Northeast Fisheries Science Center Reference Document 00-03

A Report of the 30th Northeast Regional Stock Assessment Workshop

30th Northeast Regional Stock Assessment Workshop (30th 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

April 2000

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The Stock Assessment Review Committee (SARC) meeting of the 30th Northeast Regional Stock Assessment Workshop (30th SAW) was held in the Aquarium Conference Room of the Northeast Fisheries Science Center's Woods Hole Laboratory, Woods Hole, MA during 29 November - 3 December, 1999. The SARC Chairman was Dr. Robert Mohn, Bedford Institute of Oceanography, Department of Fisheries and Oceans, Halifax, Nova Scotia. Members of the SARC included scientists from the NEFSC, the Northeast Regional Office (NERO), NMFS Headquarters, the Mid-Atlantic Fishery Management Council (MAFMC), Atlantic States Marine Fisheries Commission (ASMFC), the States of Rhode Island and Massachusetts, DFO - Canada, and Virginia Institute of Marine Sciences (Table 1). In addition, 48 other persons attended some or all of the meeting (Table 2). The meeting agenda is presented in Table 3.

Table 1. SAW-30 SARC Composition.

Robert Mohn, DFO (NMFS Consultant), Chairman

NEFSC experts chosen by the Chair:
Nancy Kohler
Ralph Mayo
Paul Rago

NMFS Northeast Regional Office:
Earl Meredith, NMFS/NERO

Regional Fishery Management Councils:
Tom Hoff, MAFMC

Atlantic States Marine Fisheries Commission/States:
Bob Beal, ASMFC
John Carmichael, NC
Alexi Sharov, MD

Other experts:
Jeffrey Hutchings, Dalhousie University
David Kulka, DFO, St. John's
John Musick, VIMS
Marta Nammack, F/PR, Silver Spring

Opening

Dr. Terrence Smith, Stock Assessment Workshop (SAW) Chairman, welcomed the meeting participants and briefly reviewed the overall SAW process. Dr. Mohn reviewed the agenda and discussed the conduct of the meeting.

Table 2. List of Participants.

NMFS, Northeast Fisheries Science Center

Frank Almeida	Paul Nitschke
John Brodziak	Loretta O'Brien
Steve Cadrin	William Overholtz
Steven Clark	Gary Shepherd
Joseph Idoine	Pie Smith
Wendy Gabriel	Terry Smith
Larry Jacobson	Tim D. Smith
Blanche Jackson	Katherine Sosebee
Jason Link	Mark Terceiro
Steven Murawski	James Weinberg
	Susan Wigley

NMFS, Northeast Regional Office

Mary Colligan	Chris Mantzaris

ASMFC/States

Sherri Archer, NY	Desmond Kahn, NY
Paul Caruso, MA	Jeremy King, MA
Vic Crecco, CT	Najih Lazar, RI
Tom Currier, MA	Matthew Mitro, ASMFC
Mark Gibson, RI	David Pierce, MA
Tom Helser, DE	Amy Schick, ASMFC
Arnie Howe, MA	Heather Stirratt ASMFC
Rob Johnston, MA	David Whittaker, MA

Anthony Chatwin, CLF
Sonja Fordham, CMC
Kenneth Frank, DFO
Lori Lefevre, NEFMC
Trevor Kenchington, Consultant
Eric Powell, Rutgers University
Ronald Smolowitz, Consultant
David Wallace, MAFMC Advisor

Table 3. Agenda of the 30th Northeast regional Stock Assessment Workshop (SAW-30) Stock Assessment Review Committee (SARC) meeting.

Aquarium Conference Room
NEFSC Woods Hole Laboratory
Woods Hole, Massachusetts
29 November (1:00 PM) - 3 December (6:00 PM) 1999

AGENDA

TOPIC	WORKING GROUP & PRESENTER(S)	SARC LEADER	RAPPORTEUR
<u>MONDAY, 29 November</u> (1:00 PM - 6:00 PM)........			
Opening			
Welcome	**Terry Smith, SAW Chairman**		**P. Smith**
Introduction	**Bob Mohn, SARC Chairman**		
Agenda			
Conduct of meeting			
Weakfish (A)	**Mark Gibson**	**David Kulka**	**Heather Stirratt**
Informal reception (7:00 PM) Quarterdeck Restaurant, Falmouth			
<u>TUESDAY, 30 November</u> (8:30 AM - 6:00 PM)........			
Skate Complex (B)	**Katherine Sosebee**	**Jack Musick**	**Mark Terceiro**
<u>WEDNESDAY, 1 December</u> (8:30 AM - 5:00 PM)........			
Tautog (C)	**Paul Caruso**	**Alexi Sharov**	**Heather Stirratt**
Atlantic Mackerel (D)	**William Overholtz**	**Ralph Mayo**	**Steve Cadrin**
<u>THURSDAY, 2 December</u> (8:30 AM - 6:00 PM)........			
Atlantic Surfclam(E)	**Jim Weinberg/Larry Jacobson**	**Tom Hoff**	**Susan Wigley**
Review Advisory Reports and Sections for the SARC Report			
<u>FRIDAY, 3 December</u> (8:30 AM - 6:00 PM)........			
SARC comments, research recommendations, and 2nd drafts of Advisory Reports			
Other business			**P. Smith**

The Process

The SAW Steering Committee, which guides the SAW process, is composed of the executives of the five partner organizations (NMFS/NEFSC, NMFS/NER, NEFMC, MAFMC, ASMFC). Working groups assemble the data for assessments, decide on methodology, and prepare documents for SARC review. The SARC members have a dual role; panelists are both reviewers of assessments and drafters of management advice. More specifically, although the SARC's primary role is peer review of the assessments tabled at the meeting, the Committee also prepares a report with advice for fishery managers known as the *Advisory Report on Stock Status*.

Assessments for SARC review were prepared at meetings listed in Table 4.

Table 4. SAW-30 Working Group meetings and participants.

Working Group and Participants		Meeting Date		Stock/Species
ASMFC Stock Assessment Subcommittee		10-11 March, 1999		**Weakfish**
V. Crecco	M. Gibson			
D. Kahn	G. Nelson			
R. O'Reilly	J. Uphoff			
		June 8-9, 1999		
V. Crecco	L. Daniel			
C. Evans	M. Gibson			
D. Kahn	J. McClain			
J. Musick	G. Nelson			
R. O'Reilly	C. Wenner			
		October 21-22, 1999		
V. Crecco	M. Gibson			
D. Kahn	J. McClain			
G. Nelson	R. O'Reilly			
G. Swihart	J. Uphoff			
A.Weber	S. Welsh			
Southern Demersal Working Group		6-8 October, 1999		**Skate Complex**
R. Beal, ASMFC	C. Bonzak, VIMS	D. Byrne, Industry	M. Colligan, NERO	
S. Doctor, Maryland	W. DuPaul, VIMS	S. Fordham, CMC	K. Frank, DFO	
M. Gibson, RI	T. Helser, DE	D. Kulka, DFO	J. Mason, NY	
R. Monaghan, NC	C. Moore, MAFMC	S. Murawski, NEFSC	D. Rader, Industry	
F. Serchuk, NEFSC	T. Smith, NEFSC	K. Sosebee, NEFSC		

ASMFC Technical Committee

Tautog

22 June, 1999; 12-13 August, 1999
15 September, 1999; 21 October, 1999

S. Archer, NY	R. Beal, ASMFC
P. Caruso, MA	M. Gibson, RI
P. Himchack, NJ	T. Helser, DE
T. Hutcheson, VA	N. Lazar, RI
M. Mitro, ASMFC	P. Piavis, MD
D. Simpson, CT	D. Shake, CT
G. White, ASMFC	

Coastal/Pelagic Subcommittee — 8-9 November, 1999 — **Atlantic Mackerel**

S. Cadrin
W. Overholtz

SAW Invertebrate Subcommittee — 4-6 October, 1999 — **Atlantic Surfclam**

T. Alspach, Sea Watch	L. Hendrickson, NEFSC
T. Hoff, MAFMC	L. Jacobson, NEFSC
R. Mann, VIMS	E. Powell, Rutgers
D. Wallace, MAFMC Advisor	J. Weinberg, NEFSC
D. Whittaker, MA	

Agenda and Reports

The SAW-30 SARC agenda (Table 3) included presentations on assessments for weakfish, the skate complex (seven species of skates including barndoor skate), tautog, Atlantic mackerel, and surfclams. 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 trawls surveys is presented in Figure 2.

SARC documentation includes two reports, one containing the assessments, SARC comments, and research recommendations (SARC Consensus Summary), and another produced in a standard format which includes the status of stocks and management advice (SARC Advisory Report). The draft reports were made available at the SAW-30 Public Review Workshops that were held during regularly scheduled NEFMC, MAFMC and ASMFC meetings (18 January, NEFMC; 10 February, ASMFC; 15 March, MAFMC). Following the Public Review Workshops, the documents are published in the NEFSC Reference Document series as the *30th SARC Consensus Summary of Assessments* (this document) and the 30th *SAW Public Review Workshop* Report (the latter document includes the final version of the Advisory Report).

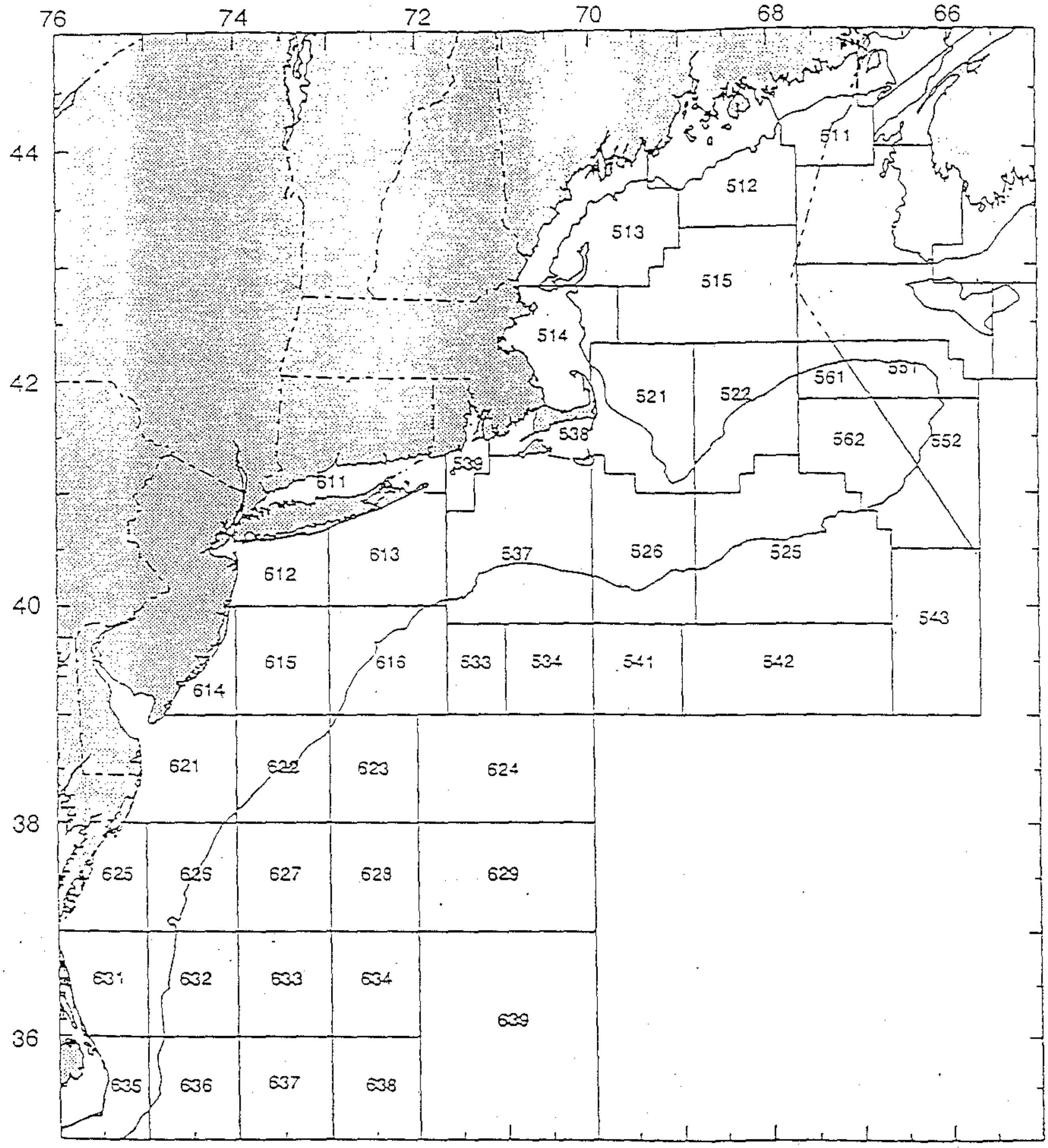

Figure 1. Statistical areas used for catch monitoring in offshore fisheries in the Northeast United States.

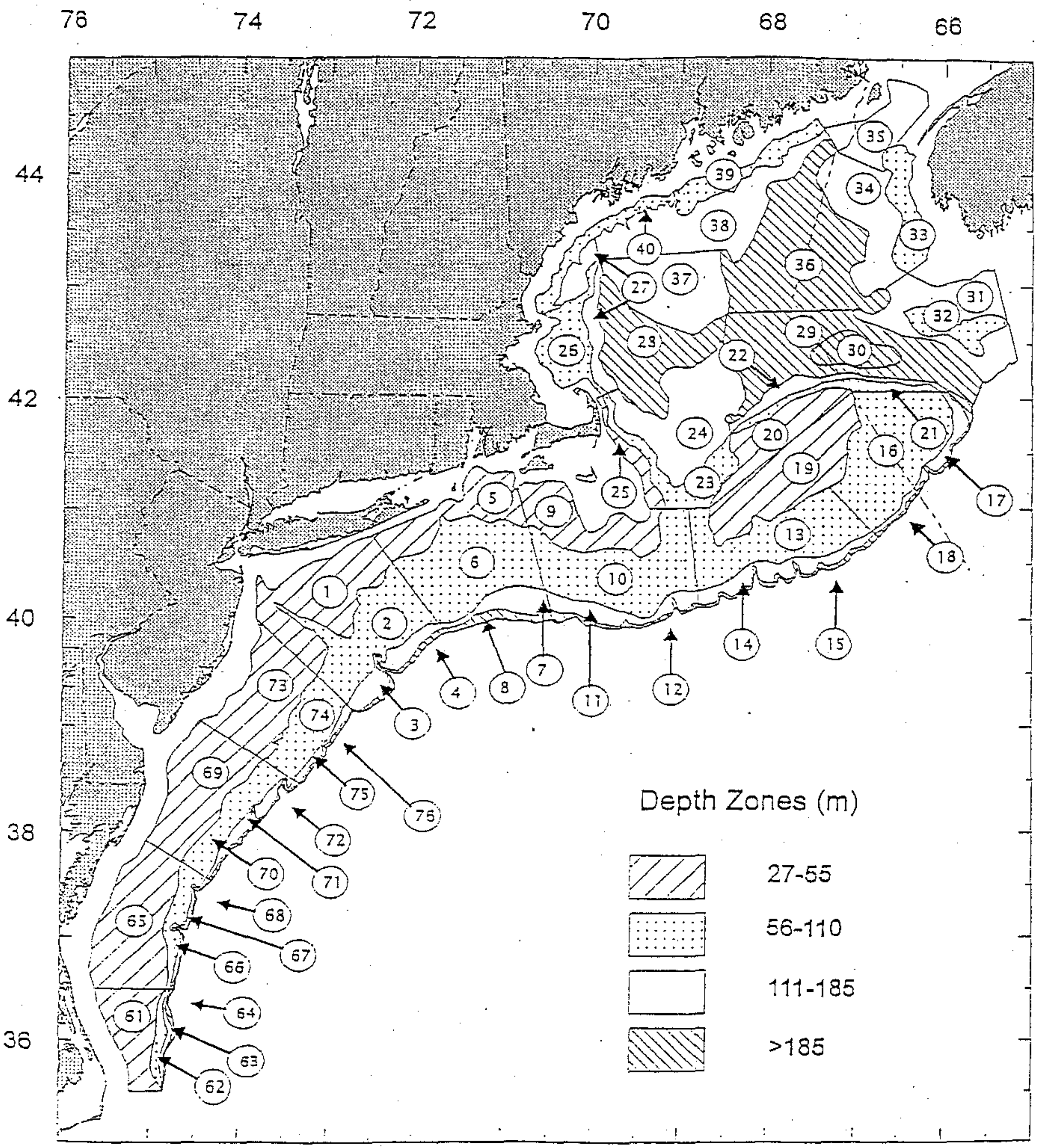

Figure 2. Offshore sampling strata used in NEFSC bottom trawl surveys.

A. WEAKFISH

TERMS OF REFERENCE

The following terms of reference were addressed for weakfish:

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

(2) Summarize available indices of stock abundance by state.

(3) Estimate age composition of recreational and commercial landings.

(4) Provide estimates of fishing mortality.

(5) Conduct a full age-based VPA and yield-per-recruit and spawning stock biomass-per-recruit analysis.

(6) Review the biological reference points used for the overfishing definition and target fishing mortality rate.

(7) Review progress towards meeting the goal in Amendment 3 to the Weakfish FMP to restore the age composition.

INTRODUCTION

Weakfish (*Cynoscion regalis*) have supported fisheries along the Atlantic coast of the United States 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 (Wilk 1979). Important wintering grounds for the weakfish stock are located on the Continental Shelf off Chesapeake Bay to Cape Lookout, North Carolina (Lockhart et al. 1996). As water temperatures rise in the spring, mature weakfish migrate to nearshore spawning grounds to complete their life cycle. Weakfish spend most of their adult life in coastal and estuarine waters, migrating onshore/offshore (Lockhart et al. 1996).

Weakfish are fast-growing and live up to 17 years (Lowerre Barbieri et al. 1995). Length at age distributions of three year-old and older weakfish show a great deal of overlap and size is a poor predictor of age. Differences in growth between sexes is not readily evident. Weakfish achieve a maximum length of about 850 mm (Lowerre Barbieri et al. 1995). Mature female weakfish (age 1+) are indeterminate batch spawners that spawn large quantities of eggs both within estuaries and nearshore waters from March to September (Lowerre-Barbieri 1996).

Weakfish occur in shallow coastal and estuarine waters where they are sought by both commercial and recreational fishers. The migratory nature and economic importance of weakfish have led to the development of coastwide management plans by the Atlantic States Marine Fisheries commission (ASMFC) in 1985 (Mercer 1985),1992 (Seagraves 1992) and 1996 (Lockhart et. al. 1996). States manage weakfish in their waters (up to 3 miles from shore) under an ASMFC plan and the National Marine Fisheries Service manages them in federal waters.

Amendment 1 to the original *Interstate Fishery Management Plan for Weakfish* adopted in October, 1991, was not successful in improving status of weakfish (Lockhart et al. 1996). Amendment 2 was implemented in April, 1995, and resulted in some improvement. However, lower than average commercial and recreational catch rates, truncated age structure, variable recruitment strength, and below average SSB mandated further improvements (Lockhart et al. 1996).

Amendment 3 of the Weakfish Plan, adopted in June 1996, was designed to reduce F to 0.50 by the year 2000 and restore extended age structure and geographical extent (Lockhart et al. 1996). Under Amendment 3, weakfish commercial fisheries have been regulated by a combination of season and area closures, and mesh regulations. Allowable mesh sizes retain 25% or less of weakfish less than 12 inches, TL. Bycatch reduction devices (BRD) have been required for shrimp fisheries in the South Atlantic to reduce mortality of age 0 and 1 weakfish. All BRD's must be certified, properly installed, and demonstrate a 40% reduction by number or 50% reduction of bycatch mortality of weakfish as compared to catch rates in a naked net. The weakfish recreational fishery has been regulated by equivalent, state-specific minimum size and possession limits. The smallest allowable minimum size is 12 inches with a 5 fish bag limit. Bag limits are not required once minimum size rises to 16 inches. Most states in the mid-Atlantic region (where most recreational harvest occurs) have a 14 inch minimum length and 10-14 weakfish bag limit (Lockhart et al. 1996).

RESEARCH SURVEY ABUNDANCE INDICES

NEFSC Fall Surveys

Age structured abundance indices were developed from stratified random bottom trawl surveys conducted by the Northeast Fisheries Science Center (NEFSC) between Cape Hatteras, North Carolina, 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, keys were coastwide. Since 1991, keys used were developed from the mid-Atlantic region. Weakfish were rarely caught in this survey north of New Jersey.

Weakfish were infrequent in the spring surveys, but were intercepted during migration by the inshore fall survey. Abundance and age-structure were greatest in the early 1980's, then declined in the late 1980's and early 1990's. Recovery began in the mid 1990's (Table 1). For example, few age 4 fish were sampled between 1985 and 1993, but the 1998 value was the highest in the time series. Abundance indices of age 2 and 3 weakfish increased in recent years and exceeded values of the 1980s. Age 0 weakfish may not be fully recruited to this gear, though the 1995 and 1998 year-classes were the largest since 1982.

SEAMAP Spring and Fall Surveys

The Southeast Area Monitoring and Assessment Program (SEAMAP) has conducted trawl surveys since 1989 between Cape Hatteras, North Carolina, and Cape Canaveral, Florida. 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 was truncated in the spring survey catch-at-age matrix (Table 2). This may be due to mortality, migration northward with maturation, or life history variation in the southern range of weakfish. Although age 0 fish were captured in the fall survey, they may not have been fully recruited to this gear. Total catch in the spring survey declined between 1994 and 1996, but has since rebounded. In the fall survey, total catch has increased erratically since 1993. Age 2 weakfish have increased in abundance since 1996 in the spring survey. In the fall survey, abundance of ages 2+ weakfish has increased by an order of magnitude since 1994.

Connecticut's Long Island Sound Trawl Program

Connecticut's Department of Environmental Protection (CTDEP) has conducted a stratified random trawl survey biweekly during June-October; 120 tows were made per year. The survey was initiated in 1984. Age 1 weakfish relative abundance was generally lower during 1990-1993 (Table 3). Since 1995, 4 year-old and older weakfish have increased greatly in relative abundance (Table 3).

New Jersey's Ocean Trawl Program

Since 1988, New Jersey Division of Fish Game and Wildlife (NJDFGW) has conducted an ocean trawl program that uses a stratified random design. Length frequency data from the months of August and October was used to develop a catch-at-age matrix from the pooled late season mid-Atlantic keys. Normal sample size for this period was 78 tows per year.

Relative abundance increased to a peak in 1995, followed by a decline (Table 4). Relative abundance in 1998 was lowest in the time series. Catches of ages 2+ were very high during 1994-1997 and moderate in 1998. Relative abundances of ages 4+ have been high since 1994 (Table 4).

Delaware's Delaware Bay Survey

The Delaware Division of Fish and Wildlife (DEDFW) has conducted a fixed station survey of Delaware Bay using a 9.2-m headrope trawl during 1966-1971, 1979-1984 and 1990-1996 (Table 5).

Length frequencies from 1966-1981 were aged with an average of the 1982-1984 keys. Ageing of 1982-1995 samples used pooled mid-Atlantic keys. Age structure during 1996-1998 was developed from survey otolith ages.

Number of weakfish per nautical mile was low during 1979-1984 (Table 5). When the survey resumed in 1990, relative abundance steadily increased through 1994, and then remained high. Ages 2+ were most abundant during 1969-1971 and after 1992. Ages 4+ were absent during 1966-1968 and 1991; their relative abundance increased steadily during 1990-1996 to the highest level recorded and then leveled off. Age 6 weakfish were present in the survey during 1969-1971, 1979-1984, 1990, were absent in 1991-1995, and then reappeared afterwards. Presence of age 7 weakfish in this survey was similar to age 6, except they reappeared in 1998.

Massachusetts' Trawl Survey, South Cape Cod

A stratified random trawl survey, conducted by the Massachusetts Division of Marine Fisheries (MADMF), catches young of the year weakfish south of Cape Cod. As a proxy to a stratified CPUE, the total number caught per year was employed (Table 6). Catches were high in the 1980s, peaking in 1985 and 1986. They declined in 1987 and remained generally low until after 1994. Catches during 1995-1998 were still below peaks seen in the mid-1980s.

Rhode Island's Narragansett Bay Trawl Survey

The Rhode Island Division of Fish and Wildlife (RIDFW) conducts a juvenile survey in Narragansett Bay. Catches of YOY have been erratic, but 1996 and 1997 relative abundances were the highest in the time series (Table 6).

New York's Peconic Bay Juvenile Trawl Survey

The New York's Department of Environmental Conservation (NYDEC) has sampled juvenile estuarine finfishes in Peconic Bay of Eastern Long Island with a 4.9-m trawl since 1985. This survey indicated strong recruitment in the last three years (Table 6).

Delaware DFW Delaware Bay Juvenile Trawl Survey

The Delaware Division of Fish and Wildlife (DEDFW) conducted a juvenile trawl survey in Delaware Bay with a 4.9-m trawl during 1982-1998. Lower indices were common prior to 1990. The highest index occurred in 1991 and YOY indices have been above average since (Table 6).

Maryland's Chesapeake Bay and Coastal Bays Juvenile Trawl Surveys

The Maryland Department of Natural Resources (MDDNR) 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 4.9-m trawls. Both indices reached a nadir in the late 1980's and have been at high levels since (Table 6).

Virginia's Chesapeake Bay Trawl Survey

The Virginia Institute of Marine Science (VIMS) conducts a trawl survey in lower Chesapeake Bay. An index of YOY weakfish relative abundance is computed using August-October tows from three river tributaries (Table 6). Largest indices occurred during 1985-1993. Indices after 1993 were equivalent to those during 1982-1984.

North Carolina's Pamlico Sound Juvenile Trawl Survey

The North Carolina Division of Marine Fisheries (NCDMF) has conducted a juvenile finfish trawl survey in Pamlico Sound since 1987 that provides relative abundance of ages 0 and 1 (Table 6). The YOY index shows no obvious trend, while the Age 1 index dipped during 1989-1992, but has since recovered.

Florida's Indian River Survey

Florida's Department of Environmental Protection (FLDEP) has conducted a trawl survey of Indian River on the Atlantic coast since 1989. The survey employed a random design and used a 6.1-m net with 3.8-mm cod-end liner for juvenile fish (Table 6). Indices were highest in 1991-1993 and declined afterwards.

FISHERY-DEPENDENT INDICES OF ABUNDANCE

Marine Recreational Fisheries Statistics Survey (MRFSS)

Catch at age per directed trip was employed as a tuning index (Table 7). Length frequencies from the MRFSS were aged with the appropriate pooled age-length key. Catch per trip of Age 2 weakfish dropped in 1989 and has remained low, reflecting imposition of larger minimum length regulations. Catch per trip of age 3 weakfish increased about three-fold after 1993, catch per trip of age 4 increased over six-fold between 1993 and 1996-1998, and catch per trip of age 5+ weakfish increased about seven-fold between 1995 and 1996-1998 (Table 7).

Florida Commercial Catch per Effort

Florida's Department of Environmental Protection (FLDEP) developed a catch per trip series from their commercial fishery records (Table 7). These landings are composed primarily of ages 1 and 2. The index, a standardized annual catch rate in pounds / trip, was developed from a general linear model that adjusted trip catches for year, month, county and time spent fishing. This index declined after an inshore gill net ban in 1995, but rebounded during 1997-1998.

LENGTH-WEIGHT RELATIONSHIPS

The estimated weight (W, in pounds)-total length (TL, in inches) relationship, based on the 1991-98 otolith age data base was :

$$W = exp(-7.906 + 2.967*ln(TL) + 0.5*0.027); \quad \textbf{(1a)}$$

where 0.027 was the mean squared error, n = 11,975, and $r^2 = 0.98$. This relationship was used throughout these analyses with two exceptions. Fish weight was calculated from MRFSS length data collected during 1979-1998:

$$W = exp(-7.276 + 2.731*ln(TL) + 0.5*0.004); \quad \textbf{(1b)}$$

where 0.004 was the mean squared error, n = 31,621, and $r^2 = 0.88$. Commercial fish weight for Virginia and north was calculated from Virginia commercial data from 1989-1998:

$$W = exp(-8.080 + 3.033*ln(TL) + 0.5*0.025); \quad \textbf{(1c)}$$

where 0.025 was the mean squared error, n = 74,613, and $r^2 = 0.95$.

The total length (TL, in mm)-fork length (FL, in mm) relationship (p. 6 in Vaughan et al. 1991) was used:

$$TL = -6.794 + 1.045 FL; \quad \textbf{(2)}$$

$r^2 = 0.996$. with n = 788.

AGEING

Scale-Otolith Age Conversion

Ageing data were available from the following states and years from scales (n=20,101): North Carolina, 1982-83 and 1988-95; Maryland. 1985-86, 1993-95 and 1997; Delaware. 1992-96; and New York, 1988-90 and 1992-97. Beginning in 1989, data have been available from the following states and years from otoliths (n=19,873): Florida, 1993-98, Georgia 1995-98, SEAMAP, 1991-98; North Carolina, 1995-98; Virginia, 1989-92, 1996, and 1998; Maryland, 1994, 1996, and 1998; Delaware, 1995-98; New Jersey, 1995-98; New York, 1995; the NEFSC Fall Trawl Survey (Albatross), 1996-98; and the U.S. Fish and Wildlife Service, 1995 and 1997.

Because of demonstrated discrepancies in assigned ages from matched scale and otolith samples (presentation by Vaughan, Daniel and Gregory at the 1998 AFS Annual Meeting; using methods of Campana et al. 1995 and Hoenig et al. 1995), only otolith-derived age-length keys were used for developing the catch-at-age matrix for 1990-1998. As only scale age-length data were available prior to 1990. catch at age vectors (by year and season), based on scale age-length keys were subsequently transformed by direct matrix application to equivalent otolith-based catch at age matrices. Since scale age-length keys during 1982-89 were only separable into season (early vs. late) and not area, only two transformation matrices from scales to otoliths were developed from the detailed scale-otolith comparison based on season. Vaughan (1998) applied various approaches to transform scale ages to otolith ages. Attempts were made to apply an inverse method suggested during the 1996 SARC (NEFSC 1998), but negative values were obtained. An EM algorithm approach (Hoenig and Heisey 1987) had also been recommended. but was not applied.

Age-Length Keys

Age-length keys were developed as described in Vaughan et al. (1991) in half-year increments coastwide from early 1982 through late 1989. Keys are now developed in 1-yr or 2-yr increments depending on data availability. Because no ageing data were available for 1984 and 1987, the keys for these years were based on 1982-83 and 1985-86, respectively. Thus, six scale-derived age-length keys were developed by season (early and late season keys for 1982-84, 1985-87 and 1988-89).

Few otolith-aged fish collected since 1990 were greater than 6 years of age (9 fish) and the plus age group began at 6 years. Years were pooled in 2-yr increments for 1990-91 through 1994-95 to reduce need to fill in for missing area/season combinations, and annually for 1996-98. Region-specific age-length keys were developed in half-year increments from early 1990 through late 1998 (four keys per 2-yr or 1-yr period). When sample size for a given length interval fell below 10. pooled data for the early (1982-1989) or late (1990-1998) time periods were used.

Mean total length (in) and mean weight (lbs, based on Eq. 1a) were calculated by age for the otolith-aged weakfish from the period 1991-98.

CATCH MATRIX DEVELOPMENT

Recreational Landings

Recreational catch estimates in weight and numbers were from the Marine Recreational Fisheries Statistical Survey (MRFSS; National Marine Fisheries Service. Fisheries Statistics and Economics Division, personal communication). Recreational catch (harvest and releases) in numbers (A+B1+B2), number dead due to harvest and release (A + BI + 20% of B2), and landings (A + B1) by weight (MT) were estimated for 1982-1998 (Table 8). The ASMFC Weakfish Technical Committee and Management Board adopted 20% mortality of released fish. The degree of precision about the recreational catch or harvest is indicated by the proportional standard error (PSE). Lower values imply greater precision, with values less than 20% generally considered adequate.

Weakfish recreational catches during 1981-1988 ranged between $3 * 10^6$ and $11 * 10^6$ fish. Catches fell to less than $3 * 10^6$ fish during 1989-1993 and then rose to $5\text{-}7 * 10^6$ fish during 1994-1998 (Table 8). Recreational weakfish harvests in weight were relatively high, ranging from 2,554 to 5,377 MT during 1982-89, but landings declined abruptly to

1008 MT in 1989 and remained low through 1995. Successive increases in recreational landings occurred from 1996 through 1998, when total Atlantic coast landings were 1,850 MT, 2,107 and 2,338 MT, respectively. The pattern in recreational harvest as numbers was similar to the pattern for harvest in weight (Table 8). Catches have risen faster than harvest in recent years, reflecting high release rates.

Recreational weakfish harvest in numbers was dominated by the mid-Atlantic (NY to VA) during 1982-1998 (Table 9). Recreational harvests of north Atlantic (ME to CT) and south Atlantic (NC to FL) states were minimal (Table 9).

Commercial Landings

Commercial landings were categorized as market (food) and scrap (bait) landings. Updated market landings in weight by fishing gear were obtained from several sources. Virginia and north landings data through 1998 were provided by NMFS Headquarters. Gear-specific landings from Delaware, Connecticut, and Massachusetts, and partially for New York were not always identified to month in recent years; state landings were proportioned out according to prior years (1985-1989) for each state, except New York where concurrent years were used. Landings from Florida (east coast) through 1991 were provided by NMFS SEFSC Miami; more recent Florida landings (1992-1998) were from the DEP Trip Ticket program. Georgia through North Carolina landings were from NMFS SEFSC Beaufort, North Carolina. A modification to Virginia landings in 1992 was made because of concerns about under-reporting of gill net, pound net, and haul seine catches that year; average (1991-1993) landings from those gears were substituted for 1992. Estimates of scrap/bait landings in weight from trawl, pound and haul seines were provided by North Carolina (DMF) and Virginia (VMRC). No scrap landings were reported from North Carolina in 1995 or 1997, and only from pound nets and haul seines from Virginia for 1995-1998. Since commercial landings are treated as a census, precision was not estimated.

Total commercial landings of weakfish from Massachusetts to Florida were about 8,000 to 10,000 MT during 1982-1988, then declined steadily to 2,873 MT by 1994 (Table 10). Since 1994, commercial landings have been between 3,000 and 4,000 MT (Table 10). Commercial landings by state were dominated by North Carolina (Table 11). Typically Virginia or New Jersey ranked second or third, and Delaware, New York, or Maryland ranked fourth to sixth. Minor or no commercial harvests were reported in New England and the remaining southern states (Table 11).

Weakfish commercial landings during 1982-1998 have been dominated by four gears: haul seines (4-12%), otter trawls (17-54%), pound nets (2-18%), and gill nets (21-56%). Landings from other gears have comprised 2-4%. Trawls dominated market landings until recently, but now gill net landings predominate (Table 12). Combined pound net and haul seine market landings now roughly equal trawl landings. Scrap landings have dropped from about 800 MT in 1982 to about 50 MT in 1998 (Table 13). Scrap landings were initially dominated by trawls, but trawl scrap landings dropped precipitously after 1993 and have remained low. Recently, most scrap landings were from pound nets (Table 13). The above data for recreational, market and scrap losses were broken into half-year increments for use in developing catch-at-age matrices for years 1982-1997 (Tables 14a and 14b).

Length Frequencies

Intercept data (length measurements) from the MRFSS were split into Middle and South Atlantic regions as in Vaughan et al. (1991). Measured lengths were combined across mode (beach vs. boat), state and wave weighted by catch of A+B1 weakfish.

Gear-specific length data from south Atlantic market (commercial) landings by gear are from North Carolina (DMF: sink gill net, winter trawl, pound net and haul seine), and MRFSS (hook & line from the South Atlantic sub-region). Length data from the Middle Atlantic market (commercial) landings, by gear, were from NMFS NEFSC (trawl for 1982-93), Virginia (gill net, pound net and haul seine for 1989-98), from Maryland (pound net for 1985-87, 1993-98; and trawl for 1994-97), from Delaware (gill net for 1988 and 1993-98), and from MRFSS (hook & line from Middle Atlantic subregion). Length data from the scrap/bait landings were from North Carolina (DMF for trawl, pound net and haul seine for 1982-98). Where length data was available for the same gear and season from more than one state, they were combined and weighted by catch in numbers from that gear and season for each state.

Concerns within the Weakfish Stock Assessment Subcommittee were raised about representativeness of mean weights of fish in landings (and hence length frequency distributions) for middle Atlantic commercial gears (i.e., gill net and pound net). Several alternate assumptions (substitutions) were investigated. The final substitution agreed upon was to use mean weights of weakfish sampled from South Atlantic gill net (1982-1988), pound net (1982-1986), and haul seine (1982-1988) for mid-Atlantic values.

A method for addressing the adequacy of length samples is based on the amount of landings per 100 fish sampled (NEFSC 1998). 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 NEFSC SARC process. With few exceptions, sampling intensity appears to be excellent for recreational (Table 8) catches and commercial market (Table 12) and scrap (Table 13) gears. Because it was desirable to split length frequencies by region (Middle 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 nonexistent, especially during the period 1982-88 in the Middle Atlantic region for commercial market gears.

By applying Eq. 1a-c to sampled length data, mean weights were calculated by fishery, gear, year and season (Tables 15a and 15b). These estimates, in turn, were used to estimate landings in numbers from commercial market and scrap weight.

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):

$$N_{ax1} = n \cdot A_{axb} \cdot L_{bx1}, \qquad \textbf{(3)}$$

where N is the vector of landings in numbers for ages 1 through (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 3 was applied separately by region (South Atlantic vs. Middle Atlantic), fishery (recreational, market, and scrap), gear (where appropriate), and season (half-year increments). Note that separate age-length keys by region (south, Florida -North Carolina, versus middle, Virginia - Massachusetts) and half-year increments were used for 1990-1998 (2-yr and late 1-yr increments). For each set of age-length keys, catch-at-age matrices were developed for recreational and commercial (market and scrap) losses. The results were summed by calendar year (Table 16).

NATURAL MORTALITY

As recommended by the Stock Assessment Review Committee during the 26th Northeast Regional Stock Assessment Workshop, M equaled 0.25 (NEFSC 1998).

ESTIMATES OF FISHING MORTALITY AND STOCK SIZE

Atlantic weakfish were considered a single stock. Scoles (1990) and Graves et al. (1991) indicated that Atlantic Coast weakfish should be managed as a single, large interdependent unit.

Virtual Population Analysis

Estimates of fishing mortality rate and stock size for Atlantic coast weakfish were made using ADAPT tuning of VPA (NEFSC Woods Hole Assessment Toolbox ver. 1.05; Gavaris 1988; Conser and Powers 1990) based on the recommendation of the 26th SARC (NEFSC 1998). This procedure compared relative abundance data at age from surveys to absolute estimates at age from VPA in a least squares calibration of terminal stock sizes (NRC 1997). Iterated VPA methods such as ADAPT do not assume separability, so the selection pattern emerges from the analysis. Past assessments of weakfish have used conventional VPA (Vaughan et al. 1991), separable VPA with auxiliary data (Gibson 1993), or Extended Survivors VPA (NEFSC 1998).

Estimates of stock size and F were made using the 1982-1999 catch at age matrix that consisted of ages 1-5 and a 6+ group. Terminal stock sizes were estimated for ages 1 through 6. Age 6 abundance was estimated so that F at age 5 could be calculated for 1998. Otherwise, F would only have been estimated for age 4 weakfish and F of other ages would be filled in by convention. Estimation of age 6 abundance involved a slight mismatch because age 6 indices were calibrated against 6+ VPA populations. This plus group has been a consistently small percentage of total catch and was unlikely to contain many fish over age 6. Other VPA conventions needed to complete the analysis were the assumptions that M was 0.25 and plus group F equaled F of the oldest true age. Fishing mortality of the oldest true age, other than in the terminal year, was estimated from the survival ratio of 3, 4, and 5 year old stock sizes. Inclusion of age 3 in this convention was a compromise because management measures reduced selectivity of age 3 fish over time. Terminal stock sizes and fishing mortality rates were not very sensitive to this convention. A sensitivity run using only ages 4 and 5 produced a terminal stock size 10% lower and fully recruited F 3% higher than the 3-5 run.

Initially, mean 1990-1993 otolith based weights at age were substituted for 1982-1989 scale weights, but calculated catch biomass (sum of estimated catch at age multiplied by mean weight at age) was lower for 1982-1989 than observed landings. Scale and otolith mean weights at age were available for 1989-1996 (Table A22 in NEFSC 1998) and annual scale mean weights at age during 1982-1989 were adjusted to otolith equivalents by multiplying them by otolith mean weight during 1989-1996 at age divided by scale mean weight at age during 1989-1996. Mean weight at age declined during 1982-1998 (Table 17). The product of catch at age and revised weights at otolith age provided a better match to observed landings (Table 18).

A total of 16 surveys (8 multiple age and 8 YOY), comprising 48 age-specific abundance indices, were available for tuning the VPA. Surveys were equally weighted. Initial VPA runs using all available indices produced an abrupt transition from low F at age 4 (0.19) to high F at age 5 (1.15) in 1998. The tuning set was reduced to include only indices from the New Jersey to North Carolina area (core indices) in order to remove this abrupt transition. Ages 4-6 from the SEAMAP spring survey and ages 5 and 6 from the NEFSC fall survey were pruned from the analysis because their catchability estimates' coefficients of variation exceeded 0.40. Fishery-dependent indices were dropped because the SARC believed sufficient fishery-independent surveys were available. The final SARC calibration (ADAPT run # 34) is referred to as the "core index" run. All surveys conducted in summer or fall and were tuned ahead to January 1 stock sizes, i.e., YOY surveys were shifted to age 1.

Uncertainty in terminal stock sizes and F rates was evaluated with bootstrapping (Efron 1982). Residuals from the original model fit were resampled randomly with replacement and added to the predicted indices to produce alternate realizations of the input indices. The model was fit 500 times to alternate index sets and outputs accumulated in frequency tables. Uncertainty was expressed as 80% confidence intervals directly from the cumulative bootstrap frequencies.

SSB, Fishing Mortality, Recruitment

Spawning stock biomass (SSB) increased to 21,500 MT in 1986, declined to around 7,000 MT during 1990-1993 and increased to about 39,000 MT by 1998 (Figure 1). Recruitment peaked at 69 million age 1 fish in 1985, declined to a low of 19 million in 1988, and increased to 40-70 million after 1992 (Figure 1). Eighty percent confidence intervals were 33,500-46,500 MT of SSB in 1998 (Figure 2) and 50.5-99.5 million recruits (Figure 3).

Mean partial recruitment during 1996-1998 was 0.09 for age 1, 0.23 for age 2, 0.55 for age 3, 0.94 for age 4, and 1.00 for ages 5 and above. It was not possible to determine the selection pattern on older weakfish because the plus group started at age 6. Directed F on weakfish age 4 and older fluctuated between 1.5 and 2.5 during 1982-1988 (omitting an anomalously low value in 1987), declined to 0.7-1.2 during 1989-1994, and then dropped to 0.2-0.3 afterwards (Figure 4). In 1998, average F of ages 4 and 5 equaled 0.21 (80% CI: 0.17-0.31; Figure 5); F equaled 0.18 at age 4 and 0.23 at age 5. Low F in the mid-1990's coincided with adoption of Amendments 2 and 3 to the *Interstate Management Plan for Weakfish*. Fully recruited F is below Amendment 3's long-term target of 0.50 (Lockhart et al. 1996). Abundance of age 6 and older weakfish reached the highest point of the time series in 1998 (Figure 6); expanded age structure is an objective of Amendment 3 (Lockhart et al. 1996). A summary of VPA results is found in Table 18 and detailed output from the core index run is in Appendix 1.

Stock and Recruitment

During 1982-1998, SSB varied seven-fold while recruitment varied three to four-fold (Figure 7) Poor year classes appeared more often when SSB was below 10,000 MT. A Ricker curve was fit to VPA based estimates of stock and recruitment (Figure 7). The slope at the origin was estimated at 7.78 (SE=1.10) age 1 weakfish per kilogram of SSB and the compensatory mortality parameter was estimated at 0.0000522 (SE=0.0000090) per MT SSB. There was a significant inverse correlation in the stock-recruit model residuals with a three year lag, indicating autocorrelation. Periodic forcing of reproductive success may lead to bias in estimated stock recruit parameters and the magnitude of this bias is related to life history and exploitation status (Armstrong and Shelton 1988). Recent research has indicated that SSB alone may be a biased indicator of reproductive potential in fish stocks including weakfish (Lowerre-Barbieri 1998, Marshall and Frank 1999). In view of this and the residual diagnostics noted above, biological reference points based on S-R properties should be interpreted cautiously.

Diagnostic and Retrospective Analysis

Survey residuals in the core index run indicated some serial patterns. Residuals of the NEFSC fall inshore (Figure 8) and North Carolina's Pamlico Sound (Figure 9) trawl surveys appeared random over time. Maryland's coastal bay (Figure 10) and Chesapeake Bay (Figure 11) YOY trawl surveys both exhibited negative residuals changing to positive. Delaware's small (Figure 12) and large trawl (Figure 13) surveys, New Jersey's ocean trawl survey (Figure 14), and Virginia's lower Chesapeake Bay trawl survey (Figure 15) exhibited mostly negative residuals in the 1980's, mostly positive residuals in the late 1980's through the early 1990's, and a tendency towards negative residuals in the mid- to late-1990's. Positive trends in residuals indicated that fitted tuning relationships between VPA populations and survey indices overestimated catchability in early years and underestimated it in later years.

Retrospective analysis indicated F was initially underestimated and abundance was overestimated (Table 19) - a trend consistent with rising catchability in the surveys. This tendency was inconsistent with NRC (1998) judgment that ADAPT generally underestimated stock size for increasing populations. Precision was moderate in the final core index run; CV's of terminal stock sizes ranged from 0.27 to 0.31 and CV's on survey catchability parameters ranged from 0.22 to 0.29.

BIOLOGICAL REFERENCE POINTS

Life History Parameters

Length and weight at otolith age were updated by Vaughan (1999) using von Bertalanffy growth curves and weight-length regressions of 1990-1998 data (Table 20). Natural mortality rate was 0.25. Ninety percent of age 1 and all older weakfish were mature (Lowerre-Barbieri 1994). Estimated longevity of weakfish was based on a single 17 year-old, but reference point models used a maximum age of 12 years since most weakfish in Lowerre-Barbieri et al. (1995; our only otolith based sample of "old" weakfish) were nearly 12 years old. Partial recruitment was 0.09 for age 1, 0.23 for age 2, 0.55 for age 3, 0.94 for age 4, and 1.00 for ages 5 and above. Proportions of F and M occurring prior to spawning were 0.5. Fishing mortality ranged from 0 to 2.0 in increments of 0.1.

Thompson-Bell Yield per Recruit Model

Amendment 3 to the ASMFC weakfish FMP established F = 0.50 as a target F to be reached by 2000 (Lockhart et al.1996). This level of F was believed to be low enough to allow weakfish to rebuild an extended age distribution and reestablish their abundance over their entire geographic range (Lockhart et al.1996). Past amendments used $F_{20\%}$ (0.34) as the target (Lockhart et al.1996).

The NMFS/NEFSC version of the Thompson-Bell yield per recruit (YPR) and spawning biomass per recruit (SSB/R) model was used to update estimates of traditional fishery reference points. Models used the mean 1996-1998 VPA selection pattern. Reference points $F_{0.1}$ and F_{max} were estimated at 0.18 and 0.27, respectively, and $F_{20\%}$ and $F_{30\%}$ equaled 0.50 and 0.31, respectively (Figure 16; Table 21). In 1998, F equaled 0.21; this value was between $F_{0.1}$ and F_{max}, provided nearly 40% of maximum spawning potential, and was below Amendment 3's target of 0.50.

Weakfish are indeterminate batch spawners, which may modify the interpretation of SSB/R (Lowerre-Barbieri 1998). Biological reference points based on SSB/R were likely overestimated because discard losses of age 0 weakfish in shrimp trawls were not accounted for. Although bycatch reduction devices (BRD) have been in widespread use in the south Atlantic shrimp trawl fishery for several years, discard mortality was not zero.

Shepherd Equilibrium Yield Model

Estimates of maximum sustainable yield (MSY), the fishing rate generating MSY (F_{msy}), and unfished SSB level were made using the VPA stock-recruit data, life history data and GENMOD implementation (Hightower and Lenarz 1989) of the Shepherd equilibrium yield approach (Shepherd 1982). The fishing rate resulting in stock collapse (F_{coll}) was also estimated. This approach linked yield and SSB based reference points to the S-R curve.

For the VPA selection pattern, MSY was estimated at 14,953 MT and F_{msy} was 0.60 (Figure 17; Table 22). Fishing mortality rate at 95% of MSY was 0.39, indicating high yields could be maintained well below F_{msy}. Stock collapse in the Shepherd model was estimated to occur at F_{coll} = 2.50. Unfished SSB was estimated at 70,966MT (Figure 17; Table 22) and the 1998 VPA estimate of SSB represented 55% of an unfished level.

STOCK STATUS SUMMARY

The Atlantic weakfish stock is at a high level of abundance and subject to low fishing mortality rates. Biomass has increased rapidly from a low point reached in the early 1990's. The VPA based estimate of SSB in 1998 was 55% of an unfished stock. Recruitment has been above average since 1993. Fishing mortality rate has been greatly reduced to 0.21 in 1998 and is below the long-term ASMFC target of 0.50. Retrospective analysis indicated F in 1998 was likely underestimated and abundance was overestimated. This directed F was slightly above $F_{0.1}$ (0.18) and below F_{max} (0.27), produced about 40% of MSP, and was well below F_{MSY} (0.60). The rapid rebuilding of the stock reflected high estimated compensatory reserve of over 7 age 1 recruits per kilogram of spawner. Stock resiliency may have been mis-estimated because 0 age group losses due to discards in the south Atlantic shrimp trawl fishery were not accounted for, potential bias in parameter estimates due to autocorrelation existed, and possible influence of age structure, indeterminate batch spawning, and other factors were not explicitly measured by SSB. Reduced F resulted in absolute and proportional increases in the abundance of weakfish age 6 and older that were consistent with ASMFC stock rebuilding objectives.

SARC COMMENTS

The SARC focused on working through problems with the catch at age matrix and reviewed multiple VPA runs and calculation of reference points. The catch at age matrix was of particular interest given the necessity of converting scale to otolith ages. Small sample sizes for older aged fish, pooling methodologies used for regional data, and assumptions about how discards were interpreted in length frequency distributions were questioned. The SARC determined that the catch-at-age matrix was corrupted by incorrect transformation of scale ages to otolith ages. A revised catch-at-age matrix was accepted by the SARC.

Sensitivity of the ADAPT VPA was investigated using numerous VPA runs. Initially, the SARC was presented with a VPA run including all coastwide survey indices. However, the SARC voiced concerns about short and long time series combinations and noted the importance of focusing on the geographical distribution of weakfish populations. The SARC accepted the core index VPA run; however, the SARC was concerned that an inappropriate message was sent to those states with omitted surveys. The SARC suggested that appropriate survey weighting might allow incorporation of indices from outside the core area. Retrospective VPA runs illustrated significant underestimation of F as time away from the terminal year increased.

The SARC concluded that information from the core index VPA should be used to calculate biological reference points and that figures illustrating the expanded size and age composition of weakfish would be useful for developing management advice.

RESEARCH RECOMMENDATIONS

Investigate source of the relatively large sum of products correction factor.

Obtain mean weights at age corresponding to the catch-weighted mean weight from the catch at age estimation process.

Review inputs to VPA, particularly CAA.

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Table A1. 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+**
1982	3.60	1.42	.33	.06	.01	.01	
1983	4	2.13	.7	.15	.04	.01	
1984	11.42	3.47	.87	.17	.04	.02	
1985	12.17	1.82	.29	.03	.01	.01	
1986	5.23	1.97	.24	.01			
1987	3.47	5.34	.78	.07	.02	.01	
1988	8.25	2.92	.64	.07	.01		
1989	10.39	1.28	.38	.05	.01		
1990	4.88	.89	.39	.03			
1991	2.60	1.33	.53	.04	.02		
1992	3.32	1.78	.54	.05	.02		
1993	1.28	1.53	.65	.08	.01		
1994	2.57	1.52	.88	.16	.04		
1995	39.34	4.71	4.23	.9	.22		
1996	4.60	3.03	1.26	.95	.35	.05	
1997	1.82	.87	.26	.12	.03		
1998	56.76	7.36	3.4	1.9	.79	.12	

Table A2. Mean number per tow of weakfish at age from SEAMAP ocean research trawl spring and fall surveys, Cape Hatteras, North Carolina, to Cape Canaveral, Florida. Fish were aged by application of the southern early and late age-length keys from samples of commercial and recreational landings.

Spring

		Age			
	n	0	1	2	TOTAL
1989	86	82.39	1.15	0.1	83.64
1990	105	23.76	0.75	0.07	24.58
1991	105	29.07	0.22	0.02	29.31
1992	105	47.06	3.15	0.12	50.33
1993	105	29.79	0.17		29.96
1994	105	2.79	0.09	0.01	2.89
1995	105	18.82	0.19	0.03	19.04
1996	105	14.92	1.34	0.23	16.49
1997		27.14	0.39	0.12	27.65
1998		84.75	6.55	0.26	91.56

Fall

		Age						
	n	0	1	2	3	4	5	TOTAL
1989	106	5.49	2.26	0.13	0.04	0.01		7.92
1990	91	3.38	0.94	0.04				4.35
1991	86	3.20	2.74	0.26	0.07	0.01		6.28
1992	94	1.04	1.41	0.26	0.02	0.01		2.75
1993	94	4.45	12.03	0.37	0.01			16.86
1994	94	21.22	5.63	0.54	0.23	0.03		27.67
1995	94	3.63	2.87	0.29	0.10	0.01		6.91
1996	94	9.22	4.16	2.61	0.26	0.12	0.03	15.79
1997		0.59	1.22	1.12	0.49	0.05		3.47
1998	94	1.81	4.67	3.24	0.64	0.37	0.03	10.76

Table A3. Mean number per tow at age of weakfish from the Connecticut DEP Long Island Sound trawl survey.

	Age					
Year	0	1	2	3	4	5
1984	2.61	0.57	0.32	0.04	0.04	0
1985	30.62	1.46	0.63	0.09	0.01	0
1986	66.25	1.14	0.18	0.03	0	0
1987	2.77	0.18	0.08	0.01	0.01	0
1988	2.80	0.09	0.03	0	0	0
1989	57.07	0.75	0.02	0	0	0
1990	22.15	1.52	0.12	0.04	0.03	0.01
1991	41.91	2.98	0.36	0.17	0.18	0.08
1992	15.25	0.51	0.10	0.08	0.10	0.05
1993	15.81	0.94	0.10	0.10	0.08	0.02
1994	64.90	2.55	0.26	0.11	0.04	0.00
1995	31.17	2.09	0.65	1.15	0.59	0.01
1996	71.29	5.79	0.47	0.50	0.76	0.26
1997	38.34	5.95	1.10	0.72	1.12	0.43
1998	15.55	3.34	0.09	0.28	0.47	0.19

Table A4. Mean number per tow of weakfish at age from stratified random New Jersey ocean trawl surveys (months of August and October). Fish were aged by application of annual age-length keys from pooled commercial and research samples.

	Age								
Year	0	1	2	3	4	5	Total	2-7+	4-7+
1988	26.01	1.94	0.36	0.27	0.03		28.61	0.66	0.03
1989	43.82	7.97	3.29	1.26	0.14		56.48	4.69	0.14
1990	14.71	4.15	7.91	1.78	0.35	0.08	28.98	10.12	0.43
1991	27.09	7.61	4.51	0.63	0.24	0.09	40.17	5.47	0.33
1992	5.95	3.19	8.42	3.09	0.58	0.14	21.37	12.23	0.72
1993	23.88	11.24	4.52	1	.32	.08	41.04	5.92	0.4
1994	37.14	22.50	30.98	5.60	1.01		97.23	37.59	1.01
1995	77.48	17.64	36.74	13.49	4.57	0.05	149.97	54.85	4.62
1996	46.27	11.89	6.62	9.81	7.65	1.57	83.81	25.65	9.22
1997	21.75	5.97	6.81	10.49	6.59	1.16	52.77	25.05	5.43
1998	3.04	3.89	2.19	2.60	1.56	0.29	13.57	6.64	1.85

Table A5. Mean number per nautical mile of weakfish at age from Delaware DFW surveys (March - December) in Delaware Bay. From 1966 - 1990, fish were aged using a pooled key; n = number of tows. Weakfish were aged individually using scales from 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	.01	0.00	0.00	0.00	0.00	187.40	4.62	0.00
1967	49	75.2	55.7	4.9	0.0	0.00	0.00	0.00	0.00	135.80	4.88	0.00
1968	36	68.1	48.7	6.2	0.1	0.00	0.00	0.00	0.00	123.10	6.29	0.00
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	16.95	6.96	5.01	1.19	0.25	0.10	0.18	0.16	31.20	8.66	0.52
1983	38	3.62	4.07	3.17	0.98	0.18	0.05	0.24	0.20	12.30	6.25	0.93
1984	46	3.02	5.27	5.67	2.23	0.51	0.19	0.22	0.14	16.90	9.13	1.39
1990	70	18.60	17.02	12.67	1.40	0.23	0.05	0.04	0.03	26.00	3.48	0.19
1991	72	22.83	16.07	13.19	1.56	0.43	0.10	0.00	0.00	54.19	4.27	0.00
1992	89	10.29	18.01	17.77	2.25	0.23	0.04	0.00	0.00	48.60	2.68	0.03
1993	83	13.15	38.09	42.34	6.98	0.78	0.14	0.00	0.00	101.50	29.80	0.50
1994	71	31.92	64.56	73.78	36.03	7.83	0.08	0.00	0.00	214.20	93.00	0.90
1995	88	35.74	39.98	87.23	19.85	8.27	0.11	0.00	0.00	191.10	74.70	5.50
1996	76	77.30	44.00	48.30	111.20	23.80	5.40	0.10	0.00	311.10	189.80	30.30
1997	85	36.44	33.41	25.00	13.87	34.60	2.96	0.47	0.00	146.75	76.90	38.30
1998	80	31.83	23.88	24.64	20.39	11.61	20.72	1.27	0.06	133.9	78.19	33.16

Table A6. Indices of age 0 and 1 weakfish from state research trawl surveys, Massachusetts to Florida.

YEAR	MADM	RIDFW	NYDEC 0	DEDFW 0	MDDNR COAST BAYS	MDDNR CHES BAY 0	VIMS 0	NCDMF 0	NCDMF 1	FLDEP 0
1982	35	2.84		11.49	18.9	0.2	10.9			
1983	48	16.5		4.47	1.9	0.84	10.85			
1984	8	23.95		6.67	1.1	0.13	6.05			
1985	774	5.64	1.52	9.25	2.9	0.98	37			
1986	111	5.65	0.29	12.79	7.7	0.37	4.6			
1987	0	15.62	0.33	5.82	1.5	0.31	17.8	16.48	50.57	
1988	0	10.06	0.11	4.73	0	0.21	21.8	96.42	34.4	
1989	73	2.84	0.57	11.11	1.7	0.14	21.3	15.63	13.24	
1990	0	16.5	0.26	8.73	4	0.59	30.01	49.55	17.05	0.05
1991	3	23.95	4.43	20.07	4.3	0.38	15.32	36.48	14.55	0.5
1992	1	5.64	1.2	14.72	4.4	1.18	15.91	42.31	19.46	0.55
1993	0	5.65	0.43	14.79	2.1	0.73	15.42	9.49	67.28	0.75
1994	8	15.62	1.72	11.47	4.3	0.92	7	68.1	70.69	0.3
1995	32	2.18	0.85	13.49	10.3	1.96	11	38.3	42.9	0.1
1996	13	38.57	4.74	12.13	6.72	1.8	7.4	70.8	31.8	0.3
1997	25	25.78	2.68	15.4	7.05	2.41	14.8	32.8	55.7	0.2
1998	14	4.17	9.9	11.35	17.1	1.1	9.9	72.4	23.3	0

Table A7. Fishery-dependent indices of abundance: MRFSS catch-per-trip-at-age and Florida DEP commercial catch per unit effort index.

	MRFSS				
	Age				FL DEP
YEAR	2	3	4	5+	
1982	0.04	0.41	0.23	0.29	
1983	1.20	0.76	0.27	0.08	
1984	1.05	0.61	0.22	0.07	
1985	0.76	0.39	0.15	0.06	
1986	1.22	0.24	0.04	0.02	10.0
1987	1.04	0.32	0.08	0.01	10.5
1988	1.24	1.35	0.36	0.08	9.5
1989	0.42	0.30	0.09	0.02	10.8
1990	0.39	0.21	0.11	0.03	10.5
1991	0.47	0.42	0.24	0.07	9.5
1992	0.30	0.29	0.24	0.09	10.0
1993	0.47	0.46	0.28	0.08	11.7
1994	0.79	1.40	0.67	0.03	9.5
1995	0.64	1.43	0.98	0.09	7.0
1996	0.27	1.03	2.10	0.65	5.5
1997	0.33	1.16	1.90	0.63	10.0
1998	0.41	1.45	2.37	0.79	12.0

Table A8. MRFSS estimates of recreational weakfish numerical catch, number harvested, and weight (kg) harvested during 1981-1998. PSE = proportional standard error. C / 100n is an expression of sampling intensity used by the SARC. Sampling is judged adequate if catch (C, includes 20% of discards) is less than 200 MT per 100 fish sampled.

Year	Numerical Catch	PSE	Number harvested	PSE	Weight harvested (MT)	PSE	C / 100n
1982	2,045,551	14.2	1,854,970	14.8	3,758	15.3	881.3
1983	5,916,269	12.4	5,642,950	12.8	5,321	12.3	327.9
1984	3,769,040	12.9	3,520,811	13.7	3,181	21.1	520.7
1985	2,775,824	9.3	2,419,670	9.4	2,490	10.6	154.1
1986	10,973,586	7.4	8,664,122	8.3	4,600	9.2	125.5
1987	5,719,807	9.8	4,871,532	11.0	3,062	14.3	161.2
1988	6,446,383	11.3	5,626,268	11.9	2,872	11.2	151.4
1989	1,674,568	7.3	1,495,391	8.0	988	7.7	69.7
1990	1,671,808	6.0	1,232,253	8.1	611	8.1	42.8
1991	2,601,480	7.2	1,812,691	7.4	966	7.4	50.9
1992	1,667,809	6.9	960,151	8.5	635	8.5	64.7
1993	2,218,559	6.4	1,079,275	9.3	500	9.3	58.9
1994	4,928,951	5.3	1,826,495	9.5	814	9.5	66.3
1995	5,696,423	5.5	1,588,079	8.7	842	8.7	97.1
1996	7,306,298	5.6	2,269,330	10.5	1,327	10.5	104.2
1997	6,832,363	4.6	2,815,654	7.5	1,675	7.5	86.3
1998	5,700,644	4.9	2,389,594	7.6	1,835	7.6	103.0

Table A9. MRFSS estimates of numbers of weakfish harvested by state during 1982-1998.

YEAR	RI	CT	NY	NJ	DE	MD	VA	NC	SC	GA	FL
1982	18614	11769	88234	104066	217821	440146	715892	200045	17342		40161
1983	74608	6363	36394	2857093	1009899	595286	354846	387871	6807	17209	293303
1984	0	1561	20133	1026043	593107	104057	782848	489468	7836		493521
1985	17092	2874	89538	812839	365693	305799	505223	217671	61788	4811	36340
1986	4595	7315	34582	2500622	914489	1947394	2418046	611363	78315	18130	129270
1987		777	7447	1666619	638342	824833	1015413	624160	18841	10802	64248
1988			13215	642032	974712	1163766	2297053	438148	1834	0	95509
1989			6436	303289	254170	226505	357864	190193	6810	8245	141880
1990	407		3057	216385	179837	370528	286458	91300	8027	2273	73963
1991		18695	28072	545665	366464	221242	351947	140826	19616	4954	115210
1992	9624	434	5282	311659	100561	137260	265645	35490	23501	1751	68943
1993		2460	12610	203915	235312	238768	108392	106737	7360	14752	148968
1994			1872	591571	300211	332846	169740	177965	46858	718	204714
1995	1568		22310	671850	406730	88695	226682	62475	29897	22437	55435
1996			16320	1104251	633920	183408	193861	90704	5695	5413	35757
1997	1415	517	112986	1028334	647529	162900	557809	184954	2039	44202	72970
1998		2183	21392	920558	455603	290051	463525	191181	15838	718	24678

Table A10. Commercial landings of weakfish (MT) during 1982-1998.

Year	Landings
1982	8,835
1983	7,926
1984	8,969
1985	7,689
1986	9,611
1987	7,743
1988	9,311
1989	6,424
1990	4,265
1991	3,943
1992	3,381
1993	3,108
1994	2,873
1995	3,220
1996	3,290
1997	3,310
1998	3,821

Table A11. Commercial landings (MT) of weakfish by state during 1982-1999.

YEAR	MA	RI	CT	NY	NJ	DE	MD	VA	NC	SC	GA	FLA EAST
1982	10	80	12	570	941	587	113	975	5467	0	0	80
1983	3	74	19	386	986	409	177	1176	4641	0	1	53
1984	2	76	14	220	1248	355	147	957	5892	0	0	57
1985	1	74	13	175	1374	449	143	944	4453	0	0	60
1986	3	58	6	163	1455	328	153	905	6491	0	0	49
1987	1	36	13	149	950	262	166	890	5220	0	0	56
1988	2	9	1	56	1058	241	378	668	6846	0	0	52
1989	1	4	1	47	662	240	337	465	4588	0	0	78
1990	1	11	1	9	439	278	300	532	2632	0	1	62
1991	1	11	10	51	533	226	149	481	2408	0	0	75
1992	1	14	2	76	427	164	175	249	2206	0	0	67
1993	1	5	1	40	379	88	82	493	1955	0	0	65
1994	0	8	5	45	315	119	129	587	1583	0	0	81
1995	0	24	3	78	393	128	31	674	1866	0	0	23
1996	0	20	3	166	373	141	60	720	1804	0	0	2
1997	0	14	5	153	470	254	87	707	1615	0	0	5
1998	0	35	7	227	819	251	111	845	1521	0	0	5

Table A12. Gear-specific commercial market (food) landings (C, in metric tons), number of lengths sampled (n) and adequacy of commercial weakfish sampling of lengths (C/n) for characterizing size distribution . Criteria used by NEFSC SARC to judge adequacy of sampling intensity is to note if landings are less than 200 t per 100 fish sampled.

	Gill net			Trawl			Pound net			Haul seine		
Year	C	n	C / 100n	C	n	C / 100n	C	n	C / 100n	C	n	C / 100n
1982	1863.2	25	7852.8	4793.2	4630	103.5	1151.2	590	195.1	976.4	1030	94.8
1983	2196.7	2624	83.7	3802.7	8016	47.4	1063.5	678	156.9	796.3	1617	49.2
1984	3040.3	6443	47.2	4193.7	8327	50.4	814.9	795	102.5	881.2	1911	46.1
1985	2774.2	5021	55.3	3209.0	9369	34.3	815.7	667	122.3	789.7	1784	44.3
1986	4087.9	5990	68.2	3884.9	10263	37.1	594.6	1856	32.0	926.6	1080	85.8
1987	3622.8	8954	40.5	2882.7	10846	26.6	738.3	1097	67.3	519.1	3228	16.1
1988	4350.5	7675	56.7	3275.9	7915	41.4	692.0	1639	42.2	779.4	1876	41.5
1989	3097.9	9378	33.0	2717.1	6545	41.5	230.3	2814	8.2	285.5	1767	16.2
1990	1873.2	8673	21.6	1553.6	7614	20.4	302.9	4239	7.1	506.9	3678	13.8
1991	1770.7	14383	12.3	1640.1	7449	22.0	258.4	3341	7.7	238.8	2738	8.7
1992	1421.5	18305	7.8	1634.6	7485	21.8	91.2	4111	2.2	215.3	2699	8.0
1993	1449.9	16978	8.5	1174.3	8388	14.0	250.4	3491	7.2	207.5	3067	6.8
1994	1522.0	11352	13.4	644.2	3936	16.4	393.0	8057	4.9	205.5	2744	7.5
1995	1513.9	11948	12.7	785.4	2977	26.4	581.9	15448	3.8	256.3	3584	7.2
1996	1851.7	12690	14.6	574.4	2620	21.9	563.0	14861	3.8	226.1	6415	3.5
1997	1614.6	13409	12.0	790.1	5231	15.1	499.5	6234	8.0	303.2	6930	4.4
1998	1794.7	6574	27.3	913.4	2987	30.6	703.5	10146	6.9	261.8	4984	5.3

Note: Purse-seine landings for 1994 (late period) was 79.3 t, n = 98, so C/100n = 80.9 t.

Table A13. Gear-specific scrap (bait) landings (C, in metric tons), number of lengths sampled (n), and adequacy of commercial weakfish sampling of lengths (C/n) for characterizing size distribution . Criteria used by NEFSC SARC to judge adequacy of sampling intensity is to note if landings are less than 200 t 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	1155	6.1	95.1	1723	5.5
1983	190.7	923	20.7	62.1	754	8.2	100.1	2017	5.0
1984	216.0	544	39.7	66.2	1046	6.3	106.5	3000	3.5
1985	391.5	1250	31.3	60.4	251	24.1	72.2	1836	3.9
1986	523.3	975	53.7	41.0	2102	2.0	85.3	3087	2.8
1987	737.1	2304	32.0	72.6	2544	2.9	72.5	1953	3.7
1988	983.3	2114	46.5	38.2	1144	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	1682	18.8	23.3	862	2.7	52.3	594	8.8
1991	188.7	2433	7.8	63.4	202	31.4	68.8	3097	2.2
1992	161.0	980	16.4	4.2	186	2.3	74.4	246	30.2
1993	195.4	1315	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	-	-	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
1997	0	-	-	30.8	11	280.0	4.4	42	10.4
1998	2.3	116	19.8	46.7	11	424.5	4.2	10	42.0

TableA14a. Recreational harvest and discards (1,000s of fish) and commercial landings (kg) for January - June, 1982-1998.
SA = South Atlantic; MA = Mid-Atlantic.

	Recreational		South Atlantic commercial					Mid-Atlantic commercial					Scrap		
Year	SA	MA	Gill net	Trawl	Pound	Haul seine	Hook & line	Gill net	Trawl	Pound	Haul seine	Hook & line	Trawl	Pound	Haul seine
1982	168.1	337.7	530.5	2859.6	40.1	147.6	5.2	529.3	430.6	400.4	77.4	20.7	540.2	28.0	26.8
1983	166.0	217.7	858.9	2242.0	30.1	210.7	3.9	299.5	276.2	325.3	20.3	18.3	114.8	21.2	46.0
1984	502.0	578.8	1514.9	2452.1	55.9	228.5	2.3	187.0	129.9	197.2	16.6	8.5	128.4	22.9	46.1
1985	223.5	466.3	1306.8	1312.8	61.6	334.8	2.2	233.6	231.9	175.2	25.9	20.8	215.5	21.2	34.6
1986	547.5	1160.7	2528.0	2115.6	21.4	457.6	1.6	229.7	211.6	125.5	8.1	20.0	384.6	12.3	40.2
1987	77.1	622.7	2075.8	1594.7	21.8	136.0	16.7	221.9	185.0	110.5	5.7	26.3	502.9	19.9	22.9
1988	132.2	2894.8	2912.3	2096.0	32.3	184.3	2.1	259.3	182.9	168.0	23.9	31.1	922.9	16.8	17.8
1989	156.1	546.6	1996.5	1346.0	12.6	56.1	2.2	225.3	139.3	78.8	12.2	15.3	67.2	9.0	9.4
1990	82.5	67.0	101.1	604.5	18.6	156.6	5.4	256.4	22.7	122.4	6.5	2.9	191.7	12.2	42.4
1991	102.4	526.1	783.2	969.0	10.5	25.9	4.9	261.8	47.2	89.8	5.6	5.4	178.0	28.8	6.8
1992	50.3	234.7	695.9	967.4	2.6	17.8	5.2	303.8	24.4	59.1	13.3	3.9	91.4	1.5	6.5
1993	101.4	95.9	701.8	776.7	2.2	31.0	2.6	161.4	10.4	35.4	7.1	3.6	159.9	6.4	0.6
1994	203.0	179.1	830.7	284.6	6.7	55.2	1.0	190.2	10.4	77.2	16.8	4.0	28.4	5.0	2.7
1995	81.9	496.8	929.6	312.7	22.7	102.5	1.8	101.2	4.2	118.4	17.2	11.0	0.0	18.2	0.8
1996	67.9	688.8	1201.7	36.9	23.6	107.6	1.0	182.5	20.0	134.2	12.1	11.9	0.0	21.5	34.4
1997	142.0	750.2	669.1	288.8	34.2	114.5	1.4	361.8	10.8	122.1	33.4	24.1	0.0	18.6	3.3
1998	99.1	814.9	877.9	206.7	36.7	111.4	2.8	340.3	28.5	208.9	26.9	38.9	0.6	30.1	3.4

Table A14b. Recreational harvest and discards (1,000s of fish) and commercial landings (kg) for July-December, 1982-1998.
SA = South Atlantic; MA = Mid-Atlantic.

	Recreational		South Atlantic commercial					Mid-Atlantic commercial					Scrap		
Year	SA	MA	Gill net	Trawl	Pound	Haul seine	Hook & line	Gill net	Trawl	Pound	Haul seine	Hook & line	Trawl	Pound	Haul seine
1982	98.9	1287.4	152.7	1000.7	136.6	677.5	1.8	652.4	506.7	575.2	74.8	23.5	91.8	42.1	68.3
1983	545.6	4768.2	253.2	472.4	87.7	539.4	2.6	787.1	815.6	621.3	26.6	42.7	76.1	41.0	54.1
1984	493.9	1995.7	444.8	532.1	117.2	606.5	1.0	896.2	1004.0	445.3	30.4	27.2	87.7	43.4	60.6
1985	99.8	1701.3	364.5	617.7	155.0	364.4	1.1	871.8	1049.5	424.6	65.3	79.3	176.3	39.3	37.7
1986	365.6	7052.3	410.0	467.5	102.6	441.2	0.3	923.9	1093.6	345.7	20.4	94.9	139.2	28.7	45.2
1987	658.2	3683.1	582.3	450.3	210.0	356.4	6.5	746.1	655.3	396.7	21.4	101.2	234.9	52.8	49.6
1988	426.2	2337.2	566.9	320.3	245.5	543.4	1.0	615.9	679.5	246.8	28.6	179.0	61.3	21.5	34.6
1989	198.0	630.5	349.3	645.3	54.6	205.6	2.5	529.5	588.9	84.6	11.8	73.4	72.7	7.9	20.9
1990	97.8	1072.9	169.5	327.9	69.5	333.6	2.0	439.9	599.9	92.7	10.7	18.5	125.3	11.1	10.0
1991	187.6	1154.3	218.5	227.5	58.3	185.1	2.0	508.8	397.8	100.0	22.3	22.7	10.9	34.7	62.1
1992	93.7	723.0	181.4	214.5	19.1	179.3	1.9	339.3	429.8	155.8	16.4	17.8	69.7	2.7	68.0
1993	198.4	911.4	235.2	112.8	13.2	145.4	2.5	352.7	275.4	199.9	24.2	19.1	35.6	5.5	7.3
1994	268.7	1796.2	195.4	134.4	31.0	125.8	2.2	307.1	215.4	278.5	7.9	25.1	10.9	17.1	4.0
1995	132.1	1710.7	245.5	107.2	33.7	134.0	3.1	239.1	362.0	407.6	2.9	43.0	0.0	7.0	0.3
1996	102.9	2496.7	174.7	141.4	21.5	99.6	0.6	294.5	376.6	384.3	7.1	35.1	7.4	15.4	12.2
1997	219.0	2499.5	228.5	113.9	36.9	133.2	1.7	356.7	377.5	306.8	22.5	47.0	0.0	12.2	1.1
1998	169.5	1965.1	158.6	13.9	12.0	106.7	1.4	419.5	665.1	446.5	17.1	52.1	1.7	16.6	0.9

Purse-seine landings in Mid-Atlantic for 1984 were 174,900 lbs.

Table A15a. Weakfish mean weight (kg) by gear for January-June, 1982-1998. SA = South Atlantic; MA = Mid-Atlantic.

	Recreational		South Atlantic commercial					Mid-Atlantic commercial					Scrap		
Year	SA	MA	Gill net	Trawl	Pound	Haul seine	Hook & line	Gill net	Trawl	Pound	Haul seine	Hook & line	Trawl	Pound	Haul seine
1982	0.48	2.99	0.60	0.65	0.32	0.27	0.48	0.60	2.99	0.32	0.27	2.99	0.10	0.10	0.12
1983	0.47	1.68	0.60	0.56	0.20	0.21	0.47	0.60	3.99	0.20	0.21	1.68	0.10	0.10	0.10
1984	0.28	1.12	0.98	0.28	0.25	0.32	0.28	0.98	2.10	0.25	0.32	1.12	0.09	0.10	0.09
1985	0.26	0.51	0.66	0.25	0.25	0.31	0.26	0.66	0.20	0.25	0.31	0.51	0.11	0.13	0.12
1986	0.37	0.27	0.60	0.31	0.24	0.30	0.37	0.60	0.21	0.37	0.30	0.27	0.10	0.10	0.10
1987	0.29	0.31	0.51	0.27	0.29	0.30	0.29	0.51	0.22	0.36	0.30	0.31	0.10	0.10	0.10
1988	0.43	0.44	0.85	0.21	0.25	0.32	0.43	0.85	0.24	0.46	0.32	0.44	0.10	0.11	0.13
1989	0.28	0.60	0.77	0.50	0.25	0.44	0.28	1.04	0.24	0.56	0.42	0.60	0.09	0.10	0.09
1990	0.28	0.69	0.68	0.32	0.24	0.19	0.28	0.94	0.24	0.34	0.41	0.69	0.08	0.10	0.09
1991	0.29	0.51	0.31	0.18	0.27	0.20	0.29	0.73	0.24	0.24	0.71	0.51	0.08	0.10	0.07
1992	0.42	0.33	0.30	0.31	0.22	0.22	0.42	0.75	0.24	0.22	0.62	0.33	0.10	0.10	0.07
1993	0.31	0.62	0.29	0.25	0.21	0.17	0.31	0.86	0.24	0.27	0.44	0.62	0.12	0.10	0.08
1994	0.35	0.37	0.41	0.52	0.29	0.23	0.35	0.68	0.24	0.17	0.30	0.37	0.09	0.13	0.09
1995	0.47	0.52	0.39	0.25	0.29	0.29	0.46	0.89	0.24	0.20	0.43	0.52	0.12	0.10	0.10
1996	0.46	0.54	0.52	0.71	0.31	0.24	0.46	0.73	0.24	0.27	0.26	0.54	0.13	0.10	0.10
1997	0.42	0.51	0.45	0.56	0.35	0.21	0.42	0.63	0.24	0.28	0.28	0.51	0.25	0.10	0.12
1998	0.46	0.60	0.59	0.73	0.30	0.36	0.46	0.78	0.24	0.32	0.30	0.60	0.40	0.10	0.12

Table A15b. Weakfish mean weight (kg) by gear for July-December, 1982-1998. SA = South Atlantic; MA = Mid-Atlantic.

	Recreational		South Atlantic commercial					Mid-Atlantic commercial					Scrap		
Year	SA	MA	Gill net	Trawl	Pound	Haul seine	Hook & line	Gill net	Trawl	Pound	Haul seine	Hook & line	Trawl	Pound	Haul seine
1982	0.69	1.85	0.75	0.20	0.31	0.28	0.69	0.75	0.59	0.31	0.28	1.85	0.10	0.12	0.13
1983	0.37	0.76	0.75	0.21	0.27	0.25	0.37	0.75	0.39	0.27	0.25	0.76	0.10	0.11	0.12
1984	0.21	0.77	0.44	0.23	0.25	0.25	0.21	0.44	0.47	0.25	0.25	0.77	0.14	0.12	0.11
1985	0.91	0.91	0.37	0.20	0.30	0.24	0.91	0.37	0.46	0.30	0.24	0.91	0.09	0.12	0.11
1986	0.34	0.45	0.46	0.28	0.25	0.24	0.34	0.46	0.54	0.25	0.24	0.45	0.11	0.11	0.11
1987	0.53	0.61	0.69	0.27	0.24	0.25	0.53	0.69	0.53	0.34	0.25	0.61	0.12	0.12	0.12
1988	0.35	0.65	0.89	0.25	0.29	0.28	0.35	0.89	0.69	0.30	0.28	0.65	0.09	0.12	0.11
1989	0.35	0.75	0.46	0.40	0.27	0.27	0.35	0.64	0.57	0.26	0.32	0.75	0.11	0.11	0.12
1990	0.42	0.45	0.33	0.20	0.24	0.24	0.42	0.49	0.28	0.21	0.29	0.45	0.10	0.11	0.11
1991	0.44	0.54	0.31	0.21	0.23	0.25	0.44	0.52	0.49	0.23	0.28	0.54	0.11	0.11	0.09
1992	0.38	0.86	0.46	0.26	0.23	0.25	0.38	0.49	0.42	0.19	0.23	0.86	0.14	0.11	0.12
1993	0.35	0.52	0.34	0.21	0.24	0.25	0.35	0.52	0.47	0.24	0.27	0.52	0.11	0.11	0.11
1994	0.42	0.50	0.34	0.24	0.29	0.33	0.42	0.60	0.47	0.20	0.17	0.50	0.21	0.12	0.12
1995	0.57	0.56	0.34	0.32	0.29	0.25	0.57	0.68	0.53	0.25	0.20	0.56	0.21	0.11	0.12
1996	0.47	0.63	0.63	0.38	0.29	0.22	0.47	0.59	0.36	0.24	0.21	0.63	0.22	0.11	0.12
1997	0.42	0.64	0.59	0.34	0.28	0.20	0.42	0.58	0.34	0.35	0.21	0.64	0.16	0.11	0.10
1998	0.48	0.79	0.68	0.42	0.23	0.26	0.48	0.77	0.34	0.32	0.27	0.79	0.23	0.11	0.11

[b] Mean weight for purse-seine landings in late 1984 were 3.38 kg.

Table A16. Catch at age (1,000s).

	Age						
Year	1	2	3	4	5	6+	Total 1-6+
1982	7893	11794	5419	2774	720	639	29239
1983	6431	121000	5702	2775	567	424	28000
1984	7533	13892	6437	3040	483	254	31640
1985	12790	10690	3134	1165	212	55	28046
1986	17032	15000	4815	1816	262	52	38978
1987	14976	13533	4254	1478	144	11	34396
1988	6952	15443	10456	6058	1042	69	40020
1989	2246	4796	4307	2918	625	84	14975
1990	8895	4537	2012	1200	590	89	17323
1991	9104	5460	2686	1355	459	56	19120
1992	4306	5684	2176	1252	527	65	14009
1993	3738	5769	2127	1134	400	48	13216
1994	3164	2876	3001	1363	199	38	10641
1995	3471	3096	3383	1580	197	54	11781
1996	1483	2056	4108	2982	1348	100	12076
1997	970	1552	2559	5035	1468	397	11981
1998	835	1709	3535	1903	2827	870	11679

Table A17. Mean weight (kg) at age on January 1.

	Age					
Year	1	2	3	4	5	6+
1982	0.106	0.212	0.307	0.483	1.076	3.033
1983	0.078	0.190	0.368	0.885	1.395	2.862
1984	0.095	0.189	0.379	0.758	1.583	2.536
1985	0.77	0.267	0.579	1.235	1.748	3.055
1986	0.152	0.262	0.758	1.759	2.819	3.173
1987	0.087	0.236	0.524	1.234	2.127	2.536
1988	0.090	0.179	0.398	0.796	1.494	3.026
1989	0.109	0.186	0.383	0.769	1.417	3.348
1990	0.072	0.145	0.408	0.955	1.263	1.710
1991	0.086	0.192	0.333	0.908	1.686	2.332
1992	0.052	0.162	0.434	0.962	1.794	4.036
1993	0.048	0.142	0.253	0.616	1.212	1.710
1994	0.106	0.189	0.339	0.453	0.813	1.710
1995	0.110	0.188	0.363	0.528	0.788	0.545
1996	0.110	0.204	0.332	0.497	0.835	2.204
1997	0.077	0.181	0.333	0.488	0.744	1.194
1998	0.107	0.170	0.303	0.492	0.719	1.314

Table A18.- Atlantic Weakfish ADAPT VPA Summary for Core Index Run. 4-5 F is directed F, the mean F of ages 4-5. Weights are in metric tons. Landings are observed weight of catch and catch biomass is calculated from catch at age and mean weight at age.

Year	Fishing mortality at age							Landings	Age 1000s		Catch Biomass
	1	2	3	4	5	6+	4-5 F	1000s		SSB	
1982	0.24	0.65	0.80	1.43	1.54	1.54	1.49	12607.5	42308	12599	12689
1983	0.21	0.75	0.84	1.65	1.81	1.81	1.73	13304.0	38597	11056	13667
1984	0.24	1.04	1.44	2.27	2.78	2.78	2.53	12166.3	40310	8991	14423
1985	0.27	0.67	0.75	1.38	1.48	1.48	1.43	10244.0	61560	12172	14297
1986	0.33	0.62	0.81	1.78	1.98	1.98	1.88	14410.0	68828	21543	23022
1987	0.39	0.51	0.38	0.68	0.69	0.69	0.69	10855.6	52815	19595	10413
1988	0.39	0.99	1.06	1.83	2.06	2.06	1.95	12254.0	24359	12564	20016
1989	0.14	0.55	0.92	1.14	1.19	1.19	1.17	7432.5	18888	8470	8819
1990	0.49	0.52	0.50	0.78	0.80	0.80	0.79	4910.5	25988	7155	6083
1991	0.44	0.69	0.72	0.83	0.86	0.86	0.85	4988.0	28950	7399	7426
1992	0.14	0.59	0.71	1.01	1.05	1.05	1.03	4097.7	38516	7192	6361
1993	0.11	0.29	0.48	1.20	1.26	1.26	1.23	3705.4	42291	6897	3594
1994	0.05	0.12	0.25	0.72	0.73	0.73	0.73	3902.7	70665	16321	4280
1995	0.10	0.07	0.21	0.21	0.22	0.22	0.22	4480.9	40045	23258	3605
1996	0.03	0.09	0.13	0.30	0.30	0.30	0.30	4998.7	55479	30589	6600
1997	0.02	0.04	0.16	0.25	0.25	0.25	0.25	5417.9	51689	32550	5884
1998	0.02	0.05	0.14	0.18	0.23	0.23	0.21	6159.1	53970	38863	6985
1999									68230		

Table A19. Atlantic weakfish ADAPT VPA core index run number 34 retrospective pattern summary.

Terminal Year of F Estimate

Data year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1994	1.49	1.73	2.52	1.43	1.88	0.68	1.91	1.09	0.68	0.63	0.56	0.36	0.15					
1995	1.49	1.73	2.52	1.43	1.88	0.68	1.94	1.15	0.76	0.78	0.86	0.78	0.30	0.12				
1996	1.49	1.73	2.52	1.43	1.88	0.68	1.95	1.16	0.78	0.83	0.98	1.07	0.53	0.14	0.18			
1997	1.49	1.73	2.52	1.43	1.88	0.68	1.95	1.16	0.78	0.84	1.00	1.11	0.58	0.16	0.20	0.23		
1998	1.49	1.73	2.52	1.43	1.88	0.68	1.95	1.17	0.79	0.85	1.03	1.23	0.73	0.22	0.30	0.25	0.20	

Terminal Year of SSB Estimate

Data Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1994	12599	11057	8993	12185	21619	19738	12892	9177	8420	10304	12147	12417	22378					
1995	12599	11056	8992	12175	21560	19628	12640	8634	7449	8327	8911	9514	20088	30557				
1996	12599	11056	8991	12173	21547	19604	12583	8512	7231	7639	8010	8854	19921	29615	42001			
1997	12599	11056	8991	12173	21547	19601	12577	8499	7207	7562	7749	8311	18748	27090	35741	38296		
1998	12599	11056	8991	12172	21543	19595	12564	8470	7155	7399	7192	6897	16321	23258	30589	32550	38863	

Terminal Year of Recruitment Estimate

Data Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1994	42309	38600	40332	61657	69176	53363	25615	21202	31081	40739	44990	58727	51907	59618				
1995	42309	38598	40315	61583	68909	52942	24651	19422	27156	35169	43279	58396	59497	68358	113544			
1996	42308	38597	40311	61566	68849	52848	24435	19026	26288	30544	48494	56483	63701	58837	95777	82130		
1997	42308	38597	40311	61564	68842	52837	24411	18982	26192	30035	45306	54012	62447	47844	63859	64430	59814	
1998	42308	38597	40310	61560	68828	52815	24359	18888	25988	28950	38516	42291	70665	40045	55479	51689	53970	68230

Table A20. Life history parameters of Atlantic Coast weakfish based on 1990-1998 otolith data used to estimate biological reference points.

Age	Length (cm)	Weight (kg)	M	Proportion Mature	Selectivity
1	20.28	0.12	0.25	0.90	0.09
2	27.11	0.26	0.25	1.00	0.23
3	33.95	0.43	0.25	1.00	0.55
4	40.78	0.63	0.25	1.00	1.00
5	47.61	1.05	0.25	1.00	1.00
6	54.45	1.61	0.25	1.00	1.00
7	61.28	2.98	0.25	1.00	1.00
8	68.12	4.92	0.25	1.00	1.00
9	74.95	5.00	0.25	1.00	1.00
10	81.78	5.68	0.25	1.00	1.00
11	88.62	5.80	0.25	1.00	1.00
12	95.45	6.00	0.25	1.00	1.00

Table A21. Thompson-Bell model yield per recruit (kg) and spawner biomass per recruit (kg) estimates for Atlantic Coast weakfish. Proportions of F and M before spawning equaled 0.5.

F	Yield per recruit	SSB per recruit	% MSP
0.0	0.000	4.36	100.00
0.1	0.241	2.72	62.41
0.18 ($F_{0.1}$)	0.302	1.99	45.66
0.2	0.309	1.84	42.28
0.27 (F_{max})	0.318	1.45	33.27
0.3	0.317	1.35	30.90
0.31 ($F_{30\%}$)	0.316	1.31	30.00
0.4	0.307	1.05	24.09
0.5 ($F_{20\%}$)	0.293	0.86	19.77
0.6	0.280	0.74	16.87
0.7	0.269	0.65	14.82
0.8	0.260	0.58	13.30
0.9	0.252	0.53	12.13
1.0	0.246	0.49	11.19
1.1	0.240	0.45	10.43
1.2	0.235	0.43	9.79
1.3	0.231	0.40	9.25
1.4	0.227	0.38	8.77
1.5	0.224	0.36	8.36
1.6	0.221	0.35	7.99
1.7	0.218	0.33	7.66
1.8	0.215	0.32	7.36
1.9	0.212	0.31	7.09
2.0	0.210	0.30	6.84

Figure A1. Atlantic Weakfish Recruitment and Spawning Biomass from ADAPT VPA

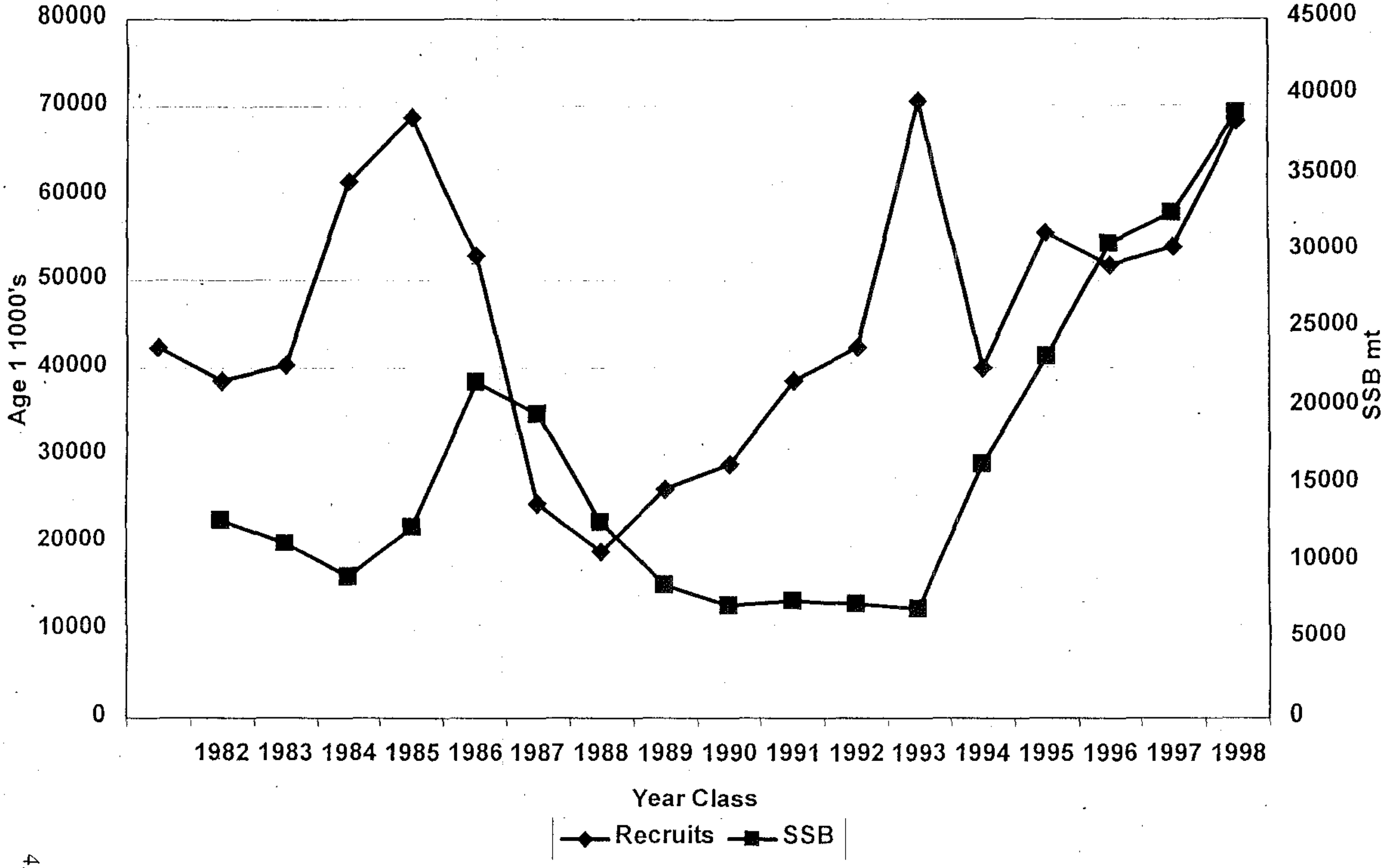


Figure A2. Atlantic Weakfish Landings and Fully Recruited F from ADAPT VPA

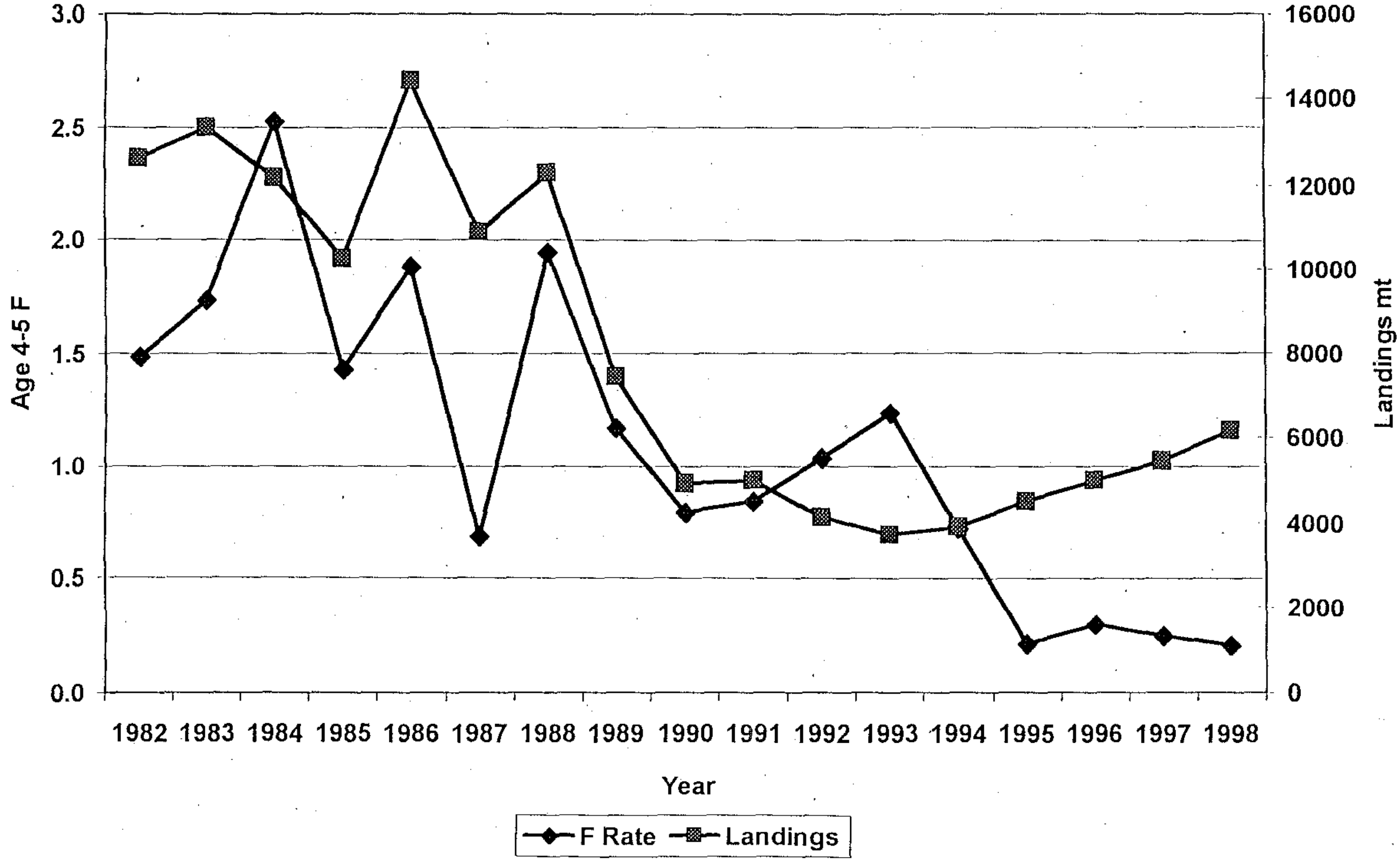


Figure A3. Precision of 1998 Weakfish Fishing Mortality Rate Estimate

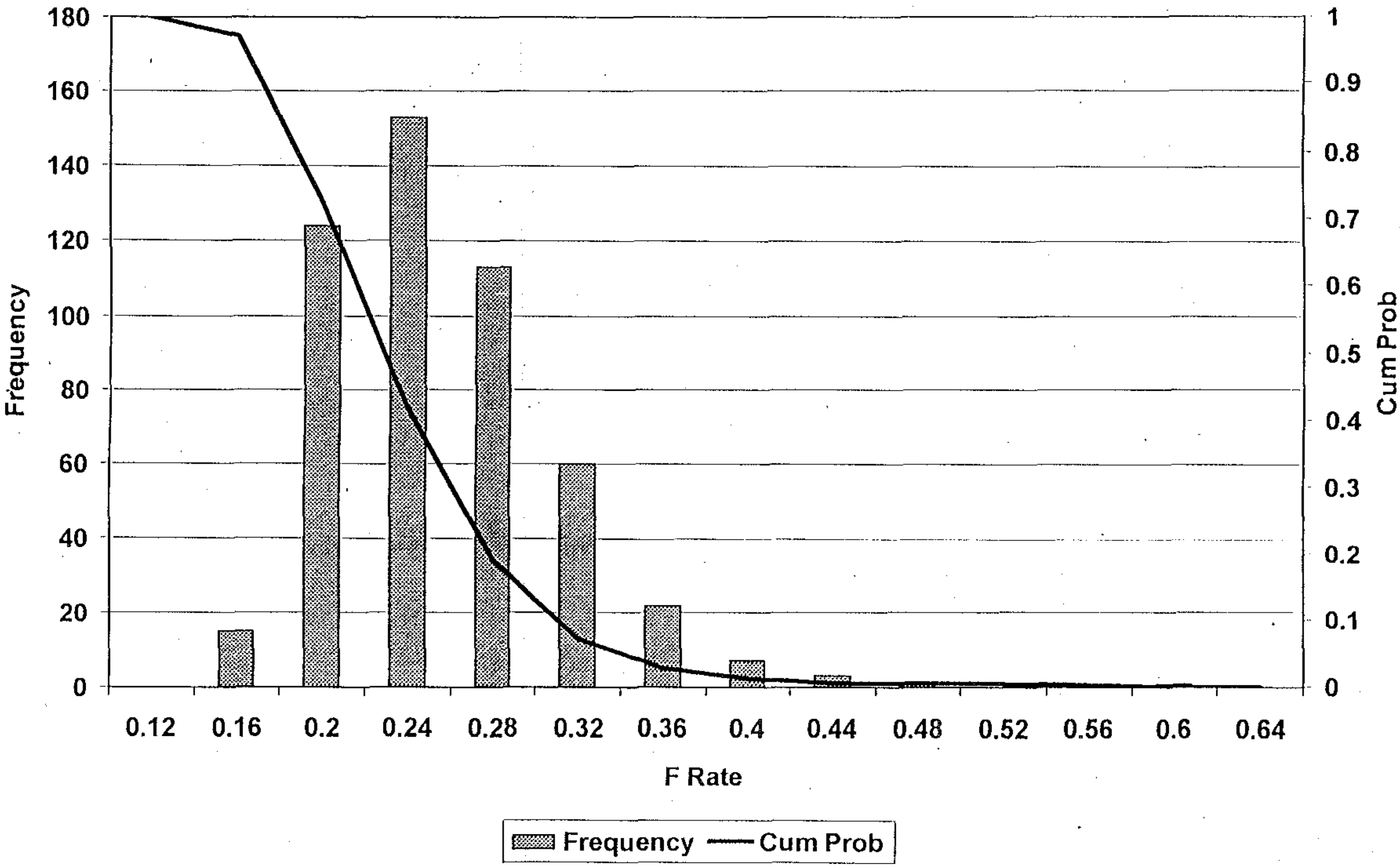


Figure A4. Precision of 1998 Weakfish SSB Estimate

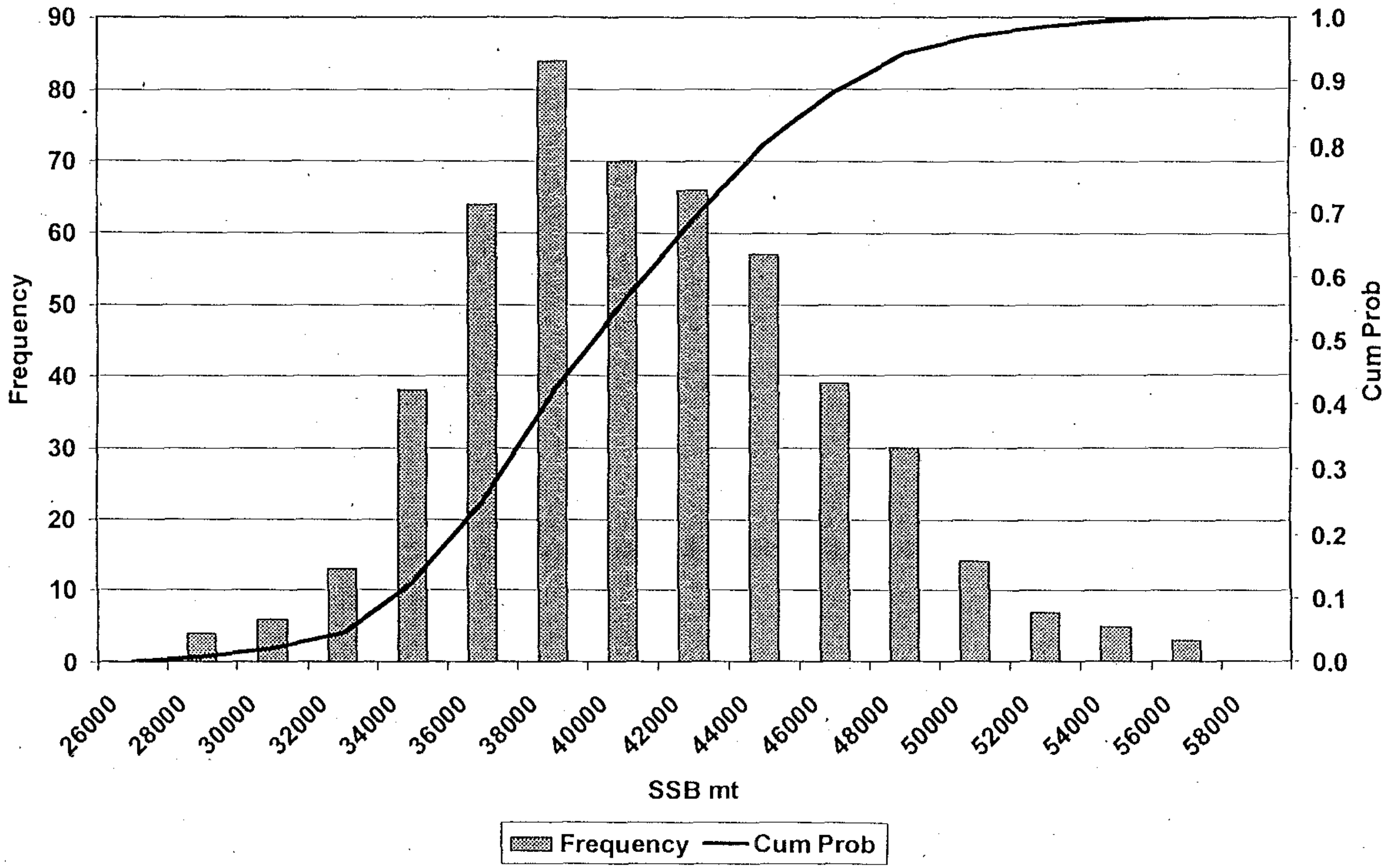


Figure A5. Precision of 1999 Weakfish Recruitment Estimate

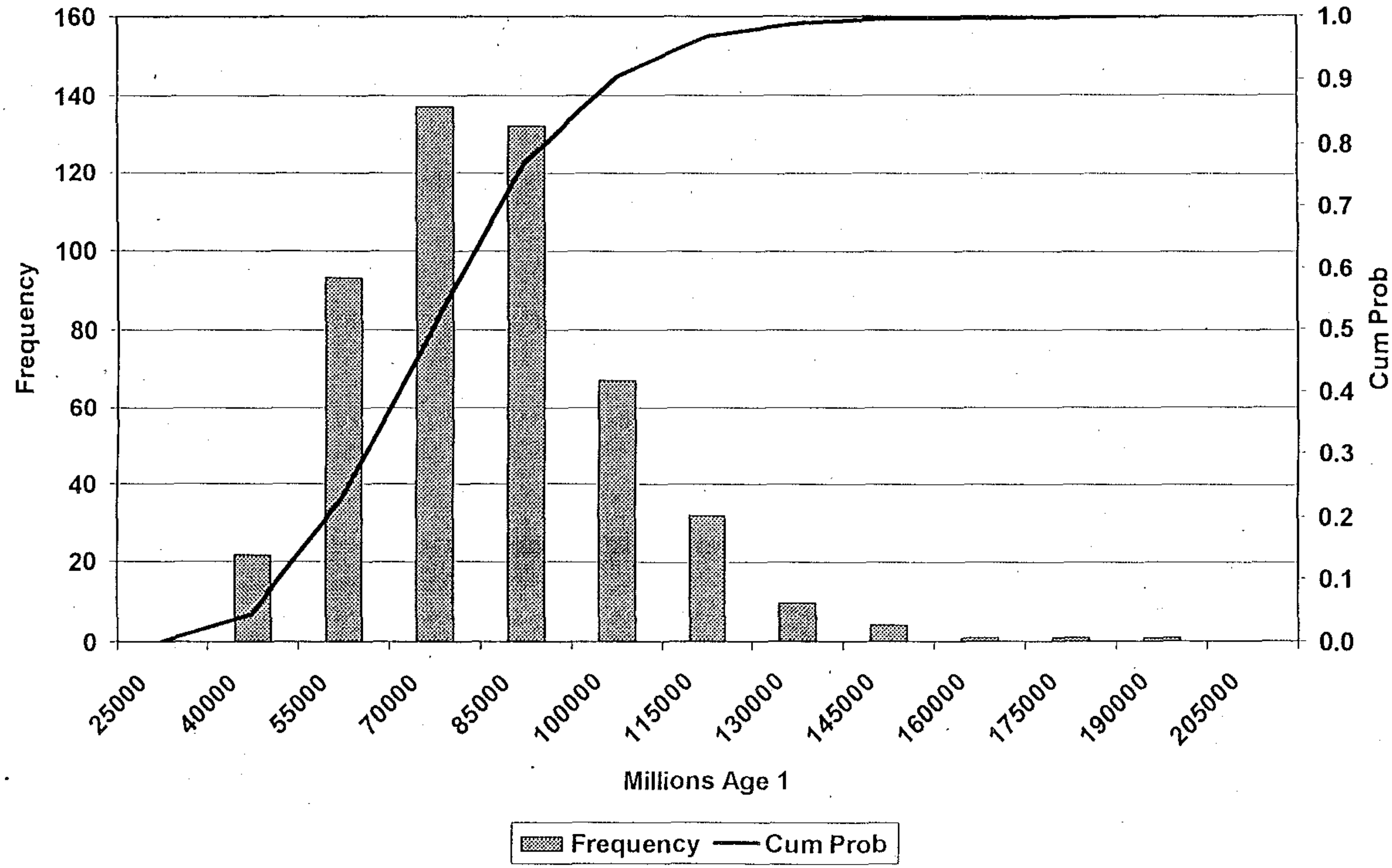


Figure A6. Abundance of age 6+ weakfish and percentage of the stock age 6 and older

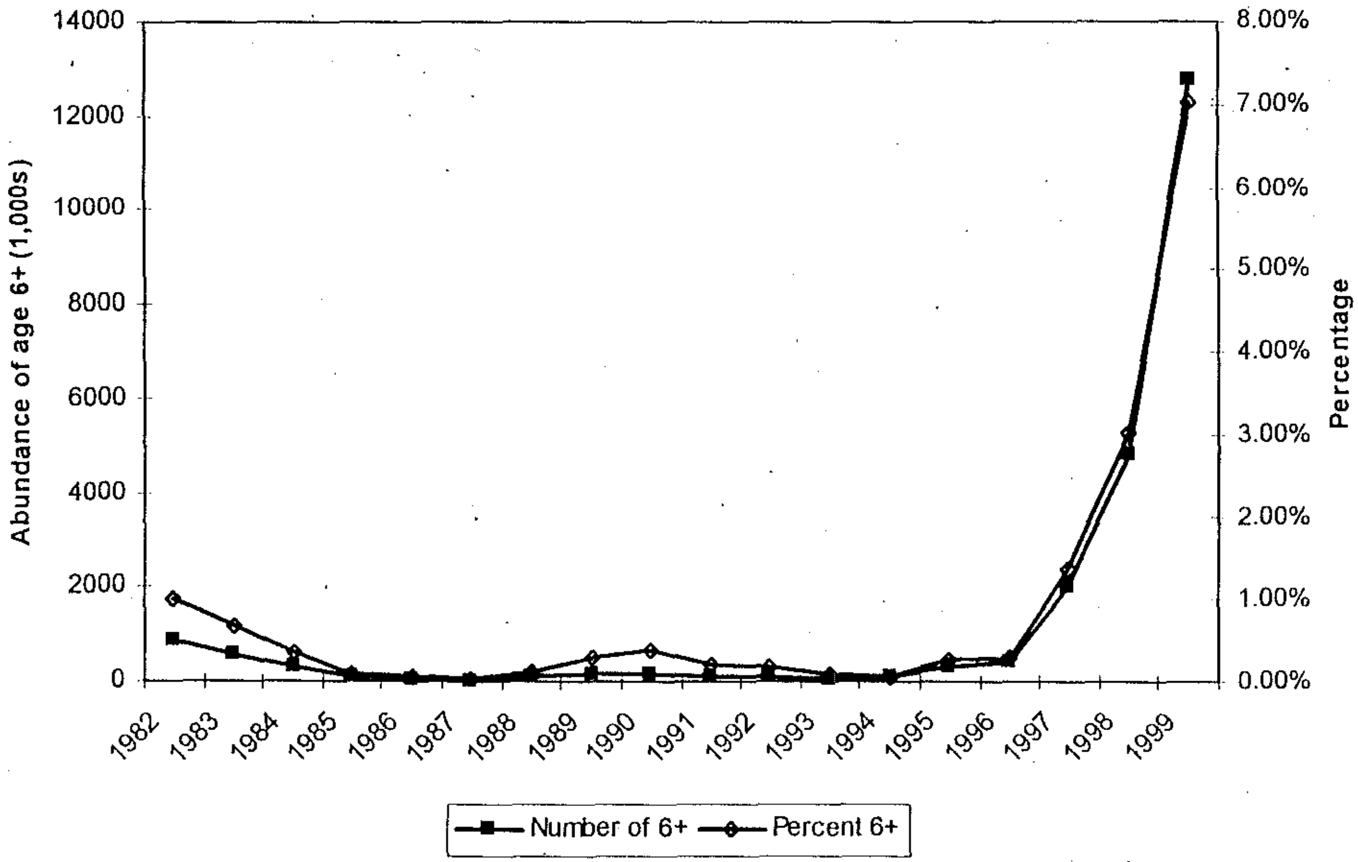


Figure A7. Atlantic Weakfish Spawning Stock and Recruitment Plot

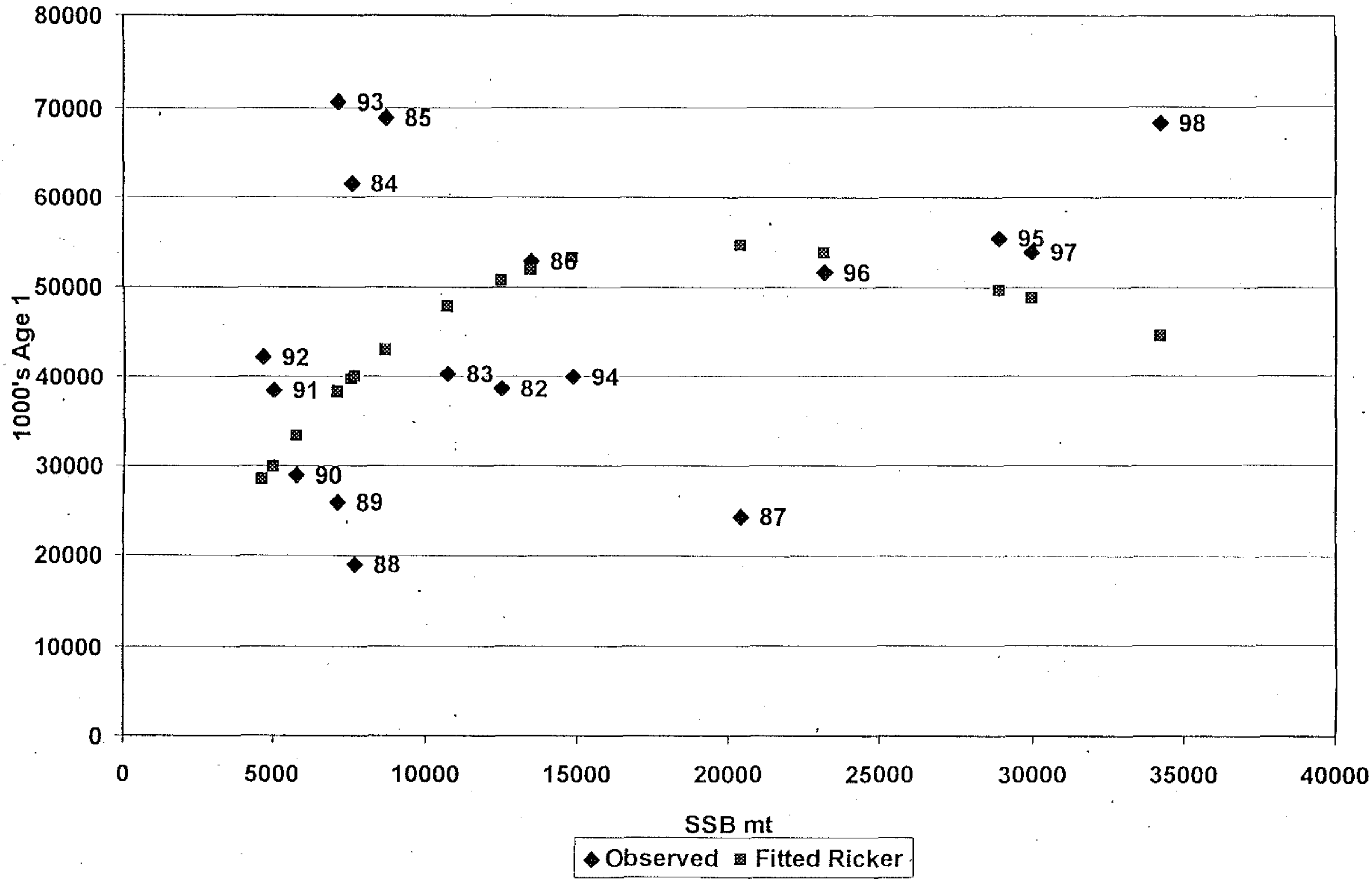


Figure A8. ADAPT Weakfish VPA Residual Plot for NMFS/NEFSC Fall Inshore Survey

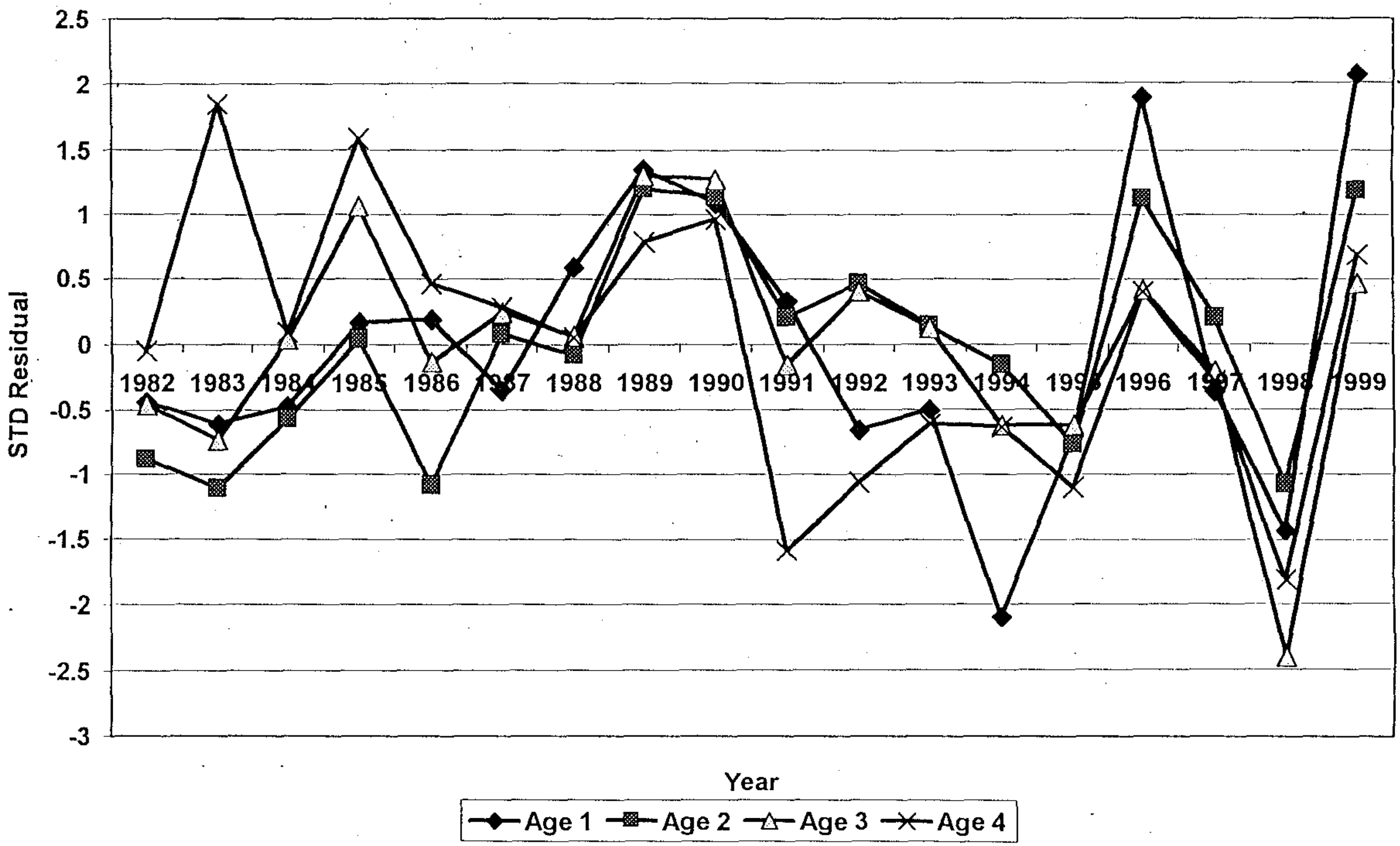


Figure A9. ADAPT Weakfish VPA Residual Plot for DEDFW Delaware Bay Large Trawl Survey

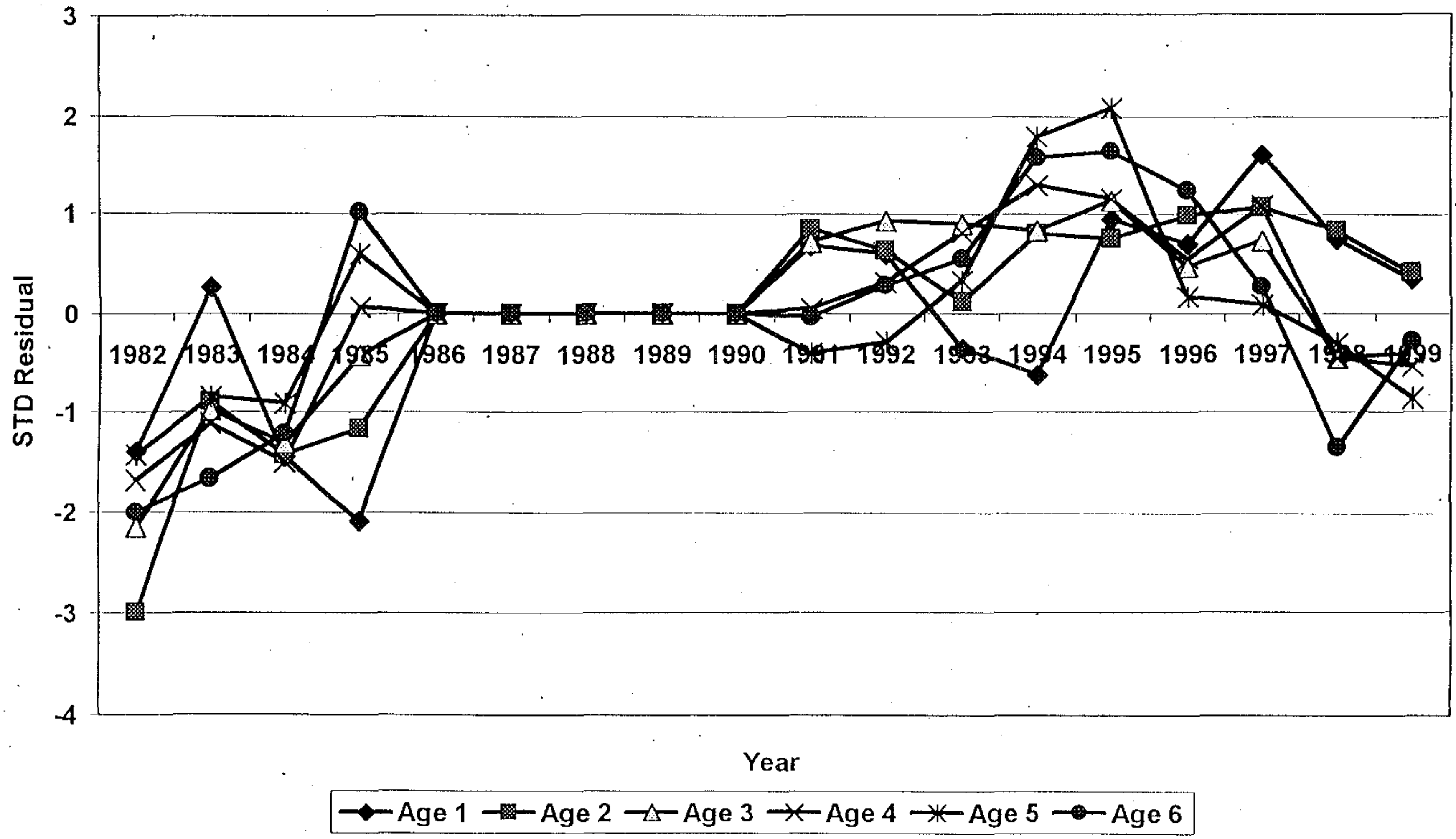


Figure A10. ADAPT Weakfish VPA Residual Plot for NJDEP Ocean Trawl Survey

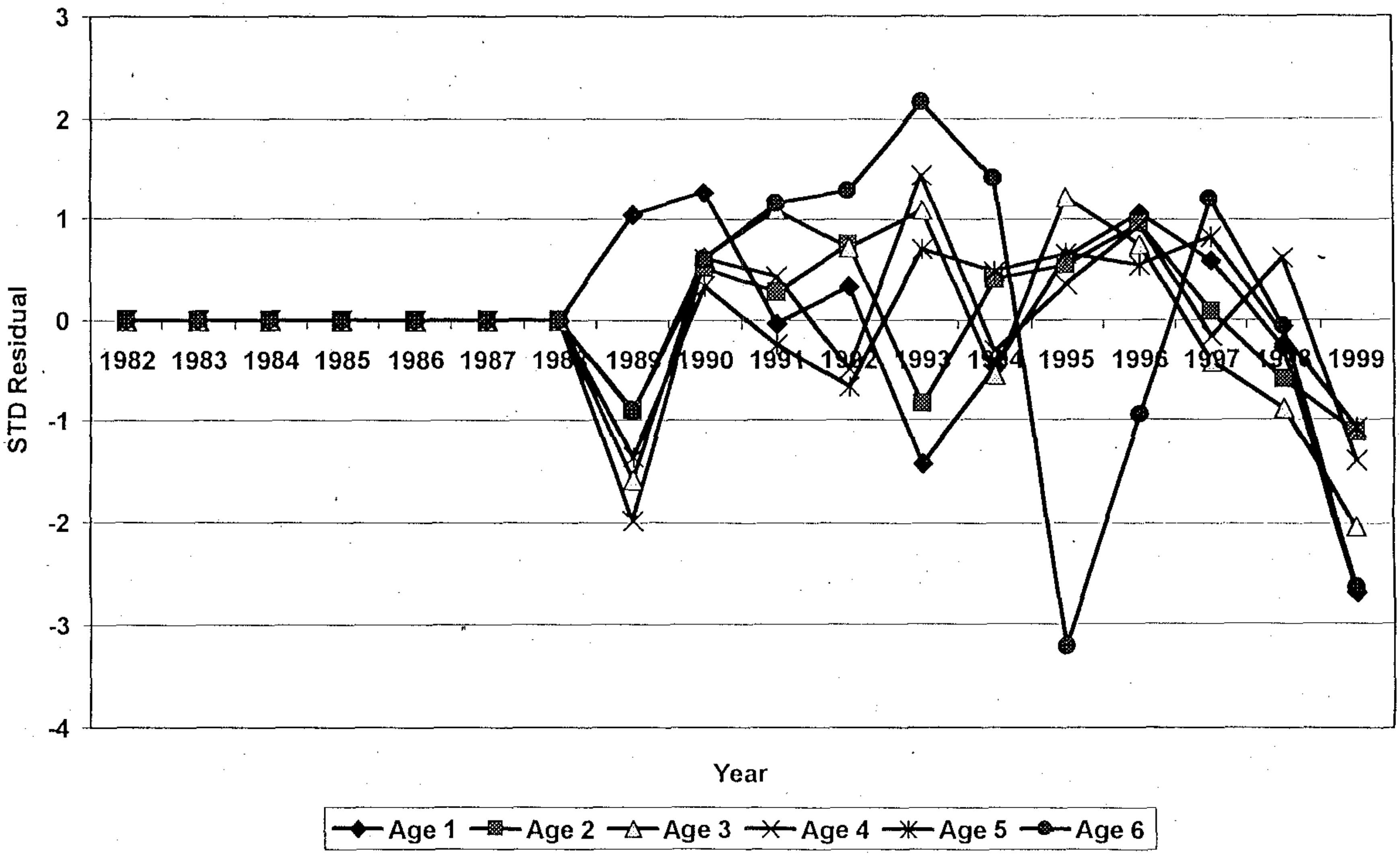


Figure A11. ADAPT Weakfish VPA Residual Plot for DEDFW Small Trawl Survey

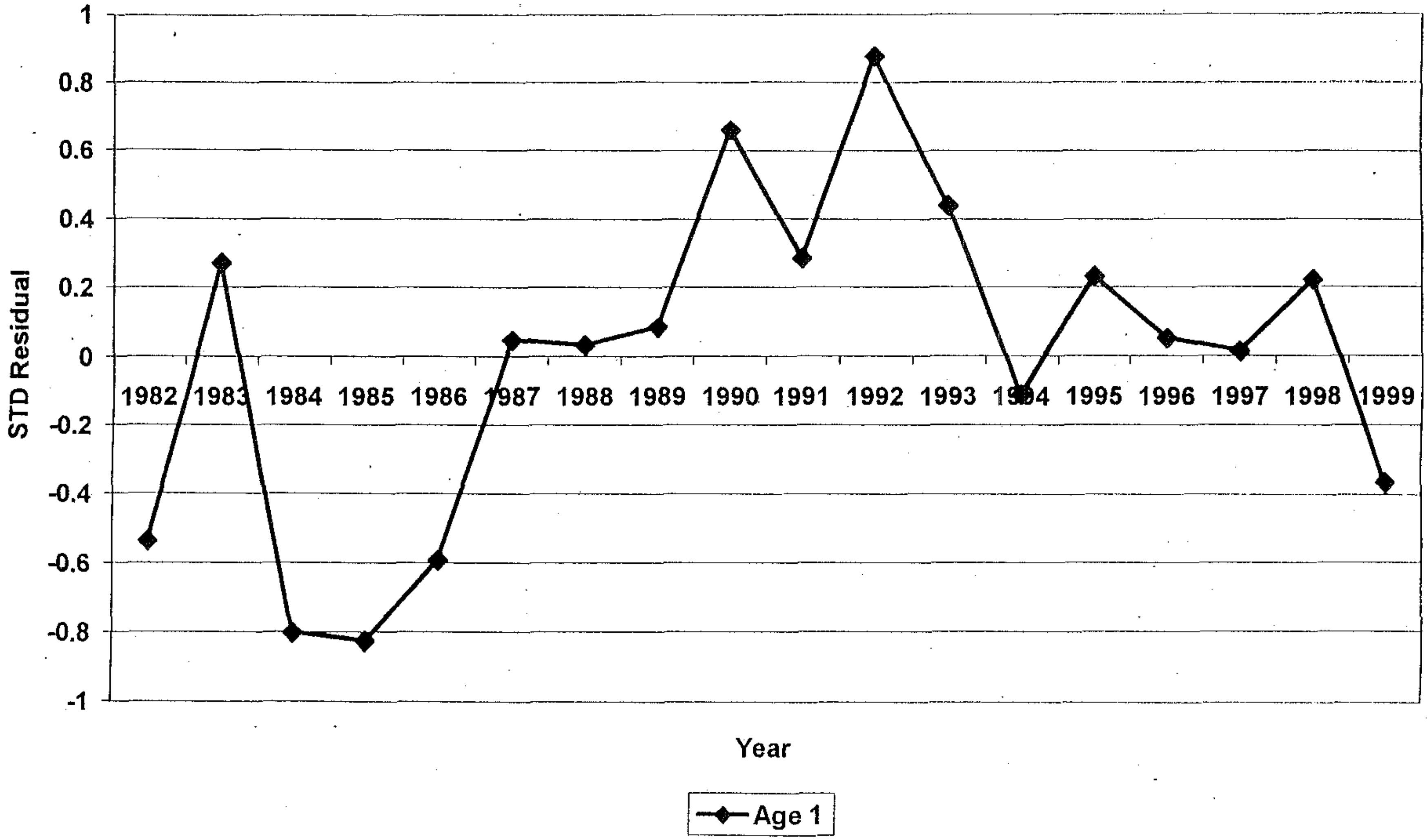


Figure A12. ADAPT Weakfish VPA Residual Plot for NCDMF Pamlico Sound Trawl Survey

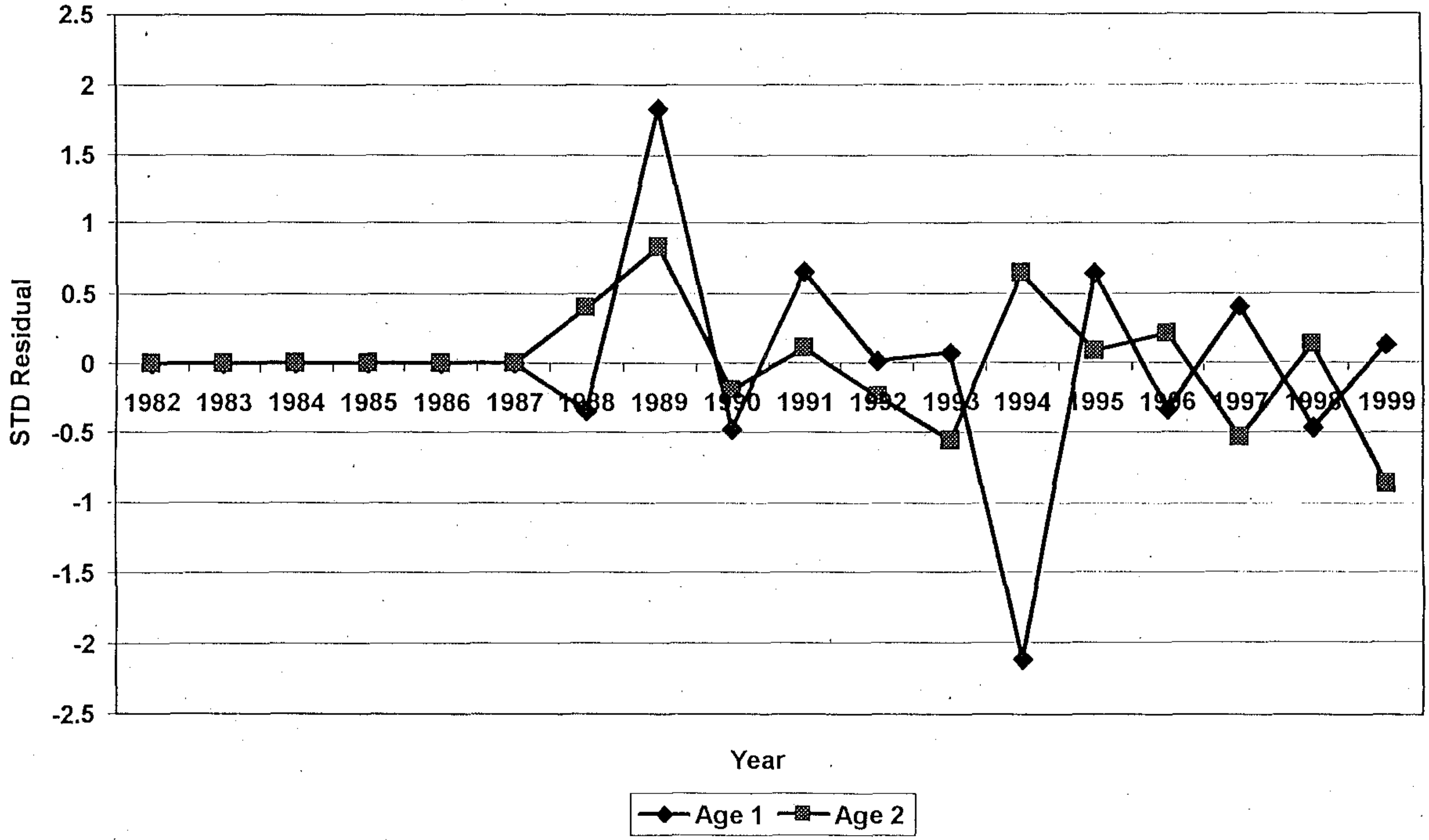


Figure A13. ADAPT Weakfish VPA Residual Plot for VIMS Lower Chesapeake Bay Trawl Survey

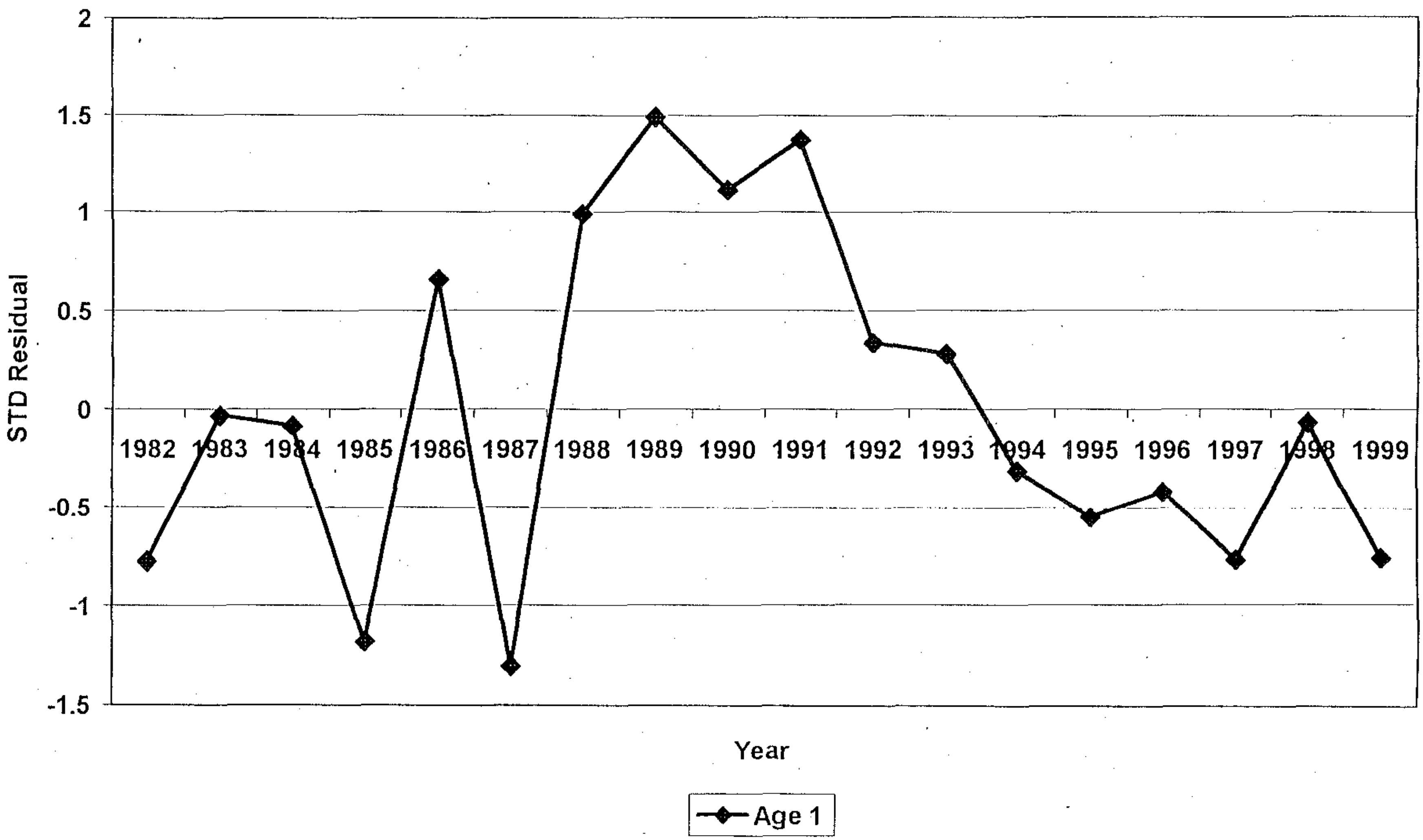


Figure A14. ADAPT Weakfish VPA Residual Plot for MDDNR Coastal Bays Trawl Survey

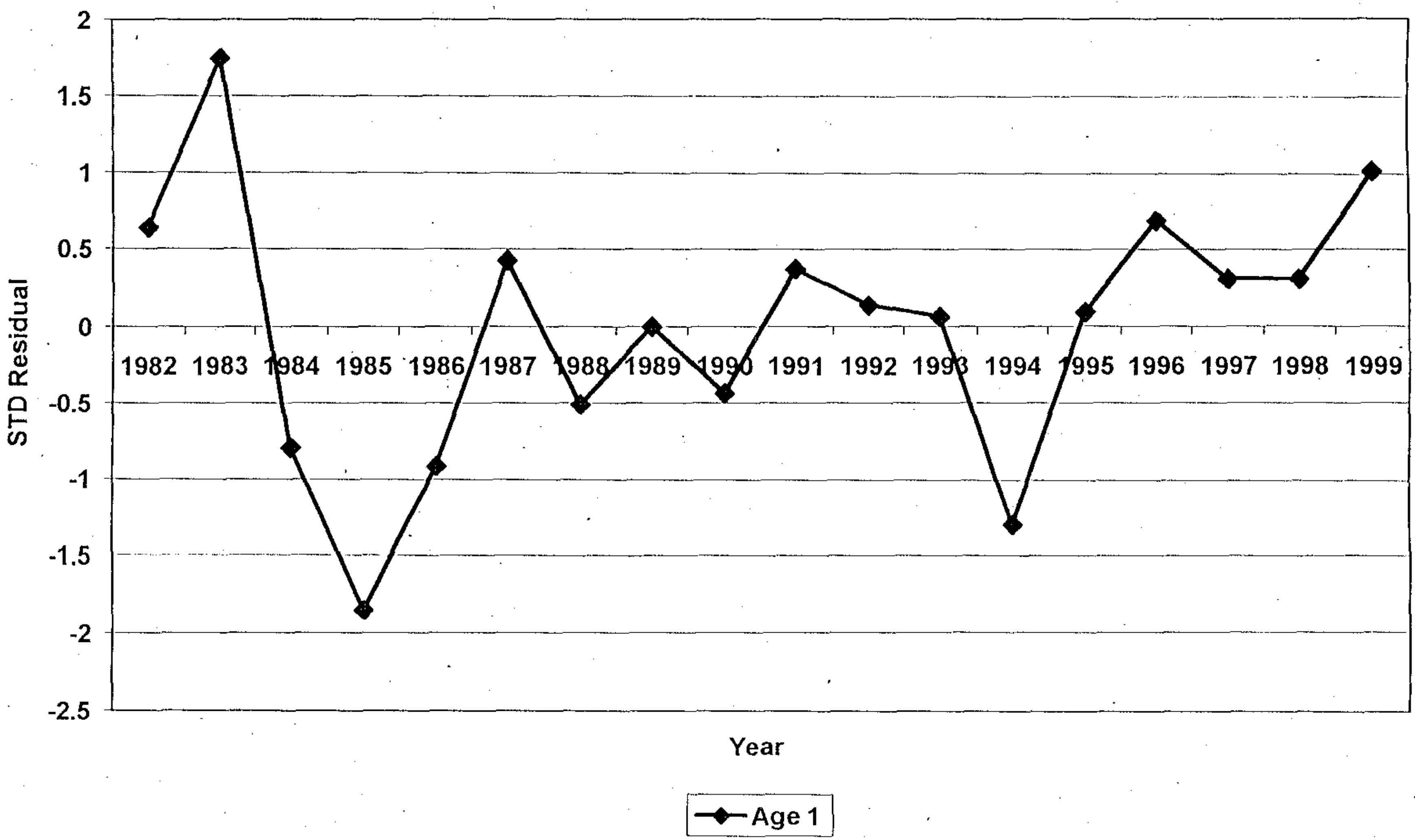


Figure A15. ADAPT Weakfish VPA Residual Plot for MDDNR Chesapeake Bay Trawl Survey

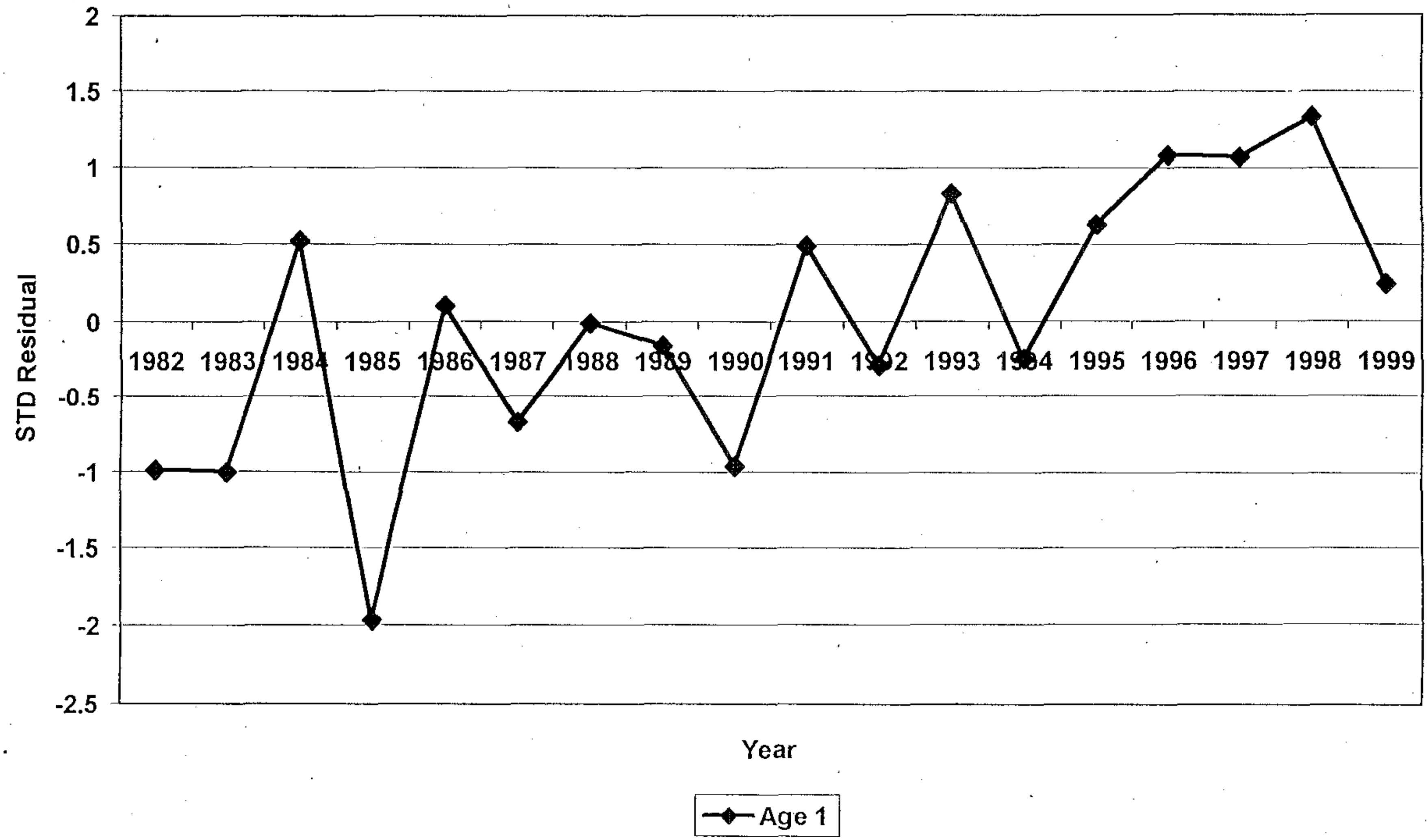


Figure A16. Atlantic Weakfish Yield and Spawning Biomass per Recruit

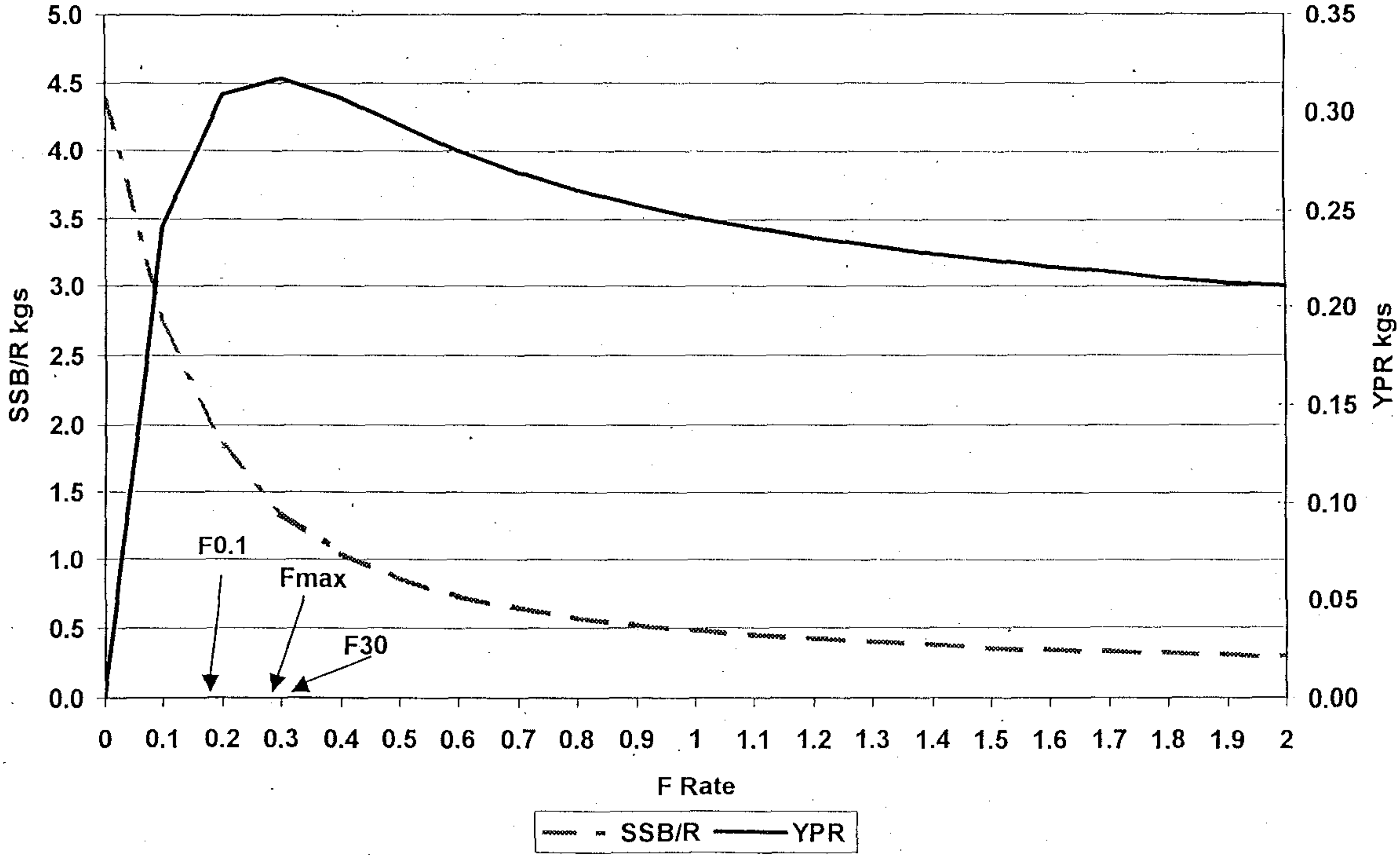
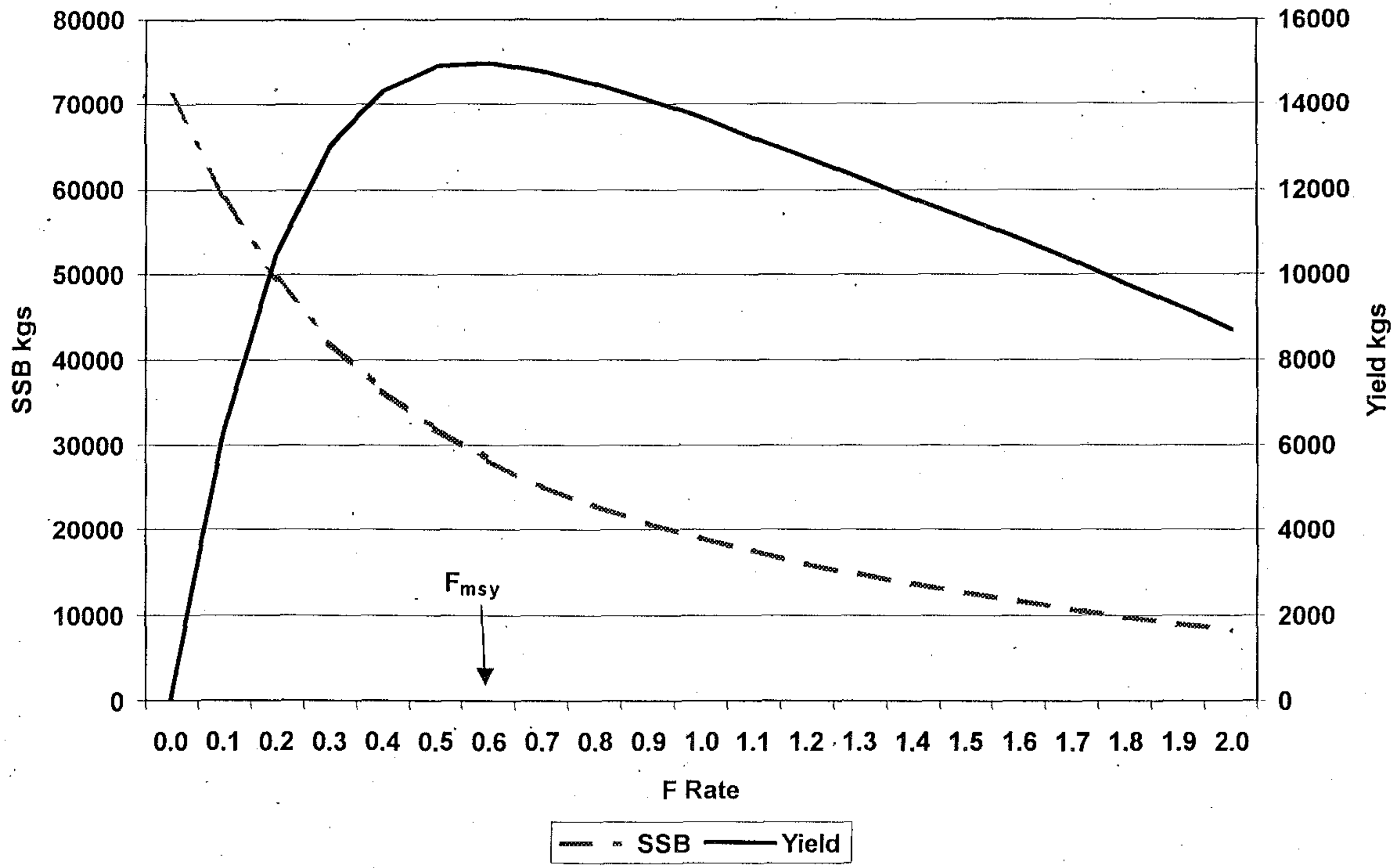


Figure A17. Atlantic Weakfish Equibrium Yield and Spawning Biomass



B. SKATE COMPLEX

TERMS OF REFERENCE

The following Terms of Reference were provided by the Stock Assessment Workshop (SAW) Steering Committee as the context for this assessment of the Northeast Region skate complex reviewed by the Stock Assessment Review Committee (SARC) 30 in November 1999:

(1) Summarize available biological studies (age and growth, maturity, etc.) for the seven species in the skate complex.

(2) Update commercial and recreational landings and survey indices through 1998/99.

(3) To the extent practicable, summarize fishery discard rates through the use of sea sampling data or other information sources.

(4) Estimate fishing mortality rates, and trends in relative or absolute stock size, and consider appropriate reference points for stock size and fishing mortality rate consistent with provisions of the Sustainable Fisheries Act (SFA).

(5) Provide an assessment of the status of the species in the complex relative to overfishing criteria, and evaluate the status of the barndoor skate resource relative to listing factors considered in the Endangered Species Act.

INTRODUCTION

The seven species in the Northeast Region (Maine to Virginia) skate complex are distributed along the coast of the northeast United States from near the tide line to depths exceeding 700 m (383 fathoms). The species are: little skate (*Raja erinacea*), winter skate (*R. ocellata*), barndoor skate (*R. laevis)*, thorny skate (*R. radiata*), smooth skate (*R. senta*), clearnose skate (*R. eglanteria*), and rosette skate (*R. garmani*). A brief discussion of commercial fishery landings and the population dynamics of little skate was presented in the report of Eleventh Northeast Fisheries Center Stock Assessment Workshop (SAW 11; NEFSC 1990).

In the Northeast region, the center of distribution for the little and winter skates is Georges Bank and Southern New England. The barndoor skate is most common in the Gulf of Maine, on Georges Bank, and in Southern New England. The thorny and smooth skates are commonly found in the Gulf of Maine. The clearnose and rosette skates have a more southern distribution, and are found primarily in Southern New England and the Chesapeake Bight. Skates are not known to undertake large-scale migrations, but they do move seasonally in response to changes in water temperature, moving offshore in summer and early autumn and returning inshore during winter and spring. Members of the skate family lay eggs that are enclosed in a hard, leathery case commonly called a mermaid's purse. Incubation time is 6 to 12 months, with the young having the adult form at the time of hatching (Bigelow and Schroeder 1953).

FISHERY DATA

<u>Commercial Fishery Landings</u>

The principal commercial fishing method used to catch skates is otter trawling. Skates are frequently taken as bycatch during groundfish trawling and scallop dredge operations and discarded. Recreational and foreign landings are currently insignificant, at less than 1% of the total fishery landings. There are currently no regulations specifically governing the harvesting of skates in U.S. waters.

Skates have been reported in New England fishery landings since the late 1800s. However, commercial fishery landings, primarily from off Rhode Island, never exceeded several hundred metric tons until the advent of distant-water fleets during the 1960s. Skate landings reached 9,500 mt in 1969, but declined quickly during the 1970s, falling to 800 mt in 1981. Landings have since increased substantially, partially in response to increased demand for lobster bait, and more significantly, to the increased export market for skate wings. Landings are not reported by species, with over 99% of the landings reported as "unclassified skates." Wings are taken from winter and thorny skates, the two species currently known to be used for human consumption. Bait landings are presumed to be primarily from little skate, based on areas fished and known species distribution patterns. Landings increased to 12,900 mt in 1993 and then declined somewhat to 7,200 mt in 1995. Landings have increased again since 1995, and the 1998 reported commercial landings of 17,000 mt was the highest on record (Table B1, Figure B1).

Commercial Fishery Discards

Preliminary commercial fishery discard estimates of skates, for all species combined, were calculated from the NEFSC Domestic Sea Sampling and Dealer Landings data for 1989-1998. The estimates were derived by gear type and primary species group caught on a sea sampled trip. A species group was considered the primary target when it constituted more than 50% of the total trip landings. This may result in an underestimation of total skate discards because some trips (2,604 of 11,834) were mixed and no species or group comprised 50% of the trip.

The commercial fishery discard rates were initially calculated as the sum of the pounds of skate discarded divided by the sum of the pounds of the single, primary species kept for all years combined, within gear type/primary species cells (Tables B2-B4). The number of trips for some of the gear type/primary species cells was small, so the data were next aggregated into species groups to derive yearly estimates for otter trawls, sink gill nets, and scallop dredges. The other fishing gears had too few trips to dis-aggregate by year. Even with the species groupings, some of the cells remained empty, requiring use of time series arithmetic average discard rates for those cells (Tables B5-B7).

The commercial fishery discard estimates are the product of Domestic Sea Sampling discard rates and the reported landings of the primary target species groups from the Dealer Landings data. Table B8 gives the sum of the discard estimates by gear type. The estimates have ranged from high values between 50,000 and 70,000 mt in 1989-1990 to a low of 14,700 mt in 1994. Otter trawls and scallop dredges account for >90% of the total discards. Over the 1989-1998 period, the biomass of total discards are estimated to be two (1998) to eight times (1989) the reported total landings. The commercial fishery discard mortality rate of skates, and therefore the magnitude of total skate discard mortality, is unknown.

Calculation of total skate discards on the primary species group/annual discard rate basis provided a higher estimate of discards in 7 of the 10 years of the Domestic Sea Sample time series, when compared with the primary species/time series discard rate estimates. On average, the primary species group/annual discard rate estimates were 5% higher (Table B9).

The discard estimates were not dis-aggregated to skate species because identification of skates is uncertain in the Domestic Sea Sampling data. However, barndoor skate may have been identified correctly when they were caught, because of their large size and distinctive ventral coloration. The discard estimates for barndoor skate were calculated as above for all years combined. The discard rates are generally low, at less than 5% of the landings of the target species group, resulting in estimates of barndoor skate commercial fishery discards of a few hundred metric tons per year. The commercial fishery discard mortality rate of barndoor skate, and therefore the true magnitude of total barndoor skate discard mortality, is unknown.

Recreational Fishery Catch

Aggregate recreational landings of the seven species in the skate complex are relatively insignificant when compared to the commercial landings, never exceeding 300 mt during the 1981-1998 times series of Marine Recreational Fishery Statistics Survey (MRFSS) estimates. Little and clearnose skates are the most frequently landed species of the complex. For little skate, total landings varied between <1000 and 56,000 fish, equivalent to <1 to 15 mt, during 1981-1998. For clearnose skate, total landings varied between 2,000 and 145,000 fish, equivalent to 2 to 232 mt, during 1981-1998. The number of skates reported as released alive averages an order of magnitude higher than the reported landed number. Party/charter boats have historically been undersampled compared to the private/rental boat sector that accounts for most of the recreational catch, and may have a different discard rate. The recreational fishery release mortality rate of skates is unknown, but is likely comparable to that for flounders and other demersal species, which generally ranges from 10-15%. Assuming a 10-15% release mortality rate would suggest that recreational fishery discard mortality is of about the same magnitude as the recreational landings.

RESEARCH SURVEY DATA

Indices of relative abundance have been developed from NEFSC bottom trawl surveys for the seven species in the skate complex, and these form the basis for most of the conclusions about the status of the complex. All statistically significant NEFSC gear, door, and vessel conversion factors were applied to little, winter, and thorny skate indices when applicable (Sissenwine and Bowman, 1978; NEFSC 1991). Juvenile little and winter skates are not readily distinguished in the field. The numbers of juveniles were split between the two species based on the abundance of the adults in the same tow. For the aggregate skate complex, the spring survey index of biomass was relatively constant from 1968 to 1980, then increased significantly to peak levels in the mid to late 1980s. The index of skate complex biomass then declined steadily until 1994, but has recently begun to increase again (Figure B2).

If the species in the complex are divided into large (barndoor, winter, and thorny) and small sized skates (little, clearnose, rosette, and smooth), it is evident that the large increase in skate biomass in the mid to late 1980s was dominated by winter and little skate (Figures B2-B3). The biomass of large sized skates has steadily declined since the mid-1980s (Figure B3, top). The recent increase in aggregate skate biomass has been due to an increase in little skate (Figure B3, bottom).

Indices of relative abundance for some of the species have also been developed from MADMF, CTDEP, VIMS, and Canada DFO research surveys and commercial fishery observer sampling.

Winter skate

NEFSC bottom trawl surveys indicate that winter skate are most abundant in the Georges Bank (GBK) and Southern New England (SNE) offshore strata regions, with few fish caught in the Gulf of Maine (GOM), or Mid-Atlantic (MA) regions (Figures B4-B7). In the NEFSC spring survey offshore strata (1968-1999), the annual total catch of winter skate has ranged from 160 fish in 1976 to 1,891 fish in 1985. In the NEFSC autumn survey offshore strata (1963-1998), the annual total catch of winter skate has ranged from 115 fish in 1975 to 1,187 fish in 1984. Calculated on a per tow basis, these spring survey catches equate to maximum stratified mean number per tow indices for the GOM-MA offshore strata of about 7.9 fish, or 16.4 kg, per tow during 1985; autumn maximum catches equate to indices of 3.7 fish, or 13.3 kg per tow, in 1984 (Tables B10-B11).

The catchability of winter skate in the recently instituted NEFSC winter bottom trawl survey (which substitutes a chain sweep with small cookies for the large rollers used in the spring and autumn surveys, to better target flatfish) is significantly higher than in the spring and autumn series, especially for smaller winter skates. NEFSC winter survey (1992-1999) annual catches of winter skate have ranged from 841 fish in 1993 to 4,055 fish in 1996, equating to a maximum stratified mean catch per tow of 43.5 fish or 25.2 kg per tow in 1996 (Table B12). The winter survey is focused in the Southern New England and Mid-Atlantic offshore regions, with a limited number of samples on Georges Bank, and no sampling in the Gulf of Maine (Figures B8-B9).

Indices of winter skate abundance and biomass from the NEFSC spring and autumn surveys were stable, but below the time series mean, during the late 1960s and 1970s. Winter skate indices increased to the time series mean by 1980, and then reached a peak during the mid 1980s. Winter skates indices began to decline in the late 1980s. Current NEFSC indices of winter skate abundance are below the time series mean, at about the same value as during the early 1970s. Current NEFSC indices of winter skate biomass are about 25% of the peak observed during the mid 1980s (Figures B10-B13).

The minimum length of winter skate caught in NEFSC surveys is 15 cm (6 in), and the largest individual caught was 113 cm (44 in) total length, during the 1979 autumn survey on Georges Bank. The median length of the survey catch has ranged from 38 cm in the 1992 winter survey to 79 cm in the 1978 spring survey. The median length of the survey catch generally declined from 1979 to the mid-1990s in both the spring and autumn surveys, but has been increasing in recent years, and is currently about 57-58 cm (23 in) (Figure B14). Length frequency distributions from the NEFSC spring and autumn surveys show several modes, most often at 40, 60, and 80 cm (Figures B15-18). The spring survey length distributions show large modes at about 40 cm during the mid-1980s through the mid

1980s through the mid 1990s, suggesting strong recruitment during that period. Truncation of the length distributions is evident in the NEFSC spring and autumn series since 1990.

Indices of abundance for winter skate are available from the Massachusetts Division of Marine Fisheries (MADMF) spring and autumn research trawl surveys in the inshore waters of Massachusetts for the years 1978-1998. Winter skate are much more abundant in state waters south of Cape Cod and areas to the west (MADMF survey strata 11-21), compared to state waters north of Cape Cod into the Gulf of Maine (MADMF survey strata 25-36). MADMF biomass indices of winter skate were moderate to high from 1981 through 1987. Thereafter, both spring and autumn indices declined to time series lows in 1989-1991. The spring index rebounded to moderate levels during 1992-1996 before dropping 75% below the time series mean of 21.3 kg/tow during 1997-1999 (Figure B19). The autumn index shows an erratic, but generally increasing trend from 1991 - 1998. The 1998 autumn value of 24.7 kg/tow is 65% greater than the autumn mean of 14.9 kg/tow (Figure B19). The mean length of MADMF survey catches of winter skate has declined over the spring time series from greater than 60 cm in 1978-1979 to 40 cm in 1999 (Figure B20). The autumn mean length declined from greater than 55 cm in 1978-1980 to 43 cm in 1991, remained stable until 1995, then increased to 55 cm in 1998 (Figure B20). Length frequency distributions from the MADMF spring and autumn surveys generally show a dominant mode at 30 to 40 cm. Recent length distributions suggest recent recruitment of winter skate may have been relatively poor.

Indices of abundance for winter skate are available from the Connecticut Department of Environmental Protection (CTDEP) spring and autumn finfish trawl surveys in Long Island Sound for the years 1984-1998 (1992 and later only for biomass). Annual CTDEP survey catches have ranged from 0 to 115 skates. CTDEP survey indices suggest that after increasing to a time series high from 1984 through 1989, winter skate in Long Island Sound has been stable at about the time series mean during the 1990s (Figure B21).

Little skate

NEFSC bottom trawl surveys indicate that little skate are abundant in the inshore and offshore strata in all regions of the northeast US coast, but are most abundant on Georges Bank and in Southern New England (Figures B22-B25). In the NEFSC spring surveys (1976-1999), the annual total catch of little skate has ranged from 3,512 fish in 1986 to 16,406 fish in 1999. In the NEFSC autumn surveys (1975-1998), the annual total catch of little skate in offshore strata has ranged from 1,124 fish in 1993 to 3,848 fish in 1982 and 4,597 fish in 1978. Calculated on a per tow basis, these spring survey catches equate to maximum stratified mean number per tow indices for the GOM-MA inshore and offshore strata of about 28 fish, or 10 kg, per tow during 1999; autumn maximum catches equate to indices of 6 fish, or 3 kg, per tow in 1978, and 15 fish, or 6 kg, per tow in 1982 (due to high variance in survey catch in 1982; Tables B13-B14).

The catchability of little skate in the recently instituted NEFSC winter bottom trawl survey (which substitutes a chain sweep with small cookies for the large rollers used in the spring and autumn surveys, to better target flatfish) is significantly higher than in the spring and autumn series. NEFSC winter survey (1992-1999) annual catches of little skate have ranged from 10,113 fish in 1994 to 18,418 fish in 1992, equating to a maximum stratified mean catch per tow of 170 fish or 66 kg per tow in 1992 (Table B15). The winter survey is focused in the Southern New England and Mid-Atlantic offshore regions, with a limited number of samples on Georges Bank, and no sampling in the Gulf of Maine (Figures B26-27).

Indices of little skate abundance and biomass from the NEFSC spring and autumn surveys were stable, but below the time series mean, during the 1970s. Little skate spring survey indices began to increase in 1982, and have reached a peak in 1999. Autumn survey indices have been relatively stable over the duration of the time series (Figures B10, B28-B30). The application of the NEFSC gear conversion factors to spring survey indices decreased the indices in 1981 and earlier years by about 75 percent.

The minimum length of little skate caught in NEFSC surveys is 6 cm (3 in), and the largest individual caught was 62 cm (24 in) total length, during the 1978 autumn survey on Georges Bank. The median length of the survey catch has ranged from 31 cm in the 1979 and 1987 spring surveys to 43 cm, most recently in the 1998 autumn survey. The median length of the survey catch has been generally stable over the duration of the spring and autumn surveys and is currently about 38 cm in the spring and 43 cm in the autumn (15 to 17 in)(Figure B31). Length frequency distributions from the NEFSC spring and autumn surveys show several modes, most often at 10, 20, 30, and 45 cm, which may represent ages 0, 1, 2, and 3 and older little skate (Figures B32-B34).

Indices of abundance for little skate are available from the Massachusetts Division of Marine Fisheries (MADMF) spring and autumn research trawl surveys in the inshore waters of Massachusetts for the years 1978-1998. Little skate are abundant in state waters south of Cape Cod and areas to the west (MADMF survey strata 11-21) and in waters north of Cape Cod into the Gulf of Maine (MADMF survey strata 25-36). MADMF biomass indices of little skate declined through the 1980's to time series lows in 1989 (autumn) and 1991 (spring). Biomass indices quickly rose to high levels in the early 1990's, but have steadily declined since then. The 1998 autumn biomass index fell to 40% below the autumn time series mean of 9.9 kg/tow, while the 1999 spring biomass index fell to 22% below the spring time series mean of 14.8 kg/tow (Figure B35). The mean length of MADMF survey catches of little skate show a modest increasing trend in the spring time series while the autumn mean length has fluctuated without trend (Figure B36). Length frequency distributions from the MADMF spring and autumn surveys often show a large mode at 45 cm, which may represent ages 3 and older little skate.

Indices of abundance for little skate are available from the Connecticut Department of Environmental Protection (CTDEP) spring and autumn finfish trawl surveys in Long Island Sound for the years 1984-1998 (1992 and later only for biomass). Little skate are the most abundant species in the skate complex in Long Island Sound, with annual CTDEP survey catches ranging from 142 to 837 skates. CTDEP survey indices suggest an increase in abundance of little skate in Long Island Sound over the 1984-1998 time series (Figure B37).

Barndoor skate

U.S. Bureau of Fisheries research surveys (Figures B38-B39) and NEFSC bottom trawl surveys (Figure B40) indicate that barndoor skate are most abundant in the Gulf of Maine, Georges Bank, and Southern New England offshore strata regions, with very few fish caught in inshore (< 27 meters depth) or Mid-Atlantic regions. Bigelow and Schroder (1953), however, noted that historically barndoor skate were found in inshore waters to the tide-line, and in depths as great as 400 meters off Nantucket. In the NEFSC spring surveys (1968-1999), the annual total catch of barndoor skate has ranged from 0 fish (several years during the 1970s and 1980s) to 22 fish in 1969. In the NEFSC autumn surveys (1963-1998), the annual total catch of barndoor skate has ranged from 0 fish (several years in the 1970s and 1980s) to 120 fish in 1963. Calculated on a per tow basis, the autumn survey catches equate to maximum stratified mean number per tow indices for the GOM-SNE offshore strata of about 0.8 fish, or 2.6 kg, per tow in 1963 (Tables B16-B17).

The catchability of barndoor skate in the recently instituted NEFSC winter bottom trawl survey (which substitutes a chain sweep with small cookies for the large rollers used in the spring and autumn surveys, to better target flatfish) is significantly higher than in the spring and autumn series and may be particularly higher for smaller skates as in winter skates. NEFSC winter survey (1992-1999) annual catches of barndoor skate have ranged from 0 fish in 1992 to 81 in 1999, equating to a maximum stratified mean catch per tow of 0.7 fish or 1.0 kg per tow in 1999 (Table B18). The winter survey is focused in the Southern New England and Mid-Atlantic offshore regions, with a limited number of samples on Georges Bank, and no sampling in the Gulf of Maine (Figure B41).

Indices of barndoor skate abundance and biomass from the NEFSC spring survey were at their highest values during early 1960s, and then declined to 0 fish per tow during the early 1980s. Since 1990, both spring and autumn survey indices have steadily increased, but are still only <10% (spring) to 25% (autumn survey) of the peak values observed in the 1960s (Figures B10, B42-B44).

The minimum length of barndoor skate caught in NEFSC surveys is 20 cm (8 in), and the largest individual caught was 136 cm (54 in) total length, during the 1963 autumn survey in the Gulf of Maine. The median length of the survey catch has ranged from 20 cm in the 1985 spring survey to 119 cm in the 1972 spring survey. The median length of the survey catch has been increasing in recent years in both the spring and autumn surveys, and is currently 70-75 cm (28-30 in; Figure B45). Length frequency distributions from the NEFSC spring and autumn surveys illustrate the decline in abundance of barndoor skate to survey catches of zero during the 1980s (Figures B46-B49). Recent catches have included individuals as large as those recorded during the peak abundance of the 1960s, but the large number of fish between 40 and 80 cm evident during the 1960s is not apparent in recent surveys. The NEFSC winter survey length frequency distributions for 1998-1999 indicate a significant recent increase in the abundance of barndoor skate at lengths less than 80 cm (Figure B50).

Research surveys and commercial fishery observer sampling conducted by Department of Fisheries and Oceans of Canada (DFO Canada) in the broad geographic area between the Gulf of St. Lawrence and Georges Bank indicate two principal area of barndoor skate concentration: Georges Bank/Fundian Channel and central Scotian Shelf (Figure

B49). Barndoor skate were sporadically encountered throughout the 1970s, were nearly absent in the 1980s, and have shown an increase in abundance since the mid-1990s on the southwestern Scotian Shelf, on Brown's Bank, and in the Gulf of Maine (Simon and Frank 1999; Figures B52-B55). The DFO Canada standardized research trawl survey begun on Georges Bank in 1986 found the abundance of barndoor skate was relatively low until the mid-1990s, but has been increasing since that time (Figures B56-B57). A broad range of sizes of barndoor skate have been encountered by DFO Canada surveys on Georges Bank, ranging from 15 to 125 cm, suggesting the current population is composed of both juveniles and adults (Figure B57). Canadian commercial fishery observer sampling of both mobile and fixed gears indicates that commercial gear may regularly capture more and larger barndoor skate than are evident in research survey catches (Figures B58-B59). Recent information from commercial fisheries indicate a much greater depth distribution than previously expected (Kulka 1999; Figures Kulka B60-B62).

Thorny skate

NEFSC bottom trawl surveys indicate that thorny skate are most abundant in the Gulf of Maine and Georges Bank offshore strata regions, with very few fish caught in inshore (< 27 meters depth), Southern New England, or Mid-Atlantic regions (Figures B63-B66). In the NEFSC spring surveys (1968-1999), the annual total catch of thorny skate has ranged from 44 fish in 1999 to 574 fish in 1973. In the NEFSC autumn surveys (1963-1998), the annual total catch of thorny skate has ranged from 60 fish in 1998 to 874 fish in 1978. Calculated on a per tow basis, these spring and autumn survey catches equate to maximum stratified mean number per tow indices for the GOM-MA offshore strata of about 2 to 3 fish, or about 6.0 kg, per tow during the early 1970s (Tables B19-20).

NEFSC survey indices for thorny skate have declined continuously over the last 30 years. Indices of thorny skate abundance and biomass from the NEFSC spring and autumn surveys were at a peak during the early 1970s, reaching 2.9 fish per tow (5.3 kg per tow) in the spring survey and 1.8 fish per tow (5.9 kg per tow) in the autumn survey. Kulka and Mowbray (1998) indicated a similar period of high abundance for thorny skate in Canadian waters. NEFSC indices of thorny skate abundance have declined steadily since the late 1970s, reaching historically low values in 1998 and 1999 that are only 10%-15 % of the peak observed in the 1970s (Figures B10, B67-B69).

The minimum length of thorny skate caught in NEFSC surveys is about 10 cm (4 in), and the largest individual caught was 111 cm (44 in) total length, most recently during the 1977 spring survey on Georges Bank. The median length of the survey catch has ranged from 31 cm in the 1988 autumn survey to 63 cm in the 1971 autumn survey. The median length of the survey catch has trended downward through most of the survey time series, but has been increasing in recent years in autumn surveys, and is currently 40-50 cm (16-20 in; Figure B70). Length frequency distributions from the NEFSC spring and autumn surveys show a pattern of decline in abundance of larger individuals consistent with an increase in total mortality over the survey time series (Figures B71-B74).

Indices of abundance for thorny skate are available from the Massachusetts Division of Marine Fisheries (MADMF) spring and waters of Massachusetts for the years 1978-1998. Thorny skate are abundant in state waters north of Cape Cod into the Gulf of Maine (MADMF survey strata 25-36). MADMF indices of thorny skate biomass have been variable over the time series, but there is a decreasing trend evident in both the spring and autumn time series. The spring index has stabilized around the median of 0.3 kg/tow throughout the 1990's, while the autumn index has been below the median of 0.6 kg/tow since 1994 (Figure B75). Low sample sizes and high variances suggest that the time series of thorny skate mean lengths from the MADMF survey are not a reliable metric of trends in this stock (Figure B76).

Smooth skate

NEFSC bottom trawl surveys indicate that smooth skate are most abundant in the Gulf of Maine and Georges Bank offshore strata regions, with very few fish caught in inshore (< 27 meters depth), Southern New England, or Mid-Atlantic regions (Figure B77). In the NEFSC spring surveys (1968-1999), the annual total catch of smooth skate has ranged from12 fish in 1996 to 179 fish in 1973. In the NEFSC autumn surveys (1963-1998), the annual total catch of smooth skate has ranged from 10 fish in 1976 to 130 fish in 1978. Calculated on a per tow basis, these spring and autumn survey catches equate to maximum stratified mean number per tow indices for the GOM-MA offshore strata of 0.6 to 1.6 fish, or about 0.6 to 0.9 kg, per tow during the 1970s (Tables B21-B22).

Indices of smooth skate abundance and biomass from the NEFSC surveys were at a peak during the early 1970s for the spring series and the late 1970s for the autumn series. NEFSC survey indices declined during the 1980s, before stabilizing during the early 1990s at about 25% of the autumn and 50% of the spring survey index values of the 1970s. There is evidence in the spring 1998-1999 indices of a recent increase in smooth skate abundance (Figures B10, B78-80).

The minimum length of smooth skate caught in NEFSC surveys is about 8 cm (3 in), and the largest individual caught was 71 cm (28 in) total length, during the 1984 autumn survey on Georges Bank. The median length of the survey catch has ranged from 26 cm in the 1993 autumn survey to 53 cm in the 1971 autumn survey. The median length of the survey catch in the GOM offshore region shows no trend over the full survey time series, and is currently at about 30 cm (12 in)(Figure B81). Length frequency distributions from the NEFSC spring and autumn surveys in the GOM offshore region show modes at 30 and 50 cm (Figures B82-B85). The relatively high abundances evident in the 1969-1983 spring surveys at the larger mode may represent the accumulated abundance at several older ages. Truncation of the larger mode is evident in the spring distributions during the 1980s and most of the 1990s. The 1999 spring survey length frequency distribution may indicate strong recruitment in the region.

Clearnose skate

NEFSC bottom trawl surveys indicate that clearnose skate are most abundant in the Mid-Atlantic offshore and inshore strata regions, with very few fish caught in Southern New England and no fish caught in other survey regions (Figure B86). In the NEFSC spring surveys (1976-1999), the annual total catch of clearnose skate has ranged from 9 fish in 1979 to 136 fish in 1993. In the NEFSC autumn surveys (1975-1998), the annual total catch of clearnose skate has ranged from 19 fish in

1983 to 129 fish in 1994. Calculated on a per tow basis, these spring and autumn survey catches equate to maximum stratified mean number per tow indices for the Mid-Atlantic offshore and inshore strata set of 1.2-1.6 fish, or about 0.8-0.9 kg, per tow during the mid 1990s (Tables B23-B24).

The catchability of clearnose skate in the recently instituted NEFSC winter bottom trawl survey (which substitutes a chain sweep with small cookies for the large rollers used in the spring and autumn surveys, to better target flatfish) is significantly higher than in the spring and autumn series. NEFSC winter survey (1992-1999) annual catches of clearnose skate have ranged from 343 fish in 1999 to 3,086 fish in 1996, equating to a maximum stratified mean catch per tow of 12 fish or 15 kg per tow in 1996 (Table B25). The winter survey is focused in the Southern New England and Mid-Atlantic offshore regions, with a limited number of samples on Georges Bank, and no sampling in the Gulf of Maine (Figure B87).

NEFSC spring and autumn survey indices for clearnose skate have been increasing since the mid-1980s. (Figures B10, B88-B90).

The minimum length of clearnose skate caught in NEFSC surveys is about 10 cm (4 in), and the largest individual caught was 78 cm (31 in) total length, during the 1971 autumn survey in the Mid-Atlantic Bight region. The median length of the survey catch has ranged from 41 cm in the 1980 spring survey to 67 cm in the 1995 spring survey. The median length of the spring survey catch has increased over the time series, from about 50 cm during the late 1970s to at about 60 cm in recent years (24 in; Figure B91). The median length of the autumn survey catch has been stable over the time series, and is also at about 60 cm. Length frequency distributions from the NEFSC spring and autumn surveys show a consistent mode at 60-70 cm that may represent the accumulated abundance of several older ages (Figures B92-B94).

Indices of abundance for clearnose skate are available from the Connecticut Department of Environmental Protection (CTDEP) spring and autumn finfish trawl surveys in Long Island Sound for the years 1984-1998 (1992 and later only for biomass). The CTDEP survey has caught very few clearnose skate, with annual catches ranging from 0 to 20 skates, although the CTDEP spring survey suggests an increase in clearnose skate abundance in Long Island Sound over the times series (Figure B95).

Indices of abundance for clearnose skate are available from the Virginia Institute of Marine Science (VIMS) trawl survey in Chesapeake Bay and its' tributaries for the years 1988-1998. The VIMS trawl survey indices suggest no trend in clearnose skate abundance over the this period (Figure B96).

Rosette skate

NEFSC bottom trawl surveys indicate that rosette skate are most abundant in the Mid-Atlantic offshore strata region, with very few fish caught in Southern New England and no fish caught in other survey regions (Figure B97). In the NEFSC spring surveys (1968-1999), the annual total catch of rosette skate has ranged from 0 fish, in 1984, to 70 fish in 1977. In the NEFSC autumn surveys (1963-1998), the annual total catch of rosette skate has ranged from 1 fish, most recently in 1982, to 45 fish in 1981. Calculated on a per tow basis, these spring survey catches equate to maximum stratified mean number per tow indices for the Mid-Atlantic offshore strata set of about 0.6 fish, or about 0.1 kg, per tow during 1977 (Tables B26-B27).

The catchability of rosette skate in the recently instituted NEFSC winter bottom trawl survey (which substitutes a chain sweep with small cookies for the large rollers used in the spring and autumn surveys, to better target flatfish) is significantly higher than in the spring and autumn series. NEFSC winter survey (1992-1999) annual catches of rosette skate have ranged from 143 fish in 1993 to 899 fish in 1996, equating to a maximum stratified mean catch per tow of 1.4 fish or 0.3 kg per tow in 1996 (Table B28). The winter survey is focused in the Southern New England and Mid-Atlantic offshore regions, with a limited number of samples on Georges Bank, and no sampling in the Gulf of Maine (Figure B98).

Indices of rosette skate abundance and biomass from the NEFSC surveys were at a peak during 1975-1980, before declining through 1986. NEFSC survey indices for rosette skate have been increasing since 1986, and recent indices are at about 50% of the peak values of the late 1970s (Figures B10, B99-B101).

The minimum length of rosette skate caught in NEFSC surveys is about 7 cm (3 in), and the largest individual caught was 57 cm (22 in) total length, during the 1971 spring survey in the Mid-Atlantic Bight region. The median length of the survey catch has ranged from 18 cm in the 1985 spring survey to 57 cm in the 1971 spring survey, during which only 1 rosette skate was caught. The median length of the survey catch has been stable over the spring and autumn time series at about 36-37 cm (14 in; Figure B102). Length frequency distributions from the NEFSC spring and autumn surveys show a consistent mode at 30-40 cm (e.g., Figures B103-106).

BIOLOGICAL DATA AND REFERENCE POINTS

Increases in NER skate landings since 1980 and the potential for rapidly expanding export markets bring into question the level at which sustainable fisheries for these species can be maintained (Holden 1973). Skates have a limited reproductive capacity, and stock size could be quickly reduced through intensive exploitation. In some areas of the world where skates have been the targets of directed fisheries, their numbers have been reduced to extremely low levels (*e.g.*, in the Irish Sea; Brander 1981).

Frisk (MS 1999) compiled a summary of available life history parameters for skate species from around the world, and developed predictive relationships between total length (L_{max}) and length of maturity (L_{mat}) and age of maturity (A_{mat}). Frisk (MS 1999) concluded that the ratio of instantaneous natural mortality to the von Bertalanffy growth coefficient (M/K ratio) was about 1.0 for elasmobranchs (including skates).

The following sections describe biological data and biological reference points for the seven individual species:

<u>Winter skate</u>
Winter skates are a relatively long-lived, slow growing species. Estimates of age and growth parameters are available for winter skate in Canadian waters (eastern Scotian Shelf) from Simon and Frank (1996), who reported the preliminary results of an age and growth study conducted at St. Mary's University by R.

Nearing. Simon and Frank (1996) reported that the study of winter skate from 12 to 100 cm found ages from 0-group to 16 years, providing von Bertalanffy parameters of L_{inf} = 114.1 cm, K = 0.14405, and t_0 = 0.00315. Simon and Frank (1996) used the relationships developed by Taylor (1958) and Hoenig (1983) to estimate a maximum age of 20.8 years and a value of M of 0.214 for winter skate. Simon and Frank (1998) found that winter skate on the eastern Scotian Shelf reached 50% maturity at about 75 cm.

Frisk (MS 1999) references McEachran (In press) as the source for a maximum length (L_{max}) of 150 cm and length of maturity (L_{mat}) of 79.5 cm. Using Frisk's (1999) predictive equations and the NEFSC survey maximum observed length of 113 cm provides estimates of L_{mat} of 85 cm and A_{mat} of 7 years.

The SARC used recent NEFSC spring and autumn survey cumulative length distributions (1994-1999), and recent landed skate cumulative length distributions from NEFSC sea sampling of the commercial fishery (1994-1999) to develop a contemporary estimate of the retained or landed length (L_{50} = 77 cm) and age of recruitment of winter skate to the commercial fisheries for use in a Thompson and Bell (1936) yield per recruit analysis (YPR). The SARC noted that this retained or landed length reflected the kept portion of the catch recorded in the sea sample data, and was much higher than might be expected given the size of trawl mesh (generally 6 inches or smaller) used in nearly all of the region's trawl fisheries. The SARC concluded that it was more reasonable to assume a length closer to that assumed for little skate (L' = 45 cm) for use in reference point and mortality rate models, and so the NEFSC survey L' = 50 cm was assumed to be more reasonable as the length of recruitment (L_{50}) to the commercial fishery for winter skate.

Growth parameters and proportions mature at age from Simon and Frank (1996, 1998) for winter skate in Canadian waters were used to estimate parameters for the YPR model. The length-weight equation from NEFSC survey data collected during 1991- 1998 was used to convert length to weight. Winter skate are estimated to attain full recruitment to the fisheries at age 3. Frisk's (1999) work suggests that the M/K ratio for skates is about 1.0. Taking into consideration the Simon and Frank (1996) estimate of K = 0.14, the SARC concluded that a value of M = 0.1, and an inferred maximum age of 30 years, is appropriate for winter skate, providing estimates of F_{max} = 0.12 and $F_{0.1}$ = 0.08 (Table B29).

The SARC has concluded that yield per recruit based reference points for winter skate in the Northeast Region are unreliable, due to the use of growth parameters from Canadian waters and the uncertainty of partial recruitment to the commercial fishery. A threshold fishing mortality reference point is therefore proposed for winter skate based on the estimate of the natural mortality rate (M). For winter skate, the SARC recommends F = M = 0.10 as a proxy for the SFA threshold fishing mortality reference point. The SARC recommends against using F_{max} as a proxy for Fthreshold due to life history considerations. The SARC proposes use of the 75th percentile value of the NEFSC autumn biomass indices for the GOM-MA offshore region during 1967-1998 as a proxy for the SFA target biomass reference point for winter skate (6.46 kg/tow), and one-half of that value as the SFA threshold biomass reference point for winter skate (3.23 kg/tow; Figure B107).

Little skate

Little skates are a relatively short-lived, fast growing species. Frisk (MS 1999) references Johnson (1979) as the source for maximum lengths (L_{max}) of 60 cm (males) and 62 cm (females) cm, A_{max} of 4 years for both sexes, L_{mat} of about 45 cm for both sexes, fecundity of 30 egg cases per year, and maximum age of 8 years. Using Frisk's (1999) predictive equations and the NEFSC survey maximum observed length of 62 cm provides estimates of L_{mat} of 50 cm and A_{mat} of 4 years; using Waring's (1984) L_{inf} value of about 53 cm provides an estimate of L_{mat} of 43 cm.

Waring (1984) investigated the age, growth, mortality, and yield per recruit of little skate in the Georges Bank-Delaware Bay region using NEFSC trawl survey data collected during 1968-1978. Waring (1984) observed a maximum age of 8 years, and estimated von Bertalanffy growth parameters of $L_{inf} = 52.73$ cm, $K = 0.352$, and $t_0 = -0.449$ years, based on interpretation of presumed annual rings in the centrum of 923 little skate vertebrae. The length-weight relationship for both sexes combined over the years of the Waring (1984) study was $\log_{10}W_g = -2.641 + 3.229 * \log_{10}L_{cm}$. Waring (1984) assumed an age-2 entry to the trawl fishery of the 1970s in estimating values of $F_{max} = 1.00$ and $F_{0.1} = 0.49$, for $M = 0.4$, but warned that fishing at the F_{max} level might result in over-exploitation of little skate due to their low fecundity.

The SARC used recent NEFSC spring and autumn survey cumulative length distributions (1994-1999), and recent landed skate cumulative length distributions from NEFSC sea sampling of the commercial fishery (1994-1999) to develop a contemporary estimate of the length ($L_{50} = 45$ cm) and age of recruitment of little skate to the commercial fisheries for use in a Thompson and Bell (1936) yield per recruit analysis (YPR). Waring's (1984) growth parameters were used to convert lengths to age. NEFSC length-weight equations from the 1991-1999 surveys were used to convert mean lengths at age to mean weights at age. In the current analysis, little skate do not approach full recruitment to the fisheries until age 4 (70% at age 3, 90% at age 4, 100% at ages 5 to 8), F_{max} is undefined, and $F_{0.1} = 0.65$, about 33% higher than Waring's (1984) analysis (Table B30).

The SARC has concluded that yield per recruit based reference points for little skate in the Northeast Region are unreliable, due to the use of outdated growth parameters from the 1970s and the uncertainty of partial recruitment to the commercial fishery. A threshold fishing mortality reference is therefore proposed for little skate based on the estimate of the natural mortality rate (M). For little skate, the SARC recommends $F = M = 0.40$ as a proxy for the SFA threshold fishing mortality reference point. The SARC proposes use of the 75th percentile value of the NEFSC spring biomass indices for the GOM-MA inshore and offshore regions during 1982-1999 as a proxy for the SFA target biomass reference point for little skate (6.54 kg/tow), and one-half of that value as the SFA threshold biomass reference point for little skate (3.27 kg/tow; Figure B107).

Barndoor skate

Barndoor skates are presumed to be a relatively long-lived, slow growing species, but no estimates of age and growth parameters are currently available. Casey and Myers (1998) proposed that barndoor skate might have characteristics similar to the European common skate, (*Raja batis*). By analogy, Casey and Myers (1998) suggested an L_{max} of

153 cm, A_{mat} of 11 years, and F of 47 egg cases per year for barndoor skate. Using Frisk's (1999) predictive equations and the NEFSC survey maximum observed length of 136 cm provides estimates of L_{mat} of 102 cm and A_{mat} of 8 years.

Graduate students and staff from the Virginia Institute of Marine Science (VIMS) have sampled barndoor skate while conducting research aboard commercial scallop vessels participating in the Sea Scallop Exemption Program in Closed Area II on Georges Bank (Gedamke and DuPaul 1999). The vessels fished with two 15 foot New Bedford style scallop dredges towing in 30-40 fathoms of water at 5-6 knots. Between June 15 and October 5, 1999, six trips lasting between 5 and 12 days were completed, with four more planned before December 31, 1999. Although barndoor skate were not a significant percentage of the total bycatch weight, they were observed frequently enough to contribute to a significant database of allometric and morphometric measurements. Biological samples, including reproductive tracts, vertebrae, and tissue samples were collected for age, growth, reproductive, and population genetics studies (Gedamke and DuPaul 1999).

To date, VIMS scientists have observed 916 barndoor skates, with 52.3% (n=479) females and 47.7% (n=437) male. Disk width, disk length, total length, clasper length, and clasper width measurements were taken from all individuals. Total length ranged from 20.0 to 129.4 cm with an average of 55.7 cm and a median of 52.9 cm. Clasper length measurements show male sexual maturity to occur at approximately 100 cm total length. Samples of reproductive tracts have also been collected to determine female maturation size (n=69) and verify the male allometric plot (n=66). In addition, vertebrae samples have been collected from 251 individuals for age and growth studies. Gedamke and DuPaul (1999) stressed that their data are preliminary, are part of an ongoing study, and are from only a portion of Closed Area II. Data has also been collected from the Nantucket Lightship Closed Area and Georges Bank Closed Area I, and the VIMS scientists are continuing their ongoing research efforts with the commercial scallop fleet.

Historical Canadian survey data (e.g., as presented in Casey and Myers (1998) from St. Pierre Bank to Brown's Bank) suggest that a substantial decline in barndoor skate biomass in the northern part of the species' range had occurred by the time that standardized NEFSC surveys began in U.S. waters in 1963. If the barndoor skate in U.S. waters are a part of the same unit stock as that in Canadian waters, then the high indices in the NEFSC surveys during the early 1960s likely indicate a biomass well below B_{MSY}. The linkage between barndoor skates in U.S. and Canadian waters, however, is unknown. For barndoor skate, there are insufficient data on age and growth to determine fishing mortality rates or propose SFA fishing mortality reference points. The SARC proposes use of the mean value of the NEFSC autumn biomass indices for the GOM-SNE offshore region during 1963-1966 as a proxy for the SFA target biomass reference point for barndoor skate (1.62 kg/tow), and one-half of that value as the SFA threshold biomass reference point for barndoor skate (0.81 kg/tow; Figure B107).

Thorny skate

Simon and Frank (1996) reported that nearly all thorny skate smaller than 50 cm sampled during a 1996 research cruise were immature, while nearly all skate larger than 50 cm were mature. These results were comparable to maturity studies of thorny skate conducted by Templeman (1982) on the Newfoundland shelf.

Frisk (1999) references Templeman (1965) for estimates of L_{max} = 102 cm and a maximum age of 20 years, which would infer a value for M of 0.2. Frisk's (1999) predictive equations and the NEFSC survey L_{max} of 111 cm provides estimates of L_{mat} of 84 cm and A_{mat} of 7 years. There are insufficient data on the age and growth of thorny skate to determine fishing mortality rates or propose SFA fishing mortality reference points. The SARC proposes use of the 75th percentile value of the NEFSC autumn biomass indices for the GOM-SNE offshore region during 1963-1998 as a proxy for the SFA target biomass reference point for thorny skate (4.41 kg/tow), and one-half of that value as the SFA threshold biomass reference point for thorny skate (2.20 kg/tow; Figure B107).

Smooth skate

Frisk's (1999) predictive equations and the NEFSC survey L_{max} of 71 cm provides estimates of L_{mat} of 56 cm and A_{mat} of 5 years. There are insufficient data on the age and growth of smooth skate to determine fishing mortality rates or propose SFA fishing mortality reference points. The SARC proposes use of the 75th percentile value of the NEFSC autumn biomass indices for the GOM-SNE offshore region during 1963-1998 as a proxy for the SFA target biomass reference point for smooth skate (0.31 kg/tow), and one-half of that value as the SFA threshold biomass reference point for smooth skate (0.16 kg/tow; Figure B107).

Clearnose skate

Frisk (1999) references McEachran (In press) as the source for estimates of L_{max} = 128 cm and L_{mat} = 66 cm, and a maximum age of 7 years Frisk's (1999) predictive equations and the NEFSC survey L_{max} of 78 cm provides estimates of L_{mat} of 61 cm and A_{mat} of 5 to 6 years. There are insufficient data on the age and growth of clearnose skate to determine fishing mortality rates or propose SFA fishing mortality reference points. The SARC proposes use of the 75th percentile value of the NEFSC autumn biomass indices for the Mid-Atlantic inshore and offshore regions during 1975-1998 as a proxy for the SFA target biomass reference point for clearnose skate (0.56 kg/tow), and one-half of that value as the SFA threshold biomass reference point for clearnose skate (0.28 kg/tow; Figure B107).

Rosette skate

Frisk (1999) references McEachran (In press) as the source for estimates of L_{max} = 46 cm and L_{mat} = 36 cm. Frisk's (1999) predictive equations and the NEFSC survey L_{max} of 57 cm provides estimates of L_{mat} of 46 cm and A_{mat} of 4 years. There are insufficient data on the age and growth of rosette skate to determine fishing mortality rates or propose SFA fishing mortality reference points. The SARC proposes use of the 75th percentile value of the NEFSC autumn biomass indices for the Mid-Atlantic offshore region during 1967-1998 as a proxy for the SFA target biomass reference point for rosette skate (0.029 kg/tow), and one-half of that value as the SFA threshold biomass reference point for rosette skate (0.015 kg/tow; Figure B107).

EVALUATION OF FISHING MORTALITY AND STOCK ABUNDANCE

The length-based mortality estimators of Beverton and Holt (1956) and Hoenig (1987) were considered for the estimation of fishing mortality rates for winter and little skates from NEFSC spring length frequency distributions. The NEFSC spring survey series exhibit both a long time series and the least evidence of continuous trends in recruitment for the two species, making it amenable for use with these estimators, which can be biased by trends or extreme variation in recruitment over time.

The Beverton and Holt (1956) estimator is:

$$Z = (K(L_{inf} - L_{bar})) / (L_{bar} - L'),$$

and the Hoenig (1987) estimator is:

$$Z = \ln [(e^{-K}(L_{bar} - L_{inf}) + L_{inf} - L') / (L_{bar} - L')].$$

For both estimators, L' = the lower limit of the length class in which the fish are assumed fully recruited to the sampling or fishing gear, and L_{bar} = the mean length of fish above L' in the sample length distributions. Hoenig's (1987) estimator reportedly avoids the positive bias in estimates calculated with the Beverton and Holt (1956) estimator for samples in which L' approaches L_{bar}. The SARC concluded that the Hoenig (1987) estimates are more reliable, and those are the fishing mortality rates referenced below. Estimates were calculated for 5 year (winter skate) and 3 year (little skate) moving groups, or windows, of years to smooth the variation in the mortality estimates caused by variations in recruitment over time.

The following sections describe estimates of mortality for winter and little skates. No age and growth parameters were available for the other five species in the complex, and so no mortality estimates have been made.

<u>Winter skate</u>

Investigation of the NEFSC spring survey length frequencies determined that the appropriate value for L' was 50 cm, based on the time series average of the 1 cm length intervals with the most abundant survey catches. The von Bertalaffy growth parameters reported in Simon and Frank (1996) were used in the mortality rate estimator, and initially a value of M = 0.2 was used based on assumed maximum age of about 20 years.

For M = 0.2, Hoenig (1987) estimates of F for winter skate were about 0.2 during the 1970s, falling to very low levels during the 1980s, and then increasing during the 1990s to 0.2-0.3. The very low to negative values of F during the 1980s with M = 0.2, however, indicated that some of the parameters used in the estimators (either the growth parameters, L', or M) might be mis-specified, and so the fishing mortality estimates may be negatively biased. Frisk's (1999) work suggests that the M/K ratio for skates is about 1.0. Taking into consideration the Simon and Frank (1996) of K = 0.14, the SARC concluded that a value of M = 0.1, and an inferred maximum age of 30 years, was appropriate for winter skate.

With M=0.1, fishing mortality on winter skate was estimated to be about 0.30, well above the proposed SFA threshold of F = 0.10, during the early to mid 1970s (Table B31, Figure B108). Fishing mortality decreased in concert with a drop in reported landings of all species of skates (Figure B1) and an increase in abundance of winter skate (Figure B11) during the late 1970s and into the mid 1980s. Fishing mortality was near or below F = 0.1 during 1979-1992 (Table B31, Figure B106). Fishing mortality on winter skate has increased during the 1990s as reported landings of all species of skates have increased (Figure B1) and the abundance of winter skate has decreased (Figure B11). The current fishing mortality rate on winter skate is estimated to be 0.39, much higher than the proposed SFA threshold of F = 0.10 (Table B31, Figure B108).

Due to the inter-annual variation in skate survey indices of abundance, the most recent three year averages of the indices were used to evaluate current status with respect to the proposed SFA biomass reference points. For winter skate, the 1996-1998 NEFSC autumn survey biomass index average of 2.83 kg/tow is below the proposed SFA biomass target and threshold reference points of 6.46 kg/tow and 3.23 kg/tow.

Little skate

Waring (1984) used catch curve analysis of the NEFSC survey catch at age data for 1968-1978 to estimate an instantaneous total mortality rate (Z) of 1.76 in the early 1970s, which declined to 0.54 in the late 1970s. Assuming values of instantaneous natural mortality (M) of 0.4-0.5, Waring (1984) inferred that fishing mortality rates therefore ranged from 1.26-1.35 in the early 1970s to 0.17 to 0.27 in the late 1970s.

Investigation of the NEFSC winter, spring, and autumn length frequencies determined that the appropriate value for L' was 45 cm in the NEFSC winter, spring and autumn surveys, based on the time series average of the 1 cm length intervals with the most abundant survey catches. Investigation of NEFSC survey cumulative length distributions (1994-1999) and recent landed skate cumulative length distributions from NEFSC sea sampling of the commercial fishery (1994-1999) indicated that the contemporary estimate of the length of recruitment to the fishery was very similar, at 43 cm, and so fishing mortality estimates with the survey L' = 45 cm are considered valid estimates of the fully recruited fishing mortality rate. The von Bertalanffy growth parameters reported in Waring (1984) were used in both mortality rate estimators, and a value of M = 0.4 was used based on an assumed maximum age of about 8 years.

The time series of little skate mortality begins with the 1982-1984 three year window (1984 in Table B32) to ensure a series with consistent survey vessel and gear catch conversion factors. Estimates of fishing mortality for little skate have risen from about 0.20 during 1984-1990 to about 0.30 during the 1990s. The estimates of fishing mortality for little skate are sensitive to small changes in the value of Lbar (about 47 cm), which is both within the large accumulation of skates between 40 and 50 cm in the most annual NEFSC spring length frequency distributions (Figures B33-B34) and within 6 cm of Linf (53 cm). The 1997-1999 increase in F (1999 in Table B32) is due to a time series low value of L_{bar}, and that in turn is due at least in part to recent increased abundance of smaller skates in the survey length distributions (Figure B34). Thus, the apparent recent increase in fishing mortality of little skate from the spring survey may be an artifact of recently improved recruitment. The current fishing mortality rate on little skate is estimated to be 0.34, lower than the proposed SFA threshold of F = 0.40 (Table B32, Figure B108).

Due to the inter-annual variation in skate survey indices of abundance, the most recent three year averages of the indices were used to evaluate current status with respect to the proposed SFA biomass reference points. For little skate, the 1997-1999 NEFSC spring survey biomass index average of 6.72 kg/tow is above the proposed SFA biomass target and threshold reference points of 6.54 kg/tow and 3.27 kg/tow.

Barndoor skate

For barndoor skate, there are insufficient data on age and growth to determine fishing mortality rates. Due to the inter-annual variation in skate survey indices of abundance, the most recent three year averages of the indices were used to evaluate current status with respect to the proposed SFA biomass reference points. For barndoor skate, the 1996-1998 NEFSC autumn survey biomass index average of 0.08 kg/tow is below the proposed SFA biomass target and threshold reference points of 1.62 kg/tow and 0.81 kg/tow.

Thorny skate

For thorny skate, there are insufficient data on age and growth to determine fishing mortality rates. Due to the inter-annual variation in skate survey indices of abundance, the most recent three year averages of the indices were used to evaluate current status with respect to the proposed SFA biomass reference points. For thorny skate, the 1996-1998 NEFSC autumn survey biomass index average of 0.77 kg/tow is below the proposed SFA biomass target and threshold reference points of 4.41 kg/tow and 2.20 kg/tow.

Smooth skate

For smooth skate, there are insufficient data on age and growth to determine fishing mortality rates. Due to the inter-annual variation in skate survey indices of abundance, the most recent three year averages of the indices were used to evaluate current status with respect to the proposed SFA biomass reference points. For smooth skate, the 1996-1998 NEFSC autumn survey biomass index average of 0.15 kg/tow is below the proposed SFA biomass target and threshold reference points of 0.31 kg/tow and 0.16 kg/tow.

Clearnose skate

For clearnose skate, there are insufficient data on age and growth to determine fishing mortality rates. Due to the inter-annual variation in skate survey indices of abundance, the most recent three year averages of the indices were used to evaluate current status with respect to the proposed SFA biomass reference points. For clearnose skate, the 1996-1998 NEFSC autumn survey biomass index average of 0.72 kg/tow is above the proposed SFA biomass target and threshold reference points of 0.56 kg/tow and 0.28 kg/tow.

Rosette skate

For rosette skate, there are insufficient data on age and growth to determine fishing mortality rates. Due to the inter-annual variation in skate survey indices of abundance, the most recent three year averages of the indices were used to evaluate current status with respect to the proposed SFA biomass reference points. For rosette skate, the 1996-1998 NEFSC autumn survey biomass index average of 0.040 kg/tow is above the proposed SFA biomass target and threshold reference points of 0.029 kg/tow and 0.015 kg/tow.

STATUS OF BARNDOOR SKATE RELATIVE TO ENDANGERED SPECIES ACT (ESA) LISTING FACTORS

Background Information

On March 4, 1999, NMFS received a petition from GreenWorld to list barndoor skate as endangered or threatened and to designate Georges Bank and other appropriate areas as critical habitat. The petitioners also requested that barndoor skate be listed immediately, as an emergency matter. Finally, the petitioner requested that other similarly appearing species of skate also be designated as threatened or endangered so as to insure the protection of the barndoor skate. On April 2, 1999, the NMFS received a second petition from the Center for Marine Conservation (CMC) to list barndoor skate as an endangered species. This second petition was considered by NMFS as a comment on the first petition submitted by GreenWorld.

The petition and comment on the petition referenced a recent paper in the journal *Science*, which presents data on the decline of barndoor skates (Casey and Myers 1998). The petitioner cites bycatch in commercial fishing gear as the major threat to the species' continued existence and also expresses concern over "inbreeding depression due to small population size." The petitioner also cites the inadequacy of existing regulatory mechanisms as a threat to the species. The comments submitted by CMC claim that barndoor skate are endangered due to overutilization for commercial purposes and the inadequacy of existing regulatory mechanisms. The CMC has also requested that the Secretary of Commerce categorize barndoor skate as "overfished" under the Magnuson Stevens Act. This assessment is part of NMFS' determination of barndoor skate status relative to the ESA listing factors and the requirements of the Magnuson Stevens Act.

ESA Listing Factors and Basis for Determination

Under Section 4(a)(1) of the ESA, a species can be determined to be endangered or threatened for any of the following factors: (1) Present or threatened destruction, modification, or curtailment of its habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) inadequacy of existing regulatory mechanisms; or (5) other natural or manmade factors affecting its continued existence. Listing determinations are based on the best scientific and commercial data available after taking into account any efforts being made by any state or foreign nation to protect the species.

To ensure that the assessment review conducted by the SARC was complete and based on the best available scientific and commercial data, NMFS solicited information on the species' current and historic distribution and abundance and any information related to the five listing factors identified above. The SARC reviewed this information, from the Marine Conservation Biology Institute, the Virginia Institute of Marine Science, the Center for Marine Conservation, and the Trawlers Survival Fund, in addition to commercial fishery and state and federal (both US and Canadian) research survey data, in developing comments on the five ESA listing factors.

The SARC reviewed barndoor skate with respect to the 5 ESA listing factors and found that there was no evidence that they were in danger of extinction or likely to become endangered within the foreseeable future throughout all or a significant portion of its range. Research surveys indicate that barndoor skate biomass in waters off the east coast of North America has declined substantially from peak levels prior to the 1960s to very low levels during the 1970s and 1980s. Recently, barndoor skate abundance and biomass have begun to increase in surveys in USA and Canadian waters. Barndoor skate also occur in waters deeper than covered by these surveys and the surveys underrepresent the abundance of larger barndoor skate. Under Section 4(a)(1) of the ESA, a species can be determined to be endangered or threatened for any of the following factors: (1) Present or threatened destruction, modification, or curtailment of its habitat or range; (2) overutilization for commercial, recreational, scientific; or educational purposes; (3) disease or predation; (4) inadequacy of existing regulatory mechanisms; or (5) other natural or manmade factors affecting its continued existence. Listing determinations are based on the best scientific and commercial data available after taking into account any efforts being made by any state or foreign nation to protect the species. With regard to each of these 5 listing factors:

(1) Barndoor skate have persisted in their core habitat in USA waters at very low abundance since the late 1960s. Although barndoor skate were not observed in survey catches in many parts of its potential range during the past two decades, it is now occurring in some areas, particularly on the western Scotian Shelf, on Georges Bank, and in offshore waters off Southern New England. There is no evidence of a contraction in range, but present low abundance may reflect local reductions in area of occupancy. Thus, the available evidence does not suggest that the habitat or range of barndoor skate has been destroyed, modified, or curtailed to an extent that threatens the existence of the species.

(2) Given the high level of distant water fleet and domestic fishing effort that occurred in the barndoor skate habitat during the last 40 years (Figure B109), fishing mortality, mainly as bycatch, was likely a factor contributing to the decline in barndoor skate abundance. Although fishing and natural mortality rates of barndoor skate cannot be quantified, the small but sustained increase in research survey catches indicates that annual survival rates are currently high enough to allow for some recovery. Therefore, it appears that barndoor skate are not currently overutilized for commercial, recreational, scientific or educational purposes.

(3) There is no scientific evidence to suggest that barndoor skate in the waters of the Northeast Coast of the USA are subject to an unusual degree of disease or predation.

(4) There are no current regulations specifically governing the harvest of barndoor skate. However, fisheries in which barndoor skate are taken as by-catch have been subject to increasingly restrictive regulations over the past decade which may have provided some protection over some parts of its range. Following the progressive implementation of the regulations, survivorship of barndoor skate has recently been high enough to allow abundance and biomass to increase to some extent. However, if current effort limitation and closed area restrictions on Georges Bank and southern New England are relaxed, continued increases in abundance may be hindered.

(5) Although the combination of continued low abundance, suspected low intrinsic rate of increase and suspected late age of maturity make barndoor skate vulnerable to extirpation, the species has persisted at low levels in USA waters over the past 30-40 years. Thus, there is no scientific evidence to suggest that barndoor skate have been subject to unusual natural or anthropogenic factors that threaten its continued existence.

CONCLUSIONS

Assessment Results

Conclusions about the status of the seven species in the northeast US region skate complex are based mainly on standardized research trawl survey data collected by the US and Canada during 1963-1999. Taken as a group, the skate biomass for the seven species in the Northeast Region is at a medium level. For the aggregate complex, the NEFSC spring survey index of biomass was relatively constant from 1968 to 1980, then increased significantly to peak levels in the mid to late 1980s. The index of skate complex biomass then declined steadily until 1994, but recently began to increase again (Figure B2). The large increase in skate biomass in the mid to late 1980s was dominated by winter and little skate. The biomass of large sized skates (>100 cm maximum length; barndoor, winter, and thorny) has steadily declined since the mid-1980s. The recent increase in aggregate skate biomass has been due to an increase in small sized skates (<100 cm maximum length; little, clearnose, rosette, and smooth), mainly little skate (Figure B3). All large-bodied skates (winter, barndoor, and thorny) and all primary skate species in the Gulf of Maine (thorny and smooth) are currently overfished, and overfishing is occurring on winter skate. Reductions in fishing mortality are required to eliminate overfishing of winter skate and to promote rebuilding of other overfished skate species.

Winter skate abundance is currently about same as in the early 1970s, at about 25% of the peak observed during the mid 1980s. Comparison of the current fishing mortality rate (NEFSC spring survey; F = 0.39) to the proposed SFA threshold fishing mortality reference point (F = M = 0.1) indicates that overfishing for winter skate is occurring (Figure B108). The 1996-1998 NEFSC autumn survey biomass index average of 2.83 kg/tow is below the proposed SFA biomass threshold reference point of 3.23 kg/tow (Figure B107). Winter skate is overfished.

Little skate abundance began to increase in the early 1980s, and has increased to the highest abundance since 1975. Comparison of the current fishing mortality rate (NEFSC spring survey; F = 0.34) to the proposed SFA threshold fishing mortality threshold reference point (F = M = 0.4) indicates that overfishing for little skate is not occurring (Figure B108). The 1997-1999 NEFSC spring survey biomass index average of 6.72 kg/tow is above the proposed SFA biomass threshold reference point of 3.27 kg/tow (Figure B107). Little skate is not overfished.

The abundance of barndoor skate declined continuously through the 1960s to historic lows during the early 1980s. Since 1990, the abundance of barndoor skate has increased slightly on Georges Bank, the western Scotian Shelf and in Southern New England, although the current NEFSC autumn survey biomass index is still less than 5% of the peak observed in 1963. The fishing mortality rate could not be estimated for the stock nor could a fishing mortality reference point be determined. The 1996-1998 NEFSC autumn survey biomass index of 0.08 kg/tow is below the proposed SFA biomass threshold reference point of 0.81 kg/tow (Figure B107). Barndoor skate is overfished.

The abundance of thorny skate has declined to historic lows. Current abundance is about 10%-15 % of the peak observed in the late 1960's to early 1970s. The fishing mortality rate could not be estimated for the stock nor could a fishing mortality reference point be determined. The 1996-1998 NEFSC autumn survey biomass index of 0.77 kg/tow is below the proposed SFA biomass threshold reference point of 2.20 kg/tow (Figure B107). Thorny skate is overfished.

The abundance of smooth skate was highest during the early 1960s and late 1970s. The fishing mortality rate could not be estimated for the stock nor could a fishing mortality reference point be determined. The 1996-1998 NEFSC autumn survey biomass index of 0.15 kg/tow is below the proposed SFA biomass threshold reference point of 0.16 kg/tow (Figure B107). Smooth skate is overfished.

The abundance of clearnose skate has been increasing since the mid 1980s. The fishing mortality rate could not be estimated for the stock nor could a fishing mortality reference point be determined. The 1996-1998 NEFSC autumn survey biomass index of 0.72 kg/tow is above the proposed SFA biomass threshold reference point of 0.28 kg/tow (Figure B107). Clearnose skate is not overfished.

The abundance of rosette skate has been increasing since 1986. The fishing mortality rate could not be estimated for the stock nor could a fishing mortality reference point be determined. The 1996-1998 NEFSC autumn survey biomass index of 0.040 kg/tow is above the proposed SFA biomass threshold reference point of 0.015 kg/tow (Figure B107). Rosette skate is not overfished.

SARC COMMENTS

The SARC noted that the landings attributable to species are very uncertain, since over 99% of the landings records are reported as "unclassified skates." This is due both to the difficulties of species identification, and the uncertainty of the relative proportions of skate landed as "wings" specifically for human consumption (likely winter or thorny skate), for use as bait (likely little skate), or as whole fish.

The SARC discussed the species identification problems which may also exist in survey data, particularly for winter and little skate at sizes less than 35 cm. Currently, the NEFSC survey data are audited such that the proportions (on a per tow basis) of winter and little skate less than 35 cm reflect the proportions greater than 35 cm, for tows with a significant mix of winter and little skate.

With the increased participation of volunteers on NEFSC surveys over the last 3-4 years, skate identification may be more uncertain than during earlier years.

The SARC discussed that assumption of the natural mortality rate for winter skate, and noted that the preference for the value of $M = 0.1$ was based on growth rate estimates available from Canadian waters (Simon and Frank, 1996; $K = 0.14$) and the work of Frisk (1998) which suggest an M/K ratio for elasmobranchs of about 1.0. The SARC further noted that application of the Hoenig (1983) method to estimate natural mortality ($\ln[M] = 1.44 - 0.982*\ln[t_{max}]$) provided an estimate of M = 0.15 for a potential maximum age of 30 years.

The SARC noted that clearnose skate have a more southern distribution compared to the other skates considered in the Northeast Region skate complex, and the survey data considered in this assessment likely reflect trends for only the northern component of the population or stock along the Atlantic coast. It was also noted that abundance of clearnose skate may be increasing in recent years due to recent declines in the abundance of the primary predators of clearnose skate, including sand tigers and other large coastal sharks.

There was general discussion among SARC members as to whether sustainable yield reference points were appropriate for large sized skates such as winter, thorny and barndoor, since they are generally characterized by relatively slow growth and low intrinsic rates of population increase. It was noted that reference points based on threshold levels or indices of spawning biomass may be more appropriate for these species, since recruitment success is more closely related to standing spawning stock biomass than for most teleost stocks. It was also noted that a major source of fishing mortality is bycatch and therefore yield based reference points may not be appropriate. The SARC acknowledged, however, that SFA reference points need to be formulated with consideration of maximum sustainable yields. Given the lack of stock-recruitment data the SARC recommended that fishing mortality rate targets be set to rate of natural mortality.

The SARC noted that historical NEFSC survey data, from the Albatross III cruises during 1948-1962, should be investigated when they become readily accessible, as they may provide valuable historical context for long term trends in skate biomass.

Research Recommendations

1) The commercial fishery statistics sampling programs should be adapted to report skates landings by species.

2) Commercial fishery size composition data should be collected by species.

3) Sea sampling of directed skate landings and skate bycatch should be increased, and the identification of the species composition of the skate catch improved.

4) Age and growth studies, for all seven species in the complex, are needed.

5) Maturity and fecundity studies, for all seven species in the complex, are needed. Use of life history models requires these data, and may prove useful in establishing biological reference points for the skate species.

6) Estimates of commercial and recreational fishery discard mortality rates, for different fishing gears and coastal regions and/or bottom types, for all seven species in the complex, are needed.

7) Studies of the stock structure of the species in the skate complex are needed to identify unit stocks. Stock identification studies, especially for barndoor, thorny, winter, and little skate, are needed.

8) Explore possible stock-recruit relationships by examination of NEFSC survey data. A

simultaneous examination of the species in the complex may prove a useful first step.

9) Investigate trophic interactions between skate species in the complex, and between skates and other groundfish.

10) Further consideration of the validity of NEFSC trawl survey catchability conversion factors for skate species is needed (diel, gear, vessel).

11) Investigate the influence of annual changes in water temperature or other environmental factors on shifts in the range and distribution of the species in the skate complex. Establish the bathymetric distribution of the species in the complex off the U.S. Northeast coast.

12) Investigate the SEAMAP survey data for clearnose and rosette skate.

13) Investigate historical NEFSC survey data from the Albatross III cruises during 1948-1962 when they become readily accessible, as they may provide valuable historical context for long term trends in skate biomass.

14) Recalculate the error distributions of the survey indices using alternative distributions.

Sources of Uncertainty

1) The species composition and size structure of landings are unknown.

2) The true level of discards and the discard mortality rate are unknown.

3) A lack of information on the stock structure of the species in the skate complex has increased the uncertainty of conclusions about historical trends in abundance, recommendations of appropriate biological reference points, and conclusions about the status of barndoor skate relative to ESA listing factors.

4) Life history data are uncertain for winter and little and incomplete and totally lacking for five species.

5) Mortality estimates based on equilibrium assumptions which are only partially met for these stocks. A preferable approach for future assessments would be an age-based method for determining mortality rates and estimates of longevity. This will require several years of future adequate length and age sampling, both from the commercial and research survey catches.

6) The proposed SFA biomass reference points are based on selected time periods of survey indices, but it is unknown how these relate to true estimates of B_{MSY}.

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Table B1. Total commercial landings of skate (mt) in NAFO subareas 5 and 6 by country from 1960-1998.

	US	USSR	Others	Total
1960	61	0	0	61
1961	36	0	0	36
1962	44	0	0	44
1963	33	0	0	33
1964	4081	0	2	4083
1965	2343	0	20	2363
1966	2738	0	106	2844
1967	2715	2121	62	4898
1968	2417	3974	92	6483
1969	3045	6410	7	9462
1970	1583	2544	1	4128
1971	900	5000	5	5905
1972	866	7957	0	8823
1973	1191	6754	18	7963
1974	2026	1623	2	3651
1975	752	3216	0	3968
1976	754	412	46	1212
1977	1143	240	35	1418
1978	1130	216	7	1353
1979	1280	79	1	1360
1980	1577	0	4	1581
1981	838	0	9	847
1982	878	0	0	878
1983	3603	0	0	3603
1984	4157	0	0	4157
1985	3984	0	0	3984
1986	4159	0	94	4253
1987	5078	0	0	5078
1988	7255	0	9	7264
1989	6717	0	0	6717
1990	11403	0	0	11403
1991	11332	0	0	11332
1992	12525	0	0	12525
1993	12904	0	0	12904
1994	8829	0	0	8829
1995	7222	0	0	7222
1996	14226	0	0	14226
1997	10952	0	0	10952
1998	16936	0	0	16936

Table B2. Discards of skates by gear type and target species. (ot = otter trawls; sgn = sink gill net; dgn = drift gill net; sd = scallop dredge; mpt = midwater pair trawls; cp = conch pots; lp = lobster pot; bt = beam trawl; mt = midwater trawl; lt = line trawl; ll = longline; pt = pair trawl; st = shrimp trawl). The discard rate is calculated as the sum of the pounds of discarded skates divided by the sum of the kept pounds of the target species when the target was more than 50% of the catch.

gear	primary species	Number of trips	Discard Rate	Landings of target species in mt 1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	skate discards in mt 1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
ot	goosefish	29	0.584	1104	474	2183	2445	2650	2429	3669	4556	4642	4170	645	277	1275	1428	1548	1419	2143	2661	2711	2436
ot	bluefish	1	0.161	55	70	200	57	21	54	141	172	202	228	9	11	32	9	3	9	23	28	33	37
ot	butterfish	12	0.008	769	418	693	645	2360	1635	642	1157	1027	407	6	3	6	5	19	13	5	9	8	3
ot	cod	96	0.573	4075	7117	4053	1833	1336	1360	583	1107	819	767	2336	4080	2323	1051	766	780	334	635	470	440
ot	croaker	13	0.001	28	0	0	0	91	62	185	301	1354	878	0	0	0	0	0	0	0	0	1	1
ot	winter flounder	31	1.375	715	756	871	678	401	433	905	1119	1786	1600	984	1039	1198	933	551	595	1244	1539	2457	2200
ot	summer flounder	131	0.765	607	234	322	538	544	749	846	860	1206	1269	464	179	246	411	416	572	647	657	922	971
ot	witch flounder	1	0.091	33	2	3	41	28	25	31	41	27	42	3	0	0	4	3	2	3	4	2	4
ot	yellowtail flounder	47	2.439	1310	5645	1559	1033	380	858	210	360	809	1039	3194	13767	3801	2520	926	2093	512	878	1972	2535
ot	American plaice	11	0.245	45	14	67	137	60	67	67	99	94	45	11	4	16	34	15	16	16	24	23	11
ot	windowpane	2	2.415	679	234	1411	437	383	43	318	241	78	160	1639	565	3409	1056	926	105	769	583	188	386
ot	flounders, nk	1	8.852	17	7	15	18	14	3	0	1	1	0	154	60	129	163	126	24	1	7	11	0
ot	haddock	2	0.862	6	22	78	99	20	1	1	6	18	210	5	19	68	85	18	1	1	5	16	181
ot	red hake	12	0.009	199	188	184	258	207	361	106	343	264	225	2	2	2	2	2	3	1	3	2	2
ot	white hake	1	0.000	37	251	308	442	145	11	41	50	6	34	0	0	0	0	0	0	0	0	0	0
ot	herring, nk	1	0.001	0	0	0	0	243	555	123	297	11	188	0	0	0	0	0	0	0	0	0	0
ot	Atlantic herring	18	0.010	487	670	1574	4079	2134	2725	2029	2114	1304	5526	5	7	15	40	21	27	20	21	13	54
ot	Atlantic mackerel	21	0.002	6604	7667	13898	7545	1984	6243	6601	9018	6065	6728	13	16	28	15	4	13	13	18	12	14
ot	ocean pout	3	0.793	989	1032	1066	174	118	124	15	32	13	1	784	818	845	138	93	98	12	26	10	1
ot	pollock	6	0.084	1641	1432	741	464	177	71	91	109	234	430	138	121	63	39	15	6	8	9	20	36
ot	scup	15	0.098	456	263	992	883	812	623	396	628	696	439	45	26	97	87	80	61	39	62	68	43
ot	black sea bass	1	0.015	9	22	6	0	28	37	1	57	17	24	0	0	0	0	0	1	0	1	0	0
ot	weakfish	18	0.353	412	471	88	160	76	76	257	210	231	290	145	166	31	56	27	27	91	74	81	102
ot	spiny dogfish	38	0.065	352	6730	4778	4286	4505	2607	2323	2747	1450	2442	23	440	312	280	294	170	152	179	95	160
ot	skates, nk	47	0.314	5445	8956	8333	9387	8982	5111	4176	11122	6878	10099	1709	2811	2615	2946	2819	1604	1311	3490	2159	3169
ot	striped bass	1	0.030	0		4	5		3	19	33	67	32	0	0	0	0	0	0	1	1	2	1
ot	tautog	7	0.069	2	8	3	12	29	8	13	16	5	5	0	1	0	1	2	1	1	1	0	0
ot	silver hake	226	0.068	13017	15178	10955	10102	11963	7529	7894	12009	10437	10141	882	1029	743	685	811	510	535	814	707	687
ot	crab, nk	2	0.055	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0
ot	horseshoe crab	49	0.104	342	221	301	356	707	304	332	534	392	777	36	23	31	37	74	32	35	56	41	81
ot	pandalid shrimp	1	0.096	37	31	21	5	7	5	14	41	48	4	4	3	2	0	1	0	1	4	5	0
ot	conchs	2	4.131	89	80	38	4	69	141	28	23	37	21	369	330	158	16	287	583	116	93	151	88
ot	sea scallop	1	0.048	3685	3912	7224	4608	3335	5703	6130	5600	3471	4339	178	189	350	223	162	276	297	271	168	210
ot	loligo	171	0.083	14473	8294	13145	11775	16068	13432	10548	5834	9468	10039	1202	689	1092	978	1335	1116	876	485	787	834
ot	illex	34	0.000	6761	11095	11765	17605	17753	17286	13496	14580	12486	21818	3	4	5	7	7	7	5	6	5	9
ot	squid, nk	6	0.217											0	0	0	0	0	0	0	0	0	0
											Total	14990	26678	18893	13249	11347	10164	9212	12644	13141	14697

Table B3. Discards of skates by gear type and target species. (ot = otter trawls; sgn = sink gill net; dgn = drift gill net; sd = scallop dredge; mpt = midwater pair trawls; cp = conch pots; lp = lobster pot; bt = beam trawl; mt = midwater trawl; lt = line trawl; ll = longline; pt = pair trawl; st = shrimp trawl) as the sum of the pounds of discarded skates divided by the sum of the kept pounds of the target species when the target was more than 50% of the catch.

		Number	Discard	Landings of target species in mt										skate discards in mt									
gear	primary species	of trips	Rate	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
sgn	goosefish	840	0.029	5	10	251	765	1424	2279	3656	3155	3614	4372	0	0	7	22	41	66	106	92	105	127
sgn	bluefish	137	0.005	405	564	394	627	613	725	436	464	1166	968	2	3	2	3	3	3	2	2	6	5
sgn	bonito	7	0.062				12	0	6	5	3	3	3	0	0	0	1	0	0	0	0	0	0
sgn	cod	2364	0.148	2890	2453	2421	1552	1145	1285	1334	1396	733	434	429	364	359	230	170	191	198	207	109	64
sgn	croaker	266	0.000	37	3	3	98	778	922	849	1181	2198	2738	0	0	0	0	0	0	0	0	0	0
sgn	winter flounder	130	0.122	29	25	16	26	28	15	42	17	22	22	4	3	2	3	3	2	5	2	3	3
sgn	witch flounder	9	0.127	0	0	1	0	6	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0
sgn	yellowtail flounder	205	0.036	8	37	48	35	13	27	118	93	54	154	0	1	2	1	0	1	4	3	2	6
sgn	American plaice	80	0.011		0		0	7	1	7	3	1	128	0	0	0	0	0	0	0	0	0	1
sgn	haddock	2	0.005	7	2	0	1			1	1	1	9	0	0	0	0	0	0	0	0	0	0
sgn	white hake	272	0.004	792	585	258	887	466	116	213	137	67	97	4	3	1	4	2	1	1	1	0	0
sgn	Atlantic mackerel	58	0.008	24	132	44	72	19	34	44	124	79	48	0	1	0	1	0	0	0	1	1	0
sgn	menhaden	49	0.000	56	155	306	467	506	503	166	176	119	140	0	0	0	0	0	0	0	0	0	0
sgn	pollock	517	0.002	2862	1533	647	548	662	268	248	164	248	561	6	3	1	1	1	1	1	0	1	1
sgn	sea raven	1	1.189						0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sgn	scup	1	0.118				0	0	1	3	4	1	0	0	0	0	0	0	0	0	0	0	0
sgn	weakfish	131	0.001	57	72	87	39	169	193	120	175	369	511	0	0	0	0	0	0	0	0	0	0
sgn	American shad	10	0.016	379	307	214	279	269	217	114	260	254	298	6	5	3	5	4	3	2	4	4	5
sgn	smooth dogfish	113	0.004			108	298	206	192	206	349	255	274	0	0	0	1	1	1	1	1	1	1
sgn	spiny dogfish	1901	0.006	3591	7449	7039	7426	11441	10482	13192	14567	13617	14408	21	44	42	44	68	62	78	86	81	85
sgn	skates, nk	70	0.023	0	3	19	62	361	537	240	445	1010	683	0	0	0	1	8	12	5	10	23	16
sgn	Spanish mackerel	33	0.000	0	4	21	6	29	27	5	9	66	67	0	0	0	0	0	0	0	0	0	0
sgn	spot	74	0.000	451	158	449	730	1010	1244	1054	831	1068	1266	0	0	0	0	0	0	0	0	0	0
sgn	tautog	24	0.074	5	14	29	35	8	15	9	10	3	1	0	1	2	3	1	1	1	1	0	0
sgn	little tuna	7	0.001				0	2	1	18	0	6	2	0	0	0	0	0	0	0	0	0	0
sgn	porbeagle	2	0.002			1		0		0		0	0	0	0	0	0	0	0	0	0	0	0
sgn	sandbar shark	12	0.027			1			2	0	1	4	1	0	0	0	0	0	0	0	0	0	0
sgn	horseshoe crab	2	0.131						1	9	8	30	18	0	0	0	0	0	0	1	1	4	2
sgn	lobster	4	0.029	7			0	4	2	1	43	33	2	0	0	0	0	0	0	0	1	1	0
sgn	loligo	1	0.003							1	0	0	3	0	0	0	0	0	0	0	0	0	0
													Total	473	428	423	320	305	345	406	414	340	318

Table B4. Discards of skates by gear type and target species. (ot = otter trawls; sgn = sink gill net; dgn = drift gill net; sd = scallop dredge; mpt = midwater pair trawls; cp = conch pots; lp = lobster pot; bt = beam trawl; mt = midwater trawl; lt = line trawl; ll = longline; pt = pair trawl; st = shrimp trawl) as the sum of the pounds of discarded skates divided by the sum of the kept pounds of the target species when the target was more than 50% of the catch.

		Number	Discard	Landings of target species in mt										skate discards in mt									
gear	primary species	of trips	Rate	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
dgn	cod	2	0.001	5	1	1		1						0	0	0	0	0	0	0	0	0	0
dgn	bluefish	32	0.001	34	67	427	74	171	230	111	410	369	331	0	0	0	0	0	0	0	0	0	0
dgn	menhaden	5	0.000	168	66	91	86	184	95	118	287	128	149	0	0	0	0	0	0	0	0	0	0
dgn	American shad	21	0.015	302	296	306	191	176	75	37	123	112	137	4	4	5	3	3	1	1	2	2	2
dgn	spiny dogfish	2	0.008		14	52	170	77	23	307	1213	1000	1288	0	0	0	1	1	0	2	9	8	10
													Total	5	5	5	4	3	1	3	11	10	12
sd	goosefish	3	0.738	395	244	66	65	1814	390	625	465	680	1058	292	180	48	48	1338	287	461	343	501	780
sd	sea scallop	175	0.246	117161	139092	134692	113309	56476	56251	58393	59786	45758	23580	28817	34211	33128	27869	13891	13835	14362	14705	11254	5800
													Total	29108	34391	33177	27917	15229	14123	14823	15047	11756	6580
mpt	goosefish	2	0.001											0	0	0	0	0	0	0	0	0	0
mpt	big-eye tuna	26	0.000				14	33	48	60				0	0	0	0	0	0	0	0	0	0
mpt	albacore tuna	10	0.001				90	20	58	25				0	0	0	0	0	0	0	0	0	0
mpt	silver hake	1	1.054											0	0	0	0	0	0	0	0	0	0
mpt	squid, nk	1	0.010											0	0	0	0	0	0	0	0	0	0
													Total	0	0	0	0	0	0	0	0	0	0
cp	conchs	1	0.620	1046	2083	1585	2462	2019	1749	1320	1501	1314	780	648	1291	982	1526	1251	1084	818	930	815	484
lp	lobster	10	0.001	22496	26137	27753	24514	25146	23597	20610	31409	36204	35252	17	20	21	19	19	18	16	24	28	27
bt	goosefish	1	1.469						27	42				0	0	0	0	0	39	62	0	0	0
mt	Atlantic mackerel	1	0.008			451		479	0	44	1155	529	20	0	0	4	0	4	0	0	10	4	0
mt	loligo	1	0.372										2	0	0	0	0	0	0	0	0	0	1
													Total	0	0	4	0	4	0	0	10	4	1
lt	cod	30	0.790	1034	499	1059	835	566	574	713	569	573	728	817	394	837	660	447	453	564	450	453	575
lt	cusk	5	0.043	33	143	325	385	362	125	54	17	25	44	1	6	14	17	16	5	2	1	1	2
lt	white hake	2	0.008	0	14	94	241	110	139	115	12	116	100	0	0	1	2	1	1	1	0	1	1
lt	ocean pout	1	1.861	0	0	0	1	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0
													Total	818	401	851	680	465	460	567	450	455	578
ll	dusky shark	1	0.000	0	17	0	40	11	1	3	2	0	4	0	0	0	0	0	0	0	0	0	0
pt	cod	4	0.071		403	520	338	435						0	28	37	24	31	0	0	0	0	0
st	cod	2	0.190	3	37	5		1		1	0	3		1	7	1	0	0	0	0	0	1	0
st	pandalid shrimp	477	0.030	3384	4227	3173	3145	2193	3544	6584	9117	6193	3571	103	129	97	96	67	108	201	278	189	109
													Total	104	136	98	96	67	108	201	278	189	109

Table B5. Discards of skates by year, gear type, and primary species category. (Principal groundfish:cod, haddock, pollock, and white hake; pelagics:herring, mackerel, butterfish, and squid; flatfish: summer flounder, winter flounder, American plaice, witch flounder, yellowtail flounder, windowpane flounder and unclassified flounders; small elasmobranchs: dogfish and skates; small-mesh groundfish: silver hake, red hake, and ocean pout). Discards are calculated as the sum of pounds of discarded skates divided by the sum of the pounds of the target species kept in each cell. Cells with zero trips are filled in with the weighted average over all years.

A. Otter Trawls

		Goosefish	Principal Groundfish	Pelagics	Flatfish	Small Elasmobranchs	Small-Mesh Groundfish	Scallops	Others	Total
1989	ntrips	1	23	21	18	8	33	0	8	112
	rate	0.700	0.695	0.214	2.306	0.103	0.053	0.048	0.041	
	mt target	1104	5759	29094	3407	5797	14206	3685	1431	64483
	mt discard	773	4002	6220	7855	596	747	178	58	20430
1990	ntrips	1	16	11	21	12	23	0	12	96
	rate	0.082	0.702	0.015	3.059	0.187	0.092	0.048	0.260	
	mt target	474	8822	28144	6891	15687	16398	3912	1166	81493
	mt discard	39	6197	430	21078	2930	1507	189	303	32673
1991	ntrips	9	25	36	26	11	42	0	13	162
	rate	0.139	0.313	0.049	2.266	0.277	0.134	0.048	0.133	
	mt target	2183	5181	41074	4248	13110	12205	7224	1654	86879
	mt discard	304	1621	2002	9627	3634	1630	350	220	19389
1992	ntrips	5	16	18	24	3	33	0	6	105
	rate	0.509	0.404	0.029	1.603	0.992	0.056	0.048	0.295	
	mt target	2445	2838	41649	2883	13673	10534	4608	1482	80112
	mt discard	1245	1146	1226	4622	13560	593	223	438	23051
1993	ntrips	0	4	8	7	6	23	0	5	53
	rate	0.584	0.516	0.001	1.058	0.124	0.067	0.048	0.710	
	mt target	2650	1678	40542	1809	13487	12288	3335	1839	77628
	mt discard	1548	866	20	1913	1666	818	161	1305	8298
1994	ntrips	0	7	11	19	3	0	0	8	48
	rate	0.584	0.255	0.007	0.633	0.035	0.071	0.048	0.014	
	mt target	2429	1443	41876	2177	7718	8014	5703	1315	70674
	mt discard	1419	368	293	1379	268	565	276	19	4586
1995	ntrips	7	7	41	46	20	26	0	28	175
	rate	0.163	0.292	0.088	0.682	0.052	0.016	0.048	0.055	
	mt target	3669	717	33440	2376	6499	8015	6130	1387	62232
	mt discard	597	209	2949	1620	336	129	297	77	6213
1996	ntrips	2	5	40	26	10	45	0	29	157
	rate	3.714	0.980	0.003	0.864	0.251	0.002	0.048	0.019	
	mt target	4556	1273	32999	2721	13868	12385	5600	2015	75417
	mt discard	16923	1248	102	2351	3477	30	271	39	24442
1997	ntrips	4	1	46	17	3	7	0	5	83
	rate	1.313	0.019	0.005	0.563	0.293	0.011	0.048	0.000	
	mt target	4642	1078	30361	4000	8329	10714	3471	3049	65643
	mt discard	6093	20	158	2252	2444	112	168	0	11248
1998	ntrips	0	2	21	13	8	3	1	3	51
	rate	0.584	2.160	0.003	1.016	0.197	0.160	0.048	0.026	
	mt target	4170	1442	44706	4156	12541	10367	4339	2697	84418
	mt discard	2436	3114	150	4223	2467	1663	210	70	14332

Table B6. Discards of skates by year, gear type, and primary species category. (Principal groundfish cod, haddock, pollock, and white hake; pelagics:herring, mackerel, butterfish, and squid; flatfish: summer flounder, winter flounder, Amwerican plaice, witch flounder, yellowtail flounder, windowpane flounder a,d unclassified flounders; small elasmobranchs. dogfish and skates; small-mesh groundfish: silver hake, red hake, and ocean pout). Discards are calculated as the sum of pounds of discarded skates divided by the sum of the pounds of the target species kept in each cell. Cells with zero trips are filled in with the weighted average over all years.

B. Sink gill nets

		Goosefish	Principal Groundfish	Pelagics	Flatfish	Small Elasmobranchs	Others	Total
1989	ntrips	2	61	0	2	5	6	76
	rate	0.537	0.004	0.007	0.446	0.010	0.023	
	mt target	5	6552	459	37	3591	961	11605
	mt discard	3	29	3	17	37	22	110
1990	ntrips	0	78	1	12	10	4	105
	rate	0.029	0.011	0.231	0.299	0.007	0.001	
	mt target	10	4573	594	62	7452	814	13505
	mt discard	0	52	137	19	50	1	259
1991	ntrips	42	555	3	11	145	16	772
	rate	0.209	0.013	0.006	0.112	0.003	0.008	
	mt target	251	3326	564	65	7166	984	12357
	mt discard	52	43	3	7	24	8	138
1992	ntrips	44	634	9	63	155	33	938
	rate	0.111	0.015	0.007	0.229	0.005	0.026	
	mt target	765	2987	818	62	7785	1546	13964
	mt discard	85	44	6	14	41	40	230
1993	ntrips	38	371	9	46	70	33	567
	rate	0.047	0.010	0.014	0.109	0.004	0.022	
	mt target	1424	2272	794	53	12009	2615	19167
	mt discard	67	22	11	6	48	58	212
1994	ntrips	107	492	7	15	230	117	968
	rate	0.038	0.002	0.163	0.001	0.009	0.004	
	mt target	2279	1668	753	43	11211	3139	19093
	mt discard	87	3	123	0	99	13	326
1995	ntrips	134	283	10	100	350	126	1003
	rate	0.025	0.002	0.080	0.024	0.007	0.002	
	mt target	3656	1795	325	167	13638	2510	22090
	mt discard	93	3	26	4	92	5	224
1996	ntrips	92	244	17	37	278	127	795
	rate	0.011	0.000	0.007	0.009	0.008	0.001	
	mt target	3155	1697	560	114	15361	2731	23617
	mt discard	36	1	4	1	128	3	172
1997	ntrips	160	237	15	54	308	89	863
	rate	0.011	0.000	0.073	0.002	0.008	0.000	
	mt target	3614	1049	453	77	14882	4947	25021
	mt discard	39	0	33	0	122	1	196
1998	ntrips	155	149	37	53	429	212	1035
	rate	0.018	0.001	0.000	0.006	0.004	0.000	
	mt target	4372	1100	488	306	15365	5578	27208
	mt discard	80	1	0	2	55	1	138

Table B7. Discards of skates by year, gear type, and primary species category. (Principal groundfish:cod, haddock, pollock, and white hake; pelagics;herring, mackerel, butterfish, and squid; flatfish: summer flounder, winter flounder, Amwerican plaice, witch flounder, yellowtail flounder, windowpane flounder a,d unclassified flounders; small elasmobranchs: dogfish and skates; small-mesh groundfish: silver hake, red hake, and ocean pout). Discards are calculated as the sum of pounds of discarded skates divided by the sum of the pounds of the target species kept in each cell. Cells with zero trips are filled in with the weighted average over all years.

C. Scallop Dredges

		Goosefish	Scallops	Totals
1989	ntrips	0	0	0
	rate	0.738	0.246	
	mt target	395	117161	117557
	mt discard	292	28817	29108
1990	ntrips	0	0	0
	rate	0.738	0.246	
	mt target	244	139092	139337
	mt discard	180	34211	34391
1991	ntrips	0	2	2
	rate	0.738	0.182	
	mt target	66	134692	134757
	mt discard	48	24513	24561
1992	ntrips	0	15	15
	rate	0.738	0.173	
	mt target	65	113309	113373
	mt discard	48	19611	19659
1993	ntrips	2	19	21
	rate	0.434	0.249	
	mt target	1814	56476	58290
	mt discard	788	14038	14826
1994	ntrips	0	23	23
	rate	0.738	0.139	
	mt target	390	56251	56641
	mt discard	287	7801	8088
1995	ntrips	1	22	23
	rate	3.474	0.314	
	mt target	625	58393	59018
	mt discard	2170	18313	20483
1996	ntrips	0	38	38
	rate	0.738	0.245	
	mt target	465	59786	60251
	mt discard	343	14670	15012
1997	ntrips	0	29	29
	rate	0.738	0.329	
	mt target	680	45758	46437
	mt discard	501	15057	15558
1998	ntrips	0	26	26
	rate	0.738	0.398	
	mt target	1058	23580	24638
	mt discard	780	9394	10174

Table B8. Discards of skates by gear type. (ot = otter trawls; sgn = sink gill net; dgn = drift gill net; sd = scallop dredge; mpt = midwater pair trawls; cp = conch pots; lp = lobster pot; bt = beam trawl; mt = midwater trawl; lt = line trawl; ll = longline;pt = pair trawl; st = shrimp trawl)

	skate discards in mt									
gear	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
ot	20430	32673	19389	23021	8298	4586	6212	24442	11248	14332
sgn	110	259	138	230	212	326	224	172	196	138
dgn	5	5	5	4	3	1	3	11	10	12
sd	29108	34391	24561	19659	14826	8088	20483	15012	15558	10174
mpt	0	0	0	0	0	0	0	0	0	0
cp	648	1291	982	1526	1251	1084	818	930	815	484
lp	17	20	21	19	19	18	16	24	28	27
bt	0	0	0	0	0	39	62	0	0	0
mt	0	0	4	0	4	0	0	10	4	1
lt	818	401	851	680	465	460	567	450	455	578
ll	0	0	0	0	0	0	0	0	0	0
pt	0	28	37	24	31	0	0	0	0	0
st	104	136	98	96	67	108	201	278	189	109
Total	51240	69203	46086	45259	25176	14711	28586	41330	28502	25855

Table B9. Comparison of estimates of total skate discard (metric tons) by initial method (primary species/gear cells, discard rates calculated as mean of the 1989-1998 time series: T), and by final method (primary species group/gear cells, discard rates calculated annually: A).

Year	Primary species, Time series (T)	Species group, Annual (A)	Percent difference (A/T)
1989	45,498	51,240	12.6
1990	62,039	69,203	11.5
1991	53,451	46,086	-13.8
1992	42,666	45,259	6.1
1993	27,420	25,176	-8.2
1994	25,201	14,711	-41.6
1995	25,212	28,586	13.4
1996	28,854	41,330	43.2
1997	25,895	28,502	10.1
1998	22,295	25,855	16.0
Mean	35,853	37,595	4.9

Table B10. Abundance and biomass from NEFSC spring surveys for winter skate for the Gulf of Maine to Mid-Atlantic region (offshore strata 1-30,33-40,61-76). The mean index, 95% confidence intervals, individual fish weight, minimum, mean, and maximum length, 5th, 50th, and 95th percentiles of length, number of nonzero tows, and number of fish caught are presented for 1968-1999.

	weight/tow			number/tow				length						nonzero	
	mean	lower	upper	mean	lower	upper	ind wt	min	5%	50%	mean	95%	max	tows	no fish
1968	2.171	1.640	2.978	0.854	0.530	1.178	2.542	32	42	56	58.6	79	112	36	232
1969	5.913	4.283	7.543	2.790	1.907	3.672	2.119	15	25	53	53.5	79	111	68	640
1970	2.645	1.627	3.663	0.971	0.626	1.317	2.723	37	43	59	61.0	83	103	44	275
1971	3.387	2.066	4.708	1.894	0.873	2.915	1.788	15	30	48	51.8	76	103	41	513
1972	4.620	3.033	6.207	2.602	1.253	3.951	1.776	15	24	48	49.5	74	97	63	634
1973	2.905	2.024	3.786	1.257	0.824	1.689	2.311	21	32	55	55.5	79	100	49	347
1974	2.091	1.352	2.830	0.943	0.505	1.381	2.218	29	34	53	55.6	76	101	46	222
1975	2.395	1.521	3.269	0.893	0.556	1.230	2.682	17	38	59	59.4	79	99	46	227
1976	2.153	1.075	3.231	0.628	0.279	0.978	3.428	22	38	64	63.1	86	97	29	160
1977	3.111	1.815	4.408	0.838	0.513	1.163	3.712	20	29	69	64.7	93	106	35	204
1978	8.275	-0.327	16.877	1.355	0.121	2.589	6.108	43	62	79	78.5	89	96	41	395
1979	1.852	1.095	2.608	0.333	0.206	0.459	5.568	23	35	78	73.5	93	105	50	204
1980	2.990	1.751	4.229	0.538	0.331	0.745	5.559	22	45	78	74.8	97	104	49	187
1981	4.140	2.905	5.376	2.083	1.199	2.966	1.988	15	22	39	47.6	91	104	56	586
1982	5.773	3.876	7.670	2.137	1.195	3.080	2.701	15	26	46	54.9	95	109	64	707
1983	14.329	8.182	20.476	3.264	1.772	4.756	4.391	15	28	67	64.4	96	108	65	817
1984	10.480	6.816	14.144	2.948	1.694	4.201	3.555	15	22	60	59.0	94	106	59	753
1985	16.373	11.119	21.627	7.861	4.653	11.069	2.083	15	22	46	54.3	94	116	65	1891
1986	10.019	6.973	13.064	3.538	2.181	4.894	2.832	15	27	58	62.2	97	108	67	969
1987	13.126	8.428	17.824	4.821	2.926	6.716	2.723	15	29	56	60.8	97	108	69	1221
1988	14.543	10.508	18.577	7.409	4.736	10.082	1.963	15	25	43	53.4	95	107	73	1827
1989	10.141	7.736	12.546	4.252	3.095	5.409	2.385	15	25	59	61.4	94	109	74	1429
1990	7.183	5.184	9.183	5.087	2.657	7.517	1.412	15	27	41	49.9	91	105	67	1678
1991	6.965	4.012	9.918	3.239	1.979	4.499	2.150	17	29	54	58.6	93	107	57	1027
1992	5.988	3.369	8.607	5.208	0.635	9.780	1.150	15	23	42	46.2	82	106	51	1303
1993	4.761	3.392	6.131	4.305	2.561	6.049	1.106	15	25	42	46.5	82	103	62	1118
1994	1.421	0.990	1.852	1.673	1.150	2.196	0.849	20	32	43	46.5	69	99	49	519
1995	2.151	1.340	2.961	1.998	1.231	2.766	1.076	15	34	44	48.4	71	103	49	476
1996	4.547	2.499	6.594	4.470	2.384	6.556	1.017	15	34	46	49.0	68	96	56	1004
1997	3.065	1.325	4.806	1.834	0.987	2.680	1.672	15	23	51	53.5	78	93	39	458
1998	1.504	0.913	2.096	1.045	0.561	1.529	1.439	15	32	51	53.4	79	94	52	341
1999	2.968	1.303	4.632	1.876	0.870	2.883	1.582	16	27	54	54.9	79	100	52	482

Table B11. Abundance and biomass from NEFSC autumn surveys for winter skate for the Gulf of Maine to Mid-Atlantic region (offshore strata 1-30,33-40,61-76). The mean index, 95% confidence intervals, individual fish weight, minimum, mean, and maximum length, 5th, 50th, and 95th percentiles of length, number of nonzero tows, and number of fish caught are presented for 1967-1998.

	weight/tow			number/tow				length						nonzero	
	mean	lower	upper	mean	lower	upper	ind wt	min	5%	50%	mean	95%	max	tows	no fish
1967	2.159	1.248	3.070	0.825	0.544	1.106	2.617	15	32	56	57.0	83	107	35	213
1968	1.865	1.264	2.466	0.928	0.573	1.284	2.009	15	25	51	51.8	80	100	56	227
1969	1.315	0.856	1.774	0.540	0.351	0.730	2.435	16	37	58	58.3	78	90	36	161
1970	2.996	1.663	4.328	1.357	0.576	2.138	2.208	21	33	54	56.0	77	97	53	331
1971	1.078	0.542	1.615	0.588	0.238	0.938	1.833	18	27	50	50.5	77	93	35	163
1972	2.958	2.113	3.804	2.071	1.413	2.728	1.429	15	24	42	46.9	74	96	64	592
1973	4.686	3.348	6.024	2.238	1.510	2.967	2.093	21	32	54	55.1	78	101	48	662
1974	2.097	1.418	2.777	1.024	0.672	1.376	2.048	17	30	52	53.6	77	103	39	262
1975	1.315	0.682	1.948	0.420	0.260	0.580	3.130	16	24	62	60.9	84	103	31	115
1976	2.655	0.918	4.392	0.766	0.257	1.274	3.468	19	22	70	59.9	83	98	21	190
1977	4.095	2.814	5.376	1.617	1.049	2.185	2.533	15	25	47	54.8	87	100	51	662
1978	4.989	3.778	6.199	1.042	0.777	1.307	4.787	15	36	77	73.6	94	105	94	762
1979	5.121	3.768	6.475	1.290	0.976	1.603	3.971	20	31	75	66.0	93	113	89	975
1980	6.233	3.806	8.660	1.558	1.015	2.100	4.002	15	37	66	66.4	95	108	60	602
1981	5.668	3.726	7.610	1.505	0.916	2.094	3.766	15	25	61	62.3	99	110	54	516
1982	8.306	4.780	11.831	3.889	0.502	7.275	2.136	15	22	35	46.7	92	112	45	950
1983	12.852	5.693	20.012	2.590	1.447	3.733	4.962	16	28	78	70.5	95	108	42	843
1984	13.323	8.465	18.181	3.653	2.450	4.857	3.647	15	21	55	59.0	95	110	52	1187
1985	9.182	6.552	11.811	2.665	1.842	3.488	3.446	15	32	79	69.7	97	107	37	827
1986	15.800	7.184	24.415	4.196	2.496	5.895	3.766	15	34	75	71.5	97	110	46	1089
1987	11.063	8.200	13.925	4.291	2.783	5.800	2.578	15	25	58	60.1	97	109	49	1165
1988	7.564	4.961	10.167	3.126	2.223	4.028	2.420	15	23	49	57.4	97	110	45	888
1989	5.081	3.288	6.874	2.084	1.422	2.745	2.439	15	27	59	61.0	96	106	48	720
1990	7.145	4.658	9.632	2.451	1.397	3.505	2.915	22	33	68	66.5	97	107	44	895
1991	4.724	3.627	5.821	2.631	1.866	3.396	1.796	17	31	48	56.3	94	106	58	941
1992	3.582	2.140	5.024	1.862	1.116	2.608	1.923	22	33	51	57.4	91	103	39	509
1993	1.905	1.280	2.530	1.458	0.965	1.951	1.307	16	33	48	52.8	88	104	50	452
1994	2.120	1.432	2.808	1.925	1.217	2.633	1.101	15	26	44	47.6	84	106	52	503
1995	1.985	1.214	2.757	1.769	1.047	2.491	1.122	17	31	46	49.4	77	102	43	424
1996	2.276	1.615	2.937	1.426	0.985	1.867	1.596	17	35	51	54.9	83	104	44	370
1997	2.455	1.150	3.760	1.611	0.738	2.484	1.524	19	34	54	55.5	79	101	55	415
1998	3.753	2.488	5.018	2.140	1.438	2.843	1.753	19	27	55	56.8	83	101	50	609

Table B12. Abundance and biomass from NEFSC winter surveys for winter skate for the Georges Bank to Mid-Atlantic region (offshore strata 1-3,5-7,9-11,13-14,16,61-63,65-67,69-71,73-75). The mean index, 95% confidence intervals, individual fish weight, minimum, mean, and maximum length, 5th, 50th, and 95th percentiles of length, number of nonzero tows, and number of fish caught are presented for 1992-1999.

	weight/tow			number/tow				length						nonzero	
	mean	lower	upper	mean	lower	upper	ind wt	min	5%	50%	mean	95%	max	tows	no fish
1992	31.571	21.666	41.476	39.759	23.811	55.707	0.794	15	24	38	42.4	74	105	62	4042
1993	10.261	6.052	14.469	10.676	2.331	19.021	0.961	15	23	41	44.1	81	106	47	841
1994	14.439	10.586	18.293	14.216	8.465	19.966	1.016	15	29	40	45.4	81	102	33	1079
1995	23.268	14.507	32.029	35.528	18.060	52.996	0.655	15	27	40	42.2	59	104	53	3773
1996	25.239	7.110	43.369	43.515	7.434	79.596	0.580	15	25	40	41.2	56	99	59	4055
1997	11.643	7.287	15.999	12.565	7.109	18.022	0.927	15	27	45	46.9	71	98	46	1414
1998	22.464	15.878	29.050	19.950	13.556	26.344	1.126	15	26	48	49.4	74	105	60	2092
1999	21.089	13.628	28.549	18.380	10.899	25.860	1.147	15	24	49	49.0	74	101	52	1932

Table B13. Abundance and biomass from NEFSC spring surveys for little skate for the Gulf of Maine to Mid-Atlantic region (offshore strata 1-30,33-40,61-76, and inshore strata 1-66). The mean index, 95% confidence intervals, individual fish weight, minimum, mean, and maximum length, 5th, 50th, and 95th percentiles of length, number of nonzero tows, and number of fish caught are presented for 1976-1999.

	weight/tow			number/tow				length						nonzero	
	mean	lower	upper	mean	lower	upper	ind wt	min	5%	50%	mean	95%	max	tows	no fish
1976	1.308	0.861	1.755	3.218	2.136	4.301	0.406	8	12	40	36.9	48	58	172	4202
1977	1.347	0.882	1.811	3.336	2.177	4.494	0.404	6	19	41	38.7	48	57	160	4218
1978	1.391	0.962	1.821	3.286	2.363	4.209	0.423	8	11	42	37.5	48	62	160	3945
1979	0.650	0.501	0.799	2.182	1.429	2.934	0.298	4	12	31	32.7	48	56	204	5684
1980	2.206	1.705	2.707	5.898	4.384	7.413	0.374	8	12	37	36.0	48	57	224	9031
1981	1.501	1.200	1.803	3.426	2.714	4.137	0.438	6	15	41	38.3	49	55	175	4113
1982	3.627	2.644	4.611	7.214	5.351	9.076	0.503	9	18	43	40.7	49	55	153	3564
1983	5.718	4.017	7.420	13.024	9.215	16.832	0.439	6	16	42	37.9	48	57	167	6365
1984	4.094	2.615	5.574	10.023	6.787	13.258	0.409	7	11	40	35.8	48	55	139	4573
1985	6.265	4.628	7.901	15.175	10.575	19.775	0.413	8	11	40	36.8	48	57	148	6535
1986	2.753	1.712	3.795	8.554	3.399	13.709	0.322	6	14	33	34.5	48	57	153	3512
1987	4.625	3.149	6.102	16.031	10.222	21.839	0.289	8	12	32	33.1	47	55	145	9584
1988	5.083	3.444	6.721	14.593	9.688	19.498	0.348	8	11	36	34.5	48	55	130	4195
1989	6.634	3.434	9.834	21.643	9.844	33.441	0.307	8	13	34	33.4	46	55	144	10760
1990	4.993	2.397	7.589	14.979	5.250	24.708	0.333	8	11	37	34.7	47	56	132	7085
1991	5.990	4.672	7.308	18.731	14.059	23.403	0.320	8	13	34	34.2	47	58	178	11986
1992	5.297	2.477	8.118	16.793	5.234	28.352	0.315	8	16	33	34.1	46	57	136	6392
1993	7.524	5.187	9.862	22.361	15.110	29.611	0.336	9	12	36	35.0	47	54	160	9574
1994	3.622	2.425	4.819	9.365	6.297	12.434	0.387	9	19	39	37.3	46	54	154	8548
1995	2.872	2.024	3.720	7.574	5.215	9.933	0.379	8	10	39	36.[illegible]	47	59	148	3801
1996	7.574	5.522	9.626	18.185	12.647	23.722	0.417	7	17	41	38.3	48	58	168	9086
1997	2.708	2.231	3.184	6.671	5.504	7.837	0.406	9	13	40	37.8	48	54	151	4840
1998	7.471	6.156	8.787	20.938	16.232	25.644	0.357	7	17	37	35.8	47	56	195	15710
1999	9.978	7.688	12.267	28.377	20.345	36.409	0.352	8	12	38	35.4	47	56	157	16406

Table B14: Abundance and biomass from NEFSC autumn surveys for little skate for the Gulf of Maine to Mid-Atlantic region (offshore strata 1-30,33-40,61-76, and inshore strata 1-66). The mean index, 95% confidence intervals, individual fish weight, minimum, mean, and maximum length, 5th, 50th, and 95th percentiles of length, number of nonzero tows, and number of fish caught are presented for 1975-1998.

	weight/tow			number/tow				length						nonzero	
	mean	lower	upper	mean	lower	upper	ind wt	min	5%	50%	mean	95%	max	tows	no fish
1975	2.379	1.508	3.249	4.858	3.063	6.654	0.490	10	18	43	40.3	49	56	118	1386
1976	2.185	1.582	2.788	4.576	3.278	5.875	0.477	8	22	43	40.6	48	58	74	1421
1977	3.172	2.271	4.072	6.589	4.683	8.495	0.481	9	22	43	40.7	49	56	122	2438
1978	2.938	2.140	3.736	5.613	3.947	7.279	0.523	10	22	44	42.0	49	62	144	3171
1979	2.902	2.343	3.461	5.944	4.790	7.098	0.488	8	21	44	41.0	49	58	177	4597
1980	2.312	1.768	2.855	5.055	4.102	6.008	0.457	9	13	43	37.9	49	55	142	2451
1981	2.779	2.175	3.382	5.847	4.479	7.215	0.475	9	19	43	39.9	49	58	111	1728
1982	5.799	2.673	8.925	15.391	6.979	23.803	0.377	9	18	36	36.4	48	56	123	3848
1983	1.990	1.340	2.639	5.244	3.268	7.219	0.379	8	17	38	36.6	49	55	100	1313
1984	2.483	1.688	3.279	5.487	3.789	7.185	0.453	10	13	43	38.3	49	56	95	1350
1985	2.423	1.629	3.217	6.103	4.006	8.199	0.397	9	17	40	37.5	49	58	119	2761
1986	1.502	1.125	1.879	4.203	2.759	5.648	0.357	10	16	36	35.7	49	55	96	1240
1987	2.311	1.532	3.090	8.104	4.084	12.124	0.285	10	14	31	32.4	48	55	96	2093
1988	1.177	0.663	1.692	3.524	2.144	4.903	0.334	9	13	34	33.8	48	56	80	1128
1989	2.321	1.091	3.552	6.698	3.574	9.823	0.347	5	13	38	35.2	48	56	100	2288
1990	1.242	0.802	1.681	3.204	1.913	4.495	0.388	9	17	40	37.3	48	54	98	1183
1991	3.552	1.494	5.610	8.854	3.301	14.408	0.401	11	24	40	39.3	47	55	102	2866
1992	1.542	1.126	1.958	4.294	2.993	5.595	0.359	6	14	38	36.0	49	63	107	1460
1993	1.180	0.805	1.555	3.136	2.174	4.099	0.376	10	14	41	36.3	49	55	115	1124
1994	1.906	1.349	2.463	4.329	3.102	5.556	0.440	9	18	42	39.4	49	59	131	1729
1995	2.682	1.795	3.569	5.527	3.739	7.316	0.485	9	21	43	41.2	48	56	118	2058
1996	2.239	1.504	2.973	5.146	3.582	6.711	0.435	9	13	42	38.1	49	60	112	1878
1997	2.148	1.533	2.763	4.825	3.407	6.243	0.445	10	21	43	40.0	49	60	109	1757
1998	2.704	1.968	3.441	5.914	4.237	7.591	0.457	10	20	43	40.2	49	57	129	1713

Table B15. Abundance and biomass from NEFSC winter surveys for little skate for the Georges Bank to Mid-Atlantic region (offshore strata 1-3,5-7,9-11,13-14,16,61-63,65-67,69-71,73-75). The mean index, 95% confidence intervals, individual fish weight, minimum, mean, and maximum length, 5th, 50th, and 95th percentiles of length, number of nonzero tows, and number of fish caught are presented for 1992-1999.

	weight/tow			number/tow				length						nonzero	
	mean	lower	upper	mean	lower	upper	ind wt	min	5%	50%	mean	95%	max	tows	no fish
1992	66.321	50.335	82.306	170.155	127.459	212.852	0.390	9	21	39	38.0	47	62	89	18418
1993	56.377	43.992	68.761	166.927	120.808	213.045	0.338	9	19	36	35.8	46	53	94	16026
1994	49.812	37.387	62.236	131.570	95.199	167.940	0.379	10	20	39	37.5	47	60	67	10113
1995	57.368	39.311	75.424	138.769	87.458	190.081	0.413	8	24	40	39.1	47	53	95	14530
1996	64.056	47.616	80.495	150.579	108.945	192.213	0.425	9	15	41	38.7	47	62	102	15701
1997	51.901	39.986	63.816	117.751	92.288	143.214	0.441	9	23	42	40.2	47	58	92	12084
1998	57.512	49.249	65.775	138.503	111.869	165.136	0.415	9	20	41	38.7	47	57	105	14492
1999	58.566	46.296	70.837	138.876	104.459	173.292	0.422	6	22	41	39.3	48	55	99	14740

Table B16. Abundance and biomass from NEFSC spring surveys for barndoor skate for the Gulf of Maine to Southern New England region (offshore strata 1-30, 33-40). The mean index, 95% confidence intervals, individual fish weight, minimum, mean, and maximum length, 5th, 50th, and 95th percentiles of length, number of nonzero tows, and number of fish caught are presented for 1968-1999.

	weight/tow			number/tow				length						nonzero	
	mean	lower	upper	mean	lower	upper	ind wt	min	5%	50%	mean	95%	max	tows	no fish
1968	0.374	0.075	0.673	0.138	0.026	0.249	2.716	41	46	61	71.7	115	118	10	21
1969	0.658	-0.364	1.681	0.145	-0.011	0.301	4.539	33	42	70	83.1	119	120	8	22
1970	0.111	0.033	0.188	0.047	0.017	0.078	2.350	45	44	62	68.2	104	105	9	10
1971	0.116	0.018	0.214	0.102	0.021	0.183	1.134	26	31	59	57.1	69	80	8	20
1972	0.222	0.028	0.416	0.023	0.005	0.041	9.617	63	62	119	104.7	123	124	6	6
1973	0.010	-0.001	0.022	0.017	0.000	0.034	0.621	51	51	51	54.1	59	60	3	3
1974	0.020	-0.005	0.045	0.017	-0.002	0.037	1.146	43	43	58	53.3	59	60	3	3
1975	0.001	-0.001	0.003	0.001	-0.001	0.003	0.900	60	60	60	60.0	60	60	1	1
1976	0.010	-0.010	0.030	0.006	-0.005	0.017	1.800	61	61	61	61.0	61	61	1	1
1977	0.000	0.000	0.000	0.000	0.000	0.000	-	-	-	-	-	-	-	0	0
1978	0.015	-0.009	0.040	0.016	-0.006	0.039	0.933	51	50	55	56.3	61	62	2	3
1979	0.000	0.000	0.000	0.000	0.000	0.000	-	-	-	-	-	-	-	0	0
1980	0.000	0.000	0.000	0.000	0.000	0.000	-	-	-	-	-	-	-	0	0
1981	0.000	0.000	0.000	0.000	0.000	0.000	-	-	-	-	-	-	-	0	0
1982	0.002	-0.001	0.005	0.002	-0.002	0.005	1.000	54	54	54	54.0	54	54	1	1
1983	0.000	0.000	0.000	0.000	0.000	0.000	-	-	-	-	-	-	-	0	0
1984	0.000	0.000	0.000	0.000	0.000	0.000	-	-	-	-	-	-	-	0	0
1985	0.001	0.000	0.002	0.007	-0.004	0.017	0.076	20	20	20	24.6	37	38	2	2
1986	0.003	-0.001	0.007	0.011	-0.004	0.026	0.250	33	33	41	37.5	41	42	2	2
1987	0.002	-0.002	0.006	0.007	-0.006	0.020	0.300	37	37	37	37.0	37	37	1	1
1988	0.000	0.000	0.000	0.000	0.000	0.000	-	-	-	-	-	-	-	0	0
1989	0.007	-0.007	0.021	0.006	-0.006	0.019	1.100	60	60	60	60.0	60	60	1	1
1990	0.000	0.000	0.000	0.000	0.000	0.000	-	-	-	-	-	-	-	0	0
1991	0.002	-0.002	0.006	0.007	-0.006	0.020	0.300	38	38	38	38.0	38	38	1	1
1992	0.136	-0.117	0.389	0.013	-0.006	0.032	10.397	41	41	117	98.2	124	125	2	4
1993	0.032	0.024	0.039	0.028	0.005	0.051	1.147	31	31	37	45.3	89	90	5	5
1994	0.084	-0.023	0.191	0.029	-0.001	0.059	2.926	46	46	65	70.1	120	121	4	6
1995	0.015	-0.007	0.037	0.012	-0.005	0.029	1.254	55	55	63	59.6	63	64	2	2
1996	0.062	-0.039	0.162	0.025	-0.003	0.054	2.465	23	23	66	63.2	111	112	4	6
1997	0.077	0.006	0.148	0.035	0.007	0.063	2.216	39	39	67	68.7	89	90	6	7
1998	0.169	-0.024	0.363	0.061	0.015	0.106	2.799	26	26	60	64.4	122	123	8	15
1999	0.279	-0.102	0.660	0.052	0.011	0.094	5.343	28	28	74	80.9	125	126	8	11

Table B17. Abundance and biomass from NEFSC autumn surveys for barndoor skate for the Gulf of Maine to Southern New England region (offshore strata 1-30, 33-40). The mean index, 95% confidence intervals, individual fish weight, minimum, mean, and maximum length, 5th, 50th, and 95th percentiles of length, number of nonzero tows, and number of fish caught are presented for 1963-1998.

	weight/tow			number/tow				length						nonzero	
	mean	lower	upper	mean	lower	upper	ind wt	min	5%	50%	mean	95%	max	tows	no fish
1963	2.633	1.604	3.663	0.762	0.468	1.056	3.458	28	44	69	74.6	121	136	47	120
1964	1.212	0.489	1.934	0.400	0.229	0.570	3.030	40	41	69	72.7	112	122	32	63
1965	1.822	1.115	2.528	0.695	0.441	0.949	2.622	27	42	67	69.9	111	134	36	95
1966	0.811	0.394	1.229	0.459	0.243	0.675	1.767	23	38	60	63.0	88	115	26	62
1967	0.438	-0.025	0.901	0.064	0.017	0.111	6.844	45	52	65	81.0	119	120	10	14
1968	0.285	0.123	0.447	0.132	0.067	0.198	2.150	42	42	67	69.1	96	132	18	29
1969	0.054	-0.003	0.111	0.035	-0.006	0.076	1.551	51	51	62	62.0	73	74	5	8
1970	0.066	-0.046	0.178	0.011	-0.005	0.027	5.868	66	66	65	89.1	128	129	2	2
1971	0.170	-0.051	0.392	0.117	-0.077	0.311	1.455	35	35	53	54.6	63	120	6	19
1972	0.096	-0.073	0.265	0.012	-0.001	0.026	7.751	59	59	70	90.3	132	133	3	3
1973	0.004	-0.001	0.009	0.008	-0.003	0.019	0.474	41	41	47	48.7	52	53	2	3
1974	0.000	0.000	0.000	0.000	0.000	0.000	-	-	-	-	-	-	-	0	0
1975	0.017	-0.016	0.049	0.010	-0.010	0.031	1.600	70	70	70	70.0	70	70	1	2
1976	0.047	0.002	0.091	0.058	-0.003	0.119	0.810	50	50	51	54.6	61	62	7	10
1977	0.000	0.000	0.000	0.000	0.000	0.000	-	-	-	-	-	-	-	0	0
1978	0.000	0.000	0.000	0.000	0.000	0.000	-	-	-	-	-	-	-	0	0
1979	0.009	-0.008	0.026	0.003	-0.003	0.009	3.000	78	78	78	78.0	78	78	1	1
1980	0.000	0.000	0.000	0.000	0.000	0.000	-	-	-	-	-	-	-	0	0
1981	0.000	0.000	0.000	0.000	0.000	0.000	-	-	-	-	-	-	-	0	0
1982	0.000	0.000	0.000	0.000	0.000	0.000	-	-	-	-	-	-	-	0	0
1983	0.000	0.000	0.000	0.000	0.000	0.000	-	-	-	-	-	-	-	0	0
1984	0.010	-0.004	0.024	0.003	0.000	0.007	2.900	61	61	84	73.0	84	85	2	2
1985	0.004	-0.004	0.012	0.002	-0.002	0.005	2.300	70	70	70	70.0	70	70	1	1
1986	0.029	-0.018	0.077	0.015	-0.002	0.032	2.008	22	22	52	51.0	90	91	3	3
1987	0.014	-0.005	0.032	0.012	-0.004	0.027	1.200	53	53	63	58.5	63	64	2	2
1988	0.007	-0.005	0.020	0.009	-0.005	0.022	0.850	34	34	33	44.8	76	77	2	2
1989	0.005	-0.005	0.014	0.002	-0.002	0.007	2.100	71	71	71	71.0	71	71	1	1
1990	0.028	-0.022	0.078	0.010	-0.005	0.024	2.964	60	60	66	76.3	95	96	2	3
1991	0.031	0.000	0.062	0.020	0.000	0.040	1.579	54	54	61	61.3	73	74	4	5
1992	0.002	-0.002	0.007	0.004	-0.004	0.013	0.550	46	46	51	49.0	51	52	1	2
1993	0.141	-0.040	0.321	0.023	0.004	0.042	6.180	45	45	74	86.6	127	128	5	6
1994	0.035	0.001	0.069	0.044	0.006	0.082	0.790	33	33	47	49.4	75	76	6	9
1995	0.111	-0.009	0.231	0.040	-0.006	0.085	2.810	48	48	62	70.9	113	114	4	10
1996	0.042	-0.020	0.104	0.023	0.000	0.046	1.841	25	25	61	59.8	92	93	4	5
1997	0.105	-0.024	0.234	0.026	0.004	0.047	4.065	36	36	79	73.3	124	125	5	5
1998	0.089	-0.036	0.214	0.026	0.002	0.050	3.453	48	48	71	73.9	120	121	4	5

Table B18. Abundance and biomass from NEFSC winter surveys for barndoor skate for the Georges Bank to Mid-Atlantic region (offshore strata 1-3,5-7,9-11,13-14,16,61-63,65-67,69-71,73-75). The mean index, 95% confidence intervals, individual fish weight, minimum, mean, and maximum length, 5th, 50th, and 95th percentiles of length, number of nonzero tows, and number of fish caught are presented for 1992-1999.

	weight/tow			number/tow				length						nonzero	
	mean	lower	upper	mean	lower	upper	ind wt	min	5%	50%	mean	95%	max	tows	no fish
1992	0.000	0.000	0.000	0.000	0.000	0.000	-	-			-		-	0	0
1993	0.123	-0.066	0.311	0.052	0.004	0.100	2.358	20	20	65	57.3	119	120	4	6
1994	0.185	-0.027	0.397	0.080	0.011	0.148	2.328	21	21	60	63.5	102	103	5	7
1995	0.362	0.121	0.603	0.198	0.056	0.340	1.828	33	33	62	63.6	88	109	11	24
1996	0.291	0.079	0.503	0.203	0.054	0.352	1.434	19	20	61	56.4	85	92	12	23
1997	0.618	0.208	1.028	0.275	0.032	0.519	2.247	35	38	65	67.7	112	117	10	28
1998	0.455	0.146	0.765	0.464	0.092	0.837	0.980	20	26	41	46.8	83	123	12	57
1999	1.053	0.347	1.760	0.709	0.318	1.099	1.486	23	27	46	53.2	113	124	22	81

Table B19. Abundance and biomass from NEFSC spring surveys for thorny skate for the Gulf of Maine to Southern New England region (offshore strata 1-30,33-40). The mean index, 95% confidence intervals, individual fish weight, minimum, mean, and maximum length, 5th, 50th, and 95th percentiles of length, number of nonzero tows, and number of fish caught are presented for 1968-1999.

	weight/tow			number/tow				length						nonzero	
	mean	lower	upper	mean	lower	upper	ind wt	min	5%	50%	mean	95%	max	tows	no fish
1968	3.181	2.137	4.225	1.600	1.067	2.134	1.987	12	16	44	47.8	91	105	60	252
1969	4.526	3.186	5.865	1.680	1.161	2.199	2.694	12	13	47	51.1	98	109	64	294
1970	4.202	3.229	5.174	1.990	1.478	2.502	2.112	12	16	41	48.2	95	110	84	363
1971	3.683	2.475	4.891	1.974	1.473	2.475	1.866	12	15	44	47.8	95	116	81	424
1972	4.984	3.757	6.212	2.219	1.773	2.665	2.246	12	16	47	50.7	94	110	91	443
1973	6.622	4.867	8.377	3.562	2.640	4.483	1.859	12	15	44	47.9	91	108	75	574
1974	3.774	2.939	4.608	2.450	1.938	2.962	1.540	9	14	43	45.8	87	106	81	376
1975	3.189	2.222	4.157	1.360	0.990	1.731	2.344	10	15	46	50.5	95	102	62	192
1976	2.895	2.041	3.750	1.671	1.281	2.060	1.733	13	15	43	47.2	90	106	79	339
1977	1.623	1.175	2.070	0.942	0.675	1.209	1.722	12	15	42	48.1	89	111	74	213
1978	1.250	0.806	1.695	0.800	0.579	1.020	1.564	10	15	49	46.8	83	97	71	191
1979	1.079	0.729	1.429	0.582	0.410	0.754	1.853	12	17	51	50.5	84	102	68	163
1980	2.105	1.308	2.901	1.319	0.880	1.757	1.596	11	13	37	43.6	92	100	60	250
1981	2.700	2.065	3.335	1.535	1.139	1.930	1.760	9	13	47	48.1	87	100	60	255
1982	2.345	1.685	3.004	1.144	0.878	1.411	2.049	10	17	53	52.4	85	97	62	218
1983	2.142	1.398	2.886	0.968	0.728	1.209	2.212	12	15	52	52.3	91	103	55	156
1984	1.453	0.818	2.087	0.608	0.462	0.755	2.389	12	16	51	53.0	96	100	40	97
1985	3.074	2.124	4.024	1.413	1.060	1.766	2.175	11	14	44	48.4	95	102	59	209
1986	2.619	1.974	3.263	1.718	1.377	2.058	1.525	10	15	38	44.0	83	98	69	276
1987	1.469	0.805	2.133	0.852	0.646	1.058	1.724	14	16	42	46.6	87	109	53	141
1988	1.173	0.735	1.612	1.106	0.766	1.446	1.061	11	14	32	38.5	82	98	59	176
1989	1.481	0.793	2.169	1.221	0.801	1.640	1.213	11	15	34	40.0	84	101	57	175
1990	1.565	0.833	2.296	1.097	0.688	1.506	1.427	14	16	39	44.5	82	99	49	167
1991	1.542	0.945	2.139	0.858	0.569	1.147	1.797	11	13	47	48.5	89	99	47	132
1992	1.092	0.621	1.564	0.612	0.384	0.840	1.784	14	15	47	48.4	89	102	31	86
1993	0.700	0.366	1.034	0.486	0.327	0.646	1.440	13	13	36	42.0	91	105	37	79
1994	0.435	0.242	0.629	0.439	0.270	0.609	0.991	12	12	37	39.3	67	92	39	80
1995	0.564	0.307	0.821	0.384	0.236	0.533	1.467	9	12	42	45.8	84	92	31	66
1996	0.371	0.178	0.563	0.321	0.106	0.535	1.156	12	12	36	40.8	80	93	24	63
1997	0.422	0.117	0.727	0.270	0.153	0.387	1.560	15	20	47	47.9	82	87	25	47
1998	0.480	0.209	0.752	0.334	0.236	0.431	1.440	12	14	35	40.8	89	98	42	85
1999	0.369	0.093	0.646	0.255	0.163	0.347	1.448	11	17	40	46.2	83	89	26	44

Table B20. Abundance and biomass from NEFSC autumn surveys for thorny skate for the Gulf of Maine to Southern New England region (offshore strata 1-30, 33-40). The mean index, 95% confidence intervals, individual fish weight, minimum, mean, and maximum length, 5th, 50th, and 95th percentiles of length, number of nonzero tows, and number of fish caught are presented for 1963-1998.

	weight/tow			number/tow				length						nonzero	
	mean	lower	upper	mean	lower	upper	ind wt	min	5%	50%	mean	95%	max	tows	no fish
1963	5.371	3.788	6.954	1.672	1.305	2.039	3.213	10	15	60	60.4	99	107	65	297
1964	4.403	3.273	5.534	1.651	1.110	2.192	2.667	10	14	49	52.7	96	110	66	278
1965	4.474	3.268	5.681	1.825	1.243	2.408	2.451	10	14	45	49.6	95	107	55	352
1966	7.971	6.163	9.780	2.371	1.855	2.886	3.362	9	13	61	59.4	95	112	72	364
1967	2.712	1.422	4.001	0.982	0.383	1.580	2.763	12	14	49	52.5	95	100	54	165
1968	4.421	3.321	5.521	1.440	1.040	1.840	3.071	12	16	55	57.5	97	107	59	217
1969	5.715	4.320	7.110	1.833	1.359	2.307	3.117	12	14	55	56.7	97	106	72	289
1970	7.347	5.630	9.065	2.216	1.474	2.958	3.316	8	19	57	60.4	98	109	77	403
1971	5.357	4.149	6.565	1.434	1.095	1.774	3.735	12	18	63	64.1	99	111	69	284
1972	4.119	2.974	5.263	1.717	1.302	2.132	2.399	12	16	51	53.1	94	105	75	306
1973	4.564	3.227	5.902	1.536	1.134	1.939	2.971	12	17	59	61.2	95	111	72	274
1974	3.038	2.166	3.910	1.392	1.025	1.759	2.182	10	14	50	51.1	89	111	79	293
1975	2.474	1.483	3.464	1.027	0.716	1.338	2.409	10	12	47	50.0	94	106	70	232
1976	1.720	1.003	2.437	0.798	0.543	1.052	2.157	12	15	44	49.1	91	103	57	143
1977	3.221	2.513	3.928	1.548	1.223	1.874	2.080	10	13	49	50.7	89	107	108	446
1978	4.291	3.473	5.109	2.145	1.643	2.648	2.000	10	16	49	51.1	88	107	155	874
1979	3.612	2.750	4.474	1.283	0.864	1.702	2.815	11	21	59	59.5	89	101	134	486
1980	4.601	3.344	5.859	1.882	1.484	2.280	2.445	11	14	54	54.4	90	100	84	416
1981	3.339	2.551	4.127	1.305	0.957	1.653	2.559	12	15	55	57.1	90	103	71	223
1982	0.646	0.312	0.981	0.393	0.194	0.592	1.644	11	13	33	43.0	85	96	31	83
1983	2.409	1.553	3.266	0.833	0.589	1.077	2.892	15	20	56	58.8	93	108	49	121
1984	2.887	1.978	3.795	1.270	0.975	1.565	2.272	10	13	48	49.8	94	107	70	211
1985	2.877	1.765	3.988	1.438	1.094	1.783	2.000	12	16	49	49.6	87	103	66	260
1986	1.629	1.068	2.189	1.019	0.771	1.266	1.598	11	15	35	44.2	83	101	61	183
1987	0.944	0.590	1.297	0.841	0.600	1.082	1.123	12	14	36	40.2	78	92	49	143
1988	1.488	0.998	1.978	1.099	0.702	1.497	1.354	13	15	31	41.5	84	101	56	208
1989	1.883	0.980	2.786	1.129	0.787	1.471	1.668	12	14	40	46.2	85	101	63	198
1990	1.704	1.090	2.318	1.040	0.744	1.335	1.639	12	17	42	47.2	85	95	53	202
1991	1.632	0.519	2.745	0.921	0.591	1.251	1.772	13	15	47	49.5	86	108	54	153
1992	0.962	0.551	1.373	0.775	0.461	1.088	1.242	12	13	36	41.2	83	99	48	144
1993	1.658	0.639	2.676	0.901	0.440	1.361	1.840	12	13	47	47.8	91	101	50	157
1994	1.509	0.343	2.675	0.981	0.311	1.652	1.538	13	17	45	46.9	84	97	41	170
1995	0.783	0.331	1.235	0.639	0.183	1.095	1.226	13	14	39	42.2	72	99	37	107
1996	0.814	0.360	1.269	0.602	0.362	0.842	1.352	14	14	39	43.3	85	99	37	102
1997	0.849	0.405	1.293	0.404	0.241	0.567	2.101	12	20	50	52.3	83	99	33	79
1998	0.648	0.297	0.999	0.307	0.145	0.468	2.113	13	14	51	52.4	87	93	30	60

Table B21. Abundance and biomass from NEFSC spring surveys for smooth skate for the Gulf of Maine to Southern New England region (offshore strata 1-30,33-40). The mean index, 95% confidence intervals, individual fish weight, minimum, mean, and maximum length, 5th, 50th, and 95th percentiles of length, number of nonzero tows, and number of fish caught are presented for 1968-1999.

	weight/tow			number/tow				length						nonzero	
	mean	lower	upper	mean	lower	upper	ind wt	min	5%	50%	mean	95%	max	tows	no fish
1968	0.211	0.080	0.342	0.484	0.129	0.838	0.436	12	24	41	42.1	58	64	17	41
1969	0.377	0.193	0.562	0.834	0.521	1.147	0.452	11	19	48	43.3	58	63	28	82
1970	0.346	0.134	0.557	0.702	0.376	1.028	0.492	9	14	47	40.9	57	61	25	68
1971	0.800	0.395	1.205	1.185	0.650	1.719	0.675	9	20	51	48.2	61	63	40	114
1972	0.621	0.355	0.886	1.016	0.582	1.450	0.611	14	20	47	44.3	59	64	34	122
1973	1.000	0.745	1.255	1.907	1.401	2.414	0.524	9	24	45	44.2	59	65	51	179
1974	1.092	0.594	1.590	2.003	1.109	2.896	0.545	9	9	47	42.7	59	63	47	172
1975	0.240	0.133	0.346	0.383	0.224	0.543	0.626	19	25	49	46.8	59	61	22	37
1976	0.534	0.413	0.655	1.150	0.870	1.429	0.464	12	16	43	39.8	57	60	49	134
1977	0.122	0.066	0.178	0.302	0.158	0.445	0.405	15	18	40	41.4	57	60	28	45
1978	0.251	0.144	0.358	0.413	0.258	0.567	0.609	24	26	50	46.7	58	61	33	56
1979	0.218	0.097	0.340	0.410	0.163	0.657	0.533	15	19	39	40.2	54	61	27	54
1980	0.484	0.316	0.651	0.948	0.625	1.271	0.510	16	20	42	41.9	56	60	42	84
1981	0.358	0.227	0.489	0.782	0.513	1.050	0.458	8	13	38	37.2	57	65	38	70
1982	0.152	0.057	0.247	0.225	0.092	0.357	0.677	11	10	52	45.6	57	64	14	23
1983	0.363	0.219	0.507	0.531	0.335	0.727	0.683	11	21	50	47.9	57	69	25	50
1984	0.065	0.010	0.120	0.124	0.026	0.221	0.523	19	20	48	39.8	59	60	9	13
1985	0.211	0.136	0.286	0.450	0.298	0.602	0.469	18	20	41	40.4	57	63	31	59
1986	0.250	0.137	0.362	0.466	0.256	0.677	0.536	20	24	48	46.7	59	65	30	93
1987	0.069	0.029	0.108	0.105	0.044	0.166	0.655	43	42	48	50.2	59	62	12	15
1988	0.115	0.044	0.186	0.328	0.175	0.480	0.350	11	13	36	36.3	57	60	24	49
1989	0.225	0.107	0.343	0.620	0.402	0.838	0.363	13	15	37	38.8	60	63	30	88
1990	0.152	0.010	0.294	0.294	0.080	0.509	0.515	11	16	46	44.0	57	62	18	40
1991	0.137	0.073	0.200	0.237	0.136	0.337	0.576	11	17	49	47.1	59	62	22	34
1992	0.063	0.025	0.101	0.104	0.035	0.172	0.608	22	40	49	48.5	56	57	12	16
1993	0.086	0.021	0.151	0.214	0.020	0.408	0.403	21	23	42	41.2	56	58	14	35
1994	0.098	0.043	0.153	0.176	0.082	0.269	0.558	29	29	47	47.1	56	58	15	30
1995	0.101	0.050	0.152	0.234	0.119	0.349	0.432	9	20	42	41.9	55	59	18	33
1996	0.036	0.014	0.058	0.084	0.038	0.129	0.429	20	19	48	43.8	53	59	10	12
1997	0.037	0.015	0.059	0.122	0.035	0.208	0.307	17	20	36	38.9	55	58	11	22
1998	0.200	0.089	0.311	0.410	0.206	0.613	0.489	9	19	46	44.6	56	60	28	77
1999	0.243	0.068	0.418	0.925	-0.074	1.924	0.262	18	20	32	35.6	51	65	23	111

Table B22. Abundance and biomass from NEFSC autumn surveys for smooth skate for the Gulf of Maine to Southern New England region (offshore strata 1-30,33-40). The mean index, 95% confidence intervals, individual fish weight, minimum, mean, and maximum length, 5th, 50th, and 95th percentiles of length, number of nonzero tows, and number of fish caught are presented for 1963-1998.

	weight/tow			number/tow				length						nonzero	
	mean	lower	upper	mean	lower	upper	ind wt	min	5%	50%	mean	95%	max	tows	no fish
1963	0.498	0.306	0.689	0.543	0.282	0.804	0.917	9	20	48	43.9	58	62	26	53
1964	0.326	0.152	0.501	0.360	0.209	0.512	0.906	9	20	42	41.7	59	64	19	35
1965	0.475	0.140	0.811	1.221	0.440	2.001	0.389	11	16	35	38.1	56	64	27	94
1966	0.323	0.175	0.471	0.867	0.519	1.216	0.372	13	17	37	38.6	58	59	28	60
1967	0.152	0.036	0.268	0.293	0.118	0.469	0.518	22	24	48	46.5	62	69	16	27
1968	0.385	0.211	0.559	0.665	0.375	0.955	0.579	17	20	48	45.9	58	62	24	56
1969	0.290	0.131	0.449	0.604	0.282	0.925	0.481	12	16	41	39.6	58	64	21	50
1970	0.232	0.121	0.343	0.530	0.289	0.771	0.437	9	13	45	38.3	59	62	25	50
1971	0.157	0.077	0.238	0.250	0.120	0.379	0.631	17	36	53	51.0	57	59	18	27
1972	0.332	0.185	0.478	0.499	0.285	0.713	0.664	16	24	49	49.8	62	64	30	52
1973	0.311	0.199	0.423	0.506	0.344	0.667	0.614	17	22	48	46.9	58	60	32	56
1974	0.123	0.055	0.192	0.180	0.088	0.273	0.684	11	11	50	48.5	60	63	13	21
1975	0.076	0.029	0.123	0.104	0.043	0.165	0.727	21	30	49	46.7	56	57	12	15
1976	0.039	0.004	0.074	0.077	0.020	0.135	0.501	17	36	41	43.9	52	60	9	10
1977	0.376	0.274	0.478	0.600	0.443	0.757	0.627	19	24	48	44.9	56	61	50	84
1978	0.450	0.240	0.661	0.635	0.359	0.912	0.709	8	25	50	48.0	59	66	49	130
1979	0.182	0.075	0.288	0.239	0.116	0.362	0.761	9	29	50	48.7	60	62	31	60
1980	0.343	0.167	0.519	0.522	0.254	0.789	0.658	15	23	52	46.4	58	62	37	60
1981	0.119	0.039	0.199	0.167	0.069	0.264	0.715	23	26	49	48.1	60	61	13	18
1982	0.039	0.007	0.071	0.074	0.025	0.123	0.521	9	9	49	41.9	63	64	11	11
1983	0.146	0.056	0.236	0.255	0.085	0.426	0.573	14	14	46	40.9	57	59	12	24
1984	0.199	0.106	0.292	0.389	0.171	0.607	0.512	14	22	37	39.2	58	71	23	39
1985	0.210	0.088	0.332	0.340	0.180	0.500	0.617	12	15	51	45.2	59	63	28	64
1986	0.209	0.118	0.300	0.392	0.216	0.567	0.534	13	21	47	45.0	63	66	24	63
1987	0.095	0.045	0.145	0.164	0.081	0.247	0.581	15	15	48	44.8	60	61	19	28
1988	0.284	0.103	0.465	0.446	0.223	0.670	0.637	20	20	51	48.3	59	65	27	90
1989	0.128	0.072	0.185	0.336	0.194	0.478	0.382	13	16	33	36.8	59	62	27	52
1990	0.194	0.120	0.268	0.332	0.202	0.462	0.584	16	23	48	46.4	58	62	27	45
1991	0.167	0.070	0.265	0.335	0.188	0.482	0.500	18	20	46	43.9	57	62	25	59
1992	0.126	0.024	0.228	0.316	0.120	0.511	0.400	12	18	43	40.0	58	60	16	56
1993	0.227	0.107	0.346	0.818	0.273	1.362	0.277	13	13	26	32.6	56	62	29	123
1994	0.099	0.030	0.169	0.269	0.105	0.433	0.370	11	11	36	38.0	57	59	17	36
1995	0.189	0.115	0.263	0.764	0.315	1.214	0.247	10	13	30	32.6	56	59	29	119
1996	0.176	0.093	0.260	0.421	0.249	0.594	0.418	15	18	46	41.6	56	59	26	55
1997	0.232	0.117	0.347	0.449	0.232	0.665	0.517	16	21	47	45.2	60	64	20	59
1998	0.028	0.005	0.051	0.108	0.021	0.194	0.263	18	17	29	35.2	51	53	11	18

Table B23. Abundance and biomass from NEFSC spring surveys for clearnose skate for the Mid-Atlantic region (offshore strata 61-76, inshore strata 15-44). The mean index, 95% confidence intervals, individual fish weight, minimum, mean, and maximum length, 5th, 50th, and 95th percentiles of length, number of nonzero tows, and number of fish caught are presented for 1976-1999.

	weight/tow			number/tow				length						nonzero	
	mean	lower	upper	mean	lower	upper	ind wt	min	5%	50%	mean	95%	max	tows	no fish
1976	0.100	0.020	0.179	0.129	0.040	0.218	0.770	26	26	43	48.5	66	67	8	12
1977	0.509	0.297	0.722	0.500	0.260	0.741	1.017	23	23	56	52.5	63	64	17	41
1978	0.211	-0.094	0.516	0.237	-0.057	0.530	0.893	20	20	57	52.2	68	69	8	21
1979	0.109	0.010	0.209	0.125	0.004	0.247	0.875	25	25	42	50.3	77	78	6	9
1980	0.319	0.100	0.538	0.456	0.136	0.775	0.700	25	25	41	45.1	64	69	14	44
1981	0.891	-0.141	1.923	0.606	0.106	1.107	1.469	24	26	60	55.9	67	72	10	44
1982	0.328	0.165	0.491	0.368	0.126	0.610	0.892	30	32	52	53.6	66	71	14	40
1983	0.138	0.005	0.270	0.127	0.003	0.252	1.081	13	13	58	51.3	65	66	7	11
1984	0.380	0.103	0.658	0.288	0.018	0.557	1.321	48	48	62	60.7	70	74	11	25
1985	0.493	-0.166	1.151	0.436	-0.203	1.076	1.129	48	48	58	59.3	69	72	10	37
1986	0.155	0.035	0.274	0.232	0.038	0.427	0.666	27	27	44	44.8	68	69	11	15
1987	0.306	0.150	0.463	0.202	0.109	0.204	1.519	49	51	63	61.9	69	72	16	20
1988	0.340	0.171	0.508	0.300	0.097	0.502	1.134	44	44	58	57.1	67	71	11	19
1989	0.424	0.258	0.590	0.415	0.275	0.554	1.023	25	25	58	52.3	68	72	14	40
1990	0.501	0.283	0.719	0.420	0.243	0.597	1.192	30	30	59	56.2	67	72	15	52
1991	0.690	0.463	0.918	0.543	0.354	0.731	1.272	27	27	62	58.8	68	71	23	59
1992	0.748	0.324	1.172	0.489	0.218	0.760	1.529	46	46	63	63.0	68	80	23	47
1993	0.856	0.479	1.233	0.656	0.216	1.096	1.305	21	33	63	58.6	70	74	12	136
1994	0.319	0.052	0.585	0.188	0.043	0.333	1.699	51	57	65	66.0	73	74	8	24
1995	0.669	0.361	0.977	0.464	0.261	0.666	1.443	46	46	67	62.4	68	74	18	32
1996	1.224	0.194	2.254	0.948	0.255	1.641	1.291	13	27	62	59.8	70	75	30	95
1997	1.290	0.885	1.695	0.972	0.542	1.403	1.326	33	39	63	61.3	71	78	22	80
1998	0.903	0.674	1.133	0.667	0.369	0.964	1.355	26	38	62	60.2	70	74	29	81
1999	0.943	0.647	1.238	0.862	0.470	1.255	1.093	26	28	59	57.3	67	72	19	54

Table B24. Abundance and biomass from NEFSC autumn surveys for clearnose skate for the Mid-Atlantic region (offshore strata 61-76, inshore strata 15-44). The mean index, 95% confidence intervals, individual fish weight, minimum, mean, and maximum length, 5th, 50th, and 95th percentiles of length, number of nonzero tows, and number of fish caught are presented for 1975-1998.

	weight/tow			number/tow				length						nonzero	
	mean	lower	upper	mean	lower	upper	ind wt	min	5%	50%	mean	95%	max	tows	no fish
1975	0.237	0.086	0.388	0.246	0.133	0.360	0.961	21	21	53	50.3	63	66	31	49
1976	0.302	0.189	0.415	0.348	0.236	0.459	0.869	18	34	52	52.1	64	69	26	54
1977	0.768	0.288	1.248	0.742	0.281	1.203	1.035	15	37	57	55.4	65	68	32	106
1978	0.156	0.073	0.240	0.224	0.086	0.363	0.697	10	10	44	40.8	64	66	14	23
1979	0.419	0.116	0.721	0.346	0.146	0.545	1.211	22	24	56	55.4	67	71	27	46
1980	0.685	0.408	0.961	0.549	0.322	0.775	1.248	33	37	59	58.1	69	72	32	80
1981	0.171	0.081	0.260	0.179	0.087	0.271	0.954	27	27	55	51.5	65	68	19	28
1982	0.213	0.099	0.326	0.183	0.095	0.271	1.163	32	43	59	58.3	67	72	26	37
1983	0.141	0.027	0.254	0.127	0.043	0.210	1.110	16	16	57	52.2	64	70	15	19
1984	0.178	0.064	0.293	0.189	0.063	0.315	0.945	34	37	53	54.0	67	83	20	32
1985	0.306	0.173	0.439	0.315	0.182	0.447	0.974	32	41	56	54.9	66	71	23	42
1986	0.545	-0.038	1.027	0.591	0.091	1.092	0.921	23	23	59	52.6	64	71	31	62
1987	0.320	0.176	0.465	0.289	0.167	0.412	1.107	15	41	56	55.5	69	70	23	42
1988	0.335	0.157	0.513	0.329	0.163	0.495	1.019	33	37	57	56.0	66	71	19	60
1989	0.273	0.075	0.471	0.324	0.064	0.584	0.843	37	37	52	52.7	63	70	20	39
1990	0.402	0.157	0.646	0.306	0.114	0.499	1.311	16	41	60	57.9	69	72	17	50
1991	0.922	0.279	1.566	0.816	0.339	1.294	1.130	35	39	58	57.1	69	71	35	119
1992	0.345	0.185	0.505	0.312	0.185	0.440	1.104	16	42	59	56.7	67	69	22	48
1993	0.495	0.145	0.844	0.474	0.188	0.759	1.044	35	40	57	56.8	66	73	27	104
1994	0.938	0.479	1.398	0.842	0.494	1.190	1.115	35	40	57	57.1	66	73	35	129
1995	0.331	0.189	0.473	0.426	0.233	0.618	0.777	14	14	51	45.5	66	72	25	63
1996	0.430	0.194	0.666	0.369	0.163	0.576	1.165	29	45	59	58.8	68	72	20	42
1997	0.614	0.296	0.932	0.484	0.281	0.688	1.269	43	43	61	60.2	69	77	27	60
1998	1.121	0.115	2.128	1.096	0.124	2.068	1.023	34	43	57	57.5	68	73	32	98

Table B25. Abundance and biomass from NEFSC winter surveys for clearnose skate for the Georges Bank to Mid-Atlantic region (offshore strata 1-3,5-7,9-11,13-14,16,61-63,65-67,69-71,73-75). The mean index, 95% confidence intervals, individual fish weight, minimum, mean, and maximum length, 5th, 50th, and 95th percentiles of length, number of nonzero tows, and number of fish caught are presented for 1992-1999.

	weight/tow			number/tow				length						nonzero	
	mean	lower	upper	mean	lower	upper	ind wt	min	5%	50%	mean	95%	max	tows	no fish
1992	5.622	3.247	7.997	5.247	2.974	7.519	1.072	23	26	59	54.7	67	93	22	551
1993	6.013	3.818	8.208	5.973	3.852	8.093	1.007	22	33	57	54.3	67	81	23	716
1994	8.854	4.037	13.672	7.692	2.152	13.233	1.151	27	33	60	57.5	69	77	16	639
1995	7.924	2.521	13.327	6.247	1.301	11.194	1.268	24	45	61	60.2	69	76	23	737
1996	14.725	8.266	21.183	11.555	6.347	16.762	1.274	22	40	61	60.0	69	77	32	3086
1997	5.522	3.154	7.890	5.069	2.158	7.980	1.089	22	35	59	56.2	70	76	32	682
1998	6.031	4.470	7.592	4.878	3.195	6.560	1.236	22	36	60	58.3	71	88	32	1091
1999	3.826	2.335	5.317	3.022	1.586	4.459	1.266	23	37	61	59.6	70	76	30	343

Table B26. Abundance and biomass from NEFSC spring surveys for rosette skate for the Mid-Atlantic region (offshore strata 61-76). The mean index, 95% confidence intervals, individual fish weight, minimum, mean, and maximum length, 5th, 50th, and 95th percentiles of length, number of nonzero tows, and number of fish caught are presented for 1968-1999.

	weight/tow			number/tow				length						nonzero	
	mean	lower	upper	mean	lower	upper	ind wt	min	5%	50%	mean	95%	max	tows	no fish
1968	0.005	-0.002	0.012	0.014	0.000	0.029	0.356	33	33	33	34.4	35	36	3	3
1969	0.001	-0.001	0.002	0.003	-0.003	0.010	0.200	37	37	37	37.0	37	37	1	1
1970	0.000	0.000	0.000	0.000	0.000	0.000	-	-	-	-	-	-	-	0	0
1971	0.005	-0.005	0.014	0.010	-0.009	0.028	0.500	57	57	57	57.0	57	57	1	1
1972	0.000	0.000	0.001	0.003	-0.003	0.010	0.100	35	35	35	35.0	35	35	1	1
1973	0.006	-0.001	0.012	0.023	-0.006	0.052	0.240	38	38	38	38.6	41	42	4	5
1974	0.005	-0.005	0.015	0.025	-0.024	0.074	0.200	41	41	41	41.0	41	41	1	1
1975	0.001	-0.001	0.003	0.005	-0.005	0.014	0.200	38	38	38	38.5	39	39	1	2
1976	0.007	0.000	0.015	0.035	-0.003	0.073	0.208	31	31	36	36.9	44	45	4	6
1977	0.102	0.019	0.186	0.552	0.107	0.998	0.185	20	26	32	33.6	37	42	11	70
1978	0.010	0.001	0.019	0.041	0.008	0.074	0.232	12	25	35	35.3	40	41	7	10
1979	0.007	0.005	0.009	0.040	0.031	0.048	0.171	13	13	34	31.6	40	41	4	10
1980	0.072	0.030	0.115	0.373	0.167	0.580	0.194	26	27	34	35.3	41	42	15	47
1981	0.013	0.001	0.025	0.057	0.006	0.109	0.231	19	28	37	36.3	41	42	6	17
1982	0.025	0.010	0.040	0.108	0.043	0.174	0.234	22	25	37	37.4	43	44	11	20
1983	0.002	-0.001	0.004	0.012	-0.006	0.029	0.147	29	29	34	34.2	35	36	2	5
1984	0.000	0.000	0.000	0.000	0.000	0.000	-	-	-	-	-	-	-	0	0
1985	0.005	-0.001	0.011	0.059	0.040	0.079	0.080	17	17	18	21.0	29	42	3	9
1986	0.002	-0.002	0.006	0.012	-0.008	0.031	0.182	32	32	35	35.3	35	36	2	2
1987	0.003	-0.002	0.009	0.017	-0.012	0.046	0.200	35	35	36	36.7	36	37	2	2
1988	0.020	-0.001	0.041	0.111	-0.002	0.223	0.180	26	26	35	32.8	35	36	4	6
1989	0.010	-0.004	0.025	0.051	-0.036	0.137	0.200	28	28	34	34.6	40	41	2	15
1990	0.010	-0.004	0.024	0.049	-0.022	0.121	0.200	36	36	35	36.0	35	36	3	3
1991	0.036	0.014	0.058	0.143	0.057	0.228	0.253	19	33	37	37.2	40	42	7	19
1992	0.014	-0.001	0.029	0.063	0.012	0.113	0.223	24	24	37	36.0	40	41	5	5
1993	0.009	0.007	0.011	0.037	0.030	0.043	0.255	38	38	37	38.6	39	40	2	5
1994	0.005	0.001	0.009	0.021	0.006	0.035	0.243	36	36	38	38.7	40	41	4	4
1995	0.010	0.000	0.020	0.056	0.003	0.110	0.173	19	19	35	32.9	36	37	3	5
1996	0.014	-0.011	0.039	0.095	-0.013	0.203	0.149	9	9	35	29.3	42	43	5	19
1997	0.028	0.022	0.033	0.138	0.091	0.186	0.200	30	30	34	35.6	41	42	4	25
1998	0.038	0.007	0.068	0.132	0.041	0.223	0.287	32	33	38	38.0	41	42	11	15
1999	0.043	0.003	0.083	0.206	0.012	0.399	0.211	15	29	37	36.7	42	43	9	16

Table B27. Abundance and biomass from NEFSC autumn surveys for rosette skate for the Mid-Atlantic region (offshore strata 61-76). The mean index, 95% confidence intervals, individual fish weight, minimum, mean, and maximum length, 5th, 50th, and 95th percentiles of length, number of nonzero tows, and number of fish caught are presented for 1967-1998.

	weight/tow			number/tow				length						nonzero	
	mean	lower	upper	mean	lower	upper	ind wt	min	5%	50%	mean	95%	max	tows	no fish
1967	0.019	0.002	0.037	0.117	0.010	0.224	0.166	10	18	34	34.3	39	42	7	17
1968	0.003	-0.001	0.008	0.023	-0.019	0.065	0.135	28	28	28	28.9	37	38	2	2
1969	0.002	-0.002	0.006	0.010	-0.009	0.028	0.200	38	38	38	38.0	38	38	1	1
1970	0.009	-0.006	0.024	0.033	-0.025	0.090	0.276	39	39	39	39.5	39	40	2	3
1971	0.001	-0.001	0.004	0.006	-0.005	0.016	0.250	40	40	40	40.5	40	41	1	2
1972	0.016	0.001	0.032	0.058	0.021	0.094	0.285	12	12	34	34.2	40	41	7	8
1973	0.012	-0.008	0.032	0.053	-0.016	0.122	0.224	16	16	28	29.0	40	41	3	5
1974	0.012	-0.002	0.026	0.079	-0.014	0.171	0.156	23	23	34	33.8	40	41	4	11
1975	0.004	-0.001	0.009	0.034	-0.001	0.070	0.122	25	25	34	33.6	38	39	4	8
1976	0.024	0.003	0.045	0.149	0.016	0.281	0.163	28	28	33	33.7	37	40	7	21
1977	0.020	-0.002	0.043	0.087	-0.011	0.185	0.231	31	31	33	35.2	40	41	5	8
1978	0.007	-0.007	0.022	0.015	-0.014	0.043	0.500	39	39	39	39.0	39	39	1	1
1979	0.010	-0.004	0.025	0.043	-0.016	0.101	0.242	22	22	35	36.1	39	40	3	6
1980	0.090	0.042	0.138	0.312	0.120	0.505	0.287	14	25	38	36.6	41	42	10	24
1981	0.079	0.011	0.148	0.296	0.052	0.539	0.268	27	28	37	37.5	41	43	10	45
1982	0.006	-0.006	0.018	0.020	-0.019	0.059	0.300	39	39	39	39.0	39	39	1	1
1983	0.001	-0.001	0.003	0.010	-0.010	0.030	0.100	12	12	12	20.7	36	37	1	3
1984	0.029	0.005	0.053	0.128	0.033	0.223	0.229	13	26	36	35.6	39	40	7	16
1985	0.005	0.004	0.007	0.036	0.019	0.054	0.146	14	14	25	28.0	35	36	5	6
1986	0.003	0.001	0.004	0.009	0.005	0.013	0.300	37	37	37	38.2	39	40	3	3
1987	0.028	0.006	0.050	0.112	0.040	0.183	0.253	11	15	38	32.7	41	42	7	10
1988	0.021	0.000	0.043	0.093	-0.002	0.188	0.228	30	30	32	35.0	41	42	5	8
1989	0.018	-0.005	0.041	0.046	-0.012	0.105	0.378	33	33	33	33.5	36	37	3	4
1990	0.023	-0.004	0.049	0.099	0.001	0.198	0.228	32	32	37	37.7	41	42	5	10
1991	0.005	-0.004	0.014	0.021	-0.009	0.051	0.237	15	15	34	31.4	34	35	3	3
1992	0.035	0.006	0.064	0.170	0.033	0.308	0.203	25	25	35	35.3	41	42	9	11
1993	0.021	0.005	0.037	0.102	0.033	0.170	0.211	25	25	37	35.1	40	41	4	8
1994	0.073	0.000	0.146	0.301	0.006	0.597	0.242	27	27	37	36.8	42	43	6	21
1995	0.039	-0.005	0.084	0.174	-0.009	0.358	0.227	19	24	35	35.1	38	39	7	13
1996	0.043	-0.014	0.100	0.273	-0.127	0.674	0.158	7	19	32	31.6	38	42	7	21
1997	0.013	0.000	0.026	0.074	-0.014	0.162	0.176	31	31	33	34.0	42	43	4	6
1998	0.050	-0.008	0.108	0.208	-0.042	0.458	0.241	33	33	37	38.1	40	41	7	22

Table B28. Abundance and biomass from NEFSC winter surveys for rosette skate for the Georges Bank to Mid-Atlantic region (offshore strata 1-3,5-7,9-11,13-14,16,61-63,65-67,69-71,73-75). The mean index, 95% confidence intervals, individual fish weight, minimum, mean, and maximum length, 5th, 50th, and 95th percentiles of length, number of nonzero tows, and number of fish caught are presented for 1992-1999.

	weight/tow			number/tow				length						nonzero	
	mean	lower	upper	mean	lower	upper	ind wt	min	5%	50%	mean	95%	max	tows	no fish
1992	0.264	0.138	0.390	1.125	0.619	1.632	0.235	16	27	36	36.4	41	45	15	230
1993	0.149	0.048	0.251	0.663	0.197	1.130	0.225	26	29	36	36.7	39	41	9	143
1994	0.199	0.148	0.249	0.761	0.608	0.914	0.261	16	28	37	36.8	40	44	15	162
1995	0.195	0.066	0.323	0.774	0.273	1.275	0.252	19	32	37	37.9	41	42	23	197
1996	0.324	0.121	0.526	1.410	0.443	2.376	0.230	19	28	36	36.3	40	46	23	899
1997	0.258	-0.051	0.567	1.079	-0.194	2.353	0.239	13	30	36	36.9	40	44	21	238
1998	0.160	0.102	0.219	0.664	0.421	0.907	0.241	15	30	36	36.5	40	45	21	350
1999	0.271	0.043	0.500	1.151	0.082	2.220	0.236	24	27	37	36.6	41	44	25	228

Table B29. Input data and results of Thompson and Bell (1936) yield and spawning biomass per recruit calculations for winter skate, for M = 0.1

```
Proportion of F before spawning:  .5000
Proportion of M before spawning:  .5000
Natural Mortality is Constant at:  .100
Initial age is:  1; Last age is: 30
Last age is a TRUE AGE
```

Age-specific Input data for Yield per Recruit Analysis

Age	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Weights Catch	Stock
1	.0000	1.0000	.0000	.059	.059
2	.2000	1.0000	.0000	.255	.255
3	1.0000	1.0000	.0000	.623	.623
4	1.0000	1.0000	.1000	1.153	1.153
5	1.0000	1.0000	.2000	1.816	1.816
6	1.0000	1.0000	.4000	2.573	2.573
7	1.0000	1.0000	.7000	3.386	3.386
8	1.0000	1.0000	.9000	4.222	4.222
9	1.0000	1.0000	1.0000	5.054	5.054
10	1.0000	1.0000	1.0000	5.861	5.861
11	1.0000	1.0000	1.0000	6.629	6.629
12	1.0000	1.0000	1.0000	7.348	7.348
13	1.0000	1.0000	1.0000	8.014	8.014
14	1.0000	1.0000	1.0000	8.623	8.623
15	1.0000	1.0000	1.0000	9.176	9.176
16	1.0000	1.0000	1.0000	9.675	9.675
17	1.0000	1.0000	1.0000	10.121	10.121
18	1.0000	1.0000	1.0000	10.519	10.519
19	1.0000	1.0000	1.0000	10.873	10.873
20	1.0000	1.0000	1.0000	11.185	11.185
21	1.0000	1.0000	1.0000	11.461	11.461
22	1.0000	1.0000	1.0000	11.703	11.703
23	1.0000	1.0000	1.0000	11.916	11.916
24	1.0000	1.0000	1.0000	12.102	12.102
25	1.0000	1.0000	1.0000	12.266	12.266
26	1.0000	1.0000	1.0000	12.408	12.408
27	1.0000	1.0000	1.0000	12.532	12.532
28	1.0000	1.0000	1.0000	12.641	12.641
29	1.0000	1.0000	1.0000	12.735	12.735
30	1.0000	1.0000	1.0000	12.817	12.817

```
Slope of the Yield/Recruit Curve at F=0.00: -->    43.0186
  F level at slope=1/10 of the above slope (F0.1): ----->    .078
    Yield/Recruit corresponding to F0.1: ----->    1.3909
  F level to produce Maximum Yield/Recruit (Fmax): ----->    .119
    Yield/Recruit corresponding to Fmax: ----->    1.4649
  F level at 50 % of Max Spawning Potential (F50): ----->    .060
    SSB/Recruit corresponding to F50: -------->    18.1308
```

Table B29 continued.

Listing of Yield per Recruit Results for:
Winter Skate - SAW30

	FMORT	TOTCTHN	TOTCTHW	TOTSTKN	TOTSTKW	SPNSTKN	SPNSTKW	% MSP
	.000	.00000	.00000	9.9852	45.4547	5.2131	39.1993	100.00
F0.1	.078	.36367	1.39090	6.8187	19.7492	2.3907	14.7897	37.73
F50%	.060	.31053	1.28401	7.3111	23.3627	2.8085	18.1308	46.25
	.100	.41683	1.45212	6.3157	16.2633	1.9768	11.6179	29.64
Fmax	.119	.45324	1.46489	5.9656	13.9785	1.6982	9.5757	24.43
	.200	.55807	1.35654	4.9392	8.0907	.9445	4.5366	11.57
	.300	.62845	1.16228	4.2436	4.9385	.5149	2.1028	5.36
	.400	.67087	1.00462	3.8257	3.4275	.3053	1.0882	2.78
	.500	.69936	.88619	3.5468	2.5910	.1921	.6083	1.55
	.600	.71988	.79705	3.3473	2.0792	.1266	.3606	.92
	.700	.73542	.72872	3.1974	1.7424	.0866	.2241	.57
	.800	.74764	.67524	3.0805	1.5081	.0611	.1448	.37
	.900	.75753	.63254	2.9867	1.3378	.0442	.0968	.25
	1.000	.76573	.59783	2.9096	1.2096	.0327	.0666	.17
	1.100	.77265	.56915	2.8451	1.1103	.0246	.0471	.12
	1.200	.77859	.54510	2.7901	1.0315	.0188	.0340	.09
	1.300	.78376	.52467	2.7427	.9676	.0146	.0250	.06
	1.400	.78831	.50711	2.7013	.9149	.0114	.0187	.05
	1.500	.79235	.49185	2.6648	.8707	.0090	.0142	.04
	1.600	.79598	.47848	2.6322	.8333	.0072	.0110	.03
	1.700	.79926	.46664	2.6030	.8011	.0058	.0085	.02
	1.800	.80225	.45609	2.5765	.7731	.0047	.0067	.02
	1.900	.80498	.44661	2.5524	.7486	.0038	.0053	.01
	2.000	.80750	.43803	2.5302	.7268	.0031	.0042	.01

Table B30. Input data and results of Thompson and Bell (1936) yield and spawning biomass per recruit calculations for little skate.

```
Proportion of F before spawning:  .5000
Proportion of M before spawning:  .5000
Natural Mortality is Constant at:  .400
Initial age is:  1; Last age is:  8
Last age is a TRUE Age;
Original age-specific PRs, Mats, and Mean Wts from file:
==> LITTSKAT.DAT
```

Age-specific Input data for Yield per Recruit Analysis

Age	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Weights Catch	Average Weights Stock
1	.0000	1.0000	.0000	.119	.119
2	.1000	1.0000	.0000	.254	.254
3	.7000	1.0000	.5000	.378	.378
4	.9000	1.0000	1.0000	.507	.507
5	1.0000	1.0000	1.0000	.614	.614
6	1.0000	1.0000	1.0000	.697	.697
7	1.0000	1.0000	1.0000	.761	.761
8	1.0000	1.0000	1.0000	.807	.807

Summary of Yield per Recruit Analysis for: Little Skate

```
Slope of the Yield/Recruit Curve at F=0.00: -->          .5027
  F level at slope=1/10 of the above slope (F0.1): ----->       .651
    Yield/Recruit corresponding to F0.1: ----->          .1179
  F level to produce Maximum Yield/Recruit (Fmax): ----->     6.995
    Yield/Recruit corresponding to Fmax: ----->          .1505
  F level at 50 % of Max Spawning Potential (F50): ----->       .342
    SSB/Recruit corresponding to F50: -------->          .2350
```

Listing of Yield per Recruit Results for: Little Skate

	FMORT	TOTCTHN	TOTCTHW	TOTSTKN	TOTSTKW	SPNSTKN	SPNSTKW	% MSP
	.000	.00000	.00000	2.9096	.9481	.8307	.4701	100.00
	.100	.07958	.04089	2.7675	.8532	.6850	.3755	79.87
	.200	.13720	.06796	2.6570	.7810	.5747	.3057	65.03
	.300	.18032	.08634	2.5695	.7252	.4896	.2533	53.88
F50%	.342	.19539	.09231	2.5378	.7053	.4594	.2350	49.99
	.400	.21360	.09917	2.4989	.6812	.4226	.2131	45.34
	.500	.24006	.10837	2.4411	.6460	.3691	.1818	38.67
	.600	.26164	.11516	2.3929	.6173	.3255	.1570	33.39
F0.1	.651	.27120	.11795	2.3714	.6047	.3063	.1463	31.11
	.700	.27964	.12030	2.3523	.5936	.2895	.1370	29.13
	.800	.29495	.12429	2.3175	.5738	.2594	.1206	25.65
	.900	.30817	.12747	2.2873	.5569	.2339	.1070	22.77
	1.000	.31976	.13004	2.2610	.5425	.2122	.0957	20.35
	1.100	.33003	.13216	2.2377	.5299	.1933	.0861	18.30
	1.200	.33922	.13394	2.2170	.5190	.1770	.0778	16.55
	1.300	.34752	.13546	2.1984	.5092	.1626	.0707	15.04
	1.400	.35506	.13676	2.1816	.5006	.1499	.0645	13.73
	1.500	.36196	.13790	2.1663	.4928	.1386	.0591	12.58
	1.600	.36831	.13889	2.1523	.4859	.1286	.0543	11.56
	1.700	.37419	.13978	2.1395	.4795	.1195	.0501	10.66
	1.800	.37965	.14056	2.1276	.4737	.1114	.0464	9.86
	1.900	.38474	.14127	2.1166	.4684	.1040	.0430	9.14
	2.000	.38950	.14191	2.1064	.4635	.0973	.0400	8.50

Table B31. Hoenig (1987) estimates of fishing mortality for winter skate estimated from NEFSC spring (GOM-MA, offshore) trawl survey length frequency distributions. Winter skate von Bertalanffy growth parameters from Simon and Frank (1996). Assumes recruitment to NEFSC survey sampling gear at 50 cm. Year of estimate is the last year of a five year moving window, to smooth the variation in estimates resulting from variation in recruitment over time.

Winter skate: Linf = 114.01 cm, K = 0.14405, Spring survey L' = 50 cm, M = 0.1

Year	Lbar	Hoenig F	Year	Lbar	Hoenig F
1972	63.9	0.29	1986	75.9	0.08
1973	64.2	0.28	1987	75.6	0.08
1974	64.3	0.28	1988	75.5	0.08
1975	64.5	0.28	1989	74.9	0.09
1976	65.0	0.26	1990	74.7	0.09
1977	67.6	0.20	1991	74.4	0.10
1978	72.0	0.13	1992	73.3	0.11
1979	74.0	0.10	1993	71.2	0.14
1980	76.4	0.08	1994	69.7	0.16
1981	77.5	0.06	1995	67.6	0.20
1982	77.6	0.06	1996	63.1	0.32
1983	77.1	0.07	1997	61.6	0.37
1984	76.8	0.07	1998	60.7	0.41
1985	76.0	0.08	1999	61.1	0.39

Table B32. Beverton-Holt (1956) and Hoenig (1987) estimates of fishing mortality for little skate estimated from NEFSC spring (GOM-MA, inshore and offshore regions) trawl survey length frequency distributions. Little skate von Bertalanffy growth parameters from Waring (1984). Assumes recruitment to NEFSC spring survey sampling gear at 45 cm in. Year of estimate is the last year of a three year moving window, to smooth the variation in estimates resulting from variation in recruitment over time.

Little skate: Linf = 52.73 cm, K = 0.352, Spring survey L' = 45 cm, M = 0.4

Year	Lbar	Hoenig F
1984	47.1	0.20
1985	47.1	0.19
1986	47.2	0.15
1987	47.2	0.17
1988	47.2	0.16
1989	47.0	0.23
1990	47.0	0.22
1991	46.9	0.26
1992	46.9	0.24
1993	46.9	0.26
1994	46.8	0.30
1995	46.8	0.30
1996	46.8	0.27
1997	46.9	0.24
1998	46.8	0.28
1999	46.7	0.34

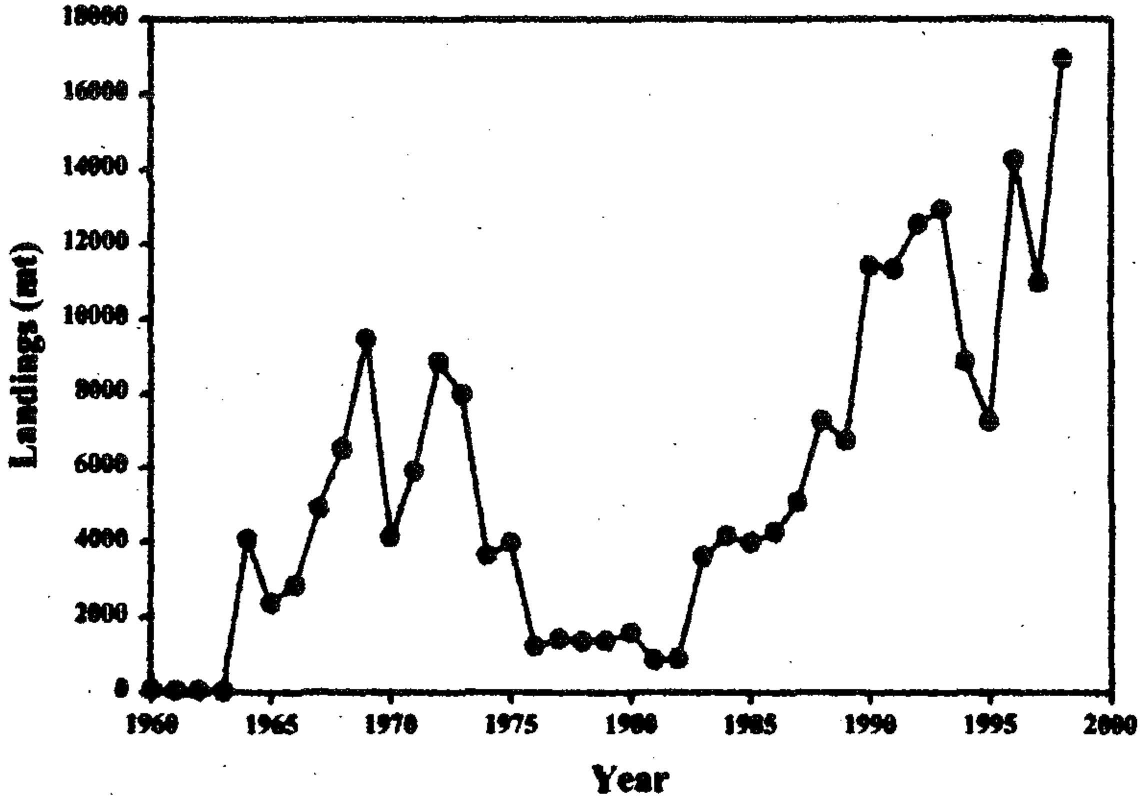


Figure B1. Total landings of skates in NAFO subareas 5 and 6.

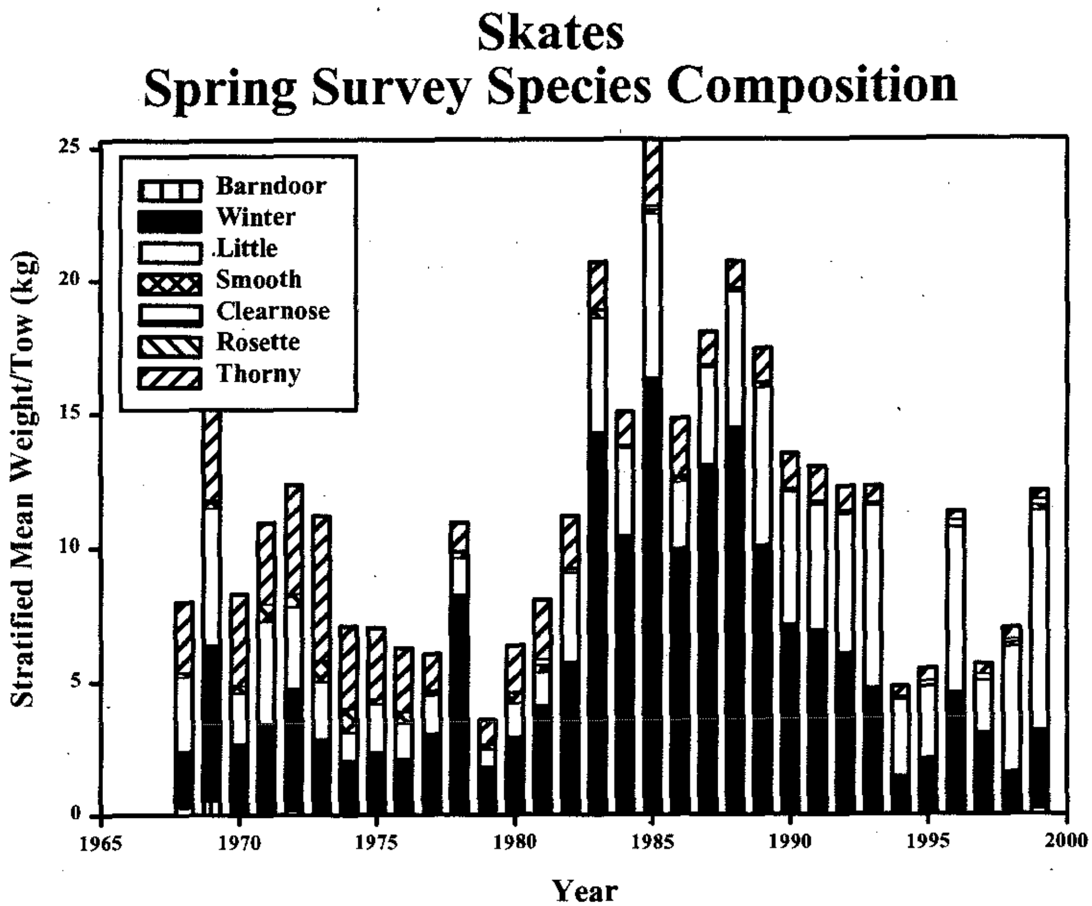
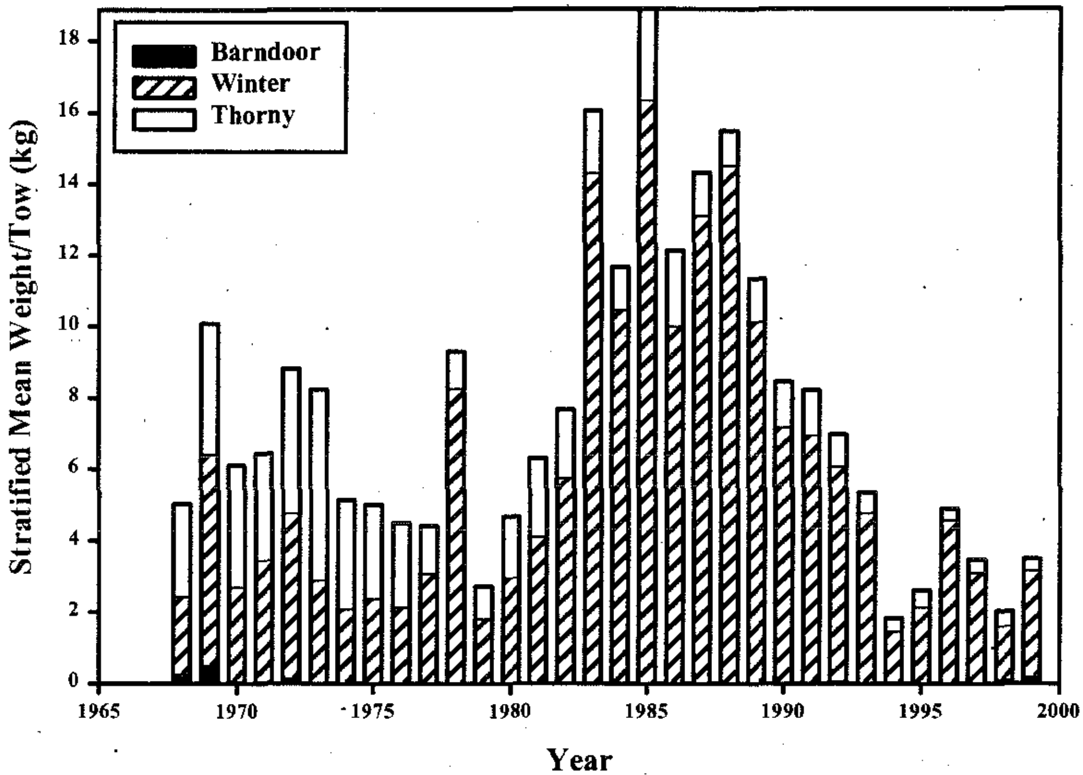


Figure B2. Species composition of skates from the spring survey.

Skates
Spring Survey Species Composition



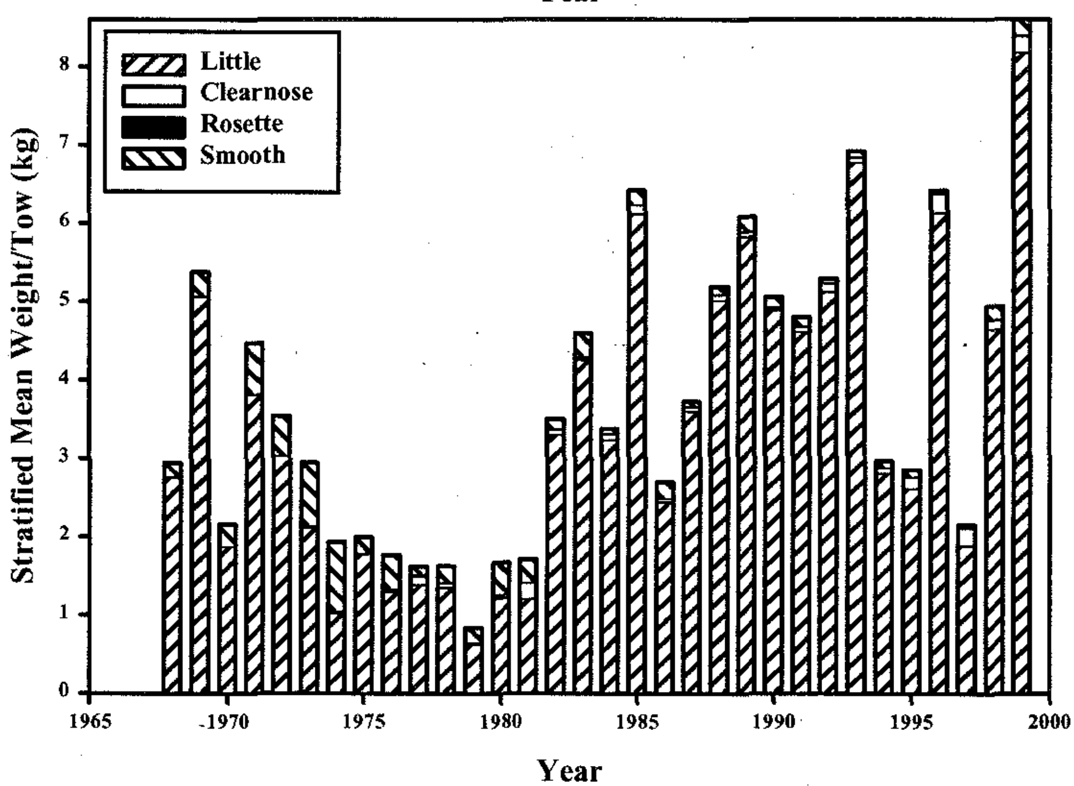
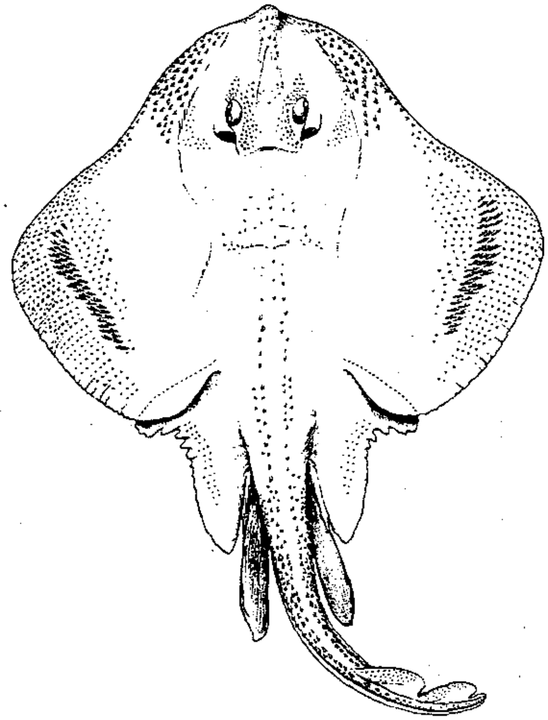
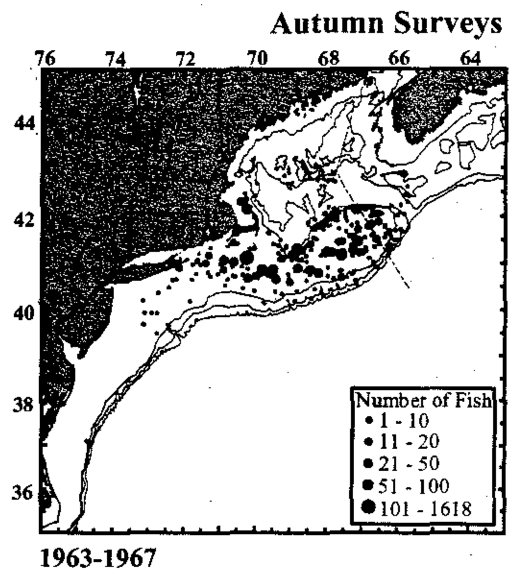
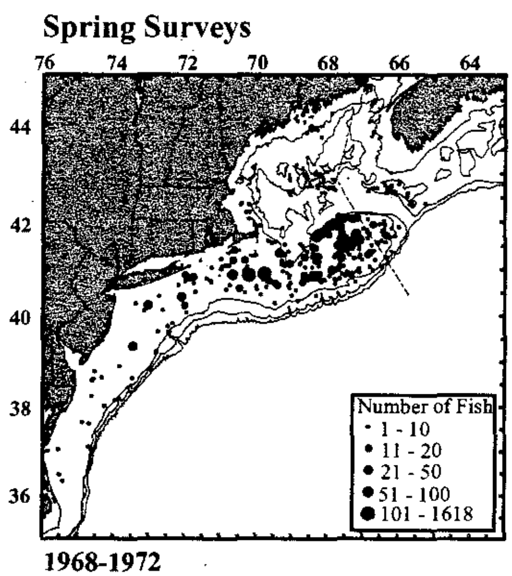


Figure B3. Species composition of skates from the spring survey. The top panel shows the composition of large species (>100 cm maximum length) while the bottom panel shows the composition of the small species (maximum length < 100cm).

Winter Skate







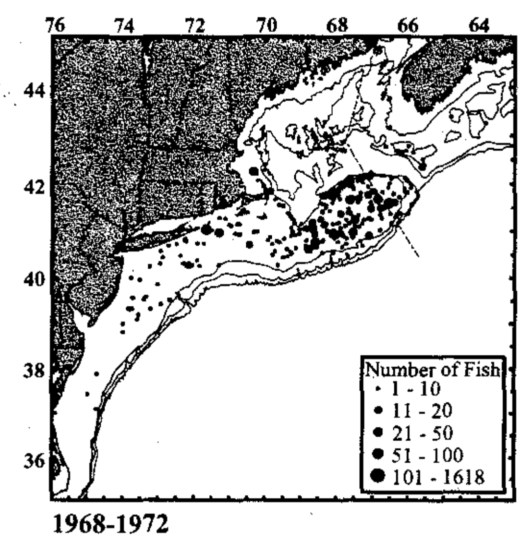


Figure B4. Distribution of winter skate in the NEFSC spring and autumn bottom trawl surveys from 1963-1972.

Winter Skate

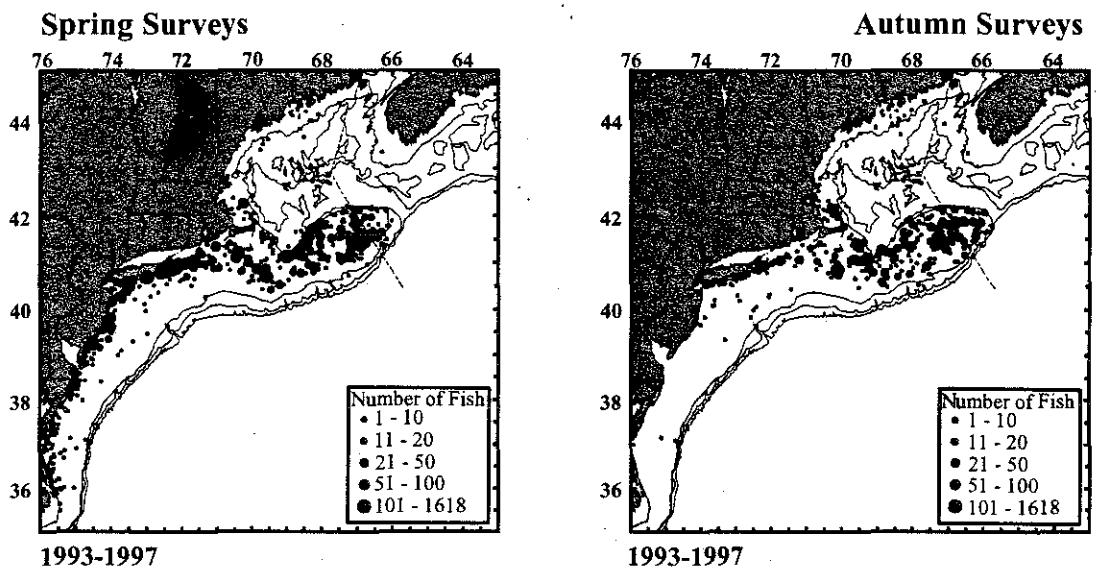


Figure B7. Distribution of winter skate in the NEFSC spring and autumn bottom trawl surveys from 1993-1997.

Winter Skate

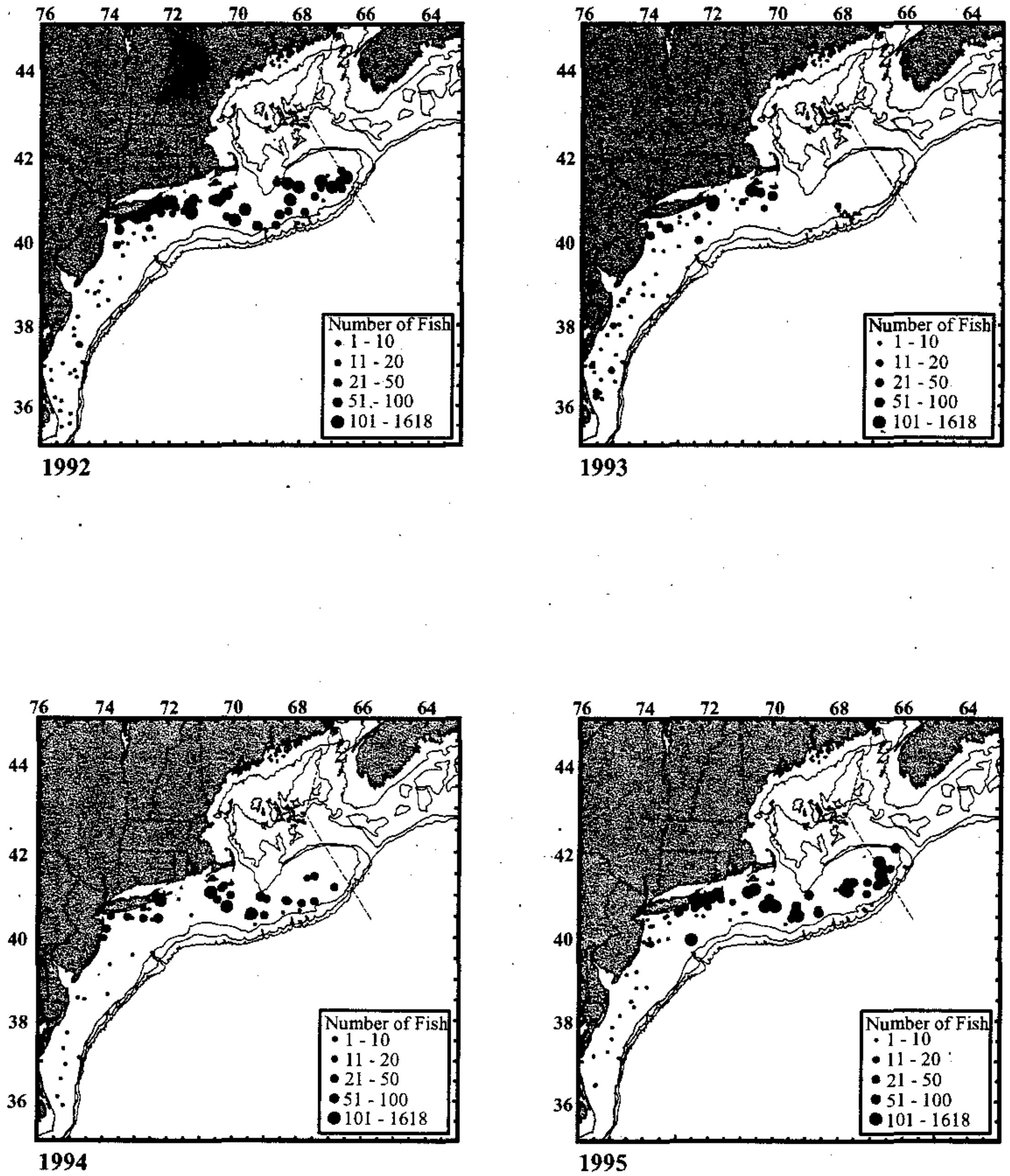


Figure B8. Distribution of winter skate in the NEFSC winter bottom trawl survey from 1992-1995.

Winter Skate

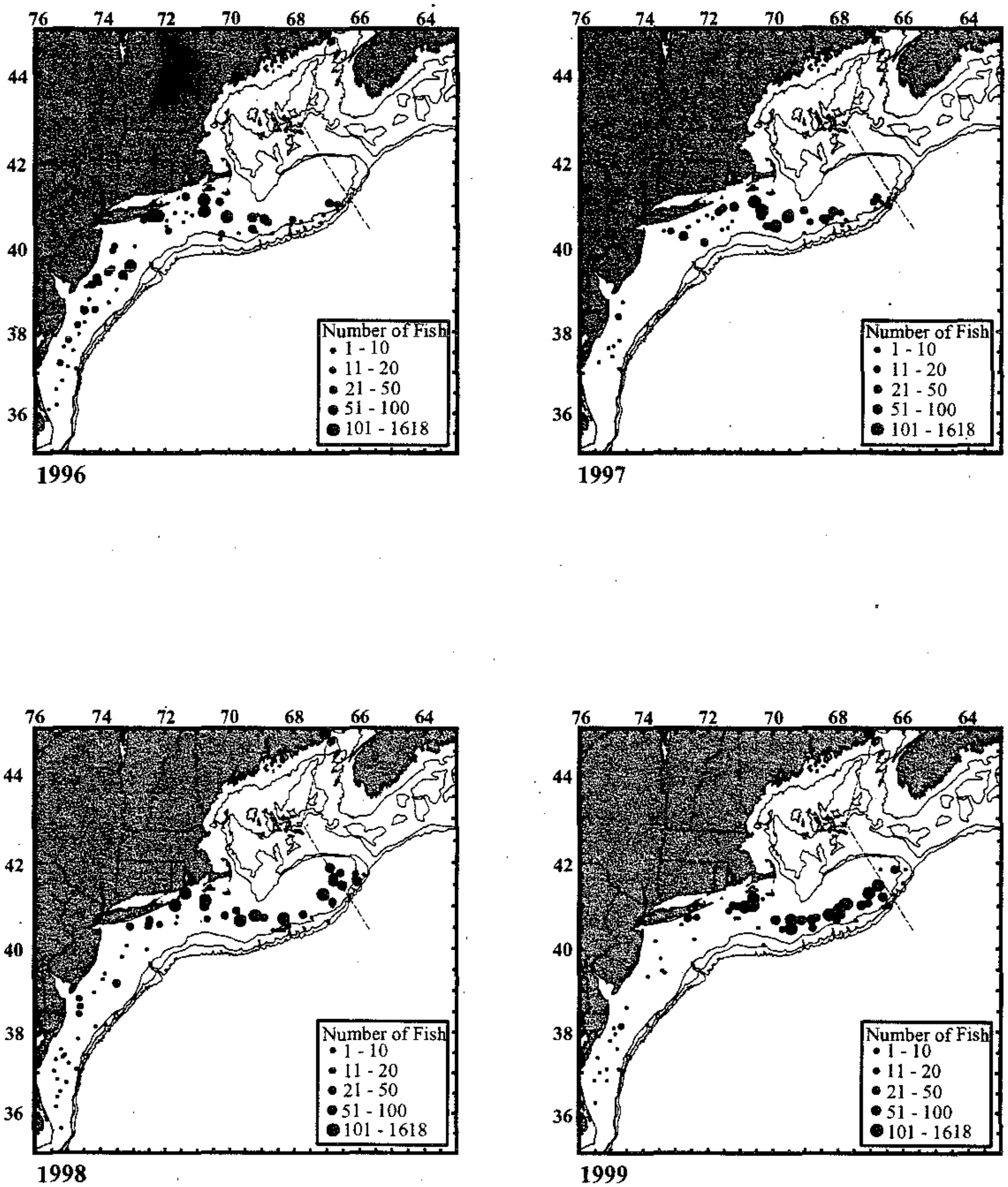
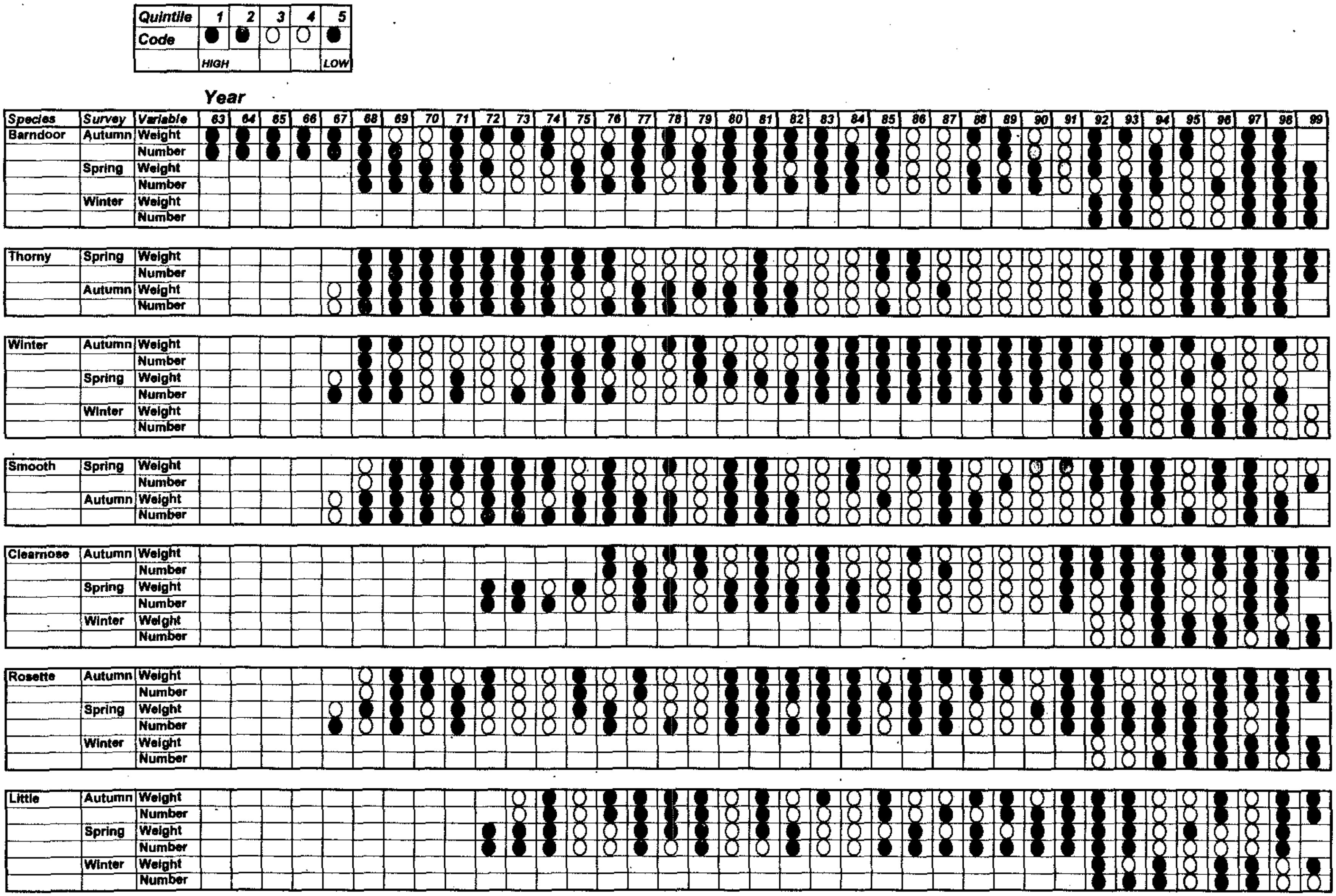


Figure B9. Distribution of winter skate in the NEFSC winter bottom trawl survey from 1996-1999.

Figure B10. Summary of NEFSC Survey Indices for the Skate Complex



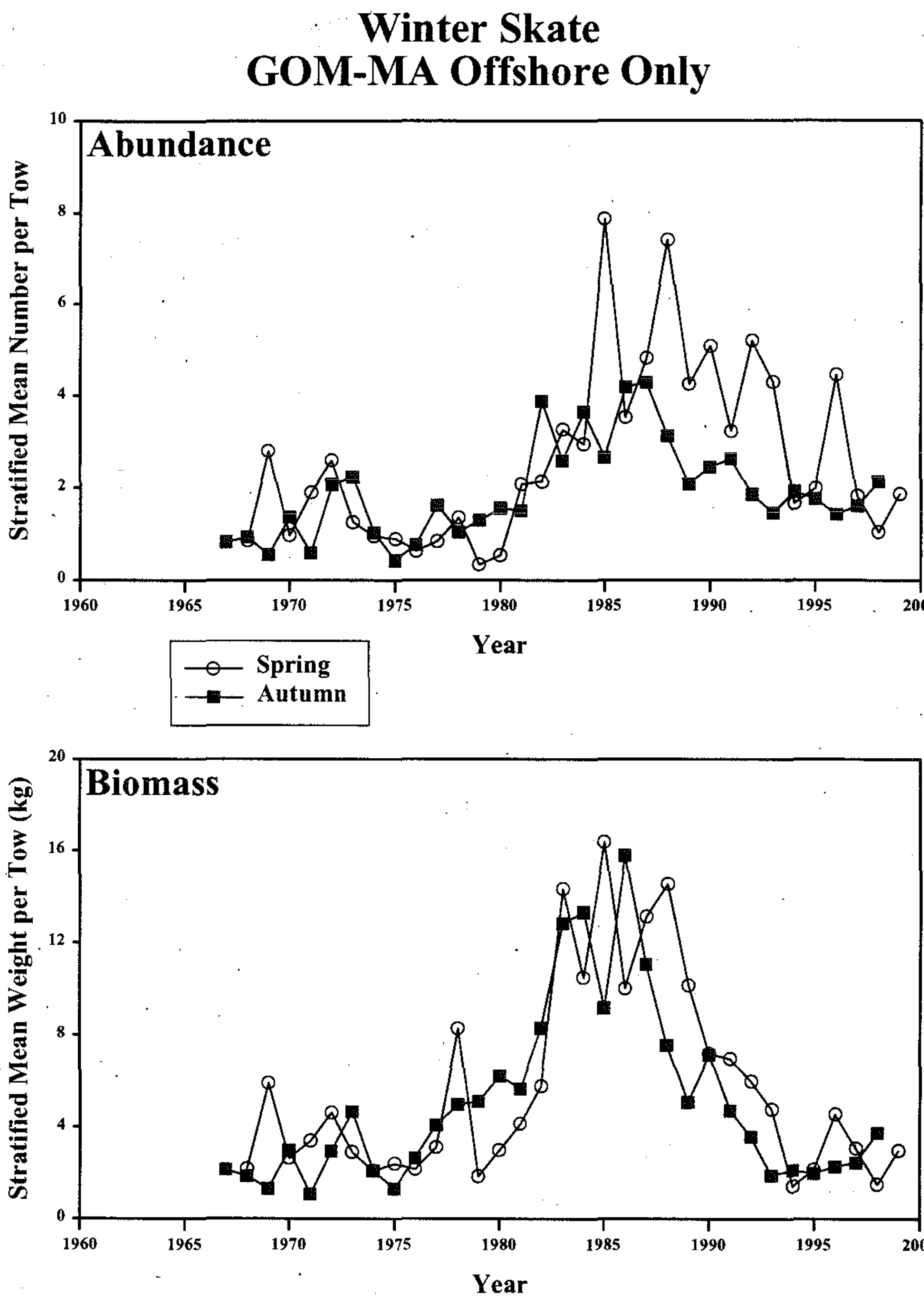
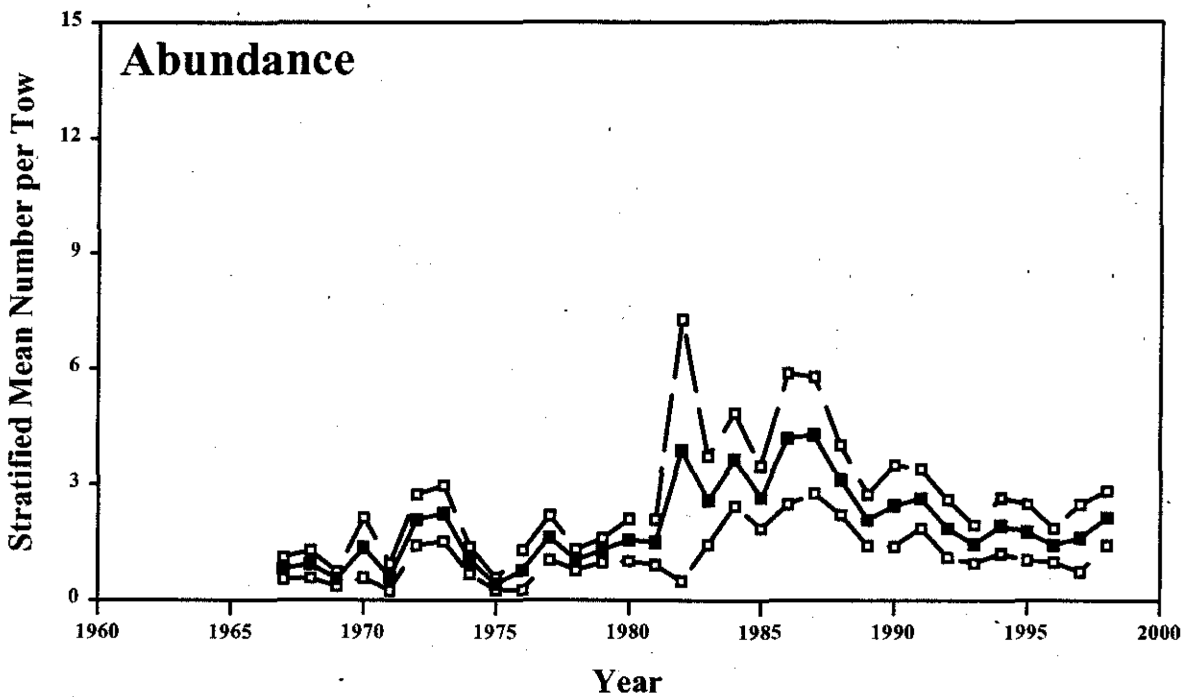


Figure B11. Abundance and biomass of winter skate from the NESFC spring (circles) and autumn (squares) bottom trawl surveys from 1967-1999 in the Gulf of Maine to Mid-Atlantic offshore region.

Winter Skate - Autumn Survey
GOM-MA Offshore Only



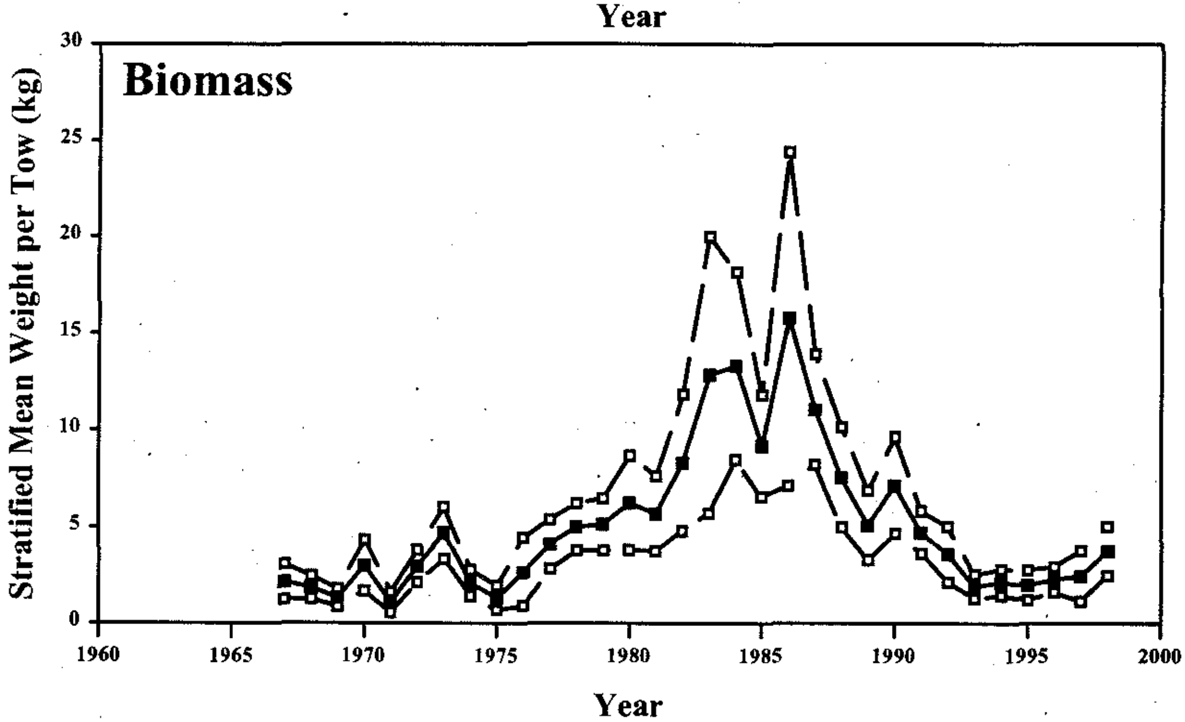
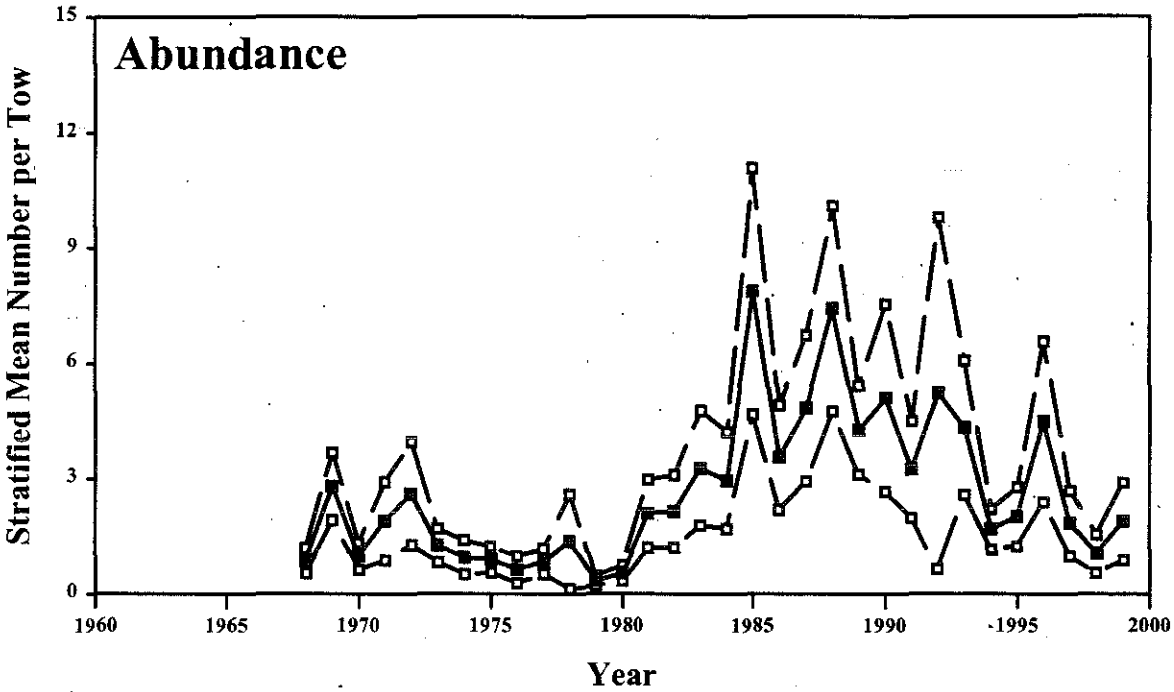


Figure B12. Abundance and biomass of winter skate from the NESFC autumn bottom trawl survey in the Gulf of Maine to Mid-Atlantic region, offshore strata only. Mean index in solid squares, 95% confidence interval in open squares.

Winter Skate - Spring Survey
GOM-MA Offshore Only



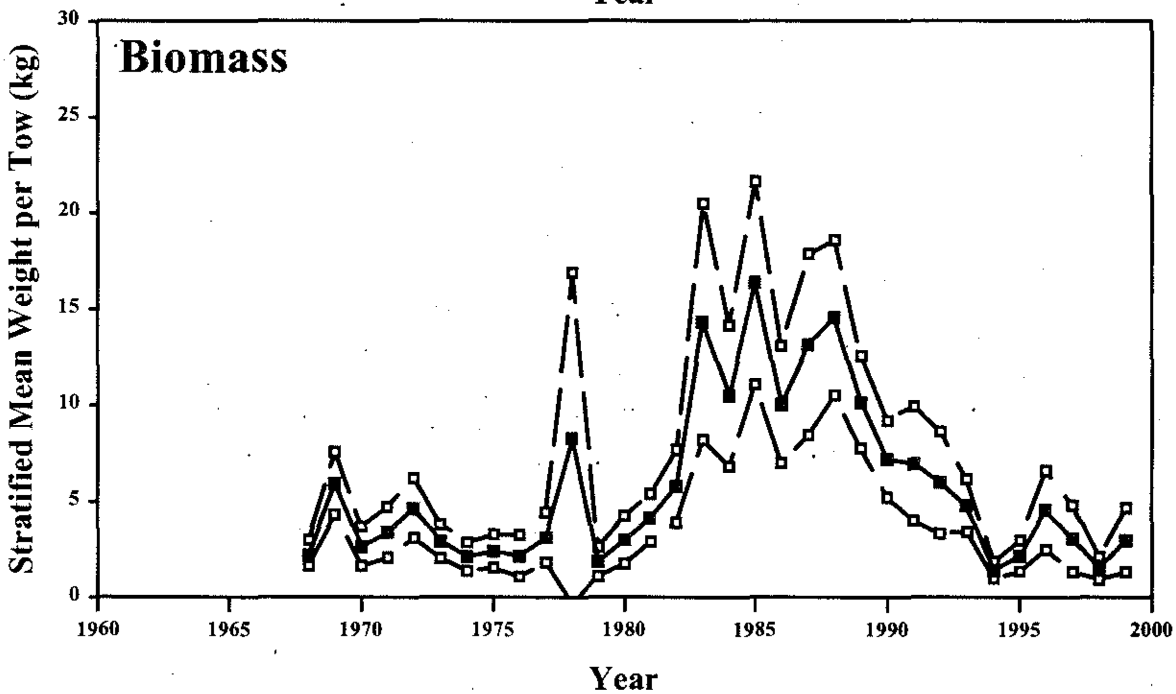


Figure B13 . Abundance and biomass of winter skate from the NESFC spring bottom trawl survey in the Gulf of Maine to Mid-Atlantic region, offshore strata only. Mean index in solid squares, 95% confidence interval in open squares.

Winter Skate
Percentiles of Length Composition

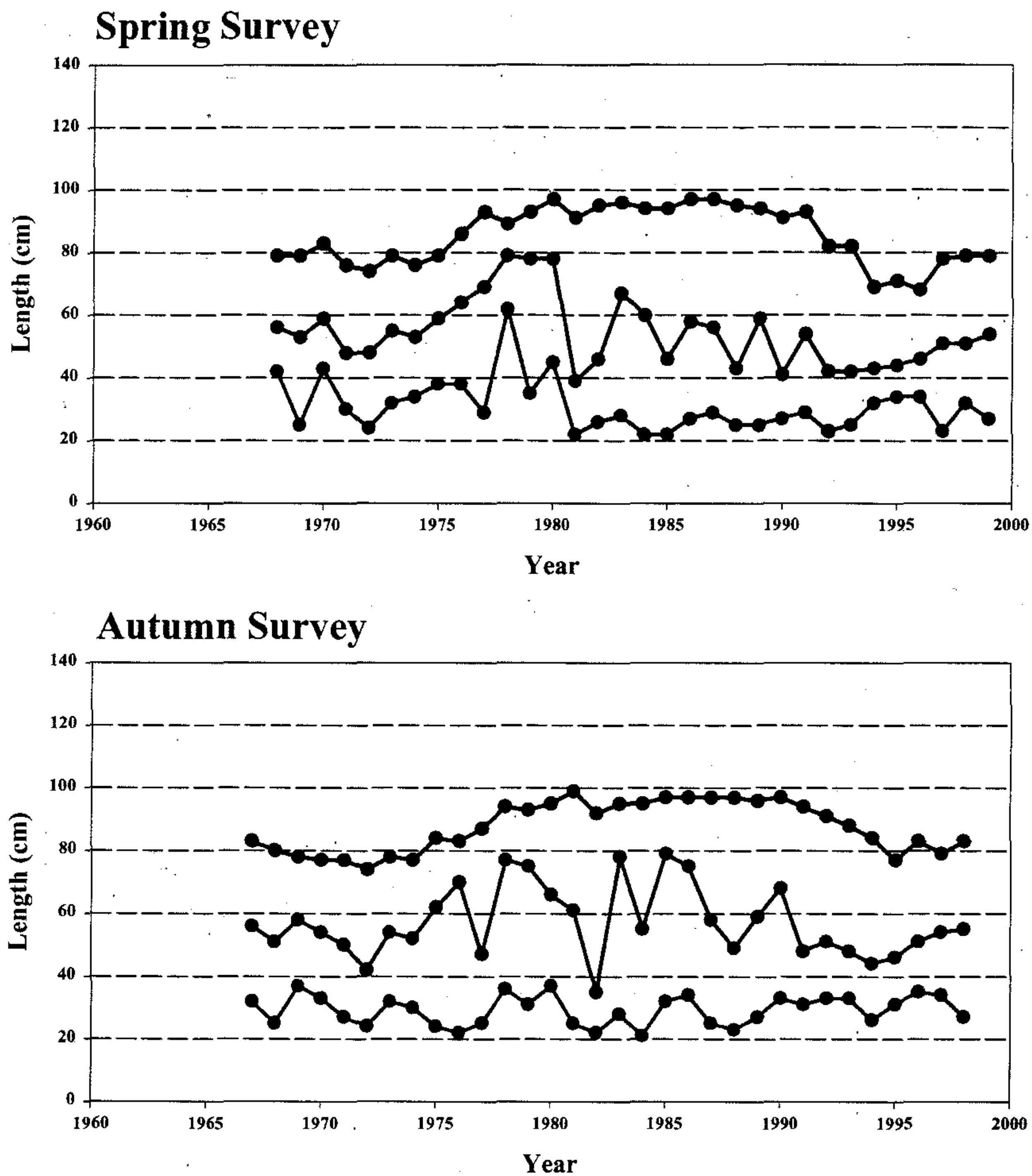


Figure B14. Percentiles of length composition (5, 50, and 95) of winter skate from the NESFC spring and autumn bottom trawl surveys from 1963-1999 in the Gulf of Maine to Mid-Atlantic offshore region.

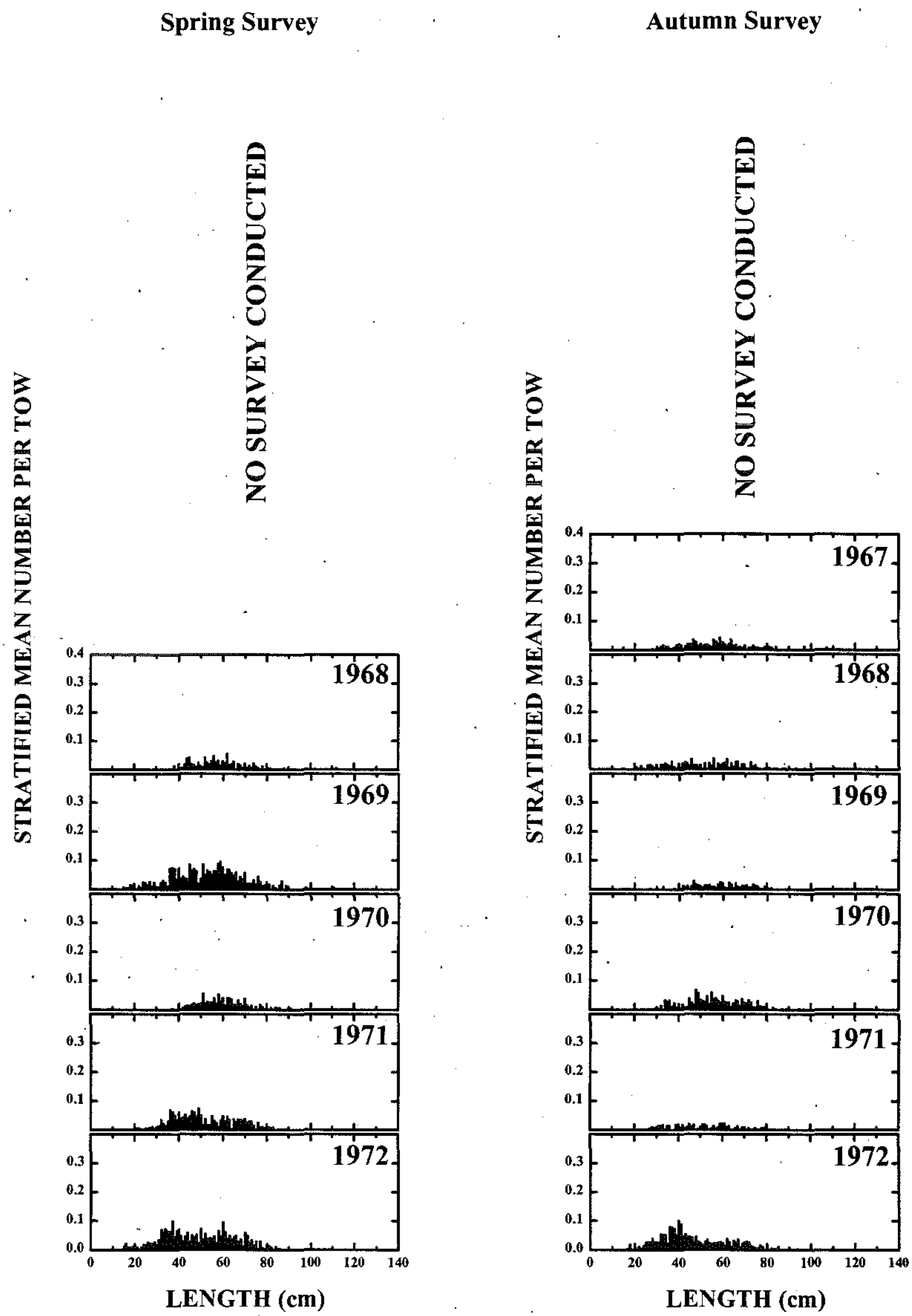


Figure B15. Winter skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Mid-Atlantic offshore regions, 1967-1972.

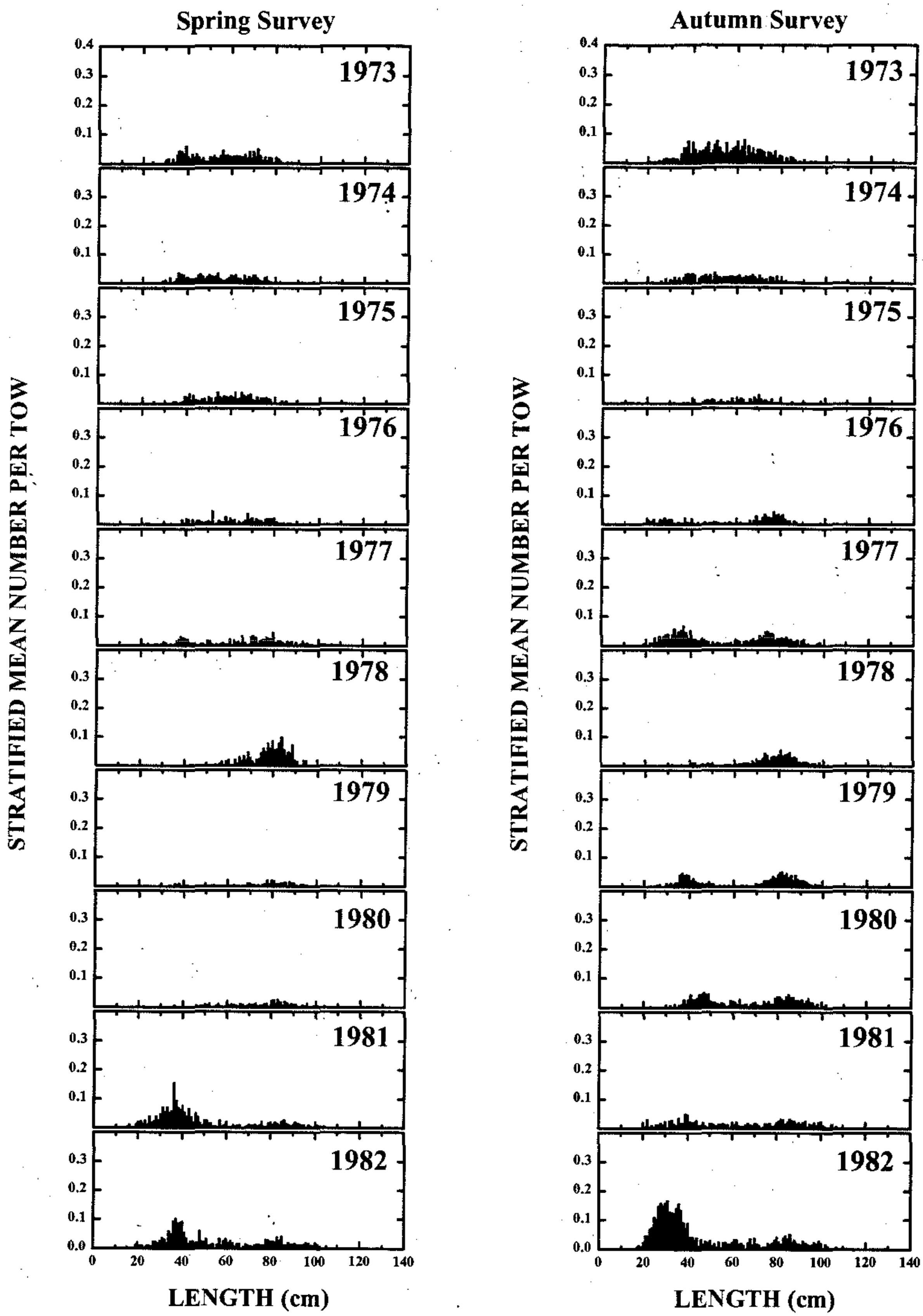


Figure B16. Winter skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Mid-Atlantic offshore regions, 1973-1982.

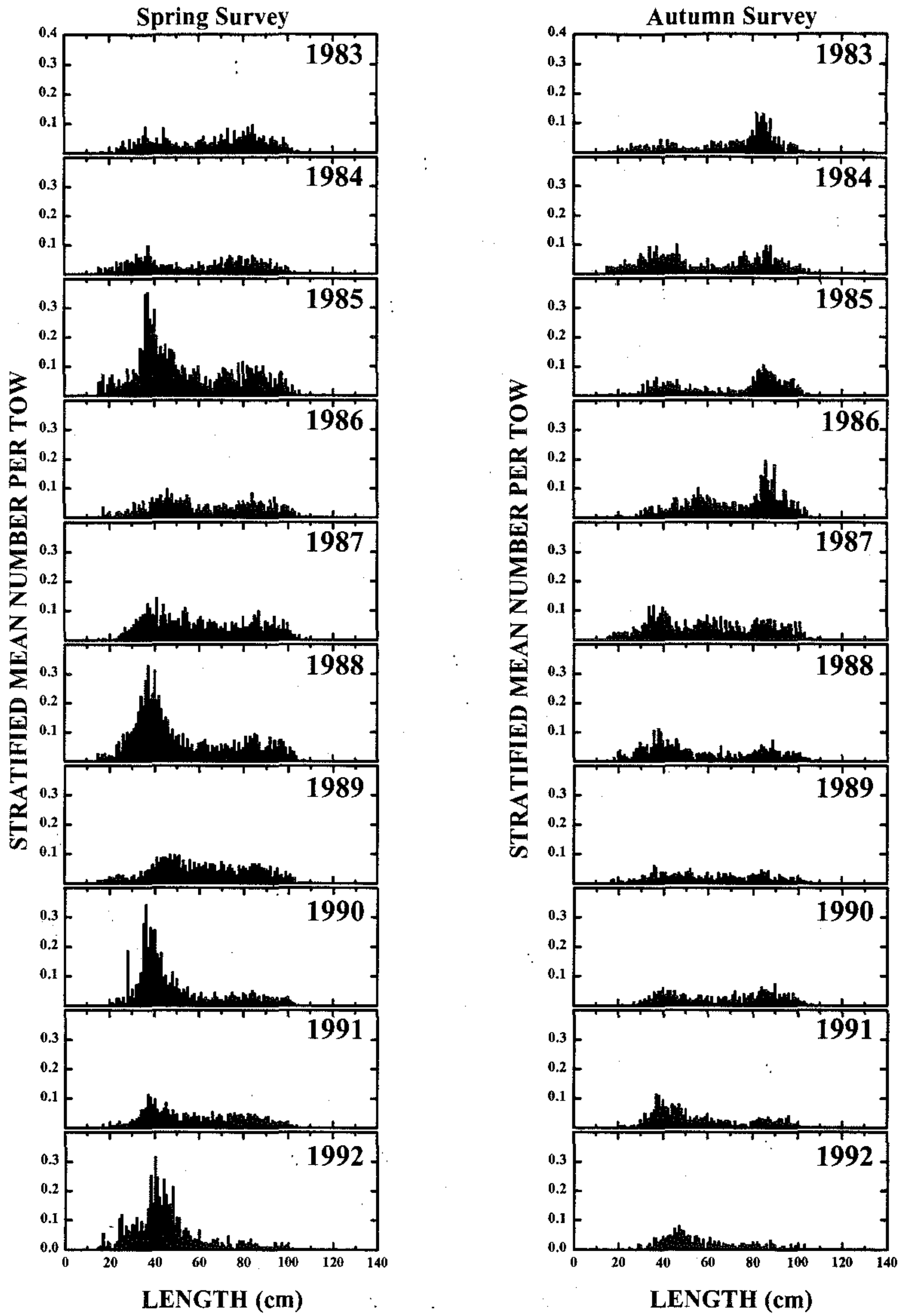


Figure B17. Winter skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Mid-Atlantic offshore regions, 1983-1992.

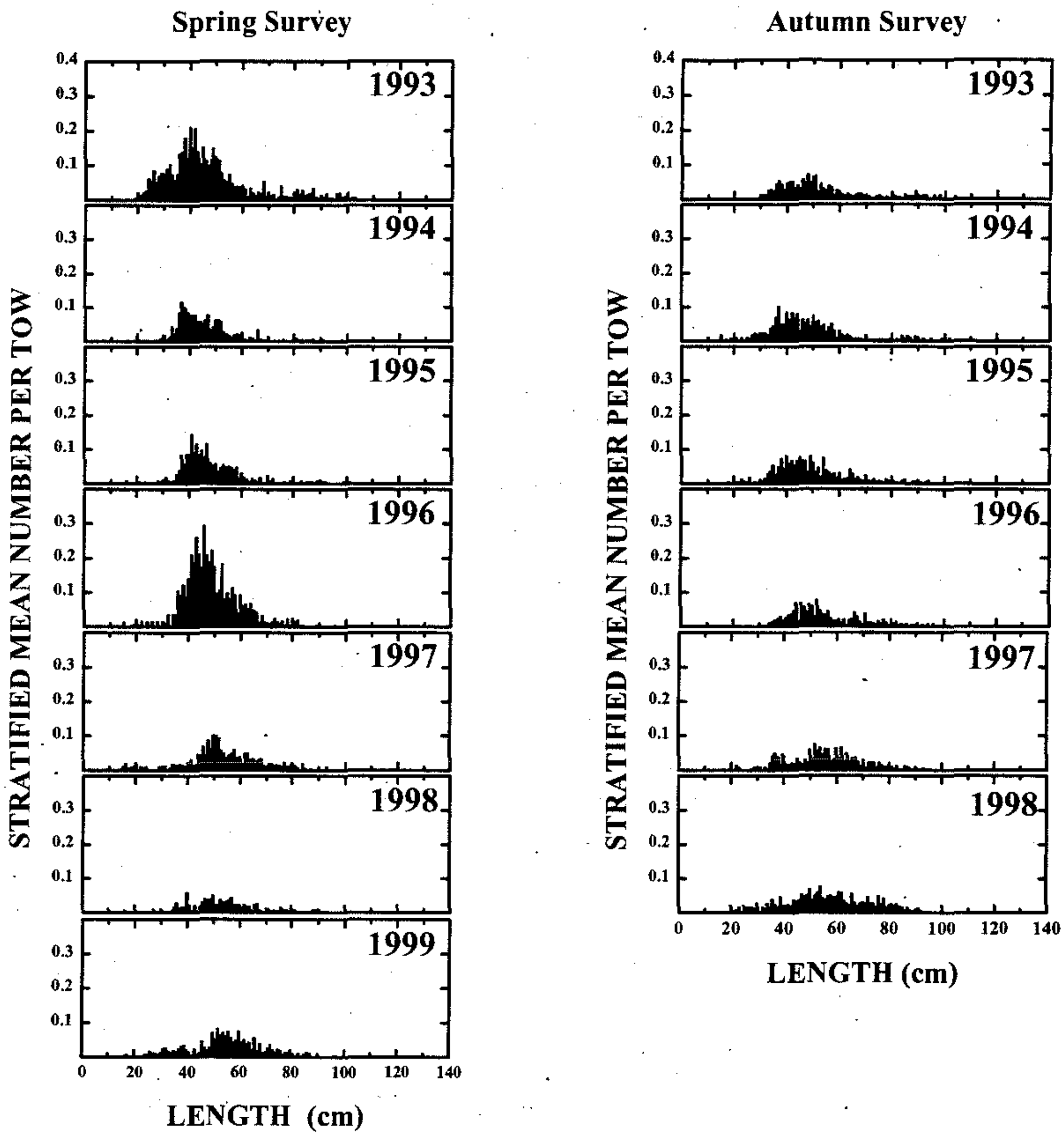


Figure B18. Winter skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Mid-Atlantic offshore regions, 1993-1999.

Winter Skate - Massachusetts Trawl Survey

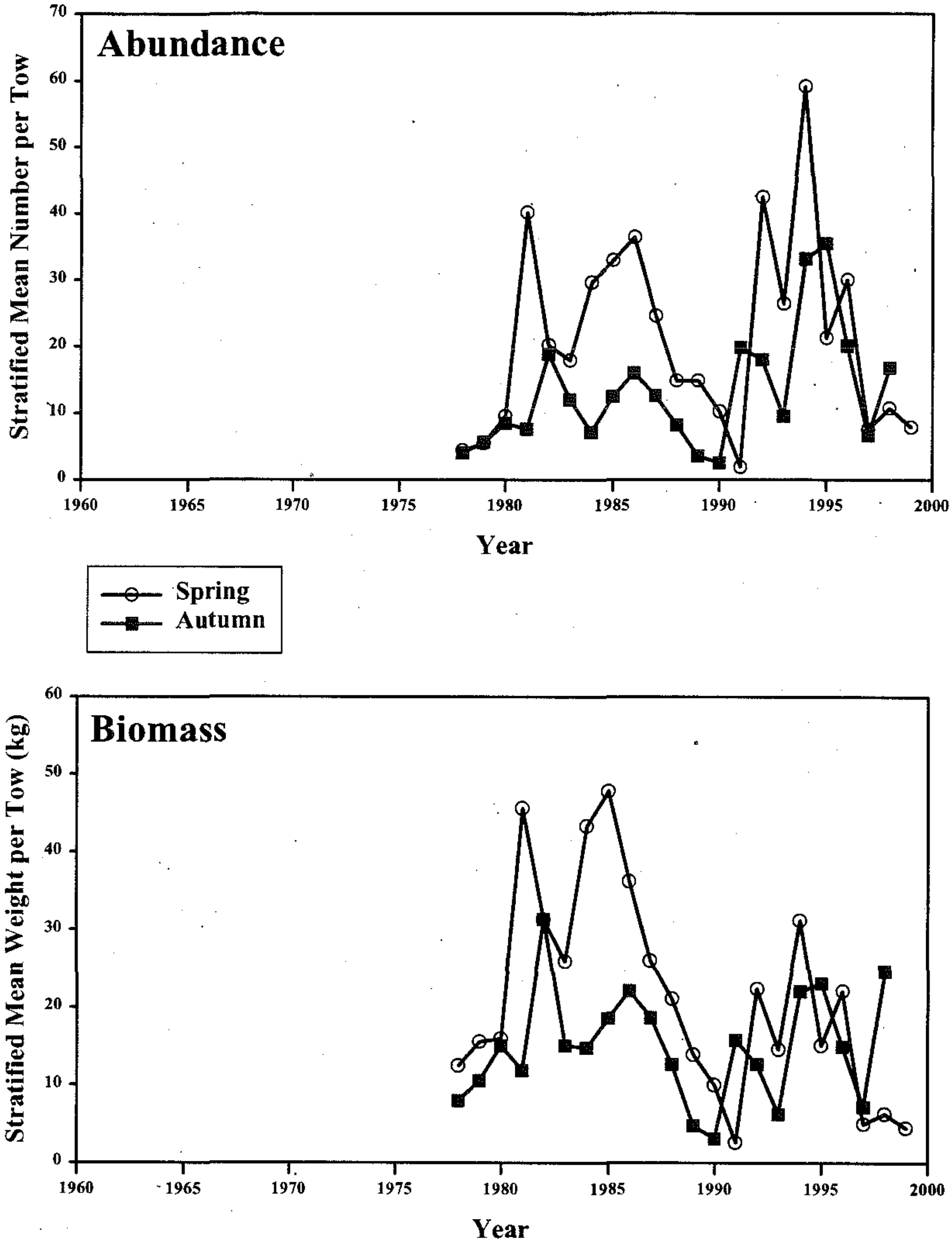


Figure B19. Abundance and biomass of winter skate from the Massachusetts spring and autumn finfish bottom trawl survey in state waters.

Winter Skate - Massachusetts Trawl Survey
Stratified Mean Length

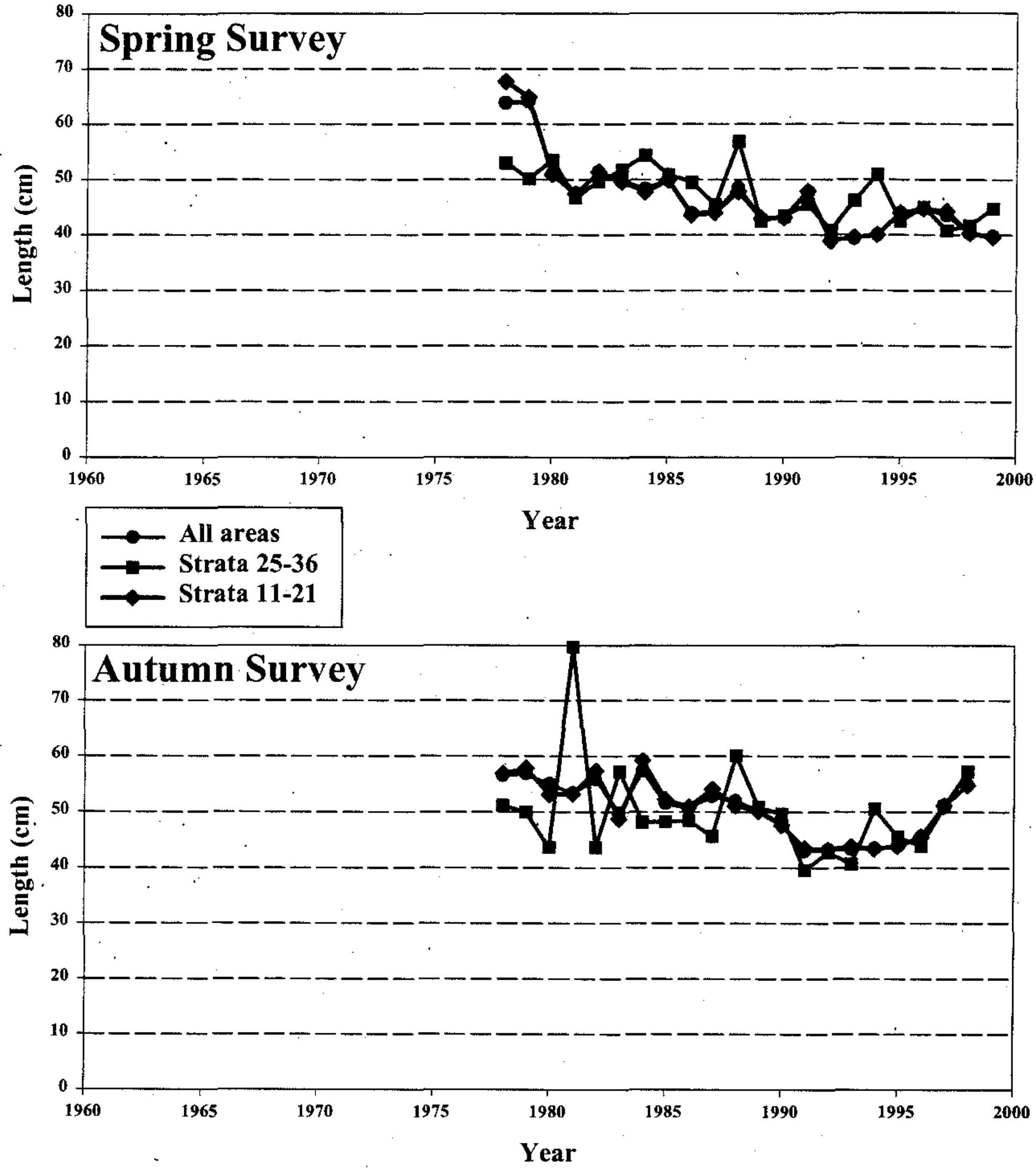


Figure B20. Stratified mean total length (cm) of winter skate from the Massachusetts spring and autumn bottom trawl surveys from 1978-1999 in three regions.

Winter Skate - CTDEP Finfish Survey

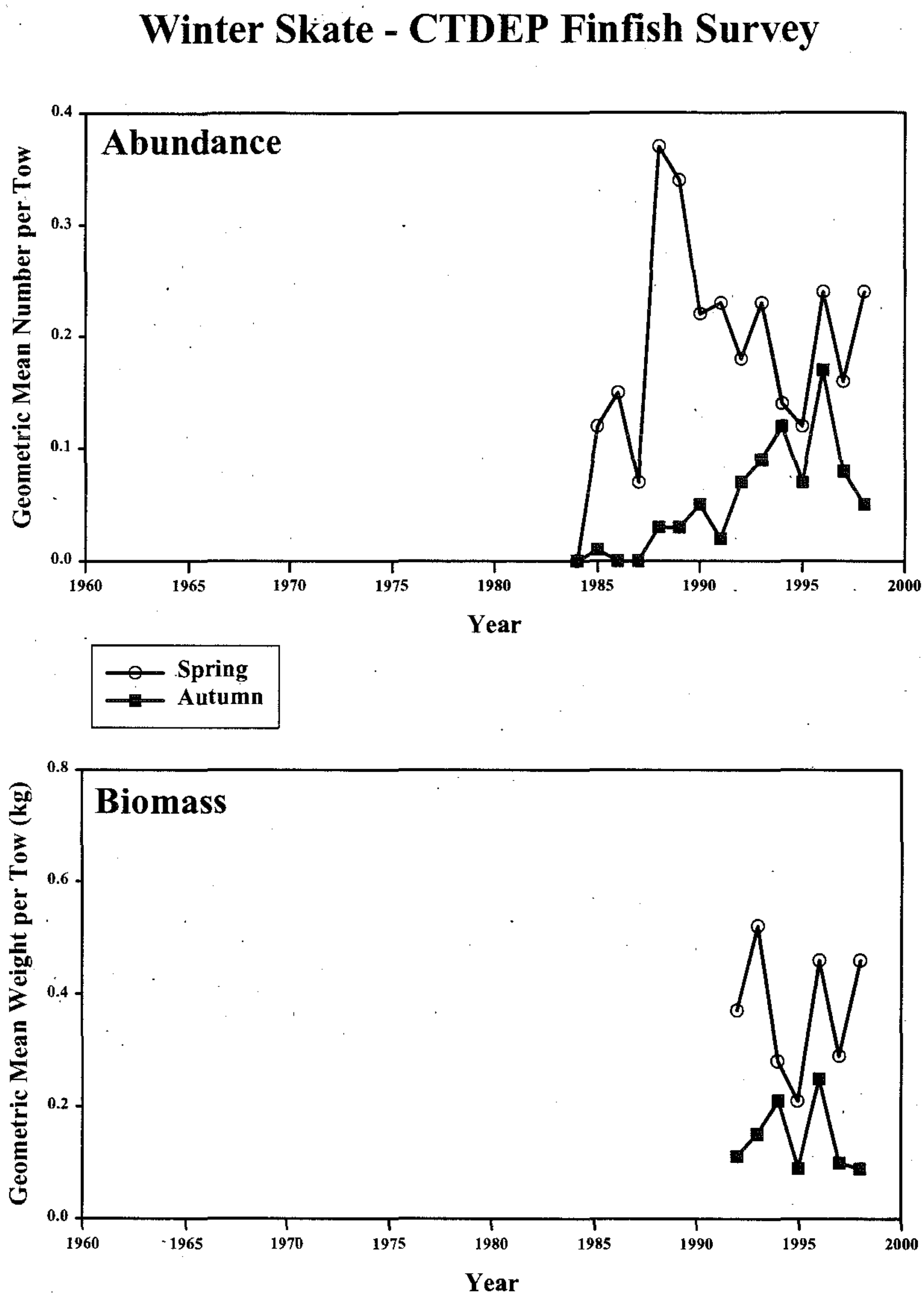
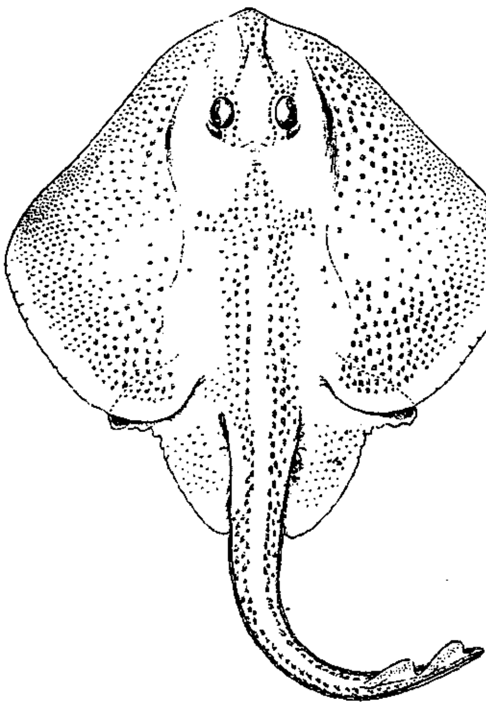
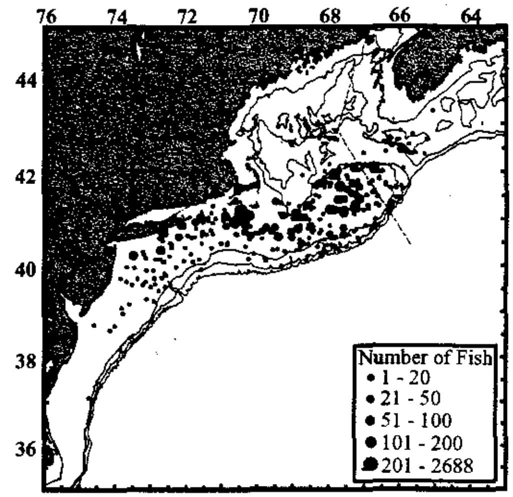


Figure B21. Abundance and biomass of winter skate from the CTDEP spring and autumn finfish bottom trawl survey in Connecticut state waters.

Little Skate

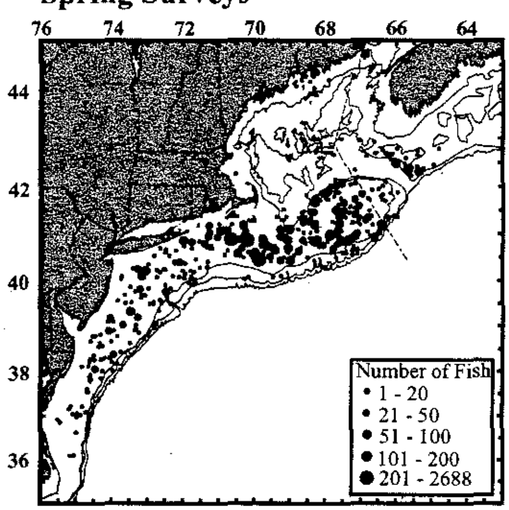


Autumn Surveys

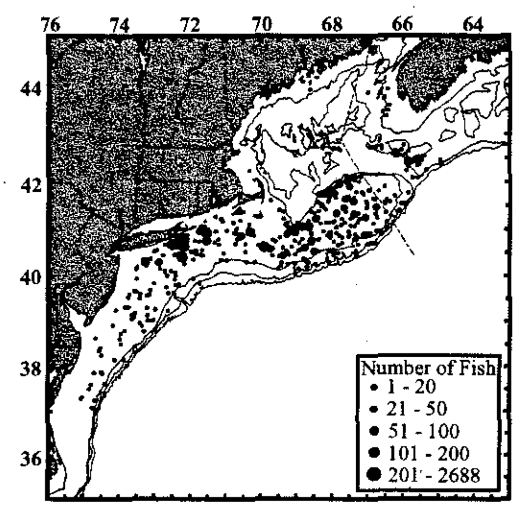


1963-1967

Spring Surveys



1968-1972



1968-1972

Figure B22. Distribution of little skate in the NEFSC spring and autumn bottom trawl surveys from 1963-1972.

Little Skate

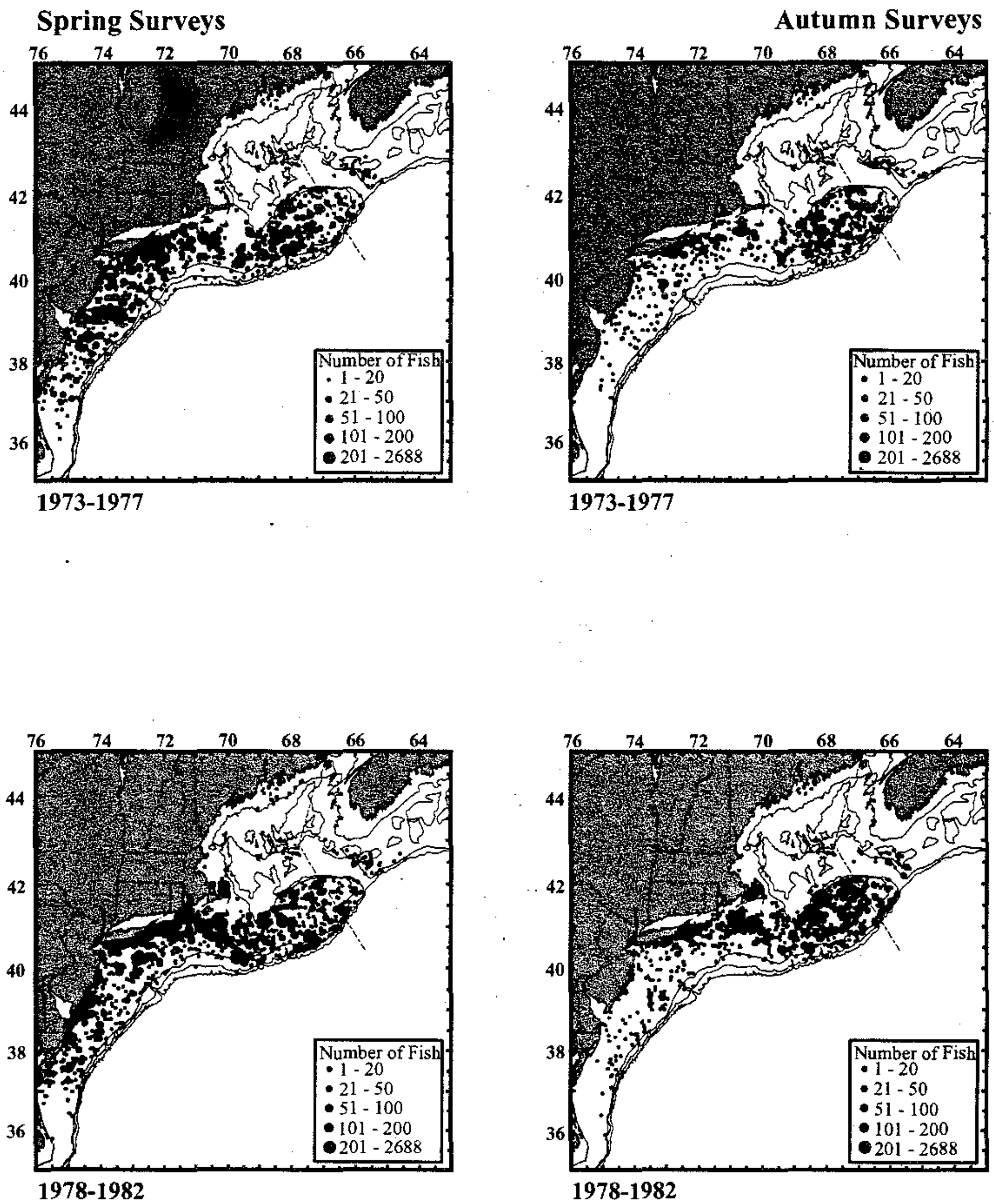


Figure B23. Distribution of little skate in the NEFSC spring and autumn bottom trawl surveys from 1973-1982.

Little Skate

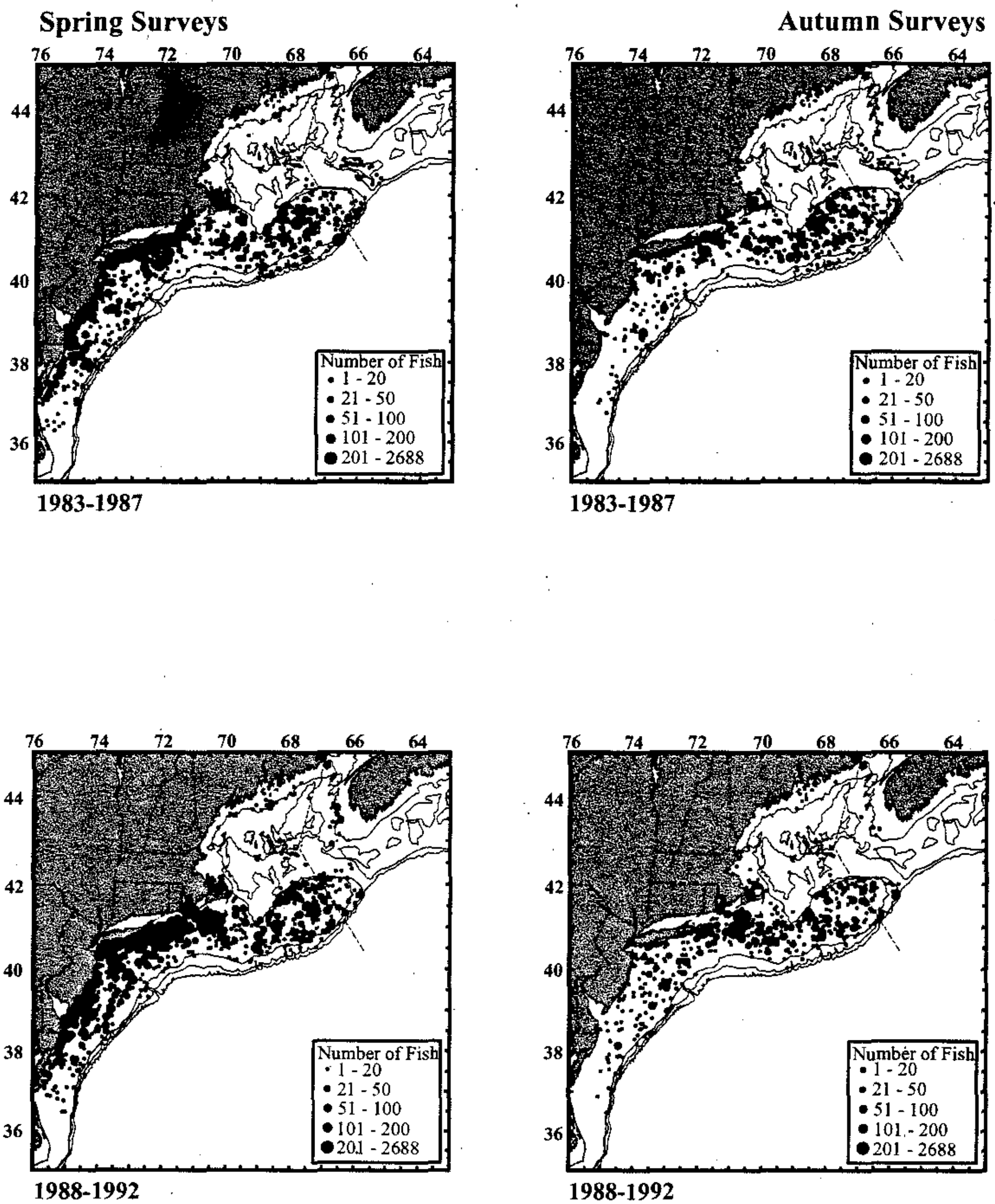


Figure B24. Distribution of little skate in the NEFSC spring and autumn bottom trawl surveys from 1983-1992.

Little Skate

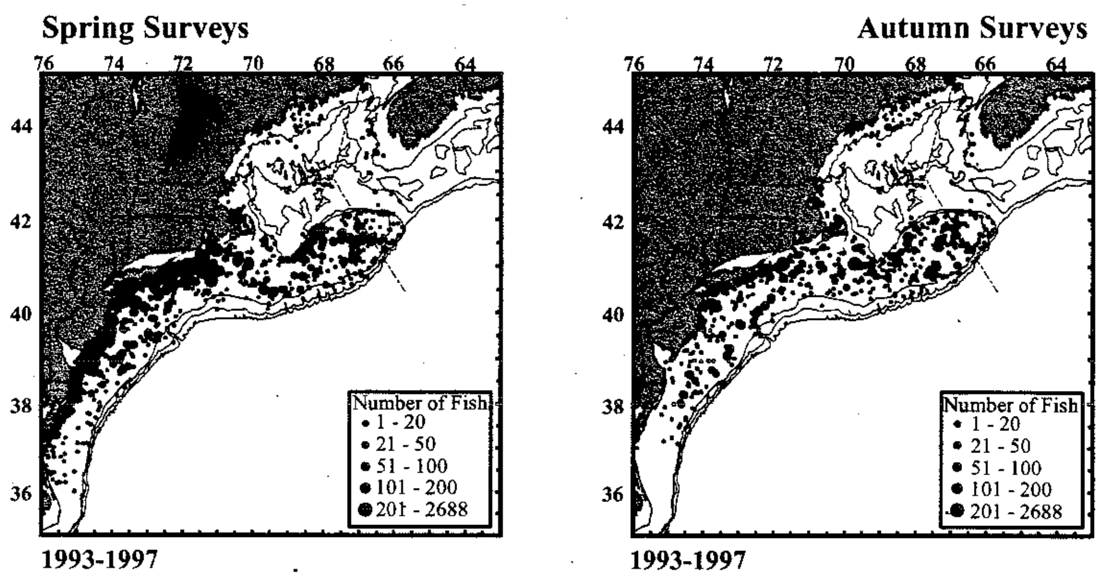


Figure B25. Distribution of little skate in the NEFSC spring and autumn bottom trawl surveys from 1993-1997.

Little Skate

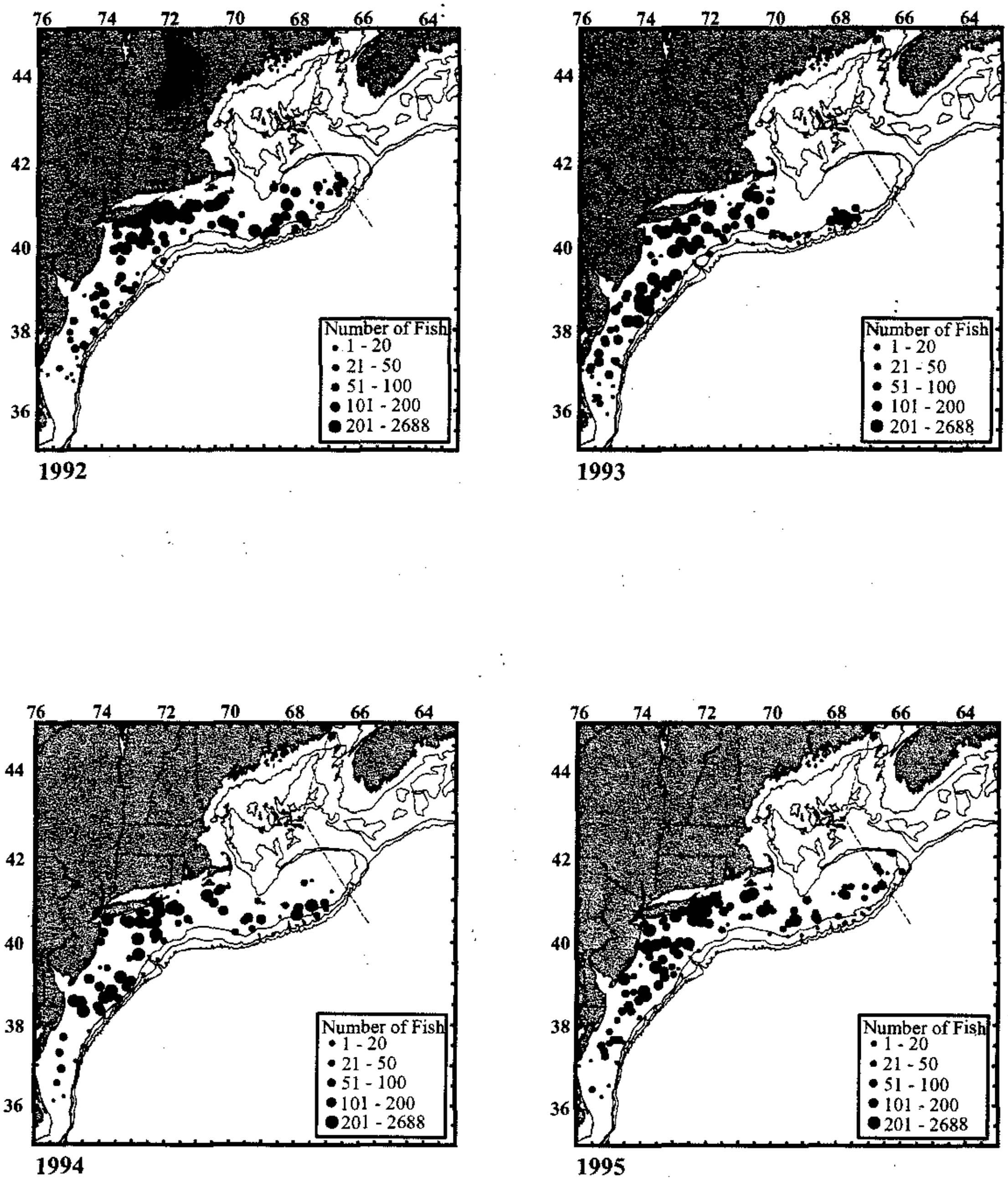


Figure B26. Distribution of little skate in the NEFSC winter bottom trawl survey from 1992-1995.

Little Skate

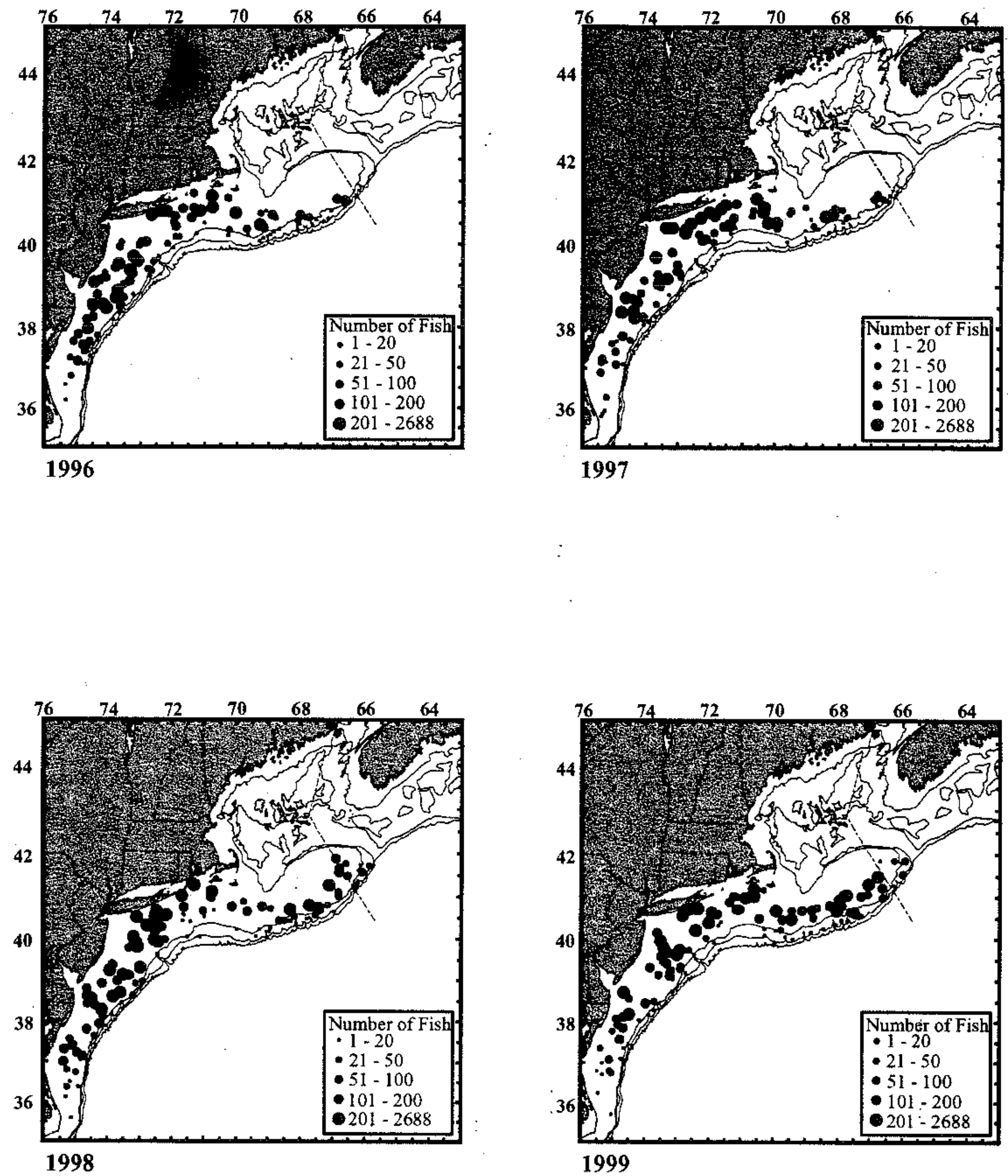
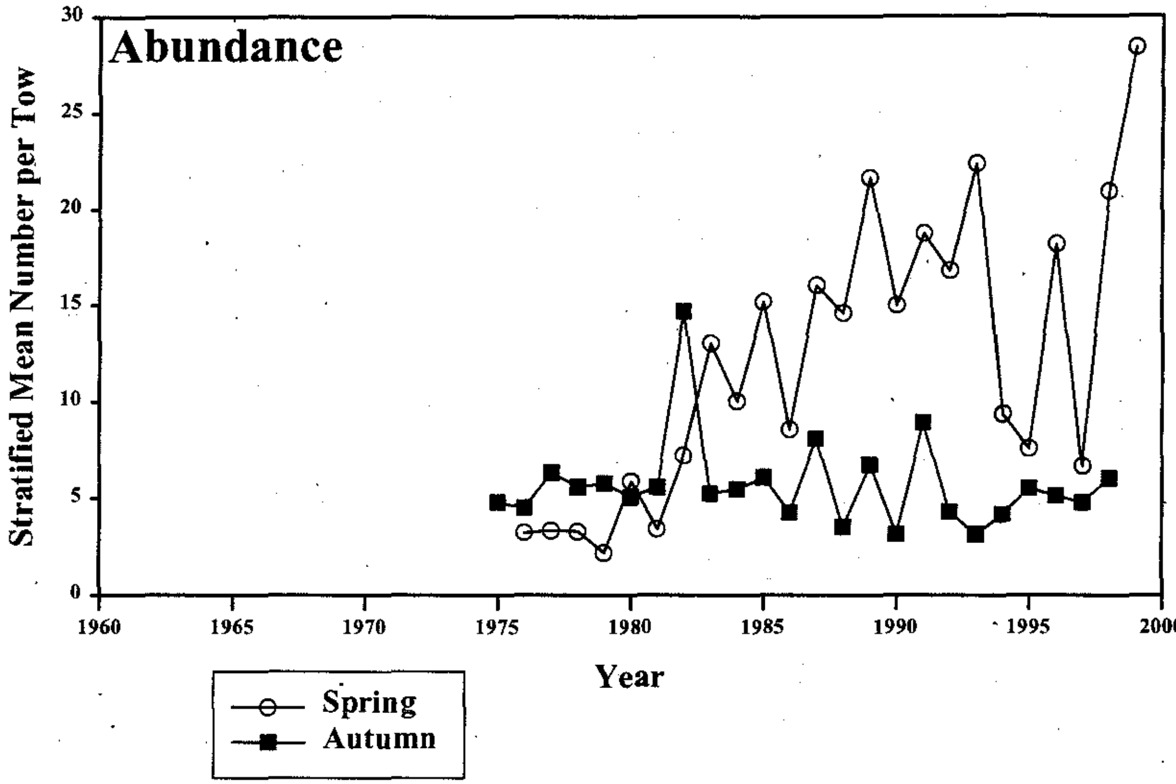


Figure B27. Distribution of little skate in the NEFSC winter bottom trawl survey from 1996-1999.

Little Skate
GOM-MA All Strata



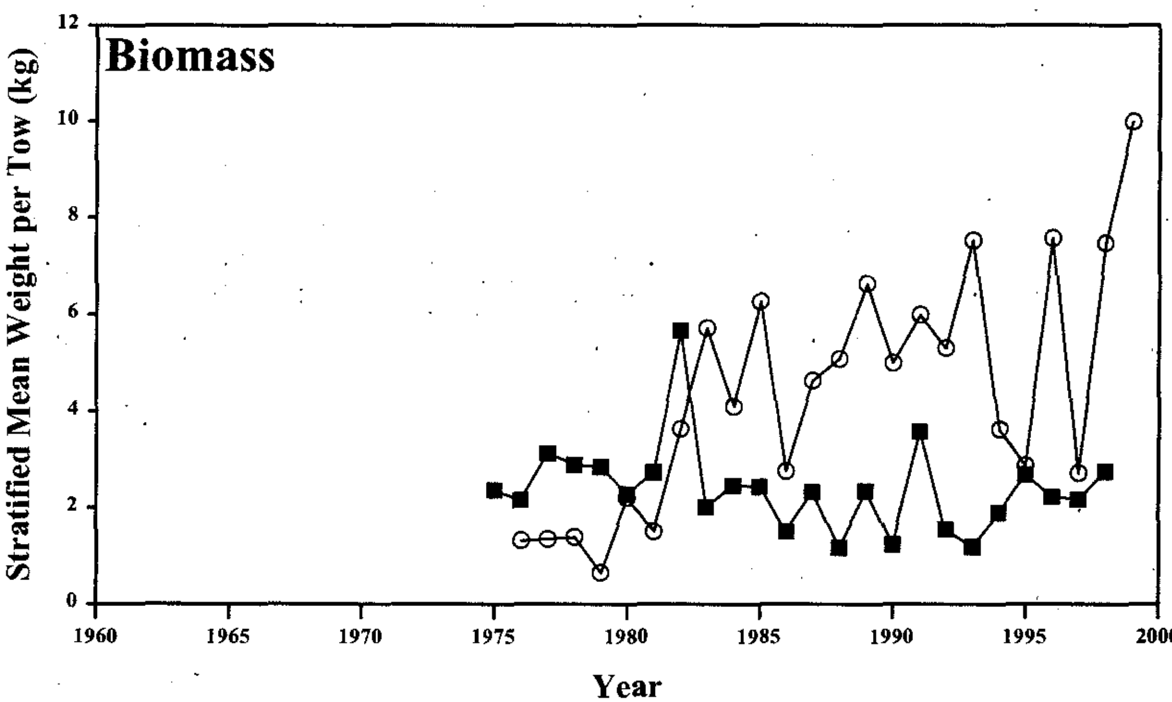


Figure B28. Abundance and biomass of little skate from the NESFC spring (circles) and autumn (squares) bottom trawl surveys from 1975-1999 in the Gulf of Maine to Mid-Atlantic offshore and inshore regions.

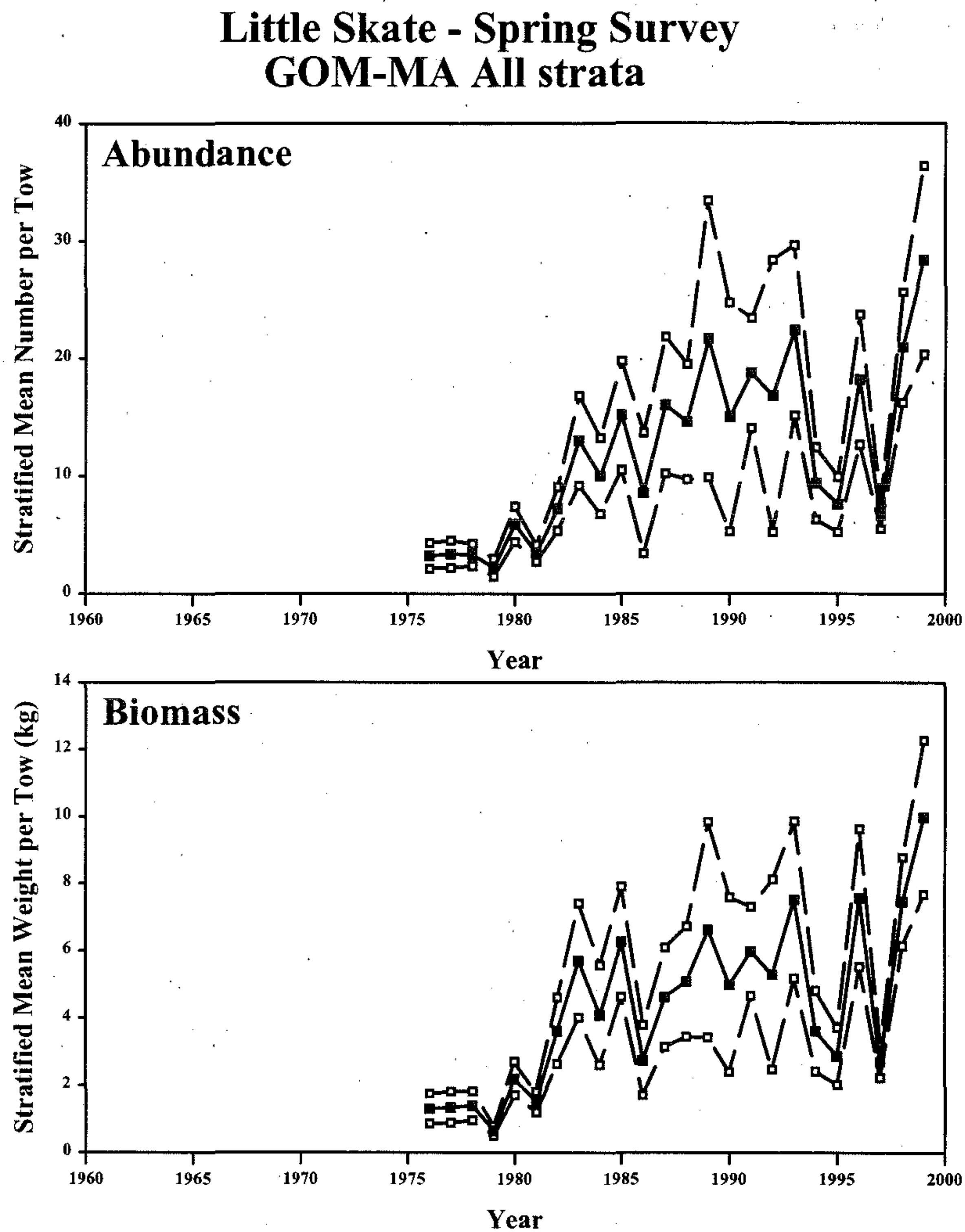


Figure B29. Abundance and biomass of little skate from the NESFC spring bottom trawl survey in the Gulf of Maine to Mid-Atlantic region, all strata. Mean index in solid squares, 95% confidence interval in open squares.

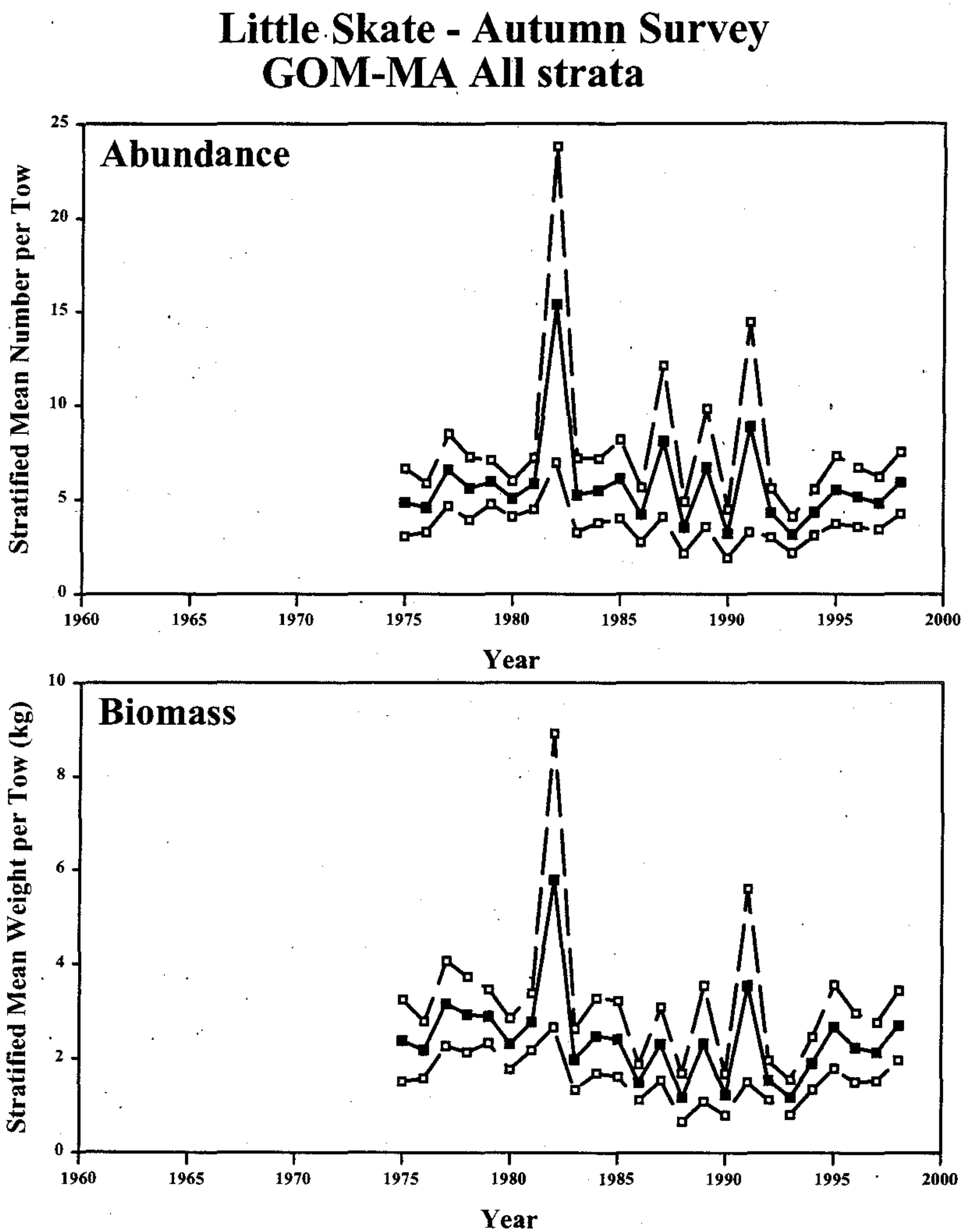
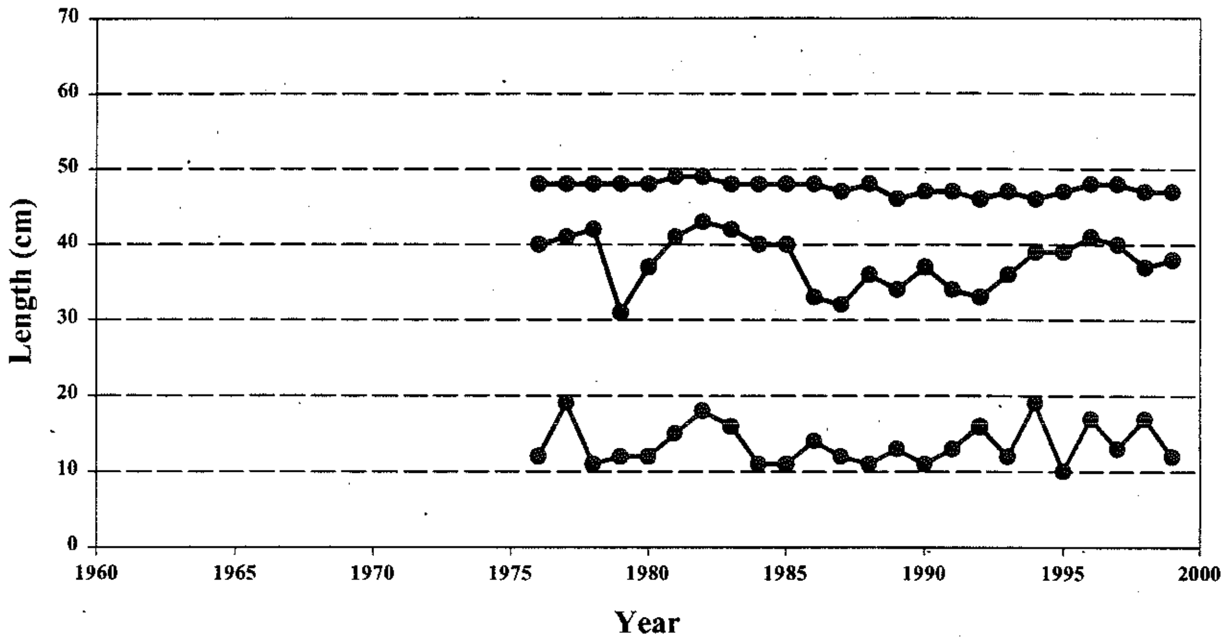


Figure B30. Abundance and biomass of little skate from the NESFC autumn bottom trawl survey in the Gulf of Maine to Mid-Atlantic region all strata. Mean index in solid squares, 95% confidence interval in open squares.

Little Skate: GOM-MA All strata
Percentiles of Length Composition

Spring Survey



Autumn Survey

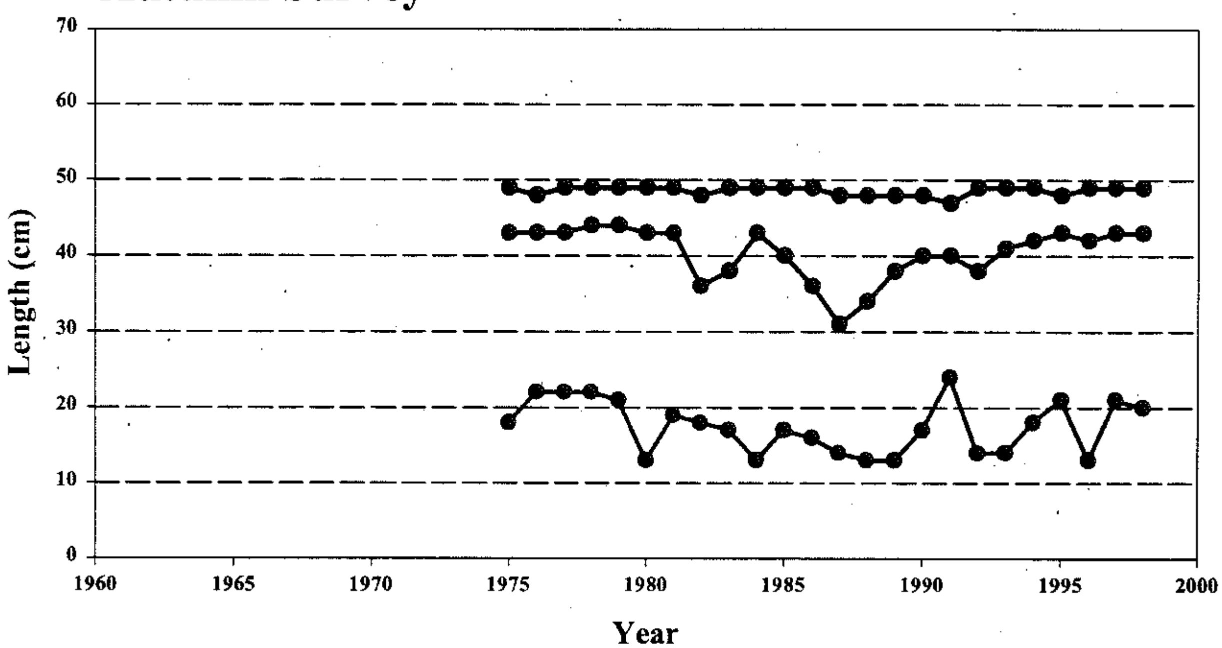


Figure B31. Percentiles of length composition (5, 50, 95) of little skate from the NESFC spring and autumn bottom trawl surveys from 1975-1999 in the Gulf of Maine to Mid-Atlantic offshore and inshore regions.

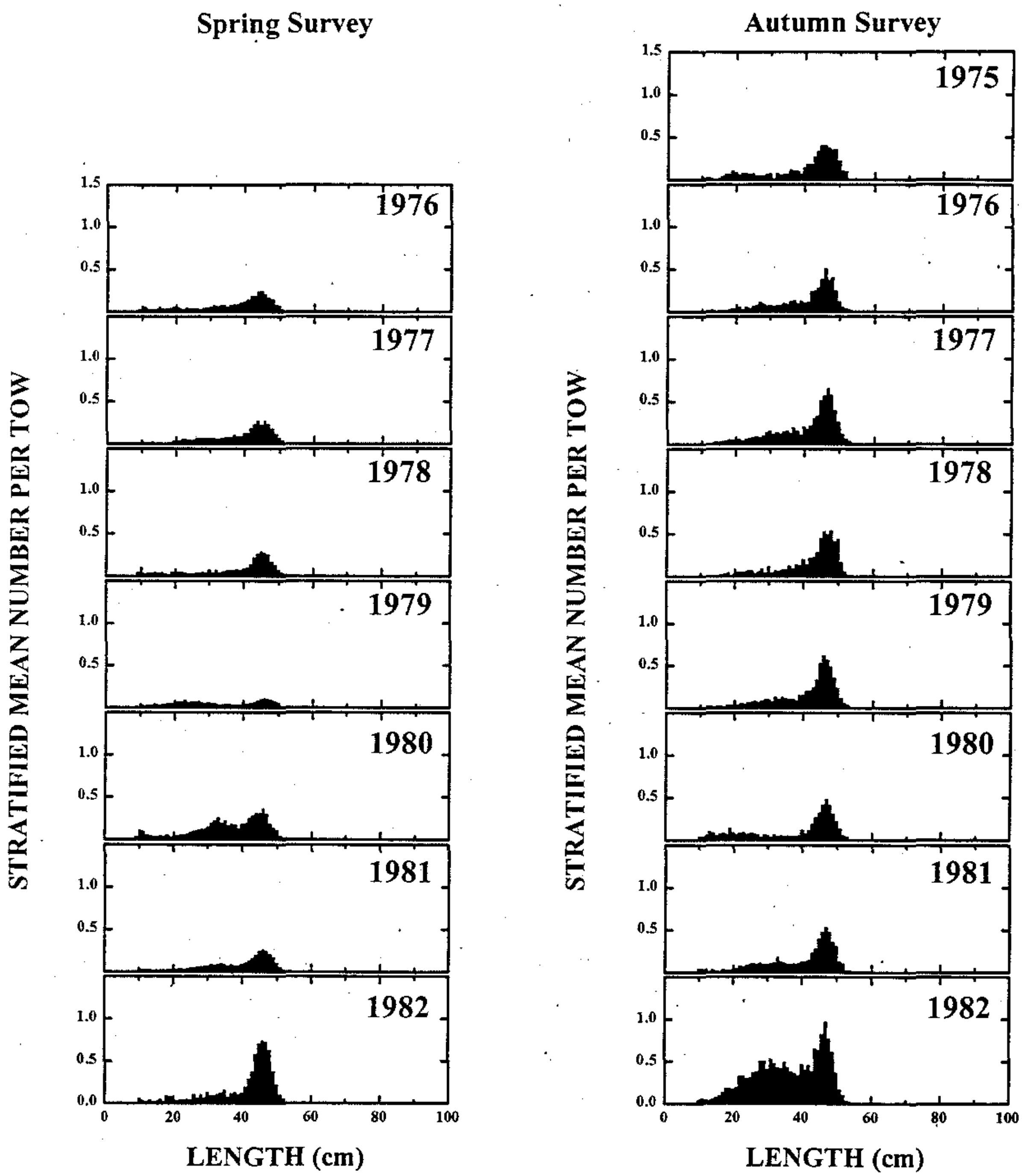


Figure B32. Little skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Mid-Atlantic offshore and inshore regions, 1975-1982.

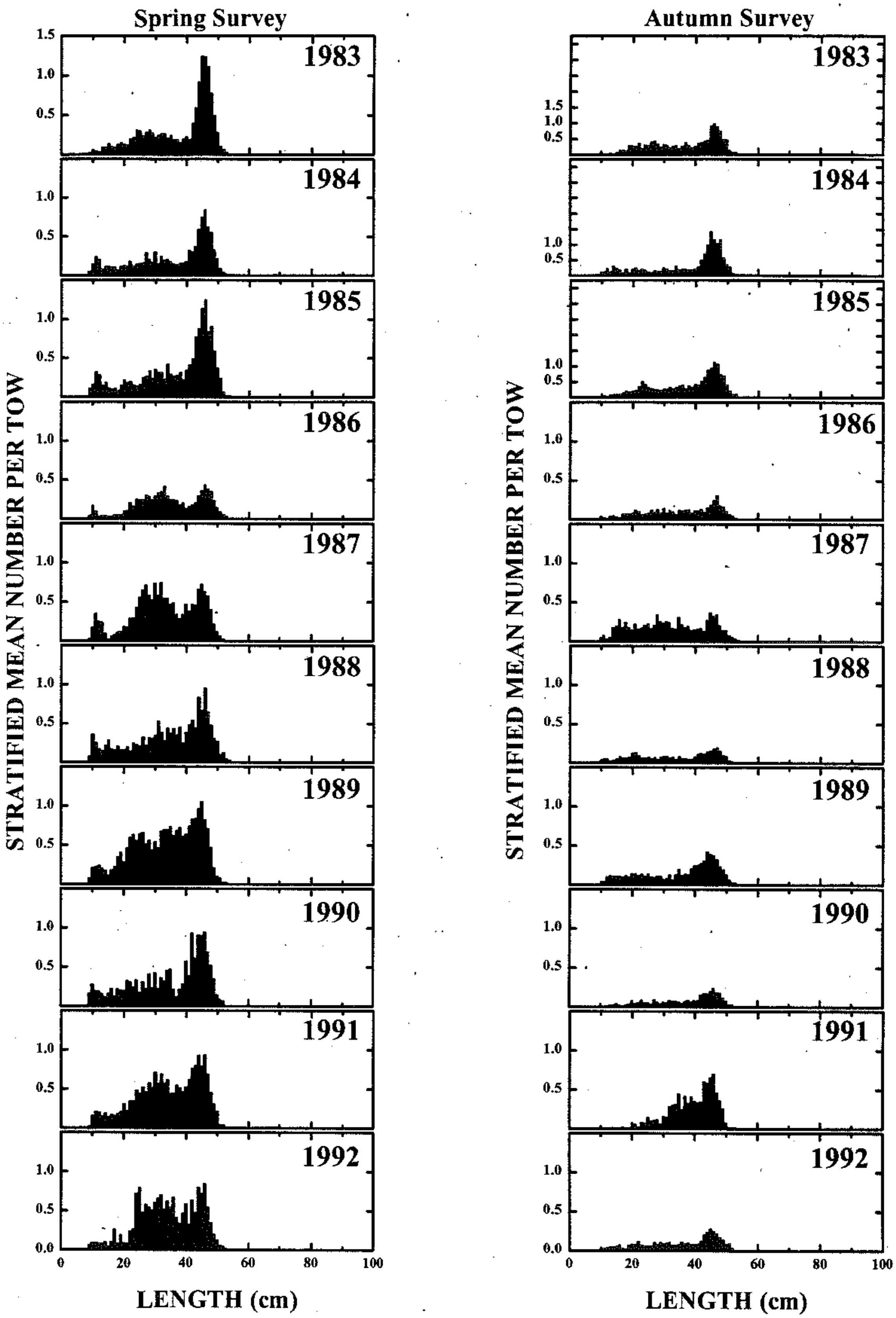


Figure B33. Little skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Mid-Atlantic offshore and inshore regions, 1983-1992.

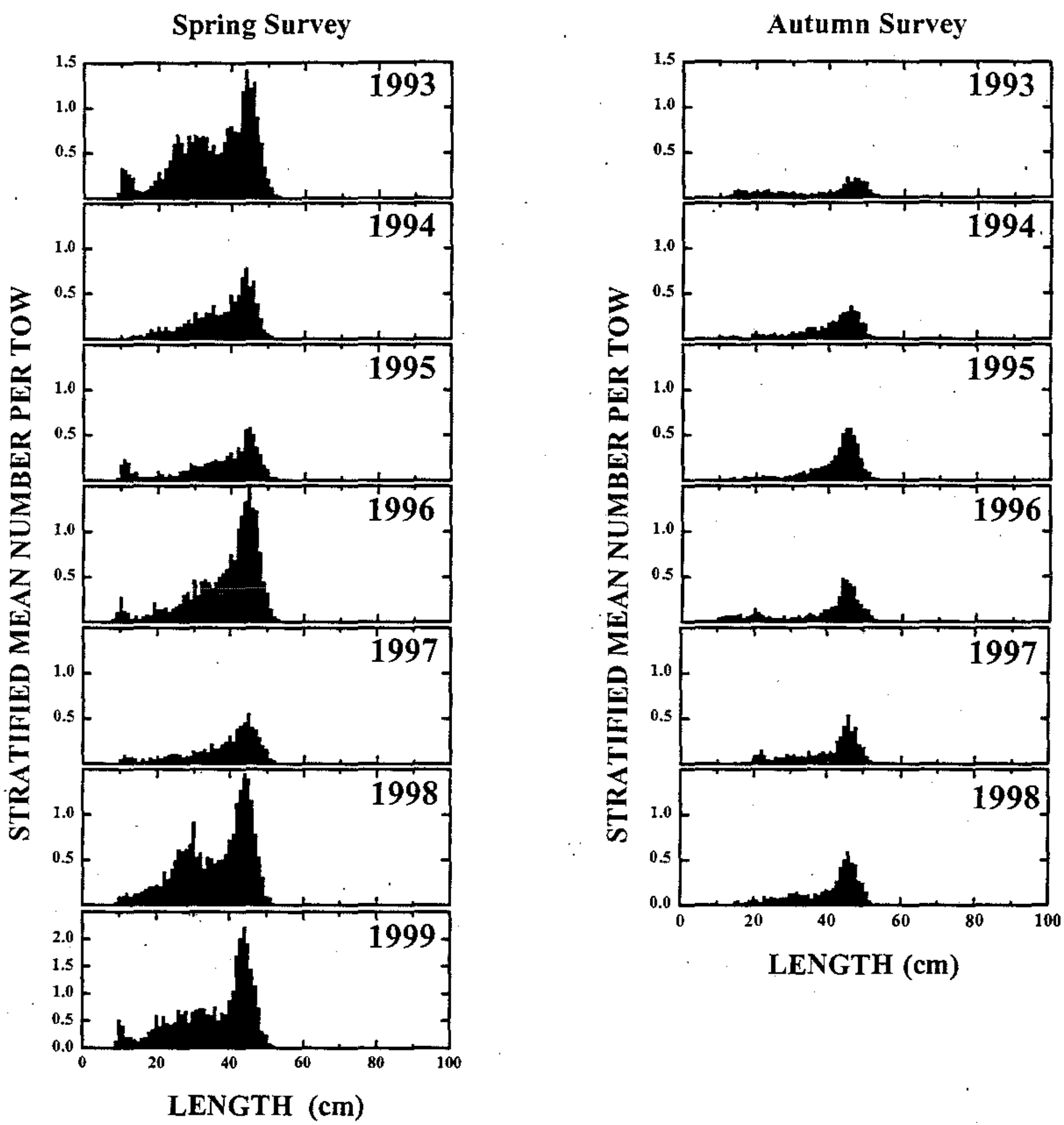


Figure B34. Little skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Mid-Atlantic offshore and inshore regions, 1993-1999.

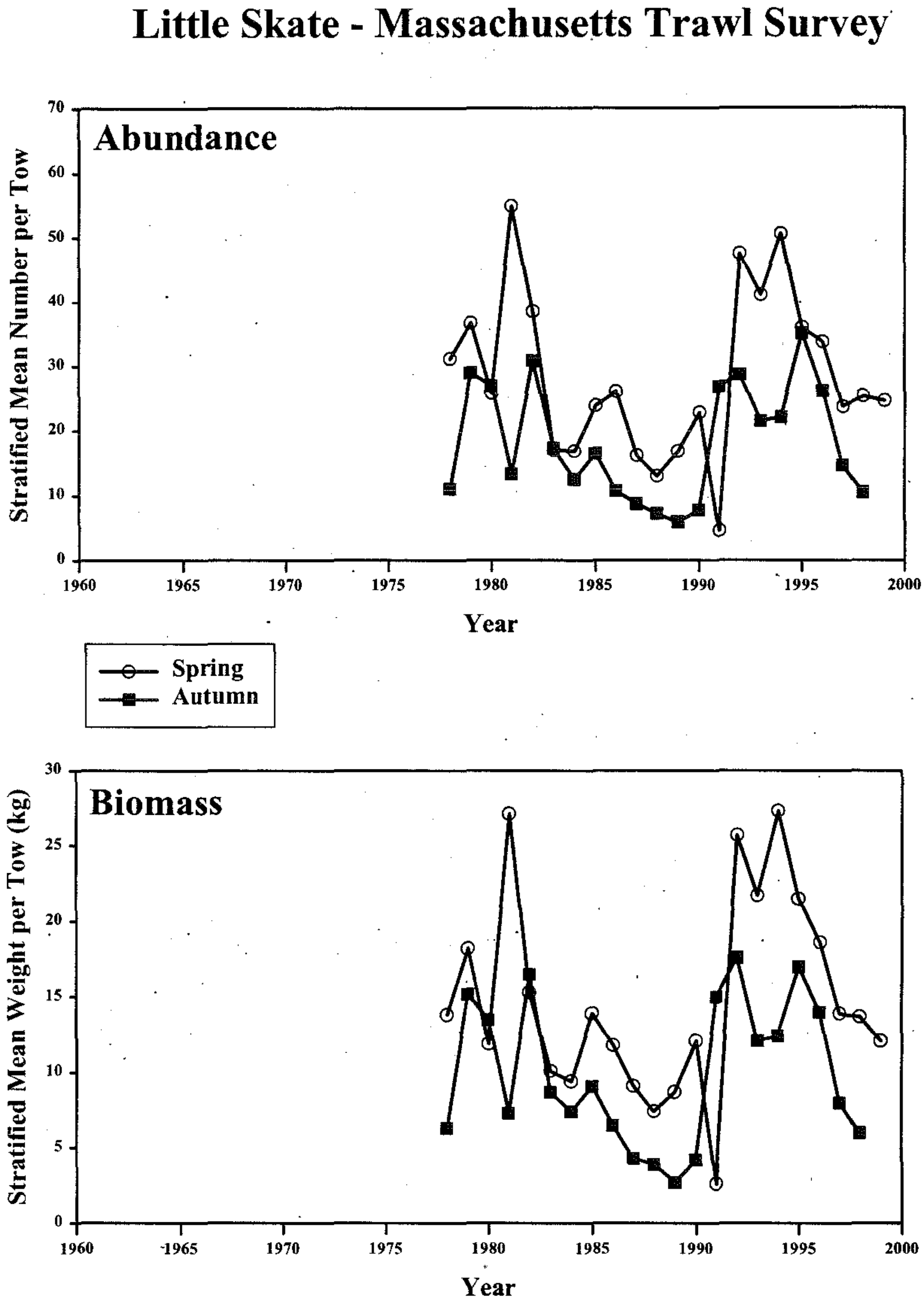


Figure B35. Abundance and biomass of little skate from the Massachusetts spring and autumn finfish bottom trawl survey in state waters.

Little Skate - Massachusetts Trawl Survey
Stratified Mean Length

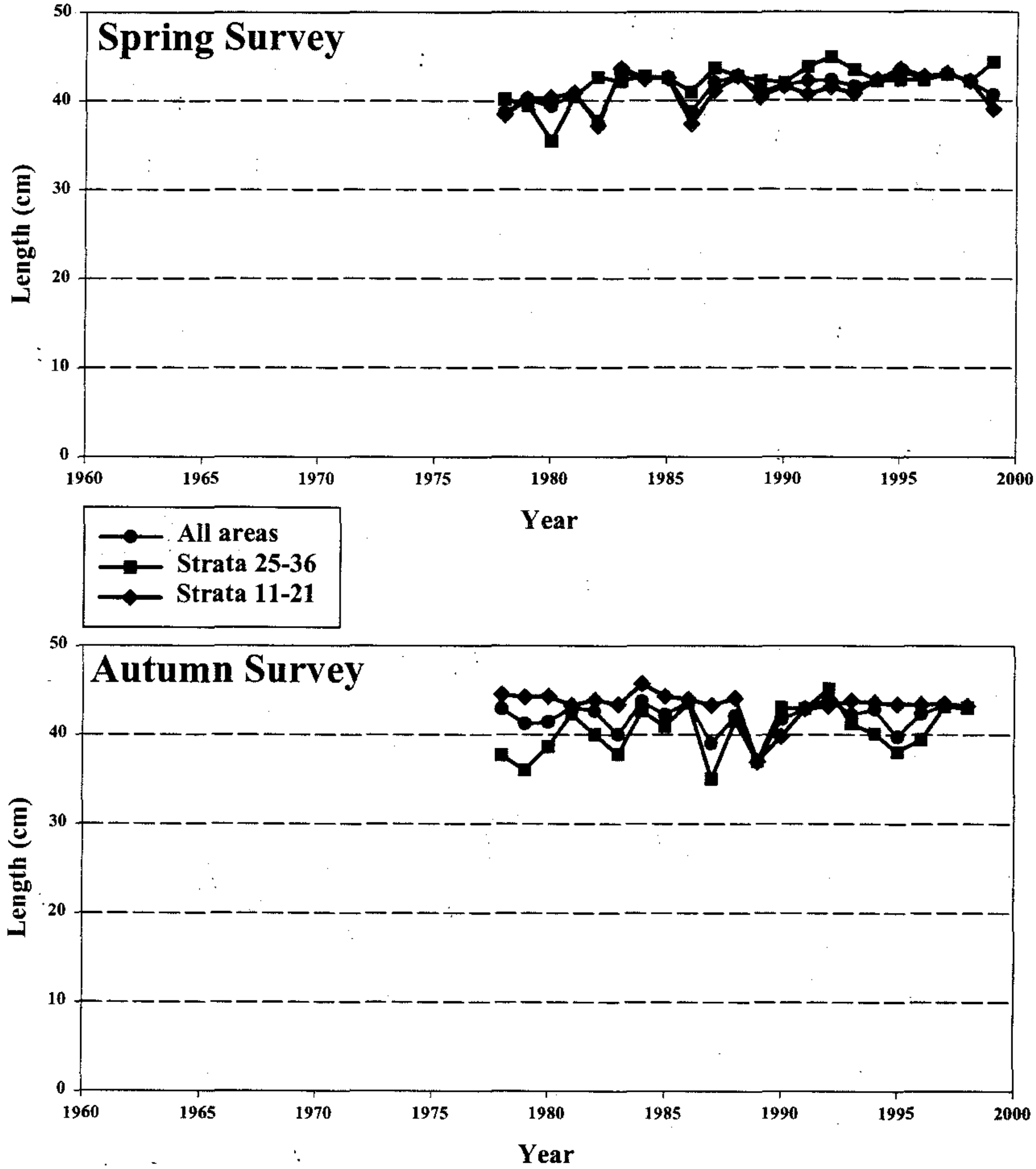


Figure B36. Stratified mean total length (cm) of little skate from the Massachusetts spring and autumn bottom trawl surveys from 1978-1999 in three regions.

Little Skate - CTDEP Finfish Survey

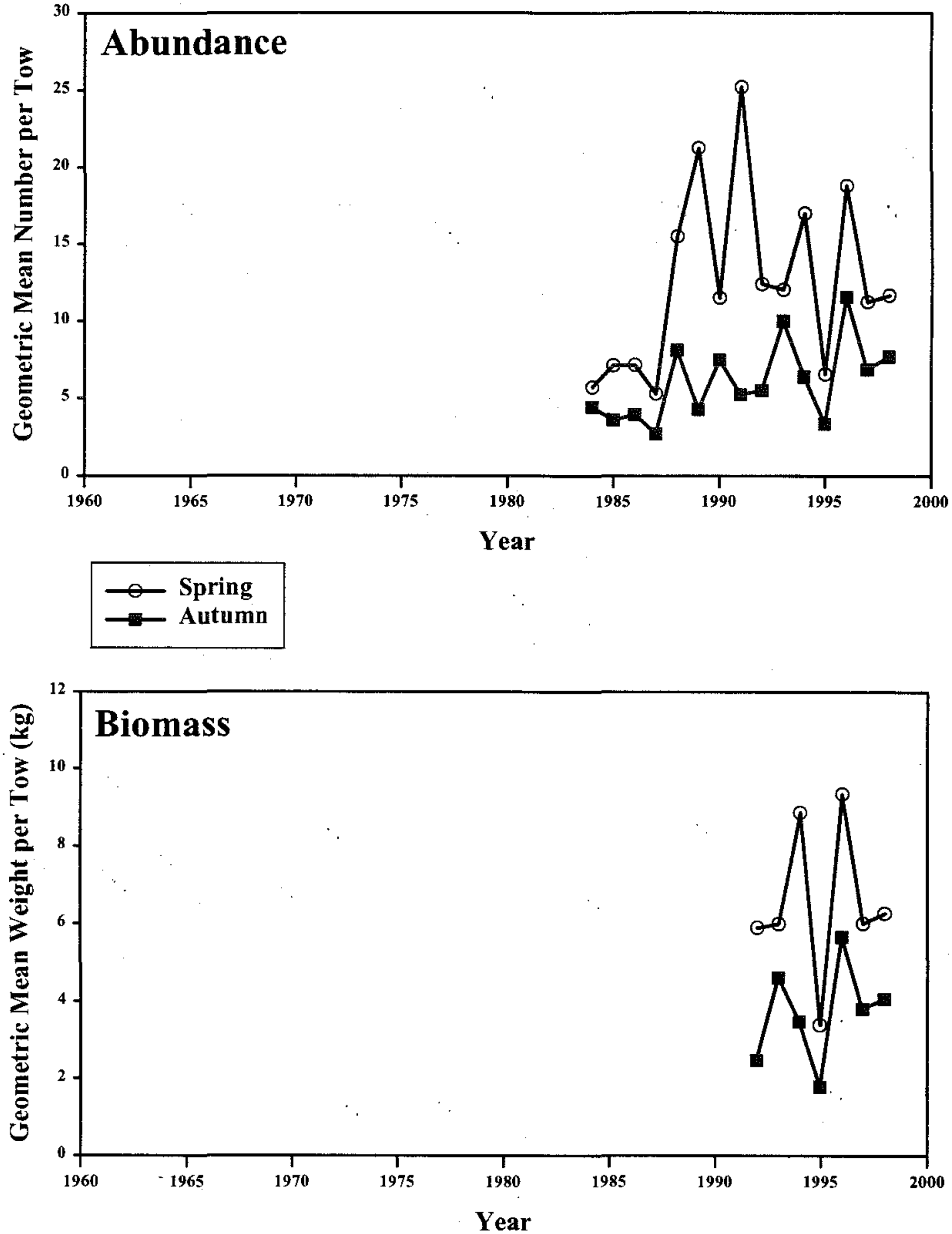


Figure B37. Abundance and biomass of little skate from the CTDEP spring and autumn finfish bottom trawl survey in Connecticut state waters.

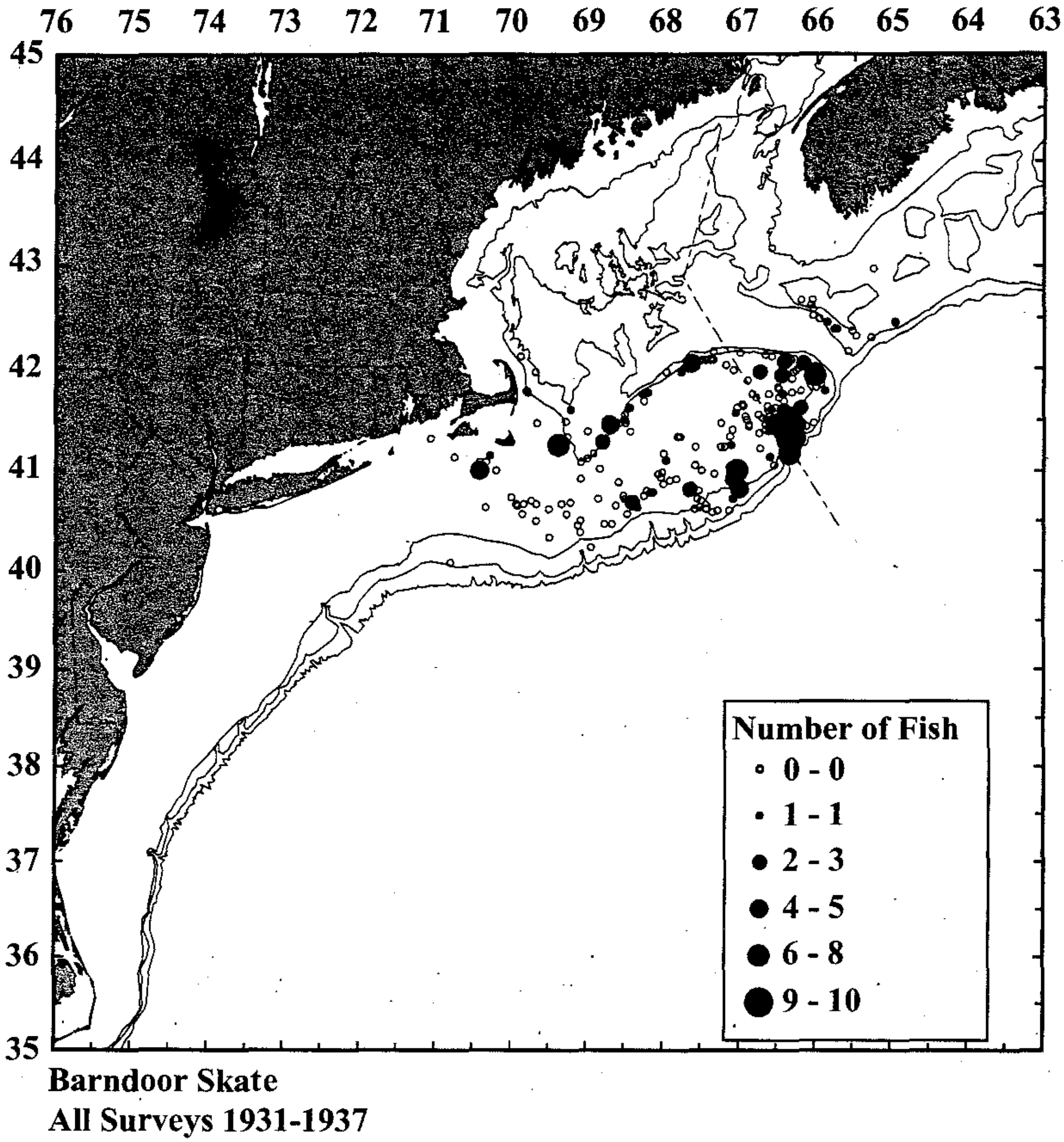
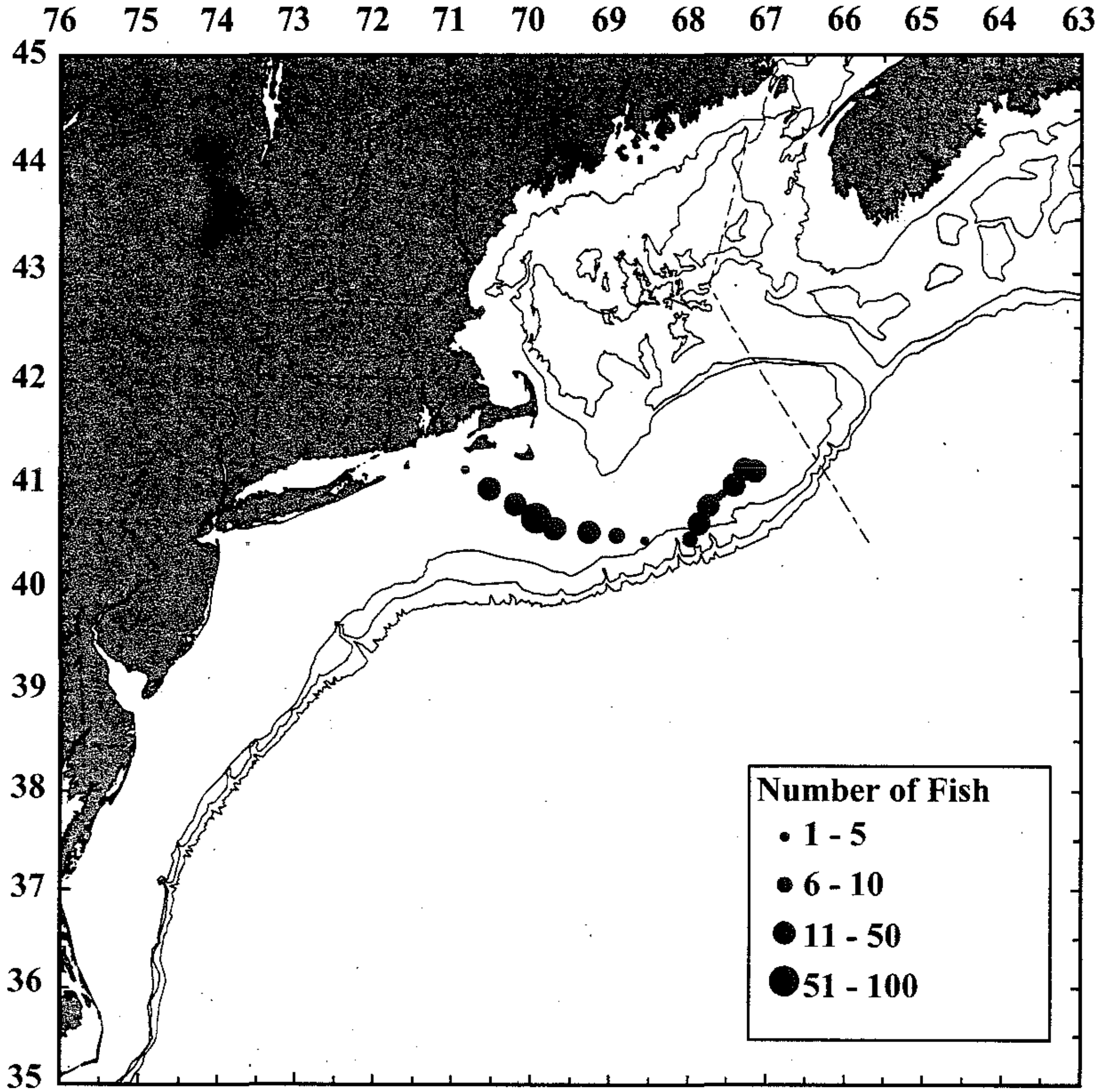
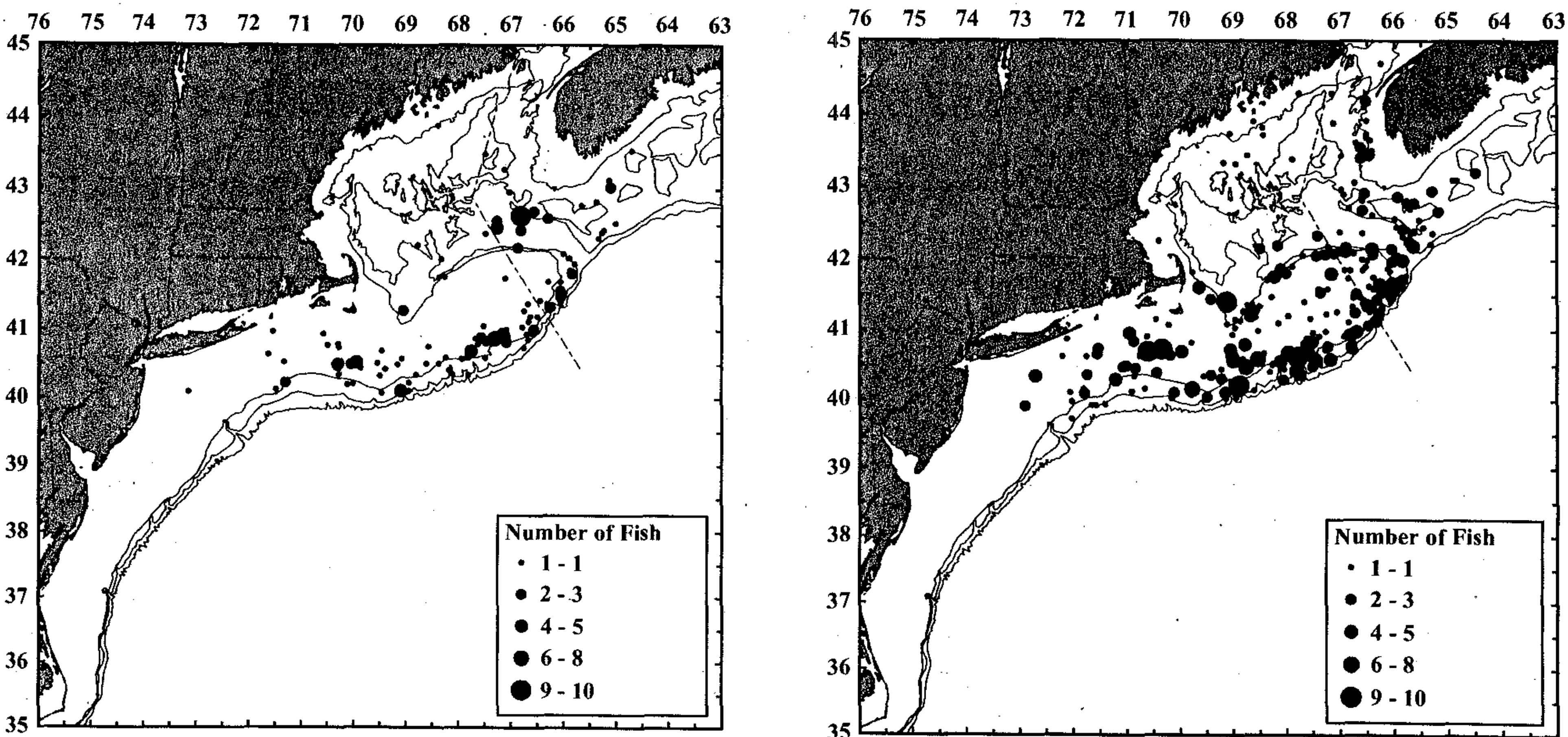


Figure B38. Distribution of barndoor skate in surveys from 1931-1937.



Barndoor Skate
Eugene H Survey June1951

Figure B39. Distribution of barndoor skate in a survey conducted on the Eugene H during June 1951.



Barndoor Skate
NEFSC Spring Surveys 1968-1999

Barndoor Skate
NEFSC Autumn Surveys 1963-1998

Figure B40. Distribution of barndoor skate in the NEFSC spring and autumn surveys from 1963-1999.

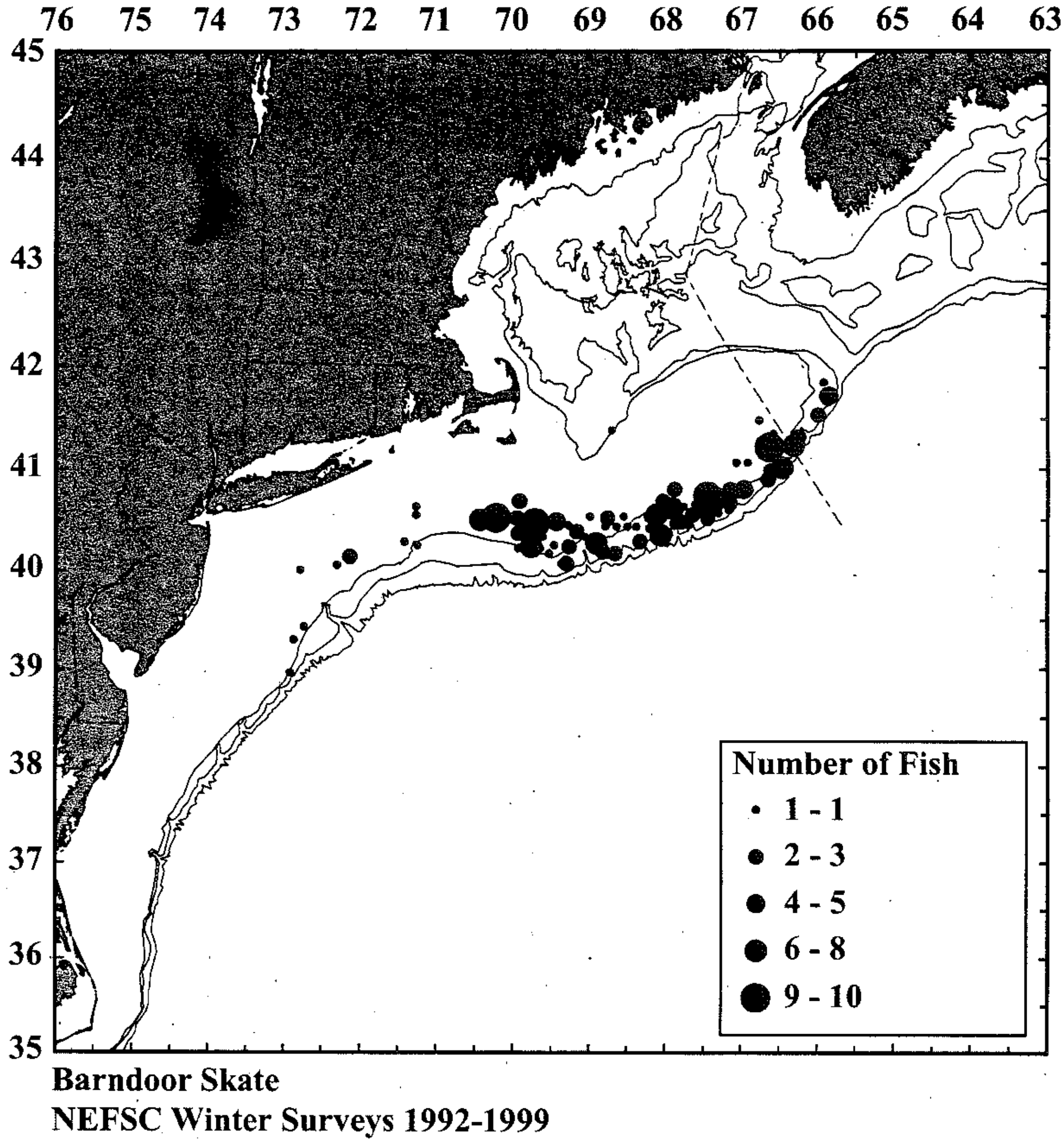


Figure B41. Distribution of barndoor skate in the NEFSC winter surveys from 1992-1999.

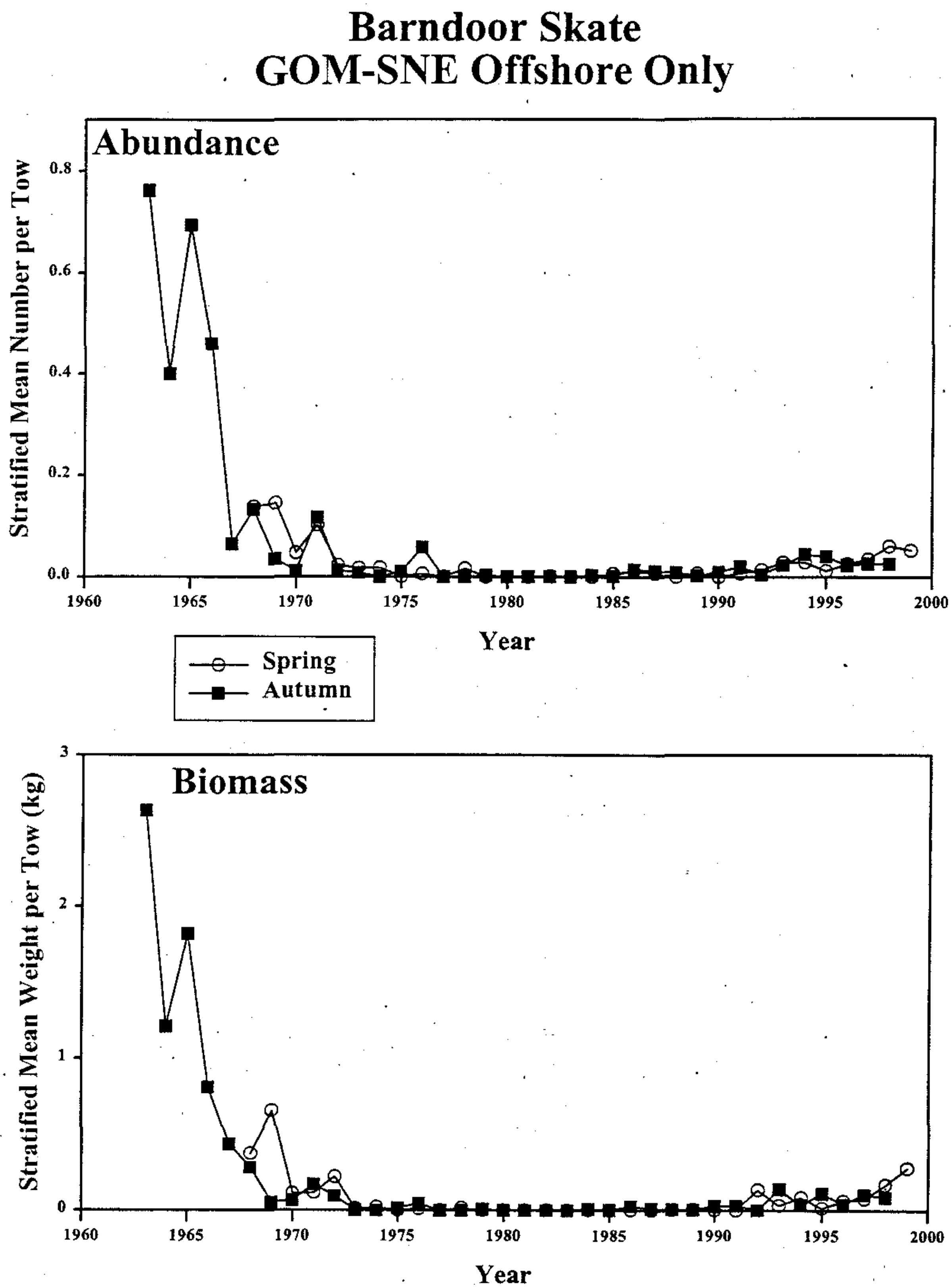


Figure B42. Abundance and biomass of barndoor skate from the NEFSC spring (circles) and autumn (squares) bottom trawl surveys from 1963-1999 in the Gulf of Maine-Southern New England offshore region.

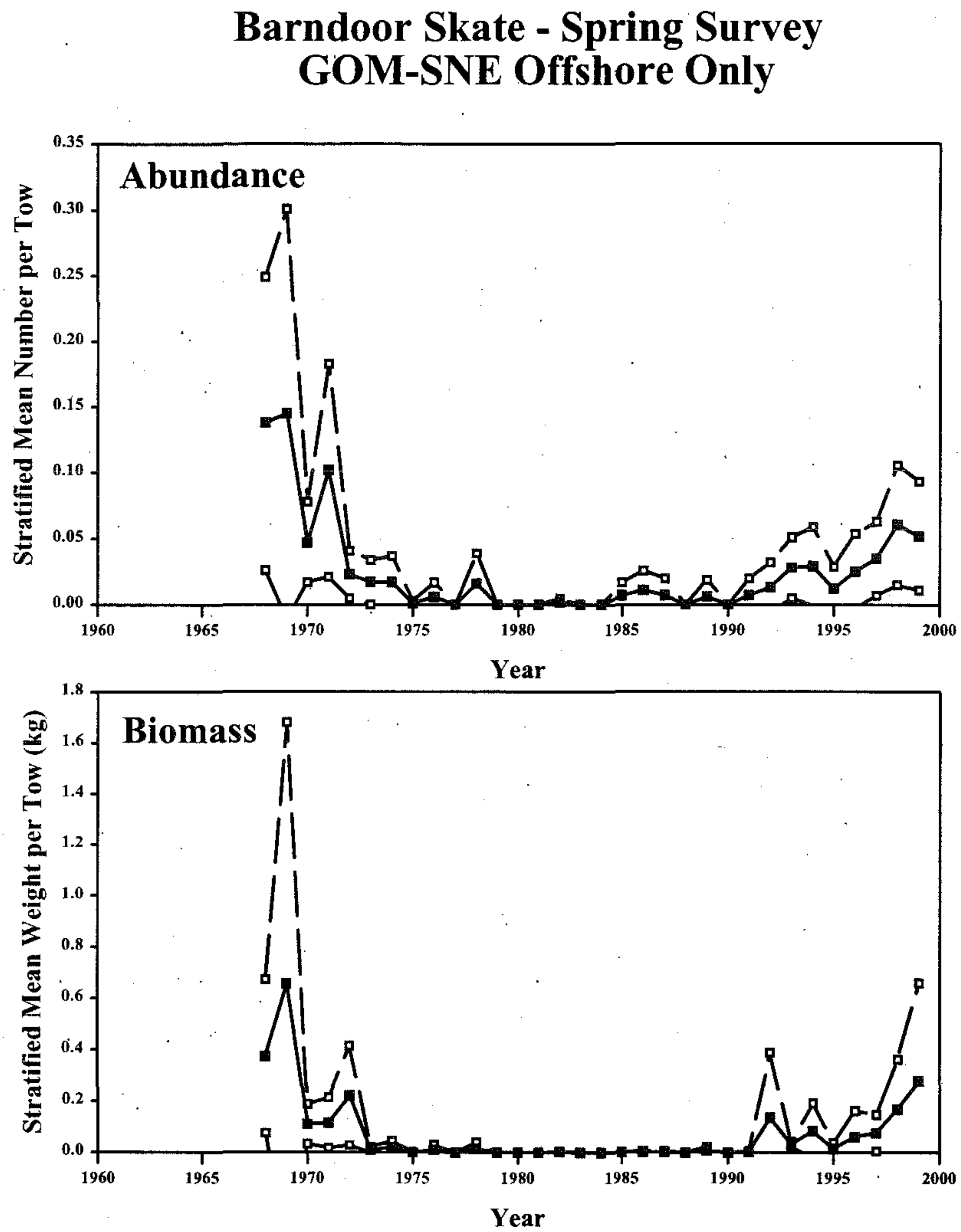


Figure B43. Abundance and biomass of barndoor skate from the NEFSC spring bottom trawl survey in the Gulf of Maine to Southern New England offshore region, offshore strata only. Mean index in solid squares, 95% confidence interval in open squares.

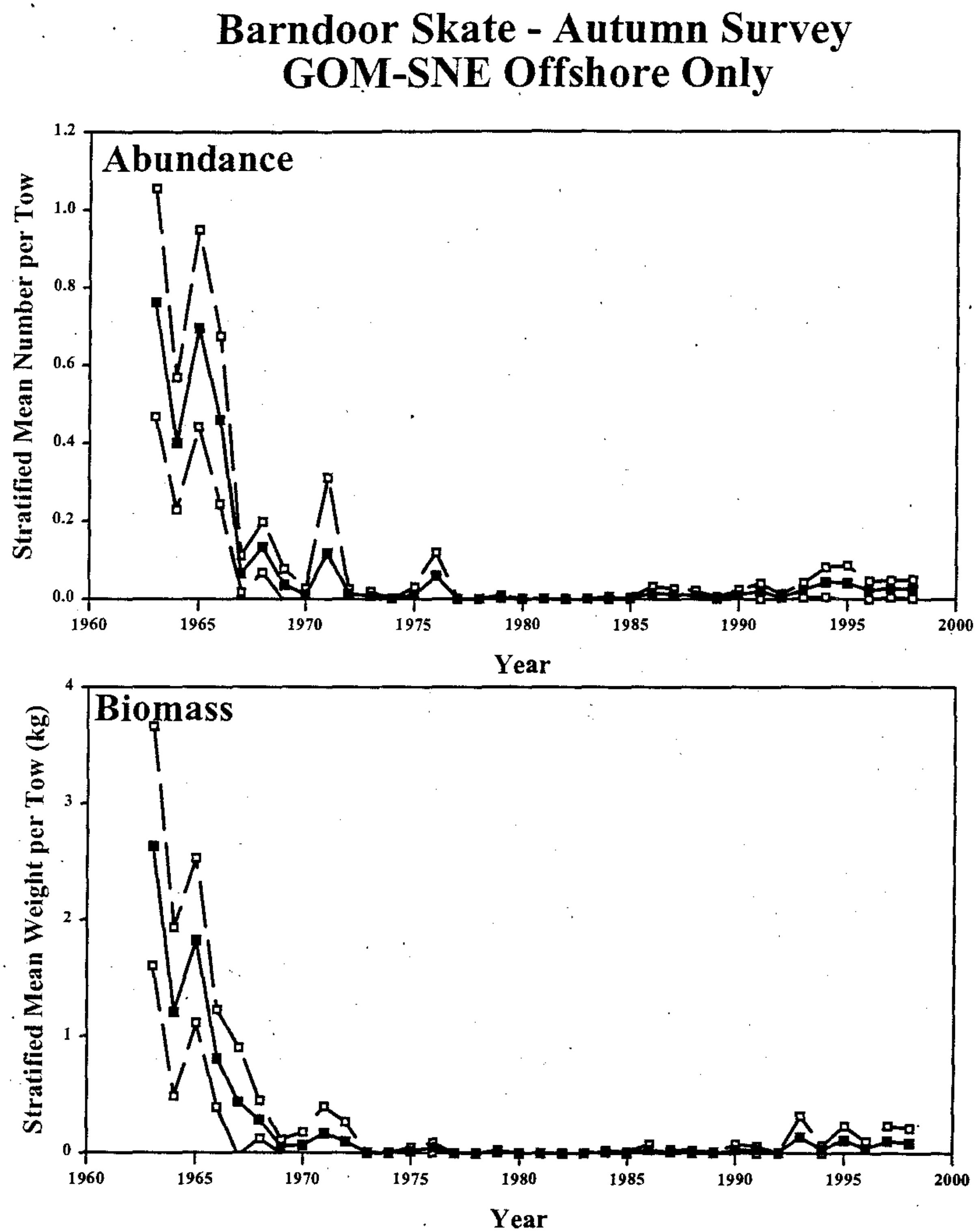
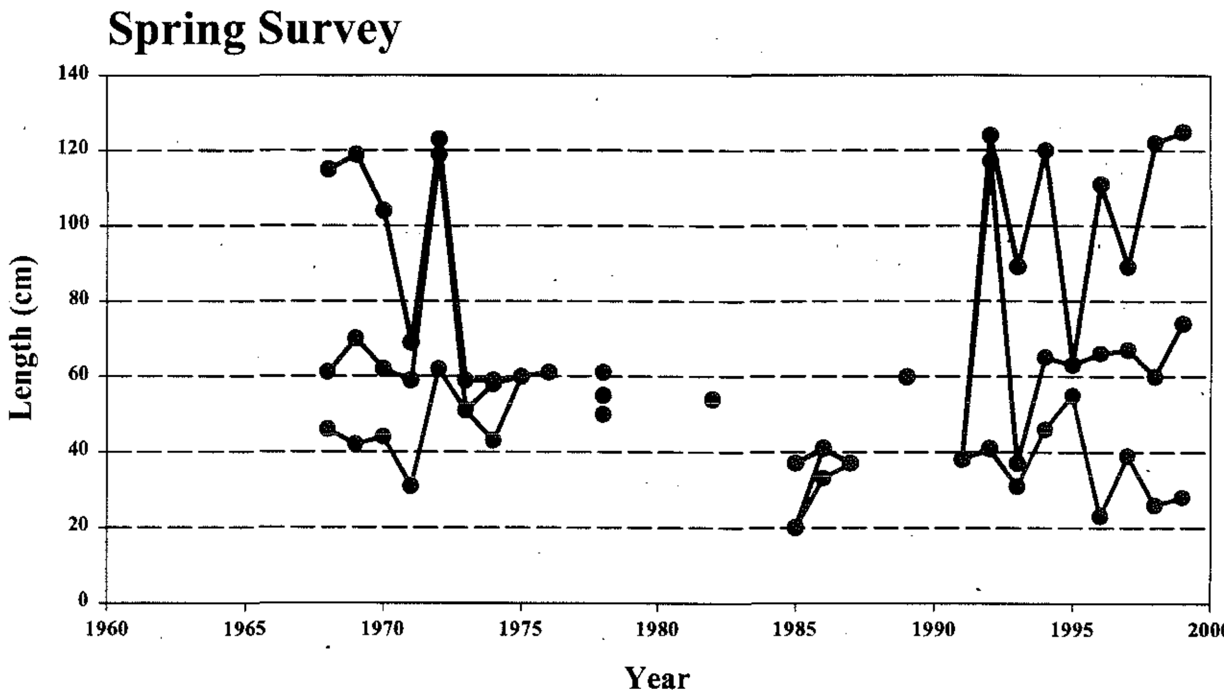


Figure B44. Abundance and biomass of barndoor skate from the NEFSC autumn bottom trawl survey in the Gulf of Maine to Southern New England region, offshore strata only. Mean index in solid squares, 95% confidence interval in open squares.

Barndoor Skate
Percentiles of Length Composition



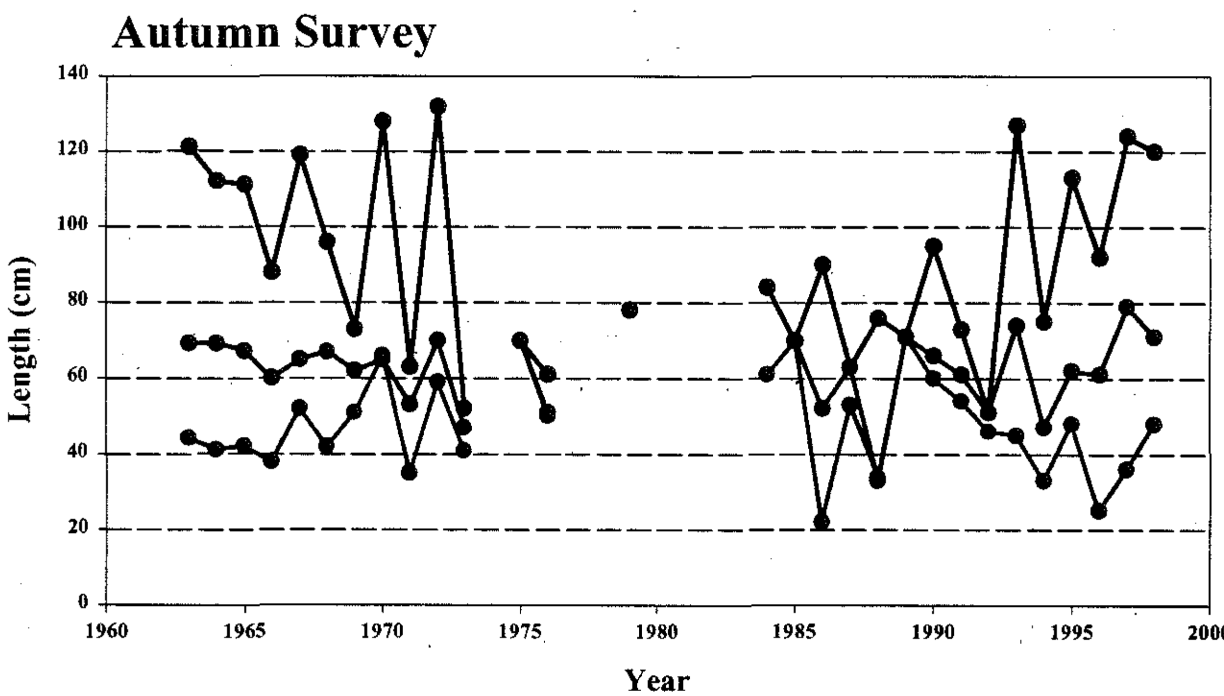


Figure B45. Percentiles of length composition (5, 50, and 95) of barndoor skate from the NESFC spring and autumn bottom trawl surveys from 1963-1999 in the Gulf of Maine to Southern New England offshore region.

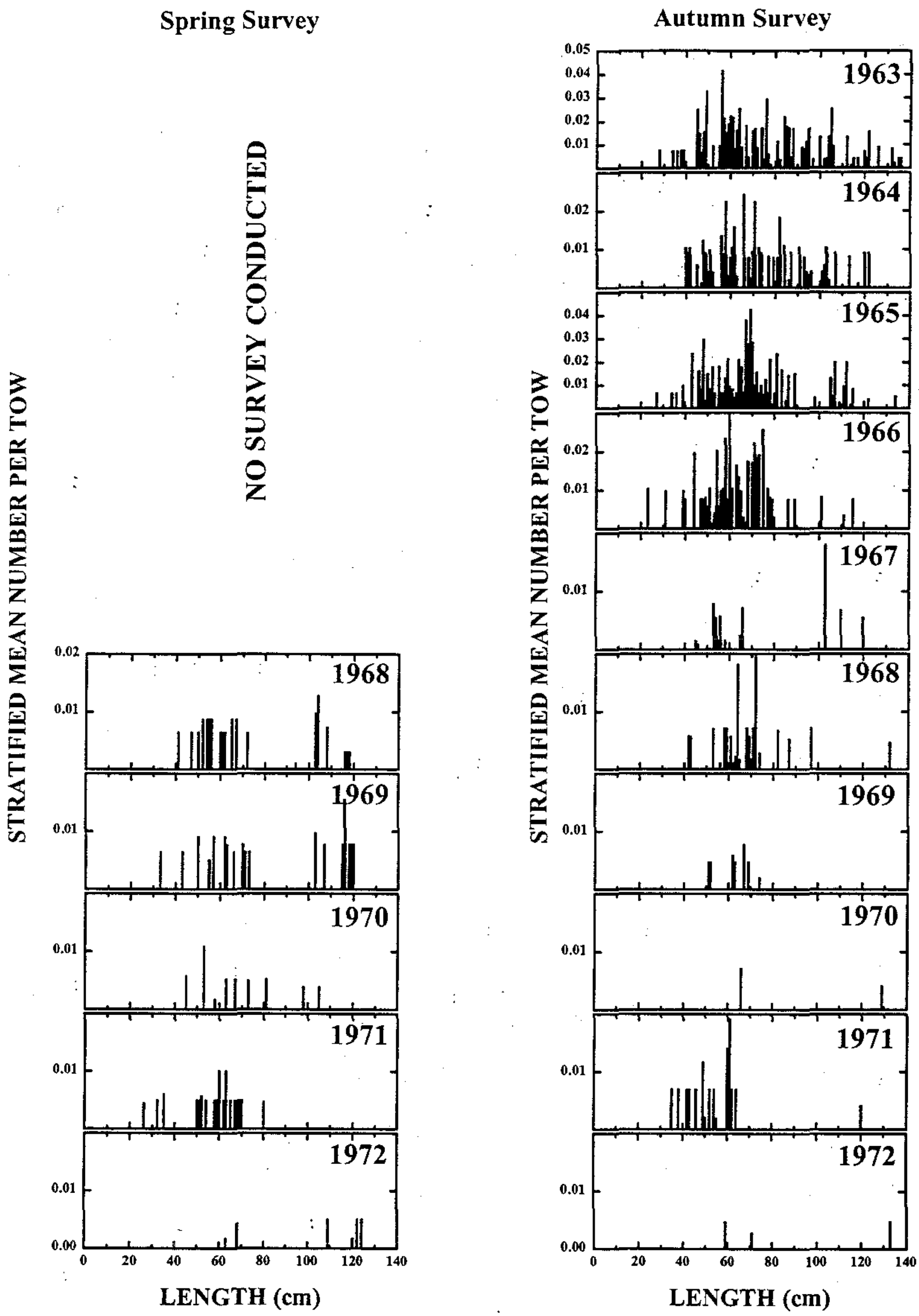


Figure B46. Barndoor skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England offshore regions, 1963-1972.

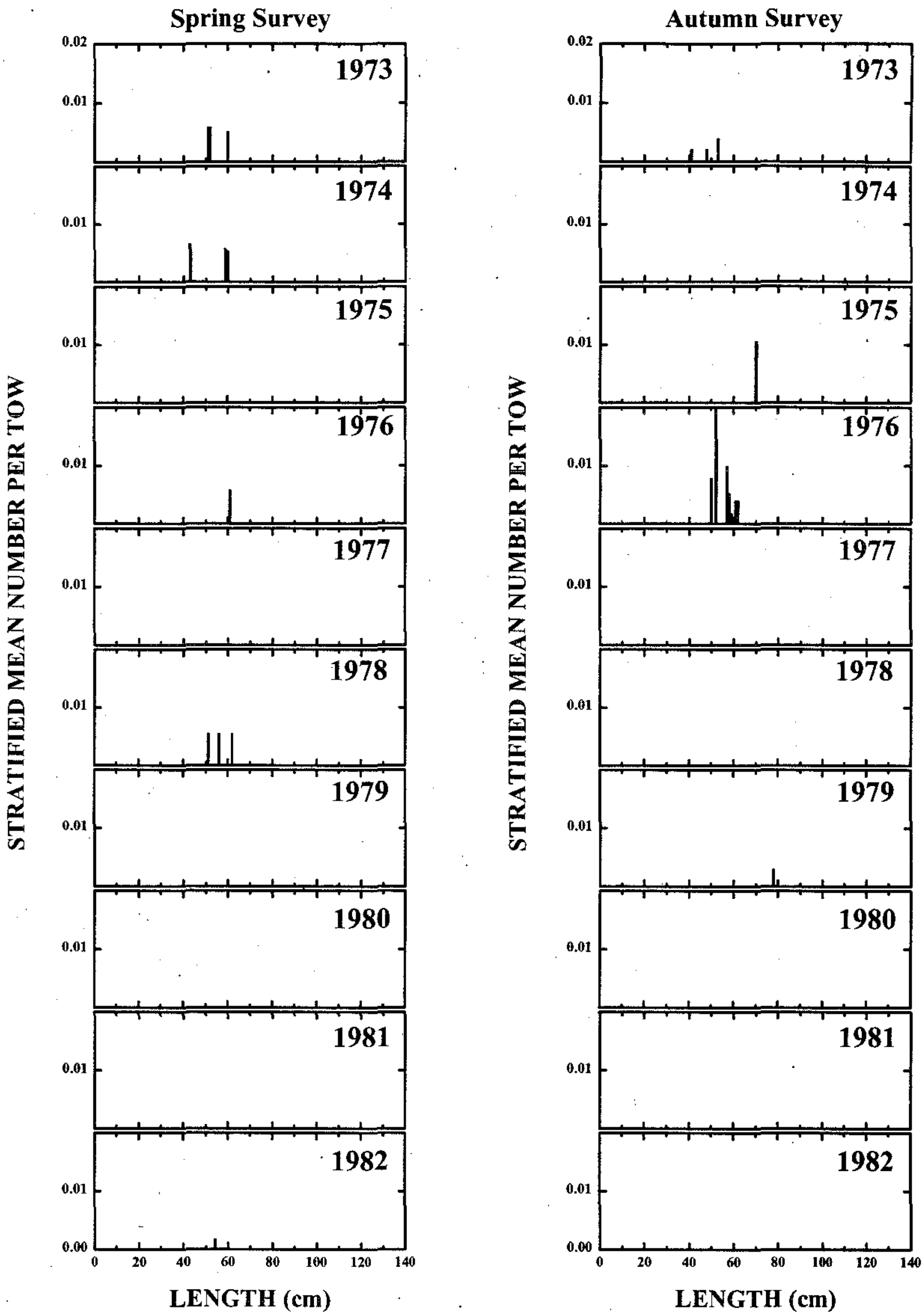


Figure B47. Barndoor skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England offshore regions, 1973-1982.

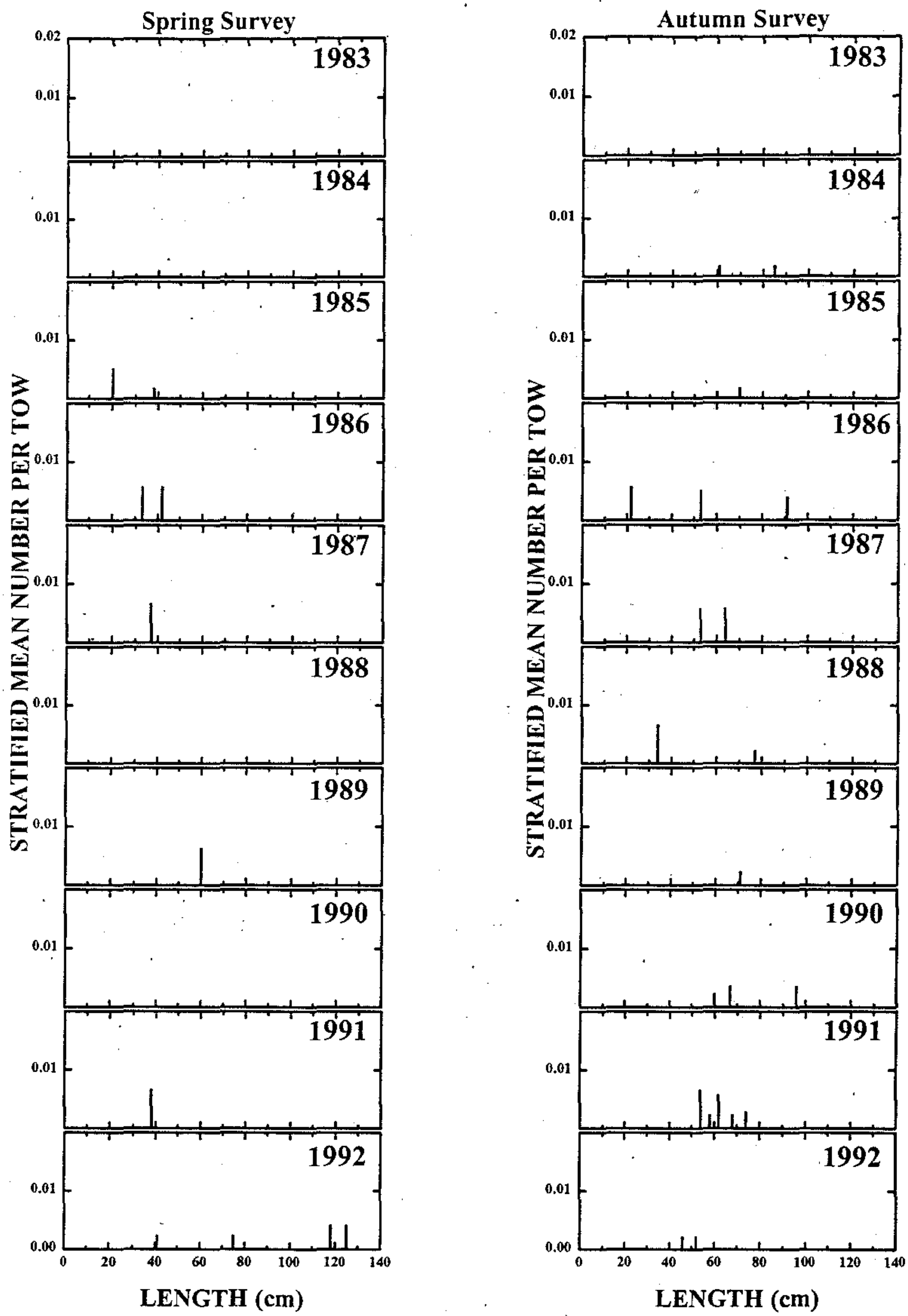


Figure B48. Barndoor skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England offshore regions, 1983-1992.

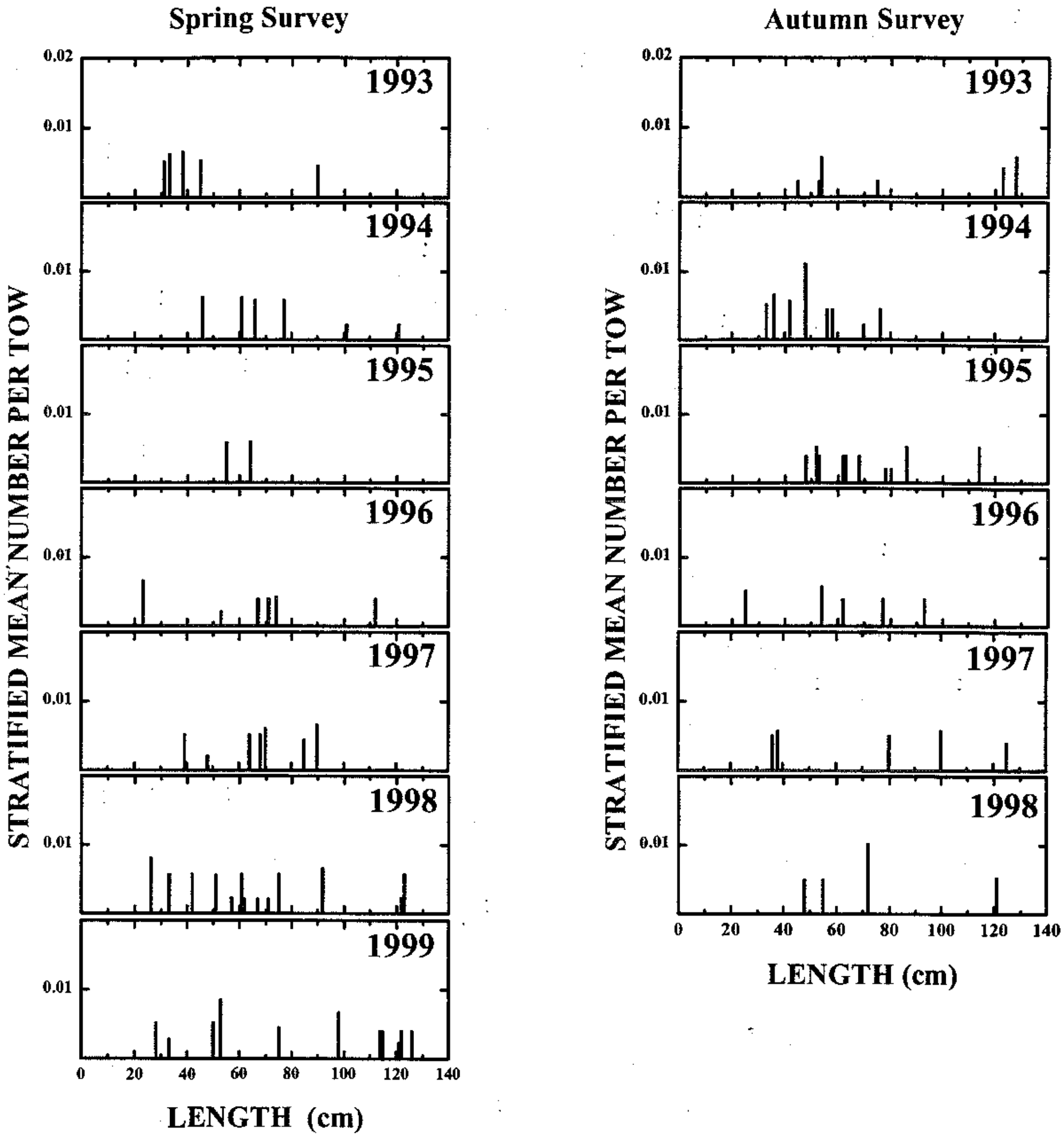


Figure B49. Barndoor skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England offshore regions, 1993-1999.

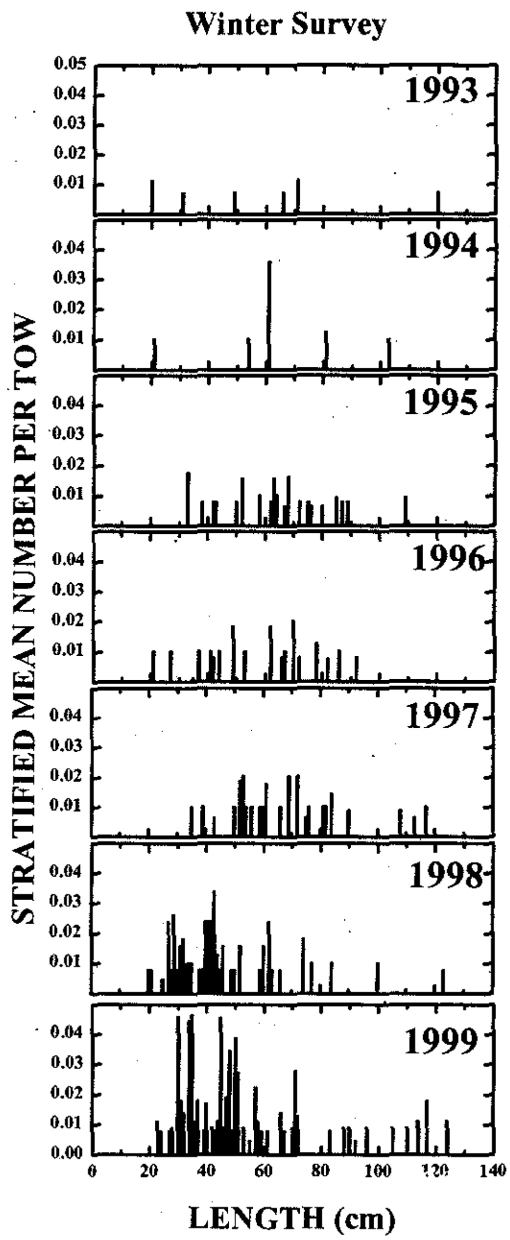


Figure B50. Barndoor skate length composition from the NEFSC winter flatfish surveys, 1993-1999.

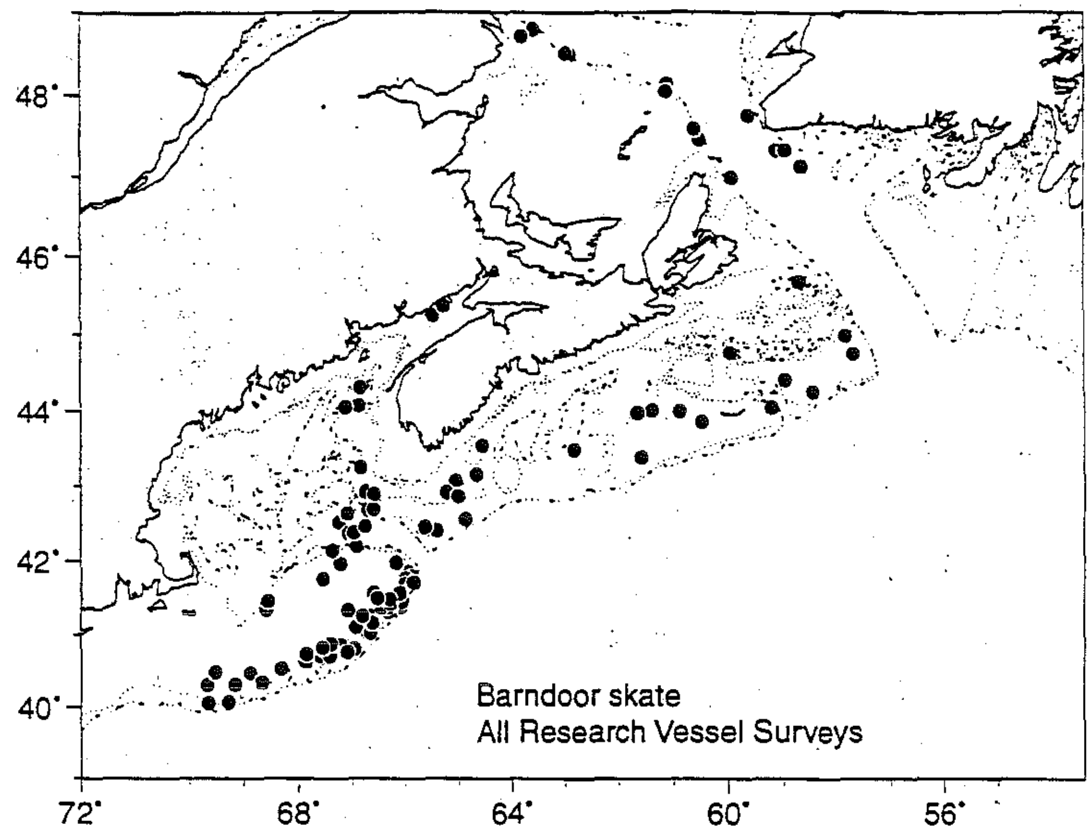


Figure B51. Occurrence of barndoor skate in Canada DFO research trawl surveys during 1970-1999.

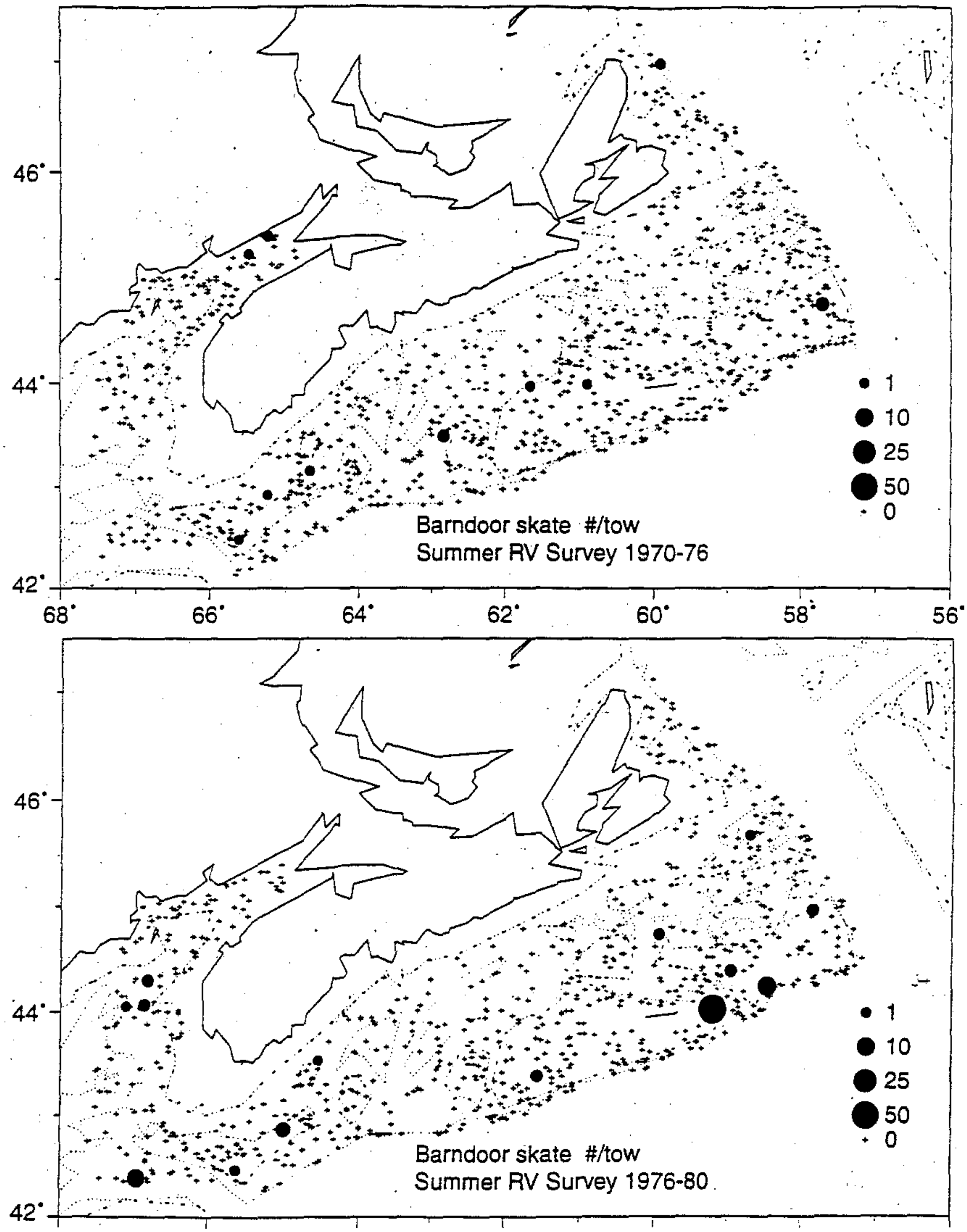


Figure B52. Distribution of barndoor skate in Canada DFO research trawl surveys on the Scotian Shelf and Browns Bank, 1970-1980.

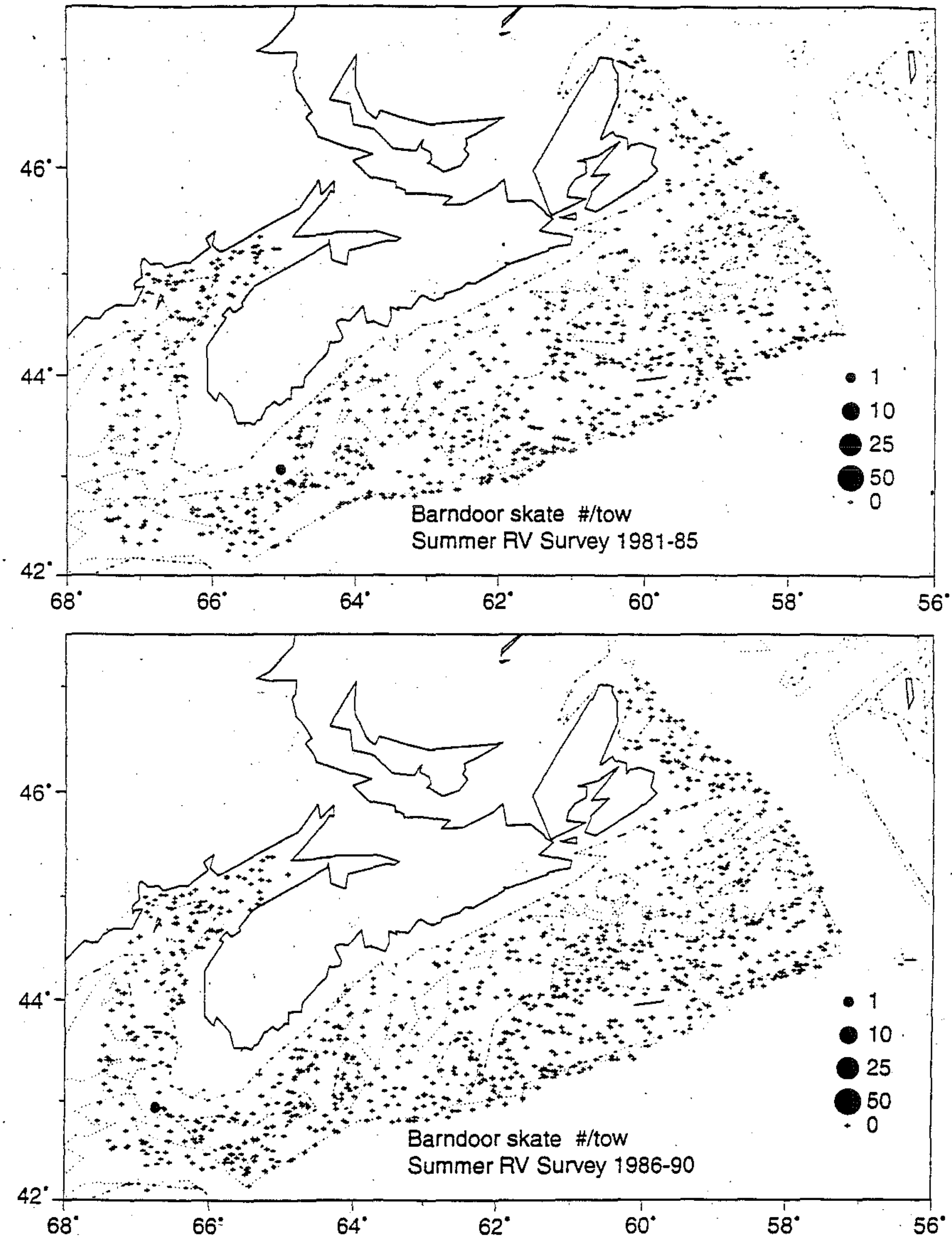
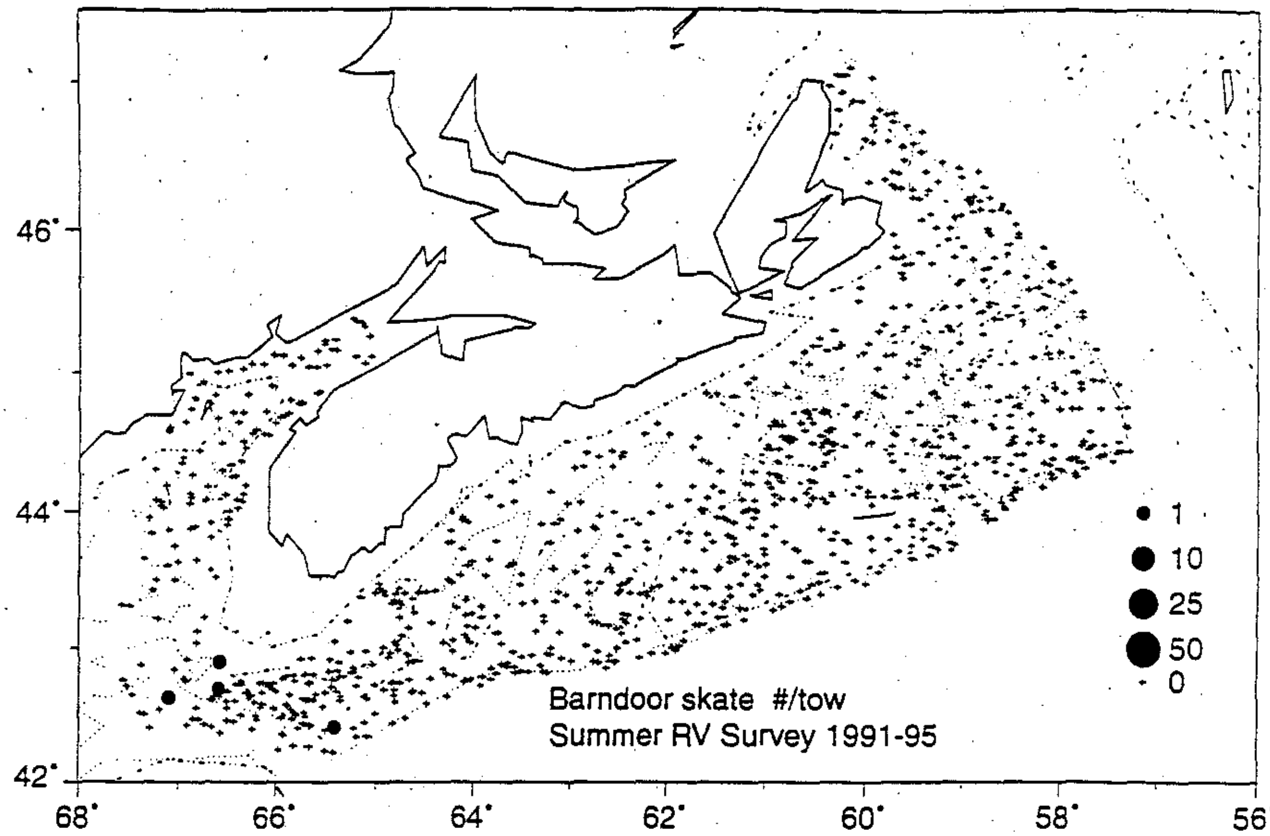


Figure B53. Distribution of barndoor skate in Canada DFO research trawl surveys on the Scotian Shelf and Browns Bank, 1981-1990.



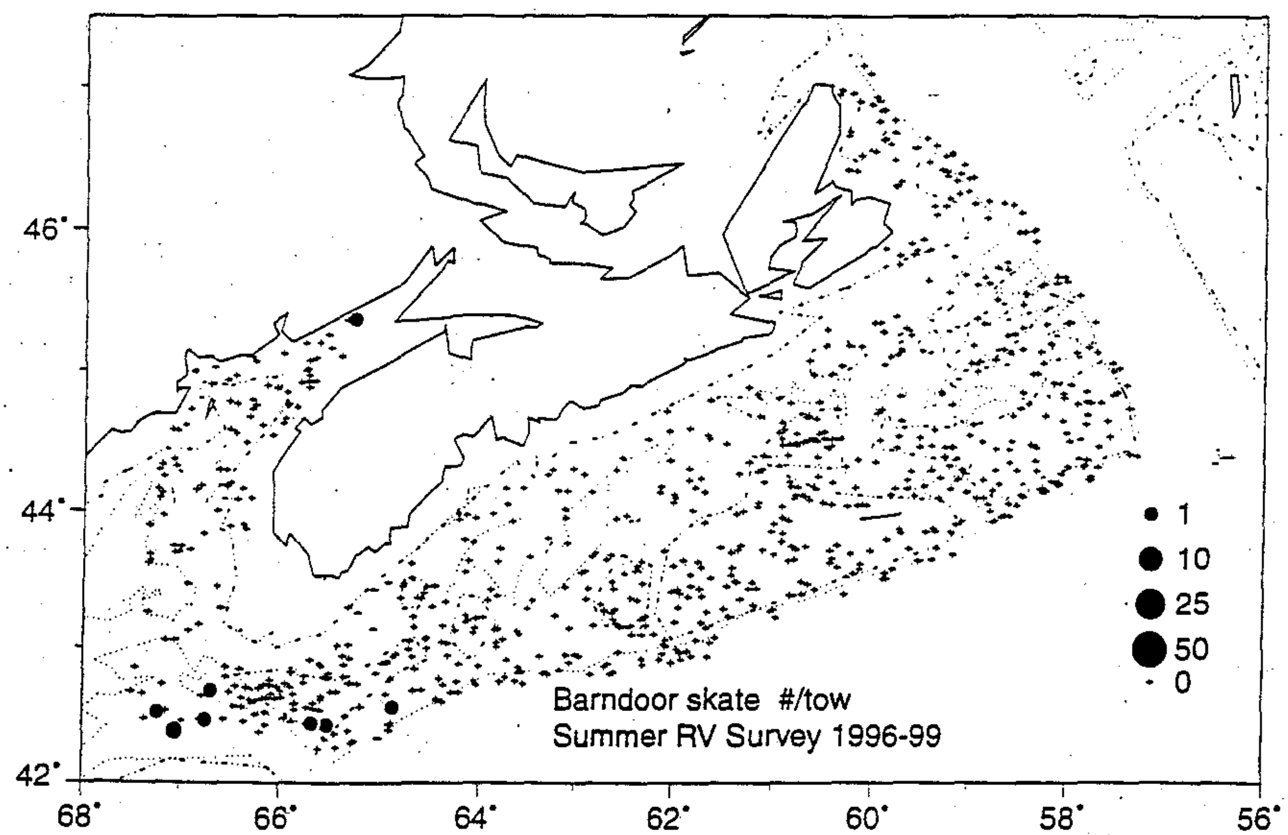


Figure B54. Distribution of barndoor skate in Canada DFO research trawl surveys on the Scotian Shelf and Browns Bank, 1991-1999.

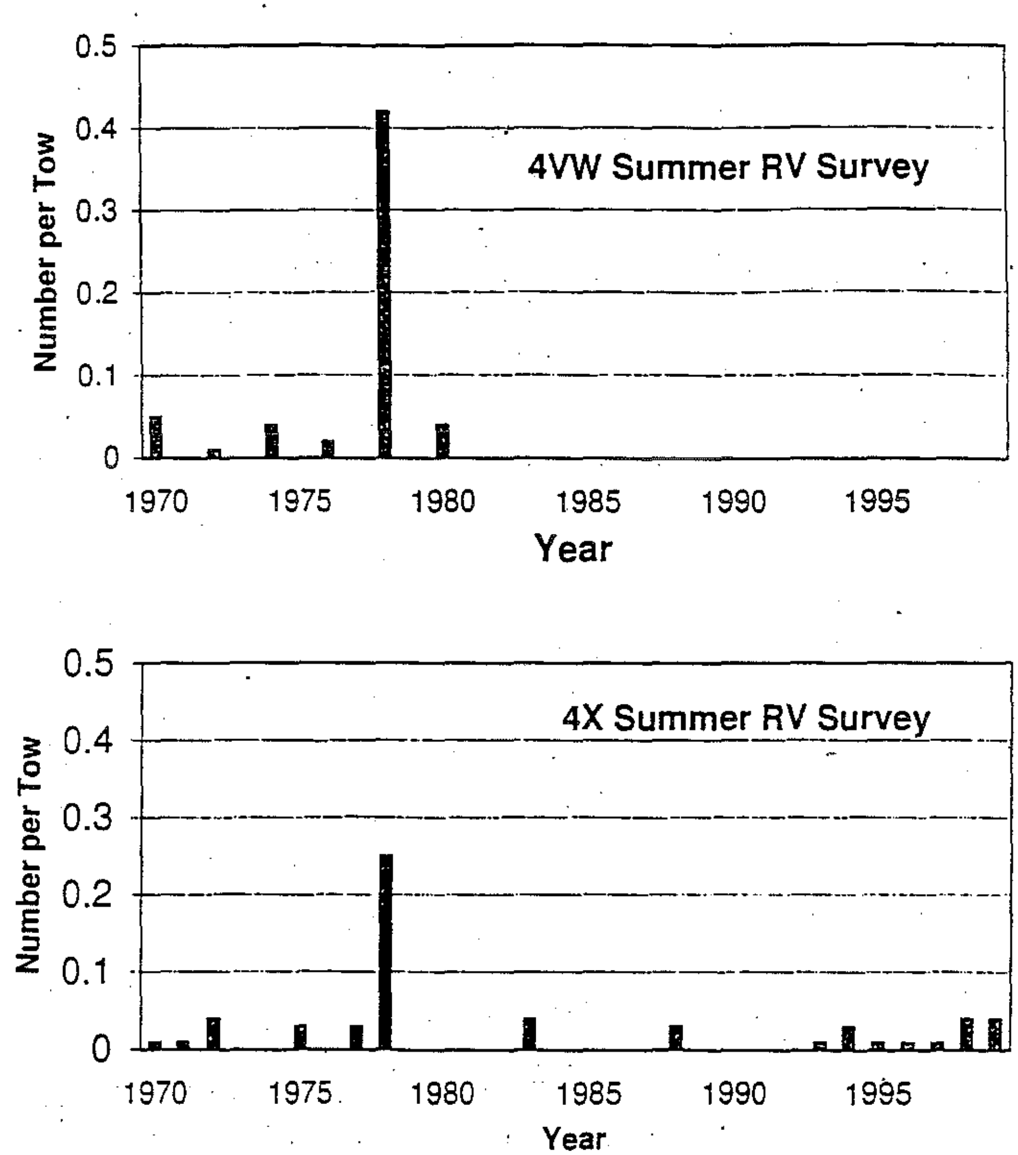


Figure B55. Canada DFO research trawl survey indices of abundance for barndoor skate (number per tow) on the eastern Scotian Shelf (4VW) and southwestern Scotian Shelf and Browns Bank (4X).

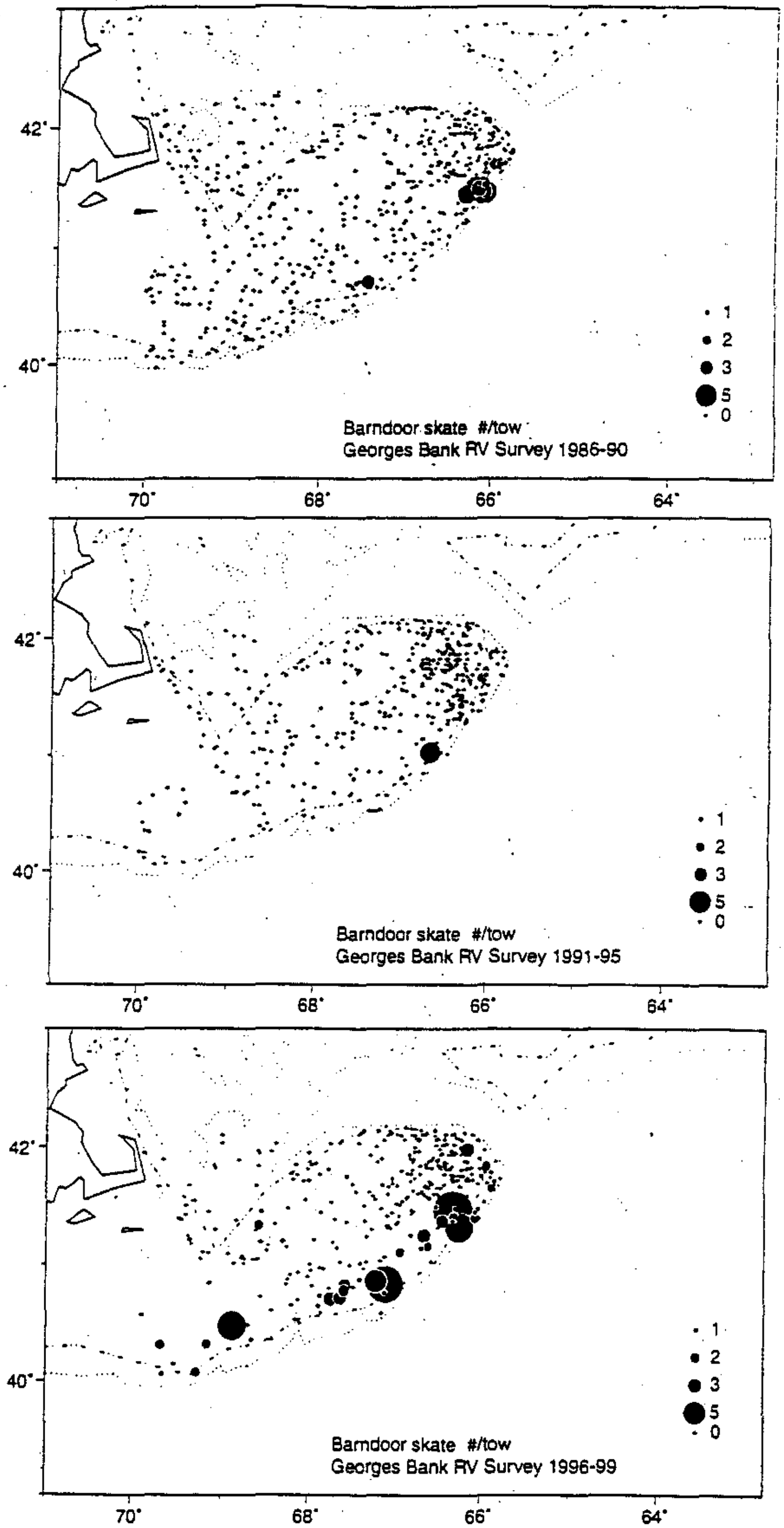


Figure B56. Distribution of barndoor skate in Canada DFO research trawl surveys on the Georges Bank, 1986-1999.

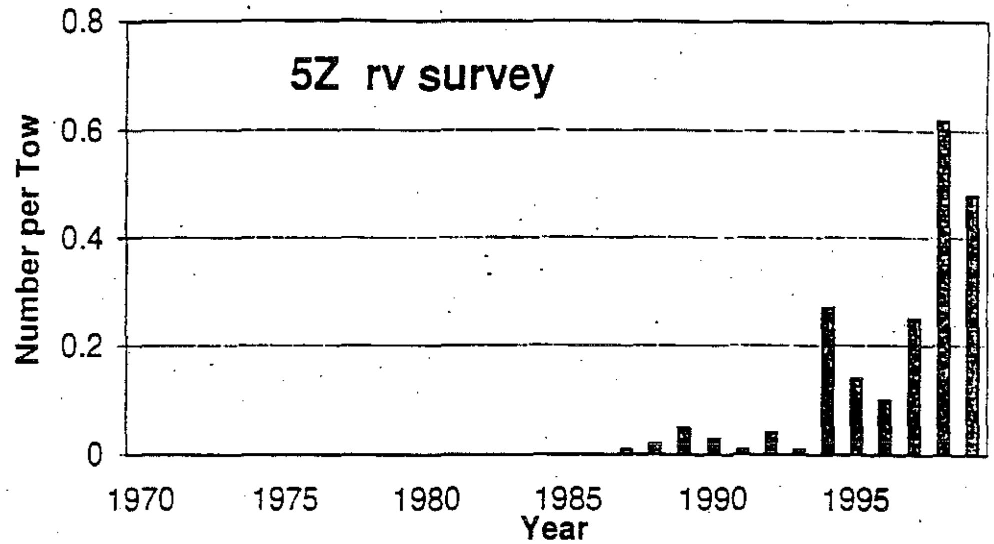


Figure 11.

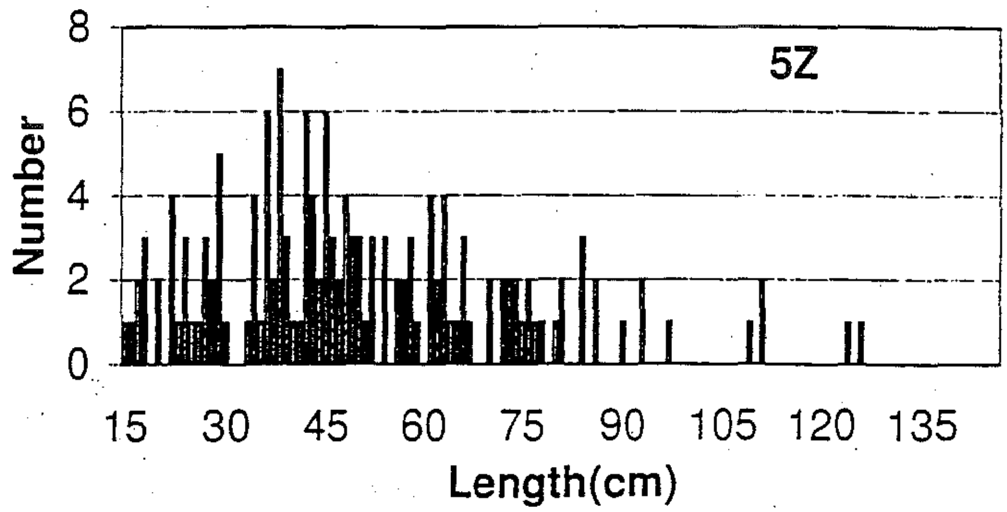


Figure B57. Canada DFO research trawl survey indices of abundance for barndoor skate: number per tow (top) and number at length (bottom) on the Georges Bank, 1986-1999.

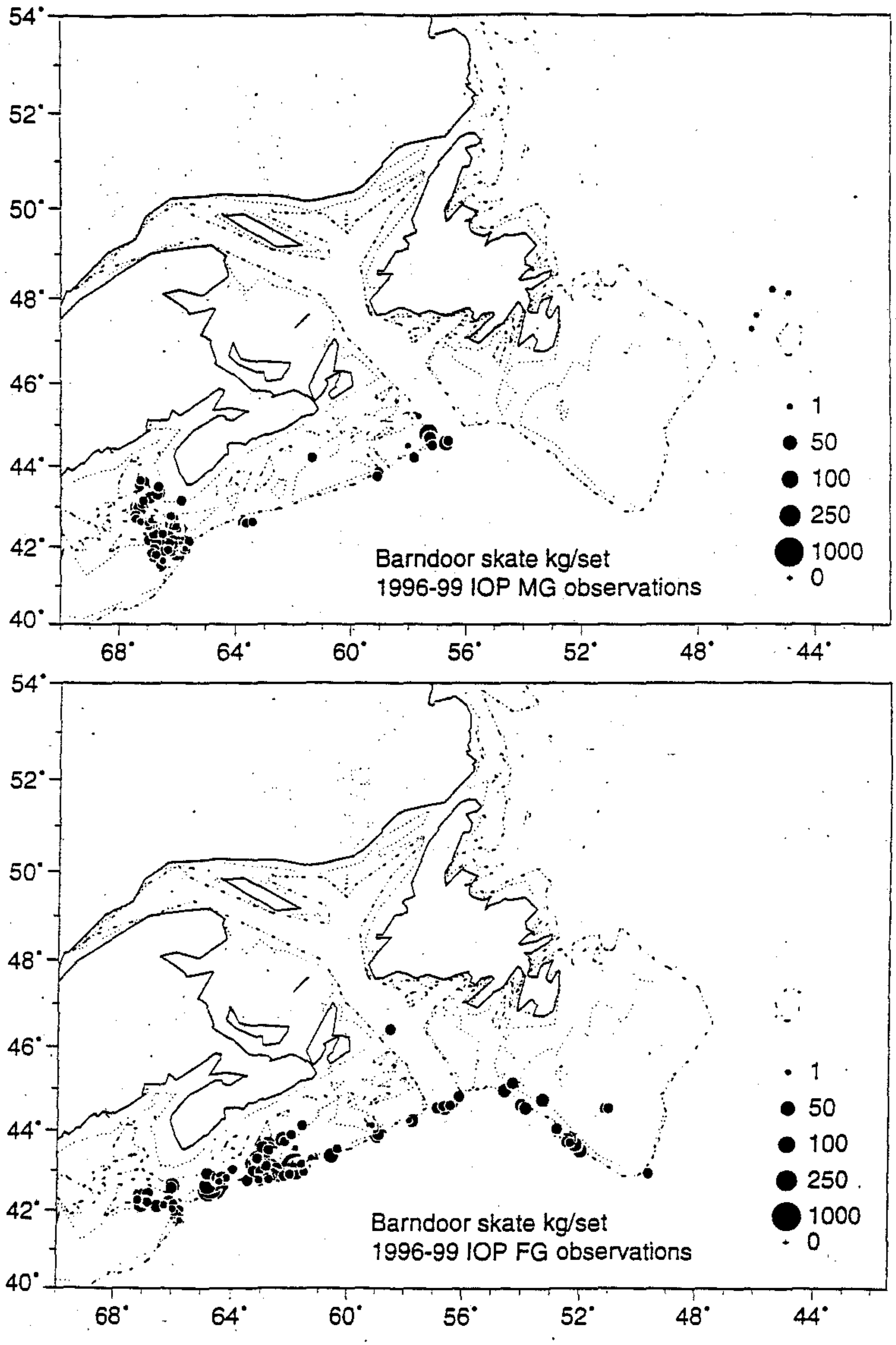
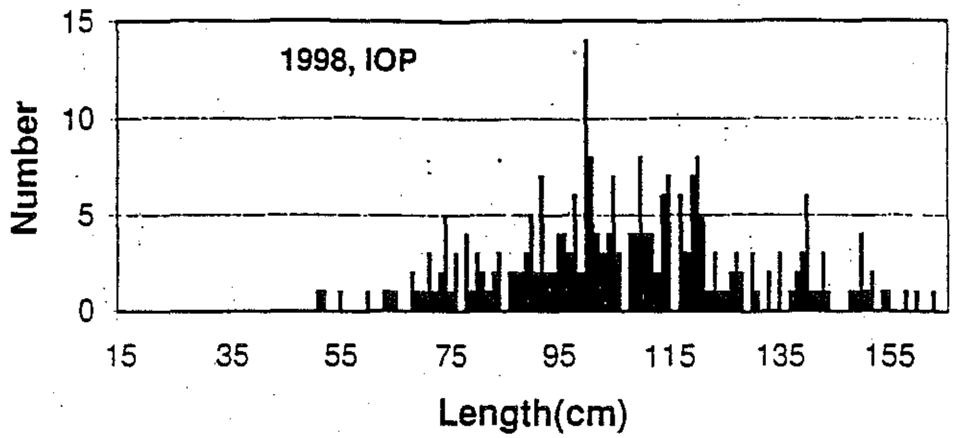


Figure B58. Distribution of barndoor skate in Canada DFO fishery observer data for mobile (top) and fixed (bottom) commercial fishing gear, 1996-1999.



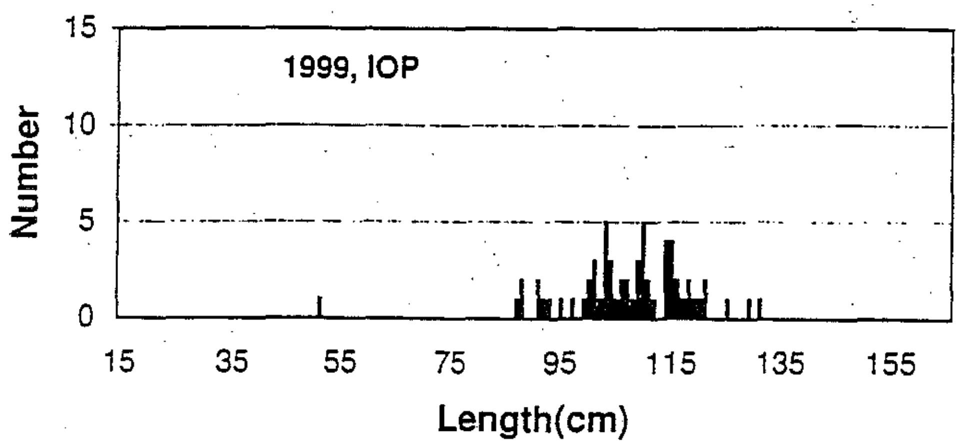


Figure B59. Length frequency distribution of barndoor skate observed in Canadian commercial fishery catches in 1998-1999.

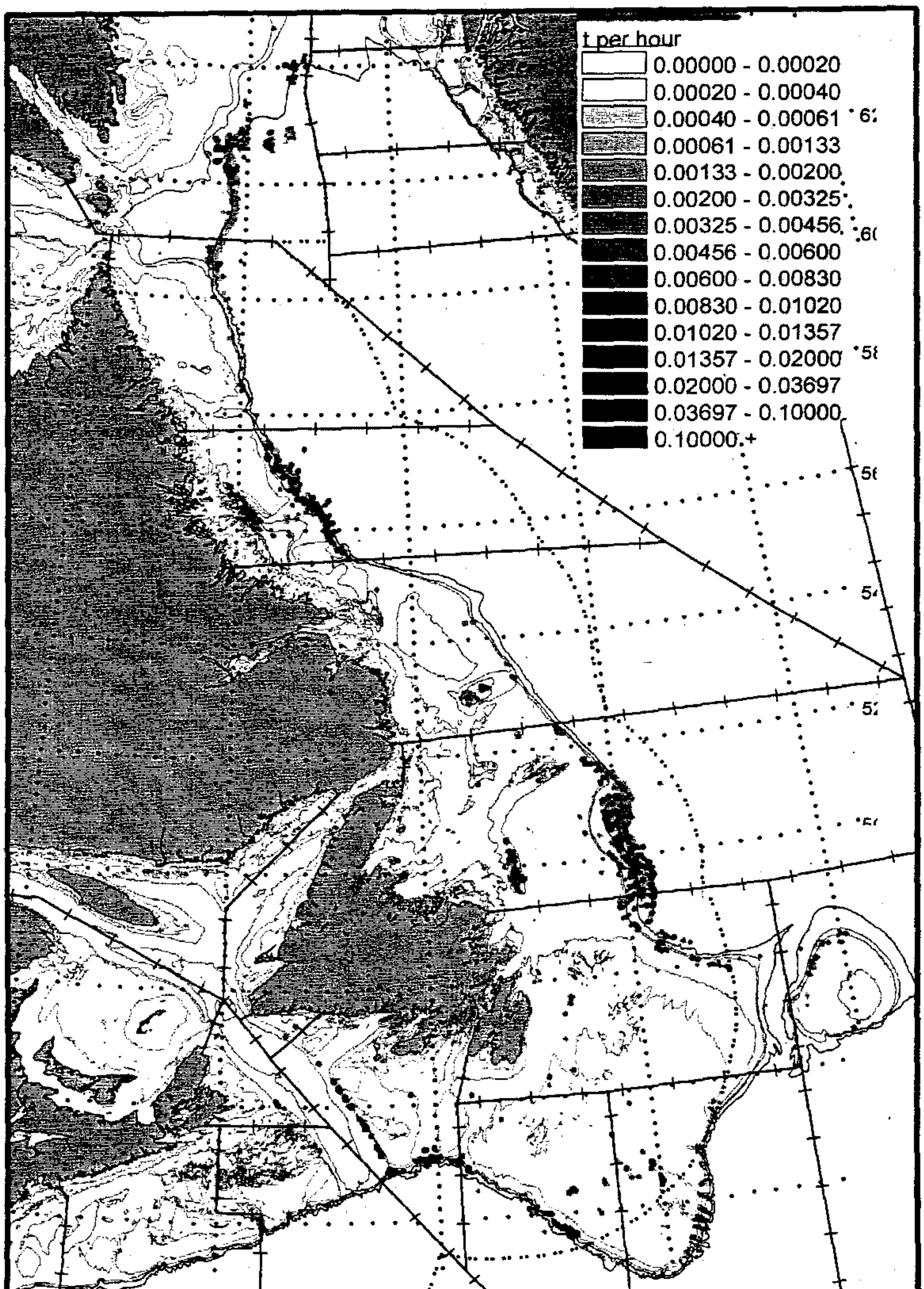


Figure B60. Distribution of barndoor skate observed in Canadian commercial fishery catches, 1983-1998.

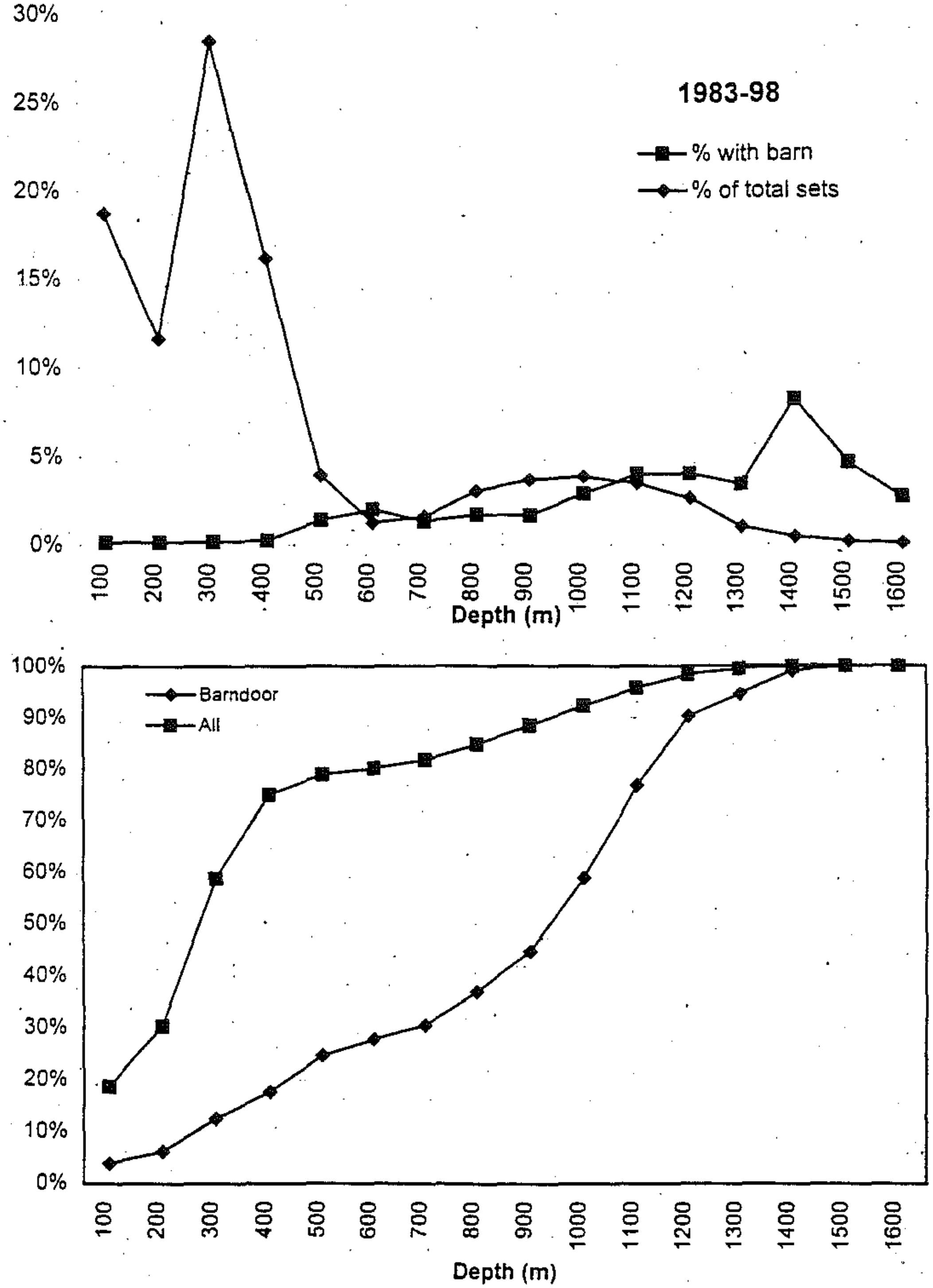


Figure B61. Distribution by depth of all Canadian commercial fishery observed sets, and sets with barndoor skate observed, for 1983-1998.

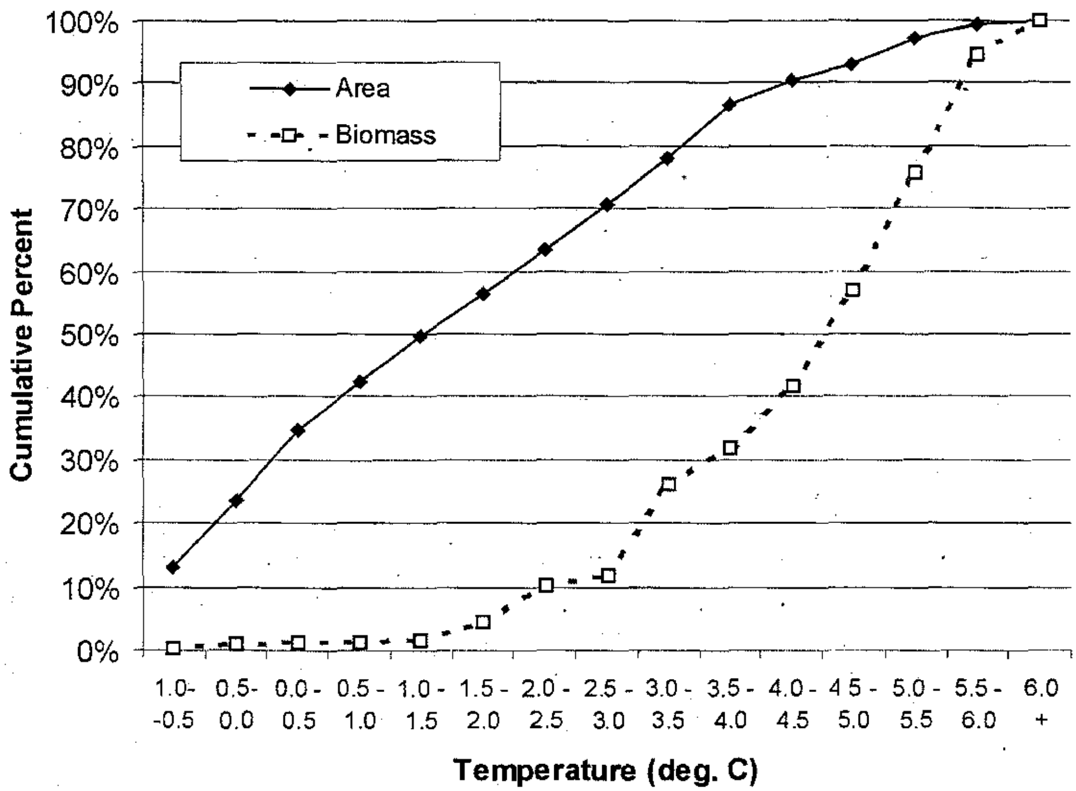
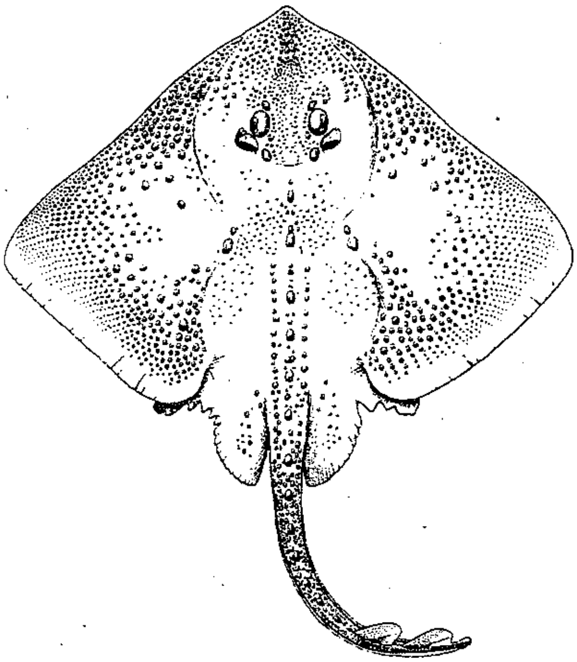
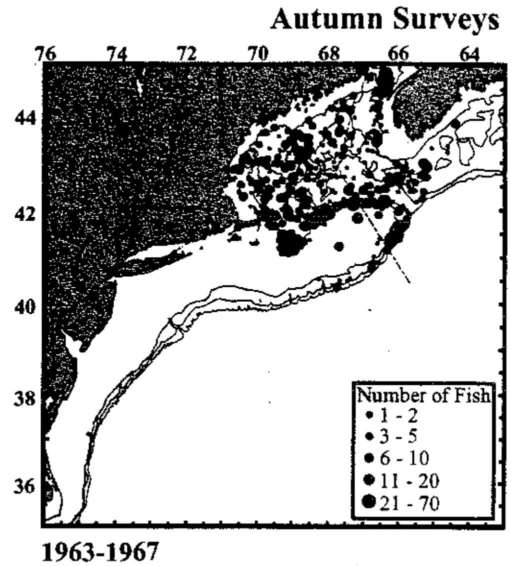
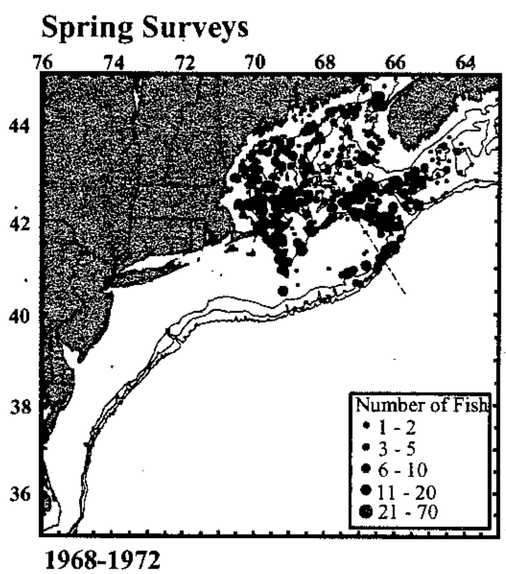


Figure B62. Distribution by temperature of Barndoor skate catch length in Canada commercial fishery observed sets, 1983-1998.

Thorny Skate







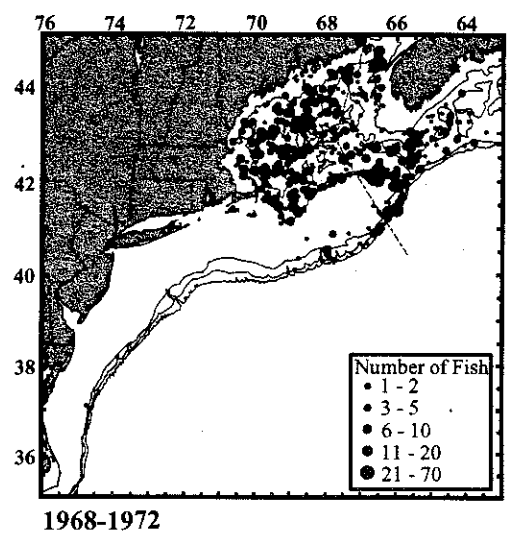


Figure B63. Distribution of thorny skate in the NEFSC spring and autumn bottom trawl surveys from 1963-1972.

Thorny Skate

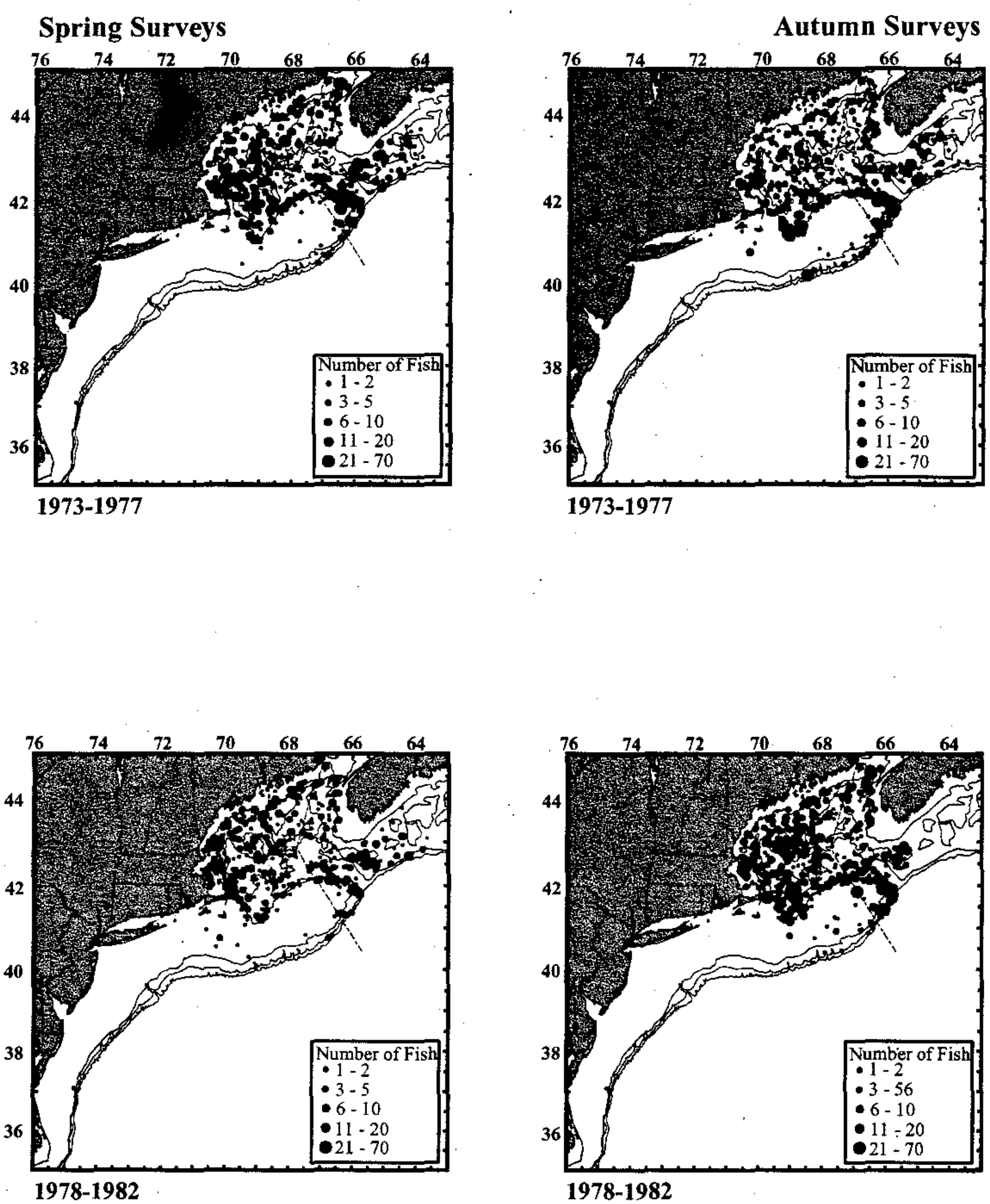


Figure B64. Distribution of thorny skate in the NEFSC spring and autumn bottom trawl surveys from 1973-1982.

Thorny Skate

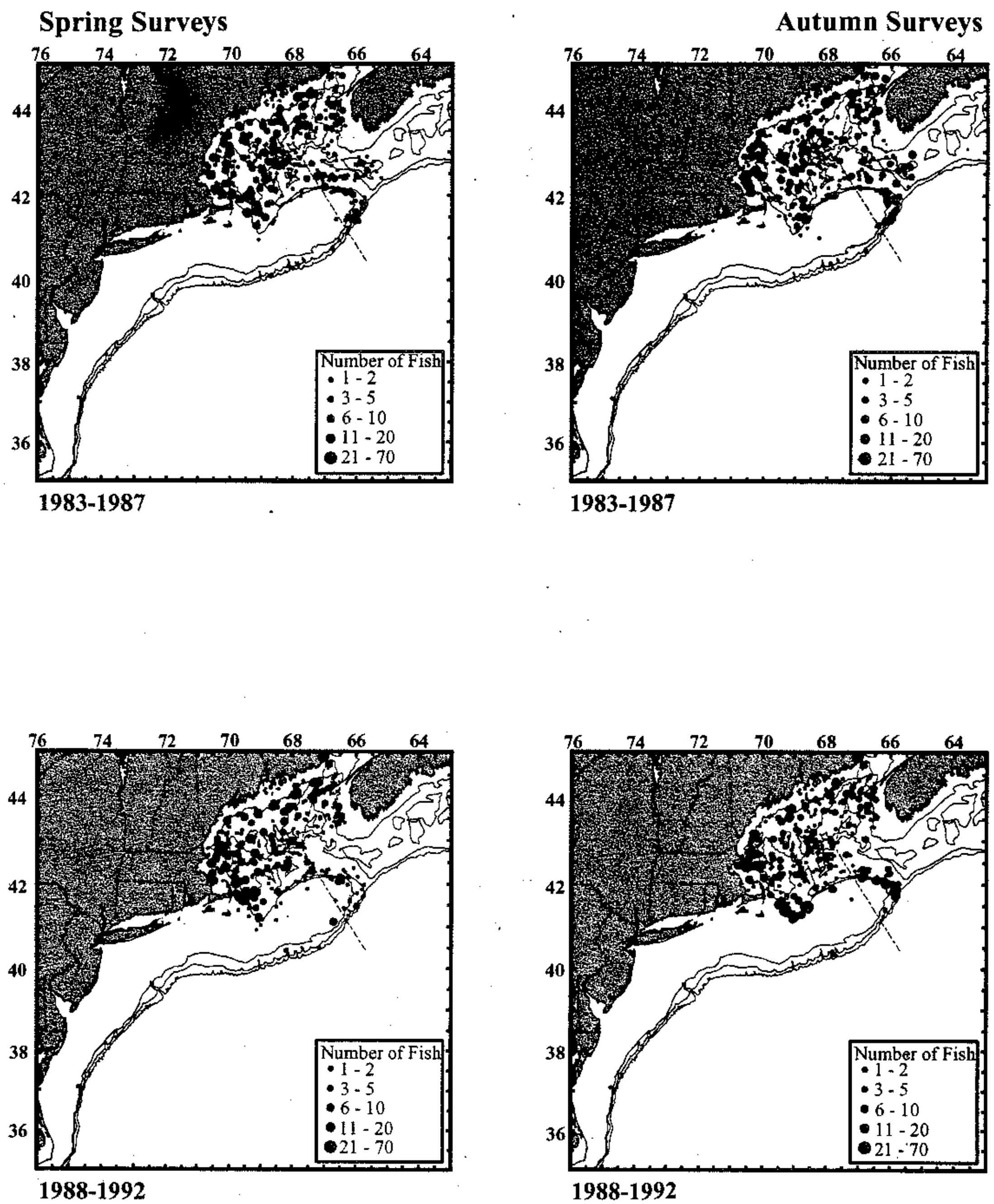


Figure B65. Distribution of thorny skate in the NEFSC spring and autumn bottom trawl surveys from 1983-1992.

Thorny Skate

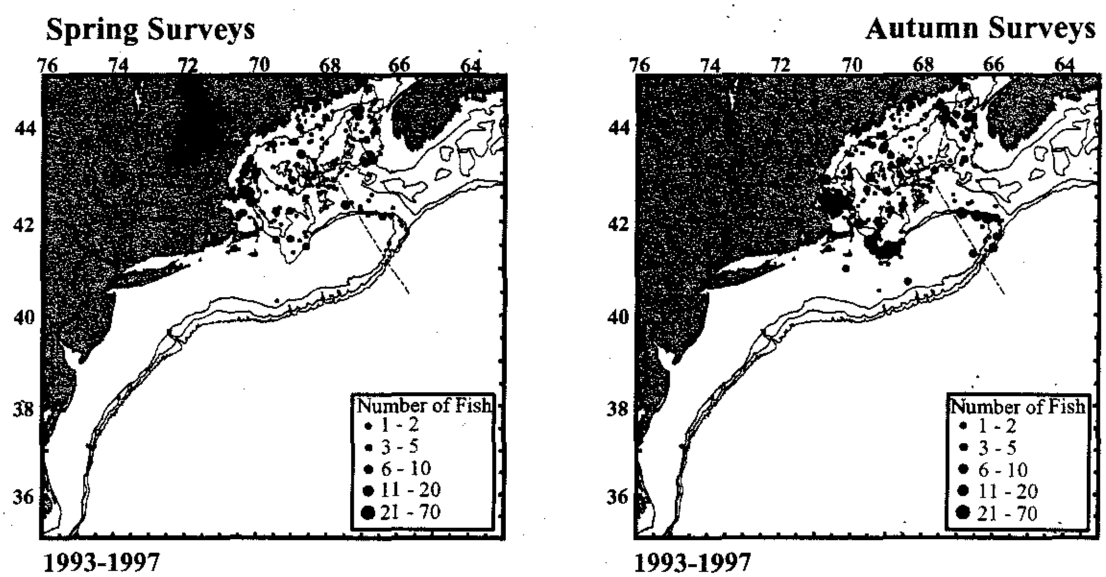


Figure B66. Distribution of thorny skate in the NEFSC spring and autumn bottom trawl surveys from 1993-1997.

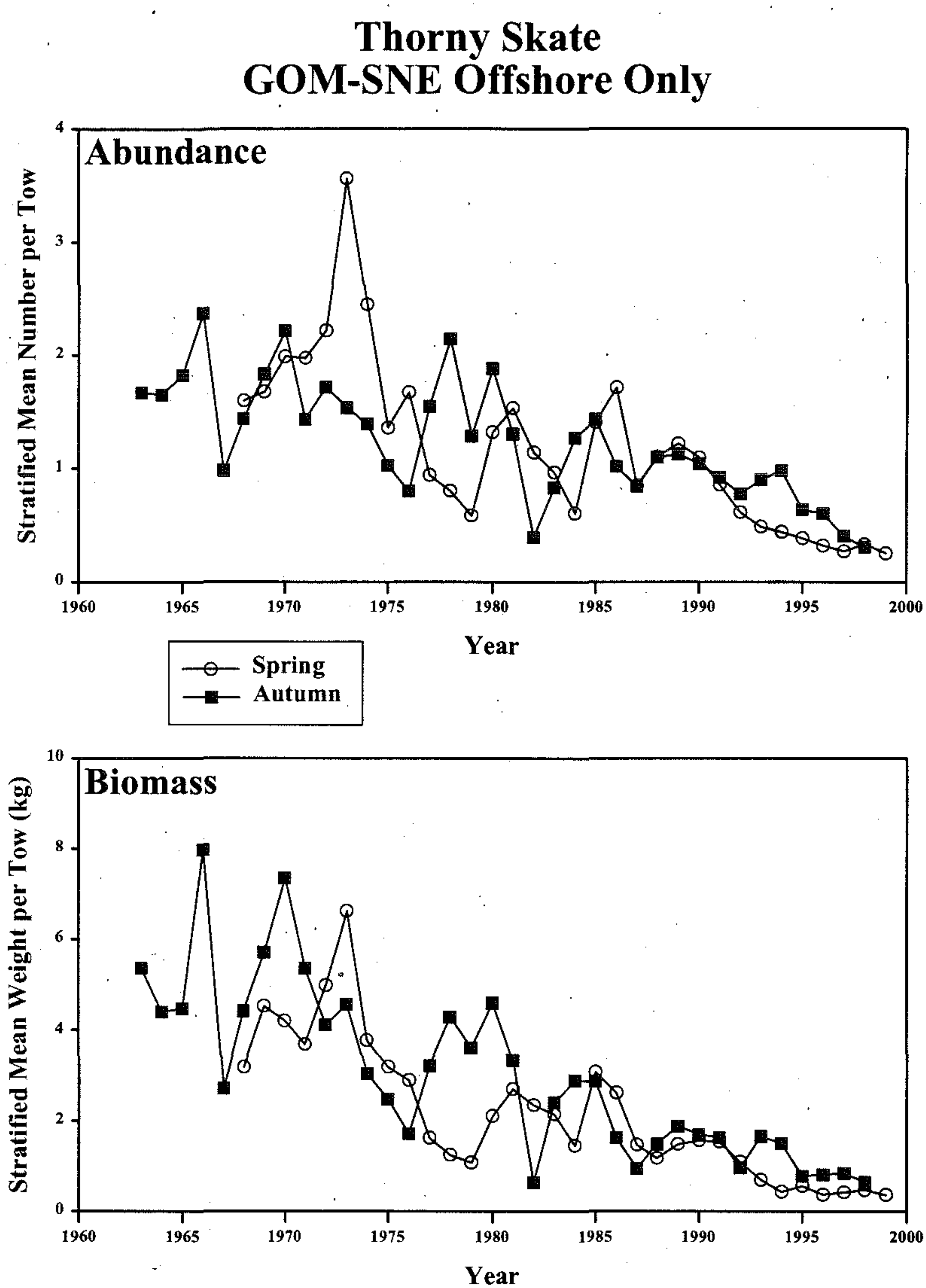


Figure B67. Abundance and biomass of thorny skate from the NESFC spring (circles) and autumn (squares) bottom trawl surveys from 1963-1999 in the Gulf of Maine to Southern New England offshore region.

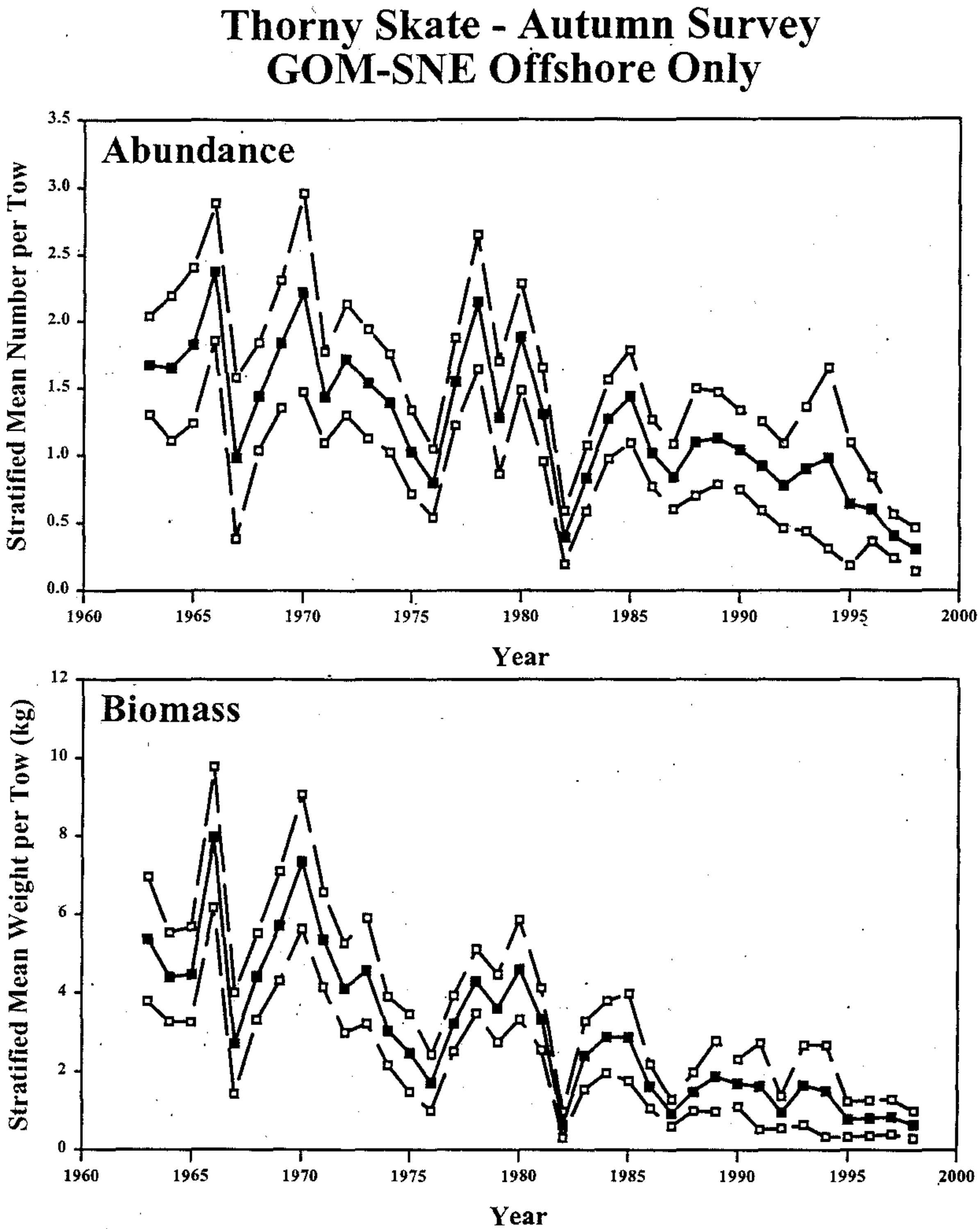
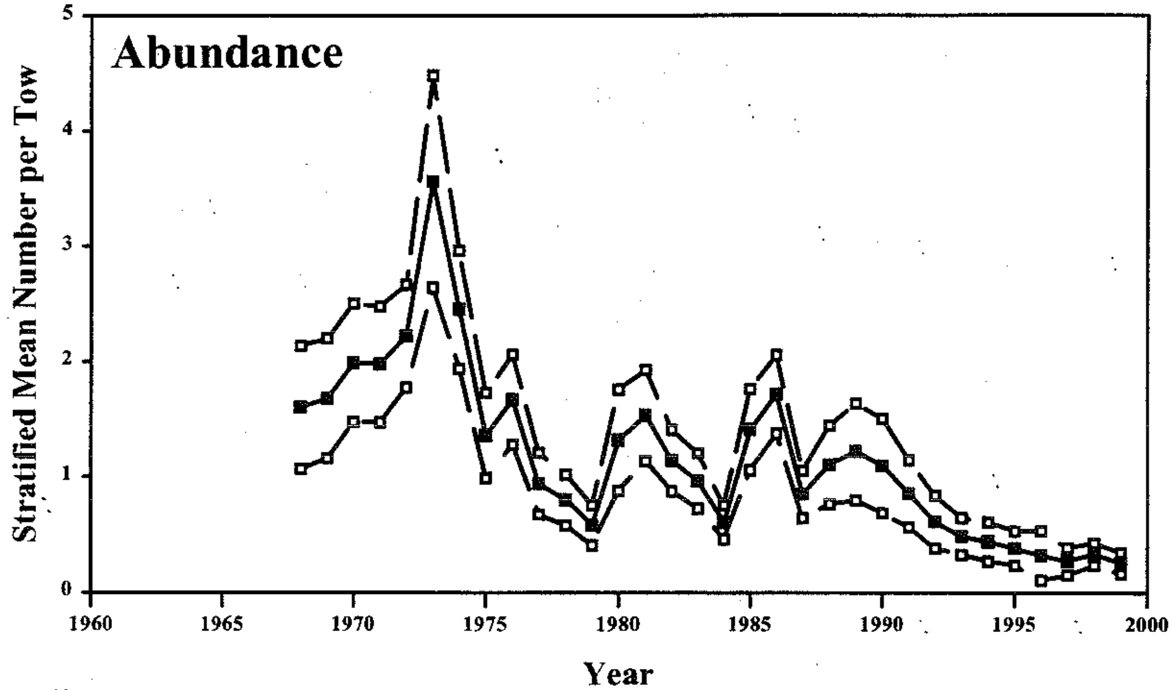


Figure B68. Abundance and biomass of thorny skate from the NEFSC autumn bottom trawl survey in the Gulf of Maine to Southern New England region, offshore strata only. Mean index in solid squares, 95% confidence interval in open squares

Thorny Skate - Spring Survey
GOM-SNE Offshore Only



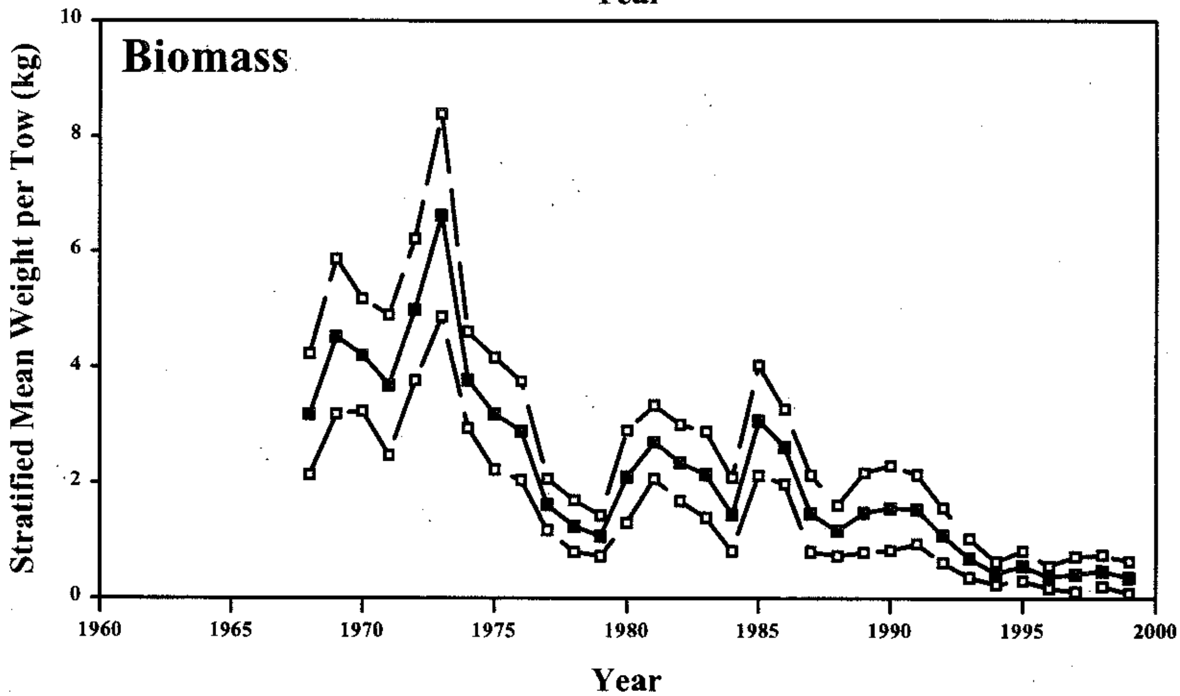
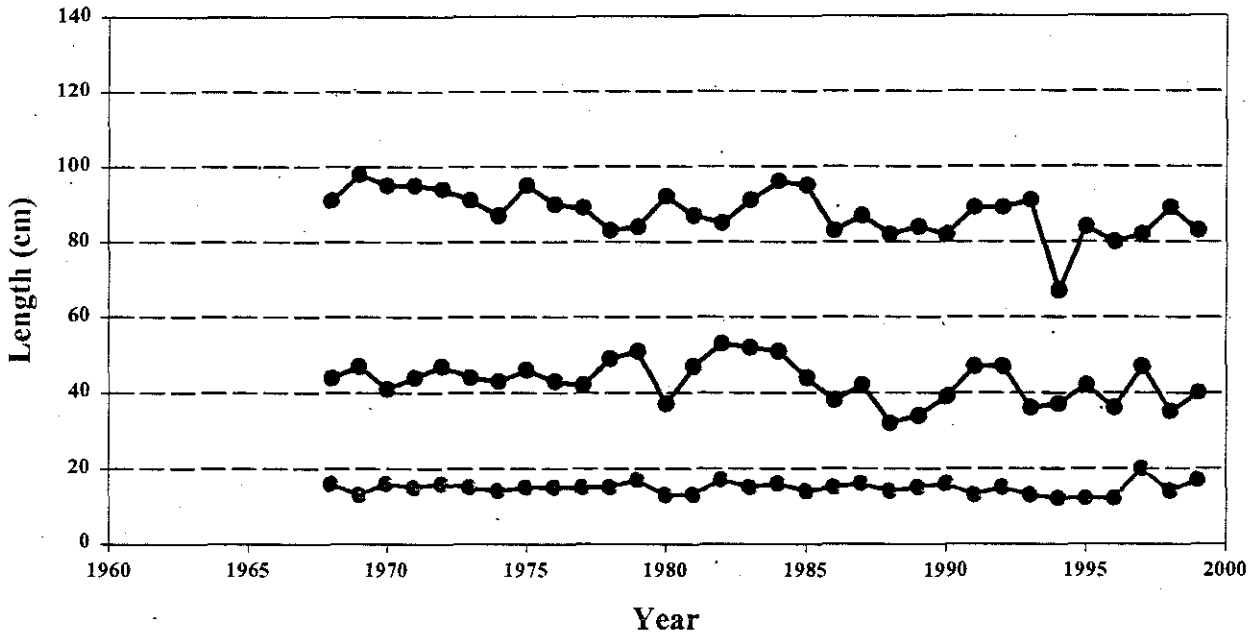


Figure B69. Abundance and biomass of thorny skate from the NESFC spring bottom trawl survey in the Gulf of Maine to Southern New England region, offshore strata only. Mean index in solid squares, 95% confidence interval in open squares.

Thorny Skate: GOM-SNE Offshore
Percentiles of Length Composition

Spring Survey



Autumn Survey

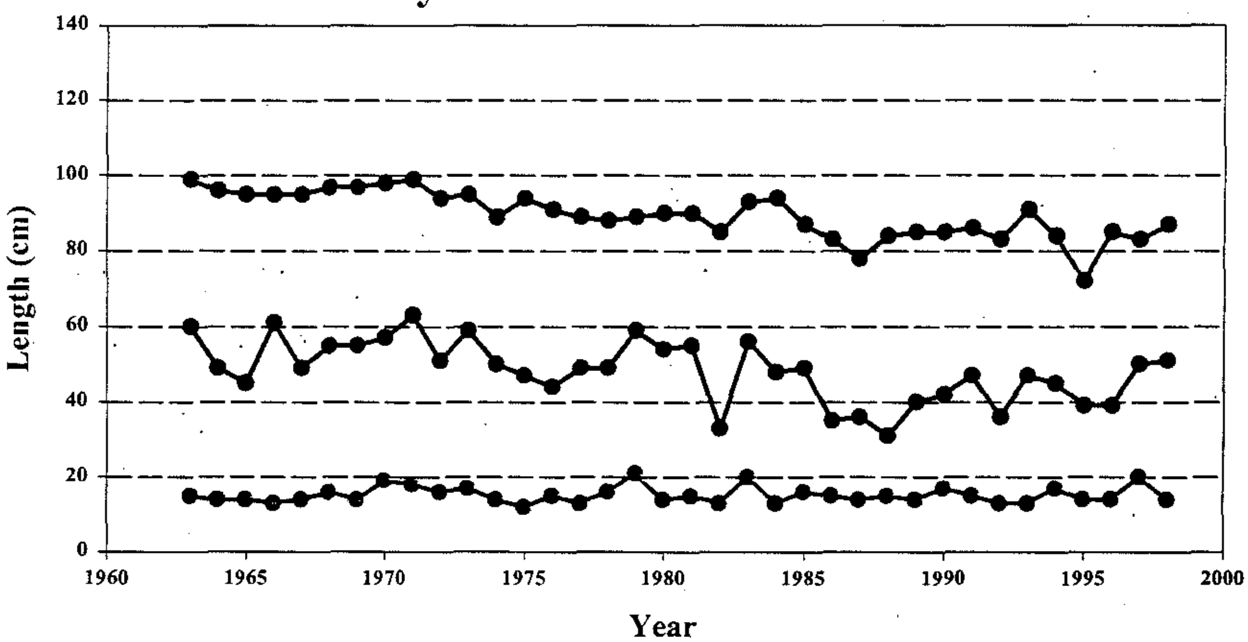


Figure B70. Percentiles of length composition (5, 50, and 95) of thorny skate from the NESFC spring and autumn bottom trawl surveys from 1963-1999 in the Gulf of Maine to Southern New England offshore region.

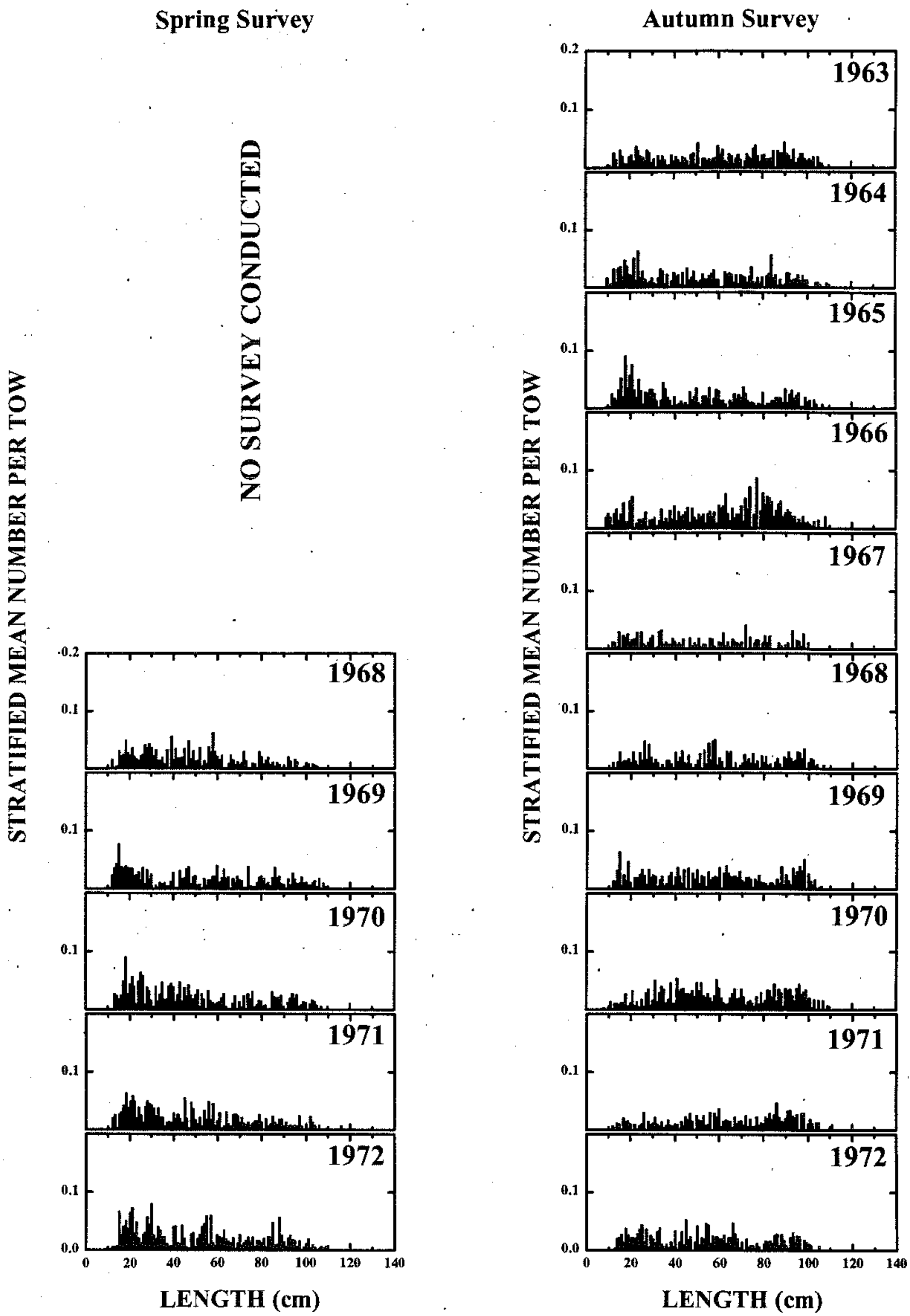


Figure B71. Thorny skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England offshore region, 1963-1972.

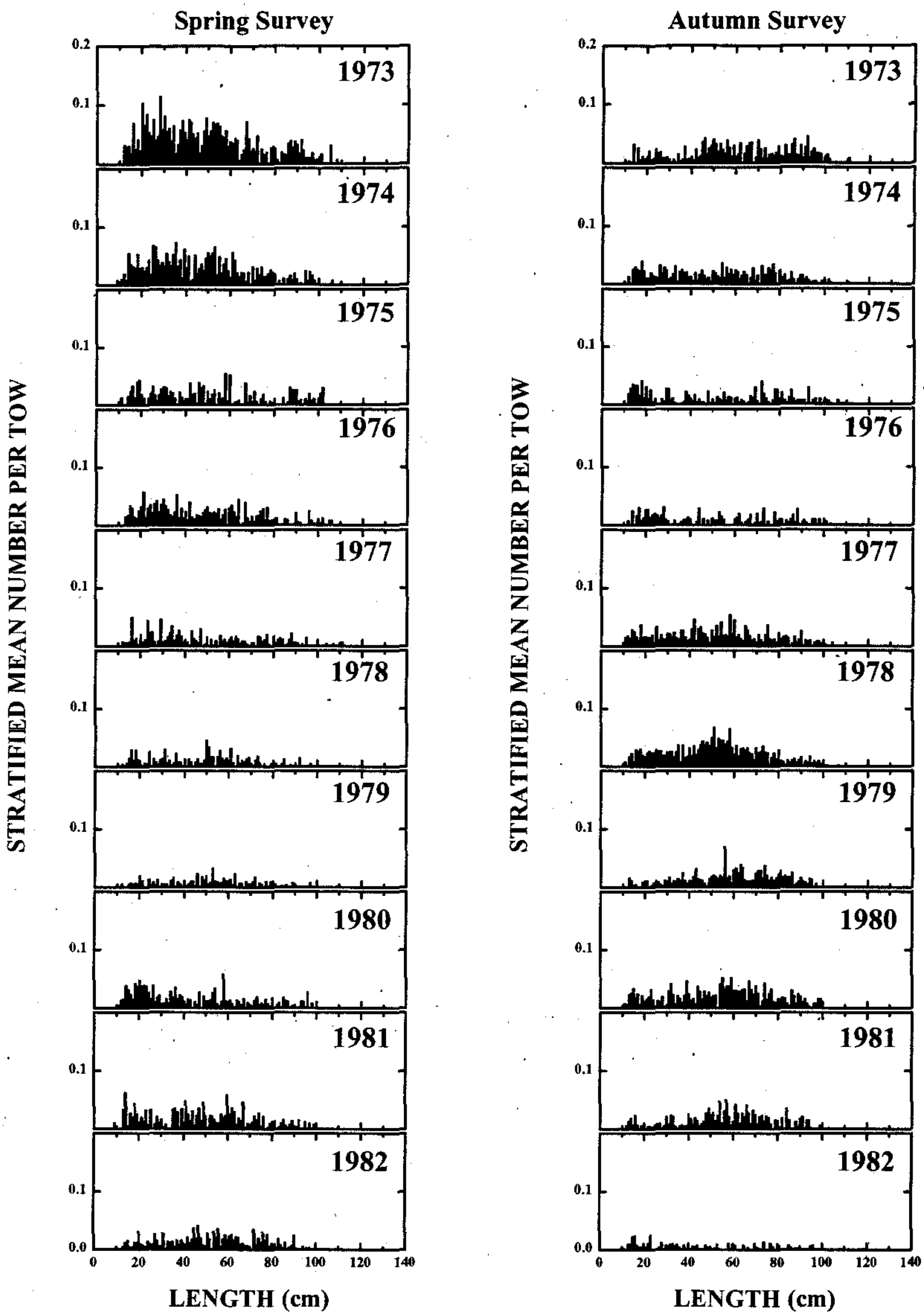


Figure B72. Thorny skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England offshore regions, 1973-1982.

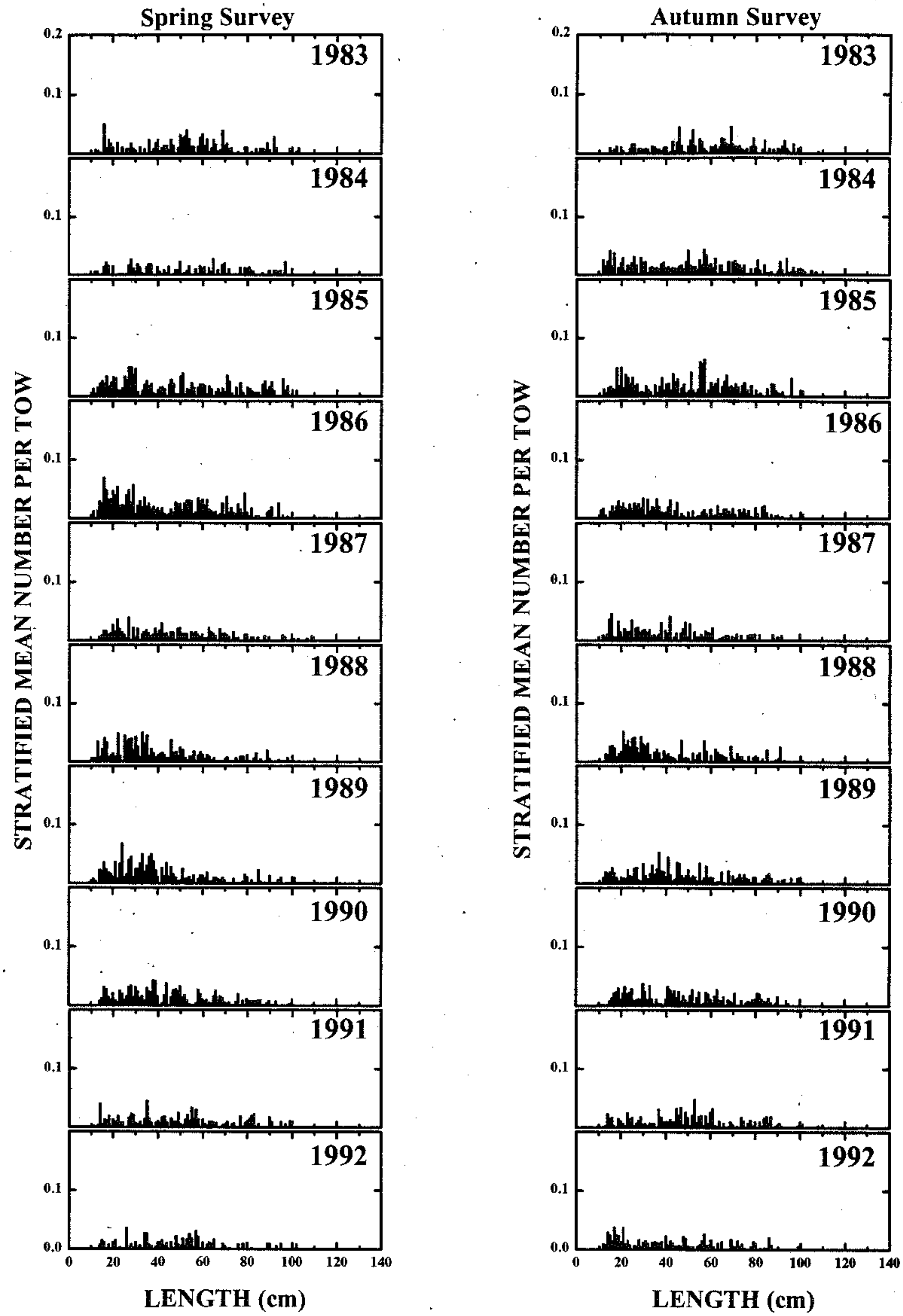


Figure B73. Thorny skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England offshore region, 1983-1992.

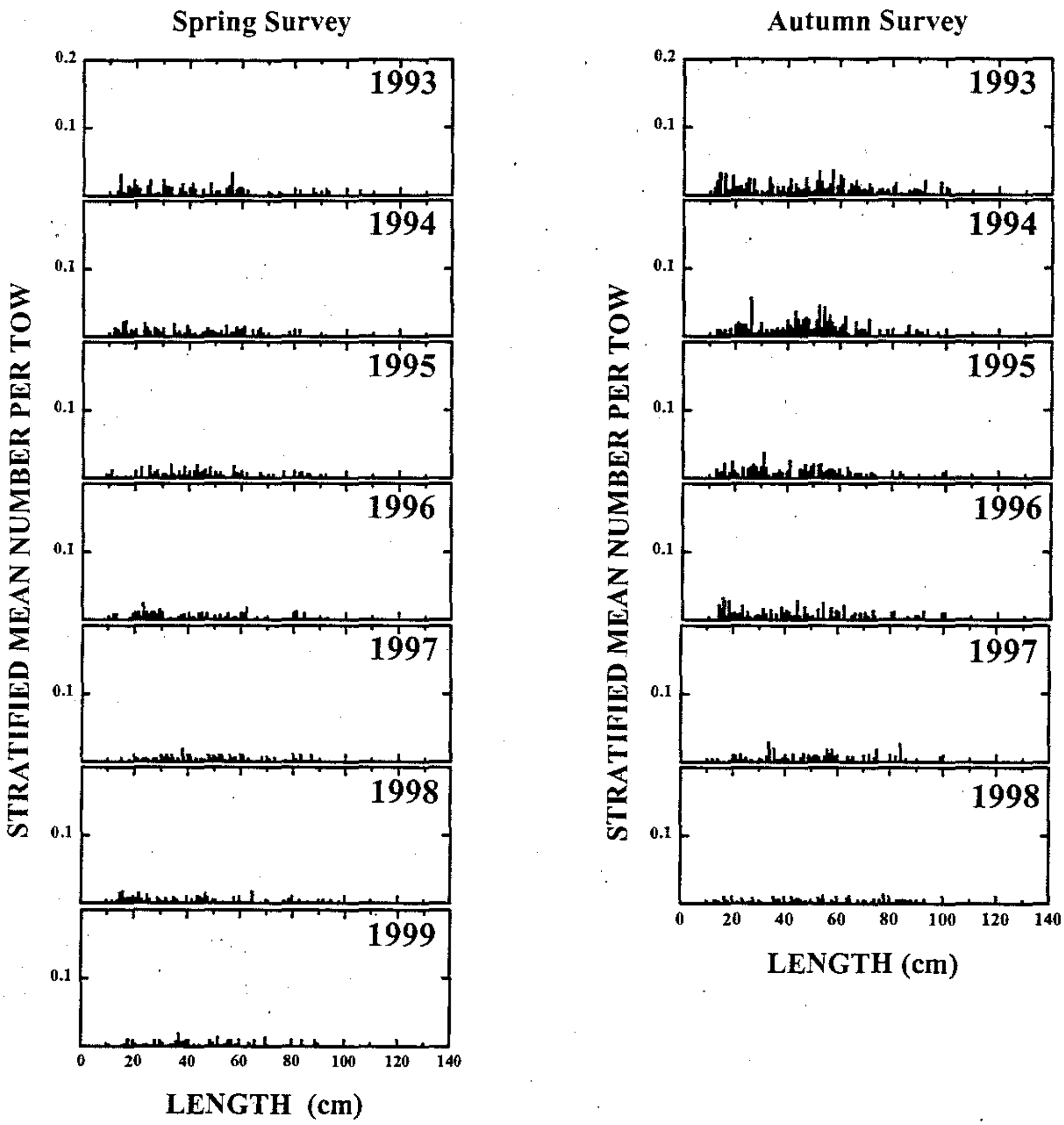


Figure B74. Thorny skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England offshore regions, 1993-1999.

Thorny Skate - Massachusetts Trawl Survey

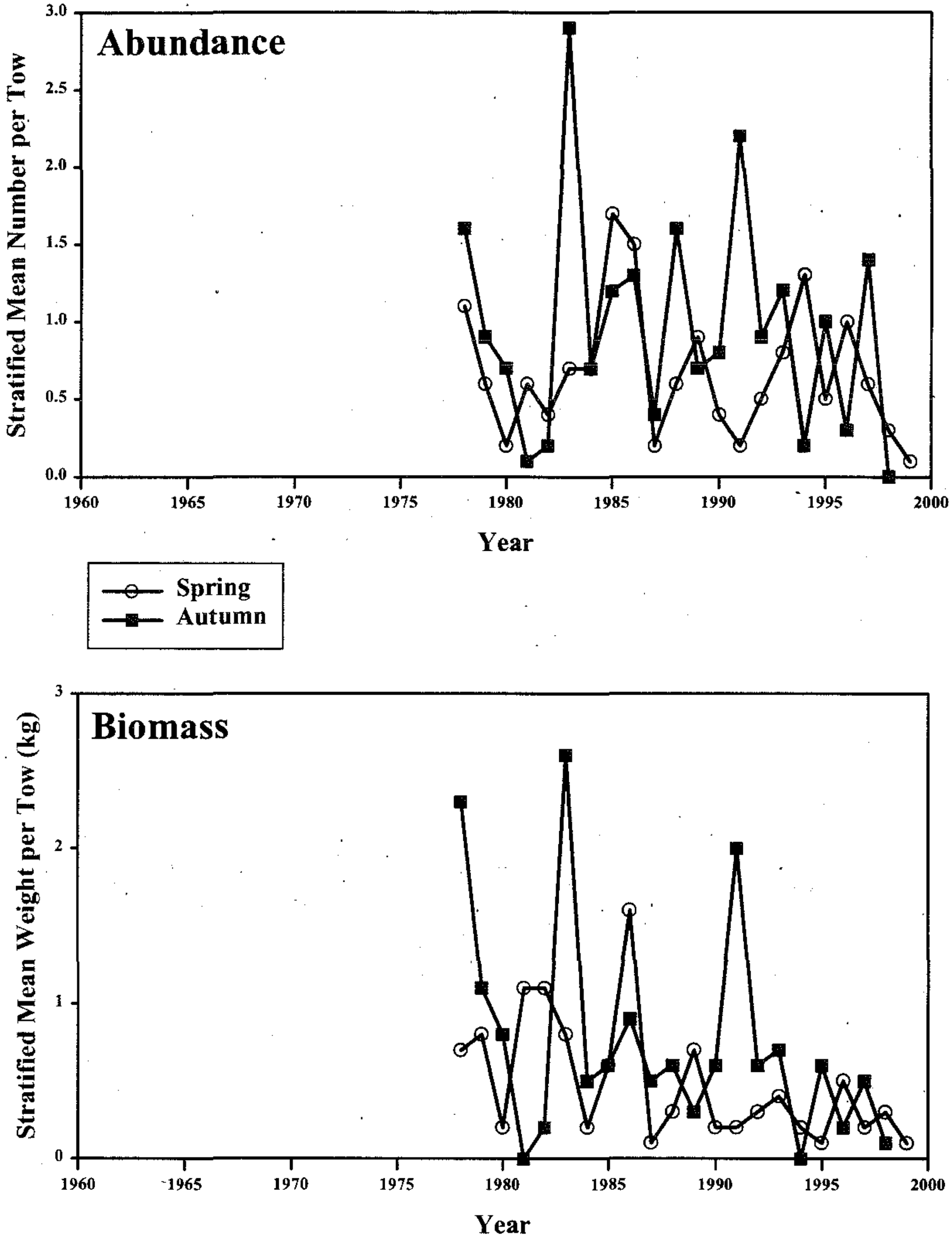


Figure B75. Abundance and biomass of thorny skate from the Massachusetts spring and autumn finfish bottom trawl survey in state waters.

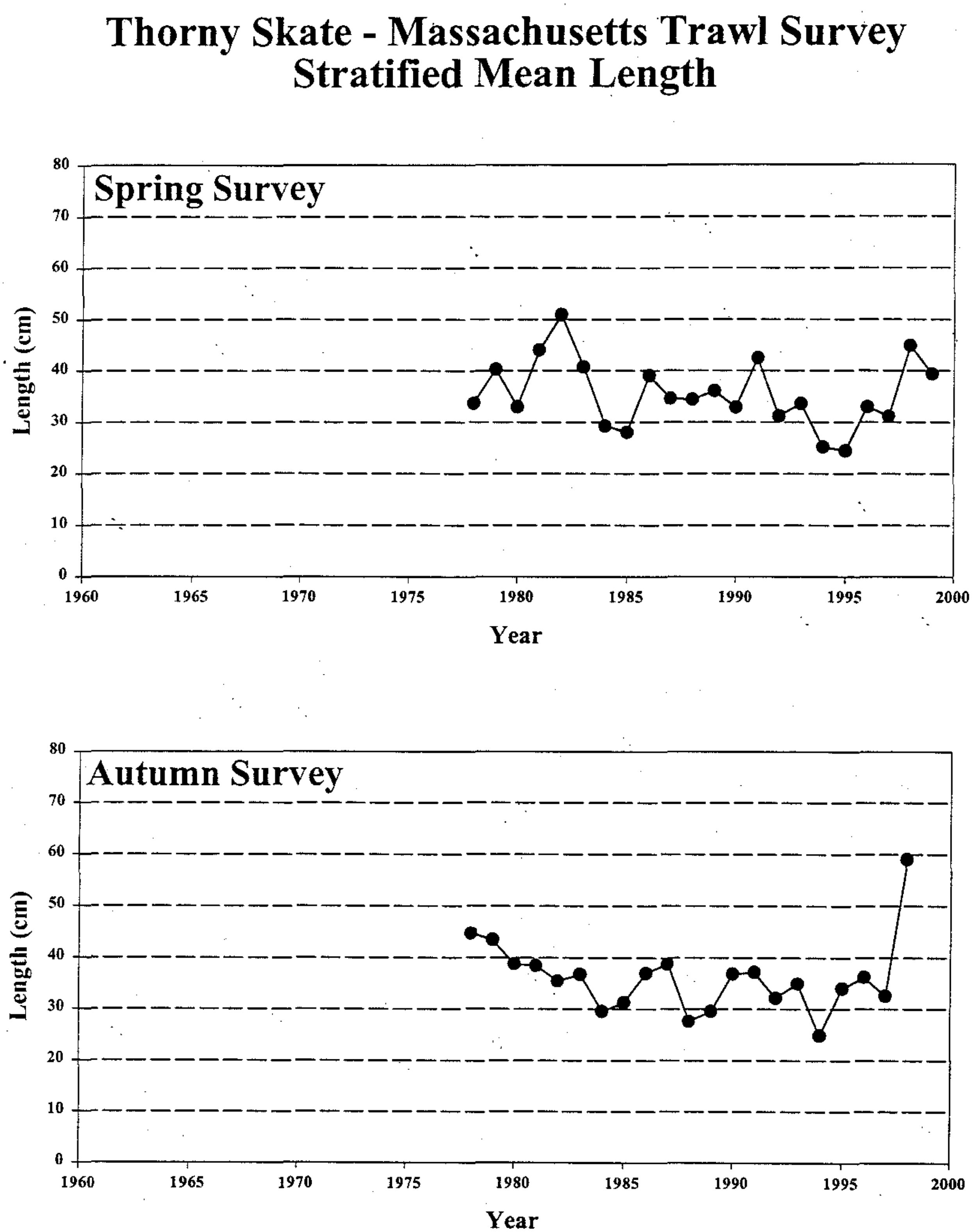
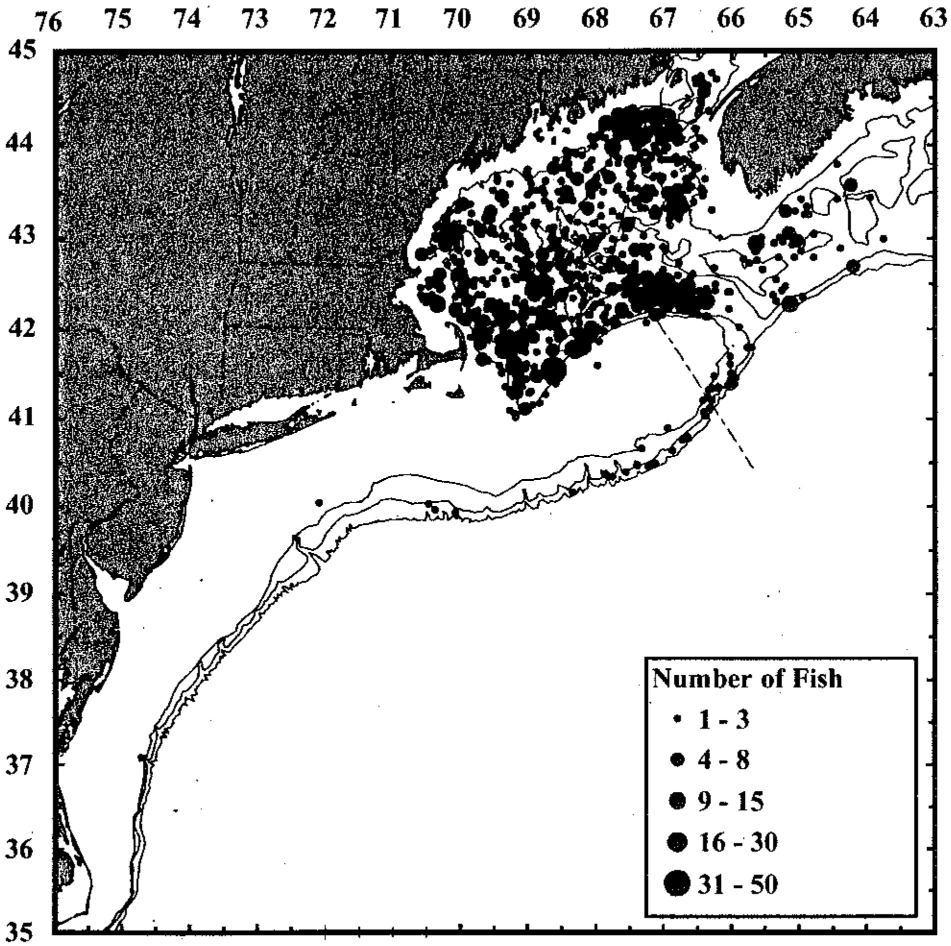
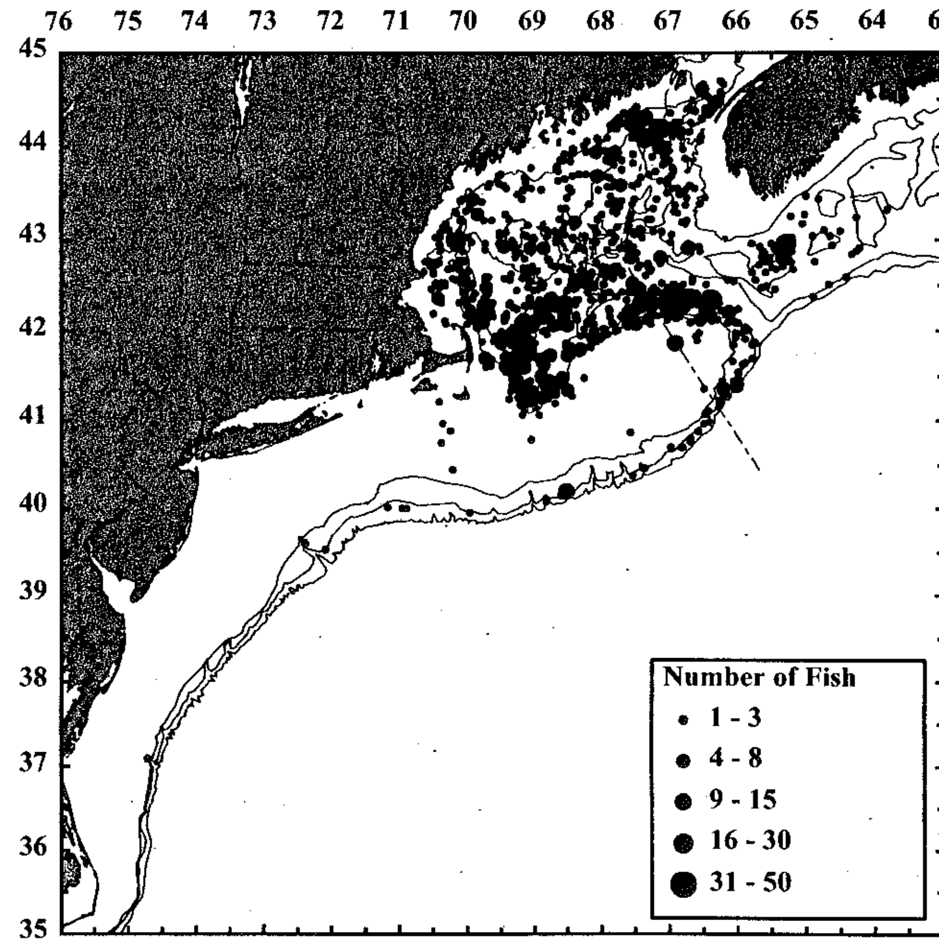


Figure B76. Stratified mean total length (cm) of Thorny skate from the Massachusetts spring and autumn bottom trawl surveys from 1978-1999.



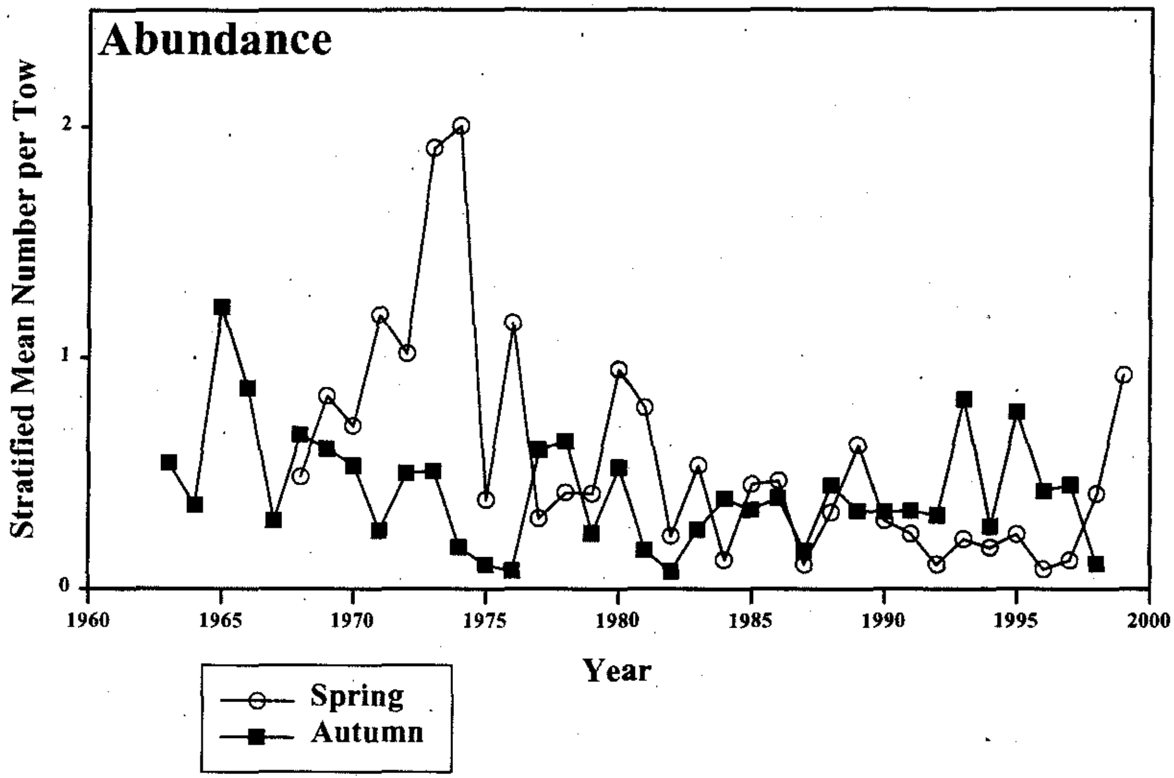
Smooth Skate
NEFSC Spring Surveys 1968-1999



Smooth Skate
NEFSC Autumn Surveys 1963-1998

Figure B77. Distribution of smooth skate in the NEFSC spring and autumn surveys from 1963-1999.

Smooth Skate
GOM-SNE Offshore Only



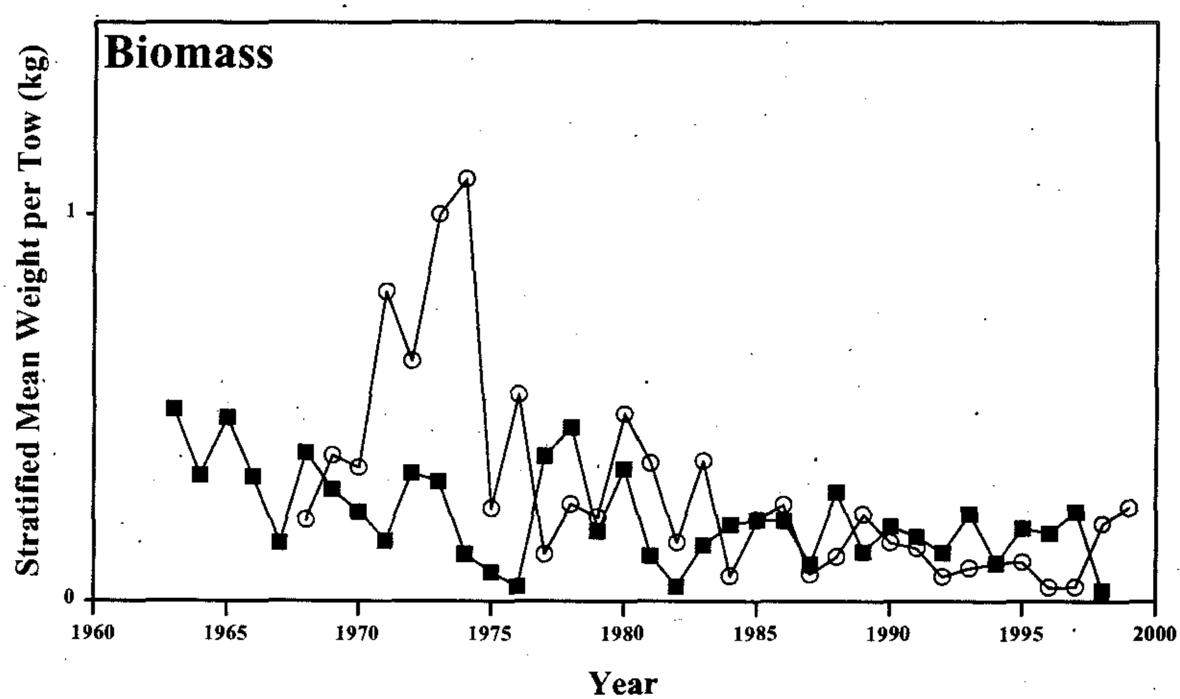


Figure B78. Abundance and biomass of smooth skate from the NEFSC spring (circles) and autumn (squares) bottom trawl surveys from 1967-1999 in the Gulf of Maine to Southern New England region.

Smooth Skate - Spring Survey
GOM-MA Offshore Only

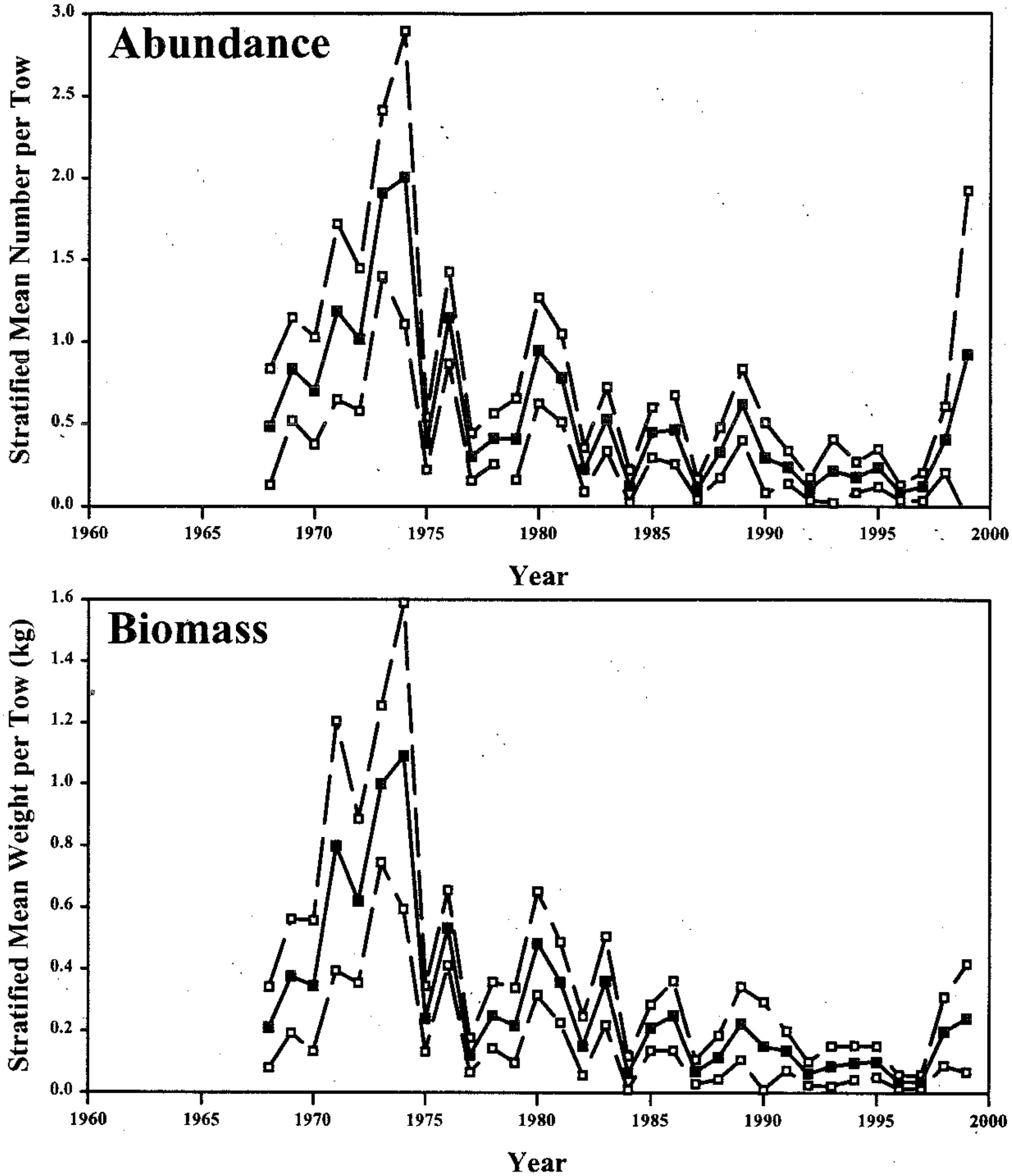


Figure B79. Abundance and biomass of smooth skate from the NESFC spring bottom trawl survey in the Gulf of Maine to Southern New England region, offshore strata only. Mean index in solid squares, 95% confidence interval in open squares.

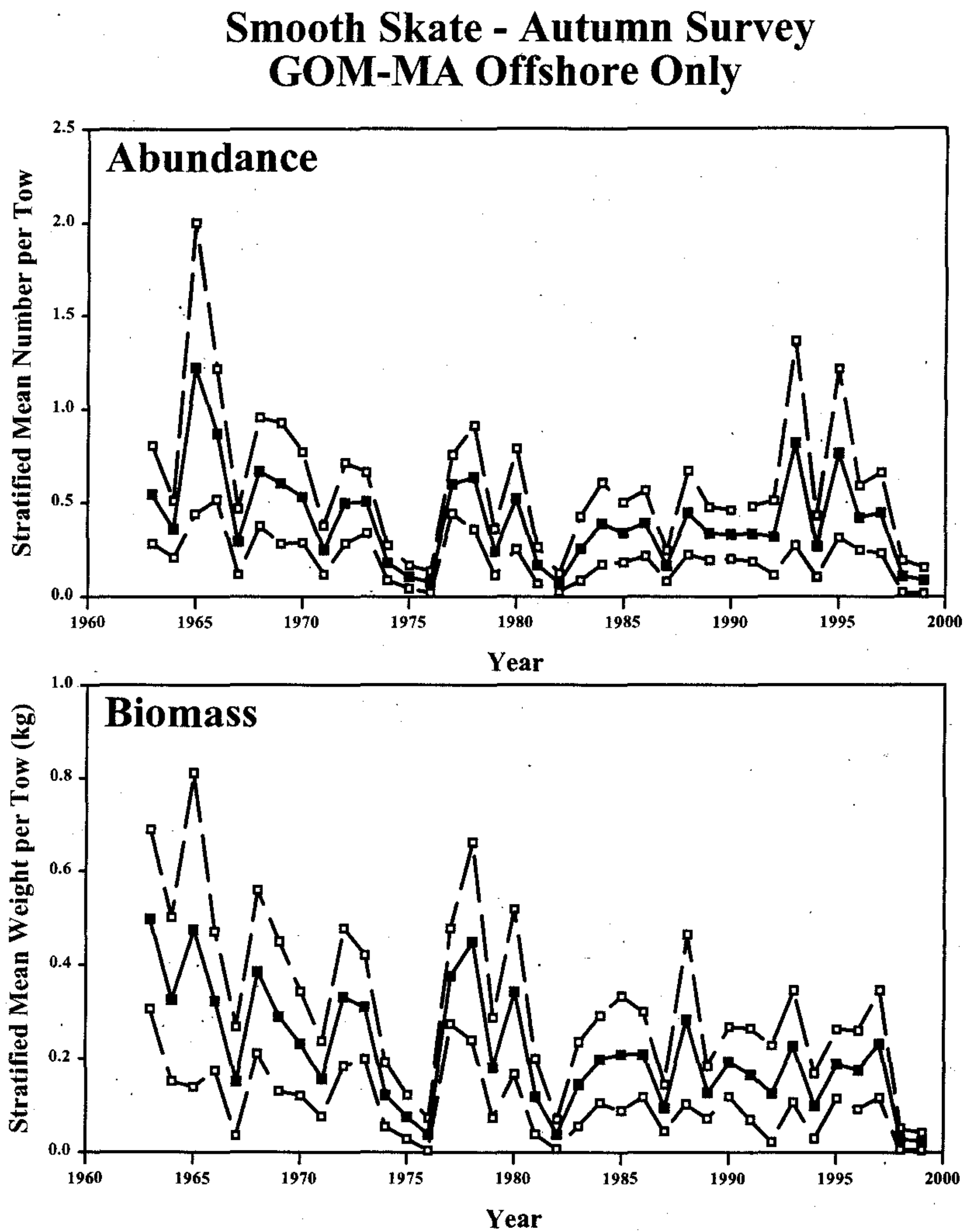


Figure B80. Abundance and biomass of smooth skate from the NEFSC autumn bottom trawl survey in the Gulf of Maine to Southern New England region, offshore strata only. Mean index in solid squares, 95% confidence interval in open squares.

Smooth Skate: GOM-SNE Offshore
Percentiles of Length Composition

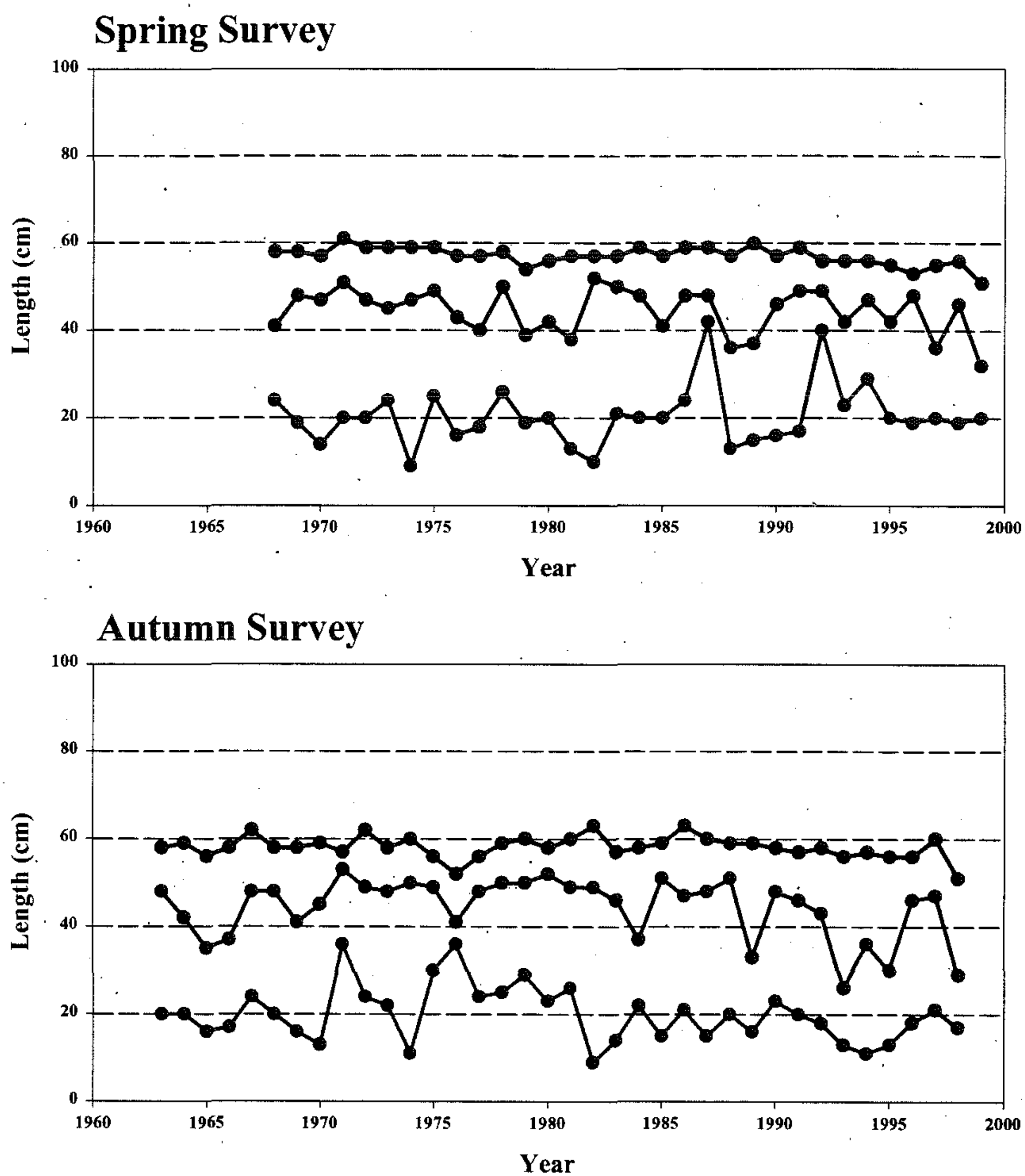


Figure B81. Percentiles of length composition (5, 50, and 95) of smooth skate from the NESFC spring and autumn bottom trawl surveys from 1963-1999 in the Gulf of Maine to Southern New England offshore region.

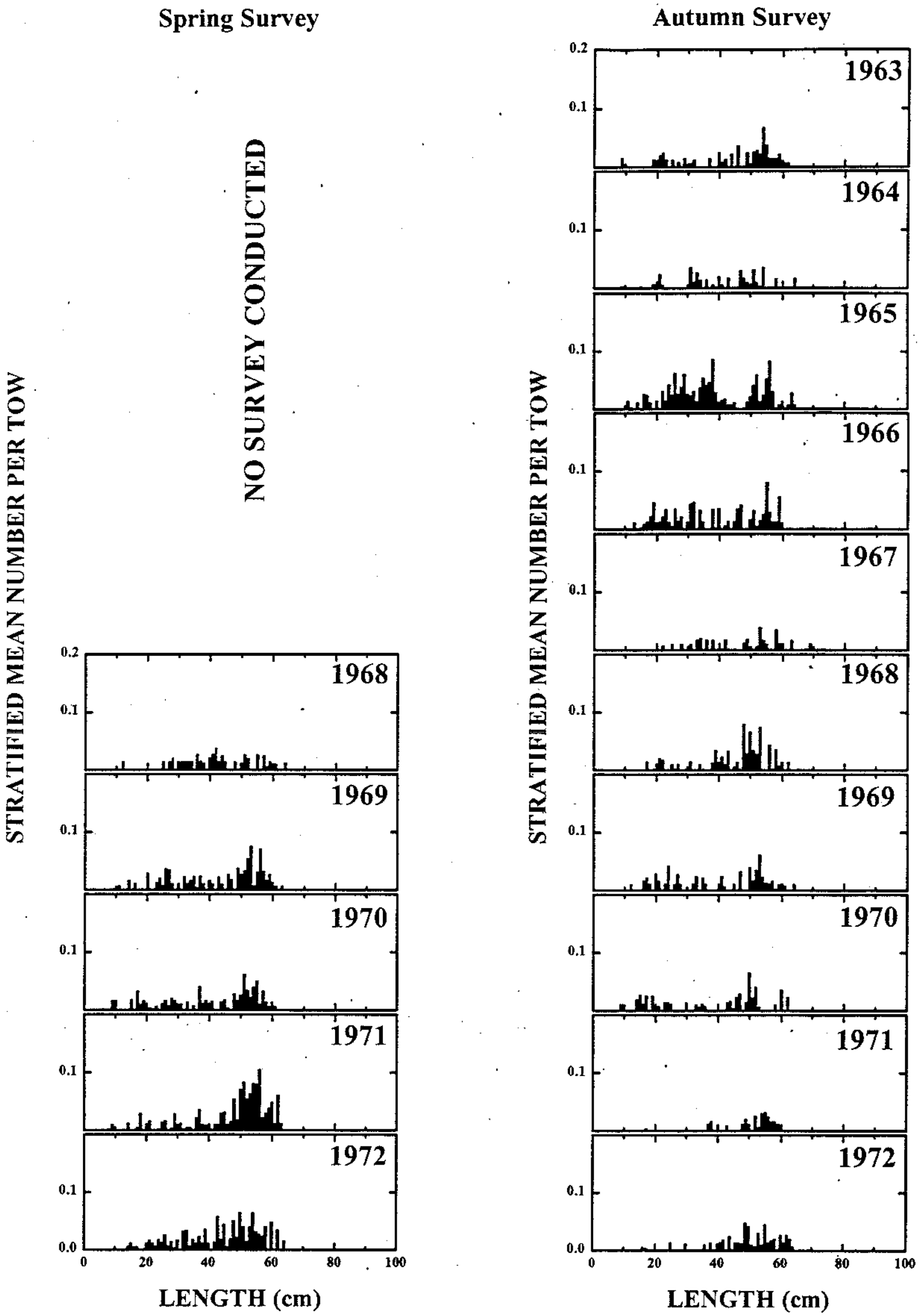


Figure B82. Smooth skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England region, 1963-1972.

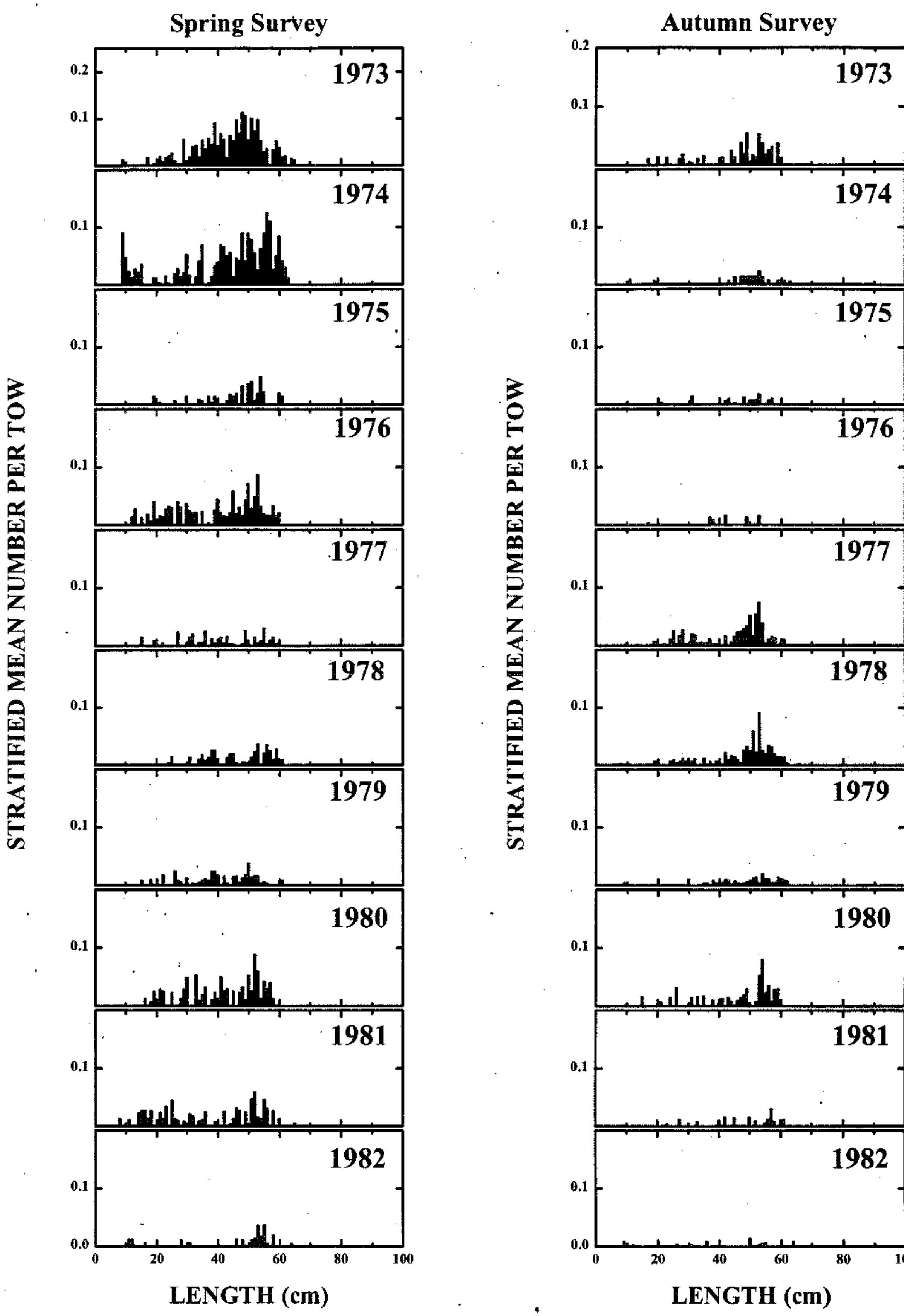


Figure B83. Smooth skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England offshore region, 1973-1982.

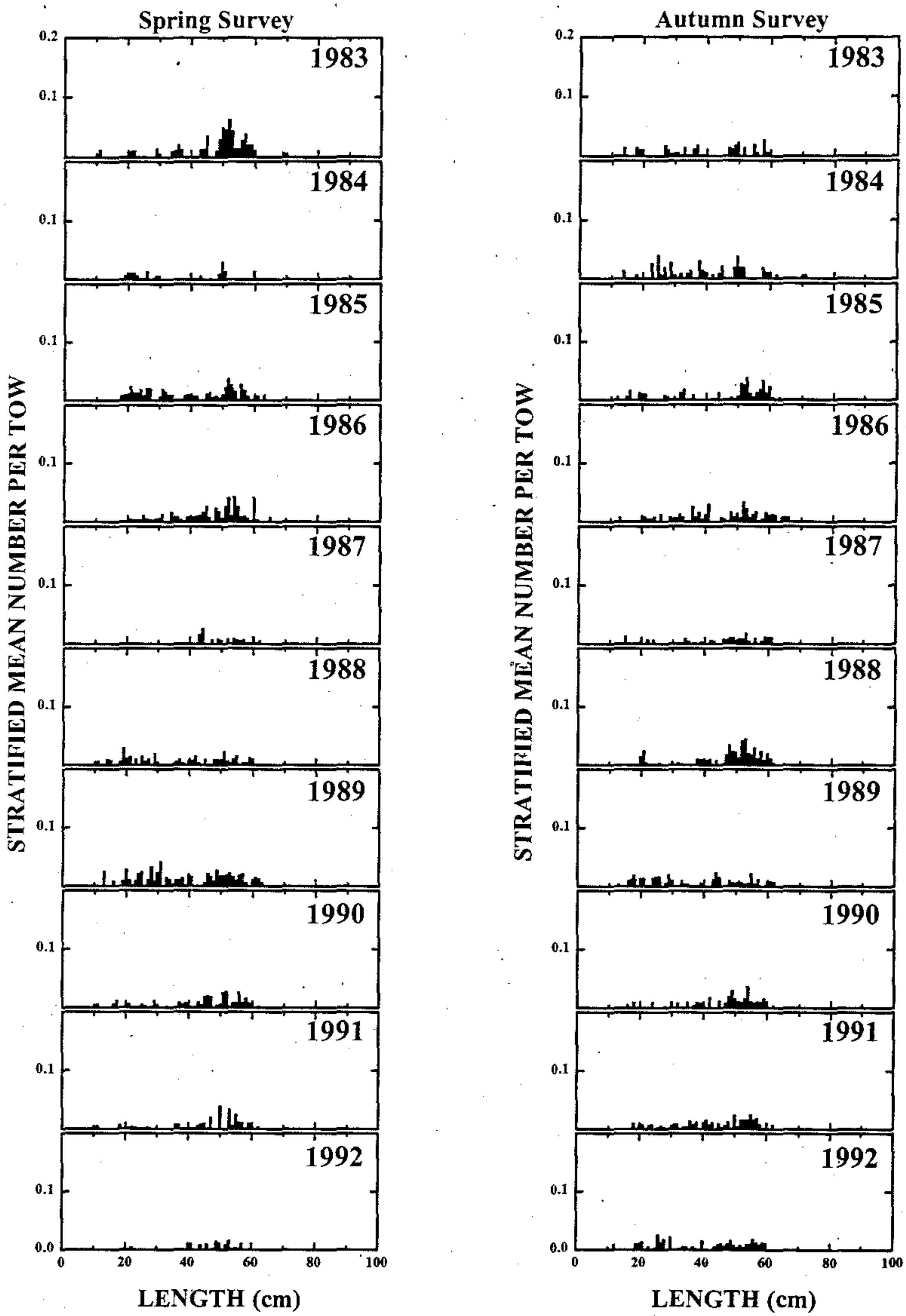


Figure B84. Smooth skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England region, 1983-1992.

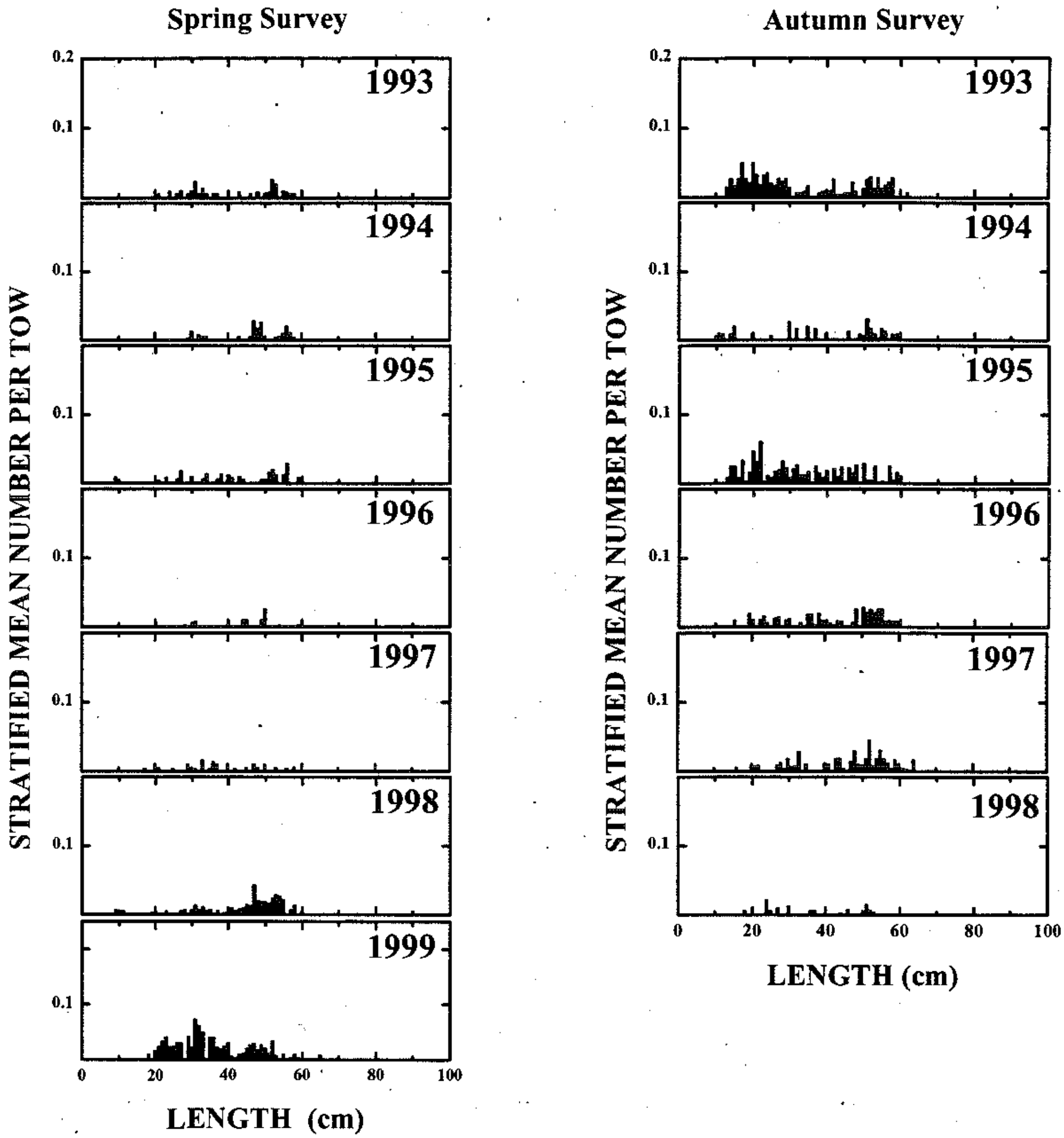
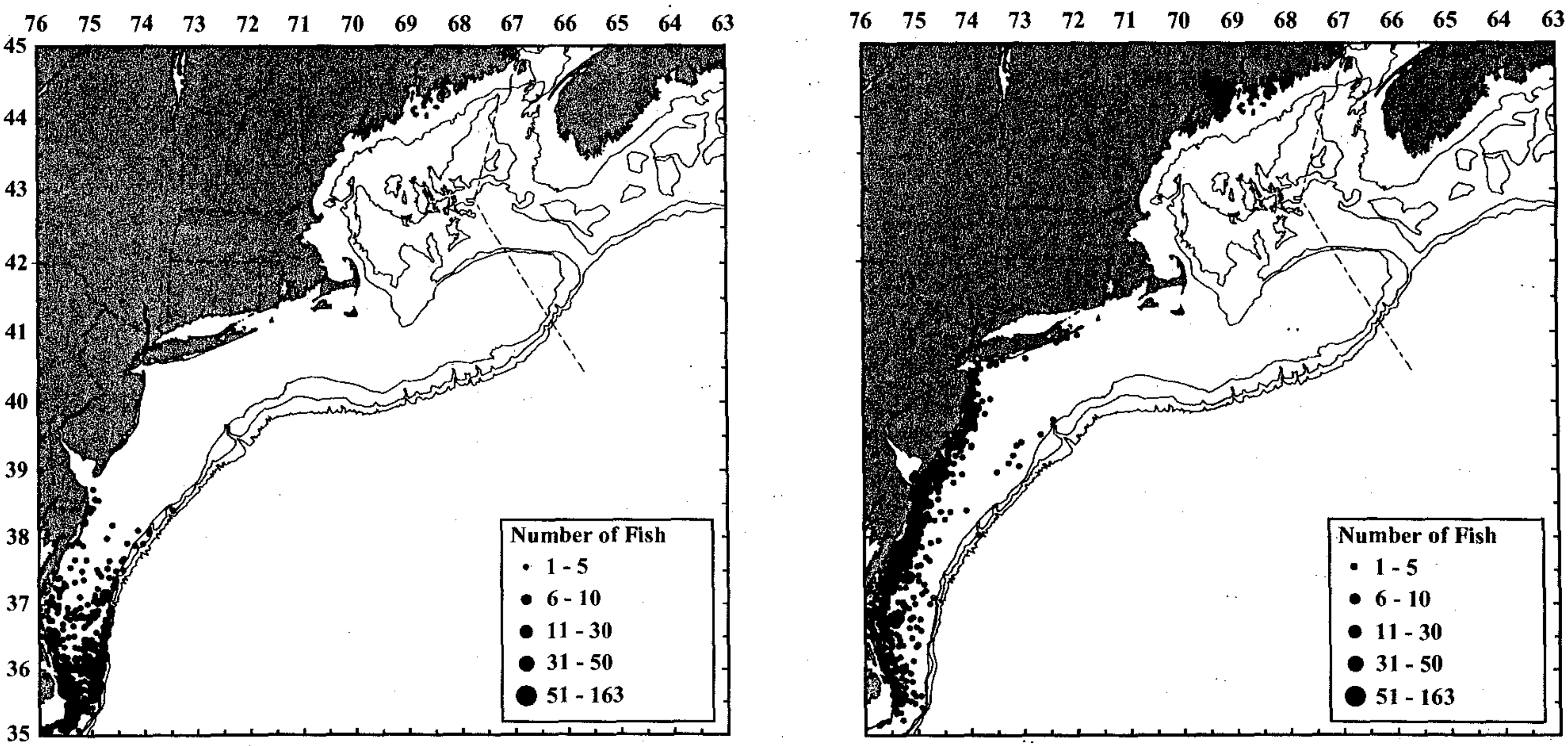


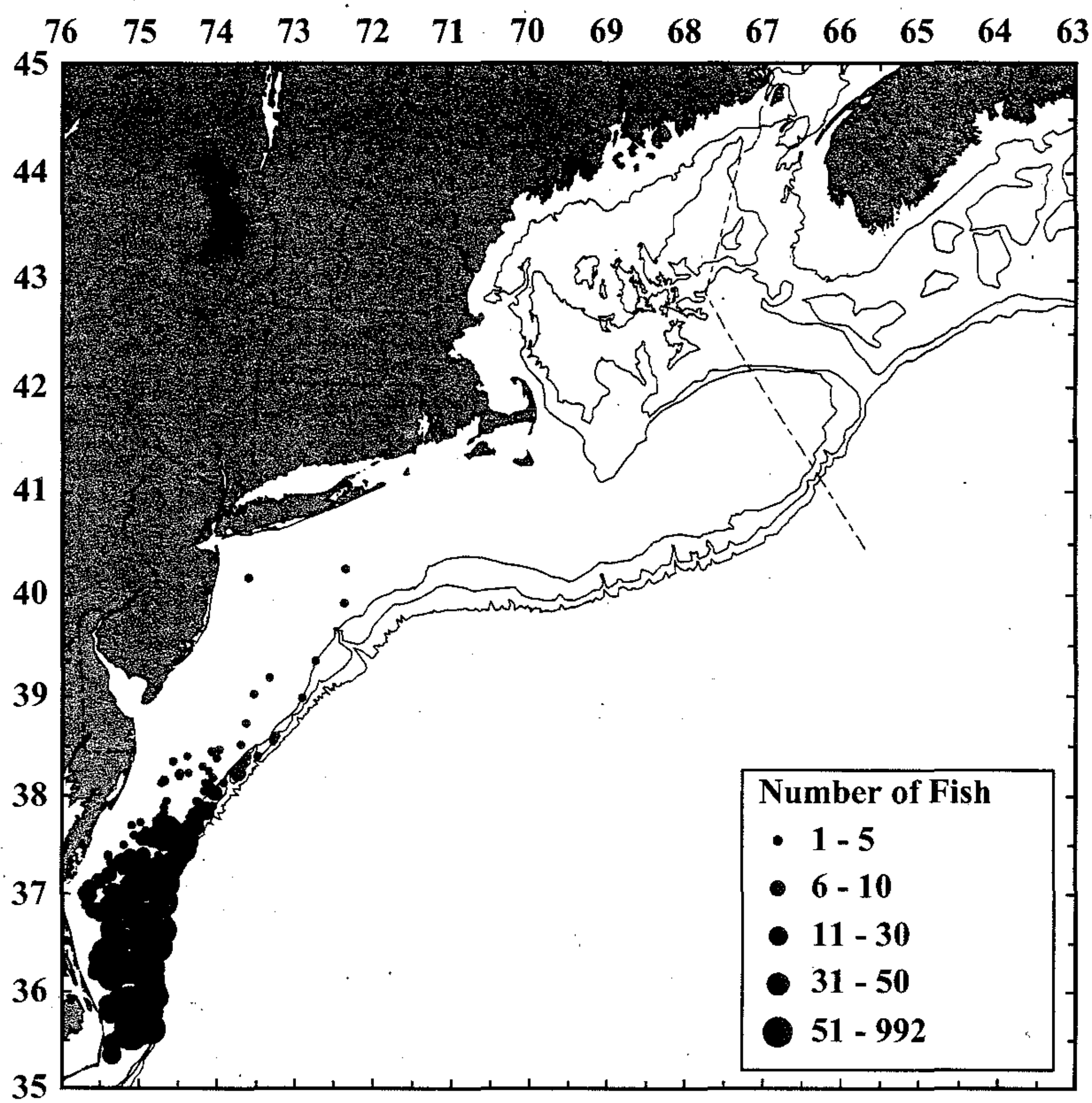
Figure B85. Smooth skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England offshore region, 1993-1999.



Clearnose Skate
NEFSC Spring Surveys 1968-1999

Clearnose Skate
NEFSC Autumn Surveys 1963-1998

Figure B86. Distribution of clearnose skate in the NEFSC spring and autumn surveys from 1963-1999.



Clearnose Skate
NEFSC Winter Surveys 1992-1999

Figure B87. Distribution of clearnose skate in the NEFSC winter surveys from 1992-1999.

Clearnose Skate
Mid-Atlantic All strata

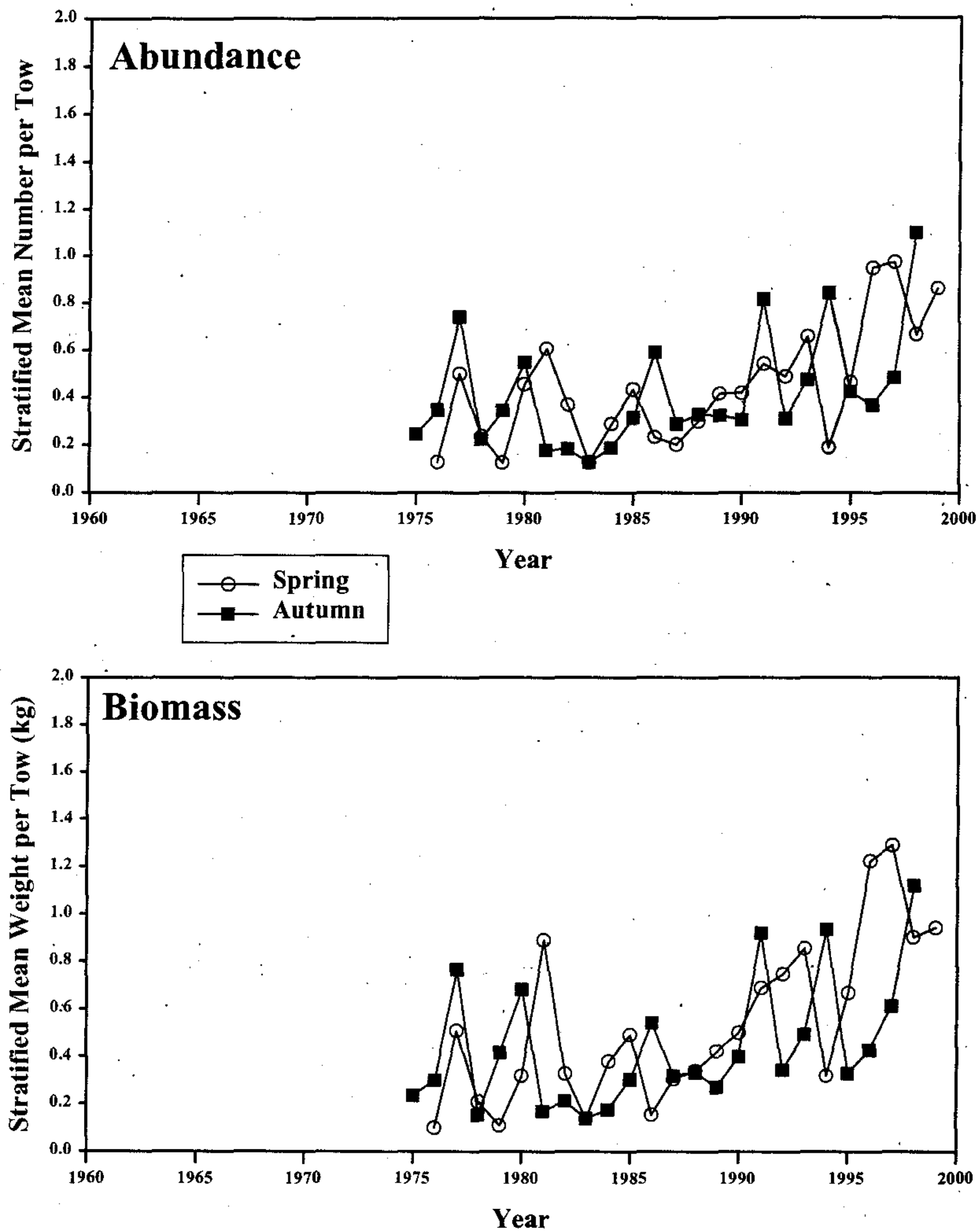


Figure B88. Abundance and biomass of clearnose skate from the NEFSC spring (circles) and autumn (squares) bottom trawl surveys from 1975-1999 in the Mid-Atlantic offshore and inshore regions.

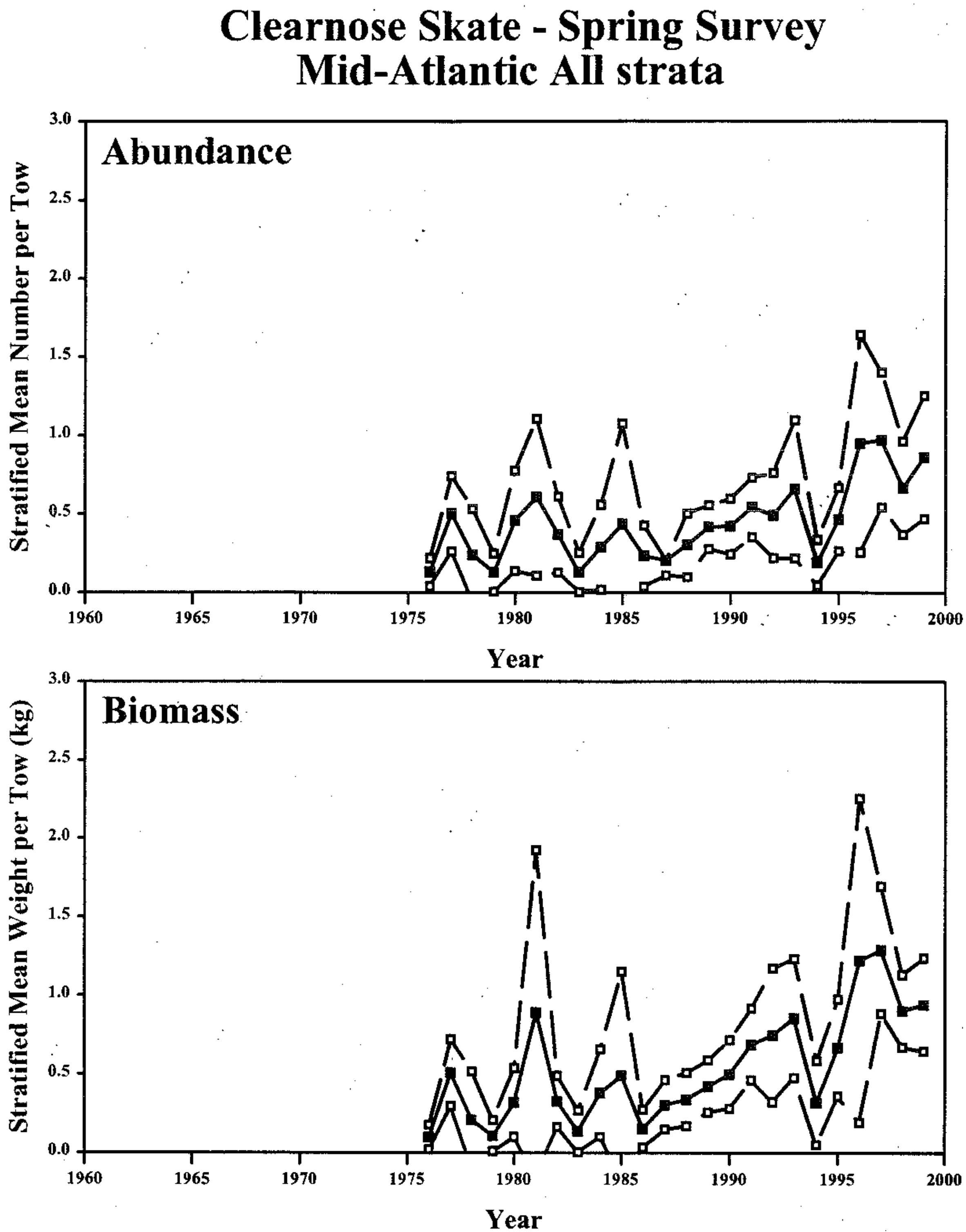


Figure B89. Abundance and biomass of clearnose skate from the NESFC spring bottom trawl survey in the Mid-Atlantic region, offshore and inshore regions. Mean index in solid squares, 95% confidence interval in open squares.

Clearnose Skate - Autumn Survey
Mid-Atlantic All strata

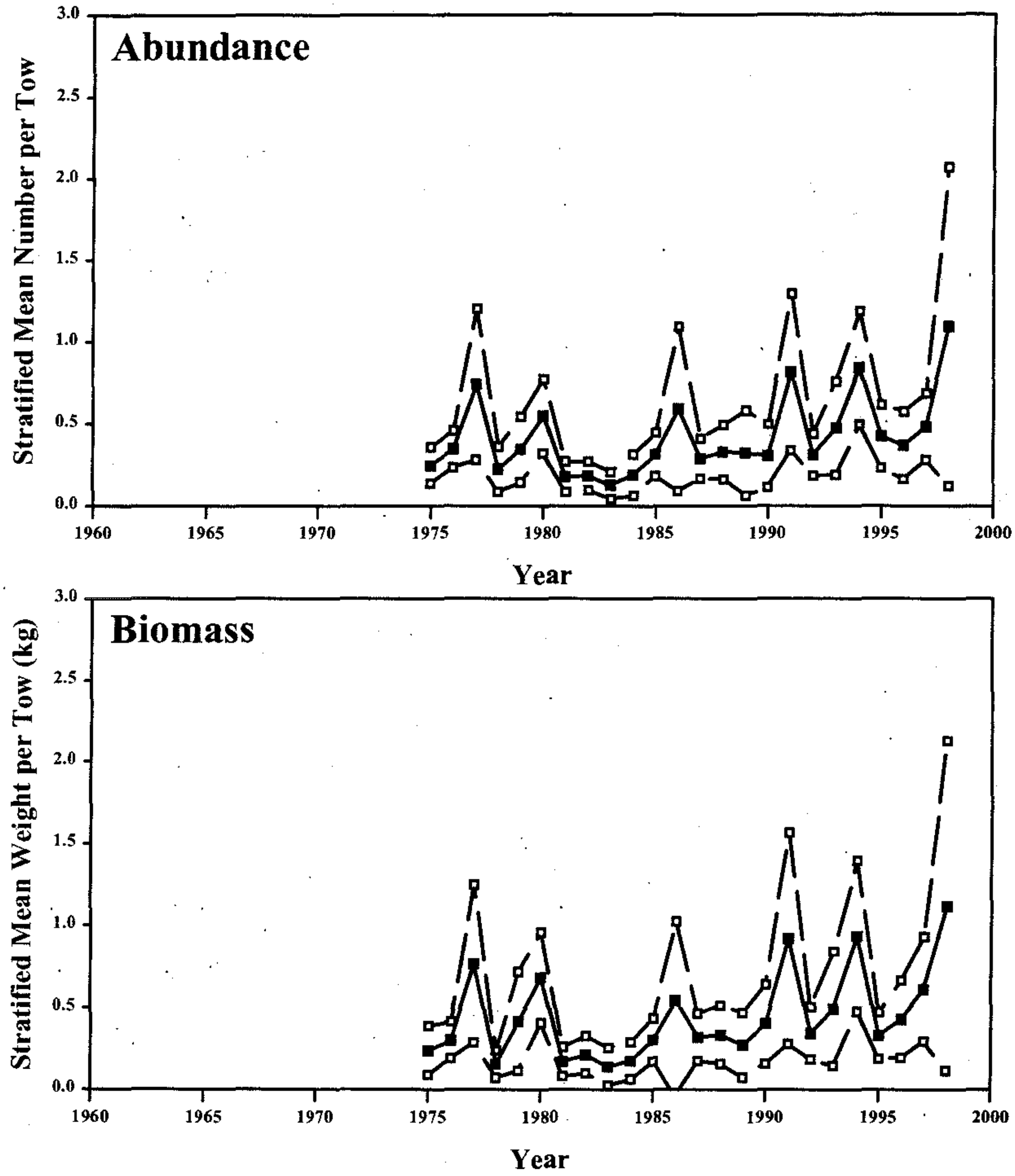
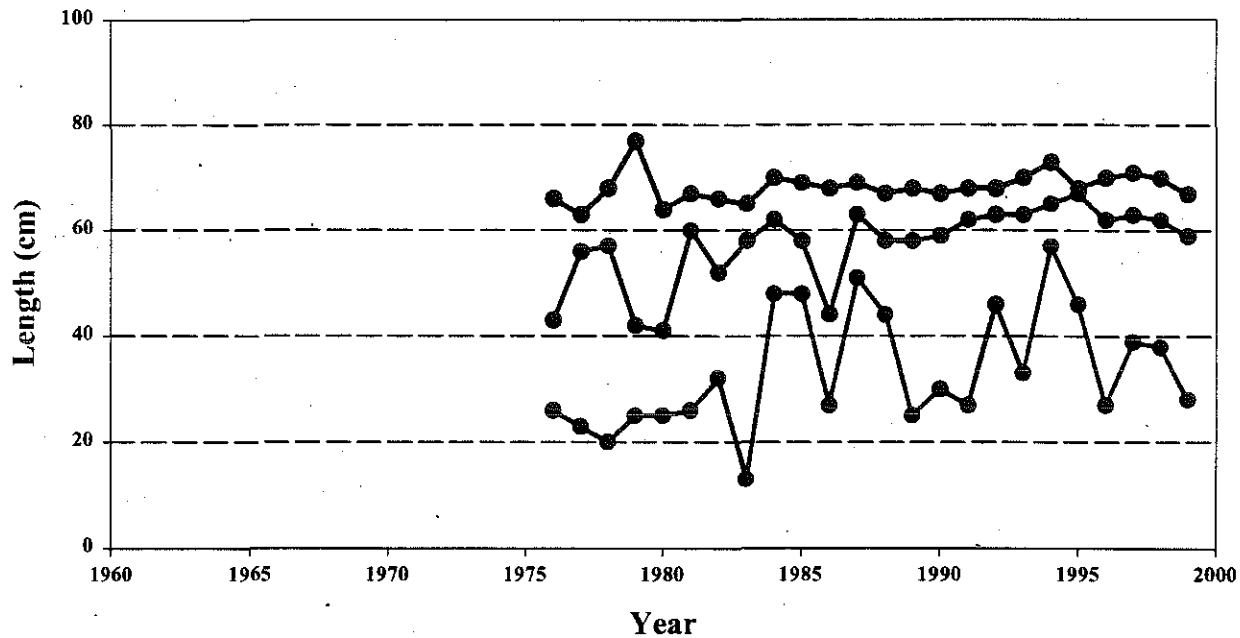


Figure B90. Abundance and biomass of clearnose skate from the NESFC autumn bottom trawl survey in the Mid-Atlantic region, offshore and inshore regions. Mean index in solid squares, 95% confidence interval in open squares.

Clearnose Skate
Percentiles of Length Composition

Spring Survey



Autumn Survey

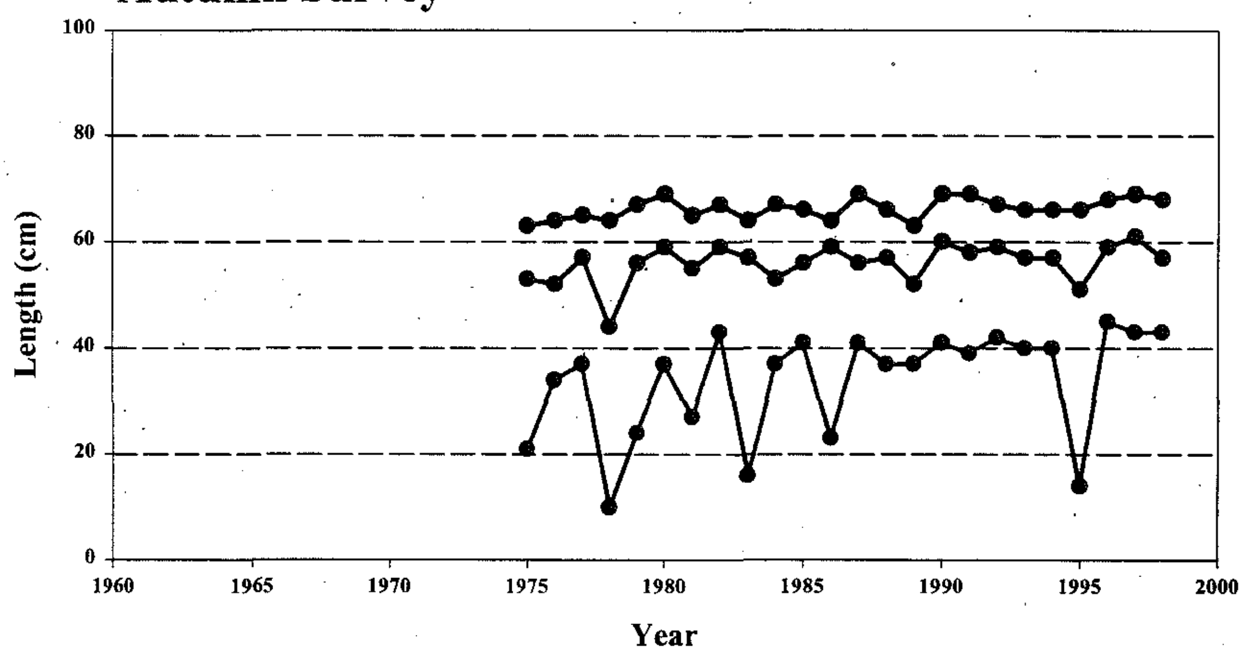


Figure B91. Percentiles of length composition (5, 50, 95) of clearnose skate from the NESFC spring and autumn bottom trawl surveys from 1975-1999 in the Mid-Atlantic offshore and inshore regions.

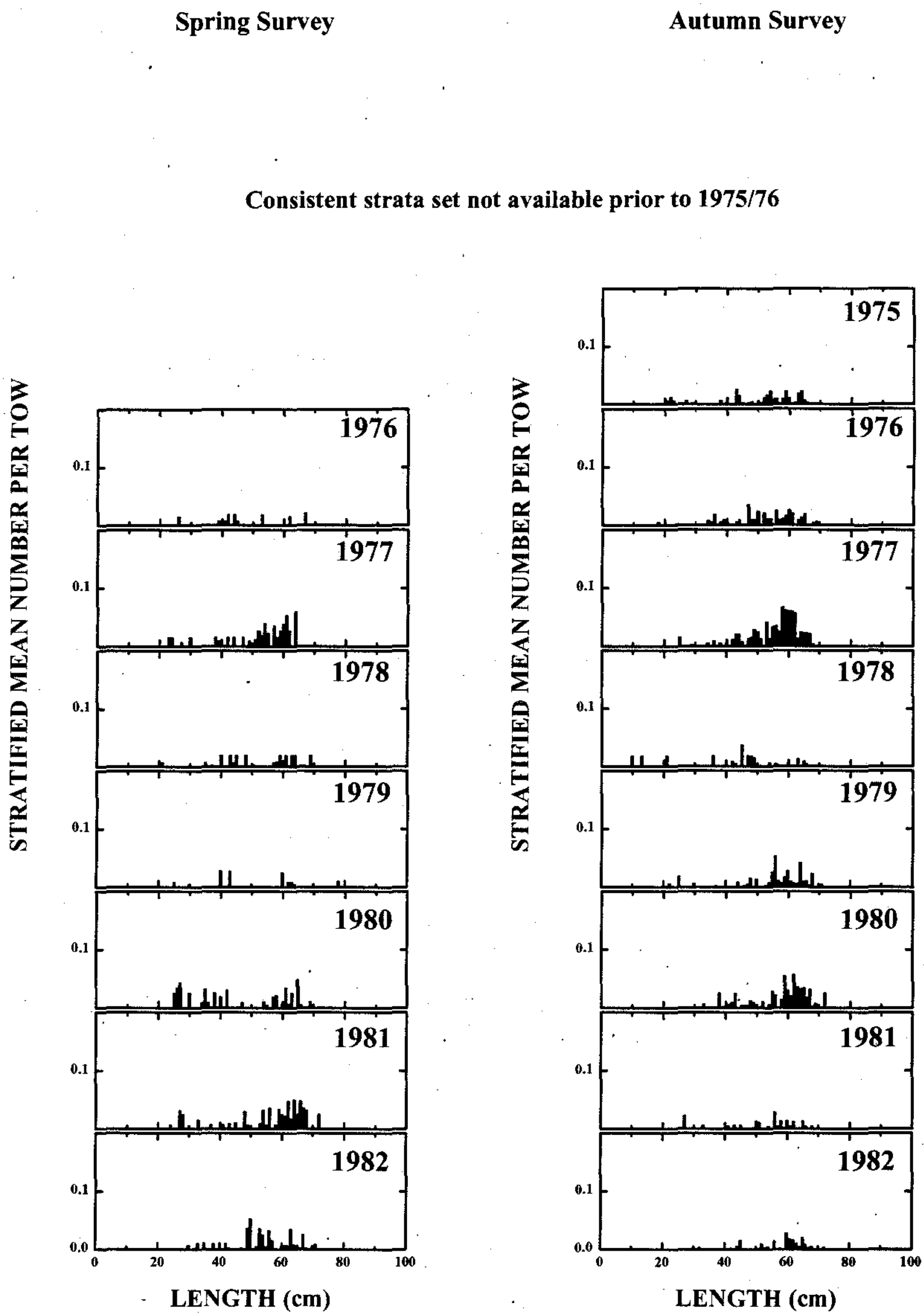


Figure B92. Clearnose skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Mid-Atlantic offshore and inshore regions, 1975-1982.

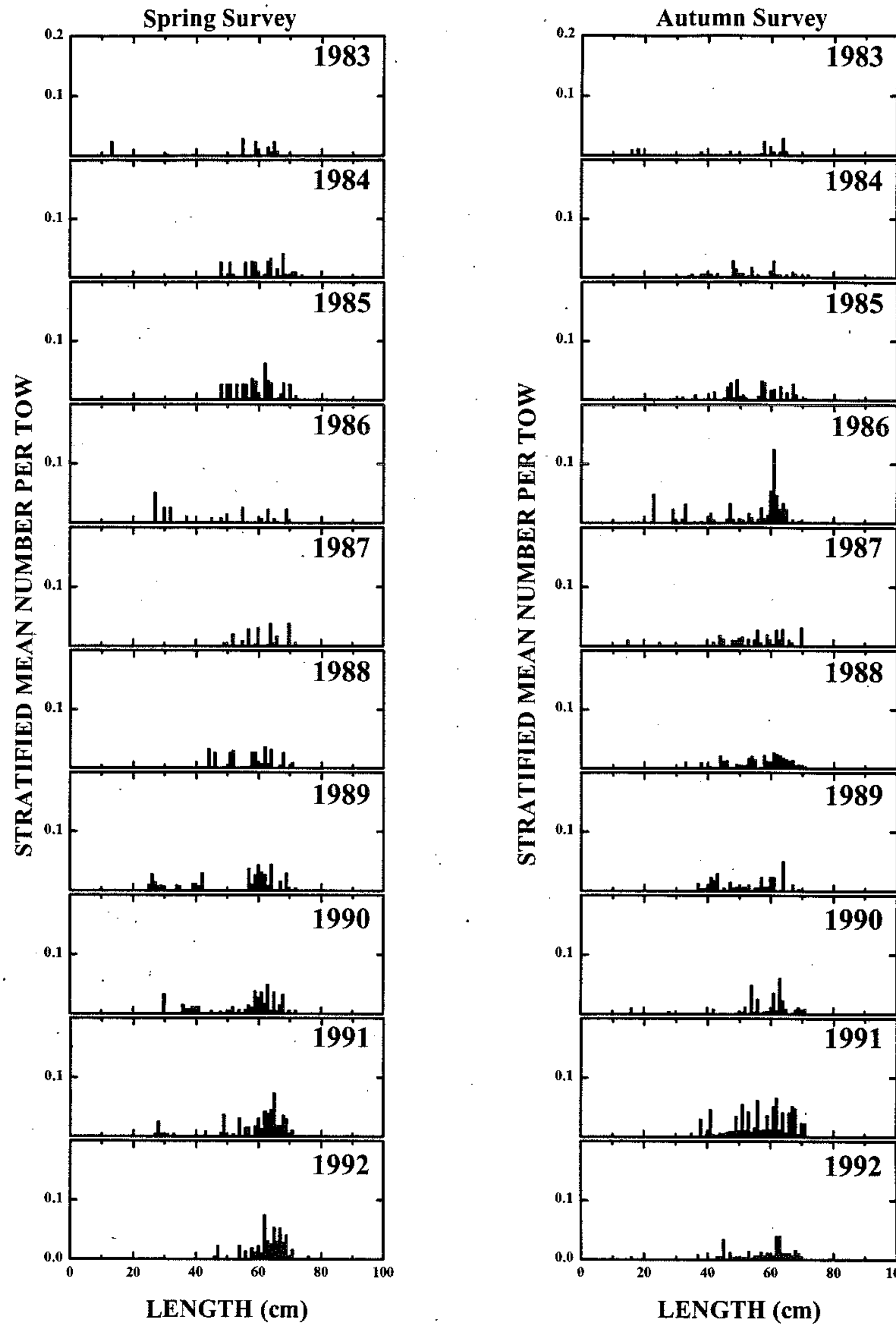


Figure B93. Clearnose skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Mid-Atlantic offshore and inshore regions, 1983-1992.

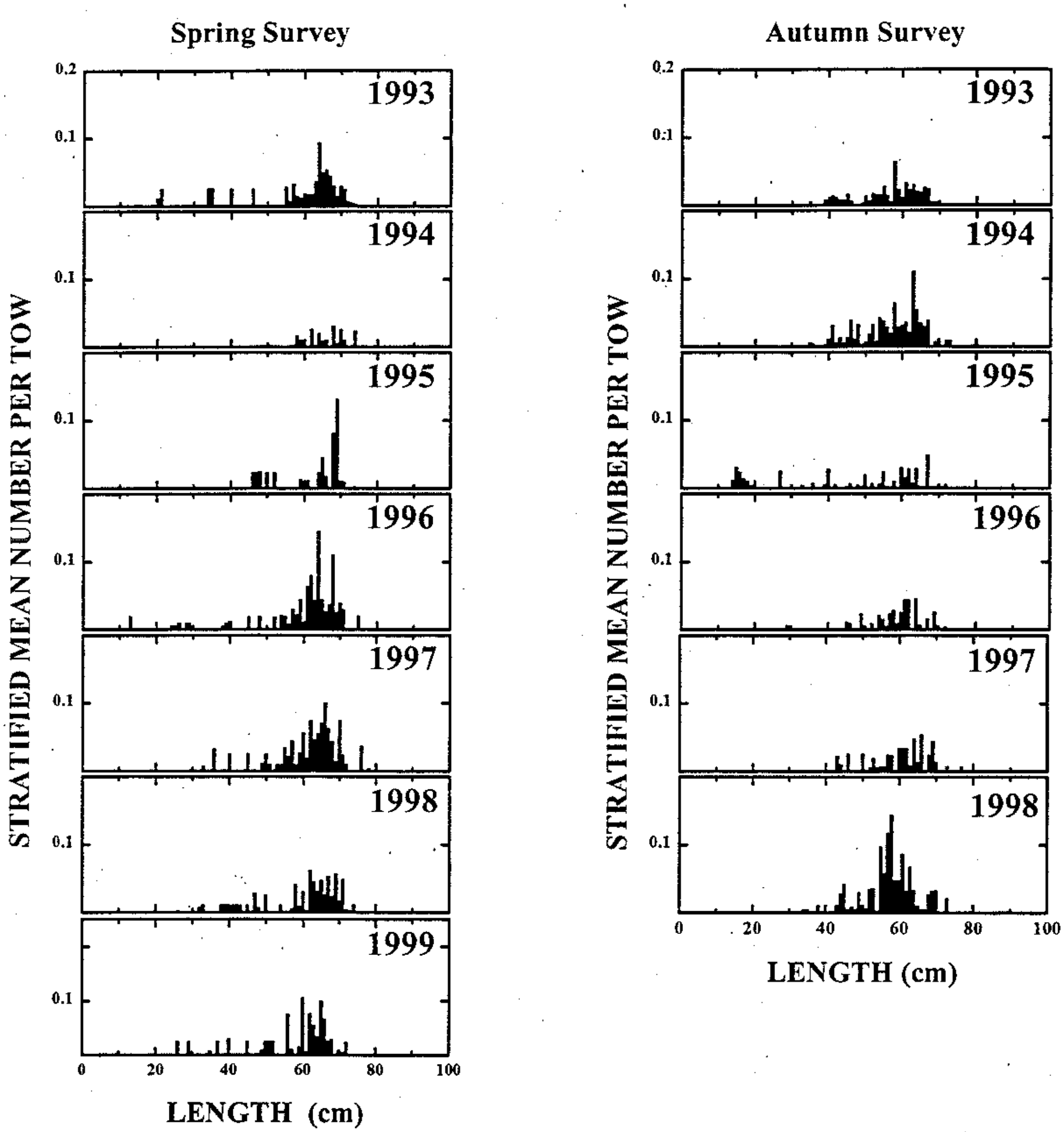
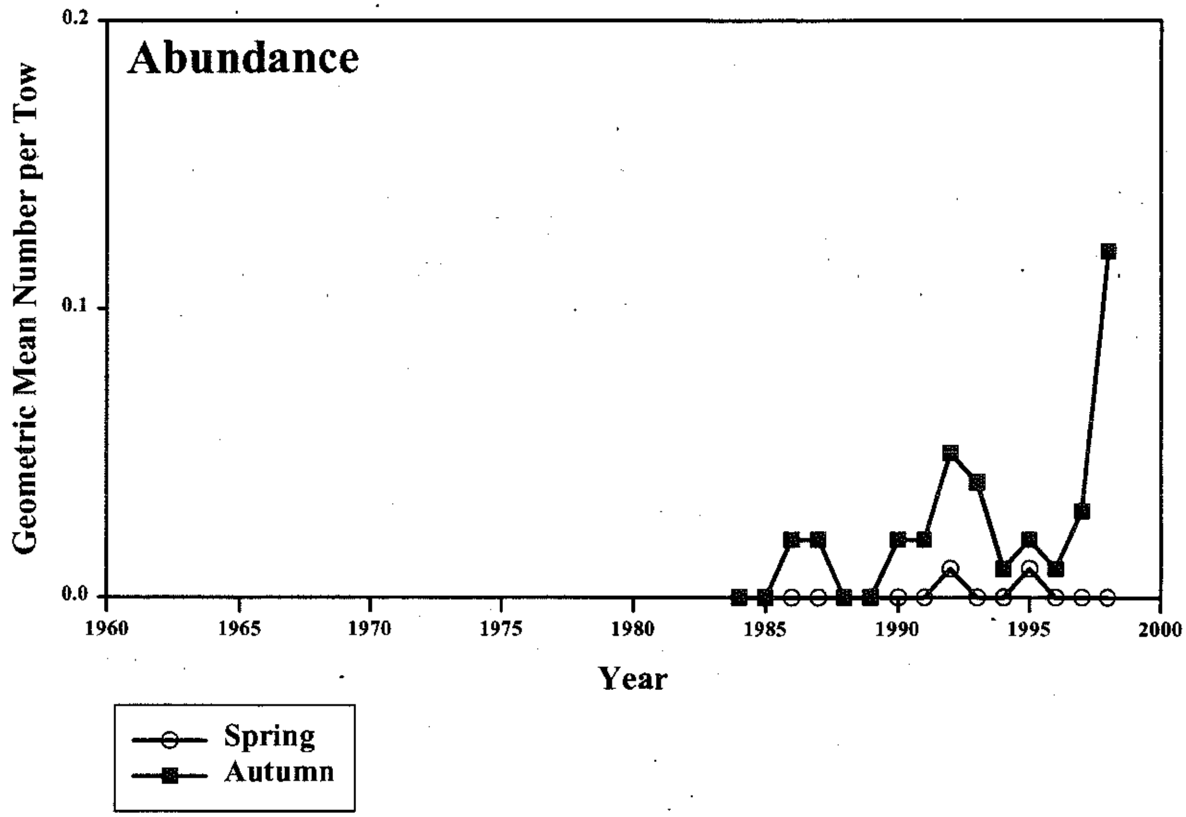


Figure B94. Clearnose skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Mid-Atlantic offshore and inshore regions, 1993-1999.

Clearnose Skate - CTDEP Finfish Survey



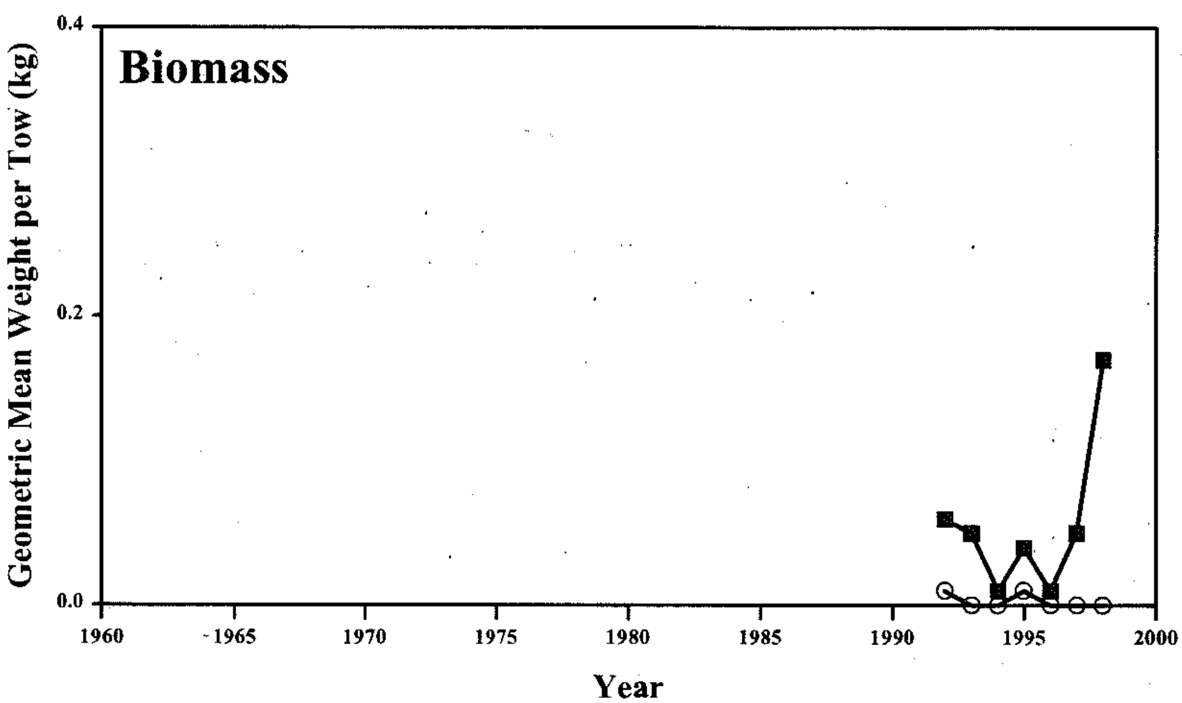


Figure B95. Abundance and biomass of clearnose skate from the CTDEP spring and autumn finfish bottom trawl survey in Connecticut state waters.

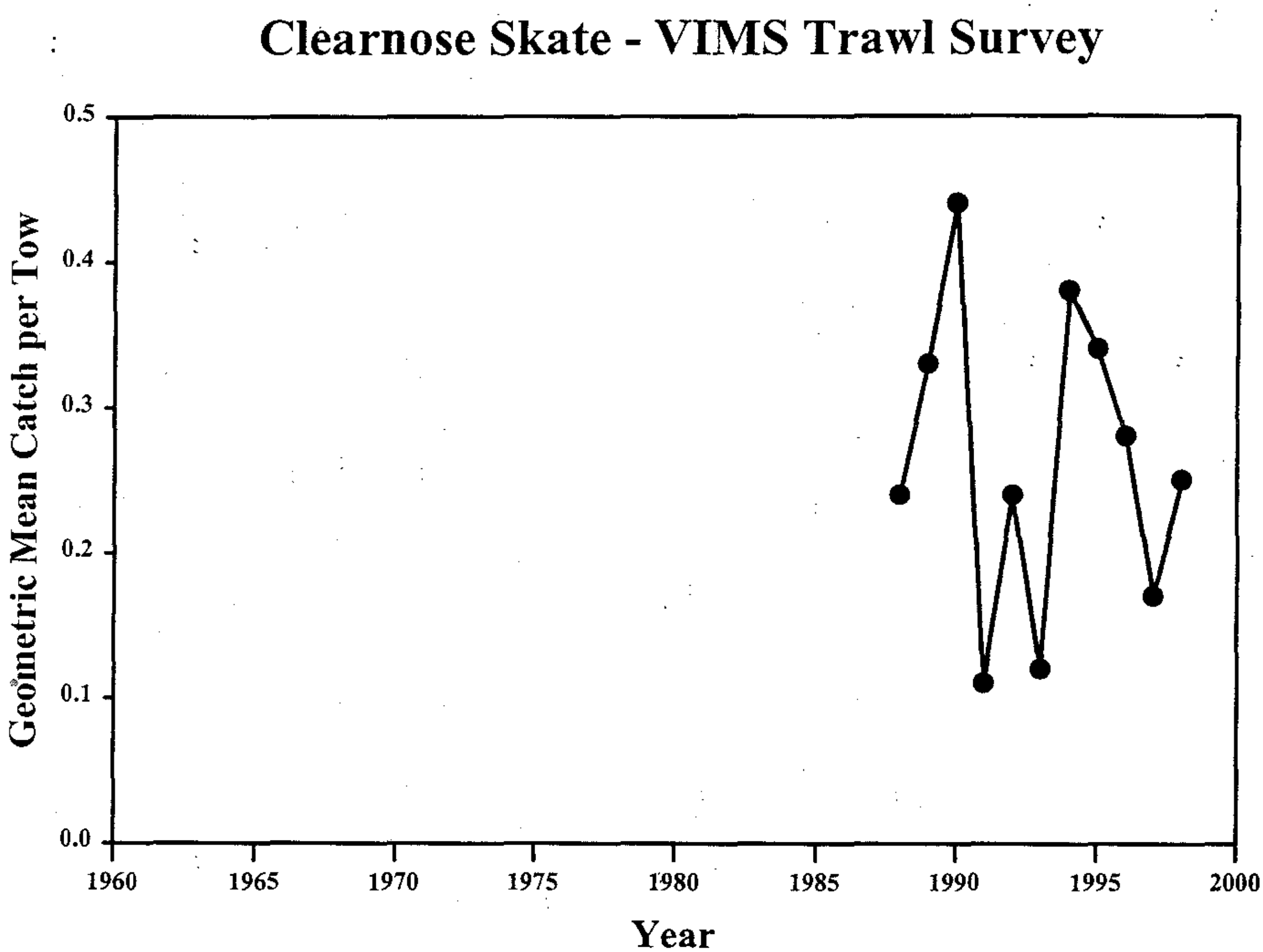
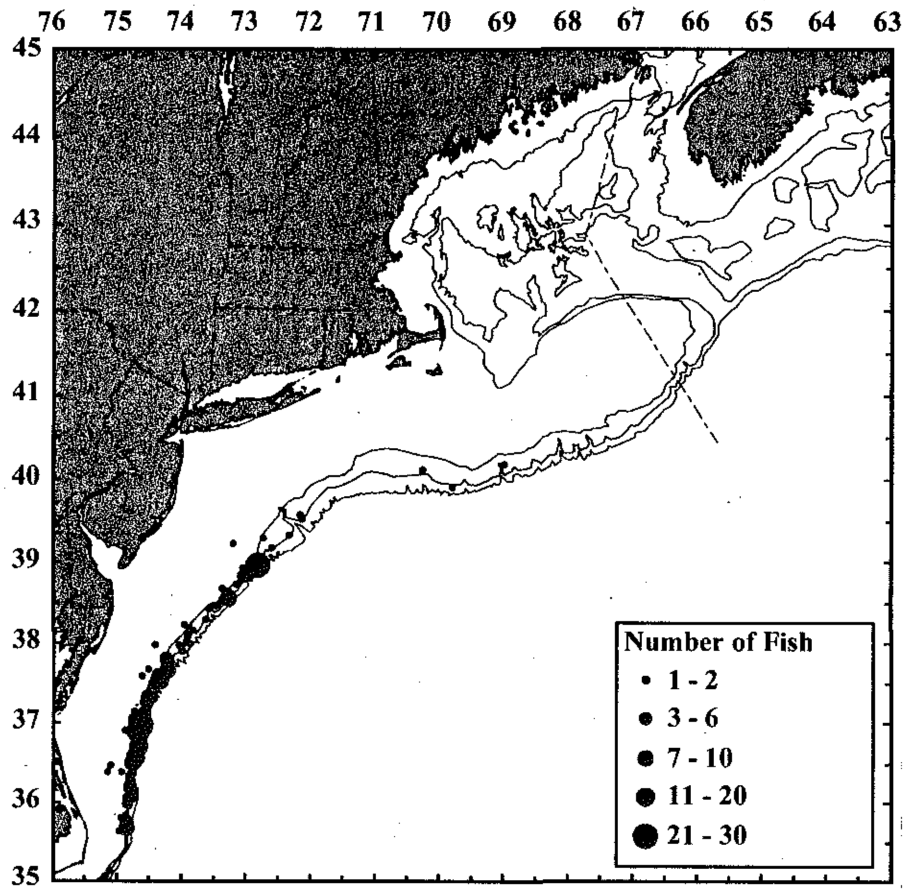
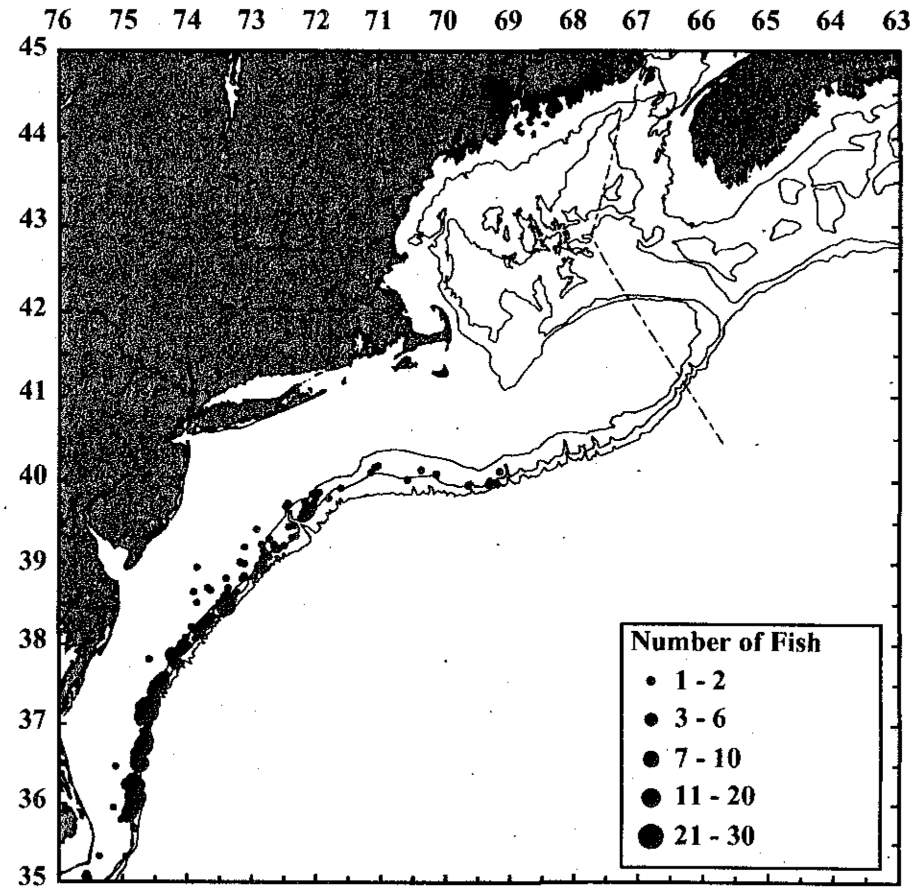


Figure B96. Abundance of clearnose skate from the VIMS trawl survey, 1988-1998.

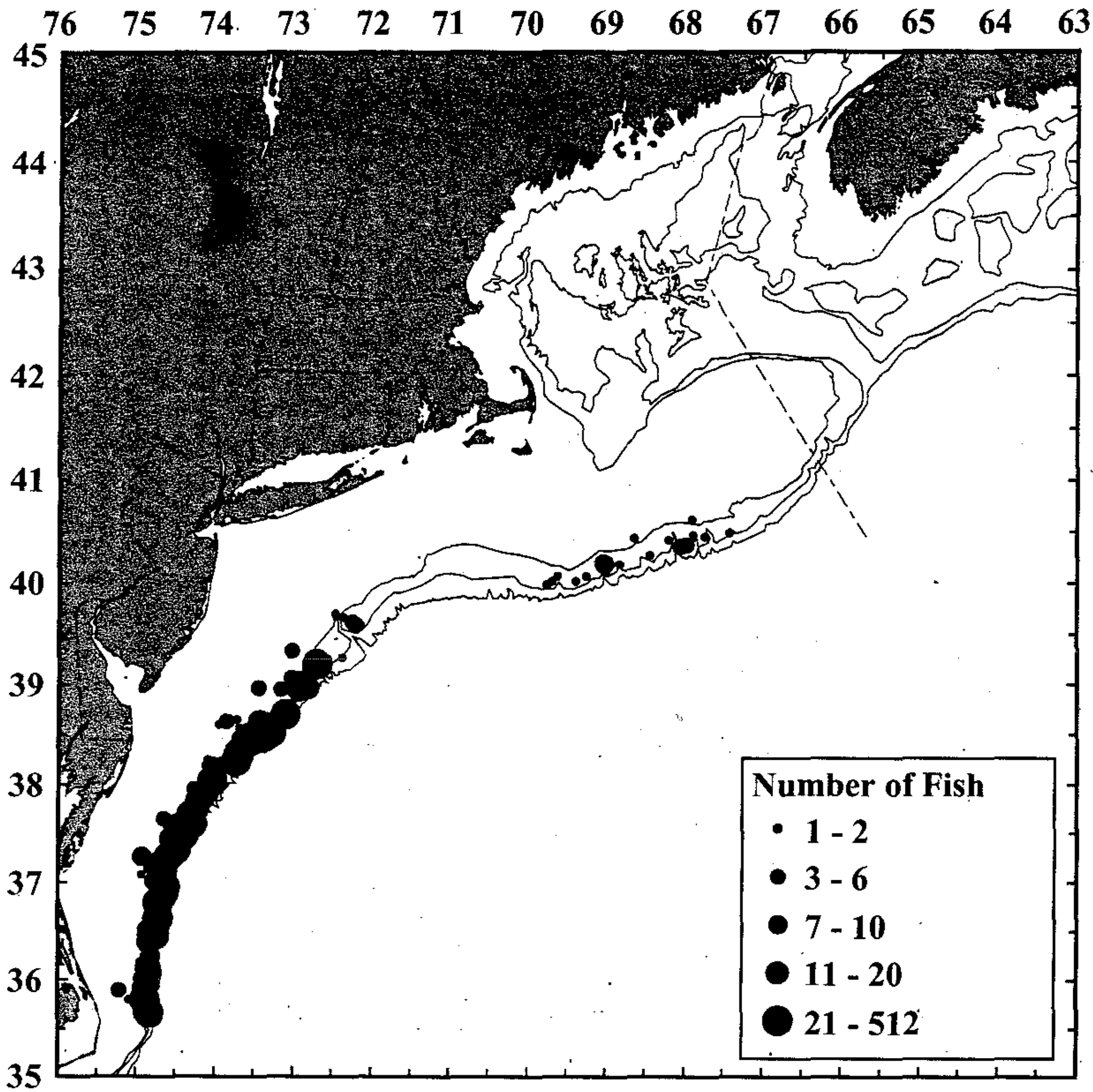


Rosette Skate
NEFSC Spring Surveys 1968-1999



Rosette Skate
NEFSC Autumn Surveys 1963-1998

Figure B97. Distribution of rosette skate in the NEFSC spring and autumn surveys from 1963-1999.



Rosette Skate
NEFSC Winter Surveys 1992-1999

Figure B98. Distribution of rosette skate in the NEFSC winter surveys from 1992-1999.

Rosette Skate
Mid-Atlantic Offshore strata

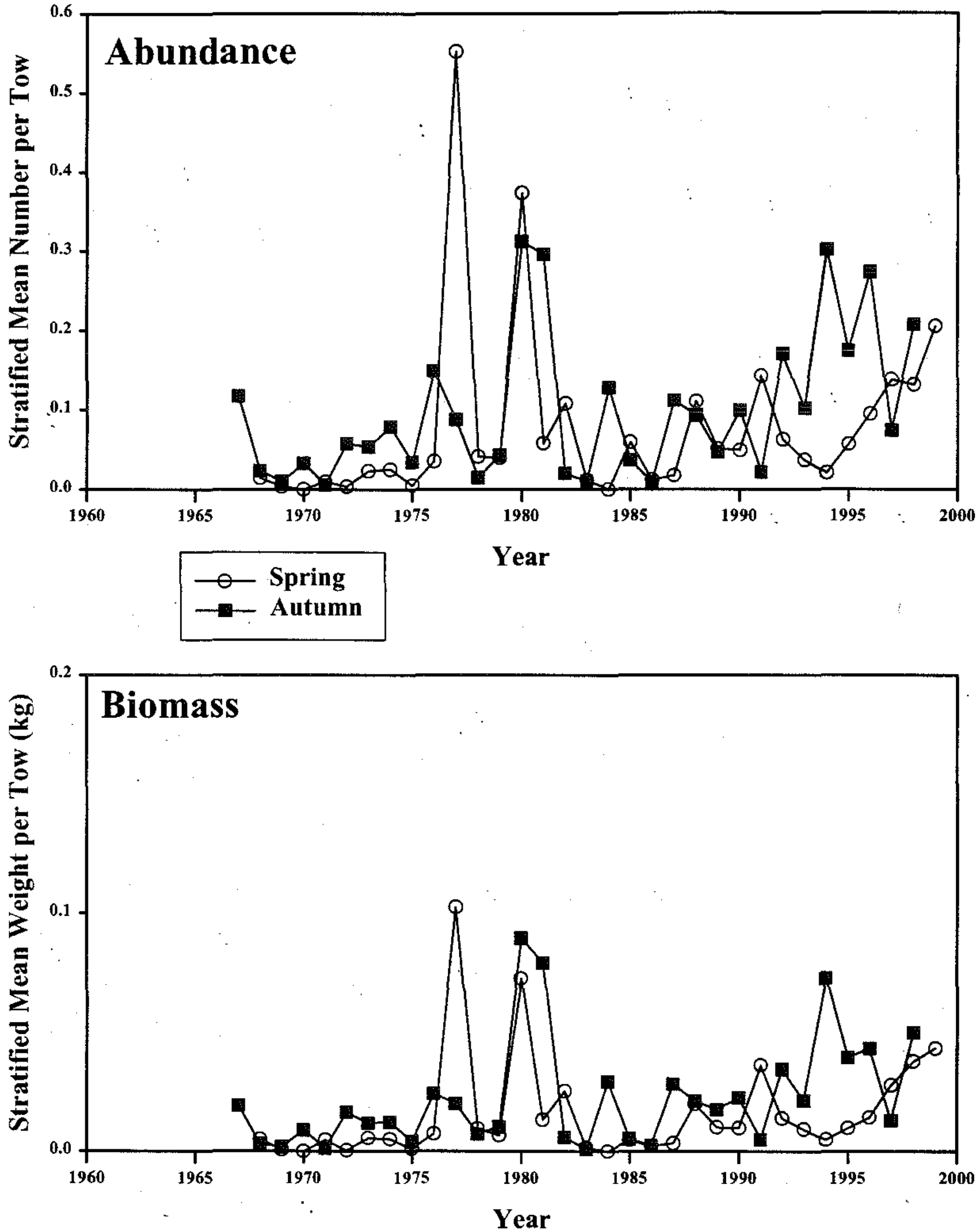


Figure B99. Abundance and biomass of rosette skate from the NESFC spring (circles) and autumn (squares) bottom trawl surveys from 1967-1999 in the Mid-Atlantic offshore region.

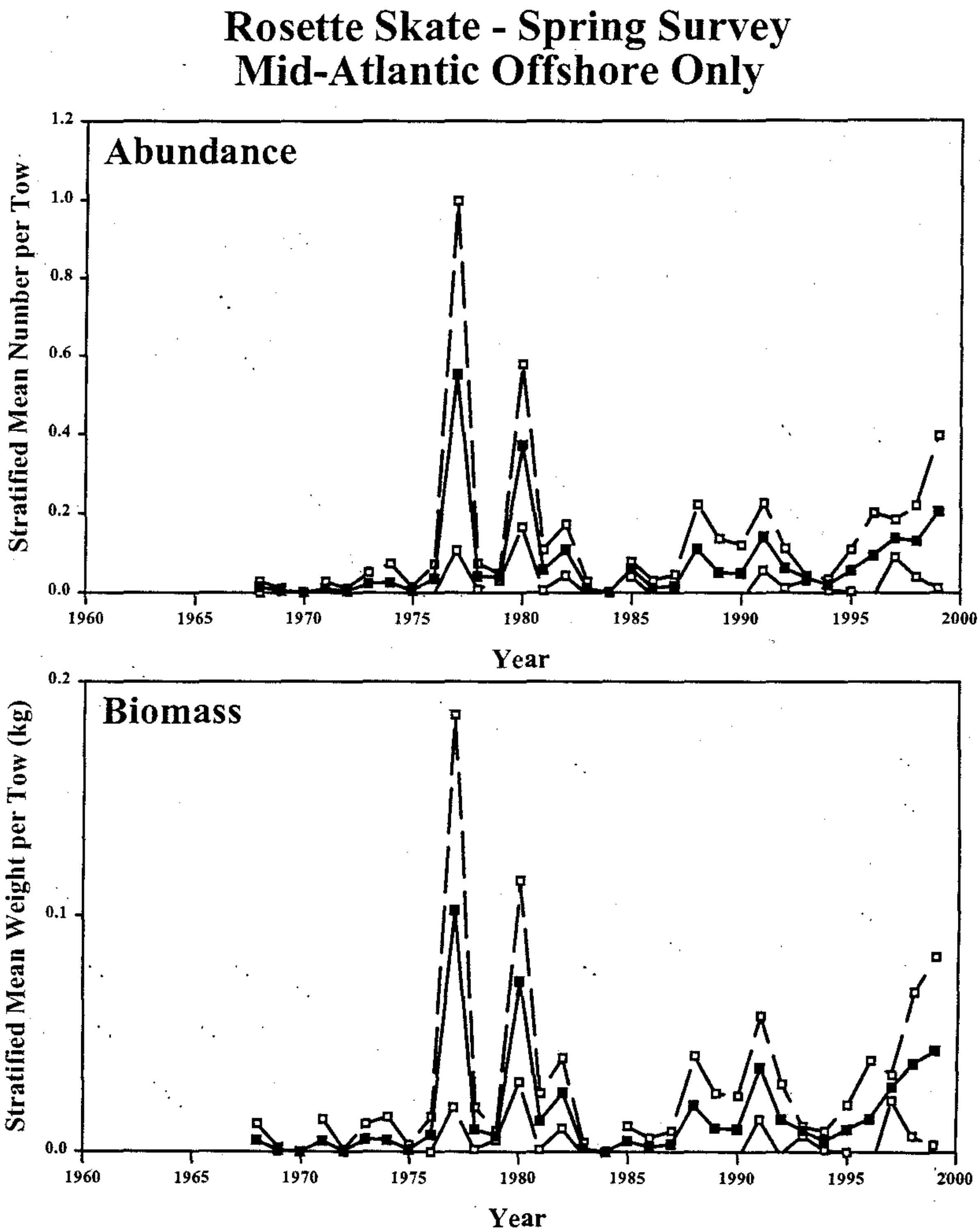
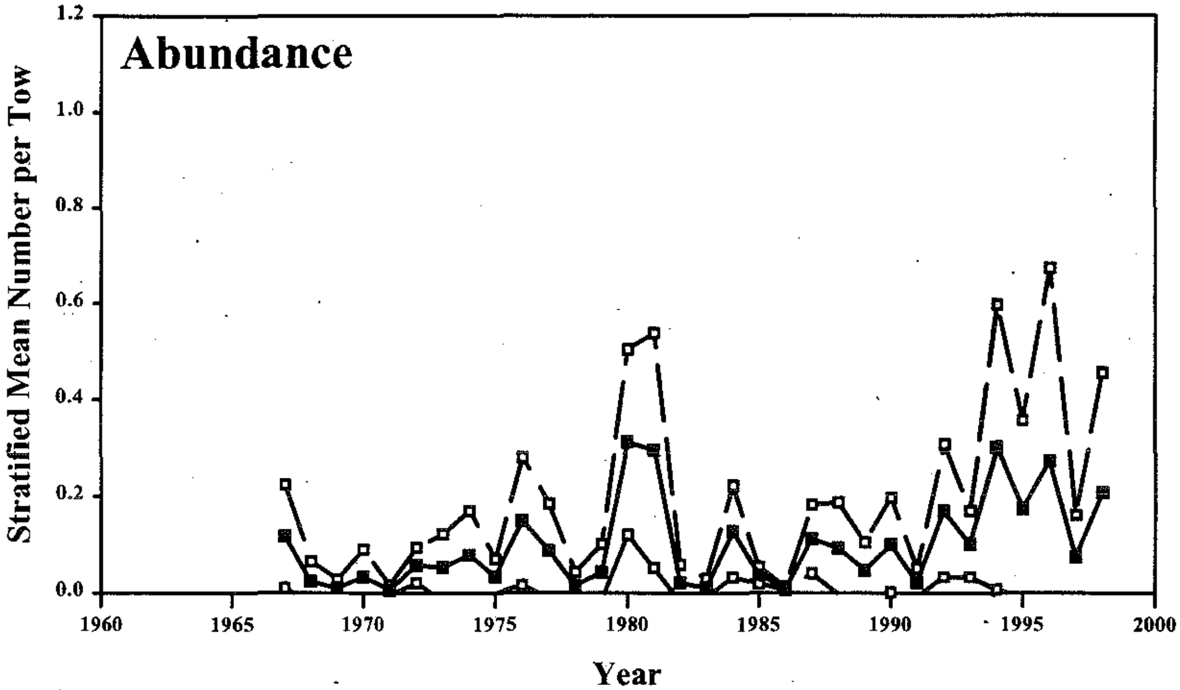


Figure B100. Abundance and biomass of rosette skate from the NESFC spring bottom trawl survey in the Mid-Atlantic region, offshore strata only. Mean index in solid squares, 95% confidence interval in open squares.

Rosette Skate - Autumn Survey
Mid-Atlantic Offshore Only



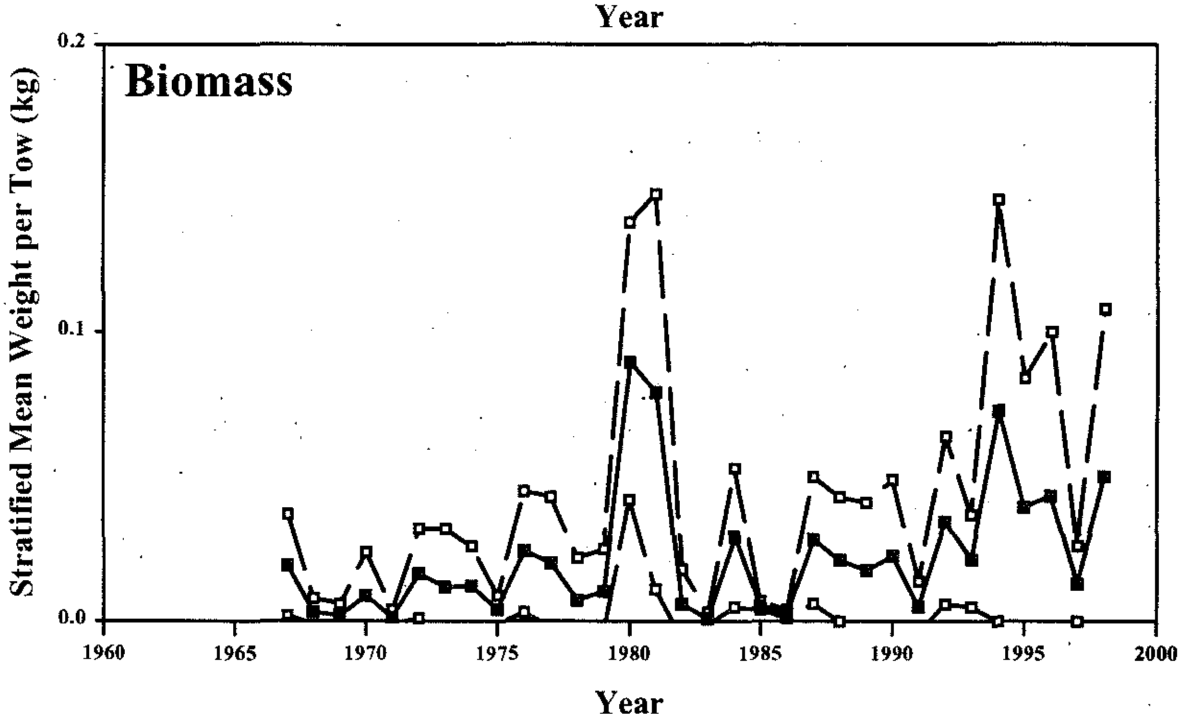
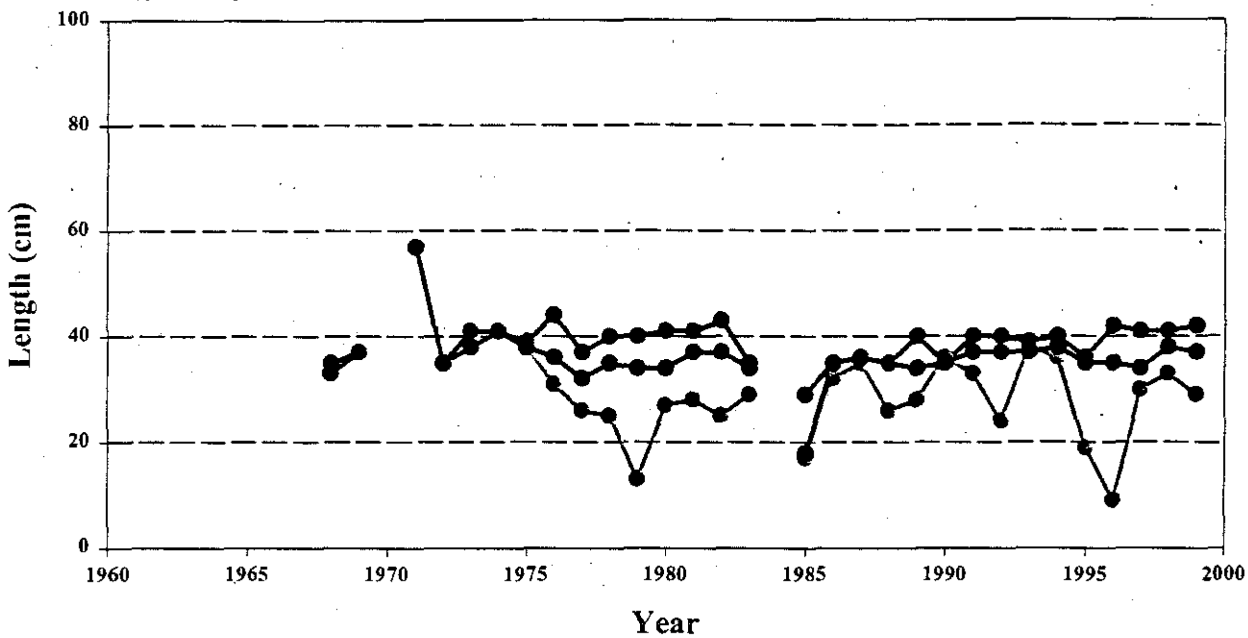


Figure B101. Abundance and biomass of rosette skate from the NESFC autumn bottom trawl survey in the Mid-Atlantic region, offshore strata only. Mean index in solid squares, 95% confidence interval in open squares.

Rosette Skate
Percentiles of Length Composition

Spring Survey



Autumn Survey

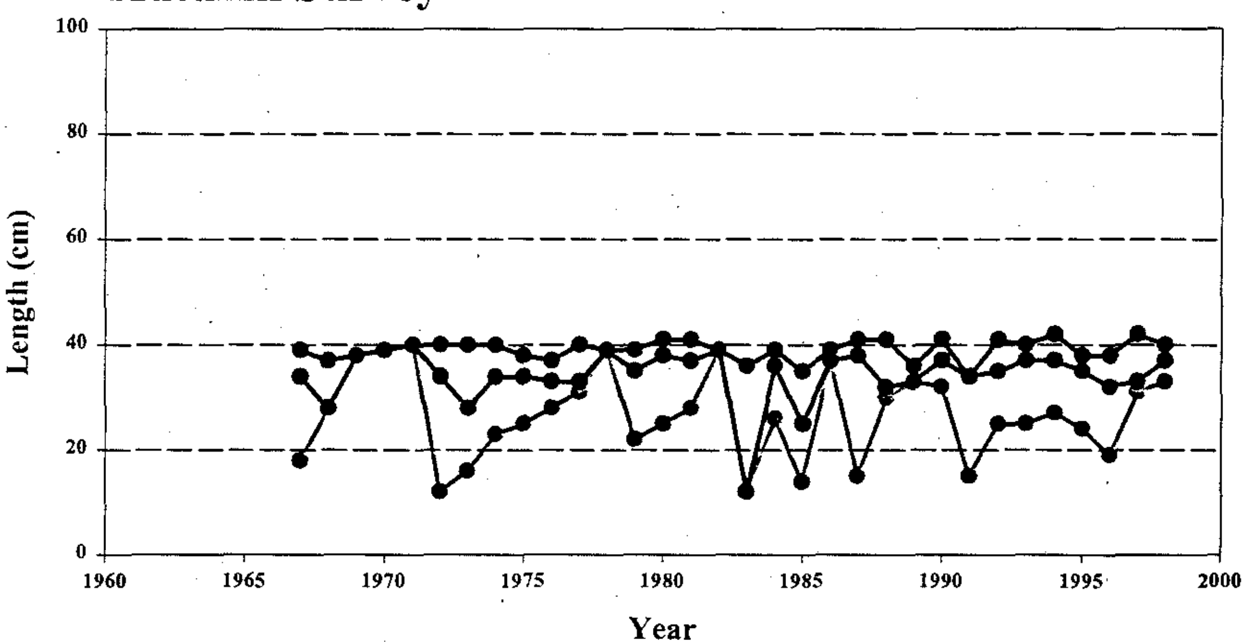


Figure B102. Percentiles of length composition (5, 50 95) of rosette skate from the NESFC spring and autumn bottom trawl surveys from 1967-1999 in the Mid-Atlantic offshore region.

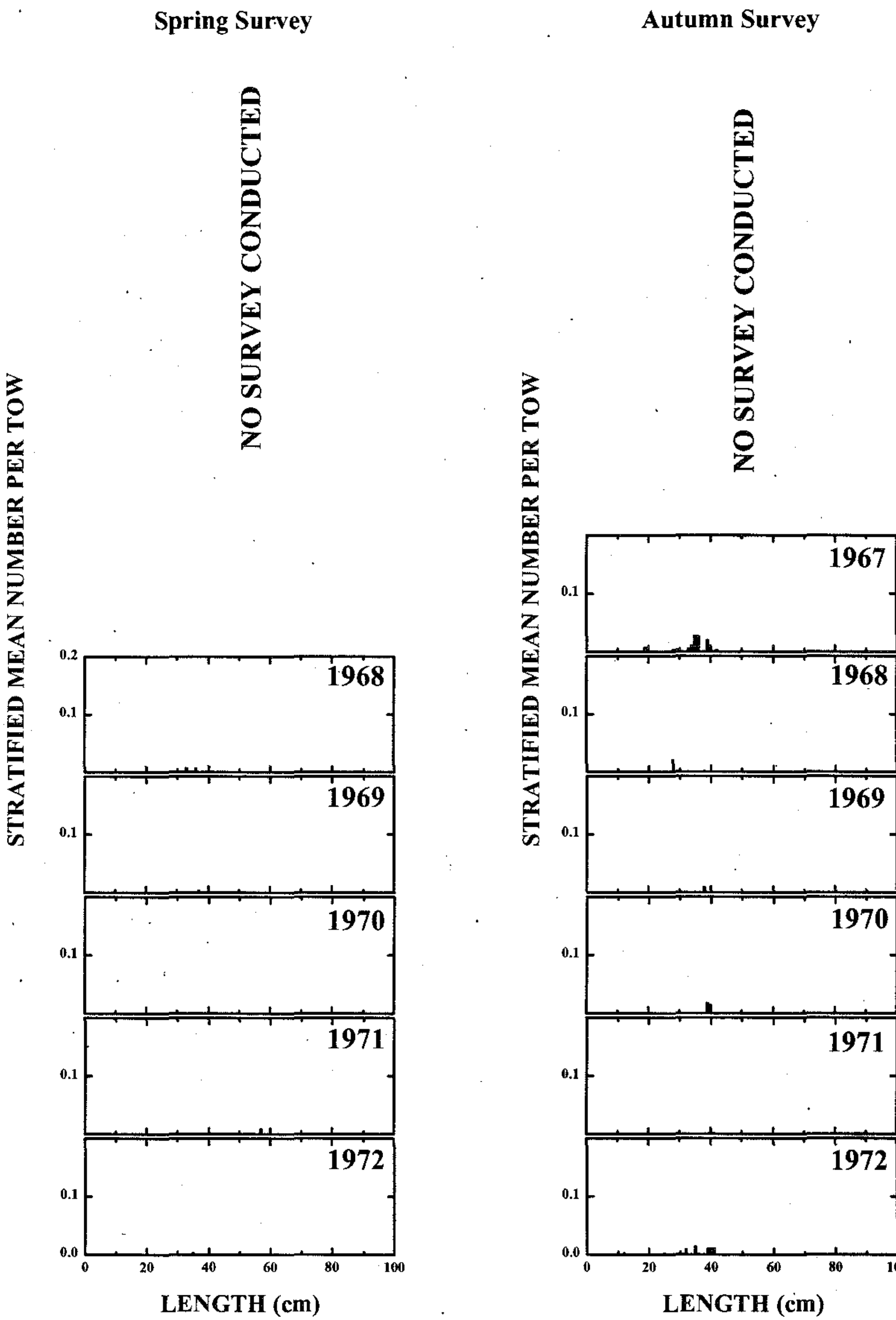


Figure B103. Rosette skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Mid-Atlantic offshore region, 1967-1972.

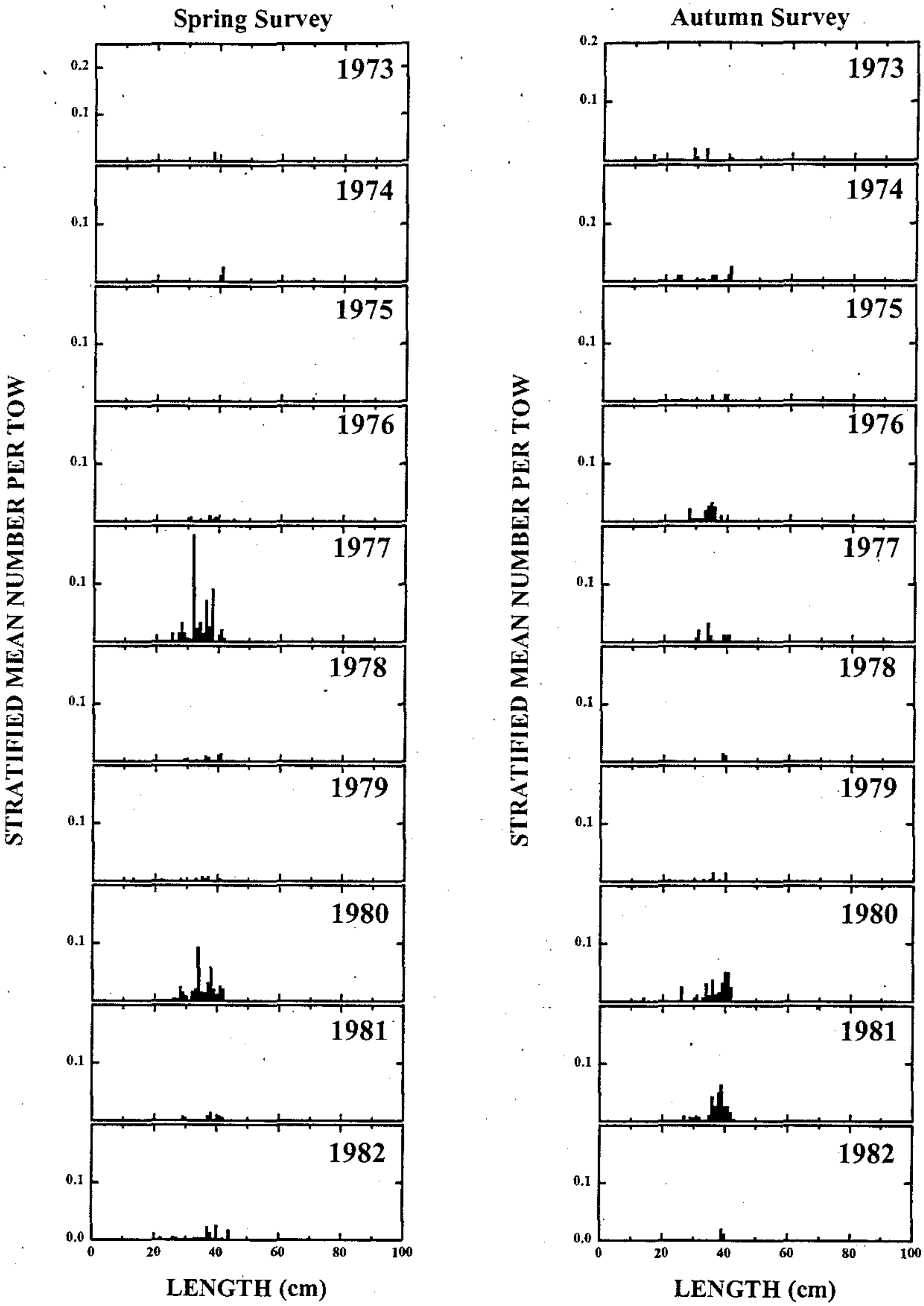


Figure B104. Rosette skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Mid-Atlantic offshore region, 1973-1982.

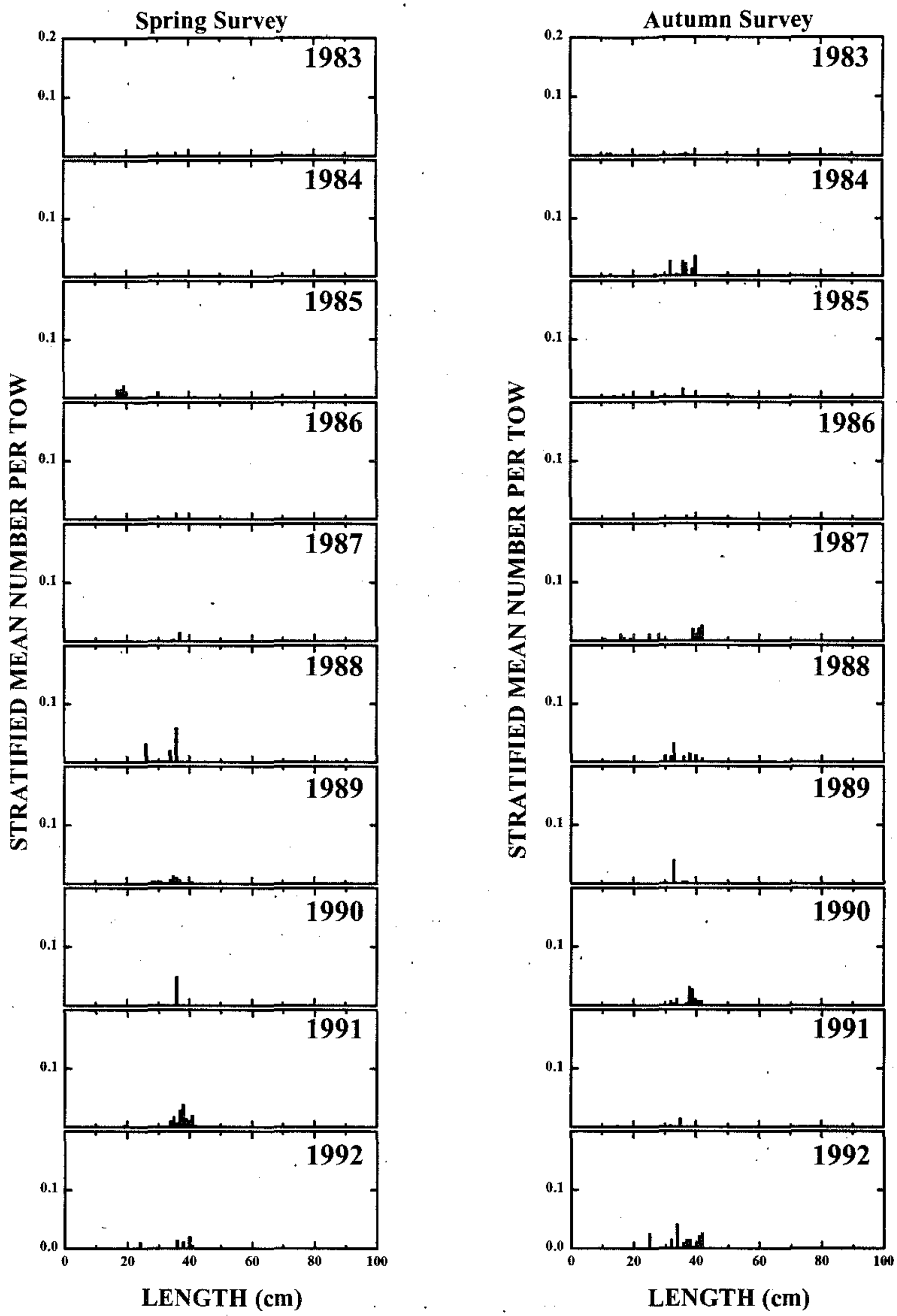


Figure B105. Rosette skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Mid-Atlantic offshore region, 1983-1992.

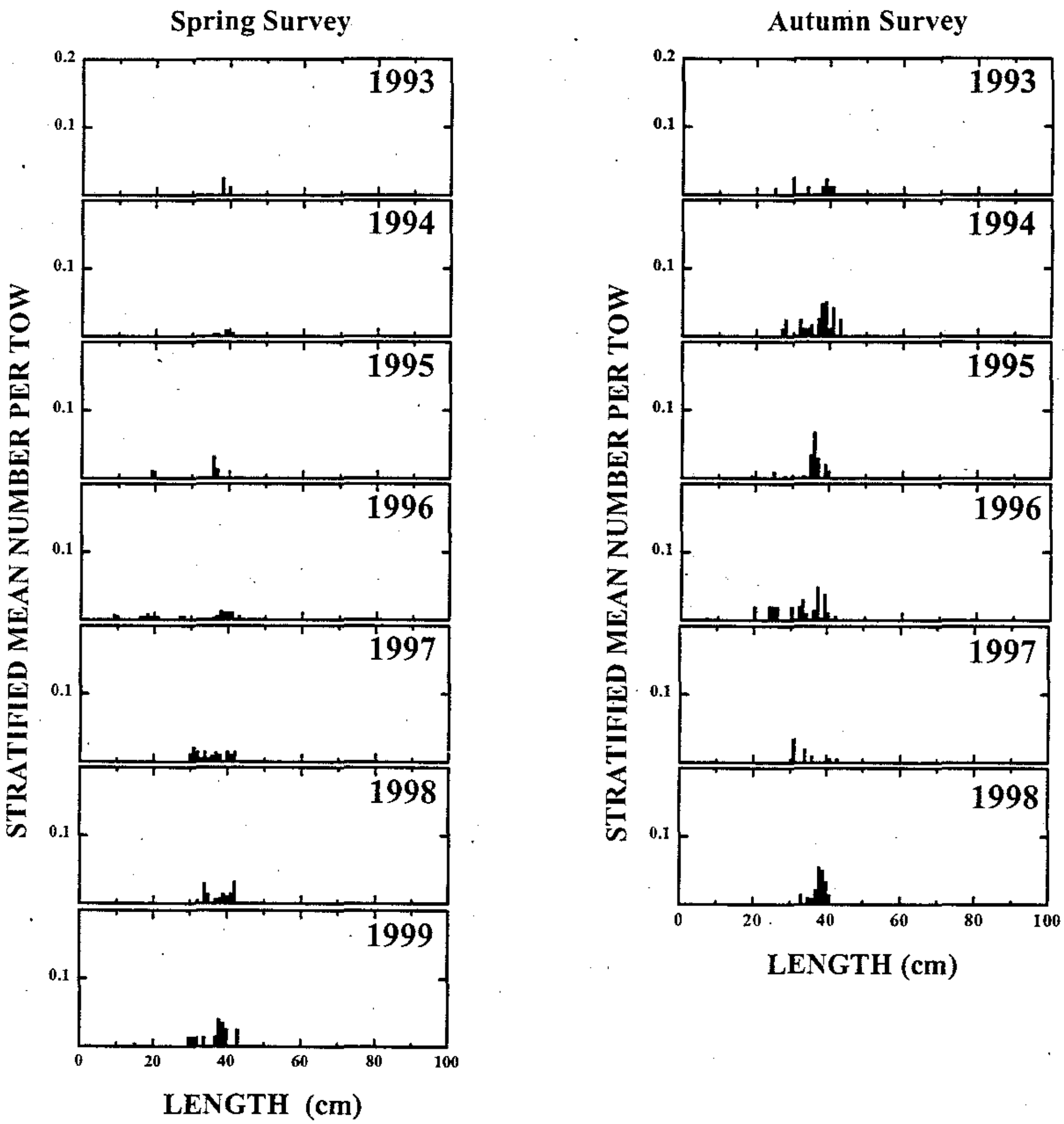


Figure B106. Rosette skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Mid-Atlantic offshore region, 1993-1999.

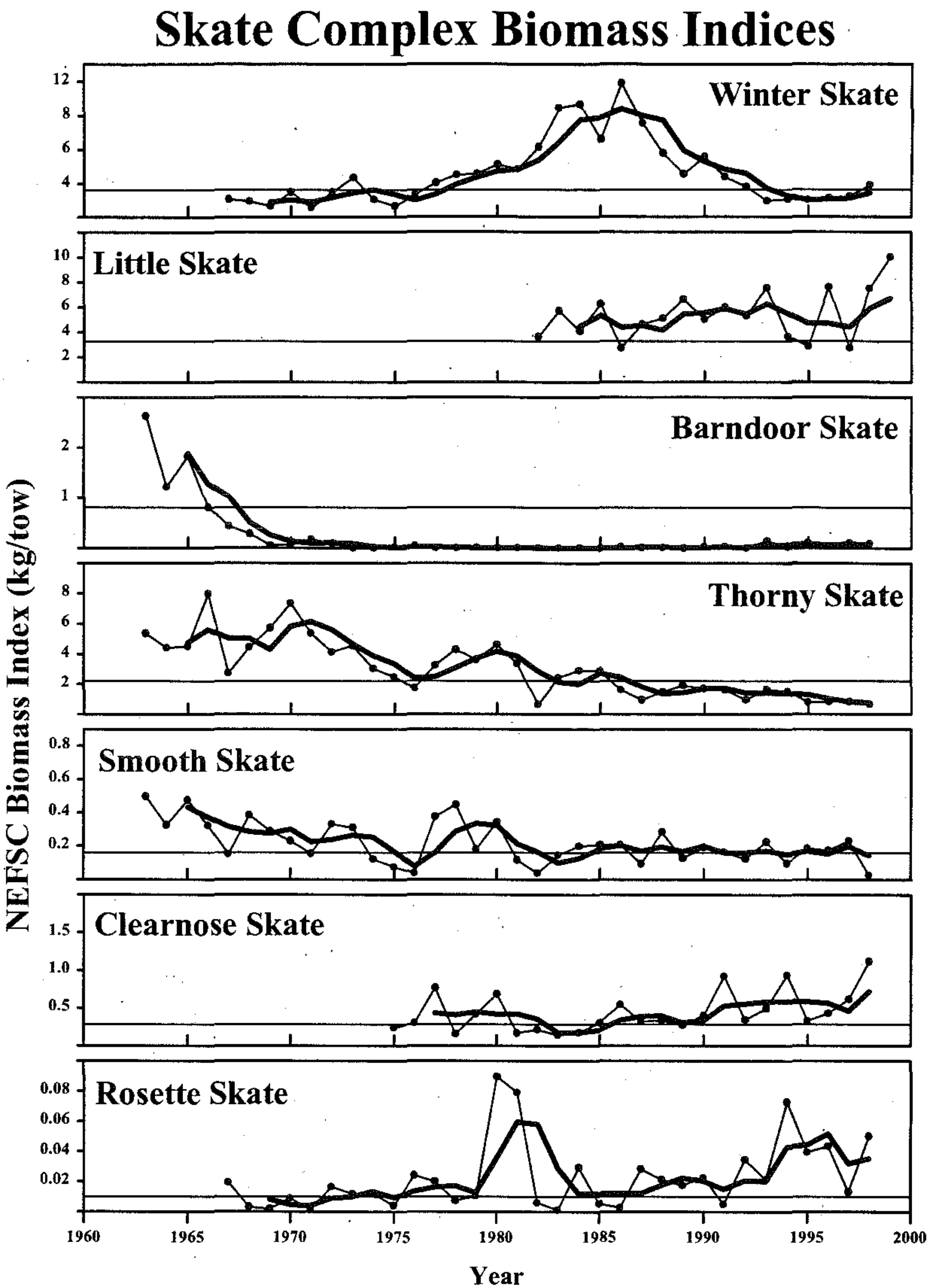


Figure B107. NEFSC survey biomass indices (kg/tow). Thin lines with symbols are annual indices, thick lines are 3-year moving averages, and the thin horizontal line are the biomass thresholds.

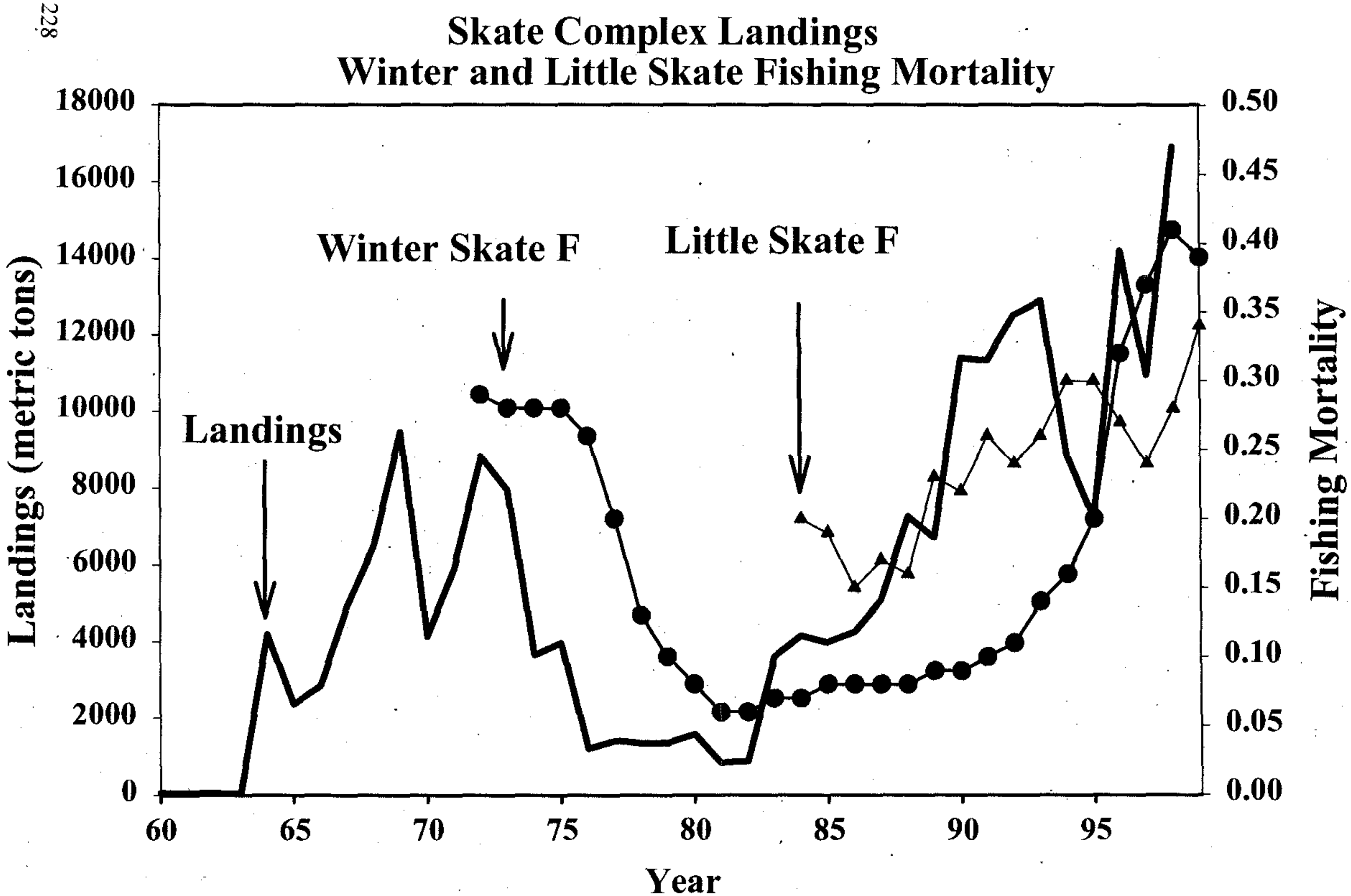
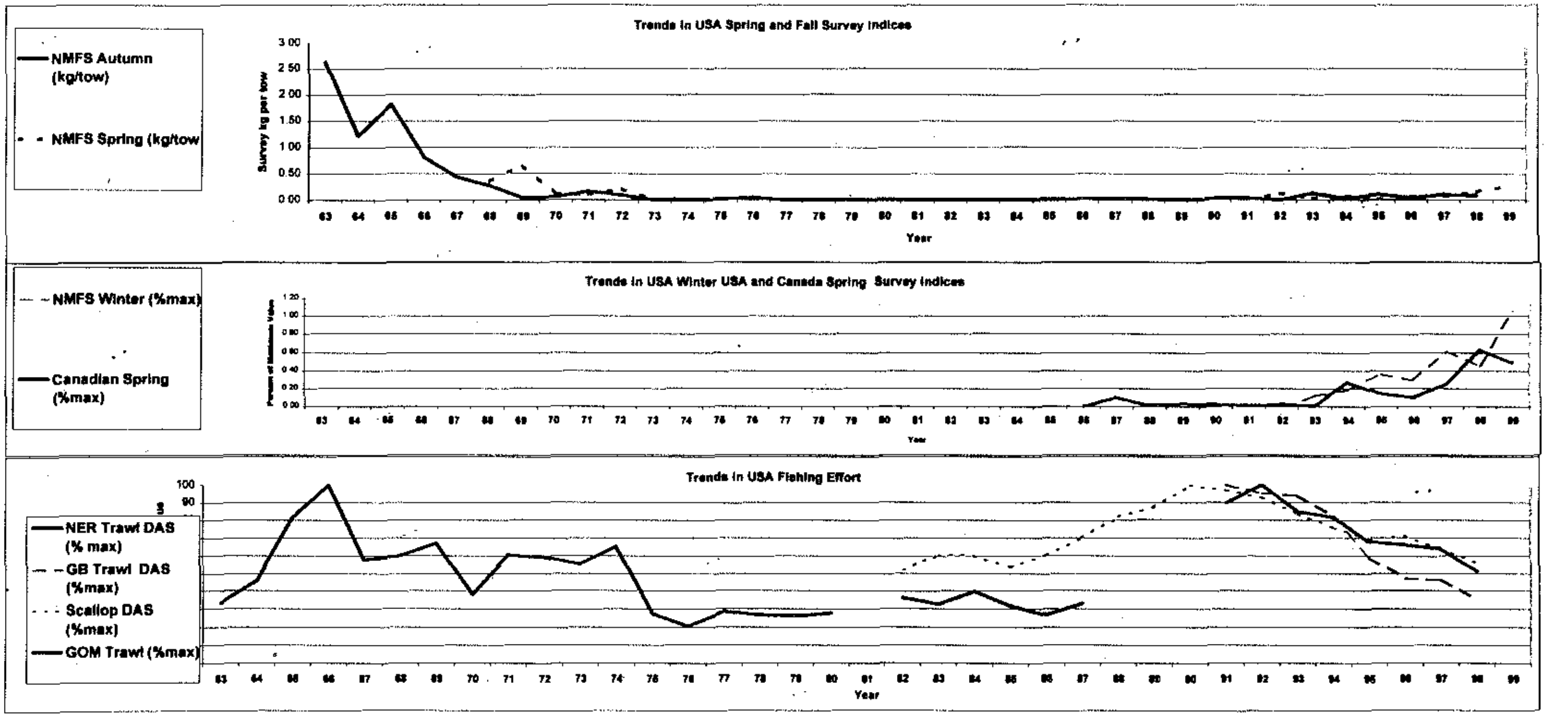


Figure B108. Commercial fishery landings of skates (all species) in the Northeast Region. Winter and little skate fishing mortality rates calculated from NEFSC spring survey length distributions.

Figure B109. Summary of Regulatory Measures that may have improved the survivorship of barndoor skates in the Northwest Atlantic.



	Regulatory Measures	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
USA	Seasonal Haddock Spawning Areas - GB								●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Seasonal Yellowtail Closed Areas - SNE																								●	●	●	●	●	●	●	●						
	Year-Round Closures - GB & SNE																																●	●	●	●	●	●
	Year-Round Closure GOM																																			●	●	●
	Rolling Closures, Gulf of Maine																														●	●	●	●	●	●	●	●
	TACs for Groundfish								●	●	●	●	●	●	●	●	●	●	●	●	●																	
	Groundfish Days at Sea Restrictions																																●	●	●	●	●	●
	Effort Buy-Out																																●	●	●	●	●	●
	Scallop DAS Reduction																														●	●	●	●	●	●	●	●
	Summer Flounder FMP Amendment 2																															—	—	—	—	—	—	—
Both	Distant Water Fleets Excluded															●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Extended Jurisdiction USA & Canada															●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Partitioning of Georges Bank USA-Can																							●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Canada	Grand Bank Closure																														●	●	●	●	●	●	●	●
	Seasonal Browns Bank Closure - Mar-April								●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Seasonal Georges Bank closure - Mar-April								●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Georges Bank Closure - Jan-June																																●	●	●	●	●	●
	ITQ Fishery in Div 4X/5Z																													●	●	●	●	●	●	●	●	●

C. TAUTOG

TERMS OF REFERENCE

The following terms of reference were developed by the ASMFC Tautog Technical Committee, during a meeting held on August 15, 1999, and were subsequently reviewed and adopted by the ASMFC Tautog Management Board.

a. Summarize recreational and commercial landings by region and state from Massachusetts to Virginia.

b. Summarize length composition and available age-length data by region (Northern Region (MA-NY), Southern Region (NJ-VA)).

c. Summarize available indices of stock abundance by state based on state bottom trawl and juvenile surveys.

d. Estimate age composition of recreational and commercial landings using age-length keys from the states Massachusetts to Virginia.

e. Provide estimates of fishing mortality on a regional basis, and if possible for the "entire stock".

f. Conduct, if possible, an age-structured analysis (VPA) and evaluate biological reference parameters using yield-per-recruit models, spawning stock biomass-per-recruit models, and a biomass dynamic model.

g. Develop tag-based estimates of survival and recovery rates.

h. Review all options for targets for inclusion in the management plan and select appropriate biological reference points.

INTRODUCTION

The Atlantic States Marine Fisheries Commission (ASMFC) identified the need for a coast-wide Fishery Management Plan (FMP) for tautog (*Tautoga onitis*) in 1993 and recommended that a plan be developed as part of its Interstate Fisheries Management Program (ASMFC 1996). The states of Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, and Virginia declared an interest in jointly managing this species through the ASMFC. The primary rationale for the development of a tautog FMP was the vulnerability of the species to overfishing. Additional concerns centered on localized overfishing and an increase in commercial fishing pressure in the middle 1980's through early 1990's. The goal of the FMP for tautog was to conserve the resource along the Atlantic coast and to maximize long-term ecological benefits, while maintaining the social and economic benefits of commercial and recreational utilization.

Prior to 1996 the tautog fisheries were not addressed by any interstate or federal management plan. Several states had adopted minimum size and/or recreational bag limits as conservation measures. Minimum size limits prior to the plan ranged from no minimum (Maryland and Virginia), to 16 inches (Massachusetts and Rhode Island). Several states had a minimum size of 12 inches (Connecticut, New York, New Jersey, and Delaware), and/or raised them just prior to plan implementation (New York increased to a 13" recreational minimum and a 14" commercial minimum). Delaware was the only state with a seasonal minimum size (15 inches from April through June; 12 inches during the remainder of the year). Massachusetts and Delaware also had implemented possession limits for commercial fisheries.

Since the first assessment and adoption of the FMP all states have implemented various restrictive management measures to reduce fishing mortality on tautog. In general, states have enacted low bag limits and/or closed seasons for their recreational fishery, and implemented seasonal closures and possession limits for their commercial fisheries. In addition, all states have adopted a higher minimum size. A compilation of existing fisheries management measures is contained in Table C1.

This assessment report outlines the fisheries and biological characteristics of tautog from Massachusetts to Virginia, and provides estimates of fishing mortality and stock size on a coast-wide basis. It may be preferable to conduct the assessment of tautog at a local or state level because spawning populations of tautog do not exhibit distant migrations and are confined to small areas. However, conducting state-level assessments was not possible in 1995 and was still not possible in 1999 because sufficient data was not available. No state has sufficient age data and many states in the Southern Region do not have fisheries independent indices of abundance. Additionally, questions concerning the delineation of appropriate stock sub-units for assessment purposes have never been adequately resolved. Accordingly, background information in this assessment is divided into Northern and Southern Regions based upon similarities in habitat types, fisheries, management histories, and available age and growth data. For fishing mortality, stock size and spawning stock biomass estimates a VPA was conducted on a coast-wide basis for management purposes and because of apparently similar stock recruitment and management histories.

Life History

Tautog is one of over 630 species composing the wrasse or labrid family and is often known by the common name "blackfish" in the northeastern United States. Most labrids are inhabitants of tropical waters, making tautog an exception to the rule. Tautog range from Nova Scotia to South Carolina (Bigelow and Schroeder 1953), however, they are most abundant between Cape Cod and Chesapeake Bay.

Tautog shares this preference for temperate waters with the cunner (*Tautogolabrus adspersus*), another labrid whose range extends even further north to Labrador. The tautog can be distinguished from the cunner in that tautog is stouter, has a higher head profile, and lacks scales on its gill covers (Bigelow and Schroeder 1953). Tautog also grow to a much larger size than cunner, with tautog growing up to 25 pounds (30 years). Cunner rarely exceed one pound in weight.

Tautog are found in association with specific structured habitats throughout their life and these habitats are important to its survival. Structured locations provide shelter during nightly dormant periods. Juveniles require places to feed and hide from predators and are often found in shallow, near-shore, submerged vegetation such as beds of algae or eel grass. Larger fish require more complex structures for shelter and locations of food sources.

Tautog normally reach sexual maturity at age 3 to 4 (Chenoweth 1963; White 1996). Mature large tautog can be sexed from external characteristics (sexual dimorphism). Male tautog are distinguished from females by a more pronounced mandibular structure and a large-diameter white spot, located laterally near the midline of the fish (Cooper 1967), although not all males exhibit dimorphic traits. Olla and Samet (1977) described the spawning process under laboratory conditions.

Adult tautog migrate inshore in the spring from offshore or nearshore wintering sites to spawn. Spawning occurs primarily at or near the mouth of estuaries and in nearshore marine waters. Inside Narragansett Bay, mature tautog returned to the same spawning site each year, but dispersed throughout the bay after spawning (Cooper 1967). However, Olla and Samet (1977) found that adult tautog did not always return to the same spawning site in the spring, and mixing of populations from different localities occur. Some of the adult population remains offshore throughout the year, especially in the Southern Region, and have been captured there in spawning condition (Olla and Samet 1977; Eklund and Targett 1990; Hostetter and Munroe 1993; White 1996).

Age and growth studies of tautog indicate a relatively slow-growing, long-lived fish with individuals over 30 years of age reported in Rhode Island, Connecticut, and Virginia. Males grow faster, attaining longer lengths than females (Cooper, 1967). Evidence suggests that females reach senescence at an earlier age than males. Growth rates from Virginia are similar to those in Rhode Island, until about age 15, (Cooper 1967), after which growth rates decrease more rapidly in northern waters (Hostetter and Munroe 1993). This work was reevaluated by the ASMFC Tautog Stock Assessment group in 1996, using growth equations developed by White (1996). The group reported discrepancies in aging methods in past studies. These discrepancies were attributed to differences in assigning birth dates and placement of the first annulus, particularly in older tautog. The reevaluation revealed similar growth rates at both ends of the species range.

Stock Structure

Tautog is a coastal species found primarily between Cape Cod and Virginia. The offshore distance and depth range of tautog appears to gradually increase towards the south and near Cape Hatteras. Although tautog do not appear to exhibit extensive along-shore migration, Briggs (1977) reported fish from Long Island bays making an offshore migration to winter in deeper waters off northern New Jersey. Tagging studies conducted by, Cooper (1967), and Lynch (1993) in Rhode Island indicate that the Narragansett Bay spawning population of tautog is local to Rhode Island's coastal waters. Tautog exhibit a high degree of fidelity to discrete spawning groups within Narragansett Bay, suggesting multiple stocks/sub-populations within the Bay. Lucy et al. (1999), confirmed limited daily and seasonal movement patterns within the Chesapeake Bay estuary. Related fishing observations suggest that discrete spawning groups exist in the waters of Long Island Sound, Delaware Bay, and Chesapeake Bay. However, for fishery management purposes localized coastal stocks were treated as one unit stock.

FISHERIES DATA

Northern Region (MA,RI,CT,and NY)

Recreational Landings

The annual harvest of tautog fluctuated

without trend from 1981 to 1985, ranging from a minimum of 1411 mt in 1985 to a maximum of 2853 mt in 1982. Harvest peaked in 1986 at 6158 mt and reached intermediate levels from 1989 to 1993. Since that time harvest has tapered off, reaching the lowest level of 387 mt in 1998 (Table C2 and Figure C1). Recreational landings in 1986 were more than twice as large as landings in adjacent years. Most of this increase occurred in Massachusetts and Rhode Island. This sudden increase seemed unreasonable for a long-lived species like tautog but to date no causes have been found that would explain this unusual data point.

The majority of tautog harvest occurred in the private boat mode (75%), followed by the shore mode (15%) and charter/party boat mode (9%). Recreational harvest occurred primarily in waters within 3 miles of shore in all years (54%). Important recreational gear types in the Northern Region are rod and reel and handlines. Many Northern Region states have an important but unquantifiable spearfishing component to their recreational fisheries.

Northern Region recreational harvest, by weight, has traditionally been dominated by New York, with approximately 42% of the total catch. Massachusetts is second in recreational landings with about 29% of the harvest; and Rhode Island and Connecticut share the remainder of the catch at 14.5 % each. Trends in the estimated numbers of fish landed in the Northern Region were similar, declining by 75% from 1991 to 1994 and declining approximately another 50% since that time (Table C3). Tautog has historically ranked seventh among target species sought by recreational anglers in the region.

Massachusetts' annual recreational harvest of tautog has fluctuated widely over time, reaching the highest level in 1986 at 3566 mt. The lowest harvest occurred in 1998 at about 44 mt (Table C2). The recreational fishery in Massachusetts is most active south of Cape Cod and occurs primarily in the spring and fall.

The recreational landings of tautog in Rhode Island peaked in 1986 at over 926 mt and declined to a low of 107.5 mt in 1995. Since then, landings have risen slightly to about 143.5 mt (Table C2). The fishery peaks during the spring and fall in Narragansett Bay.

The recreational harvest in Connecticut increased from 110 mt in 1981 to a record high of 502 mt in 1987. Between 1988 and 1993 recreational landings ranged from 90 to 476 mt. Landings in 1994 fell below 190 mt and since then have averaged about 109 mt, with a low of 39 mt reached in 1997 (Table C2). The fishery is also active in the spring and fall and mostly in Long Island Sound.

The recreational catch in New York has fluctuated from 246 to 1285 mt from 1981 to 1993, with the lowest recorded catch in 1984. Recreational harvest has averaged only 142 mt from 1994 to 1998 (Table C2).

Recreational Discards

Estimates of Northern Region recreational tautog discards or fish released (type B2 catch in numbers) from 1981 to 1993 ranged from 0.2 million fish in 1982 (8% of the total catch) to 1.4 million fish in 1991 (47% of the total catch) (Table C4). A steady increase in the proportion of total fish discarded has been observed in the region since 1987, ranging from 30% in 1987-1990 to 52% in 1993 and 61% in 1994. Estimated recreational discards have exceeded landings in the region since 1993. Recent changes to minimum size regulations are assumed to be the reason for increases in discard rates.

Simpson and Gates (1999) evaluated discard mortality of tautog in the recreational fishery for shallow waters and Lucy et al. (1999) evaluated discard mortality for deeper waters. The 2.5% discard mortality rate (mean value of Simpson and Gates) was used for this assessment because most of the recreational catch occurs in relatively shallow coastal waters.

Length frequencies of recreationally landed tautog were obtained from the Marine Recreational Fisheries Statistical Survey (MRFSS) recreational landings data and NYDEC party boat sampling (Figure C2). There was no indication of size truncation in the period 1981-1993. The size composition ranged from 20 cm to 65 cm and the distribution was approximately unimodal. Since 1994 catches have shifted away from smaller fish with the initiation of higher minimum size limits in the 1994–1996 time period. Additionally, the landing of tautog larger than about 65 cm has become a rare event since the high landings of the 1980's and early 1990's. Tautog is traditionally a shelter seeking species and a hard fighting fish; therefore, recreational anglers may be less likely to harvest the largest fish in proportion to their relative abundance in the population.

Commercial Landings

Nearly all coast-wide commercial landings of tautog occurred in the states from Massachusetts to New Jersey. Northern Region commercial landings represent about 91% of the total commercial U.S. harvest of tautog. These landings gradually increased from 125 mt in 1981 to 478 mt in 1987. Landings remained relatively steady at about 450 mt for five consecutive years after 1987, then dropped abruptly to about one half that level in 1993. From 1994 on, landings have remained at about 100 mt for the entire region (Table C5 and Figure C1).

Commercial tautog landings from 1984 to 1994 were greatest in Massachusetts, Rhode Island, and New York. Rhode Island landings have been constrained by a commercial quota since 1995, while there is some evidence to suggest that Massachusetts' and New York's landings in recent years (1997-1999) may have increased as a result of better reporting.

Otter trawls were consistently the predominant commercial gear type from 1983 to 1991, accounting for 26% to 54% of the landings. Gillnets were also important in early years. However, the majority of landings were taken by inshore lobster pots in 1982. The proportion of landings attributed to hook and line and to fish pots has increased in recent years. Hook and line gears contributed about 24% of the landings and otter trawl contributed about 26% in 1991. Commercial landings in 1998 came predominantly from hook and line gears followed by otter trawls and fish pots.

Commercial Discards

Estimates of commercial discards were not calculated because sea sampling and other data were not available. Dockside sampling of tautog is not part of the National Marine Fisheries Service Port Sampling program therefore length frequencies of commercial landings are not currently collected for tautog. The proportion of total catch attributable to commercial discards is considered negligible and therefore assumed to be zero in this assessment.

Total catch

Estimates of total tautog landings for the Northern Region are presented in Table C10. Estimates include commercial and recreational landings and exclude discards. Total catch for the 1981-1993 period in the Northern Region consisted primarily of recreational landings. Commercial landings accounted for an average of about 14% of the total Northern Region landings from 1981 to 1998. The proportion of commercial landings increased from a minimum of about 4% in 1982 to a maximum of about 19% in 1997, primarily because of declines in recreational harvest. The proportion of commercial landings declined slightly to about 18% in 1998.

Length frequency and age and growth sampling

Catch length sampling intensity was poor from 1981 to 1988 in the Northern Region, ranging from 503 mt per 100 lengths in 1987 to 221 mt per 100 lengths in 1983 (Table C7). Sampling intensified after 1988 and fluctuated from 181 mt per 100 lengths in 1992 to 78 mt per 100 lengths in 1989. Sampling intensity averaged about 98 mt per 100 lengths in 1996-1998.

Sources of the age and growth samples are presented in Table C8. Samples came primarily from fisheries independent sampling programs before 1992, and from fisheries dependent sampling programs thereafter.

Southern Region (NJ, DE, MD and VA)

Recreational landings

The annual recreational harvest of tautog in the Southern Region fluctuated around a mean of 670 mt, 1981 to 1985 and then increased to about 1508 mt in 1986. Landings remained near this level through 1993, except for a dip to about 766 mt in 1990 (Table C6 and Figure C1). Landings declined sharply to about 345 mt in 1994 and rose again to about 1472 mt in 1995, declined to about 947 mt in 1996, and declined again in 1997 and 1998 to the lowest observed landings value, about 272 mt.

The majority of recreational harvest occurred as it did in the Northern Region: in the private boat mode, the shore mode, and the charter/party boat mode. Many Southern Region states also have an important but unquantified spearfishing component to their recreational fisheries.

Harvest in numbers of fish (type A and B1 catch) peaked in 1986 at 2.8 million fish and stabilized at about 1 million fish through 1995, with the exception of about 0.6 million fish in 1994 (Table C3). Harvest dropped to about 0.4 million fish in 1997 and to 0 .1 million fish in 1998.

Recreational harvest of tautog in the Southern Region has been traditionally dominated by New Jersey, which takes between 65% and 80% of the total catch in most years. Virginia takes the second largest recreational harvest in the Southern Region (e.g., 30% in 1993 and 64% in 1994). Delaware and Maryland share the remainder of the catch in about equal proportions.

The New Jersey recreational harvest of tautog for the period 1982-1994 has fluctuated markedly, reaching a maximum of 1127.5 mt in 1992 and sharply declining thereafter (Table C2). The recreational harvest reached 18.8 mt in 1998. The primary fishing grounds extend from the beach out to about the 12-fathom contour line. Recreational fishing modes included bottom fishing (particularly the directed trips of party and charter boats), jetty fishing, and spearfishing. The primary fishing seasons are spring and fall.

The Delaware recreational harvest of tautog peaked at about 176 mt in 1987 and declined to about 90 mt in 1992 and 1993 (Table C2). However, the highest catch in numbers was recorded in 1995 (about 0.3 million fish, (Table C3). Recent harvest levels are at about 0.06 million fish. The fishery is primarily restricted to jetties, breakwaters, wrecks, and artificial reefs in the lower Delaware Bay.

The Maryland recreational harvest of tautog fluctuated greatly from year to year (Tables C2 and C3). Harvest totals ranged from as low as 0.5 mt (or about 0.0005 million fish) in 1985, to as high as about 80 mt (0.16 million fish) in 1994. Recreational landings in recent years have declined from about 83 mt (0.085 million fish) in 1997 to about 12.5 mt (0.007 million fish) in 1998. The fishery, concentrated in the Ocean City area, is most active in the spring and fall.

The Virginia recreational harvest of tautog fluctuated from a minimum of about 104 mt in 1990 to a maximum of about 640 mt in 1988. Catch in weight increased considerably in the early 1990's, increasing about 60% in 1993 and about 42% in 1994 from the previous year. However, there was little change in estimated numbers of fish landed in 1994, indicating a higher mean weight per fish as the fishery moved offshore. Recreational landings in weight have averaged about 233 mt from 1995 to 1998. MRFSS estimates in Virginia were likely underestimated because the NMFS/MRFSS program did not collect data during the first wave (January and February), during which tautog is one of the few species available to recreational fishermen.

Recreational Discards

Estimates of recreational tautog discards or fish released (type B2 catch in numbers) gradually increased from 4,521 fish in 1981 (1% of the total catch) to about 0.9 million fish in 1993 (44% of the total catch) (Table C4). The proportion of discarded fish was relatively low until recent years because there was no minimum size for tautog in Virginia and Maryland and a small minimum size in New Jersey. The discard rate increased to about 79% in 1998 as higher minimum size limits were implemented.

Length frequencies of recreational landings were obtained from the MRFSS (Figure C3). There was no indication of size truncation in the period 1981-1993. The average size range in the Southern Region (15 cm to 70 cm) was greater than in the Northern Region (20 cm to 65 cm). Smaller fish (i.e., < 28 cm) are not evident in landings since 1997 when higher minimum sizes were implemented. Landings of larger fish (i.e., > 46 cm) have not declined to levels noted in the Northern Region, possibly because of a shift in fishing pressure to offshore and previously less exploited populations.

Commercial Landings

A small proportion of the Southern Region commercial fleet targets tautog. The region's commercial landings represent only about 4 to 6% of the total coast-wide commercial harvest. Most landings occurred in New Jersey, representing about 80-97% of the total regional harvest (Table C5 and Figure C1). Southern Region commercial landings ranged from a minimum of 26 mt in 1981 to a maximum of 80 mt in 1994. Commercial landings in New Jersey and Maryland were primarily from inshore pots and traps; commercial landings in Delaware and

Virginia were primarily from the commercial hook and line fishery.

About 70% of the commercial landings from 1981 to 1989 were from state waters. Commercial landings from offshore areas may be underestimated. Inshore commercial landings declined from about 95% of the total landings in 1983 to about 56% in 1989; inshore commercial landings were at their lowest level in 1993 at about 21%. Total commercial landings in the region have declined from a pre-plan implementation average of 53 mt to 34 mt.

Commercial Discards

The NEFSC Sea Sampling Program did not cover trips of the commercial fleet targeting tautog in the Southern Region. Therefore, discard rates for the commercial fisheries in the Southern Region were not available.

Total Catch

Estimates of total tautog landings for the Southern Region are presented in Table C6. Estimates include commercial and recreational landings and excluded discards. Total catch for the 1981-1998 period in the Southern Region consisted primarily of recreational landings. Commercial landings accounted for an average of about 6% of the total Southern Region landings from 1981 to 1997; a minimum of about 3% was observed in 1986 and a maximum of about 19% was observed in 1994. There was no consistent increasing or decreasing trend in the proportion of commercial landings from 1981 to 1997. However, there was an increase to about 9% in the proportion of commercial landings in the Southern Region in 1998.

Length Frequency and Age and Growth Sampling

Catch length sampling intensity was poor from 1981 to 1988 in the Southern Region, ranging from 969 mt per 100 lengths in 1986 to 267 mt per 100 lengths in 1982 (Table C7). Sampling intensified after 1988 and fluctuated from 241 mt per 100 lengths in 1993 to 139 mt per 100 lengths in 1990. Sampling intensity averaged about 90 mt per 100 lengths in 1996-1998.

Sources of the age and growth samples are presented in Table C8. Samples came primarily from fisheries dependent sampling programs because there were few inshore trawl surveys performed in the Southern Region.

LENGTH-WEIGHT REGRESSION RELATIONSHIP

Different length-weight relationships were used for the Northern and Southern regions, based on recent studies in Rhode Island and Virginia (Hostetter and Munroe 1993; Lynch 1993). A single equation was applied for all years to calculate mean weights-at-age for both recreational and commercial catch-at-age.

Northern Region

$$\text{Weight (gram)} = 0.00891 * \text{Length (mm)}^{2.96}$$

Southern Region

$$\text{Weight (gram)} = 0.00959 * \text{Length (mm)}^{2.98}$$

Cooper (1967) and Briggs (1977) developed length-weight relationships by sex showing higher weights for females at any given size. The combined sex weight-length relationship developed for Long Island Sound was similar to that calculated in Rhode Island.

RECREATIONAL AND COMMERCIAL CATCH-AT-AGE

Age-length Keys (ALK)

Separate age–length keys were produced for the Northern and Southern Regions by pooling all available state-specific information within each region. Yearly data were pooled for three-year time periods between 1981 and 1998, based on the availability of age data, and to obtain adequate sample sizes for each key (i.e., > 700 fish per key). Single year age-length keys contained too few age samples to resolve the proportions of age-at-length for larger fish and may not be necessary for tautog given their slow growth rates and minimal variation in growth between regions. Data from the Northern and Southern Region keys were added as numbers-of-fish-at-age to form the Coast-wide key. Length classes for the keys were one-inch increments. Data from individual states within regions were not weighted. Age sample distributions by region are listed in Table C8. Following is a summary of available age data sources and created keys.

Summary of Available Age-Length Keys Used in this Assessment

Northern Region

Massachusetts Division of Marine Fisheries 1995–1998

Rhode Island Division of Marine Fisheries 1987–1993

Connecticut Department of Environmental Protection 1984–1996

New York Department of Environmental Conservation 1995–1997

Southern Region

Virginia 1979–1985 Hostetter and Munroe

Virginia 1994–1995 White

Virginia 1996 and 1997 White @ VIMS

Virginia 1998 Virginia Marine Resources Commission

Delaware 1997 Division of Marine Fisheries

Pooled age-length keys for the Northern and Southern regions:

1981-1986	Pooled Northern Region Key (n = 1,236)
1987-1989	Pooled Northern Region Key (n = 1,208)
1990-1992	Pooled Northern Region Key (n = 831)
1993-1995	Pooled Northern Region Key (n = 756)
1996-1998	Pooled Northern Region Key (n = 1,143)
1981-1989	Pooled Southern Region Key (n = 696)
1990-1995	Pooled Southern Region Key (n = 942)
1996-1998	Pooled Southern Region Key (n = 1,681)

Recreational landings-at-age

Aggregate numbers of fish caught by recreational fishermen (A+B1 type catch) were obtained from the NMFS web site and are from the Marine Recreational Fisheries Statistical Survey (MRFSS) by state for the period 1981-1998. Estimated recreational landings in number by state were added to create the total number of tautog landed by the recreational fishery for each year by region.

Catch length-frequency distributions were also obtained from the MRFSS intercept data and weighted according to the MRFSS telephone estimates using the SAS program (SAS 1993) provided by MRFSS for the years 1981-1998. The SAS program weights intercept length data by State-Wave-Area-Mode fields in the telephone survey. Intercept length data were added, prior to weighting by the telephone estimates, in the Northern Region from New York's head-boat survey for the years 1993-1998, in the Southern Region from New Jersey party boat sampling for 1994-1998, and Virginia sampling for 1994-1997. Total sample sizes for the number of fish measured per year are presented in Table C6. All data were converted to the appropriate one-inch size class bins within the SAS program.

The number of fish caught-at-length was calculated from the estimated catch per region and multiplied by the percent frequency of occurrence in the catch for each year, resulting in the recreational catch-at-length in numbers of fish for each year for each region.

Recreational Discards-At-Age

Numbers of fish released by recreational fishermen (MRFSS B2 type catch) were also obtained from the NMFS web site for each state for the period 1981-1998. Estimated recreational release numbers per state were added to create the total number of tautog released by recreational fishermen for each year by region.

The length frequency distribution data of released fish was obtained from the American Littoral Society (ALS) tagging database for the years 1981-1998. The length frequency of released fish was divided into regions and years. ALS data were combined within regions for the years 1981-1983, 1984-1986, and 1987-1989 to increase sample sizes. Additional length data were added to the Northern Region from New York's head-boat survey (1993-1998) and to the Southern Region from New Jersey's head-boat survey and tautog tournaments (1995-1998), the Virginia Game Fish Tagging Program (1995-1998), and the Virginia tautog fishing mortality study (1996-1997). The numbers of fish released per length interval were converted to proportions and multiplied by the estimated number of released fish and the chosen release mortality value for the numbers of fish-at-length lost to discard mortality.

Commercial Landings-At-Age

Tautog commercial landings data by pounds were obtained from the NMFS web site by state for the period 1981-1998. The commercial landings per state were added to obtain the total pounds of tautog landed by commercial fishermen for each year by region. The total weight in pounds was then divided by the weight of the average-sized recreational fish landed to obtain the total numbers of commercial catch per state. Numbers were then apportioned according to the recreational fishery length-frequency occurrence to obtain catch numbers-at-length by state and then summed within regions.

Commercial Discards-At-Age

Discards-at-length were not estimated because commercial discard data is not available.

Total Catch-At-Age

We multiplied catch-at-length matrices for recreational landings, recreational discards, and commercial landings by the age-length keys for the appropriate years and regions to generate catch-at-age matrices for each component of the fishery. The two regions were added together to form the Coast-wide catch-at-age matrix, creating a catch-at-age matrix for each sector of the fishery. The catch-at-age matrix for the coast is presented in Table C9. The age composition of the total catch was composed primarily of fish ages 4 to 9 for all years. Catches of age 1 tautog were negligible in recent years because of the implementation of size limits.

STOCK ABUNDANCE AND BIOMASS INDICES

Abundance indices (at age) for tautog ages 2+ were calculated from the following fishery independent surveys from Massachusetts to Virginia

Massachusetts Division of Marine Fisheries Spring Trawl Survey

The MADMF bottom trawl survey has been conducted within state waters since 1978. The strata used for developing an index of abundance for tautog were all waters south of Cape Cod. Only spring cruise data were used because the fall survey captures relatively few tautog. Indices represent the stratified mean number per tow. The indices were at high values in 1984, 1985 and 1986, and then gradually decreased to the lowest observed levels in the early 1990's. Indices revealed a very slight increase in abundance for the last 3 years (Figure C4).

Rhode Island Division of Fish and Wildlife Trawl Survey

The RIDFW bottom trawl survey has been conducted in Narragansett Bay, Rhode Island Sound, and Block Island Sound since 1979, in both the spring and fall. The majority of the tautog catch comes from Narragansett Bay. An annual stratified mean catch per tow was calculated from all areas to form an index of abundance for adult tautog. Despite the high variance in the RI index, a significant negative slope can fit the data from 1986 to 1994. The 1994 value was the lowest observed since 1979 (Figure C4). The most recent year's indices reveal a slight increase in adult abundance.

Connecticut Department of Environmental Protection trawl survey.

The CTDEP trawl survey program began in 1984 and is based on a stratified random design covering all Long Island Sound waters. A spring survey index was calculated for tautog, which showed a continuous decline since 1984. The three highest values were observed in the beginning of the survey, from 1984-1986, and all values since have fallen below the time-series mean of 1.22 (Figure C4). The most recent trends in adult abundance show a slight increase from the 1995 low.

New York Department of Environmental Conservation Juvenile Trawl Survey

The NYDEC began a small mesh trawl survey in the Peconic Bay in 1985 in order to develop a recruitment index for weakfish. The data collections were expanded in 1987 to include all finfish species. The survey runs from May through October. Data represent the geometric mean of tautog, age two and over. This index declined steadily from a high of 0.15 in 1989 to a low of 0.03 in 1994 and has remained stable since that time at values just below the time series mean of 0.06 per tow (Figure C4).

New Jersey Division Fish, Game and Wildlife Trawl Survey

The New Jersey trawl survey program has been collecting data continuously since August 1988. From 1988 through 1990 sampling cruises were performed once every two months starting in February. In 1990, the December and February surveys were dropped and replaced by a single winter survey. This pattern has continued unchanged to the present using a stratified sampling design. The stratified mean catch per tow of tautog was calculated annually. For the early part of the time series, the index remained stable at 10 fish per tow, with the high value in 1992 (Figure C4).

The 1998 index is up slightly, implying an increase in adult biomass.

NEUSCO Pot Survey
This index of abundance is for age four tautog and represents a catch per pot haul of lobster pots in the vicinity of the Millstone Nuclear Power Plant in Connecticut (Anon 1995).

The following indices of abundance for age 0 and age one tautog were used for tuning of the VPA:

Rhode Island Division of Fish and Wildlife Beach Seine Survey
For a juvenile index the geometric mean of tautog from a beach seine survey was used. Rhode Island initiated an inshore beach seine survey in 1986. Eighteen stations distributed along the Narragansett Bay shoreline are sampled once per month, from June to October. Indices from 1986 to 1993 averaged 8.33 fish per haul. Times series lows were reached in 1994 and 1995. Recent (1996 - 1998) index values have neared earlier survey values at an average of 5.5 fish per haul (Figure C5).

Connecticut Department of Environmental Protection Estuarine Seine Survey
Along the state's shoreline from Groton to Greenwich and employs a 7.6m beach seine with 6.4-mm bar mesh. The seine is towed a standardized 30 m distance with a fixed width of 4.6 m. Trends in juvenile abundance are variable through the time series ranging from a low of 0.0 in 1989 to a high of 0.98 in 1998 (Figure C5).

New York Department of Environmental Conservation Juvenile Trawl Survey
The geometric mean of age one tautog from this survey was used as a juvenile tuning index for the VPA (Figure C5). Like Connecticut, trends for the time series are quite variable ranging from 0.02 for 1987, 1988, and 1993 to a time series high of 0.32 in 1992. Recent indices (1996 and 1998) are at values approximately 50% of the 1992 high.

Marine Research Incorporated Small Mesh Trawl Survey
This index of young of the year tautog is from a beach seine survey in upper Mt. Hope Bay, Rhode Island. Monthly seine hauls are conducted at six fixed stations near the Brayton Point Power Plant with a small mesh 100 m beach seine (Figure C5).

NATURAL MORTALITY AND MATURITY

Natural mortality was assumed constant at a value of 0.15, based on Hoenig (1983), who provided a table of estimated M for 134 stocks of mollusks and crustacea using the following relationship:

$$\ln(\geq) = 1.46\text{-}1.01 * \ln(t_{max})$$

The M estimate was determined by analogy to species like dusky shark and goosefish, reported to have a similar longevity to male tautog. Simpson (1989) estimated natural mortality for males (M=0.152) and for females (M=0.142) using Pauly's method (Pauly 1980) with L¥=605mm, K=0.159, and water temperature =12 °C.

$$\log(M) = -0.0066-0.279*\log(L_{.})+0.6543*\log(K)+0.4634*\log(T)$$

Tilefish are similar in many ways to tautog, including longevity. A maximum life span of 35 years is cited along with M=0.15 for this species. Redfish longevity is greater than 50 years, corresponding to M=0.05. A natural mortality of 0.2 is used in the assessment of Atlantic Cod that lives more than 20 years.

Another commonly used method to develop estimates of natural mortality is the 3/M rule, which generates an M=0.1 for a maximum age of 31 years. The commonly observed maximum age for tautog, aside from the catch records, is less than 30 years, therefore a higher M seems reasonable and in fact the above methods, approximating M=0.15, appear appropriate for this species. The Tautog Technical Committee agreed to use M=0.15 for tautog, both sexes combined.

A maturity ogive value of 80% mature at age 3 and 100% mature at age 4+ was based on Chenoweth (1963). Spawning was assumed to occur on June 1. The proportion of natural mortality occurring prior to spawning was estimated at 0.42 (153/365 days). The proportion of F occurring before spawning was estimated as the proportion of landings occurring January through May to the total landings of the entire year (0.15).

ESTIMATES OF STOCK SIZE AND FISHING MORTALITY

ADAPT VPA

The ADAPT calibration toolbox program (WHAT) developed by the National Marine Fisheries Service was used to derive estimates of fishing mortality and stock size. The program is based on models developed by Parrack (1986), Gavaris (1988), and Conser and Powers (1990). Model runs were made using catch-at-age matrices for the coast (MA-VA). Abundance indices used to calibrate the VPA included state trawl survey indices from MA to NJ, juvenile indices from state surveys in RI, CN, and NY, a power plant in Rhode Island, and an index for age four tautog from pot sampling at a power plant in Connecticut. The final ADAPT formulation provided stock size, spawning stock biomass, and recruitment estimates for ages 1-12+ for the years 1981 to 1999, and corresponding estimates of fishing mortality for ages 1-12+, from 1981 to 1998. Coast-wide VPA revealed average F, ages 7-11 in 1998 to be 0.29, which is close to the plan interim target. Fishing mortality increased from 0.55 in 1981 to 0.71 in 1993 and then gradually declined to the 1998 estimate (Figure C6). Estimated stock size, spawning stock biomass and recruitment (Figures C7 – C9) declined from 1980's highs to low levels in the early 1990's and remain low at about 20 to 30% of past levels. Additional results are presented in Table C10.

VPA Precision

ADAPT results were resampled 200 times to provide estimates of approximate bias and produce probability distributions of spawning stock biomass and fishing mortality rates (Efron 1982). Coefficients of variation for stock size estimates from the Coast-wide VPA range from 0.20 to 0.32 for age groups 1-11. Approximate bias was about 12% for age 5, 15% for age 7, and 33% for age 1. Bias correction of stock size and F was not applied due to good precision. Cumulative distributions of SSB and fishing mortality are presented in Figures C10 and C11. There is a 90% probability that fishing mortality in 1998 is above the interim plan target of 0.24 and that SSB was less than 7,900 mt in 1998.

Tag Based Estimate of Fishing Mortality

Tag based estimates of fishing mortality were made using American Littoral Society data and the computer program MARK (White and Burnham 1997). A total of 2,723 tautog were tagged from 1983 to 1998, and 188 were recovered (7% annual recovery rate). An input matrix for analysis under the dead recoveries model was compiled for 1984-1998 tag-recapture data for the NY-NJ-DE area. Akaike's Information Criterion was used to select the model best supported by the data.

Model results show the survival rate of tautog tended to increase between 1984 and 1998. The corresponding fishing mortality estimates decreased from about F= 1.10 in 1984-1993 to about F= 0.20 in 1996-1998 (Lazar and Mitro 1999).

<u>ASPIC Runs</u>

An alternative method of estimating stock size and fishing mortality rates was conducted for comparison to results from the ADAPT analysis, and to estimate MSY-based biological reference points (B_{MSY}, F_{MSY}) for tautog stocks. For this analysis, a nonequilibrium surplus production model (ASPIC; Prager 1994, 1995) was fit to total tautog catches and survey biomass indices from the 1979-1998 fishing seasons. Relative biomass indices from Massachusetts, Rhode Island, Connecticut, and recreational LPUE (see section of Survey Indices; this document) were used calibrate the predicted biomass trajectory estimated from the production model. Initial biomass (B_1) in 1979 (expressed as a ratio to B_{MSY}), r, MSY and each survey's catchability coefficient q_i are estimable parameters in the production model for which the objective function is minimized in the logarithm scale of effort and parameters estimated using nonlinear least squares. Based on estimates of r and K, other management benchmarks can be estimated.

To estimate precision and bias associated with estimable parameters and management benchmarks the conditioned nonparametric bootstrap was performed by randomly re-sampling (200 times) values of log survey measurement errors. Production model runs were made for both the Northern (MA-NY) and Southern (NJ-VA) Regions for tautog and a combined coast-wide analysis. Recreational LPUEs were constructed from catch and effort data from the MRFSS data base and were likewise broken down into Northern and Southern stock regions, as well as regions combined for a coast-wide run.

Results of the production modeling were only reasonable for the Northern Region and for the coast-wide runs. This was most likely due to the fact that reasonable time-series of survey indices of tautog biomass were only available from states in the Northern Region (MA, RI, CT). While fishery-independent surveys have been conducted in NY (since 1985) and NJ (since 1988) these time series were relatively short compared to the time catch data was available. In addition, biomass indices for NY were negatively correlated with those of NJ and recreational LPUE. A final run was attempted using only NJ and recreational LPUE for the Southern Region, but model results indicated poor correlation among biomass indices used ($r < .035$) and the model explained very minimal variation in the observed data ($r^2 < 0.30$). Overall, the Tautog Technical Committee felt that due to the above reasons MSY-based estimates of biological reference points could not be derived for the Southern Region.

The SARC concluded that both the Northern and Coast-wide ASPIC runs were subject to considerable uncertainty. In particular, it was noted that while the model fit the data reasonably well the biological reference points were unreliable. The primary reason was that the data series, which spanned only 19 years, was too uninformative. Generally, production models require a time series encompassing a broad dynamic range in stock biomass and yield to provide dependable parameter estimates. This type of data series was not available for tautog, but rather represented the classic "one-way trip." It was also noted that production modeling may be problematic for tautog since the longevity of the species is greater than the available time series of data with which to model the stocks biomass dynamics. Therefore, ASPIC model results were not utilized to develop biological reference points and offered no other information for broader application in tautog management. Rather, the SARC relied solely on the yield and SSB-per-recruit analysis for biological reference points.

BIOLOGICAL REFERENCE POINTS

Yield per recruit (Thompson and Bell 1934) and spawning stock biomass per recruit (Gabriel et al. 1989) analyses were conducted to estimate fishing mortality rate-based biological reference points and to evaluate long-term yield. Since major fishery management measures were implemented in recent years, 5-year arithmetic mean catch weights and partial recruitment at age derived from the VPA were used as input for these analyses. Stock weights at age were assumed to be equivalent to the catch weights and the partial recruitment vector was assumed to be flat-topped after age 10. The maturation schedule at age was take from White (1996) and was assumed to represent present conditions in the stock. Natural mortality was assumed at 0.15.

Results of the analysis indicate that $F_{0.1}$ is currently estimated at 0.14, F_{max} is estimated to be 0.36, and $F_{40\%}$ is estimated to be 0.17 (Table C11 and Figure C12). At F_{max}, about 25% of the Maximum Spawning Potential (%MSP) is obtained, while at $F_{0.1}$, 44% of MSP is obtained.

PROJECTIONS OF CATCH AND BIOMASS

No projections of catch and biomass were done but the recent increase in recruitment is modest and is expected to result in an increase in biomass weight from growth, but will not result in a significant increase in harvestable stock size in the immediate future.

SARC COMMENTS

Discussions relative to the Tautog assessment involved citing minor editorial revisions for further clarification, critiques of catch-at-age, year class plus groupings, drawing conclusions from the VPA results, and questioning the reliability of the ASPIC output.

The catch-at-age plus groupings were of particular interest given the large amount of variance associated with years 16 through 18 plus groups. A truncated catch at age grouping up to 12 + was recommended by the SARC to rectify variance issues. Subsequent VPA runs utilizing this truncated age grouping addressed SARC concerns regarding the variability associated with older aged fish and those associated with a dome shaped partial recruitment pattern. As such the SARC adopted the truncated ages 12 + Coast-wide VPA run.

Critique of the revised VPA results by the SARC unearthed fishing mortality concerns surrounding decisions to assess tautog as a coast-wide population as opposed to separate stocks. Further discussion on this topic, suggested the possibility that regional variations in fishing mortality occurred due to management implementation delays in the Southern Region as compared to the implementation time frame in the Northern Region.

After careful consideration of the ASPIC model runs for tautog, the SARC concluded that both the Northern and Coast-wide ASPIC outputs were unreliable. SARC members expressed concern that the ASPIC model provided a misrepresentation of stock history relative to fishing effort (the one way trip). Therefore, ASPIC model outputs were not utilized in the estimation of the biological reference points and offered no information for broader application in tautog management. Rather the SARC relied solely on the virtual population analysis partial recruitment vectors for use in biological reference point estimation.

SUMMARY AND CONCLUSIONS

Average fishing mortality rates (ages 7-11), increased from a low of 0.12 (10% exploitation rate) in 1981 to a time series high of 0.71 (47.6 % exploitation rate) in 1993, consistent with increased fishing pressure and landings in both the recreational and commercial fisheries. Since then fishing mortality rates have declined steadily and have been substantially reduced to an estimated 0.29 (23.5% exploitation rate) in 1998. This trend is consistent with the adoption of a fisheries management plan in 1996 by the Atlantic States Marine Fisheries Commission and implementation of more stringent management measures by the individual states. However, bootstrap analysis of the 1998 fishing mortality estimates indicate that there is a 90% probability that F in 1998 was above the plan interim target of F=0.24, and well above the final plan target of F=M=0.15. Additionally, spawning stock biomass has continually declined from a time series high of approximately 43,000 mt in 1984 to lowest levels in most recent years (1997 = 6,800 mt). SSB appears to have stabilized at a low level since then. Bootstrap analysis for the 1998 SSB estimates indicate that there is a 90% probability that SSB was below 7,900 mt in 1998.

Regarding recruitment, age 1 stock sizes declined from high levels in 1981 to the lowest level in the time series in 1994. Recent juvenile surveys show signs of a good year class in 1998. Although no stock projections were made, in the absence of remarkable year classes, stock size is expected to remain low for the foreseeable future.

RESEARCH RECOMMENDATIONS

Stock discrimination studies on tautog are needed.

Port sampling of tautog catch in areas from Massachusetts to Virginia is needed to adequately characterize the size and age composition of commercial landings.

Commercial catch sampling data by gear type is needed in all states and the EEZ.

To allow for annual catch-at-age estimates, age and length sampling of tautog should be increased coast-wide. Expanded age and length sampling of tautog from recreational catches is needed, especially from the MRFSS intercept sampling of angler catch, focusing on private boat and shoreside/jetty fishing.

Commercial port sampling methodology changes should be explored and documented to preserve the integrity of the commercial landings time series for future assessments.

Fisheries independent indices (adult and juvenile) are needed for the Southern Region.

Juvenile habitat utilization in the Southern Region should be delineated
Investigate comparisons between the US Fish and Wildlife Service surveys and MRFSS surveys.

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Table C1. Summary of recreational and commercial fisheries management measures by state.

Recreational Size Limits and Bag Limits for Tautog 1996 through 1999

	1996		1997		1998		1999	
State	Size limit	Bag limit	Size limit	Bag limit	Size limit	Bag limit	Size limit	Bag limit
MA	16"	8	16"	6	16"	6	16"	6
RI	16"	8	16"	8	16"	4 (e)	16"	4 (e)
CT	12"	None	14"	4	14"	4 (f)	14"	4 (f)
NY	13"	10	14"	(c)	14"	(c)	14"	(c)
NJ	12"	None	13"		14"	(g)	14"	(g)
DE	12" (a) 15"	10 3	12"(b) 15" 13"	10 3 10	14" 15"	10(h) 3	14" 15"	10(h) 3
MD	None	None	13"		14"	5	14"	5
VA	None	None	14"	10(d)	14"	10(d)	14"	7

(a) In 1996 Delaware had a 12" size limit and a 10 fish bag limit from July 1 through March 31 and a 15" size limit and 3 fish bag limit from April 1 through June 30.

(b) In 1997 Delaware had a 12" size limit and a 10 fish bag limit from January 1 through March 31, a 15" size limit and a 3 fish bag limit from April 1 through June 30, and a 13" size limit and 10 fish bag limit from July 1 through December 31.

(c) New York has a one fish bag limit in effect from June 1 through October 6 and a 10 fish bag limit in effect from October 7 through May 31.

(d) When fishing from a for hire vessel, an individual in Rhode Island may possess no more than 1 tautog per day from January 1 through October 14 and no more than 12 tautog per day from October 15 through December 31.

(e) Connecticut has a recreational tautog fishery closure from May 1through June 14.

(f) New Jersey has a possession limit of 10 tautog from January 1 through May 31 and October 10 through December 31. The possession limit from June 1 through October 9 is 1 tautog.

(g) Delaware has a 14" size limit and a 10 fish bag limit from July 1 through Mar 31 and a 15" size limit and a 3 fish bag limit from April 1 through June 30. Delaware has an 11-day closure from September 8 through September 18.

Commercial Size Limits for Tautog from 1996 through 1999.

State	1996	1997	1998	1999
Massachusetts	16"	16"	16"	16"
Rhode Island	16"	16"	16"	16"
Connecticut	12"	14"	14"	14"
New York	16"	14"	14"	14"
New Jersey	12"	14"	14"	14"
Delaware	12" (a) 15"	12" (b) 15" 13"	14"(c) 15"	14"(c) 15"
Maryland	None	None	14"	14"
Virginia	None	14"	14"	14"(d)

(a) The Commercial tautog fishery in Delaware had a 12" minimum size from July 1 through March 31 and a 15" minimum size from April 1 through June 30

(b) Delaware had a 12" size limit from January 1 through March 31, a 15" size limit from April 1 through June 30, and a 13" size limit from July 1 through December 31.

(c) Delaware had a 14-inch minimum size limit from July 1 through March 1 and a 15" minimum size limit from April 1 through June 30.

(d) Virginia has a closed season May 1 – August 31.

Table C2. Recreational landings of tautog (A + B1 catch), by year and state, for 1981-1998, in metric tons.

Years	Massachusetts	Rhode Island	Connecticut	New York	New Jersey	Delaware	Maryland	Virginia	Total
1981	358.6	301.4	109.9	678.6	73.2	3	4.7	336.9	1866.3
1982	1463.7	352.9	277	759.8	563	194.2	41.1	123.3	3774.9
1983	833.4	279.2	208	510.2	188.2	2	3	574.8	2598.9
1984	332.9	820.9	332.8	245.8	325.3	43.4	35.9	303.9	2440.9
1985	148.8	125.8	213.7	923	336.4	65.7	0.5	135.5	1949.5
1986	3566.5	926.5	380.3	1285.1	967.3	120.1	4.6	416.5	7666.8
1987	794.4	230.2	502	1037.9	966.6	175.6	120.7	200.8	4028.1
1988	102.3	277.7	276.8	1079.7	604.1	113.3	202.7	639.6	3296.2
1989	488.2	134.7	470.9	461.8	584.8	337.2	35.6	365.8	2878.9
1990	406.1	380.8	90.7	898.3	569.9	64.7	27.1	104.1	2541.7
1991	362.4	457	294.2	1067.2	993	160.8	48.2	280.9	3663.6
1992	756.8	297.9	475.7	544.1	1127.5	83.4	72.5	116.1	3474
1993	341.4	171.8	240.9	816.8	617.6	98.8	47.7	344	2679.1
1994	169.3	149.1	189.4	265.4	149.9	69	80.4	45.9	1118.3
1995	140.3	107.5	182.6	167.7	781.4	359.9	52.6	278.2	2070.2
1996	180.2	112.9	111.5	87.6	509.5	72	12	353	1438.7
1997	75.3	136.6	38.7	150.4	219.4	92.7	83	177.5	973.6
1998	43.9	143.5	105.1	94.7	18.8	116.7	12.5	124.1	659.2

Table C3. Estimated recreational landings of tautog (A + B1 catch), for 1981-1998, by year and state, in numbers.

Years	Massachusetts	Rhode Island	Connecticut	New York	New Jersey	Delaware	Maryland	Virginia	Total
1981	228736	233508	100308	721062	132271	3457	4670	236768	1660780
1982	1051022	214938	231187	646693	583550	137328	35105	71599	2971422
1983	670508	245796	200676	612163	344580	4350	2126	579795	2659994
1984	258256	490128	287470	286077	516086	28388	42835	207192	2116432
1985	100941	115404	182318	1105234	840627	62001	486	91957	2498968
1986	1980719	671592	333396	1183114	2369852	141290	5476	322905	7008344
1987	617068	130729	312430	929887	1015123	99706	90523	126783	3322249
1988	621679	207799	234198	818382	564286	94491	107570	368320	3016725
1989	250077	116506	303782	562549	710958	249928	34709	284477	2512986
1990	233444	153433	75871	953622	841770	61526	45467	111998	2477131
1991	176905	291946	191137	871221	1067284	128985	26770	168068	2922316
1992	357949	193786	319221	413236	1018205	68769	1066255	100952	3538373
1993	216553	118775	180055	505632	773213	82475	60231	330484	2267418
1994	78483	82304	150109	196937	208003	65837	157260	231740	1170673
1995	72461	54570	120259	118006	707963	300303	43542	222186	1639290
1996	79798	55528	72558	82826	470431	57751	9695	224447	1053034
1997	39075	70628	32200	92907	196724	65133	85682	106678	689027
1998	25034	56084	66797	68887	11667	62584	6512	50923	348488

Table C4. Estimated numbers of tautog caught and released in the recreational fisheries (B2 catch), for 1981-1998, by year and state.

Years	Massachusetts	Rhode Island	Connecticut	New York	New Jersey	Delaware	Maryland	Virginia	Total
1981	1153	26806	3780	341706	1748	751	0	2022	377966
1982	16583	19764	11952	148454	76125	19720	0	290	292888
1983	113536	46703	80802	276104	92183	2015	0	64989	676332
1984	99633	165325	69881	253821	25011	486	24126	9680	647963
1985	28387	19917	46011	545460	39947	342	408	36266	716738
1986	425840	10853	34026	402949	120395	64739	3849	39971	1102622
1987	167396	37570	46981	746021	314804	3216	46556	43231	1405775
1988	178903	82792	159775	445264	263062	7484	18347	85069	1240696
1989	45042	31818	121778	436938	268629	92705	33562	34241	1064713
1990	54935	62433	44805	568868	371216	24064	35933	72297	1234551
1991	73892	105955	135700	1083037	656928	70830	17536	112752	2256630
1992	28954	72471	268382	519743	513908	59642	86638	57707	1607445
1993	67436	51057	83728	841536	438305	223263	162020	103762	1971107
1994	220081	62617	135569	357276	228139	255326	163082	57488	1479578
1995	208924	61187	74735	430070	877460	326023	71775	52409	2102583
1996	191166	58022	74095	105373	571582	54242	22251	80962	1157693
1997	105178	74774	67067	166003	420205	120049	50728	75572	1079576
1998	81409	91241	207872	516765	225293	169402	29499	77005	1398486

Table C5. Commercial landings of tautog, by year and state, for 1981-1998, in metric tons.

Years	Massachusetts	Rhode Island	Connecticut	New York	New Jersey	Delaware	Maryland	Virginia	Total
1981	46.7	31.7	9.3	36.9	24.7	0.5	0.5	0.3	150.6
1982	31.4	39.1	9.6	41	67.2	0.4	0	1.2	190
1983	26.1	64.7	15.2	40.1	45.6	0.4	0	0.8	192.6
1984	30.9	151.8	14.8	46.5	58.8	0.6	1.1	0.5	305.1
1985	28.7	182.9	22.6	38.5	56.9	1.5	1.1	0.7	332.7
1986	75.2	164.7	47.1	91.3	45.7	0.1	1.2	0.8	426.2
1987	113.4	190.7	72.2	102.2	43.2	0.2	1.7	1.2	524.9
1988	125.7	149.2	50.8	115.7	39.9	0.3	2.8	1.3	485.6
1989	159.9	97.5	45.2	129.5	23.5	0.2	1.8	3.4	461.1
1990	131.1	95.7	37.2	82.3	45	0.2	1.8	2.3	395.7
1991	160.7	168.6	24.5	102.7	42.2	0.6	1.4	2.3	503
1992	132.6	163.2	29.8	76.7	52.8	0.1	1.8	2	458.9
1993	72.7	91.4	39	40.6	69.6	0.1	0.6	2.5	316.7
1994	17	59.3	19.5	32.4	73.8	0.1	0.8	5.2	208
1995	16	43.1	9.3	33.1	52.7	0.2	2	13.6	169.9
1996	14.8	29.4	15.1	47.8	40.6	0.3	1.6	11.9	161.5
1997	29.2	18	6.6	45.8	22.6	0.4	3.5	11.6	137.5
1998	41.5	9.2	3.1	31.3	19.2	0.8	2.6	6.7	114.4

Table C6. Total landings of tautog, and the proportion of recreational landings to total landings by year and fishery, in metric tons.

Year	Commercial North	Commercial South	Recreational North	Recreational South	Total Landings	Percent Recreational
1981	124.6	26	1448.6	417.7	2017	93
1982	121.2	68.9	2853.3	921.6	3964.9	95
1983	146.1	46.8	1830.9	768	2791.7	93
1984	244.0	61.1	1732.4	708.5	2746	89
1985	272.5	60.2	1411.4	538.2	2282.3	85
1986	378.3	47.8	6158.4	1508.5	8093	95
1987	478.5	46.4	2564.4	1463.7	4553	89
1988	441.4	44.2	2657.4	1559.7	4702.8	90
1989	432.1	29	1555.6	1323.3	3340	86
1990	346.4	49.3	1775.9	765.8	2937.5	87
1991	456.5	46.5	2180.8	1482.9	4166.6	88
1992	402.2	56.7	2074.5	1399.5	3932.9	88
1993	243.8	72.9	1570.9	1108.2	2295.7	89
1994	128.1	79.9	773.1	345.2	1326.3	84
1995	101.4	68.5	598.1	1472.1	2240.2	92
1996	107.2	54.3	492.1	946.5	1600.2	90
1997	99.5	38	401	572.6	1111	88
1998	85.1	29.3	387.1	272.1	773.7	85

Table C7. Length sampling intensity for Northern and Southern Regions.

Year	Northern Landings*	Sample number	MT/100 lengths	Southern Landings*	Sample Number	MT/100 lengths
1981	1186	509	233	338	77	439
1982	1732	709	244	691	259	267
1983	1779	804	221	926	144	643
1984	1769	654	270	1174	162	725
1985	1592	325	490	933	138	676
1986	6297	1484	424	4079	421	969
1987	2754	547	503	1569	255	615
1988	2962	766	387	1556	287	542
1989	1481	1889	78	1118	744	150
1991	1832	1775	103	1162	836	139
1991	2404	1444	166	1816	838	217
1992	2225	1225	182	1894	961	197
1993	1516	1702	89	1588	659	241
1994	726	68	107	861	529	163
1995	602	537	112	1844	98	188
1996	613	835	73	1318	898	147
1997	427	596	72	670	89	75
1998	399	267	149	220	468	47

Table C8. Sample sizes and percentage distribution of samples in tautog age-length keys from recreational and commercial fisheries, and fisheries independent surveys.

Northern Region	Total Number	Number recreational	Number Commercial	Number Surveys	Percent Recreational	Percent Commercial	Percent surveys
1981-1986	1236	0	0	1236	0	0	100
1987-1989	1208	0	0	1208	0	0	100
1990-1992	831	0	0	831	0	0	100
1993-1995	756	128	136	492	17	18	65
1996-1998	1143	518	507	118	45	45	10
Southern Region	**Total Number**	**Number recreational**	**Number commercial**	**Number Surveys**	**Percent recreational**	**Percent Commercial**	**Percent surveys**
1981-1989	696	?	?	?	~20	~75	~5
1990-1995	942	222	624	96	24	66	10
1996-1998	1681	1035	639	7	62	38	.4

Table C9. Coast-wide catch-at-age matrix, in numbers of fish at age.

Year	Age 1	2	3	4	5	6	7	8	9	10	11	12+	Total
1981	7	46	117	289	336	303	302	191	145	53	24	24	1838
1982	54	125	146	248	358	423	440	348	323	209	132	387	3192
1983	80	196	284	437	449	329	320	235	205	140	86	132	2892
1984	121	220	281	262	256	204	193	154	152	114	101	308	2367
1985	68	193	427	763	884	704	586	377	302	122	73	174	4675
1986	40	126	259	526	650	736	812	678	628	413	253	668	5790
1987	58	121	218	347	416	506	515	441	356	182	122	331	3615
1988	73	166	275	386	405	434	444	370	293	165	123	437	3571
1989	14	99	369	580	505	406	348	202	152	69	45	123	2913
1990	8	72	370	571	607	437	292	191	118	65	54	135	2922
1991	2	24	235	479	627	567	438	298	195	124	100	295	3385
1992	1	29	245	466	570	468	352	245	158	105	84	236	2957
1993	5	45	195	401	480	457	357	241	142	71	41	132	2568
1994	0	14	117	249	291	240	180	136	85	44	17	42	1415
1995	0	6	84	224	419	400	308	174	99	50	28	60	1850
1996	0	17	74	220	246	217	166	106	65	44	20	47	1223
1997	0	10	51	158	164	138	111	77	42	26	12	26	814
1998	0	5	17	56	77	75	72	57	35	21	11	32	461

Table C10. VPA Output

January 1 Stock size in numbers (thousands).

Age	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1	8896	8095	6727	5842	6061	6482	6157	5243	4303	3740	3069	2611	2265	2037	2248	2445	2247	2101	5441
2	7728	7651	6918	5716	4916	5154	5542	5246	4445	3691	3212	2639	2246	1945	1753	1935	2104	1934	1808
3	6170	6609	6469	5772	4716	4052	4319	4658	4361	3734	3110	2742	2245	1892	1661	1503	1649	1802	1660
4	5226	5202	5553	5304	4707	3663	3247	3515	3754	3411	2870	2458	2133	1751	1520	1352	1225	1372	1535
5	4060	4230	4247	4374	4322	3344	2665	2473	2667	2693	2406	2026	1684	1464	1276	1100	959	908	1129
6	3045	3183	3308	3239	3527	2900	2275	1907	1753	1827	1755	1489	1215	1004	990	710	719	674	710
7	1903	2340	2347	2542	2599	2383	1813	1489	1239	1132	1167	984	848	622	641	481	410	491	510
8	2352	1357	1605	1723	2009	1693	1297	1083	869	744	703	598	520	398	368	266	260	250	355
9	1201	1847	846	1164	1340	1380	828	708	589	561	463	329	288	224	217	156	131	152	162
10	803	899	1290	538	861	874	605	383	337	366	373	217	137	116	114	95	74	74	99
11	217	642	580	981	357	628	369	352	176	226	255	206	90	52	59	52	41	39	44
12+	216	1874	874	2984	852	1646	997	1241	483	567	745	575	289	124	123	124	84	117	94
1+	41817	43928	40765	40179	36267	34197	30114	28296	24976	22691	20128	16877	13959	11629	10971	10218	9903	9913	13547

SSB using mean weights (mt).

Age	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
2	174	134	134	123	106	106	137	177	150	107	92	74	54	52	47	81	99	70
3	972	1239	1110	1183	1123	954	1022	1290	1124	1133	757	690	531	379	425	415	726	948
4	1280	2883	2998	2683	2601	2099	1876	2145	2158	2116	1952	1720	1515	1247	1128	1218	1196	1429
5	1644	3830	5310	5131	4423	3596	2888	2749	2805	2888	2843	2325	1852	1632	1470	1534	1407	1420
6	2108	3485	5397	5105	4997	4169	3243	2727	2367	2477	2572	2176	1699	1351	1338	1084	1214	1182
7	1679	3338	4585	4929	4648	4230	3091	2403	1886	1848	2016	1756	1394	1055	1005	845	737	889
8	2380	2242	3546	3908	4247	3362	2457	1895	1490	1312	1352	1193	983	772	669	526	525	488
9	1280	3509	2015	2951	3164	2968	1735	1362	1125	1077	952	669	606	476	461	339	298	339
10	968	1851	3497	1459	2366	2081	1529	881	841	879	898	522	304	284	269	243	193	190
11	381	1439	1713	3097	1061	1684	1023	987	505	646	716	586	267	145	156	145	122	114
12+	645	7651	3274	12208	3021	6270	3348	4787	1764	2165	2712	2120	1072	450	420	456	318	439
1+	13510	31600	33579	42776	31757	31519	22349	21404	16215	16649	16863	13833	10277	7842	7389	6887	6834	7508

Average F's for ages 4-11 and 7-11.

Ages	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
4-11	0.11	0.20	0.16	0.11	0.24	0.46	0.36	0.39	0.28	0.27	0.46	0.51	0.58	0.38	0.58	0.47	0.33	0.22
7-11	0.12	0.26	0.19	0.14	0.24	0.60	0.46	0.51	0.31	0.28	0.55	0.62	0.71	0.46	0.69	0.57	0.40	0.29

Table C11. Biological Reference Point calculations.

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

Run Date: 2-12-1999; Time: 15:43:03.74

COASTAL TAUTOG STOCK - 12 Year, Plus Group

Proportion of F before spawning: .2000
Proportion of M before spawning: .4000
Natural Mortality is Constant at: .150
Initial age is: 1; Last age is: 18
Last age is a PLUS group;
Original age-specific PRs, Mats, and Mean Wts from file:
==> TAUTOG.DAT

Age-specific Input data for Yield per Recruit Analysis

Age	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Weights Catch	Average Weights Stock
1	.0000	1.0000	.0000	.070	.070
2	.0100	1.0000	.1000	.210	.210
3	.0780	1.0000	.5000	.546	.546
4	.2540	1.0000	.7500	.716	.716
5	.4280	1.0000	1.0000	.787	.787
6	.5800	1.0000	1.0000	1.011	1.011
7	.7460	1.0000	1.0000	1.314	1.314
8	1.0000	1.0000	1.0000	1.557	1.557
9	1.0000	1.0000	1.0000	1.969	1.969
10	1.0000	1.0000	1.0000	2.160	2.160
11	1.0000	1.0000	1.0000	2.458	2.458
12	1.0000	1.0000	1.0000	2.793	2.793
13	1.0000	1.0000	1.0000	2.838	2.838
14	1.0000	1.0000	1.0000	3.104	3.104
15	1.0000	1.0000	1.0000	3.717	3.717
16	1.0000	1.0000	1.0000	3.950	3.950
17	1.0000	1.0000	1.0000	4.210	4.210
18+	1.0000	1.0000	1.0000	4.390	4.390

Summary of Yield per Recruit Analysis for:
COASTAL TAUTOG STOCK - 12 Year, Plus Group

Slope of the Yield/Recruit Curve at F=0.00: --> 7.8158
F level at slope=1/10 of the above slope (F0.1): -----> .144
Yield/Recruit corresponding to F0.1: -----> .4179
F level to produce Maximum Yield/Recruit (Fmax): -----> .362
Yield/Recruit corresponding to Fmax: -----> .4681
F level at 40 % of Max Spawning Potential (F40): -----> .172
SSB/Recruit corresponding to F40: --------> 3.5458

1

Listing of Yield per Recruit Results for:
COASTAL TAUTOG STOCK - 12 Year, Plus Group

	FMORT	TOTCTHN	TOTCTHW	TOTSTKN	TOTSTKW	SPNSTKN	SPNSTKW	% MSP
	.00	.00000	.00000	7.1792	9.9632	4.5908	8.8659	100.00
	.10	.20165	.36914	5.8386	5.6539	3.2893	4.7321	53.37
F0.1	.14	.24912	.41789	5.5237	4.7972	2.9836	3.9147	44.15
F40%	.17	.27219	.43558	5.3708	4.4097	2.8352	3.5458	39.99
	.20	.29291	.44810	5.2336	4.0792	2.7020	3.2316	36.45
	.30	.34688	.46626	4.8767	3.3010	2.3557	2.4941	28.13
Fmax	.36	.37114	.46814	4.7166	2.9918	2.2006	2.2022	24.84
	.40	.38359	.46777	4.6345	2.8429	2.1212	2.0620	23.26
	.50	.41076	.46417	4.4557	2.5408	1.9483	1.7782	20.06
	.60	.43204	.45911	4.3160	2.3252	1.8134	1.5764	17.78
	.70	.44937	.45387	4.2023	2.1625	1.7041	1.4247	16.07
	.80	.46390	.44891	4.1072	2.0344	1.6128	1.3058	14.73

Figure C1. Total tautog landings by year and fishery, in metric tons.

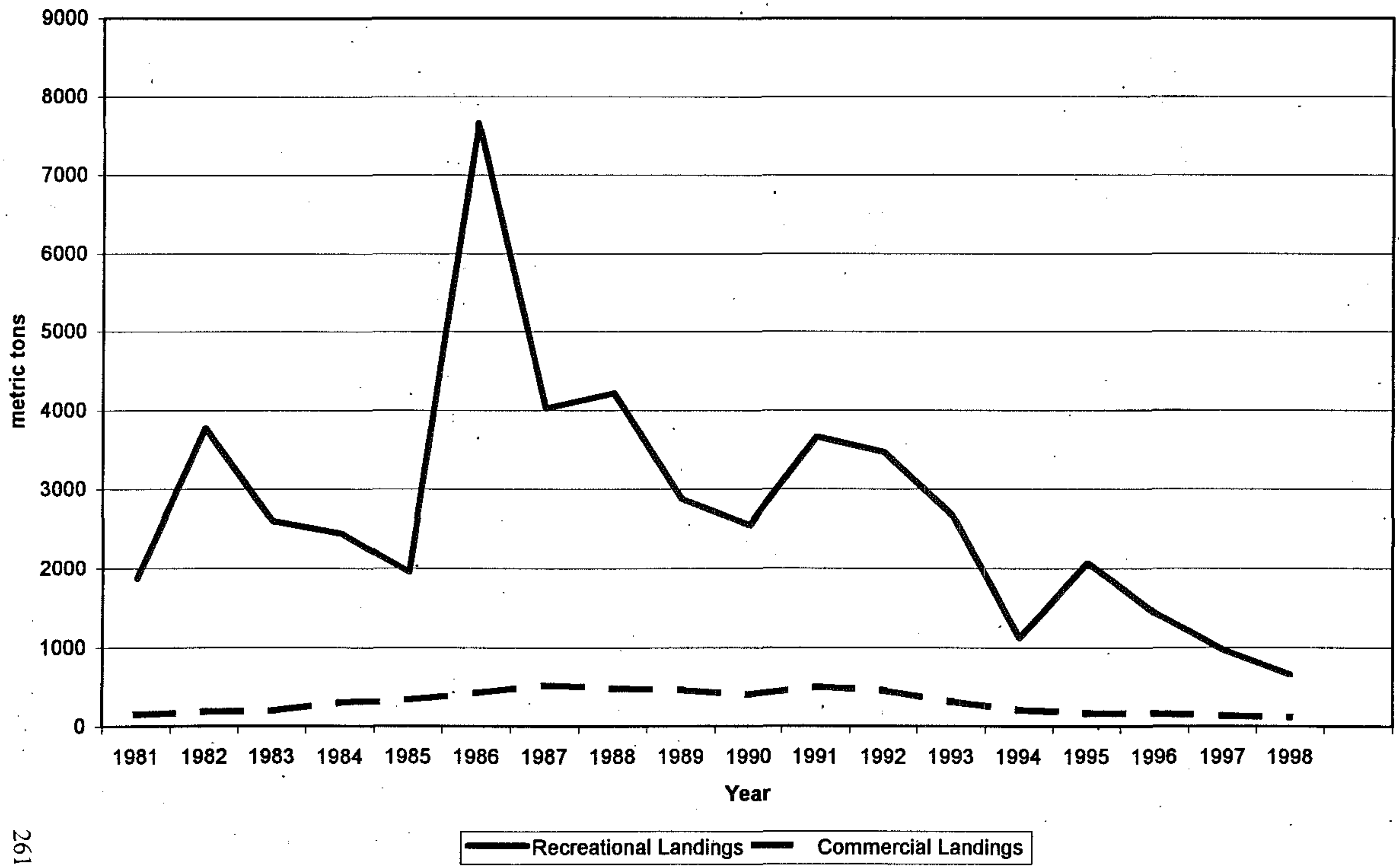


Figure C2. Northern Region recreational catch length frequencies.

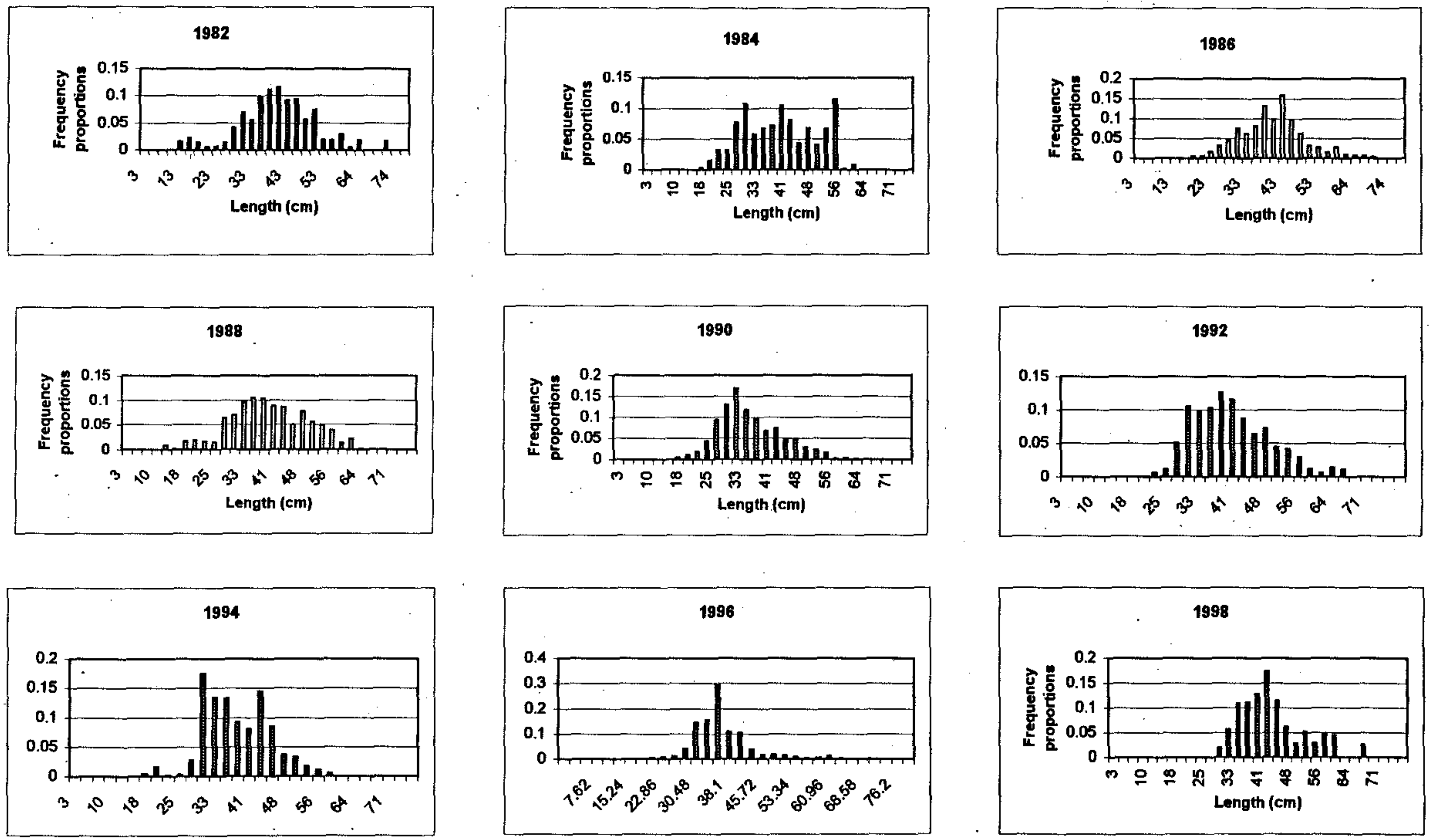


Figure C3. Southern Region recreational catch length frequencies.

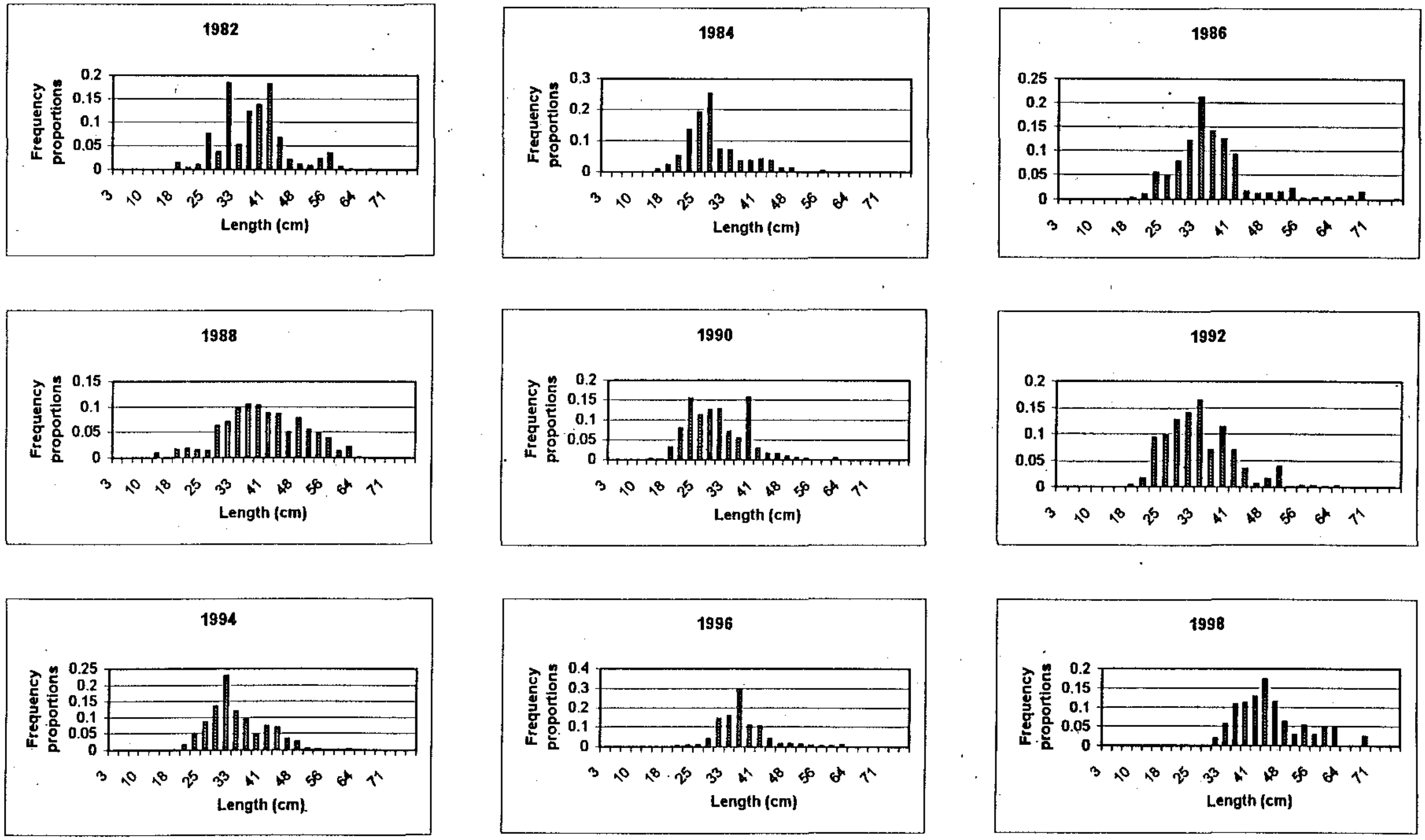


Figure C4. Z scores of tautog state survey indices, age 2+.

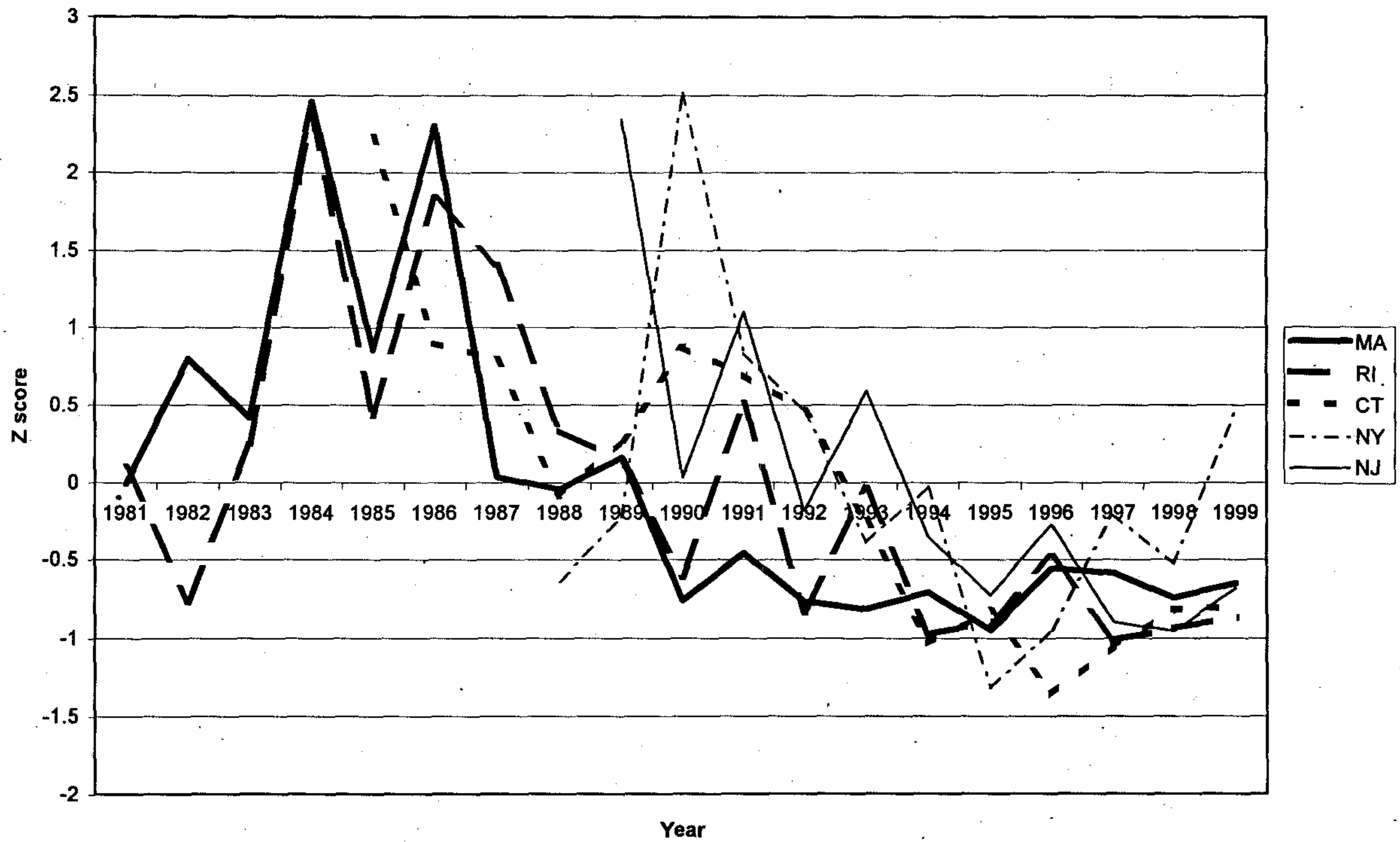


Figure C5. Juvenile Indices of abundance.

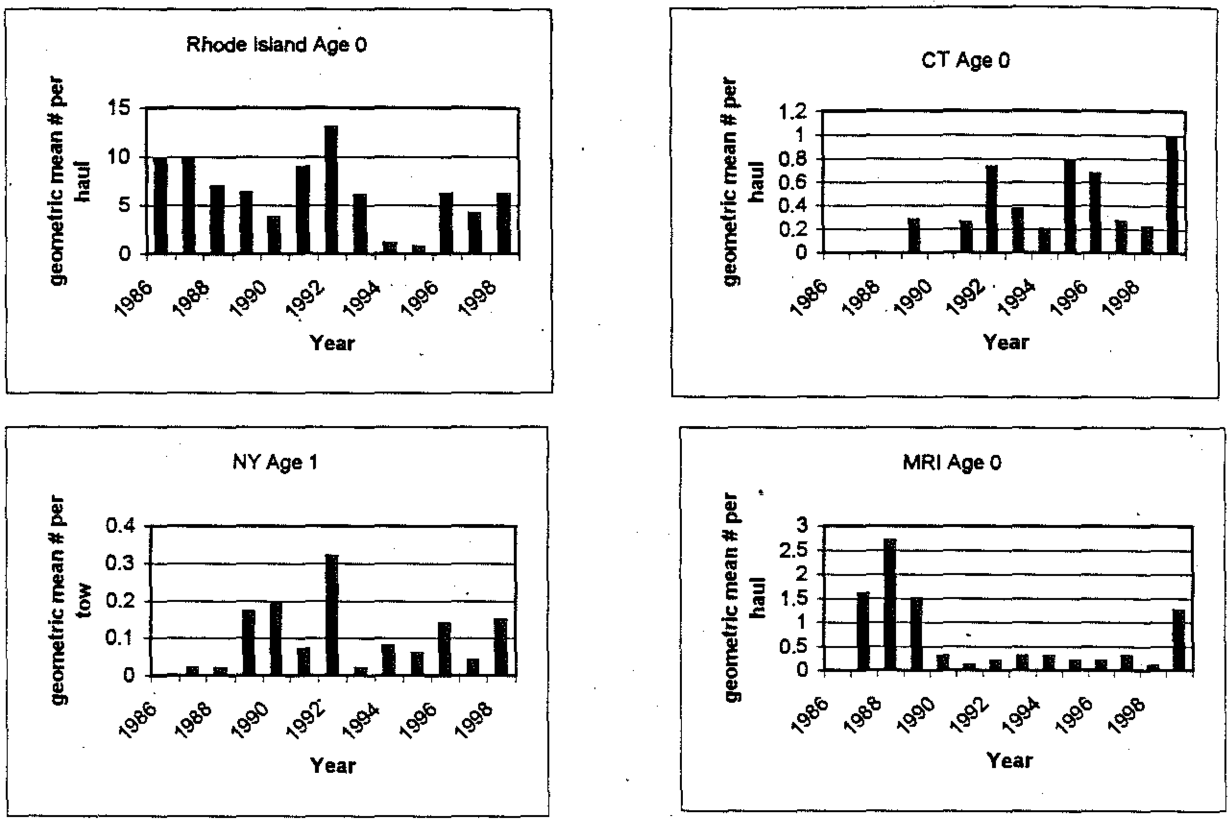


Figure C6. VPA Estimated fishing mortality for tautog.

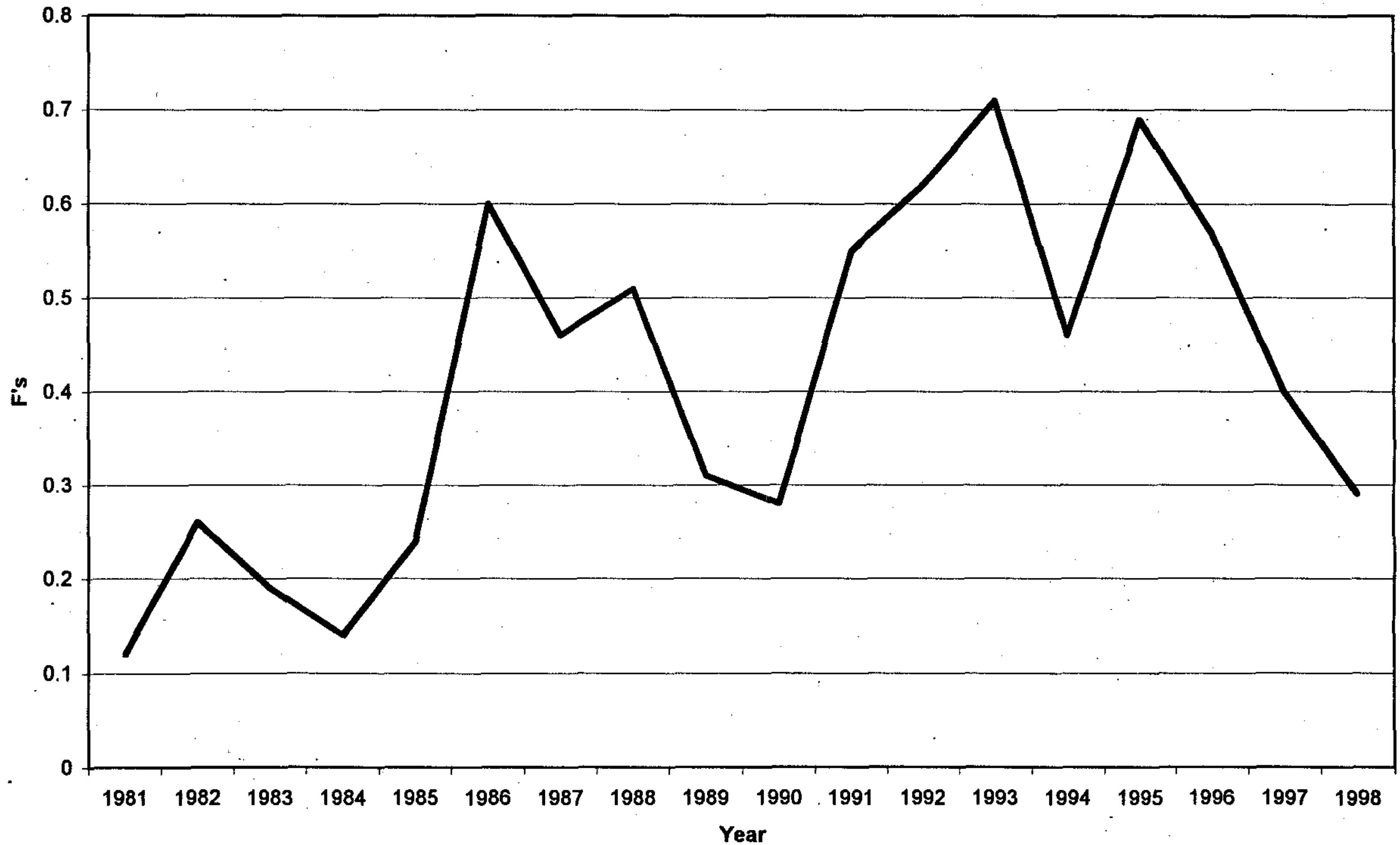


Figure C7. VPA Estimated stock size for tautog.

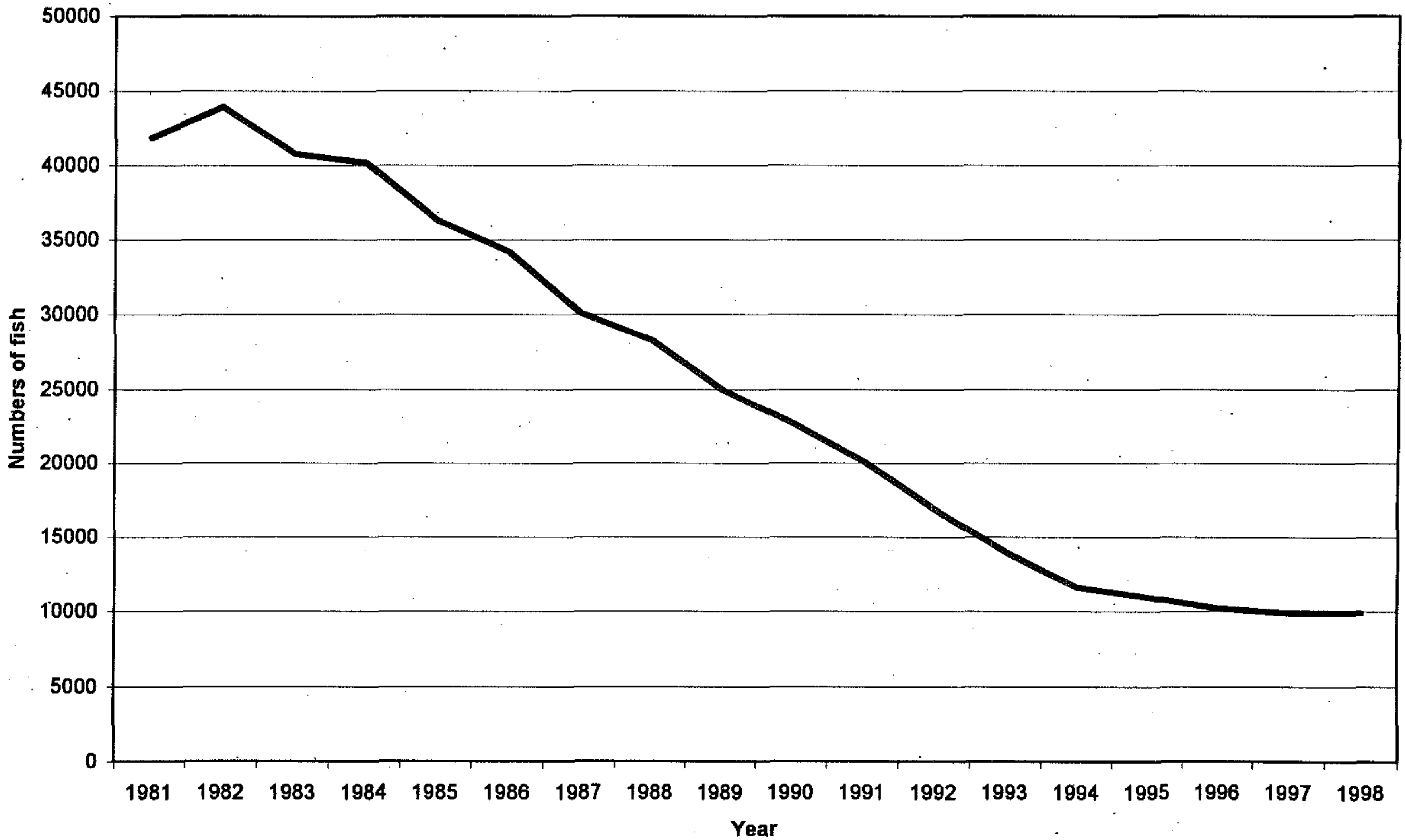


Figure C8. VPA Estimated spawning stock biomass

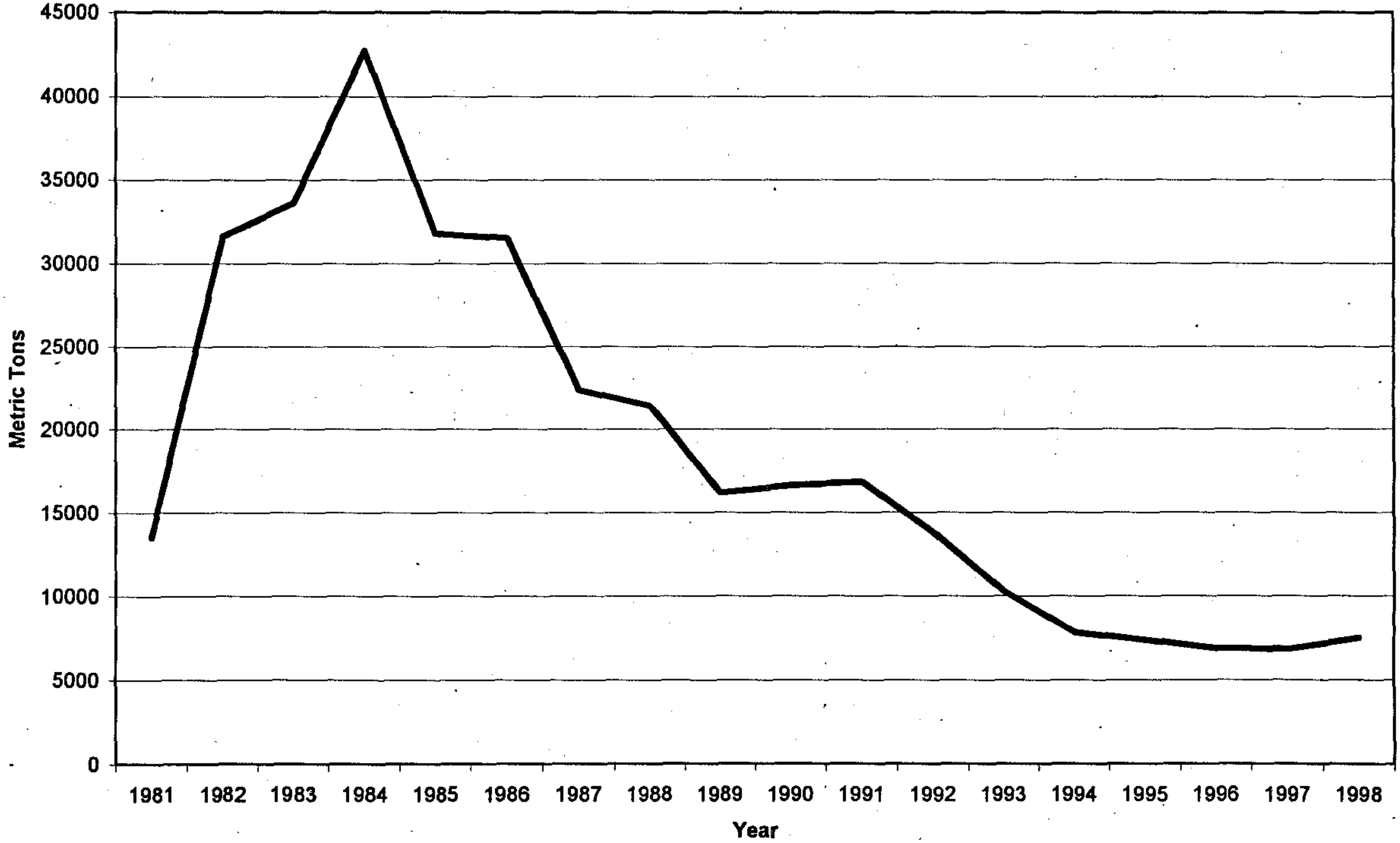


Figure C9. VPA Estimated recruitment by year class for tautog.

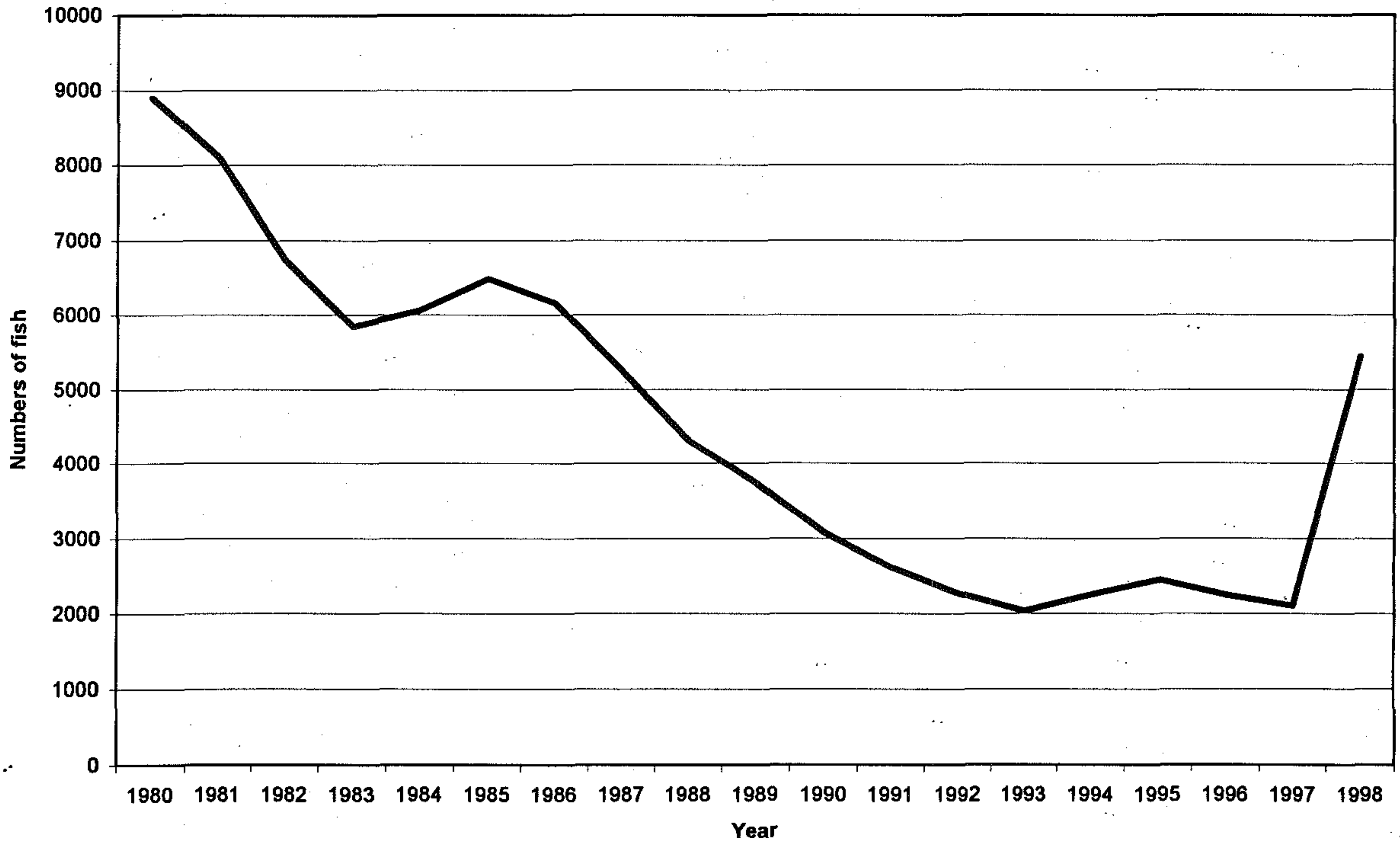


Figure C10. Precision of 1998 F estimate

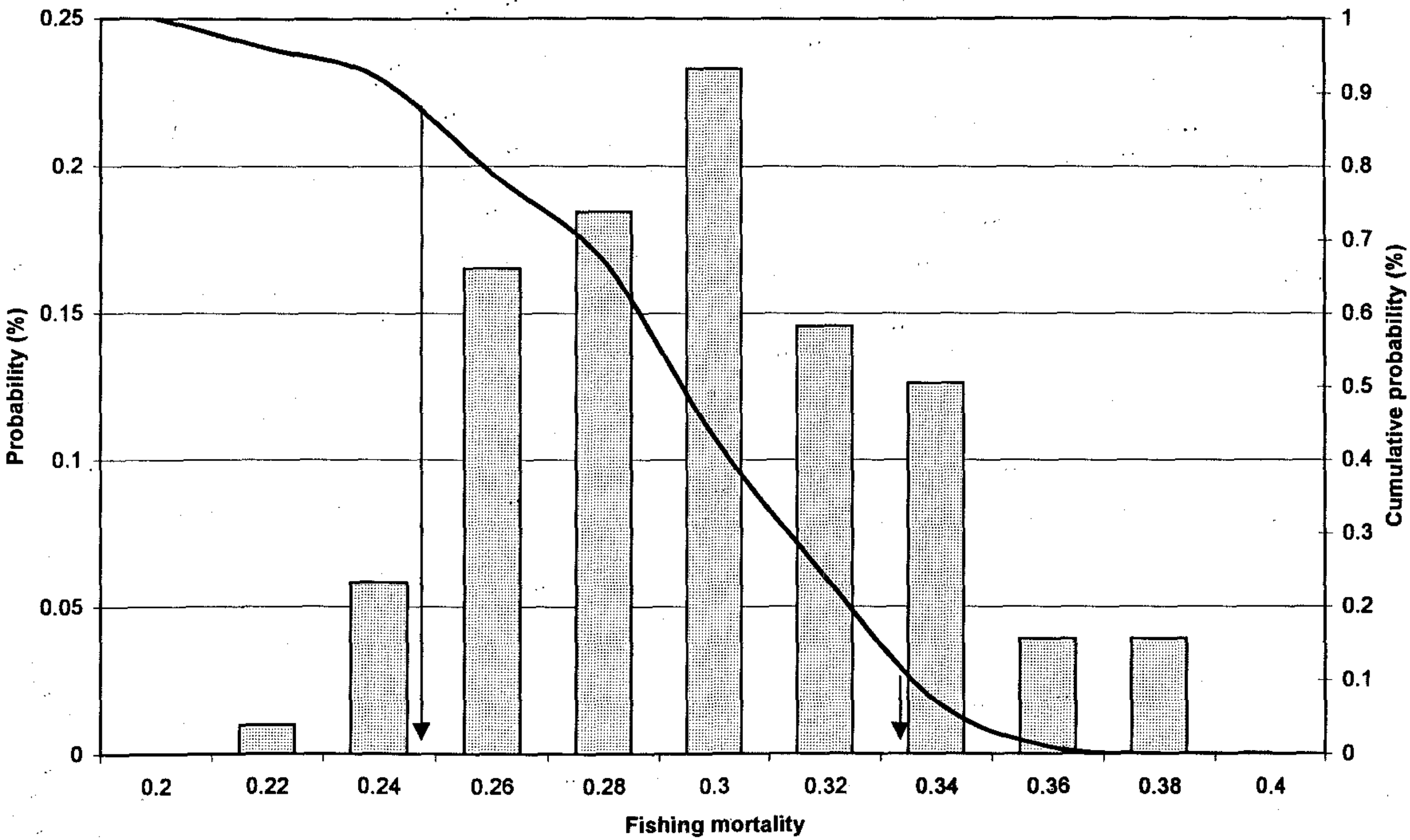


Figure C11. Precision of 1998 SSB estimates

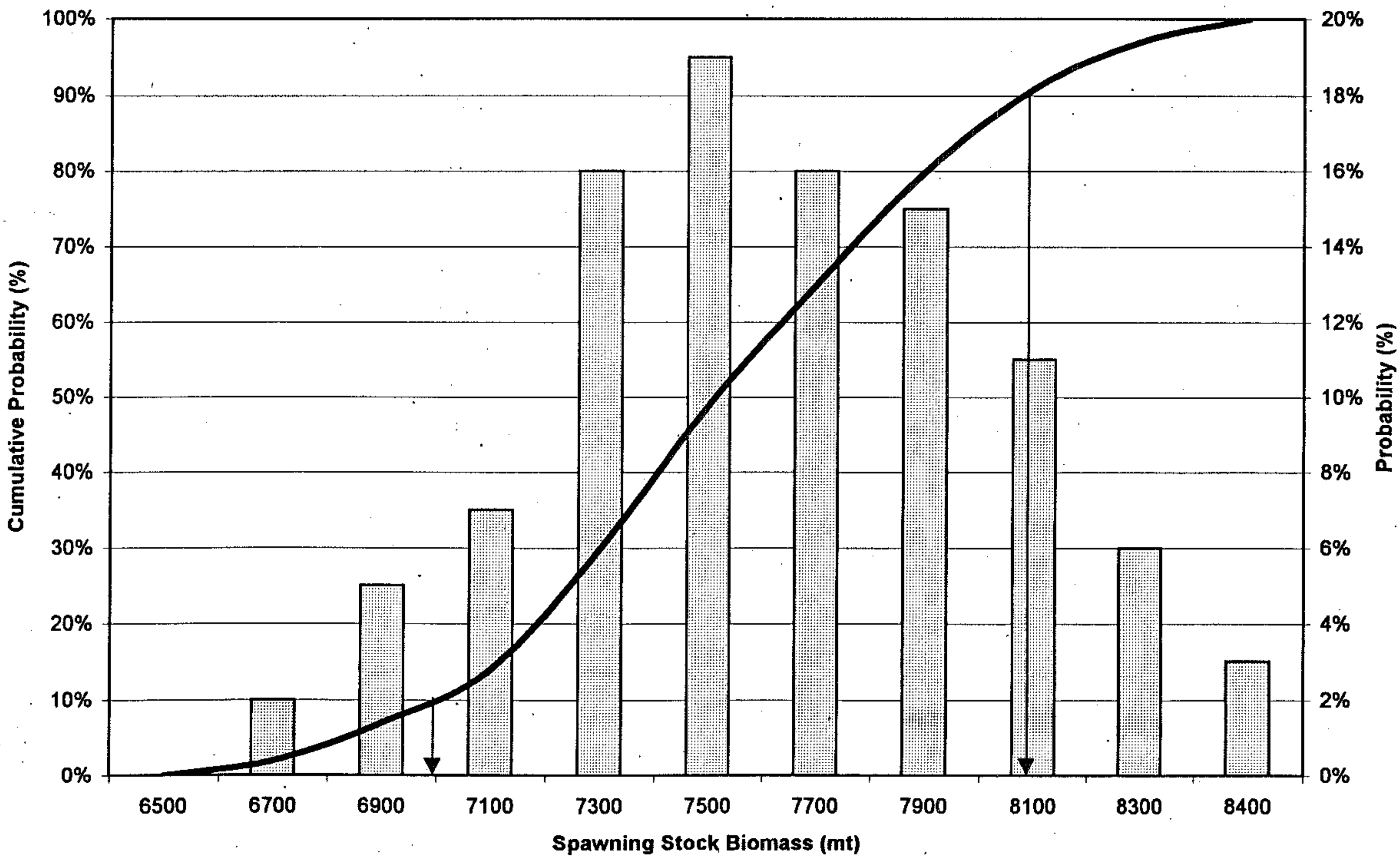
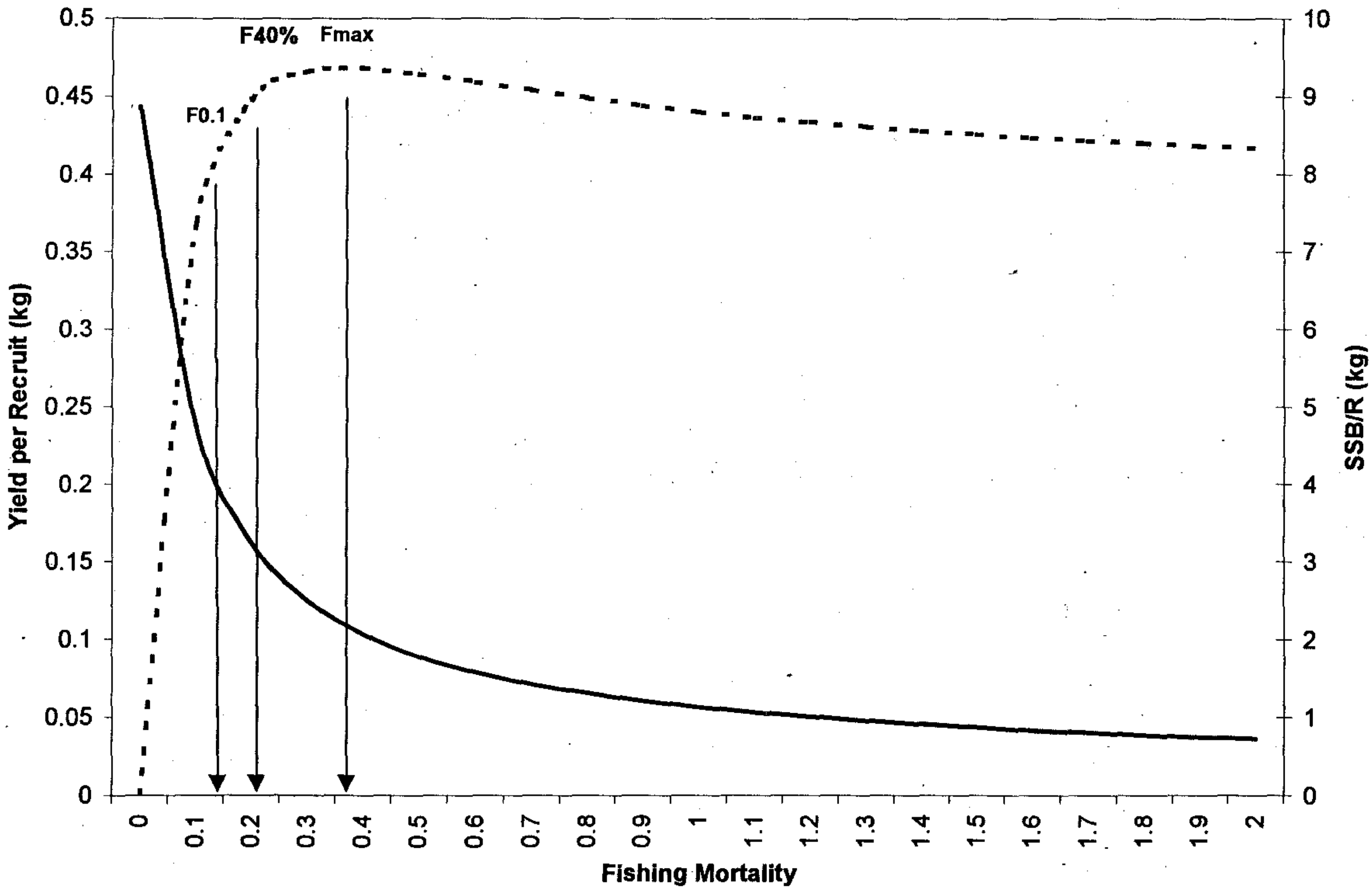


Figure C12.Yield and Spawning Stock Biomass per Recruit



D. ATLANTIC MACKEREL

TERMS OF REFERENCE

The following terms of reference were addressed for Atlantic mackerel:

1) Update the status of the Atlantic mackerel stock through 1998 and characterize the variability of estimates of stock size and fishing mortality rates.

(2) Provide projected estimates of catch for 1999 and SSB for 2000-2001at various levels of F consistent with management targets and thresholds.

(3) Evaluate fishing mortality and biomass targets and thresholds consistent with requirements of the Sustainable Fisheries Act, and recommend changes, as appropriate.

INTRODUCTION

The Northwest Atlantic stock of Atlantic mackerel has been assessed on numerous occasions during 1975-1994 (Anderson and Paciorkowski 1980, Overholtz 1991a) and the current assessment represents an update of the NEFSC (1996) analysis, adding the additional years from 1994-1998. This stock has undergone several major episodes of collapse and recovery during 1962-1998 and more recently (1990's) the stock appears to be at or near a historic high for abundance and biomass.

The fishery on this stock was historically important in the New England region and later in Canada, but changes in consumer preferences for fish caused major declines in landings for both countries. Landings from this stock averaged over 300,000 mt during the ICNAF fishery years (1968-1976), declined to less than 50,000 mt per year during 1978-1984, reached over 80,000 mt in 1987-1988, and declined to less than 40,000 mt during 1992-1998 (Figure D1). Landings by the USA during 1992-1998 have remained below 20,000 mt and Canadian landings have remained relatively constant, averaging about 20,000 mt annually. Recent landings from this stock are far below the potential yield of this productive fishery resource.

Several recent assessments suggest that the stock began to recover in the mid to late 1980s (Overholtz 1991a) and this trend as well as further recovery was confirmed in the 1994 assessment (NEFSC 1996). These analyses determined that in the early 1990s spawning stock biomass began to approach 1-2 million mt and fishing mortality rates on this stock were exceptionally low during 1985-1993. Both analyses noted several sources of uncertainty encountered in assessing this stock, notably, underreporting of catch during the ICNAF era, lack of convergence of the VPA due to very low F's, and variability in survey indices. It was recognized that any assessment of this stock would necessarily produce stock size estimates with relatively low precision, due to very low fishing rates in the 1980s and 1990s. The current assessment, susceptible to the same uncertainties, would be expected to produce relatively imprecise estimates of stock numbers at age.

STOCK STRUCTURE

Information on stock structure was summarized and reviewed by the 20th SARC

(NEFSC 1996) as follows. For the purpose of discussing stock structure, the definition of a fish stock is "an intraspecific group of randomly mating individuals with temporal or spatial integrity" (Ihssen *et al.* 1981). Sette (1950) proposed dividing the Atlantic mackerel population in the Northwest Atlantic into northern and southern contingents. However, Sette was careful to note that the contingents were not likely to have temporal integrity through successive generations. In particular, Sette (1950) stated that

> *"it is preferable to regard the two components as subdivisions of more or less stable nature enduring through several seasons, but not necessarily from one generation to another."*

Sette observed that the two spawning grounds of the Atlantic mackerel population were widely separated, with the southern ground in the Mid-Atlantic Bight and the northern ground in the Gulf of St. Lawrence. The migratory pattern of the southern contingent coincided with the observance of mackerel eggs during April-June in the Mid-Atlantic Bight. The migratory pattern of the northern contingent into the Gulf of St. Lawrence coincided with the observance of mackerel eggs there in late June and July. Based on these observations, Sette concluded that the two contingents segregated for spawning, but that (Sette 1950):

> *"the weight of evidence, if not definitely in favor of the shift of individuals from one contingent to the other, at least is sufficiently suggestive of this as to prevent the adoption of the view that the two contingents maintain their integrity throughout life and from one generation to another, as would be necessary for postulation of genetically separate stocks."*

Analyses of biochemical and meristic characteristics (MacKay 1967, MacKay and Garside 1969) and parasitological studies (Isakov 1976) have supported Sette's view; significant differences between the two contingents were not found in these studies. More recently, Maguire *et al.* (1987) examined potential biochemical differences between two samples of mackerel taken from waters off New Jersey and New York (NY84 and NY85) and two samples taken from the Gulf of St. Lawrence (BC84 and IPE85) in 1984-1985 during the spawning season. This electrophoretic study examined 20 enzymes; 6 enzymes exhibited polymorphism, 11 were monomorphic, and 3 exhibited inconsistent variation. Each of the 6 polymorphic enzymes coded for 1 locus. Allele frequencies of the 6 loci were found to conform to the Hardy-Weinberg equilibrium. When the samples were combined into U.S. (NY84 and NY85) and Canadian (BC84 and IPE85) groups, the variability of allele frequencies between U.S. and Canadian groups was not significantly different from the variability within groups at each locus. Although a cluster analysis of genetic distances between subsamples of age 2 (BC84-2) and age 3 (IPE85-3) fish from the Gulf of St. Lawrence and subsamples of age 3 (NY84-3) and age 4 (NY85-4) fish from the New York Bight suggested that Canadian samples (BC84-2 and IPE85-3) could be grouped and that U.S. samples (NY84-3 and NY85-4) could be grouped, no significant differences were detected between the resulting groups. Maguire *et al.* (1987) noted that the Gulf of St. Lawrence samples were more dissimilar genetically than the New York Bight samples, even though the same year class was present at age 2 and age 3 during consecutive years within the Canadian samples. They noted that biochemical changes associated with the onset of sexual maturation for age 2 and age 3 fish might have had an effect on the amount of detectable genetic variation. Nonetheless, their results were consistent with the approach of ICNAF to assess the Atlantic mackerel population as a single stock (ICNAF 1974).

Sette (1950) inferred that the northern and southern contingents mixed during the winter in the relatively warm waters of the convergence zone between shelf and slope waters at the edge of the continental shelf. Tagging experiments have supported this conclusion and have provided direct evidence that the northern contingent contributed to the winter fishery in the Mid-Atlantic Bight in the 1970s (Parsons and Moores 1974, Moores *et al.* 1975, Stobo 1976). Thus, although the northern and southern contingents separate during the spring, their winter distributions overlap. Size compositions of the northern and southern contingents during 1926-1935 reported in Sette (1950) suggested that the northern contingent was composed of relatively larger fish. If this pattern has been consistent through time, Canadian landings would likely have greater proportions of older fish than U.S. landings. If age was a determinant of migratory behavior, the relative sizes of the northern and southern contingents might be expected to change as the overall age structure of the stock changed. Regardless of this speculation, there is no indication that adult Atlantic mackerel consistently remain in one contingent throughout their life. At present, the most credible hypothesis is that the northern and southern contingents are dynamic components of a single stock. This hypothesis is consistent with the review of Smith *et al.* (1990) which found that the majority of genetic variation was within, not between, spawning groups of marine teleosts.

<u>Commercial Landings</u>

Historic

Landings in the USA mackerel fishery were first counted in 1804 and began to be commercially important in 1819 when landings reached 20,00 mt (Table D1, Figure D1), During 1820-1885 landings were relatively high, fluctuating between 10,000-80,000 mt, averaging roughly 40,000 mt, and peaking above 50,000 mt on numerous occasions (Table D1, Figure D1). After 1887, USA landings declined dramatically, fluctuating between 5,000 to 30,000 mt during 1987-1961 (Table D1, Figure D1). USA landings have remained relatively low during 1962-1998, ranging from 1,000 to 31,000 mt, but usually well below 10,000 mt (Table D2, Figure D1).

Canadian landings began to be routinely catalogued in 1876 with landings ranging from 9,000 to 31,000 mt during 1876-1893 (Table D1, Figure D2). Canadian landings showed a similar decline during 1894-1935 ranging from 4,000 to 11,000 mt (Table D1, Figure D2). Landings rebounded slightly from 1936-1961, ranging between 5,500 to 24,000 mt (Table D1, Figure D2). More recently Canadian landings have increased, ranging from 6,500 to 44,000 mt during 1962-1998 (Table D2, Figure D2).

Landings by foreign nations during the ICNAF era ranged between a few mt to over

390,000 mt in 1972-73 (Table D2, Figure D2). Following the collapse of the fishery in the late 1970s, foreign landings declined, ranging between 440 to 43,000 mt during 1978-1991. The majority of these landings were taken in the joint venture fishery from 1982-1991 (Table D2, Figure D2). Foreign landings ceased in 1992 (Table D2).

Cumulative landings by the USA, Canada, and foreign sources totaled 8.6 million mt during 1804-1998. Cumulative totals by country are USA, 4.1 million mt; Canada, 1.8 million mt; and ICNAF and other foreign, 2.7 million mt.

Recent Landings
Landings during 1994-1998 for the USA fishery were obtained from the commercial dealer data base in Woods Hole. Canadian landings were obtained from DFO, Canada (F. Gregoire, pers. comm., 1998).

Recreational Landings
Recreational landings for sport fisherman along the Atlantic coast were obtained from the MRFSS data base. Mackerel landings (A+B1), including fish retained (A) and fish used for bait or otherwise released dead (B1) were estimated for 1994-1998. Landings ranged from 670 to 1,735 mt without any obvious trend (Table D2). Landings for the recreational fishery prior to 1994 were taken from the last assessment (NEFSC 1996) (Table D2).

Sampling Intensity
Commercial length frequencies used to characterize USA landings were obtained from port sampling and sea sampling efforts in the Northeast Region. The mackerel fishery is strongly seasonal, with most of the landings occurring during the first 5 months of the calender year and any remaining landings during November and December. Because of stable growth patterns, length samples were aggregated over the first and second, and third and fourth calender quarters. Sampling was adequate in 1994 and improved in following years (Table D3). Most of the landings occurred during the first half of the year in all years from 1994-1998, but in 1996 some landings occurred in the second half (Table D3). Landings at age for the second half of 1996 were estimated with length data from the 3rd and 4th quarters of 1996 (Table D3). A length-weight relationship was used to estimate sample weight and expansion factors for commercial samples from 1994-1998. Length-weight parameters used in the last assessment ($a=0.0059$, $b=3.154$) were used for the estimation of commercial catch at length.

Recreational length samples obtained from the MRFSS data base were used to characterize the landings of this species by sport fisherman. Sample numbers and lengths were judged to be adequate enough to estimate recreational catch at length. Sample sizes ranged from 615 to 1548 fish (Table D3). The same length-weight equation was used to estimate sample size and expansion factors for the recreational landings data.

Age length data used for estimating commercial and recreational catch at age were obtained from commercial port samples, sea sampling, and NEFSC Spring and Winter bottom trawl surveys. Combined age-length keys were used to age commercial and recreational landings from the first and second calender quarters of 1994-1996 (Table D3). Sample sizes ranged from 321-1901 aged fish for these periods. A large number of sea sampled ages were available during 1998, accounting for the relatively large sample size in that year. The second half of 1996 was aged with commercial age samples from the second half of that year (Table D3).

Catch at Age

USA commercial and recreational catch at age for 1962-1993 were taken from the previous assessment (NEFSC 1996). Catch at age for the USA during 1994-1998 were estimated from the length and age composition and landings data previously cited (Table D4). Canadian catch at age data for 1994-1998 were obtained from DFO Canada (F. Gregoire, pers. comm. 1998) and are included in Table D4.

Commercial Mean Weights

Commercial mean weights used in the current assessment were obtained from the previous assessment for 1962-1993 and were estimated for 1994-1998. The length weight relationship used to estimate sample weights (a=0.0059, b=3.154) was used to calculate the mean weights at age for the USA commercial fishery for 1994-1998. Mean weights for the commercial fishery during 1994-1998 were calculated as weighted means of the USA and Canadian fishery catch-at-age and mean weights-at-age (Table D5).

Research Survey Indices

Standard and ln transformed spring survey indices were updated for 1994-1999. Standard indices in weight and number per tow continued to show improving trends for the stock in the mid to late 1990s (Table D6, Figure D3). The biomass index increased in 1994, declining slightly in 1995. In 1996 this index increased to a historic high, declined in 1997 and 1998, and then increased to the 3rd highest value in the series in 1999 (Table D6). Mean number per tow indices increased over the early 1990s, were generally very high and relatively stable from 1994-1998. The index reached 50.6 in 1999, the 2nd highest value in the 32 year series (Table D6, Figure D3).

Spring indices for 1984-1999 were recomputed to produce aggregated ln retransformed catch per tow indices. The biomass index for the retransformed series was relatively high with some fluctuation during the 1990s, with the highest value for 1984-1999 obtained in 1999 (Table D7). The number per tow index increased by an order of magnitude from the 1980s to the 1990s. The index was high, and relatively stable throughout the 1990s, except for 1997 (Table D7). The highest value in the series was obtained in 1999. Number per tow indices at age (ln retransformed) were updated for 1994-1999. Indices at age were generally higher, with a few exceptions, for ages 1-8 during 1992-1998 than for all other years in the 1968-1998 time-series (Table D8).

The winter bottom trawl survey began in 1992 and there are currently enough years in this time-series to include it as an index for this stock. The standard biomass and abundance indices for mackerel are generally high, but more variable than the spring indices for Atlantic mackerel. The biomass index ranged from 0.3-27.1 kg/tow during 1992-1998 (Table D9). Number per tow ranged from 1.2 to 47.7 during this same period. Ln transformed indices in biomass and number were similarly variable, ranging from 0.2-4.3 kg/tow and 0.9-14.7 fish/tow, respectively, during 1992-1998 (Table D9, Figure D4). Some of the variation in survey indices may be attributed to the more inconsistent coverage of survey strata during the winter survey.

Number per tow at age indices were produced for the winter survey, including ages 1-12

(Table D10). With the exception of 1994, an extremely low survey year, survey numbers at age appeared adequate to examine as a candidate index for inclusion in the VPA (Table D10).

Survey Weight-at-Age

Individual fish weights have been routinely collected on NEFSC bottom trawl surveys starting in 1992. Fish are weighted on calibrated electronic scales with reasonable accuracy to $\pm$ 5 gm. Age data from these samples are also collected so that relatively accurate empirical weights at age can be obtained from the NEFSC survey data.

Data from the winter and spring surveys during 1992-1999 were used to estimate calender year seasonal length weight equations for mackerel for 1992-1999. The length-weight parameters were then used in spring SURVAN runs to estimate mean weights at age for mackerel in surveys from 1992-1999 (Table D11).

Survey Distribution

Maps of spring survey catches of Atlantic mackerel were produced for 1998 and 1999 to examine the extent of the stock distribution during the late 1990s. Although the spatial extent of the stock is somewhat different in each year, both years indicate that the stock was distributed widely over a very large area (Figure D5). In 1998 mackerel were found in shallower water than in 1999, but both spring surveys indicated that mackerel occupied an extensive area from Cape Hatteras to the central part of Georges Bank. Large survey catches occurred on the western part of Georges bank and south of Long Island in both years (Figure D5).

Life History Parameters

Maturity at age (ages 1,2,3; 0.2,0.63,0.99; and 1.0 thereafter) and natural mortality (M=0.2) were the same as used in the previous assessment (NEFSC 1996).

Virtual Population Analysis Calibration

The ADAPT calibration procedure (Parrack 1986, Gavaris 1988, Conser and Powers 1990) was used to estimate stock sizes in 1999 and fishing mortality rates in 1998. The catch at age used in the calibration runs represented USA and Canadian landings during 1962-1998. Research survey indices from the NEFSC winter (1992-1998) and spring (1968-1998) bottom trawl surveys were used to calibrate the VPA. Ages 1-10 were estimated in the model runs and age 11 was considered as a plus group.

Six trial ADAPT runs were completed to examine different tuning scenarios, sets of survey indices, sets of years, and down weighting effects on terminal year estimates of fishing mortality and stock size. The 1968 and 1969 spring survey indices were dropped in all the trial runs as per previous assessments that noted the high variability in these two survey years (Overholtz 1991a; NEFSC 1996). Several of the runs used tricubic downweights on the initial years of the spring survey. Previous assessment working groups (Overholtz 1991a; NEFSC 1996) had concluded that the ICNAF fishery on mackerel (1968-1978) had probably been overly disruptive of the stock, its distribution, and behavioral mechanisms of the fish, and therefore may have affected spring survey indices during that time and perhaps several years thereafter. It is also known that commercial catches from this time period were underreported and possibly grossly underreported (Brennen 1976). Therefore, some sort of major intervention during the early part of the spring time-series (downweighting, etc.) was warranted. The reason for using this procedure was thoroughly discussed in the previous assessment (NEFSC 1996).

The first two runs: (1) an unweighted 70-98 spring survey run and (2) an unweighted 70-98 winter-spring run were used to examine whether the addition of the new winter time-series added significantly to the VPA calibration. The next run represented a repetition of the previous assessment (3) a winter-spring 77-98 run with tricubic downweights. Run (4) was an unweighted winter-spring 77-98 calibration trial. These two runs were used to ascertain if a useful calibration could be completed with only 77-98 survey data and if the run used in the previous assessment could be used again. The final two runs were (5) a 70-98 winter-spring run with tricubic downweights and (6) a 72-98 winter-spring run with tricubic downweights.

Runs 1 and 2 (Table D12) were compared to see if the addition of the winter survey improved the VPA calibration. Adding the winter survey decreased the coefficients of variation (CV) on the stock size estimates (ages 3-10) considerably, so the winter survey was included in subsequent trial runs. It was noted that in run 3 the mean square error (MSE) and CV's improved, but total stock size and spawning stock biomass (SSB) were deemed too low to accept this run (Table D12). When run 4 was examined a slight improvement in MSE, residual patterns, and stock CV's was noted, but stock size and SSB were thought to be unrealistically high. The premise of starting the downweighting procedure in 1970 at the beginning of the ICNAF fishery period, rather than in 1977 as in the previous assessment, seemed more plausible. Run 5 produced an improvement in MSE and stock CV's when compared to several of the initial runs. However when the percent of total SS table was examined, the spring survey indices in 1974-1977 were still accounting for a relatively large portion of the total SS. In addition the point estimate for SSB and 1+ stock size were still very large. Diagnostics from run 6 were somewhat improved over run 5, with the MSE, and stock CV's being smaller. In addition 1+ stock size and SSB estimates from this model run seemed more plausible when discussed and placed in a historic context.

To further examine differences between runs, retrospective analysis of runs 2,5, and 6 were produced. Since we apriori understood that this assessment is imprecise due partly to non-convergence (extremely low F's), we only examined retrospective patterns in SSB to observe the direction of changes overtime. All three trials showed a lack of convergence and a consistent pattern of overestimating SSB over time (Figure D6). Runs 5 and 6 had a particularly difficult problem with overestimation when the 1994 and 1995 terminal year runs were examined. Overall it appears that there is a severe retrospective pattern present in all the runs during the mid 1990s. This is probably due to the rapid transition from the low survey indices of the 1980s to the rapidly increasing and very high indices of the 1990s, and perhaps year effects during the 1990s.

The SARC concluded that none of the model runs were acceptable for estimating absolute stock size or fishing mortality due to the severe retrospective pattern and lack of convergence in the VPA. However, the SARC decided to retain run 4 as an example, for illustrative purposes only, of the VPA output (Table D13).

Long-Term Potential Yield and Biomass Thresholds

Maximum sustainable yields for the Atlantic mackerel stock were estimated in previous research efforts Overholtz et al. 1991b: 150,000-160,000 mt; Brodziak and Overholtz 1995: 148,000 mt. The NEFSC (1996) SARC report concluded that a reasonable long-term potential yield for this stock was 150,000 mt with an associated B_{MSY} of 1.0 million mt. More recently Overholtz (1999) estimated MSY at 326,000 mt at a SSBmsy of 887,000 mt based on a bootstrap method of repeatedly estimating biological reference points (BRP's) from stock-recruitment data for the Atlantic mackerel stock. The Overfishing Review Panel of the NEFMC adopted BRP estimates based on this work (NEFMC 1998). Additional work using the ASPIC model to estimate BRPs with data from 1970-1998 produced results that confirm the direction of stock size increases and recent low fishing mortality (Figure D7). A comparison of results from all three methods suggests that Bmsy ranges between 900,000 mt to 1.3 million mt and MSY ranges from 150,000-326,000 mt for this stock (Table D14).

SARC COMMENTS

Some aspects of the catch data were discussed by the SARC. Although the 1999 U.S. fishery was essentially over at the time of the assessment, the Canadian fishery was not, and Canadian landings and catch at age were not available for 1999. The SARC disagreed with the conclusion that mean weights at age decreased in recent years, noting that the reduction was limited to the most recent year. The SARC commented that mandatory logbooks have been required in the U.S. fishery for several years and may be a source of information for catch rates and geographic distribution.

The SARC commented on several aspects of the survey data. There was concern about the effect of gear changes on the spring survey indices. Most importantly, a larger survey net, the "Yankee 41", was used from 1973-1981. Conversion factors for the "Yankee 41" and "Yankee 36" nets were not calculated for mackerel, because there were too few observations of mackerel catches in comparative tow experiments. However, it was noted that mackerel catches in the survey were extremely low during 1973-1981, and these catches would likely decrease somewhat if adjusted for increased catchability of the "Yankee 41" trawl. SARC participants cautioned that the rapid increase in abundance indicated by the 1996 survey appeared to be unrealistic. However, the relative 1996 index was substantially reduced in the log retransformed series, suggesting that there were a few large tows influencing the 1996 index. Retransformed indices were used for calibration models. SARC members questioned the diurnal patterns of mackerel with respect to vertical movements and trawl survey catchability. Mackerel appear to be more concentrated in bottom waters during the day than at night, but cursory investigations of survey data were equivocal. The SARC noted that survey catches of young fish have greatly increased since 1994, perhaps resulting from increased availability of young fish in the survey area. SARC participants mentioned that some of the strata used for the winter survey have not been consistently sampled.

For example, stratum 16 was not sampled in 1994, when the survey index was extremely low. The SARC commented on the appearance of mackerel in the Gulf of Maine in 1998, perhaps indicating an expansion of the stock's geographic range in early spring. It was also noted that including abundance indices in Canadian waters may improve the assessment. Another research recommendation was to develop an acoustic survey to complement trawl survey indices.

The VPA calibration runs were discussed at length. The SARC agreed that the retrospective inconsistencies and sensitivities to alternative calibrations were substantial, indicating poor convergence on reliable abundance estimates because of low fishing mortalities. It was noted that recruitment of the apparently abundant 1982 yearclass was coincident with the beginning of convergence problems in VPA calibration. The justification for tri-cubic downweighting was questioned. It was defended based on previous SARC conclusions and the likely propagation of errors from ICNAF years (pre-1977) into later years, because later abundance estimates were influenced by the earlier catch, even though later catch information was more reliable. The SARC noted that another alternative would be to truncate the entire VPA to post-ICNAF years, as opposed to merely removing those years from the calibration, thereby removing the influence of catch and survey data from the ICNAF years. The SARC concluded that the retrospective problems primarily result from low F, rather than poor input data or calibration choices. It was noted that the problems apparent in historic catches and survey indices may result from curvilinear survey catchability. It was also noted that similar problems were found in the previous mackerel assessment, and despite these problems, conclusions about high stock size and low fishing mortality were defensible. The SARC concluded that an unweighted VPA calibration should be retained in the assessment report for illustrative purposes, but absolute estimates of stock size and F are not possible because of model sensitivities, retrospective inconsistencies, and large conditional variance estimates. In addition to the VPA calibration results, the SARC examined total mortality estimates directly from survey indices at age but found them difficult to interpret.

In summary, the SARC judged that the mackerel assessment will not be substantially improved until fishing mortality increases or new sources of information (*e.g.* acoustic surveys) become available. Therefore, the SARC reiterated the conclusion of SARC 20 that regular assessments of this stock are not needed until a more substantial fishery develops.

<u>Sources of Uncertainty</u>

- Retrospective inconsistencies were large.
- The VPA calibration was sensitive to alternative configurations.
- Bootstrap estimates were imprecise.
- Catch during ICNAF years (pre-1977) may be under reported.
- Availability of the stock to the survey appears to vary, creating year effects in the calibration.
- Several changes to survey sampling gear are not standardized.
- There may be diel effects in survey data.
- The relationship between stock size and survey catches may be nonlinear.
- Weights at age are likely to vary by season and area.
- Some strata are inconsistently sampled by the winter survey.

Research Recommendations

- Explore logbook data for information on catch rates and geographic distribution.
- Explore Canadian trawl survey indices for use in VPA calibration.
- Explore the feasibility of acoustic surveys for monitoring stock size.
- Examine estimates of Z calculated from research vessel survey data with respect to their usefulness in estimating natural mortality.

CONCLUSIONS

The Atlantic mackerel stock is not overfished and overfishing is not occurring. Fishing mortality continues to be very low and SSB is high. These conclusions are robust despite uncertainties in the VPA and the same conclusions can be drawn directly from trends in the spring survey index during 1968-1999.

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Table D1. U.S. and Canadian commercial landings (mt) of Atlantic mackerel in the Northwest Atlantic during 1804-1961.

YEAR	US	CANADA	YEAR	US	CANADA	YEAR	US	CANADA
1804	1631	-						
1805	1780	-						
1806	1707	-	1857	35014	-			
1807	1931	-	1858	27313	-			
1808	1583	-	1859	20695	-	1910	2569	3166
1809	1832	-	1860	48914	-	1911	5470	4088
1810	2605	-	1861	40322	-	1912	4608	4897
1811	3611	-	1862	54141	-	1913	6130	9771
1812	1221	-	1863	63703	-	1914	9516	6518
1813	780	-	1864	57579	-	1915	10550	8208
1814	278	-	1865	55200	-	1916	13450	7078
1815	3333	-	1866	49072	-	1917	16743	7576
1816	6428	-	1867	43400	-	1918	9146	8924
1817	7754	-	1868	37059	-	1919	7358	10425
1818	9619	-	1869	48187	-	1920	8737	6456
1819	20777	-	1870	66464	-	1921	4551	6601
1820	24000	-	1871	55029	-	1922	5782	11393
1821	23039	-	1872	36559	-	1923	15374	6429
1822	33267	-	1873	37327	-	1924	12292	9777
1823	33095	-	1874	54595	-	1925	22316	8511
1824	39775	-	1875	25374	-	1926	30975	5238
1825	52795	-	1876	45026	14223	1927	27365	7202
1826	32945	-	1877	22697	22474	1928	20365	5614
1827	39496	-	1878	33413	25129	1929	29079	6928
1828	49254	-	1879	37517	25994	1930	23524	8094
1829	46900	-	1880	59468	31896	1931	21493	8900
1830	64019	-	1881	66608	14699	1932	27598	8093
1831	79602	-	1882	64433	15552	1933	18838	11942
1832	46168	-	1883	38552	17520	1934	23746	8654
1833	46268	-	1884	81306	24732	1935	29517	7279
1834	52483	-	1885	56112	20281	1936	23808	10324
1835	40429	-	1886	13605	20785	1937	12064	10846
1836	36197	-	1887	15011	16415	1938	19632	12951
1837	28673	-	1888	8938	8595	1939	14782	23612
1838	22983	-	1889	4631	8646	1940	18427	16206
1839	15413	-	1890	4964	13351	1941	21024	15924
1840	10479	-	1891	8781	18393	1942	23163	13745
1841	11526	-	1892	9961	12771	1943	26981	16819
1842	15678	-	1893	11444	10220	1944	33644	15543
1843	13376	-	1894	10223	7859	1945	26609	18234
1844	17928	-	1895	5431	5775	1946	23620	13387
1845	41986	-	1896	16009	6239	1947	26668	11911
1846	37256	-	1897	4808	3783	1948	23156	11735
1847	52279	-	1898	4556	4603	1949	19079	15203
1848	62289	-	1899	6114	4708	1950	10020	12349
1849	43365	-	1900	20785	11433	1951	7142	11221
1850	50343	-	1901	15768	10501	1952	8248	9973
1851	68332	-	1902	10502	5930	1953	3875	8371
1852	41117	-	1903	11592	11352	1954	1822	11570
1853	27673	-	1904	8872	5005	1955	1756	11275
1854	28090	-	1905	10121	6828	1956	1829	9584
1855	43990	-	1906	5328	9309	1957	1097	8800
1856	44479	-	1907	11109	7001	1958	2074	7299
			1908	9449	10316	1959	1835	4286
			1909	7691	7446	1960	1396	5957
						1961	1361	5459

Table D2. Atlantic mackerel landings (mt) from NAFO Statistical Areas 2-6 during 1960-1998.

Year	USA Commercial	USA Recreational	Canada	Other Countries	Commercial Total	Grand Total
1960	1396	2478	5957	0	7353	9831
1961	1361	-	5459	11	6831	6831
1962	938	-	6865	175	7878	7978
1963	1320	-	6473	1299	9092	9092
1964	1644	-	10960	801	13405	13405
1965	1998	4292	11590	2945	16533	20825
1966	2724	-	12821	7951	23496	23496
1967	3891	-	11243	19047	34181	34181
1968	3929	-	20819	65747	90495	90495
1969	4364	-	17364	114189	135917	135917
1970	4049	16039	19959	210864	234872	250911
1971	2406	-	24496	355892	382794	382794
1972	2006	-	22360	391464	415830	415830
1973	1336	-	38514	396759	436609	436609
1974	1042	-	44655	321837	367534	367534
1975	1974	5190	36258	271719	309951	315141
1976	2712	-	33065	223275	259052	259052
1977	1377	-	22765	56067	80209	80209
1978	1605	-	25899	841	28345	28345
1979	1990	3588	30612	440	33042	36630
1980	2683	2364	22296	566	25545	27909
1981	2941	3233	19294	5361	27596	30829
1982	3330	666	16379	6647	26356	27022
1983	3805	3022	19797	5955	29557	32579
1984	5954	2457	16995	15045	37994	40451
1985	6632	2986	29855	32409	68896	71882
1986	9637	3856	31097	26507	67241	71097
1987	12310	4025	27559	36564	76433	80458
1988	12309	3251	25016	42858	80183	83434
1989	14556	1862	21142	36823	72521	74383
1990	31261	1908	23044	30678	84983	86891
1991	26961	2439	20870	15714	63545	65894
1992	11775	344	25475	0	37250	37594
1993	4666	540	26873	0	31539	32079
1994	8877	1705	20459	0	29336	31041
1995	8479	1249	17706	0	26185	27434
1996	16137	1416	20447	0	36584	38000
1997	15400	1735	18466	0	33866	35601
1998	14415	670	14964	0	29379	30049

Table D3. USA sampling of Atlantic mackerel commercial and recreational landings during 1994-1998.

Year	Commercial Lengths		All Sources Ages		Recreational Lengths
	Jan-June	July-Dec	Jan-June	July-Dec	
1994	395		321		1548
1995	700		497		905
1996	1202	1080	495	223	657
1997	2267		474		761
1998	1956		1901		615

Table D4. Atlantic mackerel commercial and recreational[1] catch at age (millions of fish) from NAFO SA 2-6 during 1962-1998.

											AGE			MEAN
YEAR	0	1	2	3	4	5	6	7	8	9	10	11+	TOTAL	AGE
1962	-	16.1	2.8	15.2	3.8	1.2	1.6	1.4	0.8	0.4	0.1	0.3	43.7	2.8
1963	-	1.1	4.2	1.3	26.3	6.0	0.3	0.2	0.2	0.2	0.1	0.1	40.0	4.1
1964	-	12.9	7.0	4.1	4.0	19.4	4.1	3.9	0.7	0.8	0.2	-	57.1	3.8
1965	-	9.0	3.6	2.9	4.0	5.2	19.5	4.2	4.0	0.7	-	-	53.1	4.7
1966	-	24.0	11.5	5.3	2.6	4.7	7.9	21.8	0.5	0.2	-	-	78.5	3.9
1967	1.8	0.8	26.7	19.8	3.5	3.3	5.1	6.1	32.3	0.3	-	-	99.7	4.8
1968	1.1	141.4	61.5	59.3	38.1	14.3	6.6	0.7	1.0	6.1	0.1	-	330.2	2.3
1969	4.0	7.1	262.1	160.7	65.8	5.7	3.0	2.0	3.1	2.2	8.3	-	524.0	2.8
1970	4.8	193.5	54.5	522.1	162.9	27.6	7.0	5.3	9.9	10.0	3.8	2.8	1,004.2	3.0
1971	2.4	74.6	294.2	127.4	558.9	203.5	34.6	8.9	3.6	4.3	8.1	7.2	1,327.7	3.6
1972	3.6	22.1	85.7	256.2	182.6	390.4	87.3	24.0	4.2	8.2	3.8	5.6	1,073.7	4.2
1973	4.0	161.8	283.2	285.1	233.6	192.4	197.2	31.2	11.0	4.1	3.8	1.6	1,409.0	3.6
1974	2.0	95.9	242.2	264.4	101.5	114.3	111.8	108.3	25.7	6.4	2.5	0.8	1,075.8	3.8
1975	3.7	373.7	431.4	113.7	100.8	58.6	67.8	51.9	50.5	12.5	2.3	1.0	1,267.9	2.8
1976	-	12.5	353.5	272.5	85.7	52.4	27.3	40.5	34.6	22.6	13.4	1.4	916.4	3.5
1977	-	2.0	27.0	101.0	54.0	12.0	9.9	5.6	6.3	3.8	3.6	0.6	225.8	3.8
1978	-	0.1	0.2	4.7	17.4	13.3	8.4	4.7	2.2	4.5	1.5	5.8	62.8	5.9
1979	-	0.4	0.6	1.3	7.1	18.6	13.1	6.2	2.6	2.2	2.3	4.2	58.6	6.2
1980	-	1.2	10.9	1.0	1.0	6.9	13.8	4.7	2.0	1.0	1.0	4.2	47.7	5.6
1981	-	16.1	7.1	9.2	1.4	2.0	6.1	11.7	4.9	2.5	0.9	2.6	64.6	4.5
1982	-	3.7	11.8	2.7	9.1	1.2	1.9	3.4	8.4	2.9	1.5	3.6	50.3	5.2
1983	-	2.2	15.3	6.5	1.9	7.0	0.7	1.2	5.5	10.2	4.2	2.3	57.0	5.5
1984	-	0.5	40.4	27.2	3.2	1.2	4.6	0.6	0.7	3.4	7.9	6.1	95.8	4.1
1985	-	3.4	1.9	135.7	33.4	2.7	0.8	3.2	0.3	0.5	2.5	8.9	193.3	3.7
1986	-	1.1	10.4	6.5	91.7	22.1	1.7	0.5	3.1	0.2	0.7	4.9	143.0	4.3
1987	-	9.7	14.2	13.3	7.5	106.9	17.5	2.6	0.4	2.1	0.3	3.5	178.0	4.7
1988	-	1.5	13.0	10.3	10.1	11.5	107.4	22.5	2.6	1.2	0.9	4.8	185.9	5.7
1989	-	1.9	14.0	11.0	7.4	6.8	2.3	85.7	4.3	0.8	0.4	1.3	135.9	5.9
1990	-	1.8	19.4	26.4	7.5	6.3	4.2	0.8	51.8	5.0	0.4	0.8	124.5	5.5
1991	-	1.2	11.7	51.8	23.0	6.1	3.9	3.9	1.5	29.9	0.9	0.3	134.1	4.8
1992	-	1.9	7.9	4.4	18.3	11.0	1.4	1.0	0.7	0.9	10.8	0.6	58.7	5.1
1993	-	1.0	8.9	12.1	7.3	19.1	10.0	1.9	0.9	1.1	0.9	7.8	71.0	5.1
1994	-	2.3	1.8	13.2	14.6	5.5	18.5	6.3	1.1	0.3	1.7	2.6	67.9	5.1
1995	-	12.7	22.0	2.8	9.9	8.3	3.1	9.6	3.1	0.3	0.1	0.7	72.7	3.7
1996	-	2.8	27.1	23.5	1.9	12.5	9.2	2.3	8.6	1.8	0.5	0.5	90.9	4.0
1997	-	6.9	20.8	21.1	10.4	1.1	8.0	6.3	2.7	6.3	1.0	0.7	85.2	4.1
1998	-	1.7	23.6	13.6	14.0	7.6	1.0	5.3	3.6	0.8	1.8	0.3	73.5	3.9

[1] Includes estimated recreational catches for 1961-1964, 1966-1969, 1971-1974, 1976-1978.

[2] Preliminary data.

Table D5. Commercial mean weight-at-age (USA and Canada) for Atlantic mackerel from 1962 to 1998 landings.

	AGE													
YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1962[1]	.130	.208	.289	.365	.433	.491	.541	.581	.614	.641	.662	---	---	---
1963	.120	.192	.264	.334	.395	.448	.492	.529	.559	.583	.602	---	---	---
1964	.116	.188	.262	.332	.395	.450	.495	.533	.564	.588	---	---	---	---
1965	.123	.200	.278	.352	.419	.477	.525	.565	.598	---	---	---	---	---
1966	.128	.209	.294	.374	.447	.509	.562	.605	.641	---	---	---	---	---
1967	.123	.202	.283	.360	.428	.489	.540	.581	.615	---	---	---	---	---
1968	.148	.241	.335	.425	.506	.576	.634	.683	.722	.753	---	---	---	---
1969	.131	.214	.300	.382	.456	.520	.574	.618	.654	.683	---	---	---	---
1970	.107	.179	.253	.324	.389	.444	.491	.530	.562	.587	.608	---	---	---
1971	.110	.181	.256	.327	.391	.446	.494	.532	.564	.589	.610	---	---	---
1972	.123	.210	.300	.386	.464	.533	.590	.638	.677	.708	.733	---	---	---
1973	.113	.189	.269	.345	.414	.473	.524	.565	.600	.628	.650	---	---	---
1974	.111	.190	.273	.352	.425	.487	.541	.585	.621	.649	.673	---	---	---
1975	.104	.176	.252	.326	.393	.451	.500	.540	.573	.600	.621	---	---	---
1976	.097	.168	.244	.316	.382	.440	.489	.530	.563	.590	.611	---	---	---
1977	.114	.198	.288	.375	.454	.524	.582	.631	.671	.703	.729	.749	---	---
1978	.192	.285	.425	.463	.509	.582	.625	.659	.673	.697	.717	.797	.705	---
1979	.190	.272	.531	.567	.579	.603	.652	.714	.752	.769	.822	.809	.842	.830
1980	.146	.376	.548	.609	.617	.635	.672	.705	.781	.743	.785	.773	.775	.778
1981	.114	.315	.523	.577	.643	.660	.674	.707	.723	.756	.772	.812	.780	.801
1982	.152	.340	.541	.606	.666	.743	.737	.722	.719	.740	.790	.811	.798	.829
1983	.098	.257	.479	.593	.628	.659	.712	.709	.705	.727	.735	.752	.744	.805
1984	.098	.162	.338	.525	.625	.657	.696	.715	.705	.709	.726	.755	.775	.770
1985	.111	.260	.277	.416	.558	.644	.677	.665	.737	.717	.715	.739	.731	.782
1986	.079	.234	.349	.366	.452	.581	.640	.729	.777	.750	.738	.717	.776	.781
1987	.107	.210	.316	.404	.411	.505	.502	.706	.747	.680	.750	.736	.781	.775
1988	.100	.222	.343	.408	.453	.484	.584	.694	.755	.815	.762	.775	.790	.761
1989	.100	.231	.375	.414	.474	.509	.529	.631	.753	.803	.816	.825	.801	.893
1990	.104	.206	.332	.450	.477	.528	.625	.572	.659	.718	.828	.806	.808	.853
1991	.145	.257	.362	.432	.506	.551	.572	.636	.640	.702	.830	.888	.818	.924
1992	.148	.261	.380	.430	.494	.549	.601	.678	.674	.686	.730	.753	---	.957
1993	.229	.249	.340	.432	.475	.533	.602	.622	.679	.691	.698	.768	---	---
1994	.156	.232	.318	.399	.492	.520	.587	.629	.705	.610	.736	---	---	---
1995	.187	.261	.343	.417	.469	.544	.554	.618	.704	.785	.703	---	---	---
1996	.218	.254	.354	.481	.482	.552	.596	.644	.692	.650	.799	---	---	---
1997	.199	.304	.383	.453	.548	.536	.573	.612	.660	.674	.723	---	---	---
1998	.149	.250	.373	.483	.535	.559	.591	.604	.656	.681	.693	---	---	---

[1] Data from 1962-1983 are from Anderson (1984).

Table D6. Stratified mean weight and number per tow of Atlantic mackerel from the NEFSC spring bottom trawl survey (offshore strata 1-25 and 61-76) during 1968-1999.

YEAR	KG PER TOW	NUMBER PER TOW
1968	5.609	70.869
1969	0.055	0.484
1970	2.200	9.356
1971	3.145	12.668
1972	1.542	8.490
1973	6.746	20.973
1974	0.656	2.241
1975	0.242	3.540
1976	0.254	1.800
1977	0.081	0.287
1978	0.345	0.970
1979	0.089	0.172
1980	0.202	0.559
1981	2.470	5.872
1982	0.854	5.167
1983	0.135	0.884
1984	2.611	16.228
1985	2.232	8.242
1986	1.264	4.178
1987	7.492	35.231
1988	4.133	16.792
1989	1.100	12.273
1990	1.548	10.748
1991	5.604	23.265
1992	4.705	24.275
1993	5.583	26.089
1994	5.987	38.638
1995	5.100	24.387
1996	11.101	40.887
1997	2.494	22.054
1998	3.378	25.110
1999	7.109	50.617

Table D7. Standard weight and number per tow and ln retransformed weight and number per tow from spring bottom trawl survey data for Altantic mackerel during 1984-1999.

Standard			Retransformed		
YEAR	KG	NUMBER	YEAR	KG	NUMBER
1984	2.611	16.228	1984	0.883	2.463
1985	2.232	8.242	1985	0.924	2.685
1986	1.264	4.178	1986	0.443	1.196
1987	7.492	35.231	1987	3.208	11.531
1988	4.133	16.792	1988	0.502	7.095
1989	1.100	12.273	1989	0.668	3.841
1990	1.548	10.744	1990	0.883	4.092
1991	5.604	23.265	1991	1.358	5.884
1992	4.705	24.275	1992	2.267	12.719
1993	5.583	26.089	1993	2.674	9.766
1994	5.987	38.638	1994	3.045	15.604
1995	5.100	24.387	1995	2.865	15.668
1996	11.101	40.887	1996	2.669	15.555
1997	2.494	22.054	1997	1.248	6.679
1998	3.378	25.110	1998	1.736	13.389
1999	7.109	50.617	1999	3.723	24.723

Table D8. Number of Atlantic mackerel per tow at age from the NEFSC Spring bottom trawl survey (offshore strata 1-25 and 61-76) during 1968-1998.

	AGE													
YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1968	12.9400	0.4150	0.1894	0.0523	0.0164	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1969	0.0297	0.1418	0.0167	0.0058	0.0003	0.0007	0.0005	0.0009	0.0004	0.0004	0.0000	0.0000	0.0000	0.0000
1970	0.2795	0.1845	1.3910	0.6115	0.1812	0.0617	0.0549	0.0877	0.0827	0.0447	0.0026	0.0000	0.0000	0.0000
1971	0.3282	0.9409	0.4383	1.1250	0.3929	0.0621	0.0141	0.0073	0.0062	0.0048	0.0035	0.0000	0.0000	0.0000
1972	0.8719	0.3077	0.5929	0.2261	0.3254	0.0583	0.0112	0.0011	0.0018	0.0004	0.0000	0.0000	0.0000	0.0000
1973	0.3514	0.3398	0.1758	0.2338	0.1262	0.2846	0.1821	0.1524	0.0460	0.0367	0.0033	0.0291	0.0181	0.0150
1974	0.3478	0.1796	0.2358	0.0478	0.0985	0.0599	0.2084	0.0912	0.0590	0.0117	0.0115	0.0000	0.0000	0.0000
1975	0.6544	0.2298	0.0409	0.0226	0.0064	0.0073	0.0043	0.0039	0.0034	0.0000	0.0000	0.0000	0.0000	0.0000
1976	0.0959	0.3871	0.0710	0.0135	0.0024	0.0006	0.0028	0.0004	0.0019	0.0003	0.0003	0.0000	0.0000	0.0000
1977	0.0095	0.0472	0.0850	0.0453	0.0154	0.0052	0.0028	0.0070	0.0038	0.0054	0.0010	0.0075	0.0000	0.0000
1978	0.0502	0.1097	0.1032	0.1943	0.0958	0.0284	0.0110	0.0027	0.0148	0.0000	0.0164	0.0000	0.0013	0.0000
1979	0.0105	0.0037	0.0072	0.0126	0.0495	0.0144	0.0103	0.0057	0.0057	0.0190	0.0042	0.0156	0.0030	0.0064
1980	0.0234	0.1877	0.0066	0.0048	0.0233	0.0489	0.0110	0.0107	0.0070	0.0017	0.0096	0.0000	0.0107	0.0064
1981	0.3355	0.1371	0.4294	0.0476	0.0463	0.1613	0.4041	0.2302	0.1385	0.0704	0.0673	0.0844	0.0769	0.1031
1982	0.4323	0.1950	0.0215	0.0979	0.0182	0.0102	0.0245	0.0965	0.0440	0.0266	0.0156	0.0122	0.0200	0.0092
1983	0.2357	0.2873	0.0222	0.0016	0.0036	0.0006	0.0002	0.0014	0.0022	0.0004	0.0008	0.0006	0.0002	0.0000
1984	0.2598	1.8014	0.6055	0.0415	0.0050	0.0432	0.0036	0.0025	0.0161	0.0470	0.0153	0.0075	0.0041	0.0098
1985	0.3382	0.0846	1.8513	0.2348	0.0277	0.0107	0.0469	0.0032	0.0097	0.0416	0.0666	0.0405	0.0119	0.0258
1986	0.1301	0.4497	0.0778	0.5908	0.1177	0.0080	0.0014	0.0196	0.0004	0.0019	0.0184	0.0101	0.0054	0.0116
1987	1.4842	1.7945	0.8742	0.3719	2.9450	0.4967	0.1427	0.0156	0.1383	0.0058	0.0406	0.0412	0.1202	0.0482
1988	0.6336	0.4577	0.3666	0.3357	0.3748	1.7688	0.4428	0.0513	0.0478	0.0405	0.0426	0.0764	0.0519	0.0118
1989	1.5826	1.6407	0.0707	0.2841	0.0087	0.0108	0.0666	0.0086	0.0050	0.0044	0.0060	0.0020	0.0029	0.0029
1990	1.3003	1.3849	0.5010	0.0157	0.0129	0.0059	0.0004	0.0762	0.0094	0.0043	0.0026	0.0014	0.0045	0.0029
1991	1.6697	0.8891	1.4843	0.5374	0.2400	0.1144	0.0578	0.0000	0.2685	0.0027	0.0000	0.0000	0.0000	0.0000
1992	2.6984	2.3787	0.5585	1.0531	0.6272	0.1155	0.1321	0.0312	0.0449	0.2642	0.0085	0.0256	0.0000	0.0000
1993	0.9331	2.2477	0.9019	0.6031	0.9864	0.4515	0.1389	0.0915	0.2184	0.0981	0.4495	0.0810	0.0000	0.0000
1994	4.1386	1.7436	2.1139	0.8699	0.2534	0.5039	0.1133	0.0512	0.0105	0.0687	0.0757	0.0822	0.0000	0.0000
1995	3.1701	3.4871	0.5893	1.1824	0.7122	0.2848	0.7191	0.2258	0.0451	0.0148	0.1084	0.0120	0.0000	0.0000
1996	4.0058	3.2257	1.3258	0.1481	0.6175	0.4196	0.1927	0.2800	0.1456	0.0238	0.0238	0.0743	0.0000	0.0000
1997	3.0378	1.1619	0.4485	0.2247	0.0254	0.1244	0.1149	0.0452	0.0702	0.0037	0.0003	0.0118	0.0000	0.0000
1998	5.6955	3.1199	0.6787	0.2863	0.1211	0.0171	0.0867	0.0633	0.0179	0.0185	0.0055	0.0000	0.0000	0.0000

Table D9. Standard weight and number per tow and ln retransformed weight and number survey data for Atlantic mackerel during 1992-1998.

Standard			Retransformed		
YEAR	KG	NUMBER	YEAR	KG	NUMBER
1992	14.813	47.694	1992	3.331	14.778
1993	4.265	17.263	1993	1.925	7.624
1994	0.254	1.161	1994	0.229	0.894
1995	27.125	74.658	1995	4.319	14.275
1996	6.828	40.034	1996	1.818	9.438
1997	3.139	20.792	1997	2.175	10.278
1998	4.123	18.332	1998	0.532	8.170

Table D10. Number of Atlantic mackerel per tow from NEFSC Winter bottom trawl survey (offshore strata 1-3,5-7,9-11,13,14,16,61-63, 65-67,69-71,73-75) during 1992-1998

	AGE												
YEAR	1	2	3	4	5	6	7	8	9	10	11	12	Total
1992	3.0523	1.4908	0.5367	1.6471	1.2904	0.3196	0.4615	0.1702	0.3949	1.6839	0.4629	0.0000	11.5104
1993	0.7766	3.4136	0.9937	0.3717	0.9014	0.6192	0.1061	0.1003	0.2490	0.0476	0.2766	0.0000	7.8558
1994	0.3244	0.1053	0.2362	0.1387	0.0284	0.0660	0.0116	0.0043	0.0000	0.0034	0.0009	0.0000	0.9190
1995	1.6475	4.0829	1.2502	2.0966	1.6930	0.9592	2.0291	0.9036	0.2251	0.1094	0.3290	0.1199	15.4455
1996	3.6854	2.4076	0.9712	0.1034	0.5132	0.3334	0.1294	0.2284	0.0864	0.0108	0.0108	0.0019	8.4818
1997	2.1225	2.0327	1.5196	0.6153	0.0429	0.2684	0.2356	0.1026	0.1566	0.0211	0.0036	0.0036	7.1233
1998	1.7823	2.8163	0.8565	0.6274	0.3459	0.0760	0.1595	0.2664	0.0381	0.1096	0.0091	0.0000	7.0871

Table D11. Mean weight of Atlantic mackerel from spring bottom trawl survey length-weight equations during 1992-1999 estimated from at-sea weight data.

	AGE											
Year	1	2	3	4	5	6	7	8	9	10	11	12
1992	.078	.187	.281	.324	.361	.404	.429	.473	.508	.480	.552	---
1993	.080	.159	.255	.371	.395	.405	.579	.535	.590	.625	.611	.760
1994	.070	.183	.237	.311	.398	.425	.459	.530	.631	.550	.586	.623
1995	.069	.172	.357	.346	.406	.475	.491	.515	.470	.622	.610	.728
1996	.076	.195	.304	.433	.442	.475	.506	.551	.570	.677	.677	.970
1997	.063	.187	.317	.414	.493	.489	.541	.574	.589	.537	.660	.721
1998	.066	.188	.319	.413	.490	.538	.578	.593	.681	.692	.693	---
1999	.069	.154	.287	.391	.464	.508	.562	.593	.569	.590	.695	---

Table D12. Estimates of parameters for Mean Square Error (MSE), Stock numbers (N3-N10), CV's of stock size (CV3-CV10)),outliers, trends in residuals, blocks of similar signed residuals (yr effect), and estimates of SSB, 1+ Stock size, and Fishing mortality from ADAPT Runs for Atlantic Mackerel.

	SPR 1	WINSPR 2	tc7798 3	7798 4	tc7098 5	tc7298 6
MSE	2.17	2.16	0.97	1.58	1.33	1.23
N3	5.0	5.0	0.6	4.8	3.3	2.0
N4	2.4	2.8	0.4	2.6	1.8	1.1
N5	1.8	2.1	0.3	2.0	1.4	0.8
N6	1.2	1.3	0.2	1.2	0.8	0.5
N7	0.3	0.2	0.03	0.2	0.1	0.08
N8	0.9	0.9	0.1	0.8	0.6	0.3
N9	0.6	0.6	0.07	0.5	0.4	0.2
N10	0.5	0.4	0.04	0.4	0.3	0.1
CV3	103	76	58	71	66	64
CV4	85	64	50	60	57	55
CV5	74	56	47	54	51	50
CV6	69	52	44	50	48	46
CV7	64	48	40	47	45	43
CV8	59	46	40	45	43	42
CV9	56	45	40	44	43	41
CV10	46	40	38	41	40	39
Outliers	0	0	3	3	2	3
Trends	2	2	2	1	3	5
Yr Effect	11	14	14	10	12	13
Surveys	S	S + W	S + W	S + W	S + W	S + W
70-76	Y	Y	N	N	Y	Y
d weight	N	N	Y	N	Y	Y
SSB	4232	4421	536	4073	2822	1748
1+ Stock	16864	17671	2187	16489	11428	7077
F	0.00...	0.00...	0.04	0.01	0.01	0.01

Table D13. VPA results for RUN 4 (Illustrative purposes only, Not to be Cited) for stock size, fishing mortality, and SSB for Atlantic mackerel during 1962-1998

STOCK NUMBERS (Jan 1) in thousands - C:\Program Files\WHAT\m997798.2

	1962	1963	1964	1965	1966	1967	1968
1	466	207	228	294	677	1925	4979
2	181	367	169	175	232	533	1575
3	1104	146	297	132	140	180	412
4	43	890	118	239	105	110	129
5	17	32	705	93	192	84	87
6	05	13	21	560	72	153	66
7	03	02	10	13	440	52	121
8	02	01	02	05	07	341	37
9	01	01	01	01	00	05	250
10	00	00	00	00	00	00	04
11	01	00	00	00	00	00	00
1+	1823	1660	1550	1511	1866	3382	7659

	1969	1970	1971	1972	1973	1974	1975
1	1950	2371	1297	1338	1170	1708	1969
2	3949	1590	1766	994	1076	812	1312
3	1234	2996	1252	1180	736	625	445
4	284	865	1980	910	734	345	272
5	71	173	561	1116	580	390	190
6	58	53	116	275	560	301	216
7	48	45	37	64	146	280	145
8	98	37	32	22	31	91	131
9	29	78	22	23	15	15	52
10	199	22	55	14	11	08	07
11	00	16	48	20	05	03	03
1+	7919	8245	7166	5956	5064	4577	4742

	1976	1977	1978	1979	1980	1981	1982
1	381	56	34	167	80	171	646
2	1274	301	44	27	136	65	126
3	684	723	222	36	22	102	47
4	262	313	501	177	28	17	75
5	132	137	208	394	139	22	13
6	103	60	101	158	306	107	16
7	115	60	40	75	117	238	82
8	72	58	44	29	56	92	184
9	62	27	42	34	21	44	71
10	31	30	19	30	26	16	34
11	03	05	73	54	108	48	81
1+	3118	1770	1327	1182	1039	922	1374

(Table D13 - Continued on next page)

Table D13. Continued

	1983	1984	1985	1986	1987	1988	1989
1	9030	371	583	130	313	940	2746
2	525	7391	303	475	105	248	768
3	92	416	6015	247	379	73	191
4	36	70	316	4802	196	298	51
5	53	27	54	229	3848	154	235
6	09	37	21	42	167	3054	116
7	12	07	26	17	33	121	2403
8	64	09	05	19	13	24	79
9	143	48	06	04	12	11	18
10	55	108	36	05	03	08	08
11	30	83	128	33	36	44	24
1+	10050	8567	7495	6000	5106	4975	6638

	1990	1991	1992	1993	1994	1995	1996
1	2474	2786	3364	638	3250	4469	4864
2	2247	2024	2280	2753	521	2658	3648
3	616	1822	1646	1860	2246	425	2157
4	146	481	1445	1344	1512	1827	346
5	35	113	373	1166	1094	1224	1487
6	186	23	87	295	938	890	995
7	92	149	15	70	233	751	726
8	1890	75	118	11	56	185	606
9	61	1501	60	96	09	45	148
10	14	45	1202	48	78	07	36
11	27	15	67	418	119	47	36
1+	7788	9033	10657	8700	10053	12529	15049

	1997	1998	1999
1	7183	744	00
2	3980	5875	607
3	2962	3240	4789
4	1744	2406	2640
5	281	1419	1957
6	1206	229	1155
7	806	980	187
8	593	654	798
9	488	483	533
10	120	394	394
11	84	66	375
1+	19448	16489	13434

(Table D13 - Continued on next page)

Table D13. Continued

FISHING MORTALITY - C:\Program Files\WHAT\m997798.2

	1962	1963	1964	1965	1966	1967	1968
1	0.04	0.01	0.06	0.03	0.04	0.00	0.03
2	0.02	0.01	0.05	0.02	0.06	0.06	0.04
3	0.02	0.01	0.02	0.02	0.04	0.13	0.17
4	0.10	0.03	0.04	0.02	0.03	0.04	0.39
5	0.08	0.23	0.03	0.06	0.03	0.04	0.20
6	0.48	0.03	0.25	0.04	0.13	0.04	0.12
7	0.68	0.10	0.56	0.44	0.06	0.14	0.01
8	0.76	0.19	0.59	2.80	0.08	0.11	0.03
9	0.56	0.42	6.47	4.14	2.90	0.07	0.03
10	0.69	0.26	1.03	4.44	0.11	0.11	0.03
11	0.69	0.26	1.03	4.44	0.11	0.11	0.03

	1969	1970	1971	1972	1973	1974	1975
1	0.00	0.09	0.07	0.02	0.17	0.06	0.24
2	0.08	0.04	0.20	0.10	0.34	0.40	0.45
3	0.16	0.21	0.12	0.27	0.56	0.63	0.33
4	0.30	0.23	0.37	0.25	0.43	0.39	0.53
5	0.09	0.19	0.51	0.49	0.46	0.39	0.42
6	0.06	0.16	0.40	0.43	0.49	0.53	0.43
7	0.05	0.14	0.31	0.54	0.27	0.56	0.50
8	0.04	0.35	0.13	0.23	0.50	0.37	0.55
9	0.09	0.15	0.25	0.51	0.37	0.63	0.31
10	0.05	0.21	0.18	0.36	0.47	0.41	0.48
11	0.05	0.21	0.18	0.36	0.47	0.41	0.48

	1976	1977	1978	1979	1980	1981	1982
1	0.04	0.04	0.00	0.00	0.02	0.11	0.01
2	0.37	0.10	0.01	0.02	0.09	0.13	0.11
3	0.58	0.17	0.02	0.04	0.05	0.11	0.07
4	0.45	0.21	0.04	0.05	0.04	0.10	0.14
5	0.58	0.10	0.07	0.05	0.06	0.10	0.11
6	0.35	0.20	0.10	0.10	0.05	0.06	0.14
7	0.49	0.11	0.14	0.10	0.05	0.06	0.05
8	0.76	0.13	0.06	0.11	0.04	0.06	0.05
9	0.52	0.17	0.13	0.07	0.05	0.06	0.05
10	0.65	0.14	0.09	0.09	0.04	0.06	0.05
11	0.65	0.14	0.09	0.09	0.04	0.06	0.05

	1983	1984	1985	1986	1987	1988	1989
1	0.00	0.00	0.01	0.01	0.03	0.00	0.00
2	0.03	0.01	0.01	0.02	0.16	0.06	0.02
3	0.08	0.07	0.03	0.03	0.04	0.17	0.07
4	0.06	0.05	0.12	0.02	0.04	0.04	0.18
5	0.16	0.05	0.06	0.11	0.03	0.09	0.03
6	0.09	0.15	0.04	0.05	0.12	0.04	0.02
7	0.12	0.10	0.14	0.03	0.09	0.23	0.04
8	0.10	0.09	0.07	0.20	0.03	0.13	0.06
9	0.08	0.08	0.09	0.06	0.21	0.13	0.05
10	0.09	0.08	0.08	0.18	0.11	0.13	0.06
11	0.09	0.08	0.08	0.18	0.11	0.13	0.06

(Table D13 - Continued on next page)

Table D13. Continued

	1990	1991	1992	1993	1994	1995	1996
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.01	0.01	0.00	0.00	0.00	0.01	0.01
3	0.05	0.03	0.00	0.01	0.01	0.01	0.01
4	0.06	0.05	0.01	0.01	0.01	0.01	0.01
5	0.22	0.06	0.03	0.02	0.01	0.01	0.01
6	0.03	0.21	0.02	0.04	0.02	0.00	0.01
7	0.01	0.03	0.08	0.03	0.03	0.01	0.00
8	0.03	0.02	0.01	0.09	0.02	0.02	0.02
9	0.10	0.02	0.02	0.01	0.04	0.01	0.01
10	0.03	0.02	0.01	0.02	0.02	0.02	0.02
11	0.03	0.02	0.01	0.02	0.02	0.02	0.02

	1997	1998
1	0.00	0.00
2	0.01	0.00
3	0.01	0.00
4	0.01	0.01
5	0.00	0.01
6	0.01	0.00
7	0.01	0.01
8	0.01	0.01
9	0.01	0.00
10	0.01	0.01
11	0.01	0.01

2,10
3,10
4,10
Average F for 2,10 3,10 4,10

	1962	1963	1964	1965	1966	1967	1968
2,10	0.38	0.14	1.00	1.33	0.38	0.08	0.11
3,10	0.42	0.16	1.12	1.50	0.42	0.08	0.12
4,10	0.48	0.18	1.28	1.71	0.48	0.08	0.12

	1969	1970	1971	1972	1973	1974	1975
2,10	0.10	0.19	0.28	0.35	0.43	0.48	0.45
3,10	0.10	0.21	0.28	0.39	0.44	0.49	0.44
4,10	0.09	0.21	0.31	0.40	0.43	0.47	0.46

	1976	1977	1978	1979	1980	1981	1982
2,10	0.53	0.15	0.07	0.07	0.05	0.08	0.08
3,10	0.55	0.15	0.08	0.07	0.05	0.08	0.08
4,10	0.54	0.15	0.09	0.08	0.05	0.07	0.08

	1983	1984	1985	1986	1987	1988	1989
2,10	0.09	0.08	0.07	0.08	0.09	0.11	0.06
3,10	0.10	0.09	0.08	0.09	0.09	0.12	0.06
4,10	0.10	0.09	0.09	0.09	0.09	0.11	0.06

(Table D13 - Continued on next page)

Table D13. Continued

	1990	1991	1992	1993	1994	1995	1996
2,10	0.06	0.05	0.02	0.03	0.02	0.01	0.01
3,10	0.07	0.06	0.02	0.03	0.02	0.01	0.01
4,10	0.07	0.06	0.02	0.03	0.02	0.01	0.01

	1997	1998
2,10	0.01	0.01
3,10	0.01	0.01
4,10	0.01	0.01

Average F weighted by N for 2,10 3,10 4,10

	1962	1963	1964	1965	1966	1967	1968
2,10	0.02	0.03	0.04	0.05	0.05	0.08	0.08
3,10	0.02	0.04	0.04	0.06	0.05	0.09	0.14
4,10	0.17	0.04	0.05	0.06	0.05	0.08	0.12

	1969	1970	1971	1972	1973	1974	1975
2,10	0.10	0.17	0.28	0.30	0.44	0.48	0.44
3,10	0.15	0.22	0.31	0.35	0.47	0.51	0.43
4,10	0.14	0.22	0.39	0.39	0.45	0.45	0.47

	1976	1977	1978	1979	1980	1981	1982
2,10	0.46	0.16	0.05	0.06	0.06	0.07	0.08
3,10	0.54	0.17	0.06	0.07	0.05	0.07	0.07
4,10	0.51	0.17	0.06	0.07	0.05	0.06	0.07

	1983	1984	1985	1986	1987	1988	1989
2,10	0.06	0.01	0.03	0.03	0.04	0.05	0.04
3,10	0.09	0.08	0.03	0.03	0.04	0.05	0.04
4,10	0.10	0.08	0.11	0.03	0.04	0.05	0.04

	1990	1991	1992	1993	1994	1995	1996
2,10	0.03	0.02	0.01	0.01	0.01	0.01	0.01
3,10	0.04	0.03	0.01	0.01	0.01	0.01	0.01
4,10	0.04	0.03	0.01	0.02	0.01	0.01	0.01

	1997	1998
2,10	0.01	0.01
3,10	0.01	0.01
4,10	0.01	0.01

(Table D13 - Continued on next page)

Table D13. Continued

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

	1962	1963	1964	1965	1966	1967	1968
1	01	00	00	01	01	03	11
2	19	33	14	15	21	48	154
3	269	31	60	27	30	38	91
4	13	251	32	66	31	32	35
5	06	10	232	31	69	30	31
6	02	05	07	220	29	65	29
7	01	01	03	05	205	23	62
8	01	01	01	01	03	171	20
9	00	00	00	00	00	03	147
10	00	00	00	00	00	00	02
11	00	00	00	00	00	00	00
1+	313	333	350	366	390	414	582

	1969	1970	1971	1972	1973	1974	1975
1	04	03	02	02	02	03	03
2	394	139	131	84	82	58	88
3	283	581	232	223	126	99	77
4	82	225	448	236	181	83	60
5	28	56	148	326	176	116	55
6	27	21	38	96	196	99	73
7	25	20	14	24	63	103	53
8	56	16	14	11	13	40	52
9	17	39	10	10	07	06	24
10	126	11	27	07	06	04	03
11	00	08	25	12	02	01	01
1+	1042	1120	1088	1031	855	613	488

	1976	1977	1978	1979	1980	1981	1982
1	00	00	00	00	00	00	01
2	84	23	05	04	20	08	14
3	101	135	58	13	08	39	17
4	56	80	165	79	15	08	36
5	33	46	81	184	74	12	07
6	34	23	46	77	167	61	10
7	40	26	20	41	68	140	52
8	25	28	24	17	34	57	116
9	25	14	24	21	14	28	46
10	13	16	12	19	17	11	22
11	01	03	47	40	76	33	58
1+	413	394	481	494	493	398	378

(Table D13. - Continued on next page)

Table D13. Continued

	1983	1984	1985	1986	1987	1988	1989
1	13	00	01	00	00	01	04
2	59	538	28	44	07	22	67
3	33	108	1148	67	92	17	49
4	18	31	103	1391	66	97	16
5	28	15	26	87	1355	58	94
6	05	21	12	21	70	1232	50
7	07	04	15	10	16	55	1099
8	41	05	03	11	08	13	43
9	91	30	04	03	08	07	11
10	35	68	23	03	02	06	05
11	20	54	81	21	23	29	18
1+	351	875	1446	1658	1648	1535	1457

	1990	1991	1992	1993	1994	1995	1996
1	03	06	07	03	06	06	16
2	187	191	257	306	66	218	312
3	152	447	468	503	544	98	463
4	54	164	522	499	479	529	115
5	13	48	156	481	427	425	531
6	85	10	42	137	395	363	397
7	48	74	08	37	112	318	325
8	944	43	68	06	29	87	283
9	35	827	36	60	05	24	73
10	09	28	729	30	44	04	21
11	21	11	45	266	68	26	21
1+	1549	1848	2337	2327	2174	2099	2556

	1997	1998
1	07	01
2	471	455
3	717	795
4	576	832
5	116	582
6	507	106
7	365	459
8	294	320
9	257	263
10	65	222
11	52	38
1+	3428	4073

Table D14. Biological reference points for Atlantic mackerel from Overholtz (1999) (S-R Approach), A trial ASPIC model run (ASPIC), and estimates of long-term potential yield from NEFSC (1996) (LPTY).

model	SSB[1] or B[2] msy	Fmsy	MSY
S-R	887,000 mt[1]	0.45	326,000 mt
ASPIC	1,350,000 mt[2]	0.14	186,000 mt
LPTY	1,000,000 mt[1]	----	150,000 mt

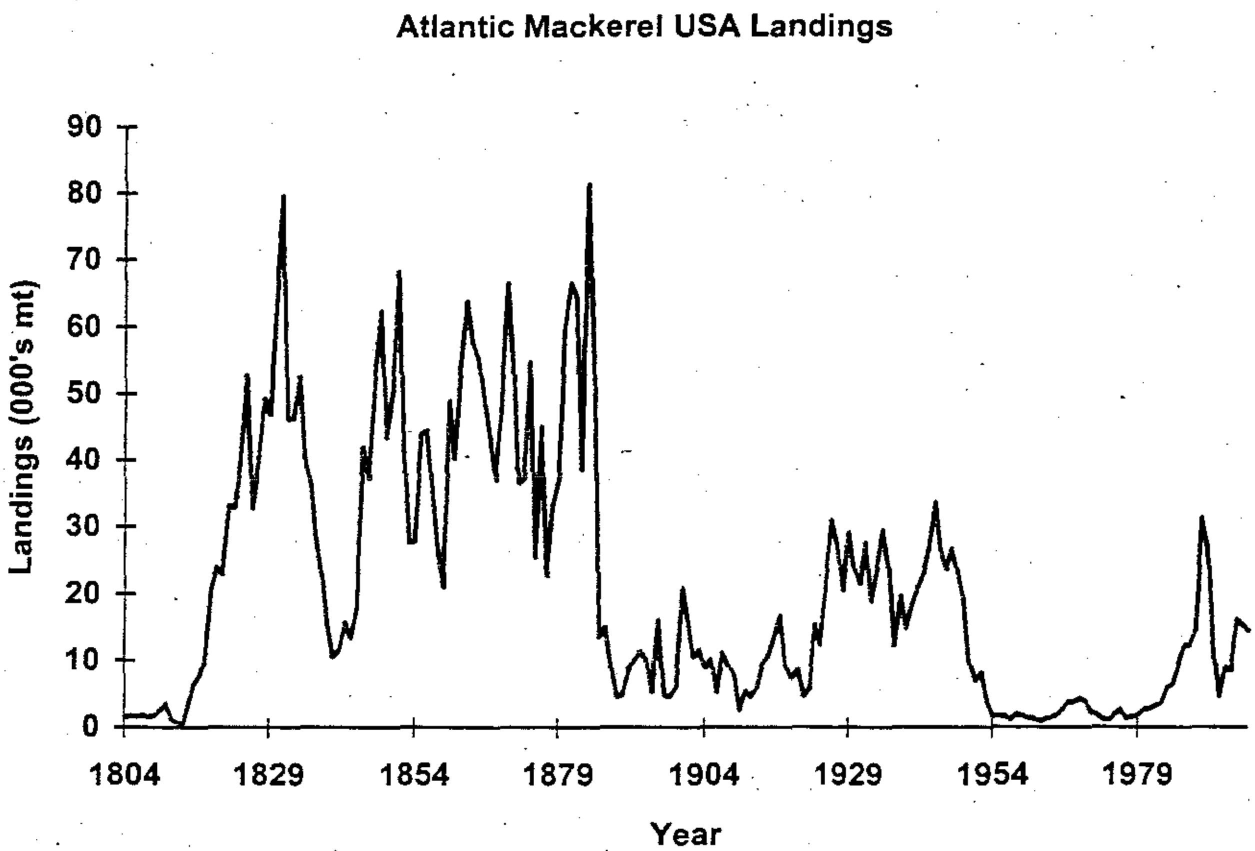

Figure D1. USA landings of Atlantic mackerel during 1804-1998.

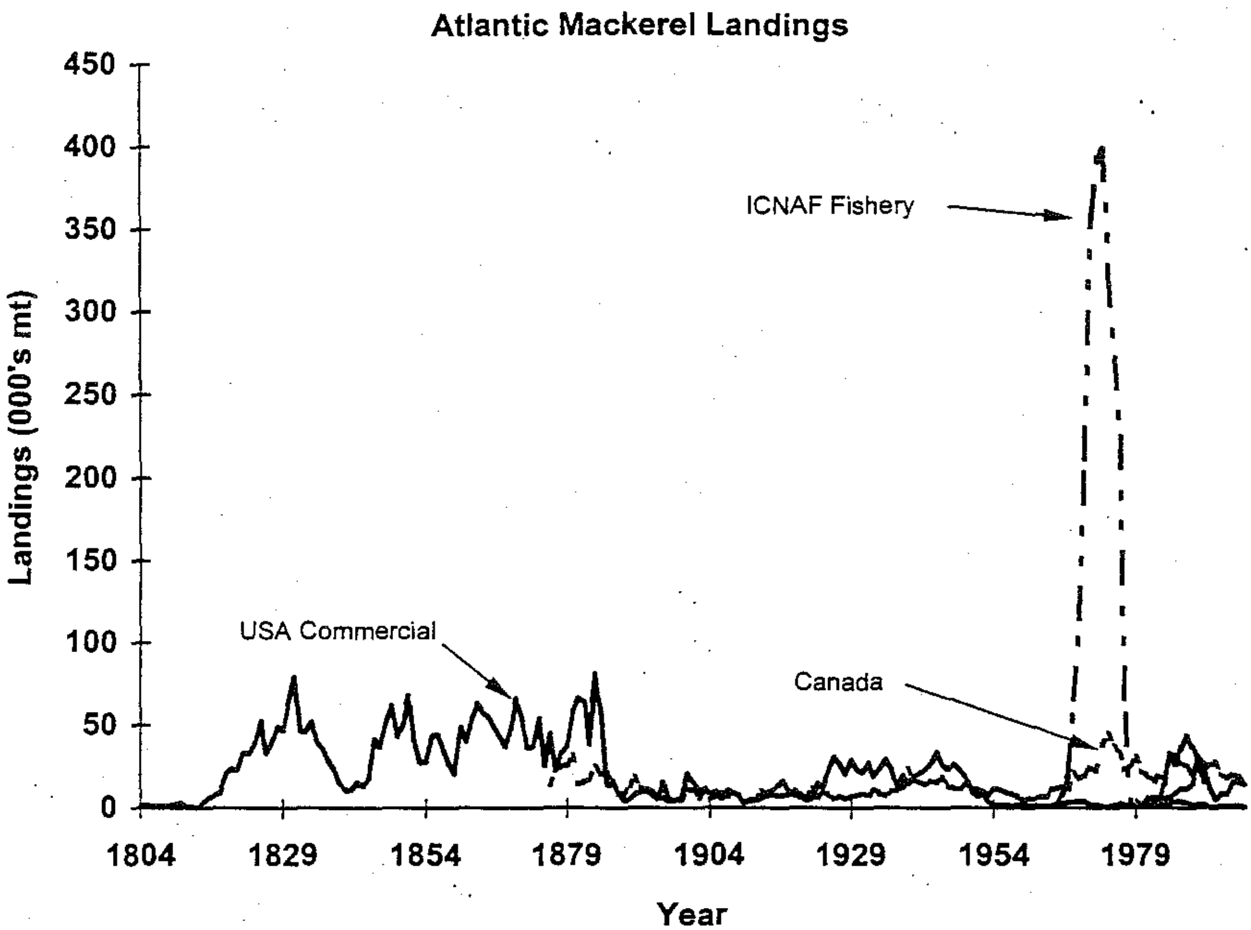

Figure D2. Landings of Atlantic mackerel by the USA, Canada, and foreign nations during 1804-1998 in SA-2-6.

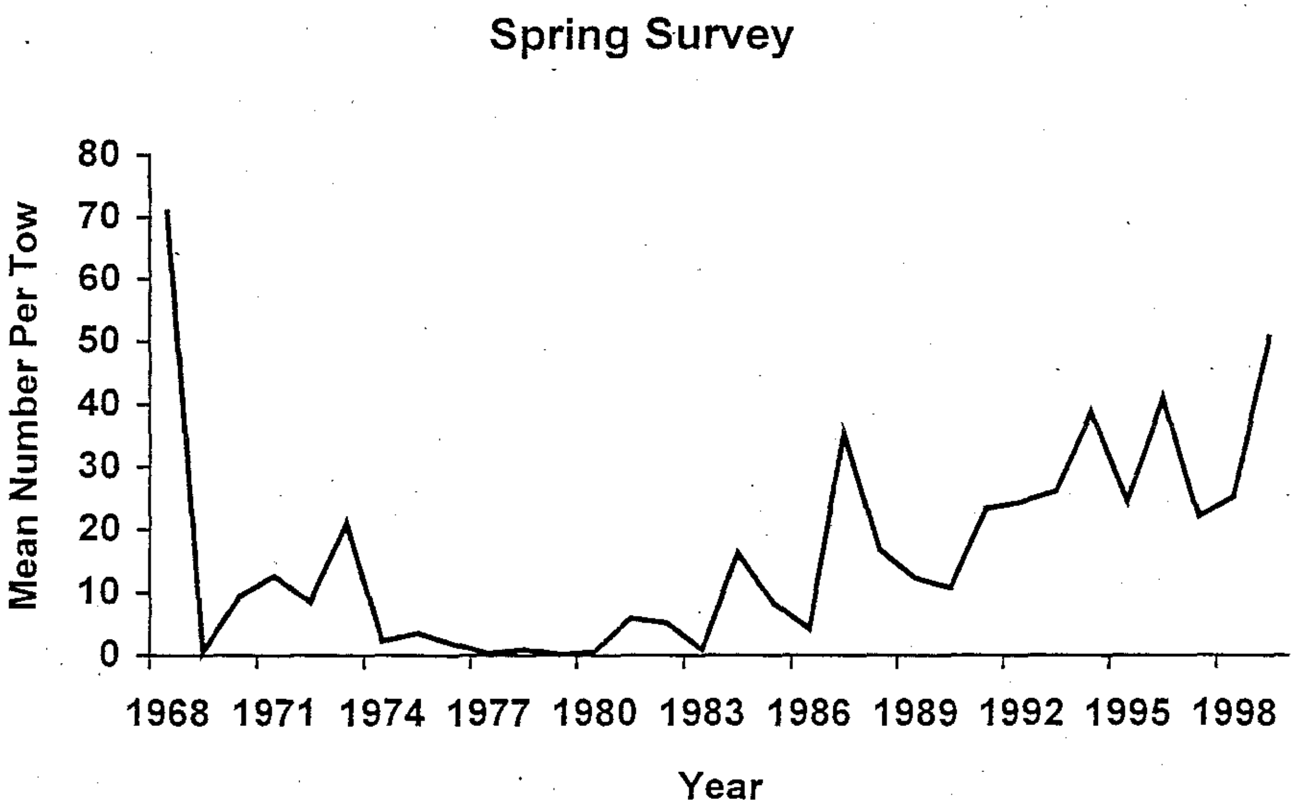

Figure D3. Spring survey indices (mean number per tow) from the NEFSC spring bottom trawl survey (Strata 1-25, 61-76) during 1968-1999.

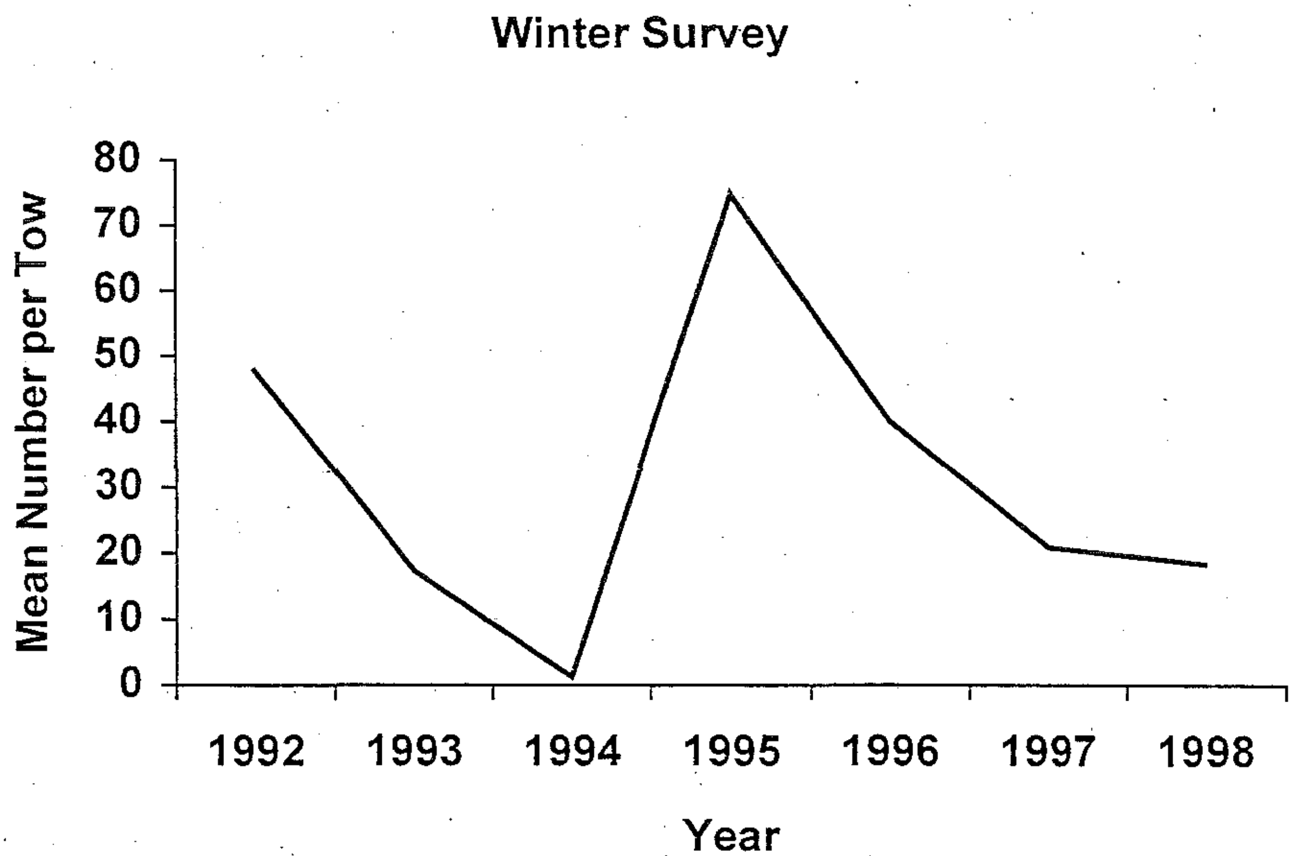

Figure D4. Winter survey indices (mean number per tow) from the NEFSC winter bottom survey (strata 1-3,5-7,9-11,13-14,16,61-63,65-67,69-71,73-76) during 1992-1998.

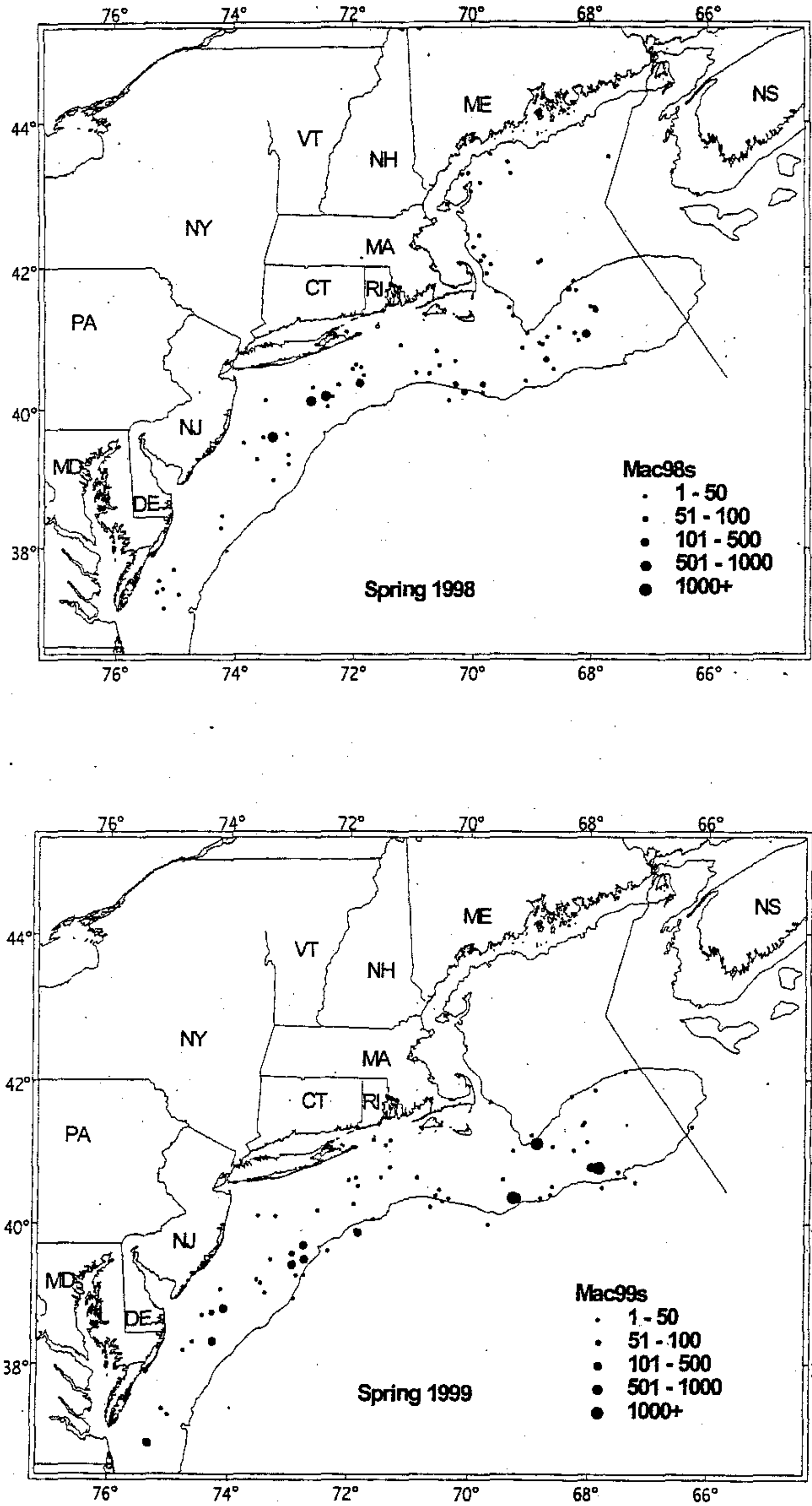

Figure D5. Distribution of Atlantic mackerel from the NEFSC spring bottom trawl survey during 1998 and 1999.

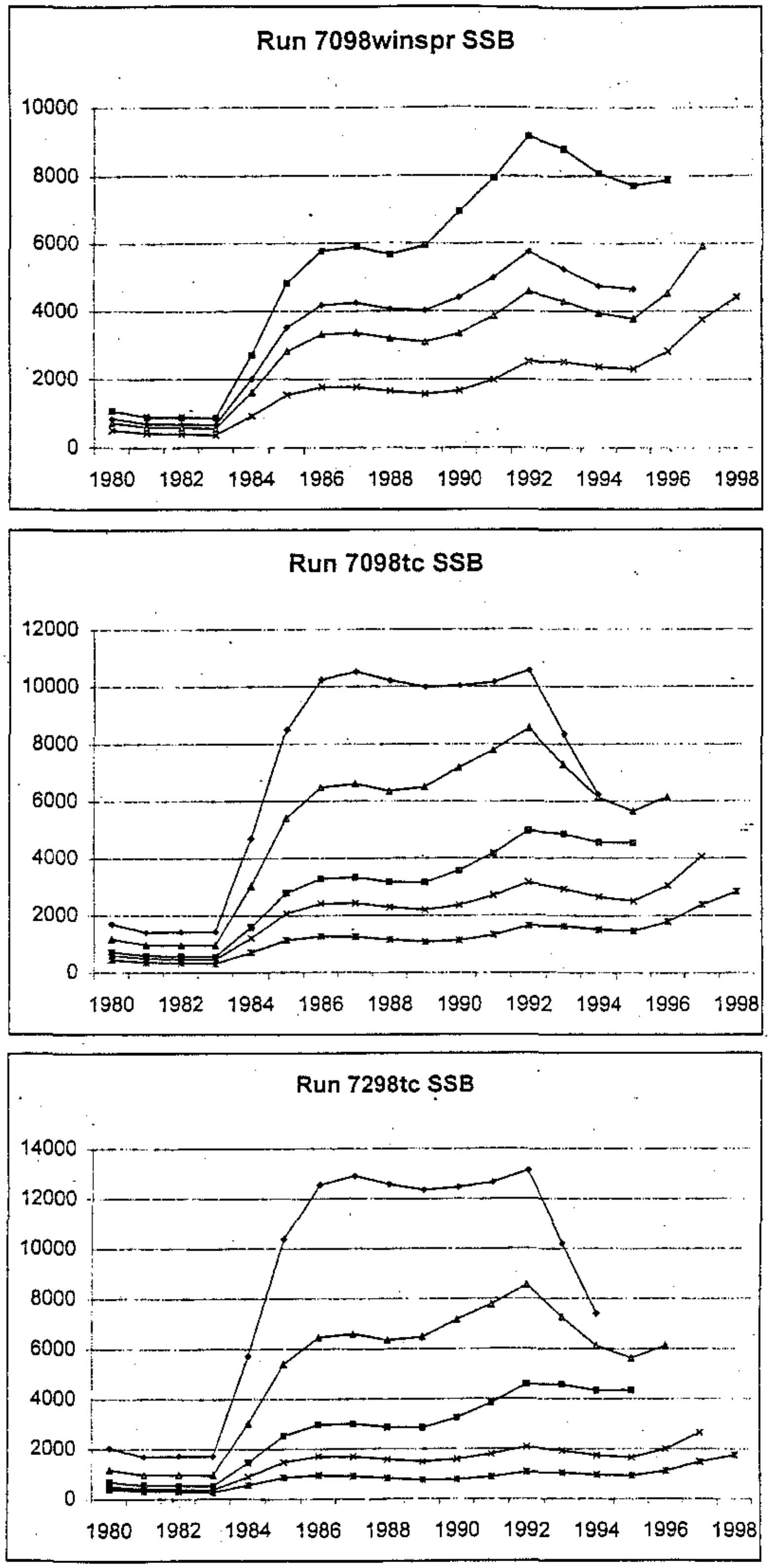

Figure D6. Retrospective analysis runs for Atlantic mackerel SSB for Runs 1, 5,6 during 1980-1998.

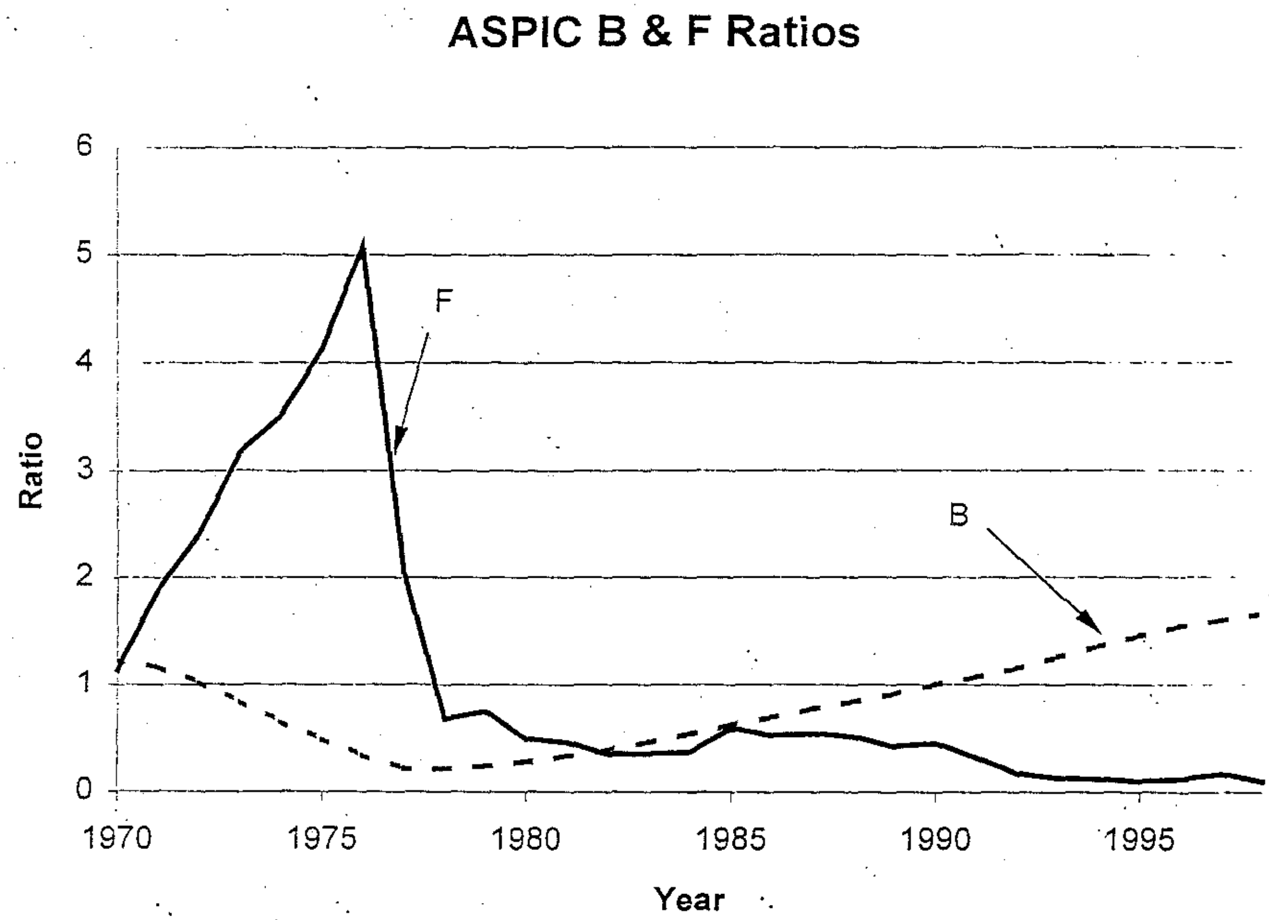

Figure D7. Ratios of F to Fmsy and biomass to Bmsy from a trial ASPIC run calibrated with spring survey data for 1970-1998.

E. SURFCLAMS

TERMS OF REFERENCE

(A) For the Atlantic surfclam resource as a whole and by region, update status and characterize uncertainty in estimates of stock size and fishing mortality.

(B) Estimate MSY or MSY proxies for the stock as a whole and by region.

(C) Review assumptions about natural mortality, refine estimates of survey dredge efficiency, and work towards developing appropriate population models.

(D) Develop and recommend options for defining overfishing targets and thresholds for surfclam consistent with the requirements of the Sustainable Fisheries Act. Determine the status of the resource with respect to appropriate overfishing targets for stock size and fishing mortality.

EXECUTIVE SUMMARY

Stock Status

1. Surfclams in federal waters (the EEZ) are managed as a single stock but this assessment was based on a number of smaller, stock assessment areas (see below).

Abbreviation	Stock Assessment Area
SVA	Southern Virginia and North Carolina
DMV	Delmarva
SNJ	Southern New Jersey
NNJ	Northern New Jersey
LI	Long Island
SNE	Southern New England
GBK	Georges Bank

2. The total surfclam stock is at a high abundance level and underexploited. Ninety-five percent confidence intervals for recent (mean 1997-1999) fishing mortality rates ranged 0.01-0.03 y^{-1} and best estimates were 0.016-0.019y^{-1}. Ninety-five percent confidence intervals for recent stock biomass levels (surfclams 100+ mm) ranged 750,000-2,300,000 mt of meats and the point estimate was 1,300,000 mt.

Commercial Catches

3. Commercial landings and effort data from 1982 to 1999 (partial year) are from mandatory vessel logbooks. Commercial length frequencies were estimated by region from samples collected by port agents.

4. Between 1965 and 1974, total landings rose from 20,000 to 44,000 mt of meats (Table E1, Figure E1). After 1974, total landings declined steadily to 16,000 mt in 1978. Landings increased throughout the early 1980s. Between 1983 and 1999, surfclam landings were fairly constant, ranging 20,000 - 25,000 mt. About 70-75% of surfclam landings are from the EEZ. The remainder are taken from state waters.

5. In calculations and model runs, catch weight was total reported landings plus discard (zero during recent years) plus an assumed 20% (of landings) indirect mortality due to fishing. In models and calculations, catches in 1999 were assumed equal to catches in 1998 because only a partial year of data were available for 1999.

6. Virtually all EEZ landings are from the Middle Atlantic region (Table E2 and Figure E2). During 1986-1999, 74-91% of Middle Atlantic landings came from the Northern New Jersey (NNJ) stock assessment region, 1-16% came from Delmarva (DMV), and 0-24% came from Southern New Jersey (SNJ).

7. The surfclam fishery in federal waters has occurred mostly in the New Jersey region since 1985 (Figure E2). Within the New Jersey region there were progressive shifts of the fishery northward and offshore during 1985-1997. By 1997, the fishery and distribution of surfclams overlapped completely. In 1999, the fishery was again carried out over most of the range of surfclams in the New Jersey region. (Figure E44).

8. Since 1997, landings from the relatively small Southern New Jersey region increased to about 24% of total landings due to fishing in a single ten-minute square close to shore at the mouth of the Delaware Bay (Figures E2-E6).

Commercial Fishing Effort

9. In the early 1980's, the Delmarva and the Southern and Northern New Jersey regions supported consistently high levels of fishing effort (15,000 - 16,000 hrs/yr) (Figure E7). Subsequently, effort declined in Delmarva, but remained high in N. New Jersey. From 1985-1990, hourly trip limits were used to manage the fishery and reported hours fishing per year in each region were well below levels during the early 1980s. Fishing effort levels stabilized in 1991, when ITQ management was implemented.

10. A fishery for surfclams developed on Georges Bank in the mid-1980s, but the area was closed in 1990 due to the presence of paralytic shellfish poison (PSP).

Commercial Catch Rates

11. Commercial catch rates in the surfclam fishery are measured in units of bushels of clams landed per hour fishing (LPUE), as reported in logbooks.

12. Six hour trip limits during 1985-1990 make reported effort per trip and LPUE unreliable for those years (NEFSC 1998a).

13. Results from generalized linear models indicate that LPUE in NNJ declined by approximately 17% from 1991 to 1999. LPUE was variable in SNJ and DMV but is currently near maximum observed values (Table E4, Figure E12).

Survey Data

14. The NMFS clam survey has been conducted since 1965, but survey data must be used carefully because of methodological changes (Tables E6 and E7). Factors that changed recently include refitting the research vessel (which affected how it rides in the water), new winches which operate at different speeds and affect tow distance, and voltage on the ship powering the pump on the dredge.

15. Dredge survey data collected since the summer survey in 1980 (cruise 8006) give useful information about trends in surfclam abundance but are difficult to interpret in some cases (Table E15). Data collected between 1978 and the winter of 1980 are less reliable but may be important because of mortality and recruitment events that occurred at that time. Data collected prior to 1978 are not comparable with survey data collected afterwards.

16. The 3.2 ton, hydraulic dredge currently used in NMFS clam surveys has a submersible pump that shoots water into the sea bottom just ahead of the 1.5m-wide dredge mouth. Jets of water from the pump turn the sea bottom into a fluid, which allows the clams to be captured more easily in most substrates.

17. Major field studies were carried out during 1997 and 1999 to understand and calibrate dredge performance because of problems with survey data collected in 1994. An underwater video camera (1997 only) and sensors (1997 and 1999) monitored the behavior of the dredge during each tow. Depletion experiments were carried out during 1997 and 1999 using commercial and NMFS research vessels to estimate the efficiency of the survey clam dredge and measure clam density. In both 1997 and 1999, survey stations occupied during previous NMFS clam surveys in unfished areas were resampled to measure changes in efficiency.

18. Improvements made to the clam survey in 1997 and 1999 allow for more accurate estimates of current surfclam biomass because tow distance was measured more accurately, variations in survey dredge efficiency were measured and because dredge efficiency estimates were used to convert survey data to biomass estimates.

Estimation of Dredge Efficiency in 1999

19. As indicated above, estimates of dredge efficiency can be used to convert survey data (clam catch in weight per standard tow) to swept area biomass. The conversion formula is $B=bA/(Ea)$ where **B** is swept area biomass, b is biomass per standard tow in the survey, E is dredge efficiency, A is the size of the area sampled and a is the area covered during a standard tow.

20. Three approaches (i.e. resampling, depletion and comparison of random stations, see above and Table E13) were used to estimate dredge efficiency (E) during 1999. The average of the estimates is 0.276 (CV 35%).

Changes to Natural Mortality Assumptions

21. Revised estimates of natural mortality (M) for surfclam were based on recent age and growth studies (Weinberg and Helser 1996) and a variety of methods. The revised estimate M=0.15 was used in basecase model runs. Sensitivity analyses used a wider range (0.1-0.2). The value assumed in previous assessments was 0.05.

10-Year Supply Model

22. The 10-year harvest policy is an obsolete hold-over from an era when surfclams were thought to recruit infrequently in large numbers (the idea was to harvest infrequent recruitment pulses). Recent data suggest that a moderate level of recruitment occurs annually and is sufficient to support the fishery. The policy and calculations evolved over time to reflect updated biological information. However, the 10-year supply policy has not been linked to MSY as required under the Sustainable Fisheries Act. In addition, it has been criticized because the 10-year planning horizon is arbitrary, calculations do not use all available information, and because recruitment is not modeled in a realistic manner. There is no need to perform 10-year supply calculations in the next assessment. They were carried out here for comparative purposes only.

23. The quota for year 2000 (19,779 mt) has already been set. A 10-year supply model run for the entire resource with M=0.05 (Tables E16 and E17, Figure E45) estimates a target harvest of 363,526 mt for the year 2001, which is almost twenty times greater than the current quota and 26% of current biomass. A run that excludes Georges Bank, gives a 281,266 mt catch in 2001. Results were moderately sensitive to the assumed natural mortality rate.

Surfclam Production Model

24. The surfclam production model (used in the previous assessment and different from surplus production and projection calculations in the KLAMZ model described below) was used to carry out short term projection calculations based on swept area biomass estimates and size composition data from the 1999 survey. However, a "basecase" run was not chosen because results were too sensitive to assumptions about natural mortality rate, dredge efficiency, selectivity of the survey gear to clams < 90 mm (selectivity), and indirect mortality from clamming.

Yield and Spawning Biomass Per Recruit

25. Thompson and Bell's (1934) method was used to estimate yield- and spawning biomass per recruit for surfclam in the NJ (NNJ plus SNJ), GBK and DMV stock assessment areas which represent extremes of growth and life history and contain 87-91% of the total biomass (Tables E26-E29).

Catch-Swept Area Model

26. Catch-swept area estimates of recent fishing mortality rates for surfclam (Table E41 and see below) were calculated as F=C/B using recent catch weight (C) and stock biomass (B) estimates. Recent stock biomass (B) was the average of efficiency adjusted swept area estimates for surfclams 100+ mm during 1997 and 1999. Recent catch (C) was the average for each area during 1997-1999. Results indicate that fishing mortality rates for surfclam were low during 1997-1999.

Stock Assessment Area	Swept Area Recent Biomass (mt)	Catch-Swept Area F (y^{-1})
SVA	3,000	0.001
DMV	304,000	0.003
SNJ	103,000	0.039
NNJ	487,000	0.033
LI	53,000	0.002
SNE	87,000	0.001
GBK	253,000	0.000
Total	1,292,000	0.017

KLAMZ Assessment Model

27. A new surfclam assessment model (KLAMZ) was developed to address research recommendations from SARC-26 (NEFSC 1998, p. 73).

28. The main difference between KLAMZ and the modified DeLury model (often used for invertebrate assessments, e.g. for surfclam in NEFSC 1995) is that population dynamic calculations in KLAMZ are based on Schnute's (1985) delay difference equation and carried out in biomass units assuming Von Bertalanffy growth (rather than a simpler difference equation in units of numbers).

29. Unlike the modified DeLury model which was used for surfclam in 1995, the KLAMZ model gave plausible results. Its success was due primarily to improved data and, in particular, efficiency corrected swept area biomass estimates for surfclam based on depletion experiments. Variances for estimates from KLAMZ were calculated by a bootstrap procedure.

30. Input data for basecase runs with KLAMZ included survey trend data for pre-recruit and new recruit abundance, survey trends in biomass for the whole stock, standardized LPUE, and efficiency adjusted swept area biomass during 1997 and 1999. Survey data were for 1978-1999 with 1979 and 1994 omitted. Data for 1979 were omitted because only a single winter survey was conducted during 1979 (rather than summer and winter surveys during 1978 and 1980). Survey data for 1994 were outliers (implausibly high) due to problems with the voltage used to power the pump on the dredge. LPUE data were for 1980-1984 and 1991-1999 (treated as two independent time series to avoid confounding by improvements to gear and increased in efficiency due to ITQ management). LPUE data for 1985-1990 were omitted because catch rates were affected by trip duration limits.

31. Recent biomass and fishing mortality estimates from KLAMZ were similar to estimates from the catch-swept area model (see below) and suggest that fishing mortality rates are low.

Stock Assessment Area	**KLAMZ Mean 1997-1999 Biomass (mt)**	**KLAMZ Mean 1997-1999 F (y^{-1})**
SVA	3,000	0.001
DMV	321,000	0.003
SNJ	62,000	0.073
NNJ	504,000	0.035
LI	46,000	0.002
SNE	85,000	0.001
GBK	238,000	0.000
Total	1,260,000	0.019

Options for the Overfishing Definintion and MSY Control Rule

32. In the absence of other policy guidance, options developed in this assessment were for biomass targets, biomass thresholds and fishing mortality thresholds in the default MSY control rule (Figure E72) recommended by NMFS (Restrepo et al. 1998) and used in the Review of Overfishing Definitions in the Northeast (Applegate et al. 1998). The

biomass target in the default MSY control rule is B_{MSY} and the default policy relies heavily on MSY assumptions and calculations.

33. The default MSY control rule defines a maximum fishing mortality rate threshold. Overfishing (as a rate) occurs by definition whenever fishing mortality is as large or larger than the fishing mortality rate threshold. The threshold fishing mortality rate used to define overfishing is reduced in the default MSY control rule whenever stock biomass falls below a biomass threshold value. According to the default rule, a stock is overfished (in terms of biomass) by definition whenever stock biomass falls below the biomass threshold level.

34. The threshold fishing mortality rate used in the default MSY control rule is F_{MSY} as long as stock biomass is above the biomass threshold. However, when stock biomass falls below the biomass threshold level, the threshold fishing mortality rate is reduced. Reductions in the threshold rate are linear from F_{MSY} at the biomass threshold to zero at a stock biomass of zero.

35. According to the Sustainable Fisheries Act, overfishing definitions must apply to the entire surfclam stock. In practice, the surfclam stock is assessed based on a number of smaller stock assessment areas with B_{MSY} and F_{MSY} estimated possibly for each. Under these circumstances, best estimates of MSY parameters for the entire surfclam stock might be sums or weighted averages of the estimates for each stock assessment area.

36. B, $B_{threshold}$ and B_{MSY} or F, $F_{threshold}$ and F_{MSY} estimates may not be reliable or available for all stock areas. In such cases, proxies or proxies for ratios (e.g. for B/B_{MSY} or F/F_{MSY}) based on the best available information should be used instead.

37. In the default MSY control rule, the biomass threshold is either ½ or ¼ B_{MSY}. Restrepo et al. (1998) recommended that the biomass threshold for surfclam should be "no less than ½ B_{MSY} to avoid the risk of stock collapse due to low spawning biomass and poor recruitment." The SARC recommends the ½ B_{MSY} option based on rebuilding isopleths that show it is more compatible with maintaining B_{MSY} target biomass levels.

38. A number of estimates and proxy options for F_{MSY} in surfclam were considered. The proxy recommended by the SARC was F_{MSY}=M. This is a common approach.

39. A number of estimates and proxy options for B_{MSY} were considered. The proxy recommended by the SARC takes B_{MSY} equal to ½ recent (mean 1997-1999) biomass for the whole (100+ mm) surfclam stock. This simple approach is reasonable because the catch-swept area and KLAMZ models indicate that recent fishing mortality rates were low (0.02). By inference, stock biomass is probably at levels near carrying capacity for surfclam.

40. Estimates of fishing and biomass thresholds and the biomass target in the default MSY control rule can be expected to change in each assessment as data accumulate and models change. Changes to estimates should not require an FMP amendment, only technical explanation.

Uncertainties

41. The most important source of uncertainty in this assessment was precision of efficiency adjusted biomass estimates for 1997 and 1999. CV's ranged from 20-79% for individual stock assessment areas and 18-21% for the stock as a whole.

42. In addition to the uncertainty measured by CV's, there is considerable uncertainty in assessment results due to applying survey dredge efficiency estimates from a small number of depletion estimates in one or two areas to regions where bottom characteristics and surfclam habitat may be quite different.

INTRODUCTION

Atlantic surfclams are large, fast-growing bivalves that occupy sandy substrates from the shallow subtidal zone to depths of about 50 m. The management and history of the surfclam and ocean quahog fisheries along the Atlantic coast of the United States were described by Murawski and Serchuk (1989). Recent papers by Weinberg and Helser (1996) and Weinberg (1998, 1999) describe individual growth rates, size- and age-structure, and recruitment in surfclams.

Surfclams were assessed in 1992, 1994 and most recently in 1997 (NEFSC 1993, 1995, 1998a,b), for SARC/SAW-15, -19 and -26, respectively. Assessments are generally done after a NMFS clam survey, which are generally conducted every 2-3 years. Uncertainty in assessment results and the necessity for additional research on abundance were highlighted at SARC-22 (NEFSC 1996a,b) because 1994 survey catch rates were anomalous and the dredge efficiency estimate from a population model was unrealistic.

Due to uncertainty about survey data from 1994, a major effort was made in 1997 to improve understanding of the performance of the dredge used in NMFS clam surveys. Clams are sampled with an 3.2 ton, hydraulic dredge, similar to that used by industry. A submersible pump, mounted above the dredge, shoots water into the sea bottom just ahead of the 1.5m-wide dredge mouth. These jets of water turn the sea bottom into a fluid, which allows the clams to be captured more easily.

An underwater video camera and sensors, used for the first time in 1997, monitored the behavior of the dredge during each tow of the 1997 survey. The video and sensor data allowed for more accurate estimates of distance towed as well as estimates of water pressure at the manifold. In addition, depletion experiments were carried out in the field in 1997 to estimate the efficiency of the NMFS clam dredge. Experiments were done in collaboration with academia and the clam industry. As an additional tool, survey stations occupied during previous NMFS clam surveys in unfished areas were resampled to measure changes in efficiency of the clam dredge over time.

Sensors, depletion experiments, and resampled stations were continued during the 1999 clam survey. The new Shipboard Computing System (SCS) and environmental sensors on the R/V DELAWARE II were used to gather continuous data on ship speed, position and dredge angle during every tow. These data allowed for a direct and improved estimate of distance sampled per tow by the dredge. Additional depletion studies to measure survey dredge efficiency were carried out in collaboration with the clam industry and academia (see Acknowledgments). Improvements made to the clam survey in 1997 and 1999 allow for more accurate estimates of current surfclam biomass because tow distance was measured more accurately, variations in survey dredge efficiency were understood and dredge efficiency estimates from depletion studies were useful for estimating surfclam biomass directly.

This report summarizes analyses and major research findings. A list of research recommendations, sources of uncertainty, and SARC comments are included. This assessment used existing, improved, and new models to estimate current stock biomass, fishing mortality and annual production for seven stock assessment regions that make up the surfclam stock. Because this fishery is highly localized and the resource is sedentary, attention was given to temporal and spatial trends in the commercial and survey data. The report also includes estimates of biological reference points, and options for overfishing definitions.

The surfclam stock was assessed based on a number of smaller, stock assessment areas (Figure E28). Name and abbreviations for the stock assessment areas are summarized (from south to north) below.

Abbreviation	Name
SVA	Southern Virginia and North Carolina
DMV	Delmarva
SNJ	Southern New Jersey
NNJ	Northern New Jersey
LI	Long Island
SNE	Southern New England
GBK	Georges Bank

COMMERCIAL DATA

Commercial landings and effort data from 1982 to 1999 (partial year) are from mandatory vessel logbooks. In many cases, 1998 landings data are used because of incomplete data from 1999. It is assumed throughout this assessment that one bushel of surfclams = 17 lbs = 7.711 kg of usable meats. 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 samples collected by port agents.

<u>Landings</u>

The surfclam fishery in the EEZ (beyond 3 miles from land) is managed with commercial catch quotas. Landings from the EEZ are typically close to annual quotas, which have been set since 1978.

Between 1965 and 1974, total landings rose from 20,000 to 44,000 mt of meats (Table E1, Figure E1). After 1974, total landings declined steadily to 16,000 mt in 1978. Strong recruitment of surfclams in the Mid-Atlantic region from Delmarva through New Jersey in the late 1970s resulted in increased landings throughout the early 1980's. Between 1983 and 1999, annual EEZ landings have been fairly constant, ranging from 20,000 - 25,000 mt. In the 1980's, approximately 75% of the landings were from the EEZ; the remainder were taken from state waters. In the 1990's, the percentage of landings from the EEZ has decreased slightly to approximately 70%. Since 1997, total EEZ landings have declined slightly.

Since 1994, virtually all EEZ landings were taken from the Middle Atlantic region. During 1986-1999, 74-91% of Middle Atlantic landings came from the Northern New Jersey stock assessment region, 1-16% came from Delmarva, and 0-24% came from Southern New Jersey (Table E2, Figure E2). This represents a shift away from the Delmarva region, which was a major source of surfclams in the late 1970's and to a lesser degree in the early 1980's. In recent years, the surfclam fishery was concentrated off the coast of New Jersey (Figures E3-E5) (NEFSC, 1998a). Starting in 1997, a significant fraction of surfclam landings were taken from a single ten-minute square close to shore at the mouth of the Delaware Bay (Figures E3-E6), which accounts for the increased fraction of landings from the southern New Jersey region (Figure E2).

Catch Rates and Effort

Effort Trends:

In the early 1980's, consistently high levels of fishery effort (15,000 - 16000 hrs/yr) took place in Delmarva and the Southern and Northern New Jersey regions (Figure E7). Effort subsequently declined in Delmarva, but remained high in N. New Jersey. From 1985-1990 hourly trip limits were used to mange the fishery and reported hours fishing per year in each region were well below levels of the early 1980s. Fishing effort levels appear stable since 1991, when ITQ management was imposed.

LPUE:

Commercial catch rates in the surfclam fishery are measured in units of bushels of clams per hour fishing. Data from every trip are reported in logbooks. Trip limits of 6-hr during 1985-1990 make reported effort per trip and LPUE unreliable for those years (NEFSC 1998a). In the Mid-Atlantic region, >70% of the annual surfclam catch is typically made by large (105+ GRT) vessels (Table E3). LPUE in the Mid-Atlantic region (Long Island to Southern Virginia) declined slightly from 1991-1999, with an increase in the 1999 (Figure 8). A fishery for surfclams developed on Georges Bank in the mid-1980s, but that area was closed in 1990 due to paralytic shellfish poison (PSP). The LPUE from Georges Bank was comparable to that in the Mid-Atlantic indicating that surfclams are abundant there (Figure 8).

In the Northern New Jersey region, LPUE increased from the early 1980s to the 1990s (Figure E9). LPUE declined in N. New Jersey throughout the 1990s, but increased in the most recent year for large vessels (Table E3, Figure E9). Since 1991 (after the period of effort regulation), LPUE decreased from 1063 kg/hr to 808 kg/hr (-24%) for vessel class 3. Although Class 2 vessels account for only a small fraction of the New Jersey landings, those vessels often have a higher LPUE than Class 3 vessels.

Off Southern New Jersey, nominal LPUE for class 2 vessels increased to over 2000 kg/hr (Table E3, Figure E10). This represents the highest LPUE among all region/vessel class combinations in 1998-1999.

In the Delmarva region, LPUE has been variable since 1991, probably due to the small number of trips taken in the region (Table E3, Figure E11). Indices have tended downward for Class 3.

General Linear Models
General linear models (GLMs) were used to standardize LPUE data and estimate year effect parameters that may measure trends in surfclam biomass. GLMs were carried out, by region, on the natural log of LPUE. Year, vessel tonclass and subregions were included as explanatory variables. "Subregions" were created by splitting each region into approximate halves. As described above, effort reporting problems from 1985-1990 confound interpretation of LPUE as a measure of relative resource abundance. Therefore, data from 1985-1990 were excluded from the analyses. GLM results from NNJ, SNJ and DMV are most important because the fishery is/has been active in these areas and NMFS research surveys have indicated that much of the stock biomass is within these regions.

There is a general trend across regions for a rise in LPUE from the early 1980s to the 1990s (Table E4, Figure E12). This is probably due to several factors including recovery of the stock biomass and age structure following the hypoxic event and heavy fishing during the 1970s, ITQ management in the 1990s, and possible changes in fleet composition and harvesting technology.

Back-transformed year coefficients from the GLMs (i.e., standardized LPUEs) follow trends in nominal LPUEs for large vessels rather closely. Model results suggest that LPUE in NNJ declined by approximately 17% from 1991 to 1999. LPUE in SNJ and DMV have been highly variable, but each is currently near the maximum of the historical time series (Table E4, Figure E12).

<u>Size Composition</u>
Length frequency distributions for surfclams landed between 1982 and 1999 are presented for the New Jersey and Delmarva regions in Figures E13 and E14, respectively. Sampling data are summarized in Table E5.

Mean length of clams landed from the Delmarva area has decreased steadily from 159 mm in 1982 to 126 mm in 1999. Small clams sampled in 1994 are probably the result of low numbers of port samples, because 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 the time series, although the percentage of small clams (90 - 110 mm) increased from 1993-1997. The proportion of clams in the 150 mm+ category increased beginning in 1991 off NNJ, and has remained high since then.

Between 1982 and 1990, average size of clams landed from S New England (approximately 150 mm - 160 mm) was greater than that from areas to the south (typically 120 mm - 140 mm, Table E5). No data are available from S. New England after 1990.

RESEARCH SURVEYS

<u>History of Changes Made to NMFS Clam Survey Gear</u>
The NMFS clam survey has been conducted since 1965, but there are problems with use of

the data series as a relative abundance index. Clam survey data must be used carefully because significant methodological changes have taken place over time. Table E6 summarizes changes that took place in the early years, including changes in and to research vessels, sampling in different seasons, changing dredges, mesh sizes, etc. Changes that have taken place in the last decade are listed in Table E7. Factors that changed recently include refitting the research vessel (which affected how it rides in the water), new winches which operate at different speeds and affect tow distance, and voltage on the ship powering the pump on the dredge.

Sensor data, 1997 and 1999

Uncertainty about dredge performance following the 1994 survey highlighted problems in interpretation of survey indices. To reduce this uncertainty, changes to operational procedures at sea were implemented in 1997 and continued in 1999.

Better monitoring of dredge performance was achieved via the Delaware II's Shipboard Computing System (SCS), 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 ten seconds. The smallest time unit for analysis was one second.

Sensor data were processed carefully following the 1997 and 1999 surveys. In cases where data were missing and not collected every second, cells were filled with the previous measurement. Sensor data were then smoothedfor analysis. Experience showed that a 7-second moving average was appropriate for smoothing the data and conserving patterns in the data.

Estimation of Distance Towed, 1997 and 1999

Before 1997, tow distance was estimated by doppler equipment which recorded only during the timed 5-min portion of the tow. Starting with 1997, this procedure was augmented by placing sensors on the dredge and ship to estimate distance towed more directly. Contact time between the dredge and 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 PCODE GPS. Dredge angle was determined from inclinometer data, collected from a sensor mounted on the dredge.

The angle of the dredge and its relation to the depth of penetration of the blade into the sediment were analyzed for SARC-26 in NEFSC 1998a,b. For computation of tow distance, the dredge was considered to be in contact with the substrate whenever its angle was 2.3 degrees or less. The maximum possible depth of the blade is 8 inches, and 2.3 degrees corresponds to a blade depth of 4 inches into the bottom. This was selected as a reasonable critical fishing angle for the dredge based on videos of the dredge while being towed, and because the action of the hydraulic jets turns the bottom into a fluid, and causes the clams to be at or near the surface. Surfclams have relatively short siphons and do not have deep burrows. Four inches, the midpoint between the maximum and minimum possible values of possible blade penetration, was adopted as the standard for the 1997 surfclam and ocean quahog assessments (NEFSC 1998a, c).

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. A sensitivity analysis performed for SARC-26 (NEFSC 1998a) suggested that the estimate is relatively insensitive across assumed critical blade depths of 2" to 6".

Distance sampled while towing was computed as the product of ship's speed, dredge width, and a dummy variable (0 or 1) indicating whether the dredge was "fishing" at that second, summed over time. During the 1999 survey, tow distance ranged from about 0.15-.30 nmi and distance sampled per tow increased with station depth (Figure E15).

Dredge Performance during a Tow

As described above, 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 in 1999 are shown in Figures E16 and E17. They were chosen to illustrate that the sensors are sensitive to bottom type. Figure E16 represents a tow done over a smooth bottom. Note that the inclinometer profile (i.e., dredge angle) is smooth. Data from a station with a rough bottom are shown in Figure E17.

Dredge Selectivity

The selectivity of the clam dredge (efficiency of capture for surfclams of different sizes) has not been determined. The body of the dredge is lined with mesh which creates openings that are approximately 2.5 x 5 cm. Long parallel bars at the mouth of the dredge represent another area where clams may escape after entering the dredge. Based on initial data collected in 1999 to estimate selectivity (Table E8), surfclams are likely to have partial selectivity until they reach a shell length of 90 mm. Data on ocean quahogs collected in the same manner during the 1997 survey indicated that ocean quahogs are likely to have partial selectivity until they reach a shell length of approximately 70 mm (NEFSC, 1998c).

Efficiency of the Clam Dredge on the R/V *Delaware II*

In addition to the stratified random clam survey, field studies were carried out in 1999 to estimate efficiency of the clam dredge on the R/V *Delaware II*. This is an important parameter to estimate because it is used in the calculation of stock biomass, and because efficiency may vary between surveys, affecting abundance trend estimates.

Resampled Stations from Earlier Surveys

A total of 21 stations from the 1997 clam survey were resampled in 1999 to examine the efficiency of the NMFS clam dredge in 1999 relative to 1997. The experiment was conducted on surfclams from Stratum #9 in the Delmarva region (see map of station locations in NEFSC 1998a). Based on logbooks, little commercial fishing had taken place at these sites between 1994 and 1999.

Assuming no change in dredge efficiency, catch of clams in 1999 was predicted from the model:

$$\text{Adjusted Catch}_{(99)} = \text{Catch}_{(97)}\, e^{-2M}$$

The model describes the decline in abundance of clams due to natural mortality (M). Natural mortality was assumed be M=0.15. In fitting the model, it was appropriate to track through time only the abundance of the clams that were available to the survey gear in 1997.

Therefore, the raw catches from 1999 were adjusted to remove clams, based on their size, that were born after the 1997 survey. In addition, those clams that were alive during the 1997 survey but were too small to catch in the dredge had to be removed from the 1999 catch per tow. From an analysis of age/length data collected in 1999 from the Delmarva region, it was determined that clams <87 mm should be subtracted from the 1999 catch. Other cutoff shell lengths ranging from 80-90mm were also examined, with little affect on the results.

Table E9 and Figure E18 summarize the resampled data set and its analysis. Following Mendenhall et. al. (1971), the ratio estimator $R = N_{(99)} / N_{(97)}$ was 0.540 (CV = 84%). The ratio estimate suggests that the efficiency of the dredge in 1999 relative to 1997 was approximately 50%, but the number is not known precisely. The point estimate of dredge efficiency for 1997 was 0.59 (CV = 27%) (NEFSC 1998a). Multiplying the relative efficiency by the 1997 efficiency estimate gives an estimate of 1999 dredge efficiency of 0.318 (CV = 88%).

Analytical Models

Early studies of clam dredge efficiency (Myer et al., 1981; Smolovitz and Nulk , 1982), did not obtain reliable estimates of dredge efficiency for the dredge currently in use or in the habitat where the clam survey is carried out. Thus, it was necessary to carry out new studies in 1997 and 1999. Results from 1997 are described in detail in NEFSC (1998a,c).

Depletion studies were used to estimate efficiency of the survey dredge. At the most basic level, a depletion study samples a closed population without replacement two or more times and uses the rate of decline in catch per unit effort to measure population abundance. The total population is estimated from the rate of decline in catch over successive samples and the total quantity caught.

Dr. Paul Rago (NEFSC) extended the model he used to estimate dredge efficiency in 1997 to explicitly consider spatial overlap of tows as a depletion experiment progresses. His negative binomial "patch" model, first used to analyze scallop dredge efficiency (NEFSC, 1999) was applied to the surfclam depletion experiments. Rago's model is described in NEFSC (1999). A summary of the fieldwork and final results are given below.

Experiments and results

All depletion experiments with surfclams were carried out between July and September, 1999 at sites shown in Figure E19. The purpose of the experiments was to estimate efficiency of the clam dredge used by the *R/V Delaware II* (DE-II). Most depletion experiments involved the DE-II and commercial vessels, but the DE-II carried out its own depletion study at a site off the coast of Virginia labeled DEII in Figure E19. These data provided a "direct" estimate of efficiency for the DE-II. Another type of experiment involved the DE-II making 4-6 set up tows at a site and then having a commercial clamming vessel perform a depletion experiment at that site. Three commercial vessels (*F/V Melissa J, F/V Jersey Girl, F/V Christy*) were involved with the experiments. Comparison of the DE-II surfclam catch from its set up tows with the estimate of density from the commercial vessel's data set provides an "indirect" estimate of DE-II dredge efficiency. Six "indirect" estimates of efficiency were obtained in this manner.

Maps of cruise tracks of the DE-II and

commercial vessel are presented for each experiment (Figures E20-E25). Figures E20-E24 can be used to see whether the setup tows were close or far from the tows of the commercial vessel. If the distance is too great, then the density at the places where the pair of vessels worked might not have been the same initially, which would invalidate the comparison. Compared to the other sites, the distance between where the two vessels sampled was relatively large for experiments MJ-1 and CH-1 (Figures E20 and E24). Two of the "indirect" estimates of efficiency were obtained very close to each other, by a single vessel (F/V *Jersey Girl*) .

Depletion Estimate-Method 1. Table E10 gives the "direct" estimates of efficiency for each of the vessels. The table also gives the number of tows made at the site, parameter estimates in the negative binomial model, and comments (from Dr. Rago) about the model solutions. The "direct" estimate of dredge efficiency from the DE-II surfclam experiment off Virginia was 0.148.

Depletion Estimate-Method 2. "Indirect" estimates of DE-II efficiency are listed, by experiment, in the last column of Table E11. Values range from 0.08 to 0.50. Taking the average of the density estimates by the *F/V Jersey Girl* at the same site, gives five independent "indirect" estimates from experiments with commercial vessels. The median of the "indirect" estimates of DE-II dredge efficiency was 0.246.

Depletion Estimate-Method 3. It was possible to estimate DE-II efficiency in one other way (by "crosscheck") which made use of the estimate of the Christy's dredge efficiency, 0.431 (Tables E11). The predicted efficiency of the DE-II = (Density $_{(DE-II)}$ / Density $_{(Christy)}$) x Efficiency $_{(Christy)}$. From this method, the estimate of DE-II efficiency was 0.243.

Comparison of Catch per Tow at Random Stations

Another approach to estimating dredge efficiency was based on the ratio of catch per tow at times t and t+1. If population levels had not changed, then a change in catch per tow would indicate a change in dredge efficiency. We computed the ratio for surfclams during 1997 and 1999 in each stock assessment area. For the whole stock we computed a weighted average of the regions with area as the weighting factor. The ratio of relative catch per tow, adjusted for tow distance in 1997 and 1999 based on sensor data, was 0.598. Assuming an efficiency of 0.59 for 1997 (NEFSC 1998a), this would imply an efficiency in 1999 of 0.353 (Table E12).

This approach differs from the Resampled Stations Analysis described earlier. The current approach is based on the assumption that the stock did not change from 1997 to 1999, and examines whether catches have changed over time across a broad spatial scale.

Influence of Sediment Type

Efficiency is likely to be a function of sediment type. Two sediment samples were collected with a VanVeen grab at each depletion site to characterize grain size (Figures E26 and E27). With the exception of site MJ-2, sediments were primarily sands of 0.25 - 1.0 mm. Site MJ-2 consisted of many stones and shell fragments >4 mm. The "indirect" estimate of efficiency for the DE-II was low at the site with large particles.

Dredge Efficiency Summary

Three approaches (i.e. resampling, depletion and comparision of random stations, see above) were described above to examine dredge efficiency, E, in 1999. The five estimates of E from these approaches are listed in Table E13. The average of the estimates is 0.276. The CV (treating each estimate as an equivalent observation and computing an unweighted sample variance) was 35%.

Survey Results

Description of Surveys

A series of 22 research vessel survey cruises were conducted between 1965 and 1999 to evaluate the distribution, relative abundance and size composition of surf clam and ocean quahog populations in the Middle Atlantic, Southern New England and Georges Bank (Figure E28).

Assessment regions were defined by groups of strata which remain fixed through time (Figure E28). The surveys are performed using a stratified random sampling design, allocating a pre-determined number of tows to each stratum. 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 length-weight equations to numbers caught in each 10 mm size category. By computing simple unweighted averages from all tows within a stratum, size frequency distributions per tow are computed by stratum. Size frequency distributions and mean number of clams per tow are computed by region by averaging over strata, weighted by stratum area.

In surveys conducted 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 distances in the 1997 and 1999 surveys were standardized by calculating tow distance from ship's velocity (measured by GPS) and contact by the dredge on the bottom as measured by the inclinometer. Distance-standardized catches per tow from 1997 and 1999 were computed by multiplying catch at each station by the ratio of (0.15/tow distance).

Locations of random stations in the 1999 clam survey are shown in Figure E29. Station intensity was greater in some areas (e.g. NNJ) because the estimation of population abundance via area-swept methods was anticipated (Figure E29). Samples were not collected from the S. Virginia - N. Carolina region, the Great S. Channel just to the west of Georges Bank, or from the NW corner of Georges Bank (Strata 67, 68). This was done to save time for additional sampling of deeper strata in potential ocean quahog habitat.

In 1999, a new policy was adopted regarding randomly chosen stations with rocky bottom that could not be sampled with the clam dredge without a high risk of severe gear damage. If the bottom was too rocky, pilots were told to search for towable bottom within 0.5 nmi of the station. If the search was unsuccessful, the log sheet for that station was filled out with a special code (SHG = 151), and the vessel moved on to the next random station. In previous surveys, pilots were likely to search for good bottom and then take a tow, even if it was a considerable distance from the original station location. This procedural change in 1999 is important in providing a better estimate of the area of clam habitat on Georges Bank (NEFSC 1998a,c). In the current assessment, individual stratum areas on Georges Bank were reduced in proportion to the fraction of tows from that stratum that had been assigned code 151 (Table E14). The effect of this was to reduce the biomass estimates for certain strata.

Length frequency distributions and survey catches for Georges Bank and S. New England are primarily based on 1999 data, although some 1997 data were used to fill in strata not sampled in 1999. The 1997 data were adjusted for the change in dredge efficiency from 1997 to 1999.

Abundance Indices

An attempt was made to develop a consistent survey time series, dating back to 1978, of standardized surfclam catch per tow for use as a measure of trends in surfclam abundance (Table E15). Catches are not adjusted for dredge efficiency, but were standardized to a tow distance of 0.15 nmi using the best available information. Both numbers and weight per standardized tow were partitioned by size class and region, and meat weight was computed with area-specific length-weight relationships. Data collected before 1980 should be considered as provisional due to changes that were made in the survey methods between 1977 and 1980 (Table E6). Sensors were used for the first time in 1997, and used in 1997 and 1999 for standardizing catch rates because they give a more accurate estimate of tow distance than doppler-based estimates. Both doppler and sensor-based estimates for 1997 and 1999 are presented (Table E15). Number and weight per standardized tow are lower using sensor-based distances, because the doppler method does not include any fishing that may occur when the dredge is set out and hauled back.

Compared to other regions, catch per tow in 1999 was high in NNJ and DMV (Table E15). The time series of numbers and weight per tow (standardized for distance) show that stock size in the NNJ region was minimal in 1978 following a well-documented hypoxic event that caused large-scale surfclam mortality. Numbers and weight increased through the 1980s, and have remained fairly high through the 1990s. The 1994 values are high relative to the rest of the series, and this is thought to have resulted from an increase in dredge efficiency in that year (NEFSC 1998a).

The DMV region also had low numbers of large clams (> 100 mm) in the late 1970s (Table E15). The high biomass in 1978 (Cruise 7807) consisted of many small, 40-70 mm, individuals captured in Stratum 85 and to a lesser degree in Stratum 9. Throughout the mid-1980s and 1990s, catch of large clams per tow has remained above that measured in the late-1970s.

Spatial Distribution of Survey Catches

Clam abundance per tow data from the 1999 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 E30-E35. On the scale of the entire coastline, surfclams were found in large patches on Georges Bank, and off S. New England, New Jersey and Delmarva. Each of these surfclam patches was separated by strata with low surfclam abundance. The abundance of medium sized clams appears greater in the Delmarva and Georges Bank regions than off New Jersey (Figures E31 and E34). The largest concentration of small animals was on Georges Bank and off southern Delmarva.

Size Frequency Distributions

Size frequency distributions from the 1999 survey are plotted in Figure E36 for all regions. Although they are not in high abundance, relatively large clams were found in Southern New England and Long Island. On average, clams increase in size from DMV to SNJ to NNJ. Mean abundance in SNJ was high compared to other regions. SNJ had the highest variance in catch of all regions sampled in 1999.

Size frequencies by stratum are given in Figures E37-E39 for the NJ and DMV regions. For the DMV region, clams in Stratum 9 are more abundant and smaller those to the north in Stratum 13. For the NJ region of the EEZ, clams are more abundant inshore (Strata 87, 88, 89) than offshore (Strata 17, 21, 25).

Temporal trends in percent size composition are shown from 1992-1999 by region (Figures E40-E43). Size composition on GBK is variable over time and this may reflect problems with obtaining a random sample from that rocky area. Size appears to have increased over time in the NNJ region (Figure E41), while it decreased over time in DMV (Figure E43).

DISTRIBUTION OF THE FISHERY RELATIVE TO SURFCLAM RESOURCE

Although surfclams are distributed from N. Carolina to Georges Bank, the surfclam fishery in federal waters has focused on the New Jersey region since 1985 (Figure E2). Within the New Jersey region there have been progressive shifts of the fishery northward and offshore from 1985 to 1997 (NEFSC 1998a). By 1997, the fishery and distribution of surfclams overlapped completely (NEFSC 1998a). In 1999 the fishery was also carried out over most of the range of surfclams in the New Jersey region (Figure E44).

The fishery started taking more landings from the single, inshore ten-minute-square at the mouth of Delaware Bay during 1997-1999. The fishery is not active off the Delmarva peninsula, where surfclams are abundant. Georges Bank is closed to harvesting, but does have a high concentration of surfclams in certain places.

STOCK SIZE MODELS AND BIOLOGICAL REFERENCE POINTS (BRPs)

This section contains results from models that estimate stock biomass, natural mortality, fishing mortality and exploitation rates, and biological reference points. As a first step, it is important to identify plausible values for the instantaneous rate of natural mortality (M, defined in terms of numbers of surfclams per year), a key parameter in most stock assessment calculations. According to the Stock Assessment Review Committee responsible for the last surfclam assessment (NEFSC 1998, p. 72, *italics added*):

"The current *[1997]* 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 aging information which has documented few animals older than age 30, even in areas not subject to massive dieoffs 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."

Revised estimates (see summary table below and details following) were based on recent age and growth studies (Weinberg and Helser 1996) and a variety of methods. Considering problems with certain estimates (see detailed descriptions below), results suggest a plausible range of M=0.10-0.20 y^{-1} in surfclam. Based on these results, M=0.15 y^{-1} was used in most analyses and values in the range 0.05-0.20 y^{-1} were used for sensitivity analyses.

Source	Range
Weinberg (1999)	0.16-0.22 y^{-1}
Hoenig (1983)	0.10-0.17 y^{-1}
Jensen (1996)	0.18-0.33 y^{-1}
5% rule	0.08-0.10 y^{-1}
Literature survey	0.09-0.20 y^{-1}
All	0.08-0.22 y^{-1}

Weinberg (1999) used age length keys, survey length composition, survey catch rates and catch curves to estimate Z (where Z is total mortality, F+M) for surfclam in the NNJ (survey stratum 88) and DMV (survey stratum 9) assessment areas. Estimates were for the 1976-1979 yearclasses in the 1980 to 1997 surveys starting at age 4 (length > 75 mm). Weinberg's (1999) data were collected following a hypoxic event off New Jersey and low surfclam biomass in both areas during 1976, followed by strong recruitment during 1976 (NNJ) and 1977 (DMV). Fishing mortality rates were likely less than 0.05 y^{-1} in both areas and certainly less than 0.1 y^{-1}. Results (see below) suggest that M for surfclams is in the range 0.16-0.22 y^{-1}.

Yearclass	**Z for NNJ Stratum 88 (y^{-1})**	**Z for DMV Stratum 9 (y^{-1})**
1976	0.26	0.33
1977	0.26	0.28
1978	0.3	0.22
1979	--	0.22
1980	--	0.26
Mean	0.27	0.26
Mean Z - F (F=0.05 y^{-1})	0.22	0.21
Mean Z-F (F=0.1 y^{-1})	0.17	0.16

Hoenig (1983) gives linear regressions for predicting Z based on maximum observed age [$\ln(Z)=\alpha+\beta\ln(A)$, where A is maximum observed age] in mollusks (β=-0.832, α= 1.23) and all types of marine organisms (β=-0.982, α= 1.44). If age data were collected from an unfished or lightly fished stock, then Hoenig's method estimates M. If age data were collected from a fully exploited stock, then it estimates an upper bound for M. Predictions are imprecise but Hoenig's method is widely used in stock assessment work to identify plausible values for M. Estimates are affected by the number of animals aged (Hoenig 1983). The oldest surfclam aged by NMFS (all surveys and all areas, including areas not affected by the 1976 and areas with no fishing) was 36 years old but maximum ages of 40 years are plausible.

Maximum Age	**Z (y^{-1}) for Mollusks**	**Z (y^{-1}) for All Organisms**
36	0.17	0.13
37	0.17	0.12
38	0.17	0.12
39	0.16	0.12
40	0.16	0.11
41	0.16	0.11
42	0.15	0.11
43	0.15	0.11
44	0.15	0.10
45	0.14	0.10

Jensen's (1996) simple theoretical result suggests that M=1.5 K , where K is a parameter in the Von Bertalanffy model for weight at age. Results (see below) based on estimates for K in each stock area suggest M for surfclams is in the range 0.18-0.33 y^{-1} (average 0.26 y^{-1}).

Assessment Area/Years	K (y^{-1})	M (y^{-1})
Average	0.176	0.26
NNJ 1989&1992	0.145	0.22
DMV 1980	0.175	0.26
DMV 1989&1992	0.117	0.18
LI (all years)	0.189	0.28
SNE (all years)	0.220	0.33
GBK (all years)	0.168	0.25
		0.26

As described above, the value M=0.05 y^{-1} used in previous assessments was chosen to give a predicted 5% of animals in a theoretical population at age 60 (a measure of typical lifespan). Assuming typical lifespans of 30, 35 and 40 years, the predicted "5% rule" gives M values of 0.10, 0.088 and 0.077. Thus, the 5% rule gives lower predicted M values than other methods.

Studies on marine bivalves with life histories similar to surfclam are summarized in Weinberg (1999, and see below). The estimate (M=0.2 y^{-1}) for an unexploited population of *S. solidissima* (Atlantic surfclam) in New Brunswick (Caddy and Billard 1976) is particularly relevant. A leukemia-like disease may explain some of the low S values reported for *Mya arenaria*. The average of estimates from literature sources is M=0.17

Species	$S=e^{-M}$ (Midrange)	M (y^{-1})	Source
Spisula solidissima (New Brunswick, unexploited population)	0.82	0.20	Caddy and Billard (1976)
Panope abrupta	0.95	0.05	Sloan and Robinson (1984)
Mya arenaria	0.73	0.32	Brousseau and Baglivo (1988); Weinberg et al. (1997)
Mercenaria mercenaria	0.91	0.09	Malinowski and Whitlatch (1988)
Yoldia notabilis	0.84	0.18	Nakaoka (1993)
Average	0.85	0.17	

10-Year Supply Model

The 10-year harvest policy is a hold-over from an era when surfclams were thought to recruit infrequently in large numbers. The policy and calculations evolved over time to reflect updated biological information. However, the 10-year supply policy has not been linked to MSY-based policies that are required under the Sustainable Fisheries Act. It is no longer applicable. Also, there is no need to perform 10-year supply calculations in the next assessment. They are carried out here for comparative purposes only.

The Mid-Atlantic Fishery Management Council has used the 10-yr harvest policy as a guide to quota setting. This policy, as applied in recent years, has been erroneously called a "mining" policy in which the resource is fished to extinction over some finite planning horizon. In reality the policy is an adaptive strategy that computes a harvest rate based on current estimates of population biomass and an assumed level of recruitment to the population. Harvest levels are recomputed each year using the predicted population size as the measure of abundance. Periodic surveys of the resource are used to update abundance levels, thereby allowing revision of harvest levels in response to actual resource conditions.

Variables in the 10-year harvest policy are:

B_t = Biomass of population at time t (biomass)
C_t = Total Landings at time t (biomass)
G = average instantaneous rate of growth of individual surfclams in the population
M = average instantaneous rate of natural mortality (abundance units)
R_t = Recruitment biomass to exploitable stock at time t. (biomass)

The basic equation for stock biomass is

$$B_{t+1} = (B_t - C_t + R_t)\, e^{(G-M)} \qquad \textbf{(1)}$$

Equation 1 assumes that catch and recruitment occur at the beginning of the year and that the escapement from fishing changes in response to growth (G) and natural mortality (M) over the remainder of the year.

Under the 10-year policy, annual harvest should be set no higher than that which would allow a 10 year supply of constant catches, given estimates of current standing stock, growth, recruitment and natural mortality. The boundary conditions are:

$$\begin{aligned} B(t) &= B_o \\ B(t+10) &= 0 \end{aligned} \qquad \textbf{(2)}$$

where *B* is biomass and *10* is the duration of the planning horizon. The catch level is given by

$$(t) = \frac{B_t}{\sum_{i=0}^{T-1} e^{(M-G)\, i}} + R_t \qquad t=1, \ldots, \qquad \textbf{(3)}$$

This policy implies simultaneous downward trends in biomass and catch and a gradual increase in exploitation rate.

The spreadsheet program developed to solve Equation 3 over time requires assumptions about level of starting biomass (which is a function of dredge efficiency), M, G, and R. Starting biomass (120+ mm) for each region is based on the 1999 clam survey (Table E22). Growth rates (G) of the biomass were based on calculations from NEFSC (1996a). In the current program, R is fixed at approximately 12% of the starting biomass. Twelve percent is the average percentage by weight from the last 5 clam surveys of the recruits in the population. As the model runs, population biomass increases every year by R, regardless of B_t. This leads to recruitment even when B_t=0, which is unrealistic (NEFSC 1996).

Results

Two runs are shown, one for the entire resource (Tables E16 and E17, Figure E45) and one for the entire resource minus Georges Bank, which has been closed to clamming since 1990 (Table E18, Figure E46). Both runs assume M=0.05. The first run includes biomass from all regions, so starting biomass (B_{1999}) is equal to 1,403,000 mt. The quota for year 2000 has already been set, and is used in the program as the harvest for year 2000 (19,779 mt). The calculated harvest for 2001, under the 10-yr policy, is 365,526 mt, which is almost twenty times greater than the current quota and 26% of current biomass. Figure E45 tracks stock biomass, harvest and exploitation rate through time under these .

The second run (Table E18), which excludes Georges Bank, starts with a slightly lower exploitable biomass of 1,146,000 mt. The solution to equation 3 in year 2001 is 281,266 mt, which is also much greater than recent quotas and 25% of current biomass.

Results change when a higher M is used, but the catch for the year 2000 is still much greater than the present quota. For example, for M=0.15, the catch in year 2001 would be 274,492 mt (19% of current biomass) and 208,737 mt (18% of current biomass), for Runs 1 and 2, respectively.

The 10-yr supply model has been criticized on scientific and technical grounds. First, the choice of the planning horizon is arbitrary, rather than being determined by standard overfishing criteria (i.e., B_{MSY}, F_{MSY}, $F_{0.1}$, F_{MAX}, $F_{\%MSP}$, etc). Second, in its current form, recruitment is not modeled in a realistic manner.

<u>Surfclam Production Model</u>

If surfclams are at target biomass levels (i.e., B_{MSY}) now, then a policy that equates catch and net production might be appropriate. This type of policy would maintain the current biomass by harvesting only the current surplus production.

Net production can be found by setting $B_{t+1} = B_t$ in Eq. 1 and solving for C_t in :

$$C(t) = B(t)\left(1 - e^{(M-G)}\right) + R(t) \quad \textbf{(4)}$$

To calculate the effects of various harvests on production of the stock, we used swept area biomass calculations from the 1999 survey abundance estimates and survey size compositions in a model for short term projection. 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 1999 research survey data. Natural mortality, M, is uncertain and range of values were explored to determine model sensitivity. 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 of the products of the observed numbers at length and the predicted average weight at length.

The model is rewritten

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

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

$$L'_{t+1} = L_t + \Delta L_{t-(t+1)}$$

where

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

Parameters in the length/weight equations were revised for N. New Jersey, Delmarva, and Georges Bank using data collected in 1997. These newer equations were calculated by averaging predicted weights at length based on new parameter estimates and estimates from Serchuk and Murawski (1980), and then reestimating the parameters. Compared to the older equations, the revised equations indicate greater meat weight at a given shell length. The revised parameters for NNJ were applied to SNJ.

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 surfclams on the bottom as well as the increased number of predators shortly after a dredge passes an area, IC was set at 20% of C in the surfclam assessment. This number is an uncertain approximation.

Four factors in this model are uncertain and could affect the results. They include natural mortality rate (M), dredge efficiency (E), selectivity of the survey gear to clams < 90 mm (Selectivity), and indirect mortality from clamming (IC). Partial selectivity by the survey dredge for individuals <90 mm would underestimate abundance in productive smaller size classes in the population, and result in an underestimate of production for the population as a whole.

Sensitivity analyses were carried out to determine the importance of uncertainty regarding M, E, and selectivity.

Results

Tables E19-E21 show results from 3 runs of the biomass production model. The first two runs differ in M (0.05 vs 0.15), but have the same selectivity, S, (1.0), indirect mortality, IC, (20%) and efficiency, E, (0.276). Run 1: Assuming M= 0.05, net production is positive in every region and the sum over all regions is 80,000 mt per year (Table E19). This result is sensitive to the assumed value of M. Run 2: In Table E20 M is assumed to equal 0.15. Under that scenario, net production is negative in 6 of the 7 regions and the sum of net production over all regions is -77,000 mt per year (Table E20). Run 3: Table E21 shows the impact partial selectivity could have on the results. In this case, M = 0.15 and selectivity of clams < 90 mm is assumed to be 0.01 (i.e., only 1 in 100 clams below 90 mm is retained). Under these assumptions, net production is positive in all 7 regions and the sum over all regions would be 1,230,000 mt per year (Table E21).

Figures E47-E52 show sensitivity analyses of net production with respect to levels of M, S, and E. Figures E47-E49 are for the entire stock, and Figures E50-E52 are for the N. New Jersey region only. There is high sensitivity in almost every case, which suggests that the model can not provide precise information about net production until more precise estimates of the input parameters are available. For example (Figure E47), if the selectivity of the dredge to small clams is < 0.10, then the stock is likely to have positive net production, regardless of M. Alternatively, net productivity is likely to be negative if selectivity is >0.10 and M >0.15. Figure E48 shows that when E is low, as this assessment suggests, the stock could have either high or low net productivity depending on whether M is <0.10 or >0.15 .

Yield and Spawning Biomass per Recruit

Thompson and Bell's (1934) method was used to estimate yield- and spawning biomass per recruit for surfclam in the NJ (NNJ plus SNJ), GBK and DMV stock assessment areas. Surfclam in the NJ, GBK and DMV areas represent extremes of growth and life history. According to 1997 and 1999 swept area biomass estimates, the NJ, GBK and DMV assessment areas contain 87-91% of the total fishable (100+ mm) stock biomass (Tables E22 and E32). Data and results for each area are summarized in Tables E23-E29. Yield-per-recruit curves for surfclam were generally flat topped with a poorly or undefined maximum (e.g. Figure E53).

Biological reference points sometimes used as proxies for F_{MSY} (Clark 1991; 1993), including F_{MAX}, $F_{0.1}$, and $F_{20\%}$ to $F_{60\%}$ were calculated for each stock assessment area. Biological reference points for the entire stock can be approximated by averaging estimates for NJ, GBK and DMV (assuming recruitment at 100 mm) with recent swept area biomass (averages for 1997 and 1999, Table E32) as weights. Surfclam stocks are likely near carrying capacity (K) in many areas. According to theory, $B_{MSY}=K/2$ so weighting by current swept area biomass may approximate weighting by B_{MSY}.

Biological reference points should be estimated based on similar assumptions used in estimating fishing mortality rates. Fishing mortality rate estimates from the catch-swept area biomass and KLAMZ models (see Section 6.4) assume that surfclam 100+ mm (catch-swept area estimates for all stock areas) or 120+ mm (catch-swept area and KLAMZ model estimates for NNJ and SNJ) are fully vulnerable to fishing. Following NEFSC (1998), we assumed that fishery selectivity in yield per recruit calculations was 50% in the age group at which surfclams reach a predicted length of 100 mm (or 120 mm) and 100% for all older ages. For example, according to the von Bertalanffy growth curve for recent years, surfclam in the NJ area reach 100 and 120 mm at ages 4 and 5. Yield per recruit runs for NJ assuming recruitment at 100 mm used 50% recruitment at age 4 and 100% recruitment at age 5. Similarly, yield per recruit runs for surfclam in the NJ area with recruitment at 120 mm used 50% recruitment at age 5 and 100% recruitment at age 6.

Yield and spawning biomass per recruit calculations may be sensitive to assumptions about growth in weight. For calculations, we estimated average meat weight at age from area-specific von Bertalanffy curves for length at age (Weinberg and Helser 1996) and area-specific, length-weight relationships (Tables E30 and E31). There was no need to force growth curves through the origin at age zero (as in NEFSC 1998) because predicted lengths were all non-zero at age 1 when yield per recruit calculations began.

Growth is density dependent in surfclam in the NNJ and DMV stock assessment areas (Weinberg and Helser 1996, Weinberg 1998). We therefore used von Bertalanffy growth curves based on data collected in 1989 and 1992 (rather than 1980) because they were probably more typical of current conditions.

Early maturity (at ages 1 or 2) is important in spawning biomass per recruit calculations for surfclam. Following NEFSC (1998), and based on a field study by Ropes (1979) and a laboratory study by Chintala and Grassle (1995), we assumed that sexual maturity was 90% in one year old surfclams and 100% in surfclams age 2+. Spawning was assumed to occur at the middle of the year and the fishery was assumed to operate continuously through the year (these assumptions had little affect on biological reference point estimates).

Yield and spawning biomass estimates were carried out at M=0.1, 0.15 and 0.2 y^{-1}. NEFSC (1998) used M=0.05 y^{-1}, a value no longer thought plausible (Section 6.0). The number of age groups in yield and spawning biomass per recruit calculations was 30 to agree with Gabriel et al.'s (1989) "3/M" rule and treated as a "plus" group.

<u>KLAMZ Assessment Model for Surfclam</u>
A new surfclam assessment model (KLAMZ) addresses a research recommendation from SARC-26 (NEFSC 1998, p. 73):

"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."

In addition, it incorporates survey dredge efficiency estimates from field studies during 1997 and 1999, new estimates of age and growth (Weinberg and Helser 1996) and all other available information with the exception of age composition data for survey catches and length composition data for survey and fishery catches. Length and age composition data were not fully utilized because KLAMZ combines many length and ages into two groups.

KLAMZ was implemented as both an Microsoft Excel worksheet and as a C++ AD-Model Builder (ADMB, Otter Software Ltd.) application. Both versions gave the same results. The Excel version makes calculations easy for the user to understand, is easier to modify, and makes graphs automatically. However, it uses the relatively inefficient and slow Excel Solver function to estimate parameters. The ADMB version is less transparent, but more efficient and speedy. Both versions can calculate bootstrap variances (Efron 1982) for any quantity calculated in the model (e.g. recent F / F_{MSY}). The AD-Model Builder version also includes delta method calculations (Seber 1982) that are fast but, based on comparison to bootstrap results for surfclam (not shown), underestimate variances (see also Jacobson et al. 1994). Both versions perform deterministic forecasts based on prespecified catch (or fishing mortality) and recruitment levels.

Comparison of KLAMZ and the Modified DeLury Models
Experience suggests that more sophisticated models will not reduce the need for information about absolute abundance in surfclam assessments. As shown below, results from the KLAMZ model in this assessment were more plausible than results for surfclam reported by NEFSC (1996) from

the DeLury model. Differences in results were due mostly to improved data and, in particular, efficiency corrected swept area biomass estimates for surfclam based on depletion experiments. When efficiency corrected swept area biomass estimates for NNJ were omitted, KLAMZ converged to implausible estimates (see below).

The main difference between KLAMZ and the modified DeLury model is that population dynamic calculations in KLAMZ use Schnute's (1985) delay difference equation, biomass units and assume Von Bertalanffy growth (rather than a simpler difference equation in units of numbers). Under assumptions of knife-edge selectivity and recruitment (see below), the delay difference model gives the same results as an age structured, Leslie matrix model with stock biomass calculated with weights at age from a Von Bertalanffy growth equation. A delay difference equation was useful for surfclam because population dynamics were probably influenced by changes in age structure. In particular, the New Jersey (NNJ and SNJ) stock areas were composed of young individuals (Weinberg 1999) who grew rapidly (Weinberg and Helser 1996) after dieoffs during the 1970's but were composed of older individuals who grew relatively slowly in recent years.

Unlike the modified DeLury model, KLAMZ did not estimate process error parameters for inter-annual variation in natural mortality. Instead, KLAMZ captured process error in recruitment parameters that changed from year to year (process errors and recruitments were aliased, Jacobson et al. 1994). Models without explicit process errors are usually more robust (Collie and Kruse 1998) and easier to estimate. However, state-space models for surfclam that partition variance into process and measurement components (Schnute and Richards 1995) are an important area of current research.

Like many other stock assessment models, KLAMZ used a closed form maximum likelihood estimator (see below) to calculate survey scaling parameters (Q, see below). This approach gives the same result as estimates by nonlinear maximization of the likelihood function. Closed form estimates were useful for surfclam, however, because the number of parameters estimated by nonlinear optimization was reduced. In addition, the trick makes the KLAMZ model more flexible because it helps separates information in the survey data related to scale (average absolute biomass) and information related to trends. In particular, it is possible to tune the KLAMZ model to survey *scale* only, *trend* only or *scale and trend.*

Tuning to scale means that the KLAMZ model is estimated so that survey data (assuming lognormal measurement errors) and available biomass (defined below) estimated in the model agree to a prespecified ratio (i.e. Q=1 or other value), *even if survey trend is ignored.* Tuning to trend only is the most common traditional approach in stock assessment work (e.g. Gavaris 1988). Tuning to scale and trends is another traditional approach for surveys that measure trends in absolute biomass (e.g. hydroacoustic or egg production estimates of spawning biomass, Jacobson et al. 1994; Deriso et al. 1996).

For surfclam, separation of scale and trend information in surveys in KLAMZ makes it easy to incorporate quantitative, statistical information about Q from depletion studies in the form of likelihood constraints and maximum likelihood estimation (see below).

Tuning to scale also means that directional constraints (another form of information) on Q values (or implied survey gear efficiency, which is related to Q as described below) are easy to impose by likelihood constraint, even if trends are ignored. For example, the analyst can penalize fits with Q values larger or smaller than a prespecified value or penalize fits that imply a survey efficiency greater than one. Likelihood constraints on Q (implied survey efficiency, or any other parameter in KLAMZ) facilitate use of all available information and make the maximum likelihood function in KLAMZ similar to the posterior distribution in a Bayesian analysis or state-space model (Schnute and Richards 1995).

Other differences are that KLAMZ calculates fishing mortality rates by "exact" solutions to the catch equation (rather than using Pope's 1972 approximation), accommodates twenty (Excel version) or more (ADMB version) indices of abundance (rather than one or two), and carries out surplus production calculations based on model results (see below).

Fishery data in KLAMZ
Catch data in KLAMZ included landings (Table E2) and estimated discards (Table D2 in NEFSC 1995). The sum of landings and discard was inflated by 20% to account for assumed non-catch mortality during fishing (NEFSC 1998). Catches were assumed measured without error.

Standardized LPUE data for 1980-1984 and 1991-1999 were available for commercial fishing in the DMV, LI, NNJ, SNJ and SVA assessment areas (Table E4). CV's for LPUE data were calculated from standard errors for log scale year effects estimated in log-linear statistical models used to standardize commercial catch rate data. CV's for standardized LPUE data were typically less than 10% and much smaller than CV's for dredge survey data. CV's for LPUE data likely overstate their precision as indices of abundance for surfclam and were therefore multiplied by ten prior to use in KLAMZ. Rescaling gave CV's for LPUE data that were in the same range as CV's for survey data.

LPUE data suggest that surfclam biomass increased in all areas after 1984 (Figure E12). Trends in LPUE were usually steeper than trends in survey data for surfclam. It is likely that increases in LPUE after 1984 were due to increased efficiency following implementation of ITQ management, improved harvesting technology, electronics or other factors not related to changes in surfclam abundance.

Survey data in KLAMZ
In contrast to swept area biomass data, survey data were assumed to measure trends only. Survey data used in KLAMZ were pre-recruits, new recuits and old recruits. Pre-recruits were surfclams in the annual growth interval immediately below the size of recruitment. For example, if recruitment occurred at 100 mm and a predicted age of 3.4 years, then pre-recuits would be surfclams in the range from a minimum bound at the predicted length at 2.4 years to a maximum length of 99 mm. Pre-recruits in year t were lagged one year and used as an index of new recruits to the fishable stock in year t+1. Indices of pre-recruits and new recruits were both used to measure trends in recruitment because the approach made maximum use of the survey data.

Ideally, survey data would have been tabulated in units of meat weight per standard tow for size groups corresponding exactly to the pre-, new and old recruit group definitions. This was not possible for surfclam in this assessment due to time constraints and database problems. Instead, existing summaries with survey data tabulated by 10 mm length groups were used.

For NNJ and SNJ, pre-recruit survey data were mean numbers per tow for surfclams 100-119 mm, new recruit survey data were mean numbers per tow for surfclams 120-129 mm, and survey data for "all" (new and old) recruits were mean weight (kg) per tow for all clams taken in the survey (Table E15). For other stock areas, pre-recruit data were mean numbers per tow for surfclams 80-100 mm, new recruit survey data were mean numbers per tow for surfclams 100-110 mm, and survey data for all recruits were mean weight (kg) per tow for all clams taken in the survey (Table E15). Survey data weights per tow were almost entirely (>90%) from surfclams larger than 120 (NNJ and SNJ) or 100 mm (other stock assessment areas). CV's for all three size groups were assumed equal to the CV's for the all recruits group. As described elsewhere, CV's for survey data were likely underestimates.

Changes (Tables E6-E7) in survey design, season, survey equipment and dredge efficiency are important issues in interpreting NMFS clam survey data. In particular, survey dredge efficiency was anomalously high in 1994 (NEFSC 1996; NEFSC 1998), probably due to changes in voltage used to run the water pump on the dredge (see above).

In the KLAMZ model, we ignored a number of changes to survey equipment which were made in 1997 when dredge survey efficiency was measured for the first time (Table E7). Survey trend data for 1997 and 1999 (Table E15) were standardized based on sensor, rather than doppler, tow distance data because sensors were less affected by changes in winch speed and other survey equipment.

Adjustments have been made to survey data to correct for changes in dredge width and mesh size but survey data collected prior to the first summer/fall survey in 1980 were not perfectly comparable to surveys carried out afterwards. However, the early data may contain important information because there was an anoxic event in the NNJ and SNJ areas during 1976 with nearly complete surfclam mortality in affected regions (Weinberg 1999). Surfclam biomass was also low in the DMV stock assessment area during 1976, possibly due to heavy fishing (Weinberg 1999). Following the anoxic event, there was strong recruitment during 1976 in the NNJ and SNJ and during 1997 in the DMV stock assessment area (Weinberg 1999). The response of surfclam at low populations sizes in the late 1970's may be important. In KLAMZ model runs, we therefore used average survey data for cruises 7801 and 7807 during 1978, omitted survey data from cruise 7901 during 1979, and used average survey data from cruises 8001 and 8006 in KLAMZ model runs. Sensitivity analyses with and without data for 1978 and 1980 were carried out to evaluate sensitivity of results.

Survey coverage was incomplete and many strata were not sampled in some stock assessment areas some (particularly early) years. Initial KLAMZ model runs used survey data for years with complete or nearly complete sampling of all strata (see following page).

Area	Years With Complete or Nearly Complete Survey Coverage
SVA	1984, 1986, 1989, 1992, 1994*, 1997
DMV, SNJ, NNJ	1978, 1980, 1981, 1982, 1983, 1984, 1986, 1989, 1992, 1994*, 1997, 1999
LI	1978, 1980, 1981, 1982, 1983, 1984, 1986, 1989, 1992, 1997, 1999
SNE	1982, 1983, 1984, 1986, 1989, 1992, 1997, 1999
GBK	1986, 1989, 1992, 1997, 1999

*1994 used in preliminary runs but omitted as an outlier after sensitivity analysis

Swept-area biomass data

Efficiency corrected swept area biomass estimates (Table E22) during 1997 (all areas) and 1999 (all but SVA) were used as a time series in the model for clams either 120+ mm (NNJ and SNJ) or 100+ mm (other stock assessment areas). CV's were the same as for the entire swept area biomass (all size groups) with adjustments for uncertainty in stock assessment area, average area swept, portion suitable habitat on Georges Bank, and other factors (Table E32). KLAMZ was tuned to trends and scale in swept area estimates with a likelihood constraint (see below) towards Q=1. In future, swept area estimates should be tuned to scale only if information about trends also exists in the series of relative survey abundance.

Population Dynamics

Schnute's (1985) delay-difference equation in the KLAMZ model for surfclam in an assessment area is:

$$B_{t+1} = (1+\rho) L_t B_t - \rho L_t L_{t-1} B_{t-1} + R_{t+1} - \rho\ L_t J_t R_t$$

where B_t is total or "fishable" (see below) biomass at the beginning of year t; ρ is Ford's growth coefficient (see below); $L_t=\exp(-Z_t)=\exp[-(F_t+M_t)]$ is the fraction of the stock that survived in year t; Z_t, F_t, and M_t are instantaneous rates for total, fishing and natural mortality; and R_t is the biomass of recruits at the beginning of year t. Years were time steps in the KLAMZ model. The growth parameter $J_t = w_{t-1,k-1} / w_{t,k}$ (where w_a is weight at age a) is the ratio of mean weight one year before recruitment (age k-1 in year t-1) and mean weight at recruitment (age k in year t). In KLAMZ, it is not necessary to specify body weights at recruitment and one year prior to recruitment (parameters v_{t-1} and V_t in Schnute 1985) because the ratio J_t and recruitment biomass contain the same information.

Length composition data for the commercial fishery (Figures E13 and E14) suggest that surfclam recruit at about 120 mm in the NNJ area and at about 100 mm in the DMV area. We assumed that conditions in the SNJ area were similar to the NNJ and that conditions in all other assessment areas were similar to DMV. KLAMZ was therefore configured to measure biomass of surfclam 120 mm and larger in the NNJ and SNJ areas and 100 mm and larger in all other stock assessment areas.

In the KLAMZ model, new recruits are R_t, the abundance of surfclams that have just entered the fishery (at either 100 or 120 mm, depending on stock assessment area) and old recruits are escapement (B_t-R_t) from the previous year. This convention is different from one often used with the modified DeLury model which refers to the first size group as "partial" recruits and the second size group as "full" recruits because partial recruits are assumed incompletely recruited to the fishery.

As suggested above, the delay-difference model gives the same results as more complicated age structured models (i.e. Leslie matrix model) if recruitment to the fishery in the age structured model is complete and "knife-edged" at age k, natural mortality is the same for all age groups, and Ford's (or the Von Bertalanffy) growth model holds. Knife-edged recruitment means that surfclam recruit to the fishery *en-masse* on their k^{th} birthday so that biomass available to the fishery and stock biomass (B_t) are the same and include all individuals age k and older.

The assumption of knife-edge recruitment at age k in KLAMZ can be relaxed by assuming KLAMZ measures fishable biomass (Butler et al. 1998, 1999). Fishable biomass is the portion of total stock biomass fully vulnerable to fishing mortality. The alternative assumption has implications that are potentially useful for surfclam. In particular, recruitment to the fishable stock can include surfclam of many ages so the biological age of recruits and selectivity at age is less important.

Ford's growth model:

$$w_a = w_{k-1} + (w_k - w_{k-1})(1+\rho^{1+a-k})/(1-\rho)$$

is mathematically the same as von Bertalanffy's more familiar growth model $\{W_a = W_{max}[1 - \exp(-K(a-t_{zero})]$ where W_{max}, K and t_{zero} are parameters$\}$. The two growth models are the same (Schnute 1985) because $W_{max} = (w_k - r\, w_{k-1})/(1-r)$, $K = -\ln(\rho)$ and $t_{zero} = \ln[(w_k - w_{k-1})/(w_k - \rho w_{k-1})] / \ln(\rho)$.

Weinberg and Helser (1996) discuss changes over time in growth of surfclam in several stock assessment areas, probably due to density dependence. KLAMZ was therefore configured to use growth parameter J_t values that can vary over time (see below). In Schnute's (1985) original formulation, components of J_t (weights at recruitment V_t and one year prior to recruitment v_{t-1}) could vary over time. When J_t changes over time (but ρ is constant), the model implicitly assumes that maximum size is changing or that surfclam are recruiting to the fishery at smaller or larger sizes relative to their maximum size.

Fishing mortality rates (F_t) for surfclam were calculated from catch data (landings plus estimated discards) and biomass by solving Baranov's catch equation numerically using Sim's (1982) algorithm. For the Excel version, Sim's algorithm was either written in C++ and compiled as a Windows DLL file or written as a Visual Basic Subroutine. Both the C++ and Visual Basic versions could be called directly from Excel (like any other Excel function). In the AD-Model Builder version, the algorithm was implemented with a fixed number (10) of Newton iterations.

There were many years with missing survey data and insufficient data to estimate surfclam recruitments in each year as a set of unconstrained annual recruitment parameters. We therefore constrained recruitment estimates in KLAMZ based on qualitative information about recruitment in the actual surfclam stock. Results in Weinberg (1996) suggest relatively smooth trends in surfclam recruitment with periods of higher and lower than average recruitments in some areas and flatter trends in other stock areas. The new recruit size group in surfclams (at about 100-115 mm or 120-130 mm, depending on assessment area) is likely made up of several age groups (Weinberg 1999). Like a weighted average, trends in new recruits as defined in the KLAMZ model are probably smoother than year to year variation in year class strength. Surfclam recruitment in KLAMZ was therefore modeled as a relatively smooth, autocorrelated random walk process:

$$R_t = e^{\Omega_t}$$

where Ω_t was an annual log-scale recruitment parameter. The random walk was constrained by penalizing changes in recruitment from one year to the next (see below).

In the ADMB version, recruitment parameters Ω_t were estimated as the product of a geometric mean parameter (μ) and annual log scale deviation parameters (ω_i) that summed (and averaged) to zero (a special type of parameter vector in AD-Model Builder):

$$\Omega_t = \mu + \omega_t$$

In the Excel version, log scale recruitment parameters (Ω_t) were estimated as annual recruitment parameters (Ω_t).

Surplus production

KLAMZ includes surplus production calculations. Annual surplus production (P_t) in an unfished surfclam stock could be computed:

$$P_t = B_{t+1} - B_t$$

In a fished stock, catch must be included in the calculation:

$$P_t = B_{t+1} - B_t + \delta C_t$$

where δ is a correction factor (MacCall 1978) that adjusts the catch in year t to "resulting" biomass at the beginning of year t+1. Resulting biomass (δ C_t) estimates the increment to stock biomass B_{t+1} that would have occurred if the catch C_t had not been taken. If the rate of individual growth in weight exceeds the mortality rate, then $\delta > 1$ and the resulting biomass would be greater than catch. If growth is slower than mortality, then $\delta < 1$ and resulting biomass would be less than catch. In short-lived and fast-growing species or stocks far from carrying capacity, the correction factor can be important.

MacCall (1978) gives an exact solution for δ and shows that it depends strongly on the difference between natural mortality and growth (M-G, where G is the instantaneous growth rate, Ricker 1975) but weakly on F (see below).

Fishing Mortality (F) ->

M-G	**δ at F=10^{-6}**	**δ at F=0.01**	**δ at F=0.05**	**δ at F=10.00**
-0.10	1.05	1.05	1.05	1.09
-0.08	1.04	1.04	1.04	1.07
-0.06	1.03	1.03	1.03	1.06
-0.04	1.02	1.02	1.02	1.04
-0.02	1.01	1.01	1.01	1.02
0.00	1.00	1.00	1.00	1.00
0.02	0.99	0.99	0.99	0.98
0.04	0.98	0.98	0.98	0.96
0.06	0.97	0.97	0.97	0.95
0.08	0.96	0.96	0.96	0.93
0.10	0.95	0.95	0.95	0.91

The functional relationship between δ and (M-G) at low fishing mortality rates typical of surfclam (e.g. F=0.05) can be approximated (R^2=100%) by the linear regression equation:

$$\delta = 1 - 0.5042 \quad (M - G)$$

Shaeffer (1957) and Pella and Tomlinson (1969) curves are often used to describe surplus production. Shaeffer's (1957) quadratic production curve assumes logistic growth:

$$P_t = \alpha B_t + \beta B_t^2$$

with carrying capacity $K=-\alpha/\beta$, $B_{MSY}=K/2$, and $MSY=\alpha K/4$ (Ricker 1975). Pella and Tomlinson's (1969) more complicated, asymmetrical production curve is:

$$P_t = \alpha B_t + \beta B_t^\gamma$$

with:

$$K = \left(-\frac{\alpha}{\beta} \right)^{1/\gamma - 1}$$

and

$$B_{MSY} = \left(-\frac{\alpha}{\gamma \beta} \right)^{1/\gamma - 1}$$

In Pella and Tomlinson's model, $MSY = \alpha B_{MSY} + \beta_{BMSY}^{\gamma}$. Pella and Tomlinson's curve is usually difficult to fit to abundance index and catch data (Hilborn and Walters 1992) but both types of curves can be fit in KLAMZ.

Options for empirical and implicit approaches to surplus production modeling

The "empirical" approach to fitting surplus production curves in KLAMZ makes no assumption about the functional relationship between production and biomass because empirical production estimates are not part of the stock assessment model tuning process. In effect, empirical calculations are carried out after KLAMZ was fit so that annual production was calculated from, but without affecting, biomass estimates.

In contrast, the "implicit" approach to fitting surplus production curves in KLAMZ assumed a relationship between surfclam production and biomass, *a priori*. The implicit approach tunes KLAMZ to abundance indices, other data and an underlying surplus production curve simultaneously. Its analogous to fitting a forward casting stock assessment model with a spawner-recruit curve while estimating the spawner-recruit parameters (e.g. Deriso 1980; Methot 1989). The assumption that a surplus production curve exists is used like data in fitting the model and constraining biomass and parameter estimates.

In the current implementation of KLAMZ, both implicit and empirical parameter estimates for the Shaeffer production model were estimated by linear regression on production and biomass estimates. In contrast, parameters for Pella and Tomlinson's production curve cannot be estimated by linear regression and were estimated along with other parameters as KLAMZ was tuned to abundance and other data. In empirical mode, the log likelihood for Shaeffer's curve was given zero weight so that goodness of fit to the production curve (which was calculated automatically by linear regression) did not affect biomass estimates. Similarly, in empirical mode, the log likelihood for Pella and Tomlinson's production curve was given very little weight (e.g. λ=0.001, see below) so that the parameters were estimated with little effect on biomass estimates. In implicit mode, the log likelihood for one or the other surplus production curve was given a likelihood weight comparable to weights used for survey data (e.g. λ=1.0). Parameters in the Pella and Tomlinson model were estimated by KLAMZ as log scale values [i.e. estimate $\ln(\gamma)$, $\ln(\alpha)$ and $\ln(-\beta)$] to stabilize the numerical optimization process.

Biological Parameters From Auxiliary Data
The natural mortality rate (M) in for surfclams was assumed to be the same for all age groups, size groups and years in KLAMZ. We used 0.15 y^{-1} for basecase runs and a range of values (0.05-0.20 y^{-1}) in sensitivity analysis.

Growth curves that predict weight at age were not available so we calculated predicted length at age based on Von Bertalanffy growth parameters for surfclam in the New Jersey (SNJ & NNJ), DMV, LI, SNE and GBK stock areas from Weinberg and Helser (1996). For lack of better information, growth in the SVA area was assumed the same as in DMV. Predicted lengths were then converted to predicted weights at age based on area-specific length-weight relationships. Finally, parameters for growth in weight were estimated by fitting Von Bertalanffy curves to predicted weights at age (Tables E30 and E31).

According to Weinberg and Helser (1996), growth rates slowed in the NJ (NNJ and SNJ) and DMV stock assessment areas between 1980 and 1989 - 1992, but not in other stock assessment areas. As described above, the delay difference model in KLAMZ accommodates variation over time in the growth parameter J_t but not in the parameter $\rho=e^{-K}$. To accommodate changes in growth in KLAMZ, special five parameter Von Bertalanffy growth curves were fit to predicted weight at age data for surfclam in the NJ and DMV regions (Table E31). Parameters in the modified growth model for surfclams were K (constant over time), $W_{Infinity,Early}$, $W_{Infinity,Late}$, $t_{0,Early}$ and $t_{0,Late}$. The subscript "Early" means 1980 and "Late" means 1989 - 1992. The growth parameter J was w_{k-1}/w_k, where k was the predicted age at which surfclam reached either 120 mm (NNJ and SNJ) or 100 mm (other stock assessment areas) and recruited to the stock in the assessment model.

In KLAMZ runs for the SNJ, NNJ and DMV stock assessment regions, $\rho=e^{-K}$ was constant but J_t was at "early" levels in years up to 1980, at "late" levels in 1989 and afterwards, and interpolated during 1981-1989:

$$J_t = \begin{cases} J_{Early} & if\ t \le 1980 \\ J_{Late} & if\ t \ge 1989 \\ J_{Early} + (J_{Late} - J_{Early})(y-1980)/9 & otherwise \end{cases}$$

Estimates of average instantaneous growth rates (G) were used in surplus production calculations to calculate the correction factor δ for catch (see above). Area-specific instantaneous growth rates were estimated as equilibrium biomass weighted averages:

$$G = \frac{\sum_{a=4}^{30} G_a b_a}{\sum_{a=4}^{30} b_a}$$

where $G_a = \ln(w_{a+1}/w_a)$ was an age specific instantaneous growth rate and weights at age (w_a) were estimated from area specific weight at age curves (see above). The term b_a was proportional to equilibrium biomass at age:

$$b_a = w_a e^{-(a-5)(M+F)}$$

where $M=0.15\ y^{-1}$ and $F=0.05\ y^{-1}$ for NNJ and $F=0.01\ y^{-1}$ for Delmarva.

Correction factors, δ, for surfclam (see below) were calculated from M-G based on biomass weighted instantaneous growth rates G, $M=0.15\ y^{-1}$, and the regression formula (see above).

	Data for 1980	Data for 1989 & 1992
Delmarva		
G (y^{-1})	0.086	0.091
M-G (y^{-1})	0.064	0.059
δ (y^{-1})	0.968	0.970
NNJ		
G (y^{-1})	0.100	0.107
M-G (y^{-1})	0.050	0.043
δ (y^{-1})	0.975	0.978

Results show that natural mortality and growth rates are nearly equal for surfclam in the NNJ and DMV areas because M-G values were near zero ($<0.07\ y^{-1}$) indicating that natural mortality and growth nearly nearly balance for surfclam 120+ mm (NNJ) and 100+ (DMV). Correction factors for DMV and NNJ were similar so we used $\delta=0.97$ for all stock areas.

Parameter Estimation and Tuning

Goodness-of-fit for observed and predicted abundance index data was computed assuming log-normal measurement errors and the negative log-likelihood component:

$$L_A = 0.5 \sum_{j=1}^{N_v} \left[\frac{\ln\left(I_{v,j} \big/ \hat{I}_{v,j} \right)}{\sigma_{v,j}} \right]^2$$

where $I_{v,t}$ was an abundance index datum for survey v, hats "^" denote model estimates, $\sigma_{v,j}$ was an observation-specific log scale standard error (calculated from an arithmetic scale CV, see below), and N_v was the number of observations.

Predicted values for surfclam abundance indices were calculated:

$$\hat{I}_{v,t} = Q_v A_t$$

where Q_v was a scaling parameter that converted biomass to units of the abundance index. A_t was available biomass:

$$A_t = s_1 R_t + s_2 (B_t - R_t)$$

and s_1 and s_2 were survey selectivity parameters for new recruits (R_t) and old recruits (B_t-R_t). Survey selectivity parameters were set at runtime (not estimated in the model) to values of either zero or one (although value between zero and one are plausible and could have been used). For example, surveys for new recruits had $s_1=1$ and $s_2=0$. Surveys for the entire stock (new and old recruits) had $s_1=1$ and $s_2=1$, and surveys for old recruits had $s_1=0$ and $s_2=1$.

Arithmetic scale CV's for abundance index data and swept area biomass estimates were converted to a log scale standard errors with:

$$\sigma_{v,j} = \sqrt{\ln\left(1+CV_{v,j}^2\right)}$$

To speed calculations and reduce the number of parameters estimated as formal parameters, a closed form maximum likelihood estimator was used to estimate scaling parameters (Q) for abundance indices:

$$Q_v = e^{\frac{\sum_{j=1}^{N_v}\left[\ln\left(\frac{I_{v,j}}{A_{v,j}}\right)\Big/\sigma_{v,j}^2\right]}{\sum_{j=1}^{N_v}\left(1/\sigma_{v,j}^2\right)}}$$

where $I_{v,i}$ was the observed value of an abundance index and N_v was the number of observations with individual weights greater than zero.

As described above, efficiency corrected swept area biomass estimates for surfclam during 1997 and 1999 were important sources of information in the KLAMZ model. The expectation Q=1 for swept area biomass data was the basis for the constraint:

$$L_Q = 0.5\left[\frac{\ln(Q/T)}{\sigma}\right]^2 = 0.5\left[\frac{\ln(Q)}{\sigma}\right]^2$$

where T=1 was the target (prior) for Q, and σ was a standard error calculated from the average CV for efficiency estimates from field studies during 1997 and 1999. The constraint and calculation for σ assumed that the distribution of Q was lognormal (an appropriate assumption because Q > 0).

Constraints on implied efficiency were considered in model development but not used in basecase runs because the constraint Q=1 for swept area biomass data was equivalent and prevented problems with implausible efficiency values (i.e. Q>1 as in NEFSC 1996). Survey dredge efficiency (E) is related to survey scaling parameters (Q) because:

$$E = QA/\bar{a}$$

where A is the area covered by the stock and $\bar{a}$ is average area swept by the dredge.

Constraints on efficiency are a topic for future research. NEFSC (1995) outlines calculation of the efficiency implied by a single survey observation but calculations for a time series may be more complicated because surfclam dredge survey data are noisy. It seems likely, for example, that implied efficiency estimates might be implausible in some years, even though the average value implied by the entire time series is not. It is also likely efficiency changes, due to gear improvements, and changes in tow length (measured by sensors and dependent on tow depth, speed, scope, etc.) will have to be modeled as well.

When surplus production model parameters were estimated implicitly, a likelihood component for goodness of fit was calculated:

$$L_P = 0.5\sum_{t=1}^{N_P} w_{v,j}\left[\frac{\left(\tilde{P}_t - P_t\right)}{\sigma}\right]^2$$

where N_p was the number of production estimates (number of years less one), $\widetilde{P}_t$ was a predicted value from the surplus production curve, P_t was the assessment model estimate, and the standard error σ was calculated from the average of bootstrap estimates of variance in P_t from a preliminary bootstrap run. No log transformation was used because surplus production can be positive or negative.

Deviations in the random walk recruitment process were penalized based on changes between successive time steps:

$$L_R = 0.5 \sum_{y=Y_2}^{Y_{max}} \left[\frac{\ln\left(R_y / R_{y-1} \right)}{\sigma} \right]^2$$

where Y_2 and Y_{max} were the second and last years in the model and σ was an assumed standard deviation. In effect, the likelihood component smoothed the recruitment estimates for surfclam. Effects of assumptions about σ for surfclam were evaluated by sensitivity analysis.

Recruitment estimates from KLAMZ were largely from abundance trend information that included survey and LPUE data. As described above, survey data for most stock assessment areas began in 1978 (the first year in the KLAMZ model for surfclam) and LPUE data began in 1980. However, survey data for the SVA, SNE and GBK assessment areas began in 1984, 1982 and 1986 and there were no LPUE data for SNE and GBK. In these cases, the constraint on recruitment estimates (described above) forced the model to estimate constant or near constant recruitments prior to the first year with survey data. In effect, the model estimated a level of constant recruitment that gave the best fit to survey data that followed.

Forward simulation models like KLAMZ and the DeLury model sometimes calculate absurdly high fishing mortality rates. A likelihood constraint used to prevent this potential problem was calculated:

$$L_F = 0.5 \sum_{y=Y_1}^{Y_{max}} d^2$$

where $d=(F_y\text{-}MaxF)^2$ if $F_y > MaxF$ and MaxF is a maximum allowed value for F (e.g. MaxF=2). If $F_y < MaxF$, then d is zero. Penalties on high F values were not important for surfclam and always zero except in sensitivity analysis.

Parameters in KLAMZ were estimated by minimizing the total negative log-likelihood:

$$\Xi = \sum_{v=1}^{N_L} \lambda_v L_v$$

where N_v was the number of likelihood components and λ's were likelihood component specific weighting factors usually set to zero (when a component was removed from calculations), one (for general likelihood calculations), or to a large value (usually 1000) for "hard" constraints. A hard constraint might be used, for example in penalizing absurdly high fishing mortality rates (F>MaxF).

Bootstrap variance estimates

Variances for estimates from KLAMZ were calculated by a simple bootstrap procedure (five hundred iterations) involving abundance data (Efron 1982). The first step was to obtain a basecase model fit. The next was to generate a large number of simulated data sets based on predicted data values and randomly sampled log scale residuals from the basecase run. Finally, KLAMZ was fit to each of the simulated data sets. Variance of estimates from the simulated data sets were used to estimate variance for estimates in the original base case fit. For simplicity and ease in calculation, and because the variances of residuals in preliminary runs were similar, residuals from the basecase fits to LPUE, survey and swept area biomass data were mixed during the bootstrap process.

Projections

KLAMZ was used to project biomass levels into the future given a set of parameters from a model fit and assumptions about future recruitment and catch or fishing mortality rates. Future recruitment and catch (or fishing mortality rate levels) are the most important feature in projections. Projections in KLAMZ could be configured to mimic the production and ten-year supply models traditionally used for surfclam (NEFSC 1998). Projections used recent values for catch and recruitment calculated automatically for a specified range of years. In bootstrap runs, estimates of recent recruitment and biomass changed so variance calculations for projections include some uncertainty about population dynamics.

Trial Runs and Results Preliminary Results for NNJ

A large number of trial KLAMZ model runs (Table E33) were made for surfclam in the NNJ area using a preliminary model that included a hard constraint (λ=1000) towards $Q_{sweptArea}$=1. The trial runs and preliminary model were used to check assumptions and make modeling decisions. NNJ was used for trial runs because it was the area of highest catches and most important to managers.

In all trial and basecase runs, the log scale standard deviation used in the likelihood component for the random walk in recruitment estimates was 0.2 . The choice was based on preliminary model fits and gave CV's for fit to pre-recruit and new recruit survey trend data that were about 40% (about the same as the sample CV's, Table E15). Smaller standard deviations gave smoother estimated recruitment time series and higher standard deviations gave more variable recruitment time series. However, changes in the assumed standard deviation for recruitment variability over the range of 0.2-0.8 had little affect on recent biomass and fishing mortality estimates. In retrospect, it might have been better to use a larger standard deviation for stock areas (NNJ, SNJ and DMV) with possibly strong trends in recruitment during the late 1970's. Another possibility would have been to use larger standard deviations for early years only. This is a topic for future research. As expected, recent (mean 1997-1999) biomass and fishing mortality rate estimates for surfclam in the NNJ region in trial runs #1-11 constrained to $Q_{SweptArea}$=1 (λ=1000) were similar (Table E34). There were, however, differences in estimates of biomass and fishing mortality for years prior to 1997 and in projections (Figures E54-E55).

Likelihood profiles based on trial runs with a range of fixed values for $Q_{SweptArea}$ were a convenient way to examine model fit and estimates in runs with a range of terminal and average biomass (Table E35). Biomass and fishing mortality estimates were strongly affected, but fit to data (as measured by negative loglikelihood and residual variance), estimates of F_{MSY} and status ratios (F/F_{MSY} and B/B_{MSY}) were hardly affected.

There was not enough information to fit the KLAMZ model for surfclam without swept area biomass data. A run (not shown) with no constraint on $Q_{SweptArea}$ converged to an implausible solution (biomass estimate about 50% less than swept area biomass data in 1999), similar to results with the modified DeLury model in NEFSC (1996). Trend data fit almost equally well over a wide range of terminal and average biomass levels (see above).

The KLAMZ model for surfclam in the SVA stock area (with swept area biomass data for 1997 but not not 1999) was much harder to estimate than for other stock areas. This suggests that a single swept area biomass observation is barely sufficient.

Natural mortality rate assumptions in trial runs affected historical (1978-1996), recent 1997-1999) and projected (2000-2011) estimates (Figures E56-E58). Projected fishing mortality rates were sensitive to M (even though assumed catches were the same in all runs) because of differences in projected recruitment and because there were no constraints on projected trends.

The result that F/F_{MSY} ratios are robust (Prager 1994) may not hold when swept area biomass data and fixed catches constrain recent estimates of F. A preliminary bootstrap run for NNJ indicated that the CV for F/F_{MSY} was large (201%) due to a few instances when the bootstrap F_{MSY} value was very small. Evidently, the data eliminated covariance in F and F_{MSY} estimates so that errors did not cancel out in the ratio.

Several runs were carried out with Schaeffer production curves estimated implicitly (Table E36). All used the same basic data configuration as trial run 4 (with empirical production calculations). Differences were weights (λ=0 in the empirical run and λ=1, 10 or 1000 in the implicit runs) for the Shaeffer curve likelihood component. The standard deviation used in scaling residuals for observed and predicted production in likelihood calculation was calculated from the mean CV (74%) for annual production estimates measured in a preliminary bootstrap run. As the likelihood weight increases, production estimates from KLAMZ moved closer to the predicted production curve. At high likelihood weights (e.g. λ=1000), the fit was almost perfect and KLAMZ was effectively a surplus production model with no process error (residual mean square error was reduced by almost 100%). Results (Table E36 and summarized below) showed that surplus production parameters related to MSY and F_{MSY} were sensitive to the likelihood weight for implicit production calculations.

Percent change from run with likelihood weight λ=0 for implicit production calculations.

	λ=1000	λ=100	λ=1	λ=0
Schaeffer Model:Carrying Capacity (K)	-10%	-9%	-3%	0%
Schaeffer Model:Bmsy (units=1000)	-10%	-9%	-3%	0%
Schaeffer Model:MSY (units=1000)	67%	46%	14%	0%
Schaeffer Model:Fmsy	110%	75%	19%	0%
Schaeffer Model:Recent Mean F / Fmsy	-51%	-41%	-16%	0%
Schaeffer Model:Recent Mean B / Bmsy	8%	7%	2%	0%
Schaeffer Model:Recent Mean C/ MSY	-40%	-32%	-12%	0%
Schaeffer Model:RMS Residual	-99%	-60%	-14%	0%

Likelihood weights for implicit production calculations are a potentially important area for future research. The default weight, based on likelihood theory, is $\lambda=1$ but the default may give too much emphasis on fit to the implicit production curve. In the case of NNJ surfclam, for example, there were two swept area biomass observations and 22 production estimates. Thus, the likelihood component for implicit surplus production estimates was potentially 22/2=11 times more important than the likelihood component for swept area biomass, even though the later probably contained real information about surfclam abundance.

Plots showing relationships between production and biomass (Figure E59) and trends over time (Figure E60) in trial runs were useful in evaluating model sensitivity and suggesting a basecase model run. Biomass and production estimates were relatively insensitive to decisions about omitting survey data for 1979, breaking the LPUE data into two time series and implicit production calculations with $\lambda=1$. In contrast, estimates were very sensitive to decisions about omitting survey data for 1994. In particular, biomass trends and production increased steeply in the mid-1990's when 1994 survey data were included. When 1994 survey data were omitted, trends were relatively flat. The increasing trend in runs with the relatively high 1994 survey data included are due to KLAMZ trying to match the high survey observation in 1994 with the lower values in earlier and later years while still meeting the constraint imposed by the swept area biomass data for 1997 and 1999.

LPUE data for surfclam in the NNJ stock assessment area during 1991-1999 were relatively flat and did not suggest an increase in the mid-1990's as suggested by the survey data for 1994. According to Table E34, and comparing scenarios #3 ("No_79; Break LPUE") and #4 ("No_79; No_94; Break LPUE; Basecase?"), the residual root mean square (RMS) decreased from 0.19 to 0.095 for recent LPUE data and from 0.40 to 0.35 for survey estimates of kg per tow when the 1994 survey data were omitted. In addition, patterns in residuals for survey and LPUE data improved. As a whole, results strongly suggest that the 1994 survey data for NNJ were outliers and should be excluded from the assessment model.

Basecase Models

Basecase models for surfclam in the NNJ and other assessment areas was similar to trial run 4 (see above) for NNJ except that the likelihood weight on the constraint $Q_{SweptArea}=1$ was $\lambda=1$ (instead of $\lambda=1000$, i.e. the constraint was relaxed). For basecase runs, survey trend data for 1979 and 1994 were omitted, LPUE data (where available) were broken into two separate time series (1980-84 and 1991-99), and empirical (rather than implicit) production calculations were carried out. Residual plots for NNJ were satisfactory and showed little evidence of lack of fit (Figures E61-E66).

For basecase runs, the hard constraint on $Q_{SweptArea}=1$ was relaxed in favor of a standard maximum likelihood approach ($\lambda=1$) so that model was not intentionally driven through the swept area biomass data and could better balance all of the available information about recent biomass. However, relaxing the constraint had little effect on results because (as shown in the likelihood profile analysis in Table E35) there was little information about the scale of biomass in the other data (survey and LPUE data fit almost equally well over a wide range of recent biomass levels).

Data from the 1979 survey were omitted from basecase runs for other areas because there was one survey during the winter of 1979 which used atypical dredge gear (Table E6).

Surveys during 1978 and 1980 were during winter and spring and also used atypical gear. There were two surveys per year during 1978 and 1980, however, and average values were probably more comparable in trend to data from later years.

Survey trend data collected during 1994 were omitted from basecase runs for NNJ and other areas because dredge efficiency was anomalously high in 1994 in many areas due to problems with the voltage of current used to run a pump on the dredge and because runs with 1994 survey data estimated implausible trends in production and biomass (see above).

Basecase runs used empirical, rather than implicit, surplus production calculations because the latter are still experimental and because there is uncertainty about how to specify the likelihood weight (λ) for goodness of fit to the surplus production curve. The implicit approach is promising but further work and additional experience are required.

Another potential problem with surplus production estimates for surfclam in the New Jersey (NNJ and SNJ) area was pointed out by reviewers. The anoxic event that eliminated surfclam in 1976 also destroyed surfclam predators. In addition, older, slower growing surfclams were replaced by younger, more productive individuals. Under conditions of normal predator abundance and surfclam age structure, the stock would probably have been less productive and increased more slowly than after the dieoff in 1976. Surplus production calculations for the New Jersey area (which use trends measured after the dieoff in 1976) may yield biased estimates of F_{MSY}.

Basecase Results

As described above, model runs for each stock area covered 1978-1999 and included projections for three years (2000-2002) using recent (1997-1999) average catch and recruitment. Biomass, recruitment and fishing mortality estimates for the entire surfclam stock were calculated as sums (biomass and recruitment) or biomass weighted averages (fishing mortality) using estimates for each assessment area. CV's for whole stock estimates were calculated from boostrap CV's for each stock assessment area using standard formulas for the variance of a sum or weighted average.

Stock Assessment Region	Biomass 1999	CV	Basecase Recent Mean Catch+Non-Catch Weight for Projection	Basecase Recent Mean Recruitment for Projection	Biomass 2002	CV	Percent Change
SVA	2,545	65%	2	0	1,632	65%	-36%
DMV	321,108	52%	919	23,140	331,495	51%	3%
SNJ	68,175	114%	4,074	12,355	80,872	116%	19%
NNJ	479,826	26%	16,138	42,017	440,938	27%	-8%
LI	47,018	72%	100	3,071	47,591	73%	1%
SNE	84,462	40%	90	4,886	82,274	38%	-3%
GBK	265,360	34%	0	28,989	334,142	35%	26%
Total	1,268,495	19%	21,323	114,458	1,318,945	20%	4%

Results (Tables E37-E40 and Figures E67-E70) suggest that surfclam biomass decreased during 1978-1999 in the SVA and SNE stock assessment areas but increased for the stock as a whole and in the in SNJ, NNJ, LI and GBK areas. In DMV, surfclam biomass increased during 1978-1988 and decreased afterwards. Recent fishing mortality rates were highest in the the SNJ and NNJ areas but low overall. Surplus production was positive for the entire stock except during 1988-1991. Areas with increasing biomass showed increasing trends in surplus production and vice-versa. Projections (Table E38, summarized below) suggest that surfclam biomass will increase slightly (4%) over the next three years.

<u>Efficiency Adjusted Swept Area Biomass</u>

Habitat area on Georges Bank was calculated as A=fR where *R* was the total area (nm^2) of survey strata in the Georges Bank assessment region with surfclam habitat. The proportion *f*=0.88% was an area weighted average of the percentage of randomly chosen survey stations in each stratum that were fishable with the survey dredge (haul code not equal 151, Table E14). For lack of data, other stock assessment regions were assumed to be 100% suitable as surfclam habitat (i.e. f=1 so that A=R).

Swept area biomass (B), adjusted for survey dredge efficiency, was computed:

$$B = \frac{DfR}{ae}$$

where *D* was the average weight of clams caught per tow (adjusted to a standard 0.15 nm tow length, kg tow^{-1}), *a* was area swept per standard tow (standard tow length times dredge width, nm^2), and *e* was dredge efficiency (probability of capture for clams in the path of the survey dredge). For convenience in variance calculations, swept area biomass (*B*) and all terms in the swept area biomass calculation (*A*, *f*, *R*, *D*, *a* and *e*) were assumed to be lognormally distributed.

Taking logs gives:

$$\ln(B) = \ln(D) + \ln(f) + \ln(R) - \ln(a) - \ln(e)$$

Neglecting covariance terms, the variance of ln(*B*) can be approximated simply as the sum of the variances for each term. Covariances involving ln(*f*) with other terms and ln(*R*) with other terms were likely zero. Covariances probably exist between ln(*D*), ln(*a*) and ln(*e*) but were igonored in calculations because their direction and magnitude were difficult to predict.

Log scale variances for terms in swept area biomass calculations were calculated from arithmetic scale coefficients of variation (Jacobson et al. 1994):

$$Var[\ln(x)] = \ln[CV(x)^2 + 1]$$

where CV(x) means coefficient of variation for x. CV's for survey data (*D*) were from standard errors for stratified means (Table E15). CV's for efficiency estimates (*e*) were from standard errors for a single depletion study on the R/V Delaware during 1997 (NEFSC 1998) or for the mean of efficiency estimates from four sources in 1999 (Table E13). The CV for average area towed (*a*) was the CV for mean tow distance during each survey. CV's of 5% were assumed for the total area of survey strata with surfclam habitat in each stock assessment region (*R*).

The CV for percent suitable surfclam habitat (f) in the Georges Bank assessment area was assumed to be 10%.

CV calculations for surfclam swept area biomass estimates likely underestimate actual uncertainty because but not all sources of variability were included and because variation in many of the terms was underestimated. For example, it is likely that CV's for standard catch rates in the survey (D) were underestimated because the variances for survey strata with zero catches and strata with a single tow were assumed to be zero. Variance calculations for swept area biomass do not include uncertainty in length-weight conversion parameters used to convert numbers of surfclams per tow in surveys to weight per tow. In addition, plots (not shown) of the CV for variation among tows in the same stratum versus number of tows increased up to about 30 tows. This suggests that the true variance among tows within a strata was underestimated in most cases because the number of tows per stratum was usually less than 30 and often as low as one.

Upper and lower bounds for 95% confidence intervals on log biomass were computed $\ln(B) \pm 1.96$ $SE[\ln(B)]$ where $SE(x)$ was the standard error of x. Crude (no bias correction, Beauchamp and Olson 1973) asymmetric arithmetic scale confidence intervals were calculated by back-transforming the bounds on the interval for ln(D).

Swept area biomass estimates with corrections for survey dredge efficiency (Table E32) had CV's that were 3-154% (average 38%) larger than CV's for the original survey data (Table E15). Ninety-five percent confidence intervals for total, efficiency adjusted, swept area biomass during 1997 and 1999 overlapped (i.e. 786-1,558 thousand mt in 1997 and 1,088-2,471 thousand mt in 1999).

Survey (Catch-Swept Area) based Biomass and Fishing Mortality Estimates

Catch-swept area estimates of recent fishing mortality rates for surfclam (Table E41) were calculated as the ratio of recent mean catch and mean biomass ($F=C/B$). In this calculation, recent stock biomass (B) was the average of efficiency adjusted swept area estimates for surfclams 100+ mm during 1997 and 1999 (some calculations with surfclams 120+ mm were also carried out, see below). Catch weight was the average of landings in 1997-1999 plus discard (zero during recent years) plus an assumed 20% indirect mortality due to fishing. The minimum size of 100 mm was chosen for biomass because surfclams in commercial catches are almost all larger than 100 mm, because the same assumption was made elsewhere in this assessment for stock assessment areas other than NNJ and SNJ, and because clams 100+ are probably equally vulnerable to commercial and survey dredges. However, the commercial fishery in the NNJ and SNJ stock assessment areas harvest clams that are predominately 120+ mm and fishing mortality estimates from the KLAMZ model for NNJ (Section 6.5) are for clams 120+. Thus, estimates from KLAMZ for surfclam 120+ mm are not completely comparable to catch-swept area estimates based on survey biomass estimates for surfclam 100+ mm.

Crude confidence intervals for F can be calculated as described above for swept area biomass (B). Assuming swept area biomass (B) lognormally distributed and ignoring variance in catch (C), the variance of $\ln(F)=\ln(C)-\ln(B)$ is the same as the variance of ln(B) and the CV of F is the same as the CV for B.

Results of catch-swept area calculations (Table E41) indicate that fishing mortality rates for surfclam 100+ mm are highest in the SNJ ($F=0.04\ y^{-1}$) and NNJ ($F=0.03\ y^{-1}$) assessment areas and near zero elsewhere. For the entire 100+ mm stock, the catch-swept area estimate is $F=0.02\ y^{-1}$.

Comparison of Catch-Swept Area and KLAMZ Results

Point estimates of recent fishing mortality rate and biomass from the two models were similar for all stock assessment areas (Table E41). Both models suggest that recent fishing mortality rates were highest in the SNJ and NNJ areas but low overall.

Standard errors and CV's for recent estimates from the KLAMZ model were smaller than from the catch-swept area model for all areas except DMV (Table 41). Differences were small for all areas except SNJ, despite different methods of calculation. Precision of estimates for SNJ from the catch-swept area model were likely more affected by the wide differences in swept area biomass estimates for surfclam in the SNJ assessment area during 1997 and 1999 and the large CV for swept area biomass in 1999 (Tables E22 and E32).

Results from both models indicate that there is little probability that recent fishing mortality exceeded $0.15\ y^{-1}$ for the whole stock or for surfclam in the NNJ area (Figure E71). However, the probability that recent fishing mortality exceeded $0.15\ y^{-1}$ in the SNJ area was about 10%.

OPTIONS FOR OVERFISHING DEFINITIONS

Overfishing definition and harvest policy choices for surfclam are policy decisions that cannot be made entirely on technical grounds. In the absence of other policy guidance, options were developed in this assessment for biomass targets, biomass thresholds and fishing mortality thresholds in the default MSY control rule (Figure E72) recommended by NMFS (Restrepo et al. 1998) and used in the Review of Overfishing Definitions in the Northeast (Applegate et al. 1998). The biomass target in the default MSY control rule is B_{MSY} and the default policy relies heavily on MSY assumptions and calculations.

The default MSY control rule calculates a maximum fishing mortality rate threshold. Overfishing (as a rate) occurs by definition whenever fishing mortality is as large or larger than the fishing mortality rate threshold. The threshold fishing mortality rate used to define overfishing is reduced in the default MSY control rule whenever stock biomass falls below a biomass threshold value.

In the default MSY control rule, the biomass threshold is $\frac{1}{2}\ B_{MSY}$. Restrepo et al. (1998) recommended that the biomass threshold for surfclam should be "no less than $\frac{1}{2}\ B_{MSY}$ to avoid the risk of stock collapse due to low spawning biomass and poor recruitment." Biomass threshold options were not analyzed in this assessment due to lack of time. However, S. Cadrin (Northeast Fisheries Science Center, pers. comm.) and reviewers at the Stock Assesment Review Committee (SARC) constructed rebuilding isopleths (Cadrin 1999) assuming deterministic population growth in a logistic model (equivalent to the Shaeffer surplus production model) and an intrinsic rate of increase $r=2F_{MSY}=0.3$ and $F_{MSY}=M=0.15\ y^{-1}$.

The ten year rebuilding isopleth for surfclam (Figure E73) shows combinations of fishing mortality and biomass levels expected to result in recovery of the surfclam stock to the target B_{MSY} level in ten years. Fishing mortality rates above the ten year isopleth slow stock recovery and fishing mortality rates above the ten year isopleth speed stock recovery. Results suggest that the default MSY control rule with a biomass threshold of ½ B_{MSY} approximates the ten year isopleth. This means that the surfclam stock would be expected to achieve target biomass levels in ten years under most of the fishing mortality rate and biomass combinations allowed under the default rule with a biomass threshold of ½ B_{MSY}. In contrast, a MSY control rule with a biomass threshold of ¼ B_{MSY} is a poor approximation to the ten year isopleth. It allows a wider range of combinations of fishing mortality and biomass that would not achieve target biomass levels in ten years. Thus, the ½ B_{MSY} threshold option appears more compatible with maintaining B_{MSY} target biomass levels. However, additional limitations on fishing mortality may be required if extreme overfishing conditions develop (e.g. when the stock is above the ten year recovery isopleth and below the MSY control rule line in Figure E73).

According to the SFA, a stock is overfished (in terms of biomass) by definition whenever stock biomass falls below the biomass threshold level. The threshold fishing mortality rate used in the default MSY control rule is F_{MSY} as long as stock biomass is above the biomass threshold. However, when stock biomass falls below the biomass threshold level, the threshold fishing mortality rate in the default MSY control rule is reduced. Reductions in the threshold rate are linear from F_{MSY} at the biomass threshold to zero at a stock biomass of zero.

According to Council staff, it will be necessary to resubmit sections of a recent amendment to the fishery management plan for surfclam that deal with overfishing definitions. Paperwork requirements are outside the scope of this assessment, however, estimates of fishing and biomass thresholds and the biomass target based on MSY can be expected to change in each assessment as data accumulate and models change. Changes to estimates should not require an amendment, only technical explanation.

According to the Sustainable Fisheries Act, overfishing definitions must apply to the entire surfclam stock so the question of stock definition for surfclam is important in this context. In practice, the surfclam stock is assessed based on a number smaller stock assessment areas with B_{MSY} and F_{MSY} estimated possibly for each. Under these circumstances, best estimates of MSY parameters for the entire surfclam stock might be sums or weighted averages of the estimates for each stock assessment area or approximated in some other way. For example, the biomass target (B_{MSY}), biomass threshold ($B_{threshold}$), and current biomass (B) for the entire surfclam stock could be computed for the entire stock or based on stock assessment areas:

$$B_{MSY} = \sum_{i=1}^{N} B_{MSY,i}$$

$$B_{threshold} = \frac{B_{MSY}}{2} \quad or \quad \frac{B_{MSY}}{4}$$

$$B = \sum_{i=1}^{N} B_i$$

where $B_{MSY,i}$ is the stock level for MSY in each of the (i=1 to N) stock assessment areas and B_i is a current biomass estimate for area i.

F_{MSY} for the entire surfclam stock might be computed directly for the whole stock or as a biomass or abundance weighted average of values from each assessment area:

$$F_{MSY} = \frac{\sum_{i=1}^{N} B_{MSY,i} F_{MSY,i}}{\sum_{i=1}^{N} B_{MSY,i}}$$

The threshold fishing mortality rate for the entire stock $F_{threshold}$ would be F_{MSY} or less (if current stock biomass is less than $B_{threshold}$). The current fishing mortality rate for the entire stock might be estimated directly or computed from estimates for each stock assessment area:

$$F = \frac{\sum_{i=1}^{N} B_i F_i}{\sum_{i=1}^{N} B_i}$$

To determine if overfishing is occurring in the surfclam fishery, managers should compare the current fishing mortality rate for the entire stock (F) to $F_{threshold}$, estimate the ratio $F/F_{threshold}$ or carry out an equivalent calculation. To determine if the surfclam stock is overfished, managers should compare current biomass for the entire stock B to $B_{threshold}$, estimate the ratio $B/B_{threshold}$, or carry out an equivalent calculation.

B, $B_{threshold}$ and B_{MSY} or F, $F_{threshold}$ and F_{MSY} estimates may not be reliable or available for all stock areas. In such cases, proxies or proxies for ratios (e.g. for B/B_{MSY} or F/F_{MSY}) based on the best available information should be used instead. If stock biomass estimates are unavailable, then best guesses of B relative to virgin biomass based on information about recent catch levels may be useful.

MSY Harvest Rule and Overfishing Parameters for Surfclam

F_{MSY}

A number of estimates and proxy options for F_{MSY} in surfclam were considered. Currently, direct estimates from KLAMZ are unreliable and only two proxies can be recommended on technical grounds: $F_{MSY}= F_{0.1}$ (best current estimate 0.17 y^{-1}) and F_{MSY}=M (0.15 y^{-1} in this assessment) for the entire stock. The proxy recommended by the SARC was F_{MSY}=M.

F_{MSY} was estimated directly in the KLAMZ model (e.g. F_{MSY}=0.22 y^{-1} from an empirical Schaeffer curve in a trial run for NNJ, see above). However, estimates were erratic for many assessment areas and generally unreliable (see above).

If direct estimates are not available, then proxies such as $F_{MSY}=F_{MAX}$, $F_{0.1}$, $F_{35\%}$-$F_{40\%}$, or M may be appropriate (see review by Clark 1991,1993). In addition, if surfclam biomass in a particular area is near B_{MSY} (unlikely based on results in this assessment), then F_{po} (the fishing mortality rate for catch equal to surplus production) from the production model for surfclam (Section 6.2) or F_{MSY}=recent F may be suitable. No relationship has been established between F_{MSY} and fishing mortality rates from the ten-year supply model for surfclam (Section 6.1) so results from the ten-year supply model are not applicable.

F_{MAX} is an upper, but not sharp, bound for F_{MSY} (Deriso 1982; Clark 1991, 1993). In surfclam, F_{MAX} tends to be implausibly high (0.27-0.75 y^{-1}, or 2-3 times M, Table E29). For this reason, F_{MAX} for surfclam is not recommended for use in the default MSY control rule.

The proxies $F_{MSY}=F_{35\%}$ to $F_{40\%}$ (0.11-0.34 y^{-1}, Table E29) are robust to assumptions about spawner-recruit relationships and approximate F_{MSY} in species (like surfclam) with M near 0.2 y^{-1} if recruitment to the fishery and sexual maturity coincide (Clark 1991; Clark 1993). However, surfclam are 90% sexually mature at age one and fully mature at age two, about 2-3 years before recruiting to the fishery (Section 6.3). Early maturity precludes use of $F_{35\%}$-$F_{40\%}$, because a relatively large portion of the expected lifetime spawning biomass for each cohort is protected by delayed recruitment to the fishery. This means that $F_{35\%}$-$F_{40\%}$ likely overestimate F_{MSY} in surfclam and can not be recommended for use in the default MSY control rule.

$F_{20\%}$ is currently used as an overfishing definition threshold in the fishery management plan for surfclam (MAFMC 1996). The $F_{20\%}$ threshold was established before the policy of defining overfishing as $F>F_{MSY}$ was established. There is little technical justification for $F_{20\%}$ as a proxy for F_{MSY} in general (Clark 1991 and 1993) and even less justification in the case of surfclam because recruitment occurs prior to recruitment to the fishery (see above). Therefore, F20% is not discussed in this assessment as a potential proxy for F_{MSY}.

B_{MSY}

A number of estimates and proxy options for B_{MSY} were considered. Direct estimates of B_{MSY} (like estimates of F_{MSY}) from the KLAMZ model were unreliable and the only proxy option recommended in this stock assessment was to take B_{MSY} equal to ½ recent (mean 1997-1999) biomass for the whole (100+ mm) surfclam stock. This simple approach, recommended by the SARC, is reasonable because the catch-swept area and KLAMZ models indicate that recent fishing mortality rates were low (0.02 y^{-1}). By inference, biomass of the entire surfclam stock is probably near the carrying capacity.

B_{MSY} was estimated directly in the KLAMZ model for surfclam in each stock area (e.g. B_{MSY}=294,000 mt from an empirical Schaeffer curve for NNJ). However, estimates were erratic for many assessment areas and unreliable (see above).

If direct estimates are unavailable, then the estimate B_{MSY}=recent biomass may be suitable if there is evidence that the stock is currently at MSY (e.g. if recent F is near F_{MSY}) but this is unlikely for surfclam because fishing mortality rates on the entire stock appear low. If recent fishing mortality rates are between zero and F_{MSY}, then the interval (½ recent biomass, recent biomass) might be used to estimate upper and lower bounds for B_{MSY}. If recent fishing morality rates are near zero, then ½ recent biomass is a reasonable approximation for B_{MSY}. It seems likely that surfclams fall into the latter category.

SOURCES OF UNCERTAINTY

With respect to estimating current biomass and fishing mortality rates for surfclam, the most important source of uncertainty in this assessment was the precision of efficiency adjusted biomass estimates for 1997 and 1999. CV's (which underestimate the actual statistical uncertainty, Section 6.4) ranged from 20-79% for individual stock assessment areas and 18-21% for the stock as a whole. This uncertainty is particularly important because the swept area biomass estimates were the cornerstone for all of the stock assessment work. Without the swept area biomass estimates, for example, there is insufficient information in historical survey time series and LPUE data to even monitor trends in abundance of surfclams accurately enough for management purposes.

In addition to the uncertainty measured by CV's, there is considerable uncertainty in assessment results due to applying survey dredge efficiency estimates from a small number of depletion estimates from one or two areas, to regions where bottom characteristics may be quite different.

With respect to estimating historical trends, the most important source of uncertainty in this assessment was imprecise clam survey data and variation in efficiency of dredge survey gear. More work will be necessary to understand and measure efficiency of dredge gear used in each survey. It is important to improve and, if possible, avoid compromising the time series of historical relative abundance estimates based on survey data.

This stock assessment used new models and new information about surfclam age and growth, which depict surfclam stocks as more resilient and robust than in previous assessments (e.g. NEFSC 1998). However, results were imprecise. Further, results with new models used by new biologists on new data are always less certain than results with the same data once the models have stood the test of time. The authors of this assessment caution against abrupt or drastic changes to take advantage of additional surfclam productivity that appears to exist.

RESEARCH RECOMMENDATIONS

Clam Dredge Survey Gear and Sensors

(1) Instruments for monitoring dredge performance (sensor packages) became an integral part of the clam survey and assessment in 1997 and 1999. Before the sensors can be used for the next survey, these instruments need maintenance by a skilled technician. Furthermore, the sensor packages are in an early state of development. Resources should be allocated to improve their design and reliability. In particular, the packages can be made smaller, different pressure sensors are needed that operate at a wider temperature range, calibration of sensors within the package needs to be made more straightforward and user friendly, and electrical connections from the ship's computer to the sensor package on the

dredge need to be better protected, more rugged, and easier to attach.

(2) Evaluate the effect of changes in pump pressure on the dredge efficiency. Delaware II's dredge pump pressure has been inconsistent through time. Before the 1999 survey started, one of the planned tests was to determine what effect pump pressure had on catch. However, due to changes in the electrical cable on the ship in 1999 it was not possible to carry out a test of the effect of pump pressure on catch.

(3) The electrical cable to the dredge is an important determinant of gear performance. An attempt should be made to purchase enough cable, and of the right type, for use in many survey years. Changing cable type within or between surveys should be avoided.

(4) Evaluate the relationship of clam size to dredge efficiency and selectivity for clams <120 mm. The dredge currently being used allows clams less than 90 mm to escape. Data on abundance of smaller pre-recruits would give a more comprehensive understanding of the clam population.

(5) Thought should be given to setting up the clam dredge as the commercial industry does with a vessel/surface mounted pump and hose to the dredge. By using a pump that has more pressure, this might eliminate major changes in gear efficiency caused by low and variable pump pressure. This would represent a major change from past methods.

(6) Using the sensor data collected in 1997 and 1999, examine statistical relationships between tow distance, station depth and winch speed. Such an analysis may make it possible to infer tow distances from early clam surveys with greater accuracy than estimates from doppler distances.

Sampling

(7) In the 1999 survey 21 stations were re-sampled from the 1997 survey. This type of sampling, as well as depletion experiments, are important in identifying potential changes in gear efficiency over time, and should be continued in future surveys.

(8) Catch has increased off southern New Jersey in the last three years. Additional effort should be made to understand the extent and patchiness of the resource in that area.

(9) Studies to quantify the level of indirect fishing mortality are needed.

Database

(10) Clam survey data are computerized but have not been incorporated into a database to facilitate processing and use. It is not possible to extract and restratify time series in a reasonable amount of time, to experiment with better approaches to dealing with missing data, calculating variances or making corrections for survey gear changes. This problem hindered development of new assessment models in this assessment.

(11) Significant amounts of the survey data, sensor data and port sample data that have been collected since 1980 have not been placed in the official NMFS electronic database. It is recommended that all of these data be entered into a comprehensive database.

Yield

(12) Data need to be gathered to estimate the amount of meat in a bushel of clams as a function of region and season.

Sediment Sampling

(13) Additional sediment samples are needed to understand the relationship between surfclam density, growth, habitat, and dredge efficiency. Sediment samples taken to a depth of 0.5 meters might provide more information, but deeper sampling will require a special sampling gear.

(14 A modified hydraulic patent tong could be designed and tested for sediment sampling in deep water.

Other

(15) Re-assess natural mortality rates again including the influence of body size.

(16) Develop a model aimed at estimating K and dealing with tradeoffs between R and M.

(17) Look at the possible negative effects of global warming on the surfclam production in some regions.

(18) Consider using a simpler spatial stratification of regions in the next stock assessment for surfclam. The use of 7 assessment regions may be unnecessary given that fishing is near zero in most assessment regions.

SARC COMMENTS

The SARC accepted the revised estimate of M = 0.15 which is based upon recent age and growth studies. The SARC noted that, for consistency, all analyses within the current assessment should use M=0.15.

The SARC agreed that the survey efficiency estimates seemed reasonable. There was some discussion on why the five separate efficiency estimates were given equal weight in estimating the overall mean; however, it was concluded that the averaging was acceptable. The survey biomass estimates based upon overall mean efficiency were accepted.

The SARC noted that, in recent years in the NNJ region, low productivity of the stock and near constant population biomass suggest that the biomass-production curve is well specified at high biomass levels. However, the curve is less certain at low levels and may overestimate production because the data were collected during a major recruitment pulse of the early 1980's.

The SARC suggested that, in the past, high levels of catch in some areas could not be sustained; given this, the SARC suggested that it may be advantageous to avoid localized depletion.

The SARC discussed the overfishing definition and the MSY-based control rule for surfclams. The SARC noted that overfishing definitions apply to the entire stock and hence, imply the possibility of increased landings in the future. The SARC also noted that it would be a Council decision whether to use more restrictive measures for management. The SARC recommended ½ the current biomass to be the proxy for B_{MSY}, under the assumption that the current biomass is largely unaffected by fishing and probably close to the carrying capacity for this species. The SARC also accepted ½ Bmsy as the proxy for $B_{Threshold}$, and F=M as the proxy for Fmsy.

The SARC discussed the choice of biomass thresholds in the context of a rebuilding strategy when biomass drops below ½ Bmsy; a linear function between zero and ½ Bmsy or a curvi-linear function representing the rate in which the stock will re-build within 10 years (using results the production model and the intrinsic growth rate). The SARC recommends a linear rebuilding schedule.

The SARC noted that the KLAMZ model yielded similar results to the catch-swept area estimates. The KLAMZ model uses all available information to provide estimates of historical biomass, F's, and projections. The catch-swept area model uses data from only recent NMFS clam surveys to estimate recent biomass.

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Table E1. 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 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	18,592	4,887	73	18,892
1984	31,862	22,888	7,086	72	18,892
1985	32,894	22,480	9,204	68	21,205
1986	35,720	24,520	10,797	69	24,290
1987	27,553	21,744	5,406	79	24,290
1988	28,824	23,377	4,873	81	24,290
1989	30,424	21,887	8,089	72	25,184
1990	32,556	24,018	8,528	74	24,282
1991	30,037	20,615	9,399	69	21,976
1992	33,831	21,685	11,722	64	21,976
1993	33,527	21,859	11,565	65	21,976
1994	31,048	21,942	9,106	71	21,976
1995	28,733	19,627	9,429	68	19,779
1996	28,775	19,771	8,980	69	19,779
1997	26,298	18,611	7,687	71	19,779
1998	24,509	18,233	6,276	74	19,779
1999	-	15,000	-	-	19,779

[1]Landings through 1982 are from the U.S. Dept. Of Commerce series "Fisheries of the United States". For 1983 - 1999, EEZ landings were computed from the logbook database, total landings were from "Fisheries of the US", and state landings were computed as (Total - EEZ landings). EEZ landings for 1999 were projected from data available August 15, 1999.

Table E2 . Annual EEZ surfclam landings from areas of the Mid-Atlantic region, and percent of Mid-Atlantic landings by region.

Year	Long Island mt	Long Island %	Northern New Jersey mt	Northern New Jersey %	Southern New Jersey mt	Southern New Jersey %	Delmarva mt	Delmarva %	Southern Virginia North Carolina mt	Southern Virginia North Carolina %
1978	0	0	1,348	31	53	1	2,927	68	0	0
1979	0	0	1,463	38	97	3	2,268	59	0	0
1980	0	0	1,692	41	132	3	2,300	56	0	0
1981	0	0	6,462	97	114	2	95	1	0	0
1982	49	4	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	4	8,787	49	1,776	10	5,303	30	1,897	11
1985	0	0	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	0	0	17,238	87	749	4	1,306	7	387	2
1988	0	0	19,196	91	195	1	1,147	5	591	3
1989	0	0	16,415	82	90	<1	3,118	16	461	2
1990	0	0	16,996	74	891	4	3,546	15	1,502	7
1991	15	<1	17,623	86	1,289	6	1,634	8	0	0
1992	61	<1	18,334	85	2,064	10	1,221	6	0	0
1993	62	<1	16,338	75	2,023	9	3,418	16	0	0
1994	71	<1	17,754	81	664	3	3,454	16	35	<1
1995	0	0	15,749	82	713	4	2,752	14	5	<1
1996	26	<1	16,077	82	1,331	7	2,237	11	0	0
1997	73	<1	14,060	76	2,934	16	1,540	8	5	<1
1998	89	<1	13,142	76	3,625	21	379	2	-	-
1999[1]	8	<1	5,204	74	1,705	24	92	1	-	-

[1] Partial year, from data available August 15, 1999.

Table E3. Comparison of Mid-Atlantic EEZ surfclam landings per unit effort (LPUE, kilograms per hour fishing time) & 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. LPUE is not shown when % is <1.

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	-	<1	959	29	1,063	71
1992	-	<1	1,018	22	851	77
1993	-	<1	1,118	20	904	79
1994	-	<1	1,058	26	791	73
1995	-	<1	1,179	29	796	70
1996	-	<1	971	35	764	65
1997	-	<1	863	28	745	72
1998	-	<1	1,031	26	663	74
1999	-	-	928	20	808	80
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	-	<1	1,003	22	1,604	78
1988	-	-	8,789	31	1,437	69
1989	514	3	1,001	47	1,200	50
1990	-	<1	1,070	37	1,237	62
1991	-	<1	1,454	39	1,701	61
1992	-	-	1,589	43	2,008	57
1993	-	<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	330	2	1,334	60	1,256	38
1998	566	2	2,272	44	1,803	54
1999	-	<1	2,427	29	1,700	70
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	-	<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	-	-	1,594	47	1,278	53
1998	-	-	1,768	81	869	19
1999	-	-	1,985	91	790	9

Table E4. Standardized commercial LPUE for surfclam, by assessment area, from loglinear models. CV's are based on the standard errors of the year coefficients.

Year	DMV	CV	LI	CV	NNJ	CV	SNJ	CV	SVA	CV
1980	1.00	0.01	1.00	0.28	1.00	0.04	1.00	0.04	1.00	0.53
1981	1.38	0.02	1.19	0.26	0.82	0.03	1.57	0.06	1.18	0.08
1982	1.10	0.02	1.14	0.28	0.48	0.03	1.25	0.04	1.47	0.08
1983	1.39	0.02	1.92	0.28	0.72	0.03	1.52	0.05	1.72	0.08
1984	2.50	0.02	1.07	0.47	1.19	0.03	2.71	0.05	2.16	0.08
1985										
1986										
1987										
1988										
1989										
1990										
1991	6.05	0.04	1.59	0.41	2.17	0.03	9.37	0.06		
1992	7.19	0.05	4.04	0.37	1.93	0.03	10.31	0.05		
1993	7.14	0.03	4.56	0.34	2.07	0.03	12.01	0.06		
1994	10.55	0.03	4.12	0.31	1.89	0.03	9.85	0.08		
1995	9.72	0.03			1.94	0.03	6.95	0.08	3.26	0.08
1996	7.97	0.03	2.32	0.41	1.81	0.03	7.00	0.06		
1997	7.71	0.04	5.02	0.30	1.73	0.03	8.85	0.05	3.95	0.24
1998	9.07	0.09	2.41	0.29	1.61	0.03	13.30	0.05		
1999	10.55	0.17	3.31	0.64	1.80	0.04	11.38	0.06		

Table E5. Summary statistics on surf clam commercial length frequency data by region/year. Data were collected by port agents taking random samples from landings.

Region/Year	Mean Length (mm)[1]	Min L	Max L	Number of Clams Measured[2]
New Jersey				
1982[3]	140.5	75	205	7477
1983	142.5	75	205	11253
1984	142.1	45	195	12751
1985	140.4	55	195	7674
1986	136.3	105	175	5130
1987	134.4	95	185	900
1988	137.7	85	165	900
1989	139.9	105	175	919
1990	136.5	95	175	901
1991	143.0	93	188	2272
1992	141.1	64	186	1710
1993	139.8	80	170	928
1994	138.5	85	185	900
1995	141.9	85	175	510
1996	138.0	85	185	1117
1997	136.7	75	195	957
1998	147.3	95	205	690
1999	151.6	115	175	120
Delmarva				
1982	159.0	85	205	7756
1983	151.5	45	205	5923
1984	138.8	95	195	3066
1985	132.0	95	175	1832
1986	130.0	95	155	1260
1987	131.4	105	165	730
1988	136.0	115	165	420
1989	136.6	115	175	866
1990	139.1	95	175	892
1991	125.5	20	183	1080
1992	123.5	73	198	1170
1993	122.4	77	155	1392
1994	109.2	85	135	119
1995	125.1	105	155	720
1996	124.0	95	155	1154
1997	127.1	95	175	1622
1998	122.7	95	155	1560
1999	125.9	105	175	900
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]	-	-	-

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. 1999 is a partial year of data.

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 after 1990.

Table E6. List of research clam surveys and gear changes from 1965-1981, and 1997-1999. Column entries were shifted to accentuate changes. Changes in the gear and survey season did not occur from August, 1980 to 1992. Sources of information for 1978-1981 are Smolowitz and Nulk 1982 and NEFSC Cruise reports. Sources of information for 1965-1977 are NEFSC 1995a and NEFSC Survey Reports. "Sensors Used" refers to the velocity, tilt and pump pressure sensors used in computing tow distance and pump performance. These were used for the first time in 1997. "-" = undetermined.

Cruise	Date	Vessel	Season	Purpose	Pump Type	Dredge Width	Mesh Size (cm)	Doppler Measured	Sensors Used
65-	5/65	Undaunted	Spring	Survey	Surface	76	5.1	-	No
65-10	10/65	Undaunted	Fall	Survey	Surface	76	5.1	-	No
66-6,11	8/66	Albatross IV	Summer	Survey	Surface	76	5.1	-	No
69-1, 7	6/69	Albatross IV	Summer	Survey	Surface	76	5.1	-	No
70-6	8/70	Delaware	Summer	Survey	Surface	122	3	-	No
SM742	6/74	Delaware	Summer	Survey	Surface	76	5.1	-	No
76-1	4/76	Delaware	Spring	Survey	Surface	122	3	-	No
77-2	1/77	Delaware	Winter	Survey	Surface	122	3	-	No
7801	1/78	Delaware	Winter	Survey	Surface	122	1.91	No	No
7807	12/78	Delaware	Winter	Survey	Surface	122	1.91	Yes	No
7901	1/79	Delaware	Winter	Survey	Submerse	152	2.54	Yes	No
7908	8/79	Delaware	Summer	Gear test	Submerse	152	2.54 & 5.08	Yes	No
8001	1/80	Delaware	Winter	Survey	Submerse	152	5.08	Yes	No
8006	8/80	Delaware	Summer	Survey	Submerse	152	5.08	Yes	No
8105	8/81	Delaware	Summer	Survey	Submerse	152	5.08	Yes	No
9704	7/97	Delaware	Summer	Survey	Submerse	152	5.08	Yes	Yes[1]
9903	7/99	Delaware	Summer	Survey	Submerse	152	5.08	Yes	Yes[2]

[1] Individual sensors were used.

[2] A new integrated sensor package was used for the first 2/3 of the cruise. After that, individual sensors were used.

Table E7. Recent gear changes related to the NMFS Clam Survey, 1992-1999. Column entries were shifted to accentuate changes. Changes in the gear and survey season did not occur from August, 1980 to 1992. Sources of information are NEFSC Cruise meetings. "-" = undetermined.

Cruise	Date	Vessel	Ship Modified	Winch Changed	Winch Speed Out (met/min)	Winch Speed In (met/min)	Voltage to Pump
pre-92					60	60	460
9203	6/92	Delaware II		---	---	80	460
9404	8/94	Delaware II			Free spool	80	480
9704	7/97	Delaware II	1/97	1/97	20	20	460
9903	7/99	Delaware II		5/99	50 - 60	50 - 60	460

Table E8. Surfclam selectivity by the clam dredge on the DE-II, during the 1999 Clam Survey. Clams were collected off NJ, June 6-11, 1999. Each clam was checked to see if it could be pushed through 2 parts of the dredge, the floor at the entrance (just bars, no liner) (I, and the lined cage (II). Girth = both valves closed, max width side to side.

	Shell Measurement:			Can SCs pass this space in the dredge?				
Count	Length (mm)	Height	Girth	I		II		
1	66	46	26	Y	EASY	Y	EASY	
2	70	52	27	Y	EASY	Y	EASY	ON SLANT
3	74	51	27	Y	EASY	Y	EASY	ON SLANT
4	79	55	31	Y		Y		
5	79	57	34	Y		Y	EASY	ON SLANT
6	83	60	31	Y	EASY	Y	EASY	ON SLANT
7	83	57	34	Y		Y	BARELY	
8	84	57	34	Y	EASY	Y		
9	84	62	35	Y		N		
10	85	61	33	Y		N		
11	86	60	36	Y		N	BARELY	
12	87	62	34	Y	CLOSE	N		
13	87	62	36	Y		N		
14	90	63	36	Y		N		
15	91	63	39	Y,N *		N		
16	94	69	38	Y,N		N		
17	95	66	38	Y,N		N		
18	96	68	38	Y,N		N		
19	105	74	45	N		N		
20	111	77	43	N		N		
21	130	87	55	N		N		
22	139	100	59	N		N		

* Y,N : CAN PASS THROUGH SOME BARS BUT NOT OTHERS.

Table E9. Comparison of catch rates in 1999 with stations resampled from the 1997 survey. Predicted values for 1999 are based on truncated size range for DMV surfclam sites. Observed Values for 1999 are truncated to the range of sizes that were available to the 1997 survey. 1999 obs values truncated at 86.9+ mm shell length. M=0.15. The formula for the variance of a ratio is from Mendenhall et al. (1971).

Station	1997 observed	1999 predicted	1999 observed	Ratio (99obs/ 99pred)	Var(Ratio)	SD(Ratio)
1	35.338	26.18	0			
2	5.793	4.29	0			
3	17.959	13.3	10.57			
4	20.276	15.02	0			
5	24.91	18.45	37.6			
6	0	0	0			
7	26.069	19.312	1.6			
8	729.928	540.744	181.2			
9	115.282	85.4	42			
10	2.897	2.14	235.2			
11	103.117	76.391	13.5			
12	0	0	2.2			
13	110.068	81.541	10.89			
14	140.772	104.286	59.65			
15	3.476	2.57	1.9			
16	112.386	83.26	10.5			
17	416.522	308.56	77			
18	48.083	35.6	50.7			
19	170.896	126.6	290.8			
20	195.227	144.63	82.8			
21	12.165	9.012	11.5			
Sum	2291.164	1697.286	1119.61	0.660	0.609	0.780

	x	y
mean	154.2987	101.7827273
n	21	

Table E10. Summary of initial direct estimates of dredge efficiency for R/V Delaware II and three commercial fishing vessels from depletion experiments.

Experiment	Model	Tows	Density (#/ft^2)	Efficiency	K	Gamma	LL(C| a,D,e,K,gamma)	Comment
DE II--Surfclam	unconstrained	54	0.467	0.148	3.56	0.141	369.46	Lack of Contrast, density and efficiency cannot be estimated simultaneously
	D=0.1 fixed		0.100	0.795	3.37	0.111	370.95	
	D=0.2 fixed		0.200	0.356	3.56	0.110	369.58	
	D=0.3 fixed		0.300	0.231	3.56	0.110	369.46	
	D=0.4 fixed		0.400	0.173	3.57	0.122	369.46	
F/V Christy	unconstrained	28	0.829	0.431	8.05	0.228	214.66	good convergence
DE II--Ocean Quahog	unconstrained	60	0.648	0.249	7.57	0.650	418.45	
F/V Jersey Girl #1	unconstrained	4	0.023	0.900	1.34	1.000	27.50	Unreliable, solution at boundaries of parameter space
F/V Jersey Girl #2	unconstrained	5	0.040	0.900	10.69	0.999	30.21	Unreliable, solution at boundaries of parameter space
F/V Jersey Girl #3	unconstrained	6	0.046	0.900	15.80	1.000	35.92	Unreliable, solution at boundaries of parameter space
F/V Melissa J #1	unconstrained	4	0.057	0.874	21.83	0.905	23.88	
F/V Melissa J #2	unconstrained	10	0.131	0.733	32.23	0.387	65.32	

Table E11. Summary of indirect estimates of dredge efficiency for R/V Delaware II through comparisons with three commercial fishing vessels from depletion experiments. Because area swept was unknown for 2 DE II tows at Melissa J site #1, the mean area/tow from other DE II setup tows was used.
The first 6 tows of the DE II Surfclam Depletion Exp. Were treated as setup tows for comparison with the F/V Christy.

Relative Catch Rates by DE II at depletion Exp Site

	Direct Experiment Results				Var(rel Density)		Setup Tow Number							Indirect Efficiency Est for DE II in 1999
Experiment	Tows	Density (#/ft^2)	Efficiency	Rel Densit	SD(rel Density)	Response Var	1	2	3	4	5	6	mean	
DE II--Surfclam	54	0.467	0.148											
0.243														
F/V Christy	28	0.829	0.431	0.069635	0.000530	catch (raw no.) :	477	340	243	525	723	387	449.2	0.084
					0.023018	area swept (ft^2) :	6663	6576	6119	6479	6436	6429	6450	
DE II--Ocean Quahog	60	0.648	0.249											
F/V Jersey Girl #1	4	0.023	0.900	0.011458	0.000015	catch (raw no.) :	108	58	88	46			75.0	0.500
					0.003819	area swept (ft^2) :	7151	7297	5593	6140			6545	
F/V Jersey Girl #2	5	0.040	0.900											0.290
F/V Jersey Girl #3	6	0.046	0.900	0.017361	0.000023	catch (raw no.) :	214	67	77	145			125.8	0.378
					0.004760	area swept (ft^2) :	10028	5739	6498	6708			7243	
F/V Melissa J	4	0.057	0.874	0.014017	0.000095	catch (raw no.) :	136	180	42	19			94.25	0.247
					0.009755	area swept (ft^2) :	6684	6817	6711	6684			6724	
F/V Melissa J	10	0.131	0.733	0.011938	0.000029	catch (raw no.) :	110	37	59				68.7	0.091
					0.005344	area swept (ft^2) :	5639	5484	6134				5752	

Predicted efficiency of DE II computed as Density (DE II)/Density(Christy) * Efficiency(Christy)

Table E12. Ratio estimator from surfclam swept area abundances in 97 and 99. If there have been no changes in biomass between 97 and 99 then this estimates the ratio of the efficiencies in the two years.

Region	N-97	N-99	area	Wtd97	Wtd99
dmv	68	32	5092	346256	162944
snj	18	42	1228	22104	51576
nnj	76	41	3440	261440	141040
li	3	9	2945	8835	26505
means				159659	95516

ratio	0.5983			
var	0.0403		97 effic	0.59
stderr	0.2008			

Assuming 97 efficiency of 0.59, the 99 efficiency would 0.353

Table E13. Summary of efficiency estimates for clam dredge on the Delaware II, in 1999.

Approach:	Efficiency Estimate
Repeated stations	0.3891
Delaware "direct" experiment	0.1480
Industry--Delaware "Indirect"	0.2456
Christy-- DE2 cross check	0.2430
Random stations, 1997 and 1999	0.3530
grand average	0.2757
Stnd. Err. Of Mean	0.0963
CV	0.3493

Table E14. Calculation of percent suitable habitat for surfclam in the Georges Bank assessment region based on the proportion of randomly chosen stations that were "good" (haul code not equal 151) and "bad" (haul code 151) during the 1999 NMFS clam survey. Percent suitable habitat was used to adjust efficiency corrected swept area biomass data for Georges Bank in 1997 and 1999.

Survey Strata With Surfclam Habitat	Stratum Area (nm^2)	Good Stations	Bad Stations	Total Stations	Percent Good
54	295	3	0	3	100%
55	386	2	0	2	100%
57	176	2	0	2	100%
59	512	4	0	4	100%
61	588	6	0	6	100%
65	184	3	0	3	100%
67	196	7	1	8	88%
68	380	5	0	5	100%
69	902	7	1	8	88%
70	544	3	0	3	100%
71	168	1	0	1	100%
72	472	6	4	10	60%
73.	526	5	4	9	56%
74	443	3	1	4	75%
Total	5772	57	11	68	
Area Weighted Average					88%

Table E15. Survey data (numbers of surfclams per standard tow) used in the KLAMZ model by stock assessment area. Nominal tow distances were used for the 7801 cruise. Tow distance for the 7807-9404 cruises were measured by doppler. Tow distances for the 9704 and 9903 were measured by doppler and bottom sensors. Survey data for pre-recruits (100-119 mm in SNJ & NNJ, 80-99 mm in other areas) were lagged forward one year in KLAMZ. Data for surveys during 1978 (cruises 7801 and 7807) and 1980 (cruises 8001 and 8006) were averaged for use in KLAMZ.

Region	Cruise	N/Tow 80-99 mm	N/Tow 100-109 mm	N/Tow 100-119 mm	N/Tow 120-129 mm	KG/Tow All Sizes	CV
DMV							
	7801	2.08	0.49	0.79	0.58	1.053	0.22
	7807	1.88	1.17	1.78	1.35	7.539	0.94
	7901	1.06	0.90	2.20	1.19	3.532	0.50
	8001	36.87	2.71	4.32	1.69	3.444	0.46
	8006	29.26	12.37	13.71	1.46	3.335	0.39
	8105	85.52	59.10	79.21	4.06	7.589	0.60
	8204	27.30	45.20	75.20	9.10	6.293	0.40
	8305	3.80	5.90	26.30	17.70	4.442	0.50
	8403	108.50	17.40	37.70	13.20	8.692	0.63
	8604	5.70	10.30	53.40	48.00	9.475	0.40
	8903	2.60	5.90	14.00	11.50	3.714	0.27
	9203	3.30	2.10	8.20	11.30	3.312	0.29
	9404	14.00	15.50	44.40	21.20	8.594	0.23
	9704-doppler	24.80	17.40	48.20	29.50	7.916	0.18
	9704-sensor	11.80	8.70	24.60	15.10	4.026	0.18
	9903-doppler	2.50	6.50	24.10	13.80	3.488	0.24
	9903-sensor	1.60	4.20	15.10	8.50	2.146	0.24
GBK							
	7801						
	7807						
	7901						
	8001						
	8006	0.42	0.07	0.14	0.00	0.022	0.00
	8105						
	8204	1.70	1.00	2.80	1.60	0.524	0.50
	8305	0.50	0.10	0.40	0.10	0.066	0.82
	8403	1.90	0.90	1.50	0.70	1.477	0.45
	8604	4.30	1.60	3.60	1.00	0.983	0.68
	8903	0.60	0.60	3.80	6.80	3.574	0.68
	9203	5.20	3.60	6.30	2.20	1.436	0.34
	9404	9.10	6.80	15.40	9.30	6.153	0.33
	9704-doppler	17.00	11.10	24.20	9.10	4.344	0.22
	9704-sensor	13.50	9.00	20.30	8.20	3.646	0.26
	9903-doppler	4.80	4.40	11.50	9.40	3.258	0.34
	9903-sensor	4.40	4.00	9.80	7.50	2.672	0.39
LI							
	7801	0.16	0.02	0.04	0.05	0.356	0.31
	7807	0.15	0.00	0.13	0.04	0.868	0.38
	7901	0.21	0.16	0.33	0.16	0.653	0.15
	8001	0.21	0.00	0.00	0.10	0.264	0.42
	8006	0.11	0.04	0.11	0.71	0.787	0.28
	8105	0.09	0.03	0.03	0.00	0.024	0.58
	8204	0.00	0.00	0.00	0.10	0.656	0.67
	8305	0.00	0.00	0.00	0.10	0.064	0.61
	8403	0.50	0.10	0.80	0.40	1.195	0.22
	8604	0.20	0.00	0.10	0.00	0.290	0.47
	8903	0.60	0.50	1.00	0.60	0.614	0.81
	9203	1.80	0.90	3.50	1.30	0.585	0.39
	9404	1.20	0.80	2.60	2.20	1.208	0.16
	9704-doppler	0.20	0.50	1.20	0.60	0.694	0.62
	9704-sensor	0.20	0.30	0.70	0.30	0.394	0.65
	9903-doppler	0.20	0.00	0.20	0.30	1.502	0.63
	9903-sensor	0.10	0.00	0.10	0.20	1.055	0.61
NNJ							
	7801	0.58	0.20	0.40	0.07	0.144	0.29
	7807	19.11	3.56	4.38	0.55	1.915	0.30

	7901	1.47	0.84	1.04	0.33	0.341	0.31
	8001	13.67	10.20	14.34	1.09	2.475	0.27
	8006	3.65	10.32	35.24	9.66	3.779	0.65
	8105	5.77	4.09	12.58	7.81	3.714	0.22
	8204	14.40	13.90	31.80	18.40	7.367	0.20
	8305	5.60	18.10	40.10	18.20	6.599	0.33
	8403	6.90	4.50	12.20	16.00	5.956	0.20
	8604	4.40	3.10	8.40	10.40	5.668	0.18
	8903	3.40	2.50	8.10	9.80	6.164	0.15
	9203	5.80	4.80	15.90	7.20	5.439	0.21
	9404	20.90	13.90	34.10	22.50	15.861	0.13
	9704-doppler	6.40	6.20	18.50	19.40	16.655	0.13
	9704-sensor	3.00	3.20	9.60	9.70	8.622	0.13
	9903-doppler	2.20	1.60	4.60	5.70	8.138	0.13
	9903-sensor	1.20	0.90	2.60	3.20	4.906	0.12
SNE							
	7801	1.51	0.65	2.38	3.24	5.525	1.00
	7807						
	7901	1.47	0.00	0.00	0.00	0.054	0.00
	8001	0.00	0.50	0.79	0.86	3.596	0.37
	8006	0.32	0.13	0.33	0.19	0.468	0.58
	8105	0.11	0.00	0.00	0.14	1.011	0.84
	8204	1.70	1.10	1.80	1.70	2.031	0.37
	8305	0.40	0.20	0.50	0.50	1.499	0.32
	8403	0.10	0.20	0.40	0.60	2.416	0.32
	8604	0.10	0.10	0.20	0.10	0.949	0.59
	8903	0.90	0.20	0.50	0.30	1.284	0.35
	9203	0.80	0.10	0.10	0.00	0.627	0.45
	9404	0.40	0.30	0.70	0.20	0.400	0.41
	9704-doppler	1.00	0.50	1.10	0.90	2.354	0.30
	9704-sensor	0.50	0.30	0.60	0.40	1.294	0.34
	9903-doppler	1.40	0.20	0.40	0.30	1.124	0.47
	9903-sensor	0.80	0.10	0.20	0.20	0.797	0.51
SNJ							
	7801	0.71	0.59	1.25	0.58	2.468	0.26
	7807	0.65	0.86	1.11	0.46	0.707	0.39
	7901	0.36	0.55	0.55	0.00	0.912	0.71
	8001	0.07	0.08	0.73	1.07	2.157	0.29
	8006	0.30	0.44	0.70	0.39	2.628	0.31
	8105	0.15	0.00	0.16	0.06	2.177	0.36
	8204	1.50	3.10	16.90	5.60	4.946	0.58
	8305	0.20	0.10	0.60	0.40	2.391	0.31
	8403	0.00	0.10	0.10	0.30	2.147	0.27
	8604	1.90	0.50	0.80	0.10	3.826	0.42
	8903	1.50	0.30	0.70	0.40	2.221	0.37
	9203	1.00	1.00	1.70	0.70	1.498	0.40
	9404	14.00	11.20	26.00	15.70	12.906	0.56
	9704-doppler	0.90	0.50	1.90	4.10	3.619	0.36
	9704-sensor	0.40	0.20	1.00	2.70	2.155	0.40
	9903-doppler	0.30	0.30	7.20	27.40	7.000	0.86
	9903-sensor	0.20	0.20	4.40	16.50	4.264	0.85
SVA							
	7801	0.18	0.13	0.13	0.05	0.197	0.29
	7807						
	7901						
	8001	11.04	13.97	15.93	0.00	0.975	0.99
	8006						
	8105	0.60	0.44	1.92	3.63	1.798	0.90
	8204	0.50	0.30	0.80	0.00	0.165	0.46
	8305	1.10	1.80	4.60	2.10	0.622	0.61
	8403	1.50	1.20	4.90	6.20	1.583	0.31
	8604	0.20	0.30	0.80	4.40	1.644	0.77
	8903	1.50	0.30	0.80	1.00	0.868	0.82
	9203	1.10	4.40	11.30	3.60	1.351	0.62
	9404	2.30	2.20	5.40	2.40	0.824	0.38
	9704-doppler	1.80	2.20	3.40	0.30	0.338	0.79
	9704-sensor	0.90	1.00	1.60	0.10	0.169	0.80
	9903-doppler						
	9903-sensor						

Table E16. Surfclam Supply Year Calculations | *Whole Stock Run with m=* | *0.05*

10 Year Harvesting Horizon Policy (with option to harvest unexploited stock)

Nov. 7, 1999

ASSUMPTIONS / INPUTS:

Full-Recruit Biomass estimate for 1999: (from SAS)

Region	Minimum Biomass
GBK	67.1 thousand mt
SNE	26.4
LI	24.4
NNJ	142.5
SNJ	42.8
DMV	57.7
SVA	4.1
Sum	365.0

Dredge Efficiency : 0.26

Sum (Adj. for Effic.) : 1403.9 thousand mt

Full Rec. Stock Biomass (1999, Exploited Area only)

Do not change value used in harvest calc:
1+exp(M)+exp(2M)+...+exp(9M) = 9.44
(note: M = m-g)

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

Year	Catch (mt)	Source
1999	19,779	1999 quota
2000	19,779	2000 quota

Conversion Fac: 17 lbs/bu

Policy: Harvest calculated for 10-yr horizon

Natural Mortality Rate, m : 0.05

Indirect Catch (eg. .2=20%) : 0.20

Overfishing Def: F_ref 0.18 = Label F_20% MSP

Portion of total biomass that is unexploited in 2000 : 0.0%

Annual Recruitment: (Pre-recruits grow to Full-Recruits)
179,281 mt. Based on mean fraction of pre-recr. wt in last 5 surveys (1989-1999). Fraction is applied to "Actual" 1999 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) : 1.00

Starting in Year (>=2001): 2001

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	Nominal Harvest from mt	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	2000	1,579,835	-	1,579,835	19,779	2,565,014	1.3%	1.3%	0.18	16.1%
==>	2	2001	1,758,044	-	1,758,044	365,526	47,402,785	**20.8%**	**20.8%**	**0.18**	16.1%
0	3	2002	1,518,265	-	1,518,265	340,124	44,108,577	22.4%	22.4%	0.18	16.1%
0	4	2003	1,306,236	-	1,306,236	317,662	41,195,599	24.3%	24.3%	0.18	16.1%
0	5	2004	1,118,744	-	1,118,744	297,799	38,619,733	26.6%	26.6%	0.18	16.1%
0	6	2005	952,950	-	952,950	280,235	36,341,965	29.4%	29.4%	0.18	16.1%
0	7	2006	806,343	-	806,343	264,704	34,327,798	32.8%	32.8%	0.18	16.1%
0	8	2007	676,703	-	676,703	250,970	32,546,726	37.1%	37.1%	0.18	16.1%
0	9	2008	562,065	-	562,065	238,826	30,971,772	42.5%	42.5%	0.18	16.1%
0	10	2009	460,694	-	460,694	228,086	29,579,085	49.5%	49.5%	0.18	16.1%

Table E17.

DOCUMENTATION AND NOTES FOR USERS (SURFCLAM SPREADSHEET) :

Total Biomass = Exploited Biomass + Unexploited Biomass (i.e., the exploited and unexploited portions of biomass are additive).

The exploited stock is impacted by harvesting whereas the unexploited stock is not. Both portions of the stock are affected by natural mortality and recruitment. The annual harvest is a variable (see next paragraph). Natural mortality is a constant, whose value is given above (see "ASSUMPTIONS"). The exploited and unexploited portions of the stock are increased by annual recruitment (assumed constant; i.e, unrelated to biomass). Recruitment was estimated empirically for the exploited area. The level of recruitment to the unexploited area is based on the recruitment to the exploited area, adjusted by a factor relating the biomass of the unexploited area to the biomass of the exploited area, in the starting year.

Estimation of annual harvest:
The annual harvest for 1999 and 2000 have been set equal to the annual quotas for those years.
For the years 1999 through 2024, the annual harvest is computed as the annual catch that could be taken from the exploited stock for 10 years, while recruitment and natur. mortal. are taking place, such that in year 11 the exploited stock is completely depleted. The stock does not actually run out after 10 years because the annual harvest is updated in each year of the simulation, based on the most recent year's biomass in the exploited region (i.e., the 10-yr calc. is made every year). Thus, the annual harvest always represents that which could be taken for an additional 10 years given the most recent exploitable biomass (B).
Calculation of nominal annual harvest (C) is based on the catch equation (note: M = m-g, the difference between natural mortality and the growth rate) :
B_1 = (B_0 - C + R)*exp(-M), where "_#" represents an annual time step.
The generalized form of the catch equation is :
B_t = B_0*exp(-Mt) + [summation from i to t:] [(R - C)*exp(-Mi)].
To get C(T), the nominal annual harvest for year T with the 10-yr horizon, the above equation is assigned the following values: B_0 = current exploitable biomass at time T, t = 10 and B_10 = 0, and then it is solved for nominal annual harvest :
C(T) = [Expl. Biomass(T) / (1 + exp(M) + exp(2M) + ... + exp(9M))] + (Ann. Recrt. to Expl. Area).

The above equation is affected in the following ways when some fraction of unexploited biomass is made exploitable in a certain year: Expl. Biomass(T) = biomass from the historically exploited area + additional biomass from the previously unexploited area. Recrt. to Expl. Area = recruitment from the historically exploited area + additional recruitment from the previously unexploited area. Recruitment to the unexploited area is decremented by the amount now added to the exploited area.

Indirect Catch is taken out of the Exploitable Biomass each year (as a percentage of the Nominal Catch) before C(T) is computed.

Using the program:
This spreadsheet was developed to be a flexible tool for examining the dynamics of clam stocks. The results depend on a number of assumptions about the biology of the species and the fraction of the stock that is exploited. These assumptions are under the control of the User, and the importance of the assumptions can be explored by changing their input values. Given this flexibility, it is the User's responsibility to interpret the results in light of the assumptions being made. When the User changes certain cells in the "Assumptions / Inputs" section the rest of the spreadsheet will be updated automatically. "Assumptions / Inputs" that the user can change include: Biomass by region for 1999, Commercial catch from 1999-2000, m, Portion of biomass that is unexploited in 1999, fraction of the unexploited biomass to start exploiting in a particular year, F_ref and its label (e.g. F_20%MSP), mean recruitment to the exploited areas and annual growth in tissue by fully recruited clams.

The "10 year harvesting horizon" is fixed (can not be changed by the user without major modifications).

Table E18. Surfclam Supply Year Calculations
10 Year Harvesting Horizon Policy (with option to harvest unexploited stock)

(Whole Stock MINUS GBK) Run with m=	**0.05**

Nov. 7, 1999

ASSUMPTIONS / INPUTS:

Full-Recruit Biomass estimate for 1999: (from SAS)

Region	Minimum Biomass
GBK	0 thousand mt
SNE	26.4
LI	24.4
NNJ	142.5
SNJ	42.8
DMV	57.7
SVA	4.1
Sum	298.0

Dredge Efficiency : 0.26

Sum (Adj. for Effic.) : 1146.0 thousand mt
Full Rec. Stock Biomass (1999, Exploited Area only)

Do not change value used in harvest calc:
1+exp(M)+exp(2M)+...+exp(9M) = 9.44
(note: M = m-g)

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

Year	Catch (mt)	Source
1999	19,779	1999 quota
2000	19,779	2000 quota

Conversion Fac: 17 lbs/bu

Policy: Harvest calculated for 10-yr horizon

	F_ref		Label
Overfishing Def:	0.18	=	F_20% MSP

Natural Mortality Rate, m : 0.05
Indirect Catch (eg. .2=20%) : 0.20

Portion of total biomass that is unexploited in 2000 : 0.0%

Annual Recruitment: (Pre-recruits grow to Full-Recruits)
Based on mean fraction of pre-recr. wt in last 5 surveys (1989-1999).
133,051 mt: Fraction is applied to "Actual" 1999 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) : 1.00
Starting in Year (>=2001): 2001

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	Nominal Harvest from mt	Expl. Area: 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	2000	1,271,709	-	1,271,709	19,779	2,565,014	1.6%	1.6%	0.18	16.1%
==>	2	2001	1,399,060	-	1,399,060	281,266	36,475,548	**20.1%**	**20.1%**	0.18	16.1%
0	3	2002	1,210,193	-	1,210,193	261,257	33,880,784	21.6%	21.6%	0.18	16.1%
0	4	2003	1,043,183	-	1,043,183	243,564	31,586,306	23.3%	23.3%	0.18	16.1%
0	5	2004	895,500	-	895,500	227,919	29,557,362	25.5%	25.5%	0.18	16.1%
0	6	2005	764,909	-	764,909	214,084	27,763,222	28.0%	28.0%	0.18	16.1%
0	7	2006	649,430	-	649,430	201,850	26,176,714	31.1%	31.1%	0.18	16.1%
0	8	2007	547,315	-	547,315	191,033	24,773,809	34.9%	34.9%	0.18	16.1%
0	9	2008	457,018	-	457,018	181,467	23,533,258	39.7%	39.7%	0.18	16.1%
0	10	2009	377,171	-	377,171	173,008	22,436,274	45.9%	45.9%	0.18	16.1%

Table E19.

Biomass Production Model – Surfclam

(1-yr projection)
Time T = 1999

INPUTS : (Assumptions)

Nat. mortality (m) :	0.05
1999 Dredge Effic. (0-1):	0.28
Non-catch mortality (0-1):	0.2
Selectivity for <90mm	1.0

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

e:/survey/progs/sc991mm.xls
Dec. 3, 1999

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	-9.469134923	2.8601764	Average of OLD and NEW
3 SNJ	-9.312103506	2.863706089	Average of OLD and NEW for NNJ
4 NNJ	-9.312141362	2.863716797	Average of OLD and NEW
5 LI	-7.9837	2.5802	Murawski
6 SNE	-7.9837	2.5802	Murawski
7 GBK	-8.27442713	2.654215866	Average of OLD and NEW

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. Data from '97 were used to fill unsampled strata from '99.

OUTPUTS :

Wt per tow by Region (grams)
NOT ADJUSTED FOR DREDGE EFFICIENCY.

Region	Time = T	Time = T + 1
SVA	74.5	117.3
DMV	2,289.5	2,384.2
SNJ	4,635.7	5,054.6
NNJ	5,348.1	5,544.5
LI	1,053.8	1,077.1
SNE	796.2	805.0
GBK	2,322.3	2,495.1

Total Biomass Estimate:

Wt per tow by Region (grams) ADJUSTED FOR THE DREDGE EFFICIENCY LISTED ABOVE. Region	Time = T	Time = T + 1	Regional Biomass (MT) Adjusted for eff. Time = T (1999)	Regional Biomass (MT) NOT Adjusted for eff. Time = T (1999)
SVA	266.1	418.8	6,425	1,799
DMV	8,176.6	8,514.9	337,309	94,447
SNJ	16,556.0	18,052.1	164,709	46,119
NNJ	19,100.3	19,801.9	532,310	149,047
LI	3,763.7	3,846.9	89,798	25,143
SNE	2,843.4	2,874.9	101,426	28,399
GBK	8,294.0	8,910.9	339,260	94,993
			1,571,238	439,947

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

ADJUSTED FOR DREDGE EFFICIENCY & INDIRECT FISHING MORT.:

Region	Change in Biomass / Tow (gr)	% change per tow	Region Area (sq n.mi)	Possible Tows/ Region	Production : Regional Change in Biomass (M Tons)	Removals : 1998 Landings (dir + indir)	Net Production of Biomass: (Production - Removals) (M. Tons)	
1 SVA	153	57.4	2980	24,142,457	3,685.1	0	3,685.1	SVA
2 DMV	338	4.1	5092	41,252,815	13,954.0	455	13,499.2	DMV
3 SNJ	1496	9.0	1228	9,948,637	14,884.0	4,350	10,534.0	SNJ
4 NNJ	702	3.7	3440	27,869,145	19,552.5	15,770	3,782.1	NNJ
5 LI	83	2.2	2945	23,858,904	1,985.2	107	1,878.4	LI
6 SNE	32	1.1	4403	35,670,885	1,125.2	0	1,125.2	SNE
7 GBK	617	7.4	5049	40,904,451	25,236.0	0	25,236.0	GBK
					80,421.9 Annual Total (MT)	20,682	59,739.9	Sum (MT)

Table E20.

Biomass Production Model -- Surfclam

(1-yr projection)
Time T = 1999

INPUTS : (Assumptions)

Nat. mortality (m) :	0.15
1999 Dredge Effic. (0-1):	0.28
Non-catch mortality (0-1):	0.2
Selectivity for <90mm	1.0

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

e:/survey/progs/sc991mm.xls
Dec. 3, 1999

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	159.0846	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	-9.489134923	2.8601764	Average of OLD and NEW
3 SNJ	-9.312103506	2.863706089	Average of OLD and NEW for NNJ
4 NNJ	-9.312141362	2.863716797	Average of OLD and NEW
5 LI	-7.9837	2.5602	Murawski
6 SNE	-7.9837	2.5602	Murawski
7 GBK	-8.27442713	2.654215866	Average of OLD and NEW

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. Data from '97 were used to fill unsampled strata from '99.

OUTPUTS :

Wt per tow by Region (grams) — NOT ADJUSTED FOR DREDGE EFFICIENCY.

Region	Time = T	Time = T + 1
SVA	74.5	106.1
DMV	2,289.5	2,157.3
SNJ	4,635.7	4,573.6
NNJ	5,348.1	5,016.9
LI	1,053.8	974.6
SNE	796.2	728.4
GBK	2,322.3	2,257.6

Total Biomass Estimate:

Wt per tow by Region (grams) ADJUSTED FOR THE DREDGE EFFICIENCY LISTED ABOVE. Region	Time = T	Time = T + 1	Regional Biomass (MT) Adjusted for eff. Time = T (1999)	Regional Biomass (MT) NOT Adjusted for eff. Time = T (1999)
SVA	266.1	378.9	6,425	1,799
DMV	8,176.6	7,704.6	337,309	94,447
SNJ	16,556.0	16,334.2	164,709	46,119
NNJ	19,100.3	17,917.5	532,310	149,047
LI	3,763.7	3,480.8	89,798	25,143
SNE	2,843.4	2,601.4	101,426	28,399
GBK	8,294.0	8,062.9	339,260	94,993
			1,571,238	439,947

ADJUSTED FOR DREDGE EFFICIENCY: (T ===> T+1 comparisons)

ADJUSTED FOR DREDGE EFFICIENCY & INDIRECT FISHING MORT.:

Region	Change in Biomass / Tow (gr)	% change per tow	Region Area (sq n.mi)	Possible Tows/ Region	Production : Regional Change in Biomass (M Tons)	Removals : 1998 Landings (dir + indir)	Net Production of Biomass: (Production - Removals) (M. Tons)	
1 SVA	113	42.4	2980	24,142,457	2,723.0	0	2,723.0	SVA
2 DMV	-472	-5.8	5092	41,252,815	-19,473.2	455	-19,928.0	DMV
3 SNJ	-222	-1.3	1228	9,948,637	-2,206.6	4,350	-6,556.6	SNJ
4 NNJ	-1183	-6.2	3440	27,869,145	-32,964.2	15,770	-48,734.6	NNJ
5 LI	-283	-7.5	2945	23,858,904	-6,749.1	107	-6,855.9	LI
6 SNE	-242	-8.5	4403	35,670,885	-8,633.9	0	-8,633.9	SNE
7 GBK	-231	-2.8	5049	40,904,451	-9,450.4	0	-9,450.4	GBK
					-76,754.4 Annual Total (MT)	20,682	-97,436.4	Sum (MT)

Table E21.

Biomass Production Model -- Surfclam

(1-yr projection)
Time T = 1999

INPUTS : (Assumptions)

Nat. mortality (m) :	0.15
1999 Dredge Effic. (0-1):	0.28
Non-catch mortality (0-1):	0.2
Selectivity for <90mm	0.01

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

e:/survey/progs/sc991mm.xls
Dec. 3, 1999

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	159.0648	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	-9.489134923	2.8601764	Average of OLD and NEW
3 SNJ	-9.312103506	2.863706089	Average of OLD and NEW for NNJ
4 NNJ	-9.312141362	2.863716797	Average of OLD and NEW
5 LI	-7.9837	2.5802	Murawski
6 SNE	-7.9837	2.5802	Murawski
7 GBK	-8.27442713	2.654215866	Average of OLD and NEW

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. Data from '97 were used to fill unsampled strata from '99.

OUTPUTS :

Wt per tow by Region (grams) — NOT ADJUSTED FOR DREDGE EFFICIENCY.

Region	Time = T	Time = T + 1
SVA	3,249.6	6,398.4
DMV	4,341.2	4,888.8
SNJ	5,152.6	5,374.6
NNJ	9,648.9	12,164.0
LI	2,853.1	4,065.7
SNE	3,163.7	4,372.9
GBK	9,261.0	11,739.3

Total Biomass Estimate:

Region	Wt per tow by Region (grams) ADJUSTED FOR THE DREDGE EFFICIENCY LISTED ABOVE. Time = T	Time = T + 1	Regional Biomass (MT) Adjusted for eff. Time = T (1999)	Regional Biomass (MT) NOT Adjusted for eff. Time = T (1999)
SVA	11,605.8	22,851.3	280,193	78,454
DMV	15,504.3	17,459.9	639,594	179,086
SNJ	18,402.0	19,195.0	183,074	51,261
NNJ	34,460.5	43,442.9	960,386	268,908
LI	10,189.5	14,520.4	243,111	68,071
SNE	11,299.1	15,617.6	403,049	112,854
GBK	33,074.8	41,926.0	1,352,908	378,814
			4,062,315	1,137,448

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

ADJUSTED FOR DREDGE EFFICIENCY & INDIRECT FISHING MORT.:

Region	Change in Biomass / Tow (gr)	% change per tow	Region Area (sq n.mi)	Possible Tows/ Region	Production : Regional Change in Biomass (M Tons)	Removals : 1998 Landings (dir + indir)	Net Production of Biomass: (Production - Removals) (M. Tons)	
1 SVA	11246	96.9	2980	24,142,457	271,494.4	0	271,494.4	SVA
2 DMV	1956	12.6	5092	41,252,815	80,674.9	455	80,220.1	DMV
3 SNJ	793	4.3	1228	9,948,637	7,889.8	4,350	3,539.8	SNJ
4 NNJ	8982	26.1	3440	27,869,145	250,330.3	15,770	234,559.9	NNJ
5 LI	4331	42.5	2945	23,858,904	103,330.4	107	103,223.6	LI
6 SNE	4318	38.2	4403	35,670,885	154,043.9	0	154,043.9	SNE
7 GBK	8851	26.8	5049	40,904,451	362,052.0	0	362,052.0	GBK
					1,229,815.7 Annual Total (MT)	20,682	1,209,133.7	Sum (MT)

Table E22. Swept area biomass data (mt) used in KLAMZ for surfclams 120+ mm in the NNJ and SNJ stock areas and 100+ mm in other stock assessment areas. Estimates for 1997 assume a survey dredge efficiency of 0.59 and estimates for 1999 assume a survey dredge efficiency of 0.26. CV's include variance due to uncertainty in stock assessment area, average area swept, portion suitable habitat on Georges Bank, and other factors.

	Sizes (mm)	1997 Survey (mt)	CV	1999 Survey (mt)	CV
SVA	100+ mm	3,272	58%	NA	NA
DMV	100+ mm	273,218	34%	335,298	27%
SNJ	120+ mm	38,227	48%	156,199	79%
SNJ	100+ mm	39,386	48%	167,254	79%
NNJ	120+ mm	409,630	30%	517,522	20%
NNJ	100+mm	439,524	30%	534,507	20%
LI	100+ mm	15,996	75%	90,438	59%
SNE	100+ mm	76,755	49%	97,988	66%
GBK	100+ mm	185,069	38%	321,265	37%

Table E23. Yield and spawning biomass per recruit data for surfclam in the New Jersey (NJ) stock assessment area. Runs with recruitment at 100 mm used 0.5, 1 and 1 for FPATTERN at ages 4-6. Runs with recruitment at 120 mm used 0, 0.5 and 1 for FPATTERN at ages 4-6.

```
TITLE:
Surfclam;NJ@100or120mm;VB=(163.7,0.217,-0.214);LW=[exp(-9.3121),2.8637]
FIRST AGE GROUP:  LAST AGE GROUP:  LAST GROUP IS PLUS:
              1               30                YES
PROPORTION OF F MORTALITY BEFORE SPAWNING SEASON:
     0.5
PROPORTION OF M MORTALITY BEFORE SPAWNING SEASON:
     0.5
```

AGE	FPATTERN	MPATTERN	MATURITY	WEIGHT IN THE CATCH	WEIGHT IN THE STOCK	relative value
1	0	1	0.9	0.00300	0.00300	1
2	0	1	1	0.01252	0.01252	1
3	0	1	1	0.02751	0.02751	1
4	0.5/0.0	1	1	0.04564	0.04564	1
5	1/0.5	1	1	0.06484	0.06484	1
6	1	1	1	0.08362	0.08362	1
7	1	1	1	0.10106	0.10106	1
8	1	1	1	0.11671	0.11671	1
9	1	1	1	0.13038	0.13038	1
10	1	1	1	0.14212	0.14212	1
11	1	1	1	0.15205	0.15205	1
12	1	1	1	0.16036	0.16036	1
13	1	1	1	0.16726	0.16726	1
14	1	1	1	0.17295	0.17295	1
15	1	1	1	0.17763	0.17763	1
16	1	1	1	0.18145	0.18145	1
17	1	1	1	0.18456	0.18456	1
18	1	1	1	0.18709	0.18709	1
19	1	1	1	0.18915	0.18915	1
20	1	1	1	0.19081	0.19081	1
21	1	1	1	0.19216	0.19216	1
22	1	1	1	0.19325	0.19325	1
23	1	1	1	0.19412	0.19412	1
24	1	1	1	0.19483	0.19483	1
25	1	1	1	0.19541	0.19541	1
26	1	1	1	0.19587	0.19587	1
27	1	1	1	0.19624	0.19624	1
28	1	1	1	0.19654	0.19654	1
29	1	1	1	0.19678	0.19678	1
30	1	1	1	0.19697	0.19697	1

Table E24. Yield and spawning biomass per recruit data for surfclam in the DMV stock assessment area.

```
TITLE:
Surfclam;DMV@100;VB=(164,0.177,-1.125);LW=[exp(-9.4891),2.8602)
FIRST AGE GROUP:  LAST AGE GROUP:  LAST GROUP IS PLUS:
            1              30                   YES
PROPORTION OF F MORTALITY BEFORE SPAWNING SEASON:
     0.5
PROPORTION OF M MORTALITY BEFORE SPAWNING SEASON:
     0.5
```

AGE	FPATTERN	MPATTERN	MATURITY	WEIGHT IN THE CATCH	WEIGHT IN THE STOCK	relative value
1	0	1	0.9	0.00593	0.00593	1
2	0	1	1	0.01414	0.01414	1
3	0	1	1	0.02495	0.02495	1
4	0.5	1	1	0.03730	0.03730	1
5	1	1	1	0.05024	0.05024	1
6	1	1	1	0.06310	0.06310	1
7	1	1	1	0.07537	0.07537	1
8	1	1	1	0.08678	0.08678	1
9	1	1	1	0.09715	0.09715	1
10	1	1	1	0.10644	0.10644	1
11	1	1	1	0.11465	0.11465	1
12	1	1	1	0.12183	0.12183	1
13	1	1	1	0.12807	0.12807	1
14	1	1	1	0.13346	0.13346	1
15	1	1	1	0.13808	0.13808	1
16	1	1	1	0.14203	0.14203	1
17	1	1	1	0.14540	0.14540	1
18	1	1	1	0.14826	0.14826	1
19	1	1	1	0.15069	0.15069	1
20	1	1	1	0.15274	0.15274	1
21	1	1	1	0.15447	0.15447	1
22	1	1	1	0.15593	0.15593	1
23	1	1	1	0.15716	0.15716	1
24	1	1	1	0.15820	0.15820	1
25	1	1	1	0.15907	0.15907	1
26	1	1	1	0.15980	0.15980	1
27	1	1	1	0.16042	0.16042	1
28	1	1	1	0.16093	0.16093	1
29	1	1	1	0.16137	0.16137	1
30	1	1	1	0.16173	0.16173	1

Table E25. Yield and spawning biomass per recruit data for surfclam in the GBK stock assessment area.

```
TITLE:
Surfclam;GBK@100;VB=(154.1,0.242,0.203);LW=[exp(-8.2744),2.6542]
FIRST AGE GROUP:  LAST AGE GROUP:  LAST GROUP IS PLUS:
          1              30                  YES
PROPORTION OF F MORTALITY BEFORE SPAWNING SEASON:
     0.5
PROPORTION OF M MORTALITY BEFORE SPAWNING SEASON:
     0.5
```

AGE	FPATTERN	MPATTERN	MATURITY	WEIGHT IN THE CATCH	WEIGHT IN THE STOCK	relative value
1	0	1	0.9	0.00161	0.00161	1
2	0	1	1	0.01028	0.01028	1
3	0	1	1	0.02485	0.02485	1
4	0.5	1	1	0.04231	0.04231	1
5	1	1	1	0.06029	0.06029	1
6	1	1	1	0.07727	0.07727	1
7	1	1	1	0.09249	0.09249	1
8	1	1	1	0.10566	0.10566	1
9	1	1	1	0.11677	0.11677	1
10	1	1	1	0.12598	0.12598	1
11	1	1	1	0.13352	0.13352	1
12	1	1	1	0.13964	0.13964	1
13	1	1	1	0.14456	0.14456	1
14	1	1	1	0.14849	0.14849	1
15	1	1	1	0.15163	0.15163	1
16	1	1	1	0.15412	0.15412	1
17	1	1	1	0.15609	0.15609	1
18	1	1	1	0.15765	0.15765	1
19	1	1	1	0.15888	0.15888	1
20	1	1	1	0.15985	0.15985	1
21	1	1	1	0.16062	0.16062	1
22	1	1	1	0.16122	0.16122	1
23	1	1	1	0.16170	0.16170	1
24	1	1	1	0.16207	0.16207	1
25	1	1	1	0.16236	0.16236	1
26	1	1	1	0.16259	0.16259	1
27	1	1	1	0.16277	0.16277	1
28	1	1	1	0.16291	0.16291	1
29	1	1	1	0.16303	0.16303	1
30	1	1	1	0.16311	0.16311	1

Table E26. Yield and spawning biomass per recruit for surfclam in the New Jersey (NJ) stock assessment area for recruitment at 100 and 120 mm and natural mortality rates (M) of 0.1, 0.15 and 0.2 y^{-1}.

Reference Point	Yield Per Recruit (kg)	Spawning Biomass Per Recruit (kg)	F (y^{-1})	Yield Per Recruit (kg)	Spawning Biomass Per Recruit (kg)	F (y^{-1})
	Recruit at 120 mm, M=0.10 y^{-1}			*Recruit at 100 mm, M=0.10 y^{-1}*		
F_{MAX}	0.050	0.221	0.37	0.046	0.225	0.26
$F_{0.1}$	0.044	0.425	0.09	0.042	0.411	0.12
F20%	0.050	0.207	0.41	0.046	0.207	0.29
F25%	0.049	0.259	0.28	0.046	0.259	0.22
F30%	0.048	0.311	0.21	0.045	0.311	0.17
F35%	0.046	0.362	0.17	0.044	0.362	0.14
F40%	0.044	0.414	0.13	0.041	0.414	0.11
F45%	0.042	0.466	0.11	0.039	0.466	0.09
F50%	0.039	0.518	0.09	0.036	0.518	0.08
F55%	0.035	0.570	0.07	0.033	0.569	0.06
F60%	0.032	0.622	0.06	0.030	0.621	0.05
F65%	0.028	0.673	0.05	0.027	0.673	0.04
	Recruit at 120 mm, M=0.15 y^{-1}			*Recruit at 100 mm, M=0.15 y^{-1}*		
F_{MAX}	0.036	0.122	0.70	0.034	0.121	0.43
$F_{0.1}$	0.031	0.236	0.19	0.030	0.222	0.17
F20%	0.036	0.107	0.96	0.033	0.107	0.51
F25%	0.036	0.134	0.58	0.033	0.134	0.37
F30%	0.035	0.161	0.40	0.033	0.161	0.28
F35%	0.034	0.188	0.30	0.032	0.188	0.22
F40%	0.033	0.214	0.23	0.030	0.214	0.18
F45%	0.031	0.241	0.18	0.029	0.241	0.14
F50%	0.028	0.268	0.15	0.027	0.268	0.12
F55%	0.026	0.295	0.12	0.024	0.295	0.10
F60%	0.024	0.321	0.10	0.022	0.321	0.08
	Recruit at 120 mm, M=0.20 y^{-1}			*Recruit at 100 mm, M=0.20 y^{-1}*		
F_{MAX}	0.028	0.073	1.79	0.026	0.074	0.69
$F_{0.1}$	0.023	0.152	0.26	0.022	0.140	0.22
F20%	-does not exist-			0.026	0.064	0.92
F25%	0.028	0.080	1.32	0.026	0.080	0.60
F30%	0.027	0.096	0.77	0.025	0.096	0.43
F35%	0.026	0.112	0.52	0.024	0.112	0.33
F40%	0.025	0.128	0.38	0.023	0.128	0.26
F45%	0.024	0.144	0.29	0.022	0.144	0.21
F50%	0.022	0.160	0.23	0.021	0.160	0.17
F55%	0.020	0.176	0.18	0.019	0.176	0.14
F60%	0.018	0.192	0.14	0.017	0.192	0.11

Table E27. Yield and spawning biomass per recruit for surfclam in the Delmarva (DMV) stock assessment area for recruitment at 100 mm and natural mortality rates (M) of 0.1, 0.15 and 0.2 y^{-1}.

Reference Point	Yield Per Recruit (kg)	Spawning Biomass Per Recruit (kg)	F (y^{-1})
	Recruit at 100 mm, M=0.10 y^{-1}		
F_{MAX}	0.035	0.180	0.27
$F_{0.1}$	0.032	0.330	0.11
F20%	0.035	0.164	0.31
F25%	0.035	0.204	0.23
F30%	0.034	0.245	0.18
F35%	0.033	0.286	0.14
F40%	0.032	0.327	0.11
F45%	0.030	0.368	0.09
F50%	0.028	0.408	0.08
F55%	0.026	0.449	0.06
F60%	0.023	0.490	0.05
F65%	0.021	0.531	0.04
	Recruit at 100 mm, M=0.15 y^{-1}		
F_{MAX}	0.026	0.097	0.47
$F_{0.1}$	0.023	0.180	0.17
F20%	0.026	0.085	0.60
F25%	0.026	0.106	0.41
F30%	0.025	0.127	0.30
F35%	0.024	0.148	0.23
F40%	0.023	0.169	0.19
F45%	0.022	0.190	0.15
F50%	0.021	0.211	0.12
F55%	0.019	0.232	0.10
F60%	0.017	0.253	0.08
	Recruit at 100 mm, M=0.20 y^{-1}		
F_{MAX}	0.020	0.060	0.87
$F_{0.1}$	0.017	0.115	0.02
F20%	0.020	0.051	1.34
F25%	0.020	0.064	0.76
F30%	0.020	0.076	0.51
F35%	0.019	0.089	0.38
F40%	0.018	0.102	0.29
F45%	0.017	0.115	0.23
F50%	0.016	0.127	0.18
F55%	0.015	0.140	0.15
F60%	0.013	0.153	0.12

Table E28. Yield and spawning biomass per recruit for surfclam in the Georges Bank (GBK) stock assessment area for recruitment at 100 mm and natural mortality rates (M) of 0.1, 0.15 and 0.2 y^{-1}.

Reference Point	Yield Per Recruit (kg)	Spawning Biomass Per Recruit (kg)	F (y^{-1})
	Recruit at 100 mm, M=0.10 y^{-1}		
F_{MAX}	0.042	0.190	0.29
$F_{0.1}$	0.038	0.354	0.12
F20%	0.042	0.180	0.31
F25%	0.042	0.225	0.23
F30%	0.041	0.270	0.18
F35%	0.039	0.314	0.14
F40%	0.037	0.359	0.12
F45%	0.035	0.404	0.10
F50%	0.033	0.449	0.08
F55%	0.030	0.494	0.07
F60%	0.027	0.539	0.05
F65%	0.021	0.531	0.04
	Recruit at 100 mm, M=0.15 y^{-1}		
F_{MAX}	0.031	0.103	0.46
$F_{0.1}$	0.027	0.194	0.17
F20%	0.031	0.094	0.53
F25%	0.031	0.118	0.38
F30%	0.030	0.141	0.29
F35%	0.029	0.165	0.23
F40%	0.028	0.188	0.18
F45%	0.026	0.212	0.15
F50%	0.024	0.235	0.12
F55%	0.022	0.259	0.10
F60%	0.020	0.282	0.08
	Recruit at 100 mm, M=0.20 y^{-1}		
F_{MAX}	0.024	0.064	0.73
$F_{0.1}$	0.021	0.123	0.23
F20%	0.024	0.057	0.93
F25%	0.024	0.071	0.61
F30%	0.023	0.085	0.44
F35%	0.023	0.099	0.34
F40%	0.021	0.114	0.27
F45%	0.020	0.128	0.21
F50%	0.019	0.142	0.17
F55%	0.017	0.156	0.14
F60%	0.016	0.170	0.11

Table E29. Average yield and spawning biomass per recruit for for surfclam in the New Jersey (NJ), Delmarva (DMV) and Georges Bank (GBK) stock areas assuming recruitment at 100 mm and natural mortality rates (M) of 0.1, 0.15 and 0.2 y^{-1}. Weights are average (1997 and 1999) efficiency corrected swept area biomass estimates for surfclam (all sizes) in the New Jersey (NJ=SNJ+NNJ), Delmarva (DMV) and Georges Bank (GBK) assessment areas.

	New Jersey	Delmarva	Georges Bank	Sum
Stock Biomass	609,195	313,269	242,128	1,164,593
Weighting Factor	0.523	0.269	0.208	1.000

Reference Point	Yield Per Recruit (kg)	Spawning Biomass Per Recruit (kg)	F (y^{-1})
	Recruit at 100 mm, M=0.10 y^{-1}		
F_{MAX}	0.042	0.206	0.27
$F_{0.1}$	0.038	0.377	0.12
F20%	0.042	0.190	0.30
F25%	0.042	0.237	0.22
F30%	0.041	0.285	0.17
F35%	0.040	0.332	0.14
F40%	0.038	0.379	0.11
F45%	0.036	0.427	0.09
F50%	0.033	0.474	0.08
F55%	0.031	0.521	0.06
F60%	0.028	0.569	0.05
F65%	0.024	0.605	0.04
	Recruit at 100 mm, M=0.15 y^{-1}		
F_{MAX}	0.031	0.111	0.45
$F_{0.1}$	0.027	0.205	0.17
F20%	0.031	0.098	0.54
F25%	0.031	0.123	0.38
F30%	0.030	0.147	0.29
F35%	0.029	0.172	0.23
F40%	0.028	0.197	0.18
F45%	0.026	0.221	0.15
F50%	0.024	0.246	0.12
F55%	0.022	0.270	0.10
F60%	0.020	0.295	0.08
	Recruit at 100 mm, M=0.20 y^{-1}		
F_{MAX}	0.024	0.068	0.75
$F_{0.1}$	0.021	0.129	0.17
F20%	0.024	0.059	1.04
F25%	0.024	0.074	0.64
F30%	0.023	0.089	0.46
F35%	0.023	0.103	0.34
F40%	0.022	0.118	0.27
F45%	0.020	0.133	0.21
F50%	0.019	0.147	0.17
F55%	0.017	0.162	0.14
F60%	0.016	0.177	0.11

Table E30. Growth model (weight at age) calculations for surfclam in the Long Island (LI), Southern New England (SNE), and Georges Bank (GBK) stock assessment areas based on length at age relationships in Weinberg and Hesler (1996). Length-weight conversion formulas use "average" parameters. Growth parameters p and J were used in KLAMZ.

	LI	SNE	GBK
Length at Age (three parameter Von Bertalanffy models)			
$L_{infinity}$	161.8	164.7	154.1
K (y^{-1})	0.251	0.3	0.242
t_o (y)	-0.443	0.319	0.203
Length at recruitment (mm)	100	100	100
Age at recruitment (y)	3.4	3.4	4.5
Predicted length one year prior to recruitment (mm)	82	77	85
Predicted length one year after recruitment (mm)	114	117	112
Length-weight conversion parameters $W=aL^b$			
a	3.410E-04	3.410E-04	2.550E-04
b	2.580	2.580	2.654
Weight at age (traditional three parameter Von Bertalanffy models, valid for ages 3+ years)			
t_o (y)	1.47572017	1.79128406	1.97274111
$W_{infinity}$ (g)	173.146247	180.991169	167.369772
K (y^{-1})	0.18902805	0.22027155	0.16766019
$p=e^{-K}$	0.8278	0.8023	0.8456
Growth parameter J			
Predicted weight at k-1 (w_{k-1})	27.52	23.88	38.43
Predicted weight at k (w_k)	52.60	54.94	58.33
J	0.5232	0.4346	0.6588

Table E31. Growth model (weight at age) calculations for surfclam off New Jersey (NJ, including both the southern SNH and northern NNJ portions), and Delmarva (DMV) stock assessment areas based on data collected during 1980 and 1989&1992 (Weinberg and Hesler 1996). Length-weight conversion formulas use "average" parameters. Growth parameters p and J were used in KLAMZ.

	NJ-1980	NJ-1989& 1992	NJ-All Years	DMV-1980	DMV-1989& 1992	DMV-All Years
Length at Age (three parameter Von Bertalanffy models)						
$L_{infinity}$	170.8	163.7		171	164	
K (y^{-1})	0.254	0.217		0.256	0.177	
t_o (y)	0.01	-0.214		0.132	-1.125	
Length at recruitment (mm)	120	120		100	100	
Age at recruitment (y)	4.8	5.9		3.6	4.2	
Predicted length one year prior to recruitment (mm)	105	109		79	88	
Predicted length one year after recruitment (mm)	131	129		116	110	
Length-weight conversion parameters $W=aL^b$						
a	9.032E-05			7.567E-05		
b	2.864			2.860		
Weight at age (five parameter Von Bertalanffy models, valid for ages 3+ years)						
t_o in 1980(y)			2.079			1.669
t_o in 1989&1992 (y)			2.557			2.121
$W_{infinity}$ in 1980 (g)			229.3			194.1
$W_{infinity}$ in 1989&1992 (g)			198.6			162.1
K (y^{-1})			0.1753			0.1484
$p=e^{-K}$			0.8392			0.8621
Growth parameter J						
Predicted weight at k-1 (w_{k-1})	59.22	66.27		24.19	23.81	
Predicted weight at k (w_k)	86.55	87.55		47.62	42.88	
J	0.6841	0.7569		0.5079	0.5553	

Table E32. Efficiency adjusted swept-area and variance calculations for surfclam (all sizes in survey dredge) during 1997 and 1999, by stock assessment area. Estimates for the SVA stock assessment region are based on 1997 survey data because there was no survey in the SVA stock assessment region during 1999. Covariances are ignored in all calculations.

	1997	Arithmetic CV (fo stratified means	Log Scal Standar Erro	1999	Arithmetic CV (fo stratified means	Log Scal Standard Erro
Survey Density (D, kg / standard tow)						
SVA	0.169	49%	0.46	0.079	59%	0.55
DMV	4.285	20%	0.20	2.290	22%	0.22
SNJ	2.347	38%	0.37	4.635	77%	0.68
NNJ	9.390	12%	0.12	5.347	12%	0.12
LI	0.394	67%	0.61	1.055	56%	0.53
SNE	1.294	39%	0.38	0.797	63%	0.58
GBK	3.155	23%	0.23	2.322	32%	0.31
All regions	3.193	9%	0.09	2.165	13%	0.13

	1997 & 1999	Assumed Arithmetic CV	Log Scal Standar Erro
Area of standard tow (a, nm²)	0.000123434	5%	0.05
Area of assessment region (R, nm²) - no correction for stations with unsuitable clam habitat			
SVA	2,980	5%	0.05
DMV	5,092	5%	0.05
SNJ	1,228	5%	0.05
NNJ	3,440	5%	0.05
LI	2,945	5%	0.05
SNE	4,403	5%	0.05
GBK	5,713	5%	0.05
All regions	25,801	2%	0.02
Fraction of region suitable as clam habitat (f)			
GBK	0.88	10%	0.10
All other area	1.00	0%	0.00

	1997 & 1999	Calculated Arithmeti c	Log Scal Standar Erro
Habitat area in assessment region (A=R*f, nm²)			
SVA	2,980	5%	0.05
DMV	5,092	5%	0.05
SNJ	1,228	5%	0.05
NNJ	3,440	5%	0.05
LI	2,945	5%	0.05
SNE	4,403	5%	0.05
GBK	5,049	11%	0.11
All regions	25,137	3%	0.03
Habitat area / tow area (A/a)			
SVA	24,142,437	7%	0.07
DMV	41,252,782	7%	0.07
SNJ	9,948,628	7%	0.07
NNJ	27,869,122	7%	0.07
LI	23,858,885	7%	0.07
SNE	35,670,856	7%	0.07
GBK	40,904,418	12%	0.12
All regions	203,647,128	6%	0.06

	1997	Arithmetic CV (fro efficiency estimator fo DE-2 experiment i 1997	Log Scal Standar Erro	1999	Arithmetic CV (for mea of estimates by different methods	Log Scal Standard Erro
Survey dredge efficiency (e)						
All regions	0.5879	27%	0.26	0.2757	14%	0.13

	1997	Arithmetic C (calculated	Log Scal Standar Erro	1999	Arithmetic C (calculated	Log Scal Standard Erro
Swept area biomass (B)						
SVA	6,953	58%	0.53	6,953	62%	0.57
DMV	300,677	34%	0.33	342,651	27%	0.26
SNJ	39,717	48%	0.46	167,254	79%	0.70
NNJ	445,129	30%	0.30	540,501	20%	0.20
LI	15,996	75%	0.66	91,299	59%	0.55
SNE	78,540	49%	0.47	103,078	66%	0.60
GBK	219,516	38%	0.37	344,524	37%	0.36
All regions	1,106,527	18%	0.17	1,596,260	22%	0.21

95% CI on swept area biomass (B)	1997-Lowe Bioun	1997-Upper Biound	1999-Lowe Bioun	1999-Upper Biound
SVA	2,437	19,833	2,285	21.157
DMV	156,082	579,225	204,440	574,300
SNJ	16,247	97,092	42,579	656 992
NNJ	248,841	796,248	368,780	792,184
LI	4,347	58,864	31,265	266,[illegible]08
SNE	31,553	195,501	31,941	332,644
GBK	106,740	451,444	169,667	699,589
All regions	785,729	1,558,301	1,047,675	2,432,097

Table E33. KLAMZ model run summaries for surfclam in the NNJ stock assessment region.

No.	*Run Label*	*Description*
1	Start	Complete survey trends; One complete LPUE series; Swept-area 97&99 w/Q=1; Empirical Schaeffer model
2	No_79	Omit 1979 survey from trends; One complete LPUE series; Swept-area 97&99 w/Q=1; Empirical Schaeffer model
3	No_79; Break LPUE	Omit 1979 survey from trends; Break LPUE into two time series (1980-84 and 1991-99); Swept-area 97&99 w/Q=1; Empirical Schaeffer model
4	No_79; No_94; Break LPUE; Basecase?	Omit 1979 and 1994 survey from trends; Break LPUE into two time series (1980-84 and 1991-99); Swept-area 97&99 w/Q=1; Empirical Schaeffer model; ***Possible basecase?***
5	No_79_to_80; Break_LPUE	Omit 1978-80 survey from trends; Break LPUE into two time series (1980-84 and 1991-99); Swept-area 97&99 w/Q=1; Empirical Schaeffer model
6	No_79; No_94_to_99; Break LPUE	Omit 79 & 97-99 survey from trends; Break LPUE into two time series (1980-84 and 1991-99); Swept-area 97&99 w/Q=1; Empirical Schaeffer model
7	No_78to80; No_97to99; Break LPUE	Omit 1978-80 & 1997-99 survey from trends; Break LPUE into two time series (1980-84 and 1991-99); Swept-area 97&99 w/Q=1; Empirical Schaeffer model
8	No_SurveyTrend; Break LPUE	No survey trend data; Break LPUE into two time series (1980-84 and 1991-99); Swept-area 97&99 w/Q=1; Empirical Schaeffer model
9	No_79; No_94; No LPUE	Omit 1978-80 & 1997-99 survey from trends; Omit LPUE; Swept-area 97&99 w/Q=1; Empirical Schaeffer model
10	No_SurveyTrend	No survey trend data; One complete LPUE series; Swept-area 97&99 w/Q=1; Empirical Schaeffer model
11	No LPUE	Complete survey trends; No LPUE; Swept-area 97&99 w/Q=1; Empirical Schaeffer model
12	Halved Biomass	Same as 4 (basecase); Reduced swept area biomass data for 1997&99 by 50%
13	High M=0.25	Same as 4 (basecase); M increased to 0.25
14	Low M=0.05	Same as 4 (basecase); M dcreased to 0.05
15	Shaeffer Wt=1.0	Same as 4 (basecase); Implicit Shaeffer w/CV(Production)=74% & Likelihood Wt=1.0
16	Schaeffer Wt=10.0	Same as 4 (basecase); Implicit Shaeffer w/CV(Production)=74% & Likelihood Wt=10.0
17	Schaeffer Wt=1000.0	Same as 4 (basecase); Implicit Shaeffer w/CV(Production)=74% & Likelihood Wt=1000.0--No process error in production
18	Q=0.9	Same as 4 (basecase); Swept-area Q=0.9
19	Q=0.8	Same as 4 (basecase); Swept-area Q=0.8
20	Q=0.7	Same as 4 (basecase); Swept-area Q=0.7
21	Q=1.1	Same as 4 (basecase); Swept-area Q=1.1
22	Q=1.2	Same as 4 (basecase); Swept-area Q=1.2
23	Q=1.3	Same as 4 (basecase); Swept-area Q=1.3

Table E34. Trial results for surfclam in the NNJ region from a preliminary version of the KLAMZ model with a hard (λ=1000) constraint on $Q_{SweptArea}$=1, M=0.15 y^{-1} and empirical Shaeffer production calculations. Other runs omitted to save space. Recent estimates of catch, biomass, and fishing mortality are averages for 1997-1999. Run 4 (with survey data for 1979 and 1994 omitted and broken LPUE data) closely resembles the basecase model run used for final estimates.

Plotting Label	#11: No LPUE	#10: No_Survey Trend	#9: No_79; No_94; No LPUE	#8: No Survey Trend; Break LPUE	#7: No 78to80; No 97to99; Break LPUE	#6: No 79; No 94_to_99; Break LPUE	#5: No 79_to_80; Break LPUE	#4: No_79; No_94; Break LPUE BASE-CASE?	#3: No_79; Break LPUE	#2: No_79	#1: Start
Biology:M	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Biology:Von Bert K	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Biology:Min J	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82
Biology:Mean J	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
Biology:Max J	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Surplus Production:Delta	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Surplus Production:CV Production	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
Constraints:Log scale standard deviation for recruitment rand	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Constraints:Target Q Swept Area Biomass-Recruits	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total Log Likelihood	135.90	3.97	67.80	2.97	19.98	61.43	63.00	72.04	102.94	103.66	144.69
Surveys-All:Weight	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Surveys-All:Obj	89.93	3.57	38.11	2.91	15.00	36.61	46.67	42.83	66.80	67.73	100.16
Surveys-All:Weight*Obj	89.93	3.57	38.11	2.91	15.00	36.61	46.67	42.83	66.80	67.73	100.16
Recruitment Random Walk:Weight	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Recruitment Random Walk:Obj	45.96	0.40	29.70	0.06	4.97	24.82	16.32	29.21	36.15	35.93	44.52
Recruitment Random Walk:Weight*Obj	45.96	0.40	29.70	0.06	4.97	24.82	16.32	29.21	36.15	35.93	44.52
Target Q Swept Area Total Biomass:Weight	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
Target Q Swept Area Total Biomass:Obj	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Target Q Swept Area Total Biomass:Weight*Obj	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shaeffer Production Model:Weight	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shaeffer Production Model:Obj	869.69	0.55	6.60	0.69	19.91	4.16	25.64	7.38	27.19	28.67	55.01
Shaeffer Production Model:Weight*Obj	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LPUE-1:Weight	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LPUE-1:Q	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LPUE-1:Obj	7.92	3.06	4.22	2.14	2.00	3.42	2.23	3.53	3.56	6.04	7.80
LPUE-1:Weight*Obj	0.00	3.06	0.00	2.14	2.00	3.42	2.23	3.53	3.56	6.04	7.80
LPUE-1:RMS Residuals	0.62	0.22	0.45	0.31	0.30	0.40	0.32	0.41	0.41	0.31	0.36
LPUE-2:Weight	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00
LPUE-2:Q	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LPUE-2:Obj	1.95	0.57	0.41	0.20	0.26	0.47	1.38	0.38	1.59	6.04	7.80
LPUE-2:Weight*Obj	0.00	0.00	0.00	0.20	0.26	0.47	1.38	0.38	1.59	0.00	0.00
LPUE-2:RMS Residuals	0.22	0.12	0.10	0.07	0.08	0.11	0.18	0.10	0.19	0.31	0.36
Pre-recruit Survey-Lag 1 Year-N/Tow:Weight	1.00	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Pre-recruit Survey-Lag 1 Year-N/Tow:Q	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pre-recruit Survey-Lag 1 Year-N/Tow:Obj	21.69	51.51	8.75	78.84	7.01	8.69	10.70	8.85	12.24	12.44	22.05
Pre-recruit Survey-Lag 1 Year-N/Tow:Weight*Obj	21.69	0.00	8.75	0.00	7.01	8.69	10.70	8.85	12.24	12.44	22.05
Pre-recruit Survey-Lag 1 Year-N/Tow:RMS Residuals	0.52	0.81	0.37	0.79	0.35	0.41	0.32	0.38	0.37	0.37	0.53
New Recruit Survey N/Tow:Weight	1.00	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
New Recruit Survey N/Tow:Q	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
New Recruit Survey N/Tow:Obj	18.93	124.63	14.43	162.15	2.43	12.77	5.25	14.47	15.17	15.25	19.27
New Recruit Survey N/Tow:Weight*Obj	18.93	0.00	14.43	0.00	2.43	12.77	5.25	14.47	15.17	15.25	19.27
New Recruit Survey N/Tow:RMS Residuals	0.48	1.08	0.39	1.12	0.17	0.43	0.19	0.40	0.38	0.39	0.48
Survey Total KG/Tow:Weight	1.00	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Survey Total KG/Tow:Q	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Survey Total KG/Tow:Obj	48.06	23.99	13.83	59.96	2.76	10.79	25.77	14.49	32.94	32.70	49.78
Survey Total KG/Tow:Weight*Obj	48.06	0.00	13.83	0.00	2.76	10.79	25.77	14.49	32.94	32.70	49.78
Survey Total KG/Tow:RMS Residuals	0.57	0.42	0.33	0.67	0.18	0.38	0.32	0.35	0.40	0.40	0.60
Swept Area Biomass (MT):Weight	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Swept Area Biomass (MT):Q	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Swept Area Biomass (MT):Obj	1.25	0.51	1.09	0.57	0.54	0.48	1.34	1.11	1.30	1.30	1.27
Swept Area Biomass (MT):Weight*Obj	1.25	0.51	1.09	0.57	0.54	0.48	1.34	1.11	1.30	1.30	1.27
Swept Area Biomass (MT):RMS Residuals	0.21	0.14	0.20	0.14	0.14	0.13	0.22	0.20	0.22	0.22	0.22
Status:Recent Mean F	0.03	0.04	0.03	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03
Status:Recent Mean B (units=1000)	512.75	496.95	511.43	498.09	497.52	495.49	516.52	512.01	515.03	515.13	513.71
Status:Recent Mean C (units=1000)	16.14	16.14	16.14	16.14	16.14	16.14	16.14	16.14	16.14	16.14	16.14
Schaeffer Model:Carrying Capacity (K)	544.68	618.37	565.95	917.64	704.83	558.80	590.62	580.64	567.38	564.92	552.18
Schaeffer Model:Bmsy (units=1000)	272.34	309.18	282.98	458.82	352.41	279.40	295.31	290.32	283.69	282.46	276.09
Schaeffer Model:MSY (units=1000)	53.64	40.41	67.09	15.06	24.60	52.50	36.18	58.01	45.08	46.42	51.55
Schaeffer Model:Fmsy	0.24	0.15	0.29	0.04	0.08	0.23	0.14	0.24	0.19	0.19	0.22
Schaeffer Model:Recent Mean F / Fmsy	0.15	0.24	0.12	0.99	0.46	0.16	0.24	0.14	0.18	0.18	0.15
Schaeffer Model:Recent Mean B / Bmsy	1.88	1.61	1.81	1.09	1.41	1.77	1.75	1.76	1.82	1.82	1.86
Schaeffer Model:Recent Mean C/ MSY	0.30	0.40	0.24	1.07	0.66	0.31	0.45	0.28	0.36	0.35	0.31
Schaeffer Model:RMS Residual	27.55	5.36	20.47	2.82	16.85	18.82	23.41	21.55	24.93	24.78	26.23

Table E35. Trial results and likelihood profiles for surfclam in the NNJ region from a preliminary version of the KLAMZ model with M=0.15 y^{-1} and empirical Shaeffer production calculations. Runs 18-23 used a range of target values (0.9-1.3) in a hard (λ=1000) constraint on the scaling parameter ($Q_{SweptArea}$) for swept area biomass data. Run 4 (with survey data for 1979 and 1994 omitted and broken LPUE data) used $Q_{sweptArea}$=1 and closely resembles the basecase model run used for final estimates. Recent estimates of catch, biomass, and fishing mortality are averages for 1997-1999.

Plotting Label	#23: Q=1.3	#22: Q=1.2	#21: Q=1.1	#20: Q=0.7	#19: Q=0.8	#18: Q=0.9	#4: No_79; No_94; Break LPUE BASE-CASE?
Biology:M	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Biology:Von Bert K	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Biology:Min J	0.82	0.82	0.82	0.82	0.82	0.82	0.82
Biology:Mean J	0.83	0.83	0.83	0.83	0.83	0.83	0.83
Biology:Max J	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Surplus Production:Delta	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Surplus Production:CV Production	0.74	0.74	0.74	0.74	0.74	0.74	0.74
Constraints:Log scale standard deviation for recruitment rand	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Constraints:Target Q Swept Area Biomass-Recruits	1.30	1.20	1.10	0.70	0.80	0.90	1.00
Total Log Likelihood	71.83	71.89	71.96	72.30	72.21	72.12	72.04
Surveys-All:Weight	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Surveys-All:Obj	42.69	42.73	42.77	43.01	42.95	42.88	42.83
Surveys-All:Weight*Obj	42.69	42.73	42.77	43.01	42.95	42.88	42.83
Recruitment Random Walk:Weight	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Recruitment Random Walk:Obj	29.14	29.16	29.19	29.29	29.26	29.24	29.21
Recruitment Random Walk:Weight*Obj	29.14	29.16	29.19	29.29	29.26	29.24	29.21
Target Q Swept Area Total Biomass:Weight	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
Target Q Swept Area Total Biomass:Obj	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Target Q Swept Area Total Biomass:Weight*Obj	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shaeffer Production Model:Weight	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shaeffer Production Model:Obj	6.15	6.48	6.88	10.11	8.90	8.03	7.38
Shaeffer Production Model:Weight*Obj	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LPUE-1:Weight	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LPUE-1:Q	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LPUE-1:Obj	3.70	3.65	3.59	3.36	3.42	3.47	3.53
LPUE-1:Weight*Obj	3.70	3.65	3.59	3.36	3.42	3.47	3.53
LPUE-1:RMS Residuals	0.42	0.42	0.42	0.40	0.40	0.41	0.41
LPUE-2:Weight	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LPUE-2:Q	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LPUE-2:Obj	0.38	0.38	0.38	0.37	0.37	0.38	0.38
LPUE-2:Weight*Obj	0.38	0.38	0.38	0.37	0.37	0.38	0.38
LPUE-2:RMS Residuals	0.10	0.10	0.10	0.09	0.09	0.09	0.10
Pre-recruit Survey-Lag 1 Year-N/Tow:Weight	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Pre-recruit Survey-Lag 1 Year-N/Tow:Q	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pre-recruit Survey-Lag 1 Year-N/Tow:Obj	8.89	8.88	8.86	8.81	8.82	8.83	8.85
Pre-recruit Survey-Lag 1 Year-N/Tow:Weight*Obj	8.89	8.88	8.86	8.81	8.82	8.83	8.85
Pre-recruit Survey-Lag 1 Year-N/Tow:RMS Residuals	0.38	0.38	0.38	0.38	0.38	0.38	0.38
New Recruit Survey N/Tow:Weight	1.00	1.00	1.00	1.00	1.00	1.00	1.00
New Recruit Survey N/Tow:Q	0.00	0.00	0.00	0.00	0.00	0.00	0.00
New Recruit Survey N/Tow:Obj	14.55	14.52	14.50	14.41	14.43	14.45	14.47
New Recruit Survey N/Tow:Weight*Obj	14.55	14.52	14.50	14.41	14.43	14.45	14.47
New Recruit Survey N/Tow:RMS Residuals	0.40	0.40	0.40	0.39	0.40	0.40	0.40
Survey Total KG/Tow:Weight	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Survey Total KG/Tow:Q	0.00	0.0δ	0.00	0.00	0.00	0.00	0.00
Survey Total KG/Tow:Obj	14.03	14.18	14.33	14.99	14.82	14.65	14.49
Survey Total KG/Tow:Weight*Obj	14.03	14.18	14.33	14.99	14.82	14.65	14.49
Survey Total KG/Tow:RMS Residuals	0.34	0.35	0.35	0.36	0.36	0.36	0.35
Swept Area Biomass (MT):Weight	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Swept Area Biomass (MT):Q	1.30	1.20	1.10	0.70	0.80	0.90	1.00
Swept Area Biomass (MT):Obj	1.13	1.12	1.11	1.08	1.09	1.10	1.11
Swept Area Biomass (MT):Weight*Obj	1.13	1.12	1.11	1.08	1.09	1.10	1.11
Swept Area Biomass (MT):RMS Residuals	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Status:Recent Mean F	0.05	0.04	0.04	0.02	0.03	0.03	0.03
Status:Recent Mean B (units=1000)	394.39	427.06	465.67	730.54	639.48	568.65	512.01
Status:Recent Mean C (units=1000)	16.14	16.14	16.14	16.14	16.14	16.14	16.14
Schaeffer Model:Carrying Capacity (K)	460.28	493.72	533.24	803.88	710.91	638.56	580.64
Schaeffer Model:Bmsy (units=1000)	230.14	246.86	266.62	401.94	355.46	319.28	290.32
Schaeffer Model:MSY (units=1000)	48.25	50.98	54.19	75.87	68.45	62.66	58.01
Schaeffer Model:Fmsy	0.25	0.25	0.25	0.23	0.23	0.24	0.24
Schaeffer Model:Recent Mean F / Fmsy	0.18	0.17	0.15	0.11	0.12	0.13	0.14
Schaeffer Model:Recent Mean B / Bmsy	1.71	1.73	1.75	1.82	1.80	1.78	1.76
Schaeffer Model:Recent Mean C/ MSY	0.33	0.32	0.30	0.21	0.24	0.26	0.28
Schaeffer Model:RMS Residual	17.55	18.66	19.98	28.97	25.88	23.48	21.55

Table E36. Trial results from a preliminary KLAMZ model for surfclam in the NNJ assessment area with a hard (λ=1000) constraint on $Q_{SweptArea}=1$, M=0.15 y^{-1}, emipirical (run 4) and implicit (runs 15-17) Shaeffer production curve calculations. Recent estimates of catch, biomass, and fishing mortality are averages for 1997-1999.

Plotting Label	#17: Shaeffer Wt=1000	#16: Shaeffer Wt=10	#15: Shaeffer Wt=1	#4: No_79; No_94; Break LPUE BASE-CASE?
Biology:M	0.15	0.15	0.15	0.15
Biology:Von Bert K	0.15	0.15	0.15	0.15
Biology:Min J	0.82	0.82	0.82	0.82
Biology:Mean J	0.83	0.83	0.83	0.83
Biology:Max J	0.84	0.84	0.84	0.84
Surplus Production:Delta	0.97	0.97	0.97	0.97
Surplus Production:CV Production	0.74	0.74	0.74	0.74
Constraints:Log scale standard deviation for recruitm	0.20	0.20	0.20	0.20
Constraints:Target Q Swept Area Biomass-Recruits	1.00	1.00	1.00	1.00
Total Log Likelihood	114.63	98.07	77.78	72.04
Surveys-All:Weight	1.00	1.00	1.00	1.00
Surveys-All:Obj	93.10	65.15	45.46	42.83
Surveys-All:Weight*Obj	93.10	65.15	45.46	42.83
Recruitment Random Walk:Weight	1.00	1.00	1.00	1.00
Recruitment Random Walk:Obj	21.22	22.83	27.53	29.21
Recruitment Random Walk:Weight*Obj	21.22	22.83	27.53	29.21
Target Q Swept Area Total Biomass:Weight	1000.00	1000.00	1000.00	1000.00
Target Q Swept Area Total Biomass:Obj	0.00	0.00	0.00	0.00
Target Q Swept Area Total Biomass:Weight*Obj	0.01	0.04	0.01	0.00
Shaeffer Production Model:Weight	1000.00	10.00	1.00	0.00
Shaeffer Production Model:Obj	0.00	1.00	4.78	7.38
Shaeffer Production Model:Weight*Obj	0.29	10.05	4.78	0.00
LPUE-1:Weight	1.00	1.00	1.00	1.00
LPUE-1:Q	0.00	0.00	0.00	0.00
LPUE-1:Obj	6.48	5.59	4.10	3.53
LPUE-1:Weight*Obj	6.48	5.59	4.10	3.53
LPUE-1:RMS Residuals	0.56	0.52	0.44	0.41
LPUE-2:Weight	1.00	1.00	1.00	1.00
LPUE-2:Q	0.00	0.00	0.00	0.00
LPUE-2:Obj	0.34	0.35	0.33	0.38
LPUE-2:Weight*Obj	0.34	0.35	0.33	0.38
LPUE-2:RMS Residuals	0.09	0.09	0.09	0.10
Pre-recruit Survey-Lag 1 Year-N/Tow:Weight	1.00	1.00	1.00	1.00
Pre-recruit Survey-Lag 1 Year-N/Tow:Q	0.00	0.00	0.00	0.00
Pre-recruit Survey-Lag 1 Year-N/Tow:Obj	19.31	12.77	9.75	8.85
Pre-recruit Survey-Lag 1 Year-N/Tow:Weight*Obj	19.31	12.77	9.75	8.85
Pre-recruit Survey-Lag 1 Year-N/Tow:RMS Residuals	0.53	0.43	0.39	0.38
New Recruit Survey N/Tow:Weight	1.00	1.00	1.00	1.00
New Recruit Survey N/Tow:Q	0.00	0.00	0.00	0.00
New Recruit Survey N/Tow:Obj	48.53	31.56	16.28	14.47
New Recruit Survey N/Tow:Weight*Obj	48.53	31.56	16.28	14.47
New Recruit Survey N/Tow:RMS Residuals	0.58	0.49	0.41	0.40
Survey Total KG/Tow:Weight	1.00	1.00	1.00	1.00
Survey Total KG/Tow:Q	0.00	0.00	0.00	0.00
Survey Total KG/Tow:Obj	17.83	14.14	13.95	14.49
Survey Total KG/Tow:Weight*Obj	17.83	14.14	13.95	14.49
Survey Total KG/Tow:RMS Residuals	0.37	0.31	0.33	0.35
Swept Area Biomass (MT):Weight	1.00	1.00	1.00	1.00
Swept Area Biomass (MT):Q	1.00	1.01	1.00	1.00
Swept Area Biomass (MT):Obj	0.61	0.73	1.04	1.11
Swept Area Biomass (MT):Weight*Obj	0.61	0.73	1.04	1.11
Swept Area Biomass (MT):RMS Residuals	0.15	0.16	0.19	0.20
Status:Recent Mean F	0.04	0.04	0.03	0.03
Status:Recent Mean B (units=1000)	497.70	499.41	508.73	512.01
Status:Recent Mean C (units=1000)	16.14	16.14	16.14	16.14
Schaeffer Model:Carrying Capacity (K)	522.05	529.43	566.05	580.64
Schaeffer Model:Bmsy (units=1000)	261.02	264.72	283.02	290.32
Schaeffer Model:MSY (units=1000)	97.13	84.97	66.05	58.01
Schaeffer Model:Fmsy	0.51	0.42	0.29	0.24
Schaeffer Model:Recent Mean F / Fmsy	0.07	0.08	0.12	0.14
Schaeffer Model:Recent Mean B / Bmsy	1.91	1.89	1.80	1.76
Schaeffer Model:Recent Mean C/MSY	0.17	0.19	0.24	0.28
Schaeffer Model:RMS Residual	0.12	8.59	18.45	21.55

Table E37. Recruit biomass (mt) estimates (1978-1999) and projections (2000-2002) from basecase KLAMZ (M=0.15 y^{-1}) runs with CV's from 500 bootstrap iterations. Projections assume recent (average 1997-1999) catch and recruitment.

Year	SVA	CV	DMV	CV	SNJ	CV	NNJ	CV	LI	CV	SNE	CV	GBK	CV	All Areas	CV
1978	0.069	0.34	16,490	0.59	5,100	1.79	6,868	0.32	1,404	1.19	9,137	0.45	6,815	0.35	45,815	0.32
1979	0.069	0.34	20,057	0.60	5,740	1.89	13,691	0.30	1,151	1.16	9,135	0.45	6,815	0.35	56,589	0.31
1980	0.069	0.34	32,102	0.61	5,121	1.69	28,943	0.30	960	1.15	9,136	0.45	6,814	0.35	83,077	0.28
1981	0.069	0.34	55,789	0.65	3,589	1.72	54,698	0.29	962	1.05	9,145	0.45	6,813	0.35	130,996	0.31
1982	0.069	0.34	64,409	0.62	3,747	1.61	83,748	0.29	1,113	0.99	9,165	0.46	6,809	0.35	168,990	0.28
1983	0.069	0.34	49,626	0.59	4,046	1.35	107,292	0.27	1,477	1.04	6,737	0.44	6,802	0.35	175,980	0.24
1984	0.069	0.34	39,667	0.56	2,820	1.23	99,019	0.27	2,058	1.24	4,364	0.47	6,790	0.35	154,718	0.23
1985	0.067	0.32	37,994	0.54	1,759	1.36	69,562	0.28	2,168	1.32	2,856	0.48	6,770	0.36	121,109	0.23
1986	0.056	0.30	29,019	0.55	1,979	1.36	61,976	0.29	1,954	1.02	2,866	0.47	6,739	0.36	104,534	0.24
1987	0.052	0.29	21,471	0.59	2,670	1.41	49,455	0.28	1,925	0.87	2,970	0.46	6,787	0.36	85,279	0.23
1988	0.055	0.29	17,814	0.61	3,099	1.46	52,248	0.26	2,204	0.82	3,565	0.46	6,524	0.35	85,453	0.21
1989	0.057	0.29	15,011	0.66	3,593	1.62	55,884	0.28	2,684	0.78	4,288	0.46	6,252	0.35	87,712	0.23
1990	0.066	0.30	10,877	0.61	4,168	1.48	45,659	0.28	3,093	0.75	5,043	0.47	6,676	0.35	75,516	0.22
1991	0.073	0.30	10,286	0.62	4,835	1.43	49,607	0.24	3,819	0.71	4,838	0.45	8,432	0.35	81,818	0.19
1992	0.081	0.31	9,753	0.75	5,683	1.42	53,648	0.25	5,200	0.70	4,656	0.44	10,711	0.36	89,652	0.20
1993	0.078	0.31	10,893	0.72	6,661	1.46	63,675	0.25	5,039	0.70	5,232	0.42	12,629	0.35	104,129	0.21
1994	0.076	0.30	13,488	0.64	7,093	1.48	63,406	0.23	4,184	0.69	5,318	0.41	15,057	0.34	108,547	0.19
1995	0.074	0.31	16,551	0.59	7,862	1.50	62,344	0.23	3,676	0.70	5,373	0.41	17,923	0.33	113,730	0.19
1996	0.072	0.32	20,243	0.57	9,149	1.49	60,574	0.24	3,401	0.72	5,398	0.41	21,298	0.34	120,063	0.20
1997	0.070	0.34	24,835	0.59	11,204	1.46	58,318	0.27	3,292	0.75	5,392	0.43	25,276	0.36	128,316	0.23
1998	0.069	0.34	25,085	0.64	11,669	1.29	42,127	0.31	2,959	0.77	4,889	0.45	25,460	0.37	112,189	0.25
1999	0.069	0.34	19,501	0.68	14,191	1.24	25,608	0.34	2,961	0.78	4,376	0.45	22,528	0.38	89,166	0.28
2000	0.069	0.34	23,140	0.59	12,355	1.31	42,017	0.26	3,071	0.77	4,886	0.44	24,421	0.36	109,890	0.23
2001	0.069	0.34	23,140	0.59	12,355	1.31	42,017	0.26	3,071	0.77	4,886	0.44	24,421	0.36	109,890	0.23
2002	0.069	0.34	23,140	0.59	12,355	1.31	42,017	0.26	3,071	0.77	4,858	0.00	24,421	0.36	109,862	0.23

Table E38. Biomass (mt) estimates (1978-1999) and projections (2000-2002) from basecase KLAMZ (M=0.15 y-1) runs with CV's from 500 bootstrap iterations. Projections assume recent (average 1997-1999) catch and recruitment.

Year	SVA	CV	DMV	CV	SNJ	CV	NNJ	CV	LI	CV	SNE	CV	GBK	CV	All Areas	CV
1978	63,153	0.42	342,096	1.50	32,953	3.34	202,786	0.55	1,404	1.19	169,029	1.01	57,641	5.29	869,063	0.74
1979	60,884	0.42	342,457	1.45	34,881	3.07	204,668	0.53	1,975	1.15	168,135	0.98	61,080	4.77	874,081	0.71
1980	57,247	0.42	354,557	1.33	36,942	2.77	219,407	0.47	2,777	1.13	166,752	0.92	66,364	4.07	904,046	0.65
1981	52,867	0.42	392,261	1.14	37,773	2.56	259,593	0.39	3,762	1.09	165,145	0.85	72,479	3.38	983,881	0.56
1982	48,170	0.42	447,189	0.96	38,750	2.35	324,304	0.33	4,970	1.05	163,492	0.78	78,799	2.79	1,105,673	0.47
1983	41,124	0.44	479,557	0.86	39,321	2.18	408,165	0.30	6,509	1.04	159,449	0.72	84,945	2.30	1,219,069	0.41
1984	32,424	0.50	500,836	0.79	37,762	2.11	487,935	0.28	8,457	1.09	151,708	0.68	90,701	1.90	1,309,824	0.36
1985	26,640	0.54	516,170	0.74	34,072	2.16	529,251	0.28	10,874	1.12	142,227	0.65	92,837	1.63	1,352,071	0.34
1986	22,672	0.56	516,981	0.71	31,737	2.14	556,090	0.28	13,071	1.11	132,271	0.62	95,366	1.39	1,368,188	0.32
1987	18,994	0.59	512,163	0.69	29,726	2.14	555,411	0.28	15,071	1.07	121,746	0.60	97,650	1.19	1,350,762	0.31
1988	16,224	0.61	500,058	0.67	29,407	2.06	550,385	0.29	17,193	1.03	112,446	0.58	100,545	1.02	1,326,260	0.30
1989	13,524	0.64	482,001	0.65	30,391	1.95	543,897	0.29	19,668	0.98	104,396	0.56	102,954	0.88	1,296,832	0.29
1990	11,282	0.67	454,820	0.65	32,084	1.83	529,471	0.29	22,491	0.93	98,429	0.54	105,685	0.76	1,254,263	0.28
1991	8,138	0.81	425,335	0.64	33,396	1.79	517,114	0.29	25,987	0.88	93,827	0.52	110,493	0.65	1,214,290	0.27
1992	7,075	0.81	397,821	0.63	35,130	1.77	508,903	0.29	30,847	0.82	90,980	0.49	118,058	0.55	1,188,814	0.26
1993	6,141	0.81	372,734	0.63	36,856	1.80	510,077	0.28	35,627	0.78	89,219	0.47	128,541	0.47	1,179,195	0.25
1994	5,325	0.81	349,302	0.63	39,241	1.82	515,614	0.28	39,405	0.76	88,075	0.45	142,457	0.41	1,179,420	0.24
1995	4,573	0.81	331,523	0.62	44,006	1.77	518,674	0.27	42,220	0.75	87,378	0.43	160,333	0.37	1,188,706	0.23
1996	3,951	0.81	321,264	0.61	49,782	1.72	522,407	0.27	44,341	0.73	86,527	0.42	182,754	0.34	1,211,028	0.22
1997	3,417	0.81	319,260	0.60	56,598	1.68	523,129	0.26	45,858	0.73	86,254	0.41	210,401	0.33	1,244,919	0.22
1998	2,947	0.82	321,348	0.59	61,672	1.69	509,682	0.27	46,614	0.72	85,709	0.40	239,573	0.32	1,267,544	0.21
1999	2,545	0.82	321,108	0.58	68,175	1.68	479,826	0.27	47,018	0.72	84,462	0.40	265,360	0.32	1,268,495	0.21
2000	2,197	0.82	324,374	0.57	72,643	1.70	465,736	0.27	47,312	0.72	83,604	0.40	290,240	0.32	1,286,106	0.22
2001	1,894	0.82	327,790	0.57	76,971	1.71	452,653	0.28	47,492	0.72	82,905	0.40	313,253	0.32	1,302,958	0.22
2002	1,632	0.82	331,495	0.57	80,872	1.71	440,938	0.28	47,591	0.73	82,274	0.37	334,142	0.33	1,318,945	0.22

Table E39. Fishing mortality (y^{-1}) estimates (1978-1999) and projections (2000-2002) from basecase KLAMZ (M=0.15 y-1) runs with CV's from 500 bootstrap iterations. Projections assume recent (average 1997-1999) catch and recruitment.

Year	SVA	CV	DMV	CV	SNJ	CV	NNJ	CV	LI	CV	SNE	CV	GBK	CV	All Areas	CV
1978	0.000	NA	0.011	3.19	0.002	1.64	0.009	0.83	0.000	NA	0.000	NA	0.000	NA	0.006	2.17
1979	0.000	NA	0.009	2.23	0.004	1.14	0.009	0.66	0.000	NA	0.000	NA	0.000	NA	0.006	1.34
1980	0.000	NA	0.008	1.37	0.005	0.88	0.010	0.46	0.000	NA	0.000	NA	0.000	NA	0.006	0.79
1981	0.000	NA	0.000	0.87	0.004	0.77	0.033	0.36	0.000	NA	0.000	NA	0.000	NA	0.009	0.35
1982	0.055	0.32	0.027	0.72	0.022	0.70	0.045	0.31	0.013	1.94	0.000	NA	0.000	NA	0.027	0.32
1983	0.126	0.35	0.022	0.68	0.047	0.66	0.024	0.29	0.043	2.61	0.005	0.80	0.000	NA	0.023	0.28
1984	0.079	0.40	0.019	0.66	0.079	0.69	0.030	0.28	0.001	2.85	0.003	0.74	0.036	0.90	0.025	0.25
1985	0.038	0.44	0.021	0.65	0.052	0.76	0.026	0.29	0.000	NA	0.004	0.70	0.026	0.88	0.022	0.28
1986	0.050	0.46	0.007	0.64	0.072	0.86	0.040	0.30	0.002	2.33	0.011	0.68	0.025	0.86	0.024	0.23
1987	0.027	0.49	0.004	0.63	0.036	0.91	0.044	0.31	0.000	NA	0.012	0.66	0.012	0.82	0.023	0.26
1988	0.048	0.52	0.003	0.62	0.009	0.82	0.049	0.32	0.000	NA	0.018	0.65	0.010	0.78	0.025	0.27
1989	0.045	0.57	0.009	0.61	0.004	0.70	0.042	0.33	0.000	NA	0.017	0.65	0.005	0.74	0.024	0.26
1990	0.188	0.73	0.010	0.60	0.039	0.63	0.045	0.33	0.000	NA	0.013	0.63	0.000	0.69	0.027	0.26
1991	0.000	NA	0.005	0.60	0.053	0.61	0.046	0.33	0.001	1.57	0.000	0.60	0.000	NA	0.023	0.29
1992	0.000	NA	0.004	0.59	0.083	0.64	0.050	0.32	0.003	1.47	0.000	0.57	0.000	NA	0.025	0.28
1993	0.000	NA	0.012	0.58	0.074	0.68	0.042	0.31	0.002	1.40	0.000	0.55	0.000	NA	0.024	0.25
1994	0.009	0.92	0.013	0.58	0.022	0.67	0.045	0.29	0.002	1.37	0.000	NA	0.000	NA	0.025	0.25
1995	0.001	0.94	0.011	0.57	0.021	0.63	0.040	0.28	0.000	NA	0.006	0.51	0.000	NA	0.022	0.24
1996	0.000	NA	0.009	0.55	0.035	0.60	0.041	0.28	0.001	1.32	0.001	0.50	0.000	NA	0.021	0.24
1997	0.002	0.94	0.006	0.54	0.069	0.60	0.035	0.27	0.002	1.31	0.000	NA	0.000	NA	0.020	0.23
1998	0.000	NA	0.002	0.53	0.079	0.64	0.034	0.27	0.002	1.32	0.002	0.49	0.000	NA	0.018	0.25
1999	0.000	NA	0.002	0.52	0.071	0.66	0.036	0.28	0.002	1.34	0.002	0.49	0.000	NA	0.018	0.25
2000	0.001	0.95	0.003	0.52	0.062	0.71	0.038	0.29	0.002	1.36	0.001	0.49	0.000	NA	0.018	0.26
2001	0.001	0.95	0.003	0.52	0.059	0.76	0.039	0.29	0.002	1.39	0.001	0.50	0.000	NA	0.018	0.27
2002	0.001	0.95	0.003	0.52	0.056	0.80	0.040	0.30	0.002	1.42	0.000	NA	0.000	NA	0.018	0.28

Table E40. Annual surplus production (mt) estimates (1978-1999) and projections (2000-2002) from basecase KLAMZ (M=0.15 y-1) runs with CV's from 500 bootstrap iterations. Projections assume recent (average 1997-1999) catch and recruitment. Note-CV's are very large in some years because production (used in the denominator when calculating CV) was near zero, not because of large variances in biomass estimates (see Table E38).

Year	SVA	CV	DMV	CV	SNJ	CV	NNJ	CV	LI	CV	SNE	CV	GBK	CV	Whole Stock	CV
1978	-2,269	0.42	3,768	5.04	1,989	4.16	3,451	1.41	571	1.31	-893	8.62	3,439	4.09	10,055	2.65
1979	-3,637	0.42	14,740	2.20	2,174	4.34	16,442	0.62	802	1.24	-1,383	8.64	5,283	4.09	34,421	1.25
1980	-4,380	0.42	40,382	1.23	985	9.01	42,156	0.40	985	1.10	-1,607	8.69	6,116	4.09	84,636	0.71
1981	-4,697	0.42	55,039	1.03	1,109	8.18	72,233	0.34	1,208	1.01	-1,653	8.82	6,320	4.10	129,558	0.53
1982	-4,732	0.42	42,927	1.14	1,326	6.63	96,809	0.29	1,596	1.05	-4,043	3.46	6,146	4.11	140,030	0.46
1983	-4,301	0.45	30,474	1.37	52	148.87	88,659	0.29	2,195	1.25	-6,958	1.87	5,756	4.12	115,878	0.49
1984	-3,576	0.51	23,852	1.53	-1,090	6.71	54,182	0.31	2,424	1.33	-9,087	1.31	4,991	4.35	71,697	0.67
1985	-3,070	0.55	10,543	2.96	-792	8.38	38,904	0.38	2,197	1.11	-9,503	1.14	4,676	4.19	42,956	0.97
1986	-2,689	0.57	-1,509	18.27	-24	243.25	19,146	0.58	2,019	0.92	-9,220	1.05	4,395	3.99	12,116	3.00
1987	-2,319	0.60	-10,101	2.54	624	8.53	16,685	0.61	2,122	0.80	-7,976	1.07	3,949	3.93	2,983	11.16
1988	-2,012	0.61	-16,598	1.49	1,226	4.35	17,388	0.74	2,475	0.74	-6,292	1.20	3,268	4.18	-545	59.53
1989	-1,706	0.64	-23,251	1.05	1,804	2.61	5,901	1.88	2,822	0.70	-4,385	1.51	3,236	3.71	-15,578	1.96
1990	-1,395	0.70	-25,214	0.93	2,415	1.85	8,694	1.22	3,496	0.67	-3,441	1.68	4,816	2.23	-10,629	2.71
1991	-1,063	0.81	-25,607	0.87	3,277	1.50	12,878	0.96	4,878	0.69	-2,810	1.81	7,565	1.31	-882	32.31
1992	-933	0.81	-23,661	0.88	4,247	1.45	23,583	0.59	4,850	0.69	-1,755	2.57	10,483	0.90	16,814	1.67
1993	-817	0.81	-19,453	0.95	4,740	1.41	24,555	0.53	3,851	0.68	-1,141	3.51	13,917	0.67	25,651	1.01
1994	-711	0.81	-13,759	1.18	5,538	1.38	23,725	0.54	2,897	0.70	-697	5.17	17,876	0.53	34,869	0.70
1995	-615	0.81	-7,055	2.03	6,606	1.40	22,065	0.56	2,122	0.80	-411	8.05	22,421	0.46	45,132	0.53
1996	-535	0.81	600	24.47	8,365	1.41	19,436	0.71	1,547	1.11	-177	17.87	27,647	0.44	56,884	0.47
1997	-464	0.81	3,880	3.86	8,489	1.18	2,919	3.99	841	1.90	-546	5.32	29,172	0.44	44,290	0.57
1998	-402	0.82	202	69.27	10,723	1.09	-14,559	0.66	508	3.07	-1,115	2.30	25,787	0.47	21,144	1.14
1999	-348	0.82	3,707	3.37	8,687	1.11	1,208	7.00	397	3.74	-727	3.23	24,880	0.47	37,804	0.57
2000	-301	0.82	4,307	2.69	8,280	1.06	2,571	3.04	277	4.98	-611	3.45	23,013	0.47	37,536	0.53
2001	-260	0.82	4,597	2.32	7,853	1.00	3,938	1.80	196	6.45	-543	4.32	20,889	0.47	36,670	0.50
2002	-225	0.82	4,649	2.08	7,447	0.94	5,228	1.22	143	8.02	-464	5.71	18,709	0.47	35,489	0.46

Table E41. Confidence intervals for recent (1997-1999) estimates of fishing mortality and stock biomass for surfclam from the catch-swept area and KLAMZ models. For catch-swept area calculations, biomass is for surfclam 100+ mm, CV's are from sample theory or by assumption, and recent fishing mortality rates are recent mean catch divided by recent mean biomass. For KLAMZ model calculations, biomass is for surfclam 120+ mm (NNJ and SNJ) or 100+ mm (other stock assessment areas), CV's are from bootstrap calculations (300 iterations), and recent fishing mortality rates are averages for 1996-1999. Confidence intervals for swept area catch estimates computed assuming that recent catches, biomass estimates and fishing mortality rates are lognormally distributed. Calculations for catch-swept area model assume a CV (e.g. 5%) for catch data and calculations for both models assume 20% non-catch mortality during fishing. Figures for the whole stock less GBK provided at request of MAFMC staff.

Multiplier for CI's (e.g. 1.96 for 95%	1.96
Assumed CV for Catch	5%

Stock Assessment Area	Recent Catch (1997 1999 Average) + 20% Indirect Mortality	CV	Log Scale SE	Recent Biomass (1997-1999 Average)	CV	Log Scale SE	CI Lower Bound	CI Upper Bound	Recent F	CV	Log Scale SE	CI Lower Bound	CI Upper Bound
Catch-Swept Area Model													
SVA	2	5%	0.050	3,272	84%	0.733	778	13,765	0.001	85%	0.735	0.000	0.003
DMV	919	5%	0.050	304,258	43%	0.410	136,294	679,214	0.003	43%	0.413	0.001	0.007
SNJ	4,074	5%	0.050	103,320	130%	0.993	14,764	723,043	0.039	130%	0.994	0.006	0.277
NNJ	16,138	5%	0.050	487,015	35%	0.339	250,678	946,168	0.033	35%	0.343	0.017	0.065
LI	100	5%	0.050	53,217	103%	0.849	10,076	281,080	0.002	103%	0.851	0.000	0.010
SNE	90	5%	0.050	87,371	85%	0.739	20,524	371,943	0.001	86%	0.741	0.000	0.004
GBK	0	5%	0.050	253,167	55%	0.514	92,482	693,037	0.000	0%	0.000	0.000	0.000
Total	21,323	5%	0.050	1,291,620	30%	0.290	731,343	2,281,122	0.017	30%	0.294	0.009	0.029
Total less GBK	21,323	5%	0.050	1,038,453	26%	0.255	630,412	1,710,604	0.021	26%	0.260	0.012	0.034
KLAMZ Stock Assessment Model													
SVA	NA	NA	NA	2,970	71%	0.639	849	10,389	0.001	70%	0.634	0.000	0.002
DMV	NA	NA	NA	320,572	52%	0.492	122,111	841,586	0.003	48%	0.458	0.001	0.008
SNJ	NA	NA	NA	62,149	114%	0.911	10,426	370,465	0.073	61%	0.563	0.024	0.221
NNJ	NA	NA	NA	504,212	25%	0.250	308,805	823,271	0.035	27%	0.265	0.021	0.059
LI	NA	NA	NA	46,497	73%	0.651	12,988	166,457	0.002	81%	0.710	0.001	0.009
SNE	NA	NA	NA	85,475	40%	0.384	40,273	181,409	0.001	42%	0.404	0.001	0.003
GBK	NA	NA	NA	238,445	34%	0.329	125,092	454,512	0.000	0%	0.000	0.000	0.000
Total	NA	NA	NA	1,260,319	19%	0.190	868,376	1,829,167	0.019	24%	0.234	0.012	0.029
Total less GBK	NA	NA	NA	1,021,874	22%	0.220	663,588	1,573,607	0.023	24%	0.234	0.015	0.036

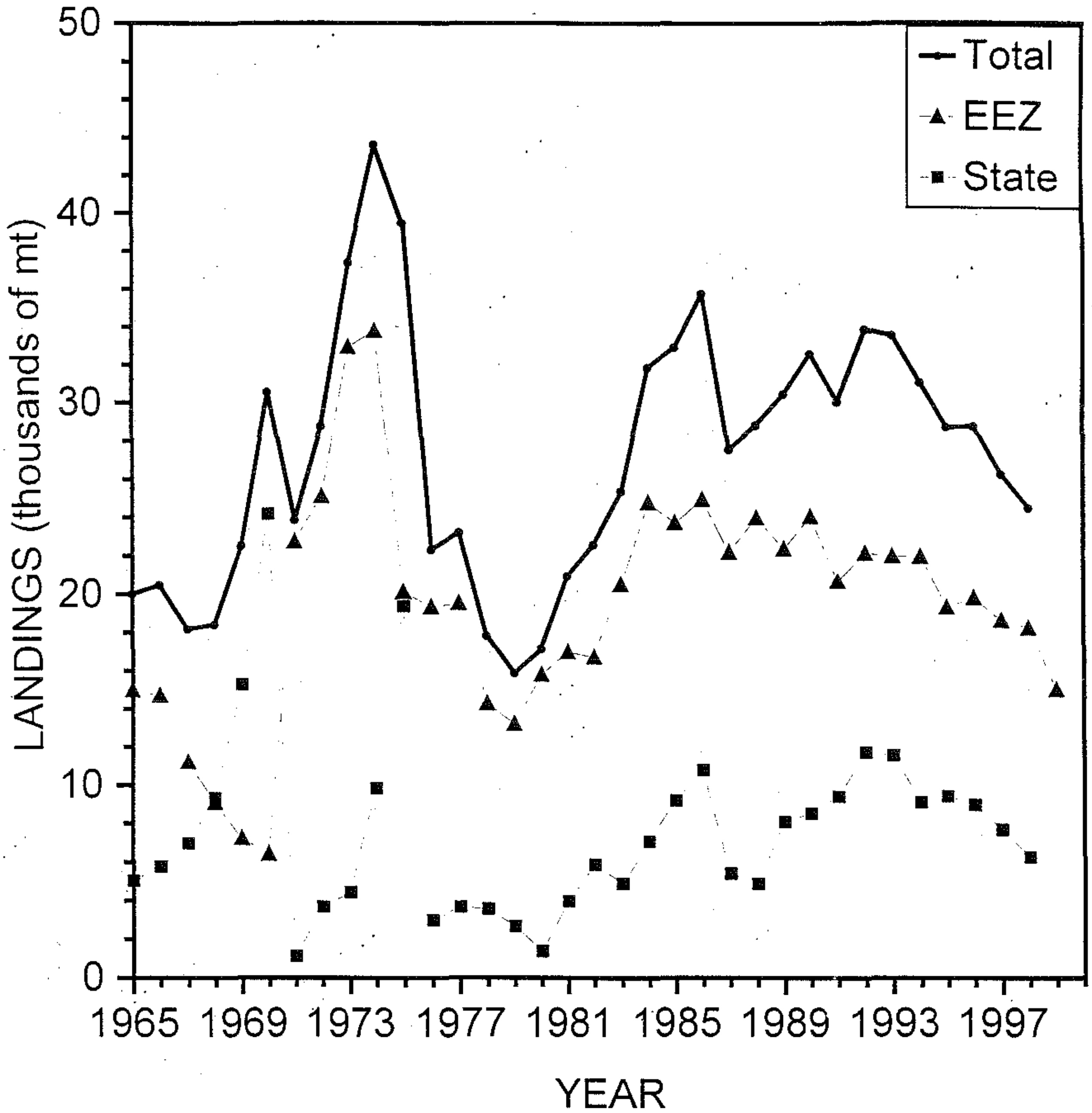


Figure E1. Landings of surfclams (thousands of mt of meats), 1965-1999. Data are for all areas (total), Exclusive Economic Zone (EEZ: 3-200 miles from the coast), and state (inshore) waters. EEZ landings for 1999 were predicted from logbook data available on 15 Aug. 1999.

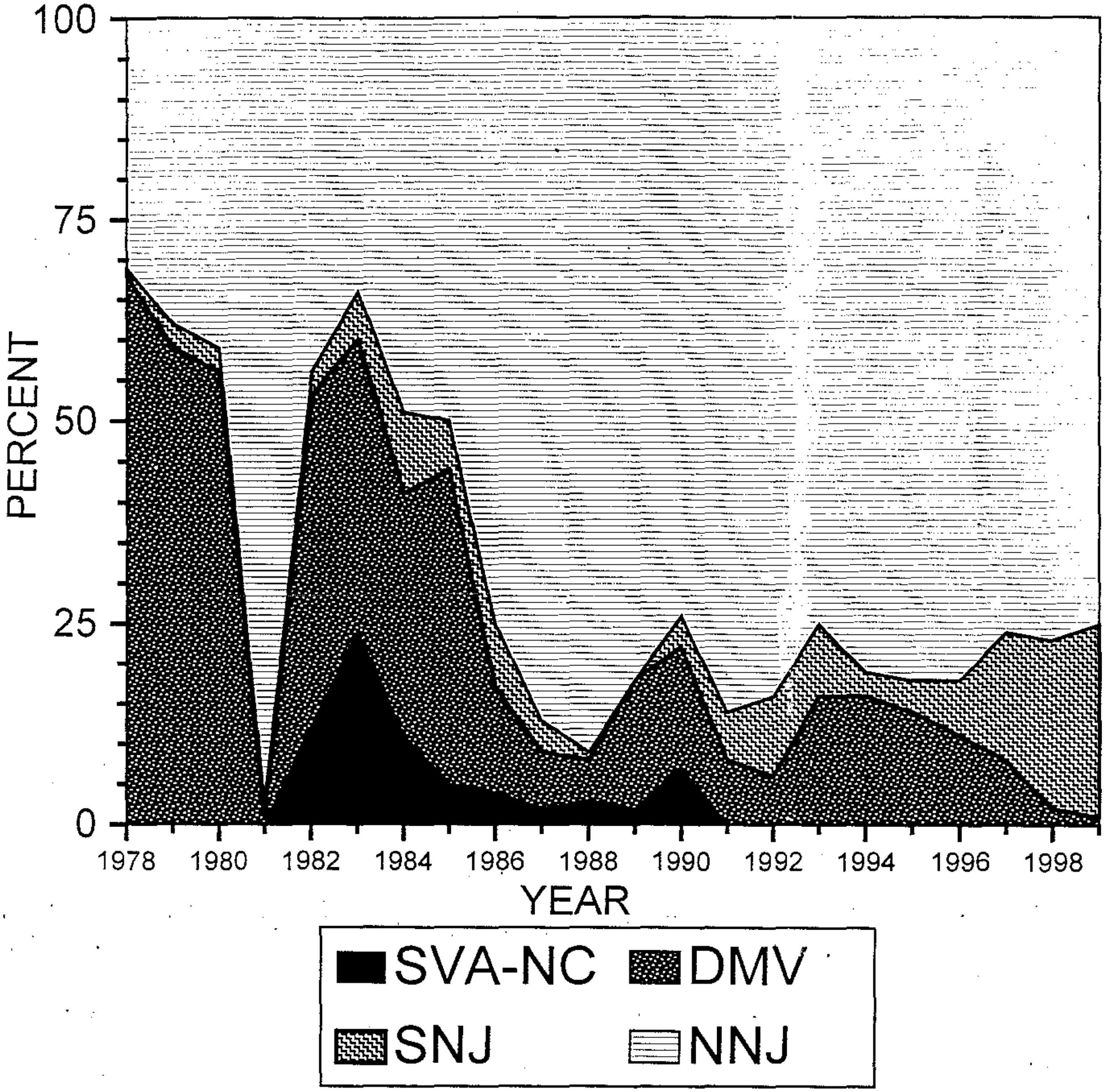


Figure E2. Proportion of surfclam landings in the Mid-Atlantic region, by area and year, 1978-1999. Landings for 1999 were predicted from logbook data available on 15 August 1999.

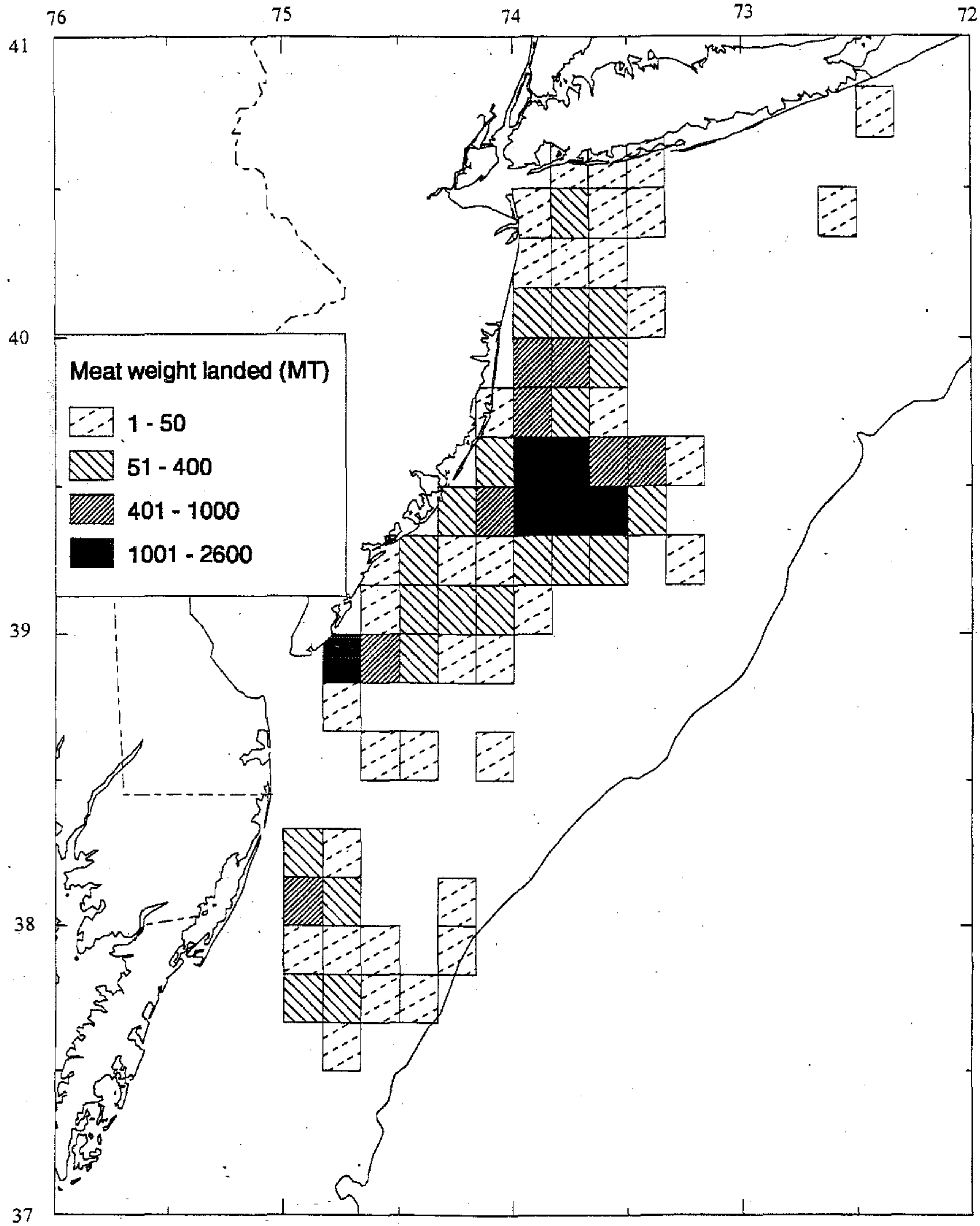


Figure E3. Distribution of surfclam landings during 1997 (sclnd8399a) by ten minute square.

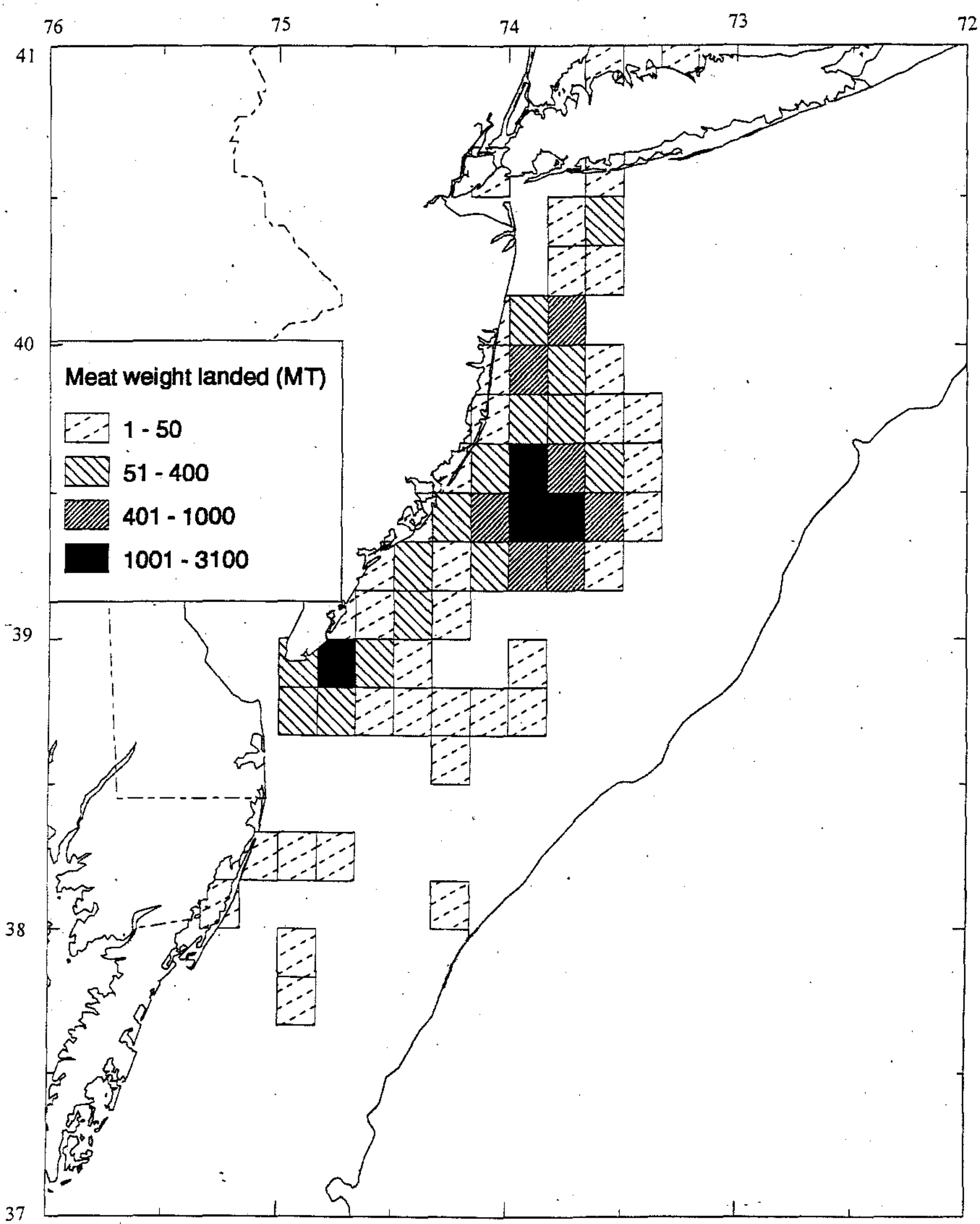


Figure E4. Distribution of surfclam landings during 1998 (sclnd8399b) by ten minute square.

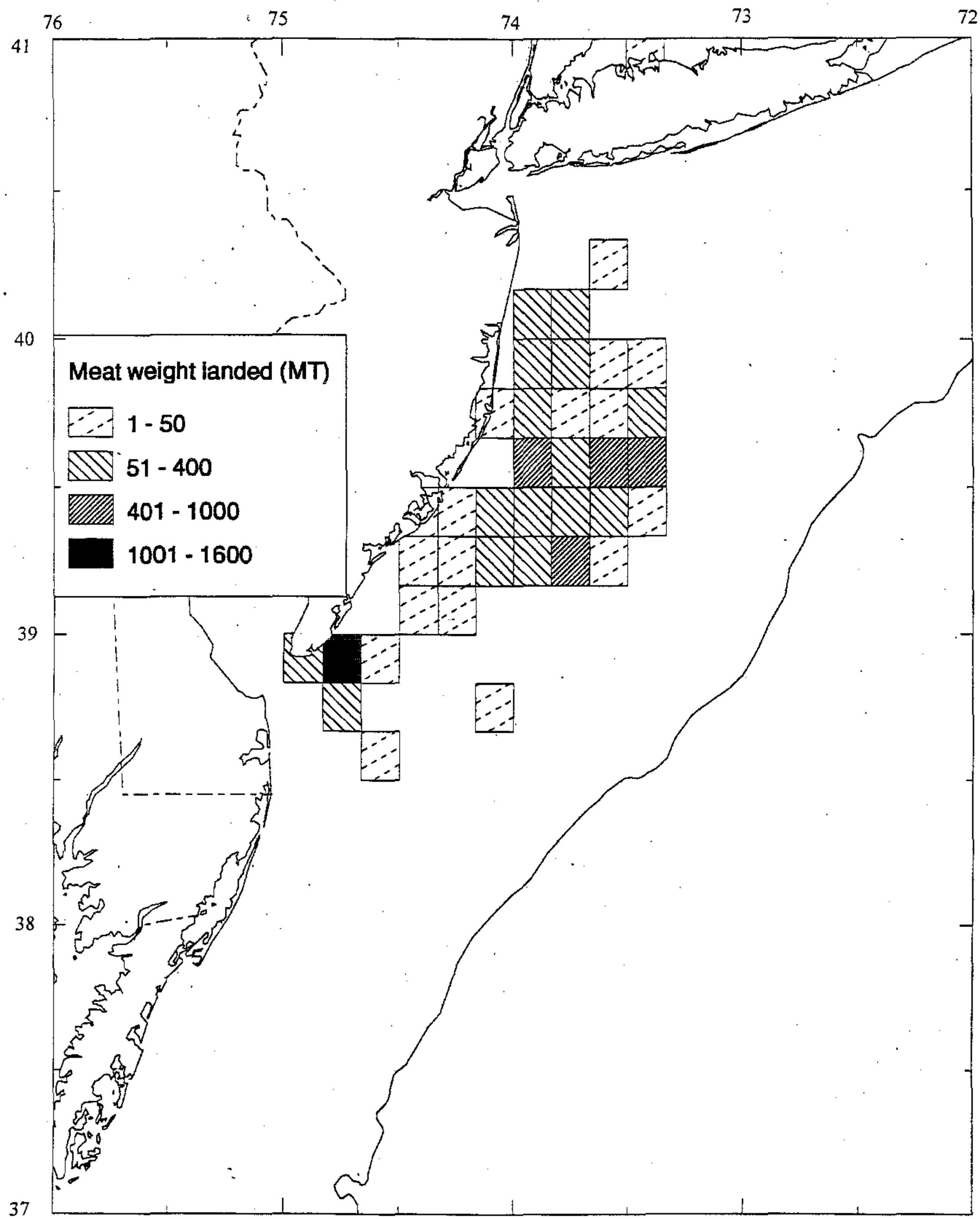


Figure E5. Distribution of surfclam landings during 1999 (sclnd8399b) by ten minute square. (Partial year).

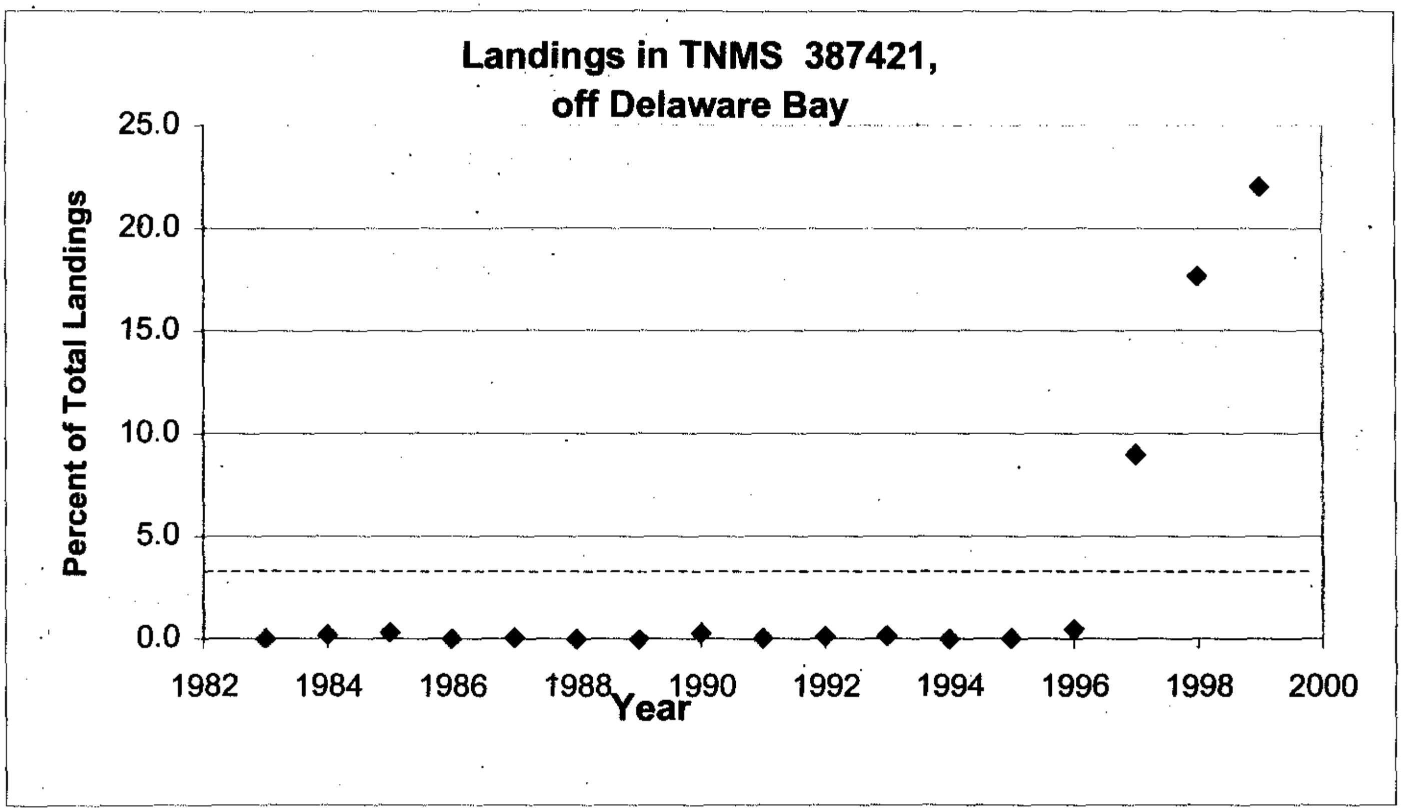


Figure E6. Surfclam landings in one ten minute square.

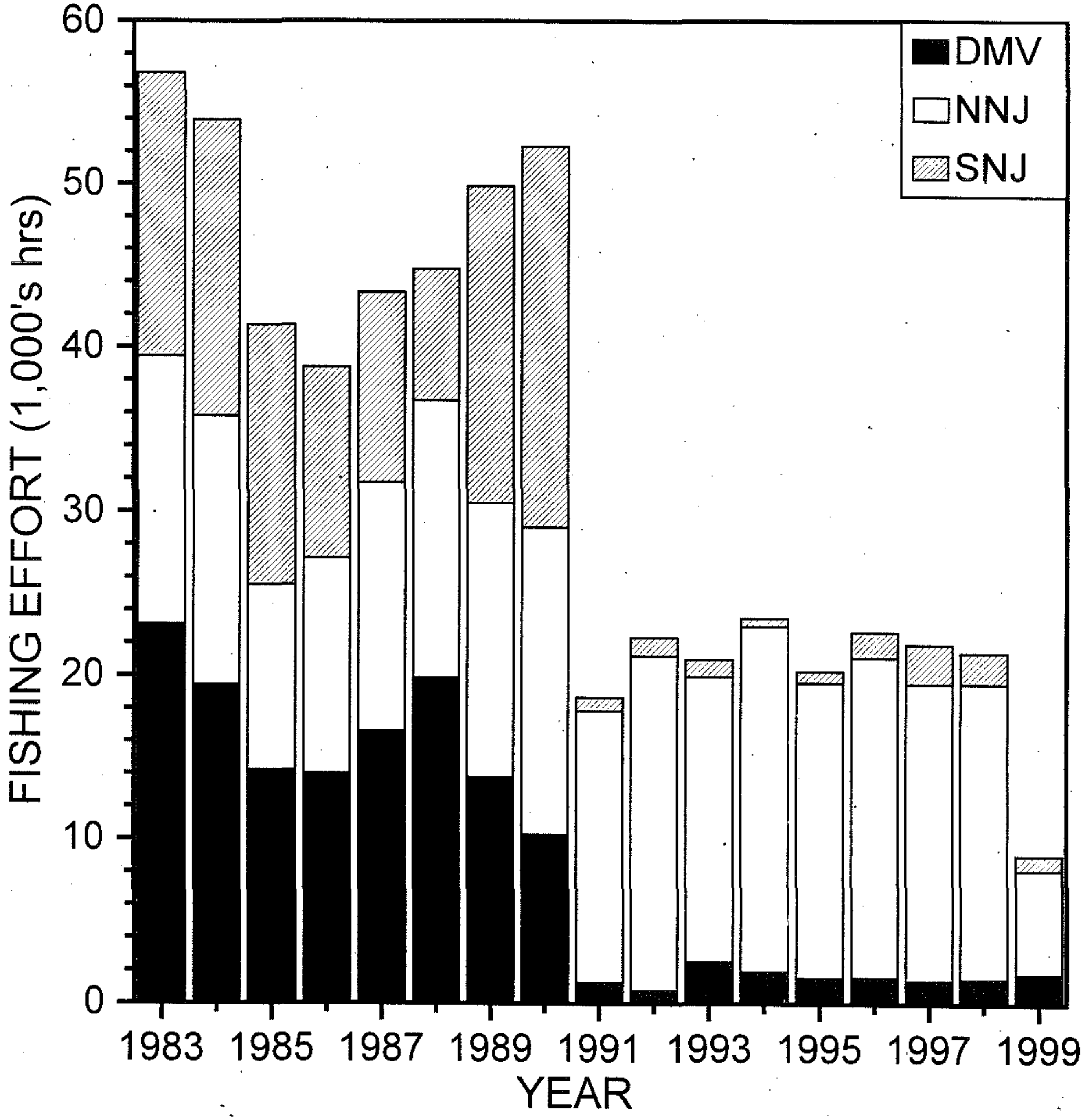


Figure E7. Total reported hours fishing during surfclam trips, by region year. 1999 data do not represent a full year.

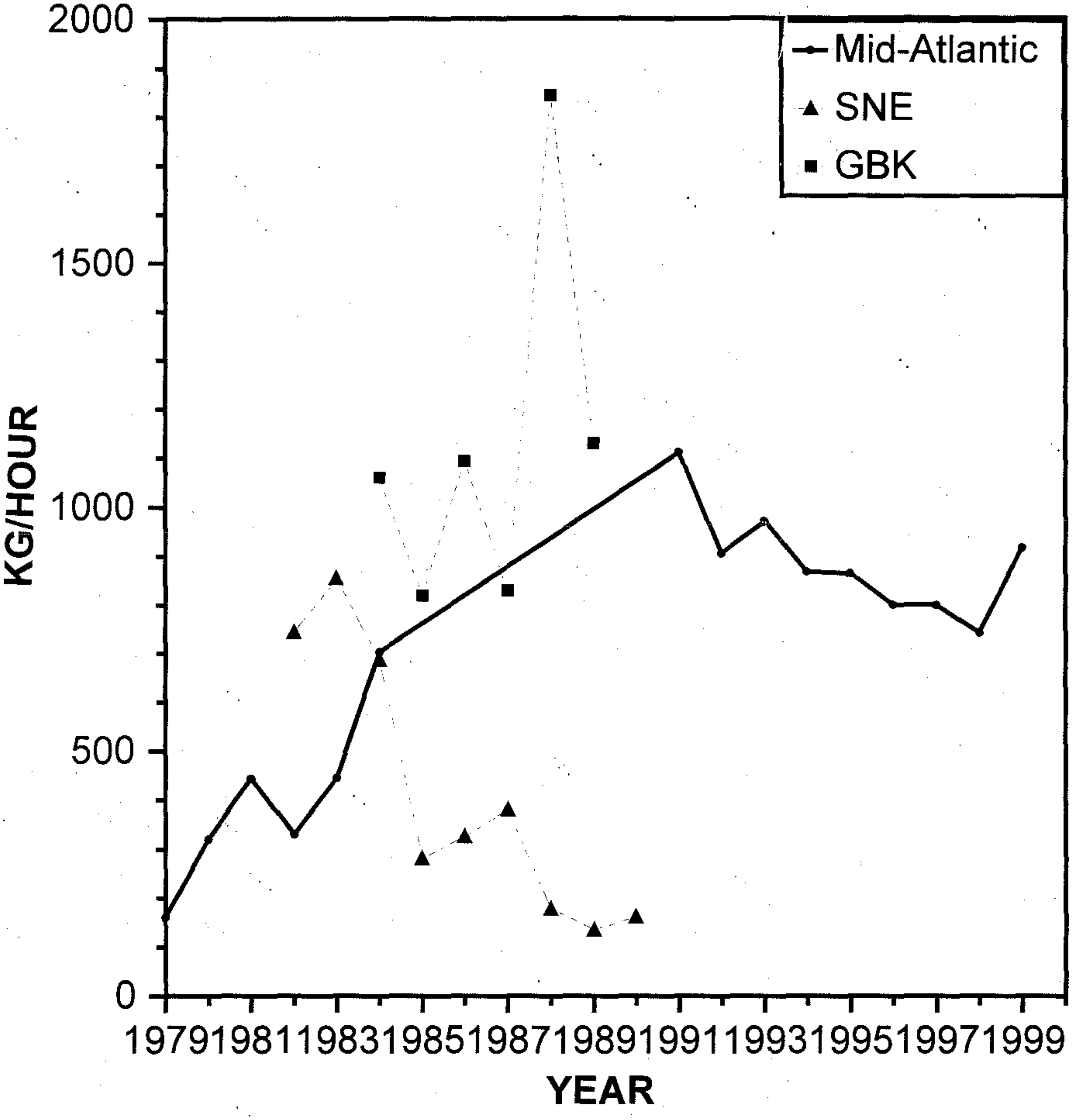


Figure E8. Landings per unit effort (kilograms per hour fished) of surfclams by Class 3 vessels(105 +GTR) by region, 1979-1999. Values were computed from logbook data.

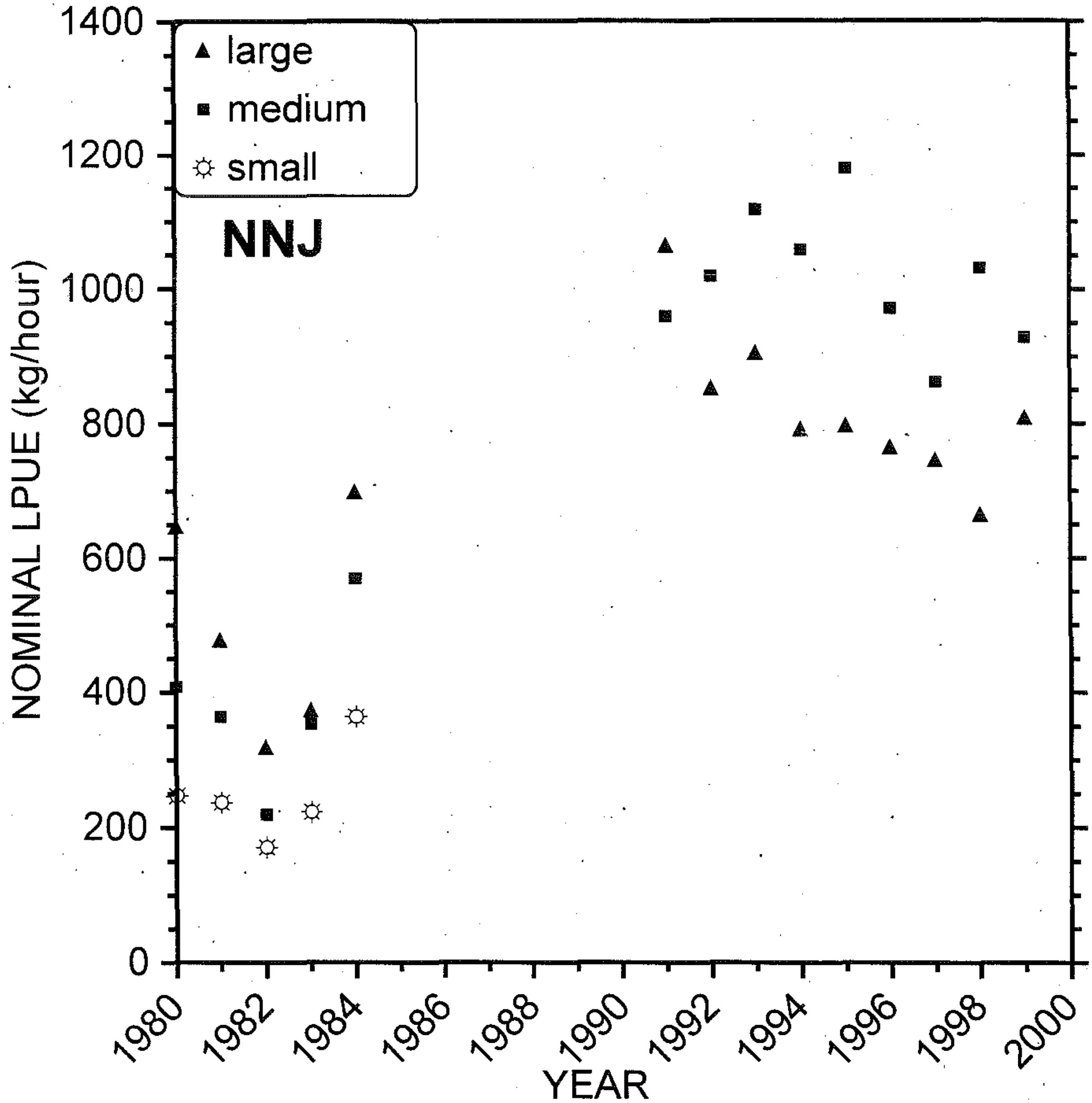


Figure E9. Landings per unit effort for N. New Jersey by vessel class.

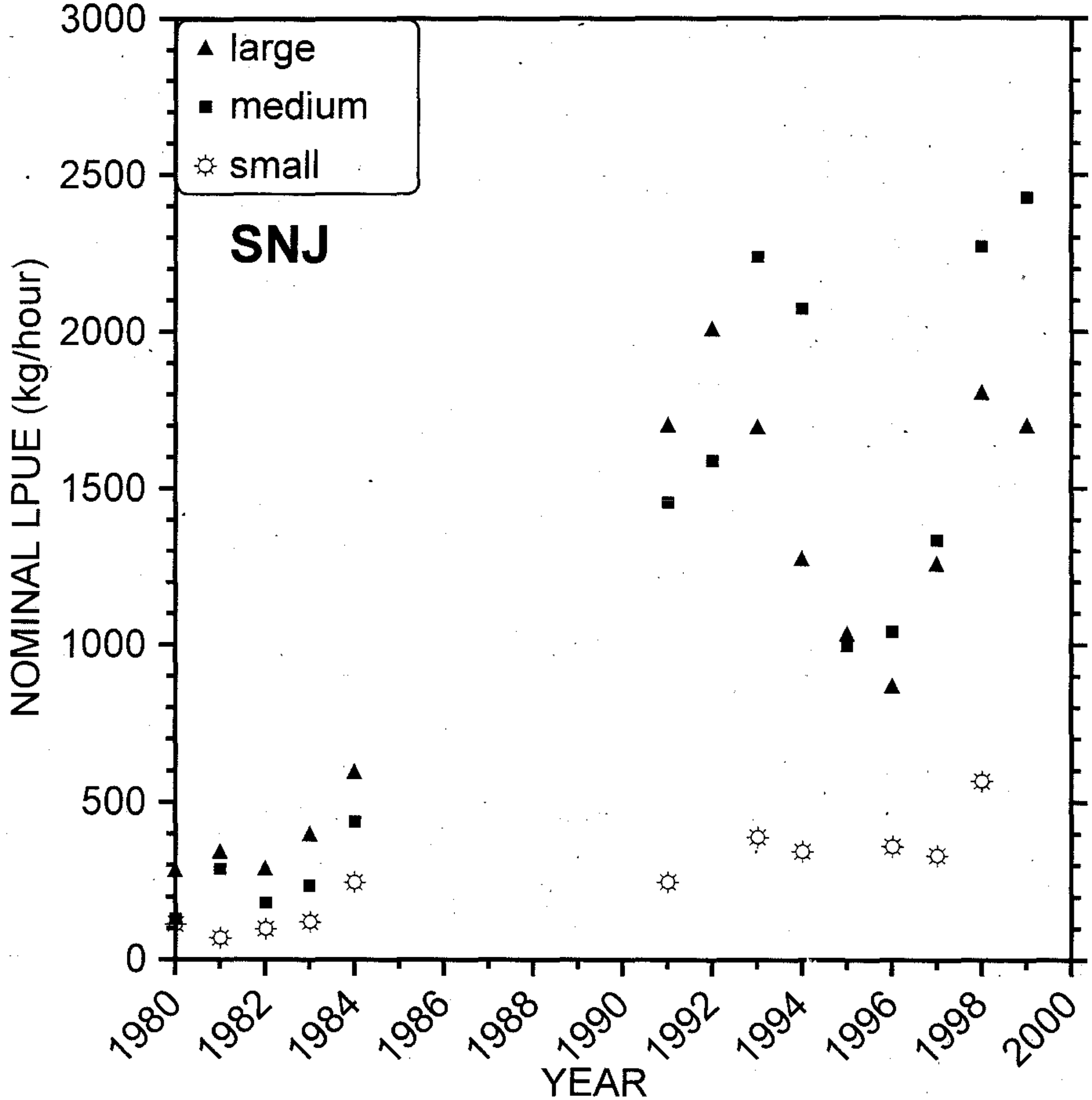


Figure E10. Landings per unit effort for S. New Jersey by vessel class.

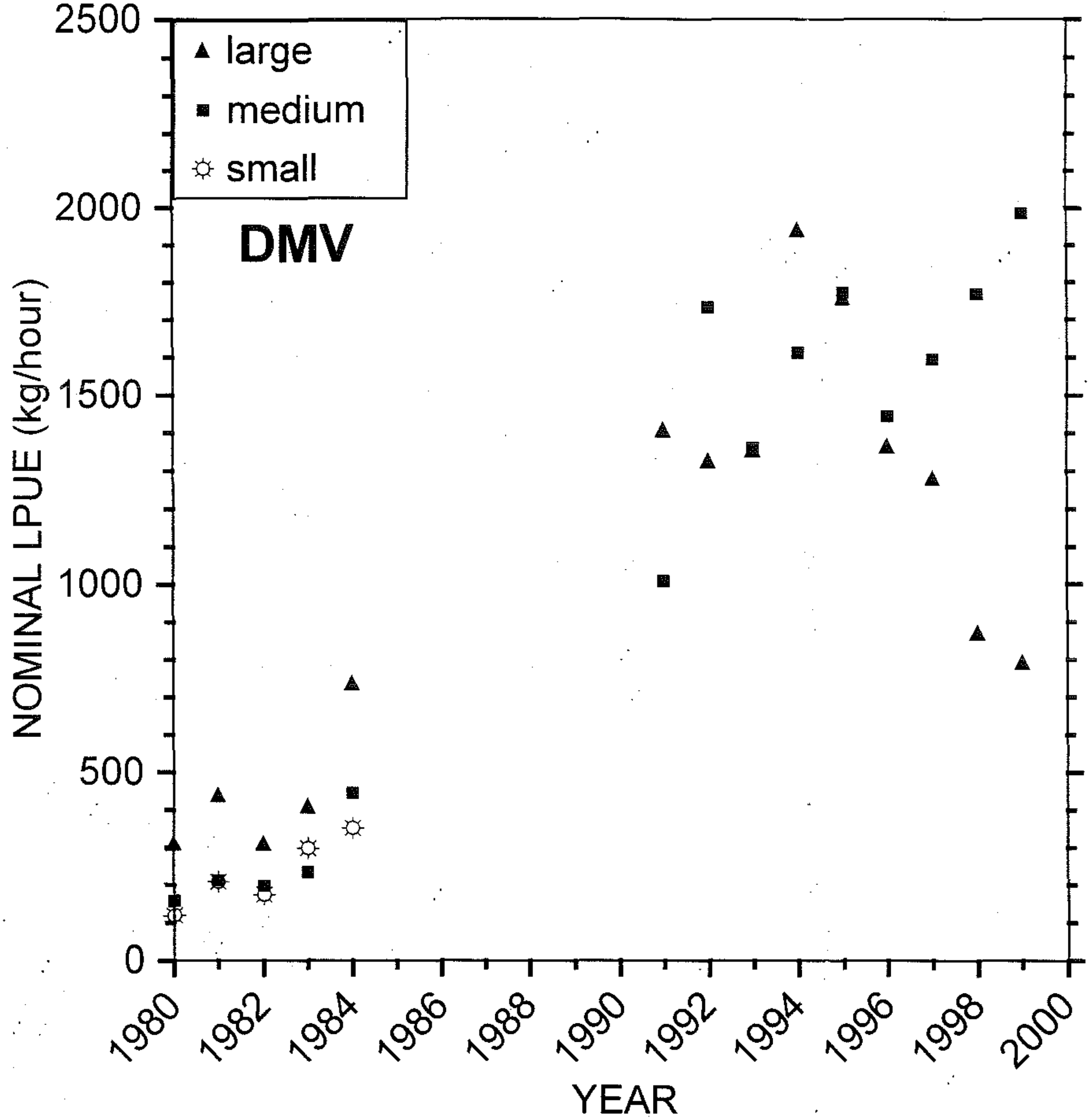
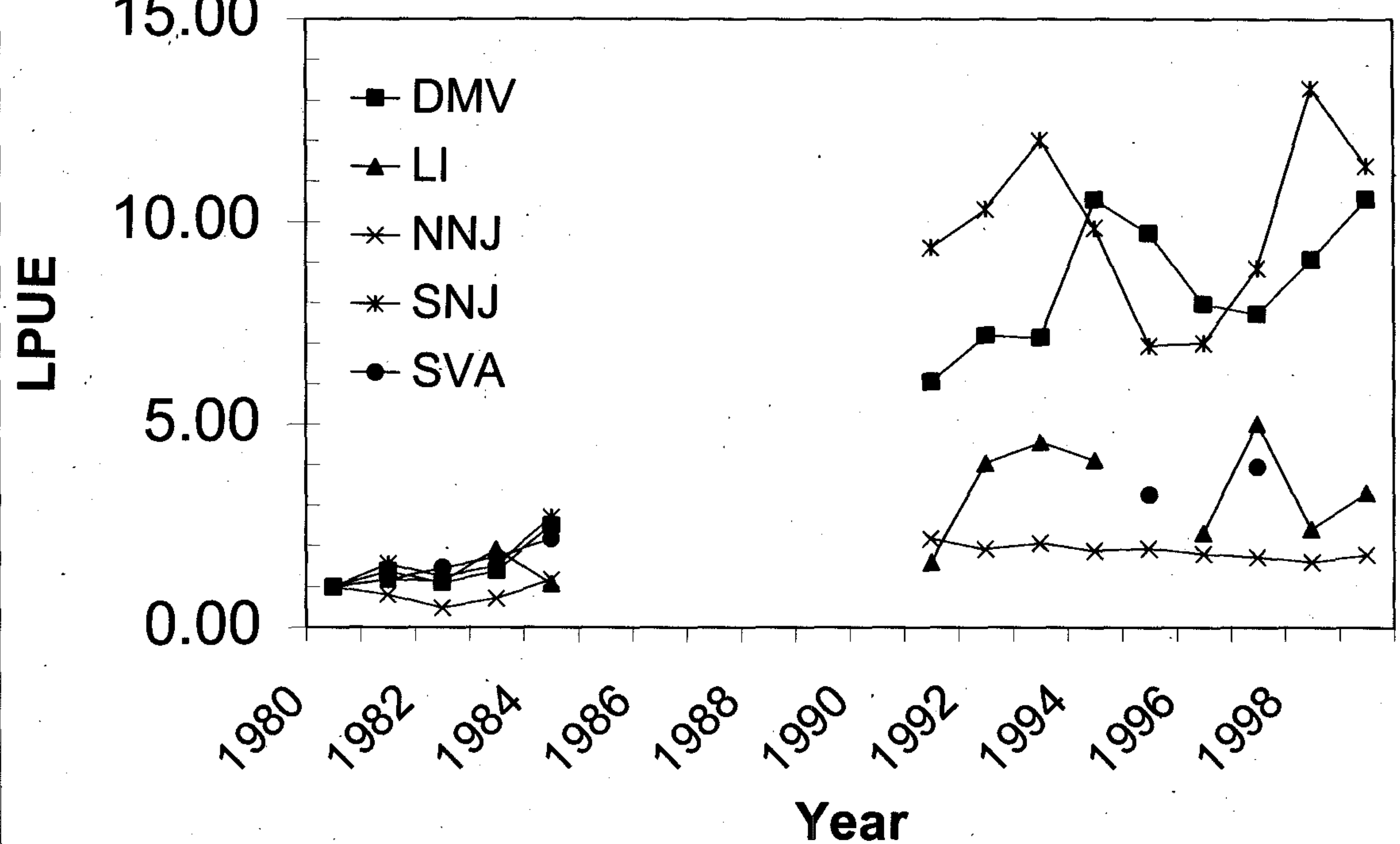


Figure E11. Landings per unit effort by vessel size class for the Delmarva region.

Figure E12. Standardized LPUE for Surfclam, Analyzed by Region



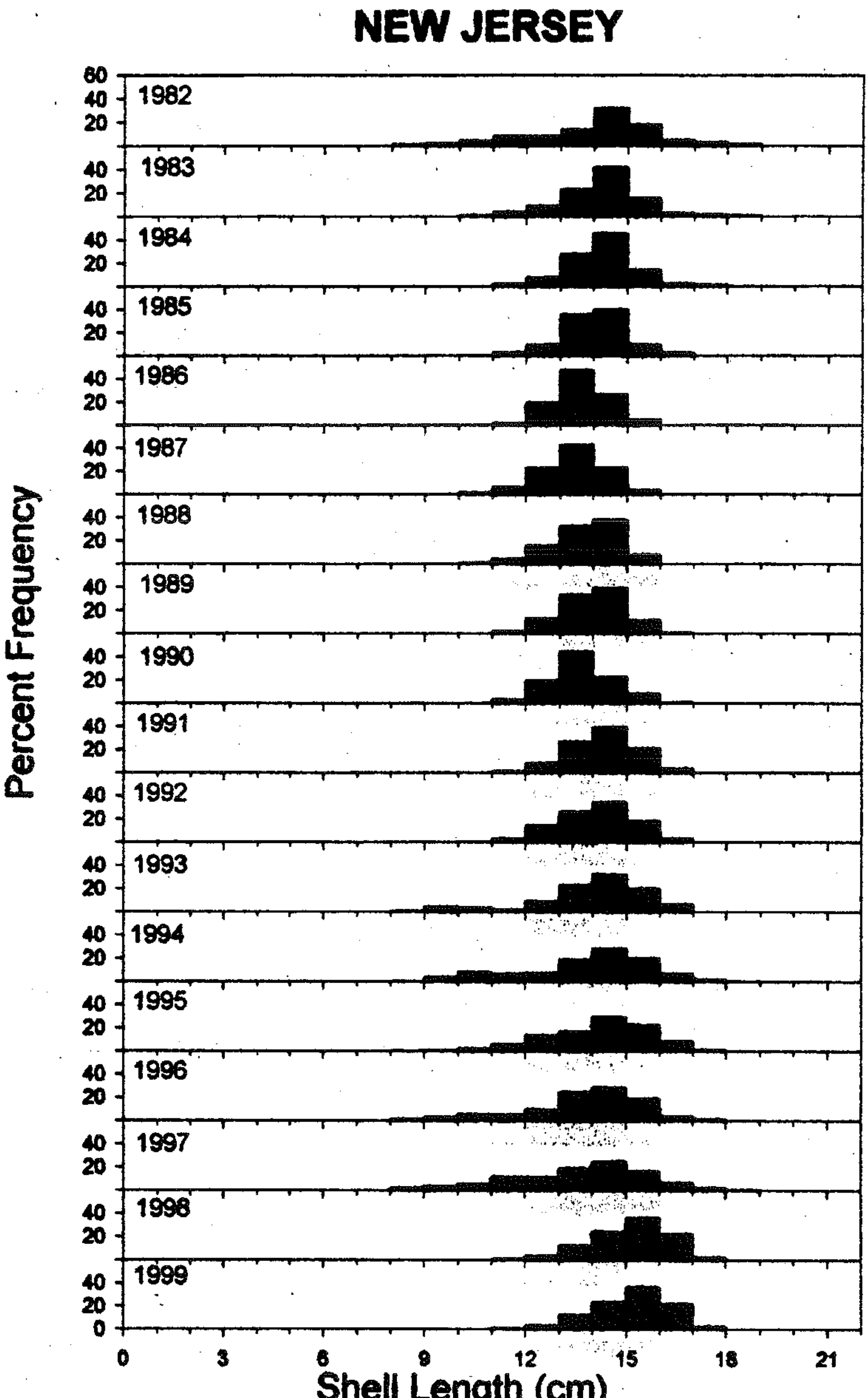


Figure E13. Length frequency of surfclam landings from the New Jersey region, 1982-1999, expressed as percent composition of shell length (cm). 1999 data are not complete.

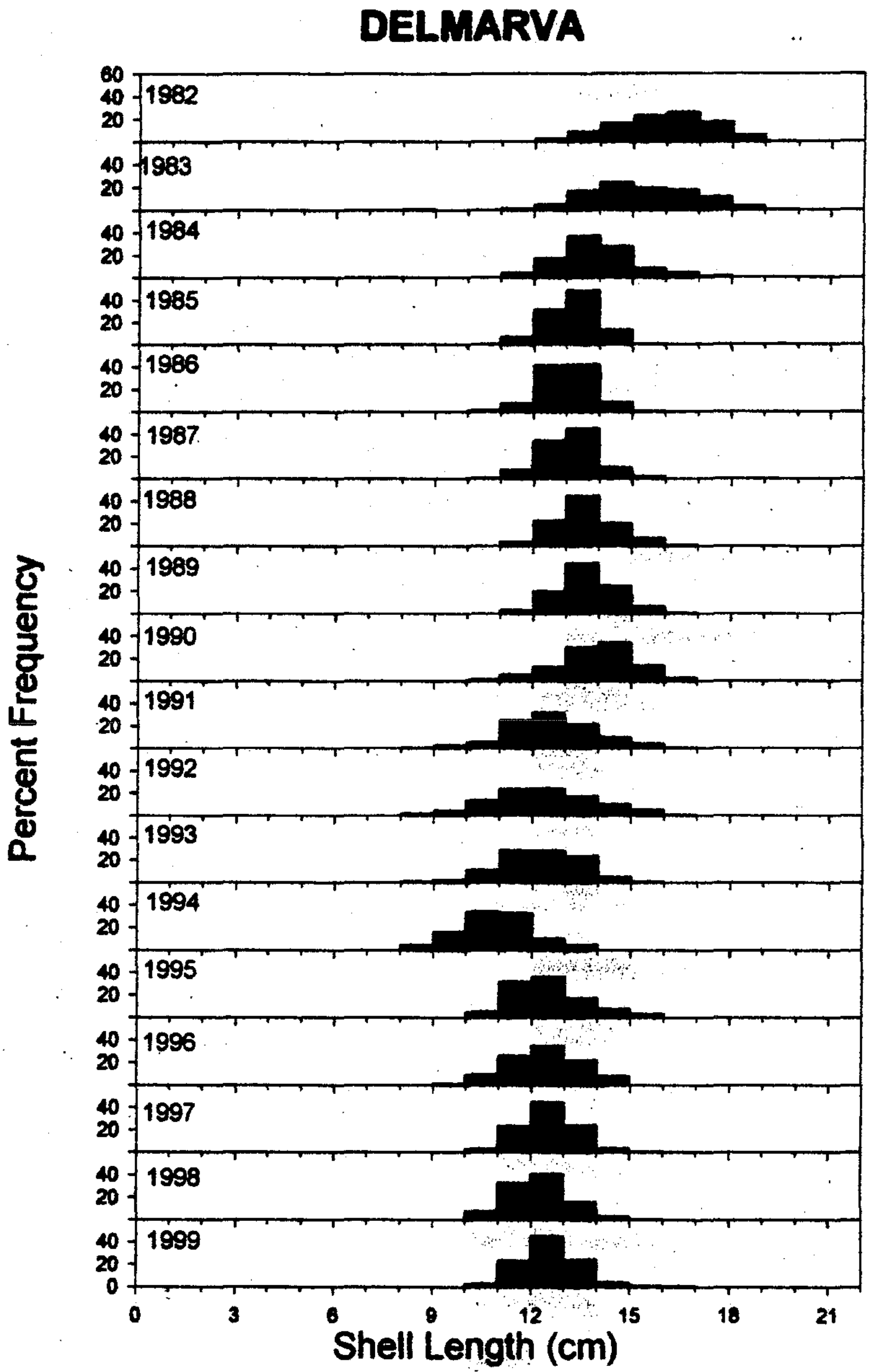
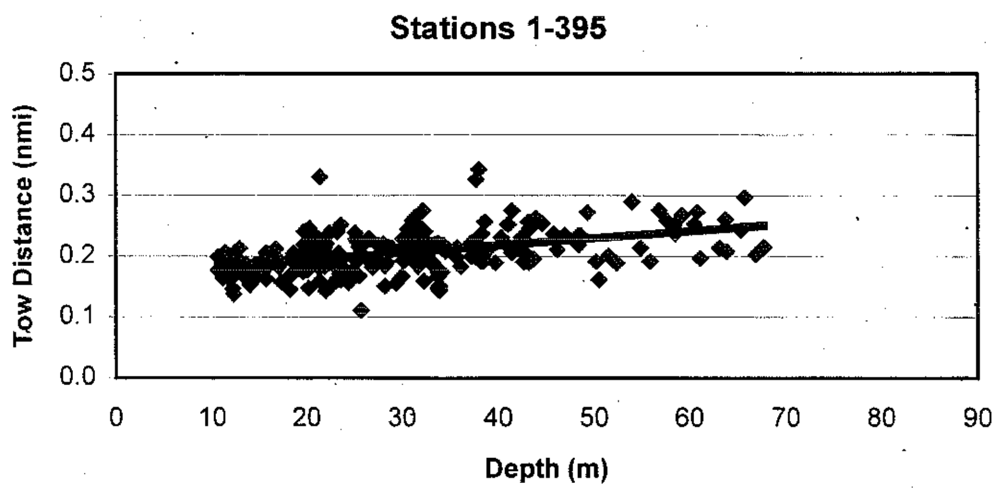


Figure E14. Length frequency of surfclam landings from Delmarva region, 1982-1999, expressed as percent composition of shell length (cm). 1999 data are not complete.



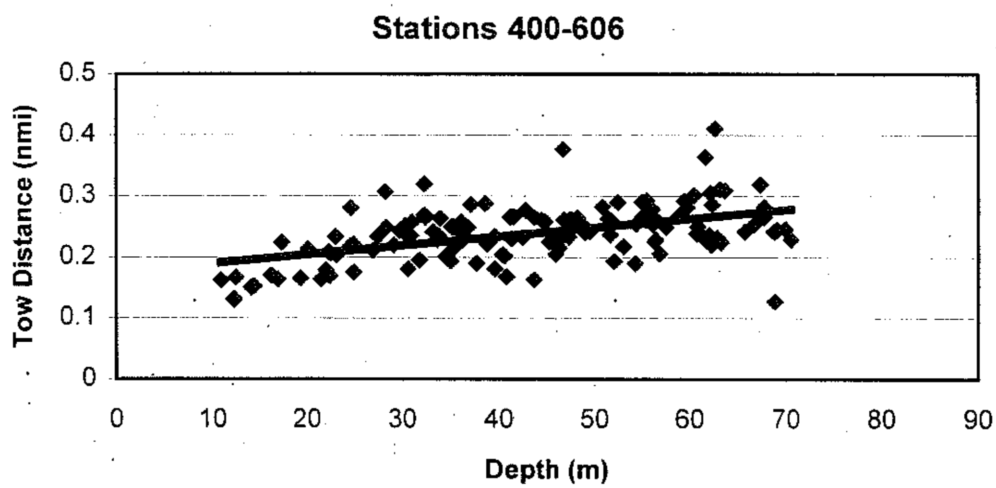


Figure E15. Tow distance vs station depth for the 1999 Clam Survey.

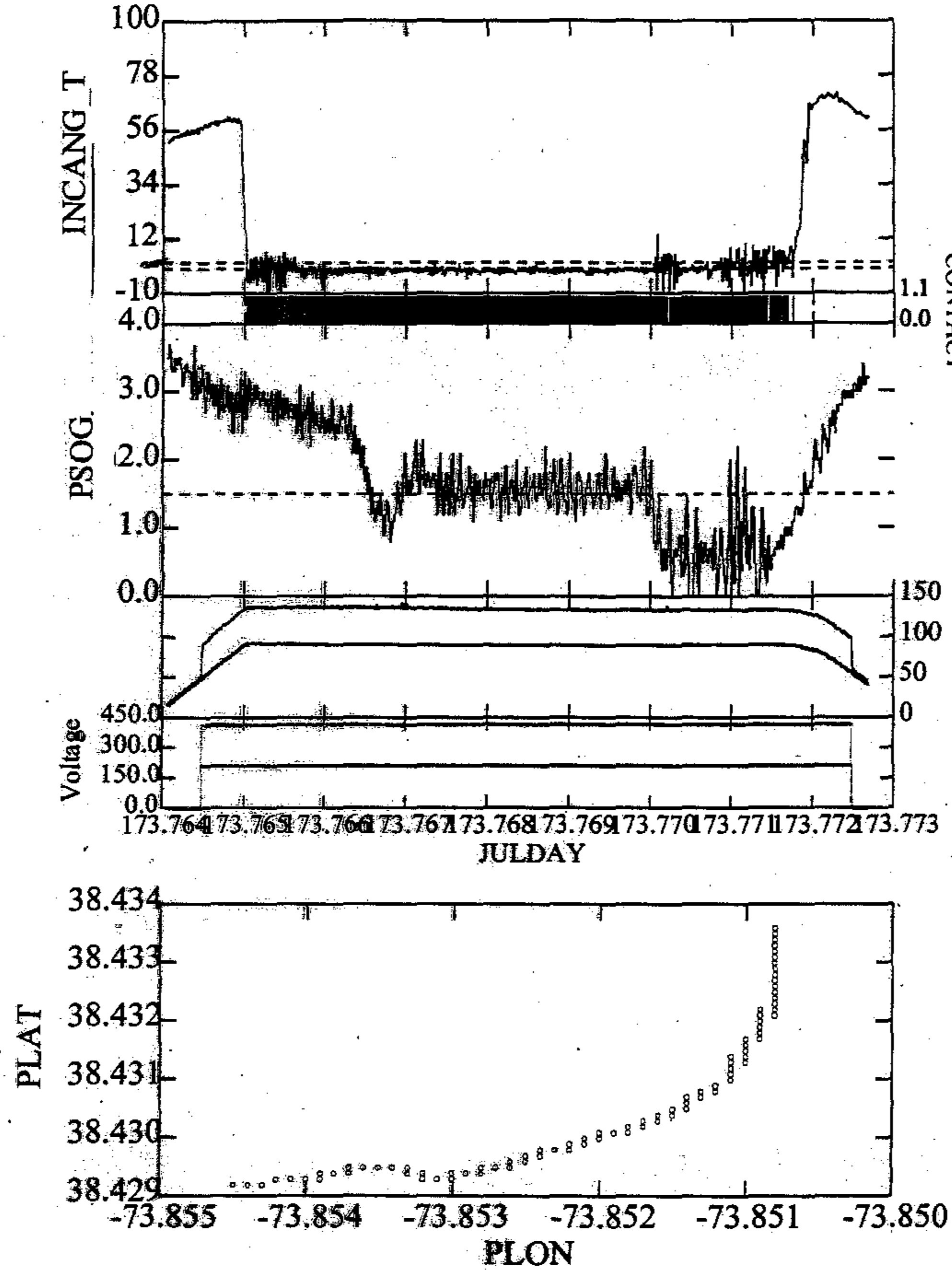


Figure E16. Sensor data from Station 263 of the 1999 NMFS Clam Survey. Note that the dredge angle was fairly constant during the tow, indicating smooth bottom.

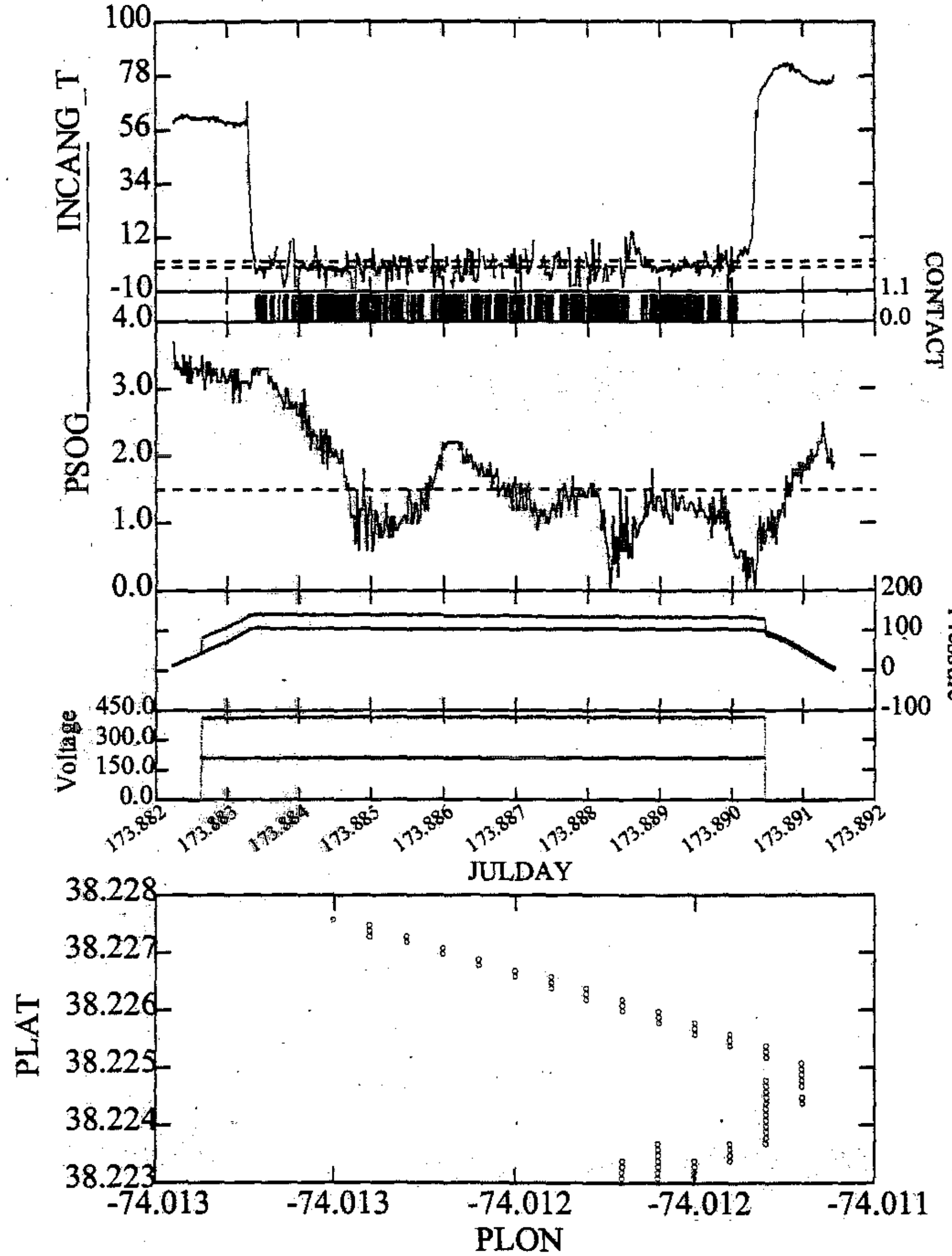


Figure E17. Sensor data from Station 265 of the 1999 NMFS Clam Survey. Note that the dredge angle was highly variable, indicating rough bottom.

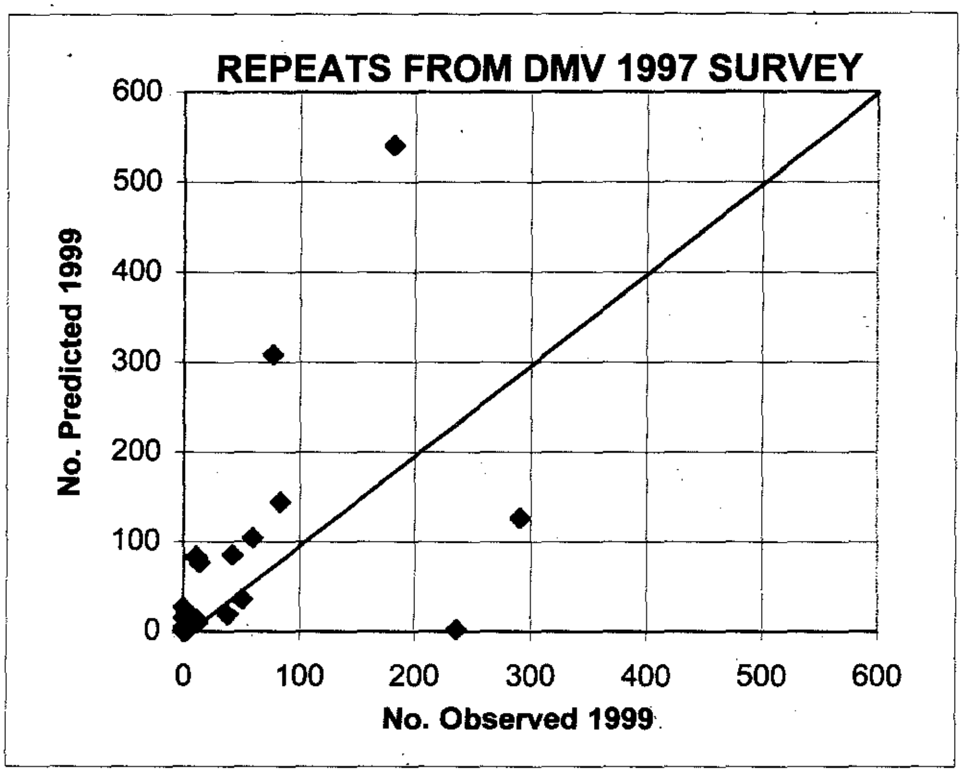


Figure E18. Results from resampling of surfclam stations in 1999 that were previously occupied in 1997. Predicted catch is based on a mortality rate of 0.15, and critical blade depth 4". Numbers were adjusted to a tow distance of 0.15 nmi.

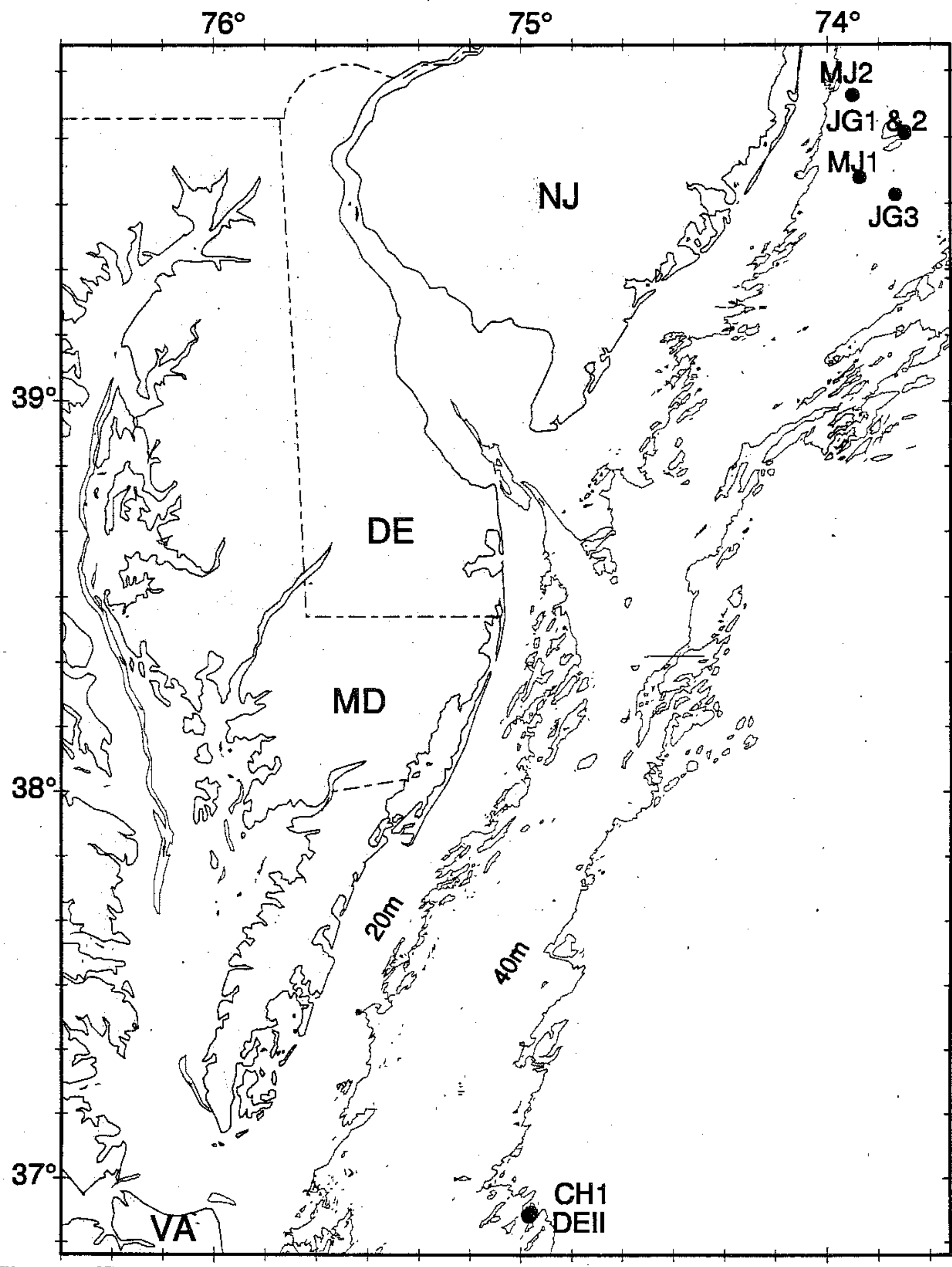


Figure E19.
Locations of surfclam depletion studies conducted by R/V DE II (6/27/99 - 6/29/99), F/V Jersey Girl (9/14/99), F/V Christy (9/25/99) and F/V Melissa J (9/28/99).

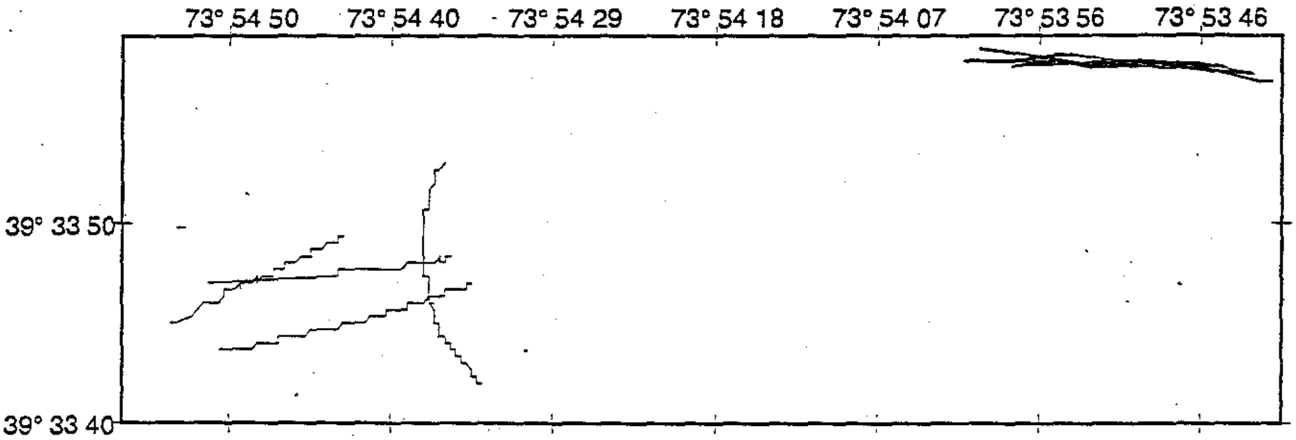


Figure E20.
Surfclam depletion towpaths by the R/V Delaware II (lighter lines) and a commercial vessel.
Site: s99-3 F/V Melissa J 09/28/99

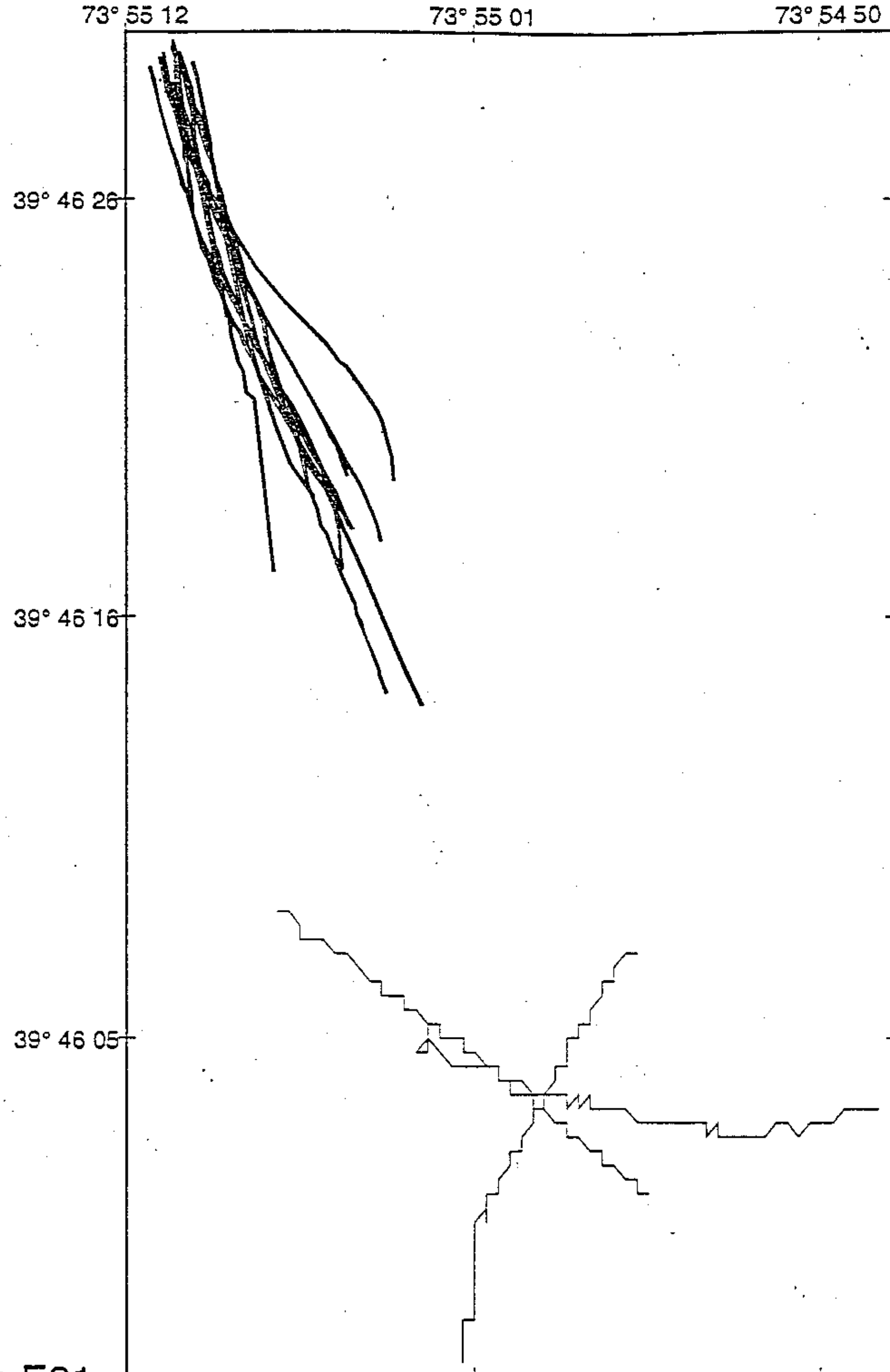


Figure E21.
Surfclam depletion towpaths by R/V Delaware II (lighter lines) and a commercial vessel.
Site: s99-4 F/V Melissa J 09/28/99

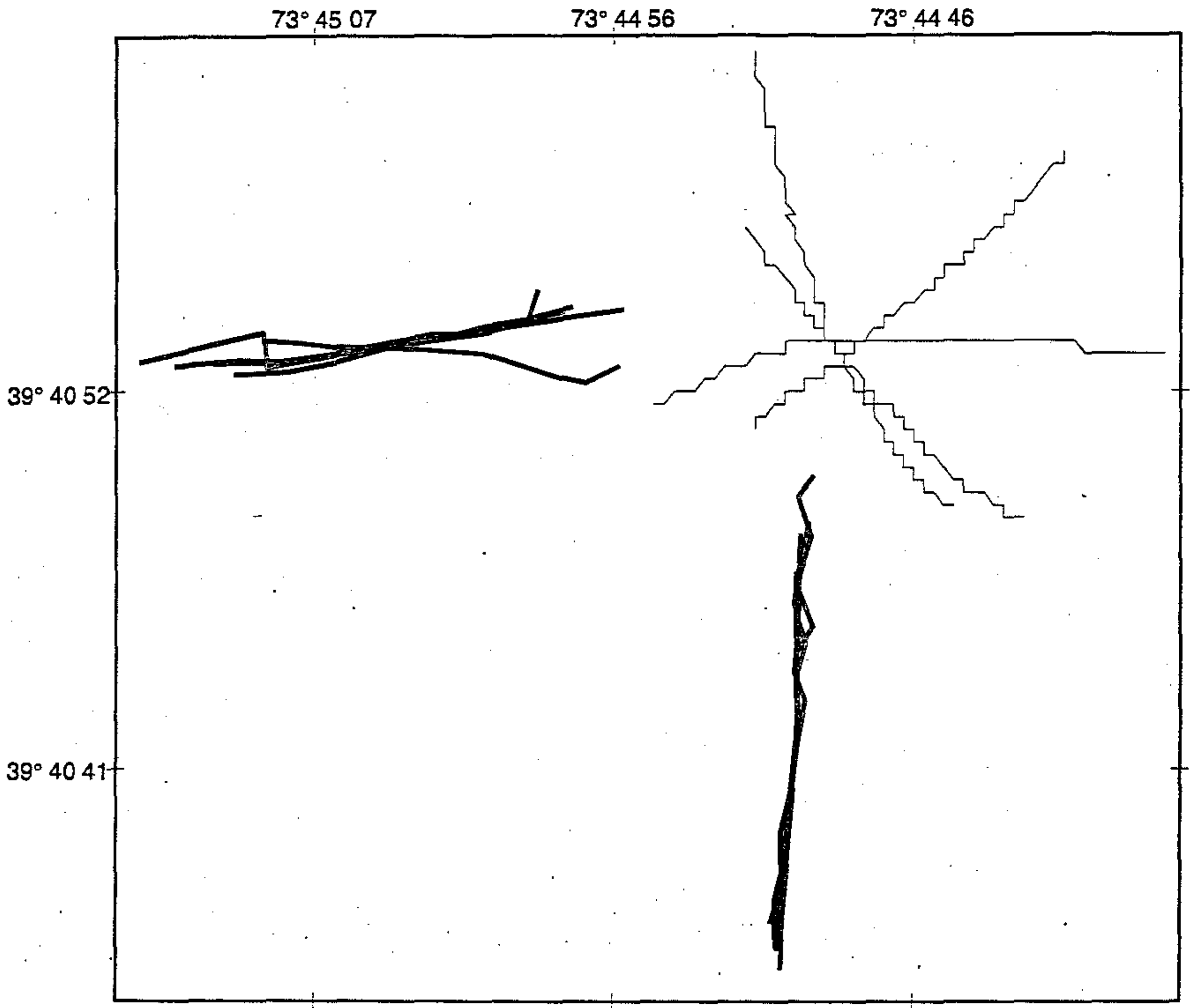


Figure E22.
Surfclam depletion towpaths by the R/V Delaware II (lighter lines) and a commercial vessel.
Site: s99-5 F/V Jersey Girl JG-1&2 09/14/99

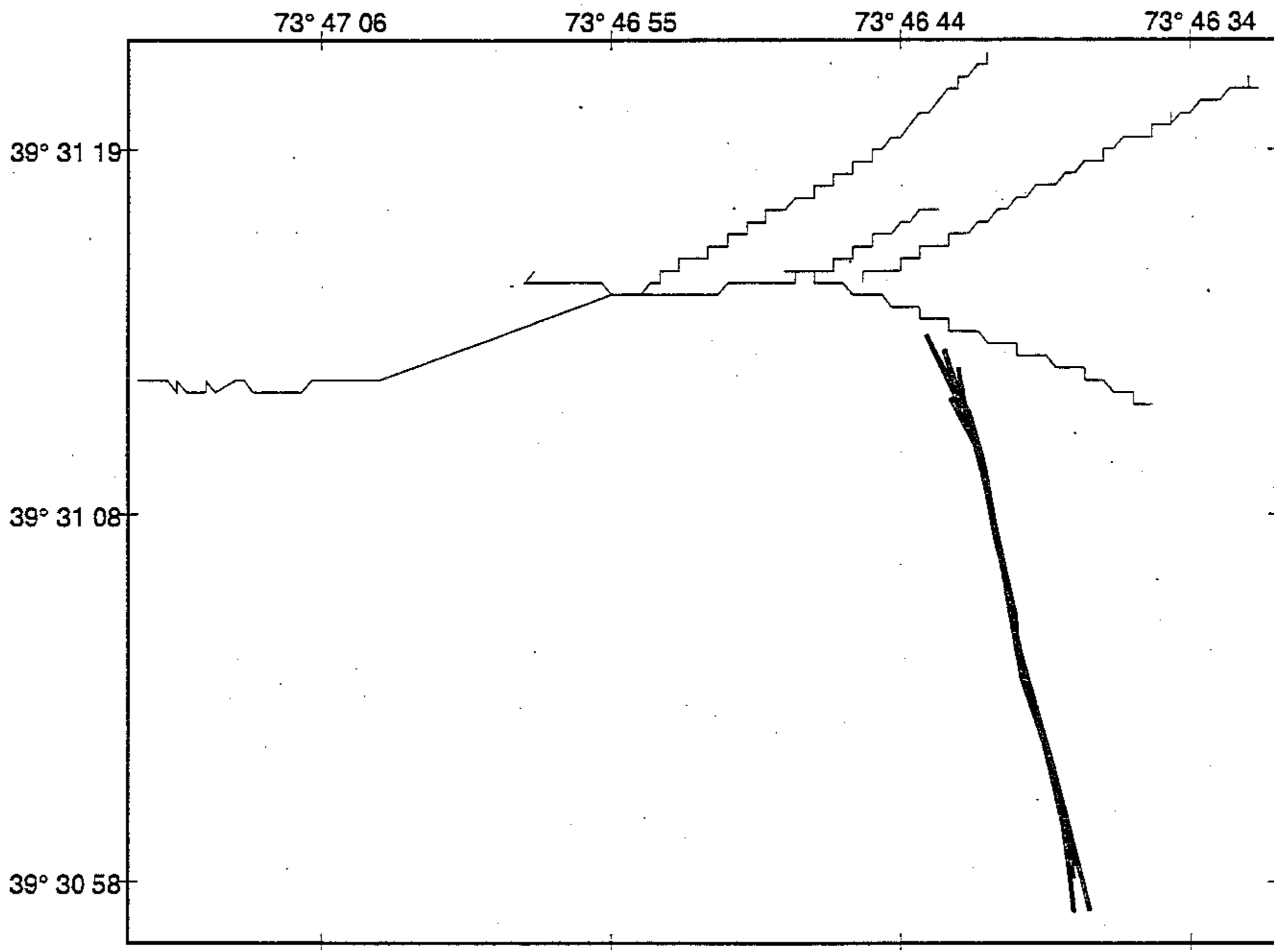


Figure E23.
Surfclam depletion towpaths by the Delaware II (lighter lines) and a commercial vessel.
Site: s99-6 F/V Jersey Girl 09/14/99

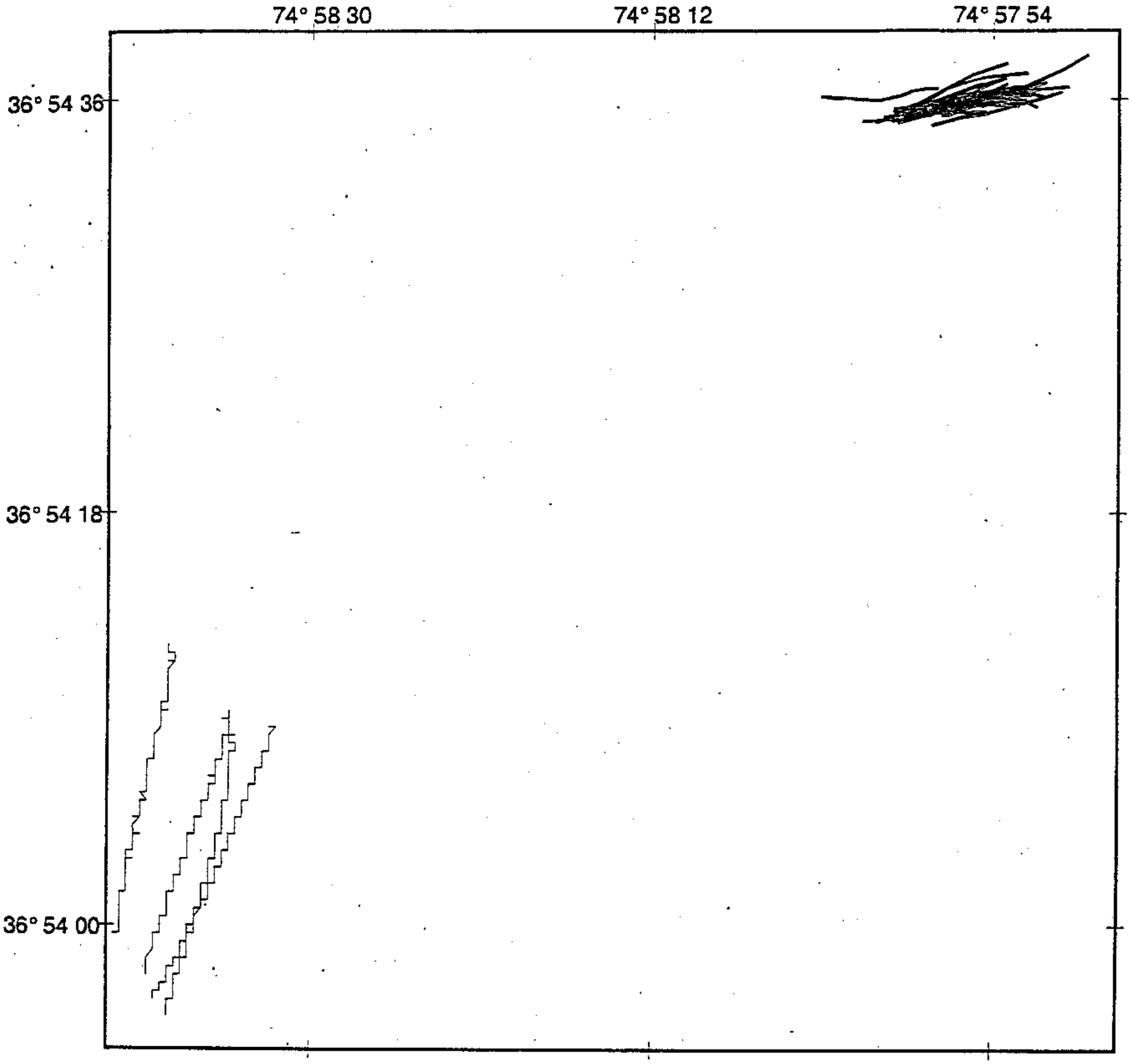


Figure E24.
Surfclam depletion towpaths by the R/V Delaware II (lighter lines) and a commercial vessel.
Site: s99-DEII F/V Christy 09/25/99

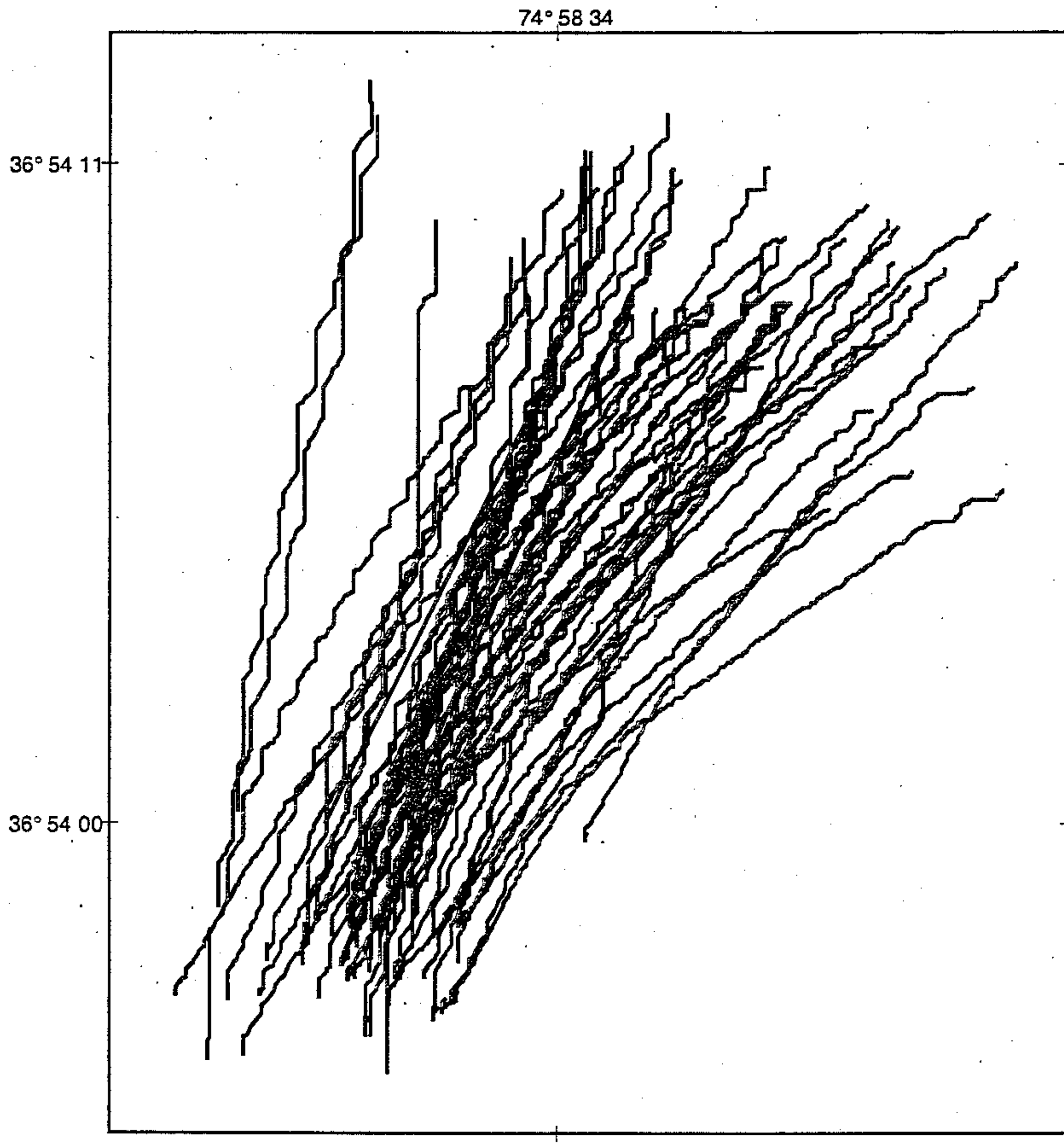
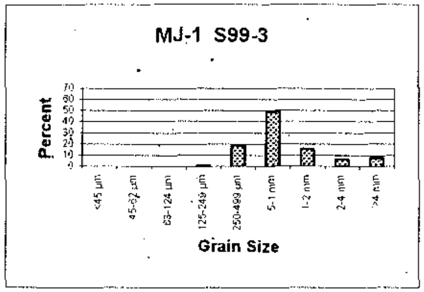


Figure E25.
Surfclam depletion towpaths conducted by the R/V Delaware II, 06/27-28/99.
Smoothed Data
Site s99-DEII

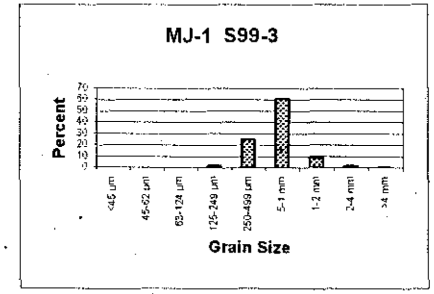
MJ-1 S99-3

Grain Size	Percent Grain Size
<45 µm	0.20
45-62 µm	0.00
63-124 µm	0.04
125-249 µm	1.86
250-499 µm	18.42
.5-1 mm	49.02
1-2 mm	15.83
2-4 mm	6.21
>4 mm	8.41
	100.00



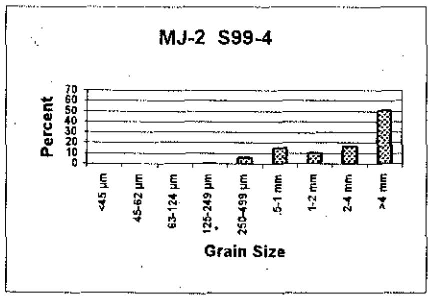
MJ-1 S99-3

Grain Size	Percent Grain Size
<45 µm	0.00
45-62 µm	0.00
63-124 µm	0.02
125-249 µm	2.07
250-499 µm	25.32
.5-1 mm	61.38
1-2 mm	8.77
2-4 mm	1.82
>4 mm	0.63
	100.00



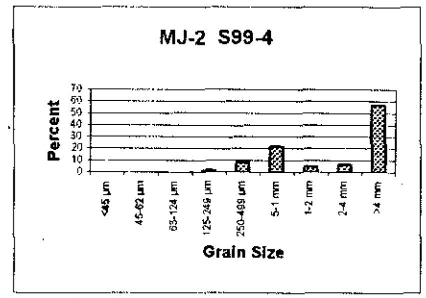
MJ-2 S99-4

Grain Size	Percent Grain Size
<45 µm	0.06
45-62 µm	0.00
63-124 µm	0.02
125-249 µm	0.56
250-499 µm	6.17
.5-1 mm	15.58
1-2 mm	10.36
2-4 mm	16.44
>4 mm	50.80
	100.00



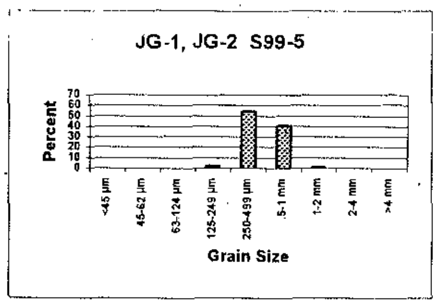
MJ-2 S99-4

Grain Size	Percent Grain Size
<45 µm	0.10
45-62 µm	0.00
63-124 µm	0.04
125-249 µm	1.83
250-499 µm	8.14
.5-1 mm	21.95
1-2 mm	4.74
2-4 mm	6.46
>4 mm	56.73
	100.00



JG-1, JG-2 S99-5

Grain Size	Percent Grain Size
<45 µm	0.00
45-62 µm	0.00
63-124 µm	0.01
125-249 µm	2.40
250-499 µm	54.46
.5-1 mm	41.39
1-2 mm	1.31
2-4 mm	0.22
>4 mm	0.20
	100.00



JG-1, JG-2 S99-5

Grain Size	Percent Grain Size
<45 µm	0.29
45-62 µm	0.00
63-124 µm	0.00
125-249 µm	0.94
250-499 µm	16.96
.5-1 mm	32.05
1-2 mm	41.68
2-4 mm	7.38
>4 mm	0.71
	100.00

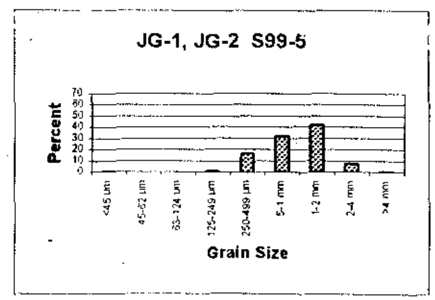
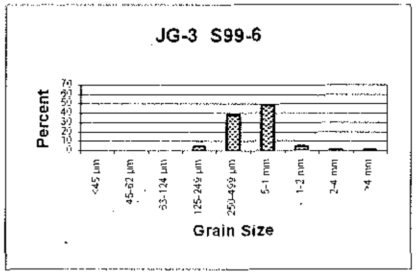
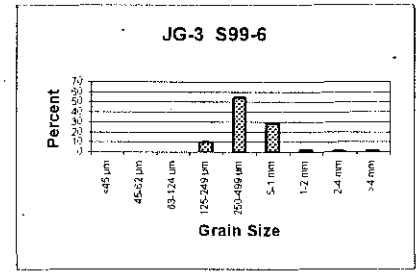


Figure E26.

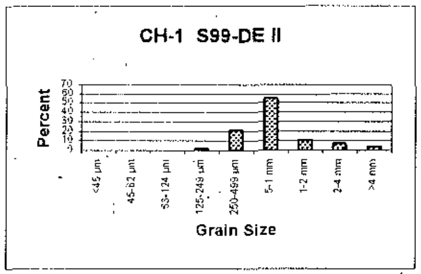
JG-3 S99-6	
Grain Size	Percent Grain Size
<45 µm	0.09
45-62 µm	0.00
63-124 µm	0.04
125-249 µm	5.09
250-499 µm	38.05
.5-1 mm	49.83
1-2 mm	4.47
2-4 mm	1.18
>4 mm	1.24
	100.00



JG-3 S99-6	
Grain Size	Percent Grain Size
<45 µm	0.00
45-62 µm	0.00
63-124 µm	0.09
125-249 µm	10.13
250-499 µm	54.91
.5-1 mm	28.53
1-2 mm	2.81
2-4 mm	1.53
>4 mm	1.99
	100.00



CH-1 S99-DE II	
Grain Size	Percent Grain Size
<45 µm	0.00
45-62 µm	0.00
63-124 µm	0.05
125-249 µm	1.81
250-499 µm	21.28
.5-1 mm	55.15
1-2 mm	10.58
2-4 mm	7.16
>4 mm	3.98
	100.00



CH-1 S99-DE II	
Grain Size	Percent Grain Size
<45 µm	0.00
45-62 µm	0.00
63-124 µm	0.01
125-249 µm	1.05
250-499 µm	19.41
.5-1 mm	54.20
1-2 mm	13.96
2-4 mm	7.22
>4 mm	4.15
	100.00

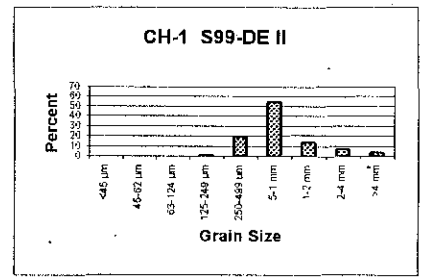


Figure E27.

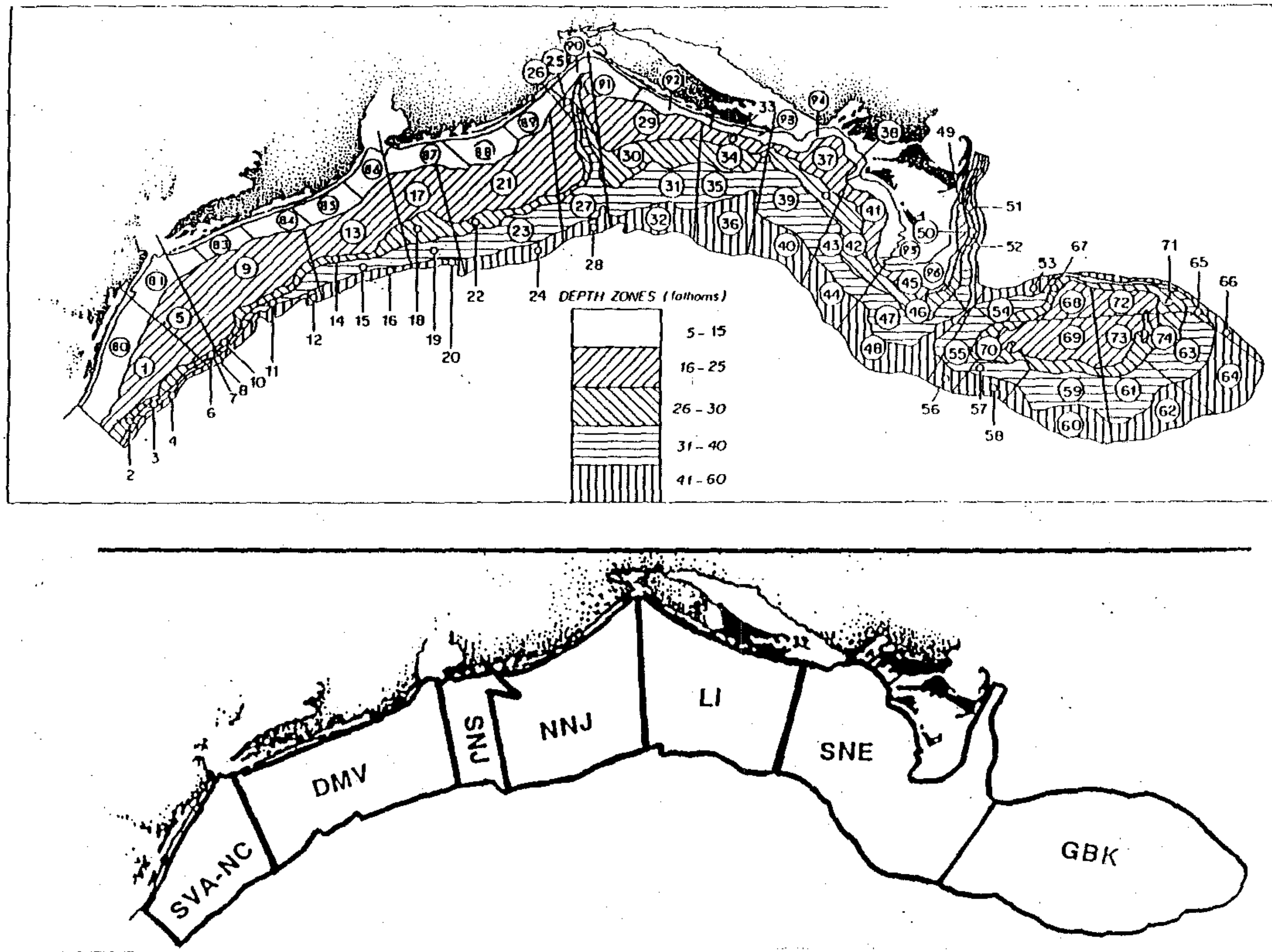


Figure E28. Survey Strata (sampling areas), National Marine Fisheries Service, Northeast Fisheries Science Center, Surfclam-Ocean Quahog Survey.

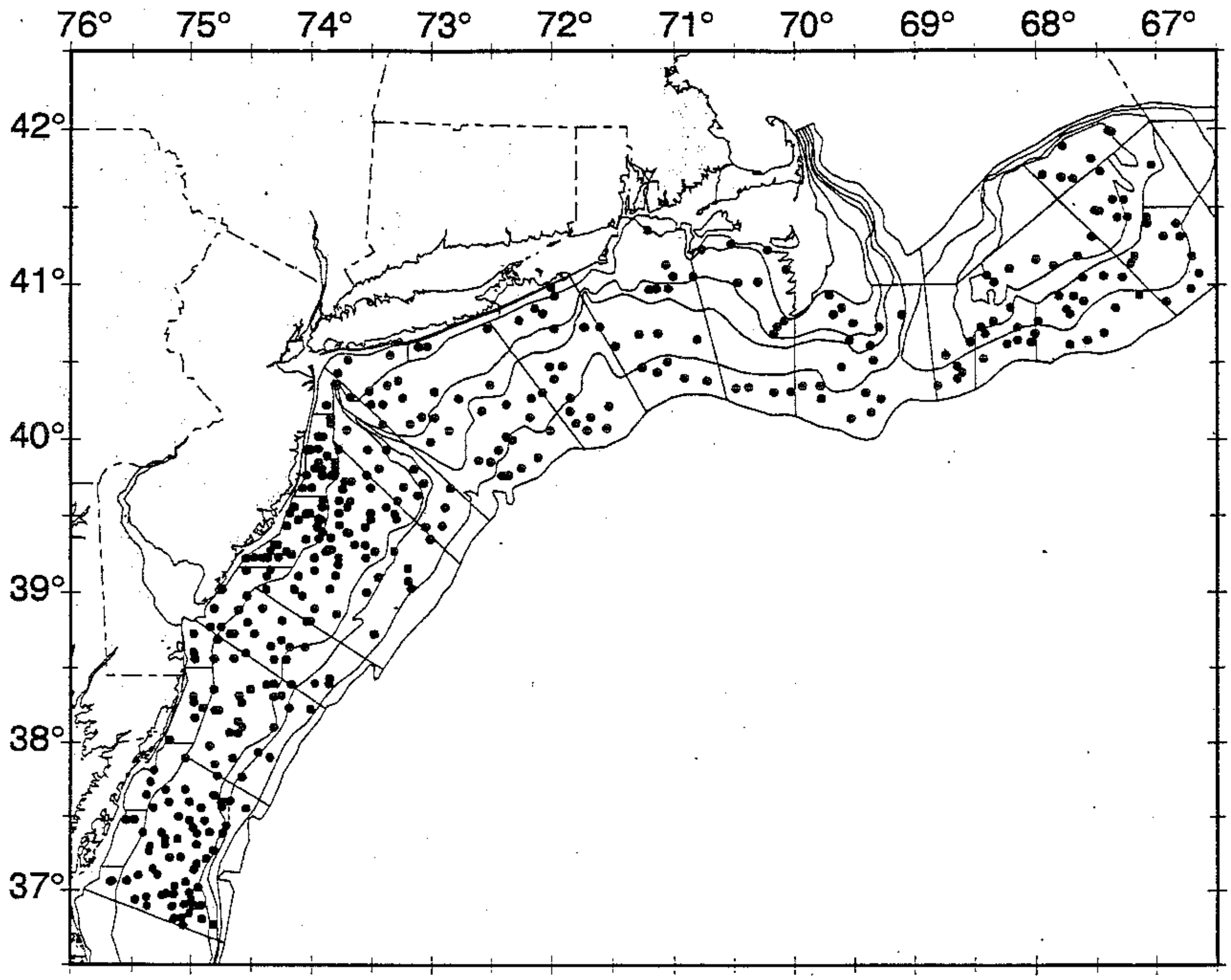


Figure E29.
Station locations from the 1999 NEFSC surfclam/ocean quahog survey.

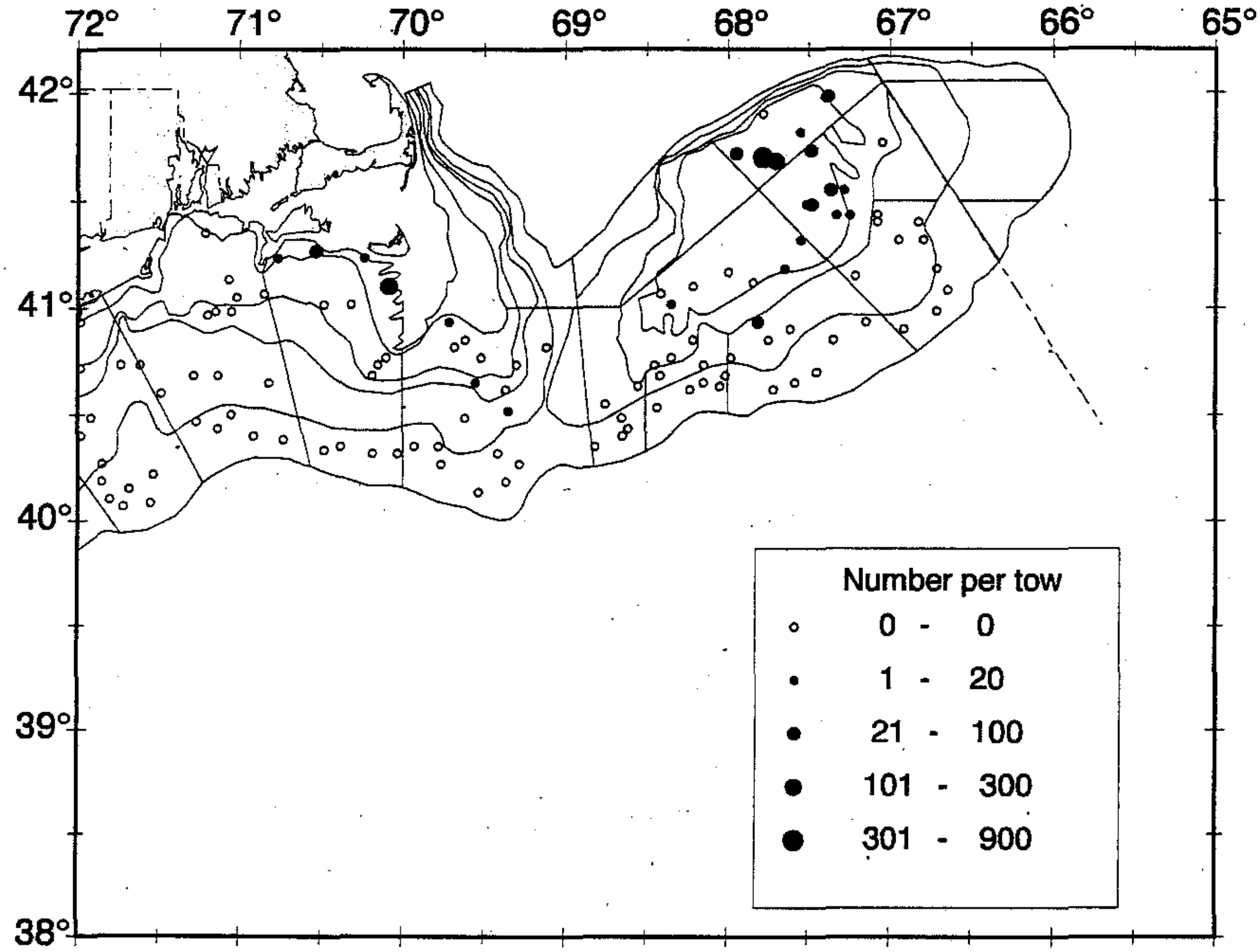


Figure E30.
Distribution of 1999 survey surfclam abundance per tow (>= 120 mm) adjusted to 0.15 n. mi. tow distance with sensor data.
Blade depth = 4 inches.

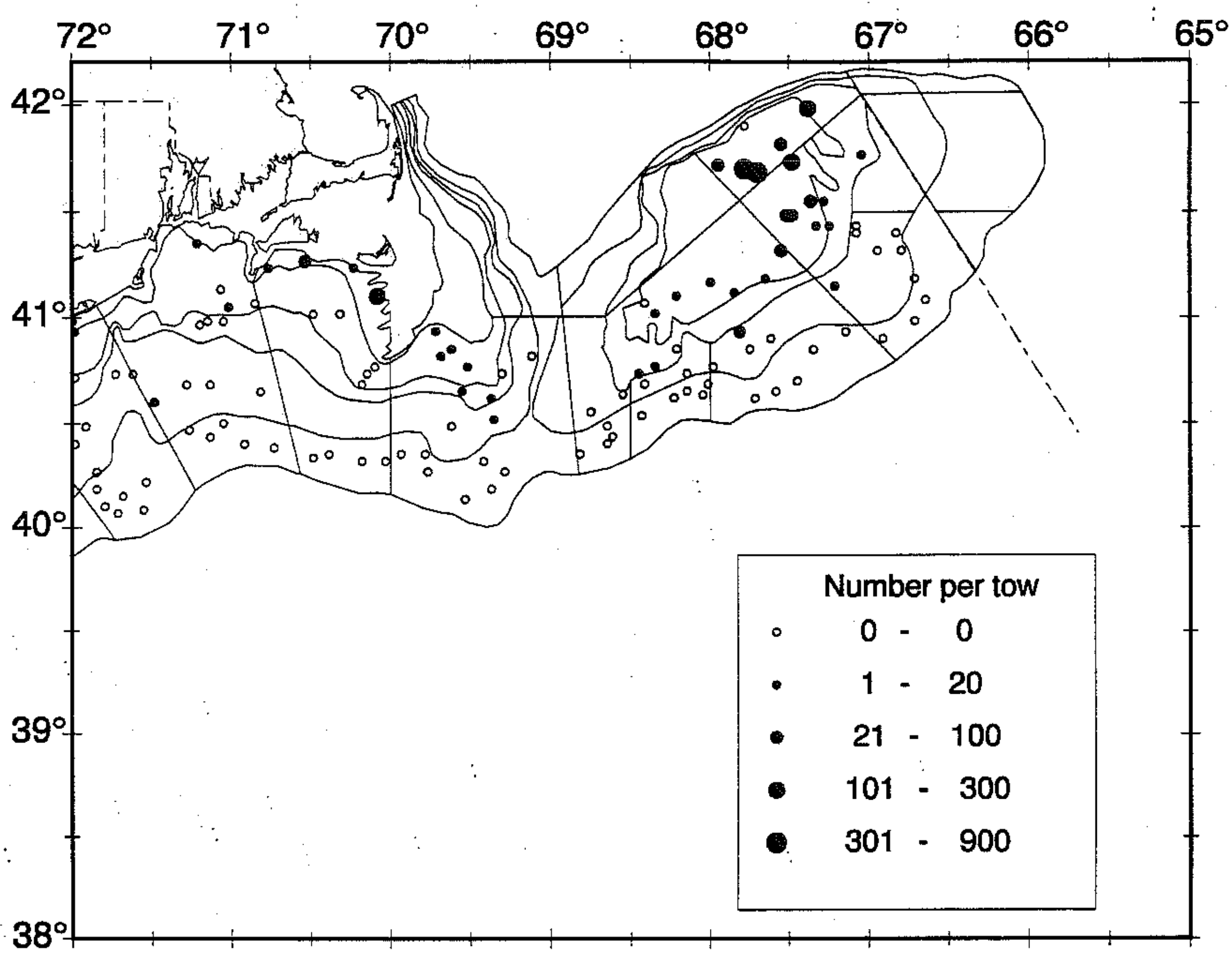


Figure E31.
Distribution of 1999 survey surfclam abundance per tow (88-119 mm) adjusted to 0.15 n. mi. tow distance with sensor data.
Blade depth = 4 inches.

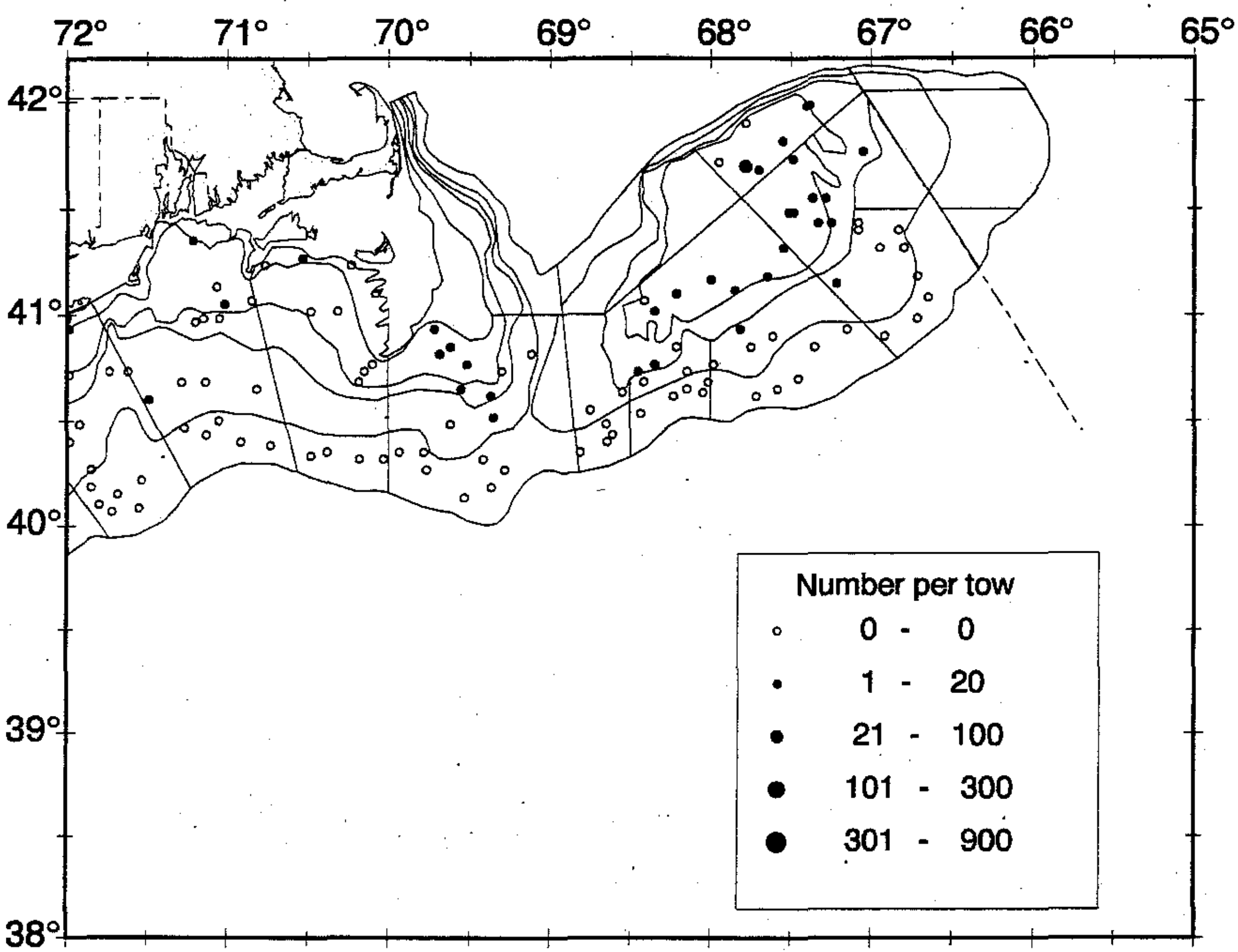


Figure E32.
Distribution of 1999 survey surfclam abundance per tow (1-87 mm) adjusted to 0.15 n. mi. tow distance with sensor data.
Blade depth = 4 inches.

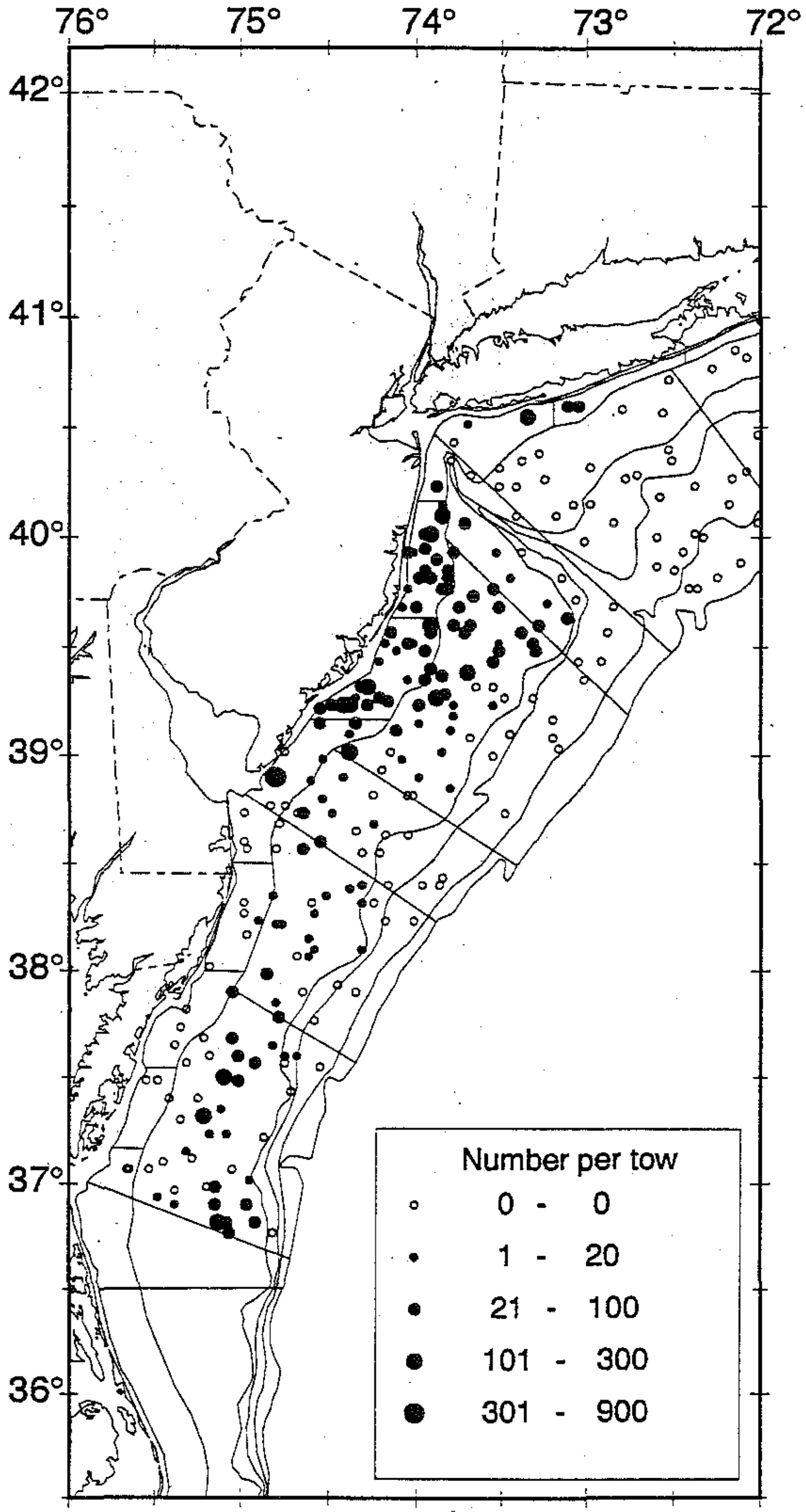


Figure E33.
Distribution of 1999 survey surfclam abundance per tow (>= 120 mm) adjusted to 0.15 n. mi. tow distance with sensor data.
Blade depth = 4 inches.

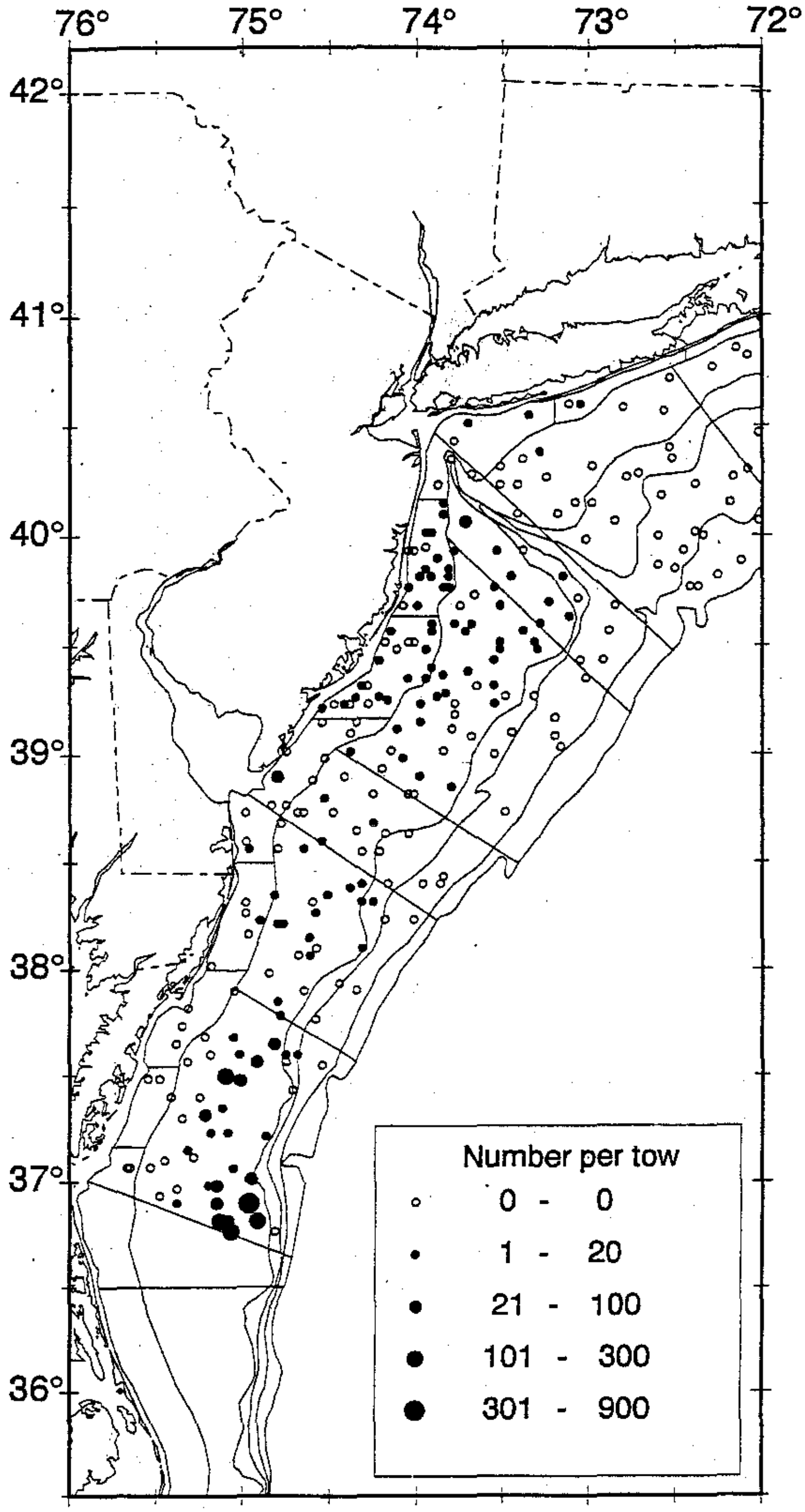


Figure E34.
Distribution of 1999 survey surfclam abundance per tow (88-119 mm) adjusted to 0.15 n. mi. tow distance with sensor data.
Blade depth = 4 inches.

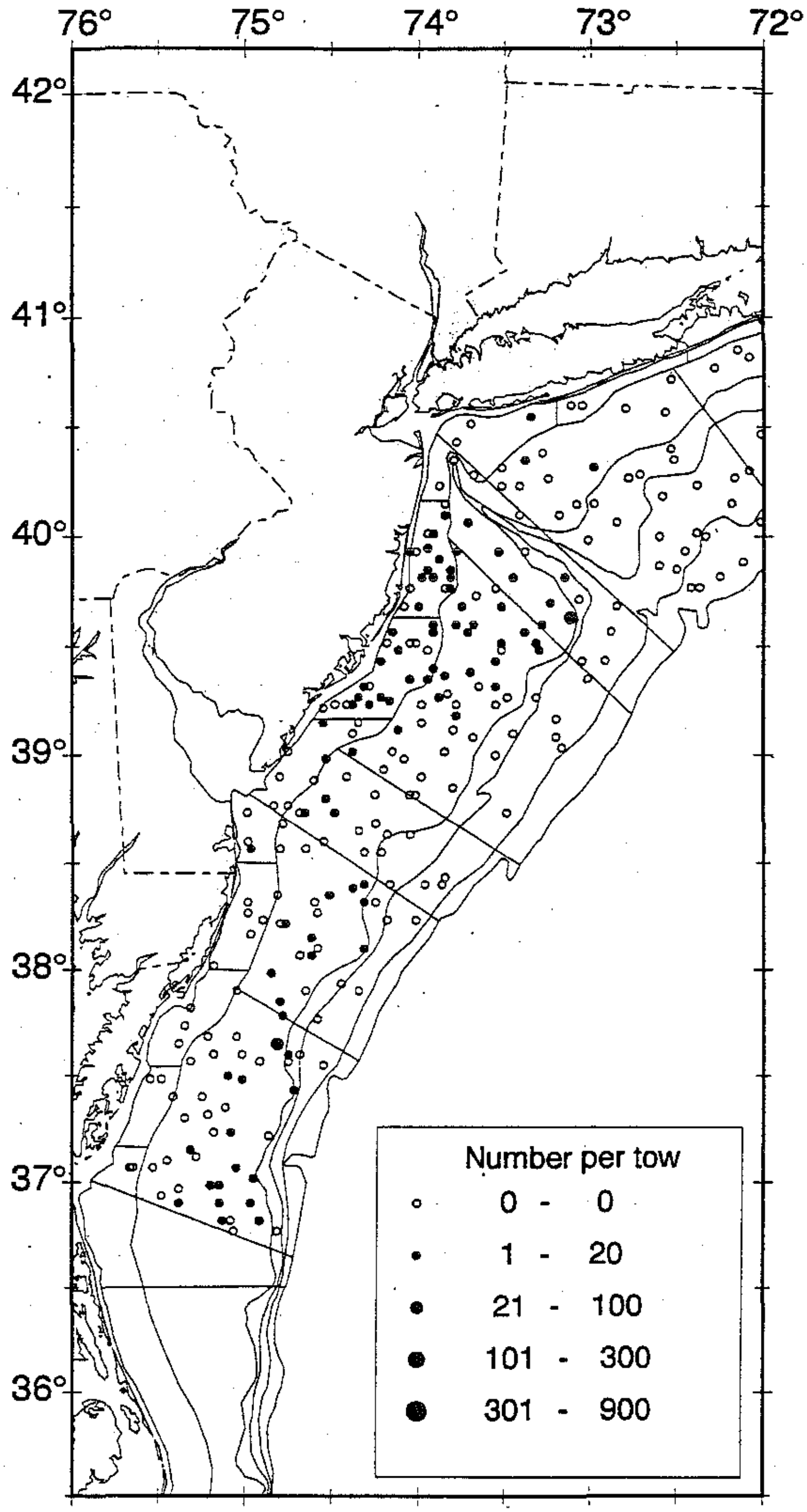


Figure E35.
Distribution of 1999 survey surfclam abundance per tow (1-87 mm) adjusted to 0.15 n. mi. tow distance with sensor data.
Blade depth = 4 inches.

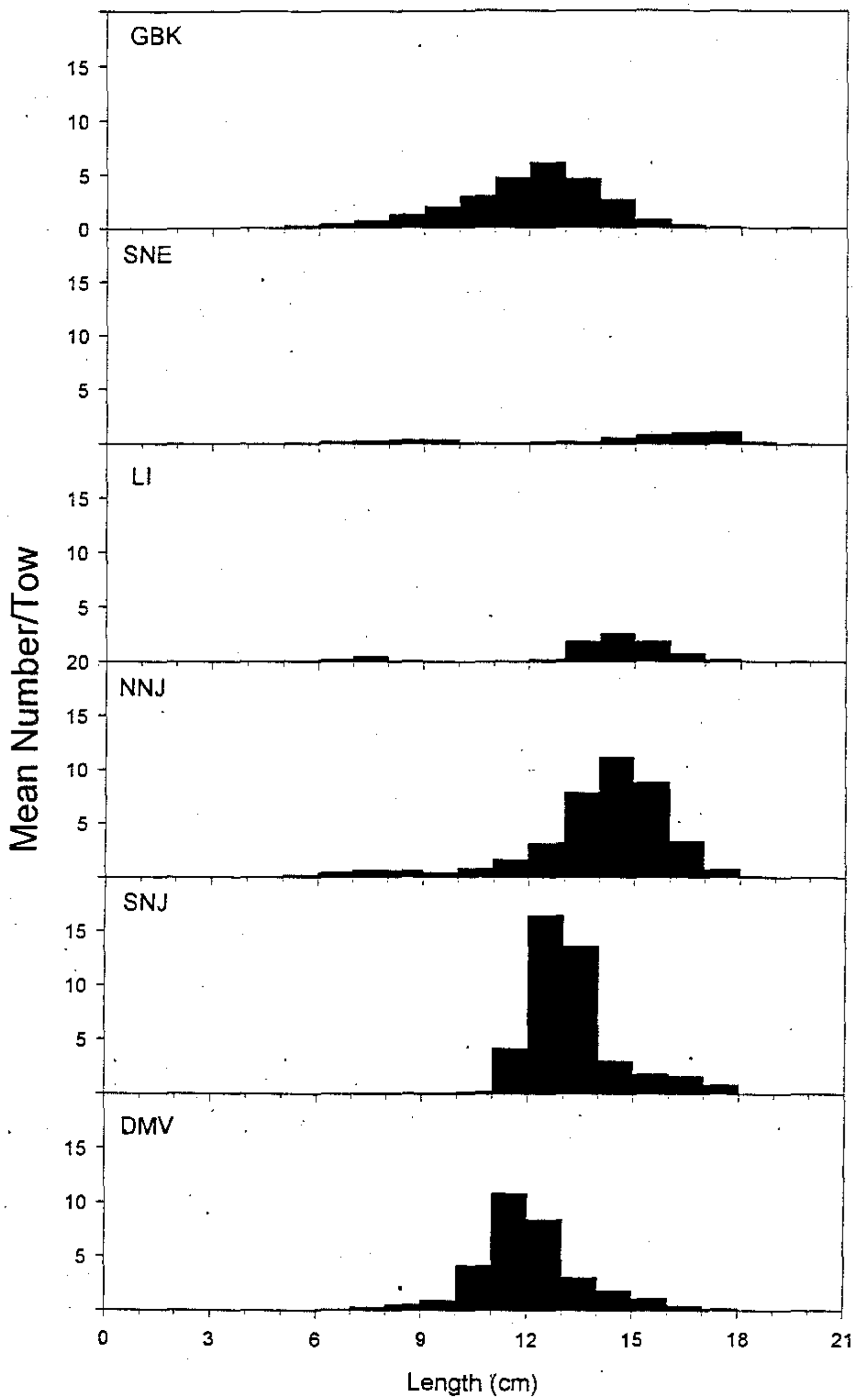


Figure E36. Size frequency distribution of surfclams, by region, based on data from 1999 survey. Number per tow is standardized to a tow distance of 278m (0.15 nmi) based on sensor data assuming a blade depth of 10.2 cm (4 in).

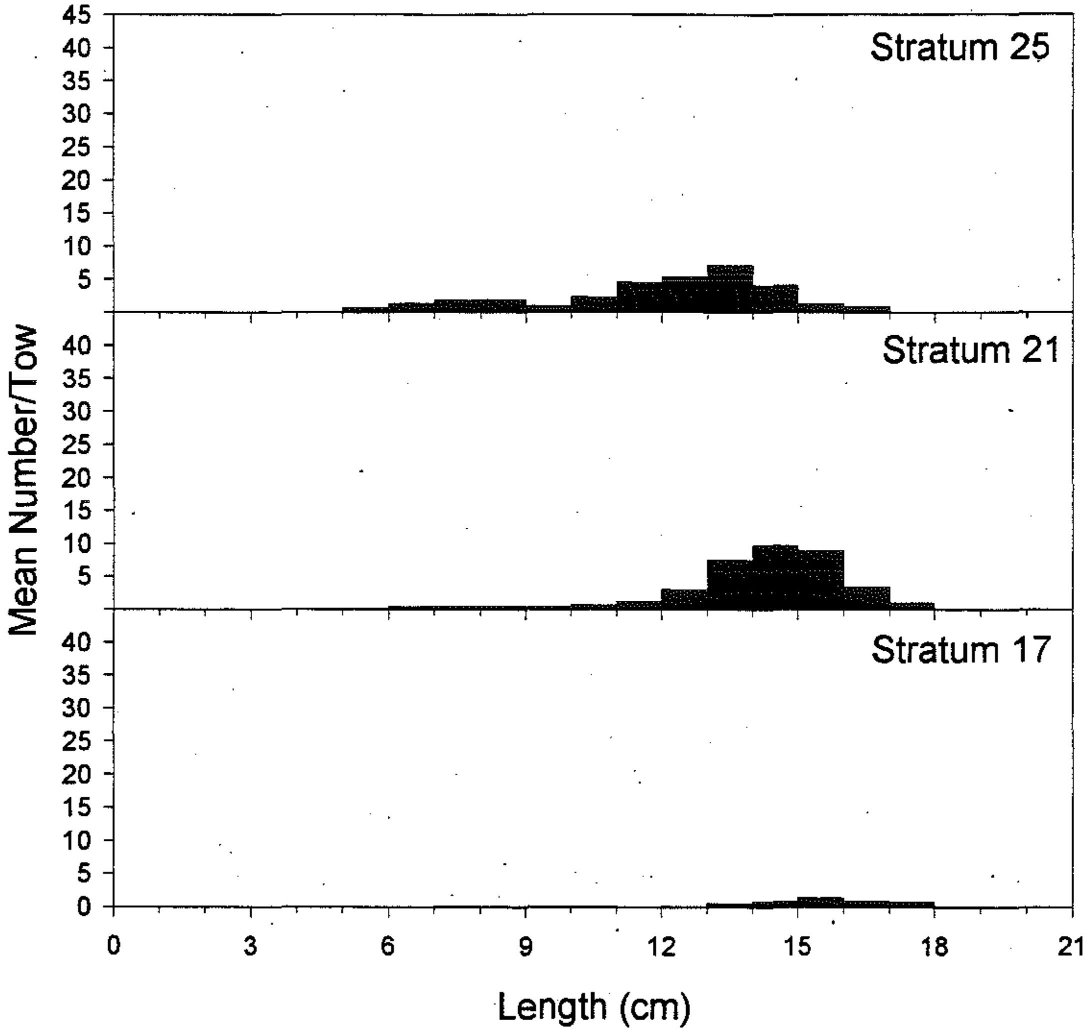


Figure E37. Surfclam size frequency distributions in the **OFFSHORE STRATA OF NEW JERSEY**. Data were collected during the 1999 NMFS survey, and standardized to a tow distance of 287 meters (0.15 n.mi.) assuming a critical blade depth of 10.2cm (4 in).

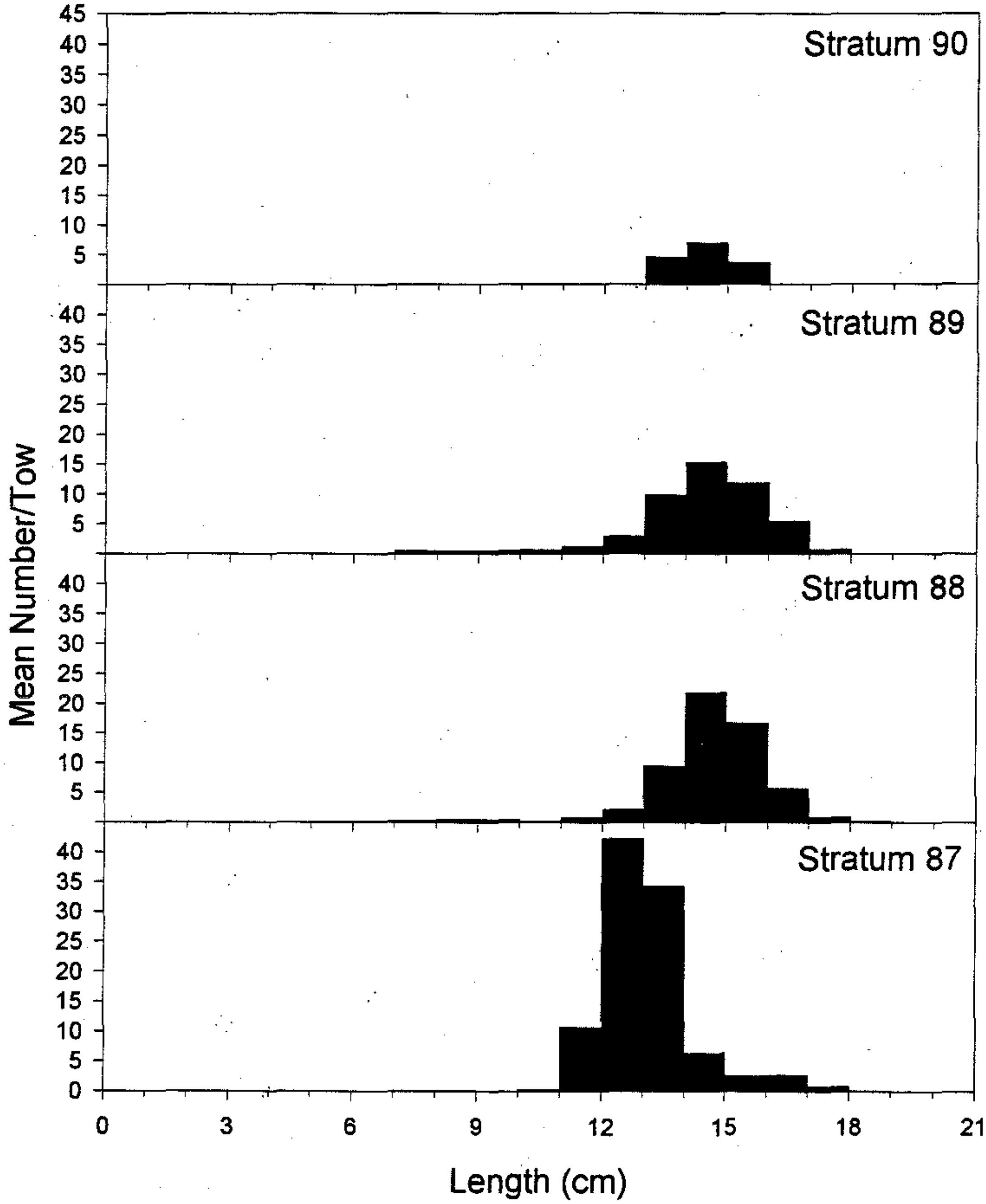


Figure E38. Surfclam size frequency distributions in the **INSHORE EEZ OF NEW JERSEY**. Data were collected during the 1999 NMFS survey, and standardized to a tow distance of 287 meters (0.15 n.mi.) assuming a critical blade depth of 10.2cm (4 in).

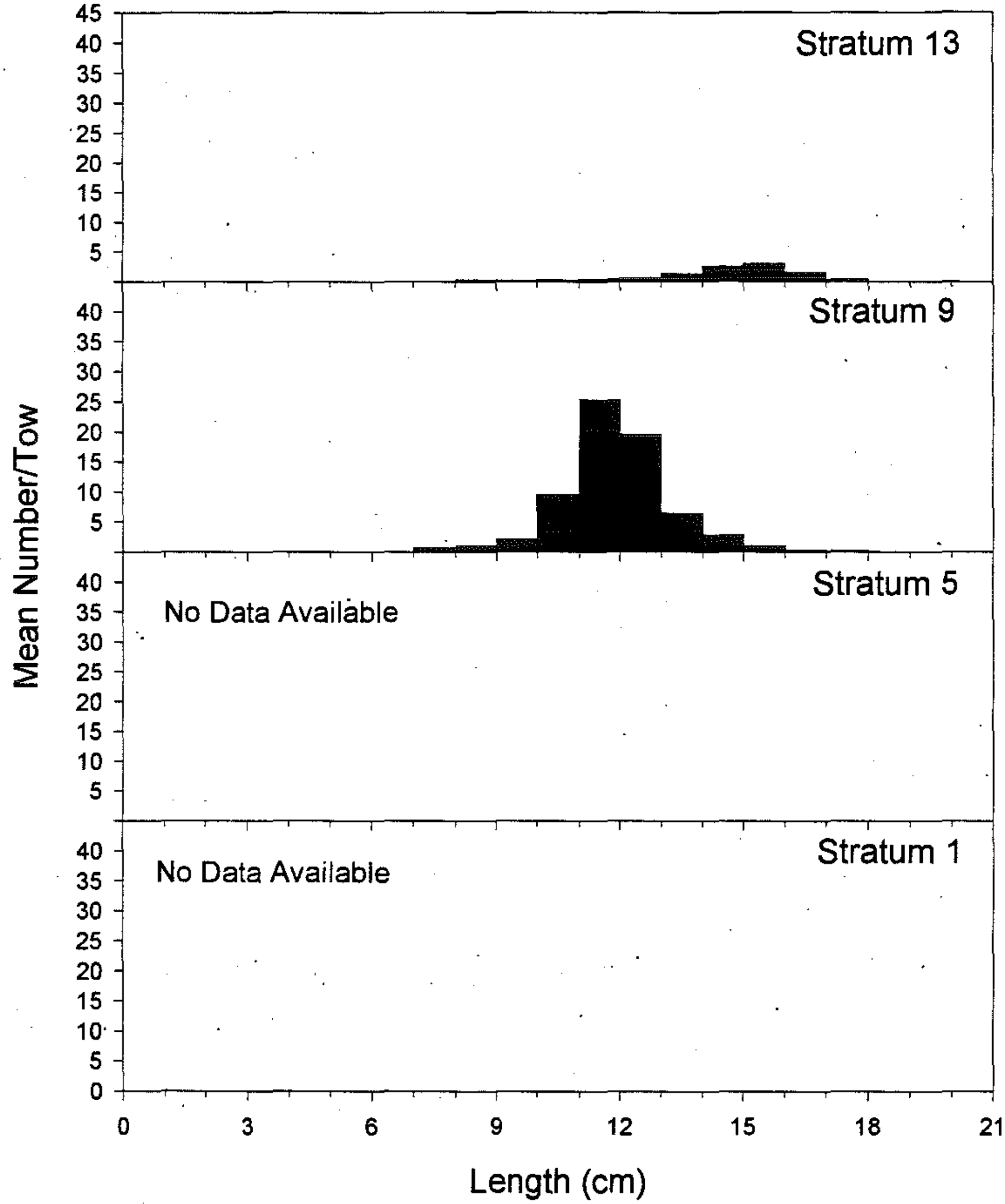


Figure E39. Surfclam size frequency distributions in the **OFFSHORE STRATA FROM DELMARVA TO N. CAROLINA**. Data were collected during the 1999 NMFS survey, and standardized to a tow distance of 287 meters (0.15 n.mi.) assuming a critical blade depth of 10.2cm (4 in).

Georges Bank

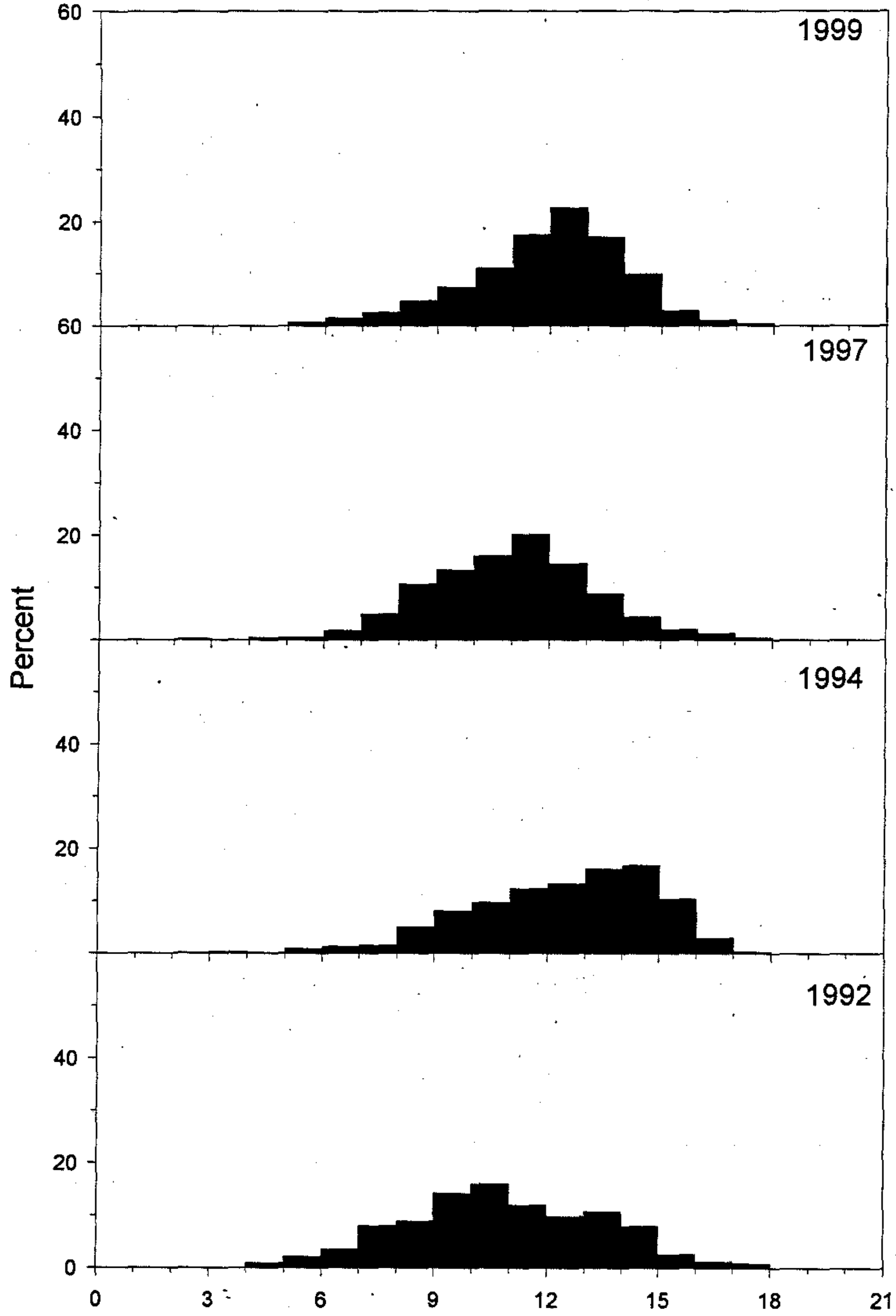


Figure E40. Percent size frequency distribution over time from research surveys. Region = GEORGES BANK.

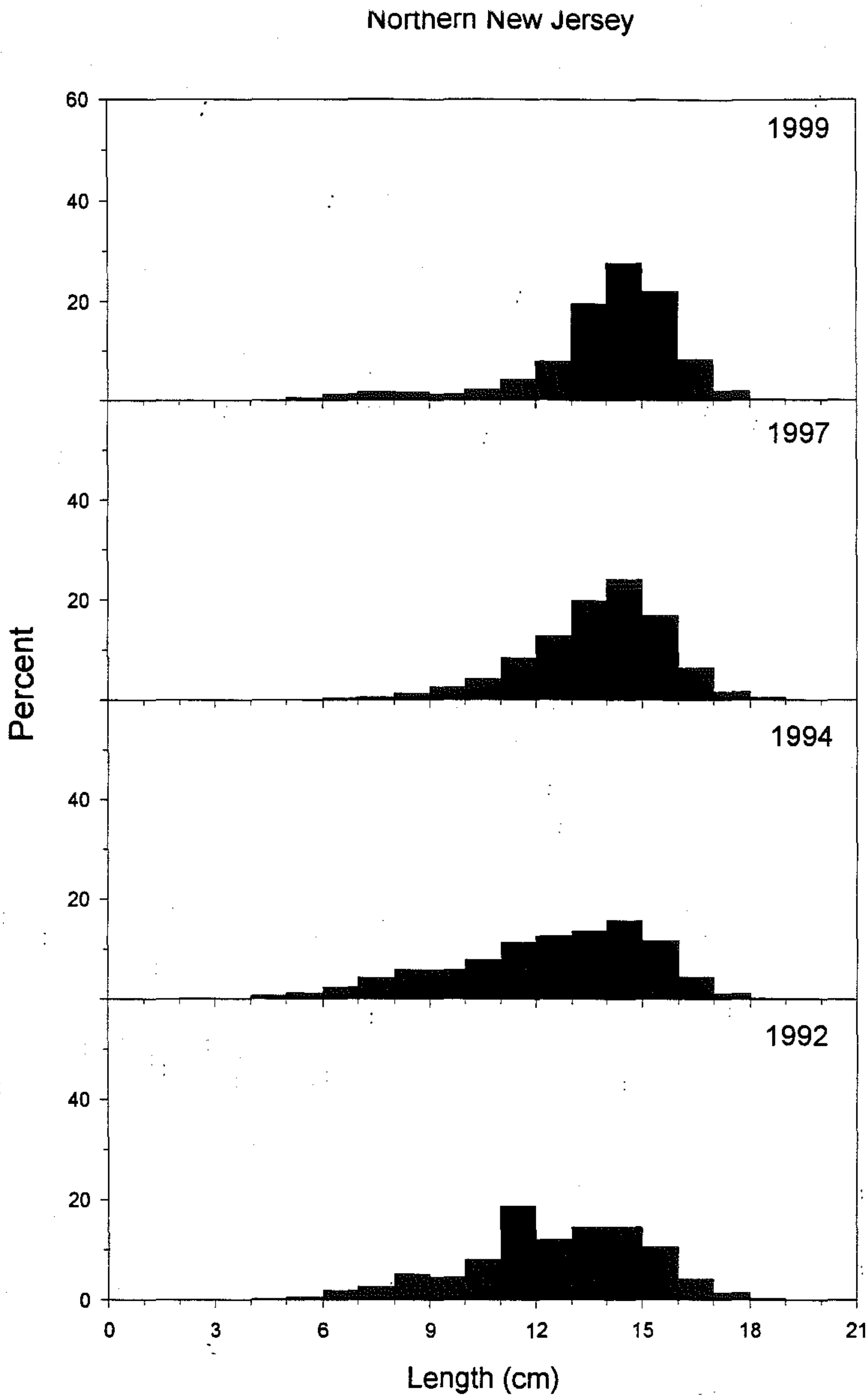


Figure E41. Percent size frequency distribution over time from research surveys. Region = NORTHERN NEW JERSEY.

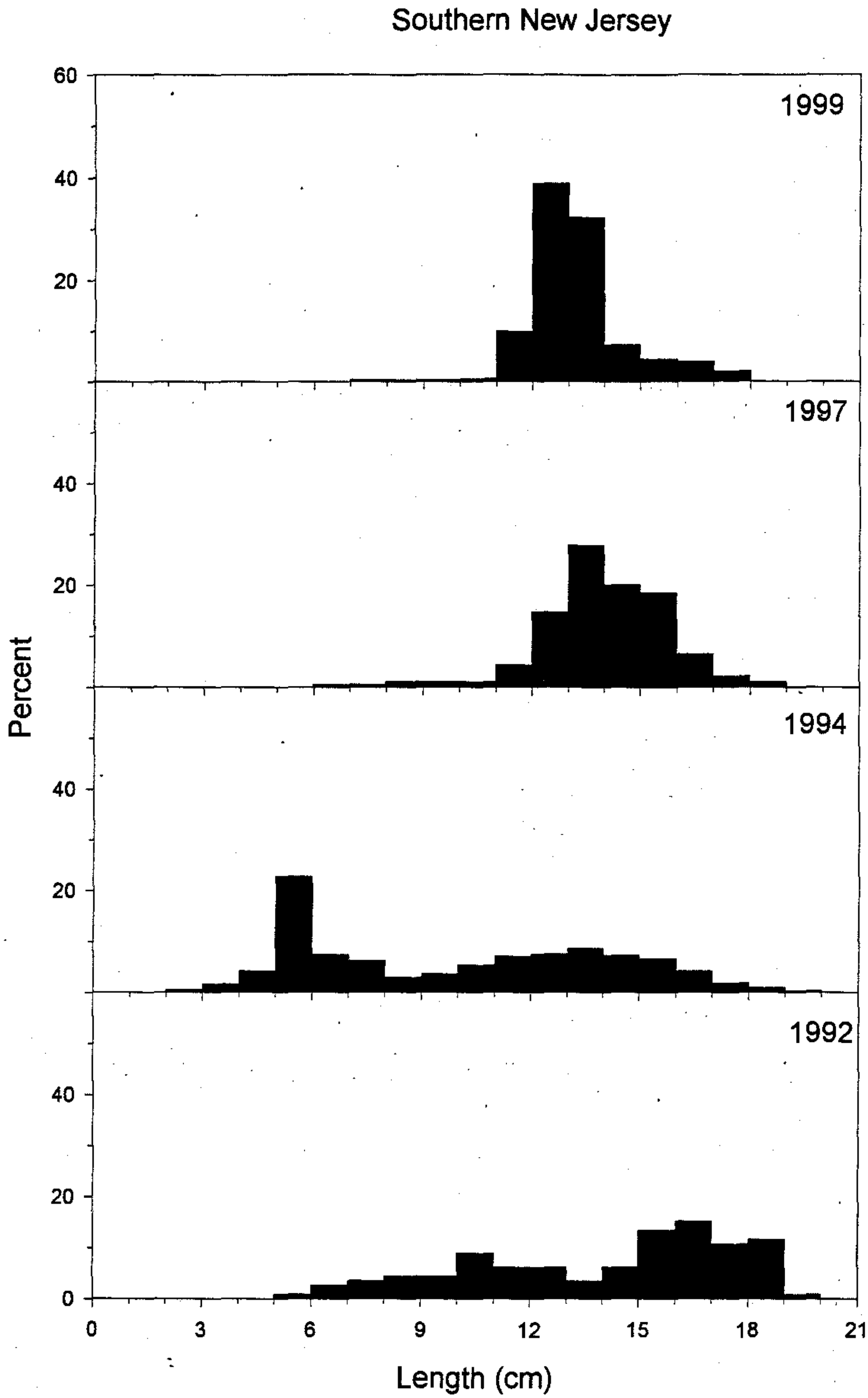


Figure E42. Percent size frequency distribution over time from research surveys. Region = SOUTHERN NEW JERSEY.

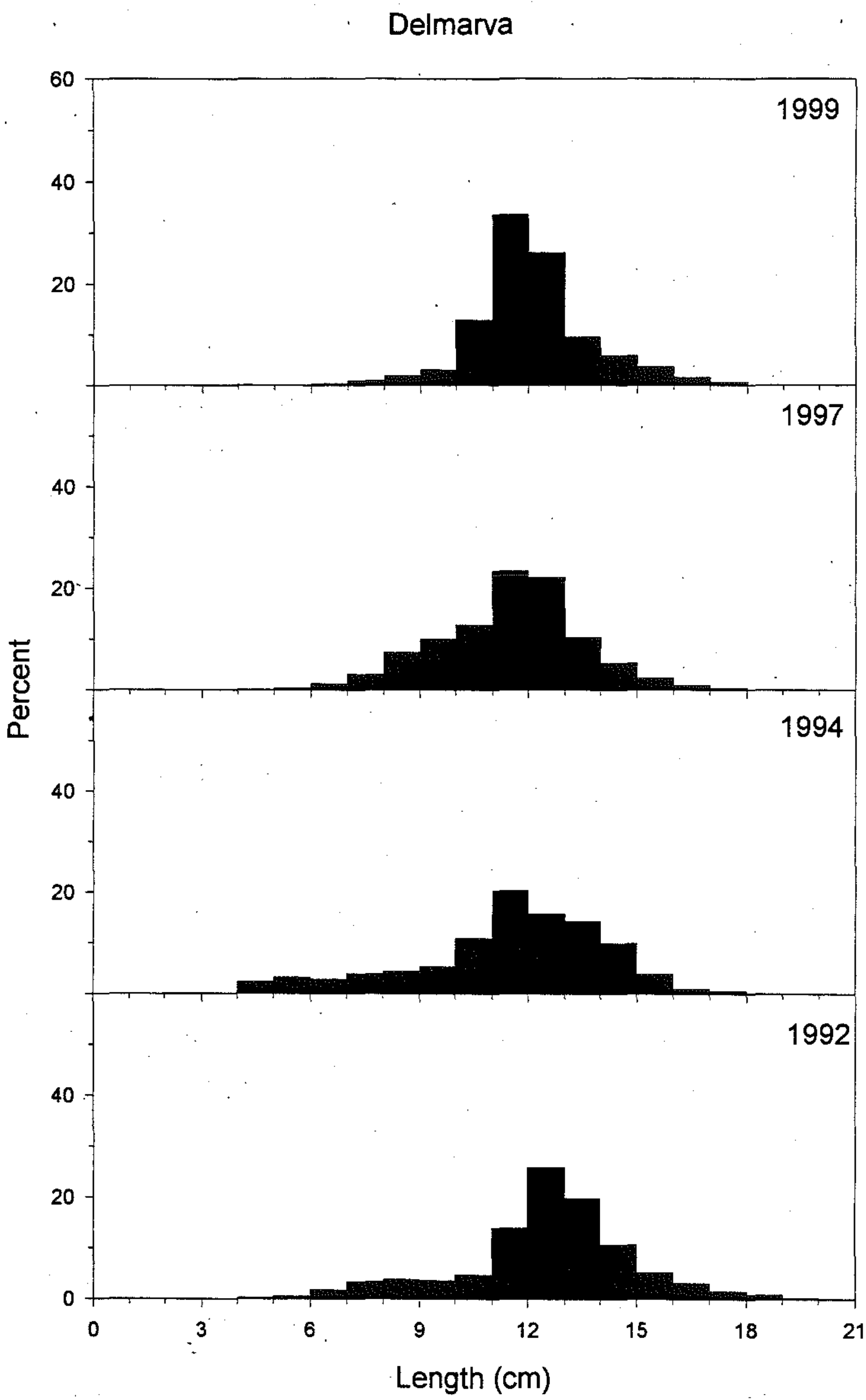


Figure E43. Percent size frequency distribution over time from research surveys. Region = DELMARVA.

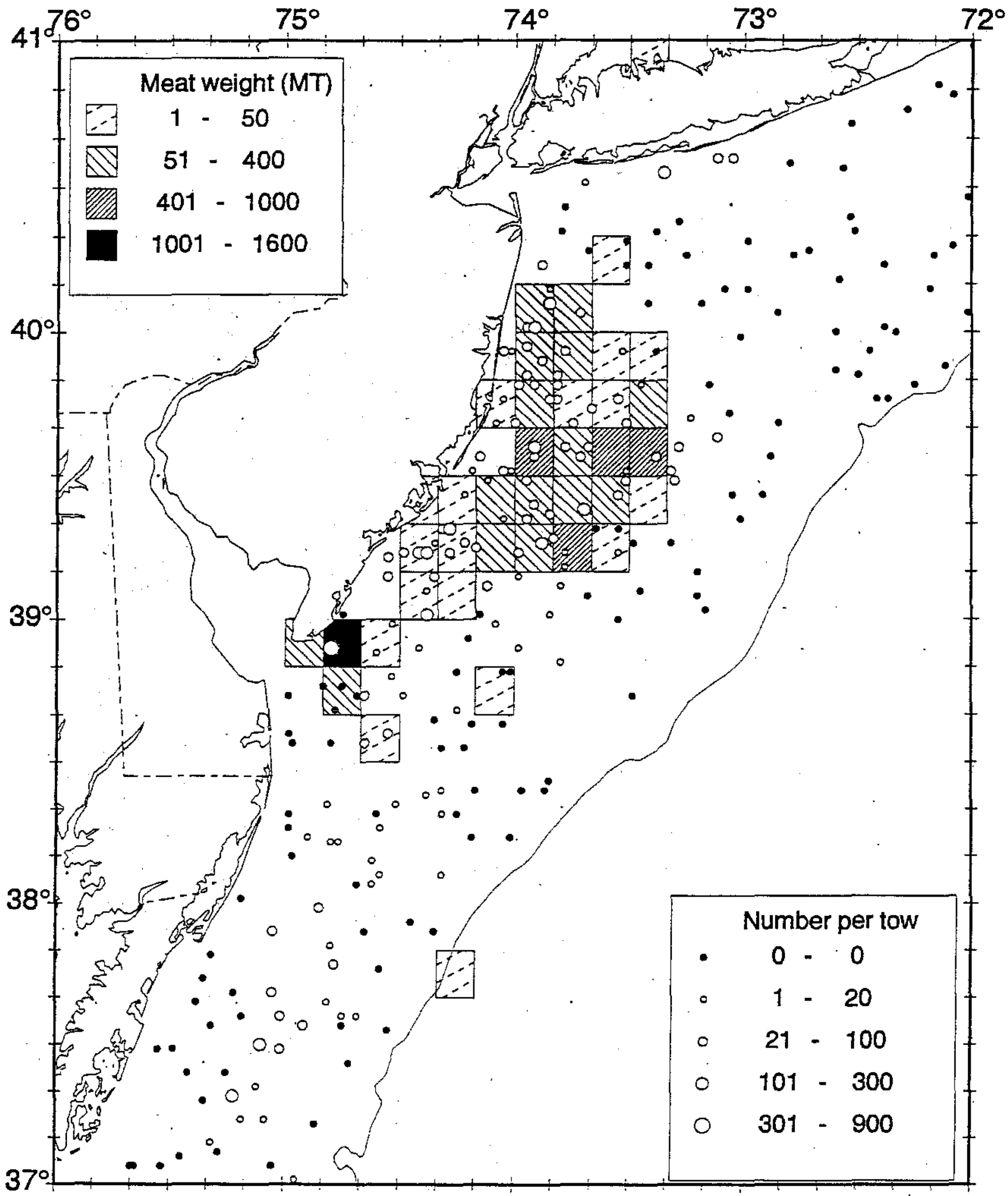
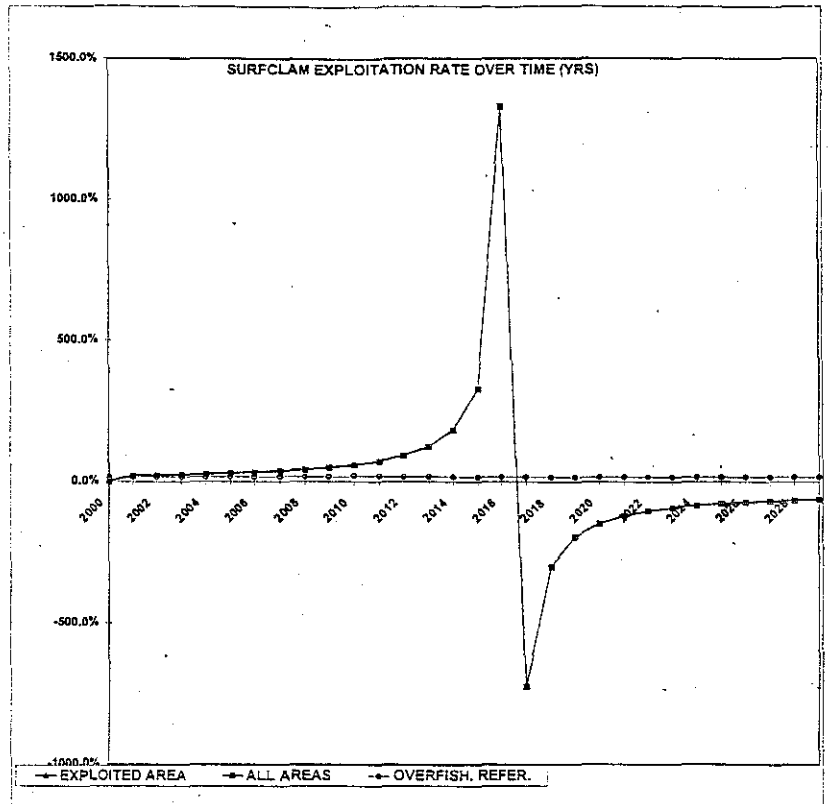


Figure E44. Distribution of 1999 survey surfclam abundance per tow (>= 120 mm), adjusted to 0.15 n. mi. tow distance with sensor data (blade depth = 4 inches) and 1999 landings (mt of meat weight, partial year).

Total Stock Run with m=	0.05



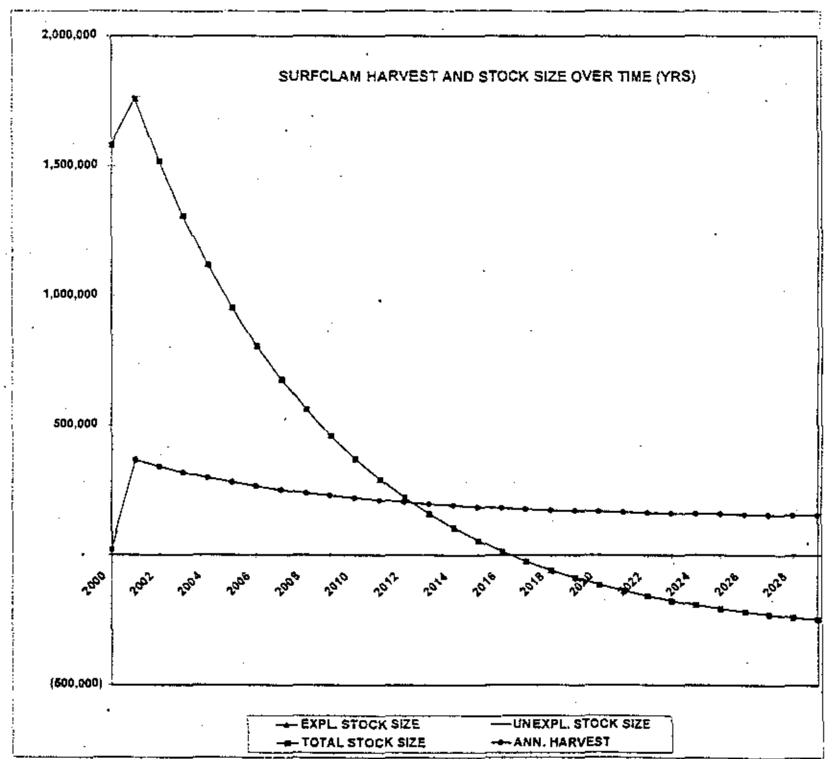
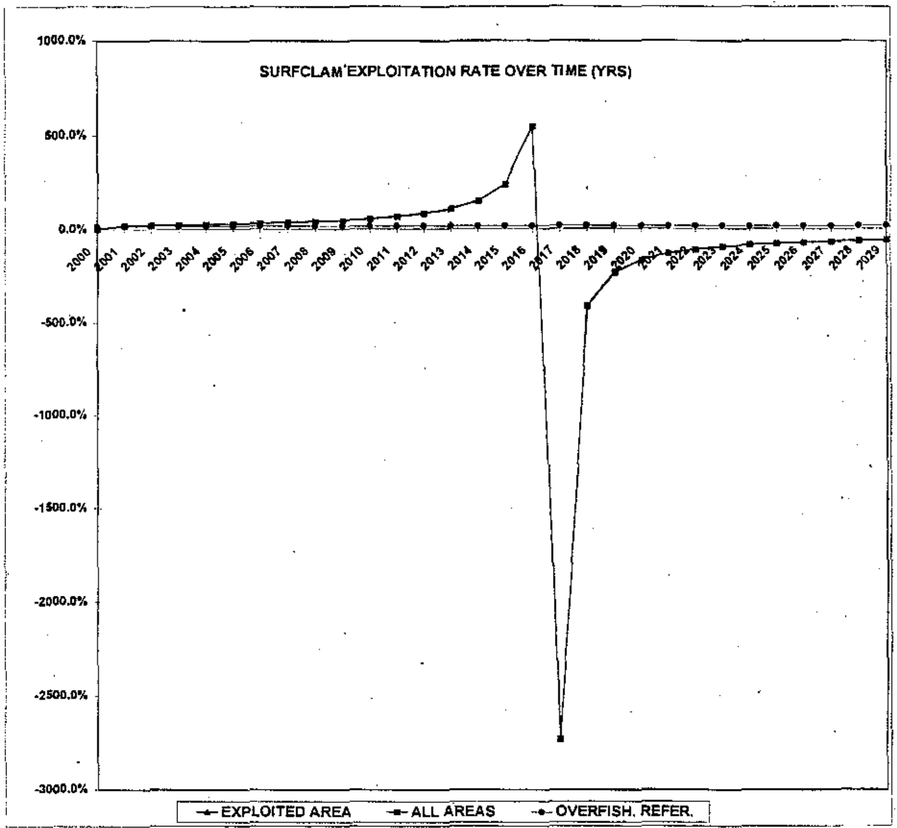


Fig. E45. Surfclam 10-yr supply model. In each year, the catch is set at that which could be taken for 10-yrs. The model assumes an average level of recruitment, and accounts for growth and natural mortality. This model does not consider "indirect" mortality from clam harvesting.

(Whole Stock MINUS GBK) Run with m= 0.05



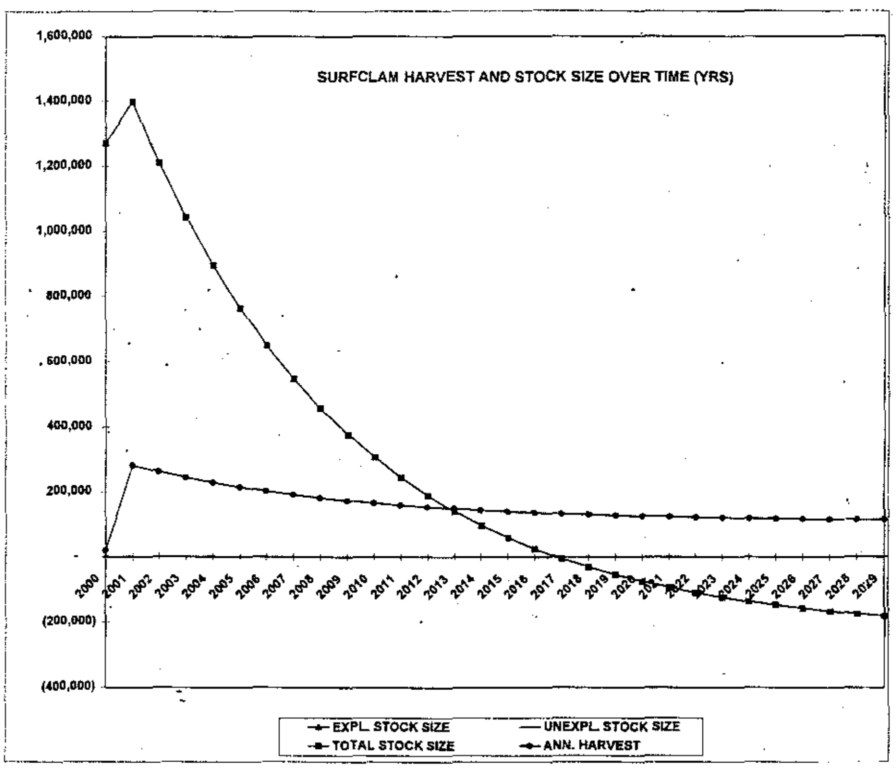


Fig. E46. Surfclam 10-yr supply model. In each year, the catch is set at that which could be taken for 10-yrs. The model assumes an average level of recruitment, and accounts for growth and natural mortality. This model does not consider "indirect" mortality from clam harvesting.

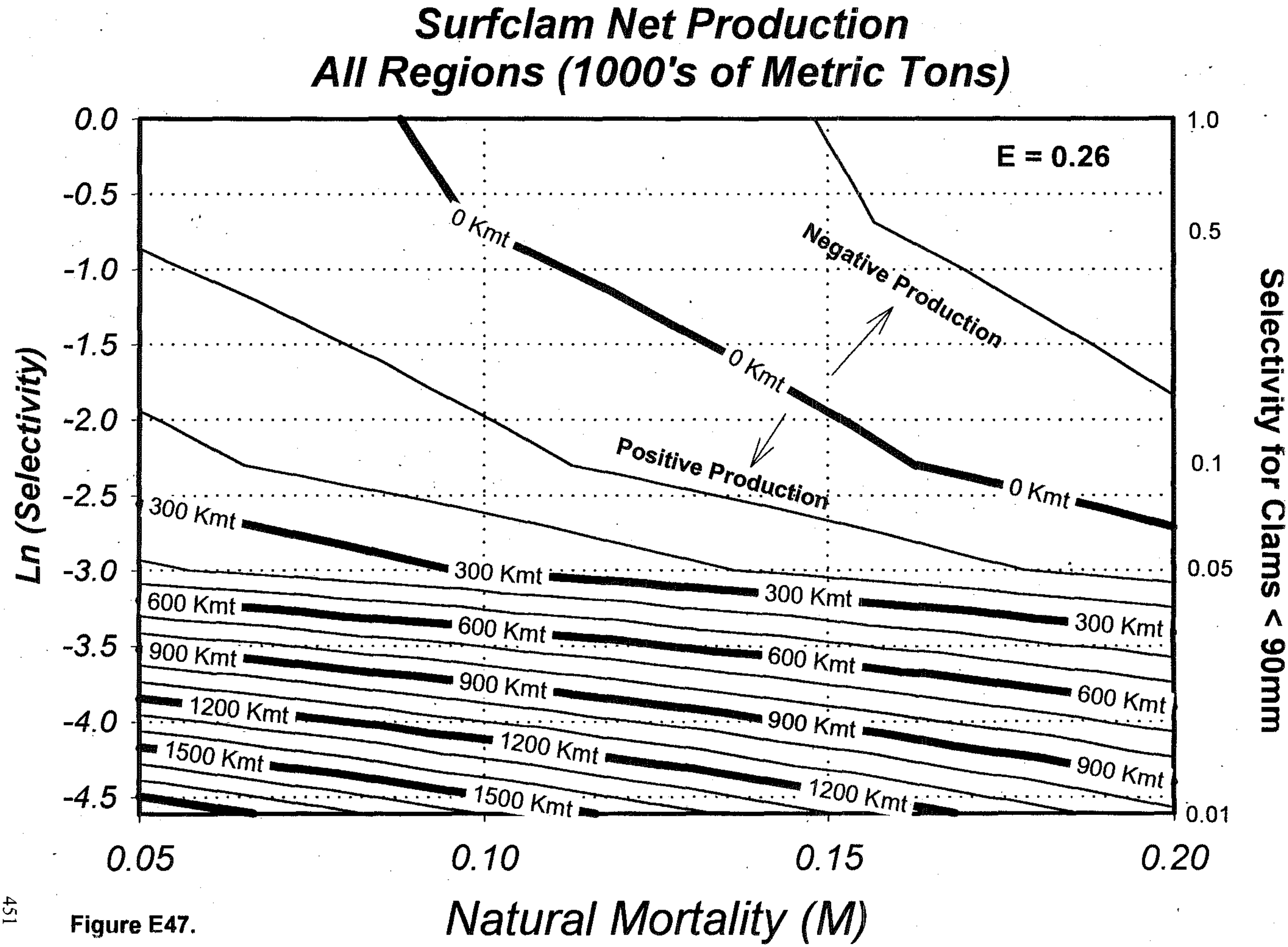
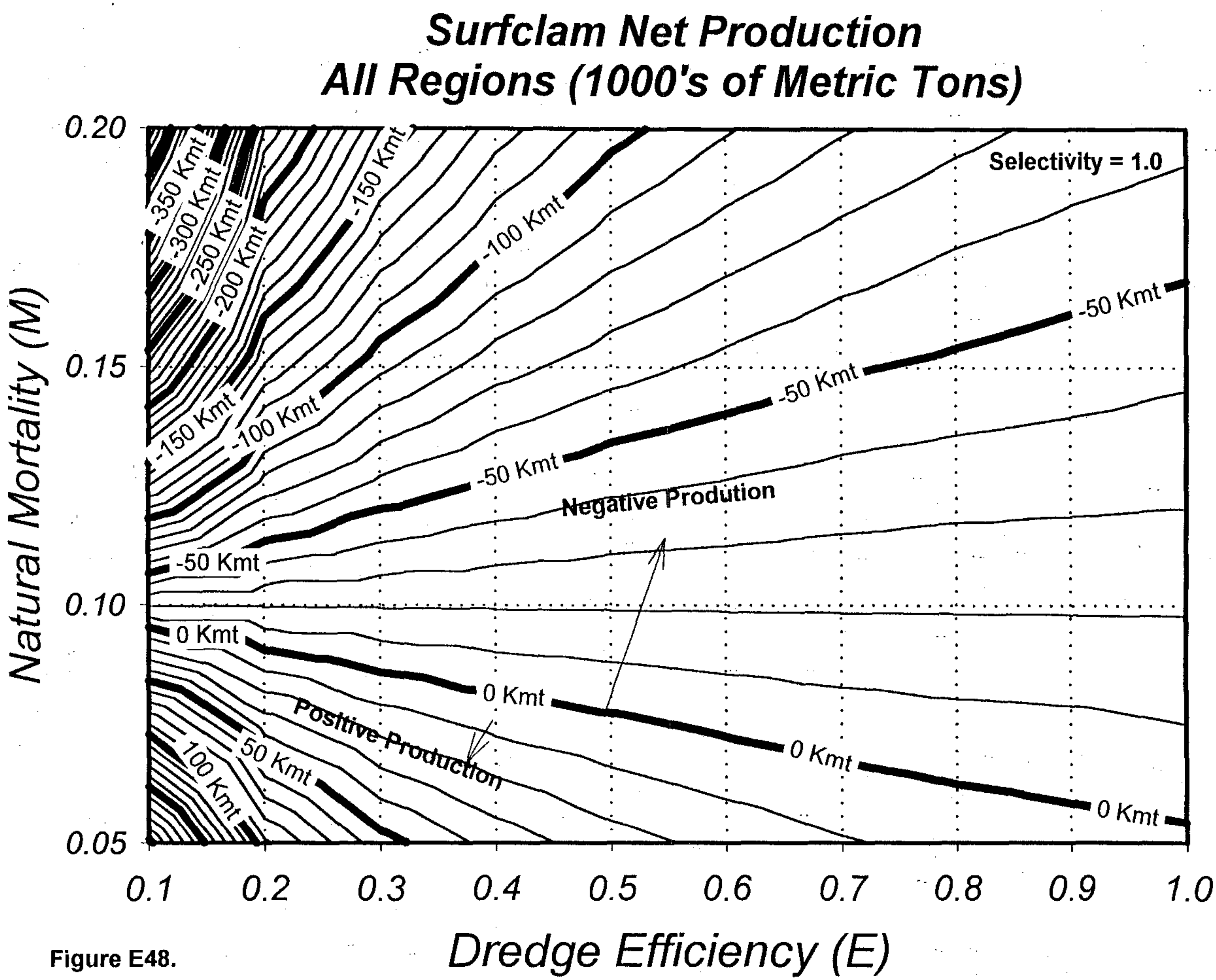

Surfclam Net Production
All Regions (1000's of Metric Tons)
E = 0.26
0 Kmt
Negative Production
Positive Production
300 Kmt
600 Kmt
900 Kmt
1200 Kmt
1500 Kmt
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
-4.5
Ln (Selectivity)
1.0
0.5
0.1
0.05
0.01
Selectivity for Clams < 90mm
0.05
0.10
0.15
0.20
Natural Mortality (M)

Figure E47.



Surfclam Net Production
All Regions (1000's of Metric Tons)
Selectivity = 1.0
-350 Kmt
-300 Kmt
-250 Kmt
-200 Kmt
-150 Kmt
-100 Kmt
-50 Kmt
0 Kmt
50 Kmt
100 Kmt
Negative Prodution
Positive Production
Natural Mortality (M)
0.20
0.15
0.10
0.05
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Dredge Efficiency (E)

Figure E48.

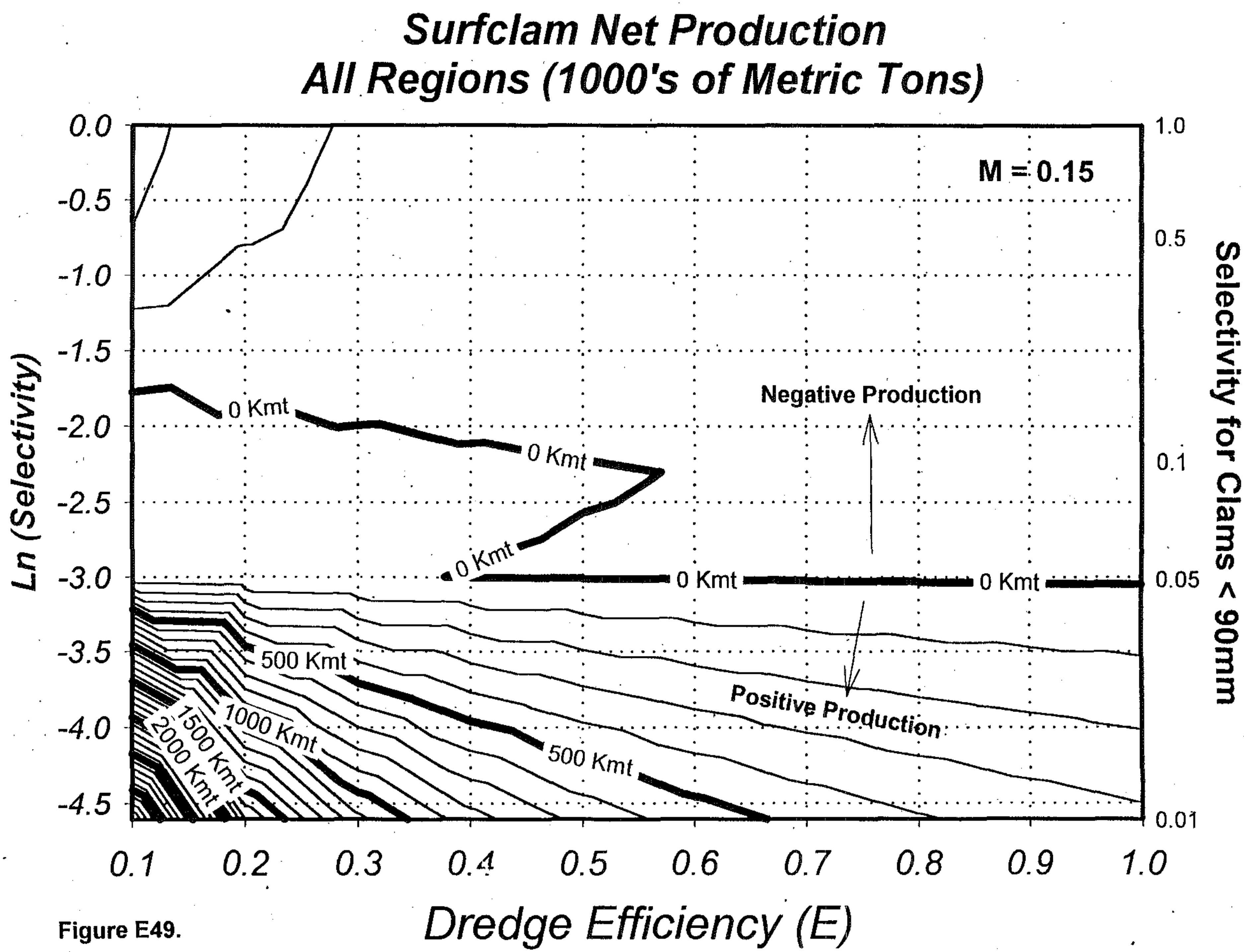

Surfclam Net Production
All Regions (1000's of Metric Tons)
M = 0.15
Ln (Selectivity)
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
-4.5
0 Kmt
0 Kmt
0 Kmt
0 Kmt
0 Kmt
Negative Production
Positive Production
500 Kmt
1000 Kmt
1500 Kmt
2000 Kmt
500 Kmt
1.0
0.5
0.1
0.05
0.01
Selectivity for Clams < 90mm
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Dredge Efficiency (E)

Figure E49.

Surfclam Net Production
Northern New Jersey (1000's of Metric Tons)

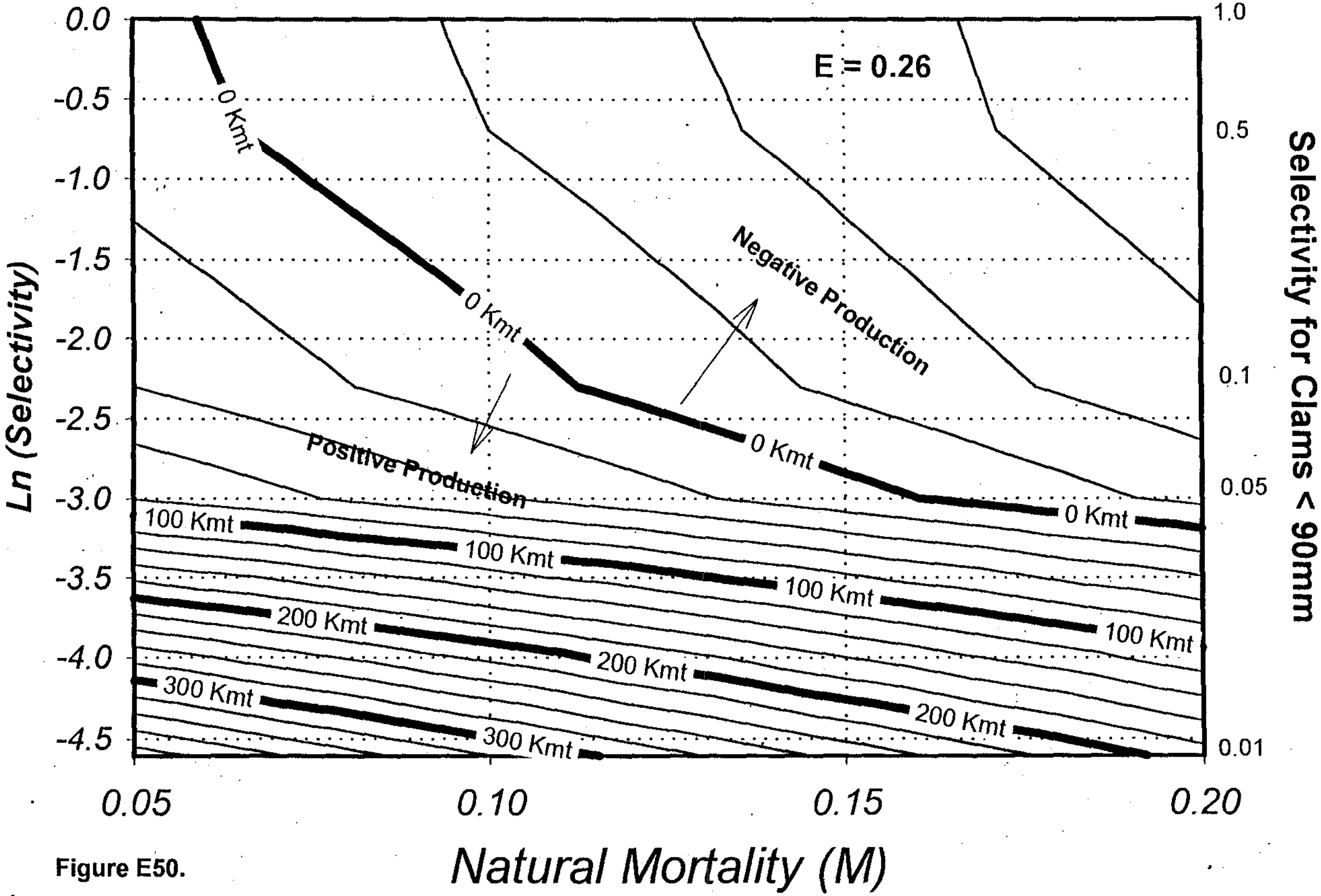


Figure E50.

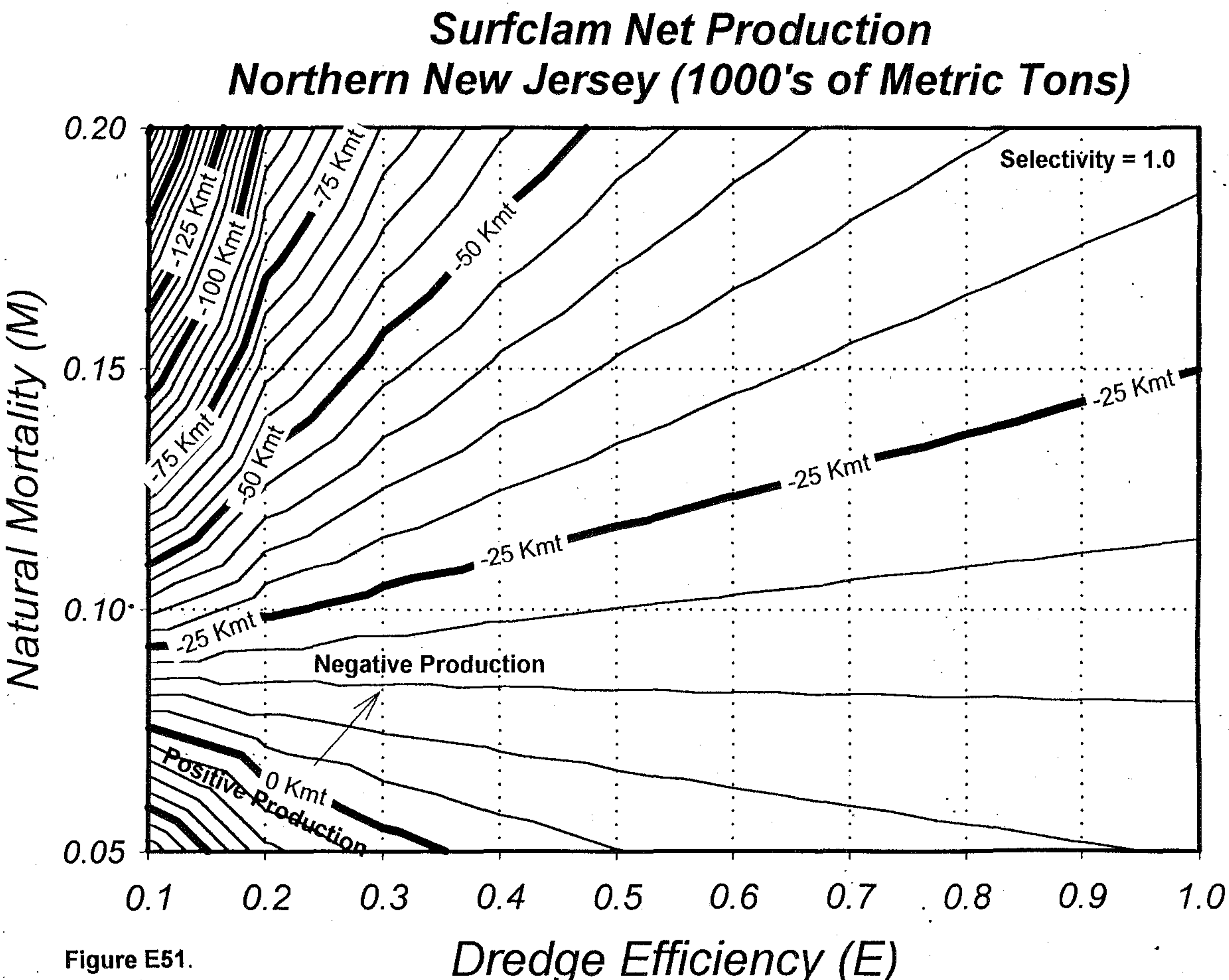

Surfclam Net Production
Northern New Jersey (1000's of Metric Tons)
Selectivity = 1.0
-125 Kmt
-100 Kmt
-75 Kmt
-50 Kmt
-25 Kmt
0 Kmt
Negative Production
Positive Production
Natural Mortality (M)
0.20
0.15
0.10
0.05
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Dredge Efficiency (E)

Figure E51.

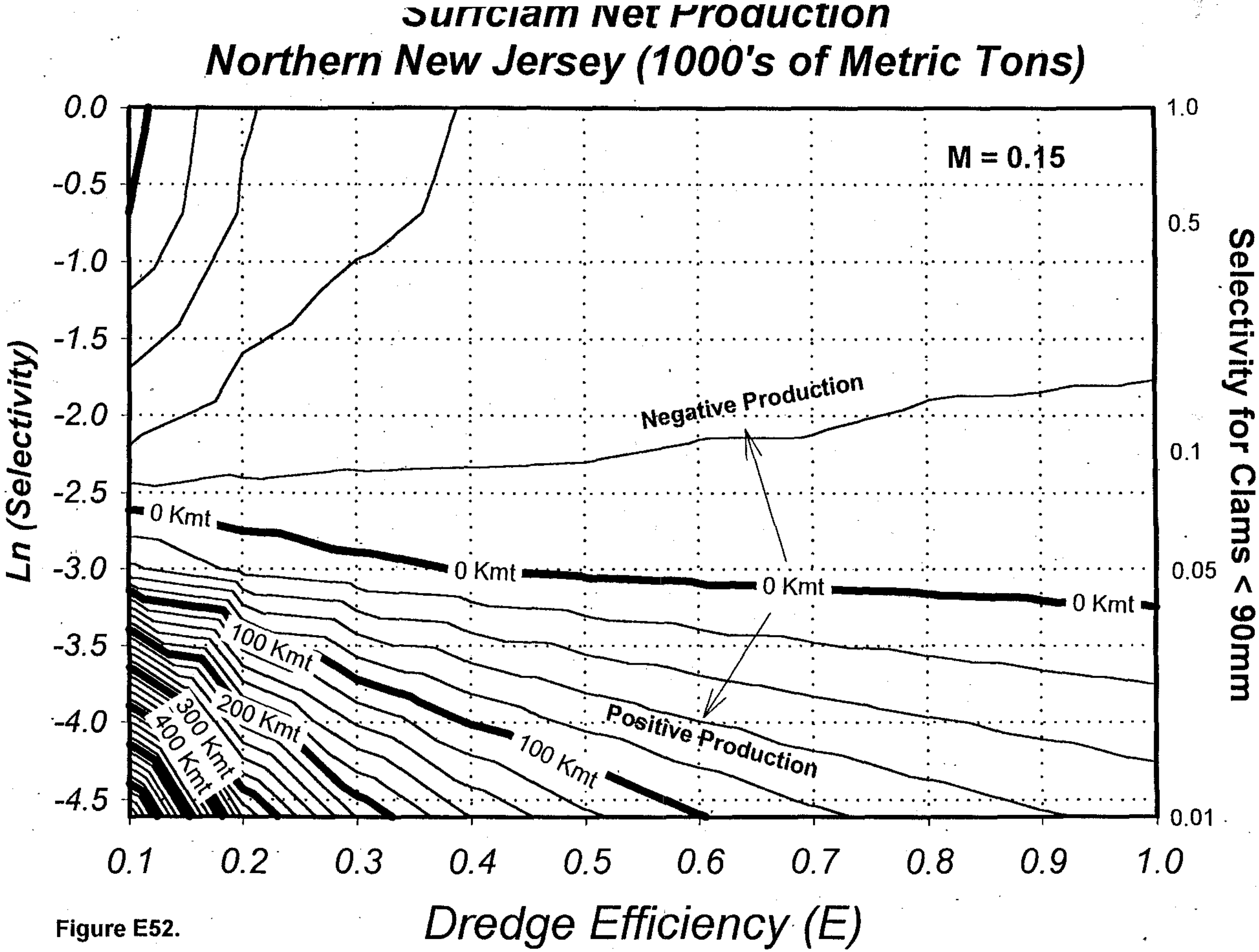
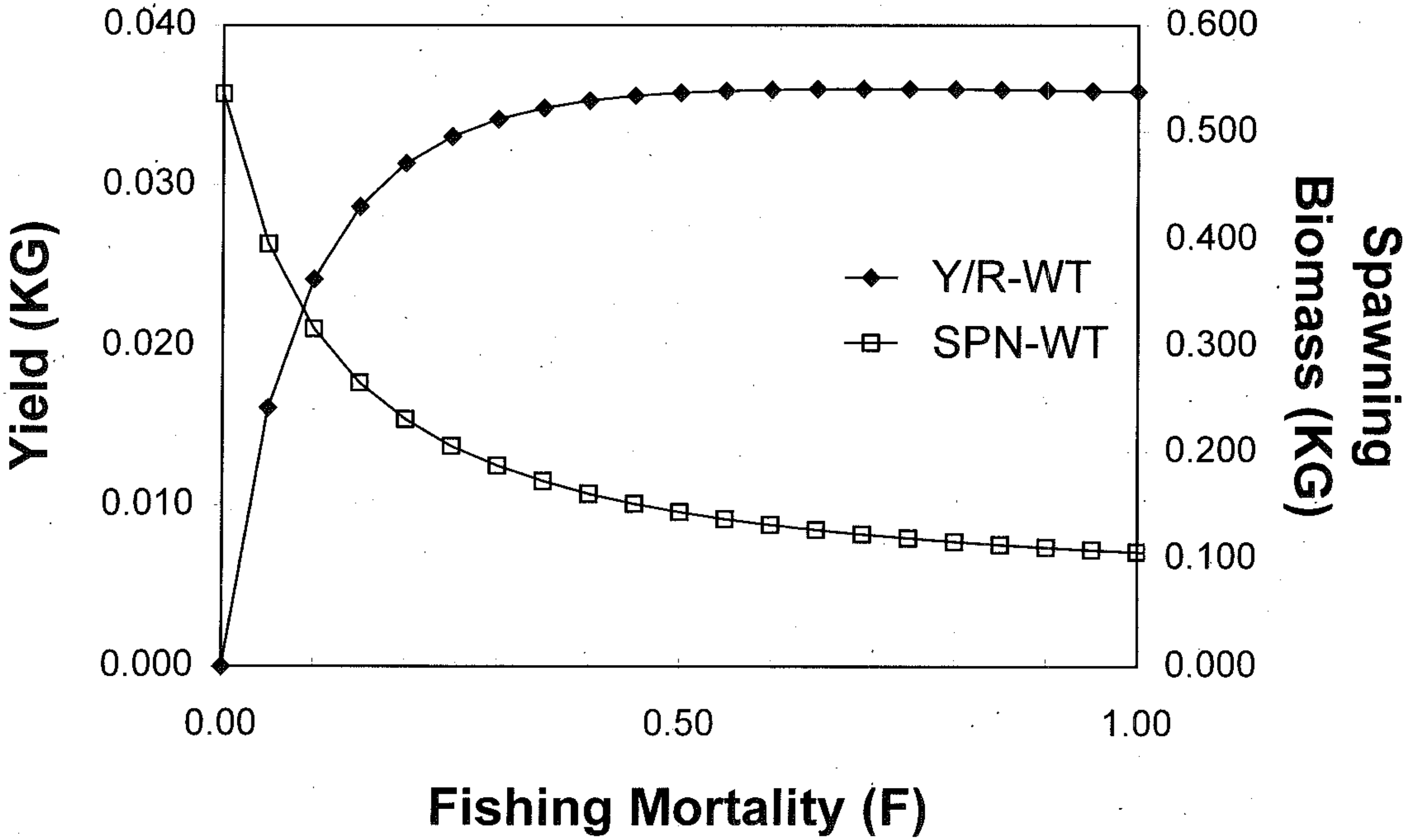

Surfclam Net Production
Northern New Jersey (1000's of Metric Tons)
M = 0.15
Negative Production
Positive Production
0 Kmt
100 Kmt
200 Kmt
300 Kmt
400 Kmt
Ln (Selectivity)
Selectivity for Clams < 90mm
Dredge Efficiency (E)
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
-4.5
1.0
0.5
0.1
0.05
0.01
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

Figure E52.

Figure E53. Yield and Spawning Biomass Per Recruit for NNJ (M=0.15, Recruit at 120 mm)



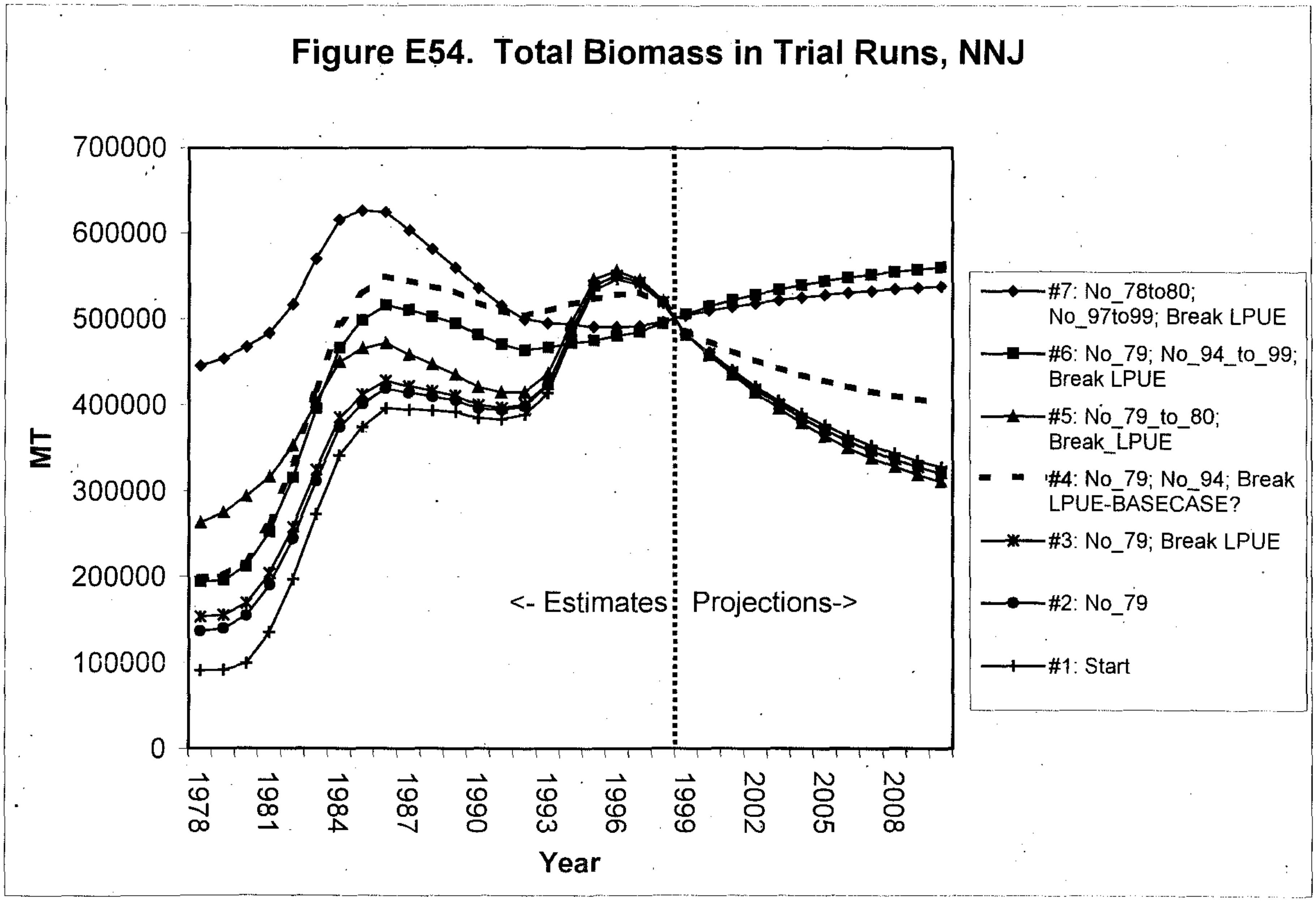


Figure E54. Total Biomass in Trial Runs, NNJ
700000
600000
500000
400000
300000
200000
100000
0
MT
<- Estimates
Projections->
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
Year
#7: No_78to80; No_97to99; Break LPUE
#6: No_79; No_94_to_99; Break LPUE
#5: No_79_to_80; Break_LPUE
#4: No_79; No_94; Break LPUE-BASECASE?
#3: No_79; Break LPUE
#2: No_79
#1: Start

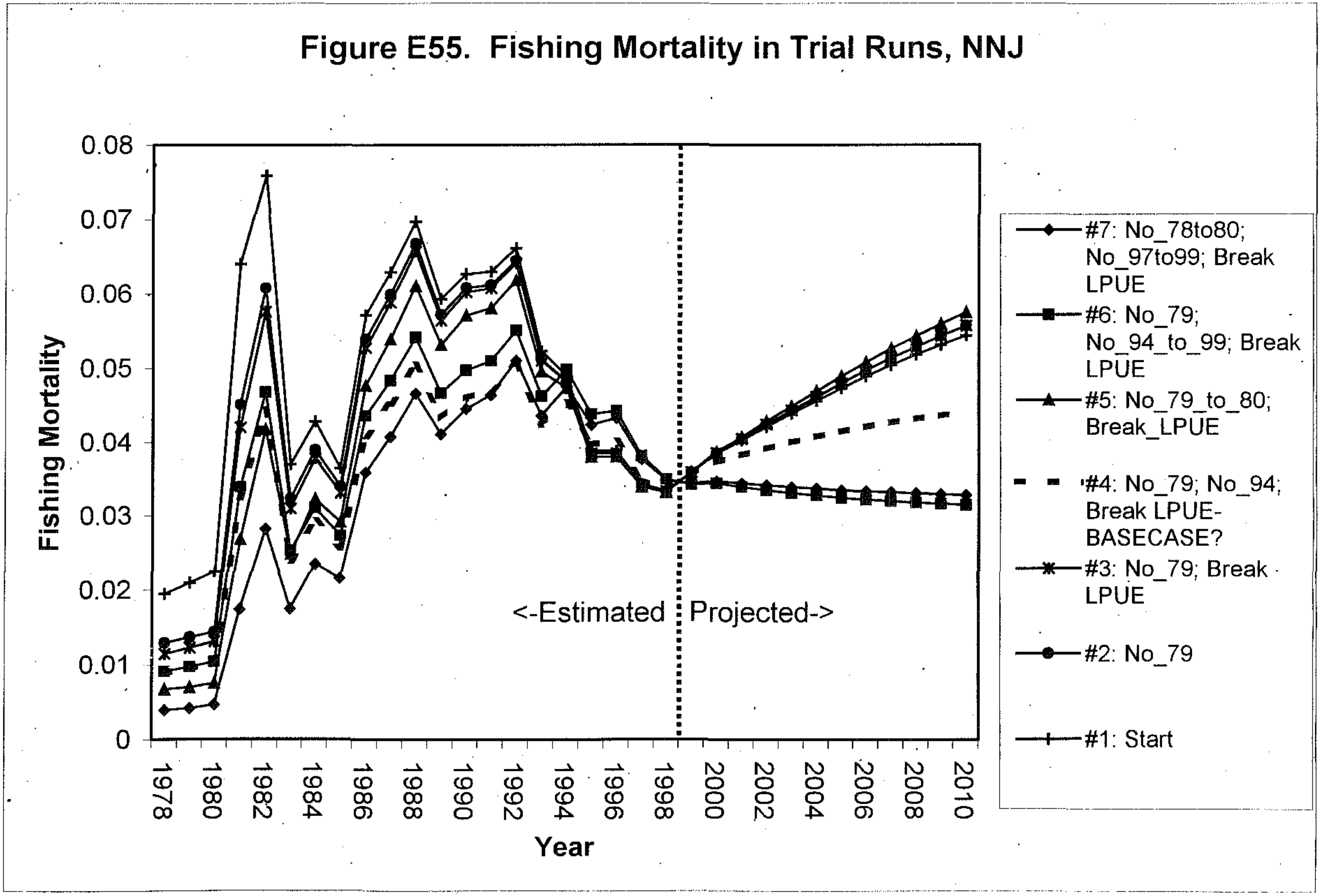


Figure E55. Fishing Mortality in Trial Runs, NNJ
Fishing Mortality
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
<-Estimated
Projected->
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
Year
#7: No_78to80; No_97to99; Break LPUE
#6: No_79; No_94_to_99; Break LPUE
#5: No_79_to_80; Break_LPUE
#4: No_79; No_94; Break LPUE-BASECASE?
#3: No_79; Break LPUE
#2: No_79
#1: Start

Figure E56. Sensitivity of Biomass Estimates to Assumed M in Trial Runs, NNJ

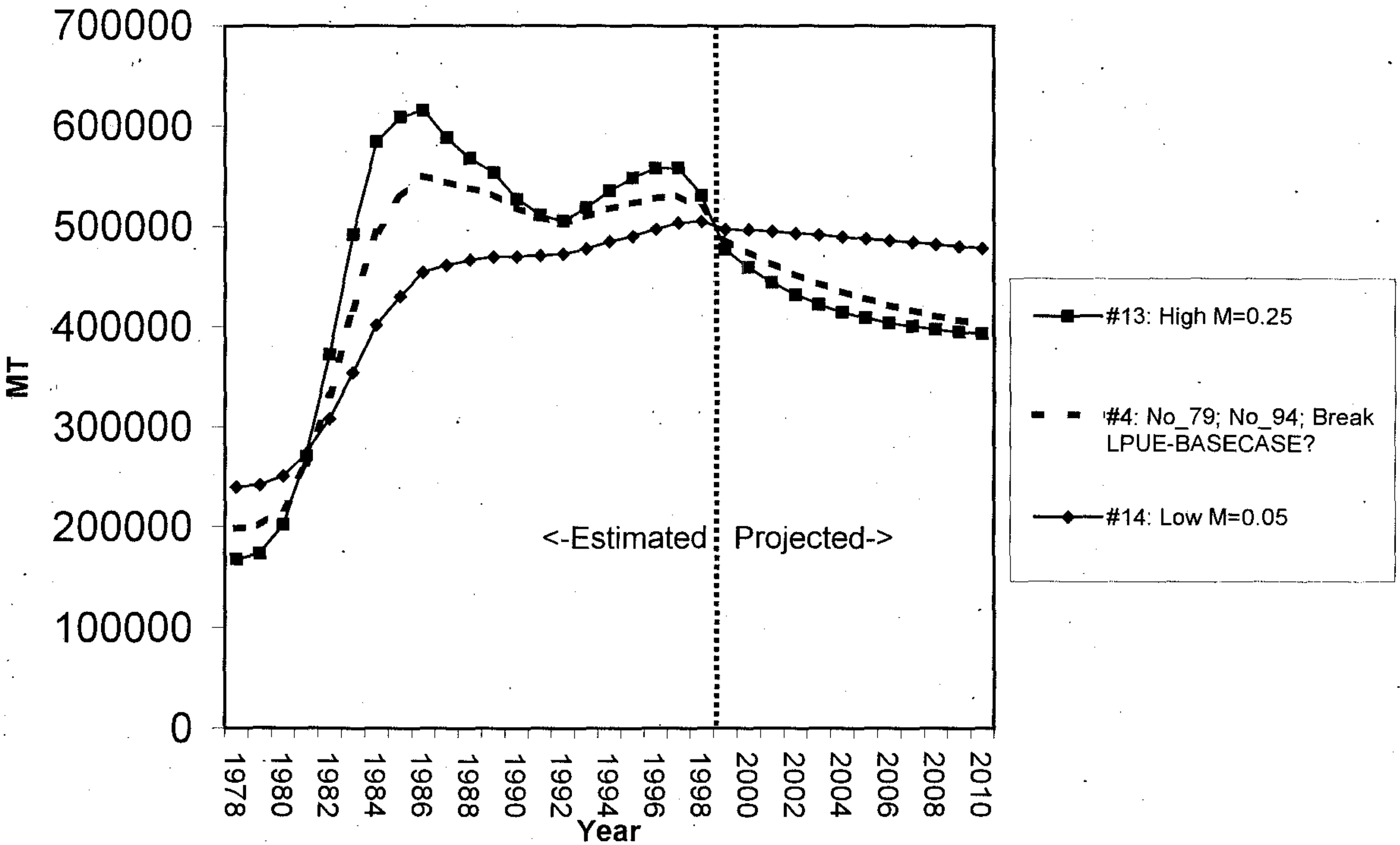


Figure E57. Sensitivity of Fishing Mortality to Assumed M in Trial Runs, NNJ

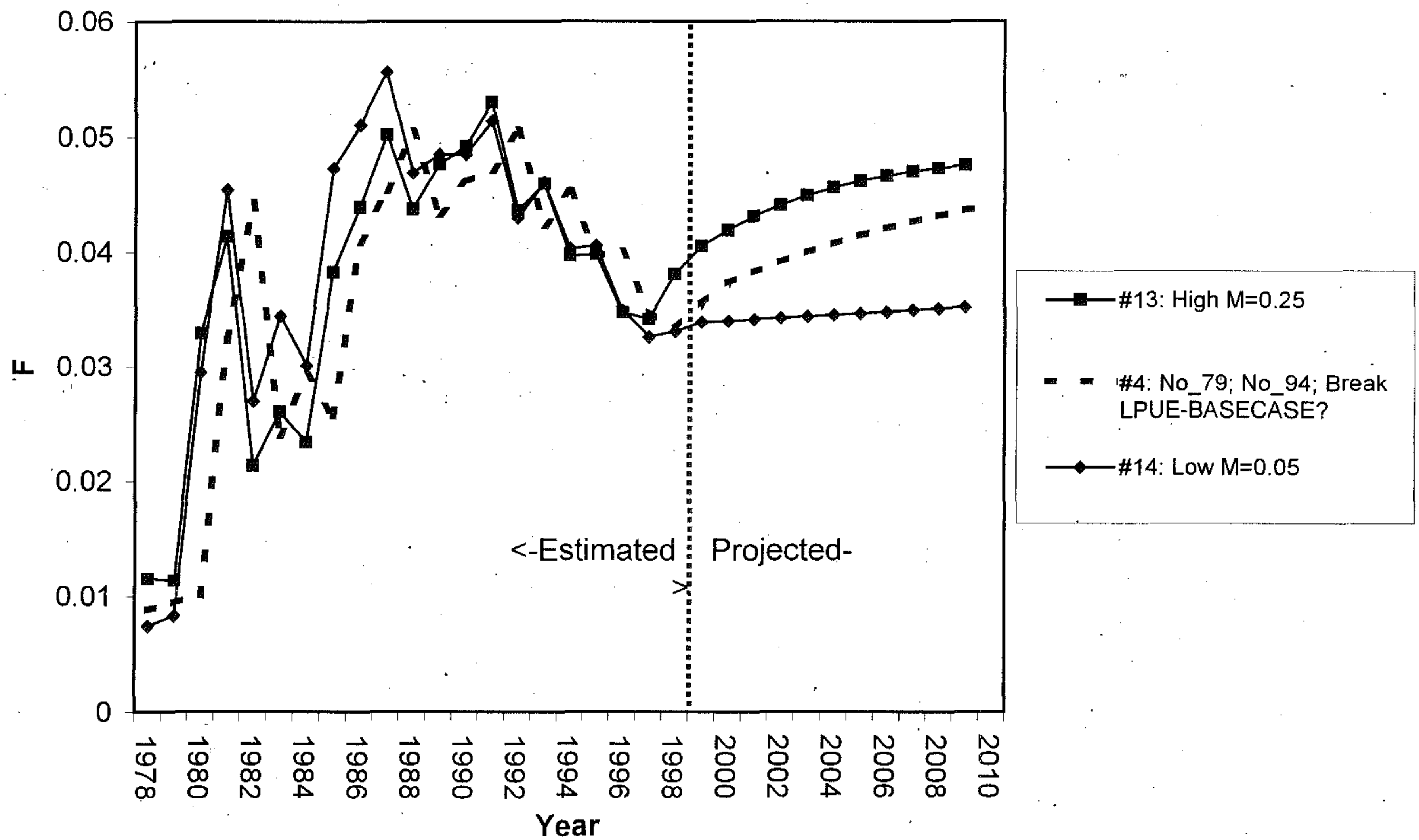


Figure E58. Sensitivity of Recruitment Estimates to Assumed M in Trial Runs, NNJ

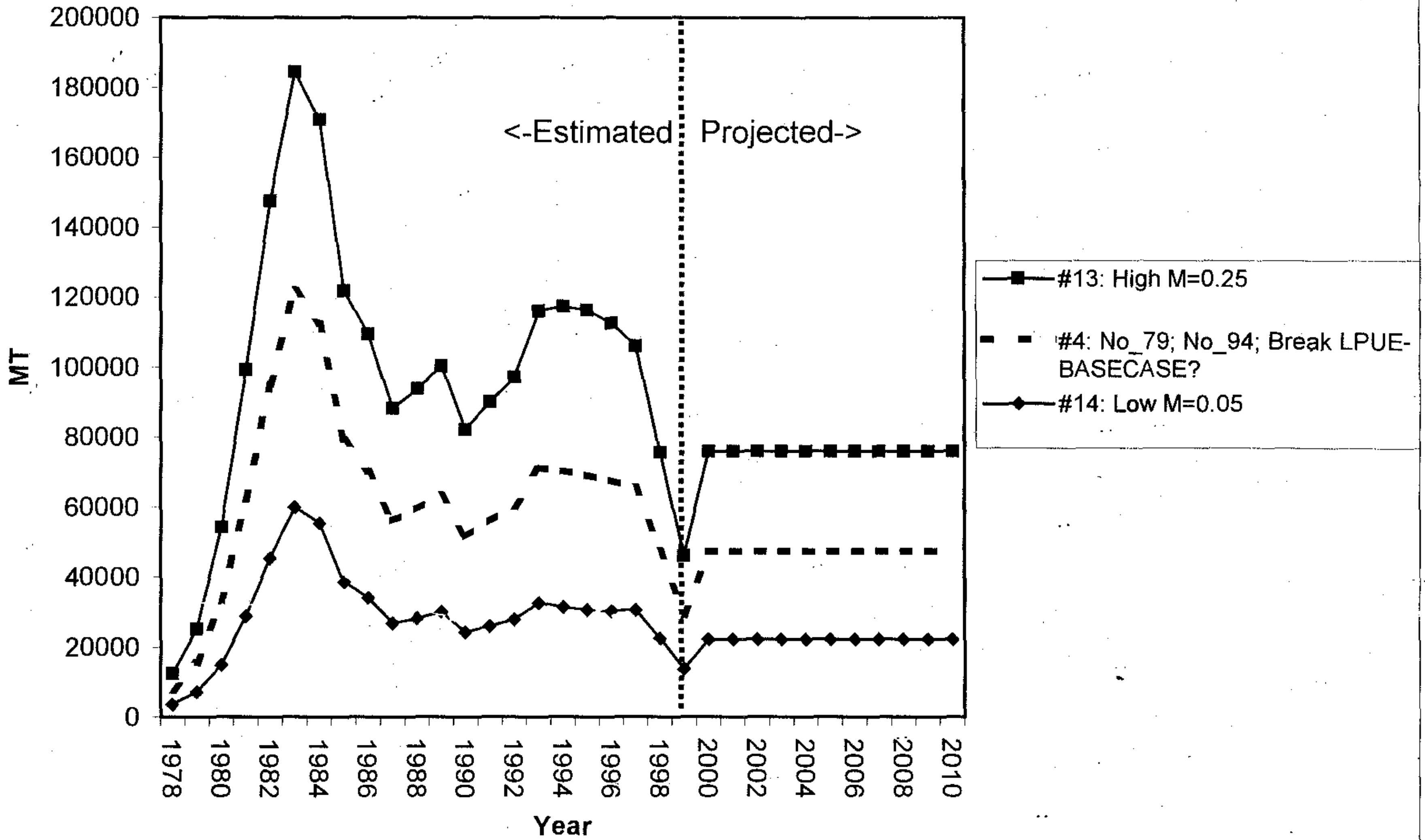


Figure E59. Sensitivity of Production and Biomass in Trial Runs, NNJ

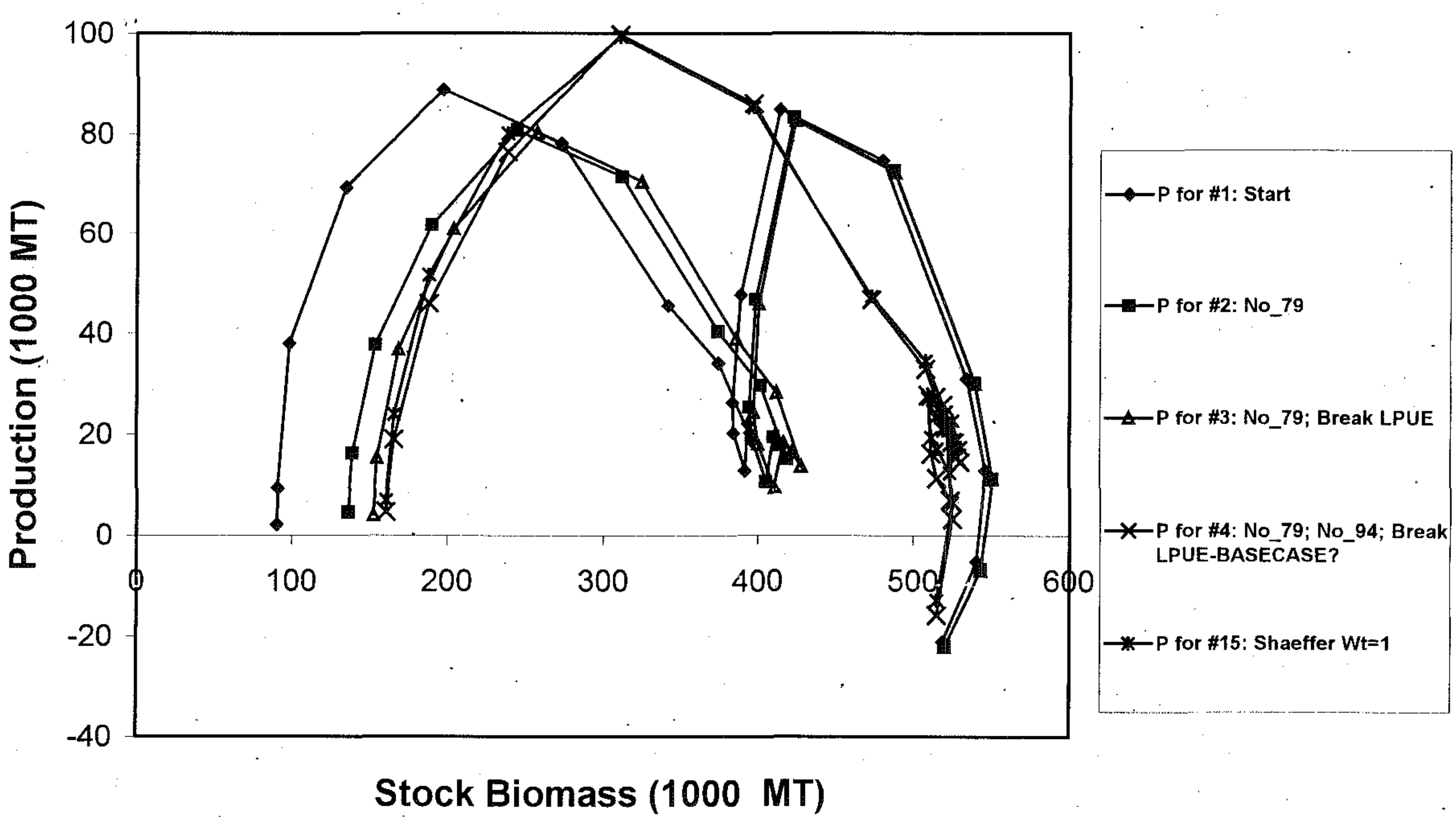


Figure E60. Sensitivity of Production and Biomass in Trial Runs, NNJ

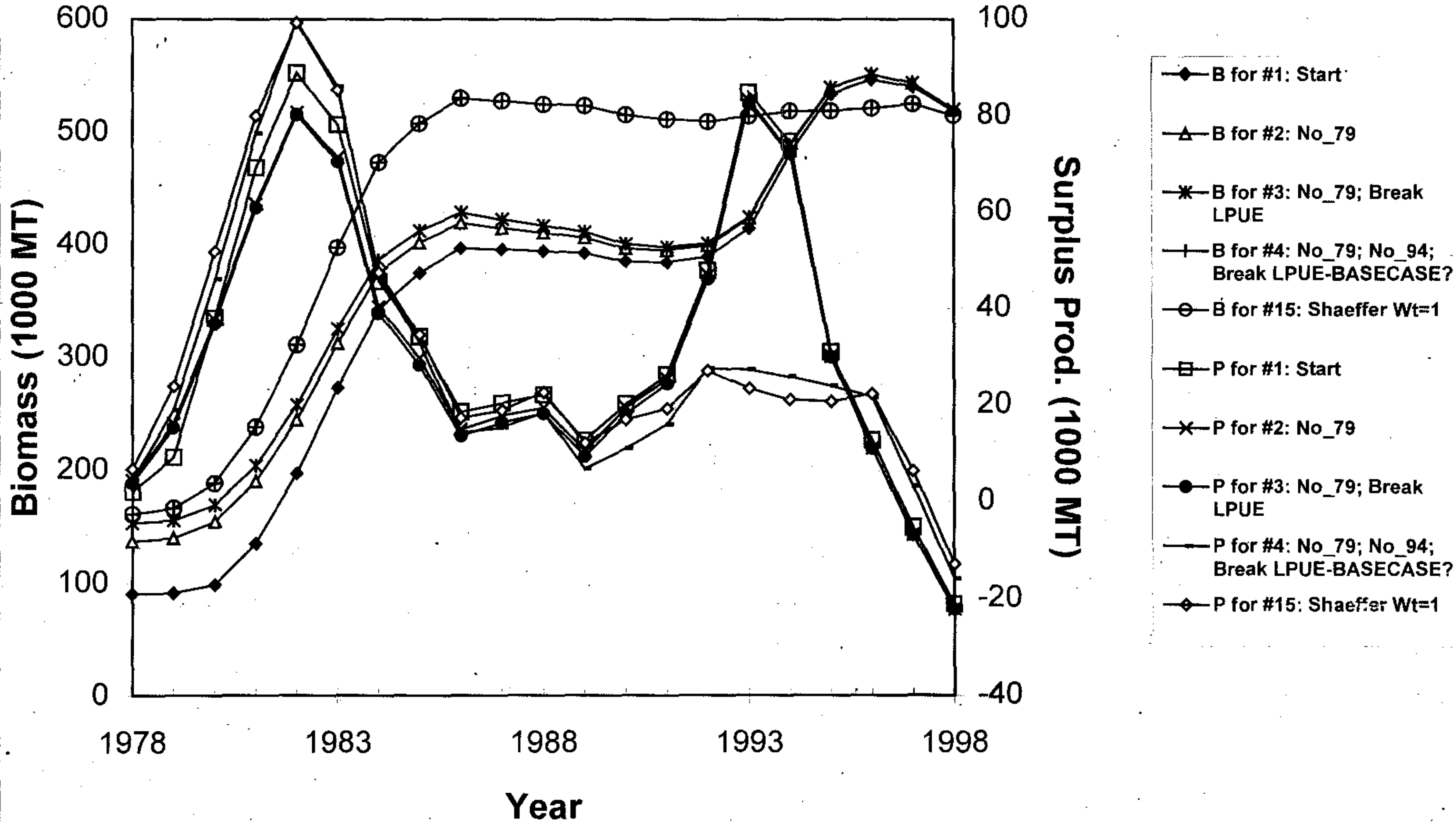


Figure E61. Observed and Predicted LPUE-1 (1980-1984), Trial Run, NNJ

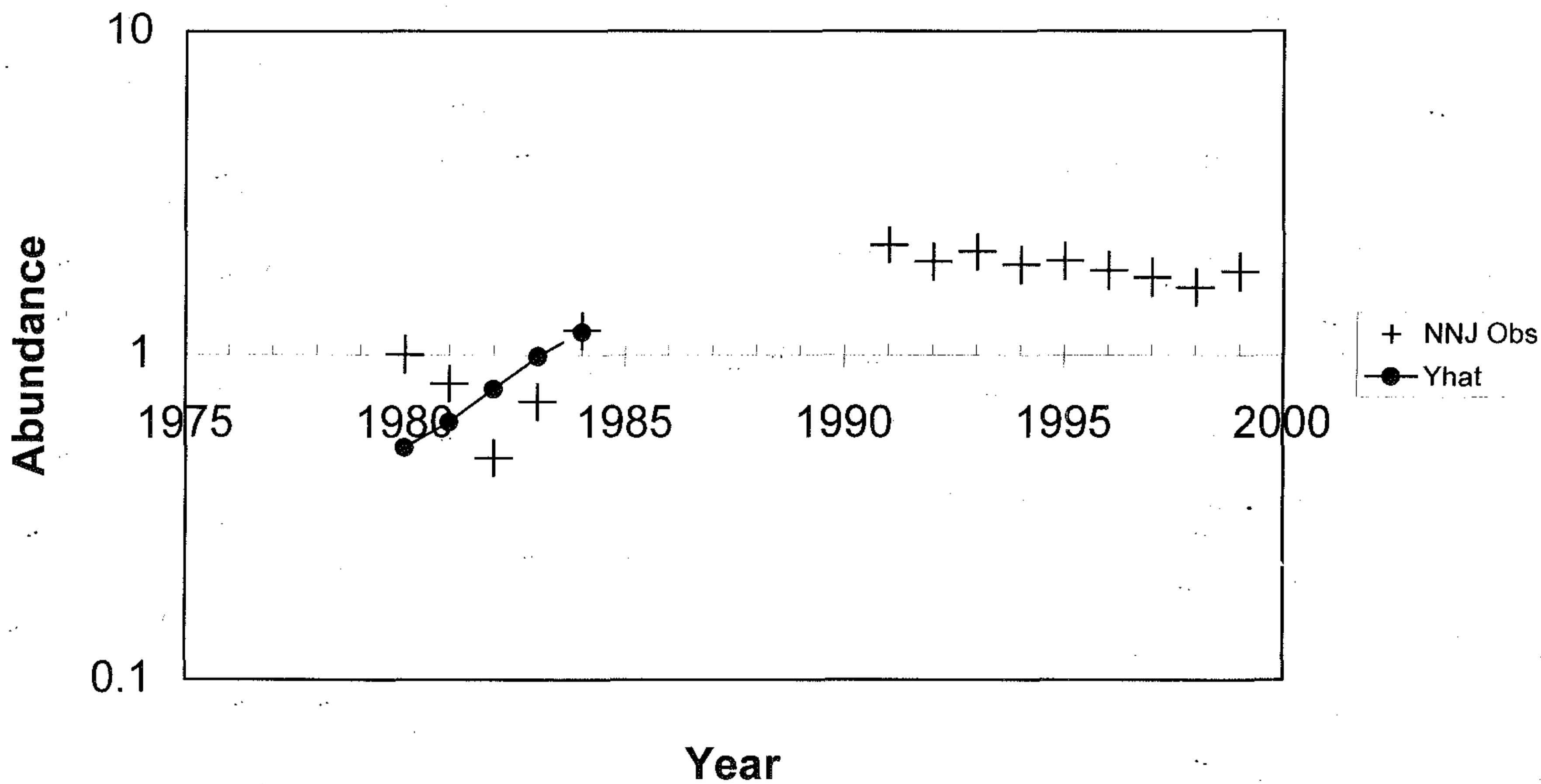


Figure E62. Observed and Predicted LPUE-2 (1991-1999), Trial Run, NNJ

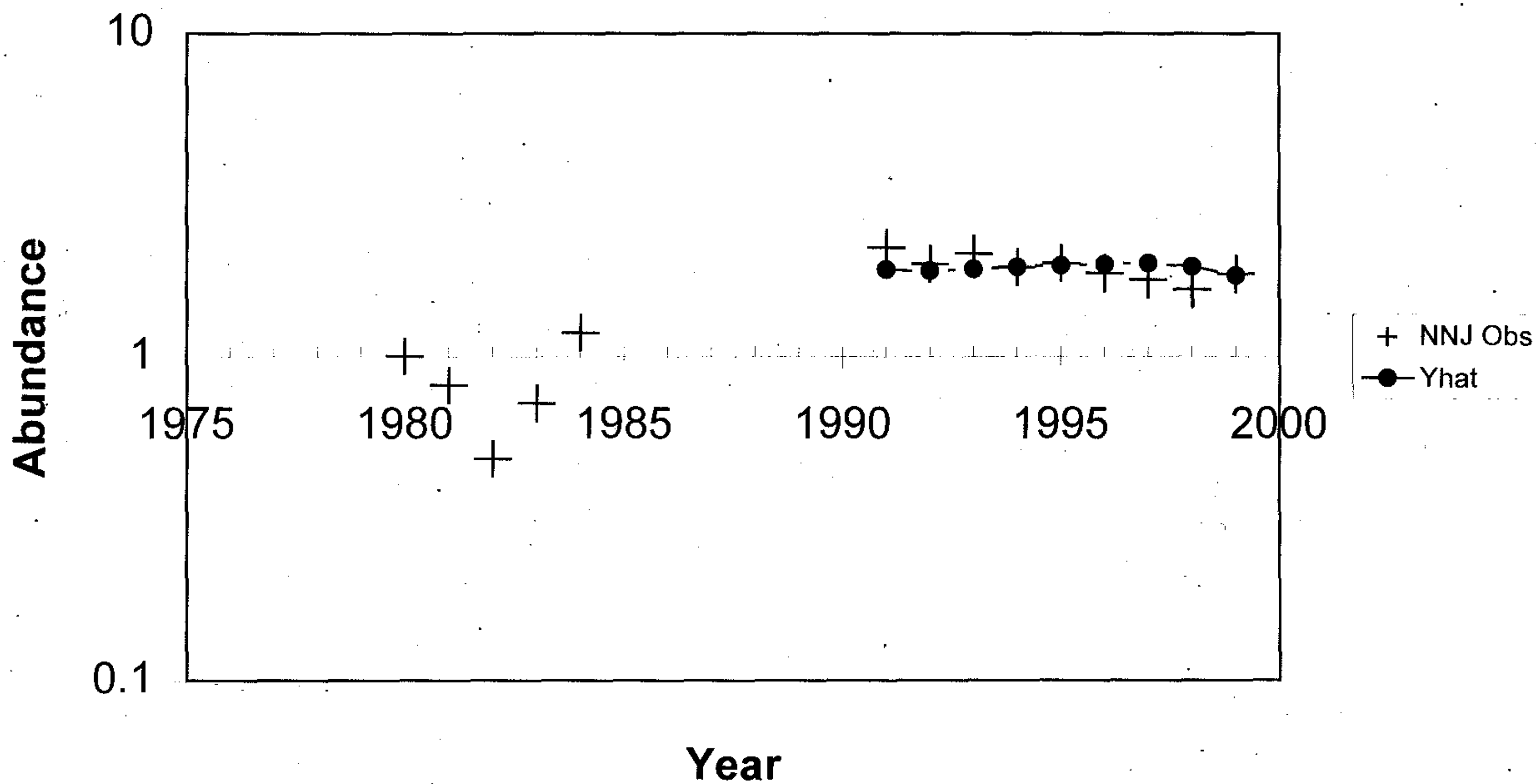


Figure E63. Observed and Predicted Survey Data (N/Tow) for Pre-recruits, Trial Run, NNJ

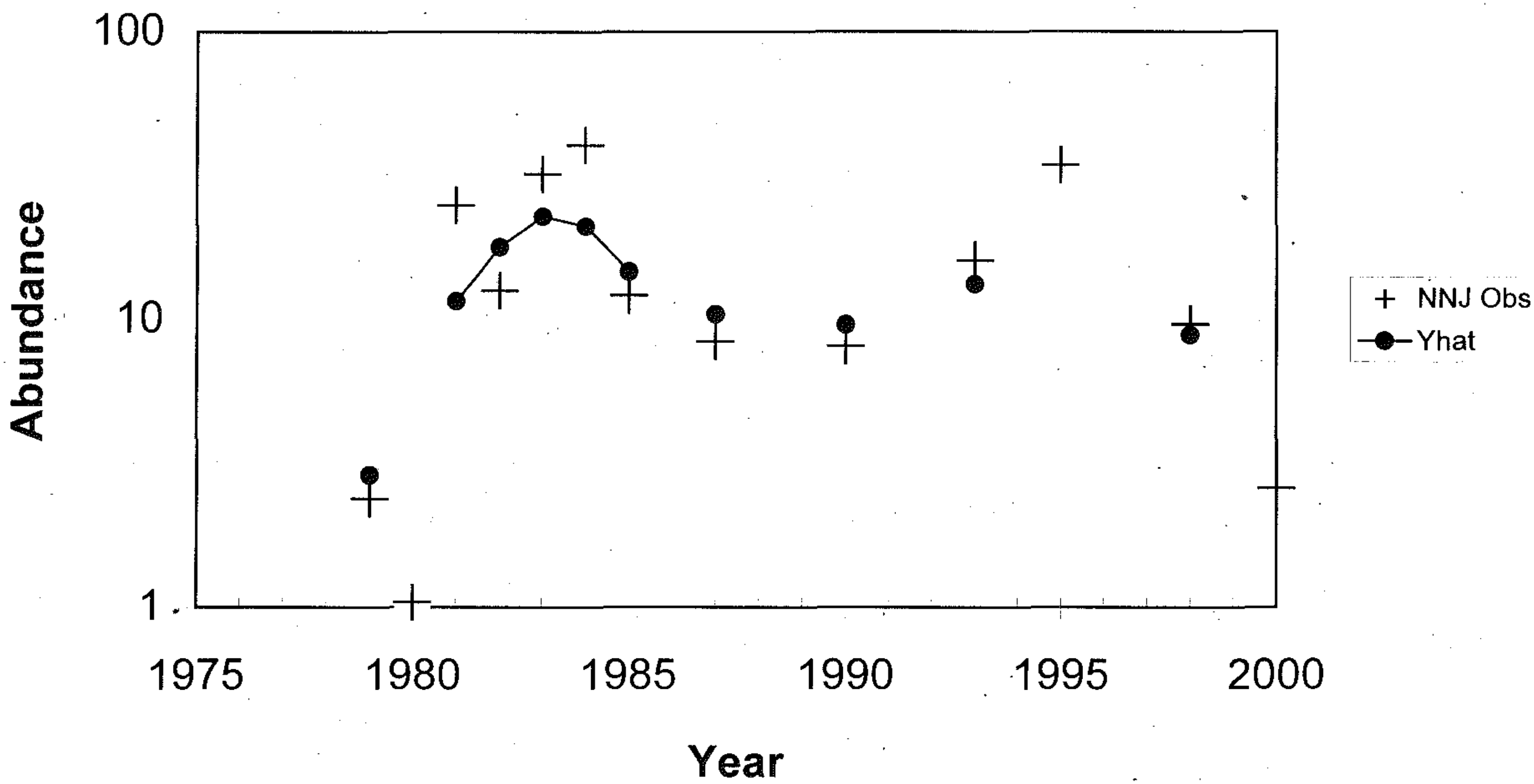


Figure E64. Observed and Predicted Survey Data (N/Tow) for New Recruits, Trial Run, NNJ

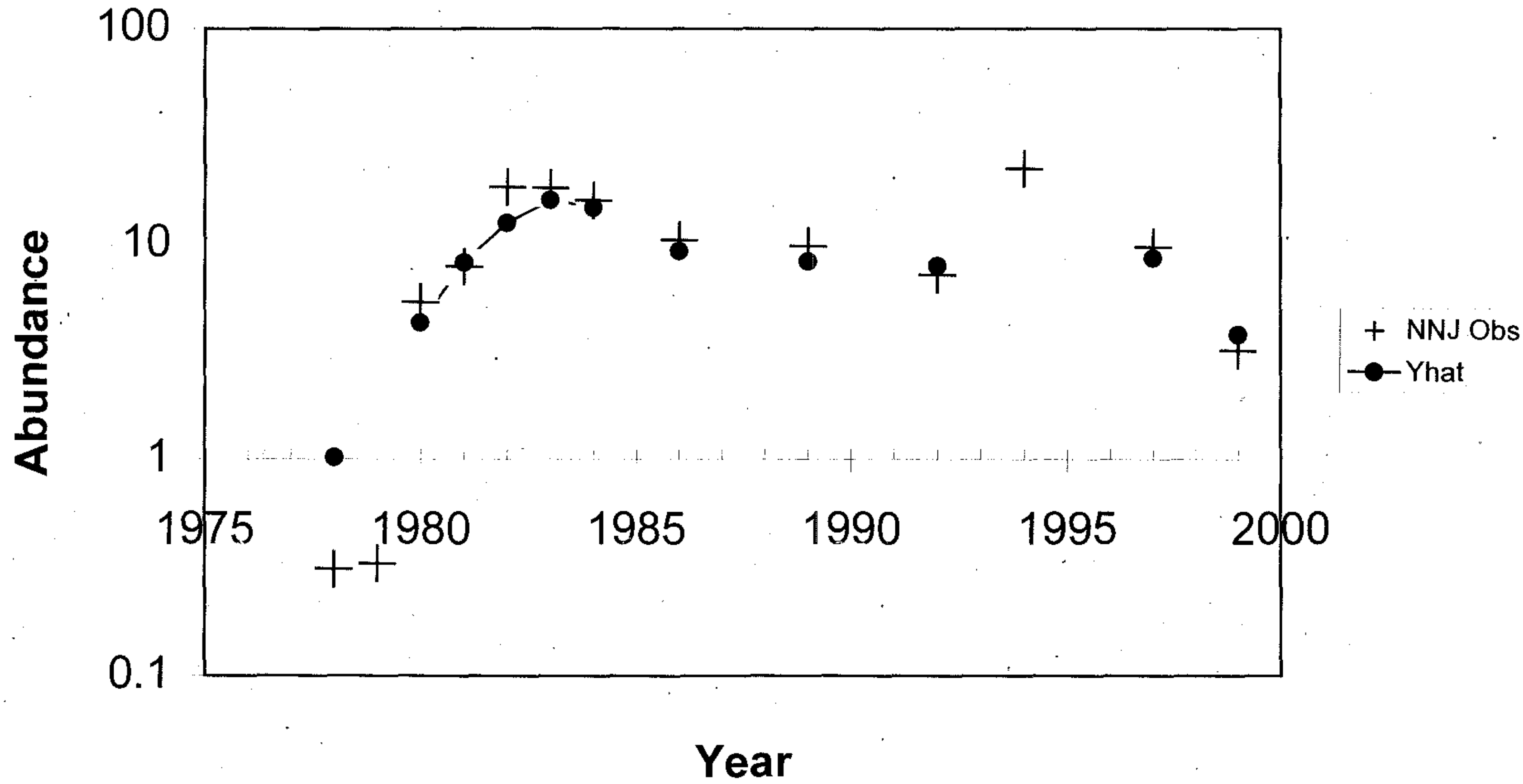


Figure E65. Observed and Predicted Survey Data (KG/Tow), New+Old Recruits, Trial Run, NNJ

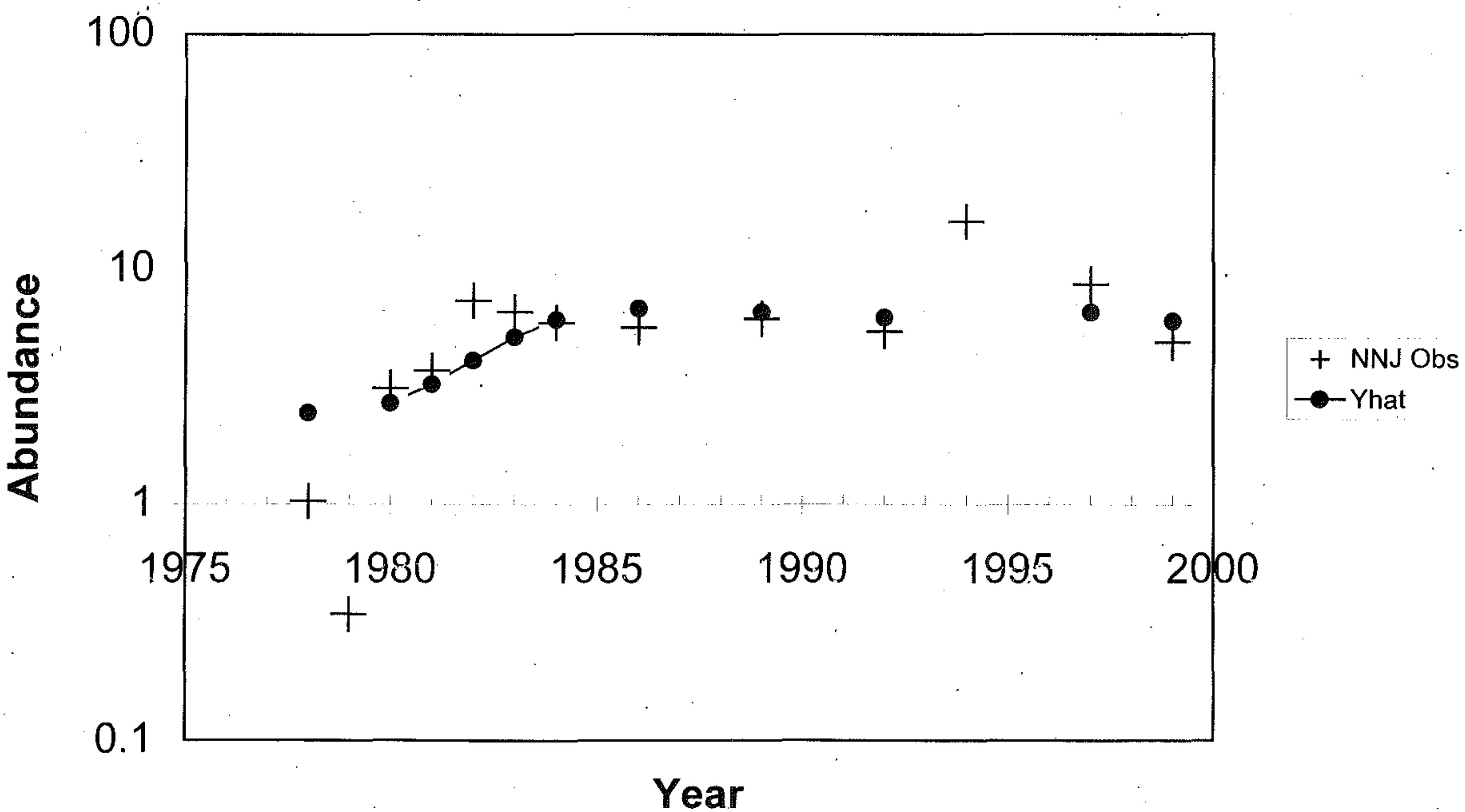


Figure E66. Observed and Predicted Swept Area Biomass (MT) for Surfclam, Trial Run, NNJ

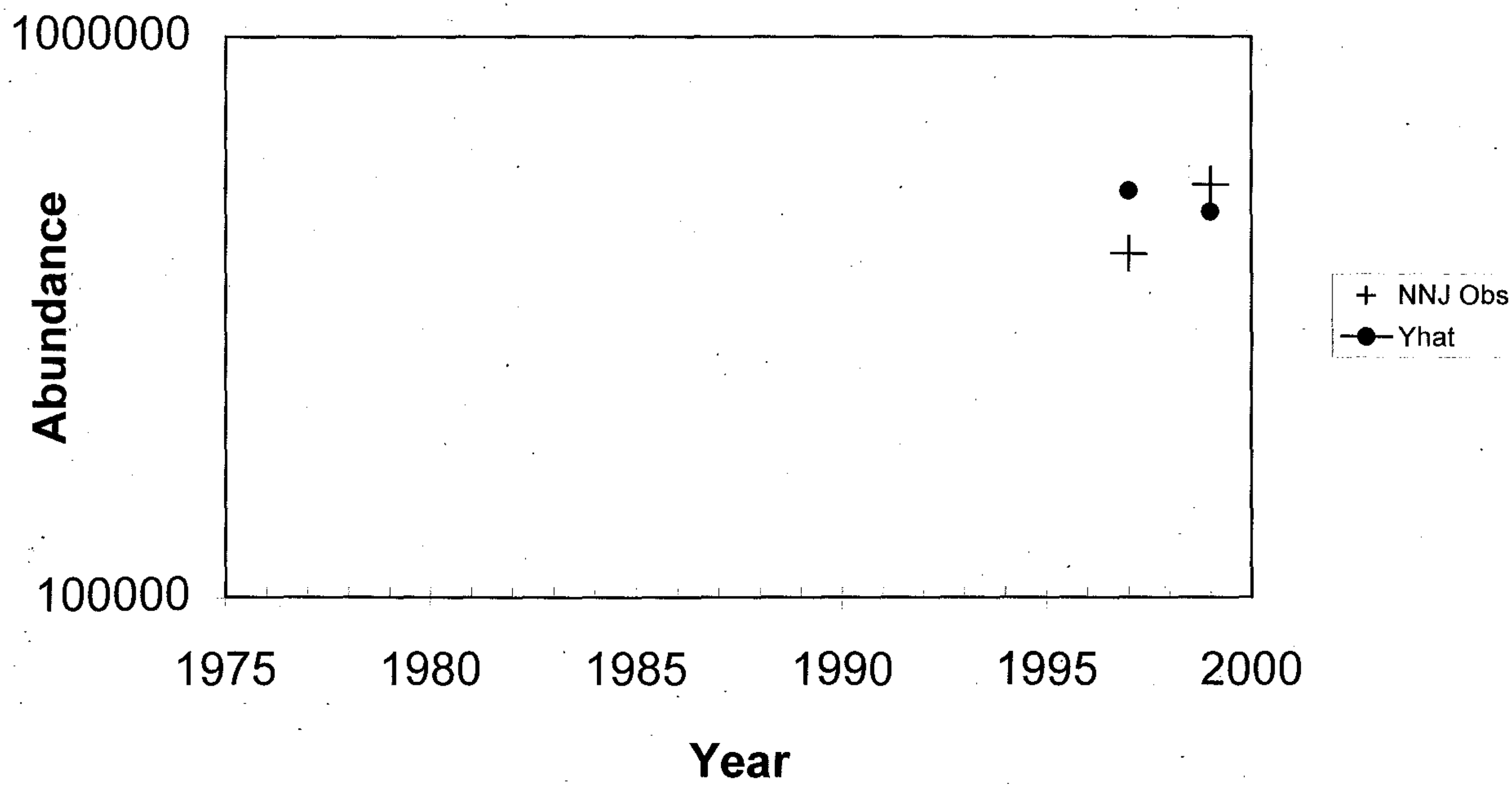


Figure E67. Surfclam Biomass from KLAMZ

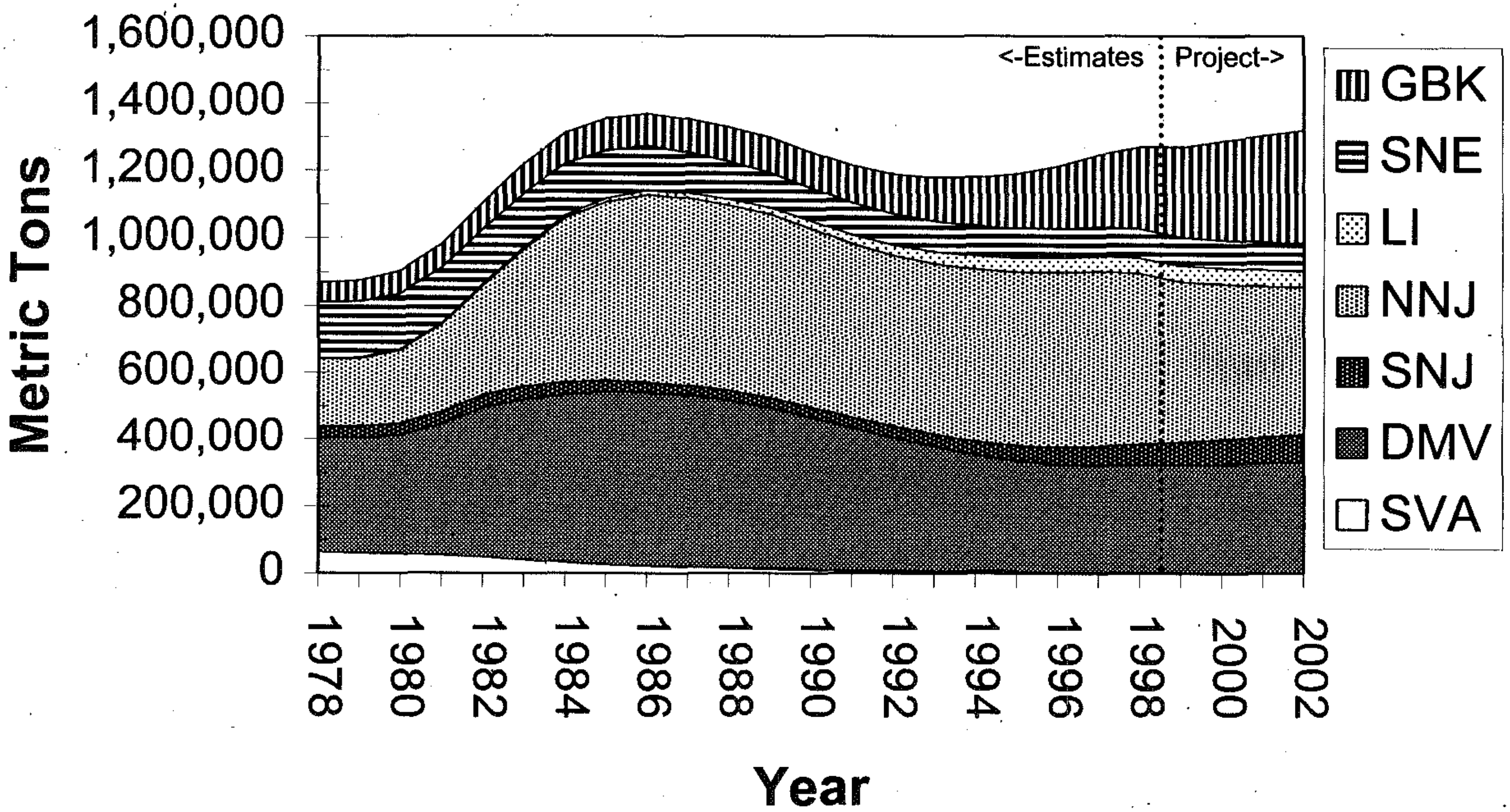


Figure E68. Fishing Mortality for Surfclam from KLAMZ

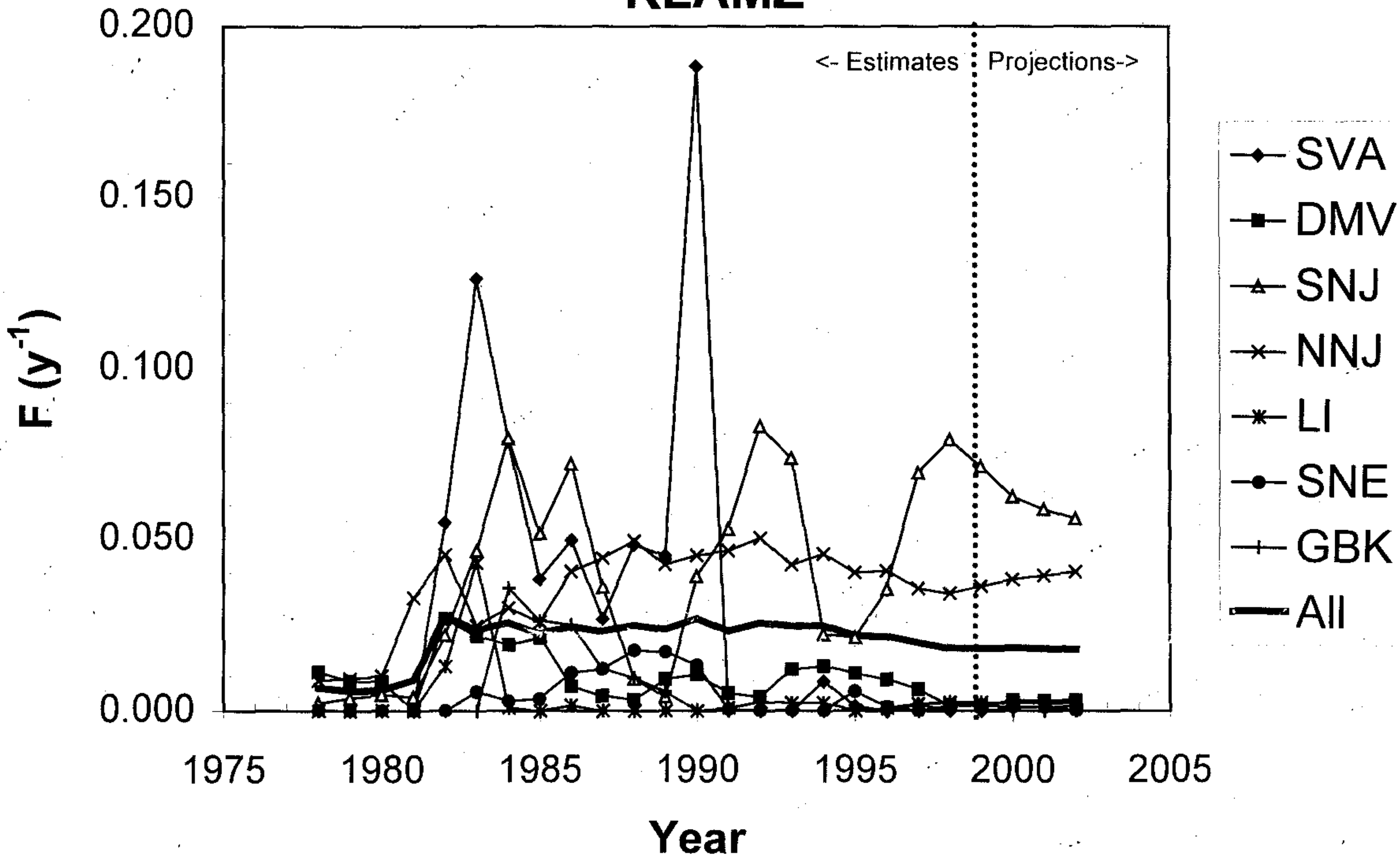


Figure E69. Surfclam Recruitment From KLAMZ

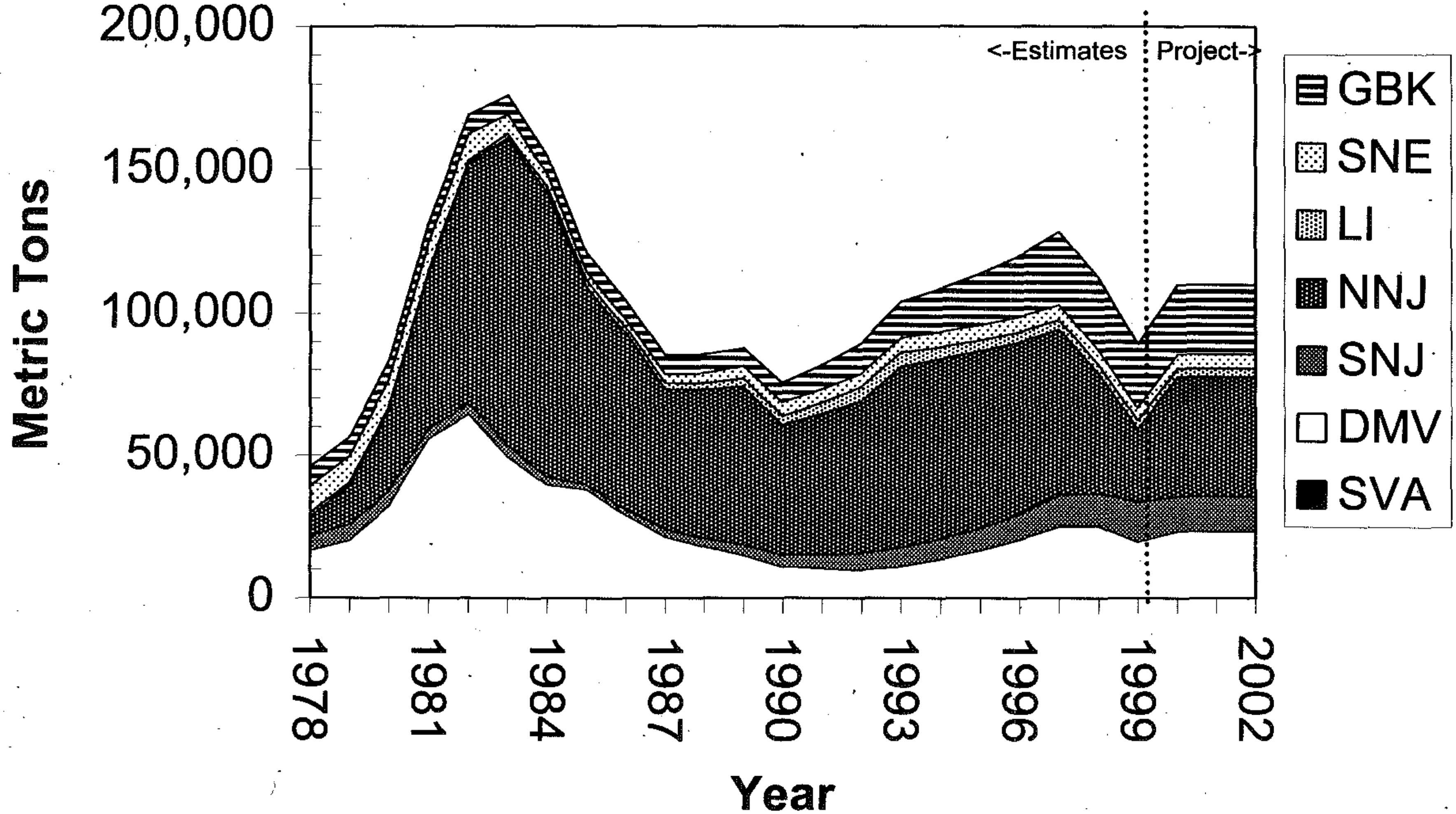


Figure E70. Annual Surplus Production for Surfclam from KLAMZ

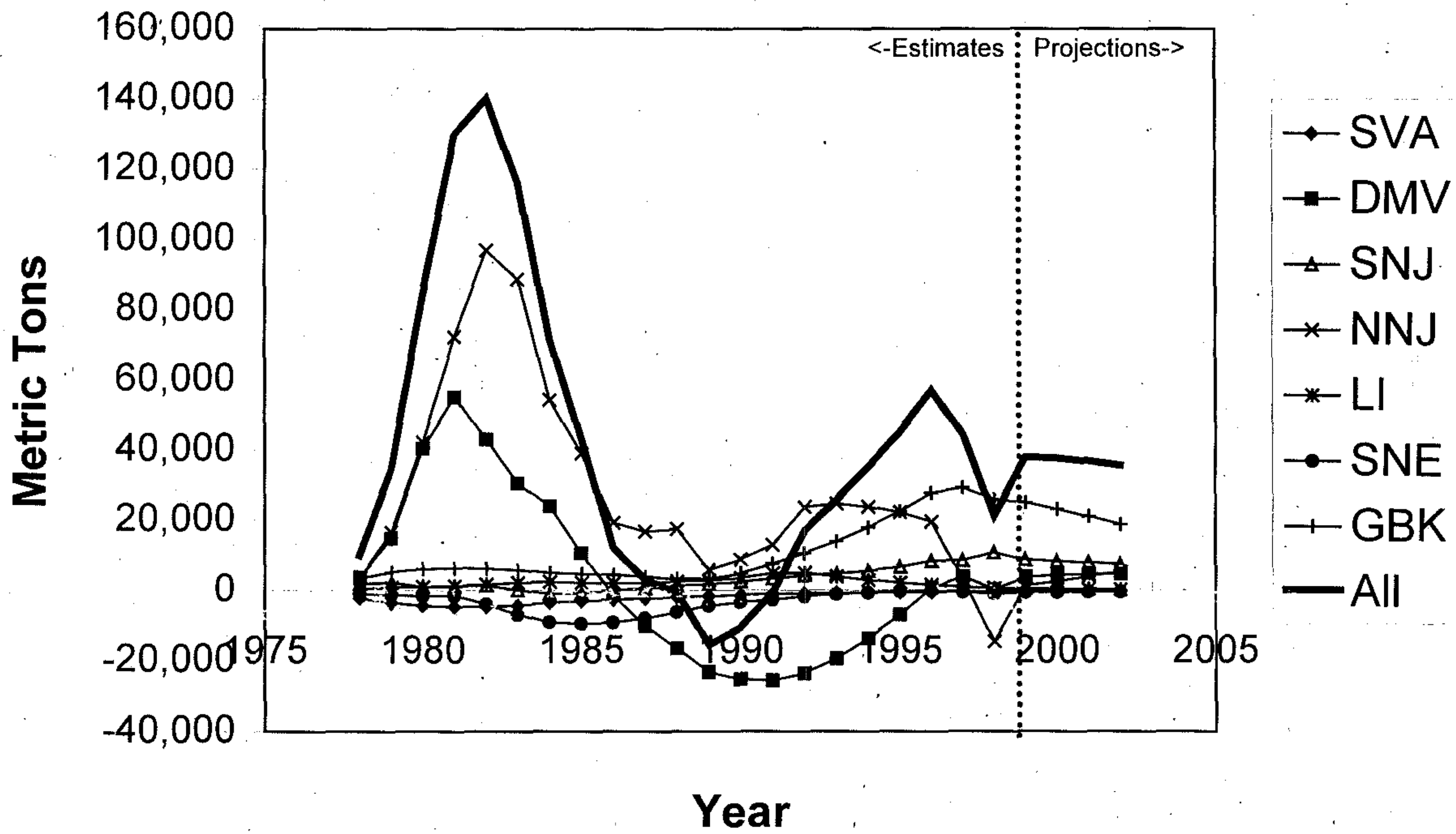


Figure E71. Cumulative Probabilities for Recent (1997-1999) Mean F on Surfclams

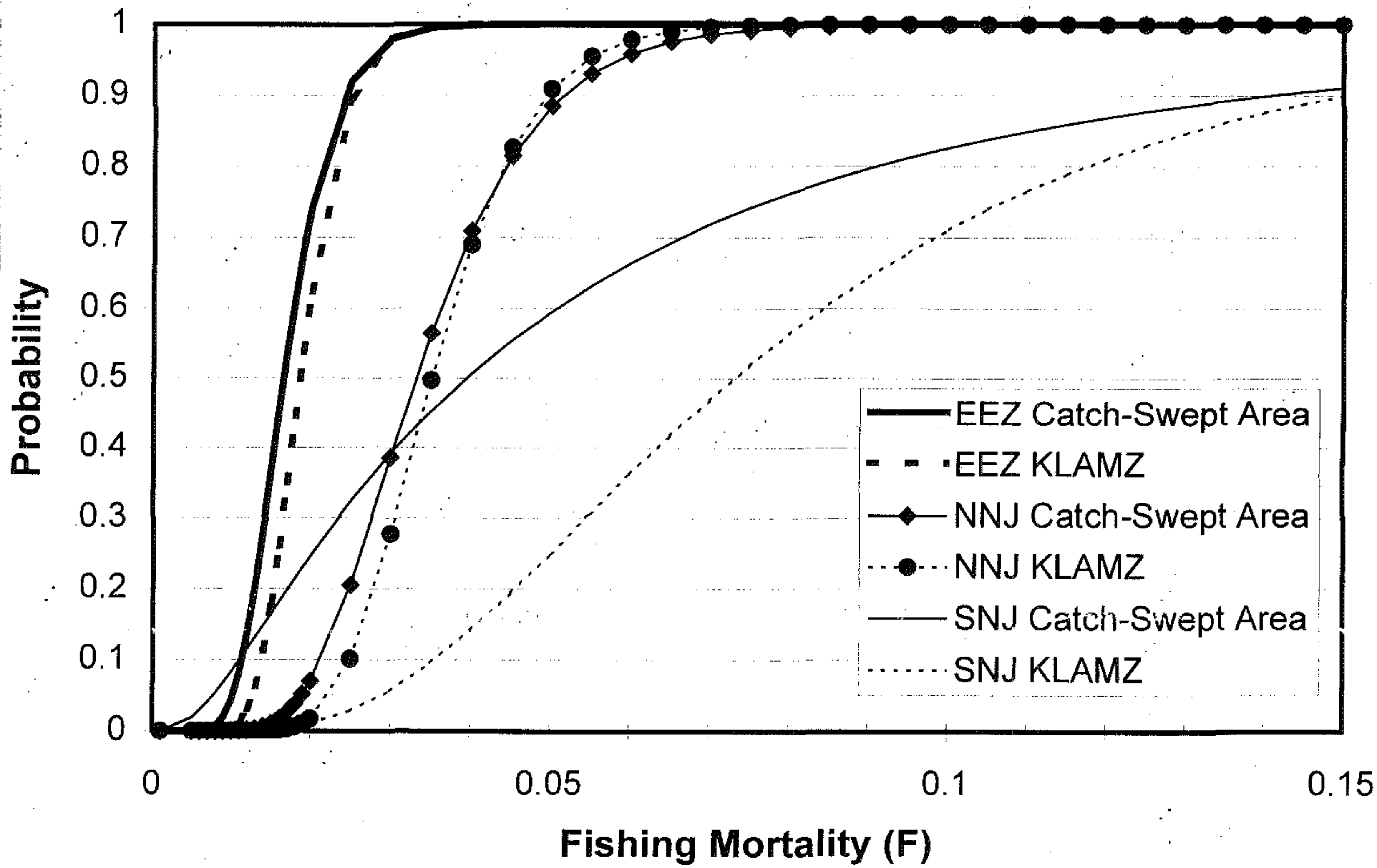


Figure E72. Default MSY Control Rule With $B_{Threshold} = B_{MSY}/2$

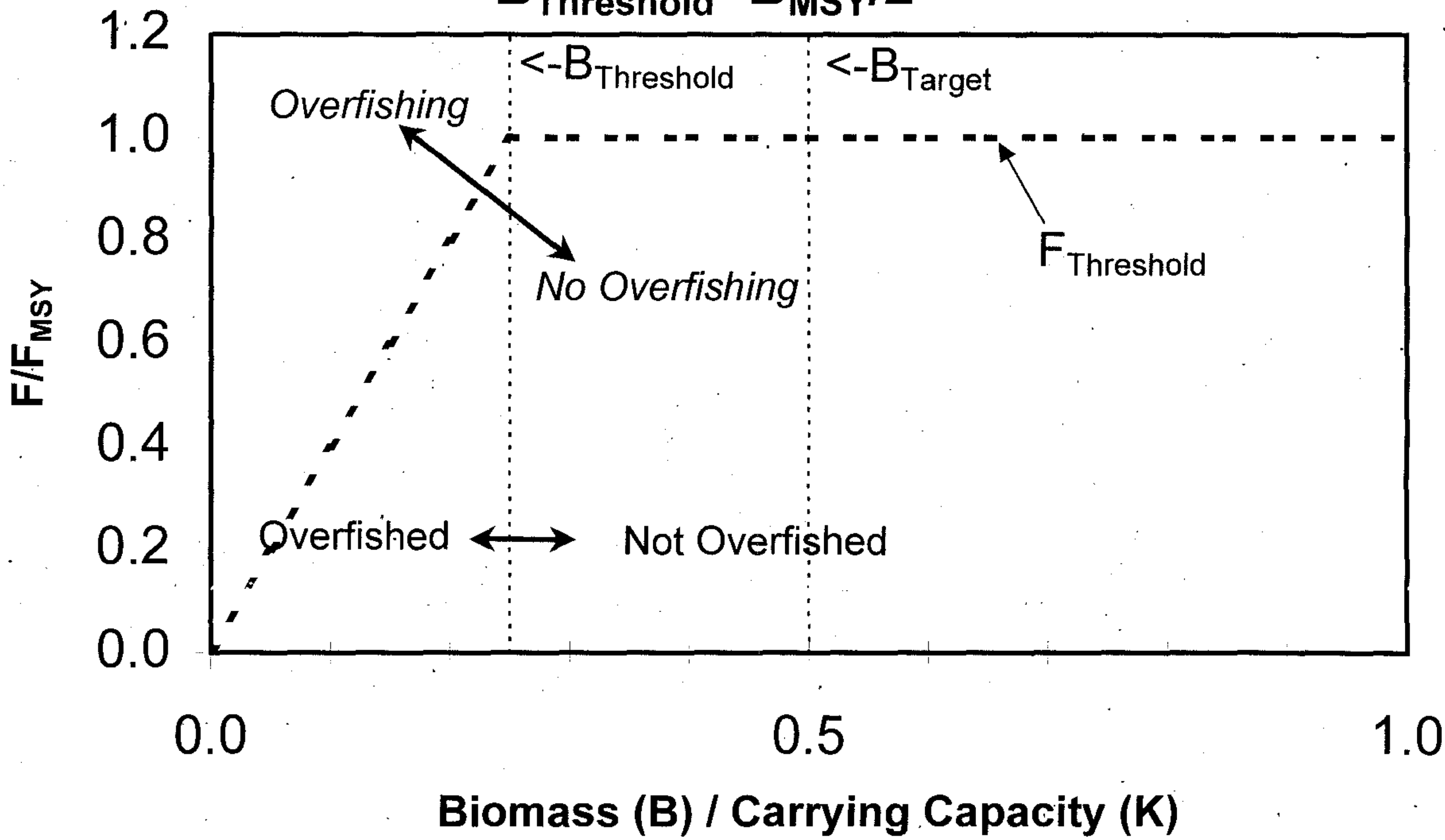


Figure E73. Rebuilding Time Isopleths and MSY Control Rules with $B_{Threshold}=B_{MSY}/2$ and $B_{MSY}/4$ ($F_{MSY}=0.15$)