1.17	1.91
1989	1.28	1.58	1.13	1.48	1.01	1.88	1.01	1.74
1990	1.28	1.62	1.40	1.96	1.00	1.78	0.97	1.78
1991	1.23	1.64	1.39	2.16	0.99	1.79	0.99	1.81
1992	1.17	1.59	1.46	2.12	1.17	1.86	1.29	2.04
1993	1.21	1.54	0.76	2.10	1.23	1.87	1.29	1.98

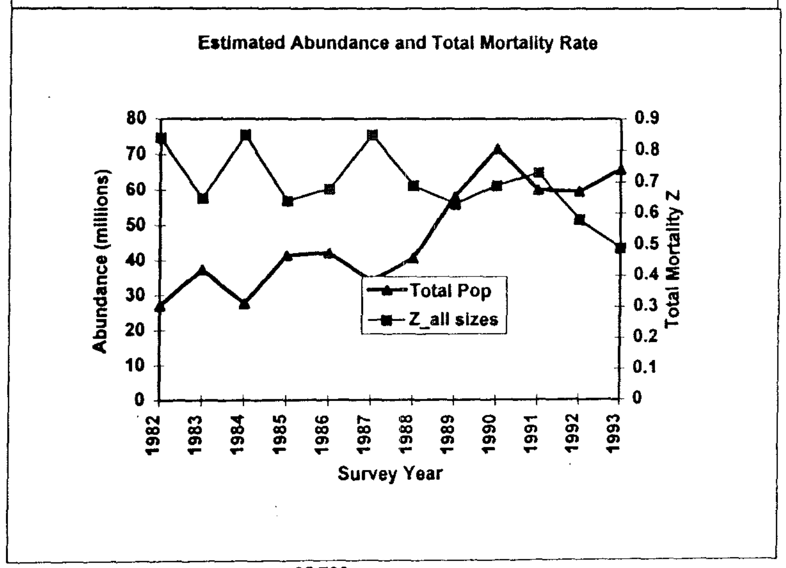
Table B13. Summary of DeLury model estimates of abundance and mortality for male lobsters in the Gulf of Maine stock.

Survey Year	Indices of Abundance Recruits	Full-Recruits	Total Catch (millions)
1982	0.0634	0.1248	13.44864
1983	0.2248	0.3351	12.85813
1984	0.0435	0.1066	14.20771
1985	0.2554	0.3821	14.09939
1986	0.2342	0.5028	12.95862
1987	0.1401	0.3588	13.65792
1988	0.256	0.1809	14.13767
1989	0.4641	0.3594	16.40924
1990	0.626	0.5454	19.06971
1991	0.3344	0.582	16.44064
1992	0.292	0.2361	16.85244
1993	0.2263	0.3902	19.12813
1994	0.821	0.8571	

Input File Name	R2.dat	
Tuning Dataset	NMFS	
Time of Survey (yr)	0	
Time of Catch (yr)	0.8	
Nat Mortality Rate	0.15	
Relative Catchability: Recruits to Full Recruits s_r	0.5	
Average Partial Recruitment Rate to Fishery	2.95E-01	
Catchability Estimate and CV	1.90E-02	0.31

Survey Year	Stock Size Estimates (millions at time of Survey) Recruits	Full Recruits	Total Mortality Z_all size	Fishing Mortality on Recruits	Full-Recruits
1982	13.824	13.297	0.84	0.32	1.08
1983	25.666	11.712	0.65	0.29	0.97
1984	8.254	19.48	0.85	0.26	0.89
1985	29.666	11.85	0.64	0.29	0.99
1986	20.34	21.901	0.68	0.24	0.81
1987	12.831	21.318	0.85	0.28	0.95
1988	26.016	14.628	0.69	0.29	0.98
1989	37.807	20.444	0.63	0.26	0.89
1990	40.759	30.907	0.69	0.27	0.91
1991	24.403	35.791	0.73	0.24	0.81
1992	30.636	29.026	0.58	0.2	0.67
1993	32.316	33.483	0.49	0.15	0.52
1994	98.419	40.422			





65.799

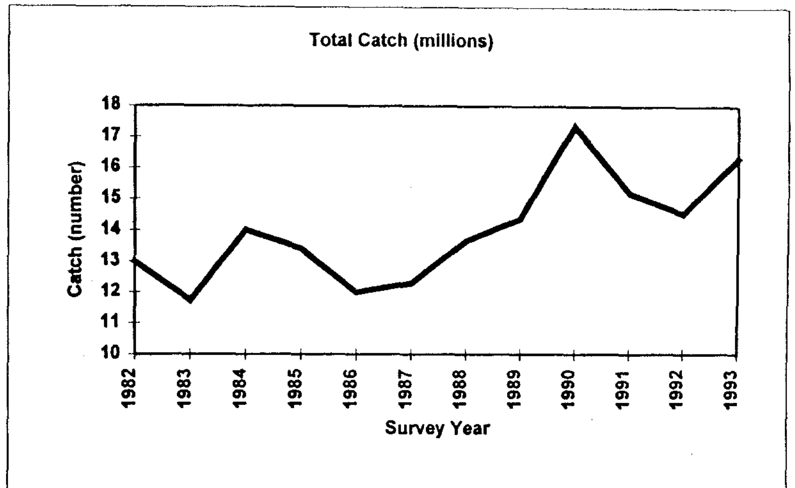
Note that the recruit population estimate for the last year (1994) is NOT a least squares estimate.
Rather, it is calculated from the observed survey indecx, the least squares estimate of q and the s_r

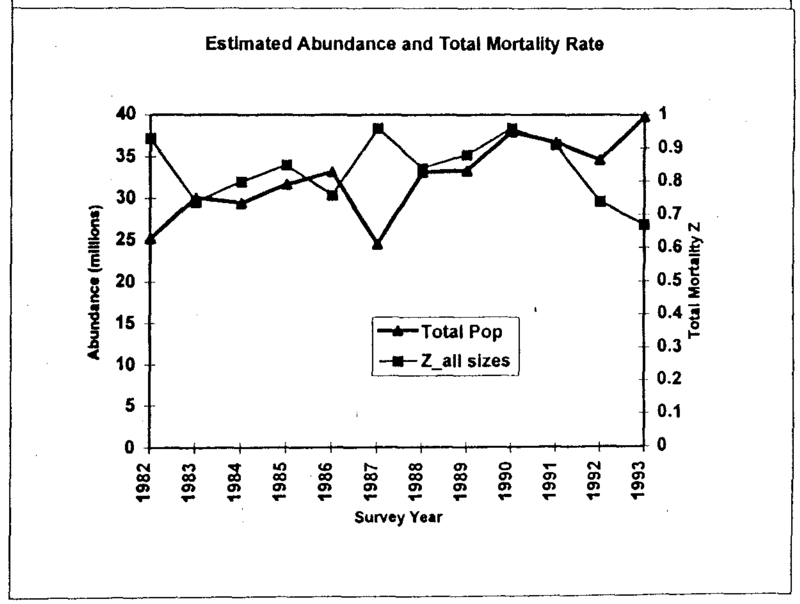
Table B14. Summary of DeLury model estimates of abundance and mortality for female lobsters in the Gulf of Maine stock.

Survey Year	Indices of Abundance: Recruits	Indices of Abundance: Full-Recruits	Total Catch (millions)
1982	0.1336	0.0728	13.00008
1983	0.2694	0.3756	11.72875
1984	0.1166	0.2211	14.00323
1985	0.3048	0.6463	13.40853
1986	0.3527	0.3507	12.001
1987	0.1049	0.2475	12.29538
1988	0.426	0.309	13.6539
1989	0.3285	0.3601	14.36669
1990	0.4766	0.3486	17.35234
1991	0.5195	0.4063	15.18497
1992	0.201	0.186	14.53992
1993	0.1962	0.3959	16.31297
1994	0.7589	0.7729	

Input File Name	R27.dat	
Tuning Dataset	NMFS	
Time of Survey (yr)	0	
Time of Catch (yr)	0.8	
Nat Mortality Rate	0.15	
Relative Catchability: Recruits to Full Recruits s_r	0.5	
Average Partial Recruitment Rate to Fishery	2.95E-01	
Catchability Estimate and CV	2.84E-02	0.23

Survey Year	Stock Size Estimates (millions at time of Survey): Recruits	Stock Size Estimates (millions at time of Survey): Full Recruits	Total Mortality: Z_all size	Fishing Mortality on: Recruits	Fishing Mortality on: Full-Recruits
1982	22.061	3.14	0.93	0.6	2.04
1983	20.155	9.939	0.74	0.33	1.11
1984	15.039	14.414	0.8	0.3	1.02
1985	18.491	13.209	0.85	0.35	1.19
1986	19.692	13.509	0.76	0.31	1.04
1987	8.902	15.598	0.96	0.32	1.09
1988	23.702	9.407	0.84	0.41	1.39
1989	18.997	14.329	0.88	0.36	1.22
1990	24.157	13.799	0.96	0.43	1.46
1991	22.095	14.597	0.91	0.39	1.32
1992	19.876	14.741	0.74	0.29	0.98
1993	23.178	16.591	0.67	0.26	0.89
1994	58.804	20.28			





Note that the recruit population estimate for the last year (1994) is NOT a least squares estimate.
Rather, it is calculated from the observed survey indecx, the least squares estimate of q and the s_r

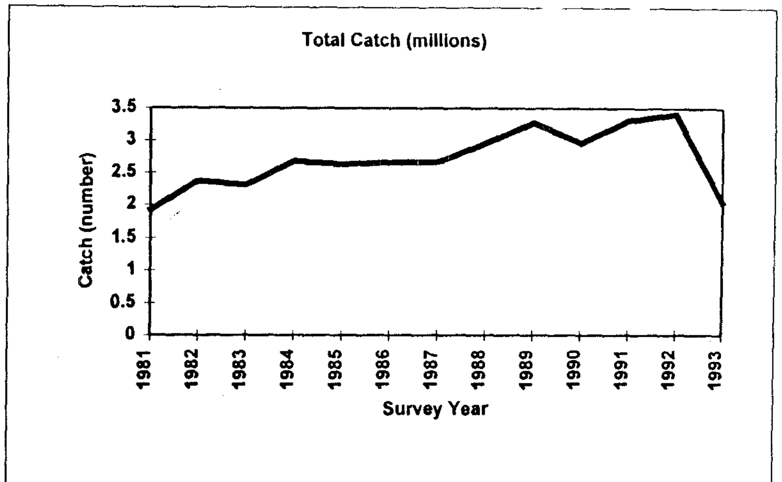
Table B15. Summary of DeLury model estimates of abundance and mortality for male lobsters in the Georges Bank and South stock.

Survey Year	Indices of Abundance: Recruits	Indices of Abundance: Full-Recruits	Total Catch (millions)
1981	0.1797	0.2028	1.919437
1982	0.1326	0.2605	2.373952
1983	0.1935	0.2034	2.31292
1984	0.0917	0.2389	2.684211
1985	0.1494	0.1867	2.631459
1986	0.1996	0.2003	2.661433
1987	0.2275	0.2127	2.665579
1988	0.1132	0.2861	2.959318
1989	0.192	0.3202	3.280997
1990	0.1408	0.2286	2.966661
1991	0.149	0.2216	3.313652
1992	0.1747	0.2308	3.411009
1993	0.1111	0.1379	2.040244
1994	0.1054	0.1439	

Input File Name	R52.dat	
Tuning Dataset	NMFS	
Time of Survey (yr)	0	
Time of Catch (yr)	0.8	
Nat Mortality Rate	0.15	
Relative Catchability: Recruits to Full Recruits s_r	0.5	
Average Partial Recruitment Rate to Fishery	2.95E-01	
Catchability Estimate and CV	9.82E-02	0.05

Survey Year	Stock Size Estimates (millions at time of Survey): Recruits	Stock Size Estimates (millions at time of Survey): Full Recruits	Total Mortality Z_all size	Fishing Mortality on Recruits	Fishing Mortality on Full-Recruits
1981	3.53	2.09	0.67	0.27	0.92
1982	2.642	2.889	0.84	0.31	1.04
1983	3.925	2.389	0.7	0.29	0.98
1984	2.152	3.125	0.99	0.35	1.17
1985	3.381	1.967	0.96	0.43	1.45
1986	3.949	2.058	0.86	0.39	1.33
1987	4.925	2.533	0.67	0.29	0.97
1988	2.835	3.814	0.81	0.28	0.94
1989	4.047	2.956	0.91	0.38	1.28
1990	3.38	2.816	0.91	0.36	1.23
1991	3.754	2.497	1.04	0.45	1.54
1992	3.537	2.212	1.27	0.58	1.97
1993	2.502	1.619	0.96	0.42	1.42
1994	2.331	1.571			

Note that the recruit population estimate for the last year (1994) is NOT a least squares estimate. Rather, it is calculated from the observed survey indecx, the least squares estimate of q and the s_r



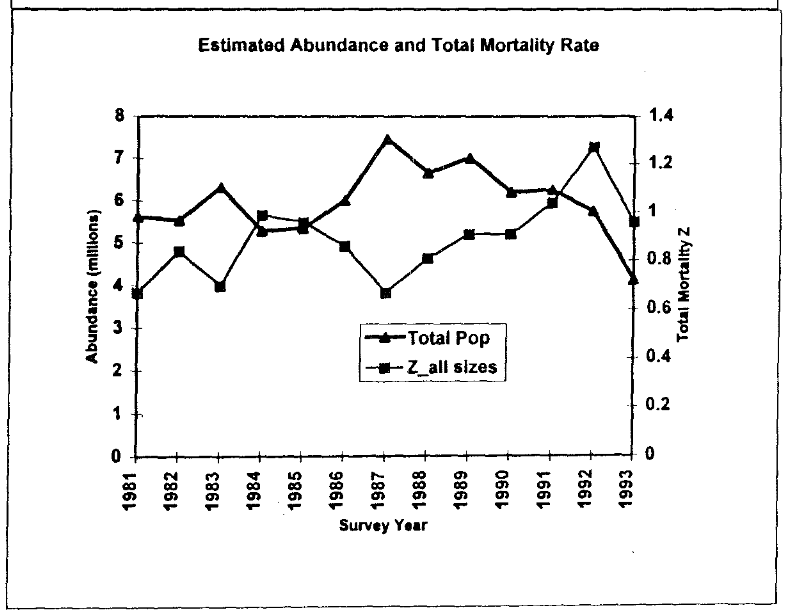


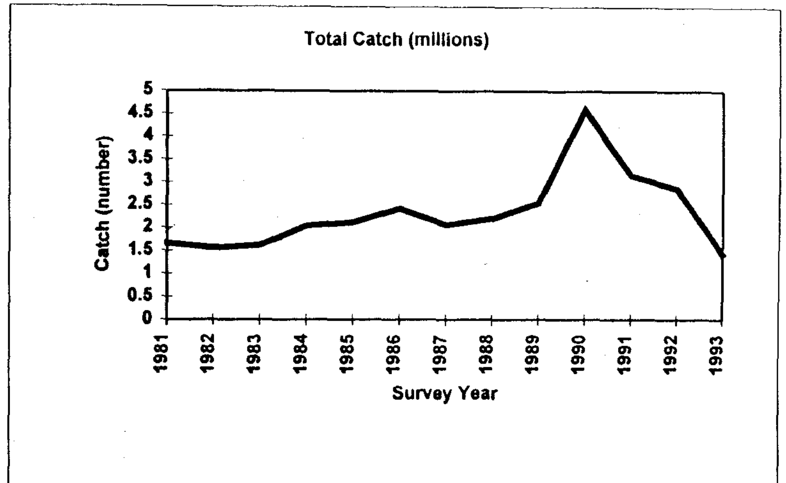
Table B16. Summary of DeLury model estimates of abundance and mortality for female lobsters in the Georges Bank and South stock.

Survey Year	Indices of Abundance: Recruits	Indices of Abundance: Full-Recruits	Total Catch (millions)
1981	0.1631	0.3461	1.667616
1982	0.1232	0.3398	1.565765
1983	0.1155	0.2688	1.624382
1984	0.1146	0.3019	2.041153
1985	0.1644	0.2312	2.121916
1986	0.1599	0.2891	2.417541
1987	0.0951	0.2061	2.065914
1988	0.0903	0.3019	2.207051
1989	0.1533	0.3038	2.539647
1990	0.1846	0.331	4.597528
1991	0.0943	0.3882	3.149092
1992	0.1817	0.3157	2.84989
1993	0.1005	0.3249	1.42352
1994	0.0225	0.2714	

Input File Name	R77.dat	
Tuning Dataset	NMFS	
Time of Survey (yr)	0	
Time of Catch (yr)	0.8	
Nat Mortality Rate	0.15	
Relative Catchability: Recruits to Full Recruits s_r	0.5	
Average Partial Recruitment Rate to Fishery	2.95E-01	
Catchability Estimate and CV	9.02E-02	0.1

Survey Year	Stock Size Estimates (millions at time of Survey): Recruits	Stock Size Estimates (millions at time of Survey): Full Recruits	Total Mortality: Z_all size	Fishing Mortality on: Recruits	Fishing Mortality on: Full-Recruits
1981	3.423	3.6	0.53	0.17	0.57
1982	2.578	4.146	0.54	0.16	0.53
1983	2.557	3.92	0.54	0.16	0.54
1984	2.484	3.785	0.66	0.21	0.71
1985	3.613	3.228	0.62	0.22	0.75
1986	3.501	3.681	0.67	0.23	0.79
1987	2.736	3.678	0.55	0.17	0.57
1988	2.578	3.705	0.61	0.19	0.64
1989	4.321	3.431	0.58	0.21	0.7
1990	5.957	4.353	0.79	0.32	1.09
1991	2.606	4.662	0.78	0.25	0.85
1992	4.373	3.317	0.7	0.27	0.92
1993	2.361	3.817	0.48	0.13	0.45
1994	0.561	3.82			

Note that the recruit population estimate for the last year (1994) is NOT a least squares estimate.
Rather, it is calculated from the observed survey indecx, the least squares estimate of q and the s_r



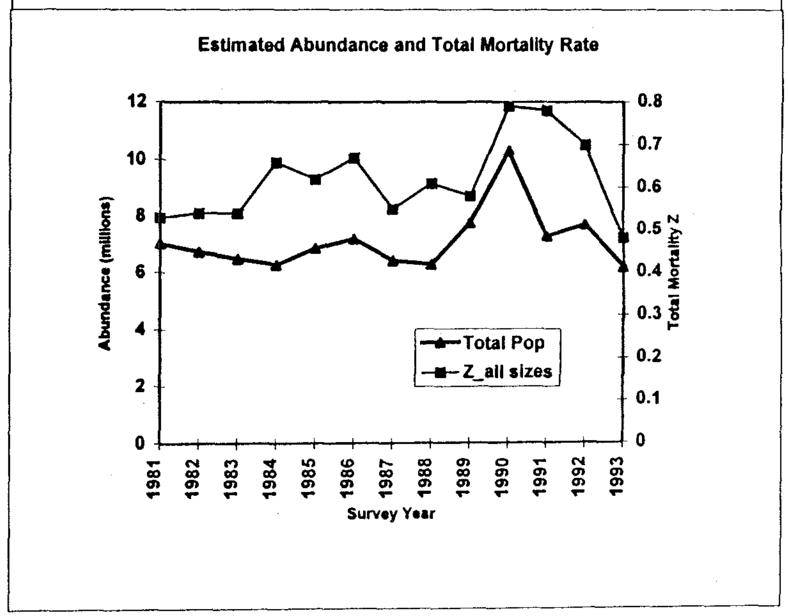
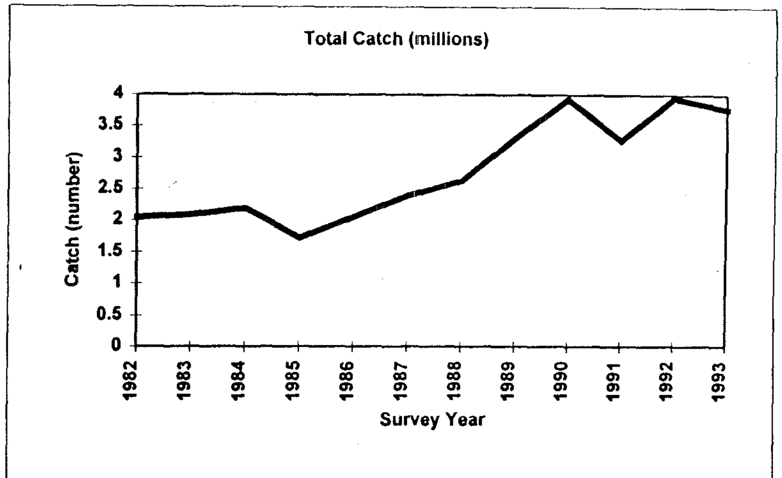


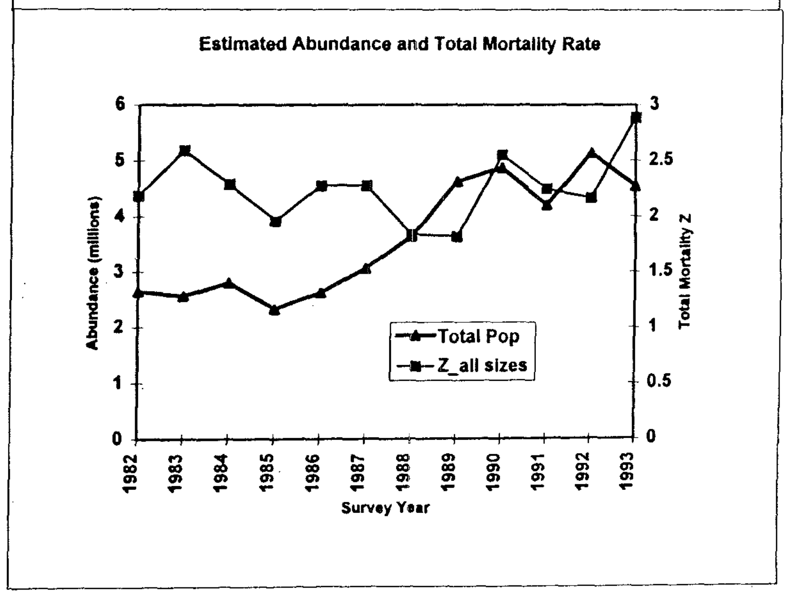
Table B17. Summary of DeLury model estimates of abundance and mortality for male lobsters in the South of Cape Cod to Long Island Sound stock.

Survey Year	Indices of Abundance: Recruits	Indices of Abundance: Full-Recruits	Total Catch (millions)
1982	0.4728	0.1213	2.048701
1983	0.2391	0.1949	2.08319
1984	1.2937	0.1597	2.192189
1985	0.7303	0.1941	1.724307
1986	0.8818	0.2366	2.053807
1987	1.0192	0.19	2.393535
1988	1.1847	0.2242	2.630755
1989	2.7849	0.4558	3.303225
1990	1.3297	0.4544	3.931714
1991	2.0268	0.2846	3.270125
1992	1.3347	0.2926	3.951377
1993	2.9682	0.4874	3.766668
1994	1.0044	0.1708	

Input File Name	R102.dat	
Tuning Dataset	RI Trawl Survey	
Time of Survey (yr)	0	
Time of Catch (yr)	0.8	
Nat Mortality Rate	0.15	
Relative Catchability: Recruits to Full Recruits s_r	0.5	
Average Partial Recruitment Rate to Fishery	2.95E-01	
Catchability Estimate and CV	7.49E-01	0.15

Survey Year	Stock Size Estimates (millions at time of Survey): Recruits	Stock Size Estimates (millions at time of Survey): Full Recruits	Total Mortality: Z_all size	Fishing Mortality on: Recruits	Fishing Mortality on: Full-Recruits
1982	2.468	0.178	2.19	1.76	5.96
1983	2.271	0.295	2.59	1.91	6.48
1984	2.612	0.193	2.29	1.84	6.23
1985	2.042	0.284	1.96	1.4	4.74
1986	2.3	0.328	2.28	1.64	5.56
1987	2.797	0.268	2.28	1.76	5.95
1988	3.325	0.316	1.84	1.4	4.73
1989	4.053	0.58	1.82	1.28	4.35
1990	4.119	0.763	2.55	1.76	5.95
1991	3.83	0.379	2.25	1.73	5.86
1992	4.69	0.443	2.17	1.67	5.66
1993	3.959	0.588	2.89	2.09	7.08
1994	2.813	0.254			





Note that the recruit population estimate for the last year (1994) is NOT a least squares estimate.
Rather, it is calculated from the observed survey indecx, the least squares estimate of q and the s_r

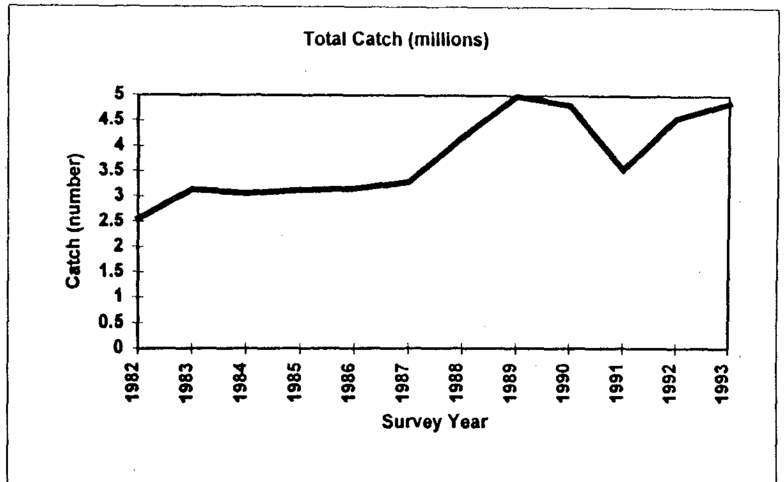
Table B18. Summary of DeLury model estimates of abundance and mortality for female lobsters in the South of Cape Cod to Long Island Sound stock.

Survey Year	Indices of Abundance: Recruits	Indices of Abundance: Full-Recruits	Total Catch (millions)
1982	0.1941	0.0118	2.552716
1983	0.2901	0.0938	3.132246
1984	0.4438	0.2116	3.061005
1985	0.4896	0.0153	3.122812
1986	0.4005	0.0368	3.15151
1987	1.4759	0.3234	3.288121
1988	0.8276	0.2193	4.178341
1989	1.0999	0.2851	4.989376
1990	1.0366	0.164	4.813554
1991	0.6828	0.1928	3.540432
1992	1.3276	0.2508	4.561052
1993	1.7121	0.2098	4.854244
1994	0.8474	0.3362	

Input File Name	R127.dat	
Tuning Dataset	RI Trawl Survey	
Time of Survey (yr)	0	
Time of Catch (yr)	0.8	
Nat Mortality Rate	0.15	
Relative Catchability: Recruits to Full Recruits s_r	0.5	
Average Partial Recruitment Rate to Fishery	2.95E-01	
Catchability Estimate and CV	1.69E-01	0.28

Survey Year	Stock Size Estimates (millions at time of Survey): Recruits	Full Recruits	Total Mortality: Z_all size	Fishing Mortality on: Recruits	Full-Recruits
1982	3.407	0.07	1.92	1.69	5.71
1983	4.15	0.511	1.56	1.12	3.8
1984	2.659	0.975	3.73	2.18	7.4
1985	3.73	0.087	2.87	2.58	8.75
1986	4.866	0.215	1.35	1.09	3.7
1987	5.181	1.314	1.2	0.71	2.39
1988	4.943	1.963	1.4	0.75	2.52
1989	5.307	1.702	1.88	1.1	3.71
1990	5.835	1.069	1.78	1.19	4.03
1991	4.601	1.165	1.41	0.85	2.87
1992	5.822	1.411	1.53	0.94	3.18
1993	8.554	1.573	1.07	0.67	2.27
1994	9.919	3.472			

Note that the recruit population estimate for the last year (1994) is NOT a least squares estimate.
Rather, it is calculated from the observed survey indecx, the least squares estimate of q and the s_r



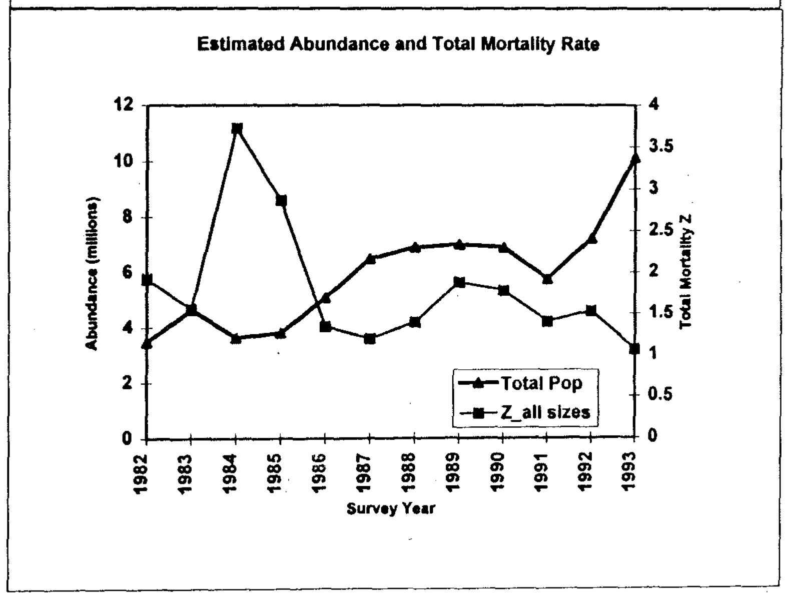
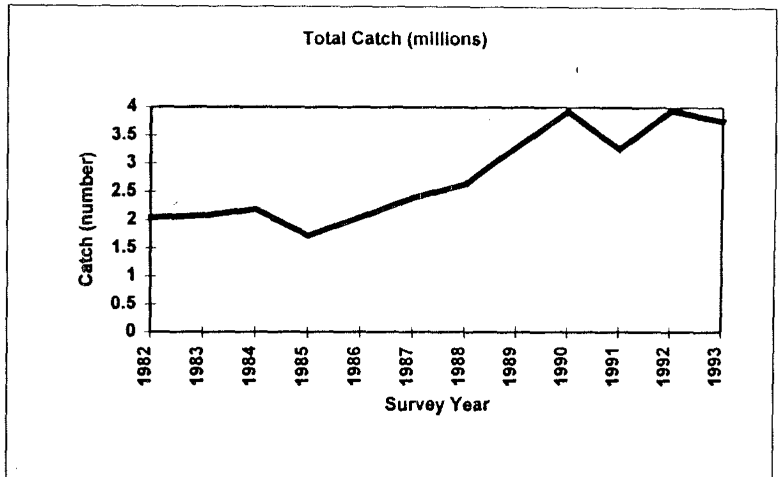


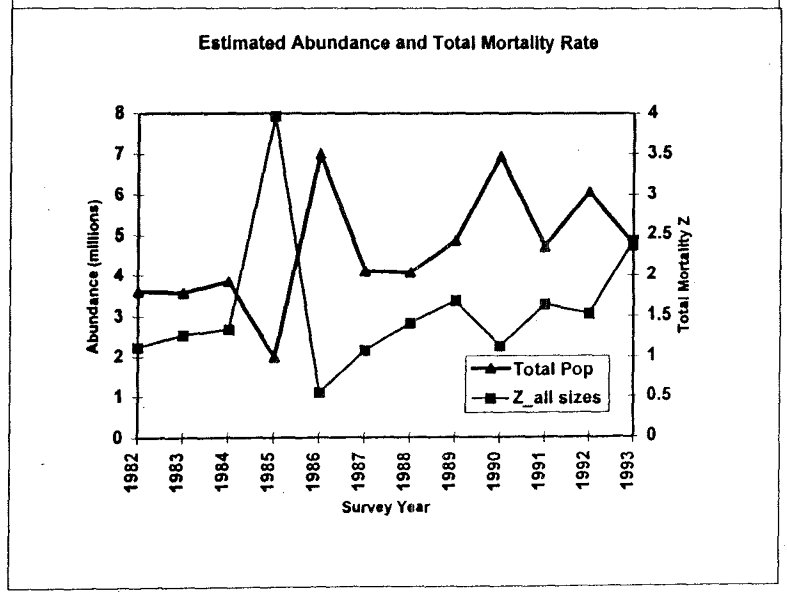
Table B19. Summary of DeLury model estimates of abundance and mortality for male lobsters in the South of Cape Cod to Long Island Sound stock.

Survey Year	Indices of Abundance: Recruits	Indices of Abundance: Full-Recruits	Total Catch (millions)
1982	0.1567	0.4291	2.048701
1983	0.5009	0.4971	2.08319
1984	1.5085	0.3626	2.192189
1985	0.6744	0.6091	1.724307
1986	0.9863	0	2.053807
1987	0	0.2248	2.393535
1988	0.298	0.6208	2.630755
1989	1.7305	0.4054	3.303225
1990	0.5934	0.163	3.931714
1991	0.2582	0.5719	3.270125
1992	1.4898	0.3266	3.951377
1993	0.8558	0.356	3.766668
1994	0.2742	0.1019	

Input File Name	R111.dat	
Tuning Dataset	NMFS Trawl Survey	
Time of Survey (yr)	0	
Time of Catch (yr)	0.8	
Nat Mortality Rate	0.15	
Relative Catchability: Recruits to Full Recruits s_r	0.5	
Average Partial Recruitment Rate to Fishery	2.95E-01	
Catchability Estimate and CV	2.89E-01	0.26

Survey Year	Stock Size Estimates (millions at time of Survey): Recruits	Stock Size Estimates (millions at time of Survey): Full Recruits	Total Mortality Z_all size	Fishing Mortality on Recruits	Fishing Mortality on Full-Recruits
1982	1.468	2.143	1.12	0.4	1.36
1983	2.391	1.18	1.27	0.63	2.13
1984	2.842	0.999	1.34	0.73	2.49
1985	0.988	1.005	3.97	1.73	5.87
1986	6.966	0.038	0.55	0.4	1.34
1987	0.073	4.038	1.08	0.28	0.94
1988	2.679	1.402	1.42	0.7	2.37
1989	3.879	0.983	1.69	1.04	3.51
1990	6.047	0.899	1.13	0.75	2.53
1991	2.472	2.248	1.64	0.7	2.36
1992	5.154	0.916	1.53	1.01	3.44
1993	3.433	1.315	2.42	1.37	4.63
1994	1.984	0.421			





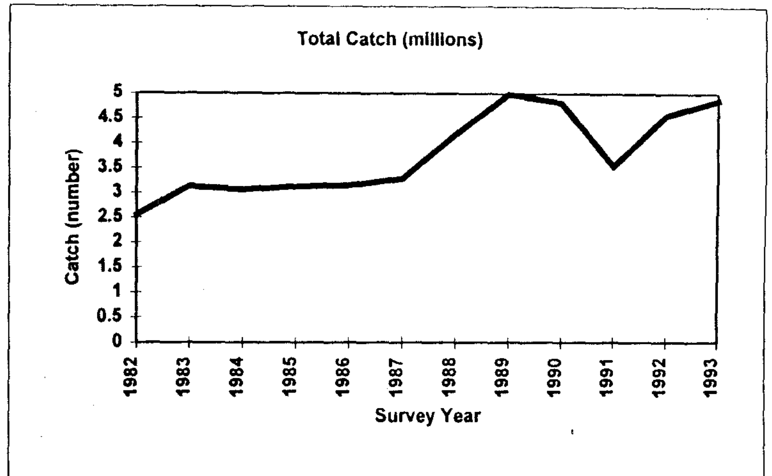
Note that the recruit population estimate for the last year (1994) is NOT a least squares estimate.
Rather, it is calculated from the observed survey indecx, the least squares estimate of q and the s_r

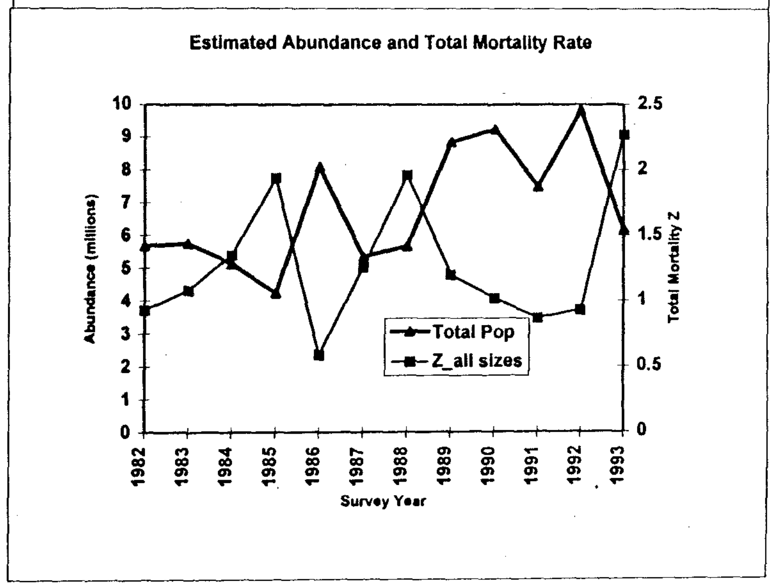
Table B20. Summary of DeLury model estimates of abundance and mortality for female lobsters in the South of Cape Cod to Long Island Sound stock.

Survey Year	Indices of Abundance: Recruits	Indices of Abundance: Full-Recruits	Total Catch (millions)
1982	0.8935	0.8614	2.552716
1983	0.5206	0.5129	3.132246
1984	0.9957	1.0306	3.061005
1985	0.681	0.3739	3.122812
1986	0.4932	0.173	3.15151
1987	0.1223	1.2389	3.288121
1988	1.2932	0.847	4.178341
1989	2.0383	0.2404	4.989376
1990	1.0328	0.733	4.813554
1991	0.5665	0.9781	3.540432
1992	1.3831	1.3891	4.561052
1993	0.2445	0.5251	4.854244
1994	0.1371	0.2462	

Input File Name	R137.dat	
Tuning Dataset	NMFS Trawl Survey	
Time of Survey (yr)	0	
Time of Catch (yr)	0.8	
Nat Mortality Rate	0.15	
Relative Catchability: Recruits to Full Recruits s_	0.5	
Average Partial Recruitment Rate to Fishery	2.95E-01	
Catchability Estimate and CV	3.57E-01	0.18

Survey Year	Stock Size Estimates (millions at time of Survey): Recruits	Stock Size Estimates (millions at time of Survey): Full Recruits	Total Mortality: Z_all size	Fishing Mortality on: Recruits	Fishing Mortality on: Full-Recruits
1982	3.62	2.061	0.93	0.42	1.42
1983	3.51	2.237	1.08	0.48	1.64
1984	3.187	1.944	1.35	0.63	2.13
1985	2.91	1.331	1.94	1.03	3.47
1986	7.488	0.607	0.59	0.37	1.25
1987	0.844	4.505	1.26	0.37	1.25
1988	4.155	1.516	1.96	1.11	3.75
1989	8.048	0.797	1.2	0.87	2.93
1990	6.591	2.657	1.02	0.52	1.76
1991	4.171	3.321	0.87	0.35	1.18
1992	6.689	3.148	0.93	0.44	1.49
1993	2.295	3.893	2.27	0.85	2.87
1994	0.819	0.637			





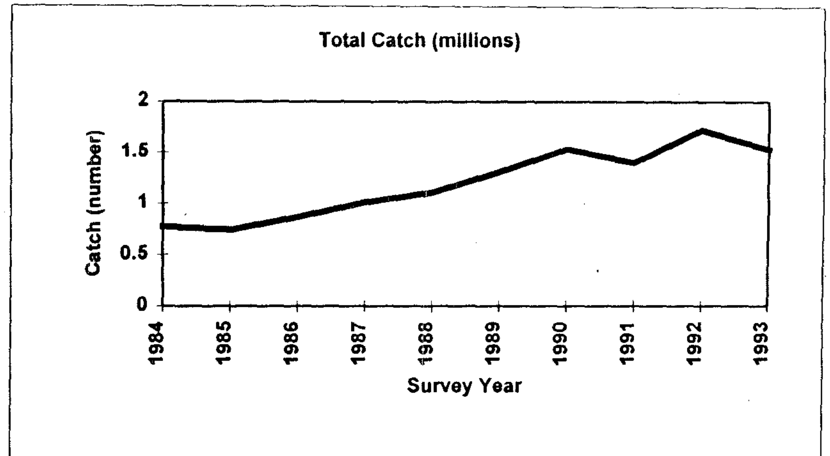
Note that the recruit population estimate for the last year (1994) is NOT a least squares estimate.
Rather, it is calculated from the observed survey indecx, the least squares estimate of q and the s_r

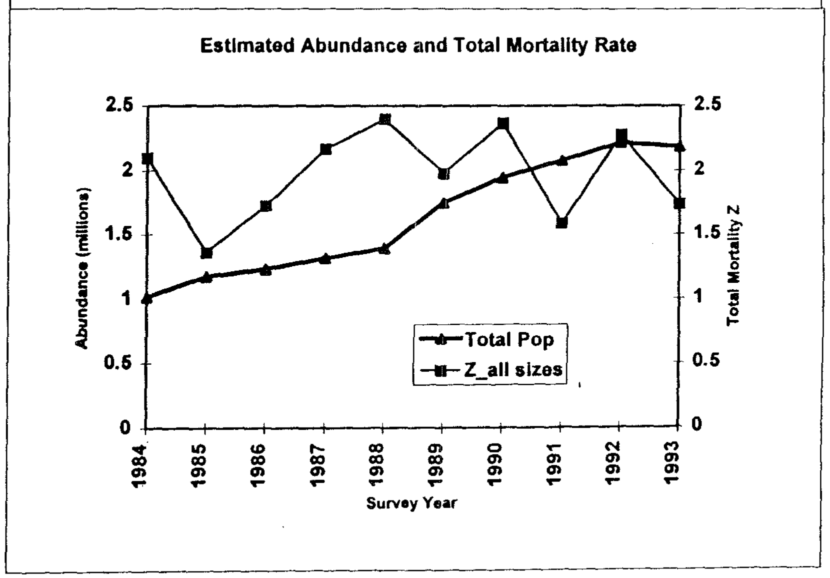
Table B21. Summary of DeLury model estimates of abundance and mortality for male lobsters in the Central and Western Long Island Sound subarea.

Survey Year	Indices of Abundance: Recruits	Indices of Abundance: Full-Recruits	Total Catch (millions)
1984	4.9903	2.6064	0.771932
1985	3.2532	1.0238	0.740622
1986	5.0757	3.3687	0.866484
1987	5.6689	1.9679	1.010114
1988	3.7752	1.297	1.106395
1989	5.6289	1.206	1.306375
1990	6.443	2.285	1.539579
1991	9.063	1.7369	1.404832
1992	10.7202	4.1511	1.731156
1993	11.8492	2.0836	1.535548
1994	10.2975	3.344	

Input File Name	R202.dat	
Tuning Dataset	CT Trawl Survey	
Time of Survey (yr)	0	
Time of Catch (yr)	0.8	
Nat Mortality Rate	0.15	
Relative Catchability: Recruits to Full Recruits s	0.5	
Average Partial Recruitment Rate to Fishery	2.95E-01	
Catchability Estimate and CV	9.73E+00	0.09

Survey Year	Stock Size Estimates (millions at time of Survey): Recruits	Stock Size Estimates (millions at time of Survey): Full Recruits	Total Mortality _all size	Fishing Mortality on Recruits	Fishing Mortality on Full-Recruits
1984	0.766	0.251	2.1	1.23	4.16
1985	1.051	0.124	1.36	0.96	3.27
1986	0.93	0.302	1.73	1	3.38
1987	1.097	0.218	2.17	1.45	4.9
1988	1.242	0.15	2.4	1.79	6.05
1989	1.624	0.127	1.98	1.56	5.28
1990	1.705	0.242	2.37	1.71	5.79
1991	1.897	0.182	1.59	1.19	4.02
1992	1.793	0.425	2.28	1.46	4.95
1993	1.959	0.227	1.74	1.27	4.31
1994	2.226	0.385			





Note that the recruit population estimate for the last year (1994) is NOT a least squares estimate.
Rather, it is calculated from the observed survey indecx, the least squares estimate of q and the s_r

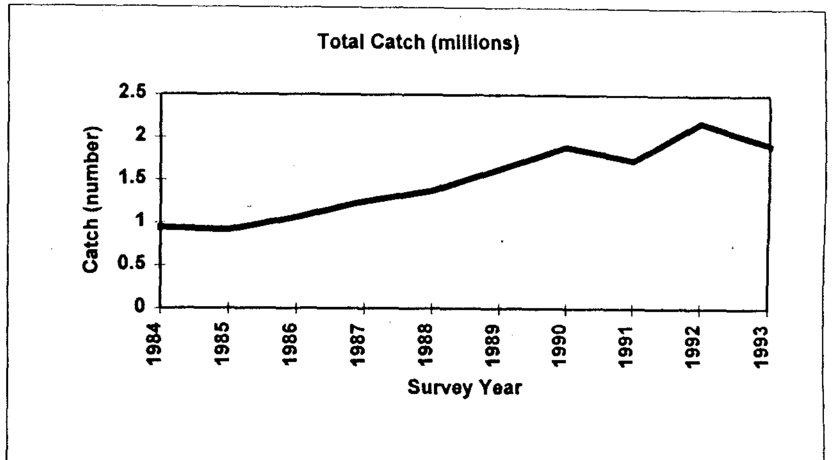
Table B22. Summary of DeLury model estimates of abundance and mortality for female lobsters in the Central and Western Long Island Sound subarea.

Survey Year	Indices of Abundance: Recruits	Indices of Abundance: Full-Recruits	Total Catch (millions)
1984	3.9969	2.8063	0.937531
1985	2.7317	1.1749	0.913313
1986	3.3177	1.5318	1.063519
1987	2.9784	1.6312	1.253175
1988	2.7538	0.7932	1.377666
1989	1.8969	0.6113	1.630143
1990	2.8125	1.0986	1.896661
1991	3.5766	1.0009	1.739839
1992	2.2561	1.2561	2.180703
1993	3.9401	1.1398	1.921098
1994	3.5432	1.6154	

Input File Name	R227.dat	
Tuning Dataset	CT Trawl Survey	
Time of Survey (yr)	0	
Time of Catch (yr)	0.8	
Nat Mortality Rate	0.15	
Relative Catchability: Recruits to Full Recruits s	0.5	
Average Partial Recruitment Rate to Fishery	2.95E-01	
Catchability Estimate and CV	3.75E+00	0.15

Survey Year	Stock Size Estimates (millions at time of Survey): Recruits	Stock Size Estimates (millions at time of Survey): Full Recruits	Total Mortality _all size	Fishing Mortality on: Recruits	Fishing Mortality on: Full-Recruits
1984	1.071	0.542	1.31	0.65	2.18
1985	1.132	0.434	1.26	0.67	2.26
1986	1.324	0.445	1.32	0.73	2.48
1987	1.225	0.473	1.95	1.08	3.67
1988	1.526	0.24	2.27	1.6	5.41
1989	1.984	0.183	2.01	1.55	5.23
1990	2.159	0.291	2.2	1.6	5.41
1991	2.14	0.272	1.82	1.32	4.47
1992	2.406	0.389	2.25	1.57	5.33
1993	2.389	0.296	1.79	1.3	4.4
1994	1.999	0.448			

Note that the recruit population estimate for the last year (1994) is NOT a least squares estimate.
Rather, it is calculated from the observed survey indecx, the least squares estimate of q and the s_r



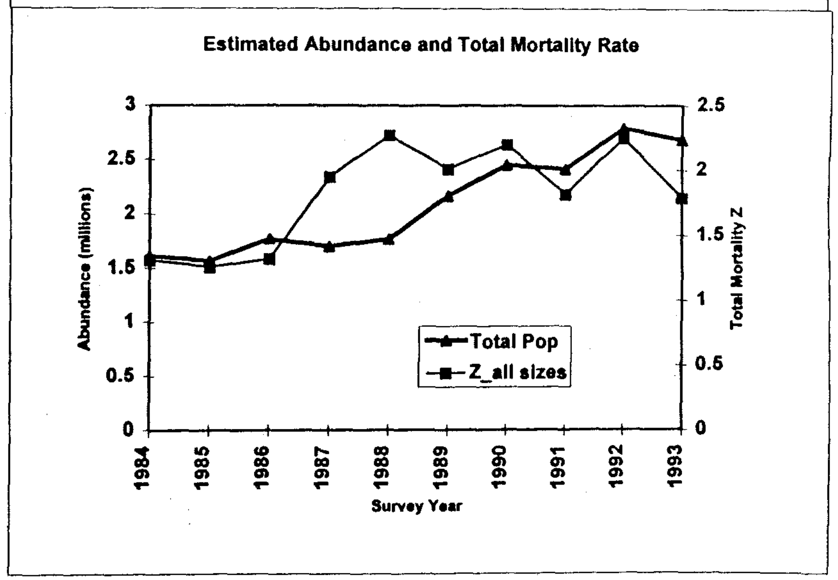


Table B23. Summary of catchability estimates and gear efficiency estimates for American lobster. Average area swept by NMFS trawl is 0.01 nm^2.

Stock	Trawl Survey	Sex	Delury Catchability Coefficient q	Strata Area (nm^2)	Ave. area (a) swept nm^2	Probability of Capture Given Encounter
GOM	NMFS	M	0.019	18470	0.01000	0.0351
		F	0.0284	18470		0.0525
GBS	NMFS	M	0.0982	41680	0.01000	0.4093
		F	0.0902	41680		0.3760
SCCLIS	NMFS	M	0.289	2413	0.01000	0.0697
		F	0.357	2413		0.0861
	RI	M	0.749	2413	0.00743	0.2433
		F	0.169	2413		0.0549
CWLIS	CT	M	9.73	871	0.01328	0.6380
		F	3.75	871		0.2459

Table B24. Summary of bootstrap estimates of average fishing mortality rates for lobsters (recruits plus full-recruits) by stock area and sex for the pooled survey years 1991-1993. No bias adjustment was applied to bootstrap estimates. The 1993 survey year includes catches through the third calendar quarter of 1994 and the 1994 survey results. Natural mortality was set to 0.15 for all runs and relative catchability of recruits was set to 0.5.

Stock	Sex	Tuning Index (Trawl Survey)	Survey Years	Run No. ID	Deterministic Estimate	Bootstrap Estimates of Average F (1991-1993)					
						Mean	10%-ile	25%ile	Median	75%-ile	90%ile
Gulf of Maine	M	NMFS	'82-93	2	0.4481	0.5268	0.3531	0.4288	0.5023	0.6148	0.7089
	F	NMFS	'82-93	27	0.6236	0.6682	0.5126	0.5720	0.6545	0.7452	0.8450
Georges Bank and South	M	NMFS	'81-93	52	0.9400	0.9531	0.8950	0.9245	0.9540	0.9817	1.0037
	F	NMFS	'81-93	77	0.5052	0.5213	0.4582	0.4944	0.5212	0.5513	0.5765
Southern Cape Cod and Long Island Sound	M	Rhode Island	'82-93	102	2.2848	2.2690	2.0700	2.1765	2.2748	2.3761	2.4510
	F	Rhode Island	'82-93	127	1.1847	1.2969	1.1026	1.1720	1.2617	1.4064	1.5474
	M	NMFS	'82-93	111	1.7140	1.8560	1.5300	1.6643	1.8147	2.0241	2.2301
	F	NMFS	'82-93	137	1.2058	1.2882	1.0867	1.1819	1.2839	1.3737	1.5105
Central and Western Long Island Sound	M	CT	'84-93	202	1.7179	1.6843	1.5696	1.6216	1.6881	1.7421	1.7936
	F	CT	'84-93	227	1.8031	1.7793	1.5877	1.6764	1.7886	1.8796	1.9547

Table B25. Population states for female lobsters.

LOBSTER EPR/YPR MODEL POPULATION STATES

gp general population

- protected by fishing only by size (min or max)
- can stay in this state, at size, up to 7 years
- must molt into new size ku or general population

ku internally fertilized

- protected by fishing only by size (min or max)
- can stay in this state, at size, only 1 year
- must molt into new size egg bearing

eb egg bearing

- total[1] protection from fishing regardless of size
- can stay in this state, at size, for 3 quarters, then must return to general population at same size for remaining quarter

vn v-notched

- total[1] protection from fishing regardless of size
- selected from egg bearing state each of 1st three quarters, and will be egg bearing for the 1st three quarters of the year in which they were notched
- can stay in this state, at size, for up to 7 years, then move to new size into either the vn_2 or kuvn state

vn_2 v-notched the previous molt (e.g., 2nd year of v-notch)
- total[1] protection from fishing regardless of size
- selected from previous year's v-notches
- not egg bearing, not internally fertilized
- can stay in this state, at size, for up to 7 years, then move to new size into general population

kuvn v-notched the previous molt (e.g., 2nd year of v-notch) <u>and</u> internally fertilized

- total[1] protection from fishing regardless of size
- can stay in this state, at size, only 1 year
- must molt into new size egg bearing

dm double molter

- a two quarter holding bin for those that will molt twice in a year
- must molt in quarter 3 to new size, 1st year of general population

1 this can be altered to allow non-compliance of regulations (e.g., scrubbing and the landing berried females)

Table B26. Parameters used for calculating biological reference points for three assessment areas for female American lobster.

Parameter		Gulf of Maine	Georges-South	S. Cape Cod-LIS
		Assessment Area		
Molt Probability[1]	α	-8.08127	-6.867	-13.39
	β	0.076535	0.058	0.1459
Molt Increment (mm)		11	7 - 22	11
Fecundity[2]	α	0.0010178	0.00658	0.0005046
	β	3.58022	3.1569	3.7580
Proportion[3] Ovigerous	α	-18.3270	-18.256	-9.720
	β	0.1957	0.18299	0.1032
Proportion V-Notched		0.5	0.0	0.0
Min/Max Size (mm)		83/127	83/NA	83/NA
Proportion Max Size		0.71	0.0	0.0
Length/Weight[4]	α	0.001167	0.000833998	0.001365
	β	2.9194	2.972	2.88726
M(hardshell)		0.10	0.10	0.10
M(softshell)[5]		0.05	0.05	0.05
Proportion of Effort (by quarter: Oct-Dec, Jan-Mar, Apr-Jun, Jul-Sep)		[0.18/0.06/0.14/0.62]	[0.33/0.17/0.20/0.30]	[0.28/0.07/0.19/0.46]

[1] Logistic model: $P_i = 1/[1 + \exp(\alpha + \beta CL)]$
[2] Power Function: $f = \alpha\ CL^{\beta}$
[3] Logistic model: $M_i = 1/[1 + \exp(\alpha + \beta CL)]$
[4] Power Function: $W = \alpha + CL^{\beta}$
[5] Additional mortality at time of molting

Table B27. Calculated F_{MAX} and $F_{10\% EPR}$ values for female lobsters by assessment area. F values and realized rates for the stock (see text). Nominal F values are shown in parentheses.

Area	$F_{10\% EPR}$	F_{MAX}
GOM	0.32 (0.57)	0.24 (0.4)
GBK	0.36 (0.56)	0.15 (0.2)
SCC-LIS	0.44 (0.75)	0.33 (0.5)

$F_{10\% EPR}$ is the fishing mortality rate resulting in a calculated lifetime egg production per recruit female equal 10% of egg production at F=0.

Table B28. Summary of Lobster Review Panel recommendations and comments by Invertebrate Subcommittee.

Panel Recommendation	**Progress/Response of Invertebrate Subcommittee**	
	Progress/Comments	**Future Work**
A. STOCK STRUCTURE		
1. Compile existing tagging data-transfer rates	CMER request for proposal prepared. URI Fisheries has been conducting a tagging study since 1994; Rhode Island DEM began an offshore tagging study in May 1996. Existing tagging studies were identified and summarized in the March 1996 paper presented to the Review Panel by the CT DEP.	Development of an integrated database may be useful particularly if coupled with GIS technology. RI studies will continue for forseeable future (probably 5 years).
2. Genetic Studies	Work in progress using micro satellite DNA markers (Irv Konfield, U. Maine, Orono)	Assess utility of satellite DNA. Apply throughout range if promising. Genetic identity of LIS population should be examined.
3. Assess Regional Contribution to Total Egg Production	Estimated approximate potential egg production from NMFS survey indices. Ongoing monitoring and sea sampling studies in RI, MA, ME and CT will provide additional information .	Spatial mapping of survey indices and projected egg production will be conducted.
4. Compile Existing Larval Data - Transfer Rates	Compilation of larval data by Fogarty (Editor) 1983. Stage IV larvae production time series from 1983-1995 has been compiled (M. Blake, CT DEP).	Will require coupling larval information with 3-D Hydrodynamic model. Connecticut time series will be continued for recruitment index. Flux of larvae with Block Island Sound could be quantified with increased spatial sampling but costs may be prohibitive.
5. Investigate Spatial Differences in Demography	Theoretical model of spatially distributed populations developed	Full parameterization of spatially distributed population model will be difficult but partial parameterization will add considerable insights.
B. LANDINGS/EFFORT/LPUE		
1. Develop Time Series of Standardized LPUE-Index Fishers	Massachusetts may have available data to examine. Licensing system in RI makes this unlikely. In Connecticut, preliminary analyses of a time series of standardized LPUE available beginning 1979 from fishers' logbook report data is summarized in report.	In RI, need better information from licensing requirements. Analysis of CT Logbook data is ongoing
2. Quantify Changes in Spatial Distribution of Effort	Data were never collected on a spatial scale sufficient to resolve important differences in fishing effort of inshore fishers. Anecdotal comments of fishers suggest gradual expansion of fishing effort offshore. Sea sampling data in MA demonstrate progressive increase in fraction of landings from outside state territorial waters. Additional insight be obtainable by examining behavior of individual fishers. Within LIS, changes in spatial distribution of effort can be quantified according to logbook fishing areas.	Begin new time series on fine scale estimation of fishing effort and investigate existing data more thoroughly.
3. Develop Area-Specific Data/Effort/LPUE	Usual approaches applied to standardization of LPUE for active gear (eg., trawl) not appropriate due to saturation effects and temperature dependencies of catch process for passive trap gear.	Will need to develop appropriate nonlinear statistical models to estimate standardized fishing effort

Table B28. (Continued)

4. *Increase Coverage of Offshore Fishery*	NMFS sponsored sea-sampling studies were intensified in 1992 and have been used to characterize size composition of offshore fishery in Statistical Area 515. RI has conducted sea-sample trips for offshore fisheries in offshore areas since 1991. Offshore landings, effort, CPUE of a small number of CT licenseholders that fish offshore are documented through logbook system. Information on other offshore regions is lacking.	Intensify sampling studies in GOM, and GB&S.
5. *Conduct Cooperative Studies with Fishers (Gear Efficiency)*	SeaGrant proposal underway with ME, NH, MA, RI fishers. See Cobb et al.	Sea Grant project to continue for 3 yrs; methodology will be continued by RI/DEM
C. DELURY ANALYSES		
1. *Evaluate Potential Biases Due to Incomplete Coverage in Different Substrates*	LCA method deals with this issue indirectly by ignoring the fishery independent measures. Sensitivity analyses of model to the relative catchability of full recruits and prerecruits was conducted.	Fine-scale habitat mapping may be useful for defining sampleable habitat, refinement of sample stratification may be possible.
2. *Analyze Effect of Different Spatial Combinations of Survey Stations*	Partially addressed; SCCLIS stock which was subdivided into WLIS.	Generalized additive models using location and substrate type may be useful for improving abundance indices. Catch data are now available by Statistical Area and quarter--permits appropriate matching of survey data with catches.
3. *Undertake Sensitivity Analyses*	Model results were examined over a range of input values.	Modeling studies planned to address panel recommendations.
4. *Introduce Routine Measures of Uncertainty*	Bootstrapping methodology was applied to each stock by sex. Empirical distributions of population and mortality estimates were generated and compared with biological reference points.	Monte Carlo studies of Delury model planned to address additional sources of uncertainty in model formulation.
5. *Examine Selectivity for Pre-recruit and Recruit Lobsters*	Sensitivity analyses in model were conducted	Post-stratification analyses of NMFS survey with respect to temperature and time of day may reduce apparent interannual variability.
6. *Investigate effects of spatial distribution/movements/ selectivity*	Tagging studies underway at URI may provide insights.	Simulations modeling studies planned.
7. *Examine Fixed vs. Random Sampling*	No analyses could be performed although the "partial replacement" sampling design has been considered for the the multispecies NMFS trawl survey. Limited implementation of such surveys have begun (winter??).	
8. *Examine Use of Multiple Survey Indices*	**Model was revised to examine inclusion of an independent estimate of total mortality. Should be possible to examine effects for SCCLIS stock in which two trawl surveys are available. For GOM and GB&S ancillary information from standardized LPUE series would need to be generated.**	Generalization of Delury model to multiple indices is easily done but operational performance (i.e., estimability of parameters) will need to be investigated via simulation studies.
D. LENGTH-COHORT ANALYSIS		
1. *Contine Development of LCA and Compare with DeLury Analysis*	Comparisons made with Delury model.	Revision of Egg-per-recruit model will allow development of testable hypotheses with respect to expected length frequency distributions. Such results, coupled with expected frequencies in field samples, could improve interpretation of results.
2. *Compare Fishery Dependent and Fishery Independent Length Frequencies*	Not done for this meeting. Seasonal decomposition of catch length frequencies improves comparability with survey.	Easily done but care necessary to match appropriate time period of fishery with survey. Large differences in size composition of inshore and offshore samples noted.

Table B28. (Continued)

3. *Include Spatial Component*	No work done for this meeting.	Linked populations can easily be generated; estimability of unique parameters is unknown but expected to be difficult owing to the large sampling variation in survey indices.
E. FISHING MORTALITY AND FISHING EFFORT		
1. *Develop Time Series of Standarized Fishing Effort - Compare with F*	Assembled available data on fishing effort and identified sources of additional data. Discussed applicability of this approach and concluded the nonlinear standardization methods will have to be developed to account for saturation and temperature effects. Data sets may be limited but initial attempts should focus on Maine data sets.	Will evaluate alternative methods for catch standardization and identify limitations of existing data.
F. EGG PRODUCTION PER RECRUIT		
1. ***Examine Sensitivity of F (10%) to Input Parameters***	Limited analyses conducted.	Revised model structure now allows for greater realism in basic processes and seasonality of population biology and fishery.
2. ***Examine Effects of Measurement Errors***	Intent of Panel in its draft report was unclear.	Review final draft of Panel Report for clarification.
3. ***Define Acceptable Level of Risk***	No progress on this aspect. Committee felt that these assignment of acceptable risk levels should be left to managers.	Simulation studies of static and dynamic model should provide distribution of expected outcomes given alternative fishing mortalities and harvest policies.
4. ***Examine Spatial Differences in F (10%)***	Model parameterized for four stock areas. Additional refinements not possible due to need for additional life history studies.	Further life-history work necessary.
5. ***Include Reproductive Output of Sub-Legal Lobster Where Needed***	Model revised to incorporate this process.	
6. ***Include Process Error in Growth, Reproduction, etc.***	Incorporated frequency distribution of growth increments for Georges Bank parameterization.	Monte Carlo studies planned to incorporate uncertainty in key processes including probabilities of molting, becoming ovigerous, and growth increments
7. ***Evaluate Effects of Mating Behavior, Sex Ratios, Size Structure***	Revised model can be used to generate realistic predictions of size compositions under different fishing mortality schedules.	Experimental work is necessary to identify implications of altered size composition and sex ratio on reproductive output.
G. FUTURE ASSESSMENT METHODS		
1. ***Deveop Models with Enhanced Size/Stage Structure***		
2. ***Include Multiple Input Series***		
3. ***Continue Use of Delury Model and LCA***		

Table B28. (Continued)

F. CHANGES IN ABUNDANCE AND RECRUITMENT		
1. Examine temperature, effort, and abundance effects on catch	Preliminary time series models for effects of temperature and effort on catch developed. (ME, MA, RI). Useful data sets for LIS have not yet been identified.	Need to incorporate abundance in models. Will sharply restrict available data series length.
2. Undertake regional examination of temperature-yield relationship	Time series models developed for ME, MA.	Expand analysis to other areas.
3. Use comparative approach (temperature, larval drift etc.)	Comparative evaluations of reproductive rates with respect to temperature have been made.	Plan for regional comparative study.
4. Examine trap effects on catch	Preliminary analysis completed for ME, MA, CT.	Finalize models, expand to other areas as possible.
5. Examine temperature effects on growth, reproduction, etc.	Completed for several Canadian locations.	Will require extensive program to obtain growth and maturity data over several years
6. Examine effects of predation, regime shifts, etc.	Analysis of NEFSC Food Habits data for lobsters as prey completed. Literature search completed. No evidence of changes in physical environment.	No clear evidence of dramatic predation effect. Will require directed studies to refine this evaluation.
7. Develop monitoring plan to detect recruitment decline	Sea Grant study in progress.	Implement Sea Grant Pilot Projection-broad scale if successful.
8. Promote Canada-US coordinated studies	Joint participation by Canada & US Scientists on assessment and planning committees accomplished.	Develop assessments which include Gulf of Maine, Bay of Fundy, Scotian Shelf.
G. BENTHIC ECOLOGY	limited discussion on this topic by Invertebrate Subcommittee.	
1. Establish field studies of density-dependent processes	Work underway by Wahle, Steneck.	
2. Test thermal limit hypothesis	Preliminary work by Steneck.	Initiated bottom temperature study in 1995.
3. Establish wide-scale collector program	Cooperative Sea Grant project underway.	

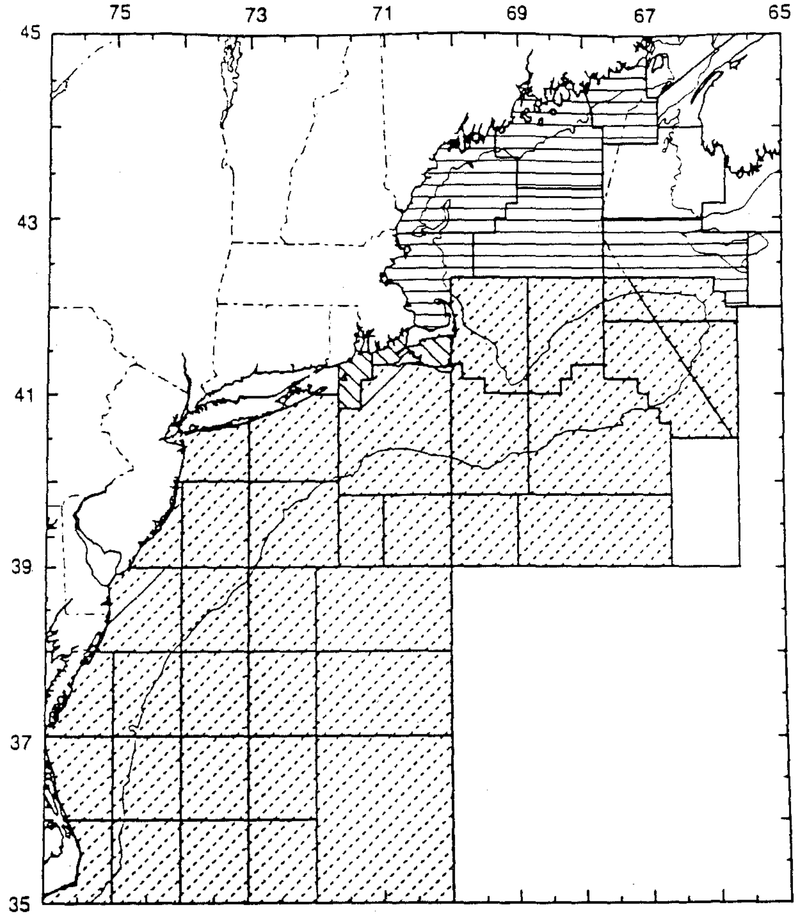


Figure B1. Statistical areas comprising stocks of American lobster.

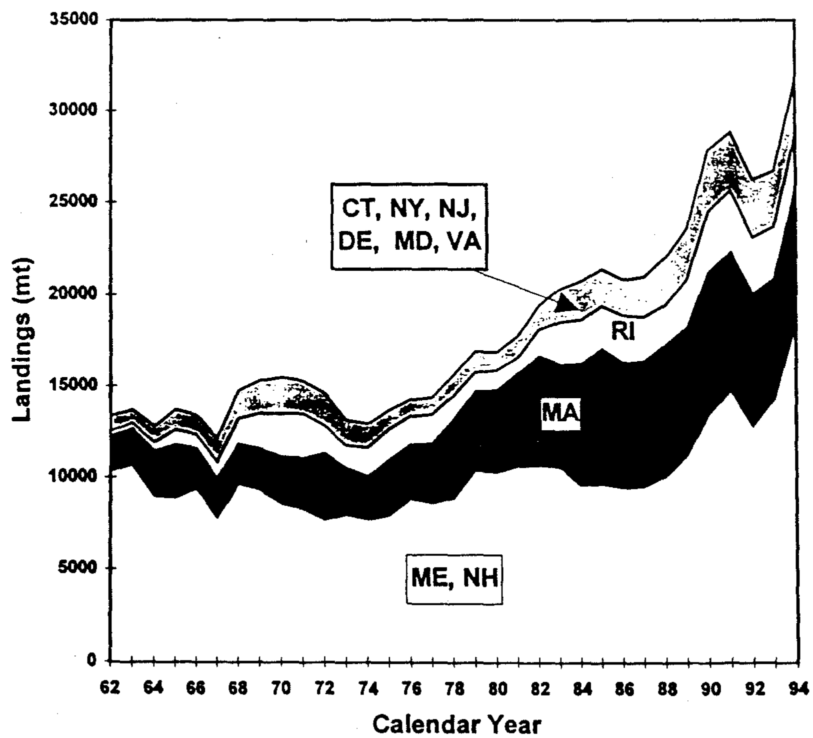


Figure B2. Summary of total commercial landings by state, 1962-1994.

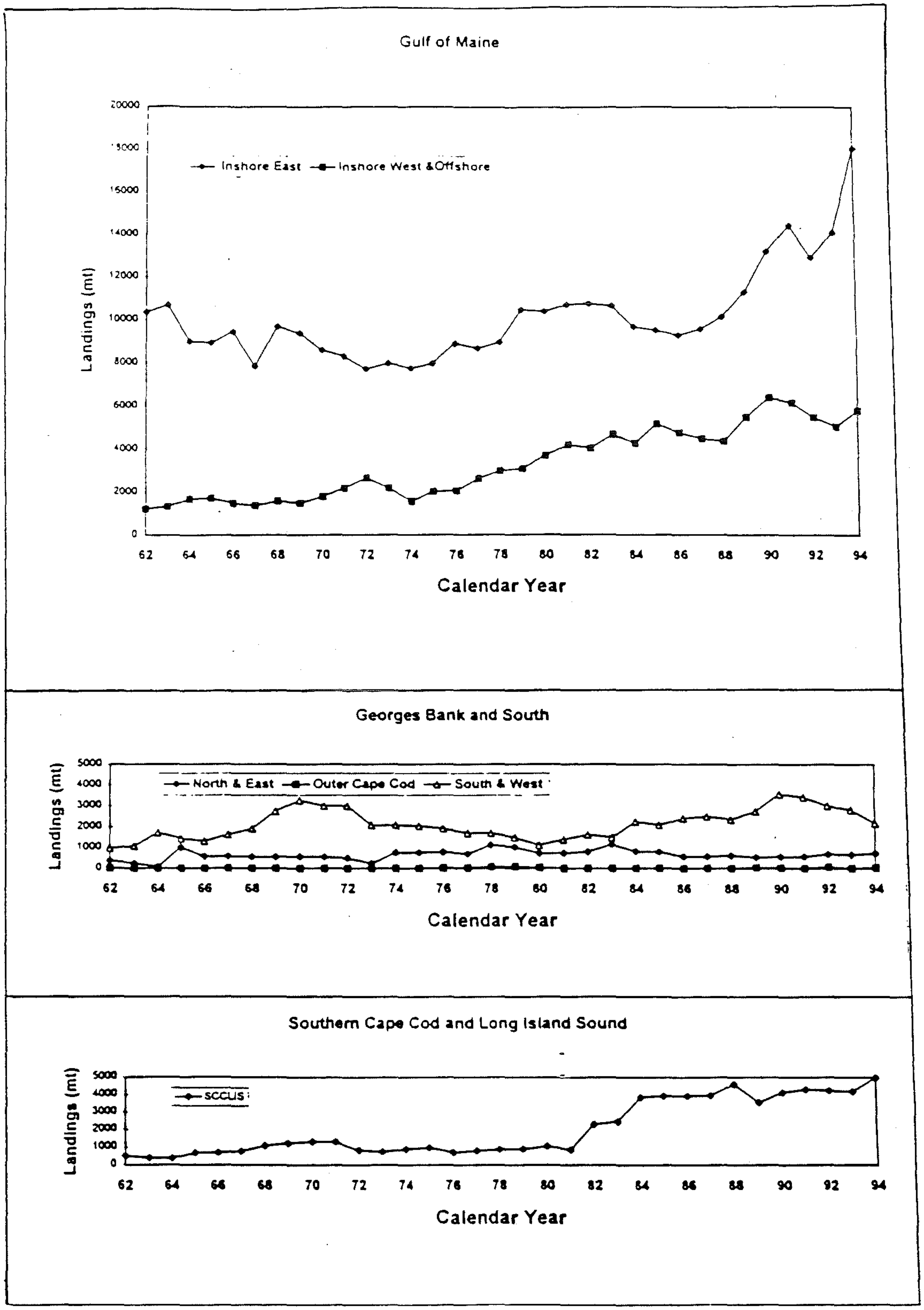


Figure B3. Summary of total commercial landings (mt) by stock area, 1962-1994.

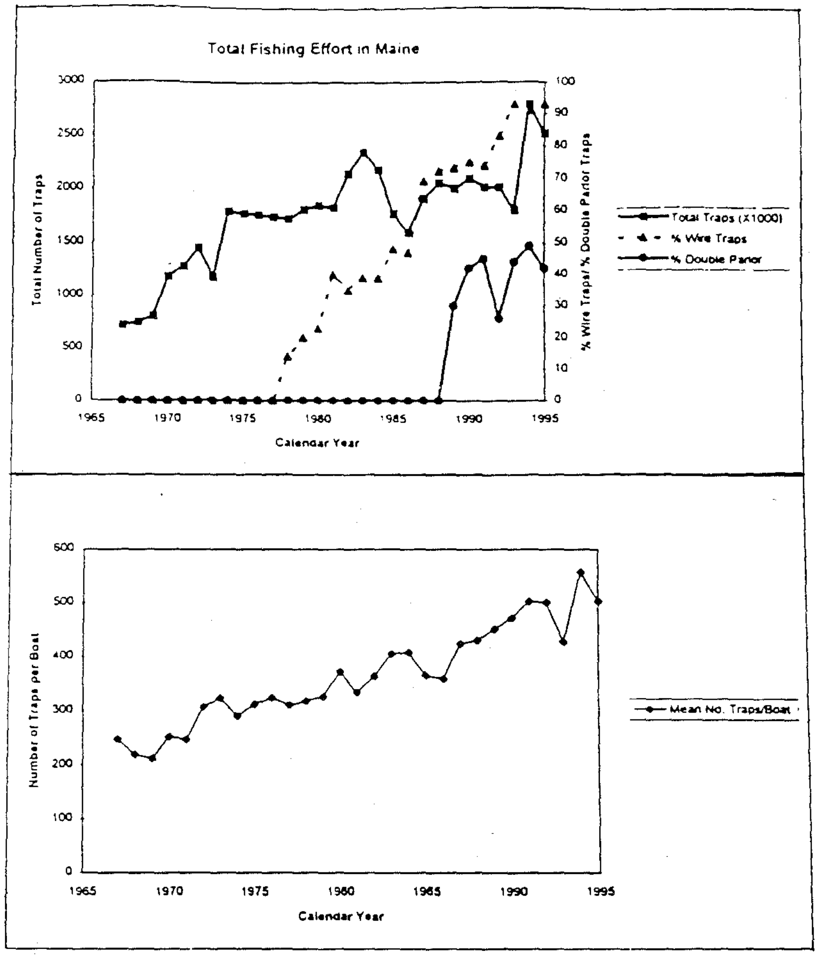


Figure B4. Trends in fishing effort in Maine (data source: J. Krouse and K. Kelly, Maine Department of Marine Resources).

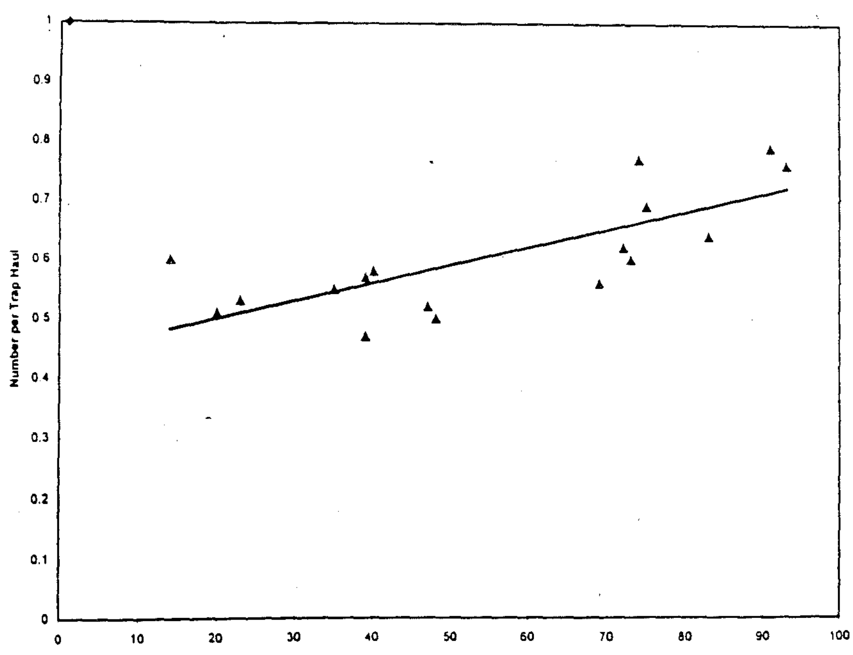


Figure B5. Catch rates (number per trap haul) of lobsters as a function of the percent of wire traps in the Maine trap fishery, 1978-1992.

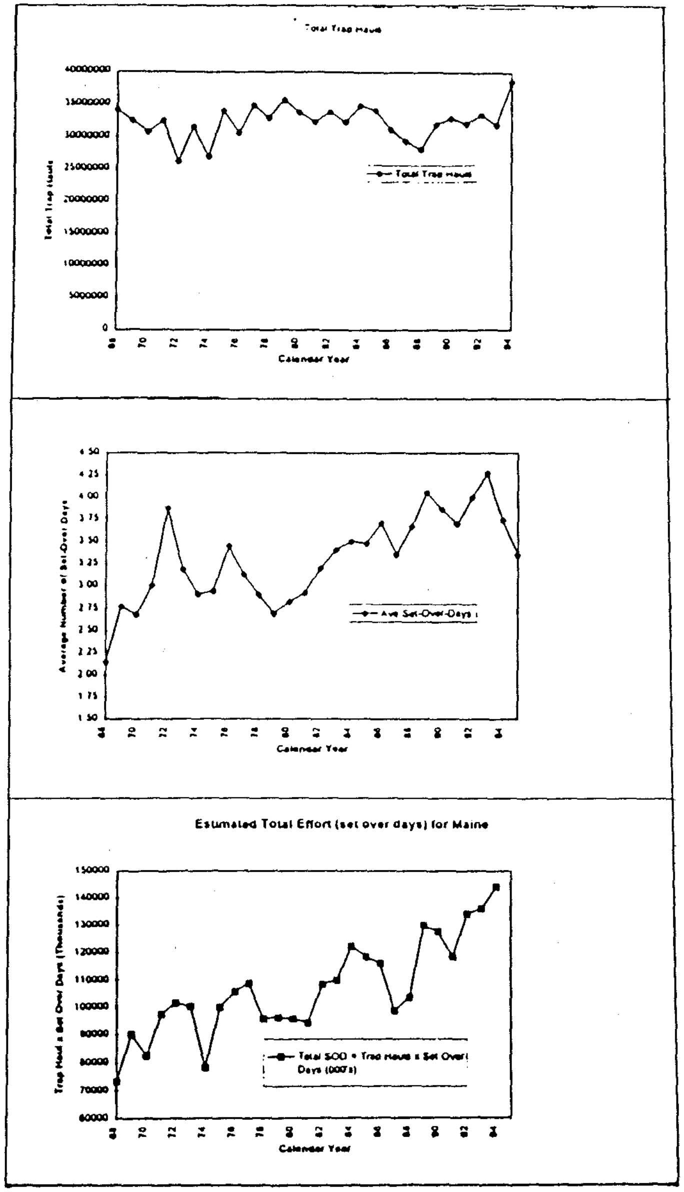


Figure B6. Estimated total number of trap hauls, average soak time (set-over days), and total effort for Maine lobster fishery, 1968-1994. (Data source: J. Krouse and K. Kelly, MEDMR.)

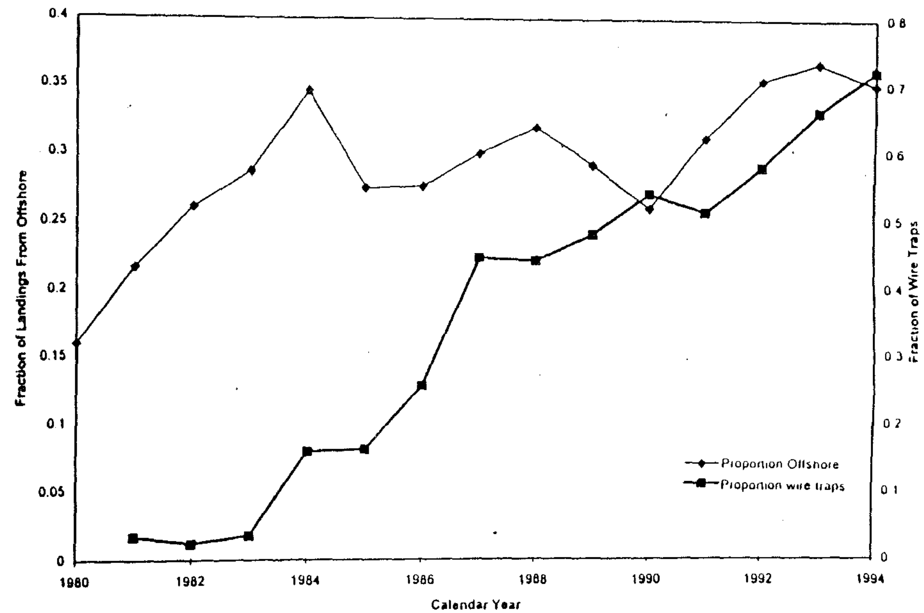


Figure B7. Fraction of Massachusetts landings caught outside state territorial waters, and proportion of wire traps observed in sea sampling trips during 1980-1994. (Data source: B. Estrella, MADMF).

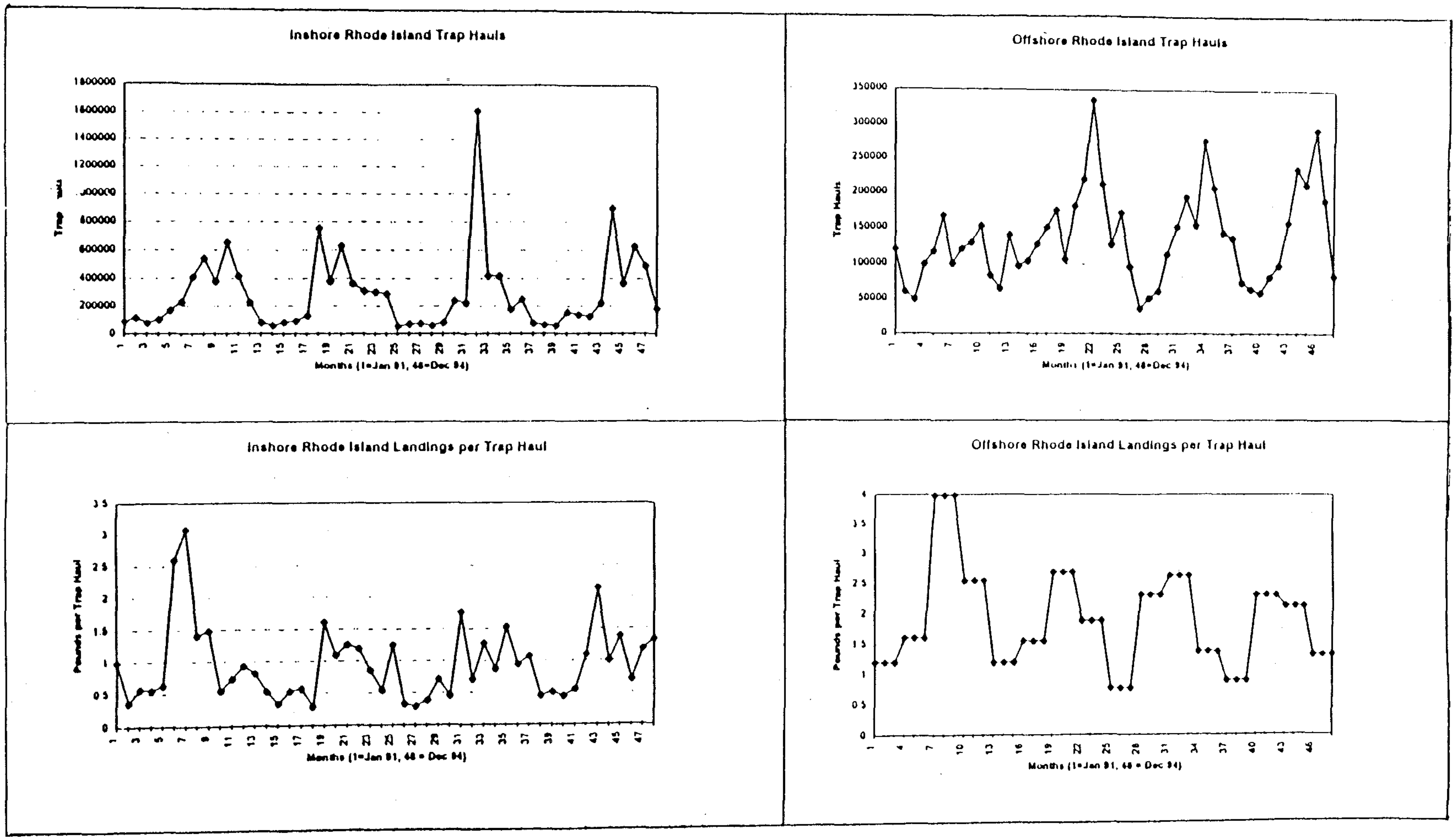


Figure B8. Trends in number of trap hauls and landings (lbs) for Rhode Island inshore and offshore lobster fisheries. (Data source: T. Angell, RI Department of Environmental Management).

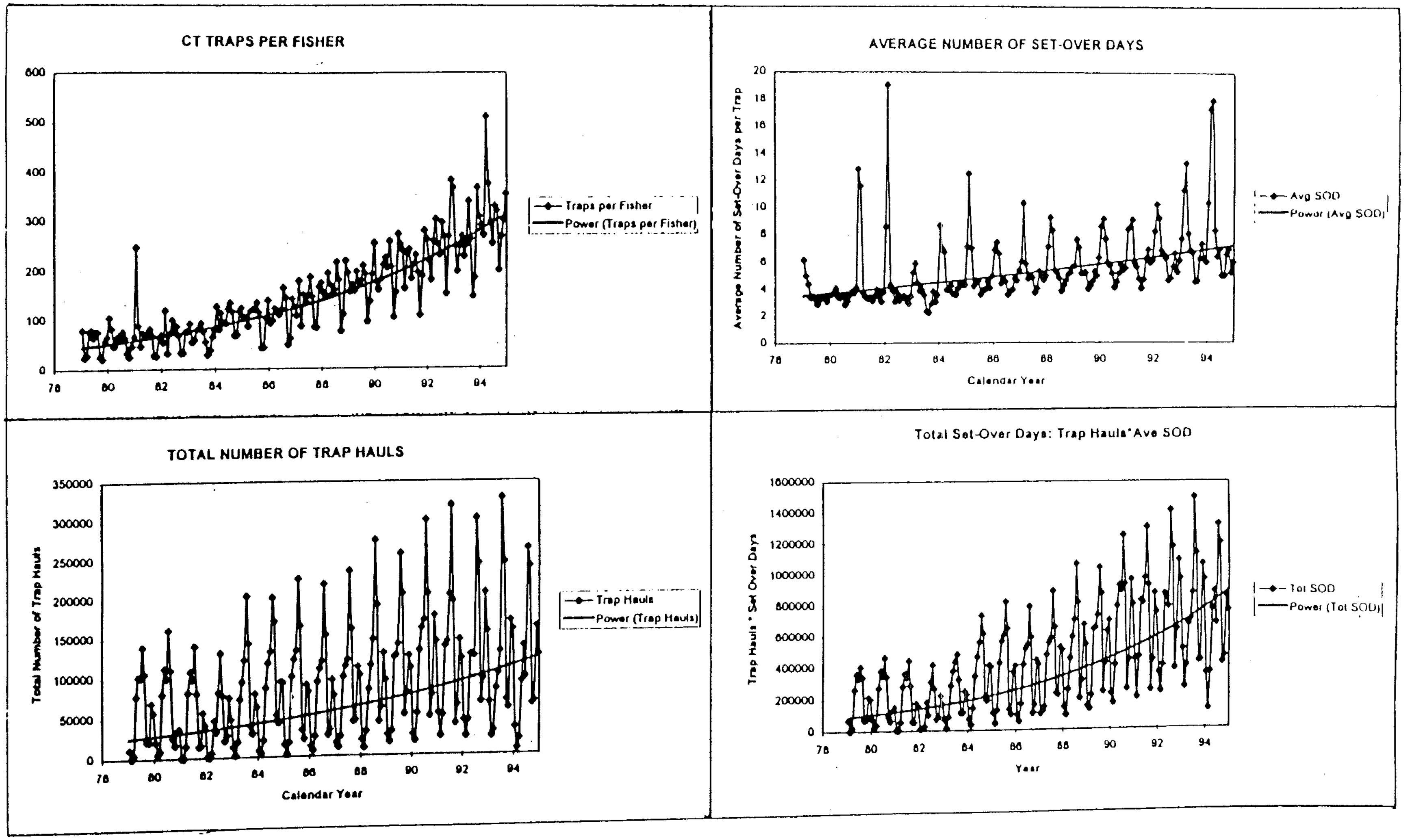


Figure B9. Trends in fishing effort in Central and Western Long Island Sound based on Connecticut resident commercial fishermen monthly logbooks.

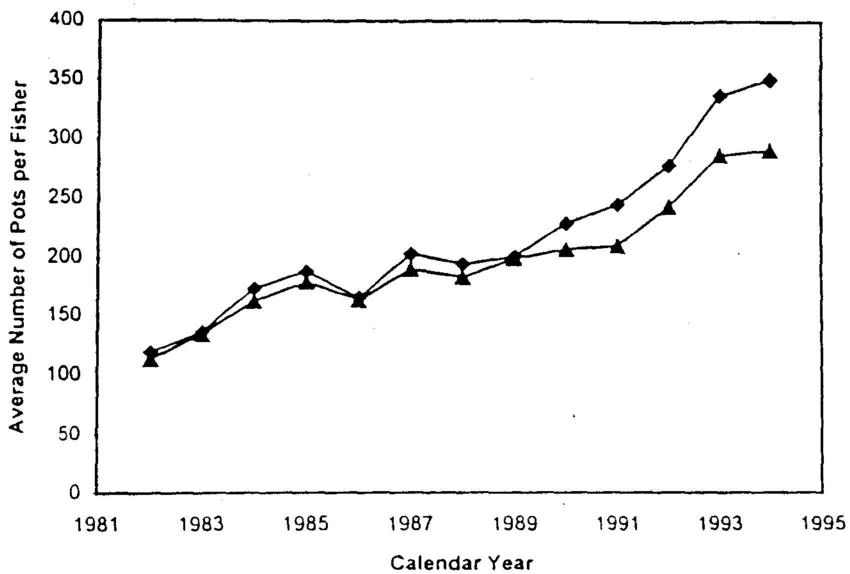


Figure B10. Estimated number of pots per fishermen for New York residents fishing in Long Island Sound and Statistical Area 611. (Data source: NY lobster permit applications.)

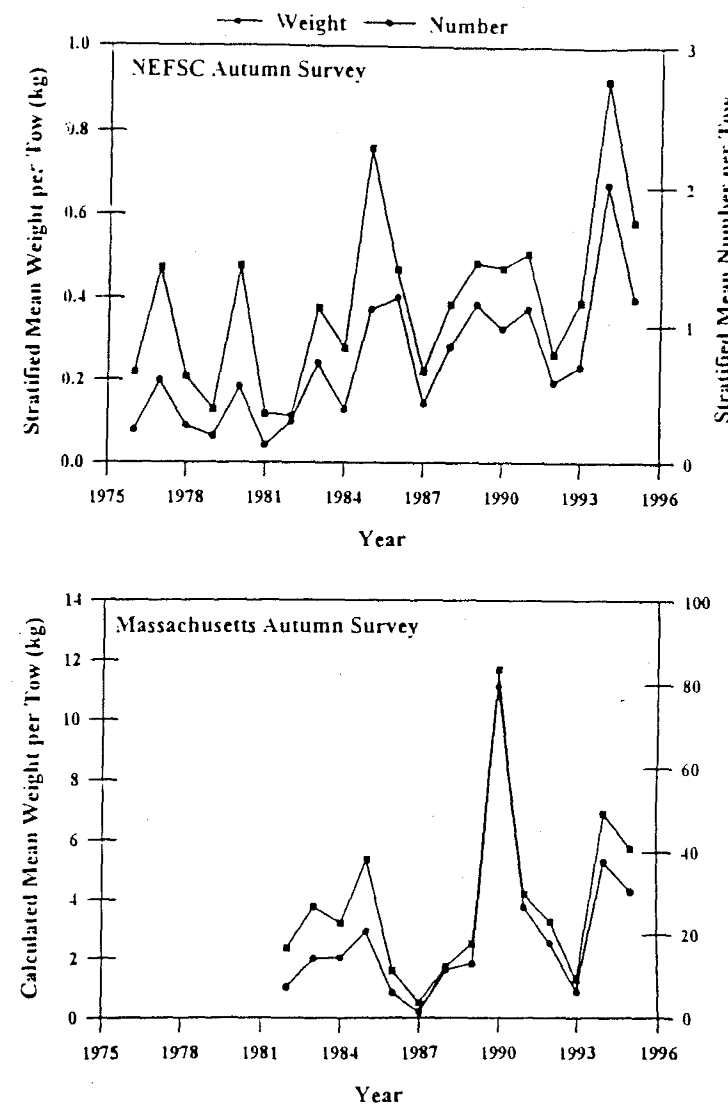


Figure B11. NEFSC and Massachusetts autumn bottom trawl survey indices (weight per tow and number per tow) for female lobsters in the Gulf of Maine assessment area.

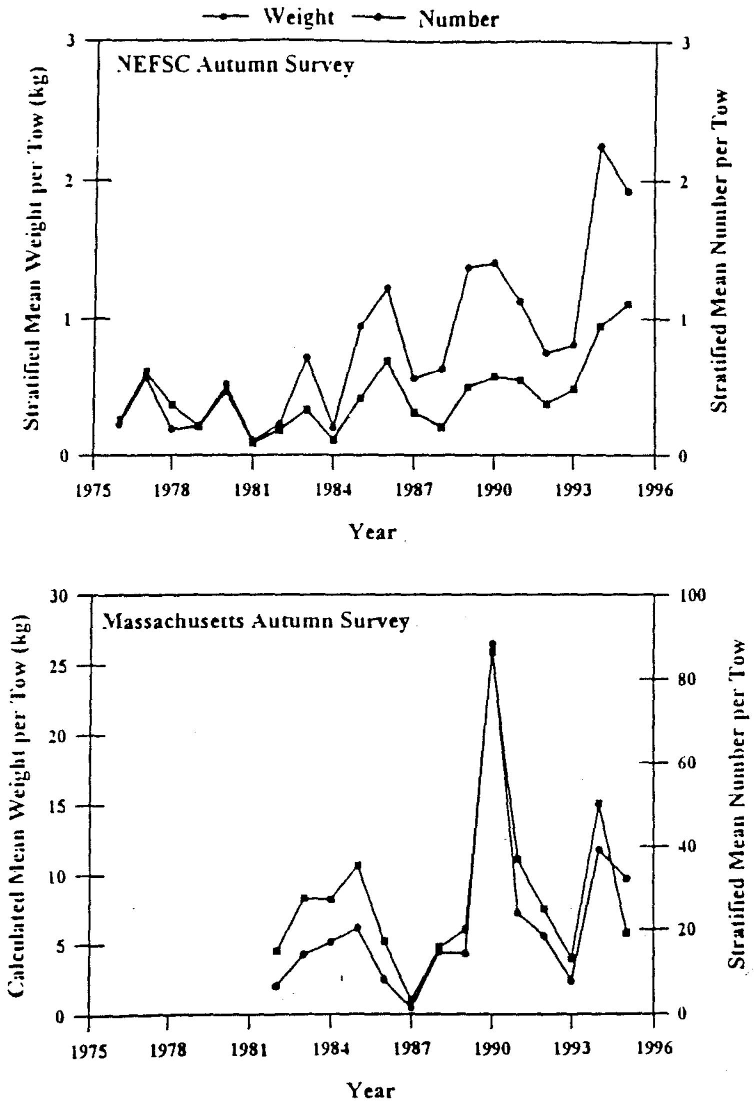


Figure B12. NEFSC and Massachusetts autumn bottom trawl survey indices (weight per tow and number per tow) for male lobsters in the Gulf of Maine assessment area.

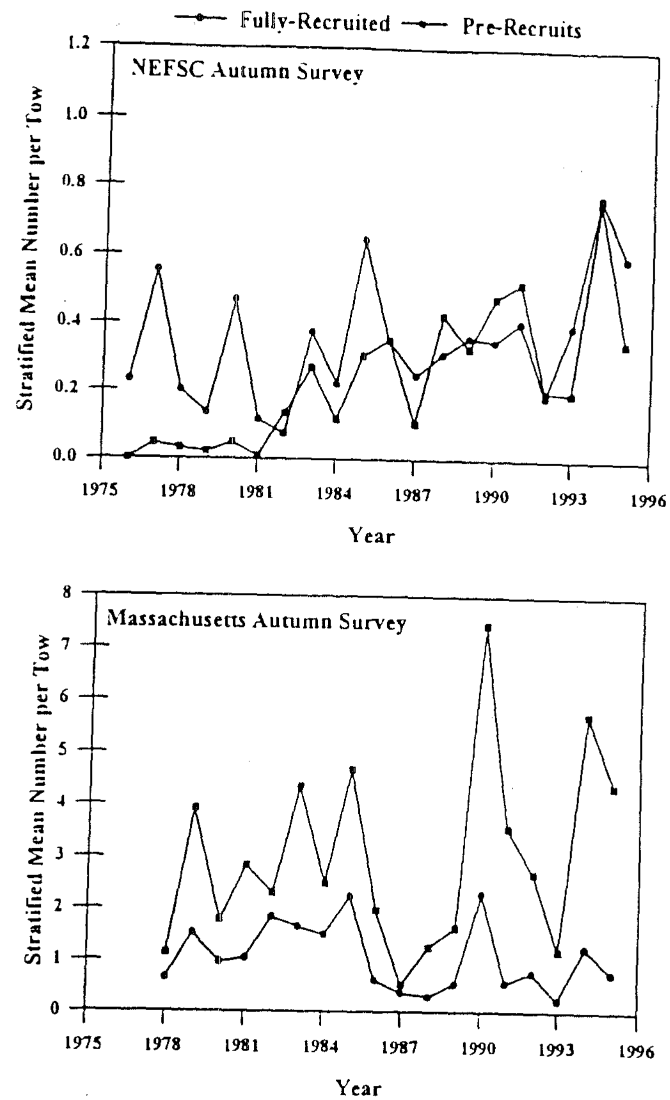


Figure B13. NEFSC and Massachusetts autumn bottom trawl survey indices (number per tow) for pre-recruit and fully-recruited female lobsters in the Gulf of Maine assessment area.

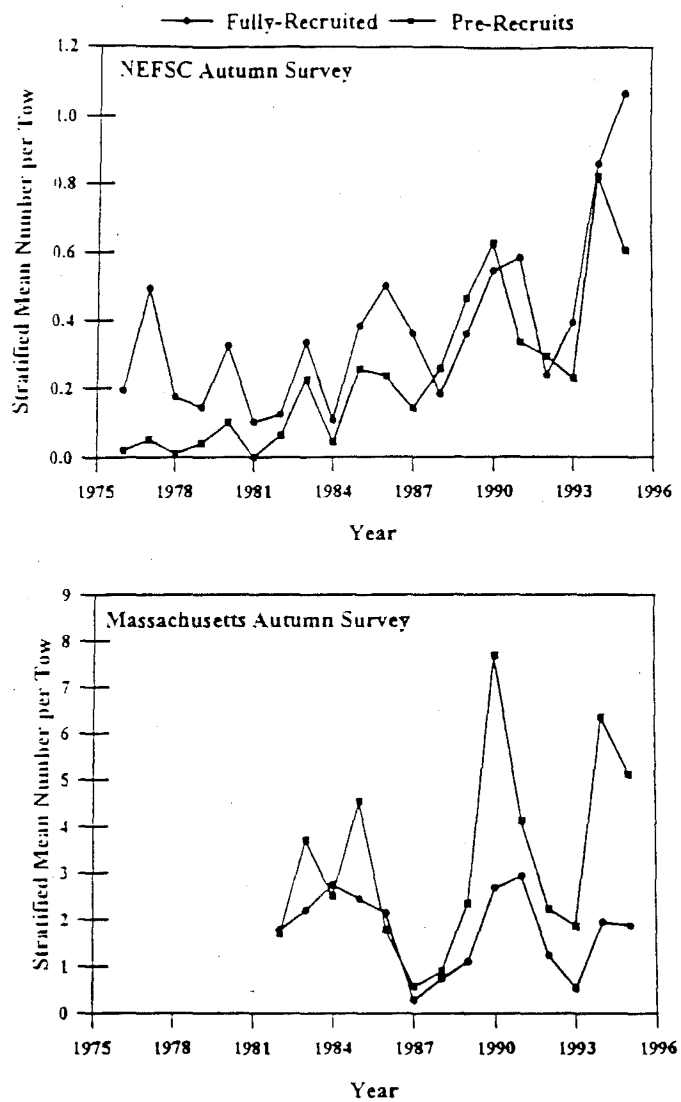


Figure B14. NEFSC and Massachusetts autumn bottom trawl survey indices (number per tow) for pre-recruit and fully-recruited male lobsters in the Gulf of Maine assessment area.

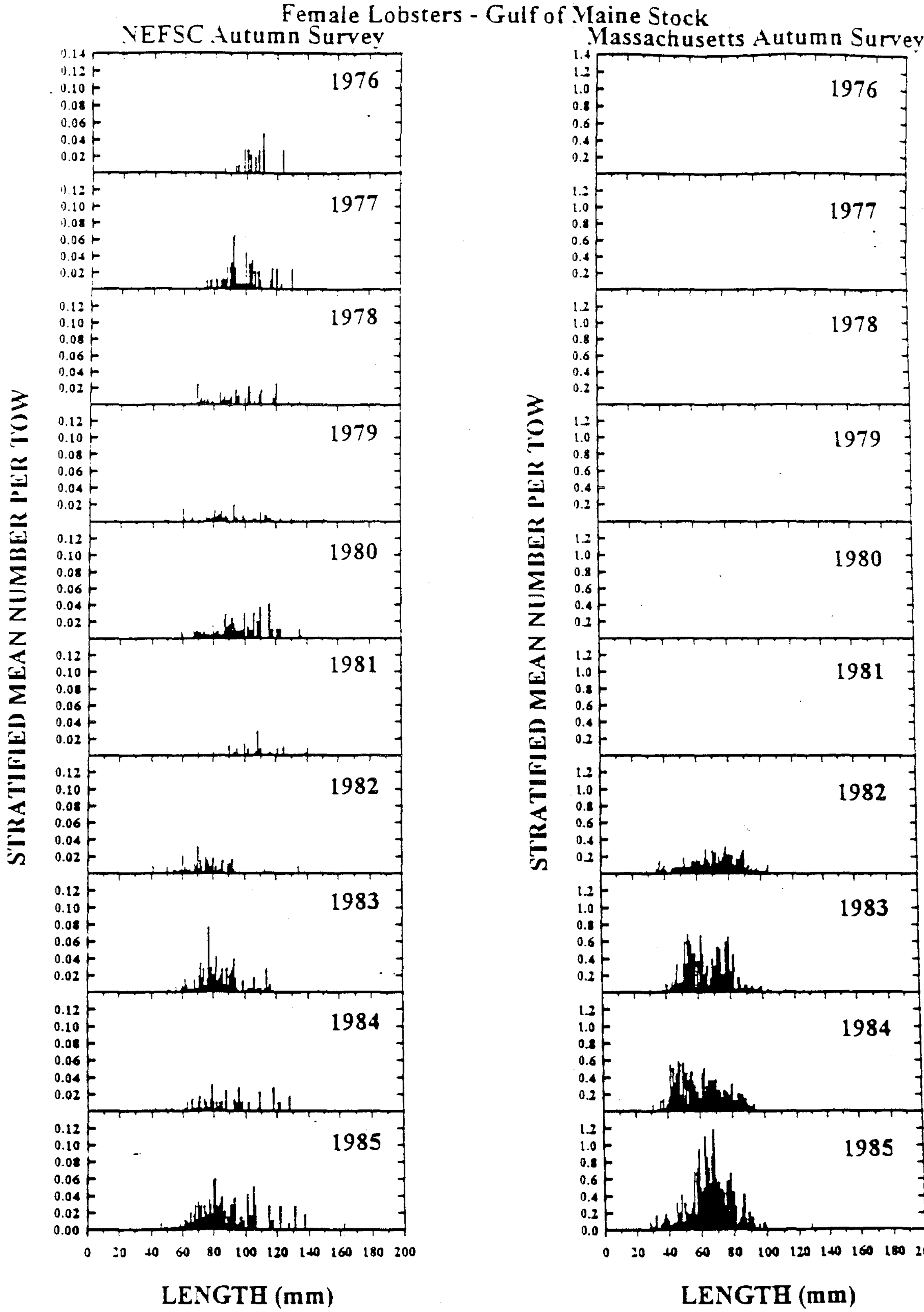


Figure B15. Stratified mean number per tow at length (carapace length, mm) for female lobsters in the Gulf of Maine assessment area from NEFSC and Massachusetts autumn bottom trawl surveys.

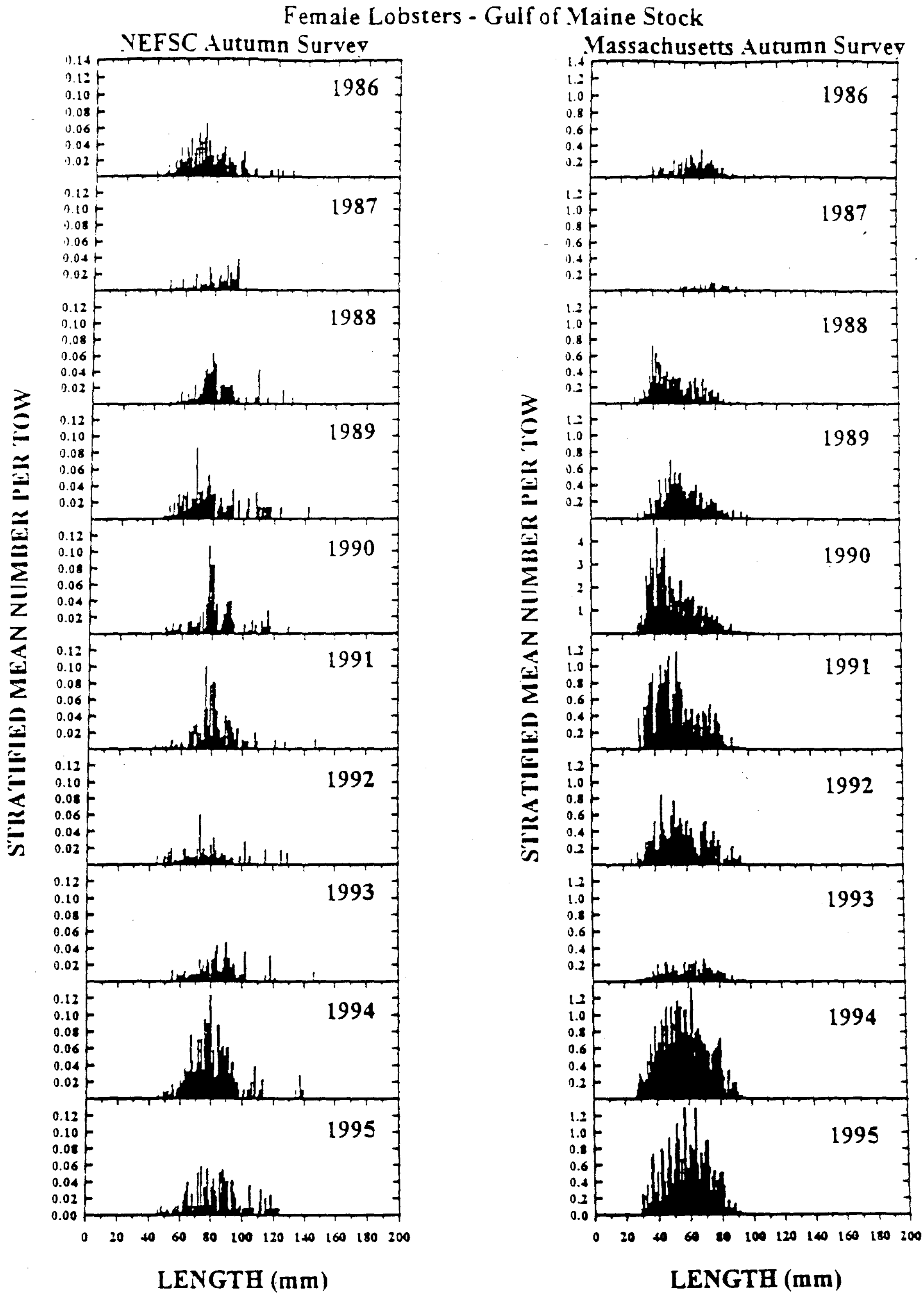


Figure B15. (Continued)

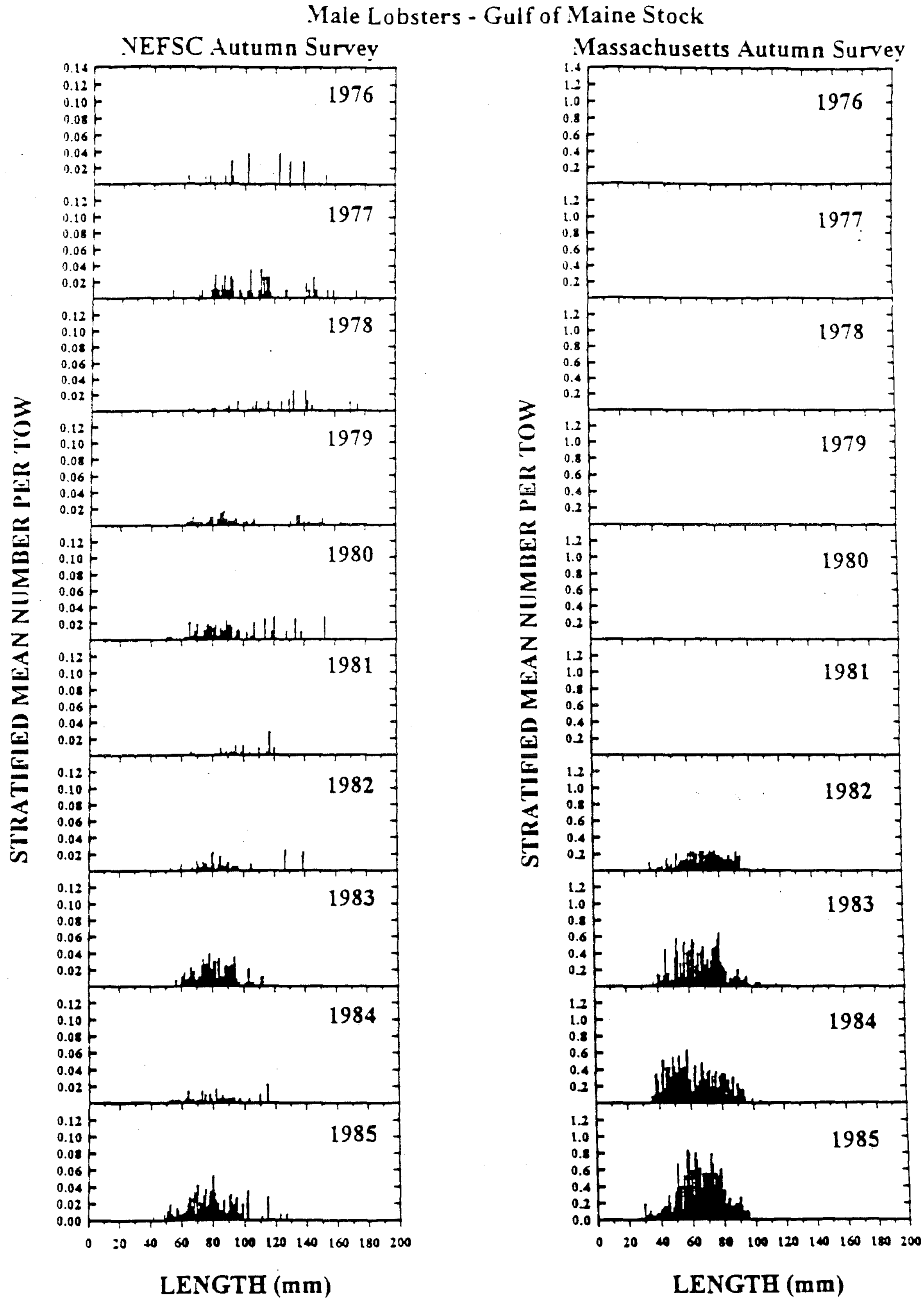
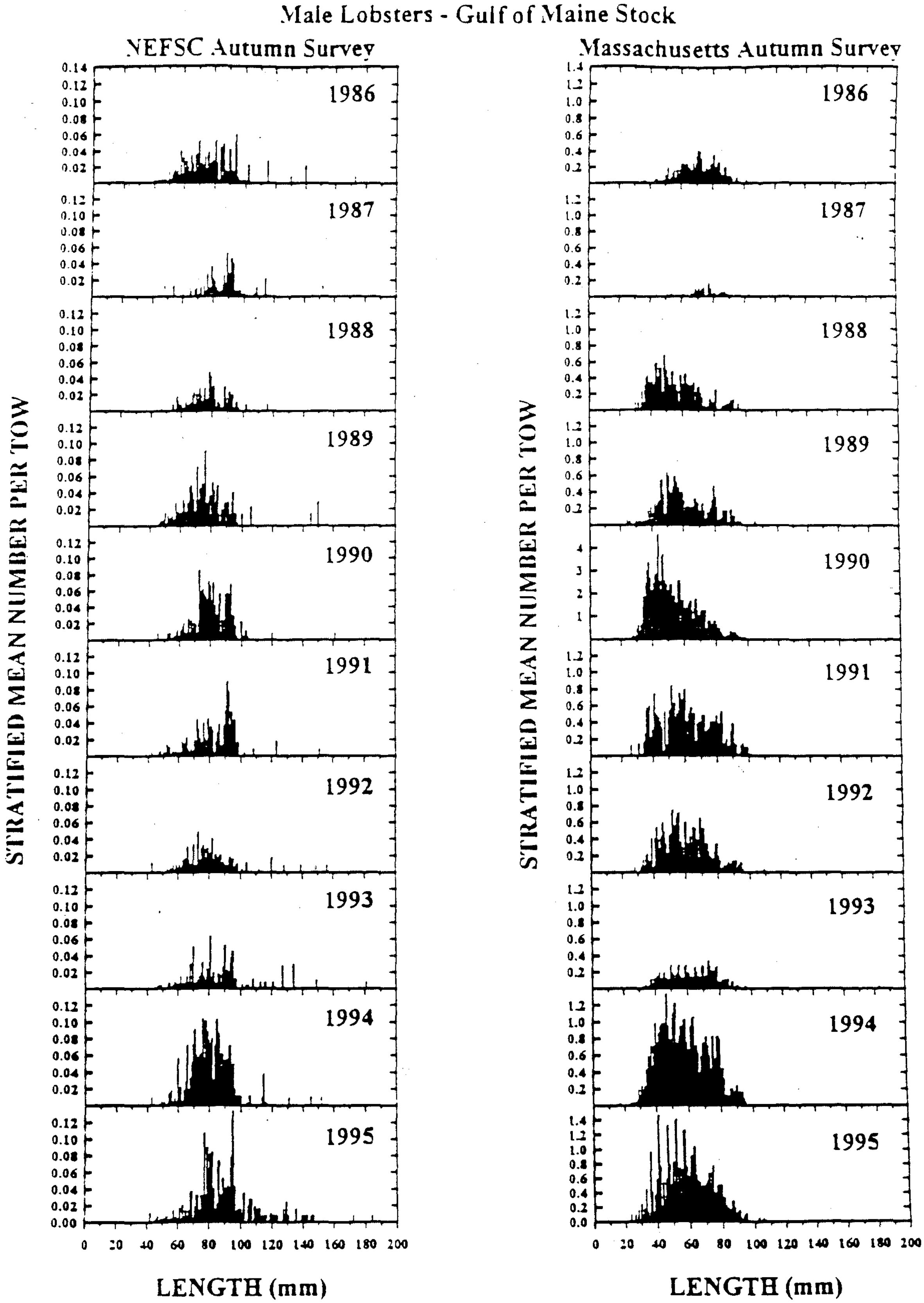


Figure B16. Stratified mean number per tow at length (carapace length, mm) for male lobsters in the Gulf of Maine Assessment area from NEFSC and Massachusetts autumn bottom trawl surveys.



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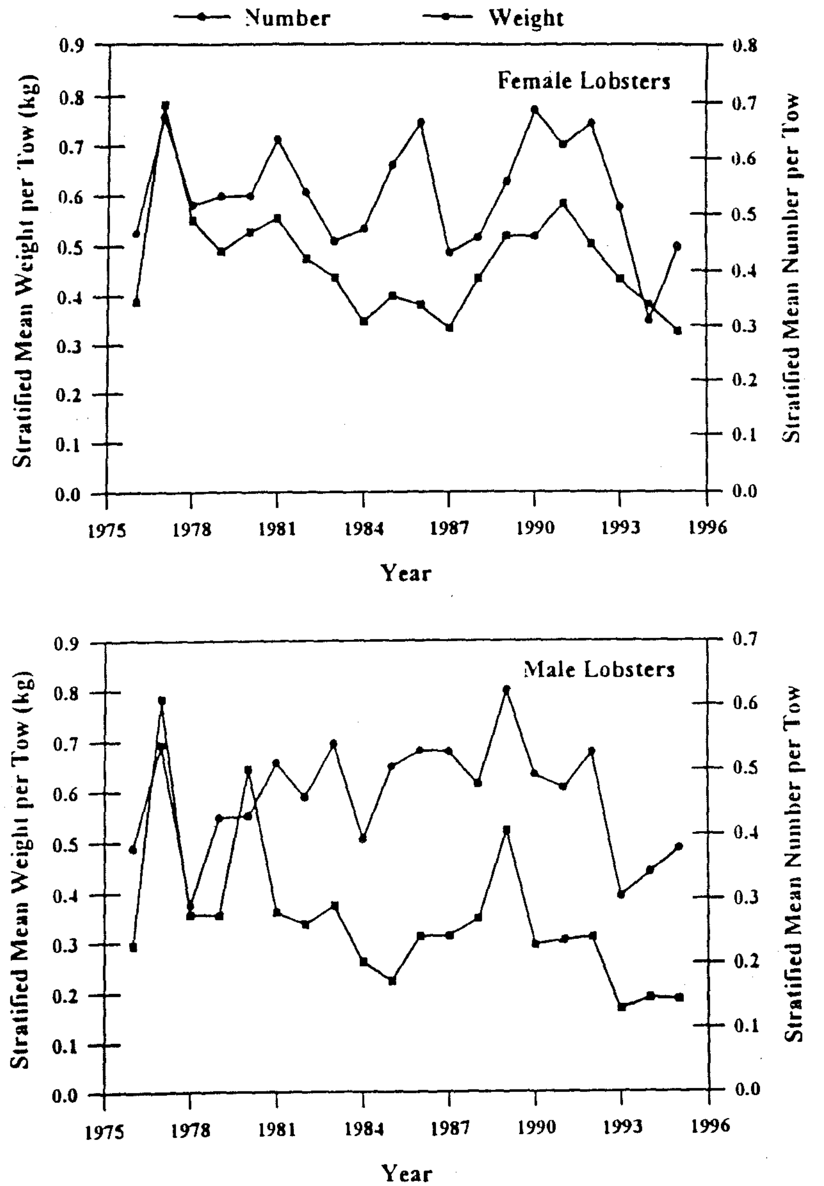

Figure B17. Abundance indices (weight per tow, number per tow) for female and male lobsters in the Georges Bank and South assessment area from NEFSC autumn bottom trawl surveys, 1976-1995.

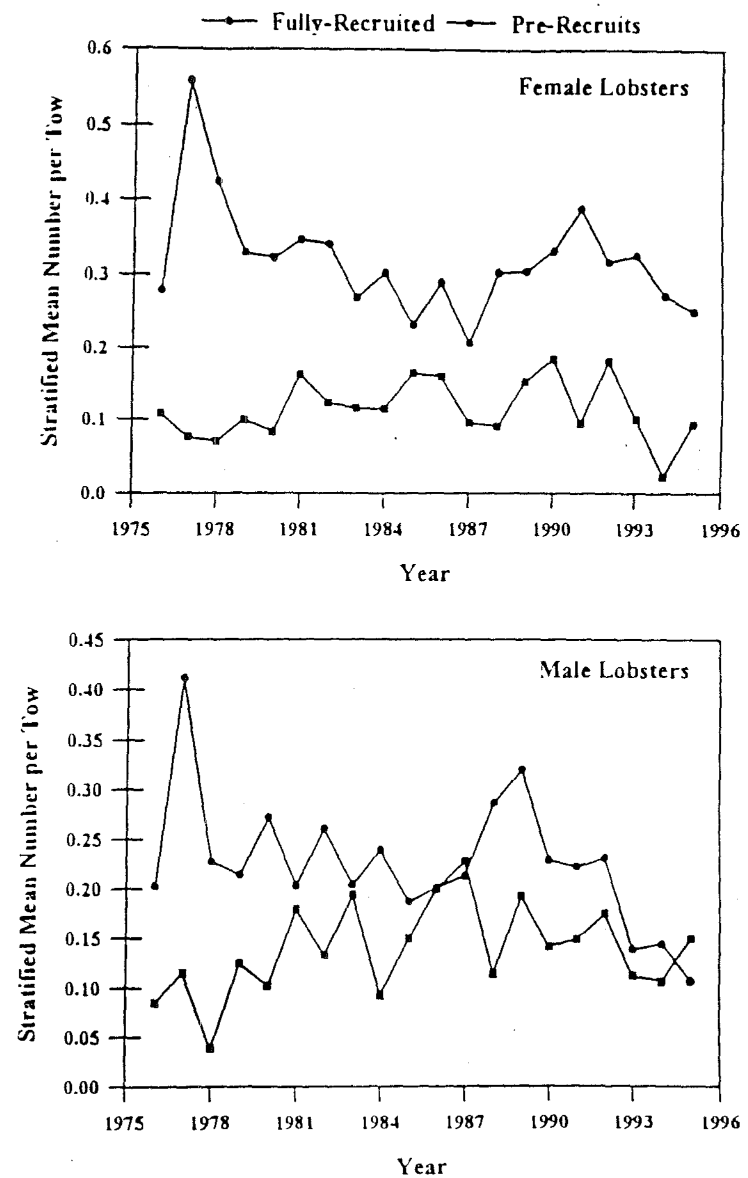

Figure B18. Abundance indices (number per tow) for pre-recruit and fully recruited female and male lobsters in the Georges Bank and South assessment area from NEFSC autumn bottom trawl surveys, 1976-1995.

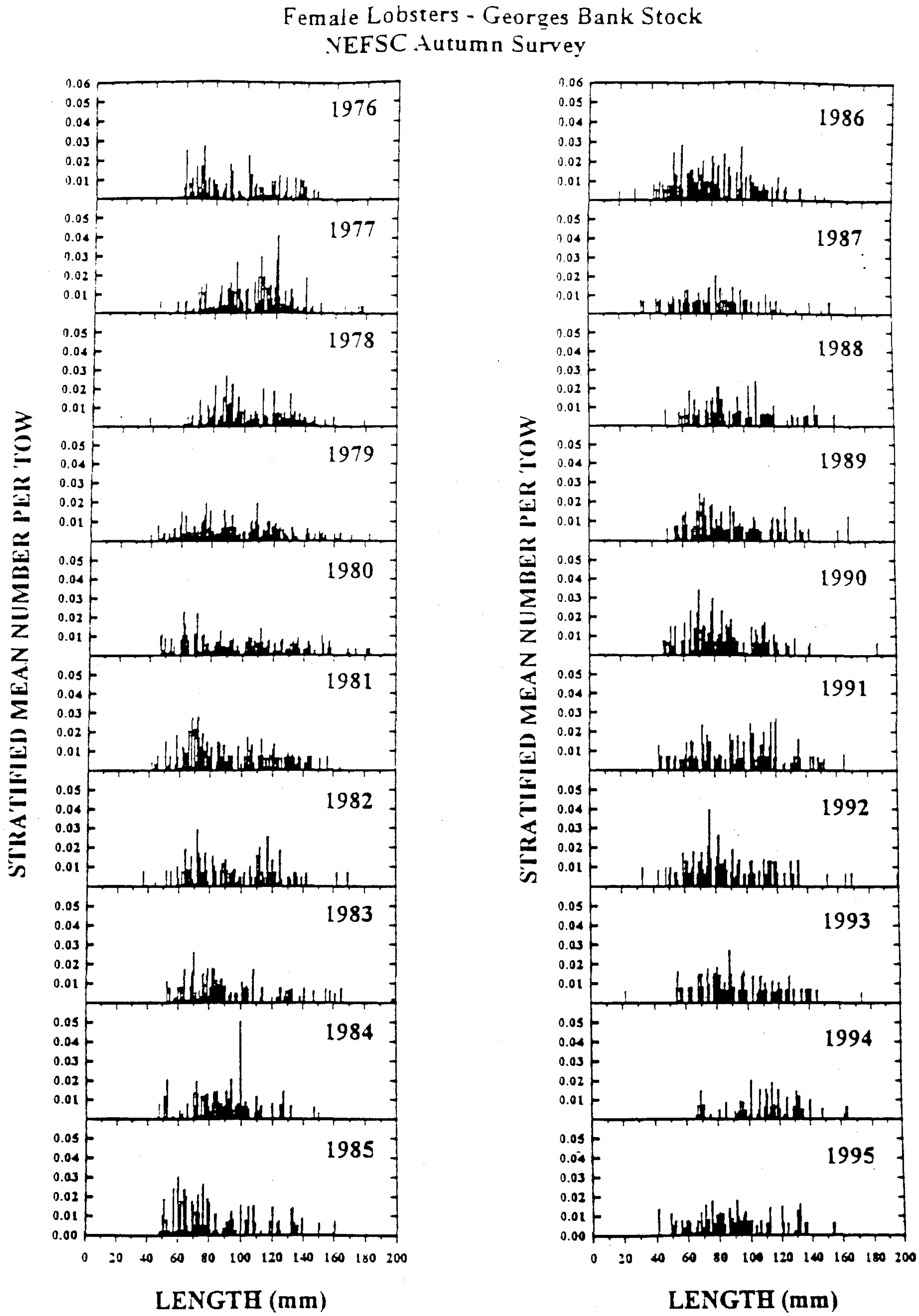

Figure B19. Stratified mean number per tow at length (carapace length, mm) for female lobsters in the Georges Bank and South Offshore assessment area from NEFSC autumn bottom trawl surveys, 1976-1995.

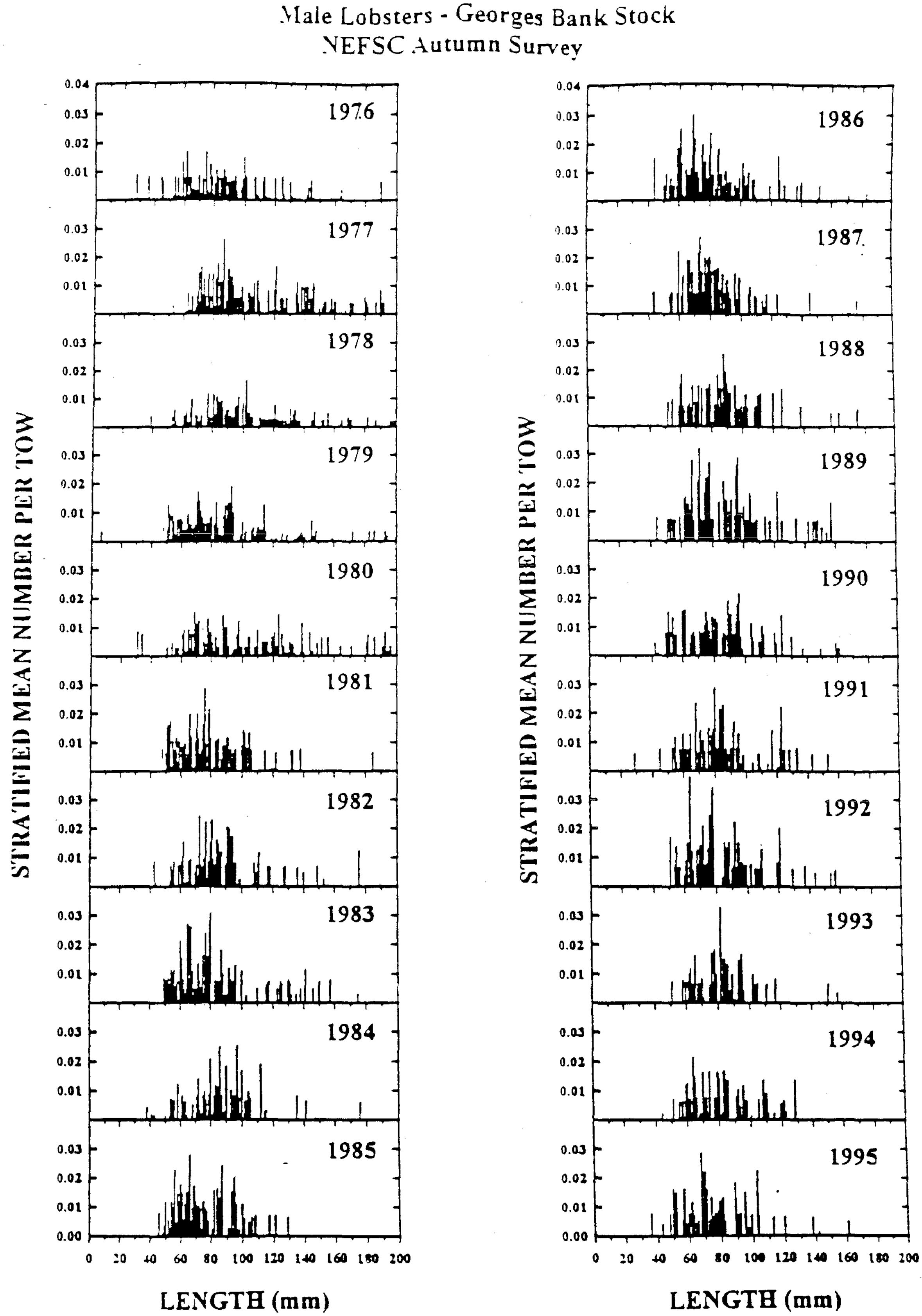

Figure B20. Stratified mean number per tow at length (carapace length, mm) for male lobsters in the Georges Bank and South Offshore assessment area from NEFSC autumn bottom trawl surveys, 1976-1995.

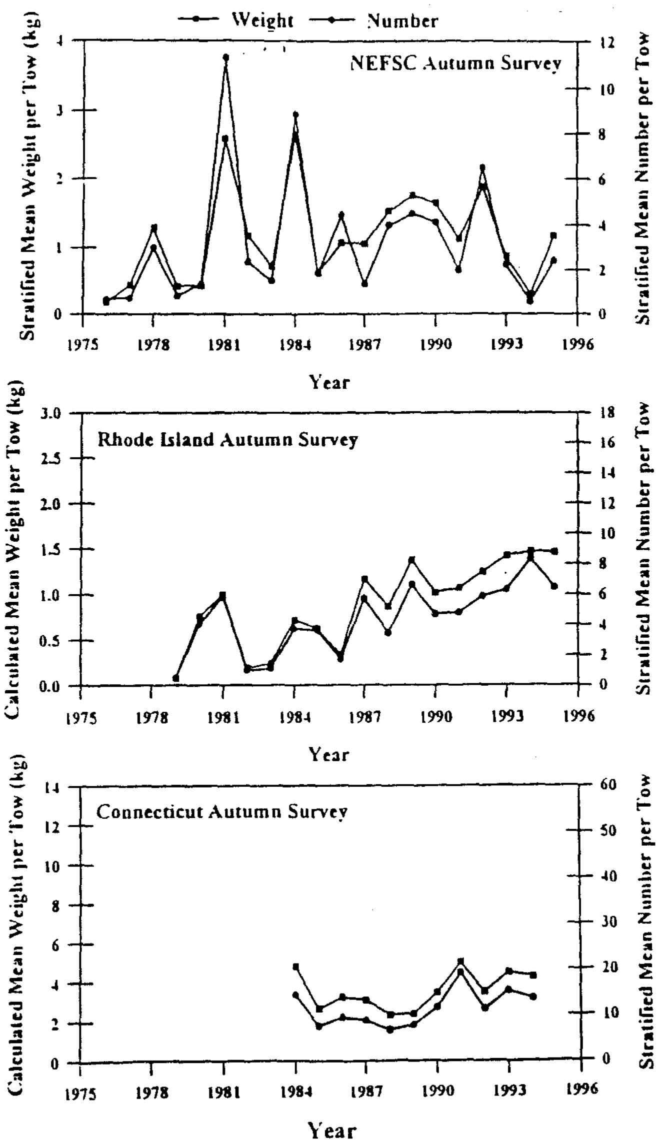

Figure B21. Abundance indices (weight per tow and number per tow) for female lobsters in the South of Cape Cod to Long Island Sound assessment area from NEFSC, Rhode Island, and Connecticut autumn bottom trawl surveys.

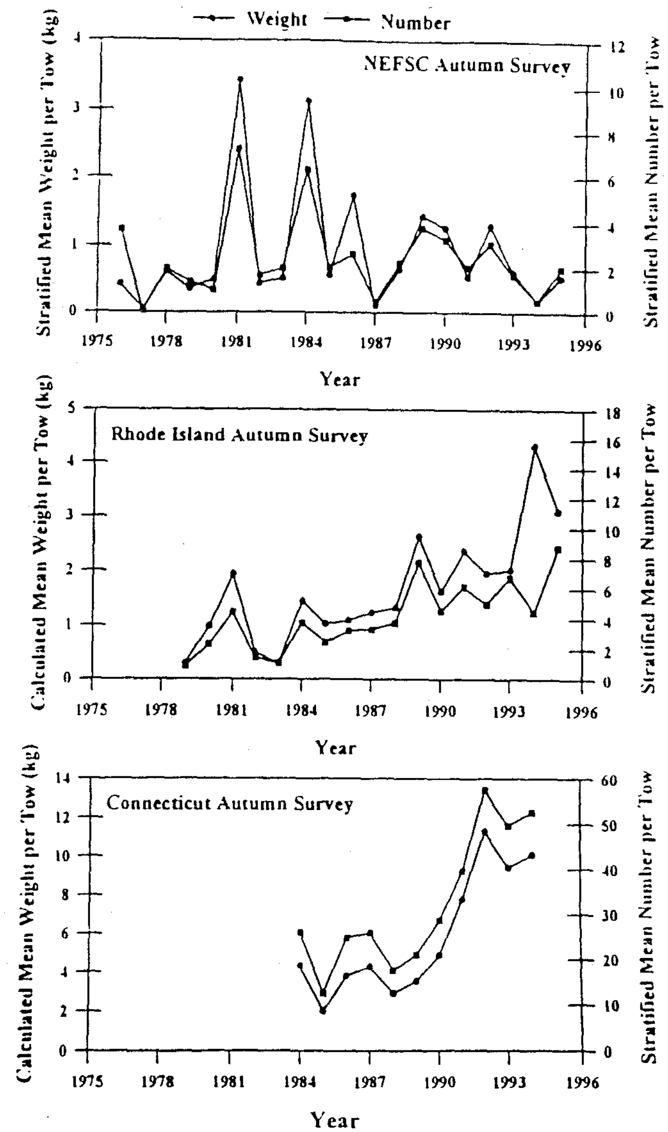

Figure B22. Abundance indices (weight per tow and number per tow) for male lobsters in the South of Cape Cod to Long Island Sound assessment area from NEFSC, Rhode Island, and Connecticut autumn bottom trawl surveys.

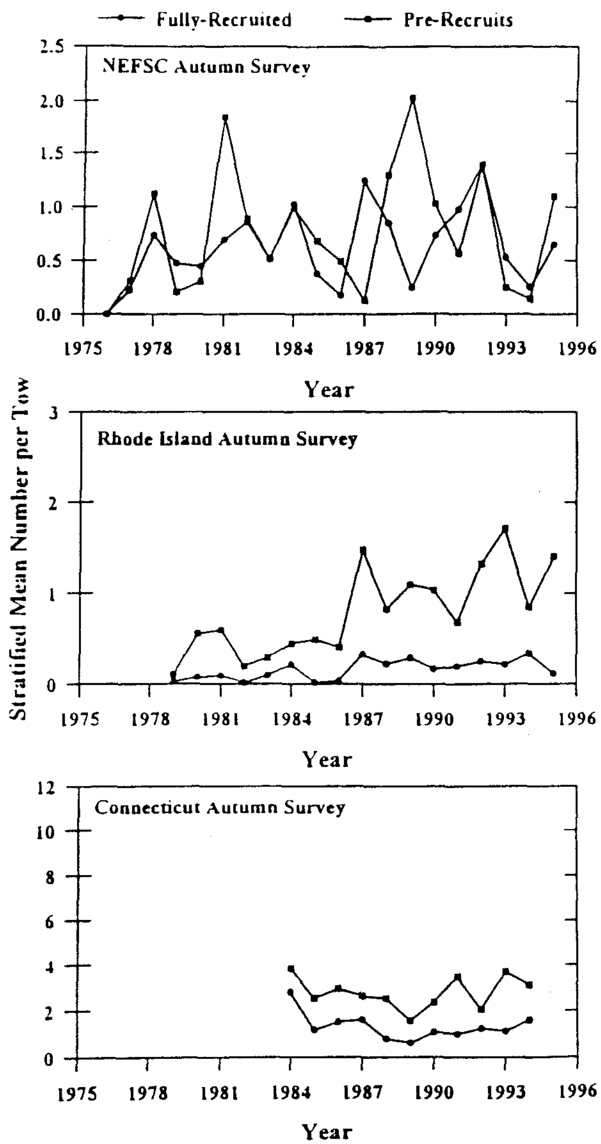

Figure B23. Abundance indices (number per tow for pre-recruit and fully recruited female lobsters in the South of Cape Cod to Long Island Sound assessment area from NEFSC, Rhode Island and Connecticut autumn bottom trawl surveys.

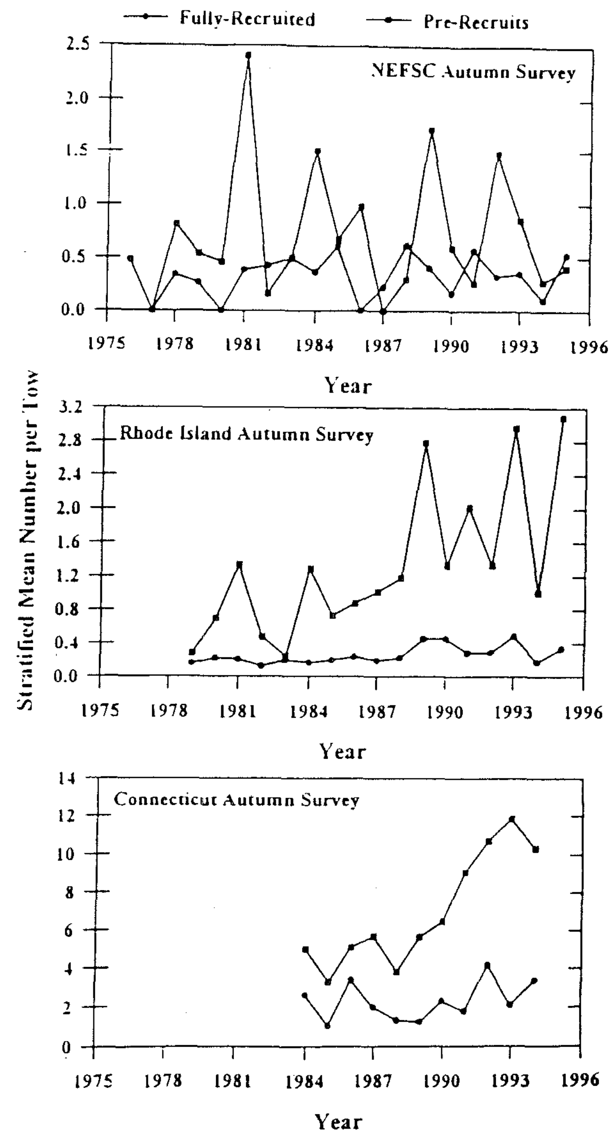

Figure B24. Abundance indices (number per tow) for pre-recruit and fully recruited male lobsters in the South of Cape Cod to Long Island Sound assessment area from NEFSC, Rhode Island, and Connecticut autumn bottom trawl surveys.

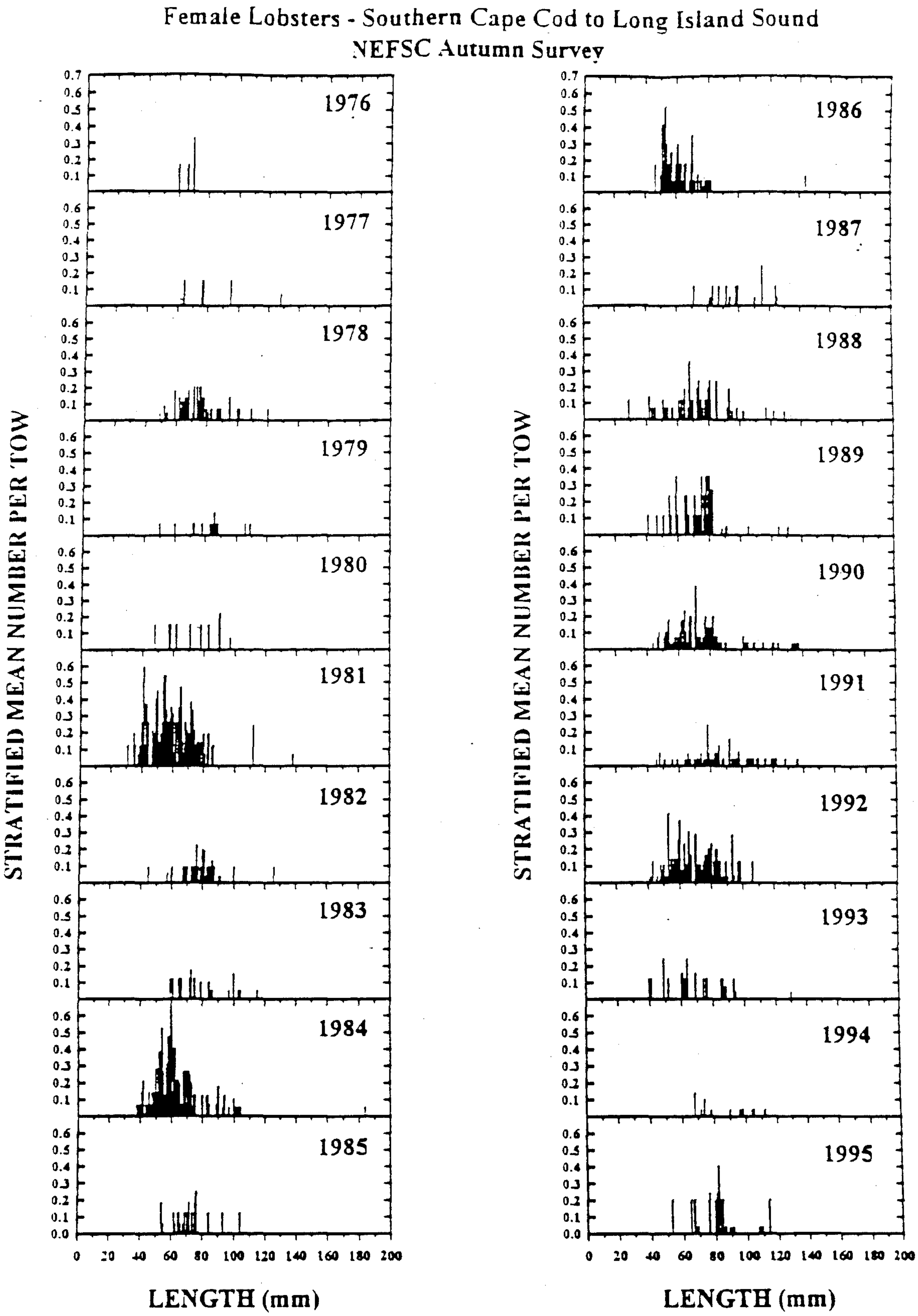

Figure B25. Stratified mean number per tow at length (carapace length, mm) for female lobsters in the South of Cape Cod to Long Island Sound assessment area from NEFSC autumn bottom trawl surveys, 1976-1995.

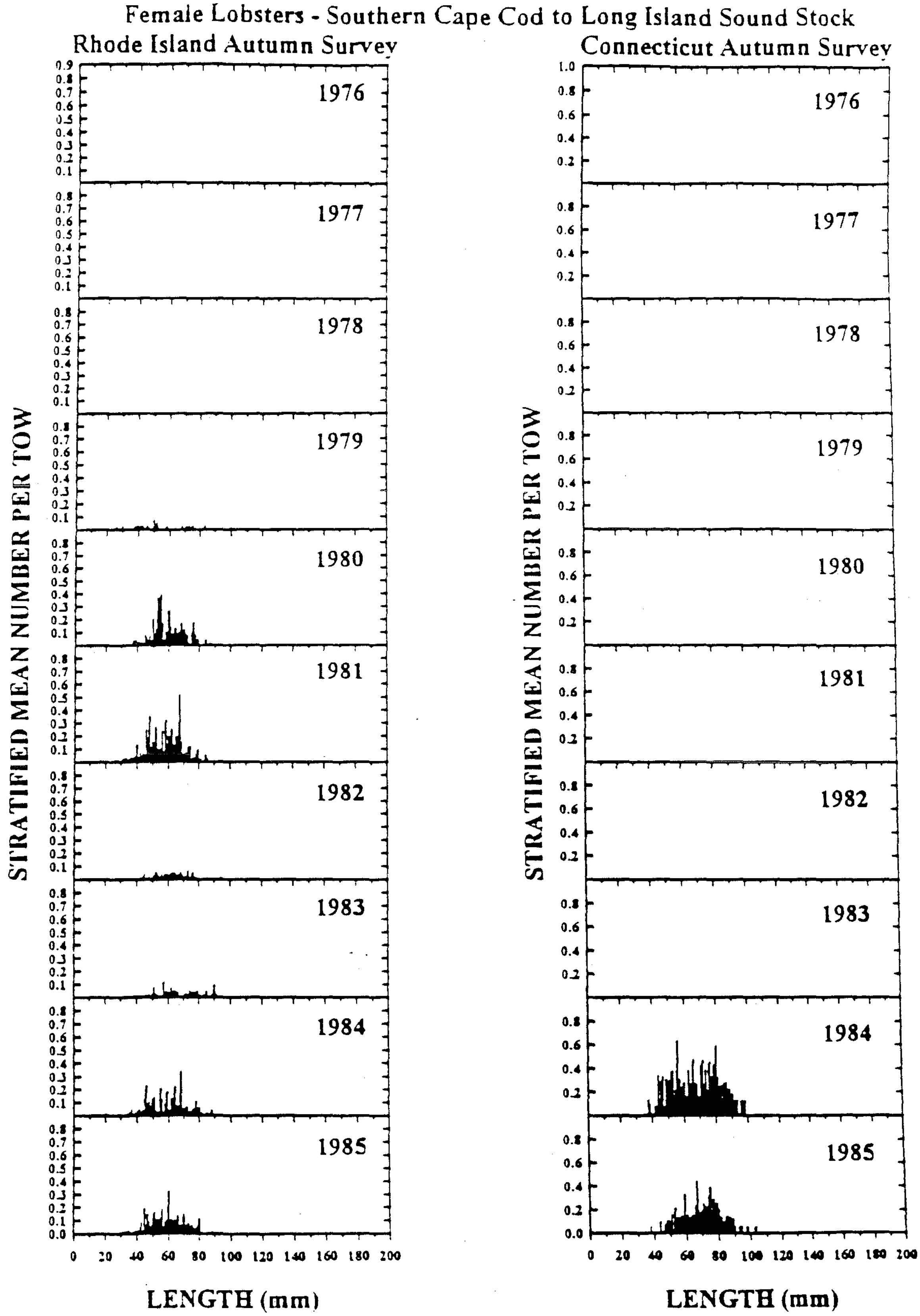

Figure B26. Stratified mean number per tow at length (carapace length, mm) for female lobsters in the South of Cape Cod to Long Island Sound assessment area from Rhode Island and Connecticut autumn bottom trawl surveys, 1976-1995.

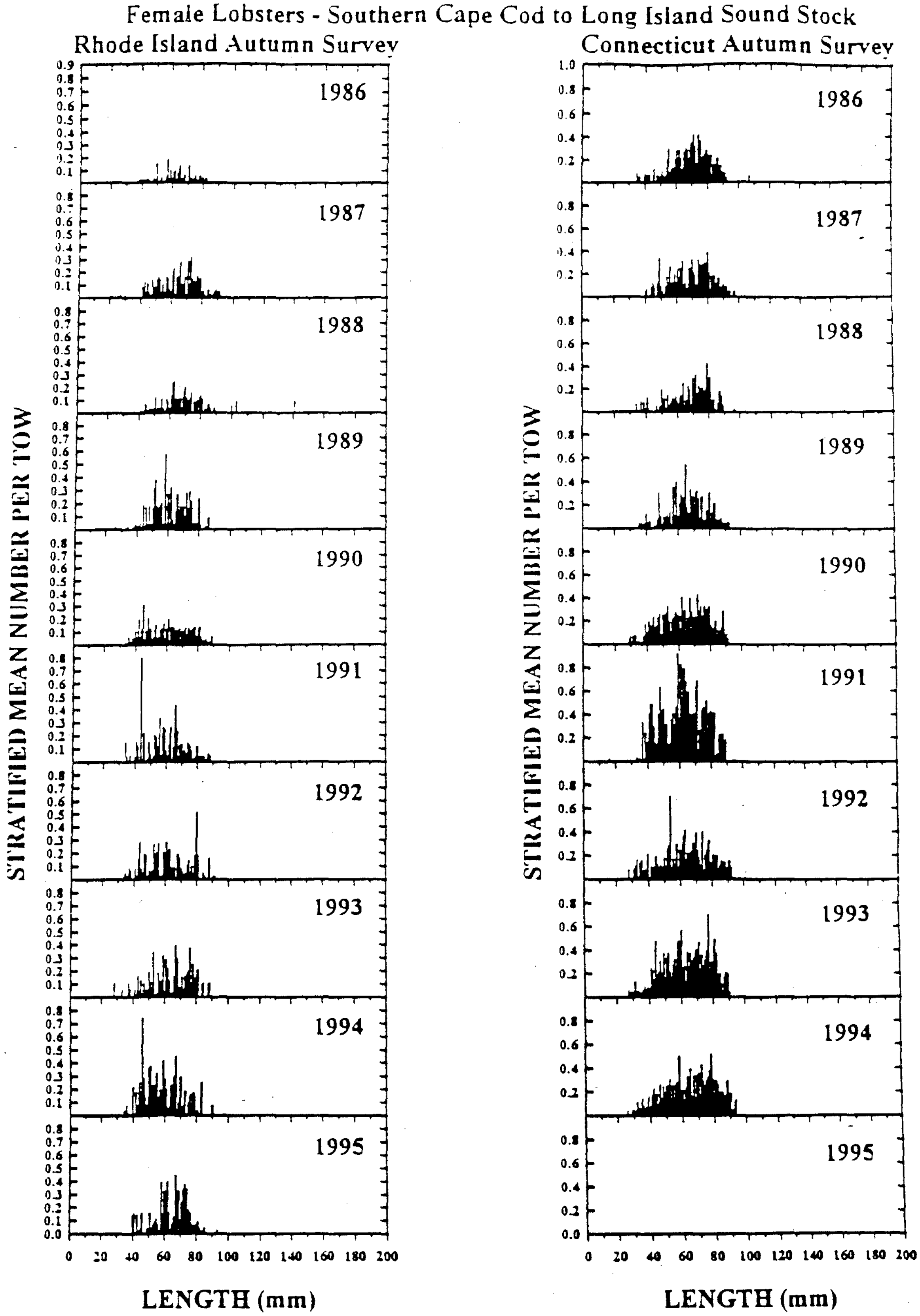

Figure B26. (Continued)

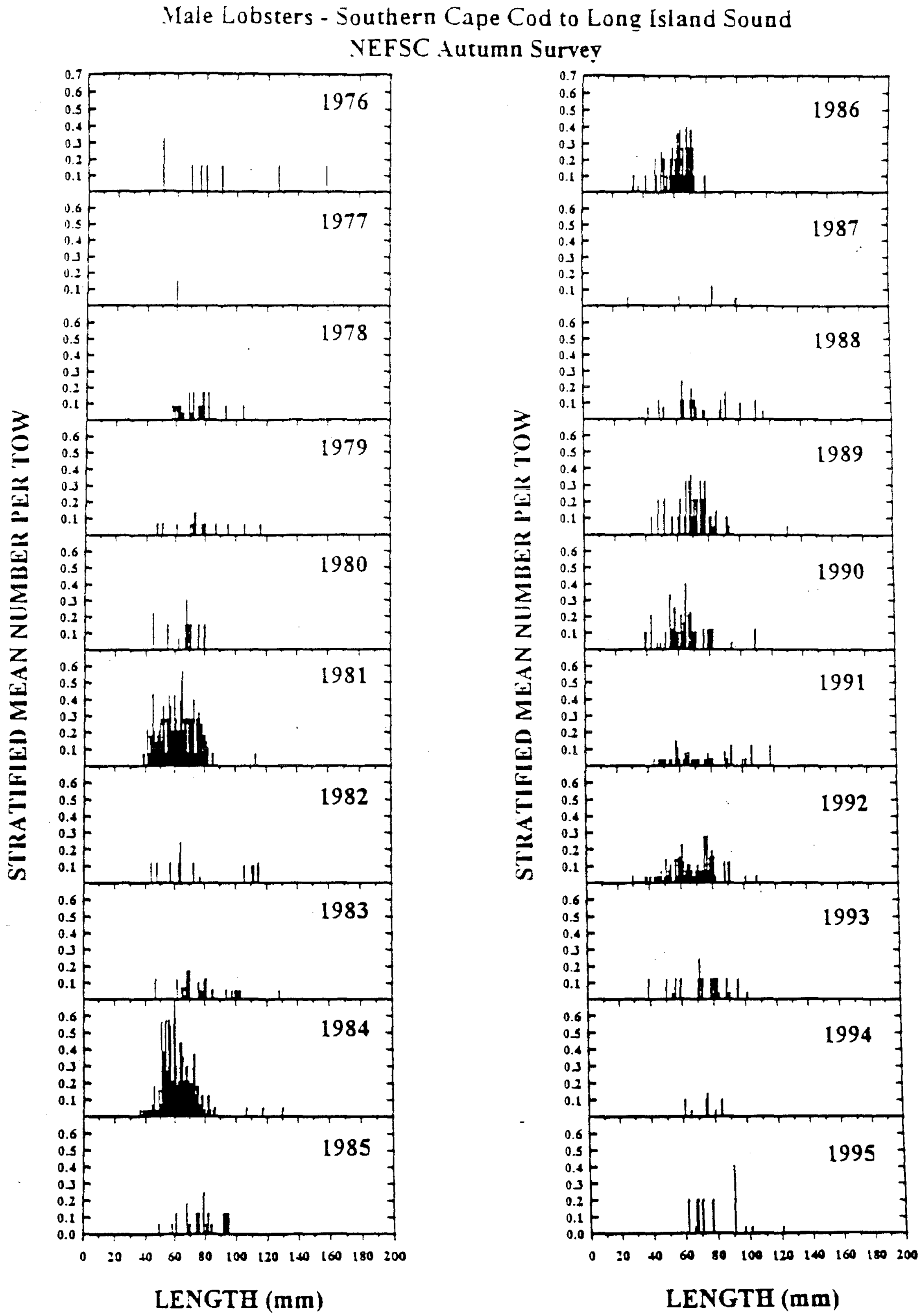

Figure B27. Stratified mean number per tow at length (carapace length, mm) for male lobsters in the South of Cape Cod to Long Island Sound assessment area from NEFSC autumn bottom trawl surveys, 1976-1995.

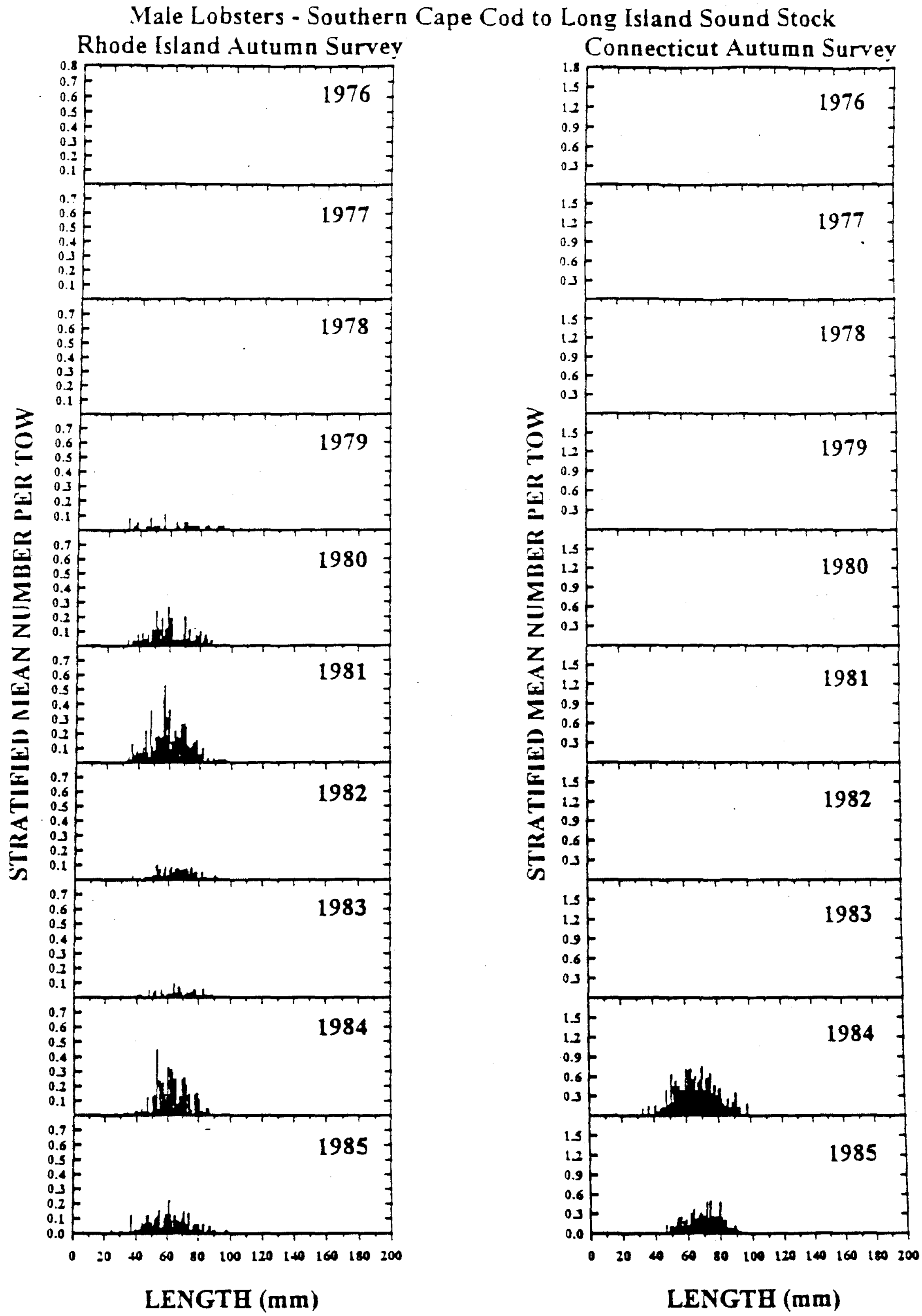

Figure B28. Stratified mean number per tow at length (carapace length, mm) for male lobsters in the South of Cape Cod to Long Island Sound assessment area from Rhode Island and Connecticut autumn bottom trawl surveys, 1976-1995.

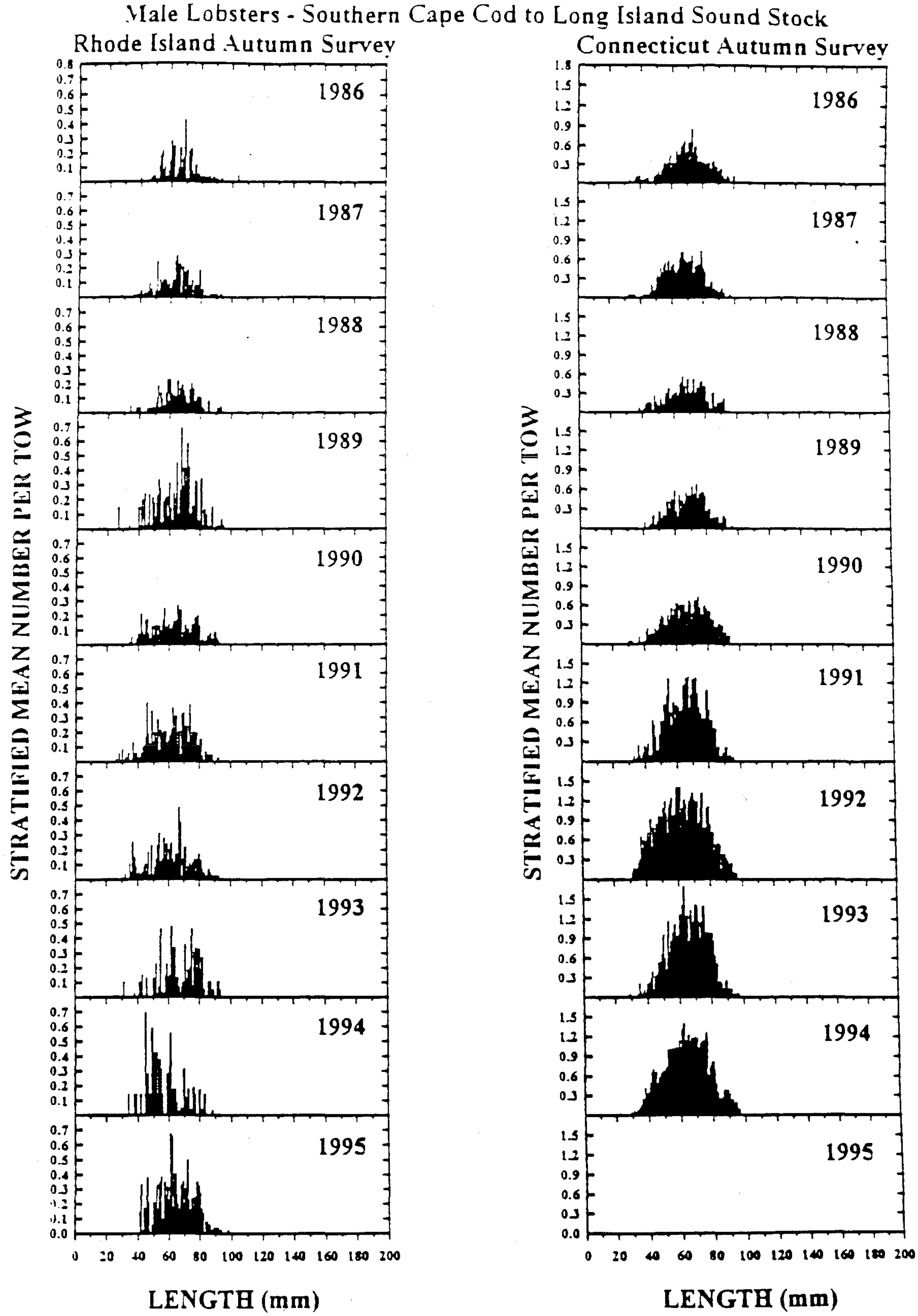

Figure B28. (Continued)

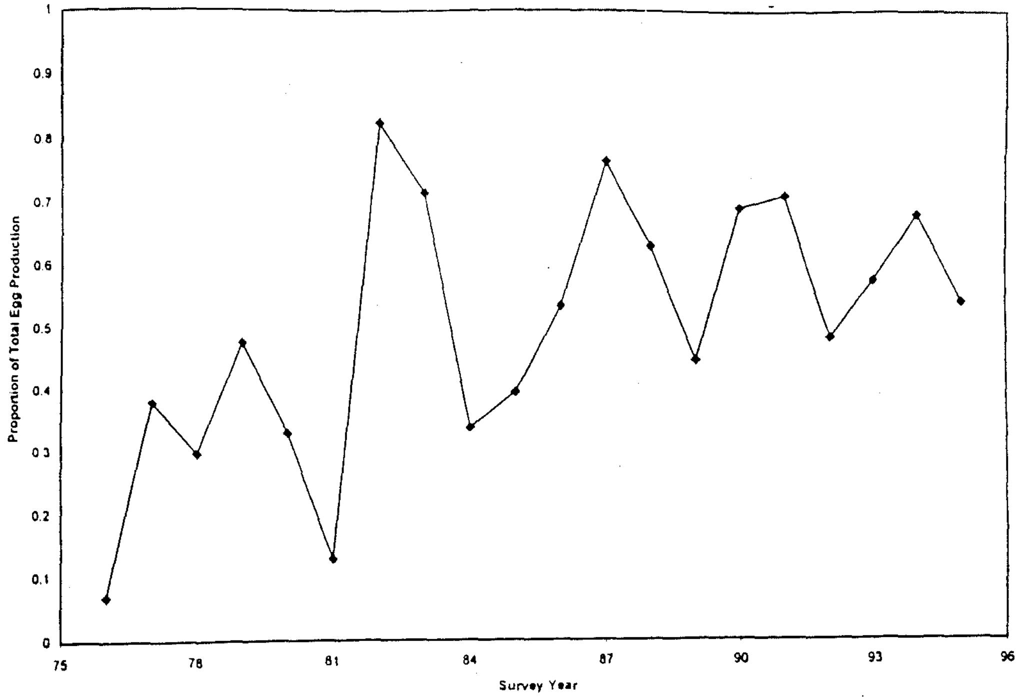

Figure B29. Proportion of egg production by lobsters within one mold above legal limit. Gulf of Maine: NMFS trawl survey.

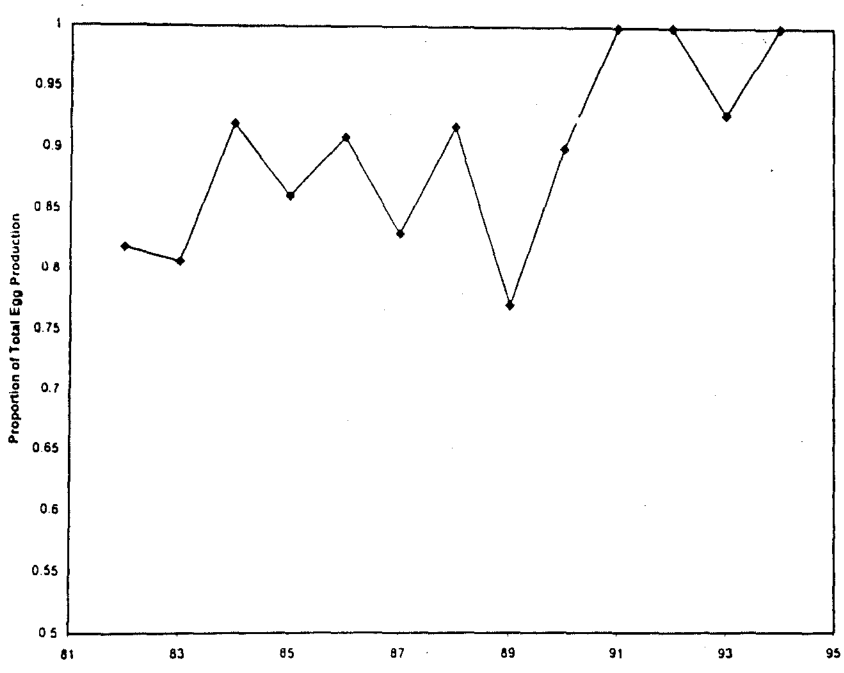

Figure B30. Proportion of egg production by lobsters ≤94 mm CL. Massachusetts trawl survey.

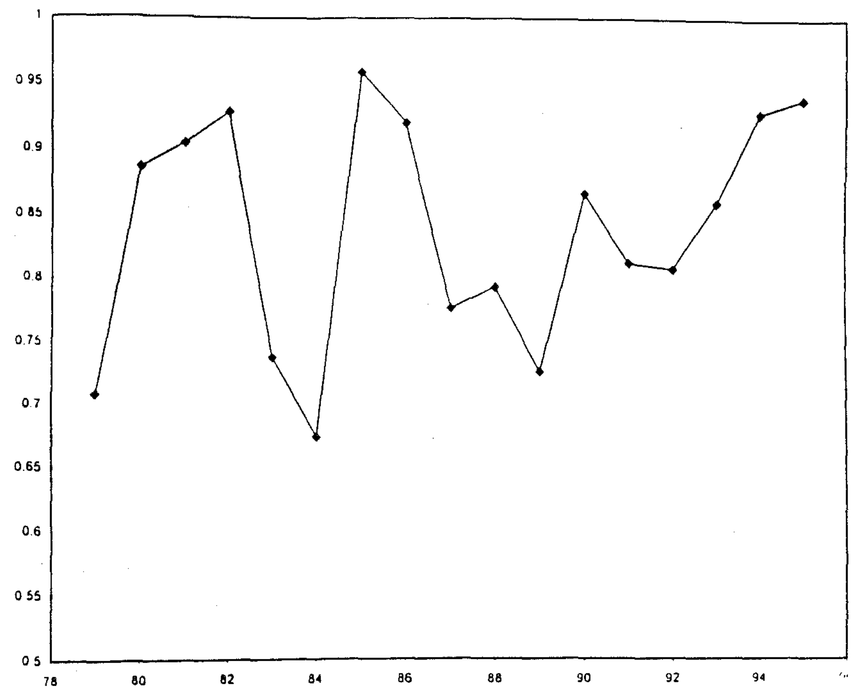

Figure B31. Proportion of total egg production by lobsters less than the minimum size limit. Rhode Island trawl survey.

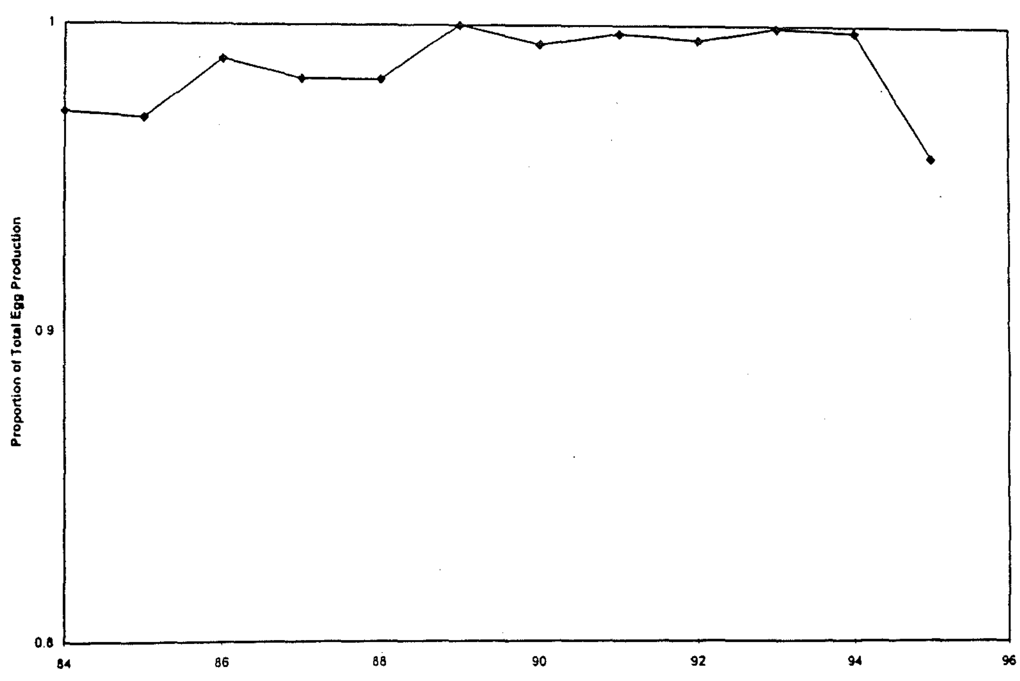

Figure B32. Proportion of total egg production by lobsters within one molt of legal limit. Connecticut trawl survey: Central and Western Long Island Sound.

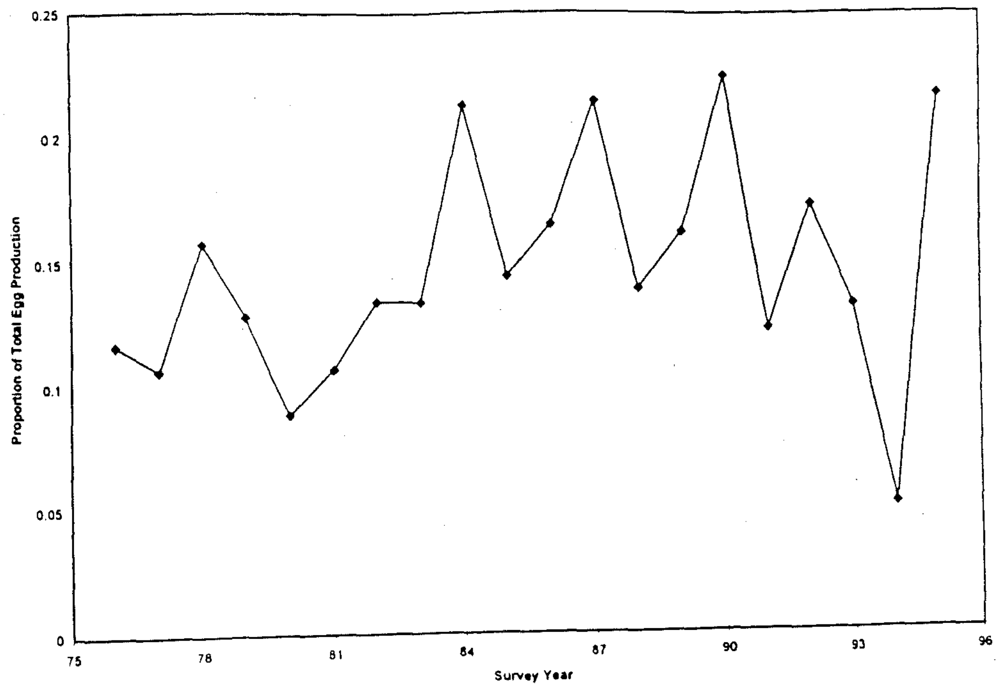

Figure B33. Proportion of egg production by lobsters within one molt above legal limit. NMFS trawl survey: Georges Bank and South.

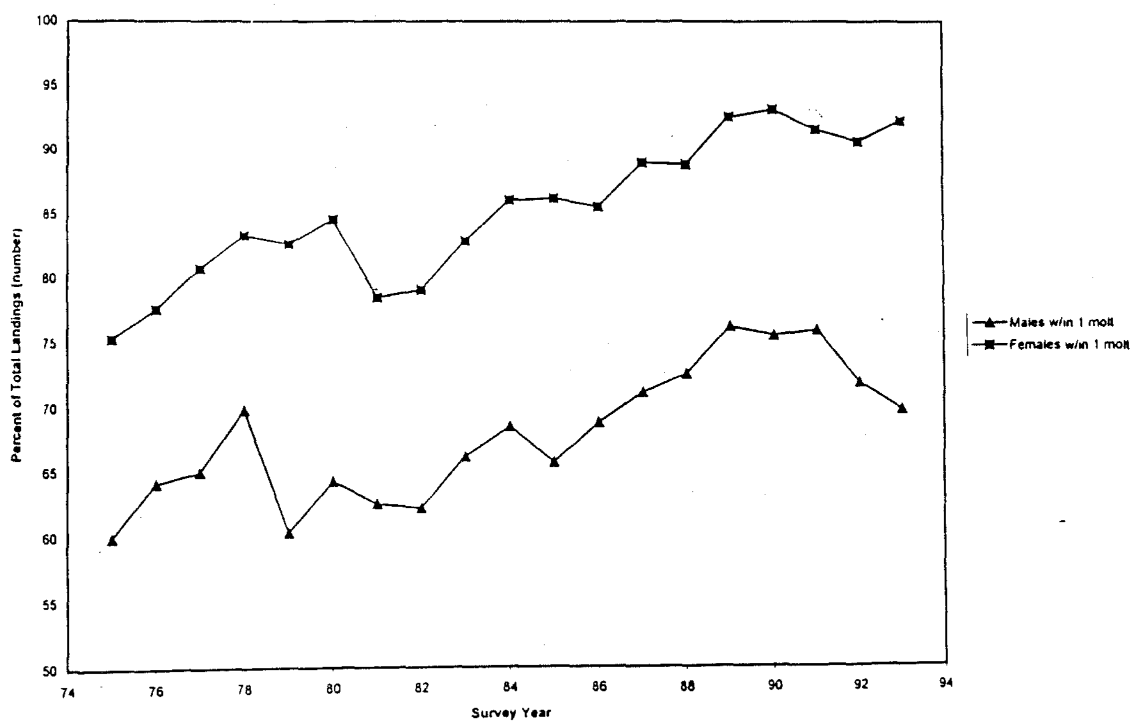

Figure B34. Percentage of landings in Statistical Areas 511-513 (Maine) within one molt increment of minimum legal size.

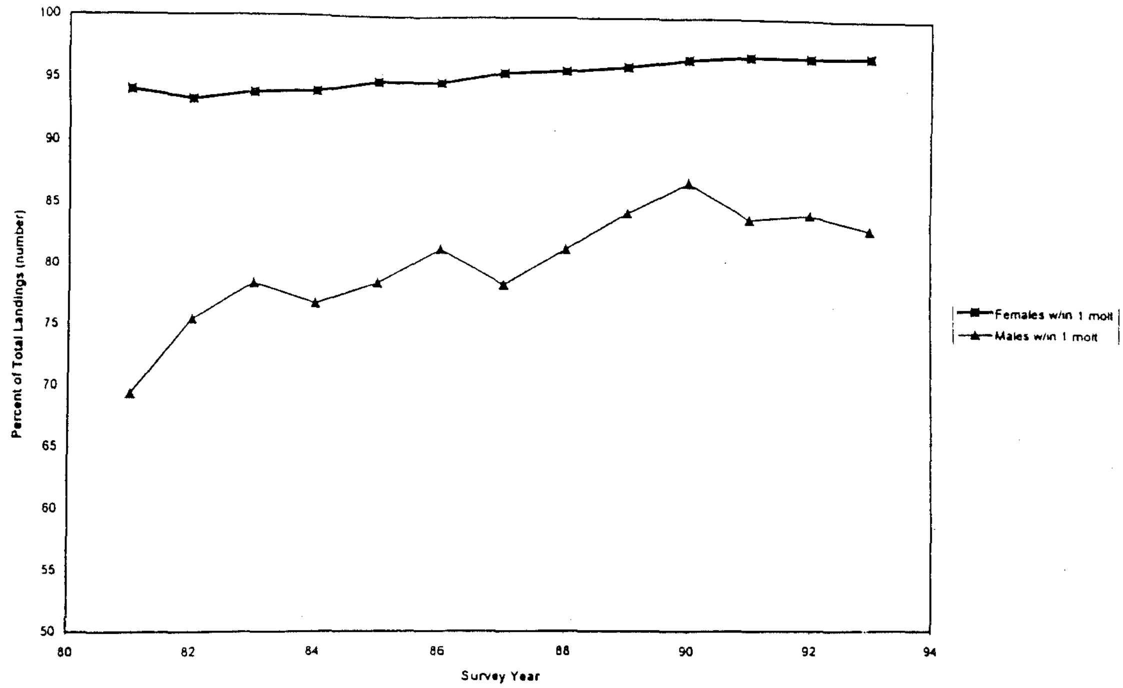

Figure B35. Percentage of landings in Statistical Area 514 (Massachusetts) within one molt increment of minimum legal size.

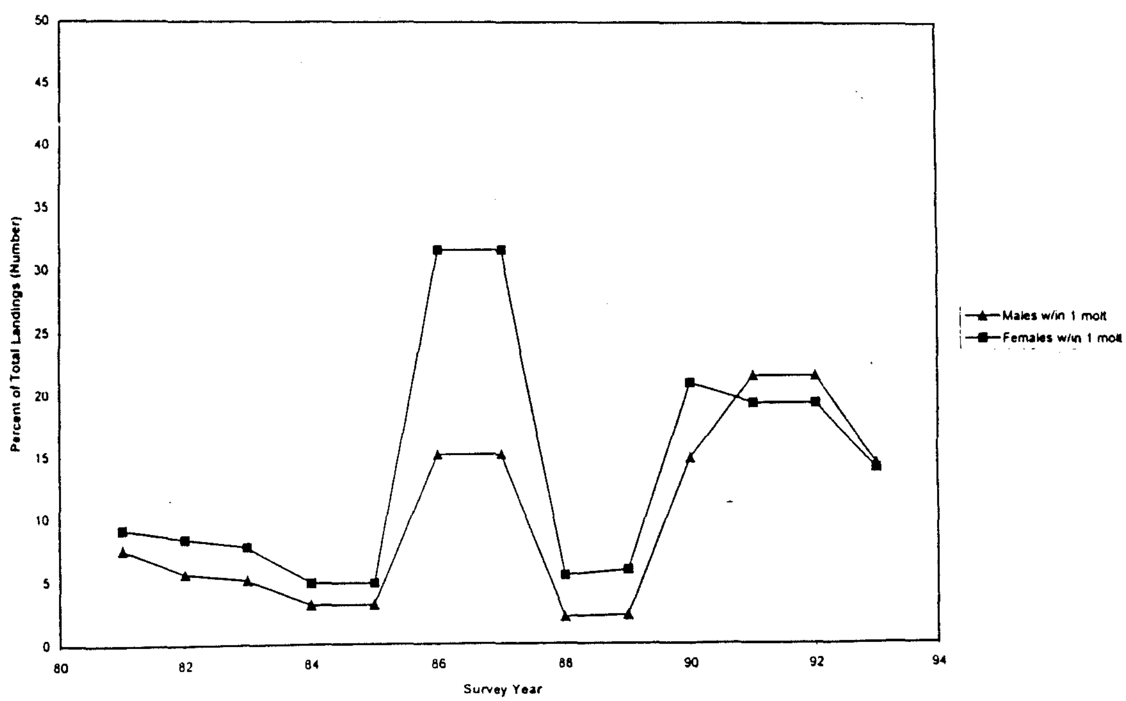

Figure B36. Percentage of landings in Statistical Area 515 (offshore Gulf of Maine) within one molt increment of minimum legal size.

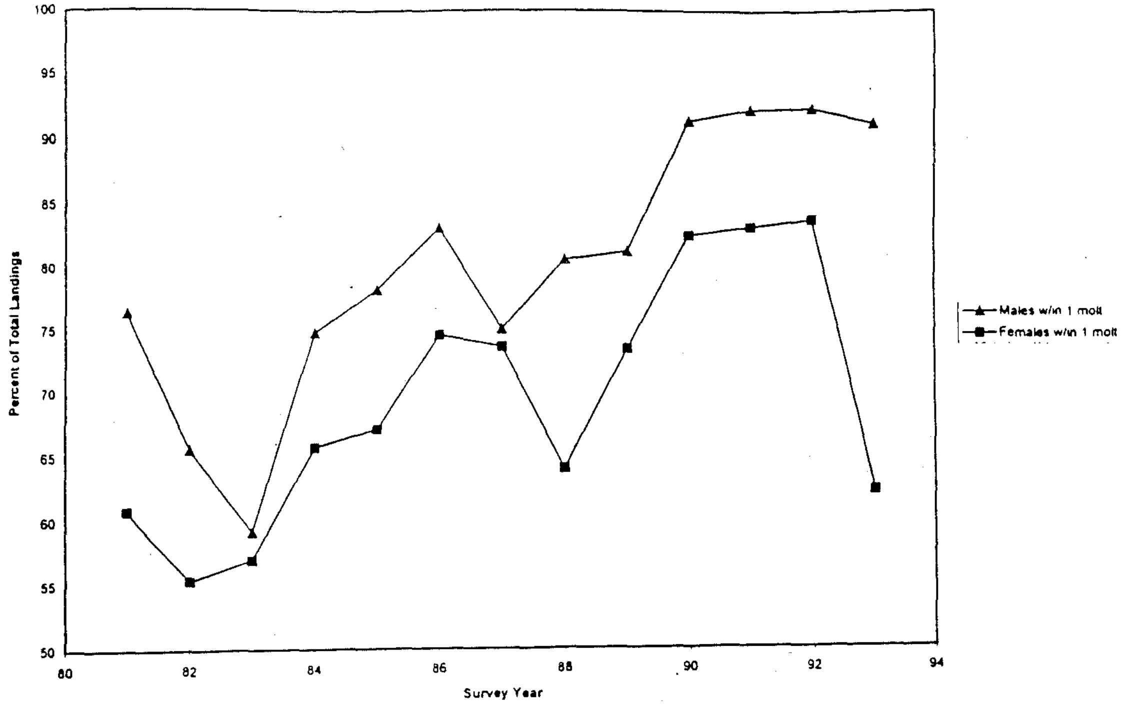

Figure B37. Percentage of landings in Georges Bank and South stock within one molt increment of minimum legal size.

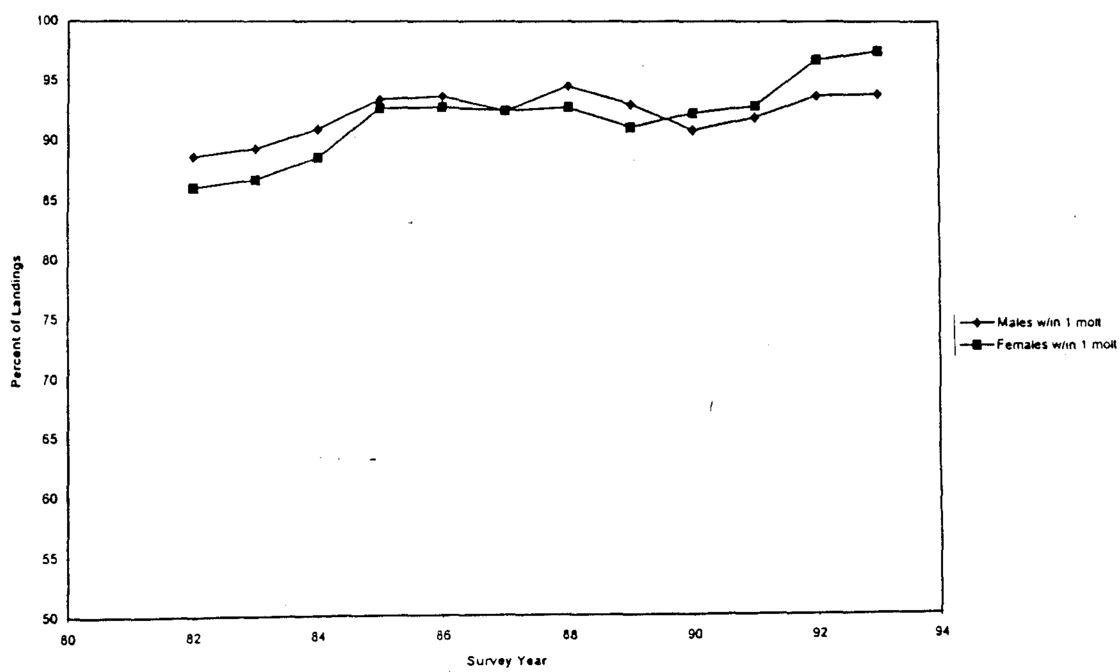

Figure B38. Percent of landings in South of Cape Cod and Long Island Sound stock within one molt increment of minimum legal size.

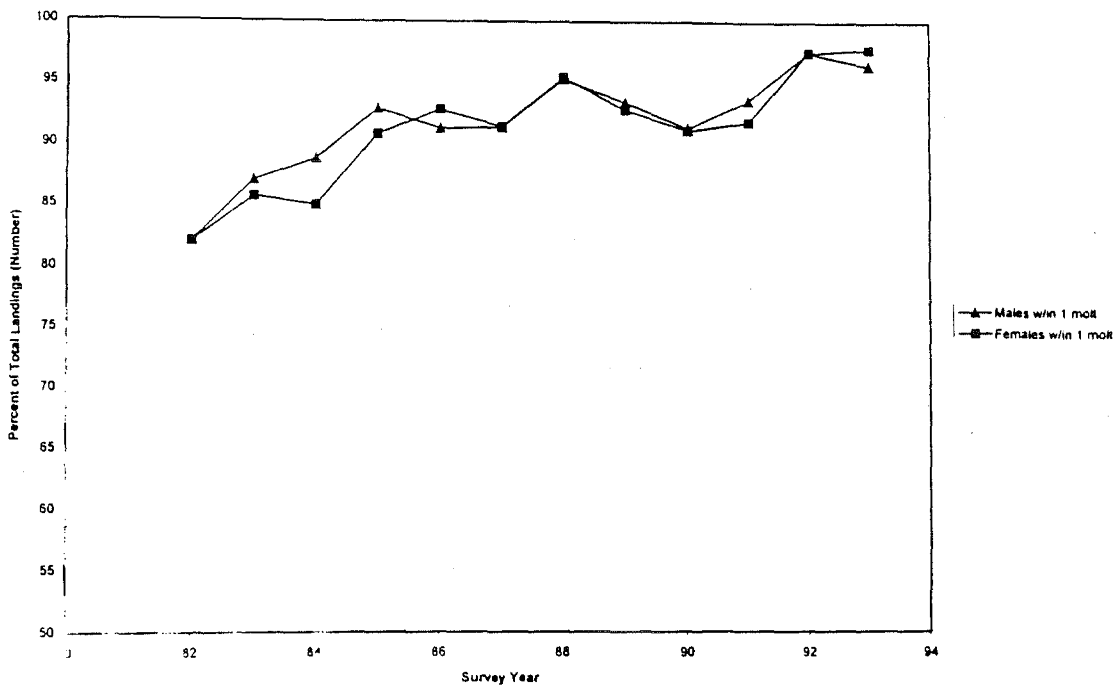

Figure B39. Percentage of landings in Central and Western Long Island Sound within one molt increment of minimum legal size.

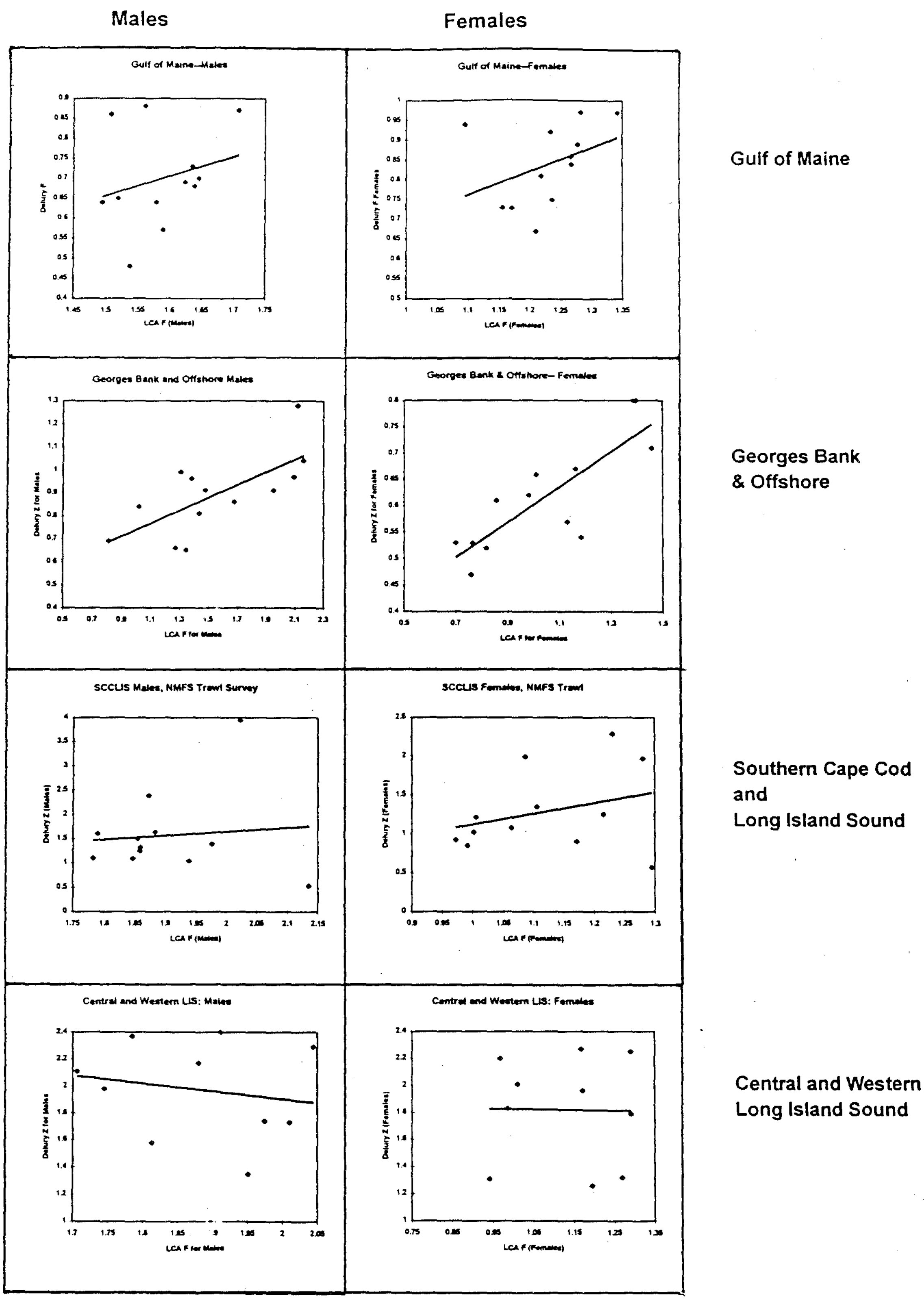

Figure B40. Comparison of mortality rate estimates for length cohort analysis (LCA) and DeLury model by stock area and sex.

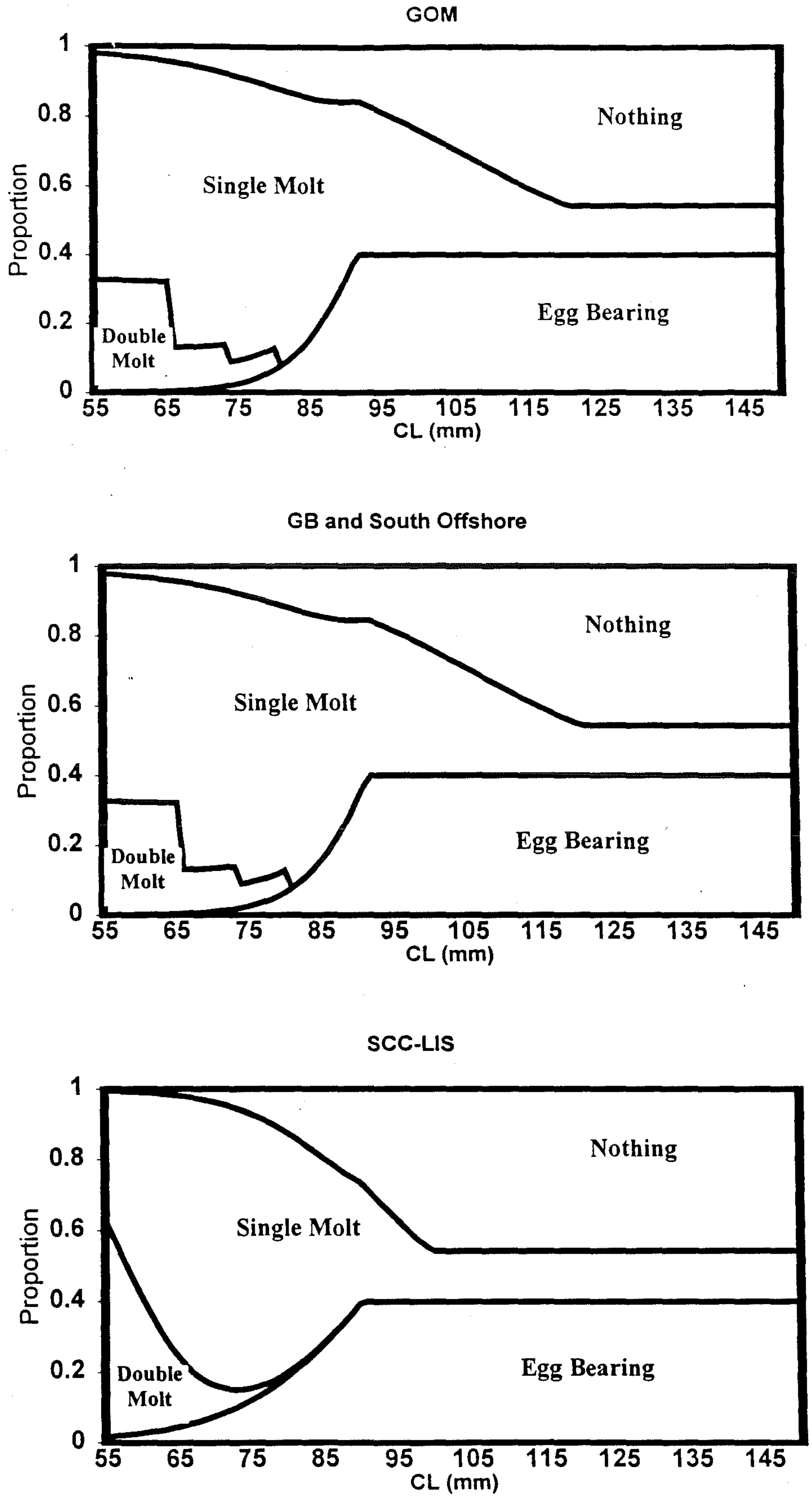

Figure B41. Annual probability of events for female American lobster.

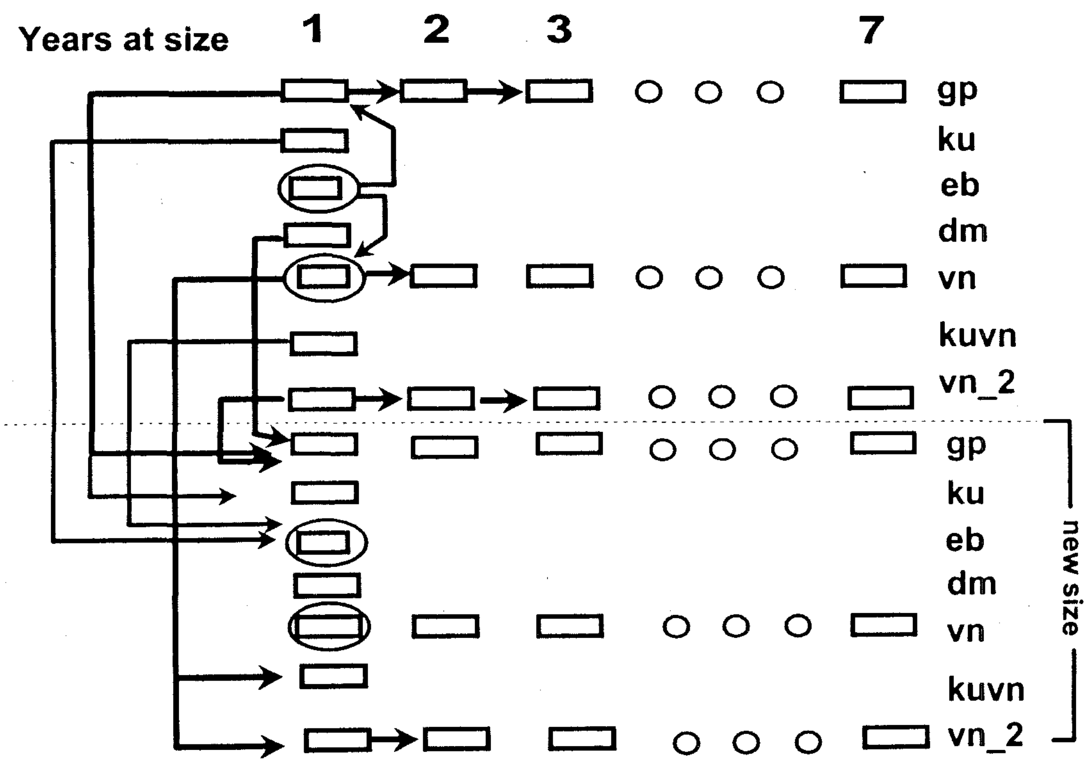

Figure B42. Flow diagram between states, time, and size for simulation of female lobsters.

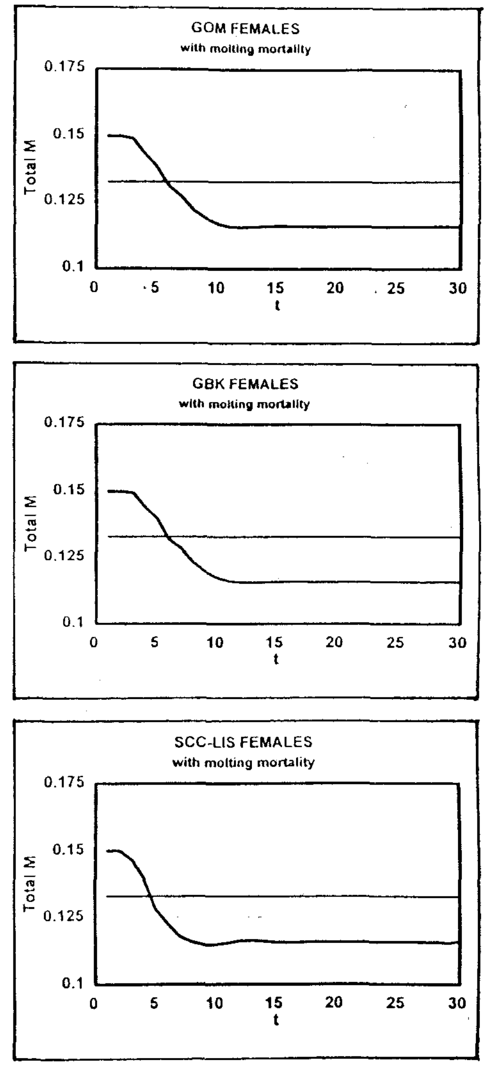

Figure B43. Total natural mortality in unfished populations of female lobsters.

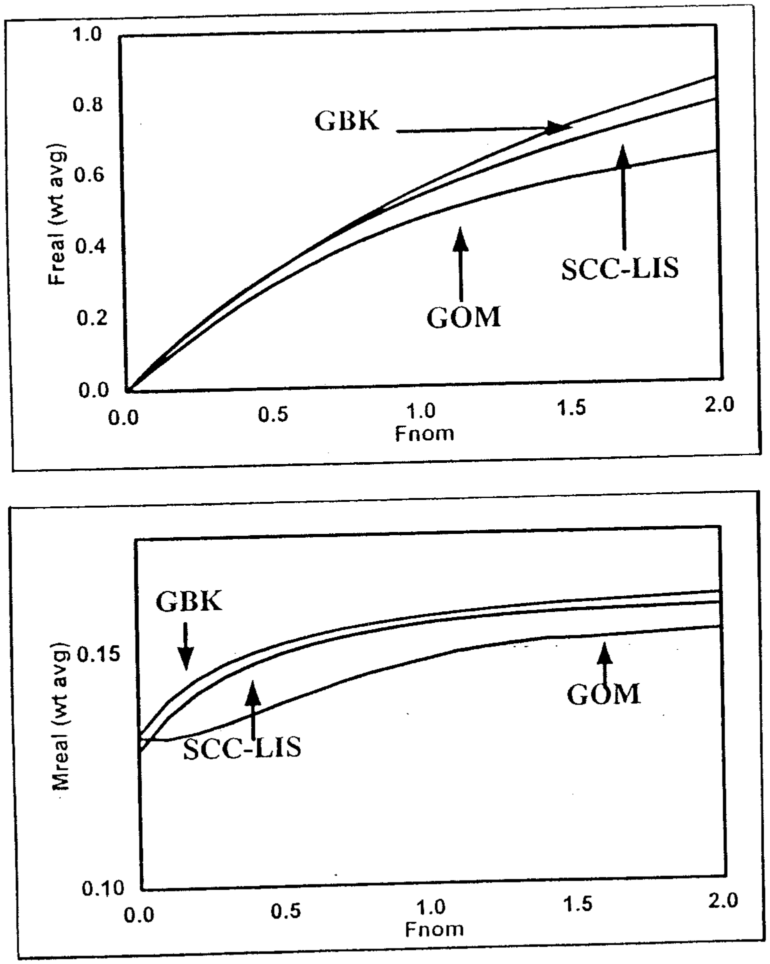

Figure B44. Realized mortality rates vs nominal fishing mortality rates by area.

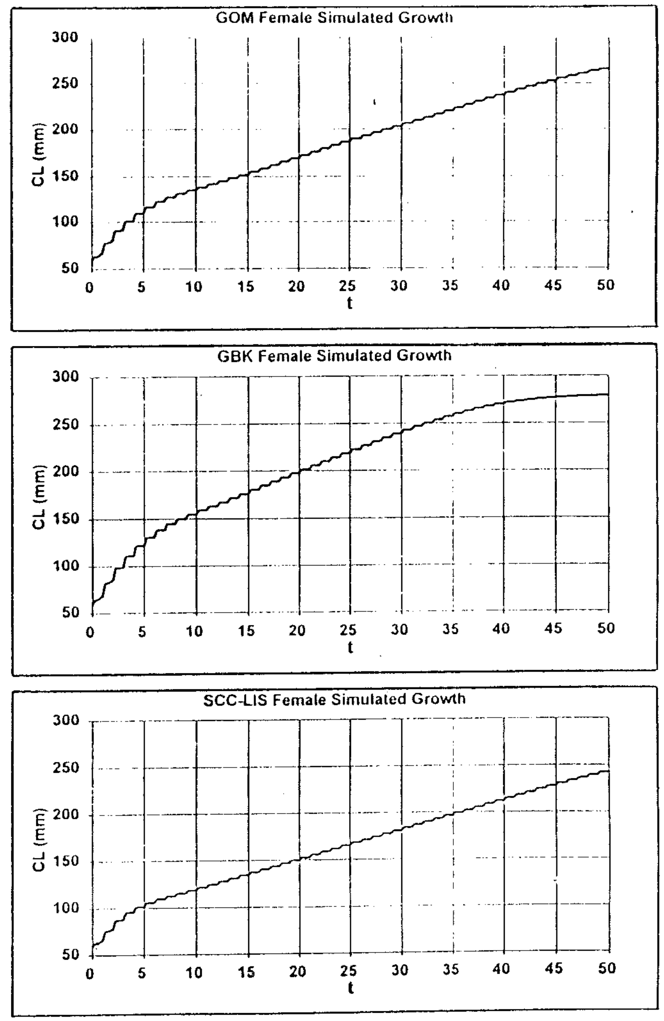

Figure B45. Simulated growth of female American lobsters by area.

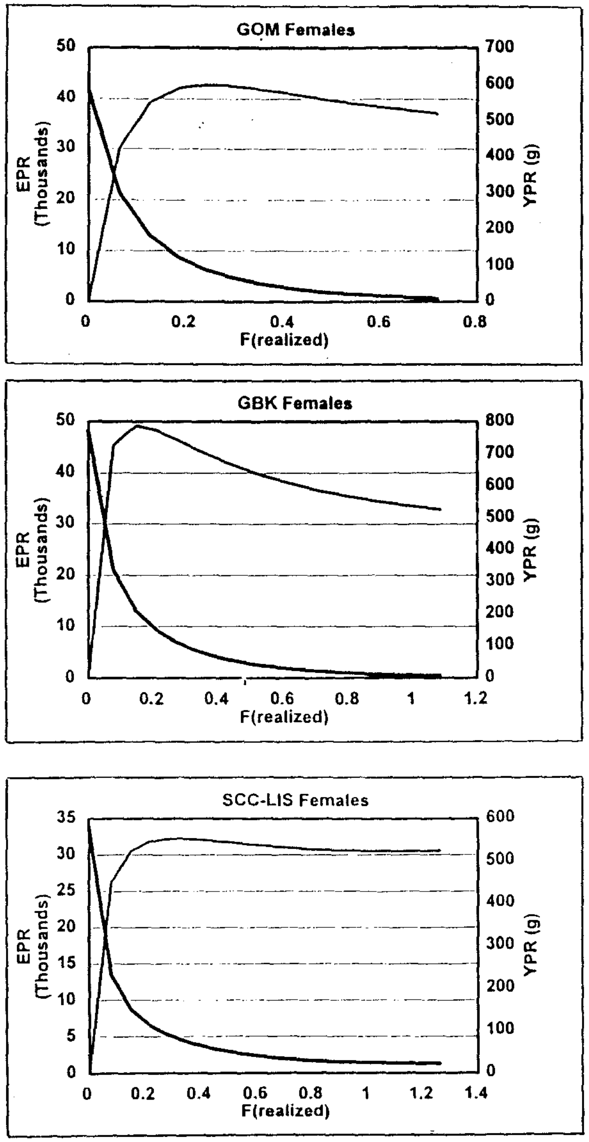

Figure B46. Egg production and yield per recruit for female lobsters by area.

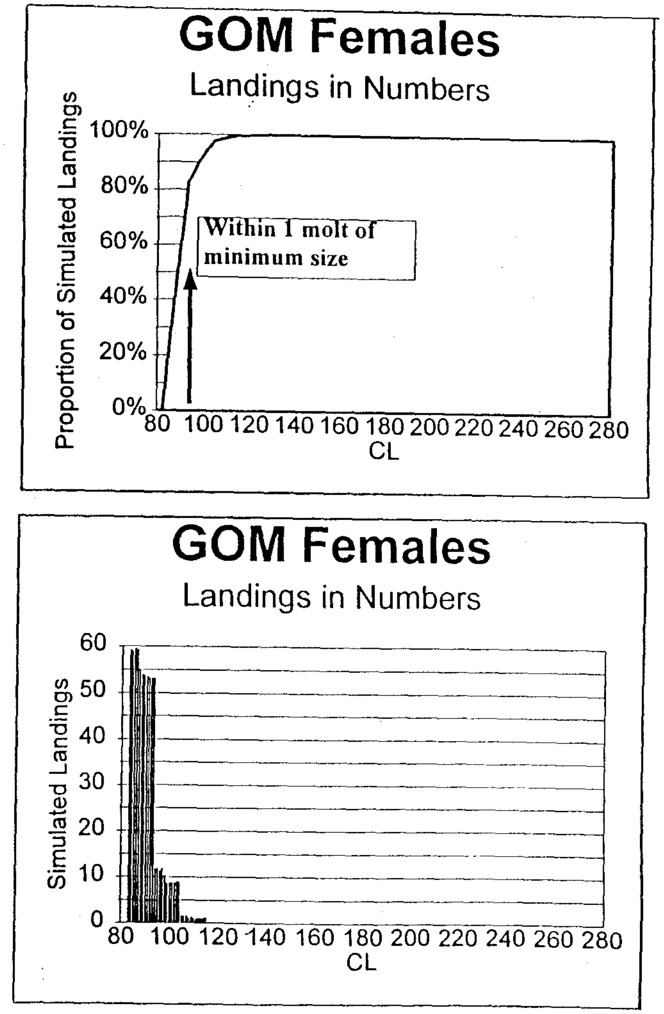

Figure B47. Simulated size composition of landings of female lobsters at current calculated fishing mortality rate for Gulf of Maine.

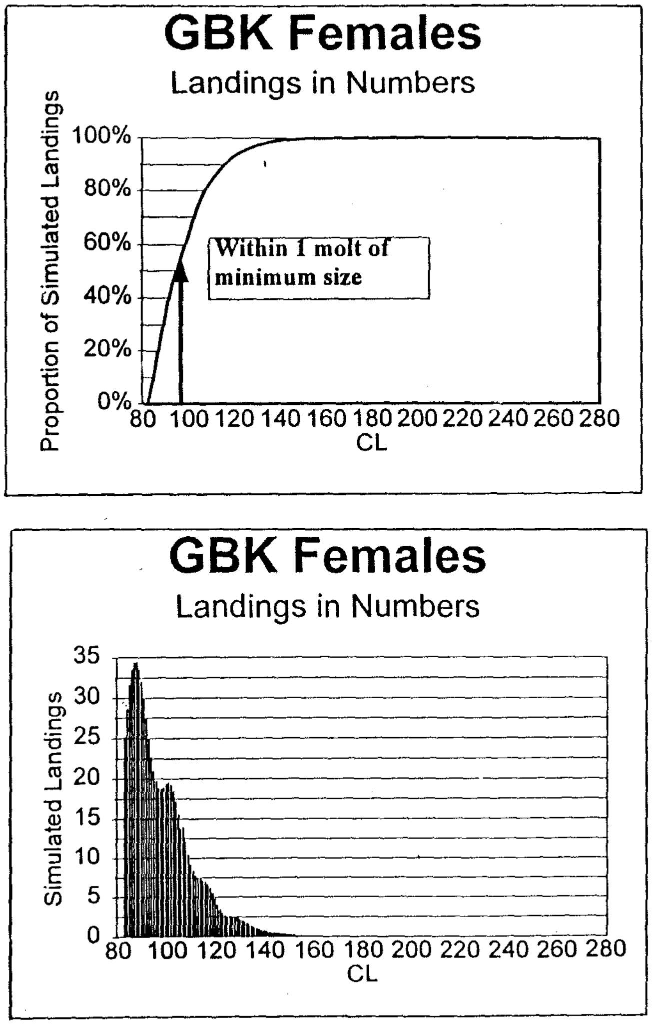

Figure B48. Simulated size composition of landings of female lobsters at current calculated fishing mortality rate for Georges Bank and South.

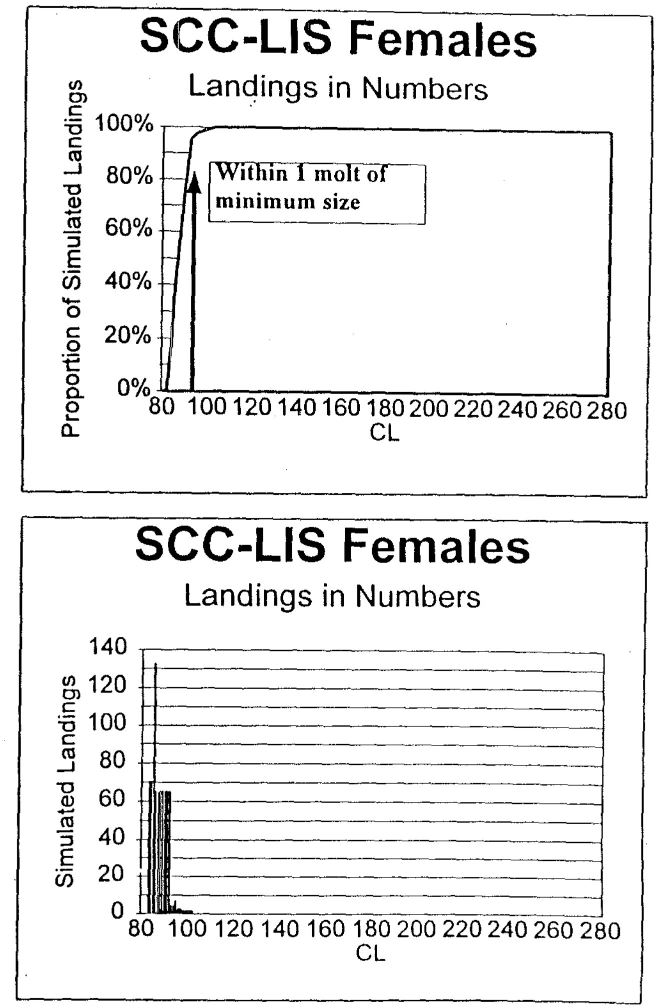

Figure B49. Simulated size composition of landings of female lobsters at current calculated fishing mortality rate for South of Cape Cod to Long Island Sound.

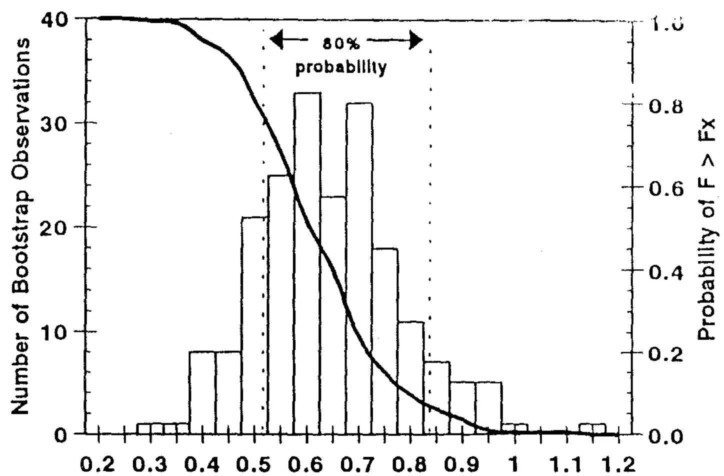

Figure B50. Bootstrap estimates of the empirical distribution of average fishing mortality rates (F_{R+N}) for the period 1991-1993 for female lobsters from the Gulf of Mainestock. Bars represent bootstrap observations; the line represents the probability of exceeding the abscissa value of F.

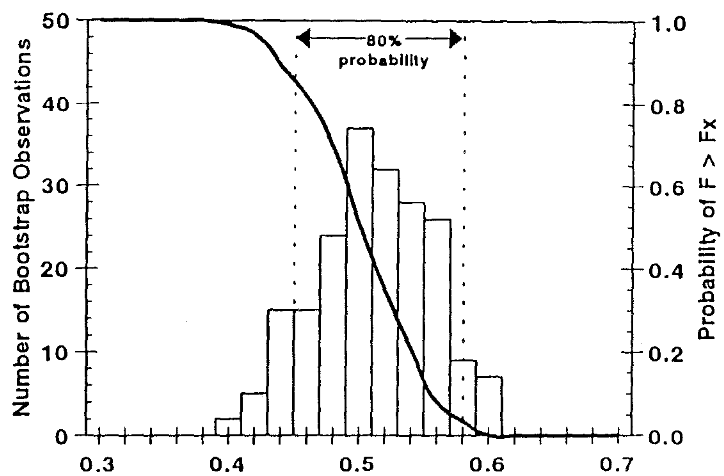

Figure B51. Bootstrap estimates of the empirical distribution of average fishing mortality rates (F_{R+N}) for the period 1991-1993 for female lobsters from the Georges Bank and South stock. Bars represent bootstrap observations; the line represents the probability of exceeding the abscissa value of F.

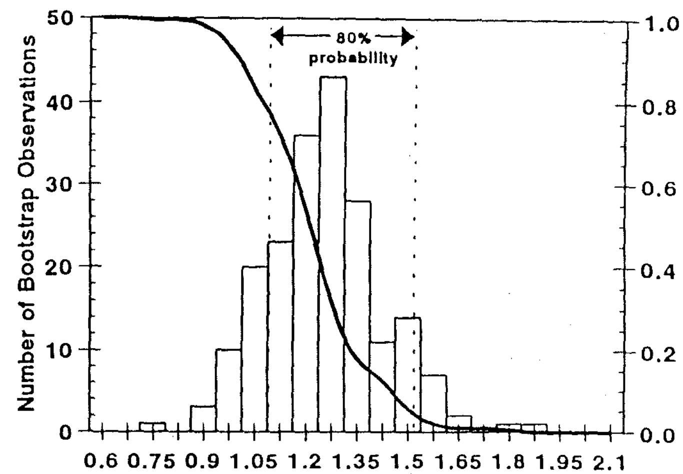

Figure B52. Bootstrap estimates of the empirical distribution of average fishing mortality rates (F_{R+N}) for the period 1991-1993 for female lobsters from the South of Cape Cod to Long Island Sound stock. Bars represent bootstrap observations; the line represents the probability of exceeding the abscissa value of F.

C. SUMMER FLOUNDER

Terms of Reference

The following terms of reference were addressed:

a. Provide updated assessment for the coastwide stock of summer flounder and provide catch and SSB options at various levels of fishing mortality.

b. Provide catch and SSB forecasts incorporating uncertainty in recruitment and stock size estimates (stochastic projections).

Introduction

For assessment purposes, the previous definition of Wilk *et al.* (1980) of a unit stock extending from Cape Hatteras north to New England was accepted. The Mid-Atlantic Fishery Management Council (MAFMC) Fishery Management Plan (FMP) for summer flounder has as a management unit all summer flounder from the southern border of North Carolina northeast to the U.S.-Canadian border. Amendment 1 to the FMP (1990) established the overfishing definition for summer flounder as $F_{MAX} = 0.23$. Amendment 2 to the FMP (August 1992) set target fishing mortality rates for summer flounder for 1993-1995 ($F_{TGT} = 0.53$) and 1996 and beyond ($F_{MAX} = 023$). Major regulations enacted under Amendment 2 to meet those fishing mortality rate targets included: 1) an annual fishery landings quota, with 60% allocated to the commercial fishery and 40% to the recreational fishery, based on the historical (1980-1989) division of landings, with the commercial allocation further distributed among the states based on their share of commercial landings during 1980-1989, 2) commercial minimum landed fish size limit at 13 in (33 cm), as established in the original FMP, 3) a minimum mesh size of 5.5 in (140 mm) diamond or 6.0 in (152 mm) square for commercial vessels using otter trawls that possess 100 lb (45 kg) or more of summer flounder, with exemptions for the flynet fishery and vessels fishing in an exempted area off Southern New England (the Northeast Exemption Area) during 1 November - 30 April, 4) permit requirements for the sale and purchase of summer flounder, and 5) annually adjustable regulations for the recreational fishery, including seasons, a 14 in (36 cm) minimum landed fish size, and possession limits.

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

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

The Fishery

Northeast Region (NER: Maine to Virginia) commercial landings for 1980-1995 were derived from the Northeast Fisheries Science Center (NEFSC) commercial landings files and quota reports. The commercial landings reporting system changed in April 1994 from voluntary dealer reports and associated vessel interviews (the 'weighout system') to mandatory dealer reports and vessel trip logbooks. The logbook data for 1994 are nearly in a form ready for routine use, but the 1995 logbook data are in a very preliminary state. For both 1994 and 1995, the dealer reports provide the distribution of landings by market category, while the vessel logbooks provide information on the location of catches and fishing effort. Thus, in much the same way as the information from vessel interviews was used to characterize the 1982 to April 1994 weighout landings under the voluntary reporting system, the data from the May to December 1994 vessel logs were used to characterize the spatial distribution of the market category landings reported by dealers. For 1995, the preliminary state of the vessel logbook data necessitated the characterization of market category landings to area on an *ad hoc* basis, with Connecticut - Maine landings assigned to sampling area 5, and New York - Virginia landings assigned to area 6. At the time of this assessment, 4,600 mt of landings were included in the dealer report database for 1995. The weekly quota reports for 1995 totaled 4,831 mt, and so the proportions at age based on 4,600 mt were raised to meet the quota report total. The NER commercial landings at age for 1994-1995 will again be revised in the next assessment when the vessel logbook database for 1994-1995 is complete and ready for routine use.

The reported total commercial landings (from quota reports) in 1995 were 6,631 mt (about 14.6 million lb), less than 1% over the final 1995 commercial fishery quota (6,628 mt). However, landings in North Carolina, as reported by the NC trip ticket system, were 2,066 mt (4.6 million lb), about 15% higher than the 1,799 mt (4.0 million lb) reported by the weekly quota monitoring system. The higher NC trip ticket reported landings were used in the assessment, providing reported total commercial landings in 1995 of 6,897 mt (15.2 million lb) (Table C1).

Recreational landings were based on statistics from the National Marine Fisheries Service Marine Recreational Fishery Statistics Survey (MRFSS) for type A + B1 landings. In 1995, recreational landings decreased to 2,496 mt (5.5 million lb), about 71% of the target quota for the fishery (3,520 mt, 7.7 million lb). Current recreational fishery landings are well below levels of the early 1980s when landings ranged between 5,000 and 14,000 mt (Table C1).

Age samples were available to construct the landings-at-age matrix for the NER (Maine - Virginia) commercial landings for the period 1982-1995 (Table C2). A landings-at-age matrix for 1982-1995 was also developed for the North Carolina winter trawl fishery (Table C3) which historically accounts for about 99% of summer flounder commercial landings in North Carolina. The matrix is based on NCDMF fishery length frequency samples and age-length keys from NEFSC commercial and spring survey data (1982-1987) or NCDMF commercial fishery data (1988-1995).

Discards from the commercial fishery during 1989-1993 were estimated using observed discards and days fished from NEFSC sea sampling trips to calculate fishery discard rates by two-digit statistical area and calendar quarter. These rates were applied to the total days fished (days fished on mobile gear trips landing any summer flounder) from the weighout database in the corresponding area-quarter cell to provide estimates of fishery discard by cell. Discard estimates were aggregated over all cells, with that total raised to reflect potential discard associated with general canvas and North Carolina EEZ landings. Because existing sea sampling length-age data are not adequate to characterize discards at this level of resolution, with large amounts of estimated discard represented by one or no length-age samples, length-age samples were applied at a coarser stratum level as needed.

A NER commercial fishery discard-at-age matrix for 1989-1993 was developed using sea sampled length frequency and age-length distribution samples from 1989-1993, assuming a commercial fishery discard mortality rate of 80%, as recommended by SAW-16 (NEFSC 1993) (Table C4). Sampling intensity was at least one sample of 100 lengths per 29 mt.

Although data are inadequate to develop a commercial discard-at-age matrix for 1982-1988, it is likely that discard numbers were small relative to landings during that period because there was no minimum size limit for fish caught in the EEZ. Discards likely increased in 1989-1993 with the initial implementation of minimum size regulations for the EEZ in 1989. Not accounting directly for commercial fishery discards will result in underestimating fishery mortality and population sizes in 1982-1988.

Sea sample discard rate and length frequency data for 1994 and 1995 were not available to the SARC. To develop estimates of total discard and discard at age for 1994-1995, arithmetic weighted (by numbers at age and year) mean 1989-1993 discard to landings ratios by weight (mt) (mean 1989-1993 proportion = 0.143), proportions at age by weight, and mean lengths and weights at age were assumed for the 1994-1995 discards (Table C4). Preliminary, unaudited sea sample data were used to evaluate the potential level of summer flounder discarding during 1994-1995. Table C5 summarizes the total of sea sample trips, observed tows catching summer flounder, and the total catch, kept, and discard of summer flounder for observed tows. The ratio of discard to kept summer flounder (in weight) from sea sample observed tows indicates relatively low levels of discarding in 1994 and 1995. Initially, the Southern Demersal Subcommittee suspected that the low discard-to-landing ratio indicated by the preliminary data reflected increased sea sampling in the Northeast Exemption Area (east of 72°30'), where discards are expected to be low, and did not reflect the magnitude of discarding in the entire fishery in 1994-1995. However, analysis of the spatial distribution of the 1994-1995 sea sample data for trips and tows catching summer flounder was performed subsequent to the Subcommittee meeting, and that analysis indicated that, as in 1989-1993, most of the trips and tows catching summer flounder were observed in areas 61 and 62 (about 50% of the trips and 40% of the tows in 1994, about 70% of the trips and 72% of the tows in 1995), west of the exempted area. Thus, the low discard level in 1994-1995 may indicate non-representative sampling of the commercial fishery. Despite uncertainty about the mechanism, the apparent decline in commercial fishery discards is encouraging.

Estimates of recreational landings at age (type A + B1) were developed from MRFSS estimates of total catch and sample length frequencies, and NEFSC commercial and survey age-length data (Tables C6 - C9). Estimates of recreational discards at age were based on assumptions that the ratios of age 0:age 1 fish in type B2 catches were the same as in A + B1 landings and that 25% of the type B2 catches die of hooking mortality. Type B2 catches have become a more significant component of total recreational catches (up to 79% in 1995) as minimum size regulations have been implemented on a state-by-state basis. Because discard lengths and weights are unobserved, mean weight at age in the discard is set equal to mean weight at age in the landings. The SARC noted that discard weight at age consequently would be overestimated (although sub-legal sized fish are observed in landings).

NER total commercial landings and discards at age, North Carolina winter trawl landings and discards at age, and MRFSS recreational landings and discards at age totals were summed to provide a total fishery catch-at-age matrix for 1982-1995 (Table C10). The numbers and proportions at age of fish age 4 and older are low and quite variable, reflecting the limited numbers of fish available to be sampled. Overall mean lengths and weights at age for the total catch were calculated as weighted means (by number in the catch at age) of the respective mean values at age from the NER commercial (Maine - Virginia), North Carolina commercial winter trawl, and recreational (Maine - North Carolina) fisheries (Tables C11-C12).

Research Survey Abundance and Biomass Indices

Age-specific mean catch rates, in numbers, from the NEFSC spring offshore survey (Table C13, 1976-1996, 1996 preliminary), NEFSC fall inshore/offshore survey (Table C14, 1982-1995), NEFSC winter offshore survey (Table C15, 1992-1996, 1996 preliminary), the Rhode Island Dept. of Fish and Wildlife fall survey (Table C16, 1980-1995), the Massachusetts Div. of Marine Fisheries (MADMF) spring and fall inshore surveys (Table C17, 1978-1995), the Connecticut Dept. of Environmental Protection (CTDEP) spring and fall trawl surveys (Table C18, 1984-1995), and the New Jersey Bureau of Marine Fisheries spring to fall trawl survey (Table C19, 1988-1994) were used as indices of abundance in VPA tuning.

Young-of-year (YOY) survey indices from the NCDMF Pamlico Sound trawl survey (1987-1995), Virginia Institute of Marine Science (VIMS) juvenile fish trawl survey (1979-1995), and Maryland Dept. of Natural Resources (MDDNR) trawl survey (1972-1995) were also used in VPA tuning (Table C20).

As part of the continuing evaluation of the summer flounder VPA in response to SAW research recommendations, correlation analyses of survey indices at age and SAW-22 VPA estimated stock numbers at age, using 1) the Spearman rank correlation coefficient on untransformed VPA estimates and survey indices, 2) the Pearson correlation coefficient on log transformed VPA estimates and survey indices, and 3) the Pearson correlation coefficient on transformed survey indices, along with examination of VPA tuning non-linear least squares residuals, were performed to judge whether indices should be retained in the tuning. Analyses were performed including only the converged years (i.e., 1982-1991) and the entire series of years in the VPA (1982-1995) in order to consider some of the surveys with short time series. A strict rule for inclusion was not applied (e.g., a significance level of 0.10 for the correlation coefficient) since some of the indices 1) were very close to meeting the strict correlation criteria, 2) met the criteria for inclusion depending on the length of the series considered, or 3) were the only survey data available for certain age groups, but failed to meet the strict criteria.

The correlation analyses and partial variances from the VPA sometimes provided a different interpretation of the goodness of fit. An index can have a large partial variance due to a few large residuals, but still show a reasonable correlation with VPA estimates, especially if the rank order of indices and VPA estimates is similar. Some indices were marginally acceptable on the basis of correlation and partial variance, but were excluded because of a trend in tuning residuals. Finally, some indices at age were included to maintain consistency of inclusion of indices at age within a survey (i.e., the CTDEP fall 3 index was retained, despite low correlation because the age 1, 2, and 4 indices were included). Even though many survey indices, and in some cases entire survey series (e.g., DEDFW 30 foot survey), were excluded from the VPA tuning, the SARC wishes to emphasize that it still considers such research survey indices to have value. Although some surveys may not reflect the coastwide trends in the abundance of summer flounder indicated by VPA, the surveys may provide accurate indices of localized summer flounder abundance and serve as useful tools for local fisheries management.

Estimates of Mortality and Stock Size

Natural Mortality Rate

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

Estimates of Mortality from ALS Tagging Data

Tagging data for summer flounder from the American Littoral Society (ALS) angler program were used to make estimates of fishing mortality. Since 1983, a total of 21,482 summer flounder have been tagged by ALS anglers. Through 1995, 1617 had been recovered. Tag release and recapture data were compiled from 1983 through 1995 by year of release. Estimates of survival rates were made using the SURVIVE framework (Smith MS 1994) which has been used extensively in striped bass and other wildlife marking studies. The statistical framework consists of a series of models which consider tag recoveries in sequential years following release to be multinomial random variables. Model structure in terms of recovery rate and survival probability proceeds from most restrictive (no time dependence) to most general (time-dependent parameters). Maximum likelihood methods are used to estimate parameters and provide a covariance matrix for the estimates. Goodness of fit, likelihood ratio tests, and Akaike's Information Criteria (AIC) are used to select the most parsimonious model which adequately fits the data. The models estimate survival rate directly which is transformed into total mortality rate. Total mortality rate was corrected for tag loss on the basis of Sprankle's (1994) study on striped bass which indicated an instantaneous loss of 0.48 per year for the ALS tags. Fishing mortality rate was estimated by subtracting M = 0.20 from corrected Z values.

SURVIVE models did not converge when using the full time series of tagging data (1983-1995). A shorter time series (1989-1995) was selected to fit a model which assumed time-independent recovery and survival rate, also known as the general model. Survival rate (S) ranged from 0.12 in 1990 to 0.36 in 1994 without a clear trend. Coefficients of variation on the survival estimates ranged from 0.03 to 0.12 and in general were proportional to the number of fish tagged. The period of inference for the survival estimate was from July of one year to July of the next year. The estimated survival rates correspond to a total instantaneous loss rate ranging from Z = 1.01 to Z = 2.11. Allowing for tag loss as estimated in the retention study and natural mortality losses, fishing mortality rate (F) ranged from F = 0.33 in the terminal year 1994-1995 to F = 1.44 in 1990-1991. Assuming no uncertainty in the natural mortality or tag loss adjustment rates, a 95% confidence interval of F in 1994-1995 was 0.10 - 0.74. Given the length frequency distribution of releases, most are age 1 fish, and so fishing mortality rates estimated from the tagging data were compared to F estimates at age 1, one calendar year later (e.g., tagging F in 1994-1995 compared to VPA age 1 F in 1995), and found to be of comparable magnitude (Table C21).

Virtual Population Analysis (VPA) Calibration

ADAPT tuning for the VPA (1982-1994) was used (Parrack 1986, Gavaris 1988, Conser and Powers 1990). In response to a research recommendation from SAW-20 (NEFSC 1996), the SARC reviewed available research survey indices and eliminated from the VPA tuning those that did not reasonably match corresponding patterns in abundance as estimated by the VPA. All indices in the VPA tuning were given equal weight. The natural mortality rate (M) was assumed to be 0.2. Fishing mortality rates in 1995 and stock numbers at ages 1-4 in 1996 were directly estimated, while numbers at age 5+ was estimated from Fs estimated in 1995. Because no recruitment indices were available for 1996, stock size at age 0 was not estimated. The F on age 4 (oldest true age) was estimated from back-calculated stock sizes for ages 2-4. The F on the age 5+ group was set equal to the rate for age 4.

Fishing mortality rates on fully recruited ages have exceeded 1.0 between 1982-1995, varying between 1.0 and 2.1 (58-85% exploitation rate). The fishing mortality rate peaked in 1992 at 2.1, but has since declined to 1.3 in 1994 and 1.5 in 1995 (Table C22, Figure C1).

Summer flounder spawn in the late autumn and into early winter (peak spawning on November 1), and age 0 fish recruit to the fishery the autumn after they are spawned. For example, summer flounder spawned in autumn 1987 (from the November 1, 1987 spawning stock biomass) recruit to the fishery in autumn 1988, and appear in VPA tables as age 0 fish in 1988. This assessment indicates that the 1982 and 1983 year classes were the largest of the VPA series at 76 and 83 million fish, respectively, at age 0. The 1988 year class was the smallest of the series at only 13 million fish. The 1994 year class is estimated at about 42 million fish, and the 1995 year class at 58 million fish, the largest since 1983 (Table C22, Figure C2).

Total stock size in 1995 (ages 0 and older) was estimated at about 100 million fish, about 61% of the peak abundance estimated for 1983 (163 million). Spawning stock biomass (SSB) on November 1, 1995 was estimated to be 15,235 mt, 80% of the peak estimated for 1983 (18,944 mt). Age 2-5+ SSB, which may be a more realistic estimate of viable spawners given the uncertain spawning potential of age 0 and age 1 summer flounder, was estimated to be 1,809 mt, about 32% of the SSB estimated for 1983 (5,707 mt) (Table C22, Figure C2). A comparison between catch biomass, as calculated in the VPA, and reported landings plus estimated discard is presented in Table C23.

In summary, the VPA results indicate that fishing mortality rates on summer flounder have declined since 1992, but are currently above the management target (F_{TGT} = 0.53 in 1995) and the overfishing definition (F_{MAX} = 0.23). Fishing mortality rates on age 1 fish in 1995 were lower relative to fully recruited ages (2-4) than in 1993-1994, and so the partial recruitment on age 1 fish in 1995 was estimated at 0.29, compared to 0.59 in 1993-1994. Spawning stock biomass has increased by 290% since 1989, but this biomass continues to be concentrated in a few age classes, with only about 12% of the total SSB at ages 2 and older and about 5% at ages 3 and older. In contrast, about 88% of the spawning stock would be expected to be age 2 and older if the stock were rebuilt and fished at F_{MAX} = 0.23. Spawning stock biomass and corresponding recruitment estimates are summarized in Figure C3.

A bootstrap procedure (Efron 1982) was used to evaluate the precision of the final VPA estimates with respect to random variation in tuning data (survey abundance indices). The procedure does not reflect uncertainty in the catch-at-age data. Two hundred bootstrap iterations were used to generate distributions of the 1995 fishing mortality rate and spawning stock biomass. The bootstrap estimate of the 1995 spawning stock biomass was relatively precise, with a corrected CV of 19%. The bootstrap mean (15,980 mt) was slightly higher than the VPA point estimate (15,235 mt). The bootstrap results suggest a high probability (>90%) that spawning stock biomass in 1995 was at least 12,000 mt, reflecting only variability in survey observations (Figure C4).

The corrected coefficients of variation for the Fs in 1995 on individual ages were 30% for age 0, 22% for age 1, and 13% for fully recruited ages. The distribution of bootstrap Fs was not strongly skewed, resulting in the bootstrap mean F for 1995 (1.52) being about equal to the point estimate from the VPA (1.51). There is an 80% chance that F in 1995 was between about 1.3 and 1.8, given variability in survey observations (Figure C5).

VPA Retrospective Analysis

Retrospective analysis of the summer flounder VPA was carried out for terminal catch years 1988-1995 using the final SAW-22 VPA configuration, but with the NEFSC winter trawl survey indices omitted because of the brevity of that series. Convergence was generally evident within 4 years prior to a given terminal year. As in the SAW-20 assessment, a retrospective pattern continued to be evident in the summer flounder VPA, with a recent tendency for F to be underestimated and stock sizes overestimated.

The retrospective analysis showed that fully recruited F (ages 2-4) was overestimated for 1988-1990, but has been underestimated since 1991. The largest retrospective error occurred for 1992 (1992 terminal year estimate of F = 1.1, 1995 terminal year estimate of F = 2.1) (Table C24). Over the terminal catch years of 1988-1995, fully recruited F was underestimated by an average of 0.20.

Spawning stock biomass was underestimated for 1988-1989, but overestimated since 1990. The largest retrospective error occurred for 1992, with SSB overestimated by 5,300 mt relative to the 1992 estimate with a 1995 terminal year (Table 58, Figure 11). Over the terminal catch years of 1988-1995, SSB was overestimated by an average of 1,310 mt.

Summer flounder recruitment at age 0 was underestimated for 1988 and 1993, but overestimated for the years 1989-1992 and 1994. The largest retrospective error occurred for 1994, with age 0 recruitment overestimated by 16.8 million fish relative to the 1994 estimate with a 1995 terminal year (Table C24). Over the terminal catch years of 1988-1995, recruitment was overestimated by an average of 6.5 million fish. For average recruitment of 32.8 million fish during 1988-1994, recruitment has been overestimated by an average of 21.6%.

Age 1 and older stock size in numbers was underestimated for 1988-1989, but overestimated for 1990-1995. The largest retrospective error occurred in the 1991 terminal year (1992 age 1+ stock size estimate of 49.3 million, 1995 terminal year estimate of 1992 age 1 stock size = 33.1 million) (Table C24). Over the terminal catch years of 1988-1995, terminal catch year + 1 age 1+ stock size (e.g., 1996 stock size estimated from the 1995 terminal catch year) was overestimated by an average of 7.7 million fish. For an average age 1+ stock size of 33.1 million fish during

1989-1995, terminal catch year + 1 age 1+ stock size has been overestimated by 23.3%.

Retrospective patterns appear in stock assessments from errors in three separate components of the analysis: 1) the catch equation itself, 2) the catch and resulting partial recruitment estimates, and 3) the indices of abundance used in calibration of terminal year F and stock size estimates (Sinclair *et al.* 1990, ICES 1991). Potential causes for the retrospective pattern present in the summer flounder VPA from each of these sources were considered.

The catch model used in the ADAPT VPA determines cohort abundance over time by assuming constant M, harvest at mid-year, and unbiased estimates of catch at age (Pope 1972). Pope's approximation of the catch equation is most accurate when Z is less than 0.7. When Z is 1.7, F is underestimated by 0.2 and abundance is overestimated in the terminal year (Hilborn and Walters 1992). The assumption of catch at mid-year would produce underestimates of F if a large majority of landings were taken in the last half of the year, which has not been the case in the summer flounder fishery in recent years (e.g., 1993-1995).

The present retrospective pattern could arise if M = 0.2 is overestimated. As described in a previous section of this report, however, it seems more likely that if M for summer flounder were to be revised, it would be revised to a higher value. The effects of an inaccurate M are complicated when there is a trend in F (Lapointe *et al.* 1989). If M decreased with age, recruitment would be underestimated in recent terminal catch years, not overestimated as in the summer flounder VPA (Sinclair *et al.* 1990).

The only partial recruitment assumption in the summer flounder assessment is that age 5+ fish are fully-recruited ($F_{5+} = F_{2\text{-}4}$). If older fish were actually less vulnerable to the fishery, abundance would be underestimated in recent terminal catch years, not overestimated as in the summer flounder VPA (Sinclair *et al.* 1990).

Underestimated catch at age from unreported landings, discarding, or unrepresentative sampling of the fisheries can also produce underestimation of F in terminal years (Sinclair *et al.* 1990, ICES 1991).

There is no independent evidence that catchability of recent surveys has changed, which would introduce an error (bias) and produce retrospective patterns. Log transformation of survey indices and age-disaggregation of indices, which are employed in the summer flounder ADAPT VPA, are techniques to minimize retrospective patterns due to errors in survey indices (Sinclair *et al.* 1990, ICES 1991).

Therefore, underestimation of the true catch is a plausible cause of the retrospective underestimation of F in the summer flounder VPA. Unreported catch and increased discarding may be associated with recent restrictions on the commercial and recreational fisheries.

The SARC concluded that regardless of the source of error responsible for the retrospective pattern in the summer flounder VPA, future quotas should be set with consideration of the direction and magnitude of this bias (underestimation of the fishing mortality rate and overestimation of stock size).

Why is the Current F Estimate so Different from the SAW-20 Estimate?

Fishing mortality (F) was estimated in the SAW-20 assessment (NEFSC 1996) to be about 0.7 (46% exploitation) in 1994 for fully recruited summer flounder (ages 2-4), and was projected to be 0.5 (36% exploitation) in 1995 if the entire quota (10,183 mt, 22.4 million lb) were landed and discards were 2,300 mt (5.1 million lb), for a total catch of 12,500 mt (27.6 million lb). In 1995, total landings used in the assessment were 9,400 mt (20.7 million lb), with discards estimated to be 2,900 mt (6.4 million lb), for a total catch of 12,300 mt (27.1 million lb). The estimates of F in 1994 and 1995 from the current assessment, however, were 1.3 (67% exploitation) and 1.5 (72% exploitation), much higher than the levels estimated at SAW-20. Several factors have combined to produce the higher estimates of fishing mortality and lower estimates of stock size in the current assessment compared to estimates from SAW-20. Exploratory runs of the SAW-20 VPA showed that revisions (use of final total catch per tow and age-length data) to the NEFSC 1995 spring, NEFSC 1994-1995 winter, and MADMF 1995 fall surveys were responsible for a decrease in estimated stock sizes and an increase in fully recruited F in the SAW-20 VPA (terminal catch year in 1994).

The subsequent addition of new survey (1995-1996) and catch data (1995) in the current assessment also resulted in higher F estimates in the summer flounder VPA. Exploratory sensitivity runs with the SAW-22 VPA showed that even if the now-obsolete SAW-20 values for the survey indices at age noted above were used in the VPA tuning, F estimates for 1994 and 1995 remain much higher than in the SAW-20 assessment estimates and projections.

These changes in the summer flounder VPA estimates of the fishing mortality rate and spawning stock biomass can be summarized as follows:

VPA	1994 F	1994 SSB	1995 F	1995 SSB
SAW-20	0.69	14,800 mt	-	-
SAW-20, 1994-1995 surveys updated with SAW-22 values SAW-20 catch	1.95	11,500 mt	-	-
SAW-22, 1994-1995 surveys use obsolete SAW-20 values, 1995-1996 surveys use SAW-22 values, SAW-22 catch	1.33	9,700 mt	1.46	12,900 mt
SAW-22	1.30	9,900 mt	1.51	15,200 mt

Biological Reference Points

The calculation of biological reference points for summer flounder using the Thompson and Bell (1934) model was detailed in the Report of the Eleventh SAW (NEFC 1990). No revised analysis was performed for the current assessment. The 1990 analysis indicated $F_{0.1} = 0.136$, $F_{MAX} = 0.232$, and $F_{20\%} = 0.270$ (Figure C6). A revision of biological reference points for summer flounder will not be undertaken until changes in the partial recruitment pattern in response to management regulations become more clearly defined.

Projections

Yield and stock size projections were made for 1996-1998 assuming that the 1996 quotas would be landed (but not exceeded) by the fisheries, and that total discards in 1996 would not exceed 1,900 mt. The projections assume that the 1989-1993 pattern of discarding in the commercial fishery would continue. The projections do not include the lower discard rates indicated by the preliminary 1994-1995 commercial fishery sea sample data. The projections do reflect the current pattern of discarding in the recreational fishery. Different discarding patterns that could develop during 1996-1998 due to trip and possession limits and fishery closures were not evaluated. The partial recruitment pattern (including discards) used in the projections was estimated as the geometric mean of F at age for 1993-1995 to reflect conditions in the fisheries resulting from the implementation of FMP amendment regulations (see **Introduction**). Mean weights at age were estimated as the arithmetic means of 1993-1995 values. Separate mean weight-at-age vectors were developed for the spawning stock, landings, and discards (Table C25).

Stochastic projections were made to estimate landings and spawning stock biomass levels under four options, given uncertainty in 1996 age 1 and older stock size estimates and 1996-1998 age 0 recruitment levels. Two hundred projections were made for each of the 200 bootstrapped realizations of 1996 stock sizes from VPA runs using algorithms and software described by Brodziak and Rago (MS 1994). Recruitment in 1996-1998 was generated randomly from recruitment levels estimated by VPA for 1991-1995. Uncertainty in partial recruitment patterns, discard rates, reported landings, or components other than survey variability was not reflected.

The Option 1 projection used SAW-22 VPA 1996 stock sizes. This projection indicated that if the 1996 quota were landed (8,400 mt) and no dramatic increase in discarding occurred, the fishing mortality rate in 1996 would be 0.52. If landings in 1997 were 9,250 mt and discards did not exceed 800 mt, there is a 50% probability that the F target for 1997 (F = 0.30) would be achieved, with a median spawning stock biomass level of 33,200 mt (Option 1; Tables C25-C26). Under Option 1, there is a 95% probability that spawning stock biomass would be at least 15,400 mt in 1996, and a 99% chance that spawning stock biomass would be at least 21,000 mt in 1997.

Option 2 also started with SAW-22 VPA 1996 stock sizes and indicated that if landings in 1997 were 8,400 mt and discards did not exceed 700 mt, there is a 50% probability that the F in 1997 would be 0.27, with a median spawning stock biomass level of 33,900 mt (Option 2). The SARC noted, however, that the fishing mortality rates associated with Options 1 and 2 would likely be greater than projected in 1996 and 1997 because of the pattern of underestimation of fishing mortality rates in the assessment.

For Options 3 and 4, the SAW-22 VPA stock sizes in 1996 were reduced to account for the recent retrospective pattern evident in the VPA (age 0 stock size reduced by 21.6%, ages 1 and older reduced by 23.3%). Under Options 3 and 4, landings of 8,400 mt and discards of 1,900 mt in 1996 would result in a realized F = 0.68, with a median SSB of 16,400 mt. Under Option 3, a reduction in landings in 1997 to 6,350 mt would be necessary to achieve F = 0.30 in 1997, with a median spawning stock biomass level of 24,100 mt. Under Option 4, again using reduced stock sizes, landings in 1997 of 8,400 mt would result in a median F in 1997 of 0.42, with a median spawning stock biomass level of 22,500 mt (Tables C25-C26). If the 1996 catch were underestimated, F in 1996 would be greater than projected under all options, and available biomass in 1997 and 1998 would be lower than projected.

Conclusions

The stock is at a medium level of historical abundance and is overexploited. The fishing mortality rate on summer flounder is high, peaking at 2.1 in 1992, and is estimated to be 1.5 for 1995 (Figure C1). The current estimate of fishing mortality is above the management targets (F_{TGT} = 0.53 in 1995, F_{MAX} = 0.23; Figure C6). There is an 80% chance that the 1995 F was between 1.3 and 1.8 (Figure C5). Spawning stock biomass (age 0 and older) has increased since 1989 (5,247 mt) to 15,235 mt in 1995, about 80% of the level estimated for 1983. The age structure of the spawning stock in 1995 remains truncated, however, with about 12% of the biomass at ages 2 and older. In contrast, about 88% of the spawning stock would be expected to be age 2 and older if the stock were rebuilt and fished over the long term at F_{MAX} = 0.23. There is an 80% chance that the 1995 spawning stock biomass was between 12,500 mt and 20,000 mt (Figure C4). Recruitment has improved in recent years, and the 1995 year class may be the best since 1983, but stock rebuilding at ages 2 and older is not occurring as projected in previous assessments (Figure C2). Due to the strength of incoming recruitment, fishing mortality in 1996 is projected to decrease to 0.52 if the 1996 quota of 8,400 mt is landed and discards do not exceed 1,900 mt. However, a recent retrospective pattern in the VPA of underestimation of F and overestimation of stock sizes suggests that recent total catch is underestimated, resulting in overly optimistic projections of landings levels associated with management targets. An historical review of previous assessments shows that projections have consistently underestimated future fishing mortality rates and overestimated stock size (Table C27).

Despite the management measures already implemented, further reductions in exploitation are needed to meet fishing mortality rate targets. These reductions are necessary because historical experience and new analyses indicate that assessments and projections have underestimated fishing mortality and overestimated stock size each year since 1991. The degree of underestimation of fishing mortality in 1996 is uncertain, but will affect all of the projections. For this reason, projection options that account for the underestimation of fishing mortality are most likely to achieve target fishing mortality rates. The presence of relatively strong incoming recruitment, which is supporting the fishery in 1996, affords an opportunity to rebuild the spawning stock biomass while allowing modest catches.

Sources of Uncertainty

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

1) VPA estimates of stock size in 1996 are not precise because they depend on imprecise and, in some cases, preliminary survey indices. The landings from the commercial fisheries used in this assessment assume no underreporting of summer flounder landings. Therefore, reported landings from the commercial fisheries should be considered minimum estimates. The SARC noted that the fishing mortality rate in the terminal year of the VPA has been underestimated in the previous assessments (NEFSC 1993, 1994, 1996), and the underestimation of the true catch is a plausible cause of this retrospective pattern. Uncertainty in partial recruitment patterns, discard rates, reported landings, or components other than survey variability is not reflected in the projections. Projected landings should be considered with caution.

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

3) Northeast Region (NER; ME-VA) commercial fishery landings-at-age estimates are based on preliminary vessel logbook data. The NER landings at age for 1994-1995 will be revised in the next assessment if the vessel logbook database for 1994-1995 is complete and ready for routine use.

4) Samples of the 1994-1995 commercial fishery discards by length interval were not available, and so those components of the catch-at-age matrix were estimated by indirect methods (see **The Fishery** section). The proportion of the catch at age which is discarded is likely to change under regulation (e.g., recreational fishery bag limits, commercial fishery trip limits and closures), but is assumed to remain constant in current projections. This will likely lead to underestimation of discards and fishing mortality rates in the projections.

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

SARC Comments

The SARC questioned if the low sampling intensity in NC from 1988 to 1990 required supplementation with NEFSC age-length keys. It was noted that the Subcommittee identified the merger of NEFSC and NCDMF samples as a possibility in future assessments. Differences in growth pattern over the broad range of the stock were suggested as a possible cause for ageing inconsistencies.

The SARC noted that the commercial fishery discards were computed based on an expansion of sea sample discard rates by summer flounder effort for mobile gear. A question was posed as to how sea sample trips are allocated and if the same boats were sampled repeatedly, which might bias the observed rates. It was noted that the same boats are not sampled repeatedly, and in fact few boats appear consistently in the NEFSC domestic sea sampling database for summer flounder. Given the preliminary nature of the discard data for 1994-1995, the SARC asked if the audit process could substantially change the results, and discussion suggested that major changes in the observed discard rate were unlikely. There was discussion concerning evidence for high grading in the form of increasing mean length during the fishing season. The SARC concluded that this would be confounded by growth effects. A suggestion was made to investigate the possibility of high grade discarding using a subset of data restricted to records where a sea sample could be matched with a vessel logbook and dealer report. The difficulties encountered to date in simply matching dealer reports and logbooks were noted.

The SARC expressed concern that age 0 and 1 fish were mixed in the catch at age. The criteria used to age summer flounder and the birthdate convention invoked to separate ages was explained. Otolith aging was proposed as an alternative to scale-based ages. It was noted that summer flounder otoliths are very difficult to interpret, and the SARC concluded that, with limited age structure, scales should be satisfactory if summer flounder ageing inconsistencies can be reconciled. The SARC noted that a DeLury model formulation might help to circumvent uncertainty in the age data used in the VPA.

It was suggested that the NEFSC fall survey index be extended backward in time to add a historical perspective. Winter survey results were scrutinized because of the large index increase in 1996. Although a relatively small number of tows (6) occurred in Areas 61 and 62, all tows in these strata had high catches in 1996. The SARC noted that tuning indices for the VPA were not smoothed with ARIMA procedures.

The SARC examined in detail the 1995 NEFSC winter survey age data, which caused substantial revisions to survey abundance at age, due to larger mean and higher variance in length at age. The SARC concluded that there was no evidence that the unusually large sized age 1 fish were restricted in distribution (e.g., only to southernmost survey strata). The SARC reviewed the results of the scale exchange between NEFSC and NCDMF and noted that it included only 1995 samples. It was recommended that this be repeated with samples from earlier years. A discussion concerning the interaction of maturation with annulus deposition and the cause of extraneous marks on summer flounder scales ensued. The SARC requested clarification on which age keys were used to age state survey samples. CTDEP and NJBMF survey length frequencies are aged using NEFSC age-length keys. In the MADMF surveys, length and age sample data are collected by the state, but ageing is done by the NEFSC.

Several questions about the ADAPT model configuration were raised including lagging of indices to stock sizes, PR pattern specification, and the influence of 1996 survey data on age 0 estimation in 1995. The SARC questioned and was briefed on important differences between the suites of indices used in trial and retrospective ADAPT runs. A review of the potential causes of retrospective pattern occurred with the SARC focusing on the underestimation of catch. The SARC suggested that the final VPA be run under the exact catch equation, rather than Pope's approximation, to determine the impact on the retrospective pattern.

Integrated catch-at-age analysis model (ICA) results for summer flounder were examined to further investigate the sensitivity of assessment conclusions. ICA is a method that can allow an estimation of the degree of error in the catch. Predicted catch is estimated as a function of abundance, mortality rate, and partial selection. Relaxation of the true catch assumption for the most recent years (1993-1995) was made for summer flounder (separable model for 1993-1995) with the thought that this might provide a better solution capability and appraisal of uncertainty in the terminal catch year estimates. There was little difference between the ICA and ADAPT VPA results. Both models show fishing mortality rates in excess of 1.0 over the 1982-1995 time series. Fishing mortality was estimated by ICA to be 1.36 in 1995. Precision of the ICA terminal year estimates was somewhat lower than the ADAPT VPA bootstrap estimates, reflecting the additional variance in fitting the catch estimates in the ICA model. The SARC concluded that the similarity between ADAPT VPA and ICA results indicates that the high fishing mortality rates estimated in this assessment compared to SAW-20 estimates are not model induced, but result from the updated and new data added in this assessment.

The SARC reviewed research survey indices of abundance for evidence of stock rebuilding and concluded that although the survey indices indicated improved recruitment, there was little evidence of age structure extension. A discussion followed regarding the amount of catch underestimation needed to cause the observed retrospective pattern in the VPA. The Canadian experience was that catch underestimation was a primary cause of retrospective pattern in VPA based assessments. The SARC noted that the historical review of summer flounder assessments showed a continuous failure to meet F targets. Concern was expressed for the fate of the 1995 year class if it were subjected to high fishing mortality. The SARC discussed the suitability of including projection results adjusted for retrospective bias. The SARC consensus was that managers should be given strong advice on the direction of the bias in terms of the likelihood of meeting F targets. In spite of the uncertainty in the assessment, the SARC concluded that the assessment provided the best estimate of the current status of the stock and was useful for management purposes.

Research Recommendations

- The SARC supports the ongoing cooperative work between the NEFSC and NCDMF to ensure consistent ageing of summer flounder.

- The Southern Demersal Subcommittee should estimate the range of additional catch during 1993-1995 that could account for the retrospective pattern observed in VPA results to address the hypothesis that the true catch is underestimated in the assessment.

- The MAFMC Summer Flounder Technical Monitoring Committee should consult with the MAFMC Demersal Committee and industry advisors concerning the adequacy of NEFSC domestic sea sampling and on the issues of underreported and undersampled landings.

- If the summer flounder assessment remains on a mid-year review schedule, it is critical that data from surveys and the fisheries be made available to the Subcommittee by the end of April.

- The NEFSC domestic sea sampling program should continue the collection of data for summer flounder, with special emphasis on a) improved areal and temporal coverage, b) adequate length and age sampling, and c) continued sampling after commercial fishery areal and seasonal quotas are reached and fisheries are limited or closed. Maintaining adequate sea sampling will be especially important in the next few years in order to monitor a) the effects of implementation of gear and closed/exempted area regulations, both in terms of the response of the stock and the fishermen, b) potential continuing changes in "directivity" in the summer flounder fishery, as a results of changes in stock levels and regulations, and c) discards of summer flounder in the otter trawl fishery once quota levels have been attained and the summer flounder fishery is closed or restricted by trip limits.

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

- Together with the SAW Assessment Methods Subcommittee, the Southern Demersal Subcommittee should conduct further testing of the sensitivity of the analysis to potential sources of bias (e.g., misreporting of landings, systematic error in surveys, incorrect assumptions about discard rates and discard mortality, misspecification of the objective function in the VPA).

- The Southern Demersal Subcommittee should continue work to extend the historic SSB/recruit time series for summer flounder by calibrating VPA results and survey time series.

- The present maturity ogive for summer flounder is based on simple gross examination of ovaries and may not accurately reflect the spawning potential of summer flounder, especially age 0 and age 1 fish. The SARC encourages completion of ongoing work (e.g., by researchers at the University of Rhode Island) to better characterize the spawning contribution of young summer flounder.

- The Southern Demersal Subcommittee should review available NEFSC egg and larval survey data and determine if they would be useful either as a tuning index or as an exogenous means to judge the likely utility of recruitment indices currently used in VPA calibration.

- The Southern Demersal Subcommittee should review alternative biological reference points and management targets for summer flounder.

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Table C1. Commercial and recreational landings (metric tons, A + B1 recreational type) of summer flounder, Maine to North Carolina (NAFO Statistical Areas 5 and 6), as reported by NMFS Fisheries Statistics Division. Recreational landings are aggregated from wave/state/mode/area estimates.

Year	Comm.	Rec.	Total	% Comm.	% Rec.
1980	14,159	14,149	28,308	50	50
1981	9,551	4,852	14,403	66	34
1982	10,400	8,267	18,667	56	44
1983	13,403	12,687	26,090	51	49
1984	17,130	8,512	25,642	67	33
1985	14,675	5,665	20,340	72	28
1986	12,186	8,102	20,288	60	40
1987	12,271	5,519	17,790	69	31
1988	14,686	6,733	21,419	69	31
1989	8,125	1,435	9,560	85	15
1990	4,199	2,329	6,528	64	36
1991	6,224	3,611	9,835	63	37
1992	7,529	3,242	10,771	70	30
1993	5,715	3,484	9,199	62	38
1994	6,588	4,111	10,699	62	38
1995	6,897	2,496	9,393	73	27
Ave.	10,234	5,950	16,183	63	37

Table C2. Commercial landings at age of summer flounder ('000), ME-VA. Does not include discards, assumes catch not sampled by NEFSC weighout has same biological characteristics as weighout catch. 1994-1995 ME-VA commercial fishery landings are a preliminary estimate (see text).

	Age										
Year	0	1	2	3	4	5	6	7	8	9	Total
1982	1,441	6,879	5,630	232	61	97	57	22	2	0	14,421
1983	1,956	12,119	4,352	554	30	62	13	17	4	2	19,109
1984	1,403	10,706	6,734	1,618	575	72	3	5	1	4	21,121
1985	840	6,441	10,068	956	263	169	25	4	2	1	18,769
1986	407	7,041	6,374	2,215	158	93	29	7	2	0	16,326
1987	332	8,908	7,456	935	337	23	24	27	11	0	18,053
1988	305	11,116	8,992	1,280	327	79	18	9	5	0	22,131
1989	96	2,491	4,829	841	152	16	3	1	1	0	8,430
1990	0	2,670	861	459	81	18	6	1	1	0	4,096
1991	0	3,755	3,256	142	61	11	1	1	0	0	7,227
1992	114	5,760	3,575	338	19	22	0	1	0	0	9,829
1993	151	4,308	2,340	174	29	43	19	2	1	0	7,067
1994	131	3,869	3,553	250	66	11	5	0	5	0	7,891
1995	538	3,410	2,825	210	45	6	1	2	0	0	7,036

Table C3. Number ('000) of summer flounder at age landed in the North Carolina commercial winter trawl fishery. The 1982-1987 NCDMF length samples were aged using NEFSC age-length keys for comparable times and areas (i.e., same quarter and statistical areas). The 1988-1995 NCDMF length samples were aged using NCDMF age-length keys.

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

Table C4. Summary of Northeast Region sea sample data to estimate summer flounder discard at age in the commercial fishery, 1989-1995. Estimates developed using sea sample length samples, age-length data, and estimates of total discard in mt. Because 1994-1995 sea sample data were not available to the Committee, arithmetic weighted (by number at age and year) mean 1989-1993 total discard (mt), proportions at age, and mean lengths and weights at age were assumed for the 1994-1995 discard. An 80% discard mortality rate is assumed.

Year	Lengths	Ages	Sea sample discard estimate (mt)	Sampling intensity (mt per 100 lengths)	Raised discard estimate (mt)	Raised estimate with 80% mortality rate (mt)
1989	2,337	54	642	26	886	709
1990	3,891	453	1,121	29	1,516	1,213
1991	5,326	190	993	19	1,315	1,052
1992	9,626	331	956	10	1,147	918
1993	3,410	406	597	18	811	650
1994						941
1995						947

Discard numbers at age (000s)

Year	0	1	2	3	Total
1989	775	1,628	94	0	2,497
1990	1,440	2,753	67	0	4,260
1991	891	3,424	<1	0	4,315
1992	1,966	1,606	57	7	3,636
1993	1,197	914	101	0	2,212
1994	1,301	2,141	66	1	3,509
1995	1,308	2,155	67	1	3,531

Discard mean length at age

Year	0	1	2	3	All
1989	25.9	31.5	44.2		30.2
1990	29.0	31.7	38.9		30.9
1991	24.0	30.9	37.0		29.5
1992	29.3	30.0	36.6	51.2	30.0
1993	29.9	32.6	34.8		31.2
1994	28.2	31.2	38.8	51.2	30.2
1995	28.2	31.2	38.8	51.2	30.2

Discard mean weight at age

Year	0	1	2	3	All
1989	0.182	0.296	0.909		0.284
1990	0.235	0.304	0.559		0.285
1991	0.124	0.275	0.491		0.244
1992	0.238	0.256	0.498	1.450	0.252
1993	0.253	0.332	0.413		0.293
1994	0.217	0.288	0.605	1.450	0.268
1995	0.217	0.288	0.605	1.450	0.268

Table C5. Summary sea sample data for trips catching summer flounder. Total trips (trips are not split for multiple areas), observed tows, catch, kept, and discard (lbs).

Year	Trips	Tows	Total catch	Total kept	Total discard	Discard: kept (%)
1989	57	413	53,714	48,406	5,308	11.0
1990	61	463	47,954	35,972	11,982	33.3
1991	82	635	61,650	50,410	11,240	22.3
1992	66	649	137,127	118,514	18,613	15.7
1993	45	410	74,982	67,603	7,379	10.9
Mean (1989-93)	62	514	75,085	64,181	10,904	18.6
1994	46	374	178,107	167,102	11,005	6.6
1995	135	1,017	244,645	236,809	7,836	3.3

Table C6. Estimated total landings [catch types A + B1 (000s)] of summer flounder by recreational fishermen. **Shore** mode includes fish taken from beach/bank and man-made structures. **P/C** indicates catch taken from party/charter boats, while **P/R** indicates fish taken from private/rental boats.

	Year													
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
North														
Shore	167	144	62	10	70	39	42	4	16	9	26	36	49	19
P/C	138	201	5	3	48	7	1	1	1	8	1	10	24	6
P/R	1,293	747	568	382	2,562	648	379	137	99	173	211	250	596	449
Total	1,598	1,092	635	395	2,680	694	422	142	116	190	238	296	669	474
Mid														
Shore	682	3,296	977	272	478	251	594	84	96	505	200	176	195	175
P/C	5,745	3,321	2,381	1,068	1,541	1,143	1,164	141	412	589	374	872	773	267
P/R	5,731	12,345	11,764	8,454	5,924	5,499	7,271	1,141	2,658	4,573	3,983	3,969	4,372	2312
Total	12,158	18,962	15,122	9,794	7,943	6,893	9,029	1,366	3,166	5,667	4,557	5,017	5,340	2,754
South														
Shore	272	523	316	504	689	115	306	91	150	51	50	113	180	48
P/C	53	52	110	81	20	1	1	1	1	1	1	1	2	1
P/R	1,392	367	1,292	292	289	162	355	117	361	159	156	236	197	100
Total	1,717	942	1,718	877	998	278	662	209	512	211	207	350	379	149
All														
Shore	1,121	3,963	1,355	786	1,237	405	942	179	262	565	276	325	424	242
P/C	5,936	3,574	2,496	1,152	1,609	1,151	1,166	143	414	598	376	883	799	274
P/R	8,416	13,459	13,624	9,128	8,775	6,309	8,005	1,395	3,118	4,905	4,350	4,455	5,165	2,861
Total	15,473	20,996	17,475	11,066	11,621	7,865	10,113	1,717	3,794	6,068	5,002	5,663	6,388	3,377

Table C7. Estimated total landings [catch types A + B1 (mt)] of summer flounder by recreational fishermen. **Shore** mode includes fish taken from beach/bank and man-made structures. **P/C** indicates catch taken from party/charter boats, while **P/R** indicates fish taken from private/rental boats.

	Year													
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
North														
Shore	87	59	17	7	25	21	32	2	16	6	20	25	30	14
P/C	85	87	4	2	45	4	<1	<1	<1	6	<1	7	14	5
P/R	875	454	388	328	2,597	582	289	141	89	150	175	181	424	371
Total	1,047	600	409	337	2,667	607	322	144	106	162	196	213	468	390
Mid														
Shore	295	1,254	399	140	293	129	329	52	56	306	126	88	112	108
P/C	3,112	2,196	1,426	609	1,093	1,098	799	125	264	364	267	534	478	185
P/R	3,085	8,389	5,686	4,187	3,521	3,596	5,003	985	1,665	2,673	2,536	2,453	2,849	1699
Total	6,492	11,839	7,511	4,936	4,907	4,823	6,131	1,162	1,985	3,343	2,929	3,075	3,439	1,992
South														
Shore	87	134	98	230	425	34	113	57	76	25	25	59	100	29
P/C	12	12	23	20	7	1	<1	<1	<1	<1	<1	<1	1	<1
P/R	629	102	471	142	96	54	166	71	161	80	91	136	103	84
Total	728	248	592	392	528	89	280	129	238	106	117	196	204	114
All														
Shore	469	1,447	514	377	743	184	474	111	148	337	171	172	242	151
P/C	3,209	2,295	1,453	631	1,145	1,103	801	127	266	371	269	542	493	191
P/R	4,589	8,945	6,545	4,657	6,214	4,232	5,458	1,197	1,915	2,903	2,802	2,770	3,376	2,154
Total	8,267	12,687	8,512	5,665	8,102	5,519	6,733	1,435	2,329	3,611	3,242	3,484	4,111	2,496

Table C8. Estimated recreational landings at age of summer flounder (000s), (catch type A + B1).

Year	Age 0	1	2	3	4	5	6	7	8	Total
1982	2,750	8,445	3,498	561	215	<1	4	0	0	15,473
1983	2,302	11,612	4,978	1,340	528	220	0	16	0	20,996
1984	2,282	9,198	4,831	1,012	147	5	<1	0	0	17,475
1985	1,002	5,002	4,382	473	148	59	0	0	0	11,066
1986	1,169	6,404	2,784	1,088	129	15	28	4	0	11,621
1987	466	4,674	2,083	448	182	1	5	6	0	7,865
1988	434	5,855	3,345	386	90	3	0	0	0	10,113
1989	74	539	946	135	16	2	5	0	0	1,717
1990	353	2,770	529	118	23	<1	1	0	0	3,794
1991	86	3,611	2,251	79	40	1	0	0	0	6,068
1992	82	3,183	1,620	90	<1	27	0	0	0	5,002
1993	71	3,470	1,981	139	<1	2	0	0	0	5,663
1994	765	3,872	1,549	171	26	<1	5	0	0	6,388
1995	356	1,931	994	54	26	16	<1	0	0	3,377

Table C9. Estimated recreational fishery discard at age of summer flounder, (catch type B2). Discards allocated to age groups in same relative proportions as ages 0 and 1 in the subregional catch, the same mean weight at age as in the landings, and assuming 25% hooking mortality.

	Numbers at age			Metric tons at age		
Year	0	1	Total	0	1	Total
1982	431	1,591	2,022	97	643	740
1983	437	2,329	2,766	77	862	939
1984	526	2,551	3,077	108	929	1,037
1985	101	514	615	24	205	229
1986	375	3,043	3,418	84	1,360	1,444
1987	265	3,024	3,289	61	1,246	1,307
1988	139	1,673	1,812	41	816	857
1989	32	208	240	8	106	114
1990	151	1,176	1,327	46	541	587
1991	59	2,443	2,502	16	1,058	1,074
1992	43	1,684	1,727	10	849	859
1993	55	3,525	3,580	14	1,826	1,840
1994	443	2,143	2,586	93	1,249	1,442
1995	517	2,698	3,215	236	1,684	1,920

Table C10. Total catch at age of summer flounder (000s), ME-NC.

	Age										
Year	0	1	2	3	4	5	6	7	8	9	Total
1982	5,604	20,378	10,149	935	328	116	67	26	4	0	37,607
1983	5,187	29,838	10,911	2,181	693	323	16	36	5	2	49,193
1984	5,118	28,113	15,454	3,180	829	95	4	5	1	4	52,803
1985	2,139	14,931	17,979	1,767	496	252	30	5	2	1	37,602
1986	2,167	18,966	11,055	3,782	316	140	58	12	3	0	36,498
1987	1,296	19,026	10,838	1,648	544	25	29	33	11	0	33,450
1988	878	21,561	14,562	2,137	644	121	19	15	6	0	39,943
1989	979	4,915	7,306	1,692	353	55	9	3	1	0	15,313
1990	1,946	9,512	2,187	995	221	30	8	2	1	0	14,902
1991	1,036	13,615	7,148	742	217	32	3	1	0	0	22,795
1992	2,205	12,269	6,047	1,125	151	70	2	1	0	0	21,869
1993	1,473	12,732	5,523	565	73	45	20	2	1	0	20,435
1994	2,645	12,283	6,431	925	207	25	13	0	5	0	22,534
1995	2,719	10,375	5,276	1,125	402	75	3	0	2	0	19,977

Table C11. Mean length (cm) at age of summer flounder catch, ME-NC.

	Age Mean length										
Year	0	1	2	3	4	5	6	7	8	9	all ages
1982	29.4	34.5	38.8	50.7	55.3	61.0	60.7	68.0	71.2		35.7
1983	28.7	34.5	40.9	46.5	48.8	51.6	60.7	60.9	69.3	72.0	36.2
1984	29.3	33.8	39.1	45.9	51.3	57.9	66.8	68.4	74.0	70.7	36.0
1985	30.5	34.8	38.8	46.8	53.9	58.6	61.5	74.5	73.3	75.0	37.5
1986	29.6	35.6	39.9	47.5	54.0	56.2	65.8	66.4	72.8		38.1
1987	29.8	35.3	39.7	46.9	55.8	63.3	65.9	63.2	73.5		37.5
1988	32.3	35.8	39.1	46.6	53.1	60.2	69.6	68.5	72.7		37.9
1989	27.1	35.8	40.8	45.5	50.6	58.5	59.1	63.1	59.0		39.1
1990	29.7	35.2	41.9	46.8	51.4	57.4	66.4	71.7	75.2		36.5
1991	25.0	34.6	40.4	47.1	54.3	61.0	61.7	68.1			36.6
1992	29.9	36.1	41.1	46.9	49.7	61.0	58.8	72.2			37.6
1993	30.2	36.9	40.7	50.4	52.9	54.7	62.6	70.6	75.5		38.0
1994	31.9	37.1	39.4	49.5	57.3	63.3	66.3		68.5		37.9
1995	32.1	37.4	39.6	44.7	52.6	62.2	70.2		70.3		38.1

Table C12. Mean weight (kg) at age of summer flounder catch, ME-NC.

Year	Age 0	1	2	3	4	5	6	7	8	9	Mean weight all ages
1982	0.254	0.418	0.616	1.447	1.907	2.795	2.673	3.758	4.408		0.500
1983	0.240	0.417	0.716	1.075	1.257	1.495	2.572	2.594	3.849	4.370	0.516
1984	0.248	0.396	0.632	1.046	1.500	2.163	3.302	3.620	4.640	4.030	0.512
1985	0.289	0.428	0.613	1.109	1.726	2.297	2.671	4.682	4.780	4.800	0.573
1986	0.253	0.453	0.668	1.160	1.739	1.994	3.311	4.000	4.432		0.602
1987	0.259	0.442	0.651	1.140	1.941	2.855	3.326	3.314	4.140		0.570
1988	0.316	0.463	0.624	1.130	1.739	2.485	3.888	3.545	4.316		0.584
1989	0.208	0.460	0.723	1.044	1.479	2.249	2.399	2.861	2.251		0.666
1990	0.251	0.431	0.810	1.169	1.538	2.121	3.461	3.951	5.029		0.536
1991	0.145	0.407	0.702	1.186	1.811	2.527	2.936	3.586			0.530
1992	0.243	0.469	0.748	1.223	1.390	2.696	2.302	4.479			0.576
1993	0.263	0.493	0.703	1.464	1.659	1.859	2.816	4.136	5.199		0.570
1994	0.325	0.518	0.638	1.351	2.074	2.849	3.412		3.724		0.583
1995	0.337	0.540	0.677	1.059	1.666	2.639	3.764		4.070		0.610

Table C13. NEFSC spring trawl survey (offshore strata 1-12, 61-76) stratified mean number of summer flounder per tow at age. Indices for 1996 are preliminary.

Year	Age 1	2	3	4	5	6	7	8	9	10	Total
1976	0.03	1.70	0.68	0.28	0.01	0.01	0.01				2.72
1977	0.61	1.30	0.70	0.10	0.09	0.01		0.01			2.82
1978	0.70	0.95	0.66	0.19	0.04	0.03	0.03			0.02	2.62
1979	0.06	0.18	0.08	0.04	0.03			0.01			0.40
1980	0.01	0.71	0.31	0.14	0.02	0.06	0.03	0.01		0.01	1.31
1981	0.59	0.53	0.17	0.08	0.05	0.03	0.02	0.01			1.48
1982	0.69	1.41	0.12	0.03							2.24
1983	0.32	0.39	0.19	0.04	0.01				0.01		0.95
1984	0.17	0.33	0.09	0.05		0.01	0.01				0.66
1985	0.55	1.56	0.21	0.04	0.02						2.38
1986	1.49	0.43	0.20	0.02	0.01						2.15
1987	0.46	0.43	0.02	0.02							0.92
1988	0.59	0.79	0.07	0.03							1.47
1989	0.06	0.23	0.02	0.01							0.32
1990	0.62	0.03	0.06								0.71
1991	0.81	0.28		0.02							1.11
1992	0.75	0.41	0.01		0.01						1.19
1993	0.87	0.34	0.04	0.01							1.27
1994	0.15	0.68	0.08	0.01							0.93
1995	0.85	0.23					0.01				1.09
1996	0.66	1.16	0.10	0.03							1.95

Table C14. NEFSC fall trawl survey [inshore strata 1-61, offshore strata ≤ 55 m (1, 5, 9, 61, 65, 69, 73)] mean number of summer flounder per tow at age.

	Age										
Year	0	1	2	3	4	5	6	7	8	9+	Total
1982	0.55	1.52	0.40	0.02							2.50
1983	0.96	1.46	0.34	0.12	0.01						2.90
1984	0.18	1.39	0.43	0.07	0.01	0.01					2.09
1985	0.59	0.80	0.46	0.05		0.02					1.92
1986	0.39	0.83	0.11	0.10		0.01					1.44
1987	0.07	0.58	0.20	0.03	0.02						0.90
1988	0.06	0.62	0.18	0.03							0.89
1989	0.31	0.21	0.05								0.57
1990	0.44	0.38	0.03	0.04							0.89
1991	0.76	0.84	0.09	0.00	0.01						1.70
1992	0.99	1.04	0.25	0.03	0.01						2.32
1993	0.23	0.80	0.03	0.01							1.07
1994	0.75	0.67	0.09	0.01	0.01						1.53
1995	1.34	0.84	0.16	0.05	0.00	0.01					2.40

Table C15. NEFSC winter trawl survey (offshore strata 1-17, 61-76; Southern Georges Bank to Cape Hatteras) mean number, mean weight (kg), and mean number at age per tow. Indices for 1996 are preliminary.

Year	Stratified mean number per tow	Coefficient of variation	Stratified mean weight (kg) per tow	Coefficient of variation
1992	12.295	15.6	4.898	15.4
1993	13.577	15.2	5.486	11.9
1994	12.051	17.8	6.033	16.1
1995	10.800	12.0	4.751	11.6
1996	31.457		12.405	

	Age								
Year	1	2	3	4	5	6	7	8	Total
1992	7.15	4.74	0.33	0.04	0.01	0.03	0.00	0.00	12.29
1993	6.48	6.69	0.31	0.05	0.02	0.02	0.00	0.00	13.58
1994	3.76	7.20	0.82	0.26	0.00	0.01	0.00	0.00	12.05
1995	7.70	3.01	0.08	0.01	0.00	0.00	0.00	0.00	10.80
1996	24.60	6.35	0.40	0.11	<0.01	0.00	0.00	0.00	31.46

Table C16. RIDFW fall trawl survey summer flounder index of abundance.

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

[1]Proportion of catch < 30 cm
[2]Proportion of 30 cm ≤ catch < 40 cm

Table C17. MADMF spring and fall survey cruises: stratified mean number per tow at age.

Spring					Age					
Year	0	1	2	3	4	5	6	7	8+	Total
1978		0.097	0.520	0.274	0.221		0.042			1.15
1979			0.084	0.087	0.147	0.048	0.011			0.37
1980		0.055	0.061	0.052	0.075	0.053	0.055	0.011		0.36
1981		0.405	0.558	0.074	0.031	0.043	0.060		0.031	1.20
1982		0.376	1.424	0.118	0.084	0.020		0.010		2.03
1983		0.241	1.304	0.544	0.021	0.009	0.003			2.12
1984		0.042	0.073	0.063	0.111	0.010				0.30
1985		0.142	1.191	0.034	0.042					1.41
1986		0.966	0.528	0.140	0.008					1.64
1987		0.615	0.583	0.012			0.011			1.22
1988		0.153	0.966	0.109	0.012					1.24
1989			0.338	0.079			0.010			0.43
1990		0.247	0.021	0.079	0.012					0.36
1991		0.029	0.048	0.010						0.09
1992		0.274	0.320	0.080		0.011	0.011			0.7
1993		0.120	0.470	0.060	0.010		0.020			0.68
1994		1.770	1.160	0.050	0.020		0.010			3.01
1995		0.450	0.890	0.040						1.38

Fall					Age					
Year	0	1	2	3	4	5	6	7	8+	Total
1978		0.011	0.124	0.024		0.007				0.17
1979			0.047	0.101		0.019				0.17
1980		0.114	0.326	0.020	0.020	0.010				0.49
1981	0.009	0.362	0.367	0.011						0.75
1982		0.255	1.741	0.016						2.01
1983		0.026	0.583	0.140	0.004					0.75
1984	0.033	0.453	0.249	0.120	0.008					0.86
1985	0.051	0.108	1.662	0.033						1.85
1986	0.128	2.149	0.488	0.128						2.89
1987		1.159	0.598	0.010	0.004					1.77
1988		0.441	0.414	0.018						0.87
1989			0.286	0.024						0.31
1990		0.108		0.012						0.12
1991	0.021	0.493	0.262	0.010						0.79
1992		1.110	0.170							1.28
1993	0.010	0.300	0.430	0.020	0.020					0.79
1994	0.050	2.130	0.070							2.25
1995	0.032	0.401	0.323	0.013						0.77

Table C18. CTDEP spring and fall trawl surveys: geometric mean number per tow at age.

Spring

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

Fall

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

Table C19. NJBMF trawl survey, April - October: mean number per tow at age.

			Age			
Year	0	1	2	3	4+	Total
1988	0.29	4.22	1.19	0.01	0.00	5.71
1989	1.25	0.54	0.40	0.01	0.01	2.21
1990	1.88	1.89	0.15	0.05	0.00	3.92
1991	1.50	3.11	0.32	0.02	0.01	4.96
1992	1.34	3.76	0.76	0.08	0.05	6.00
1993	3.52	6.95	0.27	0.04	0.02	10.79
1994	2.22	1.46	0.13	0.01	0.03	3.85

Table C20. Age 0 summer flounder research survey recruitment indices used in SAW-22 VPA tuning.

	Year class													
Survey	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
NEFSC fall	0.55	0.96	0.18	0.59	0.39	0.07	0.06	0.31	0.44	0.76	0.99	0.23	0.75	1.34
CT fall			0.00	0.24	0.17	0.08	0.02	0.00	0.03	0.04	0.01	0.08	0.13	0.15
NJ							0.29	1.25	1.88	1.50	1.34	3.52	2.22	
MD	2.0	10.6	5.4	5.6	16.2	4.6	0.5	1.3	2.1	3.1	3.5	1.6	8.2	5.0
VIMS rivers only	3.23	5.20	1.90	0.93	1.27	0.45	0.54	0.96	2.61	1.42	0.49	0.49	1.08	0.48
NC Pamlico trawl						19.86	2.61	6.63	4.27	5.85	9.41	5.13	8.17	5.59

Table C21. Summary of summer flounder mortality estimation for American Littoral Society (ALS) angler tagging data. SE = standard error. Fishing mortality estimates from tagging are for the period from e.g., July 1994 to July 1995. and are compared with VPA estimates for age 1 fish on 1 January of the second year, e.g., January 1995.

Year	Survival rate (S)	SE (S)	Total mortality (Z)	SE (Z)	M	Tag loss rate	F	VPA age 1 F
1989-90	0.17	0.12	1.77	0.71	0.20	0.48	1.09	0.64
1990-91	0.12	0.04	2.11	0.33	0.20	0.48	1.44	0.94
1991-92	0.18	0.04	1.73	0.20	0.20	0.48	1.06	0.86
1992-93	0.29	0.04	1.23	0.15	0.20	0.48	0.55	0.82
1993-94	0.19	0.03	1.65	0.15	0.20	0.48	0.97	0.91
1994-95	0.36	0.06	1.01	0.17	0.20	0.48	0.33	0.44

Table C22. Summary results from summer flounder SAW-22 VPA.

Catch at age (thousands) - SAW-22

■	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
0 ■	5604	5187	5118	2139	2167	1296	878	979	1946	1036
1 ■	20378	29838	28113	14931	18966	19026	21561	4915	9512	13615
2 ■	10149	10911	15454	17979	11055	10838	14562	7306	2187	7148
3 ■	935	2181	3180	1767	3782	1648	2137	1692	995	742
4 ■	328	693	829	496	316	544	644	353	221	217
5+■	213	382	109	290	213	96	161	68	41	36
0+■	37607	49192	52803	37602	36499	33448	39943	15313	14902	22794

■	1992	1993	1994	1995
0 ■	2205	1474	2645	2719
1 ■	12269	12732	12283	10375
2 ■	6047	5523	6431	5276
3 ■	1125	565	925	1125
4 ■	151	73	207	402
5+■	73	68	43	80
0+■	21870	20435	22534	19977

Stock numbers (Jan 1) in thousands - SAW-22

■	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
0 ■	76468	82679	49173	51168	56273	45218	13125	28212	32296	29945
1 ■	43770	57536	62998	35628	39957	44112	35849	9952	22212	24681
2 ■	15736	17397	20108	26141	15660	15553	18900	9841	3700	9579
3 ■	2370	3701	4371	2480	5134	2818	2927	2298	1447	1051
4 ■	525	1094	1056	701	431	781	816	463	350	284
5+■	334	591	134	400	283	134	197	86	64	46
0+■	139204	162997	137841	116517	117738	108617	71815	50852	60069	65585

■	1992	1993	1994	1995	1996
0 ■	33144	29345	42324	58257	0
1 ■	23579	25141	22692	32259	45236
2 ■	7887	8203	9063	7464	17023
3 ■	1375	986	1719	1601	1337
4 ■	189	108	296	570	293
5+■	88	98	60	111	123
0+■	66262	63881	76154	100262	64013

Summaries for ages 2-5+

■	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
■	18965	22783	25670	29722	21508	19287	22841	12688	5561	10960	9539

■	1993	1994	1995	1996
■	9395	11138	9747	18777

Table C22. (Continued)

Fishing mortality - SAW-22

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
0	0.08	0.07	0.12	0.05	0.04	0.03	0.08	0.04	0.07	0.04	0.08	0.06	0.07	0.05
1	0.72	0.85	0.68	0.62	0.74	0.65	1.09	0.79	0.64	0.94	0.86	0.82	0.91	0.44
2	1.25	1.18	1.89	1.43	1.51	1.47	1.91	1.72	1.06	1.74	1.88	1.36	1.53	1.52
3	0.57	1.05	1.63	1.55	1.68	1.04	1.64	1.68	1.43	1.52	2.35	1.00	0.90	1.50
4	1.17	1.20	2.02	1.52	1.66	1.47	2.06	1.85	1.19	1.86	2.15	1.38	1.48	1.51
5+	1.17	1.20	2.02	1.52	1.66	1.47	2.06	1.85	1.19	1.86	2.15	1.38	1.48	1.51

Average F for ages 2-4

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
	1.00	1.14	1.85	1.50	1.62	1.33	1.87	1.75	1.23	1.71	2.13	1.25	1.30	1.51

Backcalculated partial recruitment

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
0	0.07	0.06	0.06	0.03	0.03	0.02	0.04	0.02	0.05	0.02	0.03	0.04	0.05	0.03
1	0.58	0.71	0.34	0.40	0.44	0.44	0.53	0.43	0.45	0.51	0.36	0.59	0.59	0.29
2	1.00	0.98	0.94	0.92	0.90	1.00	0.93	0.93	0.74	0.94	0.80	0.99	1.00	1.00
3	0.46	0.88	0.81	1.00	1.00	0.71	0.80	0.91	1.00	0.82	1.00	0.73	0.59	0.99
4	0.94	1.00	1.00	0.98	0.99	1.00	1.00	1.00	0.84	1.00	0.92	1.00	0.97	0.99
5+	0.94	1.00	1.00	0.98	0.99	1.00	1.00	1.00	0.84	1.00	0.92	1.00	0.97	0.99

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

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
0	5829	6017	3547	4576	4420	3670	1253	1828	2474	1353	2433
1	6125	7219	8655	5550	5955	6947	4087	1450	3429	2806	3315
2	2624	3562	2013	3735	2268	2278	1846	1304	949	1208	945
3	1806	1405	1001	644	1248	1149	716	504	438	300	203
4	321	429	251	290	160	380	218	125	169	93	37
5+	311	311	50	230	151	111	86	36	50	21	34
0+	17015	18944	15518	15026	14203	14536	8205	5247	7510	5782	6968
2+	5062	5707	3315	4899	3827	3918	2866	1969	1606	1622	1219

	1993	1994	1995
0	2369	4172	6048
1	3826	3363	7378
2	1419	1234	1092
3	532	930	414
4	48	152	230
5+	60	46	73
0+	8254	9898	15235
2+	2059	2362	1809

Table C23. Commercial and recreational fishery landings, estimated discard, and total catch statistics (metric tons) as used in the assessment of summer flounder, Maine to North Carolina, compared with VPA estimates of total catch biomass.

	Commercial			Recreational			Total				
Year	Landings	Discard	Catch	Landings	Discard	Catch	Landings	Discard	Catch	VPA catch	VPA:catch ratio
1982	10,400	n/a	10,400	8,267	740	9,007	18,667	740	19,407	19,077	0.98
1983	13,403	n/a	13,403	12,687	939	13,626	26,090	939	27,029	25,788	0.95
1984	17,130	n/a	17,130	8,512	1,037	9,549	25,642	1,037	26,679	27,590	1.03
1985	14,675	n/a	14,675	5,665	229	5,894	20,340	229	20,569	21,970	1.07
1986	12,186	n/a	12,186	8,102	1,444	9,546	20,288	1,444	21,732	22,449	1.033
1987	12,271	n/a	12,271	5,519	1,307	6,826	17,790	1,307	19,097	19,400	1.02
1988	14,686	n/a	14,686	6,733	857	7,590	21,419	857	22,276	23,928	1.07
1989	8,125	709	8,834	1,435	114	1,549	9,560	823	10,383	10,446	1.01
1990	4,199	1,213	5,412	2,329	587	2,916	6,528	1,800	8,328	8,090	0.97
1991	6,224	1,052	7,276	3,611	1,074	4,685	9,835	2,126	11,961	12,354	1.03
1992	7,529	918	8,447	3,242	859	4,101	10,771	1,777	12,548	12,892	1.03
1993	5,715	650	6,365	3,484	1,840	5,324	9,199	2,490	11,689	11,857	1.01
1994	6,588	941	7,529	4,111	1,442	5,553	10,699	2,383	13,082	13,387	1.02
1995	6,897	947	7,844	2,496	1,920	4,416	9,393	2,867	12,260	12,364	1.008

Table C24. SAW-22 VPA retrospective analysis. All runs exclude NEFSC winter survey (conducted during 1992-1996) to facilitate a consistent retrospective time series.

Fishing mortality

Terminal year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
1988	1.0	1.1	1.8	1.5	1.6	1.4	2.1							
1989	1.0	1.1	1.9	1.5	1.6	1.3	1.9	2.0						
1990	1.0	1.1	1.9	1.5	1.6	1.3	1.9	1.7	1.4					
1991	1.0	1.1	1.9	1.5	1.6	1.3	1.9	1.7	1.2	1.4				
1992	1.0	1.1	1.9	1.5	1.6	1.3	1.9	1.7	1.2	1.5	1.1			
1993	1.0	1.1	1.9	1.5	1.6	1.3	1.9	1.8	1.2	1.7	1.9	0.9		
1994	1.0	1.1	1.9	1.5	1.6	1.3	1.9	1.8	1.2	1.7	2.2	1.3	0.9	
1995	1.0	1.1	1.9	1.5	1.6	1.3	1.9	1.8	1.2	1.6	2.1	1.3	1.3	1.5

Spawning stock biomass ('000 mt)

Terminal year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
1988	17.0	18.9	15.5	14.9	14.0	14.1	6.8							
1989	17.0	18.9	15.5	15.0	14.1	14.4	7.5	4.2						
1990	17.0	18.9	15.5	15.0	14.2	14.6	8.2	5.4	8.9					
1991	17.0	18.9	15.5	15.0	14.2	14.5	8.3	5.4	8.2	8.0				
1992	17.0	18.9	15.5	15.0	14.2	14.5	8.2	5.4	8.1	7.7	12.3			
1993	17.0	18.9	15.5	15.0	14.2	14.5	8.2	5.3	7.6	5.9	8.0	10.6		
1994	17.0	18.9	15.5	15.0	14.2	14.5	8.2	5.2	7.5	5.7	6.7	7.6	10.6	
1995	17.0	18.9	15.5	15.0	14.2	14.5	8.2	5.2	7.5	5.8	7.0	8.3	10.2	15.2

Age 0 recruitment (N, millions)

Terminal year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
1988	76.5	82.7	49.2	50.8	55.2	44.3	8.0							
1989	76.5	82.7	49.2	51.1	56.0	45.5	9.3	33.3						
1990	76.5	82.7	49.2	51.2	56.3	45.8	12.1	32.0	42.5					
1991	76.5	82.7	49.2	51.2	56.3	45.3	13.3	28.7	37.6	45.0				
1992	76.5	82.7	49.2	51.2	56.3	45.3	13.3	29.0	35.9	44.1	38.6			
1993	76.5	82.7	49.2	51.2	56.3	45.3	13.1	28.3	32.7	31.2	39.8	27.4		
1994	76.5	82.7	49.2	51.2	56.3	45.3	13.1	28.2	32.3	29.4	32.2	27.1	61.4	
1995	76.5	82.7	49.2	51.2	56.3	45.2	13.1	28.2	32.3	29.9	33.1	29.4	44.6	51.6

Age 1+ stock size (N, millions)

Terminal year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1988	62.7	80.3	88.7	65.3	61.2	62.3	57.1	17.1							
1989	62.7	80.3	88.7	65.3	61.4	63.2	57.9	18.9	28.8						
1990	62.7	80.3	88.7	65.3	61.5	63.4	58.9	22.0	30.4	46.2					
1991	62.7	80.3	88.7	65.3	61.5	63.4	58.8	22.8	28.3	40.4	49.3				
1992	62.7	80.3	88.7	65.3	61.5	63.4	58.7	22.8	28.5	39.2	47.7	50.8			
1993	62.7	80.3	88.7	65.3	61.5	63.4	58.7	22.7	27.8	36.0	34.4	41.0	37.5		
1994	62.7	80.3	88.7	65.3	61.5	63.4	58.7	22.6	27.8	35.6	32.7	33.4	31.1	55.3	
1995	62.7	80.3	88.7	65.3	61.5	63.4	58.7	22.6	27.8	35.6	33.1	34.5	33.9	43.9	60.1

Table C25. Input parameters and stochastic projection results for summer flounder: landings, discard, and spawning stock biomass ('000 mt). Starting stock sizes on 1 January 1996 (age 1 and older) are as estimated by VPA bootstrap procedure (200 iterations). Age 0 recruitment levels in 1996-1998 are selected at random from VPA estimates of numbers at age 0 during 1991-1995. Fishing mortality was apportioned among landings and discard based on the proportion of F associated with landings and discard at age during 1993-1995. Mean weights at age (spawning stock, landings, and discards) are weighted (by fishery) arithmetic means of 1993-1995 values. F_{96} is the F realized if fishery landings quotas, plus associated discard, are caught in 1996. Proportion of F, M before spawning = 0.83 (spawning peak at 1 November).

Age	Fishing mortality pattern	Proportion landed	Proportion mature	Mean weights SSB	Mean weights landings	Mean weights discards
0	0.09	0.30	0.38	0.309	0.396	0.270
1	0.47	0.62	0.72	0.517	0.554	0.463
2	1.00	0.99	0.90	0.673	0.675	0.541
3	1.00	1.00	1.00	1.291	1.291	----
4	1.00	1.00	1.00	1.800	1.800	----
5+	1.00	1.00	1.00	2.702	2.702	----

Forecast medians (50% probability level)

Option	F_{96}	1996 '000 mt Land.	1996 '000 mt Disc.	1996 SSB	F_{97}	1997 '000 mt Land.	1997 '000 mt Disc.	1997 SSB	F_{98}	1998 '000 mt Land.	1998 '000 mt Disc.	1998 SSB
1)	0.52	8.4	1.9	23.4	0.30	9.3	0.8	33.2	0.23	10.2	0.6	45.9
2)	0.52	8.4	1.9	23.4	0.27	8.4	0.7	33.9	0.23	10.4	0.6	46.8
3)	0.68	8.4	1.9	16.4	0.30	6.4	0.6	24.1	0.23	7.5	0.6	35.8
4)	0.68	8.4	1.9	16.4	0.42	8.4	0.9	22.5	0.23	6.9	0.6	33.6

Option 1: Landings in 1997 can increase to 9,300 mt and meet F_{TGT} = 0.30. Landings can increase to 10,200 mt in 1998 and meet F_{TGT} = 0.23.
Option 2: Landings in 1997 held at 8,400 mt and F is below F_{TGT} = 0.30. Landings can increase to 10,400 mt in 1998 and meet F_{TGT} = 0.23.
Option 3: 1996 STOCK SIZES REDUCED TO ACCOUNT FOR RECENT VPA RETROSPECTIVE PATTERN. Landings in 1997 must decrease to 6,350 mt to meet F_{TGT} = 0.30. Landings can increase to 7,500 mt in 1998 and meet F_{TGT} = 0.23.
Option 4: 1996 STOCK SIZES REDUCED TO ACCOUNT FOR RECENT VPA RETROSPECTIVE PATTERN. Landings in 1997 held at 8,400, F exceeds F_{TGT} = 0.30. Landings must decrease to 6,900 mt in 1998 to meet F_{TGT} = 0.23.

Table C26. Stochastic projection results for summer flounder. Assuming 8,400 mt removed in 1996, probability of exceeding 1997 target F level (0.30) for alternative 1997 quota levels; median F level in 1997; probability of not exceeding F_{MAX} (0.23) in 1997 for alternative quota levels. Top panel shows the probabilities based on original bootstrapped stock sizes, 1996 (e.g., Table C24 Options 1 and 2). Bottom panel shows the probabilities based on bootstrapped stock sizes, 1996, reduced by 21.6% for age 0 and 23.3% for age 1 and older, to reflect approximated adjustment for retrospective pattern of overestimation of stock sizes (e.g., Table C24 Options 3 and 4).

Original bootstrapped SAW-22 VPA stock sizes

Quota level, 1997 (mt)	Probability $F > 0.30$	Median F	Probability $F \leq 0.23$
6,000	0.06	0.19	0.77
7,000	0.16	0.22	0.59
8,000	0.27	0.26	0.35
8,400	0.36	0.27	0.28
8,800	0.40	0.28	0.22
9,000	0.44	0.29	0.17
9,250	0.50	0.30	0.15
10,000	0.63	0.33	0.08
11,000	0.76	0.37	0.03

Bootstrapped SAW-22 VPA stock sizes reduced by 21.6% for age 0 and 23.3% for ages 1 and older to adjust for retrospective pattern

Quota level, 1997 (mt)	Probability $F > 0.30$	Median F	Probability $F \leq 0.23$
4,000	0.06	0.18	0.77
5,000	0.22	0.23	0.51
5,900	0.37	0.28	0.27
6,000	0.40	0.28	0.24
6,350	0.50	0.30	0.17
7,000	0.65	0.34	0.09
8,000	0.83	0.39	0.03
8,400	0.87	0.42	0.02
9,000	0.92	0.45	0.01

Table C27. Summary of summer flounder projections and subsequent estimates of the fully recruited fishing mortality rate (F).

Assessment	Estimated F terminal year T	Projected F year T+1	SAW-22 VPA F	Percent difference in F SAW-22 projection
SAW-11	$F_{88} = 1.42$	$F_{89} = 1.42$	$F_{89} = 1.75$	23%
SAW-13	$F_{90} = 1.07$	$F_{91} = 1.07$	$F_{91} = 1.71$	60%
SAW-16	$F_{92} = 1.08$	$F_{93} = 0.48$	$F_{93} = 1.25$	160%
SAW-18	$F_{93} = 0.54$	$F_{94} = 0.77$	$F_{94} = 1.30$	130%
SAW-20	$F_{94} = 0.69$	$F_{95} = 0.50$	$F_{95} = 1.50$	300%
SAW-22	$F_{95} = 1.50$	$F_{96} = 0.50$	$F_{96} > 1.0?$	Mean = 135%

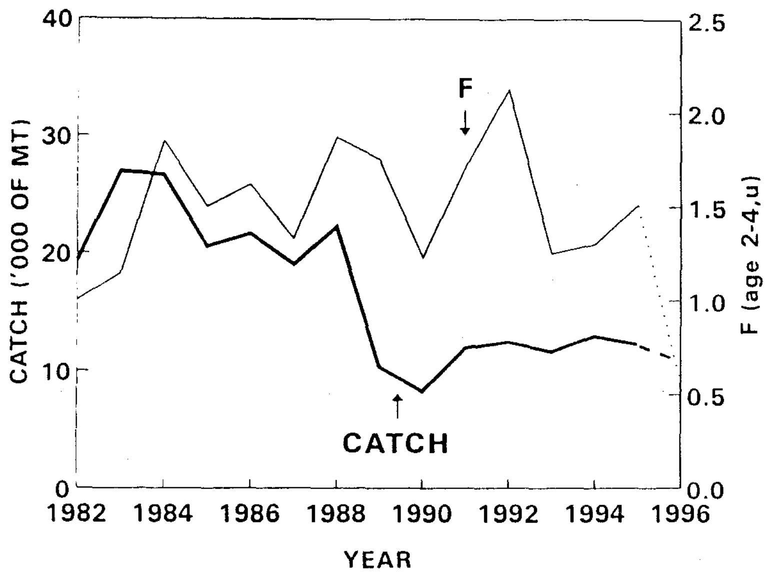

Figure C1. Total catch (landings and discard, thousands of metric tons) and fishing mortality rate (fully recruited F, ages 2-4, unweighted) for summer flounder.

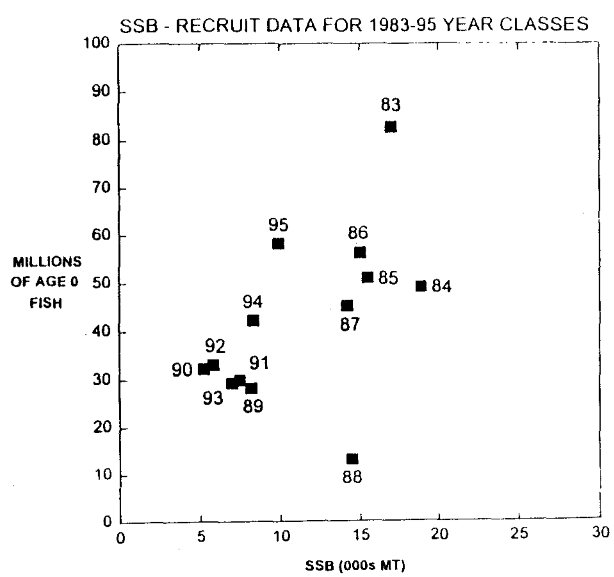

Figure C3. Summer flounder SAW-22 VPA run spawning stock biomass and recruitment estimates.

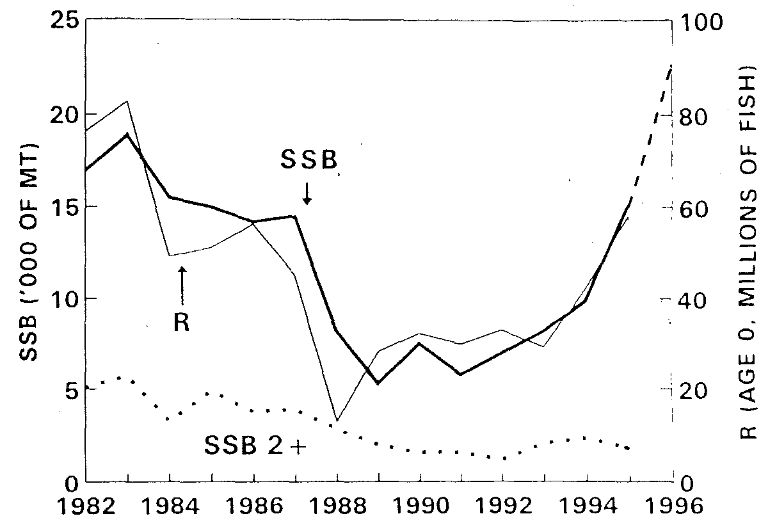

Figure C2. Spawning stock biomass (SSB ages 0-5+, thousands of metric tons) and recruitment (millions of fish at age 0) for summer flounder. Note that because summer flounder spawn in late autumn, fish recruit to the fishery at age 0 the following autumn. For example, fish spawned in autumn 1987 recruit to the fishery in autumn 1988 and appear in VPA tables at age 0 in 1988.

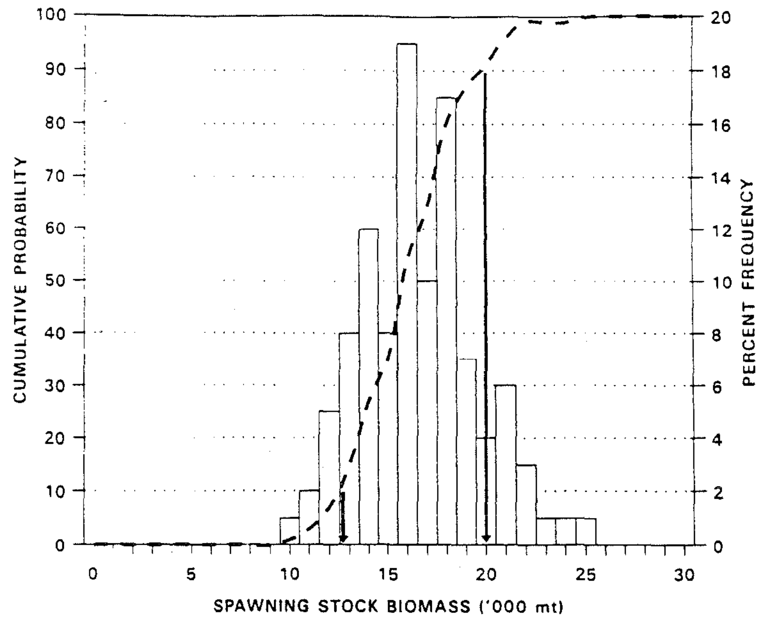

Figure C4. Precision of the estimates of spawning stock biomass on November 1, 1995 for summer flounder. Vertical bars display the range of the bootstrap estimates and the probability of individual values in the range. The dashed line gives the probability that SSB is less than any value along the X axis.

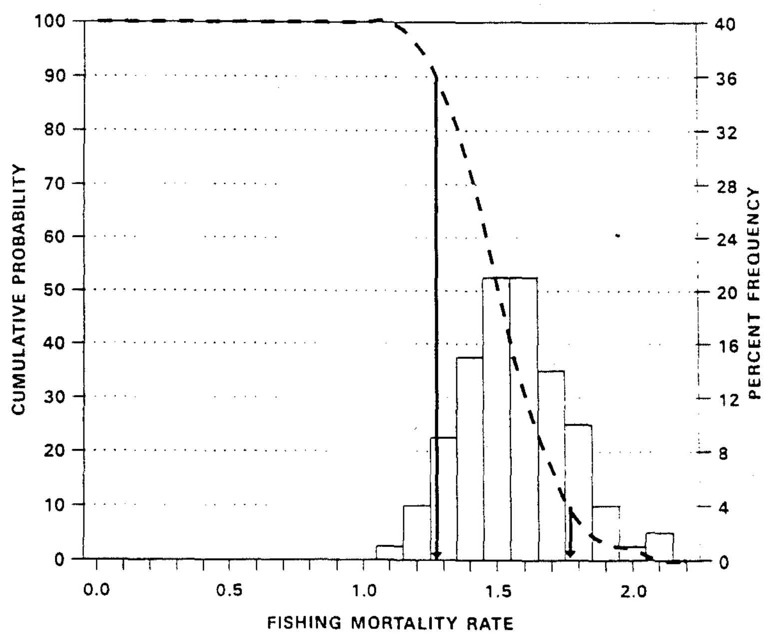

Figure C5. Precision of the estimates of fully recruited F (ages 2-4, u) in 1995 for summer flounder. Vertical bars display the range of the bootstrap estimates and the probability of individual values in the range. The dashed line gives the probability that F is greater than any value along the X axis.

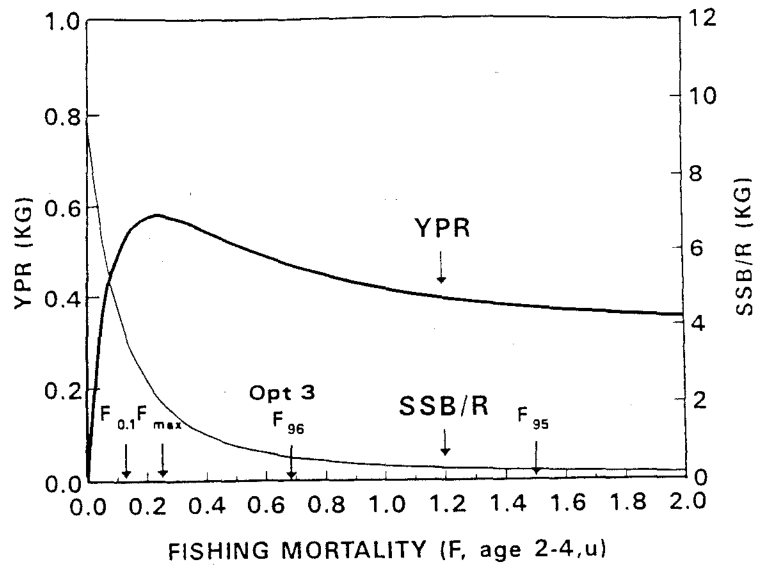

Figure C6. Yield per recruit (YPR) and spawning stock biomass per recruit (SSB/R) for summer flounder.

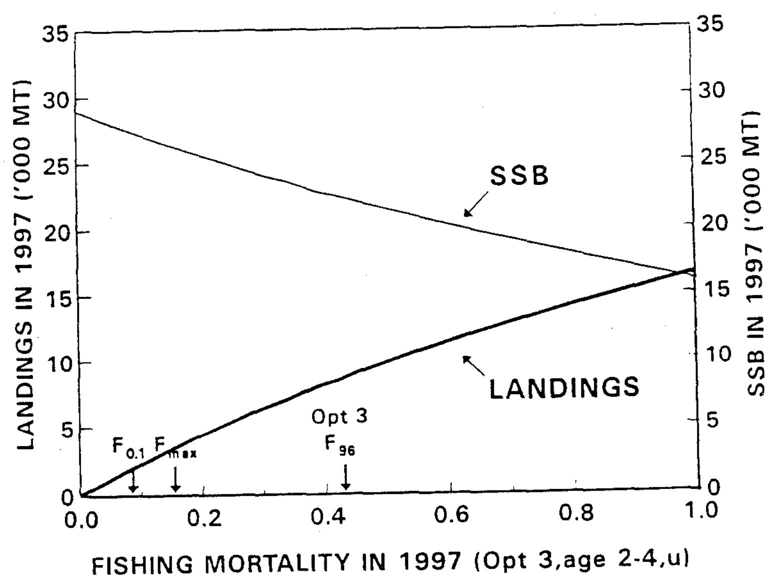

Figure C7. Projection Option 3: predicted landings in 1997 and spawning stock biomass (SSB) in 1997 of summer flounder over a range of fishing mortalities in 1997 from F = 0.0 to F = 1.

D. SURFCLAM AND OCEAN QUAHOG

Terms of Reference

The following terms of reference were addressed:

a. Update estimates of surfclam growth parameters.

b. Re-calculate surfclam biological reference points using revised growth and maturity data.

c. Incorporate growth of recruited surfclams into stochastic 'supply years' projection models and revise projections made at SARC-19.

d. Incorporate growth of surfclam and ocean quahog into spreadsheet supply year models developed for the MAFMC.

e. Extend the historical time series of commercial and R/V survey data for incorporation into DeLury population models.

Introduction

The history of surfclam and ocean quahog management along the Atlantic coast of the United States is summarized through 1986 in Murawski and Serchuk (1989). Surfclams and ocean quahogs were both recently assessed in 1992 and 1994 (NEFSC 1993 a,b, 1995 a,b), for SAW-15 and -19, respectively. Those assessments reported historical trends in commercial landings and effort by region, size composition of the landings, levels of discarding, trends in survey abundance indices, and population size structure. Using a time series beginning with 1982, estimates of exploitable surfclam biomass and fishing mortality rate were derived from a modified DeLury model (Conser 1995). The surfclam biomass estimates for 1994, derived from DeLury population models, with uncertainty incorporated via a bootstrap procedure, were then used as inputs to a stochastic depletion model which computed the number of supply years available under various harvesting scenarios and under various assumptions about recruitment. The relationship between shell length and age in surfclams was last updated using samples collected in 1978 (Serchuk and Murawski 1980).

Based on past work on surfclams, SAW-19 recommended that research be done to update estimates of growth rate and maturity (i.e., reflecting current stock status) and extend backward the time series of survey and catch data used in the DeLury model. In this report, surfclam age-length parameters are updated. These updated parameters and the most current parameters available for quahogs are then used to compute annual growth rates for surfclams and ocean quahogs, respectively. Information on growth is used to recalculate surfclam biological reference points, revise estimates of surfclam supply years, and develop spreadsheet programs for the MAFMC to aid in quota setting for surfclam and ocean quahog. Pre-1982 data are examined for incorporation into the DeLury model on surfclams. A survey-based, retrospective run of the DeLury model was carried out using a data series beginning with 1980. Sensitivity runs were carried out which examined the effect of survey frequency on the performance of the DeLury model.

Age and Length

Surfclam

Surfclam shell samples collected during the 1980, 1989, 1992, and 1994 clam surveys were used to estimate von Bertalanffy growth equation parameters:

$$l_{ij} = L_{\infty} \cdot (1 - e^{k(t_i \; t_0)}) + e_{ij} \qquad \textbf{(1)}$$

where l_{ij} is the length of the jth individual at age i, L_{∞} is the asymptotic maximum length, k is a growth coefficient that determines how quickly L_∞ is reached, t_0 is the age at which length would hypothetically be zero, and e_{ij} values are independent and identically distributed random $N(0,\sigma^2)$ variables. A subsample of surfclams, collected from each station, was retained for aging. The subsample consisted of one randomly selected individual from each 10-mm interval represented in the tow sample. Sample sizes used in parameter estimation, by age/region/time period, are given in Table D1. Figure D1 is a map showing survey strata for surfclam habitat in the EEZ. Percentages of surfclam shell samples collected from each stratum, by region and time period, are given in Table D2. Samples from the 1989 and 1992 surveys were pooled to achieve an adequate sample size.

Surfclam age was determined by counting annual rings in prepared thin sections of shell chondrophores following methods of Ropes and Shepherd (1988). Shell length (i.e., the maximum distance in the anterior posterior direction) was measured to the nearest mm. Parameter estimates were obtained using nonlinear least squares (unweighted) from the Marquardt routine in the PROC NLIN procedure in SAS (Statistical Analysis System 1985). Additional methods regarding sampling and data analysis are given in Weinberg and Helser (in press).

Updated regional parameter estimates and sample sizes for the 1980, 1989+1992, and 1994 samples are given in Table D3. Also in Table D3, for comparison, are parameter estimates from Serchuk and Murawski (1980) derived from samples collected in 1978. For the NJ and DMV regions, the lowest estimates of L_∞ were associated with the most recent sample (i.e., 1994). The parameter k has declined over time in the NJ region.

Based on a randomization test (Weinberg and Helser, in press), there is a significant difference in the von Bertalanffy growth parameter set from DMV between 1980 and a later period (1989 + 1992). There is also a significant difference between these periods in the NJ region.

Ocean Quahog

Table 3 also gives the most recent von Bertalanffy parameter estimates for ocean quahogs in the Long Island region. Both L_∞ and k are much lower than those of surfclams.

Length and Weight

The relationship between shell length in mm (L) and drained meat weight in grams (W) is described by the equation:

$$\ln(W) = \alpha + [\beta \cdot (\ln L)] \qquad (2)$$

The most recent regional estimates of the parameters in this model are given in Table D4.

Growth Rate (in weight) of Full Recruits

Expected annual growth rate in drained meat weight of full recruits was estimated from three sources of information: 1) regional age-length parameter estimates (Table D3), 2) regional length-weight parameter estimates (Table D4), and 3) regional length frequency distributions of the population based on research survey data (Figure D2 and Weinberg *et al.* 1995).

For each species/region combination, the annual growth rate of full recruits was estimated, as described below: From research survey data, the proportion of fully recruited individuals, per 10-mm length interval, was computed. Based on previous work (NEFSC 1995a,b), shell length at full recruitment was set at 120 mm in surfclams and 80 mm in ocean quahogs. For the mid-length of each fully-recruited 10-mm size interval at time t, the age-length equation was used to compute what the shell length would be 1 year later, at t+1. For each length class, the weight/length equations were used to compute weight at length at times t and t+1. Based on the proportion of individuals in each length class, both the expected weight of a full recruit and the expected annual gain in weight of a full recruit were computed. The gain in weight from t to t+1 divided by the weight at t, multiplied by 100, gave the annual percentage growth.

Several growth rate calculations were made, varying both the year of the age-length samples and the survey from which to compute the size frequency distribution of the population. For surfclams, estimated annual growth of full recruits ranged from 7.16% to 8.56% in the Delmarva region, and from 5.67% to 7.63% in the NNJ region (Table D5). Switching from the 1992 to 1994 size frequency distribution had little effect on the estimates. Ocean quahog growth rates were an order of magnitude lower than those of surfclams, ranging from 0.51% to 0.77%.

Although calculations were based on division of the population size-frequency distribution into 10-mm intervals, they could also be done using smaller intervals. The 10-mm interval is not expected to produce a biased estimate of growth, although using a smaller interval could increase precision. Although shells are supposed to be measured at sea to the nearest mm, in large individuals (e.g., greater than 90 mm) measurements may only be accurate to the nearest 5 mm.

Surfclam Biological Reference Points

Yield per Recruit (YPR) and % Maximum Spawning Potential (%MSP)

YPR analysis was last done in 1994 (NEFSC 1995a) for surfclams in the DMV and NJ regions. Two sources of new information were available for updating YPR and calculating %MSP in surfclams. First, age-length data from the 1994 research survey were collected for the NJ and DMV regions, and data from the pooled 1989+1992 research surveys were recently analyzed by Weinberg and Helser (in press). Updated parameter estimates for the age-length equations for regions along the Atlantic coast are given in Table D3. Second, new data suggest that maturity is attained earlier than was previously thought. Early work done off Virginia (Ropes 1979) indicated that 1-year-old surfclams were partially mature, and that full maturity was attained in 2-year-olds.More recently, Chintala and Grassle (1995) reported spawning by surfclams from New Jersey which were 3 months old or less (7-10 mm in shell length). Although none of the larvae produced by these young clams survived in the laboratory, gonadal examinations demonstrated that approximately 36% of the population in this size class has ripening gonads in October and November.

For analysis, partial recruitment (PR) of surfclams was set at 0.5 for age 5 and 1.0 for age 6 and greater in both the NJ and DMV regions. The PR vector was slightly different for GBK where the growth pattern was different. Maturity was set at 0.9 for 1-year-olds and at 1.0 thereafter. YPR and %MSP analyses were carried out for regions of major surfclam biomass: DMV, NJ, and GBK. Tables D6-D8 give region-specific input values and summary results. YPR and %MSP curves are shown in Figure D3. Updating the input values had little effect on $F_{0.1}$ compared with values reported in NEFSC 1995a. $F_{0.1}$ remained at 0.07 in the NJ region and at 0.08 in the DMV region. Updating caused a slightly larger impact on F_{MAX} in those regions. F_{MAX} changed from 0.21 (NEFSC 1995a) to 0.19 in the NJ region, and from 0.24 to 0.25 in the DMV region. $F_{20\%MSP}$ was 0.18 and 0.19 for the NJ and DMV regions, respectively.

Modeling Growth of Full Recruits

Having estimated the annual growth rate of surfclams and ocean quahogs, the next goal was to incorporate growth into the stochastic depletion model (NEFSC 1995a) and into new EXCEL spreadsheet models developed for the MAFMC. The effect of growth by full recruits (G) on exploitable biomass can be modelled in several ways using equations which differ in complexity and realism. Three forms were explored:

$$B_{t+1} = [B_t + R_t - C_t + ((G_t - 1) \cdot B_t)] \cdot e^{[-m_t]} \tag{3}$$

$$B_{t+1} = (B_t + R_t - C_t) \cdot e^{[g_t - m_t]} \tag{4}$$

$$B_{t+1} \;=\; [((B_t - (1/4)\cdot C_t)\cdot e^{-m/4} + R_t - (7/12)\cdot C_t)\, e^{[g-(7/12)m]} - (2/12)\cdot C_t \cdot e^{[-(2/12)\cdot m]} \qquad (5)$$

where B_t is exploitable biomass in year t, R is annual recruitment (i.e., clams growing from the pre- to full-recruit stage), C is annual catch, G is discrete growth rate of full recruits per year (where $G = W_{t+1}/W_t$), g is the instantaneous rate of growth of full recruits per year (where g = ln G), and M is the instantaneous rate of natural mortality per year. Equation (3) models growth, recruitment, and catch as discrete processes. Equation (4) is more realistic, modelling growth as a continuous process which occurs throughout the year. Equation (5) is most realistic because, in addition to having continuous growth, the year is divided into three periods (January - March, April - October, and November - December). All growth and recruitment take place in the middle period, whereas natural mortality and catch take place uniformly throughout the entire year.

Based on various simulations in which the parameters G, R, and C were varied, the dynamics of biomass vs time in Equations (4) and (5) were nearly identical; those of Equation (3) were different. Because Equation (4) captured the dynamics of the more complex equation and was simple to program, it was selected for modelling growth in both the stochastic depletion and deterministic spreadsheet models (see below).

Past Stochastic 'Supply-Year' Projections for Surfclams (NEFSC 1995a)

'Supply-Year' projections were made in the 1994 surfclam assessment (NEFSC 1995a) for the Northern New Jersey region, the Delmarva region, and for the two regions combined. The results of those calculations were summarized in Table D17 of that document (NEFSC 1995a, page 158) and are given in Table D9 of this document. To provide necessary background and methods for evaluating the current research, the following italicized text is quoted from NEFSC 1995a (pages 131-134):

<u>"Description of Projection Methods</u>

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

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

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

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

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

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

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

<u>*Starting Conditions/Assumptions*</u>

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

Northern New Jersey:

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

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

Delmarva:

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

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

1992 with a constant quota of 2470, 2717, and 2,223 mt.

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

Projection Results

Projection results for the two areas are summarized in Table D17 and Figures D26-D34. For Northern New Jersey, catches assuming the 1992-1994 average (16,986 MT) and average recruitment can be sustained for about 4 years, after which there will be insufficient biomass to generate that level of catch. Average exploitation rates increase dramatically over the duration of the fishery (Figure D26). Under scenarios of ±10% of the average catch, supply years change by about 1 year. Under conditions of 0 recruitment, average supply years decline from 4.48 to 2.93. Constant harvest rate policies result in declining catches to about 6,364 mt in year 10 under average recruitment, 1,057 mt in year 10 under 0 recruitment, and 8,258 mt in year 10 assuming higher and more variable recruitment. The quota that results in a 50% probability of sufficient resource to generate the constant catch for 10 years is 11,263 mt (66% of the 1992-1994 average).

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

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

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

Updated Stochastic Projection Results with Surfclam Growth

The stochastic projection model was revised to include growth by full recruits, according to Equation (4). In addition to adding growth, more complete data were available to update the 1994 surfclam landings from 16,285 mt to 17,754 mt for NNJ and from 2,770 mt to 3,454 mt for DMV. The mean landings from 1992-1994 changed from 16,986 mt to 17,475 mt for NNJ and from 2,470 mt to 2,698 mt for DMV. A final change to the program was incorporation of growth, natural mortality, and recruitment during 1994.

Table D9 contains original results and input settings, assuming 0% growth, from Table D17 of SAW-19 (NEFSC 1995a). Table D9, which has 0% growth of surfclams, can be compared with Table D10, for the case where the annual growth rate of full-recruits is 5.67% and 7.16% in the NNJ and DMV regions, respectively. (In addition to incorporating growth in the revised model, note that modifications listed in the preceeding paragraph were also made.). The 24 different runs of the model make different assumptions about annual catch, annual recruitment, and variance in recruitment. In this model, year 1 is 1995. Run #1, the base run for the NNJ region, changed from a mean of 4.48 supply years to 5.63 supply years. Given the low catches from the DMV region (Runs #14 - #16), adding growth to the model had no meaningful impact on that supply calculation because it was already predicted to last about 100 years. The mean of the global "NNJ + DMV" run (#23) increased from 6.7 supply years to 9.43 supply years. The calculated quota for NNJ + DMV that would last for 10 years (Run #24) increased from 16,385 mt to 19,700 mt. This latter value is similar to the actual 1995 surfclam quota (i.e., 19,779 mt).

The number of supply years varies somewhat depending on which growth rates are assumed for each region (Table D5). Therefore, analyses were carried out to determine the sensitivity of the number of supply years to the assumed annual growth rates (Table D11, Figure D4). Runs #1 and #23 were chosen for this analysis because they are baseline runs. For the NNJ region (Run #1), the mean number of supply years increased from 4.47 to 7.98 as the assumed annual growth rate changed from 0% to 12%. For the NNJ and DMV regions combined (Run #23), the number of supply years ranged from 6.60 to 20.54 over growth rates ranging from 0% to 12% in each region. In general, for growth rates less than 8%, there is little sensitivity of supply years to changes in assumed growth rate. The supply year calculation has moderate sensitivity to growth rates in the range 8% to 10%. Sensitivity is high in the range of 12% growth and greater. Finally, for Run #23, there is greater sensitivity to the assumed growth rate for the NNJ region than to that assumed for the DMV region. This is due to greater stock biomass in NNJ than in DMV.

Deterministic Spreadsheet Models, with Growth, to Computer Quotas under Specific Management Policies

Deterministic spreadsheet programs were developed in EXCEL to model temporal changes in stock biomass of surfclams and ocean quahogs under harvesting (see Equation 4). The spreadsheets are meant to be tools which allow users to examine how changes in several input assumptions would affect stock biomass and landings through time. The stochastic projection model (described above) and the deterministic models are based on the same equation, but are set up to address different questions. The stochastic projection model determines how long a supply will last given a constant harvest. In contrast, the deterministic spreadsheet models are programmed to give the annual harvest that would last for 10 years and 30 years, for surfclams and ocean quahogs, respectively. This harvest calculation is made in <u>every</u> year of the simulation based on the exploitable biomass in the region at the start of that year.

Changes to any of the spreadsheet input cells result in immediate updates of all output cells and figures, making this a useful tool for calculating quotas, performing sensitivity analyses, and examining alternatives. The simulation covers the period 1995-2024. As an example, a run of the surfclam program is shown in Tables D12 and D13, and Figure D5. Analogous runs using the ocean quahog program are in Tables D14 - D16 and Figure D6. Three ocean quahog examples are presented, each based on a different assumed level of annual recruitment. This approach is reasonable at this time because reliable estimates for this parameter are not available yet.

<u>Inputs of Deterministic Program</u>

<u>List of user-supplied inputs to deterministic programs</u>: regional exploitable biomass estimates for 1994, commercial catch estimates from 1994-1996, instantaneous rate of natural mortality per year, the portion of the stock biomass that is unexploited in 1994, a year in which to start exploiting some user-supplied fraction of the unexploited stock, annual recruitment (pre-recruits growing to full recruits) to the exploited area, annual growth of full recruits, and a fishing mortality rate corresponding to the overfishing definition.

<u>Documentation and notes for users</u>: For each species there is documentation on the calculation of the annual harvest that is consistent with the 10 and 30 management policies for the two species. Notes on using the program are included in Tables D13 and D17.

<u>Outputs of Deterministic Program</u>

<u>Tabular output</u>: A table of simulation results was produced (see sample Tables D12, D15, and D16). The columns of the table are year (1995-2024), exploitable biomass, unexploited biomass, total biomass, harvest from the exploited area corresponding to the 10-yr and 30-yr management policies for surfclam and ocean quahog, respectively, exploitation rates in the exploited area and in the entire stock, and the exploitation rate corresponding to the overfishing definition.

<u>Graphical output</u>: For each species, two graphs were produced (Figures D5 and D6). One graph depicts exploitation rate over time in the exploited area and all areas, as well as the rate corresponding to the overfishing definition. A second graph depicts trends in biomass over time in the exploited stock, unexploited stock, and total stock. It also shows the total

meat weight (i.e., biomass) to be harvested under the 10-yr or 30-yr management policies for surfclams and ocean quahogs, respectively.

Surfclam DeLury Model: Extension of Time Series before 1982

The modified DeLury models used in SAW-19 (NEFSC 1995a) were based on survey and commercial data collected from 1982-1994. Those data formed a consistent series (i.e., they had been audited, the variables measured in the same way throughout the time period, and it was not necessary to switch databases to complete variable estimation for the entire time series). The number of data points within that period was limited, not only because the period was short, but also because research surveys were not conducted annually. The goal here was to evaluate the quality of pre-1982 survey and commercial data, with the intention of running the DeLury model with a longer time series of data (1978-1994).

Examination of the early (i.e., 1978-1981) surfclam survey and commercial landings data revealed a number of uncertainties which are described in the following subsections. Because of these issues, running the DeLury model with pre-1982 data will necessitate making several assumptions which did not arise during SAW-19 (NEFSC 1995a). The issues involve transformation of the early survey data to adjust for gear changes, standardizing survey catch for tow distance, selection of a commercial database to estimate landings and mean weight of individuals landed, and estimation of discards for years when no data were collected.

Specific details about the data sets are given in the following sections; however, the SARC reached some overall conclusions about the quality of the pre-1982 data. Due to significant changes in methods between 1978 and 1980, there is uncertainty about the proper standardization factors needed to link the survey data from 1978 and 1979 with more recent survey data. Initial standardizations were based on proportional changes in dredge width and tow time. Detailed analytical comparisons of survey data sets will be required to estimate the effects of changes in mesh size, pump type and season on catch per tow. No major changes in survey methodology have occurred since August 1980. Therefore, data from surveys in 1980 and 1981 can be added to the time series and used in the retrospective DeLury model run.

Adjustment for Changes in Survey Gear between 1978 and 1981

Changes in clam survey gear over time are listed in Table D18. Because limited comparative gear testing was done and multiple factors were sometimes changed simultaneously (e.g., pump type, dredge width, and mesh size), it is difficult to estimate empirical standardization coefficients from survey data.

The dredge and type of pump were changed in 1979 (Table D18). Although the submersible pump is expected to sample more uniformly over a range of depths, no experimental data are available to estimate the effect of pump type (surface vs. submersible) on mean or variance of catch per tow.

Likewise, no data are available with which to estimate the effect of changing the dredge width (122 cm vs 152 cm) on catch per tow. In this case, a simple correction for area sampled can probably be assumed.

In addition to changes in pump type and dredge width, changes were made over 3 years in mesh opening size (1.91, 2.54, and 5.08 cm). No data were collected on surfclams to estimate the effect of changing mesh size on numbers or shell sizes of surfclams per survey tow. Some data on the effect of mesh size were collected on ocean quahogs off Long Island in 1979 (Cruise 7908) (Smolowitz and Nulk 1982). The water depth was 55 m. In the mesh study, 5 tows were taken with 2.54 cm mesh, and 8 tows were taken with 5.08 cm mesh. Analysis of those data suggests that:

1) based on chi square tests to compare size frequency distributions among tows, both mesh sizes were able to sample the two size modes in the population at that time, one at 62 mm and another at 92 mm shell length. More detailed tests for differences in size selectivity are not warranted because tows collected with the smaller mesh were subsampled (n = 30), and insufficient numbers of clams were measured to ensure that sample selection would not significantly affect the estimated size structure of the population.

2) when the larger mesh was used, more ocean quahogs (i.e., 1.7 times) were collected (Smolowitz and Nulk 1982), although the confidence intervals were wide.

Standardization of Survey Data for Tow Distance

Tow distance, through doppler readings, is a variable in the data sets from December 1978 and later. Therefore, for most of the time period catch per tow can be standardized to a common tow distance.

Selection of Database from which to Estimate Commercial Landings

The requirements for a "survey-based" run differ from an "LPUE-based" run of the DeLury model for the period 1978-1994. he former requires a reliable time series of landings from a specified region, but does not require an LPUE time series. This report will focus on data issues related to carrying out a reliable "survey-based" run for the NNJ region. (It should be noted, however, that obtaining an internally consistent time series of LPUE from 1978-1994 for an "LPUE-based" run will require consideration of additional issues.).

The s1032 database was the source of landings data from 1983-1994 used for previous DeLury analyses (NEFSC 1995a). To extend the historical time series to 1978, there are three possible data sources from which to estimate annual landings during some or all years from 1978-1982: 1) the S1032 database (logbooks), 2) NEFSC Ref. Doc. 86-11, and 3) the "weighout (WO)" database.

Estimates for 1978-1981 surfclam landings from NNJ vary depending on the data source (Table D19). The s1032 data can be assigned to regions accurately, by 10-minute square (TNMS). While the s1032 database is reliable for all years that are available, the data only go back through 1980.

For 1978-1981, the weighout (WO) database is known to be incomplete. For example, in 1978 and 1979, only landings in MA, NJ, and RI are included. In 1980 and 1981, only landings from MA, NJ, RI, and VA are included. Furthermore, pre-1982 WO data can only be assigned to location by quarter-degree square, making them imprecise geographically. Therefore, the WO database is a poor choice for estimating parameters for the DeLury model.

Lab. Ref. Doc. 86-11 (Murawski 1986) can be used to estimate landings by region, back to 1978 because the time series extends back far enough and, in the period of overlap, the annual values are close to those estimated from the s1032 database (Table D19). This applies to both the NNJ and DMV regions.

Annual Estimation of Weight per Individual from the Landings

A critical annual input to the DeLury model is the average weight of a landed individual. This is used to compute the number of clams landed from a region during a year. For the DeLury models in NEFSC 1995a, this was estimated from shell length data collected annually by port agents in the New Jersey and Delmarva regions.

Lab. Ref. Doc. 86-11, Table 3 (Murawski, 1986) lists mean shell length of surfclams in commercial catches by region from 1976-1986. Values listed in that document match closely with those reported in NEFSC (1995a) for the period of overlap. Therefore, LRD 86-11 can be used to extend the historical time series of mean shell length captured.

Estimation of Commercial Discards

Data on discarding of small surfclams have been acquired since the first quarter of 1982 (Murawski and Serchuk 1984). Therefore, no data are available on surfclam discards for any region for the 1978-1981 period. Considering that the percentages of total catch discarded in 1982, 1983, and 1984 in NJ were 33.1%, 27.8%, and 20.5%, respectively (NEFSC 1995a), there was likely to be some discarding in one or more years from 1978 and 1981. Discarding may have been minimal prior to 1981 because there were no minimum size regulations.

Retrospective Analysis with DeLury Model

The SAW-19 survey-based run of the modified DeLury model for surfclams of the Northern New Jersey region is shown in Table D20. The data time series extends from 1982-1994. Table D20 consists of three parts: inputs, deterministic results, and stochastic results. Bias-adjusted parameter estimates and their confidence intervals were calculated from 200 replications of a bootstrap procedure.

Survey and commercial landings data were examined back to 1978 in an attempt to extend the time series used by the model. Survey and commercial data from 1980 - 1994 were then used in running the model (Table D21). The s1032 database was used to estimate landings during the period 1983 - 1994. NEFSC LRD 86-11 was the source of landings for the period 1980 - 1982. The years 1978 and 1979 were not used because 1) survey indices from those years have not been reliably standardized with more recent survey data collected using different methods and 2) exploratory runs of the DeLury model suggested that the results are sensitive to relatively small changes in the early survey indices.

No discard data were available before 1982. However, exploratory runs of the DeLury model, in which the level of discarding was set at 0%, 20%, and 40% of the total catch, indicated low sensitivity of model results to the level of discarding assumed in 1980 and 1981. Therefore, an intermediate level of discarding (i.e., 20% of the catch) has been assumed (Table D21).

There is very little difference in the results between the original survey-based run used for SAW-19 (Table D20) and the run with the time series extended back to 1980 (Table D21, Figure D7). For example, based on bias-adjusted bootstrap estimates from the two models, the number of fullrecruits in the region in 1994 was 487 million (page xi of Table D20) and 460 million (page xi of Table D21) clams, respectively. From the same two models, the estimated number of recruits in the region in 1994 was 186 million (page x of Table D20) and 179 million (page x of Table D21) clams. As a final comparison, during the period from 1982 - 1993, the estimated fishing mortality rates from the two models, for all clams of recruitment size and larger, differed from each other by less than 5% in every year (page xiii of Tables D20 and D21).

Description of Simulation Experiment to Test Effect of Intermittent Surveys

The SARC expressed concern about the intermittent nature of the surf clam/ocean quahog survey and its implications for the accuracy and precision of population estimates in the DeLury model. This issue was explored by applying the DeLury model to a simulated population and deleting survey years in a number of alternative scenarios. The exercise provided a preliminary examination of the effects of intermittent surveys rather than an exhaustive study of the general properties of the DeLury model.

The simulated (i.e., true) population was patterned after the estimates for the Northern New Jersey substock presented in Table D21. Estimated catch in numbers for 1980-1994 was set equal to C(y). Prerecruit estimates for 1980-1984, 1986, 1989, and 1992 were assumed to be true and set equal to R(y). Values of R(y) for 1985, 1987-1988, 1990-1991, and 1993-1994 were generated as normally distributed random numbers with mean = 8.849499 and standard deviation = 0.284837. Values were then back-transformed to the original scale by exponentiating each realized random number.Numbers of full recruits N(y) were generated via the process equation of the DeLury model: N(y+1) = [N(y) +R(y) - C(y)] * exp(-M) where N(1980) was set to the estimated value in Table D21 (i.e., 163 million). The resulting estimates of N(y) and R(y) constituted a "known" population. The true population estimates were converted to "true" indices n(y) and r(y) by dividing each value by the estimated value of q_n = 0.07851. Observation error for the indices was introduced by assuming that observed values n'(y) and r'(y) were normally distributed with means equal to the true values n(y) and r(y), respectively, and standard deviations set at 30% and 20% of the true mean, respectively. The derived set of n'(y) and r'(y) was then used to estimate the parameters of the DeLury model. No additional process error was introduced into the model. Variability in the derived estimates was assessed by conducting 200 bootstrap simulations for each scenario. The distribution of bootstrap values was used to estimate and correct for bias.

Scenarios were developed to examine the effects of intermittent surveys. Scenario 1 represented the full model in which surveys were present each year. In Scenario 2, surveys were assumed to be present for 1980-1984 and then in alternate years through 1994. Scenario 3 examined a triennial survey frequency with surveys in 1980-1985, 1988, 1991, and 1994. Scenario 4 considered surveys every 4 years beginning in 1986 (i.e., 1980-1984, 1986, 1990, 1994). Scenario 5 was designed to mimic the actual survey pattern with observations in 1980-1984, 1986, 1989, and 1992. No value of full recruits was used for 1994, n(1994) = missing, but the pre-recruit index r'(1994) was set equal to a random value approximately equal to the geometric mean of the observed time series of r(y). This is the same assumption employed in the DeLury model formulation; an estimate of the full recruits is not necessary in the terminal year, but a value of the pre-recruit value is necessary.

Results for the full model suggested that the catchability coefficient q_n was estimated within 1% of the true value. Estimated values of R(y) agreed well with the true values in most years, but the 80% confidence interval of the pre-recruit estimates in 1982, 1987, 1988 and 1992 did not contain the true value, irrespective of the number of available indices used in the estimation (Figure D8). In contrast, the true values of the full recruits N(y) were generally found within the empirical 80% confidence intervals (Figure D8). Scenarios 2 and 3 resulted in similar patterns in which estimated values were below the true value of N(y) in 1984-1988.

As expected, a decrease in the frequency of survey observations decreased the precision of the estimates. This effect was expressed as the ratio of the size of the 80% confidence interval for a scenario to the base run (Scenario 1). For pre-recruits, the deletion of survey years increased the 80% confidence interval in Scenarios 2, 4, and 5 relative to Scenario 1 (Figure D9). Results for Scenario 3 suggest a small improvement in precision, but the generality of this result is unknown.

The change in the 80% confidence interval for full recruits was consistently positive for Scenarios 2, 4, and 5 (Figure D10). A triennial survey (Scenario 3) again showed a slight improvement in precision for early years and some degradation from 1989 onward. Simulations for Scenario 5 suggest a substantial increase in the relative confidence interval. This may be attributable to the absence of an estimate of full recruits n'(t) in the terminal year (1994). While the precision in Scenario 5 was poor, the empirical 80% confidence intervals encompassed the true values of N(t) in all years of the simulation.

Overall, the results suggest that the general precision of the DeLury estimates can be improved with increasing frequency of the survey. For the example examined herein, the accuracy did not always improve with increasing survey frequency. This result may be an artifact of the particular input data set employed. A more rigorous examination of these properties will require more intensive simulation studies under a variety of input conditions. Development of appropriate simulation experiments should be a high research priority.

Summary and Conclusions

Surfclam age-length relationships have been updated using recent samples. There are indications that growth parameters have declined over time in the New Jersey region.

The percent annual growth, in drained meat weight, of fully-recruited surfclams is approximately 5 - 8% per year. That of ocean quahogs is approximately one order of magnitude lower.

For surfclams, $F_{0.1}$ = 0.07 and 0.08 in the NJ and DMV regions, respectively. F_{MAX} = 0.19 and 0.25 in the same two regions. These updated values differ very little from the values reported in NEFSC 1995a. $F_{20\%MSP}$ = 0.18 and 0.19 in the NJ and DMV regions, respectively.

Including surfclam growth in the stochastic projection model raised the mean of the baseline run for the NNJ region from 4.5 to 5.6 supply years. Including growth in the combined NNJ + DMV run increased mean supply years from 6.7 to 9.4 years.

A spreadsheet model was developed to aid the MAFMC and others in simulating changes in stock biomass under the 10-yr and 30-yr supply horizon for surfclam and ocean quahog, respectively.

Due to significant changes in methods between 1978 and 1980, there is uncertainty about the proper standardization factors needed to link the survey data from 1978 and 1979 with more recent survey data. Detailed analytical comparisons of survey data sets will be required to estimate the effects of changes in mesh size, pump type, and season on catch per tow. No major changes in survey methodology have occurred since August 1980. Therefore, data from surveys in 1980 and 1981 can be added to the time series and used in the retrospective DeLury model run.

There was very little difference in the results between the survey-based DeLury run used for SAW-19 and the new run with the time series extended back to 1980.

Sources of Uncertainty and SARC Comments

Comments about the Invertebrate Subcommittee Working Paper

On the analysis of shell length and age in surfclams, several factors were mentioned that might have affected the parameter estimates. Factors which could affect growth rate include local population density, differences in water depth (inshore vs offshore), and differences in age composition between samples. It was also pointed out that analysis of growth increments in individual shells would provide an alternative method for estimating growth rate. Such data would eliminate possible problems from inferring growth from the terminal age and shell length of an individual.

The SARC pointed out two changes needed to make the spreadsheet models more realistic. These include 1) adding density dependence (i.e., carrying capacity) to limit the growth of the unexploited portion of the stock and 2) making recruitment a function of population size rather than a term that is independent of stock size. Results from additional field studies and from analyses of existing data would be needed to model these relationships properly in the spreadsheet. Furthermore, it was noted that harvests, computed by the spreadsheet, rely heavily on what is assumed about future recruitment. Therefore, special attention should be paid to estimation of this parameter. In addition, sensitivity analyses relating model results to what is assumed for future recruitment are justified. The SARC noted that the spreadsheet model is a tool for examining various options and assumptions. The option to start exploiting a fraction of the unexploited biomass may be too simplistic, or might cause confusion over the difference between areas that are truly closed (e.g., Georges Bank) and areas that are open but unexploited.

Regarding choice of the proper frequency for carrying out surveys, it was pointed out that the decision is more complex than considering the performance of the modified DeLury model. The decision should also be based on life history criteria such as how quickly the organism grows and how often recruitment pulses occur. Nevertheless, sampling every third year may not be sufficient from a statistical point of view because variations in survey catchability can lead to large data gaps in the time series.

The SARC discussed the relative viability of eggs and larvae produced by various sizes of clams. This information is relevant to understanding reproduction in these populations and, therefore, to biological reference points such as F at % maximum spawning potential.

Additional SARC Comments

The SARC discussed an apparent inconsistency between the catchability coefficient "q", estimated in the survey-based run of the modified DeLury model for surfclams, and the unreasonably high, implied probability of capture given encounter (i.e., $P_{C|E} = 2.2$) by the clam dredge. Several approaches were outlined for examining the causes of the inconsistency in the surfclam model. It was noted that this inconsistency applied only to surfclam and not to models that have been done for ocean quahog.

Input variables for surfclams that might be misspecified in the modified DeLury model and in the equation relating "q" to $P_{C|E}$ include: natural mortality rate (M), underreporting of catch or underestimation of the catch in numbers, area swept by the dredge (a), the interaction between a highly localized fishery and non-localized survey sampling, the impact on survey indices of a decline in surfclam growth rate over time, and the specification of survey area (A) versus the effective area of the fishery.

Field studies can be undertaken to estimate variables such as "M", "a", and $P_{C|E}$. These studies can be tied closely to a program for field verification of the DeLury model.

Other comments relative to the inconsistent "q" estimates included running the model with constraints on "q" such that the implied $P_{C|E}$ must be ≤ 1, and/or to run the model with lower weight assigned to the process error and greater weight on the measurement errors.

The SARC noted that the modified DeLury model will perform well when the exploitation rate is high, and that this situation might not exist for surfclams over the entire NNJ region. An additional suggestion was to restrict the region being modelled from the entire NNJ region to that which has been heavily exploited.

The SARC concluded that it is preferable to estimate population size from models, such as the modified DeLury model, that use a time series of catch and abundance (i.e., survey indices and/or LPUE) data compared to methods, such as swept-area biomass, relying only on a point estimate of standing stock from the most recent measurement. The SARC noted that, at the present time, additional work is needed in the next year on parameter estimation for both the modified DeLury and the swept-area biomass models.

The SARC emphasized the need to include multiple indices of abundance in models like the modified DeLury model. It was noted that alternative indices of abundance, such as LPUE, might be used to indicate changes in population size for years when no survey data are available.

The SARC discussed the 10-yr and 30-yr harvest policy used by the MAFMC for quota setting. The SARC noted that this policy is unique to surfclams and ocean quahogs. New overfishing definitions ($F_{\%MSP}$) have been proposed for these species. The SARC noted that the supply years policy of the MAFMC does not consider whether the quota exceeds surplus production (i.e., catch > recruitment + growth), leading to the mining analogy, until the allowed catch converges to the incoming recruitment.

The SARC suggested that this may be an appropriate time for the Council to revisit the question of appropriate harvest policies for the surfclam.The approach used to calculate annual landings that would afford a 10-yr or 30-yr supply uses assumptions about growth, natural mortality and future recruitment. This approach may differ from the current harvest policy, which does not deal explicitly with these assumptions. The production dynamics of the surfclam fishery had previously been modelled as a mining strategy. Given estimates of growth and recruitment, it now appears that a sustainable fishery is feasible.

Research Recommendations

Higher Priority

- Gather data on ocean quahogs to estimate and/or update seasonal and regional relationships in shell length, drained meat weight, and age.

- Utilize individual growth rate estimates and size frequency distributions for ocean quahogs to estimate annual recruitment to ocean quahog stocks.

- Carry out research to improve, test and verify the surfclam DeLury model. This includes field studies to measure the efficiency and actual tow distance of the NMFS clam dredge, field and theoretical work for reestimation of natural mortality rate (surfclams and ocean quahogs), and examination of modified DeLury model results for surfclams based on areas where exploitation rates and survey sampling intensity are high.

- Perform simulations to evaluate the sensitivity of response variables in the spreadsheet models (e.g., exploitation rates) to input variables (e.g., recruitment, M, etc.).

- Develop methods based on multiple indices of abundance to estimate stock size.

- Determine appropriate survey frequency. Increasing surfclam survey frequency to every 2 years would probably increase the precision of the De-

Lury estimates, although additional theoretical work is needed before firm conclusions can be drawn. Determining an appropriate survey frequency should also be based on the rates of recruitment and growth for species being sampled.

- Carry out experimental sampling with the *R/V Delaware II* before an entire clam survey is attempted in areas that have had little fishing effort to determine whether catches appear high or low relative to past surveys. These data can be used to better plan for future research activity with that ship (i.e., carrying out a full survey, need for gear tests).

- Use differential GPS to estimate precise tow length.

Lower Priority

- Extend time series in modified DeLury model. From existing data sets (1978-1980), try to estimate effects (on catch per survey tow) of changes in pump type, dredge width, mesh size, and survey season. If these effects can be estimated, re-standardize historical data to more recent data (1980-1994). Also, examine historical LPUE data for incorporation into LPUE-based runs.

- Carry out literature review on the relationship between reproductive success and maternal size in bivalves.

- Clarify how the variable "time fishing" is defined for surfclams and ocean quahogs. Determine whether this definition has been used consistently in the past, and take measures to assure that this variable is recorded correctly in the commercial database in the future.

- Utilize genetic studies of surfclams from Cape Hatteras to Norfolk, VA to identify stocks.

- Perform experiments to examine the hypothesis that harvesting can select for individuals with slower growth rates.

- Examine existing bioenergetics model for oysters (by Dr. E. Powell), and determine its utility to understanding surfclam and ocean quahog yield and population dynamics.

- Investigate stock-recruitment relationships in ocean quahogs.

- Examine existing data sets on surfclam growth for depth effects and the sensitivity of the parameter estimates to age composition of samples. Annual growth increments on individual shells provide another source of data for age-length analysis.

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Table D1. Age frequency distributions for number of surfclams used in age-length analyses, by region and time. (Note: This is not an age frequency distribution for the population.)

Region / Year Sample Collected	Age (yr) 0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	22-23	24-25	26-27	28-29	30+
A. DMV 80	3	99	153	71	34	33	38	37	46	31	19	15	14	7	3	4
B. DMV 89+92	1	28	52	12	30	19	36	11	6	0	0	1	1	0	0	0
C. DMV 94	4	24	59	39	29	21	27	46	35	10	2	2	1	0	0	0
D. NJ 80	0	156	352	42	16	6	10	7	2	4	3	6	13	17	8	5
E. NJ 89+92	0	114	111	119	101	113	140	45	16	1	2	2	2	2	0	6
F. NJ 94	0	45	84	76	45	57	33	46	50	32	6	2	0	0	0	0
G. LI 80	0	3	4	10	8	12	6	9	6	5	7	7	6	3	4	0
H. LI 89+92	1	17	32	9	13	4	7	5	5	2	3	1	0	1	0	0
I. SNE 80	0	5	11	21	11	6	12	7	4	7	6	2	3	1	0	1
J. SNE 89+92	1	25	21	8	1	1	4	3	9	4	3	2	4	3	4	3
K. GBK 89+92	2	67	107	52	66	26	30	22	11	9	2	0	2	0	1	0

Table D2. The percentage of surfclam shell samples collected from each stratum, by region and time period, for age-length analysis. "-" : no data. sample sizes are given in Tables D1 and D3.

Region	Stratum Number	% of Shells by Stratum within Region/Period Survey: 1980	1989+1992	1994
Delmarva				
	#9	61%	77%	77%
	#13	39%	23%	23%
New Jersey				
	#88	45%	21%	32%
	#89	31%	53%	28%
	#21	13%	22%	40%
	#25	11%	4%	-
Long Island				
	#91	22%	22%	-
	#92	11%	49%	-
	#93	40%	15%	-
	#29	27%	2%	-
	#30	-	12%	-
S. New England				
	#95	93%	54%	-
	#41	7%	-	-
	#45	-	29%	-
	#46	-	16%	-
	#47	-	1%	-
Georges Bank				
	#67	-	18%	-
	#68	-	23%	-
	#69	-	1%	-
	#72	-	19%	-
	#73	-	11%	-
	#70	-	6%	-
	#71	-	5%	-
	#74	-	3%	-
	#54, #55, #59, #61, #65	-	14%	-

Table D3. Parameters estimates, asymptotic standard errors (in parentheses), and sample sizes (n) for the von Bertalanffy growth model applied to surfclams and ocean quahogs by region and year. Surfclam parameter estimates for 1978 samples are from Serchuk and Murawski (1980). Surfclam parameter estimates for 1980 and 1989+1992 samples are from Weinberg and Helser (in press). Surfclam estimates from 1994 samples are being reported here for the first time. Ocean quahog parameter estimates for 1978 samples are from Murawski. Ropes and Serchuk (1982). Ocean quahog parameter estimates for 1978-1983 samples are from NEFSC 1990 (t_0 was estimated following Gulland 1969, Equation 3.5).

Region / Year Sample Collected	L_∞ (ASE)	k (ASE)	t_0	n
SURFCLAM:				
DMV 78	166.4 (--)	0.298 (--)	0.079 (--)	196
DMV 80	171.0 (1.238)	0.256 (0.012)	0.132 (0.139)	607
DMV 89+92	164.0 (6.076)	0.177 (0.030)	-1.125 (0.576)	197
DMV 94	149.5 (1.661)	0.343 (0.022)	0.937 (0.133)	299
NJ 78	166.6 (--)	0.273 (--)	-0.026 (--)	291
NJ 80	170.8 (1.880)	0.254 (0.012)	0.010 (0.145)	647
NJ 89+92	163.7 (1.874)	0.217 (0.012)	-0.214 (0.169)	774
NJ 94	159.6 (2.181)	0.197 (0.017)	-1.080 (0.356)	476
LI 80	162.5 (1.873)	0.244 (0.029)	-0.501 (0.560)	90
LI 89+92	161.6 (2.837)	0.252 (0.025)	-0.533 (0.316)	100
SNE 80	166.5 (2.117)	0.299 (0.032)	0.342 (0.374)	97
SNE 89+92	165.4 (2.757)	0.313 (0.031)	0.882 (0.220)	96
GBK 89+92	148.6 (2.169)	0.265 (0.017)	0.505 (0.151)	397
OCEAN QUAHOG:				
LI 78	104.95 (--)	0.020 (--)	-27.62 (--)	--
LI 78 to 83	97.28 (0.82)	0.0311 (--)	-14.967(--)	445

Table D4. Parameter estimates for the relationship between drained meat weight (gr) and shell length (mm) for surfclams and ocean quahogs, by region and time. Estimates for DMV and NJ surfclams are from Serchuk and Murawski (1980). Estimates for GBK surfclams are from Gledhill (1984). Estimates for LI ocean quahogs are from Murawski and Serchuk (1979).

Region / Year Sample Collected	Parameter α	β	n
SURFCLAM:			
DMV 80	-9.1063	2.7675	525
NJ 80	-9.2061	2.8251	461
GBK 84	-7.9967	2.5772	613
OCEAN QUAHOG:			
LI 78	-9.1243	2.7750	1351

Table D5. Regional estimates of the expected value of the percent annual growth of a fully recruited individual for surfclam and ocean quahog. Various options considered involved the year in which the shells were collected for age-length analysis and the choice of the survey from which to estimate the population size structure. Based on previous assessments (NEFSC 1995a, b), shell length at full recruitment to the fishery was assumed to be 120 mm for surfclams and 80 mm for ocean quahogs.

Region	Year of Age Len. Sample	Year of Size Freq. Dist.	% Annual Growth of Full-Recruit
SURFCLAM:			
DMV	1989+1992	1992	8.237%
	1989+1992	1994	8.559%
	1994	1992	7.284%
	1994	1994	7.157%
NNJ	1989+1992	1992	7.608%
	1989+1992	1994	7.628%
	1994	1992	5.675%
	1994	1994	5.667%
OCEAN QUAHOG:			
LI	1979	1992	0.709%
	1979	1994	0.768%
	1978-83	1992	0.510%
	1978-83	1994	0.583%

Table D6. Revised surfclam yield (g) and spawning stock biomass per recruit for the **Delmarva Region**. The age-length data are from samples collected in 1994.

```
Yield and Spawning Stock Biomass per Recruit
SCDMV94:_YPR_SSB/R_May18,1996
-----------------------------------------------
Proportion of F before spawning: 0.5000
Proportion of M before spawning: 0.5000
Natural mortality is constant at: 0.0500
Initial age is: 1  Last age is: 30
Last age is a PLUS group
Input data from file named: scdmv94.dat
-----------------------------------------------------------
 Age-specific Input data for Yield per Recruit Analysis
-----------------------------------------------------------
```

Age	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Weights Stock	Average Weights Catch
1	0.0000	1.0000	0.9000	0.0000	0.0000
2	0.0000	1.0000	1.0000	4.4000	4.4000
3	0.0000	1.0000	1.0000	17.7000	17.7000
4	0.0000	1.0000	1.0000	35.2000	35.2000
5	0.5000	1.0000	1.0000	52.6000	52.6000
6	1.0000	1.0000	1.0000	67.7000	67.7000
7	1.0000	1.0000	1.0000	80.0000	80.0000
8	1.0000	1.0000	1.0000	89.5000	89.5000
9	1.0000	1.0000	1.0000	96.7000	96.7000
10	1.0000	1.0000	1.0000	102.0000	102.0000
11	1.0000	1.0000	1.0000	105.9000	105.9000
12	1.0000	1.0000	1.0000	108.7000	108.7000
13	1.0000	1.0000	1.0000	110.7000	110.7000
14	1.0000	1.0000	1.0000	112.2000	112.2000
15	1.0000	1.0000	1.0000	113.2000	113.2000
16	1.0000	1.0000	1.0000	113.9000	113.9000
17	1.0000	1.0000	1.0000	114.4000	114.4000
18	1.0000	1.0000	1.0000	114.8000	114.8000
19	1.0000	1.0000	1.0000	115.1000	115.1000
20	1.0000	1.0000	1.0000	115.3000	115.3000
21	1.0000	1.0000	1.0000	115.4000	115.4000
22	1.0000	1.0000	1.0000	115.5000	115.5000
23	1.0000	1.0000	1.0000	115.6000	115.6000
24	1.0000	1.0000	1.0000	115.6000	115.6000
25	1.0000	1.0000	1.0000	115.7000	115.7000
26	1.0000	1.0000	1.0000	115.7000	115.7000
27	1.0000	1.0000	1.0000	115.7000	115.7000
28	1.0000	1.0000	1.0000	115.7000	115.7000
29	1.0000	1.0000	1.0000	115.7000	115.7000
30+	1.0000	1.0000	1.0000	115.7000	115.7000

```
------------------------------------------------------------
Summary of Yield per Recruit Analysis for:
SCDMV94:_YPR_SSB/R_May18,1996
------------------------------------------------------------
The slope of the yield per recruit curve at F=0: 1704.125977
F level at slope=1/10 of the above slope (F0.1): 0.081531
Yield/Recruit corresponding to F0.1:             47.657948
F level to produce Maximum Yield/Recruit (Fmax): 0.253494
Yield/Recruit corresponding to Fmax:             55.573692
F level at 0.20 of max spawning potential:       0.193149
SSB/Recruit corresponding to F=0.193149:         354.145081
```

Table D7. Revised surfclam yield (g) and spawning stock biomass per recruit for the **New Jersey Region**. The age-length data were collected in 1994.

```
Yield and Spawning Stock Biomass per Recruit
SCNJ94.DAT:_YPR_SSB/R_MAY_2_96
-----------------------------------------------
Proportion of F before spawning: 0.5000
Proportion of M before spawning: 0.5000
Natural mortality is constant at: 0.0500
Initial age is: 1  Last age is: 30
Last age is a PLUS group
Input data from file named: scnj94.dat
------------------------------------------------------------
 Age-specific Input data for Yield per Recruit Analysis
------------------------------------------------------------
```

Age	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Weights Stock	Average Weights Catch
1	0.0000	1.0000	0.9000	7.7000	7.7000
2	0.0000	1.0000	1.0000	18.2000	18.2000
3	0.0000	1.0000	1.0000	31.4000	31.4000
4	0.0000	1.0000	1.0000	46.1000	46.1000
5	0.5000	1.0000	1.0000	60.9000	60.9000
6	1.0000	1.0000	1.0000	75.2000	75.2000
7	1.0000	1.0000	1.0000	88.4000	88.4000
8	1.0000	1.0000	1.0000	100.3000	100.3000
9	1.0000	1.0000	1.0000	110.8000	110.8000
10	1.0000	1.0000	1.0000	119.9000	119.9000
11	1.0000	1.0000	1.0000	127.8000	127.8000
12	1.0000	1.0000	1.0000	134.5000	134.5000
13	1.0000	1.0000	1.0000	140.1000	140.1000
14	1.0000	1.0000	1.0000	144.9000	144.9000
15	1.0000	1.0000	1.0000	148.9000	148.9000
16	1.0000	1.0000	1.0000	152.2000	152.2000
17	1.0000	1.0000	1.0000	154.9000	154.9000
18	1.0000	1.0000	1.0000	157.3000	157.3000
19	1.0000	1.0000	1.0000	159.2000	159.2000
20	1.0000	1.0000	1.0000	160.8000	160.8000
21	1.0000	1.0000	1.0000	162.1000	162.1000
22	1.0000	1.0000	1.0000	163.1000	163.1000
23	1.0000	1.0000	1.0000	164.0000	164.0000
24	1.0000	1.0000	1.0000	164.8000	164.8000
25	1.0000	1.0000	1.0000	165.4000	165.4000
26	1.0000	1.0000	1.0000	165.8000	165.8000
27	1.0000	1.0000	1.0000	166.3000	166.3000
28	1.0000	1.0000	1.0000	166.6000	166.6000
29	1.0000	1.0000	1.0000	166.9000	166.9000
30+	1.0000	1.0000	1.0000	167.1000	167.1000

```
------------------------------------------------------------
Summary of Yield per Recruit Analysis for:
SCNJ94.DAT:_YPR_SSB/R_MAY_2_96
------------------------------------------------------------
The slope of the yield per recruit curve at F=0: 2284.201660
F level at slope=1/10 of the above slope (F0.1): 0.070975
Yield/Recruit corresponding to F0.1:             57.249420
F level to produce Maximum Yield/Recruit (Fmax): 0.191572
Yield/Recruit corresponding to Fmax:             65.289589
F level at 0.20 of max spawning potential:       0.178228
SSB/Recruit corresponding to F=0.178228:         478.662018
```

Table D8. Revised surfclam yield (g) and spawning stock biomass per recruit for the **Georges Bank Region**. Age-length samples were collected in 1989 and 1992.

```
Proportion of F before spawning: 0.5000
Proportion of M before spawning: 0.5000
Natural mortality is constant at: 0.0500
Initial age is: 1  Last age is: 30
Last age is a PLUS group
Input data from file named: scgbknew.dat
```

Age-specific Input data for Yield per Recruit Analysis

Age	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Weights Stock	Average Weights Catch
1	0.0000	1.0000	0.9000	0.6000	0.6000
2	0.0000	1.0000	1.0000	7.5000	7.5000
3	0.0000	1.0000	1.0000	20.6000	20.6000
4	0.0000	1.0000	1.0000	36.4000	36.4000
5	0.5000	1.0000	1.0000	52.5000	52.5000
6	0.5000	1.0000	1.0000	67.4000	67.4000
7	1.0000	1.0000	1.0000	80.4000	80.4000
8	1.0000	1.0000	1.0000	91.3000	91.3000
9	1.0000	1.0000	1.0000	100.2000	100.2000
10	1.0000	1.0000	1.0000	107.4000	107.4000
11	1.0000	1.0000	1.0000	113.2000	113.2000
12	1.0000	1.0000	1.0000	117.7000	117.7000
13	1.0000	1.0000	1.0000	121.2000	121.2000
14	1.0000	1.0000	1.0000	124.0000	124.0000
15	1.0000	1.0000	1.0000	126.1000	126.1000
16	1.0000	1.0000	1.0000	127.8000	127.8000
17	1.0000	1.0000	1.0000	129.1000	129.1000
18	1.0000	1.0000	1.0000	130.0000	130.0000
19	1.0000	1.0000	1.0000	130.8000	130.8000
20	1.0000	1.0000	1.0000	131.4000	131.4000
21	1.0000	1.0000	1.0000	131.8000	131.8000
22	1.0000	1.0000	1.0000	132.2000	132.2000
23	1.0000	1.0000	1.0000	132.5000	132.5000
24	1.0000	1.0000	1.0000	132.7000	132.7000
25	1.0000	1.0000	1.0000	132.8000	132.8000
26	1.0000	1.0000	1.0000	132.9000	132.9000
27	1.0000	1.0000	1.0000	133.0000	133.0000
28	1.0000	1.0000	1.0000	133.1000	133.1000
29	1.0000	1.0000	1.0000	133.2000	133.2000
30+	1.0000	1.0000	1.0000	133.2000	133.2000

```
Summary of Yield per Recruit Analysis for:
SCGBKNEW:_YPR_SSB/R_Aug3,1995
----------------------------------------------------------------
The slope of the yield per recruit curve at F=0: 1871.668579
F level at slope=1/10 of the above slope (F0.1): 0.078092
Yield/Recruit corresponding to F0.1:             50.599636
F level to produce Maximum Yield/Recruit (Fmax): 0.230728
Yield/Recruit corresponding to Fmax:             58.555462
F level at 0.20 of max spawning potential:       0.196984
SSB/Recruit corresponding to F=0.196984:         394.049347
```

Table D9. Original surfclam "supply year" calculations from stochastic projection model (SAW-19, NEFSC 1995a). Runs 4, 8 and 12 assume constant fishing mortality rates. Runs 13 and 24 give the results for a quota level that allows a 50% probability that the quota lasts 10 years under the assumption that recent levels of recruitment continue.

REGION	RUN #	INPUT CONDITIONS: CATCH ASSUMPTION	CATCH LEVEL (MT)	RECRUITMENT MEAN, (CV)	GROWTH RATE ANNUAL	RESULTS: SUPPLY YEARS : MEAN	MEDIAN	EXPLOITATION RATE IN 1995
NNJ								
	1	Mean (92-94)	16,986	7,259 (0.29)	0%	4.48	4	0.28
	2	Run 1 + 10%	18,685	7,259 (0.29)	0%	3.84	4	0.31
	3	Run 1 - 10%	15,287	7,259 (0.29)	0%	5.35	5	0.25
	4	Const. F	u = 20%	7,259 (0.29)	0%	(Avg. Landings in Yr 10 = 6364 MT)		
	5	Mean (92-94)	16,986	0 (0)	0%	2.93	3	0.28
	6	Run 5 + 10%	18,685	0 (0)	0%	2.69	3	0.31
	7	Run 5 - 10%	15,287	0 (0)	0%	3.32	3	0.25
	8	Const. F	u = 20%	0 (0)	0%	(Avg. Landings in Yr 10 = 1057 MT)		
	9	Mean (92-94)	16,986	9,858 (1.00)	0%	5.67	5	0.28
	10	Run 9 + 10%	18,685	9,858 (1.00)	0%	4.73	4	0.31
	11	Run 9 - 10%	15,287	9,858 (1.00)	0%	7.1	6	0.25
	12	Const. F	u = 20%	9,858 (1.00)	0%	(Avg. Landings in Yr 10 = 8258 MT)		
	13	Find Quota	11,263	7,259 (0.29)	0%	9.59	10	0.18
DMV								
	14	Mean (92-94)	2,470	4,212 (1.01)	0%	98.61	100	0.15
	15	Run 14 + 10%	2,717	4,212 (1.01)	0%	92.74	100	0.16
	16	Run 14 - 10%	2,223	4,212 (1.01)	0%	99.77	100	0.13
	17	Mean (92-94)	2,470	0 (0)	0%	6.34	6	0.15
	18	Run 17 + 10%	2,717	0 (0)	0%	5.82	6	0.16
	19	Run 17 - 10%	2,223	0 (0)	0%	6.99	7	0.13
	20	Mean (92-94)	2,470	1,324 (0.19)	0%	10.94	11	0.15
	21	Run 20 + 10%	2,717	1,324 (0.19)	0%	9.42	9	0.16
	22	Run 20 - 10%	2,223	1,324 (0.19)	0%	12.98	13	0.13
NNJ + DMV								
	23	Mean (92-94)	19,465	11,471 (0.55)	0%	6.7	7	0.24
	24	Find Quota	16,385	11,471 (0.55)	0%	9.81	10	0.2

Table D10. Revised surfclam "supply year" calculations from revised stochastic projection model. Results assume 5.67% annual growth of full recruits in the NNJ region and 7.16% growth in the DMV region, based on 1994 age-length samples. Runs 4, 8, and 12 assume constant fishing mortality rates. Runs 13 and 24 give the results for a quota level that allows a 50% probability that the quota lasts 10 years under the assumption that recent levels of recruitment continue.

REGION	RUN #	INPUT CONDITIONS:				RESULTS:		
		CATCH ASSUMPTION	CATCH LEVEL (MT)	RECRUITMENT MEAN, (CV)	GROWTH RATE ANNUAL	SUPPLY YEARS : MEAN	MEDIAN	EXPLOITATION RATE IN 1995
NNJ								
	1	Mean (92-94)	17,475	7,259 (0.29)	5.67%	5.63	6	0.26
	2	Run 1 + 10%	19,222	7,259 (0.29)	5.67%	4.72	5	0.29
	3	Run 1 - 10%	15,727	7,259 (0.29)	5.67%	6.94	7	0.23
	4	Const. F	u = 20%	7,259 (0.29)	5.67%	(Avg. Landings in Yr 10 = 8,355 MT)		
	5	Mean (92-94)	17,475	0 (0)	5.67%	3	3	0.29
	6	Run 5 + 10%	19,222	0 (0)	5.67%	2.72	3	0.32
	7	Run 5 - 10%	15,727	0 (0)	5.67%	3.45	3	0.26
	8	Const. F	u = 20%	0 (0)	5.67%	(Avg. Landings in Yr 10 = 1,704 MT)		
	9	Mean (92-94)	17,475	9,858 (1.00)	5.67%	8.11	7	0.25
	10	Run 9 + 10%	19,222	9,858 (1.00)	5.67%	6.42	6	0.27
	11	Run 9 - 10%	15,727	9,858 (1.00)	5.67%	10.85	9	0.22
	12	Const. F	u = 20%	9,858 (1.00)	5.67%	(Avg. Landings in Yr 10 = 10,819 MT)		
	13	Find Quota	14,150	7,259 (0.29)	5.67%	10.03	10	0.2
DMV								
	14	Mean (92-94)	2,698	4,212 (1.01)	7.16%	100	100	0.12
	15	Run 14 + 10%	---	---	---	---	---	---
	16	Run 14 - 10%	---	---	---	---	---	---
	17	Mean (92-94)	2,698	0 (0)	7.16%	7.42	7	0.16
	18	Run 17 + 10%	2,968	0 (0)	7.16%	6.65	6	0.18
	19	Run 17 - 10%	2,428	0 (0)	7.16%	8.43	8	0.15
	20	Mean (92-94)	2,698	1,324 (0.19)	7.16%	17.27	16	0.15
	21	Run 20 + 10%	2,968	1,324 (0.19)	7.16%	13.73	13	0.16
	22	Run 20 - 10%	2,428	1,324 (0.19)	7.16%	23.43	21	0.13
NNJ + DMV								
	23	Mean (92-94)	20,173	11,471 (0.55)	(as above)	9.43	9	0.22
	24	Find Quota	19,700	11,471 (0.55)	(as above)	10.03	10	0.22

Table D11. Sensitivity analysis for revised supply-year calculations. The body of the table contains the mean number of surfclam supply years given different assumptions about the annual growth rate of full recruits in NNJ and DMV.

RUN #1:

NNJ Annual Growth Rate (%)					
0%	4%	6%	8%	10%	12%
4.47	5.23	5.72	6.29	7.03	7.98

RUN #23:

		DMV Annual Growth Rate (%)					
		0%	4%	6%	8%	10%	12%
NNJ	0%	6.6	6.95	7.15	7.38	7.61	7.87
	4%	7.75	8.23	8.5	8.81	9.12	9.49
	6%	8.47	9.06	9.38	9.75	10.19	10.68
	8%	9.39	10.11	10.54	11.02	11.55	12.21
	10%	10.55	11.52	12.06	12.76	13.69	14.67
	12%	12.13	13.55	14.53	15.67	17.53	20.54

Table D12. Surfclam supply year calculations -- 10 year harvesting horizon policy (with option to harvest unexploited stock). NMFS, March 1996, NEFSC, Woods Hole.

ASSUMPTIONS / INPUTS:

Biomass estimate for 1994: (from SARC 19)

Region	Biomass	
NNJ	83.3	thousand mt
DMV	22.9	
Total	106.2	

(do not change value from "14".)
used in harvest calc:
1+exp(M)+exp(2M)+. .+exp(10M) = 14

Commercial Catch Estimate from Exploited Area (units: mt):

Year	Catch (mt)	Source
1994	21,208	database
1995	19,779	1995 quota
1996	19,200	1996 quota

Conversion Fac: 17 lbs/bu

Policy: Harvest calculated for 10-yr horizon

Natural Mortality Rate, m : 0.05

Overfishing Def: F_ref 0.18 = Label F_20% MSP

Portion of total biomass that is unexploited in 1994 : 40%

Annual Recruitment:
(Pre-recruits grow to Full-Recruits)
11,471 mt, mean (1984-1992) annual recr. to exploited areas (initially)
7,647 mt, annual recruitment in unexploited areas (initially)

Want to open part of unexploit. stock for harvest?
Enter fraction of unexpl. biomass
to make available (exploitable) : 0.50
Starting in Year (>=1997): 2009

Annual Growth of Full-Recruits:
(enter fractional increase in meat weight/ clam): 0.065
(e.g., 0.08 represents 8% / yr)

Instant. Growth Rate (g): 0.063 (do not change this value.) (computed by spreadsheet)

SIMULATION:

Marker		Year	Biomass (Expl), mt	Biomass (Unexpl), mt	Tot Biomass	Harvest from Expl. Area: mt	bushels
o	1	1995	97,723	79,472	177,195	19,779	2,565,014
o	2	1996	90,582	88,257	178,839	19,200	2,489,927
o	3	1997	83,935	97,157	181,092	17,340	2,248,715
o	4	1998	79,086	106,173	185,259	17,001	2,204,741
o	5	1999	74,517	115,306	189,823	16,681	2,163,307
o	6	2000	70,211	124,559	194,771	16,380	2,124,267
o	7	2001	66,155	133,933	200,088	16,097	2,087,482
o	8	2002	62,333	143,430	205,762	15,829	2,052,823
o	9	2003	58,731	153,050	211,781	15,578	2,020,167
o	10	2004	55,338	162,796	218,134	15,340	1,989,397
o	11	2005	52,141	172,669	224,810	15,117	1,960,405
o	12	2006	49,128	182,671	231,799	14,906	1,933,088
o	13	2007	46,290	192,804	239,094	14,708	1,907,349
o	14	2008	43,615	203,069	246,684	14,521	1,883,098
==>	15	2009	147,829	106,734	254,563	25,631	3,323,962
o	16	2010	139,288	112,002	251,290	25,034	3,246,513
o	17	2011	131,241	117,338	248,579	24,471	3,173,539
o	18	2012	123,658	122,744	246,402	23,941	3,104,781
o	19	2013	116,514	128,220	244,734	23,442	3,039,995
o	20	2014	109,782	133,768	243,550	22,971	2,978,953
o	21	2015	103,439	139,389	242,828	22,527	2,921,437
o	22	2016	97,463	145,083	242,545	22,110	2,867,244
o	23	2017	91,832	150,851	242,683	21,716	2,816,183
o	24	2018	86,526	156,695	243,221	21,345	2,768,071
o	25	2019	81,527	162,615	244,141	20,995	2,722,740
o	26	2020	76,816	168,612	245,428	20,666	2,680,027
o	27	2021	72,378	174,687	247,066	20,356	2,639,782
o	28	2022	68,196	180,842	249,039	20,063	2,601,863
o	29	2023	64,256	187,078	251,334	19,788	2,566,134
o	30	2024	60,544	193,394	253,938	19,528	2,532,470

	Year	Exploitation Rate: Expl Areas	All Areas	Overfishing Ref. Pt. Inst. Rate (F_ref) = F_20% MSP	Exploit. Rate = (F_ref / Z) * (1-exp(-Z))
1	1995	20.2%	11.2%	0.18	16.1%
2	1996	21.2%	10.7%	0.18	16.1%
3	1997	20.7%	9.6%	0.18	16.1%
4	1998	21.5%	9.2%	0.18	16.1%
5	1999	22.4%	8.8%	0.18	16.1%
6	2000	23.3%	8.4%	0.18	16.1%
7	2001	24.3%	8.0%	0.18	16.1%
8	2002	25.4%	7.7%	0.18	16.1%
9	2003	26.5%	7.4%	0.18	16.1%
10	2004	27.7%	7.0%	0.18	16.1%
11	2005	29.0%	6.7%	0.18	16.1%
12	2006	30.3%	6.4%	0.18	16.1%
13	2007	31.8%	6.2%	0.18	16.1%
14	2008	33.3%	5.9%	0.18	16.1%
15	2009	17.3%	10.1%	0.18	16.1%
16	2010	18.0%	10.0%	0.18	16.1%
17	2011	18.6%	9.8%	0.18	16.1%
18	2012	19.4%	9.7%	0.18	16.1%
19	2013	20.1%	9.6%	0.18	16.1%
20	2014	20.9%	9.4%	0.18	16.1%
21	2015	21.8%	9.3%	0.18	16.1%
22	2016	22.7%	9.1%	0.18	16.1%
23	2017	23.6%	8.9%	0.18	16.1%
24	2018	24.7%	8.8%	0.18	16.1%
25	2019	25.8%	8.6%	0.18	16.1%
26	2020	26.9%	8.4%	0.18	16.1%
27	2021	28.1%	8.2%	0.18	16.1%
28	2022	29.4%	8.1%	0.18	16.1%
29	2023	30.8%	7.9%	0.18	16.1%
30	2024	32.3%	7.7%	0.18	16.1%

Table D13. Documentation and notes for users (surfclam spreadsheet):

Total Biomass = Exploited Biomass + Unexploited Biomass (i.e., the exploited and unexploited portions of biomass are additive).

The exploited stock is impacted by harvesting whereas the unexploited stock is not. Both portions of the stock are affected by natural mortality and recruitment. The annual harvest is a variable (see next paragraph). Natural mortality is a constant, whose value is given above (see "ASSUMPTIONS"). The exploited and unexploited portions of the stock are increased by annual recruitment (assumed constant, i.e, unrelated to biomass). Recruitment was estimated empirically for the exploited area. The level of recruitment to the unexploited area is based on the recruitment to the exploited area, adjusted by a factor relating the biomass of the unexploited area to the biomass of the exploited area, in the starting year.

Estimation of annual harvest:

The annual harvest for 1994 was estimated from actual data. The annual harvests for 1995 and 1996 have been set equal to the annual quotas for those years.

For the years 1997 through 2024, the annual harvest is computed as the annual catch that could be taken from the exploited stock for 10 years, while recruitment and natur. mortal. are taking place, such that in year 11 the exploited stock is completely depleted. The stock does not actually run out after 10 years because the annual harvest is updated in each year of the simulation, based on the most recent year's biomass in the exploited region (i.e., the 10-yr calc. is made every year). Thus, the annual harvest always represents that which could be taken for an additional 10 years given the most recent exploitable biomass (B).

Calculation of annual harvest (C) is based on the catch equation (note: M = m-g, the difference between natural mortality and the growth rate) :

$B_1 = (B_0 - C + R)*\exp(-M)$, where "_#" represents an annual time step.

The generalized form of the catch equation is :

$B_t = B_0*\exp(-Mt) + [\text{summation from i to t:}]\ [(R - C)*\exp(-Mi)]$.

To get C(T), the annual harvest for year T with the 10-yr horizon, the above equation is assigned the following values: B_0 = current exploitable biomass at time T, t = 11 and $B_{11} = 0$, and then it is solved for annual harvest :

$C(T) = [\ \text{Expl. Biomass}(T) / (1 + \exp(M) + \exp(2M) + ... + \exp(10M))\ ] + (\text{Ann. Recrt. to Expl. Area})$.

The above equation is affected in the following ways when some fraction of unexploited biomass is made exploitable in a certain year: Expl. Biomass(T) = biomass from the historically exploited area + additional biomass from the previously unexploited area. Recrt. to Expl. Area = recruitment from the historically exploited area + additional recruitment from the previously unexploited area. Recruitment to the unexploited area is decremented by the amount now added to the exploited area.

Using the program:

Certain cells in the "Assumptions / Inputs" section may be changed by the user. When these are changed, the rest of the spreadsheet will be updated automatically. "Assumptions / Inputs" that the user can change include: Biomass by region for 1994, Commercial catch from 1994-1996, m, Portion of biomass that is unexploited in 1994, fraction of the unexploited biomass to start exploiting in a particular year, F_ref and its label (e.g. F_20%MSP), mean recruitment to the exploited areas and annual growth in tissue by fully recruited clams.

Although the SNJ region constitutes a small portion of the stock (about 3%), the biomass and exploitation from that area are not treated.

The "10 year harvesting horizon" is fixed (can not be changed by the user without major modifications).

Depending on the geographical area, the overfishing reference rate (F_20%MSP) ranges from 0.17 to 0.19 . Values in this range are reasonable to examine.

Table D14. Ocean quahog model. Run assumes annual recruitment to exploited area = 0% of biomass in 1994. Ocean quahog supply year calculations -- 30-year harvesting horizon policy (with option to harvest unexploited stock). NMFS, March 1996, NEFSC, Woods Hole.

ASSUMPTIONS / INPUTS:

(do not change, 43 :)
used in harvest calc.
1+exp(M)+exp(2M)+...+exp(30M) = 43

Biomass estimate for 1994: (from SARC 19)

Region	Biomass	
NJ	141.1	thousand mt
DMV	80.4	
LI	56.9	
Total	278.4	

Commercial Catch Estimate from Exploited Area (units: mt):

Year	Catch (mt)	Source
1994	19,944	database
1995	20,865	1995 quota
1996	20,185	1996 quota

Natural Mortality Rate, m: 0.02

Portion of total biomass that is unexploited in 1994 : 60%

Conversion Fac: 10 lbs/bu

Policy: Harvest calculated for 30-yr horizon

Overfishing Def: F_ref 0.0437 = Label F_25% MSP

Annual Recruitment:
(Pre-recruits grow to Full-Recruits)
0 mt, annual recr to exploited areas (initially)
0 mt, annual recruitment in unexploited areas (initially)

Want to open part of unexploit. stock for harvest?
Enter fraction of unexpl. biomass to make available (exploitable) (e.g., .5): 0.50
Starting in Year (>=1997): 2009

Annual Growth of Full-Recruits:
(enter fractional increase in meat weight/clam): 0.00760000
(e.g., 0.02 represents 2% / yr)

Instant. Growth Rate (g)
0.0076 (do not change)

SIMULATION:

Marker		Year	Biomass (Expl), mt	Biomass (Unexpl), mt	Tot Biomass	Harvest from Expl. Area: mt	bushels	Exploitation Rate: Expl Areas	All Areas	Overfishing Ref. Pt. Inst. Rate (F_ref) = F_25% MSP	Exploit. Rate = (F_ref / Z) * (1-exp(-Z))
0	1	1995	255,264	412,442	667,705	20,865	4,599,945	8.2%	3.1%	0.0437	4.2%
0	2	1996	231,503	407,347	638,851	20,185	4,450,031	8.7%	3.2%	0.0437	4.2%
0	3	1997	208,708	402,316	611,024	4,909	1,082,174	2.4%	0.8%	0.0437	4.2%
0	4	1998	201,282	397,347	598,629	4,734	1,043,670	2.4%	0.8%	0.0437	4.2%
0	5	1999	194,120	392,439	586,559	4,566	1,006,535	2.4%	0.8%	0.0437	4.2%
0	6	2000	187,214	387,591	574,805	4,403	970,722	2.4%	0.8%	0.0437	4.2%
0	7	2001	180,552	382,804	563,356	4,246	936,183	2.4%	0.8%	0.0437	4.2%
0	8	2002	174,128	378,076	552,204	4,095	902,874	2.4%	0.7%	0.0437	4.2%
0	9	2003	167,933	373,406	541,338	3,950	870,749	2.4%	0.7%	0.0437	4.2%
0	10	2004	161,958	368,793	530,751	3,809	839,767	2.4%	0.7%	0.0437	4.2%
0	11	2005	156,195	364,238	520,433	3,674	809,888	2.4%	0.7%	0.0437	4.2%
0	12	2006	150,637	359,739	510,377	3,543	781,071	2.4%	0.7%	0.0437	4.2%
0	13	2007	145,278	355,296	500,573	3,417	753,280	2.4%	0.7%	0.0437	4.2%
0	14	2008	140,109	350,907	491,016	3,295	726,478	2.4%	0.7%	0.0437	4.2%
==>	15	2009	308,410	173,286	481,696	7,254	1,599,138	2.4%	1.5%	0.0437	4.2%
0	16	2010	297,437	171,146	468,583	6,995	1,542,240	2.4%	1.5%	0.0437	4.2%
0	17	2011	286,854	169,032	455,886	6,747	1,487,366	2.4%	1.5%	0.0437	4.2%
0	18	2012	276,647	166,944	443,591	6,507	1,434,445	2.4%	1.5%	0.0437	4.2%
0	19	2013	266,804	164,882	431,686	6,275	1,383,407	2.4%	1.5%	0.0437	4.2%
0	20	2014	257,311	162,846	420,156	6,052	1,334,184	2.4%	1.4%	0.0437	4.2%
0	21	2015	248,156	160,834	408,990	5,836	1,286,713	2.4%	1.4%	0.0437	4.2%
0	22	2016	239,326	158,848	398,174	5,629	1,240,931	2.4%	1.4%	0.0437	4.2%
0	23	2017	230,811	156,885	387,696	5,428	1,196,778	2.4%	1.4%	0.0437	4.2%
0	24	2018	222,598	154,948	377,546	5,235	1,154,196	2.4%	1.4%	0.0437	4.2%
0	25	2019	214,678	153,034	367,712	5,049	1,113,129	2.4%	1.4%	0.0437	4.2%
0	26	2020	207,040	151,144	358,183	4,869	1,073,523	2.4%	1.4%	0.0437	4.2%
0	27	2021	199,673	149,277	348,950	4,696	1,035,327	2.4%	1.3%	0.0437	4.2%
0	28	2022	192,569	147,433	340,002	4,529	998,489	2.4%	1.3%	0.0437	4.2%
0	29	2023	185,717	145,612	331,329	4,368	962,963	2.4%	1.3%	0.0437	4.2%
0	30	2024	179,109	143,813	322,922	4,213	928,700	2.4%	1.3%	0.0437	4.2%

Table D15. Ocean quahog model. Trial run assuming annual recruitment to exploited area = 2% of biomass in 1994. Ocean quahog supply year calculations -- 30-year harvesting horizon polity (with option to harvest unexploited stock). NMFS, March 1996, NEFSC, Woods Hole.

ASSUMPTIONS / INPUTS:

(do not change, 43 :)
used in harvest calc:
1+exp(M)+exp(2M)+...+exp(30M) = 43

Biomass estimate for 1994: (from SARC 19)

Region	Biomass	
NJ	141.1	thousand mt
DMV	80.4	
LI	56.9	
Total	278.4	

Commercial Catch Estimate from Exploited Area (units: mt):

Year	Catch (mt)	Source
1994	19,944	database
1995	20,865	1995 quota
1996	20,185	1996 quota

Natural Mortality Rate, m: 0.02

Portion of total biomass that is unexploited in 1994 : 60%

Conversion Fac: 10 lbs/bu

Policy: Harvest calculated for 30-yr horizon

Overfishing Def: F_ref 0.0437 = Label F_25% MSP

Annual Recruitment:
(Pre-recruits grow to Full-Recruits) 5,568 mt, annual recr to exploited areas (initially)
8,352 mt, annual recruitment in unexploited areas (initially)

Want to open part of unexploit. stock for harvest?
Enter fraction of unexpl. biomass to make available (exploitable) (e.g., .5): 0.50
Starting in Year (>=1997): 2009

Annual Growth of Full-Recruits:
(enter fractional increase in meat weight/clam): 0.00760000
(e.g., 0.02 represents 2% / yr)

Instant Growth Rate (g) : 0.0076 (do not change)

SIMULATION:

Marker		Year	Biomass (Expl), mt	Biomass (Unexpl), mt	Tot Biomass	Harvest from Expl. Area: mt	bushels	Exploitation Rate: Expl Areas	All Areas	Overfishing Ref Pt. Inst. Rate (F_ref) = F_25% MSP	Exploit Rate = (F_ref / Z) * (1-exp(-Z))
o	1	1995	260,763	420,691	681,454	20,865	4,599,945	8.0%	3.1%	0.0437	4.2%
o	2	1996	242,434	423,743	666,177	20,185	4,450,031	8.3%	3.0%	0.0437	4.2%
o	3	1997	225,003	426,758	651,761	10,860	2,394,198	4.8%	1.7%	0.0437	4.2%
o	4	1998	216,997	429,736	646,733	10,672	2,352,687	4.9%	1.7%	0.0437	4.2%
o	5	1999	209,276	432,677	641,953	10,490	2,312,654	5.0%	1.6%	0.0437	4.2%
o	6	2000	201,830	435,581	637,411	10,315	2,274,045	5.1%	1.6%	0.0437	4.2%
o	7	2001	194,649	438,450	633,099	10,146	2,236,809	5.2%	1.6%	0.0437	4.2%
o	8	2002	187,723	441,283	629,006	9,983	2,200,899	5.3%	1.6%	0.0437	4.2%
o	9	2003	181,044	444,081	625,125	9,826	2,166,266	5.4%	1.6%	0.0437	4.2%
o	10	2004	174,602	446,845	621,447	9,675	2,132,865	5.5%	1.6%	0.0437	4.2%
o	11	2005	168,390	449,574	617,964	9,528	2,100,653	5.7%	1.5%	0.0437	4.2%
o	12	2006	162,398	452,270	614,668	9,387	2,069,587	5.8%	1.5%	0.0437	4.2%
o	13	2007	156,620	454,932	611,553	9,252	2,039,626	5.9%	1.5%	0.0437	4.2%
o	14	2008	151,048	457,562	608,610	9,121	2,010,731	6.0%	1.5%	0.0437	4.2%
***>	15	2009	375,753	230,080	605,832	18,581	4,096,502	4.9%	3.1%	0.0437	4.2%
o	16	2010	362,383	231,362	593,745	18,267	4,027,180	5.0%	3.1%	0.0437	4.2%
o	17	2011	349,489	232,629	582,118	17,964	3,960,324	5.1%	3.1%	0.0437	4.2%
o	18	2012	337,054	233,880	570,934	17,671	3,895,847	5.2%	3.1%	0.0437	4.2%
o	19	2013	325,062	235,115	560,177	17,389	3,833,664	5.3%	3.1%	0.0437	4.2%
o	20	2014	313,496	236,336	549,832	17,117	3,773,694	5.5%	3.1%	0.0437	4.2%
o	21	2015	302,342	237,541	539,883	16,855	3,715,858	5.6%	3.1%	0.0437	4.2%
o	22	2016	291,584	238,731	530,315	16,602	3,660,079	5.7%	3.1%	0.0437	4.2%
o	23	2017	281,209	239,907	521,116	16,358	3,606,285	5.8%	3.1%	0.0437	4.2%
o	24	2018	271,204	241,068	512,272	16,123	3,554,405	5.9%	3.1%	0.0437	4.2%
o	25	2019	261,554	242,215	503,769	15,896	3,504,371	6.1%	3.2%	0.0437	4.2%
o	26	2020	252,248	243,347	495,595	15,677	3,456,117	6.2%	3.2%	0.0437	4.2%
o	27	2021	243,273	244,466	487,739	15,466	3,409,580	6.4%	3.2%	0.0437	4.2%
o	28	2022	234,617	245,571	480,188	15,262	3,364,699	6.5%	3.2%	0.0437	4.2%
o	29	2023	226,269	246,662	472,931	15,066	3,321,414	6.7%	3.2%	0.0437	4.2%
o	30	2024	218,218	247,740	465,958	14,876	3,279,670	6.8%	3.2%	0.0437	4.2%

Table D16. Ocean quahog model. Trial run assuming annual recruitment to exploited area = 4% of biomass in 1994. Ocean quahog supply-year calculations -- 30-year harvesting horizon policy (with option to harvest unexploited stock). NMFS, March 1996, NEFSC, Woods Hole.

ASSUMPTIONS / INPUTS:

(do not change, 43 :)
used in harvest calc:
1+exp(M)+exp(2M)+...+exp(30M) = 43

Biomass estimate for 1994: (from SARC 19)

Region	Biomass	
NJ	141.1	thousand mt
DMV	80.4	
LI	56.9	
Total	278.4	

Commercial Catch Estimate from Exploited Area (units: mt):

Year	Catch (mt)	Source
1994	19,944	database
1995	20,865	1995 quota
1996	20,185	1996 quota

Natural Mortality Rate, m: 0.02

Portion of total biomass that is unexploited in 1994 : 60%

Conversion Fac: 10 lbs/bu

Policy: Harvest calculated for 30-yr horizon

Overfishing Def: F_ref 0.0437 = Label F_25% MSP

Annual Recruitment:
(Pre-recruits grow to Full-Recruits) 11,136 mt, annual recr. to exploited areas (initially)
16,704 mt, annual recruitment in unexploited areas (initially)

Want to open part of unexploit. stock for harvest?
Enter fraction of unexpl. biomass to make available (exploitable) (e.g., .5): 0.50
Starting in Year (>=1997): 2009

Annual Growth of Full-Recruits:
(enter fractional increase in meat weight/clam): 0.00760000
(e.g., 0.02 represents 2% / yr)

Instant. Growth Rate (g) : 0.0076 (do not change)

SIMULATION:

Marker		Year	Biomass (Expl), mt	Biomass (Unexpl), mt	Tot Biomass	Harvest from Expl. Area: mt	bushels	Exploitation Rate: Expl Areas	All Areas	Overfishing Ref. Pt. Inst. Rate (F_ref) = F_25% MSP	Exploit. Rate = (F_ref / Z) * (1-exp(-Z))
0	1	1995	266,262	428,940	695,202	20,865	4,599,945	7.8%	3.0%	0.0437	4.2%
0	2	1996	253,364	440,139	693,503	20,185	4,450,031	8.0%	2.9%	0.0437	4.2%
0	3	1997	241,298	451,200	692,498	16,811	3,706,222	7.0%	2.4%	0.0437	4.2%
0	4	1998	232,712	462,125	694,837	16,609	3,661,705	7.1%	2.4%	0.0437	4.2%
0	5	1999	224,432	472,914	697,346	16,414	3,618,772	7.3%	2.4%	0.0437	4.2%
0	6	2000	216,447	483,571	700,017	16,227	3,577,367	7.5%	2.3%	0.0437	4.2%
0	7	2001	208,745	494,095	702,841	16,046	3,537,435	7.7%	2.3%	0.0437	4.2%
0	8	2002	201,318	504,490	705,808	15,871	3,498,924	7.9%	2.2%	0.0437	4.2%
0	9	2003	194,155	514,756	708,911	15,702	3,461,783	8.1%	2.2%	0.0437	4.2%
0	10	2004	187,247	524,896	712,143	15,540	3,425,963	8.3%	2.2%	0.0437	4.2%
0	11	2005	180,585	534,910	715,495	15,383	3,391,418	8.5%	2.2%	0.0437	4.2%
0	12	2006	174,159	544,801	718,960	15,232	3,358,102	8.7%	2.1%	0.0437	4.2%
0	13	2007	167,963	554,569	722,532	15,086	3,325,972	9.0%	2.1%	0.0437	4.2%
0	14	2008	161,986	564,217	726,203	14,946	3,294,985	9.2%	2.1%	0.0437	4.2%
>>>	15	2009	443,096	286,873	729,968	29,909	6,593,866	6.8%	4.1%	0.0437	4.2%
0	16	2010	427,330	291,578	718,908	29,538	6,512,120	6.9%	4.1%	0.0437	4.2%
0	17	2011	412,125	296,225	708,351	29,181	6,433,282	7.1%	4.1%	0.0437	4.2%
0	18	2012	397,462	300,815	698,277	28,836	6,357,250	7.3%	4.1%	0.0437	4.2%
0	19	2013	383,320	305,349	688,668	28,503	6,283,922	7.4%	4.1%	0.0437	4.2%
0	20	2014	369,681	309,826	679,507	28,183	6,213,204	7.6%	4.1%	0.0437	4.2%
0	21	2015	356,528	314,248	670,775	27,873	6,145,002	7.8%	4.2%	0.0437	4.2%
0	22	2016	343,842	318,615	662,457	27,575	6,079,227	8.0%	4.2%	0.0437	4.2%
0	23	2017	331,608	322,928	654,536	27,287	6,015,791	8.2%	4.2%	0.0437	4.2%
0	24	2018	319,809	327,188	646,998	27,010	5,954,613	8.4%	4.2%	0.0437	4.2%
0	25	2019	308,430	331,396	639,826	26,742	5,895,612	8.7%	4.2%	0.0437	4.2%
0	26	2020	297,456	335,551	633,008	26,484	5,838,710	8.9%	4.2%	0.0437	4.2%
0	27	2021	286,872	339,656	626,528	26,235	5,783,833	9.1%	4.2%	0.0437	4.2%
0	28	2022	276,665	343,709	620,374	25,995	5,730,908	9.4%	4.2%	0.0437	4.2%
0	29	2023	266,821	347,713	614,534	25,763	5,679,866	9.7%	4.2%	0.0437	4.2%
0	30	2024	257,328	351,666	608,994	25,540	5,630,641	9.9%	4.2%	0.0437	4.2%

Table D17. Documentation and notes for users (ocean quahog spreadsheet).

Total Biomass = Exploited Biomass + Unexploited Biomass (i.e. the exploited and unexploited portions of biomass are additive).

The exploited stock is impacted by harvesting whereas the unexploited stock is not. Both portions of the stock are affected by natural mortality and recruitment. The annual harvest is a variable (see next paragraph). Natural mortality is a constant, whose value is given above (see "ASSUMPTIONS"). The exploited and unexploited portions of the stock are increased by annual recruitment (assumed constant, i.e, unrelated to biomass). Based on the slow growth rate of adult ocean quahogs and the lack of small clams in the population size structure, annual recruitment from the pre-recruit to the recruit stage was set at a low level. The level of recruitment to the unexploited area is based on the recruitment to the exploited area, adjusted by a factor relating the biomass of the unexploited area to the biomass of the exploited area, in the starting year.

Estimation of annual harvest:
The annual harvest for 1994 was estimated from actual data. The annual harvests for 1995 and 1996 have been set equal to the annual quotas for those years.
For the years 1997 through 2024, the annual harvest is computed as the annual catch that could be taken from the exploited stock for 30 years, while recruitment and natur. mortal. are taking place, such that in year 31 the exploited stock is completely depleted. The stock does not actually run out after 30 years because the annual harvest is updated in each year of the simulation, based on the most recent year's biomass in the exploited region (i.e., the 30-yr calc. is made every year). Thus, the annual harvest always represents that which could be taken for an additional 30 years given the most recent exploitable biomass (B).
Calculation of annual harvest (C) is based on the catch equation (note: M = m-g, the difference between natural mortality and the growth rate) :
B_1 = (B_0 - C + R)*exp(-M), where "_#" represents an annual time step.
The generalized form of the catch equation is :
B_t = B_0*exp(-Mt) + [summation from i to t:] [(R - C)*exp(-Mi)].
To get C(T), the annual harvest for year T with the 30-yr horizon, the above equation is assigned the following values: B_0 = current exploitable biomass at time T, t = 31 and B_31 = 0, and then it is solved for annual harvest :
C(T) = [Expl. Biomass(T) / (1 + exp(M) + exp(2M) + ... + exp(30M))] + (Ann. Recrt. to Expl. Area).

The above equation is affected in the following ways when some fraction of unexploited biomass is made exploitable in a certain year: Expl. Biomass(T) = biomass from the historically exploited area + additional biomass from the previously unexploited area. Recrt. to Expl. Area = recruitment from the historically exploited area + additional recruitment from the previously unexploited area. Recruitment to the unexploited area is decremented by the amount now added to the exploited area.

Using the program:
Certain cells in the "Assumptions / Inputs" section may be changed by the user. When these are changed, the rest of the spreadsheet will be updated automatically. "Assumptions / Inputs" that the user can change include: Biomass by region for 1994, Commercial catch from 1994-1996, m, Portion of biomass that is unexploited in 1994, fraction of the unexploited biomass to start exploiting in a particular year, F_ref and its label (e.g., F_25%MSP), mean recruitment to the exploited areas and annual growth of tissue by fully recruited clams.

The "30 year harvesting horizon" is fixed (can not be changed by the user without major modifications).

For the LI area, the overfishing reference rate (F_25%MSP) = 0.0437 .

Table D18. List of research clam surveys and gear changes from 1965-1981. Column entries were shifted to accentuate changes. Changes in the gear and survey season have not occurred since August, 1980. Sources of information for 1978-1981 are Smolovitz and Nulk (1982) and NEFSC cruise reports. Sources of information for 1965-1977 are NEFSC 1995a and NEFSC survey reports. "-": undetermined.

Cruise	Date	Vessel	Season	Purpose	Pump Type	Dredge Width (cm)	Mesh Size (cm)	Doppler Measured
65-	5/65	Undaunted	Spring	Survey	Surface	76	5.1	-
65-10	10/65	Undaunted	Fall	Survey	Surface	76	5.1	-
66-6,11	8/66	Albatross IV	Summer	Survey	Surface	76	5.1	-
69-1,7	6/69	Albatross IV	Summer	Survey	Surface	76	5.1	-
70-6	8/70	Delaware	Summer	Survey	Surface	122	3	-
SM742	6/74	Delaware	Summer	Survey	Surface	76	5.1	-
76-1	4/76	Delaware	Spring	Survey	Surface	122	3	-
77-2	1/77	Delaware	Winter	Survey	Surface	122	3	-
7801	1/78	Delaware	Winter	Survey	Surface	122	1.91	No
7807	12/78	Delaware	Winter	Survey	Surface	122	1.91	Yes
7901	1/79	Delaware	Winter	Survey	Submerse	152	2.54	Yes
7908	8/79	Delaware	Summer	Gear test	Submerse	152	2.54 & 5.08	Yes
8001	1/80	Delaware	Winter	Survey	Submerse	152	5.08	Yes
8006	8/80	Delaware	Summer	Survey	Submerse	152	5.08	Yes
8105	8/81	Delaware	Summer	Survey	Submerse	152	5.08	Yes

Table D19. Annual surfclam landings (mt, drained meats) from the EEZ by region, computed using three different data sources: sl032 database[1], NEFSC LRD 86-11 appendices[2], weighout (WO) database[3], "-": no data available.

Year	NNJ s1032	NNJ LRD	NNJ WO	DMV s1032	DMV LRD	DMV WO	SNJ s1032	SNJ LRD	SNJ WO
1976	-	-	-	-	-	-	-	-	-
1977	-	-	-	-	-	-	-	-	-
1978	-	172	1349	-	8764	2927	-	589	53
1979	-	300	1463	-	10379	2268	-	756	97
1980	1308	1231	1692	9784	10345	2299	887	497	131
1981	6433	6499	6462	5822	6463	94	429	160	114
1982	4610	4959	7440	4989	5599	6777	1439	847	434
1983	5515	5438	7474	5772	6502	7418	999	934	161
1984	8787	8356	12710	5303	5786	6654	1776	1594	112
1985	8427	8230	11072	6636	6614	8059	1077	920	347
1986	14703	-	16168	2604	-	3964	1474	-	548
1987	17238	-	17748	1306	-	1564	749	-	329
1988	19196	-	19826	1147	-	1137	195	-	64

[1]s1032 data are not available before 1980. Geographical resolution for assigning catches to regions is by 10-minute square from 1980 to the present time.

[2]Includes complete data for the period 1978-1985.

[3]Includes fishing zones 2 and 3 (i.e., 3 miles and beyond). WO data are not available before 1978, and data from the DMV region, and probably from SNJ, are known to be incomplete from 1978-1981. Geographical resolution for assigning catches to regions is by quarter degree square for the period before 1982 and by latitude and longitude (degrees, minutes) from 1982 to the present.

Table D20. DeLury model results for **Northern New Jersey** surfclam, based on survey indices and a commercial catch series from 1982-1994. BAO = 2, run number = 135. Prepared for SAW-19, in 1994.

SARC-19 Analysis.

INPUTS:

ID
Surf Clams N NJ
Prepared for SARC 19; November 1994
NMFS Survey used for calibration with the following modifications:
(1) 1994 fully-recruited index taken as missing; and
(2) 1994 recruit index replaced with mean index over 1986-94 (i.e. 13.0)
(3) Catch per tow was standardized for tow distance.
Other Notes:
(1) All recruit upper limit cut points set at 120mm
(2) Source of Commercial Catch Data: '82: WeighOut data; '83-'94: s1032
(3) Discards were estimated from interviews by port agents.

Species Code = 1 Region Code = 11

YEAR	LANDINGS	DISCARD	CATCH	LANDINGS	DISCARD	CATCH
	------ weight in mt ------			--- number in millions ----		
1982	7440	1842	9282	60.680	28.961	89.641
1983	5515	1061	6576	44.383	16.716	61.098
1984	8787	1133	9920	71.890	17.662	89.551
1985	8427	969	9396	71.304	15.105	86.409
1986	14703	1164	15867	135.738	18.143	153.881
1987	17238	707	17945	164.619	11.020	175.638
1988	19196	659	19855	171.548	10.264	181.812
1989	16415	524	16939	140.559	8.117	148.676
1990	16996	545	17541	155.698	8.435	164.133
1991	17623	248	17871	141.617	3.834	145.451
1992	18334	459	18793	152.307	7.103	159.410
1993	16338	0	16338	137.000	0.000	137.000
1994	16285	0	16285	138.579	0.000	138.579

Discard estimates assume 50% discard mortality, and use mean weight estimates of "recruits" from the survey to convert weight to numbers.

Table D20. (Continued)

MEAN WEIGHT (grams)

YEAR	NMFS SURVEY Recruits	NMFS SURVEY Fully Recruited	COMMERCIAL FISHERY Discarded Animals	COMMERCIAL FISHERY Landed Animals
1982	64	107	64	123
1983	63	107	63	124
1984	64	111	64	122
1985	64	111	64	118
1986	64	120	64	108
1987	64	120	64	105
1988	64	120	64	112
1989	65	120	65	117
1990	65	120	65	109
1991	65	120	65	124
1992	65	126	65	120
1993	65	126	65	119
1994	64	126	64	118

(1) Mean weight estimates for discards in the commercial fishery are taken to be the same as mean weight estimates of recruits from the NMFS survey.

(2) For years in which no survey was carried out, mean weights of recruits and fully-recruited were taken from the previous survey.

SIZE CUT POINTS FOR RECRUITS

YEAR	Min Length (mm)	Max Length (mm)
1982	105	120
1983	105	120
1984	105	120
1985	105	120
1986	105	120
1987	105	120
1988	105	120
1989	105	120
1990	105	120
1991	105	120
1992	105	120
1993	105	120
1994	105	120

Table 20. (Continued)

LENGTH CLASSES USED FOR SURVEY AND COMMERCIAL DATA

LENGTH CLASS	Min Length (mm)	Max Length (mm)
1	0	9
2	10	19
3	20	29
4	30	39
5	40	49
6	50	59
7	60	69
8	70	79
9	80	89
10	90	99
11	100	109
12	110	119
13	120	129
14	130	139
15	140	149
16	150	159
17	160	169
18	170	179
19	180	189
20	190	199
21	200	209

```
!
YR
1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994
!
t_s  t_c
0.5 0.5
!
M
0.05
!
N_surv
          23.45800000          45.58700000
          29.22400000          36.63100000
           9.45800000          44.11100000
        ²999.00000000        ²999.00000000
           6.58000000          41.30900000
        ²999.00000000        ²999.00000000
        ²999.00000000        ²999.00000000
           6.63000000          46.14900000
        ²999.00000000        ²999.00000000
        ²999.00000000        ²999.00000000
          13.01200000          33.70100000
        ²999.00000000        ²999.00000000
          13.0                ²999
!
```

```
Wt_mean_surv
          0.06360379           0.10726944
          0.06347296           0.10698721
          0.06414988           0.11062194
          0.06414988           0.11062194
          0.06415674           0.11962097
          0.06415674           0.11962097
          0.06415674           0.11962097
          0.06455489           0.11971184
          0.06455489           0.11971184
          0.06455489           0.11971184
          0.06461665           0.12607639
          0.06461665           0.12607639
          0.06384730           0.12561946
!
Describe_indices
#'s per survey tow were standardized to tow distance 0.15 mi.
This distance was the standard in previous years to estimate
area swept biomass.  Nonrandom tows and those with gear damage
were excluded from analysis.  Likewise, tows collected with
the abnormal tow point in Leg I in 1994 were excluded.

!
C_numbers
         60.68005172          28.96053658
         44.38270189          16.71577835
         71.88969844          17.66176289
         71.30371842          15.10524999
        135.73753058          18.14306521
        164.61861384          11.01988583
        171.54799775          10.26392478
        140.55865569           8.11712307
        155.69806667           8.43468227
        141.61666680           3.83394649
        152.30660676           7.10343195
        136.99976950           0.00000000
!
C_weight
       7440.00000000        1842.00000000
       5515.00000000        1061.00000000
       8787.00000000        1133.00000000
       8427.00000000         969.00000000
      14703.00000000        1164.00000000
      17238.00000000         707.00000000
      19196.00000000         658.50000000
      16415.00000000         524.00000000
      16996.00000000         544.50000000
      17623.00000000         247.50000000
      18334.00000000         459.00000000
      16338.00000000           0.00000000
!
t_surv_yr
0 0.25 0.5 0.75 1
!
R_availability
0 0.25 0.5 0.75 1
!

q_initial
1.0E²10 0.001 1000
!
s_r_initial
1 1 1
!
W_objfcn
1 1 4
!

proc_error_type
lognormal
!
Num_reps
200
!
boot_class
parametric
!
boot_type
LOB
!
```

Table D20. (Continued)

SARC-19 Analysis.

DETERMINISTIC RESULTS:

	PARAMETER	PAR. EST.	STD. ERR.	T-STATISTIC	C.V.
1	n 2+ 1982	3.48730E1	8.57963E0	4.06463E0	0.25
2	n 2+ 1983	4.19750E1	7.81702E0	5.36969E0	0.19
3	n 2+ 1984	5.48167E1	8.84026E0	6.20080E0	0.16
4	n 2+ 1986	5.50226E1	8.41564E0	6.53814E0	0.15
5	n 2+ 1989	4.18997E1	7.04220E0	5.94980E0	0.17
6	n 2+ 1992	3.32042E1	8.85545E0	3.74958E0	0.27
7	r 1 1982	2.02099E1	5.68272E0	3.55638E0	0.28
8	r 1 1983	2.54978E1	7.08507E0	3.59881E0	0.28
9	r 1 1984	9.30479E0	2.73194E0	3.40593E0	0.29
10	r 1 1986	6.73159E0	1.98605E0	3.38944E0	0.30
11	r 1 1989	6.69179E0	1.97089E0	3.39531E0	0.29
12	r 1 1992	1.30993E1	3.87067E0	3.38426E0	0.30
13	Surv q_n	7.42825E²2	1.74169E²2	4.26498E0	0.23

CORRELATION BETWEEN PARAMETERS ESTIMATED (SYMBOLIC FORM)

```
 1 n 2+ 1982 * + . . . . . . . . . . .
 2 n 2+ 1983 + * + . . . . . . . . . .
 3 n 2+ 1984 . + * + . . . . . . . . .
 4 n 2+ 1986 . . + * + . . . . . . . +
 5 n 2+ 1989 . . . + * + . . . . . . .
 6 n 2+ 1992 . . . . + * . . . . . . -
 7 r 1  1982 . . . . . . * . . . . . .
 8 r 1  1983 . . . . . . . * . . . . .
 9 r 1  1984 . . . . . . . . * . . . .
10 r 1  1986 . . . . . . . . . * . . .
11 r 1  1989 . .   . . . . . . . * . .
12 r 1  1992 . . . . . . . . . . . * .
13 Surv q_n  . . . + . - . . . . . . *
```

SYMBOLS:

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

Where r is the estimated correlation, M is 0.4 and L is 0.8

CALENDAR YEAR	STOCK SIZE ESTIMATES (millions at time of survey) RECRUITS	FULLY-RECRUITED	MORTALITY RATES (between surveys) Z on sizes 1+	F on size 1	F on sizes 2+
1982	272.068	469.464	0.27	0.14	0.27
1983	343.254	565.072	0.21	0.10	0.19
1984	125.262	737.948	0.16	0.06	0.12
1985	160.101	735.927	0.19	0.08	0.15
1986	90.621	740.721	0.25	0.11	0.22
1987	160.101	644.422	0.30	0.14	0.27
1988	160.101	598.213	0.30	0.14	0.27
1989	90.086	564.059	0.31	0.14	0.28
1990	160.101	480.817	0.35	0.17	0.34
1991	160.101	453.532	0.32	0.15	0.31
1992	176.345	446.999	0.35	0.17	0.34
1993	160.101	441.307	0.31	0.15	0.30
1994	175.007	441.759			

Table D20. (Continued)

```
RECRUITS = SIZECLASS 1      FULLY-RECRUITED = SIZECLASS 2+
Index of abundance for recruits is missing in 1985 1987 1988 1990 1991 1993
For these years, the recruit stock size estimates are based on the
geometric mean of recruitment in years when indices were available.
Index of abundance for fully-recruited is missing in 1985 1987 1988 1990 1991
19
    93 1994
For these years, the fully-recruited stock size estimates are based
on forward calculations from the DeLury difference equation.

Note that the recruit population estimate for the last year (1994)
is NOT a least squares estimate.  It is calculated from the observed
survey index, the least squares estimate of q, and the s_r.
```

CALENDAR BIOMASS YEAR YEAR	---- BIOMASS ESTIMATES (at time of the survey) ---- (1000 mt) RECRUITS	FULLY-RECRUITED	TOTAL BIOMASS	EXPLOITED BIOMASS	CATCH DURING (1000 mt)
1982	17.305	50.359	67.664	59.011	9.282
1983	21.787	60.455	82.243	71.349	6.576
1984	8.036	81.633	89.669	85.651	9.920
1985	10.270	81.410	91.680	86.545	9.396
1986	5.814	88.606	94.420	91.513	15.867
1987	10.272	77.086	87.358	82.222	17.945
1988	10.272	71.559	81.830	76.695	19.855
1989	5.815	67.525	73.340	70.432	16.939
1990	10.335	57.559	67.895	62.727	17.541
1991	10.335	54.293	64.628	59.461	17.871
1992	11.395	56.356	67.751	62.053	18.793
1993	10.345	55.638	65.984	60.811	16.338
1994	11.174	55.494	66.667	61.080	

CALENDAR YEAR	EXPLOITED BIOMASS	-------------- 1000 Metric Tons -------------- DELTA B	CATCH	SURPLUS PRODUCTION	PROD-BIOMASS RATIO
1982	59.011	12.338	9.282	21.620	0.3664
1983	71.349	14.302	6.576	20.878	0.2926
1984	85.651	0.894	9.920	10.814	0.1263
1985	86.545	4.968	9.396	14.364	0.1660
1986	91.513	^{2}9.291	15.867	6.576	0.0719
1987	82.222	^{2}5.528	17.945	12.417	0.1510
1988	76.695	^{2}6.262	19.855	13.592	0.1772
1989	70.432	^{2}7.705	16.939	9.234	0.1311
1990	62.727	^{2}3.266	17.541	14.274	0.2276
1991	59.461	2.593	17.871	20.463	0.3441
1992	62.053	^{2}1.242	18.793	17.551	0.2828
1993	60.811	0.269	16.338	16.607	0.2731
1994	61.080				

The SURPLUS PRODUCTION table, above, assumes that DELTA B over the course of a calendar year can be approximated by differencing the successive EXPLOITED BIOMASS estimates at time of the survey. More specifically, this assumes that the change in EXPLOITED BIOMASS between Jan 1 and the time of the survey is constant in successive years. Note also that the PRODUCTION-BIOMASS RATIO is with respect to exploited biomass at time of the survey.

Table D20. (Continued)

SUMMARY OF RESIDUALS FROM THE FITTED MODEL

MEASUREMENT ERROR -- Fully-recruited index with lognormal errors

ERROR TERM	OBSERVED	PREDICTED	WEIGHT	RESIDUAL	STD RES	%SS
n 2+ 1982	45.5870	34.8730	0.1768	0.0474	0.9111	20.8
n 2+ 1983	36.6310	41.9750	0.1768	-0.0241	-0.4631	5.4
n 2+ 1984	44.1110	54.8167	0.1768	-0.0384	-0.7389	13.7
n 2+ 1985	^{2}999.0000	54.6665	^{2}999.0000	0.0000	0.0000	0.0
n 2+ 1986	41.3090	55.0226	0.1768	-0.0507	-0.9749	23.8
n 2+ 1987	^{2}999.0000	47.8693	^{2}999.0000	0.0000	0.0000	0.0
n 2+ 1988	^{2}999.0000	44.4368	^{2}999.0000	0.0000	0.0000	0.0
n 2+ 1989	46.1490	41.8997	0.1768	0.0171	0.3285	2.7
n 2+ 1990	^{2}999.0000	35.7163	^{2}999.0000	0.0000	0.0000	0.0
n 2+ 1991	^{2}999.0000	33.6895	^{2}999.0000	0.0000	0.0000	0.0
n 2+ 1992	33.7010	33.2042	0.1768	0.0026	0.0505	0.1
n 2+ 1993	^{2}999.0000	32.7814	^{2}999.0000	0.0000	0.0000	0.0
n 2+ 1994	^{2}999.0000	32.8150	^{2}999.0000	0.0000	0.0000	0.0
SUM				-0.0461	-0.8868	66.3

MEASUREMENT ERROR -- Recruit index with lognormal errors

ERROR TERM	OBSERVED	PREDICTED	WEIGHT	RESIDUAL	STD RES	%SS
r 1 1982	23.4580	20.2099	0.1768	0.0263	0.5068	6.4
r 1 1983	29.2240	25.4978	0.1768	0.0241	0.4639	5.4
r 1 1984	9.4580	9.3048	0.1768	0.0029	0.0555	0.1
r 1 1985	^{2}999.0000	11.8927	^{2}999.0000	0.0000	0.0000	0.0
r 1 1986	6.5800	6.7316	0.1768	-0.0040	-0.0775	0.1
r 1 1987	^{2}999.0000	11.8927	^{2}999.0000	0.0000	0.0000	0.0
r 1 1988	^{2}999.0000	11.8927	^{2}999.0000	0.0000	0.0000	0.0
r 1 1989	6.6300	6.6918	0.1768	-0.0016	-0.0315	0.0
r 1 1990	^{2}999.0000	11.8927	^{2}999.0000	0.0000	0.0000	0.0
r 1 1991	^{2}999.0000	11.8927	^{2}999.0000	0.0000	0.0000	0.0
r 1 1992	13.0120	13.0993	0.1768	-0.0012	-0.0227	0.0
r 1 1993	^{2}999.0000	11.8927	^{2}999.0000	0.0000	0.0000	0.0
SUM				0.0465	0.8945	12.1

PROCESS ERROR -- DeLury equation with lognormal errors

ERROR TERM	CALCULATED	PREDICTED	WEIGHT	RESIDUAL	STD RES	%SS
n 2+ 1983	46.0625	41.9750	0.3536	0.0329	0.6320	10.0
n 2+ 1984	59.8649	54.8167	0.3536	0.0311	0.5992	9.0
n 2+ 1985	^{2}999.0000	54.6665	^{2}999.0000	0.0000	0.0000	0.0
n 2+ 1986	57.2075	55.0226	0.3536	0.0138	0.2648	1.8
n 2+ 1987	^{2}999.0000	47.8693	^{2}999.0000	0.0000	0.0000	0.0
n 2+ 1988	^{2}999.0000	44.4368	^{2}999.0000	0.0000	0.0000	0.0
n 2+ 1989	40.7355	41.8997	0.3536	-0.0100	-0.1917	0.9
n 2+ 1990	^{2}999.0000	35.7163	^{2}999.0000	0.0000	0.0000	0.0
n 2+ 1991	^{2}999.0000	33.6895	^{2}999.0000	0.0000	0.0000	0.0
n 2+ 1992	33.0816	33.2042	0.3536	-0.0013	-0.0252	0.0
n 2+ 1993	^{2}999.0000	32.7814	^{2}999.0000	0.0000	0.0000	0.0
n 2+ 1994	^{2}999.0000	32.8150	^{2}999.0000	0.0000	0.0000	0.0
SUM				0.0665	1.2792	21.6

17 residual error terms
13 parameters estimated
4 degrees of freedom

Table D20. (Continued)

SARC-19 Analysis.

STOCHASTIC RESULTS (with bao = 2; i.e., bias-corrected values are given for the column headed "BOOTSTRAP MEAN")

BOOTSTRAP OUTPUT VARIABLE: R_0
Population size (in number) of the recruits at time of the survey i.e. 50% into the calendar year

YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	2.721E2	2.886E2	3.133E1	0.12
1983	3.433E2	3.650E2	3.479E1	0.10
1984	1.253E2	1.284E2	1.462E1	0.12
1985	1.601E2	1.662E2	1.469E1	0.09
1986	9.062E1	9.234E1	1.130E1	0.12
1987	1.601E2	1.662E2	1.469E1	0.09
1988	1.601E2	1.662E2	1.469E1	0.09
1989	9.009E1	9.140E1	1.054E1	0.12
1990	1.601E2	1.662E2	1.469E1	0.09
1991	1.601E2	1.662E2	1.469E1	0.09
1992	1.763E2	1.811E2	2.204E1	0.13
1993	1.601E2	1.662E2	1.469E1	0.09
1994	1.750E2	1.867E2	1.728E1	0.10

YEAR	MIN	PERCENTILES 10	25	MEDIAN	75	90	MAX
1982	2.219E2	2.517E2	2.657E2	2.882E2	3.057E2	3.255E2	4.281E2
1983	2.876E2	3.250E2	3.402E2	3.612E2	3.861E2	4.128E2	5.231E2
1984	9.257E1	1.110E2	1.185E2	1.275E2	1.375E2	1.478E2	1.830E2
1985	1.379E2	1.485E2	1.556E2	1.652E2	1.739E2	1.830E2	2.134E2
1986	6.764E1	7.937E1	8.434E1	9.154E1	9.784E1	1.082E2	1.329E2
1987	1.379E2	1.485E2	1.556E2	1.652E2	1.739E2	1.830E2	2.134E2
1988	1.379E2	1.485E2	1.556E2	1.652E2	1.739E2	1.830E2	2.134E2
1989	6.699E1	7.839E1	8.508E1	9.042E1	9.837E1	1.051E2	1.211E2
1990	1.379E2	1.485E2	1.556E2	1.652E2	1.739E2	1.830E2	2.134E2
1991	1.379E2	1.485E2	1.556E2	1.652E2	1.739E2	1.830E2	2.134E2
1992	1.371E2	1.569E2	1.642E2	1.793E2	1.932E2	2.140E2	2.576E2
1993	1.379E2	1.485E2	1.556E2	1.652E2	1.739E2	1.830E2	2.134E2
1994	1.506E2	1.656E2	1.741E2	1.852E2	1.971E2	2.085E2	2.460E2

Table D20. (Continued)

BOOTSTRAP OUTPUT VARIABLE: N_0
Popn size (in number) of fully-recruited animals at time of the survey
i.e. 50% into the calendar year

YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	4.695E2	5.467E2	6.224E1	0.13
1983	5.651E2	6.115E2	6.578E1	0.12
1984	7.379E2	7.553E2	7.510E1	0.10
1985	7.359E2	7.555E2	7.757E1	0.11
1986	7.407E2	7.472E2	7.714E1	0.10
1987	6.444E2	6.523E2	7.918E1	0.12
1988	5.982E2	6.114E2	8.663E1	0.14
1989	5.641E2	5.963E2	9.534E1	0.17
1990	4.808E2	5.127E2	9.757E1	0.20
1991	4.535E2	4.896E2	1.055E2	0.23
1992	4.470E2	4.859E2	1.154E2	0.26
1993	4.413E2	4.829E2	1.262E2	0.29
1994	4.418E2	4.871E2	1.335E2	0.30

YEAR	MIN	PERCENTILES 10	25	MEDIAN	75	90	MAX
1982	4.020E2	4.709E2	5.028E2	5.421E2	5.897E2	6.283E2	7.372E2
1983	4.675E2	5.343E2	5.618E2	6.057E2	6.540E2	6.918E2	8.447E2
1984	6.006E2	6.661E2	7.107E2	7.515E2	7.904E2	8.551E2	1.001E3
1985	6.051E2	6.625E2	7.068E2	7.467E2	7.936E2	8.605E2	1.015E3
1986	5.836E2	6.586E2	6.957E2	7.378E2	7.808E2	8.509E2	1.041E3
1987	4.974E2	5.637E2	5.953E2	6.438E2	6.893E2	7.509E2	9.579E2
1988	4.581E2	5.135E2	5.499E2	6.014E2	6.512E2	7.210E2	9.416E2
1989	4.319E2	4.901E2	5.273E2	5.835E2	6.436E2	7.153E2	9.559E2
1990	3.458E2	4.061E2	4.428E2	5.015E2	5.618E2	6.336E2	8.742E2
1991	3.134E2	3.700E2	4.172E2	4.748E2	5.437E2	6.253E2	8.730E2
1992	2.997E2	3.564E2	4.057E2	4.668E2	5.514E2	6.267E2	8.771E2
1993	2.735E2	3.395E2	3.896E2	4.678E2	5.505E2	6.390E2	9.021E2
1994	2.610E2	3.347E2	3.881E2	4.706E2	5.567E2	6.524E2	9.291E2

Table D20. (Continued)

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

SURVEY YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	0.2716	0.3256	0.0453	0.17
1983	0.1945	0.2600	0.0447	0.23
1984	0.118[illegible]	0.1138	0.0124	0.10
1985	0.1541	0.1760	0.0370	0.24
1986	0.2165	0.2115	0.0236	0.11
1987	0.2735	0.2640	0.0354	0.13
1988	0.2750	0.2307	0.0534	0.19
1989	0.2769	0.2484	0.0551	0.20
1990	0.3381	0.2941	0.0811	0.24
1991	0.3069	0.2599	0.0925	0.30
1992	0.3440	0.2801	0.1123	0.33
1993	0.2982	0.2337	0.1117	0.37

SURVEY		PERCENTILES					
YEAR	MIN	10	25	MEDIAN	75	90	MAX
1982	0.2075	0.2727	0.2935	0.3245	0.3496	0.3902	0.5050
1983	0.1450	0.2001	0.2316	0.2593	0.2887	0.3191	0.3928
1984	0.0813	0.0975	0.1070	0.1134	0.1210	0.1303	0.1435
1985	0.0716	0.1270	0.1526	0.1762	0.2021	0.2241	0.2957
1986	0.1423	0.1806	0.1983	0.2120	0.2277	0.2405	0.2748
1987	0.1645	0.2198	0.2433	0.2638	0.2892	0.3094	0.3508
1988	0.0980	0.1666	0.1931	0.2276	0.2676	0.3002	0.3559
1989	0.1132	0.1791	0.2108	0.2449	0.2865	0.3207	0.3883
1990	0.1093	0.1945	0.2382	0.2876	0.3455	0.4043	0.5079
1991	0.0655	0.1489	0.1930	0.2516	0.3211	0.3846	0.4918
1992	0.0633	0.1499	0.1984	0.2628	0.3495	0.4342	0.5847
1993	0.0311	0.1076	0.1530	0.2143	0.3031	0.3901	0.5803

Table D20. (Continued)

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

SURVEY YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	0.2218	0.2692	0.0363	0.16
1983	0.1577	0.2112	0.0364	0.23
1984	0.1095	0.1056	0.0111	0.10
1985	0.1403	0.1602	0.0336	0.24
1986	0.2047	0.2000	0.0220	0.11
1987	0.2463	0.2374	0.0309	0.13
1988	0.2459	0.2064	0.0463	0.19
1989	0.2578	0.2327	0.0494	0.19
1990	0.2958	0.2601	0.0660	0.22
1991	0.2668	0.2299	0.0745	0.28
1992	0.2954	0.2467	0.0875	0.30
1993	0.2585	0.2091	0.0864	0.33

SURVEY		PERCENTILES					
YEAR	MIN	10	25	MEDIAN	75	90	MAX
1982	0.1712	0.2258	0.2439	0.2688	0.2888	0.3205	0.3986
1983	0.1178	0.1614	0.1869	0.2100	0.2354	0.2600	0.3194
1984	0.0758	0.0908	0.0991	0.1058	0.1122	0.1202	0.1323
1985	0.0651	0.1153	0.1384	0.1603	0.1846	0.2036	0.2666
1986	0.1350	0.1721	0.1872	0.2000	0.2157	0.2273	0.2559
1987	0.1499	0.1978	0.2192	0.2373	0.2592	0.2771	0.3094
1988	0.0909	0.1499	0.1736	0.2048	0.2389	0.2675	0.3148
1989	0.1106	0.1715	0.1997	0.2297	0.2669	0.2956	0.3562
1990	0.1067	0.1772	0.2146	0.2563	0.3019	0.3501	0.4277
1991	0.0685	0.1405	0.1767	0.2236	0.2807	0.3289	0.4065
1992	0.0726	0.1440	0.1837	0.2351	0.3047	0.3675	0.4888
1993	0.0457	0.1099	0.1478	0.1961	0.2646	0.3291	0.4694

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

SURVEY YEAR(S)	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1993 0	0.2982	0.2337	0.1117	0.37
1992 93	0.3211	0.2569	0.1119	0.35
1991 93	0.3164	0.2579	0.1050	0.33

SURVEY		PERCENTILES					
YEAR(S)	MIN	10	25	MEDIAN	75	90	MAX
1993 0	0.0311	0.1076	0.1530	0.2143	0.3031	0.3901	0.5803
1992 93	0.0472	0.1287	0.1744	0.2382	0.3257	0.4131	0.5825
1991 93	0.0548	0.1378	0.1790	0.2437	0.3225	0.4024	0.5425

Table D20. (Continued)

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

YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	1.730E1	1.836E1	1.993E0	0.12
1983	2.179E1	2.317E1	2.208E0	0.10
1984	8.036E0	8.240E0	9.377E-1	0.12
1985	1.027E1	1.066E1	9.421E-1	0.09
1986	5.814E0	5.924E0	7.249E-1	0.12
1987	1.027E1	1.066E1	9.422E-1	0.09
1988	1.027E1	1.066E1	9.422E-1	0.09
1989	5.815E0	5.900E0	6.803E-1	0.12
1990	1.034E1	1.073E1	9.481E-1	0.09
1991	1.034E1	1.073E1	9.481E-1	0.09
1992	1.139E1	1.170E1	1.424E0	0.13
1993	1.035E1	1.074E1	9.490E-1	0.09
1994	1.117E1	1.192E1	1.103E0	0.10

		PERCENTILES					
YEAR	MIN	10	25	MEDIAN	75	90	MAX
1982	1.411E1	1.601E1	1.690E1	1.833E1	1.945E1	2.070E1	2.723E1
1983	1.825E1	2.063E1	2.160E1	2.292E1	2.451E1	2.620E1	3.320E1
1984	5.938E0	7.122E0	7.602E0	8.178E0	8.822E0	9.484E0	1.174E1
1985	8.847E0	9.523E0	9.982E0	1.059E1	1.115E1	1.174E1	1.369E1
1986	4.339E0	5.092E0	5.411E0	5.873E0	6.277E0	6.945E0	8.524E0
1987	8.848E0	9.524E0	9.983E0	1.060E1	1.116E1	1.174E1	1.369E1
1988	8.848E0	9.524E0	9.983E0	1.060E1	1.116E1	1.174E1	1.369E1
1989	4.325E0	5.061E0	5.492E0	5.837E0	6.350E0	6.785E0	7.818E0
1990	8.903E0	9.583E0	1.005E1	1.066E1	1.123E1	1.181E1	1.378E1
1991	8.903E0	9.583E0	1.005E1	1.066E1	1.123E1	1.181E1	1.378E1
1992	8.861E0	1.014E1	1.061E1	1.158E1	1.248E1	1.383E1	1.665E1
1993	8.911E0	9.592E0	1.005E1	1.067E1	1.124E1	1.182E1	1.379E1
1994	9.614E0	1.057E1	1.112E1	1.182E1	1.259E1	1.331E1	1.571E1

Table D20. (Continued)

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

YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	5.036E1	5.865E1	6.676E0	0.13
1983	6.046E1	6.542E1	7.038E0	0.12
1984	8.163E1	8.356E1	8.307E0	0.10
1985	8.141E1	8.358E1	8.581E0	0.11
1986	8.861E1	8.939E1	9.228E0	0.10
1987	7.709E1	7.802E1	9.471E0	0.12
1988	7.156E1	7.314E1	1.036E1	0.14
1989	6.752E1	7.138E1	1.141E1	0.17
1990	5.756E1	6.138E1	1.168E1	0.20
1991	5.429E1	5.861E1	1.263E1	0.23
1992	5.636E1	6.126E1	1.454E1	0.26
1993	5.564E1	6.088E1	1.591E1	0.29
1994	5.549E1	6.119E1	1.677E1	0.30

YEAR	MIN	PERCENTILES 10	25	MEDIAN	75	90	MAX
1982	4.313E1	5.051E1	5.394E1	5.815E1	6.325E1	6.740E1	7.908E1
1983	5.001E1	5.717E1	6.010E1	6.480E1	6.997E1	7.402E1	9.037E1
1984	6.644E1	7.369E1	7.862E1	8.313E1	8.744E1	9.459E1	1.107E2
1985	6.694E1	7.329E1	7.819E1	8.260E1	8.779E1	9.518E1	1.123E2
1986	6.981E1	7.878E1	8.323E1	8.825E1	9.340E1	1.018E2	1.245E2
1987	5.950E1	6.743E1	7.121E1	7.702E1	8.245E1	8.982E1	1.146E2
1988	5.480E1	6.143E1	6.578E1	7.194E1	7.790E1	8.624E1	1.126E2
1989	5.171E1	5.867E1	6.312E1	6.986E1	7.704E1	8.563E1	1.144E2
1990	4.139E1	4.861E1	5.301E1	6.003E1	6.725E1	7.584E1	1.046E2
1991	3.752E1	4.430E1	4.994E1	5.684E1	6.508E1	7.486E1	1.045E2
1992	3.778E1	4.494E1	5.115E1	5.885E1	6.952E1	7.901E1	1.106E2
1993	3.448E1	4.280E1	4.912E1	5.897E1	6.941E1	8.056E1	1.137E2
1994	3.279E1	4.204E1	4.875E1	5.912E1	6.994E1	8.196E1	1.167E2

Table D20. (Continued)

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

YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	5.901E1	6.783E1	6.752E0	0.11
1983	7.135E1	7.701E1	7.389E0	0.10
1984	8.565E1	8.768E1	8.489E0	0.10
1985	8.654E1	8.890E1	8.914E0	0.10
1986	9.151E1	9.235E1	9.410E0	0.10
1987	8.222E1	8.335E1	9.842E0	0.12
1988	7.669E1	7.847E1	1.076E1	0.14
1989	7.043E1	7.433E1	1.164E1	0.17
1990	6.273E1	6.674E1	1.211E1	0.19
1991	5.946E1	6.398E1	1.306E1	0.22
1992	6.205E1	6.712E1	1.508E1	0.24
1993	6.081E1	6.625E1	1.636E1	0.27
1994	6.108E1	6.715E1	1.728E1	0.28

YEAR	MIN	PERCENTILES 10	25	MEDIAN	75	90	MAX
1982	5.275E1	5.940E1	6.310E1	6.737E1	7.273E1	7.677E1	8.814E1
1983	6.225E1	6.855E1	7.145E1	7.622E1	8.184E1	8.696E1	1.033E2
1984	7.078E1	7.744E1	8.249E1	8.701E1	9.148E1	9.908E1	1.152E2
1985	7.168E1	7.808E1	8.320E1	8.746E1	9.348E1	1.007E2	1.191E2
1986	7.280E1	8.167E1	8.592E1	9.116E1	9.657E1	1.049E2	1.284E2
1987	6.469E1	7.222E1	7.628E1	8.238E1	8.790E1	9.557E1	1.212E2
1988	5.954E1	6.629E1	7.088E1	7.721E1	8.323E1	9.232E1	1.193E2
1989	5.430E1	6.124E1	6.604E1	7.288E1	8.021E1	8.907E1	1.180E2
1990	4.616E1	5.339E1	5.821E1	6.526E1	7.287E1	8.164E1	1.114E2
1991	4.229E1	4.922E1	5.492E1	6.220E1	7.070E1	8.079E1	1.112E2
1992	4.349E1	5.021E1	5.655E1	6.501E1	7.532E1	8.562E1	1.176E2
1993	3.894E1	4.751E1	5.423E1	6.415E1	7.500E1	8.650E1	1.206E2
1994	3.765E1	4.749E1	5.426E1	6.505E1	7.620E1	8.839E1	1.242E2

Table D21. DeLury model results for **Northern New Jersey** surfclam, based on survey indices and a commercial catch series from 1980-1994. BAO = 2, run number = 233. Prepared for retrospective analysis. May 22, 1996.

Retrospective Analysis.

INPUTS:

ID c:\aplv5r\clams\scnnj R233.dat (copied from #232)

Surf Clams N NJ
Prepared for Retrospective Analysis of 1980-1994 Data; May 22, 1996
NMFS Survey used for calibration with the following modifications/notes:
(1) 1994 fully-recruited index taken as missing; and
(2) 1994 recruit index replaced with mean index over 1986-94 (i.e. 13.0)
(3) Catch per tow was standardized for tow distance and mesh size
Other Notes
(1) All recruit upper limit cut points set at 120mm
(2) Source of Commercial Catch Data: '80-'82: LRD 86-11. '83-'94: s1032
(3) This Run assumes: Discarding (20% of Catch) of recruits (105-120mm) from '80-81, followed by 50% survival of the discards. For 1982+, the source of information is NEFSC 1995a.

Species Code = 1 Region Code = 11

YEAR	LANDINGS	DISCARD	CATCH	LANDINGS	DISCARD	CATCH
	------ weight in mt ------			--- number in millions ----		
1980	1231	154	1385	6.690	2.404	9.094
1981	6499	812	7311	39.454	12.894	52.349
1982	4959	1227	6186	40.317	19.292	59.609
1983	5515	1061	6576	44.383	16.716	61.098
1984	8787	1133	9920	71.890	17.662	89.551
1985	8427	969	9396	71.304	15.105	86.409
1986	14703	1164	15867	135.738	18.143	153.881
1987	17238	707	17945	164.619	11.020	175.638
1988	19196	659	19855	171.548	10.264	181.812
1989	16415	524	16939	140.559	8.117	148.676
1990	16996	545	17541	155.698	8.435	164.133
1991	17623	248	17871	141.617	3.834	145.451
1992	18334	459	18793	152.307	7.103	159.410
1993	16338	0	16338	137.000	0.000	137.000
1994	17754	0	17754	138.579	0.000	138.579

Discard estimates assume 50% discard mortality, and use mean weight estimates of "Recruits" from the survey to convert weight to numbers. No discard data are available until 1982.

Table D21. (Continued)

MEAN WEIGHT (grams)

YEAR	NMFS SURVEY Recruits	NMFS SURVEY Fully Recruited	COMMERCIAL FISHERY Discarded Animals	COMMERCIAL FISHERY Landed Animals
1980	64	107	64	184
1981	63	114	63	165
1982	64	107	64	123
1983	63	107	63	124
1984	64	111	64	122
1985	64	111	64	118
1986	64	120	64	108
1987	64	120	64	105
1988	64	120	64	112
1989	65	120	65	117
1990	65	120	65	109
1991	65	120	65	124
1992	65	126	65	120
1993	65	126	65	119
1994	64	126	64	118

(1) Mean weight estimates for discards in the commercial fishery are taken to be the same as mean weight estimates of recruits from the NMFS survey.

(2) For years in which no survey was carried out, mean weights of recruits and fully-recruited were taken from the previous survey.

(3) Estimation of Weight per ind. in the catch: '94-'81: From the Expected weight per ind. from the CLF dist. '80: no data

SIZE CUT POINTS FOR RECRUITS

YEAR	Min Length (mm)	Max Length (mm)
1980	105	120
1981	105	120
1982	105	120
1983	105	120
1984	105	120
1985	105	120
1986	105	120
1987	105	120
1988	105	120
1989	105	120
1990	105	120
1991	105	120
1992	105	120
1993	105	120
1994	105	120

Table D21. (Continued)

LENGTH CLASSES USED FOR SURVEY AND COMMERCIAL DATA

LENGTH CLASS	Min Length (mm)	Max Length (mm)
1	0	9
2	10	19
3	20	29
4	30	39
5	40	49
6	50	59
7	60	69
8	70	79
9	80	89
10	90	99
11	100	109
12	110	119
13	120	129
14	130	139
15	140	149
16	150	159
17	160	169
18	170	179
19	180	189
20	190	199
21	200	209

```
!
YR
1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994
!
t_s  t_c
0.5 0.5
!
M
0.05
!
N_surv
          30.130              14.450
          10.535              24.010
          23.45800000         45.58700000
          29.22400000         36.63100000
           9.45800000         44.11100000
        ²999.00000000       ²999.00000000
           6.58000000         41.30900000
        ²999.00000000       ²999.00000000
        ²999.00000000       ²999.00000000
           6.63000000         46.14900000
        ²999.00000000       ²999.00000000
        ²999.00000000       ²999.00000000
          13.01200000         33.70100000
        ²999.00000000       ²999.00000000
          13.0                ²999
!
```

Table D21. (Continued)

```
Wt_mean_surv
          0.063726          0.106669
          0.063407          0.114154
          0.06360379        0.10726944
          0.06347296        0.10698721
          0.06414988        0.11062194
          0.06414988        0.11062194
          0.06415674        0.11962097
          0.06415674        0.11962097
          0.06415674        0.11962097
          0.06455489        0.11971184
          0.06455489        0.11971184
          0.06455489        0.11971184
          0.06461665        0.12607639
          0.06461665        0.12607639
          0.06384730        0.12561946
!
Describe_indices
#'s per survey tow were standardized to tow distance 0.15 mi.
Nonrandom tows and those with gear damage
were excluded from analysis.  Likewise, tows collected with
the abnormal tow point in Leg I in 1994 were excluded.
For 1980-1981, data were standardized for changes in gear to
modern gear values. Surveys used were: 8006,8105
UNITS for Catch in numbers and weight (below) are millions and MT
!
C_numbers
          6.69022          2.404219
         39.45483         12.89476
         40.3171          19.292
         44.38270189      16.71577835
         71.88969844      17.66176289
         71.30371842      15.10524999
        135.73753058      18.14306521
        164.61861384      11.01988583
        171.54799775      10.26392478
        140.55865569       8.11712307
        155.69806667       8.43468227
        141.61666680       3.83394649
        152.30660676       7.10343195
        136.99976950       0.00000000
!
C_weight
       1231.0             153.87
       6499.0             812.37
       4959.00000000     1227.00000000
       5515.00000000     1061.00000000
       8787.00000000     1133.00000000
       8427.00000000      969.00000000
      14703.00000000     1164.00000000
      17238.00000000      707.00000000
      19196.00000000      658.50000000
      16415.00000000      524.00000000
      16996.00000000      544.50000000
      17623.00000000      247.50000000
      18334.00000000      459.00000000
      16338.00000000        0.00000000
!
t_surv_yr
0 0.25 0.5 0.75 1
!
R_availability
0 0.25 0.5 0.75 1
!
q_initial
1.0E²10 0.001 1000
!
s_r_initial
1 1 1
!
W_objfcn
1 1 4
!
proc_error_type
lognormal
!
Num_reps
200
!
boot_class
parametric
!
boot_type
LOB
!
```

Table D21. (Continued)

Retrospective Analysis.

DETERMINISTIC RESULTS:

	PARAMETER	PAR. EST.	STD. ERR.	T-STATISTIC	C.V.
1	n 2+ 1980	1.28452E1	3.72475E0	3.44862E0	0.29
2	n 2+ 1981	3.18614E1	5.70239E0	5.58738E0	0.18
3	n 2+ 1982	3.57786E1	6.23886E0	5.73479E0	0.17
4	n 2+ 1983	4.35983E1	7.39657E0	5.89440E0	0.17
5	n 2+ 1984	5.55497E1	8.95976E0	6.19991E0	0.16
6	n 2+ 1986	5.56129E1	8.63265E0	6.44216E0	0.16
7	n 2+ 1989	4.20150E1	7.24408E0	5.79991E0	0.17
8	n 2+ 1992	3.31408E1	9.07527E0	3.65177E0	0.27
9	r 1 1980	2.42645E1	6.12905E0	3.95894E0	0.25
10	r 1 1981	1.04207E1	3.08513E0	3.37773E0	0.30
11	r 1 1982	1.99281E1	5.72065E0	3.48354E0	0.29
12	r 1 1983	2.53296E1	7.23948E0	3.49882E0	0.29
13	r 1 1984	9.28106E0	2.80166E0	3.31271E0	0.30
14	r 1 1986	6.72109E0	2.03823E0	3.29751E0	0.30
15	r 1 1989	6.68457E0	2.02376E0	3.30305E0	0.30
16	r 1 1992	1.30808E1	3.97335E0	3.29213E0	0.30
17	Surv q_n	7.85103E-2	1.75288E-2	4.47894E0	0.22

CORRELATION BETWEEN PARAMETERS ESTIMATED (SYMBOLIC FORM)

```
 1 n 2+ 1980 * . . . . . . . . . . . . . . . .
 2 n 2+ 1981 . * + . . . . . + . . . . . . . .
 3 n 2+ 1982 . + * + . . . . . . . . . . . . .
 4 n 2+ 1983 . . + * + . . . . . . . . . . . .
 5 n 2+ 1984 . . . + * + . . . . . + . . . . .
 6 n 2+ 1986 . . . . + * + . . . . . . . . . +
 7 n 2+ 1989 . . . . . + * + . . . . . . . . .
 8 n 2+ 1992 . . . . . . + * . . . . . . . . -
 9 r 1  1980 . + . . . . . . * . . . . . . . .
10 r 1  1981 . . . . . . . - . * . . . . . . .
11 r 1  1982 . . . . . . . . . . * . . . . . .
12 r 1  1983 . . . . + . . . . . . * . . . . .
13 r 1  1984 . . . . . . . . . . . . * . . . .
14 r 1  1986 . . . . . . . . . . . . . * . . .
15 r 1  1989 . . . . . . . . . . . . . . * . .
16 r 1  1992 . . . . . . . . . . . . . . . * .
17 Surv q_n  . . . . . + . - . . . . . . . . *
```

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

Where r is the estimated correlation, M is 0.4 and L is 0.8

CALENDAR YEAR	STOCK SIZE ESTIMATES (millions at time of survey) RECRUITS	FULLY-RECRUITED	MORTALITY RATES (between surveys) Z on sizes 1+	F on size 1	F on sizes 2+
1980	309.062	163.612	0.15	0.08	0.15
1981	132.731	405.825	0.17	0.07	0.13
1982	253.828	455.718	0.25	0.12	0.24
1983	322.628	555.320	0.22	0.10	0.20
1984	118.215	707.547	0.16	0.06	0.12
1985	162.335	700.305	0.20	0.08	0.16
1986	85.608	708.352	0.27	0.11	0.23
1987	162.335	608.863	0.31	0.14	0.29
1988	162.335	566.513	0.31	0.15	0.29
1989	85.143	535.153	0.32	0.15	0.29
1990	162.335	448.619	0.36	0.18	0.36
1991	162.335	425.029	0.33	0.16	0.33
1992	166.612	422.120	0.37	0.18	0.37
1993	162.335	408.385	0.32	0.16	0.32
1994	165.583	412.567			

Table D21. (Continued)

RECRUITS = SIZECLASS 1   FULLY-RECRUITED = SIZECLASS 2+
Index of abundance for recruits is missing in 1985 1987 1988 1990 1991 1993
For these years, the recruit stock size estimates are based on the geometric mean of recruitment in years when indices were available.
Index of abundance for fully-recruited is missing in 1985 1987 1988 1990 1991 1993 1994
For these years, the fully-recruited stock size estimates are based on forward calculations from the DeLury difference equation.

Note that the recruit population estimate for the last year (1994) is NOT a least squares estimate. It is calculated from the observed survey index, the least squares estimate of q, and the s_r.

---- BIOMASS ESTIMATES (at time of the survey) ----
(1000 mt)

CALENDAR YEAR	RECRUITS	FULLY-RECRUITED	TOTAL BIOMASS	EXPLOITED BIOMASS	CATCH DURING BIOMASS YEAR (1000 mt)
1980	19.695	17.452	37.148	27.300	1.385
1981	8.416	46.327	54.743	50.535	7.311
1982	16.144	48.885	65.029	56.957	6.186
1983	20.478	59.412	79.890	69.651	6.576
1984	7.583	78.270	85.854	82.062	9.920
1985	10.414	77.469	87.883	82.676	9.396
1986	5.492	84.734	90.226	87.480	15.867
1987	10.415	72.833	83.248	78.040	17.945
1988	10.415	67.767	78.182	72.974	19.855
1989	5.496	64.064	69.561	66.812	16.939
1990	10.480	53.705	64.184	58.945	17.541
1991	10.480	50.881	61.361	56.121	17.871
1992	10.766	53.219	63.985	58.602	18.793
1993	10.490	51.488	61.977	56.732	16.338
1994	10.572	51.826	62.399	57.112	

CALENDAR YEAR	---- 1000 Metric Tons ---- EXPLOITED BIOMASS	DELTA B	CATCH	SURPLUS PRODUCTION	PROD-BIOMASS RATIO
1980	27.300	23.235	1.385	24.619	0.9018
1981	50.535	6.422	7.311	13.734	0.2718
1982	56.957	12.694	6.186	18.880	0.3315
1983	69.651	12.411	6.576	18.987	0.2726
1984	82.062	0.614	9.920	10.534	0.1284
1985	82.676	4.804	9.396	14.200	0.1718
1986	87.480	-9.440	15.867	6.427	0.0735
1987	78.040	-5.066	17.945	12.879	0.1650
1988	72.974	-6.162	19.855	13.692	0.1876
1989	66.812	-7.868	16.939	9.071	0.1358
1990	58.945	-2.824	17.541	14.717	0.2497
1991	56.121	2.482	17.871	20.352	0.3626
1992	58.602	-1.870	18.793	16.923	0.2888
1993	56.732	0.380	16.338	16.718	0.2947
1994	57.112				

The SURPLUS PRODUCTION table, above, assumes that DELTA B over the course of a calendar year can be approximated by differencing the successive EXPLOITED BIOMASS estimates at time of the survey. More specifically, this assumes that the change in EXPLOITED BIOMASS between Jan 1 and the time of the survey is constant in successive years. Note also that the PRODUCTION-BIOMASS RATIO is with respect to exploited biomass at time of the survey.

Table D21. (Continued)

SUMMARY OF RESIDUALS FROM THE FITTED MODEL

MEASUREMENT ERROR -- Fully-recruited index with lognormal errors

ERROR TERM	OBSERVED	PREDICTED	WEIGHT	RESIDUAL	STD RES	%SS
n 2+ 1980	14.4500	12.8452	0.1508	0.0177	0.3894	2.5
n 2+ 1981	24.0100	31.8614	0.1508	-0.0427	-0.9360	14.6
n 2+ 1982	45.5800	35.7786	0.1508	0.0365	0.8015	10.7
n 2+ 1983	36.6310	43.5983	0.1508	-0.0263	-0.5760	5.5
n 2+ 1984	44.1110	55.5497	0.1508	-0.0348	-0.7628	9.7
n 2+ 1985	^{2}999.0000	54.9811	^{2}999.0000	0.0000	0.0000	0.0
n 2+ 1986	41.3090	55.6129	0.1508	-0.0448	-0.9836	16.1
n 2+ 1987	^{2}999.0000	47.8020	^{2}999.0000	0.0000	0.0000	0.0
n 2+ 1988	^{2}999.0000	44.4771	^{2}999.0000	0.0000	0.0000	0.0
n 2+ 1989	46.1490	42.0150	0.1508	0.0141	0.3105	1.6
n 2+ 1990	^{2}999.0000	35.2212	^{2}999.0000	0.0000	0.0000	0.0
n 2+ 1991	^{2}999.0000	33.3692	^{2}999.0000	0.0000	0.0000	0.0
n 2+ 1992	33.7010	33.1408	0.1508	0.0025	0.0555	0.1
n 2+ 1993	^{2}999.0000	32.0624	^{2}999.0000	0.0000	0.0000	0.0
n 2+ 1994	^{2}999.0000	32.3907	^{2}999.0000	0.0000	0.0000	0.0
SUM				-0.0775	-1.7015	60.8

MEASUREMENT ERROR -- Recruit index with lognormal errors

ERROR TERM	OBSERVED	PREDICTED	WEIGHT	RESIDUAL	STD RES	%SS
r 1 1980	30.1300	24.2645	0.1508	0.0326	0.7162	8.5
r 1 1981	10.5350	10.4207	0.1508	0.0016	0.0361	0.0
r 1 1982	23.4580	19.9281	0.1508	0.0246	0.5395	4.9
r 1 1983	29.2240	25.3296	0.1508	0.0216	0.4731	3.7
r 1 1984	9.4580	9.2811	0.1508	0.0028	0.0625	0.1
r 1 1985	^{2}999.0000	12.7450	^{2}999.0000	0.0000	0.0000	0.0
r 1 1986	6.5800	6.7211	0.1508	-0.0032	-0.0702	0.1
r 1 1987	^{2}999.0000	12.7450	^{2}999.0000	0.0000	0.0000	0.0
r 1 1988	^{2}999.0000	12.7450	^{2}999.0000	0.0000	0.0000	0.0
r 1 1989	6.6300	6.6846	0.1508	-0.0012	-0.0271	0.0
r 1 1990	^{2}999.0000	12.7450	^{2}999.0000	0.0000	0.0000	0.0
r 1 1991	^{2}999.0000	12.7450	^{2}999.0000	0.0000	0.0000	0.0
r 1 1992	13.0120	13.0808	0.1508	-0.0008	-0.0174	0.0
r 1 1993	^{2}999.0000	12.7450	^{2}999.0000	0.0000	0.0000	0.0
SUM				0.0780	1.7126	17.3

PROCESS ERROR -- DeLury equation with lognormal errors

ERROR TERM	CALCULATED	PREDICTED	WEIGHT	RESIDUAL	STD RES	%SS
n 2+ 1981	34.6207	31.8614	0.3015	0.0250	0.5495	5.0
n 2+ 1982	36.3105	35.7786	0.3015	0.0044	0.0976	0.2
n 2+ 1983	48.5382	43.5983	0.3015	0.0324	0.7101	8.4
n 2+ 1984	61.0034	55.5497	0.3015	0.0282	0.6196	6.4
n 2+ 1985	^{2}999.0000	54.9811	^{2}999.0000	0.0000	0.0000	0.0
n 2+ 1986	57.9699	55.6129	0.3015	0.0125	0.2746	1.3
n 2+ 1987	^{2}999.0000	47.8020	^{2}999.0000	0.0000	0.0000	0.0
n 2+ 1988	^{2}999.0000	44.4771	^{2}999.0000	0.0000	0.0000	0.0
n 2+ 1989	40.8534	42.0150	0.3015	-0.0085	-0.1855	0.6
n 2+ 1990	^{2}999.0000	35.2212	^{2}999.0000	0.0000	0.0000	0.0
n 2+ 1991	^{2}999.0000	33.3692	^{2}999.0000	0.0000	0.0000	0.0
n 2+ 1992	33.0027	33.1408	0.3015	-0.0013	-0.0276	0.0
n 2+ 1993	^{2}999.0000	32.0624	^{2}999.0000	0.0000	0.0000	0.0
n 2+ 1994	^{2}999.0000	32.3907	^{2}999.0000	0.0000	0.0000	0.0
SUM				0.0929	2.0384	21.8

23 residual error terms
17 parameters estimated
6 degrees of freedom

Table D21. (Continued)

Retrospective Analysis.

STOCHASTIC RESULTS (with bao = 2; i.e., bias-corrected values are given for the column headed "BOOTSTRAP MEAN")

BOOTSTRAP OUTPUT VARIABLE: R_0
Population size (in number) of the recruits at time of the survey i.e. 50% into the calendar year

YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1980	3.091E2	3.394E2	3.756E1	0.12
1981	1.327E2	1.402E2	1.640E1	0.12
1982	2.538E2	2.747E2	2.503E1	0.10
1983	3.226E2	3.465E2	3.200E1	0.10
1984	1.182E2	1.211E2	1.485E1	0.13
1985	1.623E2	1.707E2	1.407E1	0.09
1986	8.561E1	8.758E1	1.077E1	0.13
1987	1.623E2	1.707E2	1.407E1	0.09
1988	1.623E2	1.707E2	1.407E1	0.09
1989	8.514E1	8.604E1	1.104E1	0.13
1990	1.623E2	1.707E2	1.407E1	0.09
1991	1.623E2	1.707E2	1.407E1	0.09
1992	1.666E2	1.689E2	2.045E1	0.12
1993	1.623E2	1.707E2	1.407E1	0.09
1994	1.656E2	1.793E2	1.651E1	0.10

		PERCENTILES					
YEAR	MIN	10	25	MEDIAN	75	90	MAX
1980	2.545E2	2.948E2	3.115E2	3.360E2	3.596E2	3.882E2	4.535E2
1981	1.063E2	1.197E2	1.297E2	1.388E2	1.508E2	1.599E2	2.006E2
1982	2.064E2	2.438E2	2.558E2	2.723E2	2.892E2	3.091E2	3.503E2
1983	2.762E2	3.088E2	3.235E2	3.437E2	3.684E2	3.885E2	4.398E2
1984	8.902E1	1.027E2	1.096E2	1.195E2	1.288E2	1.405E2	1.706E2
1985	1.416E2	1.544E2	1.603E2	1.694E2	1.792E2	1.887E2	2.236E2
1986	6.637E1	7.409E1	7.951E1	8.697E1	9.441E1	1.020E2	1.261E2
1987	1.416E2	1.544E2	1.603E2	1.694E2	1.792E2	1.887E2	2.236E2
1988	1.416E2	1.544E2	1.603E2	1.694E2	1.792E2	1.887E2	2.236E2
1989	5.837E1	7.206E1	7.844E1	8.532E1	9.341E1	1.002E2	1.291E2
1990	1.416E2	1.544E2	1.603E2	1.694E2	1.792E2	1.887E2	2.236E2
1991	1.416E2	1.544E2	1.603E2	1.694E2	1.792E2	1.887E2	2.236E2
1992	1.227E2	1.446E2	1.550E2	1.668E2	1.813E2	1.986E2	2.238E2
1993	1.416E2	1.544E2	1.603E2	1.694E2	1.792E2	1.887E2	2.236E2
1994	1.456E2	1.598E2	1.678E2	1.773E2	1.895E2	2.007E2	2.396E2

Table D21. (Continued)

BOOTSTRAP OUTPUT VARIABLE: N_0
Popn size (in number) of fully-recruited animals at time of the survey
i.e. 50% into the calendar year

YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1980	1.636E2	1.929E2	2.624E1	0.16
1981	4.058E2	4.396E2	4.706E1	0.12
1982	4.557E2	5.020E2	5.286E1	0.12
1983	5.553E2	5.818E2	5.599E1	0.10
1984	7.075E2	7.166E2	6.626E1	0.09
1985	7.003E2	7.116E2	7.105E1	0.10
1986	7.084E2	7.122E2	7.393E1	0.10
1987	6.089E2	6.144E2	7.591E1	0.12
1988	5.665E2	5.798E2	8.353E1	0.15
1989	5.352E2	5.670E2	9.369E1	0.18
1990	4.486E2	4.798E2	9.519E1	0.21
1991	4.250E2	4.627E2	1.030E2	0.24
1992	4.221E2	4.635E2	1.131E2	0.27
1993	4.084E2	4.499E2	1.211E2	0.30
1994	4.126E2	4.600E2	1.282E2	0.31

YEAR	MIN	PERCENTILES 10	25	MEDIAN	75	90	MAX
1980	1.403E2	1.608E2	1.724E2	1.918E2	2.089E2	2.258E2	2.838E2
1981	3.273E2	3.846E2	4.081E2	4.362E2	4.666E2	4.945E2	5.881E2
1982	3.722E2	4.440E2	4.667E2	4.977E2	5.330E2	5.686E2	6.860E2
1983	4.453E2	5.134E2	5.457E2	5.746E2	6.175E2	6.586E2	7.718E2
1984	5.906E2	6.379E2	6.677E2	7.088E2	7.529E2	7.987E2	9.941E2
1985	5.733E2	6.257E2	6.618E2	7.044E2	7.494E2	7.959E2	1.010E3
1986	5.425E2	6.306E2	6.603E2	7.054E2	7.532E2	8.018E2	1.054E3
1987	4.502E2	5.304E2	5.587E2	6.083E2	6.524E2	7.065E2	9.577E2
1988	4.132E2	4.837E2	5.205E2	5.753E2	6.238E2	6.855E2	9.536E2
1989	3.813E2	4.683E2	4.991E2	5.584E2	6.210E2	6.819E2	9.630E2
1990	3.019E2	3.765E2	4.088E2	4.677E2	5.271E2	5.976E2	8.843E2
1991	2.670E2	3.496E2	3.866E2	4.526E2	5.141E2	5.883E2	8.947E2
1992	2.429E2	3.375E2	3.827E2	4.571E2	5.287E2	6.073E2	9.328E2
1993	2.105E2	3.143E2	3.665E2	4.362E2	5.188E2	6.088E2	9.486E2
1994	2.059E2	3.176E2	3.716E2	4.461E2	5.333E2	6.298E2	9.817E2

Table D21. (Continued)

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

SURVEY YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1980	0.1523	0.2215	0.0478	0.31
1981	0.1335	0.0994	0.0424	0.32
1982	0.2376	0.2983	0.0429	0.18
1983	0.2031	0.2598	0.0423	0.21
1984	0.1236	0.1207	0.0119	0.10
1985	0.1623	0.1816	0.0406	0.25
1986	0.2277	0.2232	0.0249	0.11
1987	0.2888	0.2789	0.0381	0.13
1988	0.2914	0.2481	0.0592	0.20
1989	0.2942	0.2619	0.0622	0.21
1990	0.3608	0.3089	0.0939	0.26
1991	0.3253	0.2719	0.1078	0.33
1992	0.3678	0.2912	0.1350	0.37
1993	0.3200	0.2415	0.1379	0.43

SURVEY YEAR	MIN	PERCENTILES 10	25	MEDIAN	75	90	MAX
1980	0.0616	0.1603	0.1943	0.2226	0.2522	0.2797	0.3372
1981	0.0016	0.0423	0.0692	0.0992	0.1276	0.1540	0.2725
1982	0.1904	0.2420	0.2681	0.3027	0.3274	0.3513	0.4108
1983	0.1571	0.2061	0.2294	0.2606	0.2906	0.3186	0.3628
1984	0.0827	0.1060	0.1131	0.1207	0.1283	0.1364	0.1487
1985	0.0874	0.1273	0.1513	0.1804	0.2079	0.2321	0.2922
1986	0.1415	0.1923	0.2072	0.2218	0.2406	0.2533	0.2989
1987	0.1618	0.2314	0.2544	0.2772	0.3067	0.3277	0.3895
1988	0.0830	0.1734	0.2079	0.2504	0.2874	0.3226	0.4175
1989	0.1036	0.1865	0.2196	0.2570	0.3052	0.3401	0.4530
1990	0.0899	0.1977	0.2456	0.2967	0.3733	0.4290	0.6162
1991	0.0219	0.1422	0.1968	0.2557	0.3387	0.4108	0.6790
1992	0.0265	0.1394	0.1937	0.2627	0.3673	0.4702	0.8509
1993	[2]0.0054	0.0920	0.1442	0.2149	0.3067	0.4113	0.8772

Table D21. (Continued)

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

SURVEY YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1980	0.1025	0.1495	0.0322	0.31
1981	0.1170	0.0877	0.0374	0.32
1982	0.1951	0.2453	0.0357	0.18
1983	0.1658	0.2116	0.0348	0.21
1984	0.1148	0.1120	0.0109	0.09
1985	0.1471	0.1641	0.0368	0.25
1986	0.2154	0.2111	0.0233	0.11
1987	0.2584	0.2487	0.0331	0.13
1988	0.2589	0.2202	0.0510	0.20
1989	0.2740	0.2457	0.0555	0.20
1990	0.3129	0.2709	0.0752	0.24
1991	0.2804	0.2390	0.0849	0.30
1992	0.3158	0.2589	0.1029	0.33
1993	0.2745	0.2154	0.1029	0.38

SURVEY		PERCENTILES					
YEAR	MIN	10	25	MEDIAN	75	90	MAX
1980	0.0466	0.1082	0.1304	0.1494	0.1694	0.1876	0.2341
1981	0.0022	0.0380	0.0603	0.0887	0.1121	0.1335	0.2458
1982	0.1539	0.1984	0.2204	0.2486	0.2700	0.2890	0.3405
1983	0.1277	0.1667	0.1865	0.2117	0.2367	0.2586	0.2957
1984	0.0771	0.0989	0.1052	0.1121	0.1195	0.1265	0.1382
1985	0.0787	0.1150	0.1368	0.1631	0.1889	0.2091	0.2627
1986	0.1350	0.1823	0.1969	0.2105	0.2281	0.2396	0.2790
1987	0.1462	0.2065	0.2271	0.2463	0.2718	0.2919	0.3396
1988	0.0756	0.1550	0.1858	0.2226	0.2558	0.2862	0.3585
1989	0.1021	0.1778	0.2090	0.2427	0.2857	0.3150	0.4074
1990	0.0905	0.1817	0.2204	0.2624	0.3225	0.3666	0.5119
1991	0.0326	0.1373	0.1808	0.2296	0.2933	0.3478	0.5482
1992	0.0477	0.1397	0.1849	0.2435	0.3148	0.3909	0.6700
1993	0.0188	0.0998	0.1420	0.1973	0.2677	0.3429	0.6587

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

SURVEY YEAR(S)	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1993 0	0.3200	0.2415	0.1379	0.43
1992 93	0.3439	0.2663	0.1363	0.40
1991 93	0.3377	0.2682	0.1262	0.37

SURVEY		PERCENTILES					
YEAR(S)	MIN	10	25	MEDIAN	75	90	MAX
1993 0	0.0054	0.0920	0.1442	0.2149	0.3067	0.4113	0.8772
1992 93	0.0106	0.1156	0.1685	0.2407	0.3379	0.4380	0.8641
1991 93	0.0148	0.1251	0.1767	0.2448	0.3365	0.4344	0.7935

Table D21. (Continued)

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

YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1980	1.970E1	2.163E1	2.393E0	0.12
1981	8.416E0	8.892E0	1.040E0	0.12
1982	1.614E1	1.747E1	1.592E0	0.10
1983	2.048E1	2.199E1	2.031E0	0.10
1984	7.583E0	7.768E0	9.529E-1	0.13
1985	1.041E1	1.095E1	9.029E-1	0.09
1986	5.492E0	5.619E0	6.907E-1	0.13
1987	1.041E1	1.095E1	9.030E-1	0.09
1988	1.041E1	1.095E1	9.030E-1	0.09
1989	5.496E0	5.554E0	7.126E-1	0.13
1990	1.048E1	1.102E1	9.086E-1	0.09
1991	1.048E1	1.102E1	9.086E-1	0.09
1992	1.077E1	1.091E1	1.322E0	0.12
1993	1.049E1	1.103E1	9.094E-1	0.09
1994	1.057E1	1.145E1	1.054E0	0.10

YEAR	MIN	PERCENTILES 10	25	MEDIAN	75	90	MAX
1980	1.622E1	1.879E1	1.985E1	2.141E1	2.292E1	2.474E1	2.890E1
1981	6.743E0	7.588E0	8.221E0	8.800E0	9.565E0	1.014E1	1.272E1
1982	1.313E1	1.551E1	1.627E1	1.732E1	1.840E1	1.966E1	2.228E1
1983	1.753E1	1.960E1	2.053E1	2.182E1	2.338E1	2.466E1	2.792E1
1984	5.710E0	6.589E0	7.032E0	7.663E0	8.265E0	9.014E0	1.095E1
1985	9.084E0	9.907E0	1.029E1	1.087E1	1.150E1	1.210E1	1.435E1
1986	4.258E0	4.753E0	5.101E0	5.579E0	6.057E0	6.545E0	8.092E0
1987	9.085E0	9.908E0	1.029E1	1.087E1	1.150E1	1.211E1	1.435E1
1988	9.085E0	9.908E0	1.029E1	1.087E1	1.150E1	1.211E1	1.435E1
1989	3.768E0	4.652E0	5.063E0	5.508E0	6.030E0	6.470E0	8.331E0
1990	9.142E0	9.970E0	1.035E1	1.093E1	1.157E1	1.218E1	1.444E1
1991	9.142E0	9.970E0	1.035E1	1.093E1	1.157E1	1.218E1	1.444E1
1992	7.928E0	9.345E0	1.001E1	1.078E1	1.172E1	1.283E1	1.446E1
1993	9.151E0	9.979E0	1.036E1	1.094E1	1.158E1	1.219E1	1.445E1
1994	9.299E0	1.020E1	1.071E1	1.132E1	1.210E1	1.282E1	1.530E1

Table D21. (Continued)

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

YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1980	1.745E1	2.057E1	2.799E0	0.16
1981	4.633E1	5.018E1	5.372E0	0.12
1982	4.888E1	5.385E1	5.670E0	0.12
1983	5.941E1	6.225E1	5.990E0	0.10
1984	7.827E1	7.927E1	7.329E0	0.09
1985	7.747E1	7.872E1	7.859E0	0.10
1986	8.473E1	8.519E1	8.843E0	0.10
1987	7.283E1	7.350E1	9.081E0	0.12
1988	6.777E1	6.935E1	9.992E0	0.15
1989	6.406E1	6.788E1	1.122E1	0.18
1990	5.370E1	5.744E1	1.139E1	0.21
1991	5.088E1	5.539E1	1.233E1	0.24
1992	5.322E1	5.843E1	1.426E1	0.27
1993	5.149E1	5.672E1	1.526E1	0.30
1994	5.183E1	5.779E1	1.611E1	0.31

		PERCENTILES					
YEAR	MIN	10	25	MEDIAN	75	90	MAX
1980	1.496E1	1.716E1	1.839E1	2.046E1	2.228E1	2.409E1	3.027E1
1981	3.736E1	4.391E1	4.658E1	4.980E1	5.327E1	5.644E1	6.713E1
1982	3.993E1	4.763E1	5.006E1	5.339E1	5.717E1	6.100E1	7.358E1
1983	4.764E1	5.493E1	5.839E1	6.148E1	6.607E1	7.046E1	8.258E1
1984	6.534E1	7.056E1	7.387E1	7.841E1	8.329E1	8.835E1	1.100E2
1985	6.342E1	6.921E1	7.321E1	7.792E1	8.290E1	8.805E1	1.118E2
1986	6.489E1	7.544E1	7.899E1	8.438E1	9.010E1	9.591E1	1.261E2
1987	5.385E1	6.344E1	6.684E1	7.277E1	7.804E1	8.452E1	1.146E2
1988	4.943E1	5.787E1	6.227E1	6.882E1	7.462E1	8.200E1	1.141E2
1989	4.565E1	5.606E1	5.975E1	6.684E1	7.435E1	8.163E1	1.153E2
1990	3.614E1	4.508E1	4.894E1	5.599E1	6.310E1	7.153E1	1.059E2
1991	3.196E1	4.185E1	4.628E1	5.418E1	6.155E1	7.043E1	1.071E2
1992	3.062E1	4.255E1	4.825E1	5.763E1	6.666E1	7.657E1	1.176E2
1993	2.654E1	3.963E1	4.620E1	5.499E1	6.541E1	7.676E1	1.196E2
1994	2.586E1	3.990E1	4.668E1	5.604E1	6.699E1	7.911E1	1.233E2

Table D21. (Continued)

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BOOTSTRAP OUTPUT VARIABLE:  B_RN_0_expl
Exploited biomass at time of the survey
i.e. 50% into the calendar year
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YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1980	2.730E1	3.139E1	3.218E0	0.12
1981	5.053E1	5.462E1	5.622E0	0.11
1982	5.696E1	6.259E1	6.026E0	0.11
1983	6.965E1	7.324E1	6.461E0	0.09
1984	8.206E1	8.315E1	7.575E0	0.09
1985	8.268E1	8.420E1	8.225E0	0.10
1986	8.748E1	8.800E1	9.019E0	0.10
1987	7.804E1	7.897E1	9.454E0	0.12
1988	7.297E1	7.483E1	1.039E1	0.14
1989	6.681E1	7.066E1	1.141E1	0.17
1990	5.894E1	6.295E1	1.181E1	0.20
1991	5.612E1	6.090E1	1.275E1	0.23
1992	5.860E1	6.389E1	1.469E1	0.25
1993	5.673E1	6.224E1	1.571E1	0.28
1994	5.711E1	6.351E1	1.661E1	0.29

		PERCENTILES					
YEAR	MIN	10	25	MEDIAN	75	90	MAX
1980	2.376E1	2.746E1	2.916E1	3.075E1	3.349E1	3.582E1	4.258E1
1981	4.086E1	4.822E1	5.081E1	5.404E1	5.801E1	6.144E1	7.235E1
1982	4.773E1	5.563E1	5.859E1	6.181E1	6.608E1	7.029E1	8.385E1
1983	5.690E1	6.572E1	6.881E1	7.220E1	7.710E1	8.194E1	9.589E1
1984	6.881E1	7.412E1	7.783E1	8.227E1	8.748E1	9.250E1	1.150E2
1985	6.796E1	7.459E1	7.840E1	8.336E1	8.861E1	9.396E1	1.188E2
1986	6.761E1	7.810E1	8.178E1	8.736E1	9.290E1	9.900E1	1.295E2
1987	5.898E1	6.844E1	7.198E1	7.824E1	8.391E1	9.053E1	1.216E2
1988	5.441E1	6.296E1	6.742E1	7.420E1	8.034E1	8.817E1	1.211E2
1989	4.838E1	5.830E1	6.243E1	6.946E1	7.680E1	8.464E1	1.190E2
1990	4.075E1	5.003E1	5.418E1	6.164E1	6.887E1	7.756E1	1.130E2
1991	3.653E1	4.682E1	5.146E1	5.976E1	6.739E1	7.636E1	1.142E2
1992	3.543E1	4.706E1	5.344E1	6.335E1	7.240E1	8.297E1	1.248E2
1993	3.116E1	4.470E1	5.144E1	6.050E1	7.114E1	8.289E1	1.267E2
1994	3.092E1	4.511E1	5.201E1	6.161E1	7.299E1	8.545E1	1.309E2

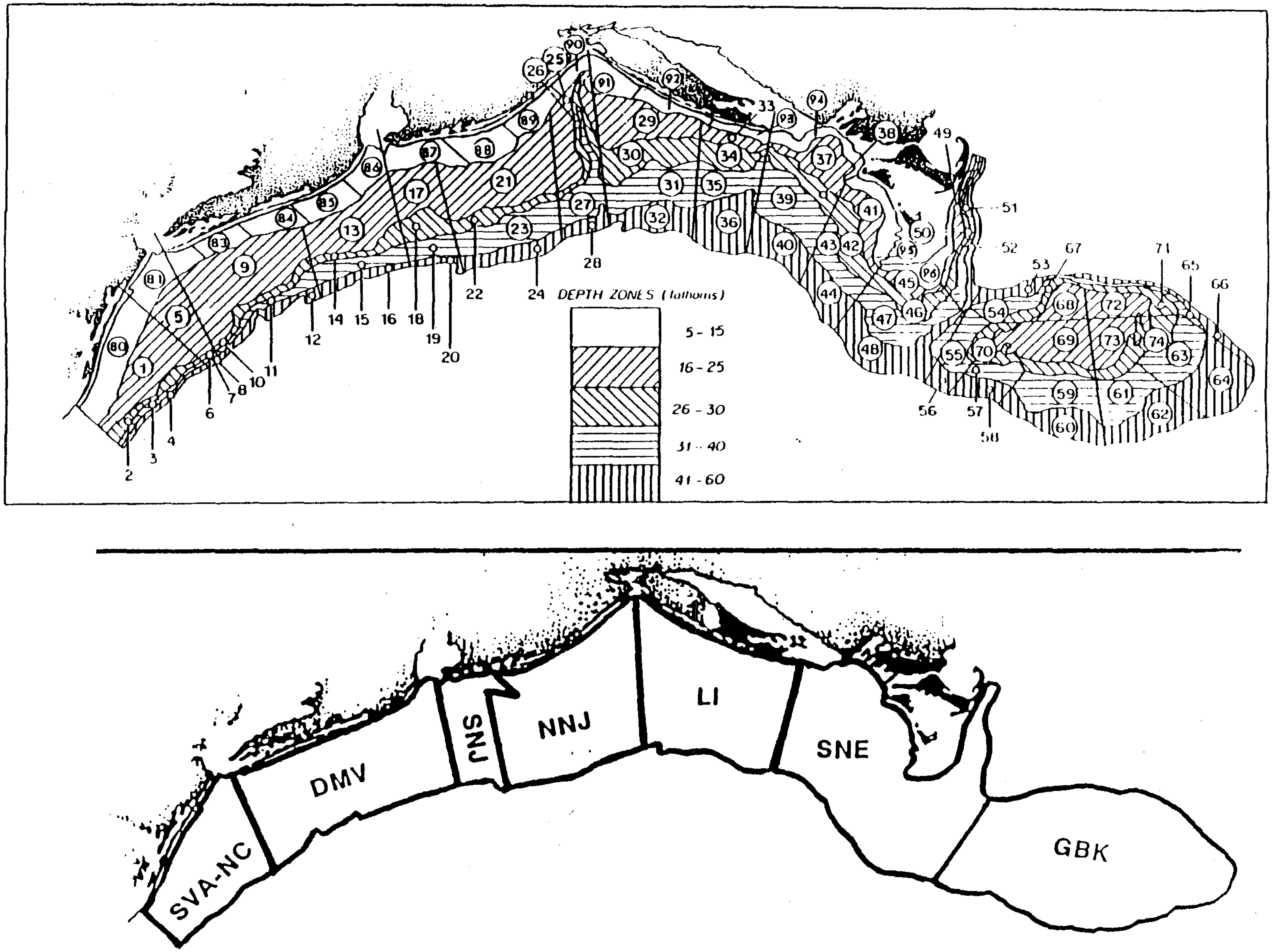


Figure D1. Survey strata (samplilng areas), National Marine Fisheries Service, Northeast Fisheries Science Center, Surf Clam-Ocean Quahog Survey.

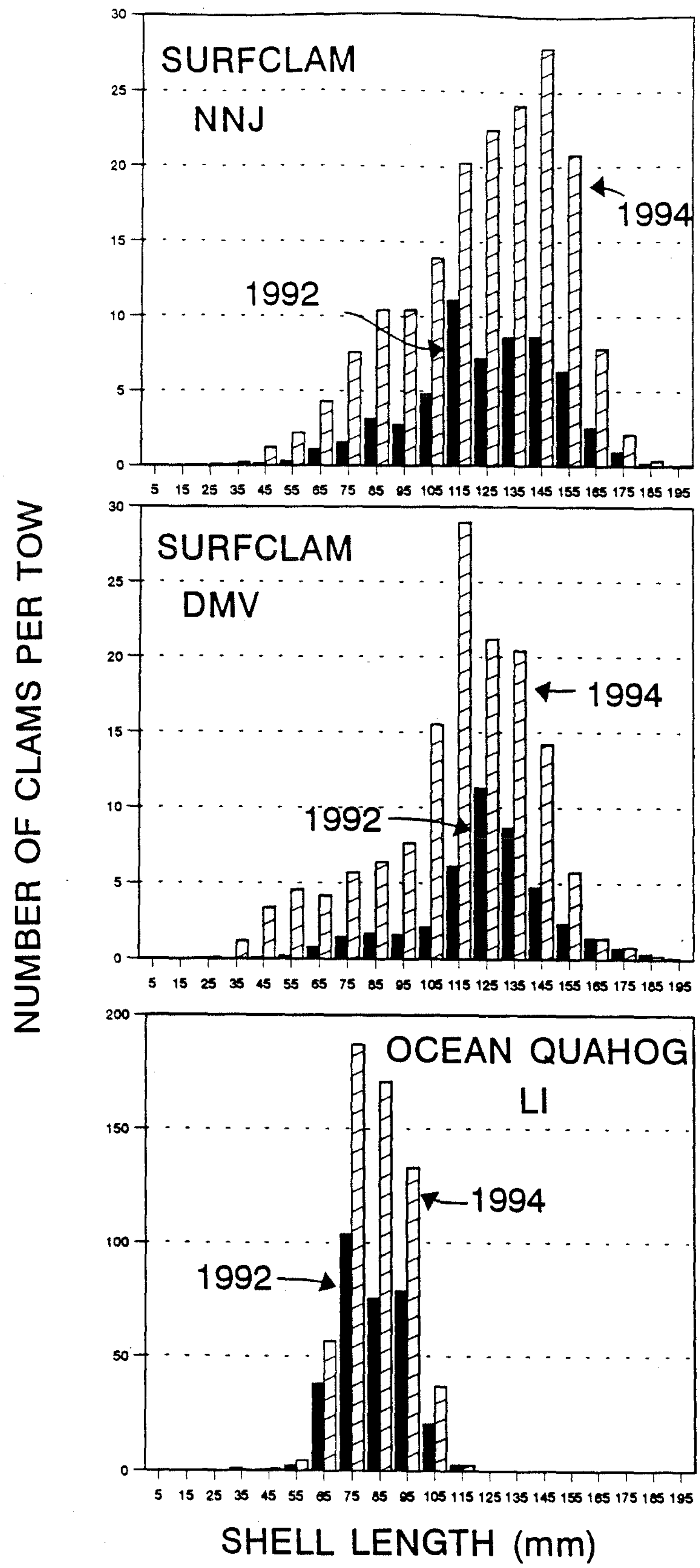


Figure D2. Regional size frequency distributions from research surveys in 1992 and 1994, for surfclam and ocean quahog. Catch was standardized to a common tow distance of 0.15 n. mi.

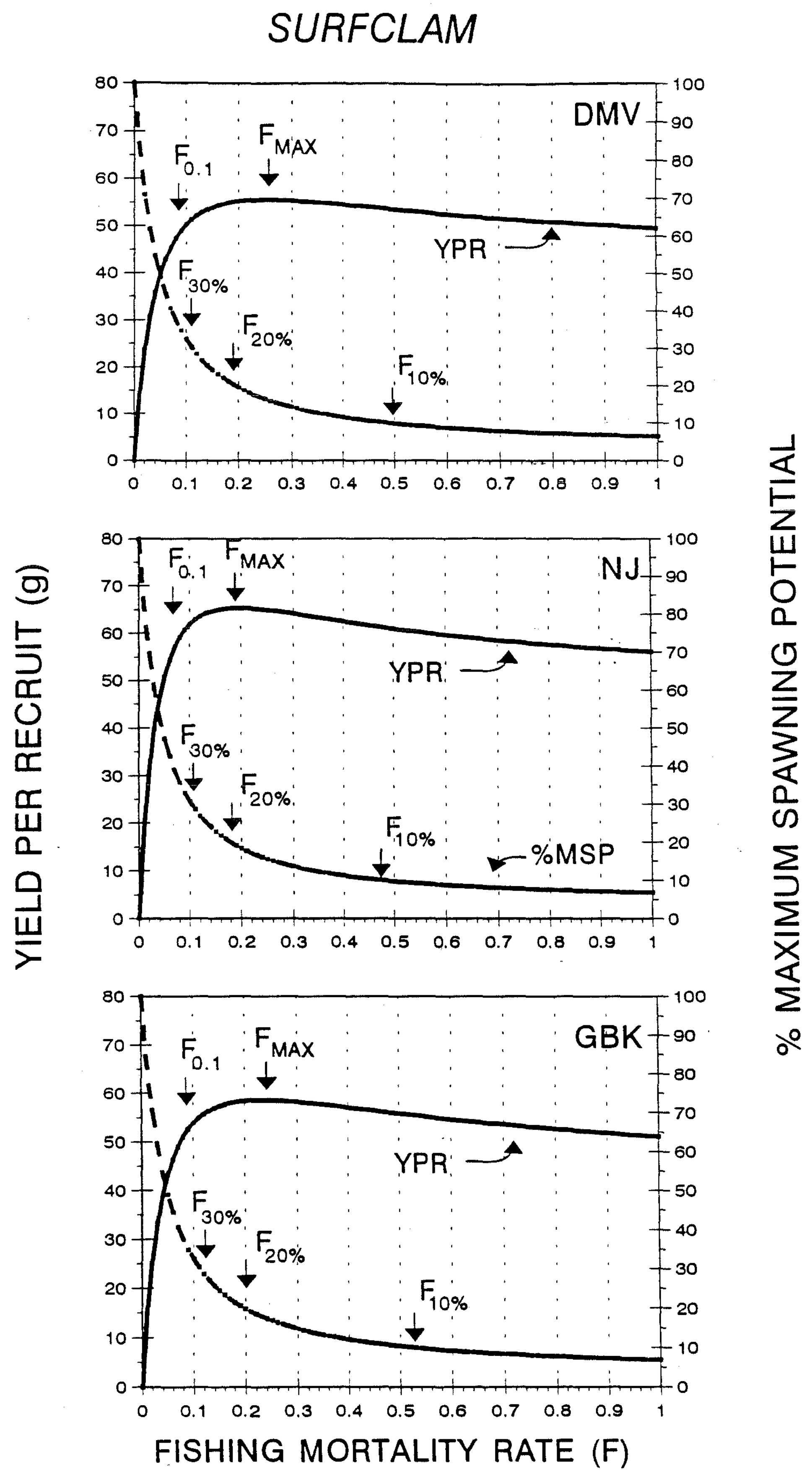
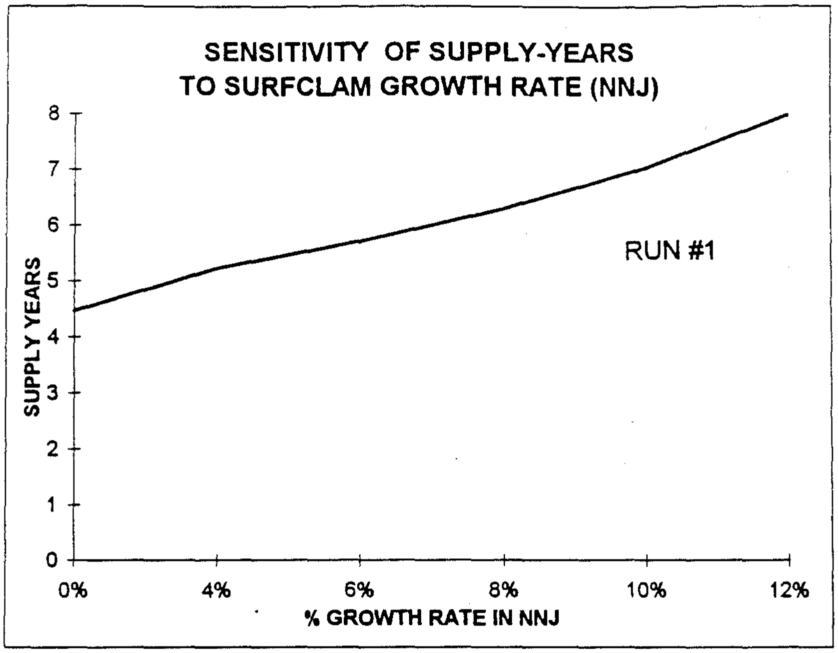


Figure D3. Updated biological reference points for surfclam by region. 1994 age-length data were analyzed for the DMV and NJ regions. 1989 + 1992 data were analyzed for GBK.



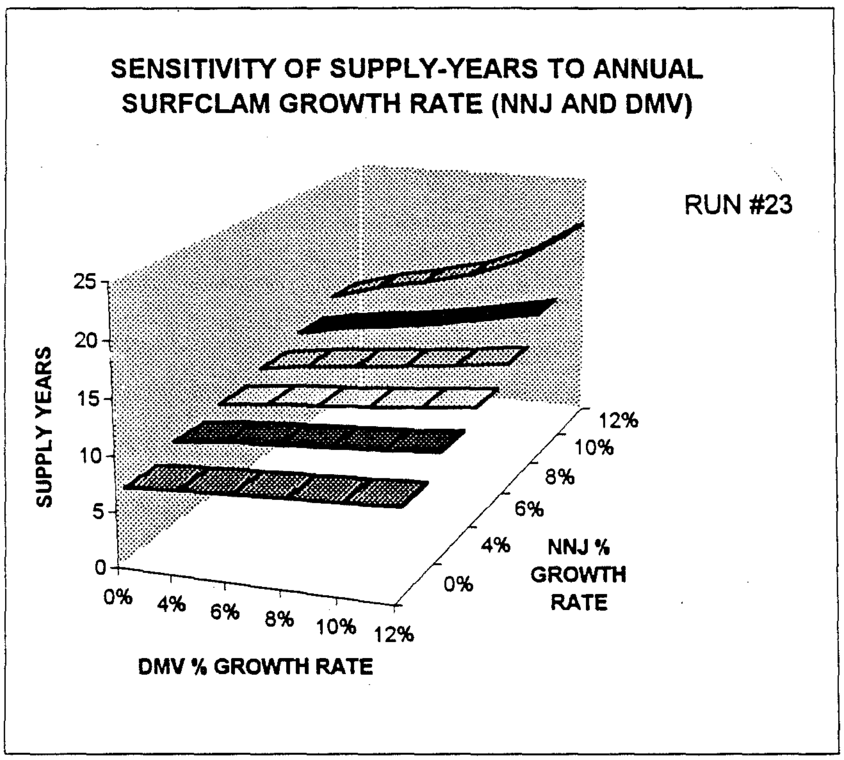


Figure D4. Sensitivity of supply years to surfclam growth rate (NNJ) and to annual surfclam growth rate (NNJ and DMV).

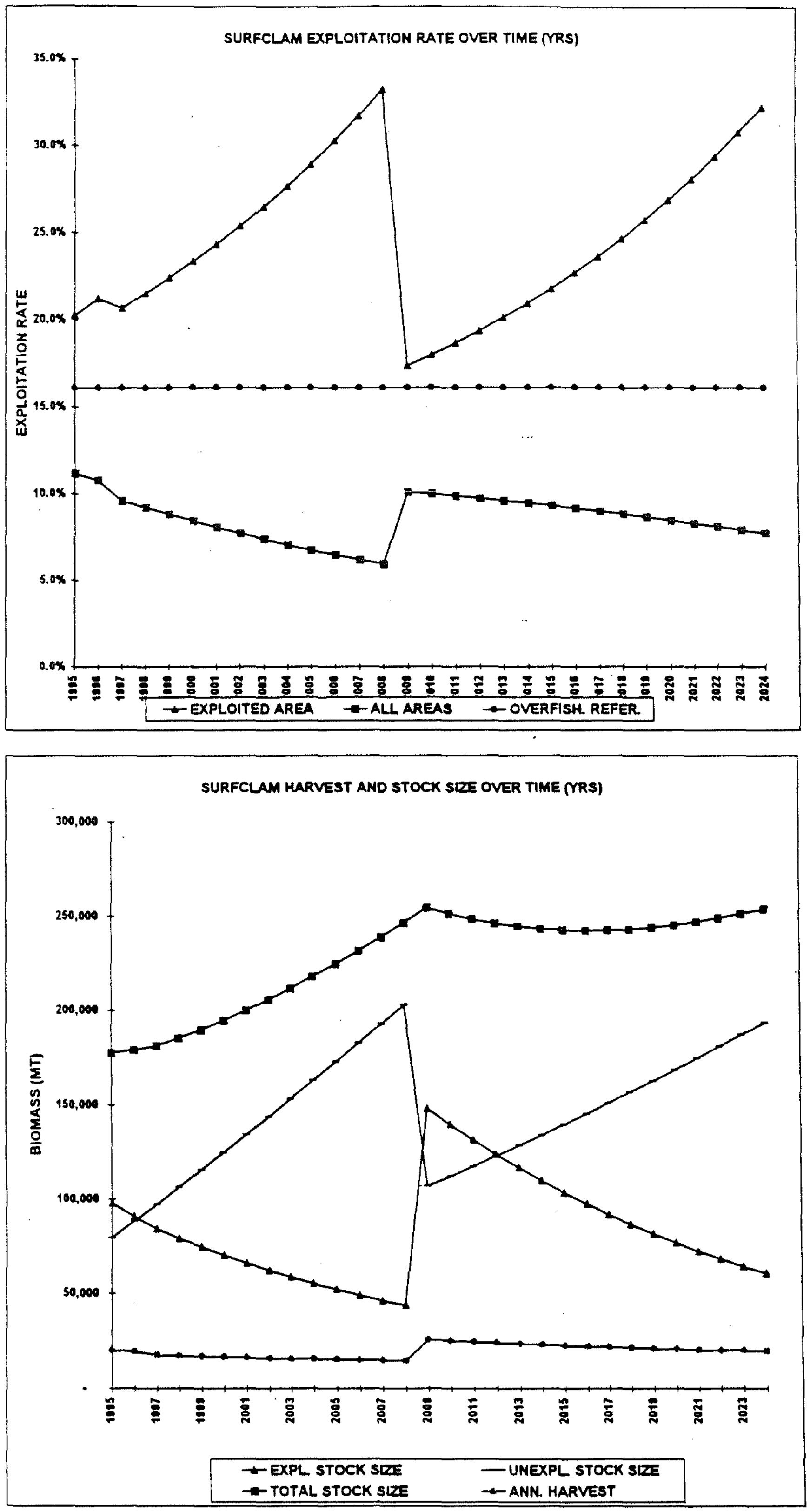
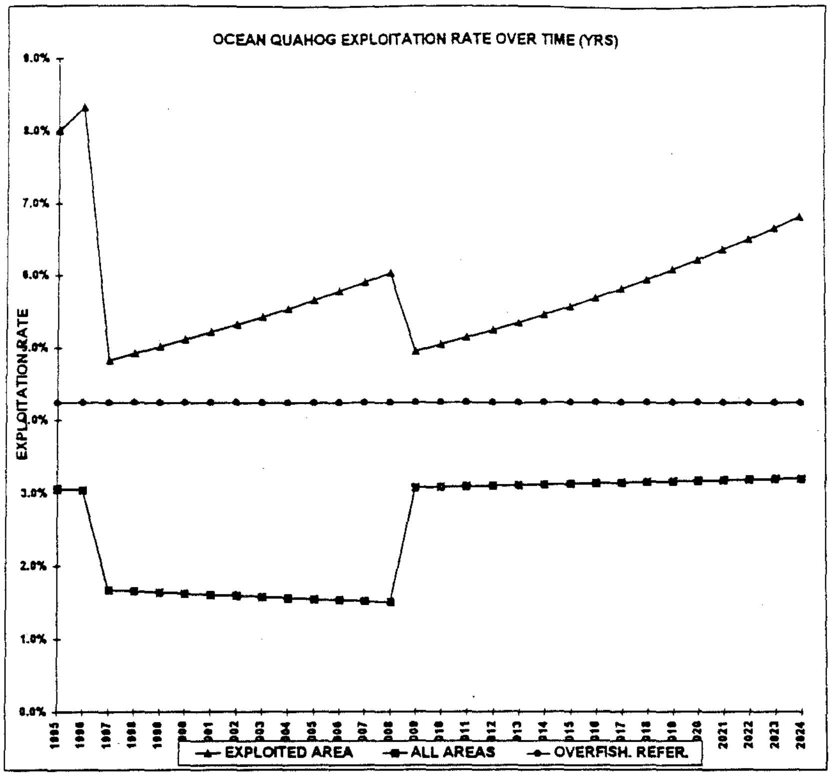


Figure D5. Surfclam exploitation rate over time (years) and surfclam harvest and stock size over time (years).



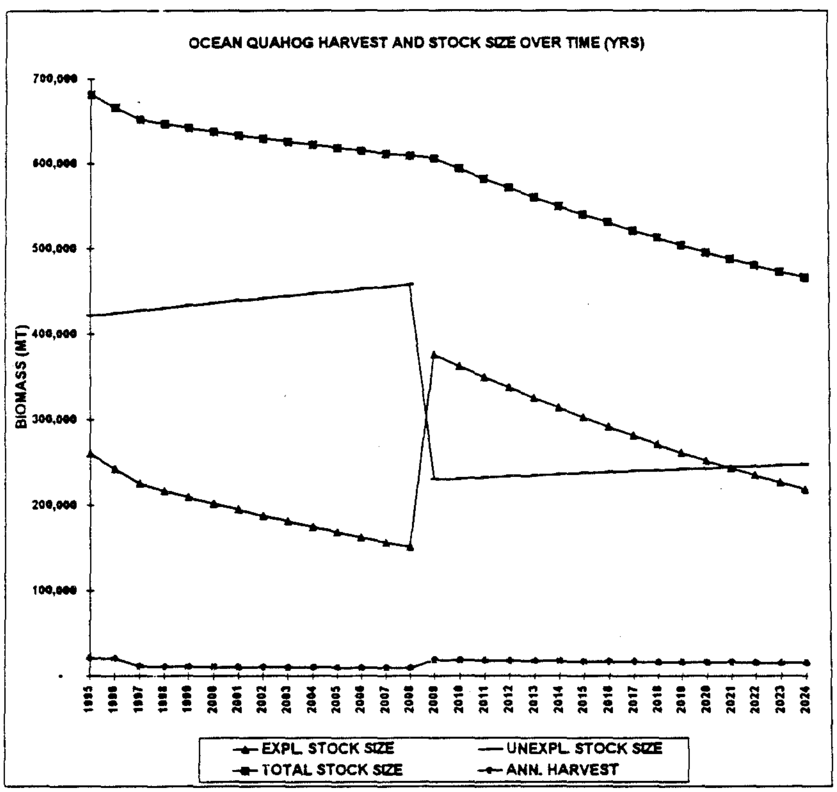


Figure D6. Ocean quahog model. Trial run assuming annual recruitment to the exploited are = 2% of the biomass in 1994.

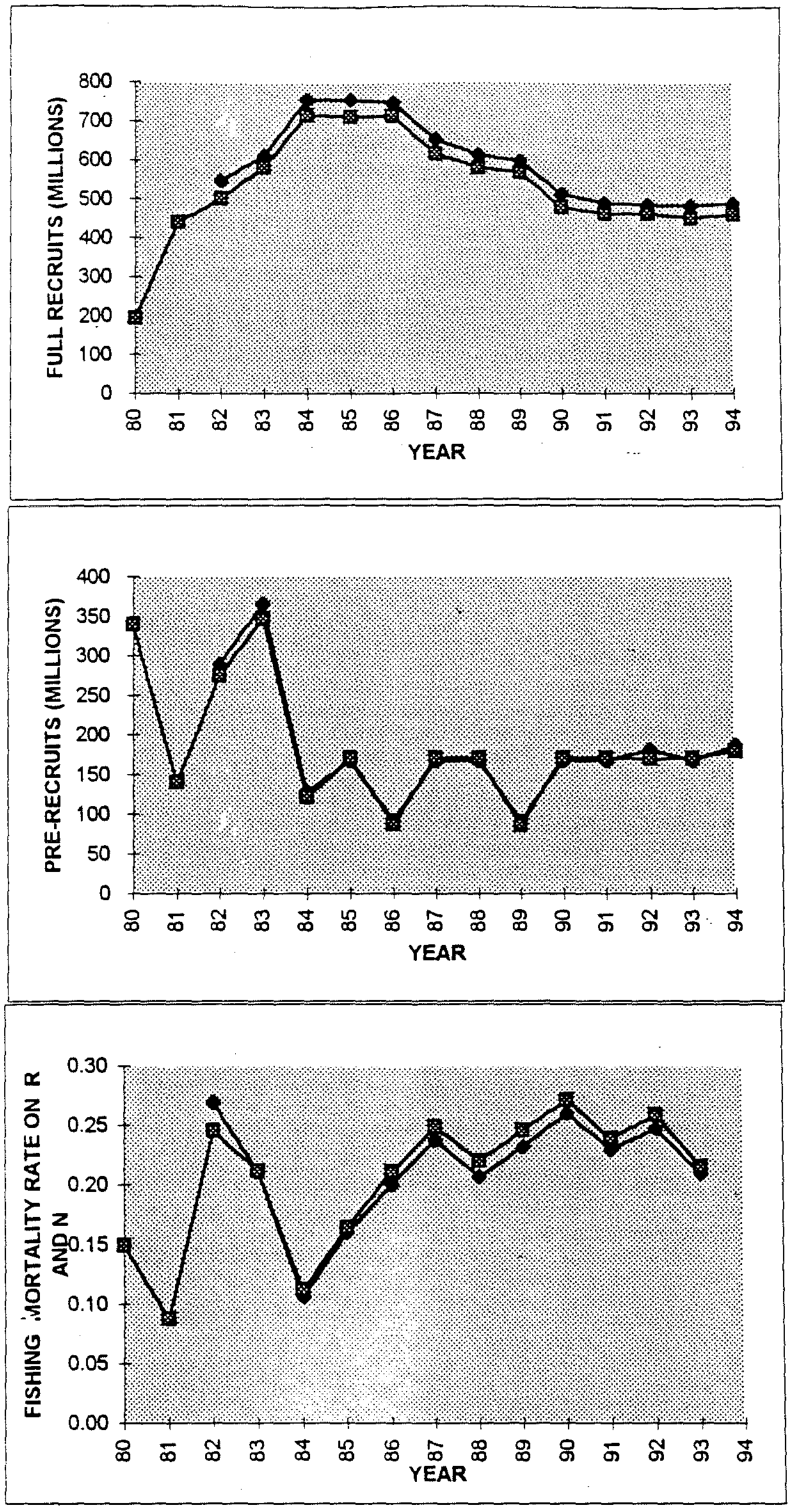


Figure D7. Comparison of results from two runs of modified - DeLury model. One run starts with 1982, the other starts with 1980.

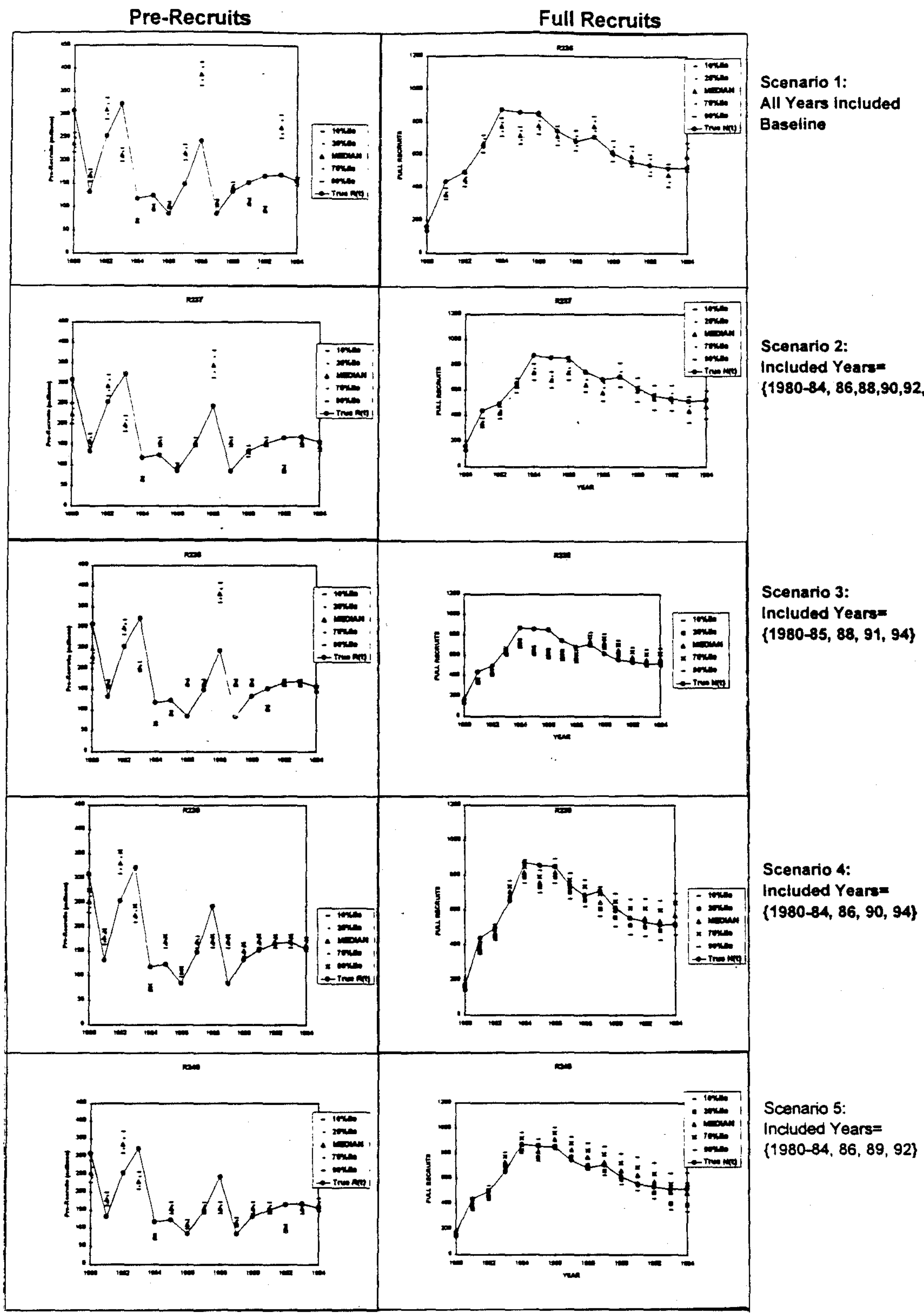
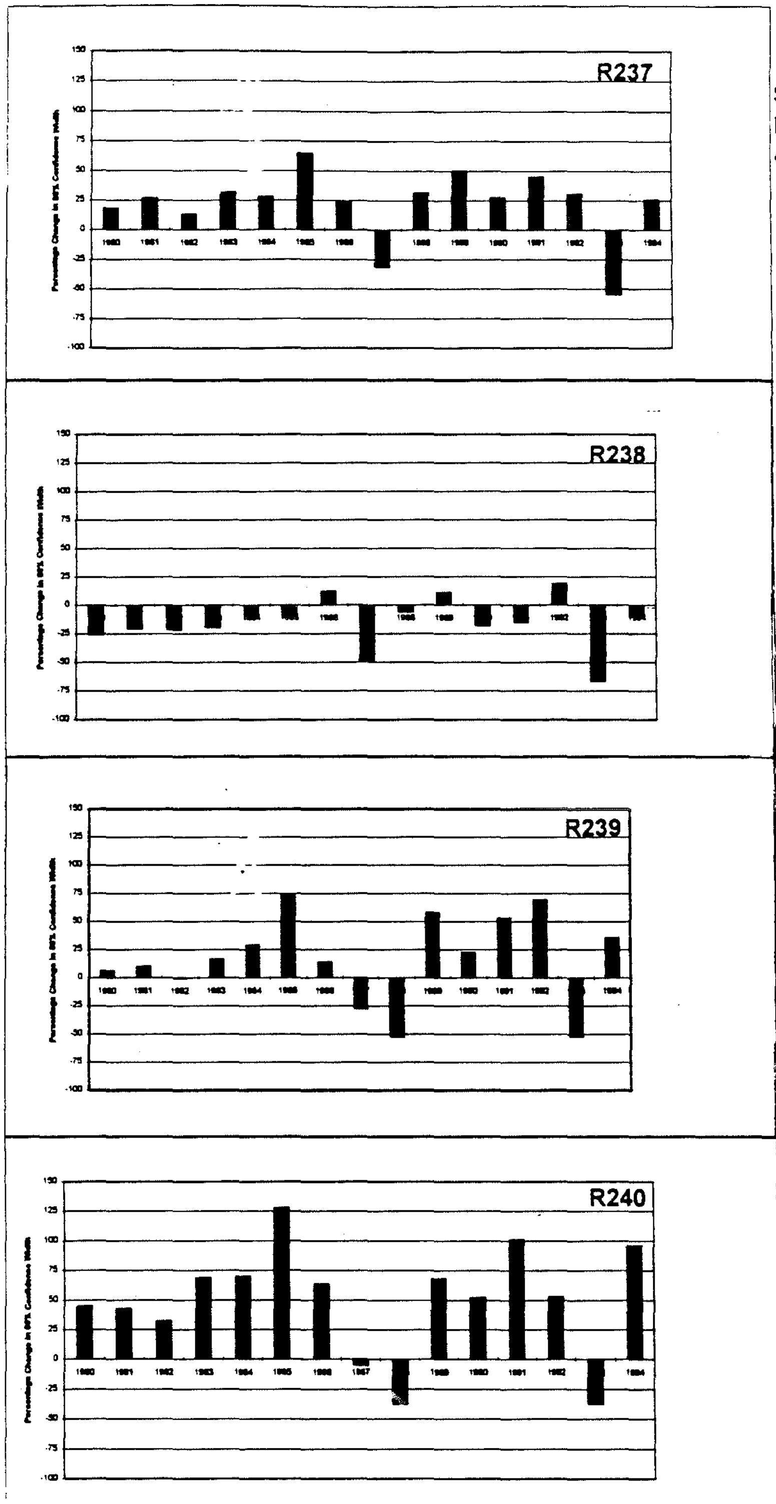


Figure D8. Comparison of true and estimated abundance estimates for pre-recruits and full recruits in the modified DeLury model for five alternative scenarios of survey data availability.

Pre-Recruits



Scenario 2:
Included Years=
{1980-84, 86,88,90,92,94}

Scenario 3:
Included Years=
{1980-85, 88, 91, 94}

Scenario 4:
Included Years=
{1980-84, 86, 90, 94}

Scenario 5:
Included Years=
{1980-84, 86, 89, 92}

Figure D9. Ratio of size of empirical confidence intervals by year for pre-recruits. Estimates are relative to Scenario 1 that incorporated all years in the estimation.

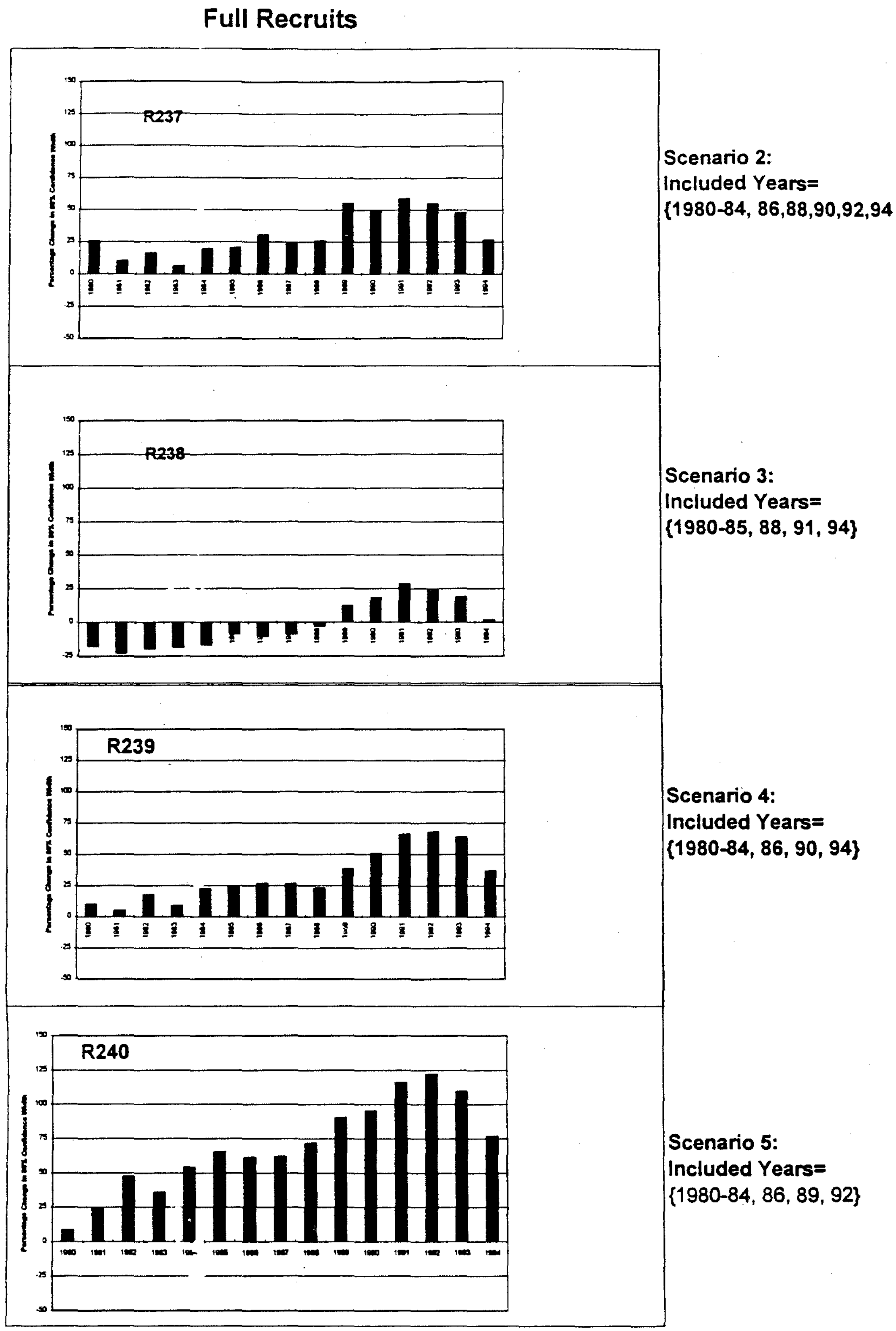


Figure D10. Ratio of size of empirical confidence intervals by year for full recruits. Estimates are relative to Scenario 1 that incorporated all years in the estimation.