Northeast Fisheries Science Center Reference Document 98-03

A Report of the 26th Northeast Regional Stock Assessment Workshop

26th Northeast Regional Stock Assessment Workshop (26th SAW)

Stock Assessment Review Committee (SARC) Consensus Summary of Assessments

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

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MEETING OVERVIEW

The Stock Assessment Review Committee (SARC) meeting of the 26th Northeast Regional Stock Assessment Workshop (26th SAW) was held at the Northeast Fisheries Science Center (NEFSC), Woods Hole, MA during 1-5 December 1997. The SARC Chairman was Dr. Emory Anderson (NEFSC). Members of the SARC included scientists from the NMFS Northeast and Southwest Fisheries Science Centers (NEFSC and SWFSC), the Mid-Atlantic Fishery Management Council (MAFMC), Atlantic States Marine Fisheries Commission (ASMFC), the States of Florida and New York, the Canadian Department of Fisheries and Oceans, and the Virginia Institute of Marine Science (Table 1). In addition, 50 other persons attended some or all of the meeting. Some, including industry representatives, took part in the discussion (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:
Kevin Friedland, NMFS/NEFSC
Wendy Gabriel, NMFS/NEFSC
Han-Lin Lai, NMFS/NEFSC
William Overholtz, NMFS/NEFSC

One person from each regional Fisheries Management Council:
Tom Hoff, MAFMC

Atlantic States Marine Fisheries Commission/State personnel:
Najih Lazar, ASMFC
Kim McKown, NY DEC
Gil McRae, FL DEP

One or more scientists from:
Canada - **Gerald Chaput, DFO, Moncton**
Academia - **John Hoenig, VIMS**
Other Regions - **Lawrence Jacobson, NMFS/SWFSC**

Opening

Dr. Emory Anderson welcomed the participants and introduced the current SARC members and Dr. Steven Murawski, Chief of the NEFSC Population Dynamics Branch, noting that the composition of the SARC varied from meeting to meeting,. He described the SAW process and the responsibilities of the SAW-26 participants, and announced the upcoming assessment meetings.

Table 2. List of participants.

National Marine Fisheries Service
Northeast Fisheries Science Center
Frank Almeida
Gavin Begg
George Bolz
John Boreman
Russell Brown
Steve Cadrin
Janet Fields
Josef Idoine
George Liles
Shih-Wei Ling
Cheryl Milliken
Steve Murawski
Helen Mustafa
Paul Nitschke
Victor Nordahl
Loretta O'Brien
Paul Rago
Fred Serchuk
Tim Sheehan
Gary Shepherd
Laura Shulman
Katherine Sosebee
Mark Terceiro
Chris Weidman
James Weinberg
Susan Wigley
Holly Yochwetz
Southeast Fisheries Science Center
Douglas Vaughan
Mid-Atlantic Fishery Management Council
Rich Seagraves
Atlantic States Marine Fisheries Commission
John Field
Delaware Division of Fish and Wildlife
Desmond Kahn
Massachusetts Division of Marine Fisheries
Paul Caruso
Tom Currier
Paul Diodati
Xi He
Arnold Howe
Jeremy King
David McCarron
Henry Milliken
Rhode Island Division of Fish and Wildlife
Mark Gibson
Center for Marine Conservation
Sonja Fordham
National Fisheries Institute
Niels Moore
New York Sea Grant
Mark Malchoff
North Carolina Fisheries Association
Bill Foster
Sea Watch International
Tom Alspach
United National Fishermen
James Fletcher
US Geological Survey
David Smith
Valerie E. Inc.
Frank Marriner
Doreen Morehouse
Wallace and Associates
David Wallace

Table 3. Agenda of the 26th Northeast Regional Stock Assessment Workshop (SAW-26) Stock Assessment Review Committee (SARC) meeting.

NEFSC Aquarium Conference Room
166 Water Street
Woods Hole, Massachusetts

1 (1:00 PM) **- 5 December** (6:00 PM) **1997**

AGENDA

TOPIC	**WORKING GROUP & PRESENTER(S)**	**SARC LEADER**	**RAPPORTEUR(S)**
MONDAY, 1 December (1:00 PM - 6:00 PM)...			
Opening Welcome Agenda Conduct of meeting	E. Anderson, Chairman		H. Mustafa
Weakfish (A)	ASMFC Weakfish Assess. Subcom. M. Gibson, D. Vaughan, D. Kahn	K. Friedland	D. Vaughan, M. Gibson
TUESDAY, 2 December (9:00 AM - 6:00 PM)...			
Surfclams (B)	Invertebrate Working Group P. Rago, J. Weinberg	T. Hoff	J. Weinberg, P. Rago
WEDNESDAY, 3 December (9:00 AM - 6:00 PM)...			
Striped Bass (C)	ASMFC Striped Bass Assess. Subcom. G. Shepherd, J. Field	N. Lazar	J. Field
Spiny Dogfish (D)	P. Rago, K. Sosebee	J. Hoenig	K. Sosebee, P. Rago
SOCIAL at the Andersons' (7:00 PM)			
THURSDAY, 4 December (9:00 AM - 6:00 PM)...			
Review Advisory Report and Consensus Summary Report sections			
FRIDAY, 5 December (9:00 AM - 6:00 PM)...			
Complete Advisory Report sections			
Review Research Recommendations			
Complete Consensus Summary Report sections			
Review SAW-26 list of recommended publications			
Other Business			H. Mustafa

The Process

The SAW process has been evolving since its establishment in 1985. Currently, there are four main components to the SAW: a Steering Committee consisting of the directors of the partner organizations (NEFSC, NER, MAFMC, NEFMC, and ASMFC); Working Groups that prepare the assessments for review; the SARC that peer reviews the assessments, provides comments and recommendations, and crafts the management advice for each stock on the agenda; and the Public Review Workshop for the presentation of the advice. Although the Workshop is normally held in two sessions as part of the NEFMC and MAFMC meetings, for SAW-26 there will also be a Workshop session for the ASMFC. The first session will be held during the 14-15 January 1998 NEFMC meeting, the second session during the 27-29 January 1998 MAFMC meeting, and the third session during the 2-6 February 1998 ASMFC meeting.

SARC Documentation

SARC documentation includes a *Consensus Summary of Assessments*, containing the terms of reference, a full description of the scientific assessment work, SARC comments, and research recommendations for each stock; and an *Advisory Report on Stock Status*. Both of these documents, when finalized, are published in the NEFSC Reference Document series. Occasionally the SARC also prepares special advisories.

SARC Responsibilities

The responsibilities of the SARC members, presenters, and rapporteurs were reviewed. Members of the SARC are encouraged to fully participate in the discussion and provide constructive comments. Presenters of working papers are either the Working Group chairs or the persons who actually did the work. Rapporteurs are expected to record the major points of discussion for inclusion in the *Consensus Summary of Assessments* sections on SARC comments and research recommendations and to assist in the preparation of subsequent drafts of the *Consensus Summary*. SARC leaders are responsible for insuring that discussion is properly documented and for serving as second rapporteurs.

Joint USA/Canada Stock Assessment Process for Transboundary Resources

To avoid duplication of effort in developing assessments of transboundary resources, a joint USA/Canada Stock Assessment Process for Transboundary Resources is being developed. The components of this process will be a Transboundary Assessment Working Group (TAWG) for the development of assessments, and a Transboundary Resources Assessment Committee (TRAC), similar to the SARC, to review the assessments. There will be 7-8 participants on the TRAC from each country. USA participants will include NMFS personnel, as well as scientists from the states, Councils, and academia. Meeting locations and chairmanship of the TRAC will alternate between Canada and the USA, with the 1998 held in Canada.

Upcoming Assessments

Joint USA/Canada assessment process for transboundary resources

The first TAWG meeting will be held in late March - early April in Woods Hole, MA and will be followed by a TRAC meeting, to review the stock assessments, to be held in St. Andrews, NB 20-24 April 1998. Since the TRAC meeting will be held in Canada, it will be chaired by the Chair of the Canadian Maritimes Regional Advisory Process (RAP). Participants will be selected nearer the dates of the meetings.

The tentative agenda for the April meetings includes Georges Bank cod, Georges Bank haddock, Georges Bank yellowtail flounder, Gulf of Maine cod, Southern New England yellowtail flounder, Gulf of Maine and Georges Bank plaice, and Georges Bank winter flounder. Although the assessments will be jointly prepared and peer reviewed, the advice will be produced separately by each country. The agreed and peer-reviewed assessments will be brought before the SAW-27 SARC for the preparation of advice for USA managers.

Tentative SAW-27 agenda

The tentative SAW-27 agenda includes ocean quahogs, Atlantic herring, Georges Bank winter flounder, Gulf of Maine/Georges Bank plaice, Gulf of Maine cod, Georges Bank cod, Georges Bank haddock, Georges Bank yellowtail flounder, Southern New England yellowtail flounder, black sea bass, and scup. As there were problems in assessing black sea bass and scup at SAW-25 due to serious data inadequacies, it is uncertain how much can be done on these two stocks at SAW-27. Summer flounder, although normally on the agenda of each spring SAW, will not be on the SAW-27 agenda because of an impending NRC review.

The SAW-27 SARC meeting will take place 22 - 26 June, with Workshop sessions sometime in August 1998.

Agenda and Reports

The SAW-26 SARC agenda (Table 3) was devoted to the review of analyses for weakfish, surfclams, striped bass, and spiny dogfish. The weakfish and striped bass assessments were reviewed within the SAW process for the first time. Surfclams were last assessed within the SAW process at SAW-22 in 1996 and spiny dogfish at SAW-18 in 1994. Working papers for review were prepared at meetings indicated in Table 4. No formal working group or committee meetings were held to assess spiny dogfish within SAW-26.

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

Draft sections of this report, as well as the advisory document, were reviewed by SARC members and subsequently assembled into a draft Report of the *26th Northeast Regional Stock Assessment Workshop (26th SAW) Stock Assessment Review Committee (SARC)* and the draft *Advisory Report on Stock Status* for distribution to the SAW Steering Committee and to the participants of the SAW-26 Public Review Workshop sessions.

The Chairman reminded the participants that current meeting documents were without status and were not to be distributed or quoted outside the meeting room.

Highlights of Presentations and Discussion

Review of ADAPT Reprogramming

Dr. Steve Murawski reported that the ADAPT tuning module for VPA used by the NEFSC Population Dynamics Branch had previously been "non-portable". Although the basis for documenting and reprogramming ADAPT from APL into FORTRAN to make it more user-friendly and transportable had been described several years earlier by Dr. Ray Conser, there had been no resources available to perform this task. The need for this had arisen in the spring of 1997 prior to SAW-24 in conjunction with the groundfish assessments and funding was provided to begin a computer programming exercise. The exercise was not limited to the ADAPT program, but included a number of analytical programs used in assessments. Dr. Laura Shulman, a bio-mathematician, was employed to perform the reprogramming task.

Three committees were formed within the Population Dynamics Branch to oversee the reprogramming task:

1. Input-Output Committee headed by Steve Cadrin.

2. Programming Committee headed by Mark Terceiro.

3. Methods Committee, to enhance existing capabilities, headed by Wendy Gabriel.

Dr. Murawski invited scientists outside the NEFSC to join these three committees and explained the ADAPT basic visual shell from which programs can be run. The reprogramming effort had proceeded successfully, and it was intended that this

Table 4. SAW-26 Working Group and ASMFC Subcommittee meetings and participants.

Working Group and Participants		Meeting Date and Place	Stocks/Species
ASMFC Weakfish Stock Assessment Subcommittee		Telephone conferences	Weakfish
V. Crecco, CT DEP (Chair)	R. O'Reilly, VA MRC		
L. Daniel, NC DMF	J. Uphoff, MD DMF		
M. Gibson, RI DFW	D. Vaughan, NMFS/SEFSC		
D. Kahn, DE DFW			
SAW Invertebrate Working Group		16 October 1996	Surfclams
T. Azarovitz, NEFSC	R. Mann, VIMS	18 February 1997	
J. Bryson, MAFMC	N. Moore, NFI	29 May 1997	
C. Byrne, NEFSC	S. Murawski, NEFSC	22-23 October 1997	
C. Carlson, F/V *Elizabeth IIC*	V. Nordahl, NEFSC	11-12 November 1997	
M. Chintala, Rutgers Univ.	E. Powell, Rutgers Univ.	NEFSC, Woods Hole, MA	
D. Cohen, Atlantic Capes	P. Rago, NEFSC (Chair)		
J. DeAlteris, URI	G. Richardson, Blount Seafood		
J. Galbraith, NEFSC	N. Targett, MAFMC		
D. Gouveia, NMFS, NER	W. Wakefield, Rutgers Univ.		
L. Hendrikson, NEFSC	D. Wallace, Wallace and Assoc.		
T. Hoff, MAFMC	C. Weidman, NEFSC/WHOI		
C. Keith, NEFSC	J. Weinberg, NEFSC		
B. Lake, NEFSC	J. Womack, Wallace and Assoc.		
H.L. Lai, NEFSC			
ASMFC Striped Bass Technical Committee		16-17 October 1997	Striped Bass
R. Allen, NJ FGW	M. Gibson, RI DFW	Annapolis, MD	
T. Baum, JN FGW	H. Johnson, NC DMF		
V. Crecco, CT DEP	P. Jones, MD DFW		
J. Field, ASMFC	D. Kahn, DE DFW		
L. Flagg, ME DNR	A. Kahnle, NY DEP		
C. Goshorn, MD DNR	N. Lazar, ASMFC		
S. Grabowski, US FWS	K. McKown, NY DEP		
D. Grout, NH, FG	R. Miller, DE DFW		
K. Haughtily, NY DEP	R. O'Reilly, VA MRC		
P. Himchak, NJ, FGW	I. Palmer, DC Fisheries		
P. Diodati, MA DMF	G. Shepherd, NMFS/NEFSC (Chair)		
E. Setzler-Hamilton,PRFBC	D. Smith, USGS		
X. He, MA DMF	R. Synder, PA FBC		
M. Gibson, RI DFW	V. Vecchio, NY DEP		
P. Rago and K Sosebee, NMFS/NEFSC		Woods Hole, MA	Spiny Dogfish

software would be used for the SAW-27 assessments in the spring of 1998.

Species Presentations

Weakfish

Weakfish have been known to reach a maximum age of 17 years. To date, however, the complicated migratory movements of this species are not well understood. As weakfish occur in shallow coastal and estuarine waters, those within 3 miles of the shore are managed by the ASMFC. In this analysis, weakfish between Massachusetts and Florida were assumed to be a single stock unit.

The presentation included an outline of the history of the fishery management plan developed in

1985 and subsequent amendments, and discussion of data and analyses, as well as a life history based longevity model.

Much of the SARC discussion involved the estimation of stock size and fishing mortality, problems with the VPA and by-catch estimation, assumptions of mortality, and aging methods. The presenters produced a number of requested runs during the meeting and did a retrospective XSA run after the meeting. The retrospective analysis and consequent changes to the advisory report were subsequently distributed to SARC members for their evaluation and approval for inclusion in this report. The SARC recommended a numbers of studies to resolve the problems associated with this assessment, including a study to better understand the aspects of weakfish migration. The SARC concluded that, although weakfish are increasing in abundance, they are fully exploited.

Surfclams

The presentation began with a summary of the history of surfclam management along the USA Atlantic coast through 1986. The current assessment included new data collected in 1997, as well as revised biological reference points for three regions. A set of analyses were devoted to the stock off the Delmarva Peninsula. Papers on surfclam growth by Weinberg and Helser (1996) and Weinberg (in press) provided background for the analysis of the 1997 data from the Delmarva region. The DeLury model, first used during SAW-19 (1994), was the basis for the 1996 SAW-22 assessment. Since that time, the R/V *Delaware II* had been refurbished and a new winch installed. Depletion experiments and other studies to determine the efficiency of the survey dredge were conducted in May-July 1997 in conjunction with the industry. New growth rate parameters were evaluated and a new production model based on growth rates was developed.

The SARC discussion focussed on data, analyses, techniques, and the relationship between the 1997 and previous surveys. With the aid of transparencies and a video, the current survey dredge operation was described. This was the first time that sensors had been used in connection with this survey. As a result, massive databases had been generated which were taking a long time to process. The analysis of a randomized block design experiment to examine the effect of scope and towing velocity was still ongoing and should be completed in time for use of the results in the next survey.

Much of the SARC discussion centered around the production model, biological reference points, the 10-year supply calculations, and the uncertainty about natural mortality. Members of the industry contributed heavily to the discussion.

The SARC concluded that the EEZ surfclam resource is at a medium level of biomass and is probably under-exploited overall.

Striped bass

The coast-wide assessment included the Albemarle Sound, Chesapeake Bay, Delaware River, and Hudson River stocks. The presentation included a review of the use of a spawning stock biomass model by Crecco and Rugolo to project quotas; a paper by Rugolo and Markham (1996) on the comparison of empirical and model-based indices of reactive spawning stock biomass; an overview of methods to estimate annual mortality from tag-recovery data by Smith and He; and the methodology for the estimation of F_{msy} for striped bass.

SARC discussion included the differences and utility of the SSB models, VPA analyses resulting in the recommendations for some very specific studies and evaluations, as well as increased sea sampling of commercial fisheries which may have high levels of discards. The SARC made a number of very specific research recommendations for studies and evaluations, including one to increase the sea sampling of commercial fisheries which may have high levels of discards.

The SARC concluded that, based on observations since 1960, the coastal complex, although fully exploited, is at a relatively high biomass level.

Spiny dogfish

Spiny dogfish occur from Labrador to Florida and are considered to be a unit stock.

The current assessment is basically an update of the 1994 SAW-18 assessment incorporating data through 1997. There were detailed analyses of trends in length composition of landings and surveys, trends in recruitment, application of a Beverton and Holt mortality estimator, comparison of observed length-specific sex ratios and predictions of a mechanistic life history model, and correction of predicted yield-per-recruit estimates from SAW-18. Implications of 1982-1996 fishing mortality patterns for yield- and pups-per-recruit were evaluated, and a new biological reference point based on pup production per recruit necessary for equilibrium was proposed. The SARC concluded that, although the stock is presently at a moderate biomass level, there has been a severe reduction in the mature component of the fishery, which can affect recruitment, and the stock is over-exploited.

General

In discussion, several members of the SARC raised the question of the appropriateness of specific management advice forthcoming from the SARC. It was suggested, based on experience elsewhere, that management advice should perhaps not be provided by the same group which does a technical review of an assessment, and that the SARC's product should only be the best possible, technically reviewed status-of-the-stocks document.

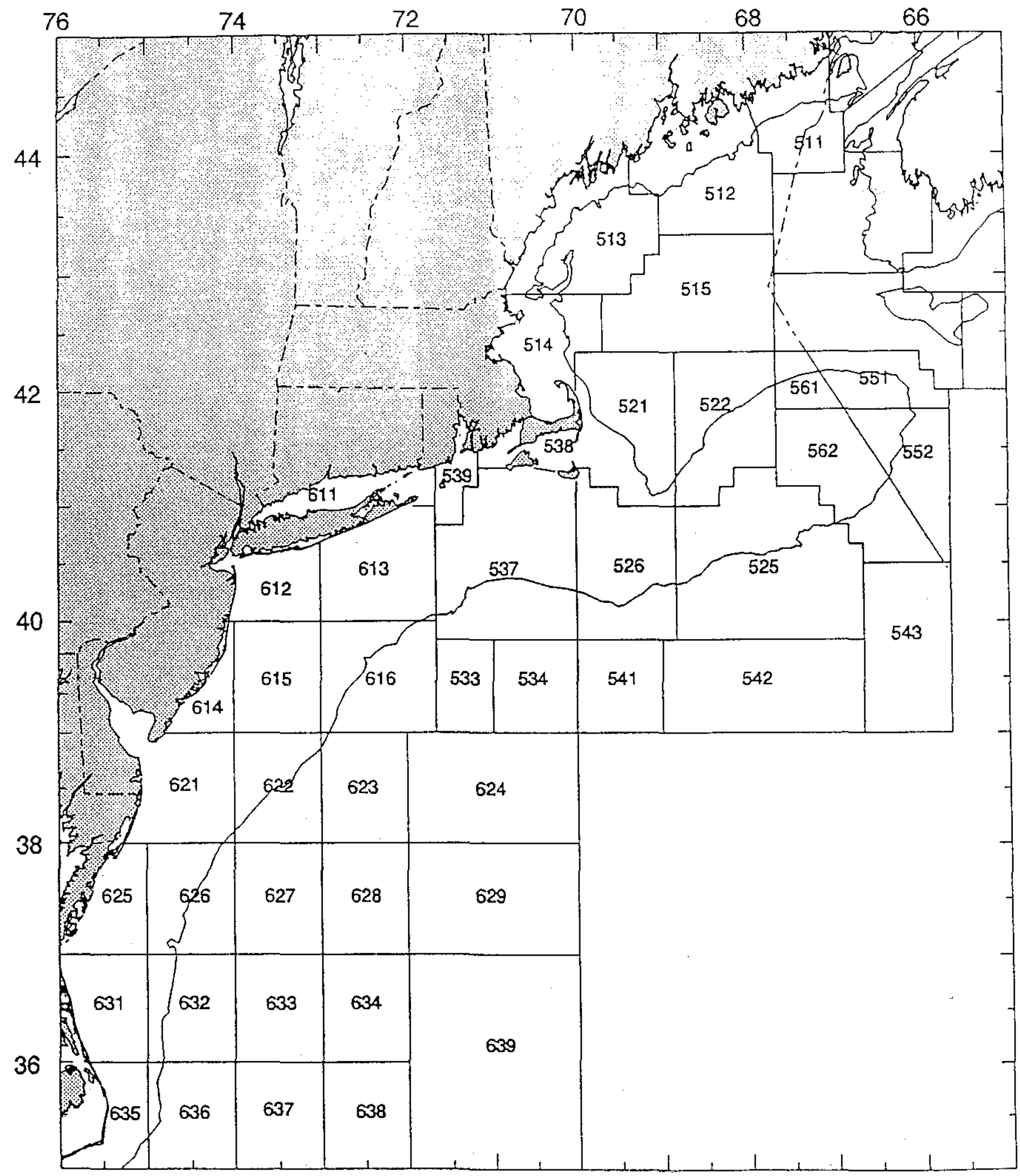

Figure 1. Statistical areas used for catch monitoring in offshore fisheries in the Northeast United States.

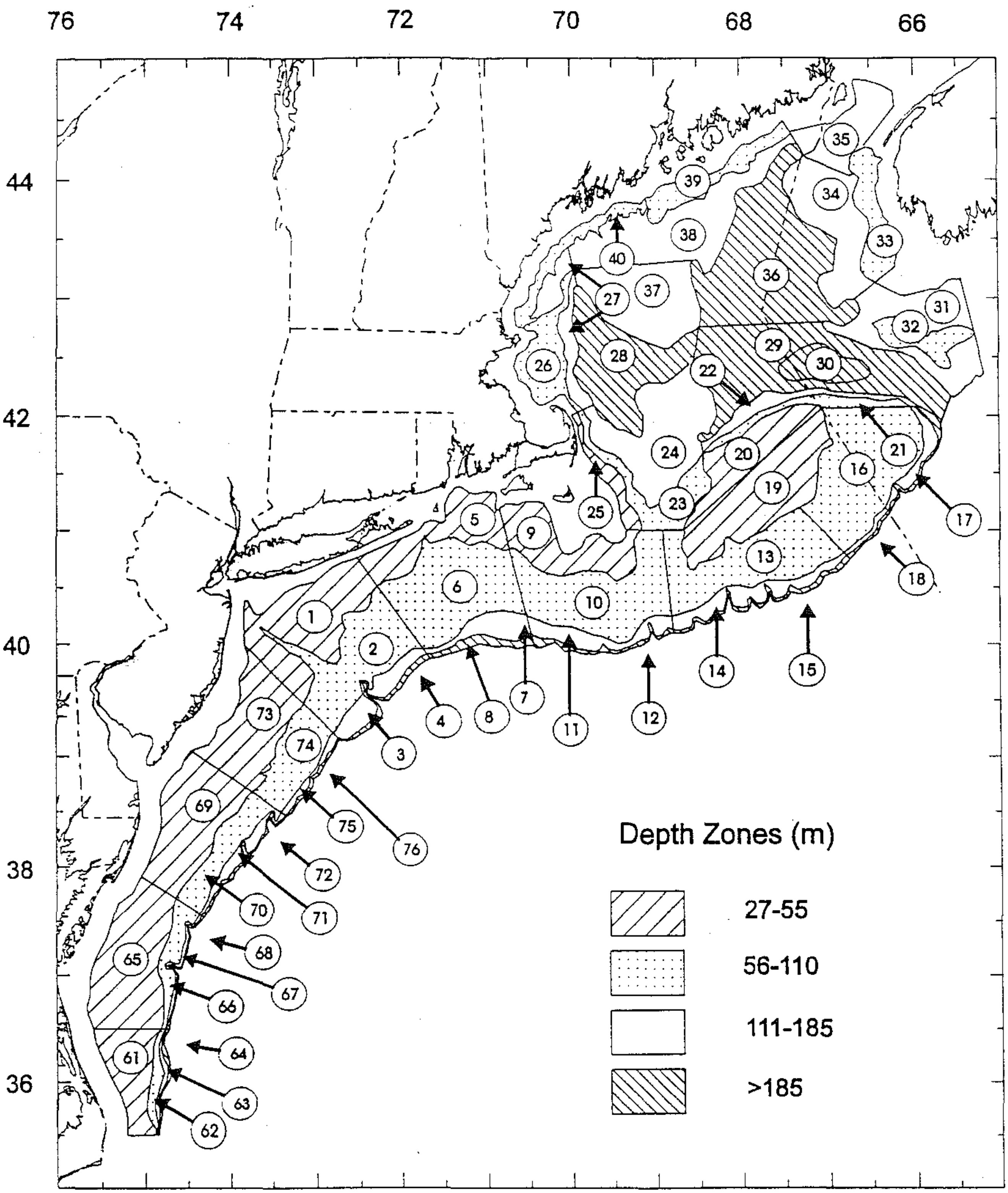

Figure 2. Offshore sampling strata used in NEFSC bottom trawl surveys.

A. WEAKFISH

Terms of Reference

a. Summarize life history, recreational and commercial landings and available age-length data by state, Florida to Massachusetts.

b. Summarize available indices of stock abundance by state.

c. Estimate age composition of recreational and commercial landings.

d. Provide estimates of fishing mortality.

e. Conduct a full age-based VPA and yield-per-recruit and spawning stock biomass-per-recruit analyses.

f. Review progress towards meeting the Plan goals in Amendment 3 to the Weakfish FMP, including mortality targets and age composition.

Introduction

Weakfish (*Cynoscion regalis*) have supported fisheries along the Atlantic coast of the US since the early 19th century. The species is distributed from Maine to Florida and is known to undergo extensive seasonal migrations, moving north in spring and summer and south during fall and winter. Weakfish occur in shallow coastal and estuarine waters where they are highly sought after by both commercial and recreational fishermen. The migratory nature and economic importance of weakfish has led to the development of coast-wide management plans by the Atlantic States Marine Fisheries Commission (ASMFC) in 1985 (Mercer 1985), 1992 (Seagraves 1991), and 1997 (Lockhart *et al.* 1996). Weakfish are managed in state waters (≤3 miles from shore) by the ASMFC Management Board (MB) with assistance from the Weakfish Technical Committee (TC) and Weakfish Advisory Panel (AP). In Federal waters of the Exclusive Economic Zone (EEZ) (from 3 to 200 miles offshore), weakfish are managed by the Fishery Management Councils and the US Department of Commerce.

Under Amendment 3 of the Weakfish Management Plan (Lockhart *et al.* 1996), fishing mortality (F) from the weakfish commercial fishery is currently regulated by a combination of measures including seasonal closures, area closures, and mesh regulations (L_{25}) at a preferred minimum size of 12 in. In addition to reducing bycatch mortality on age 0 and 1 weakfish, the Plan strongly encourages the use of bycatch reduction devices (BRD) for the shrimp fishery in the South Atlantic. The weakfish recreational fishery is regulated in the Plan by reduced daily creel limits at a preferred minimum size of 12 in. Amendment 3 of the Weakfish Plan is designed to reduce fishing mortality rates (F) to a target level of F = 0.50 by the year 2000. Several interim targets are included in the F reduction schedule. Quota management has not yet been used to regulate weakfish harvest along the Atlantic coast.

The weakfish is a fast-growing and moderately long-lived species, reaching maximum ages of 16-18 years (Mercer 1985). Male weakfish appear to grow more slowly than female weakfish, at least up to age 6 (Figure A1). Weakfish spend most of their adult life in coastal and estuarine waters, migrating onshore/offshore. Weakfish achieve a maximum size of between 81 and 89 cm total length. Mature female weakfish (age 1+) spawn large quantities of eggs both within estuaries and nearshore waters from March to September. Recent research on weakfish (Lowerre-Barbiere 1996) has indicated that female weakfish release their eggs over a period of time rather than all at once (batch spawning).

Weakfish appear to move north and inshore during the summer, and to the south and offshore during winter to depths of 100 m. Important wintering grounds for the weakfish stock are located on the continental shelf from Chesapeake Bay to Cape Lookout, North Carolina. As water temperatures rise in the spring, mature weakfish migrate to nearshore spawning grounds to complete their life cycle.

The ASMFC Weakfish Technical Committee evaluated the status of Atlantic weakfish, assuming a single unit stock. The single unit-stock concept was based on results of recent stock identification studies (Scoles 1990; Graves *et al.* 1991) which indicated that the Atlantic coast weakfish should be managed as a single, large interdependent unit.

Fishery Data

Commercial Landings

Total US commercial landings of weakfish from Massachusetts to Florida from 1970 to 1996 peaked in 1980 at 16,312 mt, then declined steadily thereafter to a low of 2,873 mt in 1994 (Table A1). The 1995 (3,220 mt) and 1996 (3,290 mt) commercial landings exceeded the 1994 landings (2,873 mt) by about 12 to 15%. Commercial landings by state have varied greatly from 1979 to 1996 (Table A2), but commercial weakfish landings from the states of Virginia and North Carolina have greatly dominated, comprising between 70 and 85% of the total coast-wide commercial landings.

Coast-wide commercial weakfish landings from 1970-1996 have been harvested with a variety of gear types including haul seines (12%), otter trawls (49%), pound nets (18%), gillnets (19%), and other (2%) (Figure A2, Tables A3a and A3b). Most of the commercial weakfish landings have been harvested from the South Atlantic (Figure A3), primarily by trawl and gillnet. In North Carolina, where annual commercial landings have been highest (Table A2), weakfish have been harvested primarily by gillnets (76%) (Tables A4a and A4b). Commercial scrap landings, or landings for industrial purposes, peaked at 4,550 mt in 1988 (Figure A4). With increasing minimum size limits and mesh regulations, scrap landings have declined to low levels.

Recreational Landings

Estimates of weakfish recreational catch (A, B1, and B2) and harvest (A and B1) by weight (kg) and number have been derived by the National Marine Fisheries Service Marine Recreational Fishing Statistics Survey (MRFSS) from 1982 to 1996 (Tables A1 and A5). The type A designation in the recreational survey refers to fish harvested and available for length measurement, whereas type B1 refers to fish harvested, but not available for sampling. The B2 designation refers to fish released alive, of which 20% were assumed to die due to hook-release mortality (i.e., 0.2 * B2). The 20% hook-release mortality rate for weakfish was based on results from recent studies on weakfish (Malchoff and Heins 1997) and on spotted seatrout (*Cynoscion nebulosus*), a closely related species (Murphy *et al.* 1995). The proportion of weakfish released (B2 catches) in the recreational fishery has risen abruptly since 1990 to over 40% of the catch (Table A5). This rise in B2 is mainly due to the implementation of higher minimum size limits (size limits from 12 to 16 in.) and lower creel limits on the weakfish recreational fishery (Lockhart *et al.* 1996).

Total recreational weakfish landings (A, B1, and 20% of B2) in weight (mt) were high (range: 2,554 mt to 5,377 mt) and relatively stable from 1982 to 1988 (Table A1), but landings declined thereafter to a low of 597 mt in 1993. Recreational landings rose to 1,850 mt in 1996 (Table A1). The pattern in recreational landings in number (N*1000) from 1982 to 1996 was similar (Table A5) to the pattern exhibited for harvest in weight.

The coast-wide recreational weakfish harvest in weight (mt) and numbers has been clearly dominated by landing from the Mid-Atlantic (NY-VA) sub-region from 1982 to 1996 (94.4%). The percentage contribution of the coast-wide recreational landings in weight (mt) from the North Atlantic (ME-CT) and South Atlantic (NC-FL) was 1.2 and 4.4%, respectively. Landings of weakfish from scrap, commercial, and recreational fisheries are compared in Figure A6.

A time series of recreational fishing effort (trips) directed on weakfish was derived from 1982 to 1996 (Table A6). Directed effort was derived as the product of the estimated total recreational trips made along the Atlantic coast times the fraction of fishing trips which indicated that weakfish was the primary or secondary finfish species sought during the MRFSS access intercept surveys by wave, fishing mode, and strata. Recreational catch per effort (CPUE) was estimated as a ratio between estimated total catch and effort. Weakfish CPUE declined to low levels between 1982 and 1985, then rose to high levels from 1986 to 1988 (Table A6), although the 1988 peak is based on an unusually low effort estimate. A second period of low CPUE occurred during 1989-1991. Weakfish CPUE has been rising steadily since 1991. The recreational CPUE index was dissagregated using the age composition data to provide age-specific tuning indices for VPA (ages 3-6).

Research Survey Abundance Indices

Fishery-Independent Surveys

NMFS fall survey

Age-structured abundance indices were developed from stratified random bottom trawl surveys conducted by the NMFS (NEFSC) between Cape Hatteras and Nova Scotia. Survey length frequencies were aged by applying annual late season age length keys from pooled commercial and research samples. During 1982-1990, the keys were coast-wide. Since 1991, the keys used were developed from the Mid-Atlantic region. Weakfish are rarely caught in this survey north of New Jersey.

Weakfish are infrequent in the spring surveys, but are intercepted during migration by the inshore fall survey. In general, abundance and age structure were strongest in the 1980s, declined in the 1990s, and have recently begun to rebuild (Table A7). For example, few age 5 fish were sampled between 1989 and 1995, but the 1996 value was the highest since 1984. No age 6 or 7+ fish have been collected since 1986, however. Abundance of ages 2 and 3 weakfish has increased by an order of magnitude in recent years, exceeding even values of the 1980s. Age 0 weakfish may not be fully recruited to this gear, though the 1995 year-class was the largest in the time series.

SEAMAP spring and fall surveys

The Southeast Area Monitoring and Assessment Program (SEAMAP) has conducted trawl surveys since 1989 which sample from Cape Hatteras to Cape Canaveral. Survey length frequencies were aged with annual late-season keys from 1989-1990 and annual late-season South Atlantic keys from 1991-1996. The keys were developed from pooled commercial and research samples.

Age structure is truncated in the survey catch-at-age matrix (Table A8). This may be due to mortality, migration northward with maturation, or life history variation in the southern range of weakfish. Although age 0 fish are captured in the fall survey, they may not be fully recruited to this gear. Total catch in the spring survey declined in recent years. The opposite has occurred in the fall survey, partly due to increasing recruitment to the age 0 category, with an order of magnitude increase in some recent years. Age 1 weakfish have declined slightly in the spring survey, but increased recently in the fall survey. In the spring survey, ages 2 and 3 weakfish declined in 1993 and 1994, but have returned to former levels in 1995 and 1996. There is no obvious trend in the fall survey catch of ages 3 and 4.

New Jersey ocean trawl program

Since 1988, New Jersey has conducted an ocean trawl program using a stratified random design. Length frequency data from the period April-October was used to develop a catch-at-age matrix from the annual late-season keys based on pooled commercial and recreational samples. Since 1991, late-season Mid-Atlantic keys were applied.

The time series shows an upward trend in the catch (Table A9). Total catch since 1994 has been higher than any previous years. Catch of ages 2-7+ has increased by an order of magnitude since 1994. In the 4-7+ grouping, an order of magnitude increase has occurred since 1995, when the first age 5 fish were also taken. Catch of age 4 weakfish jumped in 1995 as well. The age structure is beginning to fill out, although no age 6 or older fish have been taken. Age 0 weakfish are not fully recruited to this gear, and there is no obvious trend in recruitment. The 1989 and 1995 year classes had the highest catch-at-age index, while 1990 and 1992 were the weakest year classes represented.

Delaware DFW Delaware Bay trawl survey

The Delaware Division of Fish and Wildlife has conducted a fixed station trawl survey of Delaware Bay using a 30-ft headrope since 1966 in three separate contiguous periods: 1966-1971, 1979-1984, and 1990-1996 (Table A10). Length frequencies were aged with a pooled key from 1966-1989. Fish were aged individually using scales from 1990-1995 and otoliths in 1996.

The early data from the survey clearly show the recolonization of Delaware Bay by a strong 1966 year class. Total catch, in number per nautical mile, was moderate from 1982-1984, resumed in 1990 at a somewhat higher level, and increased an order of magnitude in 1993. During the 1990s, age structure has advanced from a maximum of age 3 in 1992 to age 6 in 1996. Number of 4-7+ per nautical mile has increased by three orders of magnitude since 1992. Current age structure, however, is still truncated relative to that of the 1980s. Age 0 weakfish are not fully recruited to this gear.

Massachusetts DMF trawl survey south of Cape Cod

A stratified random trawl survey conducted by the Massachusetts Division of Marine Fisheries catches young of the year weakfish south of Cape Cod. This area is likely near the northern end of the range for Atlantic weakfish. Due to sparse catches, the total number caught per year was used as an index of abundance (Table A11). Catches were high in the 1980s, peaking in 1985. They declined in 1987 and remained generally low until 1995.

Rhode Island integrated Narragansett Bay trawl index

Three agencies conduct research trawl surveys in Narragansett Bay: the Rhode Island Division of Fish and Wildlife, the University of Rhode Island Graduate School of Oceanography, and New England Power. The surveys vary in terms of spatial coverage with the utilities survey restricted to the upper Bay and the University survey in the west passage of the Bay. The RIDFW survey is bay wide. Weakfish YOY indices from these surveys were integrated into a single index. The survey values were first each reduced to Z scores. For each year, the values were averaged and then back-transformed to units on the scale of the RIDFW survey (Table A12). The largest year class occurred in 1996. Other large year classes were in 1980, 1990, and 1994. Weak year classes appeared in 1984, 1986, 1989, and 1995.

Connecticut DEP Long Island Sound trawl survey

Since 1984, the Connecticut DEP has conducted trawl surveys in Long Island Sound. The survey catches mostly YOY and age 1 weakfish as defined by examination of length frequencies (Table A13). Strong YOY indices appeared in 1996, 1994, 1991, and 1986, while weak YOY indices appeared in 1988, 1987, and 1984. The two strongest age 1 indices were 1995 and 1996, with other strong indices in 1984 and 1991. The weakest age 1 indices were from 1988-1990.

NYDEC Peconic Bay juvenile trawl survey

The New York Division of Fish, Wildlife and Marine Resources conducts a juvenile trawl survey using a 16-ft net targeting juvenile estuarine finfishes in the Peconic Bay of Eastern Long Island. Begun in 1985, the survey indicates strong year classes occurred in 1991 and 1996, with weak recruitment in 1987-1989 and 1993 (Table A14).

Delaware DFW Delaware Bay juvenile trawl survey

The Delaware Division of Fish and Wildlife conducts a juvenile trawl survey in Delaware Bay with a 16-ft net. YOY weakfish are a significant component of the catch. Data since 1982 indicate the highest value occurred in 1991, with above-average indices since then (Table A15). Lowest indices occurred in 1983, 1987, and 1988.

Maryland DNR Chesapeake Bay and coastal bays juvenile trawl surveys

The Maryland Department of Natural Resources conducts two juvenile trawl surveys, one in Chesapeake Bay from 1980 to the present and one in the coastal bays from 1972 to the present. Both employ 16-ft trawls. The Chesapeake Bay index shows high weakfish recruitment since 1992, with 1995 and 1996 the highest values recorded (Table A16). Other strong year classes occurred in 1983 and 1985. Low values occurred in 1981-1982, 1984, and 1988-1989. The coastal bays index showed strong recruitment in 1978, 1982, 1986, 1995, and 1996 (Table A17). Weak indices occurred in 1973, 1974, 1980, and 1988.

Virginia Institute of Marine Science Chesapeake Bay trawl survey

The Virginia Institute of Marine Science (VIMS) conducts a trawl survey in lower Chesapeake Bay. For weakfish, an index of recruitment is computed using August-October tows from three river tributaries. The indices for weakfish show strong year classes in 1985 and 1990, with moderate indices in 1987-1989 (Table A18). Year classes in 1991-1993 were also moderate. Poor recruitment occurred in 1979, 1981, 1984, 1986, 1994, and 1996.

North Carolina DMF Pamlico Sound juvenile trawl survey

The North Carolina Division of Marine Fisheries conducts a juvenile trawl survey in Pamlico Sound. Data are available from 1987 to the present (Table A19). Strong year classes occurred in 1988, 1994, and 1996. Weak recruitment occurred in 1987, 1989, and 1993.

Trends in indices of abundance and exploitation rate

At the request of the SARC, LOWESS smoothing (Cleveland 1979) was applied to the above indices of abundance. First, individual indices of juvenile abundance (age 0) were plotted (Figure A7), including an integrated value derived by calculating standard normal deviates for each state index, averaging over all of them, and then retransforming to the original currency of the NEFSC/NMFS inshore fall survey. The same procedure was employed for ages 1, 2, 3, 4+, and for the total (ages 1+) (Figures A8-A12). Included with these plots are indices based on catch per trip from the recreational fishery (MRFSS). Most, but not all, of these indices are seen to rise rapidly in recent years. In some cases (RI, DE surveys), the LOWESS smoothing failed to reflect a large increase in 1996.

Additionally, LOWESS smoothing of estimates of catch per effort and relative exploitation rates were requested by the SARC for the NMFS fall survey and MRFSS data sets (Figure A13). Total landings were divided by catch per effort in weight of age 1+ fish (kg/tow for the NEFSC/NMFS fall survey, and kg/trip for the MRFSS). Catch per effort is shown to bottom out in the early 1990s, while relative exploitation rates peak at about the same time.

Finally, LOWESS smoothing of catch-curve estimates of total mortaltiy (Z) based on catch in numbers of ages 4+ divided by catch in numbers of ages 3+ the previous year are plotted for combined age-specific indices (Figure A14). This was repeated for ages 5+ divided by the previous year ages 4+. Initially, the NMFS fall survey and MRFSS indices alone were combined using the method of standard normal deviates and put in MRFSS currency, and then those two indices and the NJ and DE age-specific indices were all combined and again put in MRFSS currency. Plots based on age 4+ divided by age 3+ show a downward trend in Z over recent years. Limited data at age 5+ probably resulted in less obvious trends.

Catch-At-Age Matrix

Estimates of the catch-at-age matrices for data through the 1996 calendar year were made. The catch-at-age matrices are assembled by calendar year 1982 through 1996 (15 years). Removals by recreational and commercial (market) landings, and losses to scrap/bait are included in the catch-at-age matrices described in this section. Losses due to bycatch in the shrimp trawl fishery are not estimated in this section.

Age and Growth

The weight (W in pounds) - total length (TL in inches) relationship is re-estimated based on the 1982-1996 aged data base:

$$W = exp(-7.946 + 2.985 * ln(TL) + 0.5 * 0.021) \quad (1a)$$

where 0.021 is the mean squared error, n = 11,992, and r^2 = 0.99. This relationship is used throughout these analyses with two exceptions. MRFSS fish weight is calculated from length based on MRFSS data from 1982-1996:

$$W = exp(-7.308 + 2.744*ln(TL) + 0.5*0.005) \quad (1b)$$

where 0.005 is the mean squared error, n = 27,056, and r^2 = 0.88. Commercial fish weight for Virginia and north is calculated from length based on Virginia commercial data from 1989-1996:

$$W = exp(-8.144 + 3.0548*ln(TL) + 0.5*0.023) \quad (1c)$$

where 0.023 is the mean squared error, n = 66,218, and r^2 = 0.96. The total length (TL in mm) - fork length (FL in mm) relationship (p 6 in Vaughan *et al.* 1991) was used:

$$TL = -6.794 + 1.045\ FL \quad (2)$$

where r^2 = 0.996 and n = 788.

Since 1982, aging data were available from the following states and years from scales (n = 17,010; Appendix A): North Carolina, 1982-1983 and 1988-1995; Maryland, 1985-1986 and 1993-1995; Delaware, 1992-1996; and New York, 1988-1990 and 1992-1996. Data were also available from the following states and years from otoliths (n = 12,875): Florida, 1993-1995, SEAMAP, 1991-1996; North Carolina, 1995-1996; Virginia, 1989-1992 and 1995-1996; Maryland, 1994 and 1996; Delaware, 1995-1996; New Jersey, 1995-1996; New York, 1995; and from the NEFSC fall trawl survey, 1996.

A detailed scale-otolith comparison was conducted on 2,318 weakfish (1,289 from Delaware, 95 from Maryland, 663 from North Carolina, 114 from New York, and 157 from Virginia). Because of discrepancies in assigned ages from matched scale and otolith samples (Daniel and Vaughan 1997), the Weakfish Stock Assessment Subcommittee recommended that two additional sets of age-length keys be developed: one in which scales are transformed to otoliths (Table A20), and vice versa (Table A21). The transformations are developed separately for each region and season (Mid-Atlantic vs South Atlantic, and early season vs late season). All comparison data were used to convert ages (based on otoliths or scales) rather than just those which were statistically significant to reduce possible excess accumulation of catch at age 5. Also, the catch matrix based on simply pooling ages from both scales and otoliths was updated and included for comparison purposes. Pooling across aging approaches was the method used prior to this year.

Transformation for scale ages in the primary data base to otolith ages was accomplished as follows. All otolith ages are assigned a weighting of 1. For each scale-aged fish, a series of otolith ages are assigned a weighting depending upon the area, period, and scale age as given in Table A20. Scale ages were transformed to otolith ages for all ages, not just those scale ages for which the mean otolith age was significantly different than the scale age (Campana *et al.* 1995). PROC FREQ in SAS is then used to create age-length keys, using the WEIGHT option. This weighting approach, analogous to application of an age-length key, was conducted in this fashion to allow for mixing of two different aging techniques while developing a single key. Otolith ages were transformed to scale ages for all otolith ages in a similar fashion.

Age-length keys were developed as described in Vaughan *et al.* (1991) in half-year increments coastwide from early 1982 through late 1990. Region-specific age-length keys were developed in half-year increments from early 1991 through late 1996. Sample sizes for age-length keys are summarized in Appendix A. As before, when sample size for a given length interval fell below 10, pooled data for the early (1982-1990) or late (1991-1996) time periods were used.

Mean total length (in) and mean weight (lbs, based on Equation 1a) are calculated by age for the otolith- and scale-aged weakfish from the period 1989-1996 (Table A22). Mean total lengths at age are compared for otolith- and scale-aged weakfish for the same time period (1989-1996, Figure A1a). For otolith-aged fish, mean total lengths at age are compared for male and female weakfish (Figure A1b). Estimates of natural mortality (M) based on the method of

Boudreau and Dickie (1989) are also summarized in Table A22 [see discussion of this approach in Seagraves (1992, pp 32-34)].

Catch Matrix Development

Landings

Landings data come from three sources in this report (bycatch is developed separately): 1) recreational, 2) market (commercial), and 3) scrap (commercial). Recreational catch estimates in weight and numbers are from the MRFSS, which includes estimates of type A, B1, and B2 fish (Figure A5). For this assessment, mortality of released fish is assumed to be 20%, as adopted by the ASMFC Weakfish Technical Committee and Board. The degree of precision about the recreational catch (A+B1+0.2*B2) is indicated by the proportional standard error (PSE, Van Voorhees *et al.* 1992). PSE is useful for comparing relative precision among different estimates. Lower values imply greater precision, with values less than 20% generally considered adequate.

Updated market (commercial) landings in weight by fishing gear were obtained from several sources (Figure A2a). Virginia and north landings data were provided by NMFS Headquarters for years through 1996 (Figure A3a). Because gear-specific landings were not always identified to month for recent years from DE, CT, and MA, and partially for NY; state landings were apportioned according to recent prior years (1985-1989) for each state, except NY for which concurrent years were used. Landings from Florida (east coast) through 1991 were provided by NMFS SEFSC Miami, more recent Florida landings (1992-1996) from their trip ticket program were provided by FL DEP; and Georgia through North Carolina from NMFS SEFSC Beaufort (Figure A3b). Because commercial landings are treated as a census, no measure of precision for these landings is possible.

Losses to scrap/bait were not considered in Vaughan *et al.* (1991), but were included in Vaughan (1993, 1994, 1995, 1996). Estimates of scrap/bait landings in weight from trawl, pound, and haul seines were provided by North Carolina (NC DMF) and Virginia (VMRC) (Figure A4a). No scrap landings were reported from North Carolina in 1995, and only from pound nets and haul seines from Virginia for 1995-1996.

Total landings in weight are compared in Figure A6a. The above data for recreational, market, and scrap losses are broken into half-year increments for use in developing catch-at-age matrices for years 1982-1996.

Length frequencies

Sampling of the landings for lengths are needed from the four sources of landings (or losses). Intercept data (length measurements) from the MRFSS continued to be split into Mid- and South Atlantic regions, as in Vaughan *et al.* (1991). For comparison with the annual length frequency distributions given in Vaughan *et al.* (1991), annual distributions for alternating years from 1986 through 1996 are shown in Figure A15. Note that measured lengths are combined across mode (beach vs boat), state and wave weighted by catch of A+B1 weakfish.

Length data from the South Atlantic market (commercial) landings by gear are from North Carolina (NC DMF: gillnet, trawl, pound net, and haul seine), and MRFSS (hook and line from the South Atlantic sub-region). Length data for the Mid-Atlantic market (commercial) landings by gear are from NMFS NEFSC (trawl for 1982-1993), Virginia (gillnet, pound net, and haul seine for 1989-1996), from Maryland (pound net for 1985-1987, 1993-1996; and trawl for 1994-1996), from Delaware (gillnet for 1988 and 1993-1996), and from MRFSS (hook and line from Mid-Atlantic sub-region). Length data from the scrap/bait landings are from North Carolina (NC DMF for trawl, pound net, and haul seine for 1982-1996). Where length data is available for the same gear and season from more than one state, they are combined, weighted by the catch in numbers from that gear and season for each state.

A method for addressing the adequacy of length samples is based on the amount of landings per 100 fish sampled (NEFSC 1996). A comparison of landings by fishery and gear is summarized in Tables A23-A25. Length samples that fall below the criteria of 200 mt of landings per 100 fish sampled has served as a rough indication of adequate sampling intensity in the SAW process. The sampling intensity for characterizing the recreational removals were poor for 1982-1984, and adequate since then. With few exceptions, sampling intensity appears to be excellent for commercial (market and scrap) gears. Because it was believed desirable to split length frequencies by region (Mid-Atlantic vs South Atlantic) and season (early vs late) to better represent geographic and temporal variability (Vaughan *et al.* 1991), there are region-season strata for which sampling intensity is inadequate or even nonexistent, especially during the period 1982-1988 in the Mid-Atlantic region for commercial (market) gears.

By applying Equations 1a-c to sampled length data, mean weights are calculated by fishery, gear, year, and season. These estimates, in turn, are used to estimate landings in numbers from landings in weight for commercial market and scrap landings (Figures A2b and A4b). Total landings (recreational, market, and scrap) in numbers are compared by fishery in Figure A6b.

Catch matrices

Catch in numbers are converted to catch in numbers at age using age-length keys and length frequency distributions (Vaughan *et al.* 1991):

$$N_{ax1} = n \cdot A_{axb} \cdot L_{bx1} \qquad (4)$$

where N is the vector of landings in numbers for ages 1 through a (e.g., a = 7), n is the number of weakfish landed (a scalar), A is the age-length key, and L is the length frequency distribution (vector) with b length classes (e.g., b = 15). Equation 4 is applied separately by region (South Atlantic vs Mid-Atlantic), fishery (recreational, market, and scrap), gear (where appropriate), and season (half-year increments). Note that separate age-length keys by region [South (FL-NC) vs Mid (VA-MA)] and half-year increments are used for 1991-1996. The results are summed by calendar year. For each set of age-length keys, catch-at-age matrices are developed for recreational and commercial (market and scrap) losses (Table A26 for the mixed or unadjusted keys; Table A27 for the scale-based keys; and Table A28 for otolith-based keys). The difference among these three catch matrices (unadjusted-scale-otolith) are summarized in Tables A29-A31.

Estimates of Fishing Mortality and Stock Size

Virtual Population Analysis

Estimates of fishing mortality rate and stock size for Atlantic coast weakfish were made using virtual population analysis (VPA). VPA runs were exploratory in nature owing to the high uncertainty in the catch-at-age data and retrospective diagnostics. No final VPA runs were adopted for estimates of stock sizes and fishing mortality rates. Inference about stock status from the exploratory VPA runs was limited to trend analysis. Extended survivors (XSA) tuning of VPA was used initially to assess the stock (Doubleday 1981, Darby and Flatman 1994). In general, this procedure uses relative abundance data at age from various surveys to produce terminal estimates of population abundance at age to initiate a VPA run. XSA runs were performed with and without the shrinkage option. Shrinkage is a model option used to rectify diagnostic problems such as retrospective patterns. Past assessments of weakfish have used conventional VPA (Vaughan *et al.* 1991) or separable VPA with auxiliary data (Gibson 1993). For comparison to the XSA runs, the CAGEAN model of Deriso *et al.* (1985) and the ADAPT method of Gavaris (1988) and Conser and Powers (1990) were also examined.

Estimates of stock size and fishing mortality were made using the catch-at-age matrix configured in otolith-age currency without shrimp fishery discard estimates. VPA runs without shrimp fishery discards produced fully-recruited F and SSB estimates within 2% of the runs including discard estimates suggesting that their exclusion had little influence on perceived adult stock status. A total of 8 abundance indices were used in the exploratory VPA runs. These included the NMFS/NEFSC trawl survey, MRFSS recreational CPUE, the SEAMAP trawl survey, and several state agency indices. Five indices had multiple age structure available, while three indexed a single age. Nine young-of-the-year (YOY) surveys from MA to NC were combined into a single recruitment index using Z-scores so that they would not unduly influence the analysis.

SSB and Fishing Mortality

Trends in spawning stock biomass (SSB) from various VPA models are given in Figure A16. All model runs showed a strong increase in SSB in recent years. Since 1991, SSB has increased at an average rate of 22.5% per year. Fishing mortality rate trends are graphed in Figure A17. There has been a clear reduction in fishing mortality for weakfish age 4 and older since 1990. Fully-recruited F has declined at an average rate of 21.4% per year.

Diagnostic and Retrospective Analysis

Past weakfish assessments have exhibited a notable retrospective pattern (Gibson 1995). Terminal estimates of F have been biased low relative to revised estimates after more data have been acquired. XSA VPA runs without shrinkage continued to show a retrospective pattern (Figure A18). Terminal F estimates exhibited an average bias of -30.6%. Application of shrinkage with a low influence weight improved the pattern (Figure A19).

Biological Reference Points

No new reference points were estimated in this assessment since a definitive VPA run was lacking. Past amendments to the ASMFC Weakfish Management Plan adopted $F_{20\%}$ as a biological reference point. This was last estimated at F = 0.35 (Seagraves 1991, Gibson 1995). Recent ASMFC Management Board action adopted F = 0.50 as a long-term target (year 2000) for stock rebuilding based on projections of age structure in Gibson (1995) for various F levels. An F_{msy} overfishing definition was estimated at 0.70 based on stock-recruitment data and Shepherd's (1982) equilibrium yield procedure. Interim F reduction steps in the Plan call for F = 1.27 in 1996 and F = 1.0 by 1998.

SARC Comments

The initial assessment assumed that natural mortality in weakfish was an inverse power function of body weight. Supporting arguments noted the small size of weakfish in the catch at age and empirical evidence for other species from comparative life history studies and MSVPA. Although the SARC agreed that smaller fish generally have higher natural mortality rates, they found little direct evidence to support the specific parameterization from the Boudreau-Dickie regression. Based on a longevity of 17 years and the Hoenig (1983) model, the SARC recommended that subsequent VPA runs be made with M = 0.25. Discussions followed regarding the significance of 0-group discard loss to population dynamics and ASMFC management. The SARC noted the conceptual problems involved with estimation of stock size and fishing mortality rates on age 0 fish early in the year because spawning and recruitment tends to be protracted and because of high growth rates. Further discussions noted that the constant M rate would be most suitable if age 0 fish were removed from the catch at age. A general discussion followed concerning the sensitivity of various VPA-YPR estimates to M assumptions.

While reviewing development of the catch at age, the SARC requested clarification on what constitutes "scrap", shrimp discards, and directed fishery commercial discards. Scrap was determined to be mixed fish utilized in industrial processing, of which weakfish were a significant component. They also requested the basis for the 20% loss rate applied to recreational discard estimates. Although the estimate was taken from studies on the congeneric spotted seatrout, the SARC remained concerned in view of anecdotal reports that weakfish experienced low rates of hook-and-release loss. Although sampling intensity for the fishery components was within accepted guidelines overall, concerns were expressed relative to the spatial adequacy of the samples. Following the report on aging methods, there was extensive discussion about the implications of scale- vs otolith-based aging and the method used to translate currencies. The SARC noted that the mixing of aging methodologies in an assessment increased uncertainty in the outputs. Several suggestions were made to improve continuity in the catch-at-age matrix including the E-M algorithm approach of Hoenig and Heisey (1987). Estimated age composition based on otoliths was preferred since the otoliths estimated more older fish in keeping with findings for other species. The SARC felt that the estimates of weakfish discards in the South Atlantic shrimp trawl fishery were unreliable and assumptions about M were problematic. Consequently, the SARC recommended that age 0 fish be removed from the catch-at-age matrix. Inferences about age 0 mortality rate and stock size were, therefore, not possible.

After reviewing the initial VPA, the SARC requested that the indices be LOWESS smoothed and examined along a north-south gradient. Catch-curve estimates of Z were requested for age 3+ and 4+ fish. They also requested that a relative exploitation index be derived from aggregate landings data and the most suitable biomass index. The reformulated indices of abundance generally showed increasing recruitment and extension of age structure. There was evidence of a recent reduction in relative exploitation which coincided with reductions in catch-curve Z. There were some concerns that the recent increase in abundance was availability related since the indices did not extend sequentially in terms of age structure.

After identifying problems in the initial XSA VPA runs, the SARC requested more runs without age 0 fish and with constant M = 0.25. Corrected XSA runs and preliminary ADAPT and CAGEAN analyses were prepared during the SARC meeting; however, lack of time precluded complete diagnostic evaluation. Lacking an accepted VPA, the SARC declined to endorse point estimates of F, SSB, and biological reference points. There was a discussion about the role of fishery management and environmental factors in increasing weakfish abundance.

Research Recommendations

- Biological studies should be conducted to better understand migratory aspects of the weakfish and how this relates to observed trends in weight at age.
- Studies should be conducted to quantify maturity schedules and fecundity variation in weakfish.
- Errors in landings estimates and estimates of discards in the shrimp trawl and other fisheries need to be further refined.
- Further consideration of release mortality in both the recreational and commercial fisheries is needed, and methods investigated to improve survival among released fish.
- Additional investigation is needed in developing consistent otolith-based catch matrices including the EM algorithm.
- The impact of aging errors and other statistical uncertainties in the catch-at-age matrix on virtual population analysis (VPA) should be included.
- Retrospective analyses are needed on all VPA approaches investigated.
- Further catch-at-age analysis should be conducted using otolith ages only from 1989 to 1996.

Conclusions

The available survey indices clearly show an increase in weakfish abundance in recent years. Recruitment has been above average, and there is some indication that age structure is expanding. A relative exploitation index and catch-curve estimates of Z have declined, suggesting that fishing mortality is declining. Exploratory VPA analyses show a strong increase in SSB in recent years, which is not dependent on the model used. The mean rate of SSB increase has been 22.5% per year since the low point reached in 1991. Fishing mortality rates from VPA have declined sharply since 1990. The mean rate of decline in F was 21.4% per year and was evident from all VPA model results. The weight of evidence indicates that the Atlantic weakfish stock is recovering from low abundance levels reached in the early 1990s. Continued low fishing mortality rates and good recruitment should allow for extension of the age structure to a point comparable to that observed in the early 1980s.

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Table A1. Estimated weakfish catch in metric tons. Recreational landings include catch type A (fish landed and available for sampling), type B1 (fish landed but not available for sampling), and 20% of type B2 (fish released alive, assuming a 20% discard mortality rate). Recreational catch includes catch types A1, B1, and B2. Total landings include commercial landings plus recreational landings. Total catch includes commercial landings plus recreational catch.

Year	Commercial landings	Recreational landings	Recreational catch	Total landings	Total catch
1970	3,460	N/A	N/A	N/A	N/A
1971	5,135	N/A	N/A	N/A	N/A
1972	7,291	N/A	N/A	N/A	N/A
1973	7,449	N/A	N/A	N/A	N/A
1974	6,611	N/A	N/A	N/A	N/A
1975	8,319	N/A	N/A	N/A	N/A
1976	9,466	N/A	N/A	N/A	N/A
1977	8,585	N/A	N/A	N/A	N/A
1978	9,751	N/A	N/A	N/A	N/A
1979	7,251	N/A	N/A	N/A	N/A
1980	16,312	N/A	N/A	N/A	N/A
1981	11,958	7,348	7,518	19,306	19,476
1982	8,835	3,772	3,828	12,607	12,663
1983	7,926	5,377	5,603	13,303	13,529
1984	8,969	3,197	3,260	12,166	12,229
1985	7,689	2,554	28,110	10,243	10,500
1986	9,611	4,799	5,595	14,410	15,206
1987	7,743	3,030	3,339	10,773	11,082
1988	9,311	2,943	3,228	12,254	12,539
1989	6,424	1,008	1,090	7,432	7,514
1990	4,265	645	781	4,910	5,046
1991	3,943	1,045	1,359	4,988	5,302
1992	3,381	717	1,045	4,098	4,426
1993	3,108	597	986	3,705	4,094
1994	2,873	1,095	2,215	3,968	5,088
1995	3,220	1,261	2,944	4,481	6,164
1996	3,290	1,850	3,919	5,140	7,209

Table A2. Weakfish landings by state (mt).

Year	FL	GA	SC	NC	VA	MD	DE	NJ	NY	CT	RI	MA	Total
1971	66	-	-	1,653	1,058	185	97	1,406	580	8	83	-	5,135
1972	80	-	-	3,344	1,187	142	184	1,442	829	-	82	1	7,291
1973	94	-	1	2,822	2,313	245	152	1,162	576	3	81	1	7,449
1974	58	-	1	2,747	1,390	186	127	1,219	647	6	208	22	6,611
1975	51	1	1	3,051	1,855	402	131	1,982	620	-	212	12	8,319
1976	40	-	-	3,952	1,803	198	112	2,590	610	6	148	6	9,466
1977	43	-	-	3,933	1,963	101	151	1,461	775	3	149	6	8,585
1978	54	-	-	4,921	1,766	238	136	1,753	748	8	115	11	9,751
1979	50	-	-	-	2,822	304	212	2,957	686	15	189	16	7,251
1980	100	-	6	9,227	2,831	258	822	2,221	723	4	105	14	16,312
1981	86	-	-	7,663	1,121	154	477	1,701	616	12	110	18	11,958
1982	80	-	-	5,467	975	113	587	941	570	12	80	10	8,835
1983	53	1	-	4,641	1,176	177	409	986	386	19	74	3	7,926
1984	57	-	-	5,892	957	147	355	1,248	220	14	76	2	8,969
1985	60	-	-	4,453	944	143	449	1,374	175	13	74	1	7,689
1986	49	-	-	6,491	905	153	328	1,455	163	6	58	3	9,611
1987	56	-	-	5,220	890	166	262	950	149	13	36	1	7,743
1988	52	-	-	6,846	668	378	241	1,058	56	1	9	2	9,311
1989	78	-	-	4,588	465	337	240	662	47	1	4	1	6,424
1990	62	-	-	2,632	532	300	278	439	9	1	11	1	4,265
1991	75	-	-	2,408	481	149	226	533	51	10	11	1	3,943
1992	67	-	-	2,206	249	175	164	427	76	2	14	1	3,381
1993	65	-	-	1,955	493	82	88	379	40	1	5	-	3,108
1994	81	-	-	1,583	587	129	119	315	45	5	8	-	2,873
1995	23	-	-	1,866	674	31	128	393	78	3	24	-	3,220
1996	2	-	-	1,804	720	60	141	373	166	3	20	-	3,290

Table A3a. Distribution of commercial weakfish landings by gear type in metric tons.

Year	Trawl	Gillnets	Pound nets	Haul seine	Other	Total
1970	2,053	314	612	434	47	3,460
1971	3,110	665	696	519	146	5,135
1972	4,512	1,045	1,014	522	198	7,291
1973	3,714	889	2,019	658	169	7,449
1974	3,795	669	1,372	526	250	6,611
1975	4,539	874	1,687	786	433	8,319
1976	5,686	844	1,806	763	366	9,466
1977	4,020	829	2,044	1,274	418	8,585
1978	5,135	914	1,814	1,271	617	9,751
1979	3,658	1,070	1,831	280	412	7,251
1980	8,780	2,709	2,690	1,638	496	16,312
1981	7,160	2,120	1,325	1,076	276	11,958
1982	4,789	1,814	1,084	955	192	8,835
1983	3,801	161	1,046	785	133	7,926
1984	4,110	3,006	784	866	203	8,969
1985	3,202	2,736	804	775	171	7,689
1986	3,880	4,054	580	918	179	9,611
1987	2,712	3,602	725	508	196	7,743
1988	3,254	4,325	687	777	268	9,311
1989	2,685	3,057	230	282	171	6,424
1990	1,544	829	300	505	87	4,265
1991	1,626	1,721	258	234	104	3,943
1992	1,616	1,376	88	210	92	3,381
1993	1,148	1,418	250	200	89	3,105
1994	645	1,510	387	202	129	2,873
1995	782	1,501	577	252	108	3,220
1996	574	1,851	559	207	99	3,290

Table A3b. Percentage of landings by gear type.

Year	Trawl	Gillnets	Pound nets	Haul seine	Other	Total
1970	59%	9%	18%	13%	1%	100%
1971	61%	13%	14%	10%	3%	100%
1972	62%	14%	14%	7%	3%	100%
1973	50%	12%	27%	9%	2%	100%
1974	57%	10%	21%	8%	4%	100%
1975	55%	11%	20%	9%	5%	100%
1976	60%	9%	19%	8%	4%	100%
1977	47%	10%	24%	15%	5%	100%
1978	53%	9%	19%	13%	6%	100%
1979	50%	15%	25%	4%	6%	100%
1980	54%	17%	16%	10%	3%	100%
1981	60%	18%	11%	9%	2%	100%
1982	54%	21%	12%	11%	2%	100%
1983	48%	27%	13%	10%	2%	100%
1984	46%	34%	9%	10%	2%	100%
1985	42%	36%	10%	10%	2%	100%
1986	40%	42%	6%	10%	2%	100%
1987	35%	47%	9%	7%	3%	100%
1988	35%	46%	7%	8%	3%	100%
1989	42%	48%	4%	4%	3%	100%
1990	36%	43%	7%	12%	2%	100%
1991	41%	44%	7%	6%	3%	100%
1992	48%	41%	3%	6%	3%	100%
1993	37%	46%	8%	6%	3%	100%
1994	22%	53%	13%	7%	4%	100%
1995	24%	47%	18%	8%	3%	100%
1996	17%	56%	17%	6%	3%	100%
Average	49%	19%	18%	12%	2%	100%

Table A4a. Distribution of North Carolina landings by gear type in metric tons.

Year	Trawl	Gillnet	Pound net	Haul seine	Other	Total
1970	935	31	25	117	-	1,107
1971	1,469	66	21	98	-	1,653
1972	3,000	189	26	130	-	3,344
1973	2,300	169	53	301	-	2,822
1974	2,299	106	64	278	-	2,747
1975	2,297	55	98	601	-	3,051
1976	3,115	55	192	590	-	3,952
1977	2,549	38	365	982	-	3,933
1978	3,432	198	352	939	1	4,921
1979	-	-	-	-	-	-
1980	6,400	790	861	1,176	-	9,227
1981	5,476	969	312	905	-	7,663
1982	3,854	633	176	803	-	5,467
1983	2,710	1,075	118	738	-	4,641
1984	2,977	1,924	173	819	-	5,892
1985	1,922	1,632	216	684	-	4,453
1986	2,576	2,901	124	890	-	6,491
1987	1,872	2,635	232	481	-	5,220
1988	2,393	3,450	278	725	-	6,846
1989	1,961	2,302	67	258	-	4,588
1990	922	1,133	88	488	-	2,631
1991	1,182	951	69	206	-	2,408
1992	1,162	831	22	191	-	2,206
1993	863	905	15	169	-	1,952
1994	384	984	32	177	6	1,583
1995	416	1,161	54	232	3	1,866
1996	178	1,374	42	207	3	1,804

Table A4b. Percentage of North Carolina commercial weakfish landings by gear type.

Year	Trawl	Gillnet	Pound net	Haul seine	Other	Total
1970	84%	3%	2%	11%	0%	100%
1971	89%	4%	1%	6%	0%	100%
1972	90%	6%	1%	4%	0%	100%
1973	81%	6%	2%	11%	0%	100%
1974	84%	4%	2%	10%	0%	100%
1975	75%	2%	3%	20%	0%	100%
1976	79%	1%	5%	15%	0%	100%
1977	65%	1%	9%	25%	0%	100%
1978	70%	4%	7%	19%	0%	100%
1979	N/A	N/A	N/A	N/A	N/A	N/A
1980	69%	9%	9%	13%	0%	100%
1981	71%	13%	4%	12%	0%	100%
1982	70%	12%	3%	15%	0%	100%
1983	58%	23%	3%	16%	0%	100%
1984	51%	33%	3%	14%	0%	100%
1985	43%	37%	5%	15%	0%	100%
1986	40%	45%	2%	14%	0%	100%
1987	36%	50%	4%	9%	0%	100%
1988	35%	50%	4%	11%	0%	100%
1989	43%	50%	1%	6%	0%	100%
1990	35%	43%	3%	19%	0%	100%
1991	49%	40%	3%	9%	0%	100%
1992	53%	38%	1%	9%	0%	100%
1993	44%	46%	1%	9%	0%	100%
1994	24%	62%	2%	11%	0%	100%
1995	22%	62%	3%	12%	0%	100%
1996	10%	76%	2%	11%	0%	100%

Table A5. Recreational catch estimates for Atlantic coast weakfish from the MRFSS survey[1].

Year	A+B1+B2 Catch ('000s)	PSE	A+B1 Landings (mt)
1979	5,287.0	9.0	5,898
1980	13,538.0	9.0	19,355
1981	9,629.0	10.0	7,305
1982	2,045.0	14.5	3,758
1983	5,916.0	12.7	5,321
1984	3,769.0	13.5	3,181
1985	2,776.0	9.2	2,490
1986	10,974.0	7.9	4,600
1987	5,720.0	10.6	2,953
1988	6,446.4	11.6	2,872
1989	1,674.6	7.8	988
1990	1,671.8	6.4	611
1991	2,601.5	6.5	966
1992	1,667.8	6.7	635
1993	2,218.6	6.3	500
1994	4,929.0	6.0	814
1995	5,739.4	4.9	840
1996	7,593.7	4.7	1,333

[1]MRFSS methodology change in 1981.

Table A6. Recreational catch-per-unit-effort index of Atlantic coast weakfish from the MRFSS survey[1]. Catch in 1000's includes all catch types. Effort in 1000's of directed weakfish trips.

	A+B1+B2		Total	CPUE at age							
Year	Catch	Trips	CPUE	0	1	2	3	4	5	6	7+
1979	5,518.8	1,751.5	3.15	0.017	0.768	1.203	0.616	0.381	0.115	0.023	0.027
1980	15,059.2	1,558.1	9.67	0.105	1.644	2.856	2.092	1.627	0.737	0.200	0.403
1981	9,629.0	1,322.9	7.28	0.140	1.624	1.907	1.673	1.118	0.547	0.121	0.149
1982	2,045.0	1,034.4	1.98	0.006	0.160	0.398	0.407	0.379	0.209	0.174	0.244
1983	5,916.0	1,921.7	3.08	0.009	0.271	1.479	0.894	0.295	0.057	0.040	0.033
1984	3,769.0	1,151.5	3.27	0.066	0.534	1.552	0.724	0.218	0.048	0.041	0.089
1985	2,776.0	1,929.4	1.44	0.018	0.185	0.686	0.377	0.124	0.029	0.008	0.012
1986	10,974.0	2,627.9	4.18	0.136	2.388	1.126	0.400	0.095	0.020	0.006	0.004
1987	5,720.0	1,377.9	4.15	0.058	1.249	1.339	1.181	0.277	0.039	0.005	0.005
1988	6,446.4	654.5	9.85	0.018	0.356	2.862	4.473	1.857	0.246	0.020	0.019
1989	1,674.6	1,919.9	0.87	0.008	0.078	0.296	0.285	0.175	0.026	0.002	0.002
1990	1,671.8	1,936.4	0.86	0.013	0.265	0.393	0.129	0.049	0.012	0.001	0.001
1991	2,601.5	2,560.8	1.02	0.005	0.099	0.407	0.364	0.117	0.021	0.002	0.001
1992	1,667.8	1,525.8	1.09	0.011	0.261	0.367	0.369	0.071	0.011	0.002	0.001
1993	2,218.6	1,512.6	1.47	0.008	0.116	0.746	0.420	0.149	0.026	0.001	0.000
1994	4,929.0	1,729.7	2.85	0.022	0.215	1.044	1.276	0.258	0.035	0.000	0.000
1995	5,739.4	2,171.4	2.64	0.006	0.087	0.551	1.114	0.838	0.046	0.001	0.000
1996	7,593.7	1,813.1	4.19	0.015	0.059	0.639	1.847	1.221	0.397	0.008	0.003

[1]MRFSS methodology change in 1981.

Table A7. Mean number per tow of weakfish at age from NEFSC autumn inshore bottom trawl surveys, Cape Cod to Cape Hatteras. Survey length frequencies were aged by applying annual age length keys from pooled commercial and research samples.

	Age							
Year	0	1	2	3	4	5	6	7+
1982	2.75	0.82	0.06	1.45	0.51	0.22	0.11	0.007
1983	3.25	1.36	0.44	0.03	0.41	0.05	0.05	0.04
1984	8.99	2.36	0.84	0.07	0.37	0.1	0.05	0.2
1985	10.39	1.11	0.42	0.04	0.08	0.02	0.01	-
1986	4.74	4.12	0.02	0.01	0.01	0.005	0.005	-
1987	5.28	2.46	0.93	0.14	0.004	0.003	-	-
1988	8.2	3.68	1.18	0.06	0.03	0.03	-	-
1989	8.9	3.47	0.33	0.08	0.03	0.004	-	-
1990	3.45	0.27	0.02	0.001	0.001	-	-	-
1991	2.26	0.73	0.24	0.033	0.008	0.001	-	-
1992	2.54	0.95	0.13	0.88	0.001	-	-	-
1993	1.23	1.53	0.53	0.06	0.003	-	-	-
1994	2.11	5.05	2.54	0.03	0.019	-	-	-
1995	42.74	6.25	8.73	1.1	0.38	0.013	-	-
1996	4.05	1.9	2.34	1.52	0.405	0.067	-	-

Table A8. Mean number per tow of weakfish at age from SEAMAP ocean research trawl spring and fall surveys from Cape Hatteras to Cape Canaveral. Fish were aged by application of the southern early and late age-length keys from samples of commercial and recreational landings.

SEAMAP spring							
		Age					
Year	n	0	1	2	3	4	Total
1989	86	-	81.63	1.92	0.08	-	83.63
1990	105	-	23.40	1.11	0.07	-	24.58
1991	105	-	28.92	0.38	0.03	-	29.33
1992	105	-	46.55	3.57	0.20	-	50.32
1993	105	-	29.84	0.12	-	-	29.96
1994	105	-	2.82	0.07	-	-	2.89
1995	105	-	18.89	0.13	0.02	-	19.04
1996	105	-	15.44	1.06	0.07	-	16.57
SEAMAP fall							
		Age					
Year	n	0	1	2	3	4	Total
1989	106	5.27	2.39	0.24	0.02	-	7.92
1990	91	3.42	0.85	0.08	-	-	4.35
1991	86	3.27	2.46	0.51	0.04	-	6.28
1992	94	1.57	0.99	0.17	0.02	-	2.75
1993	94	8.06	8.48	0.30	0.02	-	16.86
1994	94	21.69	5.48	0.47	0.03	-	27.67
1995	94	4.26	2.43	0.21	0.01	-	6.91
1996	94	10.37	4.50	0.84	0.08	-	15.79

Table A9. Mean number per tow of weakfish at age from stratified random New Jersey ocean trawl surveys (April - October). Fish were aged by application of annual age-length keys from pooled commercial and research samples.

		Age										
Year	n	0	1	2	3	4	5	6	7	Total	2-7+	4-7+
1988	68	12.2	0.3	0.2	0.1	-	-	-	-	12.88	0.37	0.03
1989	193	31.1	0.9	0.6	0.2	0.1	-	-	-	32.89	0.89	0.07
1990	171	6.7	2.4	2.5	0.3	0.1	-	-	-	11.99	2.91	0.10
1991	189	14.4	2.6	1.3	0.5	0.1	-	-	-	18.86	1.88	0.13
1992	191	4.0	3.7	2.4	0.5	0.1	-	-	-	10.66	2.94	0.09
1993	187	11.2	3.3	1.6	0.4	0.1	-	-	-	16.50	2.08	0.10
1994	186	18.0	11.1	7.7	2.0	0.3	-	-	-	39.11	10.02	0.35
1995	188	27.1	9.1	19.0	6.6	2.7	0.1	-	-	64.63	28.40	2.78
1996	189	18.4	11.0	6.9	9.4	2.4	0.5	-	-	48.66	19.27	2.97

Table A10. Mean number per nautical mile of weakfish at age from Delaware DFW surveys (March - December) in Delaware Bay. During 1966-1990, fish were aged using a pooled key. Weakfish were aged individually using scales during 1991-1995 and using otoliths in 1996.

		Age										
Year	n	0	1	2	3	4	5	6	7	Total	2-7+	4-7+
1966	33	148.6	34.2	4.6	0.01	-	-	-	-	187.40	4.62	-
1967	49	75.2	55.7	4.9	-	-	-	-	-	135.80	4.88	-
1968	36	68.1	48.7	6.2	0.1	-	-	-	-	123.10	6.29	-
1969	36	56.8	56.3	18.7	3.0	0.32	0.10	0.05	0.08	135.30	22.20	0.47
1970	33	31.2	48.9	30.9	7.1	1.05	0.51	0.40	0.21	120.30	40.23	2.16
1971	33	19.5	26.1	35.1	11.8	3.19	2.46	2.51	1.83	102.50	56.89	9.97
1979	100	2.7	2.5	5.1	2.6	0.71	0.43	0.46	0.37	14.90	9.65	1.95
1980	95	2.2	2.8	4.8	2.2	0.59	0.41	0.80	0.73	14.60	9.58	2.52
1981	99	4.0	1.0	2.3	1.3	0.30	0.17	0.16	0.12	9.30	4.35	0.75
1982	44	18.8	3.7	6.8	1.4	0.12	0.06	0.18	0.16	31.20	8.66	0.52
1983	38	3.6	2.5	3.8	1.5	0.32	0.18	0.24	0.20	12.30	6.25	0.93
1984	46	5.3	2.5	5.2	2.6	0.64	0.39	0.22	0.14	16.90	9.13	1.39
1990	70	10.8	11.7	2.9	0.4	0.07	0.06	0.04	0.03	26.00	3.48	0.19
1991	72	22.8	27.2	3.6	0.6	0.00	0.00	0.00	0.00	54.19	4.27	0.00
1992	89	24.8	21.2	2.6	0.0	0.03	0.00	0.00	0.00	48.60	2.68	0.03
1993	83	21.4	50.3	25.4	3.9	0.50	0.00	0.00	0.00	101.50	29.80	0.50
1994	71	8.6	113.5	68.5	23.6	0.90	0.00	0.00	0.00	214.20	93.00	0.90
1995	88	41.1	75.3	53.5	15.7	5.40	0.10	0.00	0.00	191.10	74.70	5.50
1996	76	77.3	44.0	48.3	111.2	23.80	6.40	0.10	0.00	311.10	189.80	30.30

Table A11. Massachusetts Division of Marine Fisheries total catches per year of juvenile (age 0) weakfish in research trawl surveys south of Cape Cod.

Year	Number of fish
1978	52
1979	4
1980	49
1981	113
1982	35
1983	48
1984	8
1985	774
1986	111
1987	-
1988	-
1989	73
1990	-
1991	3
1992	1
1993	-
1994	8
1995	32
1996	13

Table A12. Rhode Island Division of Fish and Wildlife integrated weakfish recruitment index (age 0) from Narragansett Bay as arithmetic means. Index is a Z-score composite from three surveys.

		95 % confidence interval	
Year	Mean	Lower	Upper
1979	3.61	-1.45	7.22
1980	20.36	-2.70	40.72
1981	10.60	1.18	21.20
1982	6.22	3.24	12.44
1983	9.17	-3.57	18.34
1984	1.51	-0.11	3.02
1985	5.28	1.66	10.56
1986	1.19	-0.47	2.38
1987	2.09	0.91	4.18
1988	7.36	1.72	14.72
1989	1.80	0.78	3.60
1990	12.73	3.61	25.46
1991	17.90	0.22	35.80
1992	4.34	2.42	8.68
1993	4.12	2.78	8.24
1994	11.54	0.90	23.08
1995	1.25	0.05	2.50
1996	38.06	25.16	76.12

Table A13. Connecticut Department of Environmental Protection weakfish recruitment indices for age 0 and age 1, 1984-1996, as geometric means.

			95% confidence interval			95% confidence interval	
Year	n	GM YOY	Low	High	GM Age 1	Low	High
1984	70.00	0.99	0.57	1.53	0.52	0.30	0.79
1985	80.00	6.17	3.71	9.91	0.25	0.13	0.38
1986	80.00	13.15	7.76	21.87	0.23	0.12	0.36
1987	80.00	0.63	0.31	1.03	0.12	0.03	0.21
1988	80.00	2.90	1.72	4.58	0.06	0.00	0.13
1989	80.00	8.68	4.87	14.96	0.02	0.00	0.04
1990	80.00	5.55	3.57	8.39	0.07	0.01	0.14
1991	80.00	11.94	7.50	18.69	0.31	0.12	0.54
1992	80.00	3.01	1.86	4.64	0.19	0.07	0.31
1993	120.00	4.10	2.86	5.75	0.13	0.06	0.20
1994	120.00	11.18	7.33	16.81	0.06	0.00	0.13
1995	80.00	5.23	3.10	8.49	0.73	0.42	1.12
1996	80.00	15.28	9.28	24.79	0.55	0.30	0.86

Table A14. New York Division of Fish, Wildlife, and Marine Resources Peconic Bay weakfish recruitment index for age 0, 1985-1996, as geometric means.

			95% confidence interval	
Year	n	GM	Lower	Upper
1985	240	1.52	1.17	1.93
1986		No data		
1987	354	0.33	0.24	0.43
1988	426	0.11	0.07	0.15
1989	420	0.57	0.42	0.73
1990	430	0.26	0.18	0.34
1991	398	4.43	3.51	5.54
1992	411	1.20	0.91	1.54
1993	414	0.43	0.31	0.56
1994	428	1.72	1.30	2.22
1995	376	0.85	0.66	1.06
1996	409	4.74	3.58	6.20

Table A15. Delaware Division of Fish and Wildlife weakfish recruitment index from Delaware Bay for age 0, 1980-1996, as geometric means.

			95% confidence interval	
Year	n	GM	Lower	Upper
1980	139	4.15	3.26	5.23
1981	149	5.98	4.62	7.68
1982	171	11.49	9,50	13.85
1983	174	4.47	3.58	5.53
1984	174	6.67	5.16	8.55
1985	175	9.25	7.34	11.59
1986	173	12.79	10.31	15.82
1987	163	5.82	4.54	7.39
1988	169	4.73	3.55	6.20
1989	168	11.11	8.80	13.97
1990	170	8.73	6.84	11.08
1991	169	20.07	16.37	24.57
1992	169	14.72	11.59	18.62
1993	170	14.79	11.56	18.85
1994	170	11.47	8.87	14.76
1995	170	13.49	10.51	17.23
1996	170	12.13	9.29	15.75

Table A16. Maryland Department of Natural Resources Chesapeake Bay weakfish recruitment index at age 0, 1980-1996, as geometric means.

		95% confidence interval	
Year	GM	Lower	Upper
1980	0.51	0.26	0.79
1981	0.25	0.11	0.40
1982	0.22	0.11	0.35
1983	1.32	0.79	2.00
1984	0.14	0.02	0.26
1985	1.66	0.84	2.82
1986	0.45	0.16	0.80
1987	0.36	0.15	0.60
1988	0.23	0.08	0.40
1989	0.15	0.01	0.31
1990	0.80	0.36	1.36
1991	0.46	0.16	0.84
1992	2.25	1.25	3.71
1993	1.08	0.54	1.80
1994	1.51	0.77	2.53
1995	6.10	3.85	9.38
1996	5.05	2.78	8.68

Table A17. Maryland Department of Natural Resources coastal bays weakfish recruitment index at age 0, 1972-1997, as geometric means.

Year	GM	95% confidence interval Lower	Upper
1972	2.9	0.3	6.7
1973	0.1	0.0	0.3
1974	0.0	0.0	0.0
1975	3.3	2.0	4.8
1976	3.5	2.0	5.2
1977	2.1	1.1	3.3
1978	9.5	5.7	14.6
1979	2.7	1.0	5.0
1980	0.7	0.0	1.9
1981	7.5	3.3	13.5
1982	18.9	7.6	39.9
1983	1.9	0.0	4.8
1984	1.1	0.1	2.3
1985	2.9	0.9	5.6
1986	7.7	3.7	13.4
1987	1.5	0.0	3.6
1988	0.0	0.0	0.0
1989	1.7	0.9	2.6
1990	4.0	2.5	5.7
1991	4.3	2.6	6.3
1992	4.4	2.4	6.9
1993	2.1	1.2	3.2
1994	4.3	3.0	6.5
1995	10.3	6.3	15.8
1996	6.7	4.3	9.8
1997	7.1	4.4	10.5

Table A18. Recruitment (age 0) indices for weakfish from the Virginia Institute of Marine Science trawl survey of rivers tributary to the Chesapeake Bay, 1979-1996, as geometric means.

Year	n	GM	95% confidence interval Lower	Upper
1979	95	7.17	4.86	10.39
1980	111	9.87	6.75	14.24
1981	99	6.01	4.32	8.24
1982	117	10.13	7.41	13.73
1983	112	10.83	8.45	13.84
1984	97	6.05	3.73	9.52
1985	81	37.02	27.82	49.15
1986	108	4.61	2.84	7.21
1987	100	17.84	12.78	24.76
1988	63	21.71	12.34	37.67
1989	63	21.26	13.20	33.88
1990	59	30.00	18.55	48.16
1991	62	15.31	9.41	24.53
1992	61	15.89	9.77	25.50
1993	63	15.41	8.43	27.53
1994	63	7.04	4.06	11.76
1995	69	11.00	6.74	17.60
1996	66	7.41	4.33	12.29

Table A19. Recruitment (age 0) indices for weakfish from the North Carolina Division of Marine Fisheries trawl survey of Pamlico Sound, 1987-1996, as arithmetic means.

Year	n	Mean	95% confidence interval Low	High	CV
1987	48	12.14	0.43	23.85	48.2
1988	48	101.5	61.18	141.82	19.9
1989	46	14.2	7.93	20.47	22.1
1990	48	50.2	28.68	71.72	21.4
1991	50	36.96	13.43	60.49	31.8
1992	49	42.71	26.69	58.73	18.8
1993	48	9.05	2.64	15.46	35.4
1994	47	68.06	43.28	92.84	18.2
1995	48	38.28	26.76	49.80	15.0
1996	49	70.84	46.76	94.92	17.0

Table A20. Transformations for converting from scale ages to otolith ages for weakfish (Daniel and Vaughan 1997).

Scale age	Otolith age	Middle Atlantic		South Atlantic	
		Early	Late	Early	Late
0	0	1.000	0.991	1.000	0.900
	1	-	0.009	-	0.100
1	0	-	0.026	-	-
	1	0.464	0.734	0.917	0.554
	2	0.453	0.201	0.083	0.446
	3	0.078	0.033	-	-
	4	0.005	0.006	-	-
2	0	-	0.009	-	-
	1	0.008	0.051	-	0.031
	2	0.277	0.754	0.739	0.708
	3	0.461	0.126	0.217	0.219
	4	0.254	0.048	0.044	0.042
	5	-	0.012	-	-
3	1	0.007	-	-	-
	2	0.007	0.152	0.024	0.008
	3	0.561	0.663	0.583	0.717
	4	0.403	0.169	0.345	0.250
	5	0.022	0.016	0.048	0.025
4	2	0.088	0.027	-	-
	3	0.736	0.097	0.009	0.013
	4	0.154	0.858	0.547	0.854
	5	0.022	0.018	0.444	0.133
5	4	0.120	0.636	-	-
	5	0.820	0.364	0.939	1.000
	6	0.040	-	0.061	-
	7+	0.020	-	-	-
6	4	0.042	-	-	-
	5	0.208	-	-	-
	6	0.625	1.000	1.000	1.000
	7+	0.125	-	-	-
7+	6	0.333	-	-	-
	7+	0.667	1.000	1.000	1.000

Table A21. Transformations for converting from otolith ages to scale ages for weakfish (Daniel and Vaughan 1997).

Scale age	Otolith age	Middle Atlantic		South Atlantic	
		Early	Late	Early	Late
0	0	1.000	0.970	1.000	1.000
	1	-	0.017	-	-
	2	-	0.013	-	-
1	0	-	0.015	-	0.029
	1	0.978	0.856	1.000	0.885
	2	0.011	0.129	-	0.086
	3	0.011	-	-	-
2	1	0.702	0.099	0.050	0.266
	2	0.290	0.802	0.850	0.723
	3	0.008	0.089	0.100	0.011
	4	-	0.010	-	-
3	1	0.093	0.028	-	-
	2	0.373	0.233	0.091	0.194
	3	0.784	0.678	0.591	0.797
	4	0.050	0.061	0.018	0.009
4	1	0.006	0.007	-	-
	2	0.201	0.105	0.011	0.041
	3	0.341	0.204	0.308	0.306
	4	0.409	0.638	0.681	0.653
	5	0.037	0.046	-	-
	6	0.006	-	-	-
5	2	-	0.307	-	-
	3	0.048	0.231	0.034	0.200
	4	0.222	0.154	0.441	0.667
	5	0.651	0.308	0.525	0.133
	6	0.079	-	-	-
6	4	0.100	-	-	-
	5	0.100	-	0.667	-
	6	0.750	1.000	0.333	1.000
	7+	0.050	-	-	-
7+	5	0.167	-	-	-
	6	0.500	-	-	-
	7+	0.333	1.000	1.000	1.000

Table A22. Mean total length and weight at age of weakfish from otolith- and scale-aged length data (1989-1996), and estimated age-specific natural mortality rate (after Boudreau and Dickie 1989). Standard error of total length in parentheses.

Age (yr)	n	TL (in)	W (lbs)	M (yr-1)
Otolith aged				
0	1,044	6.8 (0.05)	0.13	0.69
1	2,758	8.7 (0.03)	0.26	0.55
2	1,525	12.2 (0.05)	0.68	0.40
3	1,906	14.4 (0.06)	1.12	0.34
4	1,343	16.4 (0.10)	1.79	0.29
5	492	19.2 (0.23)	2.91	0.25
6	47	25.6 (0.68)	6.21	0.19
7	3	27.5 (0.65)	7.14	0.18
8	2	29.9 (1.83)	9.16	0.17
9	0	- (-)	-	-
10	1	33.3 (-)	12.50	0.15
Scale aged				
0	430	7.9 (0.07)	0.19	0.61
1	2,103	10.6 (0.04)	0.45	0.46
2	3,380	14.1 (0.05)	1.11	0.34
3	3,339	16.2 (0.06)	1.71	0.29
4	1,722	18.1 (0.09)	2.30	0.27
5	482	22.4 (0.18)	4.19	0.22
6	121	28.1 (0.31)	7.90	0.18
7	138	31.0 (0.14)	10.26	0.16
8	35	31.5 (0.26)	10.74	0.16
9	27	31.8 (0.29)	11.01	0.16
10	29	32.8 (0.28)	12.09	0.15
11	13	33.1 (0.46)	12.49	0.15
12	13	33.9 (0.47)	13.30	0.15

Table A23. Recreational weakfish landings (A+B1+0.2*B2) in numbers and weight (C in mt), precision (PSE) of landings in number, and adequacy of sampling of lengths for characterizing size distribution of landings. PSE less than 20% is considered adequate. Criteria used by SARC to judge adequacy of sampling intensity is 200 mt or less landed per 100 fish sampled.

Year	Landings ('000s)	PSE	Landings (C)	Intercepts (n)	C/100n
1982	1,892.2	14.5	3,772.2	428	881.3
1983	5,697.6	12.7	5,377.4	1,640	327.9
1984	3,570.5	13.5	3,197.1	614	520.7
1985	2,490.9	9.2	2,554.0	1,657	154.1
1986	9,126.0	7.9	4,799.2	3,825	125.5
1987	5,041.2	10.6	3,030.2	1,880	161.2
1988	5,790.3	11.6	2,943.3	1,944	151.4
1989	1,531.2	7.8	1,008.2	1,447	69.7
1990	1,320.2	6.4	645.2	1,508	42.8
1991	1,970.5	6.5	1,044.9	2,051	50.9
1992	1,101.7	6.7	716.7	1,108	64.7
1993	1,307.1	6.3	597.1	1,013	58.9
1994	2,447.0	6.0	1,094.7	1,651	66.3
1995	2,421.6	4.9	1,260.9	1,299	97.1
1996	3,356.4	4.7	1,850.5	1,776	104.2

Table A24. Adequacy of commercial weakfish sampling of lengths for characterizing size distribution of commercial market (food) landings (C, in metric tons). Criteria used by SARC to judge adequacy of sampling intensity is 200 mt or less landed per 100 fish sampled.

	Gillnet			Trawl			Pound net			Haul seine		
Year	C	n	C/100n	C	n	C/100n	C	n	C/100n	C	n	C/100n
1982	1,863.2	25	7852.8	4,793.2	4,630	103.5	1,151.2	590	195.1	976.4	1,030	94.8
1983	2,196.7	2,624	83.7	3,802.7	8,016	47.4	1,063.5	678	156.9	796.3	1,617	49.2
1984	3,040.3	6,443	47.2	4,193.7	8,327	50.4	814.9	795	102.5	881.2	1,911	46.1
1985	2,774.2	5,021	55.3	3,209.0	9,369	34.3	815.7	667	122.3	789.7	1,784	44.3
1986	4,087.9	5,990	68.2	3,884.9	10,263	37.1	594.6	1,856	32.0	926.6	1,080	85.8
1987	3,622.8	8,954	40.5	2,882.7	10,846	26.6	738.3	1,097	67.3	519.1	3,228	16.1
1988	4,350.5	7,675	56.7	3,275.9	7,915	41.4	692.0	1,639	42.2	779.4	1,876	41.5
1989	3,097.9	9,378	33.0	2,717.1	6,545	41.5	230.3	2,814	8.2	285.5	1,767	16.2
1990	1,873.2	8,673	21.6	1,553.6	7,614	20.4	302.9	4,239	7.1	506.9	3,678	13.8
1991	1,770.7	14,383	12.3	1,640.1	7,449	22.0	258.4	3,341	7.7	238.8	2,738	8.7
1992	1,420.5	18,305	7.8	1,634.6	7,485	21.8	91.2	4,111	2.2	215.3	2,699	8.0
1993	1,449.0	16,978	8.5	1,174.3	8,388	14.0	250.4	3,491	7.2	207.5	3,067	6.8
1994	1,550.3	11,352	13.7	680.4	3,936	17.3	393.0	8,057	4.9	205.5	2,744	7.5
1995	1,511.6	11,948	12.7	785.1	2,977	26.4	581.9	15,448	3.8	256.3	3,584	7.2
1996	1,851.2	12,690	14.6	574.4	2,620	21.9	563.0	14,861	3.8	207.0	6,415	3.2

Note: Purse seine landings for 1994 (late period) were 79.3 mt, n = 98, and C/100n = 80.9 mt.

Table A25. Adequacy of commercial weakfish sampling of lengths for characterizing size distribution of commercial scrap (bait) landings (C, in metric tons). Criteria used by SARC to judge adequacy of sampling intensity is 200 mt or less landings per 100 fish sampled.

	Trawl			Pound net			Haul seine		
Year	C	n	C/100n	C	n	C/100n	C	n	C/100n
1982	631.4	507	124.5	70.1	1,155	6.1	95.1	1,723	5.5
1983	190.7	923	20.7	62.1	754	8.2	100.1	2,017	5.0
1984	216.0	544	39.7	66.2	1,046	6.3	106.5	3,000	3.5
1985	391.5	1,250	31.3	60.4	251	24.1	72.2	1,836	3.9
1986	523.3	975	53.7	41.0	2,102	2.0	85.3	3,087	2.8
1987	737.1	2,304	32.0	72.6	2,544	2.9	72.5	1,953	3.7
1988	983.3	2,114	46.5	38.2	1,144	3.3	52.3	940	5.6
1989	139.8	578	24.2	16.9	733	2.3	30.3	411	7.4
1990	316.7	1,682	18.8	23.3	862	2.7	52.3	594	8.8
1991	188.7	2,433	7.8	63.4	202	31.4	68.8	3,097	2.2
1992	161.0	980	16.4	4.2	186	2.3	74.4	246	30.2
1993	195.4	1,315	14.9	11.9	313	3.8	7.9	77	10.3
1994	39.3	626	6.3	22.1	91	24.3	6.8	23	29.6
1995	0.0	-	-	25.2	36	70.0	1.1	295	0.4
1996	7.5	62	12.1	36.9	19	194.2	46.5	127	36.6

Table A26. Unadjusted weakfish catch in numbers at age ('000s) for reported recreational and commercial (market and scrap) landings, 1982-1996.

	Age								
Year	0	1	2	3	4	5	6	7+	Total
1982	501.6	12,943.4	7,046.7	2,897.7	1159.	383.2	338.4	466.7	25,737.1
1983	395.2	7,364.1	11,750.3	3,032.7	320.0	200.8	316.0	411.8	23,790.9
1984	535.6	9,694.1	13,193.3	3,410.7	380.5	141.1	157.8	265.7	27,778.9
1985	2,449.0	10,227.7	12,056.7	2,908.2	318.3	106.9	61.0	103.8	28,231.7
1986	408.4	31,351.0	3,400.1	2,854.4	747.5	132.0	84.0	42.8	39,020.1
1987	699.5	18,486.6	9,073.2	6,416.3	370.5	67.3	40.6	19.1	35,173.2
1988	675.8	9,298.9	17,305.1	12,006.7	508.9	137.9	68.7	48.0	40,050.0
1989	433.6	3,850.9	4,805.0	4,626.3	1758.	26.4	25.9	26.1	15,553.1
1990	519.6	9,295.0	6,067.9	1,589.1	643.7	75.2	20.4	14.7	18,225.6
1991	740.5	7,958.1	7,360.9	3,124.2	494.5	40.4	9.4	1.2	19,729.1
1992	281.1	4,900.0	5,197.5	2,543.8	346.3	44.3	3.8	1.3	13,318.2
1993	185.4	2,610.4	7,484.9	2,726.4	311.9	36.7	8.2	0.8	13,364.7
1994	64.6	2,260.4	3,884.0	4,125.0	629.0	66.0	1.8	0.5	11,031.3
1995	158.2	1,504.5	3,454.2	4,614.2	2,366.0	72.2	2.3	0.6	12,172.9
1996	317.7	1,446.3	2,577.6	4,182.9	2,751.0	1,050.0	9.5	2.6	12,338.8

Table A27. Scale-based weakfish catch in numbers at age ('000s) for reported recreational and commercial (market and scrap) landings, 1982-1996.

	Age								
Year	0	1	2	3	4	5	6	7+	Total
1982	501.1	12,895.3	6,871.5	2,998.1	1,341.3	325.0	339.1	465.7	25,737.1
1983	397.1	7,366.2	11,754.5	3,029.5	314.6	201.1	316.0	411.9	23,790.9
1984	536.6	10,019.3	12,902.9	3,386.4	372.2	137.2	158.1	265.5	27,778.3
1985	2,448.3	10,955.8	11,397.7	2,844.4	320.1	100.5	61.2	103.6	28,231.7
1986	408.3	31,371.8	3,445.0	2,859.1	693.7	154.5	44.9	42.8	39,020.1
1987	699.3	18,494.8	9,068.0	6,403.5	389.0	73.8	26.1	19.1	35,173.6
1988	675.8	9,295.3	17,290.3	11,987.0	548.3	137.1	68.4	47.9	40,050.0
1989	433.8	5,007.9	3,995.7	4,542.4	1,472.4	45.7	29.1	26.1	15,553.1
1990	521.7	11,447.0	3,987.4	1,530.2	633.4	69.0	22.3	14.7	18,225.6
1991	771.1	8,471.7	6,782.1	3,131.4	501.6	59.2	10.7	1.3	19,729.1
1992	311.1	5,146.1	4,938.0	2,535.8	336.3	46.5	4.0	0.6	13,318.2
1993	200.4	2,595.0	7,480.0	2,722.3	314.9	43.0	8.6	0.5	13,364.7
1994	87.1	2,371.0	3,989.0	3,841.6	682.2	58.6	1.4	0.3	11,031.3
1995	169.4	1,943.2	3,617.5	4,354.7	2,000.3	82.4	5.3	0.0	12,172.9
1996	333.3	1,740.0	3,134.5	4,114.6	2,403.6	590.5	20.4	1.9	12,338.8

Table A28. Otolith-based weakfish catch in numbers at age ('000s) for reported recreational and commercial (market and scrap) landings, 1982-1996.

	Age								
Year	0	1	2	3	4	5	6	7+	Total
1982	489.1	8,588.3	9,429.4	3,430.7	2,202.5	811.6	342.3	443.2	25,737.1
1983	386.9	4,663.1	11,452.5	4,602.8	1,777.7	345.2	252.7	310.0	23,790.9
1984	619.9	6,369.4	12,743.0	5,129.8	2,223.3	332.8	143.6	217.0	27,778.7
1985	2,622.3	6,849.3	11,785.0	4,476.5	2,074.1	264.9	63.2	96.4	28,231.7
1986	839.4	19,073.5	12,060.9	4,386.5	2,107.8	458.2	51.6	42.1	39,020.1
1987	877.3	11,416.9	12,324.4	7,017.6	3,073.8	415.3	25.5	20.0	35,170.9
1988	662.1	6,542.3	15,128.7	11,561.9	5,298.4	737.2	72.3	47.1	40,050.0
1989	428.3	2,447.3	5,144.2	4,079.1	2,863.4	535.3	29.8	25.8	15,553.1
1990	543.3	5,452.8	8,963.7	1,854.4	1,002.9	372.4	21.6	14.4	18,225.6
1991	739.7	7,408.4	6,567.7	3,449.1	1,329.1	225.0	8.8	1.2	19,729.1
1992	319.6	4,173.0	5,091.2	2,431.1	1,047.9	249.6	5.1	0.7	13,318.2
1993	216.7	2,273.5	6,117.2	3,105.0	1,402.7	238.5	9.7	1.4	13,364.7
1994	95.5	2,056.0	3,421.1	3,521.4	1,549.1	381.8	5.8	0.6	11,031.3
1995	161.8	1,604.4	3,454.4	3,917.6	2,500.2	519.6	14.4	0.4	12,172.9
1996	324.8	1,444.9	2,514.2	4,176.9	2,861.8	991.2	21.3	3.7	12,338.8

Table A29. Difference between scale-based and unadjusted weakfish catch in numbers at age ('000s) for reported recreational and commercial (market and scrap) landings, 1982-1996.

	Age							
Year	0	1	2	3	4	5	6	7+
1982	-0.4	-48.1	-175.1	100.4	181.7	-58.2	0.7	-1.0
1983	1.9	2.1	4.2	-3.2	-5.4	0.3	0.0	0.1
1984	0.9	325.1	-290.3	-24.3	-8.3	-3.9	0.3	-0.3
1985	-0.7	728.0	-658.9	-63.8	1.9	-6.4	0.2	-0.3
1986	-0.1	20.8	44.9	4.8	-53.7	22.5	-39	0.0
1987	-0.2	8.2	-5.2	-12.9	18.5	6.5	15	-0.0
1988	-0.1	-3.5	-14.8	-19.7	39.3	-0.8	-0.3	-0.0
1989	0.2	1,156.9	-809.3	-83.9	-286.5	19.3	3.3	0.0
1990	2.1	2,151.9	-2,080.6	-59.0	-10.3	-6.2	2.0	-0.0
1991	30.6	513.6	-578.8	7.2	7.1	18.8	1.3	0.1
1992	30.0	246.1	-259.6	-8.1	-10.0	2.2	0.1	-0.8
1993	15.0	-15.4	-4.8	-4.0	3.0	6.3	0.4	-0.4
1994	22.5	110.6	105.0	-283.4	53.2	-7.3	-0.4	-0.2
1995	11.2	438.6	163.4	-259.5	-366.3	10.2	3.0	-0.5
1996	15.6	293.7	556.9	-68.3	-348.0	-460.2	11.0	-0.7

Table A30. Difference between otolith-based and unadjusted weakfish catch in numbers at age ('000s) for reported recreational and commercial (market and scrap) landings, 1982-1996.

	Age							
Year	0	1	2	3	4	5	6	7+
1982	-12.4	-4,355.1	2,382.7	532.9	1,042.9	428.4	4.0	-23.4
1983	-8.3	-2,701.0	-297.8	1,570.0	1,457.7	144.4	-63.3	-101.8
1984	84.3	-3,324.8	-450.3	1,719.1	1,842.8	191.7	-14.2	-48.8
1985	173.2	-3,378.4	-271.6	1,568.2	1,755.9	158.0	2.2	-7.5
1986	431.0	-12,277.0	8,660.7	1,532.1	1,360.4	326.2	-32.3	-0.7
1987	177.8	-7,069.7	3,251.3	601.3	2,703.3	348.0	-15.1	0.9
1988	-13.8	-2,756.6	-2,176.4	-444.8	4,789.5	599.3	3.6	-0.8
1989	-5.3	-1,403.6	339.2	-547.2	1,104.5	508.8	3.9	-0.3
1990	23.7	-3,842.2	2,895.8	265.3	359.2	297.2	1.2	-0.3
1991	-0.8	-549.7	-793.2	325.0	834.6	184.6	-0.5	0.0
1992	38.6	-726.9	-106.4	-112.8	701.6	205.3	1.3	-0.7
1993	31.3	-336.9	-1,367.7	378.6	1,090.8	201.8	1.5	0.5
1994	30.9	-204.3	-463.0	-603.6	920.1	315.8	4.1	0.1
1995	3.6	99.9	0.2	-696.6	133.5	447.4	12.1	-0.1
1996	7.1	-1.4	-63.3	-6.0	110.2	-59.5	11.8	1.1

Table A31. Difference between scale-based and otolith-based weakfish catch in numbers at age ('000s) for reported recreational and commercial (market and scrap) landings, 1982-1996.

	Age							
Year	0	1	2	3	4	5	6	7+
1982	12.0	4,307.0	-2,557.9	-432.5	-861.2	-486.6	-3.2	22.5
1983	10.2	2,703.1	302.0	-1,573.2	-1,463.1	-144.2	63.3	101.9
1984	-83.3	3,649.9	160.0	-1,743.3	-1,851.0	-195.6	14.5	48.5
1985	-173.9	4,106.5	-387.3	-1,632.0	-1,754.0	-164.4	-2.0	7.2
1986	-431.1	12,298.2	-8,615.9	-1,527.4	-1,414.1	-303.7	-6.7	0.7
1987	-178.0	7,077.9	-3,256.4	-614.2	-2,684.8	-341.5	0.5	-0.9
1988	13.7	2,753.0	2,161.5	425.1	-4,750.1	-600.1	-3.9	0.8
1989	5.5	2,560.5	-1,148.5	463.3	-1,391.1	-489.5	-0.7	0.3
1990	-21.6	5,994.1	-4,976.4	-324.2	-369.6	-303.4	0.7	0.3
1991	31.4	1,063.3	214.4	-317.8	-827.5	-165.8	1.8	0.1
1992	-8.6	973.0	-153.2	104.7	-711.6	-203.1	-1.2	-0.1
1993	-16.3	321.5	1,362.8	-382.7	-1,087.8	-195.5	-1.1	-0.9
1994	-8.4	315.0	567.9	320.3	-866.9	-323.1	-4.4	-0.3
1995	7.6	338.7	163.2	437.1	-499.9	-437.2	-9.1	-0.4
1996	8.5	295.2	620.3	-62.4	-458.2	-400.7	-0.9	-1.8

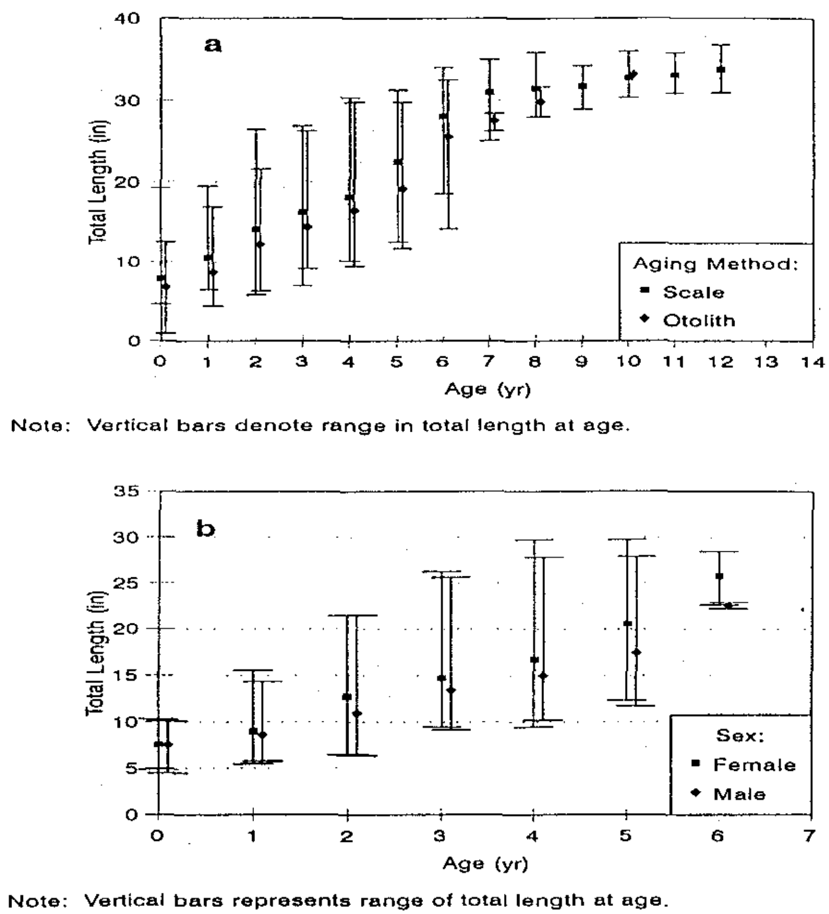

Figure A1. (a) Mean total length at age by aging technique (scale vs. otolith aged) with range for otolith-aged weakfish, 1989-1996. (b) Mean total length at age by sex (males vs. females) from otolith-aged weakfish, 1989-1996.

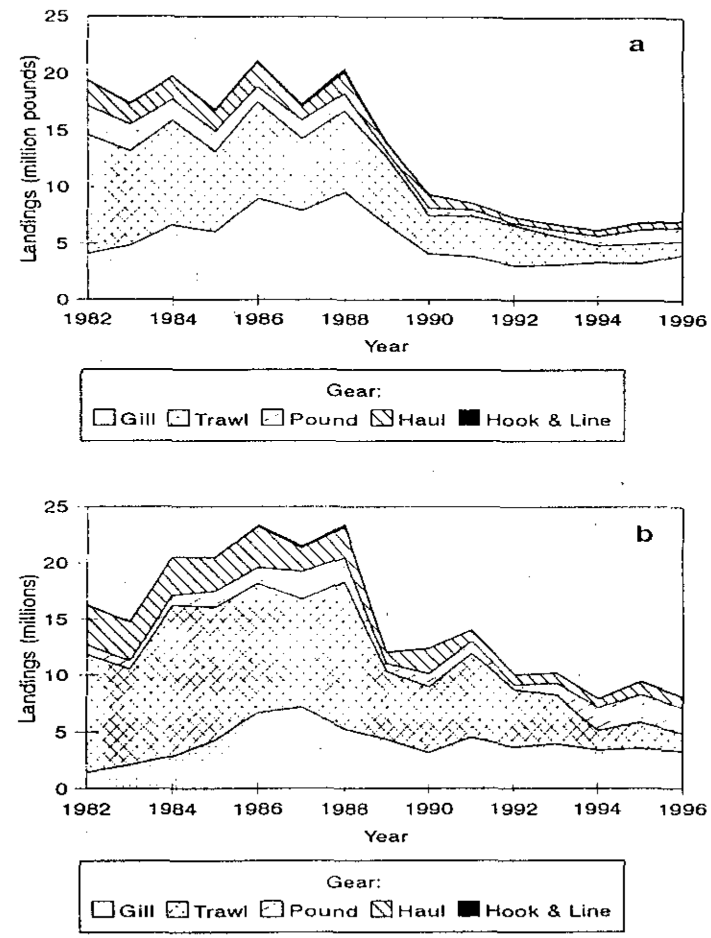

Figure A2. Commercial landings for weakfish by gear in (a) weight and (b) numbers, 1982-1996.

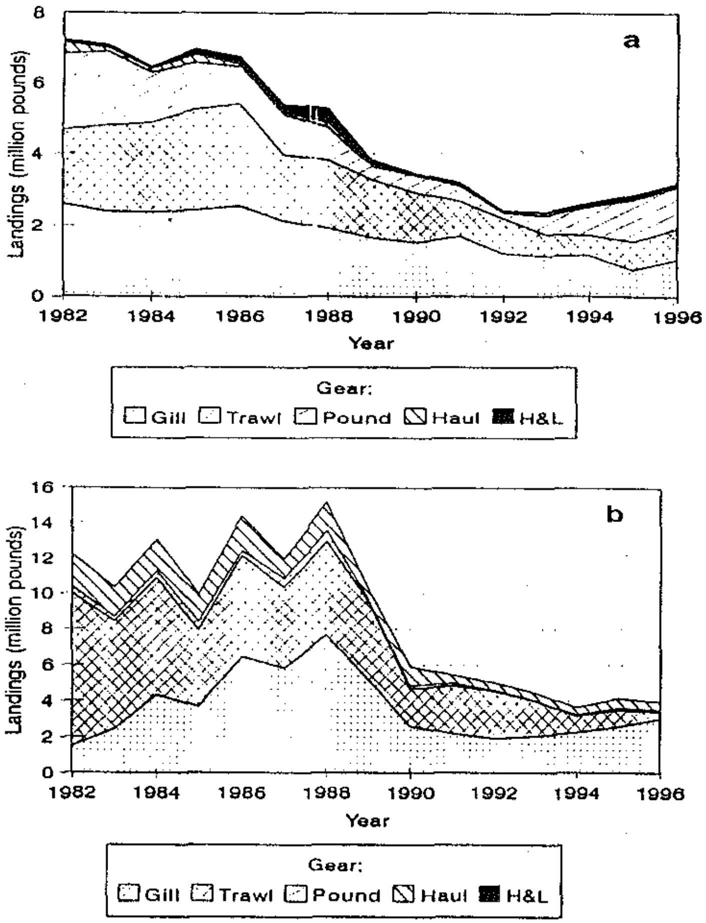

Figure A3. Commercial landings in weight for weakfish by gear in (a) Mid-Atlantic and (b) South Atlantic sub-regions, 1982-1996.

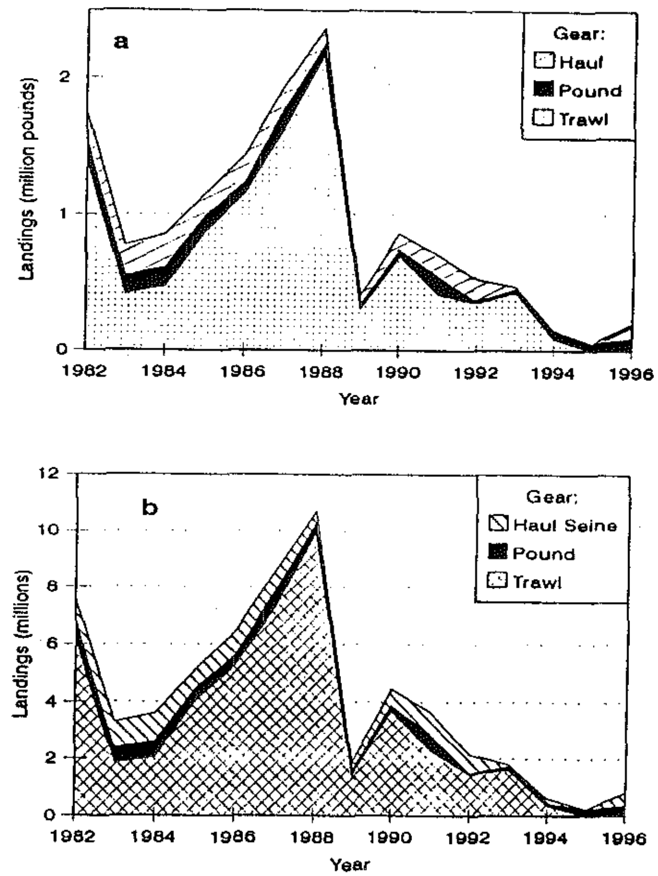

Figure A4. Recreational landings (MRFSS: A+B1+0.20*B2) for weakfish by sub-region in (a) weight and (b) numbers, 1982-1996.

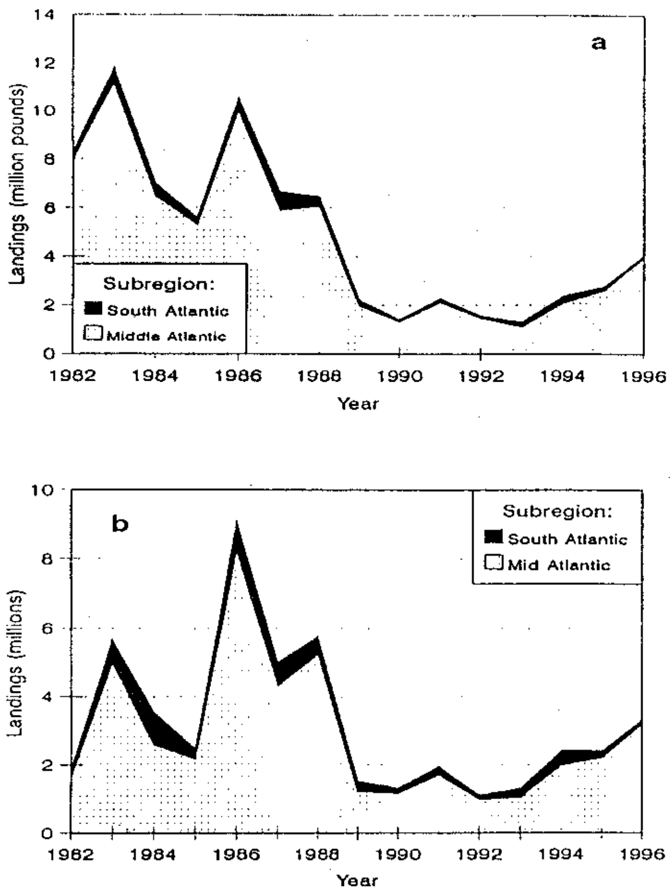

Figure A5. Scrap landings of weakfish from North Carolina and Virginia by gear in (a) weight and (b) numbers, 1982-1996. Note: no North Carolina scrap landings reported in 1995 (included with market fish).

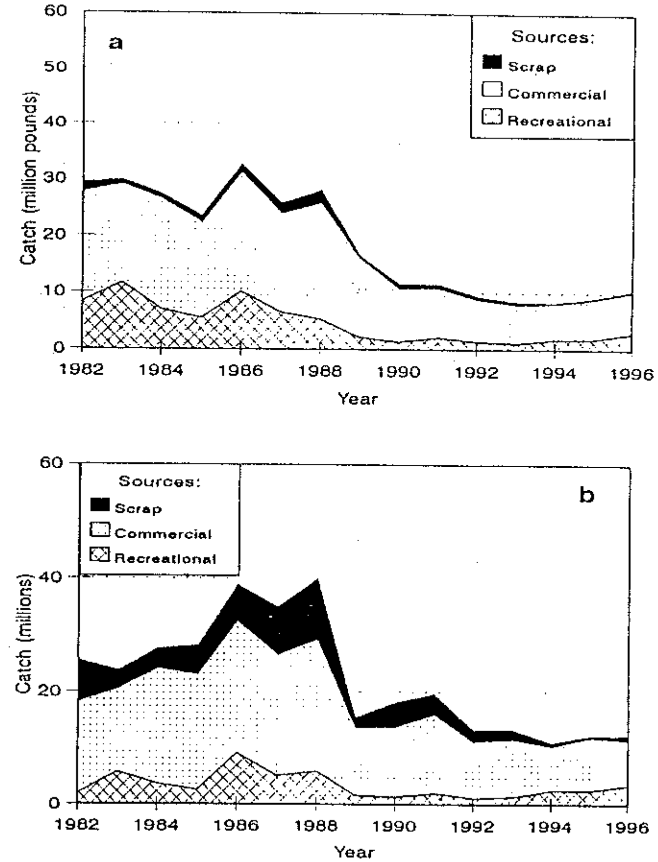

Figure A6. Total landings from recreational, market, and scrap fisheries of weakfish by source in (a) weight and (b) numbers, 1982-1996.

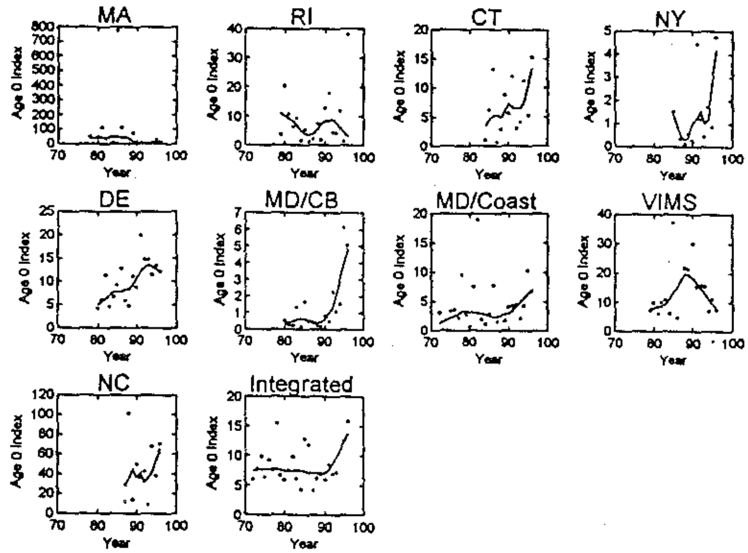

Figure A7. Plots of juvenile (age 0) weakfish indices with LOWESS smoothing by state: Massachusetts DMF survey south of Cape Cod (MA), Rhode Island integrated Narragansett Bay trawl index (RI), Connecticut DEP Long Island Sound trawl survey (CT), New York DEC Peconic Bay juvenile trawl survey (NY), Delaware DFW Delaware Bay juvenile survey (DE), Maryland DNR Chesapeake Bay (MD/CB) and coastal bays (MD/Coast) juvenile trawl surveys, VIMS Chesapeake Bay trawl survey, North Carolina DMF Pamlico Sound juvenile trawl survey (NC), and integrated juvenile index.

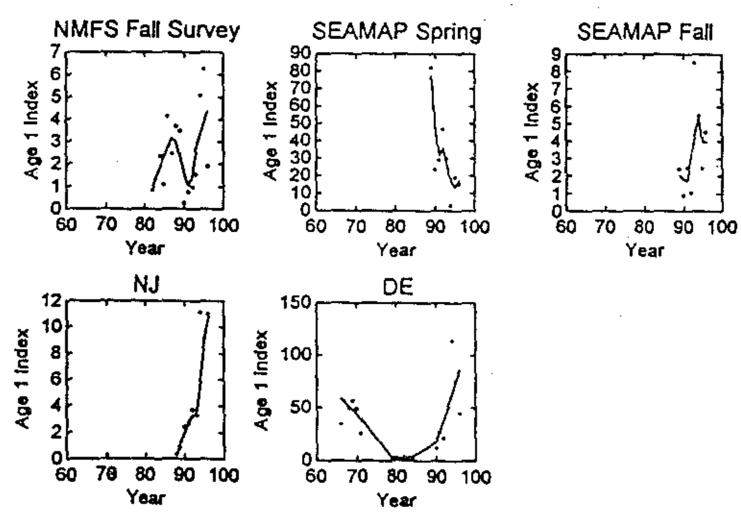

Figure A8. Plots of age 1 weakfish indices with LOWESS smoothing for NMFS fall trawl survey, SEAMAP spring and fall surveys, New Jersey ocean trawl program (NJ), and Delaware DFW trawl survey (DE).

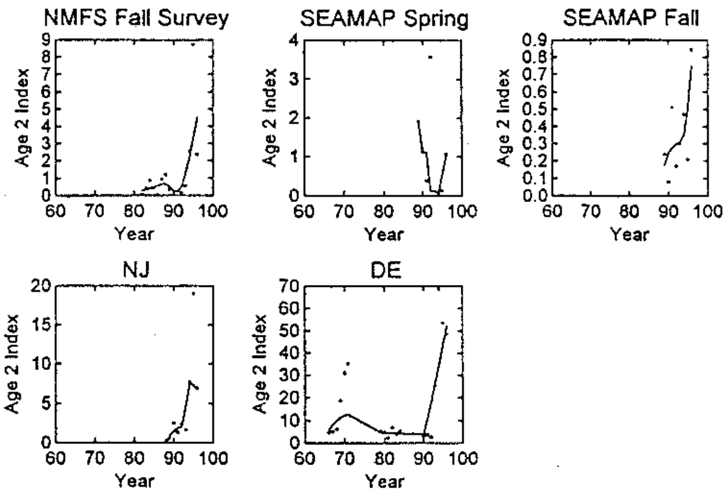

Figure A9. Plots of age 2 weakfish indices with LOWESS smoothing for NMFS fall trawl survey, SEAMAP spring and fall surveys, New Jersey ocean trawl program (NJ), and Delaware DFW trawl survey (DE).

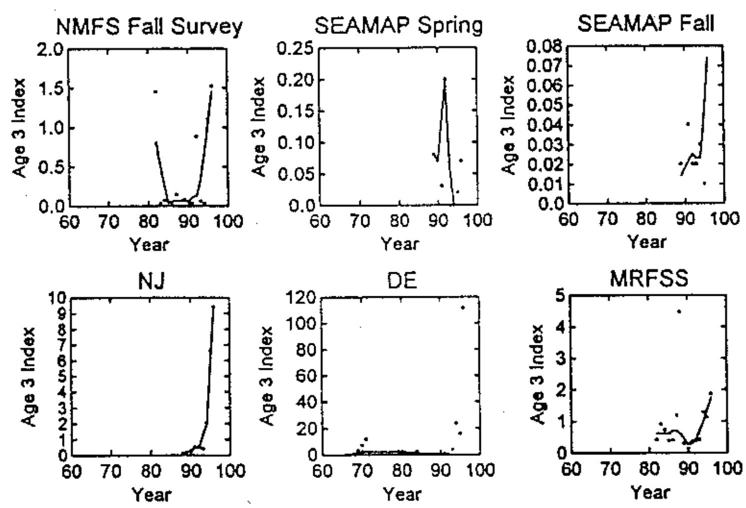

Figure A10. Plots of age 3 weakfish indices with LOWESS smoothing for NMFS fall trawl survey, SEAMAP spring and fall surveys, New Jersey ocean trawl program (NJ), Delaware DFW trawl survey (DE), and MRFSS recreational catch per trip.

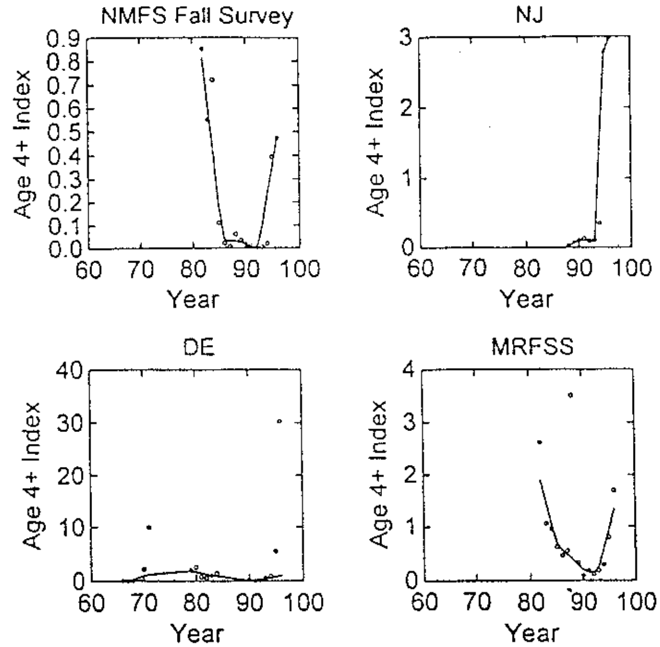

Figure A11. Plots of age 4 and older weakfish indices with LOWESS smoothing for NMFS fall trawl survey, New Jersey ocean trawl program (NJ), Delaware DFW trawl survey (DE), and MRFSS recreational catch per trip.

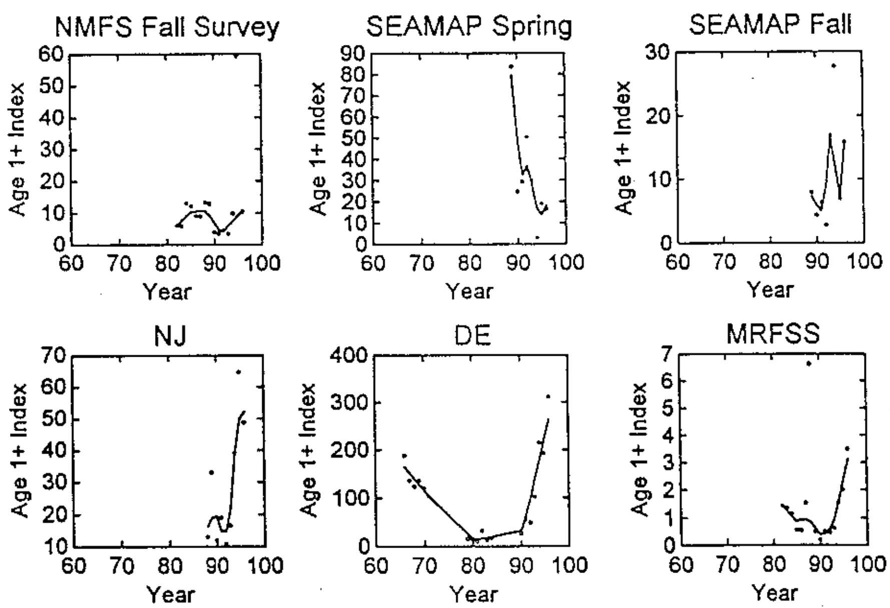

Figure A12. Plots of age 1 and older (total) weakfish indices with LOWESS smoothing for NMFS fall trawl survey, SEAMAP spring and fall surveys, New Jersey ocean trawl program (NJ), Delaware DFW trawl survey (DE), and MRFSS recreational catch per trip.

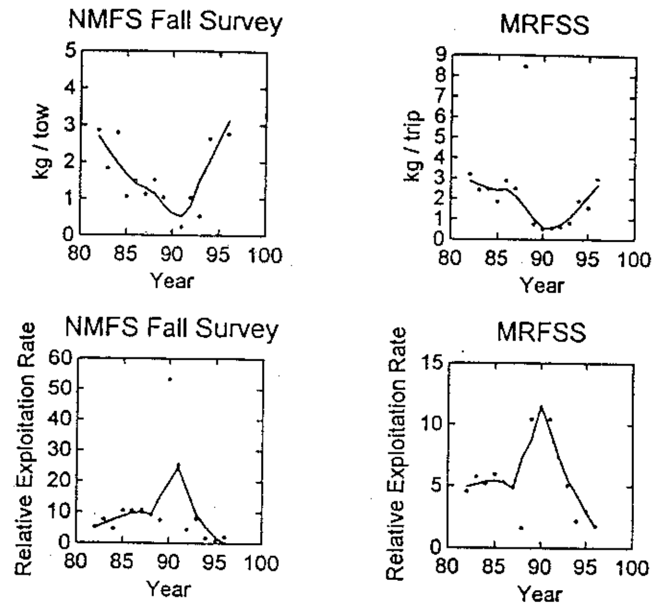

Figure A13. Catch in kilograms per unit effort for NMFS fall trawl survey (tow) and MRFSS (trip), and relative exploitation rate based on total weakfish landings divided by catch per effort. LOWESS smoothing is included in these plots.

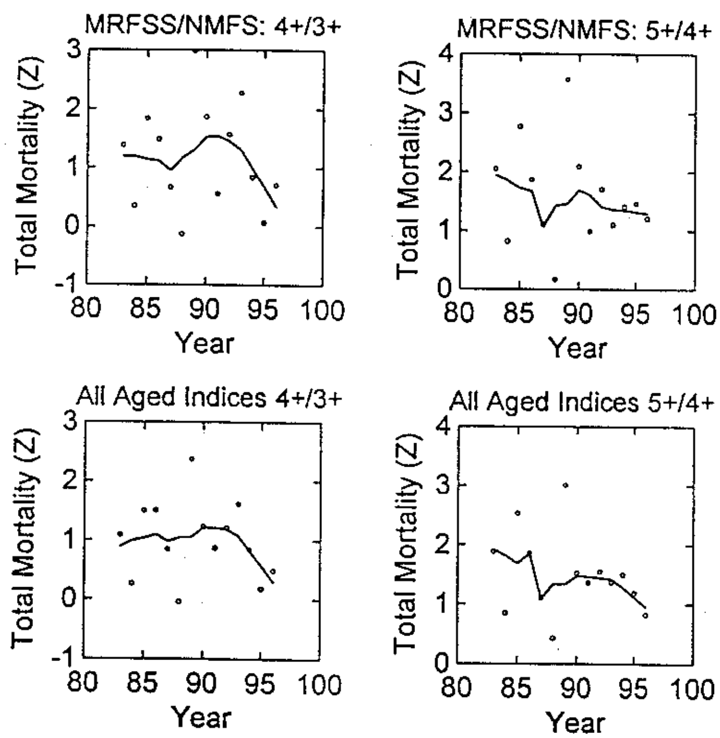

Figure A14. Total mortality (Z) with LOWESS smoothing for catch curve estimates from ages 4+/3+ and ages 5+/4+. Age specific catch in numbers by age with MRFSS and NMFS fall trawl survey combined, and aged indices combined (by averaging standard normal deviates and retransforming to MRFSS currency).

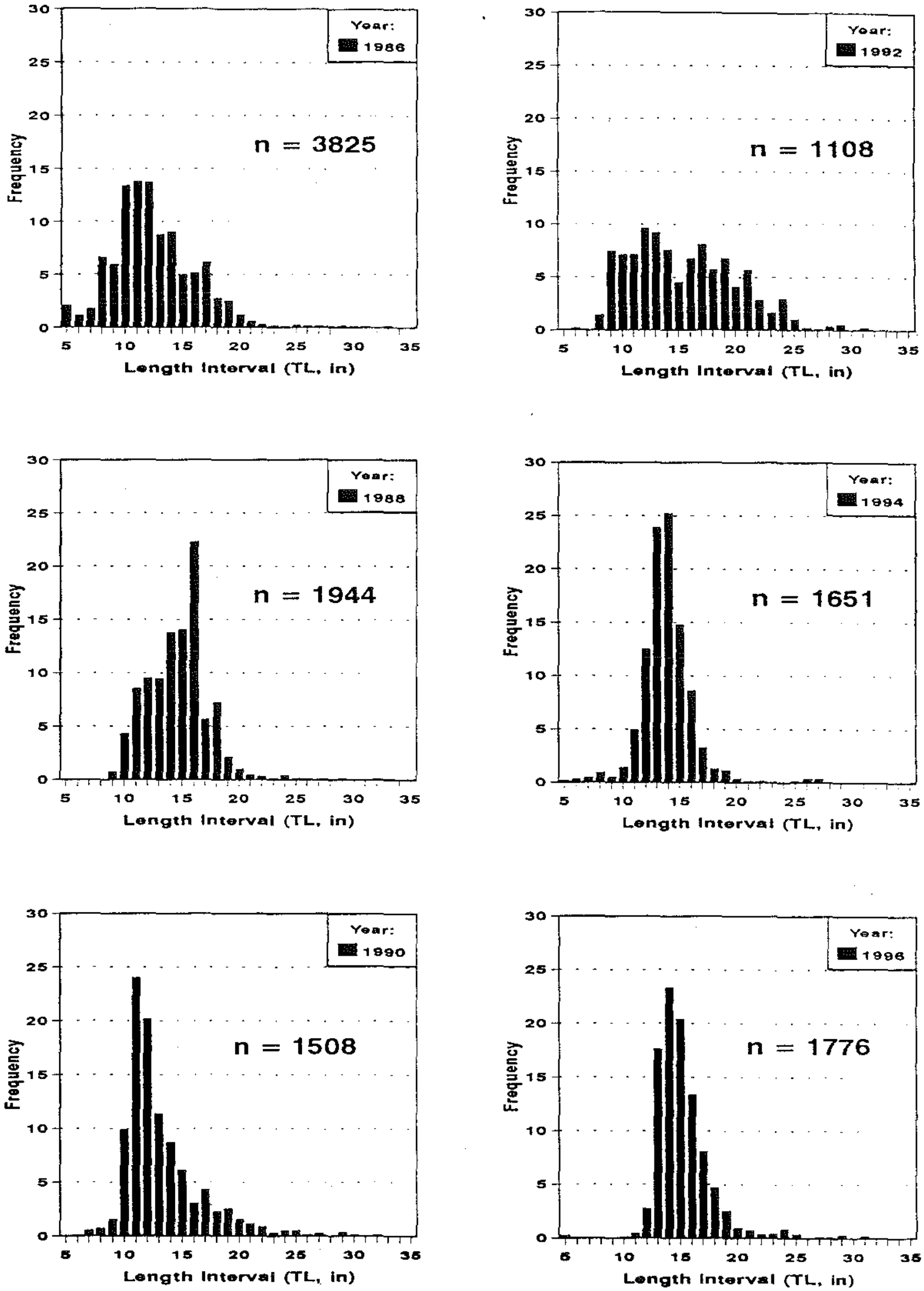

Figure A15. Annual length frequency distributions for weakfish from recreational intercepts (MRFSS), 1986-1996 (alternate years).

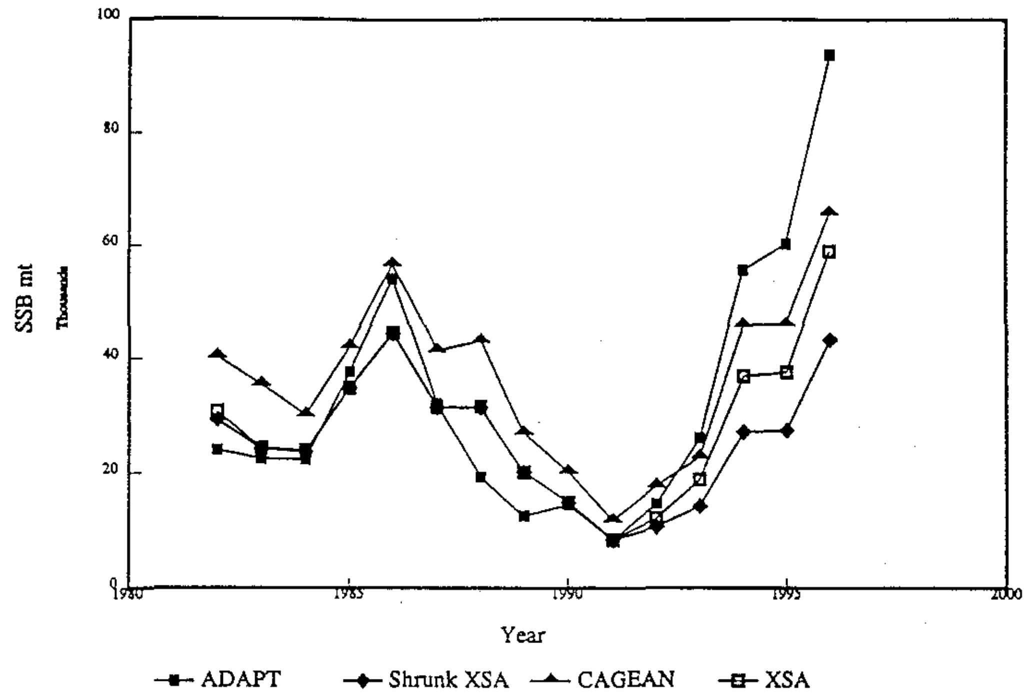

Figure A16. Comparison of XSA, CAGEAN, and ADAPT VPA model otolith results for weakfish SSB.

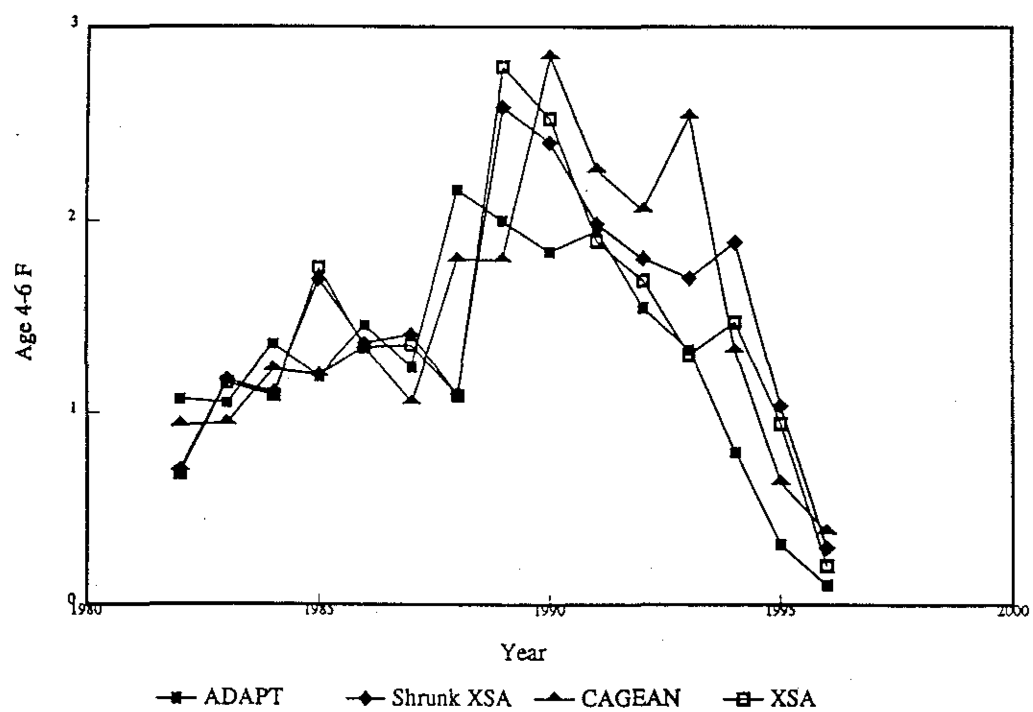

Figure A17. Comparison of XSA, CAGEAN, and ADAPT VPA model otolith results for weakfish fishing mortality.

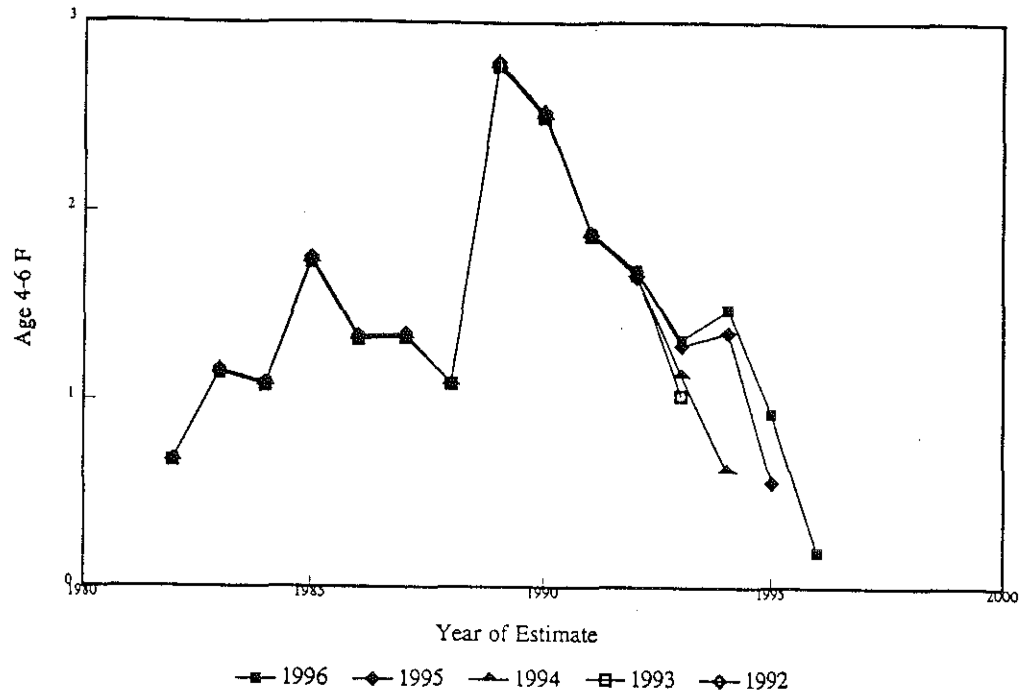

Figure A18. Weakfish XSA VPA without shrinkage retrospective pattern for fishing mortality rate.

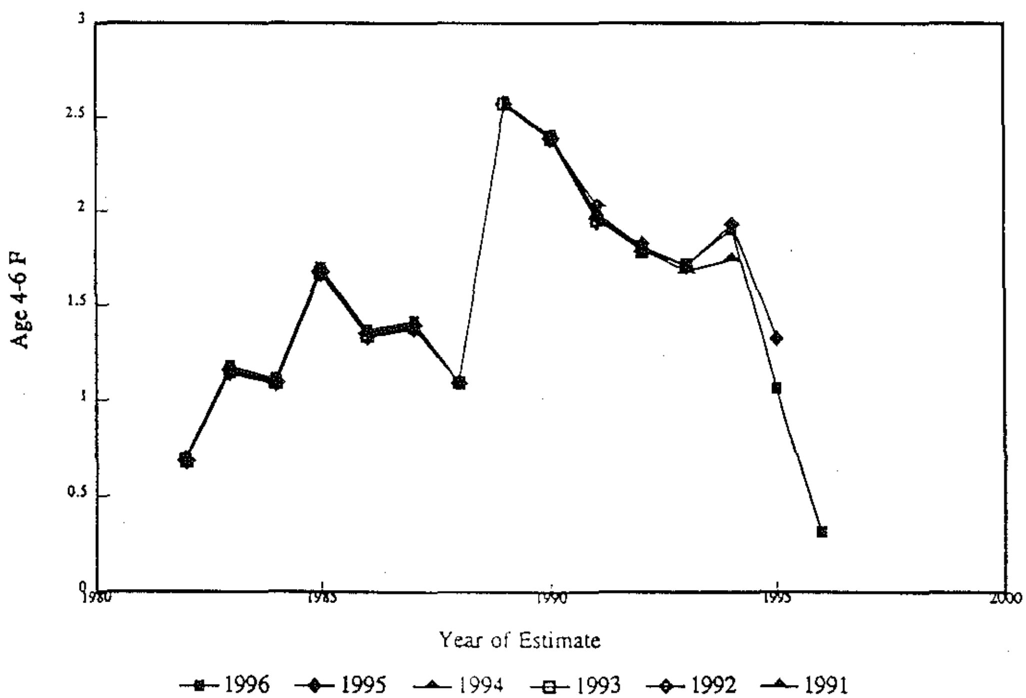

Figure A19. Weakfish XSA VPA with shrinkage retrospective pattern for fishing mortality rate.

APPENDIX A

Sample sizes for aging data

Weakfish (1982-1996): Sampling by year, season, and area (unadjusted)

Year	Season	Area	Frequency	Percent	Cumulative frequency	Cumulative percent
82	E	SA	266	0.9	266	0.9
82	L	SA	323	1.1	589	2.0
83	E	SA	321	1.1	910	3.0
83	L	SA	327	1.1	1,237	4.1
85	E	MA	102	0.3	1,339	4.5
85	L	MA	1,293	4.3	2,632	8.8
86	E	MA	307	1.0	2,939	9.8
86	L	MA	1,318	4.4	4,257	14.2
88	E	MA	357	1.2	4,614	15.4
88	E	SA	217	0.7	4,831	16.2
88	L	MA	139	0.5	4,970	16.6
88	L	SA	209	0.7	5,179	17.3
89	E	MA	515	1.7	5,694	19.1
89	E	SA	172	0.6	5,866	19.6
89	L	MA	76	0.3	5,942	19.9
89	L	SA	185	0.6	6,127	20.5
90	E	MA	80	0.3	6,207	20.8
90	E	SA	136	0.5	6,343	21.2
90	L	MA	85	0.3	6,428	21.5
90	L	SA	136	0.5	6,564	22.0
91	E	MA	423	1.4	6,987	23.4
91	E	SA	516	1.7	7,503	25.1
91	L	SA	699	2.3	8,202	27.4
92	E	MA	606	2.0	8,808	29.5
92	E	SA	1,228	4.1	10,036	33.6
92	L	MA	1,047	3.5	11,083	37.1
92	L	SA	766	2.6	11,849	39.6
93	E	MA	507	1.7	12,356	41.3
93	E	SA	462	1.5	12,818	42.9
93	L	MA	2,308	7.7	15,126	50.6
93	L	SA	912	3.1	16,038	53.7
94	E	MA	849	2.8	16,887	56.5
94	E	SA	691	2.3	17,578	58.8
94	L	MA	834	2.8	18,412	61.6
94	L	SA	548	1.8	18,960	63.4
95	E	MA	1,290	4.3	20,250	67.8
95	E	SA	937	3.1	21,187	70.9
95	L	MA	1,789	6.0	22,976	76.9
95	L	SA	997	3.3	23,973	80.2
96	E	MA	1,578	5.3	25,551	85.5
96	E	SA	1,198	4.0	26,749	89.5
96	L	MA	1,803	6.0	28,552	95.5
96	L	SA	1,333	4.5	29,885	100.0

Weakfish (1982-1996): Sampling by year, season, and area (unadjusted)

Aged by otoliths

Year	Season	Area	Frequency	Percent	Cumulative frequency	Cumulative percent
89	E	MA	129	1.0	129	1.0
90	E	MA	52	0.4	181	1.4
91	E	MA	423	3.3	604	4.7
91	E	SA	294	2.3	898	7.0
91	L	SA	438	3.4	1,336	10.4
92	E	MA	427	3.3	1,763	13.7
92	E	SA	899	7.0	2,662	20.7
92	L	MA	172	1.3	2,834	22.0
92	L	SA	496	3.9	3,330	25.9
93	E	SA	37	0.3	3,367	26.2
93	L	SA	630	4.9	3,997	31.0
94	E	SA	247	1.9	4,244	33.0
94	L	MA	309	2.4	4,553	35.4
94	L	SA	303	2.4	4,856	37.7
95	E	MA	693	5.4	5,549	43.1
95	E	SA	429	3.3	5,978	46.4
95	L	MA	1,245	9.7	7,223	56.1
95	L	SA	997	7.7	8,220	63.8
96	E	MA	751	5.8	8,971	69.7
96	E	SA	1,198	9.3	10,169	79.0
96	L	MA	1,373	10.7	11,542	89.6
96	L	SA	1,333	10.4	12,875	100.0

Weakfish (1982-1996): Sampling by year, season, and area (unadjusted)

Aged by scales

Year	Season	Area	Frequency	Percent	Cumulative frequency	Cumulative percent
82	E	SA	266	1.6	266	1.6
82	L	SA	323	1.9	589	3.5
83	E	SA	321	1.9	910	5.3
83	L	SA	327	1.9	1,237	7.3
85	E	MA	102	0.6	1,339	7.9
85	L	MA	1,293	7.6	2,632	15.5
86	E	MA	307	1.8	2,939	17.3
86	L	MA	1,318	7.7	4,257	25.0
88	E	MA	357	2.1	4,614	27.1
88	E	SA	217	1.3	4,831	28.4
88	L	MA	139	0.8	4,970	29.2
88	L	SA	209	1.2	5,179	30.4
89	E	MA	386	2.3	5,565	32.7
89	E	SA	172	1.0	5,737	33.7
89	L	MA	76	0.4	5,813	34.2
89	L	SA	185	1.1	5,998	35.3
90	E	MA	28	0.2	6,026	35.4
90	E	SA	136	0.8	6,162	36.2
90	L	MA	85	0.5	6,247	36.7
90	L	SA	136	0.8	6,383	37.5
91	E	SA	222	1.3	6,605	38.8
91	L	SA	261	1.5	6,866	40.4
92	E	MA	179	1.1	7,045	41.4
92	E	SA	329	1.9	7,374	43.4
92	L	MA	875	5.1	8,249	48.5
92	L	SA	270	1.6	8,519	50.1
93	E	MA	507	3.0	9,026	53.1
93	E	SA	425	2.5	9,451	55.6
93	L	MA	2,308	13.6	11,759	69.1
93	L	SA	282	1.7	12,041	70.8
94	E	MA	849	5.0	12,890	75.8
94	E	SA	444	2.6	13,334	78.4
94	L	MA	525	3.1	13,859	81.5
94	L	SA	245	1.4	14,104	82.9
95	E	MA	597	3.5	14,701	86.4
95	E	SA	508	3.0	15,209	89.4
95	L	MA	544	3.2	15,753	92.6
96	E	MA	827	4.9	16,580	97.5
96	L	MA	430	2.5	17,010	100.0

Weakfish (1982-1996): Sampling by source, year, and how aged (scale or otolith)

Source: NEFSC

Year	Aged	Frequency	Percent	Cumulative frequency	Cumulative percent
96	O	448	100.0	448	100.0

Source: SEAMAP

Year	Aged	Frequency	Percent	Cumulative frequency	Cumulative percent
91	O	732	17.3	732	17.3
92	O	1,395	32.9	2,127	50.2
93	O	660	15.6	2,787	65.8
94	O	235	5.6	3,022	71.4
95	O	326	7.7	3,348	79.1
96	O	886	20.9	4,234	100.0

Source: Delaware

Year	Aged	Frequency	Percent	Cumulative frequency	Cumulative percent
92	S	584	7.8	584	7.8
93	S	2,067	27.7	2,651	35.5
94	S	675	9.0	3,326	44.5
95	O	1,156	15.5	4,482	60.0
95	S	798	10.7	5,280	70.7
96	O	1,247	16.7	6,527	87.4
96	S	943	12.6	7,470	100.0

Source: Florida

Year	Aged	Frequency	Percent	Cumulative frequency	Cumulative percent
93	O	7	1.3	7	1.3
94	O	315	59.9	322	61.2
95	O	204	38.8	526	100.0

Source: Maryland

Year	Aged	Frequency	Percent	Cumulative frequency	Cumulative percent
85	S	1,396	34.8	1,396	34.8
86	S	1,627	40.6	3,023	75.4
93	S	103	2.6	3,126	78.0
94	O	309	7.7	3,435	85.7
94	S	181	4.5	3,616	90.2
95	S	185	4.6	3,801	94.8
96	O	207	5.2	4,008	100.0

Source: North Carolina

Year	Aged	Frequency	Percent	Cumulative frequency	Cumulative percent
82	S	589	7.5	589	7.5
83	S	649	8.3	1,238	15.8
88	S	426	5.4	1,664	21.3
89	S	357	4.6	2,021	25.8
90	S	272	3.5	2,293	29.3
91	S	483	6.2	2,776	35.5
92	S	599	7.7	3,375	43.1
93	S	708	9.1	4,083	52.2
94	S	689	8.8	4,772	61.0
95	O	897	11.5	5,669	72.5
95	S	508	6.5	6,177	79.0
96	O	1,645	21.0	7,822	100.0

Source: New Jersey

Year	Aged	Frequency	Percent	Cumulative frequency	Cumulative percent
95	O	281	58.5	281	58.5
96	O	199	41.5	480	100.0

Source: New York

Year	Aged	Frequency	Percent	Cumulative frequency	Cumulative percent
88	S	496	15.1	496	15.1
89	S	462	14.0	958	29.1
90	S	113	3.4	1,071	32.6
92	S	470	14.3	1,541	46.8
93	S	645	19.6	2,186	66.4
94	S	518	15.7	2,704	82.2
95	O	114	3.5	2,818	85.7
95	S	158	4.8	2,976	90.5
96	S	314	9.5	3,290	100.0

Source: Virginia

Year	Aged	Frequency	Percent	Cumulative frequency	Cumulative percent
89	O	129	8.0	129	8.0
90	O	52	3.2	181	11.2
91	O	423	26.2	604	37.4
92	O	599	37.1	1,203	74.5
95	O	387	24.0	1,590	98.5
96	O	25	1.5	1,615	100.0

B. SURFCLAMS

Terms of Reference

a. Evaluate the efficiency of current research vessel dredge surveys through field studies of dredge tow path length, size selectivity and retention of surfclams and ocean quahogs, and other factors, as appropriate.

b. Develop and implement a sampling plan for the proposed 1997 region-wide surfclam and ocean quahog survey, incorporating appropriate tests and monitoring of dredge performance and efficiency.

c. Develop, test, and implement models to estimate surfclam abundance and mortality rates, using appropriate indices of abundance and total catch.

d. Review existing biological reference points and advise on new reference points consistent with SFA requirements.

e. Assess the status of EEZ surfclam populations under management, and provide quota options consistent with biological reference points.

f. Estimate the resource level, density, and potential harvest from the surfclam beds located off Delmarva (under current FMP criteria).

g. Compare the average size, growth, and yield of Delmarva surfclams with surfclams harvested in other areas.

h. Determine if high density is constricting growth of Delmarva surfclams, and estimate an "optimal" density of surfclams off Delmarva.

I. Estimate the long-term outlook/projection for the Delmarva surfclam resource if the harvest continues at the present level.

Introduction

The history of surfclam and ocean quahog management along the Atlantic coast of the US is summarized, through 1986, in Murawski and Serchuk (1989). Surfclams were assessed in 1992 and 1994 (NEFSC 1993, 1995), for SAW-15 and SAW-19, respectively. Those assessments reported historical trends in commercial landings and effort by region, size composition of the landings, levels of discarding, trends in survey abundance indices, and population size structure. Additional comments on the uncertainty of assessment advice and the necessity for additional research on abundance were highlighted at SAW-22 (NEFSC 1996a,b).

Estimates of exploitable surfclam biomass and fishing mortality rate were derived for SAW-19 from a modified DeLury model (Conser 1995) based on a time series of catch and abundance information beginning with 1982. The surfclam biomass estimates for 1994, derived from this model 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. It was noted that the catchability of surfclams in the 1994 NEFSC survey appeared to differ substantially from previous surveys, and this was noted as a source of uncertainty for the assessment (NEFSC 1995). Additional analyses of the modified DeLury model during SAW-22 (NEFSC 1996a), with a time series extended back to 1980, produced model results that were very similar to those based on the shorter time series. The SARC noted that the modified DeLury model estimated a probability of capture given encounter for the clam dredge that was unreasonably high. Based on the unusual 1994 survey catch per tow and the unrealistic dredge efficiency estimate from the model, SAW-22 concluded that current abundance was uncertain (NEFSC 1996b). That uncertainty motivated the comprehensive list of terms of reference for the current assessment.

The current assessment relies heavily on new data collected in 1997. The data include a stratified random survey of the EEZ stock as well as experiments conducted to understand the behavior and efficiency of the NEFSC clam dredge. The new Shipboard Computing System and environmental sensors on the *Delaware II* were used to gather, for the first time, continuous data on ship speed, position, and dredge angle during every tow. These data allowed for a direct estimate of distance sampled per tow by the dredge. Depletion studies of dredge efficiency were also conducted for the first time and were carried out in a cooperative program between NMFS, the clam industry, and academia (see **Acknowledgments**). Stock biomass and net annual production were estimated for each region along the east coast of the US. Confidence intervals on stock size were obtained via a bootstrap procedure. Because this fishery is highly localized, considerable attention was also given to temporal and spatial trends in the commercial data. Detailed analyses of vessel logbook information included evaluating changes in the spatial distribution of fishing in relation to resource abundance, and the adequacy of LPUE as a measure of relative abundance.

The current assessment also includes revised biological reference points for three important regions using shell length and age data collected during the 1997 survey. These reference points are used for comparison with observed fishing mortality rates.

Finally, a set of analyses were devoted to that part of the stock off the Delmarva Peninsula. The overall purpose was to determine whether these clams were "stunted" and the extent to which their growth was affected by density. Papers by Weinberg and Helser (1996) and Weinberg (in press) on surfclam growth provided a background for analysis of the 1997 data from the Delmarva region.

This report presents an outline of technical analyses undertaken and specific conclusions regarding major research findings. A list of research recommendations, sources of uncertainty, and SARC comments are included.

Executive Summary

(TOR a) Evaluate the efficiency of current research vessel dredge surveys through field studies of dredge tow path length, size selectivity and retention of surfclams and ocean quahogs, and other factors, as appropriate

- Performance of the dredge in the 1997 survey was monitored with additional new technology including bottom contact sensors, an angle indicator (which was the main method to determine when the dredge was and was not fishing), pressure/depth sensors, amperage gauge, P-code GPS to determine ship's position and velocity, and some video monitoring of dredge performance.
- From the information available on each tow, it was possible to estimate the path length by multiplying the velocity of the ship in each 1-second interval of the tow by a 0/1 indicator of bottom contact, based on information from the angle indicator, and summing over the duration of the tow. In the 1997 survey, the average tow path length was significantly longer than in previous years owing to the slower winch pay out and retrieval speeds. Survey catches were standardized to a path length of 0.15 nm by multiplying the nominal catch by the ratio of 0.15/imputed path length, using the procedure above. Based on this procedure and associated monitoring, confidence in the estimation of path length has increased, although there is still some uncertainty based on the arbitrary assumption of an appropriate dredge angle (2.3° associated with the knife depth of 4 in) indicating bottom contact. The results were not particularly sensitive to this assumption.
- Field studies of dredge efficiency for surfclams were undertaken employing a series of six small-scale depletions at sites along the New Jersey coast. These studies involved the *Delaware II* and three commercial clam vessels. At each site, repeated dredge tows were taken wherein the catch rate on each tow (bushels and numbers of clams) vs the cumulative catch was monitored. The relationship between the decline in catch rate over the experiment and total removals was used to estimate initial site clam density (clams per unit area of the depletion site). Prior to the commercial vessel surveys, the *Delaware II* conducted eight 'set-up' tows at each site which were used to independently estimate clam density at each location. The *Delaware II* conducted its own depletion study at one site.
- Shell size selectivity between survey and commercial dredges was evaluated by comparing length compositions among the *Delaware II* set-up tows

and the commercial depletions. The *Delaware II* catches included higher frequencies of animals at small sizes (e.g., below 12 cm), but these differences in volume or weight probably do not significantly influence efficiency estimates.

- New estimators of population parameters from depletion studies based on maximum likelihood procedures were implemented and compared with those from the Leslie-DeLury model. The alternative estimators were more robust, but gave point estimates of initial population size and dredge efficiency similar to those from the traditional linear regression methods.

- Based on the depletion studies, efficiency (proportion of clams in the dredge path retained in the dredge) of the *Delaware II* dredge was estimated to range from 0.2 to 0.6 (point estimates from average density from set-up tows relative to commercial vessel depletions and the *Delaware II* study). The *Delaware II* depletion study resulted in an estimate of efficiency of 0.59 (95% CI 0.3-0.9). Commercial vessel efficiencies ranged from 0.38 to 1.0. Analyses conducted during the SARC meeting suggested that these dredge efficiency estimates are biased high. The magnitude of the bias remains to be determined. Based on the depletion studies, there is strong evidence that dredge efficiency varies by sediment type and sea state. For abundance studies, the average *Delaware II* dredge efficiency point estimate of 0.59 was used, which results in conservative (e.g., lower) biomass than if efficiency were assumed to be lower.

- During the 1997 survey, re-sampling at stations originally sampled in 1992 and 1994 surveys occurred. After adjusting for clam mortalities in the intervening years at each site (e.g., natural mortality), the catch rates in 1994 were anomalously high when compared to 1992 and 1997 results. There was no evidence that the 1997 dredge efficiency differed from that in 1992. Based on the average dredge efficiencies calculated from depletion studies, the 1994 results could be explained by high dredge efficiencies in that year.

<u>(TOR b) Develop and implement a sampling plan for the proposed 1997 region-wide surfclam and ocean quahog survey, incorporating appropriate tests and monitoring of dredge performance and efficiency</u>

- Preliminary analysis of experiments on factors influencing survey dredge catches, conducted prior to the 1997 survey, confirmed the utility of basic sampling protocols (tow speed, scope of towing hawser, dredge handling). The 1997 survey used these procedures as in previous years.

- The 1997 clam survey assessed resources in all survey areas from Southern Virginia-North Carolina through Georges Bank. A total of 304 survey dredge tows were completed in surfclam strata, with additional stations in areas containing primarily ocean quahogs. Survey effort was increased in some areas (e.g., Northern New Jersey) to assure adequate spatial coverage of stations to allow for swept-area population estimates. Average coefficients of variation in survey numbers per tow were 0.13 in Northern New Jersey and 0.18 in Delmarva, the areas containing the bulk of the Mid-Atlantic resource. CVs were greater elsewhere.

- A bootstrap procedure was used to compute means and 95% confidence intervals from the survey estimates. These bootstrap estimates are preferred, given the modest sample sizes within complex survey designs and the fact that they preclude negative CIs (e.g., are asymmetrical).

- Minimum swept-area surfclam biomass estimates and 95% CIs for 1997 were computed based on the average catch (meat weight) per tow, stratified by assessment area (e.g., a different stratified mean appropriate to each assessment region). These estimates are:

Region	Total (000s mt)			Full recruits (000s mt)		
	Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
GBK	90	172	263	53	85	120
SNE	15	46	82	15	45	83
LI	1	11	21	1	9	17
NNJ	189	240	294	168	222	277
SNJ	6	21	39	7	21	37
DMV	110	167	227	64	99	146
SVA/NC	3	6	10	2	2	2

- If an average *Delaware II* dredge efficiency of 0.59 is used, the means increase to:

Region	Total (000s mt)	Full recruits (000s mt)
	Mean	Mean
GBK	291	144
SNE	78	76
LI	19	15
NNJ	407	376
SNJ	35	36
DMV	283	168
SVA/NC	10	3

- These biomasses are significantly larger that those calculated in previous assessments of the resource, reflecting greater confidence in the use of swept-area population estimates, given the calibration studies undertaken this year. Several additional research issues related to swept-area methods remain, including precise estimates of stratum areas, and accounting for variations in dredge efficiency by depth, substrate type, and sea state, and bias in parameter estimation.

(TOR c) Develop, test, and implement models to estimate surfclam abundance and mortality rates, using appropriate indices of abundance and total catch

- EEZ surfclam catch continues to be taken primarily from the NNJ assessment area (81% in volume/weight in 1996), with minor proportions from Delmarva (11%) and Southern New Jersey and elsewhere.

- Detailed analysis of the spatial distribution of fishery catches and effort from vessel logbooks indicated an eastward and northward expansion of the fishery from 1987 to 1996. Interpretation of CPUE prior to 1991 is confounded by the maximum allowed fishing times in force in the fishery. Since 1991, however, the CPUE data present a consistent picture of the distribution and relative catch rates by the fishery in areas under exploitation. Average CPUE off NNJ has declined since 1991 (from about 1.1 to 0.7 mt of meats per hour fishing).

- The spatial distribution of the resource (based on research vessel surveys) was mapped over the distribution of the catch (based on vessel logbook data) in various years. Currently, there is little of the surfclam resource in the NNJ area outside the zone of active fishing (e.g., no additional untapped resource to which the fishery can expand). The catch and CPUE of the fishery are spatially coincident with the resource distribution from surveys. Off Delmarva and elsewhere, major portions of the resource are currently unfished due to economic considerations.

- Size composition data from the fishery indicate little change in the average composition of landings in the past several years. Animals removed from Delmarva are significantly smaller, on average, than those from New Jersey, reflecting the differences in the resources between areas. Length/weight data collected from the 1997 survey indicate that Delmarva clams have significantly lower condition factors (about 15% in meat weight at 120 mm length) that those off New Jersey.

- Potential differences in survey catchability among surveys (e.g., 1994 and 1997) preclude a reliable time-series approach to models relating fishery-independent abundance to removals. Likewise, LPUE data, although consistent over the last several years (1991-1997) in NNJ, cannot be used to model resource abundance in all areas consistently (e.g., large fractions of the Delmarva resource are not exploited and thus not reflected in the LPUE indices).

- A model of biomass production and harvesting in the various assessment areas was developed based on annual biomass production from survey-based estimates. Annual production (biomass gain from individual growth) minus losses (natural mortality, landings and unobserved fishing mortalities) was estimated for each area based on survey size compositions, length-weight parameters, growth equations (in shell length), swept-area population estimates from surveys, and natural mortality rates. Effects on net productivity of uncertainty in estimates of dredge efficiency and natural mortality were evaluated. The effects of alternative length/weight parameters and other inputs were also considered.

- Nominal results of the biomass production model indicate that net production (increases minus decreases) is about zero off NNJ, indicating that the fishery removals are approximately balanced by growth. These results are sensitive to the estimate of natural mortality (M), which is poorly known. M may likely exceed the nominal value used. Likewise, the nominal model run used a dredge efficiency of 0.59, which is the highest point value estimated experimentally and is known to have a positive bias, and thus produces a more conservative (e.g., lower) biomass estimate than if other experimentally-derived estimates of efficiency were used.

- Net biomass production is likely positive for the entire Mid-Atlantic area at 16,000 mt per year, with the majority generated off Delmarva (about 12,000 mt per year). For SNE, LI, NNJ, SNJ, and combined, new production approximately balances removals. On Georges Bank, net production is about 30,000 mt. However, this estimate is probably inflated because significant portions of the survey strata used in the swept-area biomass calculation on Georges Bank may not be suitable as surfclam habitat.

- Results of the biomass production models can be used to provide short- and long-term guidance to managers regarding removal strategies. In the short term, the production model indicated adequate resource to sustain the fishery at current removal rates for the NNJ area, wherein the bulk of the fishery is concentrated. Any additional increases in catch there would probably result in declining resource abundance, with the rate of resource decline dependent on the level of removal. Given that all the known resource is now within the area of active fishing, further continued declines in CPUE off NNJ are likely. The fishery could be expanded in the Delmarva area since that is the one Mid-Atlantic area in which there is significant annual surplus production. However, careful consideration needs to be given to the potential impacts on the NNJ area of any global quota adjustments (e.g., the sustainability of the NNJ harvest area). Owing to the apparent balance between production and removals and uncertainty in important parameters (e.g., natural mortality, dredge efficiency, non-landings mortality) in the NNJ area, increases in removals should be considered carefully. The region should be monitored at a greater frequency (e.g., resource survey every two years) and intensity (station density). Finer-scale information on the geographic locations of removals is also necessary.

<u>(TOR d) Review existing biological reference points and advise on new reference points consistent with SFA requirements</u>

- Traditional F-based reference points were revised, considering new information on growth. These revised estimates (by region) are:

Area	F_{max}	$F_{0.1}$	$F_{20\%msp}$
NNJ	0.21	0.07	0.18
Delmarva	0.21	0.07	0.18
Georges Bank	0.19	0.07	0.17

- The F-based reference points given above are likely greater than current harvest rates and should only be considered as potential LIMIT (THRESHOLD) REFERENCE POINTS. Furthermore, given the results from the biomass production approach, it is recommended that TARGET reference points be set no greater than the annual net productivity of the resource, thereby ensuring resource and fishery sustainability. To ensure sustainability of existing fisheries and resources and to proceed cautiously with new or expanded fisheries, policies which result in $F_y \leq$ min (F_{po}, $F_{0.1}$, F_{max}, $F_{10\text{-}yr}$) are recommended, where F_y = fishing mortality in year y, F_{po} = fishing mortality resulting in zero net annual stock production, and $F_{10\text{-}yr}$ = fishing mortality assuring a 10-year supply to the fishery at constant annual catch.

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

- Runs of 10-year supply calculation and a net production model, with swept-area biomass from the 1997 survey are provided along with quota options.

- Estimates of current Fs and quotas associated with various reference points are provided.

(TOR f) Estimate the resource level, density, and potential harvest from the surfclam beds located off Delmarva (under current FMP criteria)

- These data are included in area-specific results above from biomass production and supply-years calculations

(TOR g) Compare the average size, growth, and yield of Delmarva surfclams with surfclams harvested in other areas

- Based on the 1997 data, the average size and yield from clams in the Delmarva region are less than from Northern New Jersey.

(TOR h) Determine if high density is constricting growth of Delmarva surfclams, and estimate an "optimal" density of surfclams off Delmarva

- Based on published results for data collected during 1980-1994, growth is negatively correlated with density. In 1997, meat weight for a given shell length is lower at higher densities off Delmarva, but density apparently does not influence shell length. Surfclams in this area are now apparently not able to grow to shell lengths previously observed in the region. However, because of the potential confounding with environmental effects and lack of data on phytoplankton, temperatures, flow fields, etc., no definitive determination of the optimal density off Delmarva can be made at this time.

(TOR I) Estimate the long-term outlook/projection for the Delmarva surfclam resource if the harvest continues at the present level

- In the short term, the fate of the resource depends primarily on the intensity of the regional fishery. If the bulk of the resource continues to be avoided by the fishery, most animals will die of natural mortality, and annual biomass production will decline, eventually approaching the carrying capacity of the region. Density-dependent growth effects will be exacerbated. Conversely, even if exploitation rates increase, they may not be sufficient to ameliorate the slow growth rate of the Delmarva clams because of the potential effects of other environmental factors.

Commercial Data

Commercial landings and effort data from 1982 to 1997 (partial year) are from mandatory vessel logbooks. It is assumed throughout this assessment that one bushel of surfclams = 17 lbs = 7.711 kg of usable meats. Parameters relating shell length to meat weight are from Serchuk and Murawski (1980), are region specific, and were based on samples obtained in the winter. Revised length/weight information were collected during the summer 1997 resource survey aboard the R/V *Delaware II*. Vessel size class categories are: Class 1 (small, 1-50 GRT), Class 2 (medium, 51-104 GRT), and Class 3 (large, 105+ GRT). Commercial length frequencies were estimated by region from port agent sampling.

Landings

Between 1965 and 1974, total landings rose from 20,000 to 44,000 mt of meats (Table B1, Figure B1). After 1974, total landings declined steadily to 16,000 mt in 1978. Major recruitment of surfclams in the Mid-Atlantic region from Delmarva through New Jersey in the late 1970s resulted in increased landings throughout the early 1980s. Annual EEZ quotas have been set since 1978. Between 1983 and 1997, annual EEZ landings have been fairly constant, ranging from 20,000 to 25,000 mt. In the 1980s, approximately 75% of the landings were from the EEZ; the remainder were taken from state waters. In the 1990s, the percentage of landings from the EEZ has decreased slightly to approximately 70%. EEZ landings have typically been very close to the annual quota.

Since 1994, virtually all of the EEZ landings have been taken from the Mid-Atlantic region. In the period between 1986 and 1997, 74-91% of the Mid-Atlantic landings came from Northern New Jersey, 5-16% came from Delmarva, and 0-10% came from Southern New Jersey (Table B2, Figure B2). This represents a shift away from the Delmarva region which had been a major location for landing surfclams in the late 1970s and to a lesser degree in the early 1980s. In recent years, the fishery is currently focused off the coast of New Jersey (Figures B3-B5).

Landings/Effort

Effort trends

In the early 1980s, similar high annual efforts of 15,000 - 16,000 hrs were being exerted in Delmarva and Northern New Jersey (Figure B6). Effort subsequently declined in Delmarva, but remained high in Northern New Jersey. From 1985 to 1990, reported hours fishing per year in each area were well below levels of the early 1980s. Hourly trip limits were in effect during this period. Since 1991, effort has risen modestly, reflecting declining LPUE over this period (see below).

LPUE

Nominal trends: In the Mid-Atlantic region, typically >80% of the annual surfclam catch is taken by large (105+ GRT) vessels (Table B3). In the Northern New Jersey area, LPUE peaked for all vessel size classes in 1986, and has since declined (Table B3, Figure B7). Since 1991 (after the period of effort regulation), LPUE has decreased from 1,063 kg/hr to 745 kg/hr (-30%) for vessel class 3, -40% (1995-1997) for class 2, and has varied without trend for the few class 1 trips.

Off Southern New Jersey, class 3 nominal LPUE declined from 2,008 kg/hr in 1992 to 774 kg/hr in 1997 (-61%). Class 2 LPUE declined 79% between 1993 and 1997, while class 1 LPUE again varied without trend.

In the Delmarva area, LPUE since 1991 has varied widely, primarily reflecting the few number of vessel trips taken in the region. Indices have since tended downward for classes 3 and 2.

General linear models: GLMs were carried out, by region (Tables B4 and B5), on the natural log of LPUE to obtain a standardized abundance index from the commercial data. For Northern New Jersey (NNJ) and Delmarva (DMV), year, vessel ton class, and subregions were included as explanatory variables. "Subregions" were created by partitioning the NNJ and DMV regions into approximate halves.

GLM results from NNJ (Table B4) and DMV (Table B5) are most important because the fishery is active in these areas, and NMFS research surveys have indicated that these areas contain the majority of the stock biomass. Bias-corrected and back-transformed year coefficients for landings in weight per effort from the GLMs are plotted in Figure B7. The standardized LPUEs follow the nominal LPUEs of large vessels rather closely, indicating an approximate 30% decrease in LPUE since 1991 off NNJ and a sharp decline off DMV since 1994.

Effort reporting problems prior to 1991 confound the interpretation of LPUE as a consistent measure of relative resource abundance over the whole time series (1980-1997). Nevertheless, the rapid rise in LPUE in NNJ and DMV is consistent with improving resource conditions in the mid-1980s, peaking in the late 1980s-early 1990s. Modest declines in LPUE in recent years (e.g., 1991 onward) off NNJ are probably indicative of changes in the abundance of the stock, since virtually all of the resource is within the zone of coverage by the fishery (see following sections of this report).

Size Composition

Length frequency distributions for surfclams landed between 1982 and 1996 are presented for the New Jersey and Delmarva regions in Figures B8 and B9, respectively. Sampling data are summarized in Table B6. Between 1982 and 1990, the average size of clams landed from Southern New England (approximately 150 mm - 160 mm) was greater than that from areas to the south (typically 120 mm - 140 mm; Table B6). No data are available from Southern New England after 1990. Mean length of clams landed from the Delmarva area has decreased steadily from 159 mm in 1982 to 124 mm in 1997. Small clams sampled in 1994 are probably more indicative of poor sampling effort since size distributions in 1995 and 1996 were similar to those in 1991-1993.

Mean length of clams landed from the New Jersey area has remained relatively steady throughout this period (138-145 mm), although the percentage of small clams (90-110 mm) taken has increased since 1993. The proportion of clams in the 150-159 mm category increased beginning in 1991 off NNJ and has remained high since then.

Research Surveys

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

Sensor Data

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

Estimation of Distance Towed

Contact time of the dredge with the bottom was computed from data on ship's speed and dredge angle, each measured continuously during a tow. Ship's speed was measured in knots with P-code GPS. Dredge angle was determined from inclinometer data collected from a sensor mounted on the outside of the dredge at an angle of 25° (this angle was determined from field measurements and blueprints of the dredge). For data analysis, the dredge was considered to be in contact with the substrate whenever its angle was 2.3° or less during a tow. The maximum possible depth of the blade is 8 in, and 2.3° to a blade depth of 4 in into the bottom. This was selected as a reasonable critical fishing angle for the dredge 1) based on videos of the dredge while being towed, 2) because the action of the hydraulic jets turns the bottom into a fluid and causes the clams to be at or near the surface, 3) surfclams have relatively short siphons and do not have deep burrows, and 4) 4 in is the midpoint between the maximum and minimum possible values of possible blade penetration. A sensitivity analysis (below) was performed to determine how the estimate of tow distance varied as a function of critical dredge angle.

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

Dredge Performance

Sensors were used to measure when and for how long the dredge was in contact with the bottom during each tow. Examples of the sensor data collected at each station are shown in Figures B10 and B11. These were chosen because they illustrate that the sensors are sensitive to bottom type. Figure B10 represents a tow off the New Jersey coast where the bottom is sandy. Note that the inclinometer profile (dredge angle) is smooth. Figure B11 represents a station from a bottom on Georges Bank with more rocks. The angle of the dredge and its relation to the depth of penetration of the blade into the sediment are given in Table B7. When a critical blade depth is assumed (i.e., the dredge is fishing when the depth is ≥ this value) it affects the estimate of distance towed. The estimate is relatively insensitive for assumed blade depths of 2 in to 6 in (Table B7). Likewise, the catch per tow, adjusted for tow distance, is affected by the assumed blade depth. Table B8 gives the relationship between blade depth and a) number per tow and b) weight per tow. For most regions, the estimates of catch are relatively insensitive to choices of blade depth from 2 in to 6 in. Sensitivity appears greater for the Georges Bank region than for other regions.

Effects of Scope and Velocity

To determine the effect of scope and towing speed on catch, a randomized block experiment was conducted in May 1997 off the coast of New Jersey for surfclams, and off Long Island for ocean quahogs. These data have not been completely analyzed. Preliminary analyses of those data, conducted in preparation for the 1997 research survey, did not indicate that the methods (speed, scope) used in previous surveys should be altered. A final analysis will require standardization of catch per tow for tow distance.

Resampled Stations from Earlier Surveys

A set of stations from earlier surveys was resampled in 1997 to examine the efficiency of the NMFS clam dredge in 1997 relative to that in 1992 and 1994. The experiment was conducted on surfclams from Stratum 9 of the Delmarva region (n = 12 and 16 stations repeated from the 1992 and 1994 surveys, respectively) (Figure B12). Little commercial fishing had taken place at these sites between 1992 (1994) and 1997.

For each species, predicted catches of clams for 1997 were based on the model:

$$N_{97} = N_{year} \exp(-Mt)$$

where, t = 3 and 5 years for stations sampled in *year* = 1994 and 1992, respectively. The model describes the decline in abundance of clams due to natural mortality (M), which was assumed to be 0.05.

Clams that recruited to the population after the 1992 (or 1994) survey were subtracted from the observed catch in 1997 before testing the fit of the model because the model only deals with that portion of the population alive during the entire period. Those subtracted included clams born after the 1992 (or 1994) survey, as well as those that were alive during those early surveys that were too small to catch with the dredge. For surfclams, the cutoff shell lengths were 110 mm and 91.1 mm for repeats of 1992 and 1994 stations, respectively. These sizes were determined from age/length data from the Delmarva region collected in 1997.

Table B9 summarizes the fit of the 1992 and 1994 data sets to the population model. The table gives the median deviation from expectation, as well as results of the signed rank test of the null hypothesis that the median of the deviations = 0.

Figure B13 shows that, for the resampled stations from 1992, deviations in abundance from expectation were evenly distributed around 0 (i.e., the observed catches were consistent with the prediction of the model). The median deviation from the expected value was < 10 individuals for all blade depths examined (the 4-in depth is plotted in Figure B13). The signed rank test was not significant, which suggests that the efficiency of the NMFS dredge was similar in 1992 and 1997. In contrast, observed catches in 1997 from the resampled stations of 1994 were typically below the value predicted by the model (Figure B13), and the signed rank test was significant for all blade depths examined. This suggests that the efficiency of the NMFS clam dredge in 1997 was lower than that in 1994.

Depletion Experiments to Estimate Dredge Efficiency

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

Model

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

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

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

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

Six surfclam depletion experiments were carried out off the coast of New Jersey in spring/summer of 1997 (Figure B14). *[Two other depletion experiments targeting ocean quahogs were also conducted. Results from these experiments are not included herein, but will be reported at SAW-27 in June 1998.]* The primary goal was to determine the efficiency of the dredge used by the *Delaware II*, although estimates of some commercial dredges were also obtained. The efficiency of the *Delaware II* dredge was estimated by 1) direct estimation via a depletion experiment, 2) by comparing a density estimate based on eight *Delaware II* tows with the density based on a depletion experiment using a commercial vessel, and 3) by comparing density estimates of initial tows to that estimated for the entire depletion experiment. Method 3 was also applied to each commercial depletion experiment. It provided a way of checking the internal consistency of the estimate of population size, particularly the assumption of constant catchability over the experiment.

Experiments

Five separate depletion experiments of Atlantic surfclam were conducted aboard three commercial fishing vessels during June 9-11, 1997. Study locations are presented in Figure B14. A total of five depletion experiments were conducted, two replicates at each Atlantic City location, and a single, larger area was depleted off Point Pleasant. Each experiment consisted of making repeated passes with the dredge over an area approximately 2.0 microseconds in length, as close to a repeated path as possible. The width of the area depleted was 0.3-0.4 microseconds depending upon the experiment. Each tow was about 5 minutes in duration, and LORAN bearings were recorded each minute. The catch from each dredge haul was sorted and measured into US standard level bushels. Subsamples for length frequency (one bushel) and numbers per bushel (one additional bushel sample) were obtained every fifth haul. Data were recorded on standard log sheets (see Appendix A for additional details on these experiments).

In five of the experiments (PP-1, AC1-1, AC1-2, AC2-1, and AC2-2), the *Delaware II* took set-up tows to estimate virgin density in the area, and then a commercial vessel came in and depleted the area. Cruise tracks for the *Delaware II* set-up tows are shown in Figures B15-B17. In a sixth experiment (AC0), the *Delaware II* did the entire depletion (i.e., no commercial vessel was involved). Cruise tracks for that experiment are shown in Figure B18.

The catchability coefficient in the Leslie-Davis model is related to gear efficiency e by the relationship $e = (A/a)p$ where A is the total area swept at least once by the dredge and a is average area swept by an individual tow. The total area A represents the sum of all non-overlapping areas swept by the dredge. ARCINFO was used to estimate this quantity based for each experiment. Computations of average area swept were based on analyses of the vessel track coordinates for each tow. For *Delaware II* tows, a further adjustment for contact time (using inclinometer data) was made. Results of these computations are presented in Table B10.

To determine area depleted, the tows were plotted using ARCINFO and SYSTAT. Tows were excluded if a significant portion of the tow (typically greater than half) was made outside of the region covered by most of the other tows. This process was made more objective by considering tow locations relative to the 90% confidence contour of tow locations, based on the Epanechnikov-kernel function (Cressie 1988, implemented in SYSTAT). The decision was made to remove one tow from the AC1-1 experiment, and two tows from the AC1-2 experiment. Area depleted was then computed as the intersection of the remaining tows. Cruise tracks for each of these experiments are shown in Figures B18-B23. An example of the kernel function for the *Delaware II* site is depicted in Figure B24. The concentric boundaries of the bivariate nonparametric kernel correspond to 50, 75, and 90% confidence regions on the sample points. Figure B24 also shows the marginal nonparametric distribution of the sampling points in the x direction (longitude) and y direction (latitude). The marginal distributions appear to be almost normal; each marginal distribution is overlain with a corresponding normal distribution.

Results of the within-vessel depletion experiments are summarized in Tables B11-B12. Least-squares-based estimates of model parameters (Table B11) generally agree well with the MLE results with no consistent pattern of bias. The work by Gould and Pollock (1997) suggested considerable advantages of MLE over least-squares methods, apparently refuting the arguments advanced earlier by Bishir and Lancia (1996).

Parameter estimates and profile-likelihood confidence intervals of gear efficiency (defined as the probability of capture given encounter) and clam density (numbers/square meter) are summarized in Table B12. Estimates of efficiency and density were remarkably similar for the replicated experiments (i.e., contrast AC1-1 with AC1-2 and contrast AC2-1 with AC2-2). These results suggest that the depletion experiments are repeatable and are likely measuring the same quantity. Efficiency estimates for the *Delaware II* lie within the range of estimates for the commercial vessels. The derived efficiency estimates are influenced by sea state and bottom type. Moreover, the size of the area depleted is also important. Experiments AC2-1 and AC2-2 by the F/V *Jersey Girl* yielded efficiency estimates near 1.0. The tow paths for this study were relatively narrow and deviated little from the center line of the initial tow. More work on the relationship between the size of the depletion area and its implications for estimation are underway.

Between-vessel comparisons of efficiency were made by comparing the mean density estimate from eight tows by the *Delaware II* (see Table B13) with the estimate of density obtained from the commercial vessel's depletion experiment. The ratio of these two quantities is an estimator of the *Delaware II* dredge efficiency for the particular depth, substrate, and prevailing weather conditions. For example, differences in sea state could affect dredge performance, particularly for the *Delaware II* set-up tows. Weather conditions are also problematic for the depletion experiments because of potential increased variability in catch per tow. Such variation could reduce the numerical stability of the solution and introduce bias.

Between-vessel comparisons for efficiency provide valuable insight into the range of performance likely to be encountered over the course of a survey (Table B14). Results of these comparisons suggest a range of *Delaware II* efficiencies from 0.23 to 0.48. The Atlantic City site 1 (F/V *Judy Marie*) and Point Pleasant (F/V *Sheri Ann*) results lie within the 90% profile likelihood confidence interval of the *Delaware II*. Additional work is necessary to characterize the variation in this estimator as it is a function of both the variation in R/V density estimate and the F/V depletion-based estimate. As a first approximation, it is instructive to consider the range of efficiency estimates from a single comparison. Figure B25 depicts the variation in the set-up tow with the variation in density estimates from the depletion experiment; the Point Pleasant example is chosen as a specific case. The horizontal and vertical dashed lines correspond to the range of density estimates for the set-up and depletion-based experiments, respectively. The line from the origin to the point estimate is the average efficiency. Lines drawn to the upper left and lower right corners of the dashed box represent the highest and lowest estimates consistent with the observations. The 100% efficiency line (i.e., when both density estimates are equal) is shown as the line with the steepest slope. Application of this technique to each between-vessel comparison is depicted in Figure B26 (open boxes). Solid bars in Figure B26 correspond to the depletion-based estimator of efficiency confidence interval (Table B12).

One of the key assumptions in depletion studies is that the catchability coefficient is constant over the experimental duration. Unperceived reductions in efficiency would bias the slope of CPUE (y) vs. cumulative catch (x) upward and increase the population estimate. As a test of this assumption, the density estimate of the initial 3-5 tows within an experiment were compared to the overall density estimate from the experiment. This ratio should be equal to the overall estimate of efficiency of the experiment. Results of this comparison are shown in Figure B27 and Table B15. No significant departures from the null hypothesis were noted (Figure B27).

A complete summary of the raw data for the depletion experiments may be found in Appendix B. A summary of the maximum likelihood model fits, profile likelihood plots, and residuals is presented in Appendix C.

Shell-size selectivity between survey and commercial dredges was evaluated by comparing length compositions among the *Delaware II* set-up tows and the commercial depletions. The *Delaware II* catches included higher frequencies of animals at small sizes (e.g., below 12 cm), but these differences in volume or weight probably do not significantly influence efficiency estimates.

New estimators of population parameters from depletion studies, based on maximum likelihood procedures, were implemented and compared to those from the Leslie-DeLury model. The alternative estimators were more robust, but gave point estimates of initial population size and dredge efficiency similar to those from the traditional linear regression methods.

Based on the depletion studies, efficiency (proportion of clams in the dredge path retained in the dredge) of the *Delaware II* dredge was estimated to range from 0.2 to 0.6 (point estimates from average density from set-up tows relative to commercial vessel depletions and the *Delaware II* study). The *Delaware II* depletion study resulted in an estimate of efficiency of 0.59 (95% CI = 0.3-0.9). Commercial vessel efficiencies ranged from 0.38 to 1.0. Based on these studies, there is strong evidence that dredge efficiency varies by sediment type and sea state. Furthermore, it was noted that reported efficiency estimates for commercial and research vessels used in depletion experiments are biased high due to the method of analysis. Some additional analyses indicated that it should be possible to estimate the magnitude of this bias and correct the stock biomass estimates, which are currently underestimated. For abundance studies, the average *Delaware II* dredge efficiency point estimate of 0.59 was used, which results in a more conservative (e.g., lower) biomass estimate than if efficiency were assumed to be lower.

Survey Results

Description of surveys

A series of 21 research vessel survey cruises have been conducted between 1965 and 1997 (Table B16) to evaluate the distribution, relative abundance, and size composition of surfclam and ocean quahog populations in the Mid-Atlantic, Southern New England, and Georges Bank areas (Figure B28). Information from these surveys is used to predict relative year-class strength and to evaluate the effects of fishery management measures.

Assessment areas have been subdivided into strata which remain fixed through time (Figure B28). The surveys are performed using a stratified random sampling design, allocating a pre-determined number of tows to each stratum. Standardized sampling procedures used in these surveys are described in Murawski and Serchuk (1989). One tow is collected per station, and intended tow duration and speed are 5 minutes and 1.5 knots, respectively. Catch in meat weight per tow is computed by applying appropriate length-weight equations to numbers caught in each 10-mm size category. By averaging over all tows within a stratum, representative size frequency distributions per tow are computed by stratum. Representative size frequency distributions and mean number of clams per tow are also computed by region using as a weighting factor the area of each stratum within the region.

In years prior to 1997, doppler distance was used to standardize every tow's catch to a common tow distance (0.15 n. mi). As described in previous sections, tow distance in the 1997 survey was standardized by imputing tow distance from ship's velocity (measured by GPS) and contact by the dredge on the bottom as indicated by the inclinometer. Catches were then standardized by multiplying nominal catch at each station by the ratio of 0.15/imputed path length.

Confidence intervals on catch-per-tow indices were computed by two methods. A parametric confidence interval was computed assuming normal theory. Additionally, Smith's (1997) bootstrapping procedure was applied for complex survey designs. The latter approach allows for quantitative evaluation of the efficiency of the stratified random design employed for surfclams, as well as for asymmetric confidence intervals, which eliminates the difficulty associated with negative estimates at the lower bound of the interval.

Abundance indices

Stratified mean number per tow from 1965-1994 are given by region in Table B16. The 1994 survey data point stands out as a maximum for the 30-yr time series in the Northern New Jersey and Delmarva regions. The 1997 data points were considerably lower than those in 1994 in both regions.

Calculated abundance indices and associated statistics are given in Tables B17-B20 for surveys conducted in 1997, 1994, 1992, and 1989. Statistics are computed for total number per standardized tow, total catch weight (kg of meats) and catch weight of fully-recruited (e.g., ≥ 12-cm shell length) animals. These estimates are expanded to minimum swept-area population estimates (e.g., assuming 100% dredge efficiency) by determining the number of possible standard tow paths in each stratum, and multiplying by the average and upper/lower 95 percentiles.

Total minimum biomass was 664 kmt of meats in 1997 (all sizes) and 482 kmt of fully-recruited surfclams. The majority of the resource was concentrated in NNJ, Delmarva, and Georges Bank (Table B17). Similar computations for previous years gave approximately the same relative resource distributions among areas, with minimum population sizes greater in 1994 than the other years evaluated (Tables B18-B20). In general, estimates of clam abundance were relatively precise, with greatest precision computed from NNJ and DMV. Temporal estimates of minimum swept-area biomass for Georges Bank, NNJ, and Delmarva are given in Figure B29.

Areal distribution of survey catches

The distribution of sampled survey stations in 1997 is given in Figure B30. Station intensity was greater in 1997 in some areas (e.g., NNJ) since the estimation of population abundance via swept-area methods was anticipated. Clam abundance-per-tow data from the 1997 survey were partitioned into three size classes: small (1-87 mm), medium (88-119 mm), and large (≥ 120 mm) size groups. Detailed distribution data by size class are plotted in Figures B31-B36. The largest concentration of small animals was on Georges Bank and off southern Delmarva. Large animals were most abundant off New Jersey.

Size frequency distributions

Size frequency distributions from the 1997 survey are plotted in Figure B37 for the Georges Bank, Southern New England, and Long Island regions, and in Figure B38 for NJ-SVA-NC. Highest proportions of large animals were found in Southern New England and Southern New Jersey. Smallest average sizes were off SVA-NC, Georges Bank, and Delmarva.

Size frequencies by stratum for the NNJ area are given in Figures B39 and B40. DMV-NC size compositions by stratum are given in Figure B41. For NNJ, relative sizes were similar among strata, although stratum 25 had the greatest proportion of small clams. In the DMV-NC area, there was great variation in average sizes by stratum, with small clams in stratum 1 and largest clams in stratum 13.

Temporal trends in size composition for Georges Bank (Figure B42), Northern New Jersey (Figure B43), and Delmarva (Figure B44) are assessed for 1992-1997. In all cases, the size structure of animals within a region changed little over the 5-year period.

Age frequency distributions

Age-length keys from 1997 were applied to regional size frequency distributions to obtain the age composition of the NNJ and DMV surfclam populations for 1997 (Figure B45). In each region, the population consists of at least 15 cohorts. NNJ appears to be composed of a greater proportion of older individuals than DMV.

Evaluation of Survey Design

Smith (1996) presents a strategy and evaluation of the benefits in error reduction owing to the incorporation of strata in the allocation of stations, and in the specific allocation of stations within strata. His method provides an evaluation of stratified random surveys by taking the difference between the variance of the mean from the stratified random design with that assuming a simple random sample for the same data. A positive difference between the two variances indicates that the stratified design results in a smaller variance for the mean and thus the stratification providing measurable improvement over a simpler design (Smith 1996). The difference between the two variances is:

$$\widehat{Var}(\bar{y}_{srs}) - \widehat{Var}(\bar{y}_{st}) = \sum_{h=1}^{L} (1/n - W_h/n_h) W_h S_h^2 + (N-n/n(N-1))\left(\sum_{h=1}^{L} W_h(\bar{y}_h - \bar{y}_{st})^2 - \sum_{h=1}^{L} W_h(1-W_h) S_h^2/n_h\right)$$

The difference between variances can be decomposed into two components. The first term to the right of the equality, the 'allocation' component, measures the contribution of the number of dredge tows allocated to each stratum. The allocation term will be positive, zero, or negative depending on if the numbers of tows were allocated in proportion to the stratum variance, stratum size, or arbitrarily.

The second term on the right hand side determines whether the variance between strata is larger than that within strata. The larger the difference, the larger amount of information gained by employing the stratification scheme over simple random sampling.

The method was applied to evaluate the effects of station allocation and stratification in the clam survey (Table B21), based on numbers per tow and weight per tow indices. In most cases, both the allocation components and the stratification components were positive. In 1997, the stratification component accounted for about 70% more variance than the allocation component for all areas combined (both numbers and weights). In other years (especially 1994 and 1992), the two components contributed approximately equally to the variance. These analyses indicate that the allocation of stations is efficient and improves variance estimates over simple random sampling. Further, the stratification scheme itself is equally, and in some cases more, efficient than station allocation in contributing to variance reduction. The basic utility of the sampling design is thus emphasized by these analyses.

Co-Distribution of the Fishery with the Resource

This section is intended to integrate geographical information on catch locations by the fishery with research vessel survey information on the distribution and abundance of the resource. This integration is key to reconciling the declining trend in LPUE (see results in **Commercial Data** section) with the apparent large standing stock (section on Survey Results) relative to catch.

Recent information on the distribution of catches by 10-min square (based on logbook reporting) is given for 1992-1997 in Figures B3-B5. These plots document a progressive change in fishing intensity over time. A more detailed analysis was undertaken to evaluate in a systematic way the changes in latitudinal and longitudinal displacement of the fishery. Logbook data from 1985-1997 were included in the analysis. Two approaches were used. First, the frequency distributions of the longitude and latitude of individual trip catches was determined and these marginal distributions over time were plotted. Second, the distributions of survey catches were contoured over similar contours of commercial catch per trip data to evaluate the coincidence of fishing with resource distribution. These latter analyses were confined to the New Jersey region since there is little fishing elsewhere.

In order to derive latitude and longitude locations for individual fishing trips in sufficient detail for fitting of marginal distributions, the 10-min square locations of each trip catch were randomly allocated to degrees and minutes within the appropriate 10-min square. In many cases, more detailed catch locations are recorded in logbooks, but only 10-min square locations are currently recorded in the database. Based on these locations, smoothed distributions of catch latitude and longitude for each year were derived (Figures B46 and B47). From there data, there appear to be progressive shifts of the New Jersey fishery northward (Figure B46), and, more apparently, offshore (Figure B47).

The obvious shift of the fishery offshore is emphasized in plots of the contours of survey and commercial catch for 1989 and 1997 (Figures B48 and B49). The commercial catches (plotted as contours of mt/ trip with dashed lines) were primarily inshore, with the majority of high density catches off the central New Jersey coast in 1989 (Figure B48). By 1997, most high density catches are now taken much further east (east of 74° W. longitude), with few catches inshore. Likewise, survey density estimates (kg/tow, plotted as solid contour lines) show a progressive shift offshore as inshore areas were reduced in density and the fishery pursued higher catch rates offshore.

It is apparent from these contour information as well as a plot of the magnitude of survey catches by station plotted over commercial catch rates by 10-min square (Figure B50) that the fishery now (1997) is exploiting virtually all of the areal distribution of the stock off Northern New Jersey. Off Southern New Jersey, and especially in Southern Delmarva, major portions of the extant resource are not currently subject to significant harvesting (Figure B50), likely due to economic factors.

Declines in LPUE in the Northern New Jersey area (particularly since 1991) coincide with the progressive offshore (and somewhat northern) shift in fishing grounds. The fishery is apparently seeking higher catch rates for preferred sizes of clams by moving to these more distant fishing areas. The increase in frequency of clams in the 150-159 mm size class since 1991 suggests that the fishery may be targeting larger clams in recent years (particularly since the institution of the ITQ regulation scheme). Given that virtually all the area occupied by the Northern New Jersey stock is now subject to fishing, and large recruitment pulses are not apparent in survey catches, the declining trend in LPUE will likely continue off NNJ as the resource there is progressively fished down. In the section on **Stock Size Models and Biological Reference Points**, harvest levels are evaluated in relation to short-term biomass production for NNJ and the other surfclam assessment regions.

The distribution of the surfclam resource on Georges Bank and in Southern New England, relative to the presence of gravel and cobble sediment types, is presented in Figure B51. This figure emphasizes that major portions of survey strata containing the bulk of the clam resources in these regions may be unsuitable as habitat for the clams or otherwise may be unharvestable with current technology. The implication of these co-distributions of habitat type and clam abundance is that swept-area population sizes (which assume random distributions within strata) may be overestimated if the rocky habitats have lower average surfclam density than elsewhere within the strata.

Stock Size Models and Biological Reference Points

This section contains results pertaining to stock size, fishing mortality and exploitation rates, and biological reference points.

10-Year Supply Calculations

The current harvest policy adopted by the MAFMC is guided by the principal that the annual harvest should be set no higher than that which would allow a 10-year supply of constant catches, given input data on standing stock, growth, recruitment, and natural mortality. Accordingly, a series of spreadsheet calculations of harvests under various catch and fishing mortality rate policies was undertaken for the Northern New Jersey (Tables B22-B24; Figures B52-B54) and combined Mid-Atlantic assessment regions (Tables B25-B27; Figures B55-B57).

For both regions, supply-year calculations were undertaken with natural mortality rates varying from 0.05 to 0.15. Initial population sizes were minimum swept-area biomasses (section on Survey Results) divided by a dredge efficiency of 0.59, calculated from the *Delaware II* depletion study. Annual recruitment was based on the fraction of the survey catch biomass from 1989-1997 surveys that would recruit to harvestable size in one year. An assumption of the current version of the model is that annual recruitment is constant (i.e., independent of stock size). This is known to be somewhat unrealistic and was discussed during SAW-22. There are various options for modeling recruitment. However, given the available data, no single option was recommended at this time. Growth rates of the biomass were based on calculations from SAW-22. Exploitation rates were calculated as the fraction of initial exploited biomass removed by the fishery each year. The method re-calculates the harvest level which would result in a 10-year supply of constant catches each year in the simulation (e.g., simulates a re-evaluation of the resource in terms of 10-year supply implications each year).

Northern New Jersey

This run models the resource in Northern New Jersey and does not consider other regions. The 10-year supply policy for M = 0.05 results in catches increasing from about 19,800 mt in 1998 to 81,600 mt in 1999 and declining thereafter to about 60,000 mt in the 9th year of the simulation (Table B22, Figure B52). The initial exploitation rate (i.e., for 1998, using the 1998 EEZ quota) is 5%, but this increases rapidly to about 20-25%, and in all years but the first exceeds the current overfishing definition ($F_{20\%MSP}$ = 0.18; equivalent to a 16% exploitation rate). As M is increased from 0.05 to 0.15, the catches associated with the 10-year policy decline, initial exploitation rates increase slightly, and population sizes decline more steeply (Figures B53 and B54 and Tables B23 and B24). Population sizes decrease steadily and significantly throughout the simulation period. In the case of M = 0.05, biomass declines by 50% from year 2 to year 9. Declines in biomass are steeper for higher values of M.

Mid-Atlantic region (LI-SVA)

This run models the resource from LI to SVA and does not consider SNE or GBK. The 10-year supply policy for M = 0.05 results in catches increasing from 19,800 mt in 1998 to 144,000 in 1999, declining thereafter to 108,600 mt in the 9th year of the simulation (Table B25, Figure B55). Harvest rates increase from 3% in 1998 to about 20% in 1999 (in excess of the overfishing definition). As for the NNJ area, higher values of M result in lower 10-year supply catches and higher exploitation rates (Tables B26 and B27, Figures B56 and B57).

The 10-year supply approach is an *ad hoc* quantification of catch harvest policy that would assure relative continuity of catches from year to year while attempting to assess the balance between stock production and removals. Because the policy results in new '10-year' constant catches periodically, the result is less risk-prone than constant harvest policies are generally perceived. However, the policy does result in continuously declining stock sizes for the NNJ and combined Mid-Atlantic areas since removals are not necessarily balanced by growth and recruitment. For particular areas such as Delmarva and Georges Bank, the low harvest rates imply harvestable surpluses over net production (see section on Production Forecast). The 10-year supply policy may not be sufficient to meet new SFA guidelines which specify that harvest rates and stock sizes should be based on limits which produce MSY and which incorporate target management policies that are precautionary to uncertainty in population parameters (e.g., population size, M, dredge efficiency). Given that the 10-year policy may result in Fs exceeding the current overfishing definition ($F_{20\%MSP}$), the Fs can also exceed F_{msy} and, therefore, may not be consistent with the new guidelines.

Production Forecast

An alternative approach to providing management advice more consistent with SFA requirements is to evaluate, in the short term, the impact of various catch levels on the level and trajectory of stock biomass. If the resource is considered to be at appropriate levels of stock size (e.g., now), then it may be appropriate to establish explicit targets which result in catch and unaccounted fishing mortalities balancing growth and recruitment (e.g., no net change in resource abundance). Such a policy would imply stable catch rates if fishing is distributed equally over the stock (as it appears to be now off NNJ, not so off Delmarva). In order to calculate the effects of various harvests on production of the stock, swept-area biomass calculations from the 1997 survey, size compositions, and various other population dynamics assumptions were used, as described below.

A model was developed for surfclams to determine whether annual production could balance the direct and indirect losses in biomass due to fishing. The model is used for short-term projections. The equation relating numbers at length (N_L) over the 1-yr time step is:

$$\hat{N}_L^{\prime} = N_L \ e^{-M}$$

The vector of numbers at length was computed from 1997 research survey data. Natural mortality (M) was initially set at 0.05. This was the value used in previous assessments. Production in region I, P_i, is the difference in biomass (B) at the beginning and end of 1 year:

$$P_i = B_i - B_i^{\prime}$$

where B is the sum product of the observed numbers at length and the predicted average weight at length.

This is rewritten as:

$$P_i = (\sum_L a \hat{L}^{\prime b} \hat{N}_L - \sum_L a L_t^b N_L) \cdot (^1/E) \cdot (T)$$

where a and b are the parameters of the equation relating shell length (L) to meat weight, E is the efficiency of the dredge, and T is the number of tows in region I. The change in shell length over one time step is computed from:

$$L_{t+1}^{\prime} = L_t + \Delta L_{t-(t+1)}$$

where

$$\Delta L_{t-(t+1)} = (L_\infty - L_t) \cdot (1 - e^{-k})$$

Parameters in the age/length equations were revised for NNJ, DMV, and GBK using data collected in 1997. Net production (NP_i) in region I is equal to production (P) minus removals (R):

$$NP_i = (P_i - R_i)$$

where

$$R_i = (C_i + IC_i)$$

C and IC represent the landed catch and the indirect catch, respectively. Indirect catch refers to all mortality on surfclams caused by dredging, other than that landed. Based on descriptions (Myer *et al.* 1981) of damage to clams on the bottom as well as the increased number of predators shortly after a dredge passes an area, IC was set at 20% of C.

Results

Table B28 describes basic calculations implementing the production model described above. In particular, the calculation of net resource production is sensitive to estimates of dredge efficiency, natural mortality rate and error in minimum swept area biomass estimates. Assuming M = 0.05, point estimates suggest that there is a net 51,000 mt annual production all of the net surplus comes from Georges Bank (34,000 mt) and Delmarva (12,000 mt). The remaining areas produce approximately zero net production of clam biomass. [Note that the Georges Bank population may be seriously overestimated due to inclusion of non-suitable habitat in swept-area estimates, see section on **Co-Distribution of the Fishery with the Resource**]. Thus, the NNJ area, which supports the bulk of current harvests, generates approximately zero net production.

The sensitivity of these calculations to dredge efficiency and natural mortality is assessed in Figures B58-B65. Separate analyses are conducted for NNJ, DMV, all Mid-Atlantic assessment areas (LI-SVA) and all areas including the Mid-Atlantic, Southern New England, and Georges Bank regions. Two figures are given for each area. The first presents contours of net production (000s of mt) for combinations of M and dredge efficiency. The second figure expresses net production as a percentage of the estimated 1997 stock size (e.g., production rates). The nominal point representing M = 0.05 and dredge efficiency of 0.59 is indicated by an 'X' on each graph.

For Northern New Jersey, the assumption of zero (or very low) net production is robust over a wide range of parameter values (Figures B58 and B59). If M is as high as 0.1, a net decline in production of 5% per year is indicated, which approximates the annual rate of decline in LPUE since 1991 off NNJ.

For Delmarva, net production is positive, and this result is robust to values of M up to 0.09 (Figures B60 and B61). Likewise, for the Mid-Atlantic and all areas combined, nominal net production is positive.

In the short term, the production models indicate adequate resource to sustain the fishery at current removal rates for the NNJ area, wherein the bulk of the fishery is concentrated. Any additional increases in catch there would probably result in declining resource abundance, with the rate of resource decline dependent on the level of removal. Given that 1) all the known resource is now within the area of active fishing and 2) uncertainty with respect to M, dredge efficiency, and non-catch mortality, further declines in LPUE off NNJ could take place. The fishery could be expanded in the Delmarva area since that is the one Mid-Atlantic area in which there is significant annual surplus production. However, it is recommended that careful consideration be given to the potential impacts on the NNJ area of any global quota adjustments (e.g., the sustainability of the NNJ harvest area). Owing to the apparent balance between production and removals and uncertainty in important parameters (e.g., natural mortality, dredge efficiency, non-landings mortality) in the NNJ area, increases in removals should be considered carefully.

Biological Reference Points

Per-recruit calculations

Given new information on growth (i.e., age/ length), yield-and spawning-biomass-per-recruit reference points for Georges Bank (Figures B66 and B67, Table B29), Northern New Jersey (Figures 68 and 69, Table B30), and Delmarva (Figures B70 and B71, Table B31) were recomputed. Specifically, revised estimates of F_{max}, $F_{0.1}$, and $F_{20\%MSP}$ were generated. In all cases, these estimates were generally similar to those reported previously. Note that these estimates were produced with a nominal M of 0.05. The large fraction of the age structure in the 28+ age group indicates that this assumed rate may be too low.

Biological reference point calculations were based on length/weight relationships from earlier studies (Serchuk and Murawski 1980; Gledhill 1984). Values derived from 1997 samples were not used because there was considerable uncertainty about the degree to which season of collection affected these estimates. Biomass in bivalves changes greatly depending on reproductive condition. Switching to the higher meat weights associated with the 1997 data from spring/ summer may have overestimated the average yield over an entire year.

Current mortality rates

Current (e.g., 1997) exploitation (U) and instantaneous fishing mortality rates (F) were estimated by calculating the proportion of the stock biomass removed (an estimate of the utilization rate) and iterating the catch equation to solve for F {$U = F/Z*[1 - \exp(-F + M)]$}. These analyses incorporated uncertainty in minimum swept-area population estimates, calculated dredge efficiency based on the *Delaware II* experiment, and provided results for each assessment area separately (Table B32a,b). Three major components of uncertainty in the estimates of F are 1) positive bias in estimates of dredge efficiency, 2) variation in survey abundance estimates and 3) variation in gear efficiency over sampled strata. The latter two factors are not mutually exclusive. For example, variation in efficiency over depths or substrates contributes to the survey variability estimates by the bootstrapping approach. Therefore, analyses of these factors were conducted separately, first for the effects of sampling variation (i.e., bootstrap CI) on estimates of F and second for effects of variations in efficiency using the profile likelihood confidence interval from efficiency experiments on estimates of F.

These two factors were assessed as follows. The point estimate of dredge efficiency (0.59) was divided into the mean and bootstrap 95% CI to give three estimates of stock biomass in 1997 for each area. The 1996 catch (mt) was divided by these three estimates to derive exploitation rates associated with the CI of stock biomass, which were then solved for F (Table B32a). Uncertainty in the point estimate of the *Delaware II* dredge efficiency was incorporated by multiplying the CI on the efficiency estimate by the lower, mean, and upper bounds of the stock biomass estimates (Table B32b) and solving for U and F as above.

For NNJ, current exploitation rates are 0.02-0.06, depending in the method used, with the point estimate of 0.04 equivalent to an F of 0.04. The SNJ area has a similar point estimate for fishing mortality rate. Other areas show exploitation rates lower than those off New Jersey.

In Figures B72 and B73, estimated average fishing mortality rates are indicated by a vertical line within a rectangular box, and fishing mortality rates corresponding to biological reference points are indicated by symbols Both figures have the same reference points plotted, but the figures differ with respect to confidence intervals (CI) for estimated Fs. In Figure B72, the ranges of the F estimates are determined by the size of the bootstrap CI on total population biomass for each region. This is referred to as "survey" variability. In Figure B73, the width of the CI on estimated F is determined by the lower and upper confidence limits on the estimate of dredge efficiency from the *Delaware II* depletion experiment. There are three main results. First, for the regions that are currently fished heavily (New Jersey), the estimated fishing mortality rates approximate F_p. That is, current harvests are approximately equal to annual production by those regions. Estimated Fs are less than all reference Fs for the other regions, as well as for the stock as a whole. Second, for the NNJ region, the precision of the estimated F is greater when "survey" variability is considered (Figure B72) than when "efficiency" variability is considered (Figure B73). Third, in general, F_p is the minimum from the list of biological reference points.

Due to uncertainty about the natural mortality rate, biological reference points were computed over a range of Ms (Table B33). The reference point estimates are sensitive to the assumed value of M.

Delmarva

Data were collected during May -July 1997 to evaluate the relationship between length and weight in surfclams. Sample sizes and parameter estimates are given in Table B34. For all regions, meat weight at length is greater than that measured in 1980 (Serchuk and Murawski 1980). Differences may reflect seasonal changes related to time of spawning, changes in the clams over a long time-frame (10-15 years), and/or differences in methods between studies. The earlier data from NJ and DMV were collected in winter, and the clam tissue was frozen and then thawed for a biomass estimate. The 1997 data were collected in spring/summer and the tissue was weighed at sea immediately after shucking and removing all excess liquid from the clam meat with paper towels.

In 1997, the shell length of surfclams from the Delmarva region was smaller than in NNJ. The modal shell lengths in these regions were 115 mm and 145 mm, respectively (Figures B43 and B44).

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

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

Regional estimates of the parameters for 1997 are given in Table B34. Meat weight at length, or "condition", was lower in the Delmarva region than in NNJ or GBK (Figure B74). Using data collected from the Delmarva region during 1980-1992, it has been shown that the rate of shell growth as a function of clam age is density dependent (Weinberg, in press). The newly-collected 1997 data were partitioned into five density classes, listed in Table B35, and examined for differences in growth rate and condition. The weight of meat at a given length is reduced at high density in the Delmarva region (Figure B75). Density dependence becomes important at very low clam densities, <0.5 individuals per m^2. In contrast to weight and length, there was no obvious separation between the age-length curves representing different densities (Table B36, Figure B76).

SARC Comments and Sources of Uncertainty

Natural Mortality Rate

Annual production estimates and magnitudes of biological reference points for surfclams ($F_{20\%}$, F_{max}, $F_{0.1}$, F_{P0}) are sensitive to the assumed value of M over the range 0.05-0.15. The natural mortality rate currently in use (M = 0.05) is not based on any life history information, is uncertain, and may be underestimated. This is suggested by comparison of the theoretical equilibrium age distributions for various values of M with the age distributions observed in Delmarva and Northern New Jersey. Absence of old individuals may in part be due to the massive die-off from the anoxic event off New Jersey. The SARC recognized that M is difficult to estimate, but strongly recommended that studies be undertaken to estimate its value. Studies could include field experiments, modeling, and examination of surfclam age distributions from additional regions.

Commercial Data

The SARC noted that LPUE in Northern New Jersey has declined by 30% since 1991, but did not feel the decline was steep enough to conclude that significant depletion was taking place. The SARC noted that other factors, such as targeting larger clams, could have contributed to this decline. Conversely, LPUE may have been kept up by expansion of the fishery to new areas and/or increases in the average efficiency of vessels in the fleet. To clarify if the expansion of the fishery to the north and east was due to resource depletion of traditional fishing areas or to other factors, analysis of catch rate by vessel and by 10-min square was recommended. The SARC also recommended close monitoring of this area.

The SARC felt that LPUE data from 1990 and earlier should not be used with more recent data because 1) effort was not reported accurately from 1986 to 1990, related to regulations on fishing effort per trip in those years, and 2) the ITQ system was implemented in 1991. The LPUE series from 1991 to 1997 can be used.

Depletion Experiments

The SARC felt that the depletion experiments were carried out well and that they are appropriate for estimating dredge efficiency. The SARC recommended that similar experiments be conducted in the future, as needed. It was noted that reported efficiency estimates for commercial and research vessels used in depletion experiments are biased high due to the method of analysis. Some additional analyses indicated that it should be possible to estimate the magnitude of this bias and correct the stock biomass estimates, which are currently underestimated.

Survey Data

The SARC noted that the increased catches in the 1994 research survey were not likely to have been caused by random selection of stations in areas of unusually high clam density or by the influence of a few tows with huge catches. These explanations were unlikely because a large number of replicates were taken in each survey, and the high catches per tow in 1994 were observed in multiple regions and in two species.

The SARC expressed concern over both the loss of the survey time series and the use of a single survey (i.e., 1997) to derive a species assessment. The SARC recommended that efforts be made to develop approaches that could make use of a longer survey time series, if possible.

As described in SAW-22, the SARC advocates developing a population model for estimating biomass and fishing mortality rate that incorporates time series of multiple types of information, including survey and commercial abundance indices.

To emphasize the utility of the sensors, the SARC felt that the report should include a table or figure with summary statistics of tow distance by region. It also recommended that analysis be carried out to determine to what degree catch rate is related to pump pressure.

Production Estimates and Biological Reference Points

The SARC recognized the utility of the production model for localized management of the Northern New Jersey region which has supported the fishery at a consistent level for over 10 years. However, the biological reference point, F_{P0}, has limitations because it is a *status quo* catch and biomass policy that may not be appropriate in the long term. Further research is needed on this topic. The F_{P0} estimate has the following basis/assumptions: 1) the estimate of F_{P0} is based on a single survey and is highly subject to measurement error, 2) it implicitly assumes that the current stock size is optimal (maximum production), which may not be true, and 3) the estimate of annual production is sensitive to the assumed M, which is uncertain.

The SARC noted that the production model assumes that the catch is taken on the final day of the projection period. This should be stated as an assumption.

Reference points required for satisfying the 1997 SFA guidelines have not been examined yet and should be addressed. The SARC discussed which reference points would be appropriate for managing this species, but no clear choice was made. An interim approach to setting harvest levels in the surfclam fishery is required because the 10-year policy is inappropriate, and a replacement policy has not been developed yet. The SARC concluded that, in the interim, a *status quo* catch approach is appropriate. Based on trends in LPUE, the sizes of clams in the commercial catch over time, and the 1997 survey biomass estimates, the SARC felt that the recent (last 5 years) level of annual landings from the Northern New Jersey region is probably adequate to sustain the stock.

Research Recommendations

Dredge Improvements

- For future research vessel surveys, a faster winch (perhaps including a free-spool option, if feasible) needs to be employed aboard the *Delaware II*. Slow pay-out and retrieval rates of the current winch result in excessive bottom contact outside of the 'nominal' tow time, which increases uncertainty in the length of the tow path. A faster winch would also improve the ability to conduct depletion-type experiments.

- New sensors monitoring dredge performance (inclination, pump pressure, bottom contact, etc.) were incorporated into the 1997 survey. These data allowed for accurate standardization of tow path length. Currently, information from these sensors must be downloaded every few tows and multiple clocks are in use for different sensors. It is strongly recommended that the collection and archiving of this information be fully integrated with the shipboard computing system on *Delaware II* and that only a single master clock be used. This will speed data collection and quality.

- Incorporation of coaxial or standard monitoring cable into the dredge power supply would establish a real-time link to monitor dredge performance, perhaps to include video, pressure, amperage, and bottom contact. This link could improve the standardization of dredge hauls.

- Sampling effort could be more precisely controlled by the use of a movable dredge knife carrier which could be deployed remotely when the dredge is intended to fish. Such a scheme could virtually eliminate the 'shoulder' effect of continued sampling outside the nominal survey tow time.

- New sensors aboard the *Delaware II* clam dredge allow for monitoring of tow path length by integrating the velocity of the ship (measured from GPS), multiplied by dredge contact/non-contact, as indicated by the inclinometer. A more direct approach would be to incorporate a mechanical or electronic odometer directly on the dredge. This device could monitor speed and distance in real time, if the second recommendation above were adopted.

Research Survey Design and Analysis

- Annual surplus production is approximately zero in the major region that has supported the fishery throughout the 1990s (Northern New Jersey). This calculation is sensitive to the assumption of the natural mortality rate, which is poorly known. In order to assure adequate monitoring of the resource to meet management needs, fished portions of the resource need to be monitored via research vessel surveys at a frequency of every second year. Non-fished areas could be monitored less frequently as long as risk-averse management strategies for these portions of the resource are implemented.

- Precision in survey abundance indices and monitoring of interannual changes in dredge performance could potentially be enhanced with a survey strategy that incorporates a sub-set of fixed stations, with a partial replacement design. A full fixed-station design is not warranted, however, given changes in the spatial distribution of recruits and the fishery.

- Calculations of stock biomass are based on the stratified random design, with fixed stratum areas. Although this procedure results in a relatively precise estimate for major portions of the resource (New Jersey and Delmarva), alternative integrated biomass estimation methods should be considered (e.g., geostatistical techniques such as kriging or Theissen polygon or other weighting of sampling points).

- One potential source of bias in the swept-area calculations is the estimated stratum areas. These areas were derived several years ago. More accurate computerized methods (e.g., GIS) have become available. As the stratum areas proportionally influence the biomass calculations, these areas should be reviewed, and updated, as appropriate.

- Potential biases in the swept-area estimates arise when portions of the survey strata include habitat which is either not suitable for the target animal or cannot be sampled (e.g., too rough). This situation occurs for surfclams primarily on Georges Bank and in Southern New England. Bottom topography information, as well as the historical records of successful dredge hauls should be used to establish the portions of affected survey strata which should be eliminated from consideration in the stratum area weighting coefficients.

- Depletion experiments aboard the *Delaware II* and commercial vessels were an effective and efficient method to derive usable estimates of dredge efficiency. Because of the potential for interannual variation in survey dredge performance, additional depletion experiments (at some level) should be incorporated as a component of future surveys. Sites depleted by the *Delaware II* could be cross-validated by additional work with commercial vessels.

Biological Parameters

- The current assessment assumes a nominal natural mortality rate (M) = 0.05. By inference, this rate implies that, if not fished, 5% of the animals should survive to age 60. This conflicts with the aging information which has documented few animals older than age 30, even in areas not subjected to massive die-offs in 1976. Given the sensitivity of net productivity, DeLury population estimates, and YPR calculations to M, additional studies to refine the assumed M are considered a high priority. Better estimates of M could be derived by making more complete use of historical ageing information, as well as from field and laboratory studies (mark-recapture experiments, shell biochemical studies, clapper/live animal ratios, 'longevity' of clappers).

- Fishing mortality associated with animals that are not landed is potentially important in the surfclam assessment. Non-landings mortalities potentially arise from 1) animals damaged by the gear on the bottom, but not retained in the dredge, 2) animals in the vicinity of dredging that may be killed by release of sulfides or localized dissolved oxygen depletions, 3) animals which go through the sorting machines and are discarded dead, and 4) animals which are broken and retained in the sorting machines, but which are then sorted overboard by hand (e.g., for supplying to the 'hand shucked' market). Additional sea sampling combined with specific *in situ* studies are needed to estimate non-landings mortality.

- Seasonal change in condition factors of surfclams can be great, owing to changes in soft tissue mass associated with spawning and feeding. Monitoring of changes in condition are important in estimating numbers of clams that are removed from the population, since the quota is established in volume-weight units (bushels converted from meat weight). More intensive monitoring of meat weights, including cooperative sampling with industry, is recommended. As part of this research, implications of variations in environmental conditions on meat yields could result in a predictive capability, of use to industry.

- Magnitude and variability of recruitment is a key component in assessing sustainable harvest strategies. Additional research should be conducted to estimate relative and absolute recruitment (e.g., from swept-area estimates).

Potential Density Dependence of Condition Factor and Growth

- Evaluation of available evidence for density-dependent growth and condition in the Delmarva region suggested that additional studies are needed. Gradient sampling of age/length/weight, clam density, and environmental factors is necessary to establish and rank the importance of biotic and abiotic factors. Studies of clam production in relation to intraspecific density, chlorophyll flux, and other environmental factors are appropriate.

Research with Industry

- Progress in addressing several critical elements of this assessment was facilitated by direct cooperation by industry. Additional high priority projects could be undertaken in further such efforts. In particular, additional depletion-type experiments and seasonal/spatial sampling for variations in meat weight could be undertaken.

- There is a priority need for an intensive review of logbook data collection, data transcription, and interpretation of results, which could be undertaken with the assistance of vessel captains and owners. In particular, NMFS should record in computer data bases the location fished in as fine a resolution as is recorded in the logbooks. More precise location data from historical logbook submissions, especially those collected after 1990, should be re-entered into the NMFS database.

SARC Research Recommendations

- Compute the magnitude of the bias in the estimated dredge efficiencies and correct any parameters that are functions of efficiency (e.g., current and projected biomass).

- Work toward developing a multi-index based, population model for estimating biomass and fishing mortality rate that incorporates a time series of survey and commercial abundance indices.

- Estimate reference points required for satisfying the 1997 SFA guidelines.

- Determine whether there is a relationship between survey catch per tow and other variables (i.e., pump pressure, depth).

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Weinberg, J.R. (In press). Density-dependent growth in the Atlantic Surfclam, *Spisula solidissima*, off the coast of the Delmarva Peninsula, Mar. Biol.

Table B1. Total USA surfclam landings (metic tons of meats), total landings from the Exclusive Economic Zone (EEZ), landings from state waters, percent of total from the EEZ[1], and annual quotas.

Year	Total landings	EEZ landings	State waters landings	Percent of total landed[2] from EEZ	EEZ quota
1965	19,998	14,968	5,029	75	-
1966	20,463	14,696	5,766	72	-
1967	18,168	11,204	6,964	55	-
1968	18,394	9,072	9,322	49	-
1969	22,487	7,212	15,275	32	-
1970	30,535	6,396	24,139	21	-
1971	23,829	22,704	1,126	95	-
1972	28,744	25,071	3,674	87	-
1973	37,362	32,921	4,441	88	-
1974	43,595	33,761	9,834	77	-
1975	39,442	20,080	19,362	51	-
1976	22,277	19,304	2,982	87	-
1977	23,149	19,490	3,660	84	-
1978	17,798	14,240	3,558	80	13,880
1979	15,836	13,186	2,650	83	13,880
1980	17,117	15,748	1,369	92	13,882
1981	20,910	16,947	3,964	81	13,882
1982	22,552	16,688	5,873	74	18,506
1983	25,373	20,485	4,887	81	18,892
1984	31,862	24,776	7,086	78	18,892
1985	32,894	23,691	9,204	72	21,205
1986	35,720	24,923	10,797	70	24,290
1987	27,553	22,147	5,406	80	24,290
1988	28,824	23,951	4,873	83	24,290
1989	30,424	22,335	8,089	73	25,184
1990	32,556	24,027	8,528	74	24,282
1991	30,037	20,638	9,399	69	21,976
1992	33,831	22,109	11,722	65	21,976
1993	33,527	21,961	11,565	66	21,976
1994	31,048	21,942	9,106	71	21,976
1995	28,733	19,303	9,429	67	19,779
1996	28,775	19,795	8,980	69	19,779
1997	-	18,000	-	-	19,779

[1]Landings through 1996 are from the US Dept. of Commerce series "Fisheries of the United States". [2]The 1997 EEZ landings were projected from data available in the s1032 database as of September 12, 1997.

Table B2. Annual EEZ surfclam landings from areas of the Mid-Atlantic region, and percent of Mid-Atlantic landings by region.

	Long Island		Northern New Jersey		Southern New Jersey		Delmarva		Southern Virginia North Carolina	
Year	mt	%	mt	%	mt	%	mt	%	mt	%
1978	-	-	1,348	31	53	1	2,927	68	-	-
1979	-	-	1,463	38	97	3	2,268	59	-	-
1980	-	-	1,692	41	132	3	2,300	56	-	-
1981	-	-	6,462	97	114	2	95	1	-	-
1982	49	<1	7,440	44	434	3	6,777	41	1,988	12
1983	212	1	5,515	34	999	6	5,772	36	3,779	24
1984	6	<1	8,787	49	1,776	10	5,303	30	1,897	11
1985	-	-	8,427	50	1,077	6	6,636	39	772	5
1986	16	<1	14,703	75	1,474	8	2,604	13	849	4
1987	-	-	17,238	87	749	4	1,306	7	387	2
1988	-	-	19,196	91	195	1	1,147	5	591	3
1989	-	-	16,415	82	90	<1	3,118	16	461	2
1990	-	-	16,996	74	891	4	3,546	15	1,502	7
1991	15	<1	17,623	86	1,289	6	1,634	8	-	-
1992	61	<1	18,334	85	2,064	10	1,221	6	-	-
1993	62	<1	16,338	75	2,023	9	3,418	16	-	-
1994	71	<1	17,754	81	664	3	3,454	16	35	<1
1995	-	-	15,749	82	713	4	2,752	14	5	<1
1996	26	<1	16,077	82	1,331	7	2,237	11	-	-
1997[1]	24	<1	7,345	81	700	8	1,008	11	-	-

[1]The 1997 values are from data available as of September 12, 1997.

Table B3. Comparison of Mid-Atlantic EEZ surfclam landings per unit effort (LPUE, kilograms per hour fishing time) and percent of total annual catch from each region, by year, and vessel class (3 = largest) for records with catch >0 and effort >0. Data as reported in logbooks.

Region/Year	Vessel Class 1		Vessel Class 2		Vessel Class 3	
	LPUE	%	LPUE	%	LPUE	%
Northern NJ						
1980	246	5	407	36	646	59
1981	236	4	363	36	476	60
1982	170	7	219	44	317	49
1983	222	6	353	68	372	26
1984	363	5	569	72	697	23
1985	591	5	979	57	1,227	38
1986	739	3	1,300	35	1,848	61
1987	735	2	1,207	35	1,712	63
1988	725	2	1,154	33	1,699	64
1989	754	3	1,170	35	1,547	62
1990	730	2	1,188	33	1,566	66
1991	400	<1	959	29	1,063	71
1992	362	<1	1,018	22	851	77
1993	381	<1	1,118	20	904	79
1994	403	<1	1,058	26	791	73
1995	346	<1	1,179	29	796	70
1996	475	<1	971	35	764	65
1997	494	<1	706	24	745	76
Southern NJ						
1980	113	4	130	35	284	62
1981	68	5	290	32	342	63
1982	97	7	182	40	289	53
1983	121	12	236	54	399	35
1984	246	10	438	31	595	59
1985	578	4	779	12	1,216	84
1986	575	3	1,119	17	1,519	80
1987	331	<1	1,003	22	1,604	78
1988	-	-	8,789	31	1,437	69
1989	514	3	1,001	47	1,200	50
1990	227	<1	1,070	37	1,237	62
1991	247	<1	1,454	39	1,701	61
1992	-	-	1,589	43	2,008	57
1993	390	<1	2,238	54	1,694	46
1994	343	1	2,072	16	1,272	83
1995	-	-	997	14	1,033	86
1996	359	4	1,042	25	866	71
1997	286	4	461	38	774	58
Delmarva						
1980	117	2	157	21	308	77
1981	206	2	211	15	437	83
1982	173	5	197	14	309	81
1983	297	6	234	15	408	80
1984	350	5	444	15	734	80
1985	691	3	1,180	13	1,844	84
1986	624	4	1,068	13	1,934	83
1987	482	3	729	3	2,057	94
1988	532	2	1,693	10	1,959	88
1989	564	<1	1,401	13	1,945	87
1990	-	-	1,305	21	1,688	79
1991	-	-	1,008	20	1,406	80
1992	-	-	1,733	34	1,326	66
1993	-	-	1,361	44	1,353	56
1994	-	-	1,612	43	1,937	57
1995	-	-	1,772	40	1,756	60
1996	-	-	1,443	56	1,362	44
1997	-	-	1,542	38	1,247	62

Table B4. Surfclam GLM of LPUE, 1980-1997. Factors are year, subregion, tonclass. Standards are yr = 1980, tonclass = 3 (large vessels). Region is NORTHERN NEW JERSEY.

General Linear Models Procedure

Dependent Variable: L_LPUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	20	8395.54206611	419.77710331	1758.54	0.0001
Error	30035	7169.56823907	0.23870712		
Corrected Total	30055	15565.11030518			

R-Square	C.V.	Root MSE	L_LPUE Mean
0.539382	7.284032	0.48857662	6.70750276

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	17	7904.15268696	464.95015806	1947.79	0.0001
SUBREG	1	10.90365711	10.90365711	45.68	0.0001
TONCL	2	480.48572204	240.24286102	1006.43	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	17	7096.67218085	417.45130476	1748.80	0.0001
SUBREG	1	15.51229780	15.51229780	64.98	0.0001
TONCL	2	480.48572204	240.24286102	1006.43	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		6.005782497 B	150.80	0.0001	0.03982645
YEAR	1981	-0.208038622 B	-6.40	0.0001	0.03251237
	1982	-0.708810433 B	-21.89	0.0001	0.03237943
	1983	-0.280034788 B	-8.63	0.0001	0.03246366
	1984	0.229851440 B	7.08	0.0001	0.03246429
	1985	0.729814886 B	22.29	0.0001	0.03273600
	1986	1.108928325 B	34.20	0.0001	0.03242837
	1987	1.038406284 B	32.45	0.0001	0.03199532
	1988	1.007700367 B	31.73	0.0001	0.03176275
	1989	0.971681395 B	30.41	0.0001	0.03195440
	1990	1.003904383 B	31.33	0.0001	0.03204672
	1991	0.742855513 B	23.15	0.0001	0.03209229
	1992	0.606131810 B	18.95	0.0001	0.03199338
	1993	0.672037012 B	20.83	0.0001	0.03226480
	1994	0.591772853 B	18.44	0.0001	0.03209300
	1995	0.622825311 B	19.26	0.0001	0.03234127
	1996	0.570981212 B	17.63	0.0001	0.03239385
	1997	0.414909653 B	11.94	0.0001	0.03473959
	9999	0.000000000 B	.	.	.
SUBREG	2	0.210054093 B	8.06	0.0001	0.02605708
	99	0.000000000 B	.	.	.
TONCL	1	-0.631029188 B	-44.29	0.0001	0.01424756
	2	-0.105190452 B	-17.24	0.0001	0.00610320
	99	0.000000000 B	.	.	.

Table B5. Surfclam GLM of LPUE, 1980-1997. Factors are year, subregion, tonclass. Standards are yr = 1980, tonclass = 3 (large vessels). Region is DELMARVA.

General Linear Models Procedure

Dependent Variable: L_LPUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	20	9659.30433866	482.96521693	1570.71	0.0001
Error	12098	3719.91537644	0.30748185		
Corrected Total	12118	13379.21971510			

R-Square	C.V.	Root MSE	L_LPUE Mean
0.721963	9.014274	0.55451046	6.15147119

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	17	8947.75979719	526.33881160	1711.77	0.0001
SUBREG	1	0.45925039	0.45925039	1.49	0.2217
TONCL	2	711.08529108	355.54264554	1156.30	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	17	8852.14957681	520.71468099	1693.48	0.0001
SUBREG	1	12.33986859	12.33986859	40.13	0.0001
TONCL	2	711.08529108	355.54264554	1156.30	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		5.515660129 B	478.15	0.0001	0.01153550
YEAR	1981	0.321472616 B	17.95	0.0001	0.01790852
	1982	0.095192351 B	5.53	0.0001	0.01721516
	1983	0.331303554 B	17.91	0.0001	0.01849353
	1984	0.916166104 B	39.32	0.0001	0.02330300
	1985	1.823527955 B	73.89	0.0001	0.02468060
	1986	1.817312315 B	50.30	0.0001	0.03612988
	1987	1.821636140 B	35.50	0.0001	0.05132077
	1988	1.907102175 B	33.98	0.0001	0.05612989
	1989	1.970418970 B	56.54	0.0001	0.03485192
	1990	1.864371483 B	57.64	0.0001	0.03234382
	1991	1.793324173 B	41.99	0.0001	0.04271148
	1992	1.967787709 B	43.75	0.0001	0.04497657
	1993	1.961808290 B	69.66	0.0001	0.02816157
	1994	2.352956976 B	83.39	0.0001	0.02821515
	1995	2.271691510 B	71.93	0.0001	0.03158394
	1996	2.072820140 B	60.94	0.0001	0.03401448
	1997	1.938222018 B	39.00	0.0001	0.04969740
	9999	0.000000000 B	.	.	.
SUBREG	2	0.075973908 B	6.33	0.0001	0.01199275
	99	0.000000000 B	.	.	.
TONCL	1	-0.744691267 B	-32.08	0.0001	0.02321521
	2	-0.458752343 B	-39.87	0.0001	0.01150520
	99	0.000000000 B	.	.	.

Table B6. Summary statistics on surfclam commercial length frequency data by region/year. Data were collected by port agents taking random samples from landings.

Region/Year	Mean length (mm)[1]	Minimum length	Maximum length	Number of clams measured[2]
New Jersey				
1982[3]	140.5	75	205	7,477
1983	142.5	75	205	11,253
1984	142.1	45	195	12,751
1985	140.4	55	195	7,674
1986	136.3	105	175	5,130
1987	134.4	95	185	900
1988	137.7	85	165	900
1989	139.9	105	175	919
1990	136.5	95	175	901
1991	143.0	93	188	2,272
1992	141.1	64	186	1,710
1993	139.8	80	170	928
1994	138.5	85	185	900
1995	141.9	85	175	510
1996	138.0	85	185	1,117
Delmarva				
1982	159.0	85	205	7,756
1983	151.5	45	205	5,923
1984	138.8	95	195	3,066
1985	132.0	95	175	1,832
1986	130.0	95	155	1,260
1987	131.4	105	165	730
1988	136.0	115	165	420
1989	136.6	115	175	866
1990	139.1	95	175	892
1991	125.5	20	183	1,080
1992	123.5	73	198	1,170
1993	122.4	77	155	1,392
1994	109.2	85	135	119
1995	125.1	105	155	720
1996	124.0	95	155	1,154
S. New England				
1982	153.7	135	175	30
1983	150.0	125	165	30
1984	147.9	115	175	90
1985	151.6	115	175	150
1986	161.0	125	195	330
1987	160.9	115	195	569
1988	154.3	105	185	810
1989	155.8	115	185	449
1990	164.1	135	185	209
1991	[4]-	-	-	-
1992	-	-	-	-
1993	-	-	-	-
1994	-	-	-	-
1995	-	-	-	-
1996	-	-	-	-

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

Table B7. Relationship between blade depth into the sediment and dredge angle:

Blade depth (inches):	2 inches	4 inches	6 inches	8 inches
Dredge angle (degrees):	3.4	2.3	1.14	0.0

Relationship between the estimate of distance towed and the assumed blade depth required for "fishing". Data are all good tows from Cruise 9704, the 1997 NMFS clam survey. The maximum blade depth is 8 inches. N = 433 tows.

Blade depth (inches):

	2 inches	4 inches	6 inches	8 inches
Mean tow distance (n.miles):	0.26	0.25	0.23	0.19
Median tow distance (n.miles):	0.26	0.25	0.23	0.19

Table B8. Relationships between clam catch (0.15 n.mi. distance) and assumed critical blade depth. Data are all good tows from Cruise 9704, the 1997 NMFS clam survey. Traditional stratum areas and length/weight parameters are assumed.

A. Number of surfclams per tow, by region, and the assumed blade depth required for "fishing".

Blade depth (inches):

Region:	2 inches	4 inches	6 inches	8 inches
SVA	15	15	15	18
DMV	65	68	76	94
SNJ	18	18	19	21
NNJ	75	76	78	84
LI	3	3	4	4
SNE	9	9	10	11
GBK	51	56	67	91

B. Meat weight (kg) of surfclams per tow, by region, and the assumed blade depth required for "fishing". Data are all good tows from Cruise 9704, the 1997 NMFS clam survey.

Blade depth (inches):

Region:	2 inches	4 inches	6 inches	8 inches
SVA	0.2	0.2	0.2	0.2
DMV	3.8	4.0	4.5	5.6
SNJ	2.1	2.2	2.2	2.5
NNJ	8.5	8.6	8.9	9.5
LI	0.4	0.4	0.4	0.4
SNE	1.3	1.3	1.4	1.5
GBK	3.3	3.6	4.3	5.9

Table B9. For the 1992 and 1994 resampled stations, the table gives the median deviation in number of surfclams (i.e., observed - expected) collected in 1997, as well as the results of the signed rank test that the median deviation = 0. "*": p<0.05 (i.e., significant lack of fit to the model). "ns": the hypothesis that the data fit the model can not be rejected. Results are given for three assumed minimum blade depths for the dredge to be "fishing". "n": number of stations. Natural mortality rate (M) assumed: 0.05.

	Critical blade depth (inches) for "fishing"		
Resampled stations from:	≥4	≥6	≥8
1992 Survey (n = 12)	-10 [p=0.56, ns]	-8 [0.67, ns]	0 [0.91, ns]
1994 Survey (n = 16)	-73 [p=0.021, *]	-69 [0.029, *]	-62 [0.05, *]

Table B10. Summary of relevant site, vessel, and experimental characteristics of commercial and research-based depletion experiments.

Site characteristics				Vessel characteristics		Experiment characteristics			
Site name	Latitude (decimal deg)	Longitude (decimal deg)	Depth (m)	Vessel name	Dredge width (inches)	Number of tows included	Area swept (m^2)	Sum of tow areas (m^2)	Effective coverage = sum of tow areas/area swept
Point Pleasant	40.05394	-73.83124	26	F/V Sheri Ann	100	39	22140.7	42221.7	1.9070
Atlantic City 1-1	39.36074	-73.89265	30	F/V Judy Marie	100	16	8222.8	15538.1	1.8896
Atlantic City 1-2	39.36282	-73.88905	30	F/V Judy Marie	100	17	12870	27394.7	2.1286
Atlantic City 2-1	39.39349	-73.90352	30	F/V Jersey Girl	130	13	6939.2	15097.1	2.1756
Atlantic City 2-2	39.39124	-73.90023	30	F/V Jersey Girl	130	18	11613.1	21944.5	1.8896
Delaware II	-39.29403	-73.8593	30	R/V Delaware II	60	61	28137.5	36680.4	1.3036

Table B11. Comparison of parameter estimates for the Leslie-Davis depletion model. CPUE(I) = p(N-T(I-1)) where T(I-1) = cumulative catch.

	Least squares approach					
	Simple linear regression		Nonlinear regression		Maximum likelihood	
Site	N	p	N	p	N	p
Atlantic City 1.1	80.54	0.1052	76.68	0.1119	80.11	0.1006
Atlantic City 1.2	142.88	0.0715	142.88	0.0715	147.87	0.0675
Point Pleasant	549.03	0.0245	549.03	0.0245	527.38	0.0261
Atlantic City 2.1	84.52	0.1660	84.52	0.1660	81.27	0.1831
Atlantic City 2.2	137.02	0.1287	135.53	0.1393	135.54	0.1323
Delaware II	289.73	0.0143	289.73	0.0143	335.91	0.0115

Table B12. Profile-likelihood based confidence intervals for p and N in the Leslie-Davis depletion model. Efficiency = (total area depleted/average area swept) * catchability coefficient. Population density = no. of bushel * number/bushel/total area depleted.

	Efficiency=P(capture|encounter)			Population size (density)		
Site	Lower	Mean	Upper	Lower	Mean	Upper
Atlantic City 1.1	0.4472	0.6918	0.9288	0.5368	0.5929	0.7348
Atlantic City 1.2	0.4307	0.72[illegible]	0.9960	0.6005	0.6980	0.9696
Point Pleasant	0.2910	0.3792	0.4655	1.5616	1.7454	2.0586
Atlantic City 2.1	0.8273	1.0628	1.2918	0.7492	0.7769	0.8338
Atlantic City 2.2	0.8394	1.0093	1.1827	0.7648	0.7893	0.8297
Delaware II	0.2819	0.5879	0.8971	0.6129	0.7999	1.4146

Table B13. Summary statistics for *Delaware II* set-up tows at sites used by commercial vessels for depletion experiments.

									Density/meter^3			alpha= 0.1	Confidence interval on mean	
Experiment name	NMFS cruise code	NMFS sta. no.	Clam species	Clams /tow	Area towed (m^2)	Lengths measured	Density (no./m2)	Mean	Std. dev.	CV	Site	t-statistic	Lower	Upper
PP1	9703	183	SC	363	696.0439	Yes	0.5215188							
PP1	9703	184	SC	556	637.7886	Yes	0.8717622							
PP1	9703	185	SC	316	688.6773	Yes	0.4588506							
PP1	9703	186	SC	288	714.164	Yes	0.4032687							
PP1	9703	187	SC	328	695.3101	No	0.471732							
PP1	9703	188	SC	355	739.8765	No	0.4798098							
PP1	9703	189	SC	289	695.3101	No	0.4156419							
PP1	9703	190	SC	203	695.3101	No	0.2919561	0.489318	0.169205	0.345798	PP1	2.364623	0.347859	0.630777
AC1.1	9703	166	SC	146	766.464	Yes	0.1904851							
AC1.1	9703	167	SC	158	743.7997	Yes	0.2124228							
AC1.1	9703	168	SC	194	784.4147	Yes	0.2473181							
AC1.1	9703	170	SC	278	793.7288	Yes	0.3502456							
AC1.1	9703	171	SC	243	862.7941	Yes	0.2816431							
AC1.1	9703	172	SC	231	872.842	Yes	0.2646527							
AC1.1	9703	173	SC	328	802.9018	Yes	0.4085182							
AC1.1	9703	174	SC	143	722.462	Yes	0.1979343	0.269152	0.076654	0.284797	AC1.1	2.364623	0.205068	0.333237
AC1.2	9703	166	SC	146	766.464	Yes	0.1904851							
AC1.2	9703	167	SC	158	743.7997	Yes	0.2124228							
AC1.2	9703	168	SC	194	784.4147	Yes	0.2473181							
AC1.2	9703	170	SC	278	793.7288	Yes	0.3502456							
AC1.2	9703	171	SC	243	862.7941	Yes	0.2816431							
AC1.2	9703	172	SC	231	872.842	Yes	0.2646527							
AC1.2	9703	173	SC	328	802.9018	Yes	0.4085182							
AC1.2	9703	174	SC	143	722.462	Yes	0.1979343	0.269152	0.076654	0.284797	AC1.2	2.364623	0.205068	0.333237
AC2_1	9703	169	SC	135	769.9074	Yes	0.1753458							
AC2_1	9703	175	SC	101	648.7679	Yes	0.1556797							
AC2_1	9703	176	SC	156	527.7131	Yes	0.2956152							
AC2_1	9703	177	SC	106	655.7393	Yes	0.1616496							
AC2_1	9703	178	SC	88	628.0794	Yes	0.1401097							
AC2_1	9703	179	SC	123	645.4656	Yes	0.1905601							
AC2_1	9703	180	SC	154	764.6576	Yes	0.2013973							
AC2_1	9703	181	SC	106	714.3051	Yes	0.148396	0.183594	0.049818	0.271348	AC2_1	2.364623	0.141945	0.225243
AC2_2	9703	169	SC	135	769.9074	Yes	0.1753458							
AC2_2	9703	175	SC	101	648.7679	Yes	0.1556797							
AC2_2	9703	176	SC	156	527.7131	Yes	0.2956152							
AC2_2	9703	177	SC	106	655.7393	Yes	0.1616496							
AC2_2	9703	178	SC	88	628.0794	Yes	0.1401097							
AC2_2	9703	179	SC	123	645.4656	Yes	0.1905601							
AC2_2	9703	180	SC	154	764.6576	Yes	0.2013973							
AC2_2	9703	181	SC	106	714.3051	Yes	0.148396	0.183594	0.049818	0.271348	AC2_2	2.364623	0.141945	0.225243

Table B14. Efficiency of *Delaware II* dredge estimated as the ratio of the density in set-up tows to the model-based estimate of initial density.

	DE II depletion set-up tows				Commercial depletion experiments						R/V DE II: F/V
	c1	c2	c3=c1/c2	c4	c5	c6	c7=c5*c6	c8	c9=c7/c8	c10	c11=c3/c9
Site name	Ave. catch per tow (number)	Ave. area per tow (m^2)	Ave. density per tow (no./m^2)	DE II depletion-based est. efficiency	Total population (bushels)	Number per bushel	Total population (Number)	Depletion area (m^2)	Density (#/m^2)	Depletion -based comm. vessel efficiency	DE II relative efficiency (unadjusted)
Point Pleasant	337.3	695.3	0.485	0.587	527.4	73.28	38645	22140.7	1.745	0.379	0.278
Atlantic City 1-1	215.1	793.7	0.271	0.587	80.1	60.86	4875	8222.8	0.593	0.692	0.457
Atlantic City 1-2	215.1	793.7	0.271	0.587	147.9	60.75	8983	12870	0.698	0.727	0.388
Atlantic City 2-1	121.1	669.3	0.181	0.587	81.3	66.33	5391	6939.2	0.777	1.063	0.233
Atlantic City 2-2	121.1	669.3	0.181	0.587	135.5	67.63	9166	11613.1	0.789	1.009	0.229

Table B15. Comparison of efficiency estimate derived from Leslie-Davis depletion model with ratio of density in initial tows to overall density from model. Confidence limits on initial density based on t-distribution with n-1 degrees of freedom and alpha= 0.1.

Initial tows from depletion experiments												Mean, std. dev., and conf. limits for initial tows (no./m^2)					Overall Leslie-Davis estimates		Relative efficiency = initial density/ L-D density			
Site code	Fishing vessel	Day	Mon	Yr	Tow	Catch (numbers)	Catch (bushels)	Station label	Area swept (m^2)	Tow distance (km)	Density (no./m^2)	Average density (no./m^2)	Std. dev. density (no.m^2)	t-statistic (alpha/2, n-1 df)	Lower bound	Upper bound	Mean density	Efficiency	Lower bound	Average	Upper bound	Site code
PP1	SheriAnne	9	6	97	2	879	12	2	1232	0.485	0.714											
PP1	SheriAnne	9	6	97	3	907	12.38	3	1110	0.437	0.817											
PP1	SheriAnne	9	6	97	4	1081	14.75	4	1074	0.423	1.006											
PP1	SheriAnne	9	6	97	5	696	9.5	5	1123	0.442	0.620											
PP1	SheriAnne	9	6	97	6	733	10	6	1105	0.435	0.663	0.764	0.154	2.132	0.698	0.830	1.745	0.379	0.400	0.438	0.475	PP1
AC2_1	JerseyGirl	10	6	97	1	962	12.5	1	1198	0.363	0.803											
AC2_1	JerseyGirl	10	6	97	2	1083	11.75	2	1231	0.373	0.880											
AC2_1	JerseyGirl	10	6	97	3	1061	9	3	1135	0.344	0.935											
AC2_1	JerseyGirl	10	6	97	4	988	10.75	4	1221	0.370	0.809	0.857	0.063	2.353	0.820	0.894	0.777	1.063	1.055	1.103	1.150	AC2_1
AC2_2	JerseyGirl	10	6	97	1	913	13.5	1	1429	0.433	0.639											
AC2_2	JerseyGirl	10	6	97	2	1353	20	2	1571	0.476	0.861											
AC2_2	JerseyGirl	10	6	97	3	1142	16.88	3	1436	0.435	0.795											
AC2_2	JerseyGirl	10	6	97	4	609	9	4	1465	0.444	0.415	0.678	0.198	2.353	0.561	0.794	0.789	1.009	0.711	0.859	1.007	AC2_2
AC1_1	JudyMarie	11	6	97	1	624	10.25	1	978	0.385	0.638											
AC1_1	JudyMarie	11	6	97	2	251	4.13	2	935	0.368	0.269											
AC1_1	JudyMarie	11	6	97	3	548	9	3	902	0.355	0.607	0.505	0.205	2.920	0.305	0.704	0.593	0.692	0.515	0.851	1.187	AC1_1
AC1_2	JudyMarie	11	6	97	1	759	12.5	1	1140	0.449	0.666											
AC1_2	JudyMarie	11	6	97	3	486	8	3	1168	0.460	0.416											
AC1_2	JudyMarie	11	6	97	4	539	8.88	4	1209	0.476	0.446											
AC1_2	JudyMarie	11	6	97	5	418	6.88	5	1140	0.449	0.366											
AC1_2	JudyMarie	11	6	97	6	555	9.13	6	1143	0.450	0.485	0.476	0.115	2.132	0.427	0.525	0.698	0.727	0.612	0.682	0.752	AC1_2
DE II	Delaware II	5	6	97	1	285	4.25373	108	543	0.356	0.525											
DE II	Delaware II	5	6	97	2	241	3.59701	109	547	0.359	0.440											
DE II	Delaware II	5	6	97	3	300	4.47761	110	660	0.433	0.455											
DE II	Delaware II	5	6	97	4	323	4.8209	111	669	0.439	0.483											
DE II	Delaware II	5	6	97	5	371	5.53731	112	607	0.398	0.611	0.503	0.069	2.132	0.473	0.532	0.7999	0.588	0.592	0.629	0.665	DE II

Table B16. Summary of research vessel survey abundance per tow data, by year, region, and size class.

	Northern New Jersey			Delmarva		
Survey year	Recruits (105-119 mm)	Fully recruited (120+ mm)	All sizes	Recruits (103-119 mm)	Fully recruited (120+ mm)	All sizes
1965(A)[1]	-	-	38.1	-	-	27.68
1965(B)	-	-	35.7	-	-	28.02
1966	-	-	30.4	-	-	32.53
1969	-	-	34.3	-	-	26.26
1970	-	-	25.7	-	-	19.64
1974	-	-	21.4	-	-	36.66
1976	0.4	11.3	12.9	0.8	16.5	22.0
1977	0.3	1.1	2.5	0.5	9.1	11.4
1978(A)	0.3	0.7	2.1	0.6	7.6	11.6
1978(B)	1.7	1.5	45.0	1.1	6.5	622.3
1980(A)	4.2	4.1	20.3	1.8	8.5	43.9
1980(B)	19.3	8.9	34.3	3.8	7.4	31.1
1981	7.9	8.6	23.1	32.6	14.8	93.5
1982[2]	24.9	47.3	96.2	60.1	18.9	125.0
1983	31.1	38.6	86.3	24.3	31.4	63.3
1984	10.0	45.8	71.5	31.9	35.9	229.0
1986	6.9	42.5	58.1	50.0	77.5	138.7
1989	6.9	47.0	61.1	12.0	32.2	49.5
1992	13.5	34.3	59.1	7.5	29.6	43.7
1994	27.2	105.9	176.5	39.2	63.9	141.4
1997[3]	8.0	62.7	75.9	20.3	28.3	68.2

[1]Values from 1965-1981 are from NEFSC Lab. Ref. Doc. 86-14 and from Murawski and Serchuk (1989) and are standardized to a 60-in wide dredge towed for 5 min. [2]Values from 1982-1994 were standardized to a tow distance of 0.15 n. mi. based on doppler distance. [3]1997 data were standardized to 0.15 nmi with data on bottom contact of the dredge and towing speed.

Table B17. Stock size estimates in number and meat weight by region, 1997. Estimates are based on 5-mm size intervals. Program by S. Smith.

1997

Traditional Areas
Number/Tow

				Parametric						Bootstrap					
			N=	per tow (#)			per region (#)			per tow (#)			per region (#)		
Region	$Yst	$yst	(tows/region)	lower	mean	upper	lower	mean	upper	lower	mean	upper	lower	mean	upper
GBK	2.6E+09	56.04	46,389,573	23.73	56.04	88.34	1,101,010	2,599,579	4,098,194	32.27	55.50	85.18	1,496,992	2,574,621	3,951,464
SNE	3.31E+08	9.29	35,629,709	-0.24	9.29	18.82	-8,551	331,000	670,551	3.87	9.16	15.20	137,994	326,404	541,536
LI	8.14E+07	3.41	23,875,093	-11.75	3.41	18.57	-280,532	81,414	443,360	0.11	3.43	6.96	2,512	81,796	166,089
NNJ	2.116E+09	75.91	27,869,637	56.60	75.91	95.22	1,577,421	2,115,584	2,653,747	58.17	76.58	97.55	1,621,177	2,134,257	2,718,683
SNJ	1.82E+08	18.28	9,956,236	1.64	18.28	34.91	16,328	182,000	347,572	5.68	18.14	34.13	56,551	180,606	339,806
DMV	2.81E+09	68.16	41,226,526	43.18	68.16	93.14	1,780,161	2,810,000	3,839,839	47.74	68.09	94.00	1,968,154	2,807,114	3,875,293
SVA	3.48E+08	14.42	24,133,148	-11.62	14.42	40.45	-280,427	348,000	976,186	1.61	15.10	41.85	38,734	364,411	1,009,900
ALL	8.47E+09	40.50	209,135,802	31.34	40.50	49.66	6,554,316	8,470,000	10,385,684	32.23	40.72	50.48	6,740,447	8,516,010	10,557,176

Traditional Areas
Total Weight (Kg)

				Parametric						Bootstrap					
			N=	per tow (Kg)			per region (mt)			per tow (Kg)			per region (mt)		
Region	$Yst	$yst	(tows/region)	lower	mean	upper	lower	mean	upper	lower	mean	upper	lower	mean	upper
GBK	170536175	3.68	46,389,254	1.78	3.68	5.57	82,503	170,536	258,569	1.95	3.71	5.69	90,227	172,197	263,955
SNE	4.66E+07	1.31	35,545,890	-0.29	1.31	2.90	-10,308	46,565	103,083	0.44	1.30	2.32	15,558	46,103	82,434
LI	9.42E+06	0.39	24,145,826	-1.35	0.39	2.14	-32,597	9,417	51,672	0.03	0.45	0.85	724	10,764	20,524
NNJ	2.41E+08	8.64	27,893,519	6.58	8.64	10.71	183,450	241,000	298,740	6.78	8.60	10.54	189,118	239,912	293,998
SNJ	2.16E+07	2.17	9,935,396	0.29	2.17	4.04	2,881	21,560	40,139	0.61	2.13	3.93	6,075	21,182	39,056
DMV	1.67E+08	4.04	41,336,634	2.44	4.04	5.64	100,861	167,000	233,139	2.67	4.04	5.49	110,493	167,165	226,855
SVA	4.10E+06	0.17	24,117,029	-0.01	0.17	0.35	-241	4,100	8,441	0.12	0.25	0.41	2,894	6,029	9,777
ALL	6.60E+08	3.16	208,860,759	2.55	3.16	3.76	532,595	660,000	785,316	2.68	3.18	3.77	560,165	684,177	787,405

Traditional Areas
Full Recruit Weight (Kg)

				Parametric						Bootstrap					
			N=	per tow (Kg)			per region (mt)			per tow (Kg)			per region (mt)		
Region	$Yst	$yst	(tows/region)	lower	mean	upper	lower	mean	upper	lower	mean	upper	lower	mean	upper
GBK	85133171	1.84	46,389,043	1.02	1.84	2.65	47,516	85,133	122,750	1.15	1.83	2.59	53,208	84,799	120,333
SNE	4.42E+07	1.24	35,638,815	-0.31	1.24	2.79	-11,048	44,192	99,432	0.42	1.27	2.32	14,979	45,226	82,672
LI	8.30E+06	0.35	23,717,560	-1.40	0.35	2.10	-33,205	8,301	49,807	0.03	0.36	0.72	668	8,605	17,103
NNJ	2.21E+08	7.94	27,833,753	6.04	7.94	9.84	168,116	221,000	273,884	6.03	7.97	9.94	167,754	221,752	276,640
SNJ	2.07E+07	2.08	9,969,628	0.24	2.08	3.93	2,393	20,737	39,181	0.70	2.14	3.73	7,018	21,305	37,204
DMV	9.85E+07	2.39	41,203,133	1.30	2.39	3.47	53,564	98,475	142,975	1.56	2.40	3.54	64,277	99,011	145,859
SVA	2.40E+05	0.01	23,973,900	0.0001	0.01	0.02	2	240	479	0.08	0.09	0.10	1,916	2,158	2,397
ALL	4.78E+08	2.29	208,733,624	1.87	2.29	2.71	390,332	478,000	565,668	1.91	2.31	2.74	398,681	482,176	571,930

Table B18. Stock size estimates in number and meat weight by region, 1994. Estimates are based on 5-mm size intervals. Program by S. Smith.

1994
Traditional Areas
Number/Tow

				Parametric						Bootstrap					
				per tow (#)			*per region* (#)			*per tow* (#)			*per region* (#)		
Region	$Yst	$yst	N= (tows/region)	lower	mean	upper	lower	mean	upper	lower	mean	upper	lower	mean	upper
GBK	3.568E+09	76.92	46,389,751	19.68	76.92	134.16	912,950	3,568,300	6,223,649	36.43	76.21	125.60	1,689,979	3,535,363	5,826,553
SNE	1.38E+08	3.86	35,751,295	-0.51	3.86	8.24	-18,233	138,000	294,591	0.96	3.86	7.39	34,296	138,107	264,338
LI	2.98E+08	12.49	23,859,087	7.59	12.49	17.40	181,090	298,000	415,148	8.71	12.31	16.53	207,908	293,705	394,438
NNJ	4.87E+09	174.61	27,890,728	128.58	174.61	220.64	3,586,190	4,870,000	6,153,810	131.60	173.90	213.90	3,667,631	4,850,198	5,965,827
SNJ	2.05E+09	206.42	9,931,208	-60.07	206.40	472.90	-596,568	2,049,801	4,696,468	30.31	209.80	451.41	301,015	2,083,567	4,483,047
DMV	5.82E+09	141.18	41,223,969	75.46	141.18	206.91	3,110,761	5,820,000	8,529,652	85.87	139.00	214.02	3,539,902	5,730,132	8,822,754
SVA	1.07E+09	44.28	24,164,408	4.41	44.28	84.15	106,565	1,070,000	2,033,435	13.72	42.54	74.32	331,536	1,027,954	1,795,899
ALL	1.78E+10	85.20	208,920,188	63.56	85.20	106.83	13,278,967	17,800,000	22,318,944	64.93	85.68	107.57	13,565,188	17,900,282	22,473,545

Traditional Areas
Total Weight (Kg)

				Parametric						Bootstrap					
				per tow (Kg)			*per region* (mt)			*per tow* (Kg)			*per region* (mt)		
Region	$Yst	$yst	N= (tows/region)	lower	mean	upper	lower	mean	upper	lower	mean	upper	lower	mean	upper
GBK	3.19E+08	6.87	46,433,770	1.35	6.87	12.39	62,686	319,000	575,314	2.86	6.82	11.95	132,986	316,446	554,651
SNE	1.59E+07	0.45	35,333,333	-0.21	0.45	1.10	-7,420	15,900	38,867	0.08	0.45	0.88	2,764	15,865	31,233
LI	2.91E+07	1.22	23,852,459	0.65	1.22	1.80	15,504	29,100	42,934	0.79	1.21	1.66	18,908	28,790	39,566
NNJ	4.39E+08	15.77	27,837,666	11.85	15.77	19.69	329,876	439,000	548,124	12.11	15.79	19.48	337,114	439,557	542,278
SNJ	1.30E+08	13.11	9,916,095	-7.87	13.11	34.08	-78,040	130,000	337,941	2.30	12.68	34.58	22,777	125,736	342,928
DMV	3.57E+08	8.64	41,319,444	4.80	8.64	12.49	198,333	357,000	516,080	4.96	8.60	12.71	205,068	355,513	525,170
SVA	2.01E+07	0.83	24,216,867	0.27	0.83	1.39	6,539	20,100	33,661	0.48	0.90	1.32	11,593	21,894	31,971
ALL	1.31E+09	6.27	208,931,419	4.56	6.27	7.98	952,727	1,310,000	1,667,273	4.71	6.20	8.05	984,903	1,296,002	1,681,689

Traditional Areas
Full Recruit Weight (Kg)

				Parametric						Bootstrap					
				per tow (Kg)			*per region* (mt)			*per tow* (Kg)			*per region* (mt)		
Region	$Yst	$yst	N= (tows/region)	lower	mean	upper	lower	mean	upper	lower	mean	upper	lower	mean	upper
GBK	2.50E+08	5.39	46,382,189	0.64	5.39	10.14	29,685	250,000	470,315	1.86	5.32	9.70	86,271	246,660	449,768
SNE	1.33E+07	0.37	35,945,946	-0.27	0.37	1.02	-9,705	13,300	36,665	0.07	0.38	0.80	2,646	13,498	28,577
LI	2.35E+07	0.99	23,737,374	0.54	0.99	1.44	12,818	23,500	34,182	0.64	0.98	1.40	15,118	23,172	33,216
NNJ	3.57E+08	12.82	27,847,114	9.67	12.82	15.97	269,282	357,000	444,718	9.90	12.75	15.62	275,631	355,051	434,972
SNJ	1.02E+08	10.26	9,941,520	-6.86	10.26	27.39	-68,199	102,000	272,298	1.37	10.42	27.90	13,570	103,591	277,378
DMV	2.39E+08	5.80	41,206,897	3.43	5.80	8.15	141,340	239,000	335,836	3.73	5.80	8.12	153,619	239,124	334,682
SVA	6.45E+06	0.27	23,888,889	0.03	0.27	0.51	717	6,450	12,183	0.17	0.35	0.56	4,066	8,294	13,285
ALL	9.92E+08	4.74	209,282,700	3.36	4.74	6.13	703,190	992,000	1,282,903	3.56	4.77	6.08	745,884	998,906	1,273,276

Table B19. Stock size estimates in number and meat weight by region, 1992. Estimates are based on 5-mm size intervals. Program by S. Smith.

1992

Traditional Areas
Number/Tow

				Parametric						Bootstrap					
				per tow (#)			per region (#)			per tow (#)			per region (#)		
Region	$Yst	$yst	N= (tows/region)	lower	mean	upper	lower	mean	upper	lower	mean	upper	lower	mean	upper
GBK	1121211046	24.17	46,388,541	5.71	24.17	42.63	264,707	1,121,211	1,977,683	11.26	24.25	40.95	522,335	1,124,922	1,899,611
SNE	191671933	5.37	35,671,177	-1.04	5.37	11.78	-36,923	191,672	420,271	0.62	5.53	9.75	21,938	197,083	347,901
LI	199209167	8.35	23,858,814	-4.62	8.35	21.32	-110,273	199,209	508,689	1.90	8.46	13.40	45,332	201,774	319,708
NNJ	1652497691	59.30	27,869,090	33.97	59.30	84.62	946,629	1,652,498	2,358,338	37.16	59.13	85.68	1,035,615	1,647,899	2,387,824
SNJ	111669070	11.23	9,948,247	1.77	11.23	20.68	17,567	111,669	205,763	3.95	11.14	21.00	39,335	110,823	208,943
DMV	1795182347	43.52	41,252,438	18.34	43.52	68.70	756,405	1,795,182	2,833,919	24.49	43.64	74.10	1,010,272	1,800,256	3,056,806
SVA	607068612	25.15	24,142,717	-8.34	25.15	58.63	-201,358	607,069	1,415,509	2.35	25.96	64.08	56,815	626,745	1,547,138
ALL	5678509866	27.15	209,130,110	19.26	27.15	35.05	4,027,009	5,678,510	7,329,801	20.22	27.31	35.37	4,228,611	5,711,343	7,396,932

Traditional Areas
Total Weight (Kg)

				Parametric						Bootstrap					
				per tow (Kg)			per region (mt)			per tow (Kg)			per region (mt)		
Region	$Yst	$yst	N= (tows/region)	lower	mean	upper	lower	mean	upper	lower	mean	upper	lower	mean	upper
GBK	72243479	1.56	46,390,213	0.46	1.56	2.66	21,246	72,243	123,244	0.69	1.58	2.67	31,819	73,297	123,653
SNE	22350086	0.63	35,671,103	-0.44	0.63	1.69	-15,600	22,350	60,300	0.07	0.69	1.31	2,591	24,774	46,627
LI	14039784	0.59	23,858,924	-0.17	0.59	1.35	-4,091	14,040	32,171	0.15	0.61	0.93	3,555	14,647	22,217
NNJ	152509292	5.47	27,869,322	3.55	5.47	7.40	98,911	152,509	206,110	3.69	5.44	7.39	102,866	151,526	206,010
SNJ	14902795	1.50	9,948,461	0.19	1.50	2.81	1,895	14,903	27,910	0.35	1.46	2.82	3,438	14,485	28,084
DMV	136820980	3.32	41,253,386	1.55	3.32	5.08	64,062	136,821	209,584	1.92	3.39	5.37	79,083	139,808	221,531
SVA	32716242	1.36	24,143,046	-0.51	1.36	3.22	-12,237	32,716	77,672	0.10	1.44	3.50	2,479	34,742	84,563
ALL	445582658	2.13	209,134,825	1.59	2.13	2.67	333,089	445,583	558,076	1.65	2.16	2.75	344,654	451,104	574,284

Traditional Areas
Full Recruit Weight (Kg)

				Parametric						Bootstrap					
				per tow (Kg)			per region (mt)			per tow (Kg)			per region (mt)		
Region	$Yst	$yst	N= (tows/region)	lower	mean	upper	lower	mean	upper	lower	mean	upper	lower	mean	upper
GBK	40443114	0.87	46,389,294	0.24	0.87	1.51	10,981	40,443	69,905	0.36	0.86	1.49	16,733	40,104	69,037
SNE	20585226	0.58	35,670,738	-0.49	0.58	1.65	-17,508	20,585	58,678	0.05	0.62	1.24	1,855	22,234	44,188
LI	6795156	0.28	23,858,658	0.02	0.28	0.55	587	6,795	13,003	0.12	0.30	0.45	2,861	7,177	10,770
NNJ	118544048	4.25	27,869,110	2.90	4.25	5.60	80,951	118,544	156,137	2.95	4.26	5.53	82,158	118,778	154,088
SNJ	13464108	1.35	9,948,358	0.15	1.35	2.55	1,525	13,464	25,403	0.36	1.39	2.65	3,610	13,818	26,328
DMV	113585760	2.75	41,252,909	1.38	2.75	4.13	56,921	113,586	170,251	1.54	2.77	4.33	63,653	114,312	178,419
SVA	19707038	0.82	24,142,498	-0.73	0.82	2.36	-17,505	19,707	56,919	0.06	0.79	2.41	1,433	19,145	58,296
ALL	333124451	1.59	209,130,800	1.19	1.59	1.99	249,409	333,124	416,840	1.28	1.64	2.03	267,897	341,929	424,536

Table B20. Stock size estimates in number and meat weight by region, 1989. Estimates are based on 5-mm size intervals. Program by S. Smith.

1989

Traditional Areas

Number/Tow

Region	$Yst	$yst	N= (tows/region)	Parametric per tow (#) lower	Parametric per tow (#) mean	Parametric per tow (#) upper	Parametric per region (#) lower	Parametric per region (#) mean	Parametric per region (#) upper	Bootstrap per tow (#) lower	Bootstrap per tow (#) mean	Bootstrap per tow (#) upper	Bootstrap per region (#) lower	Bootstrap per region (#) mean	Bootstrap per region (#) upper
GBK	1.30E+09	42.75	30,409,357	-30.74	42.75	116.24	-934,784	1,300,000	3,534,784	6.36	43.19	114.48	193,373	1,313,380	3,481,324
SNE	2.81E+08	9.92	28,326,613	-0.02	9.92	19.84	-567	281,000	562,000	3.69	9.67	16.73	104,412	274,032	473,876
LI	1.49E+08	6.26	23,801,917	-55.75	6.26	68.28	-1,326,957	149,000	1,625,195	0.23	5.90	12.16	5,396	140,527	289,362
NNJ	1.71E+09	61.27	27,909,254	42.01	61.27	80.52	1,172,468	1,710,000	2,247,253	45.60	60.91	79.23	1,272,662	1,699,953	2,211,250
SNJ	1.49E+08	15.02	9,920,107	2.29	15.02	27.76	22,717	149,000	275,382	5.36	15.18	27.75	53,172	150,587	275,283
DMV	2.05E+09	49.59	41,338,980	22.79	49.59	76.40	942,115	2,050,000	3,158,298	25.40	49.52	77.37	1,050,010	2,047,106	3,198,397
SVA	3.25E+08	13.48	24,109,792	-11.62	13.48	38.57	-280,168	325,000	929,916	1.01	13.24	39.53	24,230	319,214	953,012
ALL	5.96E+09	32.06	185,901,435	19.07	32.06	45.06	3,545,140	5,960,000	8,376,719	22.35	31.62	43.76	4,154,897	5,878,203	8,135,047

Traditional Areas

Total Weight (Kg)

Region	$Yst	$yst	N= (tows/region)	Parametric per tow (Kg) lower	Parametric per tow (Kg) mean	Parametric per tow (Kg) upper	Parametric per region (mt) lower	Parametric per region (mt) mean	Parametric per region (mt) upper	Bootstrap per tow (Kg) lower	Bootstrap per tow (Kg) mean	Bootstrap per tow (Kg) upper	Bootstrap per region (mt) lower	Bootstrap per region (mt) mean	Bootstrap per region (mt) upper
GBK	1.33E+08	4.38	30,365,297	-3.41	4.38	12.18	-103,546	133,000	369,849	0.79	4.52	9.95	23,989	137,221	302,135
SNE	3.68E+07	1.30	28,307,692	0.07	1.30	2.53	1,982	36,800	71,618	0.62	1.41	2.19	17,661	39,829	62,008
LI	1.46E+07	0.61	23,934,426	-5.49	0.61	6.71	-131,400	14,600	160,600	0.04	0.56	1.15	952	13,291	27,545
NNJ	1.73E+08	6.19	27,948,304	4.47	6.19	7.83	124,929	173,000	218,835	4.67	6.16	7.98	130,491	172,189	222,888
SNJ	2.22E+07	2.23	9,955,157	0.61	2.23	3.86	6,073	22,200	38,427	0.90	2.19	3.52	8,952	21,752	35,053
DMV	1.54E+08	3.72	41,397,849	1.94	3.72	5.50	80,312	154,000	227,688	2.19	3.75	5.68	90,744	155,242	234,933
SVA	2.11E+07	0.87	24,252,874	-0.77	0.87	2.52	-18,675	21,100	61,117	0.12	0.88	2.61	2,835	21,321	63,334
ALL	5.54E+08	2.98	185,906,040	1.68	2.98	4.29	312,322	554,000	797,537	2.17	3.03	4.19	403,230	562,738	778,017

Traditional Areas

Full Recruit Weight (Kg)

Region	$Yst	$yst	N= (tows/region)	Parametric per tow (Kg) lower	Parametric per tow (Kg) mean	Parametric per tow (Kg) upper	Parametric per region (mt) lower	Parametric per region (mt) mean	Parametric per region (mt) upper	Bootstrap per tow (Kg) lower	Bootstrap per tow (Kg) mean	Bootstrap per tow (Kg) upper	Bootstrap per region (mt) lower	Bootstrap per region (mt) mean	Bootstrap per region (mt) upper
GBK	1.23E+08	4.05	30,370,370	-3.36	4.05	11.46	-102,044	123,000	348,044	0.60	4.31	11.53	18,076	130,957	350,307
SNE	3.48E+07	1.23	28,292,683	0.05	1.23	2.41	1,415	34,800	68,185	0.41	1.31	2.13	11,524	36,922	60,201
LI	1.23E+07	0.51	24,117,647	-4.46	0.51	5.49	-107,565	12,300	132,406	0.05	0.47	0.96	1,235	11,415	23,069
NNJ	1.54E+08	5.54	27,797,834	4.02	5.54	7.07	111,747	154,000	196,531	4.20	5.53	7.24	116,779	153,778	201,229
SNJ	2.12E+07	2.13	9,953,052	0.65	2.13	3.62	6,469	21,200	36,030	0.99	2.14	3.59	9,808	21,290	35,753
DMV	1.21E+08	2.92	41,438,356	1.46	2.92	4.39	60,500	121,000	181,914	1.71	2.94	4.37	70,860	121,829	181,003
SVA	1.88E+08	0.78	241,025,641	-0.72	0.78	2.28	-173,538	188,000	549,538	0.10	0.81	2.40	24,946	196,219	578,124
ALL	4.85E+08	2.61	185,823,755	1.38	2.61	3.84	256,437	485,000	713,563	1.81	2.67	3.91	336,898	495,778	726,385

Table B21. Examination of stratified random survey efficiencies compared to a completely random survey. Values are percentages. "Allocation": effect of sampling intensity. "Stratification": improvement due to choice of strata and their boundries.

		Number/tow		Full recruit weight	
Year	Area	Allocation	Stratification	Allocation	Stratification
1997	GBK	10.31	21.12	22.77	36.09
	SNE	8.71	38.27	9.31	34.27
	LI	7.61	-2.79	7.85	-2.62
	NNJ	2.98	7.70	3.42	13.92
	SNJ	0.27	12.21	0.26	13.48
	DMV	9.54	18.81	10.93	9.15
	SVA-NC	-23.97	-1.00	26.57	32.21
	ALL	9.21	23.52	19.27	32.66
1994	GBK	12.59	13.32	12.98	6.52
	SNE	-6.22	14.53	4.15	23.99
	LI	-1.62	88.10	-2.40	84.54
	NNJ	19.94	18.88	7.75	33.41
	SNJ	8.14	9.13	8.74	2.19
	DMV	6.84	14.90	7.19	15.52
	SVA-NC	24.97	32.97	22.86	38.70
	ALL	20.13	18.84	16.55	16.48
1992	GBK	56.40	6.70	23.42	10.87
	SNE	13.15	25.89	14.93	30.55
	LI	-4.02	43.36	-0.16	40.88
	NNJ	25.70	5.87	15.73	20.04
	SNJ	0.54	-5.12	0.51	-5.00
	DMV	10.42	7.53	10.34	8.72
	SVA-NC	19.80	-1.18	-27.67	-0.29
	ALL	35.57	8.57	19.09	19.30
1989	GBK	16.81	-1.21	16.64	-1.30
	SNE	8.21	35.65	12.49	43.79
	LI	9.10	-0.25	9.01	1.30
	NNJ	-6.26	21.07	2.28	35.79
	SNJ	7.03	16.45	6.12	18.08
	DMV	8.92	12.04	8.96	12.05
	SVA-NC	-24.61	-0.49	-24.11	-0.59
	ALL	5.93	7.46	1.85	6.88

Table B22. Surfclam supply-year calculations. NNJ run with M = 0.05. 10-year harvesting horizon policy (with option to harvest unexploited stock).

ASSUMPTIONS / INPUTS:

Full-Recruit Biomass estimate for 1997: (from S. Smith software, bootstrap)

Region	Minimum Biomass
NNJ	221.8 thousand mt
	0.0
Sum	221.8

Dredge Efficiency : 0.59

Sum (Adj. for Effic.) : 375.9 thousand mt
Full Rec. Stock Biomass (NNJ)

Do not change value
used in harvest calc:
1+exp(M)+exp(2M)+...+exp(9M) = 9

(note: M = m-g)

Commercial Catch Estimate from Exploited Area (units: mt):

Year	Catch (mt)	Source
1997	19,779	1997 quota
1998	19,779	1998 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 1997 : 0%

Annual Recruitment: (Pre-recruits grow to Full-Recruits)
Based on mean fraction of pre-recr. wt in last 4 surveys (1989-1997).
37,059 mt. Fraction is applied to "Actual" 1997 Stock Biomass
\- mt. annual recruitment in unexploited areas (initially)

Want to exploit part of unexploited stock ?
Enter fraction of unexpl. biomass to make available (exploitable) : 0.00
Starting in Year (>=1999): 1999

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 type this value,)
(computed by spreadsheet)

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_20% MSP	Exploit. Rate = (F_ref / Z) * (1-exp(-Z))
0	1	1998	398,265	-	398,265	19,779	2,565,014	5.0%	5.0%	0.18	16.1%
==>	2	1999	420,971	-	420,971	81,656	10,589,469	19.4%	19.4%	0.18	16.1%
0	3	2000	381,289	-	381,289	77,452	10,044,295	20.3%	20.3%	0.18	16.1%
0	4	2001	345,348	-	345,348	73,645	9,550,511	21.3%	21.3%	0.18	16.1%
0	5	2002	312,794	-	312,794	70,196	9,103,273	22.4%	22.4%	0.18	16.1%
0	6	2003	283,309	-	283,309	67,072	8,698,193	23.7%	23.7%	0.18	16.1%
0	7	2004	256,604	-	256,604	64,243	8,331,296	25.0%	25.0%	0.18	16.1%
0	8	2005	232,416	-	232,416	61,681	7,998,985	26.5%	26.5%	0.18	16.1%
0	9	2006	210,507	-	210,507	59,360	7,697,998	28.2%	28.2%	0.18	16.1%

Table B23. Surfclam supply-year calculations. NNJ run with M = 0.10. 10-year harvesting horizon policy (with option to harvest unexploited stock).

ASSUMPTIONS / INPUTS:

Full-Recruit Biomass estimate for 1997: (from S. Smith software, bootstrap)

Region	Minimum Biomass
NNJ	221.8 thousand mt
	0.0
Sum	221.8

Dredge Efficiency : 0.59

Sum (Adj. for Effic.) : 375.9 thousand mt
Full Rec. Stock Biomass (NNJ)

Do not change value used in harvest calc:
1+exp(M)+exp(2M)+...+exp(9M) = 12
(note: M = m-g)

Commercial Catch Estimate from Exploited Area (units: mt):

Year	Catch (mt)	Source
1997	19,779	1997 quota
1998	19,779	1998 quota

Conversion Fac: 17 lbs/bu

Policy: Harvest calculated for 10-yr horizon

Natural Mortality Rate, m : 0.10

Overfishing Def: F_ref 0.18 = Label F_20% MSP

Portion of total biomass that is unexploited in 1997 : 0%

Annual Recruitment: (Pre-recruits grow to Full-Recruits)
Based on mean fraction of pre-recr. wt in last 4 surveys (1989-1997).
37,059 mt. Fraction is applied to "Actual" 1997 Stock Biomass
\- mt, annual recruitment in unexploited areas (initially)

Want to exploit part of unexploited stock ?
Enter fraction of unexpl. biomass to make available (exploitable) : 0.00
Starting in Year (>=1999): 1999

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 type this value,) (computed by spreadsheet)

SIMULATION:

Marker		Year	Biomass (Expl), mt	Biomass (Unexpl), mt	Tot Biomass	Harvest from Expl. Area: mt	Harvest from Expl. Area: bushels	Exploitation Rate: Expl Areas	Exploitation Rate: All Areas	Overfishing Ref. Pt. Inst. Rate (F_ref) = F_20% MSP	Exploit. Rate = (F_ref / Z) * (1-exp(-Z))
0	1	1998	378,841	-	378,841	19,779	2,565,014	5.2%	5.2%	0.18	15.7%
==>	2	1999	381,723	-	381,723	69,191	8,972,911	18.1%	18.1%	0.18	15.7%
0	3	2000	336,884	-	336,884	65,416	8,483,439	19.4%	19.4%	0.18	15.7%
0	4	2001	297,312	-	297,312	62,085	8,051,463	20.9%	20.9%	0.18	15.7%
0	5	2002	262,388	-	262,388	59,146	7,670,229	22.5%	22.5%	0.18	15.7%
0	6	2003	231,567	-	231,567	56,551	7,333,777	24.4%	24.4%	0.18	15.7%
0	7	2004	204,366	-	204,366	54,262	7,036,845	26.6%	26.6%	0.18	15.7%
0	8	2005	180,361	-	180,361	52,241	6,774,792	29.0%	29.0%	0.18	15.7%
0	9	2006	159,175	-	159,175	50,458	6,543,522	31.7%	31.7%	0.18	15.7%

Table B24. Surfclam supply-year calculations. NNJ run with M = 0.15. 10-year harvesting horizon policy (with option to harvest unexploited stock).

ASSUMPTIONS / INPUTS:

Full-Recruit Biomass estimate for 1997: (from S. Smith software, bootstrap)

Region	Minimum Biomass	
NNJ	221.8	thousand mt
	0.0	
Sum	221.8	

Dredge Efficiency : 0.59

Sum (Adj. for Effic.) : 375.9 thousand mt
Full Rec. Stock Biomass (NNJ)

Do not change value
used in harvest calc:
1+exp(M)+exp(2M)+...+exp(9M) = 15
(note: M = m-g)

Commercial Catch Estimate from Exploited Area (units: mt):

Year	Catch (mt)	Source
1997	19,779	1997 quota
1998	19,779	1998 quota

Conversion Fac: 17 lbs/bu

Policy: Harvest calculated for 10-yr horizon

Natural Mortality Rate, m : 0.15

Overfishing Def: F_ref 0.18 = Label F_20% MSP

Portion of total biomass that is unexploited in 1997 : 0%

Annual Recruitment: (Pre-recruits grow to Full-Recruits)
Based on mean fraction of pre-recr. wt in last 4 surveys (1989-1997).
37,059 mt. Fraction is applied to "Actual" 1997 Stock Biomass
- mt, annual recruitment in unexploited areas (initially)

Want to exploit part of unexploited stock ?
Enter fraction of unexpl. biomass to make available (exploitable) : 0.00
Starting in Year (>=1999): 1999

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 type this value,)
(computed by spreadsheet)

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_20% MSP	Exploit. Rate = (F_ref / Z) * (1-exp(-Z))
0	1	1998	360,365	-	360,365	19,779	2,565,014	5.5%	5.5%	0.18	15.3%
==>	2	1999	346,170	-	346,170	59,744	7,747,758	17.3%	17.3%	0.18	15.3%
0	3	2000	296,524	-	296,524	56,490	7,325,857	19.1%	19.1%	0.18	15.3%
0	4	2001	253,998	-	253,998	53,703	6,964,463	21.1%	21.1%	0.18	15.3%
0	5	2002	217,571	-	217,571	51,316	6,654,898	23.6%	23.6%	0.18	15.3%
0	6	2003	186,368	-	186,368	49,272	6,389,730	26.4%	26.4%	0.18	15.3%
0	7	2004	159,640	-	159,640	47,520	6,162,590	29.8%	29.8%	0.18	15.3%
0	8	2005	136,745	-	136,745	46,020	5,968,026	33.7%	33.7%	0.18	15.3%
0	9	2006	117,134	-	117,134	44,735	5,801,365	38.2%	38.2%	0.18	15.3%

Table B25. Surfclam supply-year calculations. Mid-Atlantic (LI-SVA) run with M = 0.05. 10-year harvesting horizon policy (with option to harvest unexploited stock).

ASSUMPTIONS / INPUTS:

Full-Recruit Biomass estimate for 1997: (from S. Smith software, bootstrap)

Region	Minimum Biomass (thousand mt)
NNJ	221.8
DMV	99.0
Sum	320.8

Dredge Efficiency: 0.59

Sum (Adj. for Effic.): 543.7 thousand mt
Full Rec. Stock Biomass (1997, Exploited Area only)

Do not change value used in harvest calc:
1+exp(M)+exp(2M)+...+exp(9M) = 9
(note: M = m-g)

Commercial Catch Estimate from Exploited Area (units: mt):

Year	Catch (mt)	Source
1997	19,779	1997 quota
1998	19,779	1998 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 1997 : 8%

Annual Recruitment: (Pre-recruits grow to Full-Recruits)
Based on mean fraction of pre-recr. wt in last 4 surveys (1989-1997).
73,068 mt. Fraction is applied to "Actual" 1997 Stock Biomass
6,354 mt. annual recruitment in unexploited areas (initially)

Want to exploit part of unexploited stock ?
Enter fraction of unexpl. biomass to make available (exploitable) : 1.00
Starting in Year (>=1999): 2027

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 type this value.)
(computed by spreadsheet)

SIMULATION:

Marker		Year	Biomass (Expl), mt	Biomass (Unexpl), mt	Tot Biomass	Harvest from Expl. Area: mt	Harvest from Expl. Area: bushels	Exploitation Rate: Expl Areas	Exploitation Rate: All Areas	Overfishing Ref. Pt. Inst. Rate (F_ref) = F_20% MSP	Exploit. Rate = (F_ref / Z) * (1-exp(-Z))
0	1	1998	604,750	54,329	659,079	19,779	2,565,014	3.3%	3.0%	0.18	16.1%
0	2	1999	666,633	61,476	728,108	143,691	18,634,357	21.6%	19.7%	0.18	16.1%
0	3	2000	603,794	68,715	672,509	137,034	17,771,042	22.7%	20.4%	0.18	16.1%
0	4	2001	546,878	76,049	622,928	131,004	16,989,107	24.0%	21.0%	0.18	16.1%
0	5	2002	495,328	83,479	578,807	125,543	16,280,879	25.3%	21.7%	0.18	16.1%
0	6	2003	448,637	91,006	539,643	120,597	15,639,411	26.9%	22.3%	0.18	16.1%
0	7	2004	406,347	98,631	504,978	116,116	15,058,409	28.6%	23.0%	0.18	16.1%
0	8	2005	368,044	106,356	474,400	112,059	14,532,174	30.4%	23.6%	0.18	16.1%
0	9	2006	333,351	114,182	447,533	108,383	14,055,544	32.5%	24.2%	0.18	16.1%

Table B26. Surfclam supply-year calculations. Mid-Atlantic (LI-SVA) run with M = 0.10. 10-year harvesting horizon policy (with option to harvest unexploited stock).

ASSUMPTIONS / INPUTS:

Full-Recruit Biomass estimate for 1997: (from S. Smith software, bootstrap)

Region	Minimum Biomass (thousand mt)
NNJ	221.8
DMV	99.0
Sum	320.8

Dredge Efficiency : 0.59

Sum (Adj. for Effic.) : 543.7 thousand mt
Full Rec. Stock Biomass (1997, Exploited Area only)

Do not change value used in harvest calc:
1+exp(M)+exp(2M)+...+exp(9M) = 12
(note: M = m-g)

Commercial Catch Estimate from Exploited Area (units: mt):

Year	Catch (mt)	Source
1997	19,779	1997 quota
1998	19,779	1998 quota

Conversion Fac: 17 lbs/bu

Policy: Harvest calculated for 10-yr horizon

Natural Mortality Rate, m : 0.10

Overfishing Def: F_ref 0.18 = Label F_20% MSP

Portion of total biomass that is unexploited in 1997 : 8%

Annual Recruitment: (Pre-recruits grow to Full-Recruits)
Based on mean fraction of pre-recr. wt in last 4 surveys (1989-1997).
73,068 mt. Fraction is applied to "Actual" 1997 Stock Biomass
6,354 mt. annual recruitment in unexploited areas (initially)

Want to exploit part of unexploited stock ?
Enter fraction of unexpl. biomass to make available (exploitable) : 1.00
Starting in Year (>=1999): 2027

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 type this value.) (computed by spreadsheet)

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_20% MSP	Exploit. Rate = (F_ref / Z) * (1-exp(-Z))
0	1	1998	575,256	51,680	626,935	19,779	2,565,014	3.4%	3.2%	0.18	15.7%
0	2	1999	605,699	55,924	661,623	124,054	16,087,744	20.5%	18.7%	0.18	15.7%
0	3	2000	534,551	60,014	594,565	118,065	15,311,075	22.1%	19.9%	0.18	15.7%
0	4	2001	471,760	63,956	535,716	112,779	14,625,637	23.9%	21.1%	0.18	15.7%
0	5	2002	416,345	67,754	484,099	108,115	14,020,714	26.0%	22.3%	0.18	15.7%
0	6	2003	367,439	71,414	438,853	103,998	13,486,847	28.3%	23.7%	0.18	15.7%
0	7	2004	324,278	74,941	399,219	100,365	13,015,691	31.0%	25.1%	0.18	15.7%
0	8	2005	286,187	78,340	364,527	97,159	12,599,879	33.9%	26.7%	0.18	15.7%
0	9	2006	252,570	81,615	334,185	94,329	12,232,910	37.3%	28.2%	0.18	15.7%

Table B27. Surfclam supply-year calculations. Mid-Atlantic (LI-SVA) run with M = 0.15. 10-year harvesting horizon policy (with option to harvest unexploited stock).

ASSUMPTIONS / INPUTS:

Full-Recruit Biomass estimate for 1997: (from S. Smith software, bootstrap)

Region	Minimum Biomass (thousand mt)
NNJ	221.8
DMV	99.0
Sum	320.8

Dredge Efficiency : 0.59

Sum (Adj. for Effic.) : 543.7 thousand mt
Full Rec. Stock Biomass (1997, Exploited Area only)

Do not change value used in harvest calc:
1+exp(M)+exp(2M)+...+exp(9M) = 15
(note: M = m-g)

Commercial Catch Estimate from Exploited Area (units: mt):

Year	Catch (mt)	Source
1997	19,779	1997 quota
1998	19,779	1998 quota

Conversion Fac: 17 lbs/bu

Policy: Harvest calculated for 10-yr horizon

Natural Mortality Rate, m : 0.15

Overfishing Def: F_ref 0.18 = Label F_20% MSP

Portion of total biomass that is unexploited in 1997 : 8%

Annual Recruitment: (Pre-recruits grow to Full-Recruits)
Based on mean fraction of pre-recr. wt in last 4 surveys (1989-1997).
73,068 mt. Fraction is applied to "Actual" 1997 Stock Biomass
6,354 mt. annual recruitment in unexploited areas (initially)

Want to exploit part of unexploited stock ?
Enter fraction of unexpl. biomass to make available (exploitable) : 1.00
Starting in Year (>=1999): 2027

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 type this value,) (computed by spreadsheet)

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_20% MSP	Exploit. Rate = (F_ref / Z) * (1-exp(-Z))
0	1	1998	547,200	49,159	596,359	19,779	2,565,014	3.6%	3.3%	0.18	15.3%
0	2	1999	550,441	50,886	601,327	109,139	14,153,561	19.8%	18.1%	0.18	15.3%
0	3	2000	471,500	52,469	523,969	103,966	13,482,700	22.1%	19.8%	0.18	15.3%
0	4	2001	403,880	53,920	457,800	99,535	12,908,051	24.6%	21.7%	0.18	15.3%
0	5	2002	345,958	55,251	401,208	95,739	12,415,814	27.7%	23.9%	0.18	15.3%
0	6	2003	296,342	56,470	352,812	92,488	11,994,172	31.2%	26.2%	0.18	15.3%
0	7	2004	253,842	57,588	311,430	89,703	11,632,999	35.3%	28.8%	0.18	15.3%
0	8	2005	217,438	58,612	276,050	87,317	11,323,624	40.2%	31.6%	0.18	15.3%
0	9	2006	186,254	59,551	245,805	85,274	11,058,618	45.8%	34.7%	0.18	15.3%

Table B28.

Biomass Production Model – Surfclam

(1-yr projection)
Time T = 1997

INPUTS : (Assumptions)

Nat. mortality (m) :	0.05
Dredge Efficiency (0-1):	0.59
Non-catch mortality (0-1):	0.2

i.e.,(fraction dying\| impacted)

Area / Tow = (sq. n.mi)	0.000123434

e:/survey/progs/sc971mm.xls
Nov. 10, 1997

2-parameter vonBert. model results:

Region	vonBertal. Params L_inf	k	t	Source
1 SVA	139.4189	0.2533	0	DMV 1997
2 DMV	139.4189	0.2533	0	1997 data
3 SNJ	163.2525	0.24894	0	NNJ 1997
4 NNJ	163.2525	0.24894	0	1997 data
5 LI	159.0646	0.29792	0	89+92 data
6 SNE	167.1062	0.23438	0	89+92 data
7 GBK	152.0832	0.22387	0	89+92 data

Region	Len/Wt Params alpha	beta	Source
1 SVA	-7.0583	2.3033	Murawski
2 DMV	-9.1063	2.7675	Murawski
3 SNJ	-9.2061	2.8251	Murawski
4 NNJ	-9.2061	2.8251	Murawski
5 LI	-7.9837	2.5802	Murawski
6 SNE	-7.9837	2.5802	Murawski
7 GBK	-7.9967	2.5772	Murawski

Other notes: Catch per tow was adjusted to 0.15 nmi based on sensor data, assuming a critical cutting depth of 4 inches. A 1-mm size interval was used.
Traditional stratum areas used. Strata composing SNE and GBK were revised to follow surfclam habitat more closely.

OUTPUTS :

Production :
NOT ADJUSTED FOR DREDGE EFFICIENCY:

Region	Wt per tow by Region (grams) Time = T	Time = T + 1
SVA	169.4	266.4
DMV	4,025.8	4,238.0
SNJ	2,155.3	2,244.5
NNJ	8,621.7	9,047.3
LI	394.3	408.0
SNE	1,294.6	1,291.0
GBK	3,645.9	4,076.3

Production :
ADJUSTED FOR THE DREDGE EFFICIENCY LISTED ABOVE :

Region	Wt per tow by Region (grams) Time = T	Time = T + 1	Total Biomass Estimate: Adjusted for eff. Regional Biomass (MT) Time = T (1997)	Total Biomass Estimate: NOT Adjusted for eff. Regional Biomass (MT) Time = T (1997)
SVA	287.1	451.6	6,930	4,089
DMV	6,823.0	7,163.1	281,467	166,065
SNJ	3,653.1	3,804.2	36,343	21,443
NNJ	14,613.1	15,334.4	407,255	240,280
LI	668.3	691.5	15,945	9,408
SNE	2,194.2	2,188.1	78,269	46,178
GBK	6,179.5	6,909.0	286,662	169,131
			1,112,871	656,594

ADJUSTED FOR DREDGE EFFICIENCY: T ===> T+1 comparisons; Production :

ADJUSTED FOR DREDGE EFFICIENCY & INDIRECT FISHING MORT.: Removals : ; Net Production of Biomass:

Region	Change in Biomass / Tow (gr)	% change per tow	Region Area (sq n.mi)	Possible Tows/ Region	Regional Change in Biomass (M Tons)	Regional Biomass Contributions (%)	1996 Landings (dir + indir)	(Production - Removals) (M. Tons)	
1 SVA	165	57.3	2980	24,142,457	3,971.6	5.3	0	3,971.6	SVA
2 DMV	360	5.3	5092	41,252,815	14,854.5	19.9	2,684	12,170.1	DMV
3 SNJ	151	4.1	1228	9,948,637	1,503.4	2.0	1,597	-93.8	SNJ
4 NNJ	721	4.9	3440	27,869,145	20,102.8	26.9	19,292	810.4	NNJ
5 LI	23	3.5	2945	23,858,904	553.3	0.7	31	522.1	LI
6 SNE	-6	-0.3	4403	35,670,885	-215.7	-0.3	98	-314.1	SNE
7 GBK	729	11.8	5726	46,389,163	33,838.8	45.4	0	33,838.8	GBK
					74,608.7 Annual Total (MT)	100	23,704	50,905.1	Sum (MT)

Table B29. Summary of input parameters for yield per recruit and SSB per recruit for Georges Bank.

Proportion of F and M before Sp	0.5
Natural Mortality is constant at:	0.05
Initial Age	1
Last Age	28
Last age is a PLUS group	

von Bertalanffy Growth Parameters		
L_inf	K	t_o
152.0832	0.22387	0

LengthWeight Regression	
a	b
0.000337	2.5772

Age	Partial Recruitment Rate	Fraction Mature	Ave Wt in Stock (g)	Ave Wt in Catch (g)	Ave Shell Length (mm)
1	0	0.9	2.25	2.25	30.50
2	0	1	10.24	10.24	54.89
3	0	1	22.40	22.40	74.39
4	0	1	36.58	36.58	89.97
5	0.5	1	51.09	51.09	102.43
6	1	1	64.89	64.89	112.39
7	1	1	77.41	77.41	120.35
8	1	1	88.41	88.41	126.72
9	1	1	97.85	97.85	131.80
10	1	1	105.82	105.82	135.87
11	1	1	112.47	112.47	139.12
12	1	1	117.97	117.97	141.72
13	1	1	122.48	122.48	143.80
14	1	1	126.16	126.16	145.46
15	1	1	129.15	129.15	146.79
16	1	1	131.57	131.57	147.85
17	1	1	133.52	133.52	148.70
18	1	1	135.10	135.10	149.38
19	1	1	136.37	136.37	149.92
20	1	1	137.39	137.39	150.36
21	1	1	138.20	138.20	150.70
22	1	1	138.86	138.86	150.98
23	1	1	139.39	139.39	151.20
24	1	1	139.81	139.81	151.38
25	1	1	140.14	140.14	151.52
26	1	1	140.41	140.41	151.63
27	1	1	140.63	140.63	151.72
Plus Group					
28	1	1	140.80	140.80	151.79

Table B30. Summary of input parameters for yield per recruit and SSB per recruit for Northern New Jersey.

Proportion of F and M before Sp	0.5
Natural Mortality is constant at:	0.05
Initial Age	1
Last Age	28
Last age is a PLUS group	

von Bertalanffy Growth Parameters		
L_inf	K	t_o
163.2525	0.24894	0

LengthWeight Regression	
a	b
0.000111	2.7675

Age	Partial Recruitment Rate	Fraction Mature	Ave Wt in Stock (g)	Ave Wt in Catch (g)	Ave Shell Length (mm)
1	0	0.9	2.50	2.50	35.98
2	0	1	12.73	12.73	64.02
3	0	1	29.20	29.20	85.89
4	0	1	48.71	48.71	102.94
5	0.5	1	68.64	68.64	116.23
6	1	1	87.37	87.37	126.59
7	1	1	104.06	104.06	134.67
8	1	1	118.40	118.40	140.97
9	1	1	130.42	130.42	145.88
10	1	1	140.33	140.33	149.71
11	1	1	148.37	148.37	152.69
12	1	1	154.85	154.85	155.02
13	1	1	160.02	160.02	156.83
14	1	1	164.13	164.13	158.25
15	1	1	167.39	167.39	159.35
16	1	1	169.95	169.95	160.21
17	1	1	171.97	171.97	160.88
18	1	1	173.55	173.55	161.40
19	1	1	174.79	174.79	161.81
20	1	1	175.76	175.76	162.13
21	1	1	176.52	176.52	162.38
22	1	1	177.11	177.11	162.57
23	1	1	177.58	177.58	162.72
24	1	1	177.94	177.94	162.84
25	1	1	178.22	178.22	162.93
26	1	1	178.44	178.44	163.00
27	1	1	176.61	176.61	163.06
Plus Group					
28	1	1	178.75	178.75	163.10

Table B31. Summary of input parameters for yield per recruit and SSB per recruit for Delmarva.

Proportion of F and M before Sp	0.5
Natural Mortality is constant at:	0.05
Initial Age	1
Last Age	28
Last age is a PLUS group	

von Bertalanffy Growth Parameters		
L_inf	K	t_o
139.4189	0.25339	0

LengthWeight Regression	
a	b
0.000111	2.7675

Age	Partial Recruitment Rate	Fraction Mature	Ave Wt in Stock (g)	Ave Wt in Catch (g)	Ave Shell Length (mm)
1	0	0.9	1.52	1.52	31.21
2	0	1	7.43	7.43	55.43
3	0	1	16.67	16.67	74.23
4	0	1	27.40	27.40	88.82
5	0.5	1	38.19	38.19	100.15
6	1	1	48.20	48.20	108.94
7	1	1	57.03	57.03	115.76
8	1	1	64.54	64.54	121.06
9	1	1	70.79	70.79	125.17
10	1	1	75.90	75.90	128.36
11	1	1	80.02	80.02	130.83
12	1	1	83.31	83.31	132.75
13	1	1	85.93	85.93	134.25
14	1	1	88.00	88.00	135.40
15	1	1	89.62	89.62	136.30
16	1	1	90.90	90.90	137.00
17	1	1	91.90	91.90	137.54
18	1	1	92.68	92.68	137.96
19	1	1	93.28	93.28	138.29
20	1	1	93.76	93.76	138.54
21	1	1	94.13	94.13	138.74
22	1	1	94.41	94.41	138.89
23	1	1	94.63	94.63	139.01
24	1	1	94.81	94.81	139.10
25	1	1	94.94	94.94	139.17
26	1	1	95.05	95.05	139.23
27	1	1	95.13	95.13	139.27
Plus Group					
28	1	1	95.19	95.19	139.30

Table B32a. Fishing mortality rates (F) on surfclams by region, based on the bootstrap estimates and 95% CIs of total biomass from the 1997 survey, and the landings from 1996 (the last complete year of data). These estimates are based on the assumption that indirect mortality from clam harvesting = 0, that all landings are reported, and that M = 0.05. In this table, the efficiency is set at the maximum likelihood for the *Delaware II* experiment = 0.5879.

Efficiency Estimate	0.5879

Region	Stock estimate	Stock biomass from 1997 (mt)	1996 Catch (mt)	Exploitation rate U	Estimate of F	[U-(FA/Z)]=0 objective function
GBK	Lower CI	153,473	0	0.0000	0.0000	0.0000
	Mean	292,902	0	0.0000	0.0000	0.0000
	Upper CI	448,979	0	0.0000	0.0000	0.0000
SNE	Lower CI	26,464	82	0.0031	0.0032	0.0000
	Mean	78,420	82	0.0010	0.0011	0.0000
	Upper CI	140,218	82	0.0006	0.0006	0.0000
LI	Lower CI	1,232	26	0.0211	0.0219	0.0000
	Mean	18,309	26	0.0014	0.0015	0.0000
	Upper CI	34,911	26	0.0007	0.0008	0.0000
NNJ	Lower CI	321,684	16,077	0.0500	0.0526	0.0000
	Mean	408,083	16,077	0.0394	0.0412	0.0000
	Upper CI	500,082	16,077	0.0321	0.0335	0.0000
SNJ	Lower CI	10,333	1,331	0.1288	0.1415	0.0000
	Mean	36,030	1,331	0.0396	0.0386	0.0000
	Upper CI	66,433	1,331	0.0200	0.0208	0.0000
DMV	Lower CI	187,945	2,237	0.0119	0.0123	0.0000
	Mean	284,343	2,237	0.0079	0.0081	0.0000
	Upper CI	385,873	2,237	0.0058	0.0060	0.0000
SVA/ NC	Lower CI	4,923	0	0.0000	0.0000	0.0000
	Mean	10,255	0	0.0000	0.0000	0.0000
	Upper CI	16,630	0	0.0000	0.0000	0.0000
ALL	Lower CI	952,824	19,753	0.0207	0.0215	0.0000
	Mean	1,129,745	19,753	0.0175	0.0181	0.0000
	Upper CI	1,339,352	19,753	0.0147	0.0152	0.0000

Table 32b. Fishing mortality rates (F) on surfclams by region, based on the bootstrap estimates and 95% CIs of total biomass from the 1997 survey, and the landings from 1996 (the last complete year of data). These estimates are based on the assumption that indirect mortality from clam harvesting = 0, that all landings are reported, and that M =0.05. In this table, the efficiency is set at the maximum likelihood for the *Delaware II* experiment = 0.5879, and at lower and upper confidence interval values of 0.2819 and 0.8971, respectively.

	high	mean	low
Efficiency Estimate =	0.8971	0.5879	0.2819

Region	Stock estimate	Stock biomass from 1997 (mt)	1996 Catch (mt)	Exploitation rate U	Estimate of F	[U-(FA/Z)]=0 objective function
GBK	Lower CI	191,949	0	0.0000	0.0000	0.0000
	Mean	292,902	0	0.0000	0.0000	0.0000
	Upper CI	610,844	0	0.0000	0.0000	0.0000
SNE	Lower CI	51,391	82	0.0016	0.0016	0.0000
	Mean	78,420	82	0.0010	0.0011	0.0000
	Upper CI	163,544	82	0.0005	0.0005	0.0000
LI	Lower CI	11,999	26	0.0022	0.0022	0.0000
	Mean	18,309	26	0.0014	0.0015	0.0000
	Upper CI	38,184	26	0.0007	0.0007	0.0000
NNJ	Lower CI	267,431	16,077	0.0601	0.0636	0.0000
	Mean	408,083	16,077	0.0394	0.0412	0.0000
	Upper CI	851,054	16,077	0.0189	0.0196	0.0000
SNJ	Lower CI	23,612	1,331	0.0564	0.0595	0.0000
	Mean	36,030	1,331	0.0396	0.0386	0.0000
	Upper CI	75,140	1,331	0.0189	0.0183	0.0000
DMV	Lower CI	186,339	2,237	0.0120	0.0124	0.0000
	Mean	284,343	2,237	0.0079	0.0081	0.0000
	Upper CI	592,994	2,237	0.0038	0.0039	0.0000
SVA/ NC	Lower CI	6,721	0	0.0000	0.0000	0.0000
	Mean	10,255	0	0.0000	0.0000	0.0000
	Upper CI	21,387	0	0.0000	0.0000	0.0000
ALL	Lower CI	740,360	19,753	0.0267	0.0277	0.0000
	Mean	1,129,745	19,753	0.0175	0.0181	0.0000
	Upper CI	2,356,073	19,753	0.0084	0.0086	0.0000

Table B33. Biological reference points for surfclams of Northern New Jersey, corresponding to three assumed levels of natural mortality (M). F_{p0} = fishing mortality rate that would occur if the annual production of the region were landed (and assuming no indirect fishing mortality). NC indicates cannot be computed because annual production is negative when M = 0.10 and 0.15.

	M		
Reference point	0.05	0.10	0.15
$F_{20\%}$	0.18	0.45	1.13
$F_{0.1}$	0.07	0.14	0.20
F_{max}	0.21	0.43	0.85
F_{p0}	0.05	NC	NC

Table B34. Length and weight in surfclams. Parameter estimates for the relationship between drained meat weight (gr) and shell length (mm) for surfclams collected in June-July, 1997. Overall estimates are given by region for Northern New Jersey and Delmarva. Parameter estimates are also given by density class for the Delmarva region.

Region /Year sample collected	Partitioned by density	Density class	α	β	n
GBK 1997	No	-	-8.5583	2.7307	116
NNJ 1997	No	-	-9.4116	2.8997	149
DMV 1997	No	-	-9.9206	2.9619	702
DMV 1997	Yes	A.(Lowest)	-9.0939	2.8166	27
DMV 1997	Yes	B.	-10.4758	3.0860	23
DMV 1997	Yes	C.	-10.3642	3.0605	108
DMV 1997	Yes	D.	-9.7983	2.9341	358
DMV 1997	Yes	E. (Highest)	-9.8170	2.9375	186

Table B35. Relationship between density classes, number of surfclams per tow,and number of clams captured per square meter. Numbers are not adjusted for dredge efficiency. Catches were standardized to a tow length of 278 meters (0.15 nmi.). This distance corresponds to an area towed of 423 m^2.

Density class	No./tow (standardized)	No./m^2
A	0-	0-
B	10-	0.0236-
C	25-	0.0590-
D	50-	0.1181-
E	200+	0.4724-

Table B36. Age and length in surfclams from the Delmarva region (strata 9 and 13) in 1997 as a function of clam density. Parameter estimates, asymptotic standard errors (ASE) and sample sizes (n) for the von Bertalanffy growth model, fit to five density classes of surfclams. Estimates are from samples collected in June-July, 1997. Shell length in mm. Class "A" not fit due to low sample size. Catch per tow was standardized to 0.15 nmi, assuming a 4-in blade depth.

Density class (no./tow)	L_∞ (ASE)	k (ASE)	t_0	n
A (<10)	-	-	-	14
B (10-24.9)	138.62 (5.65)	0.2833 (.0298)	0	61
C (25-49.9)	137.69 (3.91)	0.2715 (.0201)	0	109
D (50-199.9)	138.40 (2.16)	0.2469 (.0106)	0	334
E (≥200)	143.39 (2.46)	0.2372 (.0113)	0	108

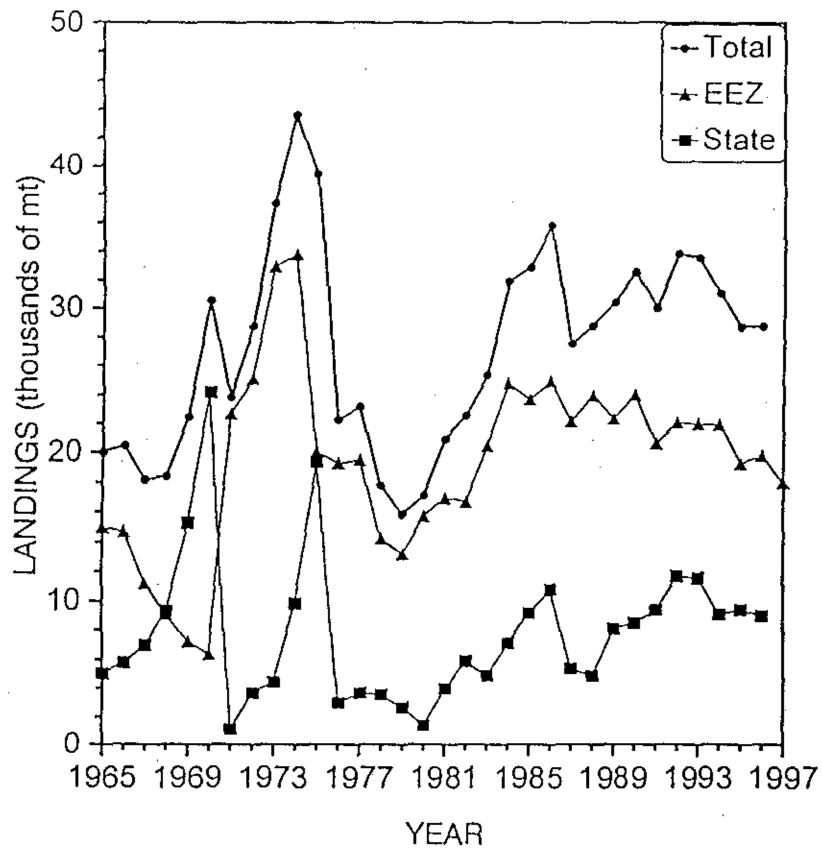


Figure B1. Landings of surfclams (thousands of mt of meats), 1965-1997. Data are for all areas (total). Exclusive Economic Zone (EEZ: 3-200 miles from the coast) and state (inshore) waters. EEZ landings for 1997 were estimated from logbook data available on September 13, 1997.

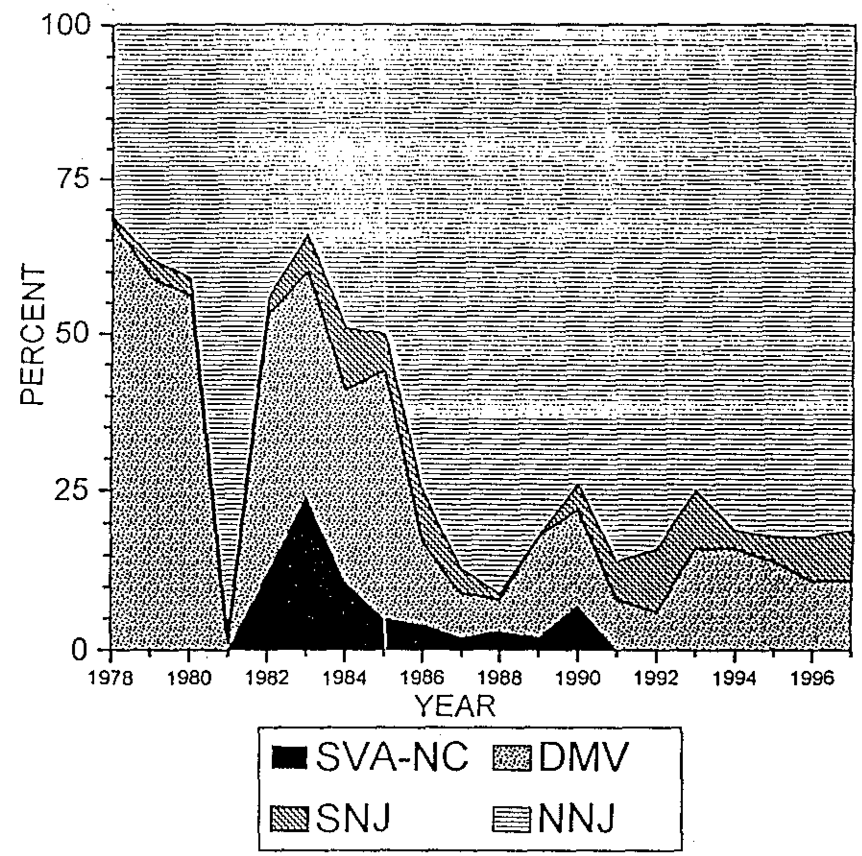


Figure B2. Proportion of surfclam landings in the Mid-Atlantic region by area and year, 1978-1997. Landings for 1997 were estimated from logbook data available on September 13, 1997.

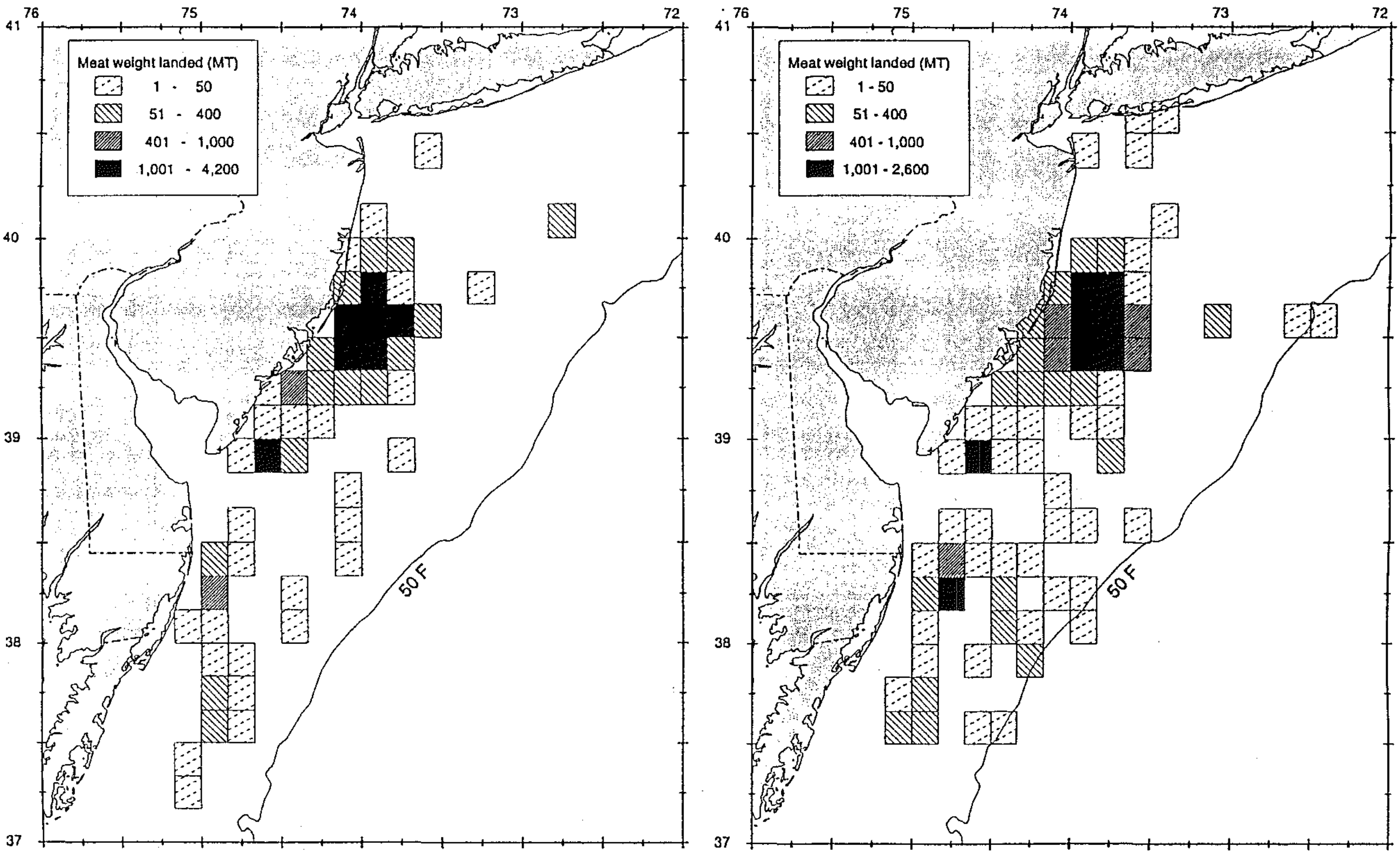


Figure B3. Distribution of surfclam landings by 10-min. squares during 1992 (left) and 1993 (right).

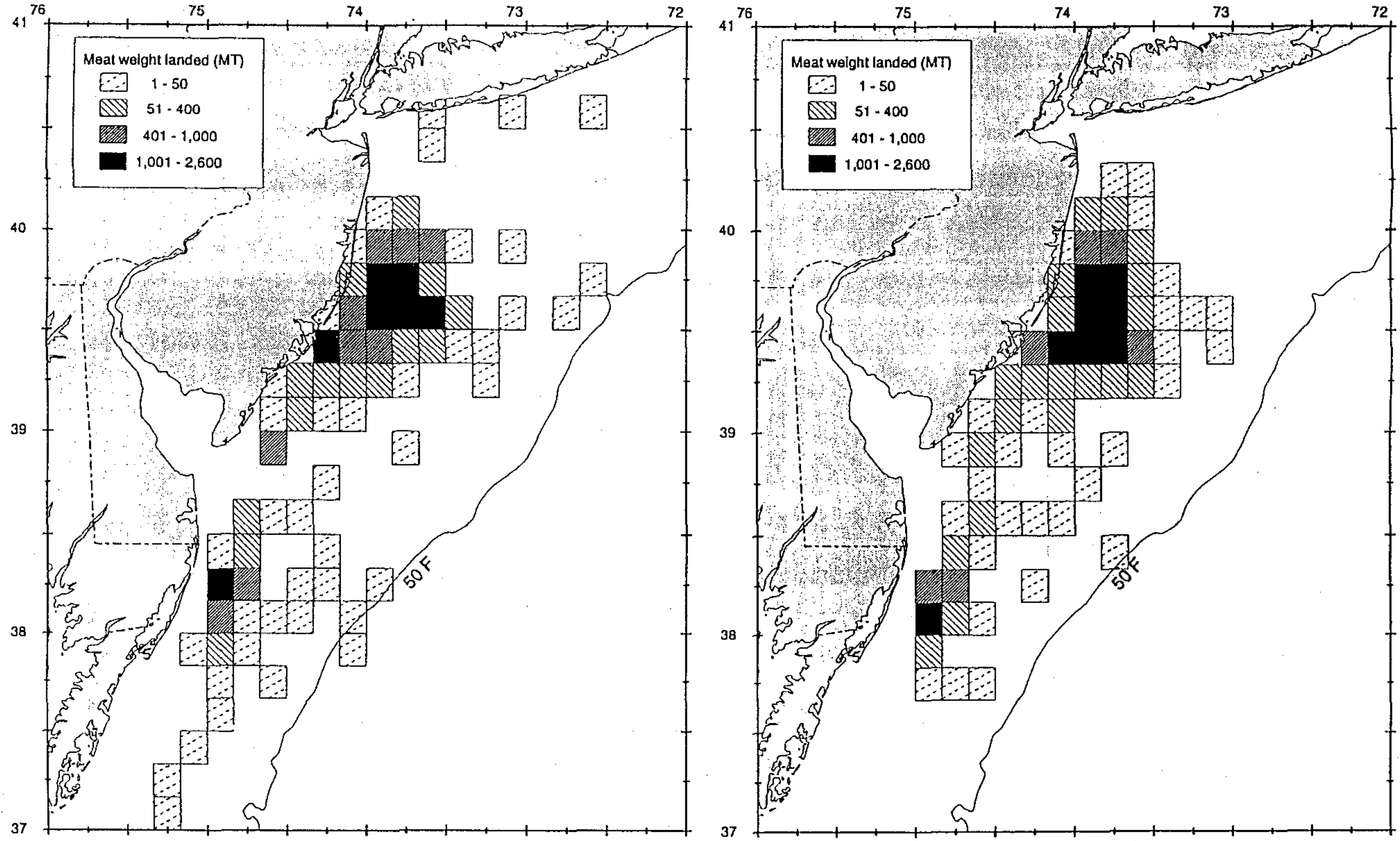


Figure B4. Distribution of surfclam landings by 10-min. squares during 1994 (left) and 1995 (right).

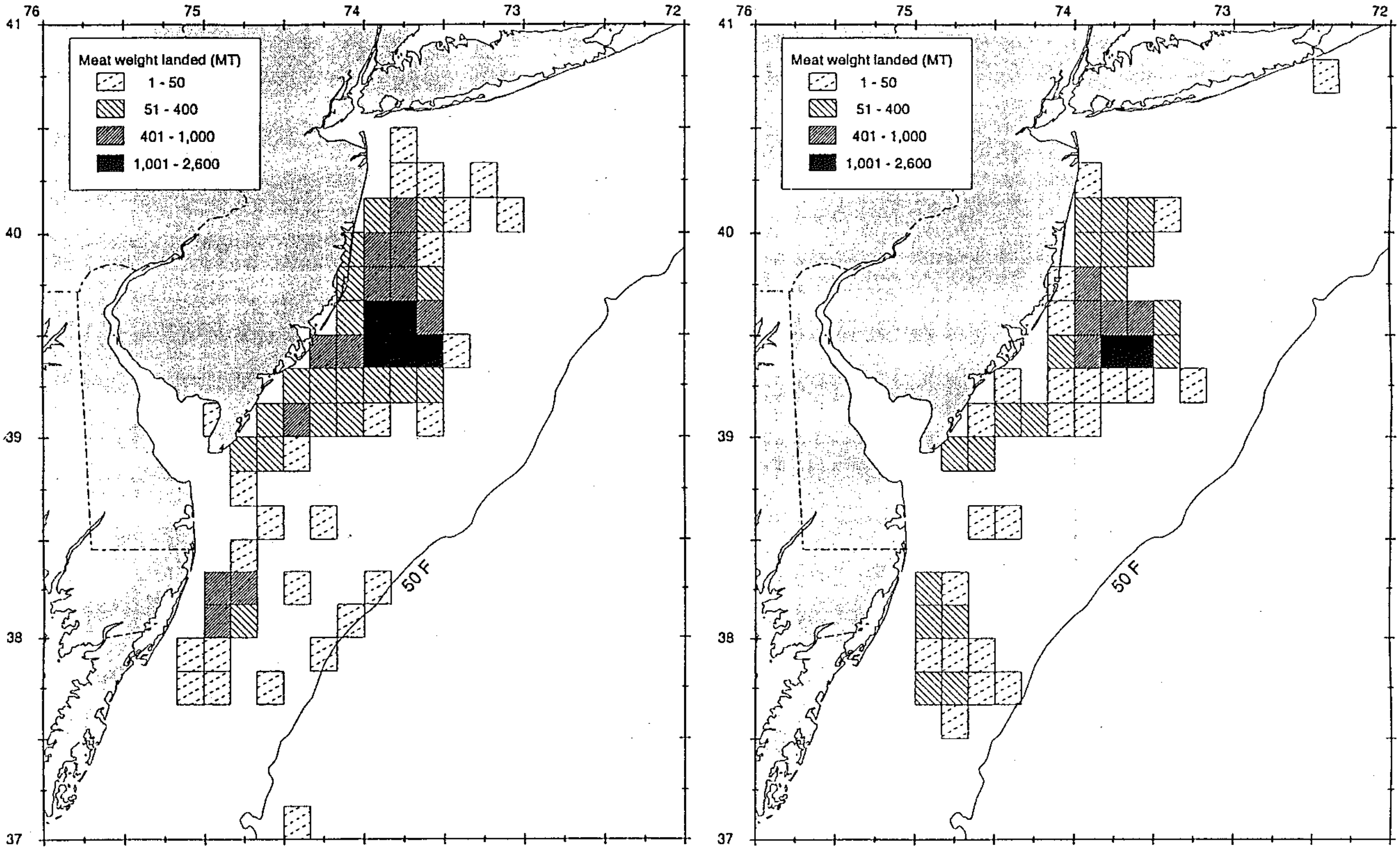


Figure B5. Distribution of surfclam landings by 10-min. squares during 1996 (left) and 1997 (right).

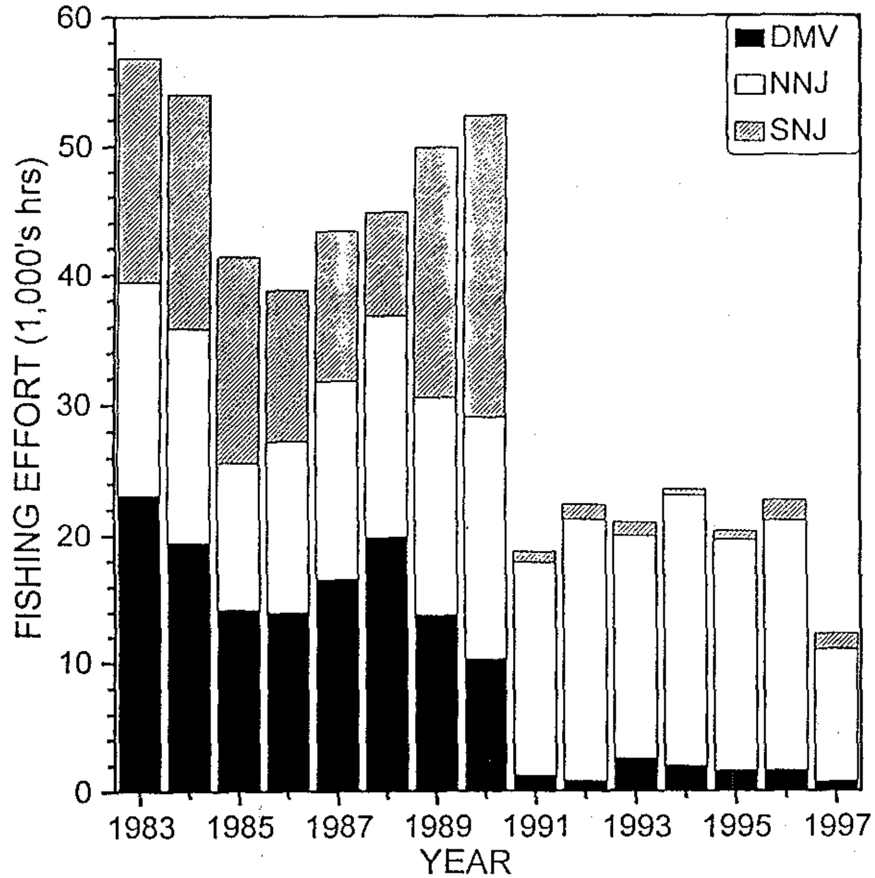


Figure B6. Total reported hours fishing during surfclam trips by region year. 1997 data no not represent a full year.

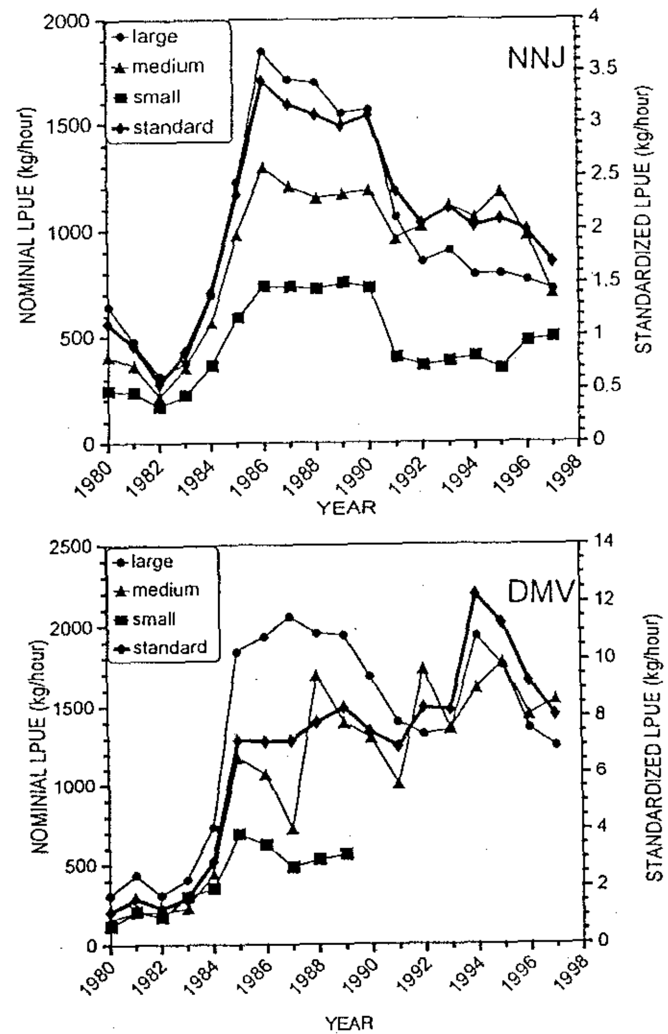


Figure B7. Nominal surfclam LPUE by year for two regions (Delmarva and Northern New Jersey) and three vessel classes (small, medium, and large). Also shown is standardized LPUE from GLM analyses.

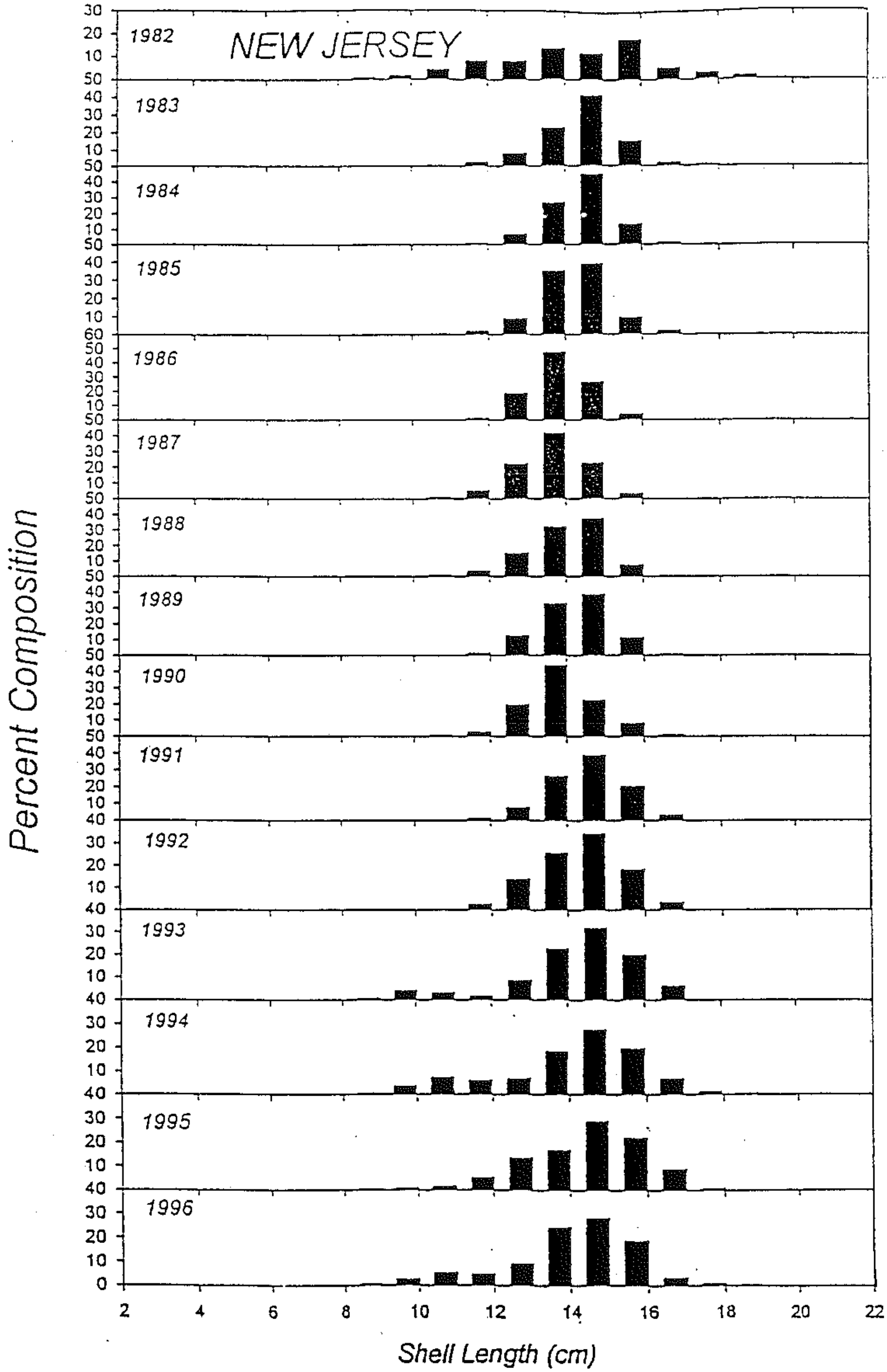


Figure B8. Length frequency of surfclam landings from New Jersey region, 1982-1996, expressed as percent composition of shell length (cm).

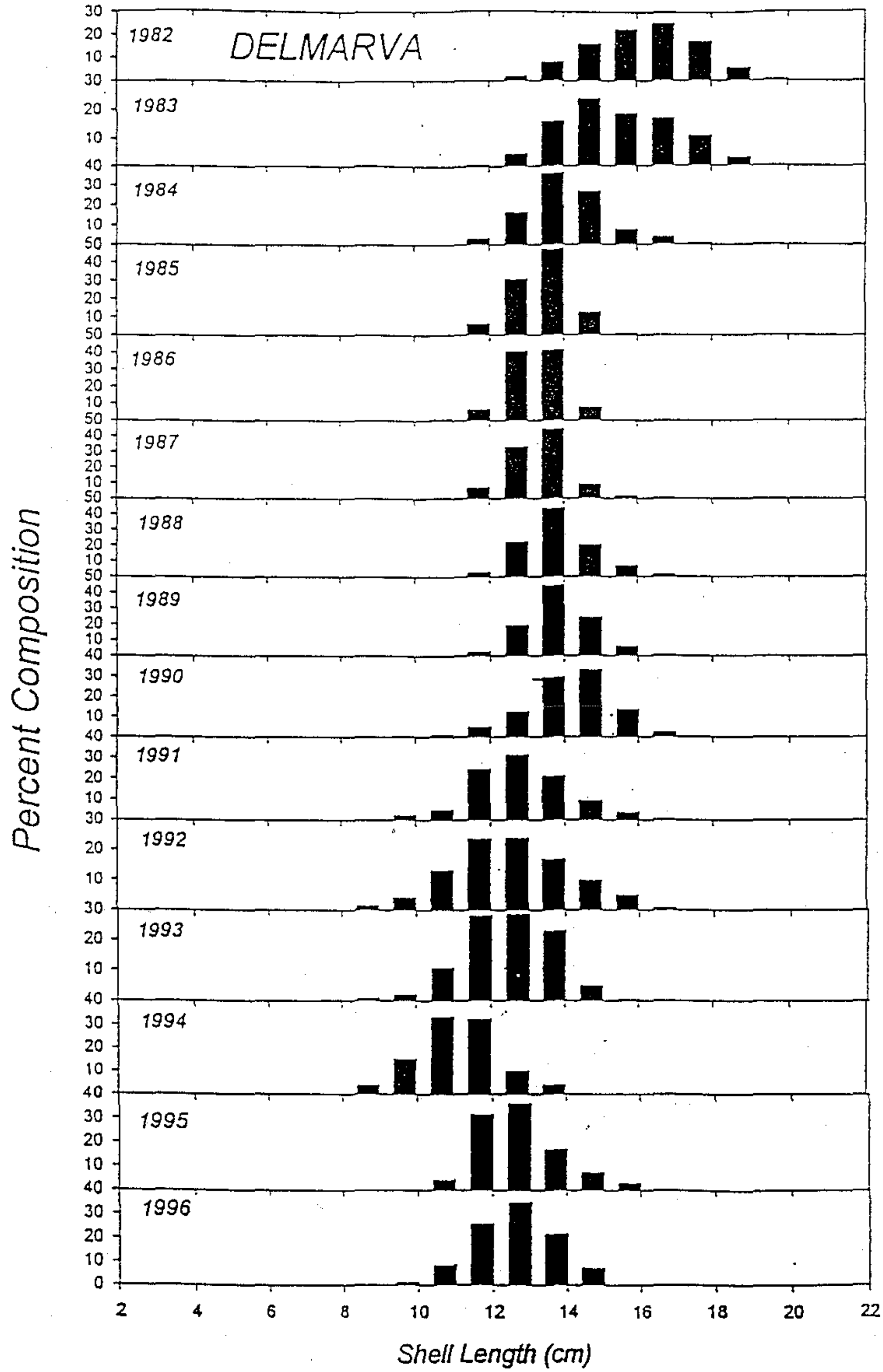


Figure B9. Length frequency of surfclam landings from Delmarva region, 1982-1996, expressed as percent composition of shell length (cm).

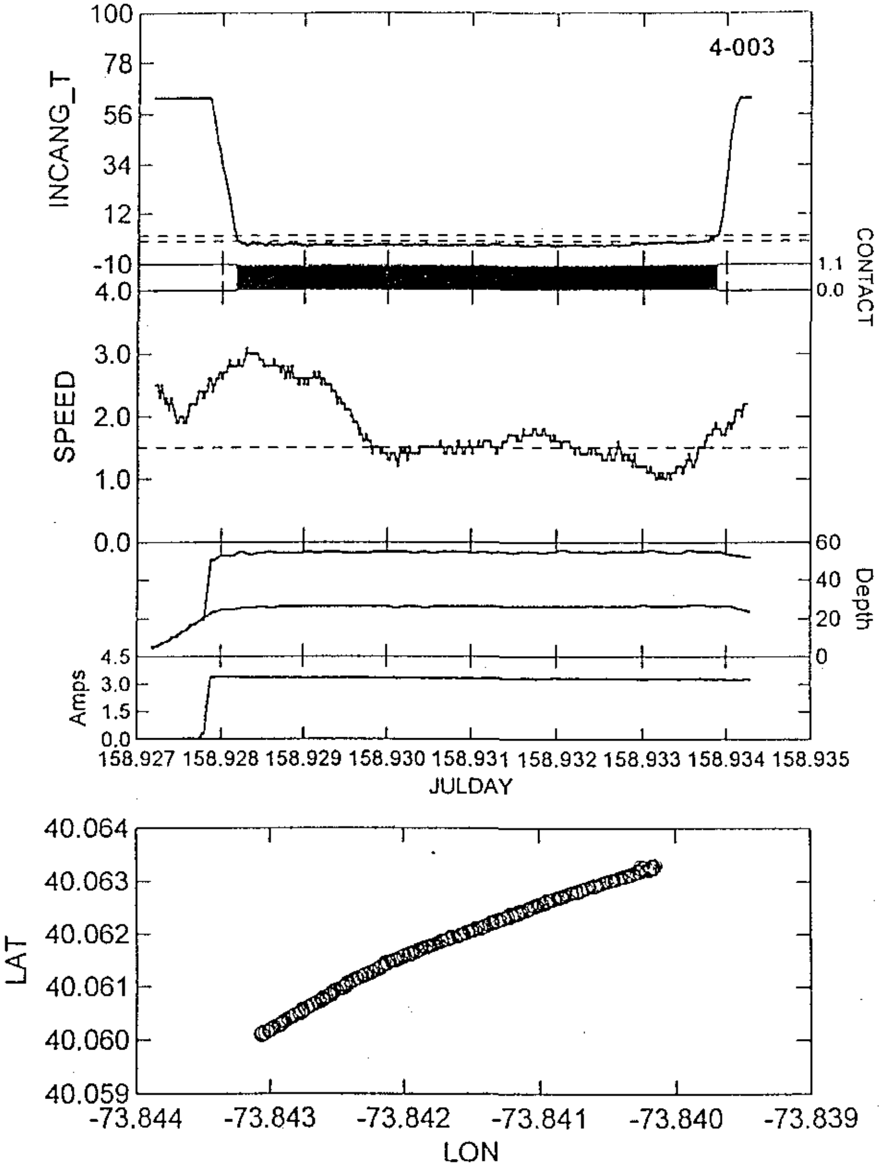


Figure B10. Example of sensor data collected at every station for 1997. This was a station off New Jersey.

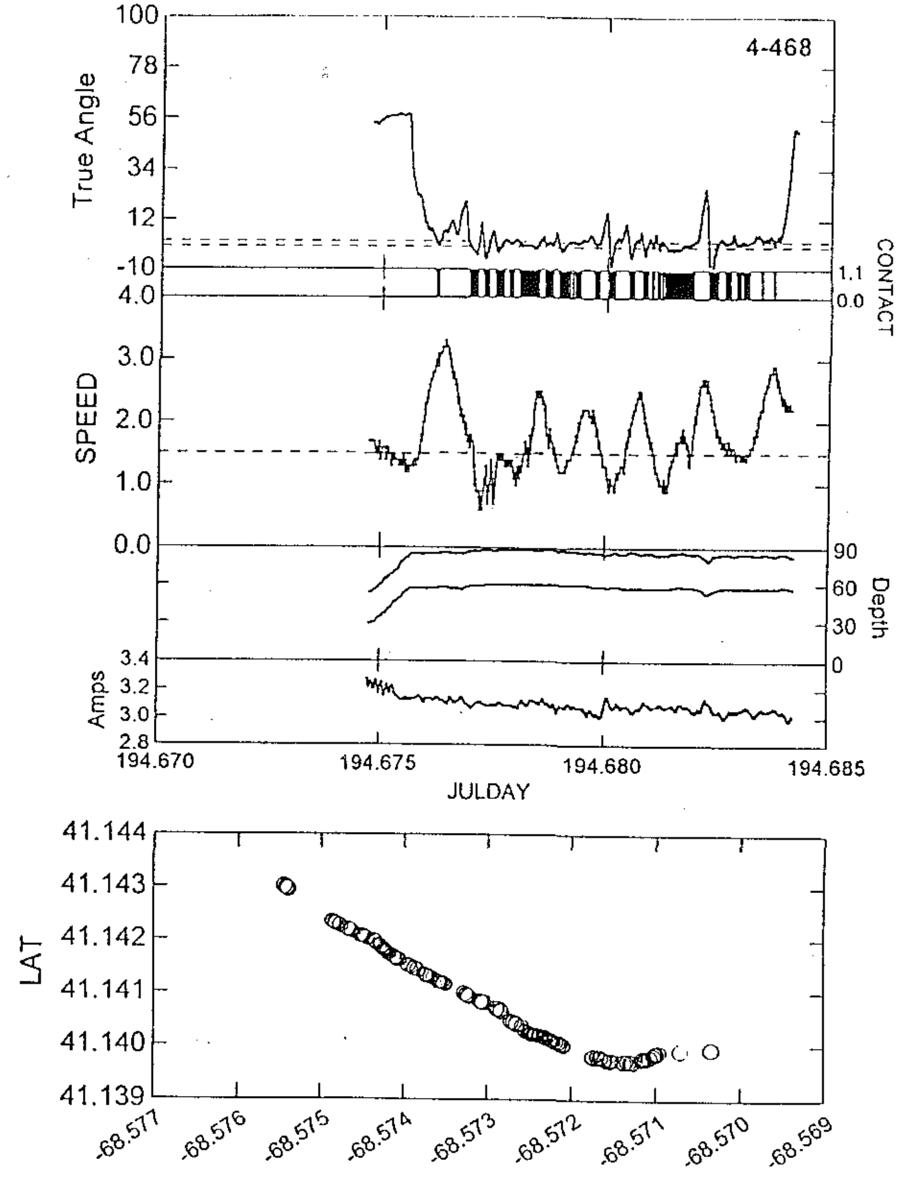


Figure B11. Example of sensor data collected at every station for 1997. This was a station on Georges Bank.

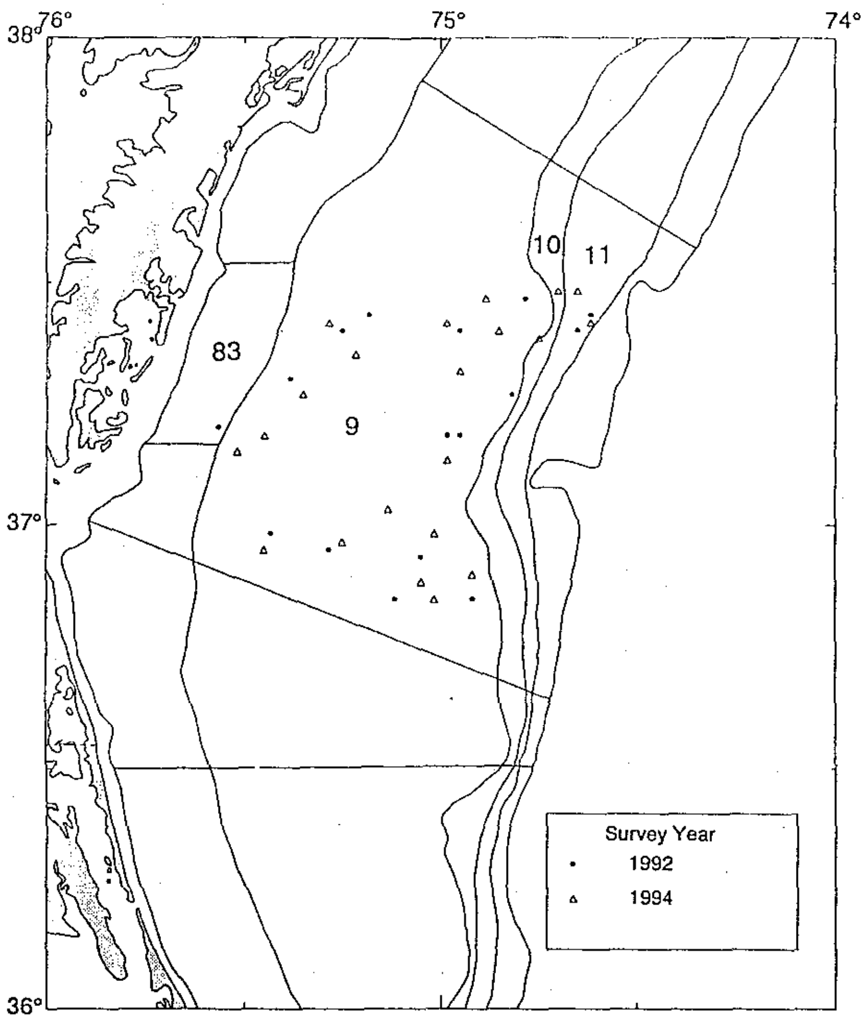


Figure B12. Clam survey stations from 1992 and 1994 that were re-sampled off Delmarva during the 1997 *Delaware II* clam survey. Stratum number is given.

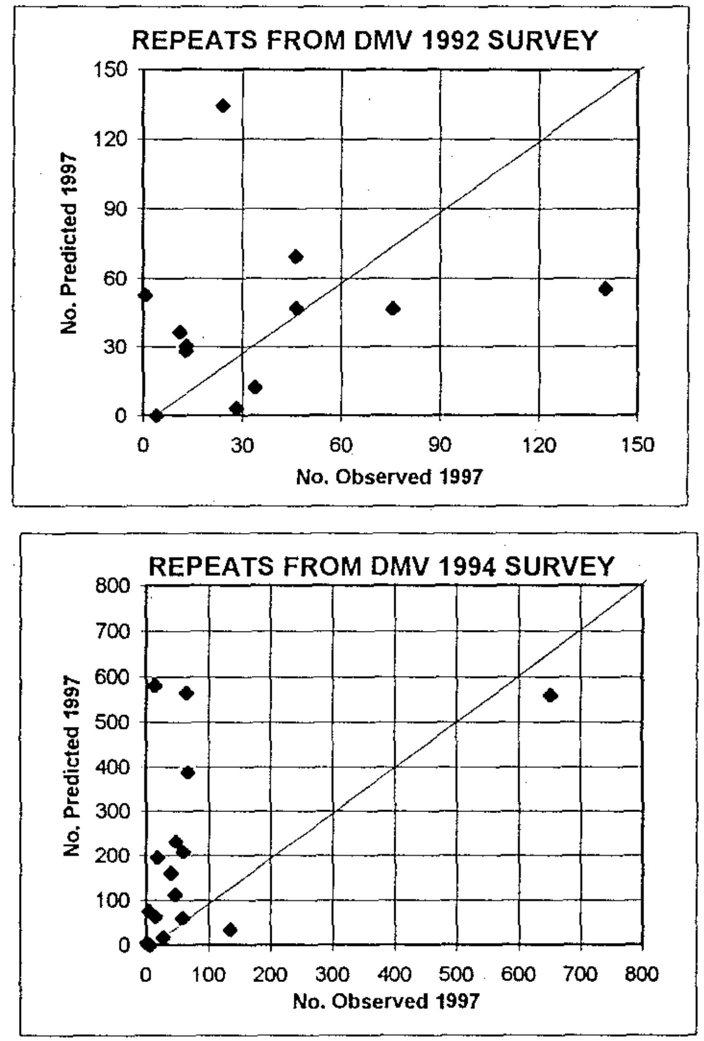


Figure B13. Results from re-sampling of surfclam stations in 1997 that were previously occupied in 1992 or 1994. Predicted catch is based on a mortality rate of 0.05. Numbers were adjusted to a tow distance of 0.15 nmi.

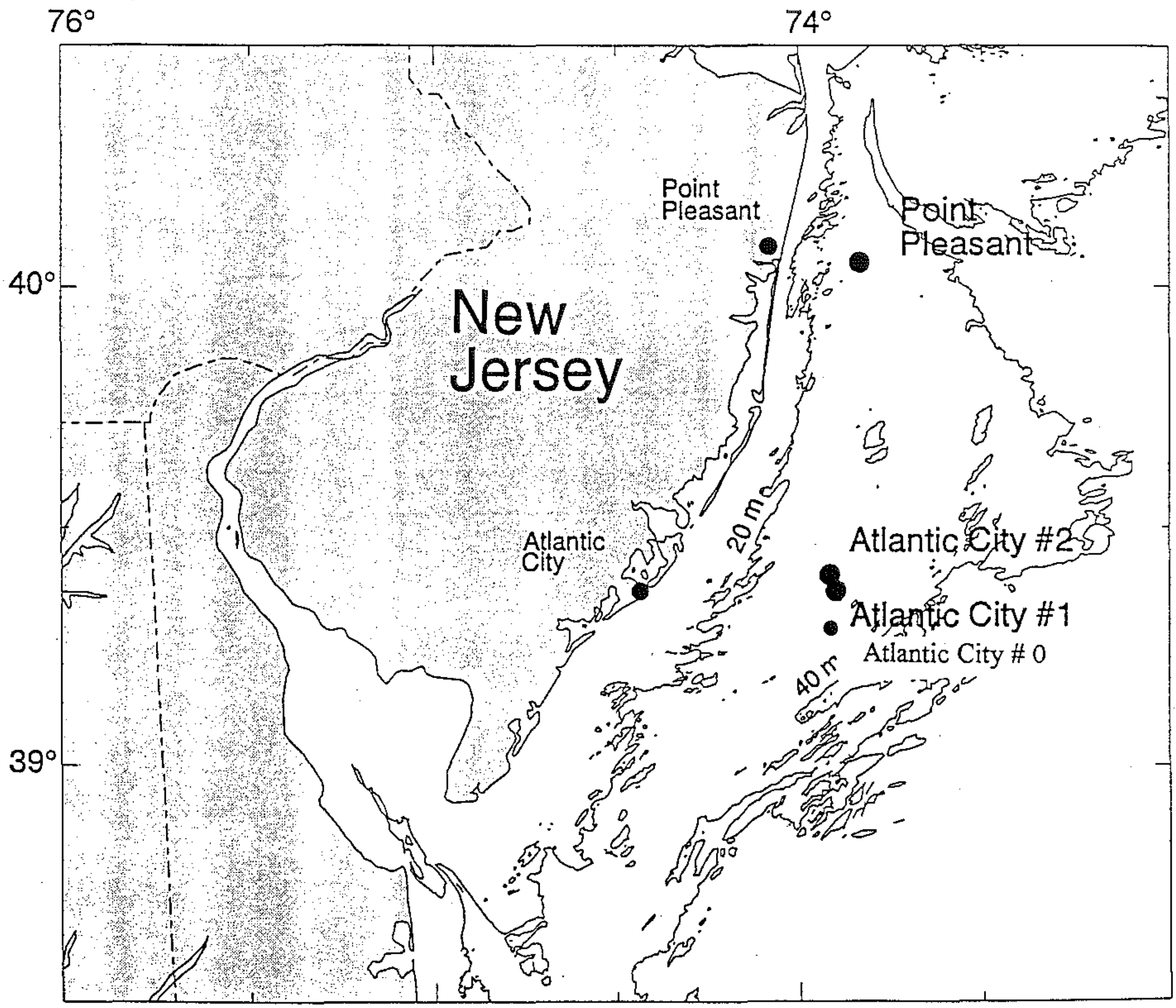


Figure B14. Locations of surfclam depletion studies conducted during June 1997.

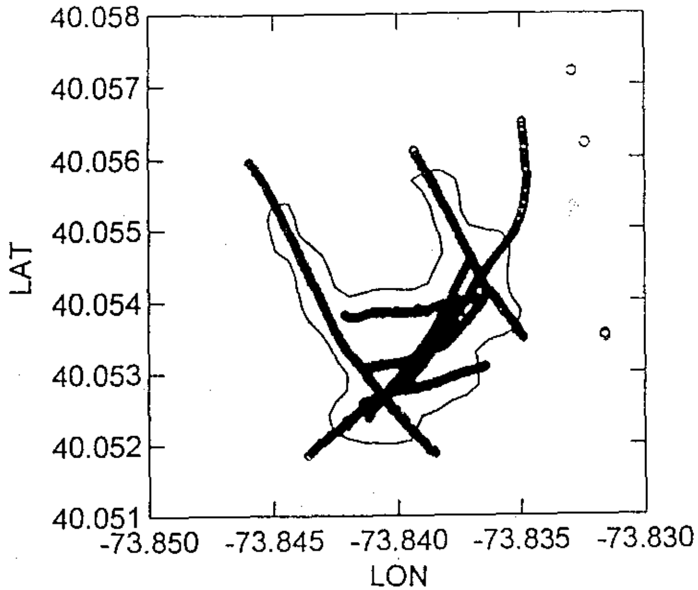


Figure B15. Point Pleasant set-up tows.

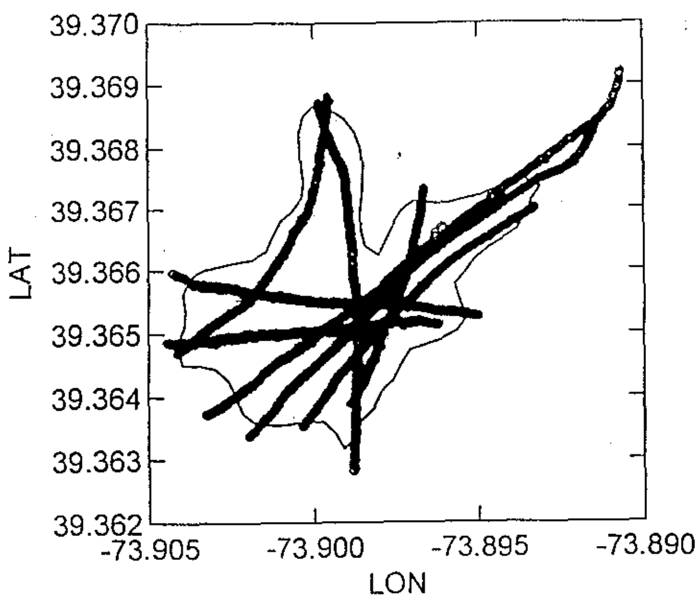


Figure B16. Atlantic City 1 set-up tows.

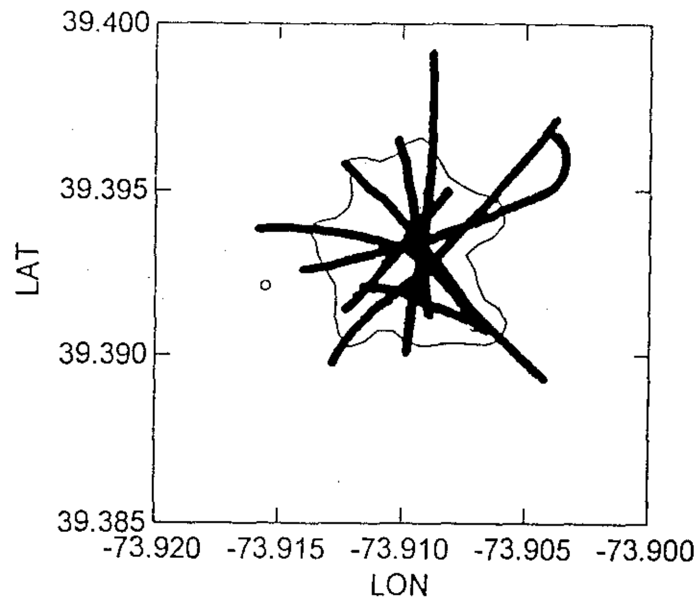


Figure B17. Atlantic City 2 set-up tows.

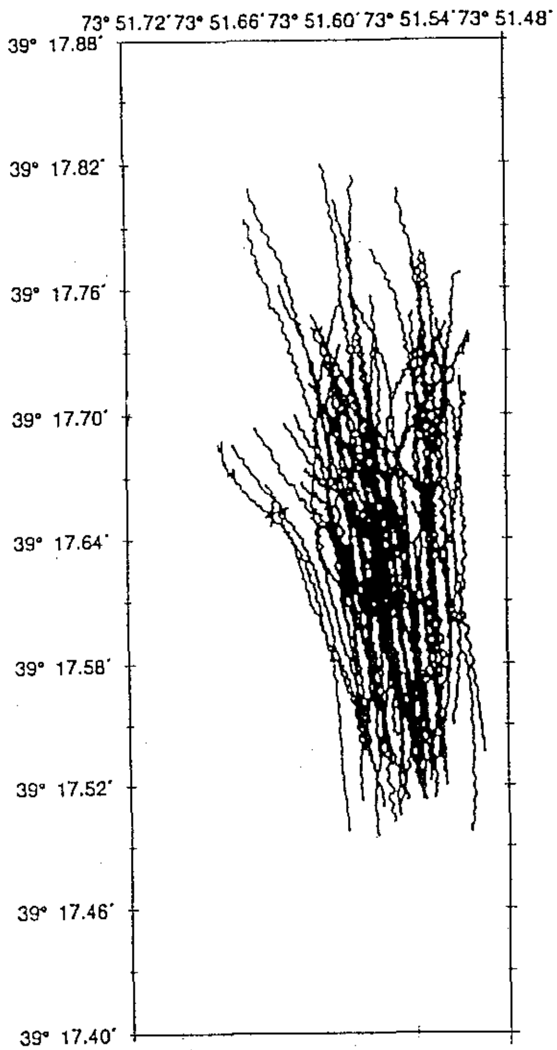


Figure B18. Depletion study AC0, conducted with the *Delaware II*, off the coast of Atlantic City, NJ. Excluded tows are 118, 120, 122, and 153.

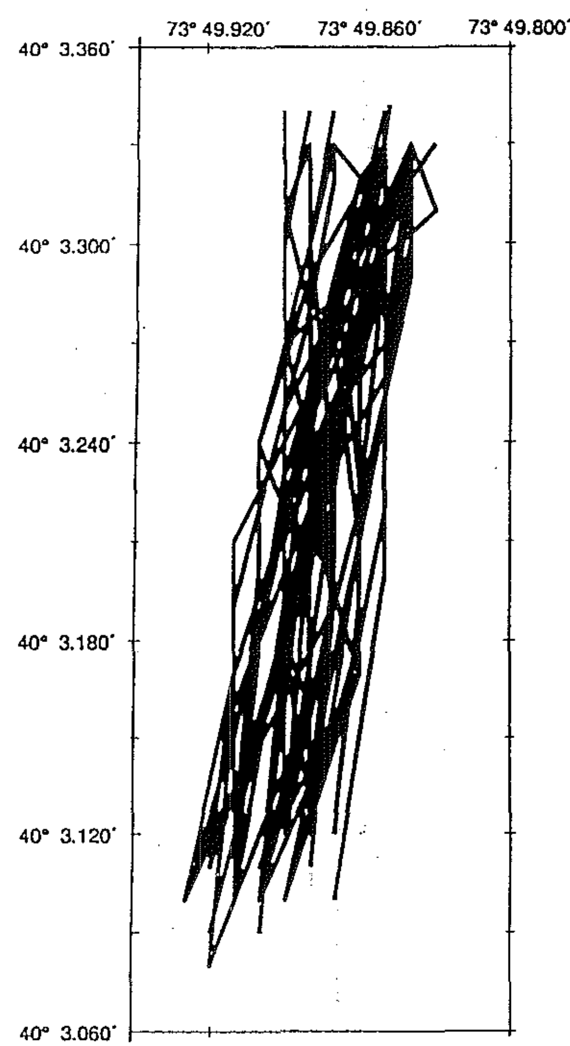


Figure B19. Depletion study PP_1 off the coast of Point Pleasant, NJ. No tows were omitted.

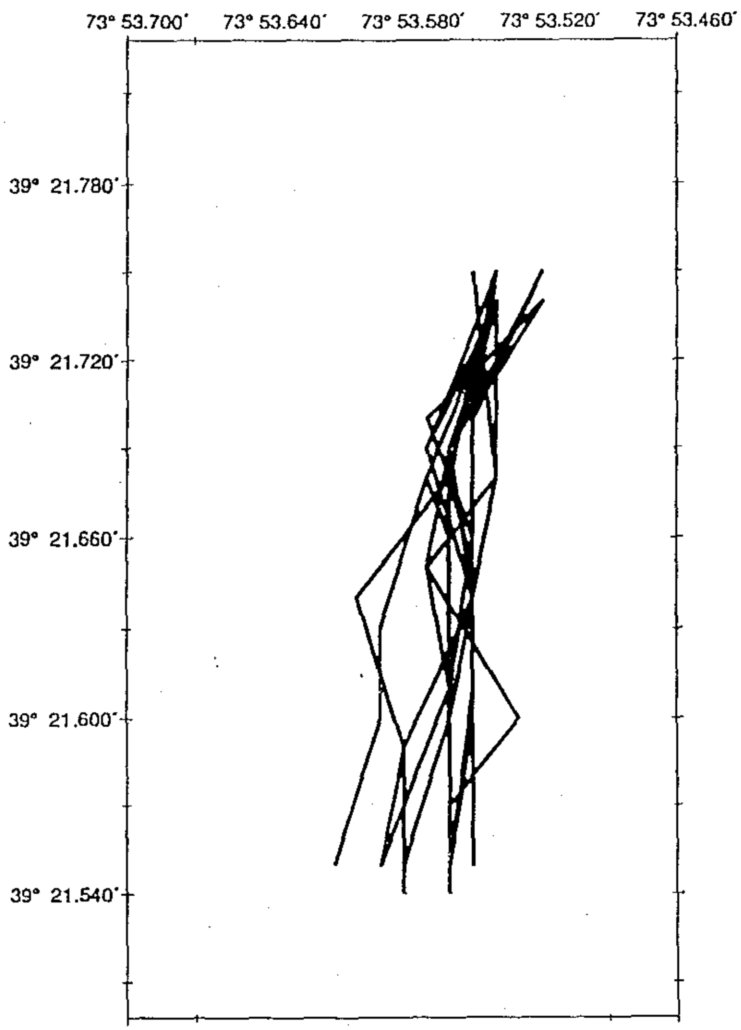


Figure B20. Depletion study AC1_1 off the coast of Atlantic City, NJ. Excluded tow 10.

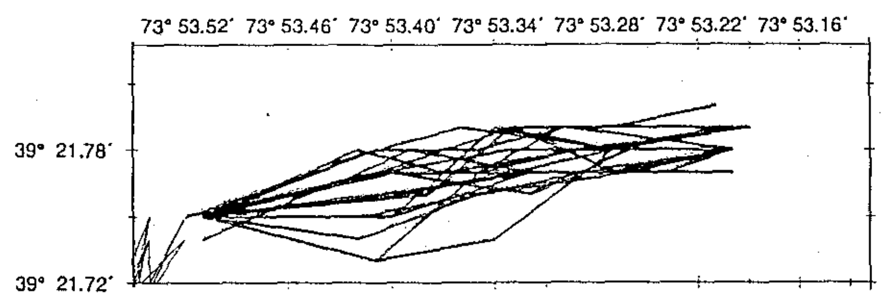


Figure B21. Depletion study AC1_2 off the coast of Atlantic City, NJ.

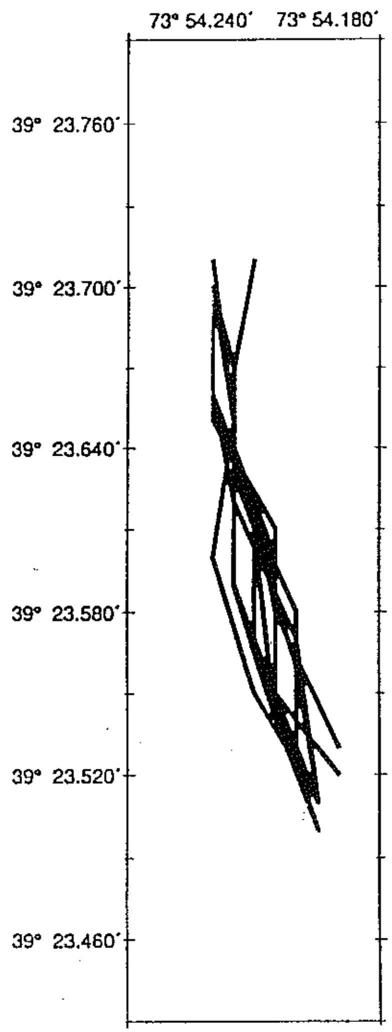


Figure B22. Depletion study AC2_1 off the coast of Atlantic City, NJ. No tows excluded.

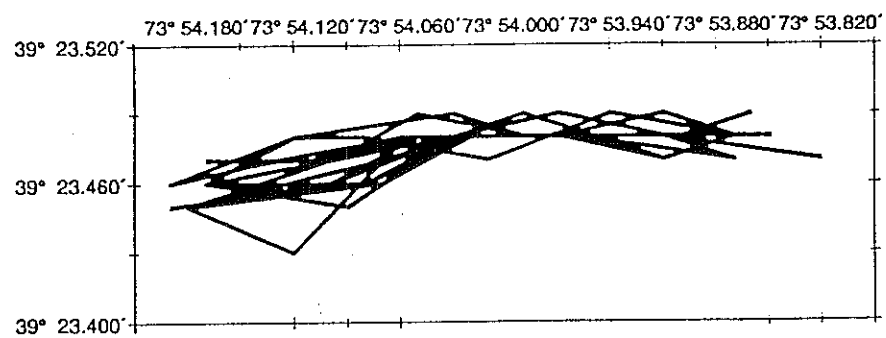


Figure B23. Depletion study AC2_2 off the coast of Atlantic City, NJ. No tows omitted.

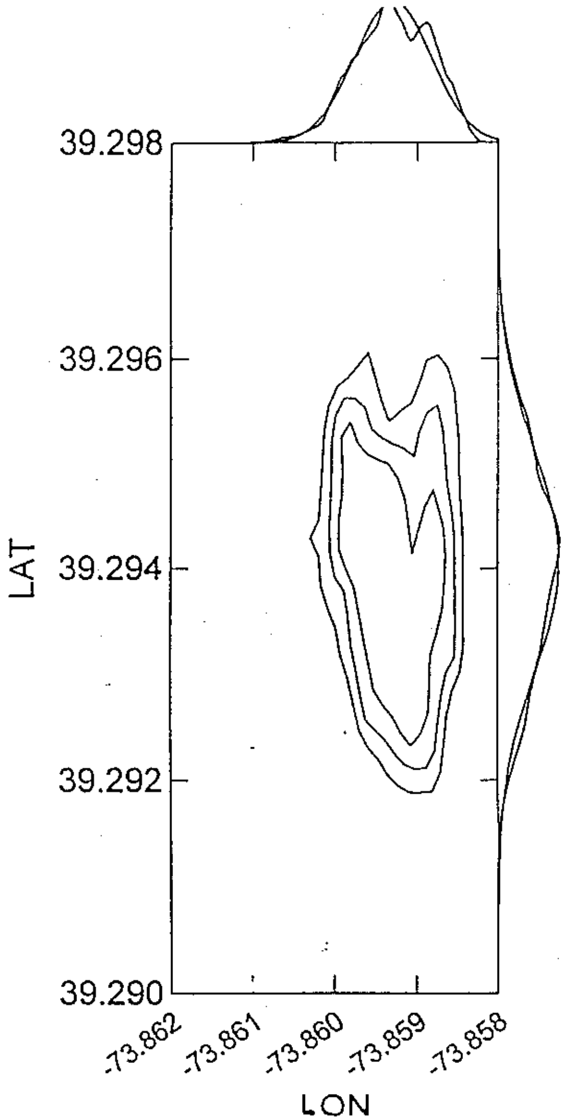


Figure B24. Kernel of tow intensity for depletion site Atlantic City #0.

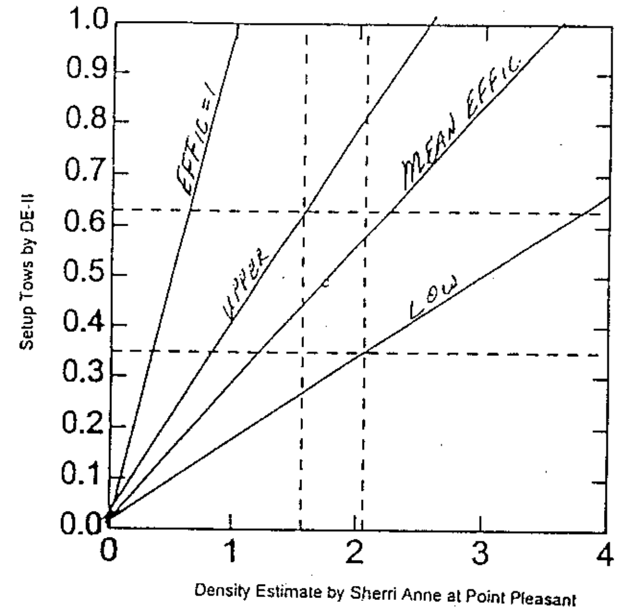


Figure B25. Point Pleasant site: *Delaware II* set-up density vs commercial fishing vessel density.

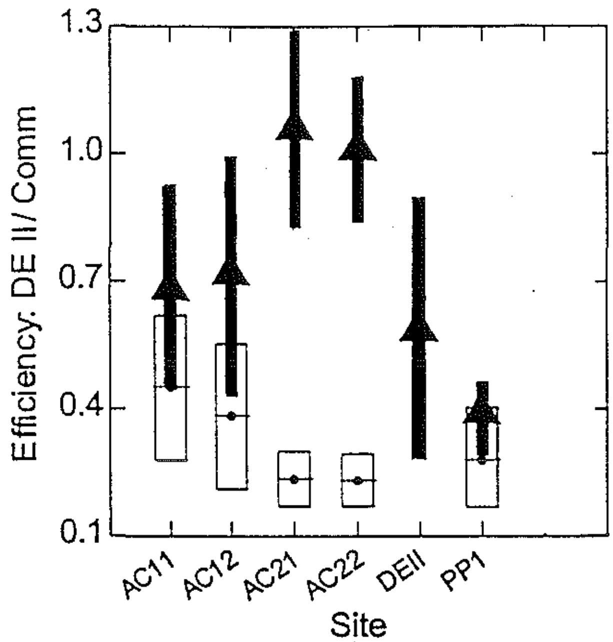


Figure B26. *Delaware II* efficiency (boxes) vs commercial vessel (triangles).

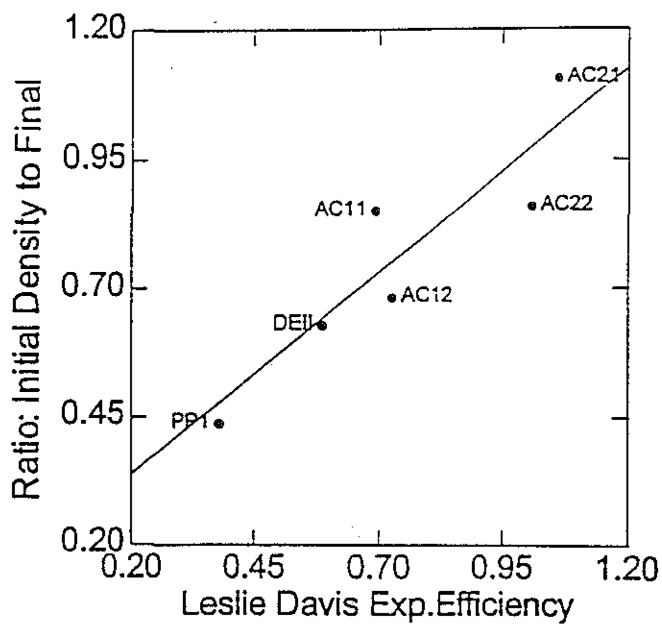


Figure B27. Initial efficiency vs experiment efficiency.

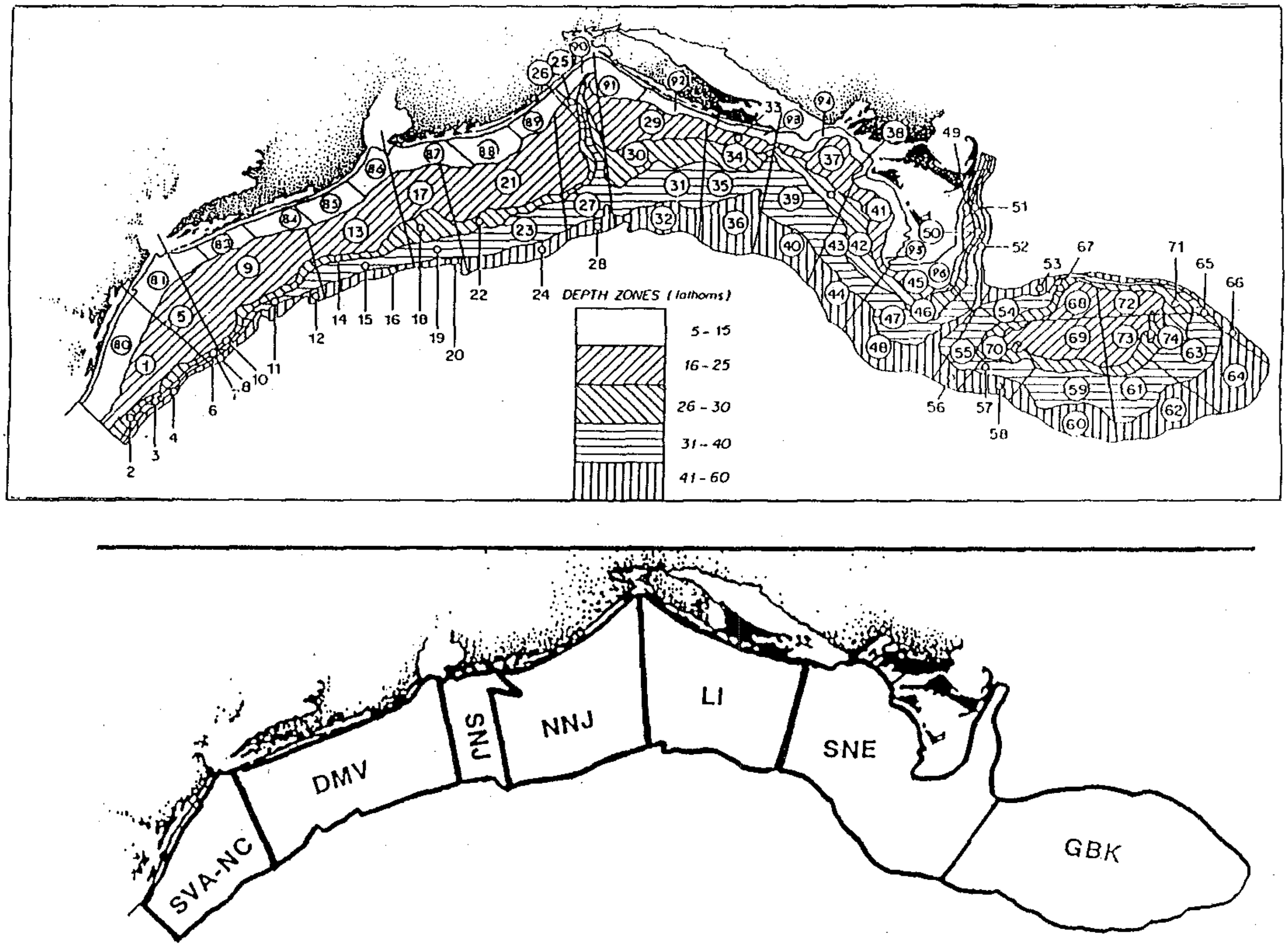


Figure B28. Survey strata (sampling areas), National Marine Fisheries Service, Northeast Fisheries Science Center, Surfclam/Ocean quahog survey.

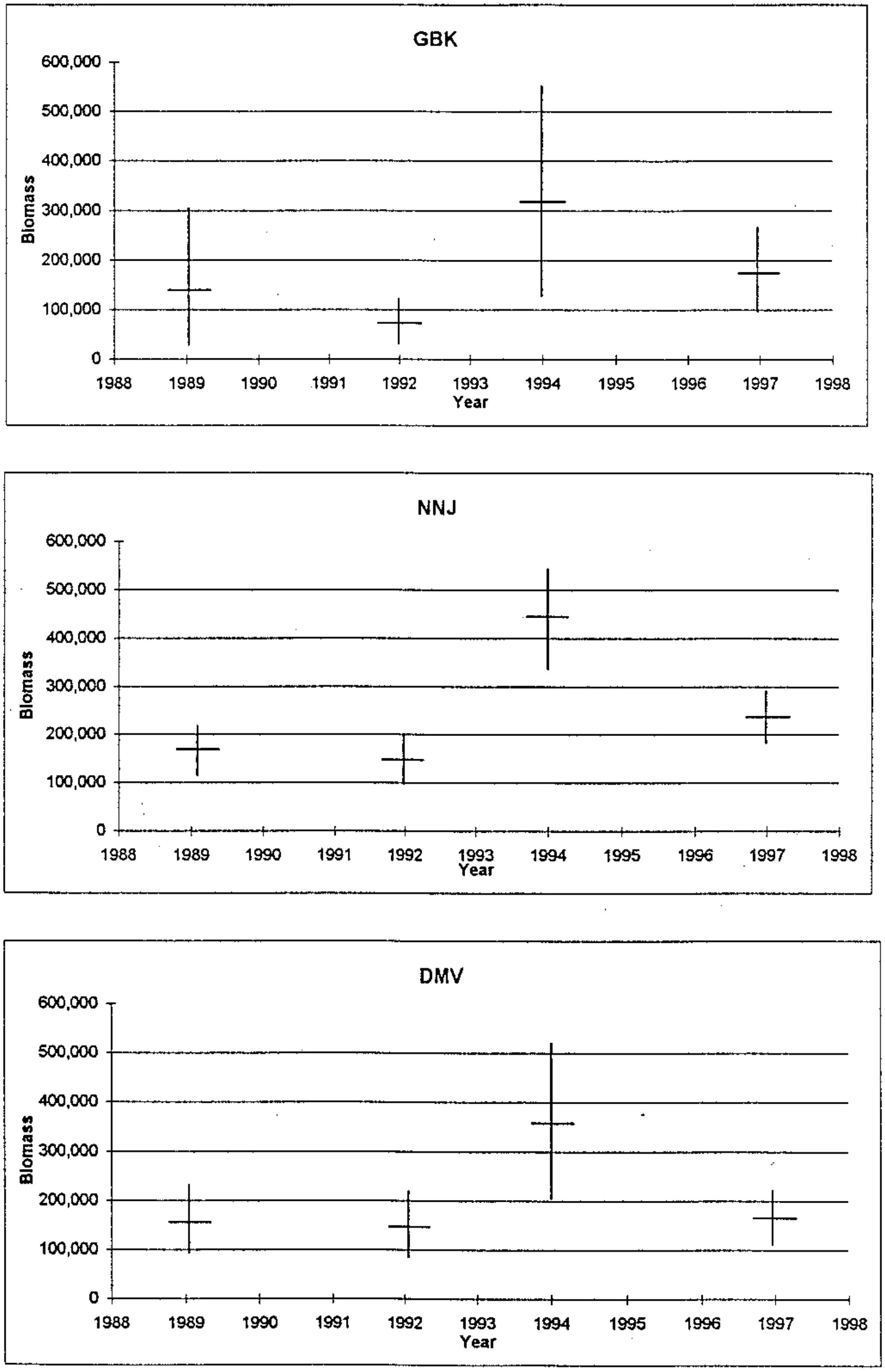


Figure B29. Minimum swept-area biomass estimates (mt) by region from research surveys. Estimates and 95% CIs are from a bootstrap procedure with 5-mm size intervals including all size classes. Biomass is not adjusted for dredge efficiency.

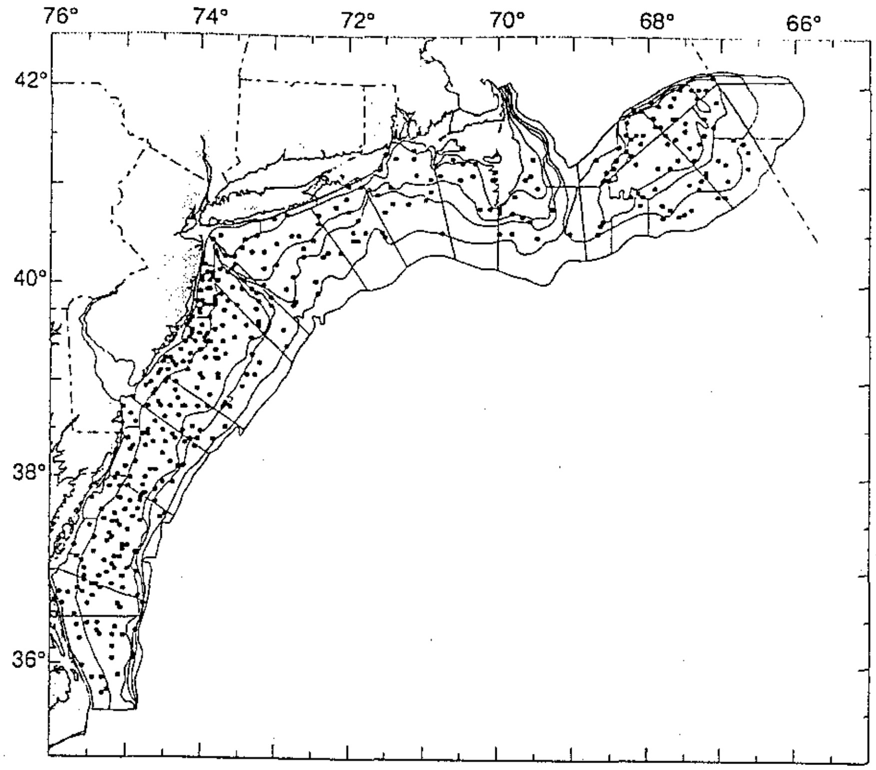


Figure B30. Random survey station of the 1997 *Delaware II* clam survey.

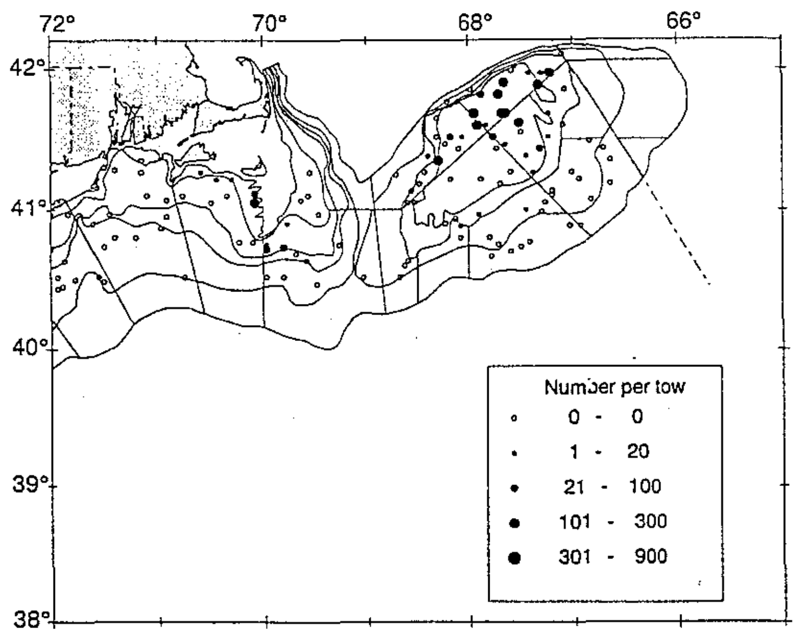


Figure B31. Distribution of 1997 survey surfclam abundance per tow (≥ 120 mm) adjusted to 0.15 nmi tow distance with sensor data. Blade depth = 4 in.

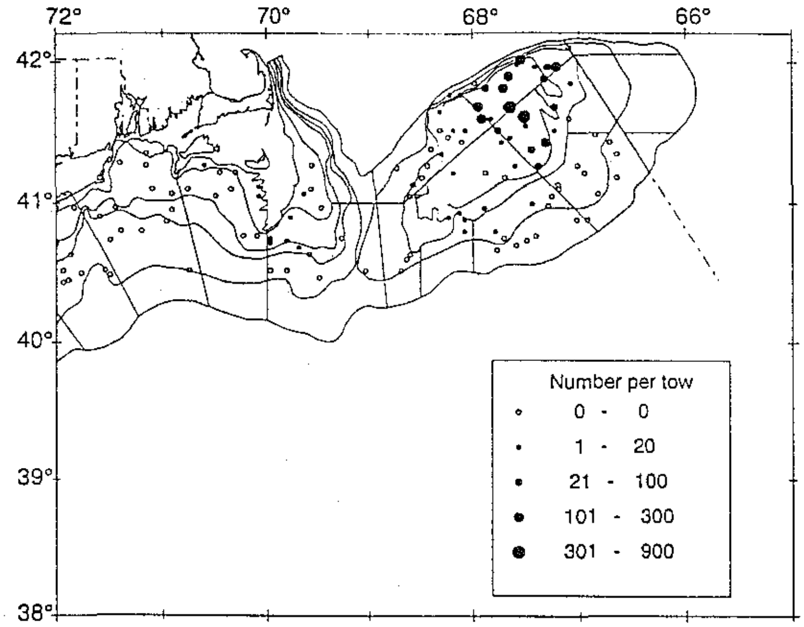


Figure B32. Distribution of 1997 survey surfclam abundance per tow (88-119 mm) adjusted to 0.15 nmi tow distance with sensor data. Blade depth = 4 in.

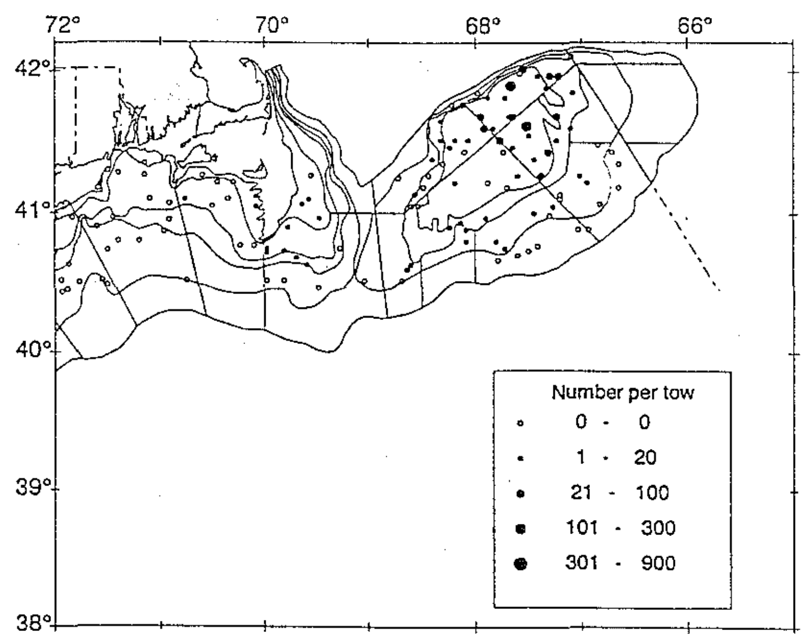


Figure B33. Distribution of 1997 survey surfclam abundance per tow (1-87 mm) adjusted to 0.15 nmi tow distance with sensor data. Blade depth = 4 in.

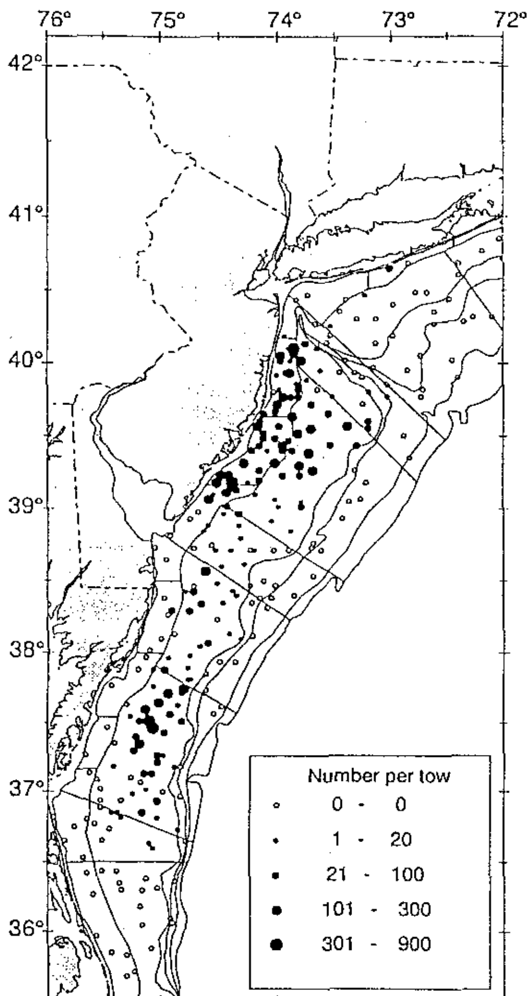


Figure B34. Distribution of 1997 survey surfclam abundance per tow (≥120 mm) adjusted to 0.15 nmi tow distance with sensor data. Blade depth = 4 in.

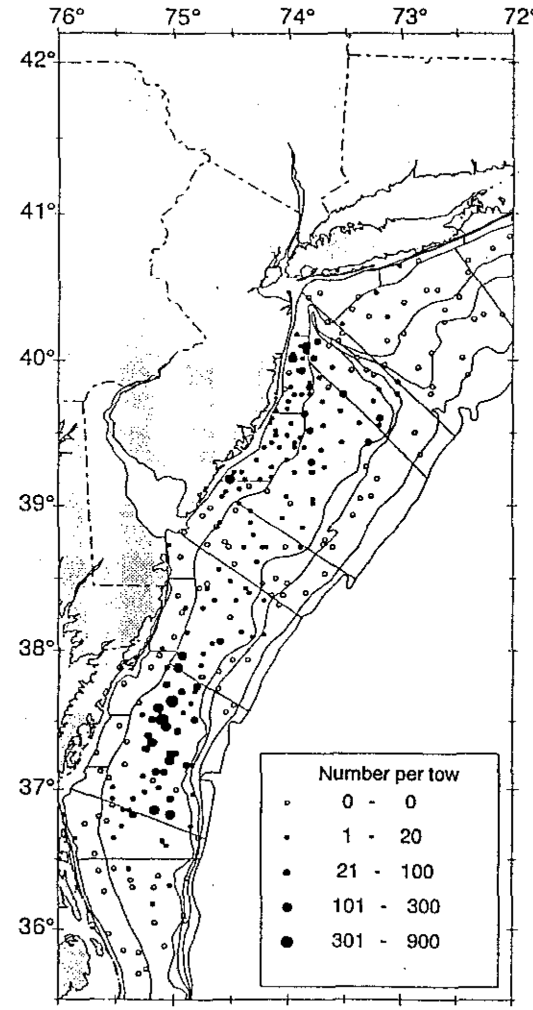


Figure B35. Distribution of 1997 survey surfclam abundance per tow (88-119 mm) adjusted to 0.15 nmi tow distance with sensor data. Blade depth = 4 in.

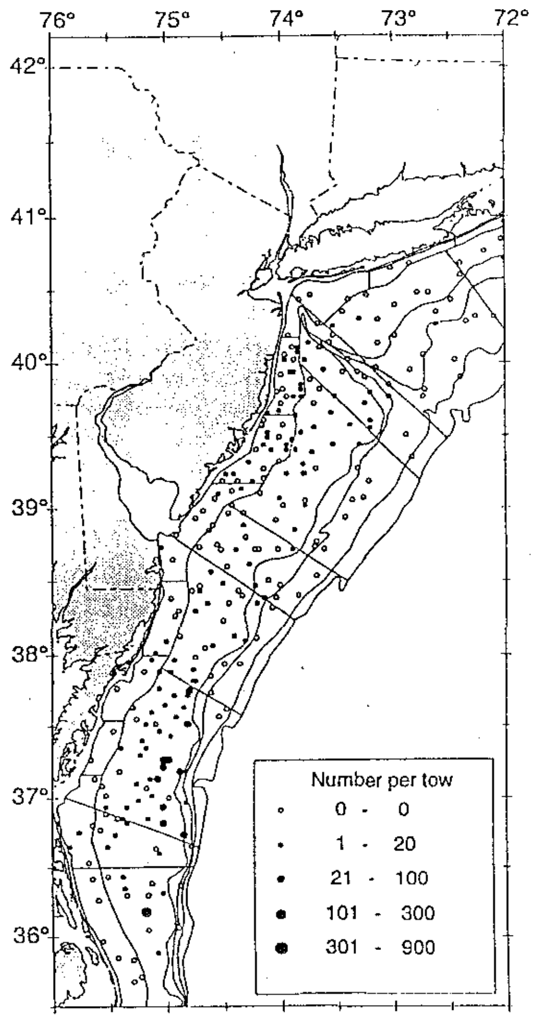


Figure B36. Distribution of 1997 survey surfclam abundance per tow (1-87 mm) adjusted to 0.15 nmi tow distance with sensor data. Blade depth = 4 in.

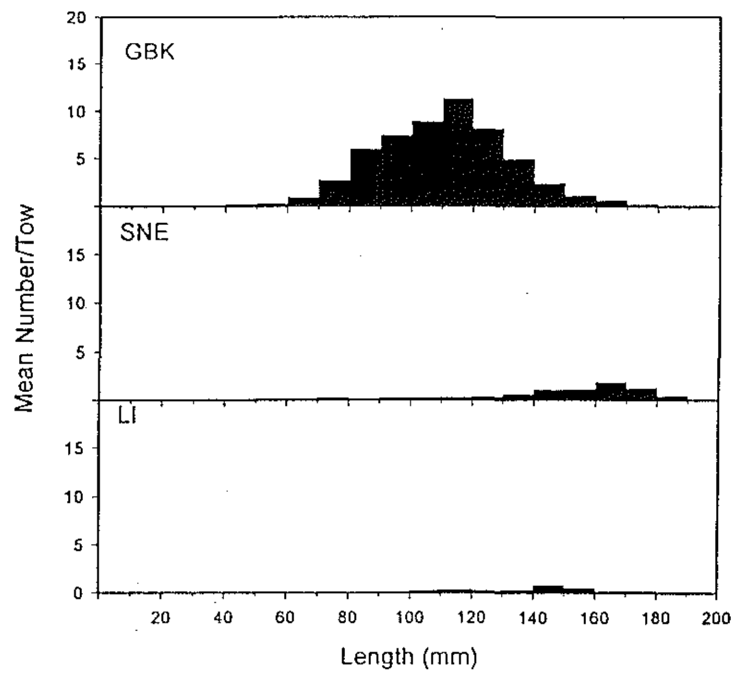


Figure B37. Size frequency distribution of surfclams, by region (northern), based on data from 1997 survey. Number per tow is standardized to a tow distance of 278 m (0.15 nmi) based on sensor data assuming a minimum blade penetration depth of 10.2 cm (4 in) for fishing.

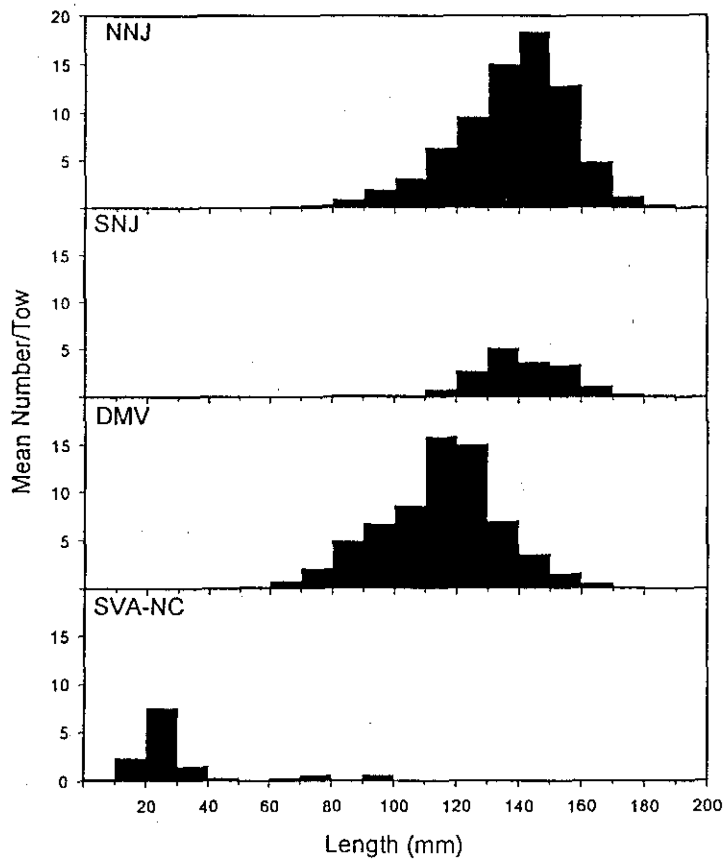


Figure B38. Size frequency distribution of surfclams, by region (southern), based on data from 1997 survey. Number per tow is standardized to a tow distance of 278 m (0.15 nmi) based on sensor data assuming a minimum blade penetration depth of 10.2 cm (4 in) for fishing.

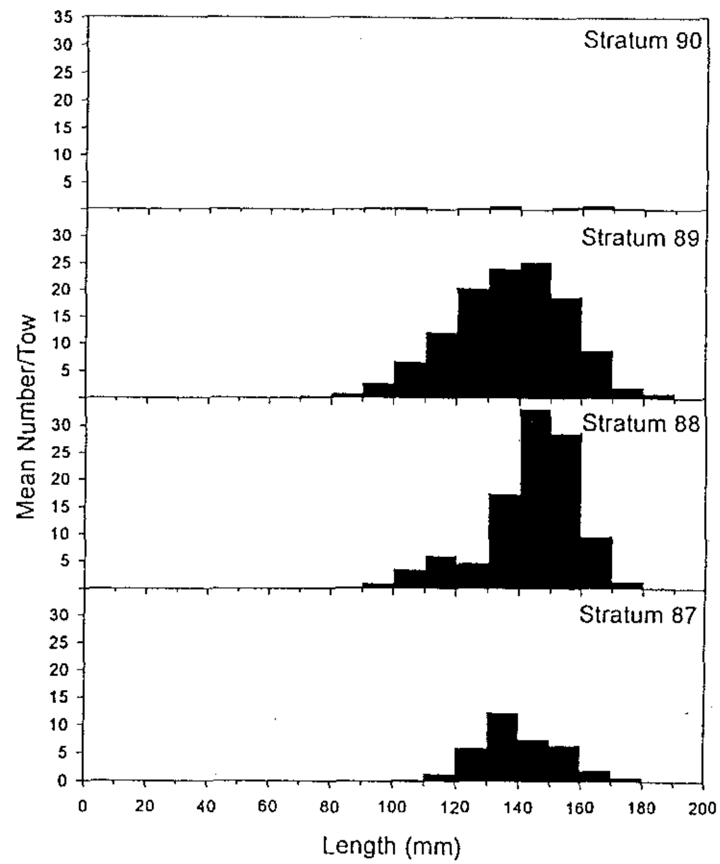


Figure B39. Surfclam size frequency distributions in the inshore EEZ off New Jersey. Data were collected during the 1997 NMFS survey and standardized to a tow distance of 287 m (0.15 nmi) assuming a critical blade depth of 10.2 cm (4 in).

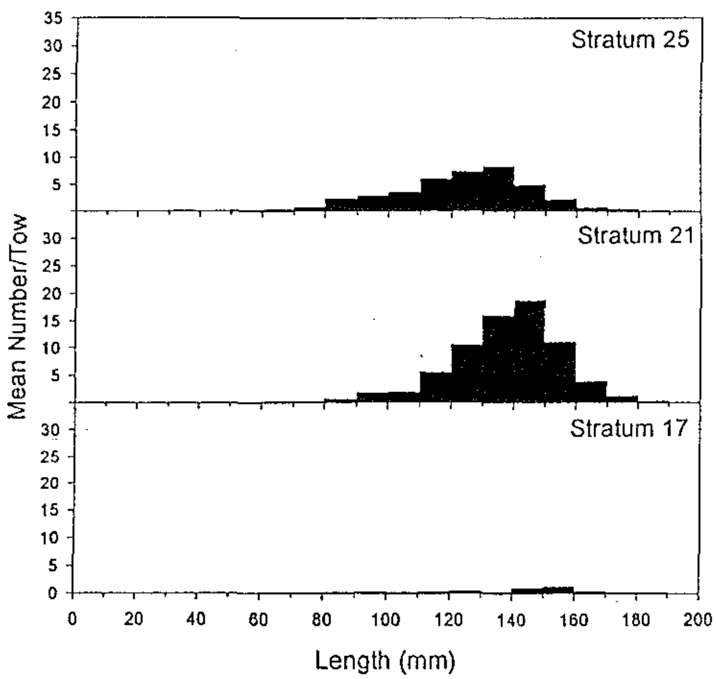


Figure B40. Surfclam size frequency distributions in the offshore strata off New Jersey. Data were collected during the 1997 NMFS survey and standardized to a tow distance of 287 m (0.15 nmi) assuming a critical blade depth of 10.2 cm (4 in).

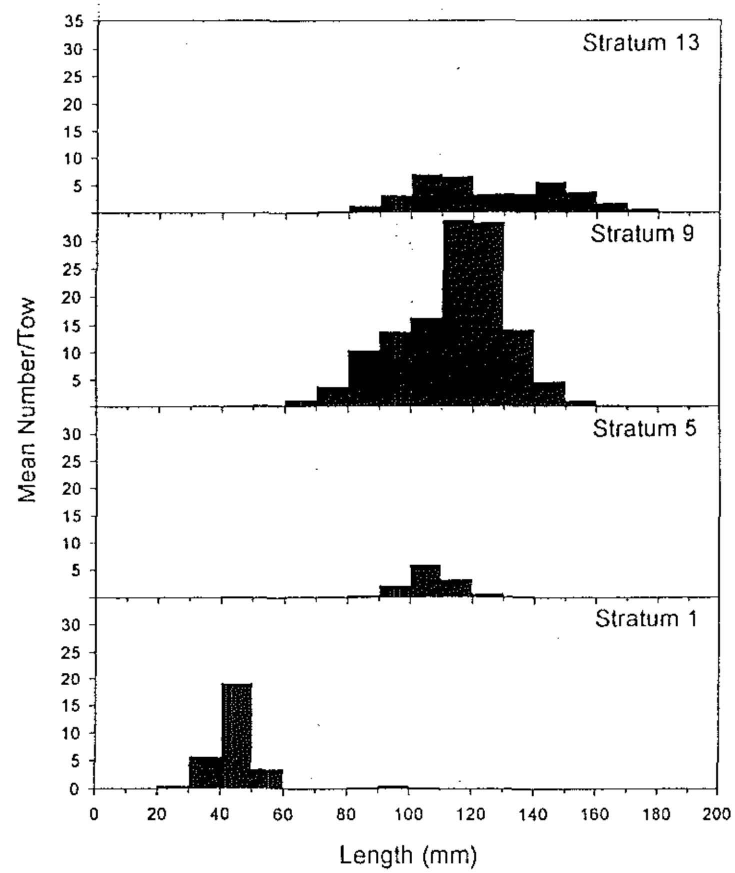


Figure B41. Surfclam size frequency distributions in the offshore strata from Delmarva to North Carolina. Data were collected during the 1997 NMFS survey and standardized to a tow distance of 287 m (0.15 nmi) assuming a critical blade depth of 10.2 cm (4 in).

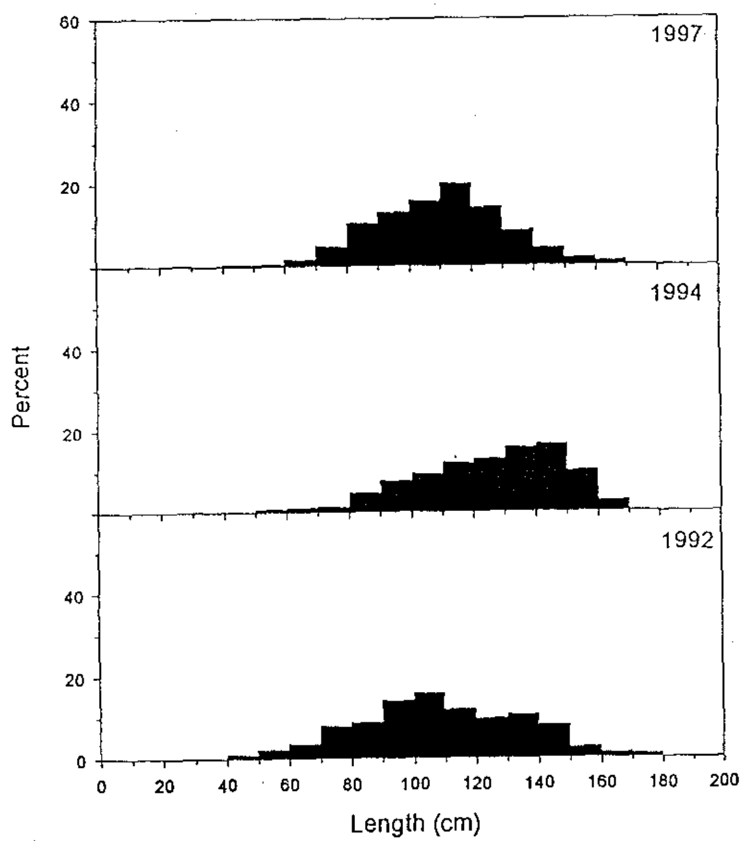


Figure B42. Percent size frequency distribution over time from research surverys. Region = Georges Bank.

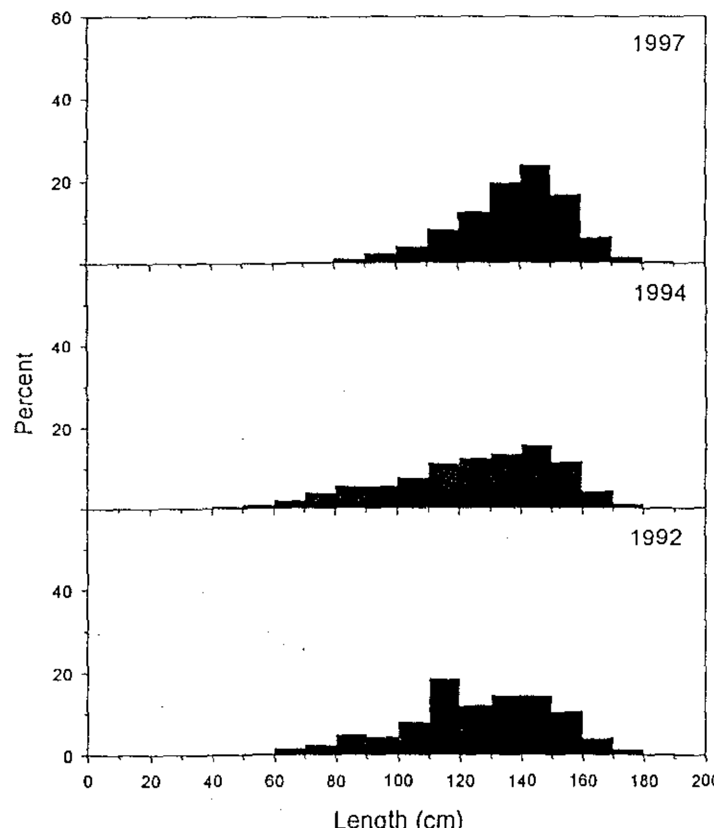


Figure B43. Percent size frequency distribution over time from research surverys. Region = Northern New Jersey.

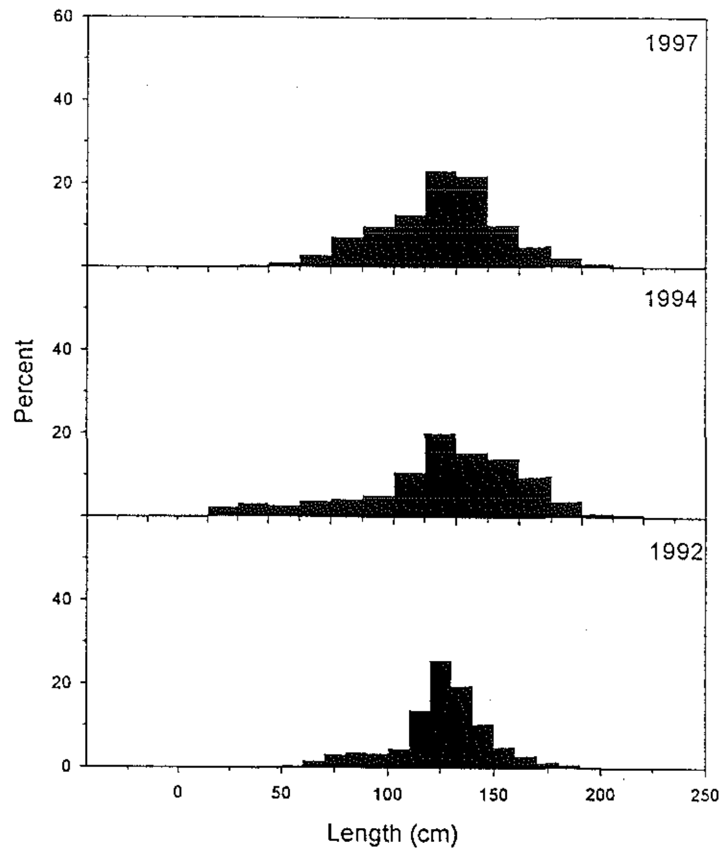


Figure B44. Percent size frequency distribution over time from research surveys. Region = Delmarva.

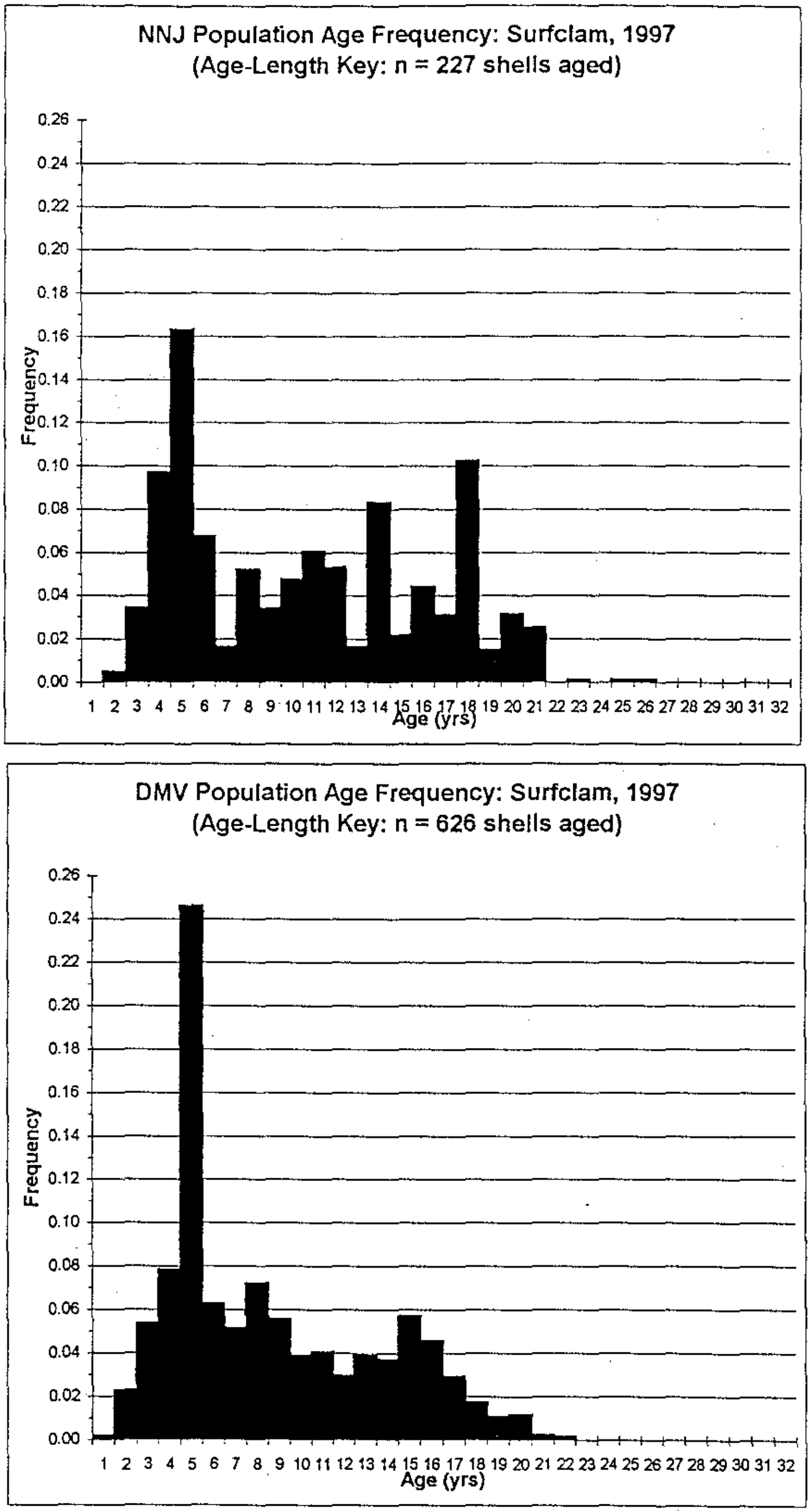


Figure B45. Age frequency distribution in 1997 for surfclams off Northern New Jersey and Delmarva. Age/length keys were applied to the size frequency distributions for each region.

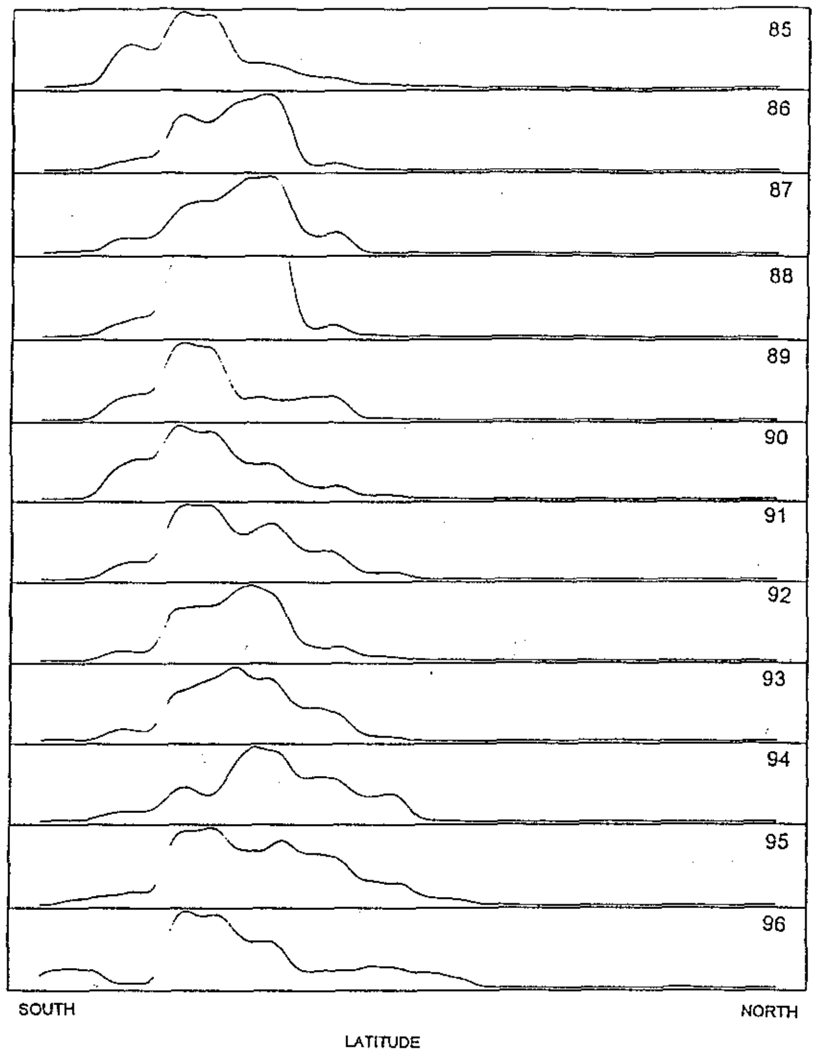


Figure B46. Frequency distribution of commercial surfclam trips by year as a function of latitude.

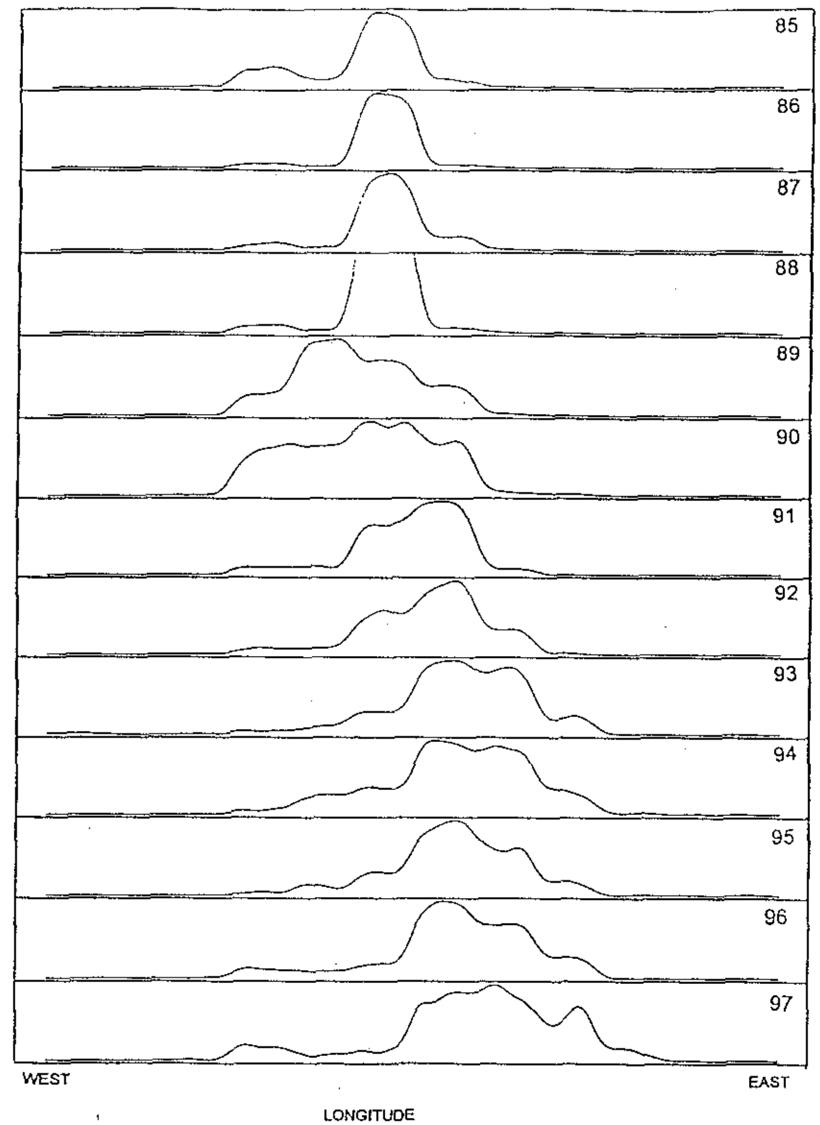


Figure B47. Frequency distribution of commercial surfclam trips by year as a function of longitude.

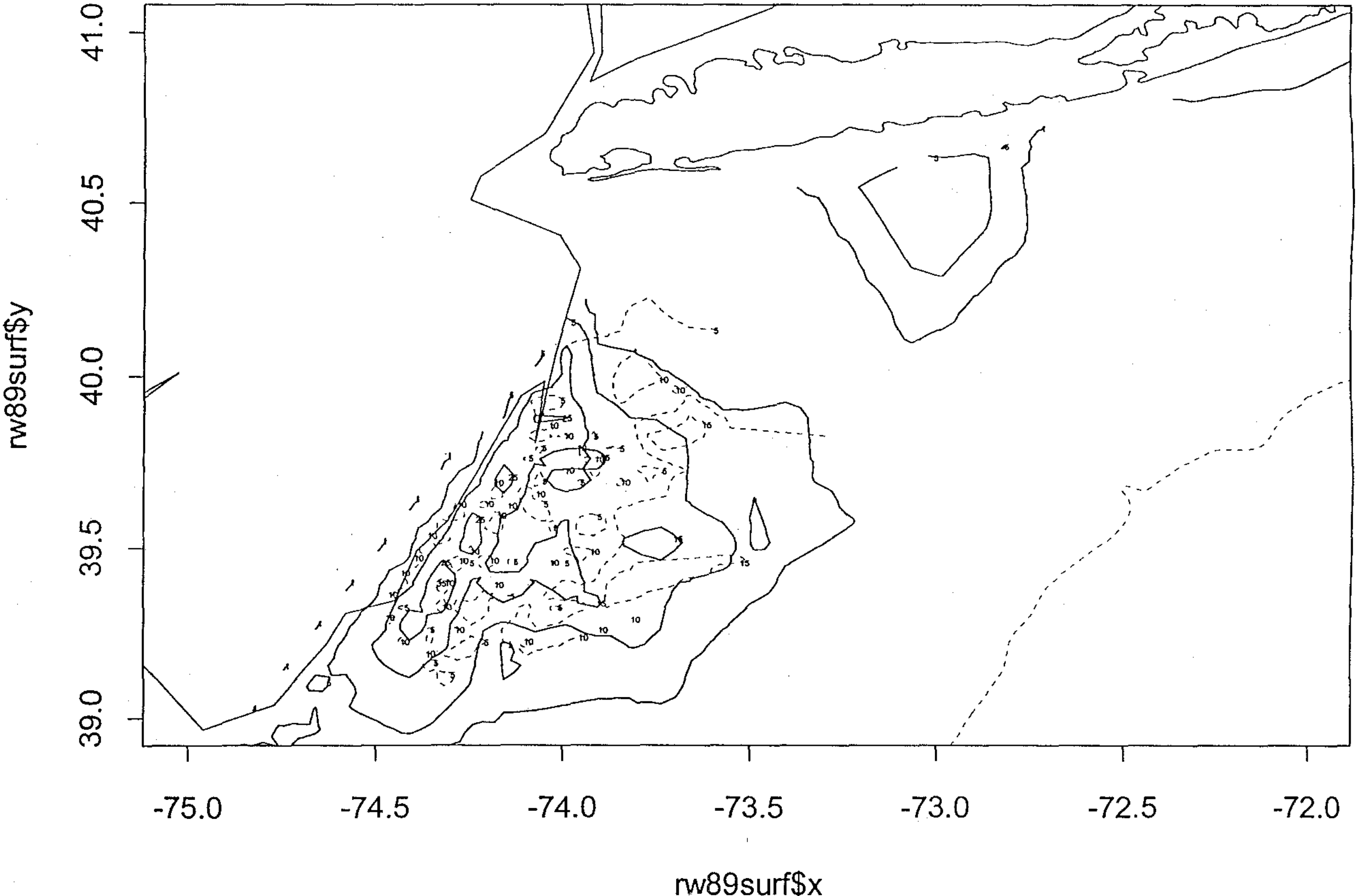


Figure B48. 1989 survey, recruit wt: kg/tow vs commercial mt/trip.

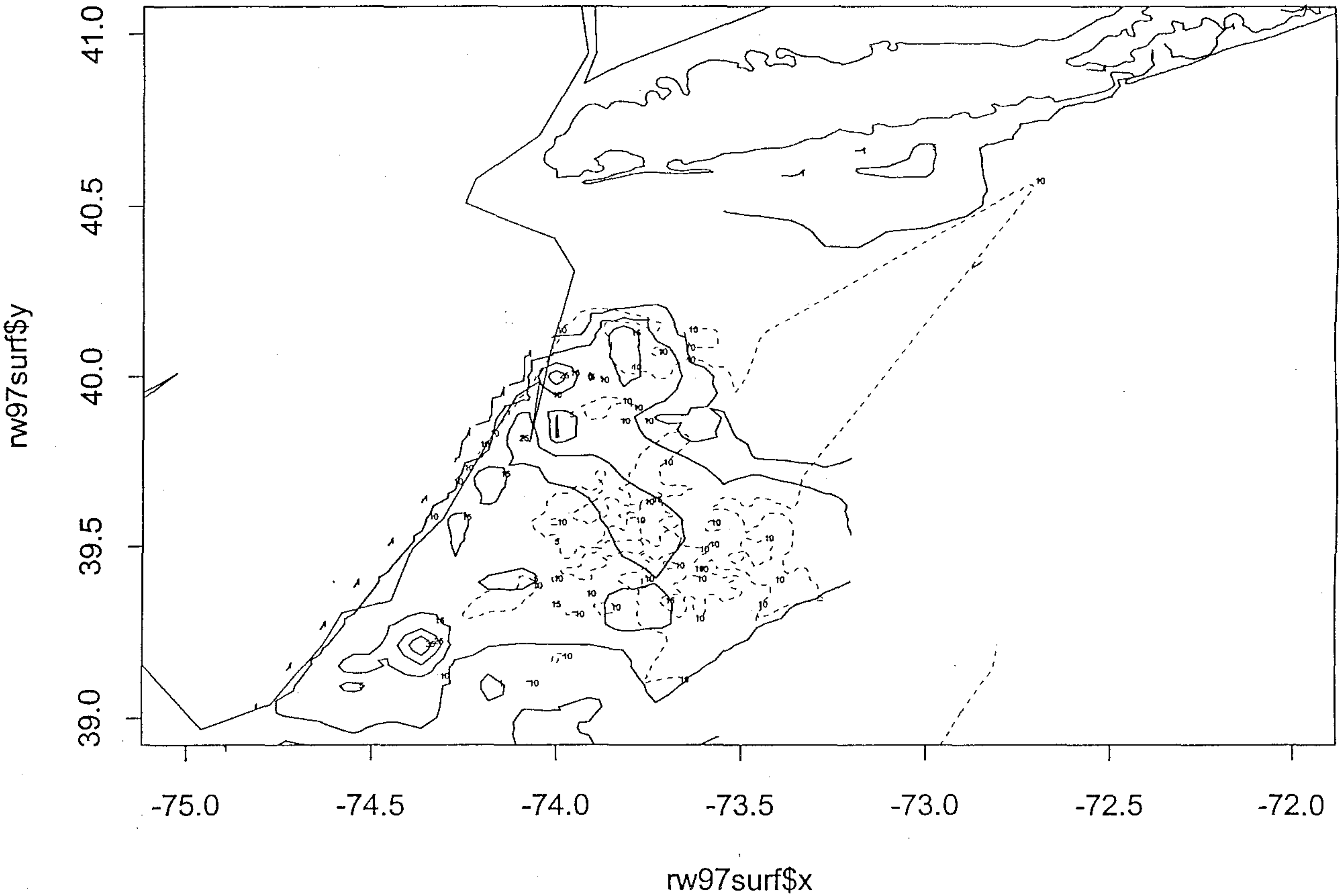


Figure B49. 1997 survey, recruited wt: kg/tow.

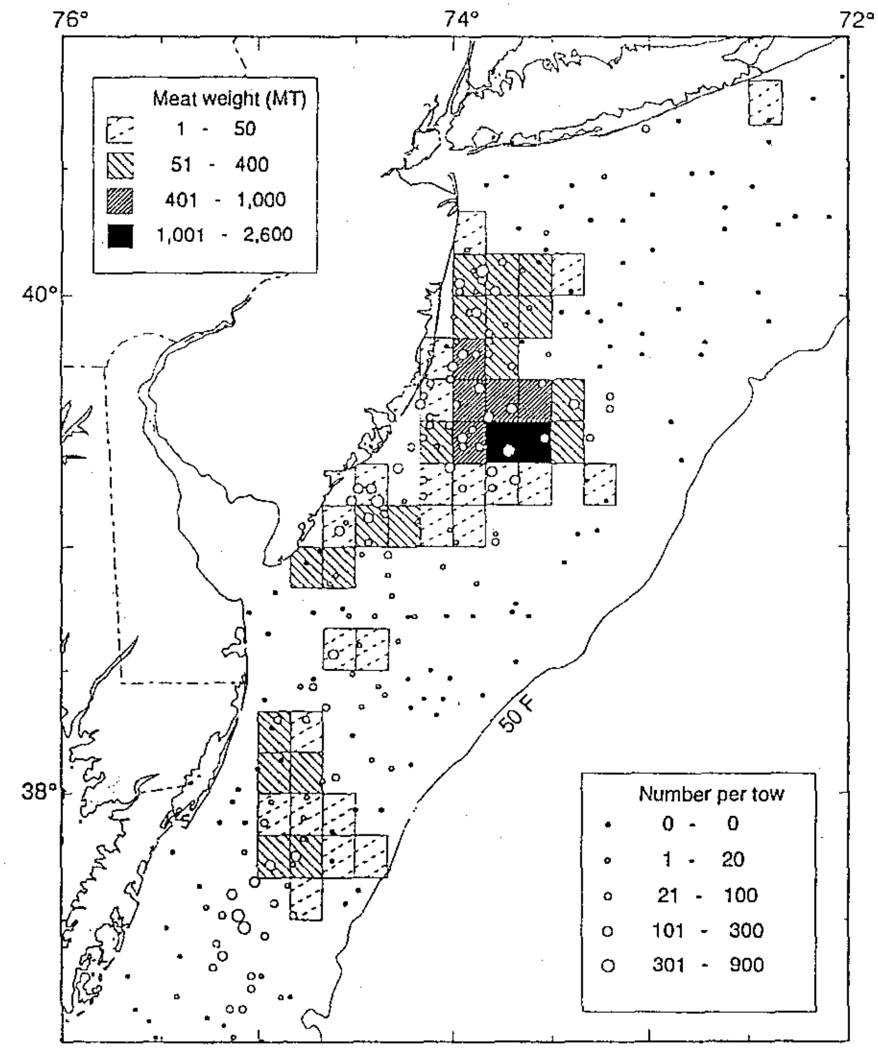


Figure B50. Distribution of 1997 survey surfclam abundance per tow (≥120 mm) adjusted to 0.51 nmi tow distance with sensor data (blade depth = 4 in) and 1997 landings (meat weight in mt).

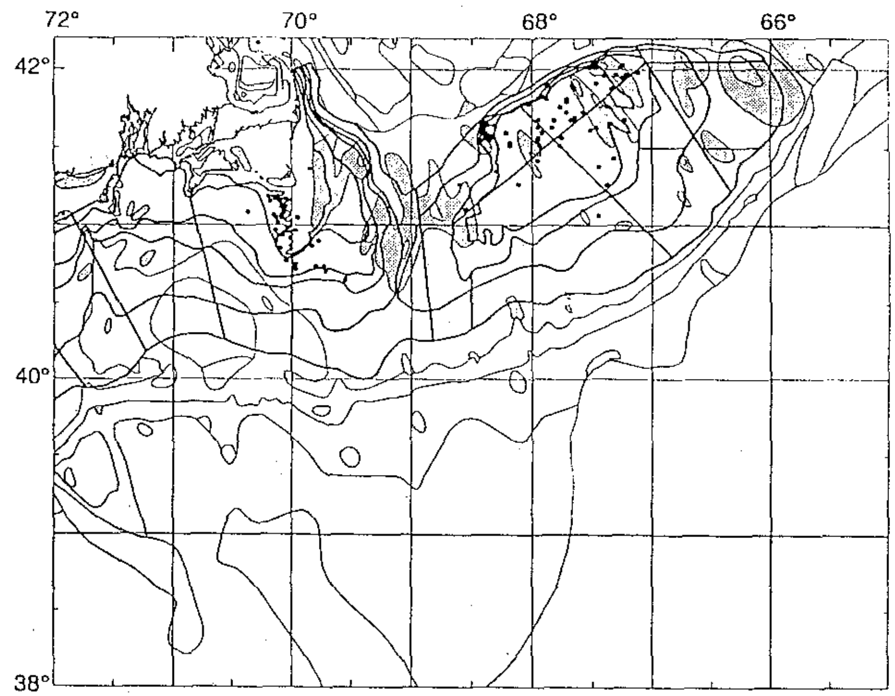


Figure B51. NEFSC survey stations where surfclam abundance exceeded 40 individuals per tow in relation to areas of unsuitable (rocky) habitat (shaded) within Georges Bank survey strata (1980-1997).

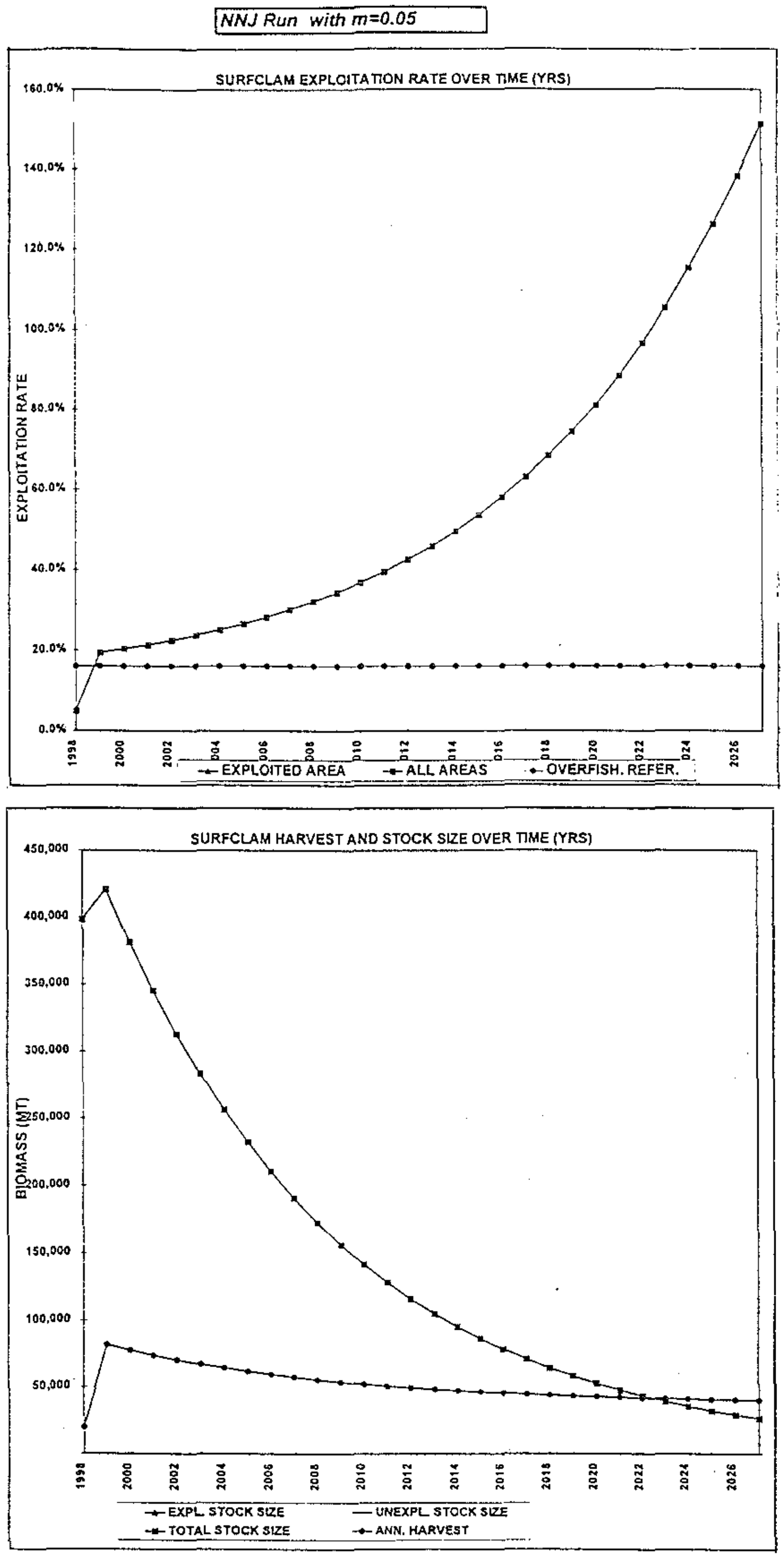


Figure B52. Surfclam 10-year supply model. In each year, the catch is set at that which could be taken for 10 years. The model assumes an average level of recruitment and accounts for growth and natural mortality. This model does not consider "indirect" mortality from clam harvesting.

NNJ Run with m=0.10

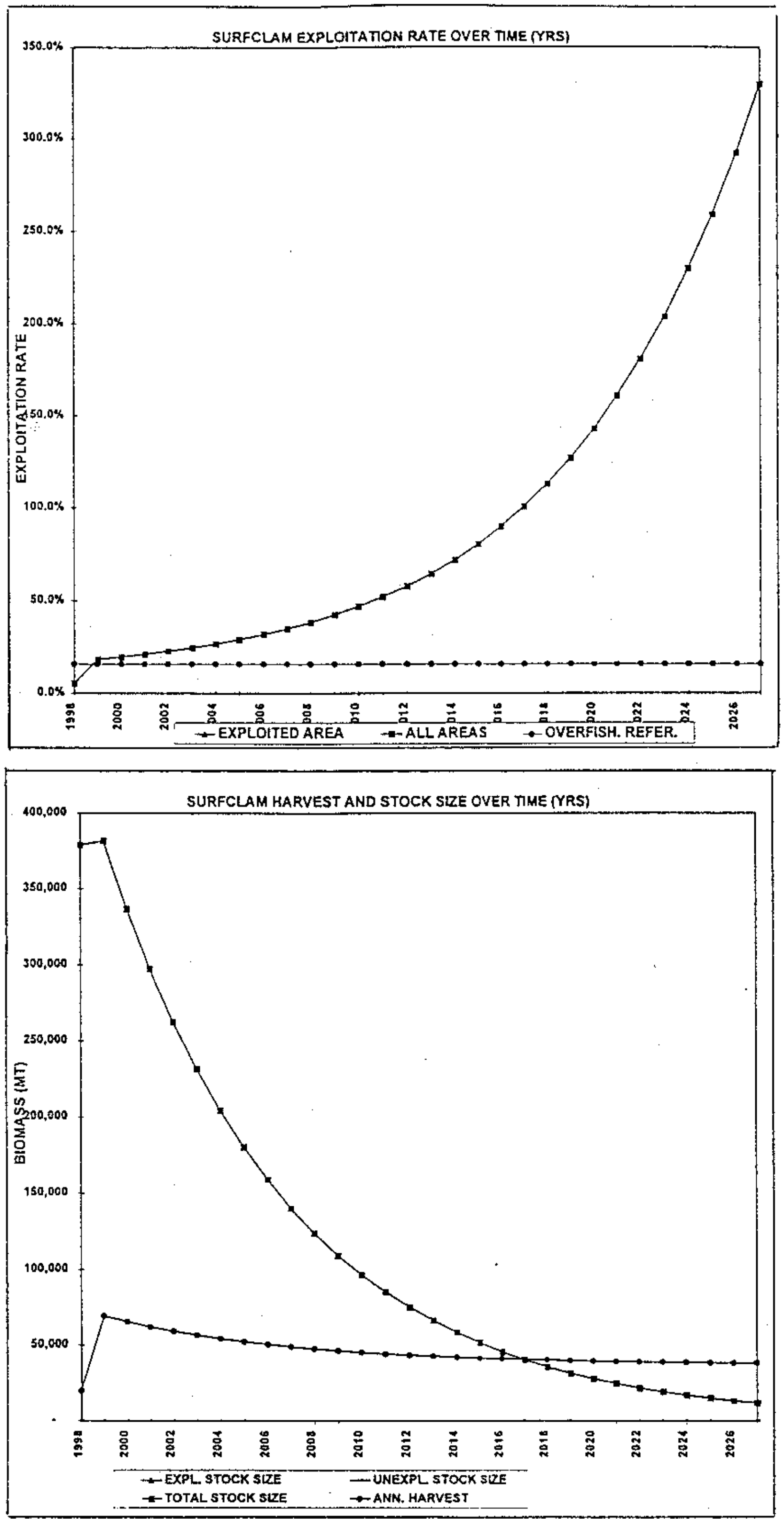


Figure B53. Surfclam 10-year supply model. In each year, the catch is set at that which could be taken for 10 years. The model assumes an average level of recruitment and accounts for growth and natural mortality. This model does not consider "indirect" mortality from clam harvesting.

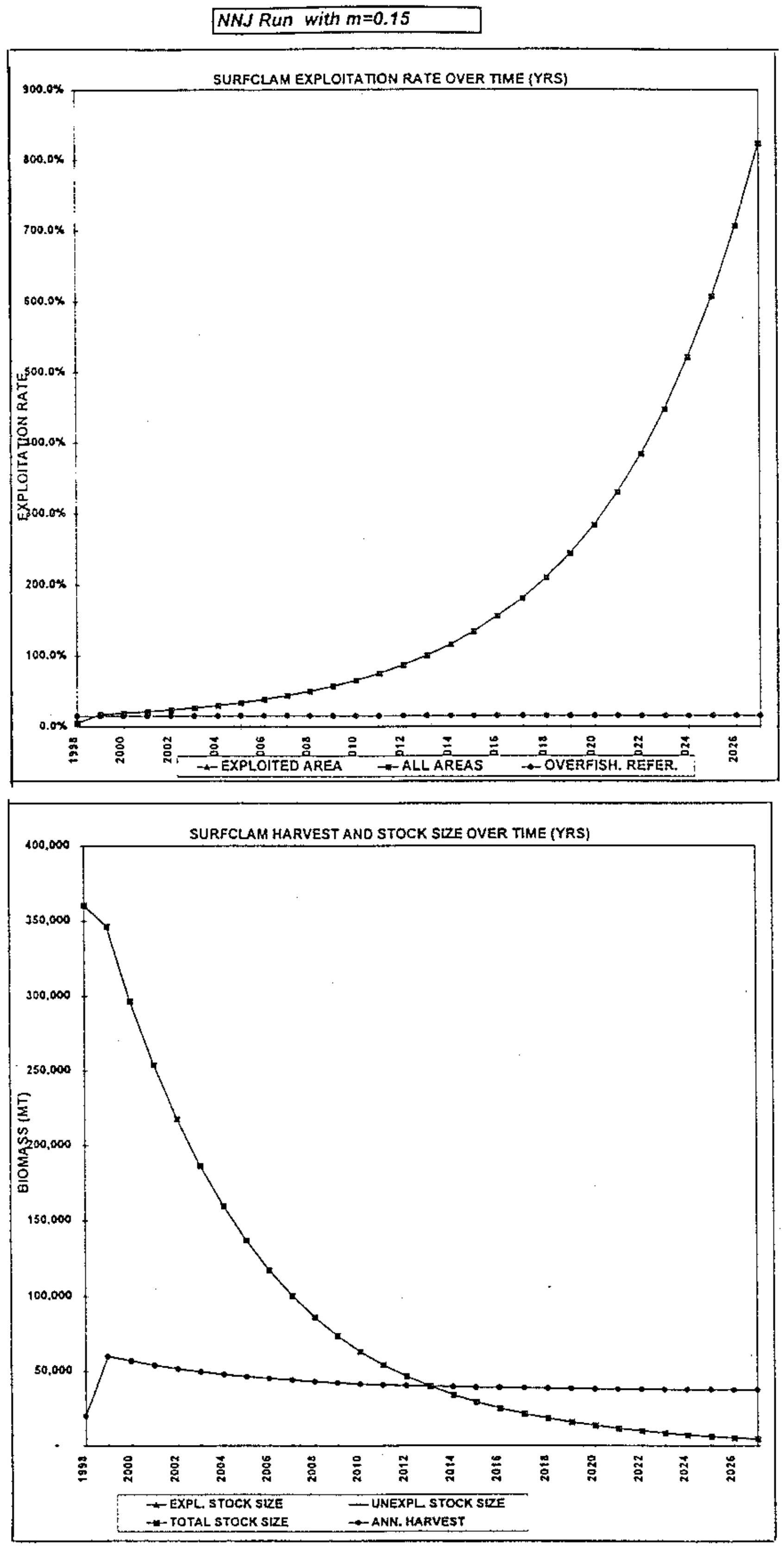


Figure B54. Surfclam 10-year supply model. In each year, the catch is set at that which could be taken for 10 years. The model assumes an average level of recruitment and accounts for growth and natural mortality. This model does not consider "indirect" mortality from clam harvesting.

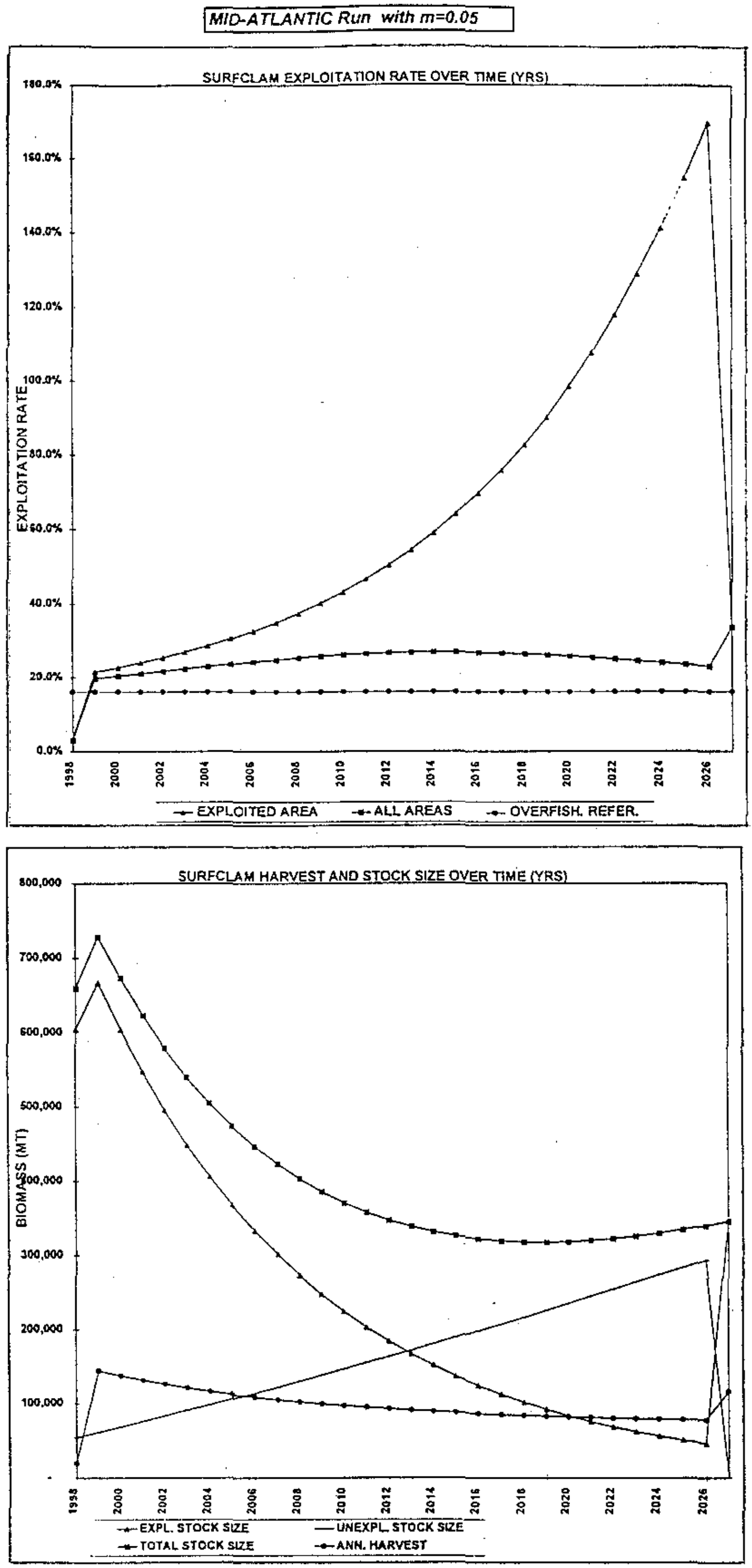


Figure B55. Surfclam 10-year supply model. In each year, the catch is set at that which could be taken for 10 years. The model assumes an average level of recruitment and accounts for growth and natural mortality. This model does not consider "indirect" mortality from clam harvesting.

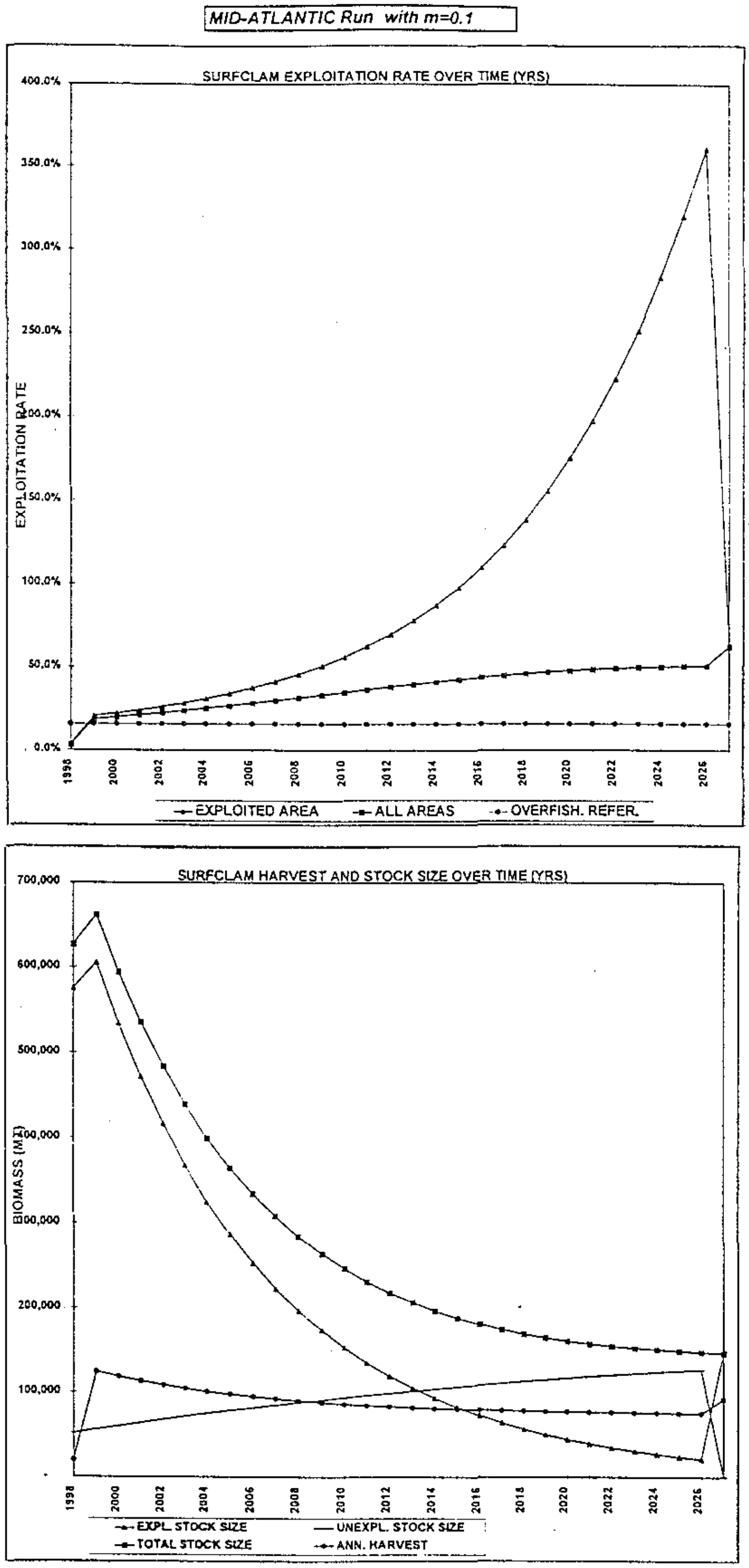


Figure B56. Surfclam 10-year supply model. In each year, the catch is set at that which could be taken for 10 years. The model assumes an average level of recruitment and accounts for growth and natural mortality. This model does not consider "indirect" mortality from clam harvesting.

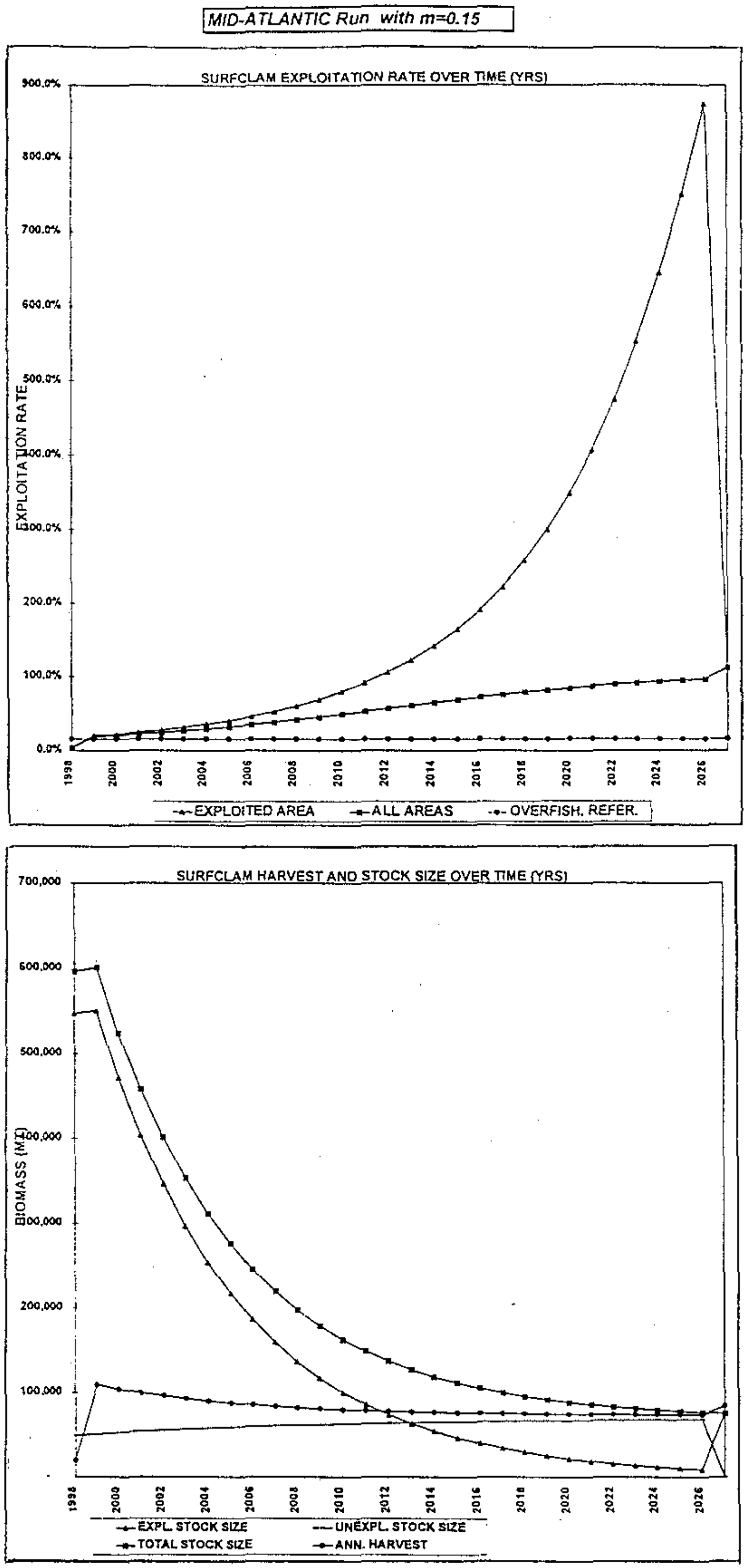


Figure B57. Surfclam 10-year supply model. In each year, the catch is set at that which could be taken for 10 years. The model assumes an average level of recruitment and accounts for growth and natural mortality. This model does not consider "indirect" mortality from clam harvesting.

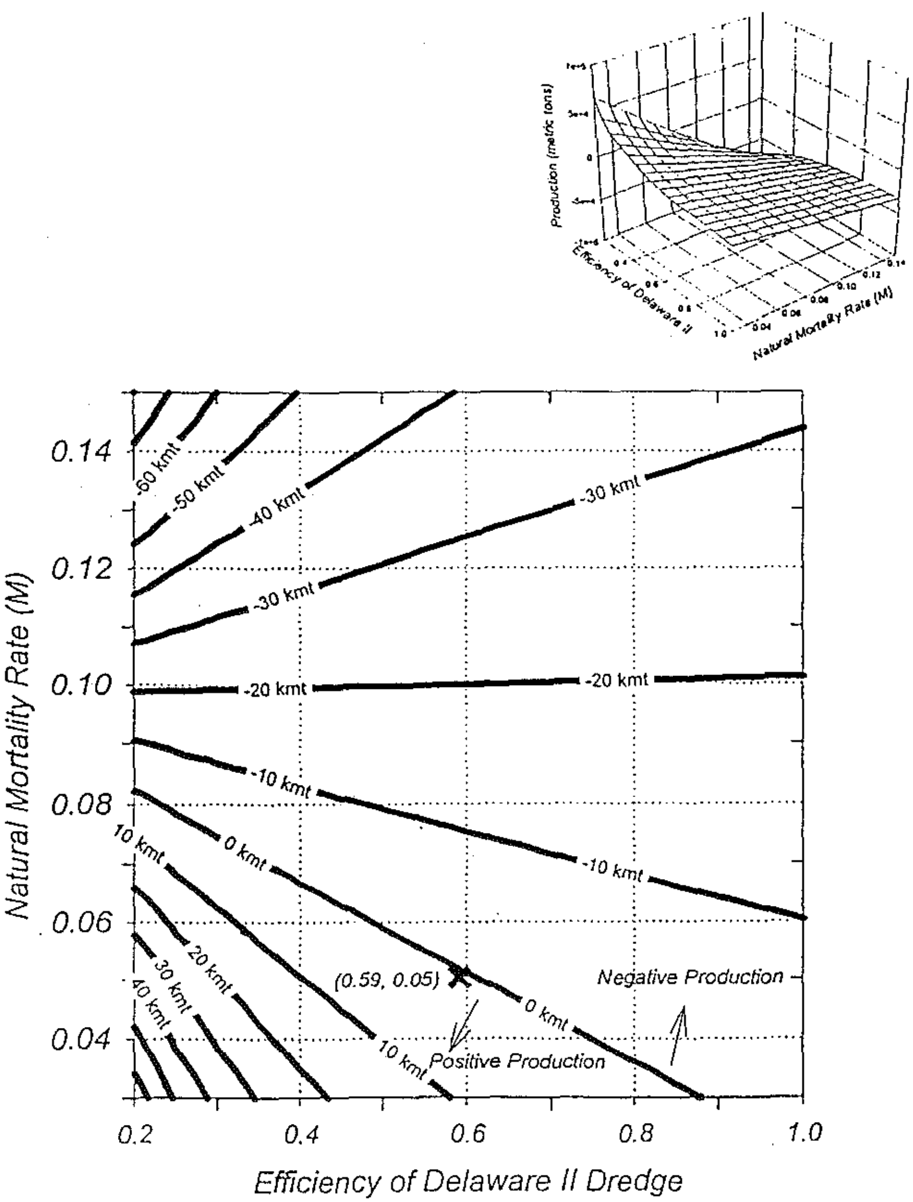


Figure B58. Net biomass production (mt of meats) in Northern New Jersey. Traditional L/W equations were used.

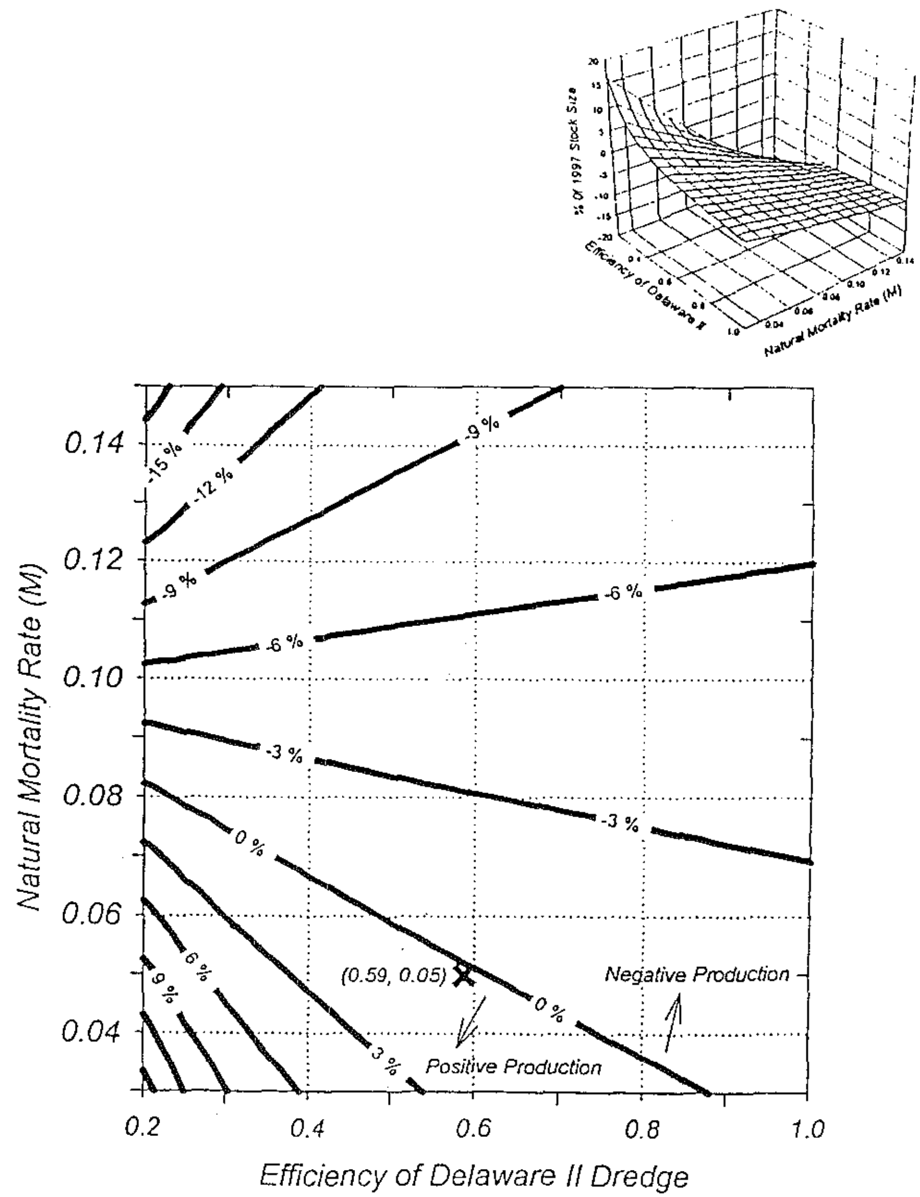


Figure B59. Net biomass production (% of 1997 stock size) in Northern New Jersey. Traditional L/W equations were used.

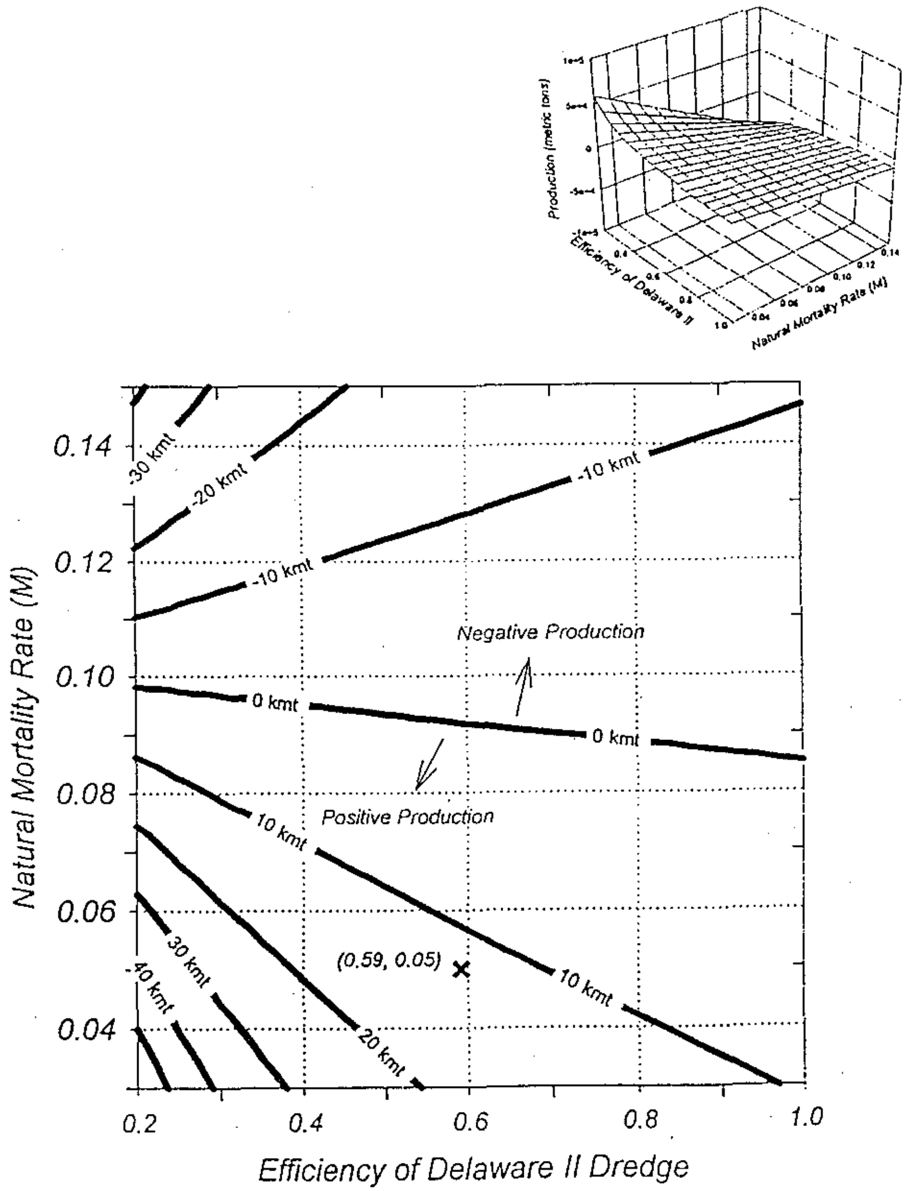


Figure B60. Net biomass production (mt of meats) in the Delmarva assessment area. Traditional L/W equations were used.

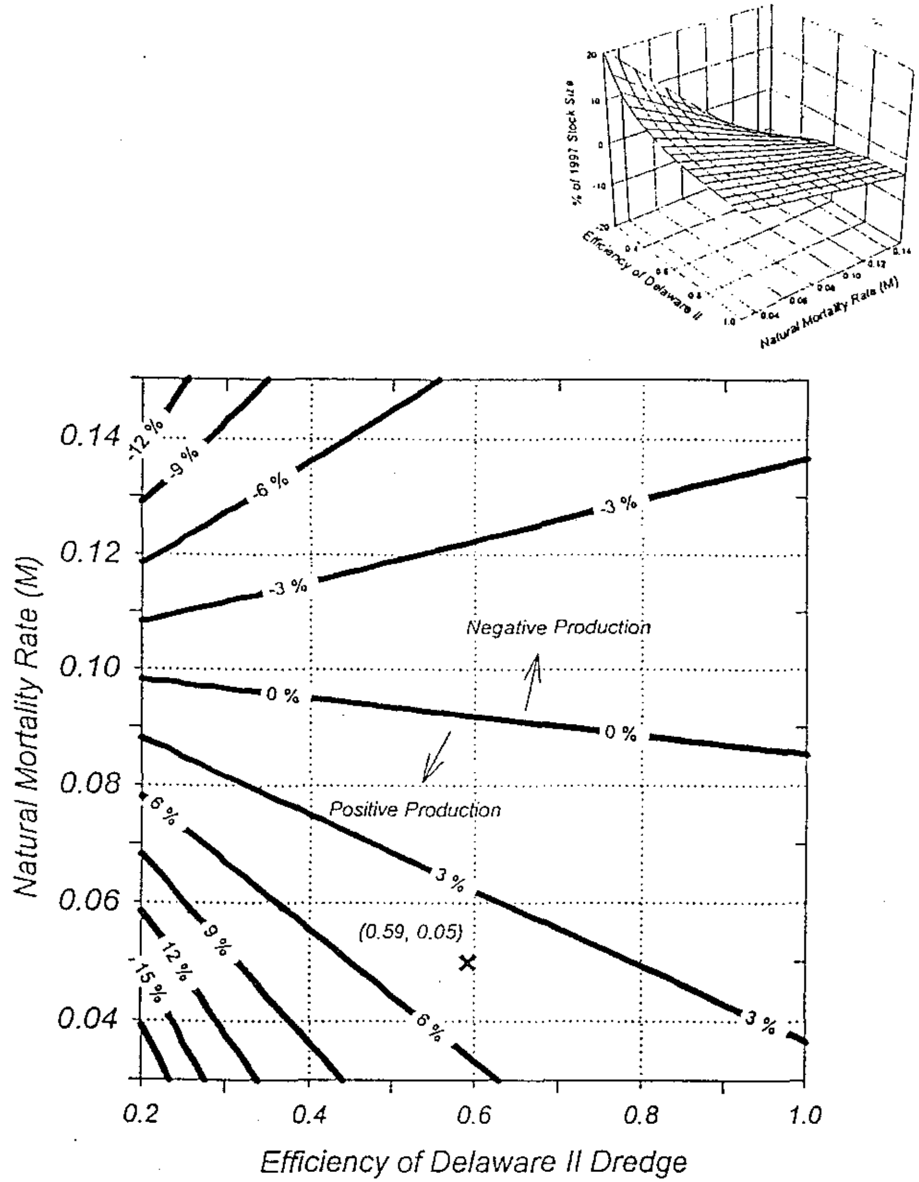


Figure B61. Net biomass production (% of 1997 stock size) in the Delmarva assessment area. Traditional L/W equations were used.

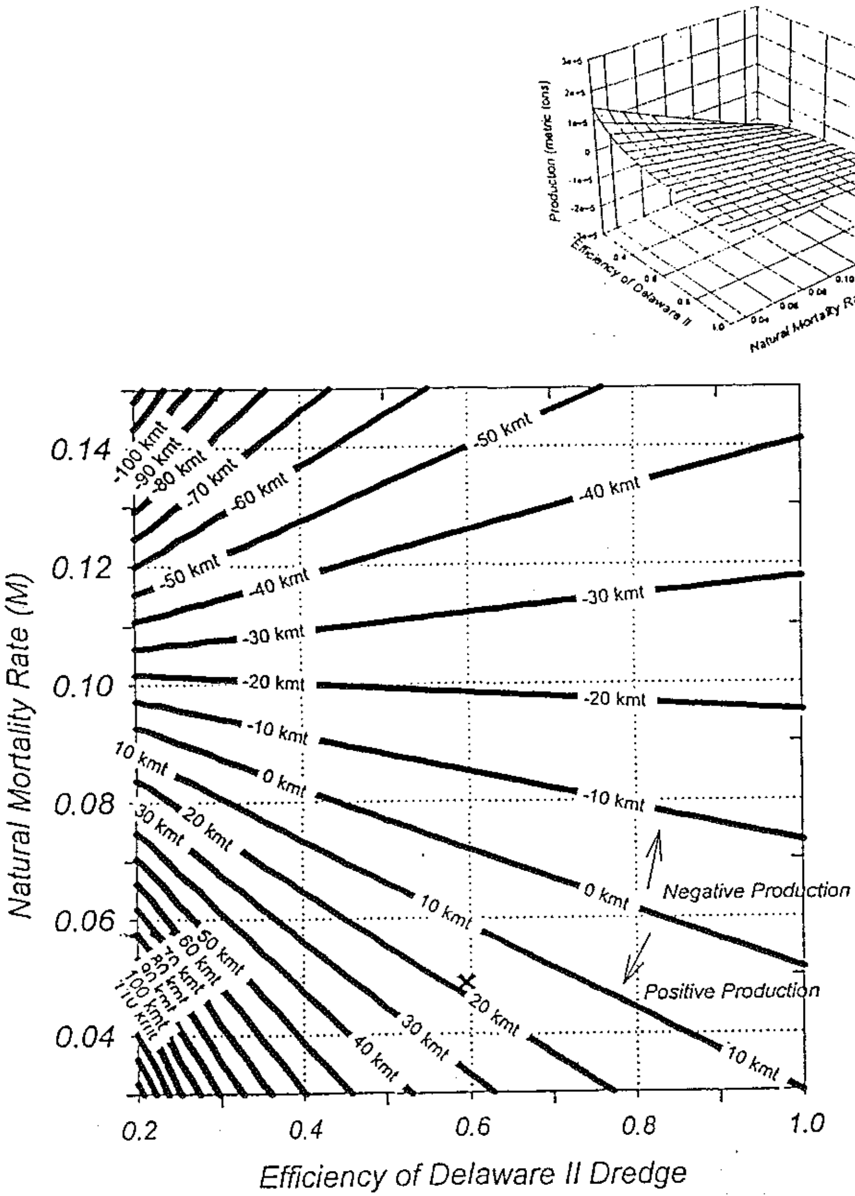


Figure B62. Net biomass production (mt of meats) in the Mid-Atlantic assessment areas (LI-SVA-NC). Traditional L/W equations were used.

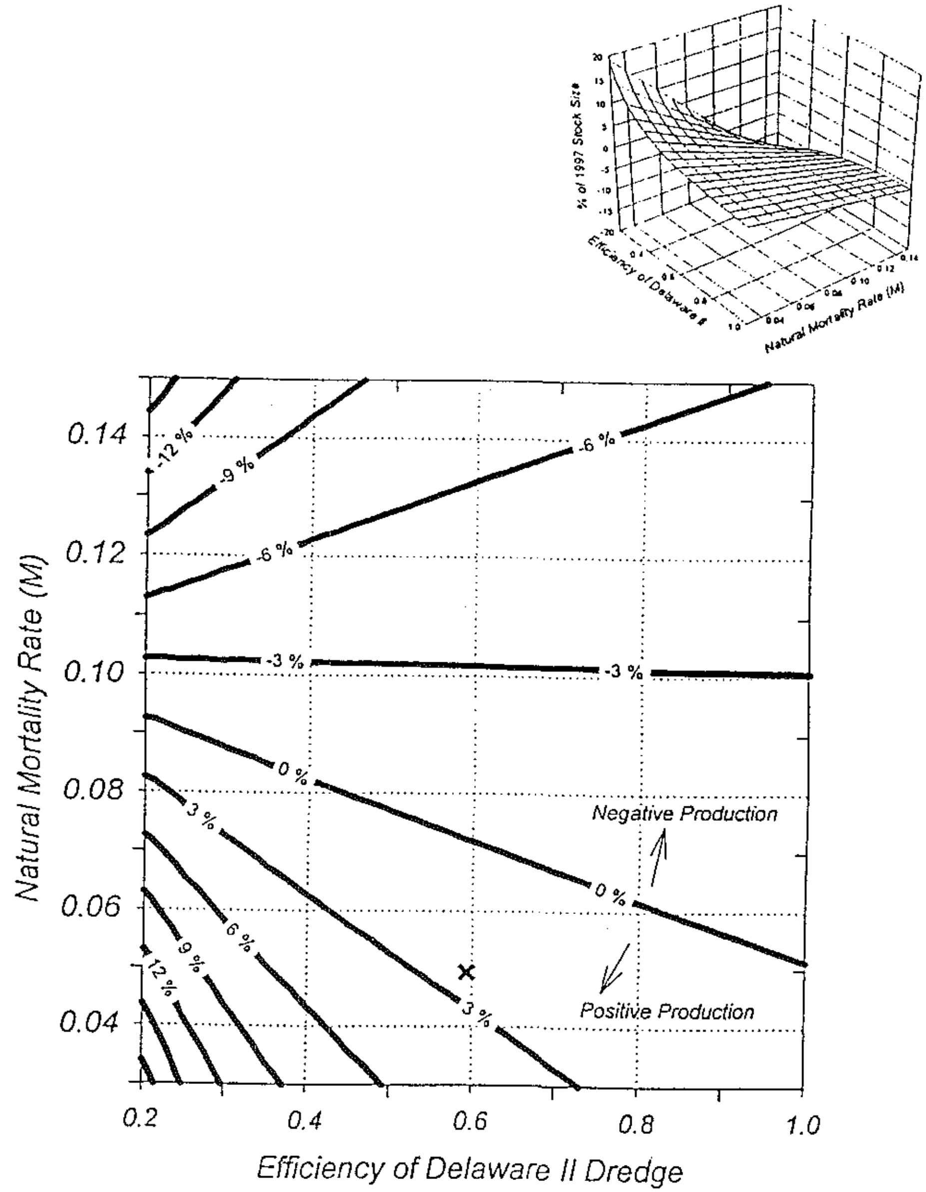


Figure B63. Net biomass production (% of 1997 stock size) in the Mid-Atlantic assessment areas (LI-SVA-NC). Traditional L/W equations were used.

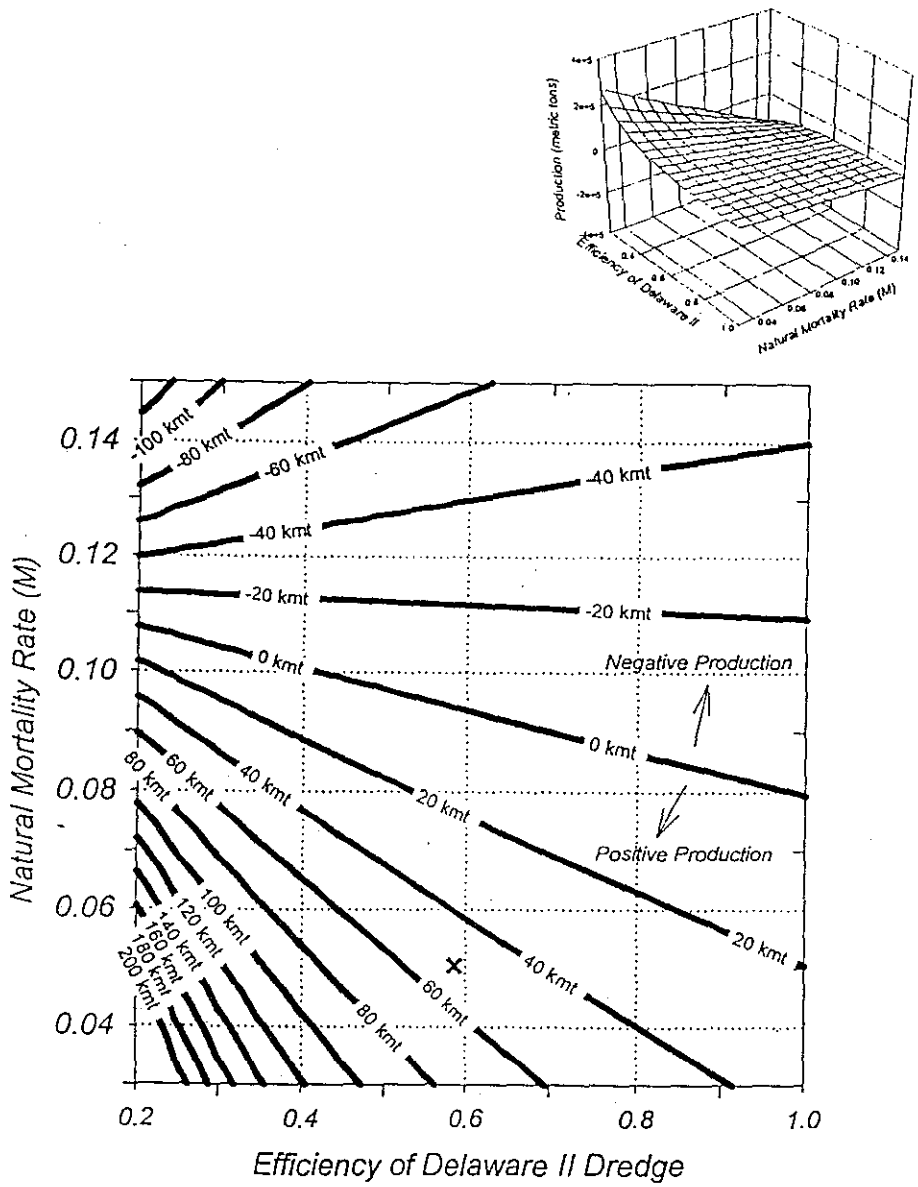


Figure B64. Net biomass production (mt of meats) in all assessment areas (MAB + GBK & SNE). Traditional L/W equations were used.

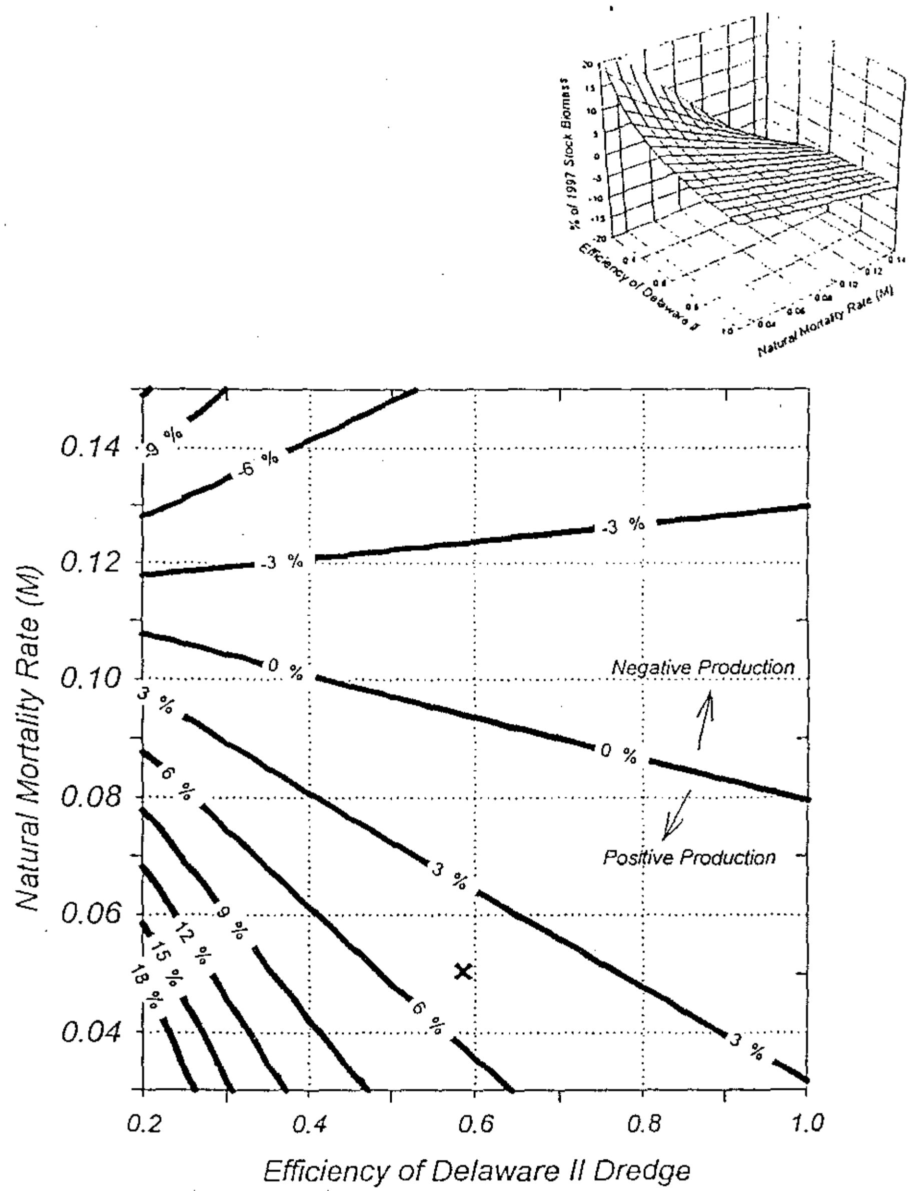
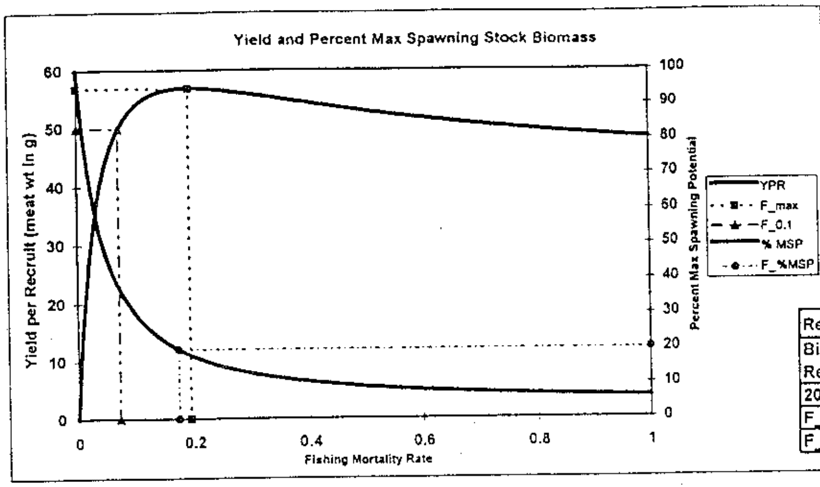


Figure B65. Net biomass production (% of 1997 stock size) in all assessment areas (MAB + GBK & SNE). Traditional L/W equations were used.



Region=	GBK-t2			
Biological Ref Pt	F	Yield	%MSP	SSB/R (g)
20% MSP	0.1738	56.79	20.0000	407.65
F_0.1	0.0724	49.87	37.8034	770.53
F_max	0.1933	56.87	18.3907	374.85

Figure B66. Summary of yield per recruit and spawning stock biomass per recruit and associated biological reference points for region = GBK-t2, where GBK = Georges Bank, DMV = Delmarva, and NNJ = Northern New Jersey. Two-parameter von Bertalanffy growth models are denoted by "-t2". The three-parameter model is denoted by "-t3".

Yield and Spawning Stock Biomass per Recruit for Region = GBK-t2

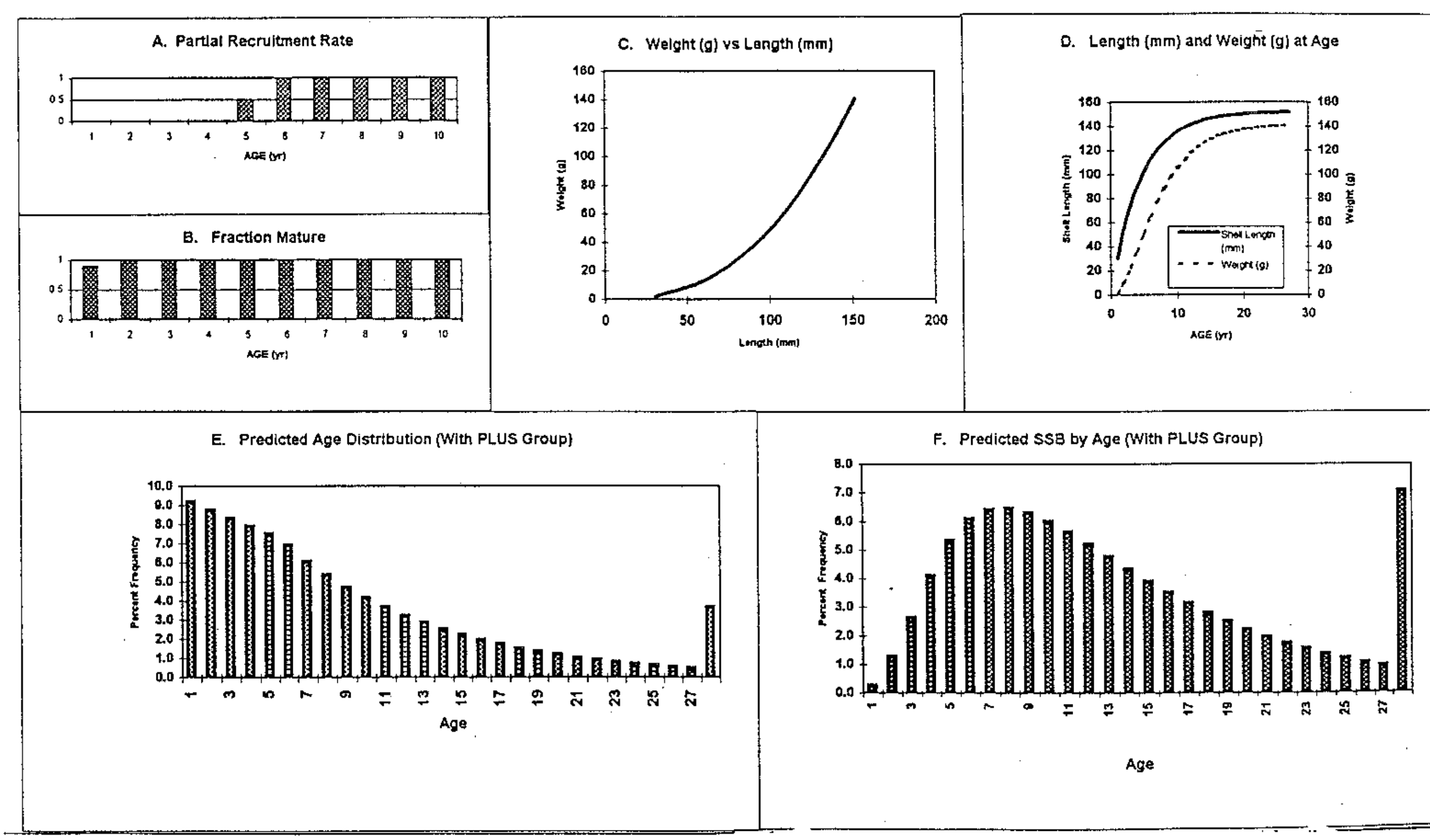
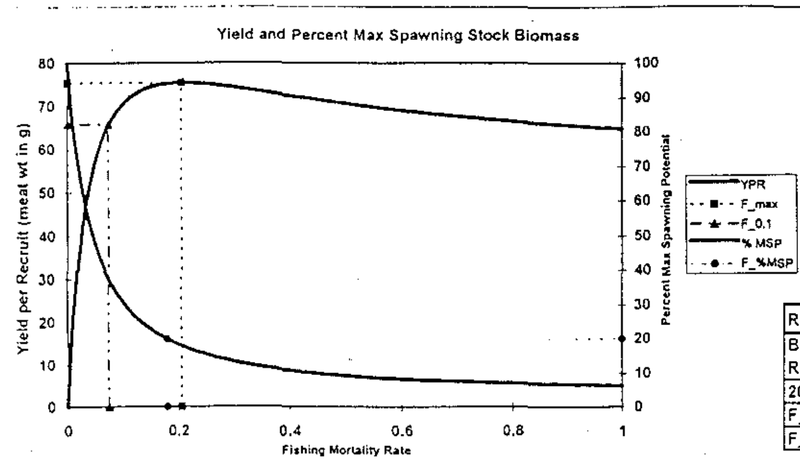


Figure B67. Summary of input parameters: A - partial recruitment, B - maturity, C - weight vs length, D - shell length and weight at age for computation of yield per recruit and spawning stock biomass per recruit. Panel E and F represent the predicted percent composition of age structure and spawning stock biomass by age, respectively, under a fishing mortality rate of $F_{0.1} = 0.056$.



Region=	NNJ-t2			
Biological Ref Pt	F	Yield	%MSP	SSB/R (g)
20% MSP	0.1791	75.24	20.0000	526.10
F_0.1	0.0745	65.81	37.6381	990.06
F_max	0.2055	75.40	17.9687	472.66

Figure B68. Summary of yield per recruit and spawning stock biomass per recruit and associated biological reference points for region = NNJ-t2, where GBK = Georges Bank, DMV = Delmarva, and NNJ = Northern New Jersey. Two-parameter von Bertalanffy growth models are denoted by "-t2". The three-parameter model is denoted by "-t3".

Yield and Spawning Stock Biomass per Recruit for Region = NNJ-t2

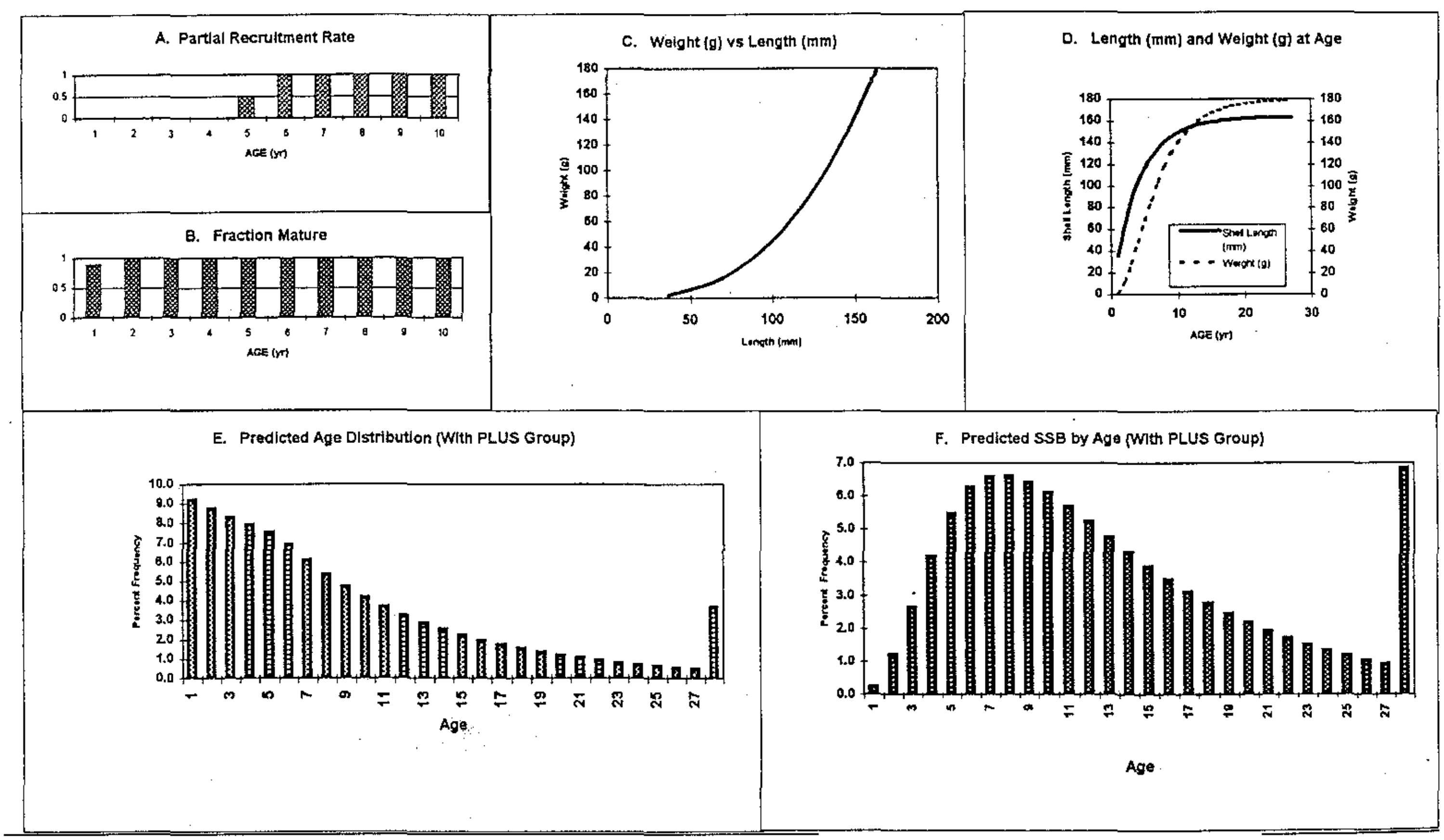
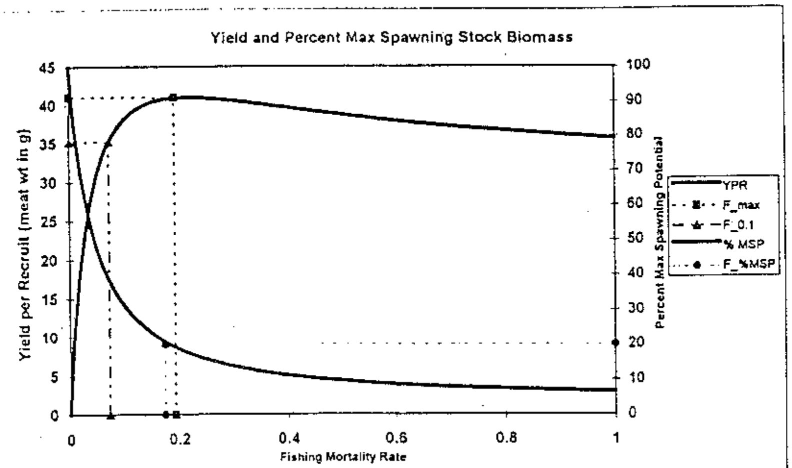


Figure B69. Summary of input parameters: A - partial recruitment, B - maturity, C - weight vs length, D - shell length and weight at age for computation of yield per recruit and spawning stock biomass per recruit. Panel E and F represent the predicted percent composition of age structure and spawning stock biomass by age, respectively, under a fishing mortality rate of $F_{0.1} = 0.0756$.



Region=	DMV-t2			
Biological Ref Pt	F	Yield	%MSP	SSB/R (g)
20% MSP	0.1738	40.81	20.0000	294.90
F_0.1	0.0724	35.20	38.7131	546.97
F_max	0.1933	40.96	19.2406	271.85

Figure B70. Summary of yield per recruit and spawning stock biomass per recruit and associated biological reference points for region = DMV-t2, where GBK = Georges Bank, DMV = Delmarva, and NNJ = Northern New Jersey. Two-parameter von Bertalanffy growth models are denoted by "-t2". The three-parameter model is denoted by "-t3".

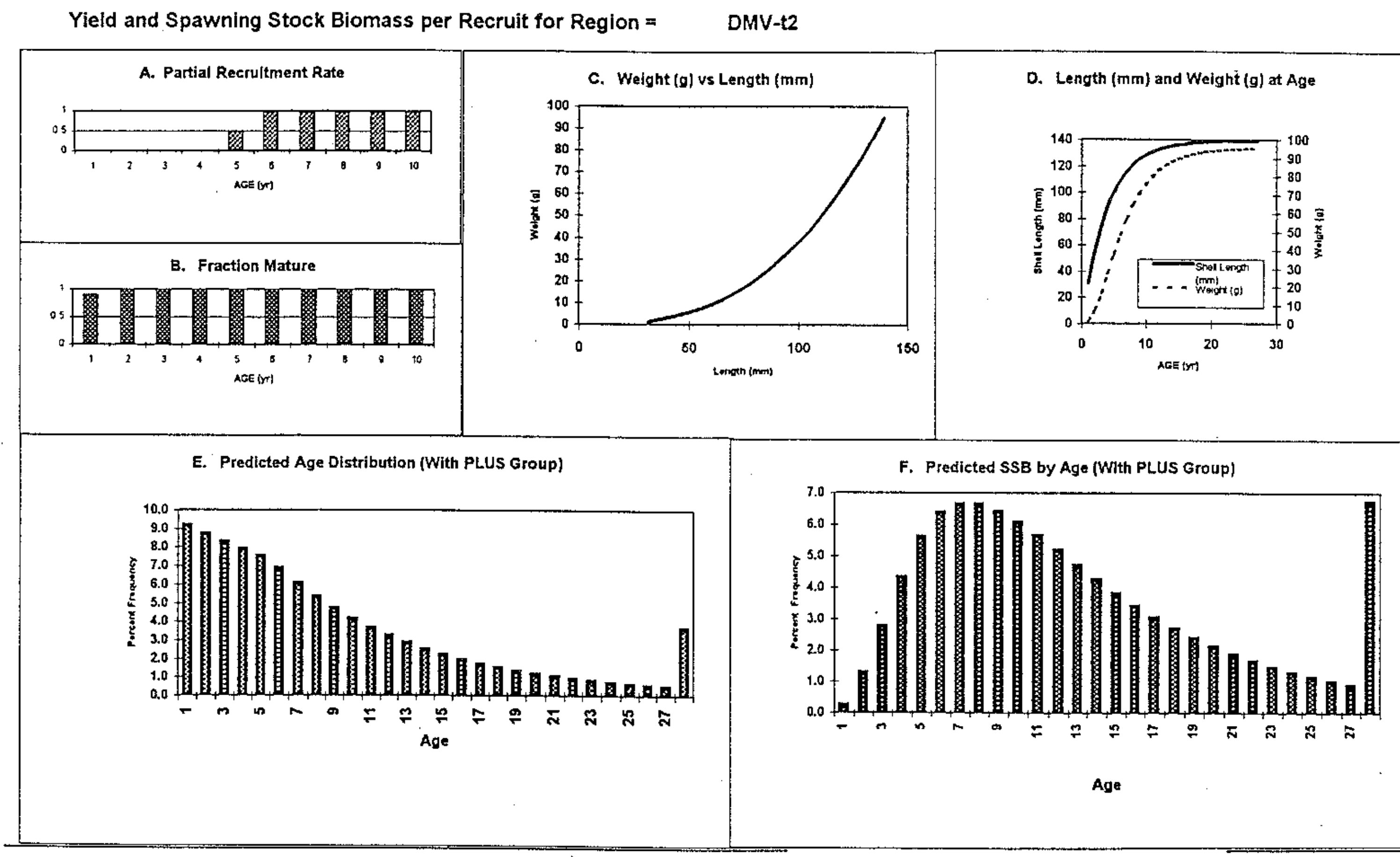


Figure B71. Summary of input parameters: A - partial recruitment, B - maturity, C - weight vs length, D - shell length and weight at age for computation of yield per recruit and spawning stock biomass per recruit. Panel E and F represent the predicted percent composition of age structure and spawning stock biomass by age, respectively, under a fishing mortality rate of $F_{0.1}$ = 0.0756.

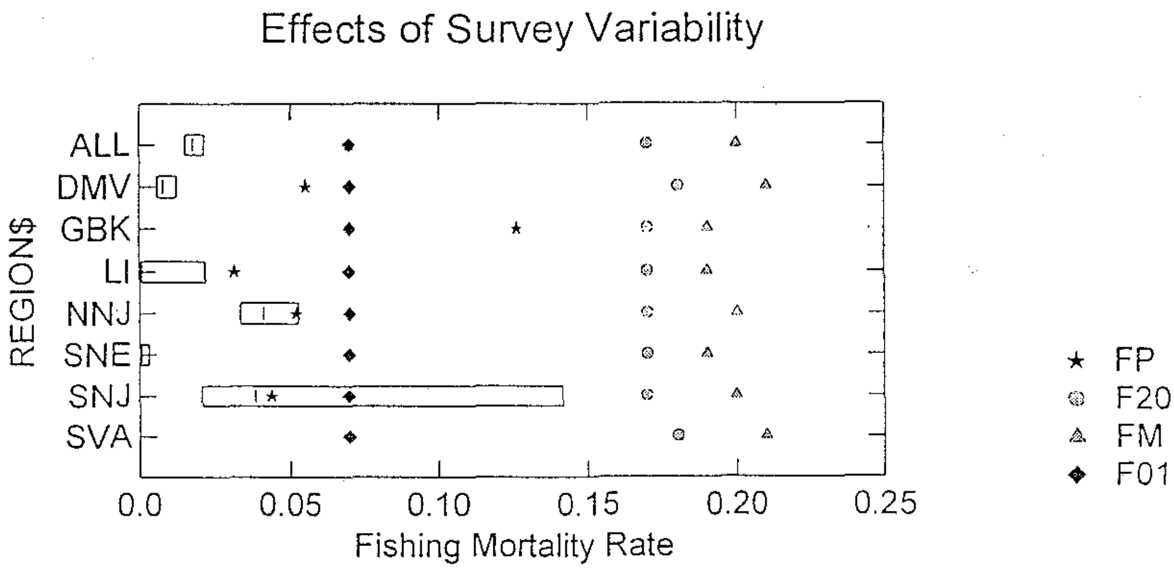


Figure B72. Estimates of fishing mortality rate (F) (boxes) and Fs corresponding to biological reference points (symbols). F_p = F given a harvest of the annual production, F_{20} = F at 20% MSP, F_M = F for maximum yield per recruit. Boxes: vertical line represents the mean estimate of F. Range enclosed by each box corresponds to the bootstrap 95% CI on total population size.

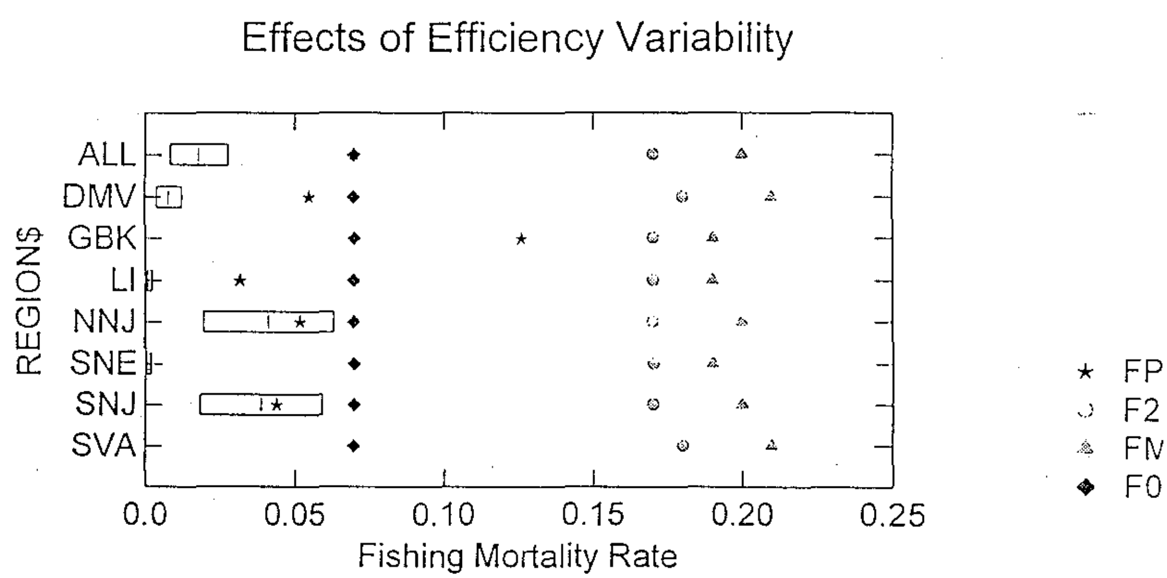


Figure B73. Estimates of fishing mortality rate (F) (boxes) and Fs corresponding to biological reference points (symbols). F_p = F given a harvest of the annual production, F_{20} = F at 20% MSP, F_M = F for maximum yield per recruit. Boxes: vertical line represents the mean estimate of F assuming a mean dredge efficiency of 0.5879. The lower and upper limits for each box correspond to calculations based on CIs representing high and low dredge efficiency, respectively.

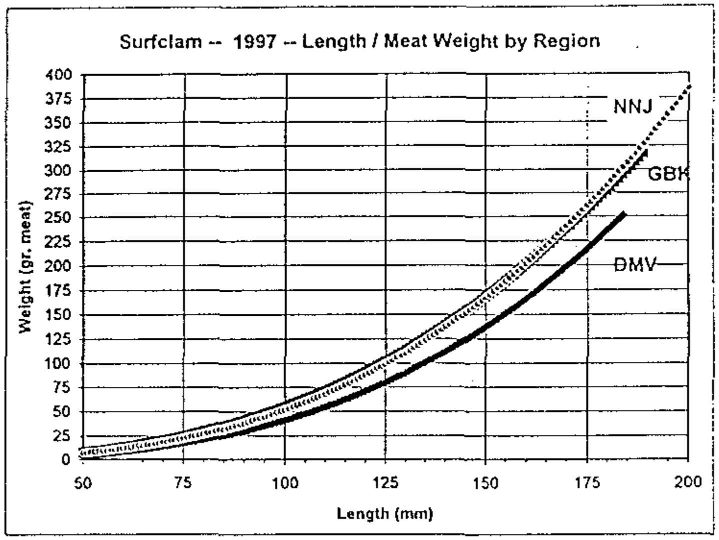


Figure B74. Surfclam shell length and meat weight by region in June-July 1997.

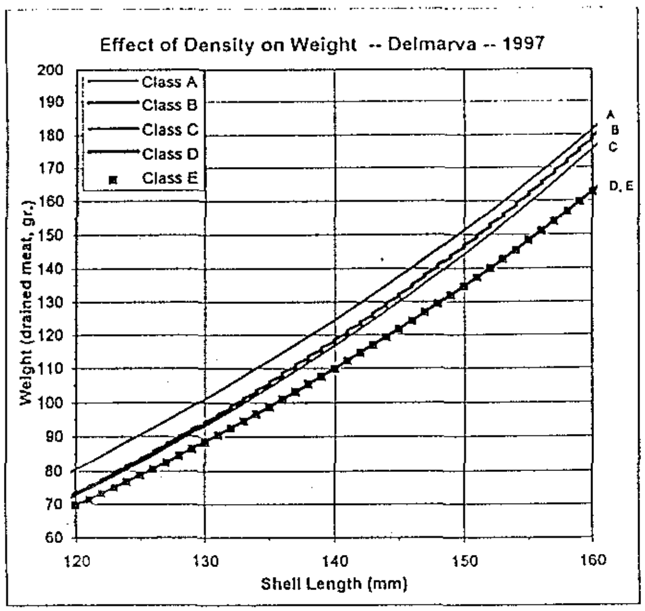


Figure B75. Surfclam shell length and meat weight as a function of surfclam density off Delmarva. Samples collected in 1997. Density classes in #/tow, standardizzed to 278 m (0.15 nmi), are "A": <10, "B": 10-24.9, "C": 25-49.9, "D": 50-199.9, "E": 200+.

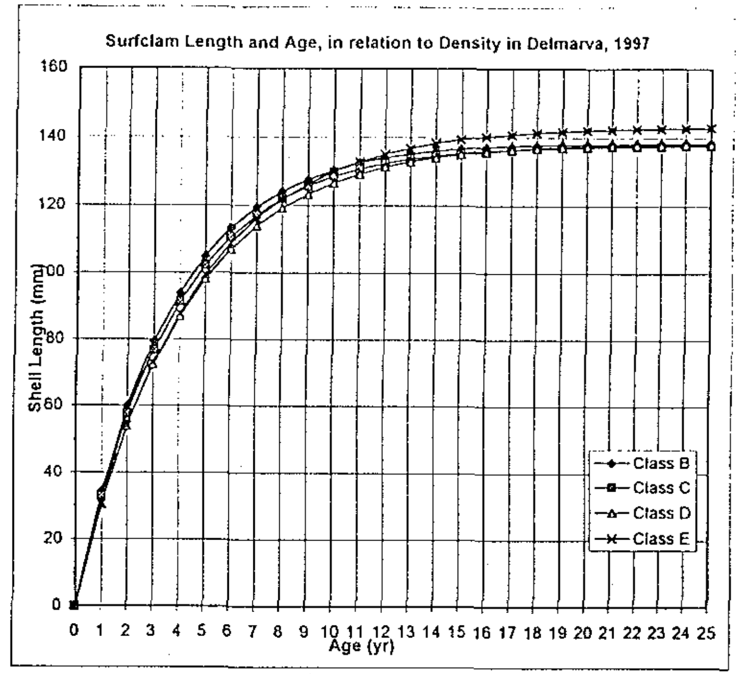


Figure B76. Surfclam shell length and age as a function of surfclam density off Delmarva. Samples collected in 1997. Density classes in #/tow, standardizzed to 278 m (0.15 nmi), are "A": <10, "B": 10-24.9, "C": 25-49.9, "D": 50-199.9, "E": 200+. Class "A" not shown because of small sample size.

APPENDIX A.
Cruise Results, Surfclam Depletion Studies
June 9-11, 1997, New Jersey Coast

Depletion Experiment #1

Location: Point Pleasant
F/V *Sherri Ann*

Date, Time: 6/9/97 0700-1545 hrs.
Seas 1-3 feet, wind NE-NW approx. 10-15 kn, skies sunny

Captain: James Harry

Owner: Tom McNulty

Science Personnel:	M. Chintalla	Rutgers
	S. Murawski	NMFS
	E. Powell	Rutgers
	C. Weidman	WHOI

Location of Experiment:
LAT: 40° 03.19'
LONG: 73° 50.35'
LORAN C x-26853.6
LORAN C y-43455.0

Water Depth: 14-15 fathoms, Knife Blade Width = 100 inches

Operations:

Two buoys deployed, tow direction due north between buoys. Approx. 200-205 feet of towing hawser. Forty dredge tows completed. A total of 10 length frequency samples were obtained.

Depletion Experiment #2

Location: Atlantic City #2, First Site
F/V *Jersey Girl*

Date, Time: 6/10/97 0900-1130 hrs.
Seas 1-3 feet, wind NE-NW approx. 10-15 kn, skies sunny

Captain: Joe Karsch

Owner: Barney Truex

Science Personnel:	M. Chintalla	Rutgers
	R. Mann	VIMS
	S. Murawski	NMFS
	C. Weidman	WHOI

Location of Experiment:
LAT: 39° 23.59'
LONG: 73° 54.62'
LORAN C x-26800.7
LORAN C y-43049.2

Water Depth: 16 fathoms

Knife Blade Width = 130 inches

Operations:

One buoy deployed, tow direction due north. A total of 13 dredge tows were completed. A total of four length frequency samples were obtained.

Depletion Experiment #3
Location: Atlantic City #2, Second Site
F/V *Jersey Girl*

Date, Time: 6/10/97 1130-1530 hrs.
Seas 1-3 feet, wind NE-NW approx. 10-15 kn, changing to southwest later in day
skies sunny

Captain: Joe Karsch

Owner: Barney Truex

Science Personnel:	M. Chintalla	Rutgers
	R. Mann	VIMS
	S. Murawski	NMFS
	C. Weidman	WHOI

Location of Experiment:

LAT: 39° 23.59'
LONG: 73° 54.62'
LORAN C x-26800.7
LORAN C y-43049.2

Water Depth: 16 fathoms

Knife Blade Width = 130 inches

Operations:

One buoy deployed, tow direction east. A total of 18 dredge tows were completed at this site. A total of four length frequency samples were obtained.

Depletion Experiment #4

Location: Atlantic City #1, First Site
F/V *Judy Marie*

Date, Time: 6/11/97 0945-1300 hrs.
Seas 1-3 feet, wind NE-NW approx. 10-15 kn,
skies sunny

Captain: Rocky

Owner: Peter LaMonica

Science Personnel:	M. Chintalla	Rutgers
	R. Mann	VIMS
	S. Murawski	NMFS
	C. Weidman	WHOI

Location of Experiment:
LAT: 39° 21.9'
LONG: 73° 53.9'
LORAN C x-26793.2
LORAN C y-43031.3

Water Depth: 16 fathoms

Knife Blade Width = 100 inches

Operations:

One buoy deployed, tow direction due north. A total of 17 dredge tows were completed at this site. A total of four length frequency samples were obtained.

Depletion Experiment #5

Location: Atlantic City #1, Second Site
F/V *Judy Marie*

Date, Time: 6/11/97 1330-1720 hrs.
Seas 1-3 feet, wind NE-NW approx. 10-15 kn, changing to SW later in the day
skies sunny

Captain: Rocky

Owner: Peter LaMonica

Science Personnel:	M. Chintalla	Rutgers
	R. Mann	VIMS
	S. Murawski	NMFS
	C. Weidman	WHOI

Location of Experiment:
LAT: 39° 21.9'
LONG: 73° 53.9'
LORAN C x-26793.2
LORAN C y-43031.3

Water Depth: 16 fathoms

Knife Blade Width = 100 inches

Operations:

One buoy deployed, tow direction east. A total of 19 dredge tows were completed at this site. A total of four length frequency samples were obtained.

4 Appendix B.

5 CATCH PER TOW DATA FOR DEPLETION EXPERIMENTS 1997

Row	Clam Species	Site Code	Fishing Vessel	Day	Mon	Year	Tow	Catch (numbers)	Catch (bushels)	Cumulative Catch	Included? (1=yes, 0=no)	Adjusted Cumulative Catch	Station Label	Adjusted Cumulative Effort	Area Swept (m^2)	TowDist (km)
8	SC	PP1	SheriAnne	9	6	97	1	36.63889	0.5	0	0	0	1	0	1130.30	0.445
9	SC	PP1	SheriAnne	9	6	97	2	879.33336	12	0.5	1	12	2	1	1231.90	0.485
10	SC	PP1	SheriAnne	9	6	97	3	907.178916	12.38	12.5	1	24.38	3	2	1109.98	0.437
11	SC	PP1	SheriAnne	9	6	97	4	1080.84726	14.75	24.88	1	39.13	4	3	1074.42	0.423
12	SC	PP1	SheriAnne	9	6	97	5	696.13891	9.5	39.63	1	48.63	5	4	1122.68	0.442
13	SC	PP1	SheriAnne	9	6	97	6	732.7778	10	49.13	1	58.63	6	5	1104.90	0.435
14	SC	PP1	SheriAnne	9	6	97	7	732.7778	10	59.13	1	68.63	7	6	1120.14	0.441
15	SC	PP1	SheriAnne	9	6	97	8	842.69447	11.5	69.13	1	80.13	8	7	1102.36	0.434
16	SC	PP1	SheriAnne	9	6	97	9	531.263905	7.25	80.63	1	87.38	9	8	1115.06	0.439
17	SC	PP1	SheriAnne	9	6	97	10	1025.88892	14	87.88	1	101.38	10	9	1191.26	0.469
18	SC	PP1	SheriAnne	9	6	97	11	806.05558	11	101.88	1	112.38	11	10	1102.36	0.434
19	SC	PP1	SheriAnne	9	6	97	12	1209.08337	16.5	112.88	1	128.88	12	11	1097.28	0.432
20	SC	PP1	SheriAnne	9	6	97	13	1025.88892	14	129.38	1	142.88	13	12	1117.60	0.440
21	SC	PP1	SheriAnne	9	6	97	14	696.13891	9.5	143.38	1	152.38	14	13	1107.44	0.436
22	SC	PP1	SheriAnne	9	6	97	15	714.458355	9.75	152.88	1	162.13	15	14	1005.84	0.396
23	SC	PP1	SheriAnne	9	6	97	16	494.625015	6.75	162.63	1	168.88	16	15	1028.70	0.405
24	SC	PP1	SheriAnne	9	6	97	17	696.13891	9.5	169.38	1	178.38	17	16	1049.02	0.413
25	SC	PP1	SheriAnne	9	6	97	18	522.470571	7.13	178.88	1	185.51	18	17	1021.08	0.402
26	SC	PP1	SheriAnne	9	6	97	19	751.097245	10.25	186.01	1	195.76	19	18	1051.56	0.414
27	SC	PP1	SheriAnne	9	6	97	20	815.581691	11.13	196.26	1	206.89	20	19	1102.36	0.434
28	SC	PP1	SheriAnne	9	6	97	21	879.33336	12	207.39	1	218.89	21	20	1089.66	0.429
29	SC	PP1	SheriAnne	9	6	97	22	696.13891	9.5	219.39	1	228.39	22	21	1150.62	0.453
30	SC	PP1	SheriAnne	9	6	97	23	879.33336	12	228.89	1	240.39	23	22	1076.96	0.424
31	SC	PP1	SheriAnne	9	6	97	24	559.109461	7.63	240.89	1	248.02	24	23	1005.84	0.396
32	SC	PP1	SheriAnne	9	6	97	25	348.069455	4.75	248.52	1	252.77	25	24	965.20	0.380
33	SC	PP1	SheriAnne	9	6	97	26	366.3889	5	253.27	1	257.77	26	25	1008.38	0.397
34	SC	PP1	SheriAnne	9	6	97	27	384.708345	5.25	258.27	1	263.02	27	26	1003.30	0.395
35	SC	PP1	SheriAnne	9	6	97	28	622.86113	8.5	263.52	1	271.52	28	27	1104.90	0.435
36	SC	PP1	SheriAnne	9	6	97	29	586.22224	8	272.02	1	279.52	29	28	1018.54	0.401
37	SC	PP1	SheriAnne	9	6	97	30	384.708345	5.25	280.02	1	284.77	30	29	980.44	0.386
38	SC	PP1	SheriAnne	9	6	97	31	604.541685	8.25	285.27	1	293.02	31	30	1125.22	0.443
39	SC	PP1	SheriAnne	9	6	97	32	512.94446	7	293.52	1	300.02	32	31	1153.16	0.454
40	SC	PP1	SheriAnne	9	6	97	33	476.30557	6.5	300.52	1	306.52	33	32	1120.14	0.441
41	SC	PP1	SheriAnne	9	6	97	34	357.595566	4.88	307.02	1	311.4	34	33	1021.08	0.402
42	SC	PP1	SheriAnne	9	6	97	35	284.317786	3.88	311.9	1	315.28	35	34	1084.58	0.427
43	SC	PP1	SheriAnne	9	6	97	36	504.151126	6.88	315.78	1	322.16	36	35	1247.14	0.491
44	SC	PP1	SheriAnne	9	6	97	37	219.83334	3	322.66	1	325.16	37	36	1109.98	0.437
45	SC	PP1	SheriAnne	9	6	97	38	274.791675	3.75	325.66	1	328.91	38	37	157.48	0.062
46	SC	PP1	SheriAnne	9	6	97	39	512.94446	7	329.41	1	335.91	39	38	683.26	0.269
47	SC	PP1	SheriAnne	9	6	97	40	219.83334	3	336.41	1	338.91	40	39	1079.50	0.425
48	SC	AC2_1	JerseyGirl	10	6	97	1	829.16625	12.5	0	1	12.5	1	1	1197.90	0.363
49	SC	AC2_1	JerseyGirl	10	6	97	2	779.416275	11.75	12.5	1	24.25	2	2	1230.90	0.373
50	SC	AC2_1	JerseyGirl	10	6	97	3	596.9997	9	24.25	1	33.25	3	3	1135.20	0.344
51	SC	AC2_1	JerseyGirl	10	6	97	4	713.082975	10.75	33.25	1	44	4	4	1221.00	0.370
52	SC	AC2_1	JerseyGirl	10	6	97	5	522.706404	7.88	44	1	51.88	5	5	1273.80	0.386
53	SC	AC2_1	JerseyGirl	10	6	97	6	497.49975	7.5	51.88	1	59.38	6	6	1260.60	0.382
54	SC	AC2_1	JerseyGirl	10	6	97	7	331.6665	5	59.38	1	64.38	7	7	1260.60	0.382
55	SC	AC2_1	JerseyGirl	10	6	97	8	323.706504	4.88	64.38	1	69.26	8	8	1260.60	0.382
56	SC	AC2_1	JerseyGirl	10	6	97	9	74.956629	1.13	69.26	1	70.39	9	9	1257.30	0.381
57	SC	AC2_1	JerseyGirl	10	6	97	10	41.789979	0.63	70.39	1	71.02	10	10	1191.30	0.361
58	SC	AC2_1	JerseyGirl	10	6	97	11	58.373304	0.88	71.02	1	71.9	11	11	1201.20	0.364
59	SC	AC2_1	JerseyGirl	10	6	97	12	116.746608	1.76	71.9	1	73.66	12	12	1092.30	0.331
60	SC	AC2_1	JerseyGirl	10	6	97	13	149.249925	2.25	73.66	1	75.91	13	13	1197.90	0.363
61	SC	AC2_2	JerseyGirl	10	6	97	1	912.9375	13.5	0	1	13.5	1	1	1428.90	0.433
62	SC	AC2_2	JerseyGirl	10	6	97	2	1352.5	20	13.5	1	33.5	2	2	1570.80	0.476
63	SC	AC2_2	JerseyGirl	10	6	97	3	1141.51	16.88	33.5	1	50.38	3	3	1435.50	0.435
64	SC	AC2_2	JerseyGirl	10	6	97	4	608.625	9	50.38	1	59.38	4	4	1465.20	0.444
65	SC	AC2_2	JerseyGirl	10	6	97	5	634.3225	9.38	59.38	1	68.76	5	5	1623.60	0.492
66	SC	AC2_2	JerseyGirl	10	6	97	6	439.5625	6.5	68.76	1	75.26	6	6	1600.50	0.485
67	SC	AC2_2	JerseyGirl	10	6	97	7	549.79125	8.13	75.26	1	83.39	7	7	1498.20	0.454

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
68	SC	AC2_2	JerseyGirl	10	6	97	8	465.26	6.88	83.39	1	90.27	8	8	1494.90	0.453
69	SC	AC2_2	JerseyGirl	10	6	97	9	321.21875	4.75	90.27	1	95.02	9	9	1511.40	0.458
70	SC	AC2_2	JerseyGirl	10	6	97	10	507.1875	7.5	95.02	1	102.52	10	10	1461.90	0.443
71	SC	AC2_2	JerseyGirl	10	6	97	11	219.78125	3.25	102.52	1	105.77	11	11	1603.80	0.486
72	SC	AC2_2	JerseyGirl	10	6	97	12	482.16625	7.13	105.77	1	112.9	12	12	1706.10	0.517
73	SC	AC2_2	JerseyGirl	10	6	97	13	152.15625	2.25	112.9	1	115.15	13	13	1508.10	0.457
74	SC	AC2_2	JerseyGirl	10	6	97	14	287.40625	4.25	115.15	1	119.4	14	14	1603.80	0.486
75	SC	AC2_2	JerseyGirl	10	6	97	15	160.9475	2.38	119.4	1	121.78	15	15	1531.20	0.464
76	SC	AC2_2	JerseyGirl	10	6	97	16	118.34375	1.75	121.78	1	123.53	16	16	1504.80	0.456
77	SC	AC2_2	JerseyGirl	10	6	97	17	67.625	1	123.53	1	124.53	17	17	1452.00	0.440
78	SC	AC2_2	JerseyGirl	10	6	97	18	33.8125	0.5	124.53	1	125.03	18	18	1501.50	0.455
79	SC	AC1_1	JudyMarie	11	6	97	1	623.785685	10.25	0	1	10.25	1	1	977.90	0.385
80	SC	AC1_1	JudyMarie	11	6	97	2	251.339988	4.13	10.25	1	14.38	2	2	934.72	0.368
81	SC	AC1_1	JudyMarie	11	6	97	3	547.71426	9	14.38	1	23.38	3	3	901.70	0.355
82	SC	AC1_1	JudyMarie	11	6	97	4	258.642845	4.25	23.38	1	27.63	4	4	1013.46	0.399
83	SC	AC1_1	JudyMarie	11	6	97	5	410.785695	6.75	27.63	1	34.38	5	5	919.48	0.362
84	SC	AC1_1	JudyMarie	11	6	97	6	182.57142	3	34.38	1	37.38	6	6	932.18	0.367
85	SC	AC1_1	JudyMarie	11	6	97	7	296.982843	4.88	37.38	1	42.26	7	7	982.98	0.387
86	SC	AC1_1	JudyMarie	11	6	97	8	304.2857	5	42.26	1	47.26	8	8	932.18	0.367
87	SC	AC1_1	JudyMarie	11	6	97	9	175.268563	2.88	47.26	1	50.14	9	9	1104.90	0.435
88	SC	AC1_1	JudyMarie	11	6	97	10	243.42856	4	50.14	0	50.14	10	9	980.44	0.386
89	SC	AC1_1	JudyMarie	11	6	97	11	281.768558	4.63	54.14	1	54.77	11	10	1003.30	0.395
90	SC	AC1_1	JudyMarie	11	6	97	12	129.625708	2.13	58.77	1	56.9	12	11	972.82	0.383
91	SC	AC1_1	JudyMarie	11	6	97	13	53.5542832	0.88	60.9	1	57.78	13	12	967.74	0.381
92	SC	AC1_1	JudyMarie	11	6	97	14	182.57142	3	61.78	1	60.78	14	13	952.50	0.375
93	SC	AC1_1	JudyMarie	11	6	97	15	38.3399982	0.63	64.78	1	61.41	15	14	934.72	0.368
94	SC	AC1_1	JudyMarie	11	6	97	16	121.71428	2	65.41	1	63.41	16	15	944.88	0.372
95	SC	AC1_1	JudyMarie	11	6	97	17	121.71428	2	67.41	1	65.41	17	16	980.44	0.386
96	SC	AC1_2	JudyMarie	11	6	97	1	759.375	12.5	0	1	12.5	1	1	1140.46	0.449
97	SC	AC1_2	JudyMarie	11	6	97	2	402.7725	6.63	12.5	1	19.13	2	2	1160.78	0.457
98	SC	AC1_2	JudyMarie	11	6	97	3	486	8	19.13	1	27.13	3	3	1168.40	0.460
99	SC	AC1_2	JudyMarie	11	6	97	4	539.46	8.88	27.13	1	36.01	4	4	1209.04	0.476
100	SC	AC1_2	JudyMarie	11	6	97	5	417.96	6.88	36.01	1	42.89	5	5	1140.46	0.449
101	SC	AC1_2	JudyMarie	11	6	97	6	554.6475	9.13	42.89	1	52.02	6	6	1143.00	0.450
102	SC	AC1_2	JudyMarie	11	6	97	7	342.0225	5.63	52.02	1	57.65	7	7	1148.08	0.452
103	SC	AC1_2	JudyMarie	11	6	97	8	326.835	5.38	57.65	1	63.03	8	8	1186.18	0.467
104	SC	AC1_2	JudyMarie	11	6	97	9	410.0625	6.75	63.03	1	69.78	9	9	1203.96	0.474
105	SC	AC1_2	JudyMarie	11	6	97	10	470.8125	7.75	69.78	1	77.53	10	10	1145.54	0.451
106	SC	AC1_2	JudyMarie	11	6	97	11	197.4375	3.25	77.53	1	80.78	11	11	1181.10	0.465
107	SC	AC1_2	JudyMarie	11	6	97	12	182.25	3	80.78	1	83.78	12	12	1145.54	0.451
108	SC	AC1_2	JudyMarie	11	6	97	13	266.085	4.38	83.78	1	88.16	13	13	1244.60	0.490
109	SC	AC1_2	JudyMarie	11	6	97	14	114.21	1.88	88.16	1	90.04	14	14	1165.86	0.459
110	SC	AC1_2	JudyMarie	11	6	97	15	197.4375	3.25	90.04	1	93.29	15	15	1143.00	0.450
111	SC	AC1_2	JudyMarie	11	6	97	16	227.8125	3.75	93.29	1	97.04	16	16	1165.86	0.459
112	SC	AC1_2	JudyMarie	11	6	97	17	486	8	97.04	0	97.04	17	16	1272.54	0.501
113	SC	AC1_2	JudyMarie	11	6	97	18	349.3125	5.75	105.04	1	102.79	18	17	1158.24	0.456
114	SC	AC1_2	JudyMarie	11	6	97	19	546.75	9	110.79	0	102.79	19	17	1209.04	0.476
115	SC	DE II	Delaware II	5	6	97	1	285	4.25373	0	1	4.253731	108	1	542.70	0.356
116	SC	DE II	Delaware II	5	6	97	2	241	3.59701	4.253731	1	7.850746	109	2	547.24	0.359
117	SC	DE II	Delaware II	5	6	97	3	300	4.47761	7.850746	1	12.32836	110	3	660.06	0.433
118	SC	DE II	Delaware II	5	6	97	4	323	4.8209	12.32836	1	17.14925	111	4	669.23	0.439
119	SC	DE II	Delaware II	5	6	97	5	371	5.53731	17.14925	1	22.68657	112	5	607.05	0.398
120	SC	DE II	Delaware II	5	6	97	6	186	2.77612	22.68657	1	25.46269	113	6	660.62	0.433
121	SC	DE II	Delaware II	5	6	97	7	250	3.73134	25.46269	1	29.19403	114	7	567.23	0.372
122	SC	DE II	Delaware II	5	6	97	8	290	4.32836	29.19403	1	33.52239	115	8	553.99	0.364
123	SC	DE II	Delaware II	5	6	97	9	284	4.23881	33.52239	1	37.76119	116	9	635.59	0.417
124	SC	DE II	Delaware II	5	6	97	10	259	3.86567	37.76119	1	41.62687	117	10	491.90	0.323
125	SC	DE II	Delaware II	5	6	97	11	335	5	41.62687	0	41.62687	118	10	504.74	0.331
126	SC	DE II	Delaware II	5	6	97	12	234	3.49254	46.62687	1	45.1194	119	11	505.44	0.332
127	SC	DE II	Delaware II	5	6	97	13	176	2.62687	50.1194	0	45.1194	120	11	555.54	0.365
128	SC	DE II	Delaware II	6	6	97	14	160	2.38806	52.74627	1	47.50746	121	12	466.80	0.306
129	SC	DE II	Delaware II	6	6	97	15	304	4.53731	55.13433	0	47.50746	122	12	498.78	0.327
130	SC	DE II	Delaware II	6	6	97	16	155	2.31343	59.67164	1	49.8209	123	13	583.00	0.383
131	SC	DE II	Delaware II	6	6	97	17	169	2.52239	61.98507	1	52.34328	124	14	633.55	0.416
132	SC	DE II	Delaware II	6	6	97	18	324	4.83582	64.50746	1	57.1791	125	15	639.12	0.419
133	SC	DE II	Delaware II	6	6	97	19	199	2.97015	69.34328	1	60.14925	126	16	585.49	0.384

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
134	SC	DE II	Delaware II	6	6	97	20	280	4.1791	72.31343	1	64.32836	127	17	532.96	0.350
135	SC	DE II	Delaware II	6	6	97	21	191	2.85075	76.49254	1	67.1791	128	18	537.90	0.353
136	SC	DE II	Delaware II	6	6	97	22	284	4.23881	79.34328	1	71.41791	129	19	565.51	0.371
137	SC	DE II	Delaware II	6	6	97	23	125	1.86567	83.58209	1	73.28358	130	20	563.70	0.370
138	SC	DE II	Delaware II	6	6	97	24	260	3.8806	85.44776	1	77.16418	131	21	509.76	0.334
139	SC	DE II	Delaware II	6	6	97	25	195	2.91045	89.32836	1	80.07463	132	22	489.86	0.321
140	SC	DE II	Delaware II	6	6	97	26	183	2.73134	92.23881	1	82.80597	133	23	472.14	0.310
141	SC	DE II	Delaware II	6	6	97	27	180	2.68657	94.97015	1	85.49254	134	24	423.06	0.278
142	SC	DE II	Delaware II	6	6	97	28	104	1.55224	97.65672	1	87.04478	135	25	442.19	0.290
143	SC	DE II	Delaware II	6	6	97	29	145	2.16418	99.20896	1	89.20896	136	26	444.00	0.291
144	SC	DE II	Delaware II	6	6	97	30	80	1.19403	101.3731	1	90.40299	137	27	469.32	0.308
145	SC	DE II	Delaware II	6	6	97	31	188	2.80597	102.5672	1	93.20896	138	28	604.79	0.397
146	SC	DE II	Delaware II	6	6	97	32	177	2.64179	105.3731	1	95.85075	139	29	587.29	0.385
147	SC	DE II	Delaware II	6	6	97	33	99	1.47761	108.0149	1	97.32836	140	30	548.97	0.360
148	SC	DE II	Delaware II	6	6	97	34	373	5.56716	109.4925	1	102.8955	141	31	597.82	0.392
149	SC	DE II	Delaware II	6	6	97	35	63	0.9403	115.0597	1	103.8358	142	32	674.03	0.442
150	SC	DE II	Delaware II	6	6	97	36	169	2.52239	116	1	106.3582	143	33	554.44	0.364
151	SC	DE II	Delaware II	6	6	97	37	145	2.16418	118.5224	1	108.5224	144	34	563.16	0.370
152	SC	DE II	Delaware II	6	6	97	38	184	2.74627	120.6866	1	111.2687	145	35	594.52	0.390
153	SC	DE II	Delaware II	6	6	97	39	251	3.74627	123.4328	1	115.0149	146	36	558.62	0.367
154	SC	DE II	Delaware II	6	6	97	40	93	1.38806	127.1791	1	116.403	147	37	509.99	0.335
155	SC	DE II	Delaware II	6	6	97	41	276	4.1194	128.5672	1	120.5224	148	38	483.26	0.317
156	SC	DE II	Delaware II	6	6	97	42	133	1.98507	132.6866	1	122.5075	149	39	428.62	0.281
157	SC	DE II	Delaware II	7	6	97	43	103	1.53731	134.6716	1	124.0448	150	40	414.82	0.272
158	SC	DE II	Delaware II	7	6	97	44	180	2.68657	136.209	1	126.7313	151	41	432.94	0.284
159	SC	DE II	Delaware II	7	6	97	45	112	1.67164	138.8955	1	128.403	152	42	548.90	0.360
160	SC	DE II	Delaware II	7	6	97	46	172	2.56716	140.5672	0	128.403	153	42	468.53	0.307
161	SC	DE II	Delaware II	7	6	97	47	188	2.80597	143.1343	1	131.209	154	43	503.89	0.331
162	SC	DE II	Delaware II	7	6	97	48	125	1.86567	145.9403	1	133.0746	155	44	691.10	0.453
163	SC	DE II	Delaware II	7	6	97	49	198	2.95522	147.806	1	136.0299	156	45	570.30	0.374
164	SC	DE II	Delaware II	7	6	97	50	179	2.67164	150.7612	1	138.7015	157	46	595.23	0.391
165	SC	DE II	Delaware II	7	6	97	51	144	2.14925	153.4328	1	140.8507	158	47	617.02	0.405
166	SC	DE II	Delaware II	7	6	97	52	228	3.40299	155.5821	1	144.2537	159	48	565.68	0.371
167	SC	DE II	Delaware II	7	6	97	53	178	2.65672	158.9851	1	146.9104	160	49	521.22	0.342
168	SC	DE II	Delaware II	7	6	97	54	182	2.71642	161.6418	1	149.6269	161	50	517.92	0.340
169	SC	DE II	Delaware II	7	6	97	55	131	1.95522	164.3582	1	151.5821	162	51	514.48	0.338
170	SC	DE II	Delaware II	11	6	97	56	113	1.68657	166.3134	1	153.2687	193	52	548.90	0.360
171	SC	DE II	Delaware II	11	6	97	57	147	2.19403	168	1	155.4627	194	53	548.90	0.360
172	SC	DE II	Delaware II	11	6	97	58	189	2.8209	170.194	1	158.2836	195	54	522.07	0.343
173	SC	DE II	Delaware II	11	6	97	59	123	1.83582	173.0149	1	160.1194	196	55	633.16	0.415
174	SC	DE II	Delaware II	11	6	97	60	102	1.52239	174.8507	1	161.6418	197	56	564.09	0.370
175	SC	DE II	Delaware II	11	6	97	61	177	2.64179	176.3731	1	164.2836	198	57	604.17	0.396
176	SC	DE II	Delaware II	11	6	97	62	124	1.85075	179.0149	1	166.1343	199	58	603.52	0.396
177	SC	DE II	Delaware II	11	6	97	63	78	1.16418	180.8657	1	167.2985	200	59	548.90	0.360
178	SC	DE II	Delaware II	11	6	97	64	114	1.70149	182.0299	1	169	201	60	562.29	0.369
179	SC	DE II	Delaware II	11	6	97	65	48	0.71642	183.7313	1	169.7164	202	61	516.42	0.339
180																

Appendix C.
Delaware II Depletion Experiment

Pop Est (bushels)	p Parameter	Area (m^2)	Density (bu/m^2)	Ave Area of Tow (m^2)	Estimated Efficiency
335.912	0.011	28137	0.011938	548.8988	0.587937

Number / Bushel
67

Density (numbers / m^2)
0.7998758

Maximum likelihood model to estimate population size using the method of Gould and Pollock 1997

Structural Model

Catch #	Tow	Catch (bu)	Obs T	Pred C	Nonlinear Least Squares (Obs-Pred)^2
285	1	4.254	0	4.145863	0.011636
241	2	3.597	4.253731	4.084994	0.238123
300	3	4.478	7.850746	4.033522	0.197216
323	4	4.821	12.32836	3.969449	0.724961
371	5	5.537	17.14925	3.900464	2.679275
186	6	2.776	22.68657	3.821228	1.092252
250	7	3.731	25.46269	3.781503	0.002516
290	8	4.328	29.19403	3.728109	0.360299
284	9	4.239	33.52239	3.666172	0.327909
259	10	3.866	37.76119	3.605517	0.067681
234	11	3.493	41.62687	3.550201	0.003325
160	12	2.388	45.1194	3.500224	1.23691
155	13	2.313	47.50746	3.466052	1.328531
169	14	2.522	49.8209	3.432948	0.829119
324	15	4.836	52.34328	3.396854	2.070627
199	16	2.97	57.1791	3.327655	0.127811
280	17	4.179	60.14925	3.285154	0.799148
191	18	2.851	64.32836	3.225353	0.14033
284	19	4.239	67.1791	3.18456	1.111435
125	20	1.866	71.41791	3.123904	1.583149
260	21	3.881	73.28358	3.097207	0.613699
195	22	2.91	77.16418	3.041678	0.017221
183	23	2.731	80.07463	3.000031	0.072193
180	24	2.687	82.80597	2.960946	0.075284
104	25	1.552	85.49254	2.922503	1.877623
145	26	2.164	87.04478	2.900291	0.541861
80	27	1.194	89.20896	2.869322	2.806605
188	28	2.806	90.40299	2.852236	0.002141
177	29	2.642	93.20896	2.812084	0.029
99	30	1.478	95.85075	2.774281	1.681352

Gould and Pollock Method			
Term	Q(p^)	Likelihood	LogLike
0	-0.01147	0.023	-16.102
1	-0.011338	0.022	-13.657
2	-0.011208	0.022	-17.053
3	-0.011079	0.022	-18.416
4	-0.010952	0.022	-21.216
5	-0.010827	0.021	-10.669
6	-0.010703	0.021	-14.383
7	-0.01058	0.021	-16.734
8	-0.010458	0.021	-16.437
9	-0.010338	0.02	-15.034
10	-0.01022	0.02	-13.623
11	-0.010103	0.02	-9.3427
12	-0.009987	0.02	-9.0774
13	-0.009872	0.02	-9.9264
14	-0.009759	0.019	-19.066
15	-0.009647	0.019	-11.757
16	-0.009536	0.019	-16.591
17	-0.009427	0.019	-11.35
18	-0.009319	0.018	-16.925
19	-0.009212	0.018	-7.4711
20	-0.009106	0.018	-15.585
21	-0.009002	0.018	-11.722
22	-0.008899	0.018	-11.032
23	-0.008797	0.017	-10.882
24	-0.008696	0.017	-6.3055
25	-0.008596	0.017	-8.8163
26	-0.008497	0.017	-4.8779
27	-0.0084	0.017	-11.496
28	-0.008304	0.016	-10.853
29	-0.008208	0.016	-4.9193

Predicted Catch	Residual	SS(N,p)	Chi-Square
3.852749	0.400982	0.1608	0.04173
3.803961	-0.20695	0.0428	0.01126
3.762705	0.714907	0.5111	0.13583
3.711349	1.109547	1.2311	0.33171
3.656056	1.881258	3.5391	0.96802
3.592545	-0.81643	0.6666	0.18554
3.560705	0.170639	0.0291	0.00818
3.517908	0.81045	0.6568	0.18671
3.468264	0.770542	0.5937	0.17119
3.419647	0.446025	0.1989	0.05818
3.375309	0.117228	0.0137	0.00407
3.335251	-0.94719	0.8972	0.269
3.307862	-0.99443	0.9889	0.29895
3.281328	-0.75894	0.576	0.17554
3.252397	1.583424	2.5072	0.77089
3.196932	-0.22678	0.0514	0.01609
3.162866	1.016238	1.0327	0.32652
3.114934	-0.26419	0.0698	0.02241
3.082237	1.156569	1.3377	0.43399
3.03362	-1.16795	1.3641	0.44966
3.012222	0.868375	0.7541	0.25034
2.967713	-0.05727	0.0033	0.00111
2.934332	-0.20299	0.0412	0.01404
2.903005	-0.21644	0.0468	0.01614
2.872191	-1.31995	1.7423	0.6066
2.854388	-0.69021	0.0151	0.0053
2.829565	-1.63554	0.0204	0.00723
2.81587	-0.0099	1.5968	0.56706
2.783687	-0.1419	0.3838	0.13787
2.753387	-1.27578	2.4316	0.88313

Residual Bounds	
-Pred Std Error	+Pred Std Error
-1.952	1.951553
-1.939	1.939157
-1.929	1.928613
-1.915	1.915406
-1.901	1.901085
-1.885	1.8845
-1.876	1.87613
-1.865	1.864821
-1.852	1.851617
-1.839	1.838593
-1.827	1.826635
-1.816	1.815764
-1.808	1.808293
-1.801	1.801025
-1.793	1.793068
-1.778	1.777713
-1.768	1.768217
-1.755	1.754767
-1.746	1.745533
-1.732	1.731712
-1.726	1.725594
-1.713	1.712797
-1.703	1.703137
-1.694	1.694021
-1.685	1.685007
-1.68	1.679776
-1.672	1.672457
-1.668	1.668405
-1.659	1.658843
-1.65	1.64979

373	31	5.567	97.32836	2.753137	7.918746
63	32	0.94	102.8955	2.673474	3.003897
169	33	2.522	103.8358	2.660019	0.018942
145	34	2.164	106.3582	2.623924	0.211366
184	35	2.746	108.5224	2.592956	0.023505
251	36	3.746	111.2687	2.553658	1.42232
93	37	1.388	115.0149	2.500051	1.236524
276	38	4.119	116.403	2.480188	2.687025
133	39	1.985	120.5224	2.421241	0.190241
103	40	1.537	122.5075	2.392836	0.731918
180	41	2.687	124.0448	2.370837	0.099685
112	42	1.672	126.7313	2.332394	0.436593
188	43	2.806	128.403	2.308473	0.247503
125	44	1.866	131.209	2.268321	0.162127
198	45	2.955	133.0746	2.241624	0.509224
179	46	2.672	136.0299	2.199336	0.223072
144	47	2.149	138.7015	2.161106	0.00014
228	48	3.403	140.8507	2.130352	1.619596
178	49	2.657	144.2537	2.081656	0.330694
182	50	2.716	146.9104	2.04364	0.45263
131	51	1.955	149.6269	2.004769	0.002455
113	52	1.687	151.5821	1.976791	0.08423
147	53	2.194	153.2687	1.952657	0.058261
189	54	2.821	155.4627	1.921261	0.809342
123	55	1.836	158.2836	1.880896	0.002032
102	56	1.522	160.1194	1.854626	0.110382
177	57	2.642	161.6418	1.832841	0.6544
124	58	1.851	164.2836	1.795038	0.003103
78	59	1.164	166.1343	1.768555	0.36527
114	60	1.701	167.2985	1.751896	0.002541
48	61	0.716	169	1.727548	1.022385

30	-0.008114	0.016	-11.593
31	-0.008021	0.016	-10.945
32	-0.007929	0.016	-6.1387
33	-0.007838	0.016	-23.193
34	-0.007748	0.015	-3.9282
35	-0.007659	0.015	-10.567
36	-0.007572	0.015	-9.0909
37	-0.007485	0.015	-11.568
38	-0.007399	0.015	-15.823
39	-0.007314	0.014	-5.8788
40	-0.00723	0.014	-17.494
41	-0.007147	0.014	-8.4531
42	-0.007065	0.014	-6.5641
43	-0.006984	0.014	-11.502
44	-0.006904	0.014	-7.1762
45	-0.006825	0.014	-12.078
46	-0.006747	0.013	-8.0522
47	-0.006669	0.013	-12.789
48	-0.006593	0.013	-11.592
49	-0.006517	0.013	-9.3505
50	-0.006442	0.013	-14.844
51	-0.006369	0.013	-11.62
52	-0.006295	0.012	-11.912
53	-0.006223	0.012	-8.5966
54	-0.006152	0.012	-7.4349
55	-0.006081	0.012	-9.6972
56	-0.006012	0.012	-12.5
57	-0.005943	0.012	-8.1563
58	-0.005874	0.012	-6.7814
59	-0.005807	0.011	-11.798
60	-0.00574	0.011	-8.2867

2.73644	2.830724	0.0048	0.00177
2.672587	-1.73229	0.0009	0.00035
2.661802	-0.13941	1.4023	0.52683
2.632872	-0.46869	8.6101	3.27022
2.60805	0.138219	2.7814	1.06647
2.576551	1.169717	0.0029	0.00114
2.533583	-1.14552	0.1365	0.05386
2.517663	1.60174	0.0523	0.02076
2.470415	-0.48534	1.6278	0.65892
2.447648	-0.91033	1.1227	0.4587
2.430015	0.256552	2.854	1.17449
2.399202	-0.72756	0.1715	0.07148
2.380029	0.425941	0.7102	0.29839
2.347846	-0.48217	0.1147	0.04887
2.326447	0.628777	0.4288	0.1843
2.292552	0.37909	0.2636	0.11498
2.26191	-0.11266	0.157	0.06941
2.237259	1.165726	0.5155	0.2304
2.198228	0.458488	0.2241	0.10195
2.167757	0.548661	0.0003	0.00016
2.136601	-0.18138	1.6037	0.7506
2.114176	-0.42761	0.2944	0.13923
2.094831	0.099198	0.3864	0.18444
2.069667	0.751229	0.0131	0.00633
2.037313	-0.20149	0.123	0.06038
2.016257	-0.49387	0.0316	0.01567
1.998796	0.642995	0.6758	0.33813
1.968496	-0.11775	0.0176	0.00894
1.947268	-0.78309	0.1805	0.09271
1.933916	-0.23242	0.5011	0.25911
1.9144	-1.19798	0.0041	0.00212

-1.645	1.644705
-1.625	1.625403
-1.622	1.62212
-1.613	1.61328
-1.606	1.605658
-1.596	1.595932
-1.583	1.582569
-1.578	1.577589
-1.563	1.562716
-1.555	1.555498
-1.55	1.549885
-1.54	1.540027
-1.534	1.533861
-1.523	1.523456
-1.516	1.516497
-1.505	1.50541
-1.495	1.495315
-1.487	1.487144
-1.474	1.474115
-1.464	1.463863
-1.453	1.453305
-1.446	1.445658
-1.439	1.439029
-1.43	1.43036
-1.419	1.419136
-1.412	1.411783
-1.406	1.405657
-1.395	1.394962
-1.387	1.38742
-1.383	1.382655
-1.376	1.375661

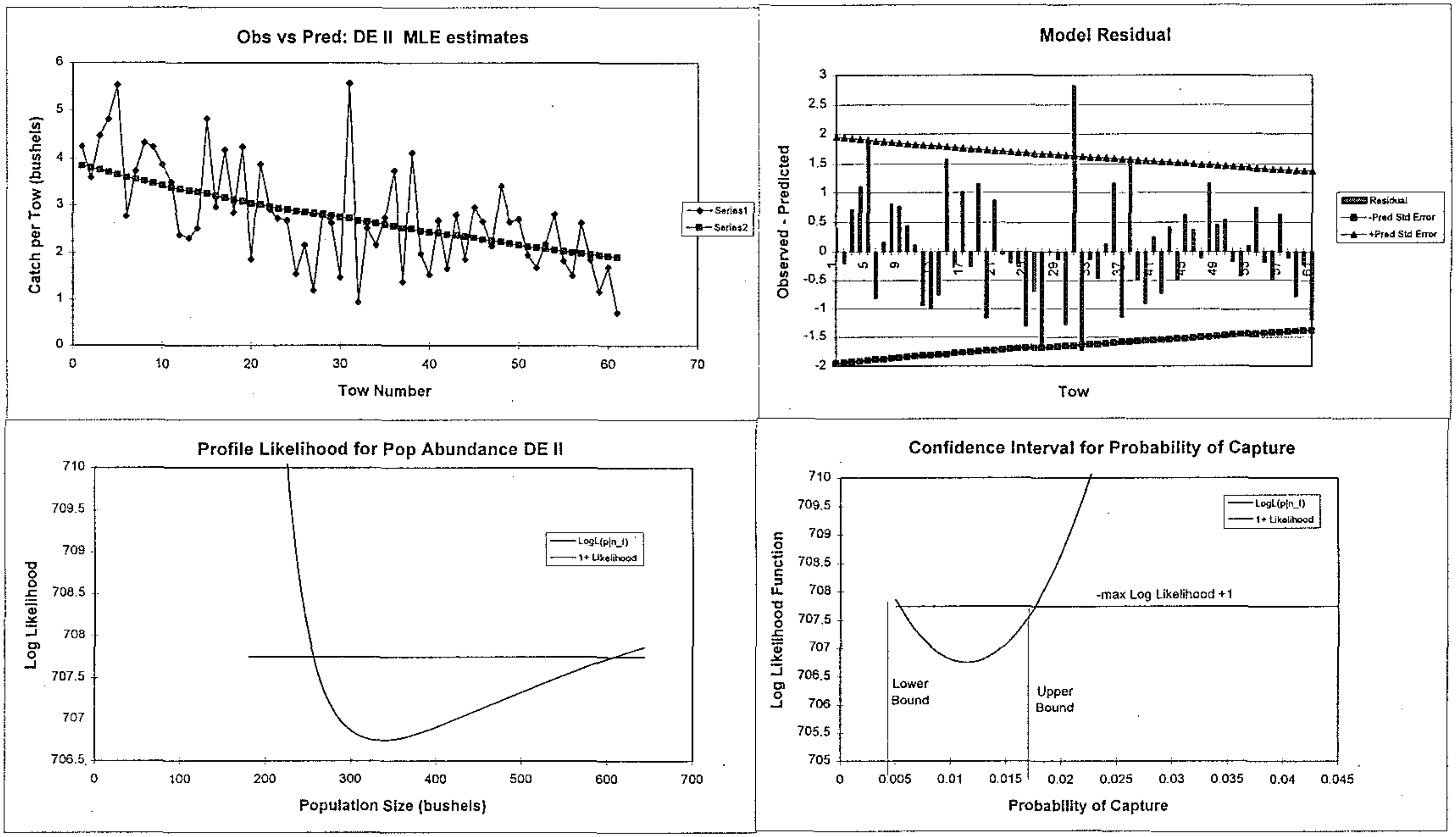
Total Catch
169.7164

Parameter Estimates			Nonlinear
N	p		SumSquares
289.7	0.01431		47.28938
Non Linear LS Model: Catch=p(N-T)			

Simple Linear Regression Estimates			
a=Np	b=-p	R_sqr	N_hat
4.146	-0.01431	0.382335	289.7275

Q	0.4947593	706.743	LogLikelihood	0.022473	48.517	17.5654		
Initial Parameter Estimates				0.89854				
p	q	N_hat					Chi2GOF	1
0.0114695	0.989	**335.912**						

Delaware II Depletion Experiment



Atlantic City Site #1. Station #1

Pop Est (bushels)	p Parameter	Area (m^2)	Number per Bushel	Total Number	Density (#/m^2)	Ave Area of Tow (m^2)	Est Efficiency	Sum of Tow Areas (m^2)
80.11005	0.101	8223	60.8571	4875.27	0.5929	1195.23	0.691752	15097

Maximum likelihood model to estimate population size using the method of Gould and Pollock 1997

Site= AC1-1

Nonlinear Least Squares

Tow	Catch (bushels)	Obs T	Pred C	(Obs-Pred)^2
1	10.25	0	8.4761	3.14672
2	4.13	10.25	7.39736	10.6756
3	9	14.38	6.9627	4.15057
4	4.25	23.38	6.01552	3.11705
5	6.75	27.63	5.56823	1.39657
6	3	34.38	4.85784	3.45158
7	4.88	37.38	4.54211	0.11417
8	5	42.26	4.02853	0.94376
9	2.88	47.26	3.50231	0.38727
10	4.63	50.14	3.19921	2.04716
11	2.13	54.77	2.71194	3.67897
12	0.88	56.9	2.48777	0.128
13	3	57.78	2.39515	2.29569
14	0.63	60.78	2.07942	0.84746
15	2	61.41	2.01312	1.91303
16	2	63.41	1.80264	0.03895
		65.41		38.3326

Parameter Estimates			
N	p		SumSquares
80.54	0.10524		38.3326
Non Linear LS Model: Catch=p(N-T)			

Simple Linear Regression Estimates			
a=Np	b=-p	R_sqr	N_hat
8.578	-0.11187	0.68828	76.6764

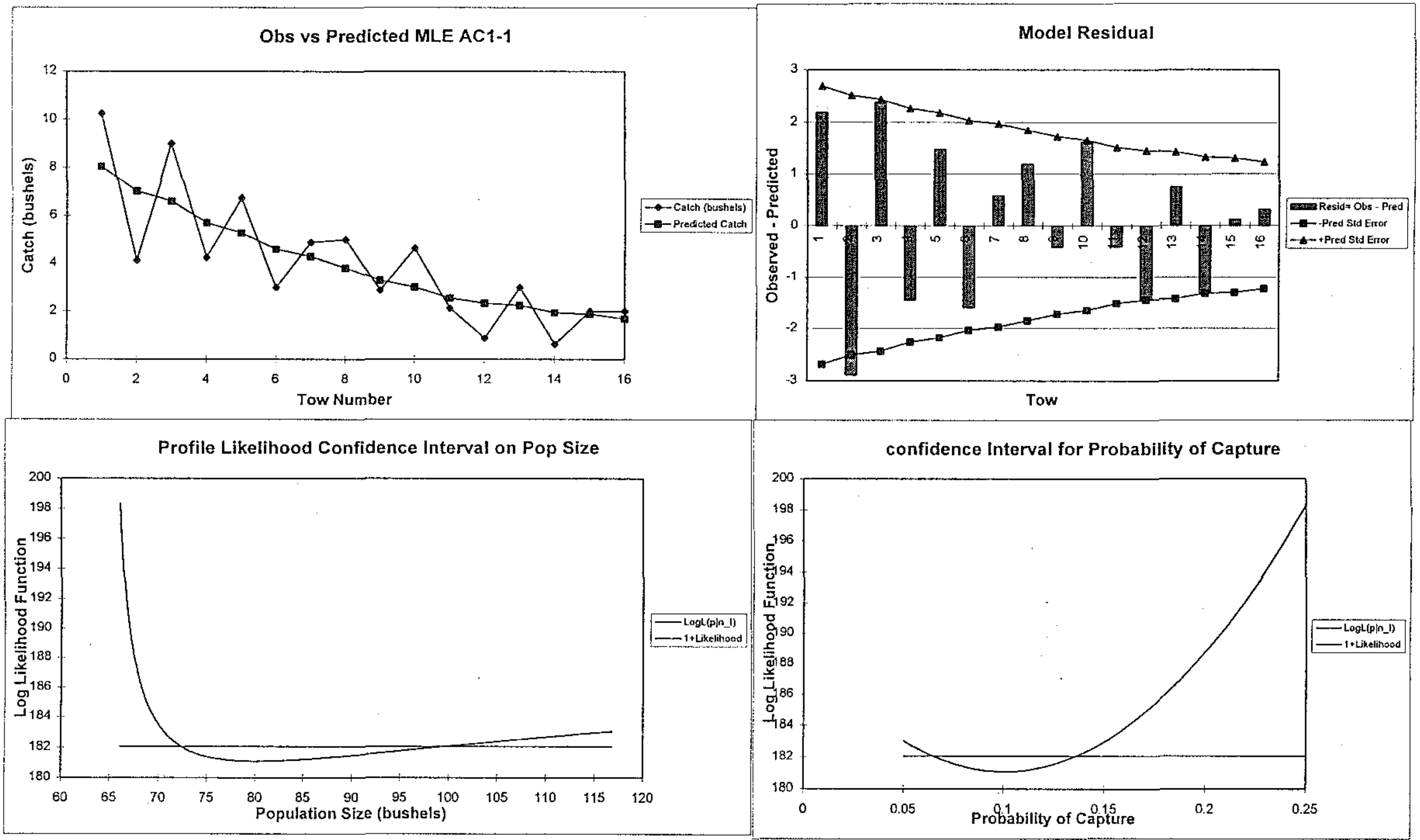
Gould and Pollock Method

Term	Q(p^)	Likelihood	LogLike	Predicted Catch	Resid= Obs Pred	SS(N,p)	Chi-Square	-Pred Std Error	+Pred Std Error
0	-0.101	0.123	-21.47	8.055072	2.194928	4.81771	0.5981	-2.692	2.692
1	-0.09	0.111	-9.087	7.024434	-2.8944336	8.37775	1.19266	-2.514	2.514
2	-0.081	0.1	-20.76	6.609162	2.3908382	5.71611	0.86488	-2.438	2.438
3	-0.073	0.09	-10.25	5.704211	-1.4542111	2.11473	0.37073	-2.265	2.265
4	-0.066	0.081	-17	5.276873	1.4731268	2.1701	0.41125	-2.179	2.179
5	-0.059	0.072	-7.873	4.59816	-1.5981602	2.55412	0.55546	-2.034	2.034
6	-0.053	0.065	-13.32	4.29651	0.5834901	0.34046	0.07924	-1.966	1.966
7	-0.048	0.059	-14.18	3.805826	1.1941745	1.42605	0.3747	-1.85	1.85
8	-0.043	0.053	-8.473	3.303075	-0.4230751	0.17899	0.05419	-1.724	1.724
9	-0.039	0.047	-14.11	3.013491	1.6165091	2.6131	0.86713	-1.646	1.646
10	-0.035	0.043	-14.6	2.547944	-0.417944	4.33496	1.70135	-1.514	1.514
11	-0.031	0.038	-6.944	2.333772	-1.4537723	0.04152	0.01779	-1.449	1.449
12	-0.028	0.035	-2.962	2.245288	0.7547117	1.86401	0.83019	-1.421	1.421
13	-0.025	0.031	-10.42	1.943638	-1.313638	1.1159	0.57413	-1.322	1.322
14	-0.023	0.028	-2.254	1.880291	0.1197085	1.56323	0.83138	-1.3	1.3
15	-0.021	0.025	-7.368	1.679191	0.3208087	0.10292	0.06129	-1.229	1.229
Q	0.183		181.1 LogLikelihood			39.3317	9.38447		

Initial Parameter Estimates			
N	p	q	N_hat
	0.101	0.899	80.11

Chi2GOF 1

Atlantic City Site #1, Station #1.



Atlantic City Site #1. Station #2

Pop Est (bushels)	p Parameter	Area (m^2)	Number per Bushel	Total Number	Density (#/m^2)	Ave Area of Tow (m^2)	Est Efficiency	Sum of Tow Areas (m^2)
147.8727	0.067	12870	60.75	8983.3	0.698	1195.23	0.7267022	21944.5

Check number of tows
1372

Maximum likelihood model to estimate population size using the method of Gould and Pollock 1997
Site= AC1-2 Tows 17 and 19 deleted

Structural Model

Tow	Catch	Obs T	Pred C	Nonlinear Least Squares (Obs-Pred)^2
1	12.5	0	10.212	5.2363
2	6.63	12.5	9.3183	7.22715
3	8	19.13	8.8445	0.71317
4	8.88	27.13	8.2727	0.36877
5	6.88	36.01	7.6381	0.5747
6	9.13	42.89	7.1464	3.93475
7	5.63	52.02	6.4939	0.74626
8	5.38	57.65	6.0915	0.50622
9	6.75	63.03	5.707	1.08788
10	7.75	69.78	5.2246	6.37782
11	3.25	77.53	4.6707	2.01832
12	3	80.78	4.4384	2.069
13	4.38	83.78	4.224	0.02434
14	1.88	88.16	3.911	4.12479
15	3.25	90.04	3.7766	0.2773
16	3.75	93.29	3.5443	0.0423
17	5.75	97.04	3.2763	6.11915
		102.79		41.4482

Parameter Estimates

N	p	SumSquares
142.9	0.07147	41.4482

Non Linear LS Model: Catch=p(N-T)

Simple Linear Regression Estimates

a=Np	b=-p	R_sqr	N_hat
10.21	-0.0715	0.6501	142.882

Gould and Pollock Method

Term	Q(p^)	Likelihood	LogLike
0	-0.067	0.1	-29.152
1	-0.063	0.09	-15.925
2	-0.059	0.08	-19.775
3	-0.055	0.08	-22.571
4	-0.051	0.07	-17.968
5	-0.048	0.07	-24.482
6	-0.044	0.06	-15.49
7	-0.041	0.06	-15.178
8	-0.039	0.06	-19.515
9	-0.036	0.05	-22.948
10	-0.034	0.05	-9.8503
11	-0.031	0.05	-9.3022
12	-0.029	0.04	-13.887
13	-0.027	0.04	-6.0921
14	-0.025	0.04	-10.759
15	-0.024	0.03	-12.676
16	-0.022	0.03	-19.838
Q	0.305		285.409 LogLikelihood

Initial Parameter Estimates

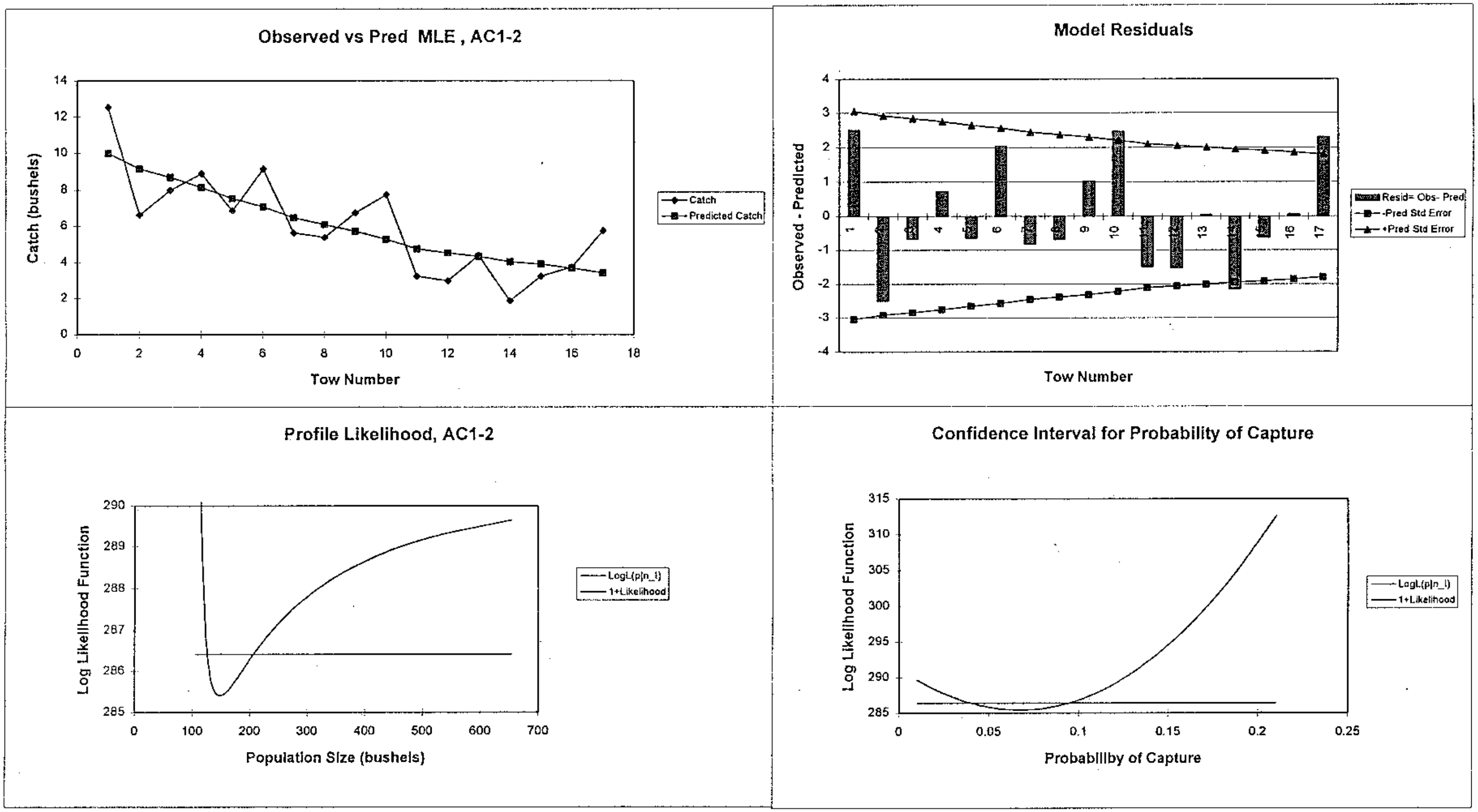
N	p	q	N_hat
	0.067	0.93	147.873

Predicted Catch	Resid= Obs Pred	SS(N,p)	Chi-Square
9.979697	2.5203028	6.35193	0.63648
9.136092	-2.506092	6.2805	0.68744
8.688643	-0.688643	0.47423	0.05458
8.148736	0.7312643	0.53475	0.06562
7.549438	-0.669438	0.44815	0.05936
7.085118	2.0448822	4.18154	0.59019
6.468948	-0.838948	0.70383	0.1088
6.088988	-0.708988	0.50266	0.08255
5.7259	1.0240995	1.04878	0.18316
5.270353	2.4796465	6.14865	1.16665
4.747318	-1.497318	2.24196	0.47226
4.527981	-1.527981	2.33472	0.51562
4.325515	0.0544848	0.00297	0.00069
4.029916	-2.149916	4.62214	1.14696
3.903038	-0.653038	0.42646	0.10926
3.6837	0.0662999	0.0044	0.00119
3.430618	2.3193816	5.37953	1.56809
		41.6872	7.44892

Chi2GOF 0.964

-Pred Std Error	+Pred Std Error
-3.051	3.051
-2.919	2.919
-2.846	2.846
-2.757	2.757
-2.653	2.653
-2.57	2.57
-2.456	2.456
-2.383	2.383
-2.311	2.311
-2.217	2.217
-2.104	2.104
-2.055	2.055
-2.008	2.008
-1.939	1.939
-1.908	1.908
-1.853	1.853
-1.789	1.789

Atlantic City Site #1, Station #2.



Point Pleasant Site #1.

Pop Est (bushels)	p Parameter	Area (m^2)	Number per Bushel	Total Number	Density (#/m^2)	Ave Area of Tow (m^2)	Est Efficiency	Sum of Tow Areas (m^2)
527.377	0.026	22141	73.278	38645	1.74543	1521.93	0.379231	42221.7

Maximum likelihood model to estimate population size using the method of Gould and Pollock 1997
Site= PP1

Structural Model

Nonlinear Least Squares

Tow	Catch	Obs T	Pred C	(Obs-Pred)^2
1	12	0	13.4396	2.07245
2	12.75	12	13.1459	0.1567
3	14.75	24.75	12.8338	3.67201
4	9.5	39.5	12.4727	8.83689
5	10	49	12.2401	5.01824
6	10	59	11.9954	3.98145
7	11.5	69	11.7506	0.06278
8	7.25	80.5	11.4691	17.8005
9	14	87.75	11.2916	7.33547
10	11	101.75	10.9489	0.00261
11	16.5	112.75	10.6796	33.8768
12	14	129.25	10.2757	13.8702
13	9.5	143.25	9.93302	0.18751
14	9.75	152.75	9.70048	0.00245
15	6.75	162.5	9.46181	7.3539
16	9.5	169.25	9.29658	0.04138
17	7.5	178.75	9.06403	2.44619
18	10.25	186.25	8.88044	1.8757
19	11.13	196.5	8.62953	6.22736
20	12	207.63	8.35721	13.27
21	9.5	219.63	8.06346	2.06364
22	12	229.13	7.83091	17.3813
23	7.625	241.13	7.53717	0.00771
24	4.75	248.75	7.35052	6.76269
25	5	253.5	7.23424	4.99185
26	5.25	258.5	7.11185	3.46649
27	8.5	263.75	6.98334	2.30027
28	8	272.25	6.77527	1.49997
29	5.25	280.25	6.57944	1.76741
30	8.25	285.5	6.45092	3.23667
31	7	293.75	6.24898	0.56404
32	6.5	300.75	6.07762	0.1784
33	4.875	307.25	5.91851	1.08892
34	3.875	312.13	5.79918	3.70246
35	6.875	316	5.70432	1.37048
36	3	322.88	5.53603	6.43146
37	3.25	325.88	5.4626	4.89558
38	7	329.13	5.38304	2.61456
39	3	336.13	5.21169	4.89157

197.306 Total SS

339.13

0

Parameter Estimates		Nonlinear SumSquares
N	q	
549	0.0245	197.306
Non Linear LS Model: Catch=p(N-T)		

Simple Linear Regression Estimates			
a=Np	b=-p	R_sqr	N_hat
13.44	-0.0245	0.5516	549.032

Gould and Pollock Method

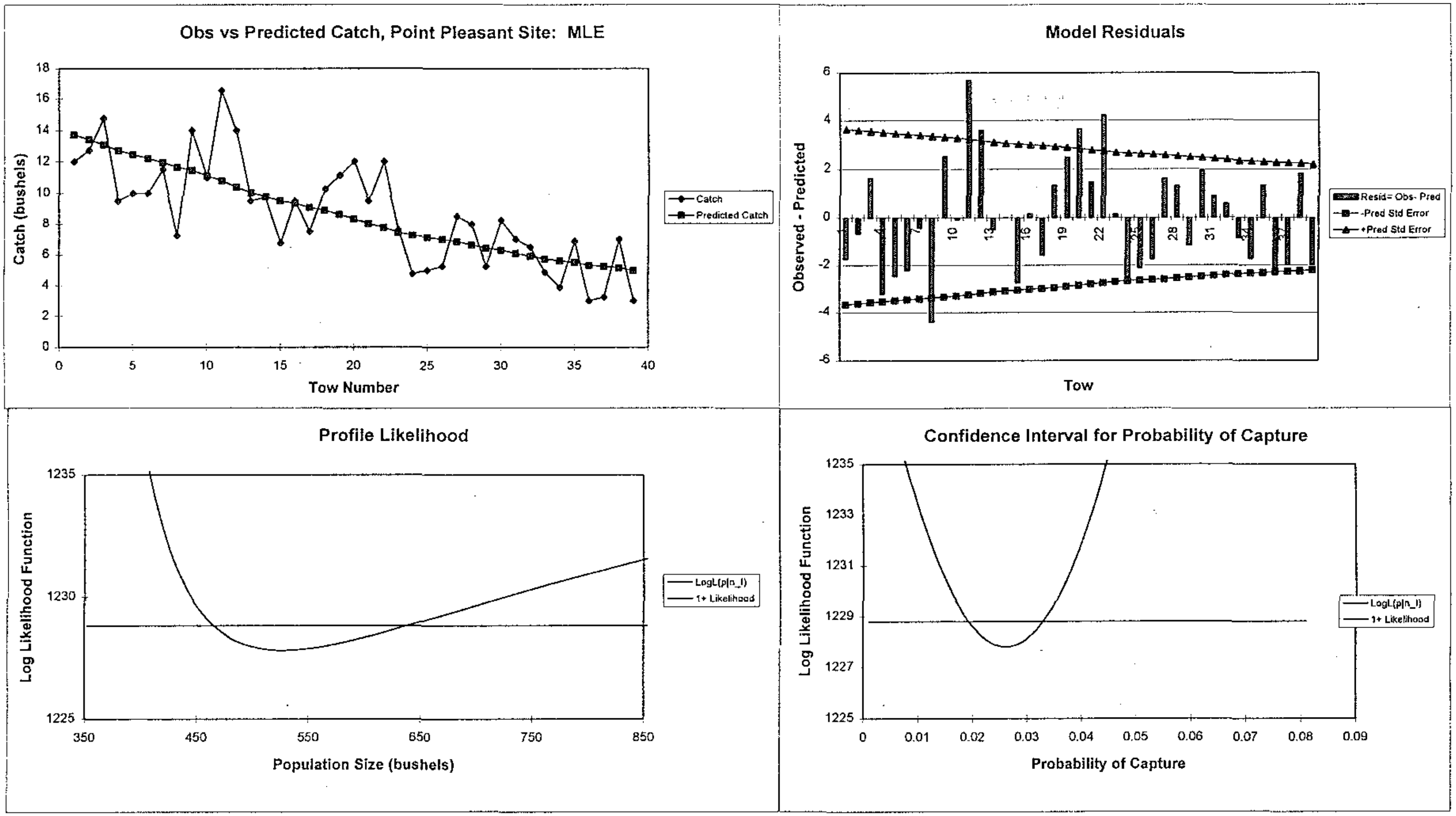
Term	Q(p^)	Likelihood	LogLike	Predicted Catch	Resid= Obs-Pred	SS(N,p)	Chi-Square	-Pred Std Error	+Pred Std Error
0	-0.03	0.04	-38.466	13.74762	-1.748	3.0542	0.22216	-3.66	3.6591
1	-0.03	0.04	-41.207	13.43481	-0.685	0.469	0.03491	-3.62	3.6173
2	-0.02	0.04	-48.06	13.10244	1.648	2.7145	0.20717	-3.57	3.5722
3	-0.02	0.04	-31.205	12.71794	-3.218	10.355	0.81421	-3.52	3.5194
4	-0.02	0.04	-33.112	12.47029	-2.47	6.1023	0.48935	-3.48	3.485
5	-0.02	0.04	-33.376	12.20961	-2.21	4.8824	0.39988	-3.45	3.4484
6	-0.02	0.03	-38.686	11.94893	-0.449	0.2015	0.01687	-3.41	3.4114
7	-0.02	0.03	-24.58	11.64915	-4.399	19.353	1.66128	-3.37	3.3683
8	-0.02	0.03	-47.835	11.46016	2.54	6.4508	0.56289	-3.34	3.3409
9	-0.02	0.03	-37.875	11.09521	-0.095	0.0091	0.00082	-3.29	3.2872
10	-0.02	0.03	-57.249	10.80846	5.692	32.394	2.99706	-3.24	3.2445
11	-0.02	0.03	-48.945	10.37834	3.622	13.116	1.26383	-3.18	3.1793
12	-0.02	0.03	-33.463	10.01339	-0.513	0.2636	0.02632	-3.12	3.1229
13	-0.02	0.03	-34.602	9.765744	-0.016	0.0002	2.5E-05	-3.08	3.084
14	-0.02	0.03	-24.133	9.511581	-2.762	7.6263	0.80179	-3.04	3.0436
15	-0.02	0.03	-34.216	9.335623	0.164	0.027	0.00289	-3.02	3.0153
16	-0.02	0.03	-27.211	9.087977	-1.588	2.5217	0.27747	-2.98	2.9751
17	-0.02	0.03	-37.459	8.892468	1.358	1.8429	0.20724	-2.94	2.9429
18	-0.02	0.03	-40.951	8.625271	2.5	6.2486	0.72446	-2.9	2.8983
19	-0.02	0.02	-44.488	8.335266	3.665	13.43	1.61126	-2.85	2.8492
20	-0.02	0.02	-35.471	8.02245	1.478	2.1832	0.27213	-2.8	2.7952
21	-0.01	0.02	-45.122	7.774805	4.225	17.852	2.29617	-2.75	2.7518
22	-0.01	0.02	-28.873	7.46199	0.163	0.0266	0.00356	-2.7	2.6958
23	-0.01	0.02	-18.112	7.263222	-2.513	6.3163	0.86963	-2.66	2.6597
24	-0.01	0.02	-19.197	7.139399	-2.139	4.577	0.64109	-2.64	2.6369
25	-0.01	0.02	-20.296	7.009059	-1.759	3.0943	0.44147	-2.61	2.6127
26	-0.01	0.02	-33.084	6.872203	1.628	2.6497	0.38557	-2.59	2.5871
27	-0.01	0.02	-31.349	6.650625	1.349	1.8208	0.27378	-2.55	2.545
28	-0.01	0.02	-20.712	6.442082	-1.192	1.4211	0.22059	-2.5	2.5048
29	-0.01	0.02	-32.765	6.305225	1.945	3.7821	0.59984	-2.48	2.4781
30	-0.01	0.02	-27.985	6.090164	0.91	0.8278	0.13592	-2.44	2.4354
31	-0.01	0.02	-26.158	5.907689	0.592	0.3508	0.05939	-2.4	2.3987
32	-0.01	0.02	-19.747	5.738247	-0.863	0.7452	0.12986	-2.36	2.364
33	-0.01	0.02	-15.799	5.611166	-1.736	3.0143	0.53719	-2.34	2.3377
34	-0.01	0.02	-28.212	5.510153	1.365	1.8628	0.33807	-2.32	2.3166
35	-0.01	0.02	-12.39	5.330936	-2.331	5.4333	1.01919	-2.28	2.2786
36	-0.01	0.02	-13.508	5.252732	-2.003	4.0109	0.76359	-2.26	2.2618
37	-0.01	0.02	-29.28	5.168011	1.832	3.3562	0.64941	-2.24	2.2435
38	-0.01	0.01	-12.628	4.985536	-1.986	3.9424	0.79076	-2.2	2.2035

Q	0.357		1227.8 LogLikelihood
Initial Parameter Estimates			
N	p	q	N_hat
	0.026	0.97	527.38

198.33 22.7491

Chi2GO 0.968

Point Pleasant Site #1.



Atlantic City Site #2. Station #1

Pop Est (bushels)	p Para meter	Area (m^2)	Number per Bushel	Total Number	Density (#/m^2)	Ave Area of Tow (m^2)	Est Efficiency	Sum of Tow Areas (m^2)
81.272671	0.183	6939	66.3333	5391.09	0.7769	1195.23	1.0627583	15538.1

Maximum likelihood model to estimate population size using the method of Gould and Pollock
Site = AC2-1

Structural Model

Nonlinear Least Squares

Tow	Catch	Obs T	Pred C	(Obs-Pred)^2
1	12.5	0	14.0325	2.34848
2	11.75	12.5	11.9573	0.04296
3	9	24.25	10.0066	1.01315
4	10.75	33.25	8.5124	5.00685
5	7.78	44	6.72771	1.10731
6	7.5	51.78	5.4361	4.25968
7	5	59.28	4.19097	0.65453
8	4.875	64.28	3.36088	2.29255
9	1.125	69.155	2.55155	2.03504
10	0.625	70.28	2.36478	3.02683
11	0.875	70.905	2.26102	1.92105
12	1.375	71.78	2.11575	0.54872
13	2.25	73.155	1.88748	0.13142
		75.405		
	Initial Parameter Estimates			24.3886

Parameter Estimates			
N	p		SumSquares
84.52	0.16602		24.3886
Non Linear LS Model: Catch=p(N-T)			

Simple Linear Regression Estimates			
a=Np	b=-p	R_sqr	N_hat
14.03	-0.166	0.89323	84.5243

Gould and Pollock Method

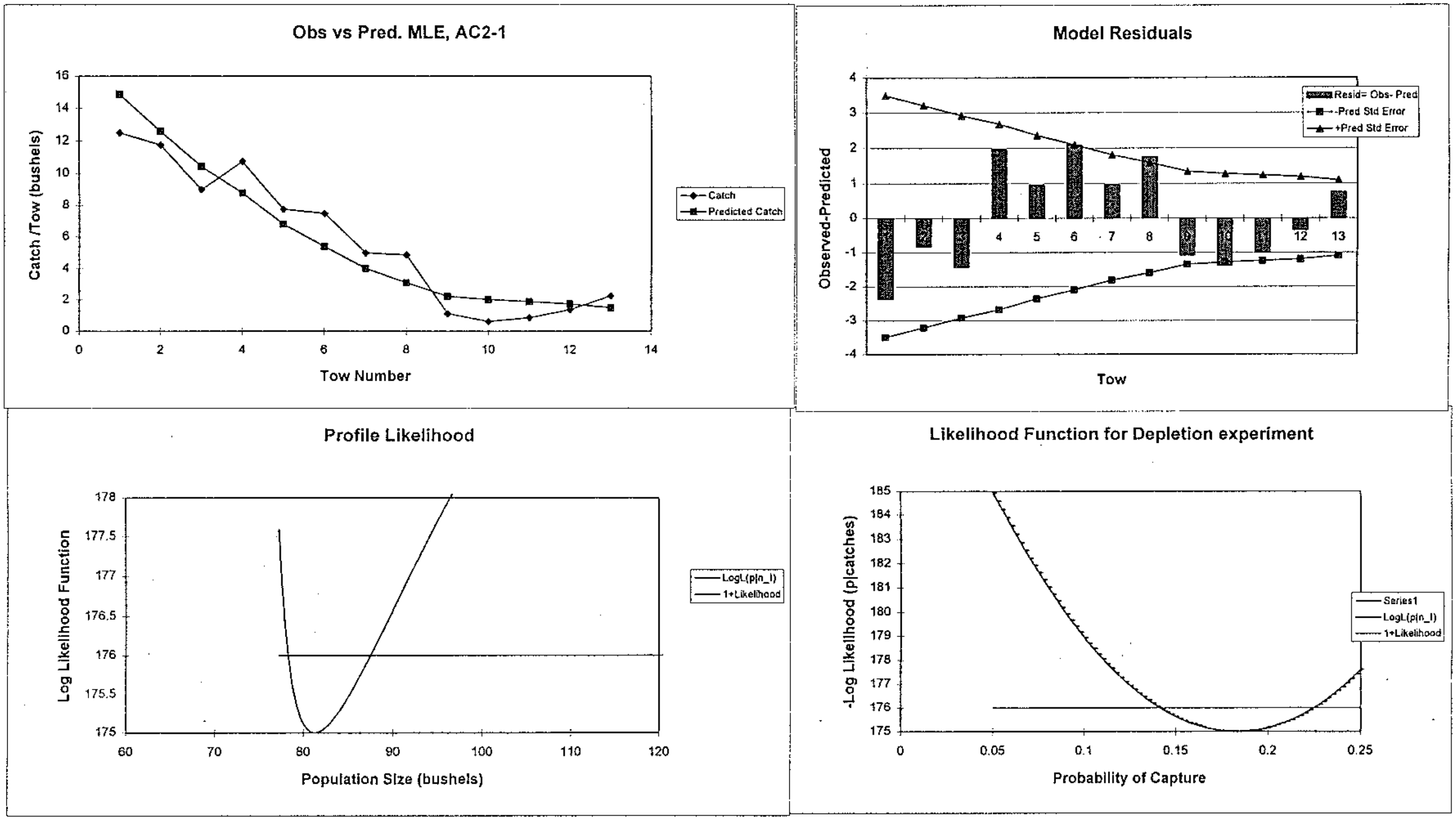
Term	Q(p^)	Likelihood	LogLike	Predicted Catch	Resid= Obs-Pred	SS(N,p)	Chi-Square	-Pred Std Error	+Pred Std Error
0	-0.183	0.197	-20.288	14.8772	-2.3772	5.65107	0.37985	-3.486	3.486
1	-0.15	0.161	-21.446	12.58904	-0.839	0.70398	0.05592	-3.207	3.207
2	-0.122	0.132	-18.247	10.43816	-1.4382	2.06832	0.19815	-2.92	2.92
3	-0.1	0.108	-23.968	8.790689	1.9593	3.8389	0.4367	-2.68	2.68
4	-0.082	0.088	-18.919	6.82287	0.9571	0.9161	0.13427	-2.361	2.361
5	-0.067	0.072	-19.755	5.398719	2.1013	4.41538	0.81786	-2.1	2.1
6	-0.054	0.059	-14.181	4.025822	0.9742	0.94902	0.23573	-1.814	1.814
7	-0.044	0.048	-14.812	3.110558	1.7644	3.11326	1.00087	-1.594	1.594
8	-0.036	0.039	-3.6456	2.218175	-1.0932	1.19503	0.53875	-1.346	1.346
9	-0.03	0.032	-2.1517	2.01224	-1.3872	1.92444	0.95636	-1.282	1.282
10	-0.024	0.026	-3.1892	1.897832	-1.0228	1.04619	0.55125	-1.245	1.245
11	-0.02	0.021	-5.2897	1.737661	-0.3627	0.13152	0.07569	-1.191	1.191
12	-0.016	0.017	-9.1107	1.485963	0.764	0.58375	0.39284	-1.102	1.102
Q	0.072		175.002	LogLikelihood		26.537	5.77424		

Initial Parameter Estimates			
N	p	q	N_hat
	0.183	0.817	81.2727

Chi2GOF 1

0.183

Atlantic City Site #2, Station #1.



Atlantic City Site #2. Station #2

Pop Est (bushels)	p Para meter	Area (m^2)	Number per Bushel	Total Number	Density (#/m^2)	Ave Area of Tow (m^2)	Est Efficiency	Sum of Tow Areas (m^2)
135.5443	0.132	11613	67.625	9166.18	0.7893	1521.93	1.009276	27394.7

Maximum likelihood model to estimate population size using the method of Gould and Pollock 1997

Site= AC2-2

Structural Model

Nonlinear Least Squares

Tow	Catch	Obs T	Pred C	(Obs-Pred)^2
1	13.5	0	17.6283	17.043
2	20	13.5	15.8914	16.88
3	16.88	33.5	13.3183	12.65
4	9	50.375	11.1472	4.6105
5	9.375	59.375	9.9893	0.3774
6	6.5	68.75	8.78315	5.2128
7	8.125	75.25	7.94688	0.0317
8	6.875	83.375	6.90155	0.0007
9	4.75	90.25	6.01704	1.6054
10	7.5	95	5.40592	4.3852
11	3.25	102.5	4.441	1.4185
12	7.125	105.75	4.02286	9.6233
13	2.25	112.875	3.10619	0.7331
14	4.25	115.125	2.81671	2.0543
15	2.375	119.375	2.26992	0.011
16	1.75	121.75	1.96436	0.046
17	1	123.5	1.73921	0.5464
18	0.5	124.5	1.61055	1.2333
		125		
				78.463

Gould and Pollock Method

Term	Q(p^)	Likelihood	LogLike
0	-0.132	0.143	-26.216
1	-0.115	0.124	-41.676
2	-0.1	0.108	-37.558
3	-0.086	0.094	-21.308
4	-0.075	0.081	-23.526
5	-0.065	0.071	-17.233
6	-0.056	0.061	-22.695
7	-0.049	0.053	-20.178
8	-0.043	0.046	-14.615
9	-0.037	0.04	-24.141
10	-0.032	0.035	-10.922
11	-0.028	0.03	-24.956
12	-0.024	0.026	-8.1999
13	-0.021	0.023	-16.092
14	-0.018	0.02	-9.3294
15	-0.016	0.017	-7.1226
16	-0.014	0.015	-4.2119
17	-0.012	0.013	-2.1769
Q	0.078		332.16 LogLikelihood

Predicted Catch	Resid= Obs-Pred	SS(N,p)	Chi-Square	-Pred Std Error	+Pred Std Error
17.92824	-4.428	19.6093	1.09377	-3.944	3.9442
16.14262	3.857	14.8794	0.92175	-3.743	3.7427
13.49725	3.378	11.4092	0.8453	-3.422	3.4223
11.26522	-2.265	5.1312	0.45549	-3.127	3.1265
10.0748	-0.7	0.48972	0.04861	-2.957	2.9567
8.834782	-2.335	5.45121	0.61702	-2.769	2.7688
7.975037	0.15	0.02249	0.00282	-2.631	2.6306
6.900355	-0.025	0.00064	9.3E-05	-2.447	2.447
5.991009	-1.241	1.5401	0.25707	-2.28	2.28
5.362734	2.137	4.56791	0.85179	-2.157	2.1572
4.37072	-1.121	1.25601	0.28737	-1.947	1.9475
3.940848	3.184	10.1388	2.57275	-1.849	1.8492
2.998434	-0.748	0.56015	0.18682	-1.613	1.613
2.70083	1.549	2.39993	0.88859	-1.531	1.5309
2.138689	0.236	0.05584	0.02611	-1.362	1.3623
1.824551	-0.075	0.00556	0.00305	-1.258	1.2583
1.593081	-0.593	0.35175	0.2208	-1.176	1.1757
1.460813	-0.961	0.92316	0.63195	-1.126	1.1259
		78.7924	9.91113		

Chi2GOF 0.871

Initial Parameter Estimates

N	p	q	N_hat
	0.132	0.868	135.54

Parameter Estimates

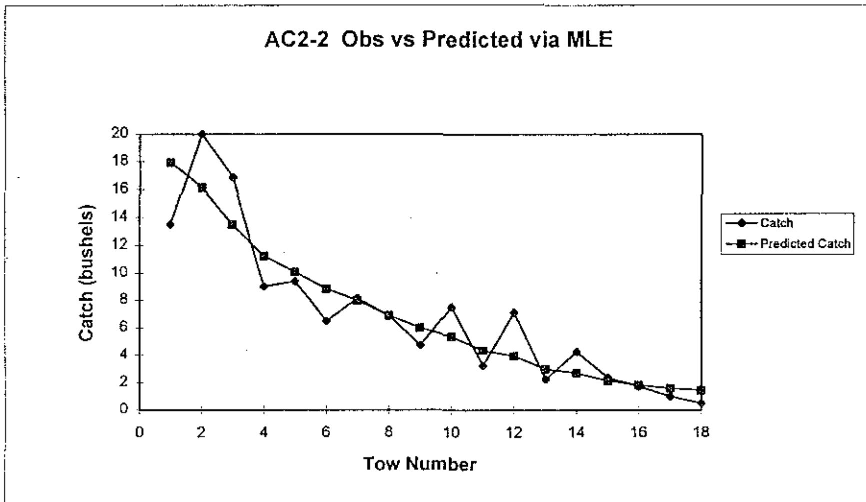
N	q	SumSquares
137	0.12866	78.463

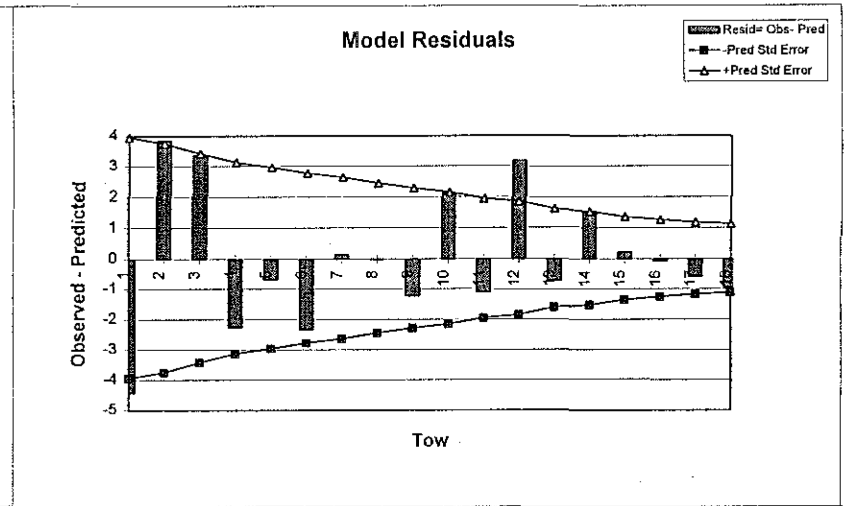
Non Linear LS Model: Catch=p(N-T)

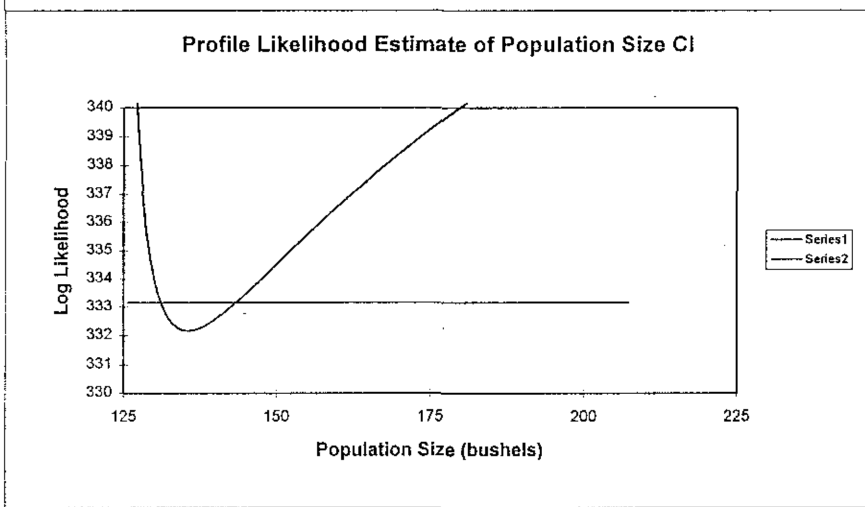
Simple Linear Regression Estimates

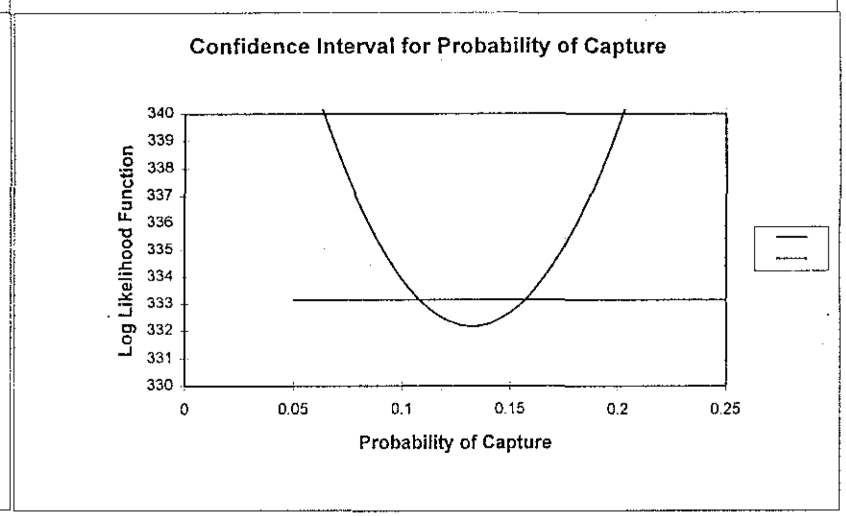
a=Np	b=-p	R_sqr	N_hat
18.88	-0.1393	0.7364	135.53

Atlantic City Site #2, Station #2.









C. STRIPED BASS

Terms of Reference

a. Assess the status of the Atlantic coast striped bass stock complex through 1996 by means of virtual population analysis and characterize the variability of estimates of stock abundance and fishing mortality rates.

b. Provide projected estimates of catch for 1998 and SSB for 1999 at various levels of fishing mortality incorporating uncertainty in recruitment and stock size estimates.

c. Estimate fishing mortality rates for specific components of the coastal stock complex using tagging data.

d. Review the estimation of F_{msy}, defined as the overfishing definition by the ASMFC Striped Bass Management Board.

e. Review the historical SSB model concept and its use in defining stock reconstruction.

f. Review the current SSB model methodology for estimating TACs under ASMFC management.

Introduction

Atlantic striped bass, *Morone saxatilis*, is an anadromous species distributed from Texas to the Canadian Maritime Provinces. Striped bass are also present on the west coast of the United States as the result of stocking in the late 1800's. Spawning occurs in brackish to freshwater portions of estuaries where juveniles remain for several years before emigrating to coastal waters. North of Cape Hatteras, striped bass undergo seasonal migrations between their estuarine spawning grounds and the Atlantic coast. Coastal migrations generally proceed northward during the spring and summer, with larger fish moving as far north as the Bay of Fundy. In the fall, the direction of migration reverses and the fish move south to overwintering areas. Although overwintering striped bass have been found from the Gulf of Maine to North Carolina, the major areas of concentration appear to be in the New York Bight and along the coast of North Carolina. In March to April, mature striped bass migrate to estuarine spawning grounds where spawning occurs over the course of several weeks. After spawning, they return to coastal waters and the feeding migration begins again.

Atlantic coastal stocks of striped bass are primarily the product of four distinct spawning stocks; Roanoke River, Chesapeake Bay, Delaware River, and Hudson River. Historically, the Roanoke stock was believed to have contributed to the mixed coastal group, but tagging records over the last several decades suggest emigration during that period has been minimal. The largest producer area is the Chesapeake Bay and includes most of the rivers and estuaries within the Bay. The second largest producer is the Hudson River, followed by the Delaware River (ASMFC 1990).

Striped Bass Management History

Striped bass have been the focus of fisheries from North Carolina to New England for several centuries and have played an integral role in the development of numerous coastal communities. Striped bass regulations in the United States date to pre-Colonial times when striped bass were prohibited from being used as fertilizer (circa 1640). During the 20th century, initial attempts at regulation were made by states during the 1940s when size limits were imposed. Minimum size limits ranged from 16 in for many coastal states to 10 in in some southern states. By the 1970s, it became increasingly evident that stronger regulations would be needed to maintain stocks at a sustainable level. Recruitment in the Chesapeake Bay stock had reached an all-time low, as determined by a juvenile survey conducted by the Maryland Department of Natural Resources since 1954. In response to the decline, the Atlantic States Marine Fisheries Commission (ASMFC) developed a fisheries management plan to increase restrictions in commercial and recreational fisheries. To strengthen the regulations, a Federal law was passed in 1984 which mandated that coast-wide regulations already implemented would be adhered to by Atlantic states between North Carolina and Maine (for striped bass management, the areas under the jurisdiction of ASMFC include coastal waters of North Carolina, Virginia, Potomac River Fisheries Commission, District of Columbia, Maryland, Delaware, Pennsylvania, New Jersey, New York, Connecticut, Rhode Island, Massachusetts, New Hampshire, and Maine).

The final version of the ASMFC plan to restore striped bass called for size regulations to protect the 1982 year class, which was the first modest size cohort since the previous decade. The objective was to increase size limits to allow at least 95% of the females in the cohort to spawn at least once. This required an increase in the size limit as the cohort grew, and resulted in a 36-in size limit by 1990. Several states, beginning with Maryland in 1985, opted for a more conservative approach and imposed a total moratorium on striped bass landings. By 1989, Massachusetts was the only state with an active commercial fishery. Fishing in the EEZ was closed in 1989 and has remained closed to all recreational and commercial striped bass fishing.

Most of the restrictive regulations were intended to restore production in Chesapeake Bay. The Hudson stock did not suffer the same decline in production, in part because the fishery in the river was closed in the 1970s as a result of PCB contamination. There was no indication of any significant production from the Delaware River stock during the 1970s and early 1980s.

In addition to the restrictions, the management plan contained a trigger mechanism to reopen the fisheries when the 3-year moving average of the Maryland juvenile index exceeded an arithmetic mean of 8.0. That level was attained with the recruitment of the 1989 year class. Consequently, the management plan was amended to allow state fisheries to reopen in 1990 under a target fishing mortality of 0.25 which was half the 1990 F_{msy} estimate of 0.5.

The management plan has been amended several times since 1990 to allow states increased flexibility in regulating fisheries. Traditionally, estuaries have been considered producer areas and have been managed under different minimum sizes than coastal waters. The rationale is that the migration of fish out of the producer areas after spawning reduces the availability of larger fish. Therefore, producer areas had a minimum size of 18 in, while coastal states had a 34-in standard.

The management plan [Amendment 4 to the FMP (ASMFC 1989)] implemented to control the reopening of the fishery in 1990 allowed an increase in the target F once the spawning stock biomass was restored to levels experienced from 1960-1972. In 1995, striped bass were declared restored by the ASMFC. The basis was the results of a model simulation of the increase in spawning stock biomass (Rugolo *et al.* 1994). The model, known as the SSB model, was a life history model which resulted in a relative index of SSB. The basis of the model was the relationship between the Maryland juvenile indices and subsequent stock size. This relationship has been demonstrated by several studies, most notably Goodyear (1985). Growth coefficients were applied to the juvenile indices and the cohorts allowed to grow over a 20-year period. Fishing mortality rates for Chesapeake Bay fisheries were applied to each cohort. An emigration rate at age was applied to each cohort which allowed fish to enter the fishing mortality regime imposed by coastal fisheries. A constant natural mortality rate at age was used. Maturity at age, by sex, was applied to surviving fish and the sum of mature striped bass across cohorts resulted in an index of relative spawning stock biomass. When the time series of SSB crossed the level comparable to the 1960-1972 average, the stock reached the criteria for a restored stock. Consequently, under Amendment 5 (1995), target F was increased to 0.31, midway between the initial F (0.25) and F_{msy}, which was revised to equal 0.4.

Amendment 5 retained the same size regulations in coastal waters (28-in minimum size, two fish per day and commercial quota), but instituted a bag limit of two fish per day at 20 in and a commercial quota in producer areas[1]. Commercial fisheries have operated under quotas based on state allocations during the period 1972-1979 (with the exception of Mary-

[1] Size limits on the coast were increased in 1994 to 34 in, but reduced in 1995 to 28 in.

land, which calculated quotas based on estimated biomass). States may adjust the minimum size, as long as the size change is compensated with a change in season length, bag limits, commercial quotas or a combination of changes. A chronology of commercial and recreational minimum sizes is summarized in Tables C1 and C2.

Fishery Data

Commercial Fishery

Landings reached 5,888 mt in 1973 then dropped sharply to a low of 63 mt in 1987. Since the reopening of the fishery in 1990, landings have been controlled by quota with the highest landings in 1996 of 2,178 mt (Table C3, Figure C1).

The predominant gear types in the commercial fisheries are gillnets, pound nets and hook and line. Commercial fisheries operate in 8 of the 14 jurisdictions regulated by the ASMFC management plan. Commercial fishing for striped bass is prohibited in New Jersey, Pennsylvania, Connecticut, New Hampshire, Maine, and the District of Columbia. Massachusetts allows commercial fishing with hook and line gear only, while other areas allow net fisheries.

The largest commercial landings are from Maryland, Virginia, PRFC, New York, and Massachusetts (Table C4). Since 1990, the Chesapeake Bay jurisdictions have accounted for 64% of the total followed by Massachusetts (18%) and New York (11%) (Figure C2).

Recreational Fishery

Striped bass recreational landings and discards were estimated using the Marine Recreational Fisheries Statistics Survey (MRFSS). This survey, administered by the National Marine Fisheries Service (NMFS), combines a telephone survey and field intercept to estimate catch and effort for the major recreational fisheries along the Atlantic coast. The precision on the estimated catch, expressed in percent standard error (PSE), is a function of the intensity of the survey coverage for each state. Most states add field intercepts for striped bass, in addition to the MRFSS allocation, in order to improve the estimates of catch and effort. Overall, the PSEs of landings and discards ranged from 39% in earlier years (1981-1985) to as low as 6.5% for the period 1990-1996[2].

Recreational landings from Maine to North Carolina has risen steadily since 1990, from a harvest (A + B1) in 1990 of 1,010 mt to 6,620 mt in 1996 (Table C5, Figure C1). This represents a 30% increase from the 1995 catch estimate of 5,080 mt and a 114% increase from the 1994 estimate of 3,084 mt. According to the MRFSS survey, more fish were caught in the last two years (1995-1996) than during 1982-1993 combined. In 1994, the coastal recreational fishery operated under a 1-fish bag limit and a 34-in minimum size. This was an increase over the 28-in minimum size in effect in 1993 (Table C2). A number of states, however, opted for the larger minimum size of 36 in. Producer areas, other than Maryland, were permitted a size limit of 18 in and a 1-fish bag limit, but harvest was capped. Maryland harvest was based on a harvest control model calculation (Rugolo and Jones 1989). Since 1995, coastal states have a 28-in minimum size and 2-fish bag limit and producer areas are allowed 2 fish at 20 in (Chesapeake Bay jurisdictions have opted for a 18-in minimum with a reduced season length). The total harvest estimate in numbers in 1996 was 1.29 million fish, representing 63% of the total landings and the record catch since 1979.

Recreational landings were highest in Maryland, followed by New York and Virginia (Figure C3). Chesapeake Bay states (MD and VA) harvested about 21% of the total landings by weight and 53% of the total harvest by number in 1996. In the North Atlantic sub-region, the majority of the landings occurred in the summer and fall (Waves 3-5), however, most of the harvest in the Mid-Atlantic sub-region took place in Wave 5 and 6 (Salz 1997). The private/rental boat mode accounted for 68% of the total catch and 64% of the total harvest in 1996. Shore mode angling accounted for 19% of the total striped bass caught, but only 2% of this catch was harvested. The party-boat/

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[2] Under the FMP, states with substantial recreational fisheries are required to augment the number of intercepts, if necessary, to produce PSEs on landings of < 20%.

charter mode accounted for 32% of the total harvest in 1996.

Overall, the percent discards (B2/(A+B1+B2)) increased from an average of 71% for the period 1982-1985 to 90% in 1986-1996 as the minimum size increased during the mid-1980s. The number of fish released increased significantly when Amendment 5 of the striped bass FMP was implemented in 1995 and reached a record 12.6 million fish in 1996. Massachusetts accounted for the greatest proportion of the total discards in 1996 (26%), followed by Maryland (22%) and New York (13%) (Table C6, Figure C4).

Catch at Age

Age data was assembled from commercial, recreational and research samples collected since 1982. Semi-annual age-length keys were developed on a regional basis. Region 1 was applied to length frequencies for the area of coastal New Jersey through Massachusetts; Region 2 was Hudson River; Region 3 was Delaware Bay; Region 4 was coastal Delaware to North Carolina; and Region 5 was the Chesapeake Bay. Age-length keys were audited for outliers. Missing age data at length were interpolated based on the numbers at age of adjacent lengths. The number of age samples available for development of age-length keys ranged from 2,104 to 17,562 and averaged 8,241 per year.

Data were generally collected in pounds and converted to metric measure in the data summaries.

Commercial Landings

Development of the striped bass commercial catch data involved expansion of landings data, stratified by state, gear and six month periods. The years included in the analysis were 1982-1996. Harvest taken in the EEZ prior to the closure (1989) were included with the state of landing regardless of the location of capture, since that information was not available. Landings were compiled from NEFSC landings data by state and gear, for 1982-1989. Landings have been more closely monitored by state agencies since 1990. Since the reopening of the fishery in 1990, New York, Delaware, Maryland, Virginia, Potomac River Fisheries Commission, North Carolina and Rhode Island have required commercial fishermen to tag individual fish prior to sale. Massachusetts has a weekly dealer reporting system and fishermen's logbooks, while Rhode Island and North Carolina also require weekly dealer reports.

Biological samples (total length in inches) from striped bass commercial landings were collected by state agencies for a variety of gear types. When length data by strata were not available, the length frequency most closely associated with the missing strata were applied. Length-weight equations from the nearest strata were used to expand length frequency to total landings.

New England

Landings for Maine in 1985 were combined with 1985 Massachusetts landings. No commercial landings were reported for New Hampshire during 1982-1996. Massachusetts landings were predominately by hook and line (>98%), with small contributions from other gears such as trawls. Landings from other gears were assumed to have the same age distribution as the hook-and-line landings. Annual length frequencies from 1982-1995, supplied by MA DMF, were sampled from July to December which corresponded with the majority of the landings. Annual autumn age/length keys were applied to the length data.

Rhode Island landings were primarily from trapnet, gillnet, and hook-and-line fisheries. Length frequencies from 1982-1986 were available from the spring trapnet fisheries and were expanded using annual spring age keys. Gillnet and hook-and-line landings were expanded, assuming the same age distribution as New York spring landings from the same gear type. Length data for 1990-1995 were available from RI gillnet and hook-and-line fisheries and were expanded using annual spring and autumn age keys, respectively.

Although Connecticut prohibits commercial fishing in state waters, landings of 1-3 mt were reported between 1982 and 1985. The age composition from

New York for the same year/season/gear combination was used and prorated based on the relative weight of the landings.

Mid-Atlantic

New York coastal fishery length frequencies, by gear, were available from 1982-1984 and 1990-1995. No length frequencies were available for 1985 or 1989. No landings were reported for 1986-1988. Lengths were converted to weight using a length-weight equation provided by New York DEP. Commercial hook-and-line landings from 1985 accounted for 26% of total landings and were expanded using the NY volunteer angler length data. The remaining 1985 landings, dominated by haul seine, were expanded, assuming the same age distribution as the hook-and-line landings. The age distribution of landings from 1990-1995 were based on random sampling of landings as reported in the annual state fishery reports. Percent at age in the samples was expanded to total landings in number. The Hudson River commercial fishery has been closed since the 1970s.

New Jersey/Delaware landings were divided into coastal or Delaware Bay landings. Landings from northern New Jersey estuaries were assumed to have the same length distribution as the coastal landings. Delaware landings were combined with New Jersey for the period 1982-1986. No commercial length frequencies were available from 1982 to 1985. Gillnet landings in 1982 and 1983 were divided by age, based on the length/age composition of New York gillnet landings. Ocean trawl landings for 1982 and 1983 were expanded based on New York pound net or haul seine length data. For 1984, trawl landings were expanded using trawl length data from New York. New Jersey had no commercial landings after 1986, and no landings were recorded for Delaware from 1986 until 1990. In the 1990s, the age composition of Delaware landings sampled by DE DFW were expanded to total number landed.

Maryland provided age composition of total landings (combined gears) for the period 1982-1984, based on random sampling by gear and expansion to the total catch. A moratorium occurred from 1985 to 1990 and no landings were reported. For the period 1990-1995, Maryland provided the expanded numbers at age by gear and fishery based on random sampling of landings. The reported number landed in the commercial fishery were redistributed to coincide with calendar year rather than fishing year. Fisheries where no age data were available were divided based on the age composition of all fisheries combined. These represented less than 5% of the total landings. Catch at age for 1996 was estimated using 1996 length frequencies and a 1995 age-length key.

Striped bass harvest during the 1980s recorded by the Potomac River Fisheries Commission were partitioned from landings, by gear, attributed to Virginia and Maryland.

Virginia length frequencies of legal size fish, by gear and season, were applied to PRFC landings. The extended size structure of landings in 1982 and 1983 was due to spring landings from anchor gillnets. The associated Virginia age data were applied. In subsequent years, landings were primarily from fall fisheries which target smaller non-migratory fish. PRFC landings in the 1990-1996 period were partitioned by age, based on samples collected by the Commission and supplemented with Virginia samples.

Virginia landings at age were based on sampling done by the Virginia Institute of Marine Science (VIMS) during the 1980s and by the Virginia Marine Resources Commission (VMRC) in the late 1980s and the 1990s. For the period 1982-1988, length frequencies by gear were applied to seasonal landings. For landings with no associated length data, either the overall age composition was applied or a gear type with similar characteristics was used. Landings-at-age data for the fishery from 1990 to 1996 were supplied by VMRC.

North Carolina landings from Albermarle Sound/ Roanoke River were excluded from this analysis. Coastal landings from 1982 to 1985 were expanded based on length and age data collected by NC Division of Marine Fisheries. The catch at age for the 1990-1992 and 1994-1995 landings were expanded based on age data provided by NC DMF. No length frequencies were available for the landings from 1993; therefore, age composition of fisheries-independent samples greater than the minimum commercial size were used. Length data for landings in 1996 were also unavailable, so the age composition for coastal landings was assumed to reflect the age structure of the mixed stock wintering off North Carolina.

Catch at age of commercial landings are summarized in Table C7.

Adequacy of Commercial Length Sampling

Commercial length sampling was evaluated by year and gear type (Table C8). Sampling generally reflected the fisheries directed at striped bass. Overall, the sampling intensity was highest for gillnets and pound nets, particularly in recent years. Sampling has ranged from 2.2 mt per sample (assuming a sample is equivalent to 100 lengths) to 59.2 mt per sample. A subjective benchmark for samples in the NEFSC has been 200 mt per sample, so striped bass sampling has been comparatively intensive.

Commercial Discards

Striped bass are not routinely encountered in fisheries sampled by the NEFSC Sea Sampling program. Sea sampling by state agencies occurs infrequently and does not provide adequate samples to estimate discards in the entire coastwide fishery. An alternative procedure was used involving tag-return data which would allow estimation of discard losses in non-directed fisheries.

The cooperative striped bass tagging program was developed to provide a database of releases and recoveries of striped bass integrated across a variety of state and Federal programs. Since 1986, nearly 168,000 striped bass have been released using an internal anchor tag supplied by the US Fish and Wildlife Service (FWS). The FWS maintains the database containing recapture information from researchers, commercial fishermen and recreational fishermen. Recapture records contain information on the disposition of the catch (killed or released) and the type of gear used.

The total number of commercial discards was estimated using the ratio of discards between commercial and recreational fisheries in the tag return data. The assumption was made that the tag reporting rate was equal from commercial and recreational fisheries. The ratio of tag recoveries was calculated for 1987-1996 for all areas combined. Sample sizes of tag returns from striped bass discarded in commercial fisheries ranged from 200 in 1987 to 2,064 in 1990 (Table C9). The 1988 sample size of recoveries was unusually low (n = 47), so an average of 1987 and 1989 recoveries was used. The ratio of commercial to recreational bycatch tags ranged from 0.76 in 1990 to 0.09 in 1996.

Recapture data included all size categories, since discards of legal size fish occurred during closed commercial fishing seasons. Recaptures from pound nets in Virginia were eliminated because of biased recapture rates (pound net fishermen using nets adjacent to the tag release area were recapturing fish and reporting tags often within a matter of days). Other trap-based tag recoveries were restricted to fish at large for longer than 20 days. Since tag-return data began in 1987, ratios for 1982-1986 were hindcast using the trend in ratios between 1987 and 1990. Subsequent to 1990, management regulations changed the size structure of discarded striped bass which biased these ratios relative to the period prior to strict regulations. The hindcast estimated a declining ratio back through time as would have been expected, given the lower size limits in the early fishery and lack of commercial quotas. The resulting ratios are presented in Table C10.

The tag ratios were multiplied by the MRFSS estimate of total recreational discards to estimate total commercial discards. Total commercial bycatch per year was estimated as:

tags from commercial discards / # tags from recreational discards) * total B2 estimates

The result of the expansion was total number of fish discarded in the commercial fishery per year among all areas combined. This total was subdivided by gear, based on the ratio of tag recoveries among gear types. Gear categories included anchor gillnets, drift gillnets, trap nets (includes pound nets), seines, fyke nets, hook and line, trawls, and other. From 1993 to 1996, the relative contribution of discards from traps, as calculated from tag recaptures, was considered biased high due to the proximity of the gear to the released fish. Therefore, the average recapture percentage by gear for the period 1987-1992 was substituted for the 1993-1996 period. Similarly, discards for 1982-1986, by gear type, were calculated using the average ratio from 1987 to 1992.

Various discard mortality rates were applied to each gear type. A 42.75% mortality was applied to anchor gillnet discards [average of 47% (Seagraves and Miller 1989) and 38.5% (MD DNR)], 8.6% to drift gillnets (Seagraves and Miller 1989), 8% to hook and line (Diodati and Richards 1996), 35% for trawls (Crecco 1990), 5% for trap and pound nets, 15% for seines, and 5% in other categories (fyke nets, etc.) based on consensus opinion of the Technical Committee. The MRFSS survey does not cover the Hudson River, so no B2 estimates were available for expansion. Discard losses from bycatch in the Hudson River shad fishery were estimated by NY DEC based on weekly sea sampling of the shad fishery, then expanded to total shad gillnet effort. Total discard losses were the sum of estimates from tag recoveries and Hudson River estimates.

The sum of the resulting coast-wide estimates ranged from 37,600 fish in 1983 (47.7 mt) to 511,100 fish in 1995 (1,139.9 mt) (Tables C10 and C14). The partial sum of estimated commercial by-catch losses reported by states were the same order of magnitude. In 1992, the year with the most complete estimates, the sum of available state estimates was 163,780 fish compared to a tag-based estimate of 178,737 fish. From 1986 to 1994, when strict commercial quotas were implemented, discards exceeded the landings. The highest estimated percentage of discards was from anchor gillnets.

The age structure of the discards was estimated by year and gear type. Percent at age from anchor gillnet discards was a composite of Maryland, Virginia, Delaware, and Hudson sampling of commercial catches or fisheries-independent surveys using commercial gear between 1982 and 1996. An average percent at age was estimated, with equal weighting among all gillnet samples. Hook-and-line samples were based on logbook data collected by MA DMF between 1990 and 1996. Prior to 1990, age composition of hook-and-line discards was not estimated. Age composition of pound net bycatch was based on sampling of Virginia pound net catches during 1982-1995. Pound net discards at age for 1996 were assumed the same as for 1995. Hudson River bycatch in the gillnet fisheries was estimated from at-sea sampling of bycatch during the shad fishery. Total annual discards by gear were expanded by the percent at age. Discards with no associated age data were assumed to have the same age composition as the overall estimate. The catch at age of commercial discards is summarized in Table C7.

Recreational Fishery

The recreational catch was determined using the MRFSS landings and discard data. In addition to the MRFSS, New Hampshire, Rhode Island, Connecticut, New York, and Maryland conducted volunteer angler survey programs for several years; NH (1993-1996), RI (1990-1996), CT (1979-1996), MD (1995-1996), and NY (1985-1996). The general purpose of these programs is to provide basic catch-and-effort data in addition to length frequency data. In some programs, anglers were asked to fill out log books indicating whether a fish was kept or released. This data was used to characterize the portion of discards (B2). Information from the American Littoral Society (ALS) tagging program was used to characterize the lengths of recreational discards. This program was initiated in the early 1960s to study patterns of seasonal migration and stock delineation of striped bass. Data from this program were available since 1983 (records of striped bass tags prior to that were not available). Lengths of tagged and recaptured fish from 1983 were used for 1982 length data. The MRFSS length frequencies in fork length were converted to total length using the following relationship from Vecchio and Greco (1997):

$$\ln(TL) = \ln(FL)*0.985+0.162$$

North Carolina landings and discards were from coastal areas only.

The age/length keys from the North Atlantic were used to substitute for missing age/length keys from the Bay jurisdictions and North Carolina coastal waters.

Recreational Landings

The MRFSS, ALS, and CT volunteer angler survey length distributions were used to characterize the total harvest of the North Atlantic sub-region for 1982-1984. For 1985-1990, lengths from the NY volunteer angler program were added to the MRFSS, ALS, and CT volunteer angler program length data. The length samples from the RI volunteer program were combined for 1990-1995 to characterize the landings. In 1996, additional samples from New Hampshire were added to characterize the New Hampshire and Maine landings. Pooled annual length frequencies were applied to each state's annual harvest taking into account the minimum size in effect for that state (Table C2). Recreational landings were dominated by ages 1-5 from 1982-1986. When the legal size increased in most states in 1987, these young age classes only represented about 11% of the total catch.

Pooled MRFSS and ALS length frequencies from Delaware, Maryland, and Virginia were used for 1982-1988 to characterize the recreational landings in Chesapeake Bay. Additional lengths from Maryland's recreational/charter fisheries for fall and spring were used from 1990 to 1995. For the 1995-1996 landings, lengths from Maryland's volunteer angler survey were added for the spring, summer, and fall harvests. Recreational landings in this area were dominated by relatively young fish because of the small legal sizes allowed in the Chesapeake Bay. Over the 1982-1996 period, ages 1-5 accounted for over 85% of the landings by number. The recreational catch at age is summarized in Table C11.

Adequacy of Recreational Sampling

Sampling intensity was calculated as metric tons of landings per hundred lengths measured by sub-region for the portion of the recreational harvest (Table C12). Sampling intensity since 1990 averaged 102 and 52 mt of landings per 100 lengths in the North Atlantic and the Mid-Atlantic sub-regions, respectively. The subjective criteria of 200 mt per 100 lengths was used as a benchmark for an adequate sample size. Based on this criterion, length frequency samples were adequate for both sub-regions, with the exception of 1982-1984 in the Maine-New Jersey sub-region.

Recreational Discards

A hooking mortality rate of 8% was used for all areas and years (Diodati and Richards 1996). Length data from volunteer angler programs show that a significant portion of the legal catch is released. However, this varies from state to state. In Connecticut, over 60% of the legal catch was released during 1996. Similar proportions were observed in Rhode Island. However, in New York and Maryland, these proportions were as low as 8% in 1995 and 1996. Because of this variation and the potential bias in the level of experience and conservation ethic of the participants, lengths below legal size were applied. With the exception of the MRFSS lengths, the same lengths used to characterize the landings were used for discards (B2), but below legal size by state and season. The sampling intensity was calculated as a ratio of lengths measured to total discard weight. Overall the proportion of fish sampled was less than 10 mt per sample for the North Atlantic area, but 1 to 220 mt per sample in the Bay areas and North Carolina. Discard catch at age is summarized in Table C11.

Hudson River

The Hudson River has a recreational striped bass fishery which is not sampled under the MRFSS program. Estimates of catch were supplied by NY DEC.

Estimates of recreational catch, landings, and discards in number and weight at age from the Hudson River were made in several steps. The recreational fishery for striped bass in the Hudson River occurs in the spring and targets pre-spawning and spawning fish. Most fish are taken from private boats and shore.

Estimates of the number of striped bass caught by boat anglers in 1991-1995 were made by multiplying reported catch rates by estimated effort. The estimated catch was then partitioned into released fish and creeled fish. Data on catch rates, percent creeled, and length of creeled and released fish were obtained from volunteer anglers. Effort was estimated by expanding observed effort during the spring at the center of the fishing reach with reported estuary- and season-wide effort from volunteer anglers. Effort estimates were periodically corroborated by areal overflights of the entire estuary. The 1996 estimate was from an access creel survey of boat and shore anglers combined with areal overflights for counts of effort. Results from 1996 were then used to expand the 1991-1995 boat estimates to account for catches by both boat and shore anglers. Catch and landings in 1980-1990 were estimated from the relationship between abundance, as measured in the bycatch of the commercial shad gillnet fishery, and catch and landings in 1991-1996. Discards losses were estimated by applying an 8% release mortality to B2 estimates.

Age composition of harvested and released fish in 1990-1991 was estimated from scale samples obtained from volunteer anglers. Age composition for 1980-1990 and 1992-1996 was estimated from age frequency of the fall recreational harvest in Connecticut advanced a year to the following spring. The data showed a positive correlation with empirical data for the 1990-1991 Hudson spring fishery.

Total weight and number of striped bass losses in commercial and recreational fisheries are summarized in Tables C13 and C14. Total catch at age is presented in Table C15.

Weight at Age

Commercial Landings

Weight at age (kg) estimated from length frequency data and length-weight equations was calculated by year, period, and state. Total weight at age was the average among states, weighted by number at age.

Weight at age in the landings varied through time, depending on the changes in management. For instance, all fisheries were open in 1982 and minimum sizes were 12 in - 16 in. The weight at age 6 was 4.1 kg. By 1989, Massachusetts was the only commercial fishery and was operating at a 36-in minimum size. Consequently, the weight at age 8 was 7.5 kg. When other fisheries reopened in 1990, weight at age 8 dropped back to 3.3 kg.

Commercial Discards

Weight at age from commercial discards was estimated from several sources. Length data of tag returns between 1987 and 1996 were subset to include fish captured and then discarded in commercial fisheries. The subset was divided among gear groups. Length frequencies were expanded and weighted by total discard losses by gear. An age-length key for spring mixed-stock fisheries were applied and length at age was calculated. The length-weight equation was a composite equation from MA, RI, NY, and VA:

$$\ln wt\,(lb) = -7.71049 + [\ln length\,(in) * 2.93999]$$

Due to a bias in size of released fish, these weights at age (converted to kg) were only used for fish less than age 5 from 1987 to 1996, for age 5 from 1990 to 1996, and age 6 from 1991 to 1996. Weight at age in the Hudson River bycatch were applied to fish older than age 8. Weight at age of recreational catch was used for fish less than age 8 from 1982 to 1986.

Total commercial weight at age is summarized in Table C16.

Recreational Landings and Discards

Length-weight relationships from Massachusetts fall sampling for three blocks of years, 1982-1986, 1987-1991, and 1992-1996, were used to calculate annual mean weights at age from the estimated age-length frequency distribution for the North Atlantic. Similar relationships from Virginia and Maryland samples were used for the Bay states and North Carolina.

Mean weight at age from striped bass in the Hudson River recreational fishery was estimated from length, weight, and age data collected from annual surveys of the spring spawning stock, 1985-1995.

Total recreational mean weights at age are summarized in Table C16.

Virtual Population Analysis

Catch-at-Age Development

Striped bass fisheries exploit native stocks within producer areas and mixed stocks along the coast. Since stock-specific catch estimates were not available from the coastal component, a VPA was developed for a mixed stock. Maximum age in the catch matrix was 23 years, but the matrix was truncated to a 15+ age group. Since minimum size along the coast in the late 1980s was 36 in, the Technical Committee felt estimation of a plus group at a younger age might compromise the ability of the VPA to estimate the age at full recruitment. Less than 1% of the total catch was included in the plus group. The age data used in the analysis were based on scale readings. Recent evidence suggests that scales may be underestimating the true age beyond age 12, based on comparison to otolith ages and known age fish (Secor *et al.* 1995). The catch beyond age 12 comprised only 1-3% of the total catch, so the ageing error would be a relatively minor problem. It is clear, however, that further research needs to be done on the age analysis for striped bass.

Fishery-Independent Indices

Fishery-independent indices collected since 1982 and used as tuning indices were:

New York Department of Environmental Conservation

An index of young of year striped bass in the Hudson River, 1982-1996, was included as a tuning index (Table C17, Figure C5). The directed striped bass survey uses a 200-ft beach seine with a 5-mm stretched mesh bag. Sampling is conducted bi-weekly from mid-August to early November at 25 fixed stations selected from a pool of 33 stations. A GM mean number per tow of age 0 was calculated. The index has been validated with the abundance of age 1 fish in Long Island Sound and age 2 estimates from Hudson River Utilities data. An index of age 1 striped bass sampled in western Long Island Sound with a beach seine during spring/summer 1985-1996 was included (Table C18, Figure C6).

Each fall since 1987, a survey of coastal migrating striped bass has been conducted from beaches of southwestern Long Island using a 1,800-ft ocean haul seine. A minimum of 10 fixed stations are sampled, and 54-60 hauls are conducted from September to November. Indices of abundance at age, calculated as mean number per haul, were included as tuning indices for ages 4-15+ (Table C19, Figure C6).

New Jersey Department of Environmental Protection

An index of young of the year striped bass in the Delaware River is calculated as mean catch per haul from a beach seine survey conducted since 1982 (Table C17, Figure C7). The survey samples 16 stations bimonthly within the Delaware River. The design uses both fixed and random station selection and samples from mid-July to mid-November using a 100-ft seine with 1/4-in mesh. Indices since 1982 were included as tuning indices in the VPA.

Delaware Division of Fish and Wildlife

A stratified random trawl survey has been conducted during the spring in Delaware Bay since 1989. An index of young of the year striped bass, calculated as mean number per tow, was used as a tuning index (Table C17, Figure C7).

Maryland Department of Natural Resources

A survey of young of the year striped bass in Maryland waters of the Chesapeake Bay has resulted in an annual abundance index since 1954. The survey is conducted at fixed stations; seven stations in the Upper Bay and Potomac River and four stations each in the Nanticoke River and Choptank River. Sampling is conducted monthly from July through September, using a 30.5-m beach seine. A validation of the index is described in Goodyear (1985). The index, calculated as geometric mean number per haul, was included as a tuning index (Table C17, Figure C8). In addition, an index of age 1 striped bass from the same survey was used in tuning (Table C18, Figure C8).

A survey of striped bass spawning areas was conducted in the Maryland tributaries of the Chesapeake Bay (Choptank River, Upper Bay, and Potomac River) during April and May of 1985-1997. A multiple mesh gillnet, with mesh sizes (inches) of 3.0, 3.75, 4.5, 5.25, 6.0, 6.5, 7.0, 8.0, 9.0, and 10.0, was set daily 10-20 times per month at stratified random stations. Catch per unit effort (number of fish per hour) was adjusted for selectivity differences between mesh sizes using the method described in Stagg (1996). In 1994, the Potomac River was not sampled, and in 1995, the Choptank River was not sampled. A composite Bay-wide index was developed using a weighted sum of the CPUE. The weighting factors were based on nursery area (Hollis 1967); with a Choptank weighting of 0.04, Potomac River weighting of 0.37, and the Upper Bay weighting of 0.59. Combined indices of abundance at ages 2-15+ were used as tuning indices in the analysis (Table C20, Figure C8).

Virginia Institute of Marine Science

A survey of striped bass young of the year in Virginia waters of the Chesapeake Bay was done annually since 1980. Eighteen fixed stations on the James, York, and Rappohannock Rivers were sampled with a 30.5-m beach seine five times a year on a bi-weekly basis from mid-July through September. An index of abundance, number of striped bass per haul, was used as a tuning index (Table C17, Figure C8).

Further details of specific juvenile surveys are available in ASMFC Special Report No. 48, 'Report of the Juvenile Abundances Indices Workshop' (Rago *et al.* 1995).

Fisheries-Dependent Indices

Massachusetts

CPUE and length frequency data from Massachusetts commercial anglers were available since 1989. Catch per hour fished (autumn 1989-1996) was subdivided for ages 6-14 based on the associated age/length data. Indices of abundance for ages 7-14 were used as tuning indices in the VPA (Table C21, Figure C6). Age 6 striped bass were not considered fully recruited to the fishery.

Connecticut

Since 1979, CT DEP has collected recreational striped bass CPUE data using volunteer angler logbooks. The CPUE (catch per trip) was subdivided into ages 1-15+ using the associated length data applied to an age-length key. The indices of abundance were used as a tuning index (Table C22, Figure C6). The fishery is prosecuted in summer/fall and was considered as a fall tuning index.

New York

CPUE of striped bass in the Hudson River commercial shad gillnet fishery (number caught per yd^2 x hrs x 10^{-3}, ages 6-15+) was available for the period 1982-1996. The abundance was estimated based on CPUE determined from sea sampling trips expanded to total effort in the shad fishery. Indices of abundance for ages 6-8 were used as tuning indices (Table C23, Figure C5). Other ages were not considered due to the selectivity of the shad gillnets on larger striped bass.

Virtual Population Analysis

A virtual population analysis for striped bass was run using the software ADAPT (Parrack 1986, Gavaris 1988, Conser and Powers 1990). The program provides the best estimate of an objective function (the difference between observed and predicted indices) using non-linear least squares methods. The model structure assumes the catch-at-age matrix is determined without error and tuning indices are representative of population abundance. The time series of the catch-at-age matrix was 1982-1996. Ages used in the VPA estimation were 1-14, with all ages equal to or greater than 15 included in a plus group. A total of 58 age-disaggregated indices were used. The VPA indices were tuned to stock sizes as of January 1 and indices were adjusted to reflect stock size as of January 1. Spring indices were considered indicative of stock size for January 1 of that year. Fall indices were adjusted forward one year to tune to stock size at the beginning of the next year; e.g., indices of age 1 fish in the fall of 1982 better reflected stock sizes of age 2 fish on January 1, 1983 than January 1, 1982. All young-of-the- year indices in year *i* were transformed to age 1 indices in year *i+1* (i.e., YOY index for 1985 = age 1 index in 1986).

Spawning was assumed to occur in April, and 33.3% of the natural mortality occurred prior to spawning, while 10% of fishing mortality was assumed to occur prior to spawning. Natural mortality was held constant among ages at 0.15. This value of M, determined by the Technical Committee, assumes a maximum age of 20 years. Maturity at age was: age 1 (0), age 2 (0), age 3 (0), age 4 (0.04), age 5 (0.13), age 6 (0.45), age 7 (0.89), age 8 (0.94), and ages 9 and older (1.0) (Rugolo and Jones 1989). Sex ratio at age was assumed equal to 50:50. Full recruitment, as determined by age at maximum fishing mortality in the VPA results, ranged from age 3 (1984) to age 12 (1994), but the peak age in the catch varied between ages 2 and 6 (Figure C9). Based on the peak age in the catch, fishing mortality of the oldest true age was estimated from the average of ages 4-14. Fishing mortality on the plus group was equivalent to F at age 14. Partial recruitment input to the model was set at 0.005 for age 1, 0.05 for age 2, 0.22 for age 3, 0.52 for age 4, 0.70 for age 5, 0.75 for age 6, and 1.0 for ages 7 and greater based on preliminary runs of the VPA.

An iterative re-weighting of the indices was used due to the mixed stock nature of the catch-at-age data and tuning indices.

Diagnostic Evaluation of VPA

The evaluation of the VPA output presented unique problems for striped bass. The input data consisted of catch from three stocks. Historically, population abundance, based on juvenile indices and landings, has varied among stocks. The Chesapeake stock was severely depleted by the early 1980s, the Delaware stock was almost completely extirpated by the 1970s, while the Hudson stock maintained a relatively stable production during the 1980s and 1990s. As a result, a stock-specific index may not be linearly related to overall population abundance, as indicated from the catch-at-age matrix. The residual patterns, as diagnostic indicators, reflect the adequacy of the indices for tuning as well as the relative contribution of that stock to the overall stock mixture. For instance, the Delaware River young-of-the-year index has increased exponentially since the mid-1980s at a much greater rate than the overall mixed stock growth. As a result, the residuals have a negative trend in early years and a positive trend in later years. The decision was made to reject indices based on the overall contribution to the residual sums of squares rather than time trends in specific indices. In addition, indices were rejected if the index was not considered representative due to gear bias or other factors.

VPA Results

The final VPA model resulted in an overall mean square residual of 0.010 (Table C24). The coefficient of variation on the population estimates ranged from 0.20 for age 4 to 0.33 at age 13, with an overall average of 0.26. The correlation among abundance estimates showed a moderate positive correlation for ages 8-13. This may be due to 'smearing' among age groups as a result of increased aging errors in older fish.

Population abundance (January 1 stock sizes) increased steadily from a low of 5.3 million fish in 1982 to a high of 40.1 million in 1997 (Figure C10). Strong year classes occurred in 1989, 1993, and 1996 (Figure C11). The 1982 year class, which was the focus of early FMPs, was only of average size coast-wide, although juvenile indices in Chesapeake Bay suggested an above-average 1982 year class. Abundance increased significantly in 1994 and 1997 due to the large 1993 and 1996 year classes.

Fishing mortality rates decreased in the mid-1980s probably as the result of management restrictions. With the reopening of the fisheries in 1990, fishing mortalities increased, but were still at or below the target F (Figure C12). In recent years, highest mortality occurred on fish greater than age 5, which are the age groups susceptible to fisheries in both coastal and producer areas. F on fully-recruited ages (ages 5-13) in 1996 was 0.31, which corresponds with the target F of 0.31. An approximation of fishing mortality in producer areas is F on ages 3-8, which was 0.26 in 1996. An overall F on ages 4-13 was equal to 0.30.

The VPA estimates of fishing mortality in 1982-1984 were lower than expected. Historical tagging estimates of F from the Chesapeake Bay during that period indicated an F possibly approaching 0.9. This uncertainty about F in the converged portion of the VPA may be the result of several factors. First, there are fewer tuning indices for the early years of the time series. Consequently, any index which overestimates relative abundance would have a greater influence in over-estimating population abundance and under-estimating fishing mortality. Second, estimates of recreational landings in Chesapeake Bay prior to 1985 may have been underestimated (Table C5). Although Maryland increased the number of intercepts in the MRFSS survey during the early 1980s, Virginia landings of 0 fish seem unrealistic. A sensitivity analysis was made by increasing the recreational catch of ages 2-4 during 1982-1985 proportional to the commercial landings. The total catches were increased by factors of 3.6, 3.1, 7.3, and 2.8 in 1982-1985, respectively. The result was an increase in F for ages 3-8 (approximation of ages in the producer area fisheries) from 0.22 to 0.36 (1982), 0.25 to 0.28 (1983), 0.21 to 0.91 (1984), and 0.17 to 0.40 (1985) (Figure C1). The changes in catch in 1982-1985 decreased the estimates of fully-recruited F in the terminal year from 0.31 to 0.23. A more modest (and realistic) under-estimation of catch (a factor of 2x) in the early years of the time series had little influence on the estimates of fishing mortality in 1982-1985 or the terminal year. Third, the VPA estimates for the mixed stock may also poorly reflect geographic variation in F. The Chesapeake stock, as referenced by the MD juvenile index), was at its lowest point in the early 1980s while production in the Hudson was relatively stable. Since the fishery within the Hudson River was closed, fishing mortality on that component of the stock may have been low to moderate. Consequently, if the proportion of Hudson fish in the mixed stock were high, the high F in the Bay would have been diluted relative to the overall mortality estimate.

The trend in partial recruitment has followed the trends in management regulations (Figure C13). At the beginning of the time series, the minimum size was generally 12-16 in. During this period, full recruitment occurred around ages 3-5. During the mid to late 1980s, the minimum sizes in coastal fisheries were steadily increased until reaching a 36-in minimum in 1990, at which point full recruitment was reached by age 9. Age at full recruitment remained between 9 and 12 until 1996. With liberalization of management restrictions in 1996 and increased effort likely associated with the large 1993 year class, full recruitment was reduced to age 5.

Spawning stock biomass of females increased from a low of 2,400 mt in 1983 to a 1996 level of 13,100 mt (Figure C11). The spawning biomass is expected to increase even further with the maturation of the 1993 and 1996 year classes.

Precision Estimates of F and SSB

Uncertainty in the results of the terminal year estimates of F and SSB in the VPA was evaluated using a bootstrap procedure (Table C25) (Efron 1982). Two hundred iterations were made to obtain standard errors, coefficients of variation (CVs), and bias estimates for stock size estimates of ages 1-13 at the beginning of 1997 and for fishing mortalities of ages 4-13 in 1996. Results indicate an 80% probability that the 1996 F was between 0.27 and 0.34 (Figure C14). The estimate of bias was less than 5% for ages 1-13. The bootstrap mean of the fully-recruited F in 1996 was 0.32 with less than a 5% bias and a CV of 0.14. The 1996 SSB of females was between 11,800 mt and 14,300 mt (Figure C15) with a probability of 80%. The bootstrapped mean SSB in 1996 was 12,918 mt with a percent bias of 0.4% and a CV of 0.1.

Retrospective Patterns

A retrospective analysis was made to determine any directional bias in the terminal year estimates. The VPA was run, without the iterative re-weighting option, using the years 1992-1996 as terminal years. Although there was some indication of an under-estimation of fishing mortality in the terminal year, there was no consistency in the direction of the bias among years (Table C26, Figure C16).

Tagging Estimates of Mortality

Estimates of 1996 fishing mortality were made using tag recovery data from several tagging programs.

Since the 1980s, striped bass have been tagged 1) on the spawning grounds in the Delaware River, Hudson River, and tributaries of the Chesapeake Bay, 2) during the fall coastal migration along Long Island, 3) during the fall sport fishery in southern Massachusetts, and 4) on the overwintering grounds of coastal North Carolina. In addition, Maryland has conducted a tagging program since 1992, and Virginia and PRFC since 1994, to determine fishing mortality during the autumn fisheries. These fisheries have traditionally targeted smaller fish which constitute the premigratory component of the stock. The release and recovery information is maintained by the US Fish and Wildlife Service office in Annapolis, MD.

Survival estimates have been made using the Brownie tag recovery model (Brownie *et al.* 1985). Recently, new software was developed called MARK (White and Burnham 1997) which was used to analysis the tag recovery matrix. The resulting estimates of fishing mortality (calculated from survival estimates assuming M = 0.15) were 0.31 from the Delaware tag releases and 0.34 from the Hudson releases. The estimate of F from the 1996 autumn fishing season in Chesapeake Bay was 0.33.

In 1994 and 1995, the estimated fishing mortality rate calculated from a bootstrap median of all tag estimates was equal to 0.25 compared with a VPA estimate of 0.24 and 0.27 in 1994 and 1995, respectively. The 1996 VPA estimate of F for ages 3-8 (an approximation of ages recruited to fisheries in producer areas, which includes the Hudson River, Delaware Bay, and Chesapeake Bay) was 0.26 compared to the tag estimate of 0.33 within the Chesapeake Bay.

Biological Reference Points

The Striped Bass Management Board adopted F_{msy} as the definition of overfishing. The current target fishing mortality is 0.31. The overfishing definition and target apply to all striped bass stocks under management by ASMFC. The estimate of F_{msy} (0.40) was made in 1990 when the fishery was reopened in all jurisdictions. In 1997, the value of natural mortality used in the assessment was changed from 0.20 to 0.15. Consequently, F_{msy} was updated and re-estimated to be 0.38.

The estimation of F_{msy} involves a Shepherd S/R model (Shepherd 1982) and a Thompson-Bell yield-per-recruit model (Thompson and Bell 1934). Prior to development of the VPA, stock-recruitment data were not directly available for the coastal migratory stock of striped bass. The model incorporated information from other stocks of striped bass or related species, and estimates of potential stock growth based on trends in abundance indices to define parameters in the Shepherd S/R model. The yield model incorporated migratory schedules of fish moving from the minimum sizes in Chesapeake Bay fisheries to the minimum size in the coastal fisheries. The resulting estimate of F_{msy} was 0.38.

Projections

A stochastic projection of total coast-wide landings, discards, and spawning stock biomass was made for the population from 1997 to 1999 (Brodziak and Rago 1994). One hundred simulations were made using a target fishing mortality of 0.31. A distribution of initial stock sizes (ages 1-15+) was the results of 200 iterations in the VPA bootstrap procedure. Recruitment in 1996 was the highest in the time series. Therefore, the bootstrapped recruitment estimates were not used to characterize recruitment at age 1 in 1998 and 1999. The distribution of recruitment was based on the relationship between the VPA recruitment estimates (age 1) and the Maryland juvenile indices for 1981-1996. The relationship was defined by the linear regression:

$$\text{recruits} = 2737.66 + 763.37(\text{MD ji}),\ r^2 = 0.86$$

which was used to estimate recruitment strength from juvenile indices for 1955-1977 and 1989-1996. Recruitment during years when stock size may have been substantially lower than current conditions (1978-1988) was not included. Recruitment inputs in the projection model were randomly selected from the 31 values. Partial recruitment, mean weights at age, and fishing mortality were the averages for 1994-1996.

The results of the stochastic projection indicate a steady rise in average female SSB, reaching 15,297 mt in 1999 (Table C27). Average recruitment ('000s) ranges from 6,417 to 6,500 between 1998 and 1999.

Median recruitment ('000s) is 5,226. Landings would decrease to 7,803 mt in 1997, but increase to 8,515 mt by 1999. Similarly, discards would increase to 3,844 mt by 1999.

Conclusions

The Atlantic coastal stocks of striped bass are at a high level of abundance and are being exploited at a sustainable level. The estimates of fishing mortality in 1996 were at the target level (0.31) and below the level of F_{msy} (0.38). Record high levels of recruitment from the 1993 and 1996 year classes should approach full recruitment by 1998 and 2001, respectively. Spawning stock biomass should continue to increase over the short term under current levels of exploitation.

SARC Comments

SSB model

The Committee felt that the original formulation of the spawning stock biomass model (SSB model) provided useful information about historic trends in Chesapeake Bay stocks of striped bass. Lack of time and information precluded an in-depth analysis of SSB model inputs, precision, and accuracy.

The current formulation of the model, used to determine changes in coast-wide exploitable stock biomass, is less robust than the VPA framework for assessing stock status and appropriate TACs. Unlike the SSB model, the VPA uses a high number of fishery-dependent and independent indices from the entire management unit to track changes in fishing mortality and cohort strength over time.

VPA

Discard estimation: The SARC felt that use of cooperative tagging data was a reasonable approach to estimate commercial discards. The accuracy of commercial discard estimates could be significantly influenced by assumptions about equal tag reporting rates, and could be improved with alternative tagging programs (e.g., high-reward tags) or alternative data collection systems.

Estimating F on oldest true age: The SARC investigated and discussed the influence of age ranges when estimating F on the oldest true age class of striped bass in the VPA. No changes are recommended at this time, but alternative approaches for setting F on the oldest age class should be explored.

Reference points: Biological reference points should be recalculated using new information from the VPA (e.g., stock-recruitment data, partial recruitment vectors) and should incorporate information on uncertainty in the reference point itself. Alternative reference points for defining overfishing should be evaluated.

TAC projections: The SARC endorsed a stochastic approach to projecting stock size and total allowable catches (TACs) through 1999. Use of recruitment indices from the entire time series ensured a more accurate estimate of stock size in the near future.

Sources of Uncertainty

1. Relative contributions to catch among the three major stocks.
2. Migration rates from the three major producer areas.
3. Age estimation using scales rather than otoliths.
4. Age distribution and estimation of commercial discards.
5. Discard mortality rates among various types of commercial gear and various environmental conditions (e.g., temperature and salinity).
6. Bias estimators in the tag-recapture models remain poorly defined.

Research Recommendations

- The Committee recommends that further study be done on the discrepancy in ages between scale-based and otolith-based ages. Particular emphasis should be placed on comparisons with known age fish determined from coded wire tags. Comparisons should be made among age readers and areas.

- An evaluation of the overfishing definition should be made relative to uncertainty in biological parameters. There is uncertainty in the maximum age, annual repeat spawning among females, age-specific natural mortality, maturity ogives, and migration rates.
- Simulation models should be developed to look at the implications of overfishing definitions relative to development of a striped bass population which will provide 'quality' fishing. Quality fishing must first be defined.
- Examination of the tag-recapture models and development of a standard method for estimating bias.
- Refine quota calculation methods which will allow better estimates among various components of the fishery.
- Increase sea sampling of commercial fisheries, such as the dogfish gillnet fishery, which may have high levels of discards.
- Examine the mechanisms which may contribute to density dependence in striped bass as modeled in the stock-recruitment relationship.
- Examine differential reporting rates between commercial and recreational fishermen using high reward tags.
- Continue in-depth analysis migrations, stock composition, etc. using mark-recapture data.

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Table C1. Commercial striped bass minimum sizes (total length in inches) of jurisdictions under the Striped Bass FMP, by season 1982-1996.

	1982		1983		1984		1985		1986		1987		1988		1989	
State	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
ME	16	-	-	-	-	-	24	-	33	-	-	-	-	-	36	-
MA	24	-	-	-	-	-	-	-	30	-	33	-	-	-	36	-
RI	16	-	-	-	-	18	-	24	-	33	-	-	-	-	34	36
NY	18	-	-	-	24	-	-	-	-	0	0	0	0	0	0	0
NJ	18	-	-	-	-	-	-	24	-	-	0	-	-	-	-	-
DE	12	-	-	-	14, 24	-	0	-	-	-	-	-	-	-	-	-
MD bay	12/14-32	-	-	14-32	-	-	0	-	-	-	-	-	-	-	-	-
MD ocean	24	-	-	-	-	-	0	-	-	-	-	-	-	-	-	-
PRFC	12-32	-	14-34	-	-	-	18-34	-	24-34	-	-	-	-	-	0	-
VA bay	14	-	-	-	-	-	18-40	-	24	-	-	-	-	-	0	-
VA ocean	24	-	-	-	-	-	-	-	30	-	-	-	33	-	0	-
NC ocean	16	-	-	-	24	-	-	-	-	-	-	-	-	-	-	0

	1990		1991		1992		1993		1994		1995		1996	
State	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
ME	-	-	-	-	-	-	-	-	-	-	33	-	-	-
MA	-	-	-	-	-	-	-	-	-	-	34	-	-	-
RI	18-26,40	-	-	-	-	-	-	-	-	-	20-26,37	-	-	-
NY	0	24-29	-	-	-	24-39	-	24-36	-	-	24-36	-	-	-
NJ	-	-	-	-	-	-	-	-	-	-	0	-	-	-
DE	28	-	18-28	-	-	-	-	-	-	-	18-28	-	-	-
MD bay	-	18-36	-	18-36	-	18-36	-	18	-	18	-	18	-	18
MD ocean	28	-	-	-	-	-	-	-	-	-	24	-	-	-
PRFC	18-36	-	-	-	-	-	-	-	-	-	18	-	-	-
VA bay	18-36	-	-	-	-	-	-	-	-	-	18	-	-	-
VA ocean	28-36	-	-	-	-	-	-	-	-	-	28	-	-	-
NC ocean	28	-	-	-	-	-	-	-	-	-	28	-	-	-

Table C2. Recreational striped bass minimum sizes (inches) of jurisdictions under the Striped Bass FMP, by season 1982-1996.

	1982		1983		1984		1985		1986		1987		1988		1989	
State	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
ME	16	-	-	-	-	-	24	-	33	-	-	-	-	-	36	-
NH	16	-	-	-	-	-	28	-	33	-	-	-	-	-	34	36
MA	24	-	-	-	-	-	-	-	30	-	33	-	-	-	36	-
RI	18	-	-	-	24	-	-	-	-	33	-	-	-	-	-	36
CT	18	-	-	-	26	-	-	-	-	-	33	-	-	-	-	36
NY	18	-	-	-	24	-	-	-	0	0	33	-	-	-	-	36
NJ	18	-	-	-	-	-	-	24	-	-	-	33	-	-	-	36
DE	12	-	-	-	14	24	0	-	-	-	-	-	-	-	-	-
MD bay	12/14 - 32	-	-	14-32	-	-	-	-	-	-	-	-	0	-	-	-
MD ocean	24	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-
VA bay	14	-	-	-	-	-	18 - 40	-	24	-	-	-	-	-	0	-
VA ocean	24	-	-	-	-	-	-	-	30	-	-	-	33	-	0	-
NC ocean	12	-	-	-	16	-	24	-	-	-	33	-	-	-	-	36

	1990		1991		1992		1993		1994		1995		1996	
State	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
ME	-	-		-	-	-	-	-	-	-	33	-	-	-
NH	-	-	-	-	-	-	-	-	-	-	32	-	-	-
MA	-	-	-	-	-	-	34	-	-	-	-	-	-	-
RI	28	-	-	-	-	-	34	-	-	-	-	28	-	-
CT	-	-	-	-	-	-	34	-	-	-	-	28	-	-
NY	38	36	-	-	-	-	-	-	-	-	-	28	-	-
NJ	28	-	-	-	-	-	-	-	34	-	-	28	-	-
DE	28	-	-	-	-	-	-	-	-	-	-	-	-	-
MD bay	-	18-36	36	18-36	36	18-36	36	18	34	-	32/26	18	32/26	18
MD ocean	28	-	-	-	-	-	-	-	-	-	-	-	-	-
VA bay	-	18-36	-	-	-	-	-	-	18	-	18-32	-	-	-
VA ocean	28	-	-	-	-	-	-	-	-	-	28	-	-	-
NC ocean	28	-	-	-	-	-	-	-	-	-	28	-	-	-

Table C3. Landings (mt) of striped bass from Maine to Virginia. Landings from 1981 to 1996 include Atlantic Ocean landings from North Carolina.

Year	Commercial	Recreational	Total
1930	883		
1931	608		
1932	509		
1933	424		
1934			
1935	629		
1936			
1937	1,756		
1938	1,579		
1939	1,553		
1940	1,075		
1941			
1942	1,780		
1943			
1944	2,579		
1945	2,160		
1946			
1947	2,085		
1948	2,726		
1949	2,543		
1950	3,128		
1951	2,444		
1952	2,148		
1953	1,960		
1954	1,759		
1955	1,906		
1956	1,686		
1957	1,619		
1958	2,266		
1959	3,317		
1960	3,524		
1961	4,042		
1962	3,567		
1963	3,879		
1964	3,558		
1965	3,278		
1966	3,820		
1967	3,924		
1968	4,169		
1969	4,912		
1970	3,999		
1971	2,890		
1972	4,012		
1973	5,888		
1974	4,536		
1975	3,416		
1976	2,494		
1977	2,245		
1978	1,764		
1979	1,290		
1980	1,895		
1981	1,744	520	2,263
1982	992	1,144	2,136
1983	639	1,217	1,856
1984	1,104	579	1,683
1985	432	372	804
1986	68	501	569
1987	63	388	451
1988	117	570	686
1989	91	332	423
1990	313	1,010	1,323
1991	460	1,651	2,111
1992	638	1,823	2,461
1993	777	2,563	3,340
1994	805	3,084	3,889
1995	1,555	5,080	6,635
1996	2,178	6,620	8,798

Table C4. Striped bass commercial landings by state (mt). Landings by calendar year. New Jersey commercial landings from the recreational fishery.

Year	ME	NH	MA	RI	CT	NY	NJ	DE	MD	PRFC	VA	NC	Total
1982	-	-	291.7	122.6	2.7	213.6	4.7	11.7	216.8	61.7	24.4	41.9	991.8
1983	-	-	101.6	89.1	1.0	140.4	8.9	3.1	171.9	74.5	24.7	23.9	639.1
1984	-	-	48.6	24.7	0.9	270.0	4.0	16.8	370.1	355.2	7.0	6.6	1,104.0
1985	0.3	-	53.9	27.8	2.5	212.8	5.5	-	0.9	100.8	27.0	-	431.8
1986	-	-	44.1	5.0	-	0.5	4.5	-	-	13.3	0.5	-	68.1
1987	-	-	35.7	0.2	-	-	-	-	-	26.3	1.0	-	63.2
1988	-	-	36.1	-	-	-	-	-	-	52.3	28.2	-	116.5
1989	-	-	90.7	-	-	-	-	-	-	-	-	-	90.7
1990	-	-	67.1	1.8	-	37.2	-	3.0	1.3	76.7	121.4	4.4	313.0
1991	-	-	106.6	12.7	-	47.6	-	9.6	86.7	98.4	95.8	2.8	460.2
1992	-	-	108.4	17.7	-	103.0	-	8.1	250.6	57.6	92.7	-	638.0
1993	-	-	119.3	18.1	-	49.4	-	12.7	415.8	64.9	96.9	-	777.2
1994	-	-	90.5	18.1	-	77.0	-	15.4	401.4	68.0	92.6	42.0	805.0
1995	-	-	354.7	68.7	-	227.2	-	17.5	388.5	90.0	253.0	155.9	1,555.4
1996	-	-	316.1	71.7	-	225.7	1.8	53.3	691.0	156.5	636.4	25.3	2,177.9

Table C5. Striped bass recreational landings by state (A+B1 number, 000's). Includes NC Atlantic Ocean landings.

Year	ME	NH	MA	RI	CT	NY	NJ	DE	MD	VA	NC	Total
1982	0.9	-	83.9	1.8	50.1	21.3	58.3	-	1.0	-	-	217.3
1983	7.2	4.6	39.3	2.0	42.8	43.8	127.9	0.1	31.7	-	-	299.5
1984	-	-	3.5	1.2	5.7	57.5	13.6	16.6	16.8	0.4	-	115.3
1985	11.9	-	66.0	0.7	15.4	23.3	13.1	-	3.0	-	-	133.3
1986	-	-	29.4	3.3	1.8	27.6	37.0	-	14.1	1.6	-	114.7
1987	-	0.1	10.8	2.4	0.5	14.8	9.3	-	4.0	2.4	-	44.4
1988	-	0.6	21.1	5.2	2.7	21.1	12.1	-	0.2	24.3	0.4	87.7
1989	0.7	-	13.0	4.3	5.8	14.8	1.3	-	-	-	-	39.9
1990	2.9	0.6	20.5	4.7	6.1	26.4	44.9	2.0	75.2	56.0	-	239.4
1991	3.3	0.3	20.8	17.2	4.9	55.5	38.3	2.7	118.5	42.2	0.4	304.1
1992	6.4	2.2	57.1	14.9	9.2	47.4	41.4	2.3	169.2	21.1	1.0	372.2
1993	0.6	1.5	58.5	17.8	19.3	83.7	64.9	4.1	177.2	78.5	0.3	506.4
1994	3.8	3.0	74.5	5.9	16.9	95.6	34.9	4.1	193.8	127.9	7.4	568.0
1995	2.0	4.4	70.1	29.8	38.9	153.8	171.0	12.6	482.0	148.4	11.5	1,124.5
1996	2.1	6.9	73.0	60.8	64.2	279.9	119.3	28.1	406.9	235.3	16.4	1,292.9

Table C6. Striped bass recreational discards by state (B2 number, '000s). Includes NC Atlantic Ocean discards.

Year	ME	NH	MA	RI	CT	NY	NJ	DE	MD	VA	NC	Total
1982	0.7	-	6.4	2.6	643.2	12.3	87.6	-	30.4	-	-	783.2
1983	-	-	34.0	5.4	-	1.5	117.8	-	213.5	12.0	-	384.2
1984	1.9	-	98.4	85.1	31.2	40.5	52.9	-	104.1	8.8	-	422.9
1985	81.2	0.1	12.4	40.6	26.9	57.5	5.5	0.7	147.1	2.6	-	374.6
1986	4.4	-	442.3	2.0	10.5	123.8	-	-	390.1	7.5	-	980.6
1987	18.1	0.4	93.7	63.8	78.4	254.0	56.7	17.0	118.4	7.6	-	708.2
1988	4.5	6.7	209.6	23.3	25.5	92.6	486.3	2.5	132.3	5.6	-	989.0
1989	16.0	4.8	193.1	38.0	125.4	365.7	266.0	4.8	114.3	72.8	-	1,200.8
1990	12.5	15.5	339.5	67.5	89.5	265.1	254.4	14.4	420.1	175.0	-	1,653.6
1991	67.5	6.6	448.7	31.0	301.5	756.7	166.2	38.3	1,036.0	208.4	0.3	3,061.0
1992	31.2	27.6	779.8	120.4	292.3	799.1	413.5	36.9	750.0	115.9	0.7	3,367.4
1993	373.1	15.0	833.6	101.0	271.3	694.1	308.3	89.5	1,556.8	100.4	1.5	4,344.6
1994	363.5	43.5	2,102.5	139.0	490.0	1,132.7	568.0	104.0	2,785.4	197.0	5.0	7,930.6
1995	505.5	302.3	3,245.7	359.2	632.3	1,163.5	678.6	106.4	2,250.6	369.9	16.6	9,630.6
1996	1,623.7	269.0	3,347.6	309.5	1,042.3	1,582.9	766.3	99.4	2,756.6	734.2	112.1	12,643.5

Table C7. Commercial catch at age ('000s), 1982-1996, Maine to coastal North Carolina.

Landings	Age														
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1982	-	45.1	200.2	117.2	22.9	5.0	3.3	2.9	1.9	4.4	5.8	7.6	2.5	2.8	6.9
1983	-	54.3	120.6	121.0	38.3	7.4	2.0	0.7	0.6	1.7	1.3	2.4	2.7	1.9	2.7
1984	-	478.3	270.1	55.6	30.6	21.7	6.4	1.7	1.0	0.8	0.1	0.3	1.1	1.0	2.1
1985	-	53.7	45.5	7.5	9.4	19.2	21.6	6.6	3.7	1.5	0.5	0.6	0.5	0.9	3.4
1986	-	0.6	6.0	3.2	0.2	0.7	1.4	1.2	0.5	0.2	0.1	0.2	0.3	1.0	2.0
1987	-	-	3.1	4.3	1.6	0.3	1.1	1.1	0.4	0.2	0.1	0.3	0.3	0.2	0.6
1988	-	-	2.1	4.0	15.5	6.5	2.8	0.5	0.5	0.2	0.3	0.1	0.3	-	0.5
1989	-	-	-	-	-	0.1	1.1	1.0	1.0	0.6	0.5	0.2	0.3	0.4	2.1
1990	-	0.7	12.6	48.0	29.6	15.1	3.1	2.4	1.1	0.5	0.3	0.1	0.4	0.3	1.4
1991	-	2.1	22.4	44.7	41.0	21.6	8.5	4.4	4.8	1.2	0.3	0.1	0.1	0.6	1.9
1992	-	0.6	32.3	58.0	46.7	41.6	22.2	11.5	8.7	6.3	1.1	0.5	0.2	0.3	0.7
1993	-	1.8	21.1	93.9	87.4	42.1	32.5	13.8	8.4	6.4	4.0	0.8	0.2	0.1	0.4
1994	-	1.2	22.9	71.6	101.5	48.3	28.5	14.9	8.9	5.3	2.5	1.3	0.2	0.1	0.3
1995	-	6.7	35.2	114.5	134.7	98.5	38.9	34.2	37.3	21.8	8.4	3.2	1.0	0.4	0.1
1996	-	0.6	50.1	127.8	179.0	161.4	120.7	52.0	29.9	18.9	11.7	9.7	2.3	1.1	1.4

Discards	Age														
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1982	-	31.6	3.6	11.5	5.6	1.3	2.4	1.0	0.4	0.1	0.1	-	-	-	-
1983	-	24.1	1.5	2.9	7.8	2.3	0.6	0.6	0.3	0.2	-	-	-	-	-
1984	-	33.6	1.6	5.8	9.7	11.3	2.8	0.1	0.6	0.1	-	0.1	-	-	-
1985	-	7.7	30.5	5.9	10.9	3.4	2.7	1.0	0.3	0.1	0.1	-	-	-	-
1986	-	5.8	20.8	100.1	28.0	13.3	4.3	1.4	0.3	-	-	-	-	-	-
1987	-	4.2	14.4	28.6	51.4	16.9	6.5	1.3	1.0	0.4	0.1	0.1	0.1	-	-
1988	-	6.1	22.6	36.6	71.0	71.7	23.2	9.1	3.1	1.7	0.2	0.2	-	-	-
1989	-	13.9	50.2	49.0	83.4	82.8	33.5	15.5	6.3	0.7	1.4	1.4	0.7	-	-
1990	-	14.5	68.7	80.9	111.9	115.7	71.6	36.3	5.9	1.5	1.4	1.5	-	-	-
1991	0.1	12.6	37.0	64.2	77.3	56.9	36.9	24.9	6.6	4.1	6.5	-	-	-	-
1992	0.1	3.7	34.2	36.7	44.4	34.7	14.8	11.2	3.4	2.4	1.0	-	-	-	-
1993	-	7.4	50.2	79.0	95.1	63.5	20.9	15.4	9.3	4.6	1.7	0.5	0.3	-	-
1994	-	31.8	47.2	45.1	88.1	84.6	39.2	12.5	6.2	3.7	0.7	0.4	-	-	-
1995	-	72.8	75.5	53.6	94.2	121.6	61.4	19.1	7.6	4.3	2.3	2.3	0.8	-	-
1996	-	27.1	114.1	76.3	61.9	58.8	30.8	14.9	6.1	4.0	0.2	0.5	-	-	-

Catch	Age														
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1982	-	76.8	203.9	128.6	28.6	6.3	5.7	3.9	2.2	4.5	5.9	7.6	2.5	2.8	6.9
1983	-	78.4	122.1	123.9	46.0	9.7	2.6	1.3	0.9	1.9	1.3	2.4	2.7	1.9	2.7
1984	-	511.8	271.8	61.4	40.3	33.0	9.3	1.9	1.6	0.8	0.1	0.3	1.1	1.0	2.1
1985	-	61.4	76.0	13.5	20.3	22.6	24.3	7.6	4.0	1.6	0.6	0.6	0.5	0.9	3.4
1986	-	6.5	26.8	103.3	28.2	14.0	5.7	2.6	0.9	0.2	0.1	0.2	0.3	1.0	2.0
1987	-	4.2	17.5	32.9	53.0	17.2	7.6	2.4	1.5	0.6	0.2	0.4	0.4	0.2	0.6
1988	-	6.1	24.7	40.6	86.4	78.2	26.0	9.7	3.7	1.9	0.5	0.3	0.3	-	0.5
1989	-	13.9	50.2	49.0	83.4	82.9	34.6	16.5	7.3	1.3	1.9	1.6	1.0	0.5	2.1
1990	-	15.2	81.3	129.0	141.5	130.8	74.7	38.6	7.1	2.1	1.7	1.6	0.4	0.3	1.4
1991	0.1	14.7	59.4	108.9	118.4	78.5	45.5	29.3	11.4	5.2	6.8	0.1	0.1	0.6	1.9
1992	0.1	4.3	66.5	94.8	91.1	76.3	37.0	22.7	12.1	8.7	2.1	0.5	0.2	0.3	0.7
1993	-	9.3	71.2	172.9	182.6	105.6	53.4	29.2	17.7	11.0	5.6	1.3	0.4	0.1	0.4
1994	-	32.9	70.0	116.7	189.6	132.8	67.8	27.4	15.1	9.0	3.2	1.7	0.2	0.1	0.3
1995	-	79.5	110.7	168.1	228.9	220.1	100.4	53.3	44.9	26.1	10.7	5.5	1.8	0.4	0.1
1996	-	27.7	164.2	204.2	240.9	220.1	151.5	66.9	36.1	22.9	11.8	10.2	2.3	1.1	1.4

Table C8. Sampling intensity of commercial landings (mt), 1982-1996.

	Hook and line		Trap/pound net		Gillnet		Fyke net	
Year	Number sampled	Landings (mt)	Number sampled	Landings (mt)	Number sampled	Landings (mt)	Number sampled	Landings (mt)
1982	978	407	1,118	94	1,381	364	-	-
1983	790	196	1,059	78	1,364	288	-	-
1984	524	194	313	173	495	540	-	11
1985	1,230	156	631	112	534	49	-	-
1986	199	55	18	3	102	6	-	-
1987	238	31	8	10	231	13	-	-
1988	352	36	48	26	867	55	4	-
1989	224	90	1,322	-	583	-	-	-
1990	1,494	97	1,485	62	3,033	145	17	1
1991	1,498	179	8,168	80	5,426	178	-	1
1992	996	160	7,604	105	6,518	354	129	2
1993	1,041	187	6,228	123	9,044	452	-	-
1994	886	63	5,082	146	10,148	444	112	-
1995	1,060	543	6,251	276	10,228	559	1,077	6
1996	1,072	459	1,773	391	3,750	1,261	27	8

	Haul seine		Otter trawl		Other gear		Total	
Year	Number sampled	Landings (mt)	Number sampled	Landings (mt)	Number sampled	Landings (mt)	Number sampled	mt/100 lengths
1982	985	64	-	20	-	1	4462	21.3
1983	338	27	-	24	-	2	3551	16.0
1984	306	146	97	33	-	-	1638	59.2
1985	-	97	-	17	-	1	2395	15.4
1986	23	-	-	4	-	68	342	20.0
1987	-	-	-	9	-	-	477	15.7
1988	598	-	-	-	-	-	1869	6.9
1989	239	-	-	1	-	-	2368	2.3
1990	214	2	-	2	-	309	6243	5.0
1991	719	6	-	13	-	-	15811	2.2
1992	451	7	-	10	-	-	15698	3.9
1993	-	10	-	5	-	-	16313	3.8
1994	138	12	-	9	-	89	16366	4.7
1995	207	7	-	9	-	-	18823	6.7
1996	433	18	-	15	-	1	7055	28.5

Table C9. Commercial by-catch estimated from ratio of recreational and commercial tag return data. Bold italicized forecasts from 1987-1990 values based on the changes in regulations and no quota.

Year	Tag returns n	Ratio of commercial to recreational by-catch	Recreational B2	Estimated commercial by-catch
1982	-	***0.20***	783,187	157,421
1983	-	***0.27***	387,794	105,480
1984	-	***0.34***	426,402	146,256
1985	-	***0.41***	392,590	162,532
1986	-	***0.49***	993,009	481,609
1987	200	0.55	721,427	397,064
1988	47	0.63	990,481	623,733
1989	1,357	0.71	1,203,905	853,651
1990	2,064	0.76	1,654,199	1,256,514
1991	1,728	0.31	3,067,385	935,969
1992	1,640	0.17	3,373,883	572,742
1993	1,585	0.22	4,349,278	965,761
1994	1,938	0.13	7,935,579	1,000,593
1995	1,486	0.15	9,645,613	1,432,717
1996	1,169	0.09	12,554,314	1,097,588

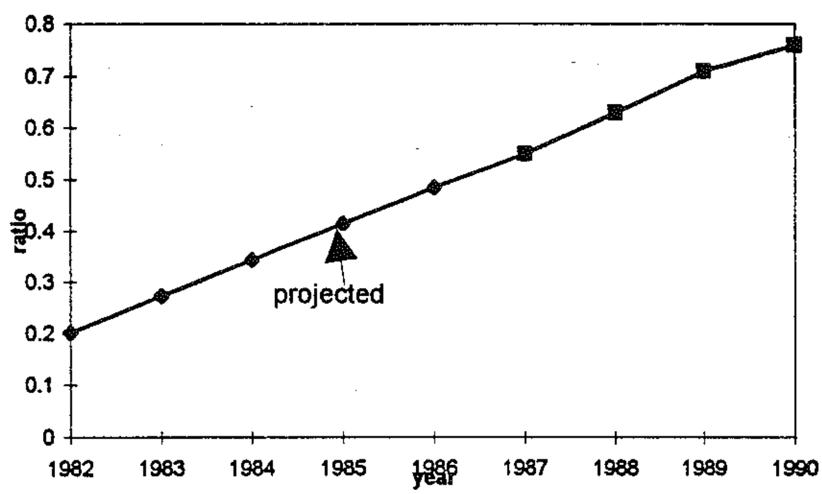

Table C10. Total number (000's) of striped bass mortalities from commercial discards by year and gear type.

Year	Anchor gillnet	Drift gillnet	Hook & line	Trawl	Trap/ pound net	Haul seine	Other	Total
1982	53.3	1.3	0.5	0.3	0.5	0.2	0.1	56.2
1983	35.7	0.9	0.3	0.2	0.3	0.1	0.0	37.6
1984	49.5	1.2	0.4	0.3	0.5	0.2	0.1	52.2
1985	55.0	1.4	0.5	0.3	0.5	0.2	0.1	58.0
1986	163.1	4.0	1.4	1.0	1.6	0.6	0.2	171.8
1987	107.6	6.5	1.3	1.4	2.2	0.0	0.3	119.3
1988	232.0	1.3	2.4	2.2	1.5	0.0	0.0	239.3
1989	318.9	2.9	2.0	1.1	1.0	2.3	0.5	328.7
1990	493.0	1.3	2.0	0.4	2.2	2.3	0.0	501.3
1991	300.1	7.1	3.7	5.6	3.7	0.8	0.4	321.5
1992	164.0	8.7	1.4	0.5	2.9	1.0	0.2	178.7
1993	327.0	8.0	2.8	2.0	3.2	1.2	0.4	344.5
1994	338.8	8.3	2.9	2.1	3.3	1.2	0.4	357.0
1995	485.2	11.9	4.1	3.0	4.7	1.7	0.5	511.1
1996	371.7	9.1	3.2	2.3	3.6	1.3	0.4	391.6

By-catch loss rates:

Anchor gillnet	0.4275	ave. of Seagraves and Miller (1989) (0.47) and MD DNR (0.385)
Drift gillnet	0.08	Seagraves and Miller (1989)
Hook and line	0.08	Diodati and Richards (1996)
Trawl	0.35	Crecco (1990)
Trap/pound net	0.05	Consensus opinion
Haul seine	0.15	NY DEP estimate
Other	0.05	Consensus opinion

Table C11. Recreational catch at age (000's), Maine to coastal North Carolina, 1982-1996.

Landings	Age															
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total
1982	-	5	36	82	25	11	17	12	9	6	5	6	1	1	1	217
1983	3	15	46	67	103	29	16	3	2	2	3	3	2	2	2	298
1984	1	18	21	17	19	18	9	3	-	1	1	-	1	3	3	115
1985	-	2	12	23	37	20	19	10	2	2	-	-	-	-	6	133
1986	9	3	5	11	13	15	14	21	8	5	3	1	1	1	4	114
1987	1	1	3	2	5	4	4	3	4	2	1	2	3	2	7	44
1988	1	8	5	5	6	11	10	12	9	3	3	3	2	3	4	85
1989	-	-	3	2	4	6	7	4	2	2	1	-	1	1	3	36
1990	-	3	19	51	31	33	28	31	15	6	4	2	4	4	6	237
1991	1	13	30	58	28	15	32	41	42	16	6	2	2	3	15	304
1992	2	15	56	50	57	25	20	39	43	36	7	4	2	5	9	370
1993	-	9	43	88	66	52	24	32	63	64	36	8	4	1	12	502
1994	1	28	96	67	68	40	33	40	67	61	28	18	2	1	9	559
1995	-	87	171	145	91	160	73	103	87	54	34	10	7	1	3	1,026
1996	-	-	143	242	139	145	244	132	101	48	30	38	11	3	1	1,277

Discards	Age															
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total
1982	2	24	17	11	5	2	2	1	-	-	-	-	-	-	-	64
1983	1	16	10	2	1	-	-	-	-	-	-	-	-	-	-	30
1984	4	13	10	4	1	1	-	-	-	-	-	-	-	-	-	33
1985	1	9	14	3	1	-	-	-	-	-	-	-	-	-	-	28
1986	2	12	32	19	8	3	1	2	-	-	-	-	-	-	-	79
1987	1	5	17	16	9	4	2	1	1	-	-	-	-	-	-	56
1988	1	16	15	16	14	8	4	2	1	-	-	-	-	-	-	77
1989	1	23	27	16	18	7	3	1	1	-	-	-	-	-	-	97
1990	3	36	35	23	9	10	8	5	2	1	-	-	-	-	-	132
1991	-	50	63	50	19	10	18	17	10	4	2	-	-	-	-	243
1992	1	32	93	55	40	13	9	12	8	5	1	-	-	-	-	269
1993	-	57	82	82	51	35	13	8	8	6	3	1	-	-	-	346
1994	5	85	183	107	110	58	33	18	17	11	4	3	-	-	-	634
1995	4	247	165	124	65	81	27	30	15	6	6	1	-	-	-	771
1996	1	71	351	218	171	111	60	16	5	-	2	-	-	-	-	1,006

Total	Age															
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total
1982	1.8	28.8	53.0	92.4	29.9	12.9	18.5	13.0	9.5	6.1	5.1	6.0	0.9	1.3	1.2	280.5
1983	3.6	32.0	56.3	69.4	104.2	29.6	16.2	2.8	2.0	1.8	3.3	3.3	2.2	2.2	1.9	330.9
1984	5.6	31.2	31.3	21.2	20.3	18.9	9.1	2.8	0.5	1.3	0.6	-	1.1	3.2	2.7	149.9
1985	1.3	11.1	26.1	27.1	38.5	20.5	19.3	9.7	2.4	1.8	0.4	0.2	-	-	5.5	164.1
1986	11.4	14.6	37.2	29.7	21.8	18.0	14.7	21.5	8.3	5.1	3.3	1.4	0.6	1.6	4.7	194.0
1987	1.4	6.8	20.6	18.9	14.5	8.0	5.7	4.2	5.0	2.4	1.3	1.6	2.9	1.9	7.1	102.5
1988	2.6	24.7	17.0	22.6	20.6	19.7	14.5	14.7	10.3	3.9	3.2	2.9	2.1	3.0	3.6	165.4
1989	0.8	23.0	30.5	19.9	22.3	13.0	11.5	4.7	3.2	2.5	1.4	0.4	0.9	1.2	3.3	138.6
1990	2.7	39.3	54.6	74.5	40.1	43.4	37.1	37.0	17.2	6.6	4.3	2.4	4.5	3.9	6.2	373.7
1991	1.9	63.2	93.3	108.5	47.4	24.9	49.8	58.3	51.4	20.5	8.0	2.8	2.8	3.0	15.7	551.5
1992	3.2	46.8	150.3	106.6	97.1	37.5	28.7	50.9	52.2	40.7	8.2	4.1	1.8	5.2	9.6	642.7
1993	0.3	66.8	126.4	171.1	117.4	88.4	36.7	42.3	71.9	72.1	39.4	8.9	4.6	1.2	12.5	860.0
1994	5.7	113.1	280.5	175.0	179.2	100.1	68.1	59.6	85.3	72.4	33.0	20.8	3.2	1.5	9.5	1,206.8
1995	3.7	335.2	336.2	270.0	156.8	241.9	100.8	132.8	103.0	60.3	40.1	10.6	7.5	1.5	3.2	1,803.6
1996	0.5	71.1	495.3	462.3	311.1	256.8	305.6	150.8	107.2	48.8	32.4	38.2	10.9	3.5	1.2	2,295.8

Table C12. Sampling intensity for striped bass recreational landings and discards, 1982-1996.

Landings (A+B1)	Maine - New Jersey			Chesapeake & Delaware Bays		
Year	Landings (mt)	Lengths	mt/100 lengths	Landings (mt)	Lengths	mt/100 lengths
1982	1,144	410	279.0	3	113	2.7
1983	1,149	519	221.4	68	102	66.7
1984	496	166	298.8	83	69	120.3
1985	367	469	78.3	6	65	9.2
1986	497	726	68.5	4	82	4.9
1987	360	175	205.7	28	86	32.6
1988	488	264	184.8	82	126	65.1
1989	332	353	94.1	-	-	-
1990	795	676	117.6	215	496	43.3
1991	1,281	1,323	96.8	370	663	55.8
1992	1,448	1,434	101.0	375	837	44.8
1993	1,949	1,678	116.2	614	1,037	59.2
1994	2,131	1,463	145.7	921	2,213	41.6
1995	3,600	4,708	76.5	1,399	2,195	63.7
1996	4,939	8,230	60.0	1,559	3,010	51.8

Discards (B2)	Maine - New Jersey			Chesapeake & Delaware Bays		
Year	Discards (mt)	Lengths	mt/100 lengths	Discards (mt)	Lengths	mt/100 lengths
1982	83.1	994	8.4	0.7	123	0.6
1983	10.3	954	1.1	5.1	123	4.1
1984	26.2	825	3.2	3.8	373	1.0
1985	22.7	1,918	1.2	7.6	135	5.6
1986	76.1	2,593	2.9	47.2	115	41.0
1987	93.1	4,402	2.1	22.1	63	35.1
1988	159.6	5,555	2.9	18.2	71	25.6
1989	192.0	7,250	2.6	43.6	24	181.7
1990	193.2	10,325	1.9	75.3	108	69.7
1991	338.5	12,743	2.7	249.0	112	222.3
1992	452.1	15,652	2.9	182.1	145	125.6
1993	489.9	14,444	3.4	339.6	198	171.5
1994	974.6	14,383	6.8	520.4	575	90.5
1995	1,176.4	12,854	9.2	483.5	676	71.5
1996	1,155.0	17,363	6.7	386.0	1,940	19.9

Table C13. Summary of striped bass catch in number (000's), 1982-1996.

	Commercial		Recreational	
Year	Landings	Discards	Landings	Discards
1982	429	58	217	64
1983	358	40	298	30
1984	871	66	115	33
1985	175	63	133	28
1986	18	174	114	79
1987	14	125	44	56
1988	33	246	85	77
1989	7	339	36	97
1990	116	510	237	132
1991	154	327	304	243
1992	231	187	370	269
1993	313	348	502	346
1994	307	360	559	634
1995	535	515	1,026	771
1996	767	395	1,277	1,006

Table C14. Commercial and recreational landings and discard total weight (mt), 1982-1996.

Commercial			Proportion
Year	Landings	Discard	discarded
1982	991.8	69.2	0.07
1983	639.1	47.7	0.07
1984	1,104.0	99.8	0.08
1985	431.8	97.1	0.18
1986	68.1	359.2	0.84
1987	63.2	283.5	0.82
1988	116.5	703.5	0.86
1989	90.7	905.0	0.91
1990	313.0	1,356.6	0.81
1991	460.2	859.3	0.65
1992	638.0	454.0	0.42
1993	777.2	823.5	0.49
1994	805.0	853.5	0.51
1995	1,555.4	1,139.9	0.42
1996	2,177.9	807.6	0.27
Recreational			Proportion
Year	Landings	Discard	discarded
1982	1,144	83.7	0.07
1983	1,217	15.4	0.01
1984	579	30.0	0.05
1985	372	30.4	0.08
1986	501	123.3	0.20
1987	388	115.1	0.23
1988	570	177.8	0.24
1989	332	235.6	0.42
1990	1,010	268.5	0.21
1991	1,651	587.5	0.26
1992	1,823	634.1	0.26
1993	2,563	829.5	0.24
1994	3,084	1,495.0	0.33
1995	5,080	1,659.9	0.25
1996	6,620	1,541.1	0.19

Table C15. Striped bass catch at age in 000's, 1982-1996, Maine to coastal North Carolina.

	Age															
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total
1982	1.8	105.4	256.7	221.0	58.4	19.2	24.2	16.8	11.7	10.6	11.0	13.7	3.4	4.1	0.8	758.8
1983	3.6	110.1	178.2	193.2	150.2	39.3	18.7	4.1	2.9	3.7	4.6	5.7	4.9	4.1	4.6	727.9
1984	5.6	542.5	302.7	82.5	60.5	51.8	18.4	4.7	2.1	2.1	0.7	0.3	2.2	4.3	4.7	1,085.2
1985	1.3	72.4	101.7	40.3	58.7	43.1	43.6	17.3	6.4	3.4	1.0	0.8	0.5	0.9	8.9	400.4
1986	11.4	21.0	63.7	132.8	49.9	32.0	20.4	24.1	9.2	5.3	3.4	1.6	0.9	2.5	6.7	384.8
1987	1.4	10.9	37.8	51.2	66.9	25.0	13.2	6.6	6.4	3.0	1.5	2.0	3.4	2.1	7.7	239.0
1988	2.6	30.7	41.9	63.2	105.9	97.1	40.5	24.5	13.9	5.7	3.6	3.2	2.4	3.0	4.1	442.4
1989	0.8	36.8	80.7	67.0	104.7	95.2	45.5	20.8	10.4	3.7	3.3	2.0	1.9	1.6	5.4	479.8
1990	2.7	54.3	135.2	202.8	181.4	173.9	111.4	75.3	24.1	8.4	5.8	3.9	4.8	4.2	7.6	995.6
1991	1.9	77.8	151.9	216.5	165.5	103.3	95.1	87.3	62.6	25.6	14.6	2.9	2.8	3.5	17.6	1,029.0
1992	3.3	50.9	216.3	200.6	187.6	113.6	65.6	73.3	63.9	49.1	10.1	4.4	1.9	5.5	10.4	1,056.6
1993	0.1	74.7	195.9	342.4	299.1	193.0	89.3	69.7	89.3	81.7	44.9	10.0	5.0	1.3	13.0	1,509.5
1994	5.6	145.7	349.4	290.4	367.5	231.3	134.1	86.0	99.3	80.5	35.3	22.0	2.9	1.1	9.8	1,861.0
1995	3.7	413.2	446.0	437.0	385.0	461.2	200.6	185.7	147.6	85.9	50.5	16.0	9.2	1.9	3.3	2,846.8
1996	0.5	98.2	658.1	664.8	550.8	476.2	455.9	215.5	142.6	70.8	43.7	47.8	13.2	4.6	2.6	3,445.3

Table C16. Total (landings and discards combined) mean weights at age (kg) for commercial, recreational, and total fishery, 1982-1996.

Commercial	Age													
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1982	-	0.72	1.20	1.55	2.41	3.97	5.40	7.19	8.17	11.17	12.34	12.63	13.90	14.22	16.09
1983	-	0.62	1.06	1.37	2.34	3.06	4.10	6.01	7.68	9.74	12.77	12.36	12.29	12.11	11.67
1984	-	0.60	1.78	1.64	2.96	3.73	4.66	5.18	7.00	7.92	11.09	12.71	11.02	13.27	16.80
1985	-	0.60	1.08	1.85	2.58	3.88	5.18	6.31	7.70	9.20	10.44	11.57	11.67	14.48	15.54
1986	-	0.62	1.08	2.53	2.45	3.18	4.43	6.41	7.62	9.12	10.43	12.44	14.48	13.02	15.55
1987	-	0.59	1.23	2.22	2.51	2.93	3.83	5.66	6.34	7.43	9.04	11.84	14.72	14.58	16.44
1988	-	0.42	0.78	1.92	3.09	4.03	4.42	4.79	5.73	5.91	10.83	11.80	13.54	14.92	17.80
1989	-	0.75	0.91	1.97	3.06	4.53	5.39	6.26	6.15	9.34	9.38	9.82	15.07	13.92	17.93
1990	-	0.55	0.87	1.78	2.09	3.82	4.91	6.01	5.91	6.41	7.88	9.25	12.19	17.08	18.94
1991	0.41	1.02	1.27	1.98	2.36	2.84	4.74	5.83	7.32	6.72	9.46	9.06	9.28	14.50	17.23
1992	0.09	0.64	1.20	1.67	2.35	3.38	4.65	5.73	7.22	9.14	9.82	11.19	13.50	16.41	18.01
1993	-	0.41	1.32	1.79	2.55	3.26	4.64	6.25	7.45	8.57	9.73	10.47	12.62	13.43	16.42
1994	-	1.11	1.38	1.90	2.63	3.11	4.98	6.49	7.43	8.15	9.41	10.06	13.03	17.59	18.20
1995	-	0.44	1.08	1.72	2.48	3.11	5.25	6.21	7.19	8.62	9.07	9.79	12.55	14.70	21.53
1996	-	0.65	0.83	1.59	1.97	2.74	4.55	7.31	7.56	8.30	9.01	11.93	12.51	11.57	17.40

Recreational															
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1982	0.13	0.44	0.68	1.52	2.44	3.64	4.66	5.38	5.74	6.84	9.03	9.40	10.47	11.16	14.93
1983	0.20	0.37	0.67	1.37	2.38	3.36	3.72	5.08	5.33	6.47	8.28	8.97	9.69	10.26	10.33
1984	0.24	0.62	0.87	1.54	2.14	2.89	5.43	5.96	6.12	7.65	7.70	7.03	10.27	11.26	13.18
1985	0.06	0.68	1.02	1.56	2.01	3.29	4.57	4.82	5.26	5.84	7.16	8.26	7.09	8.59	16.24
1986	0.14	0.55	1.41	1.93	2.43	3.07	3.77	4.89	5.21	5.99	7.67	8.62	9.26	10.64	15.95
1987	0.20	0.88	1.57	1.92	2.43	2.88	3.35	4.25	5.30	6.26	7.58	9.33	10.94	11.25	16.46
1988	0.31	1.04	1.60	2.08	3.20	3.97	4.32	4.63	5.07	5.48	8.26	10.25	11.26	11.26	16.88
1989	0.16	0.88	1.73	2.92	3.06	4.52	5.31	6.15	5.76	8.33	8.36	9.43	10.86	8.40	16.59
1990	0.08	1.02	1.54	2.53	3.27	3.88	4.90	5.91	5.62	5.84	7.26	8.96	9.08	10.27	17.36
1991	0.21	0.90	1.31	2.36	3.28	4.21	4.87	5.55	6.27	6.12	9.47	8.26	9.63	16.23	17.07
1992	0.10	0.69	1.35	2.17	3.23	4.25	5.22	5.81	6.90	7.95	9.75	12.58	13.07	10.80	17.62
1993	0.07	0.81	1.30	2.20	3.12	3.96	5.03	6.01	6.93	7.92	9.50	10.80	14.63	13.88	15.33
1994	0.24	1.03	1.77	2.42	3.10	4.03	4.89	6.06	6.68	7.45	9.77	10.74	11.25	8.50	17.74
1995	0.28	0.77	1.43	2.46	3.19	4.14	5.51	6.14	7.30	8.97	7.17	9.70	14.30	15.87	20.31
1996	0.25	0.67	1.50	2.39	3.25	4.13	5.04	5.91	6.68	7.49	8.93	10.17	13.05	15.39	17.25

Total															
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1982	0.13	0.64	1.09	1.54	2.42	3.75	4.83	5.79	6.20	8.68	10.80	11.20	12.97	13.26	15.91
1983	0.20	0.55	0.94	1.37	2.37	3.29	3.77	5.35	6.01	8.10	9.57	10.39	11.11	11.10	11.12
1984	0.24	0.60	1.69	1.61	2.67	3.39	5.07	5.65	6.76	7.76	8.41	12.65	10.65	11.75	14.75
1985	0.06	0.61	1.07	1.65	2.19	3.59	4.91	5.46	6.77	7.45	9.00	10.69	11.42	14.34	15.98
1986	0.14	0.57	1.27	2.40	2.44	3.12	3.95	5.05	5.44	6.09	7.75	9.15	10.97	11.55	15.83
1987	0.20	0.77	1.41	2.11	2.50	2.91	3.61	4.74	5.52	6.49	7.77	9.78	11.38	11.62	16.46
1988	0.31	0.91	1.10	1.98	3.11	4.02	4.38	4.70	5.24	5.62	8.58	10.39	11.50	11.31	17.00
1989	0.16	0.83	1.22	2.23	3.06	4.53	5.37	6.23	6.03	8.68	8.94	9.74	13.04	9.93	17.11
1990	0.08	0.89	1.14	2.05	2.35	3.83	4.91	5.96	5.70	5.97	7.44	9.08	9.36	10.80	17.65
1991	0.21	0.92	1.29	2.17	2.62	3.17	4.81	5.64	6.46	6.24	9.46	8.30	9.62	15.96	17.09
1992	0.10	0.69	1.30	1.93	2.81	3.67	4.90	5.79	6.96	8.15	9.77	12.44	13.10	11.15	17.65
1993	0.07	0.76	1.31	1.99	2.77	3.58	4.80	6.11	7.03	8.00	9.53	10.76	14.45	13.85	15.36
1994	0.24	1.05	1.69	2.21	2.85	3.50	4.94	6.20	6.79	7.53	9.73	10.69	11.37	9.06	17.75
1995	0.28	0.70	1.35	2.18	2.77	3.65	5.38	6.16	7.27	8.86	7.57	9.73	13.97	15.65	20.37
1996	0.14	1.05	1.47	2.32	3.22	4.52	6.39	7.11	7.81	9.20	9.31	10.09	11.36	12.45	17.30

Table C17. Young-of-year striped bass indices by system.

Year	Kennebec River (ME)	Hudson River (NY DEP)	Hudson River (NY UTIL)	Delaware River (DE)	Delaware River (NJ)	Chesapeake Bay (MD)	Chesapeake Bay (VA)
1981	-	8.86	6.61	-	0.00	0.59	1.57
1982	-	14.17	3.83	-	0.12	3.54	2.71
1983	-	16.25	6.58	-	0.03	0.61	3.40
1984	-	15.00	5.06	-	0.29	1.64	4.47
1985	-	1.92	1.07	-	0.02	0.91	2.41
1986	-	2.92	1.62	-	0.28	1.34	4.74
1987	0.35	15.90	12.82	-	0.41	1.46	15.74
1988	0.04	33.46	4.91	-	0.35	0.73	7.64
1989	0.01	21.35	5.66	0.42	1.03	4.87	11.23
1990	0.06	19.05	6.41	0.11	1.00	1.03	7.34
1991	0.25	3.60	5.03	0.18	0.47	1.52	3.76
1992	0.01	11.43	3.68	1.13	1.19	2.34	7.32
1993	0.01	12.59	7.50	1.14	1.78	13.97	18.12
1994	0.33	17.64	5.83	0.19	0.96	6.40	10.48
1995	0.02	16.23	6.04	0.42	1.98	4.41	5.45
1996	-	9.30	-	1.36	1.70	17.46	23.05
1997	-	-	-	-	-	3.91	-

Table C18. Indices of age on striped bass by system.

Year	Hudson River (NY)	Western LI (NY)	Chesapeake Bay (MD)
1981	0.25	-	0.02
1982	0.84	-	0.02
1983	0.08	-	0.32
1984	0.68	-	-
1985	1.23	0.61	0.15
1986	0.33	0.3	0.03
1987	0.16	0.21	0.05
1988	0.45	0.77	0.06
1989	0.64	1.73	0.15
1990	0.35	0.37	0.33
1991	0.65	1.24	0.19
1992	0.53	1.34	0.11
1993	0.51	0.72	0.19
1994	0.43	1.37	0.76
1995	0.9	1.26	0.12
1996	0.17	1.52	0.08
1997	-	0.71	-

Table C19. Indices at age from New York ocean haul seine survey, 1987-1996.

	Age													
Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1987	0.73	5.98	8.71	7.71	2.89	1.13	0.28	0.15	-	0.01	-	0.01	0.03	-
1988	3.29	4.73	4.86	4.49	2.65	0.90	0.45	0.13	0.07	0.02	-	0.07	0.01	0.09
1989	1.40	2.20	1.27	2.03	1.42	1.18	0.32	0.09	0.11	0.02	0.01	0.01	0.01	0.04
1990	1.85	6.49	4.38	1.93	2.12	1.60	1.28	0.47	0.19	0.04	-	0.01	0.01	-
1991	3.95	7.49	5.12	1.64	0.77	1.05	1.46	0.80	0.36	0.09	0.08	0.02	0.08	0.02
1992	0.99	4.68	3.58	1.93	0.62	0.41	0.70	0.63	0.41	0.16	0.09	0.01	0.02	0.06
1993	2.97	7.92	6.65	2.75	1.80	0.74	0.46	0.57	0.45	0.31	0.12	0.04	0.02	0.03
1994	2.10	6.70	3.22	3.15	1.91	1.29	0.56	0.56	0.58	0.28	0.32	0.06	0.06	0.02
1995	4.91	3.51	2.34	0.70	0.76	0.39	0.21	0.14	0.16	0.14	0.05	0.06	0.01	0.01
1996	6.81	46.91	7.70	2.97	0.96	0.83	0.37	0.16	0.12	0.01	0.11	0.01	0.01	-

Table C20. Maryland spawning stock survey indices at age, all systems combined for males and females combined, 1985-1997.

	Age													
Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1985	72.83	243.05	41.79	19.02	8.88	8.25	1.44	1.83	2.19	0.39	1.74	1.31	0.31	7.01
1986	62.72	164.74	467.30	7.10	4.44	3.16	2.63	0.94	0.73	-	-	0.94	0.65	2.22
1987	60.93	204.10	128.14	335.33	3.72	2.95	3.48	0.12	-	-	-	-	7.25	4.94
1988	32.21	67.75	73.47	72.33	107.36	2.16	-	-	0.73	-	0.02	-	0.08	1.86
1989	15.52	121.59	100.51	71.51	91.10	59.62	0.38	-	0.37	-	0.19	-	-	0.34
1990	25.63	182.33	204.18	88.67	68.95	67.02	52.92	0.46	0.18	0.02	0.24	0.26	0.05	0.39
1991	40.31	186.40	72.20	68.43	40.60	38.94	35.44	14.97	0.43	0.30	-	0.11	0.10	0.45
1992	17.40	240.64	199.49	63.24	84.36	59.62	41.81	19.13	8.79	0.15	-	0.03	1.09	0.72
1993	33.40	130.16	222.42	98.53	60.37	57.34	46.52	22.28	7.92	3.27	0.33	0.31	0.46	0.35
1994	11.12	37.90	67.64	98.17	37.34	20.90	30.06	12.22	3.34	0.63	0.36	0.09	-	0.05
1995	42.90	110.10	71.81	72.13	56.29	49.63	33.55	41.38	17.83	24.86	8.21	2.14	-	0.34
1996	8.38	510.92	140.80	47.65	93.05	109.70	85.01	66.80	34.79	16.59	5.05	1.66	-	-
1997	4.12	110.98	121.94	71.85	62.03	68.00	42.58	27.36	18.80	12.53	3.32	1.46	-	-

Table C21. Massachusetts commercial striped bass CPUE at age, 1990-1996

	Age									
Year	6	7	8	9	10	11	12	13	14	15+
1990	0.01	0.56	2.30	0.92	0.43	0.28	0.12	0.44	0.35	1.60
1991	-	0.86	3.51	4.99	0.92	0.31	0.31	0.07	0.25	1.79
1992	-	0.38	3.17	5.89	4.78	0.51	0.22	0.06	0.26	0.74
1993	-	0.19	1.97	6.41	8.59	5.33	0.86	0.17	0.07	0.43
1994	-	0.43	3.74	9.74	6.26	2.18	1.03	0.10	0.10	0.43
1995	0.11	1.13	5.62	9.13	6.75	2.84	1.08	0.27	0.05	0.05
1996	-	0.90	4.81	6.12	5.58	4.68	2.47	0.75	0.28	0.13

Table C22. Connecticut volunteer angler CPUE at age, 1981-1996.

	Age														
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1981	0.221	0.316	0.163	0.136	0.114	0.056	0.033	0.021	0.015	0.005	0.001	0.002	0.001	0.001	0.002
1982	0.330	0.212	0.109	0.091	0.077	0.037	0.022	0.014	0.010	0.003	0.001	0.001	-	-	0.001
1983	0.399	0.190	0.080	0.038	0.027	0.009	0.002	0.002	-	-	0.002	-	0.001	-	-
1984	0.122	0.333	0.226	0.135	0.051	0.037	0.009	0.003	-	0.001	-	0.001	0.001	-	-
1985	0.058	0.315	0.222	0.120	0.092	0.041	0.027	0.011	0.001	0.001	0.001	0.001	-	-	-
1986	0.077	0.198	0.466	0.445	0.180	0.051	0.009	0.051	0.023	0.002	-	-	-	0.008	-
1987	0.035	0.244	0.342	0.202	0.144	0.064	0.042	0.032	0.027	0.008	0.004	0.002	0.001	0.001	0.001
1988	0.021	0.522	0.280	0.179	0.152	0.118	0.049	0.028	0.007	0.002	-	-	0.001	-	-
1989	0.268	0.484	0.468	0.160	0.182	0.126	0.090	0.031	0.015	0.007	-	-	-	-	-
1990	0.174	0.582	0.555	0.273	0.119	0.126	0.148	0.127	0.053	0.017	0.005	0.005	0.002	0.003	0.003
1991	0.147	0.668	0.431	0.347	0.135	0.066	0.094	0.131	0.087	0.032	0.008	0.002	-	-	0.001
1992	0.171	0.477	0.574	0.294	0.234	0.107	0.095	0.160	0.145	0.093	0.021	0.004	0.001	-	0.002
1993	0.070	0.704	0.623	0.486	0.279	0.220	0.095	0.077	0.110	0.099	0.053	0.013	0.004	0.002	0.007
1994	0.205	0.613	0.877	0.461	0.569	0.355	0.234	0.159	0.195	0.139	0.070	0.052	0.008	0.001	0.003
1995	0.600	1.198	1.343	0.591	0.590	0.322	0.183	0.189	0.186	0.116	0.054	0.018	0.006	0.002	-
1996	0.473	1.091	2.393	0.903	0.837	0.375	0.595	0.374	0.233	0.098	0.075	0.101	0.016	0.008	0.007

Table C23. Hudson River striped bass CPUE at age from shad gillnet by-catch, 1982-1996.

	Age													
Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1982	-	0.006	0.081	0.053	0.012	0.023	0.010	0.004	0.001	-	-	-	0.001	-
1983	-	0.074	0.967	0.641	0.147	0.273	0.116	0.042	0.011	-	-	-	-	-
1984	-	0.009	0.228	0.379	0.443	0.110	0.005	0.023	-	-	0.005	-	-	-
1985	-	0.016	0.118	0.272	0.085	0.069	0.026	0.007	0.003	0.003	-	-	-	-
1986	-	0.011	0.233	0.359	0.248	0.080	0.031	0.008	-	-	-	-	-	-
1987	-	0.004	0.170	0.490	0.413	0.234	0.055	0.043	0.017	0.004	-	0.004	0.004	-
1988	0.005	0.005	0.100	0.600	0.536	0.327	0.164	0.068	0.036	0.005	-	0.005	-	-
1989	0.042	0.028	0.056	0.983	1.278	0.562	0.309	0.126	0.014	0.028	0.028	-	0.014	-
1990	-	0.048	0.254	0.396	0.856	0.682	0.365	0.095	0.032	0.032	0.032	-	-	-
1991	-	-	0.286	0.572	0.477	0.382	0.382	0.095	0.095	0.191	-	-	-	-
1992	-	0.077	0.753	1.430	0.707	0.200	0.354	0.154	0.138	0.077	-	-	-	-
1993	-	0.132	0.823	2.732	2.172	0.790	0.559	0.823	0.494	0.197	0.066	-	-	0.033
1994	-	0.185	0.955	1.509	1.755	1.047	0.277	0.185	0.246	0.031	-	0.031	-	-
1995	0.026	-	0.369	1.422	0.869	0.448	0.263	0.105	0.079	0.053	0.079	0.026	-	-

Table C24. Results of VPA for Atlantic striped bass, 1982-1996.

Natural mortality is 0.15
Oldest age (not in the plus group) is 14

For all yrs prior to the terminal year (1996), backcalculated stock sizes for the following ages used to estimate total mortality (Z) for age 14: 4 5 6 7 8 9 10 11 12 13 14
This method for estimating F on the oldest age is generally used when a flat-topped partial recruitment curve is thought to be characteristic of the stock.

F for age 15+ is then calculated from the following ratios of F[age 15+] to F[age 14]: 1.000

The following indices of abundance are used in the analysis:

2	HUD YOY	63	CT CPUE 1
3	NJ YOY	64	CT CPUE 2
4	DEL YOY	65	CT CPUE 3
5	MD YOY	66	CT CPUE 4
6	VA YOY	67	CT CPUE 5
9	WLI SV 1	68	CT CPUE 6
10	MD SV 1	69	CT CPUE 7
12	MD SSB 2	70	CT CPUE 8
13	MD SSB 3	71	CT CPUE 9
14	MD SSB 4	72	CT CPUE 10
15	MD SSB 5	73	CT CPUE 11
16	MD SSB 6	74	CT CPUE 12
17	MD SSB 7	75	CT CPUE 13
18	MD SSB 8	76	CT CPUE 14
19	MD SSB 9	81	HUD SHAD 6
20	MD SSB 10	82	HUD SHAD 7
21	MD SSB 11	83	HUD SHAD 8
22	MD SSB 12	92	NY OHS 4
23	MD SSB 13	93	NY OHS 5
24	MD SSB 14	94	NY OHS 6
25	MD SSB 15	95	NY OHS 7
55	MA COM 7	96	NY OHS 8
56	MA COM 8	97	NY OHS 9
57	MA COM 9	98	NY OHS 10
58	MA COM 10	99	NY OHS 11
59	MA COM 11	100	NY OHS 12
60	MA COM 12	101	NY OHS 13
61	MA COM 13	102	NY OHS 14
62	MA COM 14	103	NY OHS 15

ITERATIVE RE-WEIGHTS BY INDEX (chi)

■	2	3	4	5	6	9	10	12	13	14
■	0.0126	0.0026	0.0199	0.0226	0.0703	0.0232	0.0065	0.0076	0.0190	0.0129

■	15	16	17	18	19	20	21	22	23	24
■	0.0161	0.0196	0.0202	0.0084	0.0048	0.0078	0.0038	0.0039	0.0061	0.0033

■	25	55	56	57	58	59	60	61	62	63
■	0.0042	0.0320	0.0870	0.0729	0.0267	0.0188	0.0086	0.0117	0.0341	0.0076

■	64	65	66	67	68	69	70	71	72	73
■	0.0256	0.0665	0.0345	0.0224	0.0284	0.0175	0.0137	0.0030	0.0043	0.0041

■	74	75	76	81	82	83	92	93	94	95
■	0.0056	0.0053	0.0067	0.0114	0.0104	0.0074	0.0306	0.0229	0.0113	0.0084

■	96	97	98	99	100	101	102	103
■	0.0083	0.0092	0.0112	0.0101	0.0041	0.0050	0.0067	0.0105

Table C24. (Continued).

CATCH AT AGE (thousands) - SBASS96

■	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1 ■	2	4	6	1	11	1	3	1	3	2	3	0	6	4	1
2 ■	106	110	543	73	21	11	31	37	54	78	51	76	146	415	99
3 ■	257	178	303	102	64	38	42	81	136	153	217	198	350	447	659
4 ■	221	193	83	41	133	52	64	69	203	217	201	344	292	438	666
5 ■	58	150	61	59	50	68	106	106	182	166	188	300	369	386	552
6 ■	19	39	52	43	32	25	97	96	174	103	114	194	233	462	477
7 ■	24	19	18	44	20	13	41	46	112	95	66	90	136	201	457
8 ■	17	4	5	17	24	7	25	21	76	88	74	71	87	186	218
9 ■	12	3	2	6	9	7	14	11	24	63	64	90	100	148	143
10 ■	11	4	2	3	5	3	6	4	9	26	49	83	81	86	72
11 ■	11	5	1	1	3	1	4	3	6	15	10	45	36	51	44
12 ■	14	6	0	1	2	2	3	2	4	3	5	10	22	16	48
13 ■	3	5	2	1	1	3	2	2	5	3	2	5	3	9	13
14 ■	4	4	4	1	3	2	3	2	4	3	6	1	1	2	5
15 ■	8	5	5	9	7	8	4	5	8	18	10	13	10	3	3
1+■	767	729	1086	401	386	241	445	485	999	1032	1060	1521	1874	2854	3457

CAA summary for ages 3-9 3-13 4-13 5-13

■	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
3 ■	608	587	523	312	333	209	389	429	907	885	924	1287	1567	2268	3173
3 ■	647	606	529	318	344	219	404	440	930	931	990	1430	1711	2430	3350
4 ■	390	428	226	216	280	181	362	359	795	779	773	1232	1360	1983	2691
5 ■	169	234	143	175	147	129	298	290	591	561	572	888	1069	1545	2025

WT AT AGE (JAN 1) in kg.

■	1982	1983	1984	1985	1986	1987	1988	1989	1990
1 ■	0.063	0.115	0.151	0.019	0.060	0.094	0.189	0.068	0.024
2 ■	0.528	0.267	0.346	0.383	0.185	0.328	0.427	0.507	0.377
3 ■	0.972	0.776	0.964	0.801	0.880	0.896	0.920	1.054	0.973
4 ■	1.241	1.222	1.230	1.670	1.602	1.637	1.671	1.566	1.581
5 ■	2.076	1.910	1.913	1.878	2.006	2.449	2.562	2.461	2.289
6 ■	3.740	2.822	2.834	3.096	2.614	2.665	3.170	3.753	3.423
7 ■	4.589	3.760	4.084	4.080	3.766	3.356	3.570	4.646	4.716
8 ■	5.683	5.083	4.615	5.261	4.980	4.327	4.119	5.224	5.657
9 ■	5.424	5.899	6.014	6.185	5.450	5.280	4.984	5.324	5.959
10 ■	8.267	7.087	6.829	7.097	6.421	5.942	5.570	6.744	6.000
11 ■	11.011	9.114	8.254	8.357	7.599	6.879	7.462	7.088	8.036
12 ■	11.245	10.593	11.003	9.482	9.075	8.706	8.985	9.142	9.010
13 ■	14.020	11.155	10.519	12.019	10.829	10.204	10.605	11.640	9.548
14 ■	13.114	11.999	11.426	12.358	11.485	11.290	11.345	10.686	11.867
15 ■	15.910	11.120	14.750	15.980	15.830	16.460	17.000	17.110	17.650

■	1991	1992	1993	1994	1995	1996	1997
1 ■	0.116	0.036	0.018	0.141	0.145	0.036	0.066
2 ■	0.271	0.381	0.276	0.271	0.410	0.542	0.542
3 ■	1.071	1.094	0.951	1.133	1.191	1.014	2.033
4 ■	1.573	1.578	1.608	1.701	1.919	1.770	2.130
5 ■	2.318	2.469	2.312	2.381	2.474	2.649	3.041
6 ■	2.729	3.101	3.172	3.114	3.225	3.538	3.913
7 ■	4.292	3.941	4.197	4.205	4.339	4.829	5.774
8 ■	5.262	5.277	5.472	5.455	5.516	6.185	8.455
9 ■	6.205	6.265	6.380	6.441	6.714	6.936	8.174
10 ■	5.964	7.256	7.462	7.276	7.756	8.178	8.794
11 ■	7.515	7.808	8.813	8.823	7.550	9.082	10.349
12 ■	7.858	10.848	10.253	10.093	9.730	8.740	9.543
13 ■	9.346	10.427	13.407	11.061	12.220	10.513	11.649
14 ■	12.222	10.357	13.470	11.442	13.339	13.188	12.275
15 ■	17.090	17.650	15.360	17.750	20.370	17.300	17.300

Table C24. (Continued).

Weights at age at the start of the spawning season are assumed to be the same as the Jan1 weight at age estimates.

PERCENT MATURE (females)

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
5	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
6	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45
7	89	89	89	89	89	89	89	89	89	89	89	89	89	89	89
8	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94
9	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
10	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
11	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
12	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
13	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
14	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
15	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

SEX RATIO (Percent Female) BY YEAR and AGE = 50:50

RESULTS

APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

SUM OF SQUARES	6.173218
ORTHOGONALITY OFFSET.........	0.010170
MEAN SQUARE RESIDUALS	0.010038

	PAR. EST.	STD. ERR.	T-STATISTIC	C.V.
N 1	1.50988E4	4.14494E3	3.64269E0	0.27
N 2	5.06291E3	1.30217E3	3.88807E0	0.26
N 3	4.01302E3	9.39614E2	4.27092E0	0.23
N 4	9.02464E3	1.80817E3	4.99105E0	0.20
N 5	2.55901E3	5.51230E2	4.64236E0	0.22
N 6	1.29445E3	3.20813E2	4.03490E0	0.25
N 7	1.06829E3	2.65628E2	4.02175E0	0.25
N 8	1.15604E3	2.80570E2	4.12032E0	0.24
N 9	6.52442E2	1.42349E2	4.58339E0	0.22
N10	3.76760E2	8.69735E1	4.33190E0	0.23
N11	1.98092E2	5.32598E1	3.71935E0	0.27
N12	1.12550E2	3.62828E1	3.10202E0	0.32
N13	1.20386E2	3.93350E1	3.06052E0	0.33

CATCHABILITY ESTIMATES IN ORIGINAL UNITS

	ESTIMATE	STD. ERR.	C.V.
qHUD YOY	2.34881E-3	5.41161E-4	0.23
qNJ YOY	5.36126E-5	2.66309E-5	0.50
qDEL YOY	5.71357E-5	1.52667E-5	0.27
qMD YOY	4.69749E-4	8.24321E-5	0.18
qVA YOY	1.31545E-3	1.42884E-4	0.11
qWLI SV 1	1.37910E-4	2.67702E-5	0.19
qMD SV 1	1.99413E-5	6.50065E-6	0.33
qMD SSB 2	5.84728E-3	1.89706E-3	0.32
qMD SSB 3	4.47356E-2	9.34224E-3	0.21
qMD SSB 4	5.10192E-2	1.27888E-2	0.25
qMD SSB 5	4.33341E-2	9.75456E-3	0.23
qMD SSB 6	4.16383E-2	8.56239E-3	0.21
qMD SSB 7	3.99551E-2	8.12087E-3	0.20
qMD SSB 8	3.43435E-2	1.10344E-2	0.32
qMD SSB 9	2.19847E-2	9.69427E-3	0.44
qMD SSB10	1.79533E-2	6.02592E-3	0.34
qMD SSB11	1.19754E-2	6.60832E-3	0.55
qMD SSB12	9.53825E-3	5.18502E-3	0.54

Table C24. (Continued).

qMD SSB13	1.14366E-2	4.74857E-3	0.42
qMD SSB14	1.43152E-2	8.85774E-3	0.62
qMD SSB15	9.79823E-3	4.62872E-3	0.47
qMACOM 7	7.13136E-4	1.62144E-4	0.23
qMACOM 8	7.13548E-3	1.07584E-3	0.15
qMACOM 9	2.08680E-2	3.40828E-3	0.16
qMACOM 10	2.71546E-2	6.78655E-3	0.25
qMACOM 11	2.31142E-2	6.78176E-3	0.29
qMACOM 12	1.57839E-2	6.64513E-3	0.42
qMACOM 13	8.44569E-3	3.06138E-3	0.36
qMACOM 14	1.30453E-2	2.90484E-3	0.22
qCTCPUE 1	4.30805E-5	1.26024E-5	0.29
qCTCPUE 2	1.47172E-4	2.39726E-5	0.16
qCTCPUE 3	2.17015E-4	2.29059E-5	0.11
qCTCPUE 4	2.05042E-4	2.90461E-5	0.14
qCTCPUE 5	2.28504E-4	3.97777E-5	0.17
qCTCPUE 6	1.91690E-4	2.99601E-5	0.16
qCTCPUE 7	1.69601E-4	3.32924E-5	0.20
qCTCPUE 8	2.12857E-4	4.68799E-5	0.22
qCTCPUE 9	1.51835E-4	7.06722E-5	0.47
qCTCPUE10	1.34297E-4	5.22397E-5	0.39
qCTCPUE11	1.32441E-4	5.80598E-5	0.44
qCTCPUE12	1.23274E-4	4.66319E-5	0.38
qCTCPUE13	7.00379E-5	2.70533E-5	0.39
qCTCPUE14	4.54035E-5	1.56975E-5	0.35
qHDSHAD 6	6.64872E-4	1.69044E-4	0.25
qHDSHAD 7	5.05366E-4	1.34991E-4	0.27
qHDSHAD 8	3.27481E-4	1.03465E-4	0.32
qNY OHS 4	2.10755E-3	4.02958E-4	0.19
qNY OHS 5	2.11155E-3	4.61755E-4	0.22
qNY OHS 6	1.82953E-3	5.59346E-4	0.31
qNY OHS 7	1.64398E-3	5.80065E-4	0.35
qNY OHS 8	1.68003E-3	5.95557E-4	0.35
qNY OHS 9	1.76882E-3	5.95713E-4	0.34
qNY OHS10	1.65924E-3	5.12186E-4	0.31
qNYOHS 11	2.13692E-3	7.31780E-4	0.34
qNYOHS 12	9.55414E-4	4.79501E-4	0.50
qNYOHS 13	2.28803E-3	1.25598E-3	0.55
qNYOHS 14	8.96621E-4	3.55253E-4	0.40
qNYOHS 15	7.91046E-4	2.52265E-4	0.32

Partial variance (and proportion of total) by index

	■	2	3	4	5	6	9
**	■	0.00998050	0.01068167	0.00896165	0.01007822	0.00962666	0.01055901
**	■	0.01715479	0.01835998	0.01540356	0.01732277	0.01654661	0.01814915

	■	10	12	13	14	15	16
**	■	0.01033875	0.00973983	0.00931137	0.00960127	0.00921356	0.00958134
**	■	0.01777056	0.01674112	0.01600467	0.01650296	0.01583656	0.01646871

	■	17	18	19	20	21	22
**	■	0.01111807	0.01069255	0.01076888	0.01112361	0.01151662	0.01113247
**	■	0.01911009	0.01837869	0.01850988	0.01911960	0.01979513	0.01913484

	■	23	24	25	55	56	57
**	■	0.01021613	0.01005744	0.00957802	0.00963715	0.00784953	0.01137367
**	■	0.01755980	0.01728705	0.01646300	0.01656463	0.01349201	0.01954941

	■	58	59	60	61	62	63
**	■	0.01100540	0.01055387	0.01092233	0.01154821	0.01054949	0.00993955
**	■	0.01891642	0.01814033	0.01877364	0.01984942	0.01813280	0.01708441

Table C24. (Continued).

■	64	65	66	67	68	69
** ■	0.00888899	0.00817626	0.00862695	0.01003655	0.00963354	0.01098197
** ■	0.01527868	0.01405361	0.01482827	0.01725113	0.01655843	0.01887615

■	70	71	72	73	74	75
** ■	0.01073125	0.01060354	0.01103317	0.01130780	0.01196470	0.01156952
** ■	0.01844520	0.01822569	0.01896416	0.01943620	0.02056531	0.01988606

■	76	81	82	83	92	93
** ■	0.01155054	0.01006672	0.00986112	0.01009514	0.00923380	0.00879187
** ■	0.01985343	0.01730300	0.01694961	0.01735184	0.01587135	0.01511174

■	94	95	96	97	98	99
** ■	0.00884841	0.00835145	0.00829116	0.00873015	0.00863390	0.00844544
** ■	0.01520893	0.01435474	0.01425110	0.01500566	0.01484022	0.01451629

■	100	101	102	103	********
** ■	0.00955677	0.00982483	0.01056032	0.01013797	0.58179068
** ■	0.01642647	0.01688723	0.01815141	0.01742546	1.00000000

STOCK NUMBERS (Jan 1) in thousands

■	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1 ■	1378	2739	2445	3180	2710	3309	4326	5122	7291	5320	5174	6623	15638	5545	5883	15099
2 ■	966	1184	2354	2099	2736	2322	2847	3721	4408	6273	4577	4450	5700	13455	4769	5063
3 ■	887	733	917	1522	1739	2335	1988	2422	3168	3744	5327	3892	3760	4771	11196	4013
4 ■	958	525	466	508	1216	1438	1974	1672	2009	2601	3080	4384	3167	2911	3691	9025
5 ■	350	620	273	324	400	923	1189	1640	1375	1541	2037	2465	3454	2455	2099	2559
6 ■	198	247	394	179	224	298	732	925	1314	1015	1172	1579	1843	2631	1755	1294
7 ■	125	153	176	291	114	163	233	539	707	969	778	904	1179	1370	1836	1068
8 ■	131	85	114	135	210	79	128	163	421	505	746	608	694	889	993	1156
9 ■	102	97	69	94	100	158	62	88	120	293	353	573	457	517	592	652
10 ■	59	77	81	58	75	77	130	40	66	81	194	244	410	300	307	377
11 ■	34	41	63	68	46	59	64	107	31	49	46	121	133	278	178	198
12 ■	64	19	31	53	57	37	50	52	89	21	28	30	62	81	192	113
13 ■	25	42	11	26	45	48	30	40	43	73	15	20	16	33	55	120
14 ■	21	18	32	7	22	38	38	23	33	32	60	11	13	11	20	35
15 ■	42	20	35	71	59	139	52	79	59	162	113	115	82	19	11	19
1+■	5339	6600	7460	8615	9753	11423	13842	16632	21134	22677	23701	26019	36609	35264	33577	40792

Summaries for ages 3-8 3-13 4-13 5-13

■	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
3-8 ■	2649	2363	2340	2959	3903	5235	6245	7361	8995	10374	13140	13831	14097	15026	21570	19115
3-13 ■	2932	2639	2594	3257	4226	5615	6580	7686	9343	10890	13776	14820	15176	16235	22895	20576
4-13 ■	2045	1905	1677	1735	2487	3280	4592	5265	6175	7147	8449	10928	11416	11464	11699	16563
5-13 ■	1087	1380	1211	1227	1271	1842	2618	3593	4166	4546	5369	6544	8250	8553	8008	7538

FISHING MORTALITY

■	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1 ■	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 ■	0.13	0.11	0.29	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.03	0.02
3 ■	0.37	0.30	0.44	0.08	0.04	0.02	0.02	0.04	0.05	0.04	0.04	0.06	0.11	0.11	0.07
4 ■	0.29	0.51	0.21	0.09	0.13	0.04	0.04	0.05	0.12	0.09	0.07	0.09	0.10	0.18	0.22
5 ■	0.20	0.30	0.27	0.22	0.14	0.08	0.10	0.07	0.15	0.12	0.10	0.14	0.12	0.19	0.33
6 ■	0.11	0.19	0.15	0.30	0.17	0.10	0.15	0.12	0.15	0.12	0.11	0.14	0.15	0.21	0.35
7 ■	0.24	0.14	0.12	0.18	0.22	0.09	0.21	0.10	0.19	0.11	0.10	0.11	0.13	0.17	0.31
8 ■	0.15	0.05	0.05	0.15	0.13	0.09	0.23	0.15	0.21	0.21	0.11	0.14	0.15	0.26	0.27
9 ■	0.13	0.03	0.03	0.08	0.10	0.05	0.28	0.14	0.25	0.26	0.22	0.18	0.27	0.37	0.30

Table C24. (Continued).

10	0.22	0.05	0.03	0.07	0.08	0.04	0.05	0.11	0.15	0.42	0.32	0.46	0.24	0.37	0.29
11	0.44	0.13	0.01	0.02	0.08	0.03	0.06	0.03	0.23	0.40	0.27	0.51	0.35	0.22	0.31
12	0.26	0.40	0.01	0.02	0.03	0.06	0.07	0.04	0.05	0.17	0.19	0.46	0.49	0.24	0.32
13	0.16	0.13	0.25	0.02	0.02	0.08	0.09	0.05	0.13	0.04	0.14	0.31	0.25	0.37	0.30
14	0.23	0.28	0.16	0.14	0.13	0.06	0.09	0.08	0.15	0.13	0.10	0.13	0.14	0.21	0.30
15	0.23	0.28	0.16	0.14	0.13	0.06	0.09	0.08	0.15	0.13	0.10	0.13	0.14	0.21	0.30

Avg F for ages 3-8 3-13 4-13 5-13

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
3-8	0.23	0.25	0.21	0.17	0.14	0.07	0.13	0.09	0.15	0.12	0.09	0.11	0.13	0.18	0.26
3-13	0.23	0.20	0.14	0.11	0.10	0.06	0.12	0.08	0.15	0.18	0.15	0.24	0.21	0.24	0.28
4-13	0.22	0.19	0.11	0.11	0.11	0.07	0.13	0.09	0.16	0.19	0.16	0.25	0.23	0.26	0.30
5-13	0.21	0.16	0.10	0.12	0.11	0.07	0.14	0.09	0.17	0.21	0.17	0.27	0.24	0.27	0.31

BACKCALCULATED PARTIAL RECRUITMENT

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	0.00	0.00	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.29	0.21	0.65	0.13	0.04	0.05	0.04	0.07	0.05	0.03	0.04	0.04	0.06	0.09	0.07
3	0.86	0.60	1.00	0.25	0.19	0.18	0.08	0.24	0.19	0.11	0.14	0.11	0.22	0.29	0.19
4	0.65	1.00	0.48	0.30	0.58	0.41	0.13	0.30	0.47	0.23	0.23	0.17	0.21	0.48	0.62
5	0.45	0.60	0.62	0.72	0.67	0.86	0.36	0.48	0.63	0.29	0.33	0.27	0.25	0.50	0.96
6	0.25	0.37	0.35	1.00	0.78	1.00	0.55	0.78	0.63	0.28	0.34	0.28	0.30	0.57	1.00
7	0.54	0.28	0.27	0.58	1.00	0.96	0.74	0.64	0.76	0.27	0.30	0.22	0.27	0.46	0.90
8	0.34	0.11	0.10	0.49	0.61	0.99	0.83	1.00	0.88	0.49	0.35	0.26	0.30	0.69	0.78
9	0.30	0.06	0.08	0.25	0.49	0.47	1.00	0.91	1.00	0.63	0.68	0.36	0.55	0.99	0.87
10	0.49	0.11	0.06	0.22	0.37	0.45	0.18	0.71	0.62	1.00	1.00	0.89	0.49	1.00	0.84
11	1.00	0.26	0.03	0.05	0.38	0.29	0.23	0.22	0.95	0.95	0.85	1.00	0.70	0.59	0.90
12	0.60	0.79	0.02	0.05	0.14	0.63	0.26	0.28	0.20	0.40	0.59	0.89	1.00	0.65	0.91
13	0.37	0.26	0.57	0.07	0.10	0.83	0.32	0.35	0.54	0.10	0.44	0.61	0.52	0.99	0.87
14	0.53	0.55	0.36	0.48	0.60	0.64	0.32	0.51	0.61	0.30	0.32	0.25	0.28	0.56	0.87
15	0.53	0.55	0.36	0.48	0.60	0.64	0.32	0.51	0.61	0.30	0.32	0.25	0.28	0.56	0.87

MEAN BIOMASS (MT)

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	166	508	544	177	352	614	1245	761	542	1037	480	430	3485	1441	765
2	540	575	1145	1167	1442	1656	2392	2853	3619	5324	2916	3112	5483	8604	4599
3	753	554	1170	1459	2011	3031	2008	2695	3278	4388	6292	4607	5606	5681	14805
4	1196	528	629	745	2550	2763	3568	3386	3618	5007	5329	7762	6179	5412	7170
5	716	1181	594	594	844	2059	3271	4501	2787	3532	5053	5925	8618	5777	5359
6	654	690	1152	516	600	768	2535	3675	4338	2824	3788	4901	5582	8065	6253
7	499	499	784	1219	376	524	857	2567	2948	4100	3378	3812	5073	6302	9392
8	655	410	585	636	924	331	501	875	2105	2395	3797	3233	3726	4499	5764
9	550	533	427	568	480	794	263	459	566	1548	2057	3426	2535	2930	3721
10	428	563	574	385	407	457	664	307	338	386	1257	1466	2559	2074	2289
11	274	341	487	561	321	423	493	872	192	354	365	841	1022	1758	1331
12	586	149	360	525	479	324	464	457	731	150	296	242	490	653	1548
13	277	409	95	276	455	486	304	471	347	636	175	231	153	357	502
14	236	164	322	90	223	398	382	208	304	447	591	139	99	144	196
15	557	184	441	986	817	2064	783	1207	896	2415	1764	1536	1262	324	150
1+	8087	7288	9309	9903	12281	16694	19730	25292	26607	34545	37539	41666	51872	54022	63844

Summaries for ages 3-8 3-13 4-13 5-13

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
3-8	4472	3862	4914	5168	7306	9477	12740	17699	19073	22247	27637	30241	34784	35737	48744
3-13	6587	5857	6856	7483	9447	11961	14928	20264	21247	25321	31788	36448	41544	43509	58134
4-13	5835	5303	5686	6024	7436	8930	12920	17569	17969	20933	25496	31840	35938	37828	43329
5-13	4638	4775	5057	5279	4886	6166	9352	14183	14351	15926	20167	24078	29759	32416	36159

Table C24. (Continued).

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

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	22	12	11	16	37	45	63	50	60	77	92	133	101	104	122
5	44	71	31	37	49	139	187	248	192	218	308	347	502	369	333
6	157	147	235	115	124	168	489	734	948	586	770	1057	1210	1779	1284
7	236	239	301	494	177	230	344	1051	1386	1741	1285	1587	2071	2474	3638
8	327	191	234	312	461	151	231	374	1043	1164	1739	1468	1669	2136	2672
9	259	271	197	274	256	396	142	219	333	841	1030	1708	1363	1590	1896
10	226	258	262	193	227	218	343	127	185	220	647	829	1387	1068	1162
11	168	175	246	268	166	194	225	359	116	167	166	481	540	976	747
12	333	90	161	240	246	151	211	223	379	78	142	140	284	366	773
13	163	221	53	150	232	230	149	220	191	322	75	123	84	183	266
14	130	101	170	42	119	203	203	118	181	184	292	73	67	68	119
15	312	104	240	534	440	1083	415	636	486	1298	940	827	681	180	86
1+	2378	1881	2141	2674	2534	3207	3002	4359	5498	6895	7487	8773	9961	11293	13097

MEAN STOCK NUMBERS (thousands)

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	1279	2542	2268	2952	2511	3072	4016	4756	6769	4939	4803	6150	14519	5147	5463
2	844	1045	1908	1914	2530	2151	2628	3437	4067	5787	4225	4095	5222	12291	4380
3	690	590	692	1363	1584	2150	1825	2209	2875	3401	4840	3517	3317	4208	10071
4	777	385	391	452	1063	1310	1802	1518	1765	2308	2761	3901	2796	2483	3091
5	296	498	222	271	346	824	1052	1471	1186	1348	1798	2139	3024	2086	1664
6	174	210	340	144	192	264	631	811	1133	891	1032	1369	1595	2210	1383
7	103	132	155	248	95	145	196	478	600	852	689	794	1027	1171	1470
8	113	77	104	116	183	70	107	140	353	425	656	529	601	730	811
9	89	89	63	84	88	144	50	76	99	240	296	487	373	403	476
10	49	70	74	52	67	70	118	35	57	62	154	183	340	234	249
11	25	36	58	62	41	54	57	97	26	37	37	88	105	232	143
12	52	14	28	49	52	33	45	47	80	18	24	23	46	67	153
13	21	37	9	24	41	43	26	36	37	66	13	16	13	26	44
14	18	15	27	6	19	34	34	21	28	28	53	10	11	9	16
15	35	17	30	62	52	125	46	71	51	141	100	100	71	16	9
1+	4567	5755	6369	7799	8865	10489	12633	15205	19127	20544	21483	23402	33060	31313	29423

Table C25. Bootstrap estimates of precision in striped bass VPA.

Age-specific stocksizes (on Jan 1, 1997) estimated by NLLS

AGE	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1	1.511E4	1.576E4	3.595E3	0.24
2	5.109E3	5.270E3	1.300E3	0.25
3	4.015E3	4.180E3	9.041E2	0.23
4	9.030E3	9.204E3	1.808E3	0.20
5	2.561E3	2.610E3	5.554E2	0.22
6	1.296E3	1.330E3	3.198E2	0.25
7	1.070E3	1.066E3	2.527E2	0.24
8	1.157E3	1.181E3	2.514E2	0.22
9	6.530E2	6.591E2	1.366E2	0.21
10	3.771E2	3.742E2	7.104E1	0.19
11	1.984E2	1.977E2	4.806E1	0.24
12	1.137E2	1.133E2	3.310E1	0.29
13	1.206E2	1.208E2	3.766E1	0.31

BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V FOR CORRECTED ESTIMATE
6.557E2	2.542E2	4.34	1.445E4	0.25
1.615E2	9.193E1	3.16	4.947E3	0.26
1.642E2	6.393E1	4.09	3.851E3	0.23
1.740E2	1.279E2	1.93	8.856E3	0.20
4.874E1	3.927E1	1.90	2.512E3	0.22
3.452E1	2.261E1	2.66	1.261E3	0.25
-3.182E0	1.787E1	-0.30	1.073E3	0.24
2.410E1	1.778E1	2.08	1.133E3	0.22
6.106E0	9.659E0	0.94	6.469E2	0.21
-2.929E0	5.023E0	-0.78	3.800E2	0.19
-6.913E-1	3.398E0	-0.35	1.991E2	0.24
-3.955E-1	2.340E0	-0.35	1.141E2	0.29
1.231E-1	2.663E0	0.10	1.205E2	0.31

Full vector of age-specific stock sizes on Jan 1, 1997

AGE	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1	1.511E4	1.576E4	3.595E3	0.24
2	5.109E3	5.270E3	1.300E3	0.25
3	4.015E3	4.180E3	9.041E2	0.23
4	9.030E3	9.204E3	1.808E3	0.20
5	2.561E3	2.610E3	5.554E2	0.22
6	1.296E3	1.330E3	3.198E2	0.25
7	1.070E3	1.066E3	2.527E2	0.24
8	1.157E3	1.181E3	2.514E2	0.22
9	6.530E2	6.591E2	1.366E2	0.21
10	3.771E2	3.742E2	7.104E1	0.19
11	1.984E2	1.977E2	4.806E1	0.24
12	1.137E2	1.133E2	3.310E1	0.29
13	1.206E2	1.208E2	3.766E1	0.31
14	3.507E1	3.396E1	5.173E0	0.15
15	1.936E1	1.875E1	2.859E0	0.15

BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V FOR CORRECTED ESTIMATE
6.557E2	2.542E2	4.34	1.445E4	0.25
1.615E2	9.193E1	3.16	4.947E3	0.26
1.642E2	6.393E1	4.09	3.851E3	0.23
1.740E2	1.279E2	1.93	8.856E3	0.20
4.874E1	3.927E1	1.90	2.512E3	0.22
3.452E1	2.261E1	2.66	1.261E3	0.25

Table C25. (Continued).

-3.182E0	1.787E1	-0.30	1.073E3	0.24
2.410E1	1.778E1	2.08	1.133E3	0.22
6.106E0	9.659E0	0.94	6.469E2	0.21
-2.929E0	5.023E0	-0.78	3.800E2	0.19
-6.913E-1	3.398E0	-0.35	1.991E2	0.24
-3.955E-1	2.340E0	-0.35	1.141E2	0.29
1.231E-1	2.663E0	0.10	1.205E2	0.31
-1.113E0	3.658E-1	-3.17	3.619E1	0.14
-6.150E-1	2.022E-1	-3.18	1.998E1	0.14

Full vector of age-specific terminal Fs (in 1996).

AGE	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1	9.080E-5	9.376E-5	2.485E-5	0.27
2	2.257E-2	2.273E-2	5.132E-3	0.23
3	6.556E-2	6.686E-2	1.371E-2	0.21
4	2.163E-1	2.209E-1	4.513E-2	0.21
5	3.330E-1	3.401E-1	7.302E-2	0.22
6	3.462E-1	3.621E-1	7.802E-2	0.23
7	3.124E-1	3.180E-1	6.271E-2	0.20
8	2.695E-1	2.766E-1	5.308E-2	0.20
9	3.020E-1	3.124E-1	5.236E-2	0.17
10	2.891E-1	3.033E-1	6.574E-2	0.23
11	3.080E-1	3.304E-1	9.290E-2	0.30
12	3.159E-1	3.388E-1	9.243E-2	0.29
13	2.995E-1	3.133E-1	4.132E-2	0.14
14	2.995E-1	3.133E-1	4.132E-2	0.14
15+	2.995E-1	3.133E-1	4.132E-2	0.14

BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V FOR CORRECTED ESTIMATE
2.961E-6	1.757E-6	3.26	8.784E-5	0.28
1.586E-4	3.629E-4	0.70	2.241E-2	0.23
1.300E-3	9.691E-4	1.98	6.426E-2	0.21
4.633E-3	3.191E-3	2.14	2.116E-1	0.21
7.067E-3	5.164E-3	2.12	3.260E-1	0.22
1.589E-2	5.517E-3	4.59	3.303E-1	0.24
5.570E-3	4.434E-3	1.78	3.068E-1	0.20
7.143E-3	3.753E-3	2.65	2.624E-1	0.20
1.042E-2	3.702E-3	3.45	2.916E-1	0.18
1.419E-2	4.649E-3	4.91	2.749E-1	0.24
2.242E-2	6.569E-3	7.28	2.856E-1	0.33
2.296E-2	6.536E-3	7.27	2.929E-1	0.32
1.379E-2	2.921E-3	4.60	2.857E-1	0.14
1.379E-2	2.921E-3	4.60	2.857E-1	0.14
1.379E-2	2.921E-3	4.60	2.857E-1	0.14

Fully-recruited (ages 4-13) F in the terminal year (1996)

NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
2.995E-1	3.133E-1	4.132E-2	0.14

BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V FOR CORRECTED ESTIMATE
1.379E-2	2.921E-3	4.60	2.857E-1	0.14

Table C25. (Continued).

Partial recruitment vector in the terminal year (1996)

	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1	2.623E-4	2.197E-4	6.272E-5	0.24
2	6.520E-2	5.334E-2	1.369E-2	0.21
3	1.894E-1	1.569E-1	3.667E-2	0.19
4	6.247E-1	5.186E-1	1.250E-1	0.20
5	9.620E-1	7.890E-1	1.485E-1	0.15
6	1.000E 0	8.382E-1	1.438E-1	0.14
7	9.024E-1	7.415E-1	1.465E-1	0.16
8	7.785E-1	6.503E-1	1.497E-1	0.19
9	8.724E-1	7.288E-1	1.292E-1	0.15
10	8.352E-1	7.062E-1	1.511E-1	0.18
11	8.898E-1	7.629E-1	1.706E-1	0.19
12	9.124E-1	7.821E-1	1.751E-1	0.19
13	8.651E-1	7.286E-1	8.994E-2	0.10
14	8.651E-1	7.286E-1	8.994E-2	0.10
15	8.651E-1	7.286E-1	8.994E-2	0.10

BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V FOR CORRECTED ESTIMATE
-4.261E-5	4.435E-6	-16.25	3.049E-4	0.21
-1.186E-2	9.680E-4	-18.19	7.706E-2	0.18
-3.245E-2	2.593E-3	-17.14	2.218E-1	0.17
-1.061E-1	8.836E-3	-16.98	7.308E-1	0.17
-1.730E-1	1.050E-2	-17.99	1.135E0	0.13
-1.618E-1	1.017E-2	-16.18	1.162E0	0.12
-1.609E-1	1.036E-2	-17.83	1.063E0	0.14
-1.282E-1	1.058E-2	-16.47	9.067E-1	0.17
-1.436E-1	9.133E-3	-16.46	1.016E0	0.13
-1.290E-1	1.068E-2	-15.44	9.642E-1	0.16
-1.269E-1	1.206E-2	-14.26	1.017E0	0.17
-1.303E-1	1.238E-2	-14.29	1.043E0	0.17
-1.365E-1	6.360E-3	-15.78	1.002E0	0.09
-1.365E-1	6.360E-3	-15.78	1.002E0	0.09
-1.365E-1	6.360E-3	-15.78	1.002E0	0.09

Mean stock biomass during the terminal year (1996)

NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
6.391E4	6.477E4	6.679E3	0.10

BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V FOR CORRECTED ESTIMATE
8.580E2	4.723E2	1.34	6.305E4	0.11

SSB (females) at start of spawning season (1996)

NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1.311E4	1.317E4	1.301E3	0.10

BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V FOR CORRECTED ESTIMATE
5.340E1	9.198E1	0.41	1.306E4	0.10

Table C26. Striped bass retrospective analysis using unweighted runs.

		Year															
	Terminal yr	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Recruits	1993	1,769	4,722	4,121	3,717	2,545	3,136	4,314	4,479	5,904	4,561	3,251	5,194	15,253	-	-	-
(age 1)	1994	1,507	5,104	4,356	4,578	3,555	3,976	5,139	5,690	9,055	5,865	5,233	7,253	18,367	10,946	-	-
(000's)	1995	1,391	2,923	3,360	3,813	3,286	3,979	4,883	5,823	7,753	5,579	4,604	6,303	15,674	8,412	9,757	-
	1996	1,400	2,793	2,576	3,680	3,089	3,759	4,792	5,888	9,776	6,360	6,223	30,781	41,302	40,341	39,921	48,017
Stock	1993	6,124	9,254	11,422	12,573	13,015	14,116	16,062	17,888	20,809	21,649	20,871	22,145	32,903	-	-	-
size (1+)	1994	5,964	9,495	11,863	13,806	15,096	16,754	19,152	21,765	27,291	28,555	28,785	31,009	43,620	46,752	-	-
(000's)	1995	5,562	6,973	8,696	10,313	11,791	13,874	16,485	19,608	24,151	25,551	25,590	27,313	37,752	39,106	40,768	-
	1996	5,504	6,795	7,758	9,373	10,784	12,765	15,461	18,793	25,476	27,467	28,867	30,781	41,302	40,341	39,921	48,017
Fishing	1993	0.20	0.23	0.18	0.14	0.11	0.05	0.08	0.05	0.10	0.10	0.09	0.13	-	-	-	
mortality	1994	0.19	0.22	0.18	0.14	0.11	0.05	0.09	0.05	0.08	0.08	0.07	0.09	0.10	-	-	
(ages 3-8)	1995	0.21	0.23	0.20	0.16	0.13	0.06	0.11	0.07	0.11	0.09	0.07	0.09	0.11	0.17	-	
	1996	0.21	0.24	0.20	0.16	0.13	0.07	0.12	0.08	0.13	0.10	0.08	0.09	0.10	0.15	0.20	
Fishing	1993	0.20	0.18	0.12	0.09	0.08	0.04	0.09	0.06	0.11	0.11	0.09	0.12	-	-	-	
mortality	1994	0.19	0.18	0.12	0.09	0.08	0.04	0.09	0.06	0.10	0.12	0.09	0.12	0.10	-	-	
(ages 3-13)	1995	0.26	0.27	0.24	0.10	0.08	0.04	0.06	0.05	0.09	0.08	0.07	0.10	0.12	0.17	-	
	1996	0.22	0.19	0.14	0.10	0.10	0.06	0.11	0.07	0.14	0.16	0.13	0.20	0.17	0.18	0.20	
Fishing	1993	0.18	0.17	0.10	0.10	0.09	0.05	0.09	0.06	0.12	0.12	0.10	0.13	-	-	-	
mortality	1994	0.18	0.16	0.10	0.09	0.08	0.05	0.09	0.06	0.11	0.13	0.09	0.13	0.10	-	-	
(ages 4-13)	1995	0.21	0.26	0.15	0.14	0.12	0.05	0.07	0.06	0.12	0.10	0.08	0.11	0.12	0.19	-	
	1996	0.21	0.18	0.11	0.11	0.10	0.06	0.12	0.08	0.15	0.17	0.14	0.21	0.18	0.19	0.22	
Fishing	1993	0.17	0.14	0.09	0.10	0.09	0.05	0.10	0.06	0.12	0.12	0.10	0.13	-	-	-	
mortality	1994	0.17	0.13	0.09	0.10	0.09	0.05	0.10	0.06	0.11	0.13	0.10	0.13	0.10	-	-	
(ages 5-13)	1995	0.17	0.18	0.12	0.15	0.12	0.07	0.10	0.07	0.13	0.11	0.10	0.13	0.12	0.18	-	
	1996	0.20	0.15	0.10	0.11	0.10	0.06	0.13	0.08	0.15	0.18	0.15	0.23	0.19	0.20	0.22	
Female	1993	2,972	2,453	2,765	3,427	3,474	4,847	4,631	7,469	9,475	11,107	11,624	12,877	-	-	-	
SSB	1994	3,161	2,642	3,004	3,680	3,762	5,117	4,891	8,055	10,431	12,861	13,967	16,053	17,822	-	-	
(mt)	1995	2,632	2,131	2,442	3,041	2,899	3,798	3,510	5,300	6,998	8,952	9,970	11,780	13,464	15,204	-	
	1996	2,501	2,001	2,296	2,880	2,738	3,456	3,264	4,754	6,090	7,885	8,778	10,589	12,343	14,636	18,267	

Table C27. Input parameters and stochastic projection results of striped bass: landings, discard, and spawning stock biomass (female, 000's mt). Starting stock sizes on 1 January 1997 (age 1 and older) as estimated by VPA bootstrap procedure (200 iterations) for ages 1-15+. Recruitment (age 1) level in 1998-1999 selected at random from time series of recruitment equivalents determined from MD juvenile indices (1955-1977, 1989-1996). Fishing mortality pattern, proportion discarded, and mean weights (kg) are weighted (by fishery) average values from 1994-1996. Fishing mortality is the target mortality from the FMP. Percent mortality prior to spawning is 33%.

Age	Partial recruitment pattern	Proportion discarded	Female proportion mature	Overall mean weight	Mean weight landings	Mean weight discards
1	0.00	0.94	0.00	0.220	0.290	0.290
2	0.06	0.86	0.00	0.933	1.110	0.690
3	0.20	0.63	0.00	1.503	1.710	1.160
4	0.63	0.46	0.04	2.237	2.470	1.950
5	0.94	0.46	0.13	2.947	3.190	2.630
6	1.00	0.47	0.45	3.890	4.130	3.410
7	1.00	0.39	0.89	5.570	5.400	4.320
8	1.00	0.25	0.94	6.490	6.710	5.240
9	1.00	0.16	1.00	7.290	7.540	5.960
10	1.00	0.12	1.00	8.530	8.680	6.690
11	1.00	0.12	1.00	8.870	8.850	6.770
12	1.00	0.12	1.00	10.170	10.390	7.690
13	1.00	0.04	1.00	12.233	12.070	8.930
14	1.00	0.00	1.00	15.670	15.670	-
15+	1.00	0.00	1.00	18.820	18.820	-

Year	Recruitment		SSB		Landings		Discards	
	Average ('000)	Median ('000)	Average (mt)	Median (mt)	Average (mt)	Median (mt)	Average (mt)	Median (mt)
1997	15,760	15,621	13,096	12,975	7,803	7,725	3,246	3,198
1998	6,443	5,226	13,481	13,336	8,211	8,129	3,543	3,508
1999	6,500	5,226	15,297	14,993	8,515	8,393	3,844	3,815

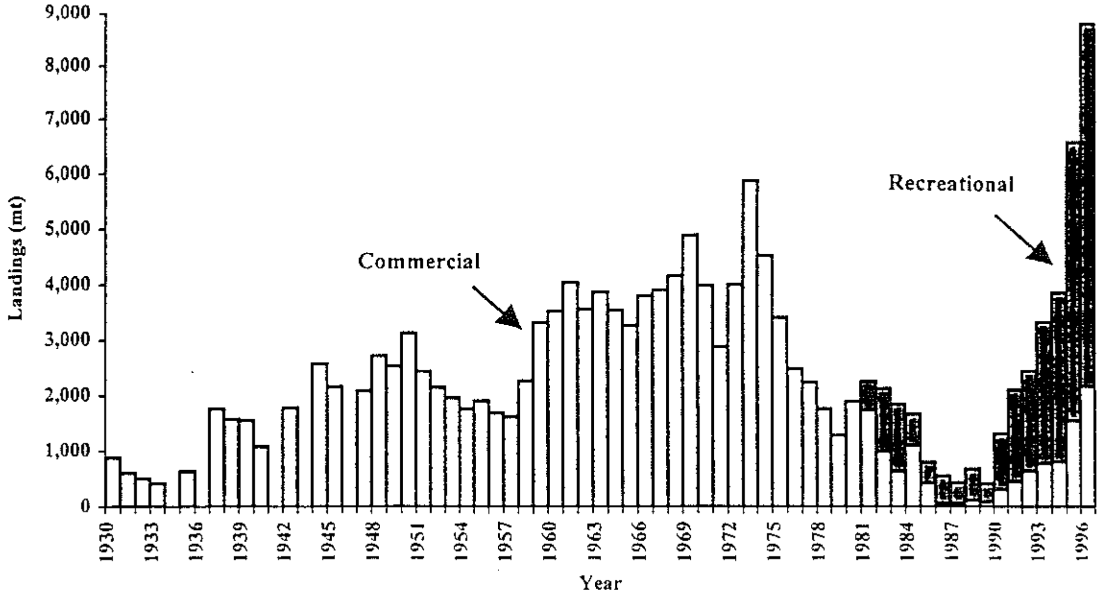

Figure C1. Striped bass commercial and recreational landings, Maine to coastal North Carolina, 1930-1996.

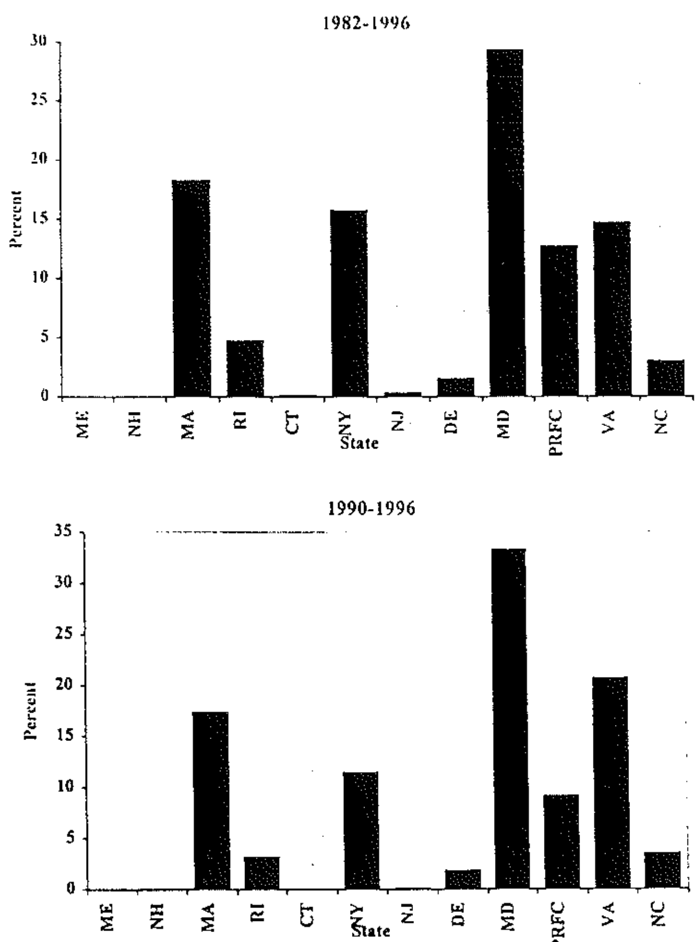

Figure C2. Percentage commercial striped bass landings in weight by state, 1982-1996 and 1990-1996.

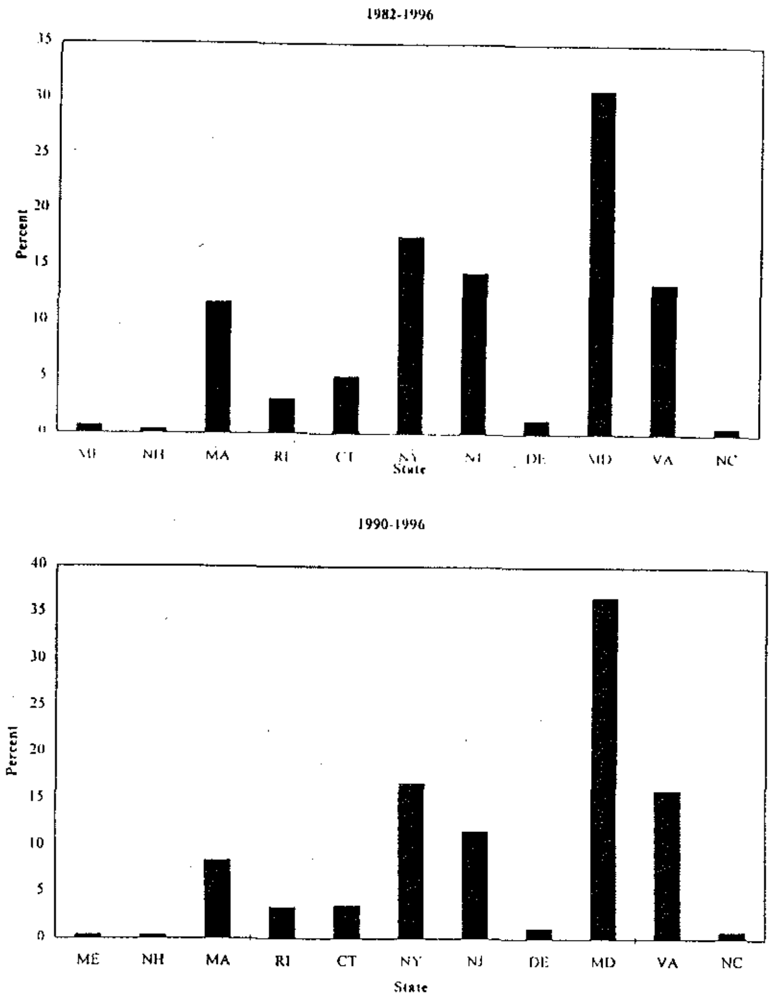

Figure C3. Percentage of striped bass recreational landings (number) by state, 1982-1996 and 1990-1996.

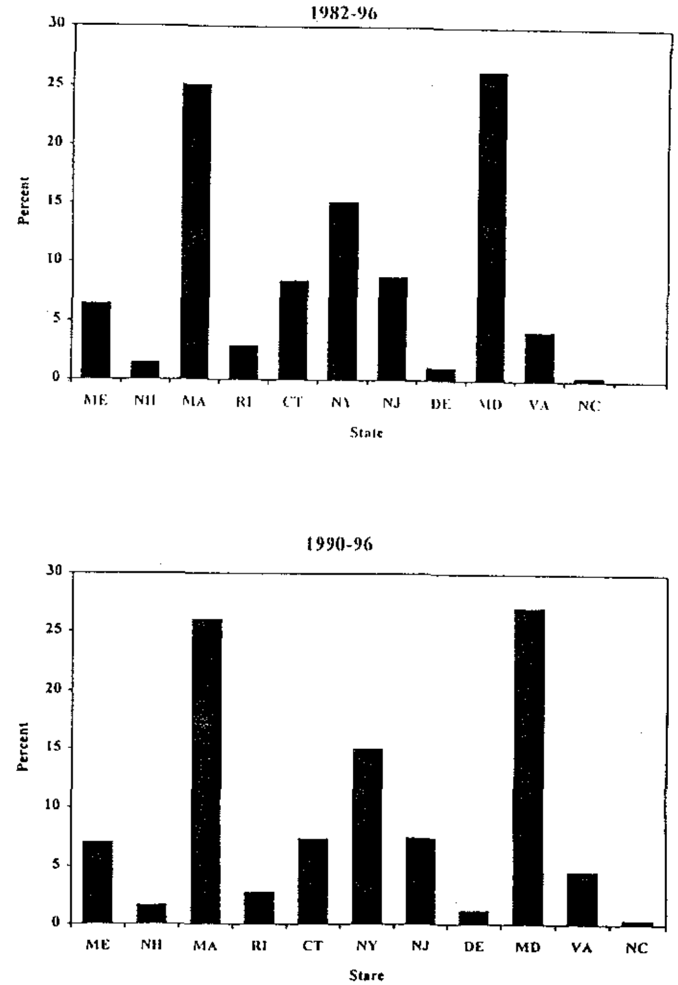

Figure C4. Percentage of striped bass recreational discards in number by state, 1982-1996 and 1990-1996.

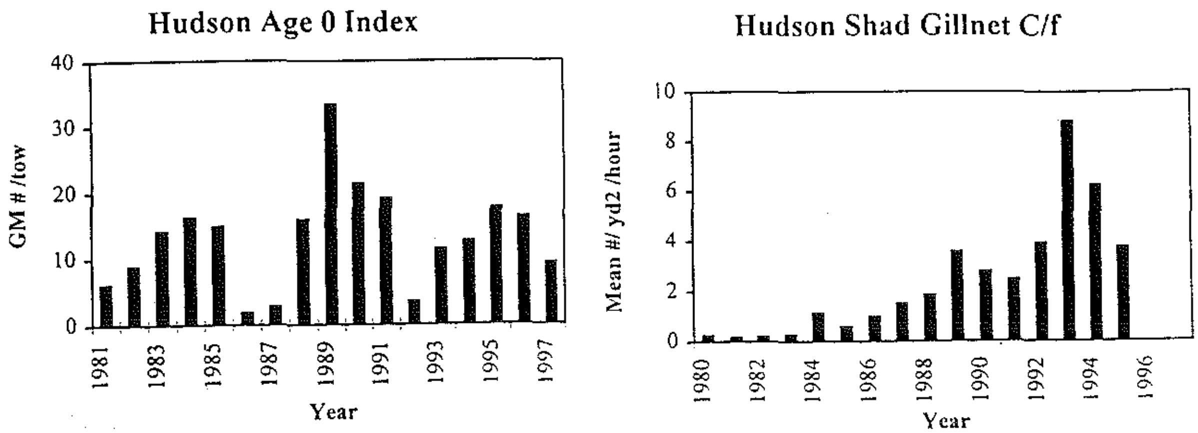

Figure C5. Fisheries-independent indices of Hudson River stock of striped bass.

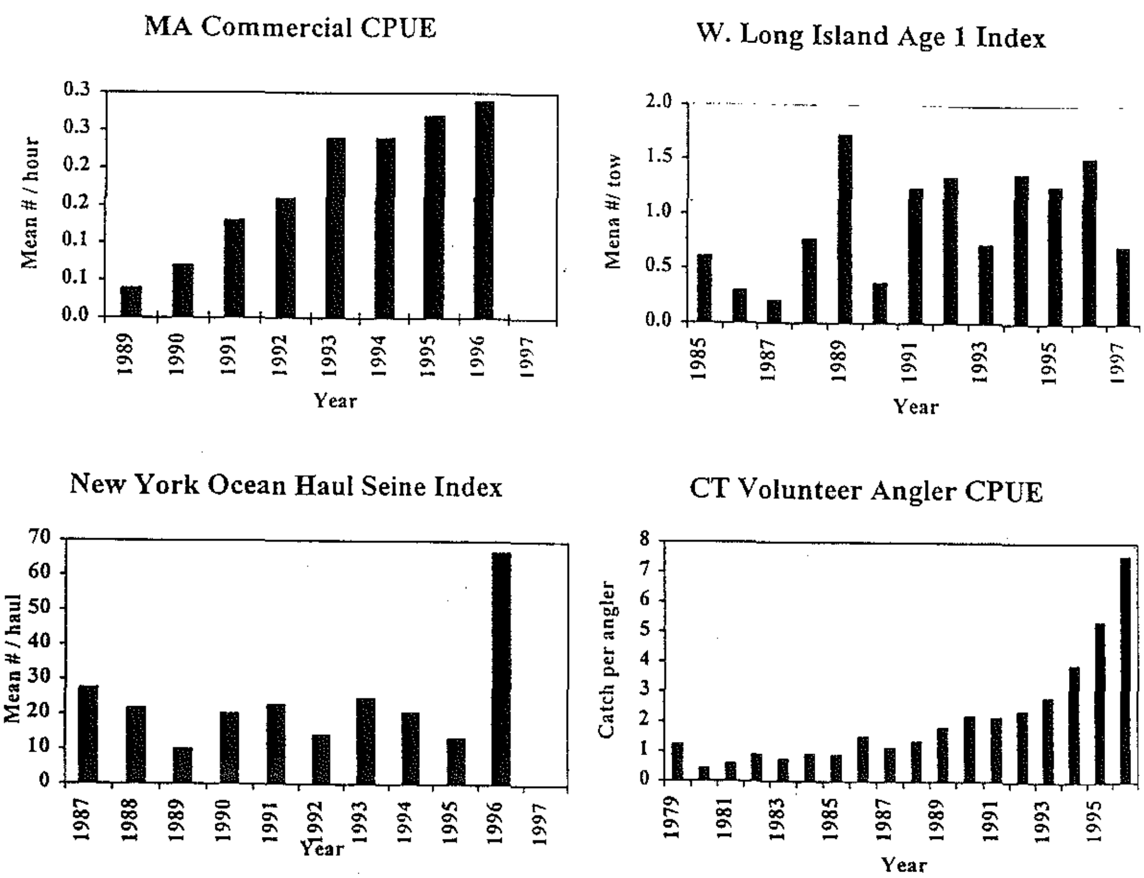

Figure C6. Indices of striped bass abundance in coastal regions.

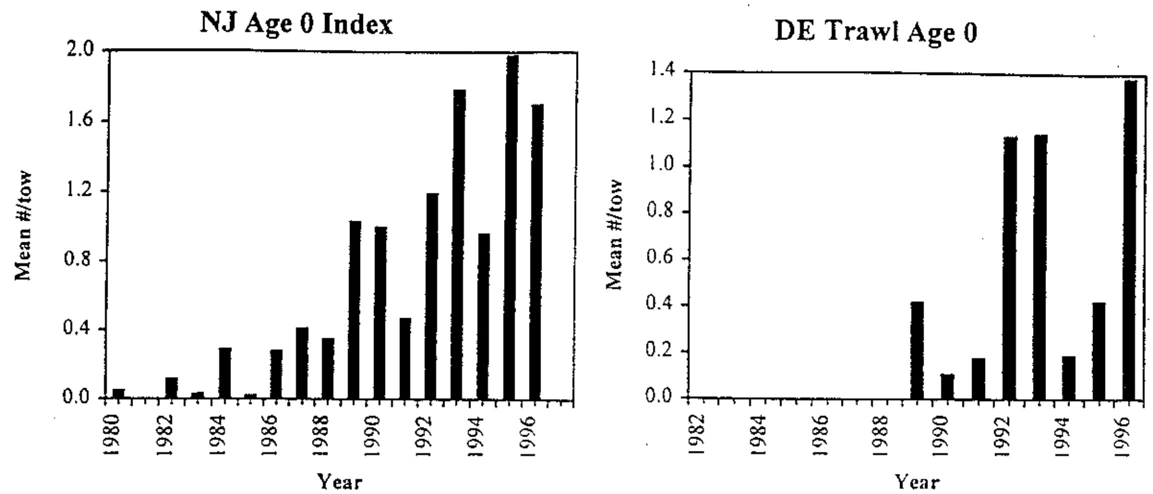

Figure C7. Indices of abundance for Delaware Bay striped bass stock.

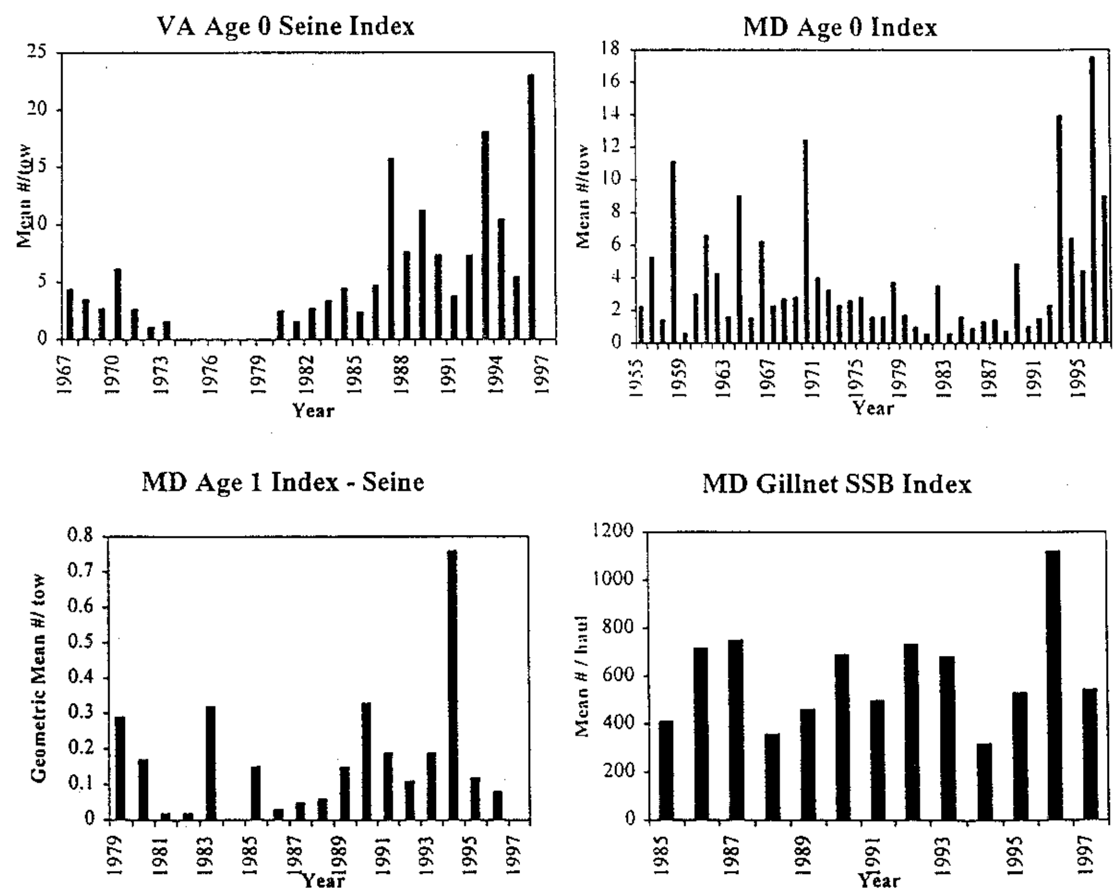

Figure C8. Indices of abundance for Chesapeake Bay striped bass stock..

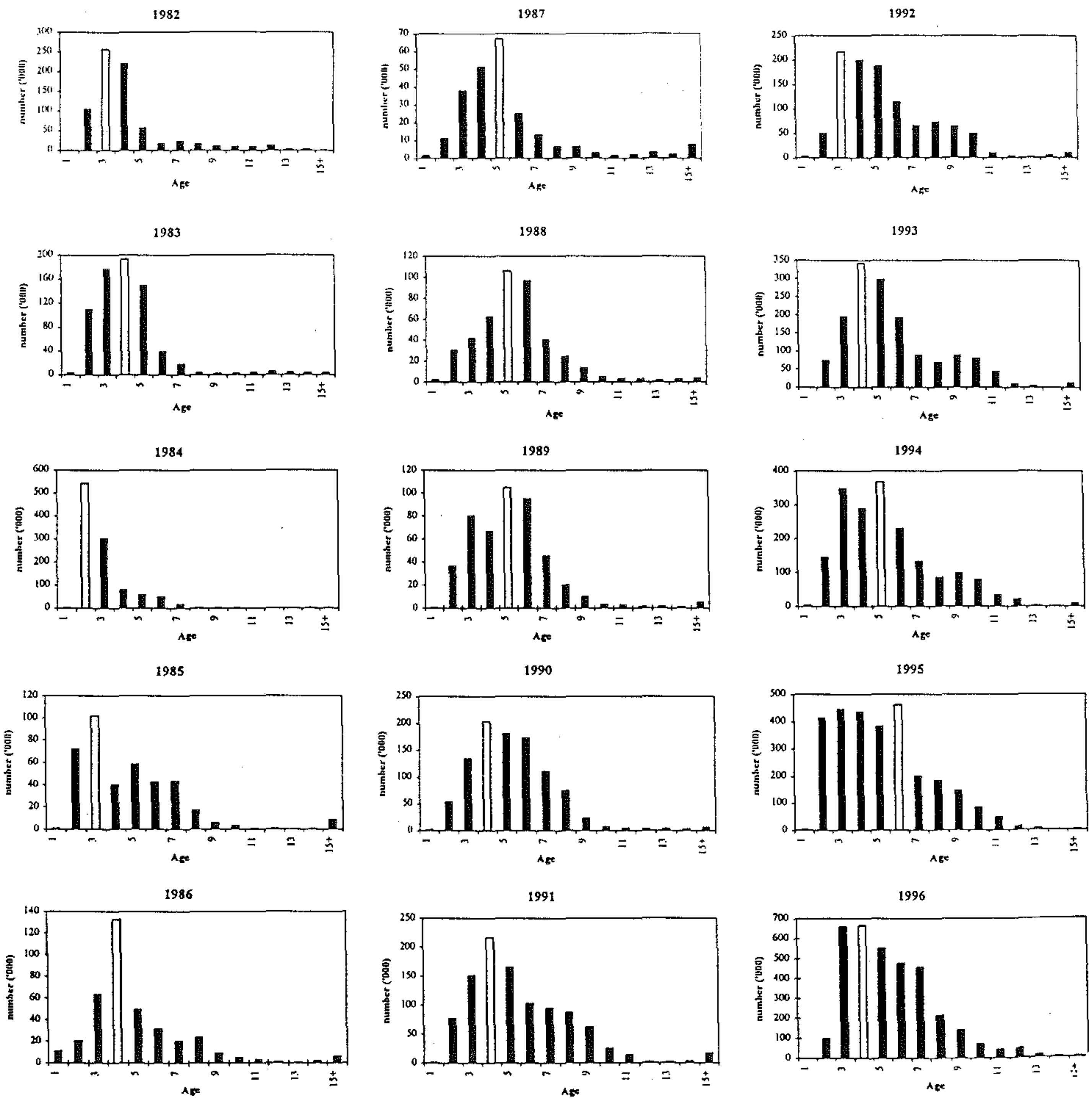

Figure C9. Striped bass catch at age by year, 1982-1996. Empty bar indicates age at maximum recruitment.

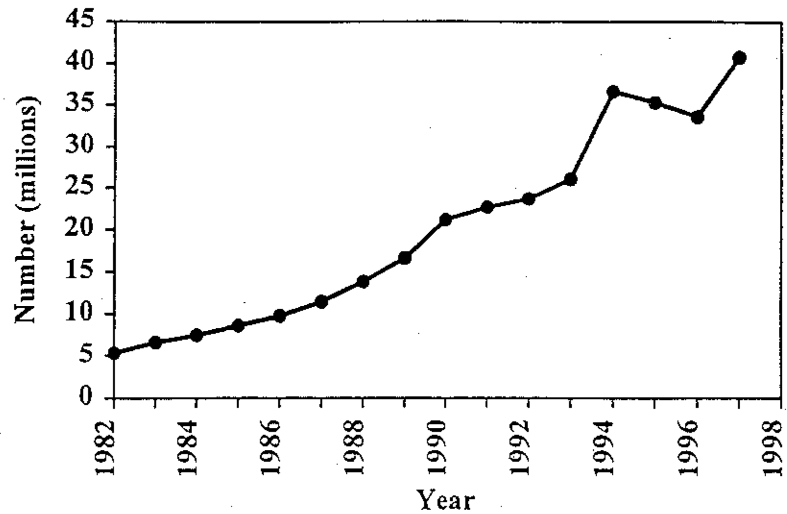

Figure C10. Estimated abundance of age 1-15+ striped bass in number, Maine to coastal North Carolina, estimated by VPA.

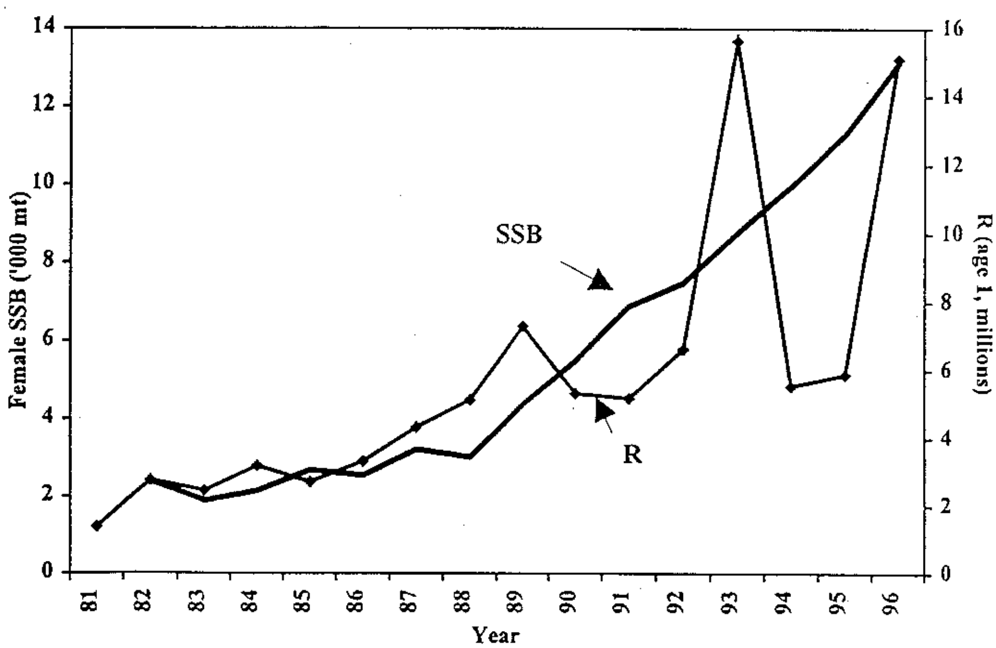

Figure C11. Striped bass spawning stock biomass (females only) and age 1 recruitment as estimated from VPA, 1982-1996. Recruitment data points correspond to year class.

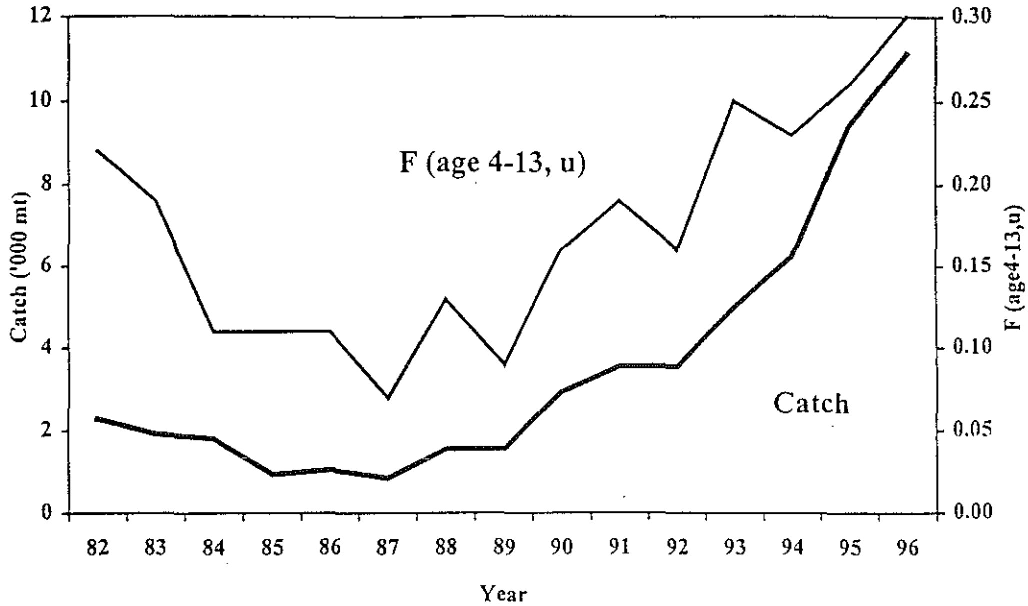

Figure C12. Total catch and fishing mortality of striped bass, Maine to coastal North Carolina, 1982-1996, determined by VPA.

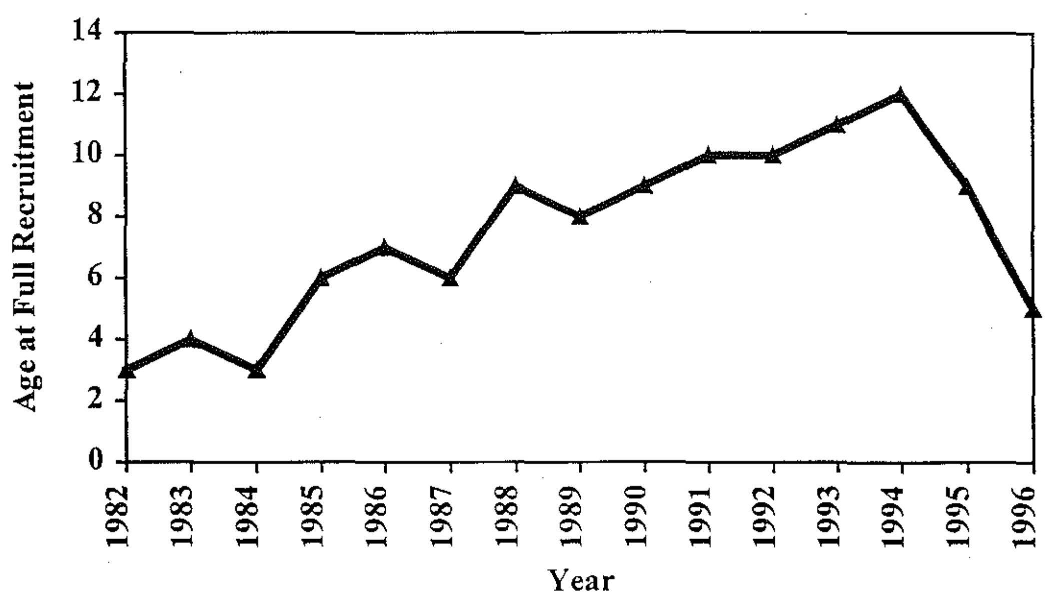

Figure C13. Age at full recruitment of striped bass, Maine to coastal North Carolina, based on back-calculated partial recruitment in VPA, 1982-1996.

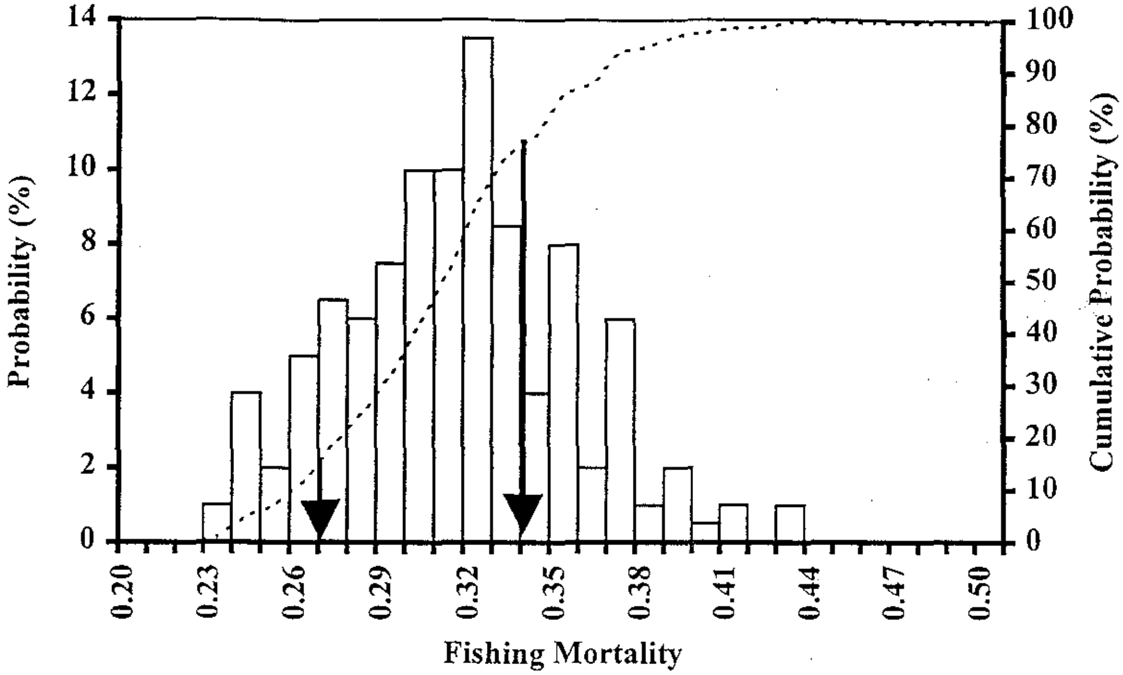

Figure C14. Precision estimate of fishing mortality (ages 4-13) for striped bass. Bars display the range of the bootstrap estimates and probability of individual values in the range. The dashed line gives the probability that fishing mortality is less than any value along the X axis.

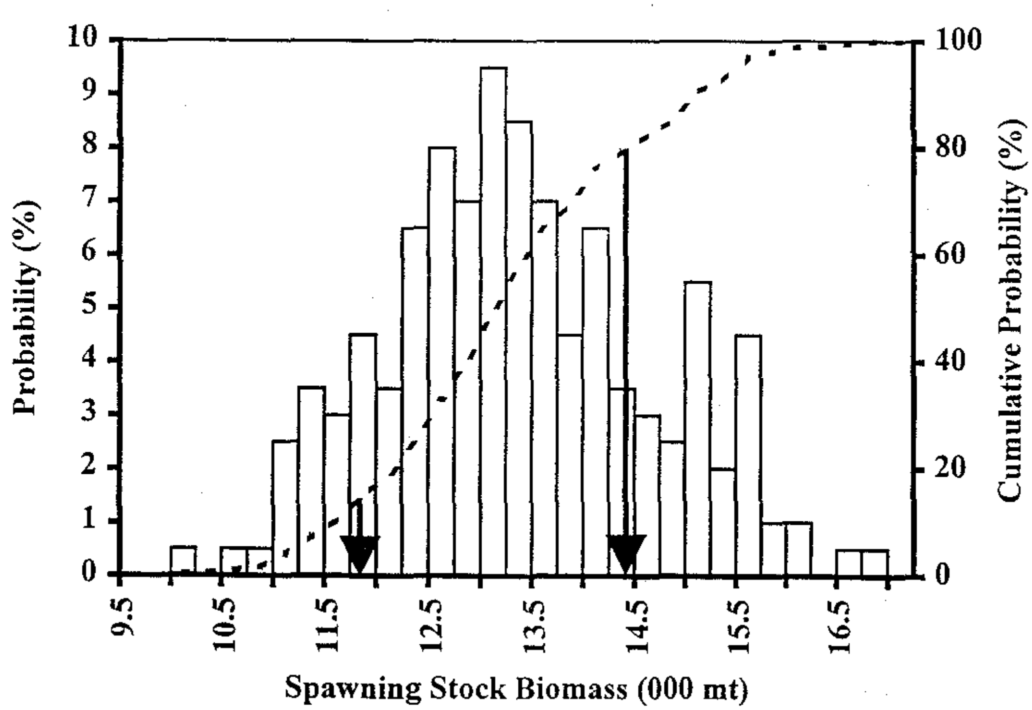

Figure C15. Precision estimate of spawning stock biomass (females only) for striped bass. Bars display the range of bootstrap estimates and the probability of individual values in the range. The dashed line gives the probability that SSB is less than any value along the X axis.

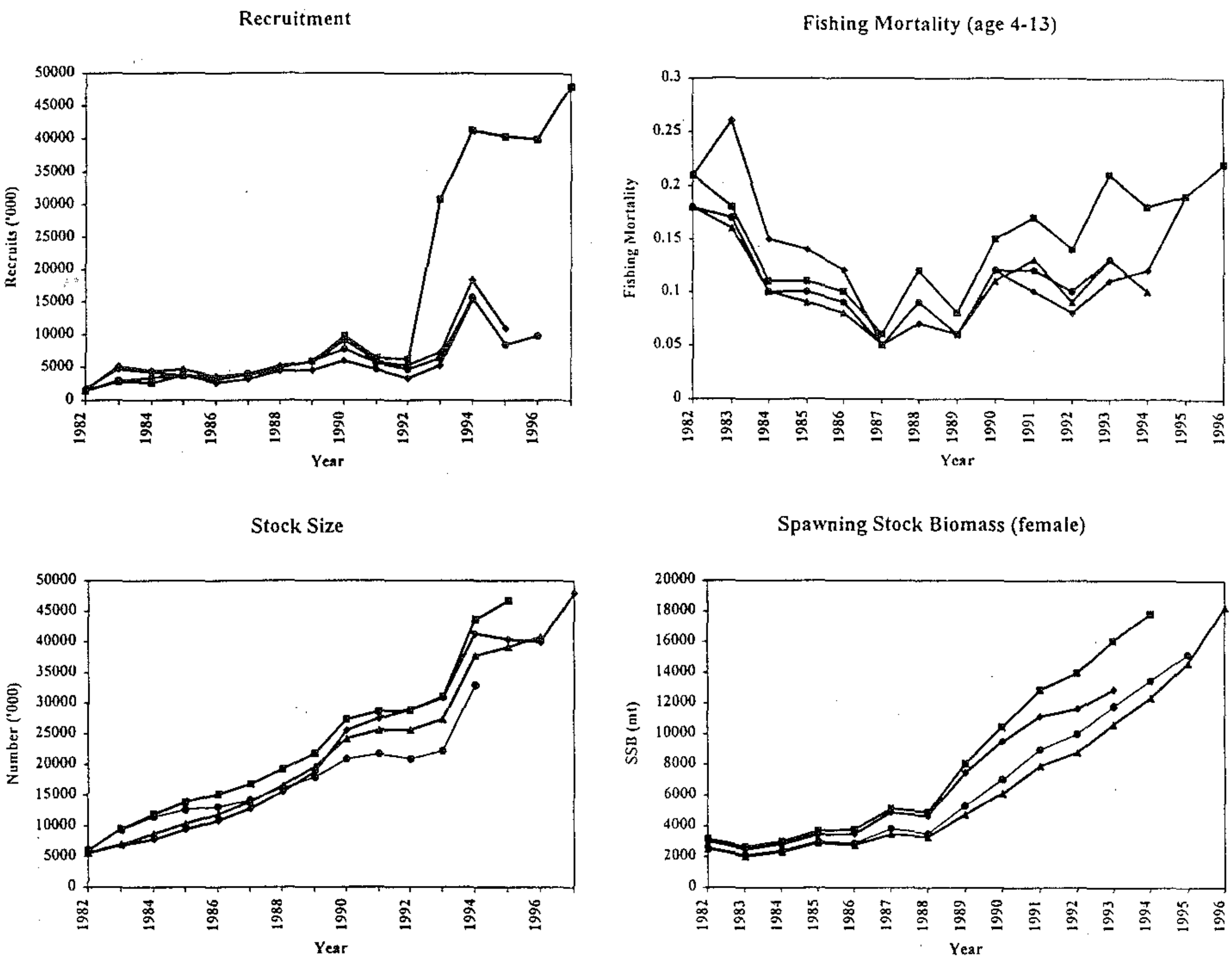

Figure C16. Results of retrospective analysis of striped bass VPA.

D. SPINY DOGFISH

Terms of Reference

a. Update the historical patterns of landings and summarize the size and sex composition of commercial landings and research survey catches of the coast-wide stock of spiny dogfish.

b. Summarize recent changes in minimum stock biomass, population rate of change, size and sex composition of commercial landings and survey indices, and fishing mortality rates.

c. Evaluate the implications for sustainable harvest rates and advise on appropriate biological reference points for this stock.

Introduction

Spiny dogfish (*Squalus acanthias*) were last assessed by the Stock Assessment Review Committee in June 1994 at SAW-18. The previous assessment incorporated landings data through 1993 and research survey data through the spring of 1994. A summary of the key findings of the SAW-18 results are summarized below:

- Total landings of spiny dogfish peaked at about 26,000 mt in the mid 1970s owing to fishing by foreign fleets. US commercial landings never exceeded 5,000 mt until 1981 and, from a level of about 4,200 mt in 1987, increased five times to over 22,000 mt in 1993.

- About 70% of the current landings are taken by sink gillnets, with most of the remainder by otter trawls. Over 95% of the landings consist of mature females ≥80 cm in length.

- Recreational catches have also increased in recent years, apparently in parallel with abundance, but they only constitute about 8% of the total landings.

- Discards from other fisheries, particularly by otter trawlers targeting groundfish, contribute an unknown, but substantial, fraction of the total mortality. Minimum estimates in 1993 suggest that an additional 25,000 mt of dogfish were discarded, of which 14,000 mt were killed.

- Graphical analysis of the spatial distribution of spiny dogfish catches from NEFSC winter, spring, summer, and autumn surveys and Canadian summer surveys confirmed a distinct seasonal migration pattern. Dogfish are located primarily in Mid-Atlantic waters in the winter and spring. By summer, they move north towards Canadian waters and into bays and estuaries where they remain throughout the autumn. Onset of cooler waters in late autumn results in a return to the south.

- A general linear model of NEFSC and Canadian survey data provided statistical evidence of a unit stock in the Northwest Atlantic.

- Minimum swept-area biomass estimates reveal a 5-fold increase in abundance over the last 30 years to about 650,000 mt in 1993. There is no evidence, however, of a continuing increase in the fishable stock (i.e., ≥80 cm in length) since 1990. Most of the increase in overall biomass appears to have been due to improved recruitment since the late 1960s. Compensatory changes in average weights appear to have contributed relatively little to the overall change in biomass.

- Mature females (≥80 cm) comprise over 95% of the landings. Apparently as a result of the dramatic increases in the fishery on mature females, commercial catch/effort and mean lengths of dogfish in commercial landings and research survey catches have decreased in the last five years.

- Commercial fishery information, research survey data, and life history parameters from the literature were used to develop a size- and sex-structured equilibrium model for dogfish. Using the concept of pups per recruit, preliminary biological reference points for fishing mortality were derived. With a minimum size limit of about 80 cm, fishing mortality rates (F) in excess of 0.2 would lead to the gradual decline of the spiny dogfish stock.

- Change-in-sex-ratio estimators were used to derive sex-specific F values. Results suggest a five-fold increase in F on females from 1991 to 1993 to levels in excess of 0.25 per year. Such rates exceed levels for maximum yield per recruit and imply reproductive rates insufficient for replacement.

- While current minimum biomass estimates of 650,000 mt are high, mature females may already be over-exploited. In view of the delayed maturation, low birth rates, and longevity of this species and experiences in shark fisheries worldwide, plans to increase exploitation rates should proceed cautiously to avoid rapid depletion of the adult stock.

This report, an update of the 1994 SAW-18 assessment, incorporates Northeast Fisheries Science Center (NEFSC) research trawl survey data through spring 1997 and commercial landings data through July 1997. Information on discard rates has not been updated nor have any further analyses of the unit stock hypothesis been conducted. New material in this report includes:

1) Detailed analyses of trends in length composition of landings and surveys.

2) Analyses of trends in recruitment.

3) Application of the Beverton and Holt mortality estimator based on mean length and development of an approximate confidence interval estimator.

4) Close agreement between observed length-specific sex ratios and predictions of a mechanistic life history model.

5) Correction to predicted yield-per-recruit estimates from SAW- 18.

6) Implications of 1982-1996 fishing mortality patterns for yield and pups per recruit.

7) Proposal of a new biological reference point for spiny dogfish based on pup production per recruit necessary for equilibrium.

Many of the initial effects of size- and sex-specific fishing that were apparent, but not yet conclusive in 1994, have been confirmed in the present assessment. Mean lengths of spiny dogfish in the landings and surveys have begun a rapid decline, minimum biomass estimates of mature females have decreased by nearly 50% since 1990, and fishing mortality rates are well above those compatible with sustainable harvest. Mean sizes in the commercial fishery have declined to the extent that the increase in total landings from 14,731 mt in 1990 to 27,241 mt in 1996 (an increase of 85%) was accompanied by a 311% increase in numbers landed. Percentage of males in the landed jumped dramatically in 1996 to 17% by weight and 25% by numbers. Historically, males had been a small (<5%) fraction of the total landings.

Estimated recruitment (i.e., dogfish ≤35 cm) in 1997 was the lowest in the 30-year time series. Moreover, low numbers and small average size of juvenile dogfish (≤35 cm) in 1997 are consistent with reduced biomass and average size of the female spawning stock. Under the present magnitude and selectivity of fishing mortality, the spawning stock will continue a rapid decline and recruitment will be below replacement. Minimum biomass estimates for the entire resource remain high, about three times greater than levels in the 1970s, but the spawning stock has declined significantly in the last seven years. The effects of fishing mortality rates since 1990 will result in a continued decline of the spawning stock, particularly when the small cohorts born in the 1990s reach maturity in 2005 and beyond.

Basic Life History

Spiny dogfish (*Squalus acanthias*) are distributed in Northwest Atlantic waters between Labrador and Florida, are considered to be a unit stock in NAFO Subareas 2-6, but are most abundant from Nova Scotia to Cape Hatteras. Seasonal migrations occur northward in the spring and summer and southward in the fall and winter, and preferred temperatures range from 7.2° to 12.8°C (Jensen 1965). In the winter and spring, spiny dogfish are located primarily in Mid-Atlantic waters but also extending onto southern Georges Bank on the shelf break. In the summer, they are located further north in Canadian waters and move inshore into bays and estuaries. By autumn, dogfish have migrated north, with high concentrations in Southern New England, on Georges Bank, and in the Gulf of Maine. They remain in northern waters throughout the autumn until water temperatures begin to cool and then return to the Mid-Atlantic.

Dogfish tend to school by size and, for large mature individuals, by sex. Dogfish are predators of some commercially-important species, mainly herring, Atlantic mackerel, and squid. Maximum reported ages for males and females in the Northwest Atlantic were estimated by Nammack (1982) to be 35 and 40 years, respectively, whereas ages as old as 70 years have been determined for spiny dogfish off British Columbia (McFarlane and Beamish 1987). In this report, a maximum age of 50 years was assumed. Sexual maturity occurs at a length of about 60 cm for males and 75 cm for females (Jensen 1965). Reproduction occurs offshore in the winter (Bigelow and Schroeder 1953), and female dogfish bear live offspring. The gestation period ranges from 18 to 22 months, with 2-15 pups (average of 6) produced. Females attain a greater size than males, reaching maximum lengths and weights of about 125 cm and 10 kg, respectively.

Fishery-Dependent Data

Commercial Landings

Commercial landings data and biological information were obtained from the NEFSC commercial fisheries database. The sex of commercial landings was not recorded routinely until 1982. The commercial landings sampling program is described in Burns *et al.* (1983). Historical records dating back to 1931 indicate levels of US commercial landings of dogfish in Subareas 5 and 6 of less than 100 mt in most years prior to 1960 (NEFC 1990). Total landings of spiny dogfish in NAFO Subareas 2-6 by all fisheries climbed rapidly from the late 1960s to a peak of about 25,600 mt in 1974 (Table D1). Substantial harvests of dogfish by foreign trawling fleets began in 1966 in Subareas 5 and 6 and continued through 1977. Since 1978, landings by foreign fleets have been curtailed, and landings by US and Canadian vessels have increased markedly. A sharp intensification of the US commercial fishery began in 1990; estimated landings in 1996 of nearly 28,000 mt were about five times greater than the 1980-1989 average. Historical landings reported in Table D1 differ from those presented at SAW-18 and reflect the incorporation of canvass data on landings. Details on the databases used to estimate landings are summarized in Appendix I.

US landings

US commercial landings of dogfish from NAFO Subareas 2-6 were around 500 mt in the early 1960s (Table D1), dropped to levels as low as 70 mt during 1963-1975 while averaging about 90 mt, and remained below 1,000 mt until the late 1970s. Landings increased to about 4,800 mt in 1979 and remained fairly steady for the next ten years at an annual average of about 4,500 mt. Landings increased sharply to 14,900 mt in 1990, dropped slightly in 1991, but continued a rapid expansion from 18,987 mt in 1992 to over 28,000 mt in 1996. Landings in 1996 were the highest recorded since 1962, exceeding previous peak years during the early 1970s when the fishing fleet was dominated by foreign vessels (Figure D1). Data for 1997 are incomplete, but at least 14,500 mt had been landed through September.

Foreign landings

A substantial foreign harvest of dogfish occurred mainly during 1966-1977 in Subareas 5 and 6. Landings, the bulk of which were taken by the former USSR, averaged 13,000 mt per year and reached a peak of about 24,000 mt in 1972 and 1974 (Table D1). In addition to the former USSR, other countries which reported significant amounts of landings include Poland, the former German Democratic Republic, Japan, and Canada. Since 1978, landings have averaged only about 900 mt annually and, except for those taken by Japan and Poland, have come primarily from Subareas 4 and 3. Canadian landings, insignificant until 1979 when 1,300 mt were landed, have been sporadic, but again totaled about 1,300 mt in 1990. The 1992 Canadian landings were about 800 mt, and probably increased in 1993 (Hunt, pers. comm.).

Gear types

The primary gear used by US fishermen to catch spiny dogfish has been otter trawls and sink gillnets (Table D2, Figure D2). The latter accounted for over 50% of the total US landings during the 1960s, while the former was the predominant gear through the 1970s and into the early 1980s. Since the late 1980s, sink gillnets have again taken most of the landings, accounting for about 70% in 1993. Spiny dogfish taken by the distant water fleets were caught almost entirely by otter trawl. Recent Canadian landings have been mainly by gillnets and longlines.

Temporal and spatial distribution

US dogfish landings have been reported in all months of the year, but most have traditionally occurred from June through September (Table D3). In recent years, however, as total landings increased sharply, substantial amounts were also taken during autumn and winter months.

As noted at SAW-18, most landings during the 1980s originated from statistical area 514 (Massachusetts Bay). Following the intensification of the fishery in 1990, statistical areas 537 (Southern New England) and 621 (off Delmarva and southern New Jersey) produced substantial quantities. In 1992 and 1993, large landings were reported from statistical areas 631 and 635 (North Carolina). Landings from 1994 onward were not prorated to statistical areas for this report.

In most years since 1979, the bulk of the landings occurred in Massachusetts (Table D4). After 1989, important landings were also made in Maine, New Jersey, Maryland, Rhode Island, and especially North Carolina ports. In 1996, North Carolina landings were roughly half those in Massachusetts.

Recreational Landings

Estimates of recreational catch of dogfish were obtained from the NMFS Marine Recreational Fishery Statistics Survey MRFSS (see Van Voorhees *et al.* 1992 for details). Recreational catch data have been collected consistently since 1979, but sex is not recorded. Methodological differences between the current survey and intermittent surveys before 1979 preclude the use of the earlier data. The MRFSS consists of two complementary surveys of anglers via on-site interviews and households via telephone. The angler-intercept survey provides catch data and biological samples, while the telephone survey provides a measure of overall effort. Surveys are stratified by state, type of fishing (mode), and sequential two-month periods (waves). For the purposes of this paper, annual catches pooled over all waves and modes and grouped by subregion (ME-CT, NY-VA, and NC-FL) were examined.

The MFRSS estimates are partitioned into three categories of numbers caught and landed: A, B1, and B2. Type A catches represent landed fish enumerated by the interviewer, while B1 are landed catches reported by the angler. Type B2 catches are those fish caught and returned to the water. Inasmuch as dogfish are generally caught with live bait and are often mishandled by anglers, 100% discard mortality was assumed. The MRFSS provides estimates of landings in terms of numbers of fish. Biological information on dogfish is generally scanty, resulting in wide annual fluctuations in mean weights. To compute total catch in mt, an average weight of 2.5 kg per fish was assumed for all years.

Total recreational catches increased from an average of about 350 mt per year in 1979-1980 to about 1,700 mt in 1989-1991 (Table D1). Since 1991, recreational landings have decreased continuously from nearly 1,500 mt to less than 400 mt in 1996. Landings by number (Figure D3) suggest a similar but less pronounced decline. Recreational landing are a small component of the total fishing mortality on spiny dogfish. Even if all of the Type B2 catch died after release, recreational catches have comprised only about 8% of the total landings. Therefore, the imprecision in the estimate of recreational landings is inconsequential relative to the commercial landings and discards.

Size and Sex Composition of Commercial Landings

The seasonal distribution of biological sampling of the landings generally coincided with the seasonal pattern of landings (Table D5). Most samples were taken in June through November. Sampling effort from January to May has been low and should be increased to more adequately assess the biological characteristics of the catches in these months. It is important to note that biological characteristics of the landings are driven primarily by the market place, particularly the acceptance of small dogfish. The major increase in small males in the 1996 landings probably reflects their acceptance by export markets as well as the availability of processing equipment for smaller dogfish. The estimated size and sex composition of the landings are based on a pooled samples over the entire year.

During 1982-1995, over 95% of the sampled landings of spiny dogfish were females greater than 84 cm. Males comprised a small fraction of the landings and were rarely observed above 90 cm in length. In 1996, landings of male dogfish increased dramatically, both in numbers and total weight (Table D6).

Shifts in length frequencies toward smaller sizes reflect the marked increase in landings since 1989. The average size of landed females appears to have decreased by more than 10 cm since 1982 (Figure D4). The average size of males has not changed appreciably (Figure D5), but there is a slight downward trend since 1990. Error bounds (dashed lines in Figures D4 and D5) represent 99% confidence intervals of the mean lengths for the period 1982-1989. Results suggest that mean lengths of females were significantly lower than the historical limits beginning in 1993, after only three years of intensive fishing (Figure D4). Male landings were negligible until 1996; the absence of a significant change from 1990 to 1995 is consistent with this fact. Note, however, the pronounced increase in landings in 1996 and rapid decline in average size of males (Figure D5).

Reductions in average weight of females (Figure D6) are dramatic, with a decline of average individual weight greater than 1.3 kg per fish since 1992. Again, the decline for males in 1996 is evident (Figure D7). Decreases in average size are consistent with increased fishing mortality, but could also be due to changes in the mix of otter trawl and sink gillnet catches. Corroboration of these trends in the research surveys (later section) suggest that these trends are the result of increased fishing mortality. The implications of sex-specific removals are considered further in the section on **Life History Model**.

Mean sizes in the commercial fishery have declined to the extent that the increase in total landings of 14,731 mt in 1990 to 27,241 mt in 1996 (an increase of 85%) was accompanied by a 311% increase in numbers landed. Percentage of males in the landings jumped dramatically in 1996 to 17% by weight and 25% by numbers (Figure D8).

Discards

Spiny dogfish have been caught and discarded during fishing operations both in the past and at present. Unfortunately, information on which to base quantitative estimates of discard has only been collected in recent years. A large-scale fisheries observer program for commercial vessels has been conducted by NEFSC since 1989 (Murawski *et al.* 1995, Anderson 1992). Species catch, effort, and associated biological and fishery data are collected for each trip. An important attribute collected during each trip, determined from skipper interviews, is the "primary species sought". Spiny dogfish discards per ton of target species were calculated from the 1993 sea sampling data, supplemented to some extent by data from 1990, 1992, and 1994. Total estimates of dogfish discards were expanded by multiplying the discard/ton ratio by the total tonnage of landings of the target species.

Recent information on the catch, discards, landings, and size composition of spiny dogfish taken on sea sampling trips aboard US fishing vessels from 1989 to early 1994 was summarized by year, gear type, and primary species sought (= target species) for SAW-18. A summary table from that report is reproduced herein (Table D7), but no further analyses were conducted for this report. The summarized sea sampling data indicate a significant level of spiny dogfish discards, but it was not possible to derive reliable annual estimates of dogfish discards for all major gear/area/target species cells.

These estimates are only provisional and are useful to the extent that 1) sea sampled trips are representative of fleet activity in each gear/area/target species cell and 2) there are some components of the fishery in which dogfish discards occur, but are not accounted for in these calculations (e.g., other gears, target species). The limited information available on the mortality of discarded dogfish suggests higher mortality rates in gillnets than in trawls. Discard rates of 75% and 50% were assumed in gillnet and otter trawl catches, respectively. Total discard estimates are subject to considerable uncertainty, however, the assumptions were considered reasonable (NEFSC 1994).

Total dogfish discards for 1993 were estimated by this method to be 25,000 mt, with 13,500 mt of these suffering mortality. Trawl components, particularly in the Mid-Atlantic and Southern New England area, probably account for the largest fraction of the dogfish discard mortalities. It must be emphasized that these estimates are provisional; further work on discard rates and the magnitude of total discard mortality is warranted.

Fishery-Independent Data

Research Vessel Abundance Indices

NEFSC surveys

The NEFSC has conducted spring and autumn trawl surveys of the USA continental shelf annually since 1963. The surveys extend from the Gulf of Maine to Cape Hatteras. Details on the stratified random survey design and biological sampling methodology may be found in Grosslein (1969), Azarovitz (1981) and NEFSC (1995). Sex of spiny dogfish was not entered into the database until 1980.

Indices of relative stock biomass and abundance for spiny dogfish were calculated from NEFSC spring and autumn bottom trawl survey data. Overall indices were determined using only the offshore strata (1-30, 33-40, and 61-76) in order to obtain longer time series (i.e., 1967-1993 for the autumn survey and 1968-1994 for the spring survey). The autumn survey could not be extended back to 1963 because sampling of the Mid-Atlantic strata (61-76) did not begin until 1967.

In both the spring and the autumn surveys, there was considerable variability in the indices (Tables D8 and D9, Figure D9). Both sets of indices indicate an overall increase in abundance and biomass since the early 1970s. The rate of change in the autumn survey has generally been less than observed for spring. At SAW- 18, it was determined that the higher variability in the fall survey is attributable to a variable fraction of the population present in Canadian waters during the NEFSC fall survey.

State surveys

Abundance indices for spiny dogfish from Massachusetts spring and autumn inshore bottom trawl surveys in 1980-1993 were higher in the autumn than in the spring reflecting the greater availability of spiny dogfish inshore in the autumn (Tables D10 and D11). As in the case of the NEFSC survey results, there was considerable year-to-year variability in these indices (Figure D10), but nevertheless some suggestion of a general increase in abundance and biomass during the period. High variability in this survey is also a reflection of the seasonal use of the area surveyed by the State of Massachusetts.

Canadian surveys

Indices of relative abundance for 1970-1993 from the Canadian summer bottom trawl survey conducted in NAFO Divisions 4VWX (Dawe, pers. comm.) were not updated for this report.

Size and Sex Compositions

Size frequency distributions of spiny dogfish (sexes combined) from the spring and autumn NEFSC surveys were examined (Figures D11-D13). The spring survey length frequencies have three modes corresponding to new recruits (≤40 cm), mature males (70-80 cm), and mature females (95 cm). Large numbers of recruits have appeared periodically in the time series, especially in the early 1970s. The length frequency patterns in the autumn survey catches are much less consistent, and there is no apparent tracking of modal lengths over time. Some compression of the maximum size categories is evident in 1990-1994.

Male length frequencies are strongly skewed and nearly truncated, as predicted by the von Bertalanffy growth model (Figures D14 and D15). Females grow much larger than males. Truncation of male length frequencies is also evident when catches of the fishable population (≥80 cm) are plotted. Very few males ≥80 cm appear over a 15-year time span (Figures D14-D17), whereas females appear in large numbers.

Massachusetts survey data (Figures D18 and D19) show the same general trend of decreasing length, particularly in the autumn survey.

The median length of the mature adult population increased steadily from 84 cm in 1968 to 95 cm in 1981. Since then, median length has declined to 82 cm in 1997 (Figure D20). The average size of dogfish less than 35 cm, (i.e., about 1 year old) has remained fairly steady between 28 and 32 cm since 1968. In 1997, a year of lowest recruitment on record, the median length was 26 cm, also the lowest on record (Figure D20). Reductions in average pup size may be related to reduction in the average size of females greater than 80 cm. NEFSC research survey results for 1997 indicated the smallest average size of mature females since 1980, exhibiting a drop of nearly 10 cm in average size.

The removal of mature female dogfish has progressed steadily since 1990. Figure D22 depicts the size composition of females greater than 70 cm. This length could be considered the minimum size at which a female could produce pups. For example, Silva's (1993) minimum size for viable pup production was 75 cm, corroborating earlier work by Templeman (1944). Since 1990, the median length of mature females has declined from 85 cm to 76 cm in 1997. Seventy five percent of the female dogfish in 1997 were below the L_{50} for maturity (i.e., length at which 50% of the females are mature). Hence, only half of the 70+ cm population is capable of producing offspring. These results, coupled with the nearly 50% reduction in abundance of females ≥80 cm (Figure D24), suggest large-scale reductions in the reproductive capacity of the stock.

Analysis of Biomass Trends

Swept-Area Method Biomass Estimate

Estimates of minimum stock biomass were determined from the NEFSC spring survey catches. Mean numbers per tow by sex and 1-cm length class were converted to average weights using the following length-weight regressions:

$$\text{females: } W = \exp(-15.0251) * L^{3.606935}$$
$$\text{males: } W = \exp(-13.002) * L^{3.097787}$$

These average weights were then multiplied by the total survey area (64,207 n mi^2) and divided by the average area swept by a 30-min trawl haul (0.01 n mi^2). Three size categories were defined (≤35 cm, 36-79 cm, and ≥80 cm) which approximately correspond to new recruits, males and immature females, and mature females, respectively (Table D12). Swept-area estimates of stock biomass are considered to be minimum estimates because vulnerability of the stock to the trawl is not incorporated. Ability to avoid the net and dispersal of the stock above the bottom are two factors that may result in lower overall estimates.

The minimum estimates exhibit high annual variation generally in excess of what is realistic for such a long-lived species. Therefore, LOWESS smoothed estimates of biomass were considered to be better measures of population trends (Figure D23). Total population biomass has been static since 1991 at about 600,000 mt. The rate of increase in overall numbers in the population appears to be decelerating and has been coupled by a slight decrease in the average length in the population. As shown previously, the apparent stability of the composite population trends belie the substantial changes within size groups.

When trends in numbers are examined by size grouping, the magnitude of the changes become evident (Figure D24). For the fishable stock (i.e., ≥80 cm), biomass estimates increased about six-fold from

1968 to a peak in 1989 of slightly below 300,000 mt. Since then the population appears to have declined to less than 150,000 mt in 1997. The 36-79 cm group continues to increase, perhaps reflecting higher levels of recruitment in the late 1970s and early 1980s (Figure D24).

As NEFSC survey catches of spiny dogfish were not routinely sexed until 1980, the available time series for male and female biomass is only half as long as for the total biomass. Since 1990, the biomass of females in the fishable stock continues a sharp decline of nearly 50% (Figure D25); the male component of the ≥80 cm biomass has been relatively stable since 1980 (Figure D25). Both female and male dogfish exhibit parallel patterns for recruits (≤35 cm) and the pre-fishery stock (Figure D25). Recent decreases in the minimum numbers of female dogfish are consistent with the removals by the commercial fishery. The implications of these sex-specific removals are considered further in the section on **Life History Model**.

Continued increase in the numbers and biomass in the 36-79 cm length ranges might be attributable to the pulses of recruitment during the early 1980s. A simple test of this hypothesis was conducted by observing that the pool of 36-79 cm dogfish consists of at least 7 or 8 cohorts. If true, then the population size between 36 and 79 cm could be written as a weighted sum of the cohorts that produced it. The general model for this approach is:

$$N_{[36\text{-}79]}(t) = s\,R(t-1) + s^2\,R(t-2) + s^3\,R(t-3) + ... + s^7\,R(t-7) \quad \textbf{(1)}$$

The s term was estimated using nonlinear least squares and plotted in Figure D26. For the 1975-1997 period, the expected value of the s parameters is 0.9456. This implies an average M of 0.06. Hence, the simple model above supports the concept that increased recruitment fueled the increase in the biomass of 36-79 cm dogfish between 1981 and 1993. The disparity between observed and predicted for 1994 onward might imply a change in total morality rate on recruits.

<u>Stock and Recruitment</u>

Spawning stock and recruitment were examined via analysis of the NEFSC spring research vessel survey data. The number of spawners was approximated as the number of dogfish ≥80 cm, corresponding to the predicted length at 50% maturity for females (Silva 1993). In most years since 1980, this size range consisted of more than 75% females; prior to 1980, sex of survey catches of dogfish was not recorded in the database. The ≥80-cm size group permitted an investigation of the entire spring time series since 1968. Using the von Bertalanffy growth model (see section on **Life History Model**), 80 cm corresponds to 10.5 yr and older females. Recruits were defined as all dogfish ≤35 cm. For male dogfish, this corresponds to a predicted age of 1.11 yr; for females, the predicted age is 1.04 yr.

Total numbers of spawners show an overall upward trend since 1968 (Figure D27) with an apparent three-fold increase through 1988 and a pronounced decline since then. The number of recruits per tow exhibits no consistent trend, although estimates appear to have become more variable since 1981. Numbers of recruits per tow are in the same range as the number of spawners, and recruits per spawner vary from 0.1 to 3. LOWESS smoothing of the recruits per spawner (not shown) suggested a gradual decline since 1968, but a linear regression of the ratio vs time was not statistically significant ($P = 0.18$).

It is particularly interesting to note that the expected number of recruits per spawner (0.73, dashed line in bottom panel of Figure D27), predicted by the life history model described later in this assessment, is close to the observed ratio since 1968. The length model computes the equilibrium length frequency of the population, given estimates of population growth rate and fishing mortality (see section on **Fishing Mortality Estimates**).

Low fecundity and longevity of dogfish suggest that interannual variations in recruitment should be small relative to most teleosts. Moreover, annual pup production should be proportional to the number of spawners. Temporal variations should be related primarily to incomplete vulnerability to the survey gear and sampling variability. These deductions from life history theory are supported by the observed patterns in the spring survey. The observed range of recruits per spawners is relatively small (0.1 to 3) and agrees well with the independent predictions of the life history model (next section). The implications for future fisheries management are clear: "strong" year classes are infrequent in dogfish and would be unlikely to permit rapid recovery of the stock if overfishing occurred.

Fishing Mortality Estimates

Spiny dogfish collected or examined during routine research vessel surveys or port sampling of commercial landings are currently not aged. Silva (1993) used the software package MULTIFAN (Fournier *et al.* 1990) to decompose the length frequencies from research cruises into age groups, but was unable to obtain accurate separation above 8 years old. This limitation restricts the utility of such methods for providing management advice on the fishable stock. In theory, tagging studies could be used to estimate total mortality rates, but no contemporary tagging programs have been conducted.

Three length-based methods were examined in this report. These include a change-in-ratio approach, the Beverton-Holt model for Z as a function of mean length, and a length-specific sex-ratio model. The last method is derived from the expected sex-specific length frequency distributions under different levels of fishing mortality and knife-edge selection for length at entry into the fishery. Close agreement between the observed and predicted values suggest that a statistical estimator can be derived. Work on this theoretical aspect is underway. Other methods based on length frequencies (e.g., Wetherall *et al.* 1987) were not attempted for this assessment, but will be considered in the future.

<u>Change-in-Ratio Method</u>

The potential utility of change-in-ratio (CIR) estimators (Seber 1982) for mortality estimation was suggested by large differences between maximum lengths of males (L_∞ = 81 cm) and females (L_∞ = 105), differential growth rates, and selection for females in the fishery. The method of Chapman and Murphy (1965) was applied to LOWESS (Cleveland 1979) smoothed estimates of male and female numbers per tow for spiny dogfish ≥80 cm in length from the NEFSC spring survey for the period 1982-1997. Length frequency samples from US commercial landings were used to characterize the sex ratio of removals. Let x_1 and x_2 represent the number of animals of type x in the population at times 1 and 2, respectively. Similarly, let y_1 and y_2 represent the comparable numbers of animals of type y. The removals of types x and y that occur between times 1 and 2 are denoted as R_x and R_y, respectively. Chapman and Murphy (1965) demonstrated that the approximate instantaneous fishing mortality rates (F) for types x and y animals can be estimated as:

$$F_x = \frac{r_1 \log_e(r_2)}{1 + 0.5 \log_e(r_2) - r_1} \quad and \quad F_y = F_x \qquad (2)$$

where

$$r_1 = \frac{R_x y_1}{R_y x_1} \quad and \quad r_2 = \frac{x_2 y_1}{x_1 y_2}$$

Chapman and Murphy (1965) illustrated that F_x and F_y are insensitive to the rate of natural mortality over the range M = 0-0.4. Note that F_x and F_y depend only on the estimated ratios and not the absolute numbers. Thus, removal ratios from the fishery are sufficient for estimation, even though the numbers removed are orders of magnitude greater than the numbers observed in the research vessel surveys.

A key assumption for application of CIR estimators is the assumption that population sex ratios before and after removals are representative. Spiny dogfish are thought to comprise a single stock in the Northwest Atlantic (NAFO Subareas 2-6) (Annand and Beanlands 1986, Scott and Scott 1988), although trans-Atlantic migrations have been recorded (Templeman 1976). The importance of transatlantic migrations is unknown, but the extent of such movements was considered negligible for the purposes of this assessment. Spiny dogfish are distributed in Northwest Atlantic waters between Labrador and Florida, but are most abundant from Nova Scotia to Cape Hatteras. Analyses of spatial and temporal abundance patterns in SAW-18 (1994) provide additional statistical evidence of a single stock

Application of the change-in-ratio (CIR) method to smoothed survey indices (Table D13) revealed an increase in mortality rates on females since 1989 and almost no change in males. Some estimates prior to 1989 are negative, indicating that the mortality signal is obscured by the noise in the data (i.e., sampling error, or interannual variations in availability). CIR estimates of F must be viewed with some uncertainty. The sex ratios in the landings may not be representative of the sex ratio in the catches. Discards contain a higher proportion of males than the landed catch (NEFSC 1994). It is evident that fishing mortality on mature females has increased since 1990. Although estimates since 1989 are all positive, further work is necessary to evaluate the utility of this approach. This increase in F on females agrees well with observed increases in landings, the changes in the female fraction in the NEFSC spring survey, and the decreases in average lengths of mature females.

Beverton and Holt Model

Instantaneous total mortality rates (Z) for dogfish were also estimated using the length-based method of Beverton and Holt (1956)

$$Z = \frac{K(L_\infty - L)}{\bar{L} - L'} \qquad (3)$$

where K and L_∞ are from the von Bertalanffy growth models and L is the stratified mean where K and L_∞ are from the von Bertalanffy growth model and L is the stratified mean length of individuals in the spring survey greater than the critical length L'. L' is the 25th percentile of length in the commercial landings. Parameters for males and females are summarized in Table D14.

Minimum estimates of 95% confidence intervals were developed from the standard error of the mean length (>L') in which the effective sample size for the survey estimate of mean length was set to 50. Use of a sample size of 50 widens the confidence interval on mean length. The probability density function (PDF) of the mean length was assumed to be normal with mean and variance set to their sample estimates from the survey data. The PDF was estimated for the range L' to L_∞ (Figure D28a) and adjusted for truncation. The corresponding estimate of F was computed for each mean value (Figure D28b) and multiplied by its probability. The resulting PDF of total mortality (Figure D28c) can be used to generate median F and confidence intervals on Z corresponding to variation in $\bar{L}$ and conditional on the von Bertalanffy growth parameters K and L_∞. The corresponding range in Z does not include variance contributed by error in estimation of K, L_∞, or L', nor any covariance among terms. These estimates should be considered minimum estimates of the potential range of Z.

Mortality rates averaged about 0.06 during the period when landings averaged about 6000 mt (Table D14). Landings nearly tripled between 1989 and 1990 and have increased since then to over 28,000 mt (Table D1). The increase in fishing mortality rates reflects the increase in landings (Table D14) with current rates near 0.25 for the last three years. If mean and standard deviation of length in the landings for 1997 remains similar to that observed in 1996, the predicted fishing mortality is about 0.4, with a confidence interval of 0.32-0.52.

Life History Model

Most attempts to assess stocks of elasmobranchs have generally suffered from insufficient data and the use of inappropriate models (Anderson 1990). One of the major data deficiencies for assessing the spiny dogfish stock in the Northwest Atlantic is age compositions of the catch. In the absence of such data to employ in preferred age-structured models (e.g., virtual population analysis), a greater dependence has to be placed on the use of biomass models and other approaches which incorporate known information about the life history parameters of dogfish (Hoenig and Gruber 1990).

Model Description

Difficulties in aging, sexual dimorphism, and mammalian-like reproduction are some of the important aspects of spiny dogfish biology relevant to the derivation of biological reference points. The size-and sex-specific nature of the contemporary US fishery present further difficulties. In spite of these apparent constraints on population growth, the spiny dogfish stock has increased greatly in the last 20 years. A model allowing insights into potential mechanisms and derivation of testable hypotheses is highly desirable as the scientific basis of future fishery management decisions. A general model of dogfish life history, incorporating literature-based, life history parameters and calibrated with empirically derived fishing mortality rates and population abundances, is described below.

The von Bertalanffy growth equation was used to estimate the length at age for dogfish.

$$L_t = L_\infty(1 - e^{-K(t-t_0)}) \qquad (4)$$

Parameters for Equation 4 were estimated by Nammack *et al.* (1985) and revised by Silva (1993) for male and female spiny dogfish (Table D15, Figure D29).

By inverting Equation 4 , it is possible to express age as a function of length, i.e., t = f(L). Therefore, the age interval corresponding to a given length interval $\{L_j, L_{j+1}\}$ is given by:

$$t_j = \frac{-\ln\left(1 - \frac{L_j}{L_\infty}\right)}{K} + t_o$$

$$t_{j+1} = \frac{-\ln\left(1 - \frac{L_{j+1}}{L_\infty}\right)}{K} + t_o \qquad (5)$$

By considering a unit length step ΔL and dividing the length range into J intervals (j = 1,...J), the variable age intervals can be defined as $\Delta t_j = t_{j+1} - t_j$. The average age of fish within the length interval L_j to L_{j+1} can be approximated as the midpoint of t_j and t_{j+1}.

The change in numbers at age over the interval Δt_j is modeled as:

$$N_{t+\Delta t_j} = N_t e^{-(F_{tj} + M)\Delta t_j} \qquad (6)$$

where F_{tj} is an age-specific mortality rate at length L_j and M is the natural mortality rate. Fishing mortality was implemented using knife-edge recruitment. The minimum length at entry to the fishery L_{crit} was set at 84 cm, which corresponded approximately to the 5th percentile of the observed length frequencies in the commercial landings.

As for most elasmobranchs, natural mortality (M) rates have not been estimated directly for spiny dogfish. Indirect estimates have been derived by analogy from life history parameters, notably, maximum longevity T_{max}. Assuming a 50-yr maximum age for spiny dogfish implies a natural mortality rate M of 0.083 in Hoenig's (1983) equation (ln Z = 1.46 - 1.01 $T_{max.}$ Wood *et al.* (1979) estimated M = 0.094 for dogfish in the Northeast Pacific off British Columbia by solving for M required to obtain a net reproductive rate of 1.0 for an unfished population. Silva (1993) employed a similar technique by assuming a variety of density-dependent mechanisms and derived the natural mortality rate necessary to balance the population growth rate. T_{max} was assumed to be 50 yr and M was computed as the level of mortality necessary to reduce the recruited population to 1% of its initial value. The derived M = 0.092, for spiny dogfish greater than 30 cm, agrees well with Wood *et al.* (1979) and the empirical value from Hoenig's (1983) equation. The smoothing parameter from Equation 1 of 0.06 is consistent with most approaches that natural mortality is less than 0.1 for spiny dogfish.

Reproduction rates for a fixed length class L_j, say R_j, can be estimated using a similar approach. The average rate of reproduction, defined as the annual number of pups surviving to a 30-cm minimum size, can be written as a function of the fraction pregnant within the length interval L_j ($f_{pregnant, Lj}$), the gestation time ($t_{gestation}$), the fraction of females in the length class ($f_{female, Lj}$), the average number of embryo pups present (litter $size_{Lj}$), and the probability surviving from the large embryo stage to 30 cm (S_o):

$$R_j = \left(\frac{f_{pregnant,L_j}}{t_{gestation}} \right) x\, f_{female,L_j}\ x\ litter\ size_{L_j}\ x\ S_o \qquad (7)$$

Parameters in Equation 2 were taken from Silva (1993). The maturation rate ($f_{pregnant,Lj}$) was estimated using a cumulative logistic function:

$$f_{pregnant,\Delta L} = \frac{e^{a + bL}}{1 + e^{a + bL}} \qquad (8)$$

The average litter size for females in size interval ΔL was approximated as a step function and ranged from 4 to 9 pups per female.

The average survival rate from pup to recruit (S_o) can be estimated indirectly using a modification of the method of Vaughan and Saila (1976). Let I and j represent indices corresponding to I-th and j-th length intervals and S_i corresponds to the fraction surviving during age interval I corresponding to length interval I is $S_i = \exp[-(F_{ti} + M)\Delta t_i]$:

$$s_o = \frac{\lambda}{R_1 + \sum_{j=2}^{K} \prod_{i=1}^{j-1} S_i R_j \,/\, \lambda^{T_j - t_{min}}} \qquad (9)$$

The parameter λ represents the finite rate of increase and T_j in Equation 7 represents the cumulative age corresponding to the j-th length interval. If a unit time step is used, then the exponent term of λ would reduce to j - 1, as in the original Vaughan and Saila publication. The parameter t_{min} represents the age corresponding to the minimum size class (30 cm). With Equation 9, it is possible to estimate the average S_o necessary to obtain a specified level of λ under a given schedule of reproduction and survival.

The expected number of female pups per recruited female dogfish (PPR) over its lifespan is equivalent to the net reproductive rate when λ = 1. Using the notation in this report, PPR is defined as:

$$PPR = S_o \left(R_1 + \sum_{j=2}^{J} \prod_{i=1}^{j-1} S_i R_j \ \Delta t_j \right) \qquad (10)$$

Model Calibration

In order to apply the life history model, it is first necessary to calibrate it to contemporary stock status. Two measures of stock status are required: total population rate of change (λ) and fishing mortality. Let λ_t be defined as N_{t+1}/N_t and represent a "pseudo-eigenvalue". If the population is not at equilibrium, the estimate λ_t will incorporate transient effects attributable to the current population structure and changes in the population parameters. By smoothing the N_t estimates, a new value, say λ', can be derived that approximates the steady-state condition of the population. Linear regression of LOWESS smoothed values of spring survey abundance for dogfish ≥70 cm (SAW-18) vs year suggests a slight rate of increase λ' = 1.044 (P = 0.075) since 1987. This overall rate of increase appears to be fueled by a steady increase in the number of males. Females, in contrast, appear to have peaked in 1991, with an average of 20 dogfish per tow. Estimates for 1994 of 13.3 females per tow are comparable to values observed in the early 1980s.

The average fishing mortality rate on females between 1986 and 1993 was 0.09. Substitution of λ = 1.044 and F = 0.09 in Equation 9 suggests that S_o is approximately 0.34.

Equation 11 provides a means of evaluating alternative hypotheses related to observed rates of population change. For example, let λ^* represent an alternative finite rate of increase. This value could be an observed historical value or a desired future value. The rates change in either fishing mortality, say α, or the change in average reproductive output, say β, can be interrelated as:

Equation 11 could be used to evaluate the feasibility alternative hypotheses related to the rapid increase in stock biomass following cessation of foreign fishing

$$= \frac{\lambda^*}{s_o \left(R_1 + \sum_{j=2}^{K} \prod_{i=1}^{j-1} e^{(-F_{\Delta t_i}\alpha - M)\Delta t_i} R / \lambda^{*\, T_j - t_{min}} \right)} \qquad (11)$$

in the late 1970s. The β parameter is related to the possible rate of increase in reproduction attributable to increased size or number of pups per female. If Equation 11 results in an estimate exceeding a large value, say 1.5, then the observed rate of increase λ^* must be related to a smaller value of α or a larger value of S_o. By placing physiologically reasonable bounds on β and α, Equation 11 can be used to assess the role of other life history parameters.

Predicted Size Frequency and Sex Ratio

One measure of the mechanistic model's validity can be obtained by comparing model predictions with survey length frequencies (Figures D30-D32). The high frequency of large individuals occurs because dogfish approach their maximum size at about 1/3 of their maximum lifespan. Hence, the larger sizes comprise many age classes. Expected population length frequencies under two levels of fishing mortality are depicted in Figure D30. The expected sex ratios for these two levels of fishing are shown in Figure D31. In general, the sex ratio "signature" for spiny dogfish should follow the general pattern predicted by the model. Results of such a comparison for each year are summarized in Figure D32. Note that this comparison does not include any tuning to match the observed sex ratio. Instead, the estimated mortality rates from the Beverton and Holt mean length model (Table D14) are substituted into the model. Overall, the theory and observation for length frequencies compared favorably over most years examined.

Yield per Recruit

Yield per recruit (YPR) can be estimated for the sex- and size-structured model as the sum of separate yield equations for males and females. The only modification to the standard yield equation is the need to account for the duration of the age interval corresponding to a unit length increment:

$$YPR = \sum_{j=1}^{J} F_{t_j} \overline{N_{t_j}}\, \overline{w_{\bar{t}_j}}\, \Delta t_j \qquad (12)$$

Average N is obtained from the standard exponential mortality model. Average weight was obtained by substituting the midpoint age (Equation 5) into the von Bertalanffy growth equation (Equation 4) to obtain a predicted average length which was then input to a length-weight regression of form $w = aL^b$. Parameters for the length-weight regression were obtained by reformulation of the predictive equations reported by Nammack (1982) (Table D15). Note that Equation 12 must be applied separately to males and females. Equation 12 can be used to generate yield per recruit for alternative levels of F and length at entry to the fishery L_{crit}.

Yield isopleths (kg/recruit) for combined sexes of spiny dogfish are depicted in Figure D33. The greatest YPR of 1.23 kg/recruit occurs at 70 cm and F = 0.25.

Pups per Recruit

The expected number of female pups per recruited female dogfish over its lifespan (PPR) is equivalent to the net reproductive rate when $\lambda = 1$. Using the notation in this report, PPR is defined as:

$$PPR = S_o \left(R_1 + \sum_{j=2}^{J} \prod_{i=1}^{j-1} S_i R_j \, \Delta t_j \right) \qquad (13)$$

As for YPR, pups per recruit were computed for various combinations of F and minimum sizes. The resulting isopleths (Figure D34) can be used to define a domain of feasible parameter combinations that will ensure population stability. For example, points interior (i.e., below and to the right) to the PPR = 1.0 isopleth would result in a gradual decline in population abundance. Results suggest that recruitment overfishing could occur at Fs as low as 0.08 when the minimum size is 65 cm. These computations, of course, do not incorporate potential density-dependent responses to exploitation. Exploration of the potential effects of compensatory responses could be investigated using Equation 11.

The yield- and pup-per-recruit analyses can be combined to define rates of harvest that ensure maximum yield while simultaneously ensuring sustainability of the resource. Superposition of the YPR and PPR isopleths (Figure D35) suggests that minimum sizes lower than 75 cm would probably result in population decline. Uncertainty in the estimation of such low levels of F would make it difficult to determine whether recruitment overfishing were occurring. Given the long life span of dogfish, the implications of recruitment overfishing would take many years to be recognized.

Discussion

The results of this assessment suggest that the spiny dogfish stock in the Northwest Atlantic has begun to decline as a consequence of the recent increase in exploitation. Swept-area estimates of the fishable biomass (defined as ≥80 cm fish) increased 6-fold from 1968 to 1989 and have since declined to less than 150,000 mt. Research vessel survey data document a steady increase in both abundance and biomass since the early 1970s, but total biomass indices in the last several years have been stable at about 600,000 mt (Figure D23). More importantly, minimum biomass indices of large fish (i.e., ≥80 cm) already have declined from about 300,000 mt in 1990 to about 150,000 mt in 1997, approximating levels observed in the 1970s (Figure D24). Owing to the targeting of females in the landings, estimated minimum biomass of females ≥80 cm has declined more sharply than the combined male-female ≥80-cm biomass. Length frequency data from both the US commercial landings (Figure D4) and research vessel survey catches (Figure D20) indicate a pronounced decrease in average length of females in recent years. In 1997, 75% of the females landed in the NEFSC spring trawl survey were below the length at 50% maturity (Figure D22) .

Following passage of the Magnuson Act and extension of the US exclusive economic zone in 1977, landings dropped dramatically due to the exclusion of foreign vessels from US waters. As more valuable groundfish stocks have declined, directed fishing for dogfish has resulted in a nearly 6-fold increase in landings in the last ten years. Landings for 1996 exceeded levels reported prior to 1976 (e.g., 25,000 mt). In addition, the discarded catch, depending on the percentage of the discards actually suffering mortality, are at least 2/3 the level of and possibly equivalent to or higher than the current reported landings. Unfortunately, historical quantitative estimates of discard are not available to permit estimation of historical total catches (i.e., landings plus discards). It should be noted that anecdotal reports of landings from former Soviet Bloc countries (Emory Anderson, NEFSC, pers. comm.) suggest relatively little discard of dogfish. Since most of the landings during that period were taken by trawlers, it is likely that a broad range of size classes were landed. Most Soviet vessels operated under high daily and monthly quota requirements that would tend to reduce discards. Hence, it is likely that the size distribution of the landings in the late 1960s and early 1970s was much different than occurred in the 1990s.

Most attempts to assess stocks of elasmobranchs have suffered from insufficient data and the use of inappropriate models (Anderson 1990). Assessments of spiny dogfish, in contrast, have benefited from excellent syntheses by Wood *et al.* (1979), and Silva (1993) and from growth information of Nammack *et al.* (1985). Earlier work by Holden (1974) on *Squalus acanthias* in the Northeast Atlantic laid a firm theoretical foundation for the utility of life history analyses. A greater dependence has to be placed on approaches which incorporate known information about the life history parameters of dogfish. Clearly, the deductions from life history models can provide useful information for management (see Hoenig and Gruber 1990, Smith and Abramson 1990, Fogarty *et al.* 1991, Cailliet 1992, Cailliet *et al.* 1992, Cortes 1995, Cortes 1996, Sminkey and Musick 1996).

An obstacle for further improvements in assessments of spiny dogfish stock in the Northwest Atlantic is the absence of age composition of the catch. Sharks are difficult to age, but recent advances (see Cailliet 1990) may permit routine updates of contemporary growth rate models. For this assessment, the conclusions regarding stock status should be relatively robust to the absence of contemporary aging data.

With an average F of 0.25 for the period 1994-1996 and average minimum length at entry to the fishery of 82 cm (Table D14), the estimated number of pups per recruit is below 1.0, and yield per recruit is less than 0.9 kg. Maximum yield per recruit (1.2 kg) occurs at an F of about 0.25 and a minimum size of 70 cm. Yield per recruit decreases with increasing minimum sizes, owing to the very slow growth rate at these ages. However, since reproduction in females occurs primarily in animals ≥80 cm, fishing mortality rates in excess of 0.15 on animals ≥80 cm results in negative female pup replacement. At an 84-cm minimum size, the maximum F that would ensure replacement recruitment is about 0.25. From sea sampling information, it is apparent that a substantial amount of fishing mortality also occurs on dogfish as small as 50 cm. Consequently, the minimum size at entry to the fishery is actually less than 84 cm. Thus, it is even more likely that current fishing mortality is at a level which will result in negative replacement. Under these conditions, the stock will eventually decline.

Recent levels of fishing mortality have exceeded the replacement rate of the stock. Removal of a large fraction of the spawning stock since 1990 will likely reverse the increase in population biomass that occurred in the late 1970s and 1980s. Biomass of males and immature females in the 36-70 cm range should decrease over the next decade as the small cohorts produced in the 1990s grow. Moreover, replacement of the spawning stock, i.e., accumulation of large females in the 100-cm range, could take another decade. Modeling efforts to evaluate potential rebuilding scenarios will be considered.

In view of the important long-term consequences of concentrated mortality on the spawning stock could have for population growth rates, a management program should be instituted expeditiously for this species. Appropriate management targets for stock biomass and fishing mortality rates should be established. Dogfish are important components of the marine ecosystem and consume commercially important species including several species of herring, Atlantic mackerel, sandlance, and others (Bowman *et al.* 1984). These factors are important ecological considerations, but it must be noted that the high levels of removals of mature females and probable high rates of discarding in the 1990s have initiated a large-scale ecosystem experiment. The consequences of this experiment will become evident over the next decade.

Although the current level of biomass is high, all indicators suggest continued reductions over at least the next five years and probably more. The present prominence of this species in the Northwest Atlantic ecosystem, several lines of evidence demonstrating the effects on stock abundance of increased fishing mortality, and a lack of understanding as to the impact of dogfish on other important fish species, constitute strong justification for prompt management action. Furthermore, given the evidence for a single unit stock of spiny dogfish in the Northwest Atlantic, joint assessment and management of this resource by the USA and Canada should be considered.

SARC Comments

The SARC recommended continued work on the change-in-ratio estimators for mortality rates and suggested several options for analyses. The SARC also noted the utility of the length-based estimators and suggested the application of alternative estimators of variance that incorporated variation in the estimates of K and L_{max}. It was noted that the Beverton-Holt estimator is based on equilibrium assumptions. When fishing mortality is increasing, F may actually be underestimated due to the transient size structure of the population.

The SARC noted the absence of projections for this species and recommended the development of a projection model. Such a model could be used to forecast the expected effects of recent reductions in spawning stock and expected contributions to the fishery from dogfish presently in the 36-79 cm range. Additional work on the stock-recruitment relationship should also be conducted with an eye toward estimation of the intrinsic rate of population increase. Work toward these objectives has begun and will likely be included as part of the work of the newly-formed Dogfish Technical Committee of the Mid-Atlantic Fishery Management Council.

Additional analyses of the effects of environmental conditions on survey catch rates should be conducted. It was postulated that at least some of the variation in abundance estimates among years might be driven by differences in temperatures at the time of the survey.

Sea sampling information was not updated in this assessment. The SARC recommended additional analyses of the data since 1994. A potential decline in discards as the directed fishery increased was hypothesized and should be testable with existing data. Further analyses of the commercial fishery is also warranted, especially with respect to the effects of gear types, mesh sizes, and market acceptability on the mean size of landed dogfish.

The SARC noted the potential importance of dogfish predation in the ecosystem and recommended further work on the diet composition. Preliminary information on recent diet composition presented to the SARC revealed very low incidence of regulated groundfish species.

The SARC noted that increased biological sampling of dogfish should be conducted on research trawl surveys. Maturation and fecundity estimates by length class will be particularly important to update. Additional work on the survey database should be done to recover and encode information on the sex composition prior to 1980.

Research Recommendations

- The SARC recommended continued work on the change-in-ratio estimators for mortality rates and suggested several options for analyses.

- The SARC noted the absence of projections for this species and recommended the development of a projection model.

- Additional work on the stock-recruitment relationship should also be conducted with an eye toward estimation of the intrinsic rate of population increase.

- Additional analyses of the effects of environmental conditions on survey catch rates should be conducted.

- The SARC recommended additional analyses of sea sampling data since 1994. Further analyses of the commercial fishery is also warranted, especially with respect to the effects of gear types, mesh sizes, and market acceptability on the mean size of landed dogfish.

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- The SARC noted that increased biological sampling of dogfish should be conducted on research trawl surveys. Maturation and fecundity estimates by length class will be particularly important to update. Additional work on the survey database should be done to recover and encode information on the sex composition prior to 1980.

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Table D1. Total spiny dogfish landings (mt, live).

Year	Canada	US	USSR	Other foreign	US recreational	Total
1962	-	235	-	-	NA	235
1963	-	610	-	1	NA	611
1964	-	730	-	16	NA	746
1965	9	488	188	10	NA	695
1966	39	578	9,389	-	NA	10,006
1967	-	278	2,436	-	NA	2,714
1968	-	158	4,404	-	NA	4,562
1969	-	113	8,827	363	NA	9,303
1970	19	106	4,924	716	NA	5,765
1971	4	73	10,802	764	NA	11,643
1972	3	69	23,302	689	NA	24,063
1973	20	89	14,219	4574	NA	18,902
1974	36	127	20,444	4069	NA	24,676
1975	1	147	22,331	192	NA	22,671
1976	3	550	16,681	107	NA	17,341
1977	1	931	6,942	257	NA	8,131
1978	84	828	577	45	NA	1,534
1979	1,331	4,753	105	82	NA	6,271
1980	670	4,085	351	248	NA	5,354
1981	564	6,865	516	458	1,789	10,192
1982	953	5,411	27	337	420	7,147
1983	-	4,897	359	105	607	5,968
1984	4	4,450	291	100	515	5,361
1985	13	4,028	694	318	1,054	6,107
1986	21	2,748	214	154	1,370	4,506
1987	280	2,703	116	23	1,362	4,484
1988	-	3,105	574	73	1,235	4,987
1989	166	4,492	169	87	1,762	6,676
1990	1,316	14,731	383	10	1,349	17,788
1991	292	13,177	218	16	1,481	15,183
1992	829	16,858	26	41	1,233	18,987
1993	1,432	20,643	-	-	1,230	23,305
1994	1,819	18,800	-	-	1,123	21,742
1995	956	22,711	-	-	692	24,359
1996	431	27,241	-	-	386	28,058

Table D2. US spiny dogfish commercial landings (mt, live) by gear type.

	Gear type					
Year	Line trawl	Otter trawl	Sink gillnet	Drift gillnet	Other gear	Total
1962	18.7	78.3	-	129.4	8.4	234.9
1963	49.8	85.5	297.2	138.3	38.8	609.6
1964	12.5	75.4	89.5	529.5	23.4	730.3
1965	55.1	52.3	129.8	228.6	22.2	488.1
1966	84.7	95.2	173.2	184.8	40.1	578.1
1967	23.9	110.8	54.9	43.1	44.9	277.5
1968	2.5	78.0	-	54.3	23.2	158.0
1969	1.9	88.4	0.5	5.9	16.7	113.4
1970	1.8	80.5	9.6	2.8	11.0	105.7
1971	-	53.0	0.6	3.5	16.2	73.3
1972	0.6	53.5	0.6	0.1	14.4	69.2
1973	0.5	76.7	1.3	5.0	5.8	89.3
1974	1.9	79.2	1.1	10.2	34.9	127.3
1975	0.3	89.4	4.1	10.3	42.8	146.9
1976	5.2	71.6	432.9	5.4	34.5	549.7
1977	2.8	102.6	796.1	2.8	27.2	931.4
1978	3.4	121.4	680.8	6.3	16.6	828.5
1979	17.8	3,517.6	1,198.3	1.5	17.6	4,752.7
1980	12.1	3,370.1	634.2	4.0	64.7	4,085.1
1981	1.0	6,287.1	560.8	7.3	8.7	6,865.0
1982	2.9	5,065.5	310.8	9.4	22.0	5,410.6
1983	0.2	3,367.5	1,517.1	6.6	5.1	4,896.5
1984	0.9	2,486.0	1,949.5	6.1	7.9	4,450.4
1985	158.7	2,844.4	1,007.6	9.8	7.6	4,028.0
1986	2.6	1,258.1	1,467.2	3.1	16.7	2,747.6
1987	7.8	1,848.1	811.7	2.9	32.8	2,703.4
1988	4.7	1,589.5	1,489.5	12.6	9.0	3,105.1
1989	138.2	486.5	3,839.0	7.5	20.8	4,492.0
1990	16.8	7,010.8	7,685.2	14.7	3.1	14,730.6
1991	31.1	5,208.6	7,805.8	107.6	23.6	13,176.6
1992	9.8	4,785.5	11,639.7	171.5	251.5	16,857.9
1993	250.8	5,100.2	15,263.1	6.9	21.9	20,642.9
1994	482.4	3,056.4	15,100.1	27.1	134.1	18,800.2
1995	1,496.8	2,818.0	17,700.8	340.9	354.2	22,710.6
1996	1,313.0	3,441.3	21,122.4	1,265.3	99.0	27,241.0

Table D3. US spiny dogfish commercial landings (mt, live) by month.

Year	Unk	Month												Total
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1964	627.9	7.3	1.4	1.2	-	12.9	31.7	-	4.8	35.9	-	-	7.4	730.3
1965	308.5	0.1	4.1	-	14.9	4.9	34.4	23.1	27.2	30.8	11.9	22.6	5.6	488.1
1966	318.4	1.5	1.8	7.8	7.1	2.1	68.7	82.0	48.9	26.6	5.5	7.6	-	578.1
1967	188.3	-	3.9	-	4.3	6.0	15.9	42.7	5.3	7.2	0.9	2.5	0.8	277.5
1968	157.6	-	-	-	-	0.1	-	-	0.2	-	-	-	-	158.0
1969	113.4	-	-	-	-	-	-	-	-	-	-	-	-	113.4
1970	102.8	-	-	-	-	-	-	0.3	1.0	0.2	0.9	0.4	<0.1	105.6
1971	72.9	<0.1	-	-	-	0.4	-	-	-	-	-	-	-	73.3
1972	60.2	-	-	-	0.1	0.4	0.3	-	-	-	1.8	4.7	1.7	69.2
1973	73.7	2.7	<0.1	-	0.7	2.4	4.3	2.4	0.3	-	1.6	0.8	0.4	89.3
1974	122.6	0.1	-	0.9	-	0.8	0.3	1.1	0.2	0.6	0.4	0.2	0.1	127.3
1975	136.0	0.2	0.1	0.4	2.6	0.3	0.2	0.2	0.1	-	0.1	3.6	2.9	146.9
1976	116.2	0.1	0.5	-	-	-	24.1	126.2	70.9	119.7	91.8	0.1	0.1	549.7
1977	95.4	-	-	-	-	30.0	259.9	120.4	169.4	136.7	98.3	4.1	17.3	931.4
1978	140.8	0.1	0.8	5.9	0.1	0.5	85.0	294.5	102.2	54.2	133.0	9.1	2.3	828.5
1979	344.3	-	-	-	-	16.7	292.4	637.0	502.3	1,043.1	1,137.5	389.8	389.5	4,752.7
1980	406.7	26.9	3.3	81.5	0.4	112.3	803.0	540.5	818.9	1,087.4	52.2	91.4	60.7	4,085.1
1981	1,729.4	1.2	0.4	-	0.8	107.6	945.4	1,121.0	1,156.8	1,005.2	698.6	98.0	0.7	6,865.0
1982	65.8	143.1	369.6	1,287.8	219.4	134.1	830.4	819.7	411.6	517.6	256.4	235.7	119.4	5,410.6
1983	45.9	3.7	3.6	-	0.3	55.8	140.8	710.0	963.2	744.5	402.5	169.2	1,656.9	4,896.5
1984	46.8	-	-	-	0.3	1.4	559.5	2,077.1	1,111.6	357.8	168.2	103.1	24.5	4,450.4
1985	71.1	-	-	0.8	1.9	275.5	690.6	753.2	785.6	588.1	642.6	175.4	43.0	4,027.9
1986	13.1	1.0	5.8	2.5	11.8	145.5	483.1	468.0	473.7	622.8	376.9	93.8	49.9	2,747.6
1987	6.0	4.8	1.5	4.0	8.6	17.6	397.1	555.8	384.6	440.5	703.6	175.5	3.9	2,703.4
1988	49.8	0.6	116.0	27.5	4.4	384.8	566.3	532.4	502.6	508.8	401.1	9.9	0.9	3,105.1
1989	15.5	0.2	-	2.0	21.2	296.9	1,134.1	713.5	961.4	924.5	374.2	41.7	6.8	4,492.0
1990	49.5	290.0	207.8	283.2	318.6	494.2	1,137.9	2,881.6	2,819.3	2,079.5	1,166.8	959.8	2,042.6	14,730.6
1991	213.7	1,609.9	1,105.2	661.4	1,298.9	1,136.8	624.5	1,421.6	962.8	840.1	353.7	965.7	1,982.6	13,176.6
1992	320.8	2,117.3	1,620.4	1,402.6	703.7	787.5	1,083.4	2,327.4	1,549.7	808.9	1,362.7	1,887.9	885.8	16,857.9
1993	281.7	1,516.3	1,631.6	834.9	260.7	517.8	2,001.0	3,423.3	3,227.4	2,587.2	1,983.3	1,075.8	1,301.8	20,642.9
1994	77.1	1,277.0	1,438.2	1,234.9	628.9	653.1	1,975.3	3,391.2	4,204.7	1,508.1	878.2	409.5	1,123.9	18,800.2
1995	28.7	1,703.4	1,432.8	1,150.9	880.3	928.8	3,386.9	4,181.5	2,208.8	1,843.9	1,887.2	1,499.9	1,577.6	22,710.6
1996	0.2	2,628.1	2,336.8	2,532.1	1,695.1	534.5	2,221.9	3,630.6	2,466.7	2,143.6	2,511.0	2,056.9	2,483.5	27,241.0
1997	-	2,178.2	1,480.1	1,306.2	688.1	1,360.6	2,094.7	2,641.0	1,885.3	863.8	NA	NA	NA	14,498.1

Table D4. US commercial landings of spiny dogfish (mt, live) by state (includes 100% unclassified dogfish).

	State											
Year	Connecticut	Delaware	Maine	Maryland	Massachusetts	New Hampshire	New Jersey	New York	North Carolina	Rhode Island	Virginia	Total
1962	2.6	-	21.6	17.4	-	-	1.6	25.2	-	0.1	166.3	234.9
1963	0.1	-	343.5	16.5	-	-	1.9	35.4	-	0.1	212.2	609.6
1964	4.7	-	102.1	12.4	-	-	0.2	33.1	-	0.4	577.5	730.3
1965	6.9	-	171.3	7.2	7.6	-	0.7	43.9	-	0.7	249.7	488.1
1966	4.9	0.2	259.6	6.7	-	-	1.5	81.7	-	0.1	223.4	578.1
1967	1.6	-	82.1	6.5	6.6	-	0.1	89.0	-	0.5	91.1	277.5
1968	22.8	-	-	7.2	0.3	-	3.3	61.8	-	0.1	62.5	158.0
1969	2.2	-	-	7.9	-	-	6.1	65.6	-	0.1	31.6	113.4
1970	8.0	-	-	6.1	2.4	-	0.6	54.1	-	0.7	33.8	105.7
1971	4.1	-	-	1.5	0.4	-	5.6	50.5	-	0.1	11.1	73.3
1972	-	-	-	2.4	0.7	-	0.1	51.4	-	8.3	6.4	69.2
1973	0.1	-	-	4.5	5.4	-	2.5	44.4	-	10.4	22.2	89.3
1974	-	0.6	-	6.5	3.2	-	0.3	79.8	-	2.2	34.6	127.3
1975	-	1.8	-	2.6	1.8	-	0.9	101.1	-	9.1	29.5	146.9
1976	1.1	-	428.3	3.1	3.1	-	1.7	93.4	-	1.7	17.2	549.7
1977	1.0	0.1	792.8	3.6	17.4	-	4.7	78.1	-	26.4	7.4	931.4
1978	2.2	0.4	647.0	7.5	31.5	31.6	6.4	88.1	-	2.8	11.1	828.5
1979	4.1	0.1	1049.6	5.4	2,964.9	140.6	392.4	96.7	-	1.6	97.6	4,752.7
1980	0.1	0.1	619.1	5.0	2,794.4	6.7	263.0	104.1	1.3	0.6	290.6	4,085.1
1981	2.0	3.8	516.2	695.4	4,523.3	-	92.5	50.1	2.0	1.7	978.1	6,865.0
1982	1.2	1.2	282.6	895.2	2,885.3	-	2.5	47.4	2.9	1.3	1291.0	5,410.6
1983	4.3	2.0	225.0	96.5	4,529.9	0.3	0.3	25.8	-	-	12.4	4,896.5
1984	2.4	2.7	565.4	117.6	3,703.2	0.1	4.1	35.0	-	11.1	8.8	4,450.4
1985	4.5	-	409.8	76.9	3,463.7	-	3.8	61.9	0.5	0.7	6.3	4,028.0
1986	8.7	-	349.1	58.6	2,165.6	-	24.0	133.9	-	2.2	5.5	2,747.6
1987	2.9	-	271.0	3.5	2,335.2	-	1.7	70.6	-	13.9	4.6	2,703.4
1988	42.8	-	218.4	10.7	2,643.6	0.2	4.6	39.2	136.9	0.3	8.6	3,105.1
1989	0.4	-	2,213.4	1.6	2,233.8	-	10.3	21.9	-	2.0	8.7	4,492.0
1990	11.0	-	2,887.6	989.7	8,077.0	84.0	2,061.2	8.2	18.8	590.1	3.0	14,730.6
1991	4.0	2.6	914.5	2,240.4	6,572.2	-	1,231.8	35.0	663.7	1,433.5	78.9	13,176.6
1992	10.1	-	779.9	1,389.5	8,335.2	182.4	1,149.7	70.6	3,916.8	919.7	103.9	16,857.9
1993	6.8	-	1,598.9	814.6	12,170.4	744.6	349.3	43.3	3,994.4	872.9	47.7	20,642.9
1994	77.1	-	822.5	648.0	10,530.0	1,178.4	512.5	107.7	4,480.5	240.6	203.0	18,800.2
1995	133.2	28.5	754.6	1,414.1	13,045.6	955.4	1,083.4	423.9	4,244.3	260.3	367.3	22,710.6
1996	320.2	-	413.3	3,243.7	12,228.7	489.7	2,102.6	602.2	6,202.4	511.9	1,126.3	27,241.0

Table D5. Numbers of spiny dogfish sampled from US commercial landings by year, month, and sex, 1982-1996.

Year	Sex	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1982	M	2	-	22	-	-	-	-	-	-	-	-	-	24
	F	198	101	281	-	-	-	-	-	-	-	-	100	680
1983	F	-	-	-	-	-	104	-	-	121	133	134	-	492
1984	M	-	-	-	-	-	1	3	4	1	-	-	-	9
	F	-	-	-	-	-	286	745	351	117	-	-	-	1,499
1985	M	-	-	-	-	-	-	1	1	14	1	4	-	21
	F	-	-	-	-	-	267	135	389	368	252	246	-	1,657
1986	U	-	-	-	-	-	232	-	-	-	-	-	-	232
	M	-	-	-	-	-	-	45	1	10	8	-	-	64
	F	-	-	-	-	-	130	129	521	168	217	-	-	1,165
1987	M	-	-	-	-	-	16	4	-	1	1	9	-	31
	F	-	-	-	-	-	457	800	257	128	243	115	-	2,000
1988	M	-	-	-	-	-	-	1	1	-	5	-	-	7
	F	-	-	-	-	371	364	238	128	230	433	-	-	1,764
1989	M	-	-	-	-	-	-	-	6	6	23	-	-	35
	F	-	-	-	-	-	352	127	137	390	369	-	-	1,375
1990	M	-	-	-	-	-	-	4	-	-	1	14	-	19
	F	-	-	-	-	-	593	775	358	135	111	123	135	2,230
1991	U	-	-	-	-	-	-	108	-	-	109	-	-	217
	M	-	-	-	-	-	11	1	12	-	-	8	3	35
	F	-	-	101	125	-	226	396	272	-	-	116	282	1,518
1992	U	-	-	-	-	-	123	-	-	-	-	-	-	123
	M	-	-	-	-	-	2	1	-	-	-	8	1	12
	F	-	-	-	109	219	409	829	503	124	296	556	142	3,187
1993	U	-	-	-	-	133	-	-	-	-	-	-	-	133
	M	-	-	-	-	-	-	-	4	19	19	-	-	42
	F	-	-	-	-	-	400	682	776	369	545	-	-	2,772
1994	U	-	-	-	-	-	-	134	-	-	-	-	-	134
	M	-	-	-	-	-	2	31	14	-	-	-	-	47
	F	-	-	-	-	-	423	758	649	262	-	-	-	2,092
1995	M	-	-	-	-	5	3	4	13	-	-	-	-	25
	F	-	-	-	-	158	373	1,124	611	-	-	-	-	2,266
1996	M	-	-	-	-	-	1	96	30	-	157	127	158	569
	F	-	-	-	-	-	142	784	504	-	96	118	18	1,662
Grand total		200	101	404	234	886	4,917	7,955	5,542	2,463	3,019	1,578	839	28,138

Table D6. Biological characteristics of US commercial landings of spiny dogfish, 1982-1996.

	Commercial landings (mt)					Mean weight (kg)		Total number caught				Mean length (cm)	
Year	Total	Females	Males	Female %	Male %	Females	Males	Females	Males	Female %	Male %	Females	Males
1982	5,410.6	5,318.9	91.7	98.30%	1.70%	4.44	2.17	1,199,204	42,325	96.59%	3.41%	97.0	84.8
1983	4,896.5	4,896.5	-	100.00%	-	4.09	-	1,197,182	-	100.00%	0.00%	94.7	
1984	4,450.4	4,439.8	10.6	99.76%	0.24%	4.42	1.76	1,004,315	6,030	99.40%	0.60%	96.7	79.4
1985	4028	4,007.2	20.8	99.48%	0.52%	4.10	1.68	976,479	12,375	98.75%	1.25%	94.8	78.1
1986	2,747.6	2,687.7	59.9	97.82%	2.18%	4.01	1.63	670,564	36,838	94.79%	5.21%	93.7	77.6
1987	2,703.4	2,684.7	18.7	99.31%	0.69%	3.78	1.70	711,085	11,022	98.47%	1.53%	92.3	78.8
1988	3,105.1	3,099.0	6.1	99.80%	0.20%	4.29	2.11	722,972	2,869	99.60%	0.40%	96.0	84.6
1989	4492	4,437.9	54.1	98.79%	1.21%	4.02	1.93	1,103,734	28,095	97.52%	2.48%	94.2	82.0
1990	14,730.6	14,675.2	55.4	99.62%	0.38%	4.00	1.77	3,669,820	31,268	99.16%	0.84%	94.1	79.8
1991	13,176.6	13,092.8	83.8	99.36%	0.64%	3.90	1.08	3,354,707	77,348	97.75%	2.25%	93.4	77.9
1992	16,857.9	16,827.0	30.9	99.82%	0.18%	3.82	1.86	4,402,269	16,576	99.62%	0.38%	92.9	81.1
1993	20,642.9	20,481.1	161.8	99.22%	0.78%	3.58	1.87	5,721,367	86,687	98.51%	1.49%	91.5	81.2
1994	18,800.2	18,558.2	242.0	98.71%	1.29%	3.17	1.84	5,846,452	131,350	97.80%	2.20%	88.1	80.9
1995	22,710.6	22,579.2	131.4	99.42%	0.58%	2.95	1.55	7,662,456	84,537	98.91%	1.09%	86.3	76.4
1996	27,241.0	22,670.6	4,570.4	83.22%	16.78%	2.65	1.56	8,567,153	2,933,039	74.50%	25.50%	84.1	76.4

Table D7. Calculations of total discard mortalities of spiny dogfish from various fisheries for 1993. Where indicated, 1993 sea sampling data are expanded to gear/area total catches.

Gear	Target species	Area	Sea sampled discard per ton[1]	Total 1993 landings[2]	Est. 1993 dogfish discards	Est. 1993 discard mort.[3]
Sink gillnet	Dogfish	GOM-SNE	0.110	6,818	750	562
	Dogfish	MAB[4]	0.135	4,000	540	405
	Groundfish (cod)	GOM	1.038	2,130	2,211	1,659
Otter trawl	Dogfish	GOM-SNE[5]	0.434	4,389	1,905	952
	Groundfish (cod)	GOM	0.924	6,391	5,906	2,953
	Groundfish (cod)	GBK[6]	0.377	11,700	4,411	2,205
	Groundfish (fluke)	SNE-MA	1.744	5,500	9,592	4,796
Total					23,315	13,532

[1]Mt of dogfish per mt of target species (given in parentheses) [2]Total 1993 landings of target species by designated gear type. Data are preliminary. [3]Assumes 75% of discards dead by gillnets, and 50% of discards dead by otter trawls. Data given in mt. [4]1994 otter trawl sampling substituted for 1993. [5]1990 otter trawl sampling substituted for 1993. [6]1992 otter trawl sampling substituted for 1993.

Table D8. Number per tow indices for spiny dogfish from NEFSC spring (1968-1997) and autumn (1967-1996) bottom trawl surveys (offshore strata 1-30, 33-40,61-76; Footnotes A-C).

	Spring				Autumn			
Year	Unsexed	Male	Female	Total	Unsexed	Male	Female	Total
1967	-	-	-	-	34.0	-	-	34.0
1968	24.3	-	-	24.3	19.7	-	-	19.7
1969	13.3	-	-	13.3	27.7	-	-	27.7
1970	15.3	-	-	15.3	16.6	-	-	16.6
1971	15.9	-	-	15.9	12.9	-	-	12.9
1972	27.6	-	-	27.6	10.5	-	-	10.5
1973	35.6	-	-	35.6	15.0	-	-	15.0
1974	39.1	-	-	39.1	4.7	-	-	4.7
1975	35.4	-	-	35.4	17.7	-	-	17.7
1976	23.1	-	-	23.1	14.9	-	-	14.9
1977	13.1	-	-	13.1	6.8	-	-	6.8
1978	22.5	-	-	22.5	26.0	-	-	26.0
1979	10.1	-	-	10.1	22.0	-	-	22.0
1980	6.1	12.9	10.0	29.0	-	1.4	3.8	5.1
1981	0.5	18.2	23.0	41.7	-	36.0	39.7	75.7
1982	-	23.7	27.8	51.6	-	6.9	6.8	13.7
1983	-	23.6	18.1	41.7	-	14.3	18.0	32.4
1984	-	13.3	9.2	22.5	-	10.6	11.9	22.5
1985	-	80.2	37.1	117.3	-	19.0	19.7	38.7
1986	-	9.5	19.3	28.7	-	12.3	15.2	27.4
1987	-	39.3	25.8	65.1	-	16.5	16.3	32.8
1988	-	29.5	35.1	64.6	-	15.5	19.9	35.3
1989	-	29.6	27.1	56.7	-	6.7	6.0	12.8
1990	-	47.8	44.0	91.8	-	14.7	11.5	26.1
1991	-	32.3	30.0	62.3	-	20.9	17.4	38.4
1992	-	38.2	41.3	79.5	-	12.9	26.2	39.1
1993	-	32.6	28.3	60.9	-	4.5	2.4	6.9
1994	-	53.4	38.1	91.5	-	16.6	14.2	30.9
1995	-	25.8	25.0	50.8	-	16.9	13.7	30.6
1996	-	52.6	44.6	97.3	-	12.8	20.1	32.8
1997	-	29.6	29.1	58.7	-	-	-	-

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

B. Spring surveys from 1973-1981 were accomplished with a '41 Yankee' trawl; in all other years, spring surveys were accomplished with a '36 Yankee' trawl. A factor of 0.71 was applied to all tows in these years (Sissenwine and Bowman, 1978).

C. During the fall of 1970, 1975, 1978, 1979, 1980, 1981, 1985, 1986, 1988, 1989, 1990, 1991, and 1993 and the springs of 1973, 1976, 1977, 1979, 1980, 1981, 1982, 1987, 1989, 1990, 1991, and 1994 the *Delaware II* was used entirely or in part to conduct the survey. All other years, the *Albatross IV* was the only vessel used for the survey. A factor of 0.79 was applied to all *Delaware II* tows (NEFSC 1991).

Table D9. Weight per tow (kg) indices for spiny dogfish from NEFSC spring (1968-1997) and autumn (1967-1996) bottom trawl surveys (offshore strata 1-30, 33-40,61-76; Footnotes A-C).

	Spring				Autumn			
Year	Unsexed	Male	Female	Total	Unsexed	Male	Female	Total
1967	-	-	-	-	34.9	-	-	34.9
1968	25.8	-	-	25.8	22.4	-	-	22.4
1969	16.1	-	-	16.1	55.3	-	-	55.3
1970	13.3	-	-	13.3	23.8	-	-	23.8
1971	24.0	-	-	24.0	15.5	-	-	15.5
1972	49.0	-	-	49.0	16.1	-	-	16.1
1973	57.1	-	-	57.1	21.7	-	-	21.7
1974	67.0	-	-	67.0	8.1	-	-	8.1
1975	45.6	-	-	45.6	20.9	-	-	20.9
1976	37.0	-	-	37.0	19.8	-	-	19.8
1977	24.1	-	-	24.1	16.1	-	-	16.1
1978	36.3	-	-	36.3	19.3	-	-	19.3
1979	13.4	-	-	13.4	26.6	-	-	26.6
1980	13.4	34.2	1.6	49.1	-	4.0	15.1	19.1
1981	0.6	20.4	48.2	69.2	-	12.7	34.9	47.6
1982	-	31.1	86.0	117.0	-	5.2	9.7	14.9
1983	-	21.1	17.7	38.9	-	13.7	22.1	35.8
1984	-	19.3	23.0	42.4	-	8.7	13.9	22.5
1985	-	100.4	66.7	167.1	-	14.6	25.0	39.7
1986	-	5.8	39.0	44.9	-	13.4	23.7	37.1
1987	-	40.6	61.7	102.3	-	10.6	11.2	21.8
1988	-	26.9	77.4	104.4	-	15.3	24.3	39.6
1989	-	34.8	43.1	77.8	-	6.1	5.5	11.5
1990	-	60.6	89.2	149.8	-	14.9	14.9	29.8
1991	-	36.5	53.0	89.5	-	24.6	26.7	51.3
1992	-	44.8	70.1	114.9	-	14.1	41.6	55.7
1993	-	35.7	52.2	87.9	-	5.1	2.1	7.2
1994	-	49.9	35.3	85.1	-	18.5	14.2	32.8
1995	-	34.8	40.0	74.8	-	16.7	11.4	28.0
1996	-	59.0	60.5	119.5	-	14.4	26.7	41.1
1997	-	37.5	44.9	82.4	-	-	-	-

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

B. Spring surveys from 1973-1981 were accomplished with a '41 Yankee' trawl; in all other years, spring surveys were accomplished with a '36 Yankee' trawl. A factor of 0.69 was applied to all tows in these years (Sissenwine and Bowman, 1978).

C. During the fall of 1970, 1975, 1978, 1979, 1980, 1981, 1985, 1986, 1988, 1989 1990, 1991, and 1993 and the springs of 1973, 1976, 1977, 1979, 1980, 1981, 1982, 1987, 1989, 1990, 1991, and 1994 the *Delaware II* was use entirely or in part to conduct the survey. All other years, the *Albatross IV* was the only vessel used for the survey. A factor of 0.81 was applied to all *Delaware II* tows (NEFSC 1991).

Table D10. Number per tow indices for spiny dogfish from the state of Massachusetts spring and autumn inshore bottom trawl surveys.

	Spring				Autumn			
Year	Unsexed	Male	Female	Total	Unsexed	Male	Female	Total
1978	10.9	-	-	10.9	149.1	-	-	149.1
1979	1.9	-	-	1.9	12.6	-	-	12.6
1980	1.7	-	-	1.7	-	0.1	4.7	4.8
1981	0.5	-	1.0	1.6	11.2	0.1	0.3	11.6
1982	-	-	2.0	2.0	-	8.2	45.9	54.1
1983	-	-	0.8	0.8	-	3.1	11.5	14.7
1984	-	1.4	5.5	6.9	-	51.1	17.4	68.5
1985	-	0.1	0.8	0.8	-	12.5	116.6	129.1
1986	-	0.1	2.2	2.2	-	45.2	77.9	123.1
1987	-	-	0.2	0.2	-	14.1	36.8	50.9
1988	-	1.5	11.5	12.9	-	34.0	181.9	215.9
1989	-	9.2	16.4	25.6	-	256.7	764.6	1,021.3
1990	-	-	2.3	2.3	-	16.3	41.5	57.8
1991	-	-	0.9	0.9	-	2.8	25.6	28.4
1992	-	-	2.2	2.2	-	51.4	67.6	119.1
1993	-	9.4	10.5	19.8	-	15.8	93.9	109.7
1994	-	-	0.2	0.2	-	18.7	1.3	20.0
1995	-	7.5	21.2	28.6	-	40.0	33.1	73.1
1996	-	-	-	-	-	14.2	21.1	35.3
1997	-	2.1	11.1	13.2	-	-	-	-

Table D11. Weight per tow (kg) indices for spiny dogfish from the state of Massachusetts spring and autumn inshore bottom trawl surveys.

	Spring				Autumn			
Year	Unsexed	Male	Female	Total	Unsexed	Male	Female	Total
1978	22.9	-	-	22.9	225.7	-	-	225.7
1979	6.4	-	-	6.4	40.2	-	-	40.2
1980	6.1	-	-	6.1	0.1	0.1	17.8	18.1
1981	2.6	-	4.3	6.9	44.9	0.2	1.3	46.4
1982	-	0.1	9.2	9.3	-	14.2	166.2	180.4
1983	-	-	3.2	3.3	-	5.0	35.6	40.6
1984	-	1.6	10.8	12.4	-	80.6	43.7	124.2
1985	-	0.1	3.4	3.5	-	18.0	297.5	315.5
1986	-	0.1	9.7	9.7	-	70.4	224.1	294.6
1987	-	-	0.9	0.9	-	20.9	105.3	126.2
1988	-	1.9	39.3	41.2	-	47.2	560.4	607.6
1989	-	4.8	14.0	18.9	-	328.9	1546.2	1875.1
1990	-	-	9.4	9.4	-	22.6	95.0	117.6
1991	-	-	4.5	4.5	-	3.4	80.7	84.1
1992	-	-	8.5	8.5	-	68.6	107.0	175.6
1993	-	10.4	19.5	29.9	-	23.3	211.7	235.0
1994	-	-	0.8	0.8	-	30.8	2.8	33.6
1995	-	9.5	34.1	43.7	-	59.6	63.6	123.2
1996	-	-	0.1	0.1	-	20.8	44.4	65.2
1997	-	2.4	20.5	22.9	-	-	-	-

Table D12. Minimum biomass estimates (thousands of mt) based on area swept by NEFSC trawl during spring surveys.

	Lengths ≥80 cm			Lengths 36-79 cm			Length ≤35 cm			
Year	Females	Males	Total	Females	Males	Total	Females	Males	Total	All lengths
1968	-	-	41.4	-	-	110.4	-	-	1.52	153.3
1969	-	-	27.4	-	-	69.3	-	-	0.66	97.3
1970	-	-	36.7	-	-	33.0	-	-	3.19	72.9
1971	-	-	103.8	-	-	27.6	-	-	2.76	134.2
1972	-	-	126.6	-	-	145.9	-	-	1.55	274.1
1973	-	-	178.7	-	-	165.3	-	-	2.58	346.5
1974	-	-	221.9	-	-	179.6	-	-	2.66	404.1
1975	-	-	105.1	-	-	125.0	-	-	3.97	234.0
1976	-	-	96.3	-	-	120.8	-	-	1.20	218.3
1977	-	-	77.3	-	-	68.0	-	-	0.53	145.9
1978	-	-	87.4	-	-	131.2	-	-	1.24	219.8
1979	-	-	52.3	-	-	18.6	-	-	1.82	72.7
1980	104.7	15.3	168.1	16.8	72.2	123.5	0.32	0.39	0.84	292.4
1981	266.5	24.4	293.8	25.5	75.1	100.6	2.14	2.80	5.06	399.5
1982	454.0	34.6	488.6	61.6	143.3	204.9	0.48	0.69	1.17	694.6
1983	77.7	30.1	107.8	36.7	98.5	135.3	3.09	3.95	7.03	250.1
1984	115.6	27.5	143.1	33.4	88.0	121.4	0.14	0.21	0.35	264.9
1985	317.0	125.5	442.6	102.5	502.5	605.0	4.01	5.10	9.10	1,056.7
1986	191.3	3.5	194.8	51.9	29.6	81.5	0.84	1.11	1.96	278.2
1987	219.1	90.5	309.6	61.5	171.7	233.1	2.46	4.76	7.22	550.0
1988	433.1	26.2	459.4	93.3	153.6	247.0	0.89	1.09	1.98	708.4
1989	162.1	40.5	202.6	100.4	158.2	258.6	1.14	1.54	2.68	463.9
1990	400.3	70.7	471.0	163.5	303.1	466.6	0.68	1.03	1.71	939.3
1991	220.4	30.0	250.3	108.4	186.3	294.7	0.98	1.43	2.41	547.4
1992	280.5	41.9	322.4	179.9	231.9	411.8	0.73	1.00	1.73	735.9
1993	234.6	27.8	262.5	104.1	198.5	302.6	0.55	0.65	1.21	566.3
1994	105.3	37.1	142.4	108.3	254.2	362.5	4.28	5.54	9.82	514.8
1995	102.4	29.5	131.9	154.0	174.5	328.5	0.25	0.35	0.59	460.9
1996	196.5	33.4	229.9	201.7	334.8	536.4	0.98	1.14	2.12	768.5
1997	83.7	17.5	101.2	205.2	209.1	414.3	0.05	0.05	0.10	515.5

Notes: Total equals sum of males and females plus unsexed dogfish. Data for dogfish prior to 1980 are currently not available by sex.

Table D13. Change in ratio estimators of fishing mortality on males and females from commercial fisheries for 1982 to 1996. Estimates are based on numbers of fish greater than 80 cm in both the spring survey and commercial landings. Estimates of survey abundance are based on LOWESS smoothed survey values with tension factor = 0.5.

	Spring survey (yr i)		Removals via fishery		Spring survey (yr i+1)		Intermediate variables		Instantaneous rates	
	Males	Females	Males	Females	Males	Females	Survey M:F			
Year(i)	X_1	Y_1	R_x	R_y	X_2	Y_2	r_1	r_2	Males	Females
1982	2.133	8.075	33.51	1,193.91	2.332	8.4058	0.1063	1.0504	0.0057	0.0549
1983	2.332	8.406	0.00	1,182.58	2.199	8.2971	0.0000	0.9551	0.0000	-0.0459
1984	2.199	8.297	4.02	998.29	2.067	8.2152	0.0152	0.9496	-0.0008	-0.0526
1985	2.067	8.215	5.30	961.75	2.325	9.5985	0.0219	0.9627	-0.0009	-0.0389
1986	2.325	9.599	12.66	641.21	2.404	10.8518	0.0815	0.9145	-0.0083	-0.0977
1987	2.404	10.85	4.98	663.09	2.504	11.7344	0.0339	0.9633	-0.0013	-0.0387
1988	2.504	11.73	2.87	718.05	2.962	12.5187	0.0187	1.1087	0.0019	0.1050
1989	2.962	12.52	21.67	1,093.30	3.069	12.9575	0.0838	1.0013	0.0001	0.0014
1990	3.069	12.96	19.75	3,646.78	3.071	12.5464	0.0229	1.0334	0.0008	0.0336
1991	3.071	12.55	26.90	3,323.77	2.967	11.4508	0.0331	1.0585	0.0019	0.0587
1992	2.967	11.45	11.05	4,342.87	2.828	9.9629	0.0098	1.0957	0.0009	0.0923
1993	2.828	9.963	38.52	3,627.44	2.669	8.9877	0.0374	1.0459	0.0017	0.0466
1994	2.669	8.988	86.63	5,471.79	2.451	7.8266	0.0533	1.0546	0.0029	0.0561
1995	2.451	7.827	23.67	6,577.00	2.227	6.6837	0.0115	1.0639	0.0007	0.0627
1996	2.227	6.684	695.89	6,633.81	1.994	5.646	0.3149	1.0602	0.0258	0.0843
1997	1.994	5.646	-	-	-	-	-	-	-	-
					Average		0.0563	1.0212	0.0021	0.0214
					Ave. (1982-1989)		0.0452	0.9882	-0.0005	-0.0141
					Ave. (1990-1996)		0.0690	1.0589	0.0049	0.0620

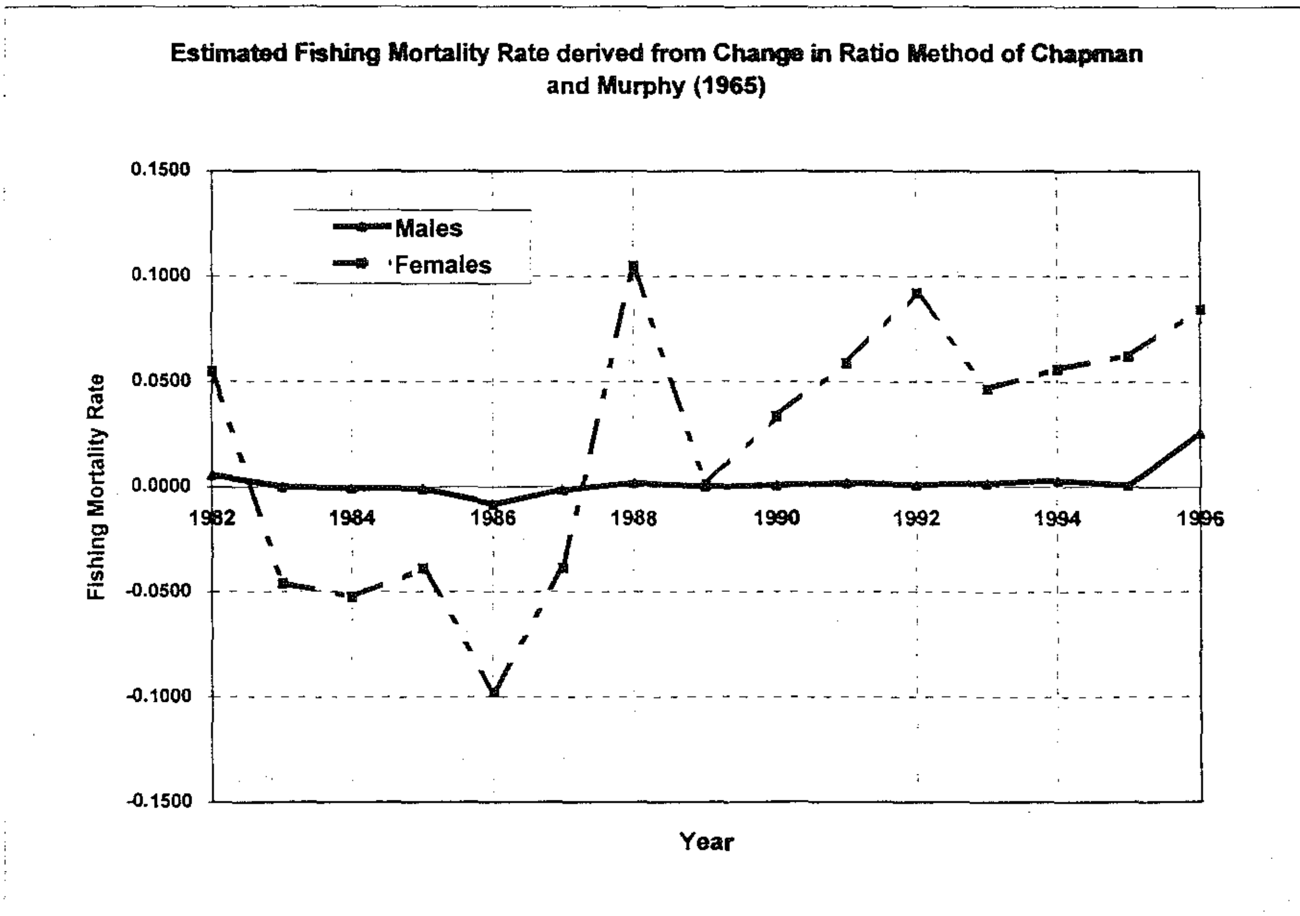


Table D14. Estimates of total (Z) and fishing (F) mortality rates using the Beverton and Holt estimator. Cutoff values for commercial landings were chosen as the 25th percentile of landed dogfish. Survey length frequency distributions were used to estimate mean size of dogfish exceeding the 25th percentile. Parameters for von Bertalanffy equation and natural mortality from text. Confidence intervals are based on the standard error of the mean length estimate in the survey. An effective sample size of 50 was assumed for this computation.

	Comm. fishery 25%ile of	NEFSC spring survey data		Biological data				Derived mortality rates			
Year	length	Lbar	SD	K	Lmax	M	Z_hat	F_hat	5%ile of F	95%ile of F	Median F
1982	93	97.818	3.2258	0.1128	105	0.092	0.168	0.076	0.0378	0.1320	0.0738
1983	91	97.229	3.5213	0.1128	105	0.092	0.141	0.049	0.0231	0.0808	0.0487
1984	93	97.962	3.5217	0.1128	105	0.092	0.160	0.068	0.0327	0.1130	0.0670
1985	91	97.623	4.4197	0.1128	105	0.092	0.126	0.034	0.0101	0.0670	0.0327
1986	91	96.988	4.0136	0.1128	105	0.092	0.151	0.059	0.0278	0.0961	0.0606
1987	87	95.621	5.3380	0.1128	105	0.092	0.123	0.031	0.0101	0.0545	0.0327
1988	92	98.394	4.4093	0.1128	105	0.092	0.117	0.025	0.0022	0.0545	0.0231
1989	90	95.630	4.0483	0.1128	105	0.092	0.188	0.096	0.0606	0.1424	0.0961
1990	90	95.898	4.0370	0.1128	105	0.092	0.174	0.082	0.0487	0.1222	0.0808
1991	89	94.892	4.5339	0.1128	105	0.092	0.194	0.102	0.0670	0.1424	0.1043
1992	88	93.240	5.1857	0.1128	105	0.092	0.253	0.161	0.1130	0.2210	0.1651
1993	87	93.336	4.7925	0.1128	105	0.092	0.208	0.116	0.0808	0.1534	0.1130
1994	84	89.320	4.6156	0.1128	105	0.092	0.332	0.240	0.1911	0.3201	0.2377
1995	82	86.886	4.3779	0.1128	105	0.092	0.418	0.326	0.2558	0.4403	0.3201
1996	80	87.291	4.3409	0.1128	105	0.092	0.274	0.182	0.1424	0.2210	0.1777
1997	80	84.607	3.4547	0.1128	105	0.092	0.499	0.407	0.3201	0.5237	0.4054

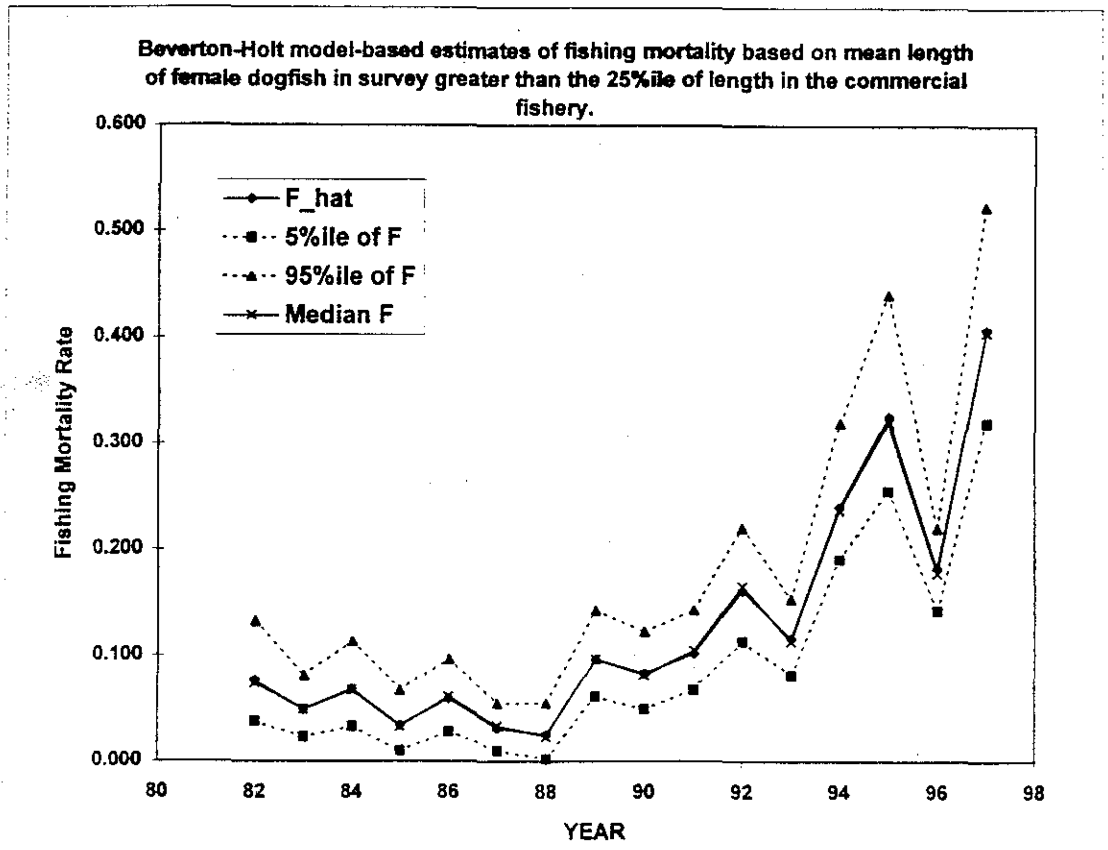


Table D15. Summary of population parameters related to growth, survival, and reproduction of spiny dogfish in the Northwest Atlantic.

Symbol	Parameter name	Sex	Value	Reference
L_∞	Maximum length	F	105	Approx 95th percentile of catch and survey data
		M	81.32	Nammack *et al.* (1985)
K	von Bertalanffy eqn	F	0.1128	"
		M	0.1578	"
t_o	Age at length = 0, von Bertalanffy eqn	F	-2.552	"
		M	-2.452	"
M	Instantaneous natural mortality rate	B	0.092	1% population at 50 yrs
F	Instantaneous fishing mortality rate	B	0.04	Change-in-ratio estimator
L_{crit}	Minimum size length in fishery	B	84 cm	Commercial landings
a	Maturation parameter, intercept	F	-46.9	Silva (1993)
		M	-59.8	"
b	Maturation parameter, slope	F	0.582	"
		M	0.999	"
$t_{gestation}$	Gestation time (yr)	F	2	Templeman (1944)
λ	Estimated finite rate of popn increase	B	1.044	Survey data
litter $size_{Lj}$	Number of large embryos per female of length class j	F	80-85cm 3.86	Silva (1993)
			86-90cm 5.03	
			91-95cm 6.07	
			96-100cm 7.00	
			101-105cm 8.33	
			106+ cm 9.50	
	Sex ratio at birth	B	50:50	Templeman (1944)
a,b	Length-weight regression $W = aL^b$	F	$W = e^{15.025}L^{3.606935}$	Reparameterization of Nammack *et al.* (1985)
		M	$W = e^{-13.002}L^{3.097787}$	"

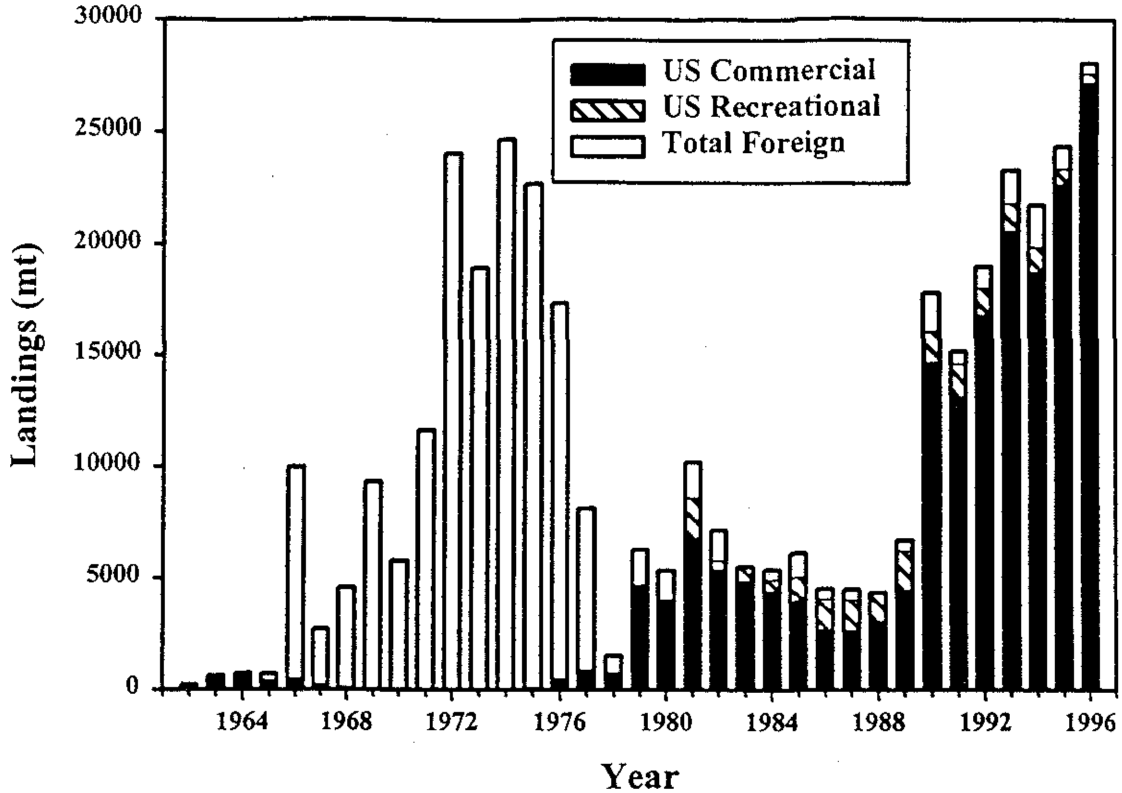


Figure D1. Landings (mt) of spiny dogfish from NAFO Subareas 2-6, 1962-1996.

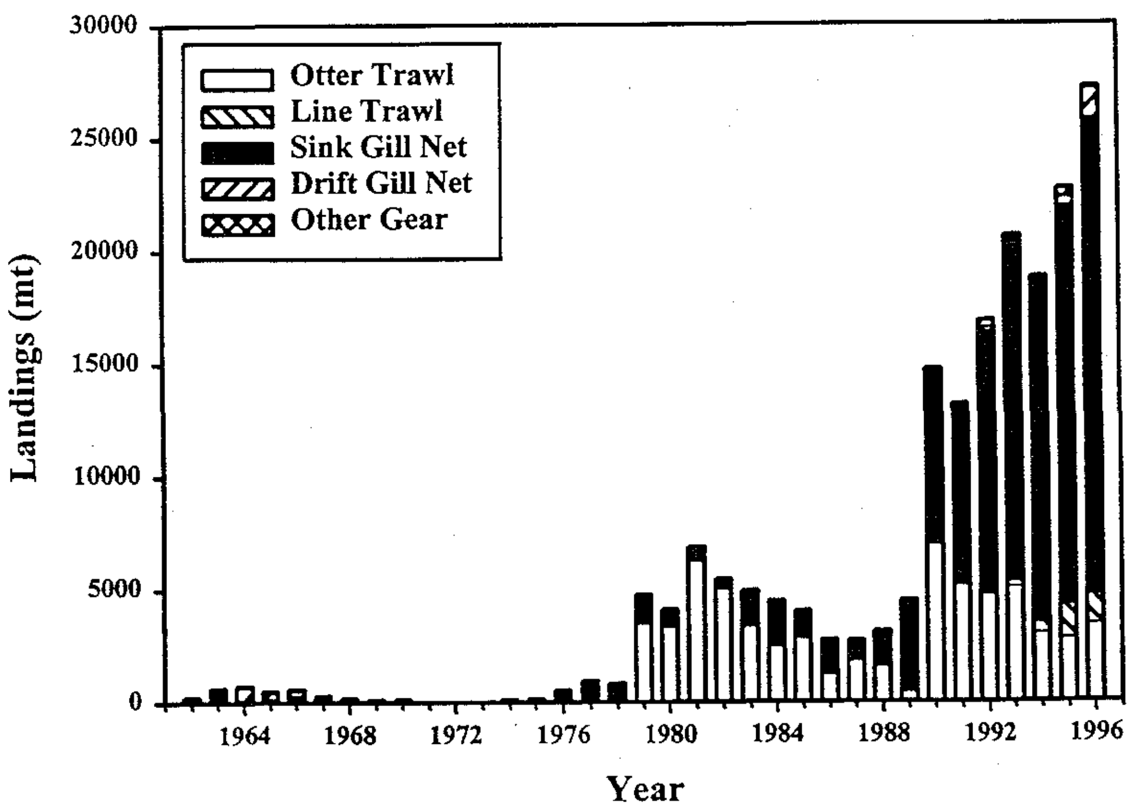


Figure D2. US landings (mt) of spiny dogfish from NAFO Subareas 2-6 by gear type, 1962-1996.

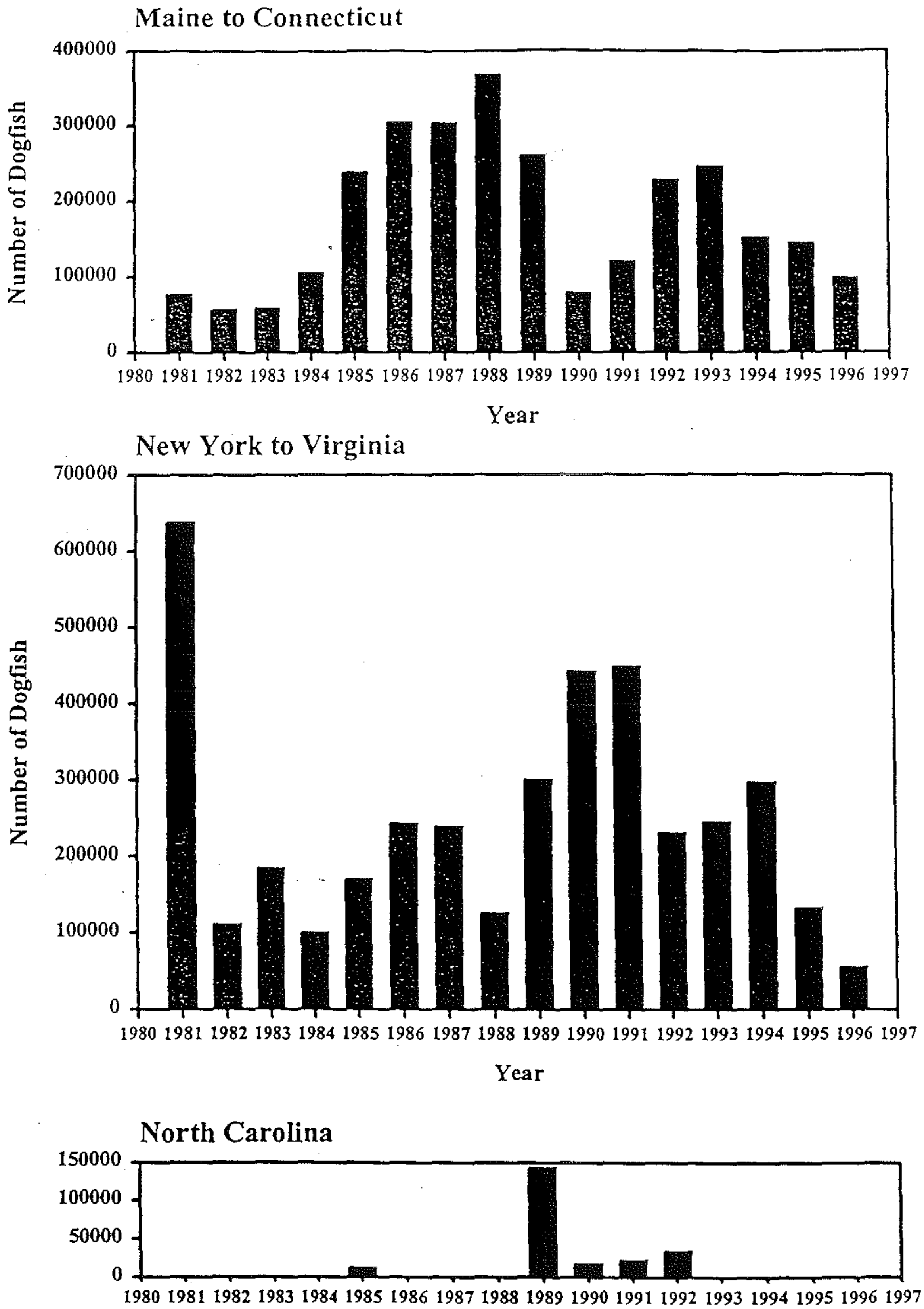


Figure D3. Estimated total recreational catch of spiny dogfish (numbers of fish) by geographical area, 1981-1996.

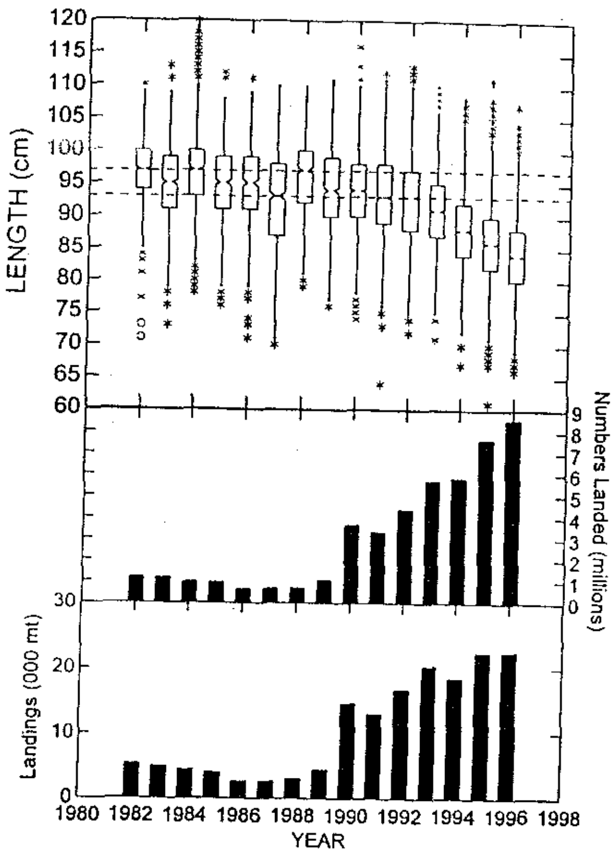


Figure D4. Box plots of length (cm) frequency distribution of female dogfish landings (top panel), total numbers landed (middle panel), and landings by weight (bottom panel), 1982-1996. For the box plots, asterisks denote outliers, the "whiskers" represent upper and lower non-parametric confidence regions, the upper and lower boundaries of the box represent the interquartile range, and the center line represents the median length. Notches on either side of the centerline represent approximate 95% confidence intervals on the median. The dashed lines in the upper panel represent the 99% parametric confidence interval on average female length for the period 1982-1989.

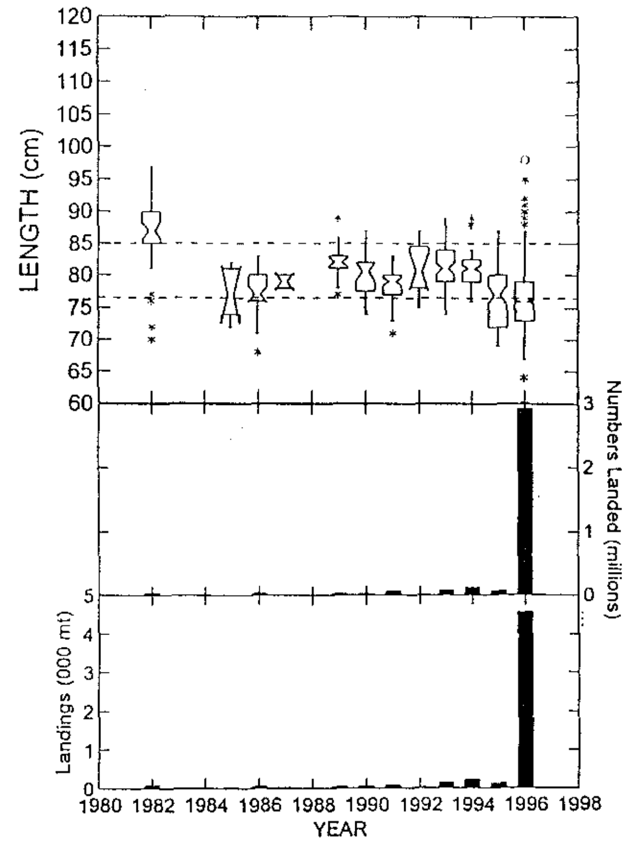


Figure D5. Box plots of length (cm) frequency distribution of male dogfish landings (top panel), total numbers landed (middle panel), and landings by weight (bottom panel), 1982-1996. For the box plots, asterisks denote outliers, the "whiskers" represent upper and lower non-parametric confidence regions, the upper and lower boundaries of the box represent the interquartile range, and the center line represents the median length. Notches on either side of the centerline represent approximate 95% confidence intervals on the median. The dashed lines in the upper panel represent the 99% parametric confidence interval on average male length for the period 1982-1989.

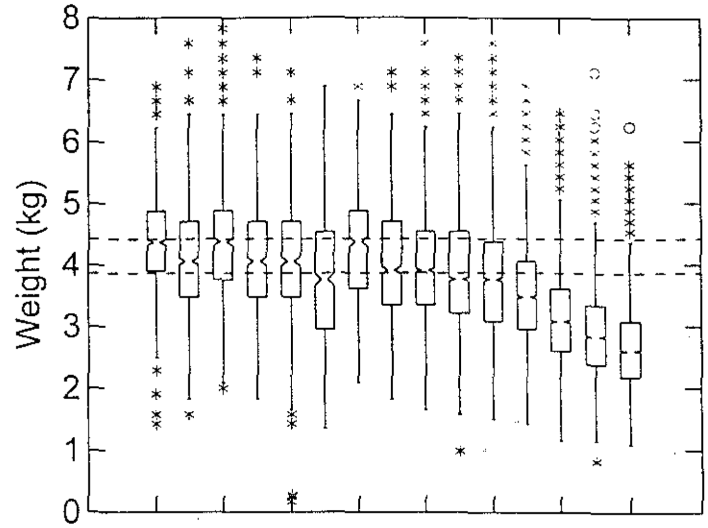


Figure D6. Box plots of average weight (kg) distribution of female dogfish landings, 1982-1996. For the box plots, asterisks denote outliers, the "whiskers" represent upper and lower non-parametric confidence regions, the upper and lower boundaries of the box represent the interquartile range, and the center line represents the median length. Notches on either side of the centerline represent approximate 95% confidence intervals on the median. The dashed lines in the upper panel represent the 99% parametric confidence interval on average female weight for the period 1982-1989.

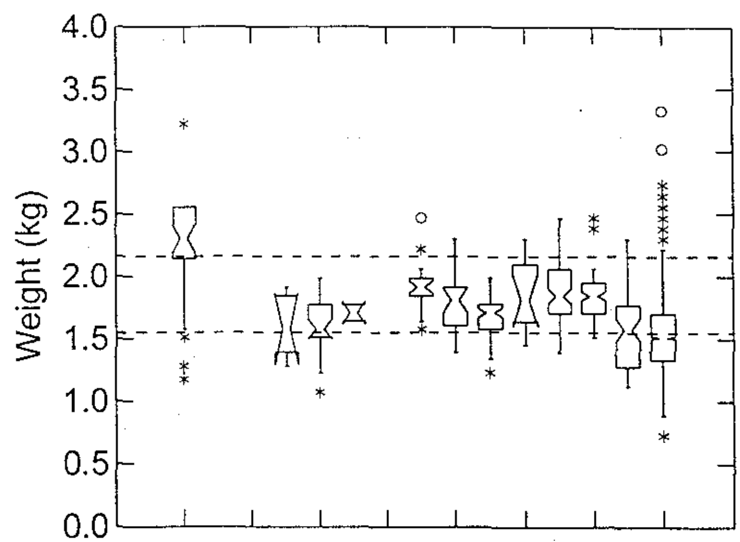


Figure D7. Box plots of average weight (kg) distribution of female dogfish landings, 1982-1996. For the box plots, asterisks denote outliers, the "whiskers" represent upper and lower non-parametric confidence regions, the upper and lower boundaries of the box represent the interquartile range, and the center line represents the median length. Notches on either side of the centerline represent approximate 95% confidence intervals on the median. The dashed lines in the upper panel represent the 99% parametric confidence interval on average male weight for the period 1982-1989.

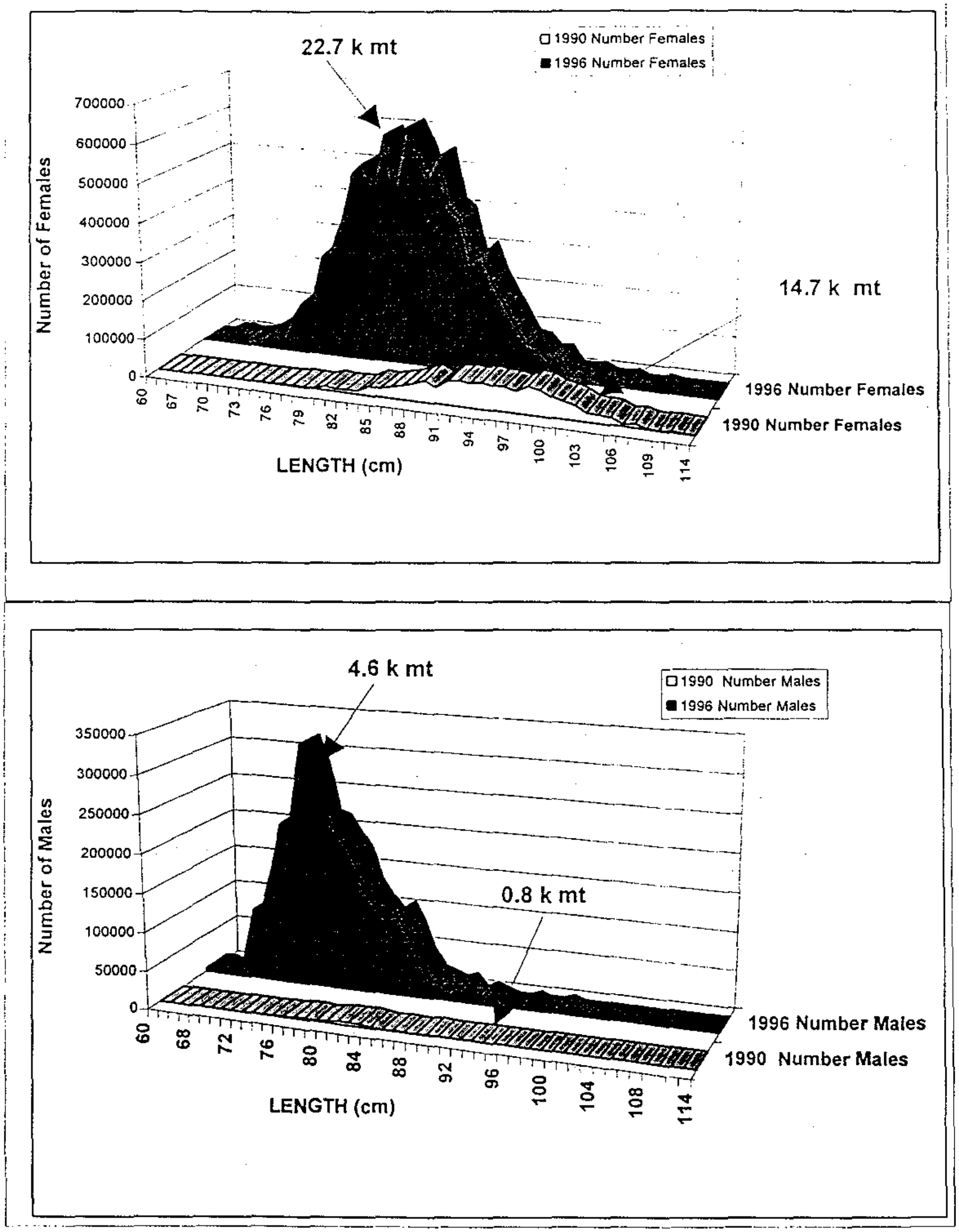


Figure D8. Comparison of length frequency distributions of landings in 1990, when the fishery first exceeded 6,000 mt, and in 1996, after seven years of landings ranging from 12,000 to 27,200 mt.

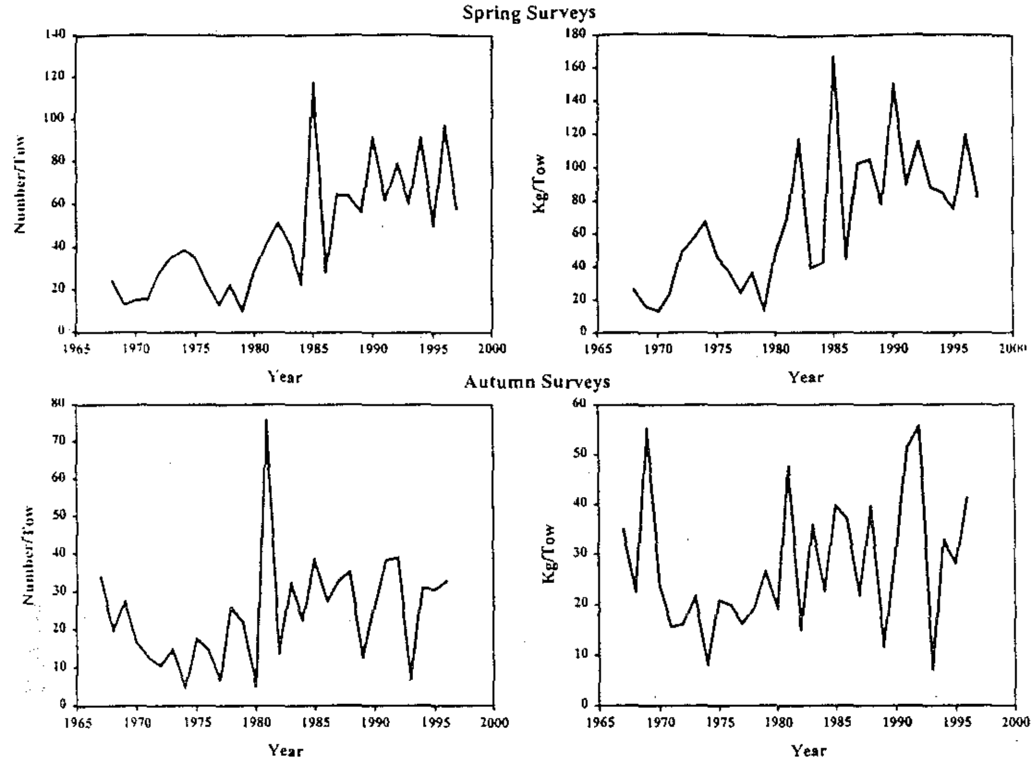


Figure D9. Abundance (mean catch per tow in number) and biomass (mean catch per tow in kilograms) indices of spiny dogfish from the NEFSC spring survey, 1968-1997, and autumn survey, 1967-1996 (offshore strata 1-30, 33-40, 61-76).

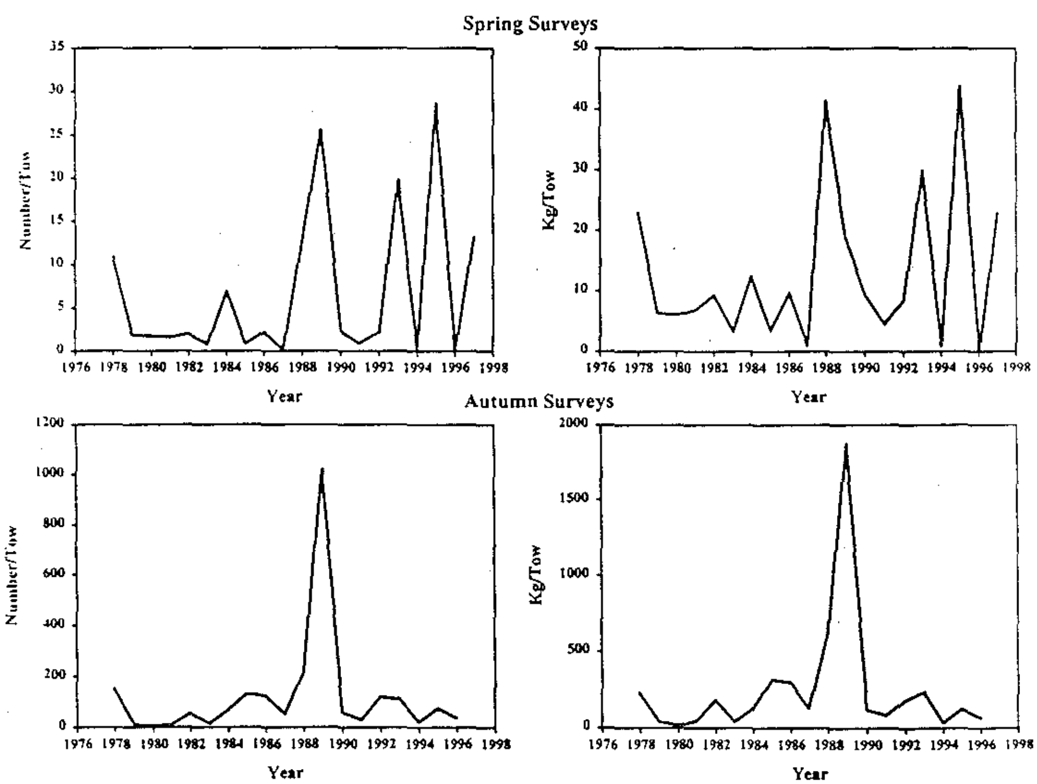


Figure D10. Abundance (mean catch per tow in number) and biomass (mean catch per tow in kilograms) indices of spiny dogfish from the Massachusetts spring survey, 1978-1997, and autumn survey, 1978-1996.

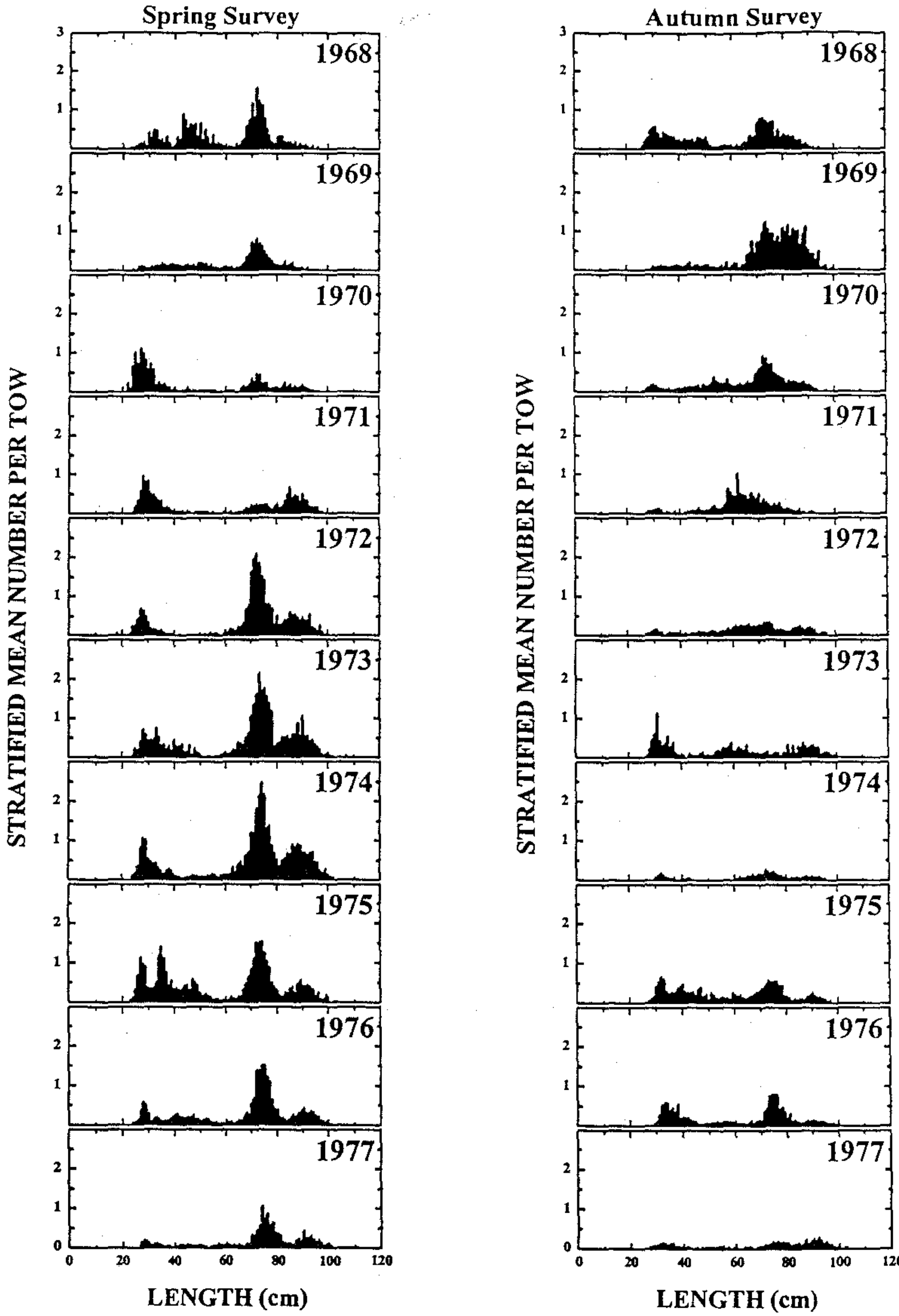


Figure D11. Length composition of spiny dogfish from the NEFSC spring and autumn bottom trawl surveys, 1968-1977 (offshore strata 1-30, 33-40, 61-76).

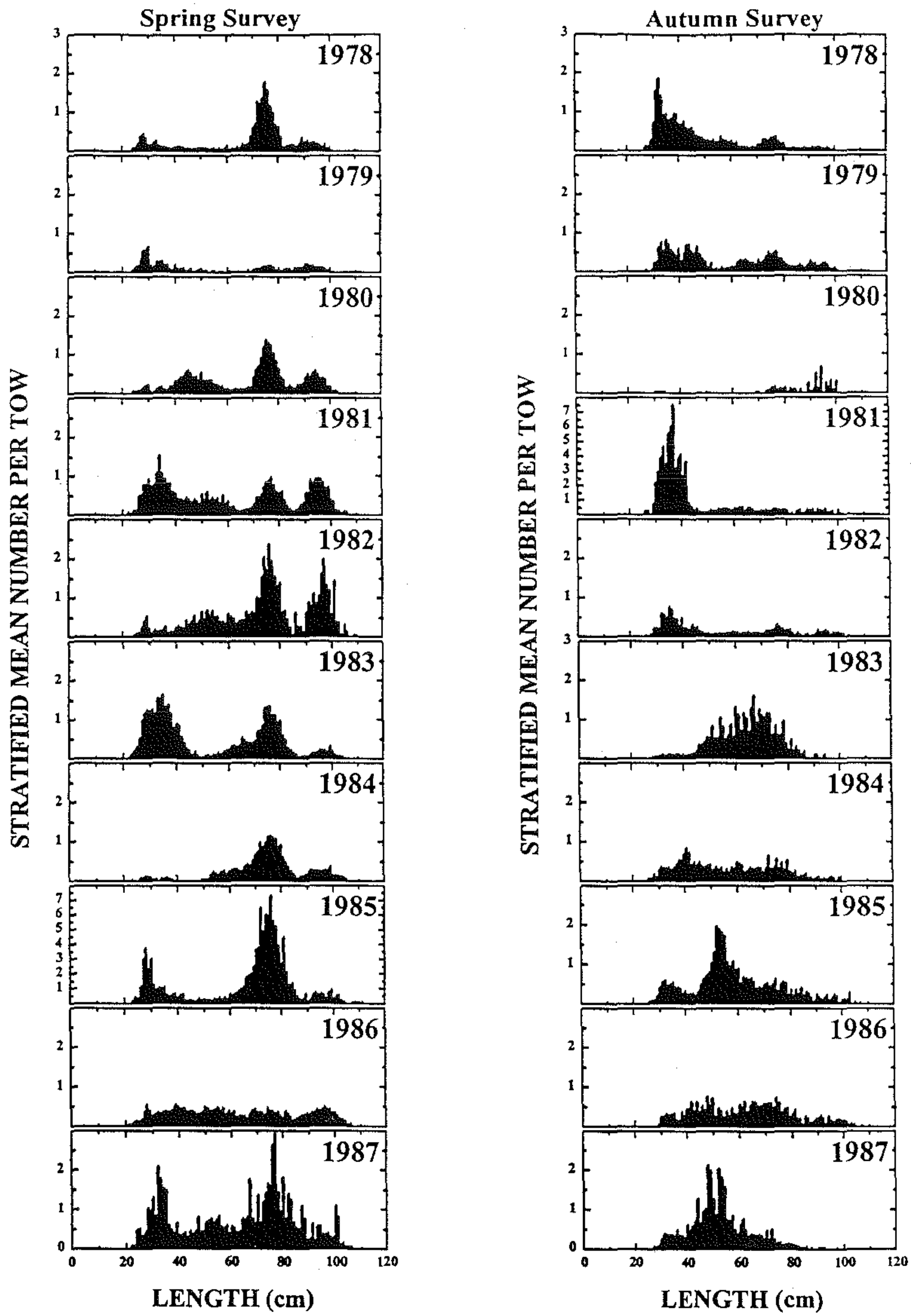


Figure D12. Length composition of spiny dogfish from the NEFSC spring and autumn bottom trawl surveys, 1978-1987 (offshore strata 1-30, 33-40, 61-76). Note the scales for spring 1985 and autumn 1981 are higher.

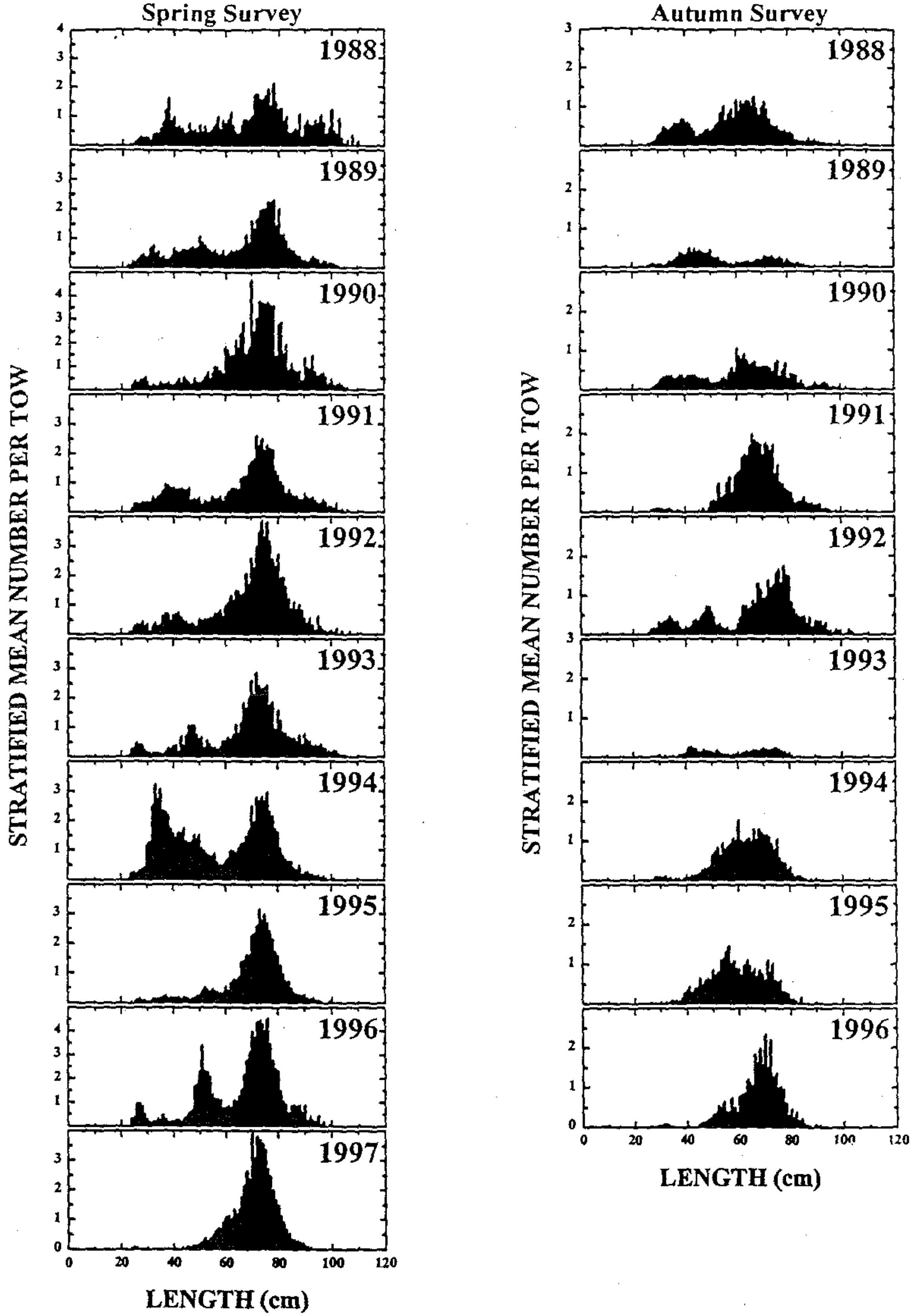


Figure D13. Length composition of spiny dogfish from the NEFSC spring and autumn bottom trawl surveys, 1988-1997 (offshore strata 1-30, 33-40, 61-76). Note the scales for spring and autumn differ and spring 1990 and 1996 are also different.

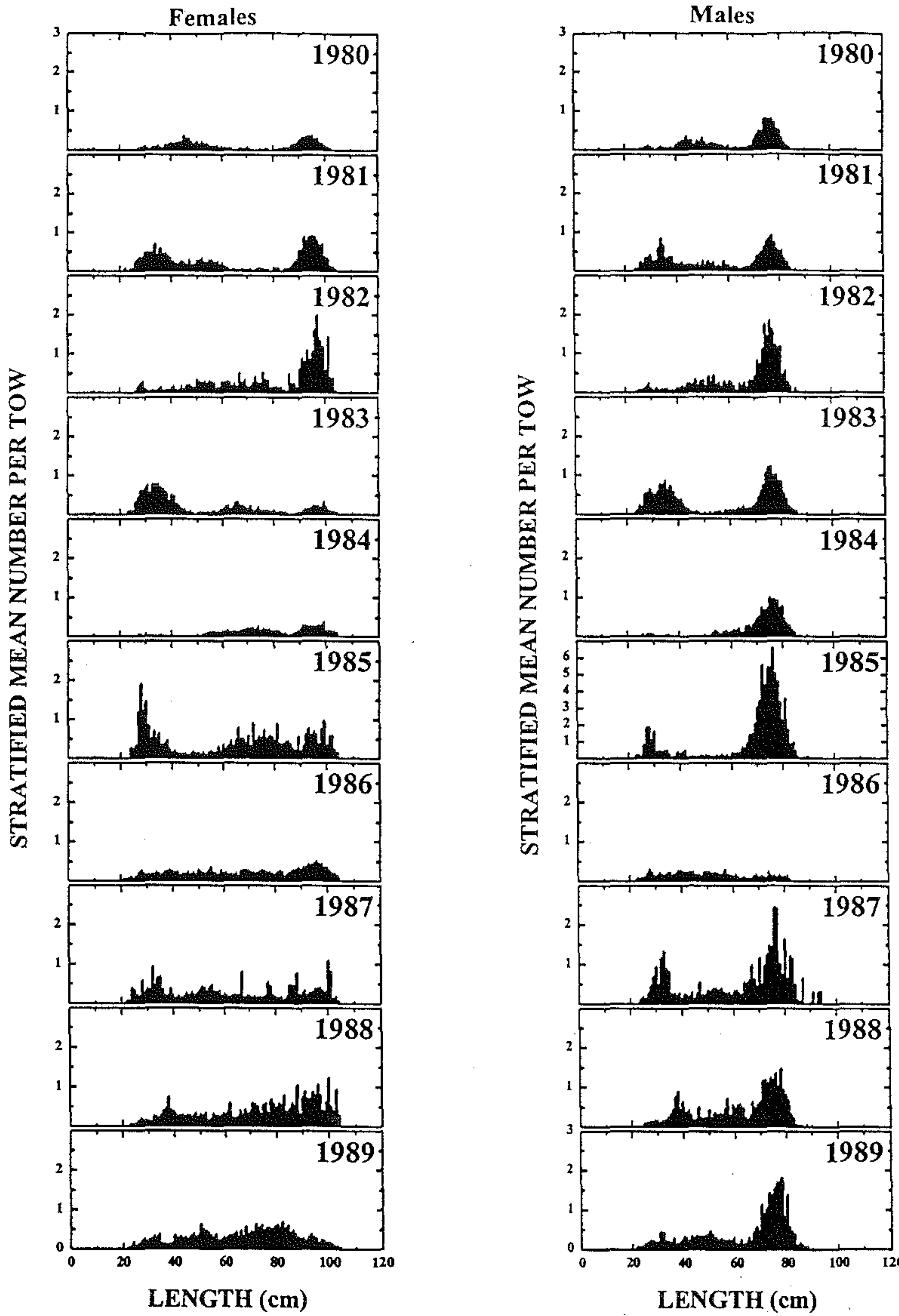


Figure D14. Length composition of male and female spiny dogfish from the NEFSC spring bottom trawl surveys, 1980-1989 (offshore strata 1-30, 33-40, 61-76). Note the scale for males in 1985 is larger.

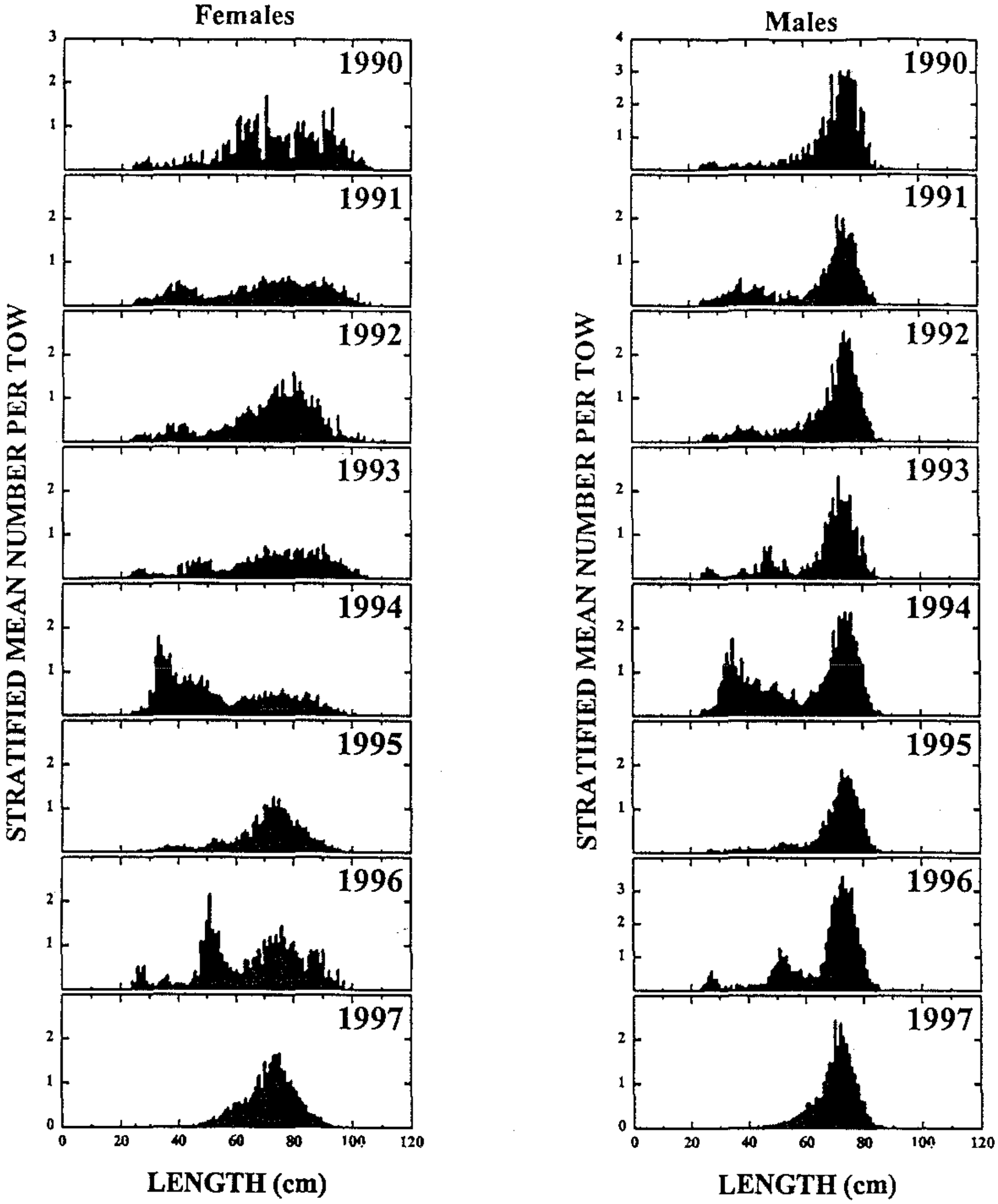


Figure D15. Length composition of male and female spiny dogfish from the NEFSC spring bottom trawl surveys, 1990-1997 (offshore strata 1-30, 33-40, 61-76). Note the scales for males in 1990 and 1996 are different.

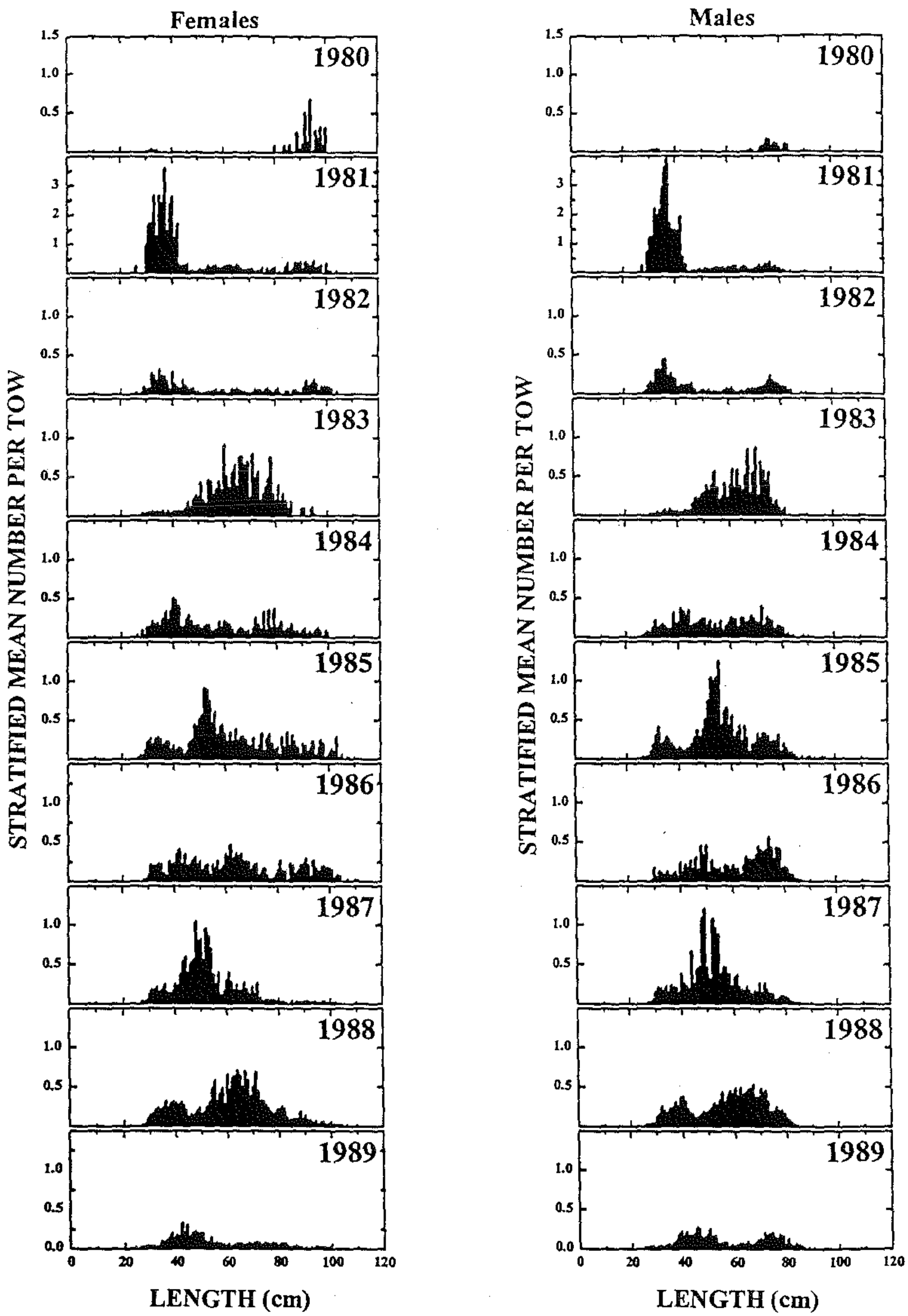


Figure D16. Length composition of male and female spiny dogfish from the NEFSC autumn bottom trawl surveys, 1980-1989 (offshore strata 1-30, 33-40, 61-76). Note the scale for males in 1981 is larger.

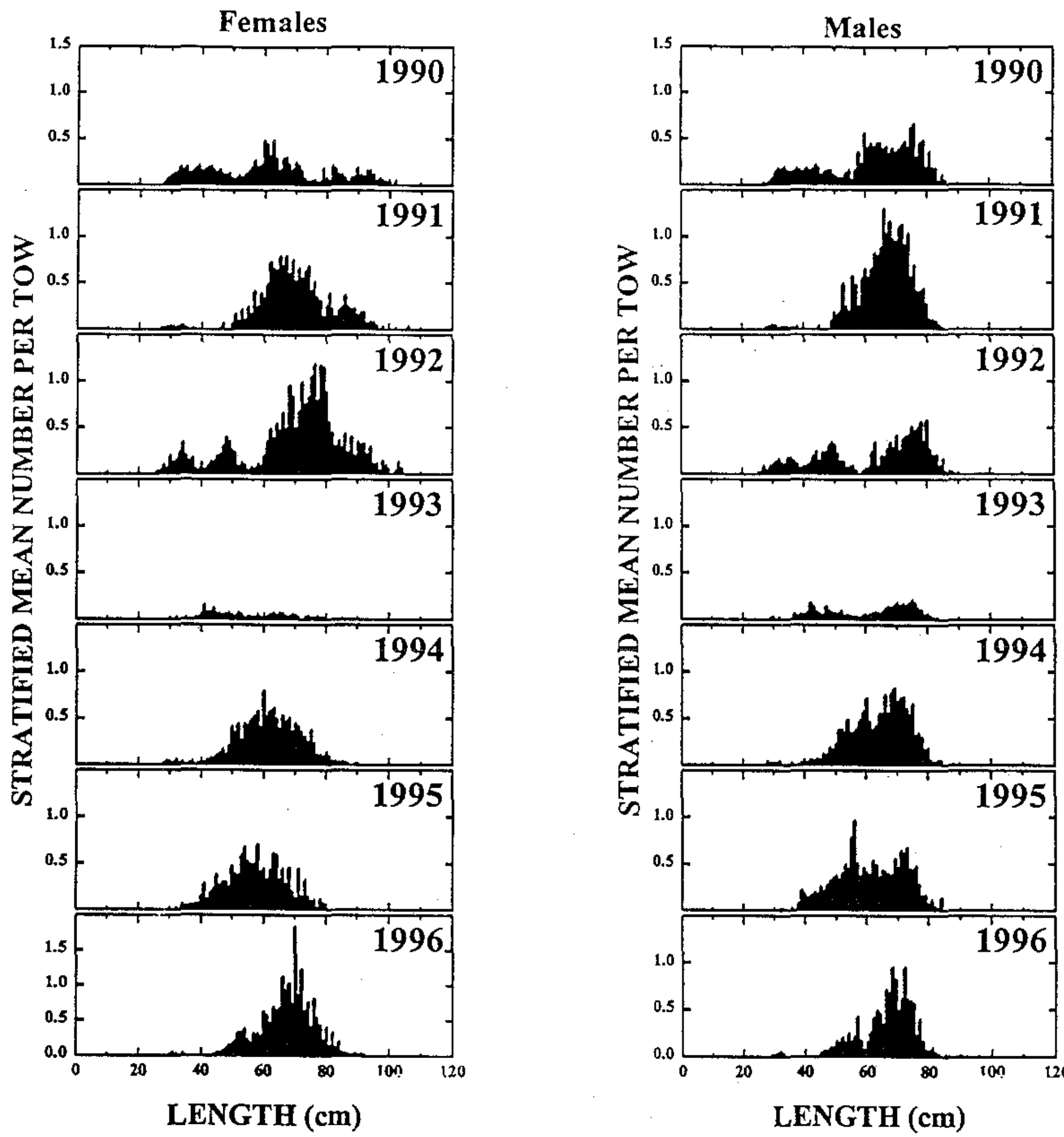


Figure D17. Length composition of male and female spiny dogfish from the NEFSC autumn bottom trawl surveys, 1990-1996 (offshore strata 1-30, 33-40, 61-76). Note the scale for females in 1996 is different.

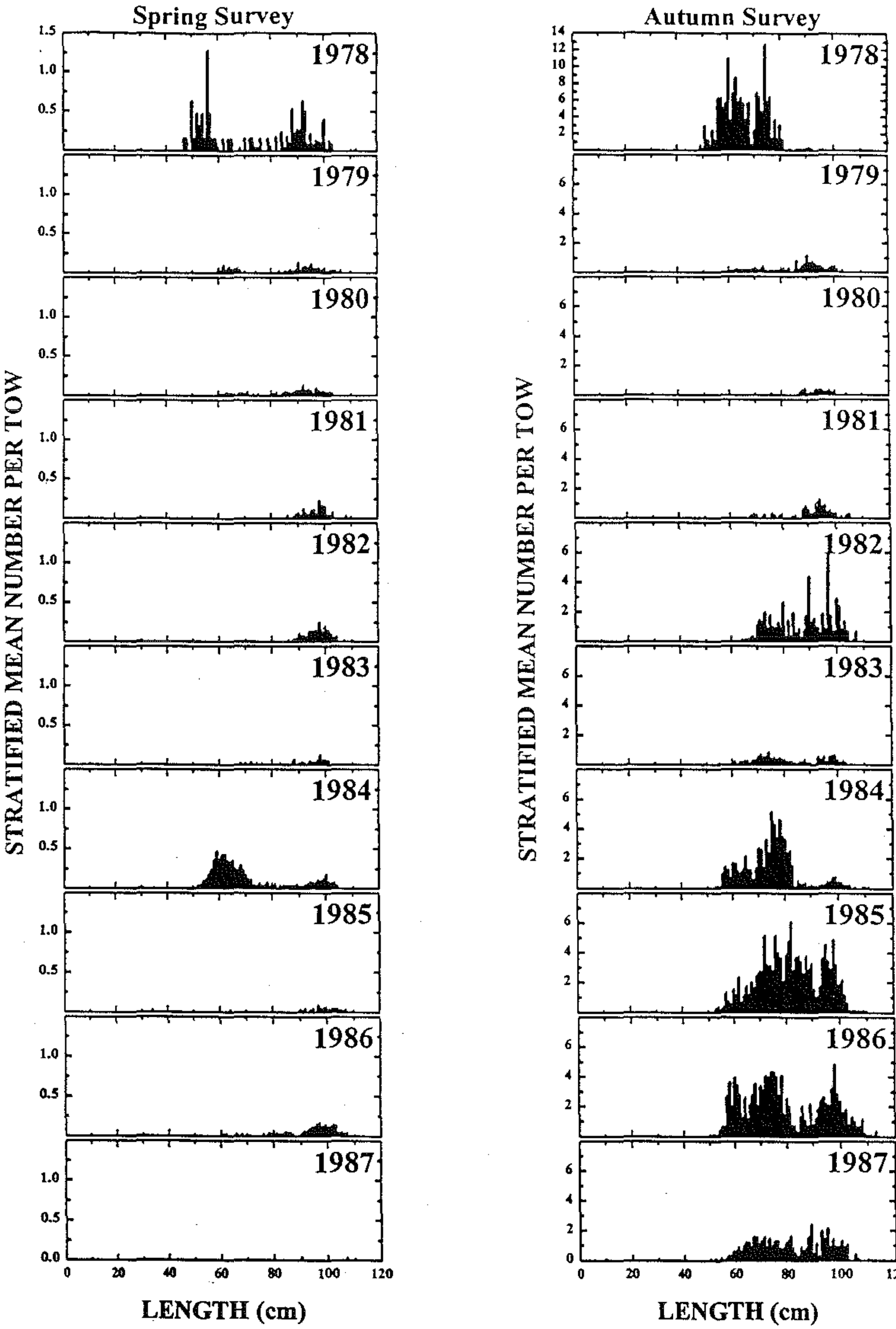


Figure D18. Length composition of spiny dogfish from the Massachusetts spring and autumn bottom trawl surveys, 1978-1987. Note the scales for spring and autumn differ, and autumn 1978 is higher.

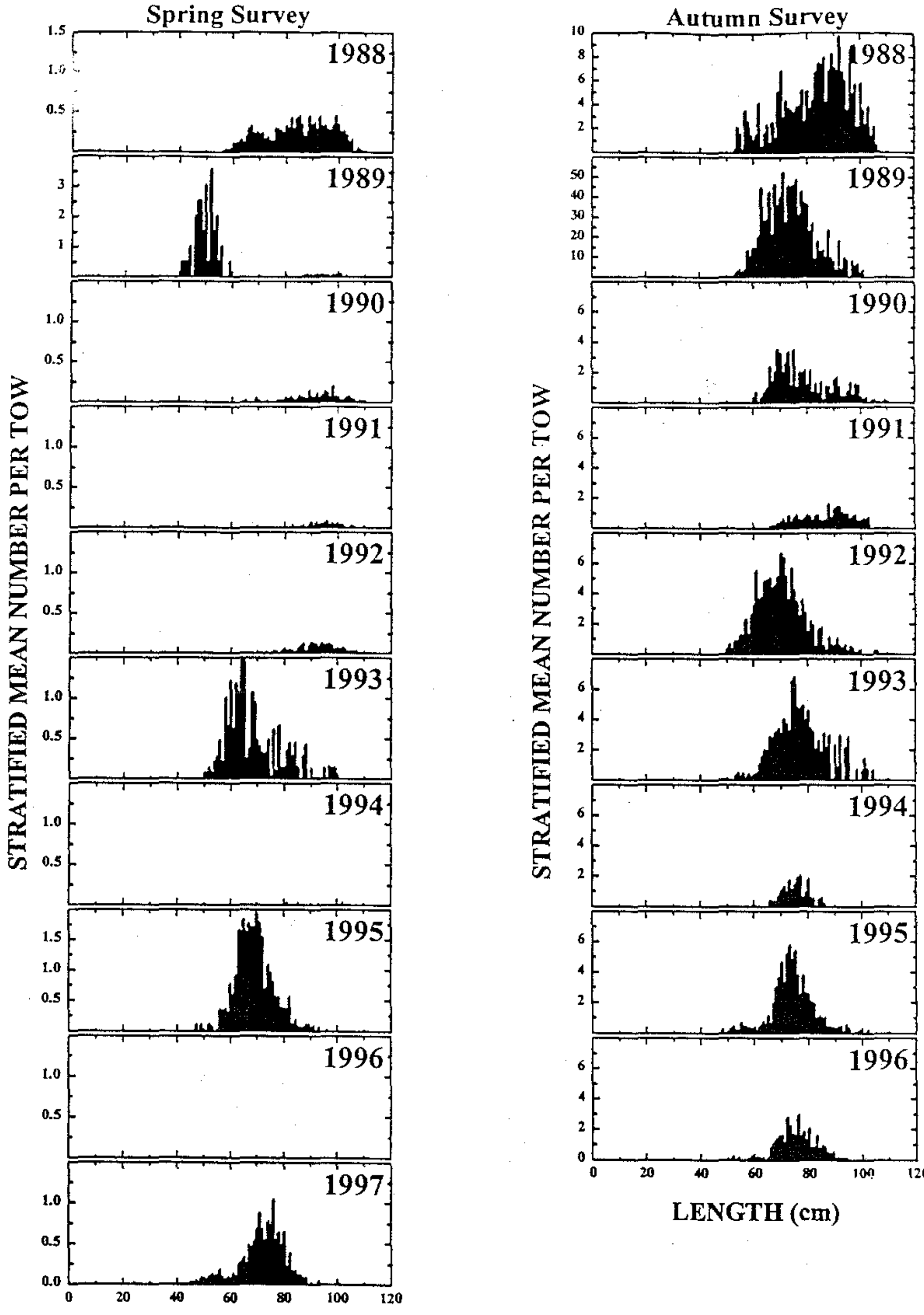


Figure D19. Length composition of spiny dogfish from the Massachusetts spring and autumn bottom trawl surveys, 1988-1997. Note the scales for spring and autumn differ, and spring (1989 and 1995) and autumn (1988 and 1989) are also different.

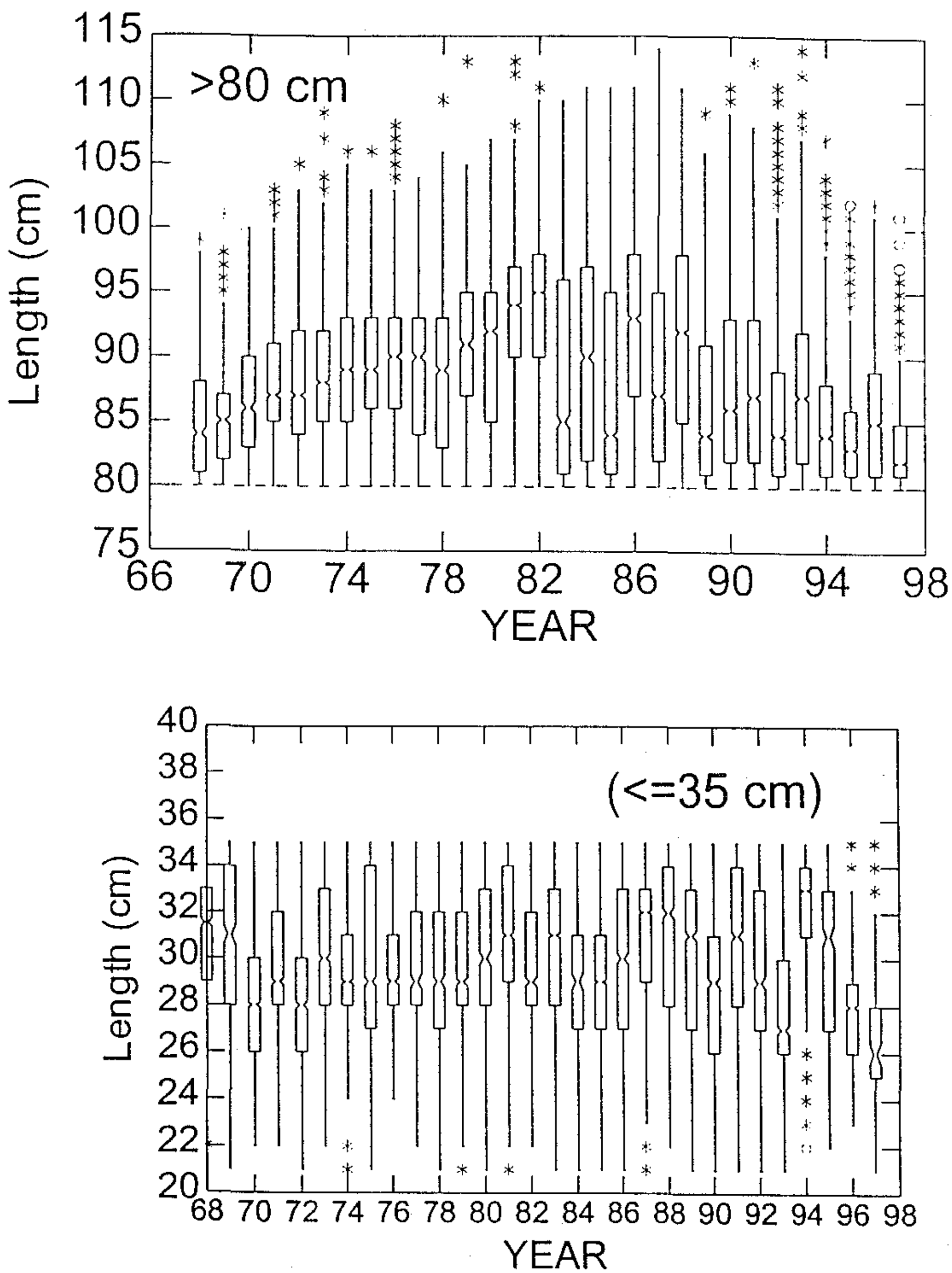


Figure D20. Box plots of the length frequency distribution of male and female spiny dogfish for two size categories: ≥80 cm and <36 cm. In the box plots, asterisks denote outliers, the "whiskers" represent upper and lower non-parametric confidence regions, the upper and lower boundaries of the box represent the interquartile range, and the center line represents the median length. Notches on either side of the centerline represent approximate 95% confidence intervals on the median.

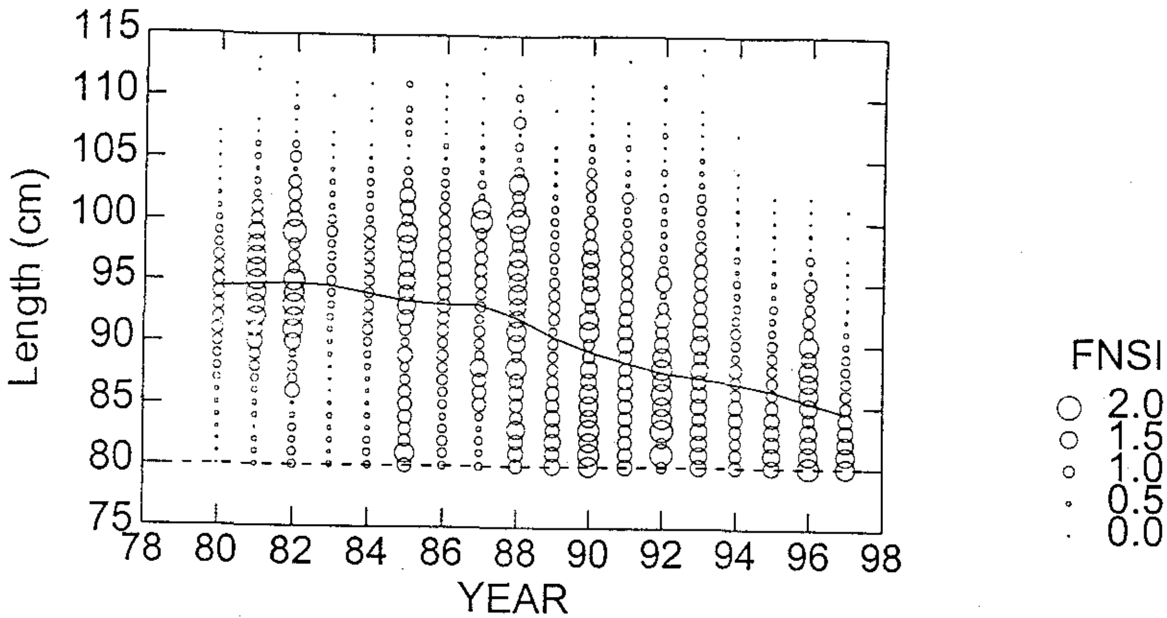


Figure D21. Length frequency distribution of female dogfish greater than L_{50} for maturity. Area of each dot size is proportional to the numbers observed in the NEFSC spring trawl survey. The trend line represents a LOWESS smoothing of the data with a tension factor of 0.5.

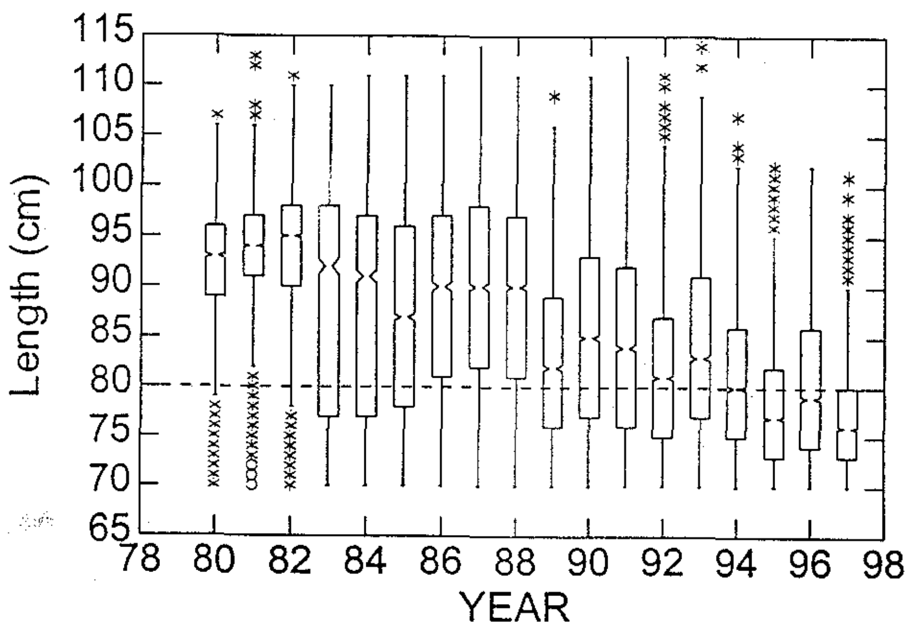


Figure D22. Box plots of the length frequency distribution of mature females (≥70 cm) from the NEFSC spring trawl survey, 1980-1997. In the box plots, asterisks denote outliers, the "whiskers" represent upper and lower non-parametric confidence regions, the upper and lower boundaries of the box represent the interquartile range, and the center line represents the median length. Notches on either side of the centerline represent approximate 95% confidence intervals on the median. The dashed line represents L_{50} for maturity, and 75 cm is the approximate lower limit on viable pup production.

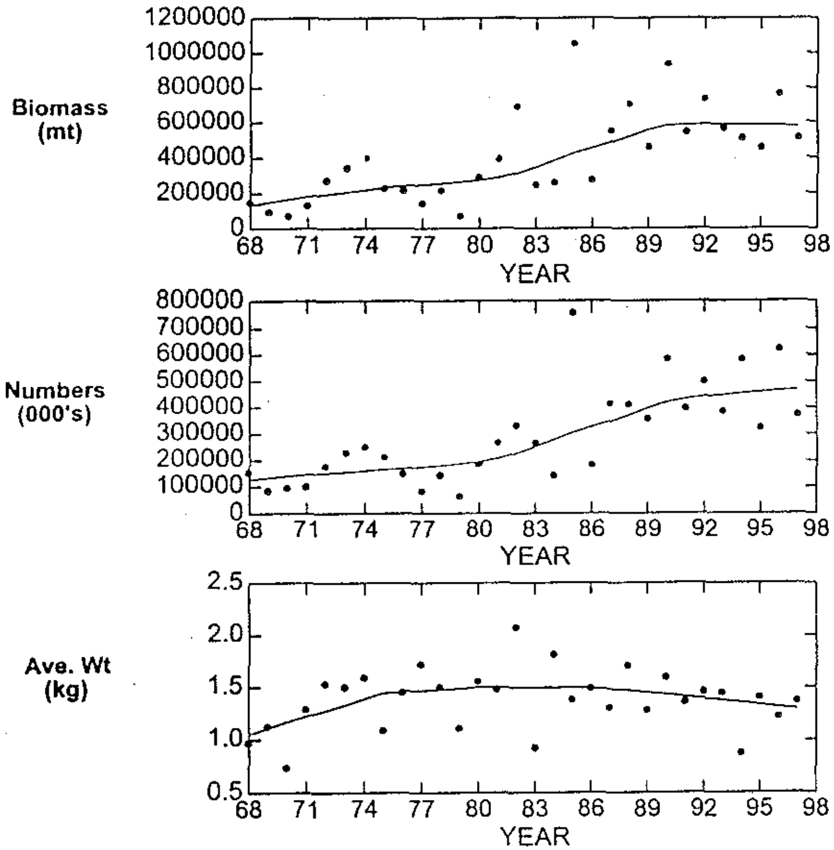


Figure D23. Estimated minimum swept-area biomass (mt), total numbers (thousands), and average weight for spiny dogfish from NEFSC spring trawl surveys, 1968-1997. Lines represent LOWESS smoothed series with tension factor = 0.5.

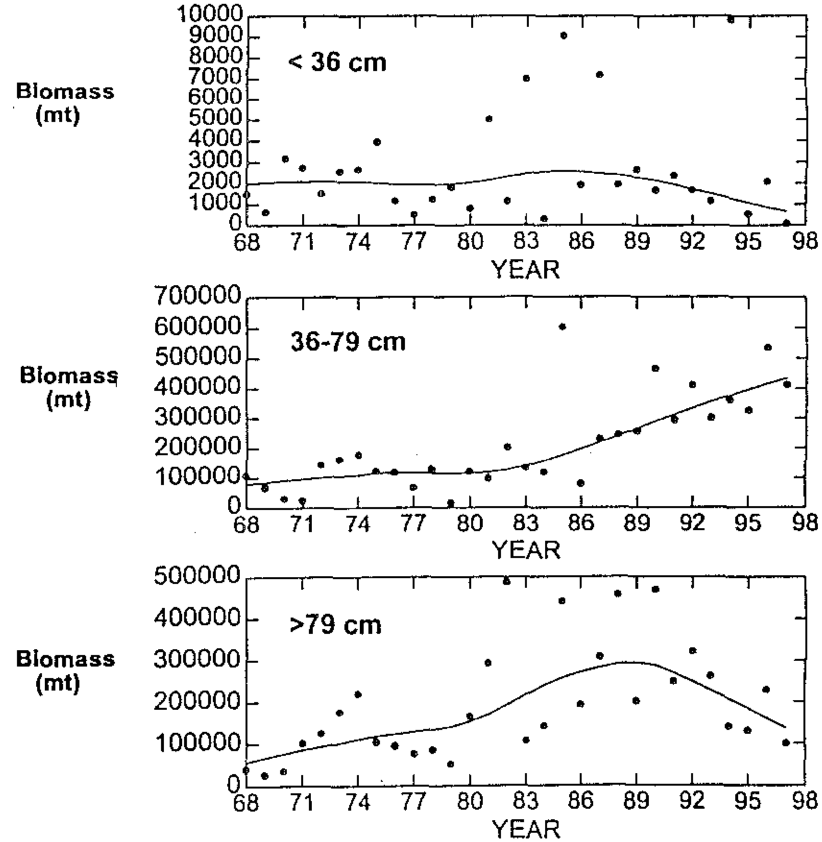


Figure D24. Estimated minimum swept-area biomass (mt) by size group for spiny dogfish from NEFSC spring trawl surveys, 1968-1997. Lines represent LOWESS smoothed series with tension factor = 0.5.

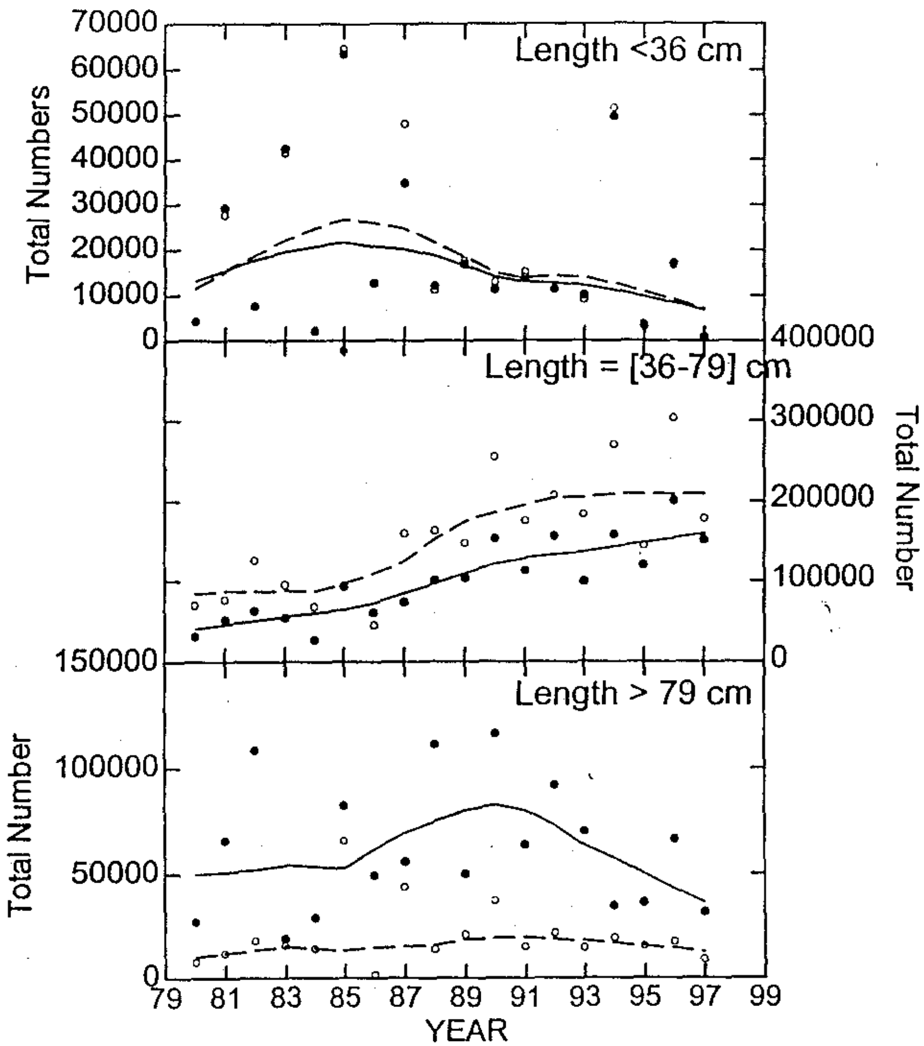


Figure D25. Estimated total number (000s) of male (open dots, dashed lines) and female (filled dots, solid lines) spiny dogfish by size class. Lines represent LOWESS smoothed series with tension factor = 0.5.

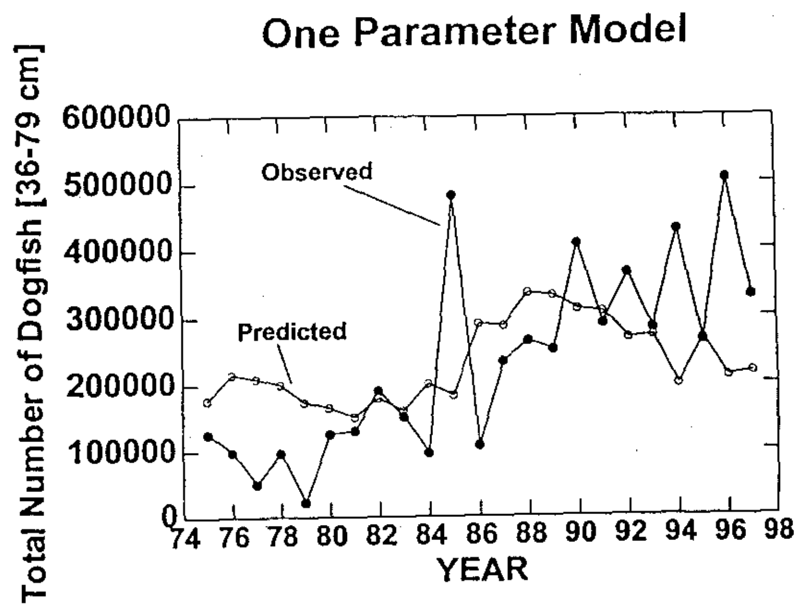


Figure D26. Comparison of observed total number (000s) of male and female spiny dogfish 36-79 cm in length with predicted number based on seven-term moving average of lagged recruits (i.e., <36 cm). One parameter model: $N_{[36\text{-}79]}(t) = s\,R(t\text{-}1) + s^2\,R(t\text{-}2) + s^3\,R(t\text{-}3) + s^4\,R(t\text{-}4) + s^5\,R(t\text{-}5) + s^6\,R(t\text{-}6) + s^7\,R(t\text{-}7)$. Smoothing parameter estimate of s = 0.9456, implying M = 0.0560. See text for details.

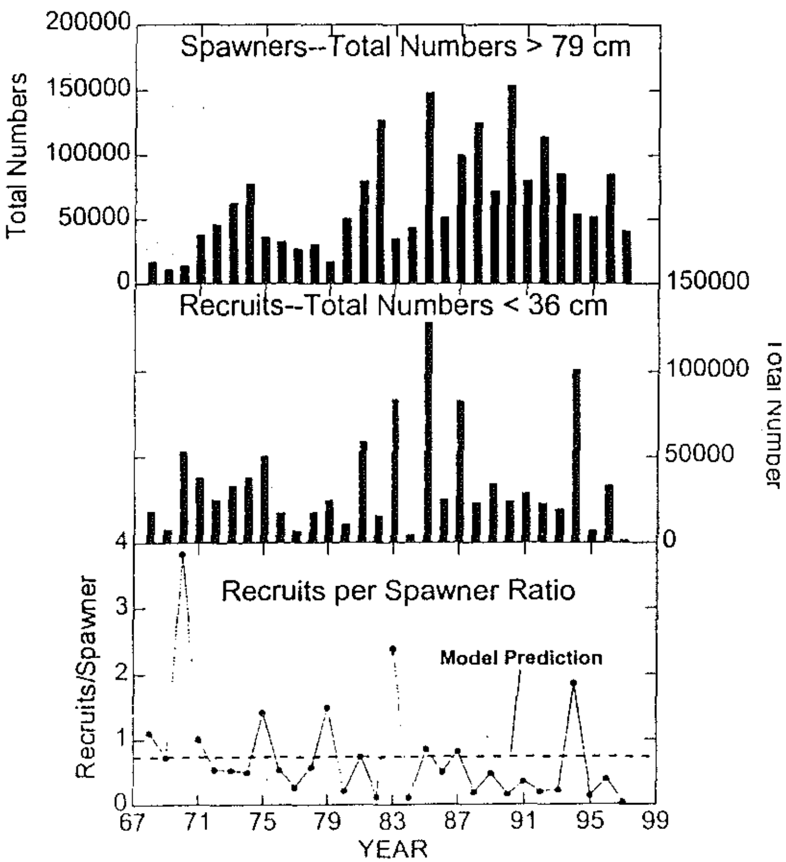


Figure D27. Total number of spawners (i.e., >79 cm), recruits (<36 cm), and spawner-recruit ratio from NEFSC spring surveys. Dashed line in the bottom panel represents the predicted ratio of recruits to spawners (= 0.73) from the life history model. Overall average for the 1968-1997 period was 0.748.

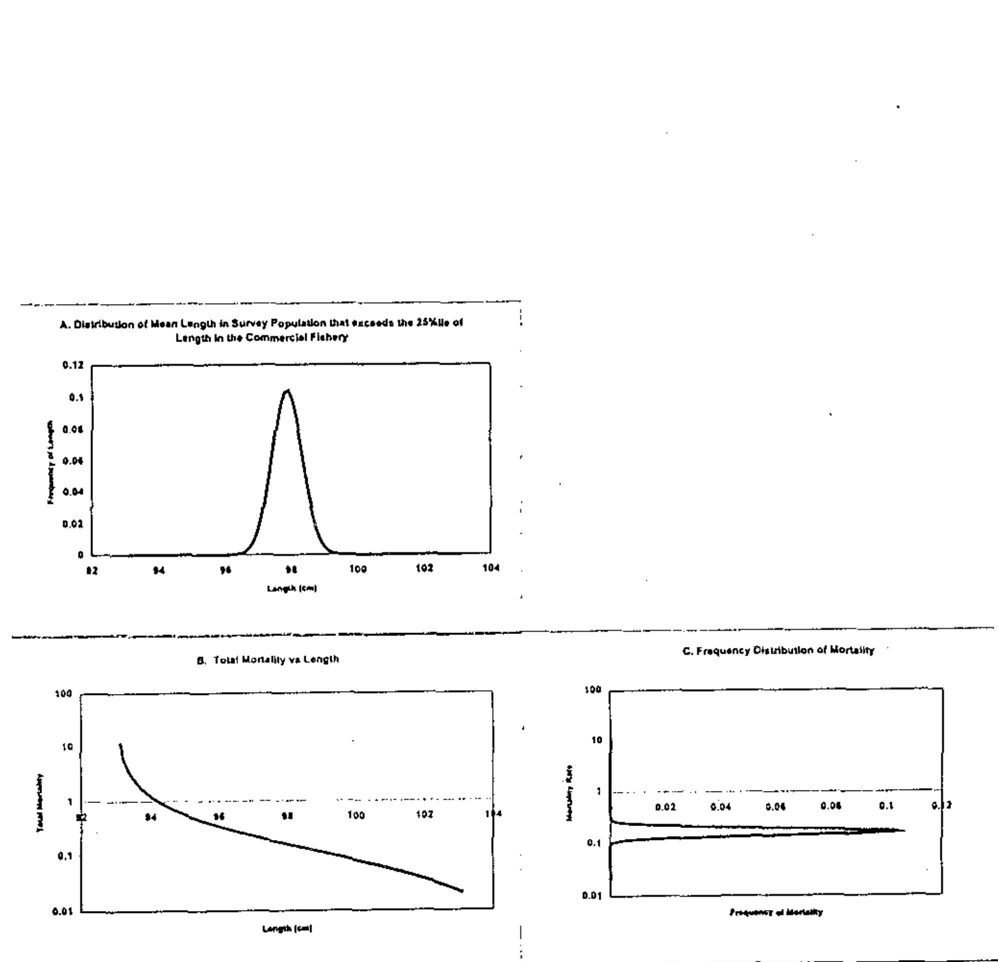


Figure D28. Schematic diagram for the computation of variance of total mortality estimate for the Beverton-Holt model. Panel A shows the distribution of mean length for the survey population exceeding the 25th percentile of length in the commercial fishery. The standard error of the mean is estimated as the standard deviation of the length divided by the square root of assumed effective sample size of 50. Panel B shows the estimate of F for each value of mean length. Panel C is the expected distribution of mortality rate estimates derived from the convolution of probabilities in Panel with the mortality estimates in Panel B.

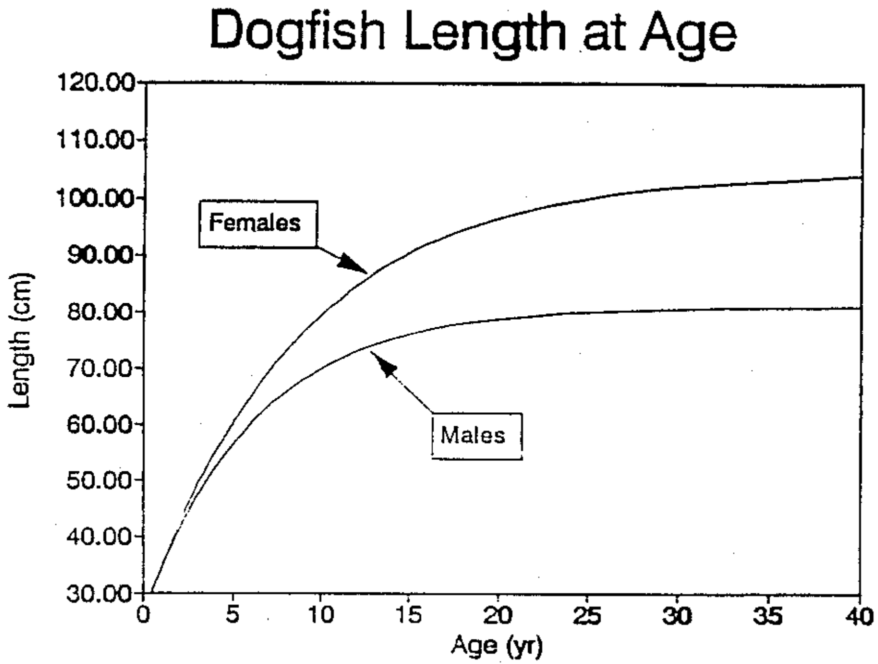


Figure D29. Von Bertalanffy growth equations for male and female spiny dogfish in the Northwest Atlantic.

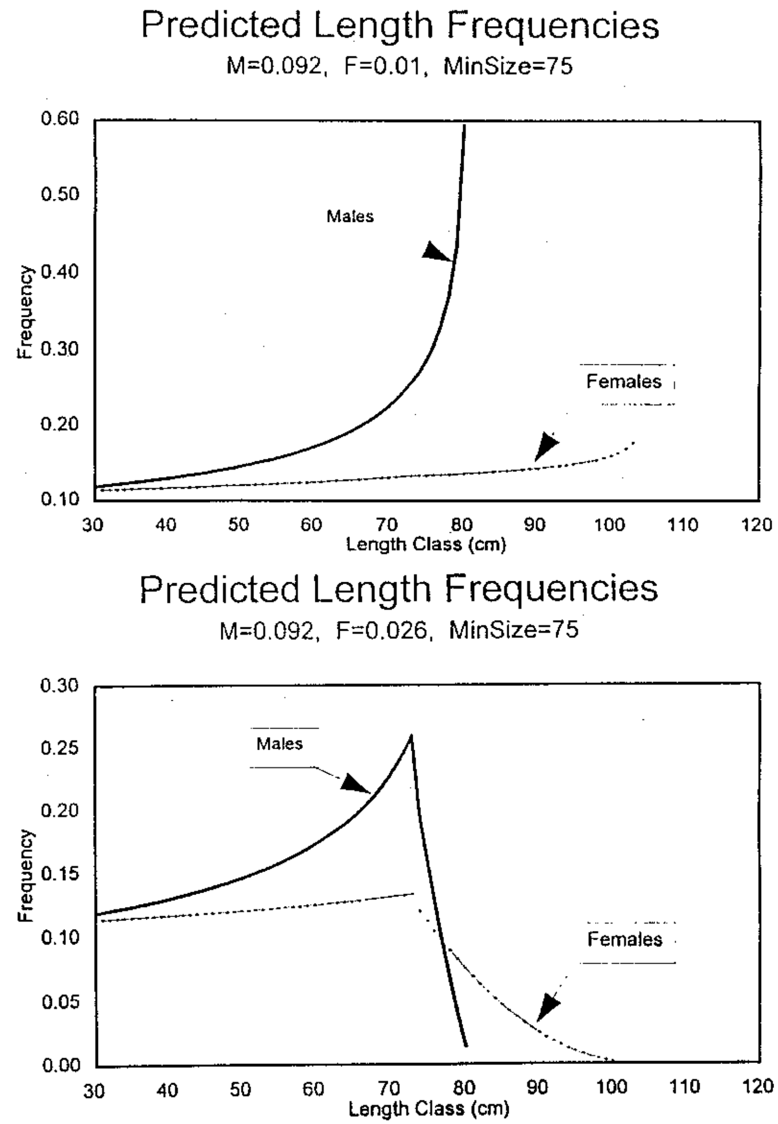


Figure D30. Predicted length frequency distributions of male and female spiny dogfish based on equilibrium model for two levels of fishing mortality. Top panel: M = 0.092, F = 0.01, and L_{crit} = 75 cm; bottom panel: M = 0.092, F = 0.26, and L_{crit} = 75 cm.

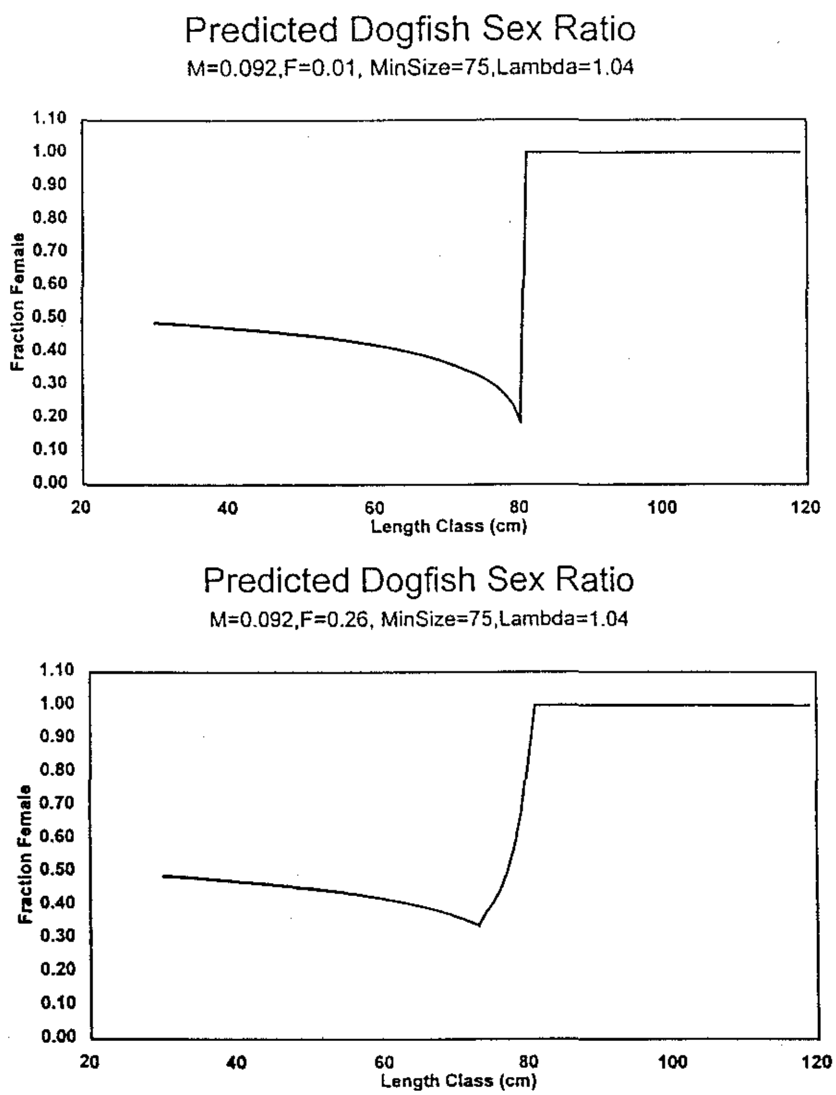


Figure D31. Predicted length-specific sex ratio (female to male) plus female spiny dogfish based on equilibrium model for two levels of fishing mortality. Top panel: M = 0.092, F = 0.01, and L_{crit} = 75 cm; bottom panel: M = 0.092, F = 0.26, and L_{crit} = 75 cm.

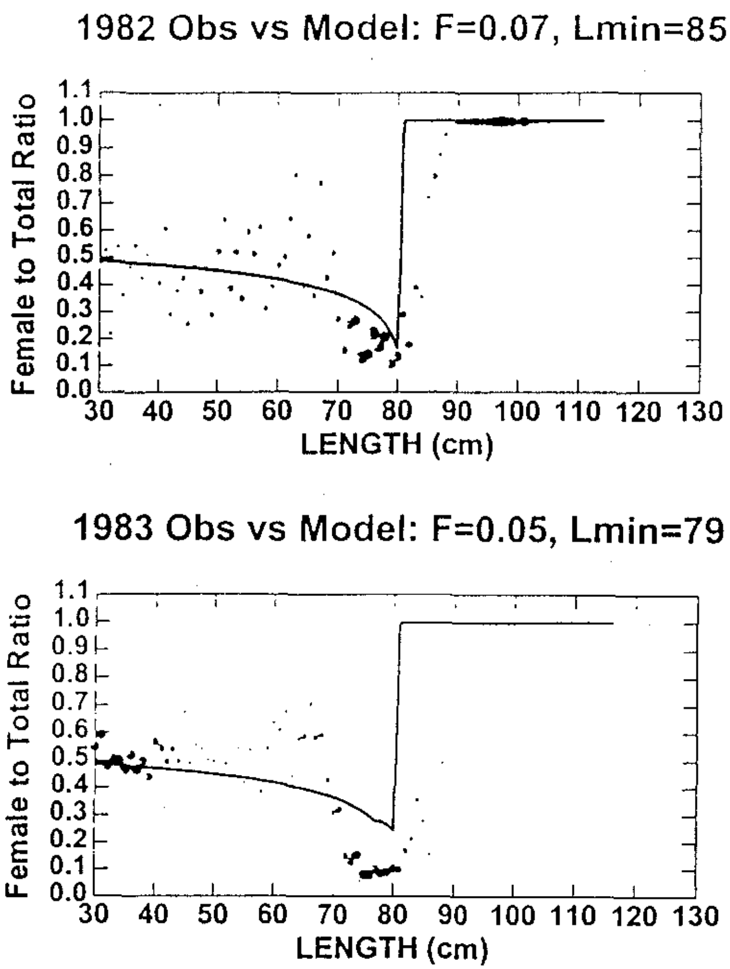


Figure D32. Comparison of observed female sex ratio (female to total) by 1-cm length interval from NEFSC spring trawl surveys, 1982-1983, with predicted sex ratio from life history model (lines). Dots representing sex ratio are scaled consistently across years, and diameters are proportional to the number of observations in the denominator. Predictions from the life history model are based on mortality rates estimated from the Beverton and Holt mean length model as specified in the caption for each subplot. No statistical fitting of the life history model was performed.

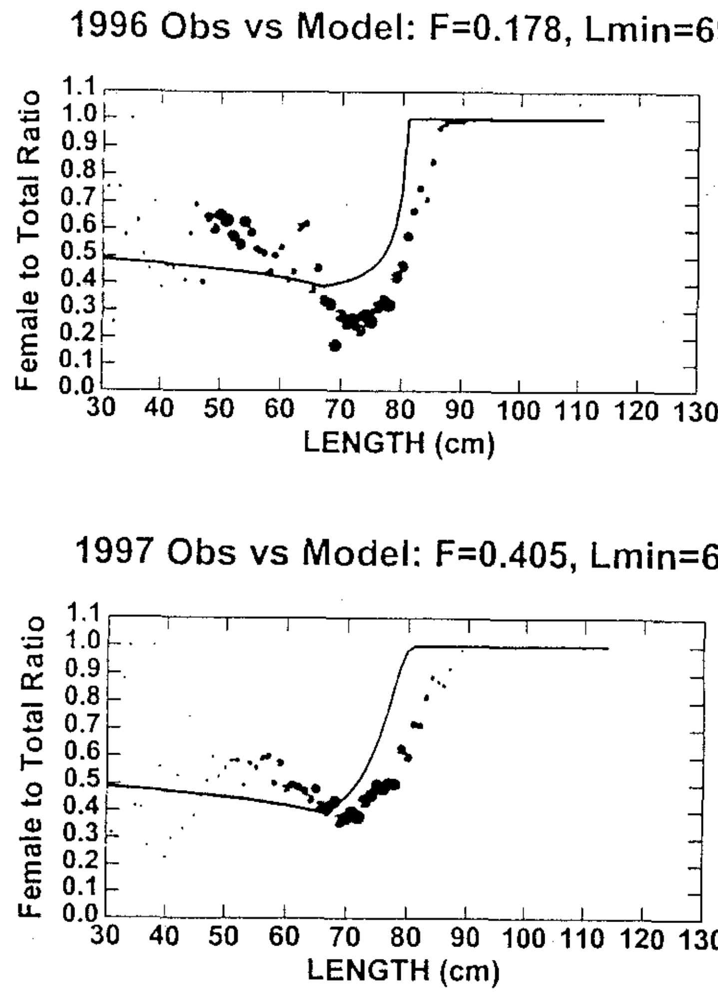
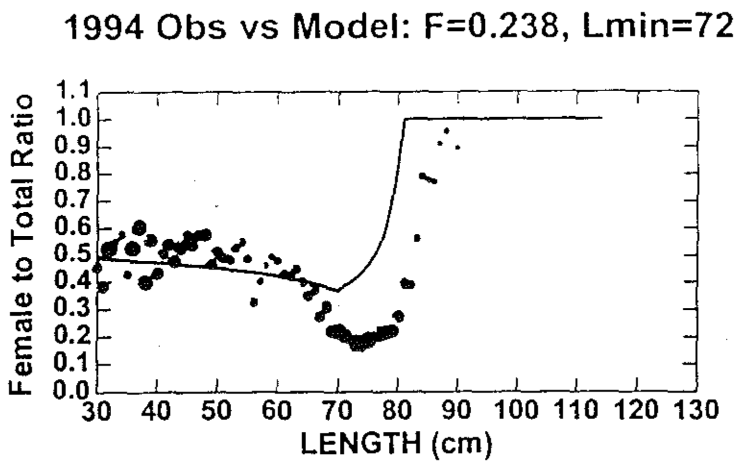


Figure D32. [continued] Comparison of observed female sex ratio (female to total) by 1-cm length interval from NEFSC spring trawl surveys, 1984-1985, with predicted sex ratio from life history model (lines).....



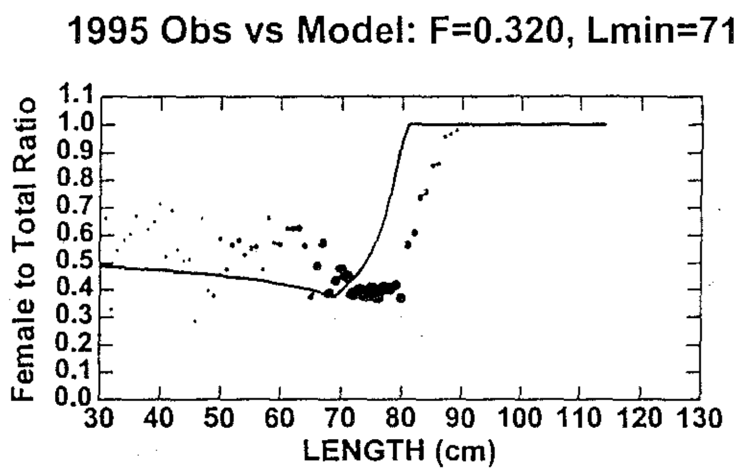
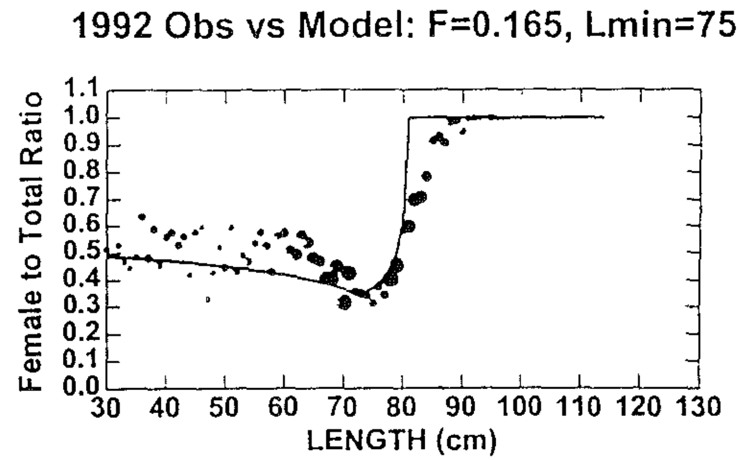


Figure D32. [continued] Comparison of observed female sex ratio (female to total) by 1-cm length interval for NEFSC spring trawl surveys, 1986-1987, with predicted sex ratio from life history model (lines).....



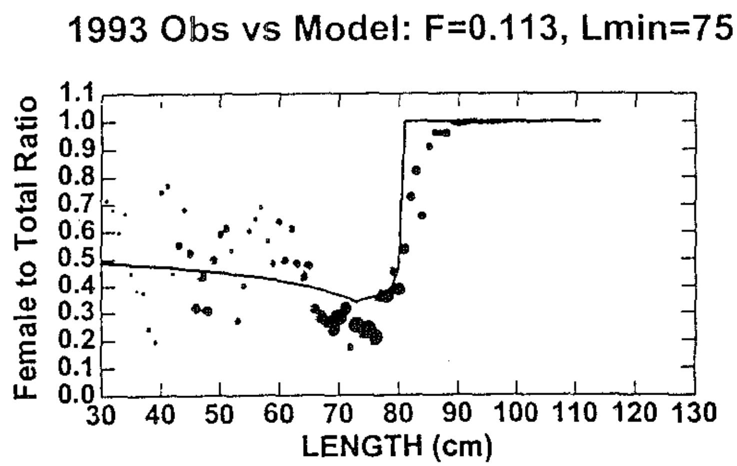


Figure D32. [continued] Comparison of observed female sex ratio (female to total) by 1-cm length interval for NEFSC spring trawl surveys, 1988-1989, with predicted sex ratio from life history model (lines).....

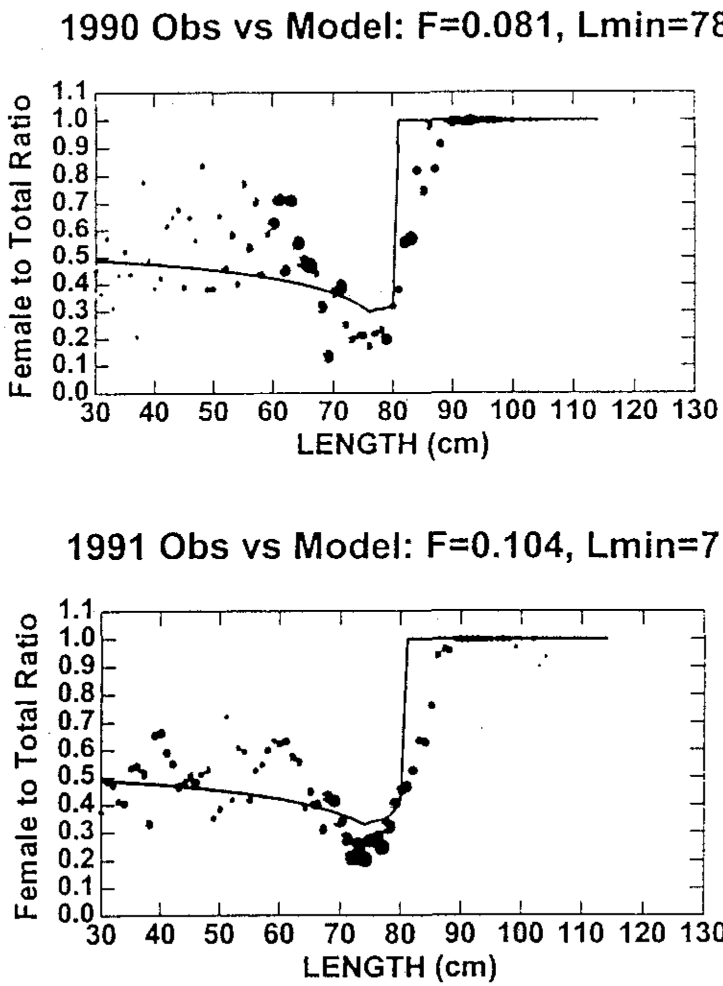


Figure D32. [continued] Comparison of observed female sex ratio (female to total) by 1-cm length interval for NEFSC spring trawl surveys, 1990-1991, with predicted sex ratio from life history model (lines).....

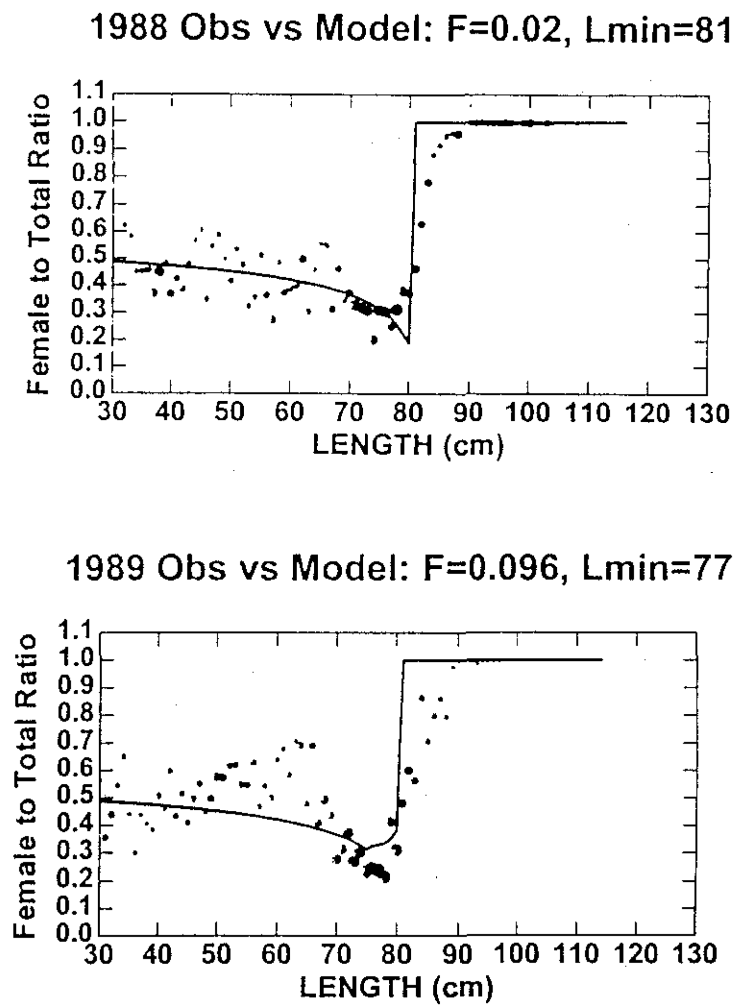


Figure D32. [continued] Comparison of observed female sex ratio (female to total) by 1-cm length interval for NEFSC spring trawl surveys, 1992-1993, with predicted sex ratio from life history model (lines).....

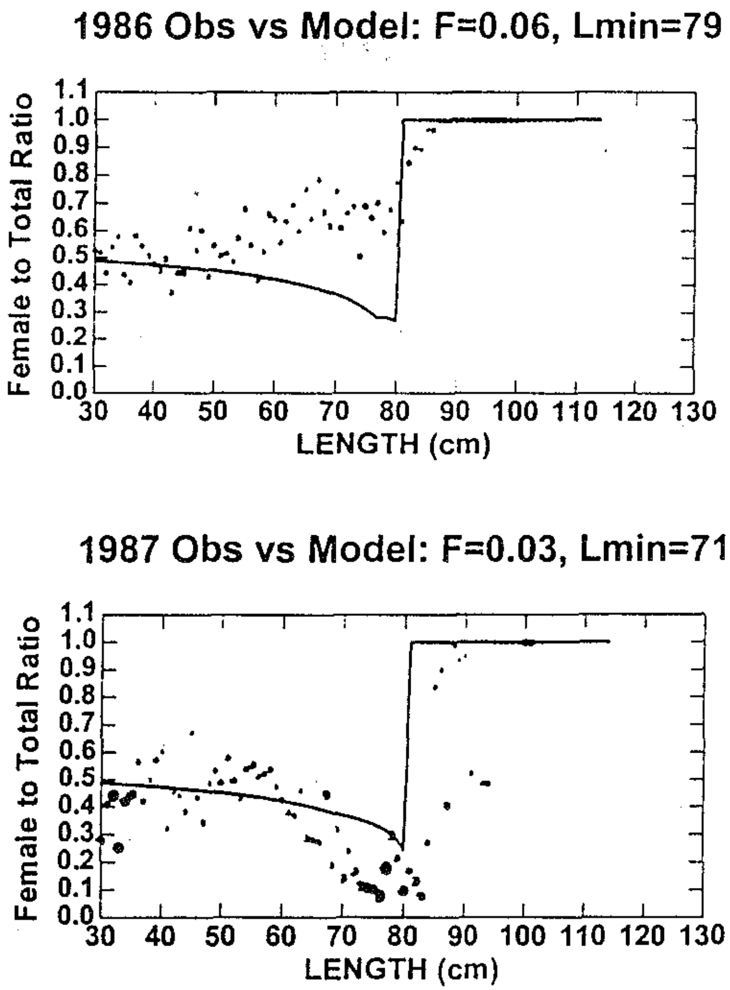


Figure D32. [continued] Comparison of observed female sex ratio (female to total) by 1-cm length interval for NEFSC spring trawl surveys, 1994-1995, with predicted sex ratio from life history model (lines).....

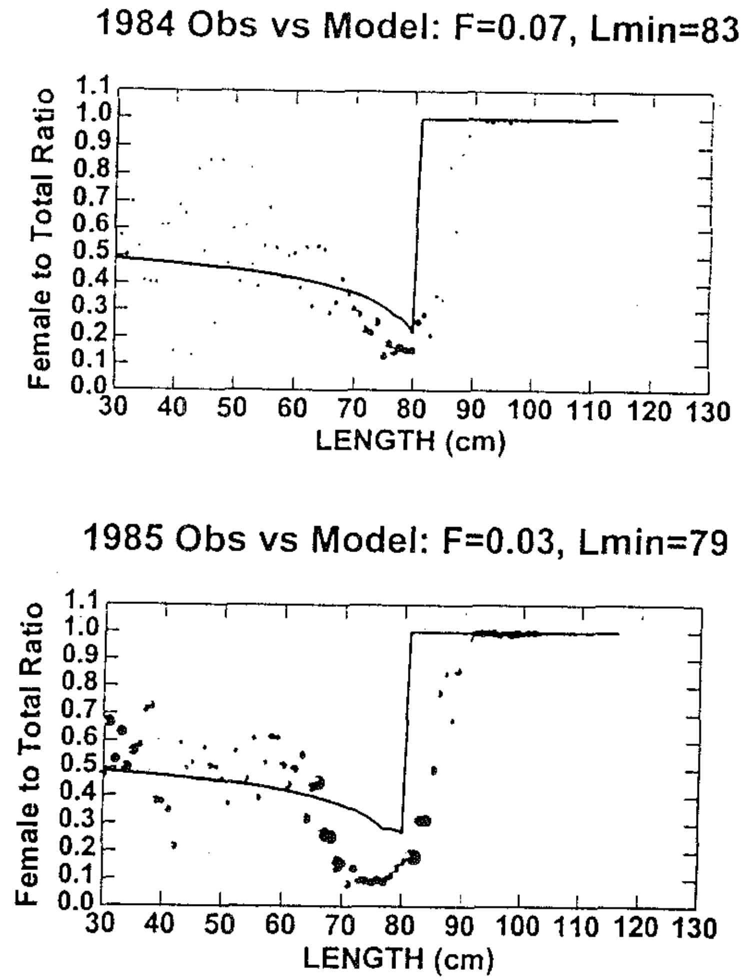


Figure D32. [continued] Comparison of observed female sex ratio (female to total) by 1-cm length interval for NEFSC spring trawl surveys, 1996-1997, with predicted sex ratio from life history model (lines).....

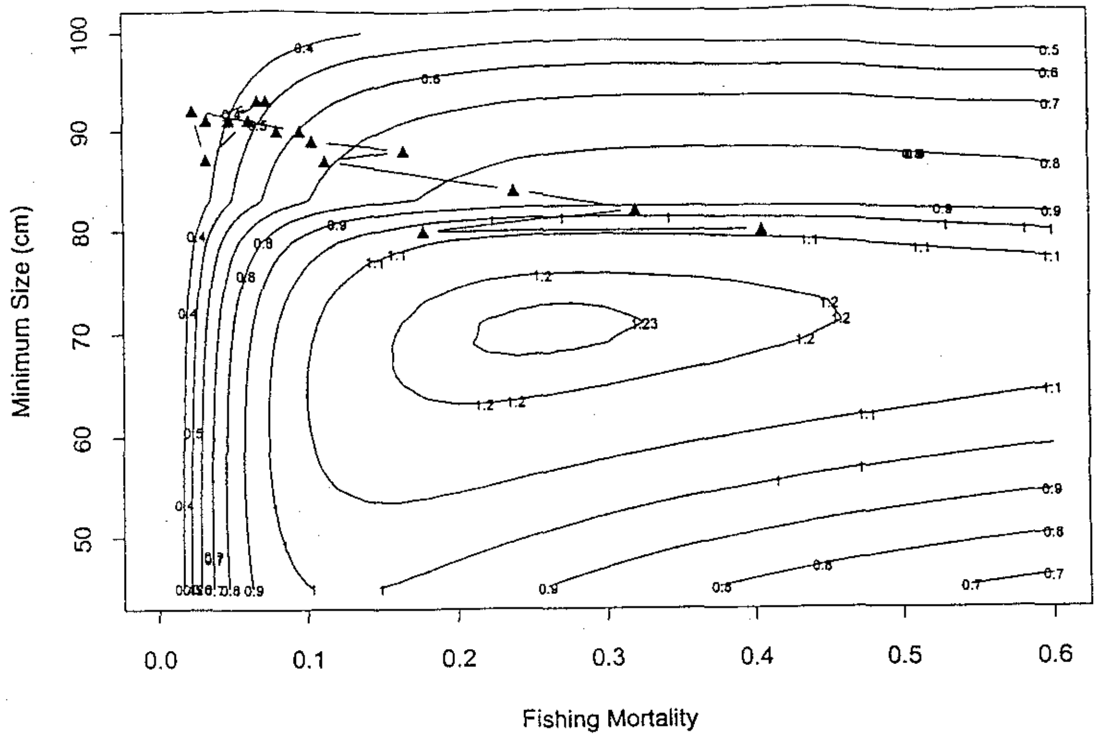


Figure D33. Yield-per-recruit isopleths for sum of male and female spiny dogfish as a function of fishing mortality rate and length at entry to the fishery. Knife-edge selection is assumed. Contour labels represent estimated yield per recruit in kg. Triangles represent the time series of estimated fishing mortality rates and lengths at entry from the Beverton and Holt model, 1982-1997. Early years in the series are on the upper left; later years are on the lower right.

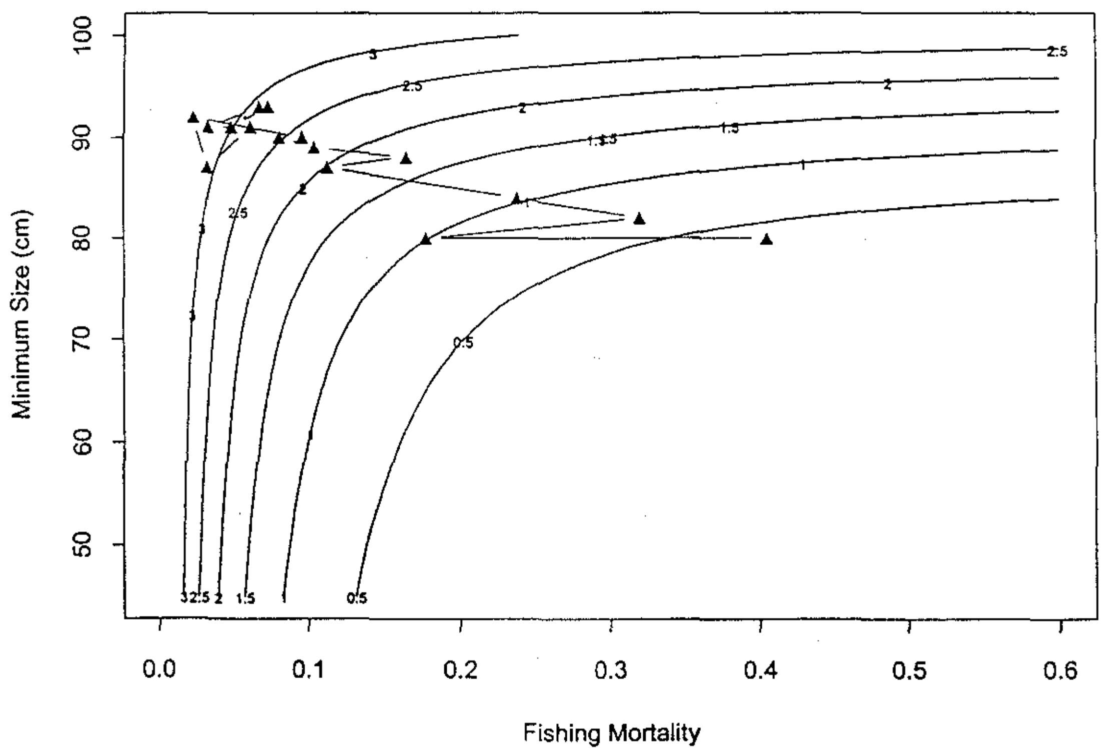


Figure D34. Female-pups-per-female-recruit isopleths (numbers) for spiny dogfish as a function of fishing mortality rate and length at entry to the fishery. Knife-edge selection is assumed. Triangles represent the time series of estimated fishing mortality rates and lengths at entry from the Beverton and Holt model, 1982-1997. Early years in the series are on the upper left; later years are on the lower right.

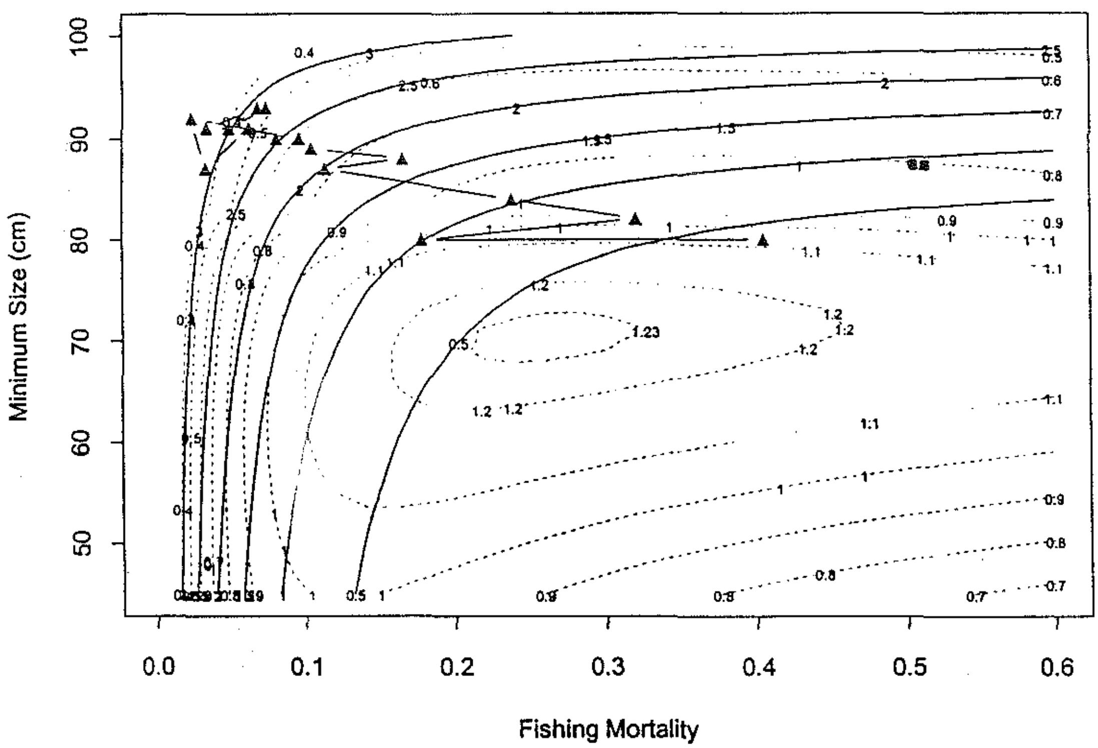


Figure D35. Superposition of female-pups-per-female-recruit (numbers) isopleths (solid lines) over yield-per-recruit (kg) isopleths (dashed lines) for spiny dogfish as a function of fishing mortality rate and length at entry to the fishery. Knife-edge selection is assumed.Triangles represent the time series of estimated fishing mortality rates and lengths at entry from the Beverton and Holt model, 1982-1997. Early years in the series are on the upper left; later years are on the lower right.

Appendix Table 1. Source of data for unclassified dogfish by state and year.

Year	CT	DE	ME	MD	MA	NH	NJ	NY	RI	VA
1962	Gen can	Gen can	Gen can	Gen can	Gen can	Gen can	Gen can	Gen can	Gen can	Gen can
1963	Gen can	Gen can	Gen can	Gen can	Gen can	Gen can	Gen can	Gen can	Gen can	Gen can
1964	Gen can	Gen can	Weighout	Gen can	Weighout	Gen can	Gen can	Gen can	Gen can	Gen can
1965	Gen can	Gen can	Weighout	Gen can	Weighout	Gen can	Gen can	Gen can	Gen can	Gen can
1966	Gen can	Gen can	Weighout	Gen can	Weighout	Gen can	Gen can	Gen can	Gen can	Gen can
1967	Gen can	Gen can	Weighout	Gen can	Weighout	Gen can	Gen can	Gen can	Gen can	Gen can
1968	Gen can	Gen can	Weighout	Gen can	Weighout	Gen can	Gen can	Gen can	Gen can	Gen can
1969	Gen can	Gen can	Weighout	Gen can	Weighout	Gen can	Gen can	Gen can	Gen can	Gen can
1970	Gen can	Gen can	Weighout	Gen can	Weighout	Gen can	Gen can	Gen can	Gen can	Gen can
1971	Gen can	Gen can	Weighout	Gen can	Weighout	Gen can	Gen can	Gen can	Gen can	Gen can
1972	Gen can	Gen can	Weighout	Gen can	Weighout	Gen can	Gen can	Gen can	Gen can	Gen can
1973	Gen can	Gen can	Weighout	Gen can	Weighout	Gen can	Gen can	Gen can	Gen can	Gen can
1974	Gen can	Gen can	Weighout	Gen can	Weighout	Gen can	Gen can	Gen can	Gen can	Gen can
1975	Gen can	Gen can	Weighout	Gen can	Weighout	Gen can	Gen can	Gen can	Gen can	Gen can
1976	Gen can	Gen can	Weighout	Gen can	Weighout	Gen can	Gen can	Gen can	Gen can	Gen can
1977	Gen can	Gen can	Weighout	Gen can	Weighout	Gen can	Gen can	Gen can	Gen can	Gen can
1978	Gen can	Gen can	Weighout	Gen can	Weighout	Gen can	Weighout	Gen can	Gen can	Gen can
1979	Gen can	Gen can	Weighout	Gen can	Weighout	Gen can	Weighout	Gen can	Gen can	Gen can
1980	Gen can	Gen can	Weighout	Gen can	Weighout	Gen can	Weighout	Gen can	Gen can	Gen can
1981	Gen can	Gen can	Weighout	Gen can	Weighout	Gen can	Weighout	Gen can	Gen can	Gen can
1982	Gen can	Gen can	Weighout	Gen can	Weighout	Gen can	Weighout	Gen can	Gen can	Gen can
1983	Gen can	Gen can	Weighout	Gen can	Weighout	Gen can	Weighout	Gen can	Gen can	Gen can
1984	Gen can	Gen can	Weighout	Gen can	Weighout	Gen can	Weighout	Gen can	Gen can	Gen can
1985	Gen can	Gen can	Weighout	Gen can	Weighout	Gen can	Weighout	Gen can	Gen can	Gen can
1986	Gen can	Gen can	Weighout	Gen can	Weighout	Gen can	Weighout	Gen can	Gen can	Gen can
1987	Gen can	Gen can	Weighout	Gen can	Weighout	Gen can	Weighout	Gen can	Gen can	Gen can
1988	Gen can	Gen can	Weighout	Gen can	Weighout	Gen can	Weighout	Gen can	Gen can	Gen can
1989	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout
1990	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout
1991	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout
1992	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout
1993	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout
1994	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout
1995	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout
1996	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout	Weighout

Notes: Gencan = General canvas database. Weighout = NEFSC commercial dealer database.

Appendix Table 2. Source of data for spiny dogfish by state and year.

Year	CT	DE	ME	MD	MA	NH	NJ	NY	RI	VA
1978	-	-	-	-	**Weighout**	-	-	-	-	-
1979	-	-	**Weighout**	-	**Weighout**	-	-	-	-	-
1980	-	-	**Weighout**	-	**Weighout**	-	**Weighout**	-	-	-
1981	-	-	**Weighout**	Gen can	**Weighout**	-	-	-	-	Gen can
1982	-	-	**Weighout**	Gen can	**Weighout**	-	**Weighout**	-	-	Gen can
1983	-	-	**Weighout**	Gen can	**Weighout**	**Weighout**	-	-	-	Gen can
1984	-	-	**Weighout**	Gen can	**Weighout**	**Weighout**	**Weighout**	-	**Weighout**	Gen can
1985	-	-	**Weighout**	Gen can	**Weighout**	**Weighout**	**Weighout**	-	-	Gen can
1986	-	-	**Weighout**	Gen can	**Weighout**	**Weighout**	**Weighout**	**Weighout**	-	Gen can
1987	-	-	**Weighout**	Gen can	**Weighout**	**Weighout**	**Weighout**	-	**Weighout**	Gen can
1988	-	-	**Weighout**	Gen can	**Weighout**	**Weighout**	**Weighout**	**Weighout**	-	Gen can
1989	-	-	**Weighout**	**Weighout**	**Weighout**	**Weighout**	**Weighout**	-	-	**Weighout**
1990	-	-	**Weighout**	**Weighout**	**Weighout**	**Weighout**	**Weighout**	-	**Weighout**	**Weighout**
1991	-	-	**Weighout**	**Weighout**	**Weighout**	**Weighout**	**Weighout**	-	**Weighout**	**Weighout**
1992	-	-	**Weighout**	**Weighout**	**Weighout**	**Weighout**	**Weighout**	-	**Weighout**	**Weighout**
1993	-	-	**Weighout**	**Weighout**	**Weighout**	**Weighout**	**Weighout**	**Weighout**	**Weighout**	**Weighout**
1994	-	-	**Weighout**	**Weighout**	**Weighout**	**Weighout**	**Weighout**	-	**Weighout**	**Weighout**
1995	**Weighout**	**Weighout**	**Weighout**	**Weighout**	**Weighout**	**Weighout**	**Weighout**	-	**Weighout**	**Weighout**
1996	-	-	**Weighout**	**Weighout**	**Weighout**	**Weighout**	**Weighout**	**Weighout**	**Weighout**	**weighout**

Notes: Gencan = General canvas database. **Weighout** = NEFSC commercial dealer database.