Northeast Fisheries Science Center Reference Document 07-10

44th Northeast Regional
Stock Assessment Workshop (44th SAW)

44th SAW Stock Assessment Report

May 2007

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07-09 *The Analytic Component to the Standardized Bycatch Reporting Methodology Omnibus Amendment: Sampling Design, and Estimation of Precision and Accuracy (2nd Edition)*, by SE Wigley, PJ Rago, KA Sosebee, and DL Palka. May 2007.

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

May 2007

Northeast Fisheries Science Center Reference Documents

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The stock assessments which are the subject of this document were peer reviewed by a panel of assessment experts known as the Stock Assessment Review Committee (SARC). Panelists were provided by the Center for Independent Experts (CIE), University of Miami. Reports from the SARC panelists and a summary report from the SARC Chairman can be found at *http://www.nefsc.noaa.gov/nefsc/saw*.

Assessment Report (44th SAW/SARC)

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INTRODUCTION TO SAW-44 ASSESSMENT REPORT

The Northeast Regional Stock Assessment Workshop (SAW) process has three parts: preparation of stock assessments by the SAW Working Groups and/or by ASMFC Technical Committees / Assessment Committees; peer review of the assessments by a panel of outside experts who judge the adequacy of the assessment as a basis for providing scientific advice to managers; and a presentation of the results and reports to the Region's fishery management bodies.

Starting with SAW-39 (June 2004), the process was revised in two fundamental ways. First, the Stock Assessment Review Committee (SARC) is now a smaller panel with panelists provided by the University of Miami's Independent System for Peer Review (Center of Independent Experts, CIE). Second, the SARC no longer provides management advice. Instead, Council and Commission teams (e.g., Plan Development Teams, Monitoring and Technical Committees) formulate management advice, after an assessment has been accepted by the SARC.

Reports that are produced following SAW/SARC meetings include: an *Assessment Summary Report* – a brief summary of the assessment results in a format useful to managers; this *Assessment Report* – a detailed account of the assessments for each stock; and the SARC panelist report – a summary of the reviewer's opinions and recommendations as well as appendices consisting of a report from each panelist. SAW/SARC assessment reports are available online at http://www.nefsc.noaa.gov/nefsc/publications/series/crdlist.htm. The CIE review reports and assessment reports can be found at http://www.nefsc.noaa.gov/nefsc/saw/.

The 44th SARC was convened in Woods Hole at the Northeast Fisheries Science Center, November 28 – December 4, 2006 to review three assessments (ocean quahog *Arctica islandica,* the northeast skate species complex [barndoor skate, *Dipturus laevis*; clearnose skate, *Raja eglanteria*; little skate, *Leucoraja erinacea*; rosette skate, *Leucoraja garmani*; smooth skate, *Malacoraja senta*; thorny skate, *Amblyraja radiate*; winter skate, *Leucoraja ocellata*)], and Atlantic surfclam *Spisula solidissima*. CIE reviews for SARC44 were based on detailed reports produced by the SAW Southern Demersal and Invertebrate Working Groups.

This Introduction contains a brief summary of the SARC comments, a list of SARC panelists, the meeting agenda, a list of working group meetings and a list of attendees (Tables 1 – 4). Maps of the Atlantic coast of the USA and Canada are also provided (Figures 1 - 5).

Outcome of Stock Assessment Review Meeting

The ocean quahog assessment was accepted by the SARC. Current biomass appears well above the B_{msy} proxy and current F appears well below the F_{msy} proxy. The SARC was concerned with the biomass estimates from the main assessment model (KLAMZ) because the model did not link long-term average recruitment to virgin biomass. The reviewers also expressed concern about the accuracy and precision of the dredge efficiency estimate, the approach used to fill missing survey data cells, the appropriateness of proxies for B_{msy} and F_{msy}, and the management of the entire offshore stock as a single unit.

Assessment results for the seven skate species were only partially accepted. The SARC rejected the estimates of the fishing mortality rate (F) as well as the proposed new Biological Reference Points (BRPs). The SARC felt that the absence of species-specific landings data made it extremely difficult to estimate F, and that estimates derived from the new model were too unreliable to accept at this time. The SARC felt that the existing BRPs were ad hoc and in need of improvement. The SARC felt that the proposed BRPs, derived from stock-recruit fits and length-based yield per recruit analysis, represented a positive step. However, the Committee did not feel that sufficient work had been done on the new BRPs to justify their use at this time. Accordingly, the assessment evaluated stock status with respect to the existing BRPs, and these results were accepted by the SARC. No absolute estimates of total biomass or spawning stock biomass were made in the assessment. Finally, the SARC accepted work which examined the NEFSC Food Habits Database to estimate skate diets and skate consumptive demand in the ecosystem.

The Atlantic surfclam assessment was accepted by the SARC, although the Committee felt that the assessment could be improved by making better use of the available data on surfclam ages by developing a fully integrated age-structured model. Some of the concerns raised earlier about the ocean quahog assessment were also raised about the surfclam assessment. In addition, the Committee questioned whether the B_{msy} proxy (one half B_{1999}) was appropriate, and suggested that this issue be reconsidered in a future assessment.

Table 1. 44th Stock Assessment Review Committee Panel.

44th Northeast Regional Stock Assessment Workshop (SAW 44)
Stock Assessment Review Committee (SARC) Meeting

November 28 – December 4, 2006
Woods Hole MA

<u>SARC Chairman (CIE):</u>

Dr. Cynthia Jones, chair
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<u>SARC Panelists (CIE):</u>

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Email: haistv@shaw.ca

Mr. Patrick Cordue, review panelist
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Wellington 6035
New Zealand
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Email: plc@isl-solutions.co.nz

Table 2. Agenda, 44th Stock Assessment Review Committee Meeting.

44th Northeast Regional Stock Assessment Workshop (SAW 44)
Stock Assessment Review Committee (SARC) Meeting

Stephen H. Clark Conference Room – Northeast Fisheries Science Center
Woods Hole, Massachusetts

November 28 – December 4, 2006

AGENDA (11-27-06)

TOPIC	PRESENTER	SARC LEADER	RAPPORTEUR
Tuesday, 28 November (1:00 – 5:00 PM)……………………………………			
Opening			
Welcome	**James Weinberg**, SAW Chairman		
Introduction	**Cynthia Jones**, SARC Chairman		
Agenda			
Conduct of Meeting			
Ocean quahog (A)	**Larry Jacobson**	**Vivian Haist**	**Toni Chute**
SARC Discussion	**Cynthia Jones**		
Wednesday, 29 November (8:30 – Noon)……………………………………			
Skates (B)	**Kathy Sosebee**	**Patrick Cordue**	**Michelle Traver**
SARC Discussion	**Cynthia Jones**		
Wednesday, 29 November (1:15 – 5:00 PM)………………………………..……			
Atlantic surfclam (C)	**Larry Jacobson**	**Vivian Haist**	**Laurel Col**
SARC Discussion	**Cynthia Jones**		

Table 2 continued.

Thursday, 30 November (8:30 – 5:00 PM) ………………..……………………

Revisit Assessments (A – C) with presenters, as needed.

Friday, 1 December (8:30 AM –) ………………………………………………

Revisit Assessments (A – C) with presenters, if needed.

SARC Report writing. (closed)

Saturday, 2 December - Monday, 4 December ……….……………………………

SARC Report writing. (closed)

Table 3. 43rd Stock Assessment Workshop, list of working groups and meetings.

Assessment Group	Chair	Species	Meeting Date/Place
SAW Southern Demersal Working Group	Paul Rago, NMFS NEFSC	**Skate complex**	Oct. 24-26, 2006 Woods Hole

Sondre Aanes	Institute of Marine Research, Bergen, Norway
Larry Alade	NEFSC
Laurel Col	NEFSC
Mike Fogarty	NEFSC
Mike Frisk	SUNY, Stony Brook
Todd Gedamke	VIMS
Dvora Hart	NEFSC
Fiona Hogan	UMass/SMAST
Chris Legault	NEFSC
Jason Link	NEFSC
Alyssa MacDonald	UMass/SMAST
Ralph Mayo	NEFSC
Hassan Moustahfid	NEFSC
Paul Nitschke	NEFSC
Mike Pennington	Institute of Marine Research, Bergen, Norway
Anne Richards	NEFSC
Gary Shepherd	NEFSC
Brian Smith	NEFSC
Katherine Sosebee	NEFSC
Michele Traver	NEFSC
Megan Tyrrell	NEFSC
Susan Wigley	NEFSC

Table 3 continued.

Assessment Group	Chair	Species	Meeting Date/Place
Invertebrate Working Group			
	Ralph Mayo, NMFS NEFSC		
		Ocean quahog	March 20-21,2006 April 25-26, 2006 Aug. 7-9, 2006 Woods Hole

T. Alspach (Sea Watch International, Ltd.)
T. Chute (Northeast Fisheries Science Center, NEFSC)
S. Feindel (Darling Marine Center)
C. Heaton (Mid-Atlantic Fishery Management Council, MAFMC)
T. Hoff (MAFMC)
L. Jacobson (NEFSC) – assessment lead
C. Pickett (NEFSC)
E. Powell (Haskin Shellfish Laboratory, Rutgers University)
R. Russell (Maine Department of Marine Resources)
D. Wallace (Wallace & Associates, Inc.)
J. Womack (Wallace & Associates, Inc.)
J. Weinberg (NEFSC)
M. Bell (Invited external participant, Lowestoft, Suffolk, UK)

Assessment Group	Chair	Species	Meeting Date/Place
Invertebrate Working Group			
	M. Terceiro, NMFS NEFSC		
		Atl. Surfclam	Sept. 25-27,2006 Oct. 16-18, 2006 Oct. 30- Nov. 1, 2006 Woods Hole

T. Alspach (Sea Watch International, Ltd.)
A. Chute (NEFSC)
H. Dobby (Invited external participant, FRS Marine Laboratory, Aberdeen, Scotland)
C. Heaton (Mid-Atlantic Fishery Management Council, MAFMC)
J. Heifitz (Invited external participant, NMFS, AKFSC)
T. Hoff (MAFMC)
L. Jacobson (Northeast Fisheries Science Center, NEFSC) – assessment lead
C. Pickett (NEFSC)
E. Powell (Haskin Shellfish Laboratory, Rutgers University)
D. Wallace (Wallace & Associates, Inc.)
J. Womack (Wallace & Associates, Inc.)
J. Weinberg (NEFSC)

Table 4. 44th SAW/SARC, List of Attendees

J. Womack	Wallace and Assoc.
T. Hoff	MAFMC
P. Nitschke	NEFSC
C. Pickett	NEFSC
D. Wallace	Wallace and Assoc.
L. Col	NEFSC
M. Terceiro	NEFSC
L. Jacobson	NEFSC
A. Applegate	NEFMC
F. Hogan	UMass/SMAST
A. MacDonald	UMass/SMAST
J. Moser	NEFSC
A. Richards	NEFSC
M. Traver	NEFSC
D. Hart	NEFSC
R. Brown	NEFSC
G. Shepherd	NEFSC
T. Alspach	Sea Watch International
L. O'Brien	NEFSC

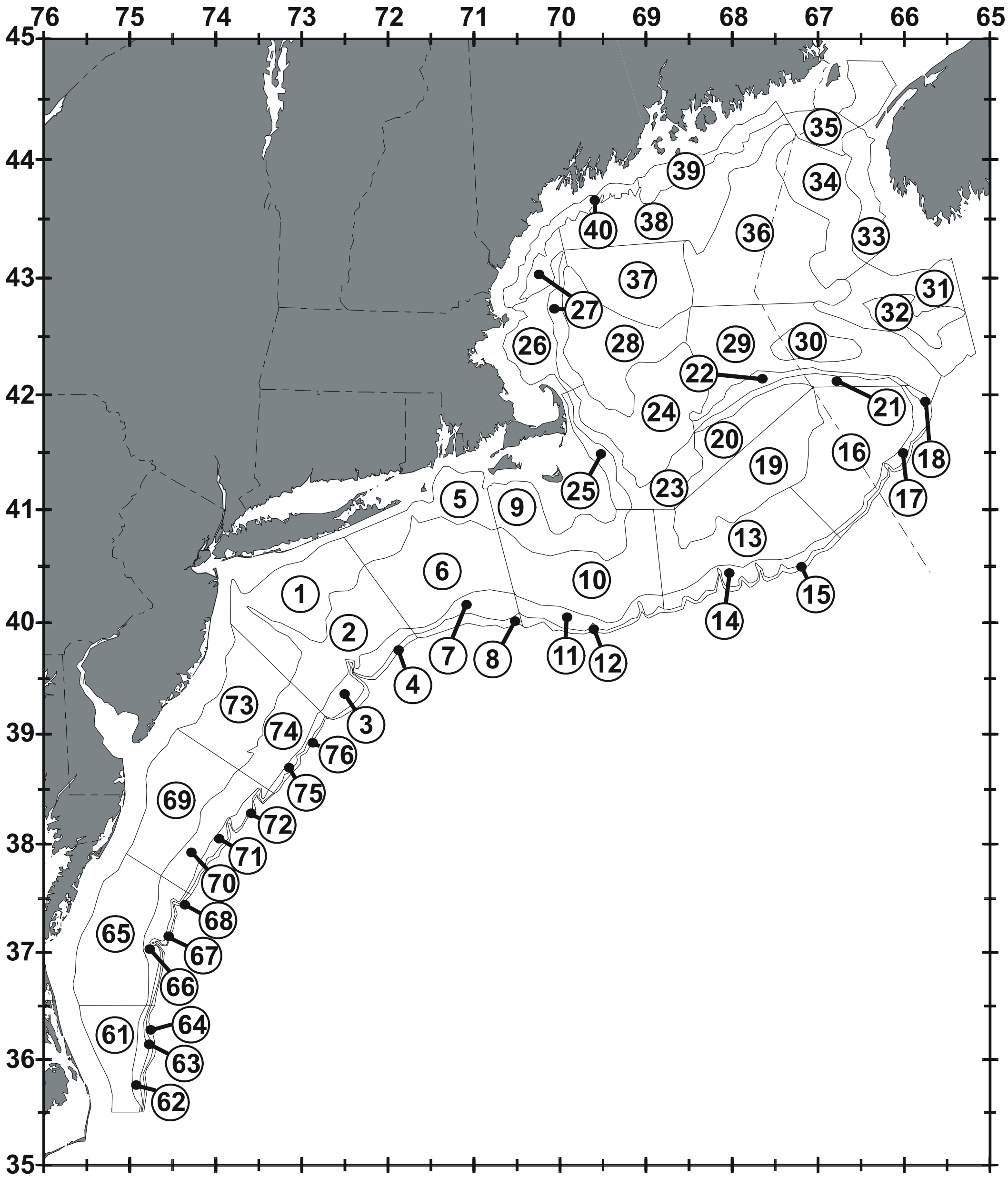

Figure 1. Offshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys.

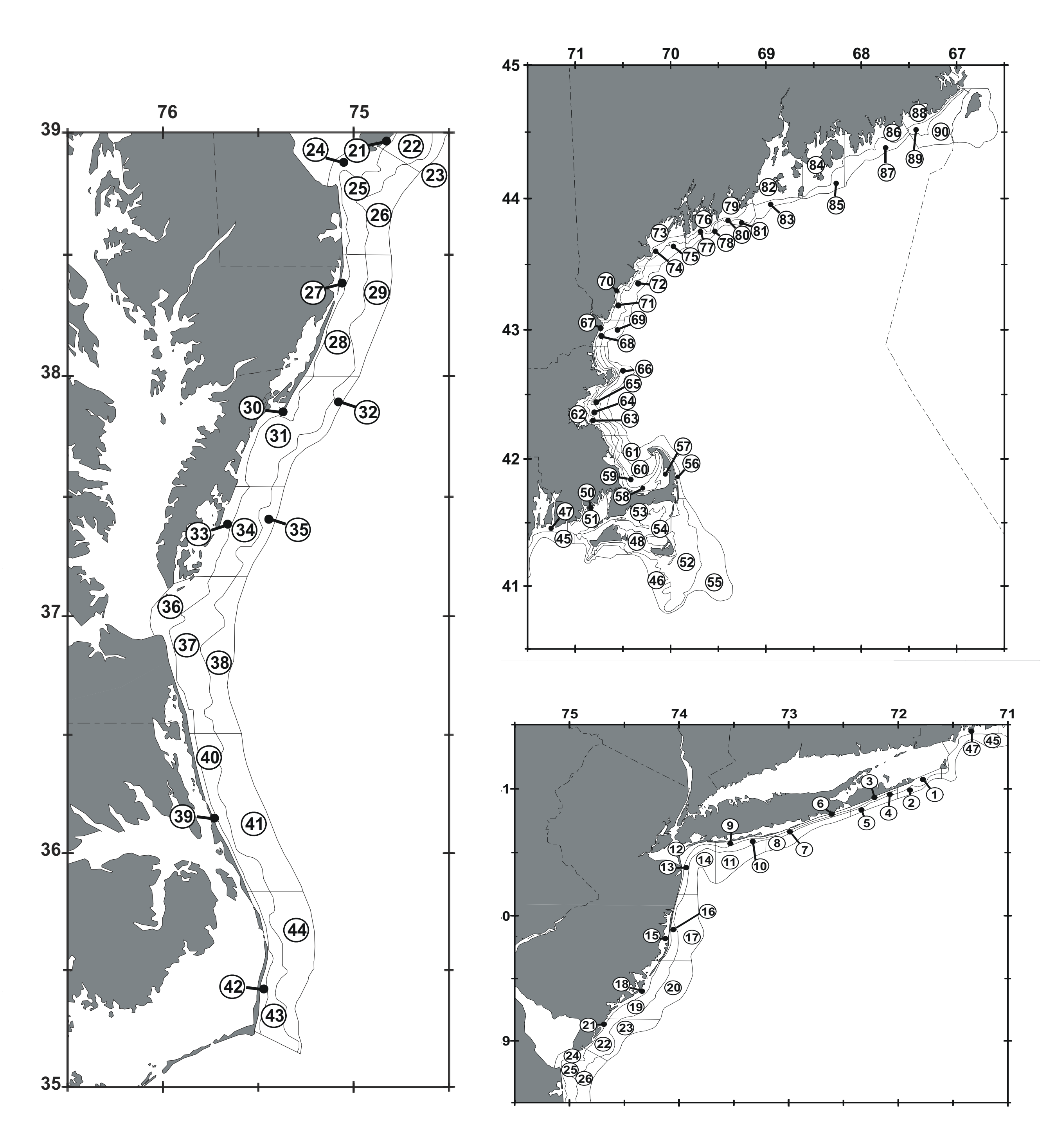

Figure 2. Inshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys.

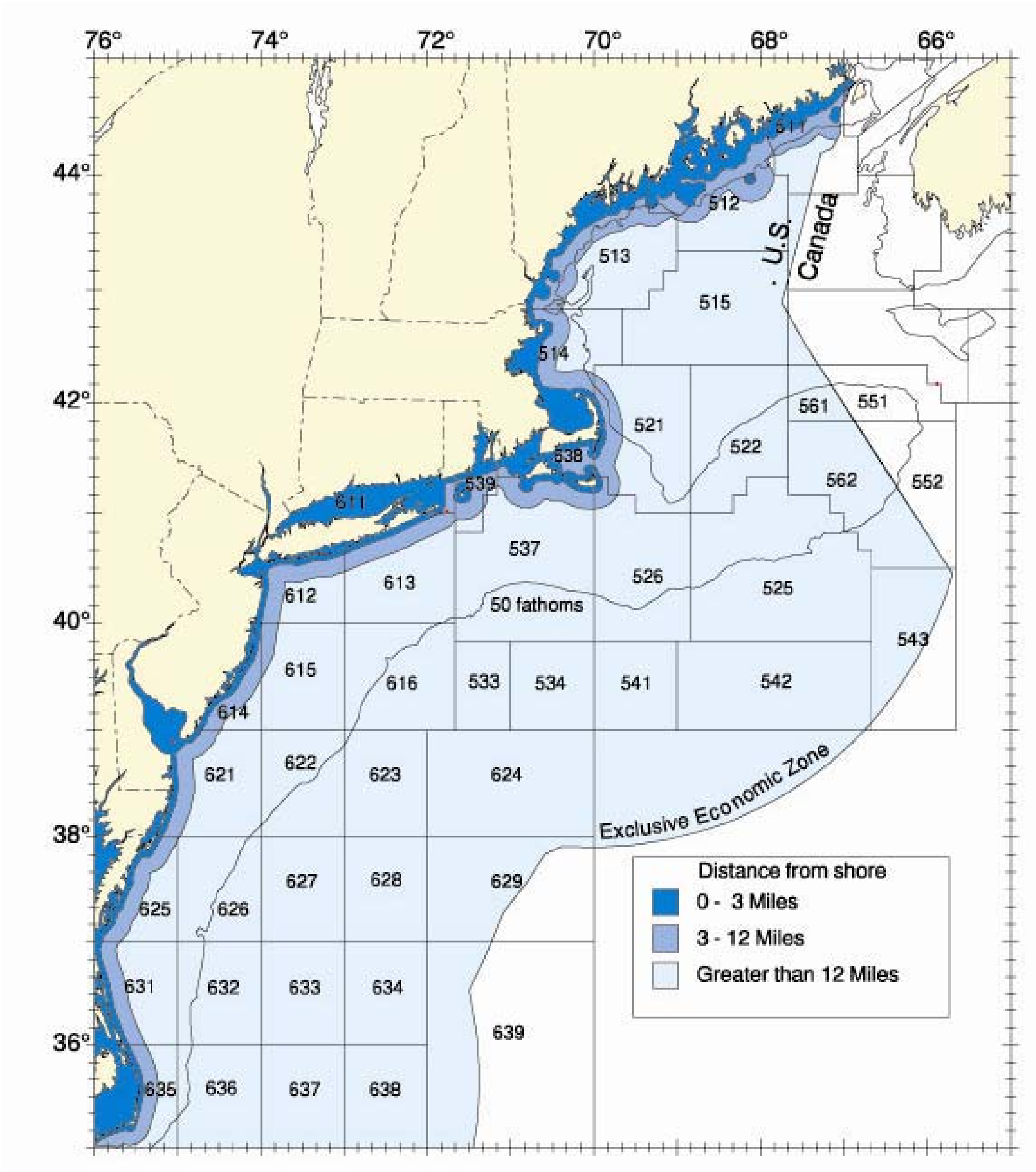

Figure 3. Statistical areas used for reporting commercial catches.

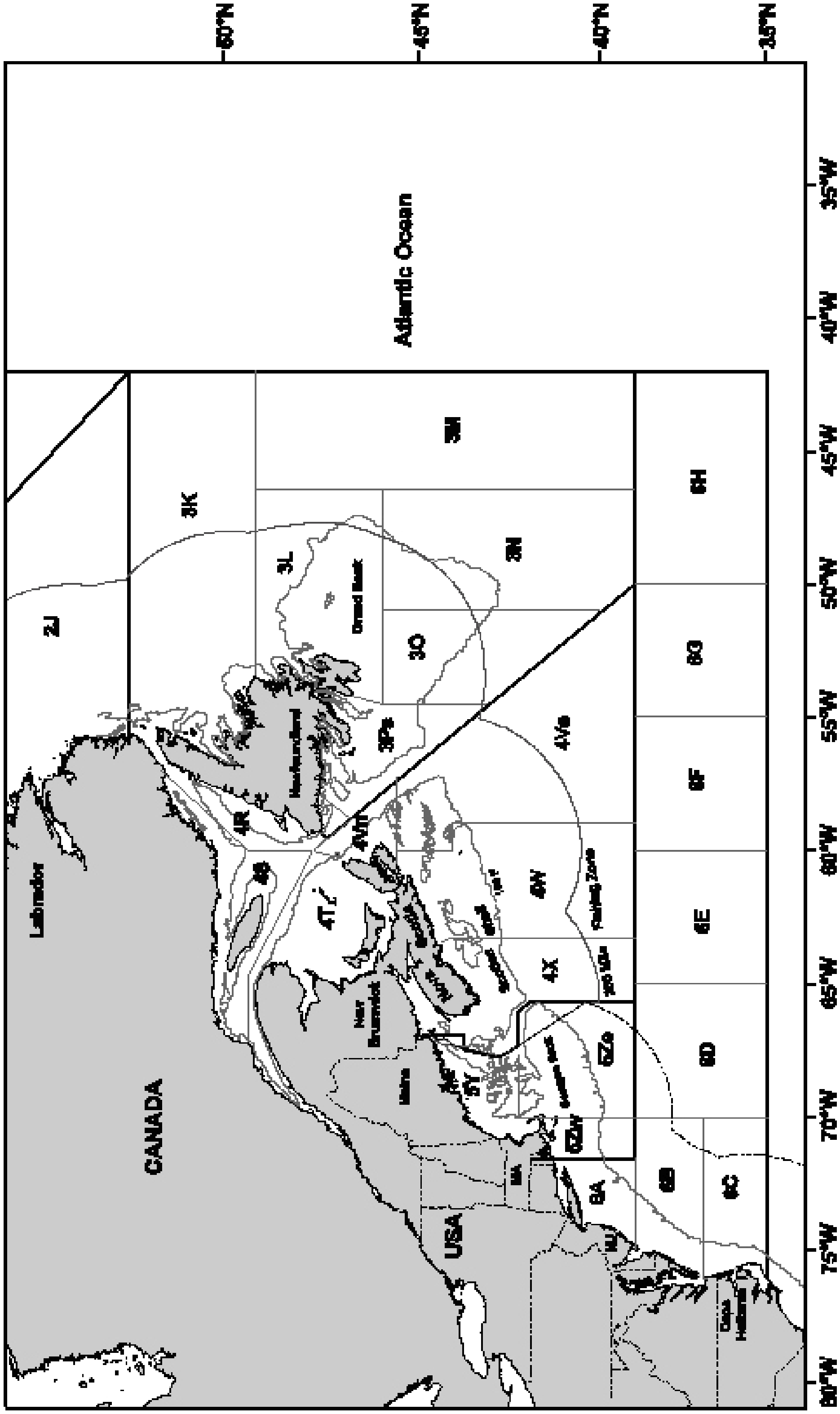

Figure 4. Catch reporting areas of the Northwest Atlantic Fisheries Organization (NAFO) for Subareas 3-6.

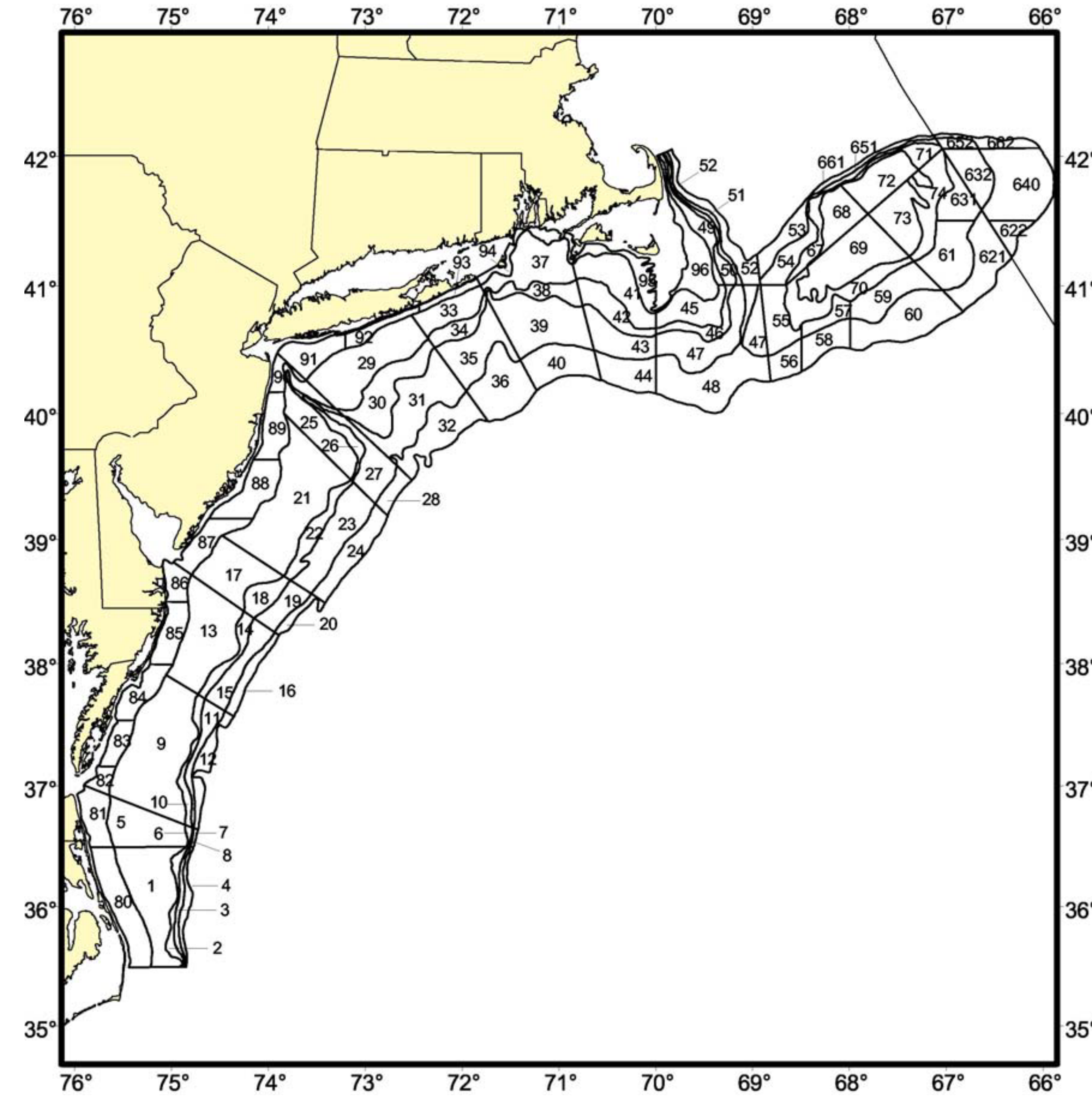

Figure 5. Clam strata for NEFSC resource surveys.

A. ASSESSMENT OF OCEAN QUAHOGS [1]

1.0 TERMS OF REFERENCE (TOR)

1. Characterize the commercial and recreational catch including landings and discards.

Completed--Commercial landings were updated through 2005. Discards are negligible. However, a 5% allowance for incidental mortality due to contact with fishing gear is used in all assessment calculations.

2. Estimate fishing mortality, spawning stock biomass, and total stock biomass for the current year and characterize the uncertainty of those estimates. If possible, also include estimates for earlier years.

Completed--Fishing mortality, fishable and total stock biomass were estimated for 1978-2005. Confidence intervals were calculated to characterize uncertainty. Spawning biomass was calculated on an approximate basis after the SARC based on reviewers' suggestions.

3. Either update or re-estimate biological reference points (BRPs; proxies for B_{MSY} and F_{MSY}), as appropriate. Comment on the scientific adequacy of existing and redefined BRPs.

Partially completed—Biomass reference points B_{1978} (a proxy for virgin biomass), the management target $B_{MSY}=1/2\ B_{1978}$ and the management threshold $B_{Threshold}=1/4\ B_{1978}$ were updated based on new information. Fishing mortality reference points ($F_{Target}=F_{0.1}$ and $F_{Threshold}=F_{25\%}$) were updated using new information about fishery selectivity and maturity in a length based per recruit model. Problems with the scientific adequacy of the current existing $F_{Threshold}$ proxy for F_{MSY} are described. However, there was insufficient time to complete analyses required to recommend an optimum alternative. This work was deferred because fishing mortality rates are very low and there was no urgency.

4. Evaluate current stock status with respect to the existing BRPs, as well as with respect to new or re-estimated BRPs (from TOR 3).

Completed—Stock biomass and fishing mortality estimates for 2005 were compared to updated reference points.

5. Recommend what modeling approaches and data should be used for conducting single and multi-year stock projections, and for computing TACs or TALs.

Completed—A simple modeling approach and data were recommended for projecting biomass and fishing mortality of the ocean quahog stock through 2010.

[1] This assessment was prepared by the Invertebrate Subcommittee. Contributing members are listed in INTRODUCTION TO SAW-44 ASSESSMENT REPORT.

6. If possible,

    a) provide numerical examples of short term projections (2-3 years) of biomass and fishing mortality rate, and characterize their uncertainty, under various TAC/F strategies and

    b) compare projected stock status to existing rebuilding schedules as appropriate.

Completed—Example calculations and projections through 2010 were carried out assuming three quota levels and at $F=F_{0.1}$.

7. Review, evaluate and report on the status of the SARC/Working Group Research Recommendations offered in recent SARC-reviewed assessments.

Completed—Several key research recommendations were accomplished in this assessment. In particular: 1) a survey was completed, reference points were calculated and biomass and fishing mortality were estimated for ocean quahog in Maine waters; 2) field data collected during 2002 and new data collected during 2005 were examined to determine if survey and commercial dredge efficiency depends on depth, sediment type or clam density; 3) survey selectivity and fishery selectivity curves were used to better interpret survey data; and 4) reference points were revised in this assessment using a new length based model and new fishery selectivity and maturity at length curves.

2.0 EXECUTIVE SUMMARY

A) This assessment for ocean quahog in the US EEZ is based on fishery data landings and LPUE data for 1978-2005 and NEFSC survey data for 1982-2005. Based on assessment results, the ocean quahog population is a relatively unproductive stock which is being fished down slowly towards its B_{MSY} reference point (½ virgin biomass, estimated as 50% of biomass during 1978) gradually after about three decades of relatively low fishing mortality.

B) Ocean quahog in the US EEZ are not overfished and overfishing is not occurring. Stock biomass during 2005 was 3.039 million mt and above the revised management target of ½ virgin biomass = 1.987 million mt. The fishing mortality rate during 2005 for the exploitable region (all areas but GBK) was F= 0.0077 y^{-1} and below the revised management target level $F_{0.1}$ = 0.0278 y^{-1}.

C) Depletion experiments carried out during 1997-2005 on a cooperative basis with the fishing industry were used to estimate the efficiency of the NEFSC survey dredge, which is the basis for estimating biomass and fishing mortality. Based on all experiments to date, the NEFSC survey dredge has a capture efficiency of 16.5%, which is less than values used in the earlier assessments (e = 0.269 in SARC38, and 0.346 in SARC31).

D) Biomass and fishing mortality estimates were improved in this assessment using new information about size selectivity of survey and commercial clam dredges.

E) The estimates of biomass and fishing mortality in this assessment do not include biomass or landings from Maine waters. However, stock biomass is small (~1%) relative to the rest of the EEZ and calculations would not change appreciably if Maine were included. As described below, the Maine fishery and stock component were assessed separately (Russell 2006). Highlights from the Maine assessment are presented here but interested persons should consult the Maine stock assessment report.

F) Biological reference points based on per recruit models ($F_{0.1}$ and $F_{25\%}$) were recalculated based on new length based per recruit model, and new fishery selectivity and maturity curves (see below).

Reference Point	Old (SARC-38)	New
$F_{0.1}$ (target)	0.0275	0.0278
F_{MAX}	0.1810	0.0760
$F_{25\%}$ (threshold)	0.0800	0.0517
$F_{50\%}$	0.0200	0.0180

G) From a technical perspective, the current threshold reference point for fishing mortality $F_{25\%}$=0.0517 y^{-1} is a poor proxy for F_{MSY} in a long-lived species like ocean quahog with natural mortality rate M=0.02 y^{-1}.

H) Proxies for virgin biomass and B_{MSY} in this assessment are substantially larger than in NEFSC (2003). In particular, the revised proxy in this assessment for B_{MSY} (½ virgin biomass) was 1.987 million mt compared to 1.5 million mt for B_{MSY} in the last assessment. The new estimates are different primarily because revised survey dredge efficiency estimates are smaller (e=0.165 instead of 0.269-0.346).

I) Biomass during 2005 was 76% of biomass during 1978 for the entire stock and 66% for the entire stock less GBK

J) Fishery LPUE, survey trends and assessment model estimates show substantial declines in stock biomass in southern regions (SVA, DMV and NJ) where the fishery has been continually active. In particular, biomass during 2005 was 5%, 34% and 44% of biomass during 1978 for SVA, DMV and NJ. Biomass trends in northern regions which did not support the fishery until recently (LI, SNE and GBK) are relatively flat and stable. Biomass during 2005 was 94%, 75% and 100% of biomass during 1978 for LI, SNE and GBK.

K) An increasingly large fraction of the stock (83% during 2005 compared to 70% during 1978) is in northern regions (LI, SNE) where fishing is relatively recent and in the GBK region, which is not fished due to risk of PSP contamination.

L) Fishing mortality rates for southern areas where the fishery has been continually active (SVA, DMV and NJ) peaked in the late 1980's and early 1990's then declined as fishing effort shifted towards the north. Fishing mortality rates in northern areas were nearly zero before 1990 and increased substantially afterwards as fishing effort shifted towards the north. Fishing mortality rates for the entire stock increased from near zero in 1978 to average about 0.006 y^{-1} (0.010 y^{-1} for the entire stock less GBK) during early 1990 through 2005.

M) Recruitment events appear to be regional and sporadic (i.e. often separated by decades). Survey length composition data show that recruitment occurs throughout the resource sporadically and at an apparently low rate. Based on survey length composition data and published studies, at least some recent recruitment (small ocean quahog) is evident in DMV, NJ, LI, SNE and GBK during recent years. The potential contribution of recent recruitment to stock biomass and productivity is unknown.

Maine waters

N) Ocean quahog in Maine waters are part of the unit stock covered by the FMP and support a small fishery that is managed under limited entry and quota systems that are separate from the individual transferable quota (ITQ) system used for ocean quahog in the rest of the EEZ.

O) The fishery and biological characteristics of ocean quahog in Maine waters are unique. In particular, the Maine fishery targets small ocean quahog for sale on the half shell market at prices roughly ten times the prices paid for larger ocean quahogs taken elsewhere in the EEZ. Management goals have for ocean quahog in Maine waters have not been described.

P) A survey and stock assessment were completed by the State of Maine for the portion of the ocean quahog stock occupying the major fishing grounds in Maine waters (Russell 2006). Most of the results presented here for the Maine fishery are from Russell (2006).

Q) Assessment results for Maine show relatively high levels of fishing effort and landings in recent years. LPUE levels have declined since the peak in 2002, but remain at relatively high levels overall.

R) Based on a per recruit model analysis, $F_{MAX} = 0.0561$, $F_{0.1} = 0.0247$ and $F_{50\%} = 0.013$ y^{-1} for ocean quahog in the major fishing grounds of Maine waters only. These reference points are provided only for comparison and do not have any special status as targets or thresholds.

S) Based on survey results and dredge efficiency estimates for Maine, the biomass of ocean quahog during 2005 that was available to the fishery in Maine waters was

22,493 mt meats. In comparison, catch (landings plus a 5% incidental mortality allowance) during 2005 was 505 mt meats.

T) Fishing mortality during 2005 in the areas surveyed and the principal fishing grounds in Maine waters was estimated to be $F = 505 \div 22{,}493 = 0.022\ y^{-1}$, which is almost equal to $F_{0.1} = 0.0247\ y^{-1}$, a reference point that would provide relatively high levels of yield while preserving some spawning stock.

3.0 INTRODUCTION

Ocean quahog (*Arctica islandica*) in the US Exclusive Economic Zone (EEZ) form a single stock for management purposes. With the exception of a relatively small component off the coast of Maine, the EEZ fishery is managed by under a single individual transferable quota (ITQ) system that was established for ocean quahog and Atlantic surfclam (*Spisula sodidissma*) in 1990. Murawski and Serchuk (1989) and Serchuk and Murawski (1997) provide detailed information about the history and operation of the fishery.

The ocean quahog fishery component off Maine is managed under a relatively small quota that is separate from the quota used to manage the ITQ fishery. The Maine component is of interest because of differences in biological, fishery, market and management characteristics. The ocean quahog assessment this year consists of two reports. The first (Russell 2006) estimates biomass, fishing mortality and per recruit reference points for the stock component in Maine waters based on a survey in 2005 and estimates of survey dredge efficiency. The second (this report) deals with the EEZ as a whole based on the NEFSC clam survey for 1982-2005 and summarized key aspects of the assessment for Maine waters.

Overfishing definitions and other management measures apply at the level of the entire stock although technical information is provided at the level of smaller stock assessment regions (Figure A1 and see below). Georges Bank (GBK) has been closed to ocean quahog harvesting since 1990 when Paralytic Shellfish Poison (PSP) was detected.

Stock Assessment Region	Abbreviation
Maine	MNE
Georges Bank	GBK
Southern New England	SNE
Long Island	LI
New Jersey	NJ
Delmarva	DMV
Southern Virginia and North Carolina	SVA

Categories and units used in this assessment are defined below.

Unit	Equivalent
Industry or Mid-Atlantic bushel (Industry bu)	1.88 ft^3
Maine (US standard) bushel (Maine bu)	1.2448 ft^3
Industry bushels x 10	Pounds meat wt
Industry bushels x 4.5359	Kilograms meat wt
Cage	32 Industry bushels
Vessel ton class 1	1-4 gross registered tons (GRT)
Vessel ton class 2	2-50 GRT
Vessel ton class 3	51-150 GRT
Vessel ton class 4	151-500 GRT
Vessel ton class 5	501-1000 GRT

Previous and current assessments

Stock assessments for ocean quahog in the EEZ were completed by NEFSC (1995; 1998; 2000; 2004). The last assessment (NEFSC 2004) concluded that the EEZ ocean quahog resource was not overfished and that overfishing was not occurring. This stock assessment arrives at the same conclusion.

The last assessment (NEFSC 2004) concluded that the qualitative condition of the stock off the coast of Maine was unknown and recommended that the Maine conduct a comprehensive survey and conduct experiments to estimate survey dredge efficiency. These recommendations were completed in this assessment and are presented in a separate report (Russell 2006).

Biological characteristics[2]

Ocean quahog are common around Iceland, in the eastern Atlantic as far south as Spain, and in the western Atlantic as far south as Cape Hatteras (Theroux and Wigley 1983; Thorarinsdottir and Einarsson 1996; Lewis et al. 2001). They are found at depths of 10-400 m, depending on latitude (Theroux and Wigley 1983; Thompson et al. 1980). The US stock is almost completely within the EEZ outside of state waters at depths of about 20-80 m. In a study of the mitochondrial cytochrome *b* gene, Dahlgren et al. (2000) did not find geographical differentiation between samples taken along the US coast from Maine to Virginia.

Ocean quahog are long-lived with some individuals aged at over 200 yrs (Jones 1983; Steingrimsson and Thorarinsdottir, 1995). Early studies of populations off New Jersey and Long Island (Thompson et al. 1980; Murawski et al. 1982) demonstrate that clams ranging in age from 50-100 years are common. In stock assessment work, adult ocean quahog are assumed to die from natural causes at the rate of about 2% annually (instantaneous rate of natural mortality M=0.02 y^{-1}).

Ocean quahog grow slowly after the first years of life (Lewis et al. 2001, Figure A56). Maximum size is typically about 110 mm in shell length (SL) although larger specimens are common. Individuals large enough to recruit to the fishery grow only 0.51-0.77% per year in meat weight and < 1 mm per year in shell length (NEFSC 2004).

Size and age at maturity are variable. Off Long Island, the smallest mature quahog found was a male 36 mm long and 6 years old; the smallest and youngest mature female was 41 mm long and 6 yr old (Ropes et al. 1984). Some clams in this region are still sexually immature at ages of 8-14 years (Thompson et al. 1980; Ropes et al. 1984).

[2] See Cargnelli et al. (1999) for additional information.

Females are more common than males among the oldest and largest individuals in the population (Ropes et al. 1984; Fritz 1991). Recruitment events are regional and infrequent in ocean quahog with decadal periods of little or no recruitment (Powell and Mann 2005).

4.0 COMMERCIAL AND RECREATIONAL CATCH (TOR-1)

Landings and quotas for the ITQ segment of the EEZ fishery are reported in different bushel units than landings and quotas for the fishery off Maine (Russell 2006). In particular, "ITQ" bushels are used for the ITQ component and "standard" bushels are used for the Maine component. Biomass and landings from both fishery components are reported in this assessment as meat weights (the weight of marketable product after removal from the shell), unless otherwise noted, because meat weights are directly comparable.

Total EEZ landings (including the ITQ and Maine fishery components) were relatively high during 1987-1996 with a peak of 22.5 thousand mt meats (Tables A1-A2 and Figure A2) or 4.9 million ITQ bushels (Table A3) during 1992. After 1996, landings declined to a low of about 15,000 mt meats (3.3 million ITQ bushels) during 2000 and then increased to about 19,000 mt meats (4.2 million ITQ bushels) during 2003. Landings declined after 2003 to about 14,000 mt meats (3.2 million ITQ bushels) during 2005, which was the lowest level since 1981. Industry sources report that low landings during the most recent years were due to low market demand. The ITQ component accounted for almost all (≥98%) of total EEZ landings during 1990-2005. Landings from Maine waters are minor in comparison to EEZ landings (Tables A2-A3 and Figure A2).

Landings from Maine waters increased steadily after 1990 to relatively high levels (≥ 326 thousand mt meats annually) during 2000-2003 (Tables A2-A3). Landings in Maine waters decreased after 2003 to 294 thousand mt meats during 2005, which was the lowest level since 1999.

Landings by the ITQ component averaged 85% of the EEZ quota during 1990-2005 (Table A1). In contrast, the 100,000 Maine bushel quota allocated for ocean quahog in Maine waters was usually exhausted during 1999-2005 with vessels leasing ITQ shares in some years to harvest more than 100,000 mt meats from Maine waters (Tables A2-A3).

Landings of quahogs from state waters outside of Maine are near zero because ocean quahog are found offshore in relatively deep water. Landings in recreational fisheries are nil because commercial clam dredges are required to harvest ocean quahog and because ocean quahog are an industrial product with no recreational value.

4.1 Prices

Nominal exvessel prices for ITQ ocean quahog landings (expressed as dollars per ITQ bushel) decreased slightly during 2001-2004 (Table A4 and Figure A3). In real terms, prices during 2004 were about the average of real prices during 1994-2004. Prices for ocean quahog harvested in Maine waters (dollars per ITQ bushel) were roughly ten times higher than prices for ocean quahogs harvested in the rest of the EEZ (Table A4 and Figure A3).

4.2 Fishing effort

Total hours fished annually in the ITQ fishery component decreased from a peak of about 40,000 hr y^{-1} during 1991-1994 to about 30,000 hr y^{-1} during 1996-2004 and then decreased to about 20,000 hr y^{-1} during 2005 (Table A5 and Figure A4). The total number of trips in the ITQ fishery decreased steadily from about 3000 trip y^{-1} during 1991 to about 1000 trips y^{-1} during 2005 (Figure A5). In contrast, hours fished and trips increased in the Maine fishery component during 1991-2005. The number of active permits (vessels with landings) remained relatively constant during 1996-2004 but declined slightly during 2005 (Figure A6). Number of active permits, and fishing effort (hours fished and numbers of trips) is high in Maine waters relative to other stock assessment regions in the EEZ (Figure A4-A6).

4.3 Landings per unit effort (LPUE)

It is useful express trends in LPUE in terms of average catch rates for an actual vessel because industry sources report that fishing in the ITQ sector is profitable when LPUE is at least 110-120 bushels h^{-1} (D. Wallace, pers. comm.). The break-even LPUE reported in the last was assessment 80 bushels h^{-1} (NEFSC 2004). The new estimate is higher because of inflation, increased steaming time to relatively distant fishing grounds, operation of new larger vessels, and increased costs for food, fuel, insurance, etc. These estimates are not applicable to fishing in Maine waters.

LPUE (LPUE, bushels landed per hour fished) in the ocean quahog fishery may be a better measure of fishing success than a measure of stock abundance because changes in abundance or biomass for regions as a whole may be masked by concentration and movement of fishing effort between regions where ocean quahog density and catch rates are high (see below). In spite of these potential problems, LPUE and NEFSC clam survey data are highly correlated (see Section 5).

Trends in LPUE were not sensitive to the details of calculation (Table A6 and Figure A7). Three measures of LPUE were calculated for each stock assessment region based on vessel size classes 3-4 for the ITQ fishery and vessel size classes 1-2 for the Maine fishery. The size classes used in calculating LPUE accounted for almost all landings. “Nominal mean LPUE” was the average catch rates for individual trips in each region and year. “Total bushels/total hours” was the ratio of total landings and total hours fished. The “standardized index” for each region was calculated from the year effects estimated in a general linear model (described below).

General linear models (GLM) used to standardize LPUE data for ocean quahog were fit to trip-level log book data. A separate model was run for each stock assessment region because trends differed among regions. The dependent variable in GLM models was log LPUE (ITQ or Maine bushels per hour fished). There was no need to add a constant before taking logs because catch was greater than zero for all trips. The models included categorical year, month and vessel effects, which were statistically significant in every case. Other factors might have been included in GLM models but vessels and months were of special interest and other model formulations gave very similar trends in standardized LPUE.

The time series of standardized LPUE for each region was computed from the back-transformed year effects with adjustments so that the indices for each area were in units of LPUE for a single vessel that fished in each of the DMV, NJ, LI and SNE stock assessment regions. A different vessel was chosen for MNE.

GLM results show that standardized LPUE during 1985 declined in the DMV, NJ and LI stock assessment regions and fluctuated without trend in the SNE region (Table A6 and Figure A8). In the Maine fishery, standardized LPUE increased during 1991-2000, decreased afterwards but was still relatively high during 2005. Differences in trends among regions are discussed in detail below.

GLM results show that LPUE is slightly higher in the DMV, NJ, LI and SNE regions during February-April (Figure A9). LPUE in the Maine fishery peaks in June.

4.4 Spatial patterns in fishery data

Spatial patterns are important in interpreting fishery data and in managing fisheries for sessile and relatively unproductive organisms like ocean quahog. The ocean quahog stock is a complicated spatial mosaic with scattered productive and profitable fishing grounds where abundance is high and where fishing mortality tends to be concentrated. The size of productive fishing grounds for ocean quahog appears to be less than the size of ten minute squares (TNMS, 10' x 10' $\cong$ 100 nm^2), which are the smallest spatial strata consistently reported on logbooks and used in this stock assessment.

As described in NEFSC (2004), spatial patterns in cumulative landings, cumulative effort and LPUE are related. The spatial distribution of landings and fishing effort in the ITQ fishery component changed markedly over time. During the 1980s, nearly all of the landings (Figure A2) and fishing effort (Figure A4-A5) were from the southern DMV and NJ stock assessment regions. As LPUE declined in the southern DMV and NH stock assessment regions (Figure A8), fishing effort and landings shifted offshore and north to the LI and SNE stock assessment regions. During 2005, in particular, the southern DMV and NJ stock assessment regions accounted for less than 20% of landings and fishing effort while the bulk of landings and effort (outside of Maine waters) were from LI (Figures A2 and A4-A6).

<u>Fishery data by ten-minute square (TNMS)</u>

All vessels that fish for ocean quahog in the EEZ use logbooks to report landings and fishing effort by TNMS for each trip. TNMS are identified by six digit numbers. For example, TNMS 436523 is a ten-minute square that lies within the one-degree square with southeast corner at 43^o N and 65^o E. TNMS are formed by dividing one-degree squares further into six columns and six rows that are 10' wide. Columns are numbered 1-6 counting from west to east and the column number is given in the TNMS name before the row number. Rows are numbered 1-6 counting from north to south. Thus, TNMS 436523 is the ten-minute square whose southeast corner is at 43^o 30' N and 65^o 40' E.

Landings (Figure A10) during 1980-1990 were concentrated in relatively few TNMS that were primarily in the south and relatively inshore. Over time, TNMS with highest landings shifted offshore and north. Landings during 2001-2005 were concentrated in the LI stock assessment region.

Fishing effort (Figure A11) was concentrated in a few southern TNMS during 1980-1990 with three adjacent TNMS having effort levels higher than 1,000 h y^{-1} and appreciable fishing effort south of 38^o N. Fishing effort spread into additional offshore and northern TNMS during 1991-1995 and 1996-2000. After 1995, there were few or no TNMS with effort levels above 1000 h y^{-1}. During 2001-2005, there was a no fishing effort south of 38^o N.

LPUE (Figure A12) was relatively high inshore and south during 1980-1990 with ten TNMS that had LPUE ≥ 161 ITQ bushels h^{-1}. LPUE in the area below 40^o S was generally high. LPUE declined in the south and fishing effort spread northward during 1991-1995 where LPUE was relatively high. During 1996-2000, LPUE declined in both the northern and southern areas. By 2001-2005, LPUE was often ≤ 80 ITQ bushels h^{-1} below 40^o S.

Trends

Trends in landings and LPUE during 1980-2005 were plotted for individual TNMS that were important in the fishery (Figures A13-A15). Important TNMS were selected by sorting TNMS according to total landings during 1980-1990, 1991-1995, 1996-2000 and 2001-2005 and then selecting the top 20 TNMS during each time period. All of the TNMS selected in this manner were combined to form a single unique set of 79 TNMS that were important to the fishery at some time during 1980-2005.

Trends in LPUE for individual TNMS tend to be relatively high in during the first years of exploitation and then to subsequently decline as effort, annual landings and cumulative landings increase over time (Figures A13-A15). Decreasing trends in LPUE appear strongest in southern areas such as TNMS 377422 to 397326 with the longest history of exploitation. LPUE does not appear to increase in a TNMS once fishing effort decreases.

Unlike LPUE which is highest in the first years of exploitation, landings and fishing effort tend to peak after 5-10 years of exploitation while LPUE is still relatively high and then to decrease over a 5-10 y period as grounds are fished down (Figures A13-A15). In some TNMS with low recent LPUE levels (e.g. TNMS 387443-397316), fishing effort increased during 2001-2005 with some increase in landings.

4.5 Bycatch and discard

Landings and catch are almost equal in the ocean quahog fishery because discards are nil. Discard of ocean quahog in the ocean quahog fishery does not occur because undersize animals are automatically released by automatic sorting equipment. However, some incidental mortality occurs. Based on Murawski and Serchuk (1989), NEFSC (2004) assumed incidental mortality rates of ≤ 5% for ocean quahog damaged during fishing but not handled on deck. As in previous assessments, fishing mortality and other stock assessment calculations in this report assume 5% incidental mortality rates (i.e. landings x 1.05 = assumed catch).

Bycatch of ocean quahog probably occurs in fishing for Atlantic surfclam but has not been quantified and is certainly minor. Off DMV and SVA in the southern end of the ocean quahog's range, survey catches including both surfclam and ocean quahog have become more common in recent years as surfclam have shifted towards deeper water in response to warm water conditions (Weinberg et al. 2005). However, mixed loads of surfclam and ocean quahog are not acceptable to processors and it is not practical to sort catches at sea so that vessels would tend to avoid areas where both species might be caught.

Bycatch and discard of ocean quahogs in other fisheries is nil. Ocean quahogs are not vulnerable to bottom trawls, scallop dredges (because they are too deep in sediments), or hook and line gear.

4.6 Commercial size-composition data

Commercial length composition data (shell lengths, SL) for ocean quahogs collected by port agents from landings indicate that the size composition of ocean quahog captured in the DMV stock assessment region differed during 1987-1994, 1995-2000 and 2001-2005 (Figure A16). Lengths for DMV during 1987-1994 and 2001-2005 were similar.

Commercial length composition data for NJ were stable during 1982-2002 with smaller ocean quahog landed during 2003-2005 (Figure A17). Length data for LI include relatively high proportions of large individuals (11-12 cm SL) during 1997-1999 (Figure A18). Length data for SNE during 1998-2005 were generally stable but with smaller ocean quahog landed during 1997-2000 (Figure A19). According to NEFSC (2004), smaller sizes landed from SNE during 1997-2000 were due to vessels targeting specific beds with relatively small ocean quahogs that had relatively high meat yield.

4.7 Fishery selectivity

Commercial fishery selectivity estimates used in this assessment for ocean quahog are from Thorarinsdottir and Jacobson (2005) who estimated selectivity of commercial dredges that harvest ocean quahog off Iceland. The selectivity curve $s_L = 1/\left(1 + e^{7.63 - 0.105L}\right)$, where L is shell length in mm, indicates that about 10%, 50% and 90% of ocean quahog are available to the fishery at 51, 72, and 93 mm SL (9, 28 and 86 y, based on the growth curve in Figure A59).

Dredges and towing speed in the US fishery are very similar to dredges and tow speed used in the selectivity experiments. The dredge used for selectivity experiments was 24 ft (7.35 m) in length, 5 ft (1.5 m) high and 12 ft (3.65 m) wide. The cutting blade was 10 ft (3.05 m) wide and set to penetrate sediments to a depth of 3 in (8 cm). The dredge was made of steel bars with intervening spaces of 1 ¼ in (3.5 cm) and was towed at about 2.1 knots (3.9 km h^{-1}). Water pressure supplied to jets on the dredge from a pump on the ship was about 109 psi (7.5 bars). Water pressure levels in the US fishery are usually lower (~80 psi) but water pressure probably has relatively little effect on size selectivity. Fishery selectivity curves are used in tracking trends in fishable biomass, estimating fishing mortality and in calculating biological reference points.

5.0 MORTALITY AND STOCK BIOMASS (TOR-2)

Mortality and stock biomass estimates for ocean quahog in the US EEZ are based on triennial NEFSC clam surveys, cooperative field studies used to measure survey dredge efficiency, and fishery data.

5.1 NEFSC Clam Surveys-Results

NEFSC clam surveys have been conducted since 1965 and are the main source of fishery-independent information about long term trends in abundance, biomass (Table A7, Figure A20), recruitment (Figure A21), stock distribution (Figures A22-A25 and Appendices A7-A8) and population length composition (Figure A26) for ocean quahog in the EEZ. The small area of coastal Maine waters is not covered by the NEFSC clam survey but it is minor in terms of stock biomass (20 vs. 2,700 thousand mt meats, Russell 2006) and landings (500 vs. 14,000 mt meats).

Based on survey data and in general terms (see below for details), fishable abundance (mean number per tow), stock biomass (mean kg tow) and spawning biomass (mean kg/tow) declined during 1982-2005 in southern areas (SVA, DMV and NJ) where the bulk of fishing has occurred while fishable biomass in northern areas (LI, SNE and GBK) remained relatively high and stable (with the exception of GBK in the 1999 survey). LI is the only area with clear evidence of strong recruitment after 1982 based on survey length and recruit trend data. In particular, length data from LI show ocean quahog at 65 mm SL during 1978 that grew slowly over time and became indistinguishable from the rest of the LI stock by about 1994 (Figure A26). Recruitment trend data for LI are higher prior to 1994 than afterwards and variable in other regions (Figure A21). Trends in spawning and stock biomass were nearly the same.

<u>Survey methods</u>

Survey data used in this assessment were from surveys during 1982-2005 by the *R/V Delaware II*, which were carried out during the summer (June-July), using the standard NEFSC survey hydraulic dredge with a submersible pump, 152 cm (60 in) blade 5.08 cm and small 5.08 cm (2 in) mesh liner. The survey dredge differs from commercial dredges in being smaller, using the small mesh liner, and in having the pump mounted on the dredge, rather than the deck of the vessel. The survey dredge used since 1982 catches ocean quahog as small as 50 mm SL with some reliability.

Surveys prior to 1982 were not used in this assessment because they were carried out during different seasons, used other sampling equipment or, in the case of 1981, have not been integrated into the clam survey database (Table A7 in NEFSC 2004). The last stock assessment for ocean quahog (NEFSC 2004) used survey data for 1978-1980 assuming that catchability was different during than in later surveys. In effect, the data for 1979-1980 were treated as a short separate survey time series that had little or no effects on stock assessment estimates. Catchability coefficients for earlier surveys were much different than for surveys since 1981 (NEFSC 2004).

NEFSC clam surveys are organized around NEFSC shellfish strata which are combined to define stock assessment areas (Figure A1). Most of ocean quahog landings originate from areas covered by the survey. The survey did not cover GBK and SVA completely in all years and strata in other areas are occasionally missed (Table A8). Strata not sampled during a particular survey are filled by borrowing data from the same stratum in the previous and/or next survey, if data are available (NEFSC 2004). Survey data are never borrowed from surveys behind the previous or beyond the next survey.

Surveys follow a stratified random sampling design, allocating a pre-determined number of tows to each stratum. Stations used to measure trends in ocean quahog abundance are either random or nearly random. A few nearly random tows were added in previous surveys to ensure that important areas were sampled. Other non-random stations are occupied for a variety of purposes but not used to estimate relative trends in ocean quahog abundance.

A standard tow is nominally 0.125 nm (m) in length (i.e. 5 minutes long at a speed of 1.5 knots). However, sensor data indicate that the actual tow lengths are greater (Weinberg et al. 2002 and see below).

Occasionally, randomly selected stations are found too rocky or rough to tow. In these cases during surveys since 1999, a search for fishable ground is made in the vicinity (0.5 nm) of the original station (NEFSC 2004). If no fishable ground is located, the station is given a special code (SHG=151) and the research vessel moves on to the next station. The proportion of random stations that cannot be fished is used to estimate the proportion of habitat in a stratum or region that is suitable habitat for ocean quahog, which is used in calculation of ocean quahog biomass from survey data (see below).

Following most survey tows, all ocean quahog and Atlantic surfclam in the survey dredge are counted and shell length is measured to the nearest mm. A few very large catches may be subsampled. Mean meat weight (kg) per tow is computed with shell length-meat weight (SLMW) equations from NEFSC (2004).

SLMW relationships used with survey data to track trends in survey meat weight per tow are region-specific. SLMW relationships used for survey data in this analysis (Table A9) were the same as in the last assessment (NEFSC 2004). They were derived by averaging SLMW curves from the 1997 and 2002 surveys, which were based on fresh tissue minus shell weighed at sea. Samples from earlier surveys were from frozen meats.

NEFSC clam survey require a great deal of additional adjustments after extraction from the database and before they are used in trend or swept-area biomass calculations (e.g. adjustments for tow distance and fishery or survey selectivity). Clam survey database parameters that would be required to replicate each analysis are listed in Table A10).

<u>Survey gear selectivity</u>

NEFSC (2004) estimated selectivity curves for ocean quahog in the NEFSC clam dredge based on catches by a commercial dredge with a small mesh liner during 2003 and survey catches in the same area during 2002. The selectivity curve $s_L = 1/\left(1 + e^{8.122-0.119L}\right)$ indicates that 50% of ocean quahog are fully available to the NEFSC clam dredge at about 68 mm SL, which can be compared to 73 mm for commercial dredges (Figure A27). The survey dredge tends to take smaller ocean quahogs than commercial dredges because of the relatively small 2 in liner in the survey dredge. Based on sizes retained by the survey dredge (NEFSC 2004), the survey dredge selectivity curve is reliable for ocean quahog $\geq$ 50 mm SL.

Survey, stock and fishable abundance and biomass

Catch and length composition data for ocean quahog $\geq$ 50 mm SL from the NEFSC clam survey were used to estimate abundance and length composition for the stock as a whole. In particular, $N_L = n_L / s_L$ where N_L is mean stock numbers or biomass per tow at length L, n_L is survey catch and s_L is survey selectivity.

Abundance and length composition for the fishable stock (i.e. available to the fishery) were estimated by correcting stock estimates for fishery selectivity. In particular, $\eta_L = \phi_L N_L$ where η_L is fishable abundance and ϕ_L is fishery selectivity. Fishable abundance can be estimated directly from survey data for ocean quahog $\geq$ 50 mm SL using $\eta_L = n_L \phi_L / s_L$ (Figure A27).

Calculation of stock abundance and biomass occasionally produces very large estimates for small sizes where selectivity is small (near zero) when ratios n_L / s_L become very large. Calculation of fishable abundance and biomass from survey data does not suffer from this problem because the adjustment of small sizes is relatively modest (Figure A27).

Spawning stock biomass

Trends in spawning stock biomass for ocean quahog were estimated based on survey data by applying a maturity at length relationship for ocean quahog from Thorarinsdottir and Jacobson (2005) to survey length composition for the stock as a whole (i.e. after correction for survey dredge selectivity). In particular, $S_L = m_L N_L w_L$ where S_L and w_L are spawning biomass and mean body weight (from a length-weight relationship) See Section 6 for more information about the maturity curve.

<u>2005 Survey</u>

The 2005 NEFSC clam survey was carried out during late May to early June. There were three legs (stations 1-182 during May 24-June 2, stations 183-250 during June 9-June 17, and stations 251-433 during June 22-29). Four hundred and thirty three stations were occupied. Sensor data used to monitor dredge performance were collected at 399 stations. Two hundred and eighty random and nearly random stations were used to calculate trends in ocean quahog abundance. The set of strata covered during the 2005 survey was similar to strata covered during previous surveys except that no stations were occupied in the most northern (GBK) and southern (SVA) stock assessment regions (Table A8).

Trends in survey, stock and fishable mean kg per tow were calculated for ocean quahog ≥ 50 mm SL in each region (Table A7 and Figure A20). Smaller ocean quahog taken in surveys were not included because catches of small individuals is very low and because selectivity curves used to calculate stock and fishable abundance are not valid below 50 mm SL. Trends in survey, stock and fishable numbers and weight per tow for the same region were generally similar.

The precision of survey trend data from the 2005 survey was typical but results for DMV were relatively imprecise with high coefficients of variation (CV) due to a single large tow in stratum 15 (Table A7). CVs for trend data from surveys during 1982-2005 averaged about 0.3, 0.2, 0.2 and 0.3 in the DMV, NJ, LI and SNE regions.

As described below, trends in NEFSC clam survey data are complicated by changes in survey dredge efficiency.[3] In particular, survey data for 1994 were judged not comparable to survey data from other surveys because power to the dredge used to run the submersible pump during 1994 was set to 480 instead of 460 volts and dredge efficiency was artificially increased during 1994.

Dredge performance

After the 1994 survey, sensors were used to monitor depth (ambient pressure), differential pressure, voltage, hertz and amperage of power supplied to the dredge, x-tilt (side to side), y-tilt (front to back) and ambient temperature during survey fishing operations. At the same time, sensors on board the ship monitor electrical frequency, GPS position, vessel bearing and vessel speed. All sensor data are recorded at 1 second intervals.

Good tows have characteristic sensor data patterns that are easy to interpret (Figure A28). Anomalous patterns indicate potential problems with the tow or sensors.

[3] "Efficiency" of a clam dredge is the probability that an ocean quahog in the path of the dredge will be caught. Efficiency of capture may differ between quahog of difference size and the definition used here applies to quahog large enough to be fully available to the sampling gear. Efficiency estimates for the survey dredge are used with a variety of other information to estimate the "catchability" coefficients for NEFSC clam surveys that relate survey catches to stock abundance and biomass.

Differential pressure, amperage and y-tilt are particularly important. Differential pressure is one of the factors affecting the flow of water through the jets in front of the dredge blade. Amperage measures the work done by the pump in moving water through the jets. If water is blocked at the entrance to the pump, then both amperage and differential pressure will be low. If water is blocked downstream of the pump, then amperage will be low and differential pressure will be high. Y-tilt can be used to determine if the dredge is on the bottom with the blade in the sediment.

Differential pressure data collected during the 2005 clam survey show a spike early in the first leg (Figure A29) coinciding with a drop in amperage that was due to a faulty screen on the input to the dredge system that allowed rocks to enter and fill the manifold, which is downstream from the pump. The screen was repaired, rocks removed and the affected stations were reoccupied.

Differential pressure appeared to jump from about 40 to about 50 psi beginning at approximately station 221 during the second leg of the 2005 NEFSC clam survey at the same time that amperage might have declined (Figure A29). The timing of the change coincided with malfunction and repair of electrical equipment on the ship that supplies power to the pump on the dredge.

The apparent jump in differential pressure during the second leg of the 2005 survey triggered a careful analysis of survey sensor data and dredge performance (Appendix A1). The apparent problem with differential pressure was determined to stem from sensor drift. In particular, differential pressure measurements before and after the pump was turned on were generally biased high after station 220 to the same extent at each station. The difference between ambient measurements at the surface and during fishing for each tow (another way to estimate differential pressure) was usually about 40 psi and approximately equal to differential pressures measured in the normal manner during the first leg. The alternate estimates of differential pressure did show a slight but steady decline in differential pressure during the survey presumably due to wear on the pump (Appendix A1).

In the course of investigating the problems with differential pressure, a number of stations with poor dredge performance were identified based on problems with differential pressure, amperage, vessel speed, and y-tilt (Appendix A2). Four of the problematic stations (218, 225, 262 and 282) were in areas of typical ocean quahog habitat and would not have been omitted following standard survey procedures.[4] Stations 218, 225, 262 and 282 from omitted from further analysis. Similar problems may have occurred in earlier surveys but can not be detected or removed for lack of sensor data. Analysis of sensor data from the 2002 survey will be analyzed to determine if similar problems occurred during 2002.

Tow distance

Tow distance was estimated for each station in the 2005 NMFS clam survey based on speed over ground (SOG) data from the ship's GPS and dredge inclinometer data from the SSP. SOG was assumed to be the same for the ship and dredge.

Following NEFSC (2003), the dredge was assumed to be fishing effectively whenever the smoothed y-tilt was $\leq 5.16^{o}$ (see below). Based on the geometry of the

[4] Standard survey procedures omit stations with database Station Type-Haul Type-Gear Condition (SHG) codes greater than 136.

dredge, the blade penetrates the sediments to a depth of 1 inch when the y-tilt is 5.16^{o}. Penetration increases as the y-tilt decreases.

Tow distance calculations for the 2005 survey were the same as in NEFSC (2003) except that missing values were interpolated as described below. The first step was to replace missing SOG and inclinometer data for each station with interpolated values from a cubic spline. The second step was to smooth the original plus interpolated SOG and inclinometer data with a centered seven point moving average (e.g. the smoothed value for $t = 3$ was the average for $t = 1$ to 7).[5] The final step was to compute the effective tow distance for each tow d_j using:

$$d = \frac{\sum_t \delta_t s_t}{3600}$$

where t was a one-second interval, δ_t was a dummy variable equal to one when the dredge was fishing effectively (smooth y-tilt $\leq 5.16^{o}$) and zero otherwise, s_t was SOG (knots) and 3600 is the number of seconds per hour. Tow distances calculated in this manner and used in this assessment for surveys during 1997-2002 (see below) were the same as in NEFSC (2003). The median tow distance for 2005 was consistent with median tow distances from the 1999 and 2002 surveys (see below). As pointed out in NEFSC (2003), the median tow distance for 1997 was 0.4-0.7 nm larger than median tow distances from other surveys because a slower winch was used to deploy the survey dredge (Table C7 in NEFSC 2003).

Year	Median Tow Distance (NM)
1997	0.26
1999	0.22
2002	0.19
2005	0.21

Tests showed that the new interpolation procedure had a negligible effect on tow distance estimates for the 2005 survey because missing values were rare. Similar results would likely be obtained for the 2002 survey, which also used the survey sensor package. Effects of interpolation on tow distance estimates were not investigated for 1997 and 1999 surveys but may be larger because sensor data from the 1997 and 1999 surveys were collected using less precise sensors with recording intervals that were sometimes longer than one second. This is a topic for future research.

[5] Steps 1-2 were done in SAS (note that interpolation precedes smoothing).

```
proc expand data=sdata1 out=sdata2 to=second;
    by station;
    ID TowTime;
   convert TiltY=SmoothAngle / transform=(cmovave 7);
    convert GPS1_SOG=SmoothSOG / transform=(cmovave 7);
  run;
```

Tow distance vs. depth

Tow distance is a key variable in estimating swept area biomass (see below). Weinberg et al. (2002) show that tow distance increases with depth for the NEFSC clam survey dredge when the dredge is deployed as in actual clam surveys. Regression analysis was used to determine if depth measurements could be used to infer tow length at survey stations when sensor data are not available. Based on graphical relationships (Figure A30), linear regression models were used, e.g. $d_j = \alpha + \beta D_j$ where d_j was tow distance in nm (calculated from sensor data assuming the dredge was fishing when the smoothed y-tilt was $\leq 5.16^o$), and D_j was average depth of the tow in meters as measured from the ship. Data used in the analysis were for random survey tows only (tows with database code RANDLIKE > 0). Tows with sensor-based tow distances < 0.125 nm were omitted from the analysis because they were likely aborted or test tows.

A stepwise regression procedure was used to select the best model from a range of models based on the AIC statistic. In the Splus programming language, the simplest model considered was:

```
Smallest <- lm(d~1)
```

where "~1" indicates that the model consists of the mean for the entire data set. The most complicated model was:

```
Biggest<- lm(d ~ CRUISE + D / CRUISE)
```

which is equivalent to a separate regression models relating tow distance and depth in each of the 1997, 1999, 2002 and 2005 surveys (Figure A30).

The most complicated model was selected as the best model by the stepwise procedure based on AIC. The best model was statistically significant (p<0.0001) and all parameters were statistically significant at the p=0.1 level (see below).

	Estimate	Standard Error	t-test	p-value
Survey effects (intercept parameters)				
Intercept	0.182	0.002	91.0098	0
1997	-0.02	0.0028	-7.2647	0
2002	-0.0093	0.0015	-6.1114	0
2005	-0.0046	0.0013	-3.6898	0.0002
Depth effects (slope parameters)				
Depth	0.0009	0	20.0054	0
1997	0.0001	0.0001	1.8697	0.0618
2002	-0.0001	0	-2.7522	0.006
2005	0.0001	0	2.5433	0.0111

```
Residual standard error: 0.02809 on 1179 degrees of freedom
Multiple R-Squared: 0.4634
F-statistic: 145.4 on 7 and 1179 degrees of freedom, the p-value is 0
```

Residual plots indicated reasonably good model fit although distributions of residuals were skewed either to the left or right for some surveys. Based on the regression analysis, tow distance increases by an average of about 0.0009 nm (1.7 m) per meter of depth.

Results show that missing tow distance data for NEFSC clam survey stations could be replaced with estimates based on depth from a survey-specific linear model. Unfortunately, differences among surveys were large enough to be important in estimating tow distance and should not be ignored. It does not appear that a single or average depth-tow distance relationship could be used to estimate tow distance for previous surveys with no sensor data for measurement of tow distances.

<u>Commercial and survey dredge efficiency</u>

Dredge efficiency is defined for this assessment as the probability of capture (i.e. of being handled on deck) for an ocean quahog that is in the path of the dredge and large enough (e.g. 83+ SL in a survey dredge or 90+ mm SL in commercial dredge, see below) to be fully selected by the dredge used in the experiment. Dredge efficiency for smaller ocean quahog is the product of the overall dredge efficiency for fully selected sizes and the selectivity for the particular size.

Collaborative "depletion" experiments were conducted following NEFSC clam surveys in 1997-2005 to estimate commercial and survey dredge efficiency (Figure A31). Commercial dredge efficiency estimates are of considerable interest but are most important in estimating efficiency of the survey dredge deployed from the *R/V Delaware II* during NEFSC clam surveys. Commercial dredges are inherently more efficient than the survey dredge (due to higher pressure water jets) and tend to select larger ocean quahog. In this assessment differences in the size of catches are accommodated by restricting analysis to sizes large enough to be fully selected by survey and commercial gear used in the experiment (see below).

Considerable progress has been made since the last assessment, but efficiency estimates for ocean quahog are still more uncertain and difficult than for Atlantic surfclam (NEFSC 2003). Dredge efficiency is harder to estimate for ocean quahog because they are found in deeper water (which makes dredge position data less reliable) and because they burrow deeper into sediments (and are probably sampled less efficiently) to a degree that depends on environmental conditions.

All depletion experiments for ocean quahog involve fishing repeatedly in the same area, usually until a significant decline in catch per tow is noted. Sensors and GPS equipment are have been used since 1999 to track the performance of the dredge and position of the vessel during each tow (vessel position is used as a proxy for dredge position). Experiments during 1997-1998 used loran positions noted by hand. The accuracy of position information is an important consideration (see below). Catch and position data are used in a statistical analysis (see below) to estimate the efficiency of the dredge used in the experiment.

In a "Delaware II" depletion experiment, the *R/V Delaware II* and NEFSC survey dredge are used to make depletion tows. The efficiency of the survey dredge is estimated from the depletion tow data directly using the "Patch" model (Rago et al., in press and see below). One Delaware II depletion experiment has been completed for ocean quahog (experiment OQ1999-01 DE2 in Table A11).

In "commercial" depletion experiments, a commercial vessel and dredge are used for depletion tows. The efficiency of the commercial dredge is estimated directly using the Patch model.

Commercial depletion experiments can be used to estimate survey dredge efficiency also if the *R/V Delaware II* conducts setup tows prior to the commercial depletion experiment in the same or immediately adjacent area (see below). About five non-overlapping setup tows are typically carried out. Sixteen commercial depletion experiments have been completed by commercial vessels of which thirteen included setup tows (Table A11 and Figure A31).

Patch model

The Patch model was used exclusively to estimate depletion experiment data in this assessment. It has become a standard approach used in NEFSC stock assessment work for a variety of shell- and sedentary demurral finfish including Atlantic sea scallops NEFSC (2004b), ocean quahog (NEFSC 2004), Atlantic surfclam (NEFSC 2003) and goosefish (NEFSC 2005). Other estimators used for ocean quahog in previous assessments were either *ad-hoc* or based on estimators involving assumptions that are tenuous for ocean quahog (e.g. complete mixing after each depletion tow). Now that a sufficient number of depletion experiments have been completed, it is possible to use Patch model estimates exclusively.

The Patch model was used to estimate three parameters for each depletion experiment (initial ocean quahog density, dredge efficiency, and a measure of dispersion) by maximizing the likelihood of the observed catches under the assumptions that the dredge path is known and that the catches are sampled from a negative binomial distribution. The key point is that it is not necessary to assume ocean quahogs mix randomly (except in relatively small cells) after every depletion tow. Ideally, GPS is used to monitor the position of the ship (a proxy for position of the dredge) at one second intervals during each tow (see below). In computing the likelihood for the catch in each tow, the model considers the number of times each grid sampled during the tow had been swept by the dredge in previous tows. Likelihood profiles are used to compute confidence intervals for all model estimates and residual plots (observed – predicted catches) can be used to judge model fit.

Revised estimators for survey dredge efficiency based on setup tows

Efficiency of the NEFSC clam survey dredge is estimated from commercial depletion experiment results by relating densities measured by the *Delaware II* in setup tows to initial density estimated from a commercial depletion experiment by the Patch model (Rago et al., in press). In particular:

$$e = \frac{d}{D}$$

where e is estimated efficiency of the NEFSC survey dredge, d is density (number ft^{-2}) estimated from setup tows by survey dredge, and D is density estimated by the Patch model. In this context, d is understood to measure survey catch rates while D is understood to measure the actual density of quahog on the bottom of the ocean within the boundaries of the depletion experiment site. Previous ocean quahog assessments (NEFSC 1998; NEFSC 2000; NEFSC 2004) used a different formula that is incorrect:

$$e = \frac{d}{D} E$$

where $E \leq 1$ is efficiency of the commercial dredge as estimated by the Patch model (note that this formula is correct if E=1, which is appropriate if D is absolute initial density). For this assessment, all depletion experiments were reanalyzed using the correct formula and other changes described below. All other things being equal, the corrected formula increases research survey dredge efficiency estimates (and decreases swept-area biomass estimates) because $E < 1$ so that $d/D \geq (d/D)E$.

Revised assumptions about dredge selectivity

It is important that data used in the Patch model include only length groups that are (or are nearly) fully selected. For survey efficiency estimates from setup tows and commercial depletion experiments, size groups fully selected by *both* the survey and commercial gear should be used. This restriction is important for two reasons. Firstly, the estimator $e=d/D$ requires that d and D be for the same fully recruited size groups. Secondly, Patch model estimates of E will be biased low if small size groups (with lower selectivity) are included.

Previous assessments (NEFSC 1998; NEFSC 2000; NEFSC 2004) assumed that Patch model estimates were valid as long as the survey dredge and commercial dredge used in the depletion experiment had "similar selectivity" for size groups included in the analysis. Commercial sampling equipment (dredge and shaker table) used in depletion experiments was usually adjusted prior to sampling so that the catch rates for small ocean quahog increased and the modified commercial and survey length composition data were made more similar. Decisions about which size groups to include in an analysis were made in previous assessment after experiments were completed based on length composition data from setup and depletion tows. In practice, length groups actually used in estimation varied from experiment to experiment (e.g. 71+ mm for the OQ2000-1, 76+ mm for the OQ2000-2, and all size groups for the OQ2002-1 to OQ2002-4 depletion studies). In experiments during 1997-1999 that used only one type of gear, all size groups were used.

Revised depletion study catch data

For this assessment, all depletion experiments during 1997-2005 were analyzed or reanalyzed using depletion experiment catch data (numbers of ocean quahog per tow) for size groups that were at least 85% selected by all gear used in the experiment. In particular, catches for commercial depletion experiments and setup tows were for ocean quahog 90+ mm SL and catches for Delaware II depletion experiments were for ocean quahog 83+ mm SL. Based on selectivity curves (Figure A27), 87% and 93% of ocean quahog are selected by commercial and survey dredges at 90 mm SL. As mentioned above, commercial equipment was usually adjusted prior to use in depletion experiments so that commercial selectivity at 90 mm SL was likely higher than 90%. Data analyzed from Delaware II depletion experiments were for ocean quahog 83+ mm SL because survey dredge selectivity is 85% at that size.

The decision to use the size at 85% selectivity as the cutoff was pragmatic. A higher selectivity cutoff level might be preferred on mathematical grounds but the variability of catch data decreased when fewer sizes were included. For example, data from the OQ2000-1 depletion experiment were used to estimate commercial dredge efficiency but could not be used to estimate survey dredge efficiency because relatively few ocean quahog 90+ mm were taken in setup tows. In OQ2000-1 setup tows, large ocean quahog comprised only 6% of the setup catch on average.

Calculation of catch of ocean quahog larger than a specified size (e.g. 90+ mm) requires information about the catch in bushels in each tow, the number of clams per bushel ("bushel counts"), and the proportion of clams larger than 90+ mm (from length measurements. Ideally:

$$n_{t,90+} = B_t n_t p_{t,90+}$$

where B_t is catch in bushels for tow t, n_t is the number of ocean quahogs in a sample bushel and $p_{t,90+}$, is the proportion of the length sample that was at least 90 mm SL.

Bushel counts and length data measurements were not collected from every tow during depletion experiments. During most experiments, one bushel of ocean quahog was counted and one bushel was measured at intervals of 3-5 tows, and occasionally at longer intervals (Table A11). In some cases, the number of broken clams was recorded so that the number measured plus broken provided additional information about numbers per bushel.

A convention was developed to objectively calculate the number of ocean quahog above a specific size for tows without bushel counts or length data. For example, if an experiment consisted of 10 tows with samples taken on tows 2, 6 and 9, then n_2 was used for tows 1-2. The average of n_2 and n_6 was used for tows 3-5. The average of n_6 and n_9 was used for tows 7-8. Finally, n_9 was used for tows 9-10. In previous assessments, a variety of conventions (including the one used in this assessment) was employed for different tows and different depletion experiments.

In theory, bushel counts should increase and proportions of large individuals in catches should decrease as a depletion study is carried out and large ocean quahog are preferentially removed from the study site. This pattern was not, however, consistently observed.

Length and bushel count data from depletion and setup tows appears more important than recognized in previous assessments. More detailed length data (e.g. 1 bushel per tow) should therefore be collected during future depletion experiments. Lengths and bushel counts were likely under-sampled in depletion experiments to date (Table A11)

Accuracy and precision of position data

Cell sizes used in Patch model runs for this assessment are 20-25 ft (Table A11). Previous assessments used 10-25 ft. Position data used in the Patch model for ocean quahog depletion experiments should be recorded at (or interpolated to) intervals ≤ 0.00001 degrees to avoid missing cells (see below). Position data recorded to 0.0001 degrees, for example, are too coarse, because the wrong cell would be assigned frequently due to imprecision in position measurements. This recommendation assumes that vessel position is an accurate proxy for dredge position. The accuracy of GPS data as information about dredge position likely deteriorates with depth. Problems with position information may be exaggerated to some extent for ocean quahog, which are found in relatively deep water. Potential effects of inaccurate position data should be evaluated by simulation analysis. Position data were smoothed prior to use in this assessment to account for imprecise position data from some depletion experiments (see below).

Distance in feet for a change in latitude or longitude at 40° N.

	Distance in Feet	
Degrees	Latitude	Longitude
1	364,560	279,269
0.1	36,456	27,927
0.01	3,646	2,793
0.001	365	279
0.0001	36.5	27.9
0.00001	4	3
0.000001	0.4	0.3

Position data used in the Patch model should be recorded at (or interpolated to) intervals ≤ 4 second intervals to avoid skipping cells too frequently between position observations. The target tow speed for the *R/V Delaware II* during depletion tows is 1.5 knots or 2.5 ft sec^{-1}. Commercial vessels probably average about 2 knots or 3.4 ft sec^{-1} during commercial operations tows (D. Wallace, Wallace and Associates, pers. comm.) and about 3 knots or 5 ft sec^{-1} during depletion tows (E. Powell, Rutgers University, pers. comm..). Thus, sampling (or interplation) at intervals of 1-3 seconds is recommended because the *R/V Delaware II* crosses a 20 ft cell in 8 seconds and a commercial vessel crosses a 20 ft cell in 4 seconds (see below). Smaller cell sizes require more frequent sampling or interpolation. Position data were interpolated in this assessment to account for relatively long sampling intervals in some depletion experiments (se below).

Time in seconds required to cross Patch model cells 15-25 ft wide at vessel speeds of 1.5 and 2 knots.

	Vessel speed (knots)	
Feet	1.5	3
15	5.9	2.9
20	7.9	3.9
25	9.9	4.9

Smoothed position data for depletion experiments

Position data for 1997-2005 depletion experiments were from original Loran or GPS records. Start and stop times for GPS data were the same as used in the last assessment).

Position data from depletion studies during 2000-2005 were recorded to 10^{-6} degrees at one second intervals based on differential GPS or the equivalent (Table A11). However, position data from the 1999 Delaware II depletion study from GPS were recorded to only 0.0001 degrees and position data from loran readings in depletion studies during 1998-1998 were recorded to an accuracy of about 0.0001 degrees.

To avoid problems with erratic "stair pattern" tow tracks from coarse position data, original position data from all depletion experiments were smoothed prior to further analysis (Appendix A3). The smoother was a cubic spline when the number of observations $n \geq 15$, a quadratic polynomial when the number of observations was $5 \leq n < 15$ or a straight line when $2 \leq n < 5$. Smooth lines were fit using latitude or longitude as the dependent variable and order of collection (a crude measure of time) as the independent variable. Smoothed values were used in subsequent calculations, instead of the original data. Decisions about smoothing were ad-hoc but consistently applied and seemed to result in plausible tow paths for further analysis (Appendix A3). Fortunately, survey dredge efficiency estimates were from recent depletion studies with generally accurate position data sampled at relatively frequent intervals. With accurate data at frequent intervals, smoothing had very little effect of tow path data.

No position data were available for 2 out of 60 tows in the 1999 Delaware II depletion experiment. Crude estimates of the start and stop locations for these tows from previous assessments from a previous assessment were used instead.

Before analysis in the patch model, original or smoothed position data were interpolated along straight lines to a distance of 5 ft (~ 1- 2 second intervals) to ensure that all cells that were crossed by the dredge would be recorded as "hits" in the Patch model program. This was apparently not done for all depletion experiments in previous assessments and it is possible that not all hits were included in previous estimates. In future assessments, interpolation should be based on the model (e.g. cubic spline) used to smooth the original position data, rather than by linear interpolation.

Assumptions about cell size

All depletion studies were analyzed or reanalyzed using consistent and updated assumptions about cell size and indirect effects, which are closely related. Rago et al. (in press) suggested that the cell size be set at twice the width of the dredge used in the depletion experiment. They point out that decisions about cell size reflect a compromise between the accuracy of position data and the tenability of the assumption that animals mix within cells after each tow. Dredges used in depletion experiments were mostly ≥ 10 ft wide with the exception of the commercial dredge in the OQ1997-1 commercial depletion experiment and the 5 ft dredge used in the OQ1999-1 (DE-2) Delaware II depletion experiment (Table A11).

In this assessment, the cell size in Patch model analyses was set at twice the dredge width or 20 ft, whichever was larger. This approach basically follows the advice in Rago et al. (in press) for all experiments during 2000-2005 while assuming that positional accuracy (particularly for experiments during 1997-2005) was never better than 20 ft. Patch model estimates for ocean quahog were moderately sensitive to the assumed cell size (Figure A32). In particular, efficiency estimates tend to increase and density estimates tend to decrease as the cell size assumed in the Patch model increase.

Indirect effects

The "gamma" parameter in the Patch model is used to measure indirect effects (ocean quahog lost from the study site without being counted on deck). In this assessment gamma was fixed at the ratio of the dredge width and cell width (γ=0.5) so that no indirect effects were assumed to occur. The gamma parameter is theoretically estimable but estimation has proven difficult in practice because the estimate for gamma is correlated with other estimates in the model and dependent on assumptions about cell size (Rago et al., in press). The previous assessment assumed indirect effects (γ=0.75) in depletion experiments during 1997-2000 and no indirect effects (γ=0.5) in depletion experiments during 2002. As shown in Rago et al. (in press) efficiency and density estimates from the Patch model tend to decrease as the assumed level of γ increases.

Sensitivity to initial parameter estimates

Patch model estimates were not sensitive to the starting values for parameter estimates. After an initial Patch model run for each experiment was completed, the model was rerun several times to determine if results were sensitive to starting parameter values. In particular, the model was rerun at least four times with HD/LE, LD/HE, HD/HE and LD/LE where HD, LD, HE and LE stand for higher and lower starting density values and higher and lower starting efficiency values. In general, higher starting values were 2-3 times higher than the initial estimate and lower starting values were one-half to one-third of the initial estimate. The estimate providing the best fit to the catch data (smallest negative log-likelihood) was the best estimate.

2005 Depletion experiments

In 2005, five new commercial depletion experiments were completed with five setup tows and 17-21 depletion tows per site (Figures A33-A37). No Delaware II depletion studies were carried out for ocean quahog during 2005. Details about depletion studies during 2002 are described in NEFSC 2004, experiments during 1998 and 1999 are described in NEFSC (2000) and experiments during 1997-1998 are described in NEFSC (1998).

Survey sensor package equipment (with the exception of GPS and a backup depth sensor) did not function during ocean quahog depletion tows by the commercial vessel during 2005 due to battery failure, with the exception of initial tows at the OQ2005-6 depletion site.

The survey data that are available for 2005 commercial depletion tows (Figure A38) indicate that the commercial dredge was not always horizontal and hard on bottom at the OQ2005-06 depletion site due to the combined effect of low scope and choppy seas. The estimated efficiency for OQ2005-06 may have been reduced by these factors. The OQ2005-06 site was in the deepest water (65 m, Table A11) and conducted in choppy seas. The commercial dredge was deployed at this site with lower scope because the hose used to supply water to the dredge was relatively short. The sea was calmer and shallower at towing scope was greater at other relatively shallow depletion sites for ocean quahog during 2005. Although no sensor data are available, it is likely that the commercial dredge towed well at the other 2005 ocean quahog depletion sites.

As in previous years, commercial sampling equipment (dredge and shaker table) used in 2005 was adjusted to increase catch of relatively small ocean quahog. However, length composition data for the setup and depletion tows at each site during 2005 indicate that the selectivity of the two dredges differed (Figure A39). Confidence intervals and residual plots (Appendix A4) indicate that efficiency and density estimates from experiments during 2005 were reasonably precise.

Depletion study results

For this assessment, all depletion experiments for ocean quahog during 1997-2005 were analyzed or reanalyzed using the Patch model based on revised data, assumptions and procedures described above. All of the underlying data, with the exception of the raw GPS position information collected during depletion studies during 1999-2005, were reevaluated. Residuals and confidence intervals for Patch model parameters are shown for each depletion experiment in Appendix A4. Estimates and model fit are summarized in Tables A11-A12. To build a bridge between new and old results, differences between efficiency and density estimates in this and previous assessments are summarized in Table A13.

Estimates from commercial depletion experiments during 1997-1998 and the Delaware II depletion experiment during 1999 are probably less reliable than estimates from experiments during 2000-2005. Position data were relatively imprecise in depletion experiments prior to 2000 (Table A11). Goodness of fit to depletion catch data was poor for the OQ1998-1 and OQ1999-1 (DE-2) experiments (Appendix A4). Average annual commercial efficiency estimates from experiments during 1997 (E=0.592) and 1998 (E=0.860) were outside the range of average annual estimates for later years (i.e. E=0.615, 0.588 and 0.559 during 2000-2005). The OQ1999-1 (DE-2) survey dredge efficiency estimate was anomalously high and the corresponding density estimate was anomalously low, relative to estimates from later commercial depletions with setup tows.

There were no clear relationships between dredge efficiency and density or depth (Figure A40). There is, however, a suggestion of a negative correlation between survey dredge efficiency and sediment size.

Revised Patch model estimates of commercial and survey dredge efficiency from historical depletion experiments were smaller than previous estimates with a few exceptions (Table A13). Revised density estimates were always smaller but the revised and previous density estimates are not comparable because they are for different size groups.

The seventeen commercial dredge efficiency estimates indicate that efficiency of commercial dredges is highly variable with E = 0.15 to 1.00 (Tables A11-A12 and Figure A42). The average and median of estimates of commercial efficiency were 0.60 (CV=24%) and 0.66 (CV=14%).

Twelve survey dredge efficiency estimates were available, eleven from commercial depletion experiments with setup tows and one from a depletion study by the *R/V Delaware II* (Tables A11-A12). Survey dredge efficiency estimates were also variable (e = 0.098 to 0.990, Figure A43). Omitting the estimate from the OQ1999-1 (DE-2) experiment, which was anomalously high, survey dredge efficiency estimates ranged 0.098-0.297. The average and median of estimates of survey efficiency were 0.248 (CV=29%) and 0.165 (CV=18%). The ratio of median commercial efficiency and median survey dredge efficiency indicates that the NEFSC survey dredge is about one-quarter as efficient as commercial dredges (Table A12). Survey dredge efficiency estimates did not appear correlated with commercial dredge efficiency estimates (Figure A41).

Density estimates for ocean quahog 90 mm SL (Table A11-A13 and Figure A42) ranged 0.007-0.295 ft^{-2}. The smallest density estimate (0.007 ft^{-2}) was from the OQ1999-1 (DE-2) survey depletion experiment, which gave an anomalously small survey dredge efficiency estimate. The highest density estimates (0.226-0.295 ft^{-2}) were the OQ2002-1 and OQ2002-2 depletion experiments.

Best survey dredge efficiency estimate

The "best" estimates for survey dredge efficiency (e=0.165, CV=18%), commercial dredge efficiency (E=0.66, CV=14%) and ocean quahog density (D=0.082 ocean quahog ft^{-2}, CV=13%) were the medians of all available estimates from ocean quahog depletion experiments during 1999-2005 (Table A12). Medians were used because they are robust to anomalous estimates, such as the high estimate for survey dredge efficiency from the OQ1999-1 (DE-2) experiment and the low estimate of commercial dredge efficiency from the OQ1997-3 experiment (Table A11).

The new best estimate of survey dredge efficiency (*e*=0.165) is smaller than the estimates used in the last assessment NEFSC (2004) for the 1997 survey (*e*=0.346) and for the 1999-2000 surveys (*e*=0.269).

Ideally, efficiency estimates would be survey specific because differences in sampling efficiency are possible. However it is not possible at present to estimate dredge efficiency for each survey with sufficient precision.

Depletion experiments-building a bridge

As described above, factors that contribute to the differences between the previous and revised estimates are:

1) Revised computer programs
2) Corrected formula for survey dredge efficiency based on setup tows.
3) Cell size assumed in the Patch model set to the larger of 20 ft or twice the dredge width (affects OQ1997-01 and OQ1999-1 DE-2 only);
4) Depletion and setup catch data for ocean quahog 90+ mm SL (affects all depletion studies during 1997-2002);
5) Revised position data (new smoothing and interpolation, affects all studies during 1997-2002);
6) No indirect effects, i.e. γ = ratio of dredge width and cell size (affects all depletion studies during 1997-2000);

Not all changes apply to each depletion experiment.

To build a bridge between old and new results, effects on efficiency and density estimates due to individual factors for the OQ1998-1 and OQ2002-1 depletion experiments are shown in Table A14. In the OQ2002-1 experiment, estimates were most sensitive to using the correct formula, revised position data, and revised catch data while the density estimate was most sensitive to using catch data for ocean quahog 90+ mm SL only. In the OQ1998-1 experiment, estimates were most sensitive to using the revised position and catch data.

<u>Repeat stations</u>

Stations from previous and the current survey are repeated during each survey to help detect potential changes in sampling efficiency. Catch data for stations sampled twice during the 2005 survey and during both the 2002 and 2005 surveys were analyzed for this assessment but results are not presented here because the repeat stations were in Atlantic surfclam habitat where ocean quahog catches were very low.

5.2 Efficiency corrected swept area biomass

Efficiency corrected swept area biomass (ESB) estimates were for years (1997, 1999, 2002 and 2005) when NEFSC clam surveys collected sensor data for each tow. Sensor data are important because ESB calculations require accurate measurements of tow distance. Differences in ESB estimates between this assessment and NEFSC (2004) for 1997-2002 are described in detail below under the heading “Building a bridge”.

ESB estimates (Table A15) for ocean quahog were calculated:

$$B = \frac{B'}{e}$$

where:

$$B' = \frac{\overline{\chi} A'}{a}(1+\phi)u$$

In ESB calculations, *e* is the best estimate of survey dredge efficiency for ocean quahogs, $\overline{\chi}$ is mean catch of fishable ocean quahog per standard tow based on sensor data (kg tow^{-1}, see below), *A'* is habitat area (nm^2), a= 0.0008225 nm^2 tow^{-1} is the area that would be covered by the 5 ft wide survey dredge during a standard tow of 0.15 nm, and u=10^{-6} converts kilograms to thousand metric tons. *B'* is the minimum swept-area biomass prior to correction for survey dredge efficiency.

The term ϕ used in ESB calculations is new in this assessment. It is the fraction of total biomass in deep water strata off LI (strata 32 and 36), SNE (strata 40, 44, 48) and GBK (strata 56, 58, 60 and 62) that were sampled only during 1999. According to NEFSC (2000), deep water strata accounted for 0%, 2% and 13% of total biomass in the LI, SNE and GBK regions during 2005. Data for deep water strata sampled only during 1999 are otherwise omitted in calculations and, in particular, calculation of mean catch per tow $\overline{\chi}$. NEFSC (2004) used a slightly different approach for GBK in the last assessment which gave essentially the same results.

Habitat area for ocean quahogs in each region was estimated:

$$A' = Au$$

where $\underline{u}$ is the proportion of random tows in the region not precluded by rocky or rough ground (ocean quahogs occupy smooth sandy habitats), and *A* is the total area computed by summing GIS area estimates for each survey stratum in the region. Mean catch per standard tow ($\overline{\chi}$) is the stratified mean catch of fishable ocean quahog for individual tows after adjustment to standard tow distance based on tow distance measurements from sensor data (d_s):

$$\chi_i = \frac{C_i d}{d_s}$$

Only random tows were used in calculations of ESB. Tows without sensor data, with gear damage or poor pump performance were excluded from ESB calculations.

Following NEFSC (2004), and as described above, tow distance was measured for each station assuming that the dredge was fishing when the blade penetrated the sediments to a depth of at least one inch. Thus, the tow distance at each station was the sum of the distance covered while the dredge angle was ≤ 5.2°.

ESB estimates for the entire ocean quahog stock during 1997-2005 (Table A15) were computed using a formula that facilitated variance calculations (see below):

$$B_{total} = \frac{B'_{total}}{e} = \frac{\sum_r B'_r}{e}$$

The 80% confidence intervals for efficiency corrected total fishable biomass during 1997, 1999, 2002 and 2005 overlapped suggesting that the estimates were not significantly different (Table A15).

Catch-ESB Mortality estimates

Fishing mortality rates were estimated directly from the ratio of catch (landings plus an assumed 5% incidental mortality allowance) and ESB data for each region and year (Table A16). Biomass levels change slowly in ocean quahog, fishing and natural mortality rates are low for ocean quahog, and the survey during June provides a good approximation to average biomass. It was advantageous to use the ratio estimator because the surveys occur in June and because it was easy to include a wide range of uncertainties in variance calculations (see below).

Uncertainty in ESB and mortality estimates

Variance estimates for ESB and related mortality estimates were important in using and interpreting results (Tables A15 and A16). Formulas for estimating ESB and mortality for a single stock assessment region are products and ratios of constants and random variables. Random variables in calculations are typically non-zero (or at least non-negative) and can be assumed to be approximately log normal. Therefore, we estimated uncertainty in ESB and related mortality estimates using a formula for independent log normal variables in products and ratios (Deming 1960):

$$CV\left(\frac{ab}{c}\right) = \sqrt{CV^2(a) + CV^2(b) + CV^2(c)}$$

where $ln(ab/c)$, $ln(a)$, $ln(b)$ and $ln(c)$ are normally distributed. The accuracy of Deming's formula for ESB estimates was checked by comparison to simulated estimates (NEFSC 2002). CV's by the two methods were similar as long as variables in the calculation were log normally distributed. In addition, distributions of the simulated products and ratios were skewed to the right and appeared lognormal.

CV estimates for terms used in ESB and related estimates (Tables A15-A16 and Figures A44-A45) were from a variety of sources and were sometimes just educated guesses. The CV for best estimate of survey dredge efficiency (e) was CV=0.177 calculated by bootstrapping the median (15,000 bootstrap iterations) (Table A12). For lack of better information, CVs for sensor tow distances (d), area swept per standard tow (a), total area of region (A), percent suitable habitat (u), and catch were all assumed to be 10%. The CV for area swept (a) is understood to include variance due to Doppler distance measurements and variability in fishing power during the tow due, for example, to rocky or muddy ground.

Uncertainty in estimates for combined assessment regions

ESB for combined stock assessment areas was estimated as described above. Variance calculations accommodated covariance among regional estimates due to using a single estimate of survey dredge efficiency:

$$CV^2(B_{total}) = CV^2(e) + CV^2(B'_{total})$$

Previous assessments used the formula:

$$Var(B_{total}) = \sum_r Var(B_r)$$

where *Var(x)* is the variance of *x*. The formula used previously was incorrect because it assumed that efficiency and biomass estiamtes for each region were independent. The new formula makes the estimated confidence intervals for ESB and fishing mortality wider.

<u>Building a bridge</u>

Efficiency corrected swept-area biomass estimates in this assessment are almost double the estimates in the previous assessment (Table A19). For example, total stock biomass during 2002 was 2.1 million mt in NEFSC (2004) while the revised estimate in this assessment is 3.8 million mt. Several factors are responsible for this change in the estimates for 2002: 1) changes to spreadsheet software used in computations, 2) an error in the survey data for 2002 (but not for other years); 3) accounting for ocean quahogs on GBK that are too deep to be taken in the survey (13% of total stock biomass); 4) use of fishable biomass rather than 70+ mm biomass, and 5) new estimates of survey dredge efficiency. Of all the factors, the revised survey dredge efficiency (followed by the corrected survey data for 2002) was the most important factor contributing to higher ESB estimates in this assessment (Table A19).

5.3 "VPA" estimates

VPA estimates of biomass and fishing mortality are useful for stock assessment regions where the KLAMZ model (see below) is not applicable. Assuming no recruitment and that growth exactly balances natural mortality, ocean quahog biomass on January 1st and annual fishing mortality rates (Figure A46-A50) can be estimated for each stock assessment region using a simple virtual population analysis or "VPA" approach (NEFSC 2004). Efficiency corrected swept-area biomass estimates for 1999, 2002 and 2005 are averaged and used to anchor the calculations. Averages for 1999-2005 are used because the estimates for individual years are less precise (Table A15).

The VPA biomass estimate for January 1, 2002 is:

$$b_{2002} = \frac{B_{1999} + B_{2002} + B_{2005}}{3} - \frac{C_{2002}}{2}$$

where b_y is the VPA biomass estimate for January 1 in year *y*, B_y is the efficiency corrected swept area biomass for June in year *y*, C_{2002} is total catch weight (landings plus a 5% allowance for incidental mortality). The first ratio on the right-hand side is average efficiency corrected swept-area biomass during 1999-2005 and used as an estimate of biomass in June of 2002. Catch for 2002 is divided by two prior to subtraction because NEFSC clam surveys occur during June, when the year is half over.

Biomass estimates for years prior to 2002 were calculated:

$$b_{y<2002} = b_{2002} + \sum_{i=y}^{2001} C_i$$

Biomass estimates for years after 2002 were calculated:

$$b_{y>2002} = b_{2002} - \sum_{i=2002}^{y} C_i$$

Fishing mortality rates from VPA estimates were calculated by solving the catch equation with instantaneous rates for natural mortality and somatic growth both zero.

5.4 KLAMZ Model

KLAMZ (see Appendix A5 for a complete technical description) is a forward projecting stock assessment model based on the Deriso-Schnute delay-difference equation (Deriso 1980; Schnute 1985; Quinn and Deriso 1999). The delay-difference equation is an implicitly age structured population dynamics model that is mathematically identical to explicitly age-structured models if fishery selectivity is "knife-edged", somatic growth follows the von Bertalanffy equation, and natural mortality is the same for all age groups in each year. Knife-edge selectivity means that all individuals alive in the model during the same year experience the same fishing mortality rate. Natural mortality rates and growth parameters can change from year to year in the KLAMZ model but are assumed to be the same for all individuals alive during the same year. The model is implemented in AD Model Builder and Excel but only the AD Model Builder version was used in this assessment.

The main assumptions in the KLAMZ model for ocean quahog are: recruitment is constant over time, fishery selectivity is knife-edged; the natural mortality rate is low or constant, and growth in weight can be described by a von Bertalanffy growth curve. Recruitment is assumed constant (at levels always estimated to be very low) because no recruitment index is available. The assumption of constant recruitment is used for ocean quahog because no reliable recruitment index current exists, recruitment levels are apparently very low, and trends in stock dynamics are appear due primarily to fishing mortality.

KLAMZ model runs for ocean quahog that linked virgin biomass calculations with estimated biomass during 1978 were explored during the SARC review for this assessment. NEFSC (2000) used an equvilent virgin biomass approach. NEFSC (2004) compared several approaches and ultimately rejected the virgin biomass approach due to poor fit to survey data. As shown during the review for this assessment, models for ocean quahog that linked initial and virgin biomass in this assessment did not yield plausible results in some cases and fit to survey data was substantially reduced.

Recruitment to the ocean quahog fishery is not knife-edged but occurs at sizes of 51-86 mm SL (Figure A27). Under these circumstances, KLAMZ is an approximate model can be use to track trends in fishable (instead of total) biomass. Fishable biomass is dominated by relatively large individual ocean quahogs that are readily captured (see research recommendations).

Despite the assumption of knife-edge selectivity, KLAMZ is a relatively robust model (i.e. with little or no retrospective bias) that has been used successfully in previous assessments for ocean quahog (NEFSC 2004) and other species. It provides useful estimates of long-term biomass and fishing mortality, performs relatively well with very limited information about age and growth and when explicitly age-structured models are difficult to apply. One of the chief reasons for the utility of the KLAMZ model is statistical simplicity. The models used for ocean quahog in this assessment, for example, estimates only 2-3 parameters.

Model configurations

Configurations of the KLAMZ model for ocean quahog in each region were similar to the "best" configurations identified in the last assessment (NEFSC 2004) following a thorough analysis of a wide range of alternate configurations. Changes are highlighted in the descriptions below.

KLAMZ model estimates were for ocean quahog in the DMV, NJ, LI and SNE regions during 1977-2005. The model was not used for SVA because survey data for SVA are noisy and incomplete. The KLAMZ model was fit to data for GBK for sensitivity analysis. Following NEFSC (2004), the KLAMZ model was not used to make best estimates for GBK because no fishing occurs there, the survey time series is short (1986-2002) and because apparent trends in stock biomass are not clear (see "GBK at virgin biomass?" below).

Data used in KLAMZ models for ocean quahog in this assessment were: NEFSC clam survey biomass trends and associated CV's for 1982-2005; efficiency corrected swept-area biomass estimates for 1997-2005 (see below); and catch during 1977-2005 (landings plus a 5% allowance for incidental mortality). LPUE data are included in the model but only for comparative purposes (i.e. they had nil effect on model estimates).

NEFSC (2004) chose to omit LPUE data entirely but the decision was unnecessary because it is useful to compare model trends with LPUE data and because the LPUE data have no effect on model estimates. LPUE data did not affect estimates in this assessment because the likelihood component for trends in LPUE data was set to a very low level (10^{-6}) and the survey scaling parameter Q for LPUE was calculated using a closed form maximum likelihood estimator (i.e. Q was not estimated as a formal parameter). LPUE data did not affect variances estimates because LPUE data did not affect goodness of fit to other data.

Catch data for ocean quahog were assumed accurate and not estimated in the model. NEFSC clam survey data were used to measure trends in biomass. NEFSC clam survey data for 1994 were omitted because electrical voltage supplied to the pump on the survey dredge was set to 480 v, rather than 460 v, artificially increasing dredge efficiency during the 1994 survey (NEFSC 2004). Efficiency corrected swept-area biomass estimates for 1997-2005 are used to measure the scale of recent biomass levels but are not used to measure trends. Recruitment is assumed to be constant at some low level or zero. The natural mortality rate was M=0.02 y^{-1}, except in DMV (see below).

As described above, the KLAMZ model in this assessment estimates trends in fishable biomass. In contrast NEFSC (2004) modeled biomass of ocean quahog 70+ mm SL. Survey data used in the model are trends in mean fishable biomass while survey data used by NEFSC (2004) were trends in ocean quahog 70+ mm SL. Based on the fishery selectivity curve for ocean quahog, 50% of ocean quahog are selected by commercial dredges at about 73 mm SL. Thus, the previous and current assumptions about recruitment to the fishable stock are reasonably compatible.

Assumptions about growth are the same as in the last assessment. In particular, the growth parameters $\rho=e^K$ (where K=0.0176 is the von Bertalanffy growth parameter for weight), $J_t = w_{k-1}/w_k$ = 0.9693 (where w_j is predicted weight at age j) are constant and the same for all regions (NEFSC 2004). These growth parameters mean that quahogs in the model are slow growing, and that quahog recruit to the fishery (reach 70 mm SL) at age k=26 (Figure A59). Growth patterns differ among regions (Lewis et al. 2001 and Figure A56) but ocean quahog are difficult to age and there is too little information available to use region-specific growth curves (NEFSC 2000). The growth curve used in KLAMZ models for all areas but GBK was estimated from data collected in the Mid-Atlantic Bight where fishing occurs. Lewis et al.'s (2001) growth curve was used for GBK sensitivity analysis runs.

An assumed level of variance in instantaneous somatic growth rates (IGR) for old recruits is used to help estimate the initial age structure of ocean quahogs in the initial years of the model (Appendix A5). For ocean quahog in each region, IGR values during 1979-1980 were estimated assuming a lognormal distribution with arithmetic mean equal to the estimated IGR for 1981 and an arithmetic CV for years 1981-2005 estimated in a preliminary run. For ocean quahog, this constraint is unimportant because estimated age structures were stable due to assumptions about recruitment and low mortality rates.

ESB data are very important in KLAMZ models for ocean quahog as a source of information about biomass scale. Trends in ESB data during 1997-2005 were ignored in modeling because the time series is short (four years) and because information about trends from the NEFSC clam survey is already provided by the clam survey biomass index for 1982-2005. To use ESB data as a measure of scale while ignoring trend (see Appendix A5), the likelihood component for trends in ESB data were set to 10^{-6} so that the survey scaling parameter Q was calculated but the trend was ignored. Information in ESB data about biomass scale is contained in the estimated survey scaling parameter Q.

As described in Appendix A5, the likelihood of the survey scaling factor is calculated assuming that estimates of Q are from a lognormal prior distribution:

$$L = 0.5\left[\frac{\ln(Q)-\tau}{\varphi}\right]^2$$

where L is the negative log likelihood, $\varphi = \sqrt{\ln(1+CV)}$ and $\tau = \ln(\overline{q}) - \frac{\varphi^2}{2}$ is the mean of the log normal distribution. For ocean quahog ESB data, the mean of the prior $\overline{q}$ = $ln(1) = 0$ if ESB data measure stock biomass accurately and CV=0.177 is the bootstrap coefficient of variation (standard deviation / mean) for the median survey dredge efficiency used in calculating ESB (Table A12).

Parameters estimated

KLAMZ models for ocean quahog in this assessment estimate either two or three parameters by maximum likelihood and numerical optimization. The three parameters potentially estimated are logarithms of: 1) biomass at the beginning of 1977, 2) escapement biomass (total biomass less biomass of new recruits) at the beginning of 1978, and 3) annual recruitment biomass (which is assumed constant over time for each region). In models where recruitment estimates were very low, recruitment was fixed at an assumed value that was nearly zero (1 kg y^{-1}) and the other two parameters were estimated.

Fishing mortality rates are calculated solving the catch equation numerically. Survey scaling parameters were calculated using a closed form maximum likelihood estimator.

Variance estimates

Variances for biomass and fishing mortality estimates and for model parameters can be estimated by the delta method using exact derivatives calculated by AD Model Builder libraries or by bootstrapping (Appendix A5). Estimates in this assessment were from the delta method.

KLAMZ Results-DMV

As in the previous assessment (NEFSC 2004), estimated recruitment was near zero and hard to estimate in preliminary runs for DMV. The annual recruitment level was therefore fixed at very low value (1 kg y^{-1}) in final runs.

The KLAMZ model for ocean quahog in the DMV area (Figure A48) fit NEFSC survey and LPUE data well (LPUE data did not affect model estimates). The CV of arithmetic scale residuals (26%) for NEFSC survey data was smaller than the mean CV (32%) for mean kg/tow survey data but within the range of observed values (21%-53%). The estimated survey scaling parameter for ESB data was Q=0.98 indicating that the model was able to match the observed ESB biomass levels on average during 1995-2005 using the catch data and trends in NEFSC survey data.

Biomass estimates for DMV declined steadily after 1978. Estimated fishable biomass during 2005 was 34% of the estimate for 1978 (Figure A48). During 2005, fishable biomass was 101,000 mt (CV 18%) and mean fishing mortality was 0.0094 y^{-1} (CV 18%).

KLAMZ Results-NJ

The KLAMZ model for ocean quahog in the NJ area (Figure A49) fit NEFSC survey and LPUE data well (LPUE data did not affect model estimates). The CV of arithmetic scale residuals (32%) for NEFSC survey data was larger than the mean (19%) and range (14%-24%) of CV values for mean kg/tow survey data. The estimated survey scaling parameter for ESB data was Q=0.95 indicating that the model was able to match the observed ESB biomass levels on average during 1995-2005 using the catch data and trends in NEFSC survey data.

Biomass estimates for NJ declined steadily after 1978. Estimated fishable biomass in NJ during 2005 was 44% of the estimate for 1978. During 2005, fishable biomass was 401,000 mt (CV 17%) and mean fishing mortality was 0.0017 y^{-1} (CV 17%).

KLAMZ Results-LI

The KLAMZ model for ocean quahog in the LI area (Figure A50) fit NEFSC survey data well. The model fit LPUE data well (Figure A50) except during early years (1986-1993) when the fishery was becoming established and LPUE was relatively high but falling rapidly reflecting, perhaps, fishing down on the very best ocean quahog beds (LPUE data did not affect model estimates). The CV of arithmetic scale residuals (28%) for NEFSC survey data was larger than the mean (19%) and at the upper bound of the range (14%-28%) of CV values for mean kg/tow survey data. The estimated survey scaling parameter for ESB data was Q=1.0 indicating that the model was able to match the observed ESB biomass levels on average during 1995-2005 using the catch data and trends in NEFSC survey data.

Biomass estimates for LI increased steadily after 1978 until 1992 when fishing mortality increased to maximum levels. Estimated fishable biomass in LI during 2005 was 94% of the estimate for 1978 and 90% of the maximum estimated biomass during 1992. During 2005, fishable biomass was 678,000 mt (CV 18%) and mean fishing mortality was 0.016 y^{-1} (CV 18%).

KLAMZ Results-SNE

The KLAMZ model for ocean quahog in the SNE area (Figure A51) did not fit NEFSC survey data or LPUE data as well as for other areas (LPUE data did not affect model estimates). Predicted survey values from the KLAMZ model decreased slowly in all years. Trends is fishable biomass based on mean survey kg/tow and LPUE data suggest an increasing trend in biomass before 1994 and a decreasing trend afterwards. These patterns are discussed in detail below.

The CV of arithmetic scale residuals (24%) for NEFSC survey data was smaller than the mean 29%) but within the range (18%-47%) of CV values for mean kg/tow survey data. The estimated survey scaling parameter for ESB data was Q=0.99 indicating that the model was able to match the observed ESB biomass levels on average during 1995-2005 using the catch data and trends in NEFSC survey data.

Biomass estimates for SNE decreased steadily after 1978 until 1996 when landings and fishing mortality increased to peak levels. After 1996, biomass decreased at a slightly faster rate. Estimated fishable biomass in SNE during 2005 was 75% of the estimate for 1978. During 2005, fishable biomass was 595,000 mt (CV 18%) and mean fishing mortality was 0.003 y^{-1} (CV 18%).

Uncertainty about historical estimates and hypotheses about lack of fit

The apparent lack of fit to survey trend and LPUE data for SNE contributes uncertainty to historical biomass estimates but has little effect on estimates for recent years which were anchored by efficiency corrected swept area biomass data. However, future assessments should consider more complicated models that address hypotheses described below that might explain upward trends in fishable biomass prior to 1994 and decreasing trends afterwards.

It is possible that the upward trend in LPUE during 1984-1993 reflects an exploration phase during which the fishery searched for and located prime fishing grounds. However, this explanation does not apply to survey trend data.

Changes in recruitment patterns and the assumption of constant recruitment in the KLAMZ model might explain the difference between trends in KLAMZ model estimates and survey trend and LPUE data. However, survey trends in fishable biomass are not consistent with survey length and recruit trend data. In particular, survey length data (Figure A26) and survey recruit abundance data (Figure A21) do not suggest strong recruitment prior to 1994 and weak recruitment afterwards. Survey length data for 1980-1994 do not show a mode of small ocean quahog recruiting to fishable size while survey trend data and LPUE were increasing. Survey length data after 1994 do not show reductions in recruits while survey trend and LPUE data were decreasing. Survey recruit abundance data seem, in particular, to suggest higher recruitment after 1994.

Changes in landings and fishing mortality may explain the trends in survey trend and LPUE data. Annual landings were low (0 to 1,000 mt) during 1978-1994 while the survey trend and LPUE data were increasing. After 1994, landings increased dramatically (2,000 to 9,000 mt) during while survey trend and LPUE data were decreasing.

KLAMZ–methods for GBK trial and sensitivity runs

For the first time, the KLAMZ model was applied to GBK on a trial basis and to conduct sensitivity analyses. The trial run indicated increasing biomass in GBK since 1986. Rapidly increasing biomass estimates were due to the short and noisy survey trend data for GBK (Figure A20) and in particular the relatively low 1990 survey observation. The sensitivity analysis consisted of a run with the 1990 survey observation omitted.

The KLAMZ model for GBK covered 1986-2002 using NEFSC clam survey data for the same period when sampling was relatively consistent in all strata (Table A8). Survey data for 1994 were excluded due to problems with the pump voltage. Catches were zero in all years. In other respects, the configuration of the KLAMZ model for GBK was identical to the configuration used for ocean quahog in other stock assessment areas.

Based on Lewis et al. (2001), ocean quahog growth is faster on Georges Bank than in southern areas. A von Bertalanffy growth curve was therefore fit to weight at age information for ocean quahog in GBK to obtain growth parameters used in the KLAMZ model. The weight at age information was obtained by converting Lewis et al.'s (2001) growth curve for length to meat weight at age using length-weight parameters for GBK (Table A9). The resulting von Bertalanffy curve for growth in weight ($W_a = 41.07\left(1-e^{-0.04525(\mathrm{a}-0.3695)}\right)$ where W_a was meat weight (g) at age a years) closely approximated the weight at age information. The growth parameters used in the KLAMZ model were $\rho=e^{-0.04525}= 0.9558$ and $J = {w_{k-1}}/{w_k}$ = 15.59/16.66 = 0.9362 where w_k was the meat weight at age 13 which is approximately when ocean quahog reach 70 mm SL and become available to fishing (if fishing occurs).

Confidence intervals for estimated biomass on GBK were computed assuming that errors were from a lognormal distribution. In particular, the 95% bounds for the biomass estimate B were computed $Be^{\pm 1.96\sigma}$ where $\sigma = \sqrt{\left(1+CV^2\right)}$ and CV is the arithmetic scale coefficient of variation. The CV was the ratio of the biomass estimate and arithmetic standard deviation estimated in the KLAMZ model using AD-Model builder libraries and the delta method.

Recruitment and surplus production rates from the KLAMZ model for GBK were compared to results from the LI region where a strong recruitment event occurred and where biomass appears to have increased at least slightly during some years (Figure A50). Recruitment estimates (assumed constant) in the two regions were divided by the area (nm^2) of each region to make estimates for the two regions comparable on a per unit area basis. The annual instantaneous surplus production rate for each region is $\overline{P} = \overline{G} + \overline{r} - M$ where $\overline{G}$ and $\overline{r}$ are average rates for somatic growth and recruitment. The average growth rate is the mean of annual rates which are computed automatically in KLAMZ (Appendix A5). The average recruitment rate is the mean of annual recruitment rates which were computed $r_t = R_t / \overline{B}_t$ with the average biomass during each year $\overline{B}_t$ computed automatically in KLAMZ (Appendix A5).

KLAMZ–results for GBK trial and sensitivity runs

The estimated trends from KLAMZ model runs for GBK (Figures A52-A53) were judged implausible and not used for GBK because of the short survey time series (six observations during 1986 to 2002), frequency of survey strata that were not sampled

(Table A8), lack of catch data due to no fishing on GBK, no contrast in biomass levels due to catch that are usually used in stock assessment modeling to measure stock productivity, interannual variability and lack of consistent trend in survey data over time, statistically insignificant trend in survey data (see below under the heading "GBK at virgin biomass?"), lack of LPUE data to serve as corroboration, lack of evidence for recruitment in survey length data, and lack of historical biomass estimates for 1978 that might be used to calculate historical biomass. In addition, KLAMZ model estimates for GBK seemed implausible because the average surplus production rate and average recruitment per unit area for GBK were substantially higher than estimates for LI where a strong recruitment trend occurred and where biomass levels may have increased.

The trial model fit NEFSC clam survey data after 1994 better than before 1994 (Figure A52). With the 1998 survey observation omitted, the model fit was much better (Figure A53). The estimated survey scaling parameter for ESB data was Q=0.98 in both runs indicating that the model was able to match the observed ESB biomass levels during 1995-2005.

In the trial run (Figure A52), estimated biomass increased by about 99% from 735,000 mt during 1985 to 1,466,000 mt during 2002 (5% per year). Means for annual recruitment and surplus production rates on GBK during 1985-2002 were 2.3 and 8.8 times larger than for LI. Mean recruitment per unit area on GBK (Figure A52) was twice as high as on LI. The 95% confidence interval for trends in estimated biomass (Figure A52) was broad and, at the extremes, included scenarios with stable trends.

In the sensitivity run omitting the 1989 survey (Figure A53), the increasing trend in biomass was not as steep. In particular, estimated biomass increased by about 48% from 940,000 mt during 1985 to 1,389,000 mt during 2002 (2.4% per year). Means for annual recruitment and surplus production rates on GBK during 1985-2002 were 1.6 and 5 times larger than for LI. Mean recruitment per unit area on GBK (Figure A54b) was 1.5 times as high as on LI. The 95% confidence interval for trends in estimated biomass (Figure 56) was broad and largely compatible with scenarios with stable trend.

"Best" Estimates

KLAMZ model estimates were used at the best source of information about DMV, NJ, LI, and SNE during 1977-2005. VPA estimates were used for SVA and efficiency correct swept area biomass estimates were used for GBK (VPA and efficiency corrected swept-area biomass estimates for GBK are the same because no fishing has occurred there). NEFSC (2004) used VPA estimates for LI instead of KLAMZ model estimates. However, KLAMZ model estimates appear useful with addition of the 2005 survey data.

Biomass of ocean quahog and the entire stock less GBK during 1978-2005 was estimated by summing best estimates for each stock assessment area. Fishing mortality in large areas was computed by solving the catch equation with total catch, total biomass and M=0.02 y^{-1}. CV's were not calculated for whole stock biomass or fishing mortality estimates because of difficulties accommodating covariance in the estimates for individual area that was due to using the same survey efficiency estimates as prior information.

Best estimates (Table A20 and Figure A54) show declines in ocean quahog biomass for southern regions (SVA, DMV and NJ) where the fishery has been continually active. In particular, biomass during 2005 was 5%, 34% and 44% of biomass during 1978 for SVA, DMV and NJ (Table A21).

Best estimates of biomass in northern regions, which did not support the fishery until recently (LI, SNE and GBK), are relatively flat and stable. LI biomass actually increased during 1978-1992 before fishing occurred. Biomass during 2005 was 94%, 75% and 100% of biomass during 1978 for LI, SNE and GBK (Table A21). Biomass during 2005 was 76% and 66% of biomass during 1978 for the entire stock and the entire stock less GBK (Table A21).

Best estimates of fishing mortality rates (Figure A55) for southern areas where the fishery has been continually active (SVA, DMV and NJ) peaked during the late 1980's and early 1990's then declined as fishing effort shifted towards the north (Figures A4-A6 and A11). Fishing mortality rates in northern areas (Figure A55) were nearly zero before 1990 and increased substantially in later years as fishing effort shifted towards the north. Fishing mortality rates for the entire stock increased from about 0.003 y^{-1} during 1978 to an average of about 0.006 y^{-1} (0.010 y^{-1} for the entire stock less GBK) during the early 1990s through 2005.

Proportions of total fishable biomass at various density levels

Best biomass estimates and survey data were combined to partition best biomass estimates into components found in areas with a range of biomass density levels. Biomass density is important to profitability of the ocean quahog fishery because it determines commercial catch rates. Biomass density was measured as survey catch per tow (fishable kg/tow) because commercial catch rate data for random locations and the entire stock area were not available. The analysis used random NEFSC clam survey tows during 1980-2005 (1994 excluded) that were in areas deep enough (≥20 m) to be ocean quahog habitat. All survey data was from random stations so that the survey data would measure survey catch rates across the study area on average.

Survey data for stock assessment regions other than GBK were grouped into ten-year time intervals to increase sample size. Five surveys during 1980-1989, three surveys during 1990-1999 (excluding 1994), and two surveys during 2000-2005 were used in the analysis. Survey data for GBK were grouped into two intervals 1966-1992 and 1997-2002 and analyzed as a single group (1966-2002) because GBK was covered in fewer surveys and sample size was lower. The 1994 survey was excluded from all analyses because of problems with survey dredge efficiency and electrical voltage of current supplied to the pump.

Survey tow data were grouped by 5 kg/tow biomass density categories (e.g. catches of 0-4.9 kg/tow were assigned to the same biomass density category). The grouped data were used to calculate the proportion of fishing grounds occupied by ocean quahog at each biomass density level, as well as the proportion of fishable biomass on fishing grounds at each biomass density level (see below).

Proportions of fishable biomass in one region during a single time period were calculated:

$$X_L = \frac{p_L K_L}{\sum_j p_j K_j}$$

where p_L is the proportion of random survey tows in biomass density category L, K_L is mean survey fishable kg/tow for random stations in the same biomass density category, and the summation in the denominator is over all biomass density categories. The percentage of random tows in each biomass density category p_L is an estimate of the proportion of fishing grounds in each biomass density category. Total biomass at each density level during 2005 was calculated by multiplying the proportions X_L for each region by the best estimate of total biomass in each region.

Results (Table A17) show reductions in the proportions of areas with high catch rates (p_L) and the proportion of total stock biomass in areas of high catch rates (X_L) within the southern DMV and NJ stock assessment regions where the most of the fishing for ocean quahog occurred historically. Proportions were variable in LI and SNE where less fishing has occurred.

During 2005 (Table A18), the largest component (19% or 575 thousand mt meats) of total fishable stock biomass was on GBK in the highest (25+ kg/tow) biomass density category. In contrast, stock biomass levels in density categories larger than 10 kg/tow were low for other regions.

Building a bridge

Best estimates in this assessment are higher than in the previous assessment (NEFSC 2004) due mostly to the change in estimated survey dredge efficiency (Table 21). As expected, the ratios between current and previous biomass estimates were similar to ratios for efficiency corrected swept area biomass levels (Table A19).

GBK at virgin biomass?

This section describes a hypothesis that fishable biomass on GBK has increased substantially since 1978 due to relatively fast growth and recruitment. The hypothesis is new and untested for GBK which has never been fished and is usually assumed to be at a high "virgin" level. The hypothesis is important because it affects estimates of stock productivity, decisions about biomass reference points (i.e. virgin biomass) and stock status determinations. No fishing occurs on GBK due to potential for PSP contamination, but experimental ocean quahog fisheries in the area are planned. Reviewer's comments and suggestions are important and will be considered in the next assessment. However, they will not affect choice of the best biomass estimates for this assessment.

Best estimates for GBK in this and recent assessments assume a flat biomass trend since 1978 at an equilibrium "virgin" level (NEFSC 2000; NEFSC 2004). In particular, averages of efficiency corrected swept area biomass estimates during 1997-2002 were used as estimates of average biomass over longer time periods. As described above, preliminary KLAMZ model runs for GBK are not suitable for estimating long term trends in ocean quahog biomass at this time primarily due to limited prior to 1986.

Analysis of NEFSC survey data for GBK is complicated because survey coverage tends to be spotty on GBK (Table A8). During 1986-2002, survey coverage was relatively complete but 14% (18 out of 126) strata had no tows in a given year (Table A8). Only five strata (55, 57, 59, 71 and 73) were sampled during all seven years. As described above, the survey during 1994 is not comparable to other surveys during 1986-2002 because of voltage problems. Thus, only six survey observations are available for analyzing trends in ocean quahog recruitment and biomass on GBK.

Lewis et al. (2001) carried out a spatially detailed analysis of NEFSC survey data for GBK focusing on growth, spatial patterns in length composition and trends in abundance by size. The major finding was that small ocean quahog were present and that recruitment was apparently occurring on GBK during the 1990s. Lewis et al. (2001) noted that size distributions from the 1980s had a single mode and were dominated by large individuals, 75-90 mm SL. In contrast, bimodal size distributions were observed and small individuals (< 70 mm SL) often represented 20-50% of the catch in numbers at stations during the 1990s along the southeast flank of GBK. The small individuals were attributed to spawning during the 1980s. Lewis et al. (2001) did not evaluate the potential contribution of small ocean quahog to the fishable biomass for the stock as a whole.

Lewis et al. (2001) estimated a a von Bertalanffy growth curve for GBK that showed faster growth to maximum size than the growth curve for ocean quahog in the Mid-Atlantic Bight (Figure A56). Faster growth should result in higher productivity on GBK. Based on both growth curves, ocean quahog growth is relatively rapid during the first years of life and much slower in older individuals as they grow large enough to enter the fishery. The size at 50% selectivity to the commercial fishery (72 mm SL) is a reference point that separates recruits and the fishable stock. At 72 mm SL, ocean quahog on GBK grow about 1.5 mm SL per year while ocean quahog in other areas grow about 0.8 mm SL per year (Figure A56). The corresponding percentage increase in meat weight growth at 72 mm is 6% per year for GBK and 3% per year for other areas (Figure A56).

Survey length data

The survey length composition data presented in this assessment and used by Lewis et al. (2001) show that small ocean quahog and presumably recruitment occurs throughout the range of the ocean quahog stock (Figure A26 and see Section 7). The clearest example is in LI where length compositions during the 1970s and 1980s have an obvious mode due to recruitment of small individuals. As pointed out by Lewis et al. (2001), small ocean quahog were more common on GBK after 1990 and this pattern is evident in length composition data used in this assessment (Figure A26). Compared to other areas, however, length composition data for GBK are stable with relatively few small individuals and little apparent recruitment (Figure A26).

It is unlikely that ocean quahog in GBK too small to be taken in the survey (< 50 mm SL) are escaping detection by growing to fishable size during the time between surveys. Annual growth increments in GBK are 3 mm for ocean quahog 50 mm SL and increments decrease with size. Thus, a small 50 mm SL ocean quahog would be expected to growth to no more than 59 mm SL during the three year interval between surveys. Moreover, based on the growth curve for TBK, ocean quahog 50 mm SL are about age 4 y and recruits to the fishable stock at 70 mm SL are about age 14 y so that at least 10 y would be required to grow to fishable size from 50 mm SL.

Trends

Survey trends were computed for 1986-2002 (excluding 1994) using data (uncorrected for survey gear selectivity, Table A23) for ocean quahog < 70 mm SH (mean numbers per tow to measure recruitment) and ≥ 70+ mm (mean weight per tow to measure recruited stock biomass). Strata with no tows were filled by borrowing (see above), which is the standard procedure for ocean quahog.

The time series of mean weight per tow biomass indices for GBK are short (6 data points, Figure A57) but seem to suggest increasing trends. Regression lines fit to the two time series seem to indicate that biomass of ocean quahog 70+ increased rapidly and that biomass of smaller ocean quahog <70 mm increased slowly during 1986-2002. Neither regression was statistically significant (*p-value*=0.43 for ocean quahog < 70 mm SL and *p-value*=0.21 for ocean quahog 70+ mm). The apparently increasing trends were due largely to relatively low mean kg/tow in the 1989 survey (Figure A57).

6.0 BIOLOGICAL REFERENCE POINTS (TOR-3)

The Atlantic Surfclam and Ocean Quahog Fishery Management Plan (FMP, Amendment 12) defines biological reference points used as management targets and thresholds for stock biomass and fishing mortality. Targets are intended to represent desirable stock conditions. Thresholds are intended to identify overfishing (fishing mortality too high) and overfished (stock biomass too low) stock conditions.

Biological reference points used in managing US fisheries including the fishery for ocean quahog are linked in policy and law to maximum sustained yield (MSY) concepts. In particular, the overfishing threshold is meant to be smaller than or equal to F_{MSY}, the fishing mortality rate that provides MSY. Fishing mortality levels higher than F_{MSY} constitute overfishing.

The biomass and fishing mortality targets specified in the FMP for ocean quahogs are $B_{Target} = B_{MSY}$, which is assumed be one-half of the virgin biomass *for the whole stock*, and $F_{Target} = F_{0.1}$ *for the exploited region* (whole stock less GBK) The biomass and fishing mortality thresholds are $B_{Threshold} = ½ B_{MSY}$ and $F_{Threshold} = F_{25\%}$ (the fishing mortality rate that reduces life time egg production for an average female to 25% of the level with no fishing). The FMP does not specify whether the thresholds apply to the whole stock or exploited region only.

Biological reference points for ocean quahog defined in the FMP were recalculated for this assessment resulting in substantial changes to $F_{25\%}$ and F_{MAX} (the fishing mortality rate that maximizes yield per recruit). The new and old estimates for $F_{0.1}$ are similar (Table A24 and Figure A58). Sensitivity analysis indicates that assumptions about natural mortality had substantial effect on estimated reference points (Table A24).

In recalculating biological reference points, the Invertebrate Subcommittee noted that the current threshold reference point for fishing mortality (new estimate $F_{25\%}$=0.0517 y^{-1}, Table A24) is a poor proxy for F_{MSY} in a long-lived species like ocean quahog with natural mortality rate M=0.02 y^{-1} (Clark 2002; Thorarinsdottir and Jacobson 2005). From a purely technical perspective, it would be advantageous to reconsider biological reference points in the FMP for ocean quahog and their application to the entire or exploited portions of the stock.

Simulation analyses in Clark (2002) show that the highest sustainable catches for long lived stocks like ocean quahog are achieved when lower fishing mortality rates are applied at relatively high stock biomass levels. The same simulations show that fishing at $F_{25\%}$ would eventually depress stock spawning stock biomass to less than 25% of the virgin level, a level likely far below B_{MSY}. In the simulations, long-term yield from unproductive stocks was maximized at fishing mortality rates lower than $F_{50\%}$ (Clark 2002). Fortunately, the ocean quahog fishery is currently managed under an individual ITQ system with a quota on landings that keeps fishing mortality rates lower than both $F_{0.01}$ and $F_{25\%}$. The current quota is based on market demand and other economic factors.

Revised biomass reference points (building a bridge)

New proxies for virgin biomass and B_{MSY} in this assessment are substantially larger than in NEFSC (2003). The proxy for virgin ocean quahog biomass was recalculated using the best estimates of stock biomass during 1978 for each region (3.973 million mt including GBK, Table A20). The proxy for B_{MSY} (½ virgin biomass) in this assessment 1.987 million mt including GBK. Proxies for virgin biomass and B_{MSY} in NEFSC (2004) were smaller (3.3 and 1.5 million mt). The new estimates are larger mainly because of changes in survey dredge efficiency estimates (e=0.165 instead of 0.269-0.346). In addition, the new reference points are fishable biomass rather than biomass 70+ mm SL.

Fishing mortality reference points (building a bridge)

Biological reference points for fishing mortality were calculated for ocean quahog in this assessment using a length-based per-recruit model that is part of the NEFSC Stock Assessment Toolbox.[6] The length-based model is similar to the Thompson and Bell (1934) age-based model except that selectivity, maturity and growth are specified in terms of length, rather than age. The length-based approach is advantageous for ocean quahog because fishery selectivity and maturity are better known in terms of length than age (Figure A59).

Biological assumptions for reference point calculations in this assessment were generally comparable to assumptions in the last assessment (Figure A60). The ascending logistic fishery selectivity curve in per recruit model calculations was the same as in calculation of fishable survey biomass trends. The von Bertalanffy growth curve for length at age was the same as used earlier in this assessment for the MAB (Figure A59). Length-weight parameters ($ln(\alpha)$ = -9.242, β = 2.821) were averages for the stock as a whole.

Maturity at length was from Thorarinsdottir and Jacobson (2005) for ocean quahog in Icelandic waters with 10%, 50% and 90% of female ocean quahog mature at 40, 64, and 88 mm SL (2, 19, and 61 y, based on the growth curve in Figure A59). Based on the size range of samples (G. Thorarinsdottir, pers. comm..), the maturity curve is probably valid for ocean quahog in the size range used to estimate fishing mortality.

Maturity information for ocean quahog in the US EEZ is scant (see review in Cargnelli et al. 1999) but all available information and age-based per-recruit model calculations in the last assessment are compatible with the maturity at length estimates for ocean quahog in Icelandic waters (Figure A60).

7.0 STOCK STATUS (TOR-4)

Ocean quahog in the US EEZ are not overfished and overfishing is not occurring. Stock biomass during 2005 was 3.039 million mt (Table A20) and above the revised management target of ½ virgin biomass = 1.987 million mt (Figure A61). The fishing mortality rate during 2005 (all areas but GBK) was F= 0.0077 y^{-1} (Table A20), which is below the revised management target level $F_{0.1}$ = 0.0278 y^{-1} (Figure A61)

[6] Contact Alan Seaver (Alan.Seaver@noaa.gov), Northeast Fisheries Science Center, Woods Hole, MA, USA for information and access to the Stock Assessment Toolbox.

Biological condition of the entire EEZ stock

The ocean quahog population is a relatively unproductive with total biomass gradually approaching the B_{MSY} reference point (½ virgin biomass, estimated as 50% of biomass during 1978) gradually after about three decades of relatively low fishing mortality (Table A20 and Figures A54-A55).

Based on survey data (Figure A20), LPUE data (Figure A8) and best estimates for 1977-2005 (Figure A54), declines in stock biomass are most pronounced in southern regions (SVA, DMV and NJ) where the fishery has been active longest. In particular, stock biomass was below the ½ virgin level during 2005 in SVA, DMV and NJ (Table A21).

An increasingly large fraction of the stock (42% during 2005 compared to 38% during 1978, Table A25) is in northern regions (LI and SNE) where fishing is relatively recent and in the GBK region, which is not fished due to risk of PSP contamination (Figure A54).

Fishing effort and mortality

Fishing effort has shifted to offshore and northern grounds over time as catch rates and abundance in the south declined (Figures A2, A4, A8 and A54). Analysis of LPUE data for individual 10' squares indicates considerable fishing down on fishing grounds that historically supplied the bulk of landings (Figures A13-A15). There is no clear indication that LPUE increased on historical grounds after fishing effort was reduced.

Fishing mortality rates during 2005 are relatively low for the entire stock (F=0.0045 y^{-1}) and for the fishable stock (F=0.0077 y^{-1}), which excludes GBK (Figure A55). Fishing mortality rates in the south where biomass was relatively low during 2005 decreased substantially over the last decade to low levels (F = 0.0, 0.0094 and 0.0017 y^{-1} for SVA, DMV and NJ) during 2005. Fishing mortality rates for LI increased abruptly during 1992 as effort increased, declined and then increased to F=0.0145 y^{-1} in 2005. The fishing mortality rate in LI during 2005 is comparable to fishing mortality rates in southern areas as they were fished down to relatively low biomass levels.

Productivity under fishing

Questions about the potential productivity of ocean quahog are becoming important as the stock is fished down from high virgin levels to B_{MSY}. Uncertainties about productivity are close related to choice of an accurate F_{MSY} proxy and other decisions that affect sustainability and fishery profitability.

Ocean quahog in the EEZ do not currently show a clear increase in stock productivity, due to higher recruitment and increased growth rates, that would be expected as biomass declines to B_{MSY} levels. Given the long periods between settlement and recruitment and slow growth once ocean quahog reach fishable size, any increase in stock productivity may be delayed (Powell and Mann 2005).

Recruitment events appear to be regional and sporadic (i.e. often separated by decades). Survey length composition data show that recruitment occurs throughout the resource sporadically and at an apparently low rate. Based on survey length composition data, some recent recruitment is evident in DMV, NJ, LI, SNE and GBK during recent years (Figure A26). Lewis et al. (2001) describe recruitment on GBK during the 1990s. Powell and Mann (2005) used a lined commercial dredge on a directed survey during 2002 and detected recruitment in some regions across the Mid-Atlantic Bight. Slow growth at sizes large enough to recruit to the fishery probably reduces the contribution of new recruits to fishery productivity (A62).

Information about growth of ocean quahog is sparse (Lewis et al. 2001). It is not possible to detect potential changes in growth at this time or to detect differences among regions (other than in GBK).

Biological condition of ocean quahog in Maine waters

The State of Maine carried out a survey and a stock assessment was completed for a portion of the ocean quahog stock in Maine waters (Russell 2006). The survey and assessment cover the principal fishing grounds in Maine waters. The fishery and biological characteristics of ocean quahog in Maine coastal waters are unique. In particular, the fishery targets small ocean quahogs for sale on the half shell market at prices roughly ten times the price paid in the rest of the EEZ. Most of the information in this section is from the assessment report for Maine waters (Russell 2006).

Biological and fishery information for Maine waters were used in the length based per recruit model (also used for the rest of the EEZ, see Section 6) to estimate conventional biological reference points for *Maine waters* only. In particular, F_{MAX} = 0.0561, $F_{0.1}$ = 0.0247 and $F_{50\%}$ = 0.013 y^{-1} for ocean quahog in Maine waters.

Assessment results for Maine show relatively high levels of fishing effort (Figure A4) and landings in recent years (Figure A2). LPUE levels have declined since the peak in 2002, but remain at relatively high levels overall (Figure A8).

Based on survey results and dredge efficiency estimates, stock biomass available to the fishery during 2005 was about 22,493 mt meats. In comparison, catch (landings plus a 5% incidental mortality allowance) during 2005 was 505 mt meats. The biomass estimate and catch data are for the area surveyed which includes the main areas of commercial fishing in Maine waters. Biomass in Maine waters is underestimated to the extent that it excludes ocean quahog outside the area where fishing occurs and the survey was carried out.

Fishing mortality during 2005 the assessed was estimated to be $F = 505 \div 22{,}493 = 0.022\ y^{-1}$, which is almost equal to $F_{0.1} = 0.0247^{-1}$ calculated from a per recruit model for ocean quahog in Maine waters. The $F_{0.1}$ estimate for Maine waters has no special significance in policy because, based on the FMP, biological reference points used in defining management targets and thresholds are estimated for and applied to the entire stock.

Management goals have not been described for ocean quahog in Maine waters but maximization of long term catch is a likely candidate. Based on simulation analyses for long-lived and unproductive fish species (Clark 2002), fishing mortality rates as low as $F_{50\%}$ =0.013 y^{-1} may be required if spawning stock must be conserved to maximize long term catch levels.

The importance of maintaining spawning stock in Maine waters may be low if the bulk of recruits originate in the EEZ outside of the relatively small Maine fishing grounds. In that case, $F_{0.1}$=0.0247 y^{-1} might be useful reference point for maximizing long term catch because it would probably provide relatively high levels of yield while preserving some spawning potential. If spawning biomass in Maine waters is completely irrelevant, then long term catch might be maximized by fishing at F_{MAX} = 0.0561 y^{-1}. However, F_{MAX} is likely to require high levels of fishing effort and the estimate of F_{MAX} is sensitive to small changes in growth and fishery selectivity parameters.

8.0 TAL and PROJECTIONS (TOR-5 & 6)

Under current quota regulations, annual total allowable landings (TAL) for ocean quahog during 2007 is 24,190 mt meats (5.333 million bushels). The quota and TAL will result in a fishing mortality rate of approximately $F = 24{,}190 \div 1{,}775{,}000 = 0.014$ y^{-1} for the exploitable portion of the stock (excluding GBK) and $F = 24{,}190 \div 3{,}039{,}000 = 0.008$ y^{-1} for the stock as a whole if biomass during 2007 is similar to biomass during 2005 (1,775 and 2,698 million mt). TAL levels for longer time periods and for constant levels of fishing mortality can be calculated by projection, as described below.

Projections

A simple method for making short term projections for ocean quahog biomass, catch and fishing mortality is demonstrated in this section with example calculations. Example calculations assume either: 1) constant regional catch at 4, 5.33 and 6 million bushels; 2) constant fishing mortality at the manager's target level, $F_{0.1} = 0.0275$ y $^{-1}$. In the calculations wit $F_{0.1}$, for example, predicted landings could be used as TAL.

All projection calculations use the following equations to represent biomass dynamics:

$$X = G + r - M - F$$
$$B_{t+1} = B_t e^X$$
$$F = \frac{C}{B} \quad or \quad C = FB$$

where X is the net instantaneous annual rate of change, G is the instantaneous rate for somatic growth in weight, r is the rate for recruitment, $M = 0.02$ y^{-1} is the natural mortality rate, C is catch (e.g. quota for landings + 5%), and B is fishable biomass.

When catch is assumed known, the fishing mortality rate F can be calculated iteratively (e.g. Solver in Excel). When F is known, catch can be calculated directly.

Input data for projections are summarized in Table A26. Estimates of initial biomass (in 2005) and fishing mortality during 2005 were best estimates from Table A15. Catches (landings + 5%) in 2006 are assumed to be the same as in 2005. In projections with constant $F = F_{0.01} = 0.0278$ y^{-1} for exploited regions (excluding GBK) the proportions of catch in each region during 2006-2010 are assumed to be the same as in 2005. In projections for GBK, which is virgin and normally assumed to be at equilibrium carrying capacity in stock assessment work, rates for fishing mortality, natural mortality, growth and recruitment were zero so that stock biomass in GBK did not change over time. All of the projections suggest that the stock as a whole will continue to decline gradually over time (Table A27-A30). The decline is relatively rapid with $F = F_{0.01}$ (Table A31).

The method for ocean quahog is deterministic and does not consider natural variability in recruitment, growth or natural mortality. However, uncertainty in short term projections is primarily due to uncertainty in initial biomass estimates. Recruitment, natural mortality and growth of ocean quahog occur at low rates that have little effect on short term projections. Thus, CVs for efficiency corrected swept area biomass during 2005 (see below) can serve as reasonable measures of uncertainty in projections.

CVs for projected biomass levels from Table A15.							
SVA	DMV	NJ	LI	SNE	GBK	Total less GBK	Total
104%	55%	30%	31%	36%	32%	24%	24%

If uncertainty in short-term biomass projections is lognormal, then bounds for an asymmetric 95% confidence interval around projected biomass can be computed $Be^{\pm 1.96\sigma}$ where $\sigma = \sqrt{\ln\left(CV^2 + 1\right)}$.

9.0 RESEARCH RECOMMENDATIONS (TOR-7)

Recommendations from the previous assessment and new research recommendations are described sequentially.

Recommendations from last assessment

- A complete survey and a valid survey dredge efficiency estimate are needed by the State of Maine to assess ocean quahogs off the coast of Maine.

A directed survey for ocean quahog that covered the main fishing grounds in Maine waters was completed by the Maine Department of Marine Resources during 2005 (Russell 2006). Data from box core and dredge sampling during 2006 were used to estimate survey dredge efficiency. The 2005 survey and efficiency estimate were used to estimate fishing mortality and biomass for ocean quahog in Maine waters (Russell 2006).

- Explore whether efficiency of the DE-II dredge and commercial dredges are affected by depth, sediment type, and clam density. This could be examined experimentally, or by having an efficient commercial dredge repeat stations sampled by the RV DE-II. Also, evaluate non-extractive methods to estimate dredge efficiency and survey the resource.

Data collected during 2002 and new data collected during 2005 were examined in this assessment to determine if dredge efficiency depends on depth, sediment type or clam density. Additional data and analysis are required, however, to address this research recommendation. Non-extractive methods for estimating dredge efficiency were not investigated.

- Identify whether there are major differences in life histories and population dynamics between regions, and consider treating the EEZ stock as metapopulations.

A review of life history characteristics and analysis of population dynamics of ocean quahog in Maine waters was completed (Russell 2006). Alternate spatial based management approaches were not addressed in this assessment.

- Consider using ecological estimates of carrying capacity (based on available food, maximum size, predation, amount of suitable habitat) to evaluate/validate model estimates of virgin biomass.

Ecological estimates of carrying capacity were not addressed in this assessment. However, information suggesting that ocean quahog biomass on GBK (a virgin area) is increasing was examined and presented for review.

- Re-examine the rate of incidental mortality to ocean quahogs caused by commercial dredges.

No new field work or data analysis were carried out to address the research recommendation.

- Consider applying the relative selectivity function to the entire survey time series.

A survey selectivity curve was estimated for ocean quahog in the EEZ and a fishery selectivity curve estimated for ocean quahog off Iceland were used to better interpret survey data.

- Consider whether future stock assessment models should be based on age and abundance, rather than shell length and weight.

No progress.

- There is little information regarding F_{MSY} and B_{MSY} or suitable proxies for long lived species like ocean quahog. Traditional proxies (e.g., $F_{MSY} = F_{25\%\ MSP}$, $F_{MSY} = M$, $F_{MSY} = F_{0.1}$ and B_{MSY} at one-half virgin biomass) may be inappropriate for long lived organisms. The question of F_{MSY} and B_{MSY} proxies should be considered.

Traditional reference points from per recruit calculations were revised in this assessment using a new length based model and new estimates of fishery selectivity and maturity at length. Recent simulation work for long-lived rockfish and results for Icelandic ocean quahog were reviewed. The simulation results indicate that $F_{0.1}$ and $F_{25\%}$ are likely poor proxies for F_{MSY} in a long-lived organism like ocean quahog. Based on the simulations $F_{50\%}$ may be a better proxy. These issues could be taken up the next time the fishery management plan is revised.

- Survey coverage of Georges Bank needs to be a priority in NMFS EEZ survey. Strata along the Hague line may need to be re-stratified and biomass estimates recalculated to include only US areas.

GBK was not surveyed during 2005 due to competing priorities for sampling in southern areas. However, this remains an important issue, particularly in view of hypotheses that stock biomass is increasing on GBK. Different stratification schemes were not investigated.

- If the management system requires accurate position information (e.g. VMS) from fishery vessels, evaluate the possible improvements to assessments using catch and location information from this source.

The working group discussed this topic but it is not mentioned in the report because the discussions were preliminary.

- Investigate the use of survey data collected prior to 1978.

No progress.

<u>New Recommendations (not prioritized)</u>

- The *R/V Delaware II* may not be available for use on NEFSC clam surveys after 1998 and it appears likely that the clam survey will become a cooperative effort with sampling from a commercial vessel. Both the *R/V Delaware II* and commercial vessel should be used during 1998 so that catch rates, efficiency and selectivity patterns for the two vessels can be compared and calibrated. Planning should commence immediately.
- Fishing mortality and biomass reference points used as proxies for F_{MSY} and B_{MSY} should be reevaluated in the next assessment.
- Additional estimates of survey dredge efficiency from cooperative depletion studies are required.
- Develop a length (and possibly age) structured stock assessment model for ocean quahog that makes better use of survey and fishery length composition data which may provide better estimates of recruitment trends.
- Conduct further experimental work to determine the relationship between dredge efficiency, depth, substrate and clam density. A comprehensive study coincident with the next NEFSC clam survey would be most useful. The experimental design should include sufficient contrast in variables that may affect dredge efficiency.
- Cover GBK in the next NEFSC clam survey.
- Investigate the survey data from GBK during the 1989 survey to determine why it is low relative to survey observations during earlier years. This may be important in determining if biomass is increasing in GBK.
- Survey strata with no tows are a particular problem in the GBK region. The current procedure for filling holes in survey data involves borrowing data from adjacent surveys. This may not be optimal for ocean quahog surveys and GBK in particular. In the next assessment, consider filling holes in the GBK survey data using a model with stratum and year effects.
- Evaluate possible increasing trends in biomass for ocean quahog on GBK.
- Evaluate effects and contribution of recruitment to stock productivity.
- Improve estimates of biological parameters for age, growth (particularly of small individuals), and maturity for ocean quahog in both the EEZ and in Maine waters.
- Survey dredge and commercial dredge efficiency estimates should be reevaluated by field work during the next NEFSC clam survey. The next survey may be the last opportunity to estimate survey dredge selectivity. The commercial dredge selectivity curve was used in this assessment was estimated from field studies done off Iceland

where conditions may differ. Repeat tow experiments (i.e. survey stations reoccupied by commercial vessels) may be useful for this purpose.

- In the next assessment, projection calculations should be carried out using a model that is basically the same as the primary stock assessment model used to estimate biomass and fishing mortality (e.g. delay-difference population model in KLAMZ).
- Recommendations for future depletion studies.
    - It was difficult to find areas with high concentrations of ocean quahog for depletion experiment sites during 2005. However, areas with lower densities of ocean quahog can be used if depletion tow distance is increased.
    - Revised estimators for survey dredge efficiency based on commercial depletion experiments and setup tows use data for relatively large ocean quahog (i.e. 90+ mm) only. Future depletion sites should contain reasonably high densities of large individuals.
    - In future, every effort must be made to collect and record precise location data at short time intervals during depletion studies.
    - Collect length and bushel count data from survey and depletion tows more frequently (e.g. every 1-2 tows). It might be advantageous to measure fewer individuals sampled from more tows.
    - Analyze results from previous depletion studies to determine if differences between bushel counts and length composition data from different tows in the same depletion experiment are significantly different. Use the results to modify sampling protocols as appropriate.
    - Changes in length composition during a depletion experiment might be incorporated into efficiency estimation by, for example, including selectivity parameters in the Patch model. Efficiency estimates (and commercial selectivity) might be more precise because more size groups would be included in catch data.
    - It would be useful to analyze efficiency estimates in terms of season because ocean quahog are believed to change their depth in sediments on a seasonal basis.
- The next stock assessment should review the M=0.02 y-1 assumption for ocean quahog.
- In the next assessment, KLAMZ model runs with two recruitment parameters should be explored for LI and SNE. Survey length composition show more recruitment prior to 1994 than afterwards. Model fit was not as good for SNE as other stock assessment regions.
- KLAMZ model runs for GBK should be explored further in the next assessment.

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OCEAN QUAHOG TABLES

Table A1. Landings (1,000 mt meats) for ocean quahog during 1967-2005 from dealer data (state + EEZ waters) and logbooks (EEZ only). Landings from state waters are calculated approximately by subtracting logbook landings from dealer landings. The EEZ quota and ratio of EEZ landings and EEZ quota are shown for comparison. Data for 2005 are preliminary and may be incomplete.

Year	Dealer Database	EEZ (Logbook)	State Waters (Logbook - Dealer)	Percent Landings in EEZ	EEZ Quota	EEZ Landings / Quota (%)
1967[a]	0.020	0.000	0.020	0.000		
1968	0.102	0.000	0.102	0.000		
1969	0.290	0.000	0.290	0.000		
1970	0.792	0.000	0.792	0.000		
1971	0.921	0.000	0.921	0.000		
1972	0.634	0.000	0.634	0.000		
1973	0.661	0.000	0.661	0.000		
1974	0.365	0.000	0.365	0.000		
1975	0.569	0.000	0.569	0.000		
1976	2.510	1.854	0.656	0.739		
1977	8.411	7.293	1.118	0.867		
1978	10.415	9.197	1.218	0.883		
1979	15.748	14.344	1.404	0.911	13.608	105%
1980[b,c]	11.623	13.407	-1.784	1.153	15.876	84%
1981	11.202	13.101	-1.899	1.170	18.144	72%
1982	16.478	14.234	2.244	0.864	18.144	78%
1983	16.200	14.586	1.615	0.900	18.144	80%
1984	17.939	17.974	-0.035	1.002	18.144	99%
1985	22.035	20.726	1.310	0.941	22.226	93%
1986	20.585	18.902	1.683	0.918	27.215	69%
1987	22.709	21.514	1.195	0.947	27.215	79%
1988	21.007	20.273	0.734	0.965	27.215	74%
1989	23.147	22.359	0.788	0.966	23.587	95%
1990	21.235	20.965	0.270	0.987	24.040	87%
1991	22.119	22.063	0.056	0.997	24.040	92%
1992	22.871	22.476	0.395	0.983	24.040	93%
1993	24.843	21.876	2.968	0.881	24.494	89%
1994	21.159	20.985	0.174	0.992	24.494	86%
1995	23.253	21.107	2.145	0.908	22.226	95%
1996	21.122	20.061	1.062	0.950	20.185	99%
1997	19.930	19.628	0.302	0.985	19.581	100%
1998	18.098	17.896	0.201	0.989	18.144	99%
1999	17.557	17.381	0.175	0.990	20.412	85%
2000	14.899	14.722	0.176	0.988	20.412	72%
2001	17.234	17.068	0.165	0.990	20.412	84%
2002	18.144	17.947	0.198	0.989	20.412	88%
2003	18.997	18.815	0.182	0.990	20.412	92%
2004	17.788	17.650	0.138	0.992	22.680	78%
2005		13.629	-13.629		24.190	56%

[a] Landings for 1967-1979 are from NEFSC (1990)
[b] Landings for 1980-1993 from NEFSC (2003).
[c] For 1980-2005, "Dealer Database Total" landings are from commercial landings databases (CFDETS or CFDERS), EEZ landings are from logbooks (Maine included), and "State Waters (Dealer-Logbook)" landings are the difference. Logbook landings are more accurate. In some years, logbook landings exceeded dealer database totals slightly.

Table A2. Ocean quahog landings (mt meats) by stock assessment region reported in logbooks for the US EEZ. Data for 1980-2003 are from logbooks and differ from the previous assessment (NEFSC 2004) because additional landings from other/unknown regions ("UNK") were allocated to regions in this assessment and because NEFSC (2004) treated Maine landings as other/unknown. Landings for 1978-1979 are not from logbooks and less reliable. Data for 2005 are preliminary and may be incomplete. Based on Maine reports, UNK amounts during 2002 were probably from Maine waters.

YEAR	SVA	DMV	NJ	LI	SNE	GBK	MNE	UNK	Grand Total
1978		1,290	6,350					2,775	10,415
1979		5,450	6,030					4,268	15,748
1980	0	4,230	7,750	6	0			1,421	13,407
1981	56	3,637	8,402	3	0			1,003	13,101
1982	6	4,598	8,538	0	0			1,092	14,234
1983	0	5,396	8,249	21	629	0	0	291	14,586
1984	6	7,164	8,857	0	822	0	0	1,125	17,974
1985	160	7,200	10,676	40	693	0	0	1,956	20,726
1986	0	8,236	9,053	396	568	0	0	649	18,902
1987	0	10,533	9,077	1,180	696	0	0	27	21,514
1988	42	11,715	7,014	640	841	0	0	20	20,273
1989	0	6,439	14,100	605	1,196	0	0	20	22,359
1990	14	3,685	15,590	739	934	0	3	0	20,965
1991	0	4,839	14,575	1,674	865	0	110	0	22,063
1992	0	2,378	6,942	11,939	1,143	0	75	0	22,476
1993	0	1,953	10,205	8,642	1,020	0	56	0	21,876
1994	0	992	6,938	12,014	954	0	65	22	20,985
1995	0	699	5,356	9,526	5,412	0	114	0	21,107
1996	0	736	4,864	5,943	8,350	0	142	26	20,061
1997	0	1,072	4,229	5,141	8,968	0	218	0	19,628
1998	0	1,365	2,684	6,856	6,736	0	218	39	17,896
1999	0	1,090	3,038	6,329	6,618	0	279	27	17,381
2000	0	1,048	3,318	4,745	5,083	49	357	123	14,722
2001	0	894	4,560	5,692	4,694	13	326	889	17,068
2002	0	1,732	2,781	9,113	3,884	0	387	51	17,947
2003	0	896	3,692	11,617	2,177	0	359	73	18,815
2004	0	634	2,795	10,631	3,283	0	307	0	17,650
2005	0	932	664	9,688	2,015	0	294	35	13,629

Table A3. Ocean quahog landings by stock assessment region as reported in logbooks for the US EEZ. Figures are 1000 ITQ bushels except for Maine, which are reported as both ITQ and Maine bushels. Data for 2005 are preliminary and may be incomplete. Based on Maine reports, UNK amounts during 2002 were probably from Maine waters.

YEAR	SVA	DMV	NJ	LI	SNE	GBK	MNE	MNE (Maine bushels)	UNK	Grand Total
1980	0	933	1,709	1	0	0	0		313	2,956
1981	12	802	1,852	1	0	0	0		221	2,888
1982	1	1,014	1,882	0	0	0	0		241	3,138
1983	0	1,190	1,819	5	139	64	0	0	64	3,280
1984	1	1,580	1,953	0	181	248	0	0	248	4,211
1985	35	1,587	2,354	9	153	431	0	0	431	5,001
1986	0	1,816	1,996	87	125	143	0	0	143	4,310
1987	0	2,322	2,001	260	153	6	0	0	6	4,749
1988	9	2,583	1,546	141	185	4	0	0	4	4,474
1989	0	1,420	3,108	133	264	4	0	0	4	4,934
1990	3	812	3,437	163	206	0	1	1	0	4,623
1991	0	1,067	3,213	369	191	0	24	37	0	4,901
1992	0	524	1,530	2,632	252	0	16	25	0	4,980
1993	0	431	2,250	1,905	225	0	12	19	0	4,841
1994	0	219	1,530	2,649	210	5	14	21	5	4,653
1995	0	154	1,181	2,100	1,193	0	25	38	0	4,691
1996	0	162	1,072	1,310	1,841	6	31	47	6	4,476
1997	0	236	932	1,133	1,977	0	48	73	0	4,400
1998	0	301	592	1,511	1,485	9	48	72	9	4,026
1999	0	240	670	1,395	1,459	6	62	93	6	3,931
2000	0	231	732	1,046	1,121	27	79	119	27	3,381
2001	0	197	1,005	1,255	1,035	196	72	109	196	4,065
2002	0	382	613	2,009	856	11	85	129	11	4,097
2003	0	198	814	2,561	480	16	79	120	16	4,284
2004	0	140	616	2,344	724	0	68	102	0	3,993
2005	0	206	146	2,136	444	8	65	98	8	3,110

Table A4. Real and nominal prices (dollars per ITQ bushel) for ocean quahogs landed by ITQ and Maine vessels. Real prices are 1991 dollars. Information for ITQ vessels from dealer data. Information for Maine vessels from MAFMC (2005). Price data for Maine vessels (originally prices for Maine bushel) were converted to prices per ITQ bushel). Adjustments for inflation from the US Bureau of Labor Statistics for unprocessed shellfish.[a]

	ITQ		Maine	
Year	Nominal	Real	Nominal	Real
1994	$4.44	$4.20		
1995	$4.30	$3.56		
1996	$4.12	$3.40		
1997	$4.13	$2.39		
1998	$4.23	$2.41		
1999	$4.24	$2.53		
2000	$4.35	$2.55		
2001	$5.54	$3.23		
2002	$5.47	$3.33		
2003	$5.37	$3.08	$61.73	$35.43
2004	$5.26	$3.02	$59.55	$34.17

Table A5. Ocean quahog fishing effort (hours fished) by stock assessment region in the US EEZ based on logbook data. Figures for 1983-2003 differ from NEFSC (2003) because additional other/unknown ("UNK") trips were allocated to region and because data for subtrips (deliveries from the same trip to different dealers) were counted only once. Data for 2005 are preliminary and may be incomplete. Based on Maine reports, UNK amounts during 2002 were probably from Maine waters.

YEAR	SVA	DMV	NJ	LI	SNE	GBK	MNE	UNK	Grand Total
1983	0	7,131	13,932	50	1,535	0	0	56	22,704
1984	15	11,096	15,488	0	2,523	0	0	1,231	30,353
1985	204	10,058	17,890	87	2,066	0	0	2,955	33,260
1986	0	12,260	14,350	361	1,145	0	0	1,012	29,127
1987	0	15,812	14,704	806	1,340	0	0	49	32,711
1988	64	19,100	11,598	615	1,639	0	0	64	33,079
1989	0	12,124	24,262	797	2,327	0	0	50	39,560
1990	25	8,166	29,327	1,283	1,838	0	286	0	40,924
1991	0	12,048	30,397	1,844	1,433	0	17,110	0	62,832
1992	0	5,513	15,998	13,148	1,964	0	13,424	0	50,047
1993	0	4,622	25,457	12,883	1,783	0	5,720	0	50,465
1994	0	2,260	20,543	19,165	2,082	0	5,056	57	49,162
1995	0	1,621	13,598	16,015	8,561	0	5,731	0	45,526
1996	0	1,521	9,340	10,238	11,866	0	8,404	54	41,422
1997	0	2,742	9,382	8,295	13,515	0	11,734	0	45,669
1998	0	3,225	6,983	10,509	10,639	0	11,631	79	43,066
1999	0	2,595	7,623	9,132	12,258	0	10,821	90	42,518
2000	0	2,517	7,966	7,071	10,542	63	12,215	612	40,986
2001	0	2,170	10,844	7,813	11,404	22	13,113	1,454	46,820
2002	0	4,290	6,683	11,605	7,797	0	16,779	85	47,240
2003	0	2,617	10,764	16,099	4,596	0	17,832	108	52,016
2004	0	2,476	7,953	14,478	6,665	0	19,013	0	50,586
2005	0	3,500	1,935	12,437	4,019	0	16,572	129	38,591

Table A6. Commercial landings per unit effort (LPUE) for ocean quahog by region. Figures for Maine are for vessels in ton class groups 1-2 (1-50 GRT). Figures for all other regions are for vessels in ton class groups 3-4 (51-500 GRT). "Nominal Mean LPUE" is the simple average of LPUE for each trip in the region during the year. "Total Bushels / Total Hours" is total landings divided by total hours fished. "Standardized Index" is back-transformed year effects from a general linear model with year, month and vessel effects. The standardized indices are adjusted to the LPUE level of a single randomly chosen vessel (ton class 4 for the EEZ and ton class 1 for Maine) during June of each year. Data for 2005 are preliminary and may be incomplete.

	DMV				NJ			
Year	Nominal Mean LPUE	Total Bushels / Total Hours	Standardized Index	CV	Nominal Mean LPUE	Total Bushels / Total Hours	Standardized Index	CV
1980	153	139	165	0.15	119	118	113	0.19
1981	149	140	159	0.15	122	118	113	0.19
1982	151	143	176	0.15	135	130	120	0.19
1983	175	167	201	0.15	138	131	124	0.19
1984	154	142	181	0.15	133	126	119	0.19
1985	167	158	192	0.15	140	132	124	0.19
1986	157	148	169	0.15	144	139	125	0.19
1987	159	147	158	0.15	136	136	116	0.19
1988	144	135	141	0.15	137	133	110	0.19
1989	127	117	131	0.15	133	128	105	0.19
1990	106	99	118	0.15	123	117	95	0.19
1991	94	89	102	0.15	110	106	82	0.19
1992	100	95	104	0.15	101	96	84	0.19
1993	105	93	105	0.15	95	88	75	0.19
1994	104	97	97	0.15	80	74	68	0.19
1995	102	95	91	0.16	93	87	79	0.19
1996	119	107	101	0.16	121	115	100	0.19
1997	93	86	90	0.15	105	99	86	0.19
1998	100	93	92	0.15	109	85	75	0.19
1999	96	93	88	0.15	95	88	80	0.19
2000	98	92	86	0.15	96	92	82	0.19
2001	90	91	76	0.16	98	93	80	0.19
2002	93	88	83	0.15	94	91	77	0.19
2003	77	74	68	0.15	79	74	63	0.19
2004	66	56	60	0.16	88	77	67	0.19
2005	61	59	56	0.15	80	76	64	0.18

Table A6 (continued).

Year	LI Nominal Mean LPUE	LI Total Bushels / Total Hours	LI Standardized Index	LI CV	SNE Nominal Mean LPUE	SNE Total Bushels / Total Hours	SNE Standardized Index	SNE CV
1980								
1981	123	123						
1982								
1983	91	93			91	90		
1984					73	72	73	0.17
1985	106	102			75	74	79	0.18
1986	262	242	267	0.23	115	109	114	0.17
1987	322	323	319	0.20	122	115	117	0.17
1988	232	230	210	0.22	114	113	113	0.17
1989	176	167	190	0.21	127	113	118	0.17
1990	180	127	221	0.23	129	112	136	0.17
1991	205	200	212	0.18	135	133	134	0.17
1992	207	200	227	0.15	119	128	164	0.17
1993	159	148	174	0.15	115	126	179	0.17
1994	152	138	161	0.15	100	101	142	0.17
1995	145	131	159	0.15	145	139	119	0.17
1996	136	128	149	0.16	164	155	137	0.17
1997	144	137	157	0.16	156	146	126	0.17
1998	155	144	160	0.16	147	140	120	0.17
1999	165	153	172	0.16	126	119	106	0.17
2000	156	148	163	0.16	109	106	99	0.17
2001	165	161	177	0.16	93	91	88	0.17
2002	182	173	178	0.15	122	110	122	0.17
2003	169	160	168	0.15	116	104	106	0.17
2004	179	162	166	0.15	115	109	106	0.17
2005	177	172	151	0.06	113	111	108	0.17

Table A6 (continued).

	MNE			
Year	Nominal Mean LPUE	Total Bushels / Total Hours	Standardized Index	CV
1980				
1981				
1982				
1983				
1984				
1985				
1986				
1987				
1988				
1989				
1990	3.50	3.56		
1991	2.06	2.15	2.09	0.031
1992	1.89	1.85	1.89	0.031
1993	3.18	3.00	2.52	0.033
1994	4.95	4.25	3.95	0.032
1995	6.98	6.62	6.18	0.032
1996	5.92	5.61	5.55	0.031
1997	6.64	6.20	5.86	0.030
1998	6.73	6.23	5.55	0.030
1999	9.66	8.60	7.58	0.030
2000	10.05	9.73	8.30	0.030
2001	8.45	8.28	7.28	0.030
2002	8.02	7.67	7.14	0.030
2003	7.06	6.71	6.01	0.029
2004	5.58	5.37	4.76	0.029
2005	6.14	5.91	5.03	0.027

Table A7. Trends in survey, stock and fishable abundance and biomass for ocean quahog ≥ 50 mm SL during 1982-2005 based on NEFSC clam survey data. Mean numbers per tow (N/Tow) and mean meat weight per tow (KG/Tow) are for a standard 0.15 nm tow with adjustments for tow distance based on Doppler data. Figures include original plus borrowed tows. For example, "Number Strata" for a particular year includes strata sampled by the survey during the same year plus strata sampled by tows borrowed from the previous and subsequent surveys. Survey data for 1994 are excluded because of gear problems that artificially boosted sampling efficiency. Survey coverage was incomplete on GBK prior to 1986 and GBK was not sampled during 2005.

		Survey				Stock				Fishable						
Region	Year	N/Tow	CV	KG/Tow	CV	N/Tow	CV	KG/Tow	CV	N/Tow	CV	KG/Tow	CV	Number Tows	Number Positive Tows	Number Strata With Data
SVA	1982	0.039	0.00	0.002	0.00	0.039	0.00	0.002	0.00	0.038	0.00	0.002	0.00	5	1	2
SVA	1983	1.892	0.58	0.099	0.58	1.917	0.58	0.101	0.58	1.854	0.58	0.097	0.58	10	3	2
SVA	1984	0.189	0.85	0.010	0.87	0.191	0.84	0.010	0.87	0.185	0.85	0.010	0.87	14	2	2
SVA	1986	0.285	0.00	0.013	0.00	0.294	0.00	0.013	0.00	0.275	0.00	0.012	0.00	9	1	2
SVA	1989	0.392	0.00	0.018	0.00	0.401	0.00	0.019	0.00	0.380	0.00	0.018	0.00	9	1	2
SVA	1992	0.000	.	0.000	.	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	9	0	2
SVA	1997	0.154	0.00	0.004	0.00	0.282	0.00	0.006	0.00	0.132	0.00	0.003	0.00	9	1	2
SVA	1999	0.081	0.55	0.002	0.61	0.182	0.50	0.003	0.54	0.069	0.56	0.002	0.61	19	2	2
SVA	2002	0.045	1.00	0.001	1.00	0.133	1.00	0.002	1.00	0.037	1.00	0.001	1.00	10	1	2
SVA	2005	0.000	.	0.000	.	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	9	0	2
DMV	1982	79.162	0.32	2.956	0.34	86.645	0.31	3.156	0.33	73.837	0.32	2.786	0.34	59	24	6
DMV	1983	86.228	0.49	2.549	0.42	106.611	0.52	2.988	0.45	76.158	0.48	2.301	0.41	54	28	6
DMV	1984	52.011	0.35	1.667	0.30	63.193	0.36	1.904	0.31	46.650	0.34	1.530	0.30	78	34	6
DMV	1986	75.681	0.23	2.532	0.22	86.737	0.24	2.800	0.22	68.939	0.23	2.342	0.22	61	28	6
DMV	1989	64.366	0.58	1.801	0.46	82.482	0.62	2.179	0.51	55.961	0.55	1.606	0.44	69	31	6
DMV	1992	71.982	0.36	2.285	0.31	85.405	0.40	2.589	0.33	64.676	0.35	2.093	0.30	69	25	6
DMV	1997	47.743	0.21	1.669	0.21	56.440	0.22	1.847	0.21	43.721	0.21	1.557	0.21	73	28	6
DMV	1999	28.359	0.29	0.948	0.27	33.388	0.29	1.056	0.27	25.821	0.29	0.878	0.26	70	23	6
DMV	2002	31.814	0.25	1.106	0.23	38.774	0.26	1.232	0.23	29.139	0.24	1.032	0.22	71	19	6
DMV	2005	19.407	0.49	0.694	0.53	24.842	0.45	0.776	0.50	17.906	0.50	0.652	0.53	66	21	6

Table A7 (cont.)

Region	Year	Survey				Stock				Fishable				Number Tows	Number Positive Tows	Number Strata With Data
		N/Tow	CV	KG/Tow	CV	N/Tow	CV	KG/Tow	CV	N/Tow	CV	KG/Tow	CV			
NJ	1982	112.339	0.20	3.555	0.20	129.333	0.20	3.918	0.20	102.545	0.20	3.302	0.20	100	50	13
NJ	1983	86.092	0.21	2.832	0.21	98.417	0.21	3.090	0.21	79.201	0.21	2.649	0.21	98	55	13
NJ	1984	143.533	0.24	4.531	0.24	165.861	0.24	4.998	0.24	131.075	0.24	4.208	0.24	153	80	13
NJ	1986	142.520	0.23	4.847	0.23	158.243	0.24	5.213	0.23	132.170	0.23	4.555	0.22	103	52	13
NJ	1989	73.510	0.22	2.193	0.21	90.578	0.21	2.491	0.21	66.320	0.22	2.020	0.21	110	52	13
NJ	1992	88.043	0.18	3.023	0.17	97.822	0.18	3.246	0.17	81.725	0.18	2.843	0.17	110	52	13
NJ	1997	122.262	0.15	4.273	0.15	135.780	0.16	4.576	0.15	113.720	0.15	4.028	0.15	124	59	13
NJ	1999	59.480	0.15	2.019	0.14	72.266	0.15	2.221	0.14	54.889	0.15	1.900	0.14	132	61	13
NJ	2002	89.793	0.23	3.229	0.24	101.123	0.22	3.456	0.23	83.825	0.24	3.059	0.24	127	60	13
NJ	2005	47.076	0.16	1.568	0.15	62.364	0.15	1.769	0.15	43.117	0.15	1.473	0.14	103	54	13
LI	1982	278.856	0.15	7.021	0.16	434.976	0.16	9.325	0.15	239.652	0.15	6.258	0.16	43	37	9
LI	1983	185.877	0.21	5.232	0.21	253.508	0.22	6.355	0.21	163.619	0.21	4.742	0.21	38	36	9
LI	1984	235.154	0.17	6.536	0.16	318.987	0.18	7.967	0.17	206.330	0.17	5.906	0.16	71	63	9
LI	1986	311.430	0.22	8.625	0.21	416.390	0.23	10.480	0.21	273.066	0.22	7.782	0.21	36	31	9
LI	1989	226.213	0.34	5.062	0.29	367.492	0.38	7.152	0.33	190.104	0.33	4.384	0.28	40	36	9
LI	1992	323.335	0.18	8.313	0.16	465.234	0.20	10.625	0.17	279.032	0.17	7.401	0.16	42	36	9
LI	1997	401.643	0.16	11.156	0.16	518.847	0.17	13.351	0.16	353.149	0.16	10.049	0.16	42	35	9
LI	1999	232.273	0.17	6.280	0.15	310.519	0.19	7.671	0.16	202.716	0.17	5.628	0.14	45	41	9
LI	2002	253.059	0.21	6.969	0.20	330.414	0.21	8.385	0.20	222.209	0.21	6.268	0.20	43	40	9
LI	2005	151.233	0.18	4.122	0.19	218.396	0.19	5.121	0.18	132.758	0.18	3.717	0.19	45	39	9

Table A7 (cont.)

Region	Year	Survey				Stock				Fishable				Number Tows	Number Positive Tows	Number Strata With Data
		N/Tow	CV	KG/Tow	CV	N/Tow	CV	KG/Tow	CV	N/Tow	CV	KG/Tow	CV			
SNE	1982	277.607	0.27	6.981	0.25	345.845	0.28	8.222	0.26	245.458	0.27	6.283	0.25	48	30	10
SNE	1983	173.213	0.29	4.163	0.30	237.689	0.31	5.149	0.29	151.399	0.29	3.727	0.30	58	37	10
SNE	1984	188.458	0.27	4.753	0.29	234.355	0.26	5.588	0.28	166.802	0.27	4.280	0.29	69	38	10
SNE	1986	289.151	0.31	6.961	0.31	394.360	0.35	8.561	0.32	253.117	0.31	6.226	0.31	27	23	9
SNE	1989	274.664	0.19	6.707	0.18	353.181	0.21	8.050	0.19	241.358	0.19	6.003	0.18	34	29	10
SNE	1992	333.079	0.19	8.634	0.19	400.104	0.19	9.947	0.19	297.003	0.19	7.814	0.20	36	31	10
SNE	1997	292.893	0.54	6.128	0.45	447.963	0.61	8.405	0.52	246.944	0.52	5.335	0.43	39	27	10
SNE	1999	252.431	0.54	6.169	0.48	312.910	0.56	7.316	0.51	221.840	0.53	5.510	0.47	39	30	10
SNE	2002	180.674	0.22	5.103	0.22	206.737	0.22	5.663	0.22	164.245	0.22	4.697	0.22	29	28	9
SNE	2005	178.281	0.28	3.944	0.24	395.499	0.44	5.882	0.29	154.795	0.27	3.547	0.24	29	25	7
GBK	1986	276.488	0.19	6.207	0.18	427.632	0.23	8.633	0.20	232.206	0.19	5.313	0.18	48	21	16
GBK	1989	90.805	0.26	2.371	0.26	124.548	0.25	2.950	0.25	78.933	0.26	2.098	0.26	79	38	16
GBK	1992	346.253	0.21	9.225	0.21	485.713	0.19	11.427	0.20	302.841	0.21	8.208	0.21	74	41	16
GBK	1997	269.762	0.19	7.058	0.19	389.377	0.19	8.969	0.18	234.251	0.19	6.274	0.19	83	44	18
GBK	1999	273.398	0.17	7.806	0.19	365.971	0.16	9.391	0.18	241.903	0.17	7.060	0.19	77	47	18
GBK	2002	328.367	0.18	9.059	0.19	478.136	0.15	11.247	0.18	288.963	0.18	8.149	0.19	61	38	15

Table A8. Number of random and nearly random NEFSC survey tows used to estimate trends in abundance of ocean quahog. Figures in each cell are the number of tows in calculations for each combination of stratum and cruise. Figures in plain text are the number of original tows (without borrowing). Bold and outlined figures are for cells with zero tows originally that were filled by borrowing tows from the same strata during previous and/or subsequent cruises. Black cells are for cells with zero tows that could not be filled by borrowing. Note that there were too few tows in GBK during 1982-1984 and 2005 to calculate abundance indices for GBK during these years.

		Survey Year										
Region	Stratum	1982	1983	1984	1986	1989	1992	1994	1997	1999	2002	2005
SVA	5	4	9	13	8	8	8	8	8	***16***	8	8
	6	1	1	1	1	1	1	1	1	***3***	2	2
DMV	9	30	26	35	29	37	37	39	39	38	39	39
	10	2	2	3	3	3	3	3	3	3	3	3
	11	2	2	***4***	2	2	2	2	2	2	2	2
	13	19	18	25	20	20	20	21	22	19	20	20
	14	2	2	3	3	3	3	5	3	3	3	3
	15	4	4	***8***	4	4	4	5	4	5	4	4
NJ	17	11	11	18	12	12	12	12	14	12	12	12
	18	3	3	***6***	3	3	3	3	3	3	3	3
	19	3	3	***6***	3	3	3	3	3	3	3	3
	21	18	18	22	19	20	20	23	26	39	29	29
	22	3	3	***6***	3	3	3	5	3	3	3	3
	23	7	6	***11***	5	4	5	5	5	5	5	5
	25	9	9	13	8	9	9	9	12	8	9	9
	26	2	2	***5***	3	3	3	3	3	3	3	3
	27	4	4	***8***	4	4	4	4	4	4	4	4
	87	8	7	10	9	9	9	9	9	9	16	16
	88	15	15	24	17	20	20	20	21	22	20	20
	89	15	15	21	15	18	17	17	19	18	18	18
	90	2	2	3	2	2	2	2	2	2	2	2
LI	29	11	10	***20***	10	10	10	10	10	11	10	10
	30	7	8	***14***	6	6	6	6	6	7	6	6
	31	9	7	***12***	5	7	8	8	8	9	8	8
	33	4	4	***8***	4	4	4	5	4	4	4	4
	34	2	2	***4***	2	2	2	5	2	2	2	2
	35	4	2	***4***	2	5	6	6	6	6	6	6
	91	3	2	4	4	3	3	3	3	3	3	3
	92	2	2	3	2	2	2	2	2	2	2	2
	93	1	1	2	1	1	1	1	1	1	2	2

Table A8 (continued).

Region	Stratum	Survey Year 1982	1983	1984	1986	1989	1992	1994	1997	1999	2002	2005
SNE	37	7	4	7	3	6	3	5	4	4	3	3
	38	3	2	5	3	3	3	5	3	3	3	3
	39	6	4	6	2	5	5	5	5	5	5	5
	41	6	5	7	5	6	6	6	6	5	6	6
	45	3	7	9	4	4	4	4	4	4	3	3
	46	2	5	5	3	2	3	5	3	3	2	2
	47	4	3	4	2	2	4	5	4	3	1	1
	94	1	2	2		1	1	2	2	4	2	2
	95	4	14	11	4	4	4	4	4	4	4	4
	96	12	12	13	1	1	3	2	4	4		
GBK	54		3	3	3	6	3	3	3	3	0	0
	55	3	3	3	3	1	3	3	3	2	2	2
	56								4	4	4	
	57			2	2	1	2	5	2	2	2	2
	58								5	5	5	
	59	1	4	5	1	2	6	5	5	4	5	5
	60			2	2	2	4	2	5	5	5	5
	61	8	1	6	5	12	7	6	6	6	6	6
	62			1	1	1	4	4	4	4	4	4
	65			3	3	5	2	2	3	4	1	1
	67		5	5	5	7	7	7	7	7		
	68	1	8	7	3	6	6	5	5	5		
	69	2	5	11	6	6	6	7	6	7	7	
	70	1	2	6	4	8	4	4	4	3	2	2
	71		2	2	3	1	2	3	3	1	2	2
	72	2	10	8	1	8	8	8	8	6	6	
	73	1	1	4	3	6	6	6	6	5	6	6
	74	3	4	1	3	7	4	4	4	3	3	3

Table A9. Parameter estimates for the relationship between shell length (L, mm) and drained (fresh, not frozen) meat weight (W, g) in ocean quahog (NEFSC 2004). The equation for the relationship is $W=e^{\alpha}L^{\beta}$.

Region	Alpha	Beta
SVA	-9.042313	2.787987
DMV	-9.042313	2.787987
NJ	-9.847183	2.949540
LI	-9.233646	2.822474
SNE	-9.124283	2.774989
GBK	-8.969073	2.767282

Table A10. Clam survey database parameters used to extract survey data for ocean quahog in this assessment. Parameters were the same for all regions. Negative parameter values are ignored in database calculations.

Database Parameter	Survey length composition	Trends < 70 mm SL	Trends in survey, stock and fishable biomass	Efficiency corrected swept-area biomass
DISTANCE_TYPE	TREND	TREND	TREND	SENSORS
USEINCHESDOWN	1	1	1	1
LENGTH_BIN_SIZE_MM	10	1000	1000	1000
FIRST_LENGTH_MM	1	0	50	50
FIRST_BIN_IS_PLUSGROUP	-1	-1	-1	-1
LAST_LENGTH_MM	250	69	250	250
LAST_BIN_IS_PLUSGROUP	-1	-1	-1	-1
SVSPP_TO_USE	409	409	409	409
AREAKIND	GIS	GIS	GIS	GIS
REV_DATE_FOR_AREAS	2002	2002	2002	2002
REV_DATE_FOR_LW	2000	2000	2000	2000
FIRST_JWSTCODE	-1	-1	-1	-1
LAST_JWSTCODE	-1	-1	-1	-1
FIRST_RANDLIKE	1	1	1	1
LAST_RANDLIKE	2	2	2	2
FIRST_STATION	-1	-1	-1	-1
LAST_STATION	-1	-1	-1	-1
FIRST_HAUL	1	1	1	1
LAST_HAUL	3	3	3	3
FIRST_GEARCOND	1	1	1	1
LAST_GEARCOND	6	6	6	6
FIRST_STRATUM	-1	-1	-1	-1
LAST_STRATUM	-96	-96	-96	-96
FIRST_REGION_CODE	1	1	1	1
LAST_REGION_CODE	6	6	6	6
WRITE_TOW_DATA	1	1	1	1
WRITE_STRATUM_DATA	1	1	1	1
FIRST_CRUISE	-199700	-199700	-199700	199700
LAST_CRUISE	-200509	-200509	-200509	200509
SurvSelxAlpha	8.122	8.122	8.122	8.122
SurvSelxBeta		-0.119	-0.119	-0.119
FisherySelxAlpha		7.63	7.63	7.63
FisherySelxBeta		-0.105	-0.105	-0.105
NOMINAL_TOW_DISTANCE_NM		0.15	0.15	0.15
MINVALIDDOPPLER		0.04	0.04	0.04
MAXVALIDDOPPLER		0.3	0.3	0.3
FILLHOLZ		1	1	1

Table A11. Patch model estimates of efficiency for commercial and NEFSC survey clam dredges based on depletion experiments during 1997-2005. "NA" means not available.

Study area						Depletion Tows						Patch Model							Setup Tows (if applicable)				
Experiment	Region	Latitude (decimal degrees)	Longitude (decimal degrees)	Depth (m)	Mean Sediment Size (microns)	Depletion Study Vessel	Depletion Date	Ship Position Data (source / nominal accuracy / time interval)	N tows used	N Bushel Counts / Length samples	Depletion Vessel Blade Width (ft)	Cell Size (ft)	Density (N ft^{-2})	Depletion Vessel Efficiency	k	γ	Neg. Log likelihood	Fit to Catch Data (R2s)	Setup Date	Setup or RV Depletion Stations	Density (N ft^{-2})	NEFSC Dredge Efficiency	Foornotes
OQ2005-1	LI	40.5190	72.0762	57	536	F/V Lisa Kim	Sep-05	GPS / 6 ft / 6 sec	20	4 / 4	10	20	0.073	0.183	1.97	0.50	127.0	Ok	Jun-05	165, 231-234	0.0120	0.165	1
OQ2005-2	LI	40.3896	72.3895	53	438	F/V Lisa Kim	Sep-05	GPS / 6 ft / 6 sec	21	4 / 4	10	20	0.047	0.402	8.57	0.50	131.8	Ok	Jun-05	162, 235-238	0.0080	0.169	1
OQ2005-3	LI	40.6422	72.6517	35	267	F/V Lisa Kim	Sep-05	GPS / 6 ft / 6 sec	20	4 / 4	10	20	0.085	0.733	9.57	0.50	125.9	Ok	Jun-05	3, 239-242	0.0101	0.119	1
OQ2005-4	LI	40.6882	72.1815	46	308	F/V Lisa Kim	Sep-05	GPS / 6 ft / 6 sec	17	4 / 4	10	20	0.027	0.815	12.31	0.50	89.4	Ok	Jun-05	168, 243-246	0.0042	0.154	1
OQ2005-6	LI	40.0555	72.4167	65	554	F/V Lisa Kim	Sep-05	GPS / 6 ft / 6 sec	20	4 / 4	10	20	0.137	0.660	2.55	0.50	146.3	Ok	Jun-05	252-256	0.0210	0.153	1
Mean				*51*	*421*				*19.6*				*0.074*	*0.559*	*6.99*						*0.0110*	*0.152*	
CV for Mean				*10%*	*14%*				*3%*				*25%*	*21%*	*29%*						*25%*	*6%*	
OQ2002-1 (LK-1)	LI	40.7276	71.7373	60	331	F/V Lisa Kim	Mar-02	GPS / 1 ft / 6 sec	24	5 / 5	10	20	0.295	0.489	6.56	0.50	173.1	Ok	Jun-02	5 - 9	0.0290	0.098	1, 2, 5
OQ2002-2 (LK-2)	LI	40.1031	73.1911	48	277	F/V Lisa Kim	Mar-02	GPS / 1 ft / 6 sec	22	4 / 4	10	20	0.165	0.785	10.57	0.50	149.7	Ok	Jun-02	25- 29	0.0245	0.149	1, 2
OQ2002-3 (LK-3)	NJ	38.8149	73.8133	50	195	F/V Lisa Kim	Mar-02	GPS / 1 ft / 6 sec	20	4 / 4	10	20	0.081	0.777	11.57	0.50	133.4	Ok	Jun-02	213 - 217	0.0239	0.297	1, 2
OQ2002-4 (LK-4)	DMV	37.8876	74.6449	48	135	F/V Lisa Kim	Mar-02	GPS / 1 ft / 6 sec	24	5 / 5	10	20	0.073	0.254	12.46	0.50	136.0	Ok	Jun-02	272 - 276	0.0210	0.287	1, 2,9, 16
Mean				*52*	*235*				*22.5*				*0.153*	*0.576*	*10.29*						*0.0704*	*0.178*	
CV for Mean				*6%*	*18%*				*4%*				*34%*	*22%*	*13%*						*65%*	*0.274*	
OQ2000-1 (JN-1)	LI	40.6022	71.9875	58	N/A	F/V John N	Mar-00	GPS / 1 ft / 30 sec	22	5 / 5	12.5	25	0.100	0.730	5.55	0.50	157.4	Ok	Jun-99	194 - 199	NA	NA	1, 2,6
OQ2000-2 (JN-2)	LI	40.3945	72.5430	48	N/A	F/V John N	Mar-00	GPS / 1 ft / 30 sec	16	4 / 3	12.5	25	0.062	0.554	15.10	0.50	98.1	Ok	Jun-99	178 - 180	0.0145	0.234	1, 2,7,11,12, 17
OQ2000-3 (DM-1)	LI	40.5830	72.7968	40	N/A	F/V Danielle Maria	May-00	GPS / 1 ft / 30 sec	27	6 / 6	10	20	0.089	0.560	4.57	0.50	184.2	Ok	Jun-99	3 - 8	0.0147	0.165	1, 2,8,10,12, 18
Mean									*21.7*				*0.084*	*0.615*	*8.405*						*0.0146*	*0.199*	
CV for Mean									*15%*				*14%*	*9%*	*40%*						*1%*	*17%*	
OQ1999-01 DE2	LI	40.6023	71.9848	57	N/A	R/V Delaware II	Jun-99	GPS / 36 ft / 1 sec	60	8 / 8	5	10	0.007	0.990	4.05	0.25	253.1	Poor		N/A		0.990	14, 15
OQ1998-1 (SH-3)	LI (Shinnecock)	40.7665	72.1795	41	N/A	F/V Cape Fear	3/1/11998 8	Loran / 40 ft / 30 sec.	14	3 / 3	10	20	0.017	1.000	3.48	0.50	76.5	Poor					1, 13
OQ1998-2 (SH-2)	LI (Shinnecock)	40.7220	72.0075	45	N/A	F/V Cape Fear	Mar-98	Loran / 40 ft / 30 sec.	23	5 / 5	10	20	0.067	0.869	10.57	0.50	140.3	Ok		NA		NA	15
OQ1998-3 (NS-1)	SNE (Nantucket Shoals)	40.4670	69.4830	63	N/A	F/V Cape Fear	Apr-98	Loran / 40 ft / 30 sec.	24	5 / 5	10	20	0.255	0.710	7.56	0.50	195.5	Ok					15
Mean									*20.3*				*0.113*	*0.860*	*7.204*								
CV for Mean									*16%*				*64%*	*10%*	*29%*								
OQ1997-1 (SH-1)	LI (Shinnecock)	40.2695	72.2985	58	N/A	F/V Laura Ann	Jul-97	Loran / 40 ft / 30 sec.	28	7 / 7	7.75	20	0.083	0.458	10.57	0.39	164.2	Ok					1,3
OQ1997-2 (WW-1)	NJ (Wildwood)	38.5095	74.1115	49	N/A	F/V Agitator	Aug-97	Loran / 40 ft / 30 sec.	28	13 / 6	10	20	0.084	0.150	2.37	0.50	176.0	Ok		NA		NA	1,4
Mean				*51*					*19.6*				*0.180*	*0.592*	*6.01*								
CV for Mean				*8%*					*19%*				*45%*	*23%*	*25%*								

SEE FOOTNOTES ON NEXT PAGE

[1] NA
[2] NA
[3] Depletion tows 1, 2, 12 & 18 omitted per NEFSC 1998, Figure E18
[4] Depletion tows 1, 19, 23 & 27 omitted per NEFSC 1998, Figure E21
[5] Setup station 5 dropped because sensor tow distance < 0.04 nm
[6] Length composition data collected at setup tow 194 only for OQ2000-1 (indicated 6% of catch >= 90 mm SL), setup data not useable.
[7] Length composition data collected at setup tow 178 only for OQ2000-2 (indicated 28% of catch >= 90 mm SL), used for all setup tows.
[8] Length composition data collected at setup tows 3 and 6 only for OQ2000-3 (average 33% and 28% of catch >= 90 mm SL), used for all setup tows.
[9] Length composition data collected at setup tow 272 only for OQ2000-4 (33% of catch >= 90 mm SL), used for all setup tows.
[10] Sensor tow distance missing for setup station 4, average tow distance at stations 3, 5, 6, 7, 8 used instead.
[11] Depletion tow 1 omitted because it was outside the study area.
[12] Adjustments for apparent trends in numbers per bushel during depletion experiment.
[13] Original estimates appear to have used incorrect mean number per bushel in depletion tows
[14] Missing GPS location data at survey stations 198 and 216 (depletion tows 5 and 23) replaced by approximate start/stop locations and interpolation.
[15] Anomalously high bushel count and length data at station 200 not used.
[16] One setup tow with length data for OQ2002-4.
[17] One setup tow with length data for OQ2000-2.
[18] Two setup tows with length data for OQ2000-3.

Table A12. Summary of new and revised density, commercial dredge efficiency, and survey dredge efficiency estimates for ocean quahog 90+ mm SL from the Patch model and setup tows.

Statistic	Density (N ft^{-2})	Commercial Vessel Efficiency	NEFSC Dredge Efficiency
N experiments	18	17	12
Minimum	0.007	0.150	0.098
Maximum	0.295	1.000	0.990
Median	0.082	0.660	0.165
Mean	0.097	0.596	0.248
Distribution of point estimates[1]			
sd	0.141	0.267	0.241
CV (sd/mean)	1.453	0.448	0.972
Lo 95%	0.000	0.073	0.000
Hi 95%	0.373	1.000	0.722
Distribution of average estimates[1]			
se	0.033	0.065	0.070
CV (se/mean)	0.236	0.243	0.289
Lo 95%	0.032	0.469	0.112
Hi 95%	0.162	0.723	0.385
Distribution of median estimates[2]			
se	0.011	0.091	0.029
Robust CV (se/median)	0.132	0.138	0.177
Lo 95%	0.047	0.402	0.136
Hi 95%	0.089	0.733	0.261

[1] Parametric statistics.
[2] Bootstrap statistics (15,000 iterations).

Table A13. Original (used in the last assessment, NEFSC 2004) and revised ocean quahog density and efficiency estimates from the Patch model based on depletion experiments during 1997-2002. Percent change is (Revised-Previous).Previous x 100. "NA" means not available. Previous and revised density estimates are shown but are not directly comparable because they are based on different size groups.

Experiment	Density (D, n ft^{-2})[a]			Commercial efficiency (E)			Setup Density (d, n ft^{-2})			Survey efficiency (e)		
	Previous	Revised	% Change	Previous	Revised	% Change[c]	Previous	Revised	% Change[c]	Previous	Revised	% Change[c]
OQ2002-1	0.550	0.295	-46%	0.653	0.489	-25%	0.068	0.029	-57%	0.081	0.098	21%
OQ2002-2	0.345	0.165	-52%	0.810	0.785	-3%	0.067	0.024	-64%	0.158	0.149	-6%
OQ2002-3	0.111	0.081	-27%	0.816	0.777	-5%	0.037	0.024	-36%	0.275	0.297	8%
OQ2002-4	0.101	0.073	-27%	0.599	0.254	-58%	0.080	0.021	-74%	0.474	0.287	-39%
OQ2000-1[b]	0.413	0.100	-76%	0.950	0.730	-23%	0.169	NA	NA	0.389	NA	NA
OQ2000-2[b]	0.095	0.062	-35%	0.922	0.554	-40%	0.054	0.015	-73%	0.524	0.234	-55%
OQ2000-3[b]	0.180	0.089	-51%	0.734	0.560	-24%	0.053	0.015	-72%	0.216	0.165	-24%
OQ1999-01 DE2	0.306	0.007	NA	NA	NA	NA	NA	NA	NA	0.470	0.990	111%
OQ1998-1	0.105	0.017	-84%	0.950	1.000	5%	NA	NA	NA	NA	NA	NA
OQ1998-2	0.242	0.067	-73%	0.401	0.869	117%	NA	NA	NA	NA	NA	NA
OQ1998-3	0.570	0.255	-55%	0.950	0.710	-25%	NA	NA	NA	NA	NA	NA
OQ1997-1	0.440	0.083	-81%	0.488	0.458	-6%	NA	NA	NA	NA	NA	NA
OQ1997-2	0.060	0.084	39%	0.256	0.150	-41%	NA	NA	NA	NA	NA	NA

[a] Previous and revised density estimates are shown for completeness but are not comparable because they are based on different size groups.
[b] Survey efficiencies calcuated based on information in NEFSC (2000, Tables C12 and C13) using e=d/D*E.
[c] Percent change is (Revised - Previous) / Previous.

Table A14. Effects of new data and methods on efficiency and density estimates for ocean quahog from the Patch model and setup tows (where available).

Data and methods	Density (D, n/ft^2)	Commercial Efficiency (E)	Setup Tow Density (d, n/ft^2)	Survey Efficiency (e)
		OQ1998-2		
Original[1]	0.242	0.401	NA	
Step 1[2]	0.253	0.383		
Step 2[3]	NA	NA		
Step 3[4]	0.109	0.489		
New[5]	0.067	0.869		
		OQ2002-1		
Original[6]	0.550	0.653	0.068	0.081
Step 1[2]	0.550	0.653	0.068	0.081
Step 2[3]	0.550	0.653	0.068	0.124
Step 3[4]	0.255	0.553	0.029	0.114
New[5]	0.295	0.489	0.029	0.098

[1] From Table A10 in NEFSC (2004)
[2] Step 1 uses new programs and original data
[3] Step 2 is like step 1 but with correct formula for survey dredge efficiency
[4] Step 3 is like step 2 but with new catch data for 90+ mm SL
[5] New estimates are the current best estimates and like step 3 but with revised position data
[6] From Tables C11-C12 in NEFSC (2000)

Table A15. Efficiency corrected swept-area biomass estimates (1,000 mt) and CVs for the fishable stock of ocean quahog during 1997, 2000, 2002 and 2005 by stock assessment region. Figures for SVA and GBK during 2005 were taken from 2003 because no data were available for 2005.

	Estimate	CV
INPUT: Nominal tow distance (d_n, *nm*)	0.15	
INPUT: Dredge width (nm)	0.0008225	
Area swept per standard tow (a, nm^2)	1.23375E-04	10%

Area of assessment region (A, nm^2) - no correction for stations with unsuitable clam habitat

	Estimate	CV
S. Virginia and N. Carolina (SVA)	712	10%
Delmarva (DMV)	4,071	10%
New Jersey (NJ)	6,510	10%
Long Island (LI)	4,463	10%
Southern New England (SNE)	4,922	10%
Georges Bank (GBK)	7,821	10%
Total	28,499	

INPUT: Fraction suitable habitat (u)

	Estimate	CV
S. Virginia and N. Carolina (SVA)	100%	10%
Delmarva (DMV)	100%	10%
New Jersey (NJ)	100%	10%
Long Island (LI)	100%	10%
Southern New England (SNE)	96%	10%
Georges Bank (GBK)	90%	10%

Habitat area in assessment region (A', nm2)

	Estimate	CV
S. Virginia and N. Carolina (SVA)	712	14%
Delmarva (DMV)	4,071	14%
New Jersey (NJ)	6,510	14%
Long Island (LI)	4,463	14%
Southern New England (SNE)	4,714	14%
Georges Bank (GBK)	7,039	14%

INPUT: Biomass fraction in unsurveyd deep water

	Estimate	CV
S. Virginia and N. Carolina (SVA)	0%	10%
Delmarva (DMV)	0%	10%
New Jersey (NJ)	0%	10%
Long Island (LI)	0%	10%
Southern New England (SNE)	2%	10%
Georges Bank (GBK)	13%	10%

INPUT: Original survey mean catch from fishable stock (kg/tow, for tows adjusted to nominal tow distance using sensors)

	Estimates for 1997	CV	Estimates for 1999	CV	Estimates for 2002	CV	Estimates for 2005	CV
S. Virginia and N. Carolina (SVA)	0.0013	100%	0.0007	55%	0.0004	100%	0.0004	100%
Delmarva (DMV)	0.6528	23%	0.4449	26%	0.6863	24%	0.4221	48%
New Jersey (NJ)	1.7341	15%	0.9728	14%	1.8614	23%	1.0441	14%
Long Island (LI)	4.5648	17%	3.0065	14%	3.4414	17%	2.1812	16%
Southern New England (SNE)	2.2252	37%	2.6964	45%	3.2654	26%	2.2555	24%
Georges Bank (GBK)	2.6710	16%	3.1454	18%	3.8760	17%	3.8760	17%

Swept-area biomass without efficiency correction (B', 1000 mt):

	Estimates for 1997	CV	Estimates for 1999	CV	Estimates for 2002	CV	Estimates for 2005	CV
S. Virginia and N. Carolina (SVA)	0.0076	102%	0.0040	59%	0.0022	102%	0.0022	102%
Delmarva (DMV)	21.5388	30%	14.6803	33%	22.6452	31%	13.9280	52%
New Jersey (NJ)	91.4993	25%	51.3297	24%	98.2159	30%	55.0929	24%
Long Island (LI)	165.1265	26%	108.7572	24%	124.4894	26%	78.9022	26%
Southern New England (SNE)	86.7210	42%	105.0878	49%	127.2624	33%	87.9046	31%
Georges Bank (GBK)	172.2007	26%	202.7813	27%	249.8861	26%	249.8861	26%
Total fishable biomass less GBK	365	17%	280	21%	373	16%	236	16%
Total fishable biomass	537	14%	483	17%	623	14%	486	16%

	Estimates for 1997	CV	Estimates for 1999	CV	Estimates for 2002	CV	Estimates for 2005	CV
INPUT: Survey dredge efficiency (e)	0.165	18%	0.165	18%	0.165	18%	0.165	18%

Efficiency adjusted swept area fishable biomass (B, 1000 mt)

	Estimates for 1997	CV	Estimates for 1999	CV	Estimates for 2002	CV	Estimates for 2005	CV
S. Virginia and N. Carolina (SVA)	0.046	104%	0.024	61%	0.013	104%	0.013	104%
Delmarva (DMV)	131	35%	89	37%	137	36%	84	55%
New Jersey (NJ)	555	31%	311	30%	596	35%	334	30%
Long Island (LI)	1,002	32%	660	30%	755	32%	479	31%
Southern New England (SNE)	526	46%	638	52%	772	37%	533	36%
Georges Bank (GBK)	1,045	31%	1,230	32%	1,516	32%	1,516	32%
Total fishable biomass less GBK	2,214	24%	1,698	28%	2,261	24%	1,431	24%
Total fishable biomass	3,258	23%	2,928	24%	3,776	23%	2,947	24%

Lower bound for 80% confidence intervals on fishable biomass (1000 mt, for lognormal distribution with no bias correction)

	Estimates for 1997	Estimates for 1999	Estimates for 2002	Estimates for 2005
S. Virginia and N. Carolina (SVA)	0.015	0.012	0.004	0.004
Delmarva (DMV)	84	56	88	44
New Jersey (NJ)	378	213	385	229
Long Island (LI)	675	452	509	324
Southern New England (SNE)	302	340	487	342
Georges Bank (GBK)	708	823	1,021	1,021
Total fishable biomass less GBK	1,627	1,199	1,667	1,060
Total fishable biomass	2,448	2,153	2,830	2,189

Upperbound for 80% confidence intervals on fishable biomass (1000 mt, for lognormal distribution with no bias correction)

	Estimates for 1997	Estimates for 1999	Estimates for 2002	Estimates for 2005
S. Virginia and N. Carolina (SVA)	0.137	0.050	0.040	0.040
Delmarva (DMV)	202	141	215	163
New Jersey (NJ)	814	454	923	488
Long Island (LI)	1,488	962	1,122	706
Southern New England (SNE)	918	1,197	1,225	833
Georges Bank (GBK)	1,542	1,839	2,251	2,251
Total fishable biomass less GBK	3,012	2,405	3,066	1,931
Total fishable biomass	4,336	3,982	5,039	3,967

Table A16. Ocean quahog fishing mortality estimates based on catch and efficiency corrected swept-area biomass for fishable ocean quahog during 1997, 1999, 2002 and 2005. CV's are based on analytical variance calculations assuming log normality, and include uncertainty in catch, survey data, swept-area, amount of suitable habitat, and survey dredge efficiency.

INPUT: Upper bound incidental mortality allowance	5%
INPUT: Assumed CV for catch	10%

INPUT: Landings (1000 mt, discard ~ 0)	**Estimates for 1997**	**Estimates for 1999**	**Estimates for 2002**	**Estimates for 2005**
S. Virginia and N. Carolina (SVA)	0.000	0.000	0.000	0.000
Delmarva (DMV)	1.072	1.092	1.737	0.935
New Jersey (NJ)	4.229	3.043	2.788	0.665
Long Island (LI)	5.141	6.338	9.139	9.713
Southern New England (SNE)	8.968	6.628	3.895	2.021
Georges Bank (GBK)	0.000	0.000	0.000	0.000
Total	19.409	17.102	17.559	13.334

Catch (1000 mt, landings + upper bound incidental mortality allowance)				
S. Virginia and N. Carolina (SVA)	0.000	0.000	0.000	0.000
Delmarva (DMV)	1.126	1.146	1.824	0.981
New Jersey (NJ)	4.441	3.195	2.928	0.699
Long Island (LI)	5.398	6.655	9.596	10.199
Southern New England (SNE)	9.416	6.960	4.090	2.122
Georges Bank (GBK)	0.000	0.000	0.000	0.000
Total	20.380	17.957	18.437	14.001

INPUT: Efficiency Corrected Swept Area Biomass for Fishable Stock (1000 mt)	**Estimates for 1997**	**CV**	**Estimates for 1999**	**CV**	**Estimates for 2002**	**CV**	**Estimates for 2005**	**CV**
S. Virginia and N. Carolina (SVA)	0	104%	0	61%	0	104%	0	104%
Delmarva (DMV)	131	35%	89	37%	137	36%	84	55%
New Jersey (NJ)	555	31%	311	30%	596	35%	334	30%
Long Island (LI)	1,002	32%	660	30%	755	32%	479	31%
Southern New England (SNE)	526	46%	638	52%	772	37%	533	36%
Georges Bank (GBK)	1,045	31%	1,230	32%	1,516	32%	1,516	32%
Total fishable biomass less GBK	2,214	24%	1,698	28%	2,261	24%	1,431	24%
Total fishable biomass	3,258	23%	2,928	24%	3,776	23%	2,947	24%
Fishing mortality (y^{-1})								
S. Virginia and N. Carolina (SVA)	0.000	104%	0.000	62%	0.000	104%	0.000	104%
Delmarva (DMV)	0.009	37%	0.013	39%	0.013	37%	0.012	56%
New Jersey (NJ)	0.008	32%	0.010	32%	0.005	37%	0.002	32%
Long Island (LI)	0.005	NA	0.010	NA	0.013	33%	0.021	33%
Southern New England (SNE)	0.018	47%	0.011	53%	0.005	39%	0.004	37%
Georges Bank (GBK)	0.000	NA	0.000	NA	0.000	NA	0.000	NA
Total fishable biomass less GBK	0.009	26%	0.011	29%	0.008	26%	0.010	26%
Total fishable biomass	0.006	25%	0.006	26%	0.005	25%	0.005	26%

Lower bound for 80% confidence intervals for fishing mortality (y^{-1}, for lognormal distribution with no bias correction)	**Estimates for 1997**	**Estimates for 1999**	**Estimates for 2002**	**Estimates for 2005**
S. Virginia and N. Carolina (SVA)	NA	NA	NA	NA
Delmarva (DMV)	0.005	0.008	0.008	0.006
New Jersey (NJ)	0.005	0.007	0.003	0.001
Long Island (LI)	NA	NA	0.008	0.014
Southern New England (SNE)	0.010	0.006	0.003	0.003
Georges Bank (GBK)	NA	NA	NA	NA
Total fishable biomass less GBK	0.007	0.007	0.006	0.007
Total fishable biomass	0.005	0.004	0.004	0.003

Upper bound for 80% confidence intervals for fishing mortality (y^{-1}, for lognormal distribution with no bias correction)				
S. Virginia and N. Carolina (SVA)	NA	NA	NA	NA
Delmarva (DMV)	0.014	0.021	0.021	0.023
New Jersey (NJ)	0.012	0.015	0.008	0.003
Long Island (LI)	NA	NA	0.019	0.032
Southern New England (SNE)	0.032	0.021	0.009	0.006
Georges Bank (GBK)	NA	NA	NA	NA
Total fishable biomass less GBK	0.013	0.015	0.011	0.014
Total fishable biomass	0.009	0.009	0.007	0.007

Table A17. Proportions of total fishable ocean quahog biomass during 1980-2005 at a range of survey biomass density levels, by region.

Years	Fishable biomass density levels (kg/tow) from survey data: 0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25+	Sum of Proportions (check)	Total Number of Tows	Total Number of Surveys
Proportions of tows (and stock area) at each survey catch rate level:									
Southern Virgina (SVA)									
1980-1989	1.00						1.00	47	5
1990-1999	1.00						1.00	37	3
2000-2005	1.00						1.00	19	2
Delmarva (DMV)									
1980-1989	0.90	0.04	0.03	0.01	0.01	0.02	1.00	317	5
1990-1999	0.92	0.05	0.01	0.01	0.00		1.00	207	3
2000-2005	0.96	0.02	0.01	0.01			1.00	131	2
New Jersy (NJ)									
1980-1989	0.84	0.07	0.03	0.02	0.02	0.03	1.00	458	5
1990-1999	0.82	0.11	0.04	0.02	0.01		1.00	307	3
2000-2005	0.92	0.05	0.02			0.01	1.00	183	2
Long Island (LI)									
1980-1989	0.57	0.21	0.12	0.06	0.01	0.04	1.00	218	5
1990-1999	0.49	0.19	0.12	0.10	0.02	0.07	1.00	121	3
2000-2005	0.64	0.24	0.06	0.02	0.01	0.02	1.00	84	2
Southern New England (SNE)									
1980-1989	0.75	0.09	0.08	0.03	0.02	0.03	1.00	245	5
1990-1999	0.67	0.16	0.08	0.04	0.01	0.04	1.00	114	3
2000-2005	0.65	0.23	0.07	0.04	0.02		1.00	57	2
Georges Bank (GBK)									
1986-1992	0.82	0.06	0.03	0.01	0.01	0.06	1.00	201	3
1997-2002	0.68	0.10	0.07	0.03	0.05	0.07	1.00	219	3
All years	0.75	0.08	0.05	0.02	0.03	0.07	1.00	420	6
Mean survey catch rate (kg/tow) at each survey catch rate level (p_L):									
Southern Virgina (SVA)									
1980-1989	0.054								
1990-1999	0.007								
2000-2005	0.002								
Delmarva (DMV)									
1980-1989	0.490	5.856	11.604	18.761	21.994	31.082			
1990-1999	0.413	7.133	13.556	17.734	21.847				
2000-2005	0.307	7.888	11.960	15.524					
New Jersy (NJ)									
1980-1989	0.848	7.115	12.577	17.033	20.956	35.668			
1990-1999	0.647	6.845	11.748	17.546	23.198				
2000-2005	0.938	6.166	12.707			29.972			
Long Island (LI)									
1980-1989	1.703	7.100	12.281	17.431	20.781	38.945			
1990-1999	1.252	7.523	12.508	16.974	22.793	30.846			
2000-2005	1.779	6.894	12.780	16.666	20.087	39.638			
Southern New England (SNE)									
1980-1989	1.002	7.084	12.200	17.286	21.627	33.942			
1990-1999	1.001	7.461	11.993	17.384	20.904	36.563			
2000-2005	1.387	7.238	12.077	16.226	21.845				
Georges Bank (GBK)									
1986-1992	0.627	6.874	12.945	16.049	23.225	44.962			
1997-2002	0.626	7.681	12.370	16.595	23.386	40.787			
All years	0.627	7.381	12.535	16.413	23.349	42.576			
Proportions of stock biomass at each survey catch rate level (X_L):									
Southern Virgina (SVA)									
1980-1989	1.00						1.00		
1990-1999	1.00						1.00		
2000-2005	1.00						1.00		
Delmarva (DMV)									
1980-1989	0.23	0.12	0.15	0.12	0.07	0.31	1.00		
1990-1999	0.30	0.27	0.15	0.20	0.08		1.00		
2000-2005	0.43	0.26	0.13	0.17			1.00		
New Jersy (NJ)									
1980-1989	0.22	0.15	0.14	0.09	0.10	0.29	1.00		
1990-1999	0.23	0.34	0.20	0.17	0.07		1.00		
2000-2005	0.49	0.17	0.16			0.19	1.00		
Long Island (LI)									
1980-1989	0.15	0.22	0.23	0.15	0.03	0.22	1.00		
1990-1999	0.08	0.18	0.19	0.21	0.07	0.28	1.00		
2000-2005	0.22	0.32	0.15	0.08	0.05	0.18	1.00		
Southern New England (SNE)									
1980-1989	0.18	0.16	0.22	0.13	0.08	0.23	1.00		
1990-1999	0.12	0.22	0.18	0.14	0.03	0.30	1.00		
2000-2005	0.21	0.38	0.19	0.13	0.09	0.00	1.00		
Georges Bank (GBK)									
1986-1992	0.11	0.10	0.08	0.05	0.08	0.58	1.00		
1997-2002	0.07	0.12	0.13	0.07	0.16	0.45	1.00		
All years	0.08	0.11	0.11	0.06	0.13	0.50	1.00		

Table A18. Proportions of total 2005 stock biomass at a range of survey density levels, by region.

Region	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25+	Total
			Survey catch rate level (kg/tow)				
			Total 2005 biomass (mt meats)				
Southern Virgina (SVA)	17	0	0	0	0	0	17
Delmarva (DMV)	43,532	26,628	13,459	17,470	0	0	101,089
New Jersy (NJ)	195,400	68,833	63,047	0	0	74,354	401,634
Long Island (LI)	151,198	217,001	100,560	52,457	31,612	124,762	677,590
Southern New England (SNE)	123,098	225,647	115,846	77,824	52,388	0	594,802
Georges Bank (GBK)	82,714	148,850	163,456	87,709	206,009	574,872	1,263,610
Total	595,959	686,960	456,369	235,460	290,008	773,987	3,038,741
			Total 2005 biomass (bushels)				
Southern Virgina (SVA)	3,731	0	0	0	0	0	3,731
Delmarva (DMV)	9,597,036	5,870,504	2,967,208	3,851,373	0	0	22,286,120
New Jersy (NJ)	43,077,930	15,174,947	13,899,368	0	0	16,391,987	88,544,232
Long Island (LI)	33,333,071	47,840,106	22,169,510	11,564,629	6,969,113	27,504,966	149,381,395
Southern New England (SNE)	27,138,182	49,746,067	25,539,371	17,157,064	11,549,366	0	131,130,049
Georges Bank (GBK)	18,235,073	32,815,497	36,035,560	19,336,384	45,416,674	126,736,217	278,575,405
Total	131,385,021	151,447,120	100,611,016	51,909,450	63,935,154	170,633,170	669,920,932
			Percent of total 2005 biomass				
Southern Virgina (SVA)	0.001%	0.000%	0.000%	0.000%	0.000%	0.000%	0.001%
Delmarva (DMV)	1.43%	0.88%	0.44%	0.57%	0.00%	0.00%	3.33%
New Jersy (NJ)	6.43%	2.27%	2.07%	0.00%	0.00%	2.45%	13.22%
Long Island (LI)	4.98%	7.14%	3.31%	1.73%	1.04%	4.11%	22.30%
Southern New England (SNE)	4.05%	7.43%	3.81%	2.56%	1.72%	0.00%	19.57%
Georges Bank (GBK)	2.72%	4.90%	5.38%	2.89%	6.78%	18.92%	41.58%
Total	19.61%	22.61%	15.02%	7.75%	9.54%	25.47%	100.00%

Table A19. Calculations to build a bridge between efficiency corrected swept area biomass estimates for ocean quahog during 2002 in NEFSC (2004) and new estimates in this assessment. Columns show cumulative effects from each change in data and methods starting with NEFSC's (2004) estimates on the left and ending with the new estimates on the right.

Region	NEFSC (2004)	Step 1 (New spread sheet)	Step 2 (Correct survey data)	Step 3 (Add biomass in deep water)	Step 4 (Use fishable biomass)	This assessment (New efficiency estimate	Ratio (New / NEFSC(2004)
			Data and configuration				
Efficiency	0.269	0.269	0.269	0.269	0.269	0.165	0.61
Size groups in Patch model	70+	70+	70+	70+	Fishable	Fishable	NA
Deep water percentage	0%	0%	0%	13%	13%	13%	NA
Survey data	Erroneous	Erroneous	Correct	Correct	Correct	Correct	NA
			2002 efficiency corrected swept-area biomass estimates (1000 mt)				
SVA	0.01	0.01	0.01	0.01	0.01	0.01	1.93
DMV	71	71	89	89	84	137	1.93
NJ	330	330	383	383	365	596	1.81
LI	454	454	498	498	463	755	1.66
SNE	428	437	511	511	473	772	1.80
GBK	833	833	875	989	929	1,516	1.82
Total less GBK	1,283	1,292	1,481	1,481	1,385	2,261	1.76
Total	2,116	2,125	2,356	2,470	2,314	3,776	1.78

Table A20. "Best" fishable biomass and fishing mortality estimates for ocean quahog during 1978-2005, by stock assessment region and for the entire EEZ stock (with and without GBK).

	SVA	DMV		NJ		LI		SNE		GBK		Entire stock less GBK	Entire Stock
Model	VPA	KLAMZ		KLAMZ		KLAMZ		KLAMZ		Mean ESB 1997-2002 (Same as VPA)		NA	NA
	Estimate	**Estimate**	**CV**	**Estimate**	**CV**	**Estimate**	**CV**	**Estimate**	**CV**	**Estimate**	**CV**	**Estimate**	**Estimate**
Scaling parameter for swept area biomass	1 (assumed)	0.99	NA	0.95	NA	1.00	NA	0.99	NA	1 (assumed)	NA	NA	NA
Recruitment (1000 mt)	NA	0 (assumed)		0.541	0.43	9.860	0.34	4.799	1.06	NA		15.199 (excludes SVA)	15.199 (excludes SVA & GBK)
Fishable Stock Biomass (1000 mt)													
1978	0.338	299	0.10	904	0.22	718	0.26	788	0.32	1,264	0.19	2,710	3,973
1979	0.338	292	0.10	879	0.22	721	0.25	782	0.31	1,264	0.19	2,674	3,938
1980	0.338	280	0.10	855	0.21	723	0.24	777	0.30	1,264	0.19	2,636	3,900
1981	0.338	270	0.11	831	0.21	726	0.24	771	0.29	1,264	0.19	2,599	3,862
1982	0.275	261	0.11	807	0.21	729	0.23	765	0.28	1,264	0.19	2,562	3,826
1983	0.268	251	0.11	783	0.20	732	0.22	759	0.27	1,264	0.19	2,525	3,789
1984	0.268	240	0.11	761	0.20	734	0.22	753	0.26	1,264	0.19	2,489	3,753
1985	0.261	228	0.12	738	0.20	737	0.21	747	0.25	1,264	0.19	2,450	3,714
1986	0.075	216	0.12	713	0.20	739	0.20	741	0.24	1,264	0.19	2,409	3,672
1987	0.075	203	0.12	691	0.19	742	0.20	735	0.24	1,264	0.19	2,370	3,634
1988	0.075	189	0.13	669	0.19	743	0.20	729	0.23	1,264	0.19	2,330	3,594
1989	0.031	173	0.14	650	0.19	745	0.19	723	0.22	1,264	0.19	2,291	3,555
1990	0.031	163	0.15	625	0.19	747	0.19	717	0.21	1,264	0.19	2,252	3,515
1991	0.017	157	0.15	598	0.19	749	0.18	711	0.21	1,264	0.19	2,214	3,478
1992	0.017	149	0.15	573	0.19	749	0.18	705	0.20	1,264	0.19	2,176	3,440
1993	0.017	143	0.16	556	0.18	740	0.18	699	0.20	1,264	0.19	2,139	3,402
1994	0.017	139	0.16	536	0.18	734	0.18	693	0.19	1,264	0.19	2,102	3,366
1995	0.017	135	0.16	520	0.18	724	0.18	688	0.18	1,264	0.19	2,067	3,331
1996	0.017	131	0.16	505	0.18	718	0.18	678	0.18	1,264	0.19	2,033	3,296
1997	0.017	128	0.16	492	0.18	714	0.18	665	0.18	1,264	0.19	2,000	3,263
1998	0.017	125	0.16	479	0.18	712	0.18	652	0.18	1,264	0.19	1,968	3,231
1999	0.017	121	0.17	468	0.17	708	0.18	642	0.18	1,264	0.19	1,938	3,202
2000	0.017	117	0.17	457	0.17	705	0.18	631	0.18	1,264	0.19	1,910	3,173
2001	0.017	114	0.17	445	0.17	703	0.18	622	0.18	1,264	0.19	1,884	3,148
2002	0.017	111	0.17	433	0.17	700	0.18	614	0.18	1,264	0.19	1,857	3,121
2003	0.017	107	0.17	422	0.17	694	0.18	607	0.18	1,264	0.19	1,830	3,093
2004	0.017	104	0.17	412	0.17	685	0.18	601	0.18	1,264	0.19	1,802	3,065
2005	0.017	101	0.18	402	0.17	678	0.18	595	0.18	1,264	0.19	1,775	3,039

Table A20 (continued).

Fishing mortality rate													
1978	0.0000	0.0044	0.10	0.0097	0.22	0.00000	NA	0.0000	NA	0.0000	0.00	0.0039	0.0026
1979	0.0000	0.0191	0.10	0.0095	0.22	0.00000	NA	0.0000	NA	0.0000	0.00	0.0059	0.0040
1980	0.0000	0.0172	0.10	0.0103	0.21	0.00001	0.24	0.0000	NA	0.0000	0.00	0.0051	0.0034
1981	0.2085	0.0148	0.11	0.0111	0.21	0.00000	0.24	0.0000	NA	0.0000	0.00	0.0051	0.0034
1982	0.0252	0.0195	0.11	0.0116	0.21	0.00000	NA	0.0000	NA	0.0000	0.00	0.0056	0.0037
1983	0.0000	0.0224	0.11	0.0109	0.20	0.00003	0.22	0.0009	0.27	0.0000	0.00	0.0058	0.0039
1984	0.0257	0.0326	0.11	0.0126	0.20	0.00000	NA	0.0012	0.26	0.0000	0.00	0.0072	0.0048
1985	1.2454	0.0358	0.12	0.0163	0.20	0.0001	0.21	0.0010	0.25	0.0000	0.00	0.0085	0.0056
1986	0.0000	0.0407	0.12	0.0134	0.20	0.0006	0.20	0.0008	0.24	0.0000	0.00	0.0079	0.0052
1987	0.0000	0.0539	0.13	0.0134	0.19	0.0016	0.20	0.0010	0.24	0.0000	0.00	0.0091	0.0059
1988	0.8817	0.0649	0.14	0.0106	0.19	0.0009	0.20	0.0012	0.23	0.0000	0.00	0.0087	0.0057
1989	0.0000	0.0383	0.14	0.0221	0.19	0.0008	0.19	0.0017	0.22	0.0000	0.00	0.0098	0.0063
1990	0.6092	0.0230	0.15	0.0255	0.19	0.0010	0.19	0.0013	0.21	0.0000	0.00	0.0094	0.0060
1991	0.0000	0.0317	0.15	0.0249	0.19	0.0023	0.18	0.0012	0.21	0.0000	0.00	0.0100	0.0064
1992	0.0000	0.0163	0.16	0.0123	0.19	0.0161	0.18	0.0016	0.20	0.0000	0.00	0.0104	0.0066
1993	0.0000	0.0139	0.16	0.0187	0.19	0.0118	0.18	0.0015	0.20	0.0000	0.00	0.0103	0.0065
1994	0.0000	0.0073	0.16	0.0132	0.18	0.0166	0.18	0.0014	0.19	0.0000	0.00	0.0100	0.0063
1995	0.0000	0.0053	0.16	0.0105	0.18	0.0133	0.18	0.0080	0.19	0.0000	0.00	0.0103	0.0064
1996	0.0000	0.0057	0.16	0.0098	0.18	0.0084	0.18	0.0125	0.18	0.0000	0.00	0.0099	0.0061
1997	0.0000	0.0085	0.16	0.0087	0.18	0.0073	0.18	0.0137	0.18	0.0000	0.00	0.0099	0.0060
1998	0.0000	0.0112	0.16	0.0057	0.18	0.0097	0.18	0.0105	0.18	0.0000	0.00	0.0091	0.0056
1999	0.0000	0.0092	0.17	0.0066	0.17	0.0090	0.18	0.0105	0.18	0.0000	0.00	0.0090	0.0054
2000	0.0000	0.0091	0.17	0.0074	0.17	0.0068	0.18	0.0082	0.18	0.0000	0.00	0.0077	0.0047
2001	0.0000	0.0084	0.17	0.0110	0.17	0.0086	0.18	0.0080	0.18	0.0000	0.00	0.0091	0.0054
2002	0.0000	0.0160	0.17	0.0065	0.17	0.0132	0.18	0.0064	0.18	0.0000	0.00	0.0097	0.0058
2003	0.0000	0.0085	0.17	0.0089	0.17	0.0170	0.18	0.0036	0.18	0.0000	0.00	0.0103	0.0061
2004	0.0000	0.0062	0.17	0.0069	0.17	0.0157	0.18	0.0055	0.18	0.0000	0.00	0.0098	0.0058
2005	0.0000	0.0094	0.18	0.0017	0.17	0.0145	0.18	0.0034	0.18	0.0000	0.00	0.0077	0.0045

Table A21. Ocean quahog biomass in 2005 as a percentage of biomass in 1978, based on best estimates.

SVA	DMV	NJ	LI	SNE	GBK	Entire stock less GBK	Entire Stock
5%	34%	44%	94%	75%	100%	66%	76%

Table A22. Comparison of best estimates for ocean quahog biomass during 2004 from the previous (NEFSC 2004) and current assessments.

Assessment	SVA	DMV	NJ	LI	SNE	GBK	Entire stock less GBK	Entire Stock
			1978 Biomass Estimates (Virgin Biomass)					
This assessment	0.338	299	904	718	788	1,264	2,710	3,973
NEFSC (2004)	0.297	298	455	534	386	655	1,674	2,329
Ratio (new/old)	1.1	1.0	2.0	1.3	2.0	1.9	1.6	1.7
			2004 Biomass Estimates					
This assessment	0.0169	103.8	411.5	685	601.3	1264	1801.603121	3065
NEFSC (2004)	0.013	91	284	478	349	655	1,201	1,856
Ratio (new/old)	1.3	1.1	1.5	1.4	1.7	1.9	1.5	1.7

Table A23. Mean numbers per tow for ocean quahog < 70 mm SL and mean weight per tow for ocean quahog 70+ mm SL in NEFSC clam surveys on GBK during 1986-2002 (1994 omitted due to high pump voltage).

Year	< 70 mm SL (N tow^{-1})	CV	70+ mm SL (KG tow^{-1})	CV
1986	40.5	0.60	5.7	0.17
1989	7.0	0.32	2.3	0.26
1992	31.7	0.35	9.0	0.21
1997	62.0	0.35	6.6	0.19
1999	35.3	0.34	7.5	0.19
2002	39.7	0.18	8.7	0.20

Table A24. Biological reference points for ocean quahog from a length based per-recruit model with sensitivity analyses. Biological reference points from an age based per-recruit model in the last assessment (NEFSC 2004) are shown for comparison.

			Natural Mortality (M)		Fishery selectivity L50%		Growth parameter K		Maturity L50%	
Reference Point	Old (SARC-38)	New basecase[A]	Half basecase (M_{LO}=0.01 y^{-1})	Double basecase (M_{HI}=0.04 y^{-1})	Basecase - 5 mm ($L50_{LO}$ = 73 - 5 = 67 mm)	Basecase - 5 mm ($L50_{HI}$ = 73 + 5 = 78 mm)	Basecase - 30% (K_{LO} = 0.0311 * 0.7 = 0.0218 y^{-1})	Basecase + 30% (K = 0.0311 * 1.3 = 0.0404 y^{-1})	Basecase - 5 mm ($L50_{LO}$ = 64 - 5 = 59 mm)	Basecase + 5 mm ($L50_{HI}$ = 64 + 5 = 69 mm)
$F_{0.1}$ (target)	0.0275	0.0278	0.0160	0.0618	0.0254	0.0300	0.0288	0.0277	0.0278	0.0278
F_{MAX}	0.1810	0.0760	0.0361	0.2300	0.0632	0.0896	0.0882	0.0722	0.0760	0.0760
$F_{25\%}$ (threshold)	0.0800	0.0517	0.0291	0.1249	0.0429	0.0617	0.0564	0.0501	0.0561	0.0478
$F_{50\%}$	0.0200	0.0180	0.0110	0.0402	0.0158	0.0205	0.0192	0.0177	0.0190	0.0171

[A] In the basecase run: M=0.02 y^{-1}, growth parameters (L_{max}=97.28 mm; K=0.0311 y^{-1}) are from NEFSC (2002); maturity (α=-5.92; b=0.0927) and fishery selectivity (a=-7.63; b=0.1054) parameters are from Thorarinsdottir and Jacobson (2005); and length-weight parameters (ln a=-9.242; b=2.821) are from an average length-weight curve for all stock assessment areas.

Table A25. Percentage of ocean quahog biomass in each stock assessment region during 1978 and 2005. Percentages for SVA, DMV, NJ, LI, SNE and GBK in the same row sum to 100%.

Year	SVA	DMV	NJ	LI	SNE	GBK	Entire stock less GBK
1978	0.009%	8%	23%	18%	20%	32%	68%
2005	0.001%	3%	13%	22%	20%	42%	58%

Table A26. Input data for ocean quahog projections.

Year	**SVA**	**DMV**	**NJ**	**LI**	**SNE**	**GBK**	**Total Less GBK**	**Total**
				Somatic growth rate (G y^{-1})				
2005	0.0045	1.0600E-07	0.0013	0.0101	0.0066	0	0.0064	0.0037
				Recruitment rate (r = Recruitment / Average Biomass in 2005 y^{-1})				
2005	0.0060	1.0038E-08	0.0014	0.0146	0.0081	0.0000	0.0086	0.0050
				Natural mortality (M y^{-1})				
2005	0.0200	0.0200	0.0200	0.0200	0.0200	0	0.0200	0.0117
				Initial Biomass				
2005	0.017	101	402	678	595	1,264	1,775	3,039
				Landings (mt y^{-1})				
2005	0.000	0.890	0.634	9.251	1.924	0	12.6990	12.6990
				Catch (landings + 5% allowance for incidental mortality, mt y^{-1})				
2005	0.000	0.935	0.665	9.713	2.021	0	13.3340	13.3340
				Fishing mortality (F y^{-1})				
2005	0.0000	0.0094	0.0017	0.0145	0.0034	0	0.0077	0.0045

Table A27. Projected biomass and fishing mortality for ocean quahog during 2005-2010 based on a 4 million bushel (18,144 mt meats) annual quota during 2007-2010. Landings during 2006 are assumed the same as in 2005. Proportions of total catch in each year for each region are the same as in 2005.

Year	SVA	DMV	NJ	LI	SNE	GBK	Total Less GBK	Total
				Somatic growth rate ($G\ y^{-1}$)				
2005	0.0045	0.0000	0.0013	0.0101	0.0066	0.0000	0.0064	0.0037
				Recruitment rate (r = Recruitment / Average Biomass in 2002 y^{-1})				
2005	0.0060	0.0000	0.0014	0.0146	0.0081	0.0000	0.0086	0.0050
				Natural mortality ($M\ y^{-1}$)				
2005	0.0200	0.0200	0.0200	0.0200	0.0200	0.0000	0.0200	0.0117
				Net instantaneous rate of change, less fishing ($X - F = G + r - M\ \ y^{-1}$)				
2005	-0.0095	-0.0200	-0.0174	0.0047	-0.0052	0.0000	-0.0050	-0.0029
				Fishing mortality first year ($F\ \ y^{-1}$)				
2005	0.0000	0.0094	0.0017	0.0145	0.0034	0.0000	0.0077	0.0045
				Landings (mt meats y^{-1})				
2005-2006	0	1	1	9	2	0	13	13
2007-2010	0	1	1	13	3	0	18	18
				Catch (mt meats y^{-1}, landings+ 5% allowance for incidental mortality)				
2005-2006	0	1	1	10	2	0	13	13
2007-2010	0	1	1	14	3	0	19	19
				Initial Biomass				
2005-2006	0	101	402	678	595	1,264	1,775	3,039
				Projected biomass (mt meats)				
2006	0	98	394	671	590	1,264	1,753	3,016
2007	0	95	387	664	585	1,264	1,731	2,995
2008	0	92	379	654	579	1,264	1,703	2,967
2009	0	89	372	643	573	1,264	1,676	2,940
2010	0	86	364	632	567	1,264	1,649	2,912
				Projected fishing mortality rate ($F\ y^{-1}$)				
2006	0.000	0.010	0.002	0.015	0.003	0.000	0.008	0.004
2007	0.000	0.014	0.002	0.021	0.005	0.000	0.011	0.006
2008	0.000	0.015	0.003	0.021	0.005	0.000	0.011	0.006
2009	0.000	0.015	0.003	0.022	0.005	0.000	0.011	0.007
2010	0.000	0.016	0.003	0.022	0.005	0.000	0.012	0.007

Table A28. Projected biomass and fishing mortality for ocean quahog during 2005-2010 based on a 5.333 million bushel (24,189 mt meats) annual quota during 2007-2010. Landings during 2006 are assumed the same as in 2005. Proportions of total catch in each year for each region are the same as in 2005.

Year	SVA	DMV	NJ	LI	SNE	GBK	Total Less GBK	Total
				Somatic growth rate (G y^{-1})				
2005	0.0045	0.0000	0.0013	0.0101	0.0066	0.0000	0.0064	0.0037
				Recruitment rate (r = Recruitment / Average Biomass in 2002 y^{-1})				
2005	0.0060	0.0000	0.0014	0.0146	0.0081	0.0000	0.0086	0.0050
				Natural mortality (M y^{-1})				
2005	0.0200	0.0200	0.0200	0.0200	0.0200	0.0000	0.0200	0.0117
				Net instantaneous rate of change, less fishing (X - F = G + r - M y^{-1})				
2005	-0.0095	-0.0200	-0.0174	0.0047	-0.0052	0.0000	-0.0050	-0.0029
				Fishing mortality first year (F y^{-1})				
2005	0.0000	0.0094	0.0017	0.0145	0.0034	0.0000	0.0077	0.0045
				Landings (mt meats y^{-1})				
2005-2006	0	1	1	9	2	0	13	13
2007-2010	0	2	1	18	4	0	24	24
				Catch (mt meats y^{-1}, landings+ 5% allowance for incidental mortality)				
2005-2006	0	1	1	10	2	0	13	13
2007-2010	0	2	1	19	4	0	25	25
				Initial Biomass				
2005-2006	0	101	402	678	595	1,264	1,775	3,039
				Projected biomass (mt meats)				
2006	0	98	394	671	590	1,264	1,753	3,016
2007	0	95	387	664	585	1,264	1,731	2,995
2008	0	92	379	649	578	1,264	1,697	2,961
2009	0	88	371	633	571	1,264	1,663	2,927
2010	0	85	363	618	564	1,264	1,630	2,893
				Projected fishing mortality rate (F y^{-1})				
2006	0.000	0.010	0.002	0.015	0.003	0.000	0.008	0.004
2007	0.000	0.019	0.003	0.028	0.007	0.000	0.015	0.009
2008	0.000	0.020	0.003	0.029	0.007	0.000	0.015	0.009
2009	0.000	0.021	0.003	0.030	0.007	0.000	0.015	0.009
2010	0.000	0.021	0.004	0.030	0.007	0.000	0.016	0.009

Table A29. Projected biomass and fishing mortality for ocean quahog during 2005-2010 based on a 6 million bushel (27,215 mt meats) annual quota during 2007-2010. Landings during 2006 are assumed the same as in 2005. Proportions of total catch in each year for each region are the same as in 2005.

Year	SVA	DMV	NJ	LI	SNE	GBK	Total Less GBK	Total
Somatic growth rate (G y^{-1})								
2005	0.0045	0.0000	0.0013	0.0101	0.0066	0.0000	0.0064	0.0037
Recruitment rate (r = Recruitment / Average Biomass in 2002 y^{-1})								
2005	0.0060	0.0000	0.0014	0.0146	0.0081	0.0000	0.0086	0.0050
Natural mortality (M y^{-1})								
2005	0.0200	0.0200	0.0200	0.0200	0.0200	0.0000	0.0200	0.0117
Net instantaneous rate of change, less fishing (X - F = G + r - M y^{-1})								
2005	-0.0095	-0.0200	-0.0174	0.0047	-0.0052	0.0000	-0.0050	-0.0029
Fishing mortality first year (F y^{-1})								
2005	0.0000	0.0094	0.0017	0.0145	0.0034	0.0000	0.0077	0.0045
Landings (mt meats y^{-1})								
2005-2006	0	1	1	9	2	0	13	13
2007-2010	0	2	1	20	4	0	27	27
Catch (mt meats y^{-1}, landings+ 5% allowance for incidental mortality)								
2005-2006	0	1	1	10	2	0	13	13
2007-2010	0	2	1	21	4	0	29	29
Initial Biomass								
2005-2006	0	101	402	678	595	1,264	1,775	3,039
Projected biomass (mt meats)								
2006	0	98	394	671	590	1,264	1,753	3,016
2007	0	95	387	664	585	1,264	1,731	2,995
2008	0	91	379	647	577	1,264	1,694	2,957
2009	0	88	371	629	570	1,264	1,657	2,921
2010	0	84	363	611	563	1,264	1,620	2,884
Projected fishing mortality rate (F y^{-1})								
2006	0.000	0.010	0.002	0.015	0.003	0.000	0.008	0.004
2007	0.000	0.021	0.004	0.032	0.007	0.000	0.017	0.010
2008	0.000	0.022	0.004	0.033	0.008	0.000	0.017	0.010
2009	0.000	0.023	0.004	0.034	0.008	0.000	0.017	0.010
2010	0.000	0.024	0.004	0.035	0.008	0.000	0.018	0.010

Table A30. Projected biomass and fishing mortality for ocean quahog during 2005-2010 based on $F=F_{0.1}=0.0278\ y^{-1}$ for exploitable region (total area less GBK) during 2007-2010. Landings during 2006 are assumed the same as in 2005. Proportions of total catch in each year for each region are the same as in 2005.

Year	SVA	DMV	NJ	LI	SNE	GBK	Total Less GBK	Total
Somatic growth rate (G y^{-1})								
2005	0.0045	0.0000	0.0013	0.0101	0.0066	0.0000	0.0064	0.0037
Recruitment rate (r = Recruitment / Average Biomass in 2002 y^{-1})								
2005	0.0060	0.0000	0.0014	0.0146	0.0081	0.0000	0.0086	0.0050
Natural mortality (M y^{-1})								
2005	0.0200	0.0200	0.0200	0.0200	0.0200	0.0000	0.0200	0.0117
Fishing mortality (F y^{-1})								
2005-2006	0.0000	0.0094	0.0017	0.0145	0.0034	0.0000	0.0077	0.0045
2007-2010	0.0278	0.0278	0.0278	0.0278	0.0278	0.0000	NA	NA
Net instantaneous rate of change X = G + r - F - M y^{-1})								
2005-2006	-0.0095	-0.0294	-0.0190	-0.0098	-0.0086	0.0000	-0.0127	-0.0074
2007-2010	-0.0373	-0.0478	-0.0452	-0.0231	-0.0330	0.0000	NA	NA
Initial Biomass								
2005	0.017	101	402	678	595	1,264	1,775	3,039
Projected biomass (mt meats)								
2006	0.017	98	394	671	590	1,264	1,753	3,016
2007	0.016	94	377	656	571	1,264	1,696	2,960
2008	0.016	89	360	641	552	1,264	1,642	2,905
2009	0.015	85	344	626	534	1,264	1,589	2,853
2010	0.014	81	329	612	517	1,264	1,538	2,802
Catch (landings + 5% allowance for incidental mortality, mt y^{-1})								
2006	0.0	0.9	0.7	9.7	2.0	0.0	13.3	13.3
2007	0.0	3.2	2.3	33.8	7.0	0.0	46.4	46.4
2008	0.0	3.1	2.2	32.1	6.7	0.0	44.1	44.1
2009	0.0	3.0	2.1	30.8	6.4	0.0	42.3	42.3
2010	0.0	2.9	2.0	29.7	6.2	0.0	40.8	40.8
Landings (95% of catch, mt y^{-1})								
2006	0.0	0.9	0.6	9.2	1.9	0.0	12.7	12.7
2007	0.0	3.1	2.2	32.1	6.7	0.0	44.0	44.0
2008	0.0	2.9	2.1	30.5	6.4	0.0	41.9	41.9
2009	0.0	2.8	2.0	29.2	6.1	0.0	40.1	40.1
2010	0.0	2.7	1.9	28.2	5.9	0.0	38.7	38.7
Projected fishing mortality rate (F y^{-1})								
2006	0.000	0.009	0.002	0.014	0.003	0.000	0.008	0.004
2007	0.000	0.035	0.006	0.052	0.012	0.000	0.027	0.016
2008	0.000	0.035	0.006	0.051	0.012	0.000	0.027	0.015
2009	0.000	0.035	0.006	0.050	0.012	0.000	0.027	0.015
2010	0.000	0.036	0.006	0.049	0.012	0.000	0.027	0.015

Table A31. Summary of example projections.

Year	Biomass All Regions (1000 mt)	Biomass less GBK (1000 mt)	Landings (1000 mt)	*F* All Regions (y^{-1})	*F* less GBK (y^{-1})
Quota = 4 million bushels (18,144 mt meats)					
2006	3,016	1,753	13	0.004	0.008
2007	2,995	1,731	18	0.006	0.011
2008	2,967	1,703	18	0.006	0.011
2009	2,940	1,676	18	0.007	0.011
2010	2,912	1,649	18	0.007	0.012
Quota = 5.333 million bushels (24,189 mt meats)					
2006	3,016	1,753	13	0.004	0.008
2007	2,995	1,731	24	0.009	0.015
2008	2,961	1,697	24	0.009	0.015
2009	2,927	1,663	24	0.009	0.015
2010	2,893	1,630	24	0.009	0.016
Quota = 6 million bushels (27,215 mt meats)					
2006	3,016	1,753	13	0.004	0.008
2007	2,995	1,731	27	0.010	0.017
2008	2,957	1,694	27	0.010	0.017
2009	2,921	1,657	27	0.010	0.017
2010	2,884	1,620	27	0.010	0.018
$F = F_{0.1}$=0.028 y^{-1} in exploited regions (F=0 for GBK)					
2006	3,016	1,753	13	0.004	0.028
2007	2,960	1,696	44	0.016	0.028
2008	2,905	1,642	42	0.015	0.028
2009	2,853	1,589	40	0.015	0.028
2010	2,802	1,538	39	0.015	0.028

OCEAN QUAHOG FIGURES

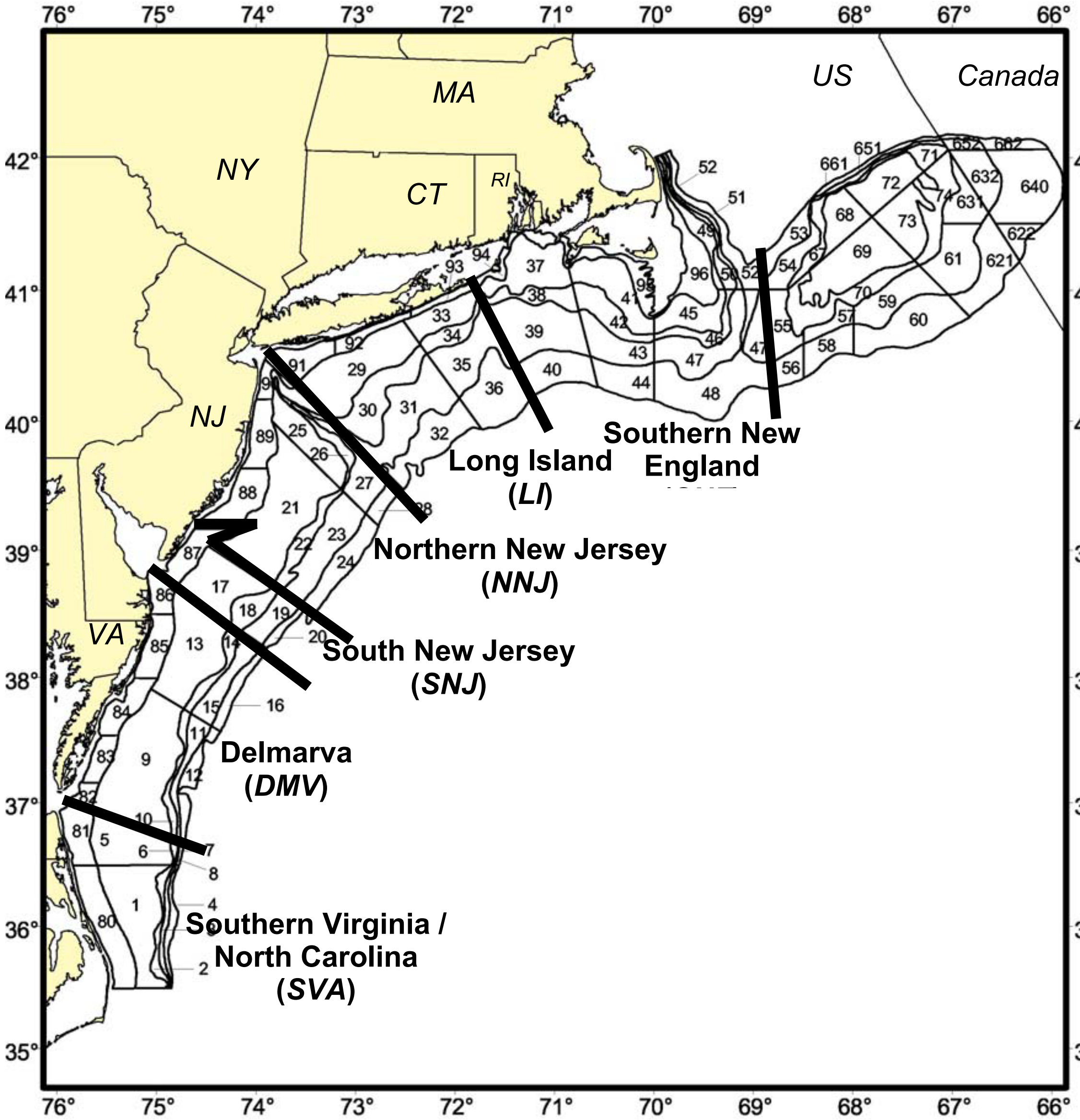


Figure A1. Stock assessment regions for ocean quahog in the US EEZ, with NEFSC shellfish survey strata numbers and boundaries.

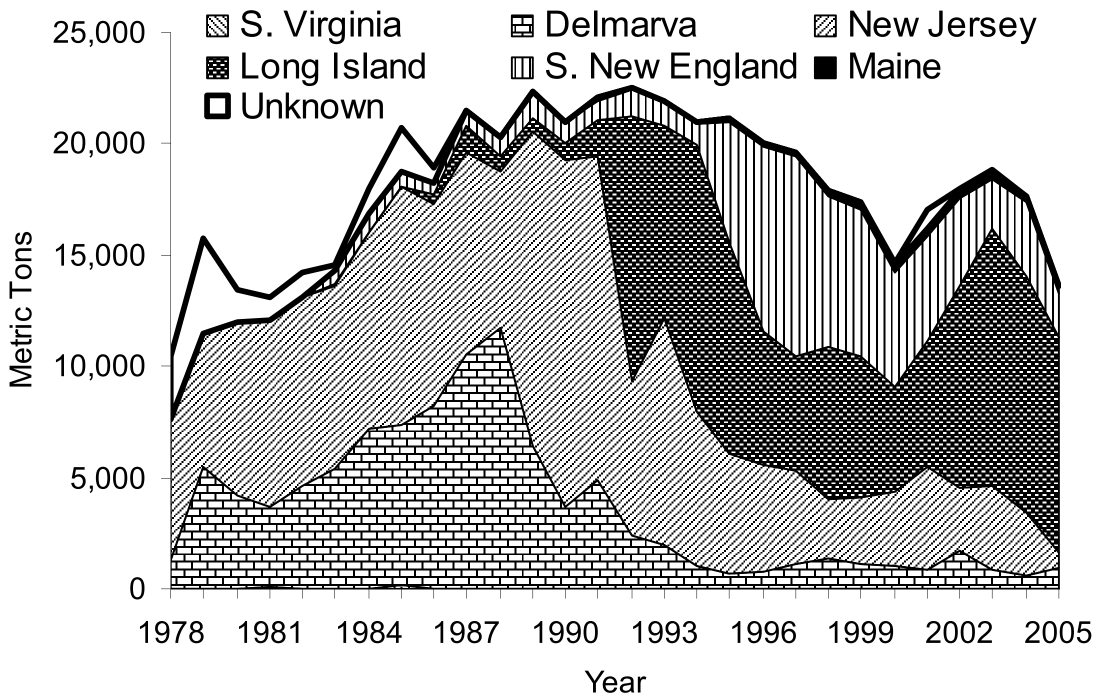
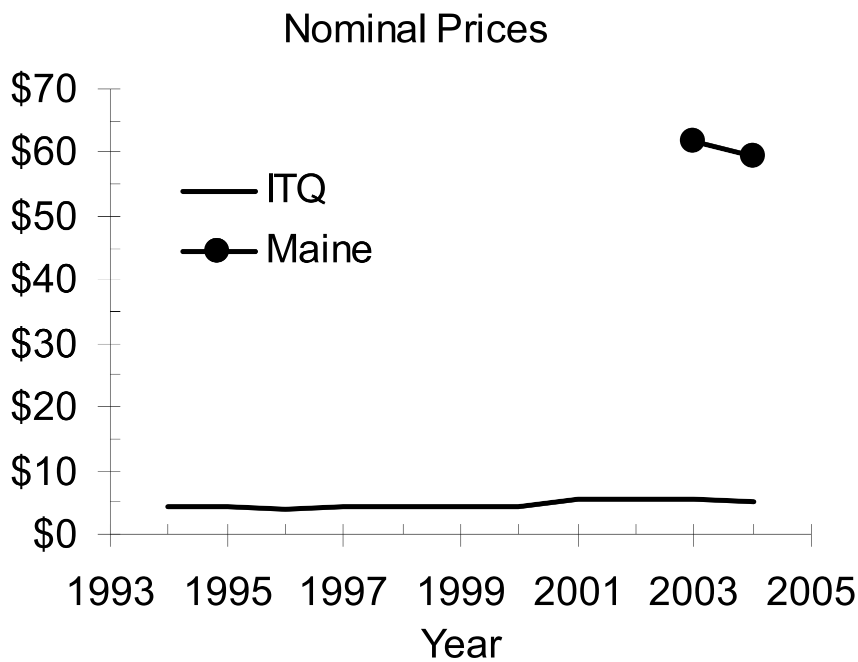


Figure A2. Ocean quahog commercial landings (meat weights) from the US EEZ during 1978-2005. Data for 2005 are preliminary and may be incomplete.



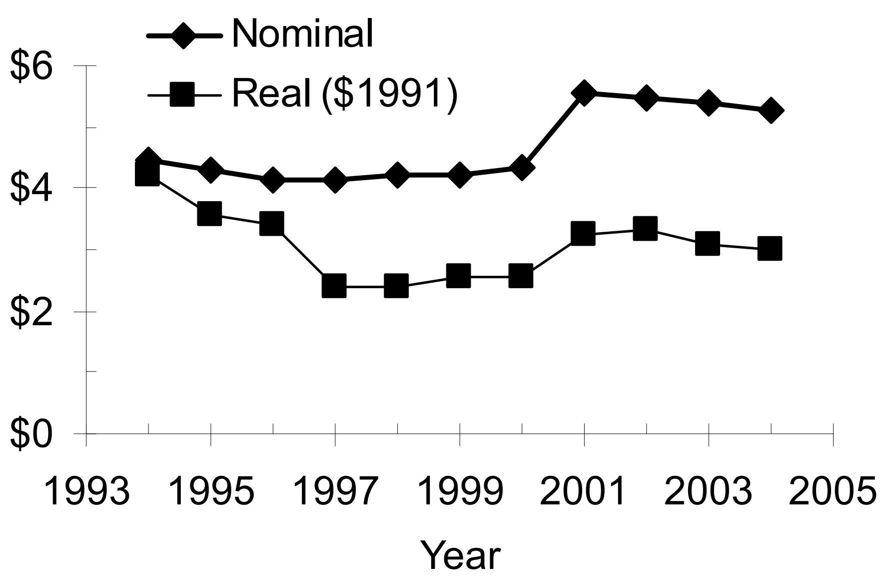


Figure A3. Real and nominal exvessel prices for ocean quahog in the ITQ and Maine fishery components.

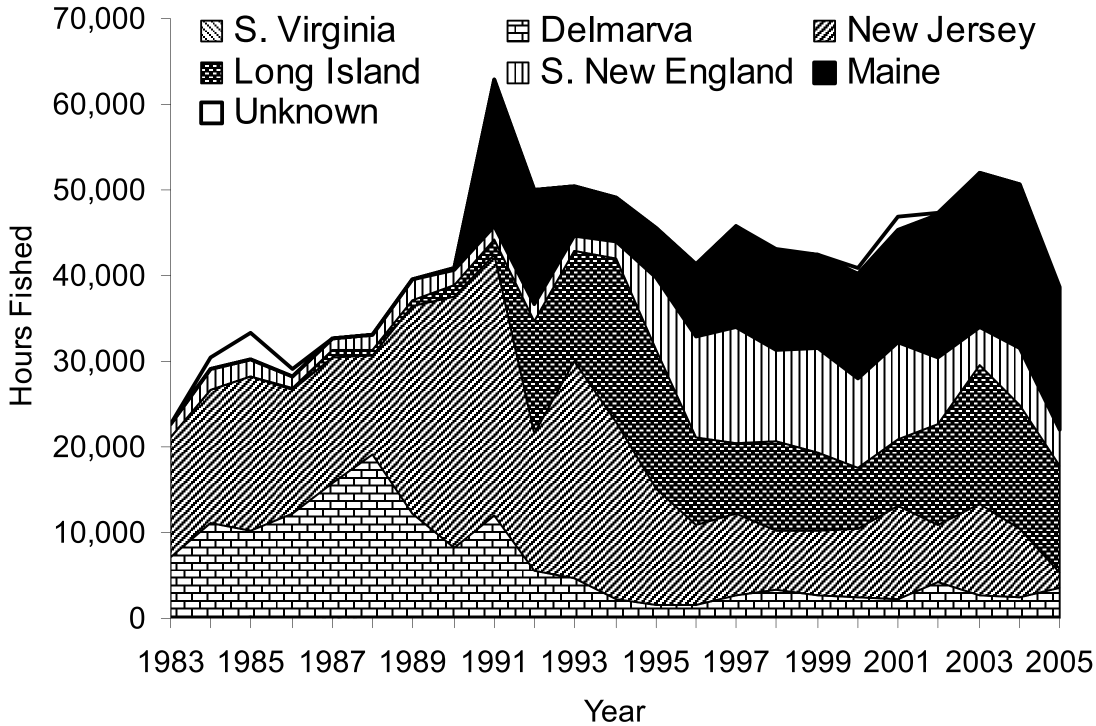


Figure A4. Hours fished for ocean quahog in the US EEZ during 1983-2005 based on logbook records.

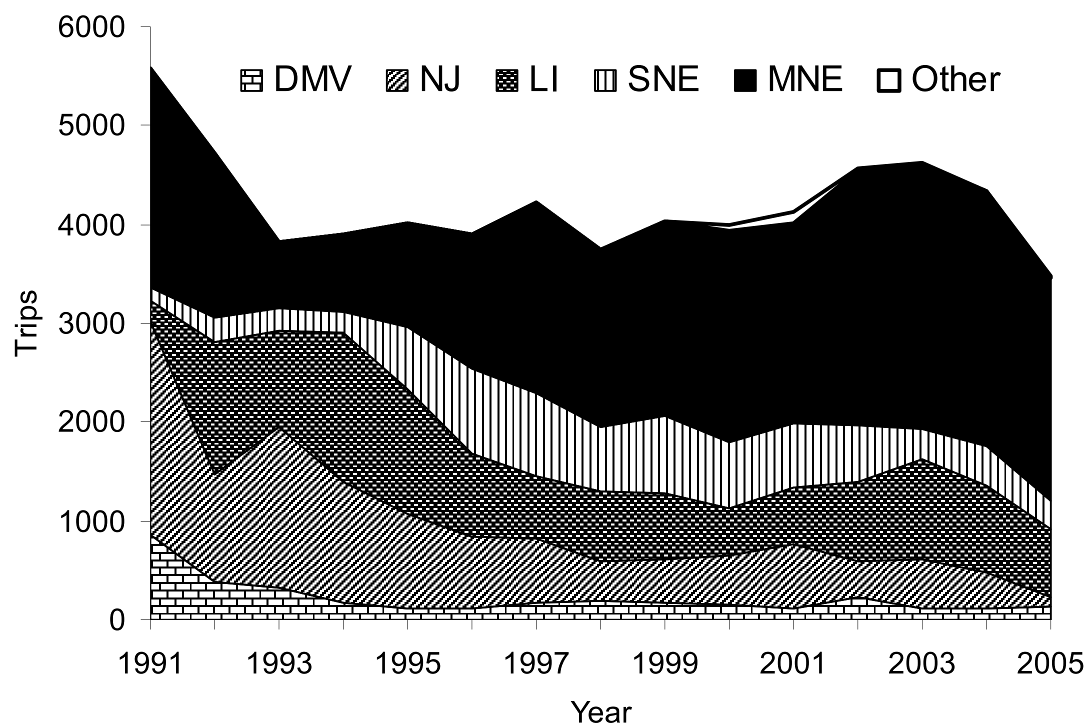


Figure A5. Number of trips for ocean quahog in the US EEZ during 1991-2004 based on logbook records.

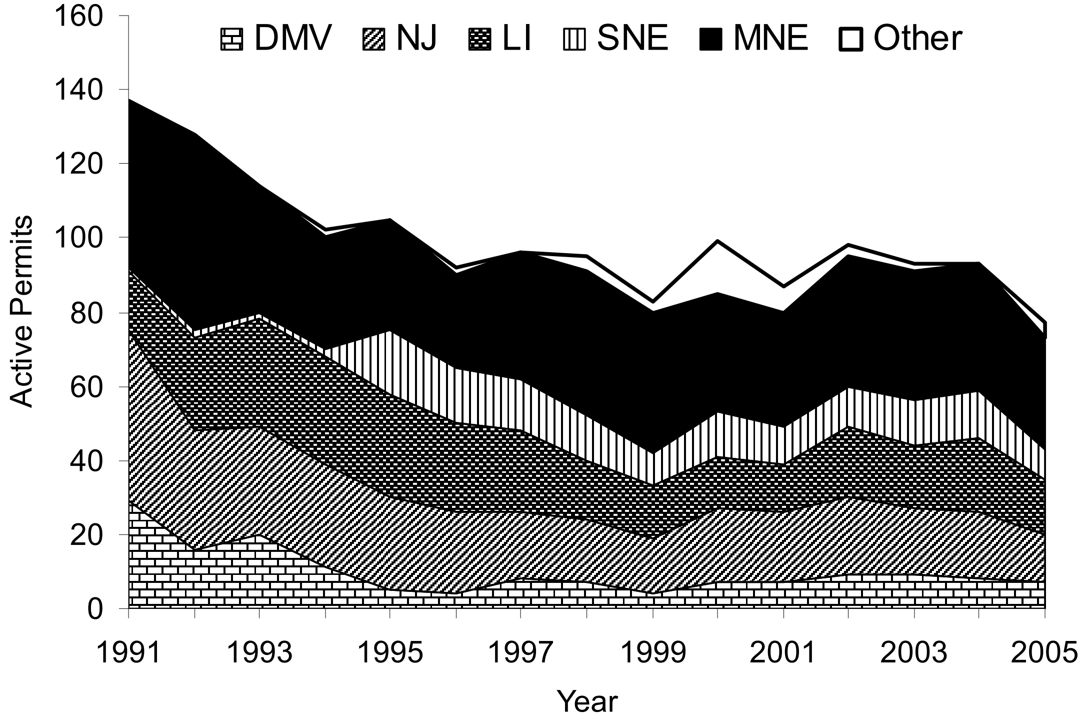
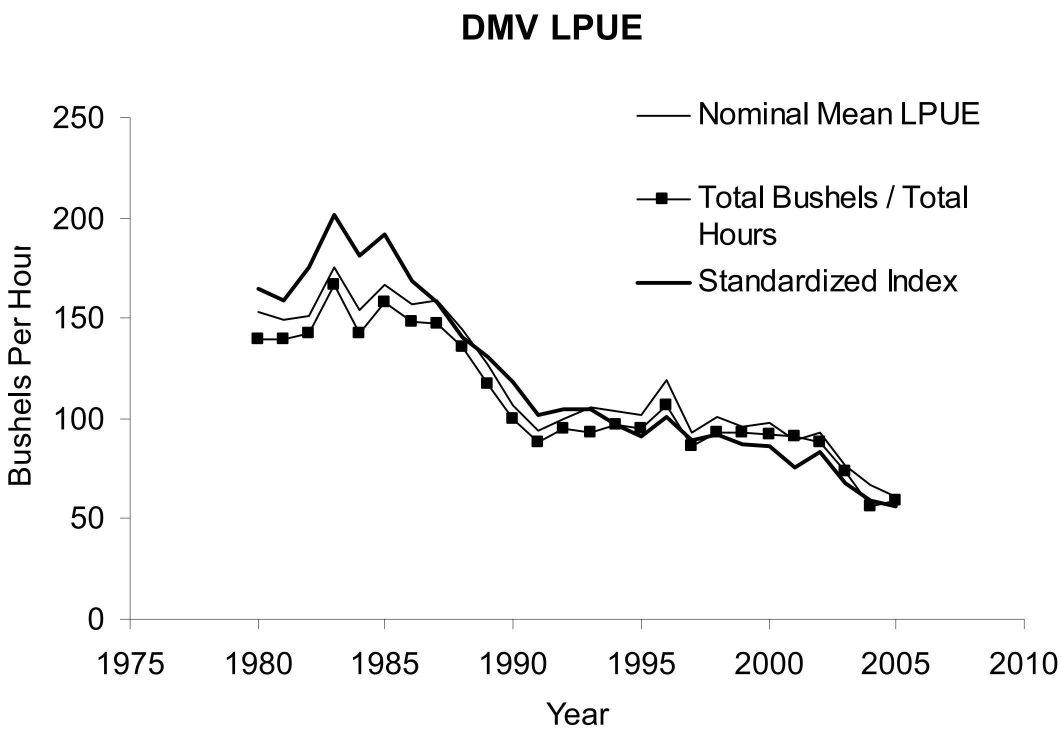


Figure A6. Number of active permits (fishing vessels) for ocean quahog in the US EEZ during 19910-2004 based on logbook records. The total number of permits in the graph for any year may exceed the total number of active permits in the fishery because some vessels fished in more than one area.



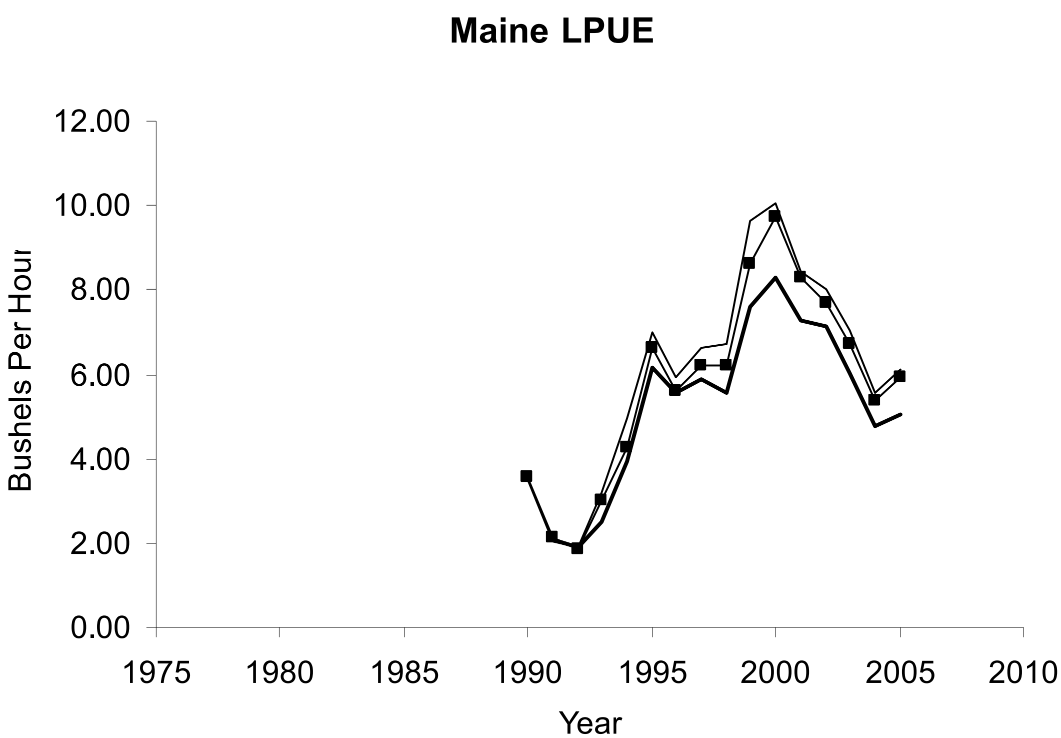


Figure A7. Trends in three measures of LPUE for ocean quahog in the DMV (ITQ bushels per hour) and MNE (Maine bushels per hour) stock assessment regions.

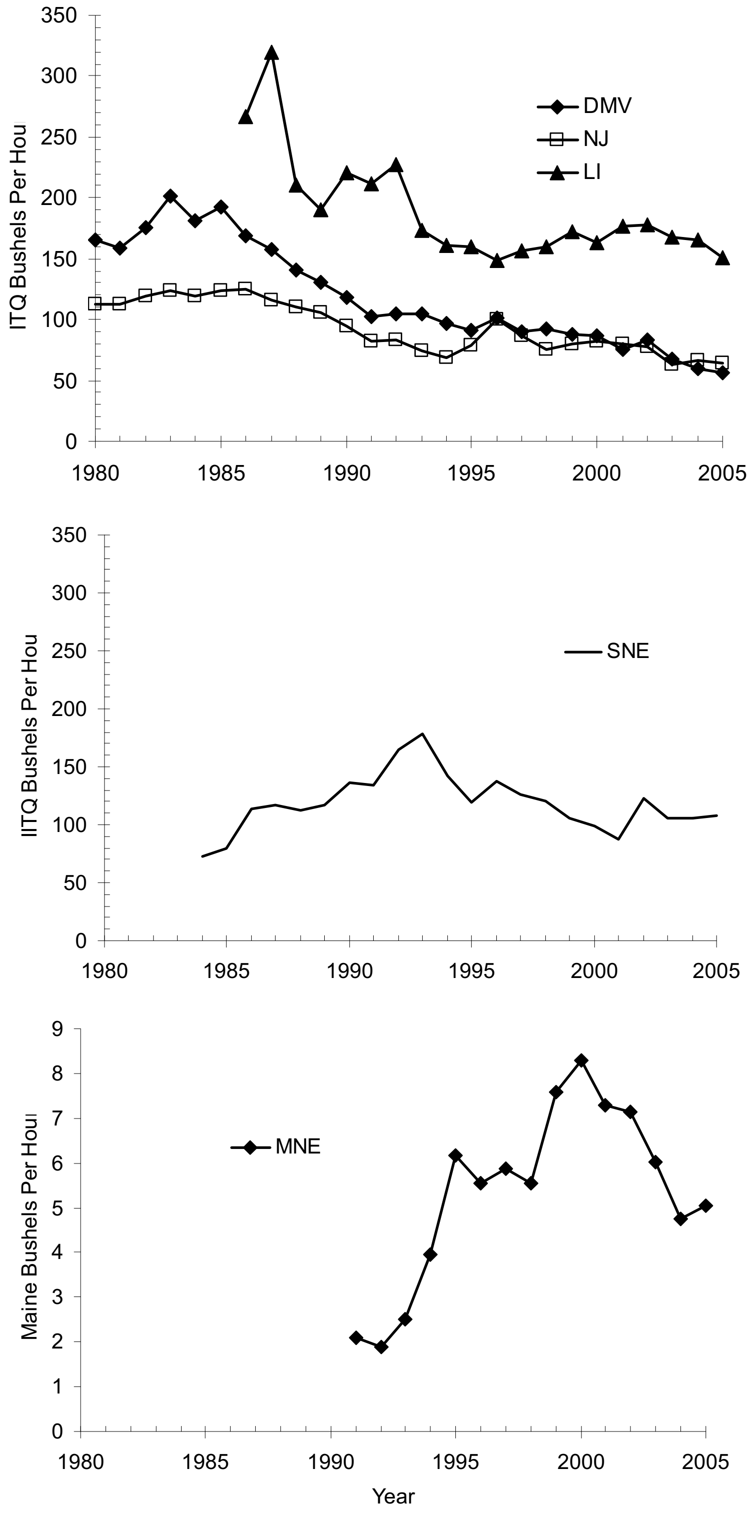


Figure A8. Trends in standardized LPUE for ocean quahog during 1980-2005 by stock assessment region.

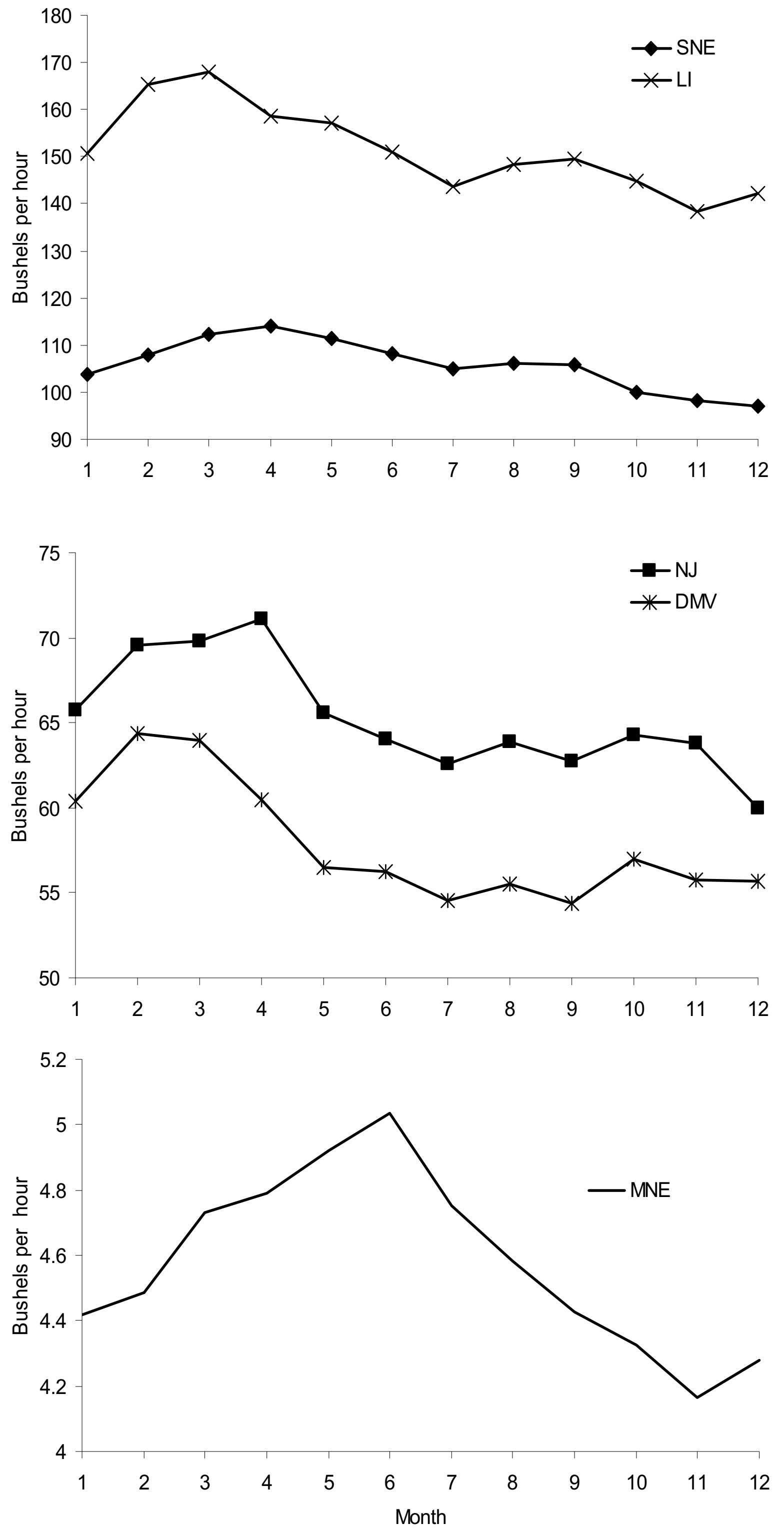


Figure A9. Trends in standardized LPUE month effects for ocean quahog during 1980-2005 by stock assessment region.

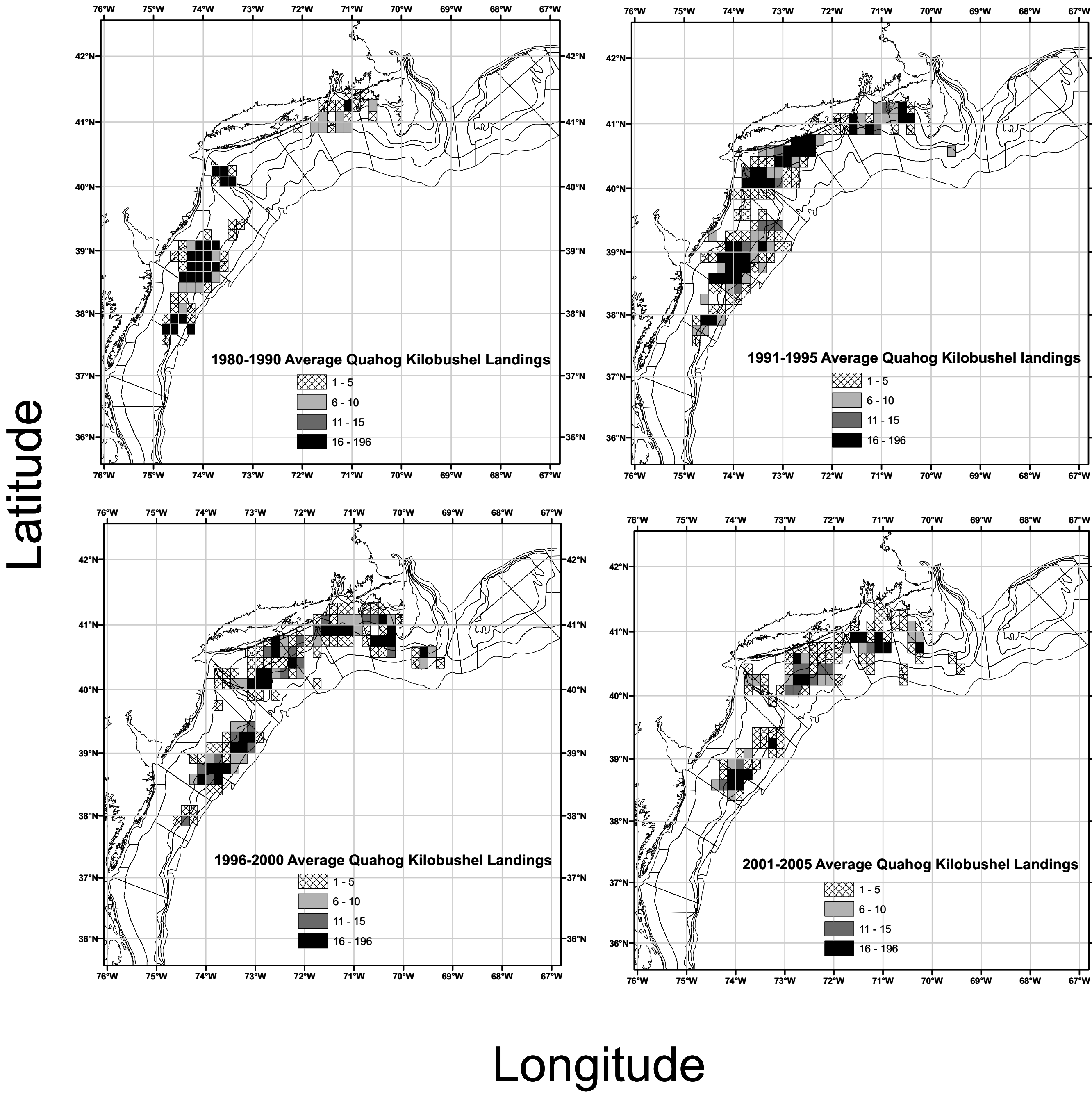


Figure A10. Spatial patterns in average annual landings (1000 ITQ bushels y^{-1}) for ocean quahog from logbook records. Data in TNMS far offshore reflect errors in logbook data.

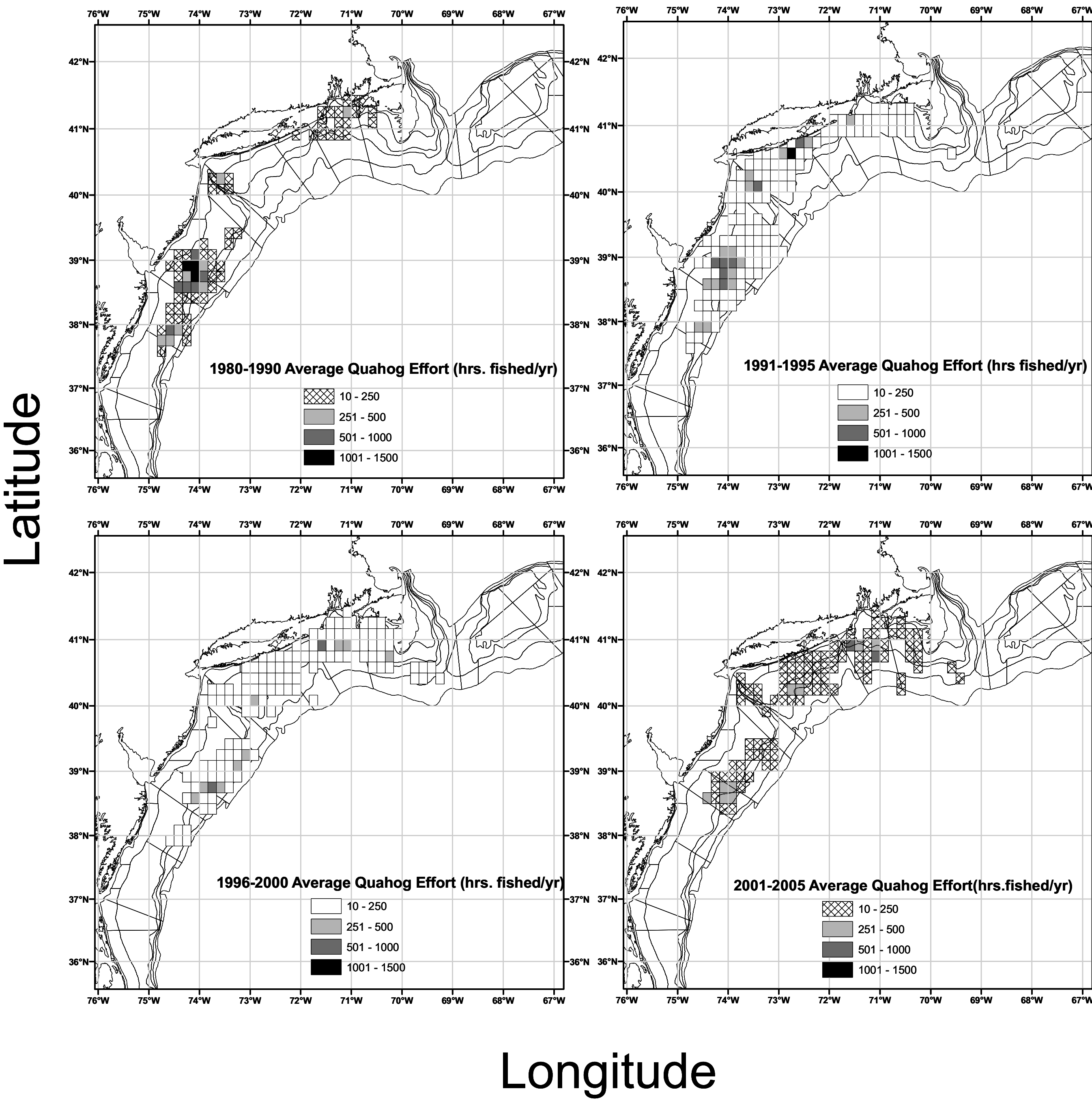


Figure A11. Spatial patterns in average annual fishing effort (hours fished y^{-1}) for ocean quahog from logbook records. Data in TNMS far offshore reflect errors in logbook data.

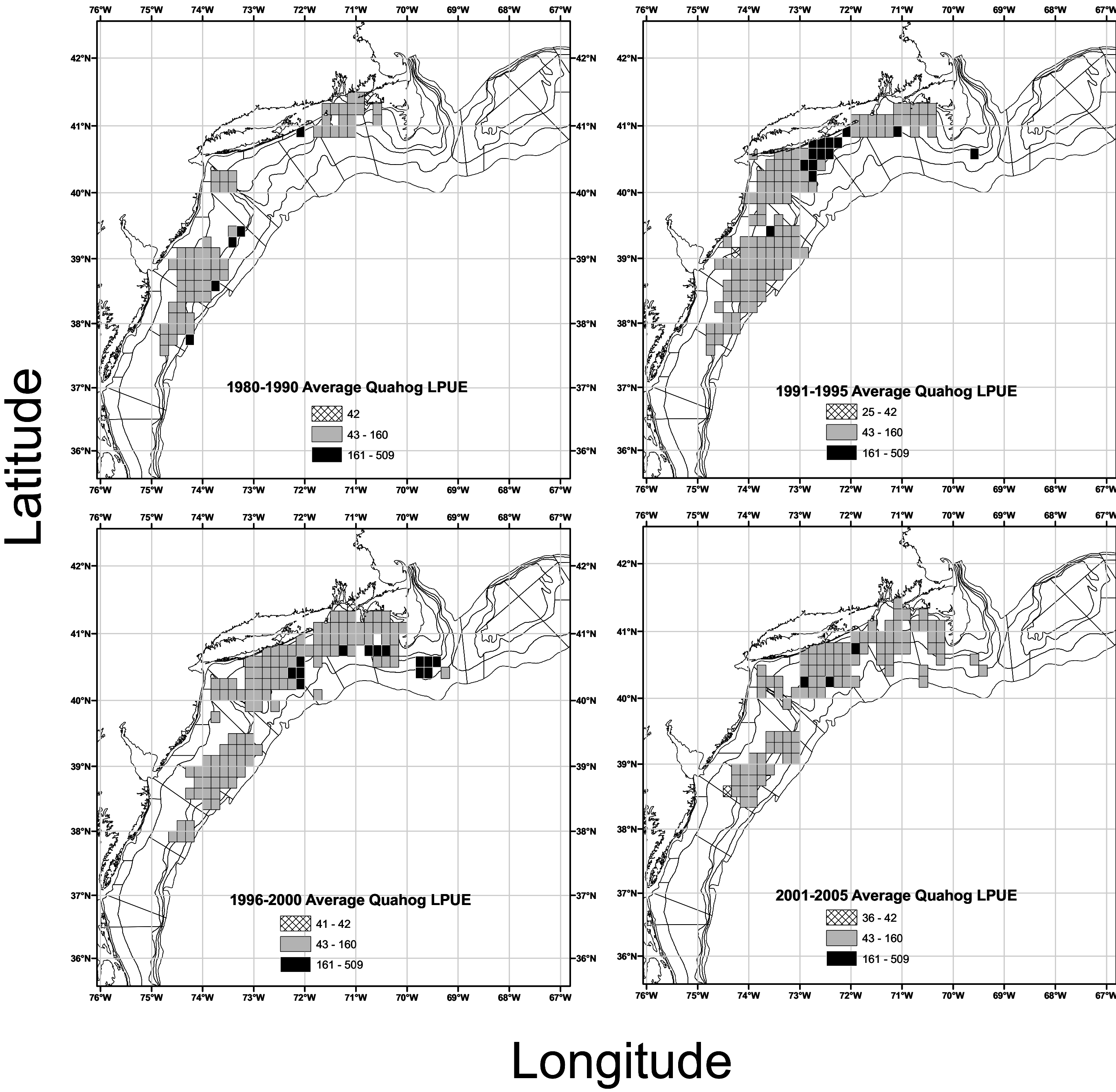


Figure A12. Spatial patterns in average LPUE (ITQ bushels per hours fished) for ocean quahog from logbook records. Data in TNMS far offshore reflect errors in logbook data.

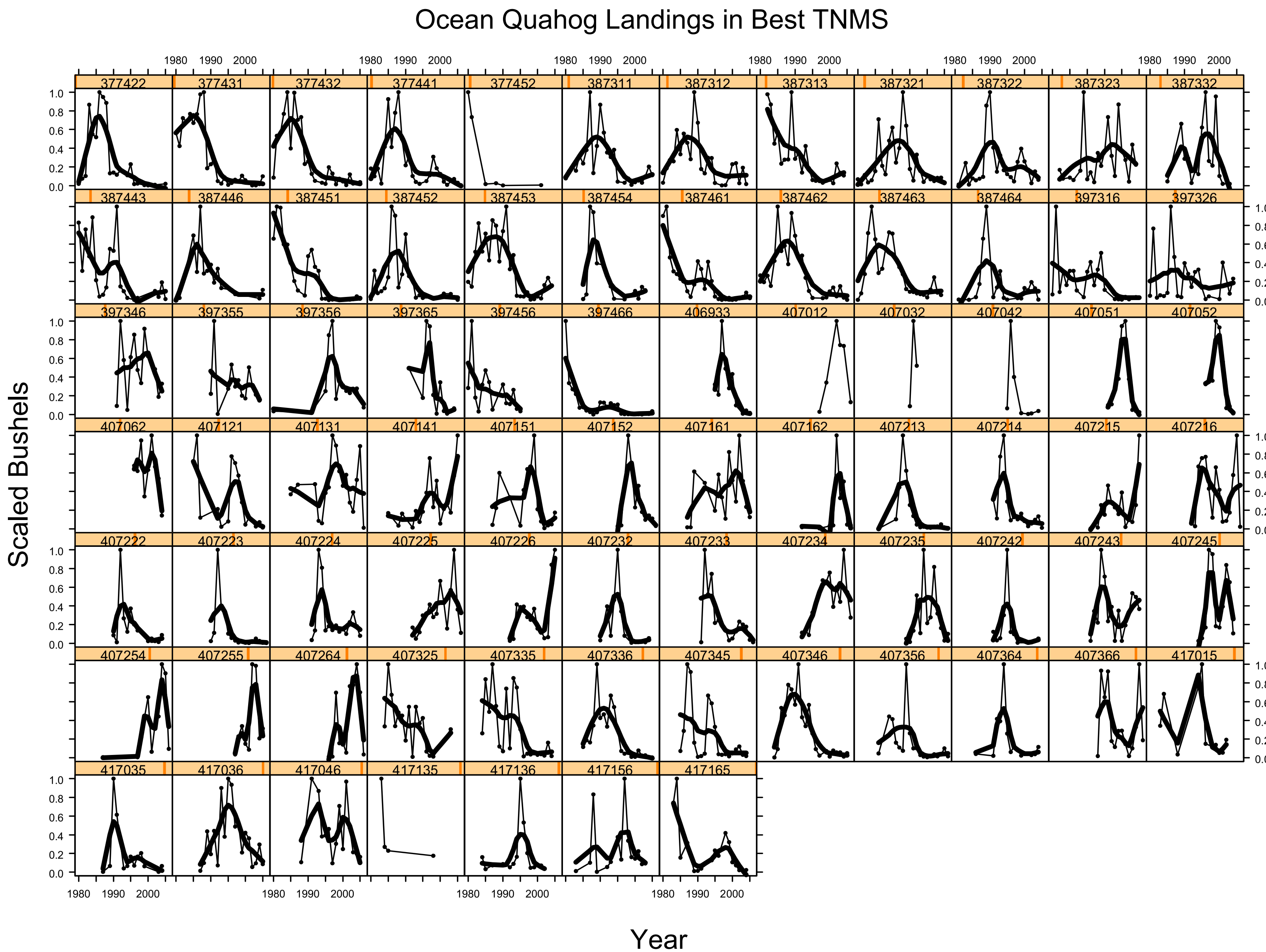


Figure A13. Trends in total annual landings (ITQ bu y^{-1}, vessel ton class 3-4) for ocean quahog in important TNMS during 1980-2005.

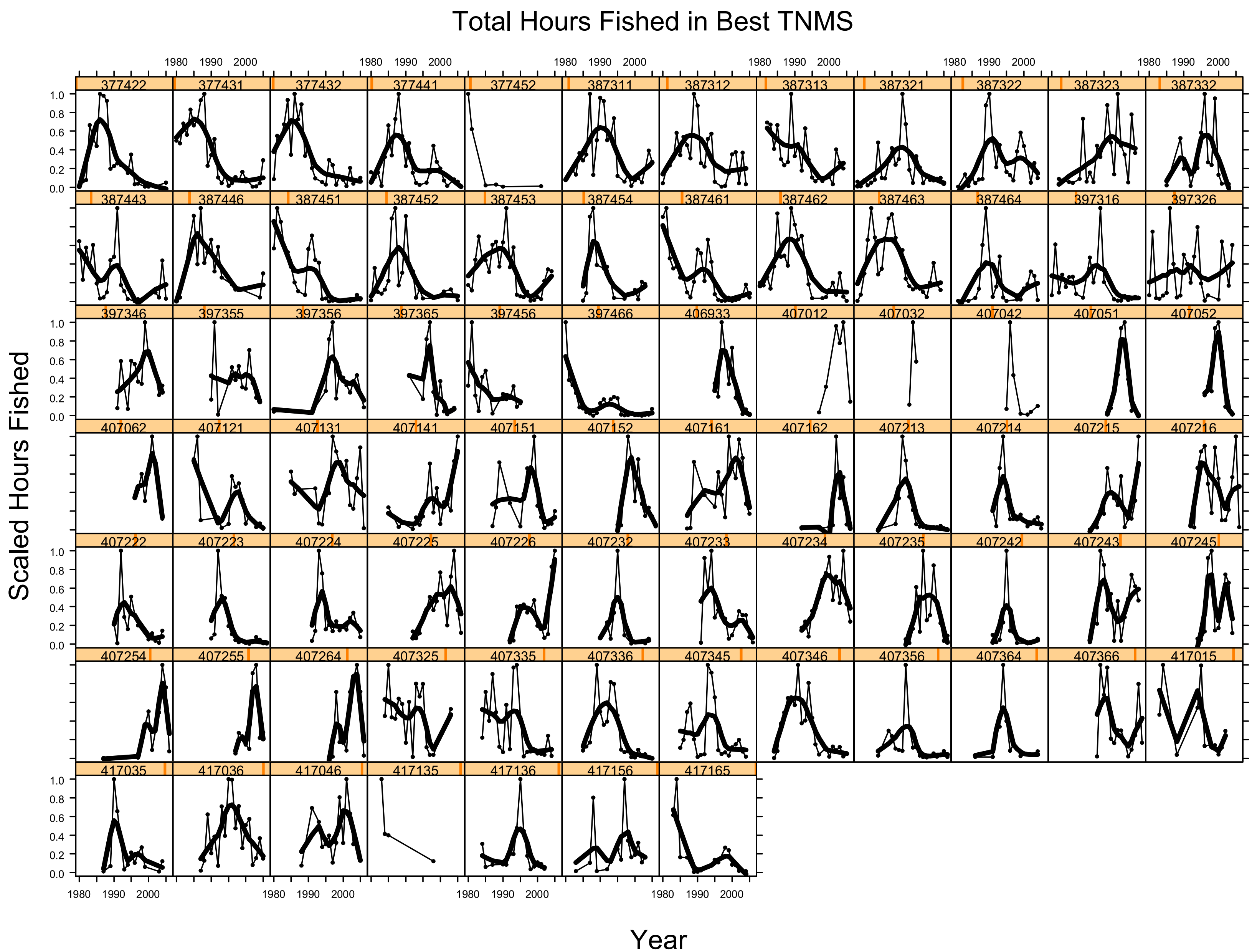


Figure A14. Trends in total annual fishing effort (hours fished y^{-1}, vessel ton class 3-4) for ocean quahog in important TNMS during 1980-2005.

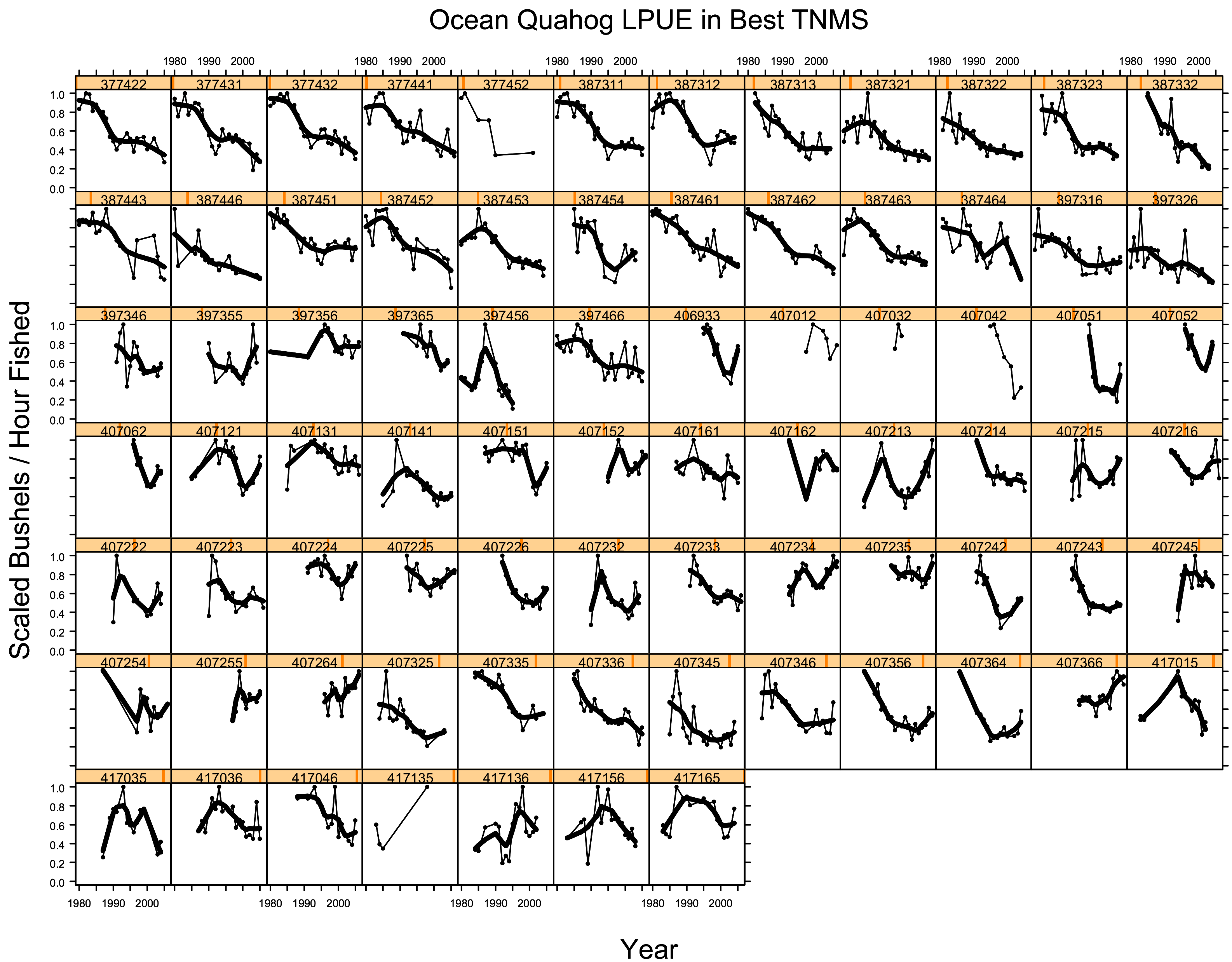


Figure A15. Trends in annual LPUE (ITQ bushels per hours fished, vessel ton class 3-4) for ocean quahog in important TNMS during 1980-2005.

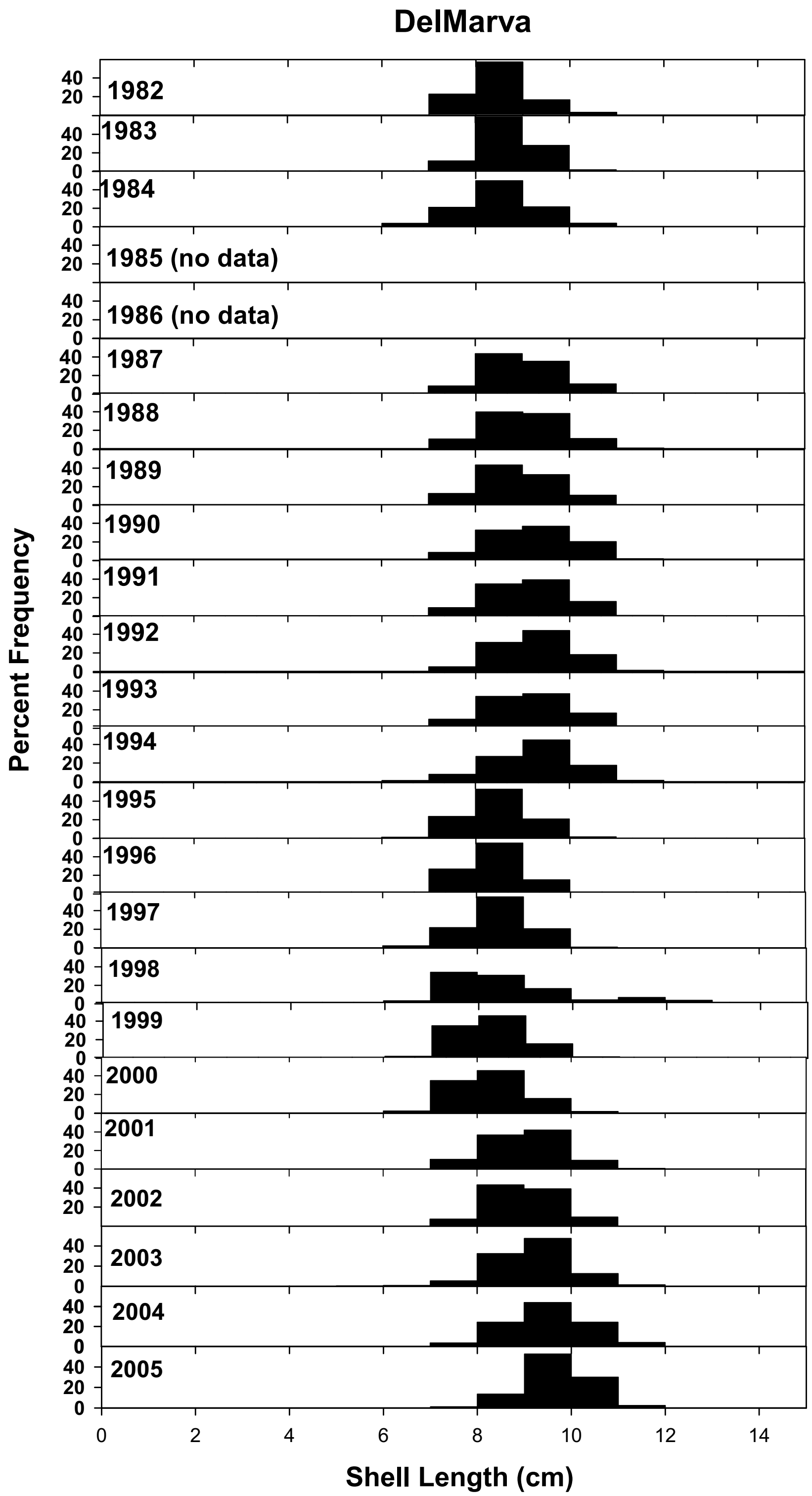


Figure A16. Commercial length composition data for ocean quahog landed in the DMV stock assessment region.

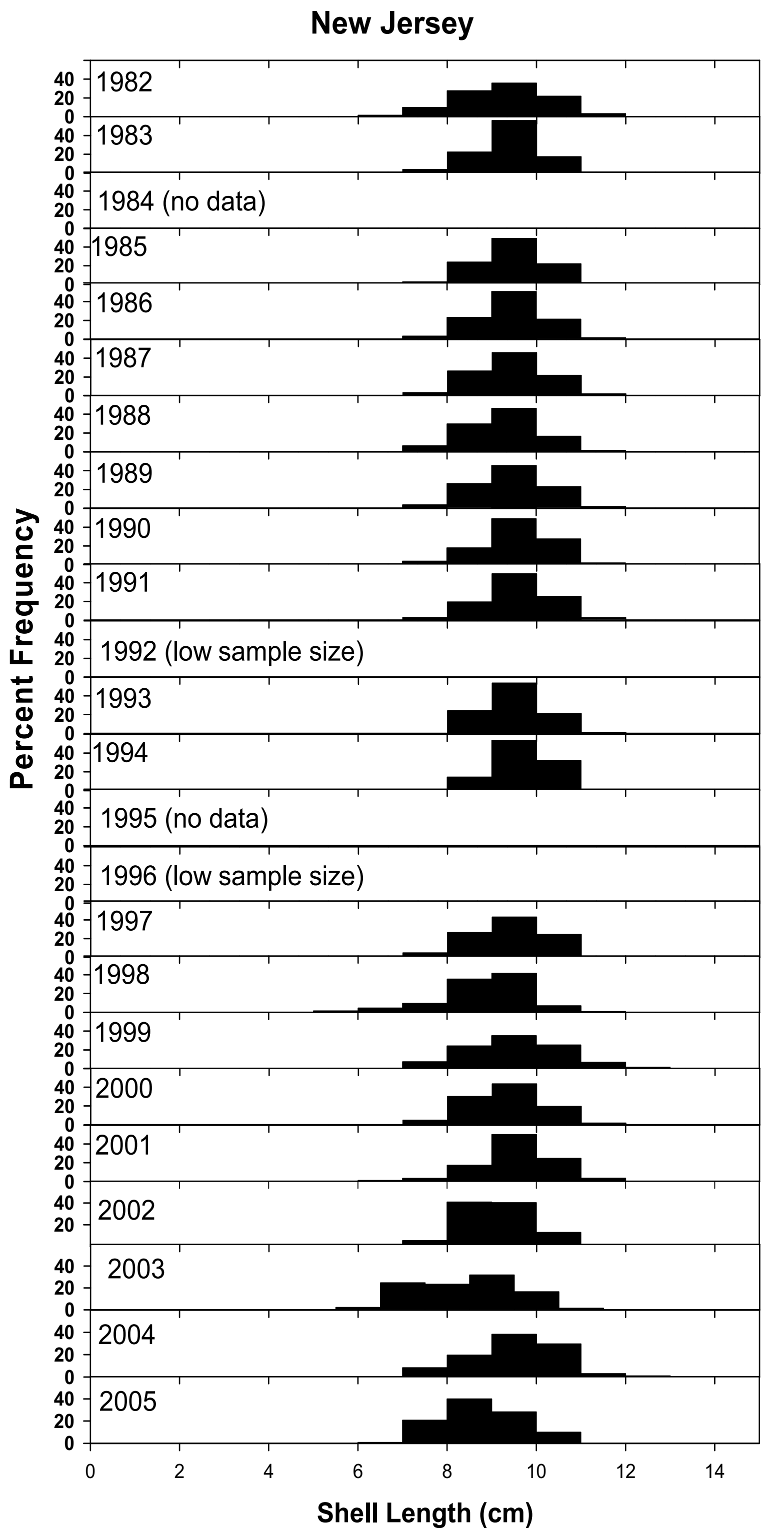


Figure A17. Commercial length composition data for ocean quahog landed in the NJ stock assessment region.

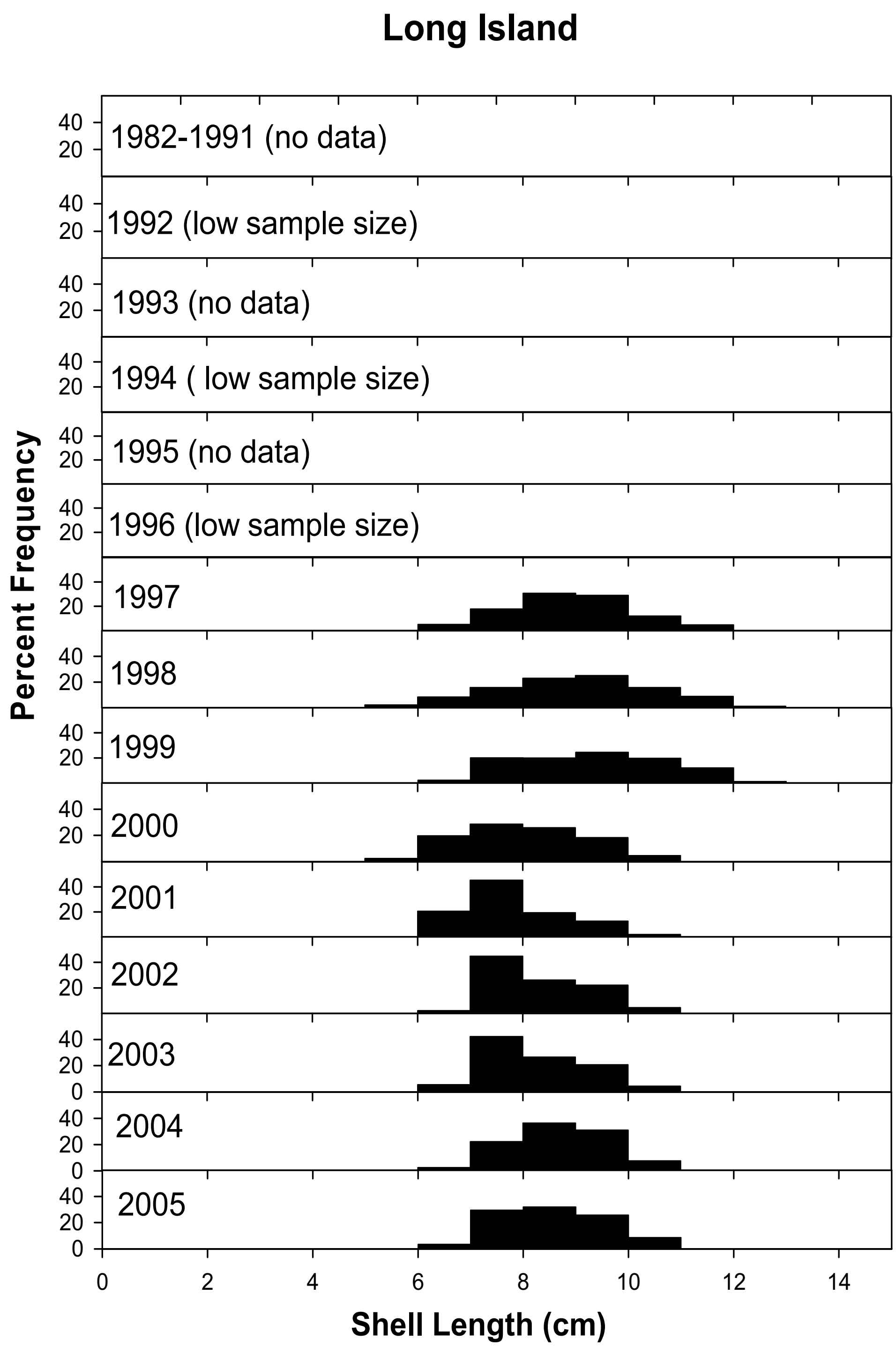


Figure A18. Commercial length composition data for ocean quahog landed in the LI stock assessment region.

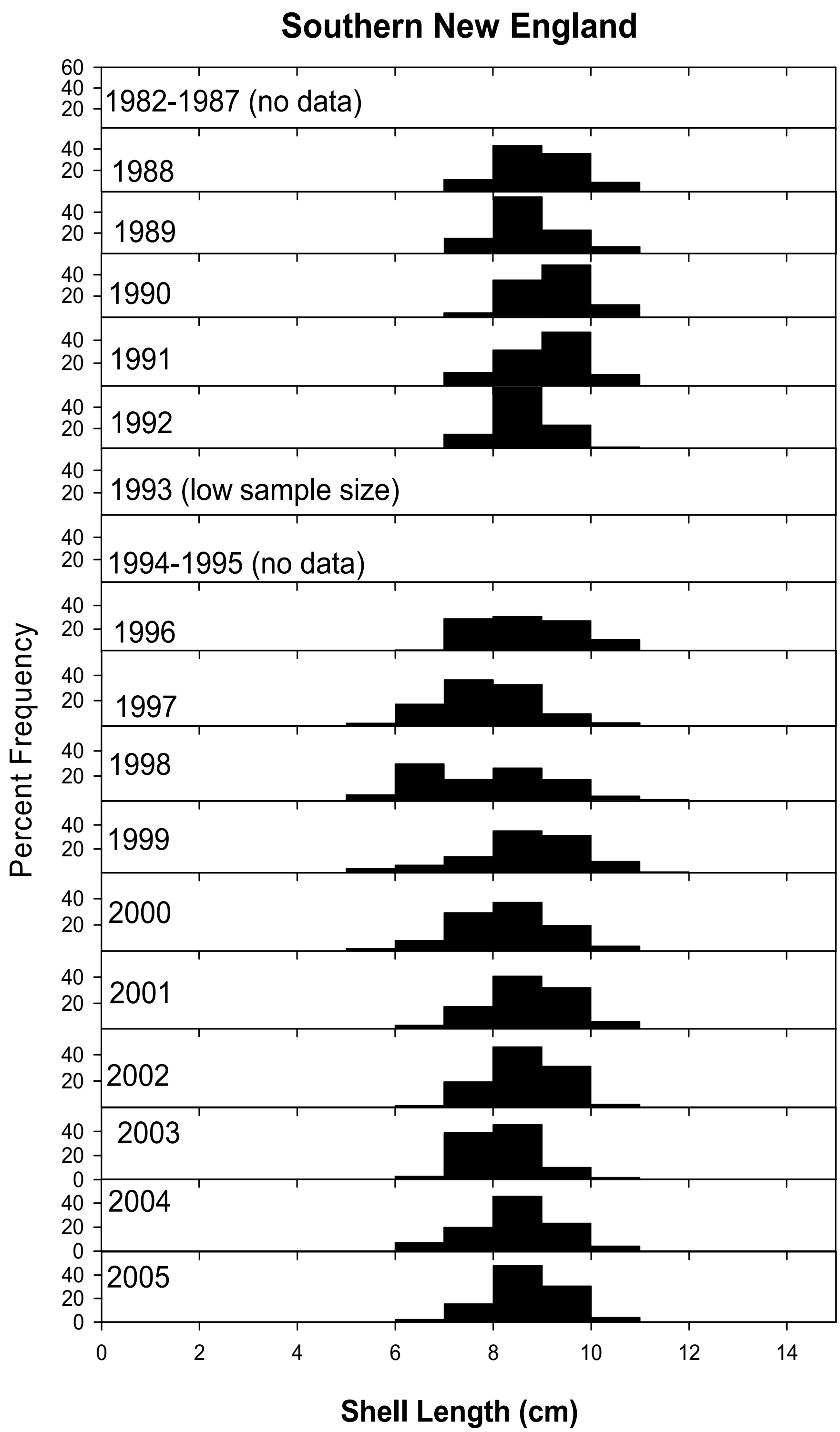


Figure A19. Commercial length composition data for ocean quahog landed in the SNE stock assessment region.

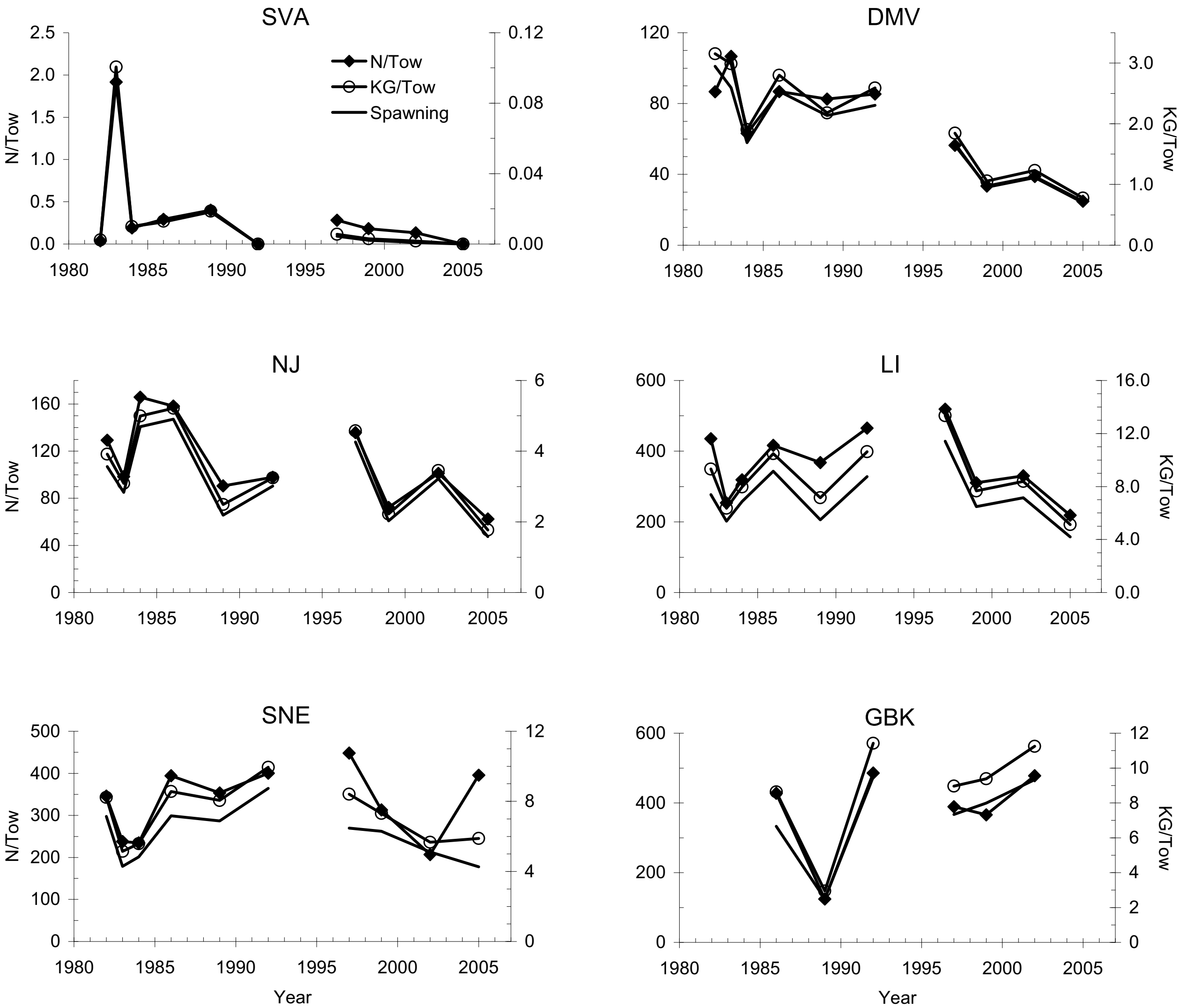


Figure A20. NEFSC clam survey trends for ocean quahog stock abundance (mean n/tow), biomass (mean kg/tow), and spawning biomass (mean kg/tow) during 1982-2005. Data for 1994 are omitted because of electrical problems with pump voltage that artificially increased dredge efficiency. Survey data shown in graphs were adjusted based on survey selectivity to estimate trends for the entire stock.

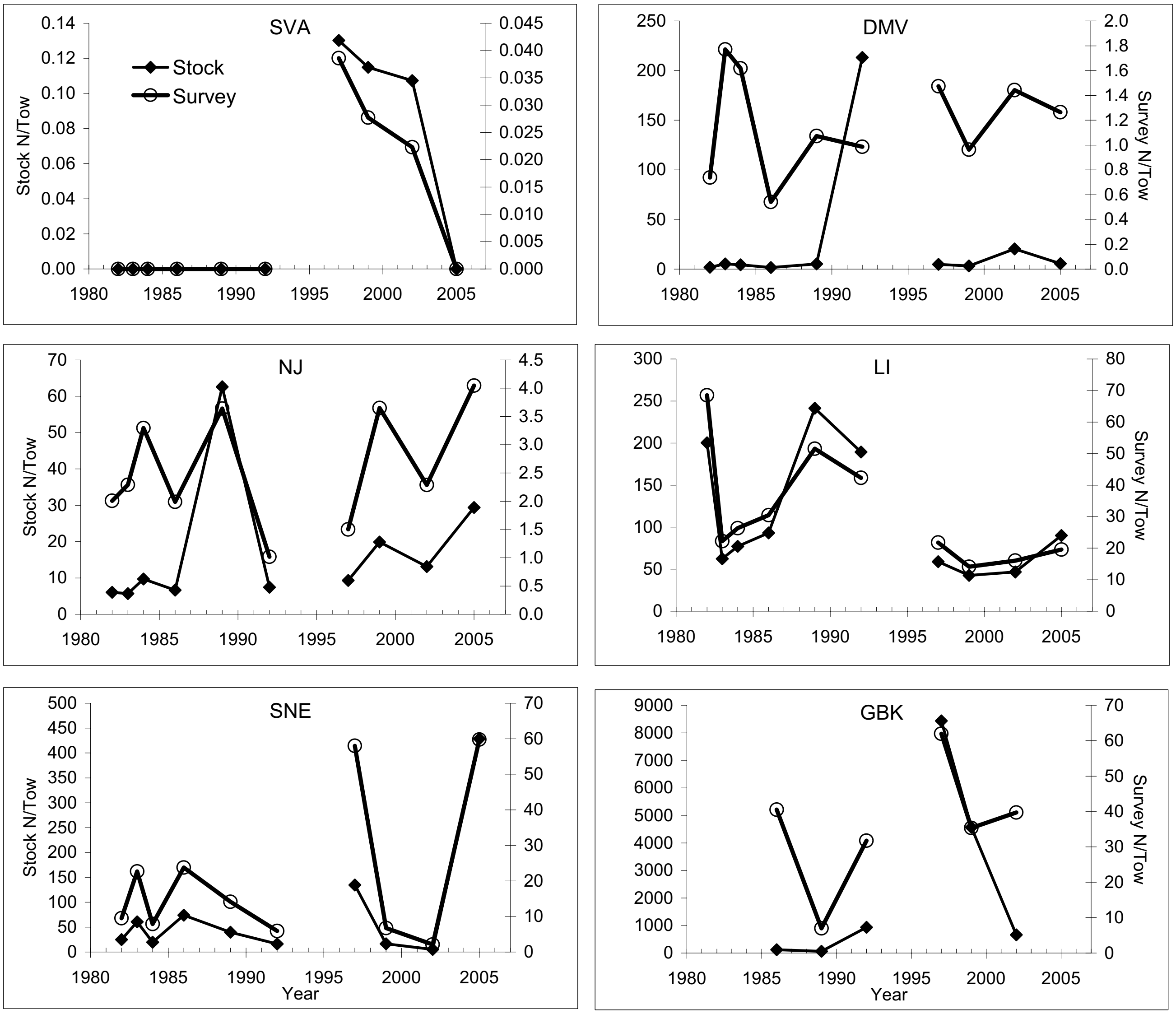


Figure A21. NEFSC clam survey trends for ocean quahog recruit (<70 mm SL) abundance (mean n/tow) during 1982-2005. Trends are shown with ("Stock") and without ("Survey") corrections for survey dredge selectivity. Data for 1994 are omitted because of electrical problems with pump voltage that artificially increased dredge efficiency. The apparent outlier for stock n/tow in DMV during 1992 is due to a relatively large catch of small ocean quahog which was increased substantially when adjusted for survey dredge selectivity.

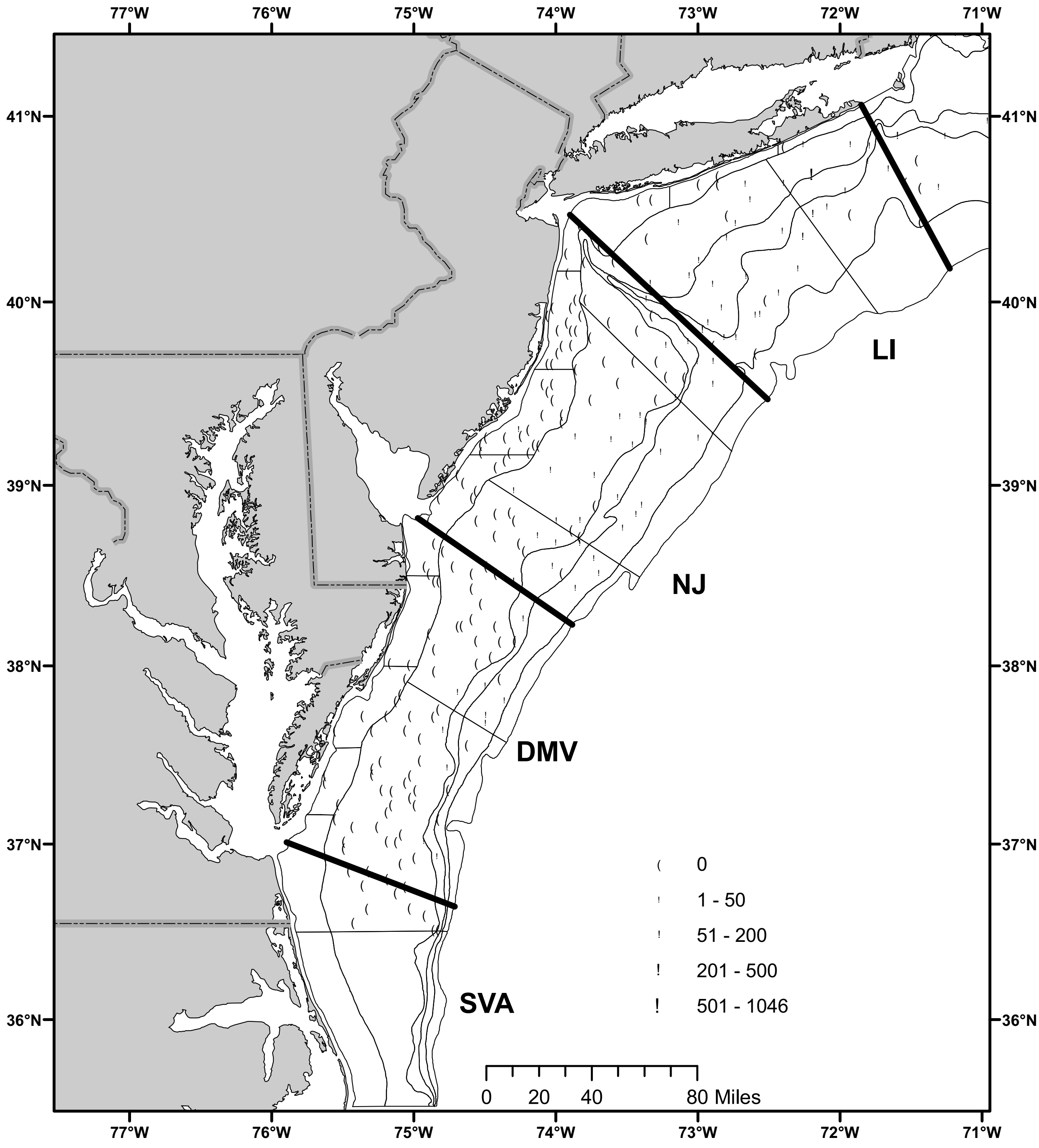


Figure A22. Location and size of recruit ocean quahog (<70 mm) catches in 2005 NEFSC clam survey, between Long Island and Cape Hatteras.

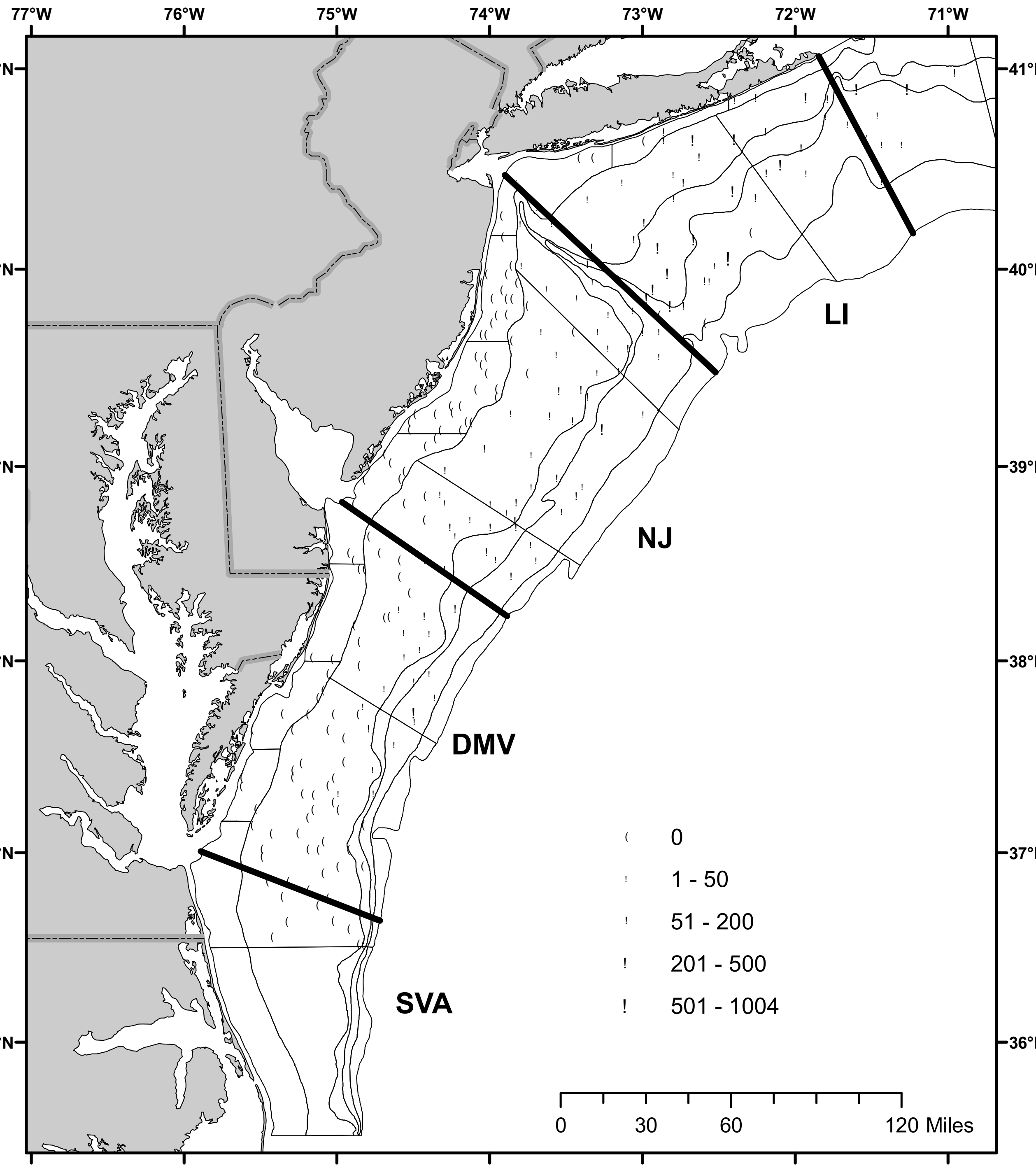


Figure A23. Location and size of large ocean quahog (70+ mm) catches in 2005 NEFSC clam survey, between Long Island and Cape Hatteras.

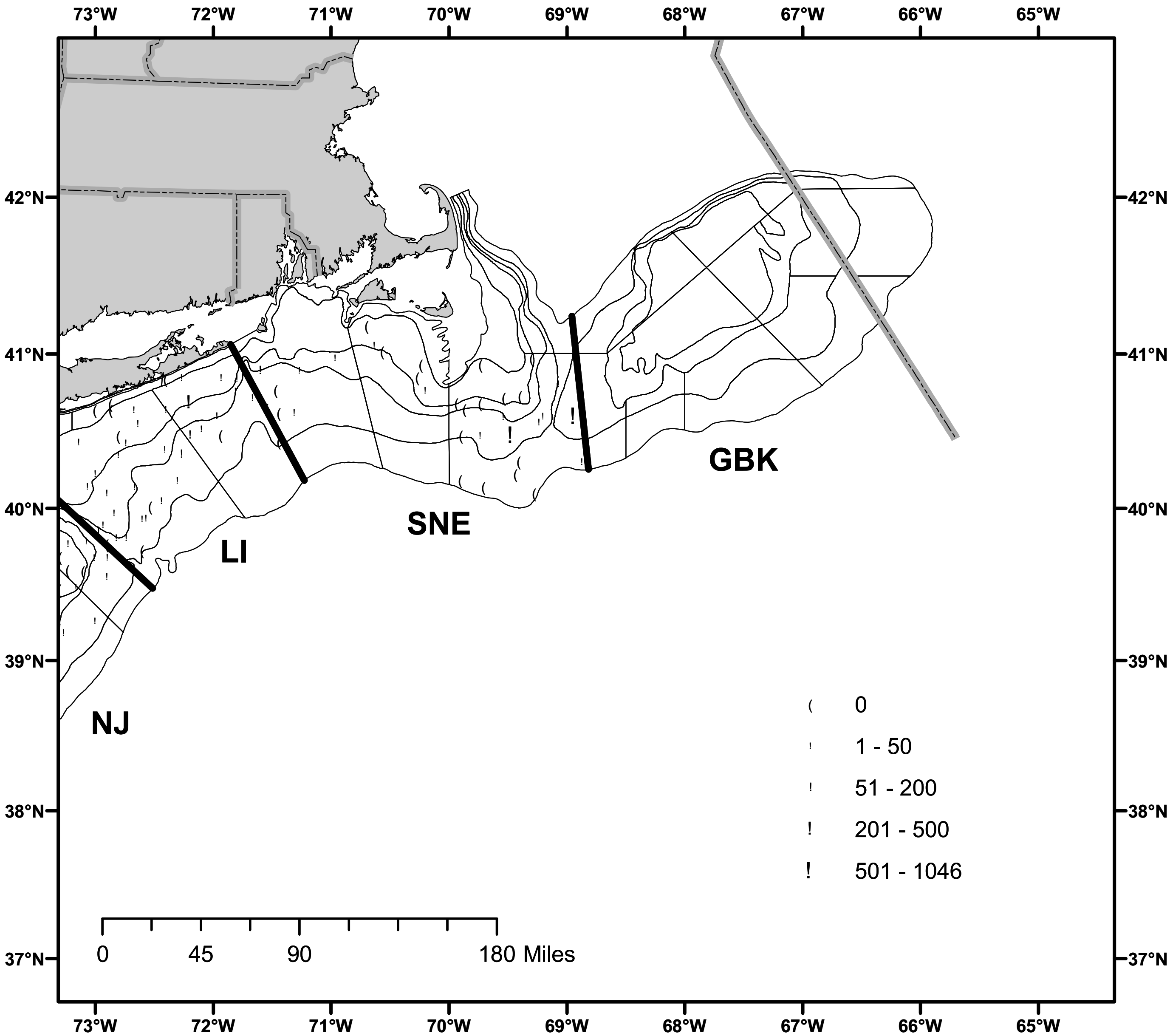


Figure A24. Location and size of recruit ocean quahog (<70 mm) catches in 2005 NEFSC clam survey, between Georges Banks and Long Island.

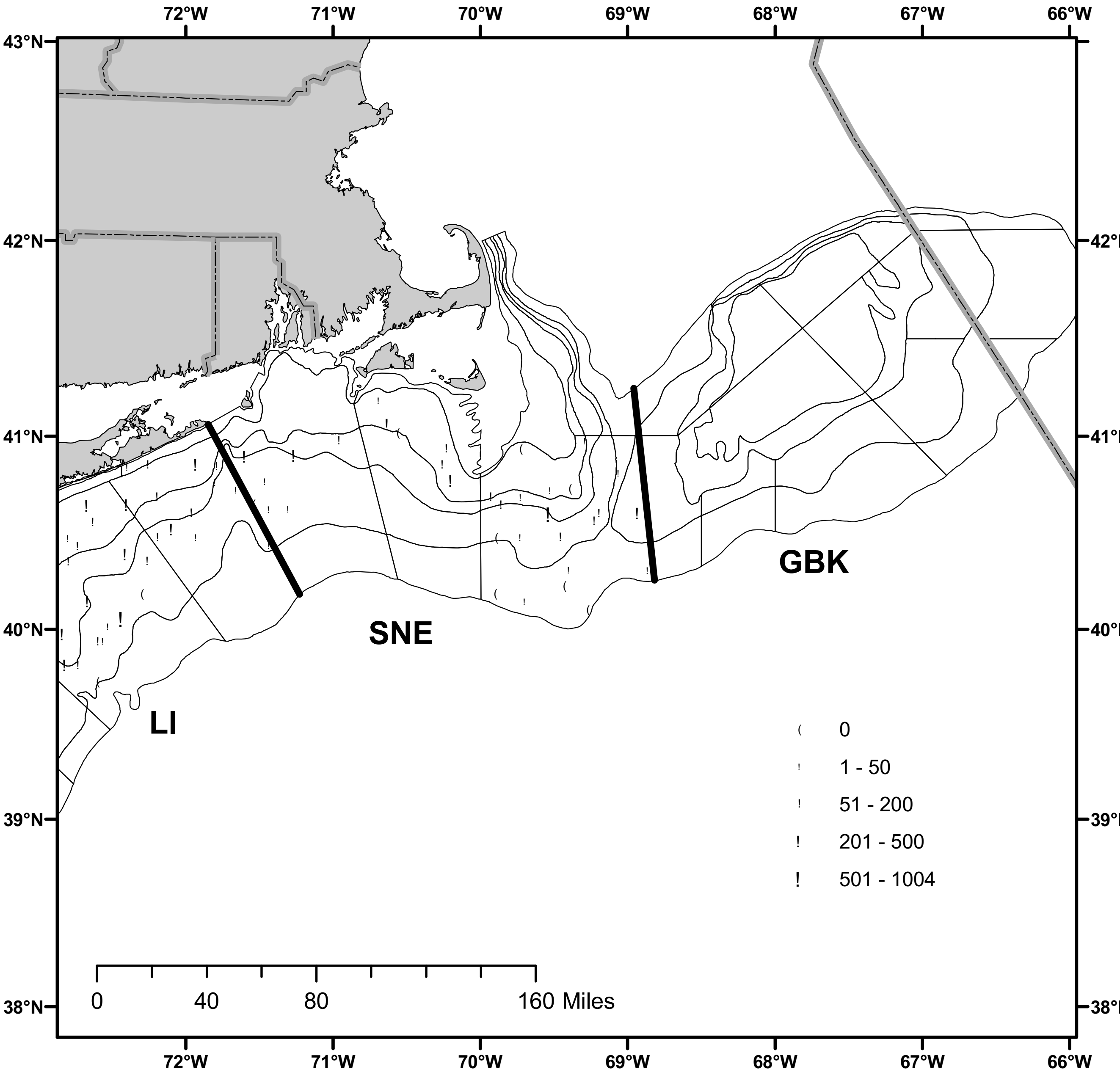


Figure A25. Location and size of large ocean quahog (70+ mm) catches in 2005 NEFSC clam survey, between Georges Bank and Long Island.

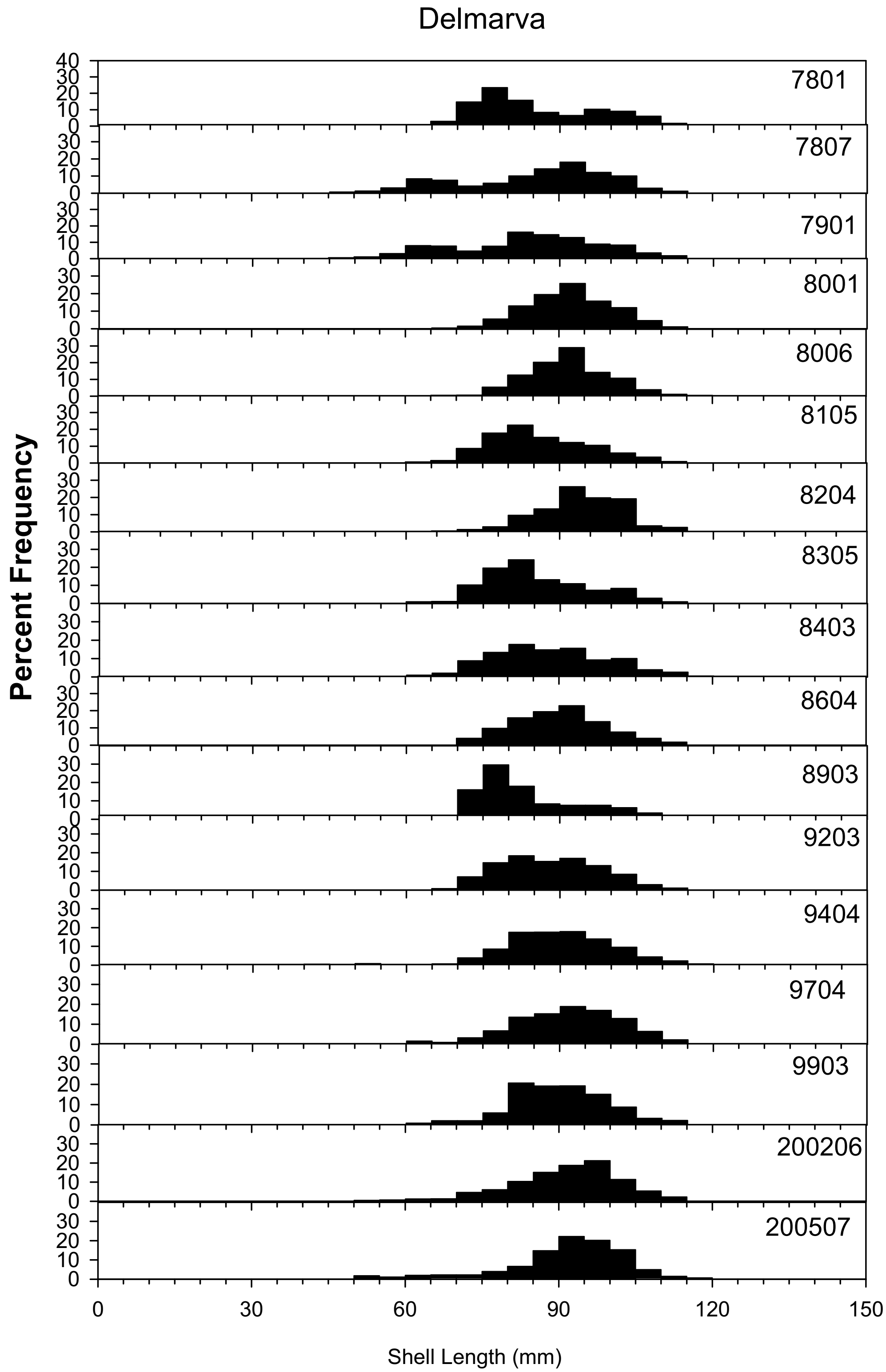


Figure A26. Length composition for ocean quahog in NEFSC clam surveys, by region. Frequencies are proportional to mean numbers per tow at length, without adjustment for survey dredge selectivity.

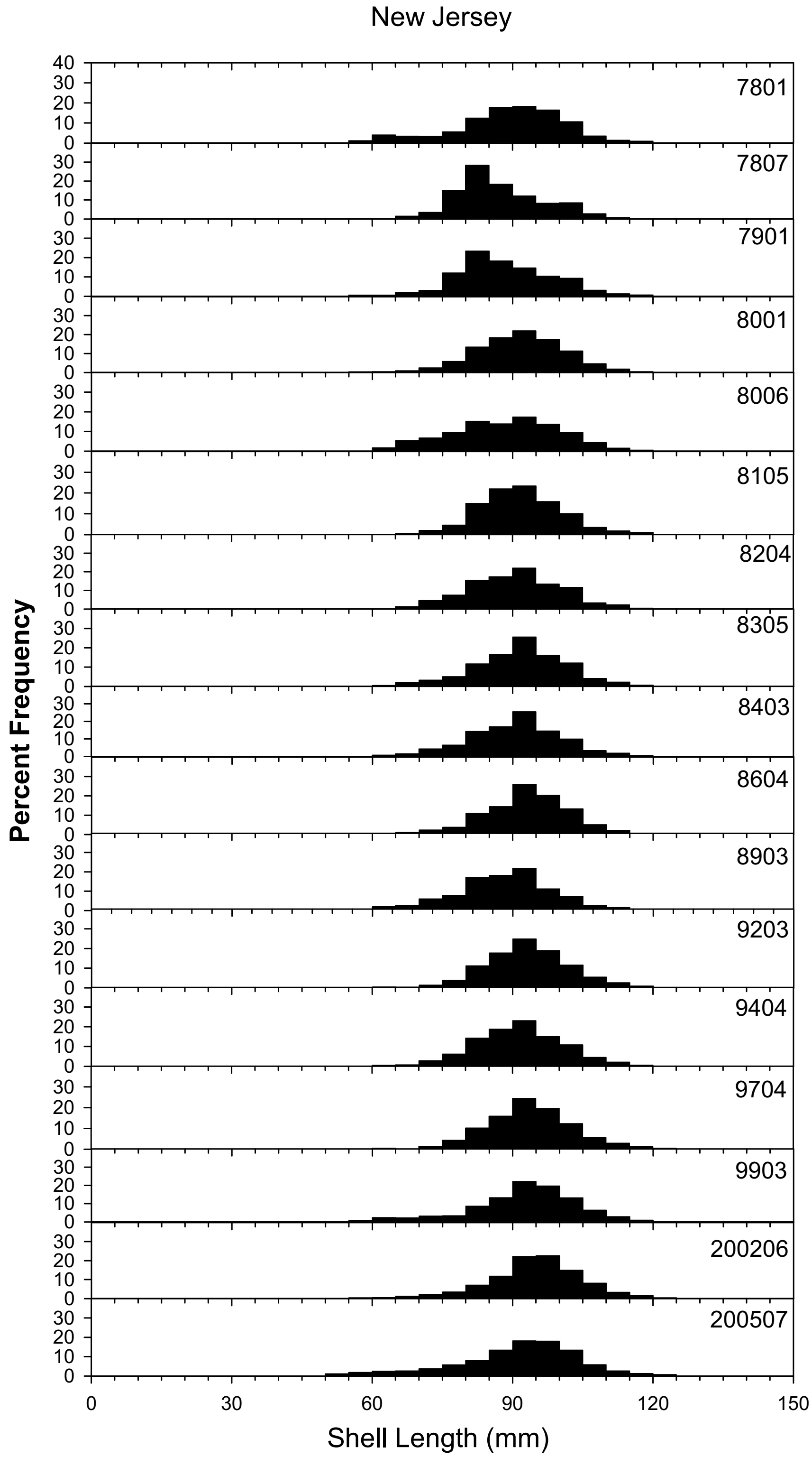


Figure A26 (continued)

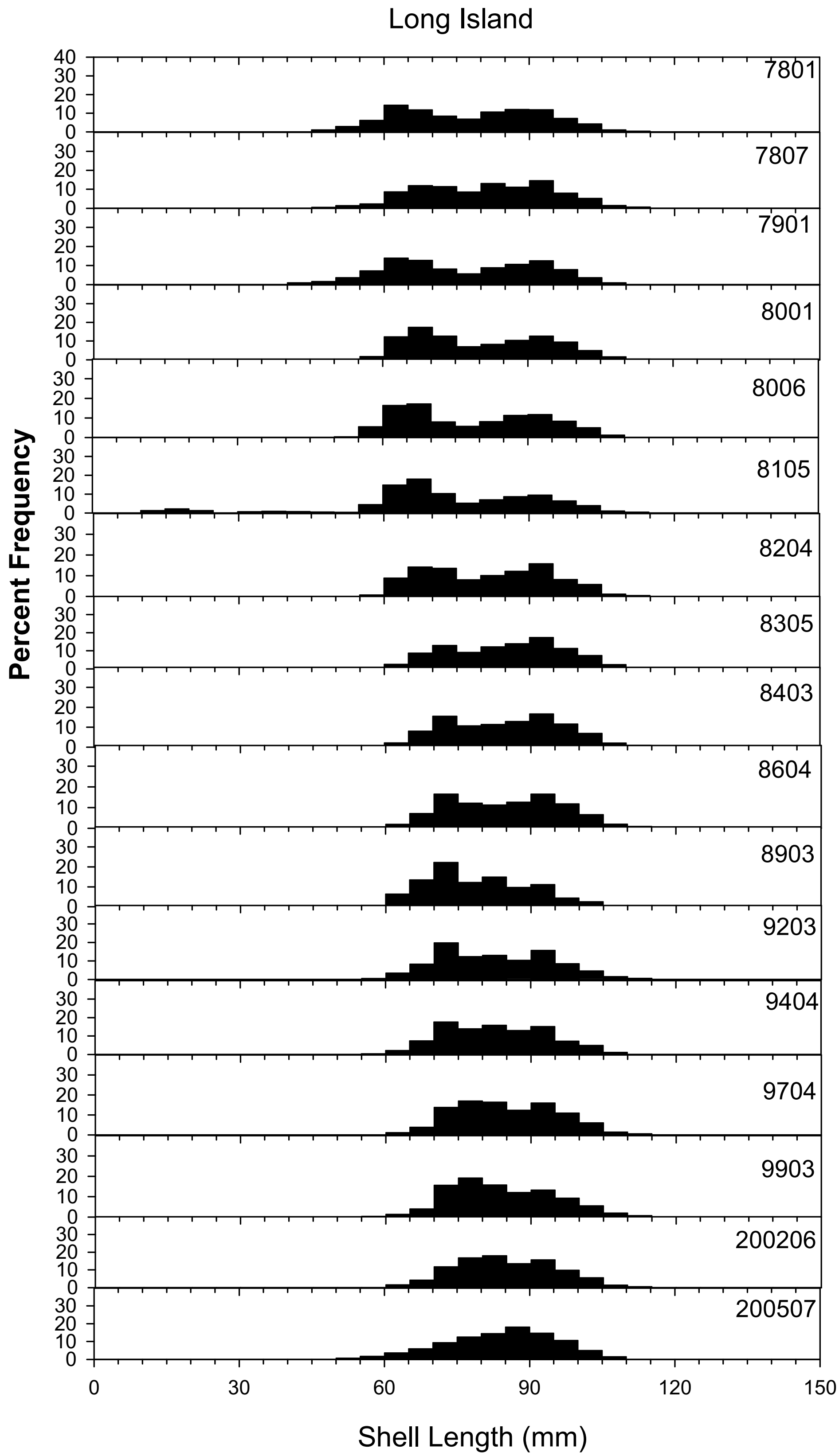
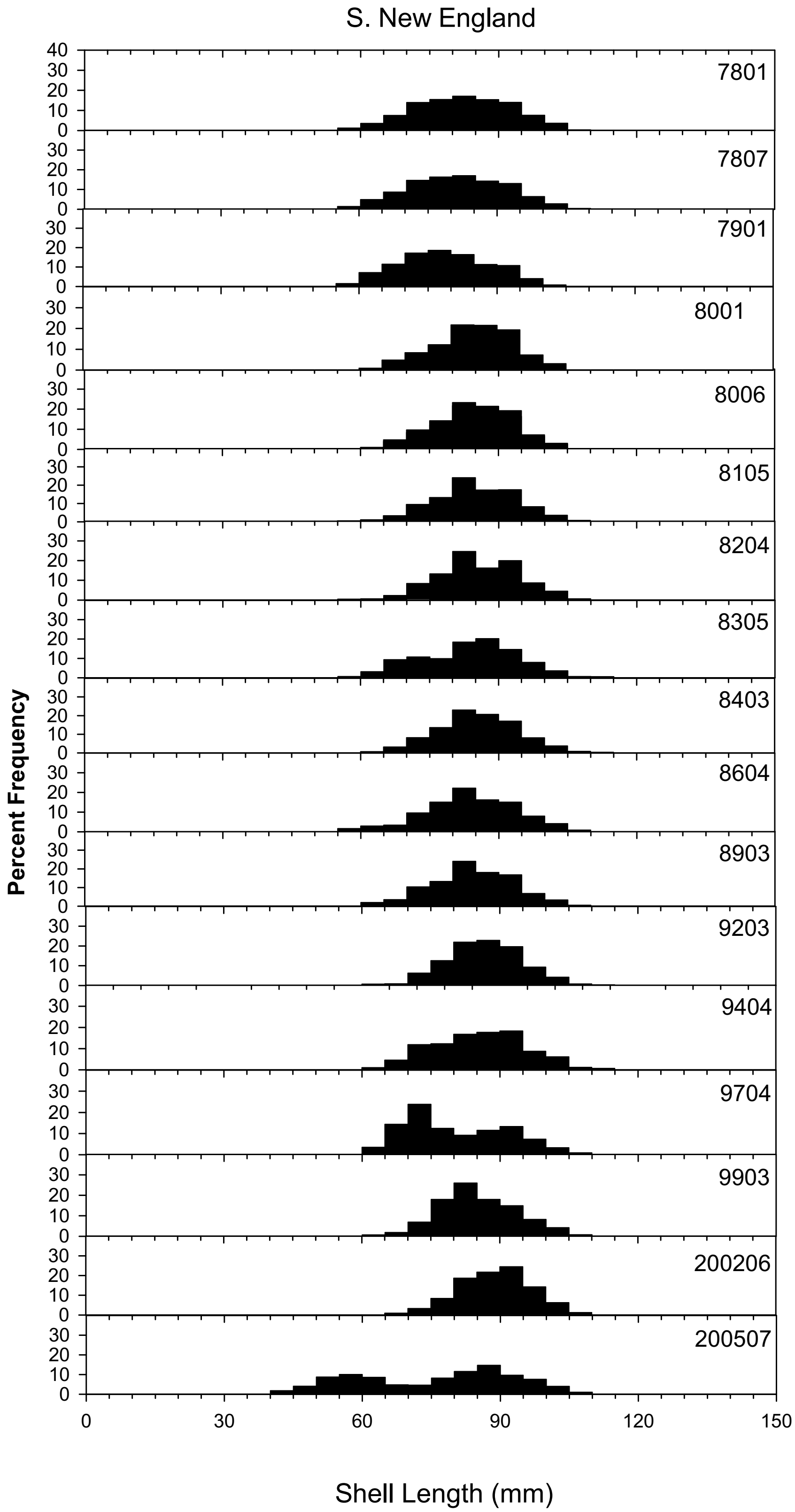


Figure A26 (continued)



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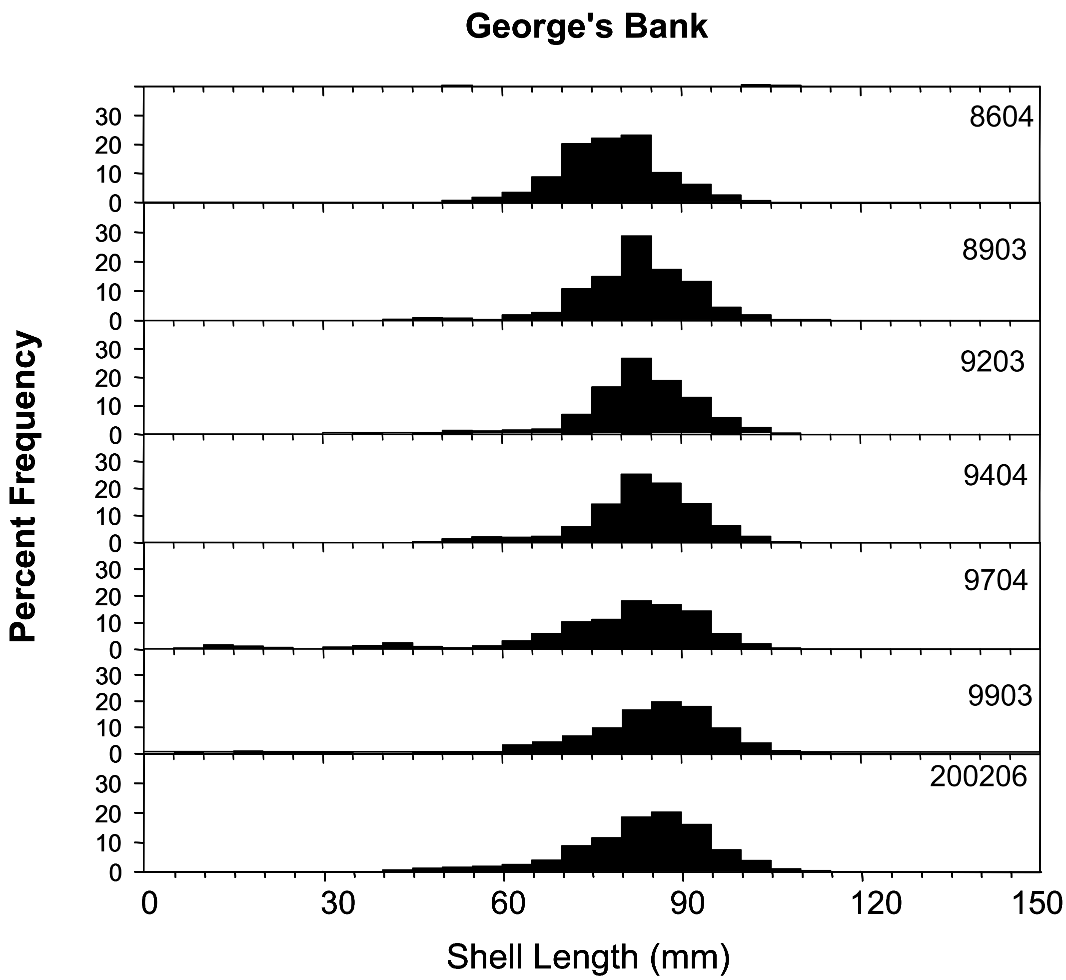


Figure A26 (continued)

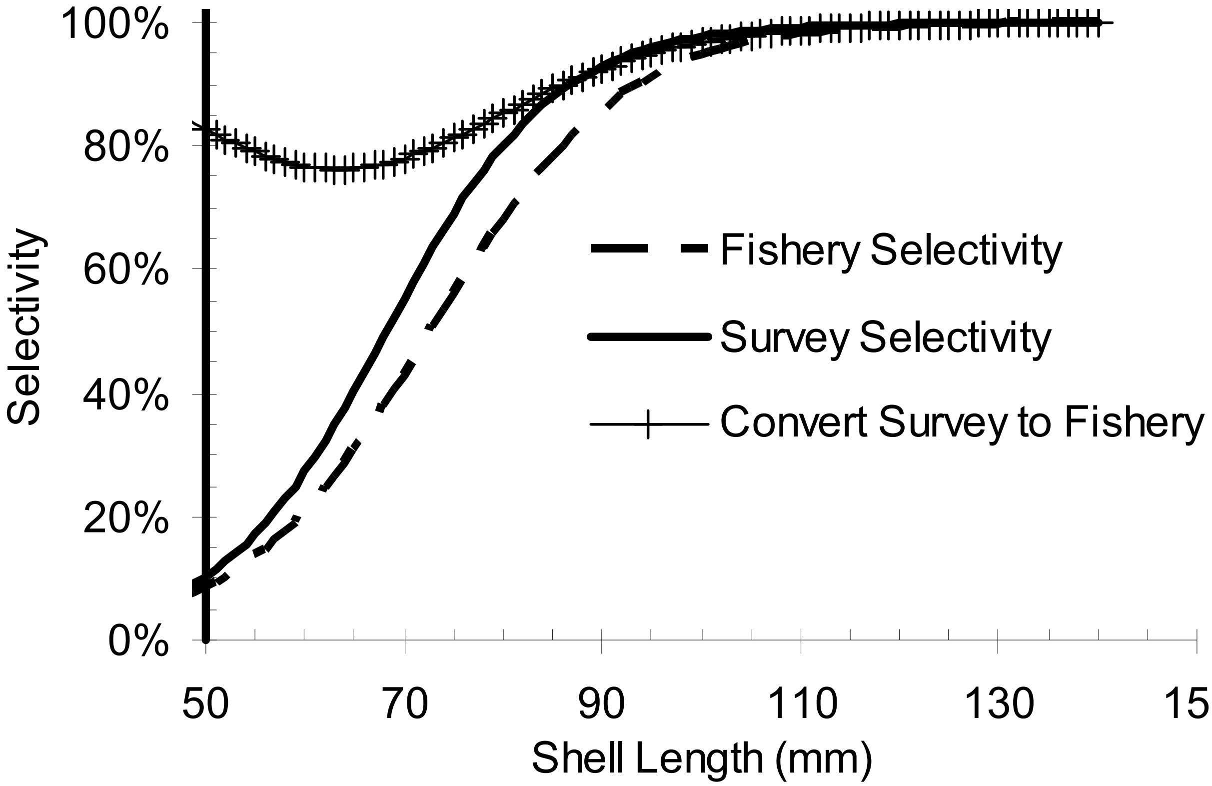


Figure A27. Fishery and survey selectivity curves for ocean quahog. The ratio of the fishery and survey selectivity curves, which can be used to convert survey abundance at size directly to fishable abundance at size, is also shown.

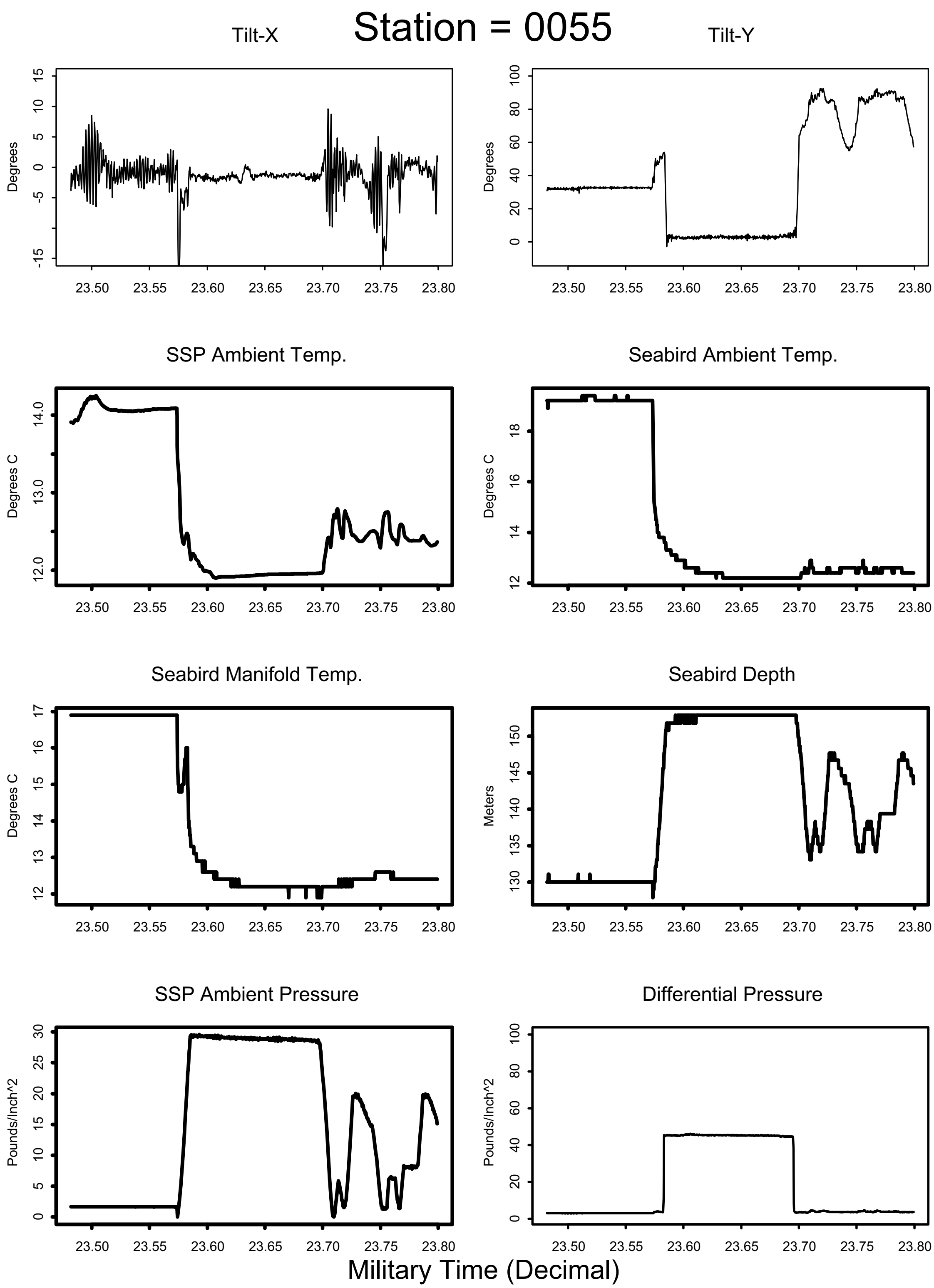


Figure A28. Survey sensor package data for an NEFSC clam survey tow with acceptable dredge performance.

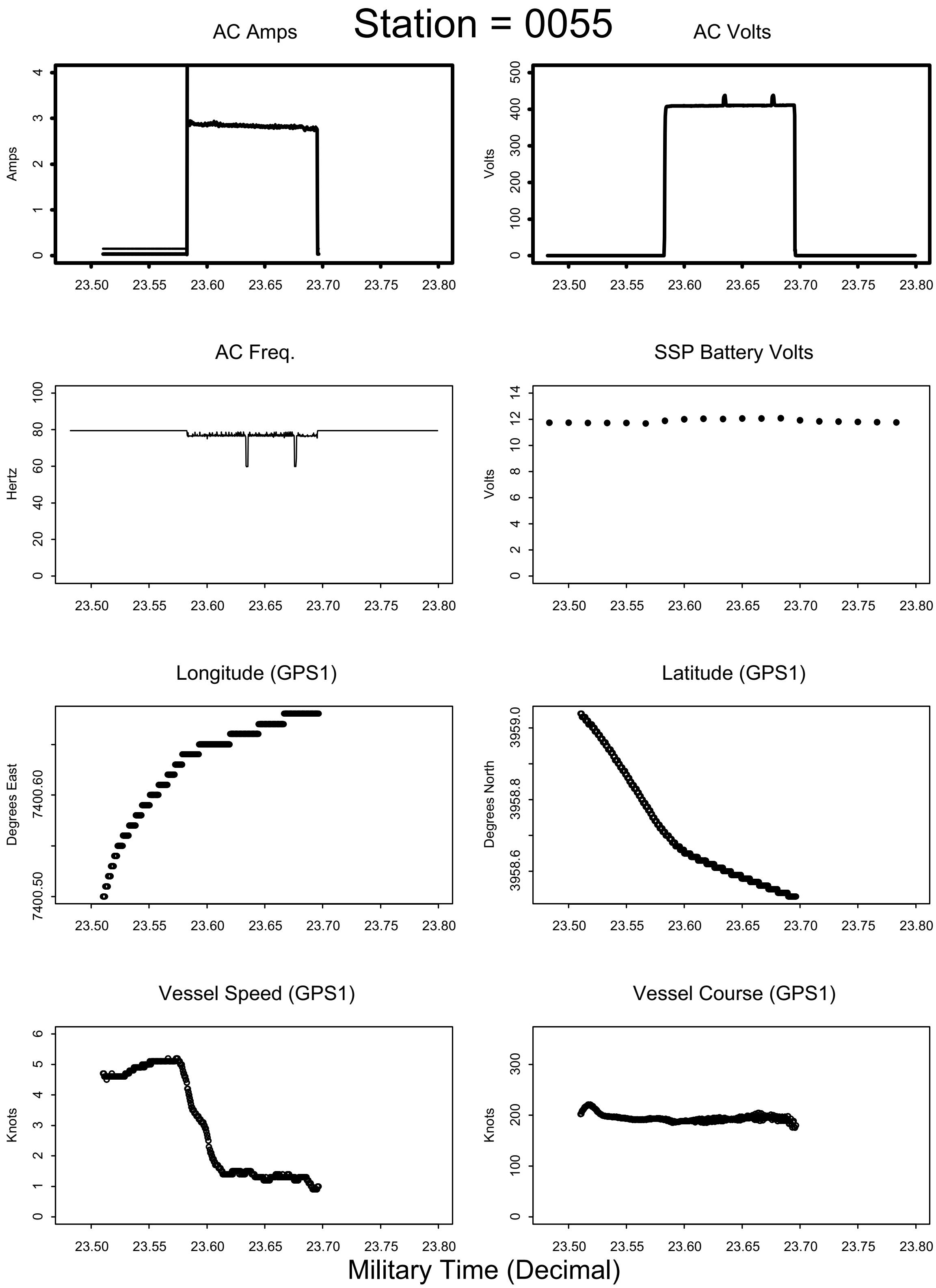


Figure A28. (continued)

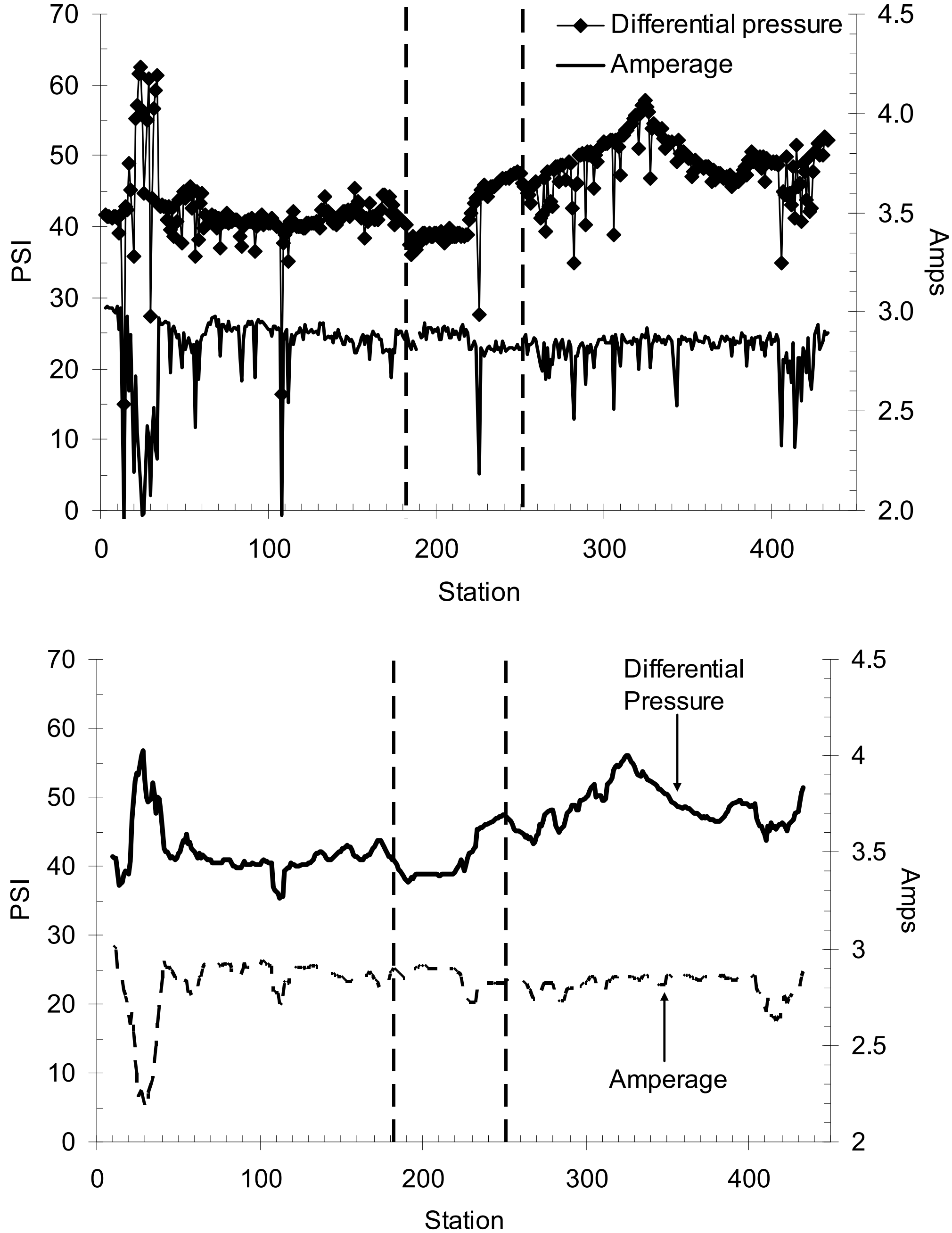
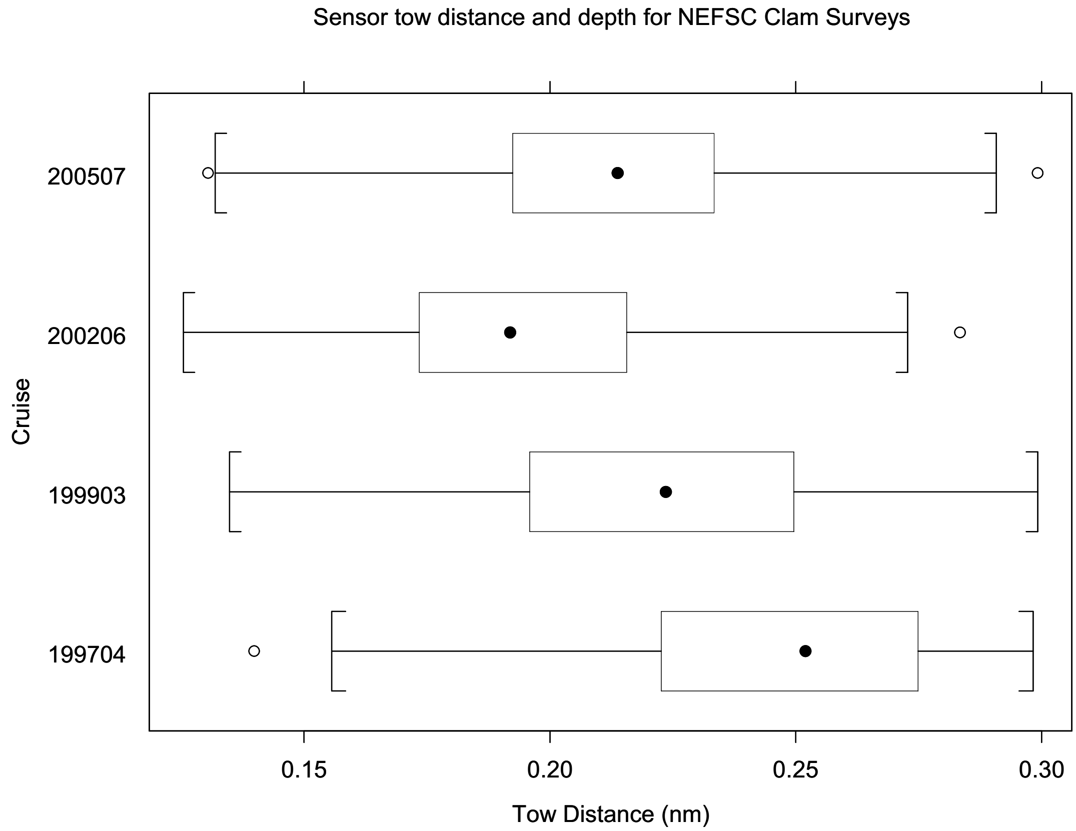


Figure A29. Differential pressure and amperage measured by sensors on the survey dredge during the 2005 NEFSC clam survey. Vertical lines separate the first, second and third legs. *Top*: Mean values for each station. *Bottom*: Mean values for each station smoothed by a seven point moving average.



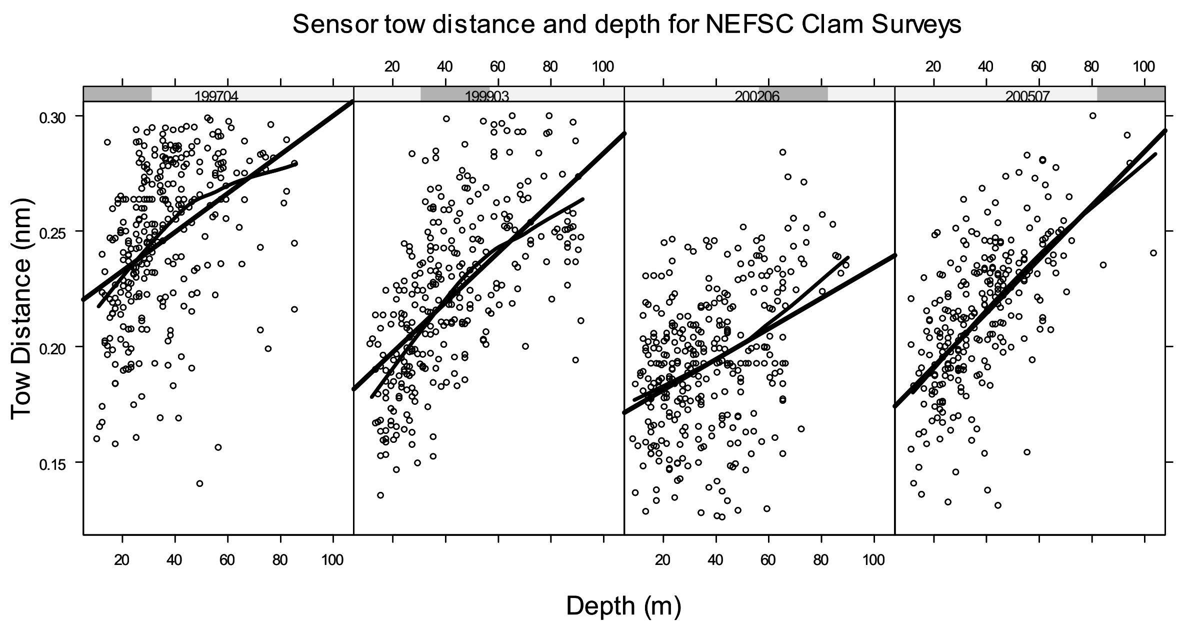


Figure A30. Tow distance measurements for NEFSC clam surveys from sensor data (top) and tow distance as a function of depth (bottom). Straight lines in the bottom panel show the best regression model. Curved lines are from loess regression and are intended to show trends.

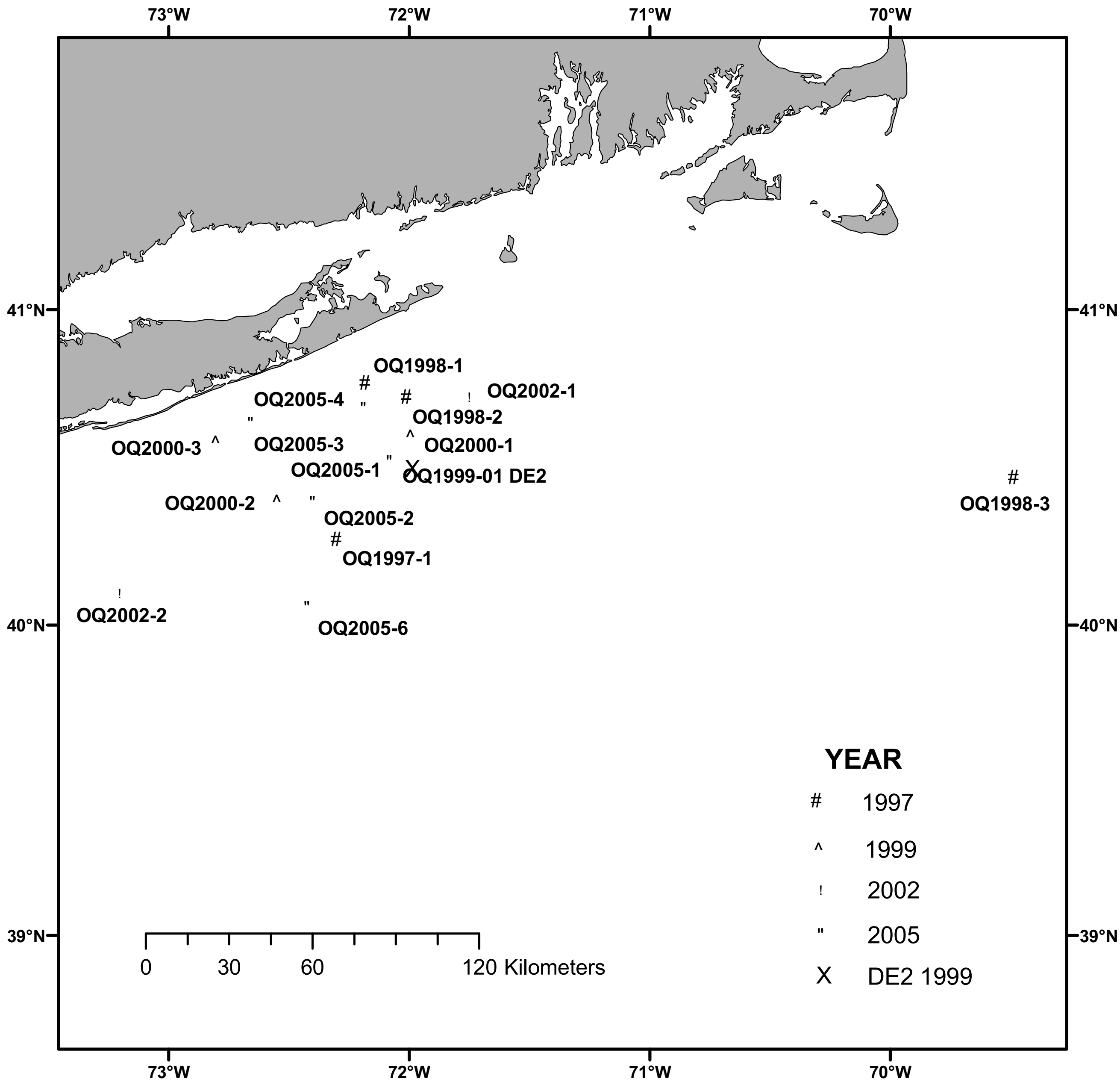


Figure A31a. Locations of ocean quahog depletion experiments off the Long Island area, 1997-2005.

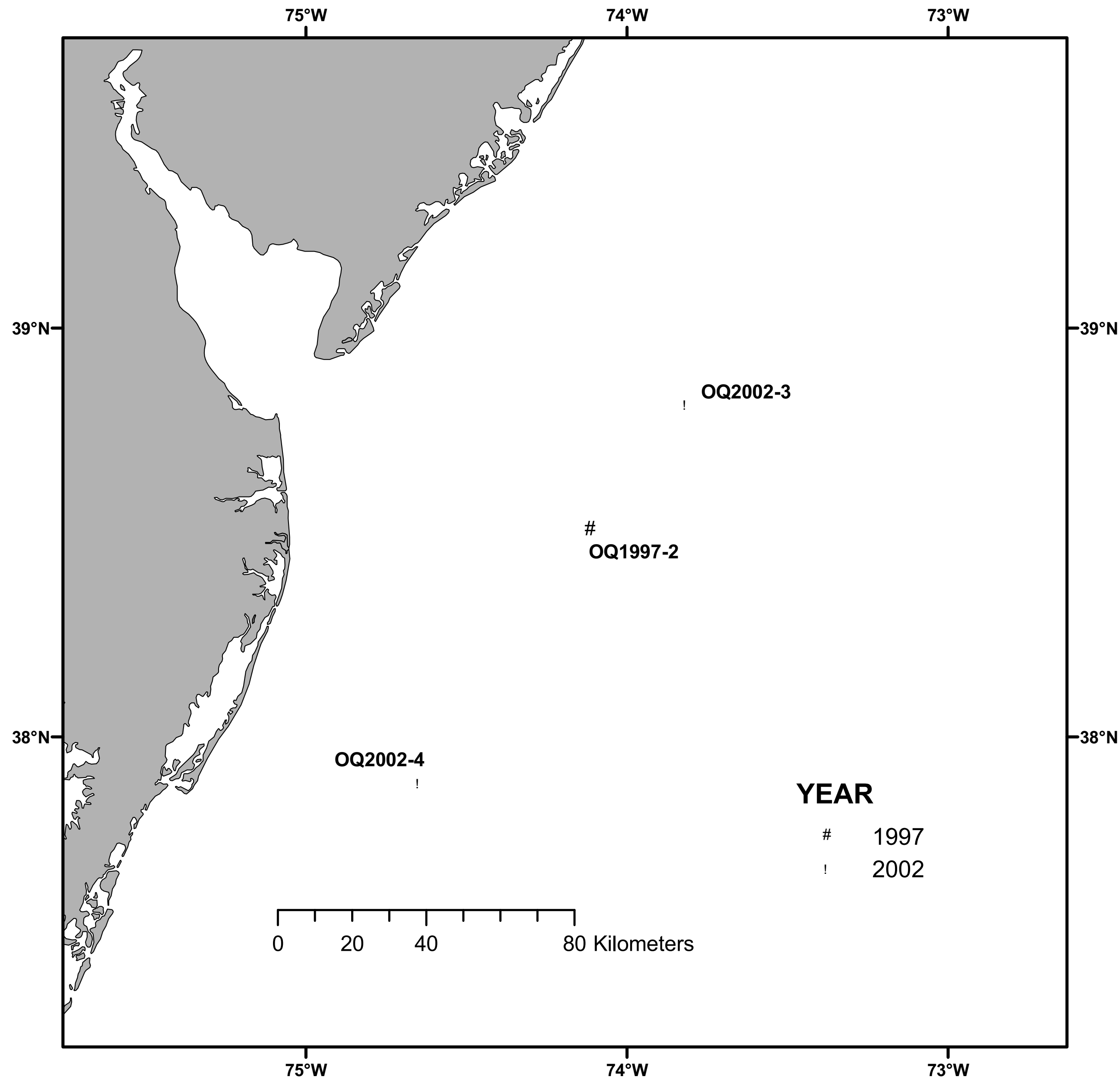


Figure A31b. Locations of ocean quahog depletion experiments off the New Jersey-Delmarva area, 1997-2005.

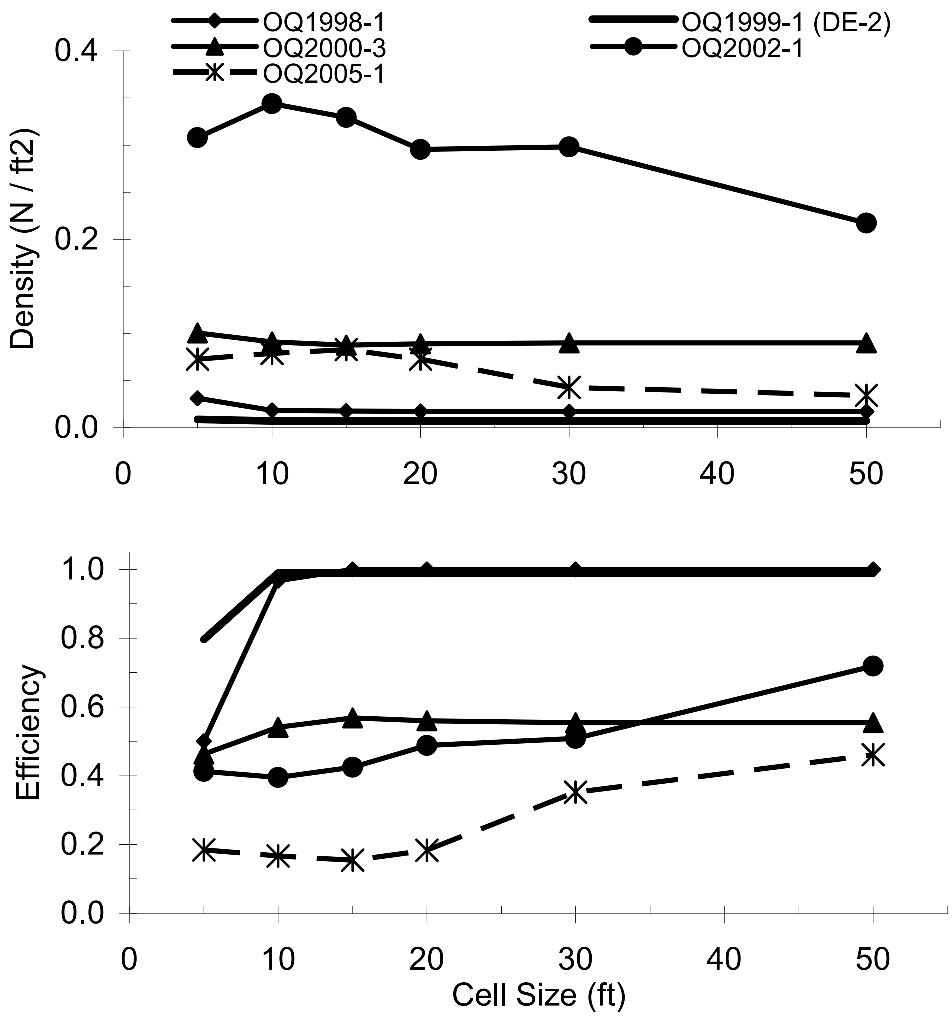


Figure A32. Sensitivity of Patch model estimates of ocean quahog density and dredge efficiency from depletion experiments and the Patch model. All of the experiments shown in the figure except OQ1999-1 (DE-2) were commercial experiments with a 10 ft dredge. The OQ1999-1 (DE-2) experiment was a Delaware II depletion experiment using a 5 ft dredge. The default cell size for Patch model analysis was 20 ft in all cases.

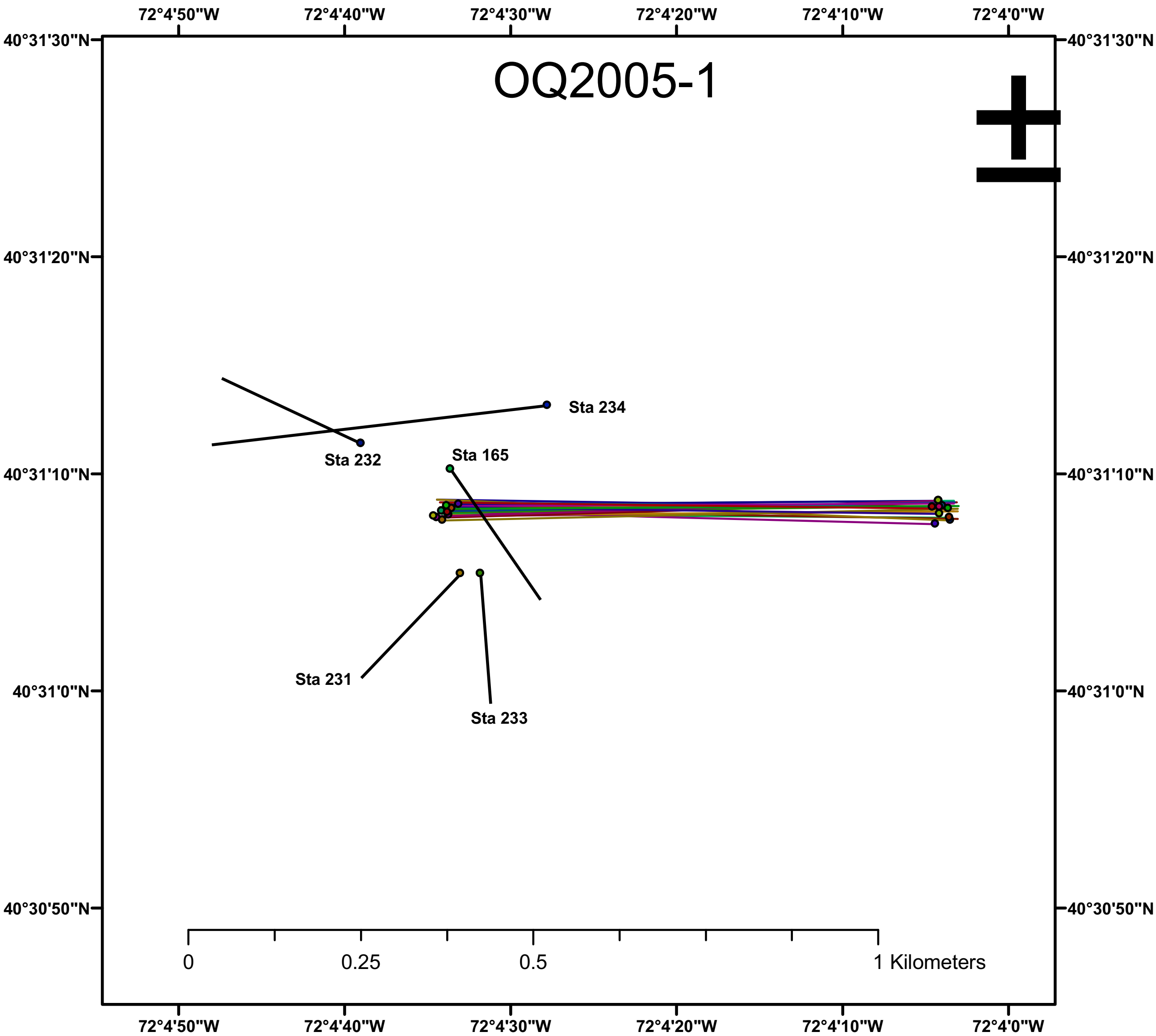


Figure A33. Setup and depletion tows for the OQ2005-1 ocean quahog depletion study. Setup tows by the *R/V Delaware II* are identified by station numbers. Depletion tows by the *F/V Lisa Kim* are tightly clustered along parallel tracks. Tow paths appear straight because they are shown as straight lines between start and stop points.

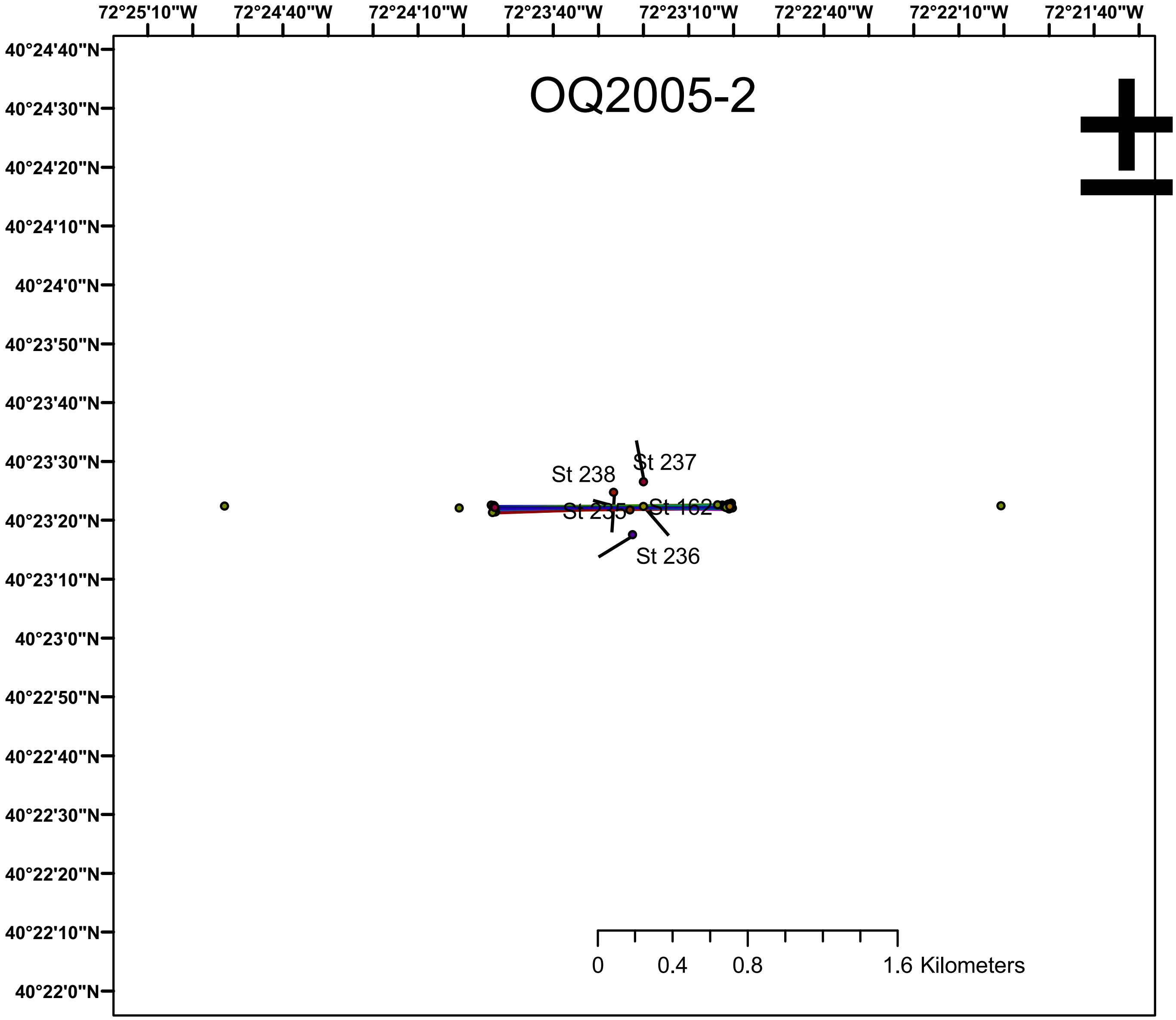


Figure A34. Setup and depletion tows for the OQ2005-2 ocean quahog depletion study. Setup tows by the *R/V Delaware II* are identified by station numbers. Depletion tows by the *F/V Lisa Kim* are tightly clustered along parallel tracks. Tow paths appear straight because they are shown as straight lines between start and stop points.

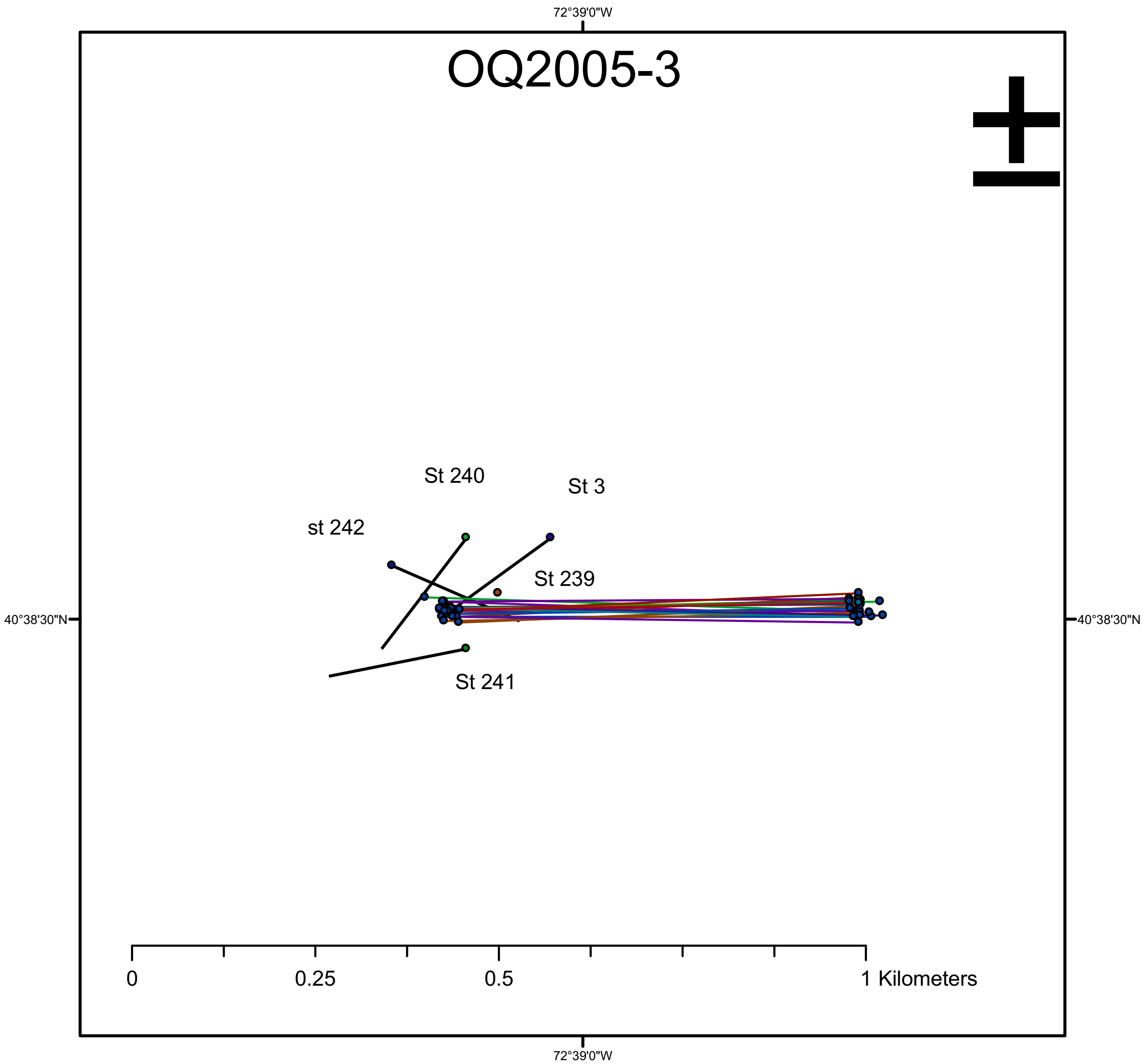


Figure A35. Setup and depletion tows for the OQ2005-3 ocean quahog depletion study. Setup tows by the *R/V Delaware II* are identified by station numbers. Depletion tows by the *F/V Lisa Kim* are tightly clustered along parallel tracks. Tow paths appear straight because they are shown as straight lines between start and stop points.

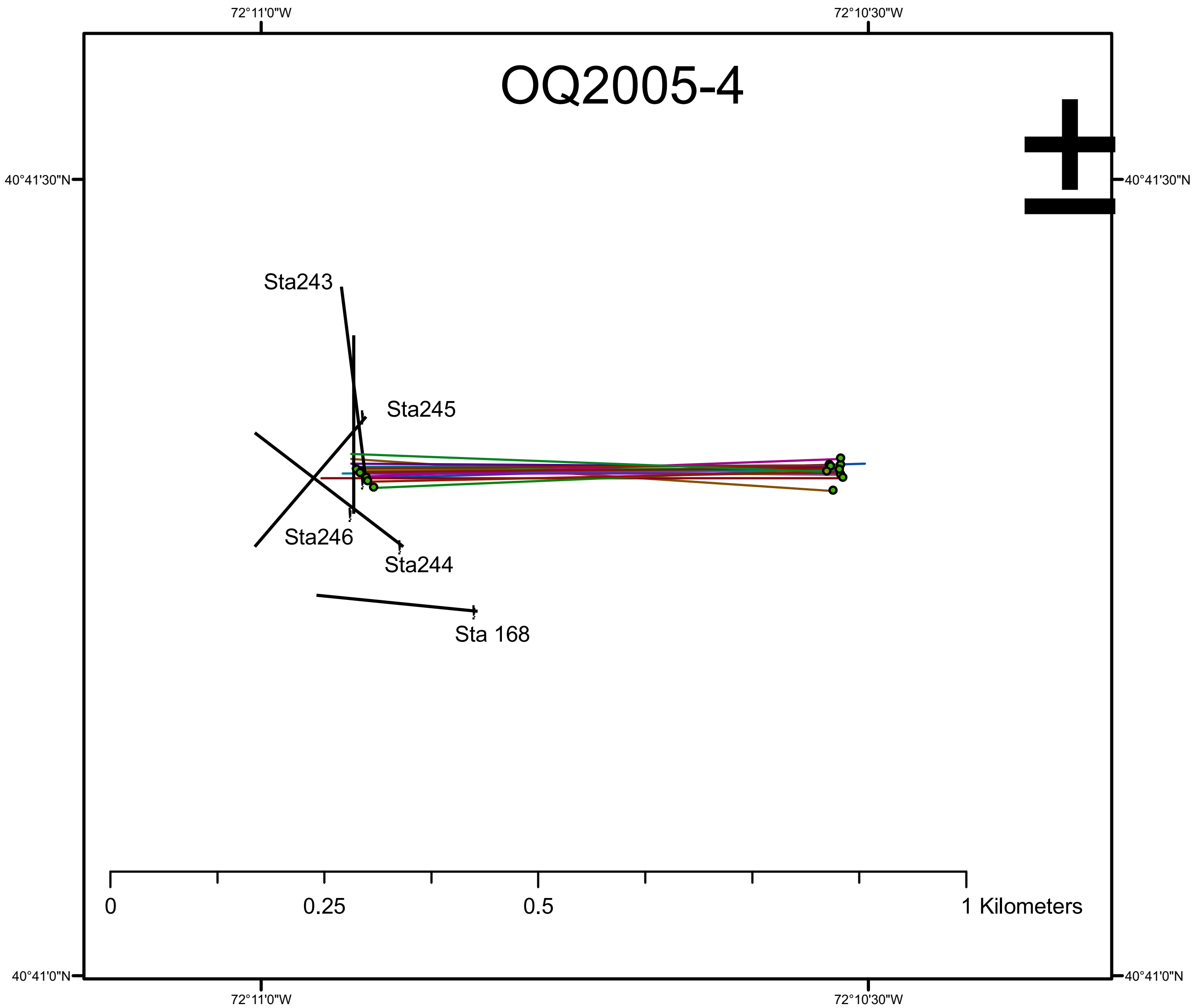


Figure A36. Setup and depletion tows for the OQ2005-4 ocean quahog depletion study. Setup tows by the *R/V Delaware II* are identified by station numbers. Depletion tows by the *F/V Lisa Kim* are tightly clustered along parallel tracks. Tow paths appear straight because they are shown as straight lines between start and stop points.

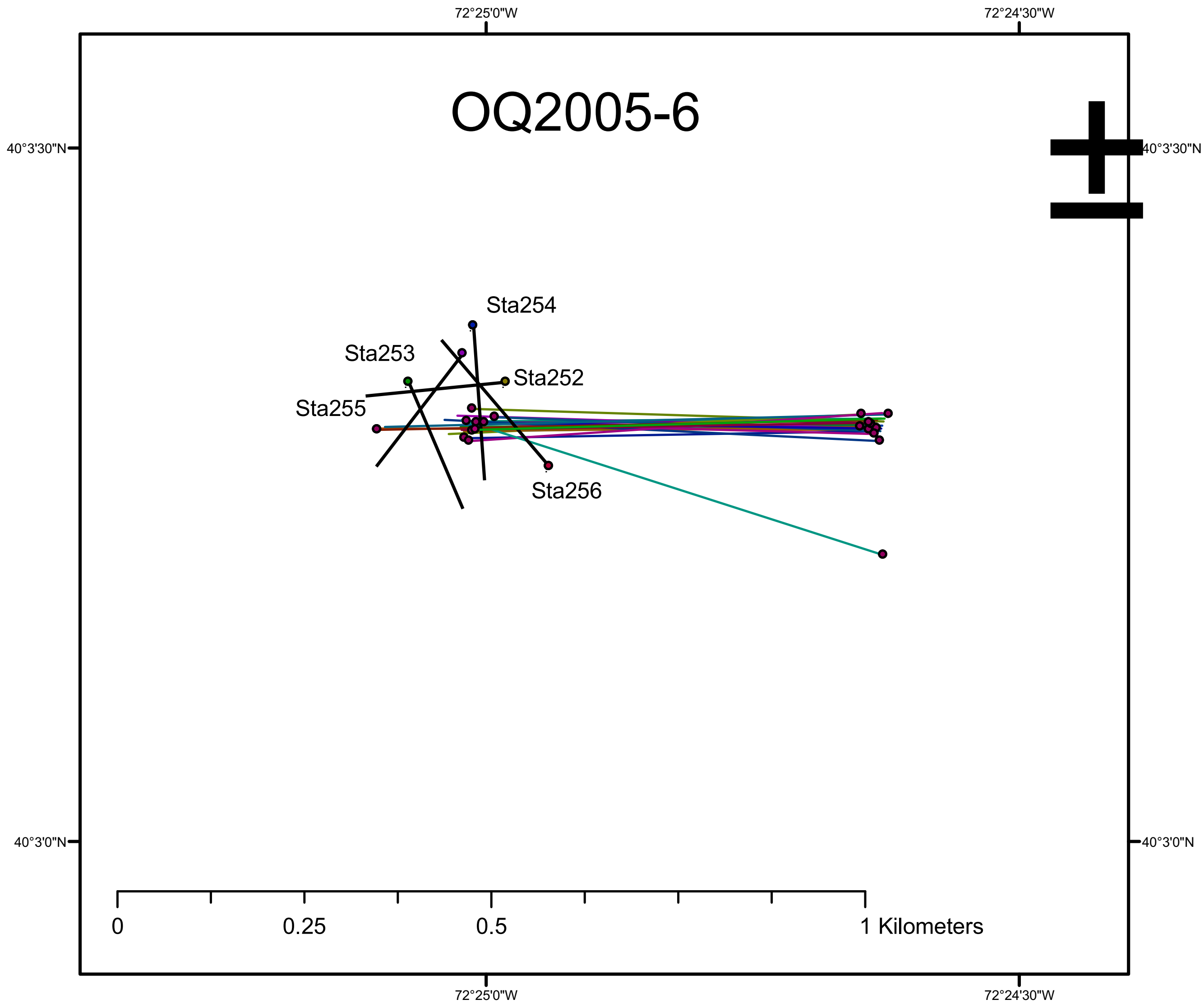


Figure A37. Setup and depletion tows for the OQ2005-6 ocean quahog depletion study. Setup tows by the *R/V Delaware II* are identified by station numbers. Depletion tows by the *F/V Lisa Kim* are tightly clustered along parallel tracks. Tow paths appear straight because they are shown as straight lines between start and stop points.

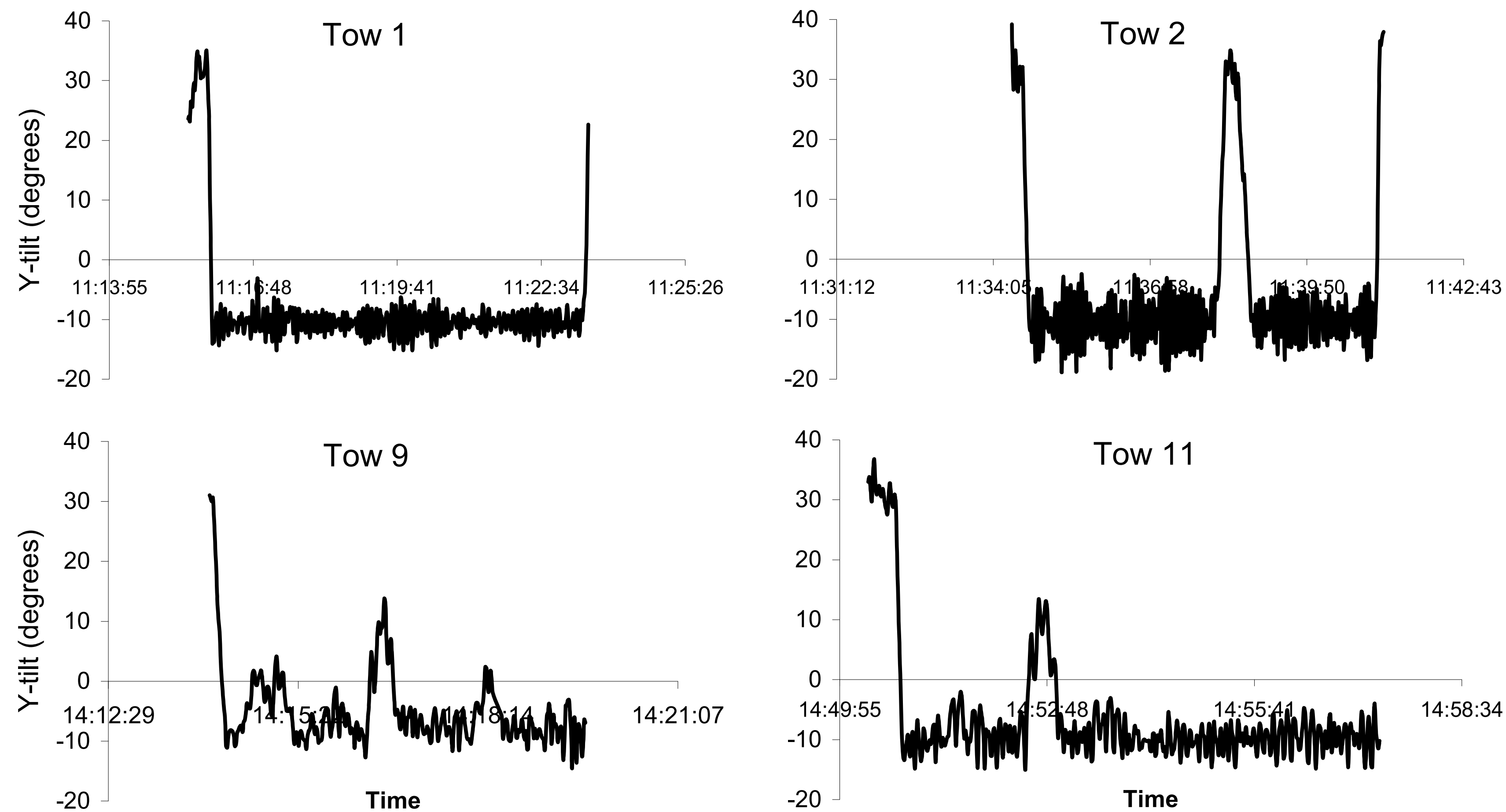


Figure A38. Inclinometer data for selected tows by a commercial dredge at depletion experiment site OQ2005-06, which was carried out in relatively deep water with a short pump hose and under choppy conditions. Data missing at end of tows 9-11 because of low sensor batteries.

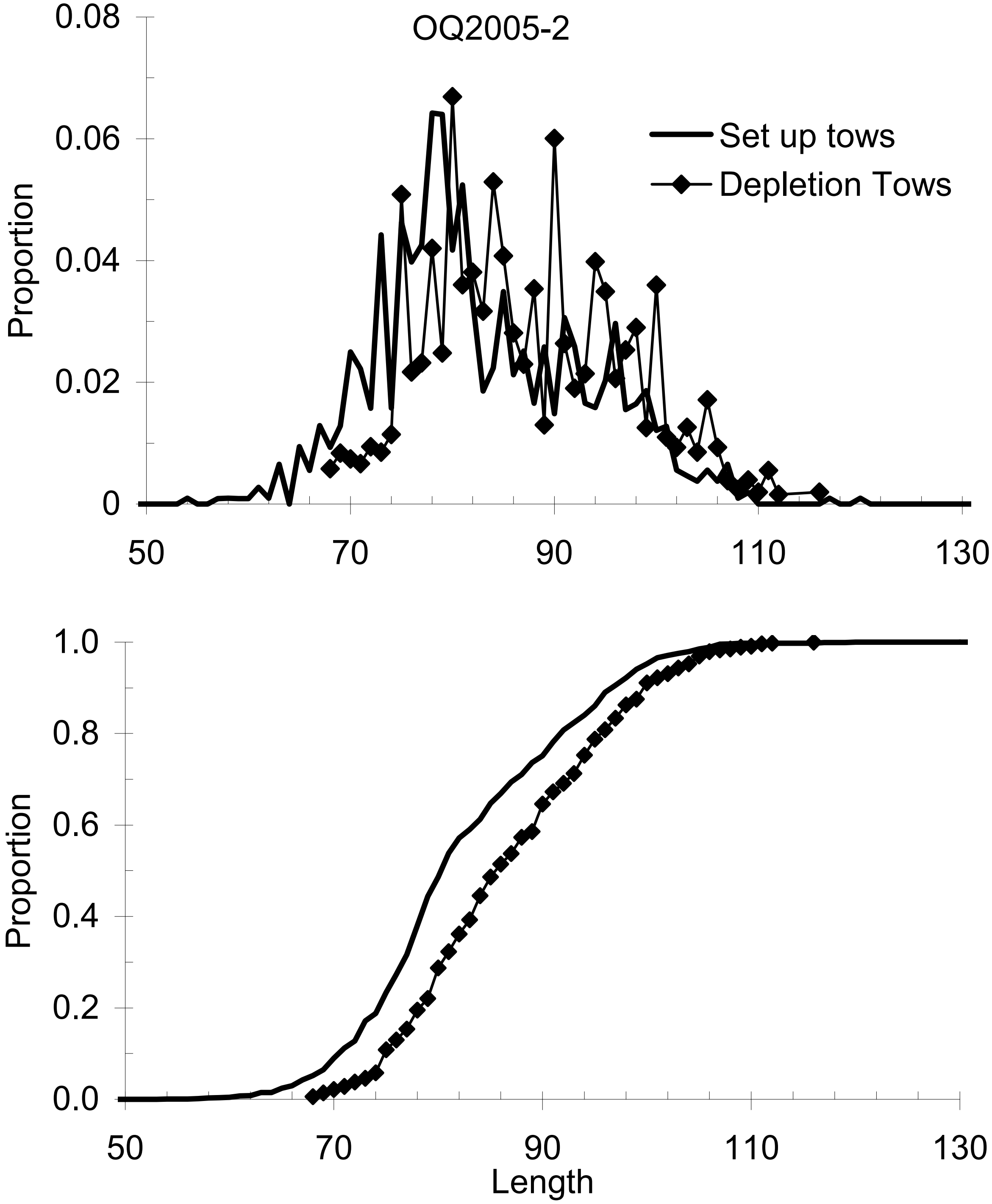


Figure A39. Length composition data from setup and depletion tows at a typical 2005 depletion site for ocean quahog (OQ2005-02).

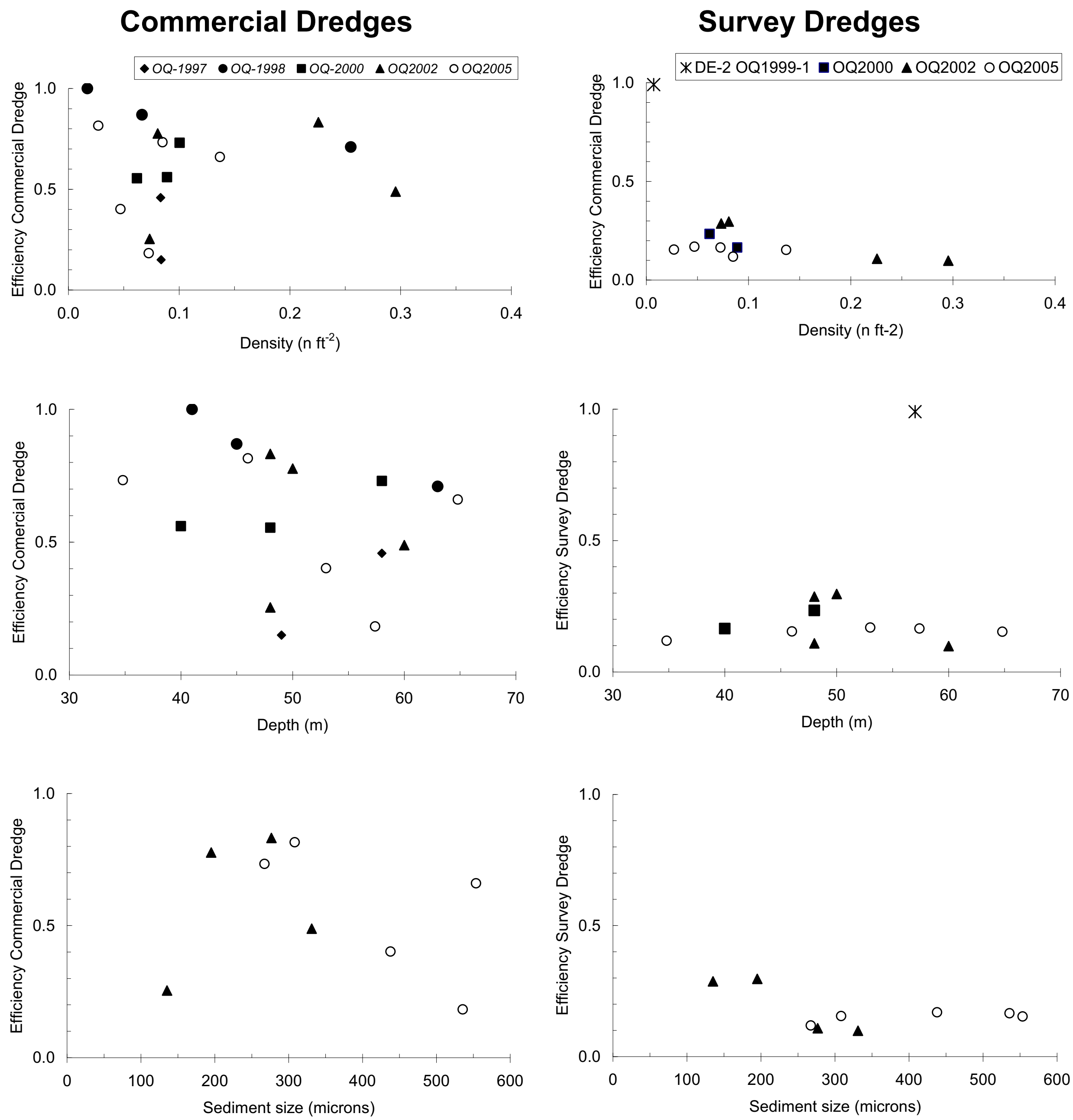


Figure A40. Patch model dredge efficiency estimates vs. depth, estimated density from the Patch model and mean sediment size for ocean quahog in hydraulic dredges used on commercial vessels during depletion studies and the hydraulic dredge used during research surveys by the *F/V Delaware II*. All data shown in plots on the left hand side are efficiency estimates for commercial vessels used in depletion studies. All data shown in plots on the right hand side are efficiency estimates for the R/V Delaware II based on commercial depletion estimates with setup tows by the Delaware II or, in the case of "DE-2 OQ1999-1", a depletion study carried out directly by the R/V Delaware II.

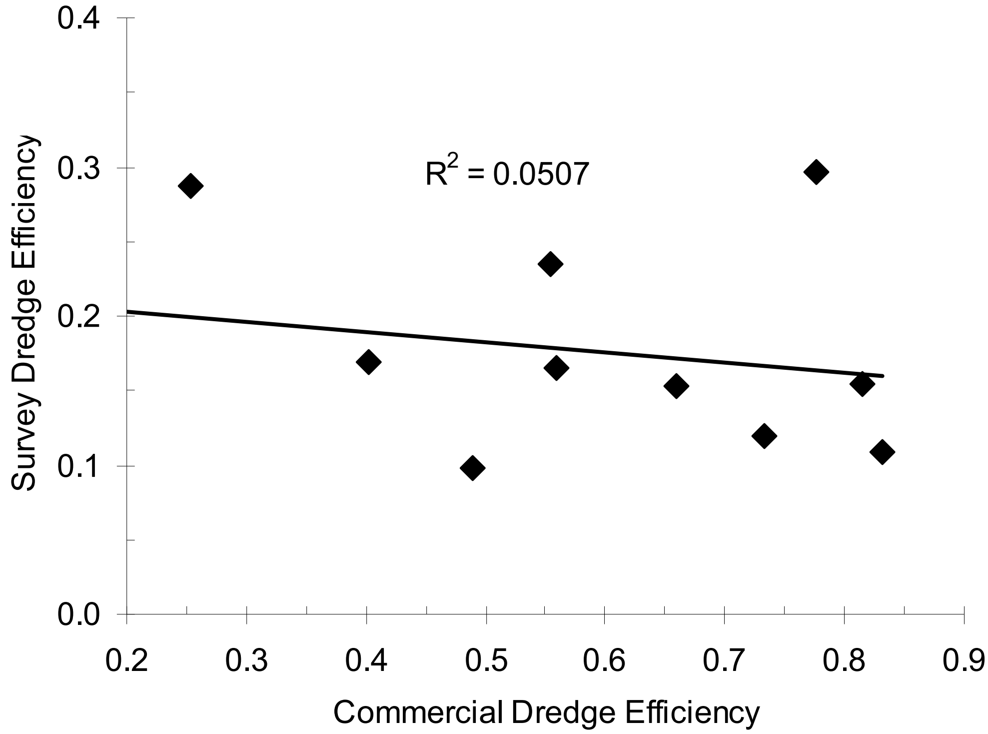


Figure A41. Survey dredge efficiency estimates for ocean quahog from depletions studies by commercial vessels and by the R/V Delaware II.

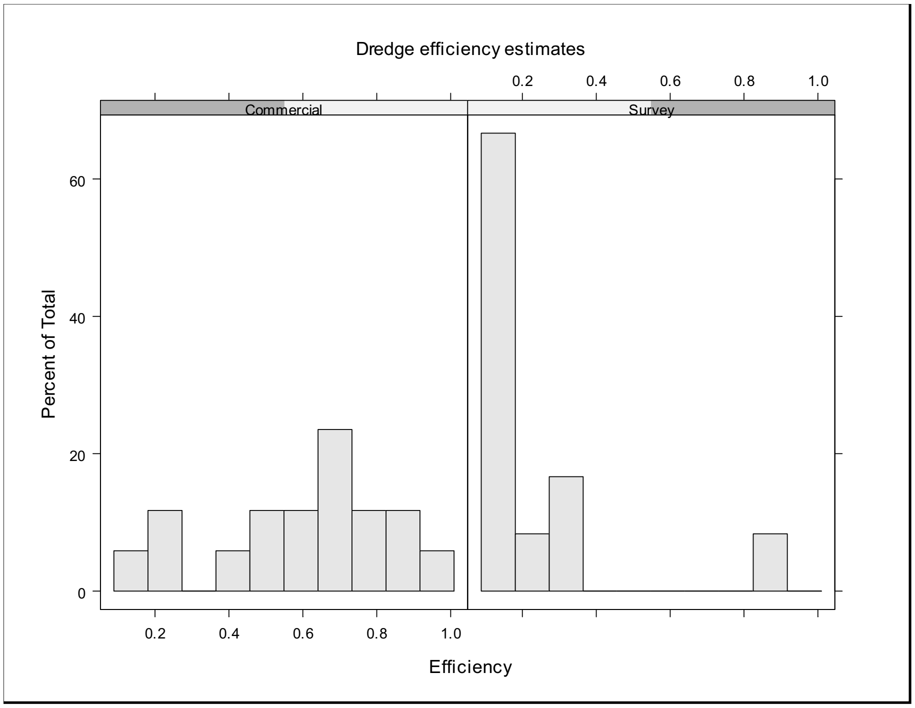


Figure A42. Distribution of survey dredge efficiency estimates for ocean quahog from depletion studies by commercial vessels and by the survey vessel (*R/V Delaware II*).

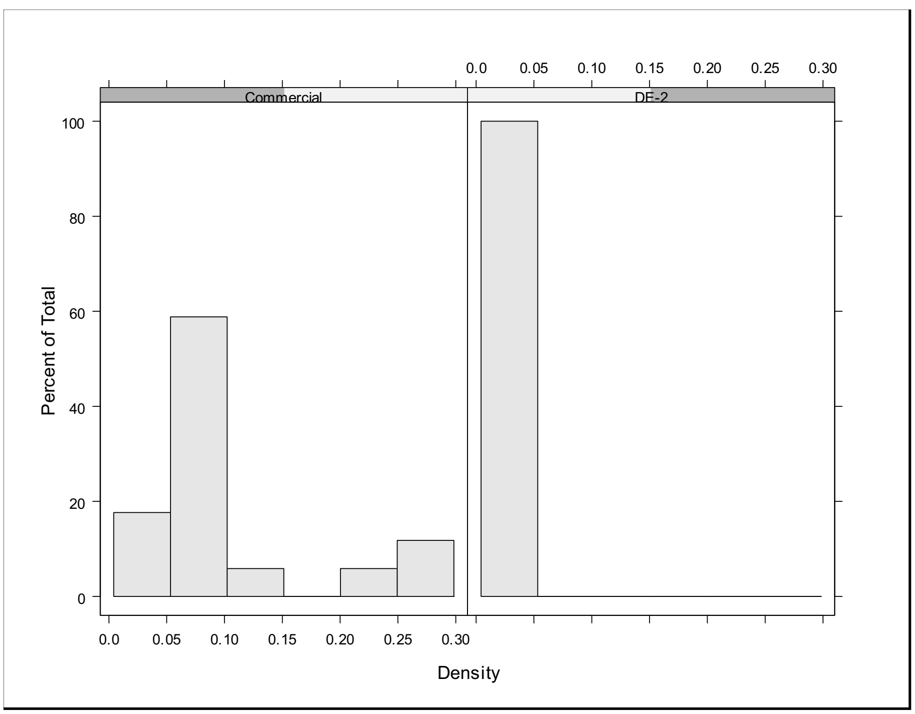


Figure A43. Distribution of ocean quahog density estimates (n ft^{-2}) for ocean quahog 90+ mm SL from depletion studies by commercial vessels and by the survey vessel (*R/V Delaware II*).

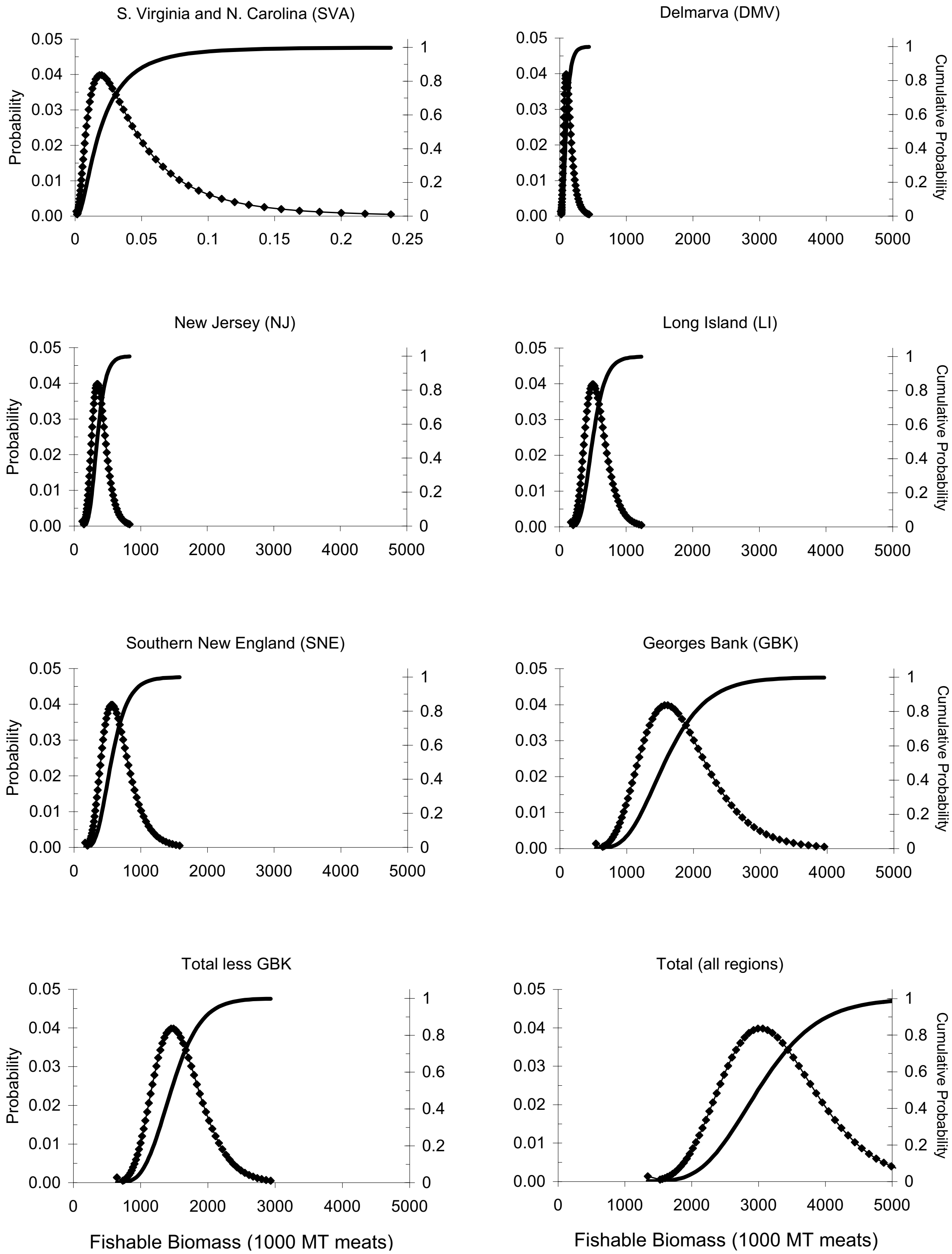


Figure A44. Uncertainty in efficiency corrected swept area biomass estimates for fishable ocean quahog during 2005. Note that the x-axis differs in the panel for SVA but is the same in all other panels to facilitate comparisons.

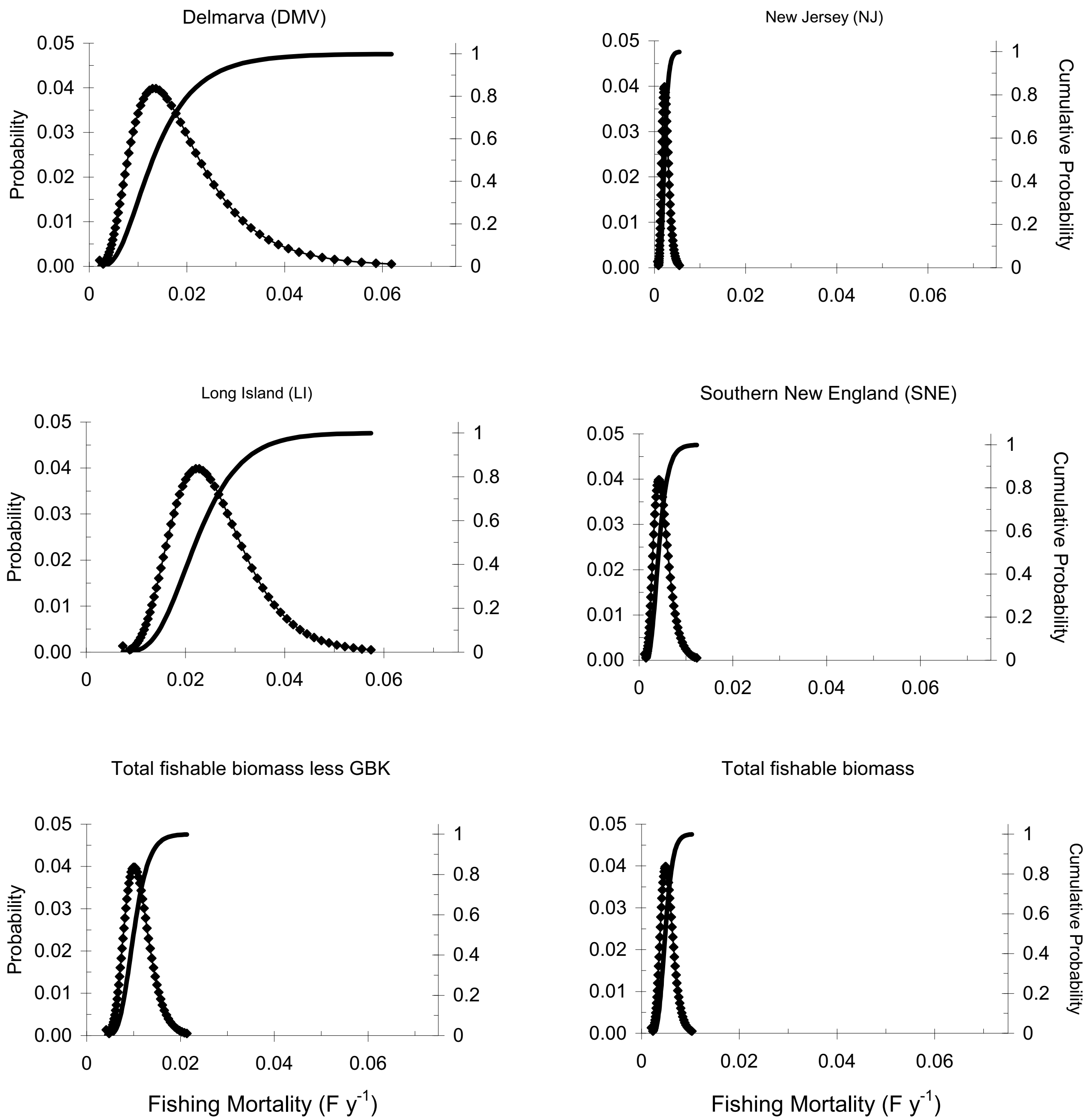


Figure A45. Uncertainty in fishing mortality estimates for ocean quahog during 2005 based on catch data and efficiency corrected swept-area biomass. X-axes are scaled to the same maximum to facilitate comparisons.

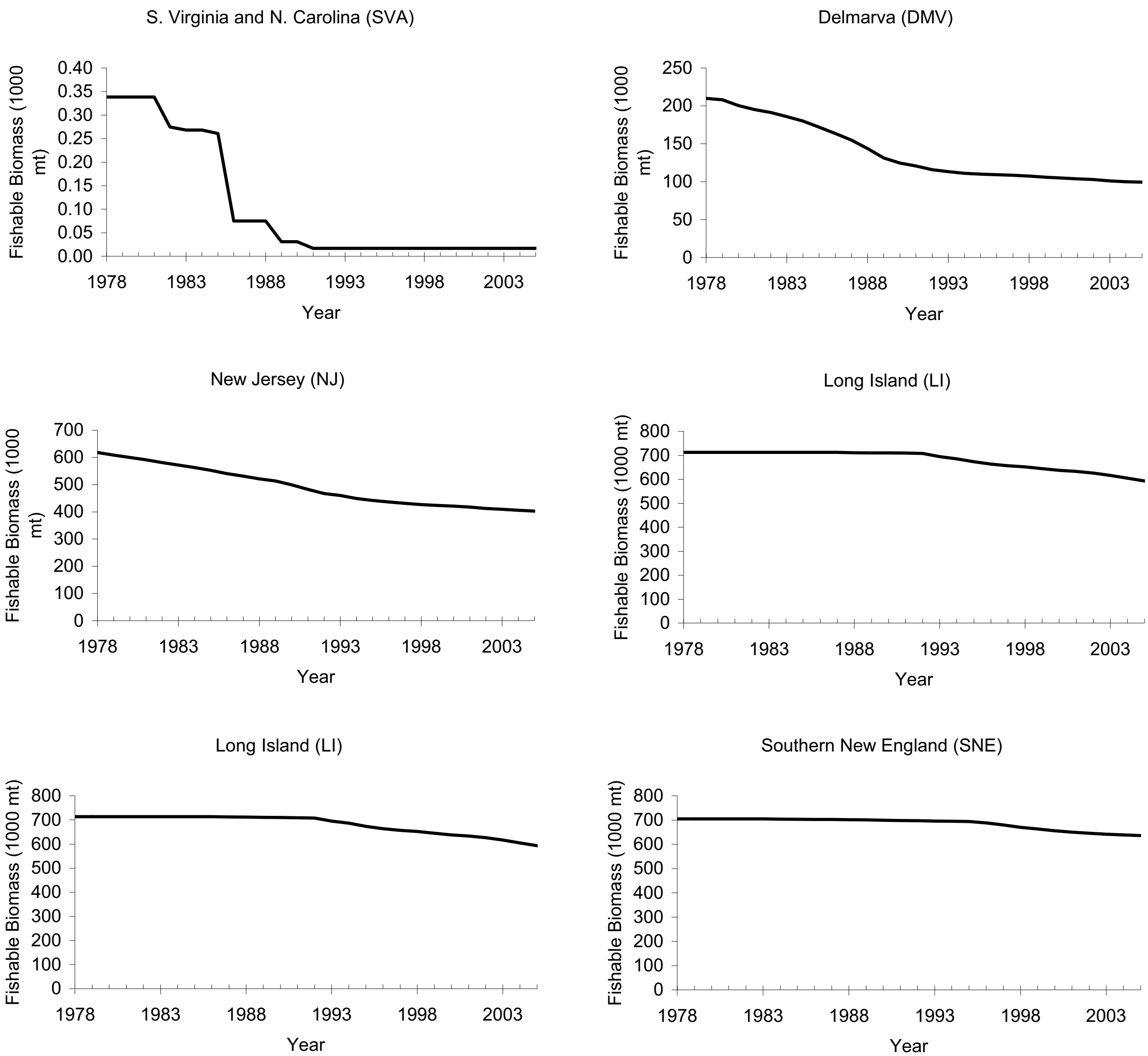
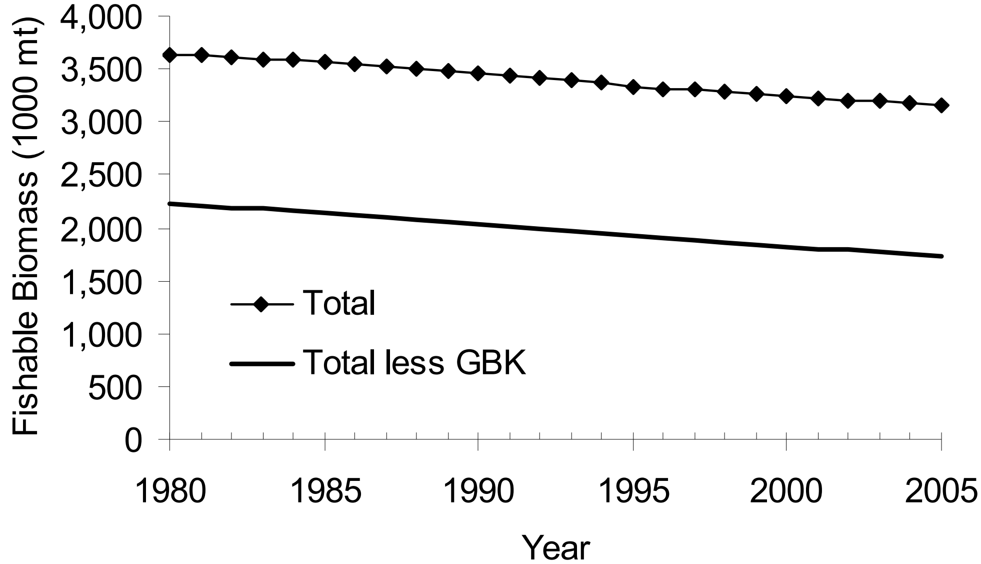


Figure A46. Trends in fishable biomass for ocean quahog from the "VPA" model, by region.



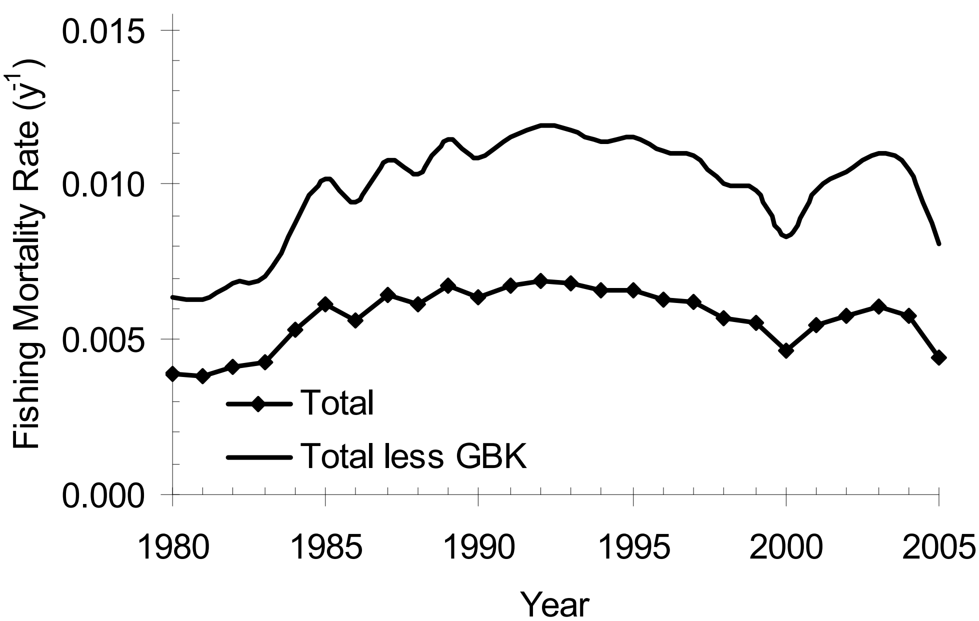


Figure A47. Trends in fishable biomass and fishing mortality for ocean quahog from the "VPA" model.

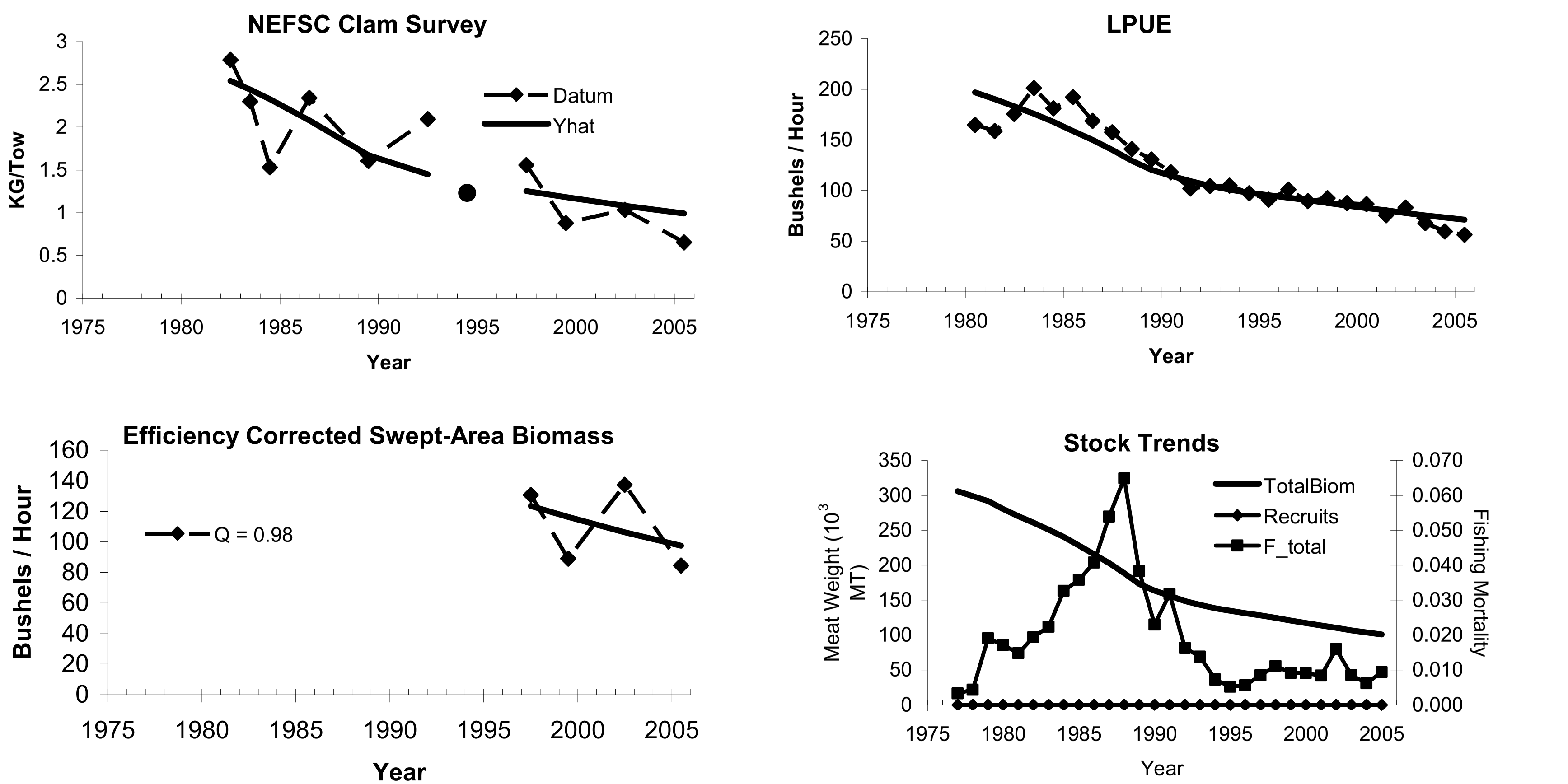


Figure A48. KLAMZ model results for ocean quahog in the DMV stock assessment region. The bottom right panel shows population estimates. Other panels show goodness of fit to trend data. The survey scaling parameter estimate for efficiency corrected swept-area biomass data used as prior information is shown in the bottom left panel. Trends in efficiency corrected swept area biomass and LPUE data did not affect model estimates and are shown for comparison only.

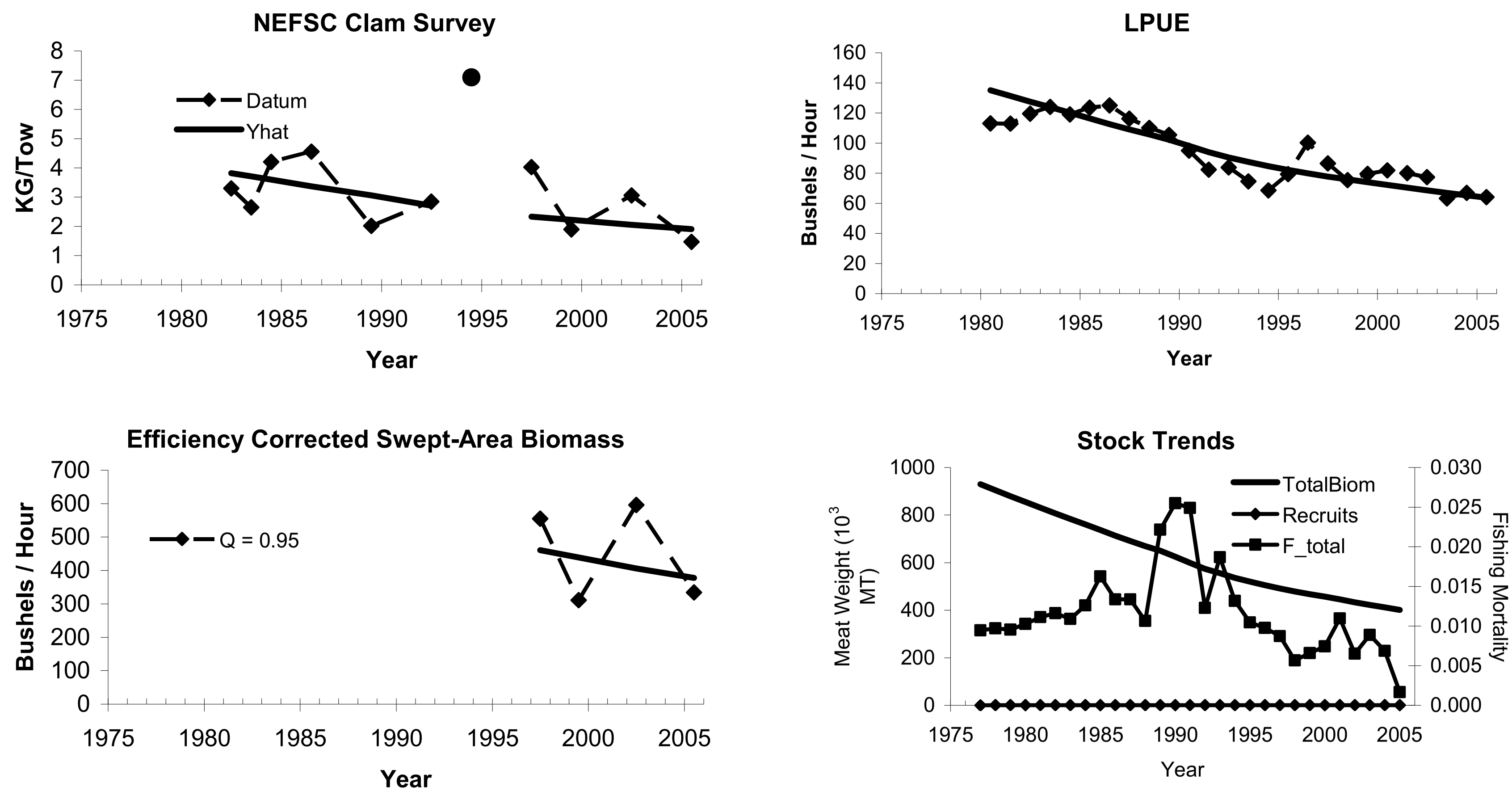


Figure A49. KLAMZ model results for ocean quahog in the NJ stock assessment region. The bottom right panel shows population estimates. Other panels show goodness of fit to trend data. The survey scaling parameter estimate for efficiency corrected swept-area biomass data used as prior information is shown in the bottom left panel. Trends in efficiency corrected swept area biomass and LPUE data did not affect model estimates and are shown for comparison only.

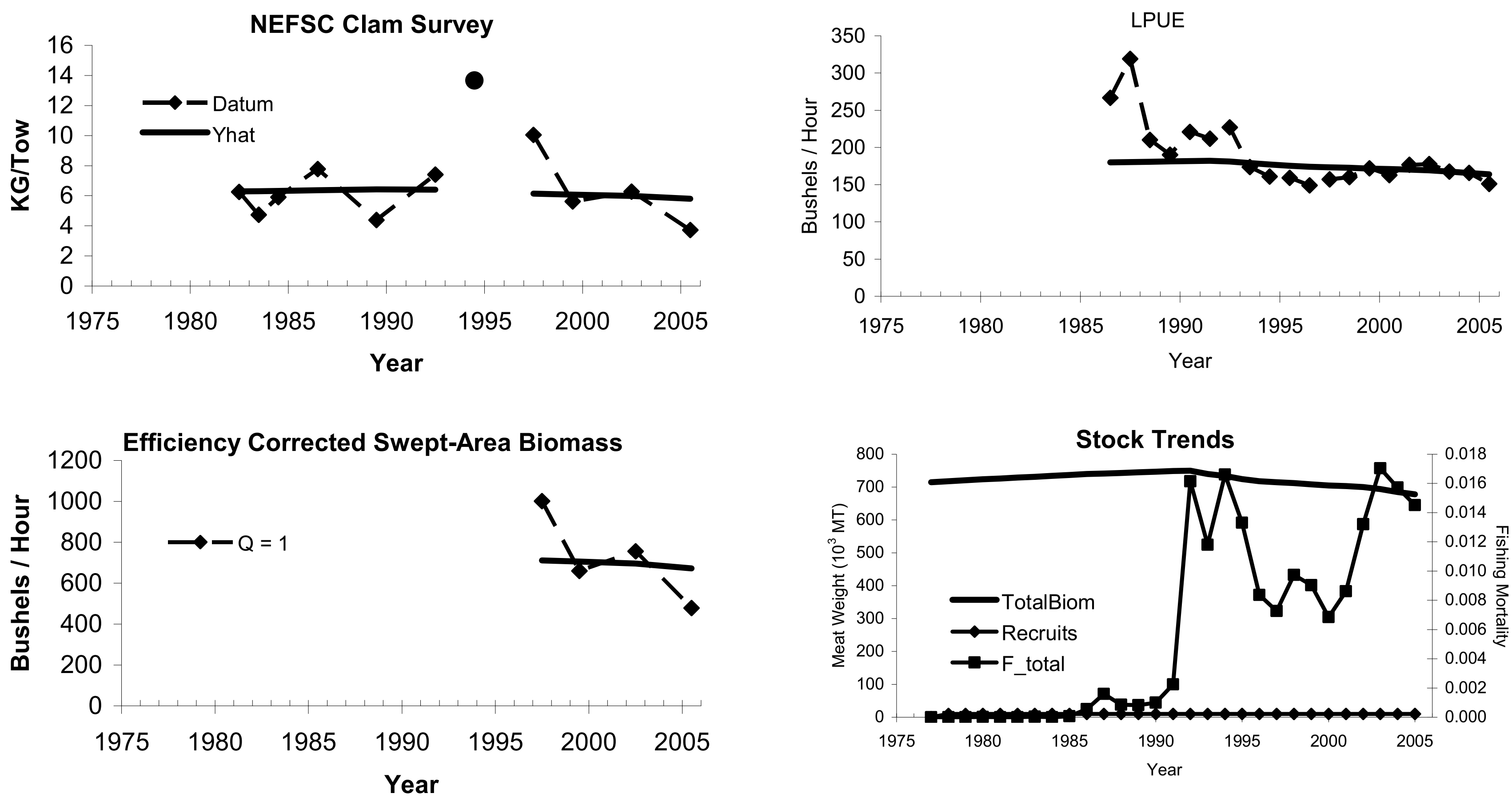


Figure A50. KLAMZ model results for ocean quahog in the LI stock assessment region. The bottom right panel shows population estimates. Other panels show goodness of fit to trend data. The survey scaling parameter estimate for efficiency corrected swept-area biomass data used as prior information is shown in the bottom left panel. Trends in efficiency corrected swept area biomass and LPUE data did not affect model estimates and are shown for comparison only.

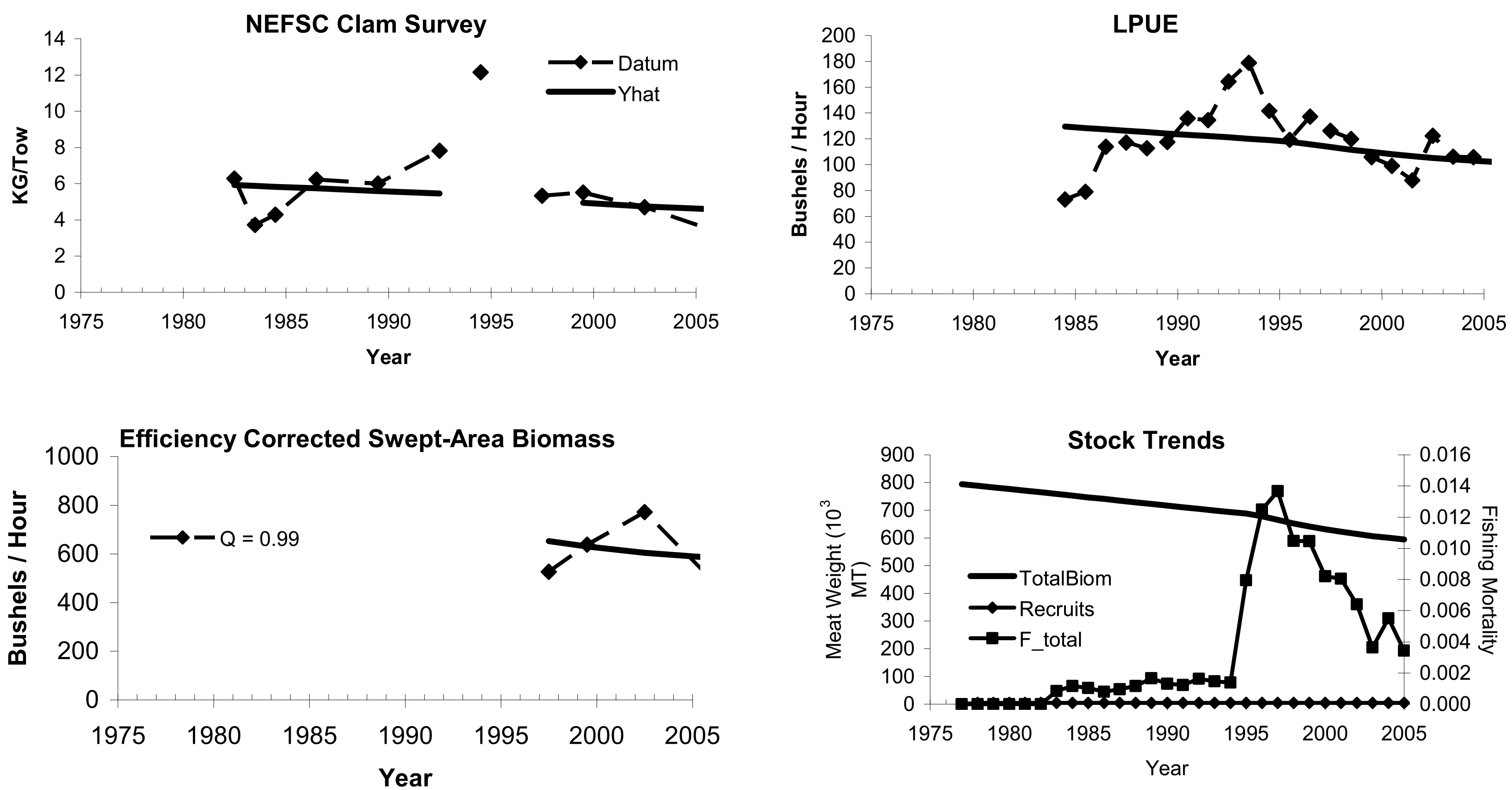
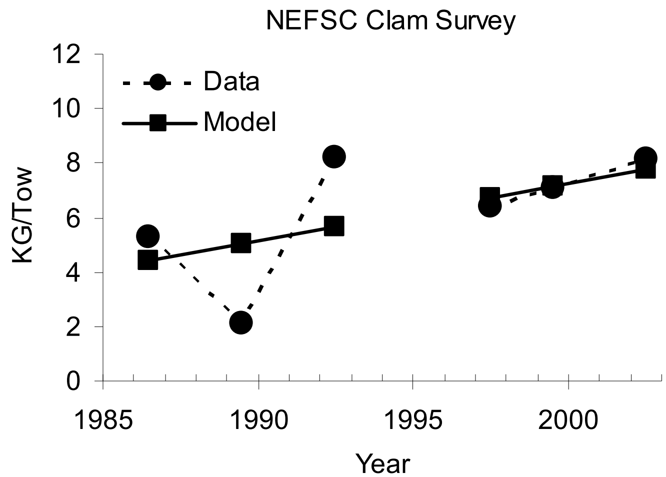
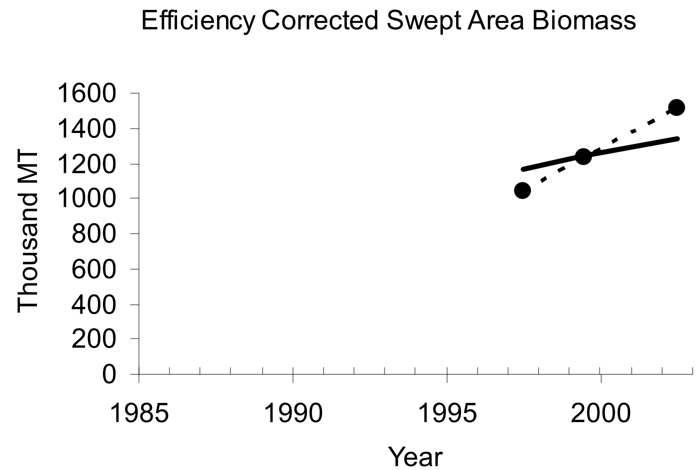
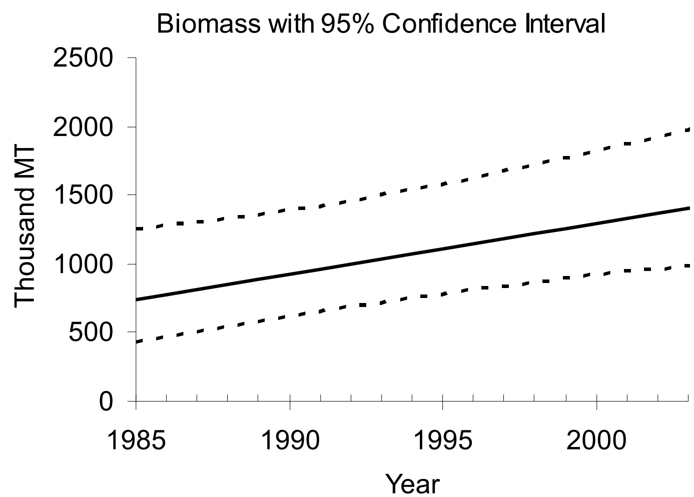


Figure A51. KLAMZ model results for ocean quahog in the SNE stock assessment region. The bottom right panel shows population estimates. Other panels show goodness of fit to trend data. The survey scaling parameter estimate for efficiency corrected swept-area biomass data used as prior information is shown in the bottom left panel. Trends in efficiency corrected swept area biomass and LPUE data did not affect model estimates and are shown for comparison only.





Q for efficiency corrected swept area biomass =	0.98



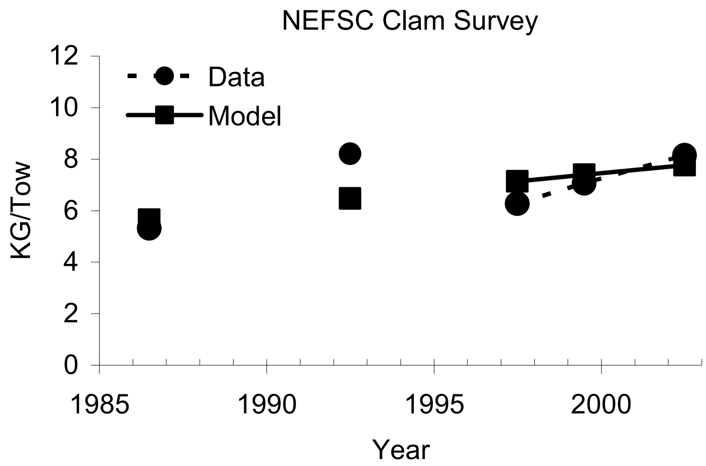
Mean instantaneous rates

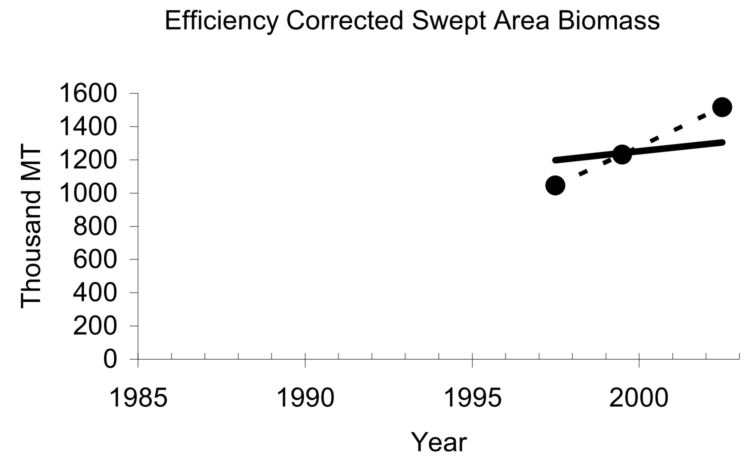
Rate	GBK	LI	GBK/LI
M=	-0.020	-0.020	1.0
G=	0.022	0.010	2.2
R=	0.031	0.014	2.3
Surplus prod. rate	0.034	0.004	8.8

Mean recruits per unit area

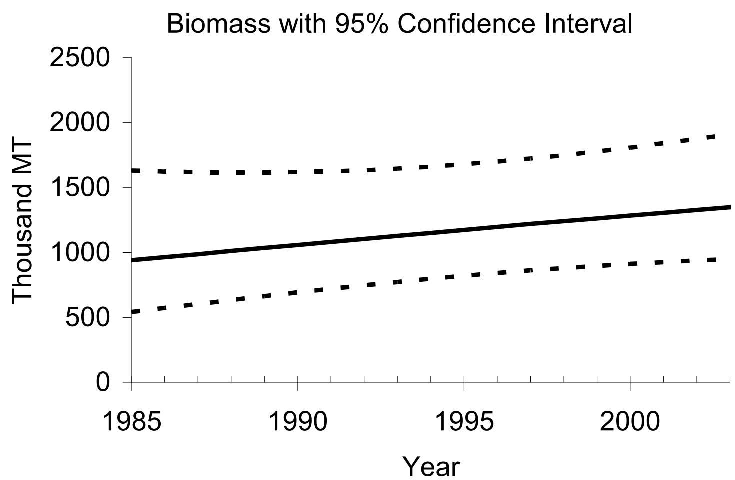
	GBK	LI	GBK/LI
Recruits (MT / year)	34.2	9.9	3.5
Area (nm^2)	7821	4463	1.8
Recruits/Area	0.0044	0.0022	2.0

Figure A52. Results from a trial run of the KLAMZ model for ocean quahog in the GBK stock assessment region during 1986-2002 with all survey data in the model.





Q for efficiency corrected swept area biomass = 0.98



Mean instantaneous rates

Rate	GBK	LI	GBK/LI
M=	-0.020	-0.020	1.0
G=	0.017	0.010	1.7
R=	0.022	0.014	1.6
Surplus prod. rate	0.019	0.004	5.0

Mean recruits per unit area

	GBK	LI	GBK/LI
Recruits (MT / year)	25.4	9.9	2.6
Area (nm^2)	7821	4463	1.8
Recruits/Area	0.0033	0.0022	1.5

Figure A53. Results from a sensitivity run of the KLAMZ model for ocean quahog in the GBK stock assessment region with survey data for 1989 removed.

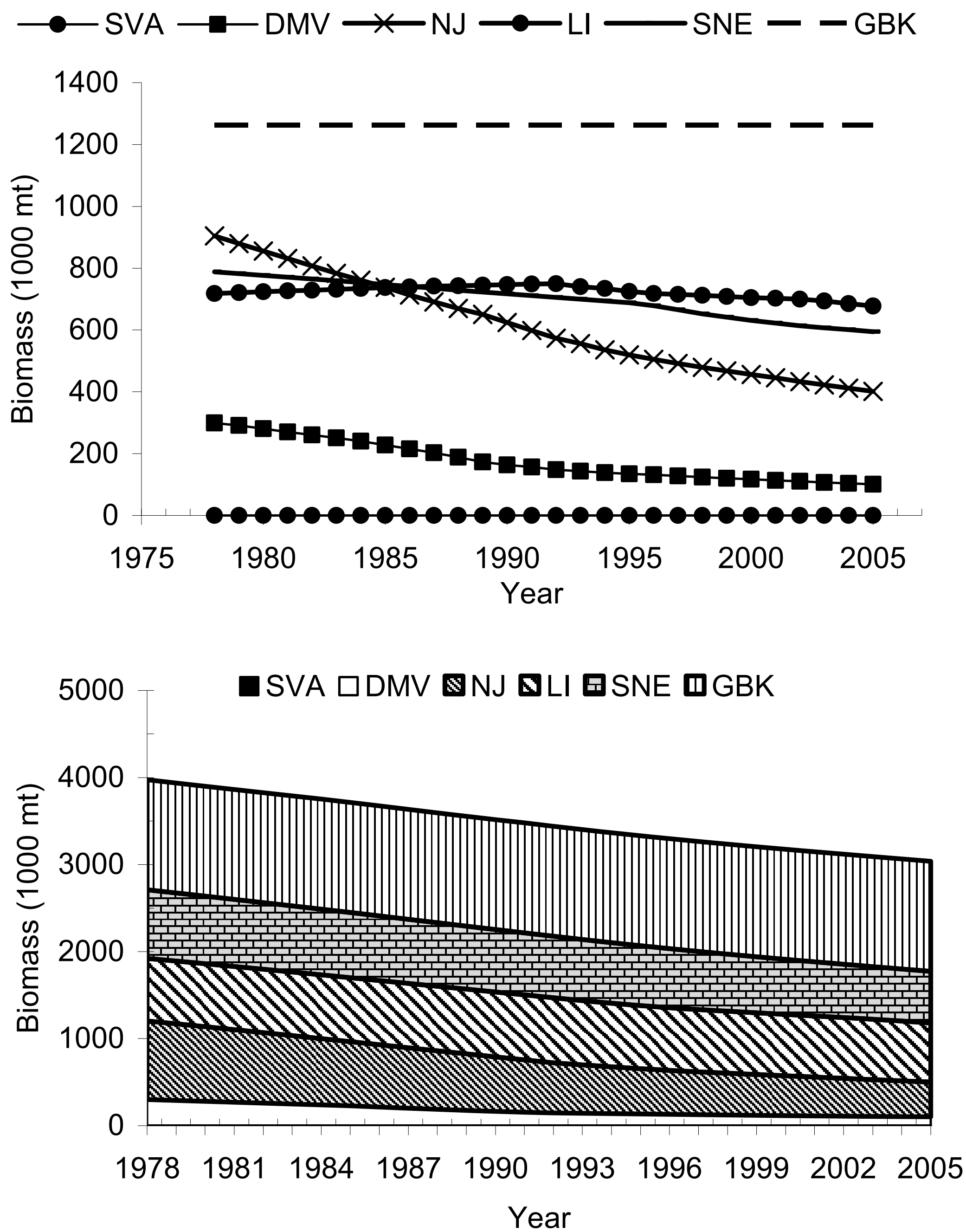


Figure A54. Best biomass estimates for ocean quahog in the US EEZ.

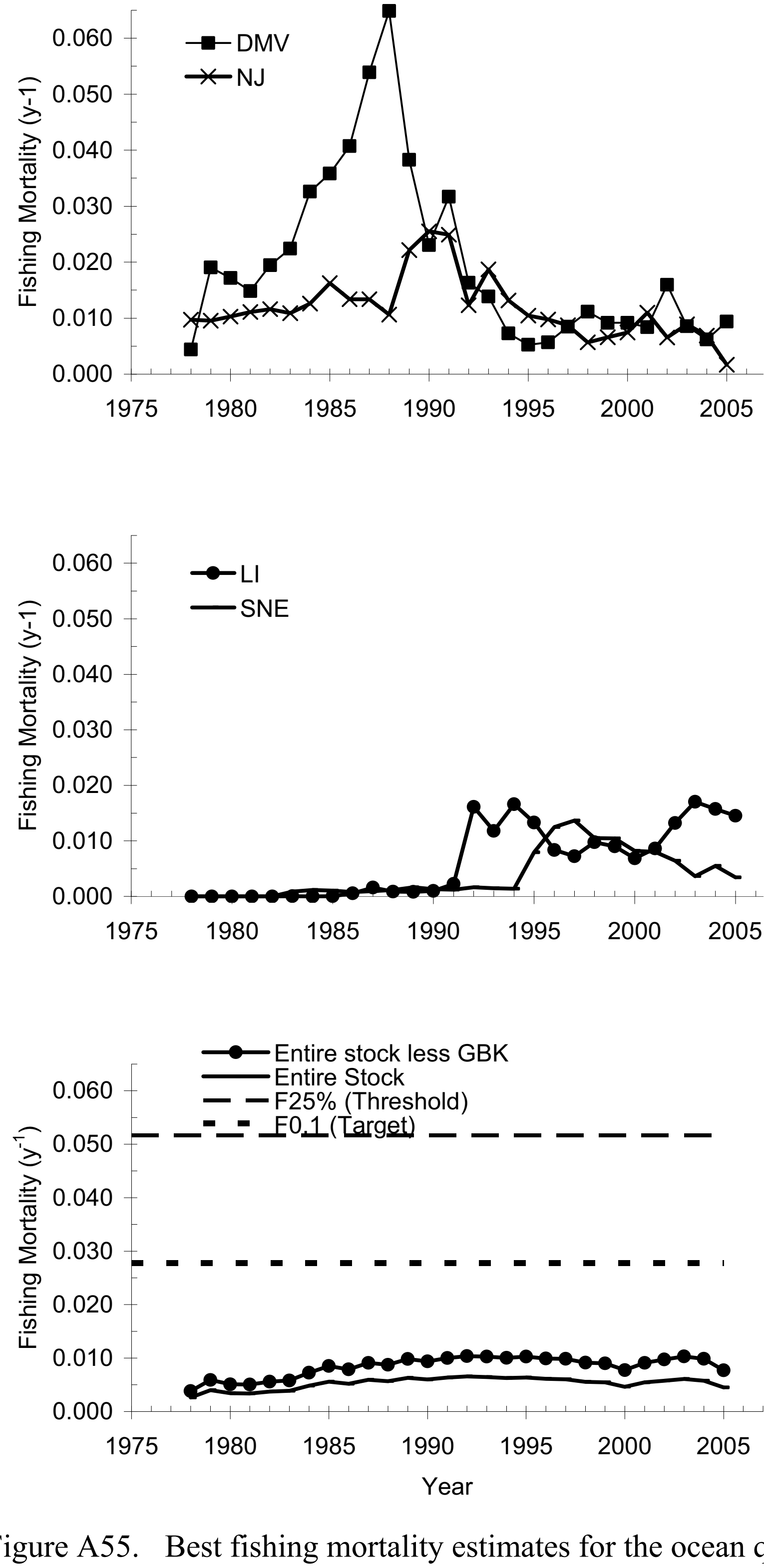


Figure A55. Best fishing mortality estimates for the ocean quahog stock in the US EEZ and the total stock less GBK.

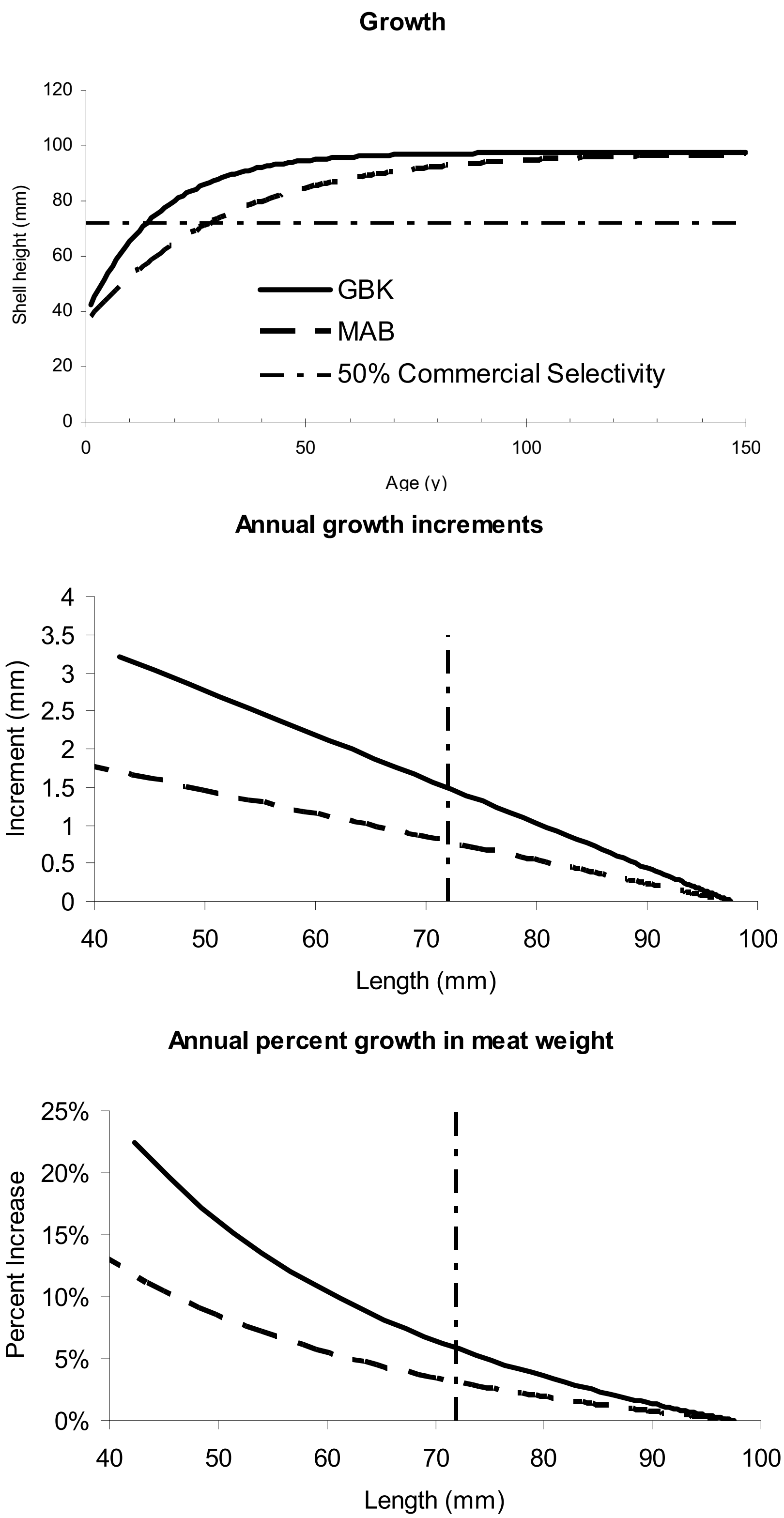


Figure A56. Growth, annual growth increments and percent annual change in meat weights for ocean quahog in GBK and in the Mid-Atlantic Bight (MAB) based on von Bertalanffy growth curves. The growth curve for GBK is from Lewis et al. (2001). The growth curve for MAB is used in this assessment for the fishable ocean quahog stock (which excludes GBK).

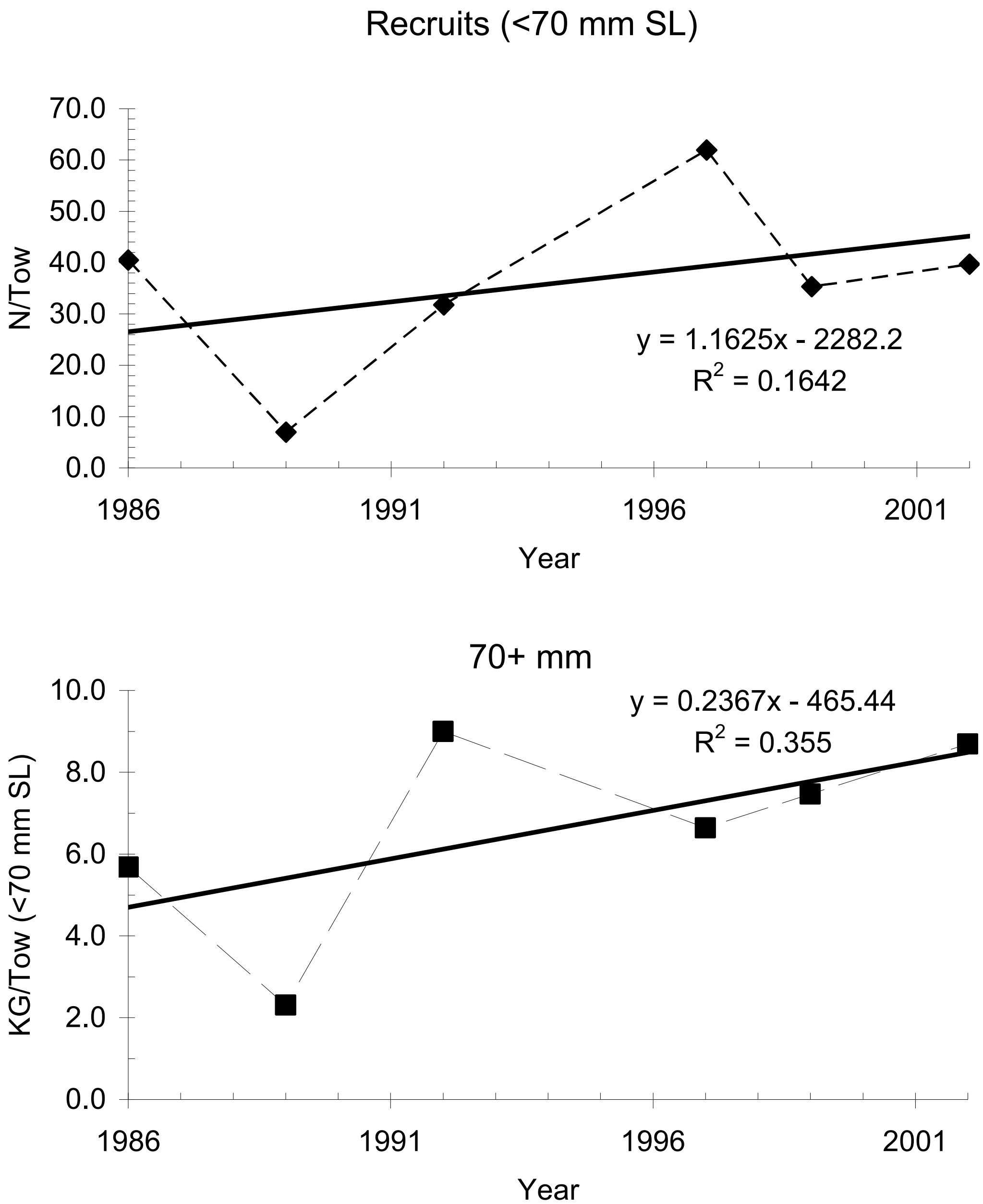


Figure A57. Trends in survey biomass (no correction for selectivity) for ocean quahog from NEFSC clam surveys during 1986-2002 (1994 omitted due to high pump voltage).

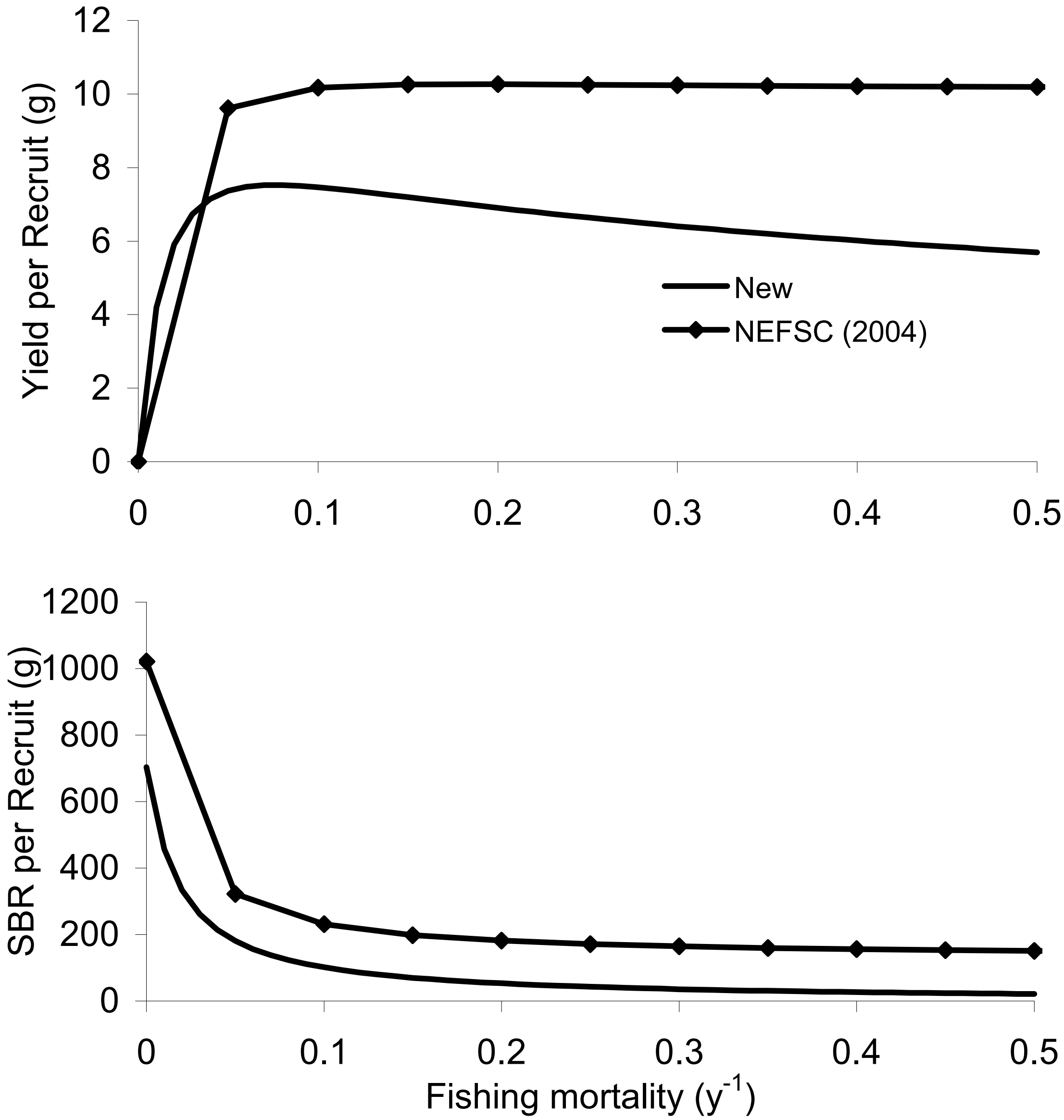


Figure A58. Per recruit model results from a new length based per recruit model and from NEFSC (2004).

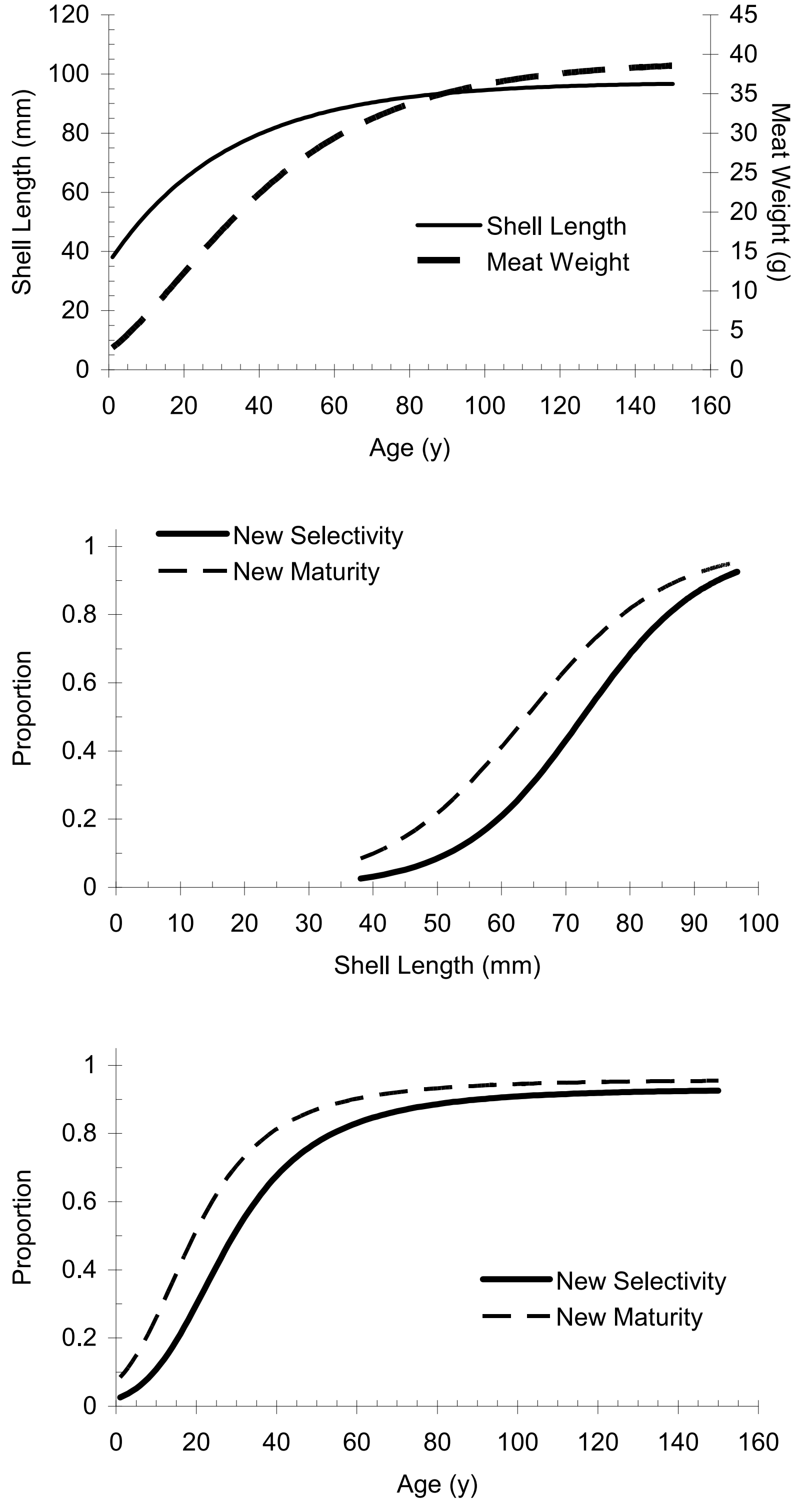


Figure A59. Growth, maturity and fishery selectivity curves used in length-based per recruit model used to calculate biological reference points for ocean quahog. Maturity and selectivity (originally functions of length, middle panel) were expressed as functions of age (bottom panel) by inverting the growth curve.

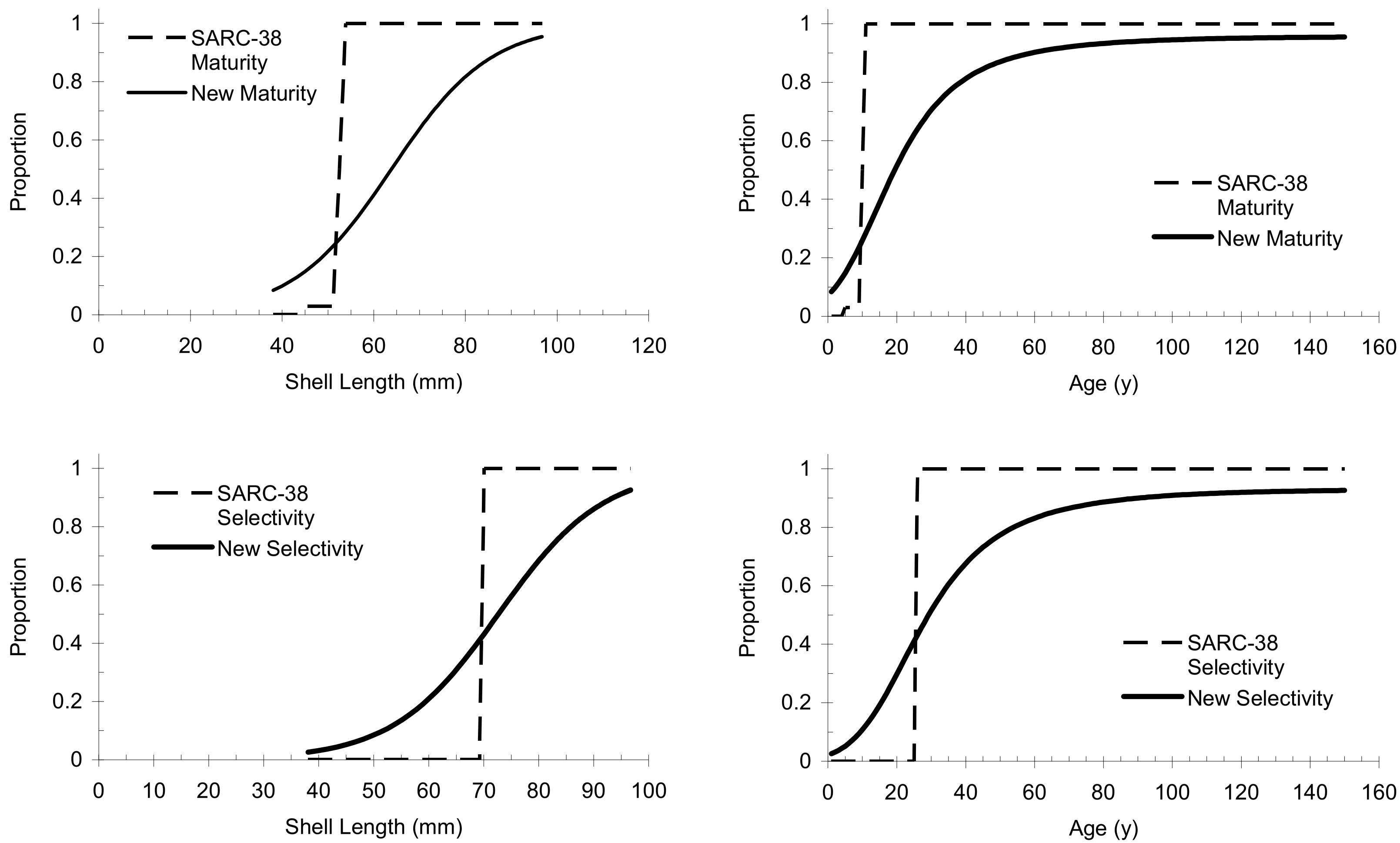


Figure A60. New and old (SARC-38 in NEFSC 2004) maturity and fishery selectivity curves used in per recruit models for ocean quahog.

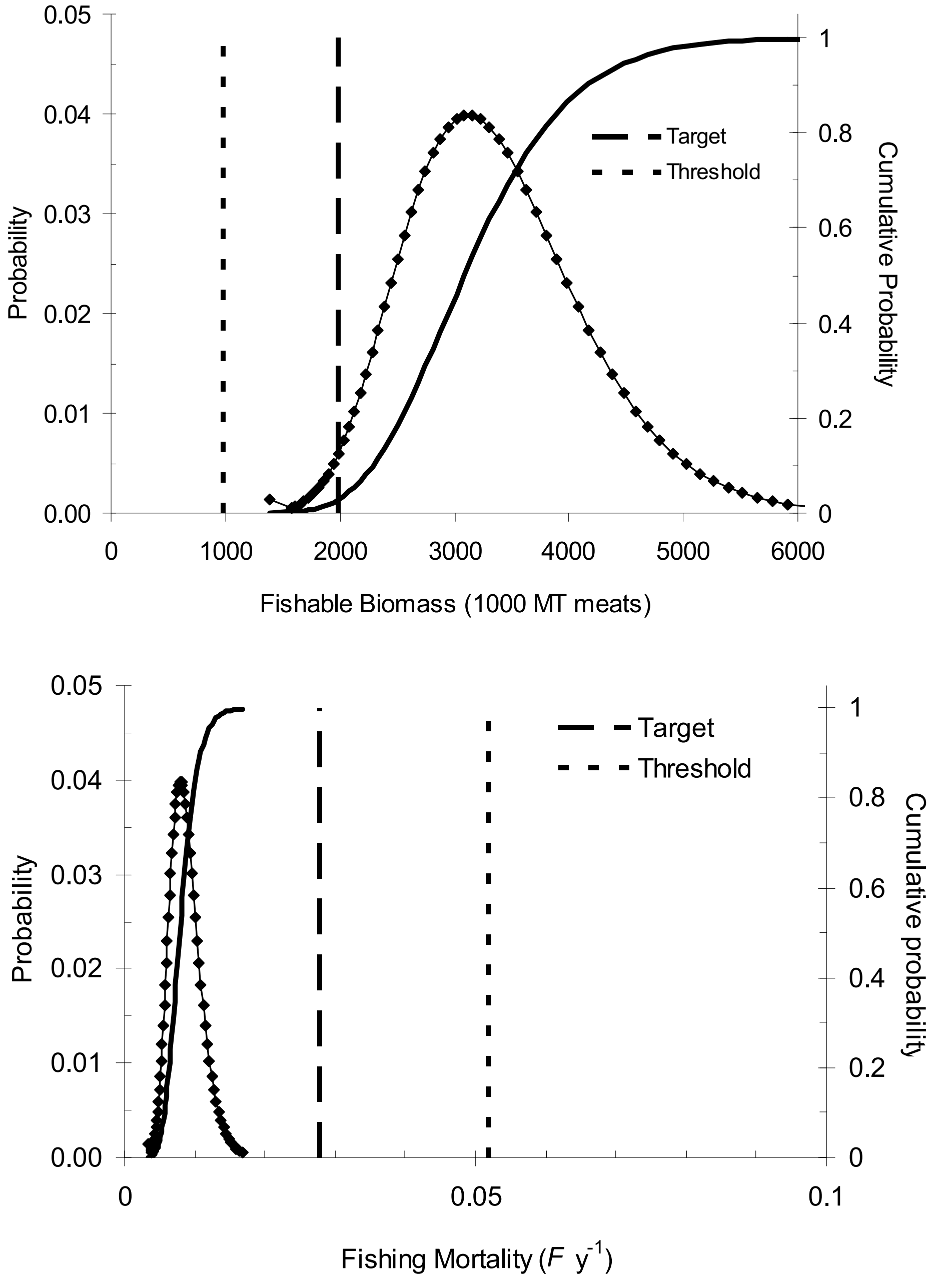


Figure A61. Best estimates of fishable ocean quahog biomass for the entire ocean quahog stock (top) and fishing mortality for the exploitable stock (excluding GBK) during 2005, with confidence intervals and reference points. The confidence intervals are approximate and based on the CV for the efficiency corrected swept-area biomass estimates for 2005.

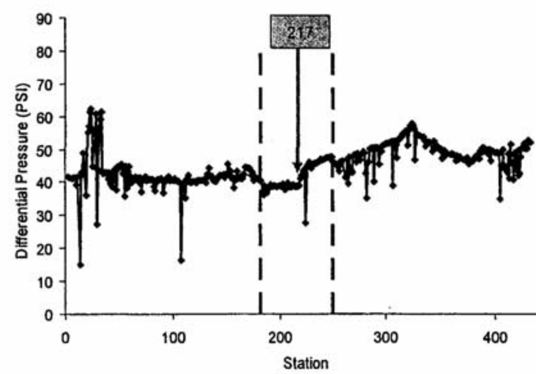
OCEAN QUAHOG APPENDICES

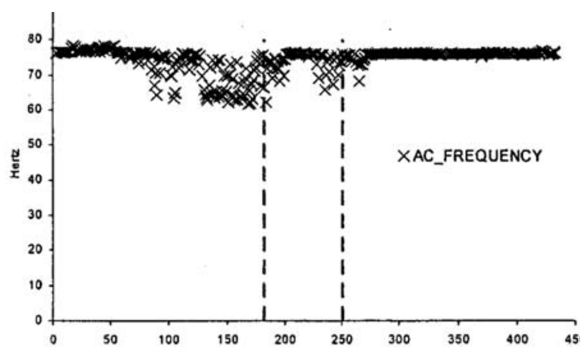
APPENDIX A1. Survey sensor package data from the 2005 NEFSC clam survey. Differential pressure and other data were analyzed to determine if the pump on the survey dredge performed as expected.

R/V Delaware II Clam Dredge Pump Performance[7]

Introduction

From an initial review of the Survey Sensor Pack (SSP) data, the dredge pump manifold differential pressure showed a significant variation over the course of the survey's three cruise legs (See Figure 1). This variation was sporadic during the first survey leg with the pressure spikes being attributed to blocked manifold nozzles from visual inspections at the dredge's retrieval. This however, can not explain the consistent upward trend in the manifold differential pressure starting in the middle of the 2nd survey cruise leg which continued to the middle of the 3rd leg with a then subsequent small falling trend towards the end of the survey. The numerous and sporadic pressure drop spikes that were also noted were not readily explainable by any events that occurred during the survey cruise.





Appendix A1. Figure 1 - SSP Manifold Differential Pressure   Figure 2 - AC Pump Frequency

It was also noted that the frequency recorded also showed a large variation during the ends of the 1st and 2nd survey legs and was consistently higher than the 60 hertz that should have been expected (See Figure 2).

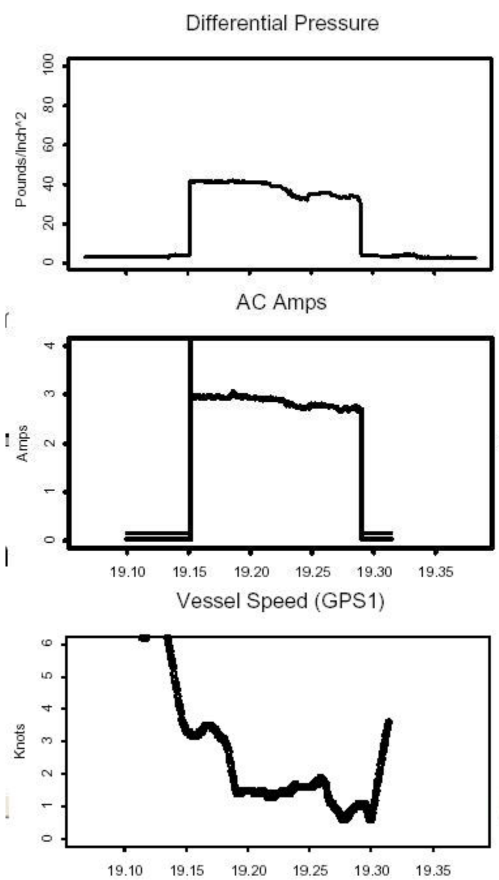
An overheated wire connection on the clam survey package's main breaker was discovered during station 217's tow and temporarily repaired for the remainder of the 2nd survey leg. The clam survey package's main breaker was replaced at the completion of the 2nd survey leg.

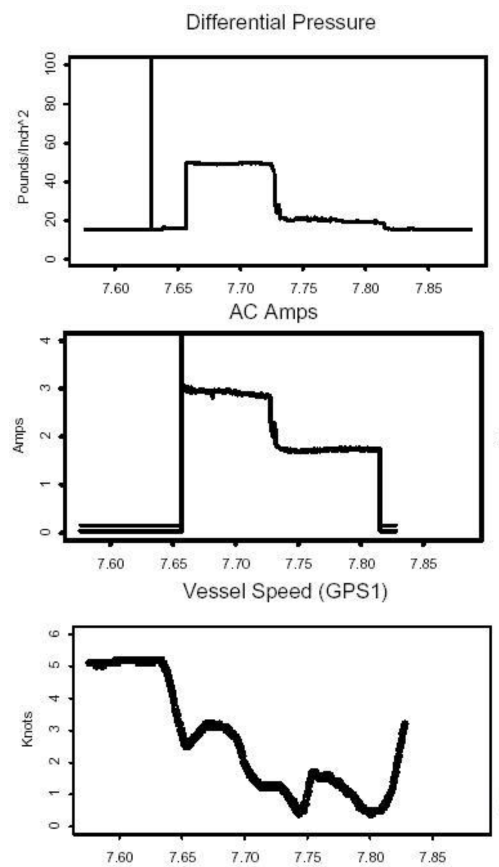
To first investigate these anomalies, a visual inspection of the clam survey sensor data plots for all of the survey tows was done. In particular the Y-Tilt (dredge angle), Manifold Differential Pressure, Pump AC Amps/Volts/Frequency, and Vessel Speed were reviewed. Each tow was graded in an Excel worksheet to summarize the basic characteristics as noted below.

[7] Prepared by John Womack, Wallace and Associates, Ltd.

- Good/Bad Tow or Missing Sensor Data
- Approximate Manifold Differential Pressure
- Manifold Clogging or Pump Intake Blockage
- Erratic Dredge Angle (Y-Tilt); Front Middle, and End of Tow
- Dredge Pump Frequency; Front Middle, and End of Tow
- Tow Speed; Front Middle, and End of Tow
- Did a Low Speed Spike Occur (Tow speed < ½ knot)?

The first discovery is the explanation the sporadic pressure drop spikes in the manifold differential pressure. These pressure drop spikes are likely being caused by a temporary blockage of the pumps intake or the pump ingesting the discharge from the dredge manifold which somehow disrupts the pump's intake flow.



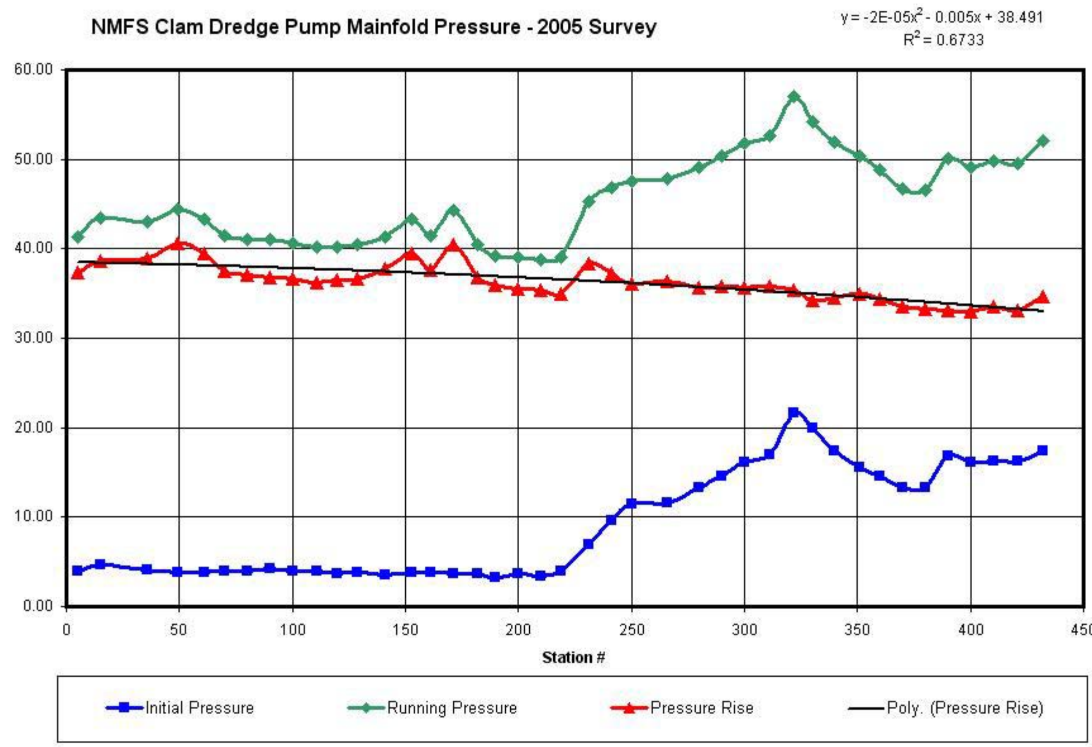


Appendix A1. Figure 3 - Station #71 Tow   Figure 4 - Station #405 Tow

Figure 3 shows a typical tow where this pump intake blockage has likely occurred. Note that there is a corresponding drop in the dredge pump's amps draw as the manifold pressure drops. This is typical for a centrifugal style pump such as is on the clam dredge. The drop in pressure could be minor as in Figure 3 or very substantial as shown in Figure 4. Figure 4 is likely an example of the pump ingesting the manifold discharge as it occurred when a very low speed spike, less than 1/2 knots, also occurred.

The visual inspection of the senor plots also revealed the likely cause for the variation in the general trend of the pump manifold pressure. Using Figures 3 and 4, note that the differential pressures recorded before the pump was started were significantly different. For Figure 3 the starting value is about 5 PSI and for Figure 4 the value is about 15 PSI, a significant difference. Based on this, the following sensor values were graphed on a 10 station interval (those stations with obvious problems were ignored and the next nearest good station was selected, see Figure 5).

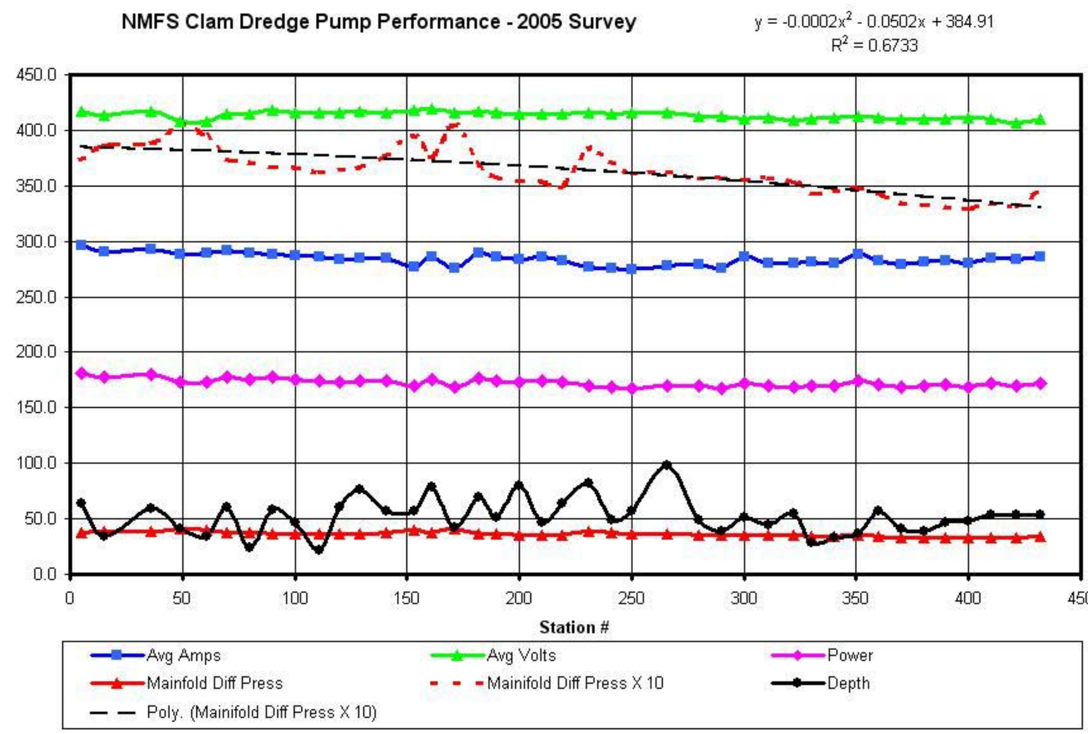
Manifold Differential Pressure Before Starting the Dredge Pump.
Manifold Differential Pressure After Starting the Dredge Pump.
Difference Between the After and Before Starting Values (Pump Pressure Rise)



Appendix A1. Figure 5

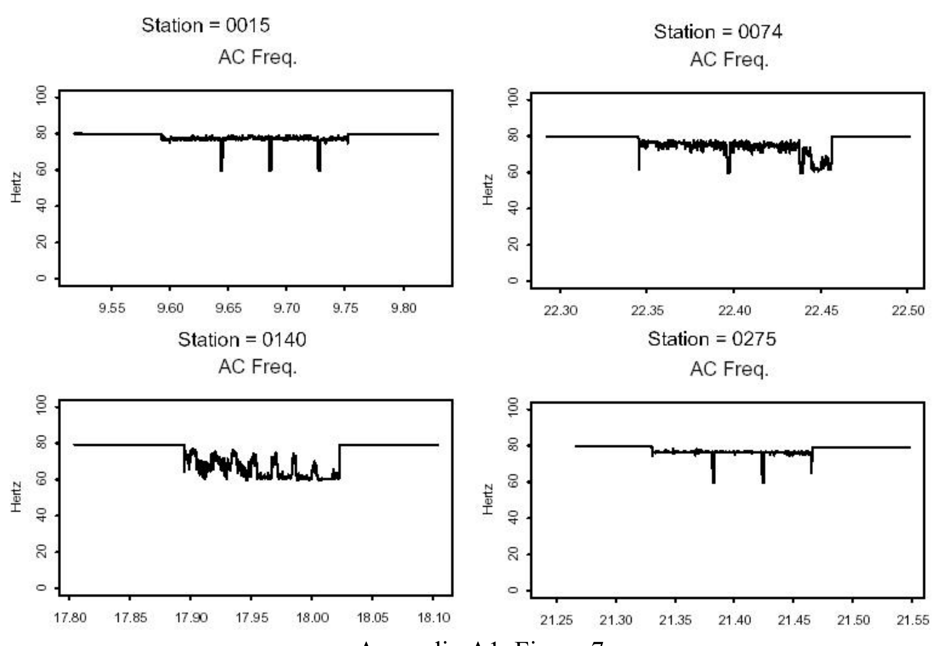
From Figure 5 the pressure rise in the dredge pump manifold is fairly steady with a consistent downward trend that is typical of a centrifugal pump becoming worn from sand/silt ingestion over the survey. The spikes at stations 49, 153, 171, and 231 are likely due to minor clogging of the manifold nozzles as there is a corresponding drop in the amps draw from the pump. This is shown in Figure 6 which also graphs the amps draw, AC voltage, pump power, and tow depth.

Based on this the conclusion is the general performance of the clam dredge pump was fairly uniform over the entire survey and the previous noted variations in the manifold differential pressure are likely due to a calibration drift in the SSP sensor. Interestingly this drift starts to occur at about station 217, which is when the problem with the main clam package breaker was noticed and repaired. How the breaker problem could cause a sensor drift is not known as the SSP package uses an internal DC battery completely separate from the AC system containing the clam package breaker.



Appendix A1. Figure 6

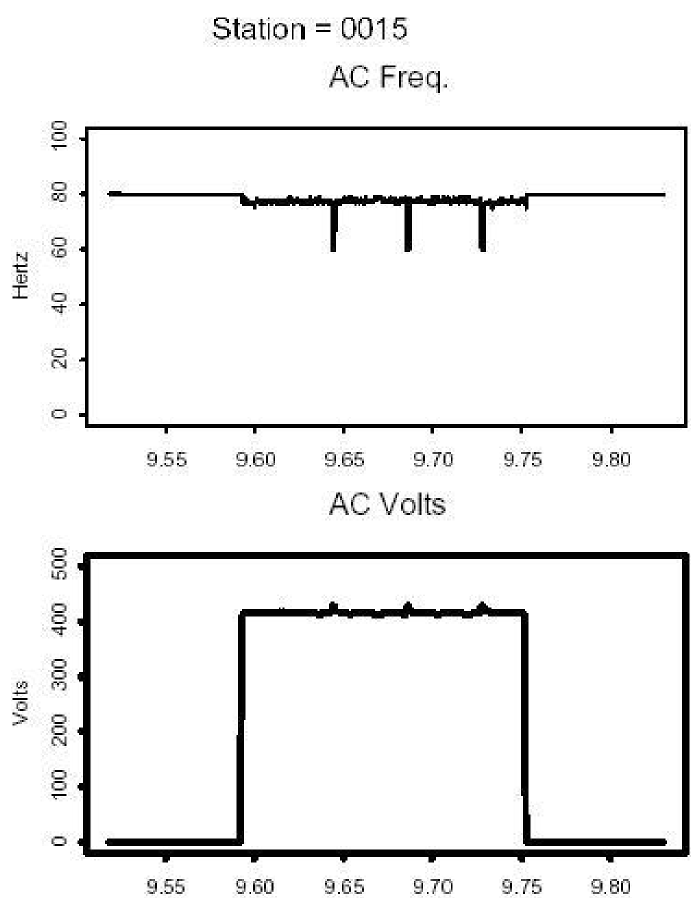
The variation that occurred in the recorded frequency remains a mystery even after the review of the sensor plots and conversations with the ship's engineer. The value should be very steady and between 59 and 61 hertz which is the output from the ship's generator. Figure 7 shows the typical variation in frequency that occurred during the survey.



Appendix A1. Figure 7

The frequency was fairly steady at the start of the survey, and then started a gradual degradation during the last half of the survey's first leg. This degradation in recorded values was not consistent with wide variations between tows. Shortly after the start of the 3rd leg at about station 271, the problem appears to have cleared itself and the frequency was very steady for the remainder of the survey. While there is no direct explanation for this change, it does not to appear to have had any effect on the performance of the clam dredge. The hertz values seen by the pump during the survey are likely have to been the steady standard 59 to 61 hertz values shown on the ship's main switchboard. The changes are likely a problem is in the calibration of the sensor for the frequency not being at 60 hertz and some type of sensor interference for the variations experienced.

The last observation from the sensor plots and data is the occurrence of a rhythmic spike in the AC frequency and volts sensor plots. This occurred throughout the entire survey and a typical example is shown in Figure 8. As with the frequency variation discussed above this appears to be a sensor problem. First it is impossible for a generator to vary its speed as would be shown in the frequency plot. In addition there is no corresponding spikes in the amps or pump pressure that should occur if the volts were truly spiking.



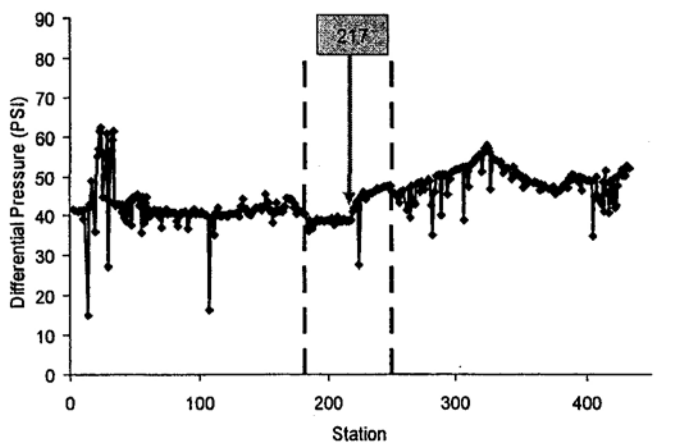
Appendix A1. Figure 8

APPENDIX A2. Clam survey tows with poor performance. This appendix describes a proposal for using sensor data to identify NEFSC clam survey tows with poor performance. Current criteria for identifying tows with poor performance are based on data recorded on deck by the watch chief after each tow. In particular, the survey variable "HAUL" can be used to describe problems with tow duration, and the survey variable "GEARCOND" describes the condition of the dredge after a tow. The proposal described below uses sensor data collected on the dredge and on board the ship. Sensor based criteria could not be applied to data for surveys before 1997 because sensors were not used on the ship. The proposal is for discussion and review and does not represent a recommendation by the Invertebrate Subcommittee.

NMFS R/V Delaware II Clam Survey Dredge Development of Good/Bad Tow Selection Criteria[8]

Introduction

From a review of the Survey Sensor Pack (SSP) data from the NMFS 2005 Surf Clam and Ocean Quahog survey, the survey dredge's basic parameters showed a significant variation in the over the course of the survey's three cruise legs. This was primarily both a general upward trend in the manifold's differential pressure and sporadic pressure spikes over the survey (see figure 1). In addition there were occasionally tows that experienced significant variations in the dredge's fore and aft towing angle.



Appendix A2. Figure 1 - Average Survey Dredge Manifold Pressure vs. Survey Station Number

From a previous report (Appendix A2), these parameter variations were explored and their potential effect on the survey dredge's sampling efficiency reviewed. The general upward manifold pressure trend was attributed to a sensor calibration drift, not a true change in manifold pressure, and thus had no likely affect on the dredge's efficiency. The survey tows with manifold pressure spikes and the variations in the dredge's towing angle however were likely causing a significant change in the dredge's sampling efficiency, with the most extreme cases probably preventing the dredge from fishing at all.

Since these survey tows with the manifold pressure spikes and the towing angle variations have a significantly different, and unknown, sampling efficiency than the survey's overall efficiency determined by the depletion studies and other methods,

[8] Prepared by John Womack, Wallace and Associates, Inc.

inclusion of them in the survey will likely create a bias in the final survey results. Because of this, those survey tows that have some of their key parameters that differ significantly from the normal values should be excluded from the survey as “bad” tows.

Key Dredge Performance Parameters

The following general parameters are recorded from the SSP and onboard ship sensors for each of the NMFS clam dredge’s survey tows.

Tilt-X - Side to side dredge angle.
Tilt-Y - Fore and aft dredge towing angle.
SSP Ambient Temperature - Sea water temperature at the dredge.
SSP Ambient Pressure - Ambient sea water pressure at the dredge (depth).
Differential Pressure - Dredge’s water manifold deferential pressure.
AC Amps - Dredge pump’s amperage draw.
AC Volts - Dredge pump’s voltage.
AC Freq - Dredge pump’s frequency.
Vessel Speed - Speed of the DEII

Of these parameters, the two key ones for the dredge’s sampling efficiency are;

Tilt-Y - Fore and aft dredge towing angle.
Differential Pressure - Dredge’s water manifold differential pressure.

Both of these are the parameters that are directly associated with how the dredge fishes. The Tilt-Y parameter will indicate if the dredge’s knife is in sufficient contact with the sea bottom to be in a fishing position. The Differential Pressure indicates if sufficient water is being forced through the dredge’s manifold to adequately liquefy the sea bottom.

The AC Amps, AC Volts, and AC Freq are not key parameters as any changes in them will be reflected in the manifold Differential Pressure values. Similarly, Vessel Speed is also not a key parameter in determining a good or bad tow. In this case any vessel speed variations (and thus the survey dredge) are handled in the standardization of each tow to a set “standard” tow distance. SSP Ambient Temperature and Pressure are not key parameters, as they have no effect on overall dredge performance.

2005 NMFS Ocean Clam Survey Average Survey Dredge Tow Angle

Station #	Average Towing Angle - Degrees
20	2.56
29	2.14
39	2.39
50	2.71
59	2.53
69	2.03
78	1.94
90	2.52
103	2.22
114	2.47
124	2.52
134	2.89
143	2.23
152	2.24
159	2.29
162	2.28
173	2.47
262	2.21
270	2.13
280	2.11
291	1.72
303	2.29
313	2.24
322	2.32
335	2.54
Average	2.32
Average Deviation	0.19
Median	2.29

The Tilt-Y and Manifold Pressure parameters will each be handled separately, but with a similar method, in determining a good or bad survey tow. A bad tow would then occur when either parameter varies by a specified difference from their normal values.

Good/Bad Tow Tilt-Y Selection Criteria

The Tilt-Y parameter is a fixed fishing, not fishing (i.e. pass/fail) situation. From previous studies of the NMFS survey dredge the knife theoretically makes contact with the bottom at 4.4 degrees and is fully down at 0 degrees, referenced to the dredge side runners. For the selection criteria the pass/fail cutout was set at the mid point of 2.2 degrees when the knife is at its half fishing depth in the sea bottom.

The dredge however does not tow with the side runners level as the aft end of the dredge will settle into the trough created in the ocean bottom by the water manifold while the forward dredge end rides on the bottom surface. From the table above this angle is approximately 2.3 degrees. This angle needs to be added to the 2.2 degree pass/fail point above to adjust for the dredge towing angle from the SSP data, which gives an adjusted pass/fail point of 4.5 degrees.

To use this set point, the SSP data will be evaluated by first calculating the total time the dredge Tilt-Y towing angle is above the 4.5 degree set point versus the total time the dredge was on the bottom. The tow will be deemed a bad tow if this time equals or exceeds 20% of the total towing time. For the four quahog strata survey stations deemed as a bad tow, the resultant time values using the 4.5 degree set point are tabulated below. Based on these Tilt-Y criteria, Station 218 is considered to be a bad tow and should be removed from the survey.

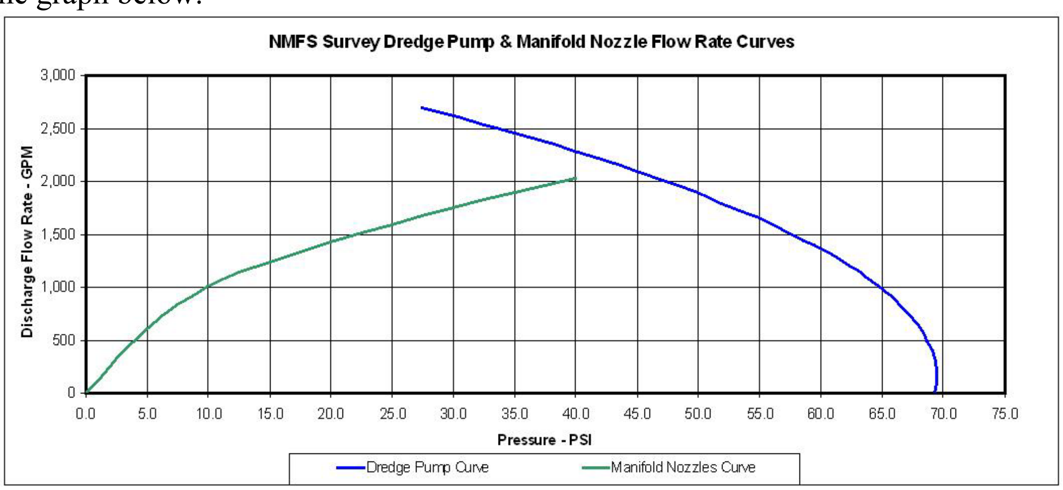
Good/Bad Dredge Towing Angle Time Summary - Seconds

Station #	218	225	262	282
Time Above 4.5 Degrees	111	120	64	78
Time Below 4.5 Degrees	337	545	485	469
Total Survey Tow Time	448	665	549	547
Precent Time Above 4.5 Degrees	24.8%	18.0%	11.7%	14.3%

Good/Bad Tow Manifold Pressure Selection Criteria

While the Tilt-Y parameter could be handled as a "Knife Edged" pass/fail selection criteria, this will not work for the Manifold Pressure parameter. First there are two different problem modes that can occur, a manifold pressure above or below the normal value. In addition a linear variation in the pressure doesn't correspond into a linear variation in the water flow through the nozzles.

When the manifold pressure drops below the normal value (37-39 PSI), this is indicating a blocked pump intake which is restricting water flow through the manifold nozzles. A manifold pressure increase on the hand is indicating a blockage in the manifold and/or nozzles. This blockage though is also restricting the water flow through the manifold nozzles. These variations in water flow versus manifold pressure are shown in the graph below.



Because of this non-linearity, the good/bad selection criteria for the Manifold Pressure parameter will need to take into account the magnitude of the difference from normal values. That is the farther the Manifold Pressure value at a given time is from the normal value, the larger the influence that time period will have on the tow being declared a bad tow. This will allow for several different bad tow scenarios to be designated. They are.

1) A small increase or decrease in pressure over the entire tow period.
2) A large increase or decrease in pressure over a short portion of a tow.
3) A combination of small or large pressure variations during a tow.

The selection criteria time period weighting factor (WF) for the Manifold Pressure parameter will be formatted using the following formulas.

WF = 2 x (MP-40)/40 when the Manifold Pressure is Higher than Normal or
WF = 1 when the Manifold Pressure is in the Normal range or
WF = 2 x ((35-MP)/35 x 0.83) when the Manifold Pressure is Lower than Normal
where MP = SSP measured Manifold Pressure in PSI.

The "0.83" is used to bring the potential below value range (0 to 35 PSI) into same magnitude as the potential above value range (40 to 69 PSI or 29 PSI range). An average normal Manifold Pressure value of 35-40 PSI was selected based on previous analysis of the 2005 SSP survey data in "R/V Delaware II Clam Dredge Pump Performance" which showed a range in manifold pressure from 39 PSI at the start to 36 PSI at the end of the survey. The doubling of the difference is used to account for the non-linearity by increasing the weighting factor disproportionably for Manifold Pressures farther from the normal value.

For the SSP data the weighting factor will be calculated for each data point which represents a one second time interval. The weighting factors for each second period will then be added to get a total weighted towing time. A bad tow will be declared when this weighted towing time exceeds the actual towing time that was within the normal range by more then 25%. See sample table below for examples.

Based on these Manifold Pressure criteria, Stations 225, 262, and 282 are considered to be a bad tow and should be removed from the survey.

Good/Bad Manifold Pressure Time Summary - Seconds

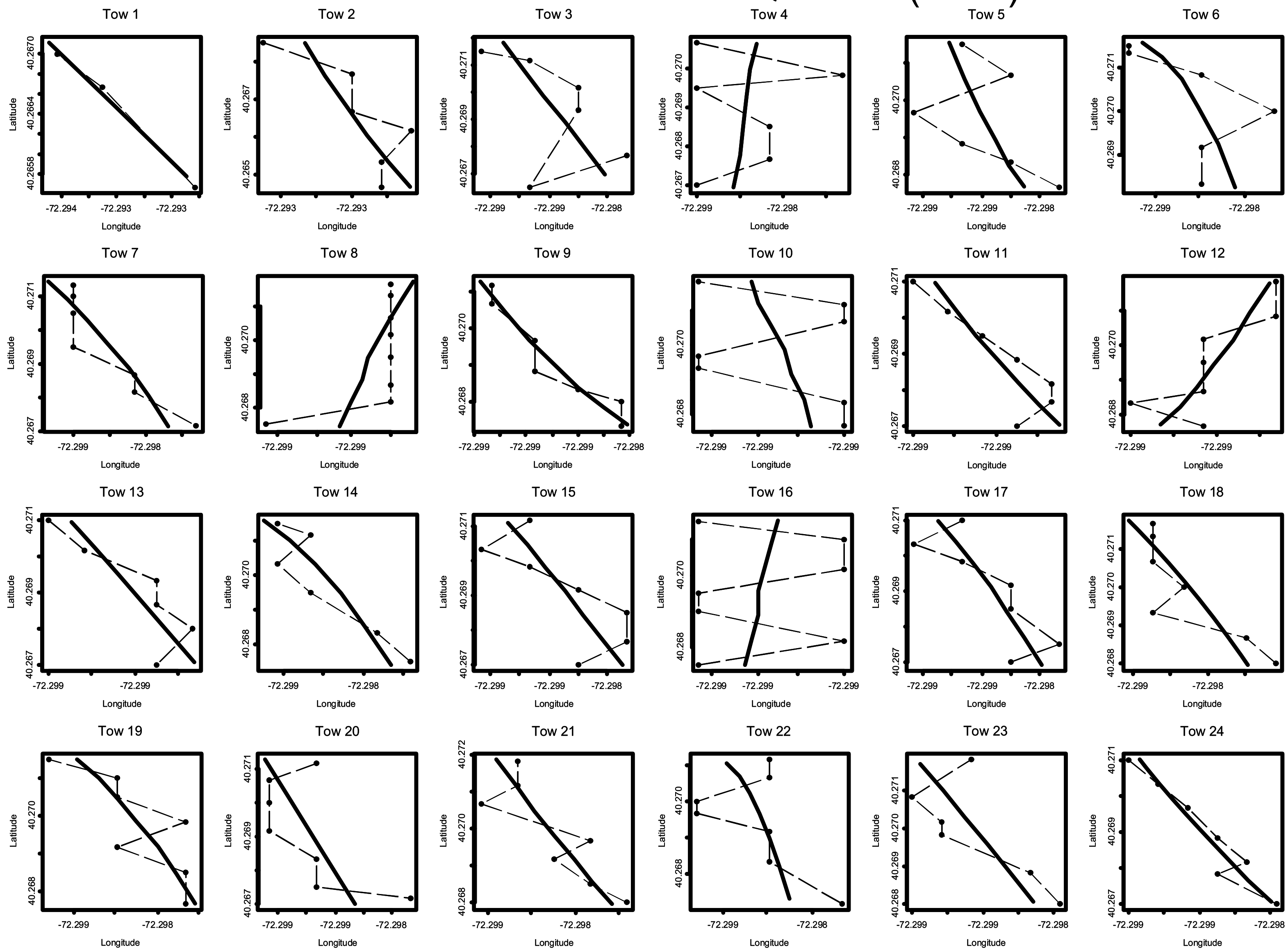
Station #	218	225	262	282
Weighted Time Above 40 PSI	0.00	0.13	0.00	0.00
Time in Normal Range	14	337	190	159
Weighted Time Below 35 PSI	0.335	446.83	156.62	398.33
Precent Time Outside Normal	2.4%	132.6%	82.4%	250.5%

NMFS Clam Survey Dredge - Manifold Pressure Good/Bad Tow Selection Criteria Examples

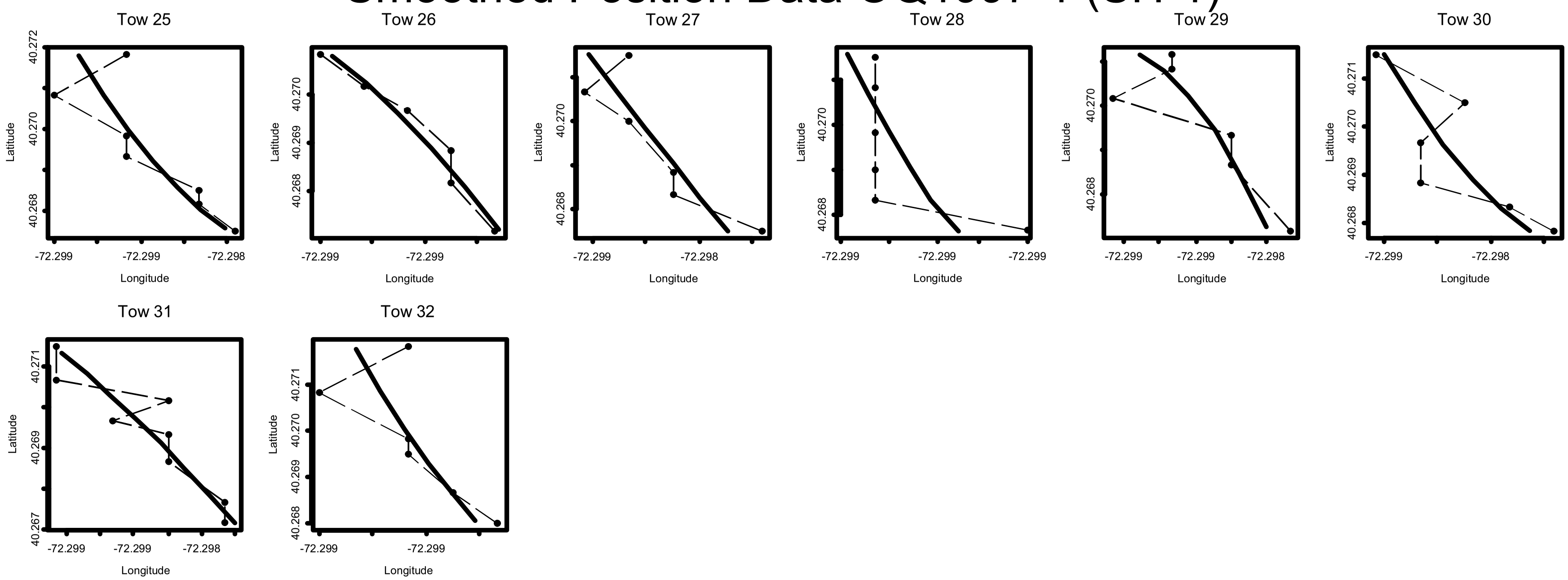
	Good Survey Tow				Bad Tow - Pressure Slightly Abv Normal				Bad Tow - Pressure Slightly Abv Normal				Bad Tow - Pressure Moderatly Abv Normal				Bad Survey Tow - Exterme Pressure Spikes			
Time	Manifold Pressure PSI	Over Range Weighting Factor	In Normal Weighting Factor	Under Range Weighting Factor	Manifold Pressure PSI	Over Range Weighting Factor	In Normal Weighting Factor	Under Range Weighting Factor	Manifold Pressure PSI	Over Range Weighting Factor	In Normal Weighting Factor	Under Range Weighting Factor	Manifold Pressure PSI	Over Range Weighting Factor	In Normal Weighting Factor	Under Range Weighting Factor	Manifold Pressure PSI	Over Range Weighting Factor	In Normal Weighting Factor	Under Range Weighting Factor
1	38	0.00	1.00	0.00	41	0.05	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
2	38	0.00	1.00	0.00	41	0.05	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
3	38	0.00	1.00	0.00	41	0.05	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
4	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	62	1.10	0.00	0.00
5	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	62	1.10	0.00	0.00
6	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	62	1.10	0.00	0.00
7	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	62	1.10	0.00	0.00
8	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	62	1.10	0.00	0.00
9	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	12	0.00	0.00	1.09
10	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	12	0.00	0.00	1.09
11	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	12	0.00	0.00	1.09
12	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	12	0.00	0.00	1.09
13	40	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	12	0.00	0.00	1.09
14	40	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	12	0.00	0.00	1.09
15	40	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	38	0.00	1.00	0.00
16	40	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	38	0.00	1.00	0.00
17	40	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	38	0.00	1.00	0.00
18	40	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	38	0.00	1.00	0.00
19	40	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	38	0.00	1.00	0.00
20	40	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	38	0.00	1.00	0.00
21	40	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	38	0.00	1.00	0.00
22	40	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	38	0.00	1.00	0.00
23	40	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	38	0.00	1.00	0.00
24	40	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	38	0.00	1.00	0.00
25	40	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	38	0.00	1.00	0.00
26	40	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	38	0.00	1.00	0.00
27	40	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	38	0.00	1.00	0.00
28	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	38	0.00	1.00	0.00
29	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	38	0.00	1.00	0.00
30	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	38	0.00	1.00	0.00
31	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	38	0.00	1.00	0.00
32	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	38	0.00	1.00	0.00
33	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	45	0.25	0.00	0.00	38	0.00	1.00	0.00
34	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
35	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
36	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
37	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
38	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
39	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
40	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
41	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
42	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
43	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
44	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
45	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
46	38	0.00	1.00	0.00	41	0.05	0.00	0.00	42	0.10	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
47	38	0.00	1.00	0.00	41	0.05	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
48	38	0.00	1.00	0.00	41	0.05	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
49	38	0.00	1.00	0.00	41	0.05	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
50	38	0.00	1.00	0.00	41	0.05	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
51	38	0.00	1.00	0.00	41	0.05	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
52	38	0.00	1.00	0.00	41	0.05	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
53	38	0.00	1.00	0.00	41	0.05	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
54	38	0.00	1.00	0.00	41	0.05	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
55	38	0.00	1.00	0.00	41	0.05	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
56	38	0.00	1.00	0.00	41	0.05	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
57	38	0.00	1.00	0.00	41	0.05	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
58	38	0.00	1.00	0.00	41	0.05	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
59	38	0.00	1.00	0.00	41	0.05	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
60	38	0.00	1.00	0.00	41	0.05	0.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00	38	0.00	1.00	0.00
60	WF Sums	0.0	60.0	0.0	WF Sums	3.0	0.0	0.0	WF Sums	4.3	17.0	0.0	WF Sums	7.5	30.0	0.0	WF Sums	5.5	49.0	6.5
	% Over+Under of All		0%		% Over+Under of All		100%		% Over+Under of All		25%		% Over+Under of All		25%		% Over+Under of All		25%	

APPENDIX A3. Original and smoothed position data for ocean quahog depletion experiments, during 1997-2005 by tow.

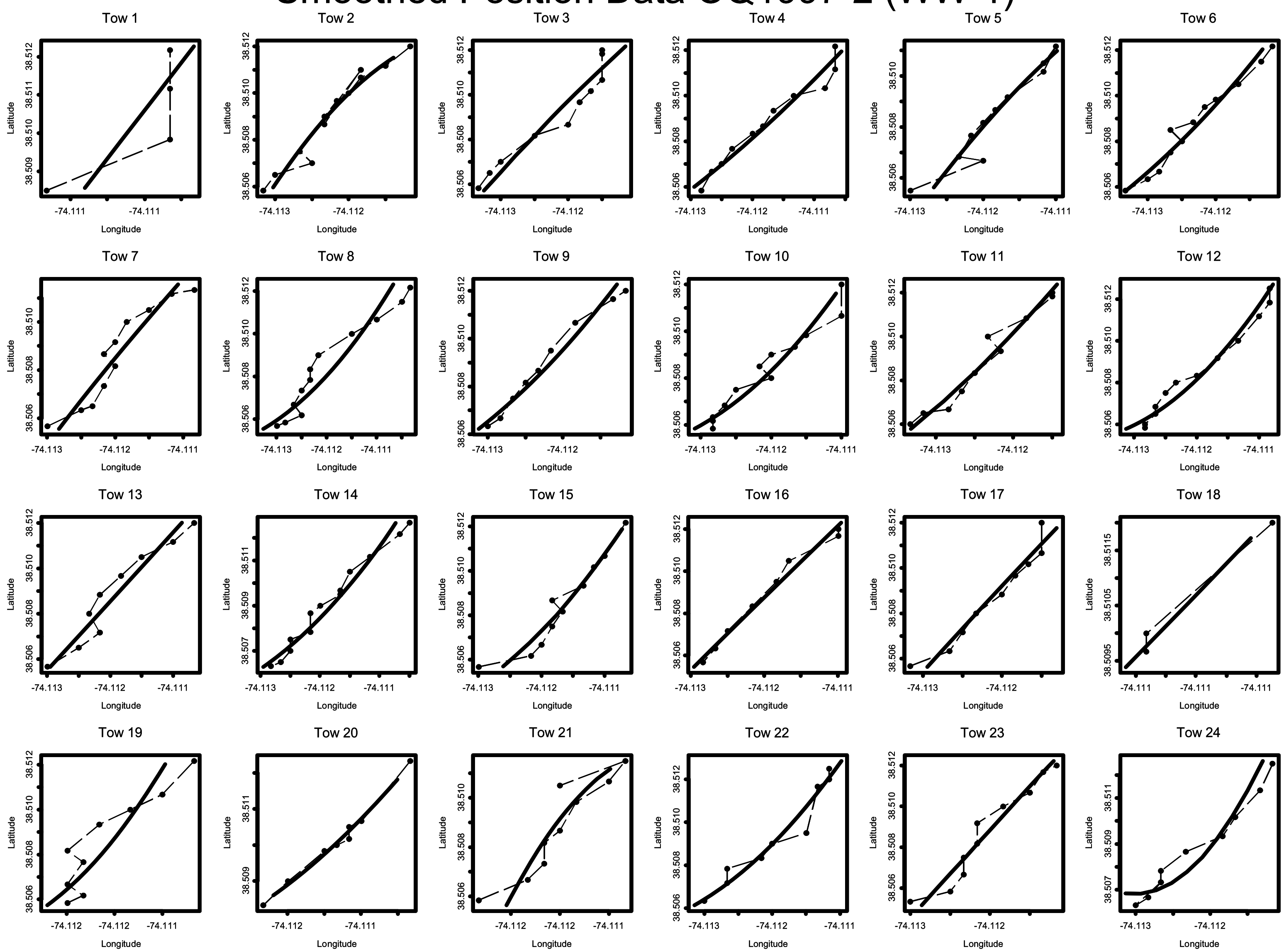
Smoothed Position Data OQ1997-1 (SH-1)



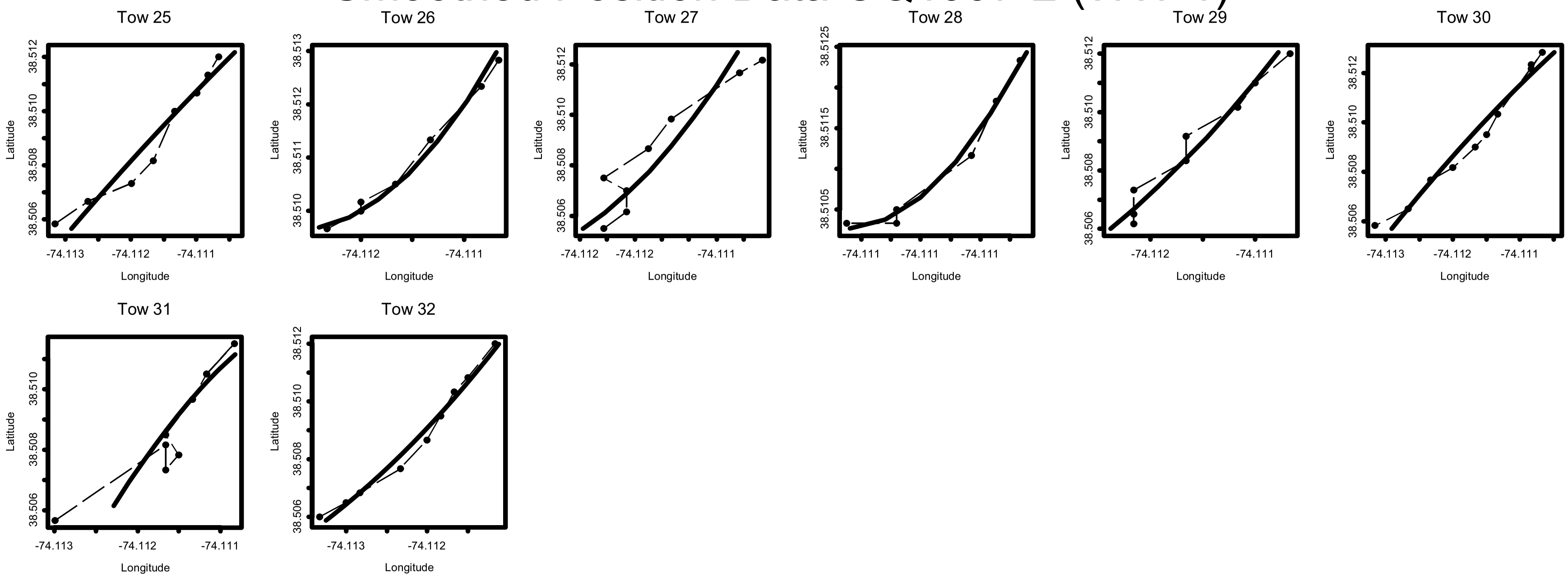
Smoothed Position Data OQ1997-1 (SH-1)



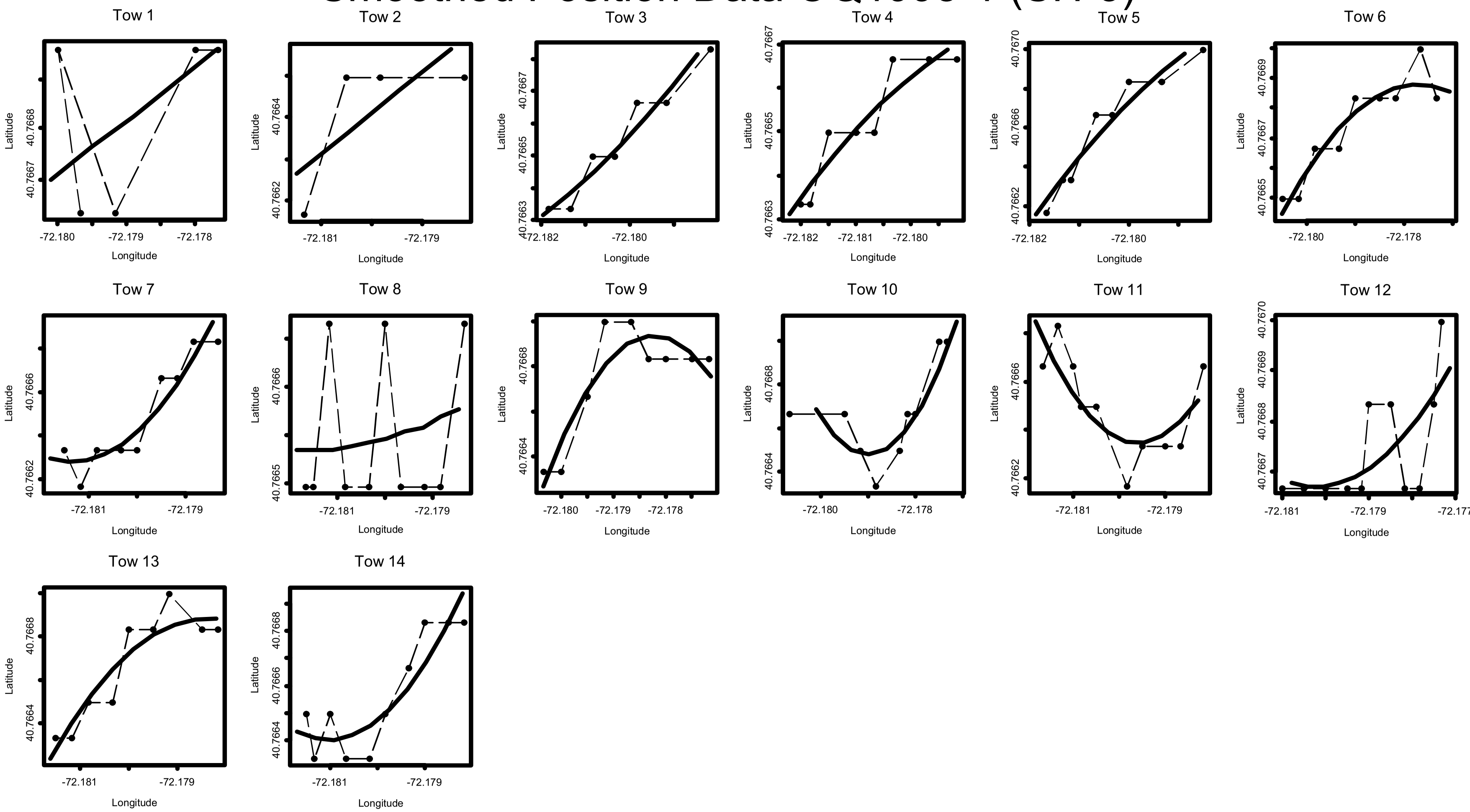
Smoothed Position Data OQ1997-2 (WW-1)



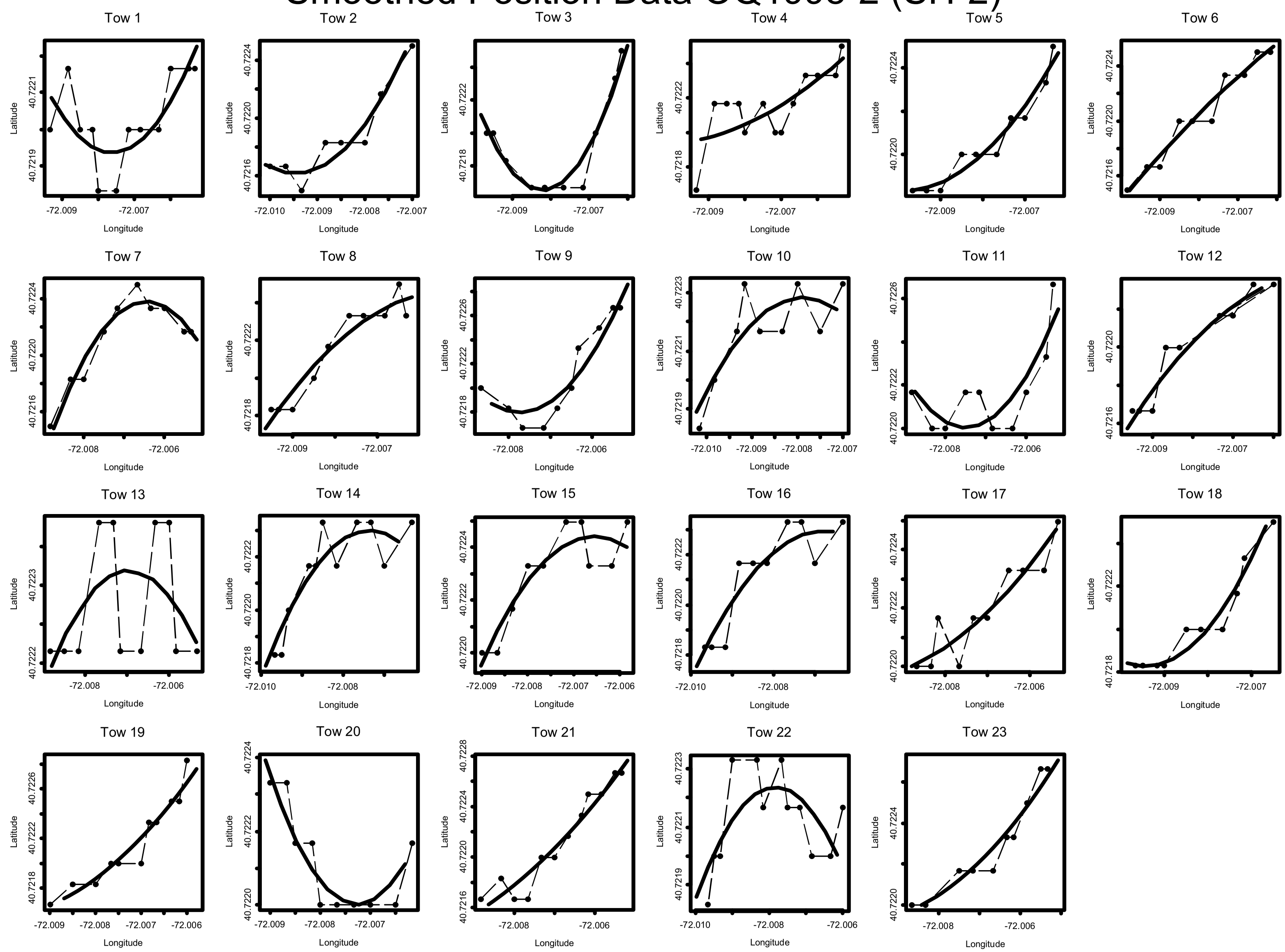
Smoothed Position Data OQ1997-2 (WW-1)



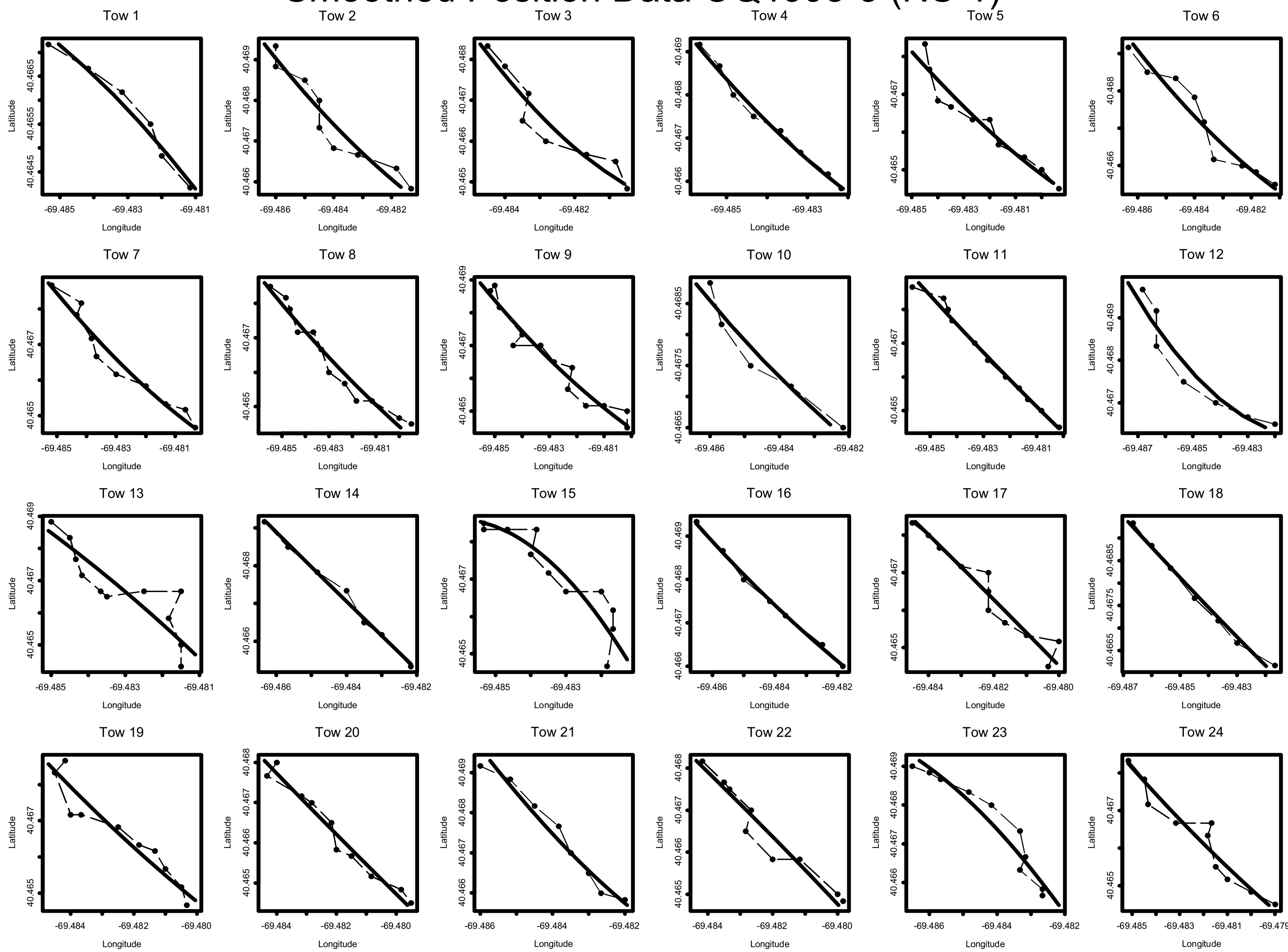
Smoothed Position Data OQ1998-1 (SH-3)



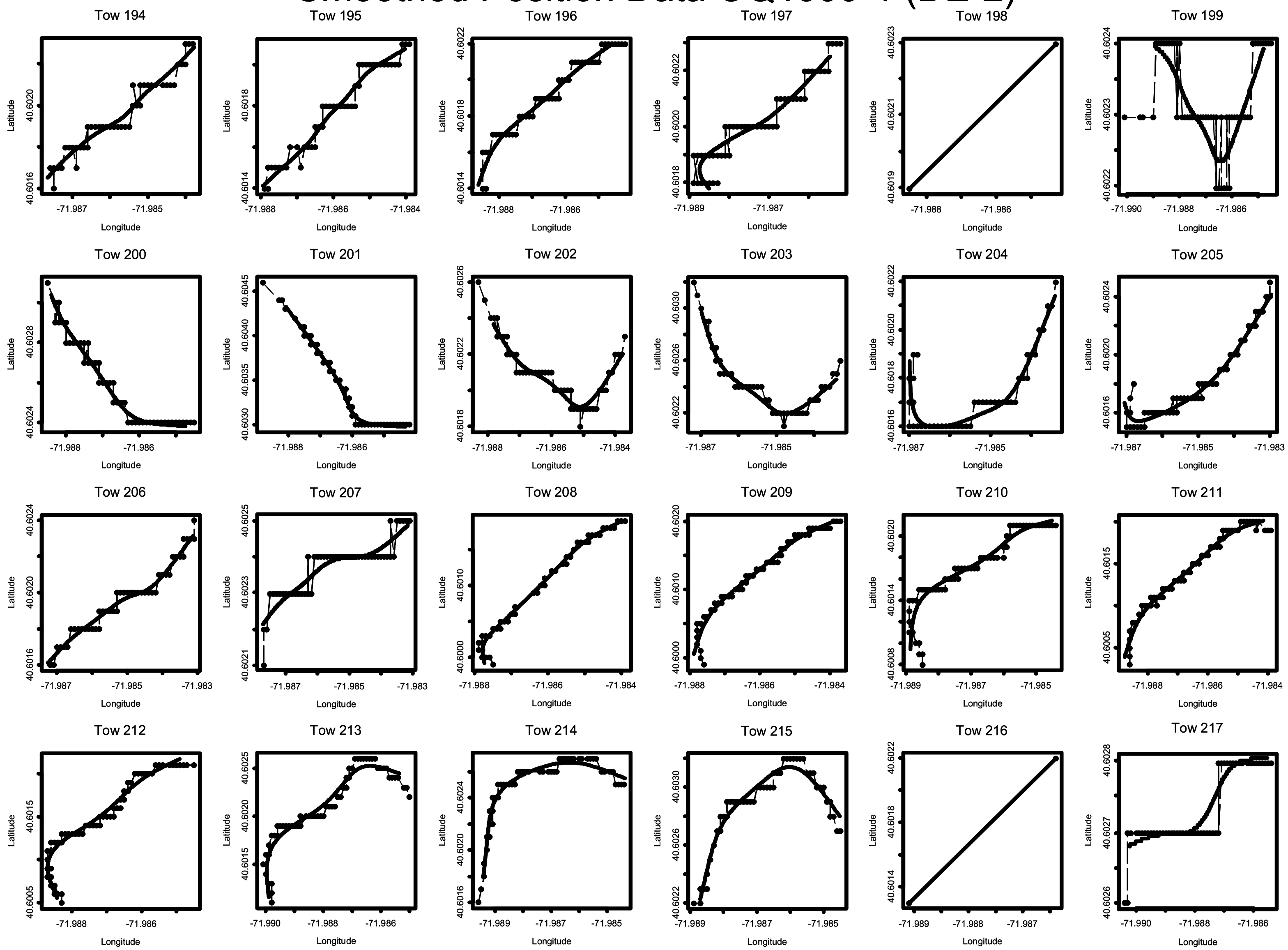
Smoothed Position Data OQ1998-2 (SH-2)



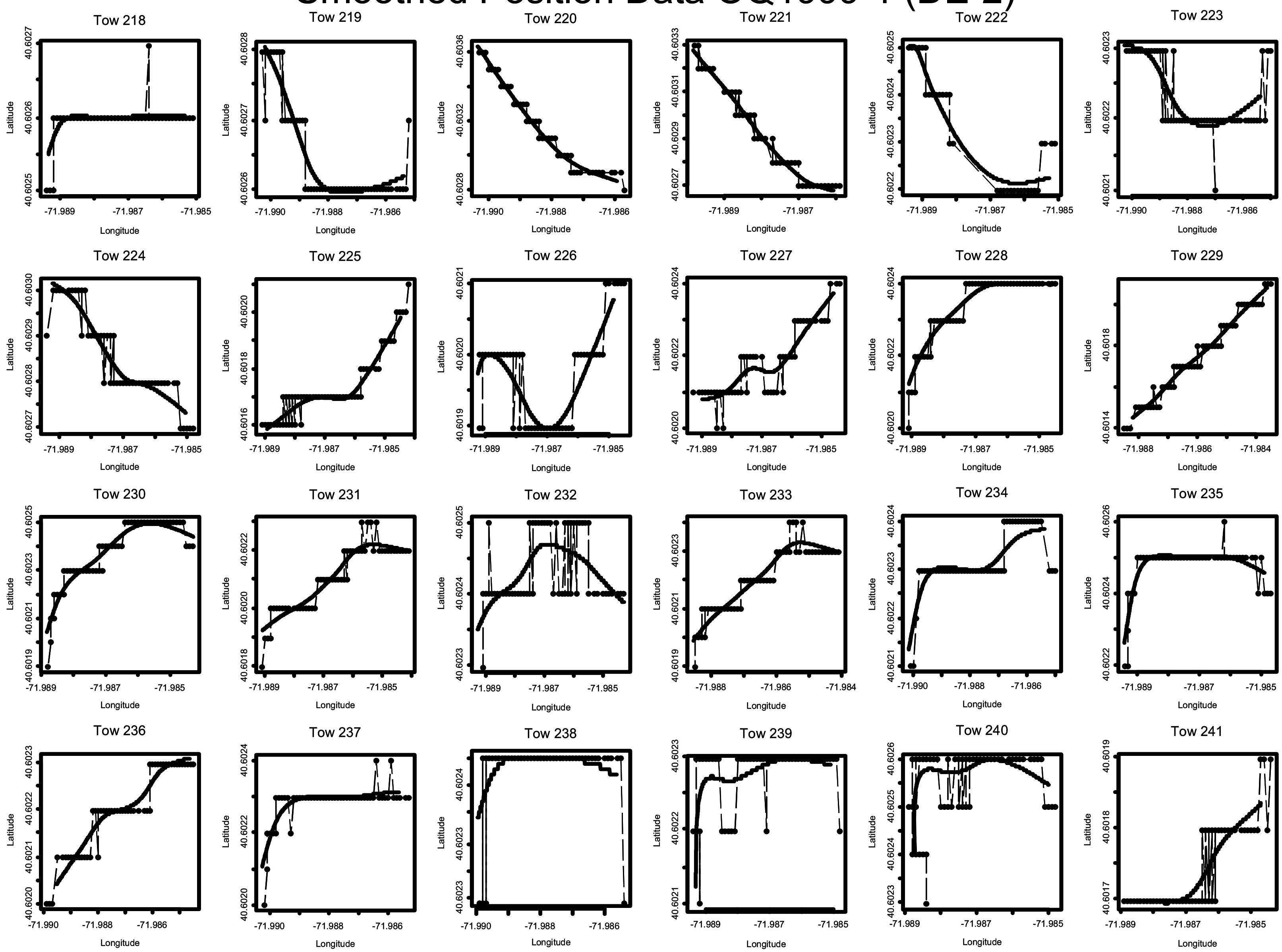
Smoothed Position Data OQ1998-3 (NS-1)



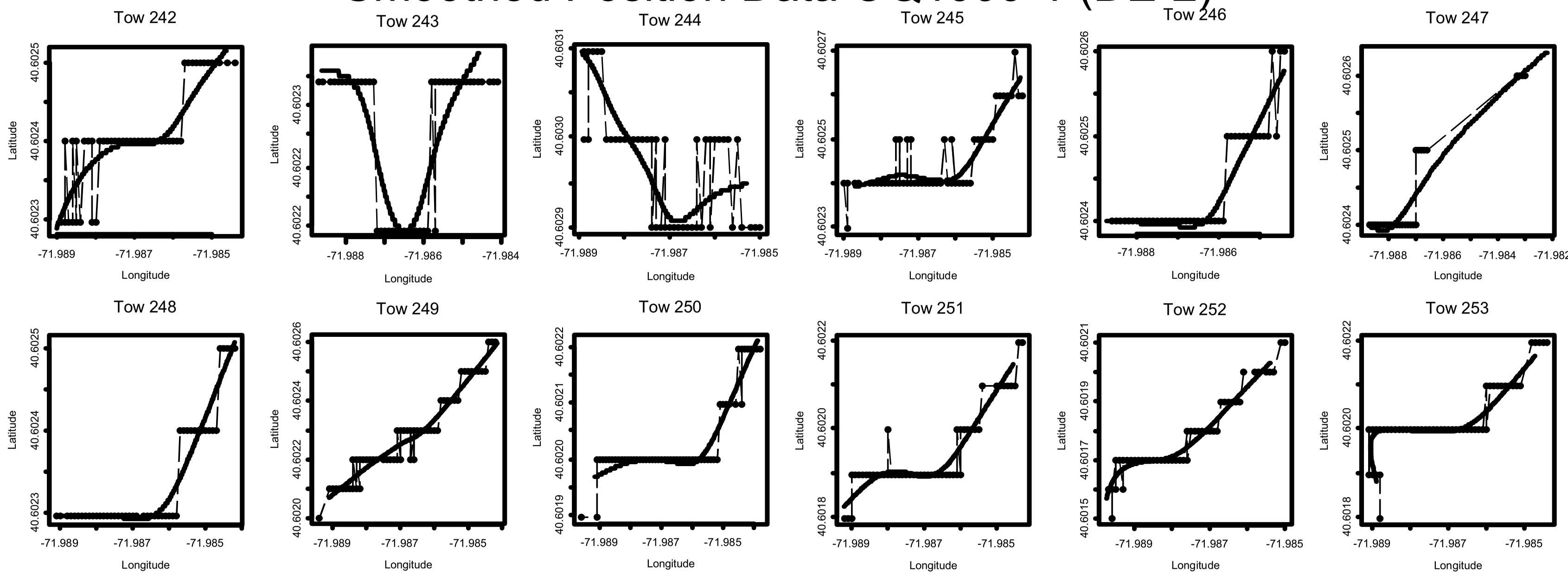
Smoothed Position Data OQ1999-1 (DE-2)



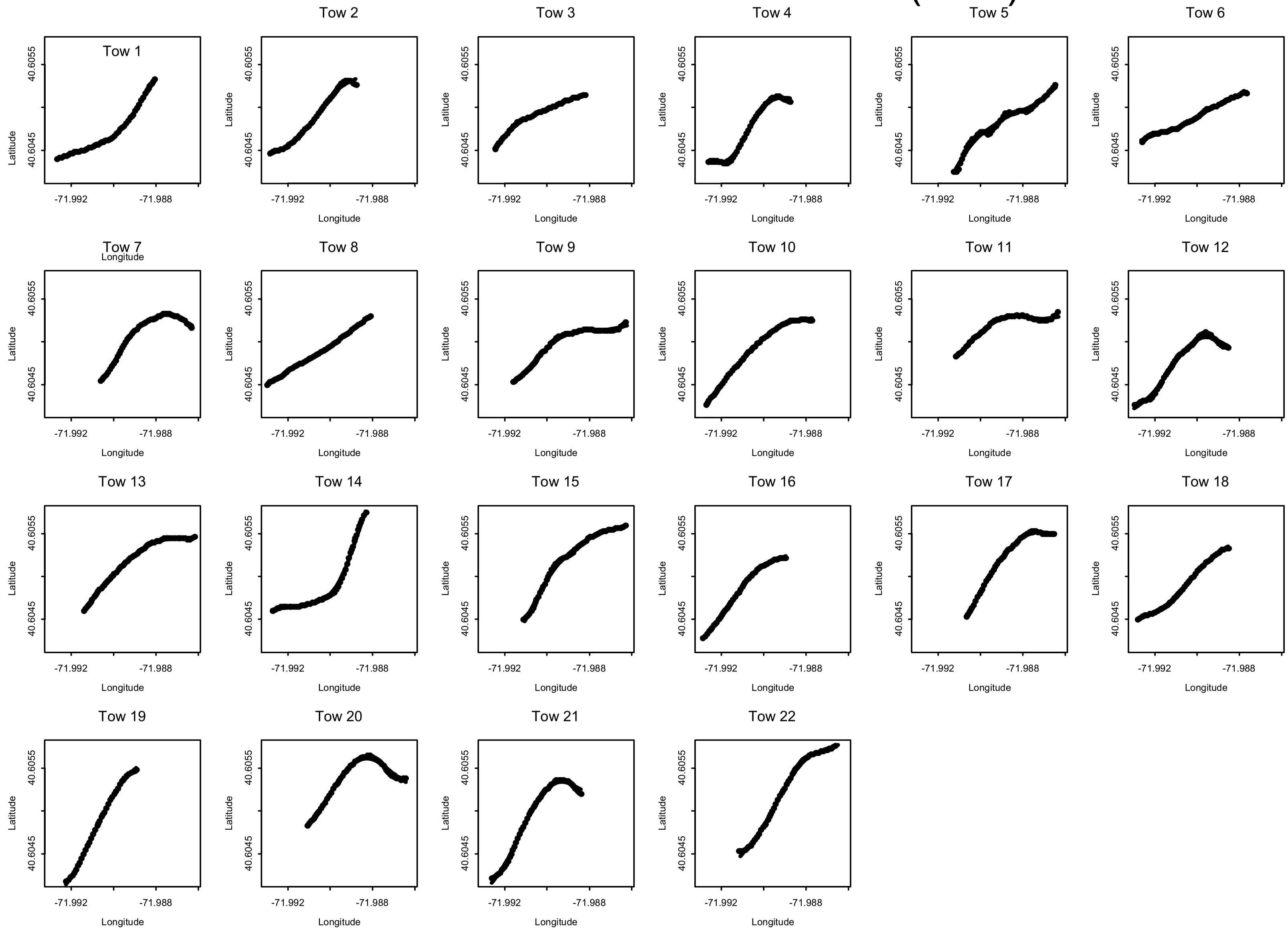
Smoothed Position Data OQ1999-1 (DE-2)



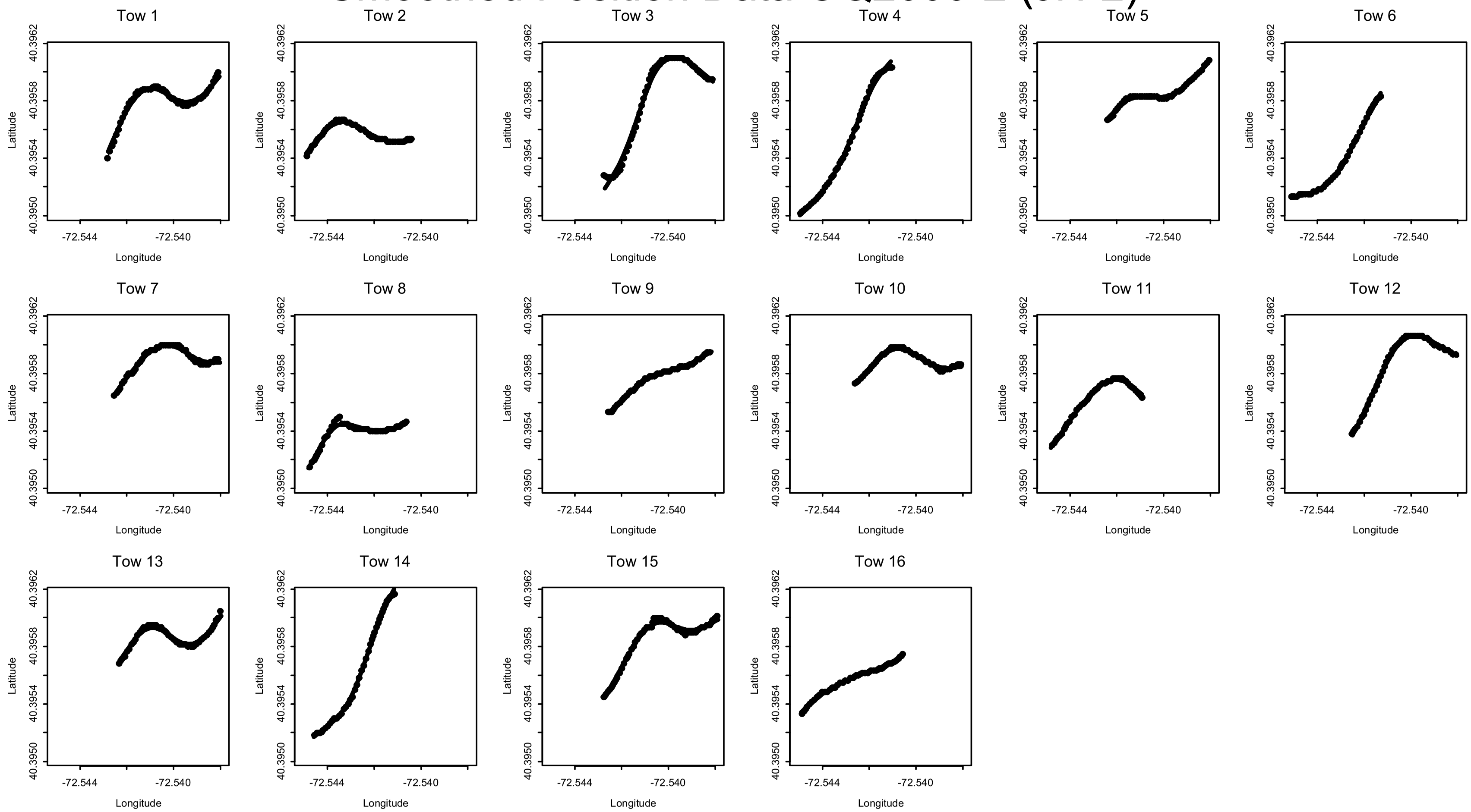
Smoothed Position Data OQ1999-1 (DE-2)



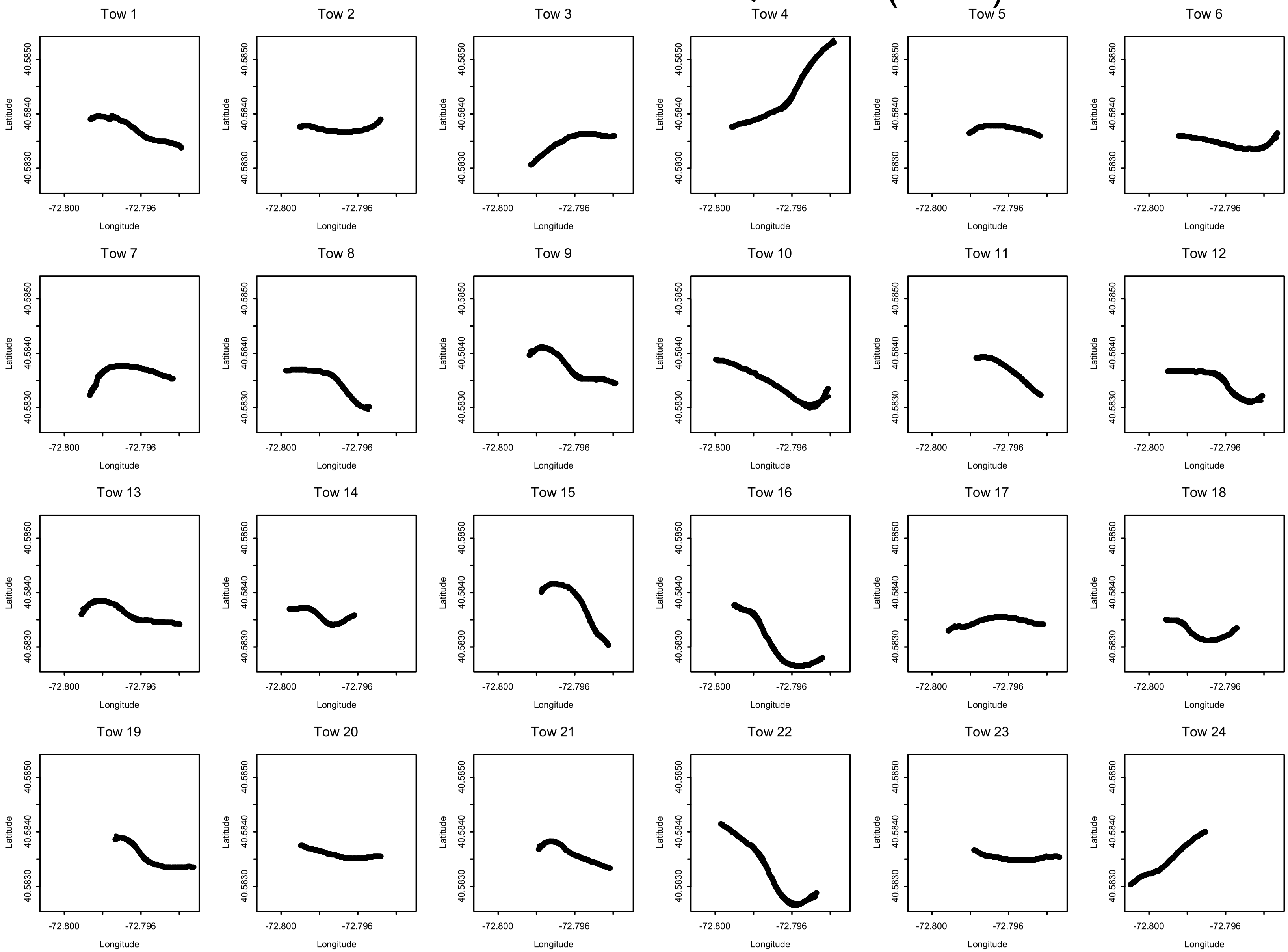
Smoothed Position Data OQ2000-1 (JN-1)



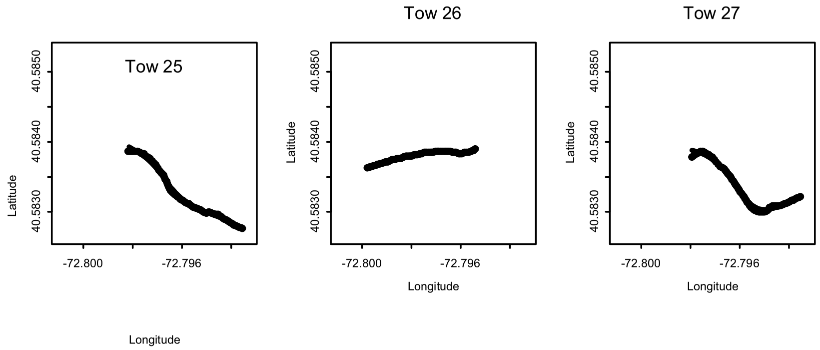
Smoothed Position Data OQ2000-2 (JN-2)



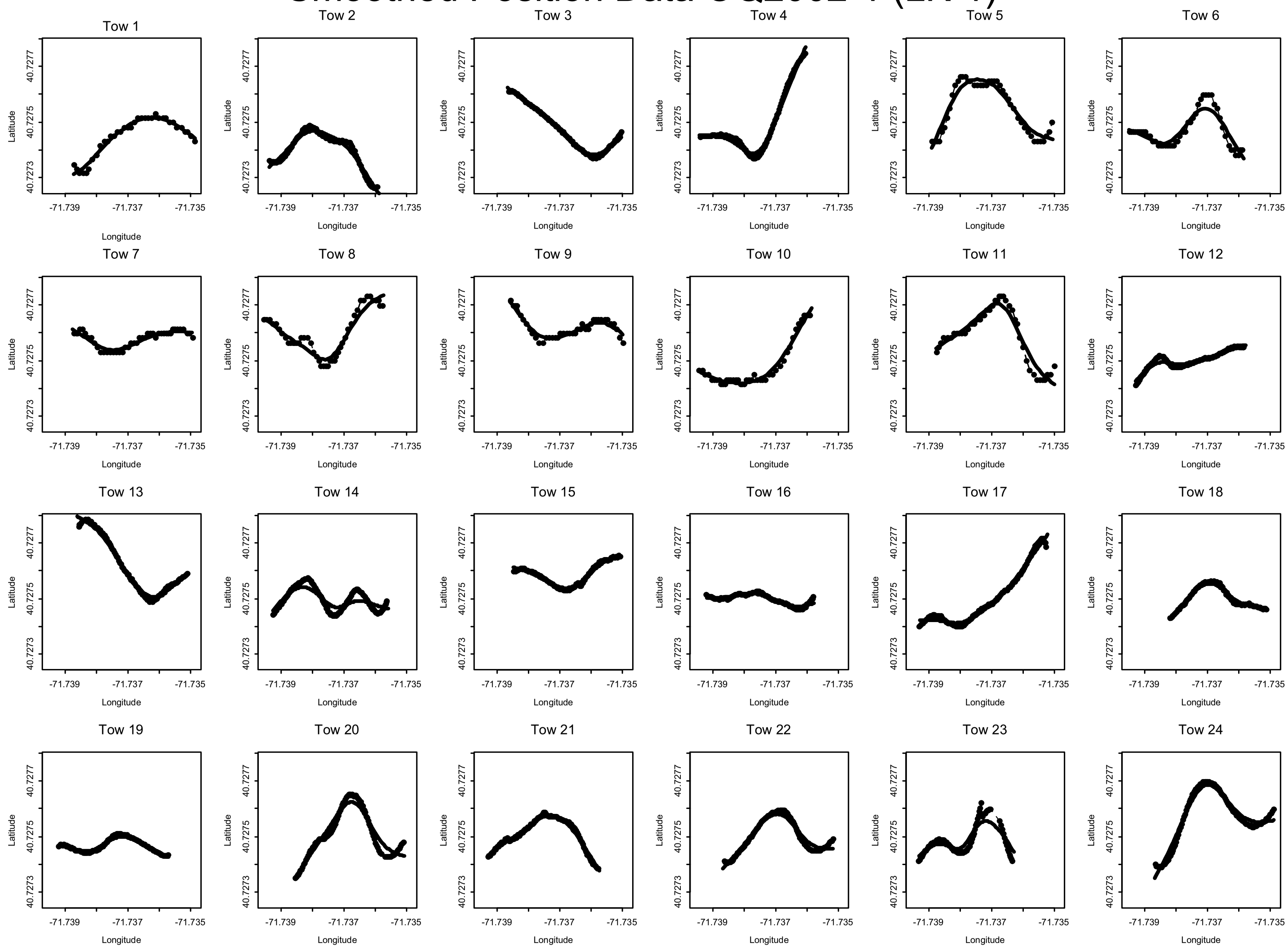
Smoothed Position Data OQ2000-3 (DM-1)



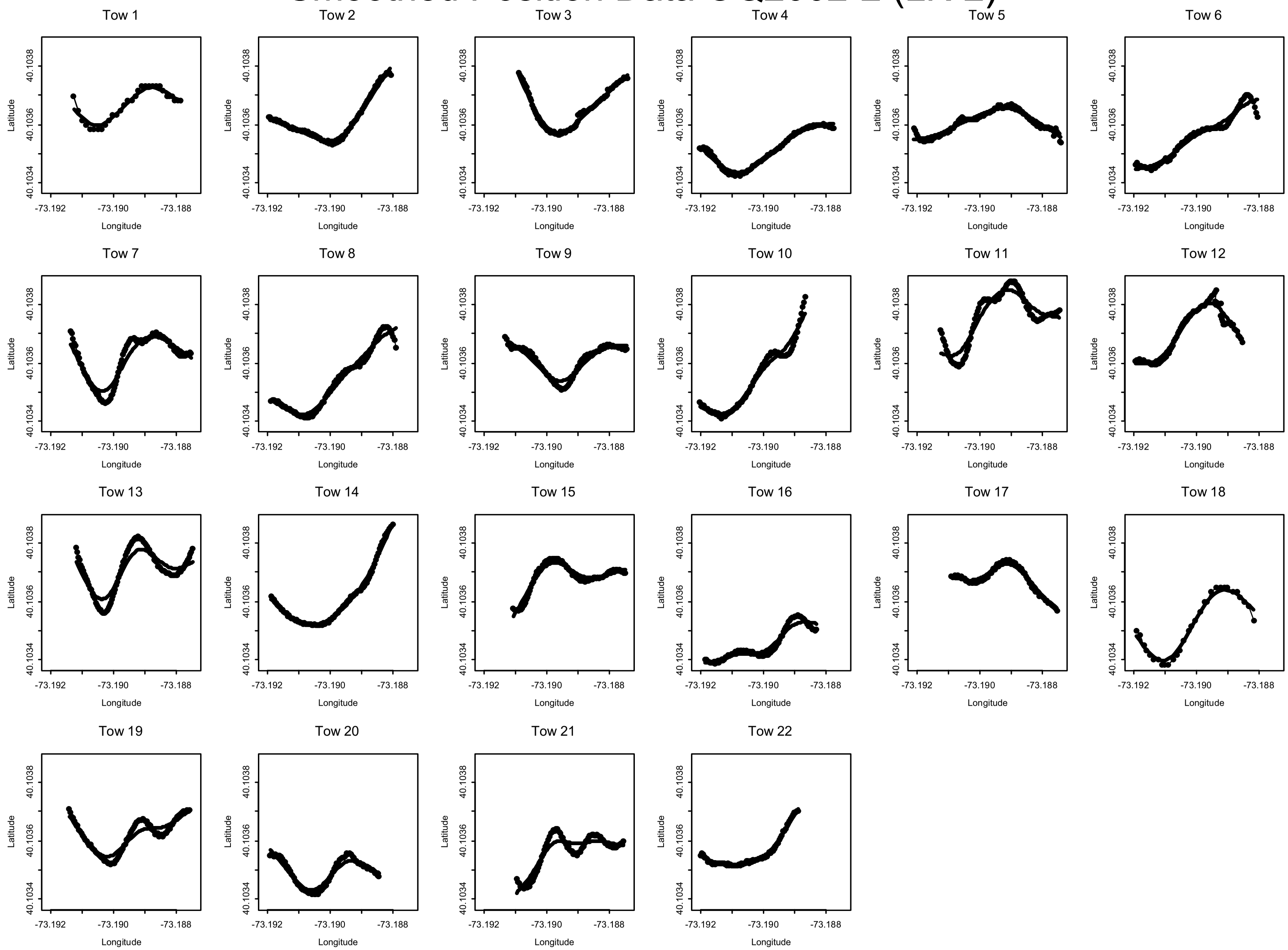
Smoothed Position Data OQ2000-3 (DM-1)



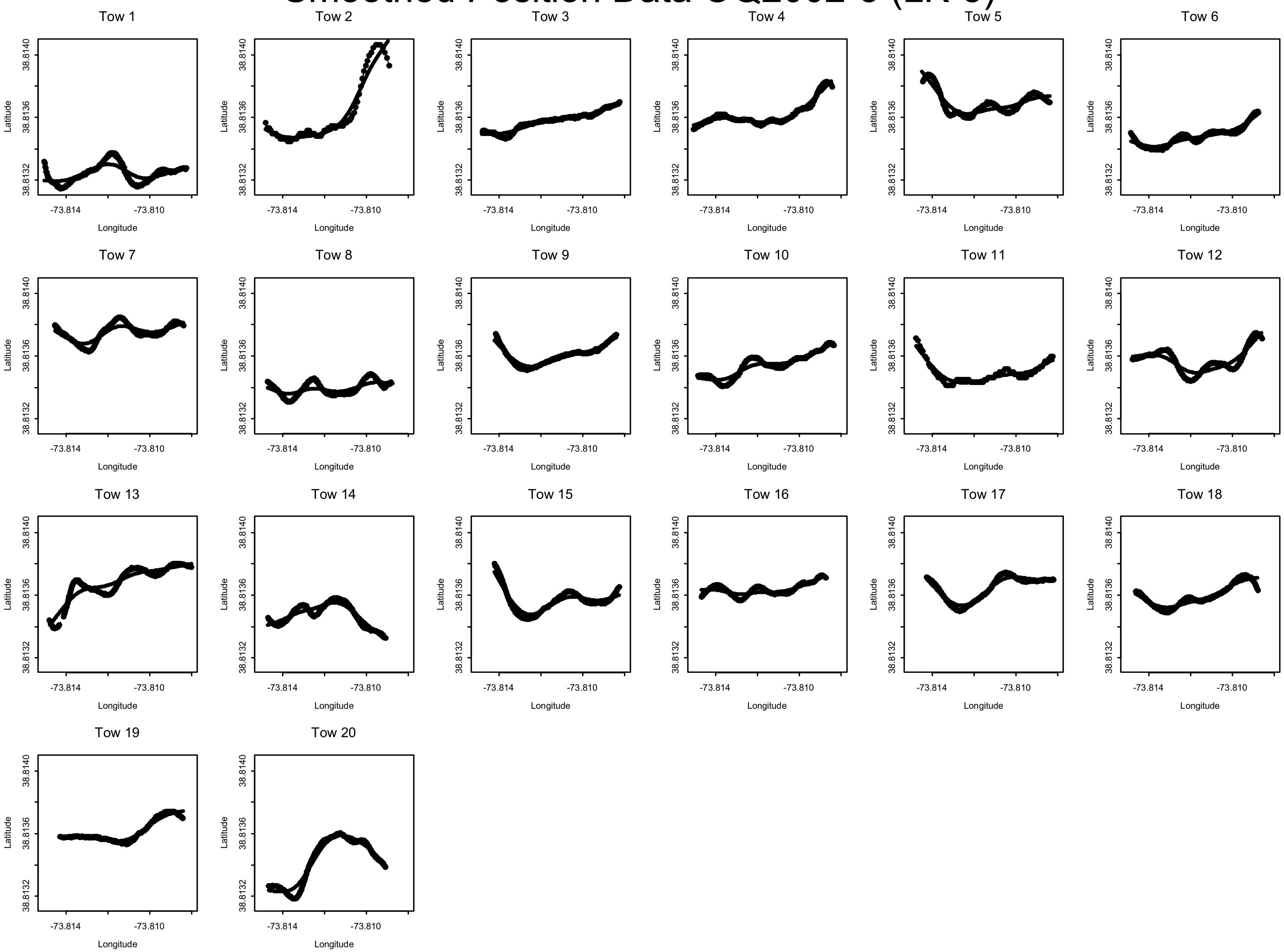
Smoothed Position Data OQ2002-1 (LK-1)



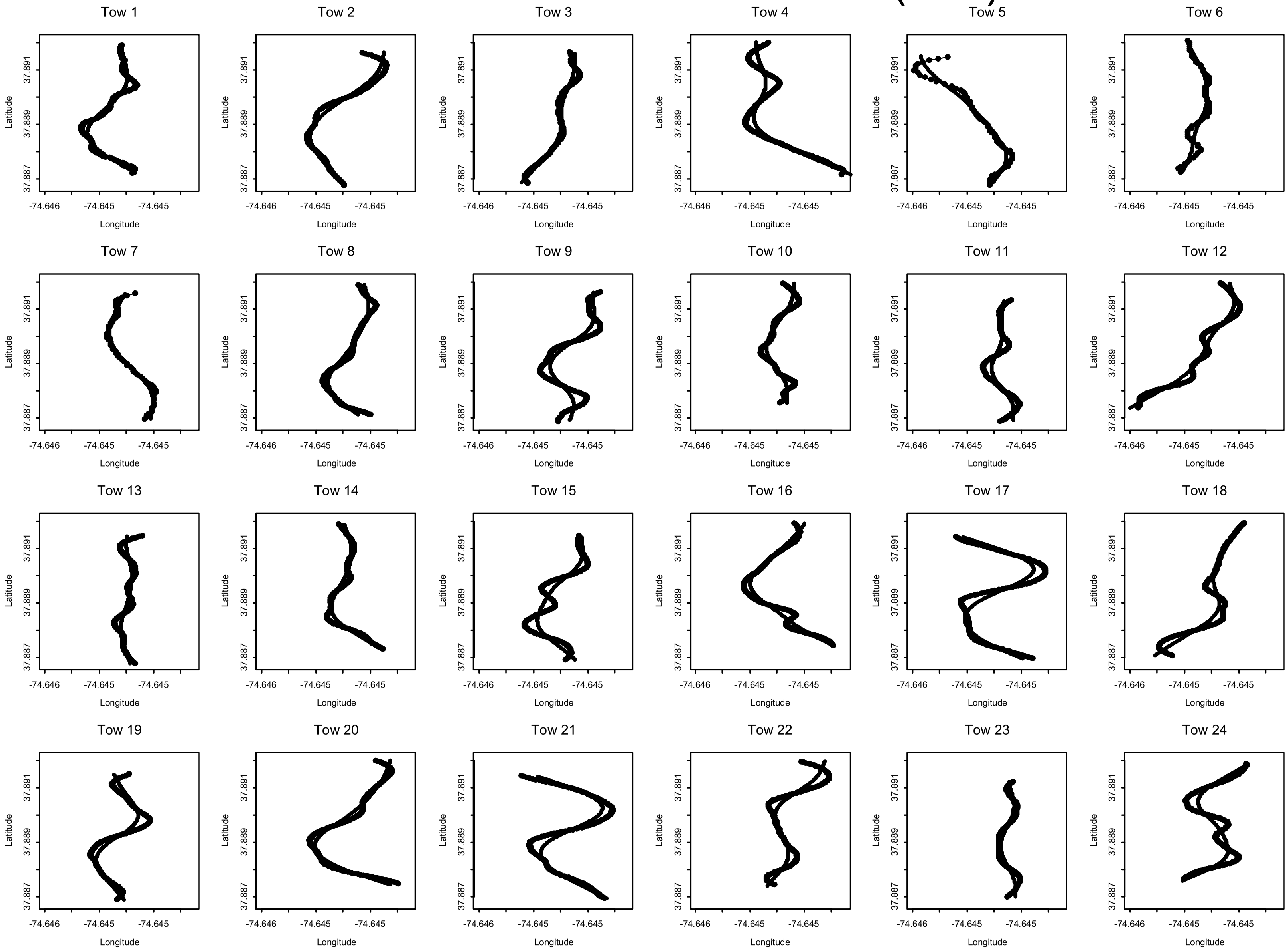
Smoothed Position Data OQ2002-2 (LK-2)



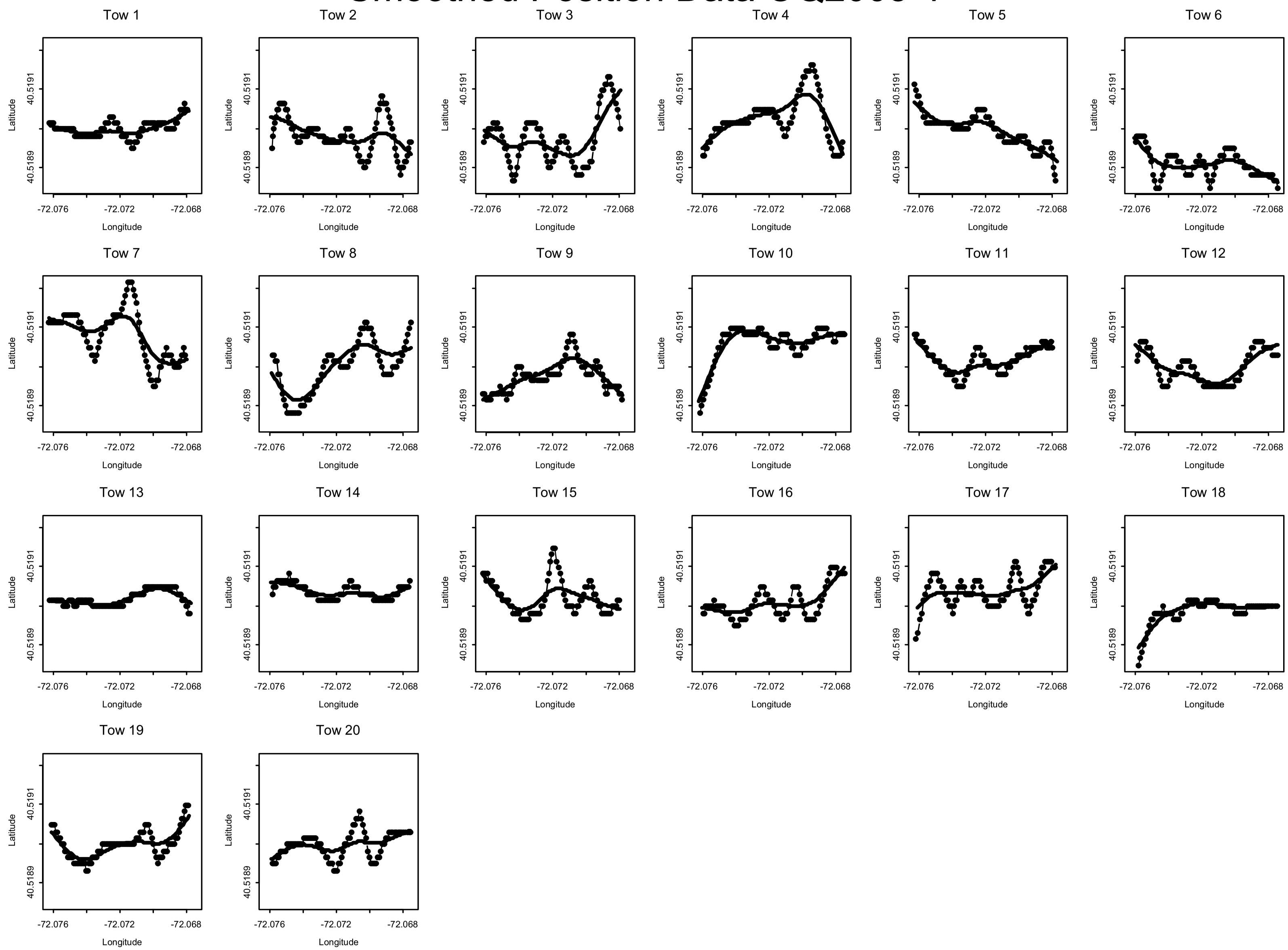
Smoothed Position Data OQ2002-3 (LK-3)



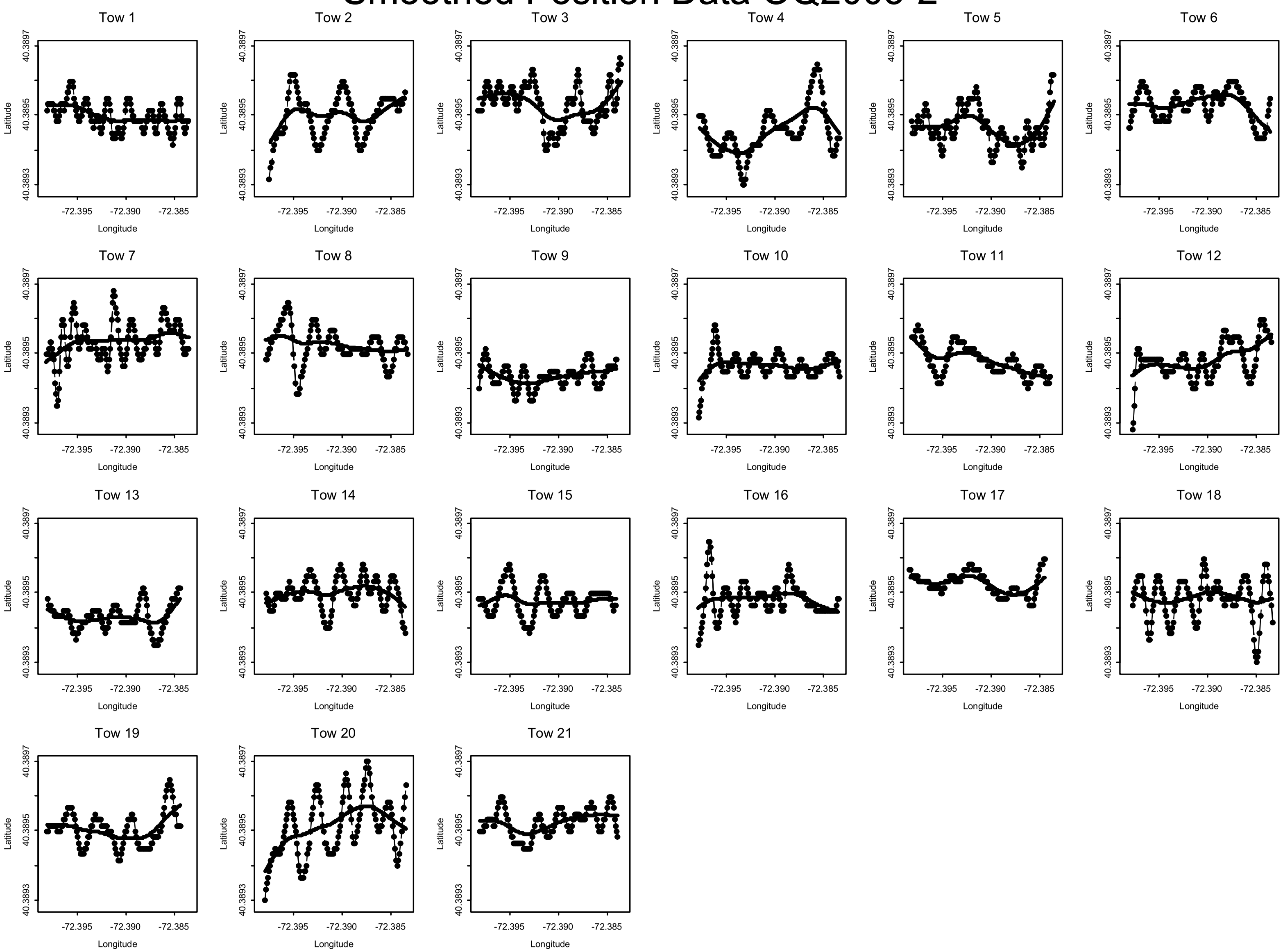
Smoothed Position Data OQ2002-4 (LK-4)



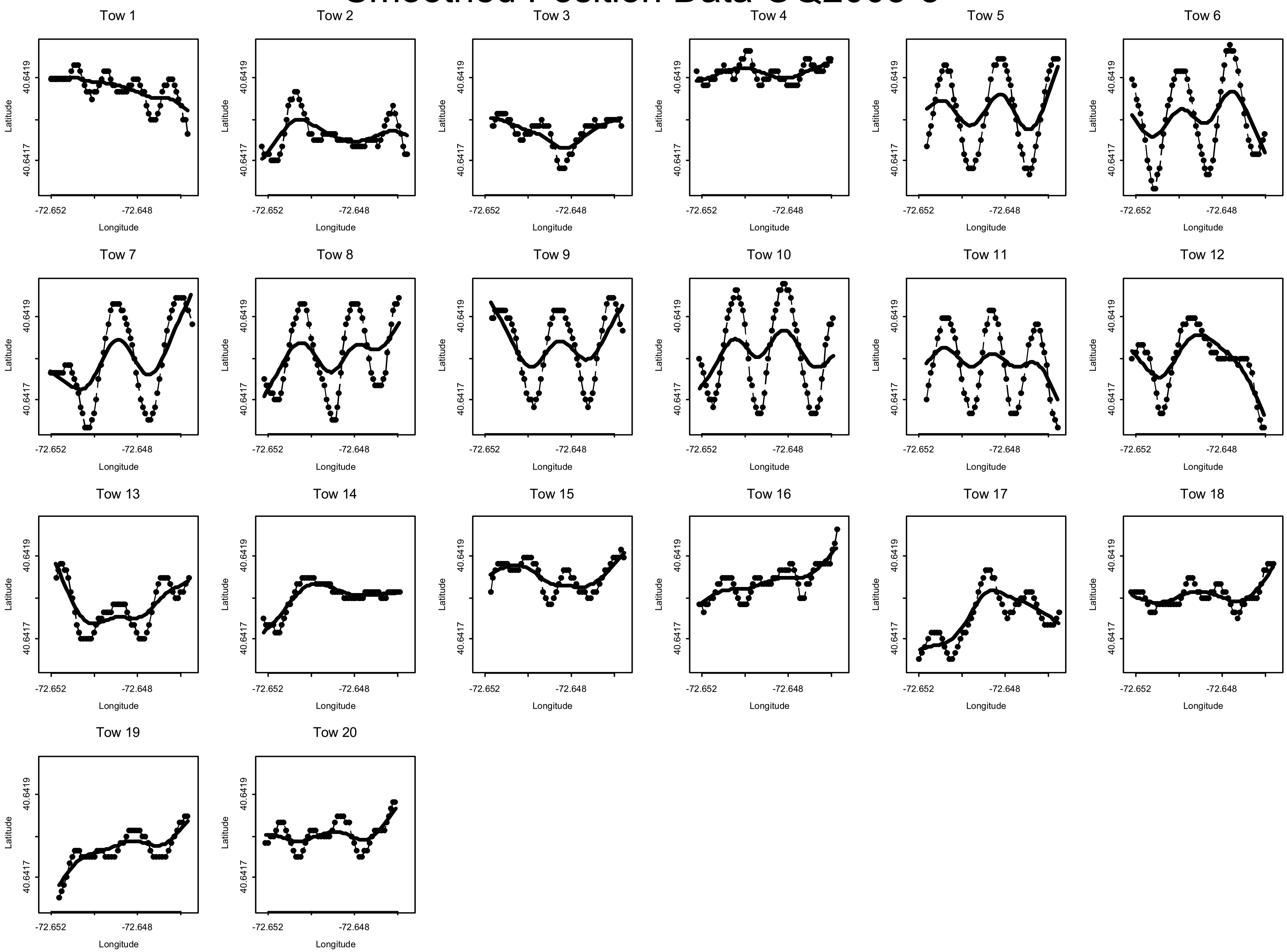
Smoothed Position Data OQ2005-1



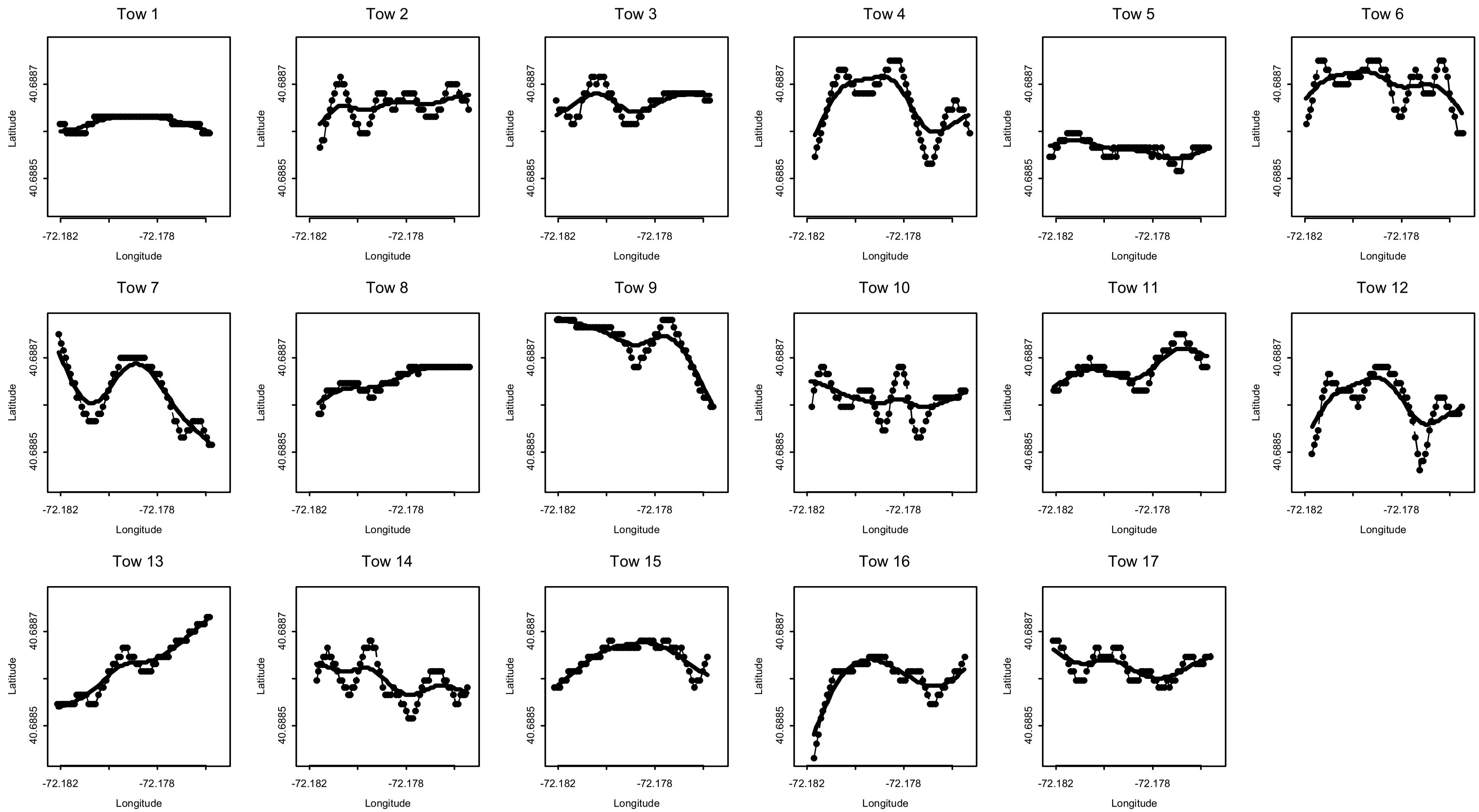
Smoothed Position Data OQ2005-2



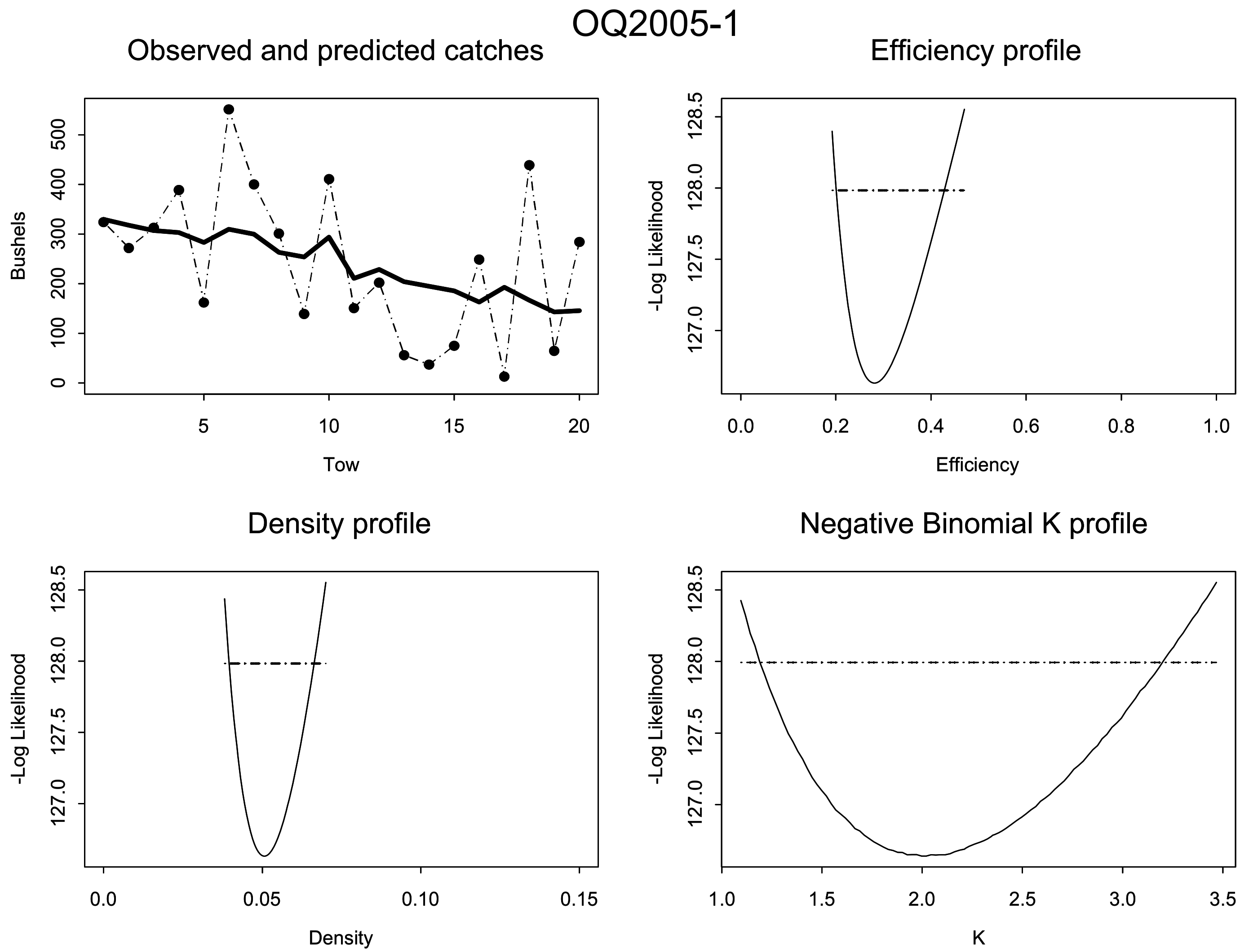
Smoothed Position Data OQ2005-3

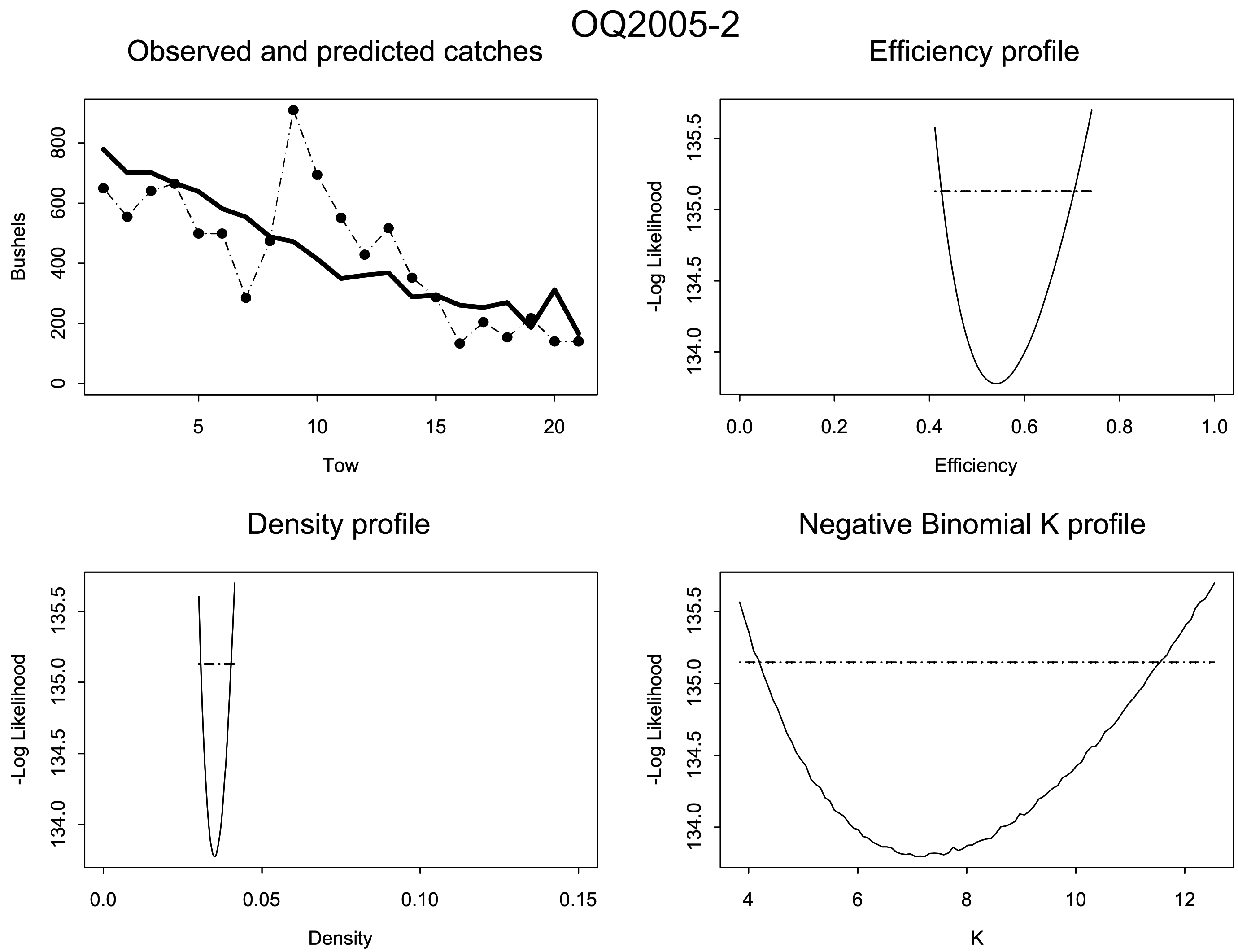


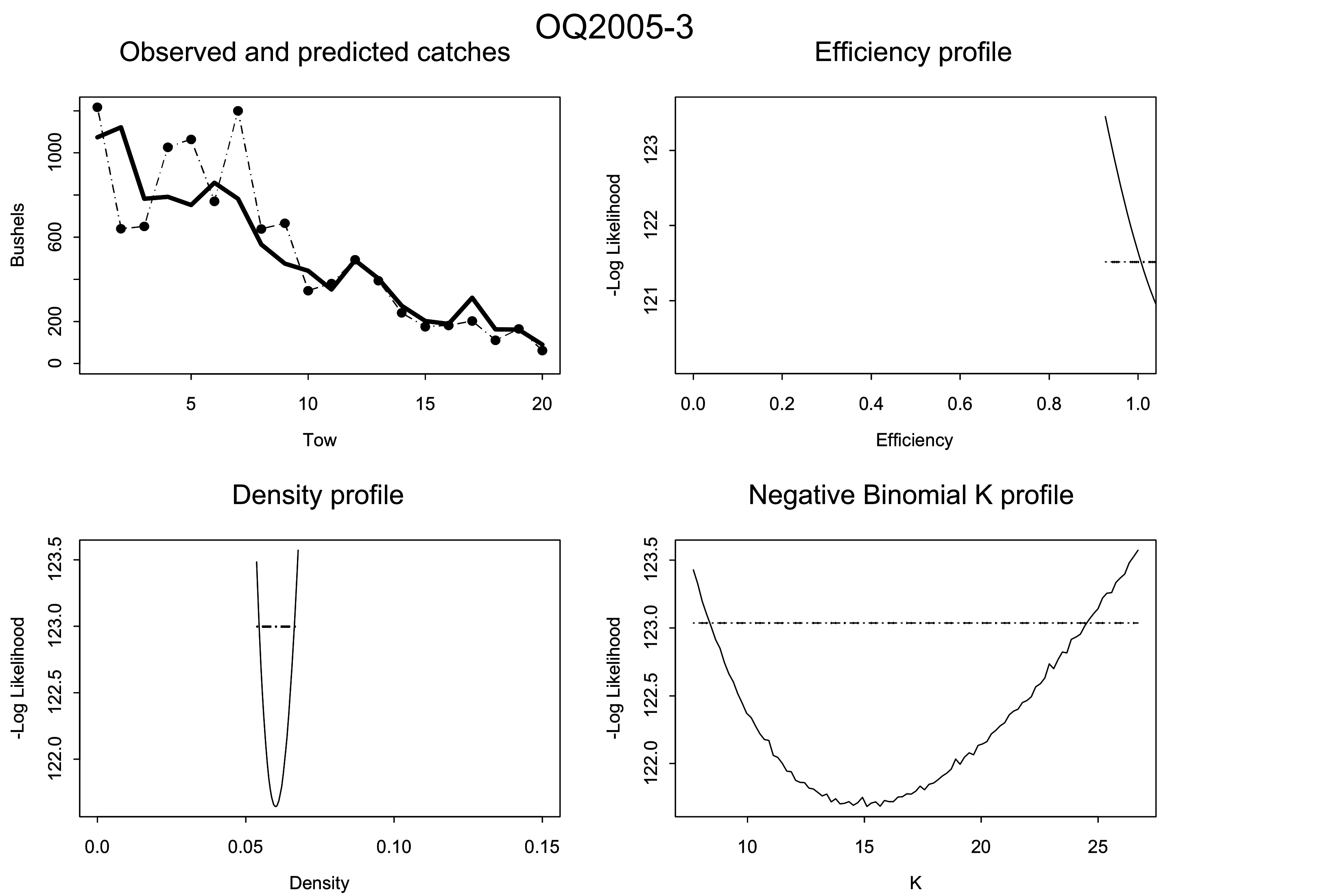
Smoothed Position Data OQ2005-4

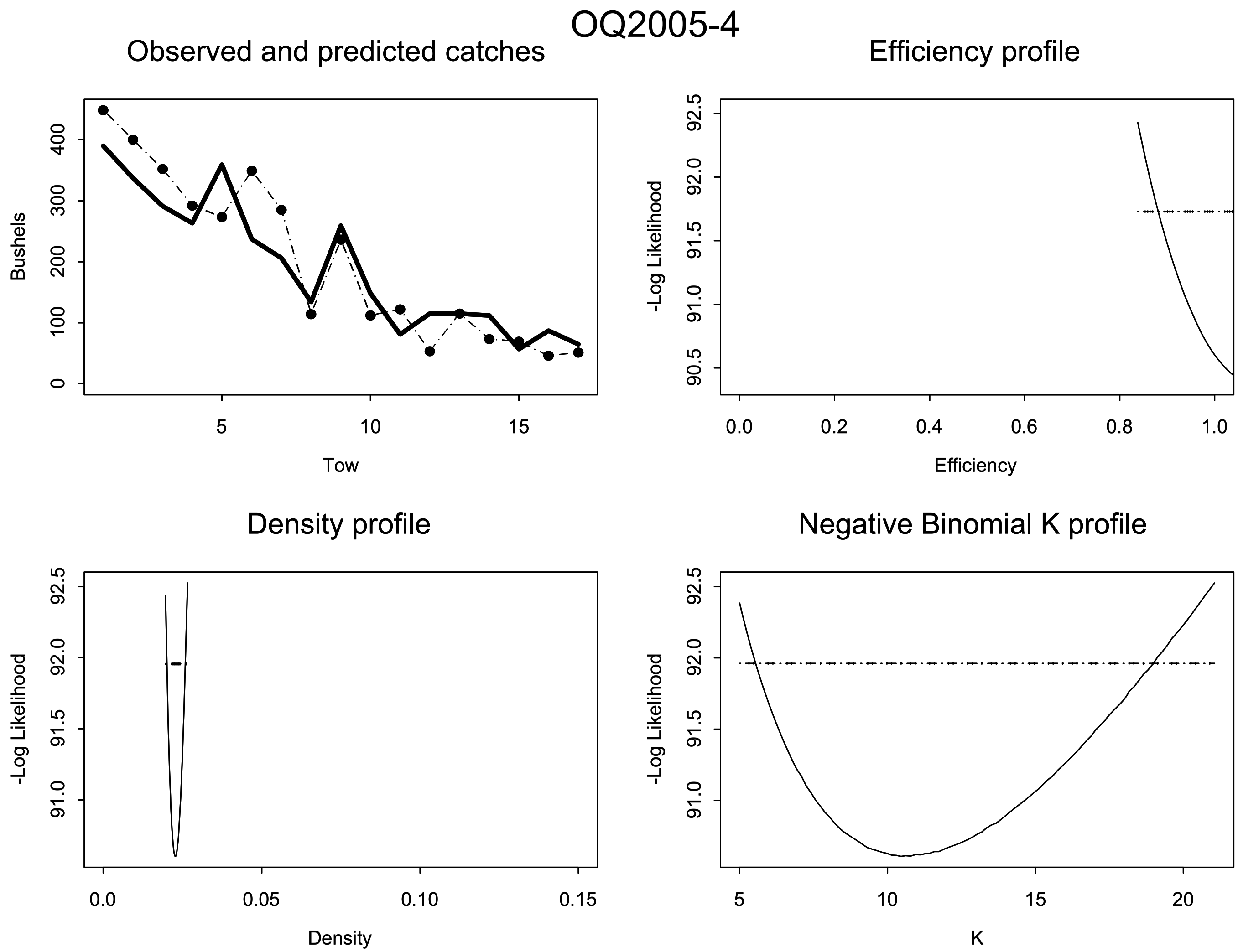


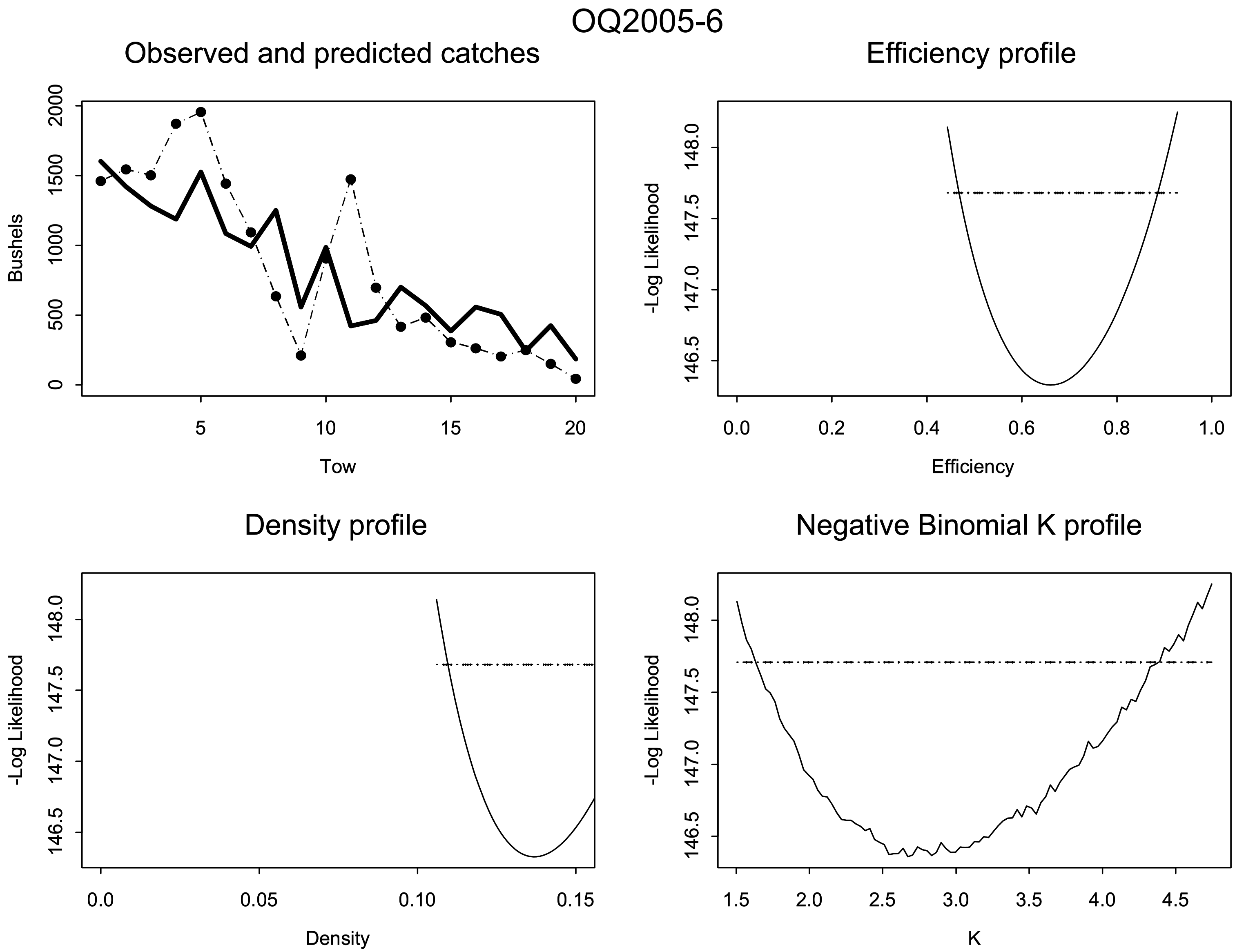
APPENDIX A4. Goodness of fit and likelihood profile plots for ocean quahog depletion experiments with 95% confidence intervals.

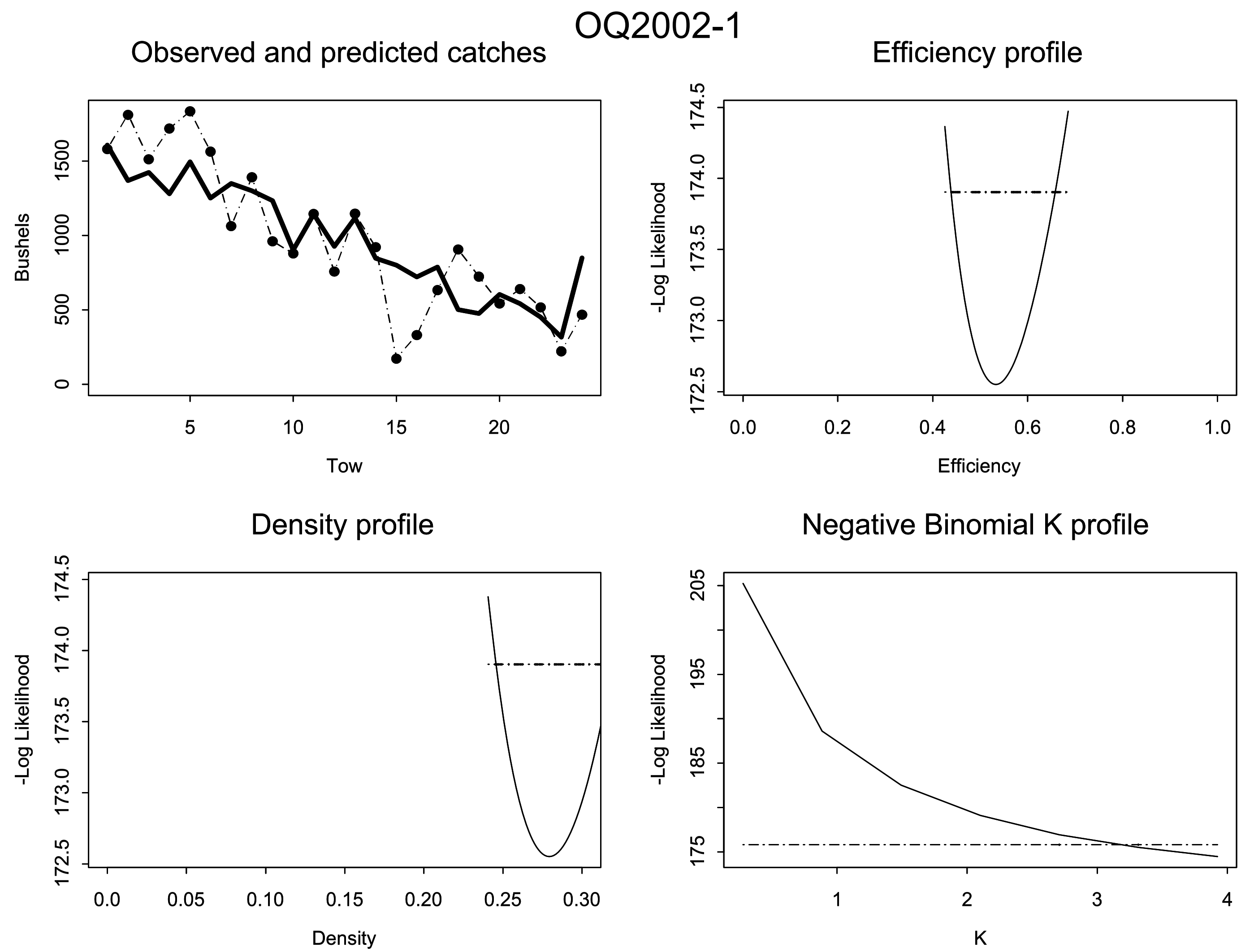

OQ2005-1
Observed and predicted catches
Bushels
0
100
200
300
400
500
5
10
15
20
Tow
Efficiency profile
-Log Likelihood
127.0
127.5
128.0
128.5
0.0
0.2
0.4
0.6
0.8
1.0
Efficiency
Density profile
-Log Likelihood
127.0
127.5
128.0
128.5
0.0
0.05
0.10
0.15
Density
Negative Binomial K profile
-Log Likelihood
127.0
127.5
128.0
128.5
1.0
1.5
2.0
2.5
3.0
3.5
K

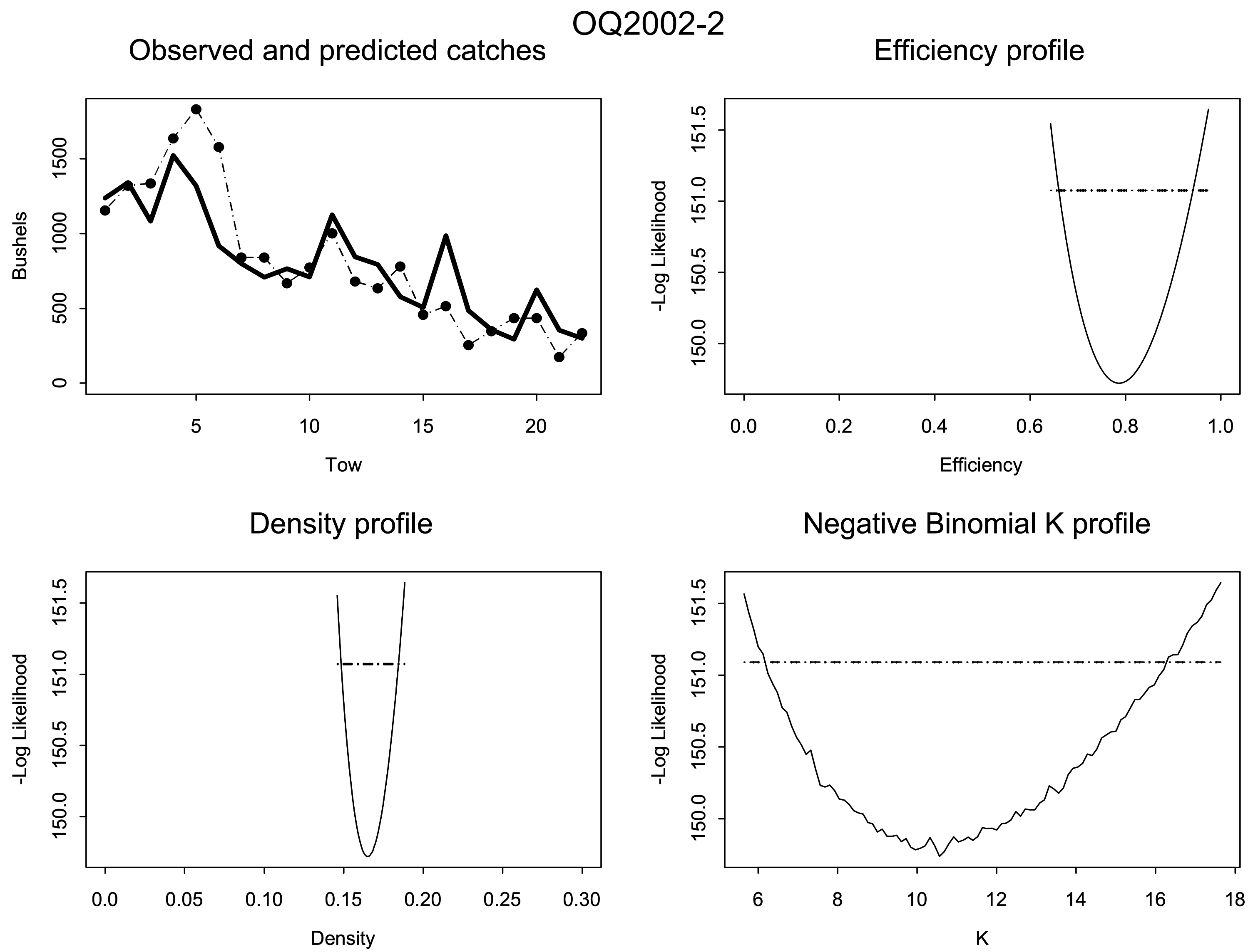

OQ2005-2
Observed and predicted catches
Bushels
0
200
400
600
800
5
10
15
20
Tow
Efficiency profile
-Log Likelihood
134.0
134.5
135.0
135.5
0.0
0.2
0.4
0.6
0.8
1.0
Efficiency
Density profile
-Log Likelihood
134.0
134.5
135.0
135.5
0.0
0.05
0.10
0.15
Density
Negative Binomial K profile
-Log Likelihood
134.0
134.5
135.0
135.5
4
6
8
10
12
K


OQ2005-3
Observed and predicted catches
Bushels
0
200
600
1000
5
10
15
20
Tow
Efficiency profile
-Log Likelihood
121
122
123
0.0
0.2
0.4
0.6
0.8
1.0
Efficiency
Density profile
-Log Likelihood
122.0
122.5
123.0
123.5
0.0
0.05
0.10
0.15
Density
Negative Binomial K profile
-Log Likelihood
122.0
122.5
123.0
123.5
10
15
20
25
K

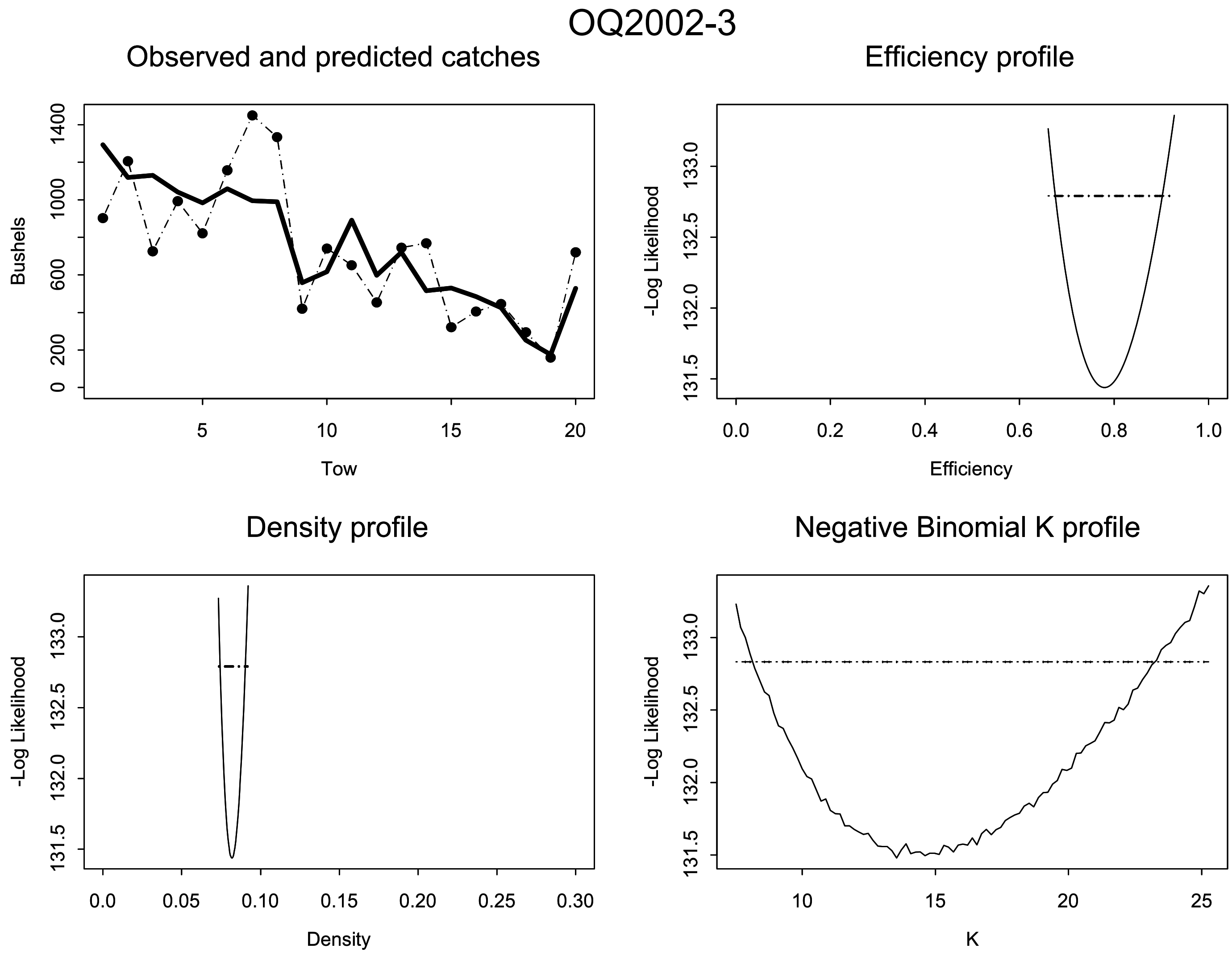

OQ2005-4
Observed and predicted catches
Bushels
0
100
200
300
400
5
10
15
Tow
Efficiency profile
-Log Likelihood
90.5
91.0
91.5
92.0
92.5
0.0
0.2
0.4
0.6
0.8
1.0
Efficiency
Density profile
-Log Likelihood
91.0
91.5
92.0
92.5
0.0
0.05
0.10
0.15
Density
Negative Binomial K profile
-Log Likelihood
91.0
91.5
92.0
92.5
5
10
15
20
K

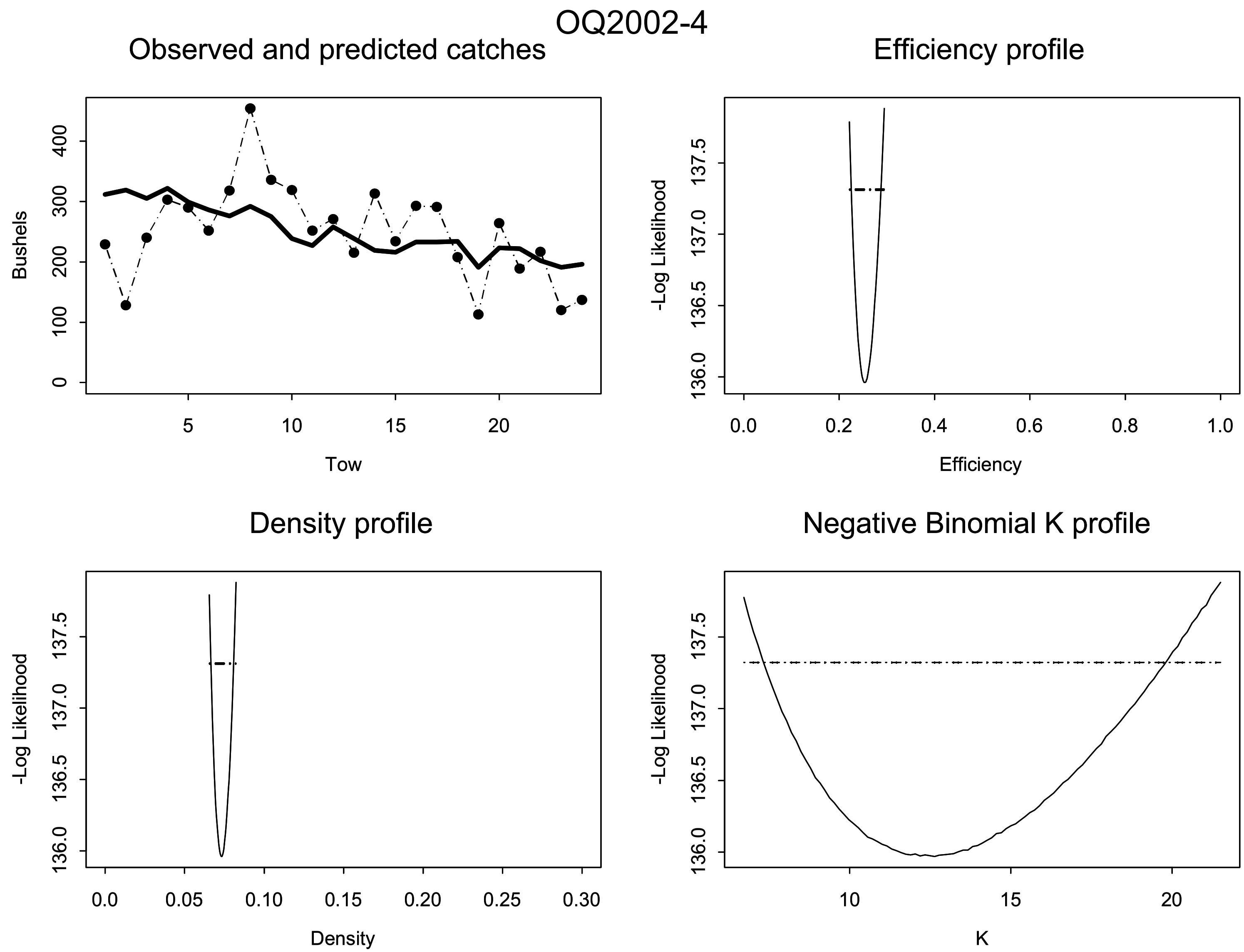

OQ2005-6
Observed and predicted catches
Bushels
Tow
Efficiency profile
-Log Likelihood
Efficiency
Density profile
-Log Likelihood
Density
Negative Binomial K profile
-Log Likelihood
K

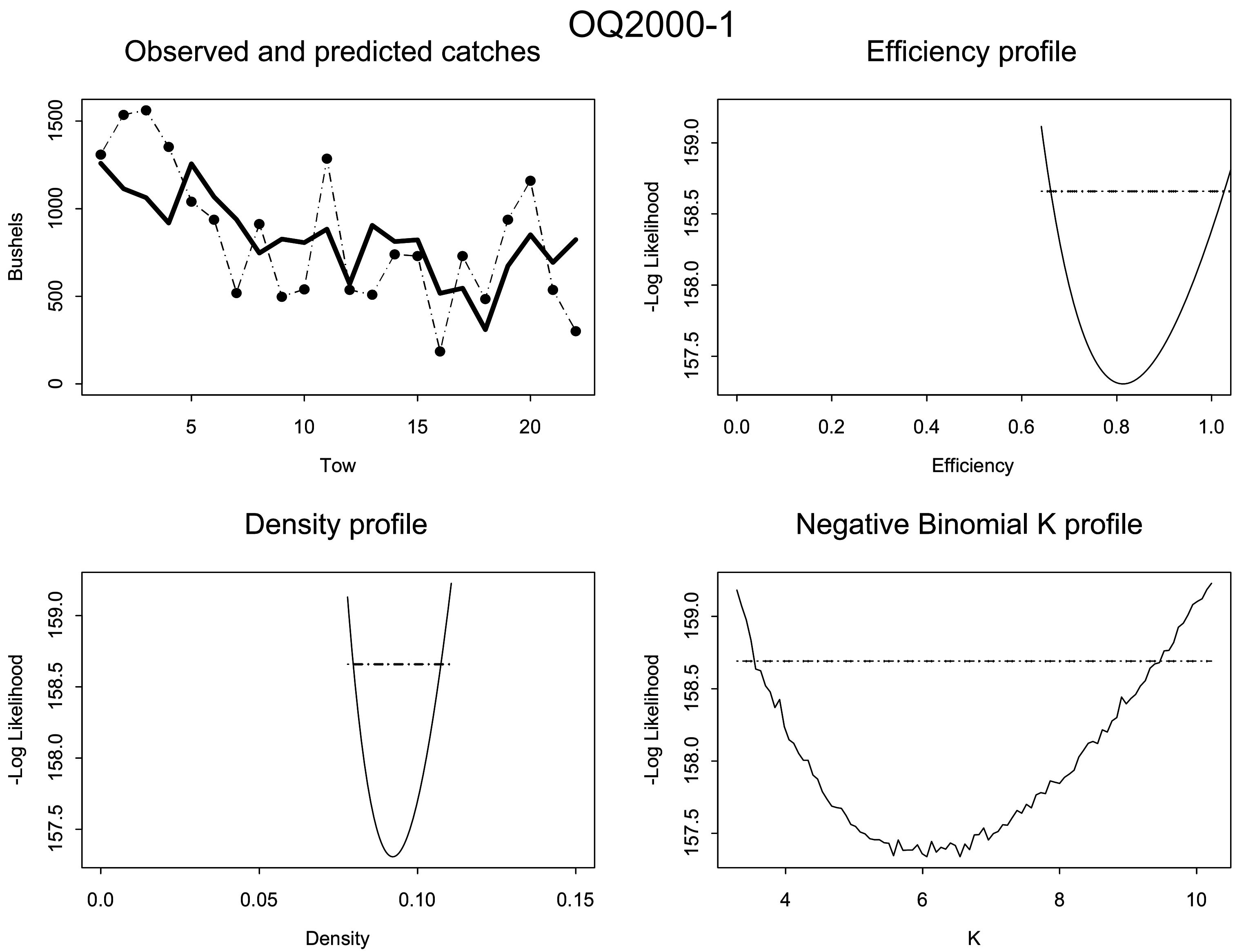

OQ2002-1
Observed and predicted catches
Bushels
0
500
1000
1500
5
10
15
20
Tow
Efficiency profile
-Log Likelihood
172.5
173.0
173.5
174.0
174.5
0.0
0.2
0.4
0.6
0.8
1.0
Efficiency
Density profile
-Log Likelihood
172.5
173.0
173.5
174.0
174.5
0.0
0.05
0.10
0.15
0.20
0.25
0.30
Density
Negative Binomial K profile
-Log Likelihood
175
185
195
205
1
2
3
4
K

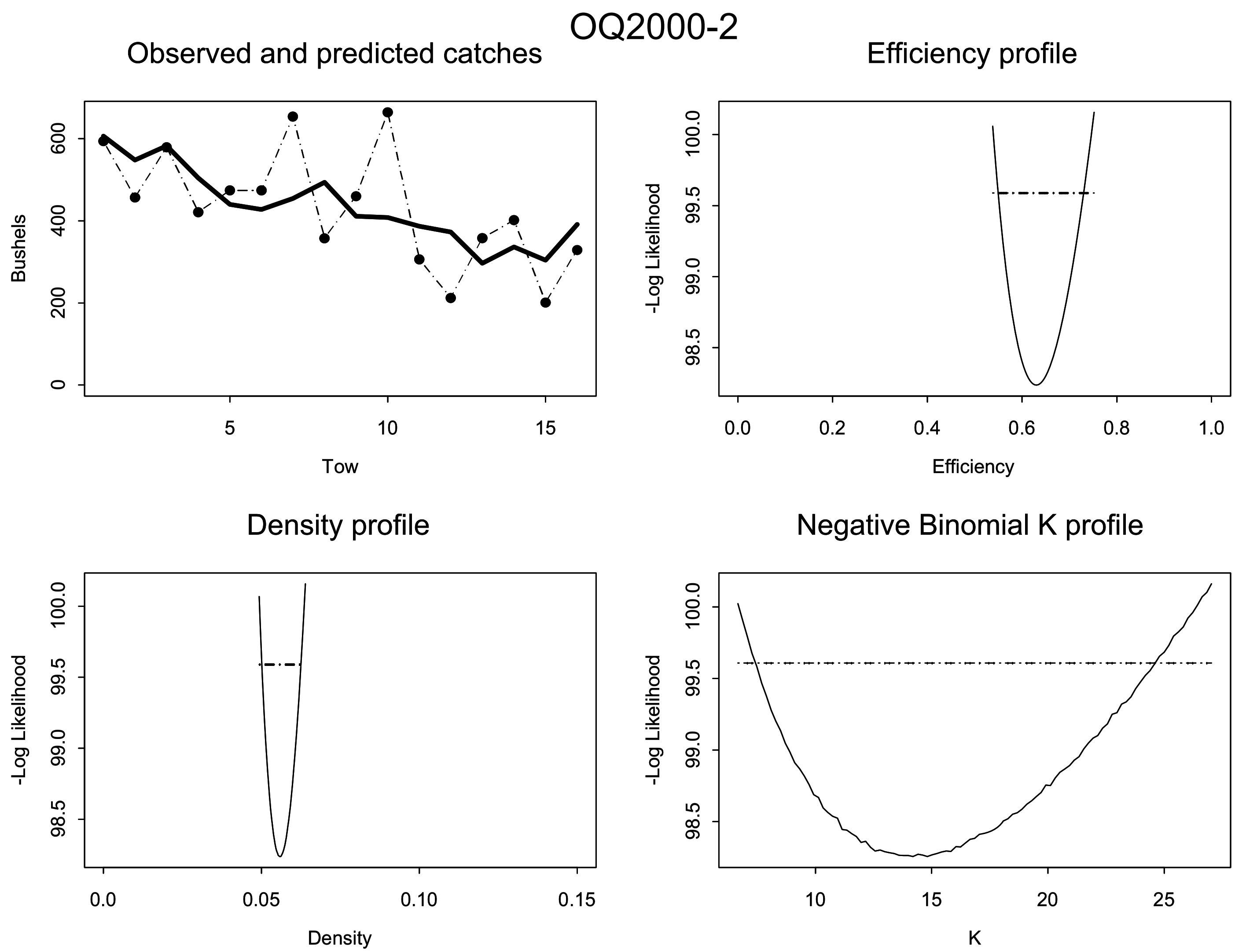


OQ2002-2
Observed and predicted catches
Bushels
0
500
1000
1500
5
10
15
20
Tow
Efficiency profile
-Log Likelihood
150.0
150.5
151.0
151.5
0.0
0.2
0.4
0.6
0.8
1.0
Efficiency
Density profile
-Log Likelihood
0.0
0.05
0.10
0.15
0.20
0.25
0.30
Density
Negative Binomial K profile
-Log Likelihood
6
8
10
12
14
16
18
K

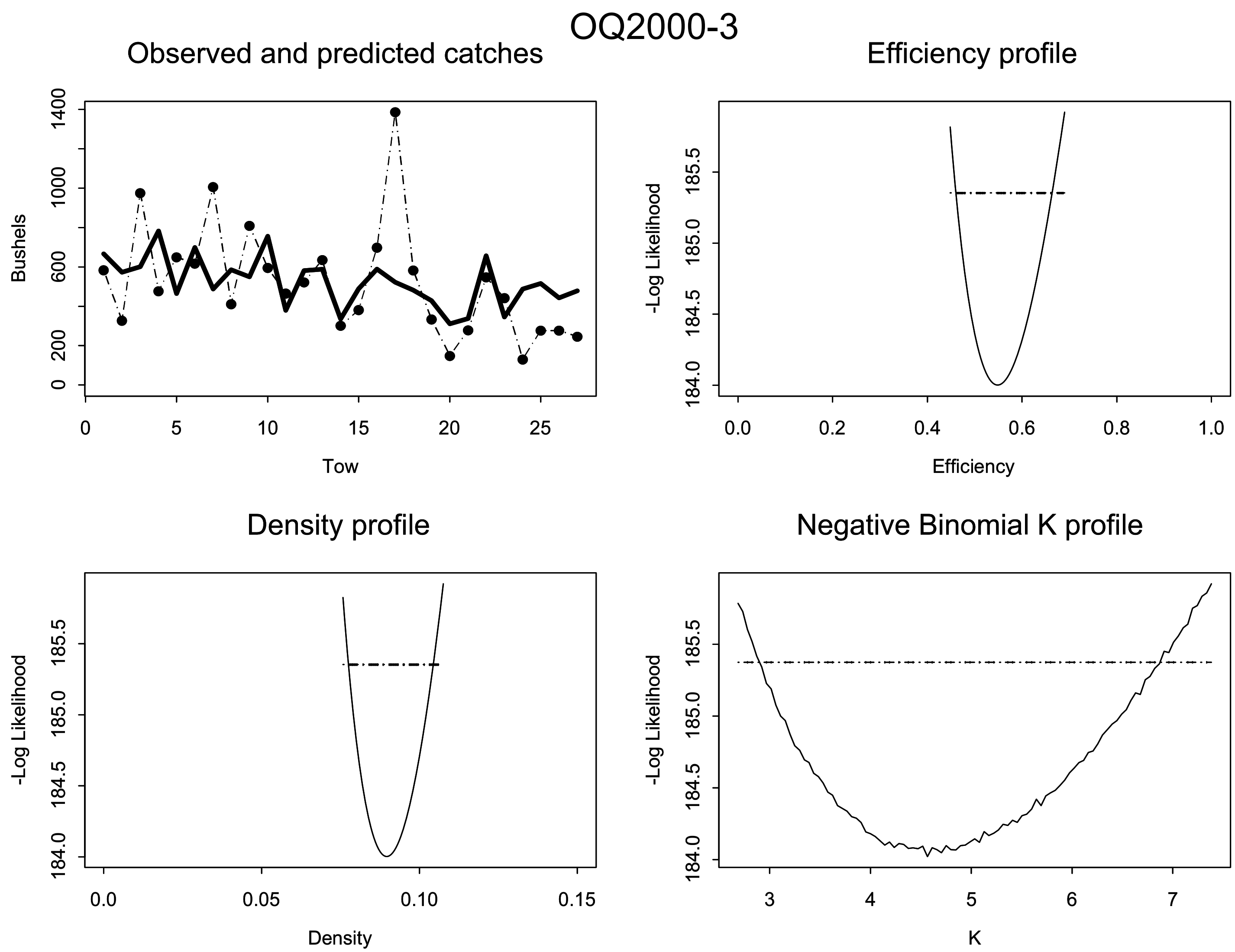

OQ2002-3
Observed and predicted catches
Bushels
0
200
600
1000
1400
5
10
15
20
Tow
Efficiency profile
-Log Likelihood
131.5
132.0
132.5
133.0
0.0
0.2
0.4
0.6
0.8
1.0
Efficiency
Density profile
-Log Likelihood
131.5
132.0
132.5
133.0
0.0
0.05
0.10
0.15
0.20
0.25
0.30
Density
Negative Binomial K profile
-Log Likelihood
131.5
132.0
132.5
133.0
10
15
20
25
K


OQ2002-4
Observed and predicted catches
Bushels
0
100
200
300
400
5
10
15
20
Tow
Efficiency profile
-Log Likelihood
136.0
136.5
137.0
137.5
0.0
0.2
0.4
0.6
0.8
1.0
Efficiency
Density profile
-Log Likelihood
136.0
136.5
137.0
137.5
0.0
0.05
0.10
0.15
0.20
0.25
0.30
Density
Negative Binomial K profile
-Log Likelihood
136.0
136.5
137.0
137.5
10
15
20
K

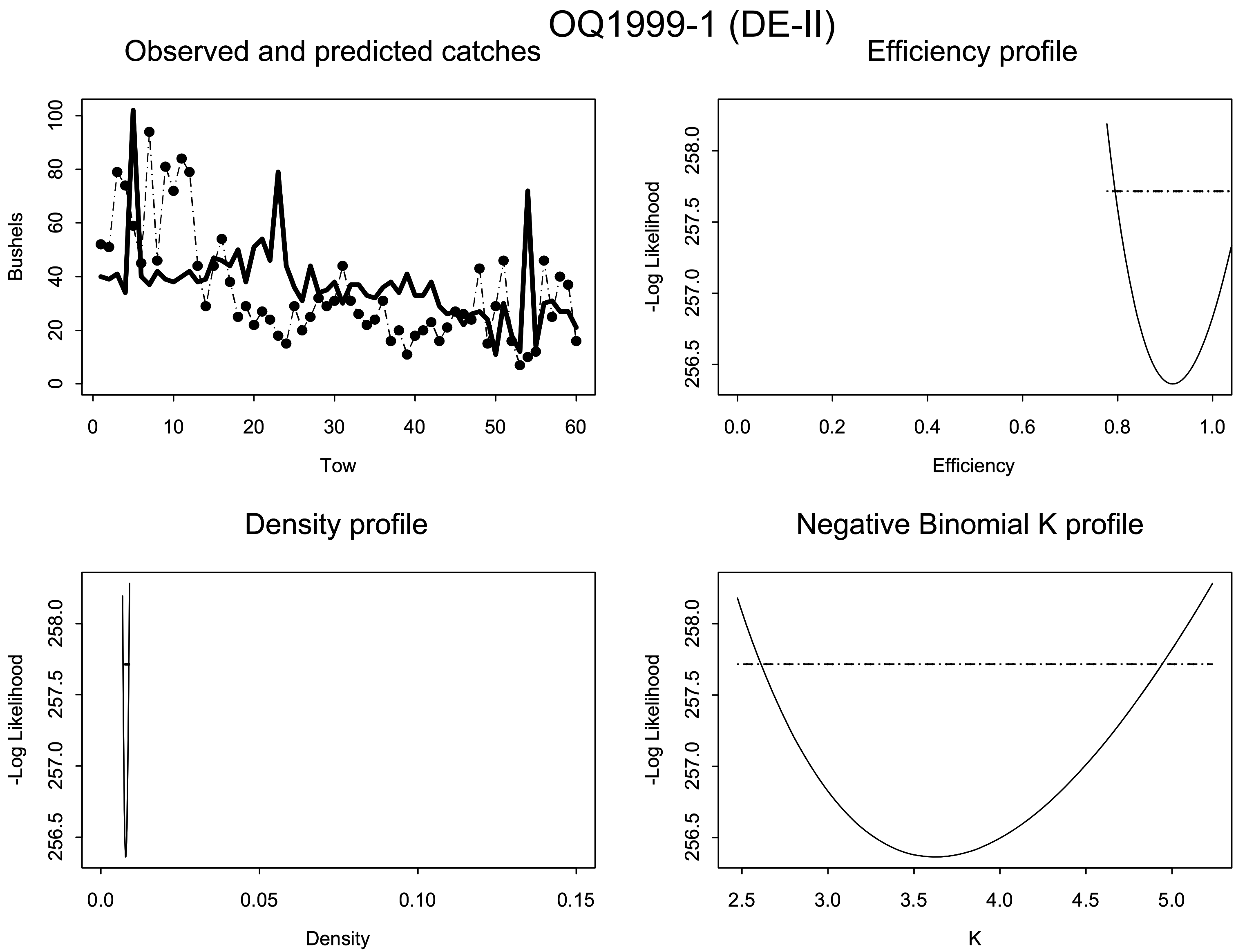

OQ2000-1
Observed and predicted catches
Bushels
0
500
1000
1500
5
10
15
20
Tow
Efficiency profile
-Log Likelihood
157.5
158.0
158.5
159.0
0.0
0.2
0.4
0.6
0.8
1.0
Efficiency
Density profile
-Log Likelihood
157.5
158.0
158.5
159.0
0.0
0.05
0.10
0.15
Density
Negative Binomial K profile
-Log Likelihood
157.5
158.0
158.5
159.0
4
6
8
10
K



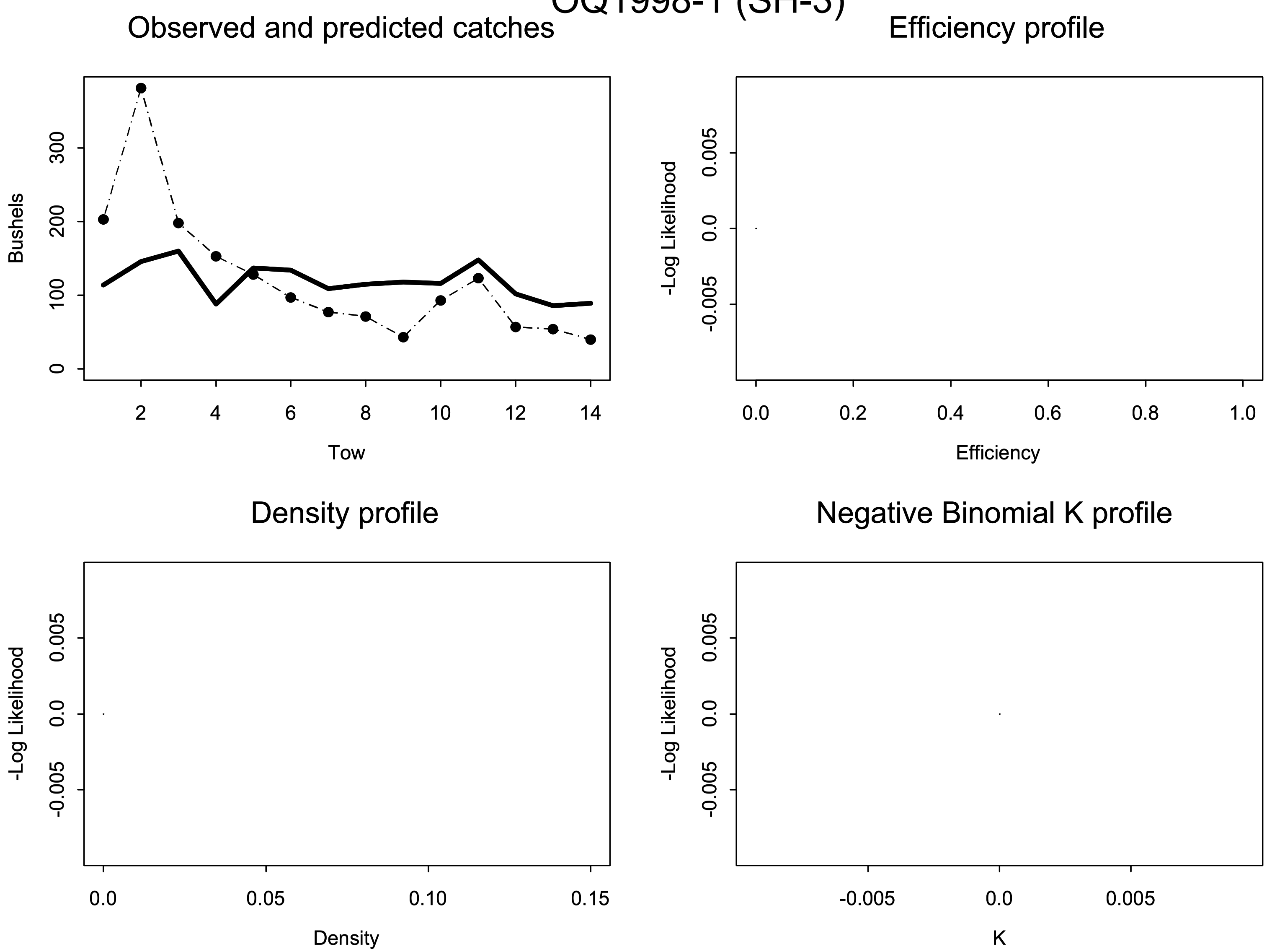
OQ2000-2
Observed and predicted catches
Bushels
0
200
400
600
5
10
15
Tow
Efficiency profile
-Log Likelihood
98.5
99.0
99.5
100.0
0.0
0.2
0.4
0.6
0.8
1.0
Efficiency
Density profile
-Log Likelihood
98.5
99.0
99.5
100.0
0.0
0.05
0.10
0.15
Density
Negative Binomial K profile
-Log Likelihood
98.5
99.0
99.5
100.0
10
15
20
25
K



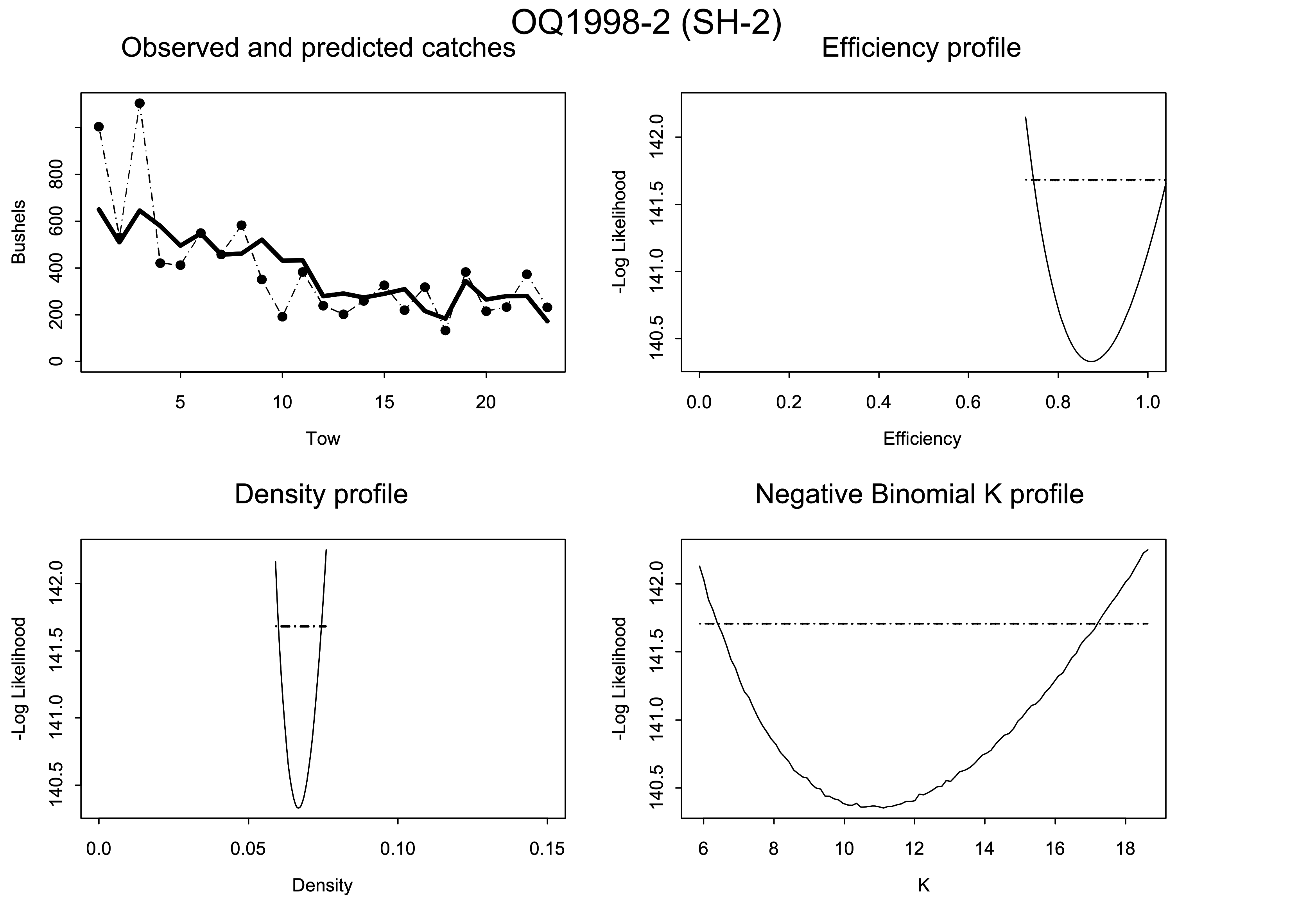
OQ2000-3
Observed and predicted catches
Bushels
Tow
Efficiency profile
-Log Likelihood
Efficiency
Density profile
-Log Likelihood
Density
Negative Binomial K profile
-Log Likelihood
K


OQ1999-1 (DE-II)
Observed and predicted catches
Bushels
Tow
0
20
40
60
80
100
0
10
20
30
40
50
60
Efficiency profile
-Log Likelihood
Efficiency
256.5
257.0
257.5
258.0
0.0
0.2
0.4
0.6
0.8
1.0
Density profile
-Log Likelihood
Density
256.5
257.0
257.5
258.0
0.0
0.05
0.10
0.15
Negative Binomial K profile
-Log Likelihood
K
256.5
257.0
257.5
258.0
2.5
3.0
3.5
4.0
4.5
5.0

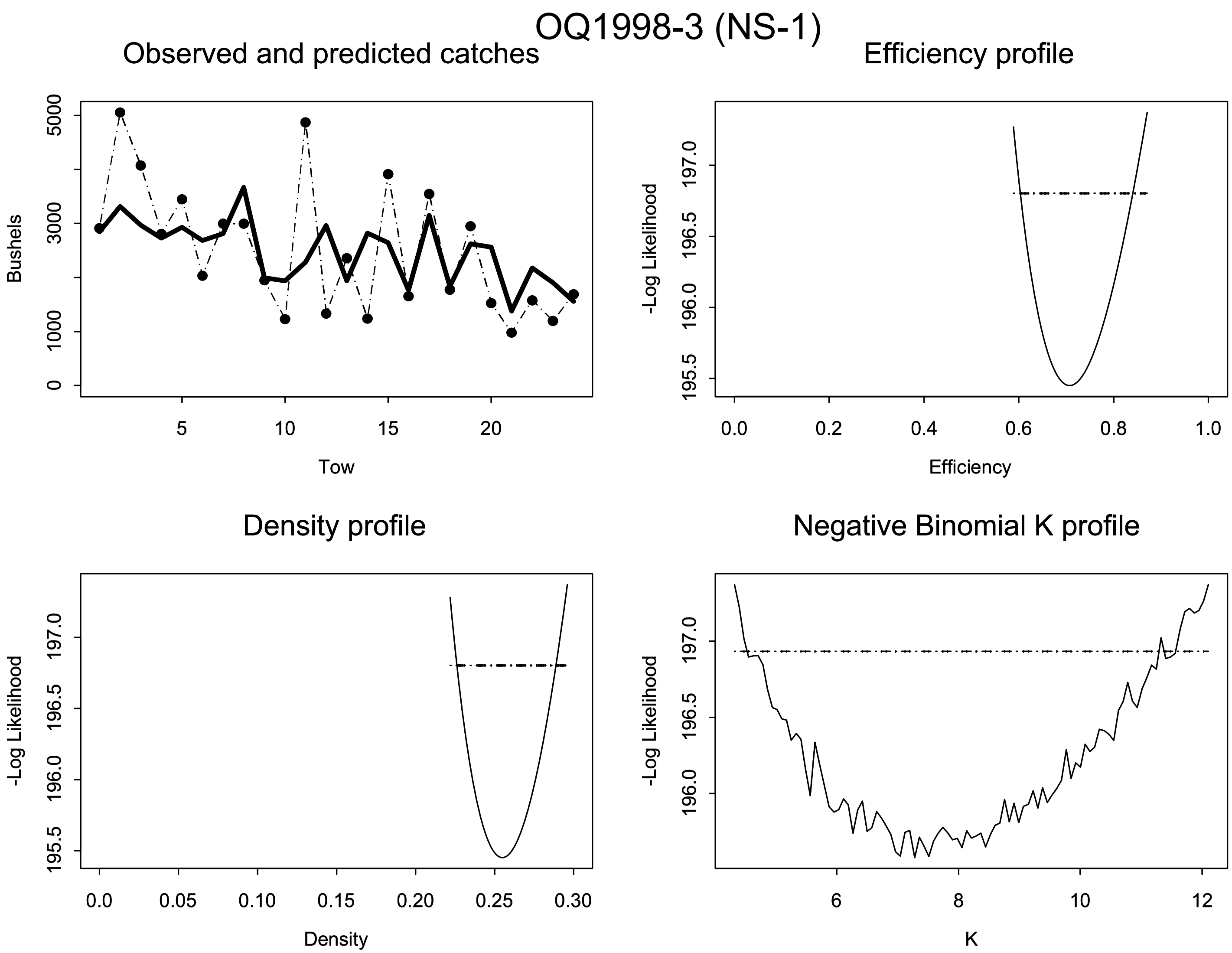
OQ1998-1 (SH-3)



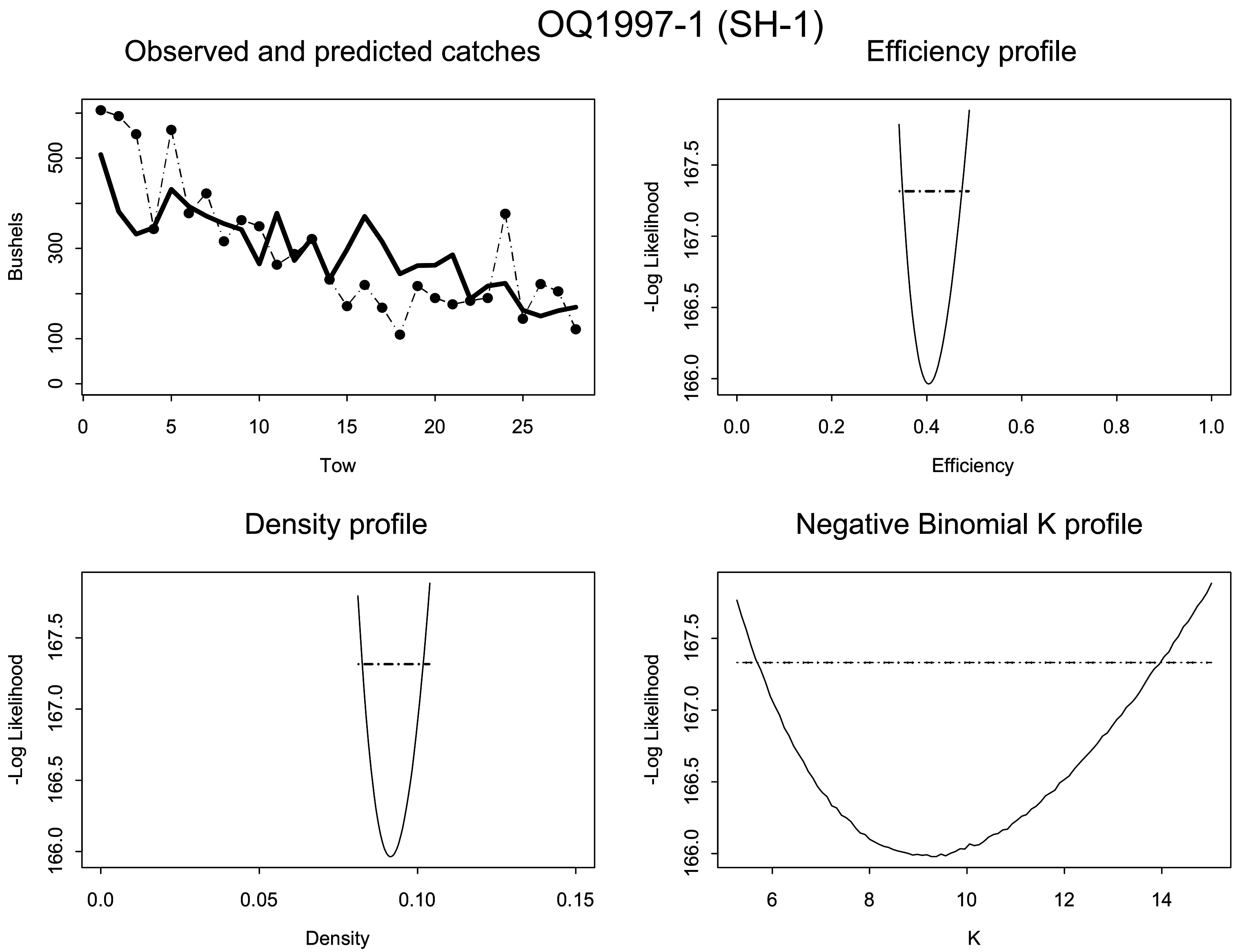
Observed and predicted catches
Bushels
0
100
200
300
2
4
6
8
10
12
14
Tow
Efficiency profile
-Log Likelihood
-0.005
0.0
0.005
0.0
0.2
0.4
0.6
0.8
1.0
Efficiency
Density profile
-Log Likelihood
-0.005
0.0
0.005
0.0
0.05
0.10
0.15
Density
Negative Binomial K profile
-Log Likelihood
-0.005
0.0
0.005
-0.005
0.0
0.005
K

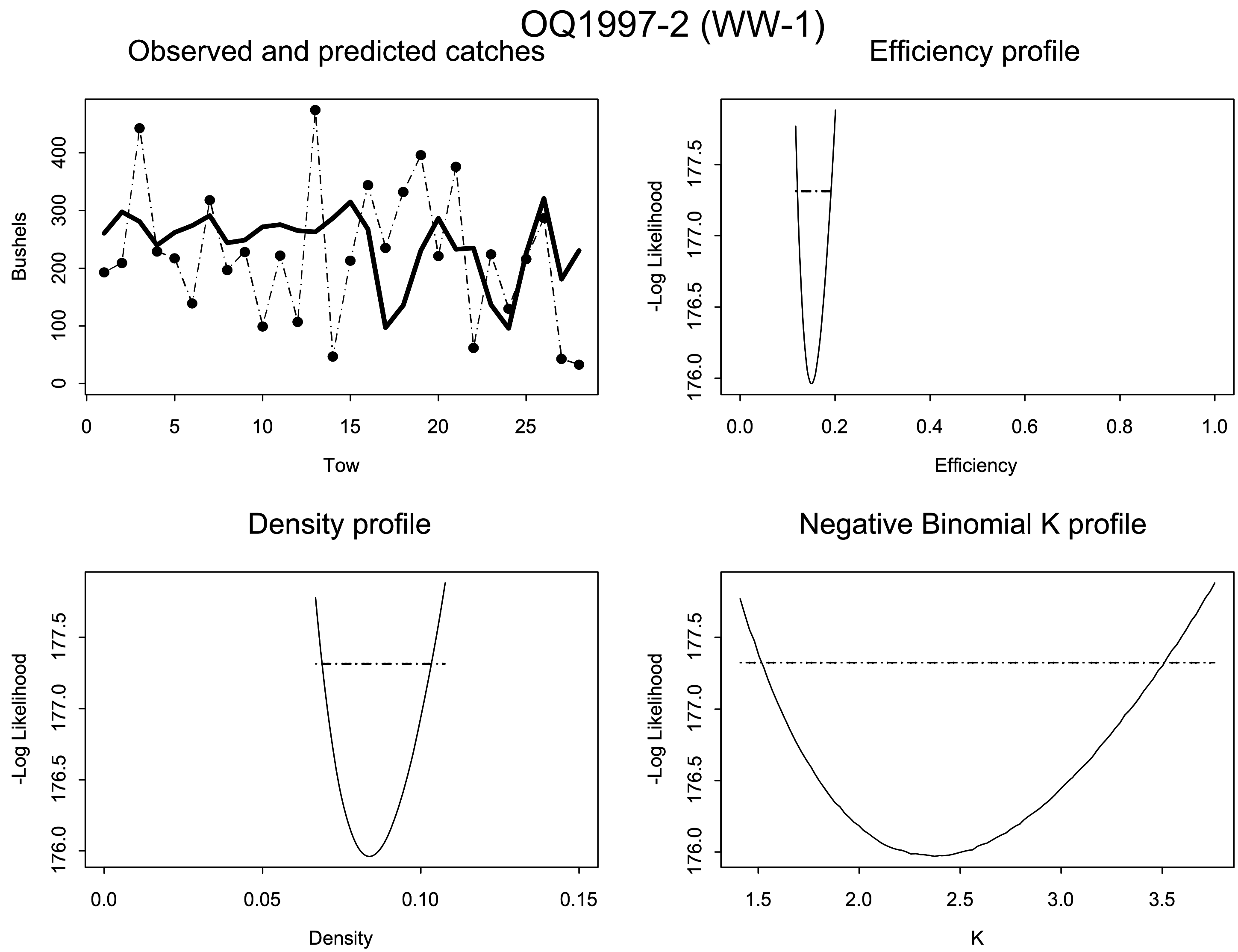


OQ1998-2 (SH-2)
Observed and predicted catches
Bushels
0
200
400
600
800
5
10
15
20
Tow
Efficiency profile
-Log Likelihood
140.5
141.0
141.5
142.0
0.0
0.2
0.4
0.6
0.8
1.0
Efficiency
Density profile
-Log Likelihood
140.5
141.0
141.5
142.0
0.0
0.05
0.10
0.15
Density
Negative Binomial K profile
-Log Likelihood
140.5
141.0
141.5
142.0
6
8
10
12
14
16
18
K



OQ1998-3 (NS-1)
Observed and predicted catches
Bushels
0
1000
3000
5000
5
10
15
20
Tow
Efficiency profile
-Log Likelihood
195.5
196.0
196.5
197.0
0.0
0.2
0.4
0.6
0.8
1.0
Efficiency
Density profile
-Log Likelihood
195.5
196.0
196.5
197.0
0.0
0.05
0.10
0.15
0.20
0.25
0.30
Density
Negative Binomial K profile
-Log Likelihood
196.0
196.5
197.0
6
8
10
12
K


OQ1997-1 (SH-1)
Observed and predicted catches
Bushels
0
100
300
500
0
5
10
15
20
25
Tow
Efficiency profile
-Log Likelihood
166.0
166.5
167.0
167.5
0.0
0.2
0.4
0.6
0.8
1.0
Efficiency
Density profile
-Log Likelihood
166.0
166.5
167.0
167.5
0.0
0.05
0.10
0.15
Density
Negative Binomial K profile
-Log Likelihood
166.0
166.5
167.0
167.5
6
8
10
12
14
K


OQ1997-2 (WW-1)
Observed and predicted catches
Bushels
0
100
200
300
400
0
5
10
15
20
25
Tow
Efficiency profile
-Log Likelihood
176.0
176.5
177.0
177.5
0.0
0.2
0.4
0.6
0.8
1.0
Efficiency
Density profile
-Log Likelihood
176.0
176.5
177.0
177.5
0.0
0.05
0.10
0.15
Density
Negative Binomial K profile
-Log Likelihood
176.0
176.5
177.0
177.5
1.5
2.0
2.5
3.0
3.5
K

APPENDIX A5. Technical description of the KLAMZ stock assessment model.

Larry Jacobson
NEFSC, Woods Hole
May 25, 2007

The KLAMZ assessment model is based on the Deriso-Schnute delay-difference equation (Deriso 1980; Schnute 1985; Quinn and Deriso 1999). The delay-difference equation is a relatively simple and implicitly age structured approach to counting fish in either numerical or biomass units. It gives the same results as explicitly age-structured models (e.g. Leslie matrix model) if fishery selectivity is "knife-edged", if somatic growth follows the von Bertalanffy equation, and if natural mortality is the same for all age groups in each year. Knife-edge selectivity means that all individuals alive in the model during the same year experience the same fishing mortality rate.[9] Natural and fishing mortality rates, growth parameters and recruitment may change from year to year, but delay-difference calculations assume that all individuals share the same mortality and growth parameters within each year. The KLAMZ model includes simple numerical models (e.g. Conser 1995) as special cases because growth can be turned off so that all calculations are in numerical units (see below).

As in many other simple models, the delay difference equation explicitly distinguishes between two age groups. In KLAMZ, the two age groups are called "new" recruits (R_t in biomass or numerical units at the beginning of year t) and "old" recruits (S_t) that together comprise the whole stock (B_t). New recruits are individuals that recruited at the beginning of the current year (at nominal age k).[10] Old recruits are all older individuals in the stock (nominal ages k+1 and older, survivors from the previous year). As described above, KLAMZ assumes that new and old recruits are fully vulnerable to the fishery. The most important differences between the delay-difference and other simple models (e.g. Prager 1994; Conser 1995; Jacobson et al. 1994) are that von Bertalanffy growth is used to calculate biomass dynamics and that the delay-difference model captures transient age structure effects due to variation in recruitment, growth and mortality exactly. Transient effects on population dynamics are captured exactly because, as described above, the delay-difference equation is algebraically equivalent to an explicitly age-structured model with von Bertalanffy growth.

[9] In applications, assumptions about knife-edge selectivity can be relaxed by assuming the model tracks "fishable", rather that total, biomass (NEFSC 2000a; 2000b). An analogous approach assigns pseudo-ages based on recruitment to the fishery so that new recruits in the model are all pseudo-age k. The synthetic cohort of fish pseudo-age k may consist of more than one biological cohort. The first pseudo-age (k) can be the predicted age at first, 50% or full recruitment based a von Bertalanffy curve and size composition data (Butler et al. 2002). The "incomplete recruitment" approach (Deriso 1980) calculates recruitment to the model in each year R_t as the weighted sum of contributions from two or more biological cohorts (year-classes) from spawning during successive years (i.e. $R_t = \sum_{a=1}^{k} r_a \Pi_{t-a}$ where k is the age at full recruitment to the fishery, r_a is the contribution of fish age k-a to the fishable stock, and Π_{t-a} is the number or biomass of fish age k-a during year t).

[10] In some applications, and more generally, new recruits might be defined as individuals recruiting at the beginning or at any time during the current time step (e.g. NEFSC 1996).

The KLAMZ model incorporates a few extensions to Schnute's (1985) revision of Deriso's (1980) original delay difference model. Most of the extensions facilitate tuning to a wider variety of data that anticipated in Schnute (1985). The KLAMZ model is programmed in both Excel and in C++ using AD Model Builder[11] libraries. The AD Model Builder version is faster, more reliable and probably better for producing "official" stock assessment results. The Excel version is slower and implements fewer features, but the Excel version remains useful in developing prototype assessment models, teaching and for checking calculations.

The most significant disadvantage in using the KLAMZ model and other delay-difference approaches, beyond the assumption of knife-edge selectivity, is that age and length composition data are not used in tuning. However, one can argue that age composition data are used indirectly to the extent they are used to estimate growth parameters or if survey survival ratios (e.g. based on the Heinke method) are used in tuning (see below).

Population dynamics

The assumed birth date and first day of the year are assumed the same in derivation of the delay-difference equation. It is therefore natural (but not strictly necessary) to tabulate catch and other data using annual accounting periods that start on the assumed biological birthday of cohorts.

Biomass dynamics

As implemented in the KLAMZ model, Schnute's (1985) delay-difference equation is:

$$B_{t+1} = (1+\rho)\,\tau_t\,B_t - \rho\,\tau_t\,\tau_{t-1}\,B_{t-1} + R_{t+1} - \rho\,\tau_t\,J_t\,R_t$$

where B_t is total biomass of individuals at the beginning of year t; ρ is Ford's growth coefficient (see below); $\tau_t=exp(-Z_t)=exp[-(F_t+M_t)]$ 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 new recruits (at age k) at the beginning of the year. The natural mortality rate M_t may vary over time. Instantaneous mortality rates in KLAMZ model calculations are biomass-weighted averages if von Bertalanffy growth is turned on in the model. However, biomass-weighted mortality estimates in KLAMZ are the same as rates for numerical estimates under the assumption of knife-edge selectivity because all individuals are fully recruited. The growth parameter $J_t = w_{t-1,k-1} / w_{t,k}$ 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).

It is not necessary to specify body weights at and prior to recruitment in the KLAMZ model (parameters v_{t-1} and V_t in Schnute 1985) because the ratio J_t and recruitment biomass contain the same information. Schnute's (1985) original delay difference equation is:

$$B_{t+1} = (1+\rho)\,\tau_t\,B_t - \rho\,\tau_t\tau_{t-1}\,B_{t-1} + w_{t+1,k}N_{t+1} - \rho\tau_t w_{t-1,k-1}\,N_t$$

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To derive the equation used in KLAMZ, substitute recruitment biomass R_{t+1} for the product $w_{t+1,k} N_{t+1,k}$ and adjusted recruitment biomass $J_t R_t = (w_{t-1,k-1}/w_{t,k})\, w_{t,k}\, N_{t,k} = w_{t-1,k-1}\, N_t$ in the last term on the right hand side. The advantage in using the alternate parameterization for biomass dynamic calculations in KLAMZ is that recruitment is estimated directly in units of biomass and the number of growth parameters is reduced. The disadvantage is that numbers of recruits are not estimated directly by the model. When required, numerical recruitments must be calculated externally as the ratio of estimated recruitment biomass and the average body weight for new recruits.

Numerical population dynamics

Growth can be turned on off so that abundance, rather than biomass, is tracked in the KLAMZ model. Set J_t=1 and ρ=0 in the delay difference equation, and use N_t (for numbers) in place of B_t to get:

$$\mathrm{N}_{t+1} = \tau_t\, \mathrm{N}_t + \mathrm{R}_{t+1}$$

Mathematically, the assumption J_t=1 means that no growth occurs the assumption ρ=0 means that the von Bertalanffy K parameter is infinitely large (Schnute 1985). All tuning and population dynamics calculations in KLAMZ for biomass dynamics are also valid for numerical dynamics.

<u>Growth</u>

As described in Schnute (1985), biomass calculations in the KLAMZ model are based on Schnute and Fournier's (1980) re-parameterization of the von Bertalanffy growth model:

$$\mathrm{w}_a = \mathrm{w}_{k-1} + (\mathrm{w}_k - \mathrm{w}_{k-1})\,(1+\rho^{1+a-k})\,/\,(1-\rho)$$

where w_k=V and w_{k-1}=v. Schnute and Fournier's (1980) growth model is the same as the traditional von Bertalanffy 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 because $W_{max} = (w_k - \rho\, w_{k-1})/(1-\rho)$, $K = -ln(\rho)$ and $t_{zero} = ln[(w_k - w_{k-1})/(w_k - \rho\, w_{k-1})] / ln(\rho)$.

In the KLAMZ model, the growth parameters J_t can vary with time but ρ is constant. Use of time-variable J_t values with ρ is constant is the same as assuming that the von Bertalanffy parameters W_{max} and t_{zero} change over time. Many growth patterns can be mimicked by changing W_{max} and t_{zero} (Overholtz et al., 2003). K is a parameter in the C++ version and, in principal, estimable. However, in most cases it is necessary to use external estimates of growth parameters as constants in KLAMZ.

<u>Instantaneous growth rates</u>

Instantaneous growth rate (IGR) calculations in the KLAMZ model are an extension to the original Deriso-Schnute delay difference model. IGRs are used extensively in KLAMZ for calculating catch biomass and projecting stock biomass forward to the time at which surveys occur. The IGR for new recruits depends only on growth parameters:

$$G_t^{New} = \ln\left(\frac{w_{k+1,t+1}}{w_{k,t}}\right) = \ln(1+\rho-\rho J_t)$$

IGR for old recruits is a biomass-weighted average that depends on the current age structure and growth parameters. It can be calculated easily by projecting biomass of old recruits S_t=B_t-R_t (escapement) forward one year with no mortality:

$$S_t^* = (1+\rho)S_t - \rho\tau_{t-1}B_{t-1}$$

where the asterisk (*) means just prior to the start of the subsequent year t+1. By definition, the IGR for old recruits in year t is $G_t^{Old} = \ln\left(S_t^*/S_t\right)$. Dividing by S_t gives:

$$G_t^{Old} = \ln\left[(1+\rho) - \rho\tau_{t-1}\frac{B_{t-1}}{S_t}\right]$$

IGR for the entire stock is the biomass weighted average of the IGR values for new and old recruits:

$$G_t = \frac{R_t G_t^{New} + S_t G_t^{Old}}{B_t}$$

All IGR values are zero if growth is turned off.

Recruitment

In the Excel version of the KLAMZ model, annual recruitments are calculated $R_t = e^{\Omega_t}$ where Ω_t is a log transformed annual recruitment parameter, which is estimated in the model. In the C++ version, recruitments are calculated based on log geometric mean recruitment (μ) and a set of annual log scale deviation parameters (ω_t):

$$\Omega_t = \mu + \omega_t$$

The deviations ω_t are constrained to average zero.[12] With the constraint, estimation of μ and the set of ω_t values (1+ n years parameters) is equivalent to estimation of the smaller set (n years) of Ω_t values.

Natural mortality

Natural mortality rates (M_t) are assumed constant in the Excel version of the KLAMZ model. In the C++ version, natural mortality rates may be estimated as a constant value or as a set of values that vary with time. In the model:

$$M_t = me^{\varpi_t}$$

where $m=exp(\pi)$ is the geometric mean natural mortality rate, π is a model parameter that may be estimated (in principal but not in practical terms), and ϖ_t is the log scale year-specific deviation. Deviations may be zero (turned off) so that M_t is constant, may vary in a random fashion due to autocorrelated or independent process errors, or may be

[12] The constraint is implemented by adding $L = \lambda\overline{\varpi}^2$ (where $\overline{\varpi}$ is the average deviation) to the objective function, generally with a high weighting factor (λ = 1000) so that the constraint is binding.

based on a covariate.[13] Model scenarios with zero recruitment may be initializing the parameter π to a small value (e.g. 10^{-16}) and not estimating it.

Random natural mortality process errors are effects due to predation, disease, parasitism, ocean conditions or other factors that may vary over time but are not included in the model. Calculations are basically the same as for survey process errors (see below).

Natural mortality rate covariate calculations are similar to survey covariate calculations (see below) except that the *user should standardized covariates to average zero over the time period included in the model*:

$$\kappa_t = K_t - \overline{K}$$

where κ_t is the standardized covariate, K_t is the original value, and $\overline{K}$ is the mean of the original covariate for the years in the model. *Standardization to mean zero is important because otherwise m is not the geometric mean natural mortality rate* (the convention is important in some calculations, see text).

Log scale deviations that represent variability around the geometric mean are calculated:

$$\varpi_t = \sum_{j=1}^{n} p_j \kappa_t$$

where n is the number of covariates and p_j is the parameter for covariate j. These conventions mean that the units for the covariate parameter p_j are 1/units of the original covariate, the parameter p_j measures the log scale effect of changing the covariate by one unit, and the parameter m is the log scale geometric mean.

Fishing mortality and catch

Fishing mortality rates (F_t) are calculated so that predicted and observed catch data (landings plus estimated discards in units of weight) "agree" to the extent specified by the user. It is not necessary, however, to assume that catches are measured accurately (see "Observed and predicted catch").

Fishing mortality rate calculations in Schnute (1985) are exact but relating fishing mortality to catch in weight is complicated by continuous somatic growth throughout the year as fishing occurs. The KLAMZ model uses a generalized catch equation that incorporates continuous growth through the fishing season. By the definition of instantaneous rates, the catch equation expresses catch as the product:

$$\hat{C}_t = F_t \overline{B}_t$$

where $\hat{C}_t$ is predicted catch weight (landings plus discard) and $\overline{B}_t$ is average biomass.

[13] Another approach to using time dependent natural mortality rates is to treat estimates of predator consumption as discarded catch (see "Predator consumption as discard data"). In addition, estimates of predator abundance can be used in fishing effort calculations (see "Predator data as fishing effort").

Following Chapman (1971) and Zhang and Sullivan (1988), let $X_t=G_t-F_t-M_t$ be the net instantaneous rate of change for biomass.[14] If the rates for growth and mortality are equal, then $X_t=0$, $\overline{B}_t = B_t$ and $C_t = F_t B_t$. If the growth rate G_t exceeds the combined rates of natural and fishing mortality ($F_t + M_t$), then $X_t > 0$. If mortality exceeds growth, then $X_t < 0$. In either case, with $X_t \neq 0$, average biomass is computed:

$$\overline{B}_t \approx -\frac{\left(1-e^{X_t}\right)B_t}{X_t}$$

When $X_t \neq 0$, the expression for $\overline{B}_t$ is an approximation because G_t approximates the rate of change in mean body weight due to von Bertalanffy growth. However, the approximation is reasonably accurate and preferable to calculating catch biomass in the delay-difference model with the traditional catch equation that ignores growth during the fishing season.[15] Average biomass can be calculated for new recruits, old recruits or for the whole stock by using either G_t^{New}, G_t^{Old} or G_t.

In the KLAMZ model, the modified catch equation may be solved analytically for F_t given C_t, B_t, G_t and M_t (see the "Calculating F_t" section below). Alternatively, fishing mortality rates can be calculated using a log geometric mean parameter (Φ) and a set of annual log scale deviation parameters (ψ_t):

$$F_t = e^{\Phi+\psi_t}$$

where the deviations ψ_t are constrained to average zero. When the catch equation is solved analytically, catches must be assumed known without error but the analytical option is useful when catch is zero or very near zero, or the range of fishing mortality rates is so large (e.g. minimum F=0.000001 to maximum F=3) that numerical problems occur with the alternative approach. The analytical approach is also useful if the user wants to reduce the number of parameters estimated by nonlinear optimization. In any case, the two methods should give the same results for catches known without error.

Surplus production

Annual surplus production is calculated "exactly" by projecting biomass at the beginning of each year forward with no fishing mortality:

$$\mathrm{B}_t^* = (1+\rho)\,\mathrm{e}^{-M}\,\mathrm{B}_t - \rho\,\mathrm{e}^{-M}\,\mathrm{L}_{t-1}\,\mathrm{B}_{t-1} - \rho\,\mathrm{e}^{-M}\,\mathrm{J}_t\,\mathrm{R}_t$$

By definition, surplus production $P_t=B^*_t-B_t$ (Jacobson et al. 2002).

Per recruit modeling

Per recruit model calculations in the Excel version of the KLAMZ simulate the life of a hypothetical cohort of arbitrary size (e.g. R=1000) starting at age k with constant

[14] By convention, the instantaneous rates G_t, F_t and M_t are always expressed as numbers ≥ 0.

[15] The traditional catch equation $C_t = F_t(1-e^{-Z_t})B_t/Z_t$ where $Z_t=F_t+M_t$ underestimates catch biomass for a given level of fishing mortality F_t and overestimates F_t for a given level of catch biomass. The errors can be substantial for fast growing fish, particularly if recent recruitments were strong.

M_t, F (survival) and growth (ρ and J) in a population initially at zero biomass. In the first year:

$$B_1 = R$$

In the second year:

$$B_2 = (1+\rho)\,\tau\, B_1 - \rho\,\tau\, J\, R_1$$

In the third and subsequent years:

$$B_{t+1} = (1+\rho)\,\tau\, B_t - \rho\,\tau^2\, B_{t-1}$$

This iterative calculation is carried out until the sum of lifetime cohort biomass from one iteration to the next changes by less than a small amount (0.0001). Total lifetime biomass, spawning biomass and yield in weight are calculated by summing biomass, spawning biomass and yield over the lifetime of the cohort. Lifetime biomass, spawning biomass and yield per recruit are calculated by dividing totals by initial recruitment (R).

Status determination variables

The user may specify a range of years (e.g. the last three years) to use in calculating recent average fishing mortality $\overline{F}_{\mathrm{Re}\,cent}$ and biomass $\overline{B}_{\mathrm{Re}\,cent}$ levels. These status determination variables are used in calculation of status ratios such as $\overline{F}_{\mathrm{Re}\,cent} / F_{MSY}$ and $\overline{B}_{\mathrm{Re}\,cent}/\mathrm{B_{MSY}}$.

Goodness of Fit and Parameter Estimation

Parameters estimated in the KLAMZ model are chosen to minimize an objective function based on a sum of weighted negative log likelihood (NLL) components:

$$\Xi = \sum_{v=1}^{N_{\Xi}} \lambda_v L_v$$

where N_{Ξ} is the number of NLL components (L_v) and the λ_v are emphasis factors used as weights. The objective function Ξ may be viewed as a NLL or a negative log posterior (NLP) distribution, depending on the nature of the individual L_v components and modeling approach. Except during sensitivity analyses, weighting factors for objective function components (λ_v) are usually set to one. An arbitrarily large weighting factor (e.g. λ_v =1000) is used for "hard" constraints that must be satisfied in the model. Arbitrarily small weighting factors (e.g. λ_v =0.0001) can be used for "soft" model-based constraints. For example, an internally estimated spawner-recruit curve or surplus production curve might be estimated with a small weighting factor to summarize stock-recruit or surplus production results with minimal influence on biomass, fishing mortality and other estimates from the model. Use of a small weighting factor for an internally estimated surplus production or stock-recruit curve is equivalent to fitting a curve to model estimates of biomass and recruitment or surplus production in the output file, after the model is fit (Jacobson et al. 2002).

Likelihood component weights vs. observation-specific weights

Likelihood component weights (λ_v) apply to entire NLL components. Entire components are often computed as the sum of a number of individual NLL terms. The NLL for an entire survey, for example, is composed of NLL terms for each of the annual survey observations. In KLAMZ, observation-specific (for data) or instance-specific (for constraints or prior information) weights (usually w_j for observation or instance j) can be specified as well. Observation-specific weights for a survey, for example, might be use to increase or decrease the importance of one or more observations in calculating goodness of fit.

NLL kernels

NLL components in KLAMZ are generally programmed as "concentrated likelihoods" to avoid calculation of values that do not affect derivatives of the objective function.[16] For x~N(μ,σ^2), the complete NLL for one observation is:

$$L = \ln(\sigma) + \ln\left(\sqrt{2\pi}\right) + 0.5\left(\frac{x-u}{\sigma}\right)^2$$

The constant $\ln\left(\sqrt{2\pi}\right)$ can always be omitted because it does not affect derivatives. If the standard deviation is known or assumed known, then ln(σ) can be omitted as well because it is a constant that does not affect derivatives. In such cases, the concentrated negative log likelihood is:

$$L = 0.5\left(\frac{x-\mu}{\sigma}\right)^2$$

If there are N observations with possible different variances (known or assumed known) and possibly different expected values:

$$L = 0.5\sum_{i=1}^{N}\left(\frac{x_i-\mu_i}{\sigma_i}\right)^2$$

If the standard deviation for a normally distributed quantity is not known and is (in effect) estimated by the model, then one of two equivalent calculations is used. Both approaches assume that all observations have the same variance and standard deviation. The first approach is used when all observations have the same weight in the likelihood:

$$L = 0.5N\ln\left[\sum_{i=1}^{N}(x_i-u)^2\right]$$

where N is the number of observations. The second approach is equivalent but used when the weights for each observation (w_i) may differ:

$$L = \sum_{i=1}^{N} w_i\left[\ln(\sigma) + 0.5\left(\frac{x_i-u}{\sigma}\right)^2\right]$$

In the latter case, the maximum likelihood estimator:

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[16] Unfortunately, concentrated likelihood calculations cannot be used with MCMC and other Bayesian approaches to characterizing posterior distributions. Therefore, in the near future, concentrated NLL calculations will be replaced by calculations for the entire NLL. At present, MCMC calculations in KLAMZ are not useful.

$$\hat{\sigma} = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \hat{x})^2}{N}}$$

(where $\hat{x}$ is the average or predicted value from the model) is used for σ. The maximum likelihood estimator is biased by $N/(N\text{-}d_f)$ where d_f is degrees of freedom for the model. The bias may be significant for small sample sizes but d_f is usually unknown.

Landings, discards, catch

Discards are from external estimates (d_t) supplied by the user. If $d_t \geq 0$, then the data are used as the ratio of discard to landed catch so that:

$$D_t = L_t \Delta_t$$

where $\Delta_t = D_t/L_t$ is the discard ratio. If $d_t < 0$ then the data are treated as discard in units of weight:

$$D_t = abs(d_t).$$

In either case, total catch is the sum of discards and landed catch ($C_t = L_t + D_t$). It is possible to use discards in weight $d_t < 0$ for some years and discard as proportions $d_t > 0$ for other years in the same model run. If catches are estimated (see below) so that the estimated catch $\hat{C}_t$ does not necessarily equal observed landings plus discard, then estimated landings are computed:

$$\hat{L}_t = \frac{\hat{C}_t}{1 + \Delta_t}$$

and estimated discards are:

$$\hat{D}_t = \Delta_t \hat{L}_t.$$

Calculating F_t

As described above, fishing mortality rates may be estimated based on the parameters Φ and ψ_t to satisfy a NLL for observed and predicted catches:

$$L = 0.5 \sum_{t=0}^{N} w_t \left(\frac{\hat{C}_t - C_t}{\kappa_t} \right)^2$$

where the standard error $\kappa_t = CV_{catch} \hat{C}_t$ with CV_{catch} and weights are w_t supplied by the user. The weights can be used, for example, if catch data in some years are less precise than in others. Using observation specific weights, any or every catch in the time series can potentially be estimated.

The other approach to calculating F_t values is by solving the generalized catch equation (see above) iteratively. Subtracting predicted catch from the generalized catch equation gives:

$$g(F_t) = C_t + \frac{F_t(1 - e^{X_t})}{X_t} B_t = 0$$

where $X_t = G_t - M_t - F_t$. If $X_t = 0$, then $\overline{B}_t = B_t$ and $F_t = C_t/B_t$.

If $X_t \neq 0$, then the Newton-Raphson algorithm is used to solve for F_t (Kennedy and Gentle 1980). At each iteration of the algorithm, the current estimate F_t^i is updated using:

$$F_t^{i+1} = F_t^i - \frac{g\left(F_t^i\right)}{g'\left(F_t^i\right)}$$

where $g'\left(F_t^i\right)$ is the derivative F_t^i. Omitting subscripts, the derivative is:

$$g^{'}(F) = -\frac{Be^{-F}\left[\left(e^F - e^{\gamma}\right)\gamma + e^{\gamma}F\gamma - e^{\gamma}F^2\right]}{X^2}$$

where $\gamma = G\text{-}M_t$. Iterations continue until $g\left(F_t^i\right)$ and $abs\left[g\left(F_t^{i+1}\right) - g\left(F_t^{i+1}\right)\right]$ are both less than a small number (e.g. ≤ 0.00001).

Initial values are important in algorithms that solve the catch equation numerically (Sims 1982). If $M_t + F_t > G_t$ so that $X_t < 0$, then the initial value F_t^0 is calculated according to Sims (1982). If $M_t + F_t < G_t$ so that $X_t > 0$, then initial values are calculated based on a generalized version of Pope's cohort analysis (Zhang and Sullivan 1988):

$$F_t^0 = \gamma_t - \ln\left[\frac{\left(B_t e^{0.5\gamma_t} - C_t\right)e^{0.5\gamma_t}}{B_t}\right]$$

F for landings versus F for discards

The total fishing mortality rate for each year can be partitioned into a component due to landed catch ${}^{L}F_t = \frac{D_t}{C_t}F_t$, and a component due to discard ${}^{D}F_t = \frac{L_t}{C_t}F_t$.

Predator consumption as discard data

In modeling population dynamics of prey species, estimates of predator consumption can be treated like discard in the KLAMZ model as a means for introducing time dependent natural mortality. Consider a hypothetical example with consumption data (mt y^{-1}) for three important predators. If the aggregate consumption data are included in the model as "discards", then the fishing mortality rate for discards ${}^{d}F_t$ (see above) would be an estimate of the component of natural mortality due to the three predators. In using this approach, the average level of natural mortality m would normally be reduced (e.g. so that $m_{new} + {}^{d}\overline{F} = m_{old}$) or estimated to account for the portion of natural mortality attributed to bycatch.

Surplus production calculations are harder to interpret if predator consumption is treated as discard data because surplus production calculations assume that F_t=0 (see above) and because surplus production is defined as the change in biomass from one year to the next in the absence of fishing (i.e. no landings or bycatch). However, it may be useful to compare surplus production at a given level of biomass from runs with and without consumption data as a means of estimating maximum changes in potential fishery yield if the selected predators were eliminated (assuming no change in disease, growth rates, predation by other predators, etc.).

Effort calculations

Fishing mortality rates can be tuned to fishing effort data for the "landed" catch (i.e. excluding discards). Years with non-zero fishing effort used in the model must also have landings greater than zero. Assuming that effort data are lognormally distributed, the NLL for fishing effort is:

$$NLL = 0.5\sum_{y=1}^{n_{eff}} w_y \left[\frac{\ln\left(E_y / \hat{E}_y\right)}{\sigma}\right]^2$$

where w_y is an observation-specific weight, n_{eff} is the number of active effort observations (i.e. with $w_y > 0$), E_y and $\overline{E}_y$ are observed and predicted fishing effort data, and the log scale variance σ is a constant calculated from a user-specified CV.

Predicted fishing effort data are calculated:

$$\hat{E}_y = \zeta F_y^{\vartheta}$$

where $\zeta = e^u$, $\vartheta = e^b$, and u and b are parameters estimated by the model. If the parameter b is not estimated, then ϑ=1 so that the relationship between fishing effort and fishing mortality is linear. If the parameter b is estimated, then $\vartheta \neq 1$ and the relationship is a power function.

Predator data as fishing effort

As described under "Predator consumption as discard data", predator consumption data can be treated as discard. If predator abundance data are available as well, and assuming that mortality due predators is a linear function of the predator-prey ratio, then both types of data may be used together to estimate natural mortality. The trick is to: 1) enter the predator abundance data as fishing effort; 2) enter the actual fishery landings as "discard"; 3) enter predator consumption estimates of the prey species as "landings" so that the fishing effort data in the refer to the predator consumption data; 4) use an option in the model to calculate the predator-prey ratio for use in place of the original predator abundance "fishing effort" data; and 5) tune fishing mortality rates for landings (a.k.a. predator consumption) to fishing effort (a.k.a. predator-prey ratio).

Given the predator abundance data κ_y, the model calculates the predator-prey ratio used in place of fishing effort data (E_y) as:

$$E_y = \frac{\kappa_y}{B_y}$$

where B_y is the model's current estimate of total (a.k.a "prey") biomass. Subsequent calculations with E_y and the model's estimates of "fishing mortality" (F_y, really a measure of natural mortality) are exactly as described above for effort data. In using this approach, it is probably advisable to reduce m (the estimate of average mortality in the model) to account for the proportion of natural mortality due to predators included in the calculation. Based on experience to date, natural mortality due to consumption by the suite of predators can be estimated but only if m is assumed known.

Initial population age structure

In the KLAMZ model, old and new recruit biomass during the first year (R_1 and $S_1 = B_1 - R_1$) and biomass prior to the first year (B_0) are estimated as log scale parameters. Survival in the year prior to the first year ("year 0") is $\tau_0 = e^{-F_0 - M_1}$ with F_0 chosen to obtain catch C_0 (specified as data) from the estimated biomass B_0. IGRs during year 0 and year 1 are assumed equal ($G_0 = G_1$) in catch calculations.

Biomass in the second year of as series of delay-difference calculations depends on biomass (B_0) and survival (τ_0) in year 0:

$$\mathrm{B}_2 = (1+\rho)\,\tau_1\,\mathrm{B}_1 - \rho\,\tau_1\,\tau_0\,\mathrm{B}_0 + \mathrm{R}_2 - \rho\,\tau_1\,\mathrm{J}_1\,\mathrm{R}_1$$

There is, however, there is no direct linkage between B_0 and escapement biomass ($S_1 = B_1 - R_1$) at the beginning of the first year.

The missing link between B_0, S_1 and B_1 means that the parameter for B_0 tends to be relatively free and unconstrained by the underlying population dynamics model. In some cases, B_0 can be estimated to give good fit to survey and other data, while implying unreasonable initial age composition and surplus production levels. In other cases, B_0 estimates can be unrealistically high or low implying, for example, unreasonably high or low recruitment in the first year of the model (R_1). Problems arise because many different combinations of values for R_1, S_1 and B_0 give similar results in terms of goodness of fit. This issue is common in stock assessment models that use forward simulation calculations because initial age composition is difficult to estimate. It may be exacerbated in delay-difference models because age composition data are not used.

The KLAMZ model uses two constraints to help estimate initial population biomass and initial age structure.[17] The first constraint links IGRs for escapement (G^{Old}) in the first years to a subsequent value. The purpose of the constraint is to ensure consistency in average growth rates (and implicit age structure) during the first few years. For example, if IGRs for the first n_G years are constrained[18], then the NLL for the penalty is:

$$L_G = 0.5 \sum_{t=1}^{n_G} \left[\frac{\ln\left(G_t^{Old} \big/ G_{n_G+1}^{Old} \right)}{\sigma_G} \right]^2$$

where the standard deviation σ_G is supplied by the user. It is usually possible to use the standard deviation of Q_t^{Old} for later years from a preliminary run to estimate σ_G for the first few years. The constraint on initial IGRs should probably be "soft" and non-binding ($\lambda \approx 1$) because there is substantial natural variation in somatic growth rates due to variation in age composition.

The second constraint links B_0 to S_1 and ensures conservation of mass in population dynamics between years 0 and 1. In other words, the parameter for escapement biomass in year 1 is constrained to match an approximate projection of the biomass in year 0, accounting for growth, and natural and fishing mortality. The constraint is intended to be binding and satisfied exactly (e.g. $\lambda = 1000$) because incompatible values of S_1 and B_0 are biologically impossible. In calculations:

[17] Quinn and Deriso (1999) describe another approach attributed to a manuscript by C. Walters.

[18] Normally, $n_G \leq 2$.

$$S_1^p = B_0 e^{G_1 - F_0 - M_1}$$

where S_1^p is the projected escapement in year 1 and B_0 is the model's estimate of total biomass in year 0. The instantaneous rates for growth and natural mortality from year 1 (G_1 and M_1) are used in place of G_0 and M_0 because the latter are unavailable. The NLL for the constraint:

$$L = \left[\ln \left(\frac{S_1^p}{S_1} \right)^2 \right]^2 + \left(S_1^p - S_1 \right)^2$$

uses a log scale sum of squares and an arithmetic sum of squares. The former is effective when S_1 is small while the latter is effective when S_1 is large. Constants and details in calculation of NLL for the constraint are not important because the constraint is binding (e.g. λ=1000).

Equilibrium pristine biomass

It may be useful to constrain the biomass estimate for the first year in a model run towards an estimate of equilibrium pristine biomass if, for example, stock dynamics tend to be stable and catch data are available for the first years of the fishery, or as an alternative to the approach described above for initializing the age structure of the simulated population in the model. Equilibrium pristine biomass $\widetilde{B}_0$ is calculated based on the model's estimate of average recruitment and with no fishing mortality (calculations are similar to those described under "Per-recruit modeling" except that average recruitment is assumed in each year).[19] The NLL term for the constraint is:

$$L = \ln \left(\frac{\widetilde{B}_0}{B_0} \right)^2$$

Pristine equilibrium biomass is used as a hard constraint with a high emphasis factor (λ) so that the variance and constants normally used in NLL calculations are not important.

Estimating natural mortality

As described above, natural mortality calculations involve a parameter for the geometric mean value (m) and time dependent deviations (ϖ_t, which may or may not be turned on). Constraints on natural mortality process errors and natural mortality covariates can be used to help estimate the time dependent deviations and overall trend. The geometric mean natural mortality rate is usually difficult to estimate and best treated as a known constant. However, in the C++ version of the KLAMZ model, $m=e^{\pi}$ (where π is an estimable parameter in the model) and estimates of m can be conditioned on the constraint:

$$L = 0.5 \left[\frac{\ln \left(w / w_{Target} \right)}{\sigma_{\varpi}} \right]^2$$

[19] Future versions of the KLAMZ model will allow equilibrium initial biomass to be calculated based on other recruitment values and for a user-specified level of F (Butler et al. 2003).

where w_{Target} is a user supplied mean or target value and σ_{ϖ} is a log scale standard deviation. The standard deviation is calculated from an arithmetic scale CV supplied by the user. Upper and lower bounds for m may be specified as well.

Goodness of fit for trend data

Assuming lognormal errors[20], the NLL used to measure goodness-of-fit to "survey" data that measure trends in abundance or biomass (or survival, see below) is:

$$L = 0.5 \sum_{j=1}^{N_v} \left[\frac{\ln\left(I_{v,j} \big/ \hat{I}_{v,j} \right)}{\sigma_{v,j}} \right]^2$$

where $I_{v,t}$ is an index datum from survey v, hats "^" denote model estimates, $\sigma_{v,j}$ is a log scale standard error (see below), and N_v is the number of observations. There are two approaches to calculating standard errors for log normal abundance index data in KLAMZ and it is possible to use different approaches for different types of abundance index data in the same model (see below).

Standard errors for goodness of fit

In the first approach, all observations for one type of abundance index share the same standard error, which is calculated based on overall goodness of fit. This approach implicitly estimates the standard error based on goodness of fit, along with the rest of the parameters in the model (see "NLL kernels" above).

In the second approach, each observation has a potentially unique standard error that is calculated based on its CV. The second approach calculates log scale standard errors from arithmetic CVs supplied as data by the user (Jacobson et al. 1994):

$$\sigma_{v,t} = \sqrt{\ln\left(1 + CV_{v,t}^2\right)}$$

Arithmetic CV's are usually available for abundance data. It may be convenient to use $CV_{v,t}$=1.31 to get $\sigma_{v,t}$=1.

There are advantages and disadvantages to both approaches. CV's carry information about the relative precision of abundance index observations. However, CV's usually overstate the precision of data as a measure of fish abundance[21] and may be misleading in comparing the precision of one sort of data to another as a measure of trends in abundance (e.g. in contrasting standardized LPUE that measure fishing success, but not abundance, precisely with survey data that measure trends in fish abundance

[20] Abundance indices with statistical distributions other than log normal may be used as well, but are not currently programmed in the KLAMZ model. For example, Butler et al. (2003) used abundance indices with binomial distributions in a delay-difference model for cowcod rockfish. The next version of KLAMZ will accommodate presence-absence data with binomial distributions.

[21] The relationship between data and fish populations is affected by factors (process errors) that are not accounted for in CV calculations.

directly, but not precisely). Standard errors estimated implicitly are often larger and more realistic, but assume that all observations in the same survey are equally reliable.

Predicted values for abundance indices

Predicted values for abundance indices are calculated:

$$\hat{I}_{v,t} = Q_v A_{v,t}$$

where Q_v is a survey scaling parameter (constant here but see below) that converts units of biomass to units of the abundance index. $A_{v,t}$ is available biomass at the time of the survey.

In the simplest case, available biomass is:

$$A_{v,t} = s_{v,New} R_t e^{-X_t^{New}\Delta_{v,t}} + s_{v,Old} S_t e^{-X_t^{Old}\Delta_{v,t}}$$

where $s_{v,New}$ and $s_{v,Old}$ are survey selectivity parameters for new recruits (R_t) and old recruits (S_t); $X_t^{New} = G_t^{New} - F_t - M_t$ and $X_t^{Old} = G_t^{Old} - F_t - M_t$; $j_{v,t}$ is the Julian date at the time of the survey, and $\Delta_{v,t}=j_{v,t}/365$ is the fraction of the year elapsed at the time of the survey.

Survey selectivity parameter values ($s_{v,New}$ and $s_{v,Old}$) are specified by the user and must be set between zero and one. For example, a survey for new recruits would have $s_{v,New}$=1 and $s_{v,Old}$=0. A survey that measured abundance of the entire stock would have $s_{v,New}$=1 and $s_{v,Old}$=1.

Terms involving $\Delta_{v,t}$ are used to project beginning of year biomass forward to the time of the survey, making adjustments for mortality and somatic growth.[22] As described below, available biomass $A_{v,t}$ is adjusted further for nonlinear surveys, surveys with covariates and surveys with time variable $Q_{v,t}$.

Scaling parameters (Q) for log normal abundance data

Scaling parameters for surveys with lognormal statistical errors were computed using the maximum likelihood estimator:

$$Q_v = e^{\frac{\sum_{i=1}^{N_v}\left[\ln\left(\frac{I_{v,i}}{A_{v,i}}\right) \big/ \sigma^2_{v,j}\right]}{\sum_{j=1}^{N_j}\left(1 \big/ \sigma^2_{v,j}\right)}}$$

where N_v is the number of observations with individual weights greater than zero. The closed form maximum likelihood estimator gives the same answer as if scaling parameters are estimated as free parameters in the assessment model assuming lognormal survey measurement errors.

[22] It may be important to project biomass forward if an absolute estimate of biomass is available (e.g. from a hydroacoustic or daily egg production survey), if fishing mortality rates or high or if the timing of the survey varies considerably from year to year.

Survey covariates

Survey scaling parameters may vary over time based on covariates in the KLAMZ model. The survey scaling parameter that measures the relationship between available biomass and survey data becomes time dependent:

$$\hat{I}_{v,t} = Q_{v,t} A_{v,t}$$

and

$$Q_{v,t} = Q_v e^{\sum_{r=1}^{n_v} d_{r,t} \theta_r}$$

with n_v covariates for the survey and parameters θ_r estimated in the model. Covariate effects and available biomass are multiplied to compute an adjusted available biomass:

$$A'_{v,t} = A_{v,t} e^{\sum_{r=1}^{n_v} d_{r,t} \theta_r}$$

The adjusted available biomass $A'_{v,t}$ is used instead of the original value $A_{v,t}$ in the closed form maximum likelihood estimator described above.

Covariates might include, for example, a dummy variable that represents changes in survey bottom trawl doors or a continuous variable like average temperature data if environmental factors affect distribution and catchability of fish schools. Dummy variables are usually either 0 or 1, depending on whether the effect is present in a particular year. With dummy variables, Q_v is the value of the survey scaling parameter with no intervention ($d_{r,t}$=0).

For ease in interpretation of parameter estimates for continuous covariates (e.g. temperature data), it is useful to center covariate data around the mean:

$$d_{r,t} = d'_{r,t} - \overline{d'_r}$$

where $d'_{r,t}$ is the original covariate. When covariates are continuous and mean-centered, Q_v is the value of the survey scaling parameter under average conditions ($d_{r,t}$=0) and units for the covariate parameter are easy to interpret (for example, units for the parameter are $1/{}^{o}C$ if the covariate is mean centered temperature in ^{o}C).

It is possible to use a survey covariate to adjust for differences in relative stock size from year to year due to changes in the timing of a survey. However, this adjustment may be made more precisely by letting the model calculate $\Delta_{v,t}$ as described above, based on the actual timing data for the survey during each year.

Nonlinear abundance indices

With nonlinear abundance indices, and following Methot (1990), the survey scaling parameter is a function of available biomass:

$$Q_{v,t} = Q_v A^{\Gamma}_{v,t}$$

so that:

$$\hat{I}_{v,t} = \left(Q_v A^{\Gamma}_{v,t}\right) A_{v,t}$$

Substituting $e^{\gamma}=\Gamma+1$ gives the equivalent expression:

$$\hat{I}_{v,t} = Q_v A_{v,t}^{e^{\gamma}}$$

where γ is a parameter estimated by the model and the survey scaling parameter is no longer time dependent. In calculations with nonlinear abundance indices, the adjusted available biomass:

$$A'_{v,t} = A_{v,t}^{e^{\gamma}}$$

is computed first and used in the closed form maximum likelihood estimator described above to calculate the survey scaling parameter. In cases where survey covariates are also applied to a nonlinear index, the adjustment for nonlinearity is carried out first.

Survey Q process errors

The C++ version of the KLAMZ model can be used to allow survey scaling parameters to change in a controlled fashion from year to year (NEFSC 2002):

$$Q_{v,t} = Q_v e^{\varepsilon_{v,t}}$$

where the deviations $\varepsilon_{v,t}$ are constrained to average zero. Variation in survey Q values is controlled by the NLL penalty:

$$L = 0.5 \sum_{j=1}^{N_v} \left[\frac{\varepsilon_{v,j}}{\sigma_v} \right]^2$$

where the log scale standard deviation σ_v based on an arithmetic CV supplied by the user (e.g. see NEFSC 2002). In practice, the user increases or decreases the amount of variability in Q by decreasing or increasing the assumed CV.

Survival ratios as surveys

In the C++ version of KLAMZ, it is possible to use time series of survival data as "surveys". For example, an index of survival might be calculated using survey data and the Heinke method (Ricker 1975) as:

$$A_t = \frac{I_{k+1,t+1}}{I_{k,t}}$$

so that the time series of A_t estimates are data that may potentially contain information about scale or trends in survival. Predicted values for a survival index are calculated:

$$\hat{A}_t = e^{-Z_t}$$

After predicted values are calculated, survival ratio data are treated in the same way as abundance data (in particular, measurement errors are assumed to be lognormal). Selectivity parameters are ignored for survival data but all other features (e.g. covariates, nonlinear scaling relationships and constraints on Q) are available.

Recruitment models

Recruitment parameters in KLAMZ may be freely estimated or estimated around an internal recruitment model, possibly involving spawning biomass. An internally estimated recruitment model can be used to reduce variability in recruitment estimates (often necessary if data are limited), to summarize stock-recruit relationships, or to make use of information about recruitment in similar stocks. There are four types of internally estimated recruitment models in KLAMZ: 1) random variation around a constant mean; 2) random walk around a constant mean (autocorrelated variation); 3) random variation around a Beverton-Holt recruitment model; and 4) random variation around a Ricker recruitment model. The user must specify a type of recruitment model but the model is not active unless the likelihood component for the recruitment model is turned on ($\lambda > 0$).

The first step in recruit modeling is to calculate the expected log recruitment level $E[ln(R_t)]$ given the recruitment model. For random variation around a constant mean, the expected log recruitment level is the log geometric mean recruitment:

$$E\left[\ln\left(R_t\right)\right] = \sum_{j=1}^{N} \ln\left(R_j\right) \Big/ N$$

For a random walk around a constant mean recruitment, the expected log recruitment level is the logarithm of recruitment during the previous year:

$$E\left[\ln\left(R_t\right)\right] = \ln\left(R_{t-1}\right)$$

with no constraint on recruitment during the first year R_1.

For the Beverton-Holt recruitment model, the expected log recruitment level is:

$$E\left[\ln\left(R_t\right)\right] = \ln\left[e^{a} T_{t-\ell} \Big/ \left(e^{b} + T_{t-\ell}\right)\right]$$

where $a=e^{\alpha}$ and $b=e^{\beta}$, the parameters α and β are estimated in the model, T_t is spawning biomass, and ℓ is the lag between spawning and recruitment. Spawner-recruit parameters are estimated as log transformed values (e^{α} and e^{β}) to enhance model stability and ensure the correct sign of values used in calculations. Spawning biomass is:

$$T_t = m_{new} R_t + m_{old} S_t$$

where m_{new} and m_{old} are maturity parameters for new and old recruits specified by the user. For the Ricker recruitment model, the expected log recruitment level is:

$$E\left[\ln\left(R_t\right)\right] = \ln\left(S_{t-\ell} e^{a - bS_{t-\ell}}\right)$$

where $a=e^{\alpha}$ and $b=e^{\beta}$, and the parameters α and β are estimated in the model.

Given the expected log recruitment level, log scale residuals for the recruitment model are calculated:

$$r_t = \ln\left(R_t\right) - E\left[\ln\left(R_t\right)\right]$$

Assuming that residuals are log normal, the NLL for recruitment residuals is:

$$L = \sum_{t=t_{first}}^{N} w_t \left[\ln(\sigma_r) + 0.5 \left(r_t / \sigma_r \right)^2 \right]$$

where λ_t is an instance-specific weight usually set equal one. The additional term in the NLL [$ln(\sigma_r)$] is necessary because the variance σ_r^2 is estimated internally, rather than specified by the user.

The log scale variance for residuals is calculated using the maximum likelihood estimator:

$$\sigma_r^2 = \frac{\sum_{j=t_{first}}^{N} r_j}{N}$$

where N is the number of residuals. For the recruitment model with constant variation around a mean value, t_{first}=1. For the random walk recruitment model, t_{first}=2. For the Beverton-Holt and Ricker models, $t_{first}=\ell+1$ and the recruit model imposes no constraint on variability of recruitment during years 1 to ℓ (see below). The biased maximum likelihood estimate for σ^2 (with N in the divisor instead of the degrees of freedom) is used because actual degrees of freedom are unknown. The variance term σ^2 is calculated explicitly and stored because it is used below.

Constraining the first few recruitments

It may be useful to constrain the first ℓ years of recruitments when using either the Beverton-Holt or Ricker models if the unconstrained estimates for early years are erratic. In the KLAMZ model, this constraint is calculated:

$$NLL = \sum_{t=1}^{t_{first}-1} w_t \left\{ \ln(\sigma_r + 0.5 \left[\frac{\ln\left(R_t / E\left(R_{t_{first}}\right)\right)}{\sigma_r} \right]^2 \right\}$$

where t_{first} is the first year for which expected recruitment $E(R_l)$ can be calculated with the spawner-recruit model. In effect, recruitments that not included in spawner-recruit calculations are constrained towards the first spawner-recruit prediction. The standard deviation is the same as used in calculating the NLL for the recruitment model.

Prior information about abundance index scaling parameters (Q)

A constraint on one or more scaling parameters (Q_v) for abundance or survival indices may be useful if prior information is available (e.g. NEFSC 2000; NEFSC 2001; NEFSC 2002). In the Excel version, it is easy to program these (and other) constraints in an *ad-hoc* fashion as they are needed. In the AD Model Builder version, log normal and beta distributions are preprogrammed for use in specifying prior information about Q_v for any abundance or survival index.

The user must specify which surveys have prior distributions, minimum and maximum legal bounds (q_{min} and q_{max}), the arithmetic mean $(\bar{q})$ and the arithmetic CV for the prior the distribution. Goodness of fit for Q_v values outside the bounds (q_{min}, q_{max}) are calculated:

$$L = \begin{vmatrix} 10000\,(Q_v - q_{\max})^2 \text{ if } Q_v \geq q_{\max} \\ 10000\,(q_{\min} - Q_v)^2 \text{ if } Q_v \leq q_{\min} \end{vmatrix}$$

Goodness of fit for Q_v values inside the legal bounds depend on whether the distribution of potential values is log normal or follows a beta distribution.

Lognormal case

Goodness of fit for lognormal Q_v values within legal bounds is:

$$L = 0.5\left[\frac{\ln(Q_v) - \tau}{\varphi}\right]^2$$

where the log scale standard deviation $\varphi = \sqrt{\ln(1 + CV)}$ and $\tau = \ln(\bar{q}) - \frac{\varphi^2}{2}$ is the mean of the corresponding log normal distribution.

Beta distribution case

The first step in calculation goodness of fit for Q_v values with beta distributions is to calculate the mean and variance of the corresponding "standardized" beta distribution:

$$\bar{q}' = \frac{\bar{q} - q_{\min}}{D}$$

and

$$Var(q') = \left(\frac{\bar{q}\;CV}{D}\right)^2$$

where the range of the standardized beta distribution is $D = q_{max} - q_{min}$. Equating the mean and variance to the estimators for the mean and variance for the standardized beta distribution (the "method of moments") gives the simultaneous equations:

$$\bar{q}' = \frac{a}{a+b}$$

and

$$Var(q') = \frac{ab}{(a+b)^2(a+b+1)}$$

where a and b are parameters of the standardized beta distribution.[23] Solving the simultaneous equations gives:

$$b = \frac{(\bar{q}' - 1)\left[Var(q') + (\bar{q}' - 1)\bar{q}'\right]}{Var(q')}$$

and:

$$a = \frac{b\bar{q}'}{1 - \bar{q}'}$$

Goodness of fit for beta Q_v values within legal bounds is calculated with the NLL:

[23] If x has a standardized beta distribution with parameters a and b, then the probability of x is

$$P(x) = \frac{x^{a-1}(1-x)^{b-1}}{\Gamma(a,b)}.$$

$$L = (a-1)\ln(Q'_v) + (b-1)\ln(1-Q'_v)$$

where $Q'_v = Q_v / (Q_v - q_{\min})$ is the standardized value of the survey scaling parameter Q_v.

Surplus production modeling

Surplus production models can be fit internally to biomass and surplus production estimates in the model (Jacobson et al. 2002). Models fit internally can be used to constrain estimates of biomass and recruitment, to summarize results in terms of surplus production, or as a source of information in tuning the model. The NLL for goodness of fit assumes normally distributed process errors in the surplus production process:

$$L = 0.5 \sum_{j=1}^{N_P} \left(\frac{\widetilde{P}_j - P_j}{\sigma} \right)^2$$

where N_p is the number of surplus production estimates (number of years less one), $\widetilde{P}_t$ is a predicted value from the surplus production curve, P_t is the assessment model estimate, and the standard deviation σ is supplied by the user based, for example, on preliminary variances for surplus production estimates.[24] Either the symmetrical Schaefer (1957) or asymmetric Fox (1970) surplus production curve may be used to calculate $\widetilde{P}_t$ (Quinn and Deriso 1999).

It may be important to use a surplus production curve that is compatible with recruitment patterns or assumptions about the underlying spawner-recruit relationship. More research is required, but the asymmetric shape of the Fox surplus production curve appears reasonably compatible with the assumption that recruitment follows a Beverton-Holt spawner-recruit curve (Mohn and Black 1998). In contrast, the symmetric Schaefer surplus production model appears reasonably compatible with the assumption that recruitment follows a Ricker spawner-recruit curve.

The Schaefer model has two log transformed parameters that are estimated in KLAMZ:

$$\widetilde{P}_t = e^{\alpha} B_t - e^{\beta} B_t^2$$

The Fox model also has two log transformed parameters:

$$\widetilde{P}_t = -e\left(e^{e^{\alpha}}\right) \frac{B_t}{e^{\beta}} \log\left(\frac{B_t}{e^{\beta}} \right)$$

See Quinn and Deriso (1999) for formulas used to calculate reference points (F_{MSY}, B_{MSY}, MSY, and K) for both surplus production models.

Catch/biomass

[24] Variances in NLL for surplus production-biomass models are a subject of ongoing research. The advantage in assuming normal errors is that negative production values (which occur in many stocks, e.g. Jacobson et al. 2001) are accommodated. In addition, production models can be fit easily by linear regression of P_t on B_t and B_t^2 with no intercept term. However, variance of production estimate residuals increases with predicted surplus production. Therefore, the current approach to fitting production curves in KLAMZ is not completely satisfactory.

Forward simulation models like KLAMZ may tend to estimate absurdly high fishing mortality rates, particularly if data are limited. The likelihood constraint used to prevent this potential problem is:

$$L = 0.5\sum_{t=0}^{N}\left(d_t^2 + q^2\right)$$

where:

$$d_t = \left| \begin{array}{c} Ft - \Phi \ \textit{if} \ Ft > \Phi \\ 0 \ \textit{otherwise} \end{array} \right.$$

and

with the threshold value κ normally set by the user to about 0.95. Values for κ can be linked to maximum F values using the modified catch equation described above. For example, to use a maximum fishing mortality rate of about $F \approx 4$ with M=0.2 and G=0.1 (maximum X=4+0.2-0.1=4.1), set $\kappa \approx F/X(1-e^{-X})$=4 / 4.1 (1-e^{-4})=0.96.

Uncertainty

The AD Model Builder version of the KLAMZ model automatically calculates variances for parameters and quantities of interest (e.g. R_t, F_t, B_t, F_{MSY}, B_{MSY}, $\overline{F}_{\text{Re}\,cent}$, $\overline{B}_{\text{Re}\,cent}$, $\overline{F}_{\text{Re}\,cent}/F_{MSY}$, $\overline{B}_{\text{Re}\,cent}/B_{MSY}$, etc.) by the delta method using exact derivatives. If the objective function is the log of a proper posterior distribution, then Markov Chain Monte Carlo (MCMC) techniques implemented in AD Model Builder libraries can be used estimate posterior distributions representing uncertainty in the same parameters and quantities.[25]

Bootstrapping

A FORTRAN program called BootADM can be used to bootstrap survey and survival index data in the KLAMZ model. Based on output files from a "basecase" model run, BootADM extracts standardized residuals:

$$r_{v,j} = \frac{\ln\left(I_{v,j} \big/ \hat{I}_{v,j} \right)}{\sigma_{v,j}}$$

along with log scale standard deviations ($\sigma_{v,j}$, originally from survey CV's or estimated from goodness of fit), and predicted values $\left(\hat{I}_{v,j}\right)$ for all active abundance and survival observations. The original standardized residuals are pooled and then resampled (with replacement) to form new sets of bootstrapped survey "data":

$${}^{x}I_{v,j} = \hat{I}_{v,j} e^{r\sigma_{v,j}}$$

where r is a resampled residual. Residuals for abundance and survival data are combined in bootstrap calculations. BootADM builds new KLAMZ data files and runs the KLAMZ model repetitively, collecting the bootstrapped parameter and other estimates at each iteration and writing them to a comma separated text file that can be processed in

[25] MCMC calculations are not available in the current version because objective function calculations use concentrated likelihood formulas. However, the C++ version of KLAMZ is programmed in other respects to accommodate Bayesian estimation.

Excel to calculate bootstrap variances, confidence intervals, bias estimates, etc. for all parameters and quantities of interest (Efron 1982).

Projections

Stochastic projections can be carried out using another FORTRAN program called SPROJDDF based on bootstrap output from BootADM. Basically, bootstrap estimates of biomass, recruitment, spawning biomass, natural and fishing mortality during the terminal years are used with recruit model parameters from each bootstrap run to start and carryout projections.[26] Given a user-specified level of catch or fishing mortality, the delay-difference equation is used to project stock status for a user-specified number of years. Recruitment during each projected year is based on simulated spawning biomass, log normal random numbers, and spawner-recruit parameters (including the residual variance) estimated in the bootstrap run. This approach is similar to carrying out projections based on parameters and state variables sampled from a posterior distribution for the basecase model fit. It differs from most current approaches because the spawner-recruit parameters vary from projection to projection.

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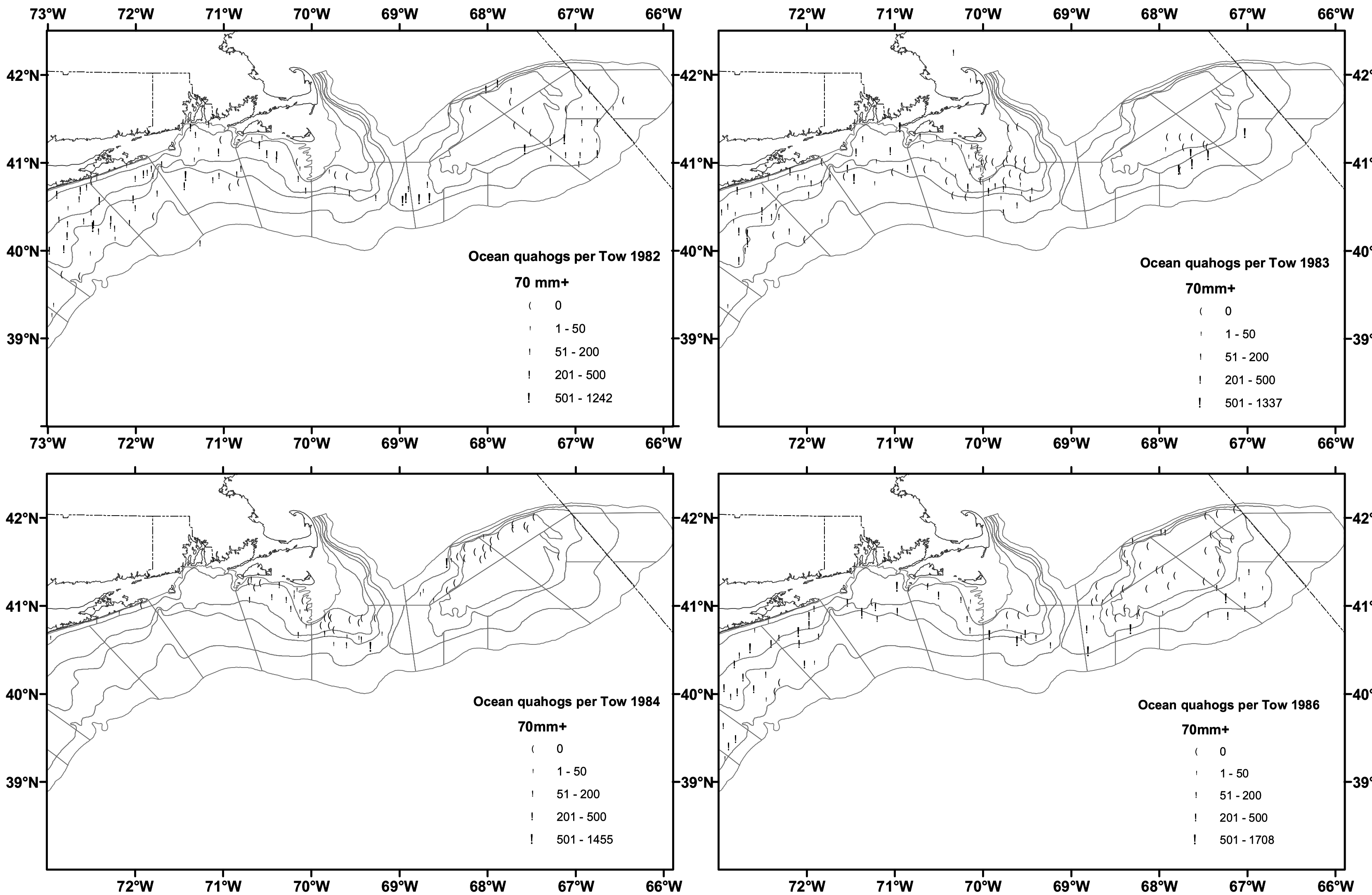
APPENDIX A6. Location and size of northern ocean quahog (70+ mm SL) survey catches between Georges Bank and Long Island, 1982-2005.



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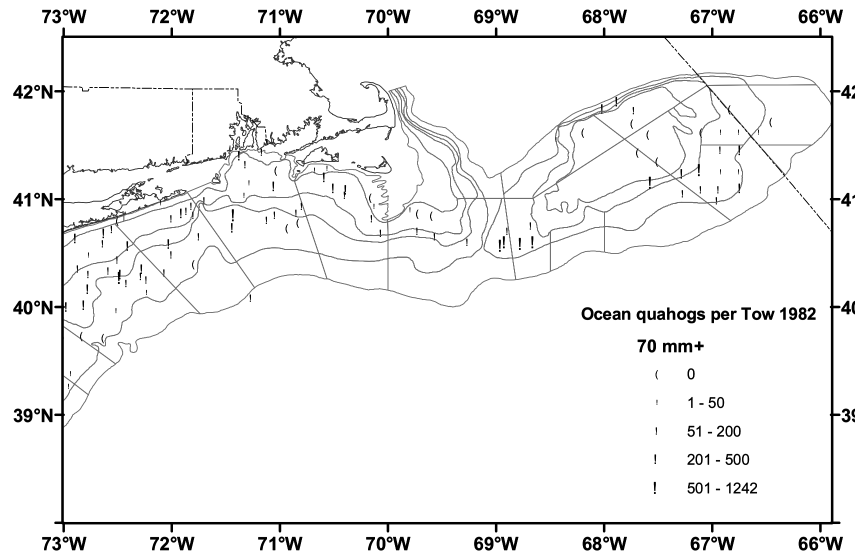

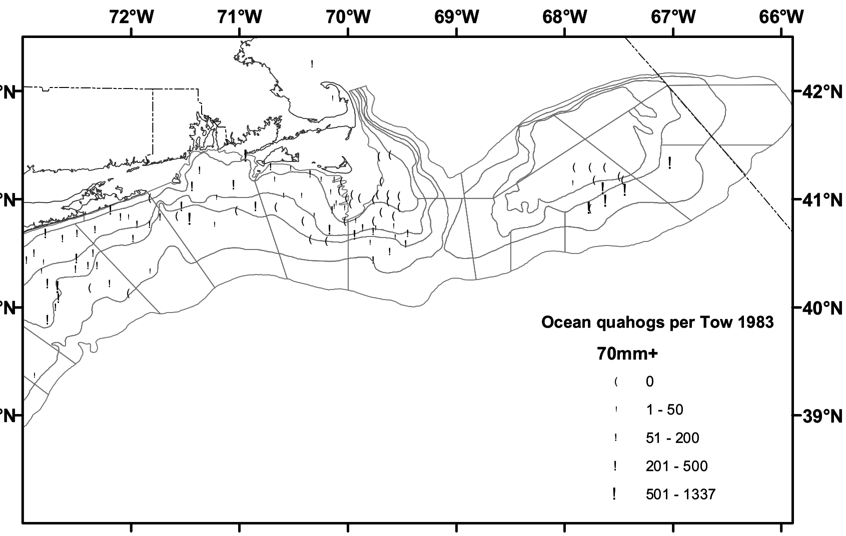

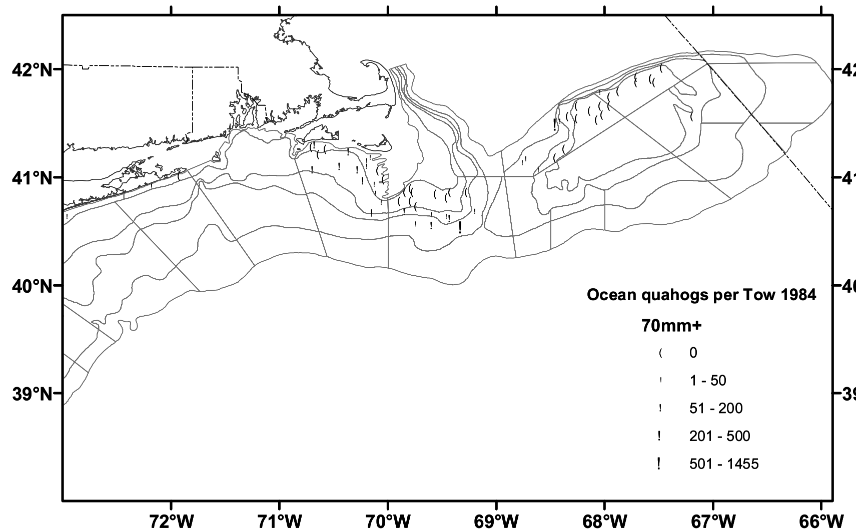

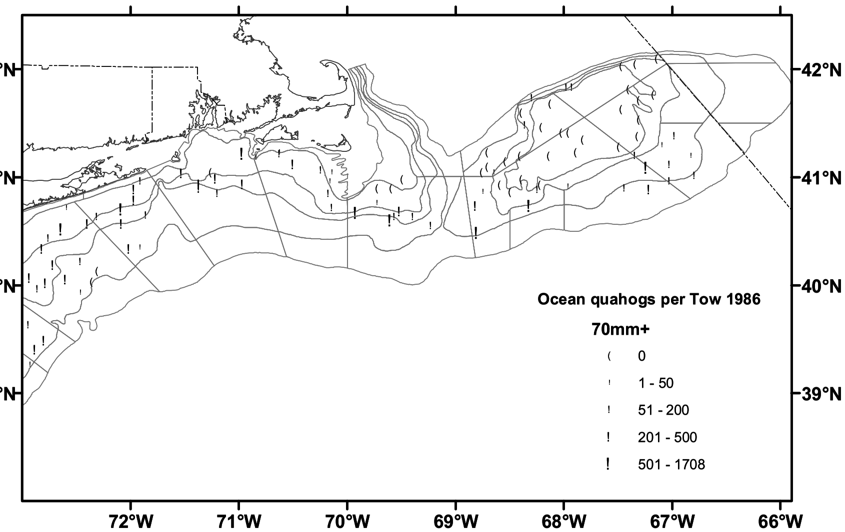

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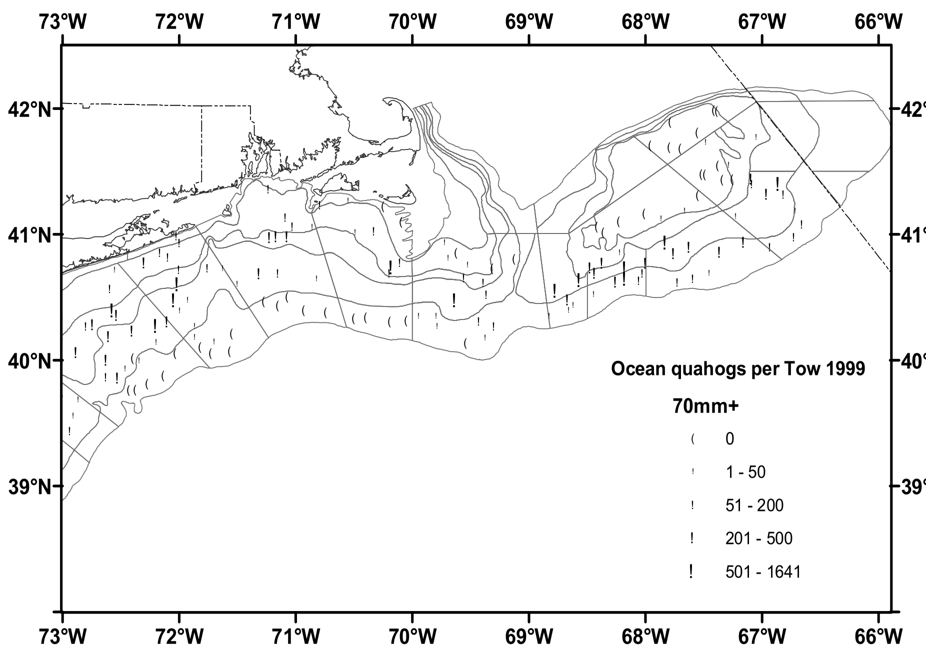
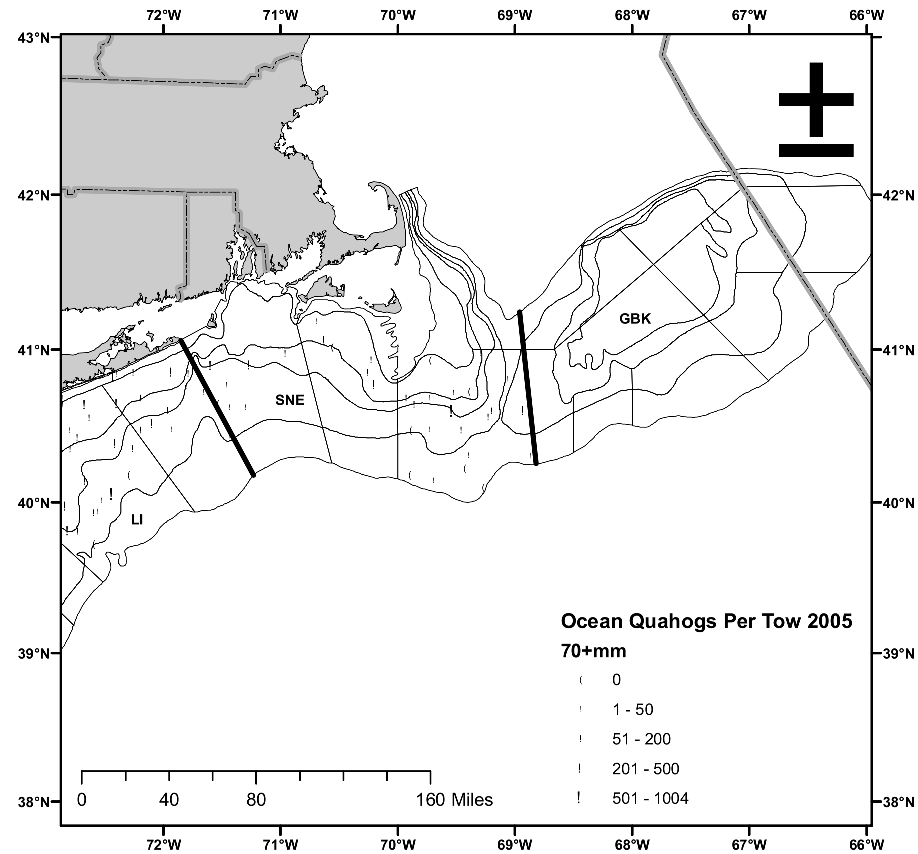
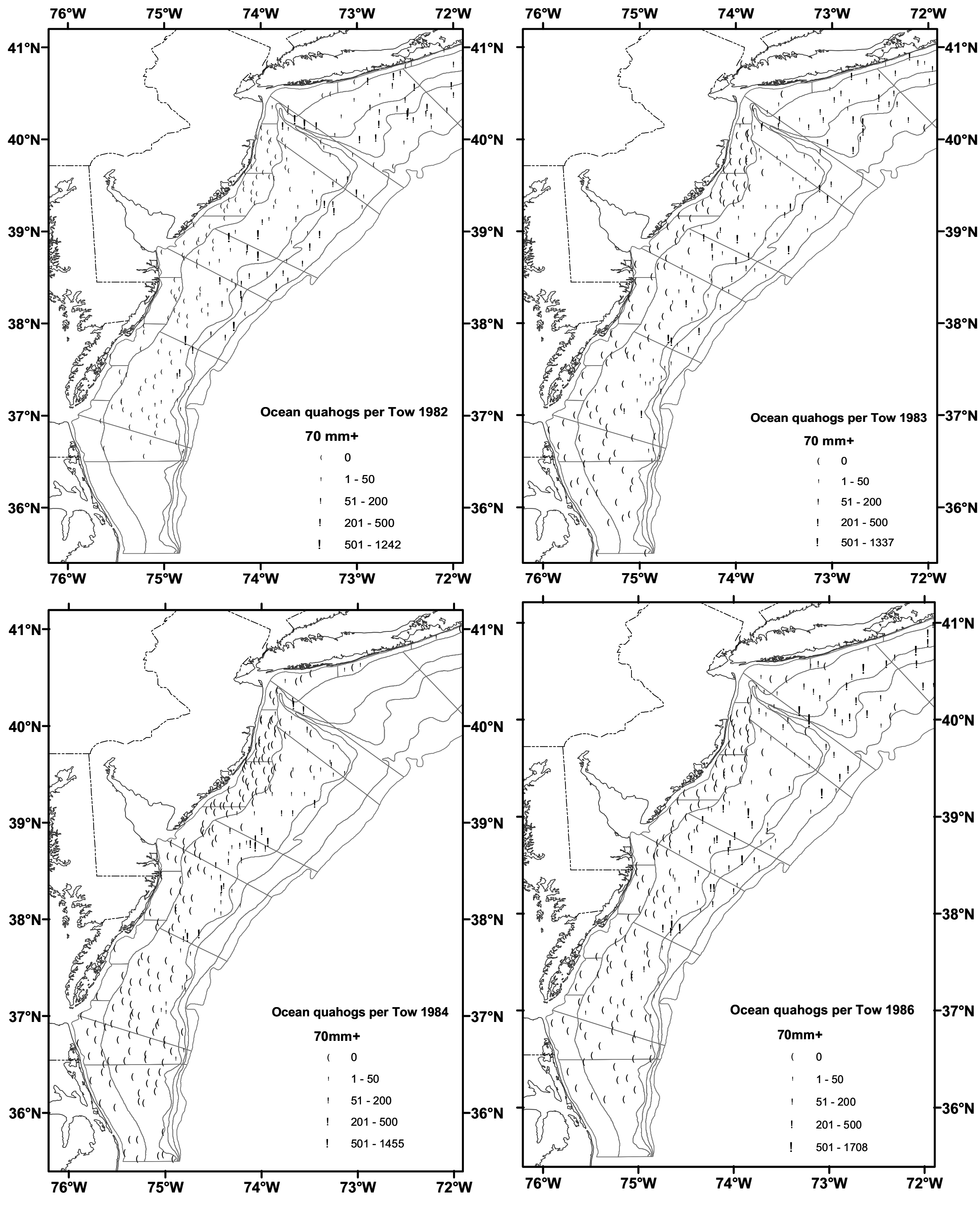




Appendix A6. (cont.)

APPENDIX A7. Location and size of Mid-Atlantic ocean quahog (70+ mm SL) catches. Mid-Atlantic Bight, 1982-2005.



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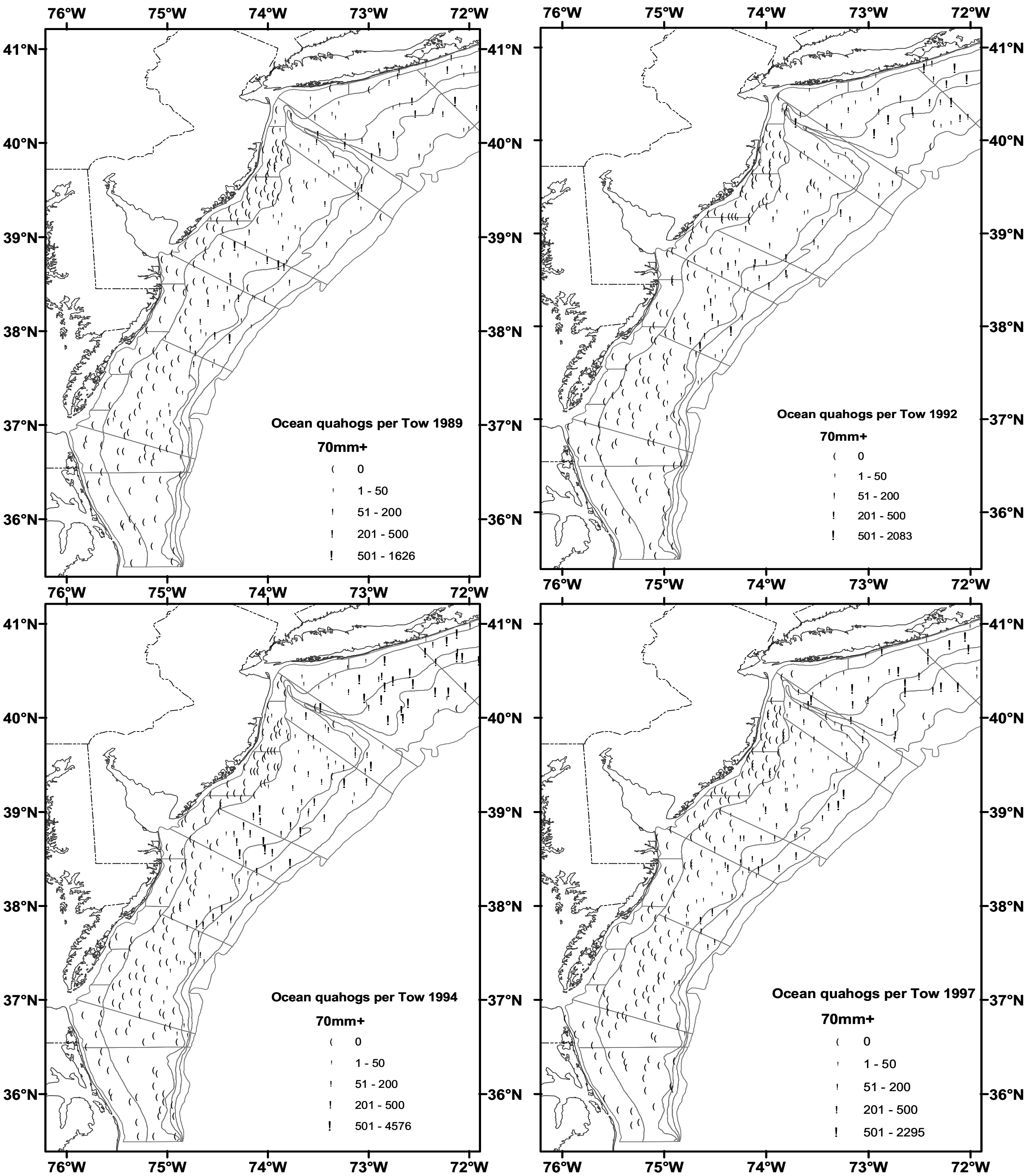

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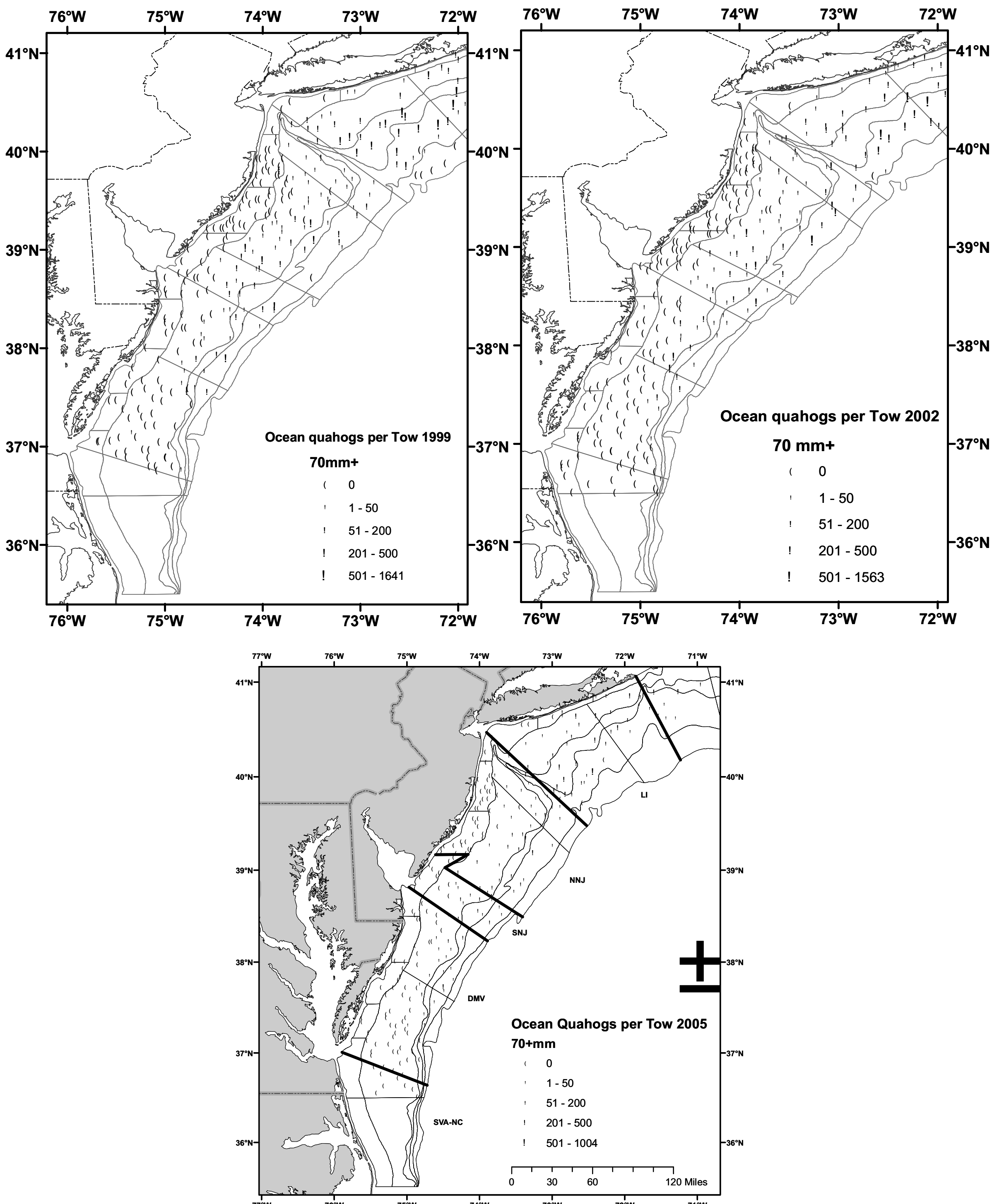

Appendix A7. (cont.)

APPENDIX A8. Stock Assessment for Ocean Quahog in Maine Waters

Prepared by Robert Russell (assessment lead, Maine Department of Marine Resources, BoothBay Harbor, ME) and the Invertebrate Subcommittee

Executive Summary

The Maine ocean quahog resource is a unique segment of the quahog stock in Federal waters. As of 1999 under Amendment 10 to the Fishery Management Plan (FMP) for Atlantic Surfclam and Ocean Quahog, Maine was given a separate annual quota of 100,000 "Maine" bushels (bushels used to record landings in Maine are 66% as large as bushels used to report landings in the rest of the EEZ). Fishing is carried out using a "dry" dredge (with no water jets to loosen sediments).

Maine quahogs, often referred to as "mahogany" clams are a substitute for *Mercinaria mercinaria* in the half shell market. Maine quahogs are harvested at a much smaller size (38-64 mm shell length) than MidAtlantic quahogs (89-140 mm shell length).

Landings peaked in Maine in 2002 at 147,191 bushels and have fallen since to a level of 98,153 bushels in 2005. During this time period paralytic shellfish poisoning (PSP) kept many productive beds closed.

The State of Maine conducted a pilot survey for ocean quahogs in 2002 which provided useful information on abundance and distribution along with estimates of key biological parameters. Results from the pilot study were used to plan and narrow the focus of the 2005 survey.

Lacking from the pilot study was an estimate of dredge efficiency which is required to estimate biomass and mortality rates from landings and survey data. Based on data from boxcore samples and "follow on" survey tows during 2005-2006, the efficiency of the commercial dredge used during the 2005 survey was 16.1%. In other words, 16.1% of relatively large (fully recruited) ocean quahogs in the path of the dredge are captured in each pass.

Based on survey density data and estimated dredge efficiency, the biomass of harvestable ocean quahogs during 2005 in the commercial fishing grounds (54 nm^2) surveyed off Maine is 22,493 mt meat weight. Based on the ratio of landings and biomass, the fishing mortality rate in the commercial fishing grounds surveyed off Maine is F=0.022 y^{-1}.

Biological reference points have not been established for the Maine segment of the ocean quahog stock. However, a per recruit model analysis with parameters for the Maine segment of the stock was used to estimate reference points that are often used in fishery management. Based on per recruit modeling, F_{max}=0.0561, $F_{0.1}$=0.0247 and $F_{50\%=}$0.013 y^{-1}.

$F_{0.1}$=0.0247 y^{-1} (corresponding to a harvest rate of 2.5% per year) might be a reasonable reference point for managers if the goal is to maximize yield per recruit while preserving some spawning stock. Simulation analysis (Clark 2002) indicates that $F_{50\%=}$0.013 (1.3% per year) might be a reasonable reference point for managers if the goal was to preserve enough spawning potential to maintain the resource in the long term. The estimated fishing mortality rate during 2005 F=0.022 y^{-1} is nearly equal to $F_{0.1}$=0.0247 y^{-1} and the assumed natural mortality rate M=0.02 y^{-1} but higher than $F_{50\%}$=0.013.

Survey size frequency distributions indicate differences in the size of quahogs between the "western" and "eastern" beds inside the commercial fishing grounds. Larger quahogs were found in eastern beds that had been closed to fishing for three year due to PSP.

Size frequency distributions from boxcores showed signs of recent settlement in the eastern bed (quahogs less than 5 mm SL). However size classes between 5 and 35 mm SL were entirely missing throughout the survey indicating that recruitment is sporadic. Although growth is relatively rapid in Maine waters, it may be 3 decades or longer before these recruits become large enough to enter the fishery.

Stock assessment advice concerning ocean quahog in Maine waters would be easier to provide if management goals were formulated and if biological reference points for biomass and fishing mortality were defined.

Introduction

The Maine fishery for Ocean quahogs, although harvesting the same species (*Artica islandica*), is persecuted in a different way and fills a different sector of the shellfish market than the rest of the EEZ fishery. The Maine "mahogany" quahog is harvested at a smaller size (38-64 mm or 1.5-2.5 in shell length, SL) than elsewhere in the EEZ fishery where ocean quahogs are harvested at 89-140 mm (3.5-5.5 in) SL.

Ocean quahog from Maine waters are marketed as a less expensive alternative for *Mercenaria mercinaria* (Maine DMR 2003). Harvesting takes place year round with the highest market demand during the summer holidays (Memorial Day through Labor Day). During this peak harvest period 30-40 out of a total of 57 license holders may land some volume of product.

The majority of the vessels in the Maine fleet are between 10.7-13.7 m (35-45 ft) and classified as "undertonnage" or "small" in issuing permits. All of the vessels use a "dry" dredge (with no hydraulic jets to loosen the sediments) with a cutter bar set by regulation at no more than 0.91 m (36 in). There are no restrictions on any other dimension of the dredge.

Quahog Fishing in Maine takes place in relatively few locations along the coast north of 43 degree 50 minute latitude (Figure 1). Historically the bulk of fishing activity has taken place between Mt. Desert Rock and Cross Island with two significant quahog beds south of Addison and Great Wass Island covering an area of approximately 60 square nautical miles.

The Maine fishery began to expand into Federal waters in the 1980's due in part to PSP closures within state waters. In 1990 it was determined that this fishing activity conflicted with the Magnuson-Stevens Fishery Management Conservation Act which calls for a stock to be managed as a unit throughout its range. The Maine fishery was granted "experimental" status from 1990-1997. In 1998, the Maine fishery was fully incorporated under Amendment 10 of the FMP and given an initial annual quota of 100,000 bushels based on historical landings data. There was no independent assessment of the resource available at that time. The State of Maine is responsible under Amendent 10 to certify harvest areas free of PSP and to conduct stock assessments.

In 2002 the State of Maine conducted a pilot survey to assess the distribution and abundance of quahogs along the Maine coast (MEDMR 2003[27]). This survey was a critical first step in establishing distribution, size composition and relative abundance information for the Maine fishery and for directing the design of the current survey work. While this initial survey provided valuable

[27] Available with assessment for reviewer's convenience.

information it did not have the resources to estimate dredge efficiency and therefore was not able to estimate total biomass or biological reference points. The survey during 2005 focused effort on two issues: determining dredge efficiency, and mapping quahog densities in the region of highest commercial activity.

Estimates of biomass and mortality presented in this report are only for the commercial beds south of Addison and Jonesport/GreatWass Maine. This approach was chosen due to available resources and because it was conservative. Other quahog beds are known to exist along many parts of the Maine coast. If mortality targets could be met using the estimates from the primary fishing grounds then biomass outside the survey area can act as a *defacto* preserve.

Fishery Data

Data throughout this report is presented in metric units. In some cases there are specialized terms and conversion factors which are listed below.

"MidAtlantic" bushels of Ocean Quahogs x 10	=	lbs meat.
"MidAtlantic" bushels of ocean quahogs x 4.5359	=	kg meat
1 "MidAtlantic" (= "industry") bushel	=	1.88cubic feet
1 "Maine" (= "US Standard") bushel	=	1.2448 cubic feet
"Undertonnage" vessel	=	1-4.9 GRT
"Small" vessel	=	5-49.9 GRT
1 "Maine" bushel	=	0.0049 mt meat weight

In 2005 there were 57 ocean quahog licenses in the State of Maine. Of these 57 licenses 30 reported landings. The number of active licenses has decreased each year since 2002 when 38 licenses had reported fishing activity.

Landings have also decreased steadily since 2002 when they were at a recorded high of 147,191 Maine bushels (TableZ 1). Landings for 2005 were 98,153 Maine bushels. LPUE in recent years tracked downward with landings until the 2005 season when it showed a slight increase from 5.37 to 5.85 Maine bushels per hour towing (Figure 2). This increase may be an artifact of the open and closed status of parts of the main commercial beds due to PSP because the most productive quahog bed was reopened at the end of 2005 after a 3 year closure.

Incidental mortality in ocean quahog off Maine is an important topic for future research. Maine has a very high level of fishing activity relative to the size of the fleet. Approximately 16,766 hours of fishing took place during 2005 representing over 67,000 tows at 8 min per tow. Using standard industry dredge dimensions and tow speeds this level of fishing activity represents 28.68 nautical miles^2 of bottom swept by commercial dredges.

All catches are tagged and vessel logbooks are submitted to track quota status. Marine Patrol has not had enough resources to check the validity of logbook entry or to confirm the vessels on purchased quota are reporting accurately.

Research Surveys

With the limited funds dedicated for survey work on quahogs, it was decided to focus all of the 2005 survey effort on the primary commercial fishing grounds south of Addison and Great Wass. This decision is important in the interpretation of all following data as results because estimates pertain only to these two beds and not to the coast of Maine as a whole. Vessel logbooks and the 2002 independent survey abundance indices show that the majority of fishing activity and a sizable portion of the resource was in this region (Figure 3).

The first step in designing the survey was to establish a 1 km^2 grid overlay using Arcveiw 3.2 over the known commercial beds. Based on number of days at sea, 260 sites (tows) could be completed. The centers of the 260 1 km^2 grids covering the commercial beds were selected as start points for survey tows (Figure 4). These points were transferred to The Cap'n Voyager Software for use on board the survey vessel.

The Quahog bed south of Addison, (referred to as "western") had been the only open fishing grounds for 3 years due to PSP issues in other beds. The quahog bed south of Great Wass Island, (referred to as "eastern") had been unfished for 3 years but had previously been one of the most productive fishing grounds.

Survey gear and procedures

The commercial vessel F/V Promise Land is a 12.8 m (42 ft) Novi Style dragger piloted by Capt. Michael Danforth that was contracted to perform all the survey drag operations. All survey tows were conducted using the same dredge with dimensions: cutter bar 0.91 m (36 in), 2.44 m (8 ft) long x 1.83 m (6 ft) wide x 1.22 m (4 ft) high, overall weight 1,361 kg (3,000 lbs), bar spacing all grills 19.05 mm (¾ in) (Figure 5). The survey dredge was the same dredge used by the F/V Promise Land during normal fishing activity.

As the vessel approached the start of a tow, bottom type and the feasibility of conducting a tow were assessed. If suitable bottom was not immediately present at the predetermined start point, the vessel would start crossing runs within the grid. If after 5 to 6 crosses no towable bottom or a tow path free of fixed lobster gear could not be found, then the grid location was deemed untowable, a note was made, and the captain continued on to the next site. When a suitable tow path was found within a grid the dredge was lowered to the bottom by free-spooling until the ratio of cable length to depth was 3:1. Once the desired cable length was reached the drum was locked, a two minute timer was started and a GPS point was taken.

Tows were made into the current at approximately 6.48 km/hr (3.5 knots) speed over ground (average tow 214 m). After two minutes elapsed, a second GPS point was taken and the dredge was brought to the surface.

Tow distances calculated using the start and stop GPS points are good estimates of the distance actually traveled by the dredge. The manner in which the dredge is set and retrieved does not create a situation in which the dredge continues to fish as it is retrieved or before the drum is locked. In particular, the weight of the dredge keeps it in place on the bottom when the drum is unlocked at the end of the tow. In addition, the practice of backing the vessel toward the stopping point at the end of each tow means that the dredge was unlikely to travel very far at the end of the tow as it is lifted into the water column.

After the dredge was retrieved and before it was brought on board the vessel, excess mud was cleaned from the dredge by steaming in tight circles with the dredge in the vessel's prop wash (Figure 6). Once on board, the dredge was emptied and photographed with a digital camera (Figure 7). The contents were placed on a shaker table (Figure 8), bycatch was noted and then all live quahogs were sorted out from the catch. From each tow a 5 L subsample of quahogs was taken at random (the entire catch was taken if catch was less than 5 L). The subsample was used to estimate tow counts, volume, and size frequency of the catch. The remainder of the catch was placed in calibrated buckets to determine total catch volume.

All data collected on board during operations were entered into a Juniper Systems handheld Allegro field computer running Data Plus Professional Software. All GPS data were collected using a pair of Garmin Etrex handheld units and transmitted in real time to the Allegro and a laptop running Cap'n Voyager Software. Data entry screens on the Allegro for the abundance survey consisted of: 1) trip information (date, time out, weather, sea state, time in, and comments); 2) site information (depth, bottom type, start tow GPS position, speed, end tow GPS position, and comments); 3) catch information (sample portion 5 L or all, volume, weight, count, photo id, size frequency 5 L or all, and comments); and 4) bycatch information (species, abundance).

The lengths (longest dimension) of all subsampled quahogs were measured to the nearest 0.01 mm and entered into the Allegro handheld using a Fowler Ultra-Cal IV digital caliper with an RS232 port. Estimated counts of quahogs were made by counting the number of clams in the 5 L sample and then expanding that value using the total volume of the catch. All data were analyzed using Excel with variances calculated using a bootstrap program (10,000 iterations) written by Dr. Yong Chen at the University of Maine, Orono.

Tow distances were determined by The Cap'n Software and were checked using ESRI ArcInfo software. All data from the tows were standardized to a 200 m tow prior to further analysis.

Dredge efficiency

The Maine dry dredge is much less efficient (2-17%, ME DMR 2003) than hydraulic dredges used in the rest of the EEZ which can be up to 95% efficient (Medcolf and Caddy, 1971). A reliable estimate of dredge efficiency is needed to convert survey densities to a biomass estimate (NEFSC 2004).

One method of estimating dredge efficiency is through depletion experiments which are used to measure survey dredge efficiency for NEFSC clam surveys in Federal waters. Depletion studies for ocean quahog involve sensor and data processing equipment that were not readily available. The dry dredge used in the Maine survey is relatively small compared to the depth of fishing. We hypothesized that it would be difficult to control the dredge precisely given the depth, size of dredge and strong currents in the region off Maine.

For the conditions off Maine is was determined that the best approach to estimating dredge efficiency would be through the use of a boxcore samples (to directly estimate quahog density) followed by survey tows in the same area. Considering only ocean quahog available to the fishery, the ratio of density measured by "follow on" dredge tows divided by boxcore density is an estimate of survey dredge efficiency (Thorarinsdottir and Jacobson 2005).

The *F/V Promise Land* with its large A frame and winches was able to deploy the 544 kg (1,200 lb) Ocean Instruments 610 boxcore with a core capacity of 0.062 m^2 and maximum penetration up to 60 cm (Figure 9). Follow on tows were conducted using the same gear used during all previous portions of the survey.

Boxcore work was conducted at three locations during three separate trips, one in August of 2005, one in January of 2006 and the last in April 2006. In all three experiments, follow on survey tows were made the day after the cores had been taken. The locations sampled were in the eastern quahog bed in an area of relatively high abundance (Figure 10). This area was also selected because it was a closed fishing ground during the August 2005 trip which would eliminate the possibility of the boxcore sites being commercially towed before follow on tows could be made. In January and April 2006 the region had been reopened to commercial fishing. However, VHF radio announcements describing the type of work underway were broadcast to local fisherman who were very cooperative and stayed well away from the experimental areas until all follow on tows could be completed the next day. Data entered into the Juniper Systems Allegro field computer included information about: 1) the trip (date, start tow, end tow), core (core #, core length, count, volume, weight, count of newly settled).

Each experiment began by establishing a single long towpath. To do this, the vessel was slowed to the standard tow speed of 3.5 kts and a GPS point was taken and plotted. After 2 min steaming along a fixed heading, a second GPS point was taken and plotted. These waypoints determined the endpoints for the follow on commercial tows and the path for boxcore sampling. Cores were then taken haphazardly along the tow path (60 for the August 2005 trip, 34 on the January 2006 trip and 30 on the April 2006 trip).

Once a core was brought on board it was measured for overall length and sieved through a large screen (1cm^2 mesh size). All quahogs were counted and their total volume and weight were measured.

During coring operations, it was noted that the upper 1-2 cm of very soft sediment contained recently settled quahogs (< 5mm length). The number of quahogs in this size range were recorded separately for all further cores and newly settled quahogs were retained to be preserved. During the January and April 2006 trips the top 5 cm of each core was removed and washed separately through a 300 μ sieve and all quahogs <5mm SL were preserved.

It was noted during boxcore sampling during the August 2005 boxcore trip that there was a change in sediment type beginning around 12-15 cm from the surface of each core. At this transition the sediment turned to a matrix of solid clay and old quahog shell. None of the live quahogs found in the cores in 2005 were below this transition. To assess this, the maximum depth within the core of live quahogs was measured during the 2006 trips.

After the maximum number of cores had been completed for a given trip the commercial dredge was deployed at one of the endpoints of the established tow path. Standard commercial towing was conducted for 2 min along the same path as the cores had been taken allowing the dredge to tow from one endpoint to the next. After each round of coring, 6 tows were made along the same path, three in one direction and 3 opposing to help mitigate any effect from tide.

<u>Dredge survey results</u>

A total of 259 1km 2 survey grids were selected for sampling (TableZ2). Out of the 259 there were 183 (121 in the western bed and 62 in the eastern bed) or 70.7% that were towable. Only two stations were untowable due to fixed lobster gear or other known obstructions. The remainder of the untowable sites were due to inappropriate substrate.

Calculations of fishable area were reduced by the area of the sites that were untowable. Total biomass calculations are based only on the towable area (183 km^2). The site that had a known obstruction was not included as it is not fished by area harvesters because of the risk to their gear and the site with lobster gear was not included based on personal comments from Capt. Mike Danforth that it was an area of hard untowable substrate. Tow distance, catch volume and counts were all standardized to a 200m tow. Actual tow distances averaged 214 m.

The density plot for the survey (Figure 11) shows the highest concentration of biomass in the eastern bed. The eastern section had been closed to quahog fishing for almost three years. Substrate data (Figure 12) from Kelly et al. (1998) show the complexity of the substrate in the eastern section with highest quahog densities found near the boundary of hard rocky substrate with gravels, sands or mud. Substrate data collected independently using sidescan imaging showed that Kelly et al.'s (1998) substrate information was relatively accurate. However, in some cases substrate labeled as "sand" or "gravel-sand mix" near our most productive tows may have been shell hash from old quahog beds that was seen in boxcores from the same area.

Size frequencies for all subsampled quahogs (n=20,737) taken during the survey are shown in Figure 13. Size frequencies were also plotted separately for quahogs sampled from the western and eastern beds (Figure 14). The western bed had a mean SL of 47.6 mm ± 4.6 mm and the eastern bed had a mean SL of 52.4 mm ± 5.1 mm. Cumulative size frequency distributions and a Kolmogorov-Smirnov test were used to test the null hypothesis that the size frequency distributions in the eastern and western areas were the same (Zar 1999). The null hypothesis was rejected ($p=0.001$)

Because the two beds have differing size compositions and abundance levels, it was decided to calculate abundance for the two beds separately before estimating combined abundance for the entire survey area. Abundance estimates (see below) assume a dredge efficiency of 0.161 (Table Z3 shows effects of different dredge efficiencies on abundance and bushel estimates).

To estimate the total biomass for the commercial fishing grounds the size frequency distributions were converted to proportion of the population in each 1 mm size bin. Shell length (L) was converted to meat wet weight (W) using $W=4.97\text{x}10\text{-}6 \text{ x } L^{3.5696}$ (Maine DMR 2003). Meat weights were converted to total biomass (meats and shells) by applying the average meat yield from the pilot survey of 17.5% and combining the values for the separate beds.

Variable	**Bed**	**Estimate**	**CV**
Abundance	Western	1.7108×10^9	8%
	Eastern	2.4058×10^9	11%
	Total	4.1163×10^9	8%
Bushels	Western	1.715×10^6	9%
	Eastern	2.787×10^6	11%
	Total	4.502×10^6	9%
Total Biomass (mt)	Western	47,704	8%
	Eastern	94,977	13%
	Total	128,529	7%
Meat Weight (mt)	Western	8,348	8%
	Eastern	16,621	11%
	Total	22,493	8%

Box core results

Efficiency estimates from box core experiments are presented based on sizes taken in the commercial fishery (35mm SL and greater). The estimated dredge efficiency was 16.1% with a 95% bootstrap confidence interval of 11.4%-21.6%.

Another important result from the boxcore work was that the average depth of live quahogs in the region sampled was no deeper than 9.55 cm (CV 20%)._The standard commercial dry dredge has cutting teeth that are set to a depth of 7.62cm. We did not see evidence of anaerobic quahogs located deep in the sediments as has been reported elsewhere (Chenowith and Dennison,1993; Taylor 1976). Based on these results, it would seem that the majority of quahogs in this region would be impacted after one pass of a dredge.

Per recruit modeling

Biological and fishery parameters from a variety of sources were used to carry out a per recruit analysis for ocean quahog in Maine waters. Age at length and growth information was taken from Kraus et al. (1992). Von Bertalanffy growth parameters estimated from a sample of 663 quahogs from Machias Bay were: $L_{inf} = 59.470 \pm 2.089$, $K = 0.055 \pm 0.006$, and $t_o = -0.235 \pm 0.483$. The growth curves from Maine indicate relatively fast growth the first few years of life in comparison to curves for other areas (Figure 19). Length-weight parameters were from the 2002 Maine Quahog survey: $W = 4.97 \times 10^{-6} * L^{3.5696}$. Length-weight curves for the Maine ocean quahogs and the rest of the EEZ stock were similar (Figure 20). Size at maturity data estimates were based on Rowell et al. (1990) who found that females became fully mature at an average size of 49.2mm for a quahog stock in Nova Scotia, Canada.

Fishery selectivity was modeled as a linear ramp function that was zero at 37 mm SL and one at 47mm. Following surveys, quahog of various sizes were pushed through the grates on the commercial dredge (19.05 mm, 3/4 in. bar spacing) to see what sizes might be retained. Clams from 34mm to 38mm generally passed through the grate with some getting caught. After 41mm almost all clams were thick enough to be retained. The regression model for shell depth and shell length in Feindel (2003) shows that a 19.05 mm (¾ in) bar spacing is the thickness of an ocean quahog with 38.7 mm SL.

The per recruit model used in this analysis was a length based approach which can be downloaded from the Northeast Fisheries Science Center as part of the NMFS Stock Assessment Toollbox.[28] The length based per recruit model was also used by Thorarinsdottir and Jacobson (2005). The biological reference points estimated in per recruit modeling for ocean quahog were F_{max} =0.0561, $F_{0.1}$=0.0247 and $F_{50\%}$ =0.013 y^{-1} (Figure 18).

Sensitivity analysis (Figure 21) shows biological reference points from the per recruit model for ocean quahog are most sensitive to fishery selectivity parameters and, in particular, the length at which ocean quahogs in Maine waters become fully recruited to the fishery.

Fishing mortality rate

For this report fishing mortality is estimated as the catch in biomass/average biomass^{-1}. The survey during 2005 took place over a period of two months and mortality rates are relatively low so that survey biomass is a good proxy for average biomass. Following NEFSC (2004), the catch for 2005 used in fishing mortality estimation was landings plus a 5% allowance for incidental mortality to account for clams that are killed during fishing activity but not harvested. Catch including the 5% incidental mortality allowance for 2005 was 505 mt and the biomass estimate was 22,493 mt giving F=505÷22,493 = 0.022 y^{-1}. Thus, the estimated fishing mortality rate is roughly equal to $F_{0.1}$ but higher than $F_{50\%}$.

Stock Status

Ocean quahog biomass in Maine waters was 22,493 mt meat weight and 2.7 million mt meat weight for the EEZ stock as a whole during 2005. It is not necessary to evaluate stock status of ocean quahog in Maine waters relative overfishing definitions because the stock component off Maine is a relatively small part of the EEZ stock as a whole. Overfishing definitions apply to the EEZ stock as a whole.

It was not possible to evaluate current biomass levels relative to a biological reference points associated with maximum productivity, depleted stock or historical levels because no appropriate biological reference points or historical biomass estimates are available.

The fishing mortality rate during 2005 F=0.022 $y^{-1}$was almost equal to $F_{0.1}$=0.0247 and the assumed natural mortality rate M=0.02 y^{-1} but almost double $F_{50\%}$ =0.013 y^{-1}. $F_{0.1}$ might be a

[28] Contact Alan.Seaver@noaa.gov for information about the NMFS Stock Assessment Toolbox.

reasonable reference point for managers if the goal is to maximize yield per recruit while preserving some spawning stock. Simulation analysis (Clark 2002) indicates that $F_{50\%}$ (1.3% per year) might be a reasonable reference point for managers if the goal was to preserve enough spawning potential to maintain the resource in the long term. However, preservation of spawning potential may not be necessary if recruitment originates mostly outside of Maine waters.

There is evidence of recent recruitment (newly settled ocean quahog < 5 mm SL) in one of the beds that were surveyed. However, although growth is relatively rapid in Maine waters, it may be 3 decades or longer before these recruits become large enough to enter the fishery.

Stock assessment advice concerning ocean quahog in Maine waters would be easier to provide if management goals were formulated and if biological reference points for biomass and fishing mortality were defined.

Research Recommendations

1. Impact on habitat and substrate should be investigated for the Maine Dredge along with good estimates of area swept by fishing activity,
2. More work needs to be done to determine age, growth rates and size/age at maturity for Maine ocean quahogs. New digitized methods may help in this process.
3. Need better estimates of gear selectivity.

Acknowledgements

This report was completed with extensive help from the Captains and crews of the F/V Promise Land and F/V Whitney and Ashley. Additional assistance was provided by Scott Feindel, Larry Jacobson and the NEFSC Invertebrate (Clam) working group.

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**Maine Ocean Quahog Report -- Appendix - **Paired Tows Experiment

Survey design

The current (2005) survey for ocean quahogs was conducted using a substantially larger vessel (F/V Promise Land 12.8m) and drag than the 2002 survey vessel the F/V Whitney and Ashley (11m). In order to link the data from the 2002 pilot survey with the 2005 survey we needed a correction factor between the two vessels and drags. One concern with the pilot survey from industry members had been that the drag on the Ashley and Whitney was to light to get a good sample of the quahogs on bottom and would tend to underestimate abundance. The State of Maine contracted the original vessel, captain and drag to conduct side by side tows with the current survey vessel on April 16, 2005. It was determined that the two vessels would steam to an area in the closed fishing grounds that had a relatively high abundance of quahogs and conduct 8 coordinated close side by side tows in three replicate areas, 24 tows in all.

Survey gear

Each vessel was equipped with the same survey gear as had been used during their respective trips. Once a suitable tow path had been established both vessels in unison deployed there dredges and let out equal lengths of cable (Figure 22). The captain of the F/V Promise Land was responsible for setting the pace and path of towing and for radioing the precise start and stop times for a tow. Tow positions were recorded onboard the F/V Promise Land. Once both dredges had been recovered and washed in the vessel wake all live quahogs were removed and placed in graduated containers to determine total volume. Either a 5L subsample or the entire catch, which ever was greater, was taken for count estimates and size frequency measurements.

Data collection

Both vessels were equipped with a Allegro handheld field computer and data was entered under the categories: trip information (date, vessel, weather, sea state), tow information (tow number, depth, bottom type, start tow gps, speed, end tow gps, weight 5L, count 5L, estimated total count), size information (length). All tow locations were also entered into the Cap'n Voyager software. All data was analyzed in Excel and bootstrapped using Dr. Chen's program.

<u>Paired tows results</u>

Results from the side by side tows indicate a 2.5:1 ratio between the F/V Promise Land and the F/V Whitney and Ashley. The data collected from the tows was bootstrapped 10,000 times to estimate the standard error and 95% CI (Figure 23) Mean number per tow from the F/V Promise land was 1452 (CV 14%). Mean number per tow from F/V Whitney and Ashley was 583 (CV 13%).

The size frequency distribution from quahogs collected from subsamples during the tows (Figure 24) indicates a difference in selectivity between the two drags. A K/S test run on cumulative fractions shows a difference in the two distributions at the 0.02 level (Figure 25). The square mesh liner in the dredge on the F/V Whitney and Ashley was 19.05mm on a side while the bar spacing on the F/V Promise Land is 19.05mm. The smallest quahog present in both dredges subsamples is only 1 mm different at 35mm and 36mm SL respectively. Bar spacing may play a role in the selectivity difference since a square grid would have many more intersections to trap smaller animals or increase the likelihood of clogging the dredge with mud.

The size frequencies not only show that the lighter drag on the F/V Whitney and Ashley retained smaller quahogs it did not sample larger quahogs present in the area. This effect would not be caused by smaller openings but is an indication that the dredge may under sample larger quahogs. If smaller quahogs need to be closer to the surface because of siphon length or substrate availability than the lighter drag on the F/V Whitney and Ashley would have a bias to select a smaller quahog than a heavier dredge that can cut deeper into the substrate. Also the tow speeds set by the F/V Promise Land were faster than those regularly used by the F/V Whitney and Ashley. The lighter drag may not have been as effective at the slightly higher speeds used in the paired towing. The 2002 survey had two types of tows. Those conducted randomly through out the State and those done systematically based on distance from reported commercial catches. The systematic survey may be biased towards heavy catch areas so only the random sites that overlap the 2005 survey area were used for this rough comparison. Area biomass estimates from the 2002 pilot study are based on 25 completed tows.

The current estimate for the region which overlaps many of the same stations is based on 183 completed tows at a much finer scale. This may partly explain the differences between the two estimates. Also three years of fishing has taken place since the initial survey in which nearly 467,000 Maine bushels have been landed from the same region.

The updated 2002 estimate for the current survey area is 5.99 x 10^6 bushels with a 95%CI within 47% of the mean. The estimate from the 2005 survey is 4.502 x 10^6 bushels with a 95%CI within 25.4% of the mean.

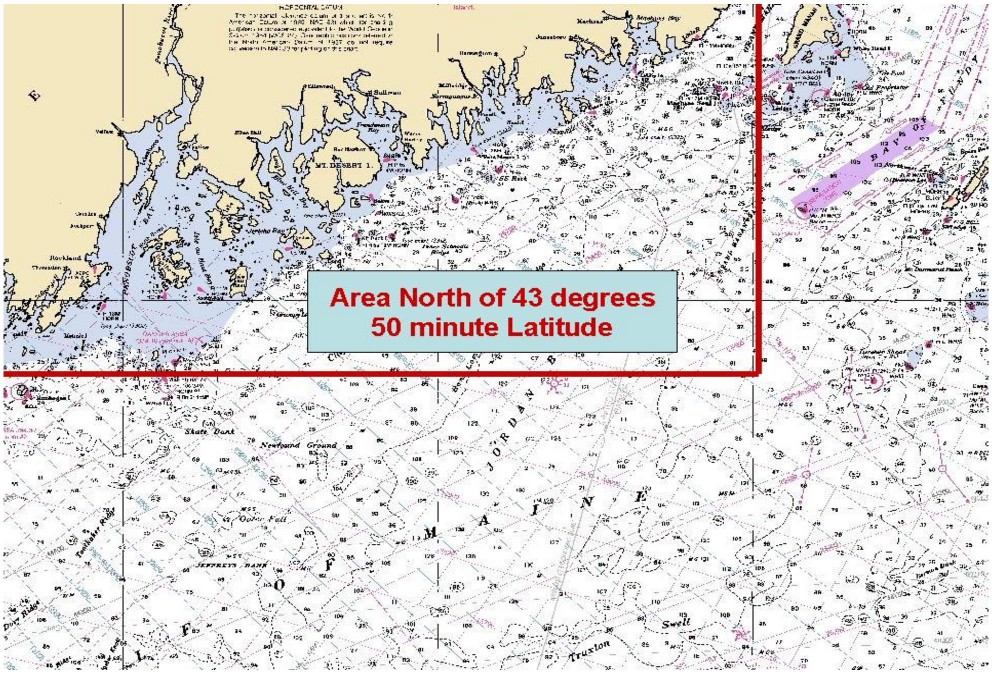
Year	Landings(Maine bushels) all vessel classes combined	Landings (only records with both effort and catch>0)	Effort (hrs fished)	Nominal LPUE (ME bushel/hr)
1990	1018	1018	286	3.56
1991	36679	34360	17163	2.00
1992	24839	24519	13469	1.82
1993	17144	17144	5748	2.98
1994	21672	21672	5106	4.24
1995	37912	37912	5747	6.60
1996	47025	47025	8483	5.54
1997	72706	72706	11829	6.15
1998	72466	72152	11745	6.14
1999	93015	92285	11151	8.28
2000	121274	119103	12739	9.35
2001	110272	110272	13511	8.16
2002	147191	147191	19681	7.48
2003	119675	119675	17853	6.70
2004	102187	102187	19022	5.37
2005	98153	98153	16766	5.85

Appendix A8. Table 1. Landings data for 1990-2005 from vessel logbooks. LPUE is reported for those records with both catch and effort data.

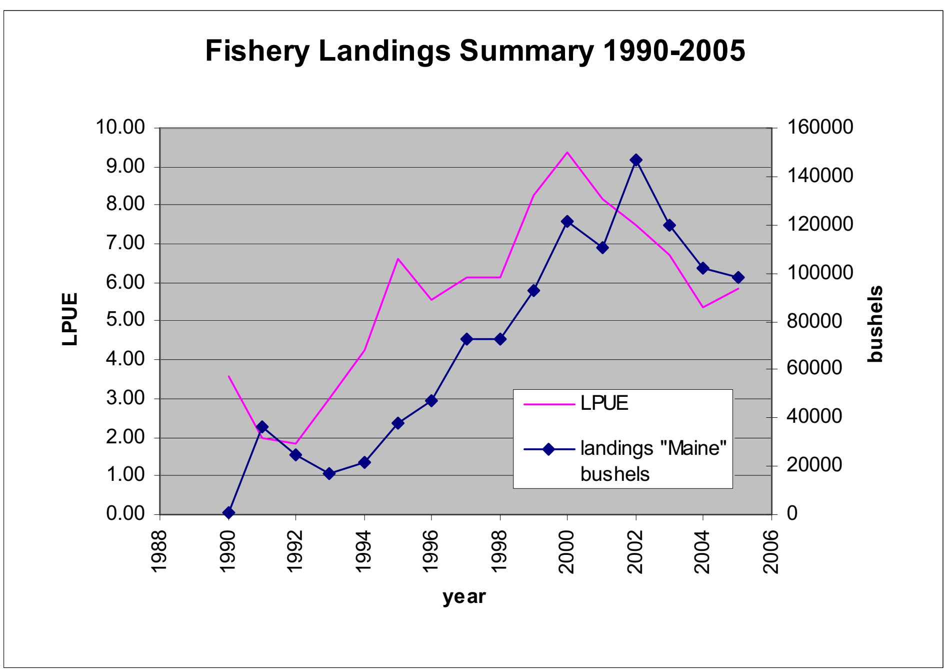
		sizes selected by dredge(>34mm SL)				all sizes		
		lower 95%	**average**	upper 95%		lower95%	**average**	upper 95%
Efficiency %		11.4	16.1	21.6		3.9	5.4	7.1
east	mean	3.3977E+09	2.4058E+09	1.7932E+09		9.9317E+09	7.1729E+09	5.4554E+09
	se	3.6358E+08	2.5744E+08	1.9189E+08		1.0628E+09	7.6757E+08	5.8378E+08
west	mean	2.4161E+09	1.7108E+09	1.2752E+09		7.0625E+09	5.1007E+09	3.8794E+09
	se	1.9464E+08	1.3782E+08	1.0272E+08		5.6894E+08	4.1090E+08	3.1251E+08
all	mean	5.8134E+09	4.1163E+09	3.0682E+09		1.6993E+10	1.2273E+10	9.3341E+09
	se	4.6013E+08	3.2580E+08	2.4284E+08		1.3450E+09	9.7138E+08	7.3880E+08

Bushel Estimates based on 10,000 bootstrap runs				
Efficiency (%)		11.4	16.1	21.6
east	mean	3.936E+06	2.787E+06	2.078E+06
	se	4.156E+05	2.943E+05	2.193E+05
west	mean	2.422E+06	1.715E+06	1.278E+06
	se	2.209E+05	1.564E+05	1.166E+05
all	mean	2.160E+01	4.502E+06	3.356E+06
	se	1.793E+09	3.872E+05	2.886E+05

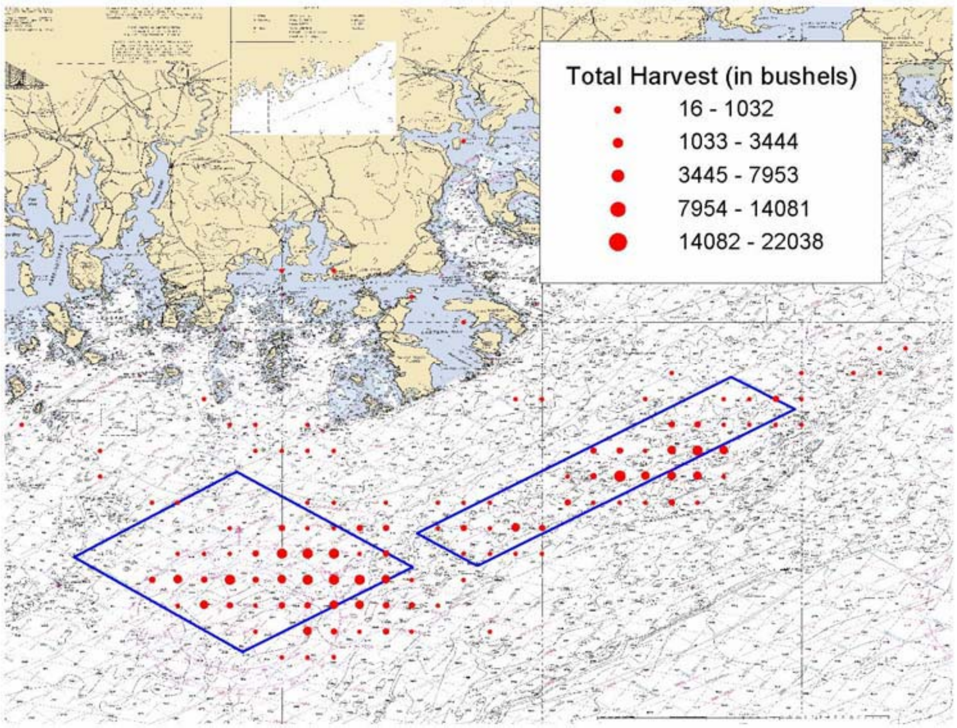
Appendix A8. Table 2. Effects of efficiency estimates on count and bushel estimates.



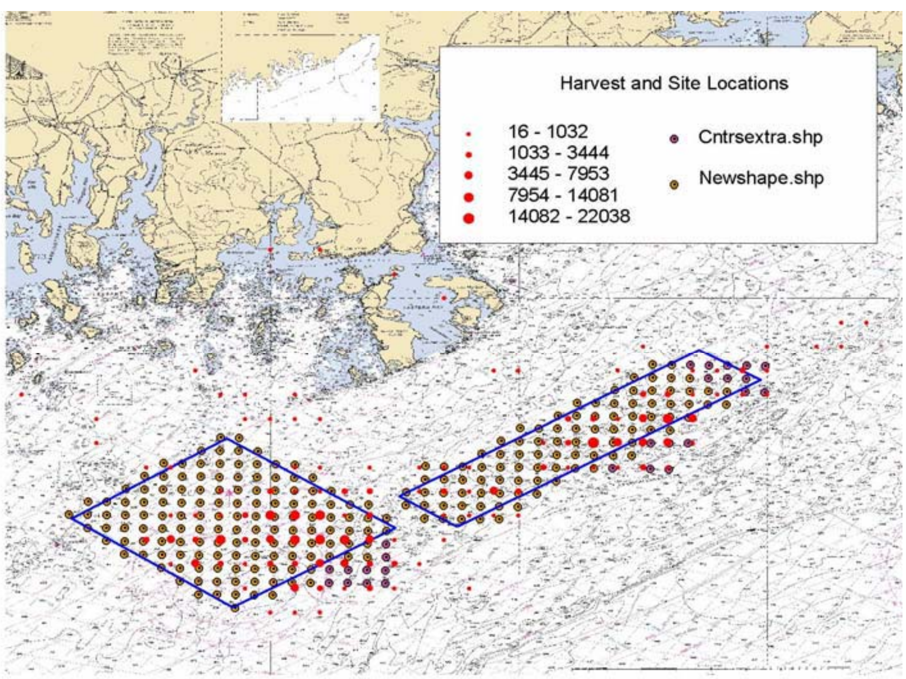
Appendix A8. Figure 1. Under the current Surfclam/Ocean Quahog FMP, the Maine fishing area is defined as north of the 43^{o} 50' N. This line roughly splits the Maine coast in two.



Appendix A8. Figure 2. Catch and effort trends in the Maine quahog fishery. In 2002 one of the primary quahog beds was closed due to PSP. It was reopened in the last quarter of 2005.



Appendix A8. Figure 3. Commercial harvest locations during 2003-2005. Point size represents total bushels reported to that location by all vessels.

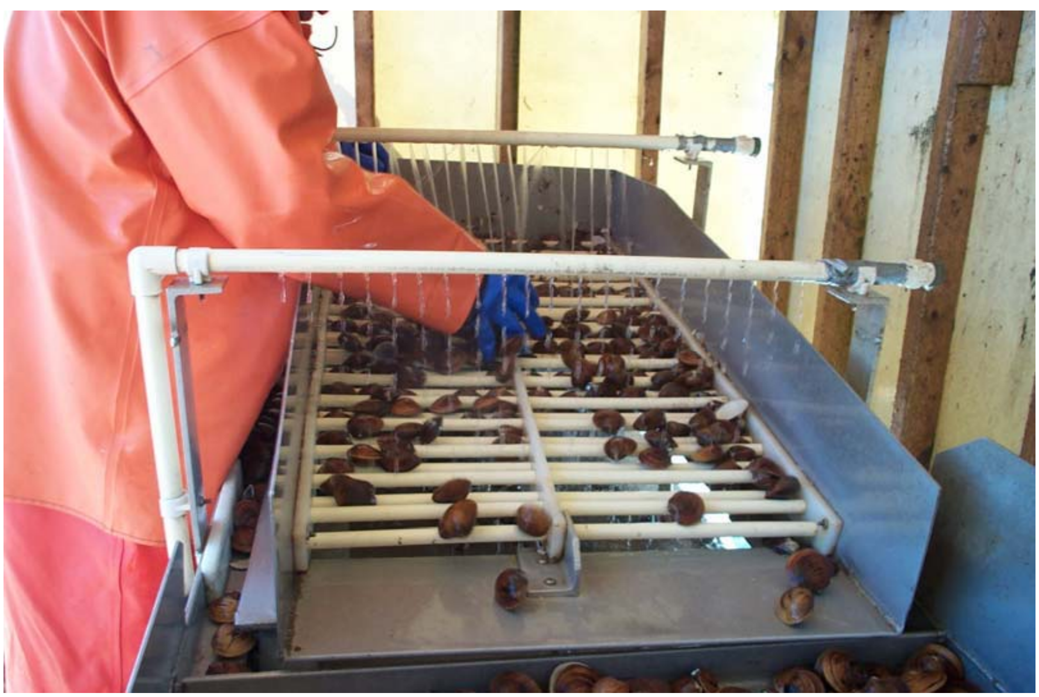


Appendix A8. Figure 4. Spatial grids for abundance survey in relation to commercial activity.

Appendix A8. Figure 5. Commercial drag used in all surveys in 2005.

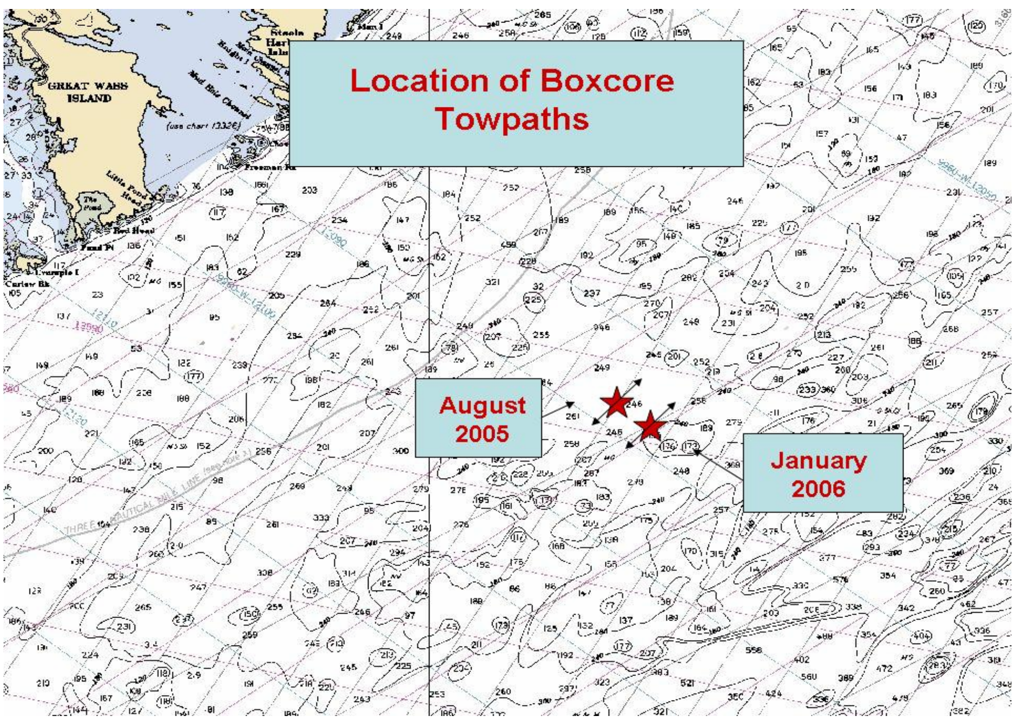
Appendix A8. Figure 6. Cleaning the catch before it is brought on board. This practice is used in commercial operations as well.

Appendix A8. Figure 7. Typical catch as it comes on board. Tow duration 2 minutes.

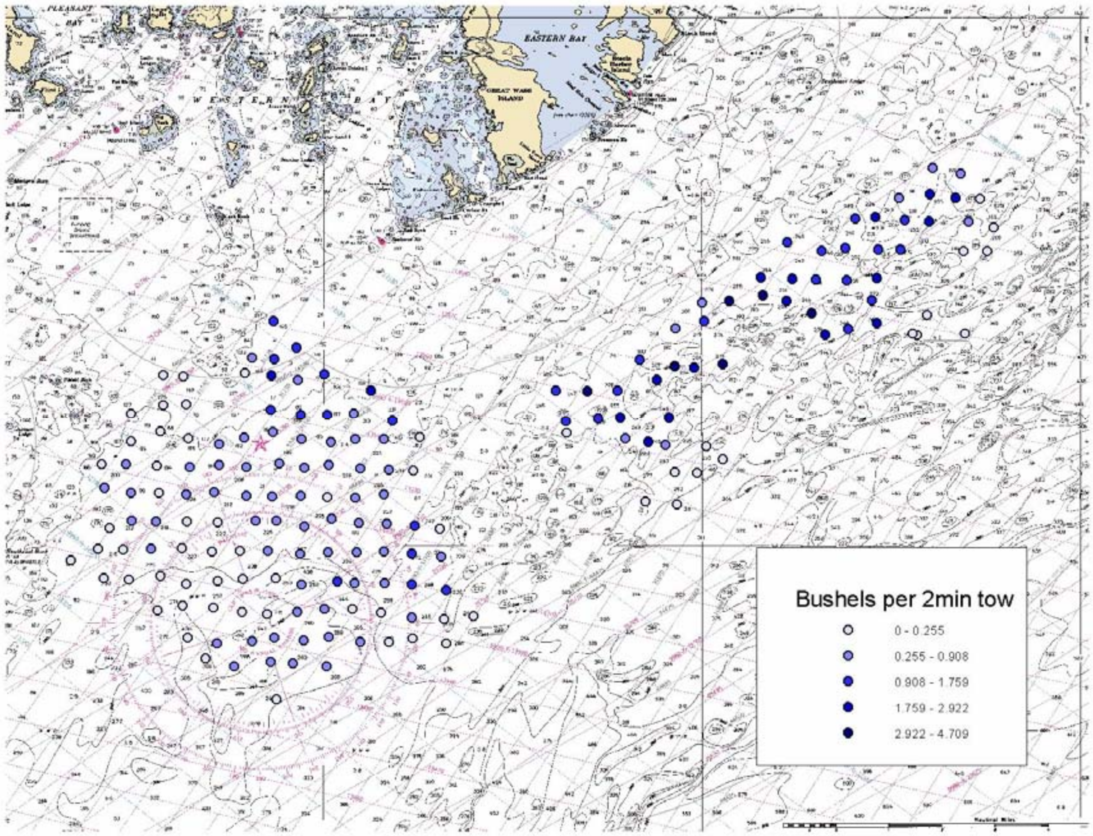


Appendix A8. Figure 8. The catch being processed on a standard shaker table.

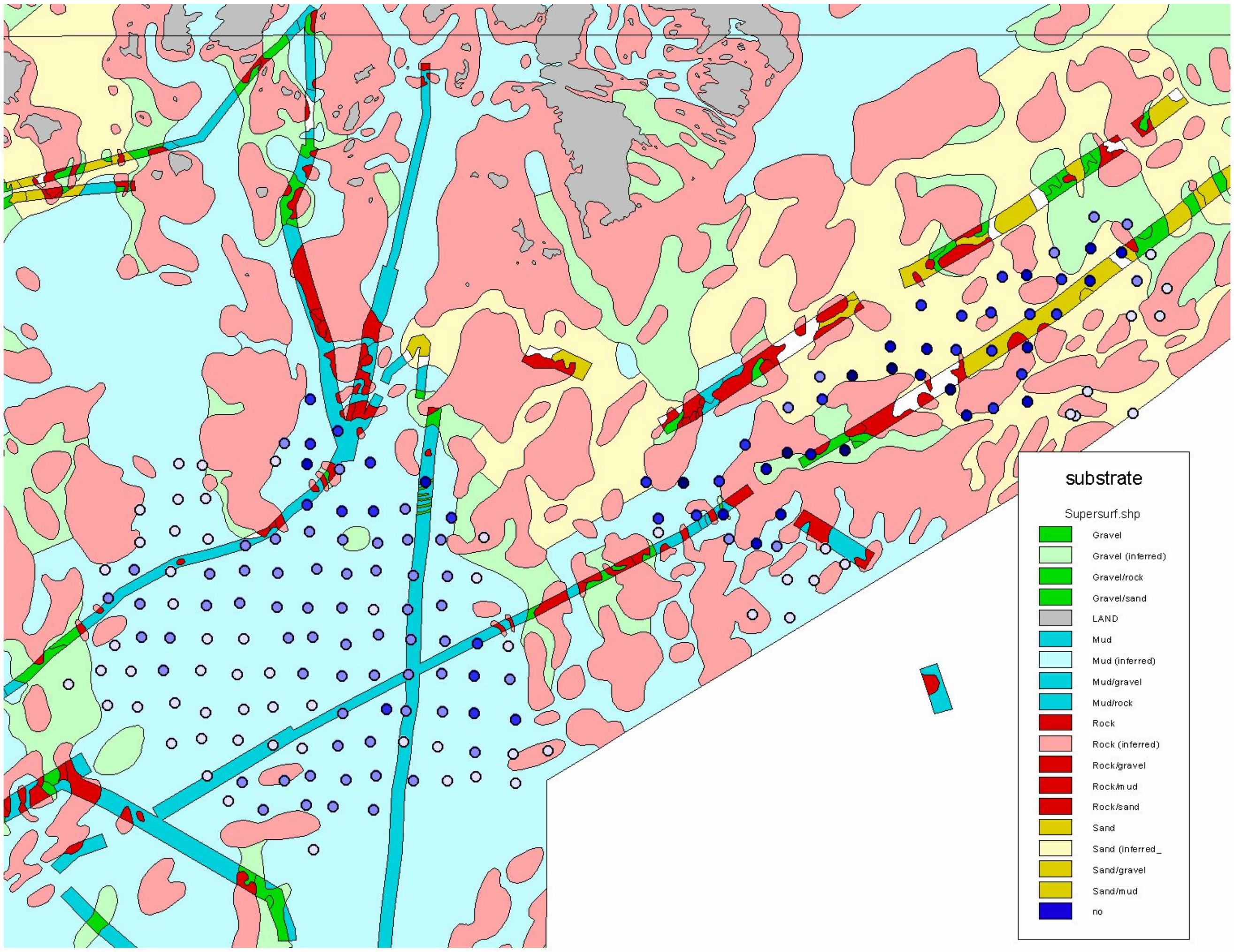
Appendix A8. Figure 9. Ocean Instruments 610 Boxcore along with a typical core sampled.



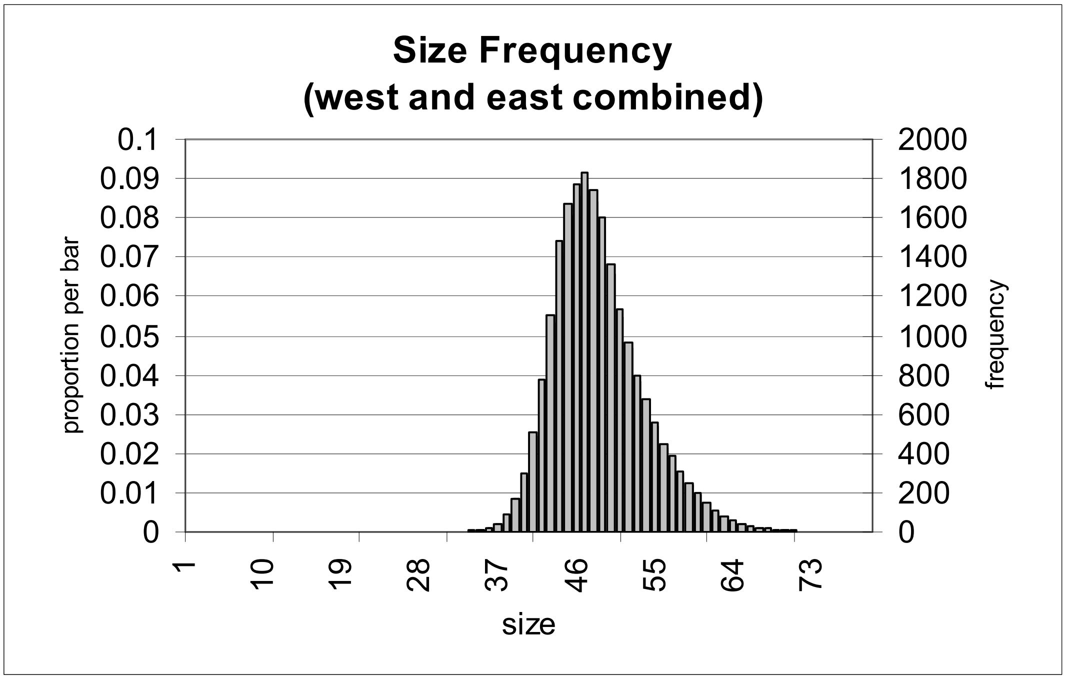
Appendix A8. Figure 10. Locations of Boxcore samples.
Areas with high quahog density were chosen from the abundance survey results.



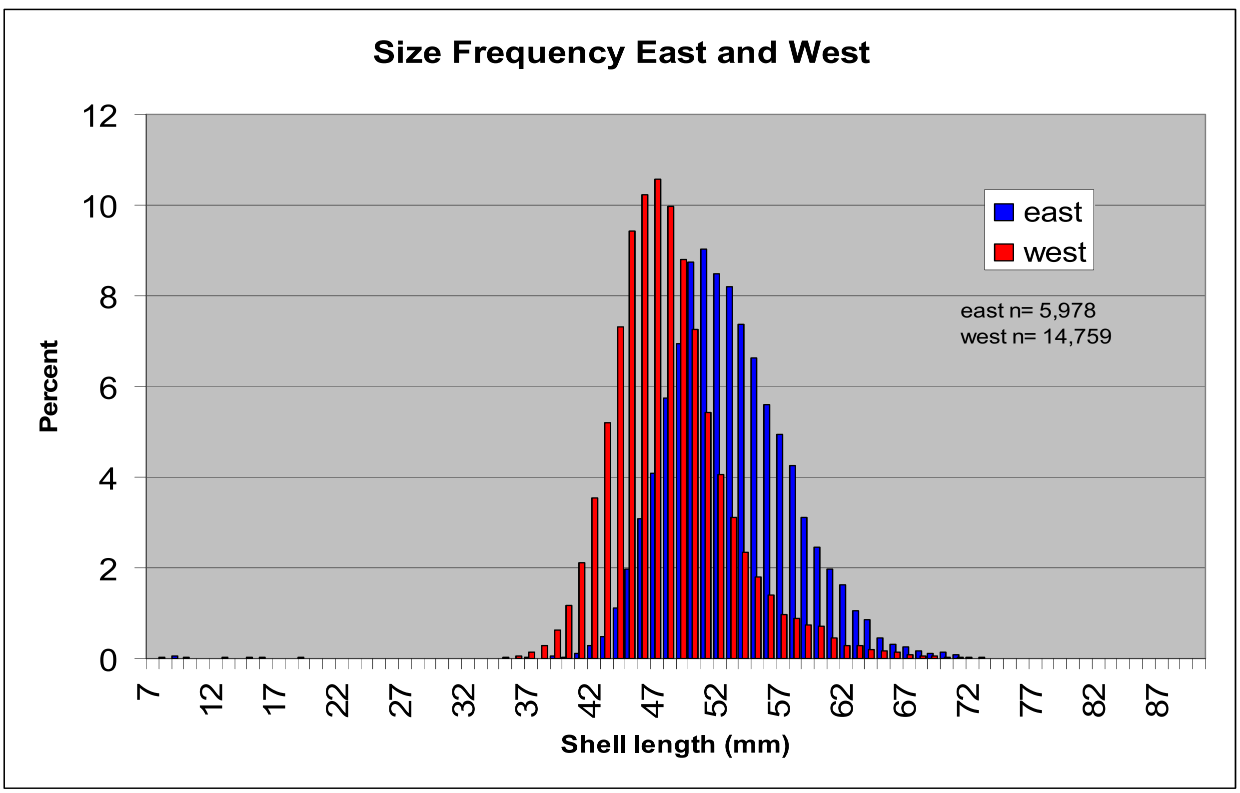
Appendix A8. Figure 11. Density Plot from towable 2005 survey locations.



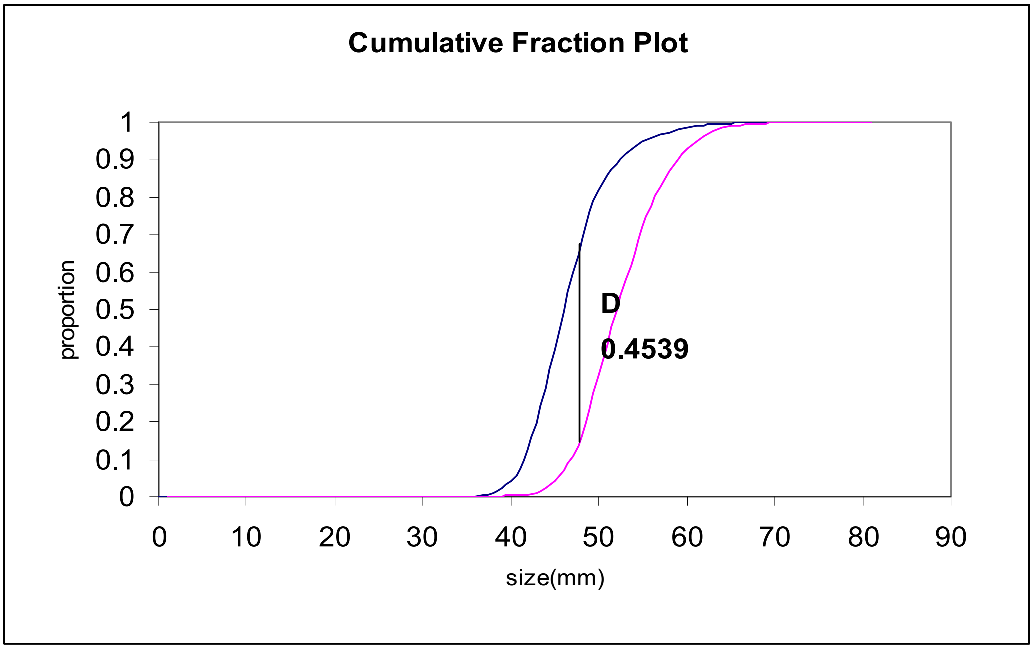
Appendix A8. Figure 12. Survey tows overlay on substrate data from Joe Kelly.



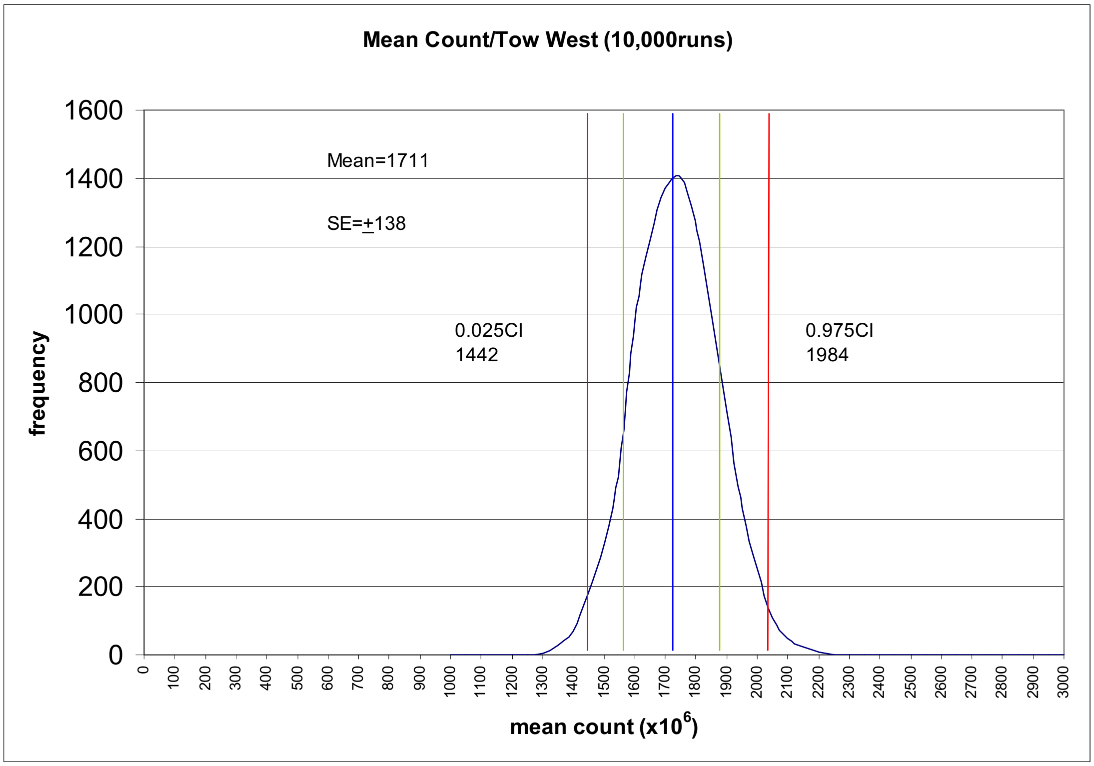
Appendix A8. Figure 13. Size frequencies for all tows in the western and eastern beds.



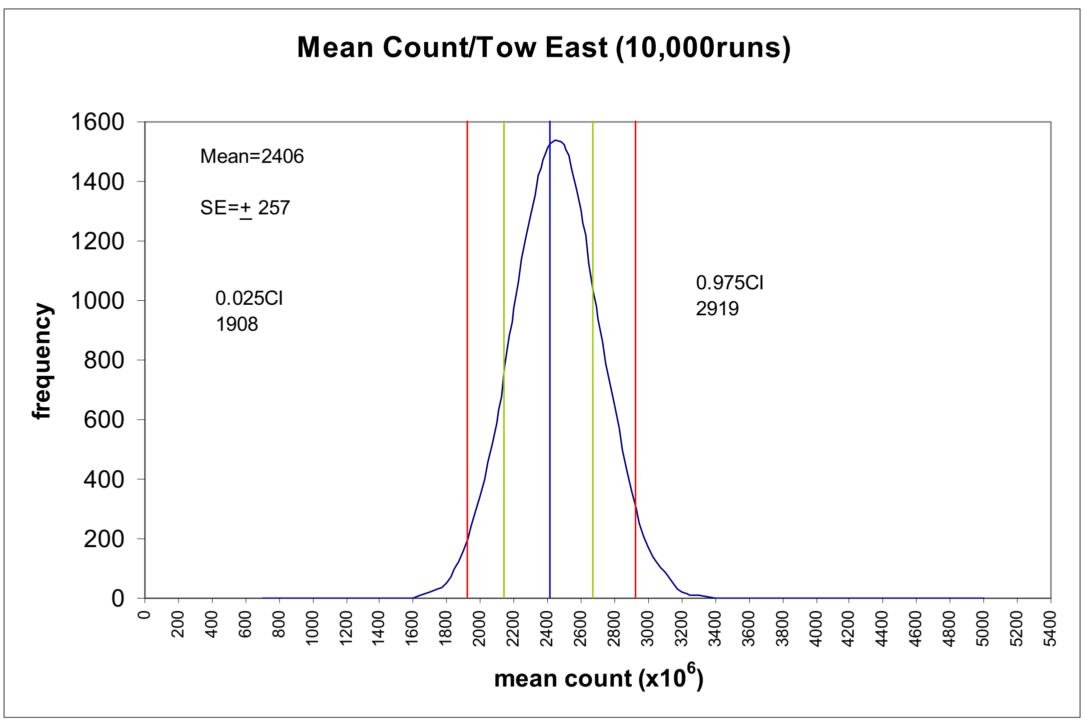
Appendix A8. Figure 14. Size frequencies for western and eastern bed. Used as basis for K/S test



Appendix A8. Figure 15. Cumulative distributions for length composition in the western and eastern beds. The curves are significantly different at the *p*=0.001 level.

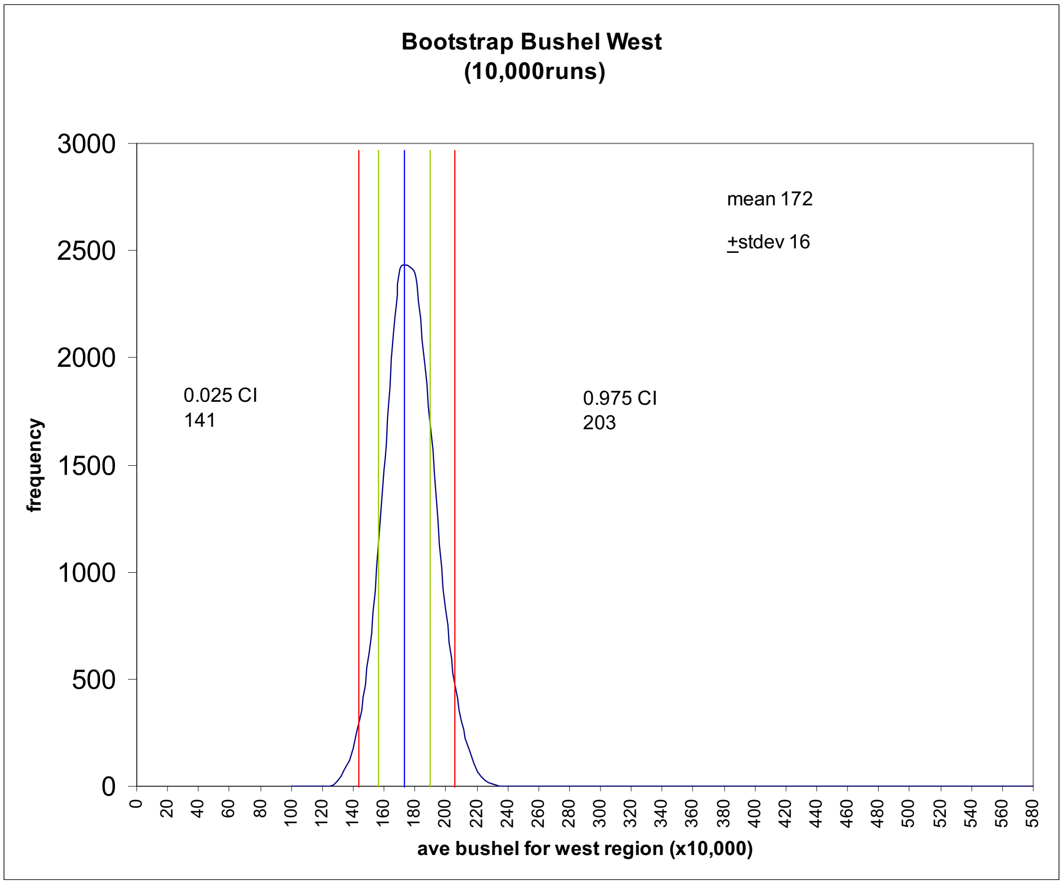


A

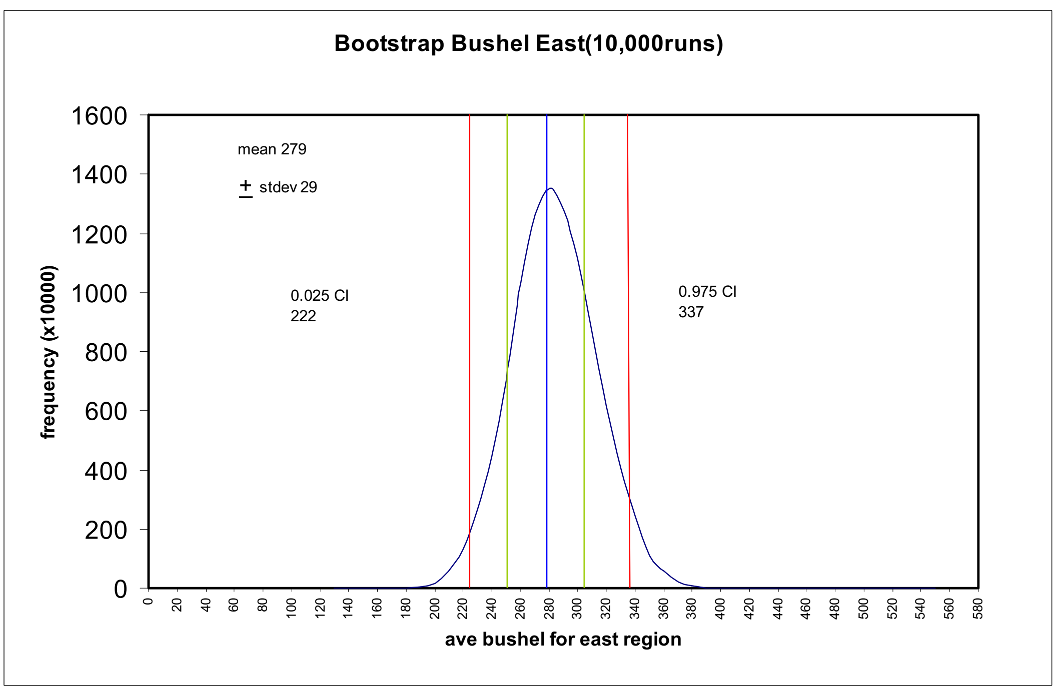


B

Appendix A8. Figure 16. Results from bootstrap runs on mean count per tow split by west (A) east (B) and on bushels per tow split west (C, next page) east (D, next page).

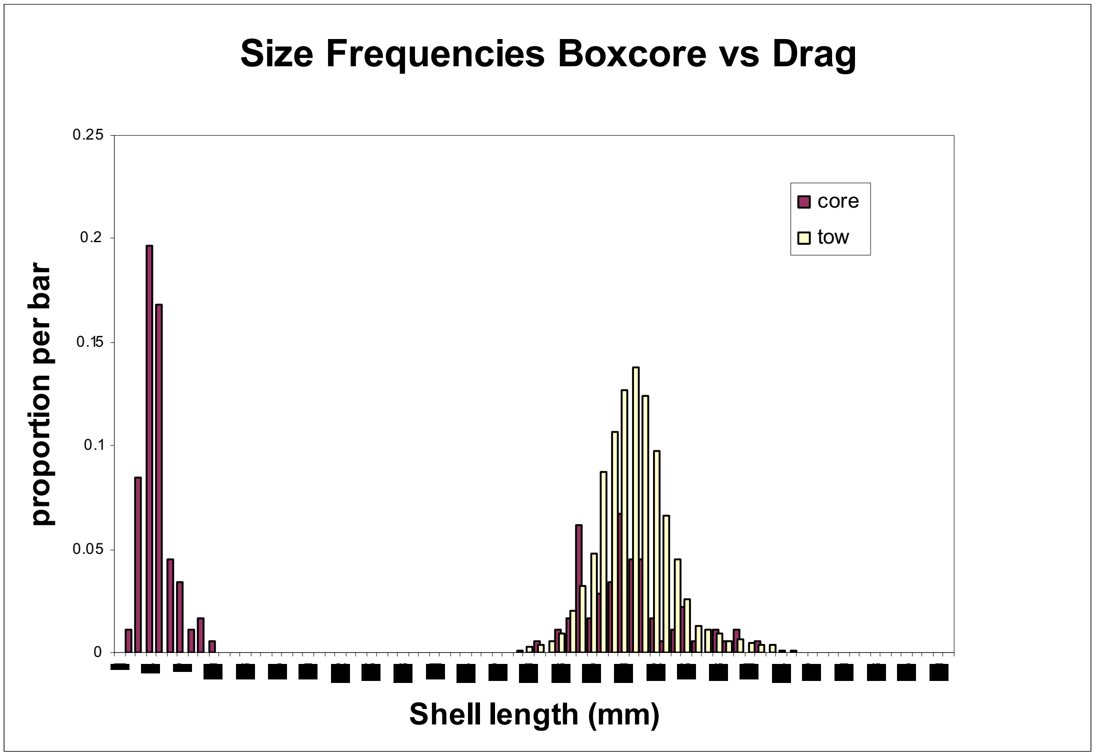


C

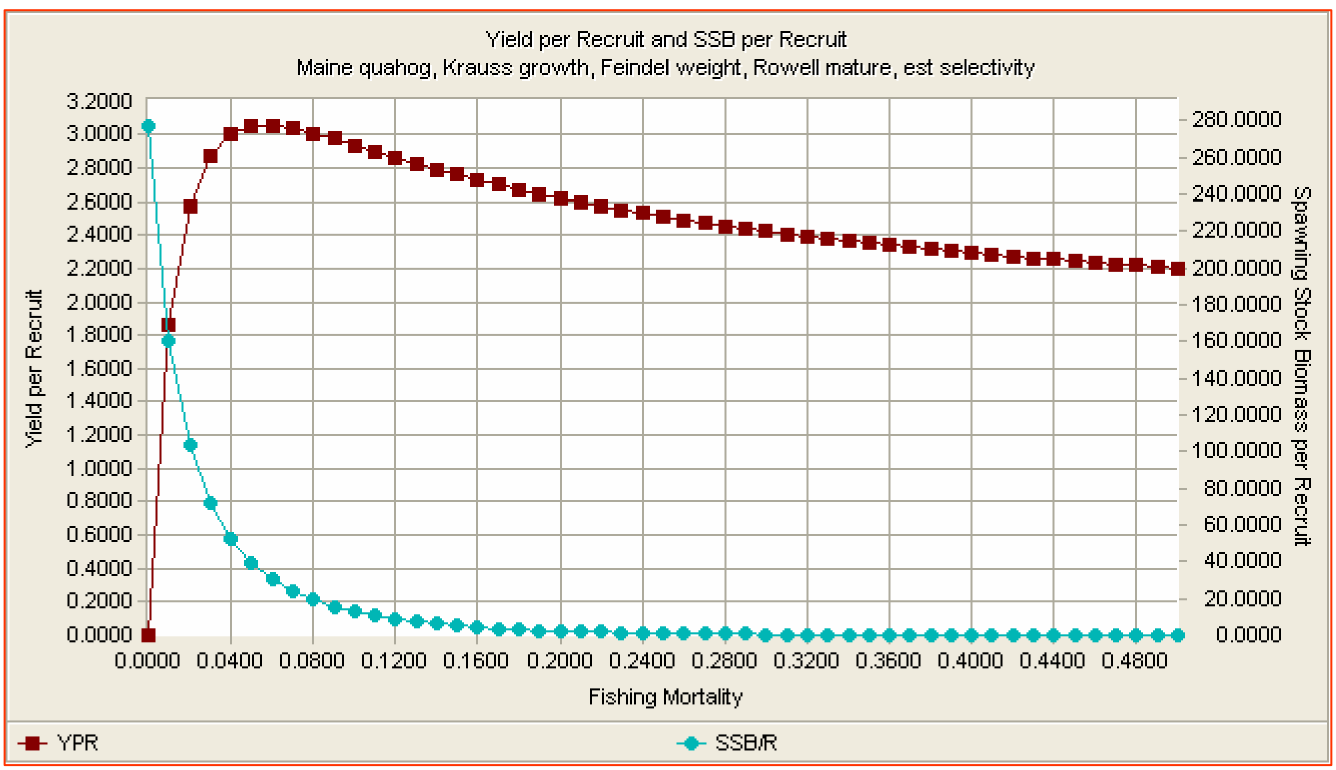


D

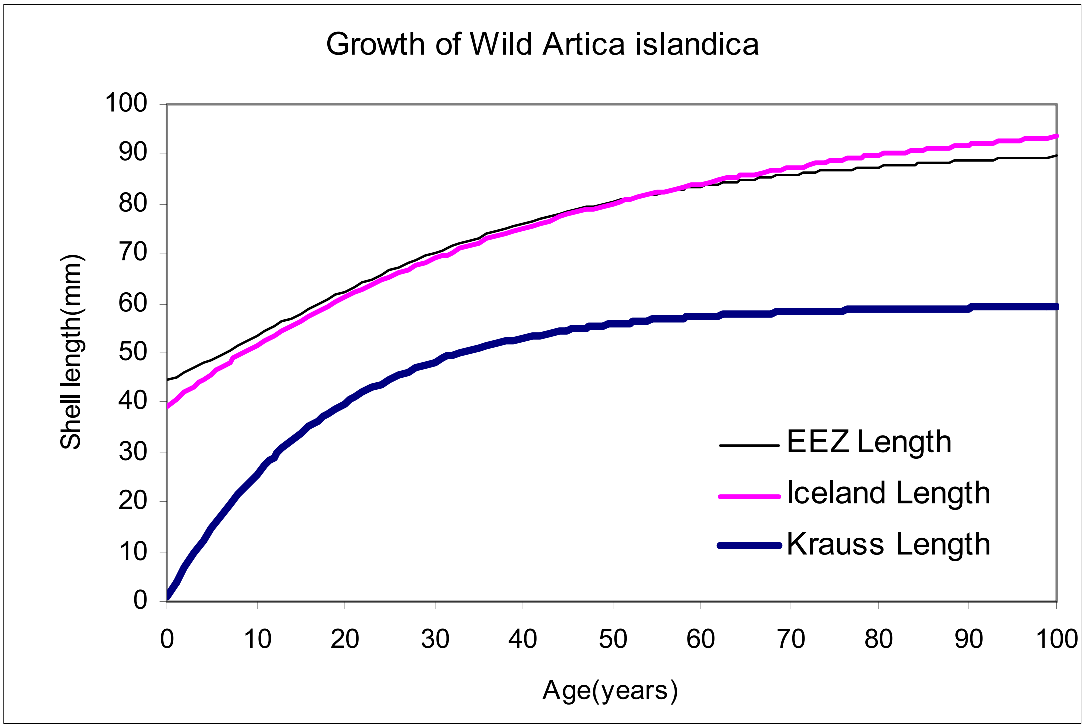
Figure 16. (cont.)



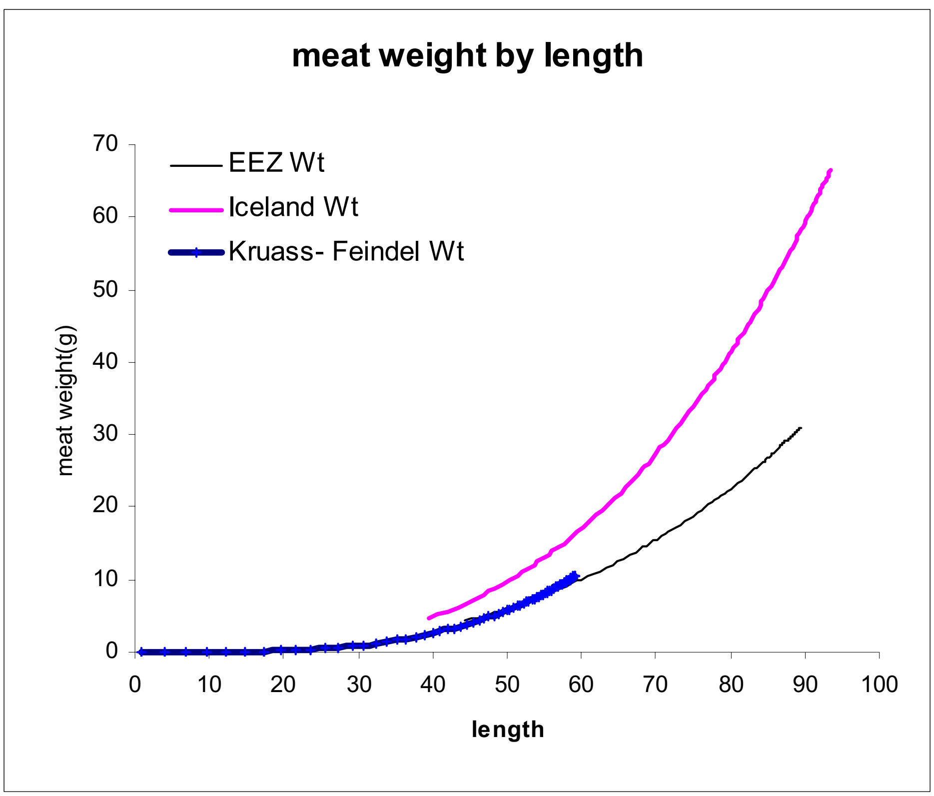
Appendix A8. Figure 17. Size frequencies from boxcore and follow on tows.



Appendix A8. Figure 18. Per recruit model results for Maine ocean quahogs.



Appendix A8. Figure 19. Three growth curves for quahog. Data for the Krauss curve was from Maine.



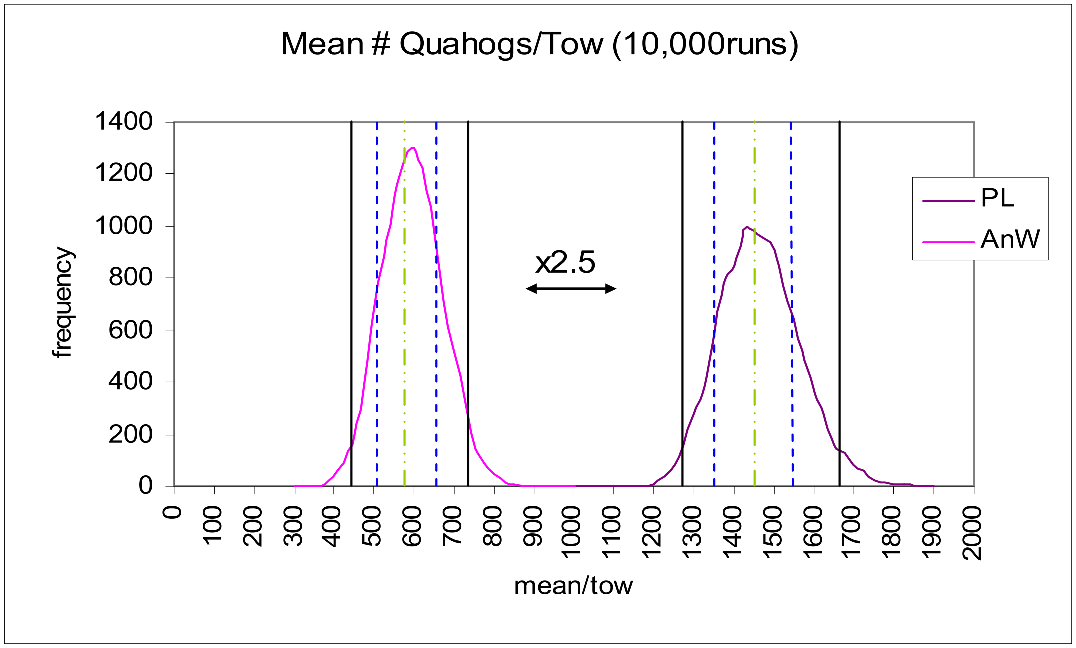
Appendix A8. Figure 20. Meat weight shell length relationships for three quahog stocks. Data for the Kruass-Feindel curve was from Maine.

Fully recruited length			
length	F-01	Fmax	F50%MSP
30	0.0196	0.0348	0.0109
35	0.0215	0.0419	0.0116
40	0.0242	0.0543	0.0126
45	0.0275	0.0801	0.0143
50	0.0319	0.168	0.018
55	0.0376	-1	0.0309

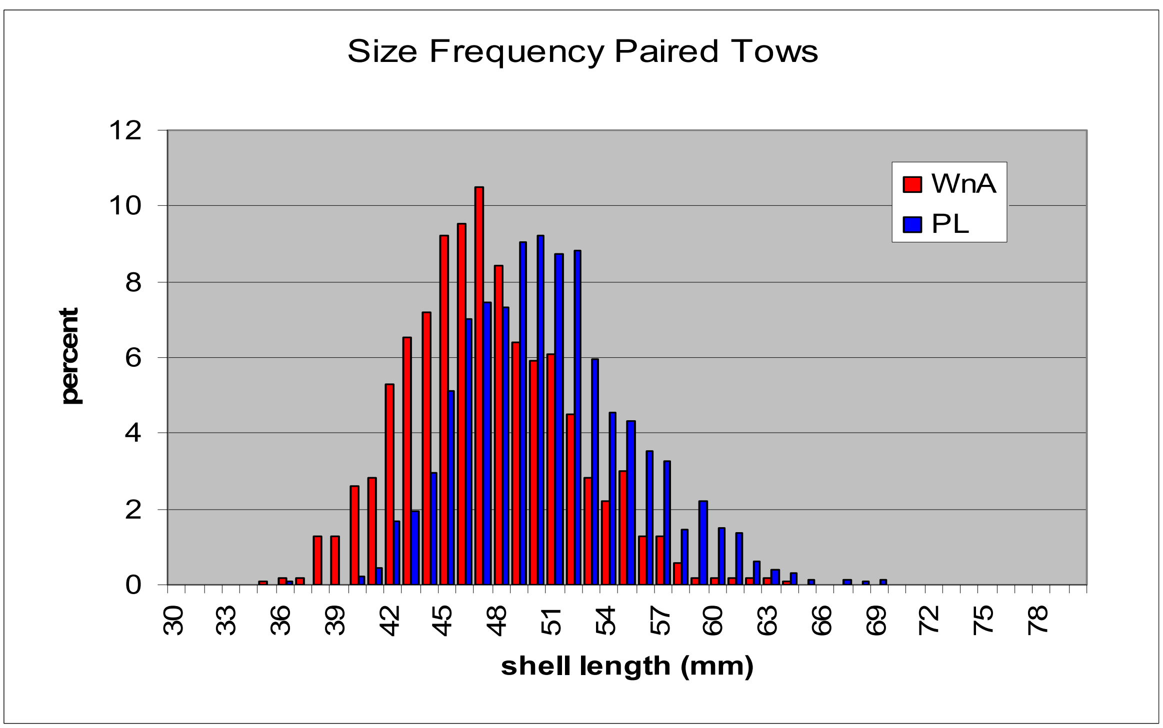
Fully Mature			
length	F-01	Fmax	F50%MSP
30	0.0253	0.0604	0.0168
35	0.0253	0.0604	0.0164
40	0.0253	0.0604	0.0157
45	0.0253	0.0604	0.0146
50	0.0253	0.0604	0.013
55	0.0253	0.0604	0.0105
60	0.0253	0.0604	-1
65	0.0253	0.0604	-1

Appendix A8. Figure 21. Sensitivity of YPR to size at recruitment and maturity.

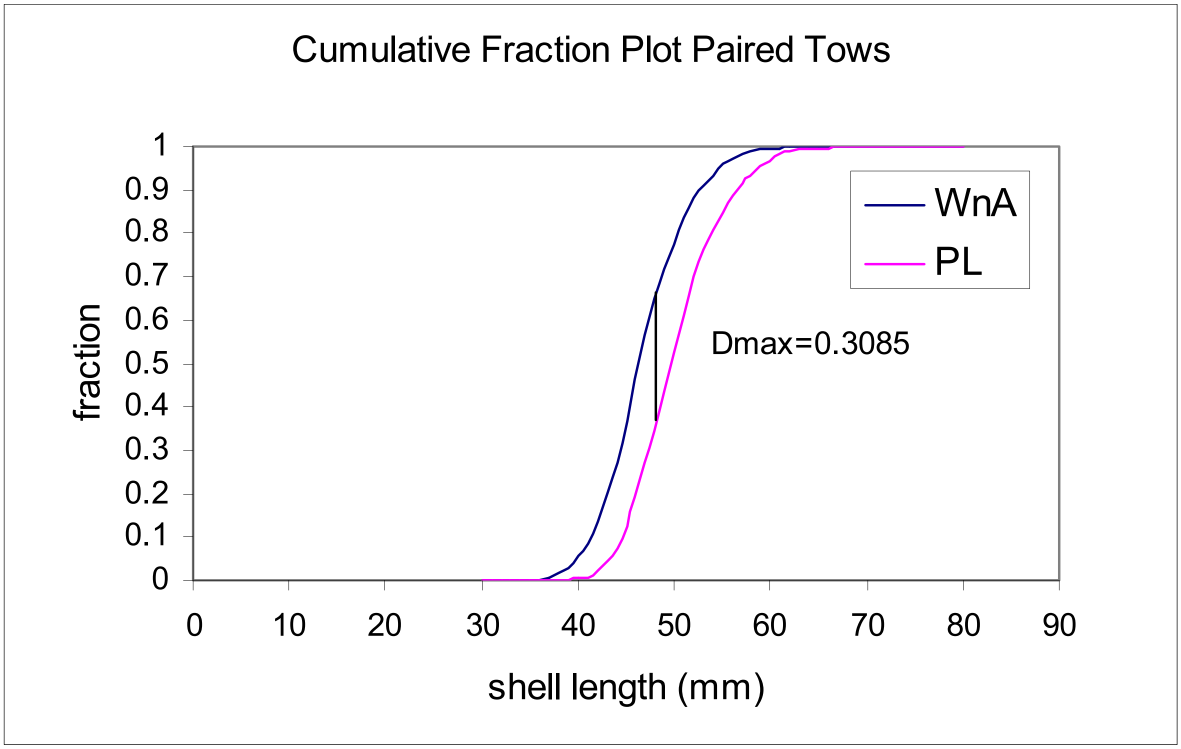
Appendix A8. Figure 22. Side by side towing operations underway.



Appendix A8. Figure 23. Results from both bootstrap runs for the paired tows between the F/V Promise Land and the F/V Whitney and Ashley. The F/V Promise Land has a catch ratio to the F/V Whitney and Ashley of 2.5:1



Appendix A8. Figure 24. Size frequencies for the two vessels in the paired tow experiments.



Appendix A8. Figure 25. Cumulative distribution plots for length data in paired tows.

B. ASSESSMENT OF NORTHEAST SKATE SPECIES COMPLEX

Report of the SAW Southern Demersal Working Group
(Members are listed at front of Report)

(EDITOR'S NOTE: In this skate assessment report, tables and figures are numbered according to Term of Reference, TOR. For example, Figure 3.1 would be the first figure for TOR 3.)

1.0 EXECUTIVE SUMMARY AND TERMS OF REFERENCE

TOR 1. Characterize the commercial and recreational catch including landings and discards.

The principal commercial fishing method in the directed skate fishery 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. There are few regulations governing the harvesting of skates in U.S. waters. Skates have been reported in New England fishery landings since the late 1800s. Reported commercial fishery landings, primarily from off Rhode Island, however, never exceeded several hundred metric tons until the advent of distant-water fleets and the industrial fishery during the 1950s and 1960s. Skate landings reached 9,500 mt in 1969 primarily from the distant water fleet, but declined quickly during the 1970s, falling to 800 mt in 1981. Since that time, landings have increased, 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 were likely taken from large-bodied skates (winter, thorny and barndoor), with winter and thorny skate 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 increased again and the 2004 reported commercial landings of 16,073 mt were the highest on record. Estimates of discards suggest they may be 2-4 times larger than the average landings. The commercial fishery discard mortality rates by species are unknown.

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 time series of Marine Recreational Fishery Statistics Survey (MRFSS) estimates. 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.

TOR 2. Estimate fishing mortality, spawning stock biomass, and total stock biomass for the current year and characterize the uncertainty of those estimates. If possible, also include estimates for earlier years.

Fishing Mortality

(EDITOR'S NOTE: MODEL-BASED FISHING MORTALITY ESTIMATES WERE PROPOSED; BUT THEY WERE REJECTED BY THE REVIEW PANEL)

Total Biomass

NEFSC survey data were the primary source of information to index biomass of skate species. Indices of winter skate abundance and biomass from the NEFSC 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 20% of the peak observed during the mid 1980s. Indices of little skate abundance and biomass from the NEFSC spring were stable, but below the time series mean, during the 1970s. Little skate spring survey indices began to increase in 1982, reached a peak in 1999, and declined thereafter. Indices of barndoor skate abundance and biomass from the NEFSC autumn surveys were at the highest values during early to late 1960s, and then declined to 0 fish per tow during the early 1980s. Since 1990, autumn survey indices have steadily increased, with the survey nearing the peak values found in the 1960s. NEFSC autumn survey indices for thorny skate have declined continuously over the last 40 years. NEFSC indices of thorny skate abundance have declined steadily since the late 1970s, reaching a historically low value in 2005 is less than10% of the peak observed in the 1970s. Indices of smooth skate abundance and biomass from the NEFSC autumn survey were at a peak during the late 1970s. NEFSC survey indices declined during the 1980s, before stabilizing during the early 1990s at about 25% of the values of the 1970s. NEFSC spring and autumn survey indices for clearnose skate increased from the mid-1980s through 2000 and have since declined to about average values. 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 increased from 1986 through 2001, declined slightly and recent indices are near the peak values of the late 1970s.

Spawning Stock Biomass:

Winter skate SSB generally follows the pattern of the autumn total biomass index with very low values in the 1970s followed by the large expansion of the size composition in the 1980s. The index of SSB declined in the mid- to late 1990s, increased slightly, and is currently at low values. Little skate SSB has been fairly stable through the time series with slightly higher values from 1999-2004 than in the 1980s and early 1990s. The pattern in barndoor skate SSB indices is much the same as that of total biomass with high values in the early 1960s, followed by very low to nonexistent values in the 1970s and

1980s, and then a consistent increase in the 1990s and 2000s. The decline in thorny skate SSB indices is more pronounced than for the total biomass index. Smooth skate SSB indices are very variable, but exhibit a slight decline over the time series. Clearnose skate SSB has increased over the time period. Rosette skate SSB has been variable but has generally increased.

TOR 3. Either update or redefine biological reference points (BRPs; proxies for BMSY and FMSY), as appropriate. Comment on the scientific adequacy of existing and redefined BRPs.

Existing Reference Points:

Biomass reference points (Figure B2) are based entirely on survey data because commercial catches are not available by species. For all species except barndoor, the B_{msy} proxy (B_{target}) is estimated as the 75th percentile of the appropriate survey series for that species (see Summary Status Table). For barndoor skate, the B_{msy} proxy is the average of the autumn survey biomass indices from a short period, 1963-1966. This period is used for barndoor skates because the survey captured few barndoor skates for a protracted period after these years. The stocks are declared to be overfished when the three-year moving average of the NMFS trawl survey index (mean weight per tow) is less than one half of the 75th percentile of mean weight per tow of the reference survey series for that species ($B_{threshold}$).

The overfishing definition is based on changes in survey biomass indices. In any year, if the three-year moving average of the survey biomass index for a skate species declines by more than a critical percentage from the previous year's moving average, then fishing mortality is assumed to be greater than F_{msy} and overfishing is assumed to be occurring for that skate species. The critical percentages for each species are given in the Summary Status Table (below).

Proposed Reference Points:

(EDITOR'S NOTE: NEW REFERENCE POINTS WERE PROPOSED; HOWEVER THEY WERE NOT ACCEPTED BY THE REVIEW PANEL)

TOR 4. Evaluate current stock status with respect to the existing BRPs, as well as with respect to updated or redefined BRPs (from TOR 3).

Summary Status Table – Northeast Skate Species – Basis: **Existing Reference Points**

Species	Series	Btarget	Bthresh	Current	Status	Target Percent	Current	Status
Winter	GOM-MA Off Autumn 67-98	6.46	3.23	3.34	Not Overfished	-20	-22.9	Overfishing
Little	GOM-MA All Spring 82-99	6.54	3.27	4.59	Not Overfished	-20	-15.9	No Overfishing
Barndoor	GOM-SNE Off Autumn 63-66	1.62	0.81	0.96	Not Overfished	-30	9.8	No Overfishing
Thorny	GOM-SNE Off Autumn 63-98	4.41	2.20	0.56	Overfished	-20	-11.2	No Overfishing
Smooth	GOM-SNE Off Autumn 63-98	0.31	0.16	0.18	Not Overfished	-30	3.7	No Overfishing
Clearnose	MA All Autumn 75-98	0.56	0.28	0.63	Not Overfished	-30	-16.2	No Overfishing
Rosette	MA Offshore Autumn 67-98	0.029	0.015	0.049	Not Overfished	-60	9.7	No Overfishing

TOR 5. Review, evaluate and report on the status of the SARC/Working Group Research Recommendations offered in recent SARC-reviewed assessments.

Completed. See Section 5.

TOR 6. Examine the NEFSC Food Habits Database to estimate diet composition and annual consumptive demand for seven species of skates for as many years as feasible.

Most skates are benthivorous in their feeding habits. A clear prominence on *Cancer* crabs, other crabs, amphipods, polychaetes and similar benthic macrofauna and megafauna was apparent in the diets of these skates. Some of the larger skates- barndoor, thorny, and winter- can be piscivorous, particularly with ontogeny. The vast majority of fish (or fish-like) prey for these skates were small pelagic fishes and squids.

Save winter and little skates, overall consumption by most skate stocks is a relatively small amount of biomass flow. Most total consumption by any particular species of skate was scaled singularly by the abundance of that species. The vast majority of consumptive removals by all skates except little and winter was < 20 MT per year.

As an aggregate group, skates consume a very small fraction of the total energy flow in the ecosystem. Skate consumptive removal is two to three orders of magnitude lower than biomass or production of skate prey. When abundance estimates are scaled by gear efficiency, it is possible that skates could consume a notable fraction of forage fish and squid biomass relative to what is removed by a fishery. Yet most of those forage fish stocks are at relatively high levels of abundance.

2.0 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 (*Leucoraja erinacea*), winter skate (*L. ocellata*), barndoor skate (*Dipturus laevis)*, thorny skate (*Amblyraja radiata*), smooth skate (*Malacoraja senta*), clearnose skate (*Raja eglanteria*), and rosette skate (*L. garmani*).

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).

The last stock assessment for the skate complex was conducted in 1999 at SARC/SAW 30 (NEFSC 2000). At that time there was no Fishery Management Plan (FMP) in place. The National Marine Fisheries Service had been petitioned to list barndoor skate as endangered based on a paper published by Casey and Myers (1998) and was also asked to assess the other species in the complex. SARC 30 found no cause to list barndoor as endangered but recommended that the species remain on the candidate species list as well as to put thorny skate on the candidate species list. Biomass reference points were developed for all seven species and four were listed as overfished. Fishing mortality reference points were developed for winter and little skate and overfishing was occurring for winter skate.

Following SARC 30, an FMP was developed by the New England Fishery Management Council (NEFMC) when they were informed of the overfished status of thorny and barndoor (winter and smooth biomass increased in the 1999 autumn survey and were no longer considered overfished). The FMP was implemented in September of 2003 with a primary requirement for mandatory reporting of skate landings by species by both dealers and vessels. The FMP prohibited possession of barndoor and thorny skate, as well as smooth skate from the Gulf of Maine. A trip limit of 10,000 lbs was implemented for winter skate with a Letter of Authorization for the bait fishery (little skate) to exceed the trip limit. Biomass reference points developed at SARC 30 were maintained, but new fishing mortality reference points were developed.

3.0 TOR 1. Characterize the commercial and recreational catch including landings and discards

3.1 Commercial Fishery Landings

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 and the industrial fishery during the 1950s and 1960s. Skate landings reached 9,500 mt in 1969, but declined quickly during the

1970s, falling to 800 mt in 1981 (Table B1.1, Figure B1.1). Landings then increased markedly, partially in response to increased demand for lobster bait, and more significantly, to the increased export market for skate wings. Landings increased to 12,900 mt in 1993 and then declined somewhat to 7,200 mt in 1995. Landings increased again and the 2004 reported commercial landings of 16,073 mt were the highest on record (Table B1.1, Figure B1.1).

United States landings of skates are reported in all months (Table B1.2). There is a relatively even distribution of landings across months, but the summer months do show a slightly higher percentage, probably due to the increased demand for lobster bait during those months.

Skate landings are primarily from Massachusetts and Rhode Island (mainly New Bedford and Point Judith) with 85-95% of the landings occurring in those two states (Table B1.3). Landings from other states did occur back through time and the table somewhat reflects better reporting as more states reported in the NMFS database. Also, the difference in total landings between Table B1.1 and B1.3 is likely the result of landings from the industrial fishery not included in the Weighout database. These landings were sampled during the 1960s and 1970s for species composition and prorated. Skates accounted for about 10% of those landings.

Otter trawls are the primary gear used to land skates in the United States, with some landings coming from sink gill nets (Table B1.4). In the last couple of years, landings from longline gear have increased slightly in importance. The increase in other gear reflects the new reporting system implemented in 2004.

Landings are generally not reported by species, with over 99% of the landings reported as Aunclassified skates@ until the FMP was implemented in September of 2003 (Table B1.5). Wings are most likely 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 of barndoor and thorny skate are being reported by the dealers even though there is a possession prohibition for those two species. There are also wings reported for rosette, little and smooth which are known to be too small for wings. The distribution of skate landings by state and species also shows that some species are landed in areas that they do not occur (Table B1.6). For example, in 2004, barndoor were landed in Virginia which is too far south for barndoor skate.

3.2 Commercial Fishery Discards

Discard estimates from SAW/SARC 30 were revised in this assessment. The previous method, which employed primary species groups to bin the discard data, was found to be a biased estimator (NEFSC 2006). Instead, the ratio-estimator used in this assessment is based on the methodology described in Rago et al. (2005). It relies on a d/k ratio where the kept component is defined as the total landings of all species within a "fishery". A fishery is defined as a homogeneous group of vessels with respect to gear type, season, and geographic region. Each of these attributes is an observable property and easily defined within existing data bases. Moreover, it is not dependent on ambiguous properties such as "target species" or imprecise self-reported attributes such as area fished.

The discard ratio for spiny dogfish in stratum h is the sum of discard weight over all trips divided by sum of kept weights over all trips:

$$\hat{R}_h = \frac{\sum_{i=1}^{n_h} d_{ih}}{\sum_{i=1}^{n_h} k_{ih}} \qquad (1)$$

where d_{ih} is the discards for dogfish within trip i in stratum h and k_{ih} is the kept component of the catch for all species. R_h is the discard rate in stratum h. The stratum weighted discard to kept ratio is obtained by weighted sum of discard ratios over all strata:

$$\hat{R} = \sum_{h=1}^{H} \left(\frac{N_h}{\sum_{h=1}^{H} N_h} \right) \hat{R}_h \qquad (2)$$

The total discard within a stratum is the product of the estimate discard ratio R and the total landings for the fishery in stratum h, i.e., $D_h = R_h K_h$.

Annual estimated discards by fishery for 1989-2005 are summarized in Table B1.7. Total discards in 1990 were estimated to be about 80,000 mt. Most of this came from the otter trawl fishery. However, in the first two years, there were no estimates of discards from the scallop dredge fishery, which represent a significant portion in later years. The peak in the estimates was in 1992 at almost 90,000 mt, almost half came from the scallop dredge fishery. Estimates have since declined except for 2002 which was inflated by one blue crab pot trip which is probably not representative of that fishery. Estimates in recent years are still higher than reported landings but are much lower than the estimates from the early 1990s. This is likely due to reduced effort in the multispecies groundfish fishery as well as the scallop dredge fishery. Sampling of the three main gear types (otter trawl, sink gill net, and scallop dredge) has improved in recent years (Tables B1.8-B1.10).

The discard estimates were not dis-aggregated to skate species because species identification is uncertain in the Domestic Observer Program. Catches of skates by species were mapped to determine if the data were potentially useful. Winter and little skate distributions look reasonable (Figures B1.2-B1.3). Barndoor distribution from the observer data shows fairly substantial amounts off Virginia and North Carolina (Figure B1.4). These are unlikely to be correctly identified. The distributions of thorny and smooth are also curious showing catches in the Mid-Atlantic (Figures B1.5-B1.6). The reverse is true for clearnose and rosette (Figures B1.7-B1.8). These two species have a southern distribution and the maps show considerable amounts of fish found in the Gulf of Maine. The length compositions of kept and discarded fish also show that there are identification problems (Figures B1.8-B1.15). In particular, the length frequency for kept little skate has fish that are 60 to 80 cm which is a larger size than this species can attain. The same thing occurs for smooth and rosette showing larger sizes than is possible.

3.3 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. Data from 1999 through 2005 were similar in magnitude.

4.0 TOR 2. Estimate fishing mortality, spawning stock biomass, and total stock biomass for the current year and characterize the uncertainty of those estimates. If possible, also include estimates for earlier years.

4.1 Research survey data – Total Stock Biomass

Indices of relative abundance from NEFSC bottom trawl surveys form the basis for most of the conclusions about status of the seven species in the skate complex. The NEFSC trawl survey has been conducted in the autumn from the Gulf of Maine to Southern New England since 1963 (Azarovitz 1981) and the Mid-Atlantic was added in 1967 (Figure B2.1). A spring survey was started in 1968 with stations <= 27 m added in 1975 (Figures B2.2-2.4). All statistically significant NEFSC gear, door, and vessel conversion factors were applied to little, winter, and smooth skate indices when applicable (Sissenwine and Bowman, 1978; NEFC 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, but then increased to peak levels in the mid to late 1980s. The index of skate complex biomass then declined steadily until 1994, but increased until 2000 and has since decreased (Figure B2.5A). 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 (Figure B2.5B,C). The biomass of large sized skates steadily declined from the mid-1980s to the mid-1990s and has since been stable (Figure B2.5B). The increase in aggregate skate biomass from the mid-1990s to 2000 was due to an increase in little skate and the subsequent decline is also due to little skate (Figure B2.5C).

Indices of relative abundance for some of the species have also been developed from MADMF and CTDEP research surveys.

The previous SARC computed variance estimates for the survey indices assuming a normal error distribution. A recommendation was made to explore alternate error distributions since this assumption may not hold at very low stock sizes and results in confidence intervals which are below zero. Another alternative to assuming any error distribution is to use bootstrap methods. The bootstrap methodology of Smith (1997) was implemented using the Splus software written by Stephen Smith (DFO, Halifax). In order to bootstrap the NEFSC survey data, some strata had to be combined to ensure that at least two tows were made in each stratum during each year (Table B2.1). The second figure in each species section shows the stratified mean without combining strata, the mean combining strata and the bootstrapped mean.

Winter skate

NEFSC spring and autumn 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 (NEFSC 2000; Figure B2.6). In the NEFSC spring survey offshore strata (1968-2006), 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 (1963-2005), 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 B2.2-B2.3).

The catchability of winter skate in the 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 (1992-2006) 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 B2.4). 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 B2.7). The NEFSC scallop dredge survey also catches winter skates mostly on Georges Bank (Figures B2.8-B2.9). The scallop survey also does not sample in the Gulf of Maine and on the very shallowest portions of Georges Bank.

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 (Figure B2.10). Winter skate indices increased to the time series mean by 1980, and then reached a peak during the mid 1980s. Winter skate 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 20% of the peak observed during the mid 1980s (Figures B2.10). The combining of strata did not have much impact on the stratified mean (Figures B2.11-B2.14).

The minimum length of winter skate caught in NEFSC surveys is 15 cm (6 in), and the largest individual caught was 116 cm (46 in) total length, during the 1985 spring survey on Georges Bank (Tables B2.2-B2.4). The median length of the survey catch has ranged from 28 cm in the 2003 winter survey to 79 cm in the 1978 spring survey and the 1985 autumn survey. The median length of the survey catch generally declined from 1979 to the mid-1990s in both the spring and autumn surveys, increased through 2002, and then declined slightly to currently remain about 45-52 cm (18-20 inches)(Figure B2.15). Length frequency distributions from the NEFSC spring and autumn surveys show several modes, most often at 40, 60, and 80 cm (Figures B2.16-B2.20). The spring survey length distributions show large modes at about 40 cm during 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.

The strata set used for bootstrapping the winter survey differed from the standard consistent strata set used for the information in Table 2.4. Given that the strata on Georges Bank were not sampled in some years, the set for bootstrapping was limited to Southern New England to the Mid-Atlantic (Table B2.1). This created more of a difference between the original mean, with usually a lower index when Georges Bank was included in the original (Figure B2.21-B2.22). The indices of both abundance and biomass fluctuated without trend through the series.

The difference between the original mean and the combined strata mean in the scallop survey was due to the bootstrapped mean consisting of only strata which caught some winter skate (Figures B2.23-B2.24) while the original was the entire scallop survey strata set. There are no biomass estimates from 1985 through 2000 since no weights were taken at sea and the survey in 1999 was completed on a commercial scalloper and therefore the data are not comparable. Abundance was high in the mid-1980s, declined through the 1990s, increased through 2000 and then declined.

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 1978-2006. 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 again to low values in the late 1990s and remaining low through 2006 (Figure B2.25). The autumn index is more erratic, but generally shows the same pattern.

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 1984-2006 (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 declined slightly (Figure B2.26).

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 (NEFSC 2000, Figure B2.27). In the NEFSC spring surveys (1976-2006), the annual total catch of little skate has ranged from 3,512 fish in 1986 to 16,406 fish in 1999 (Table 2.5). In the NEFSC autumn surveys (1975-2005), the annual total catch of little skate has ranged from 1,124 fish in 1993 to 6,523 fish in 2003 (Table 2.6). 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 18 fish, or 7.7 kg, per tow in 2003 (Tables B2.5-B2.6).

The catchability of little skate in the 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 (1992-2006) annual catches of little skate have ranged from 8,870 fish in 2003 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 B2.7). 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 B2.28). The NEFSC scallop dredge survey also catches little skates in all areas of sampling (Figures B2.29-B2.30). The scallop survey also does not sample in the Gulf of Maine, on the very shallowest portions of Georges Bank and parts of Southern New England.

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, reached a peak in 1999, and declined thereafter (Figure B2.31). Autumn survey indices have been relatively stable over the duration of the time series, with a slight increase in recent years (Figure B2.31). The application of the NEFSC gear conversion factors to spring survey indices decreased the indices in 1981 and earlier years by 75 percent. The combining of strata had slightly more impact for little skate than for winter skate, since many of the inshore strata were combined (Figures B2.32-B2.35).

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 44 cm, most recently in the 2005 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 42 cm in the spring and 43 cm in the autumn (17 inches)(Figure B2.36). 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 B2.37-B2.40).

The strata set used for bootstrapping the winter survey differed from the standard consistent strata set used for the information in Table 2.7. Given that the strata on Georges Bank were not sampled in some years, the set for bootstrapping was limited to Southern New England to the Mid-Atlantic (Table B2.1). This created more of a difference between the original mean, with usually a higher index when Georges Bank was included in the original (Figure B2.41-B2.42). The indices of both abundance and biomass declined through 2000, increased for a few years and subsequently declined..

The difference between the original mean and the combined strata mean in the scallop survey was due to the bootstrapped mean consisting of only strata which caught some little skate (Figures B2.43-B2.44) while the original was the entire scallop survey strata set. There are only differences in the early part of the time series when more strata were sampled. There are no biomass estimates from 1985 through 2000 since no weights were taken at sea and the survey in 1999 was completed on a commercial scalloper and therefore the data are not comparable. Abundance indices increased to a peak in 2000 and have subsequently declined.

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 1978-2006 (Figure B2.45). 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, and have since fluctuated without trend.

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 1984-2006 (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 1984-2006 time series followed by a decline (Figure B2.46).

Barndoor skate

NEFSC bottom trawl surveys (Figure B2.47) 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 Schroeder (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 (1968-2006), the annual total catch of barndoor skate has ranged from 0 fish (several years during the 1970s and 1980s) to 196 fish in 2006 (Table B2.8). In the NEFSC autumn surveys (1963-2005), the annual total catch of barndoor skate has ranged from 0 fish (several years in the 1970s and 1980s) to 120 fish in 1963 (Table B2.9). 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 B2.8-B2.9).

The catchability of barndoor skate in the 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 (1992-2006) annual catches of barndoor skate have ranged from 0 fish in 1992 to 355 in 2006, equating to a maximum stratified mean catch per tow of 3.2 fish or 3.0 kg per tow in 1999 (Table B2.10). 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 B2.48). The NEFSC scallop dredge survey also catches barndoor skates primarily on Georges Bank (Figure B2.48). The scallop survey also does not sample in the Gulf of Maine, on the very shallowest portions of Georges Bank and parts of Southern New England.

Indices of barndoor skate abundance and biomass from the NEFSC spring and autumn surveys were at their highest values during early to late 1960s, and then declined to 0 fish per tow during the early 1980s. Since 1990, both spring and autumn survey indices have steadily increased, with the spring survey at the highest value and the autumn survey nearing the peak values found in the 1960s (Figure B2.49). The combining of strata did not have much impact on the stratified mean (Figures B2.50-B2.53).

The minimum length of barndoor skate caught in NEFSC surveys is 20 cm (8 inches), 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 stable in recent years in both the spring and autumn surveys, and is currently 70-75 cm (28-30 in; Figure B2.54). 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 B2.55-B2.59). Recent catches have included individuals as large as those recorded during the peak abundance of the 1960s, and the large number of fish between 40 and 80 cm evident during the 1960s is now apparent in recent surveys.

The strata set used for bootstrapping the winter survey differed from the standard consistent strata set used for the information in Table 2.10. Given that the strata on Georges Bank were not sampled in some years, the set for bootstrapping was limited to Southern New England to the Mid-Atlantic (Table B2.1). This created more of a difference between the original mean, with usually a lower index when Georges Bank was included in the original (Figure B2.60-B2.61). The indices of both abundance and biomass have increased substantially from 1993 to 2006. The NEFSC winter survey length frequency distributions for indicate a significant increase in the abundance of barndoor skate at lengths less than 80 cm (Figure B2.62).

The difference between the original mean and the combined strata mean in the scallop survey was due to the bootstrapped mean consisting of only strata which caught some barndoor skate (Figures B2.63-B2.64) while the original was the entire scallop survey strata set. There are no biomass estimates from 1985 through 2000 since no weights were taken at sea and the survey in 1999 was completed on a commercial scalloper and therefore the data are not comparable. Abundance indices increased consistently while the biomass indices have been more variable.

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 (Figure B2.65). In the NEFSC spring surveys (1968-2006), the annual total catch of thorny skate has ranged from 29 fish in 2006 to 574 fish in 1973 (Table 2.11). In the NEFSC autumn surveys (1963-2005), the annual total catch of thorny skate has ranged from 35 fish in 2005 to 874 fish in 1978 (Table 2.12). Calculated on a per tow basis, these spring and autumn survey catches equate to maximum stratified mean number per tow indices for the GOM-SNE offshore strata of about 2 to 3 fish, or about 6.0 kg, per tow during the early 1970s (Tables B2.11-2.12).

The NEFSC scallop dredge survey also catches thorny skates primarily on the edges of Georges Bank (Figure B2.66). The scallop survey also does not sample in the Gulf of Maine, on the very shallowest portions of Georges Bank and parts of Southern New England. A summer shrimp survey is conducted in the Gulf of Maine which also catches thorny skate (Figure B2.66). Indices from this survey have not been updated.

NEFSC spring and autumn survey indices for thorny skate have declined continuously over the last 40 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 and1.8 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 2005 and 2006 that are less than10% of the peak observed in the 1970s (Figure B2.67). The combining of strata did not have much impact on the stratified mean (Figures B2.68-B2.71).

The minimum length of thorny skate caught in NEFSC surveys is about 10 cm (4 inches), and the largest individual caught was 111 cm (44 inches) total length, most recently during the 1977 spring survey on Georges Bank (Tables B2.11-B2.12). The median length of the survey catch has ranged from 23 cm in the 2003 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 stable in recent years in autumn surveys, and is currently 40-50 cm (16-20 inches; Figure B2.72). 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 B2.73-B2.77).

The difference between the original mean and the combined strata mean in the scallop survey was due to the bootstrapped mean consisting of only strata which caught some thorny skate (Figures B2.78-B2.79) while the original was the entire scallop survey strata set. There are no biomass estimates from 1985 through 2000 since no weights were taken at sea and the survey in 1999 was completed on a commercial scalloper and therefore the data are not comparable. Abundance indices declined from a peak in 1986 while the biomass indices declined since 2001.

Indices of abundance for thorny 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 1978-2006. 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 0.2 kg/tow throughout the 2000's, while the autumn index has been below the median of 0.6 kg/tow since 1994 except for 2001 and 2002 (Figure B2.80).

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 B2.81). In the NEFSC spring surveys (1968-2006), the annual total catch of smooth skate has ranged from 12 fish in 1996 to 179 fish in 1973 (Table B2.13). In the NEFSC autumn surveys (1963-2005), the annual total catch of smooth skate has ranged from 10 fish in 1976 to 130 fish in 1978 (Table B2.14). 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 B2.13-B2.14).

The NEFSC scallop dredge survey also catches smooth skates primarily on the edges of Georges Bank (Figure B2.82). The scallop survey also does not sample in the Gulf of Maine, on the very shallowest portions of Georges Bank and parts of Southern New England. A summer shrimp survey is conducted in the Gulf of Maine which also catches smooth skate (Figure B2.82). Indices from this survey have not been updated.

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 (Figure B2.83). 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. The combining of strata did not have much impact on the stratified mean (Figures B2.84-B2.87).

The minimum length of smooth skate caught in NEFSC surveys is about 8 cm (3 inches), and the largest individual caught was 73 cm (29 inches) total length, during the 2000 autumn survey on Georges Bank (Tables B2.13-B2.14). 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-SNE offshore region shows no trend over the full survey time series, and is currently at about 40 cm (16 in) (Figure B2.88). Length frequency distributions from the NEFSC spring and autumn surveys in the GOM offshore region show modes at 30 and 50 cm (Figures B2.89-B2.93). 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 indicated strong recruitment in the region.

The difference between the original mean and the combined strata mean in the scallop survey was due to the bootstrapped mean consisting of only strata which caught some smooth skate (Figures B2.94-B2.95) while the original was the entire scallop survey strata set. There are no biomass estimates from 1985 through 2000 since no weights were taken at sea and the survey in 1999 was completed on a commercial scalloper and therefore the data are not comparable. Abundance indices were low at the beginning of the time series and have since increased.

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 B2.96). In the NEFSC spring surveys (1976-2006), the annual total catch of clearnose skate has ranged from 9 fish in 1979 to 136 fish in 1993 (Table B2.15). In the NEFSC autumn surveys (1975-2005), the annual total catch of clearnose skate has ranged from 19 fish in 1983 to 221 fish in 2001 (Table B2.16). 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 and 2000s (Tables B2.15-B2.16).

The catchability of clearnose skate in the 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 (1992-2006) 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 B2.17). 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 B2.97).

NEFSC spring and autumn survey indices for clearnose skate have been increased from the mid-1980s through 2000 and have since declined to about average values (Figure B2.98). The combining of strata had more impact for clearnose skate than for other species, since many of the inshore strata were combined and the most southern strata were combined into one stratum (Figures B2.99-B2.102).

The minimum length of clearnose skate caught in NEFSC surveys is about 10 cm (4 inches), and the largest individual caught was 93 cm (33 in) total length, during the 1992 and 2000 winter surveys in the Mid-Atlantic Bight region (Tables B2.15-B2.17). 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 inches; Figure B2.103). 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 B2.104-B2.107).

The strata set used for bootstrapping the winter survey differed from the standard consistent strata set used for the information in Table 2.17. Given that the strata on Georges Bank were not sampled in some years, the set for bootstrapping was limited to a few Southern New England strata and the Mid-Atlantic (Table B2.1). This created more of a difference between the original mean, with usually a lower index when Georges Bank was included in the original (Figure B2.108-B2.109). The indices of both abundance and biomass have generally fluctuated without trend.

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 had caught very few clearnose skate, with annual catches ranging from 0 to 20 skates through 1998, but the indices have increased in Long Island Sound over the times series (Figure B2.110).

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 Georges Bank and no fish caught in the Gulf of Maine or inshore (Figure B2.111). In the NEFSC spring surveys (1968-2006), the annual total catch of rosette skate has ranged from 0 fish, in 1970 and1984, to 70 fish in 1977 (Table B2.18). In the NEFSC autumn surveys (1967-2005), the annual total catch of rosette skate has ranged from 1 fish, most recently in 1982, to 46 fish in 1999 (Table B2.19). 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 B2.18-B2.19).

The catchability of rosette skate in the 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 (1992-2006) annual catches of rosette skate have ranged from 143 fish in 1993 to 1029 fish in 2003, equating to a maximum stratified mean catch per tow of 2.8 fish or 0.7 kg per tow in 2003 (Table B2.20). 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 B2.112).

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 increased from 1986 through 2001, declined slightly and recent indices are near the peak values of the late 1970s (Figure B2.113). The combining of strata had more impact for rosette skate than for other species, since the deep offshore strata were combined with the next deepest stratum and the most southern strata were combined into one stratum (Figures B2.114-B2.117).

The minimum length of rosette skate caught in NEFSC surveys is about 7 cm (3 inches), and the largest individual caught was 57 cm (22 inches) total length, during the 1971 spring survey in the Mid-Atlantic Bight region (Tables B2.18-B2.20). 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 inches; Figure B2.118). Length frequency distributions from the NEFSC spring and autumn surveys show a consistent mode at 30-40 cm (Figures B2.119-B2.123).

The strata set used for bootstrapping the winter survey differed from the standard consistent strata set used for the information in Table 2.17. Given that the strata on Georges Bank were not sampled in some years and the deepwater strata which are important for rosette skate were not sampled until 1998, the set for bootstrapping was limited to a few Southern New England strata and the Mid-Atlantic from 1998 on (Table B2.1). This created more of a difference between the original mean, with usually a lower index when Georges Bank was included in the original (Figure B2.124-B2.125). The indices of both abundance and biomass increased through 2002 and have subsequently declined.

4.2 Research survey data – Spawning Stock Biomass

Maturity information was available in some form for all species to split the survey length information into mature and immature animals (Table 2.21). The series chosen for each species was the same as chosen for reference points at SARC30. There is a protracted spawning as females likely lay eggs year round so there is no need to pick a season based on spawning time. As it is generally the longest running series, the autumn survey was used for all species except little skate. For little skate, the spring series from 1982 on was used; this date was chosen to avoid gear conversion issues.

Winter skate SSB generally follows the pattern of the autumn total biomass index with very low values in the 1970s followed by the large expansion of the size composition in the 1980s (Table B2.22; Figure B2.126). The index of SSB declined in the mid- to late 1990s, increased slightly, and is currently at low values. Little skate SSB has been fairly stable through the time series with slightly higher values from 1999-2004 than in the 1980s and early 1990s (Table B2.22; Figure B2.126). The pattern in barndoor skate SSB indices is much the same as that of total biomass with high values in the early 1960s, followed by very low to nonexistent values in the 1970s and 1980s, and then a consistent increase in the 1990s and 2000s (Table B2.22; Figure B2.126). The decline in thorny skate SSB indices is more pronounced than for the total biomass index (Table B2.22; Figure B2.126). Smooth skate SSB indices are very variable, but exhibit a slight decline over the time series (Table B2.22; Figure B2.126). Clearnose skate SSB has increased over the time period (Table B2.22; Figure B2.126). Rosette skate SSB has been variable but has generally increased (Table B2.22; Figure B2.126).

4.3 Fishing mortality estimates

The length-based mortality estimators of Beverton and Holt (1956) and Hoenig (1987) were considered for the estimation of fishing mortality rates for winter, little, barndoor, thorny, and clearnose skates from NEFSC spring and autumn length frequency distributions. Only these five species were analyzed since age and growth information is available for these species and unavailable for rosette and smooth (Table 2.21).

(EDITOR'S NOTE: MODEL-BASED FISHING MORTALITY ESTIMATES WERE PROPOSED; THEY ARE NOT SHOWN BECAUSE THEY WERE NOT ACCEPTED BY THE REVIEW PANEL)

4.3.1 Mortality from Mean Length Gedamke and Hoenig (2006) Method

Gedamke and Hoenig (2006) developed a method to estimate mortality from mean length data in nonequilibrium situations. It is an extension of the Beverton-Holt length-based mortality estimator that assumes constant recruitment throughout the time series and mortality at fixed levels for certain periods within the time series. The approach allows for the transitory changes in mean length to be modeled as a function of mortality rate changes. After an increase in mortality, mean length will gradually decrease due to larger animals being less prevalent in the population. After a decrease in mortality, mean length will increase slowly due to growth of the fish in the population. The rates of change in both cases depend on the von Bertalanffy growth parameters and the magnitude of change in the mortality rates. Since the method requires only a series of mean length above a user defined minimum size and the von Bertalanffy growth parameters, it can be applied in many data poor situations. Gedamke and Hoenig (2006) demonstrated the utility of this approach using both simulated data and an application to data for goosefish caught in the NEFSC fall groundfish survey.

(EDITOR'S NOTE: FISHING MORTALITY ESTIMATES WERE PROPOSED; THEY ARE NOT SHOWN BECAUSE THEY WERE NOT ACCEPTED BY THE REVIEW PANEL)

4.3.2 Thorny Skate Length Tuned Model (LTM)

Introduction

A forward projecting length tuned model (LTM) was modified to fit only survey abundance indices and survey size information for the estimation of fishing mortality rates. Results from this analysis were compared to the Hoenig length based estimates to help determine the influences of assuming equilibrium conditions. The LTM model does not assume equilibrium conditions since fishing mortality estimates in year n will influence the population size structure in year n+1. However the initial population in year one of the model is calculated assuming equilibrium conditions.

Herein we used a simple forward projecting age-based model tuned with age-3 recruitment (estimated from fish in the survey that were between 35 and 45 cm), survey numbers of 40+ cm fish and length frequency of the 40+ cm fish. The Length Tuned Model was developed in the AD model builder framework. The model estimates fishing mortality and relative recruitment changes each year, fishing mortality to produce the initial population length frequency (F_{start}), and Qs for each survey index. Initial population abundance was fixed since no catch information can be used to scale the model in terms of abundance.

(EDITOR'S NOTE: RESULTS FROM THIS MODEL ARE NOT SHOWN BECAUSE THEY WERE NOT ACCEPTED BY THE REVIEW PANEL)

5.0 TOR 3. Either update or redefine biological reference points (BRPs; proxies for BMSY and FMSY), as appropriate. Comment on the scientific adequacy of existing and redefined BRPs.

5.1 Current Reference Points

The existing biomass reference points were developed at SARC 30 (NEFSC 2000) with B_{msy}Proxy formulated as the 75th percentile of the given time series of each species, except barndoor (Table B3.1) and half that value for $B_{threshold}$. It was assumed that all species had at some time passed through B_{msy} at some point in the time series. For barndoor skate, the mean of the first four years of the autumn survey were used instead, given that biomass had been extremely low during most of the time series. To reduce the variability in the survey estimates, a three-year moving average of the survey indices was proposed to evaluate stock status for all species.

The fishing mortality reference points developed at SARC 30 were not accepted by the NEFMC and a different method for evaluating fishing mortality was developed by the Plan Development Team (PDT). The thresholds for fishing mortality are based on annual percentage declines of the three-year average of the NEFSC trawl survey time series chosen for the biomass reference points. The percentages are specified for each species individually based on historical variation within the survey. The thresholds also include what is termed a precautionary "backstop" that indicates that overfishing is occurring if the trawl survey mean weight per tow declines for three consecutive years. The main part of the definition is that overfishing is occurring when the three-year moving average of the given survey biomass index declines by more than the average CV of the time series.

5.2 Alternative Reference Points

(EDITOR'S NOTE: ALTERNATIVE REFERENCE POINTS WERE PRESENTED; THEY ARE NOT SHOWN BECAUSE THEY WERE NOT ACCEPTED BY THE REVIEW PANEL)

6.0 TOR 4. Evaluate current stock status with respect to the existing BRPs, as well as with respect to updated or redefined BRPs (from TOR 3).

6.1 Current Reference Points

For winter skate, the 2003-2005 NEFSC autumn survey biomass index average of 3.34 kg/tow is below the biomass target of 6.46 kg/tow but above the threshold reference point of 3.23 kg/tow (Figure B4.1). Winter skate is not overfished. The 2003-2005 average of 3.34 kg/tow was more than 20% below the 2002-2004 average of 4.34 kg/tow (Table B4.1), therefore overfishing is occurring for winter skate.

For little skate, the 2004-2006 NEFSC spring survey biomass index average of 4.59 kg/tow is below the biomass target of 6.54 kg/tow but above the threshold reference point of 3.27 kg/tow (Figure B4.1). Little skate is not overfished. The 2004-2006 average of 4.56 kg/tow was less than 20% below the 2003-2005 average of 5.65 kg/tow (Table B4.1), therefore overfishing is not occurring for little skate.

For barndoor skate, the 2003-2005 NEFSC autumn survey biomass index average of 0.96 kg/tow is below the biomass target of 1.62 kg/tow but above the threshold reference points of 0.81 kg/tow(Figure B4.1). Barndoor skate is not overfished. The 2003-2005 average of 0.96 kg/tow was above the 2002-2004 average of 0.88 kg/tow (Table B4.1), therefore overfishing is not occurring for barndoor skate.

For thorny skate, the 2003-2005 NEFSC autumn survey biomass index average of 0.56 kg/tow is below the biomass target and threshold reference points of 4.41 kg/tow and 2.20 kg/tow (Figure B4.1). Thorny skate is overfished. The 2003-2005 average of 0.56 kg/tow was less than 20% below the 2002-2004 average of 0.63 kg/tow (Table B4.1), therefore overfishing is not occurring for thorny skate.

For smooth skate, the 2003-2005 NEFSC autumn survey biomass index average of 0.18 kg/tow is below the biomass target of 0.31 kg/tow but above the threshold reference point of 0.16 kg/tow(Figure B4.1) . Smooth skate is not overfished. The 2003-2005 average of 0.18 kg/tow was above the 2002-2004 average of 0.17 kg/tow (Table B4.1), therefore overfishing is not occurring for smooth skate.

For clearnose skate, the 2003-2005 NEFSC autumn survey biomass index average of 0.63 kg/tow is above the biomass target and threshold reference points of 0.56 kg/tow and 0.28 kg/tow (Figure B4.1). Clearnose skate is not overfished. The 2003-2005 average of 0.63 kg/tow was less than 30% below the 2002-2004 average of 0.75 kg/tow (Table B4.1), therefore overfishing is not occurring for clearnose skate.

For rosette skate, the 2003-2005 NEFSC autumn survey biomass index average of 0.049 kg/tow is above the biomass target and threshold reference points of 0.029 kg/tow and 0.015 kg/tow (Figure B4.1) . Rosette skate is not overfished. The 2003-2005 average of 0.049 kg/tow was above the 2002-2004 average of 0.045 kg/tow (Table B4.1), therefore overfishing is not occurring for rosette skate.

7.0 TOR 5. Review, evaluate and report on the status of the SARC/Working Group Research Recommendations offered in recent SARC-reviewed assessments.

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

> *Since the implementation of the Skate Complex FMP, there is a requirement to report landings of skates by species. However, training is needed to improve the accuracy of the reporting.*

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

> *Observers are collecting landings and discarded size composition by species. However, more training is needed to improve the accuracy of the data.*

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.

> *Observer coverage was increased in 2004 and 2005 primarily for the multi-species groundfish fisheries which have a large bycatch of skates. Observer coverage of scallop fisheries has improved as well. More training is needed to improve the accuracy of the species identification.*

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

> *Studies have been conducted for five of the seven species (Frisk 2004,Gedamke 2006, Gedamke et al. 2005, Gelschleiter 1998, Sulikowski et al. 2005) and samples have been collected by NEFSC for the other two species.*

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.

> *Maturity studies estimating L_{50} have been conducted for barndoor (Gedamke 2005), winter and little (Frisk 2004), and thorny (Sulikowski et al. 2006). Sosebee (2005) estimated size at first maturity for all seven 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.

> *Not completed.*

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.

> *Not completed.*

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.

Stock-recruit relationships have been examined for five of the species in the complex. The second method is not appropriate for skates.

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

Considerable progress has been made.

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

Not completed.

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.

Work has been done on winter skate to explore the changes in abundance between the Scotian Shelf and Georges Bank (Frisk et al, in review).

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

Not completed.

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.

Not completed.

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

Instead of assuming an error distribution, confidence intervals were derived using the bootstrap methods of Smith (1997).

8.0 TOR 6. Examine the NEFSC Food Habits Database to estimate diet composition and annual consumptive demand for seven species of skates for as many years as feasible.

8.1 Introduction

Skate food habits were evaluated for all seven species in the skate complex. The total amount of food eaten and the type of food eaten were the primary food habits data examined. From these basic food habits data, diet composition, per capita consumption, total consumption, and the amount of prey removed by skates were calculated. Contrasts to total energy flows in the ecosystem and fishery removals of commercially targeted skate prey were conducted to fully address the Term of Reference.

8.2 Methods

Each skate was analyzed separately; emphasizing at least two if not three size classes as appropriate (Table B6.1). These size classes correspond to notable changes in diet and life history and also minimized low data density (i.e., number of stomachs sampled) for each size class. Each skate was analyzed for a particular bottom trawl survey strata set germane for each case (Table B6.1). For all the estimates, small winter skates (< 30 cm) were grouped with immature little skates. Estimates were analyzed on an annualized basis for each species, save instances were data density of stomach samples was too low. In those cases data were evaluated across 5-year time blocks. Although the food habits data collections started quantitatively in 1973, not all species of skates were sampled during the full extent of this sampling program. For more details on the food habits sampling protocols and approaches, see Link and Almeida (2000). Where data are available, they are used except in the case of little skate (see above for discussion on why those estimates begin in 1982). This sampling program was a part of the NEFSC bottom trawl survey program; for background and context, further details of the survey program can be found in Azarovitz (1981) and NEFC (1988).

Basic Food Habits

To estimate mean stomach contents (S_i), each skate had the total amount of food eaten (as observed from food habits sampling) calculated for each size class, temporal and spatial scheme. The denominator in the mean stomach contents (i.e., the number of stomachs sampled) was inclusive of empty stomachs. These means were weighted by the number of tows in a temporal and spatial scheme as part of a two-stage cluster design. Further particulars of these estimators can be found in Link and Almeida (2000). Units for this estimate are in g.

To estimate diet composition (D_{ij}), the amount of each prey item was summed across all skate stomachs. These estimates were then divided by the total amount of food eaten in a size class, temporal and spatial scheme, totaling 100%. These estimates are proportions and were only presented for those major prey comprising >85% of the total for each size class, temporal and spatial scheme. Further particulars of these estimators can be found in Link and Almeida (2000).

Consumption Rates

To estimate per capita consumption, the gastric evacuation rate method was used (Eggers 1977, Elliott and Persson 1978). There are several approaches used for estimating consumption, but this approach was chosen as it was not overly simplistic (as compared to % body weight; Bajkov 1935) or overly complex (as compared to highly parameterized bioenergetics models; Kitchell et al. 1977). There has been extensive use of these models (Durbin et al. 1983, Ursin et al. 1985, Pennington 1985, Overholtz et al. 1991, 1999, 2000, Tsou & Collie 2001a, 2001b, Link & Garrison 2002, Link et al. 2002, 2006, Overholtz & Link 2007). Units are in g year^{-1}.

Using the evacuation rate model to calculate consumption requires two variables and two parameters. The per capita consumption rate, C_i is calculated as:

$$C_i = 24 \cdot E_i \cdot \overline{S_i}^{\gamma}$$

where 24 is the number of hours in a day and the evacuation rate E_i is:

$$E_i = \alpha e^{\beta T} \qquad ;$$

and is formulated such that estimates of mean stomach contents (S_i) and ambient temperature (T; here used as bottom temperature from the NEFSC bottom trawl surveys (Taylor and Bascunan 2000; Taylor et al. 2005) are the only data required. The parameters α and β are set as values chosen from the literature (Tsou and Collie 2001a, 2001b, Overholtz et al. 1999, 2000). The parameter γ is a shape function is almost always set to 1 (Gerking 1994).

To evaluate the performance of the evacuation rate method for calculating consumption, a simple sensitivity analysis was executed. The first phase of the sensitivity analysis fixed the two parameters and two variables, varying them one at a time. These varied across both the normal range from the data or literature and across proximal orders of magnitude to the normative range. The second phase varied all two pairs of values simultaneously, presented as surface plots to denote areas of rapid change and areas of relative stability (flat surfaces).

Scaling Consumption

After per capita consumption rates were estimated for each skate in a size class, temporal and spatial scheme, those estimates were scaled up to an annual and stock wide basis, C:

$$C = 365 \cdot C_i \cdot N_i$$

where N_i is the swept area estimate of abundance for each skate in each size class, temporal and spatial scheme and 365 is the number of days in a year.

This total consumption was partitioned for the major prey items of each skate by multiplying it by the diet composition of each prey (D_{ij}) to provide an estimate of prey removals by each skate. Both the total consumption and the amount of prey removed by each skate are presented as metric tons year^{-1}.

To evaluate the consumptive demands of a skate stock and the predatory removals of a skate stock in a broader ecosystem context, two contrasts were executed. First, comparisons of total consumption by each skate and by all skates combined were compared to the amount of energy flows for the entire ecosystem. These total energy flows were calculated in a recent energy budget (Link et al. 2006). Skate consumption is presented as a percentage of total energy flows in the ecosystem.

Second, the total amount of commercially targeted prey eaten by skates was treated as a removal and summed across all skates. These estimates were then compared to concurrently estimated fishery landings to provide an evaluation of potential competition between skates and fisheries on some of their major prey.

One concern of this approach is that the abundance estimates used to scale per capita skate consumption up to total population level consumption were not corrected for catchability or gear efficiency of the bottom trawl survey. To evaluate the potential effect of this factor, efficiencies of 100, 50, 25 and 10% were applied to estimates of total prey removal by all skates.

8.3 Results

Sensitivity analysis

The fixed values for all parameters were mean stomachs, S_i = 10, mean bottom temperature, T = 10, scaling coefficient α = 0.02, and exponent coefficient β = 0.111. The parameters are consistent with literature values for other elasmobranchs (Tsou and Collie 2001a, 2001b).

Examining the sensitivity to mean stomach contents demonstrates a clear linear relationship to per capita consumption across the full range of observed skate stomachs (Figure B6.1a). This is obvious the one factor that most highly data driven and represents an intuitive relationship- the more food measured that a skate eats, the higher the annual per capita consumption. The range of food consumed can be anywhere from 50 g to 60 kg, consistent with observed food habits for this species complex.

Examining the sensitivity to mean bottom temperature demonstrates a curvilinear relationship with per capita consumption (Figure B6.1b). The upper tail of the range (i.e., > 15^{o}C) represents an increase up to 10-20 kg consumed per year. However, the per capita consumption in the range of typical temperatures encountered by skates are on the order of 4-6 kg per year.

Examining the sensitivity to changes in α similarly demonstrates a curvilinear relationship with per capita consumption (Figure B6.2a), albeit with α presented on a logarithmic scale. This relationship is much more convex than with temperature, with consumption values where α ~ 0.1 approaching 30 kg per year. However, within the range of α typically reported from the literature (α = 0.01 to 0.05) results in a consumption on the order of 5-10 kg per year.

Examining the sensitivity to changes in β also demonstrates a curvilinear relationship with per capita consumption (Figure. B6.2b). At the upper tail of the analysis with > 0.2 results in a consumption estimate of 15-20 kg per year. However, within the range of β typically reported from the literature (β = 0.1 to 0.12) results in a consumption on the order of 5-7 kg per year.

The most sensitive factor, when within normal range, is mean stomach contents of these skates.

Examining some salient pairs, one sees that categorically when looking at the upper end of mean stomach contents versus β, α or T (Figures B6.3-B6.5) there is a clear spike at the upper range of any of those three factors with stomach contents. These peaks can result in per capita consumption estimates of over 300 kg per year. However, when one looks at the typical range of β, α or T the surfaces are much flatter and more stable, even at the upper range of S_i. A similar pattern emerges when comparing β and α (Figure B6.6). Yet even this maximum-maximum range is on the order of 120 kg per capita consumption per year, much less than when including S_i. This surface is also much flatter than the other ones that include S_i.

To put the sensitivity analysis in perspective, when both parameters were within the normal range, the change to per capita consumption was < half to one order of magnitude. The temperature variable across the maximum possible range only changes the per capita consumption by < an order of magnitude. Most observed temperature ranges are << quarter of an order of magnitude.

An order of magnitude change in the amount of food eaten results in an order of magnitude change in per capita consumption. Variance about any particular species of skate has a CV of ~50%. Thus, within any given species for each size class, temporal and spatial scheme, the variability of S_i is likely to only influence per capita consumption by half an order of magnitude or less.

Estimates of abundance, and changes in estimates thereof, are likely going to dominate the scaling of total consumption by a broader range of magnitudes than the parameters and variables requisite for an evacuation method of estimating consumption.

Winter Skate

The mean stomach contents for winter skate show a relatively stable amount of food eaten for both size classes (Figure B6.7a). Small winter skates (< 30 cm) were grouped with immature little skates. In instances with large error bars, there is an appearance of a major increase in food eaten during the early 1980s, yet this may be due to limited sample sizes during that period. Except the early 1980s, the number of empty stomachs has remained similar across the time period, averaging ~ 20% and ~25% for the medium and large size classes respectively (Figure B6.7b).

The mean length of skates sampled for stomach contents was consistent over time, averaging approximately 45 cm and 80 cm for medium and large size classes respectively (Figure B6.8a). There is a relationship between the size of skates and the amount of food eaten by skates, despite the wide variability in a few years (Figure B6.8b).

The temperature for these strata (and the environment which this skate was experiencing) ranged between 7 and 10^{o}C (Figure B6.9a).

The per capita consumption of this skate (Figure B6.9b) generally tracks the amount of food eaten (Figure B6.7a). Values average approximately 2 kg per year for the medium size class and between 9 kg per year for the large size class.

Total minimal estimates of swept area abundance (Figure B6.10a) are generally comparable to estimates noted above. There was generally no trend for all three size classes over the entire time period except the large size. The large winter skates class exhibited a peak in the 1980s followed by a notable decline in the 1990s, with some recovery now apparent in more recent years. This is one of the more abundant skate species.

Total consumption when scaled to the population level generally tracks abundance more than any other contributing factor (Figure B6.10b). Both size classes show a peak in the 1980s, consistent with the observed peak in the abundance of the larger size class (Figure B6.10a). Estimates here for total consumptive demand by this skate range between 20,000 and 180,000 MT per year.

The diet composition of winter skate is reflective of the generally benthivorous diet of all skates and the piscivorous nature of particularly larger skates (Table B6.2). Major prey of this skate are primarily forage fishes (herrings, hakes) or benthic megafauna (crabs, shrimp). The category other fish refers to those species that are not primarily commercially targeted. The category other crabs refers to those crabs that are not in the genus *Cancer* or Paguroidean family.

When allocating total consumption of winter skate proportionally to each prey item, forage fish, squids, and benthic macrofauna are clearly the major amount of prey removed by this skate (Figures B6.11-B6.12). Up to 80,000 MT of a particular prey item can be removed by this skate in any given year.

Little Skate

The mean stomach contents for Little Skate show an increasing amount of food eaten in the 1980s for the both size classes, followed by a more stable amount during the past 20 years (Figure B6.13a). The number of empty stomachs has remained mostly similar across the time period, averaging ~10% for both size classes (Figure B6.13b). Recall that small winter skates (< 30 cm) are grouped in with the immature little skates.

The mean length of skates sampled for stomach contents was consistent over time, averaging approximately 20 cm and 45 cm for immature and mature size classes (Figure B6.14a). There is a clear relationship between the size of skates and the amount of food eaten by skates (Figure B6.14b).

The temperature for these strata (and the environment which this skate was experiencing) ranged between 7 and 11^{o}C (Figure B6.15a).

The per capita consumption of this skate (Figure B6.15b) generally tracks the amount of food eaten (Figure B6.13a). Values average approximately 500 g per year for immatures and 2.5 kg per year for matures.

Total minimal estimates of swept area abundance (Figure B6.16a) are generally comparable to estimates noted above. There were some fluctuations during the later 1990s and early 2000s, but these were centered about, and returned to, the long term average abundance. This was the most abundant skate species in the ecosystem.

Total consumption when scaled to the population level generally tracks abundance more than any other contributing factor (Figure B6.16b). Both size classes exhibit a reasonably stable amount of food eaten, but the total consumption is dominated by the mature size class (Figure B6.16a). Estimates here for total consumptive demand by this skate range between 100,000 and 350,000 MT per year.

The diet composition of little skate is reflective of the generally benthivorous nature of all skates (Table B6.3). Most of the major prey of this skate are comprised of benthic macrofauna (polychaetes, amphipods) or benthic megafauna (crabs, bivalves).

When allocating total consumption of little skate proportionally to each prey item, benthic invertebrates are clearly the major amount of prey removed by this skate (Figure B6.17). Up to 100,000 MT of a particular prey item can be removed by this skate in any given year.

Barndoor Skate

The mean stomach contents for barndoor skate show a relatively stable amount of food eaten for the immature size class (Figure B6.18a). In the larger size class there are instances with large error bars, giving an appearance of a major decline in food eaten circa 2002 to 2003. Yet this may be due to limited sample sizes during 2002. The number of empty stomachs has remained similar across the time period, averaging ~25% for both size classes (Figure B6.18b).

The mean length of skates sampled for stomach contents was consistent over time, averaging slightly less than 60 cm and slightly over 100 cm for immature and mature size classes respectively (Figure B6.19a). There is a clear relationship between the size of skates and the amount of food eaten by skates, despite the wide variability in a few years (Figure B6.19b).

The temperature for these strata (and the environment which this skate was experiencing) ranged between 7 and 9^{o}C, declining slightly in more recent years (Figure B6.20a).

The per capita consumption of this skate (Figure B6.20b) generally tracks the amount of food eaten (Figure B6.18a). Values typically range approximately 5 kg per year for immatures and between 10 to 20 kg per year for matures.

Total minimal estimates of swept area abundance (Figure B6.21a) are generally comparable to estimates noted above. There was a generally increasing trend for both size classes over time, although numbers are still relatively low.

Total consumption when scaled to the population level generally tracks abundance more than any other contributing factor (Figure B6.21b). Both size classes show a peak in 2002, consistent with the observed peak in mean stomach contents (Figure B6.18.a). Estimates here for total consumptive demand by this skate range between 4,000 and 16,000 MT per year.

The diet composition of barndoor skate is reflective of the generally benthivorous nature of all skates and the piscivorous nature of particularly larger skates (Table B.6.4). Most of the major prey of this skate are comprised of forage fishes (herrings, hakes) or benthic megafauna (crabs, shrimp). The category other fish refers to those species that are not primarily commercially targeted. The category other crabs refers to those crabs that are not in the genus *Cancer* or Paguroidean family.

When allocating total consumption of barndoor skate proportionally to each prey item, herrings, Pandalid shrimps, and *Cancer* crabs are clearly the major amount of prey removed by this skate (Figure B6.22). Up to 8,000 MT of a particular prey item can be removed by this skate in any given year.

Thorny Skate

The mean stomach contents for thorny Skate show a relatively stable amount of food eaten for two of the three size classes, with medium skates exhibiting a slight increase (Figure B6.23a). Aside from the 1976 to 1980 time period (five year block), the number of empty stomachs has remained similar across the time period, averaging ~15 to 20% for all size classes (Figure B6.23b).

The mean length of skates sampled for stomach contents was consistent over time for all three size classes, averaging approximately 20 cm, 45 cm, and slightly less than 80 cm for the small, medium and large size classes respectively (Figure B6.24a). There is a clear relationship between the size of skates and the amount of food eaten by skates (Figure B6.24b).

The temperature for these strata (and the environment which this skate was experiencing) ranged between 7 and 9°C, declining slightly in more recent years (Figure B6.25a).

The per capita consumption of this skate (Figure B6.25b) generally tracks the amount of food eaten (Figure B6.23a). Values average approximately 500 g per year for the small size class,1.5 kg per year for the medium size class, and 12 kg per year for the large size class.

Total minimal estimates of swept area abundance (Figure B6.26a) are generally comparable to estimates noted above. There was a clear declining trend for all size classes over time, although numbers are still relatively low.

Total consumption when scaled to the population level generally tracks abundance more than any other contributing factor (Figure B6.26b). All three size classes show a peak in the early 1980s, consistent with the observed peak in mean stomach contents (Figure B6.23a). Estimates here for total consumptive demand by this skate range between 10,000 and 40,000 MT per year.

The diet composition of thorny skate is reflective of the generally benthivorous nature of all skates and the piscivorous nature of particularly larger skates (Table B6.5). Most of the major prey of this skate are comprised of forage fishes (herrings, hakes) or benthic megafauna (crabs, euphasiids). The category other fish refers to those species that are not primarily commercially targeted. The category other crabs refers to those crabs that are not in the genus *Cancer* or Paguroidean family.

When allocating total consumption of thorny skate proportionally to each prey item, herrings, squids, polychaetes, silver hake and other fish are the major amount of prey removed by this skate (Figures B6.27-B6.28). Up to 8,000 MT of a particular prey item can be removed by this skate in any given year.

Smooth Skate

The mean stomach contents for Smooth Skate show a relatively stable amount of food eaten for both size classes (Figure B6.29a). The number of empty stomachs has remained stationary across the time period, albeit with a wide range of variability (particularly for immatures), averaging ~15 to 20% for both size classes (Figure B6.29b). There were no empties for one part of the time series.

The mean length of skates sampled for stomach contents was consistent over time, averaging around 20-25 cm and 50 cm for immature and mature size classes respectively (Figure B6.30a). There is a clear relationship between the size of skates and the amount of food eaten by skates (Figure B6.30b).

The temperature for these strata (and the environment which this skate was experiencing) ranged between 7 and 10^{o}C (Figure B6.31a).

The per capita consumption of this skate (Figure B6.31b) generally tracks the amount of food eaten (Figure B6.29a). Values typically range between 0.5 to 1 kg per year for immatures and 2 to 3 kg per year for matures. Because these stomachs were calculated in five year time blocks, these estimates reflect that periodicity.

Total minimal estimates of swept area abundance (Figure B6.32a) are generally comparable to estimates noted above. There was a lot of variability and the abundance of both size classes varied without trend.

Total consumption when scaled to the population level generally tracks abundance and amount of food consumed more than any other contributing factors (Figure B6.32b). Both size classes are highly variable, with the majority of the consumption for this population occurring in the mature size class.. Estimates for total consumptive demand by this skate range between 1,000 and 5,000 MT per year.

The diet composition of smooth skate is reflective of the generally benthivorous nature of all skates (Table B6.6). Most of the major prey of this skate are comprised of common benthic megafauna (pandalids, euphausiids).

When allocating total consumption of smooth skate proportionally to each prey item, pandalid shrimp and euphausiids are clearly the major amount of prey removed by this skate (Figure B6.33). Up to 2,000 MT of a particular prey item can be removed by this skate in any given year, but values are typically on the order of 500 to 1,000 MT.

Clearnose Skate

The mean stomach contents for Clearnose Skate show a relatively stable amount of food eaten for the immature size class (Figure B6.34a). The same is true for the larger size class. In the larger size class there may be a slightly increasing trend in the amount of food eaten. In the instance with large error bars there is an appearance of a major change in the amount of food eaten. Again this may be due to limited sample sizes during that 2005. The number of empty stomachs has remained stationary across the time period, albeit with a wide range of variability (particularly for immatures), averaging ~25 to 30% for both size classes (Figure B6.34b).

The mean length of skates sampled for stomach contents was consistent over time, averaging around 45-50 cm and 60-65 cm for immature and mature size classes respectively (Figure B6.35a). There is a clear relationship between the size of skates and the amount of food eaten by skates, despite the wide variability in one year (Figure B6.35b).

The temperature for these strata (and the environment which this skate was experiencing) ranged between 9 and 13^{o}C (Figure B6.36a).

The per capita consumption of this skate (Figure B6.36b) generally tracks the amount of food eaten (Figure B6.34a). Values typically range approximately 1 to 2 kg per year for immatures and 5 kg per year for matures. Because these stomachs were calculated in five year time blocks, these estimates are similar in that periodicity.

Total minimal estimates of swept area abundance (Figure B6.37a) are generally comparable to estimates noted above. There was a generally increasing trend for both size classes over time, although numbers are still relatively low.

Total consumption when scaled to the population level generally tracks abundance and amount of food consumed more than any other contributing factors (Figure B6.37b). Both size classes show a peak in 2002, consistent with the observed peak in abundance and mean stomach contents during that five year period (Figures B6.37a and B6.34a). Estimates here for total consumptive demand by this skate range between 2,000 and 18,000 MT per year.

The diet composition of clearnose skate is reflective of the generally benthivorous nature of all skates (Table B6.7). Most of the major prey of this skate are comprised of common benthic megafauna (crabs, misc. crustaceans). The category other crabs refers to those crabs that are not in the genus *Cancer* or Paguroidean family.

When allocating total consumption of clearnose skate proportionally to each prey item, other crabs, *Cancer* crabs, squids are clearly the major amount of prey removed by this skate (Figure B6.38). Up to 8,000-10,000 MT of a particular prey item can be removed by this skate in any given year, but values are typically on the order of 2,000 to 4,000 MT.

Rosette Skate

The mean stomach contents for Rosette Skate show a relatively stable amount of food eaten for both the immature and mature size classes (Figure B6.39a). The number of empty stomachs was again around 30%, but increased slightly in more recent years (Figure B6.39b).

The mean length of skates sampled for stomach contents was consistent over time, averaging approximately 22 cm and 38 cm for immature and mature size classes respectively (Figure B6.40a). There is a clear relationship between the size of skates and the amount of food eaten by skates (Figure B6.40b).

The temperature for these strata (and the environment which this skate was experiencing) ranged between 9 and 12°C (Figure B6.41a).

The per capita consumption of this skate (Figure B6.41b) generally tracks the amount of food eaten (Figure B6.39a). Values average approximately 200 g per year for immatures and 800g per year for matures.

Total minimal estimates of swept area abundance (Figure B6.42a) are generally comparable to estimates noted above. There was a peak in 2001 for matures and 2002 for immatures. No major trend for both size classes was evident.

Total consumption when scaled to the population level generally tracks abundance more than any other contributing factor (Figure B6.42b). The mature size classes shows a peak in 2001 and the immatures show a peak in 2002, consistent with the observed abundances (Figure B6.42a). Estimates here for total consumptive demand by this skate range between 50 and 500 MT per year.

The diet composition of rosette skate is reflective of the generally benthivorous nature of all skates (Table B6.8). Most of the major prey of this skate are comprised of some form of benthic macrofauna (amphipods, polychaetes) or megafauna (crabs, shrimp). The category other crabs refers to those crabs that are not in the genus *Cancer* or Paguroidean family.

When allocating total consumption of rosette skate proportionally to each prey item, benthic macrofauna are clearly the major prey removed by this skate. Pandalid shrimps, squids, and *Cancer* crabs are also removed by this skate but in lesser amounts (Figure B6.43). Up to 70 MT of a particular prey item can be removed by this skate in any given year, but more typically 10-30 MT.

All Skates relative to the ecosystem and fisheries on major prey

The total amount of skate consumption across all skates has averaged around 230,000 MT over the past 25-30 years (Figure B6.44). This represents a relatively small amount of the total energy flow in the ecosystem. There is 3.9 x 10^9 MT of total throughput through the ecosystem (Link et al. 2006) and skate consumption represents less than 0.006% of that total energy flow in the system. The total removal of most major skate prey relative to their standing stock biomass (B) or annual production (P) is small (Table B.6.9). Estimates of B and P tend to be at least two to three orders of magnitude greater than C by all skates for any particular prey item.

Those prey which are commercially important species and which are also important skate prey can be removed by skates at a rate comparable to their fisheries (Figure B.6.44; Table B.6.10). In the minimum swept area scenario, most skate prey are on the order of one quarter or less of what is landed for those prey, with the exception of red hake. When decreasing gear efficiencies are incorporated, the relative removal by skate consumption compared with fishery removals becomes much higher. With gear efficiencies of 50%, about half of fishery removals are removed by skate consumption for the two squids and silver hake, with over double removed by skates relative to the fishery for red hake. The pattern continues with increasingly less efficient assumptions, with squids and silver hake removed by skates up to twice of what is removed by the fishery at the lowest assumed value (10%), while red hake is up to 10 times what is removed by the fishery. The only exception is herrings, which although have a large amount of biomass removed by skates, remain a relatively small amount of removals compared to those fishery removals.

Finally, it is worth noting that some of the potential species interactions of interest- e.g. skates eating yellowtail flounder, winter flounder, sea scallops, etc.- were not of sufficient magnitude to analyze. In fact, each of the species just mentioned as examples only comprised a very small (<<0.1% of the diet) for only one or two skate species.

8.4 Summary

Most skates are benthivorous in their feeding habits. A clear prominence on *Cancer* crabs, other crabs, amphipods, polychaetes and similar benthic macrofauna and megafauna was apparent in the diets of these skates. Some of the larger skates- barndoor, thorny, and winter- can be piscivorous, particularly with ontogeny. The vast majority of fish (or fish-like) prey for these skates were small pelagic fishes and squids.

Save winter and little skates, overall consumption by most skate stocks is a relatively small amount of biomass flow. Most total consumption by any particular species of skate was scaled singularly by the abundance of that species. The vast majority of consumptive removals by all skates except little and winter was < 20 MT per year.

As an aggregate group, skates consume a very small fraction of the total energy flow in the ecosystem. Skate consumptive removal is two to three orders of magnitude lower than biomass or production of skate prey. When abundance estimates are scaled by gear efficiency, it is possible that skates could consume a notable fraction of forage fish and squid biomass relative to what is removed by a fishery. Yet most of those forage fish stocks are at relatively high levels of abundance.

9.0 SOURCES OF UNCERTAINTY FOR ASSESSMENT

1) The species composition and size structure of landings are generally 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, and recommendations of appropriate biological reference points.

4) Life history data are from localized areas for barndoor, thorny, and clearnose and incomplete or totally lacking for two other 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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SKATE TABLES

Table B1.1. Total commercial landings of skate (mt) in NAFO subareas 5 and 6 by country from 1960-2005. U.S. landings are from NAFO database from 1964-1988, weighout from 1989-2005.

	US	USSR	Others	Total
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	6707	0	0	6707
1990	11403	0	0	11403
1991	11332	0	0	11332
1992	12525	0	0	12525
1993	12904	0	0	12904
1994	8783	0	0	8783
1995	7217	0	0	7217
1996	14213	0	0	14213
1997	10945	0	0	10945
1998	13829	0	0	13829
1999	11684	0	0	11684
2000	13360			13360
2001	13120			13120
2002	13004			13004
2003	15005			15005
2004	16073			16073
2005	13885			13885

Table B1.2. U.S. commerical landings (mt, live wt) of skates (all species) by month from 1964-2005.

	Month													
year	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
1964	4050.3	2.0	3.9	3.6	3.1	2.0	1.6	0.9	1.3	1.6	2.0	2.1	6.4	4081.0
1965	2304.4	5.4	7.2	7.5	4.3	2.4	0.4	0.6	1.2	0.6	2.3	2.6	4.2	2343.0
1966	2707.1	6.4	7.3	6.0	1.0	0.9	0.2	0.1	0.7	1.7	1.4	2.4	2.9	2738.0
1967	2643.3	15.1	7.3	18.1	7.7	3.0	1.6	0.6	0.4	1.8	6.1	2.9	7.1	2715.0
1968	2381.3	10.3	1.9	5.3	1.3	1.5	1.3	1.5	2.6	3.0	2.8	2.5	1.7	2417.0
1969	2993.4	4.1	6.2	5.7	6.2	2.5	2.3	3.1	3.2	3.0	5.0	5.7	4.6	3045.0
1970	1513.4	6.1	8.6	13.9	7.0	4.1	3.4	5.6	5.3	8.3	4.1	2.1	1.1	1583.0
1971	836.7	4.9	6.2	8.5	7.3	7.7	2.7	3.0	2.8	3.5	8.2	3.9	4.7	900.0
1972	780.1	7.2	6.9	12.1	12.3	9.1	4.9	5.7	7.8	4.3	4.2	5.9	5.5	866.0
1973	1104.1	8.3	3.9	10.4	12.4	7.1	6.7	7.1	7.0	8.1	7.1	4.7	4.1	1191.0
1974	1945.9	5.7	4.9	5.6	12.3	8.0	4.6	4.4	12.3	6.7	5.2	2.6	7.8	2026.0
1975	637.9	7.3	10.1	16.6	16.2	13.0	7.3	6.7	7.6	9.8	5.6	6.9	6.9	752.0
1976	641.8	8.4	12.5	19.2	22.4	9.6	4.3	8.1	4.7	6.9	3.1	6.3	6.8	754.0
1977	994.7	15.4	19.7	27.9	20.0	9.0	8.9	6.8	11.0	7.0	8.8	9.3	4.5	1143.0
1978	827.4	19.3	24.7	11.7	29.8	30.5	46.4	33.9	26.2	23.2	20.9	19.3	16.7	1130.0
1979	787.4	24.8	24.8	46.5	62.6	50.4	28.1	29.4	55.5	38.8	42.1	52.9	36.5	1279.6
1980	961.1	61.5	112.6	121.1	82.8	63.9	27.3	26.4	24.4	22.8	27.4	20.5	25.4	1577.2
1981	509.9	33.9	30.8	54.4	31.1	26.7	25.3	15.1	24.5	23.1	12.3	19.2	31.9	838.4
1982	449.5	30.4	23.3	54.0	47.5	58.2	18.9	25.3	35.1	32.3	34.4	31.3	38.2	878.1
1983	2720.3	84.1	95.9	134.0	95.4	102.3	76.3	44.1	66.1	53.3	37.0	56.6	37.5	3603.0
1984	3325.7	99.4	127.3	134.9	108.6	84.0	36.7	30.9	29.0	25.9	37.0	54.2	63.0	4156.5
1985	3220.7	85.4	85.5	150.6	142.7	31.6	29.9	33.2	29.9	28.8	37.7	59.3	48.6	3984.1
1986	3173.4	98.6	89.7	149.7	147.8	91.8	36.4	33.7	49.0	28.2	72.6	86.3	102.5	4159.5
1987	3638.7	83.8	114.3	207.7	227.0	245.3	106.2	40.3	53.0	33.8	87.6	101.5	139.1	5078.4
1988	5141.7	281.6	338.2	378.7	284.0	150.3	74.5	154.5	137.9	75.0	54.1	66.2	118.8	7255.5
1989	4157.8	240.1	150.3	227.1	454.3	292.6	102.6	142.2	272.3	221.9	174.8	173.0	98.4	6707.3
1990	4252.9	136.6	182.0	424.8	834.4	948.5	1174.9	763.8	818.7	624.4	265.9	542.3	433.4	11402.5
1991	4255.9	464.0	423.8	460.9	606.0	419.8	370.4	658.1	925.7	515.5	565.5	958.9	708.0	11332.3
1992	4782.2	517.3	457.7	510.1	567.1	564.3	816.2	764.4	718.2	862.3	639.1	771.1	555.4	12525.3
1993	4860.4	335.1	265.6	471.2	741.7	875.2	823.2	1005.6	859.1	712.4	535.5	864.0	555.0	12904.0
1994	175.5	338.2	309.8	291.7	501.5	855.1	1238.4	780.9	1263.7	960.6	937.7	787.3	342.9	8783.3
1995	1.0	183.7	285.7	413.6	515.5	752.0	915.7	768.4	752.2	557.7	724.8	897.2	449.7	7217.1
1996	2.3	224.6	229.3	206.5	360.1	1012.0	1389.7	1539.8	1577.6	1720.4	2440.4	2411.8	1098.4	14212.8
1997		530.8	469.9	597.5	395.5	969.4	1127.6	1181.8	1189.6	1062.3	1084.2	1305.2	1031.1	10944.8
1998		518.9	589.8	625.4	814.9	1403.4	1702.2	1643.9	1512.7	1551.5	1224.9	1277.1	964.5	13829.2
1999		511.2	401.0	591.8	678.6	1295.5	1436.2	1039.3	1137.7	1388.8	1055.8	1250.0	898.1	11683.9
2000		668.1	615.2	1024.2	826.2	1187.7	1594.2	1188.5	1534.6	1270.1	946.4	1583.6	921.1	13359.9
2001		802.4	588.6	956.2	967.3	984.0	1058.2	1150.5	1465.1	1197.3	1115.1	1692.1	1143.7	13120.5
2002		742.3	730.7	783.2	1093.9	773.5	1372.6	998.7	1488.6	1247.8	1352.1	1264.4	1156.3	13004.0
2003		548.3	447.6	857.4	1043.7	1006.6	1183.0	1632.9	1867.9	1889.1	1993.3	1563.3	971.9	15004.9
2004		538.3	1279.4	1305.0	1391.0	1155.1	1456.9	2008.7	1557.9	1573.6	1115.7	1541.6	1150.2	16073.4
2005		869.9	1201.7	1070.1	1187.4	1098.5	1289.7	1650.4	1585.9	1320.7	824.4	987.2	798.7	13884.6

Table B1.3. U.S. Commercial landings (mt, live wt) of skates (all species) by state from 1964-2005. Data are from weighout database.

	STATE											
year	CT	DE	ME	MD	MA	NH	NJ	NY	NC	RI	VA	Total
1964					28.2					2.4		30.7
1965					38.1					0.4		38.6
1966					30.1					0.8		30.9
1967					71.1					0.5		71.7
1968					35.7							35.7
1969					51.6							51.6
1970					69.0					0.6		69.6
1971					61.9					1.4		63.3
1972					85.2					0.7		85.9
1973			1.5		80.9					4.6		86.9
1974			8.8		67.2					4.1		80.1
1975			14.9		94.8					4.4		114.1
1976			36.2		74.9					1.1		112.2
1977			62.6		82.0					3.7		148.3
1978			86.9		161.8		2.9			50.9		302.6
1979			181.1		259.0		0.7			51.5		492.2
1980			197.5		297.5		0.4			120.7		616.1
1981			151.2		137.3	2.2	0.8			37.0		328.4
1982			175.0		210.4	3.9	0.1			39.3		428.7
1983			258.8		455.0	3.3	0.6			165.0		882.7
1984			230.8		445.4	2.6	0.7			150.8	0.5	830.8
1985			144.5		409.3	2.3	2.4			204.9		763.3
1986			107.6		363.8	1.1	10.8	55.0		447.2	0.6	986.1
1987			168.9		746.2	20.6	8.9	133.1		361.9		1439.7
1988			81.9		1376.2	51.9	10.5	172.2		420.9		2113.7
1989	12.2		99.8		2030.1	18.6	18.2	107.7		4420.0	0.7	6707.3
1990	146.9		47.1	1.7	5742.0	10.5	8.8	162.4		5282.1	1.1	11402.5
1991	113.3		16.9		5696.1	12.4	125.4	56.9		5310.7	0.6	11332.3
1992	97.0		45.1	0.6	5923.3	10.1	267.2	231.1		5950.1	0.8	12525.3
1993	237.9		167.1	4.1	6118.5	9.5	376.1	168.2		5820.3	2.3	12904.0
1994	175.5		442.9	46.6	6616.4	37.2	186.1	225.3		1047.1	6.4	8783.3
1995	309.3		349.2	45.6	2926.5	24.6	291.4	141.7		3111.5	17.3	7217.1
1996	432.0		267.4	55.8	9016.9	20.3	339.2	164.2		3908.8	8.3	14212.8
1997	357.5		221.0	97.8	3933.4	17.0	794.8	374.5	9.4	5131.4	8.1	10944.8
1998	441.9		162.2	95.6	6322.4	19.1	807.8	575.0	9.1	5372.5	23.6	13829.2
1999	518.3		218.8	63.5	4809.3	26.3	636.8	396.8	2.6	4911.9	99.6	11684.0
2000	493.8		138.0	65.6	6517.8	38.4	564.6	387.7	20.6	4825.3	308.2	13360.0
2001	618.9		138.2	55.5	6683.5	33.2	624.7	366.8	0.1	4536.2	63.4	13120.5
2002	367.6		137.2	52.0	6335.0	24.5	582.4	462.9	0.3	5029.6	12.7	13004.0
2003	433.7		76.4	26.9	8098.0	14.9	448.7	353.3	0.8	5516.6	35.7	15004.9
2004	441.7	0.0	13.3	6.2	10075.9	10.6	374.3	222.7	0.5	4882.6	45.7	16073.4
2005	47.6		10.9	8.4	8989.2	9.4	334.8	157.5	0.5	4296.0	30.3	13884.6

Table B1.4. U.S. Commercial landings (mt, live wt) of skates (all species) by gear type fromo 1964-2005. Landings are from weighout database.

	gear				
year	longline	otter trawl	other	sink gillnet	Total
1964	0.1	30.5		0.0	30.7
1965	0.3	38.2		0.0	38.6
1966		30.9			30.9
1967		71.7			71.7
1968		35.7			35.7
1969		51.5		0.0	51.6
1970	0.6	68.8	0.0	0.2	69.6
1971	1.1	62.0		0.1	63.3
1972	3.7	80.8	0.1	1.3	85.9
1973	7.0	77.9	1.9	0.2	86.9
1974	10.5	64.3	0.2	5.1	80.1
1975	11.7	101.4	0.1	0.8	114.1
1976	16.2	93.3	0.2	2.5	112.2
1977	13.4	126.8	0.9	7.2	148.3
1978	4.4	290.0	3.2	5.0	302.6
1979	18.4	456.0	5.8	12.0	492.2
1980	16.5	577.9	6.0	15.6	616.1
1981	5.1	311.7	1.2	10.4	328.4
1982	2.0	408.4	7.4	10.8	428.7
1983	3.4	846.2	22.5	10.6	882.7
1984	5.0	796.5	19.1	10.3	830.8
1985	3.7	721.5	17.8	20.3	763.3
1986	6.6	954.4	14.2	10.9	986.1
1987	22.4	1384.4	16.1	16.8	1439.7
1988	5.7	2070.7	22.2	15.2	2113.7
1989	30.6	6636.1	27.3	13.4	6707.3
1990	3.8	11339.6	47.7	11.5	11402.5
1991	24.3	11169.9	77.0	61.1	11332.3
1992	21.9	12242.5	35.1	225.8	12525.3
1993	63.4	11913.6	204.6	722.3	12904.0
1994	197.2	7194.4	357.4	1034.3	8783.3
1995	97.1	5777.2	400.7	942.1	7217.1
1996	51.8	12944.3	134.4	1082.3	14212.8
1997	47.7	8822.8	471.6	1602.8	10944.8
1998	53.2	11724.8	576.4	1474.8	13829.2
1999	48.5	10059.3	144.9	1431.3	11684.0
2000	34.9	11464.0	72.0	1789.0	13360.0
2001	12.0	10835.0	27.7	2245.9	13120.5
2002	32.8	9667.7	31.0	3272.4	13004.0
2003	97.1	10254.3	43.0	4610.6	15004.9
2004	136.9	10694.3	2217.0	3025.3	16073.4
2005	342.7	7744.3	2532.9	3264.7	13884.6

Table B1.5. U.S. landings (mt, live wt) of skates by species and markey category from 1964-2005. Landings are from weighout database.

	Species and Market Category																	
YEAR	Uncl.	Uncl.	Winter	Winter	Little	Little	Barndoor	Barndoor	Thorny	Thorny	Smooth	Smooth	Clearnose	Clearnose	Rose	Rose	Total	
	Whole	Wings	Whole	Wings	Whole	Wings	Whole	Wings	Whole	Wings	Whole	Wings	Whole	Wings	Whole	Wings	Whole	Wings
1964	30.7																30.7	0.0
1965	38.6																38.6	0.0
1966	30.9																30.9	0.0
1967	71.7																71.7	0.0
1968	35.7																35.7	0.0
1969	51.6																51.6	0.0
1970	69.6																69.6	0.0
1971	63.3																63.3	0.0
1972	85.9																85.9	0.0
1973	86.9																86.9	0.0
1974	80.1		0.0														80.1	0.0
1975	114.1																114.1	0.0
1976	112.2																112.2	0.0
1977	148.3																148.3	0.0
1978	302.6																302.6	0.0
1979	492.2																492.2	0.0
1980	616.1																616.1	0.0
1981	328.4																328.4	0.0
1982	277.2	151.4															277.2	151.4
1983	169.6	713.0															169.6	713.0
1984	68.1	762.8															68.1	762.8
1985	68.3	695.0															68.3	695.0
1986	262.6	723.5															262.6	723.5
1987	87.5	1352.2															87.5	1352.2
1988	74.2	2039.6															74.2	2039.6
1989	4163.1	2544.2															4163.1	2544.2
1990	5002.9	6399.6															5002.9	6399.6
1991	5069.2	6262.5			0.6												5069.7	6262.5
1992	5860.5	6664.7															5860.5	6664.7
1993	5526.6	7377.5	0.0														5526.6	7377.5
1994	703.4	8079.9															703.4	8079.9
1995	3095.1	3985.5			136.6												3231.7	3985.5
1996	3981.5	10230.8	0.4		0.2												3982.0	10230.8
1997	5369.1	5575.6															5369.1	5575.6
1998	5391.8	8437.4			0.0												5391.8	8437.4
1999	5026.7	6655.2					2.1										5028.7	6655.2
2000	3633.4	8690.5	0.0		1036.0	0.1	0.0										4669.4	8690.6
2001	4399.5	8718.6	2.2		0.0	0.1						0.1					4401.7	8718.8
2002	4396.9	8606.9				0.1		0.1									4396.9	8607.1
2003	4327.8	10650.0	0.8	26.0	0.2						0.1						4328.8	10676.0
2004	998.5	8451.6	2.8	2697.5	2867.4	8.6	0.3	0.1	0.0	95.6	1.0	927.2	3.5	16.6		2.7	3873.6	12199.8
2005	142.2	6710.1	59.3	3301.4	3465.3	15.6	0.3	5.4	1.5	126.2	0.6	1.0	32.5		16.6	5.9	3718.3	10165.6

Table B1.6. U.S. landings (my, live wt) of skates by state, species and market category for 2004-2005.

		Species and Market Category																	
		Uncl.	Uncl.	Winter	Winter	Little	Little	Barndoor	Barndoor	Thorny	Thorny	Smooth	Smooth	Clearnose	Clearnose	Rosette	Rosette	Total	
YEAR	State	Whole	Wings	Whole	Wings	Whole	Wings	Whole	Wings	Whole	Wings	Whole	Wings	Whole	Wings	Whole	Wings	Whole	Wings
2004	CT	369.9	71.8															369.9	71.8
	DE	0.0																0.0	0.0
	ME	0.0	12.2		1.2													0.0	13.3
	MD	1.0	2.4		2.7	0.1												1.1	5.1
	MA	17.7	6482.2	0.2	2467.9	97.5				0.0	83.4	0.1	926.8				0.1	115.5	9960.4
	NH		5.1		5.4						0.1							0.0	10.6
	NJ	1.5	131.2	0.3	135.5	103.0	2.7				0.1							104.8	269.5
	NY	23.3	183.6	1.2	0.6	0.7	0.1				12.0	1.0	0.3					26.1	196.7
	NC		0.5															0.0	0.5
	RI	584.1	1538.6	1.2	84.2	2666.1	5.8										2.6	3251.3	1631.3
	VA	1.1	24.1					0.3	0.1					3.5	16.6			4.9	40.8
	Total	998.5	8451.6	2.8	2697.5	2867.4	8.6	0.3	0.1	0.0	95.6	1.0	927.2	3.5	16.6		2.7	3873.6	12199.8
2005	CT	0.1	47.5															0.1	47.5
	ME		10.2		0.5		0.2											0.0	10.8
	MD	2.3	6.1															2.3	6.1
	MA	60.2	5699.4	21.7	3071.7	21.1			1.3	1.5	111.6	0.0	0.7					104.5	8884.8
	NH	0.0	9.4															0.0	9.4
	NJ	0.4	120.1	24.4	110.7	45.0	1.1	0.1				0.4		32.5				102.9	231.9
	NY	12.3	96.6	0.4	1.5	12.7	0.2	0.2	4.1		12.6	0.0	0.3			16.6		42.2	115.3
	NC		0.5															0.0	0.5
	RI	66.6	690.9	12.8	116.9	3386.5	14.1				2.0	0.2	0.1				5.9	3466.1	829.9
	VA	0.3	29.3															0.3	29.3
	Total	142.2	6710.1	59.3	3301.4	3465.3	15.6	0.3	5.4	1.5	126.2	0.6	1.0	32.5		16.6	5.9	3718.3	10165.6

Table B1.7. Discards (mt) of skates (all species) by gear type, empty cells not filled in. Dashes indicate no sampling.

year	Line Trawl	Longline	Otter Trawl	Scallop Trawl	Pair Trawl	Shrimp Trawl	Sink Gill Net	Scallop Dredge	Mid-Water	Lobster Pot	Blue Crab Pots	Scottish Seine	Grand Total
1989	-	-	56,622	-	-	85	127	-	-	-	-	-	56,834
1990	-	0	77,805	-	-	258	624	-	-	-	-	-	78,687
1991	865	0	45,775	-	-	283	289	6,391	0	0	-	-	53,602
1992	1,438	30	45,334	-	0	245	452	39,705	0	0	-	-	87,204
1993	45	0	28,388	-	188	36	375	22,866	0	31	-	-	51,929
1994	0	0	32,458	-	-	13	856	10,525	0	0	-	-	43,852
1995	0	0	37,564	-	-	9	767	18,074	0	0	-	-	56,414
1996	-	-	32,693	-	-	35	1,090	18,321	-	0	-	-	52,139
1997	-	0	10,032	-	-	1	537	15,606	-	0	-	-	26,176
1998	-	-	14,051	-	-	-	593	14,626	-	0	-	-	29,270
1999	-	-	16,827	-	-	-	1,057	15,901	0	5	-	-	33,789
2000	-	-	29,121	-	-	-	1,130	12,099	0	29	-	-	42,379
2001	-	-	42,461	365	-	0	609	6,070	0	-	-	18	49,523
2002	39	-	43,740	268	-	-	2,015	15,651	0	-	12,375	7	74,095
2003	15	-	32,370	-	-	11	946	14,977	0	0	-	1	48,320
2004	29	-	27,341	161	-	0	803	4,970	1	-	-	0	33,306
2005	825	-	13,824	35	-	2	2,180	2,794	0	0	-	-	19,660

Table B1.8. Discards of skates (all species) by year, quarter, region in the otter trawl fishery.

	Quarter		1			2			3			4	
year	Region	MA	NE	Total	MA	NE	Total	MA	NE	Total	MA	NE	Total
1989	ntrips	5	17	22	4	41	45	8	61	69	9	31	40
	dkratio	0.39	0.46	0.85	0.14	0.53	0.67	0.36	0.26	0.63	0.19	0.55	0.74
	mt kept	11518.8	26350.1	37868.9	6714.3	31405.5	38119.8	4064.5	25253.5	29317.9	7752.5	23253.9	31006.4
	mt discard	4512.8	12032.2	16545.1	959.5	16701.5	17660.9	1481.2	6645.4	8126.7	1451.5	12838.0	14289.5
1990	ntrips	6	19	25	14	21	35	7	19	26	9	31	40
	dkratio	0.19	1.07	1.25	0.27	0.31	0.57	0.55	0.09	0.65	0.53	0.83	1.36
	mt kept	10138.7	24999.5	35138.2	6461.9	34303.9	40765.8	6290.4	36062.4	42352.8	9441.0	30440.1	39881.1
	mt discard	1906.5	26639.7	28546.2	1721.8	10582.1	12303.9	3480.4	3307.3	6787.7	5040.2	25126.8	30166.9
1991	ntrips	14	33	47	16	32	48	4	50	54	26	70	96
	dkratio	0.00	0.44	0.45	0.27	0.36	0.63	0.30	0.13	0.43	0.50	0.28	0.78
	mt kept	16912.8	25727.2	42639.9	8472.2	36335.0	44807.2	7471.0	34737.4	42208.4	8531.8	28014.7	36546.5
	mt discard	75.6	11380.9	11456.5	2261.8	13125.6	15387.5	2224.1	4506.5	6730.6	4284.0	7916.4	12200.4
1992	ntrips	23	50	73	7	22	29	8	27	35	9	27	36
	dkratio	0.10	0.15	0.25	0.18	0.20	0.38	0.36	0.15	0.51	2.23	0.20	2.43
	mt kept	16904.2	25446.7	42350.9	9844.7	34956.2	44800.9	8824.5	32091.6	40916.1	8116.0	25267.4	33383.5
	mt discard	1685.7	3872.0	5557.7	1725.5	7039.5	8765.0	3174.9	4775.2	7950.1	18113.0	4947.9	23060.8
1993	ntrips	6	22	28	1	19	20	6	20	26	7	20	27
	dkratio	0.03	0.09	0.12	0.04	0.17	0.22	0.34	0.14	0.48	0.45	0.39	0.84
	mt kept	13935.0	21406.8	35341.9	7901.6	25493.7	33395.3	11231.0	32291.3	43522.3	8574.6	22867.3	31441.8
	mt discard	458.3	1949.5	2407.8	353.8	4454.8	4808.6	3796.3	4538.5	8334.8	3873.5	8963.0	12836.5
1994	ntrips	7	27	34	7	8	15	5	7	12	6	17	23
	dkratio	0.28	0.06	0.35	0.61	0.29	0.90	0.04	0.17	0.21	0.19	0.36	0.55
	mt kept	12155.0	19965.4	32120.4	9501.8	25000.2	34502.0	10347.3	30239.9	40587.2	8896.6	21156.9	30053.5
	mt discard	3458.5	1213.5	4672.0	5804.7	7197.6	13002.3	458.4	5012.0	5470.4	1684.6	7629.0	9313.5
1995	ntrips	14	28	42	24	14	38	55	34	89	23	36	59
	dkratio	0.59	0.24	0.83	0.37	0.57	0.93	0.19	0.08	0.26	0.61	0.17	0.78
	mt kept	10333.9	17824.5	28158.4	9046.2	22296.0	31342.2	9312.1	22265.7	31577.8	7927.5	18288.8	26216.3
	mt discard	6059.3	4257.9	10317.2	3305.4	12602.6	15908.0	1731.2	1696.9	3428.1	4867.7	3042.9	7910.6
1996	ntrips	7	13	20	23	27	50	38	37	75	27	30	57
	dkratio	0.74	0.20	0.95	0.02	0.42	0.44	0.05	0.02	0.07	0.13	0.20	0.32
	mt kept	16936.5	19091.2	36027.7	9961.4	22962.2	32923.6	7991.5	25032.9	33024.5	7188.8	23399.7	30588.5
	mt discard	12590.4	3877.6	16468.0	210.7	9573.8	9784.5	439.4	468.4	907.7	918.4	4614.4	5532.9
1997	ntrips	21	35	56	4	12	16	16	14	30	2	4	6
	dkratio	0.07	0.21	0.29	0.02	0.02	0.04	0.00	0.05	0.06	0.00	0.13	0.14
	mt kept	12575.2	20684.8	33260.0	6727.7	23291.1	30018.8	10470.8	23696.7	34167.6	8466.1	20440.2	28906.3
	mt discard	936.3	4430.1	5366.4	165.0	474.4	639.5	25.4	1277.5	1302.9	31.2	2691.8	2723.0
1998	ntrips	16	11	27	2	8	10	2	8	10	21	10	31
	dkratio	0.06	0.13	0.19	0.02	0.06	0.08	0.23	0.14	0.37	0.12	0.03	0.15
	mt kept	16831.8	22972.5	39804.3	14843.1	23525.3	38368.4	13115.2	25717.9	38833.1	8815.1	19348.0	28163.1
	mt discard	1023.2	2974.7	3997.9	342.0	1435.3	1777.3	3008.1	3663.3	6671.4	1035.4	569.4	1604.8
1999	ntrips		8	8	8	15	23	12	14	26	16	32	48
	dkratio		0.01	0.01	0.14	0.03	0.18	0.01	0.45	0.46	0.16	0.19	0.35
	mt kept	15344.9	18411.2	33756.1	8725.0	21760.3	30485.3	7118.7	21341.5	28460.2	7325.7	19526.1	26851.8
	mt discard	0.0	215.8	215.8	1243.8	713.5	1957.4	49.8	9699.1	9748.9	1137.6	3767.2	4904.8
2000	ntrips	26	39	65	12	64	76	18	34	52	10	39	49
	dkratio	0.05	0.10	0.15	0.02	0.27	0.29	0.01	0.21	0.22	1.15	0.42	1.56
	mt kept	14877.0	21346.9	36223.9	5950.7	21128.2	27078.9	8364.9	22829.2	31194.1	5876.9	20991.7	26868.6
	mt discard	688.1	2235.0	2923.1	126.9	5742.0	5868.9	75.2	4782.0	4857.2	6755.9	8715.7	15471.6
2001	ntrips	15	41	56	18	42	60	51	64	115	17	71	88
	dkratio	0.00	0.09	0.09	0.00	1.20	1.20	0.02	0.19	0.21	0.05	0.19	0.23
	mt kept	8094.4	24244.4	32338.8	4421.5	25921.7	30343.2	4140.7	23630.8	27771.5	6097.0	22826.9	28924.0
	mt discard	12.1	2263.5	2275.5	4.2	31189.8	31194.0	95.9	4377.6	4473.5	287.0	4230.5	4517.6
2002	ntrips	20	30	50	12	23	35	46	118	164	2	134	136
	dkratio	0.18	0.24	0.41	0.08	0.34	0.42	0.07	0.21	0.28	3.30	0.32	3.62
	mt kept	7526.3	24873.4	32399.7	3699.4	24286.7	27986.2	4023.8	22163.7	26187.5	5140.9	18687.4	23828.2
	mt discard	1329.2	5882.3	7211.5	295.0	8365.1	8660.0	295.8	4681.9	4977.6	16976.5	5914.2	22890.6
2003	ntrips	10	129	139	26	110	136	14	125	139	20	120	140
	dkratio	0.12	0.38	0.51	0.11	0.39	0.50	0.11	0.17	0.28	0.65	0.25	0.90
	mt kept	7393.9	25623.8	33017.7	2490.9	21671.6	24162.5	2985.1	20810.0	23795.1	5595.9	22225.4	27821.3
	mt discard	923.0	9743.7	10666.7	273.6	8408.8	8682.4	328.5	3576.2	3904.6	3664.6	5451.5	9116.0
2004	ntrips	64	108	172	45	95	140	68	172	240	105	206	311
	dkratio	0.08	0.25	0.33	0.06	0.40	0.46	0.02	0.11	0.14	0.13	0.12	0.25
	mt kept	7807.8	26579.0	34386.8	11345.3	27943.0	39288.2	15427.4	40193.4	55620.7	5445.7	21202.4	26648.2
	mt discard	621.8	6592.1	7213.9	675.4	11153.7	11829.1	377.0	4599.3	4976.4	695.9	2625.3	3321.1
2005	ntrips	49	122	171	22	86	108	39	386	425	45	244	289
	dkratio	0.07	0.08	0.15	0.11	0.15	0.26	0.16	0.20	0.37	0.16	0.15	0.31
	mt kept	6411.6	18855.5	25267.2	3799.1	18326.2	22125.3	4915.6	22562.7	27478.3	4081.5	18581.5	22663.0
	mt discard	423.1	1502.4	1925.5	432.6	2664.6	3097.3	802.6	4598.5	5401.1	651.7	2748.8	3400.5
Total	ntrips	303	732	1035	245	639	884	397	1190	1587	354	1122	1476

Table B1.9. Discards of skates (all species) by year, quarter, region in the sink gill net fishery.

	Quarter		1			2			3			4	
year	Region	MA	NE	Total	MA	NE	Total	MA	NE	Total	MA	NE	Total
1989	ntrips					1	1		46	46		57	57
	dkratio					0.003	0.003		0.007	0.007		0.010	0.010
	mt kept	431.8	2040.0	2471.9	1211.7	5244.3	6456.0	1170.4	8526.7	9697.1	463.4	5257.3	5720.7
	mt discard	0.00	0.00	0.00	0.00	16.94	16.94	0.00	58.32	58.32	0.00	51.68	51.68
1990	ntrips		25	25		48	48	1	31	32	1	38	39
	dkratio		0.130	0.130		0.053	0.053	0.000	0.004	0.004	0.000	0.013	0.013
	mt kept	700.9	1678.6	2379.5	954.8	5737.3	6692.1	837.9	10564.8	11402.6	892.6	4939.3	5831.9
	mt discard	0.00	218.63	218.63	0.00	303.91	303.91	0.00	38.67	38.67	0.00	62.98	62.98
1991	ntrips		16	16		176	176		489	489		277	277
	dkratio		0.041	0.041		0.013	0.013		0.011	0.011		0.009	0.009
	mt kept	828.6	1672.8	2501.3	1612.5	7011.9	8624.4	1767.8	7800.7	9568.5	1349.7	4459.2	5808.9
	mt discard	0.00	68.40	68.40	0.00	92.28	92.28	0.00	87.37	87.37	0.00	40.98	40.98
1992	ntrips	1	86	87		414	414		392	392		291	291
	dkratio	0.000	0.119	0.119		0.034	0.034		0.006	0.006		0.009	0.009
	mt kept	880.5	1455.1	2335.7	1951.2	5490.3	7441.5	1846.4	8376.8	10223.2	1012.4	5051.0	6063.5
	mt discard	0.00	173.48	173.48	0.00	184.36	184.36	0.00	48.00	48.00	0.00	45.86	45.86
1993	ntrips	1	68	69		282	282	7	140	147	11	260	271
	dkratio	0.000	0.032	0.032		0.030	0.030	0.001	0.010	0.011	0.002	0.007	0.010
	mt kept	1750.7	1252.2	3002.9	2380.1	6082.4	8462.5	2452.2	10138.7	12590.9	1787.7	5717.3	7505.0
	mt discard	0.00	39.72	39.72	0.00	183.08	183.08	1.57	105.34	106.91	4.22	41.34	45.55
1994	ntrips	55	68	123	39	15	54	50	23	73	74	57	131
	dkratio	0.009	0.037	0.047	0.008	0.029	0.036	0.001	0.034	0.035	0.014	0.044	0.058
	mt kept	1107.5	1172.4	2279.8	2461.1	6644.2	9105.3	3117.1	11326.8	14443.9	1680.3	4112.8	5793.1
	mt discard	10.40	43.62	54.02	18.85	191.22	210.07	2.93	383.98	386.91	24.28	180.55	204.83
1995	ntrips	153	18	171	78	42	120	46	51	97	99	30	129
	dkratio	0.013	0.084	0.096	0.019	0.036	0.056	0.000	0.009	0.009	0.014	0.028	0.042
	mt kept	1283.7	1348.9	2632.6	2788.3	8653.6	11441.9	2096.2	10745.0	12841.2	2785.1	4708.2	7493.3
	mt discard	16.30	112.75	129.06	53.23	315.16	368.39	0.25	97.67	97.92	39.99	131.74	171.73
1996	ntrips	134	12	146	81	24	105	51	18	69	70	17	87
	dkratio	0.014	0.020	0.034	0.018	0.103	0.121	0.004	0.017	0.021	0.009	0.003	0.012
	mt kept	3389.9	1098.8	4488.7	4764.0	6689.6	11453.6	2943.2	10938.8	13882.0	4167.8	5000.9	9168.7
	mt discard	47.76	21.98	69.74	84.08	689.16	773.25	12.77	182.35	195.12	36.47	15.30	51.77
1997	ntrips	147	10	157	73	23	96	40	18	58	57	14	71
	dkratio	0.015	0.006	0.021	0.047	0.010	0.058	0.000	0.003	0.003	0.010	0.010	0.020
	mt kept	8163.2	1359.3	9522.5	4616.8	6592.9	11209.7	3548.2	8536.0	12084.1	5667.0	3813.9	9480.8
	mt discard	125.63	7.54	133.18	218.51	68.90	287.41	1.35	22.53	23.88	55.03	37.64	92.67
1998	ntrips	188	10	198	35	37	72	9	32	41	40	54	94
	dkratio	0.008	0.006	0.014	0.023	0.007	0.030	0.009	0.018	0.027	0.017	0.009	0.025
	mt kept	8538.8	1382.1	9921.0	5875.8	5415.3	11291.1	3267.8	9226.5	12494.3	6232.9	5000.3	11233.2
	mt discard	71.21	8.40	79.62	135.85	38.88	174.73	30.65	161.65	192.30	103.78	43.00	146.78
1999	ntrips	32	16	48	21	30	51	13	35	48	24	35	59
	dkratio	0.017	0.015	0.032	0.074	0.023	0.098	0.002	0.002	0.004	0.017	0.059	0.077
	mt kept	8560.1	1761.6	10321.7	5777.6	5943.7	11721.2	2697.0	5512.7	8209.8	4082.3	3816.2	7898.5
	mt discard	146.98	26.51	173.49	430.14	138.43	568.57	4.15	13.23	17.38	70.38	226.76	297.14
2000	ntrips	31	23	54	21	51	72	9	32	41	31	37	68
	dkratio	0.001	0.012	0.013	0.005	0.034	0.039	0.000	0.149	0.149	0.010	0.057	0.067
	mt kept	7225.6	1805.9	9031.4	4500.2	4153.9	8654.0	3568.8	4576.9	8145.8	3835.0	3795.3	7630.3
	mt discard	4.70	22.23	26.93	22.14	140.94	163.08	0.00	684.21	684.21	38.04	218.04	256.08
2001	ntrips	24	19	43	27	30	57	6	21	27	24	17	41
	dkratio	0.002	0.058	0.060	0.008	0.048	0.055	0.000	0.036	0.036	0.005	0.020	0.025
	mt kept	5146.0	1447.6	6593.6	4217.9	4430.2	8648.1	2829.4	4197.0	7026.4	4360.6	4889.5	9250.1
	mt discard	9.11	84.05	93.16	33.07	210.43	243.50	0.00	153.06	153.06	22.72	96.42	119.14
2002	ntrips	12	18	30	12	16	28	5	25	30	17	31	48
	dkratio	0.001	0.013	0.014	0.067	0.079	0.146	0.000	0.034	0.034	0.004	0.278	0.282
	mt kept	4899.9	2547.1	7447.0	3913.9	4313.5	8227.4	2844.2	4080.2	6924.4	3560.2	4405.0	7965.2
	mt discard	2.84	33.09	35.93	261.06	341.15	602.21	0.00	137.38	137.38	14.85	1224.80	1239.65
2003	ntrips	6	18	24	18	109	127	11	172	183		122	122
	dkratio	0.004	0.135	0.138	0.019	0.030	0.049	0.000	0.023	0.023		0.048	0.048
	mt kept	5278.3	2351.2	7629.5	4951.6	4880.3	9831.9	2441.0	5653.1	8094.1	3972.1	5034.5	9006.7
	mt discard	19.27	316.30	335.57	93.44	147.82	241.26	0.81	128.49	129.30	0.00	239.49	239.49
2004	ntrips	1	107	108	1	133	134	1	341	342	26	269	295
	dkratio	0.000	0.036	0.036	0.000	0.032	0.032	0.000	0.018	0.018	0.064	0.024	0.088
	mt kept	4968.4	7776.7	12745.0	4123.3	4009.8	8133.2	2966.2	4649.4	7615.6	3577.1	3362.5	6939.7
	mt discard	0.00	281.90	281.90	0.00	126.71	126.71	0.00	85.87	85.87	229.51	79.49	309.00
2005	ntrips	8	133	141	24	45	69		389	389	8	197	205
	dkratio	0.030	0.182	0.212	0.209	0.088	0.296		0.035	0.035	0.043	0.018	0.062
	mt kept	5093.9	1299.4	6393.2	4760.1	4255.5	9015.6	2925.2	5756.6	8681.8	3739.0	3363.0	7102.0
	mt discard	151.75	236.98	388.72	993.77	372.65	1366.43	0.00	200.67	200.67	162.42	62.18	224.60
Total	ntrips	793	647	1440	430	1476	1906	249	2255	2504	482	1803	2285

Table B1.10. Discards of skates (all species) by year, quarter, region in the scallop dredge fishery.

	Quarter		1			2			3			4	
year	Region	MA	NE	Total	MA	NE	Total	MA	NE	Total	MA	NE	Total
1989	ntrips												
	dkratio												
	mt kept	10086.6	23291.0	33377.5	15880.9	28652.0	44532.8	10428.4	25176.9	35605.4	5278.9	18667.2	23946.0
	mt discard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1990	ntrips												
	dkratio												
	mt kept	10987.0	17618.5	28605.6	14895.0	30679.0	45574.0	14342.6	30581.7	44924.2	7677.8	19732.3	27410.1
	mt discard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1991	ntrips										1	1	2
	dkratio										0.56	0.18	0.74
	mt kept	10896.2	23586.6	34482.8	18918.4	31037.2	49955.5	10741.8	23977.9	34719.7	6046.7	16561.7	22608.4
	mt discard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3366.0	3024.7	6390.7
1992	ntrips	1	2	3	1	3	4	1	2	3	1	4	5
	dkratio	0.20	0.36	0.55	0.11	0.24	0.35	0.12	0.59	0.71	0.26	0.40	0.66
	mt kept	7389.5	17974.8	25364.3	12121.3	25380.6	37501.9	11000.5	24564.0	35564.6	5325.4	18270.0	23595.4
	mt discard	1452.4	6390.4	7842.8	1274.9	6192.9	7467.8	1322.4	14390.4	15712.7	1410.8	7270.6	8681.4
1993	ntrips	3	4	7	3	4	7	1	2	3	1	3	4
	dkratio	0.45	0.20	0.65	0.52	0.14	0.66	0.53	0.18	0.71	0.76	0.52	1.28
	mt kept	4536.8	13875.1	18412.0	6136.5	13124.9	19261.4	5650.6	11626.6	17277.2	3277.8	10498.7	13776.5
	mt discard	2030.6	2758.9	4789.6	3188.3	1795.5	4983.8	2989.8	2145.0	5134.8	2506.4	5451.2	7957.7
1994	ntrips	4	3	7	3	1	4		4	4	3	5	8
	dkratio	0.38	0.20	0.57	0.05	0.17	0.22		0.08	0.08	0.50	0.21	0.71
	mt kept	5189.9	7542.7	12732.6	10500.5	9248.8	19749.4	9023.3	9236.0	18259.3	4719.4	8918.3	13637.7
	mt discard	1958.8	1472.3	3431.1	551.3	1541.6	2092.9	0.0	765.9	765.9	2356.8	1878.8	4235.6
1995	ntrips	6	3	9	2	3	5	3	2	5		5	5
	dkratio	0.26	0.32	0.59	0.39	0.04	0.44	0.07	0.26	0.33		0.83	0.83
	mt kept	5765.1	7520.0	13285.1	11081.4	13823.0	24904.4	7007.7	10248.7	17256.4	2340.3	7278.6	9618.9
	mt discard	1522.5	2424.8	3947.3	4348.7	605.9	4954.5	520.6	2619.9	3140.5	0.0	6031.6	6031.6
1996	ntrips	6	7	13	4	5	9	3	4	7	4	5	9
	dkratio	0.24	0.13	0.38	0.46	0.10	0.56	0.23	0.14	0.38	1.11	0.41	1.52
	mt kept	3368.3	5907.8	9276.1	10880.0	13675.2	24555.2	6904.9	12142.7	19047.6	2663.1	9855.3	12518.4
	mt discard	823.5	782.0	1605.5	5022.2	1378.6	6400.8	1606.2	1738.1	3344.3	2959.9	4010.7	6970.6
1997	ntrips	6	6	12	5	2	7	4	3	7	1	2	3
	dkratio	0.55	0.26	0.81	0.55	0.14	0.69	0.33	0.36	0.69	0.10	0.10	0.20
	mt kept	3375.8	7265.0	10640.9	7523.7	11622.1	19145.8	5540.9	9175.7	14716.6	2206.1	7496.9	9703.0
	mt discard	1840.2	1890.2	3730.5	4153.4	1620.5	5773.9	1803.5	3314.1	5117.6	228.2	755.8	984.0
1998	ntrips	1		1	6	2	8	3	2	5	6	6	12
	dkratio	0.10		0.10	0.38	0.13	0.52	0.47	0.64	1.11	0.60	0.27	0.87
	mt kept	3212.1	6498.3	9710.4	6420.8	9324.1	15744.9	4168.5	7997.0	12165.5	2778.4	6975.2	9753.6
	mt discard	310.1	0.0	310.1	2455.6	1236.1	3691.7	1961.9	5089.6	7051.5	1656.4	1915.9	3572.2
1999	ntrips				1	2	3	4	1	5	2	5	7
	dkratio				0.29	0.10	0.38	0.56	0.33	0.89	0.04	0.09	0.14
	mt kept	3981.4	7393.9	11375.2	11211.7	16989.1	28200.8	6866.1	16967.2	23833.3	2229.0	15535.5	17764.5
	mt discard	0.0	0.0	0.0	3198.7	1638.8	4837.5	3833.0	5673.7	9506.7	92.6	1464.1	1556.6
2000	ntrips	4	3	7	6	25	31	11	107	118	7	93	100
	dkratio	0.05	0.22	0.26	0.15	0.18	0.33	0.03	0.06	0.09	0.14	0.03	0.17
	mt kept	5085.8	9377.8	14463.5	19064.4	22542.1	41606.5	14563.1	19221.4	33784.5	5843.4	16750.7	22594.0
	mt discard	232.5	2038.5	2271.0	2945.8	4008.4	6954.3	478.3	1117.1	1595.4	823.7	454.6	1278.3
2001	ntrips		17	17	22	18	40	8	17	25	12	11	23
	dkratio		0.02	0.02	0.03	0.03	0.07	0.06	0.04	0.09	0.04	0.06	0.10
	mt kept	7693.3	15218.8	22912.1	24272.2	31980.4	56252.7	22261.8	25588.2	47850.0	14665.1	19349.4	34014.4
	mt discard	0.0	366.6	366.6	847.8	995.2	1843.1	1241.1	899.7	2140.8	555.7	1163.9	1719.5
2002	ntrips	7	4	11	1	22	23	12	22	34	7	20	27
	dkratio	0.08	0.08	0.16	0.10	0.06	0.16	0.08	0.11	0.19	0.07	0.08	0.14
	mt kept	11123.6	17851.7	28975.3	30540.0	34154.5	64694.5	28493.7	30490.7	58984.4	14310.0	19683.6	33993.6
	mt discard	835.8	1509.2	2345.0	3015.8	2132.3	5148.1	2385.2	3304.9	5690.1	962.1	1506.2	2468.3
2003	ntrips	15	14	29	14	6	20	17	17	34	15	24	39
	dkratio	0.11	0.07	0.18	0.05	0.10	0.15	0.05	0.09	0.14	0.06	0.08	0.13
	mt kept	11318.7	16164.5	27483.3	35699.1	36028.7	71727.8	31001.4	30538.0	61539.3	19571.0	22027.6	41598.6
	mt discard	1214.6	1111.0	2325.6	1739.3	3689.0	5428.2	1538.6	2863.9	4402.4	1149.6	1670.8	2820.4
2004	ntrips	9	13	22	27	28	55	56	26	82	35	54	89
	dkratio	0.08	0.09	0.17	0.04	0.04	0.07	0.03	0.06	0.09	0.05	0.04	0.09
	mt kept	16614.0	18777.6	35391.5	11961.7	16771.9	28733.6	2262.9	6101.8	8364.7	1616.5	9072.8	10689.3
	mt discard	1353.9	1662.9	3016.8	447.6	619.9	1067.5	65.7	355.2	420.9	83.1	382.1	465.1
2005	ntrips	28	33	61	24	28	52	70	43	113	38	25	63
	dkratio	0.06	0.05	0.11	0.03	0.06	0.09	0.05	0.05	0.10	0.07	0.04	0.11
	mt kept	972.3	9753.4	10725.7	1958.8	17194.4	19153.2	2204.5	14651.3	16855.7	1129.5	6036.1	7165.6
	mt discard	55.6	528.7	584.4	54.5	996.4	1050.9	101.6	733.4	835.0	76.8	246.5	323.2
Total	ntrips	90	109	199	119	149	268	193	252	445	133	263	396

Table B2.1. Strata from the NMFS spring/fall, winter, and scallop surveys which were combined for bootstrapping.

Spring/Fall-Offshore	Spring/Fall-Inshore	Winter Survey	Winter Rosette	Scallop Survey
1010	3020+3030+3040+3050	1010	1020	6060
1020	3060+3070+3080	1020	1030	6070
1030 +1040	3090+3100+3110	1030	1100	6100
1050	3120+3130+3140	1050	1110+1120	6110
1060	3150+3160+3170	1060+1070	1610	6140
1070 +1080	3180+3190	1080	1620+1630+1640	6150
1090	3200	1090	1650	6180
1100	3210-3220	1100	1660	6190
1110+1120	3230	1110	1670+1680	6220
1130	3240+3250+3260	1610	1690	6230
1140	3270+3280+3290	1620+1630	1700	6240
1140+1150	3300+3310	1650	1710+1720	6250
1160	3320	1660+1670	1740	6260
1170	3330+3340	1690	1750+1760	6270
1170+1180	3350	1700+1710		6280+6290
1190	3360+3370	1730		6300
1200	3380	1740+1750		6310
1210	3390+3400			6330
1220	3410			6340
1230	3420+3430			6350
1240	3440			6460
1250	3450+3460			6470
1260	3550			6490
1270	3550+3560			6500
1280	3580+3590+3600+3610+			6510
1290+1300	3630+3640+3650+3660			6520
1330+1340+1350 (1)				6530
1360				6540
1370				6550
1380				6580
1390+1400				6590
1610+1620+1630+				6600
1640+1650 (clearnose/rosette)				6610
1650+1660 (winter/little)				6621+6622
1670				6631+6631+6640
1670+1680				6651+6652
1690				6661+6662
1700				6710+6720
1710+1720				6740
1730				
1740				
1750+1760				

Table B2.2. 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 1968-2006.

	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
2000	4.358	2.273	6.443	1.998	1.041	2.954	2.181	15	34	62	62.2	82	99	57	457
2001	3.496	1.889	5.103	2.350	0.912	3.787	1.488	20	27	44	52.1	82	100	48	556
2002	3.132	1.650	4.614	1.688	0.949	2.426	1.856	15	29	59	58.6	82	93	48	407
2003	2.799	1.471	4.127	2.047	1.164	2.931	1.367	15	29	49	53.4	82	100	61	606
2004	2.446	1.512	3.379	1.547	1.015	2.080	1.581	18	29	50	54.6	85	97	56	356
2005	1.757	0.869	2.645	1.672	0.470	2.874	1.051	15	30	45	48.6	75	97	52	375
2006	3.041	1.020	5.062	3.067	0.465	5.668	0.992	15	24	43	47.2	75	99	55	779

Table B2.3. 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 1967-2005.

	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
1999	5.089	2.080	8.098	2.642	1.320	3.963	1.927	15	31	58	58.0	80	111	53	966
2000	4.378	2.390	6.366	2.535	1.351	3.718	1.727	18	25	56	55.5	82	99	45	756
2001	3.887	2.442	5.333	2.165	1.415	2.914	1.796	15	32	58	57.8	83	98	53	601
2002	5.600	3.417	7.782	2.323	1.535	3.111	2.411	16	33	66	63.9	87	101	55	743
2003	3.386	2.111	4.662	1.498	0.928	2.068	2.260	16	33	62	63.0	87	104	43	435
2004	4.031	2.632	5.430	1.942	1.343	2.542	2.075	15	33	62	60.4	87	102	50	611
2005	2.615	1.791	3.439	1.671	1.005	2.337	1.565	18	31	52	55.1	81	98	54	475

Table B2.4. 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 1992-2006. Stratum 16 not sampled in 1993, 2000, 2002-2006. Strata 13 and 14 not sampled in 2003. Stratum 63 not sampled in 1993. Stratum 14 not sampled in 2005.

	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
2000	11.315	4.814	17.815	5.697	2.799	8.596	1.986	18	27	56	57.6	88	101	33	486
2001	28.634	19.682	37.585	15.555	9.234	21.875	1.841	16	30	58	57.5	84	100	76	2025
2002	28.733	17.246	40.220	15.982	6.565	25.400	1.798	15	24	49	55.1	88	107	53	1849
2003	17.425	7.871	26.979	29.540	-6.318	64.399	0.590	15	15	28	34.8	75	99	34	1662
2004	26.618	13.793	39.444	13.833	9.244	18.422	1.924	15	31	55	58.0	86	102	58	1342
2005	19.424	8.976	29.872	16.081	6.327	25.836	1.208	16	26	48	50.3	76	95	46	972
2006	32.411	12.125	52.697	18.233	9.593	26.874	1.778	15	30	56	57.4	86	102	60	1776

Table B2.5. 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 1976-2006.

	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	36.1	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
2000	8.596	6.647	10.545	19.677	15.270	24.083	0.437	9	21	41	38.9	47	57	179	15367
2001	6.835	4.297	9.372	15.347	9.900	20.794	0.445	8	18	42	39.5	48	58	154	6978
2002	6.444	4.546	8.341	16.280	11.306	21.254	0.396	8	11	42	37.7	48	57	154	11983
2003	6.486	4.505	8.486	15.116	10.195	20.036	0.429	9	22	42	40.1	48	55	169	6919
2004	7.219	5.374	9.064	17.039	11.917	22.162	0.424	7	25	42	39.9	47	57	147	9866
2005	3.241	2.305	4.177	7.328	5.515	9.141	0.442	8	13	43	38.9	48	53	138	3108
2006	3.323	1.892	4.753	7.878	4.544	11.211	0.422	7	11	42	38.4	48	55	138	2771

Table B2.6. 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 1975-2005.

	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
1999	3.210	2.344	4.076	7.698	5.042	10.355	0.417	6	21	41	38.4	48	58	143	2289
2000	2.550	1.607	3.493	5.711	3.761	7.661	0.447	10	22	43	40.1	49	63	116	1759
2001	2.845	2.032	3.658	6.044	4.265	7.823	0.471	10	22	43	41.4	49	57	130	1985
2002	3.375	2.371	4.379	7.358	5.170	9.545	0.459	9	23	43	40.8	49	54	135	2515
2003	7.740	5.218	10.261	18.199	11.697	24.702	0.425	10	18	41	39.3	48	55	141	6523
2004	2.265	1.388	3.141	4.556	2.714	6.399	0.497	8	26	43	42.3	49	57	122	2270
2005	3.766	2.281	5.252	7.606	4.698	10.515	0.495	9	21	44	41.8	49	55	122	2437

Table B2.7. 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 1992-2006. Stratum 16 not sampled in 1993, 2000, 2002-2006. Strata 13 and 14 not sampled in 2003. Stratum 63 not sampled in 1993. Stratum 14 not sampled in 2005.

	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
2000	50.7247	37.806	63.643	115.572	87.597	143.547	0.439	8	20	42	39.5	47	53	92	10722
2001	47.429	38.584	56.274	105.749	85.050	126.447	0.449	8	11	42	39.7	48	63	120	12956
2002	63.3207	49.704	76.937	149.228	116.464	181.993	0.424	8	23	42	40.2	48	56	110	17329
2003	63.943	44.340	83.546	151.185	105.428	196.943	0.423	9	24	41	40.0	48	54	62	8870
2004	71.8027	50.398	87.208	162.456	128.807	196.106	0.442	10	25	41	40.5	47	54	94	13822
2005	64.149	45.820	82.478	140.444	93.239	187.648	0.457	9	25	42	40.9	47	54	68	9544
2006	59.2538	48.374	70.134	116.433	96.399	136.467	0.509	9	23	43	42.1	49	55	87	12687

Table B2.8. 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 1968-2006.

	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
2000	0.473	0.246	0.699	0.138	0.076	0.200	3.419	19	20	68	71.4	125	127	14	29
2001	0.170	0.032	0.307	0.141	0.048	0.234	1.200	20	20	52	54.8	77	115	13	30
2002	0.477	0.233	0.721	0.129	0.047	0.212	3.690	35	35	66	77.3	127	133	13	26
2003	0.885	0.341	1.429	0.302	0.172	0.432	2.928	19	19	54	64.0	126	132	23	64
2004	0.103	0.039	0.167	0.111	0.032	0.189	0.928	19	19	55	50.6	81	89	12	24
2005	0.670	0.120	1.221	0.319	0.073	0.565	2.101	26	33	68	68.1	109	122	15	59
2006	1.706	-0.995	4.407	0.586	-0.087	1.260	2.910	19	19	69	69.9	123	134	22	196

Table B2.9. 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 1963-2005.

	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
1999	0.300	0.051	0.549	0.085	0.041	0.130	3.511	23	23	54	68.0	120	121		13	15
2000	0.288	0.054	0.521	0.054	0.023	0.085	5.360	29	29	89	85.5	121	122		12	15
2001	0.543	0.050	1.036	0.149	0.052	0.247	3.635	24	40	75	75.5	121	126		16	34
2002	0.778	0.351	1.205	0.269	0.130	0.407	2.893	26	27	59	68.0	119	129		24	59
2003	0.553	0.255	0.852	0.251	0.157	0.345	2.203	22	22	48	57.1	115	120		29	55
2004	1.295	0.677	1.913	0.229	0.122	0.336	5.662	42	47	80	90.1	124	128		23	58
2005	1.036	0.482	1.590	0.360	0.207	0.513	2.877	18	25	64	68.1	118	132		29	73

Table B2.10. 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 1992-2006. Stratum 16 not sampled in 1993, 2000, 2002-2006. Strata 13 and 14 not sampled in 2003. Stratum 63 not sampled in 1993. Stratum 14 not sampled in 2005.

	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
2000	2.718	0.153	5.284	1.081	0.518	1.643	2.515	19	19	56	62.78	122	126	12	69
2001	1.373	0.375	2.370	0.929	0.168	1.691	1.477	19	30	60	58.7	95	127	21	107
2002	2.126	0.506	3.746	0.950	0.441	1.459	2.238	18	29	58	63.9	119	126	24	123
2003	0.872	0.429	1.316	0.776	0.227	1.324	1.125	26	31	46	52.0	90	131	11	47
2004	3.397	1.214	5.581	1.786	0.972	2.601	1.902	18	30	53	60.9	116	130	23	247
2005	1.061	0.542	1.581	1.23101	0.703	1.759	0.862	18	19	44	47.8	84	102	21	103
2006	3.015	1.519	4.511	3.171	1.622	4.719	0.951	20	29	51	52.9	78	111	37	355

Table B2.11. 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 1968-2006.

	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
2000	0.423	0.166	0.680	0.470	0.013	0.927	0.900	12	12	24	34.0	82	89	28	103
2001	0.493	0.217	0.769	0.221	0.080	0.362	2.234	14	33	56	57.7	80	92	16	35
2002	0.333	0.138	0.529	0.248	0.127	0.369	1.340	13	15	38	42.0	88	93	24	53
2003	0.594	0.268	0.920	0.332	0.203	0.461	1.790	19	19	50	50.9	86	102	30	57
2004	0.368	0.178	0.557	0.212	0.128	0.296	1.731	15	15	47	49.3	91	95	22	48
2005	0.435	0.154	0.716	0.371	0.167	0.576	1.171	16	17	44	44.4	76	89	19	62
2006	0.201	0.035	0.366	0.186	0.020	0.352	1.079	12	14	41	41.9	83	87	15	29

Table B2.12. 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 1963-2005.

	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	1.268	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
1999	0.479	0.249	0.710	0.326	0.195	0.457	1.469	13	14	41	46.3	87	94	38	72
2000	0.832	0.391	1.274	0.374	0.239	0.510	2.224	13	17	49	52.7	92	102	27	70
2001	0.332	0.087	0.577	0.294	0.157	0.430	1.129	16	17	44	44.1	74	82	23	60
2002	0.436	0.188	0.684	0.260	0.126	0.393	1.679	14	15	35	44.2	85	95	25	52
2003	0.742	0.450	1.035	0.930	0.168	1.691	0.798	12	14	23	34.2	74	89	34	175
2004	0.710	0.272	1.148	0.358	0.167	0.550	1.980	14	18	45	50.1	87	90	23	65
2005	0.224	0.092	0.357	0.205	-0.034	0.443	1.096	13	18	39	42.6	76	90	17	36

Table B2.13. 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 1968-2006.

	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
2000	0.060	0.025	0.095	0.220	-0.021	0.460	0.272	10	10	27	30.9	59	62	13	30
2001	0.058	0.020	0.096	0.125	0.058	0.192	0.466	19	28	46	44.6	57	60	16	25
2002	0.184	0.096	0.271	0.482	0.297	0.667	0.381	10	13	45	40.4	55	61	26	78
2003	0.224	0.161	0.287	0.642	0.429	0.348	0.348	14	19	40	40.4	55	59	36	95
2004	0.262	0.141	0.383	0.650	0.278	1.022	0.403	12	19	43	42.3	56	60	32	125
2005	0.457	0.125	0.788	1.207	0.288	2.126	0.378	10	27	42	42.4	53	60	22	178
2006	0.203	0.005	0.401	0.531	-0.009	1.072	0.382	19	21	41	41.3	56	62	22	71

Table B2.14. 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 1963-2005.

	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
1999	0.070	0.032	0.109	0.110	0.050	0.171	0.638	22	22	50	48.7	60	62	16	22
2000	0.154	0.083	0.226	0.318	0.190	0.447	0.485	10	11	45	42.3	59	73	27	55
2001	0.287	0.169	0.405	0.565	0.349	0.781	0.507	17	23	49	46.5	58	62	29	84
2002	0.111	0.067	0.155	0.209	0.140	0.278	0.533	15	24	50	46.2	60	62	25	32
2003	0.190	0.076	0.304	0.646	0.248	1.045	0.294	10	14	39	36.3	52	62	30	84
2004	0.214	0.126	0.303	0.467	0.283	0.652	0.458	18	24	47	45.3	55	59	29	58
2005	0.131	0.039	0.224	0.291	0.143	0.439	0.451	15	17	47	43.1	59	62	18	44

Table B2.15. 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 1976-2006.

	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
2000	1.391	1.046	1.736	1.140	0.789	1.491	1.221	24	40	59	59.4	70	76	31	126
2001	1.380	0.674	2.087	1.097	0.456	1.738	1.258	42	49	62	60.8	68	72	19	74
2002	0.836	0.281	1.392	0.617	0.241	0.993	1.355	29	42	62	60.5	69	74	23	59
2003	0.622	0.366	0.879	0.448	0.265	0.631	1.389	49	49	62	62.7	75	76	16	35
2004	0.433	0.050	0.815	0.376	0.049	0.703	1.151	35	35	59	56.2	70	72	9	23
2005	0.569	0.030	1.109	0.414	0.008	0.820	1.374	42	42	61	61.2	70	73	11	27
2006	0.567	0.189	0.946	0.420	0.179	0.661	1.350	36	41	63	60.7	68	72	18	39

Table B2.16. 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 1975-2005.

	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
1999	1.053	0.536	1.570	0.928	0.525	1.332	1.134	15	32	61	57.8	69	71	41	84
2000	1.032	0.422	1.642	0.795	0.353	1.238	1.298	14	47	60	60.5	69	74	29	61
2001	1.614	1.092	2.136	1.494	0.984	2.004	1.081	13	15	59	55.2	68	73	41	221
2002	0.891	0.372	1.411	0.863	0.317	1.409	1.033	14	38	55	56.0	68	73	27	63
2003	0.661	0.417	0.906	0.640	0.456	0.823	1.034	15	30	54	54.5	71	78	38	81
2004	0.709	0.201	1.217	0.590	0.172	1.008	1.201	37	43	62	60.1	69	75	18	55
2005	0.524	0.192	0.855	0.452	0.207	0.697	1.159	26	37	62	59.6	71	74	30	71

Table B2.17. 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 1992-2006. Stratum 16 not sampled in 1993, 2000, 2002-2006. Strata 13 and 14 not sampled in 2003. Stratum 63 not sampled in 1993. Stratum 14 not sampled in 2005.

	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
2000	10.102	5.693	14.510	8.864	4.579	13.150	1.140	25	42	59	58.2	69	93	43	1449
2001	8.316	5.624	11.008	6.599	4.240	8.957	1.260	25	43	61	60.6	69	86	41	1300
2002	12.223	8.343	16.102	8.864	5.886	11.843	1.379	23	39	63	61.6	70	74	51	1704
2003	19.637	13.819	25.455	15.769	10.902	20.635	1.245	23	39	62	59.1	70	81	36	2260
2004	11.566	7.743	15.389	10.162	6.344	13.979	1.138	20	35	60	58.1	70	80	38	1880
2005	6.036	3.837	8.235	5.078	2.425	7.731	1.189	24	44	60	59.1	70	82	26	1047
2006	11.723	4.862	18.585	11.085	4.693	17.477	1.058	23	35	57	56.7	70	77	41	1916

Table B2.18. 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 1968-2006.

	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
2000	0.026	0.009	0.043	0.106	0.040	0.171	0.247	30	32	37	38.0	41	42	7	15
2001	0.010	-0.005	0.025	0.041	-0.012	0.095	0.244	21	21	40	38.2	40	41	4	4
2002	0.019	-0.007	0.045	0.076	-0.029	0.180	0.252	12	12	38	34.1	39	40	3	5
2003	0.028	-0.002	0.057	0.115	0.003	0.226	0.241	9	24	38	37.0	39	41	5	17
2004	0.023	-0.009	0.055	0.084	-0.025	0.193	0.276	30	32	39	39.2	40	41	3	7
2005	0.050	-0.029	0.128	0.216	-0.131	0.564	0.229	13	31	37	36.7	40	41	5	21
2006	0.012	0.007	0.016	0.051	0.020	0.081	0.230	25	25	39	35.5	40	41	5	8

Table B2.19. 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 1967-2005.

	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
1999	0.067	0.038	0.096	0.380	0.182	0.578	0.177	12	18	34	32.6	41	42	8	46
2000	0.033	-0.006	0.073	0.134	-0.015	0.283	0.248	26	30	35	36.5	39	40	7	10
2001	0.121	-0.007	0.249	0.472	-0.016	0.961	0.257	11	34	39	38.6	43	44	10	28
2002	0.052	0.009	0.095	0.347	0.045	0.648	0.150	8	8	30	28.0	40	42	11	29
2003	0.033	0.016	0.051	0.136	0.071	0.200	0.247	33	33	36	37.4	39	41	7	18
2004	0.048	0.003	0.092	0.231	0.030	0.432	0.206	19	29	35	35.5	37	40	8	29
2005	0.065	0.001	0.129	0.286	-0.004	0.575	0.227	30	30	35	36.4	39	40	7	24

Table B2.20. 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 1992-2006. Stratum 16 not sampled in 1993, 2000, 2002-2006. Strata 13 and 14 not sampled in 2003. Stratum 63 not sampled in 1993. Stratum 14 not sampled in 2005.

	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
2000	0.344	0.198	0.491	1.357	0.725	1.989	0.254	8	28	37	37.5	43	47	34	740
2001	0.437	0.185	0.690	1.718	0.797	2.640	0.254	9	24	38	37.6	41	46	36	790
2002	0.723	0.140	1.307	2.655	0.603	4.708	0.272	8	29	38	38.3	42	47	34	913
2003	0.670	0.195	1.144	2.774	0.802	4.745	0.242	8	26	37	36.9	41	47	28	1029
2004	0.300	0.171	0.429	1.192	0.653	1.730	0.252	16	31	37	37.8	41	46	29	784
2005	0.189	0.090	0.289	0.716	0.357	1.076	0.264	12	30	38	38.2	43	45	19	281
2006	0.437	0.209	0.665	1.738	0.821	2.654	0.251	8	31	37	37.7	42	45	28	513

Table B2.21. Estimates of size at 50% maturity, length-weight parameters (Wigley et al 2003) and Von Bertalanffy Parameter estimates used to estimate SSB and to calculate Hoenig mortality estimates. Clearnose data, in parentheses, refers to diak width.

Species (Study)	L50	ln(a)	b	Linf	K	t0
Winter (Frisk 2004)	76	-13.1531	3.3199	122.1	0.07	-2.06
Little (Frisk 2004)	44	-12.4462	3.128	56.1	0.19	-1.17
Barndoor (Gedamke et al. 2005)	116	-13.3224	3.2919	166.3	0.14	-1.2912
Thorny (Sulikowski 2005, 2006)	88	-12.088	3.1197	124.0	0.12	-0.35
Smooth (Sosebee 2005)	50	-13.0139	3.1812			
Clearnose(Gelsleichter 1998; Sosebee 2005)	66	-13.8683	3.4235	94.3(61.8)	0.17	-0.88
Rosette (Sosebee 2005)	34	-12.5504	3.0718			

Table B2.22 Estimates of spawning stock biomass indices from NEFSC surveys using sizes at 50% maturity as knife-edge cutpoints.

	Winter	Little	Barndoor	Thorny	Smooth	Clearnose	Rosette
1963			0.796	3.934	0.202		
1964			0.227	2.799	0.091		
1965			0.135	2.848	0.297		
1966			0.000	4.673	0.218		
1967	0.553		0.063	1.411	0.126		0.022
1968	0.338		0.073	2.857	0.229		0.001
1969	0.183		0.000	3.668	0.190		0.002
1970	0.534		0.060	5.155	0.152		0.009
1971	0.151		0.047	3.921	0.134		0.002
1972	0.464		0.077	2.593	0.244		0.010
1973	0.892		0.000	2.987	0.189		0.001
1974	0.377		0.000	1.368	0.080		0.013
1975	0.327		0.000	1.344	0.039	0.003	0.005
1976	1.117		0.000	0.943	0.015	0.019	0.020
1977	1.863		0.000	1.450	0.201	0.076	0.015
1978	3.008		0.000	1.514	0.288	0.007	0.004
1979	3.400		0.000	1.569	0.112	0.073	0.009
1980	3.663		0.000	1.972	0.217	0.166	0.070
1981	3.513		0.000	1.312	0.079	0.016	0.070
1982	4.203	2.744	0.000	0.261	0.035	0.038	0.005
1983	7.598	4.058	0.000	1.065	0.073	0.006	0.001
1984	7.253	2.655	0.000	1.480	0.095	0.041	0.024
1985	8.514	4.184	0.000	1.077	0.169	0.069	0.003
1986	12.279	1.599	0.000	0.653	0.152	0.030	0.002
1987	7.768	2.168	0.000	0.209	0.062	0.085	0.021
1988	5.594	2.936	0.000	0.521	0.207	0.072	0.011
1989	3.753	2.832	0.000	0.709	0.073	0.028	0.002
1990	6.129	2.983	0.000	0.790	0.122	0.072	0.023
1991	3.499	2.854	0.000	0.734	0.116	0.341	0.003
1992	2.083	2.384	0.000	0.292	0.079	0.080	0.033
1993	1.012	3.875	0.134	0.700	0.146	0.110	0.018
1994	0.841	1.742	0.000	0.434	0.072	0.184	0.063
1995	0.536	1.706	0.000	0.189	0.081	0.097	0.033
1996	0.793	4.551	0.000	0.318	0.128	0.083	0.029
1997	0.664	1.601	0.052	0.333	0.167	0.269	0.009
1998	1.576	3.634	0.062	0.319	0.016	0.234	0.051
1999	1.331	5.078	0.118	0.145	0.062	0.442	0.055
2000	1.753	4.424	0.048	0.420	0.102	0.371	0.028
2001	1.397	4.783	0.250	0.066	0.226	0.376	0.129
2002	3.154	4.858	0.366	0.196	0.094	0.261	0.034
2003	1.912	4.401	0.161	0.233	0.106	0.353	0.032
2004	2.222	4.340	0.773	0.365	0.146	0.259	0.043
2005	1.005	2.455	0.285	0.047	0.082	0.253	0.057
2006		2.472					

Table B.2.23.

(EDITOR'S NOTE: BASED ON THE REVIEWER'S COMMENTS, THIS TABLE WAS NOT INCLUDED IN THIS REPORT. THE TABLE HAD ESTIMATES OF FISHING MORTALITY RATE.)

Table B3.1. Current estimates of biomass-based reference points for skates. The estimates for barndoor skate are an average of 1963-1966 biomass estimates.

	75^{th} percentile through 1998/1999	
	Bmsy	Bthreshold
Winter	6.46	3.23
Little	6.54	3.27
Barndoor	1.62	0.81
Thorny	4.41	2.20
Smooth	0.31	0.16
Clearnose	0.56	0.28
Rosette	0.029	0.015

Tables B.3.2 – B.3.24.

(EDITOR'S NOTE: BASED ON THE REVIEWER'S COMMENTS, THESE TABLES WERE NOT INCLUDED IN THIS REPORT. THE TABLES HAD CALCULATIONS FOR ALTERNATIVE REFERENCE POINTS.)

Table B4.1. Fishing mortality overfishing definition for skates based on the average coefficient of variation in the survey. The percentages are percent change from one three-year moving average to the next.

	Winter	Little	Barndoor	Thorny	Smooth	Clearnose	Rosette
	-20%	-20%	-30%	-20%	-30%	-30%	-60%
1992	-8.8	-7.6	-3.8	-17.6	-0.4	4.5	37.7
1993	-33.9	15.6	180.7	-1.1	6.7	5.6	-2.0
1994	-25.5	-12.6	2.0	-2.9	-13.0	0.9	110.9
1995	-21.0	-14.8	61.3	-4.3	13.8	-0.8	3.8
1996	6.2	0.4	-34.3	-21.4	-9.8	-3.6	16.4
1997	5.3	-6.5	37.3	-21.2	28.6	-19.1	-38.4
1998	26.3	35.0	-8.6	-5.5	-26.9	57.5	11.1
1999	33.2	13.5	109.2	-14.5	-24.2	28.8	22.5
2000	17.0	29.2	37.1	-0.9	-23.6	15.0	15.3
2001	1.0	-2.4	66.0	-16.1	102.3	15.4	47.1
2002	3.8	-13.9	42.5	-2.6	8.1	-4.4	-6.9
2003	-7.2	-9.6	16.5	-5.6	6.5	-10.5	0.2
2004	1.1	1.9	40.7	25.0	-12.4	-28.6	-35.4
2005	-22.9	-15.9	9.8	-11.2	3.7	-16.2	9.7
2006		-18.7					

Table B6.1. The size class, temporal, and spatial scheme for each species of skate analyzed for food habits and consumptive demand. S = small, I = immature, M = medium if small and large used; M = mature if immature used, L = large. All size class cutoffs are in cm. * small winter skates were combined with immature little skates to account for potential identification concerns.

	Barndoor Skate	Clearnose Skate	Little Skate	Rosette Skate	Smooth Skate	Thorny Skate	Winter Skate
SVSPP Code	022	024	026	025	027	028	023
Survey Strata Set	01010-01300, 01330-01400, 01351	03150-03440, 01610-01760	01010-01300, 01330-01400, 01351, 01610-01760, 03010-03660	01610-01760	01010-01300, 01330-01400, 01351	01010-01300, 01330-01400, 01351	01010-01300, 01330-01400, 01351, 01610-01760
Temporal Resolution	2000-2005, annual	1977-2005, 5 year block	1982-2005, annual	1999-2005, annual	1977-2005, 5 year block	1977-2005, 5 year block	1977-2005, annual
Size Class:							
S or I	< 80	> 60	< 30*	< 30	< 30	< 30	< 30*
M	> 80	< 60	> 30	> 30	> 30	30-60	30-60
L						> 60	> 60

Table B6.2. Diet composition of Winter Skate. All values are expressed as whole numbers rather than percentages. Relmsw = relative mean stomach weight, on average for the size class and time period given. AR = animal remains, a well-digested, highly unresolved category.

Average of relmsw

size	year	Ammodytes sp	AMPHIP	ANNELI	AR	Ocean Quahog	Bivlaves	Cancer Crabs	Cephalopods
L	1977	34.7883	1.1151	16.1104	1.8018	0	31.6042	2.8984	0
	1978	9.1416	0.3733	6.1801	0.3855	0	75.5169	1.1059	0.1892
	1979	73.7314	0.0606	4.4508	0.3653	0	2.4664	0.2792	7.8195
	1980	74.8072	0.4227	5.7829	0.33	0	0.2152	0.101	6.8373
	1981	0	0	30	0	0	30	0	0
	1982	91.2966	0.2233	1.7462	0	0	2.9283	0.0339	0
	1983	57.2636	0.557	6.7124	0	0	0.7889	0.0158	28.4001
	1984	38.6564	0.2036	9.6358	6.39	0	8.0751	0.3393	1.6964
	1985	26.1441	0.1519	14.5265	7.8159	0	19.3497	0	0
	1986	57.8759	0.161	8.1314	1.7104	0	6.6367	0.89008	0.174
	1987	68.9832	0.9335	4.538	0.3145	0	4.9612	0.1444	2.5226
	1988	14.1556	3.8149	18.2329	1.8148	0	18.681	2.9517	0.6408
	1989	57.8982	2.6138	10.5248	0.8638	0	6.5784	1.0156	2.5556
	1990	61.5874	1.0104	10.7318	0.7482	0	2.94998	0.3936	4.00574
	1991	9.7544	1.993	21.9212	4.0085	0	13.7766	6.0475	5.3519
	1992	1.4303	0.6805	10.9025	5.0016	0	28.1566	1.3148	6.5655
	1993	2.9578	0.9914	15.7606	2.4767	0	20.4295	1.1054	1.5599
	1994	0.3127	0.3522	11.5075	3.0172	0	15.7535	0.3412	0.1191
	1995	3.0589	4.3303	17.8107	2.9335	0	23.0905	0.3205	0.4261
	1996	10.2108	2.9927	17.9021	1.1398	0	17.0806	0.9197	0.6826
	1997	3.6859	2.5315	18.5626	5.28	0	23.1485	0.3195	2.2127
	1998	3.45	6.4344	11.8438	2.8744	0.1378	13.8658	0.55	1.5957
	1999	19.3976	1.4069	13.3698	1.4272	0	11.9809	0.5869	0.3011
	2000	14.5178	0.4276	6.8924	1.3873	0	11.1621	0.7002	1.5818
	2001	1.191	1.8195	14.4265	4.5131	0	16.3827	0.1874	3.1485
	2002	4.0646	0.737	26.908	5.499	0	5.4904	0.7994	3.8507
	2003	0.1559	0.3344	14.1453	4.4303	0	11.0987	1.9911	5.1759
	2004	0.1282	0.2008	5.4805	2.4003	0	2.8519	0.138	0.8424
	2005	2.1766	0.3827	18.8812	6.8834	0	8.089	3.1772	6.6144
L Total		25.61455172	1.284689655	12.88340345	2.614224138	0.004751724	14.93480276	0.98854069	3.271363448
M	1977	0	20.325	12.0142	0.28	0	1.0465	34.2272	0
	1978	0	11.6814	29.486	0.8055	0	35.7206	4.7204	0
	1979	0	16.7283	36.1091	0.4556	0	7.9411	4.7838	0.017
	1980	38.7963	8.5821	9.6549	0.9287	0	0.8476	1.5162	0.1771
	1982	15.4397	28.8344	10.4294	0	0	24.5399	8.998	0
	1983	0	39.2857	7.1429	20.0549	0	0	0	0
	1984	0	3.0879	93.3492	0	0	0	0	0
	1985	51.049	8.1185	18.4557	5.069	0	1.7341	0	0
	1986	51.3168	18.745	2.9367	1.7842	0	4.6162	1.767	0
	1987	7.7234	39.6367	12.3679	2.964	0	2.5606	1.1097	0
	1988	3.6755	38.7602	26.6014	3.9648	0	3.9932	0	0
	1989	8.3739	25.4202	19.6796	4.2656	6.2822	8.4461	0.6232	0
	1990	36.4389	29.3789	12.222	0.8788	0	0.29943	0	0.0163
	1991	2.1857	51.4331	18.6345	3.5268	0	0.7188	0.74025	0.5427
	1992	0.0469	34.4342	13.5198	5.7735	0	3.2513	0.1417	1.3798
	1993	0	33.1032	16.7179	5.5919	0	5.3766	2.1322	1.0174
	1994	0	41.543	14.5147	5.3447	0	8.654	2.7233	0.4492
	1995	0.1835	51.212	13.9893	8.889	0	4.1136	1.8596	0.9826
	1996	3.0931	36.3057	22.8254	4.1233	0	10.6487	0.5013	1.3918
	1997	5.0252	25.4724	20.8091	7.361	0	15.4438	0.7226	0.1474
	1998	1.5468	36.25	22.4302	7.4626	0	2.7811	5.5239	1.0114
	1999	2.9608	25.2697	25.3716	5.8763	0	7.7258	3.4833	0.3986
	2000	8.2531	22.7353	12.2333	10.8327	0	12.6313	1.4515	0
	2001	0	33.2962	13.5332	11.661	0	8.7183	0.5397	0.8191
	2002	0	24.8558	12.6022	21.1887	0	0.2428	1.0147	5.4117
	2003	0	45.38	11.7798	9.9764	0	5.4389	0.487	0.1534
	2004	0	22.1021	28.255	8.7639	0	2.16154	2.957	0.13625
	2005	0.3733	13.9579	12.1404	14.8442	0	7.6895	4.013	0.3297
M Total		8.445782143	28.06910357	19.63590714	6.166682143	0.224364286	6.690763214	3.072733929	0.513623214

size	year	CITARC	Herrings	CRAFAM	CRUSTA	DECAPO	Other Crabs	GADFAM	GADMOR	ISOPOD	MELAEG
L	1977	0	0	0.6408	0.1664	0.0506	0.4563	0.0647	0	1.473	0
	1978	0	0	0.26554	0.0127	0.00827	0.26951	2.4706	0	0.4958	0
	1979	0	0	0.1202	0.3049	0.0168	0.2862	0	0	0.387	0
	1980	0	0	0.0082	0.0925	0	0	0	0	0.1697	0
	1981	0	0	0	0	0	0	0	0	0	0
	1982	0	0	0	0	0	0	0	0	0.1837	0
	1983	0	0	0.0394	0	0	0	0	0	0.7479	0
	1984	0	0	0.8143	0.0679	0	9.6358	0	0	4.3768	0
	1985	0	0	0	3.6377	0	0.428	0	0	10.915	0
	1986	0	0	0.08453	0	0.03978	0.56562	0	0	0.6222	0
	1987	0	0	0.0845	0.5224	0	1.2535	0	0	0.2731	0
	1988	0	1.0391	0.1583	3.9573	0	1.9275	0	0	0.2154	0
	1989	0	0.6985	0.1909	0.2027	0.1755	0.0873	1.1847	0	1.8933	0
	1990	0	5.23715	0.05983	0.01749	0	0.08714	0	0	0.99164	0
	1991	0	7.6393	0.0879	0.6008	0	0.9731	0	0	0.5654	0
	1992	0	3.7958	1.1828	1.3869	0.0487	3.4787	0.1703	0	0.9135	0
	1993	0	3.9948	0.6027	0.0308	0	3.1099	2.2536	0	1.5385	0
	1994	0	6.111	0.5105	0	0	2.2163	0	0	2.0271	0
	1995	0.1202	0	1.0186	0.2019	0	1.3034	0	0	2.4347	0
	1996	0	1.7574	0.2543	0	0	2.5581	0	0	1.2198	0
	1997	0	0	1.2508	0.0062	0	0.5494	0	0	4.24	0
	1998	0	5.1224	0.8445	0.2941	0	1.0659	0	0	1.6781	0
	1999	0	23.3094	0.1833	0.00215	0.01791	0.24244	1.15164	0	1.5202	0
	2000	0	12.6656	0.1447	0.0111	0.003	0.1402	1.6967	0	1.9122	0
	2001	0	10.8217	0.276	0.2548	0	0.337	0	0	2.2309	0
	2002	0	9.3279	0.0904	0.5551	0	0.3932	0	0	0.3608	0
	2003	0.0786	0	1.1471	0.1441	0	3.4326	2.1839	0	0.5019	2.0966
	2004	0.0092	1.3161	0.1687	0.9406	0	0.1515	0.0733	0	2.607	0
	2005	0	2.6587	1.9086	0.0061	0	0.4223	0	0	3.1069	0
L Total		0.007172414	3.292925862	0.418531034	0.462642759	0.012433103	1.219686552	0.387911724	0	1.710397931	0.072296552
M	1977	0	0	6.0846	1.947	1.3594	7.4561	0	0	4.0231	0
	1978	0	0	6.9526	1.1978	0.0042	0	0	0	3.404	0
	1979	0	0	5.7755	3.2408	0	0.3236	0	0	10.914	0
	1980	0	0	25.9766	2.4302	0	1.1897	0	0.3994	1.3768	0
	1982	0	0	3.0675	0	0	0	0	0	8.0777	0
	1983	0	0	0	13.7363	0	8.79121	0	0	0	0
	1984	0	0	0	3.5629	0	0	0	0	0	0
	1985	0	0	0.95821	3.66462	0	0.22603	0	0	5.4765	0
	1986	0	0	0.497	3.5146	0	0.2783	0	0	0.8117	0
	1987	0	0	4.0476	0.5465	0	0.1165	0	0	8.9806	0
	1988	0	0	0.785	14.6442	0	1.8877	0	0	0.3517	0
	1989	0	0	3.807	2.6209	0.0754	1.0442	0	0	8.6089	0
	1990	0	0.22566	1.4562	5.3126	0	0.3284	0	0	5.94723	0
	1991	0.09126	0	2.60541	2.89256	1.1256	4.02683	0	0	3.9855	0
	1992	0	0	12.8109	9.4805	0	3.7615	0	0	6.2407	0
	1993	0.2539	0.0093	9.5566	1.4723	0	4.0628	0	0	10.257	0
	1994	0	0	10.3039	0.0281	0	3.5254	0	0	9.6467	0
	1995	0	0	4.5012	0.0974	0	2.5888	0	0	2.9405	0
	1996	0	0.3639	4.2009	0.4814	0	2.7452	0	0	8.0433	0
	1997	0.1492	0	4.73991	1.09615	0	2.44478	0	0	7.2351	0
	1998	0	1.5969	5.6768	0.1632	0	3.1289	0	0	4.8426	0
	1999	0	0	3.0559	0.3938	0	5.0842	0	0	6.624	0
	2000	0	0	2.56066	0.26953	0.04648	2.63823	0	0	5.5895	0
	2001	0	0	7.6341	0.9575	0.0385	2.4707	0	0	11.9913	0
	2002	0	6.0709	4.5835	2.8388	0	1.1708	0	0	2.0207	0
	2003	0	0	0.4552	1.7561	0	2.7126	2.3998	0	2.9394	0
	2004	0	0	4.4843	2.391	0.0409	0.3484	0	0	5.41112	0
	2005	0	0	26.3045	1.61	0	1.7668	0	0	5.4483	0
M Total		0.017655714	0.295237857	5.817199643	2.940955714	0.096088571	2.289917143	0.085707143	0.014264286	5.399569643	0

size	year	Silver Hake	MOLLUS	OPHFA2	OTHFIS	PAGFAM	Pandalid Shrim	PARDEN	PECFA1	PENFAM	SCOFAM	Red Hake
L	1977	0.0527	0.0015	0	2.6554	0	0.0258	0	0	0	0	0
	1978	0	0.01331	0	2.53288	0.13827	0.11665	0	1.88034	0	0	0
	1979	4.48973	0.03907	0	4.36516	0.22034	0.06912	0	0	0	0	0
	1980	0	0.0027	0	7.8622	0.1241	0.3675	0	0	0	0	0
	1981	0	0	0	30	0	0	0	0	0	0	0
	1982	0	0	0	3.4002	0	0.0037	0	0	0	0	0
	1983	0	0	0	3.2187	0	0	0	0	0	0	0
	1984	0	0.0679	0	11.5359	0	1.6286	0	0	0	0	0
	1985	7.0615	0.4211	0	8.107	1.2069	0	0	0	0	0	0
	1986	0.3978	0	0	19.0138	0	0.0373	0	1.4918	0	0	0
	1987	0	0	0	14.0074	0	0.1025	0	2.8792	0	0	0
	1988	0.052	7.2938	0	8.366	0.8209	0.9629	0	0.8659	0	0	0.4546
	1989	0.8776	4.7325	0	6.4005	0.084	0.0439	0	0	0	0	0
	1990	0.19601	2.4209	0	5.31306	0.42959	0.0246	0	0	0	1.57441	0
	1991	1.18257	4.96174	0	8.22955	0	0.16043	0	3.47122	0	0.4074	0
	1992	3.7666	5.5066	7.6631	11.5003	0.0308	0.5998	0	2.8496	0	1.4599	0.2628
	1993	6.3264	2.3966	5.5658	10.3281	0	5.1837	3.6339	0	0.1461	0	0.0792
	1994	4.0317	2.2	1.2833	18.7643	0	0.917	0	0	0	3.395	0.2089
	1995	0	2.3794	3.2138	6.0422	0	2.5312	0	0	0.0481	16.2276	1.9563
	1996	0	3.1095	10.5204	14.6408	0	0.64	0	0	0	0	4.22
	1997	0	0.2019	12.8603	19.0435	0	0.4899	0	0	0	0	0
	1998	0.7253	0.7816	20.8517	25.1586	0	0.0986	0	0	0	1.175	0.0326
	1999	1.6703	0.79762	4.06758	4.85029	0.00681	0.60143	0	0.07678	0.20474	3.5215	0.4351
	2000	14.2754	3.0854	7.4485	14.5717	0.0771	0.3435	0	0.234	0	3.9276	0.0424
	2001	0	4.8056	13.3988	9.3181	0	0.6114	0	0	0	2.7987	0
	2002	0	6.343	7.1694	15.4211	0	0	0	0	0	0	0
	2003	0.5241	2.5945	8.2898	24.7023	0	0.8976	0	0	0	0	11.3018
	2004	0.1717	2.2956	39.0076	18.6994	0	0.0357	0	0	0	2.2953	3.2049
	2005	0	0.716	3.3815	15.2547	0	0.1657	10.136	0	0.4711	0	7.7969
L Total		1.579358966	1.971304828	4.99039931	11.83803931	0.108234828	0.574432069	0.474824138	0.474097931	0.030001379	1.268358966	1.034327586
M	1977	0	0.0374	0	0.1514	7.7749	0.7639	0	0	0	0	0
	1978	0	1.3175	0	2.2291	0.4246	0	0	0	0	0	0
	1979	0	0	0	6.8909	1.099	1.6892	0	0	0	0	0
	1980	0	0	0	1.4296	3.8875	1.5318	0	0	0	0	0
	1982	0	0	0	0	0	0	0	0	0	0	0
	1983	0	0	0	0	2.1978	0	0	0	0	0	0
	1984	0	0	0	0	0	0	0	0	0	0	0
	1985	0	0.17786	0	0	2.84573	0	0	0	0	0	0
	1986	0	0	0	2.03753	0	0	0	4.50575	0	0	0
	1987	0	0.4594	0	18.3097	0.688	0.1997	0	0	0	0	0
	1988	0	1.3885	0	3.0459	0	0.0851	0	0	0	0	0
	1989	0.10965	5.52411	0	0	3.78832	0.31411	0	0	0	0	0
	1990	0	2.7858	0	0.8132	1.1968	0.2657	0	0	0	0	0
	1991	0.09561	0	0	5.29823	0	0.6104	0	0	0	0	0
	1992	1.8814	0.6017	0	0.32069	0	1.50877	0	0.63299	0	0	0
	1993	0	0.7154	0	1.2105	0	3.8077	0	0	0	0	0
	1994	0	0.1512	0	0.683	0	0.7089	0	0	0	0	0
	1995	0.27735	0.30902	0.38315	0.49529	0	1.75698	0	0	0	0	0.04291
	1996	0	0.0073	1.0536	1.6231	0.0042	0.591	0	0	0	0	0
	1997	0	1.09779	0	0.2202	0	0.31509	0	0	0	0	0.0098
	1998	0	0.52459	0	3.24879	0.00719	1.58384	0	0	0	0	0.14372
	1999	0	1.0655	0	1.9777	0.0189	0.8801	0	0	0	0	0
	2000	0	0.02912	0	8.9254	0.48245	0.23	0	0	0	0	0.353
	2001	0	2.2278	0.5204	0.8336	0	0.2875	0	0.1927	0	0	0
	2002	0	2.0063	0	7.3949	0.8673	0	0	0	0	0	0.0555
	2003	0	0	3.5591	10.9034	0	0.2302	0	0	0	0	0
	2004	5.10939	3.09708	0	8.07624	0	0	0	1.88025	0	0	0.545
	2005	1.4931	0.3621	0	3.4603	0.0995	0.0249	0	0.056	0.2488	0	0
M Total		0.320232143	0.8530525	0.197008929	3.199238214	0.906506786	0.620888929	0	0.259560357	0.008885714	0	0.041068929

Table B6.3. Diet composition of Little Skate. All values are expressed as whole numbers rather than percentages. Relmsw = relative mean stomach weight, on average for the size class and time period given. AR = animal remains, a well-digested, highly unresolved category.

Average of relmsw															
size	year	Amphipods	Polychaetes	AR	Bivalves	Cancer Crabs	Crangon sp	CRUSTA	CUMACE	DECAPO	DECCRA	EUPFAM	ISOPOD	MOLLUS	OTHFIS
I	1973	75.5229	2.6145	0.7776	0	0	12.5426	5.9489	0.4893	0.0743	0.1311	0	0.6094	0	0
	1974	53.8589	3.1152	0.935	0	1.7517	18.68	11.7976	0.583	0	0	0	8.6485	0	0.1002
	1975	54.1678	10.2228	7.8196	0	0.2554	11.422	5.9236	4.103	0	0.0203	0	0.4973	0	0
	1976	24.2307	25.9101	22.9743	0.7039	0.7202	16.1323	5.3765	0.2278	0	0.53184	0	1.7507	0	0.2362
	1977	41.9874	1.95485	4.4916	0	3.7224	25.39845	4.3551	0.79	0	1.3751	0	14.2902	0	0
	1978	55.4855	10.74415	0.86475	0.62585	1.6998	18.693225	7.3281	1.44435	0	0.1645	0	0.4064	0	0.54185
	1979	86.2462	5.5332	0.3966	0	0.28609	0.09753	2.23667	5.0802	0	0	0	0.1235	0	0
	1980	56.686	0	0.8306	0	0	0	27.3463	14.7633	0	0	0	0	0	0
	1981	44.8052	0	22.72725	0	0	0	0	0	0	9.0909	14.2857	9.0909	0	0
	1982	45	25	0	0	0	30	0	0	0	0	0	0	0	0
	1983	0	0	0	0	0	100	0	0	0	0	0	0	0	0
	1984	100	0	0	0	0	0	0	0	0	0	0	0	0	0
	1985	5.2239	9.82145	0	0	0	0	55.1706	0	0	0	7.4627	5.80355	0	0
	1986	36.6921	3.36755	14.76355	0	0	15.44555	0.0639	18.02575	0	0	0	9.11225	0	0
	1987	75.42415	4.01755	3.3418	0.27705	0.2078	9.6629	5.065625	0	0	0.42115	0	0.3536	0	0
	1988	41.7981	3.01725	45.7329	0.79575	0	0.26525	7.09764	0.132625	0	0	0	0	1.160475	0
	1989	69.5313	0.1075	10.99075	0.19225	0.15685	12.21955	0.60265	2.81055	0	0.39998	0	0.8918	0.0683	0.04555
	1990	57.2468	29.92905	7.48655	0	0.1127	0.3522	1.85965	0	0	2.49645	0	0.28175	0	0.0939
	1991	62.4026	12.981	7.07065	0.38935	0.19695	2.6245	5.5276	0	0.0513	2.1173	0	0.1848	0.31845	0
	1992	72.6229	3.66295	8.57995	0.1877	0.0135	5.51245	0.6556	0	0	2.7367	0.04505	4.71735	0.07505	0.27625
	1993	52.7453	4.86995	13.20905	0.6045	0.8602	4.796245	1.055905	0.0408	0	2.059955	0.48765	15.35385	0.20965	0
	1994	59.329	3.827	18.3083	0.0301	1.8747	7.7217	0.65875	0.11025	0	2.25465	0.34625	0.67505	0.0852	1.6716
	1995	62.12805	5.29875	24.73045	0.352	0.412785	2.442755	0.04215	0.05615	0	0.21945	0.15955	0.280695	0	0.015
	1996	70.7763	8.3752	8.37785	1.1566	1.27135	5.3172	0.27785	1.13205	0.0198	0.97177	0.6309	1.30595	0.001	0.0619
	1997	49.87355	2.78135	10.8209	0.1444	1.24885	7.1385	0.76745	0.08995	0	23.33145	0.0093	2.0098	0	0.29435
	1998	75.65775	5.09465	12.44975	0	0.3068	3.5149	0.48865	0.007	0	0.2997	0.18885	1.38965	0	0.0653
	1999	66.70955	2.77175	15.82975	0.3519	0.16225	12.3963	0.01545	0.3654	0	0.61735	0	0.1799	0	0.07615
	2000	49.3828	7.4174	24.16185	0.2473	5.74685	8.3829	0.03755	0.053	0.02615	2.31195	0.16345	1.04335	0	0.1741
	2001	58.5002	7.2223	15.5369	0.26325	0.4521	10.4683	2.24915	0.01145	0.0372	0.4235	0.0458	2.1261	0	1.6139
	2002	23.5909	2.8502	53.4331	0.01245	0.20765	2.10295	11.75655	0.16825	0.00622	0.029535	0.58135	2.2788	0	0.4974
	2003	72.2283	3.10175	12.40965	0	0.2098	2.6736	8.8459	0	0	0.2535	0.11365	0.08305	0	0
	2004	46.1465	5.5776	34.7175	0	0.4078	5.3635	1.5543	0.9756	0	0.3741	0.3286	0.614	2.9487	0
	2005	9.9833	17.14165	10.1226	0	0	54.585975	2.393575	0.1451	0	0	4.87785	0.1554	0.00035	0
I Total		52.89664737	7.082173684	13.32159649	0.209908772	0.721892281	11.3626093	5.137099298	1.350658772	0.006239298	1.828195088	1.037275439	2.741610351	0.119046491	0.196331579
M	1973	9.3509	11.1866	9.3192	1.0927	30.2959	5.0624	2.8476	0.0052	0	6.6	0	0.9781	0.3301	0.6085
	1974	17.1761	16.6309	11.2079	0.7992	9.0957	10.0717	10.4175	0.0116	0.967	2.1131	0.0101	3.5639	0.3726	3.8615
	1975	22.7124	24.7736	11.3597	0.9527	10.8911	3.4751	4.9181	0.0198	0.2287	0.2484	0	1.5095	0.5572	1.4375
	1976	23.8271	11.2718	11.4467	8.5691	10.4906	12.0797	1.8459	0.0096	0	2.1834	0.0162	1.908	0.4204	4.0829
	1977	18.6095	7.0788	10.1578	7.0674	22.2862	4.2996	10.46	0.0178	0.0876	1.9611	0.0009	1.5844	3.7551	1.0402
	1978	10.001	15.9678	3.0209	1.5317	47.1393	3.0385	3.8204	0.0325	0.4166	1.53	0.0436	2.3264	0.0106	1.2833
	1979	26.9768	16.1419	1.8496	0.4133	6.8783	2.0777	10.4186	1.3448	0.0505	26.7253	0	1.6915	0	0.2096
	1980	20.713	18.7392	0.135	1.741	14.084	5.6156	3.1105	0.0198	7.4051	0	0	3.6154	0	1.0279
	1981	9.0732	8.301	4.8347	17.2959	0	6.4789	2.8569	0	0	15.929	0.847	0.1145	0.407	2.0145
	1982	13.748	17.8538	3.8492	8.7706	6.0323	21.2072	0.6762	0.9551	0	12.6041	0	0	0	3.5956
	1983	9.3336	6.9919	1.9744	0	5.7238	32.9915	0	0	0	12.8901	0	0.2792	3.7294	1.0637
	1984	24.4972	11.8478	0.574	25.6166	11.7104	11.1507	0	0	0	7.3559	0	2.1957	0	0
	1985	9.8352	16.1631	4.0668	2.6404	6.8996	6.9006	10.2332	0	0	9.7657	7.5867	2.2999	0.2965	11.7444
	1986	13.0858	11.1112	8.516	18.7736	6.8075	3.8616	3.3019	0.0104	0.1001	13.2322	0.0138	2.8538	3.3389	2.1192
	1987	26.1142	9.2215	9.2875	21.7286	6.0334	2.142	1.5492	0	0	6.3482	0	2.342	0.029	6.0675
	1988	17.4612	10.621	4.5013	0.8196	6.7101	1.2756	8.8327	0	0.2653	25.8005	0.2995	0.5592	13.2704	2.3217
	1989	27.2409	9.1444	1.1104	1.8631	16.4164	9.3337	3.0275	0.0048	0.2675	10.9219	0.121	1.8548	2.9981	1.7967
	1990	36.0534	12.7152	1.8785	2.5035	11.4366	2.93893	7.38857	0.004	0.11182	7.67882	0.9669	2.0682	1.8294	2.582
	1991	30.1916	9.1244	5.126	7.8619	5.6822	4.9042	1.6128	0.0115	0.1392	15.3101	0.4885	1.022	8.4123	3.6377
	1992	30.5949	10.5714	17.6521	4.0907	4.3544	3.8668	0.8229	0.043	0.0621	16.4467	0.2173	2.8541	0.8338	1.0494
	1993	21.8877	9.5611	9.0973	11.6482	6.2901	8.9296	3.0068	0.013	0.3711	13.4677	0.037	4.6828	0.6338	2.0133
	1994	23.9723	6.3579	10.3234	10.0049	19.4798	3.0517	0.3075	0.0046	0.0104	19.0023	0.0434	1.1038	0.1833	1.8394
	1995	38.5002	13.2905	9.9274	6.5699	9.982	4.0476	0.0763	0.062	0	7.9769	0.8879	0.6827	0.2901	1.3379
	1996	21.6962	13.6588	7.5195	19.7085	11.2168	4.1527	0.2882	0.6391	0.0274	8.7263	0.4264	2.8277	0.1238	2.352
	1997	29.826	9.9631	11.0365	6.1268	4.22	9.2365	0.8049	0.0138	0.007	11.4907	0.1122	7.1647	0.0142	3.8194
	1998	20.8384	14.9168	12.5857	15.2282	7.43693	6.39932	0.29927	0.0108	0.00218	8.68967	0.3426	2.1366	2.6693	2.7892
	1999	27.6761	11.0634	11.1705	9.171	15.6743	3.6304	0.3067	0.006	0.1306	10.0349	0.1904	2.7536	0.2061	2.3035
	2000	49.5482	8.1924	5.4309	3.9251	9.0629	4.0032	0.4877	0.0041	0.0833	9.3371	0.1197	3.3216	0.104	1.7645
	2001	33.5795	12.0391	12.7589	5.821	5.7128	8.5728	0.4321	0.0745	0.5667	5.978	0.3053	2.6175	0.7551	4.5832
	2002	11.269	15.3683	17.7477	2.123	8.90261	5.05613	8.3787	0.0331	0.06293	6.17648	0.652	3.568	3.948	5.7482
	2003	18.39	10.9124	14.1008	15.0199	7.7451	4.90148	1.04514	0.0345	0	8.85857	0.2362	0.5602	0.0745	5.0066
	2004	33.1495	10.3471	15.4235	1.953	9.4717	4.3574	1.69	0.1804	1.2372	4.0855	2.8807	3.1308	1.3602	3.7031
	2005	12.8203	17.8528	15.2943	1.4071	13.4348	5.6494	7.2221	0.0891	0.022	8.2928	1.294	1.9324	0.6805	4.77939
M Total		22.41664848	12.39336364	8.311639394	7.358733333	11.13932242	6.81091697	3.40866303	0.110754545	0.382494848	9.629134545	0.549675758	2.184939394	1.564657576	2.835863333

Table B6.4. Diet composition of Barndoor Skate. All values are expressed as whole numbers rather than percentages. Relmsw = relative mean stomach weight, on average for the size class and time period given. AR = animal remains, a well-digested, highly unresolved category.

Average of relmsw																					
size	year	Amphipods	Polychaetes	AR	Cancer Crabs	Cephalopods	Gulf Stream Fl	Herrings	Sculpins	Crangon sp.	Misc. Crustace	Other Decapo	Other Crabs	Other Shrimp	Other Gadids	Haddock	Silver Hake	Other Fish	Pandalid Shrin	4-Spot Flound	Red Hake
I	2000	0.7427	0.2991	2.8809	22.6514	1.5297	0	0	0.8498	6.2149	2.0871	0.5099	18.3763	0	0	0	0	7.8522	35.3804	0	0
	2001	0.7133	0	5.9933	12.8295	0	0	0	0	13.36	1.951	0	37.7268	1.0691	0	0	0	4.0691	16.133	0	2.0516
	2002	0	0.4252	0	99.5748	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2003	2.0959	0	6.0816	19.9694	1.5536	3.1072	0	0	4.1445	8.0505	0	3.884	0	0	6.5251	0	8.2623	34.3112	0	0
	2004	6.8	0	6.6	0	0	0	0	0	0	86.6	0	0	0	0	0	0	0	0	0	0
	2005	1.8177	2.1368	17.3875	2.5964	7.8348	0	0	0	4.4682	0.4986	2.3742	14.9872	0	0	0	28.49	2.018	13.2241	0	0
I Total		2.028266667	0.47685	6.49055	26.27025	1.819683333	0.517866667	0	0.141633333	4.697933333	16.5312	0.480683333	12.49571667	0.178183333	0	1.087516667	4.748333333	3.700266667	16.50811667	0	0.341933333
M	2000	0	0	2.1777	42.2249	0	0	0	6.5494	0	2.3578	0	35.3696	0.6942	1.9648	0	0	4.5846	1.4409	0	0
	2001	0	0	2.6148	0	0.3486	0	13.0738	0	0.3051	0.3922	0	17.2138	0	0	0	19.1168	46.0198	0.9152	0	0
	2002	0	0	0.5464	0	0	0	76.5027	22.9508	0	0	0	0	0	0	0	0	0	0	0	0
	2003	0	0	0	0.6912	0	0.6912	0	0	0	0	0	14.1705	0	0	4.3779	0	31.682	1.7281	40.7834	0
	2005	0	0	0	0	0	0	0	0	0	0	0	10.5556	0	0	0	0	55.5556	33.8889	0	0
M Total		0	0	1.06778	8.58322	0.06972	0.13824	17.9153	5.90004	0.06102	0.55	0	15.4619	0.13884	0.39296	0.87558	3.82336	27.5684	7.59462	8.15668	0

Table B6.5. Diet composition of Thorny Skate. All values are expressed as whole numbers rather than percentages. Relmsw = relative mean stomach weight, on average for the size class and time period given. AR = animal remains, a well-digested, highly unresolved category.

Average of relmsw																					
size	yr5block	AMPHIP	Polychates	AR	CANFAM	Cephalopods	Herrings	COTFAM	CRUSTA	DECAPO	Other Crabs	DECSHR	Euphasiids	GADFAM	ISOPOD	Silver Hake	MYXFAM	Other Fish	PAGFAM	PANFAM	Eelpouts
L	1980	0.0045	6.8735	4.6104	0	25.8802	14.0075	1.4822	0.4429	0.2638	4.1529	0.0806	7.5955	0	0.051	0	0	18.1005	0.4854	2.7318	0
	1985	0.0025	12.1353	0	0	3.3438	19.0013	0	11.9558	0	2.8931	1.4711	6.5125	0	0.1042	0.1226	0	24.4413	0.7355	0.0245	0
	1990	0.1046	21.9766	2.2966	2.9578	1.5085	0	4.1685	2.4911	0.0605	1.6456	0.562	2.6139	0	0.1446	1.1174	18.0884	26.6331	1.0775	7.3239	1.6761
	1995	0.1301	18.4137	2.7967	0.621	5.7432	13.7189	1.0417	0.4895	0.0033	3.1396	2.0259	1.2446	0	0.1757	4.9213	4.7583	31.3286	0.058	2.825	0.9996
	2000	0.0022	17.6495	3.9802	8.7956	9.3973	5.5025	0	0.6662	0	1.0237	0.8359	2.7579	4.1981	0.097	4.0945	1.1167	26.2667	0.0323	3.3883	0.089
	2005	0.057	15.492	4.4218	2.2763	0.738	7.967	0.1294	2.8677	0	4.8401	1.3736	0.7067	0	0.1337	4.6365	5.7187	34.3856	0	4.7184	5.511
L Total		0.05015	15.42343333	3.017616667	2.441783333	7.7685	10.03286667	1.136966667	3.1522	0.0546	2.949166667	1.058183333	3.57185	0.699683333	0.1177	2.48205	4.947016667	26.8593	0.398116667	3.501983333	1.379283333
M	1980	2.9141	31.5092	3.9862	0.0198	20.2259	0	0	4.815	0	0.1237	8.3622	21.6269	0	0.0934	0	0	0.079	0.5478	2.1649	0
	1985	3.753	45.8674	4.899	0	3.4379	0	0	30.3753	0	0	0	6.9403	0	2.1773	0	0	1.2892	0	0	0
	1990	3.1013	48.021	7.3477	0	3.7721	0	0.4541	5.6863	1.3622	0.9415	2.1101	7.3214	0	0.8013	3.2053	0.2003	7.4659	0.1669	1.3868	0.0267
	1995	5.6257	47.7582	7.5481	0.0282	8.431	0.3173	0.3172	1.41974	0	4.57394	2.75967	2.9876	0.02256	2.3586	1.00584	0.2714	3.5945	0.01974	7.3759	1.4439
	2000	3.983	39.7988	11.3891	1.7119	2.4382	2.8684	1.5803	1.6588	0	8.0853	0.7252	3.7284	0	0.9931	0	0	1.6316	0	8.5634	1.3476
	2005	1.8674	30.532	15.1764	1.7059	5.0556	0	0	9.5489	0.0415	8.3613	6.439	2.8705	0	0.84	0	1.6612	5.9285	0	7.4606	0.0831
M Total		3.54075	40.5811	8.391083333	0.577633333	7.226783333	0.53095	0.391933333	8.91734	0.23395	3.680956667	3.399361667	7.579183333	0.00376	1.210616667	0.701856667	0.355483333	3.33145	0.122406667	4.491933333	0.48355
S	1980	21.8678	38.5983	19.375	0.2323	2.8162	0	0	5.6664	0.01936	0	0	1.3162	0	1.8194	0	0	0	0.37743	0	0
	1985	7.1084	51.4458	0.7229	0	0	0	0	0.9639	0	0	0	29.1165	0	7.6305	0	0	0	0	0	0
	1990	13.9988	37.7039	15.6824	0	4.5051	0	0	5.7283	0	6.0819	0	3.3789	0	3.8519	0	0	3.1761	0	0.6758	0
	1995	26.1389	29.1592	21.9225	0	1.3807	0	0	2.5174	0	1.0872	0	5.6218	0	4.0207	0	0	3.0276	0	1.4438	0
	2000	38.4094	24.136	14.7403	0	0	0	0	0.4074	1.52775	0.45833	0.6493	3.8381	0	4.4152	0	0	0	0	2.64811	0.1731
	2005	12.9264	21.8365	27.2561	0	0	0	0	15.0627	0	0.109	0	13.3842	0	1.7657	0	0	0.218	0	4.52316	0
S Total		20.07495	33.81328333	16.61653333	0.038716667	1.450333333	0	0	5.057683333	0.257851667	1.289405	0.108216667	9.442616667	0	3.917233333	0	0	1.070283333	0.062905	1.548478333	0.02885

Table B6.6. Diet composition of Smooth Skate. All values are expressed as whole numbers rather than percentages. Relmsw = relative mean stomach weight, on average for the size class and time period given. AR = animal remains, a well-digested, highly unresolved category.

Average of relmsw																
size	yr5block	AMPHIP	ANNELI	AR	Cancer Crabs	Crangon sp.	Misc. Crustace	Other Decapo	Other Crabs	Decapod Shrin	Euphasiids	GADFAM	MERBIL	MYSIDA	Pandalid Shrin	OTHFIS
	1980															
I	1985	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0
	1990	25.5072	0	17.3913	0	0	11.014	0	0	0	38.8406	0	0	5.7971	0	0
	1995	0	0	14.9425	0	0	21.7241	17.2414	0	0	0	40.3448	0	5.7471	0	0
	2000	33.7185	2.395	38.1688	0	3.7815	4.2017	0	0	0	6.8277	0	0	2.1008	5.8298	0
	2005	9.9932	2.435	44.1366	0	1.2784	19.298	0	1.8263	5.4788	7.0768	0	0	2.1306	4.8853	0
I Total		13.84378	0.966	22.92784	0	1.01198	11.24756	3.44828	0.36526	1.09576	30.54902	8.06896	0	3.15512	2.14302	0
M	1980	0	0	0.974	3.8277	9.2047	7.288	16.192	0	16.6234	0	0	0	0.1065	42.4603	0.0572
	1985	1.0017	11.5192	10.0167	0	4.0067	4.5075	0	0	0	34.5576	0	0	0	30.384	4.0067
	1990	1.3291	0.217	9.1141	0	1.9169	9.8085	0.2713	1.4955	3.0923	49.0786	0.7053	2.4955	0	4.8102	11.8357
	1995	0.3283	1.4304	6.8296	0	0.4072	13.2809	0	2.794	1.5244	7.963	0	22.8866	0.0693	26.0084	8.634
	2000	2.2124	0.6341	10.6603	2.4559	3.1884	3.1664	0	8.62	3.2415	5.4317	0	11.5312	0.2531	34.2183	4.923
	2005	1.3192	1.5846	13.3123	2.3746	1.9784	27.6493	0.0916	2.6112	3.7497	5.5229	0.0458	1.0535	0.3893	26.5792	5.5011
M Total		1.031783333	2.564216667	8.4845	1.443033333	3.450383333	10.9501	2.75915	2.586783333	4.705216667	17.0923	0.125183333	6.3278	0.136366667	27.41006667	5.826283333

Table B6.7. Diet composition of Clearnose Skate. All values are expressed as whole numbers rather than percentages. Relmsw = relative mean stomach weight, on average for the size class and time period given. AR = animal remains, a well-digested, highly unresolved category.

Average of relmsw		analcat												
size	yr5block	AMMFAM	ANNELI	AR	BIVALV	Cancer Crabs	Cephalopods	Misc. Crustace	DECAPO	Other Crabs	OPHFA2	Other Fish	SERFA2	SOLFAM
I	1980	0	0.497	1.7597	0.3006	30.6196	3.2767	0.2182	2.0069	34.9254	0	12.5642	0	0
	1985	0.80335	1.06525	2.02465	1.0842	22.74435	1.63835	8.00895	1.00345	33.2557	0	11.34335	0	0
	1990	1.6067	1.6335	2.2896	1.8678	14.8691	0	15.7997	0	31.586	0	10.1225	0	0
	1995	0	5.0256	0.6391	0	32.2353	0	12.5359	0	2.2386	33.5783	1.8737	6.0441	0
	2000	0	5.8414	5.973	4.1183	9.3624	6.3996	5.5937	0.1422	32.9217	0.7901	12.5543	0.2844	0
	2005	0	0	0	5.5127	14.8842	23.1533	0.3308	0	18.7431	4.9614	13.5612	0	0
I Total		0.32134	2.5995	2.13228	2.35988	20.39412	6.56592	6.89566	0.42982	24.08296	7.86596	10.13518	1.2657	0
M	1980	0	0	0	0	0	0	0	0	0	0	100	0	0
	1985	0	0	0	16.667	33.3333	0	0	0	0	0	50	0	0
	1990	5.9811	0.2723	0	0	27.3371	3.104	3.7212	0	26.9831	10.8913	7.5876	0	0
	1995	0	0.4189	0.3491	0	13.5727	0	0	0	9.6008	5.1204	66.7183	0	0
	2000	0.9146	0.3593	0.4717	0.7186	6.2759	0	0.8493	0	21.273	16.332	35.1313	1.5056	3.6487
	2005	0	0.6081	0.827	1.4975	15.4281	55.3925	0.2737	0	8.1955	0	5.4731	0	0.608116667
M Total		1.149283333	0.276433333	0.274633333	3.147183333	15.99118333	9.749416667	0.807366667	0	11.00873333	5.390616667	44.15171667	0.250933333	0.3317

Table B6.8. Diet composition of Rosette Skate. All values are expressed as whole numbers rather than percentages. Relmsw = relative mean stomach weight, on average for the size class and time period given. AR = animal remains, a well-digested, highly unresolved category.

Average of relmsw																
size	year	Amphipods	Polychates	AR	Cancer Crabs	Cephalopods	Crangon sp.	CRUSTA	DECAPO	DECCRA	EUPFAM	ISOPOD	MYSIDA	OPHFA2	OTHFIS	Pandalid Shrir
I	1999	39	0	25	0	0	36	0	0	0	0	0	0	0	0	0
	2000	7.5949	68.3544	3.7975	0	0	0	0	0	0	7.5949	0	0	0	12.6582	0
	2001	20.5231	14.3538	32.3077	0.5077	0	1.5385	0	0	9.2308	10	0	0	0	0	0
	2002	41.6667	0	55.5556	0	0	2.7778	0	0	0	0	0	0	0	0	0
	2003	1.476	0	15.4982	0	0	0	0	0	0	3.69	9.2251	70.1107	0	0	0
	2004	27.4396	4.8352	19.3407	16.4396	15.956	15.3846	0	0	0	0.6044	0	0	0	0	0
	2005	33.3333	33.3333	0	0	33.3333	0	0	0	0	0	0	0	0	0	0
I Total		24.43337143	17.2681	21.64281429	2.421042857	7.041328571	7.957271429	0	0	1.318685714	3.127042857	1.317871429	10.01581429	0	1.808314286	0
M	1999	4.9591	2.7248	16.1035	0	6.812	28.0109	6.1308	0	6.485	10.8992	0	0	1.7166	2.0436	13.5695
	2000	10.8001	19.2824	5.781	3.6232	2.4155	2.8986	0.3019	1.4493	41.3225	3.1099	2.5403	0.0141	0.6341	4.1969	1.3285
	2001	3.8652	11.6428	34.2567	7.7999	1.8569	3.8175	4.1822	1.1543	4.5416	5.2278	8.2474	3.3291	2.5227	1.0874	1.2045
	2002	1.2109	35.4328	19.8984	10.6054	4.3681	0.9143	0.8127	0	2.7631	1.0402	1.2475	1.796	7.3141	4.1447	6.1764
	2003	3.9116	2.5885	26.1675	7.7745	0	7.6681	2.9048	0	30.7168	5.3685	8.5319	0	0	3.0903	0.6692
	2004	10.1379	6.0664	19.3729	8.6131	2.7056	2.2766	4.6414	0	36.5099	1.3206	0.2416	0.51	1.3206	2.3218	3.8651
	2005	12.5	11.8532	18.8578	0.4212	8.7244	19.3542	0.4091	0	1.1211	3.3895	1.8051	0.0722	12.6354	0.0722	2.4067
M Total		6.769257143	12.7987	20.06254286	5.548185714	3.840357143	9.277171429	2.768985714	0.371942857	17.63714286	4.336528571	3.230542857	0.817342857	3.734785714	2.422414286	4.174271429

Table B6.9. Comparison of total skate consumptive removal of major skate prey relative to standing biomass and production estimates of those prey (from Link et al. 2006); these estimates are integrated across the entire ecosystem for the period 1996-2000. All values are in MT. C = consumptive removal of the prey by skates, as averaged during the period 2000-2006; B = biomass, P = production.

	C	B	P
Polychaetes	3.23×10^4	4.30×10^6	1.08×10^7
Molluscs	3.24×10^4	2.80×10^6	9.27×10^6
Cephalopods	5.91×10^3	3.13×10^5	3.03×10^5
Herrings & Mackerel	5.09×10^3	2.04×10^6	7.55×10^5
Euphasiids and similar crustaceans	2.12×10^3	1.89×10^6	2.69×10^7

Table B6.10. Comparison of fishery landings of major skate prey with total skate consumptive removal of major commercially targeted skate prey across different assumed gear efficiencies used to estimate skate abundance. All values represent an average from 2000-2005 and are in MT. The C/L ratio contrasts the consumption to the fishery landings as a unitless scalar; values > 1 indicate more of the prey is consumed by skates than is removed by the fishery..

	Fishery Landings	100% Efficiency	50%	25%	10%
Illex and Loligo	2.53×10^4	5.91×10^3	1.18×10^4	2.36×10^4	5.91×10^4
C/L ratio	-	0.23	0.47	0.93	2.33
Silver Hake	9.37×10^3	2.15×10^3	4.30×10^3	8.59×10^3	2.15×10^4
C/L ratio	-	0.23	0.46	0.92	2.29
Red Hake	9.95×10^2	1.15×10^3	2.29×10^3	4.58×10^3	1.15×10^4
C/L ratio	-	1.15	2.30	4.60	11.51
Herrings	1.16×10^5	5.09×10^3	1.02×10^4	2.04×10^4	5.09×10^4
C/L ratio	-	0.04	0.09	0.18	0.44

SKATE FIGURES

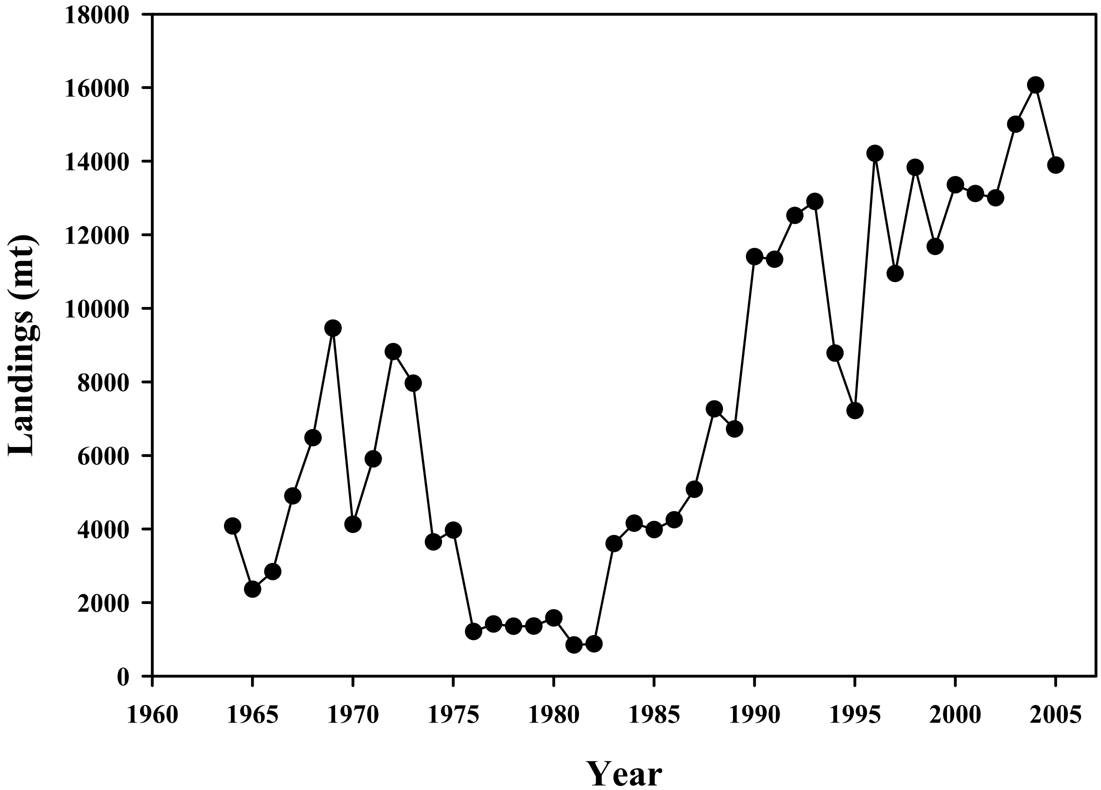


Figure B1.1. Total landings of skates in NAFO subareas 5 and 6.

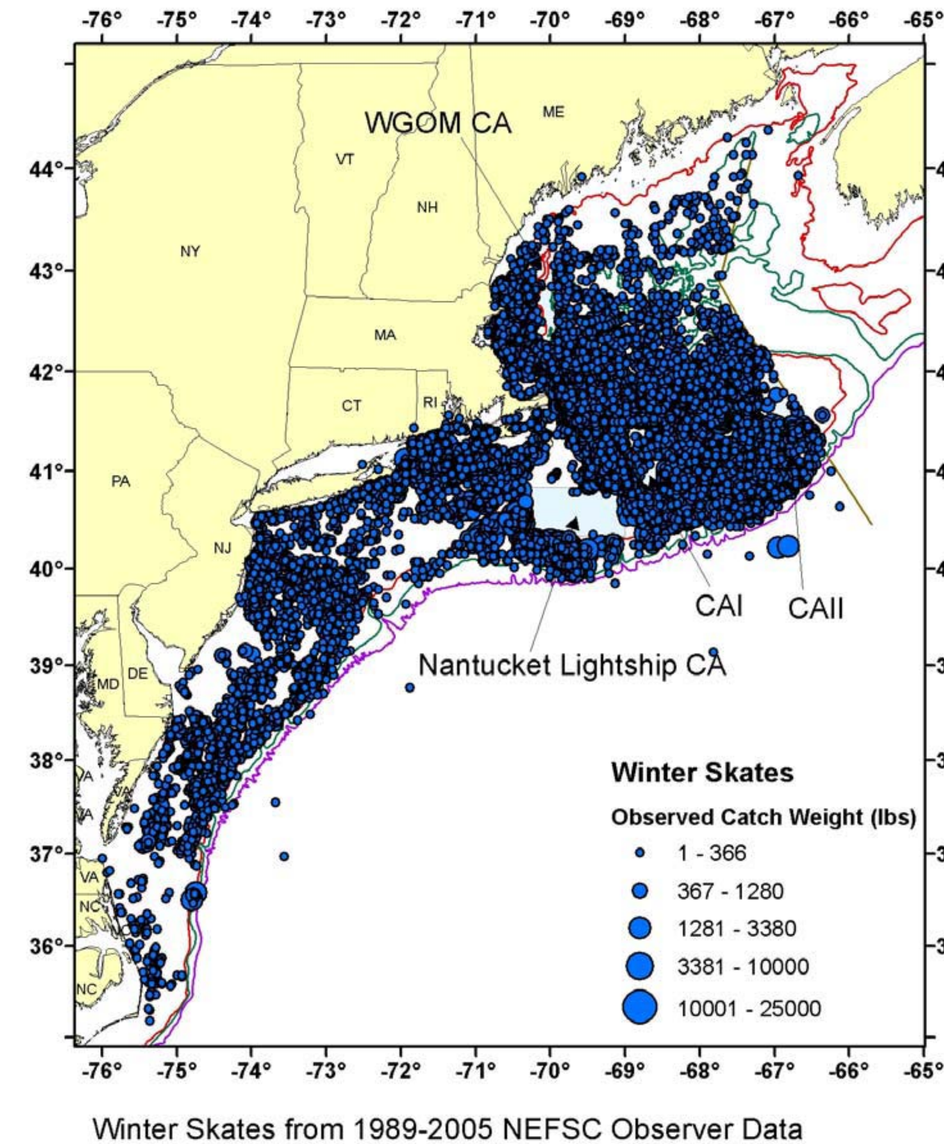


Figure B1.2. Distribution of winter skates from the Observer Program, 1989-2005.

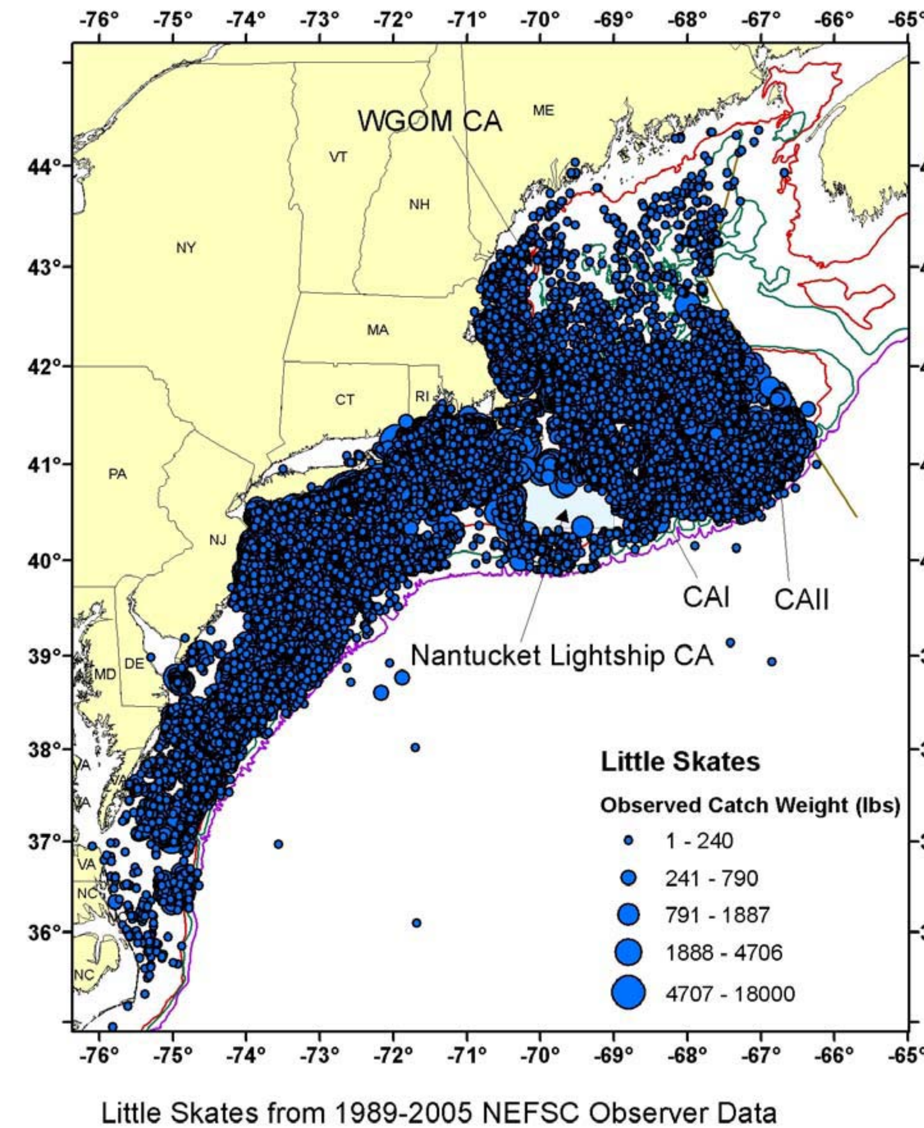


Figure B1.3. Distribution of little skates from the Observer Program, 1989-2005.

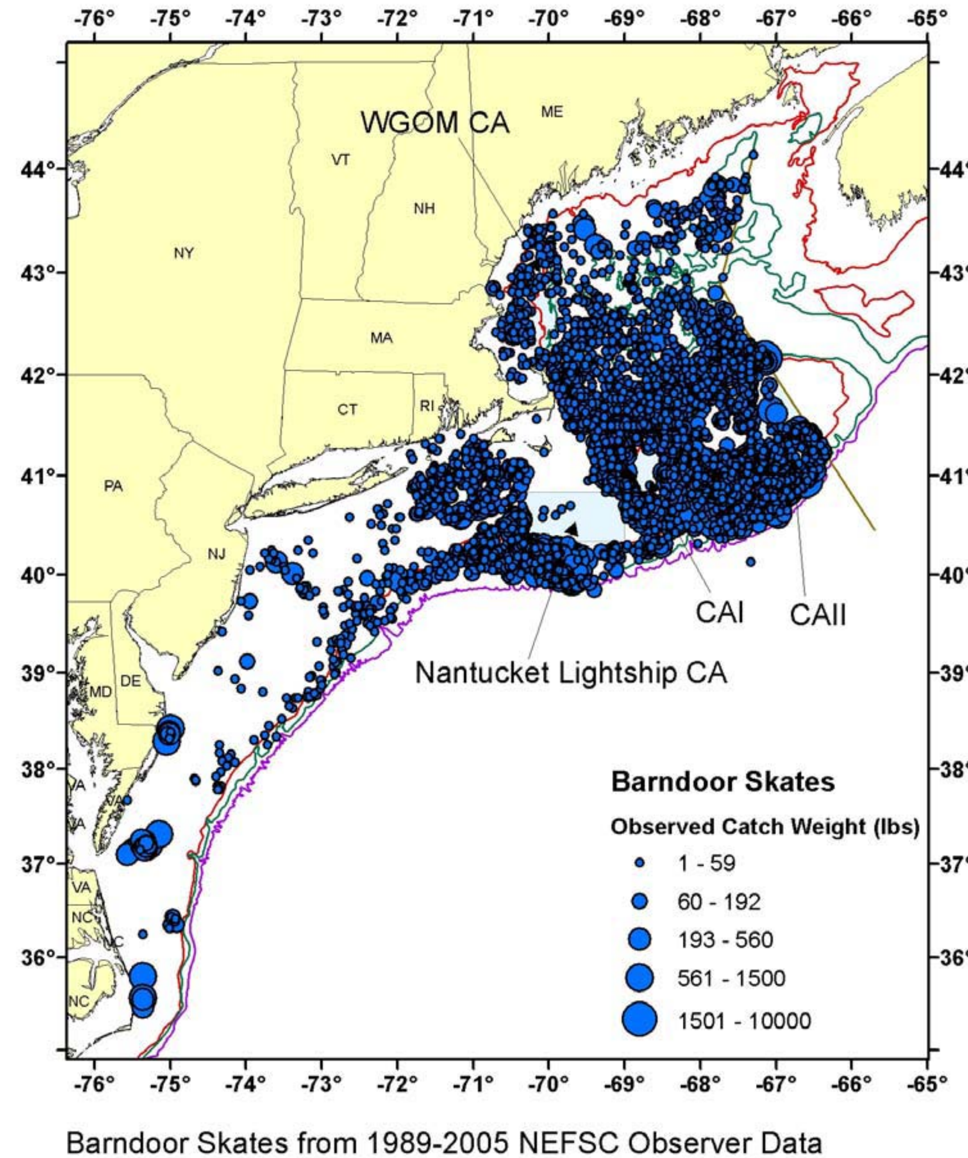


Figure B1.4. Distribution of barndoor skates from the Observer Program, 1989-2005.

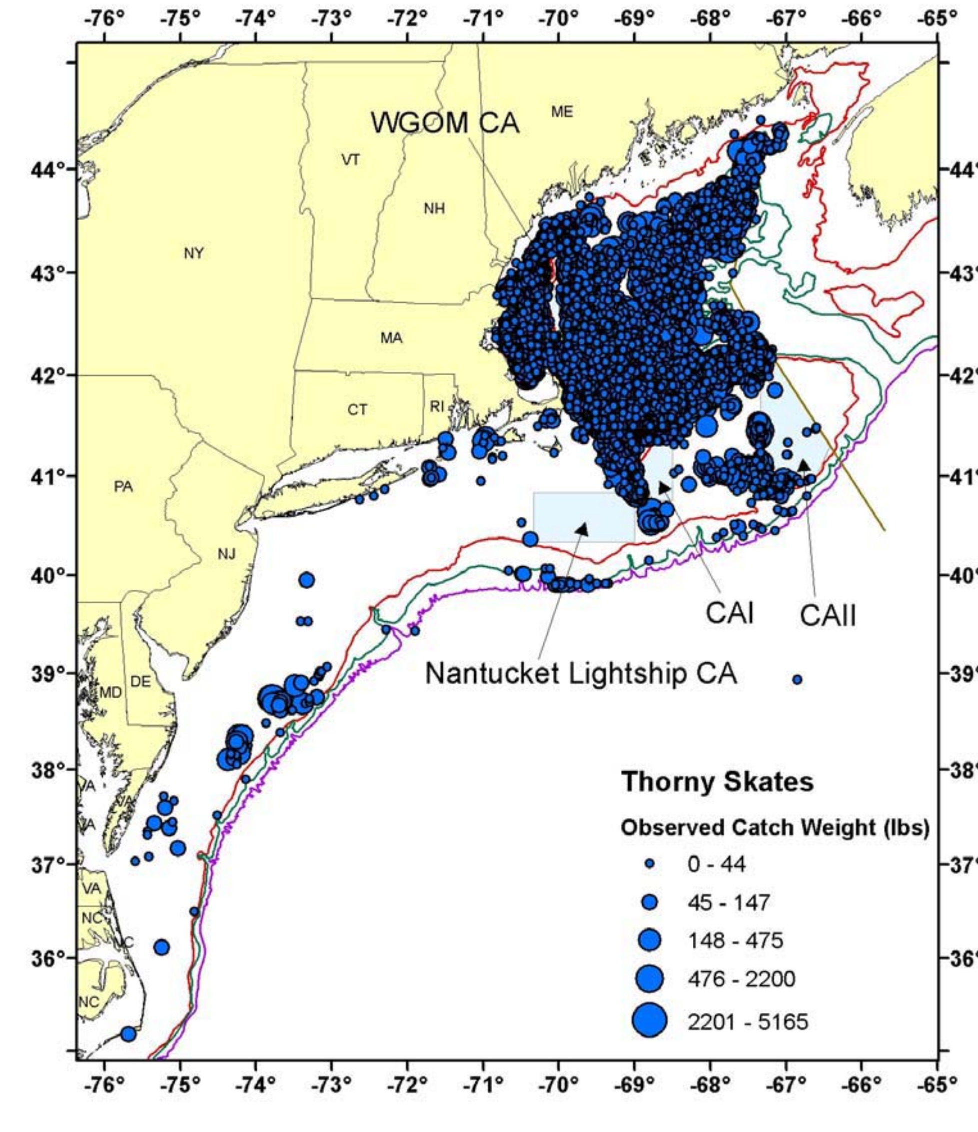


Figure B1.5. Distribution of thorny skates from the Observer Program, 1989-2005.

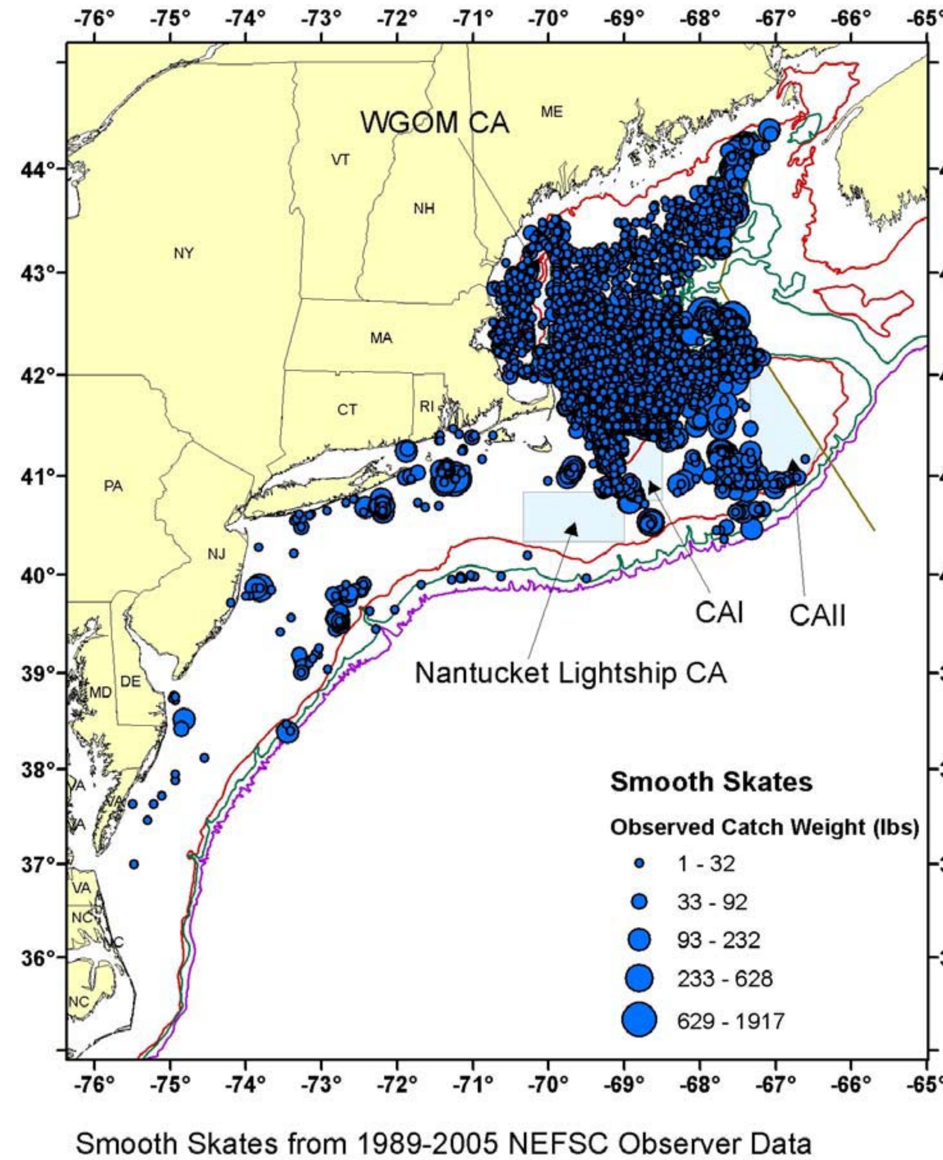


Figure B1.6. Distribution of smooth skates from the Observer Program, 1989-2005.

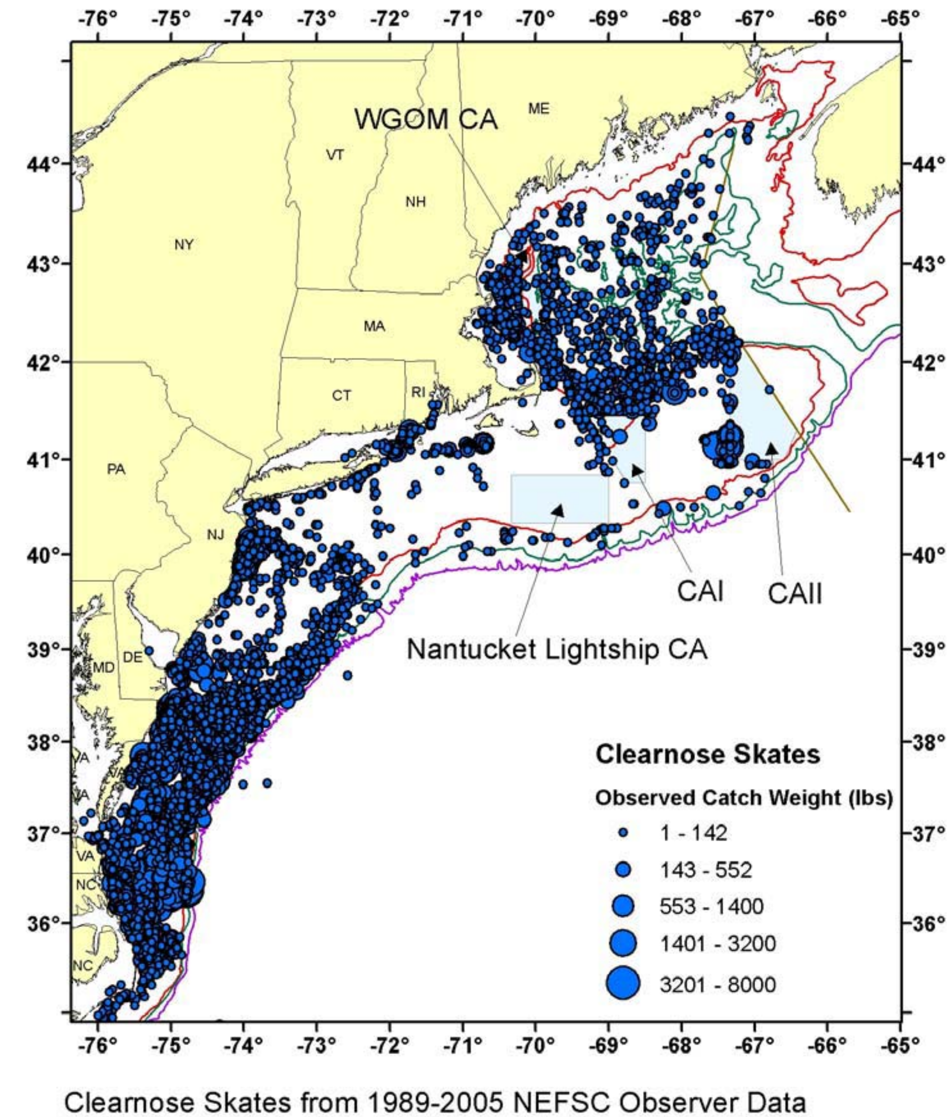


Figure B1.7. Distribution of clearnose skates from the Observer Program, 1989-2005.

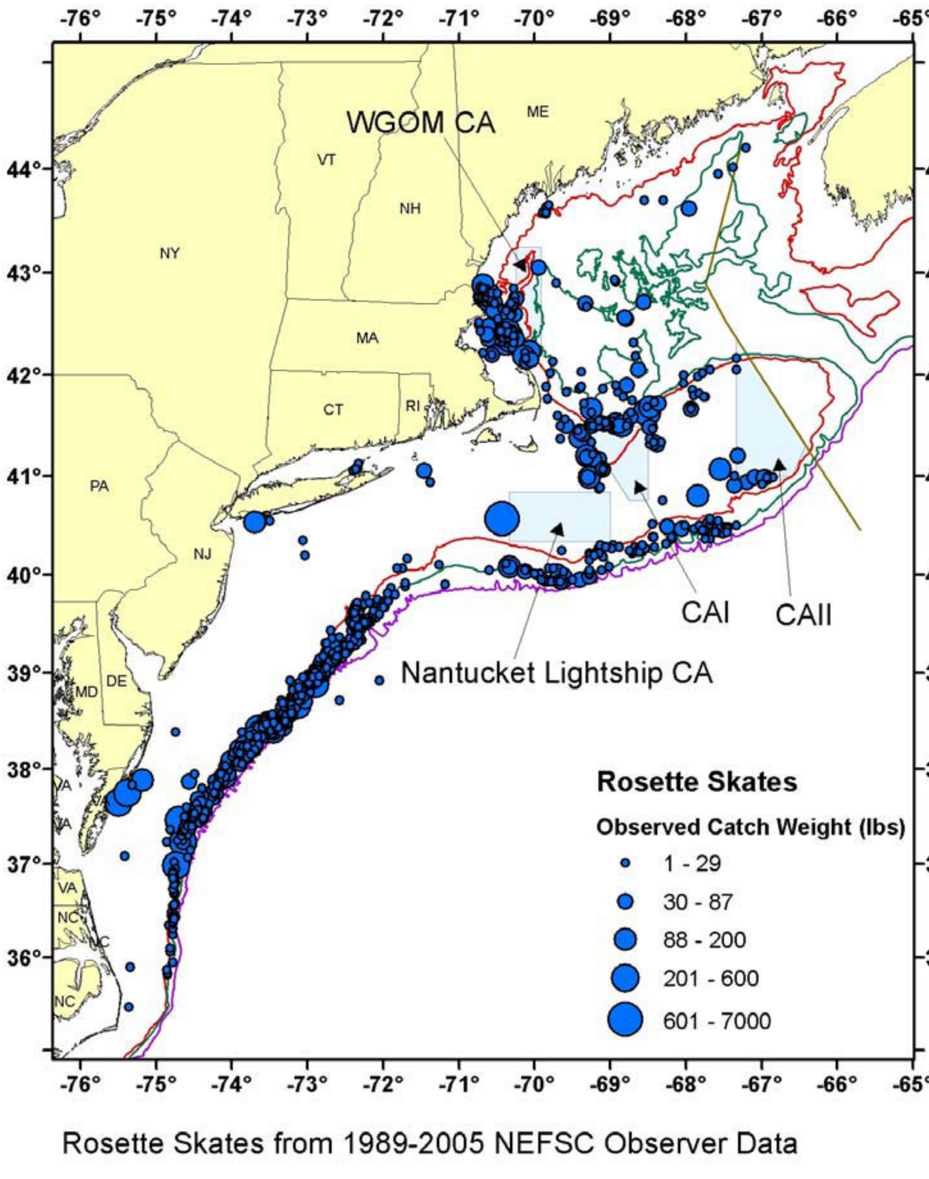


Figure B1.8. Distribution of rosette skates from the Observer Program, 1989-2005.

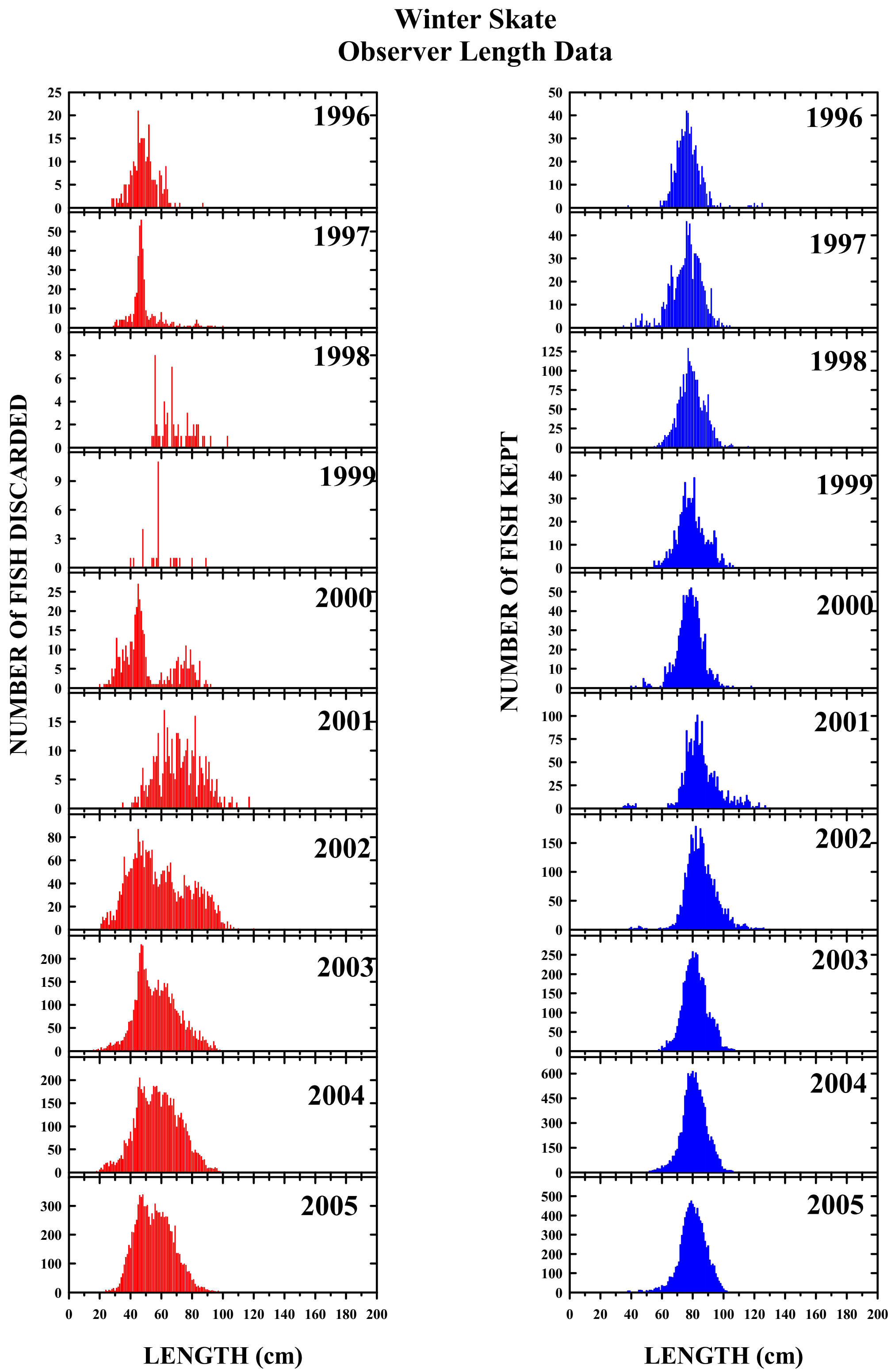


Figure B1.9. Winter skate length composition from the NEFSC observer program 1996-2005.

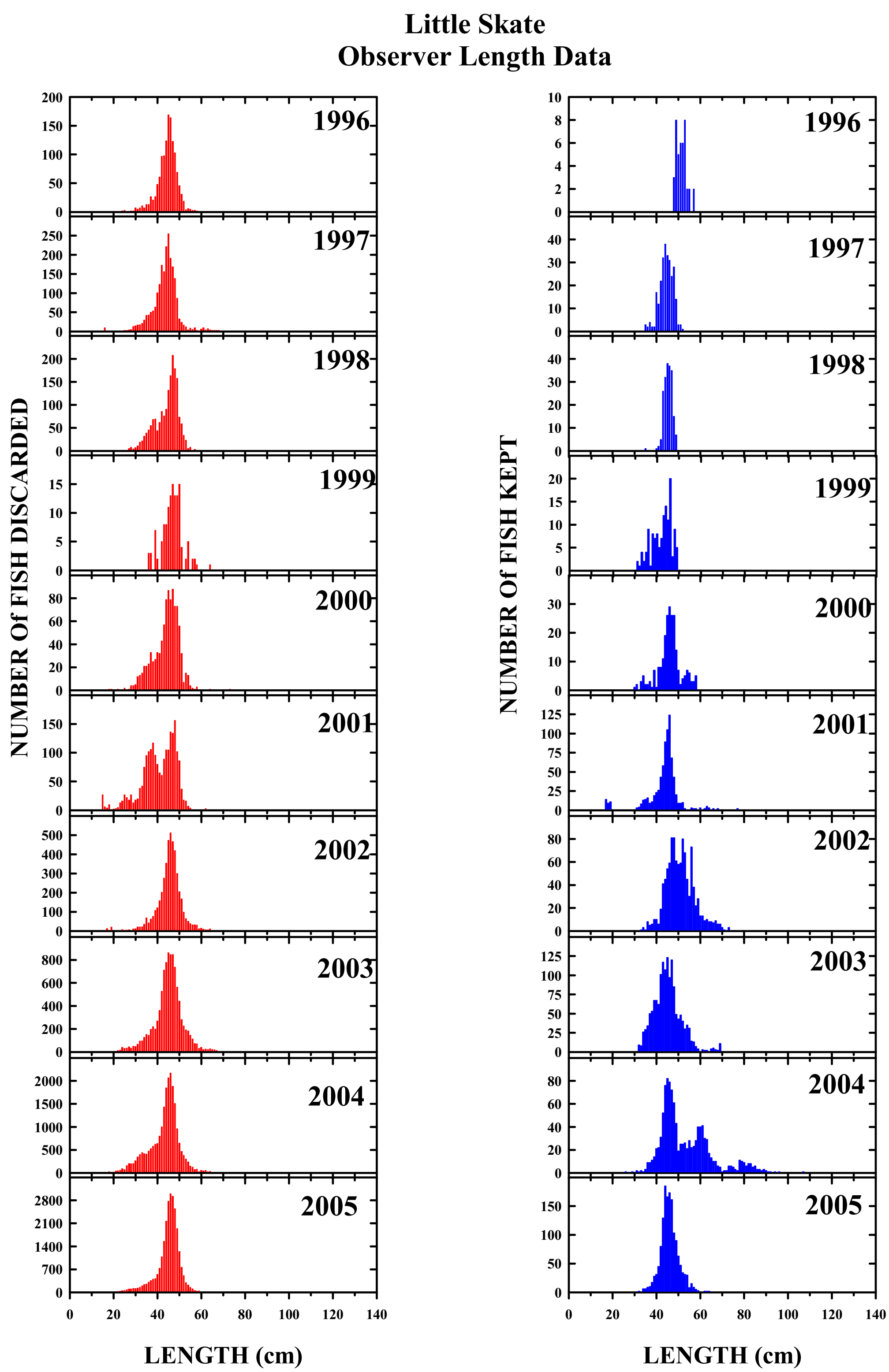


Figure B1.10. Little skate length composition from the NEFSC observer program 1996-2005.

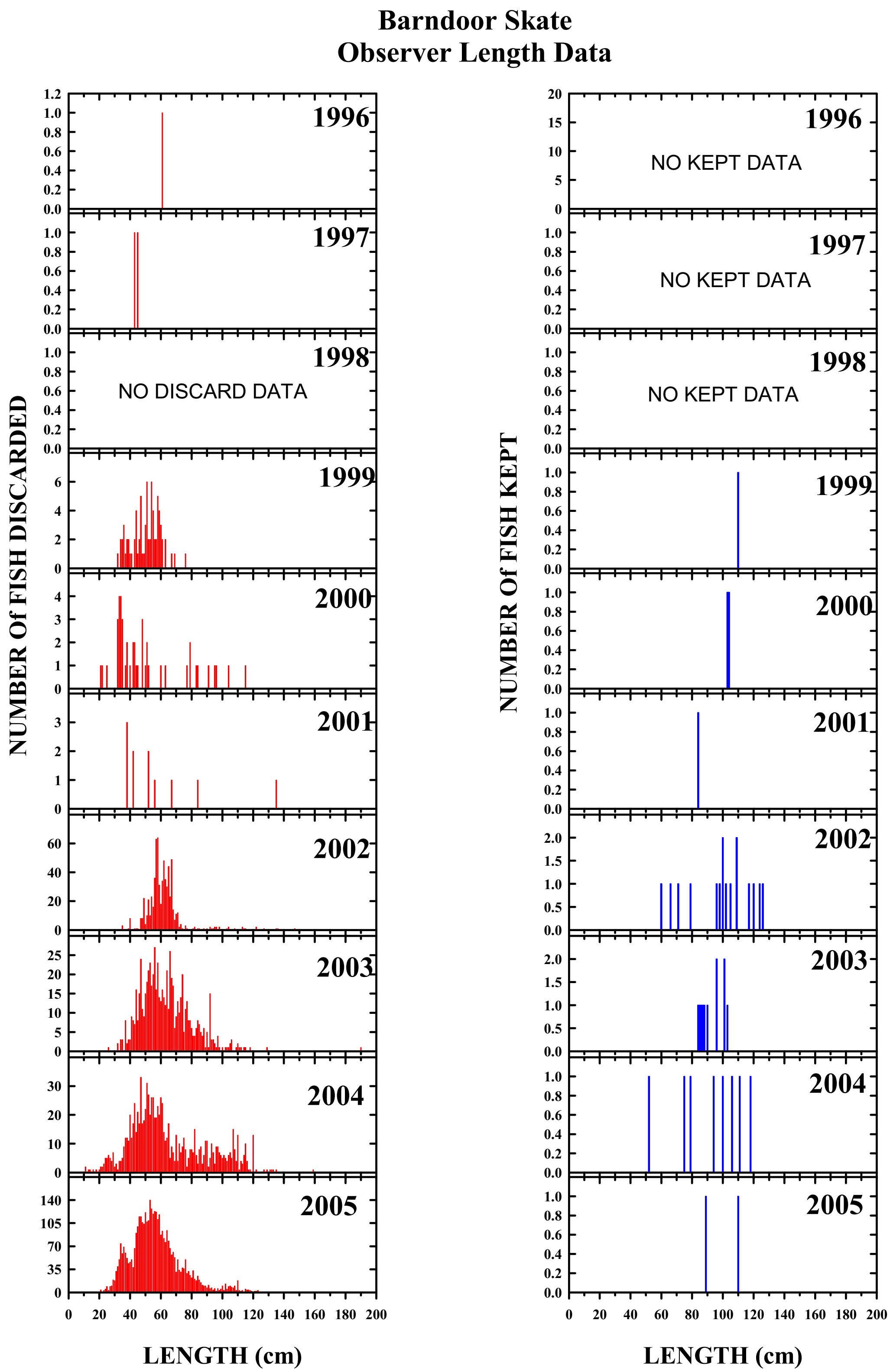


Figure B1.11. Barndoor skate length composition from the NEFSC observer program 1996-2005.

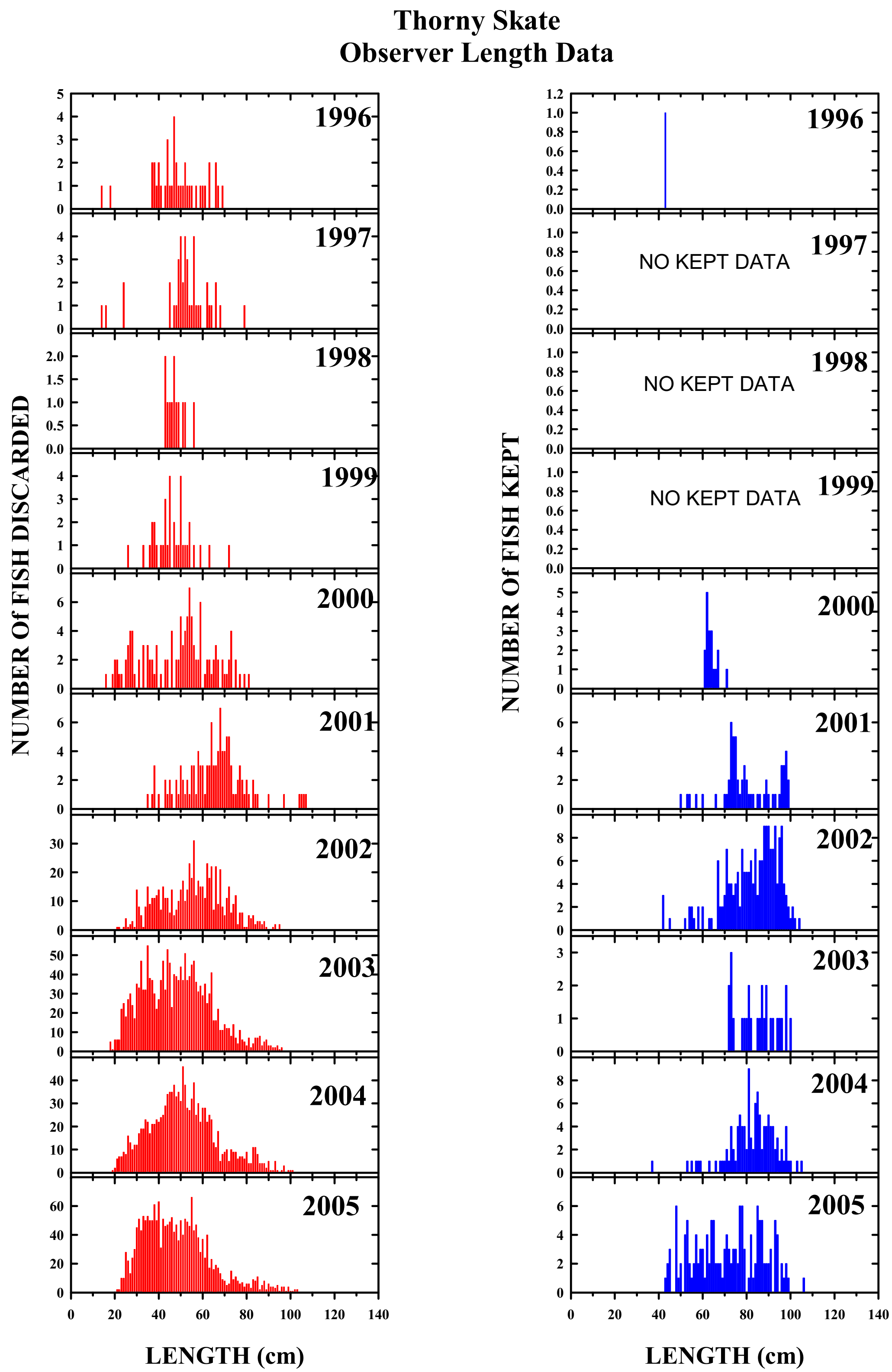


Figure B1.12. Thorny skate length composition from the NEFSC observer program 1996-2005.

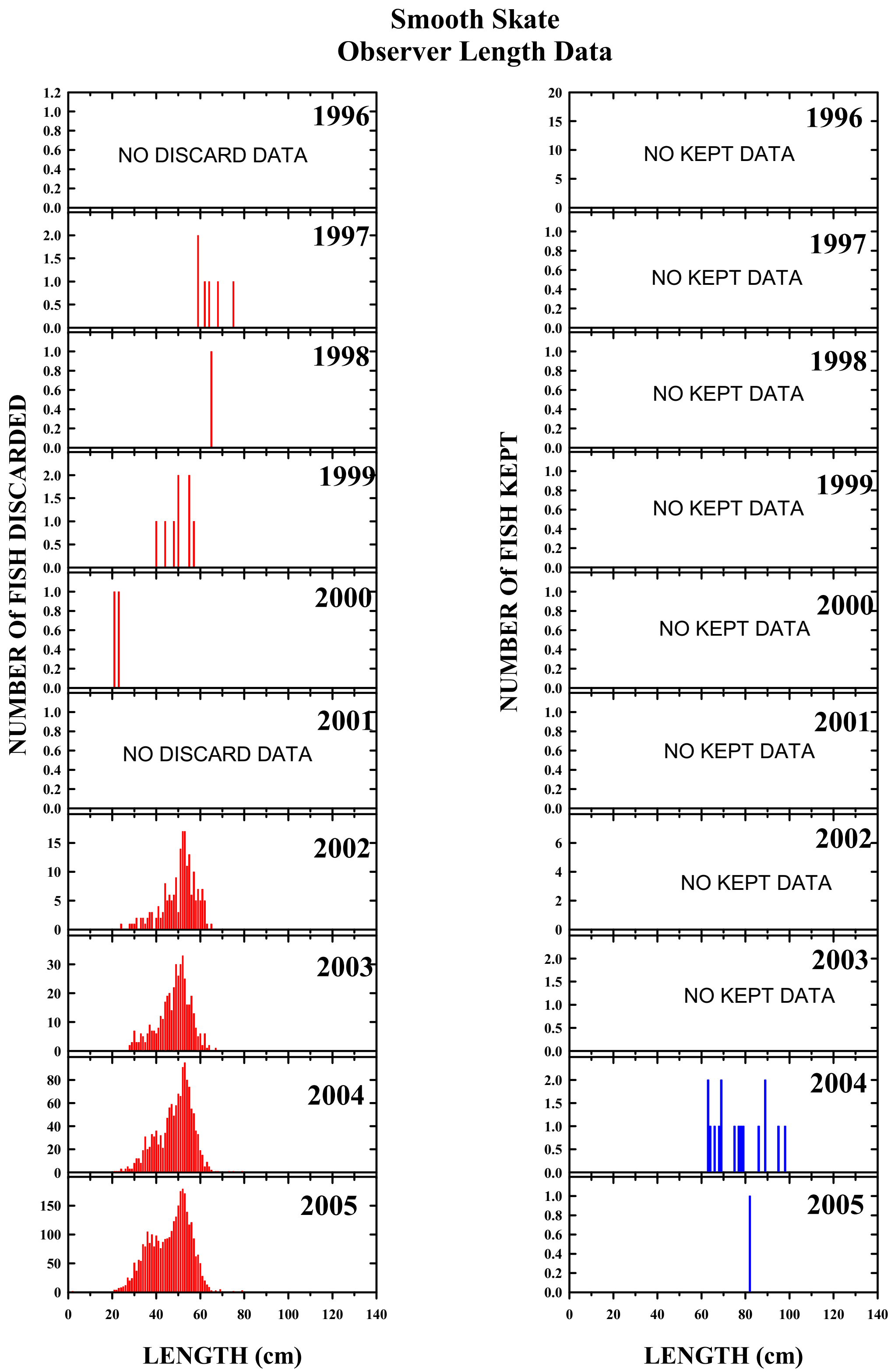


Figure B1.13. Smooth skate length composition from the NEFSC observer program 1996-2005.

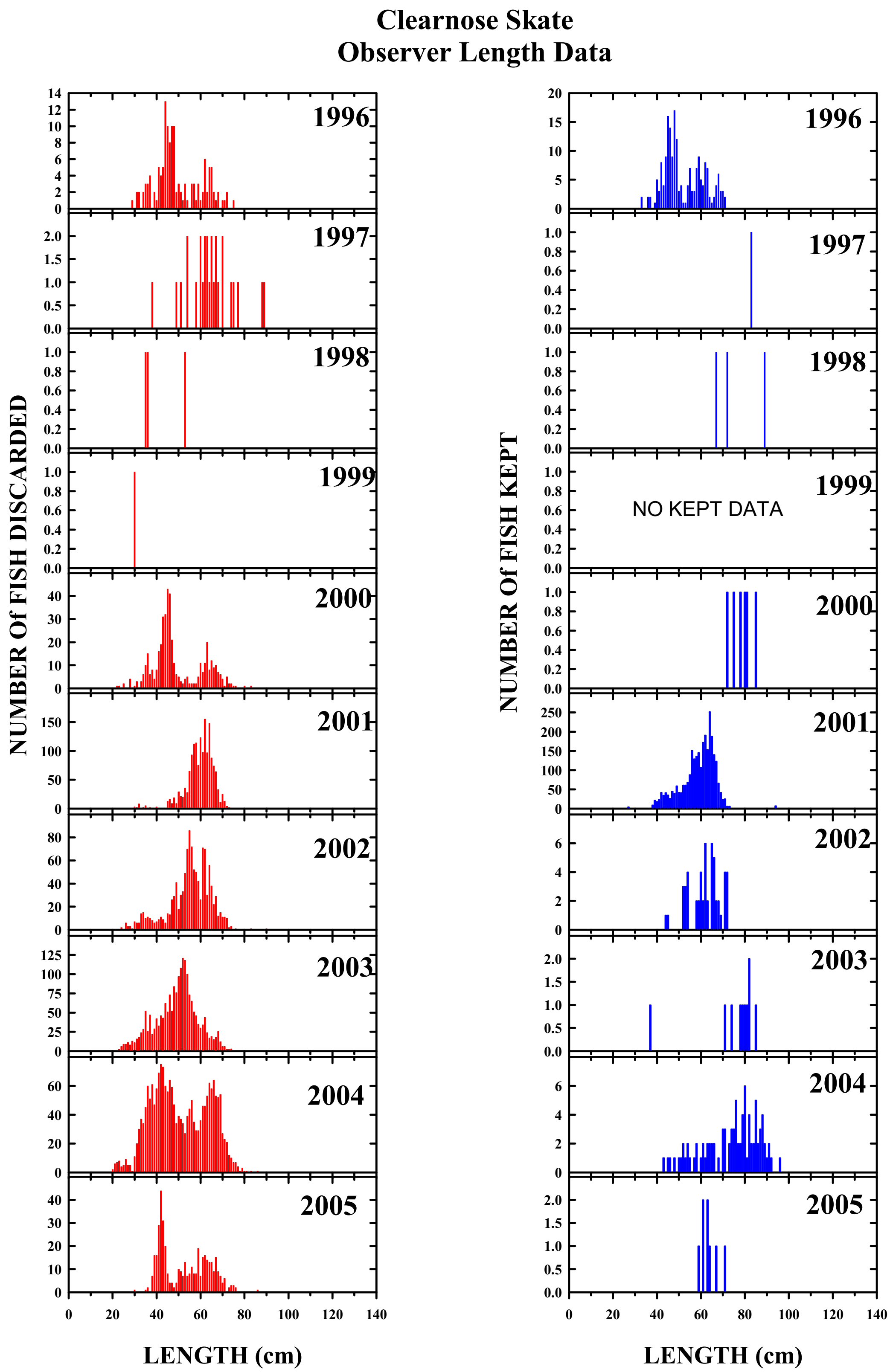


Figure B1.14. Clearnose skate length composition from the NEFSC observer program 1996-2005.

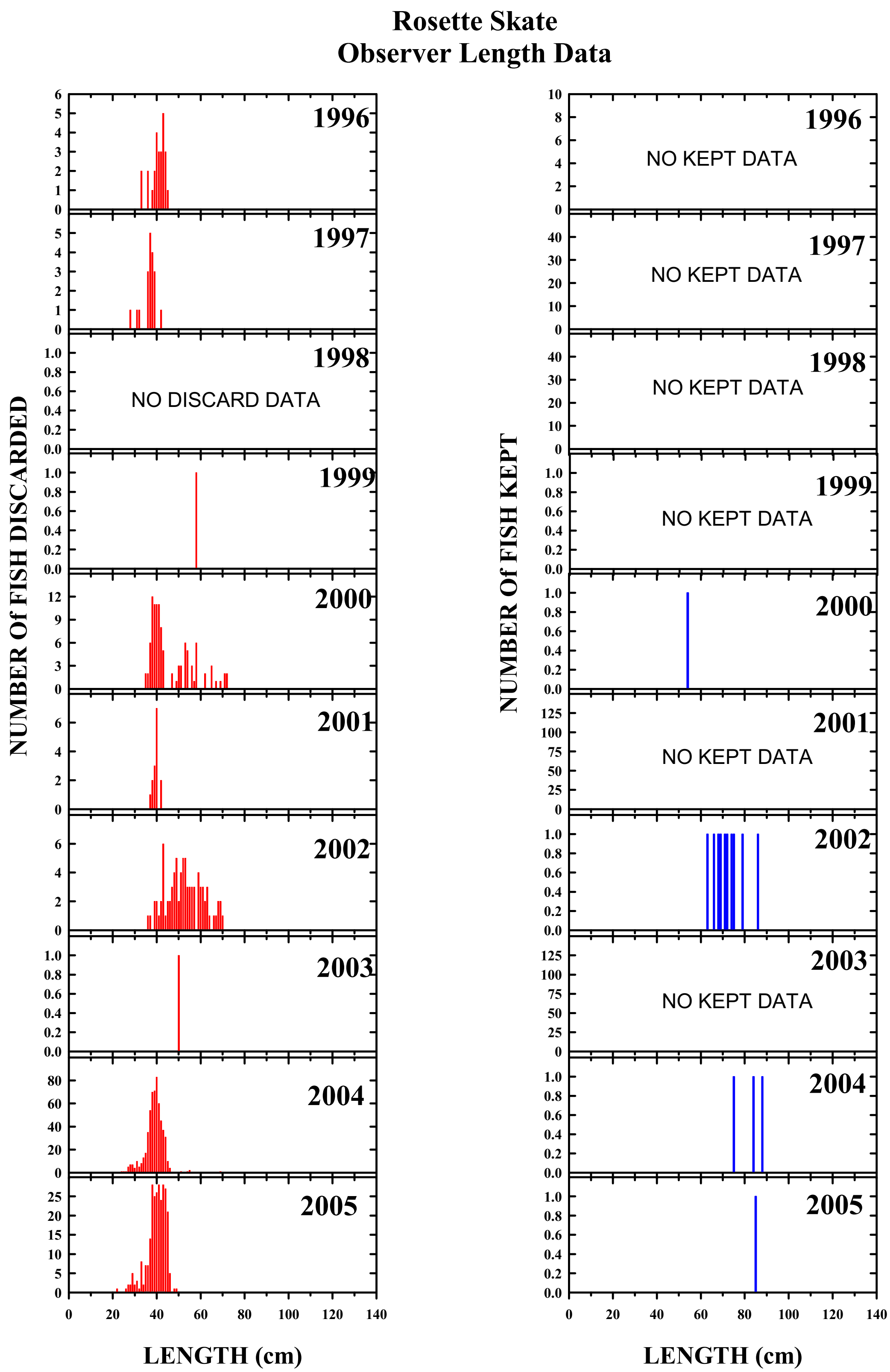


Figure B1.15. Rosette skate length composition from the NEFSC observer program 1996-2005.

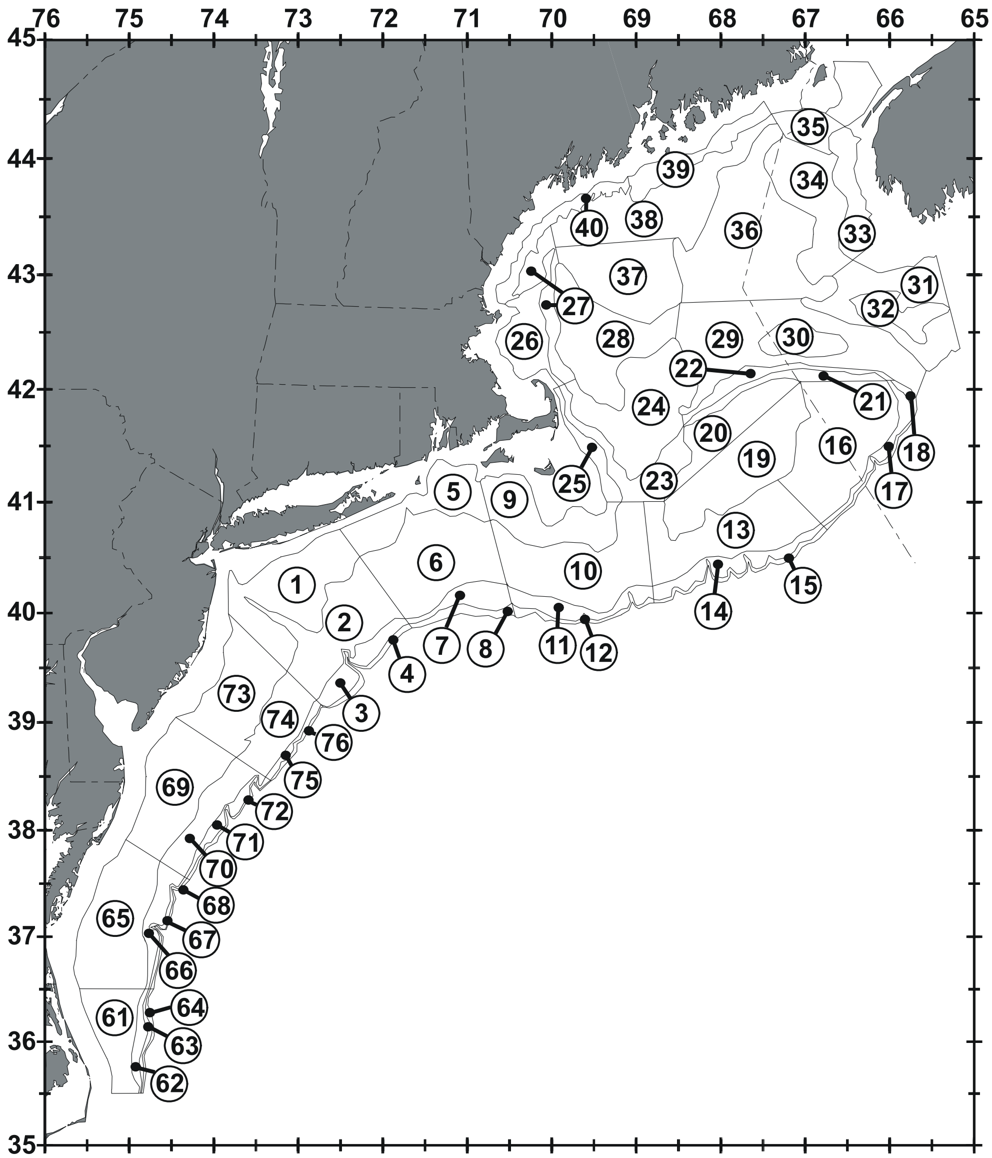


Figure B2.1. Map of offshore strata sampled in the NEFSC spring, autumn, and winter surveys.

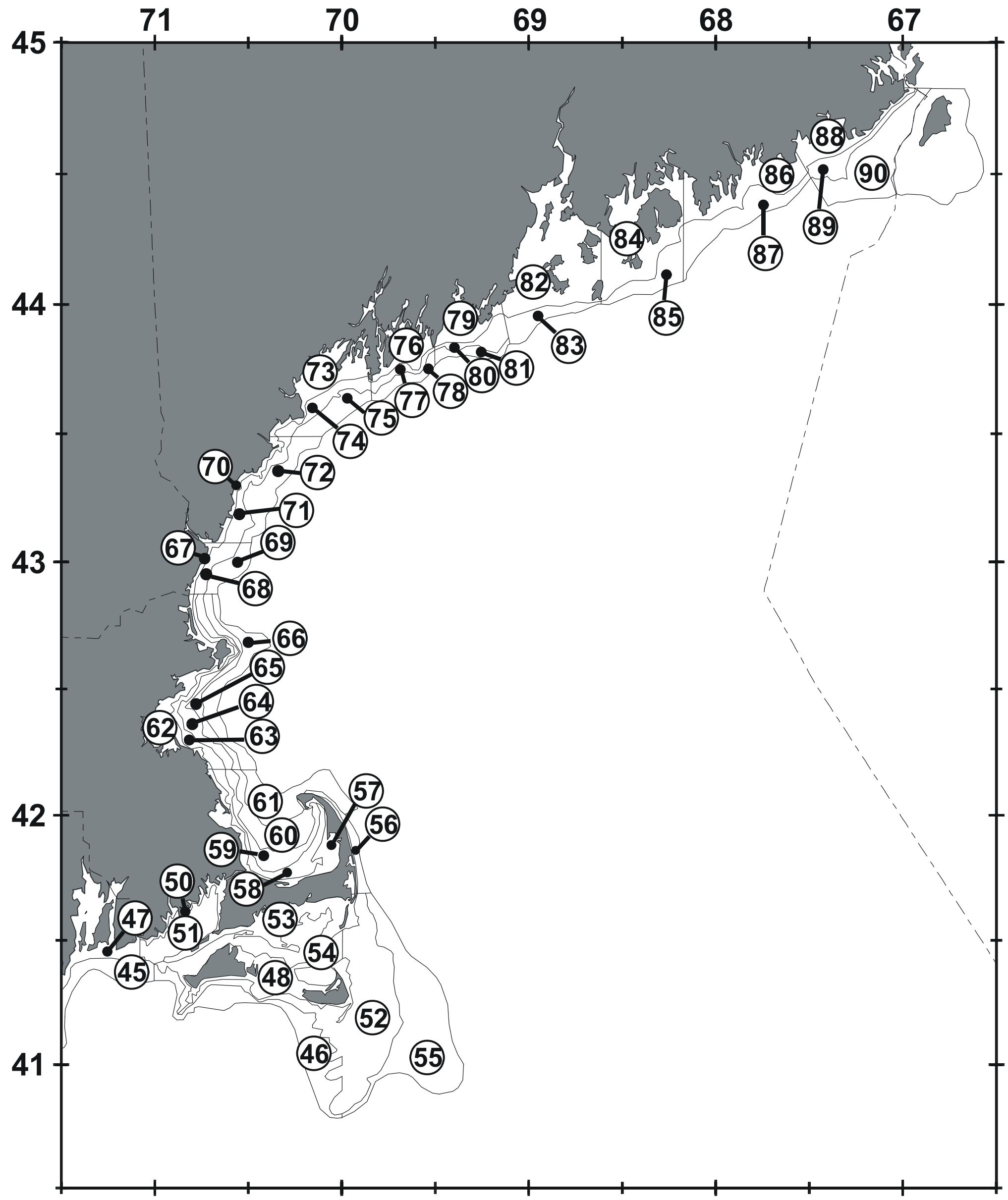


Figure B2.2. Map of inshore strata sampled in the NEFSC spring and autumn surveys in the Gulf of Maine.

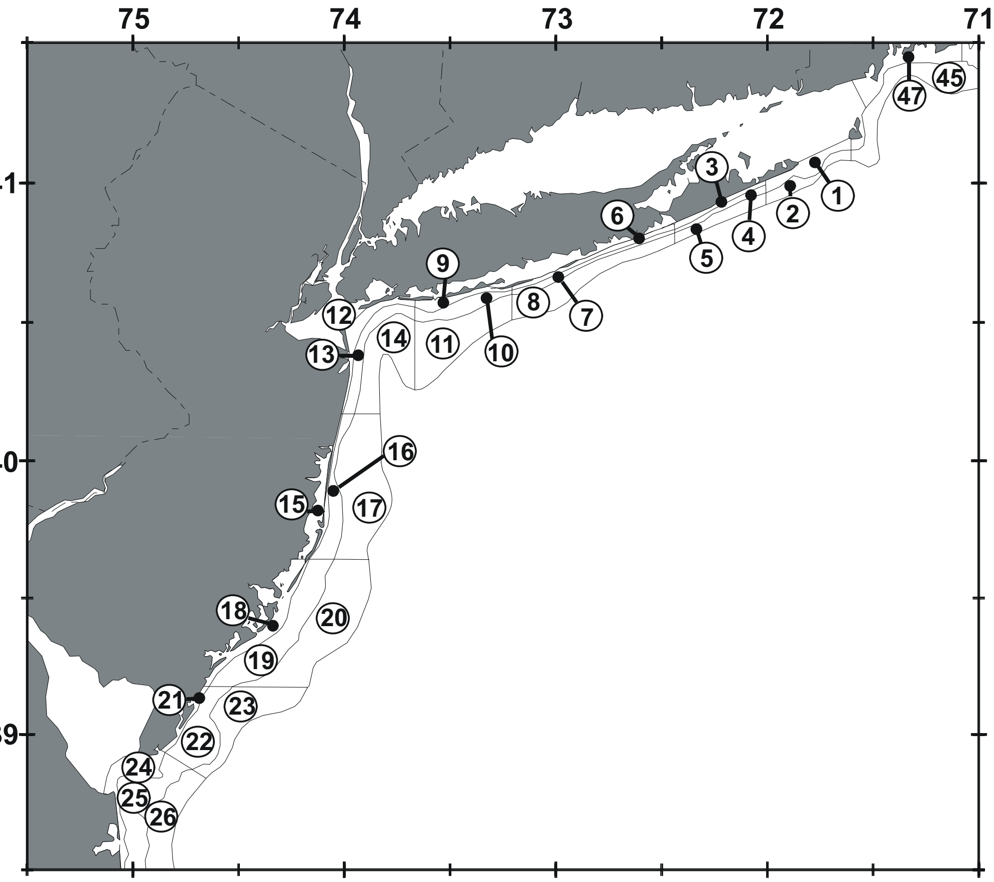


Figure B2.3. Map of inshore strata sampled in the NEFSC spring and autumn surveys in Southern New England.

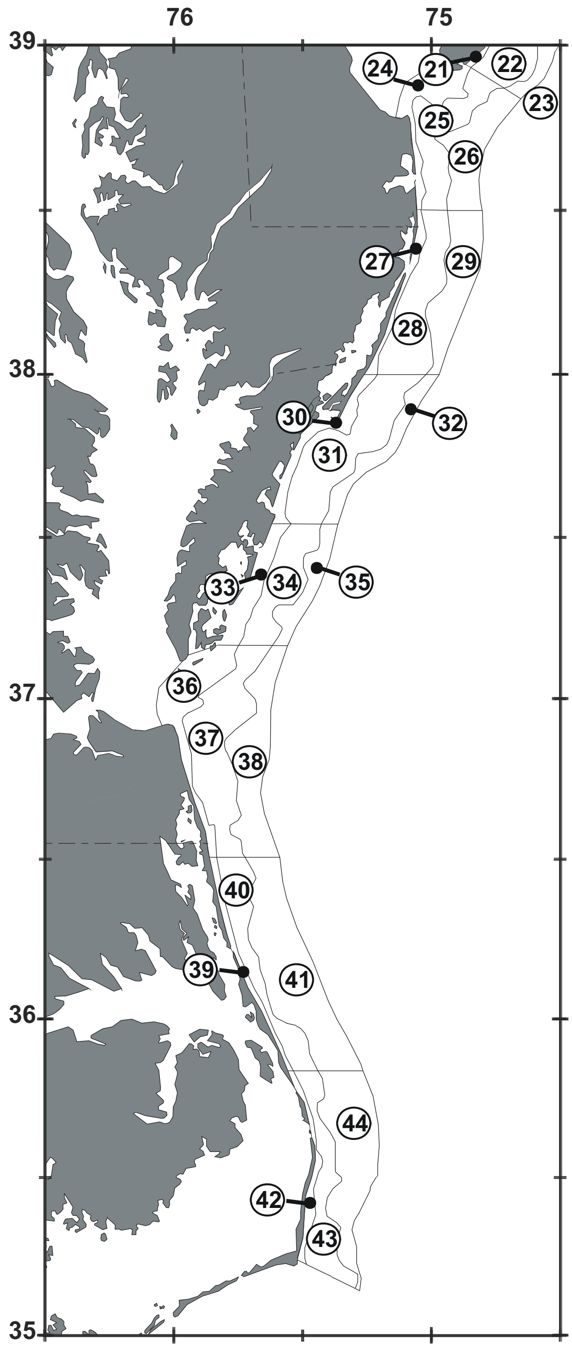


Figure B2.4. Map of inshore strata sampled in the NEFSC spring and autumn surveys in the Mid-Atlantic.

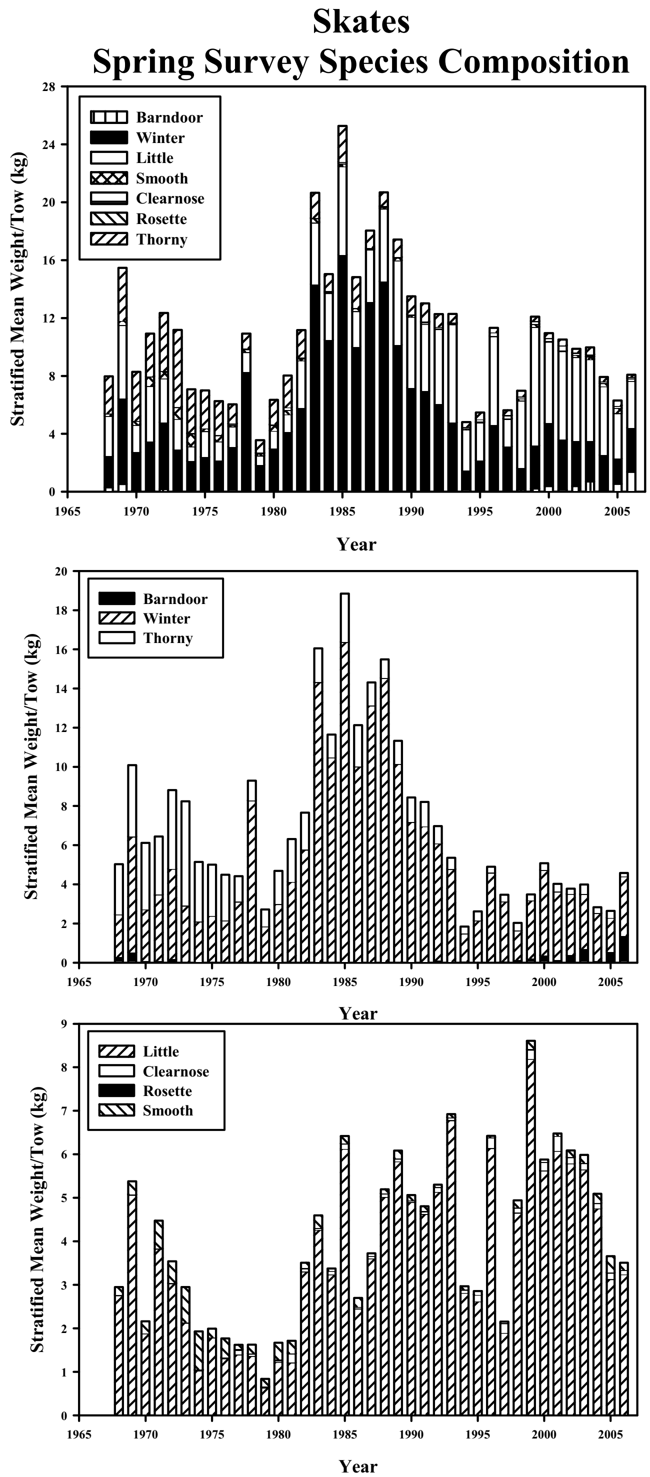


Figure B2.5. Species composition of skates from the spring survey. Panel A shows the composition of all species, panel B shows the composition of large species (>100 cm maximum length), and panel C shows the composition of the small species (maximum length < 100cm).

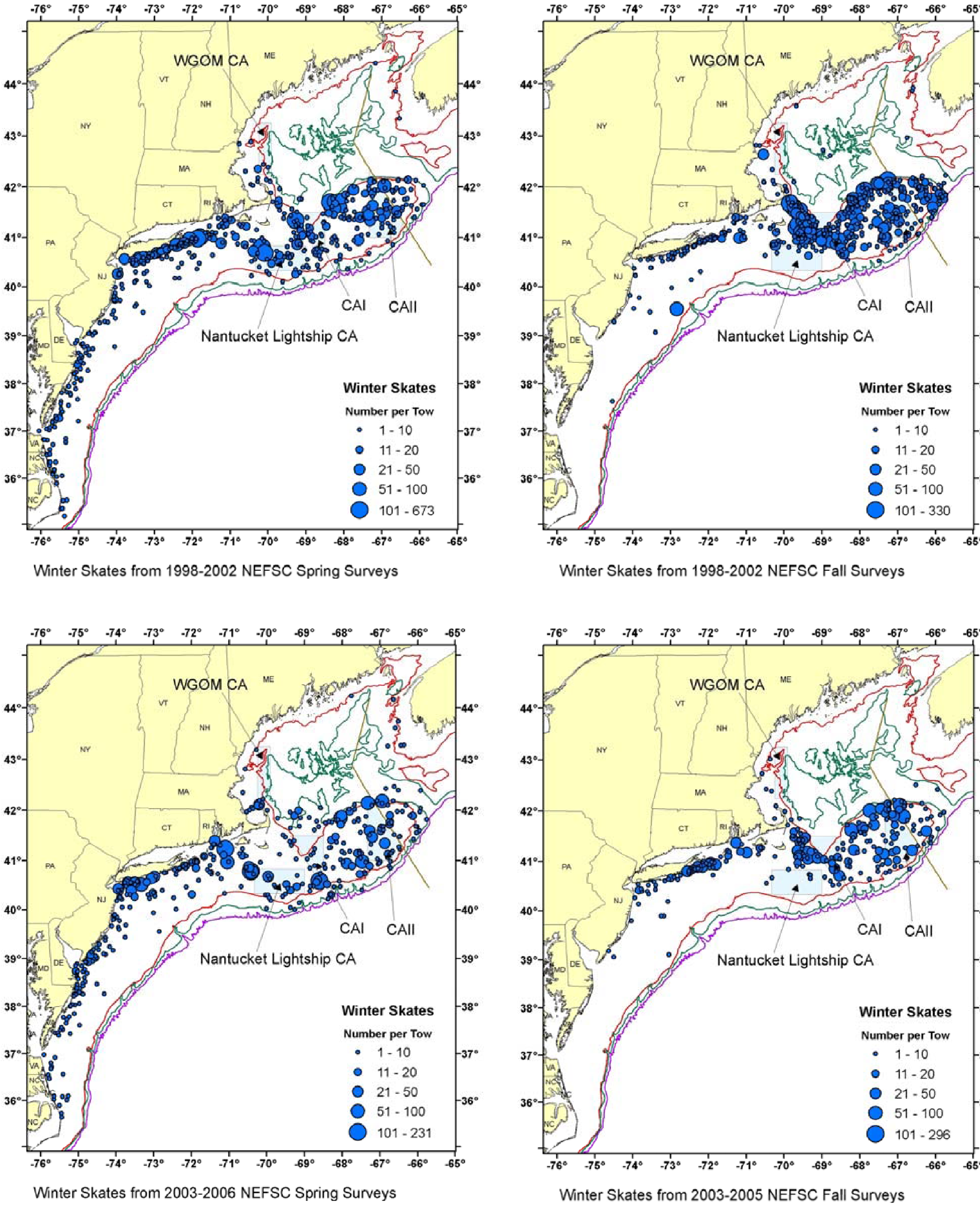
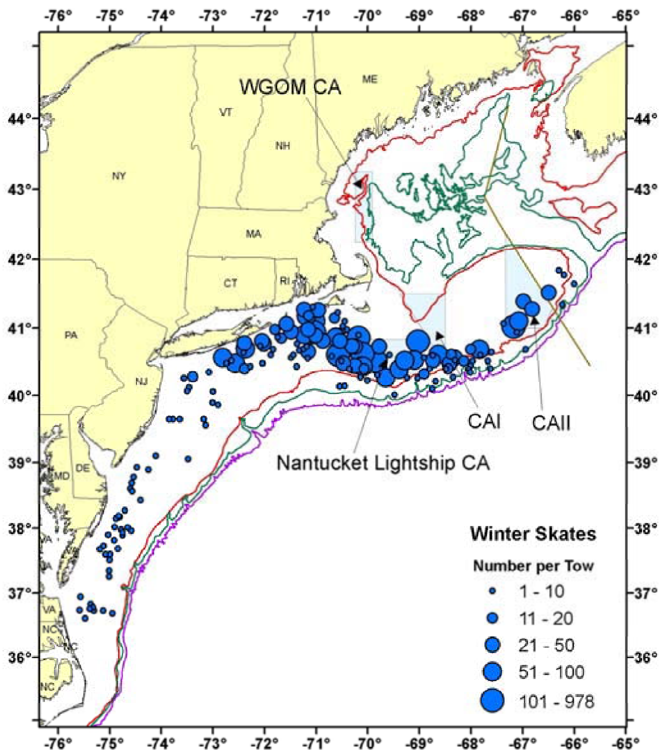
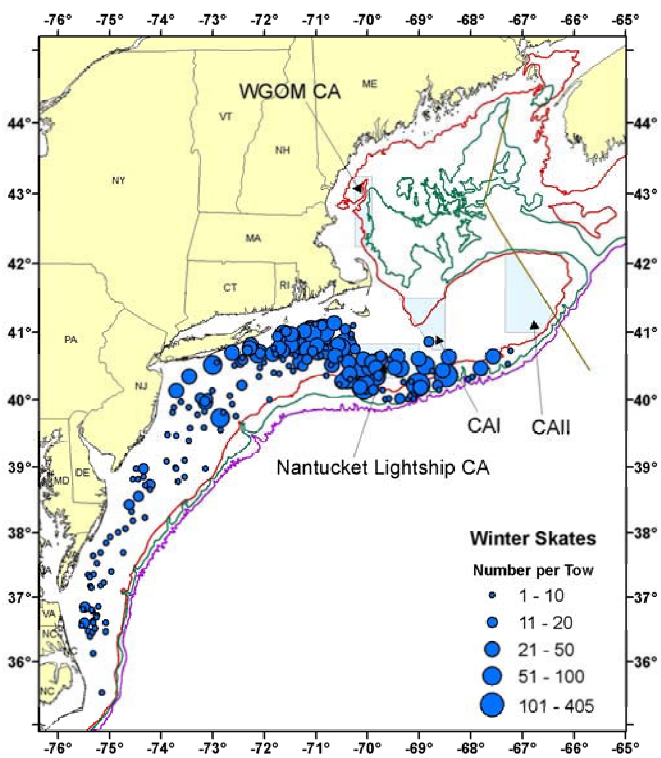


Figure B2.6. Distribution of winter skate from the spring and autumn NEFSC surveys from 1998-2006.



Winter Skates from 2000-2002 NEFSC Winter Surveys



Winter Skates from 2003-2006 NEFSC Winter Surveys

Figure B2.7. Distribution of winter skate from the NEFSC winter surveys from 2000-2006.

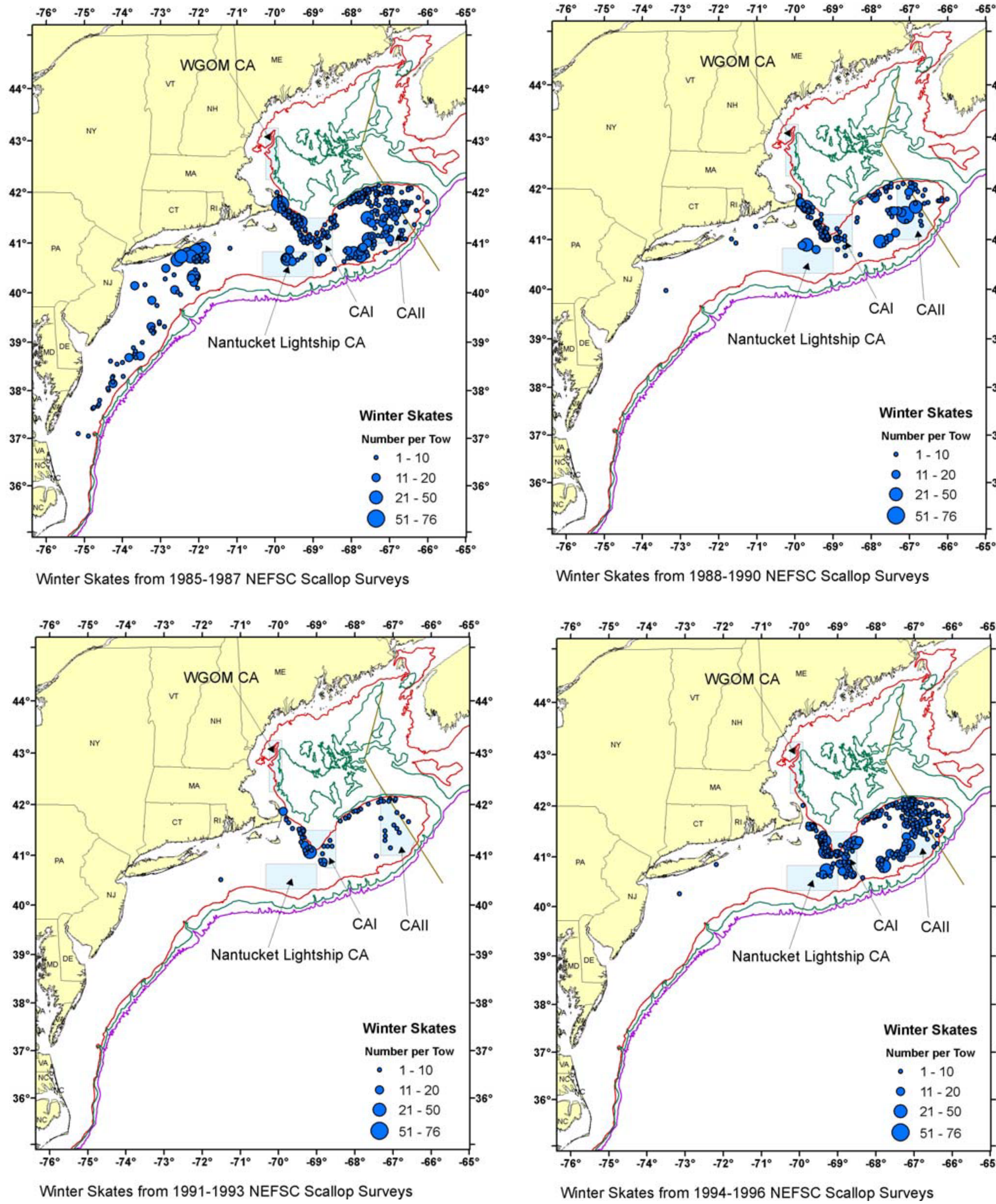
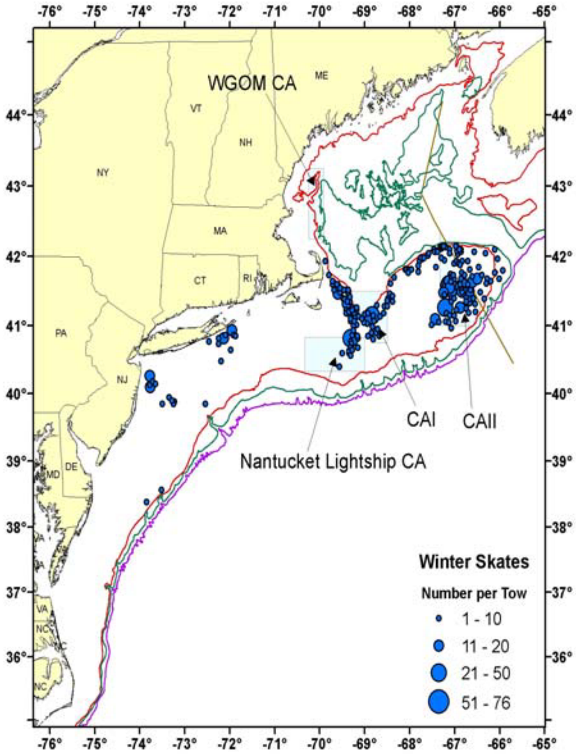
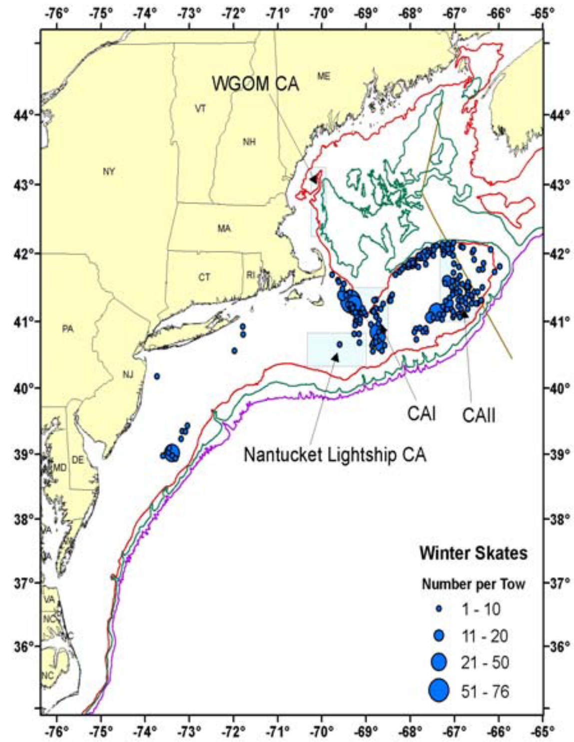


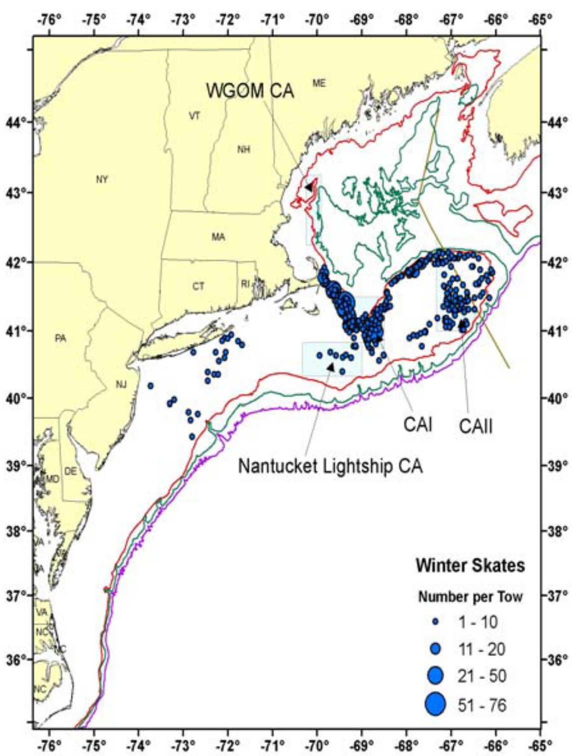
Figure B2.8. Distribution of winter skate from the NEFSC scallop surveys from 1985-1996.



Winter Skates from 1997-1999 NEFSC Scallop Surveys



Winter Skates from 2000-2002 NEFSC Scallop Surveys



Winter Skates from 2003-2006 NEFSC Scallop Surveys

Figure B2.9. Distribution of winter skate from the NEFSC scallop surveys from 1997-2006.

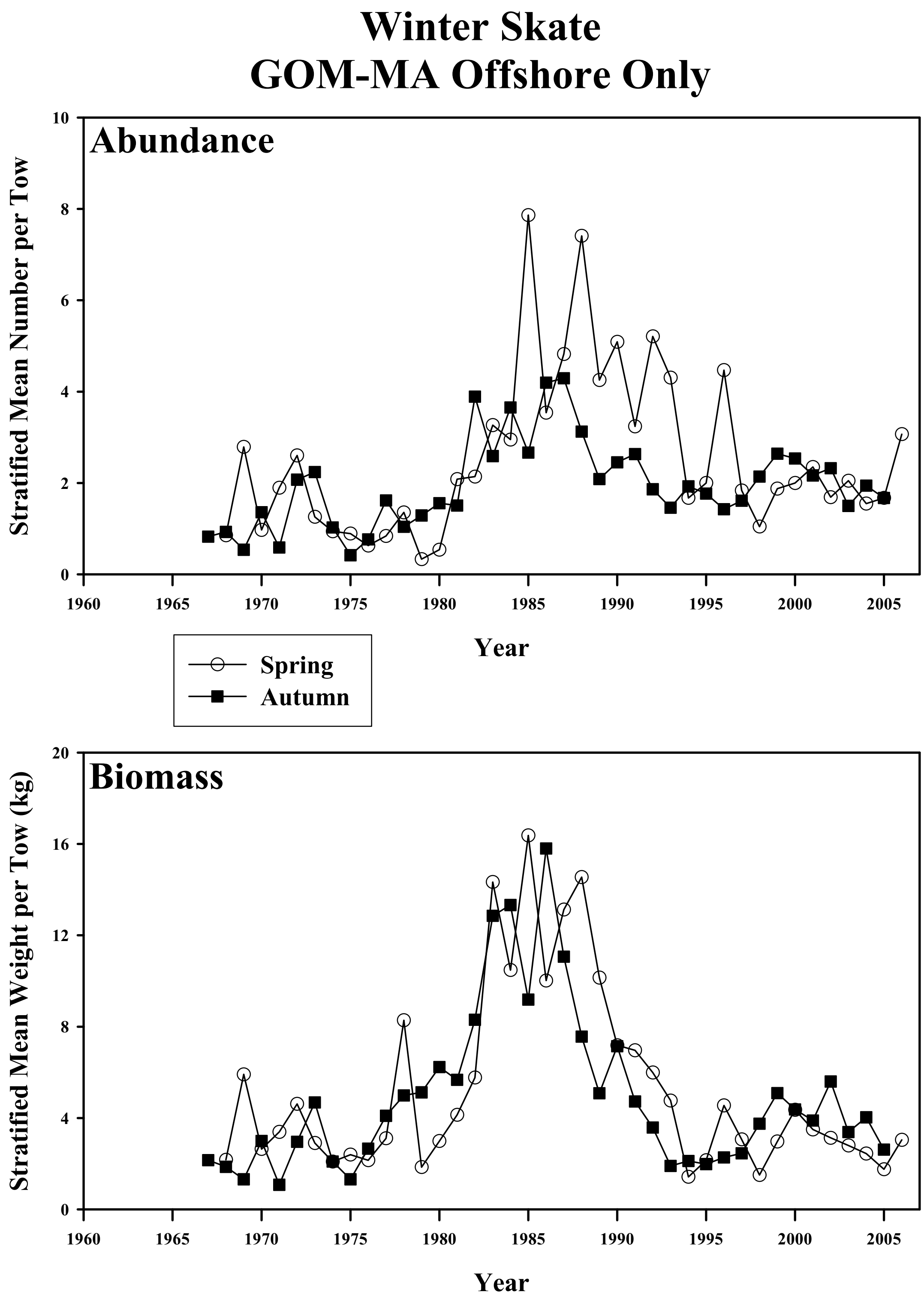


Figure B2.10. Abundance and biomass of winter skate from the NESFC spring (circles) and autumn (squares) bottom trawl surveys from 1967-2006 in the Gulf of Maine to Mid-Atlantic offshore region.

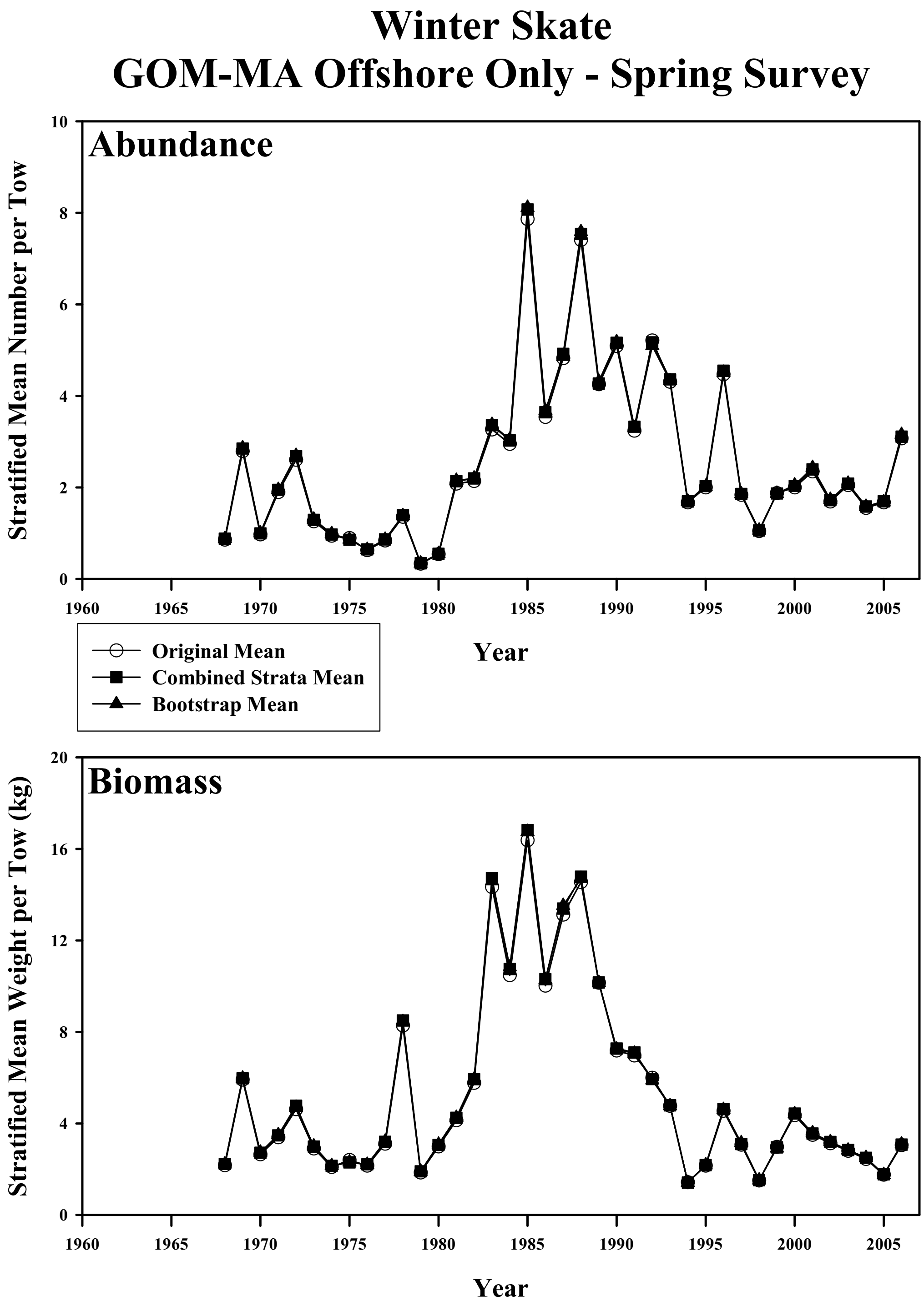


Figure B2.11. Abundance and biomass of winter skate from the NESFC spring bottom trawl surveys from 1968-2006 in the Gulf of Maine to Mid-Atlantic offshore region. The circles represent the original stratified mean, the squares represent the mean combining strata for bootstrapping, and the triangles represent the bootstrapped mean.

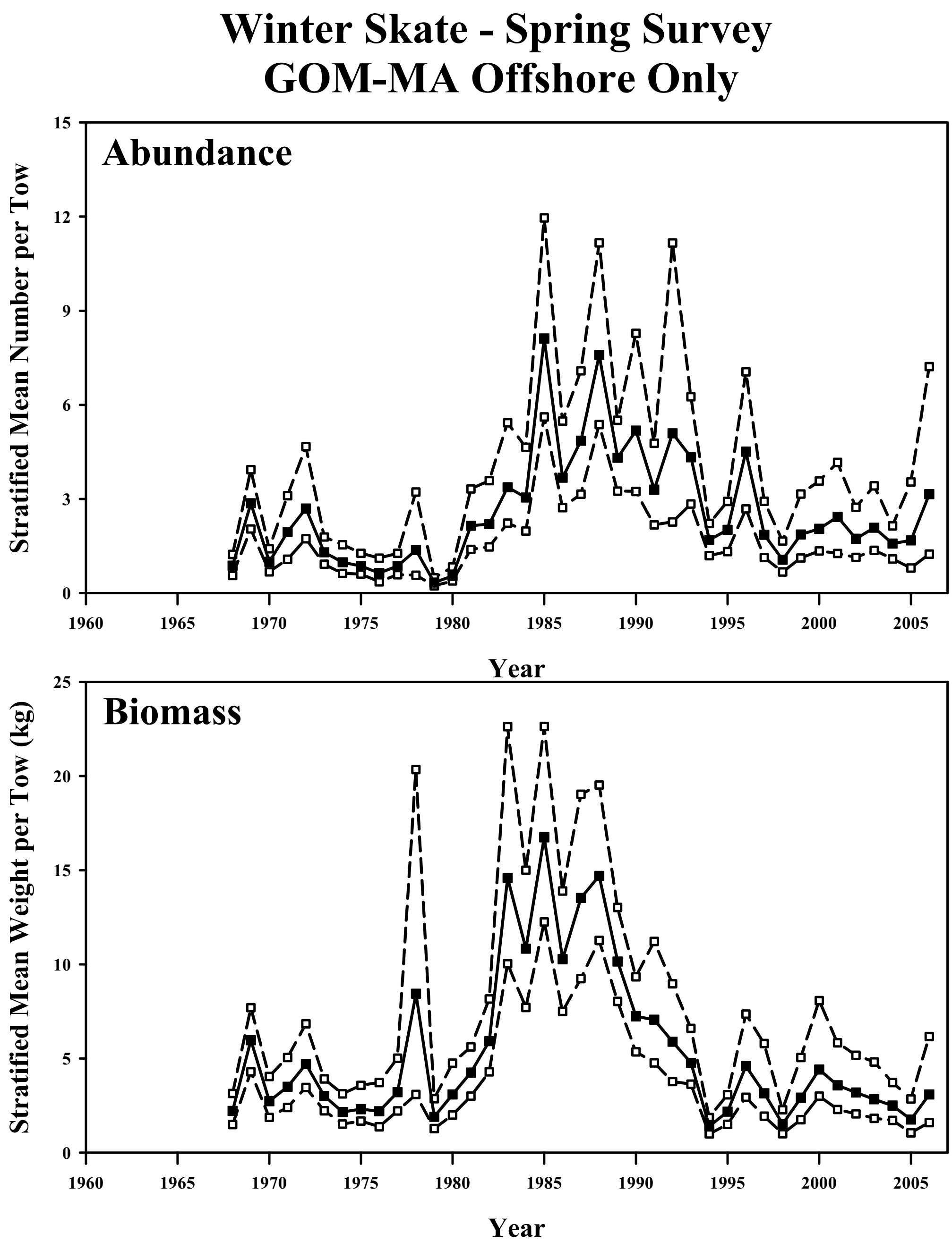


Figure B2.12. Bootstrapped abundance and biomass of winter skate from the NESFC spring bottom trawl survey in the Gulf of Maine to Mid-Atlantic region, offshore strata only. Mean index in solid squares, 95% confidence interval in open squares.

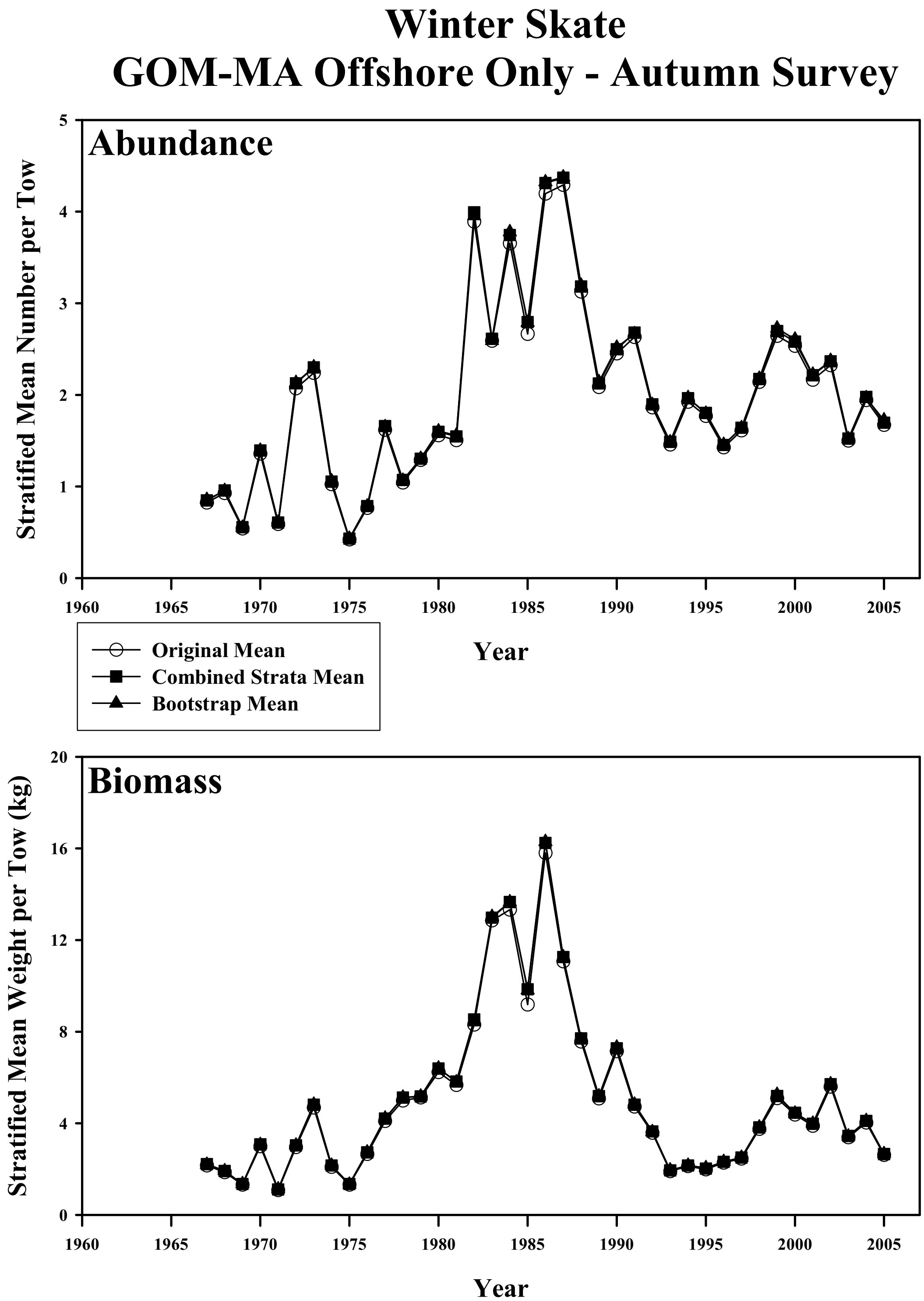


Figure B2.13. Abundance and biomass of winter skate from the NESFC autumn bottom trawl surveys from 1967-2005 in the Gulf of Maine to Mid-Atlantic offshore region. The circles represent the original stratified mean, the squares represent the mean combining strata for bootstrapping, and the triangles represent the bootstrapped mean.

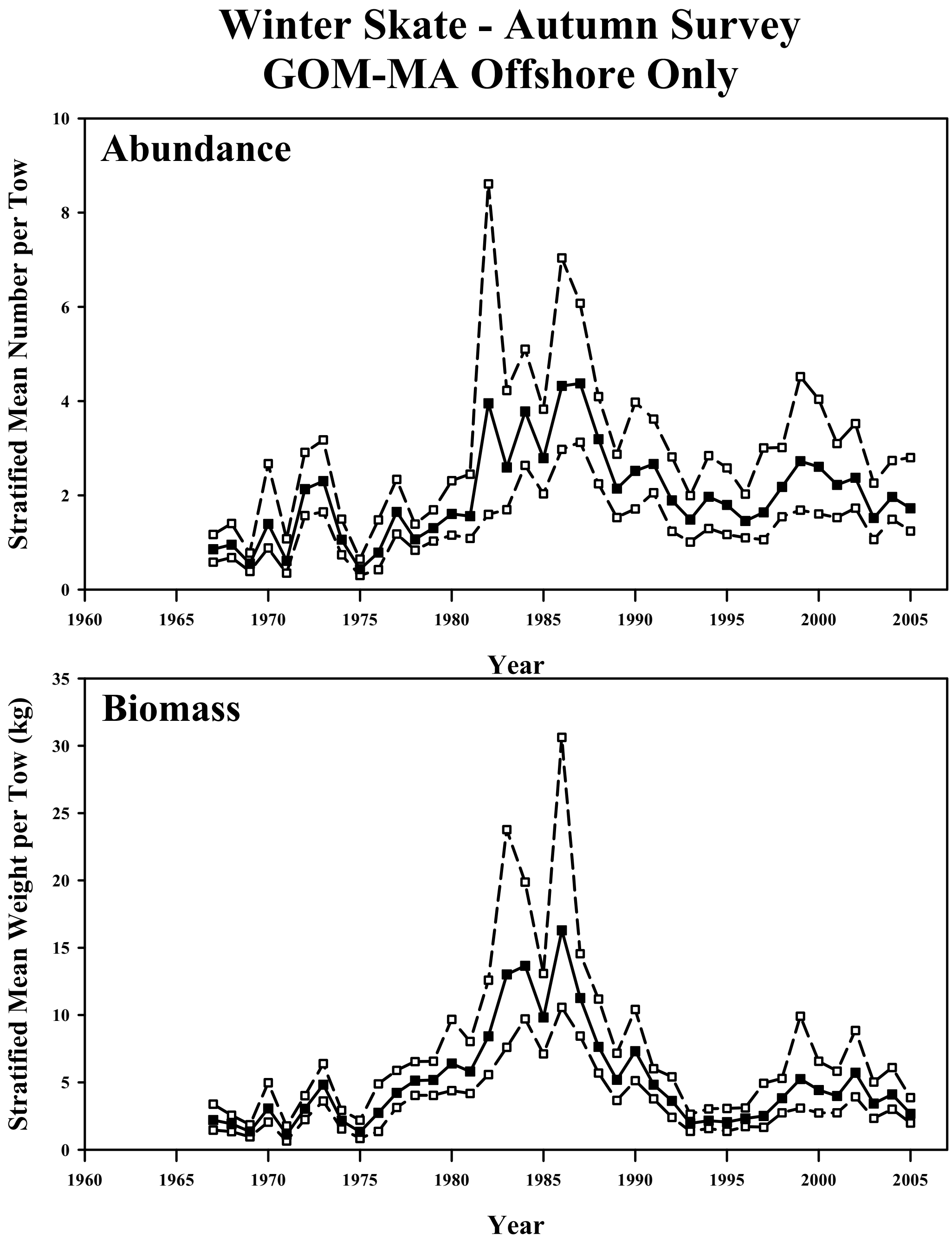
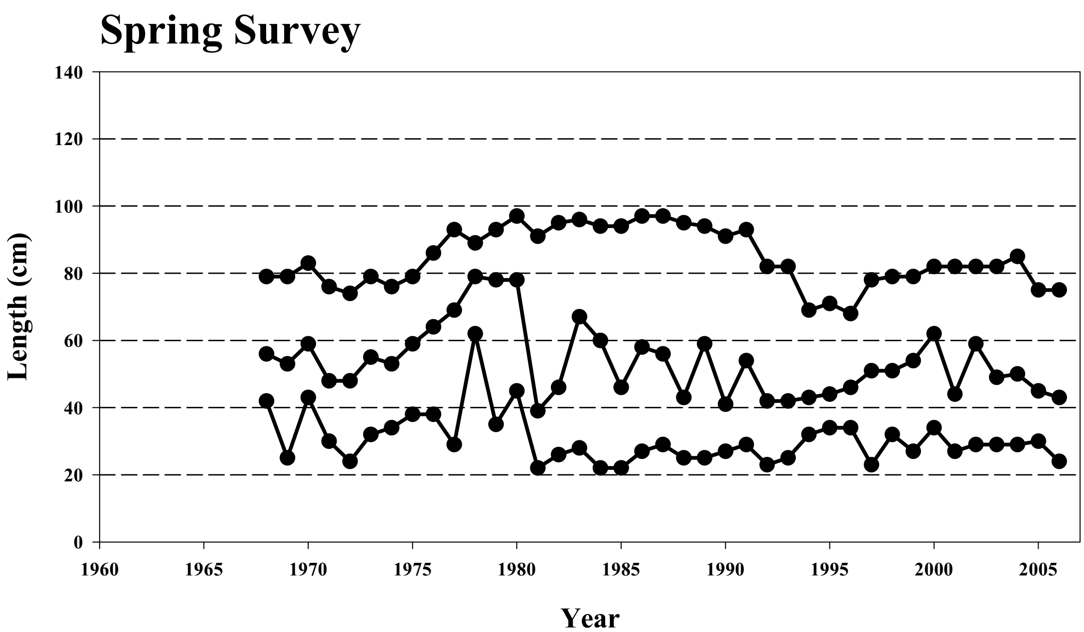


Figure B2.14. Bootstrapped abundance and biomass of winter skate from the NESFC autumn bottom trawl survey in the Gulf of Maine to Mid-Atlantic region, offshore strata only. Mean index in solid squares, 95% confidence interval in open squares.

Winter Skate
Percentiles of Length Composition



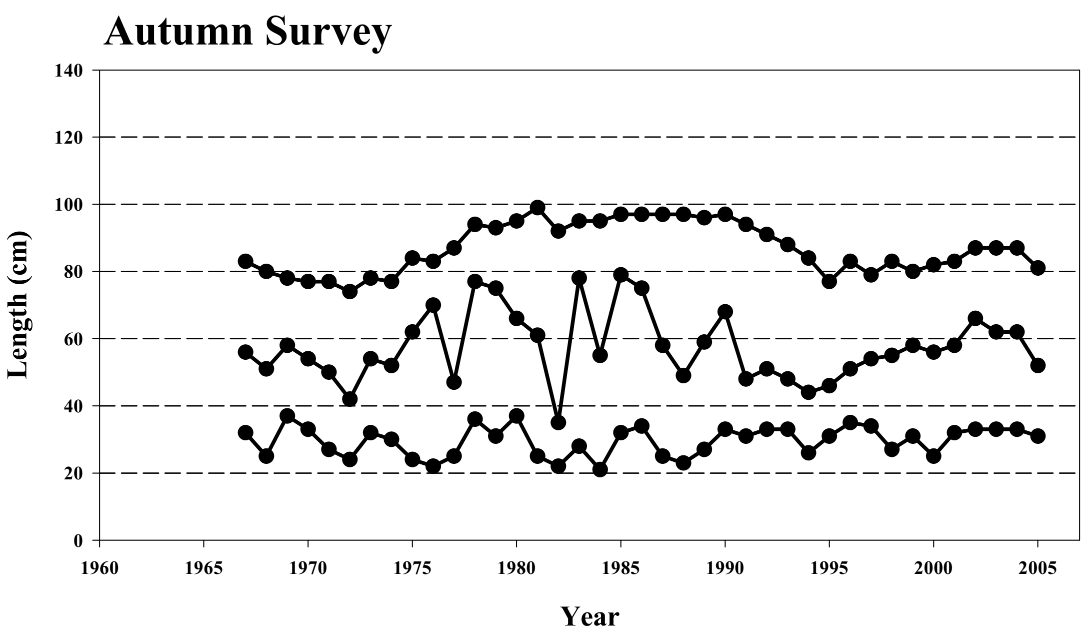


Figure B2.15. Percentiles of length composition (5, 50, and 95) of winter skate from the NESFC spring and autumn bottom trawl surveys from 1967-2006 in the Gulf of Maine to Mid-Atlantic offshore region.

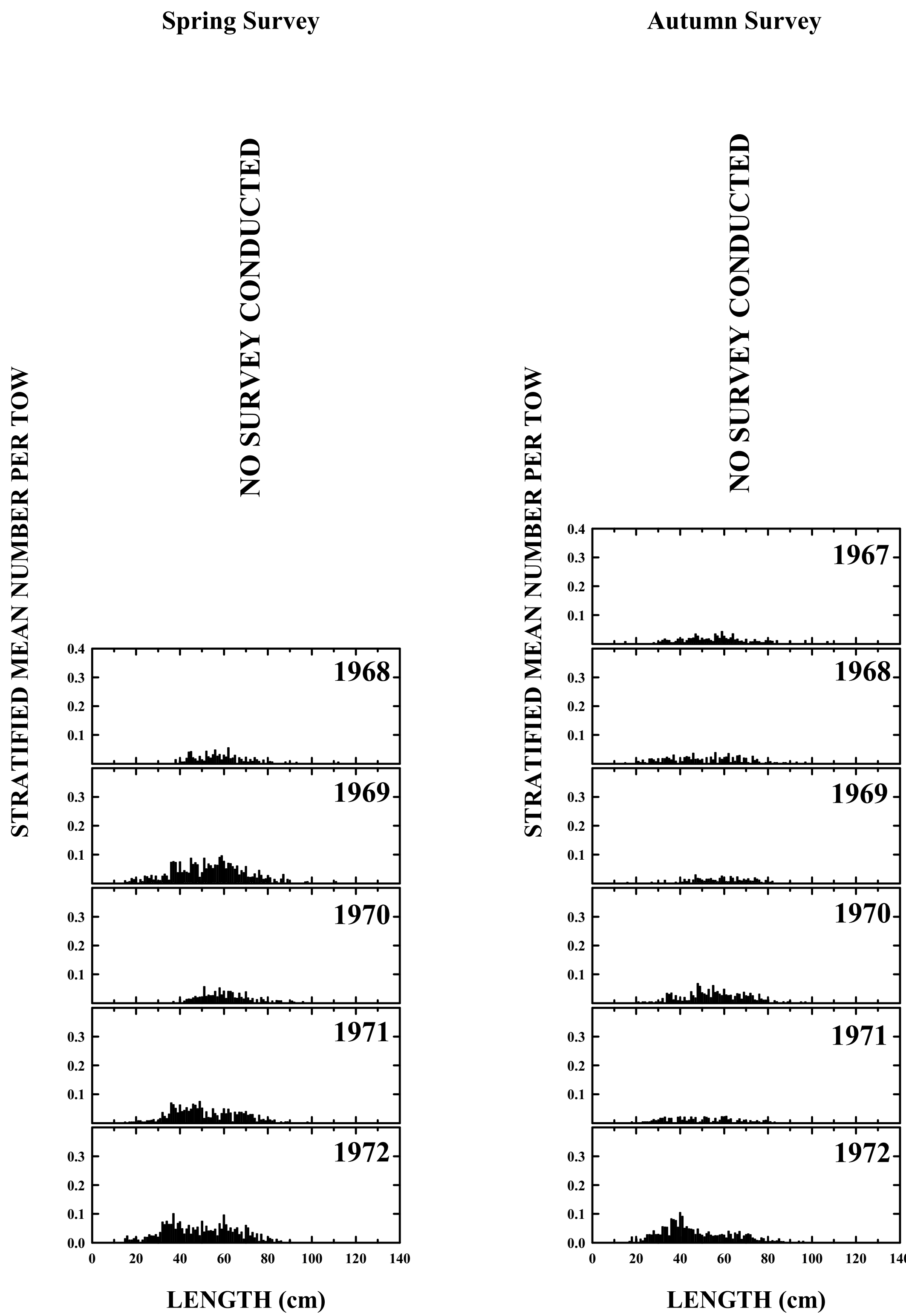


Figure B2.16. Winter skate length composition from the NEFSC spring and autumn trawl surveys in the Gulf of Maine to Mid-Atlantic offshore regions, 1967-1972.

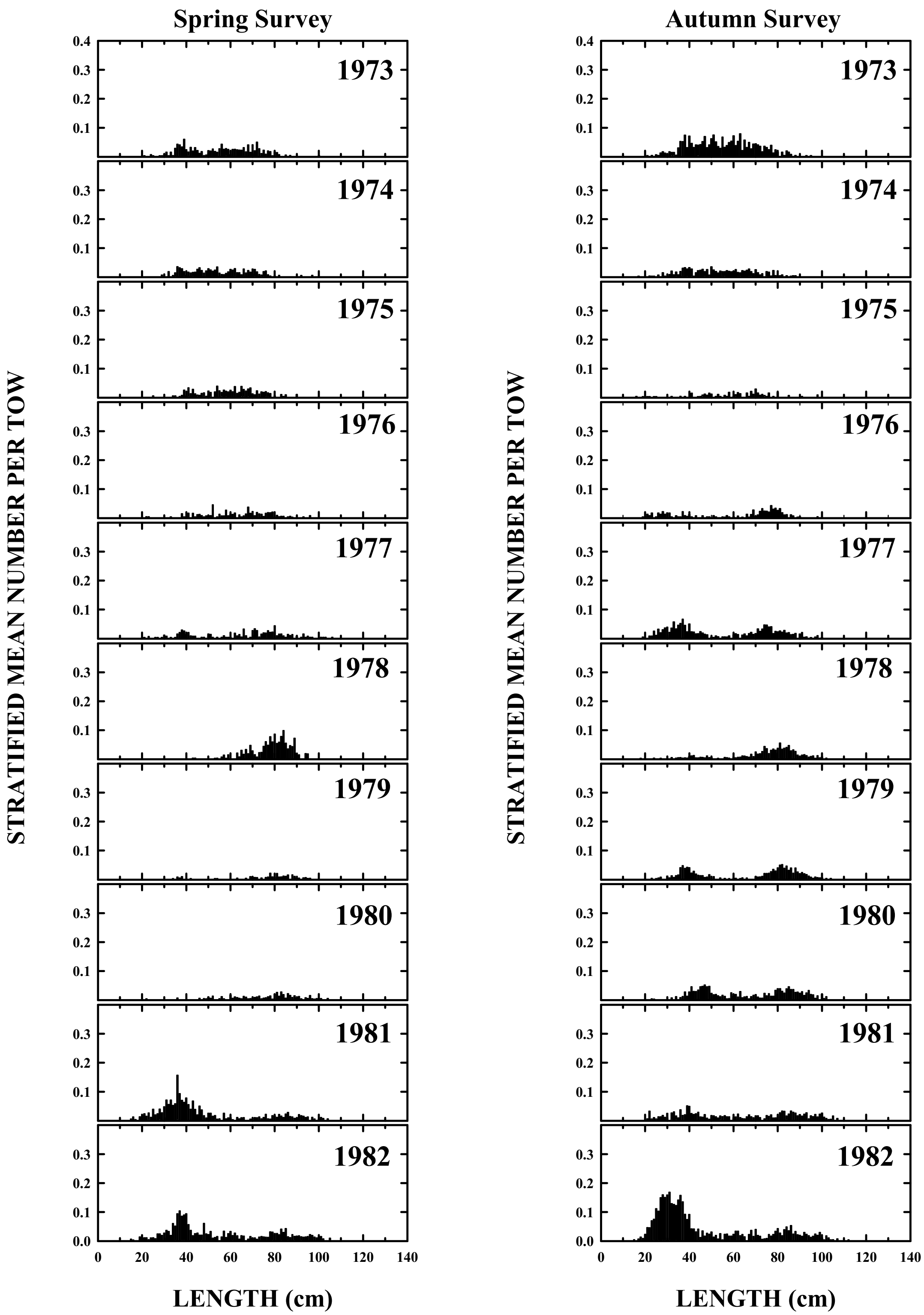


Figure B2.17. Winter skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Mid-Atlantic offshore regions, 1973-1982.

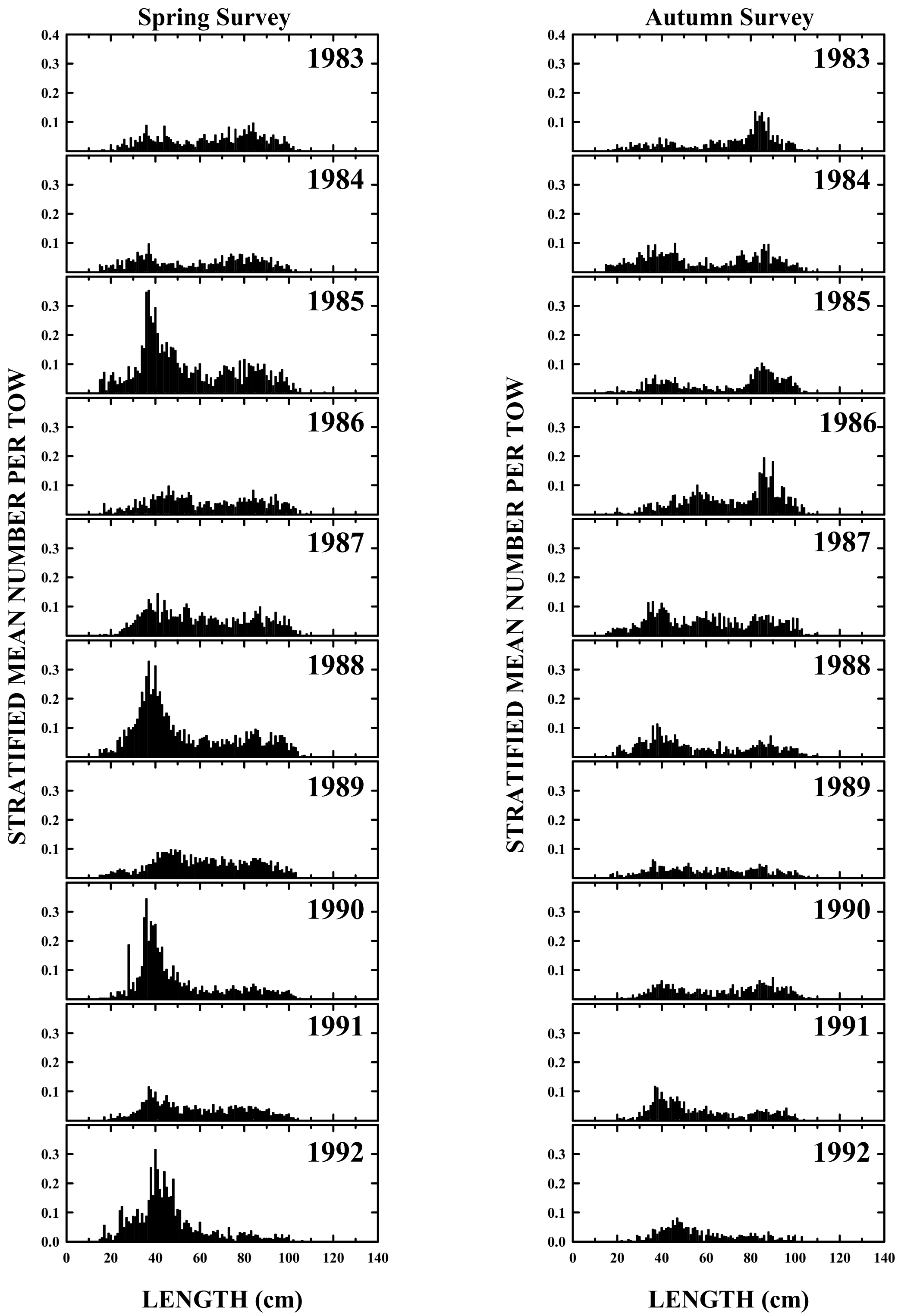


Figure B2.18. Winter skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Mid-Atlantic offshore regions, 1983-1992.

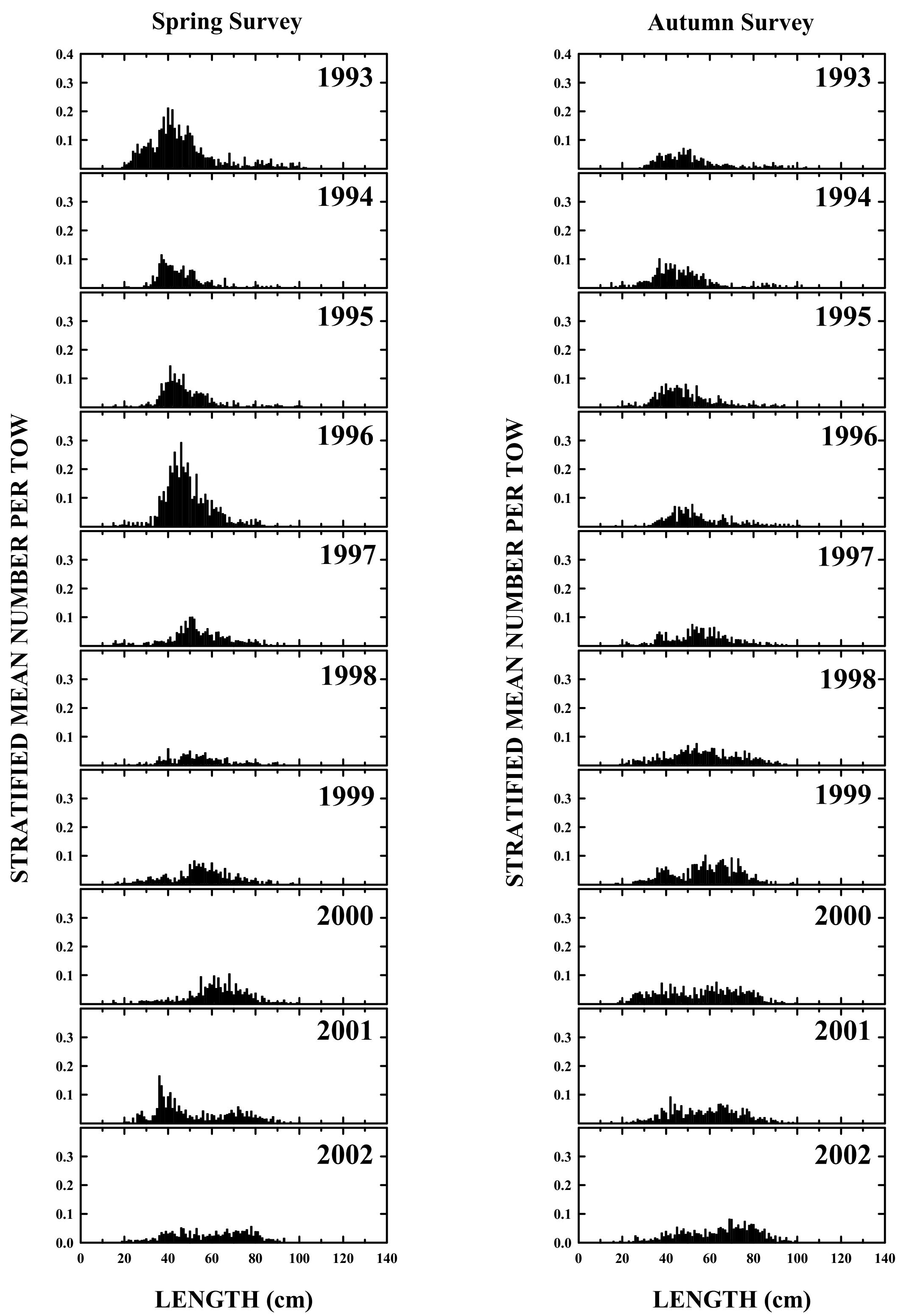


Figure B2.19. Winter skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Mid-Atlantic offshore regions, 1993-2002.

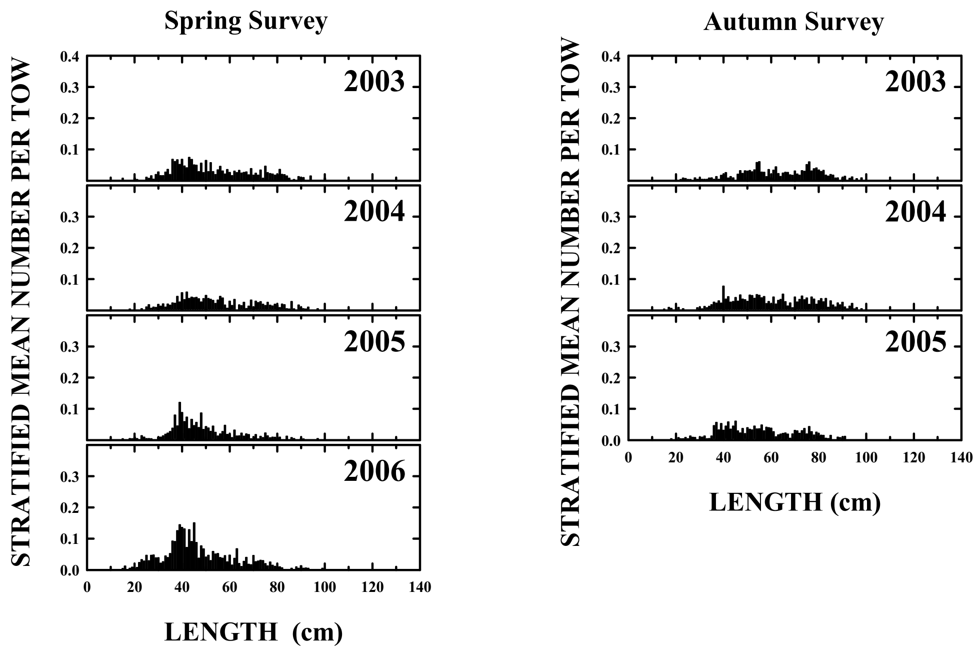


Figure B2.20. Winter skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Mid-Atlantic offshore regions, 2003-2006.

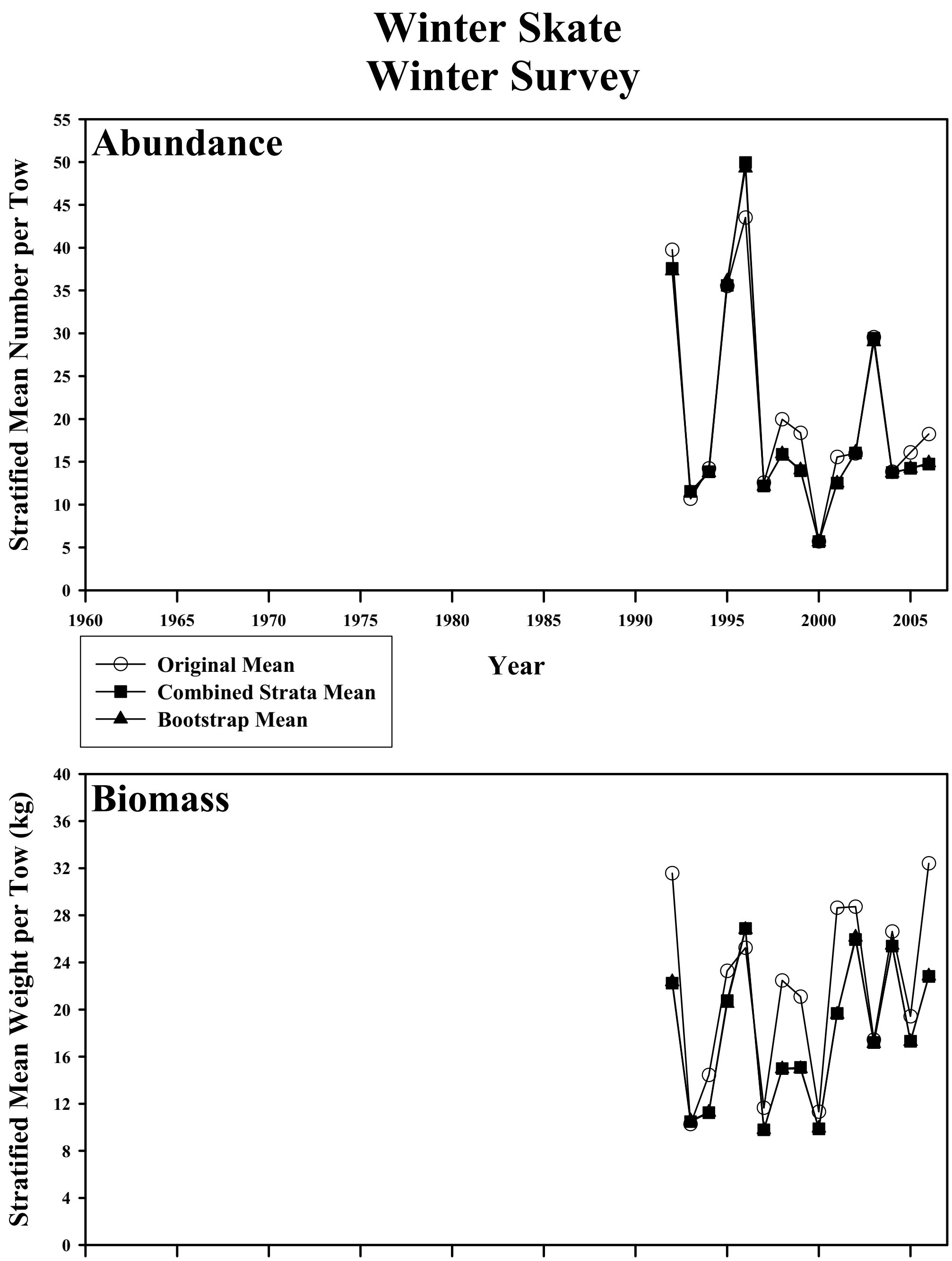


Figure B2.21. Abundance and biomass of winter skate from the NESFC winter bottom trawl surveys from 1992-2006. The circles represent the original stratified mean, the squares represent the mean combining strata for bootstrapping, and the triangles represent the bootstrapped mean.

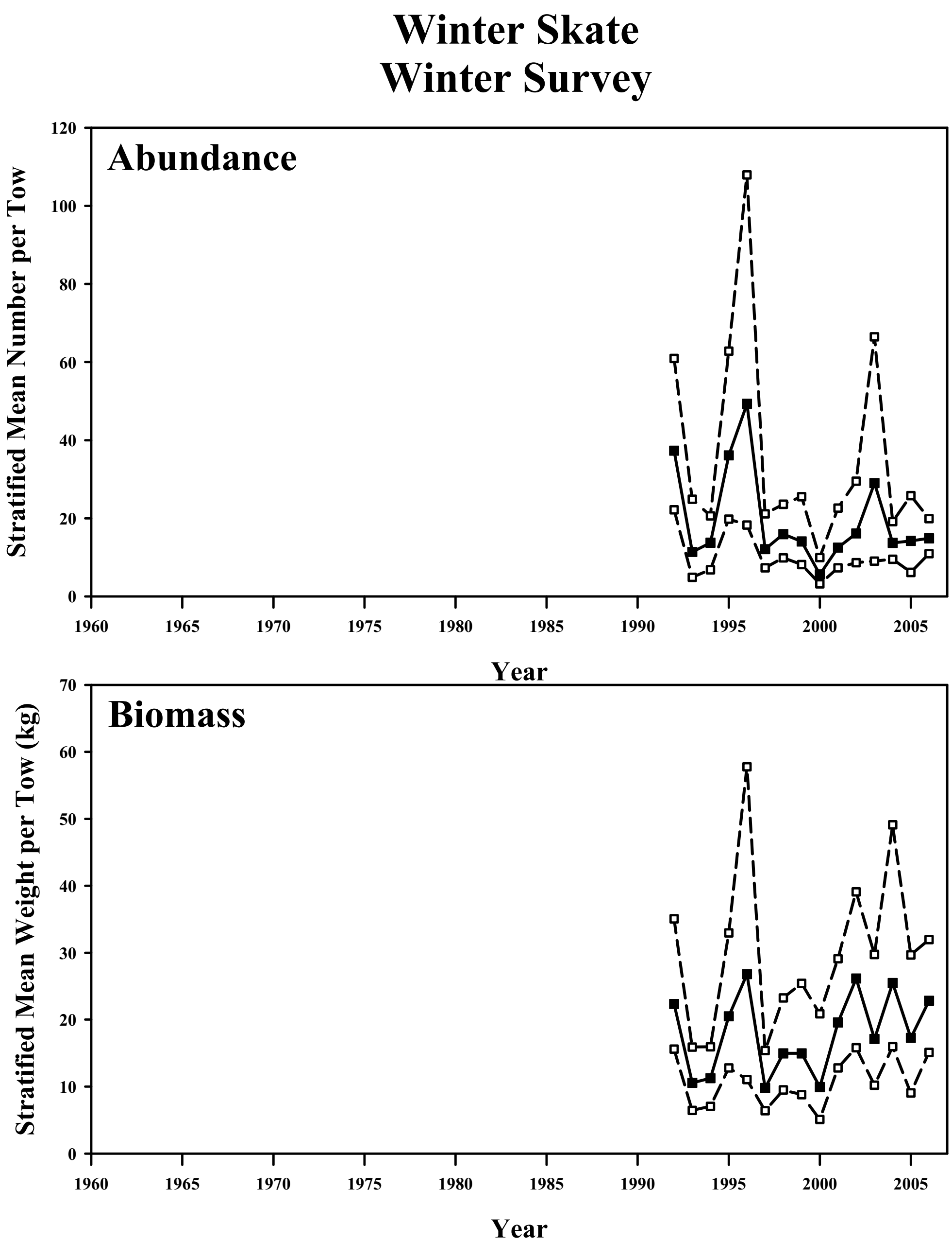


Figure B2.22. Bootstrapped abundance and biomass of winter skate from the NESFC winter bottom trawl survey. Mean index in solid squares, 95% confidence interval in open squares.

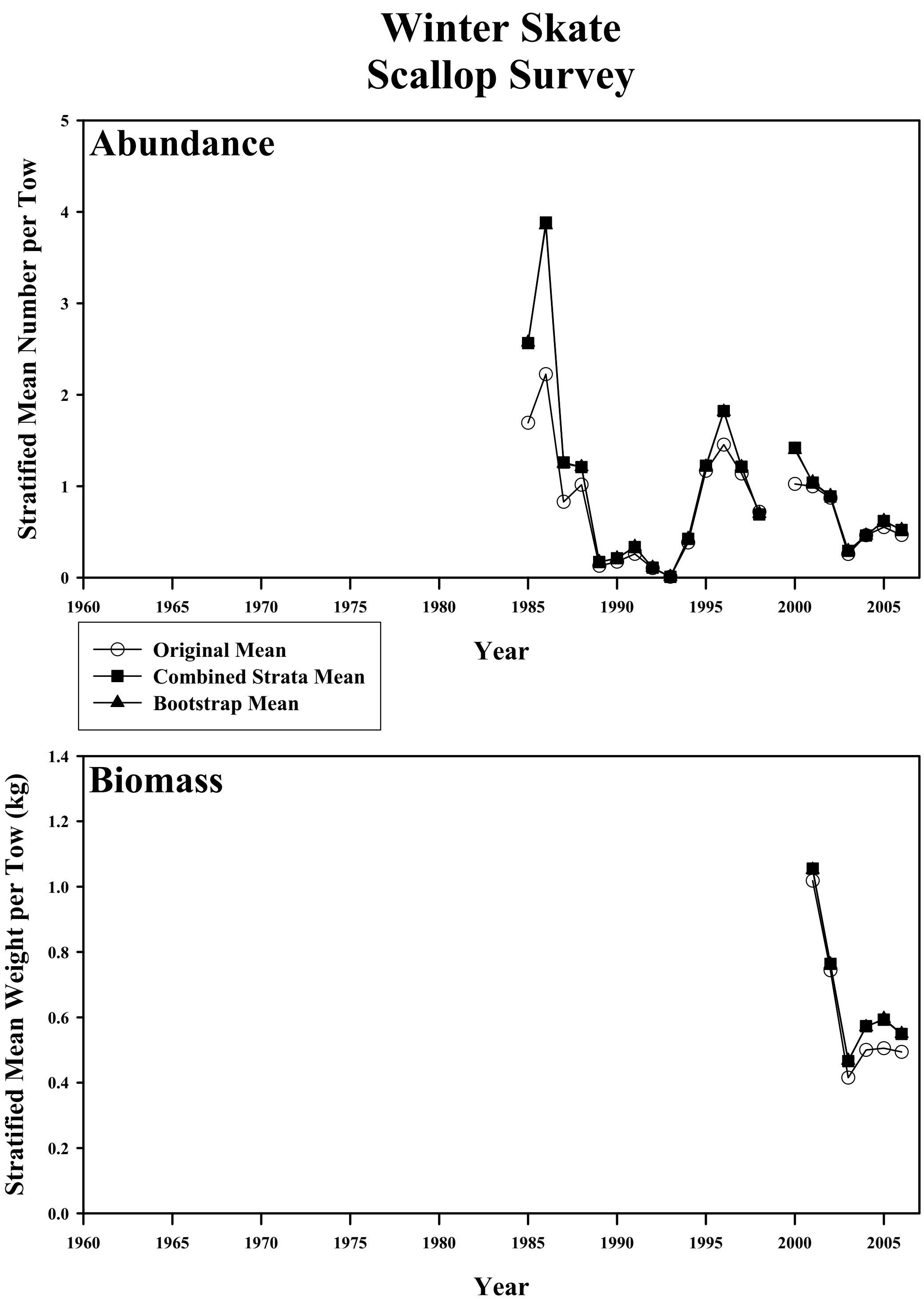


Figure B2.23. Abundance and biomass of winter skate from the NESFC scallop surveys from 1985-2006. The circles represent the original stratified mean, the squares represent the mean combining strata for bootstrapping, and the triangles represent the bootstrapped mean.

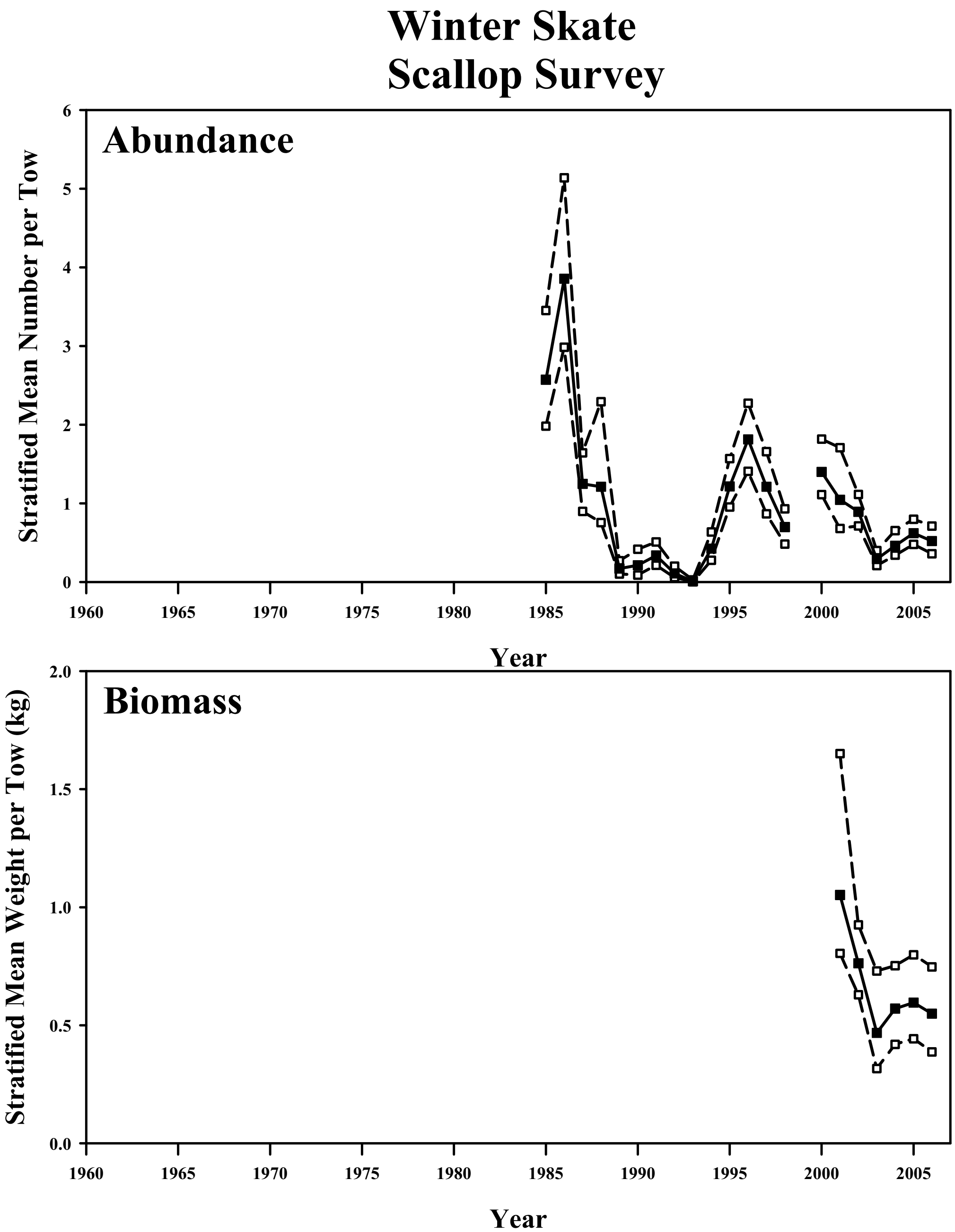


Figure B2.24. Bootstrapped abundance and biomass of winter skate from the NESFC scallop survey. Mean index in solid squares, 95% confidence interval in open squares.

Winter Skate - Massachusetts Trawl Survey

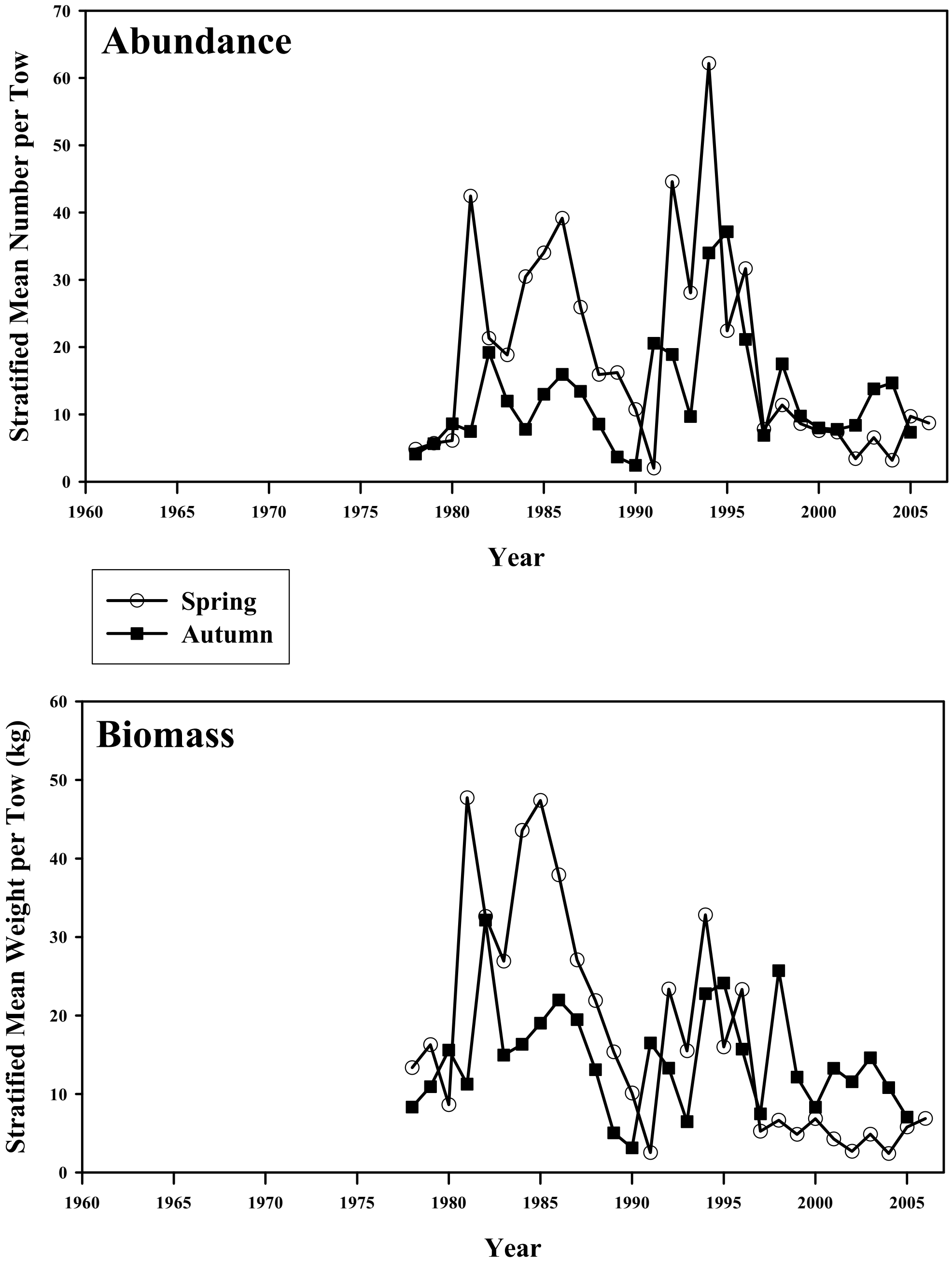


Figure B2.25. Abundance and biomass of winter skate from the Massachusetts spring and autumn finfish bottom trawl survey in state waters (strata 11-36).

Winter Skate - CTDEP Finfish Survey

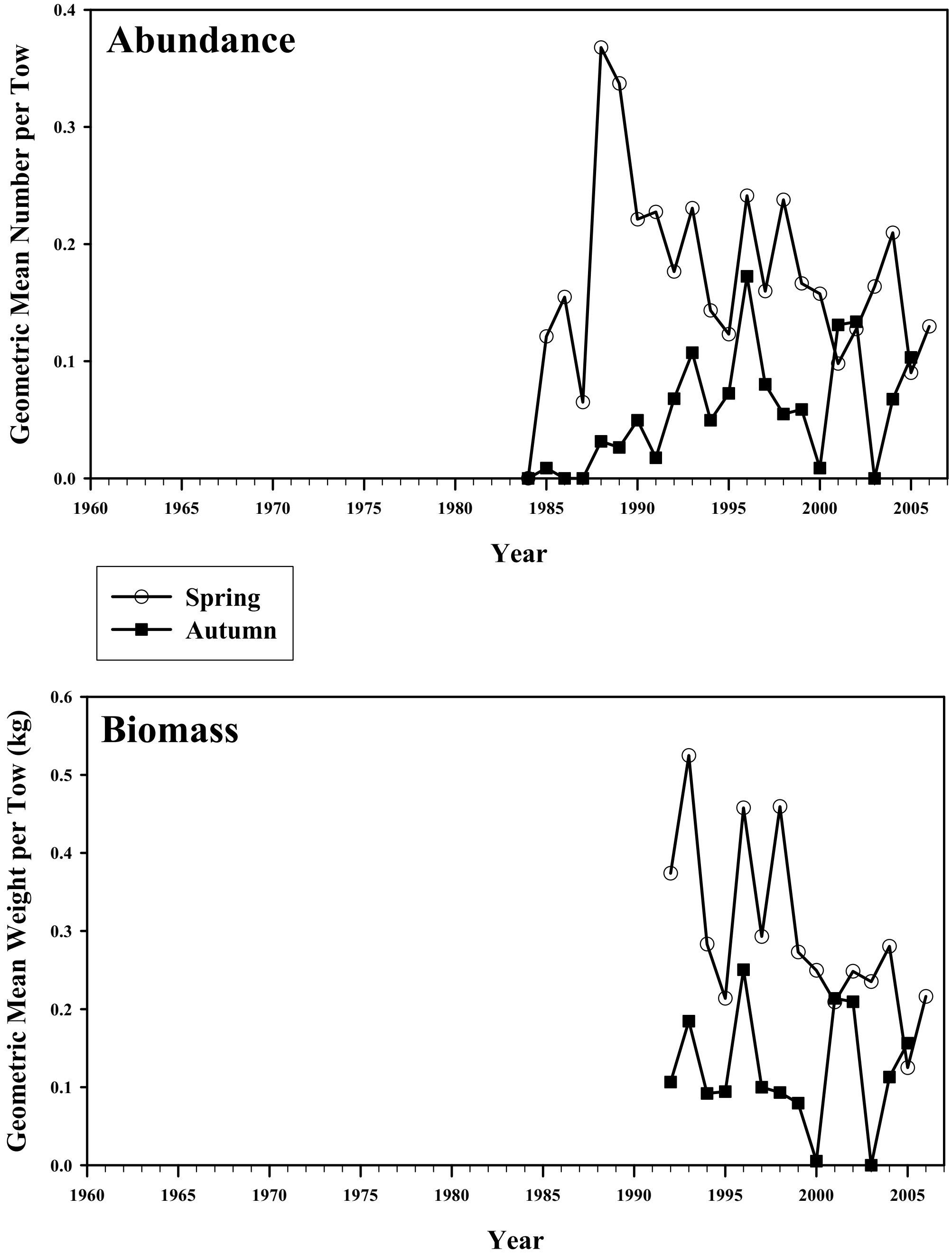


Figure B2.26. Abundance and biomass of winter skate from the CTDEP spring and autumn finfish bottom trawl survey in Connecticut state waters, 1984-2006.

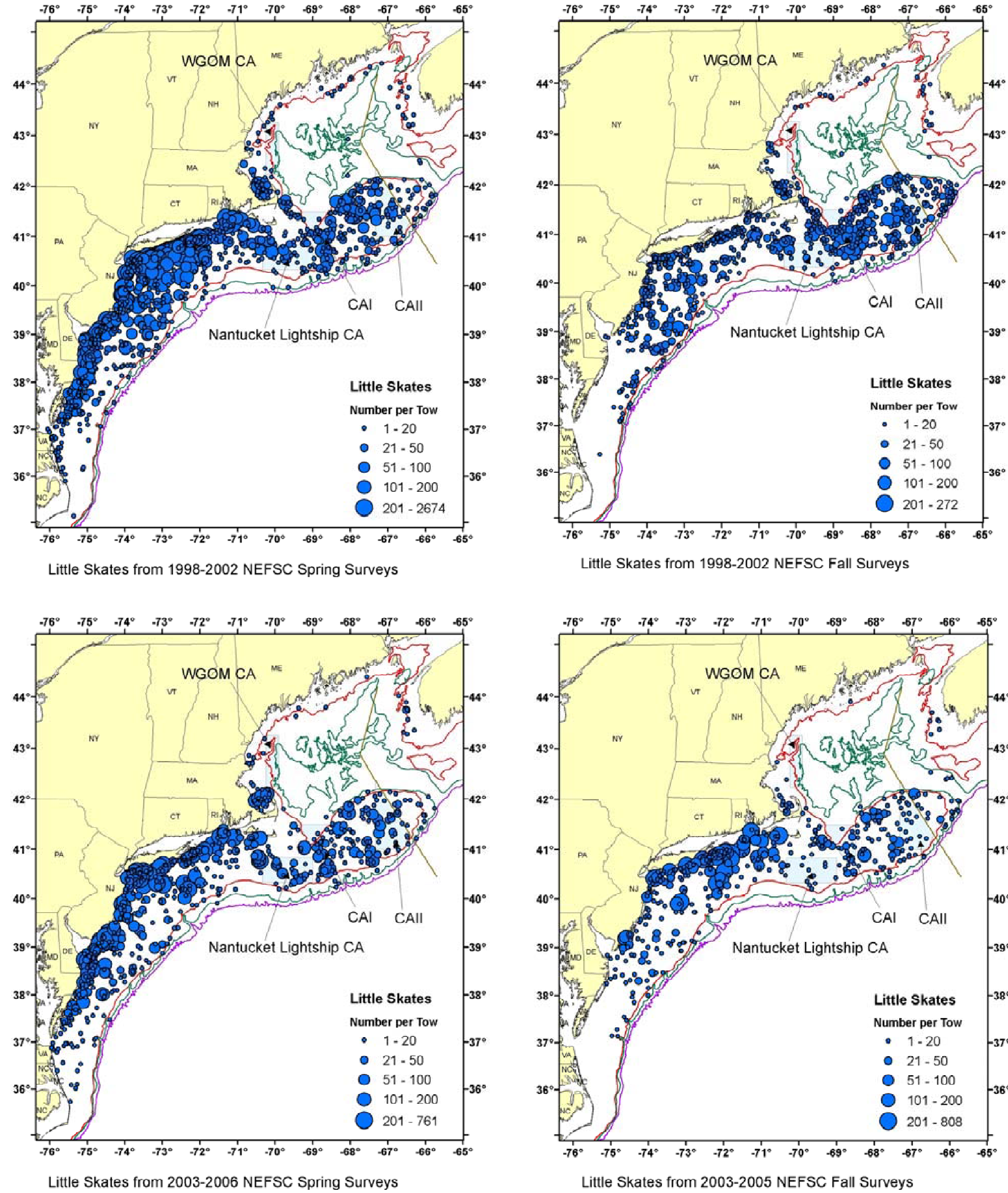
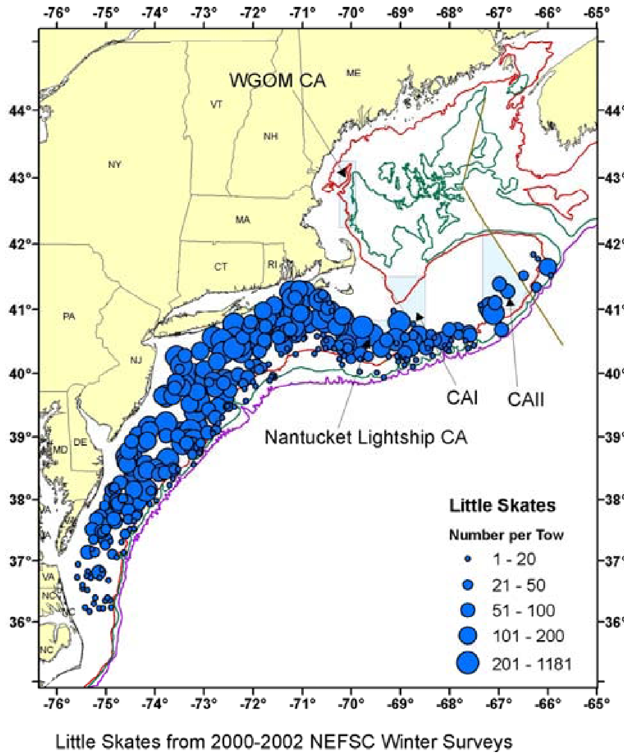


Figure B2.27. Distribution of little skate from the spring and autumn NEFSC surveys from 1998-2006.



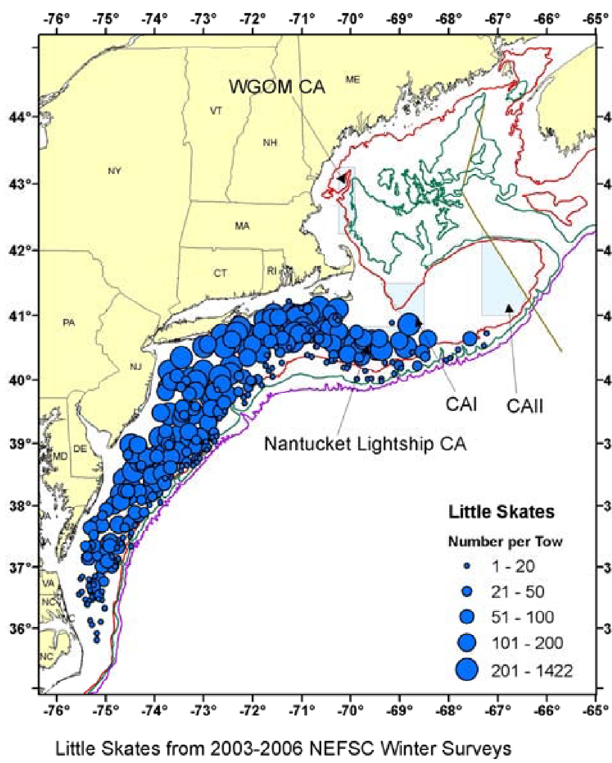
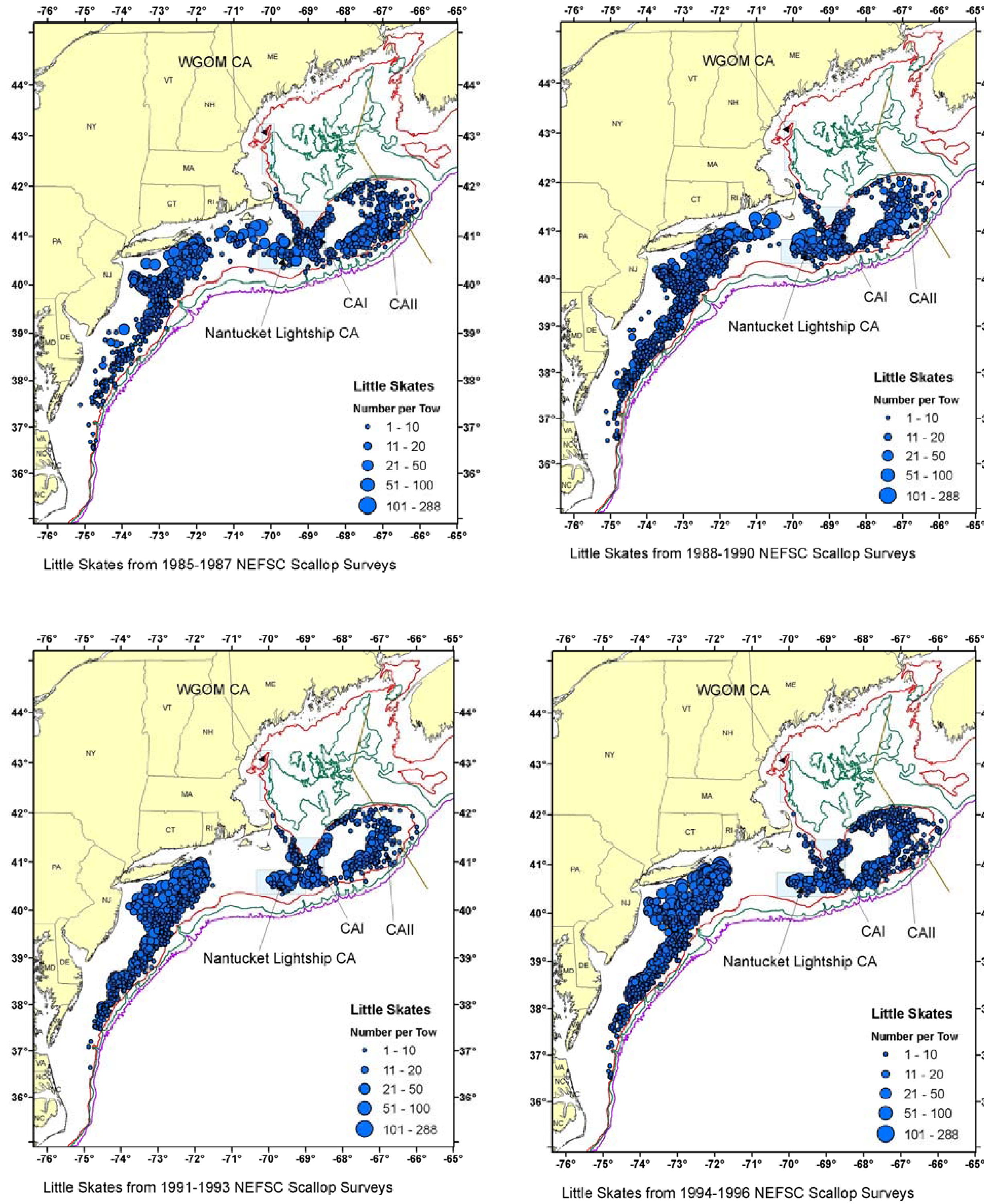


Figure B2.28. Distribution of little skate from the NEFSC winter surveys from 2000-2006.



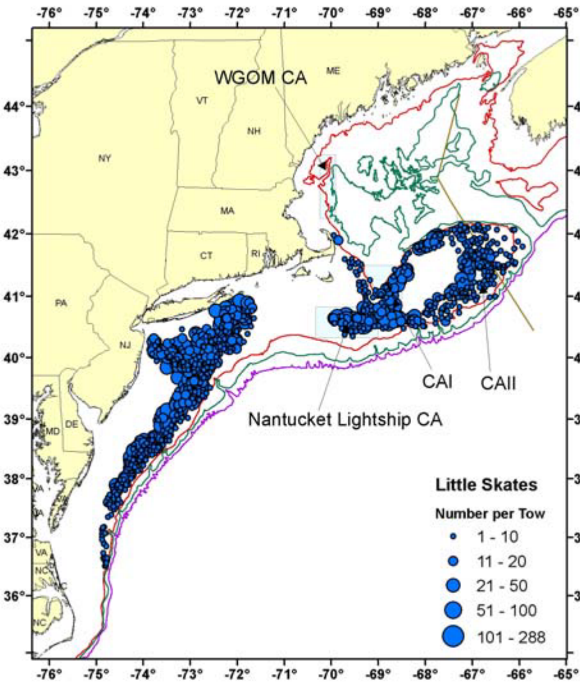
Little Skates from 1985-1987 NEFSC Scallop Surveys

Little Skates from 1988-1990 NEFSC Scallop Surveys

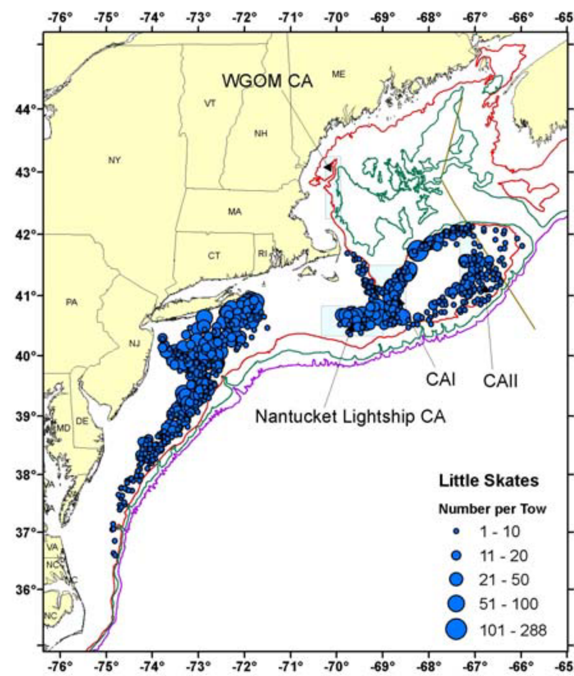
Little Skates from 1991-1993 NEFSC Scallop Surveys

Little Skates from 1994-1996 NEFSC Scallop Surveys

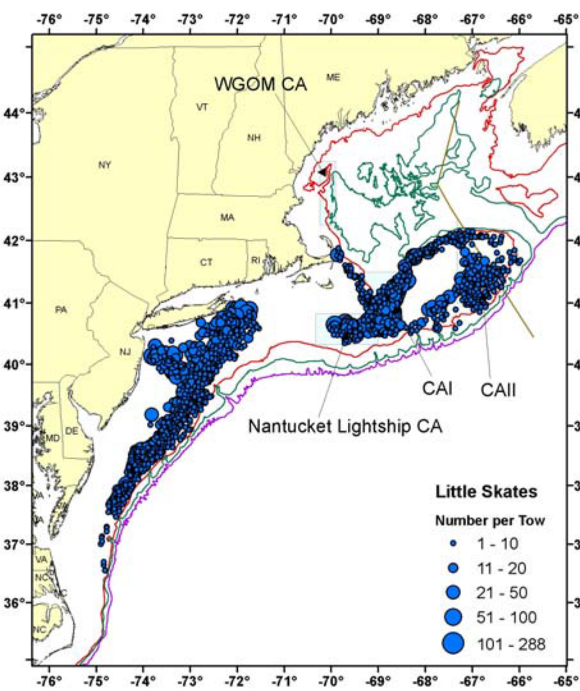
Figure B2.29. Distribution of little skate from the NEFSC scallop surveys from 1985-1996.



Little Skates from 1997-1999 NEFSC Scallop Surveys



Little Skates from 2000-2002 NEFSC Scallop Surveys



Little Skates from 2003-2006 NEFSC Scallop Surveys

Figure B2.30. Distribution of little skate from the NEFSC scallop surveys from 1997-2006.

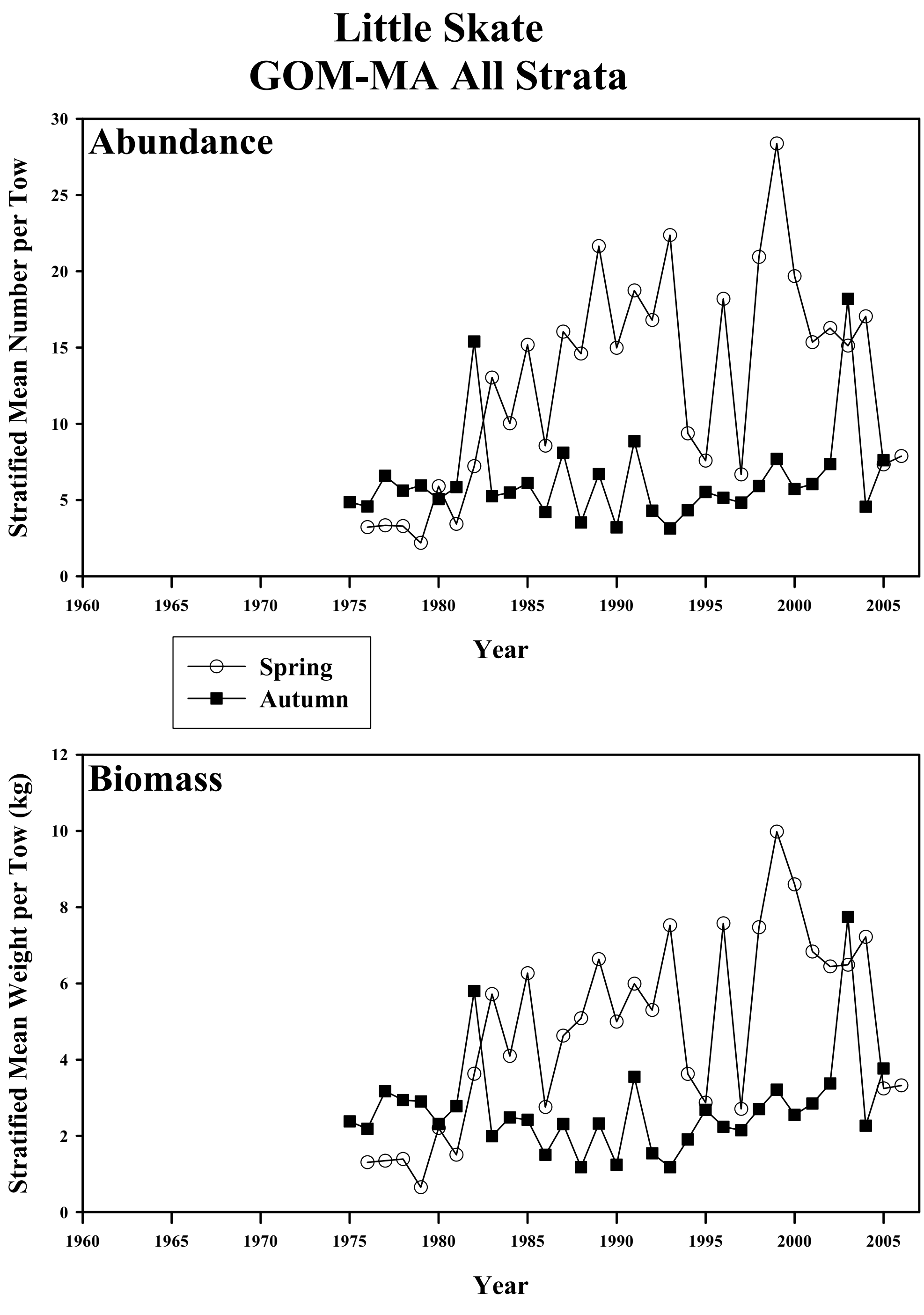


Figure B2.31. Abundance and biomass of little skate from the NESFC spring (circles) and autumn (squares) bottom trawl surveys from 1975-2006 in the Gulf of Maine to Mid-Atlantic (all strata).

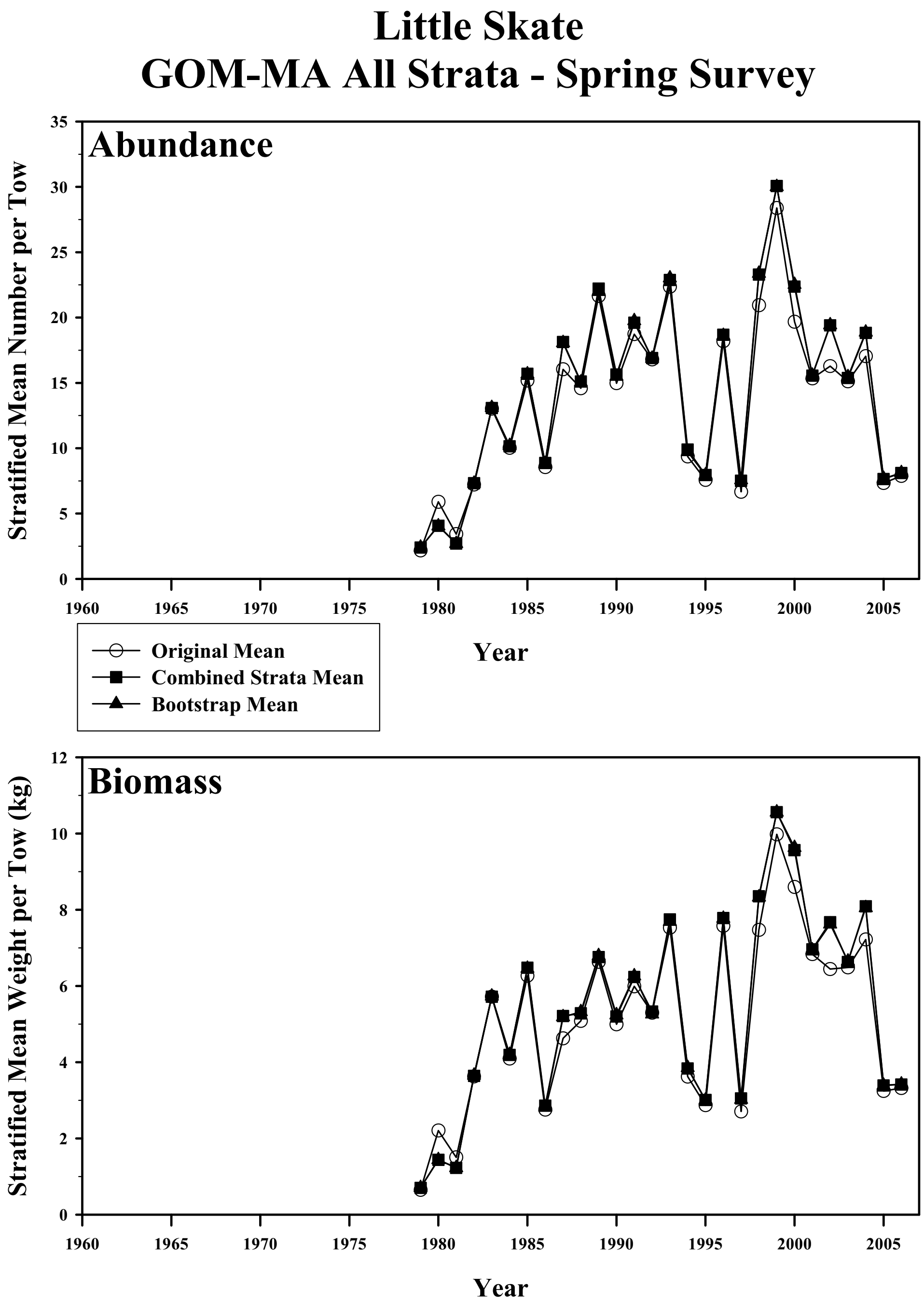


Figure B2.32. Abundance and biomass of little skate from the NESFC spring bottom trawl surveys from 1979-2006 in the Gulf of Maine to Mid-Atlantic (all strata). The circles represent the original stratified mean, the squares represent the mean combining strata for bootstrapping, and the triangles represent the bootstrapped mean.

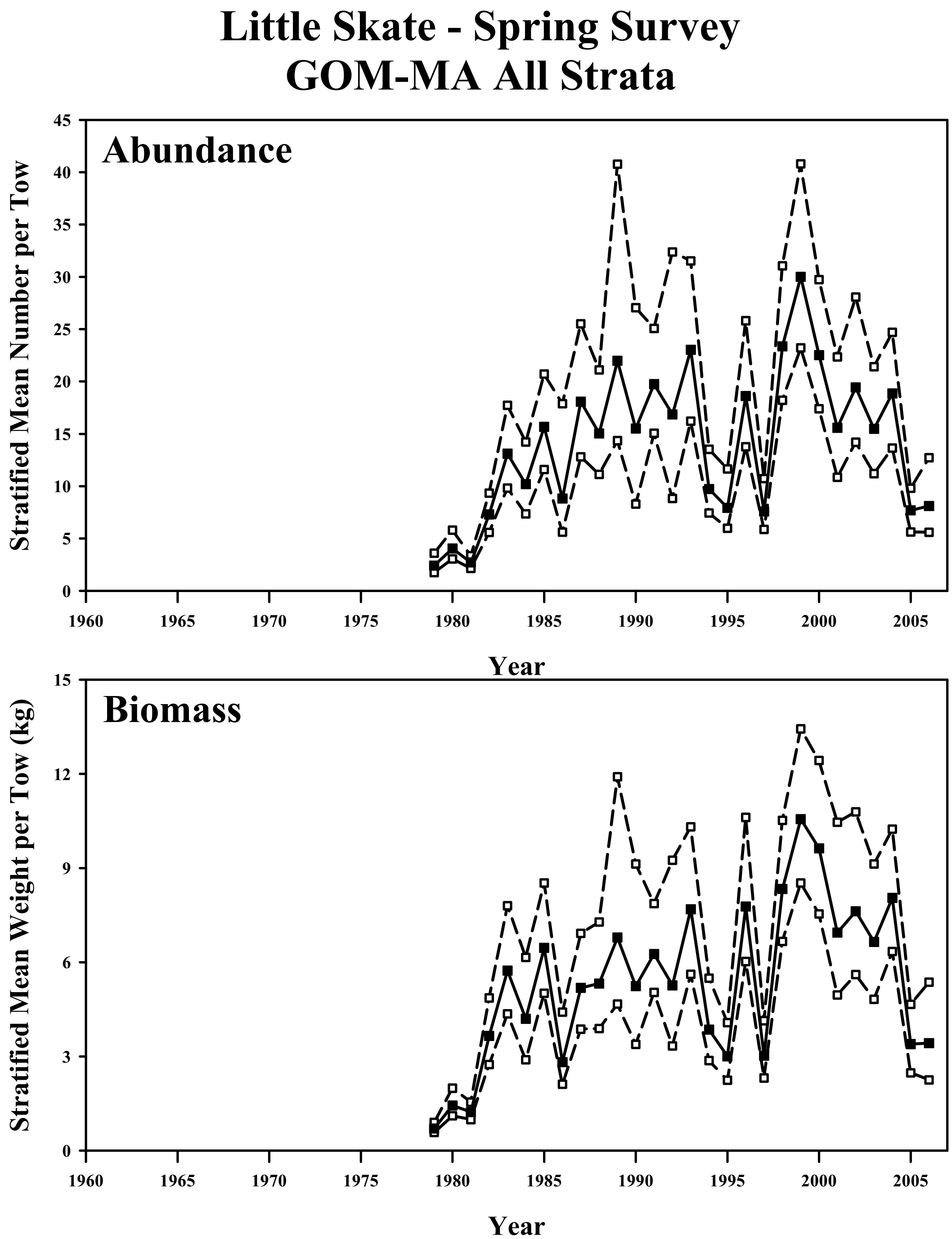


Figure B2.33. Bootstrapped abundance and biomass of little skate from the NESFC spring bottom trawl survey in the Gulf of Maine to Mid-Atlantic region (all strata). Mean index in solid squares, 95% confidence interval in open squares.

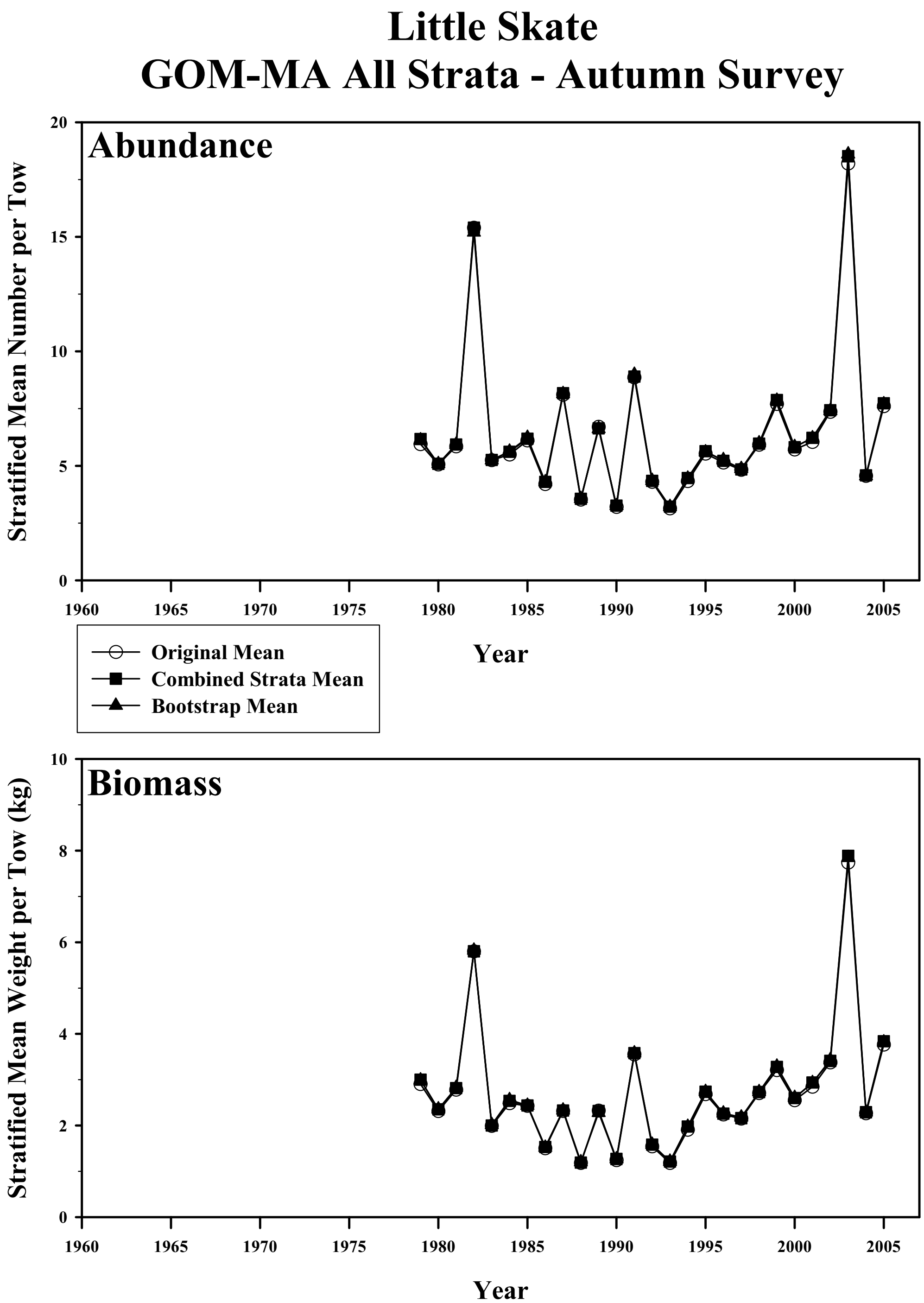


Figure B2.34. Abundance and biomass of little skate from the NESFC autumn bottom trawl surveys from 1979-2005 in the Gulf of Maine to Mid-Atlantic (all strata). The circles represent the original stratified mean, the squares represent the mean combining strata for bootstrapping, and the triangles represent the bootstrapped mean.

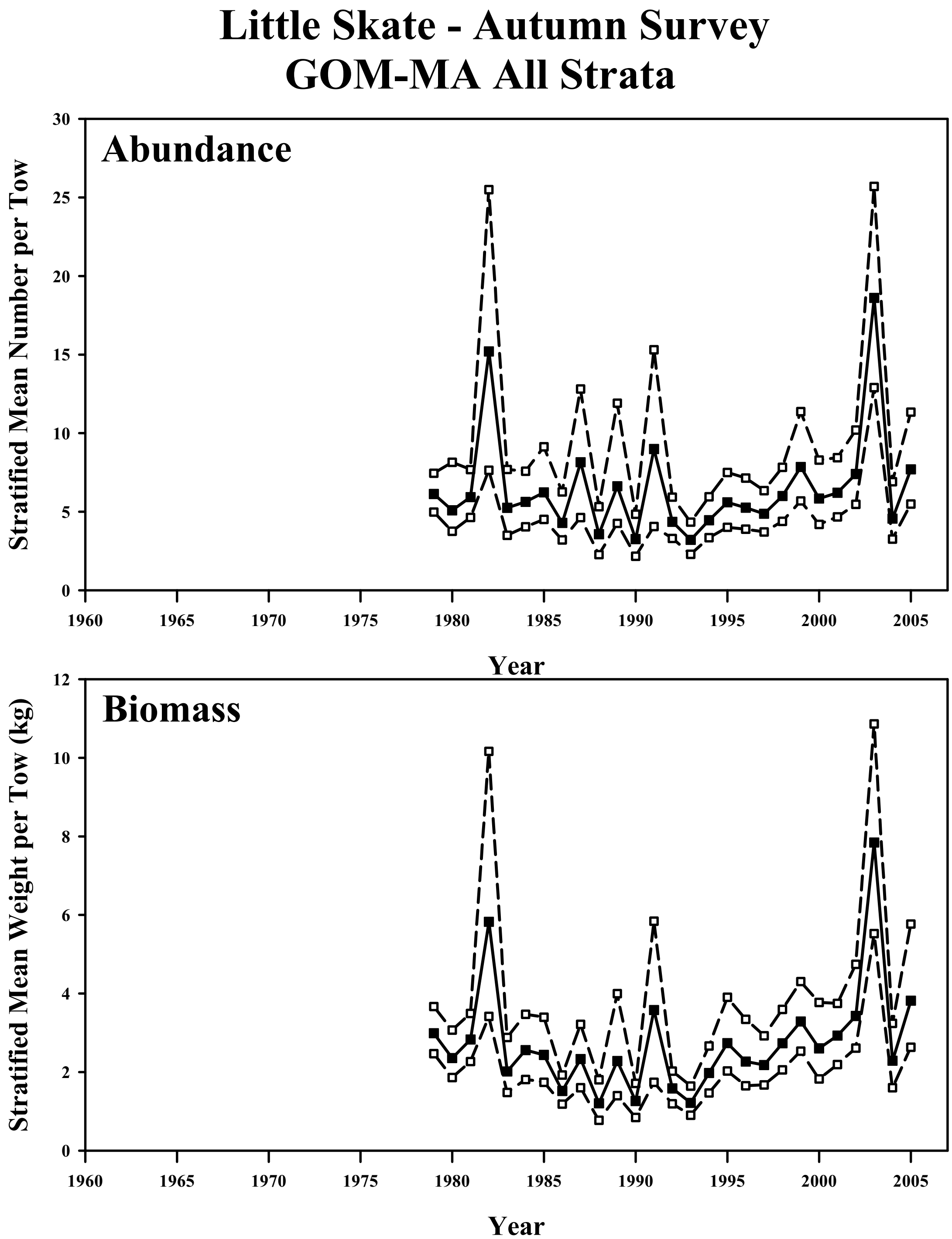
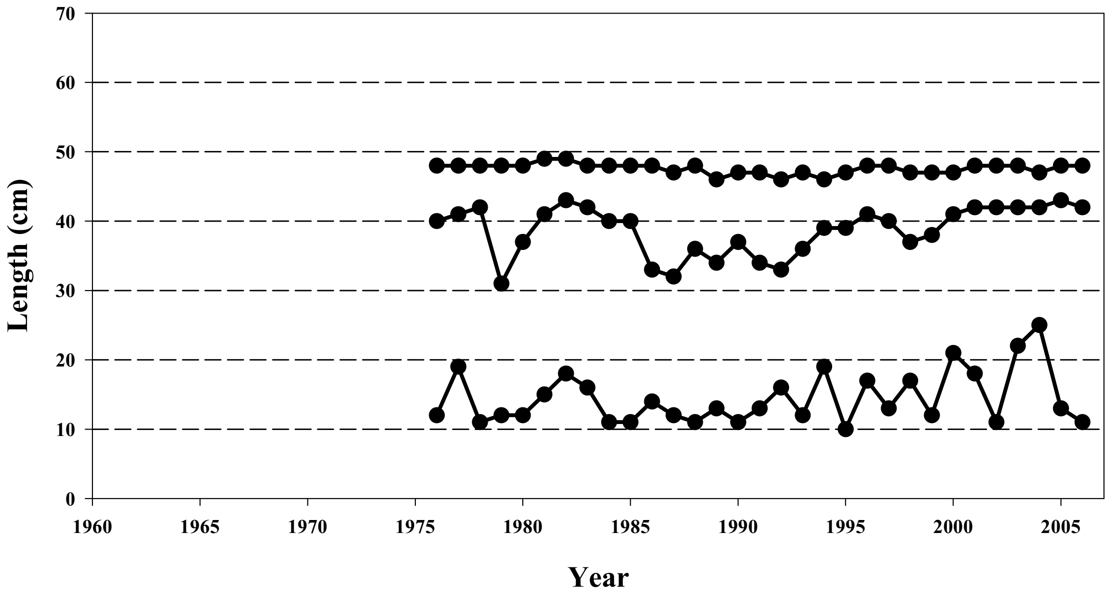


Figure B2.35. Bootstrapped abundance and biomass of little skate from the NESFC autumn bottom trawl survey in the Gulf of Maine to Mid-Atlantic region (all strata). Mean index in solid squares, 95% confidence interval in open squares.

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

Spring Survey



Autumn Survey

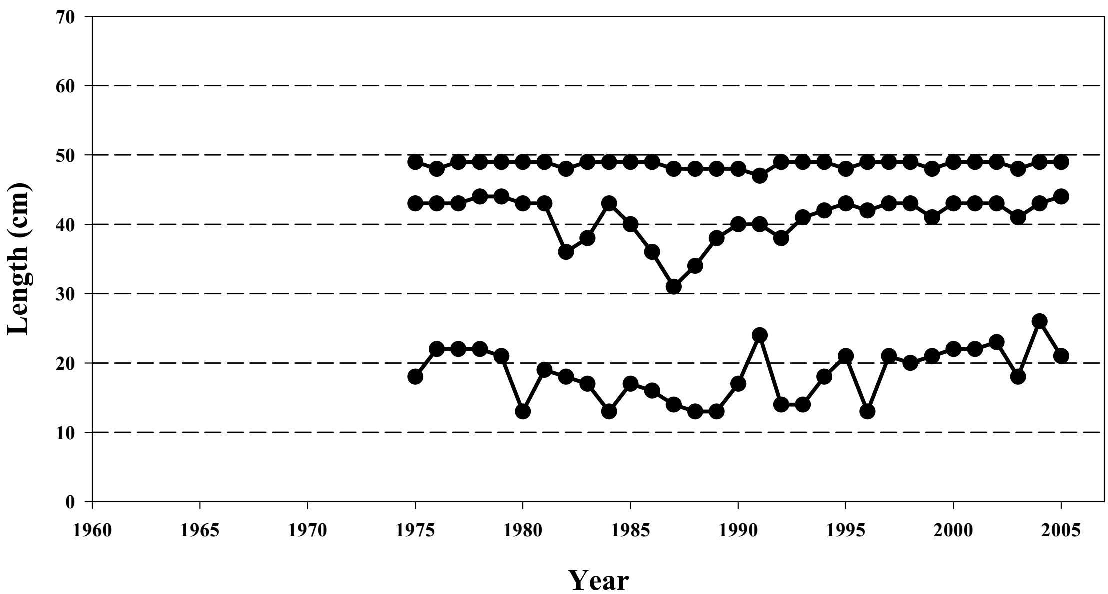


Figure B2.36. Percentiles of length composition (5, 50, and 95) of little skate from the NESFC spring and autumn bottom trawl surveys from 1975-2006 in the Gulf of Maine to Mid-Atlantic region (all strata).

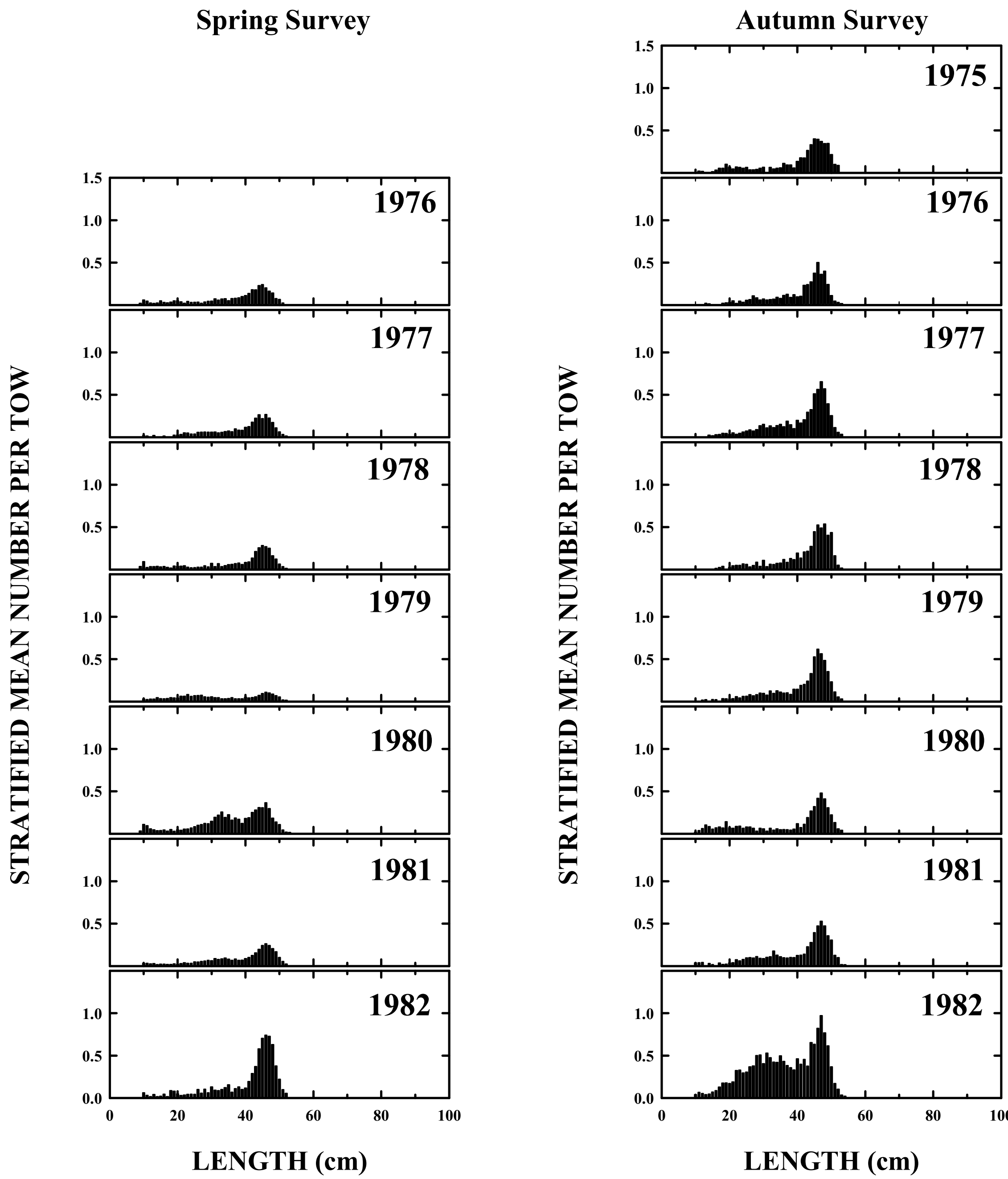


Figure B2.37. Little skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Mid-Atlantic (all strata), 1975-1982.

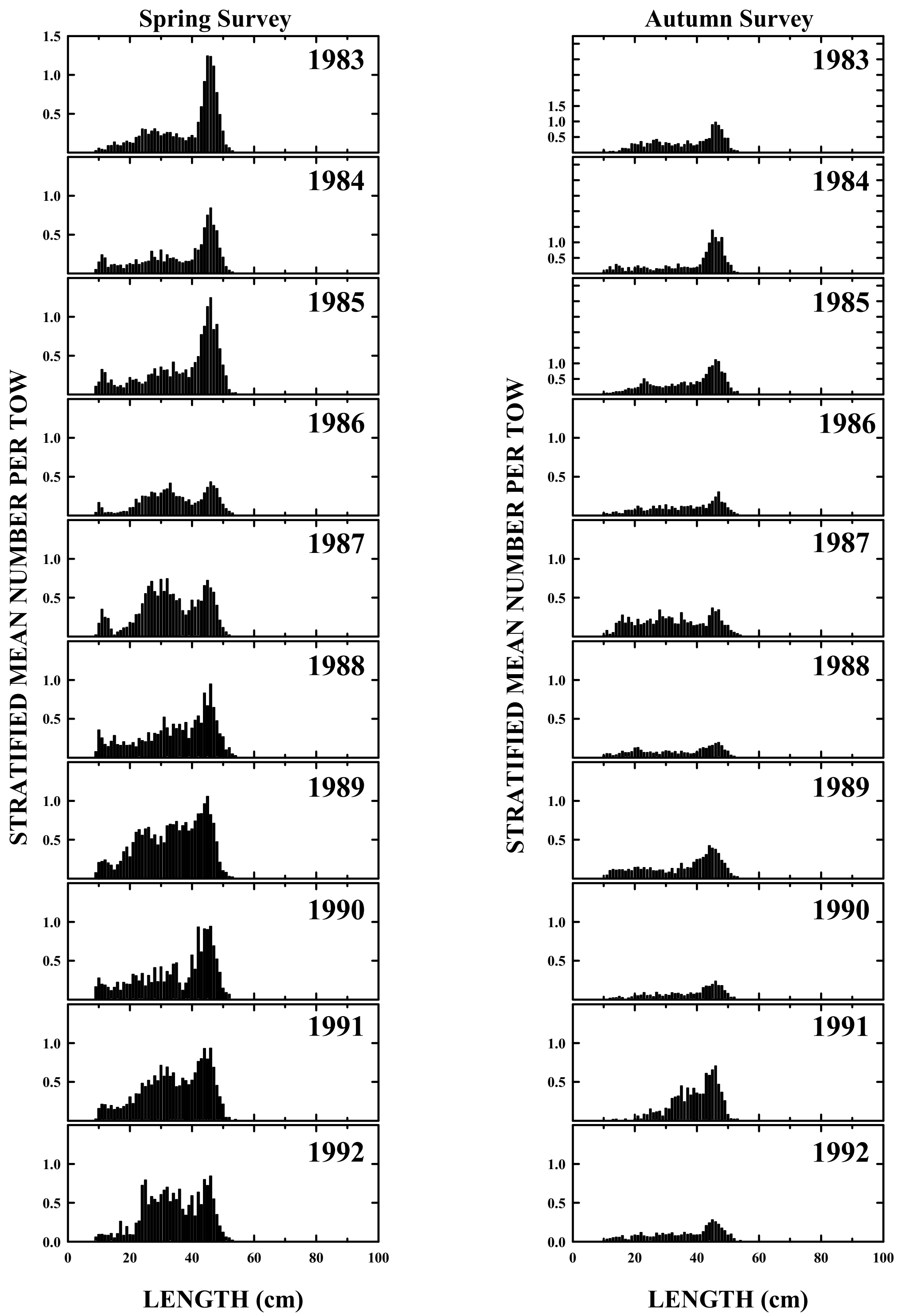


Figure B2.38. Little skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Mid-Atlantic (all strata), 1983-1992.

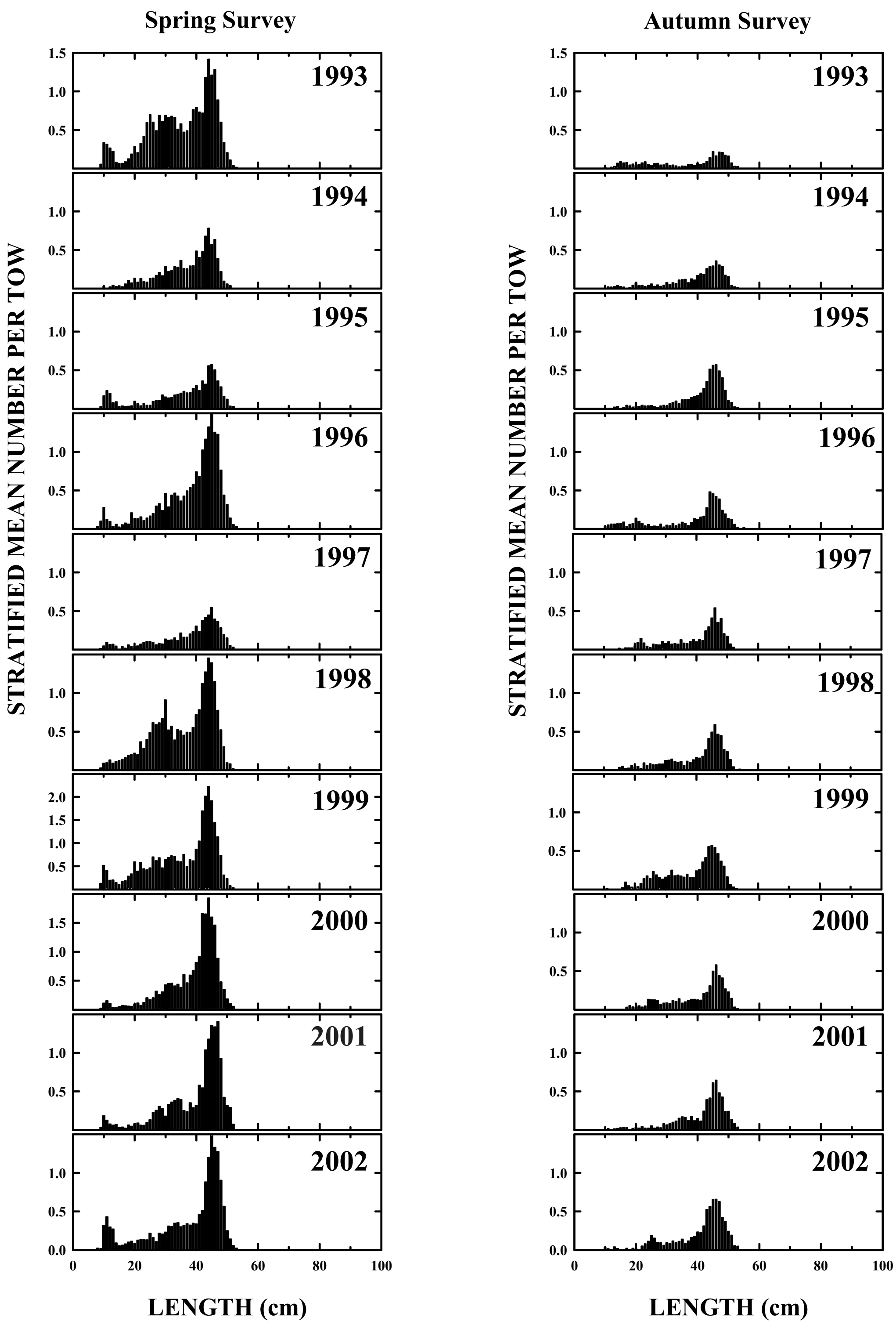


Figure B2.39. Little skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Mid-Atlantic (all strata), 1993-2002.

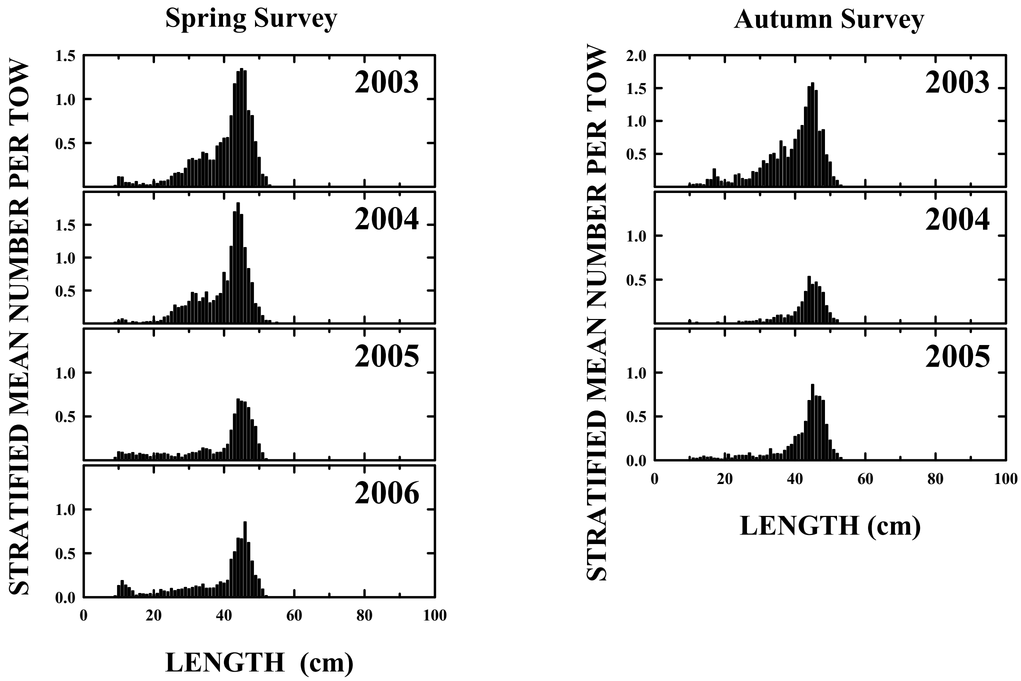


Figure B2.40. Little skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Mid-Atlantic (all strata), 2003-2006.

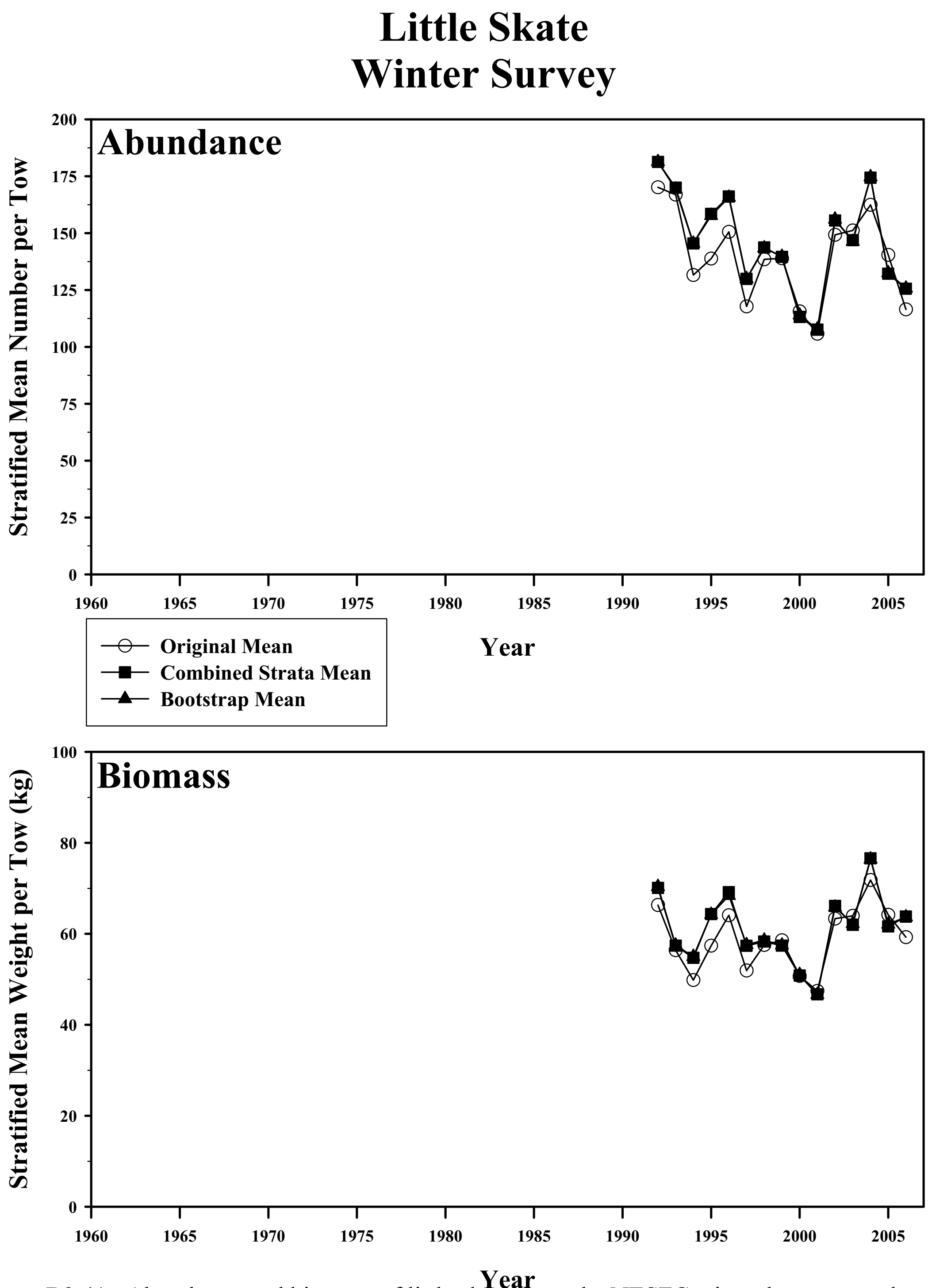


Figure B2.41. Abundance and biomass of little skate from the NESFC winter bottom trawl surveys from 1992-2006. The circles represent the original stratified mean, the squares represent the mean combining strata for bootstrapping, and the triangles represent the bootstrapped mean.

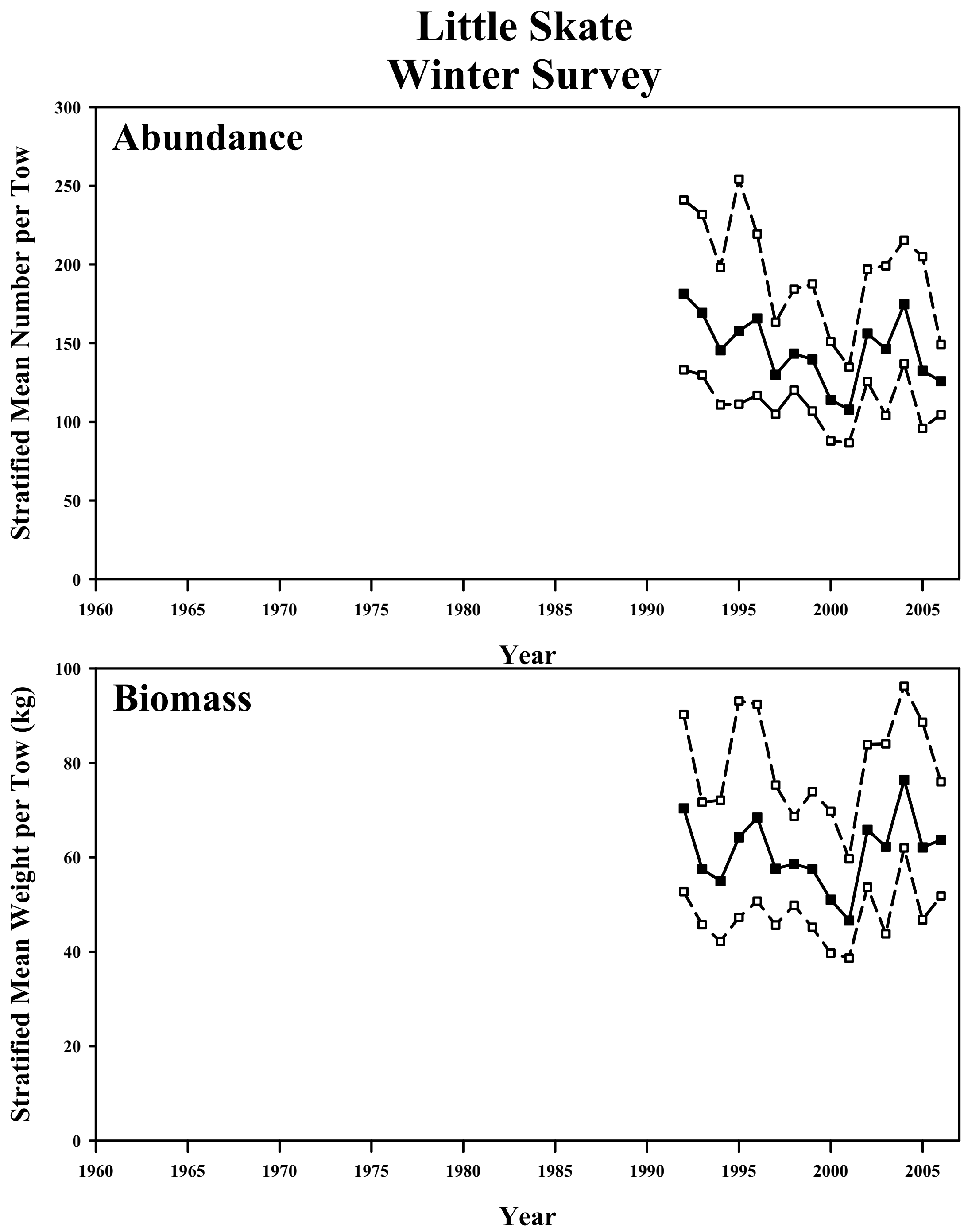


Figure B2.42. Bootstrapped abundance and biomass of little skate from the NESFC winter bottom trawl survey. Mean index in solid squares, 95% confidence interval in open squares.

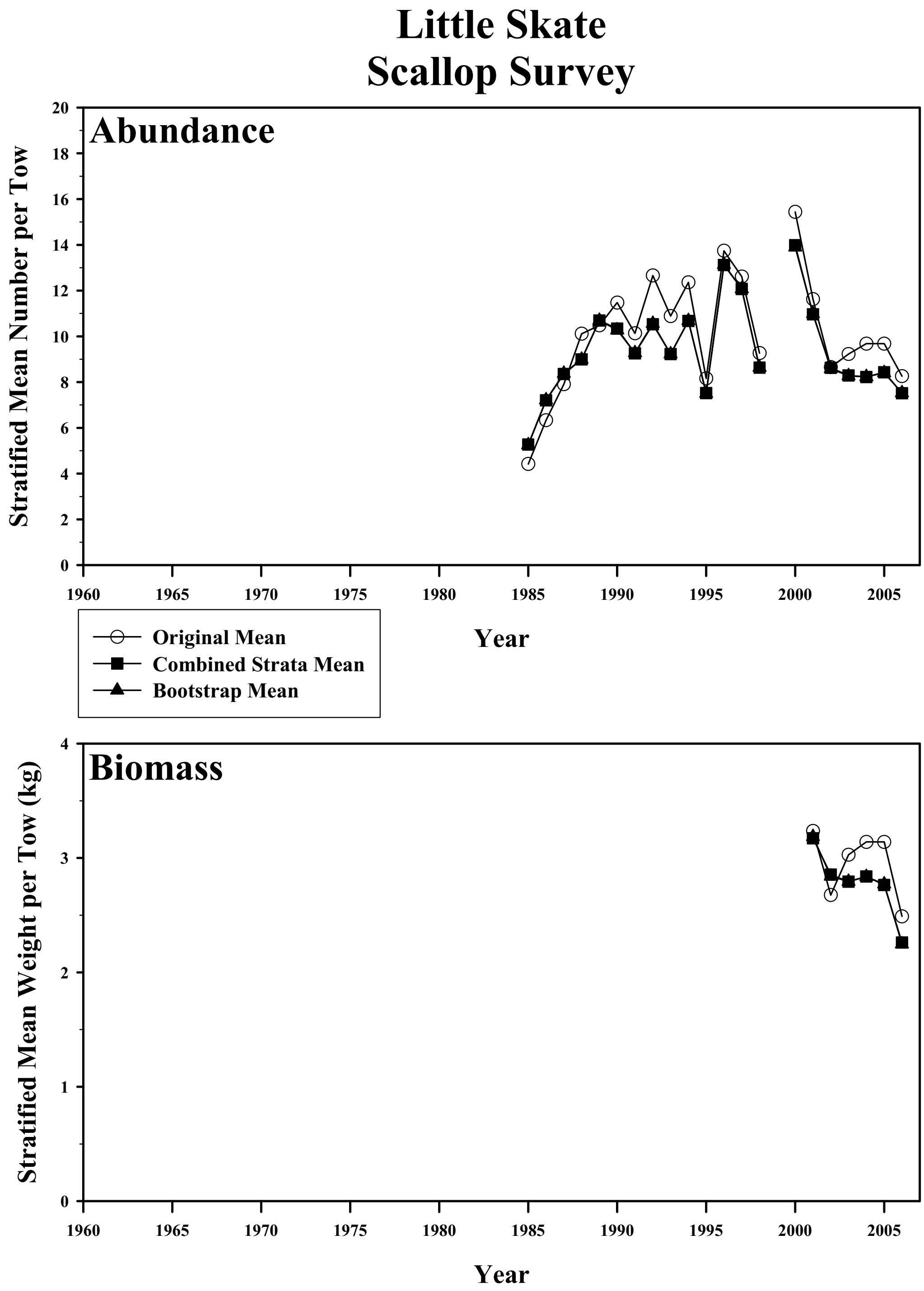


Figure B2.43. Abundance and biomass of little skate from the NESFC scallop surveys from 1985-2006. The circles represent the original stratified mean, the squares represent the mean combining strata for bootstrapping, and the triangles represent the bootstrapped mean.

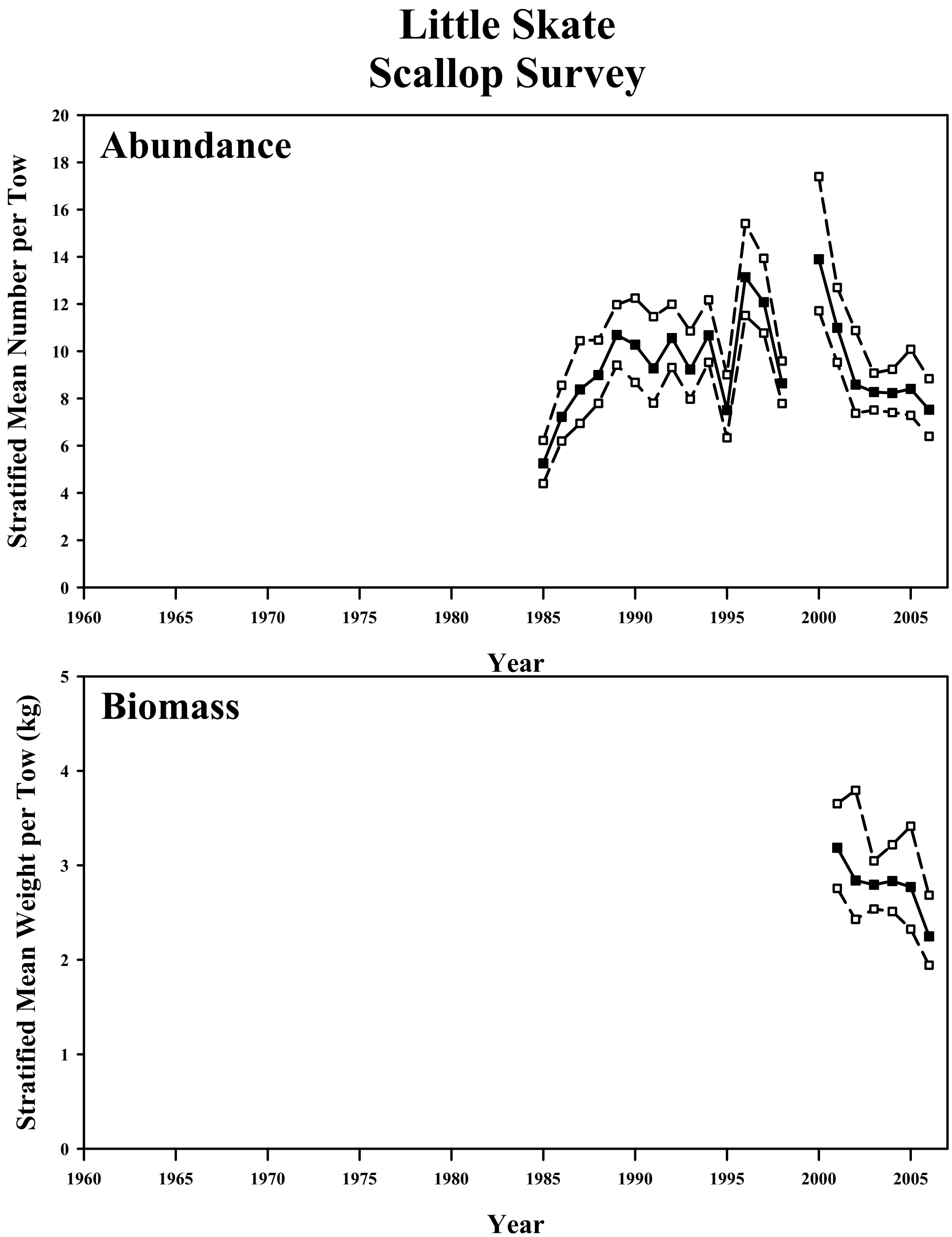


Figure B2.44. Bootstrapped abundance and biomass of little skate from the NESFC scallop survey. Mean index in solid squares, 95% confidence interval in open squares.

Little Skate - Massachusetts Trawl Survey

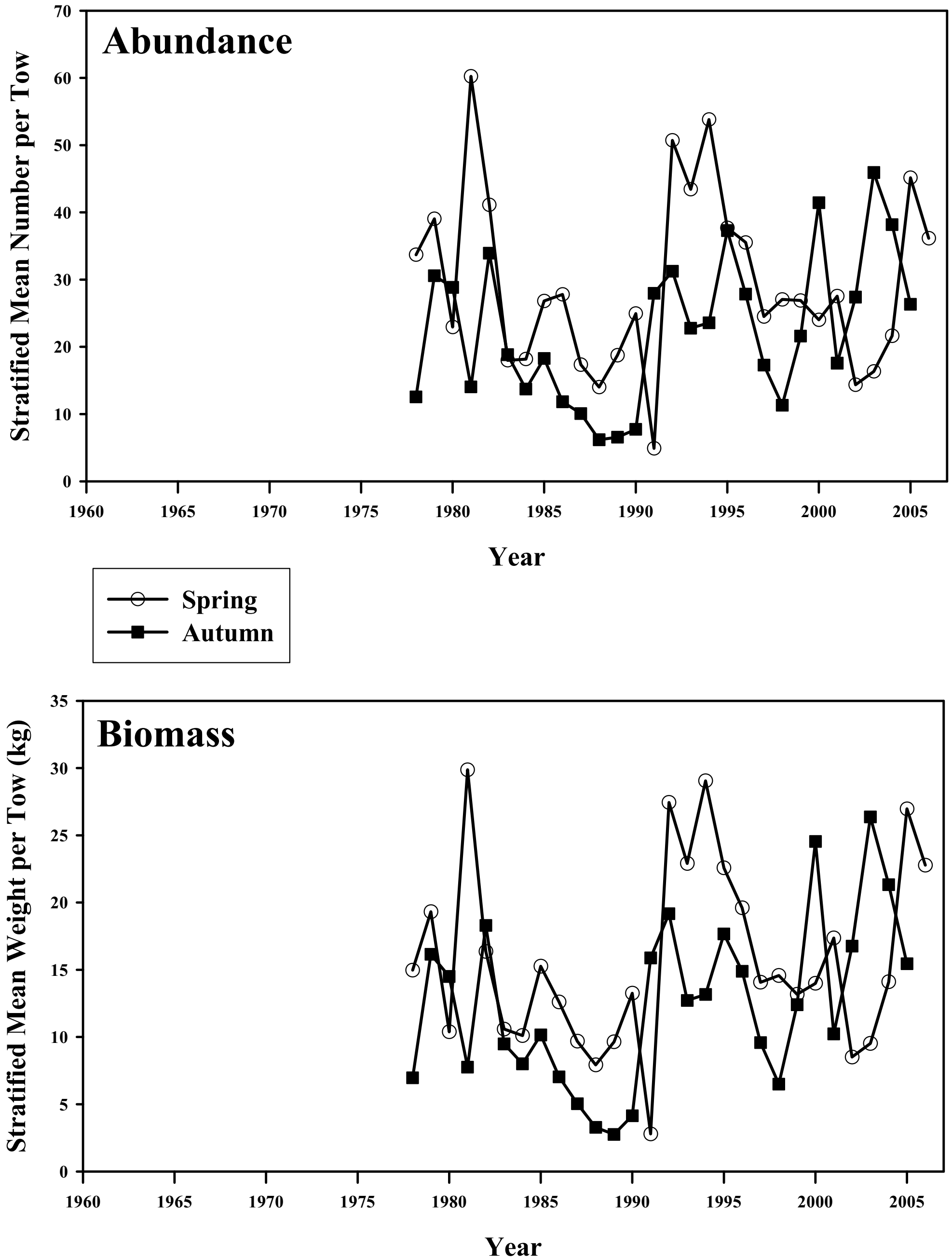


Figure 2.45. Abundance and biomass of little skate from the Massachusetts spring and autumn finfish bottom trawl survey in state waters (strata 11-36).

Little Skate - CTDEP Finfish Survey

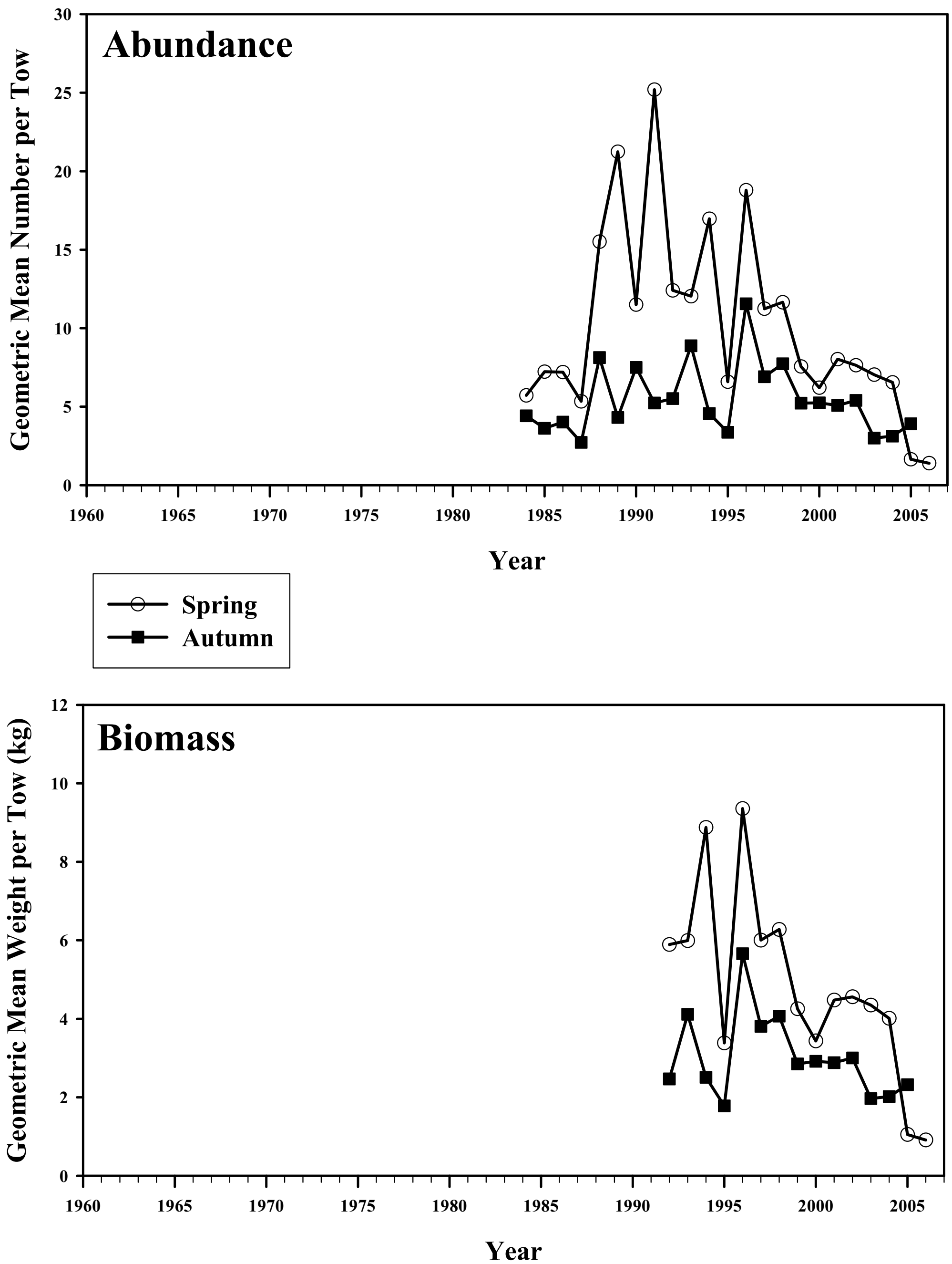
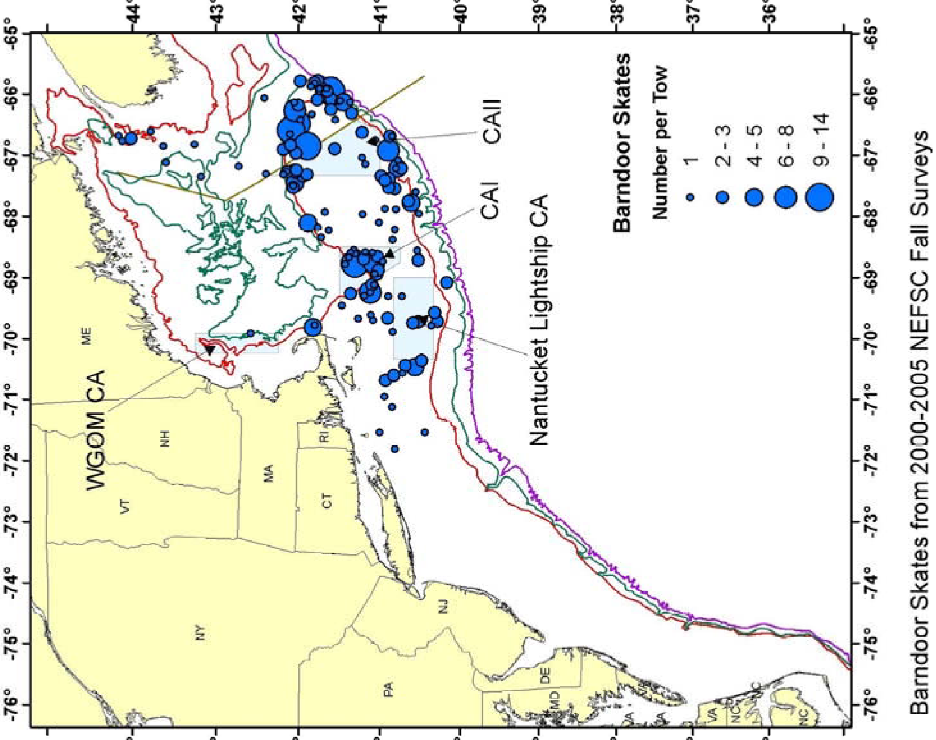


Figure B2.46. Abundance and biomass of little skate from the CTDEP spring and autumn finfish bottom trawl survey in Connecticut state waters, 1984-2006.



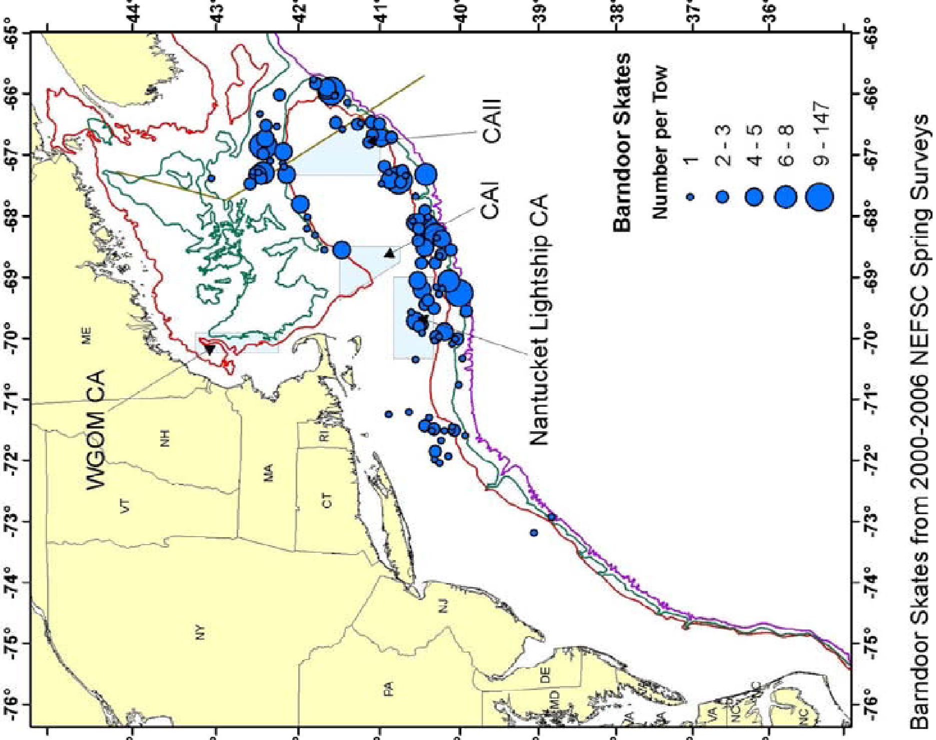


Figure B2.47. Distribution of barndoor skate from the spring and autumn NEFSC surveys from 2000-2006.

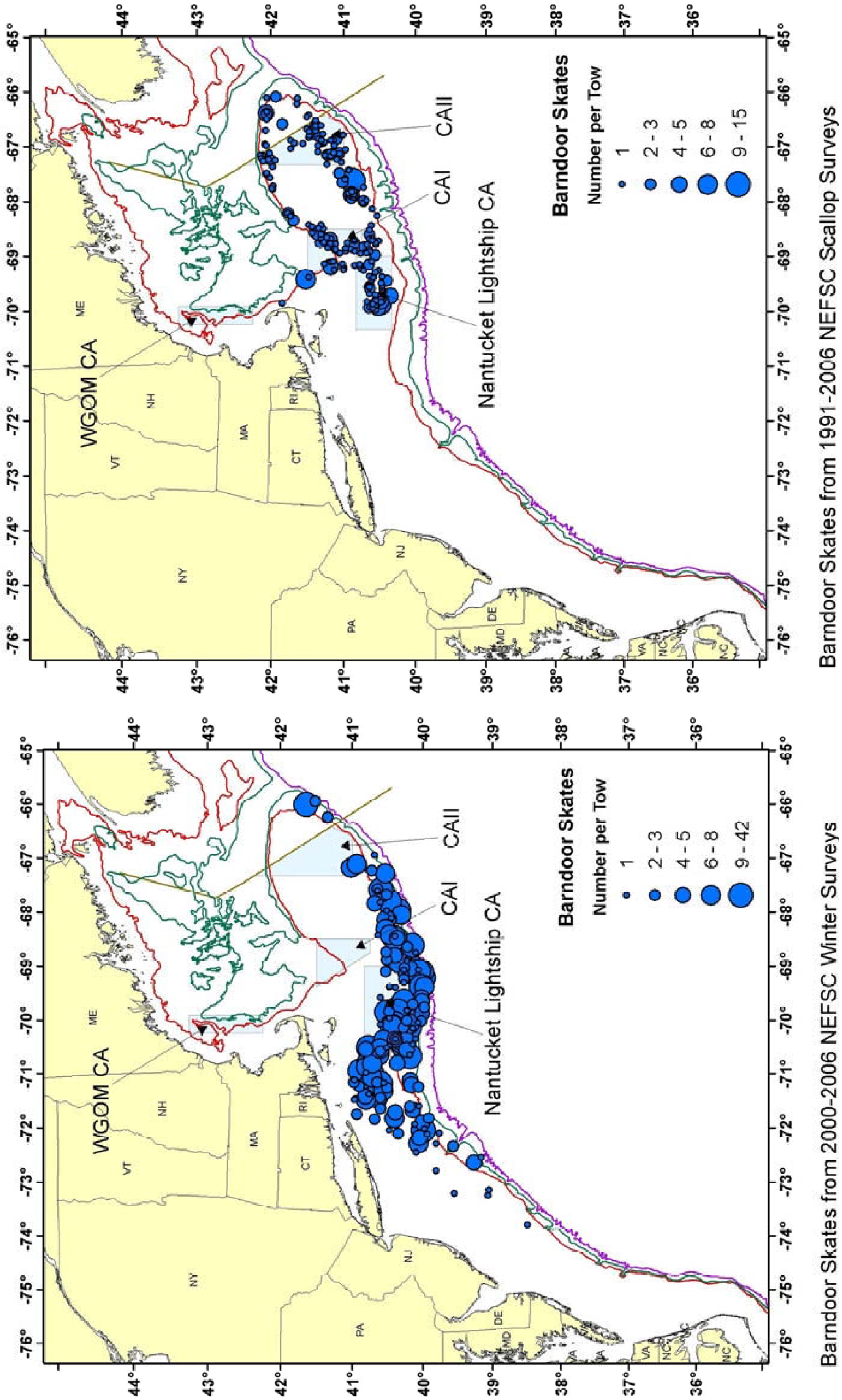


Figure B2.48. Distribution of barndoor skate from the winter NEFSC surveys from 2000-2006 and the NEFSC scallop surveys from 1991-2006.

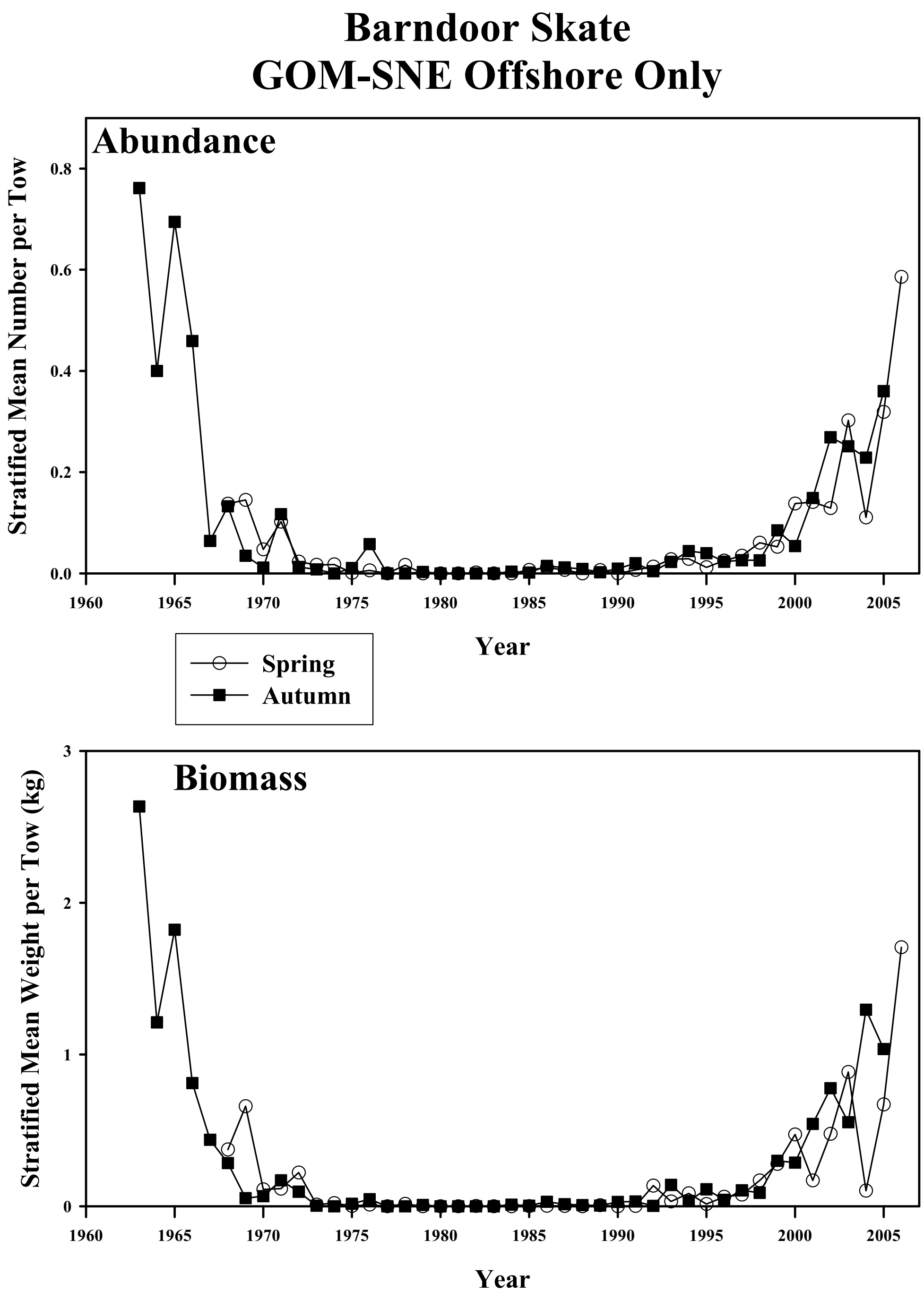


Figure B2.49. Abundance and biomass of barndoor skate from the NESFC spring (circles) and autumn (squares) bottom trawl surveys from 1963-2006 in the Gulf of Maine to Southern New England offshore region.

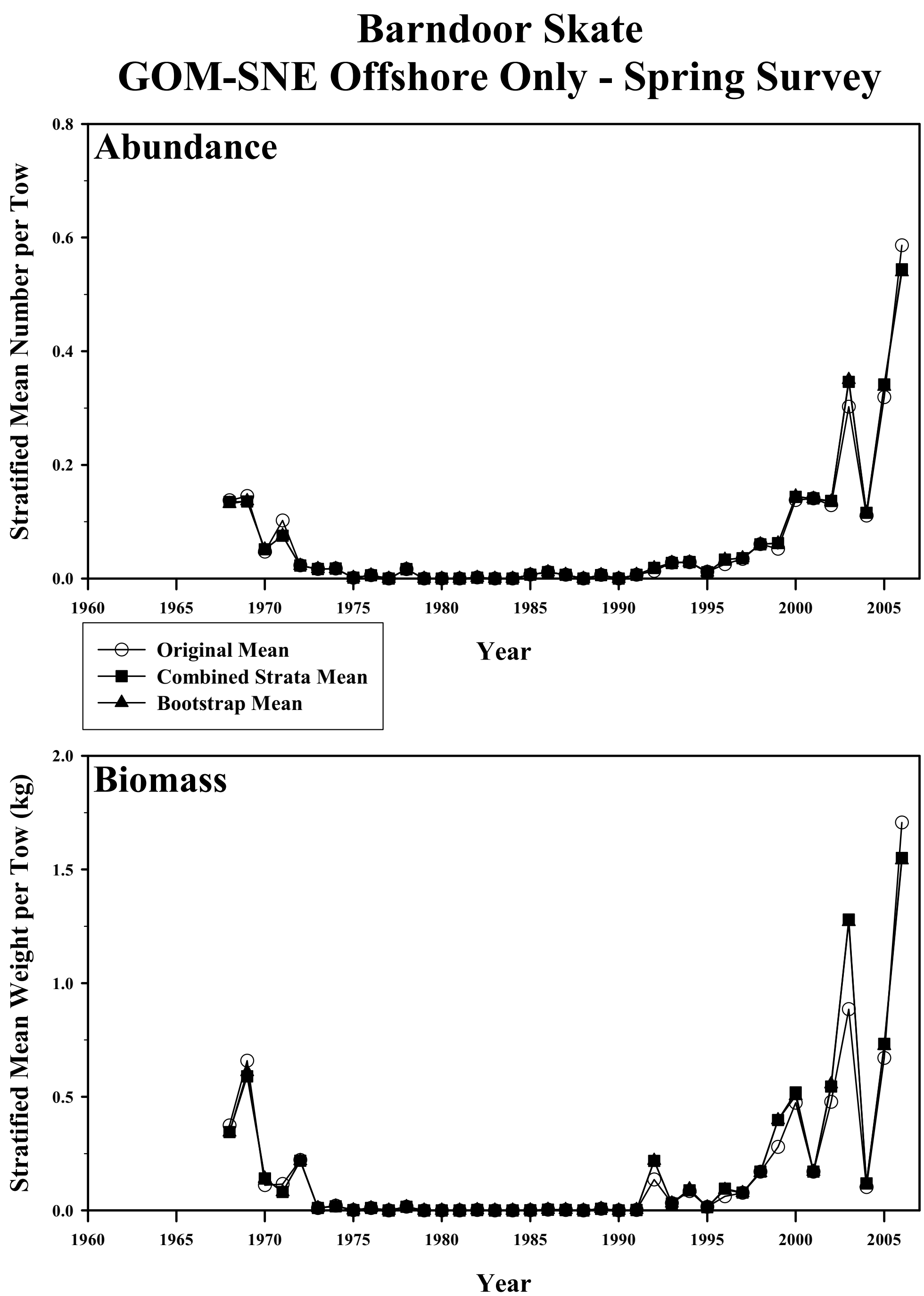


Figure B2.50. Abundance and biomass of barndoor skate from the NESFC spring bottom trawl surveys from 1968-2006 in the Gulf of Maine to Southern New England offshore region. The circles represent the original stratified mean, the squares represent the mean combining strata for bootstrapping, and the triangles represent the bootstrapped mean.

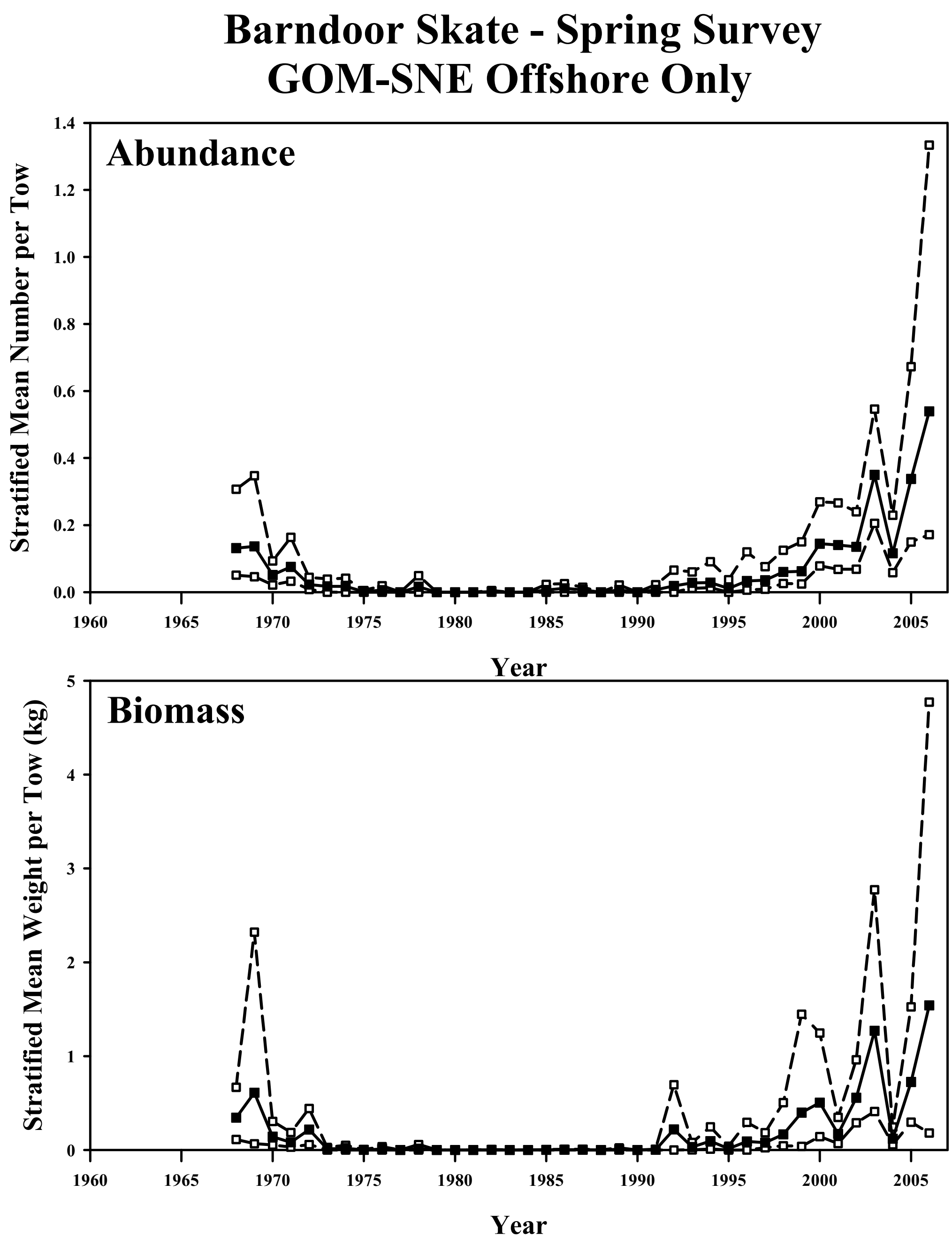


Figure B2.51. Bootstrapped abundance and biomass of barndoor skate from the NESFC spring bottom trawl survey in the Gulf of Maine to Southern New England offshore region. Mean index in solid squares, 95% confidence interval in open squares.

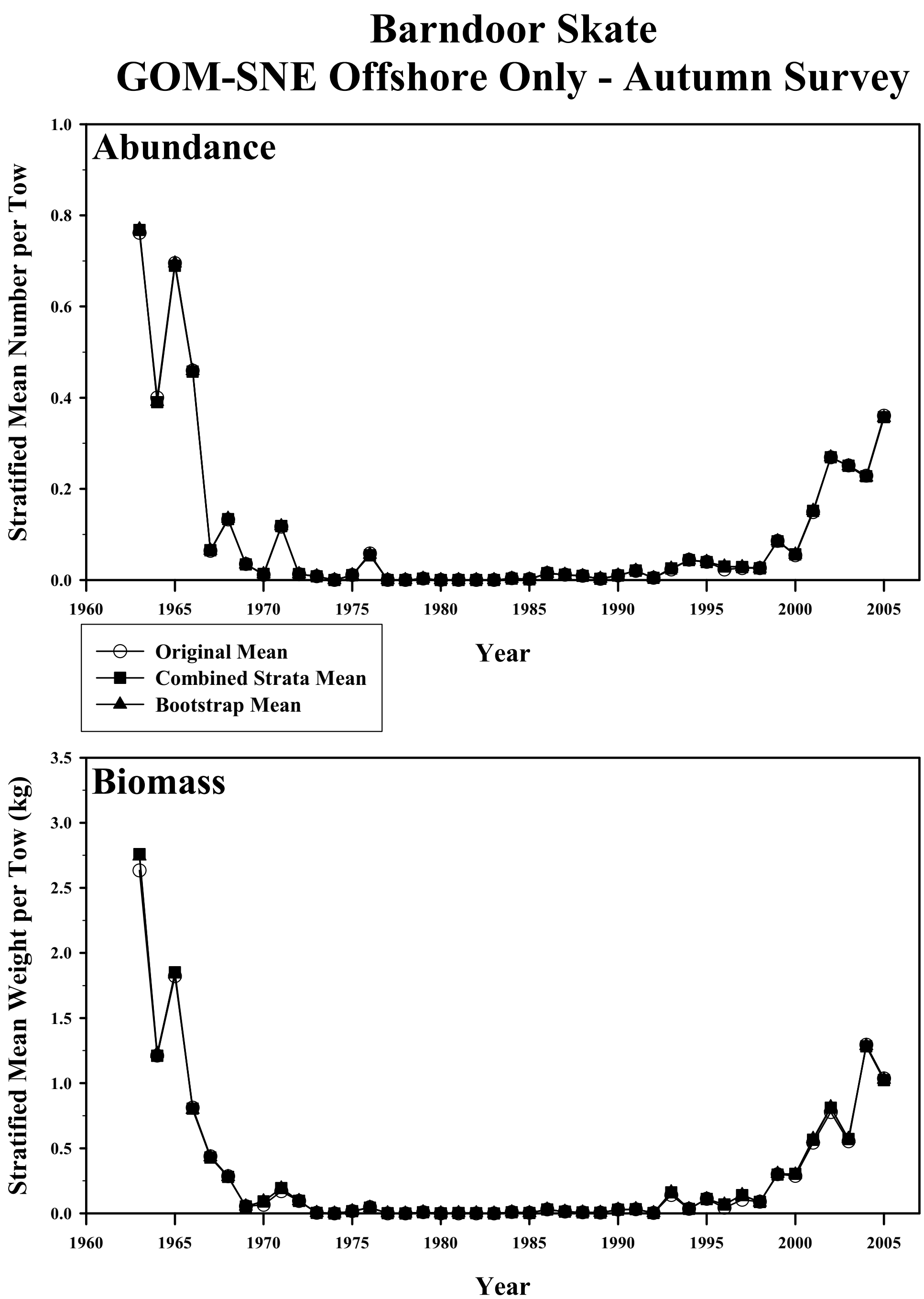


Figure B2.52. Abundance and biomass of barndoor skate from the NESFC autumn bottom trawl surveys from 1963-2006 in the Gulf of Maine to Southern New England offshore region. The circles represent the original stratified mean, the squares represent the mean combining strata for bootstrapping, and the triangles represent the bootstrapped mean.

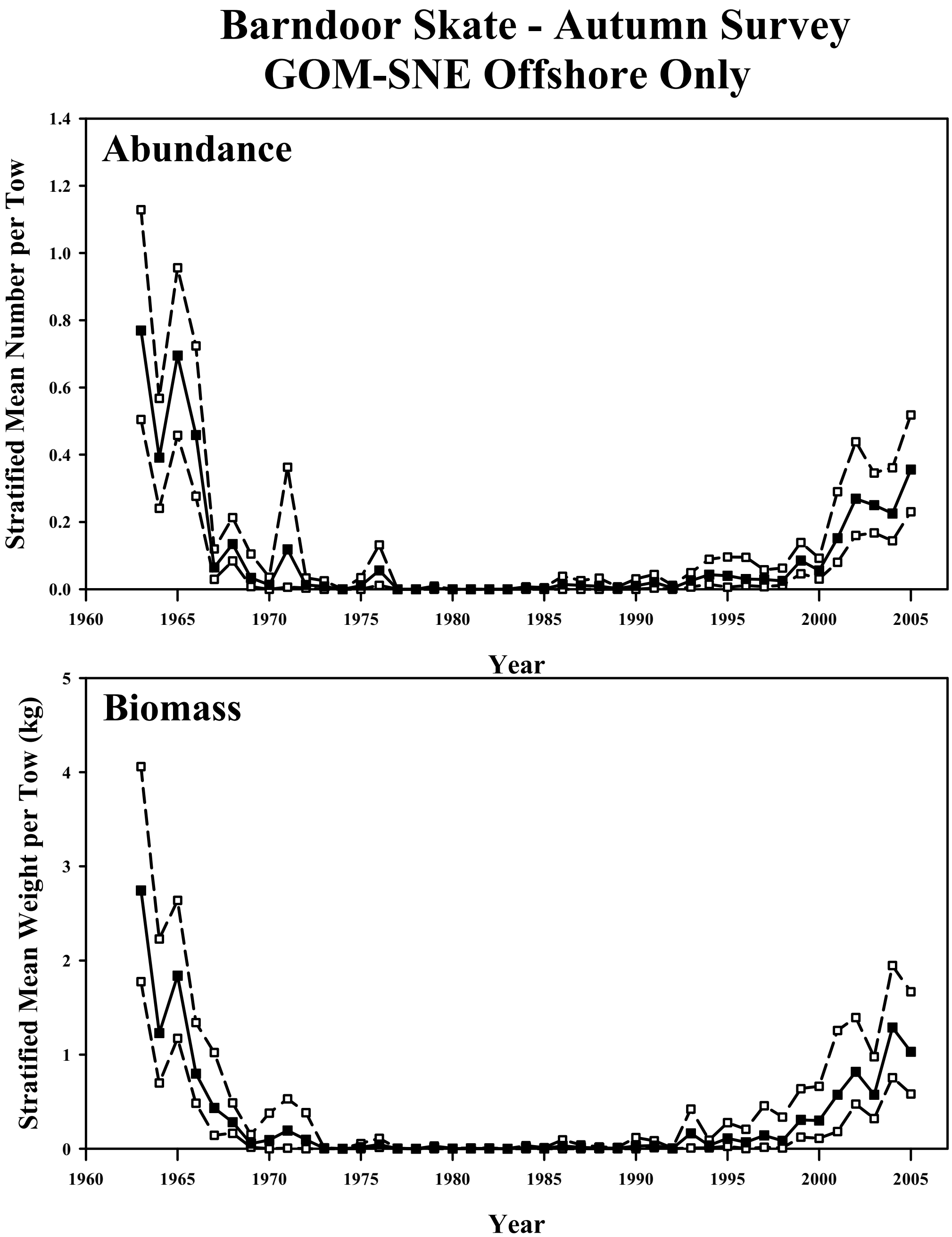


Figure B2.53. Bootstrapped abundance and biomass of barndoor skate from the NESFC autumn bottom trawl survey in the Gulf of Maine to Southern New England offshore region. Mean index in solid squares, 95% confidence interval in open squares.

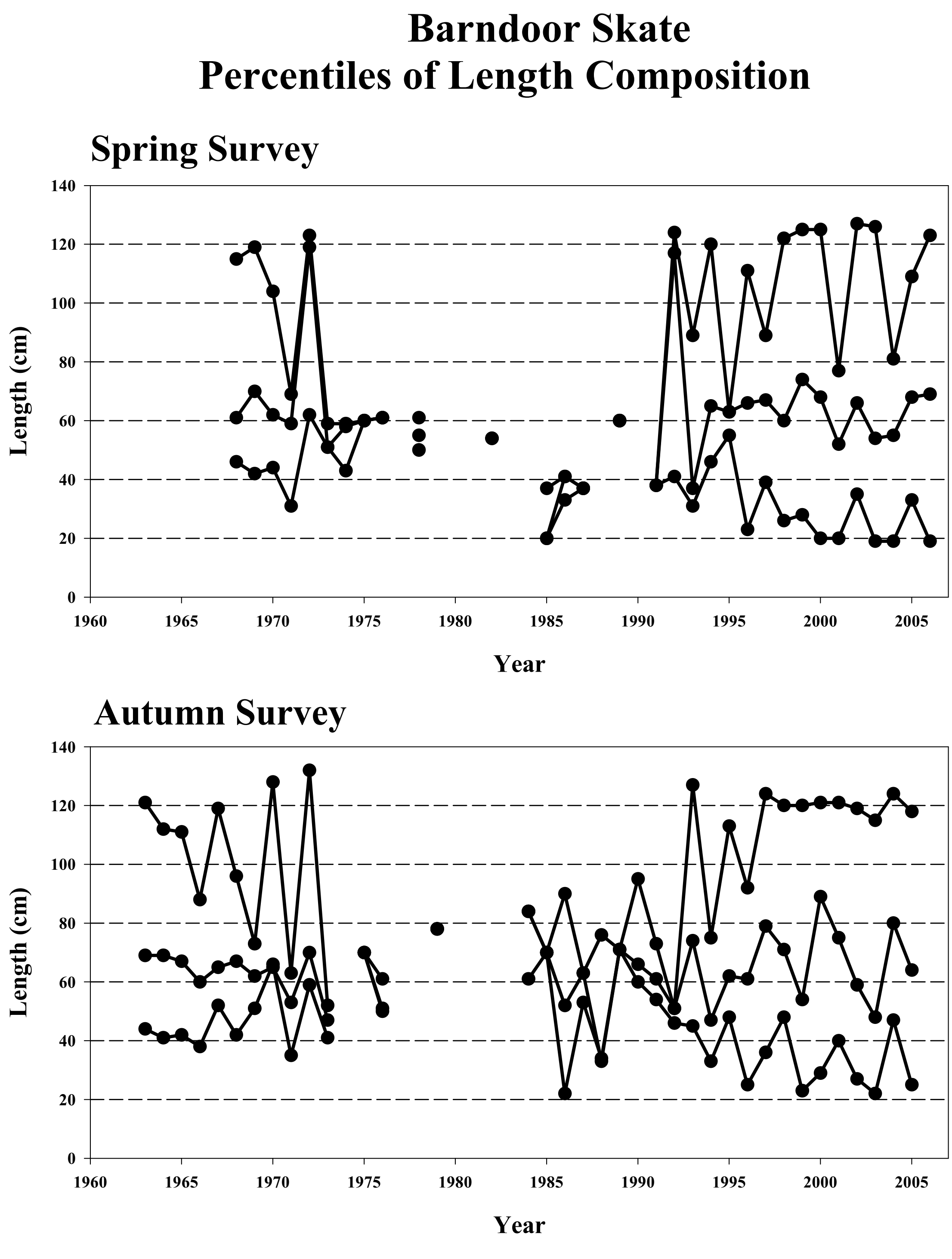


Figure B2.54. Percentiles of length composition (5, 50, and 95) of barndoor skate from the NESFC spring and autumn bottom trawl surveys from 1963-2006 in the Gulf of Maine to Southern New England offshore region.

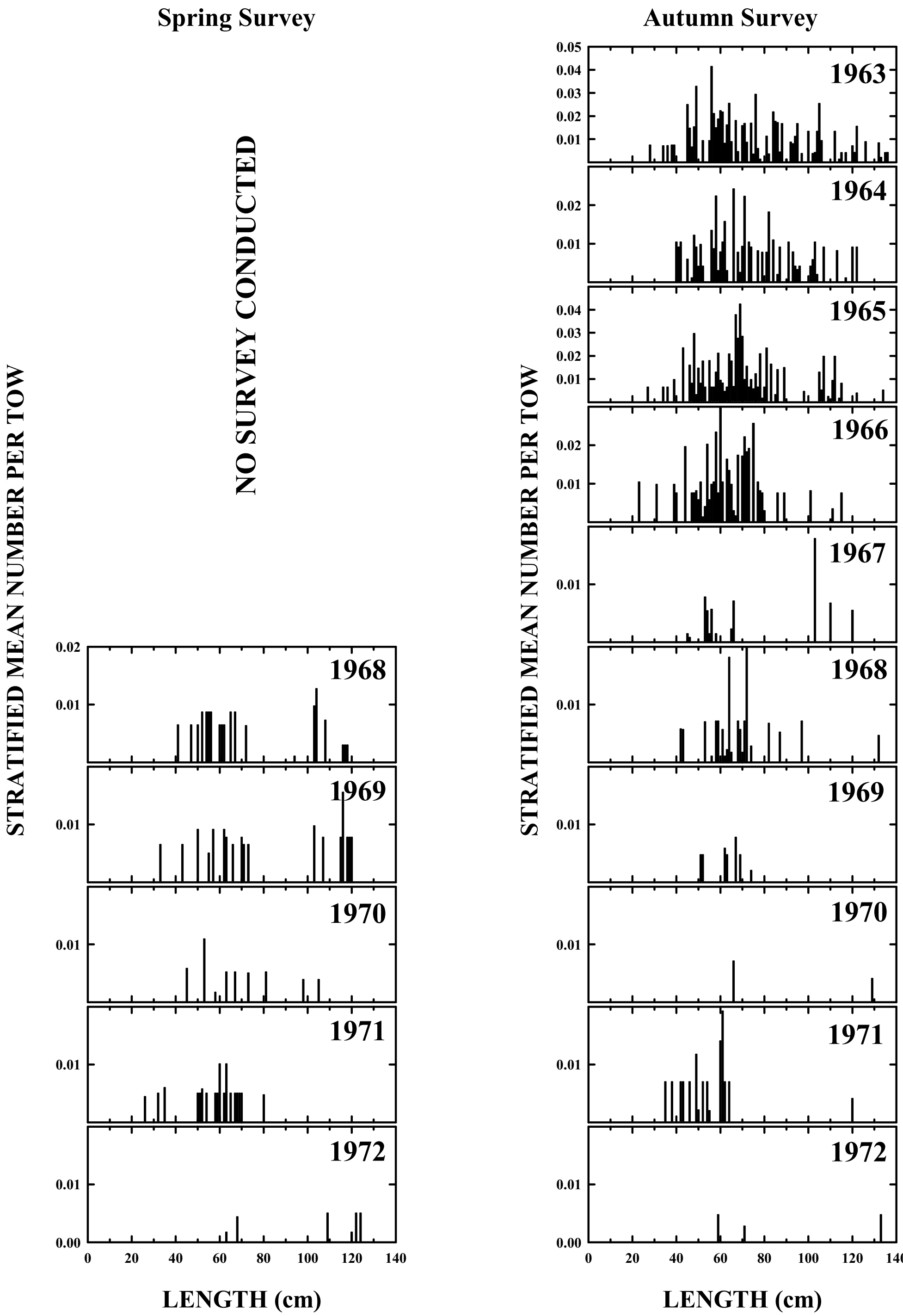


Figure B2.55. Barndoor skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England offshore region, 1963-1972.

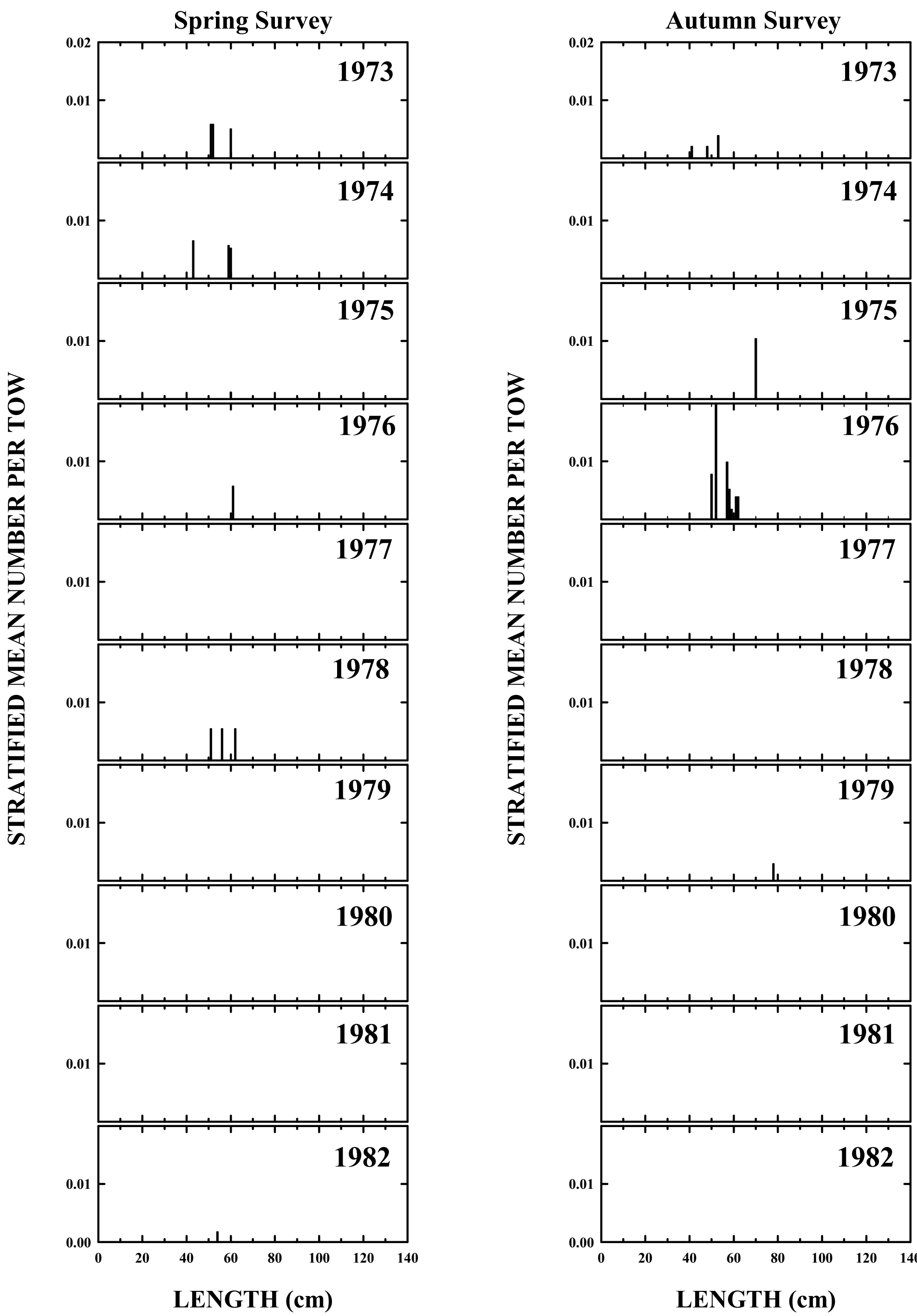


Figure B2.56. Barndoor skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England offshore region, 1973-1982.

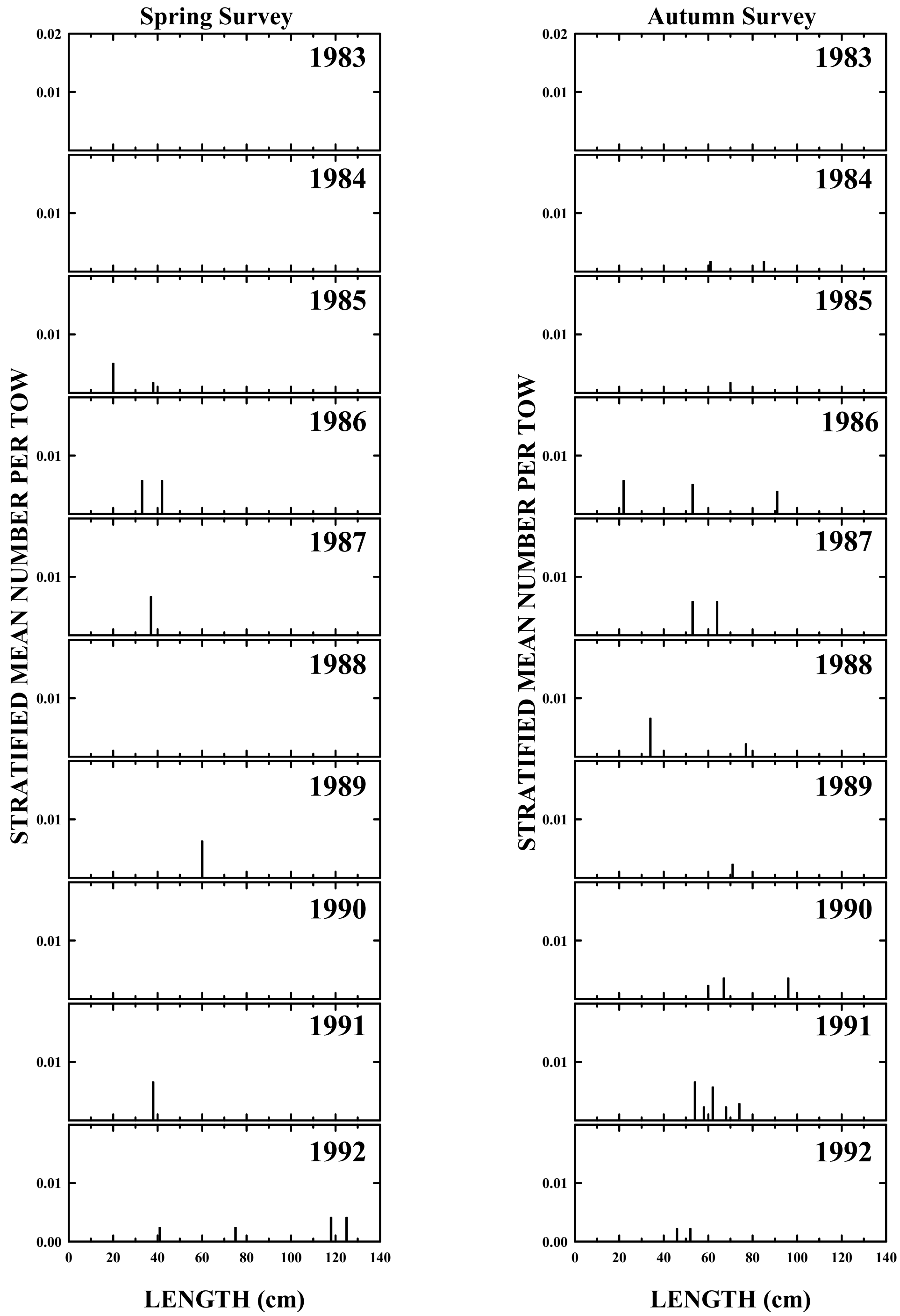


Figure B2.57. Barndoor skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England offshore region, 1983-1992.

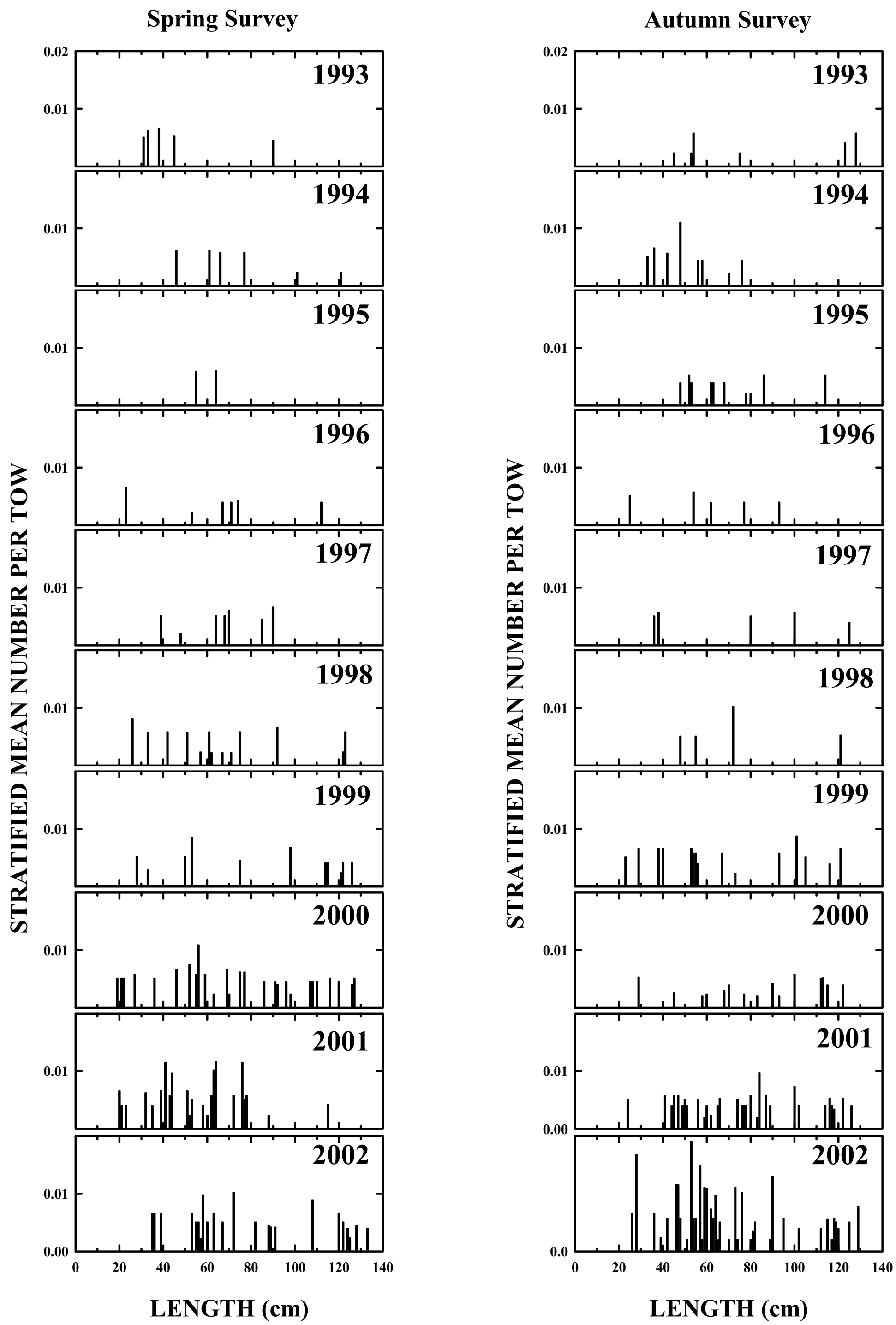


Figure B2.58. Barndoor skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England offshore region, 1993-2002.

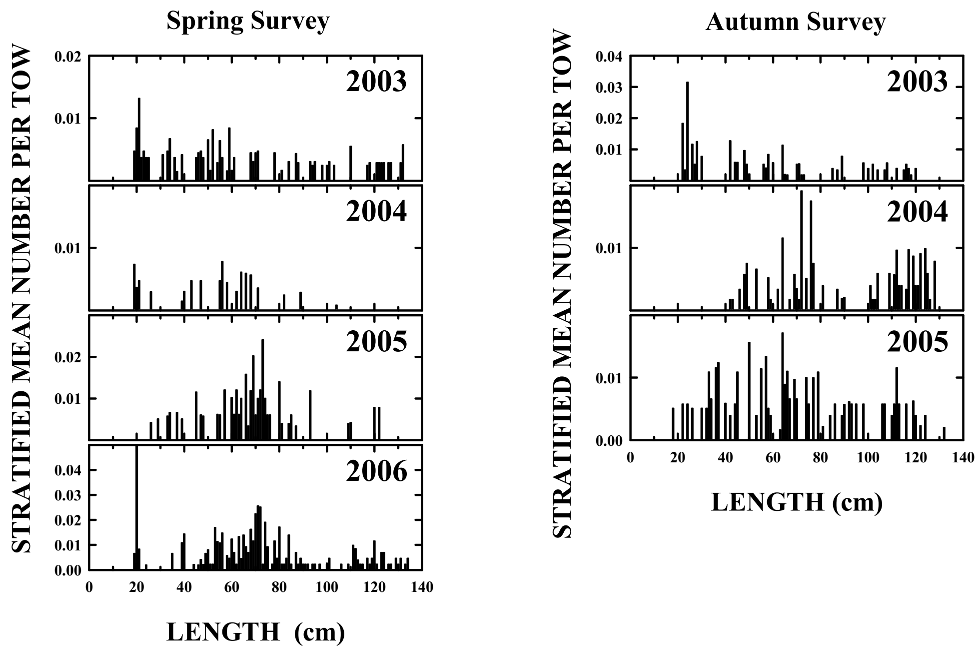


Figure B2.59. Barndoor skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England offshore region, 2003-2006.

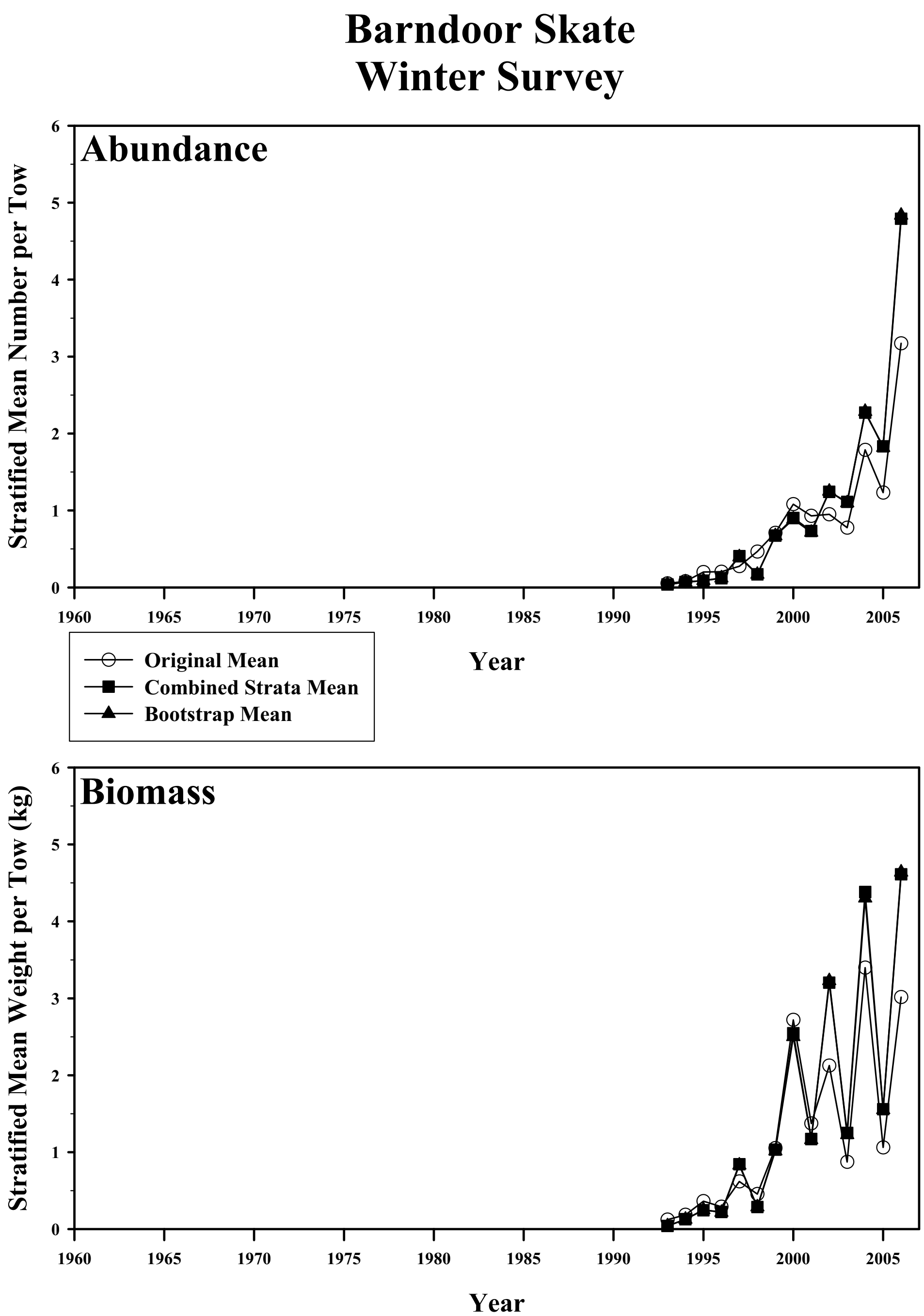


Figure B2.60. Abundance and biomass of barndoor skate from the NESFC winter bottom trawl surveys from 1993-2006. The circles represent the original stratified mean, the squares represent the mean combining strata for bootstrapping, and the triangles represent the bootstrapped mean.

Barndoor Skate
Winter Survey

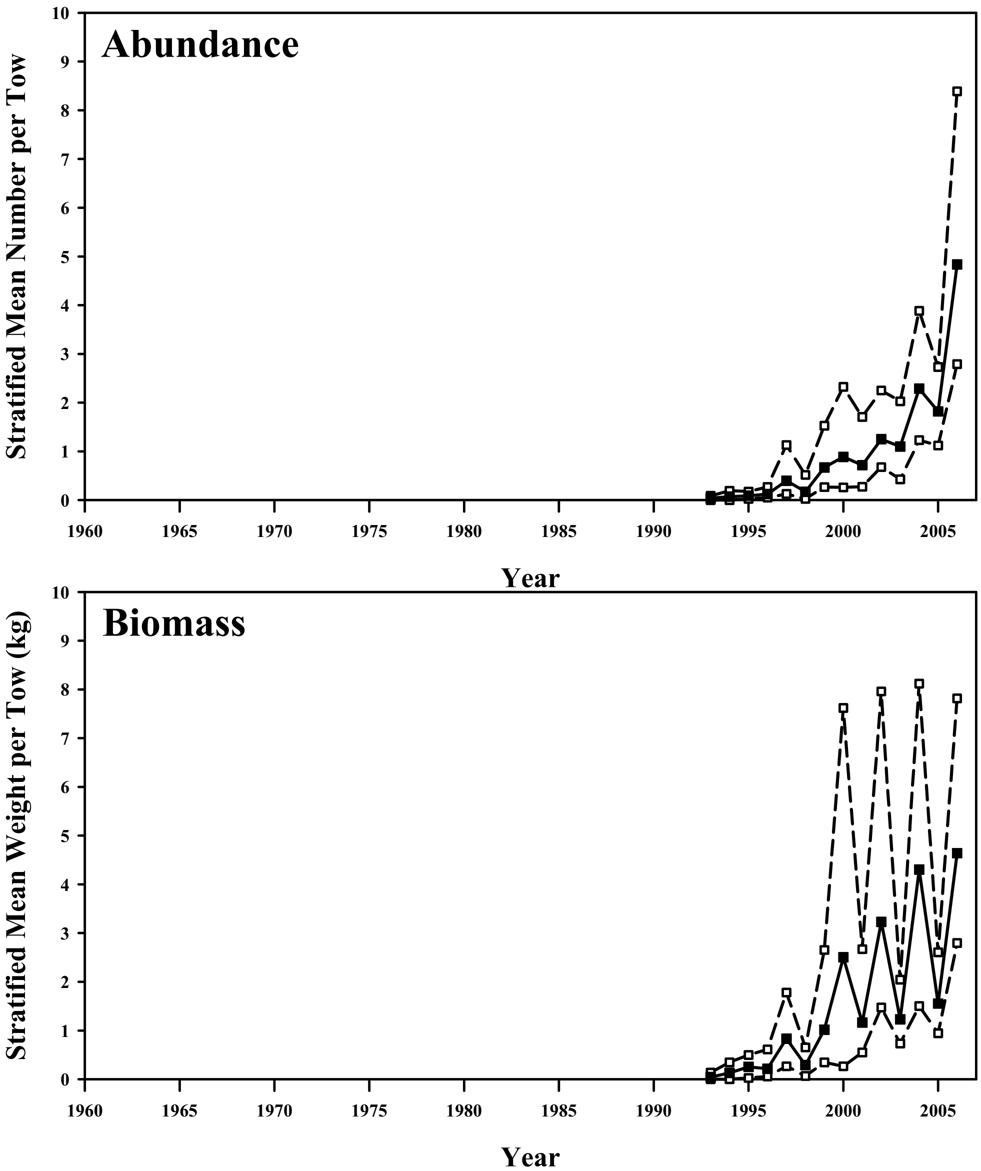


Figure B2.61. Bootstrapped abundance and biomass of barndoor skate from the NESFC winter bottom trawl survey. Mean index in solid squares, 95% confidence interval in open squares.

Winter Survey

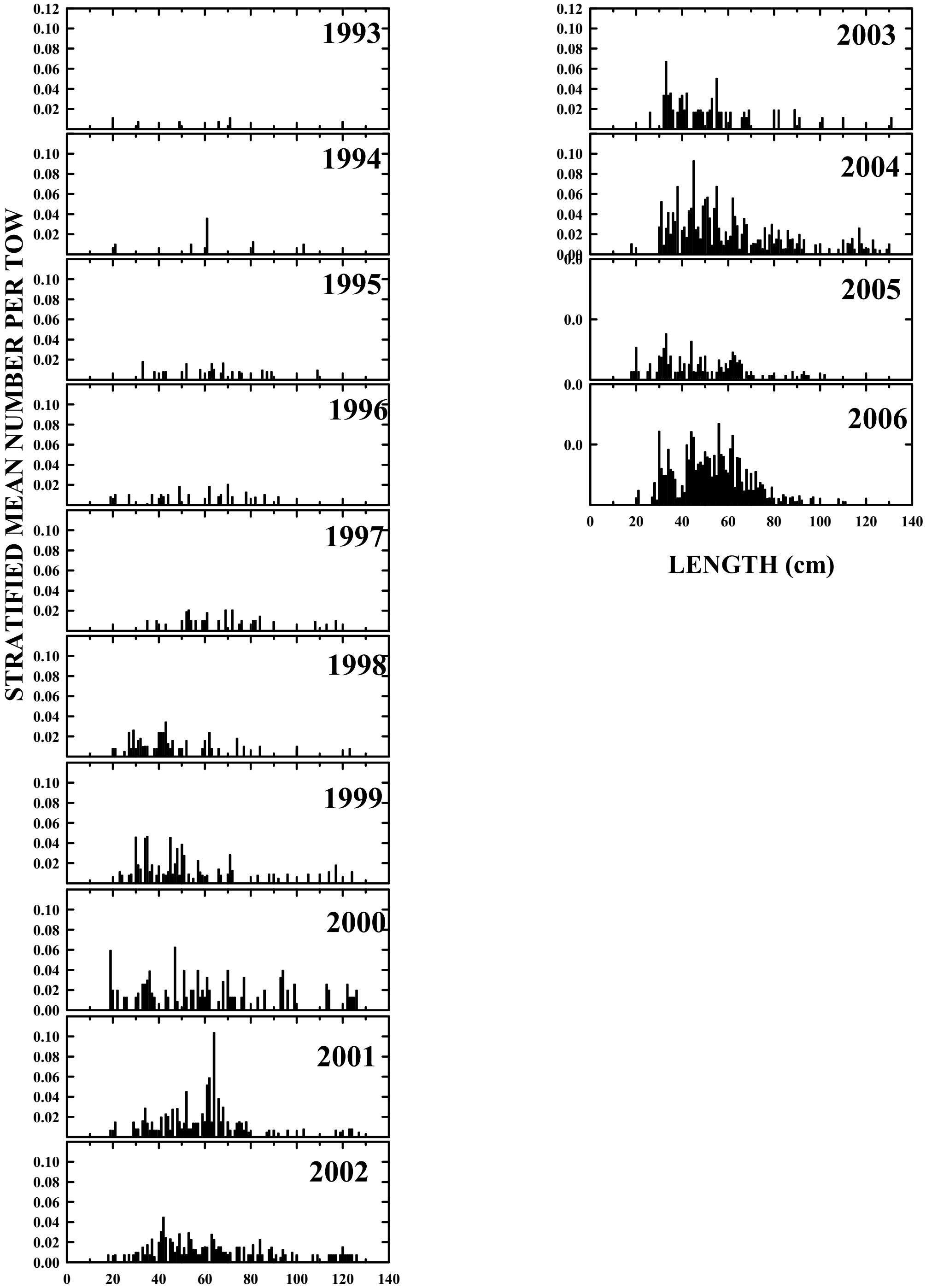


Figure B2.62. Barndoor skate length composition from the NEFSC winter flatfish surveys, 1993-2006.

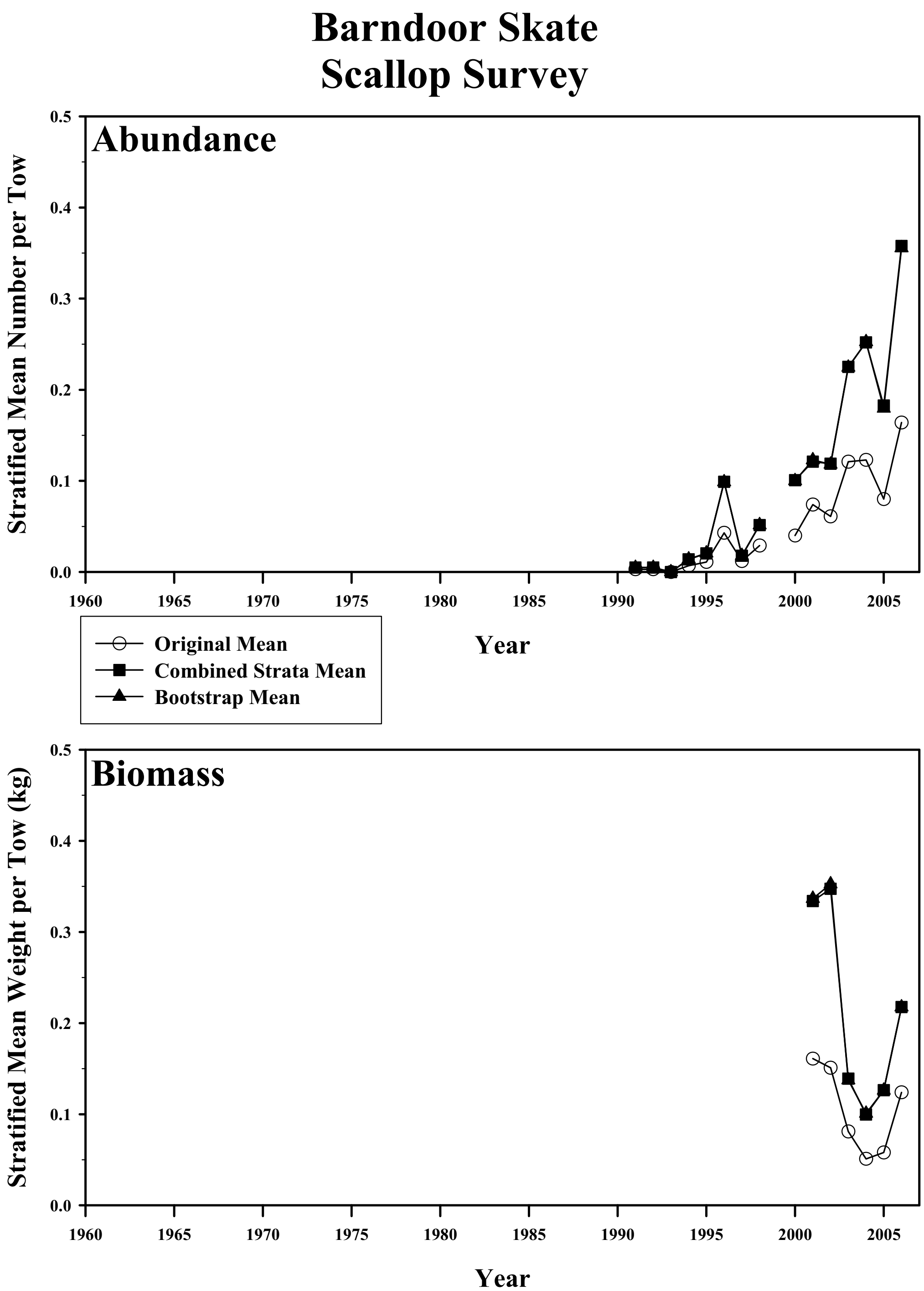


Figure B2.63. Abundance and biomass of barndoor skate from the NESFC scallop surveys from 1991-2006. The circles represent the original stratified mean, the squares represent the mean combining strata for bootstrapping, and the triangles represent the bootstrapped mean.

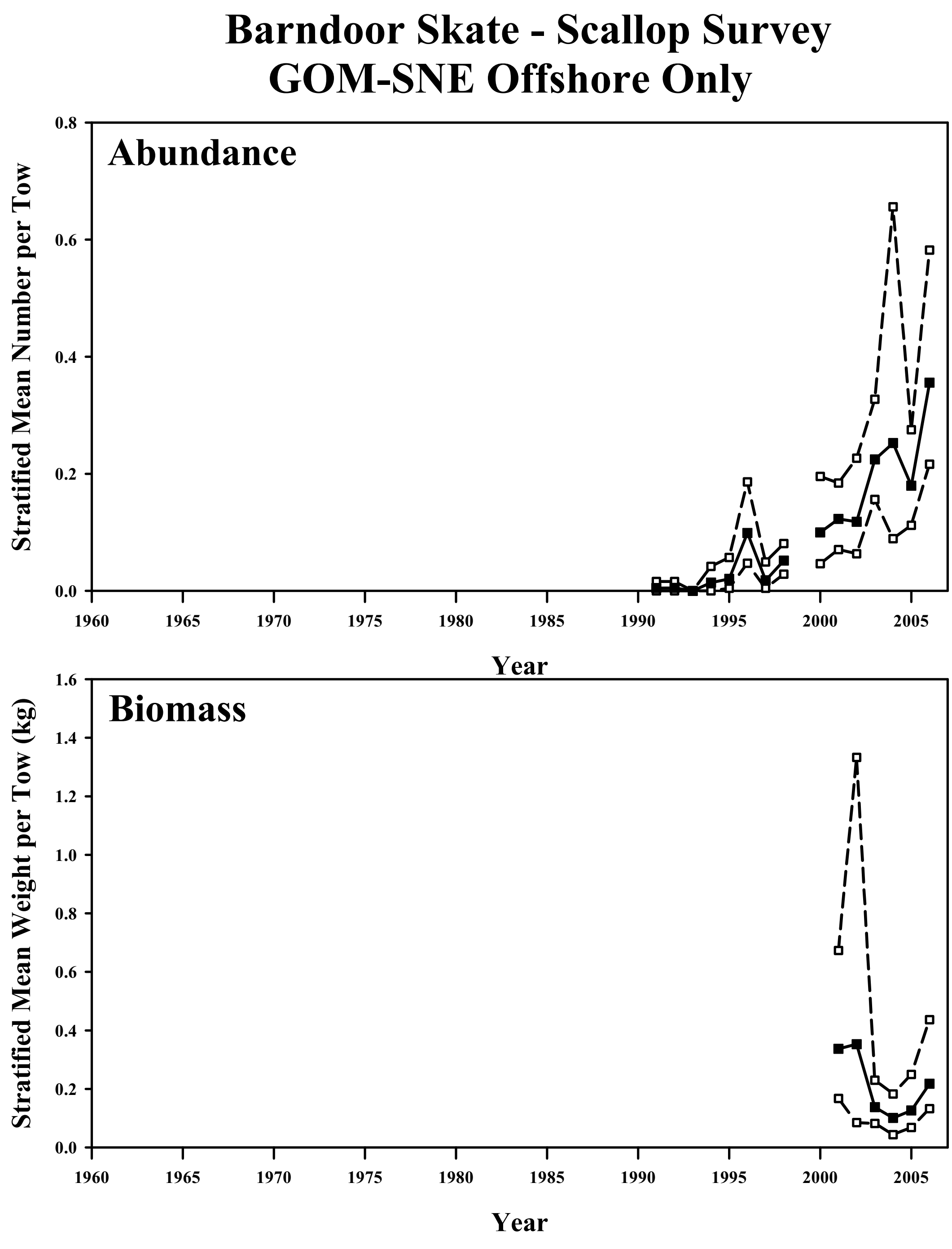


Figure B2.64. Bootstrapped abundance and biomass of barndoor skate from the NESFC scallop survey. Mean index in solid squares, 95% confidence interval in open squares.

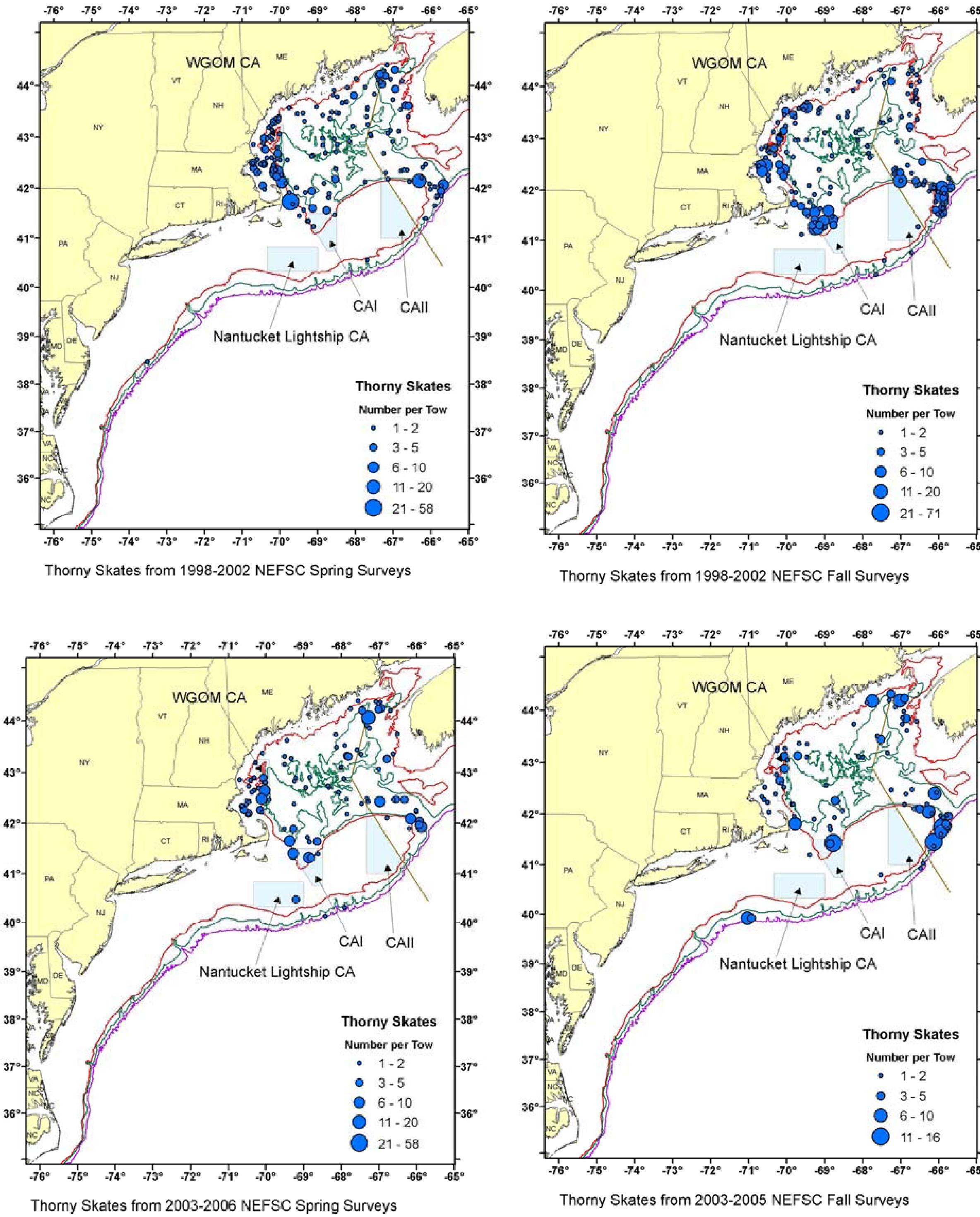


Figure B2.65. Distribution of thorny skate from the spring and autumn NEFSC surveys from 1998-2006.

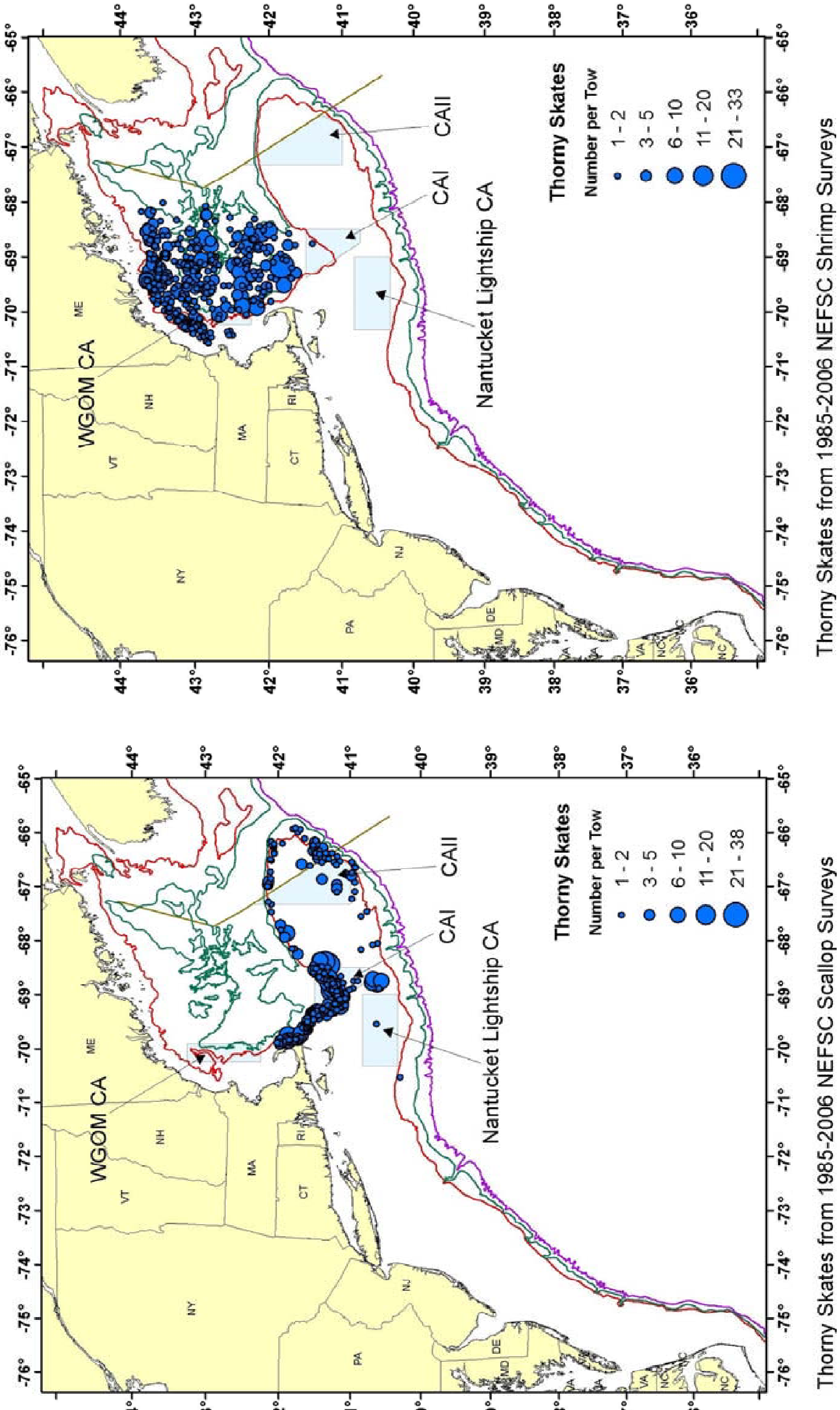


Figure B2.66. Distribution of thorny skate from the NEFSC scallop and shrimp surveys from 1985-2006.

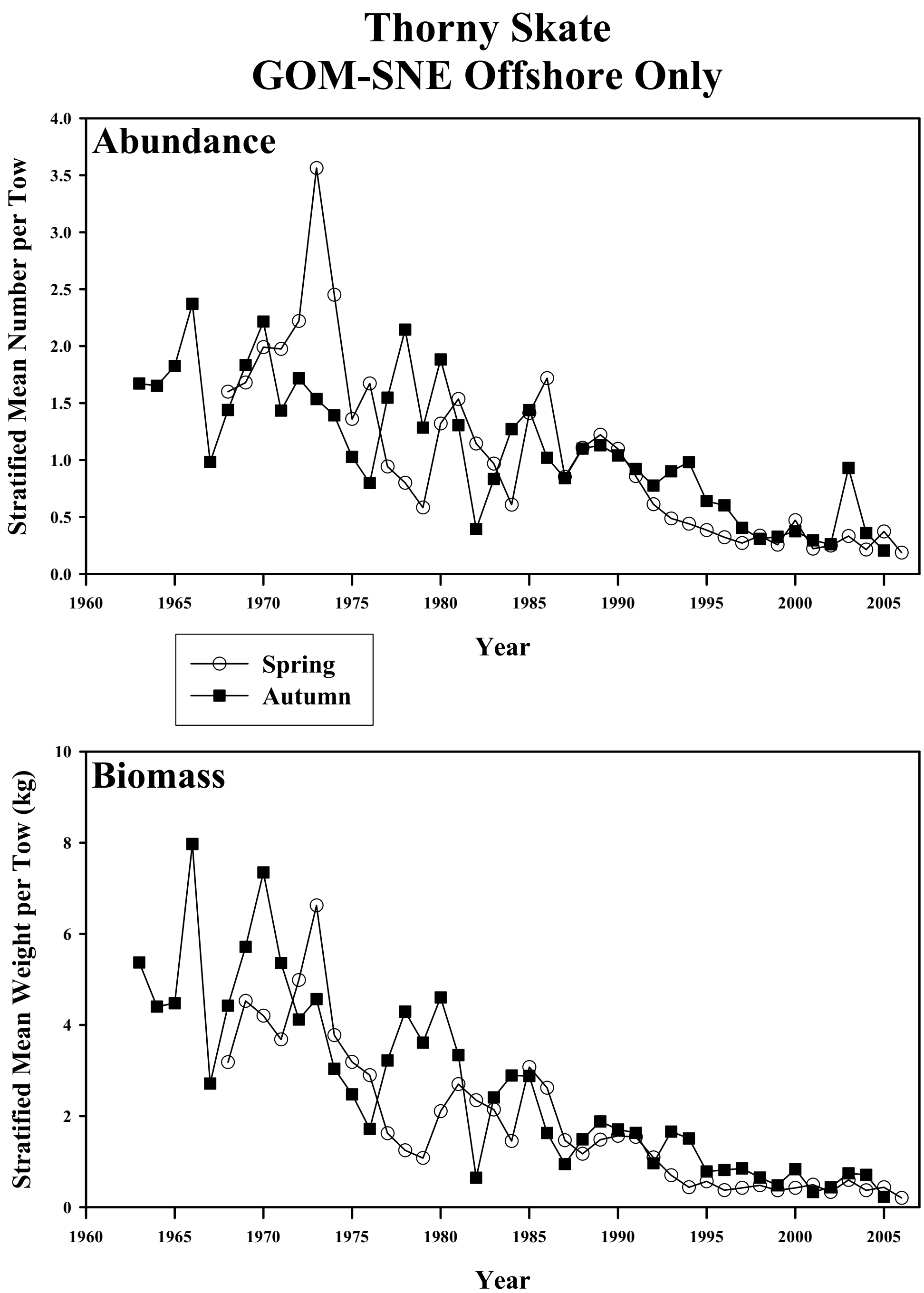


Figure B2.67. Abundance and biomass of thorny skate from the NESFC spring (circles) and autumn (squares) bottom trawl surveys from 1963-2006 in the Gulf of Maine to Southern New England offshore region.

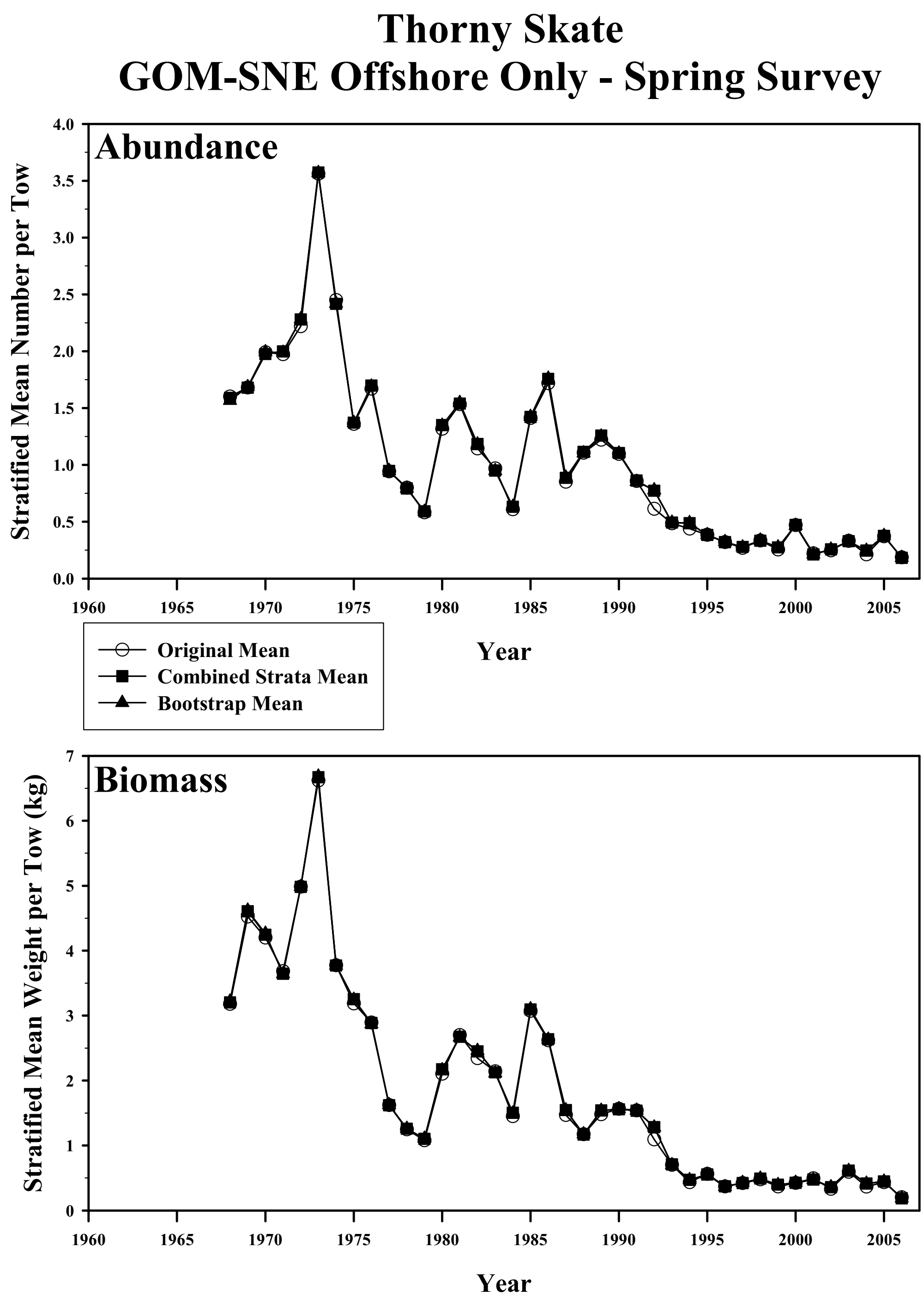


Figure B2.68. Abundance and biomass of thorny skate from the NESFC spring bottom trawl surveys from 1968-2006 in the Gulf of Maine to Southern New England offshore region. The circles represent the original stratified mean, the squares represent the mean combining strata for bootstrapping, and the triangles represent the bootstrapped mean.

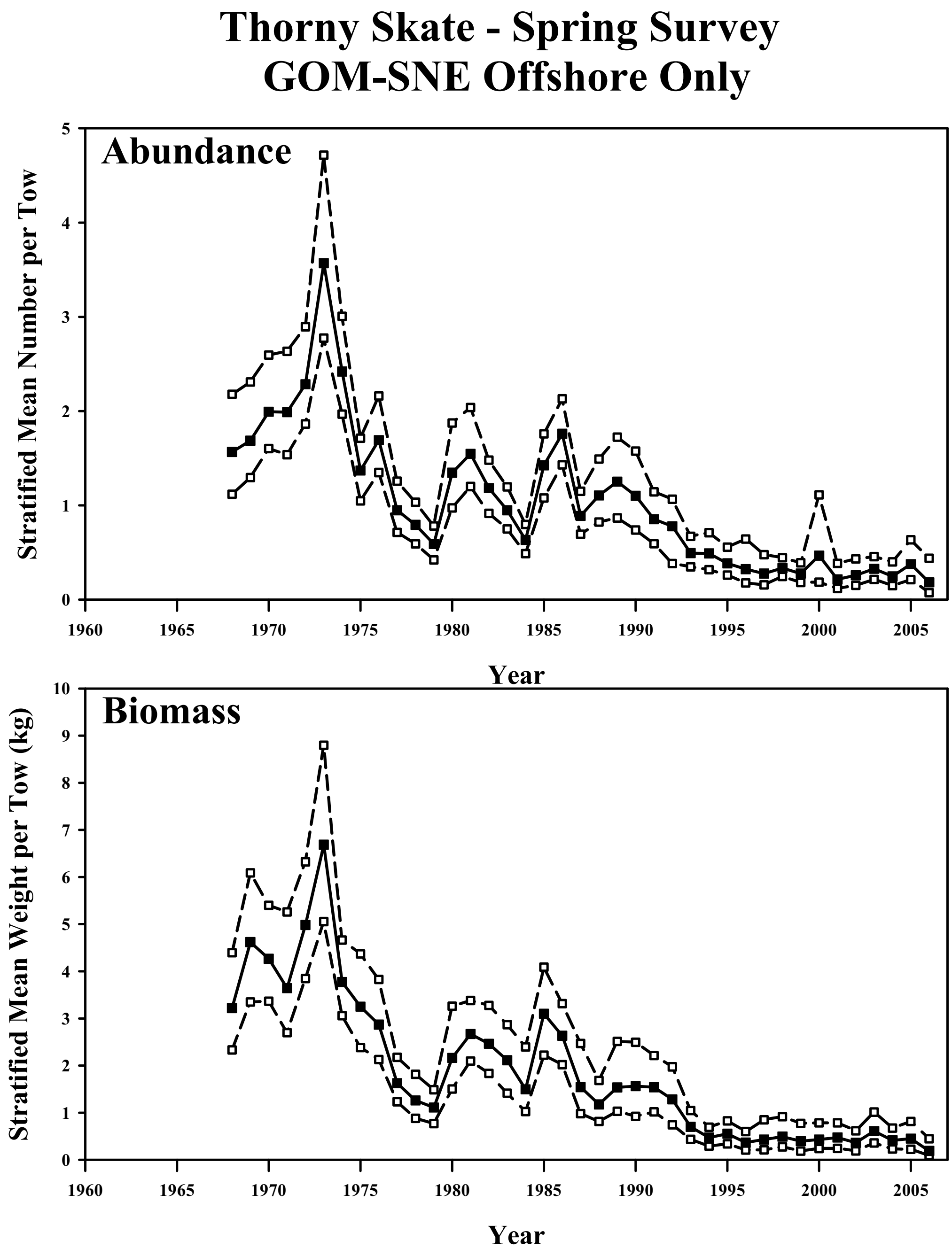


Figure B2.69. Bootstrapped abundance and biomass of thorny skate from the NESFC spring bottom trawl survey in the Gulf of Maine to Southern New England offshore region. Mean index in solid squares, 95% confidence interval in open squares.

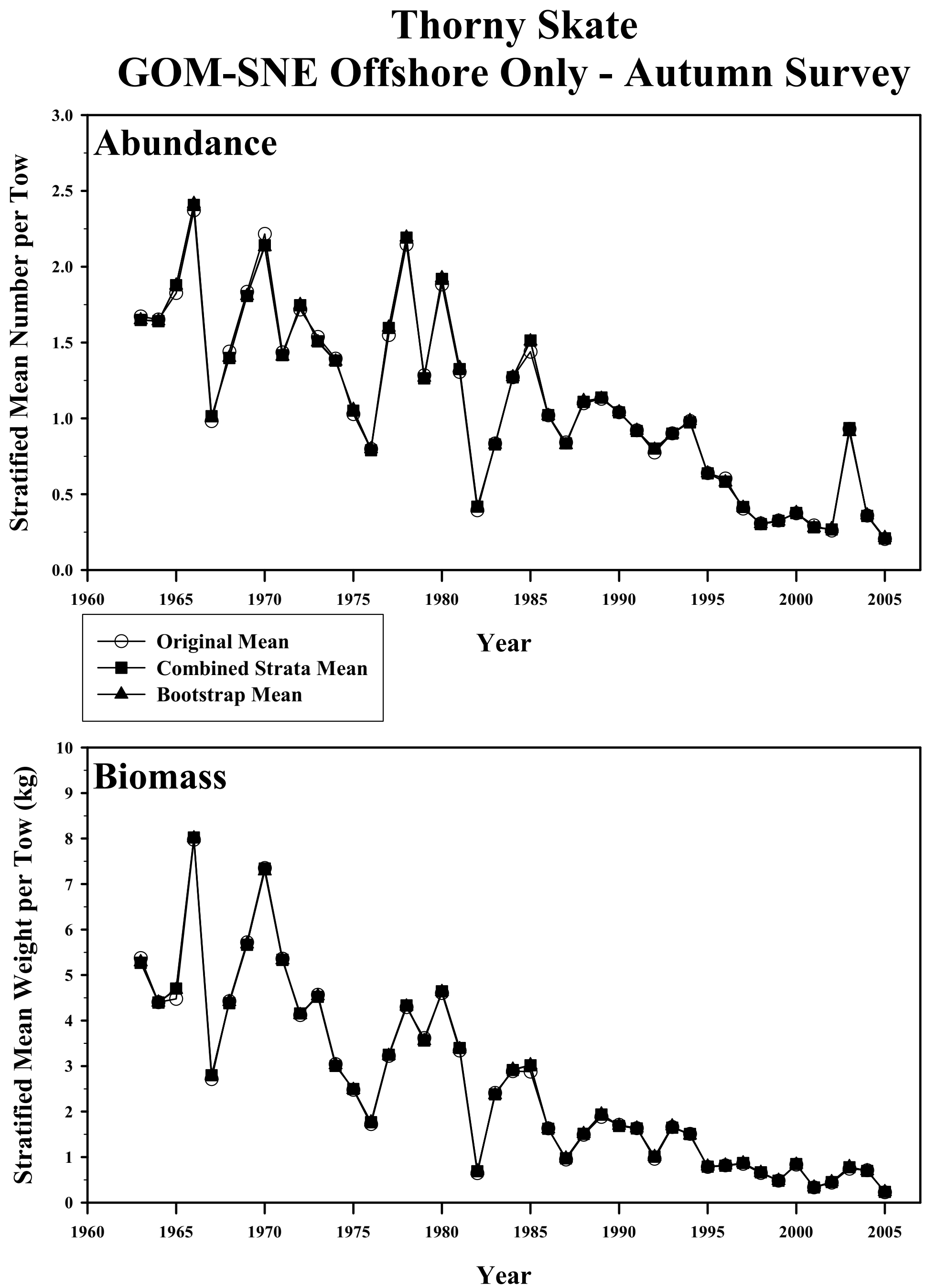


Figure B2.70. Abundance and biomass of thorny skate from the NESFC autumn bottom trawl surveys from 1968-2006 in the Gulf of Maine to Southern New England offshore region. The circles represent the original stratified mean, the squares represent the mean combining strata for bootstrapping, and the triangles represent the bootstrapped mean.

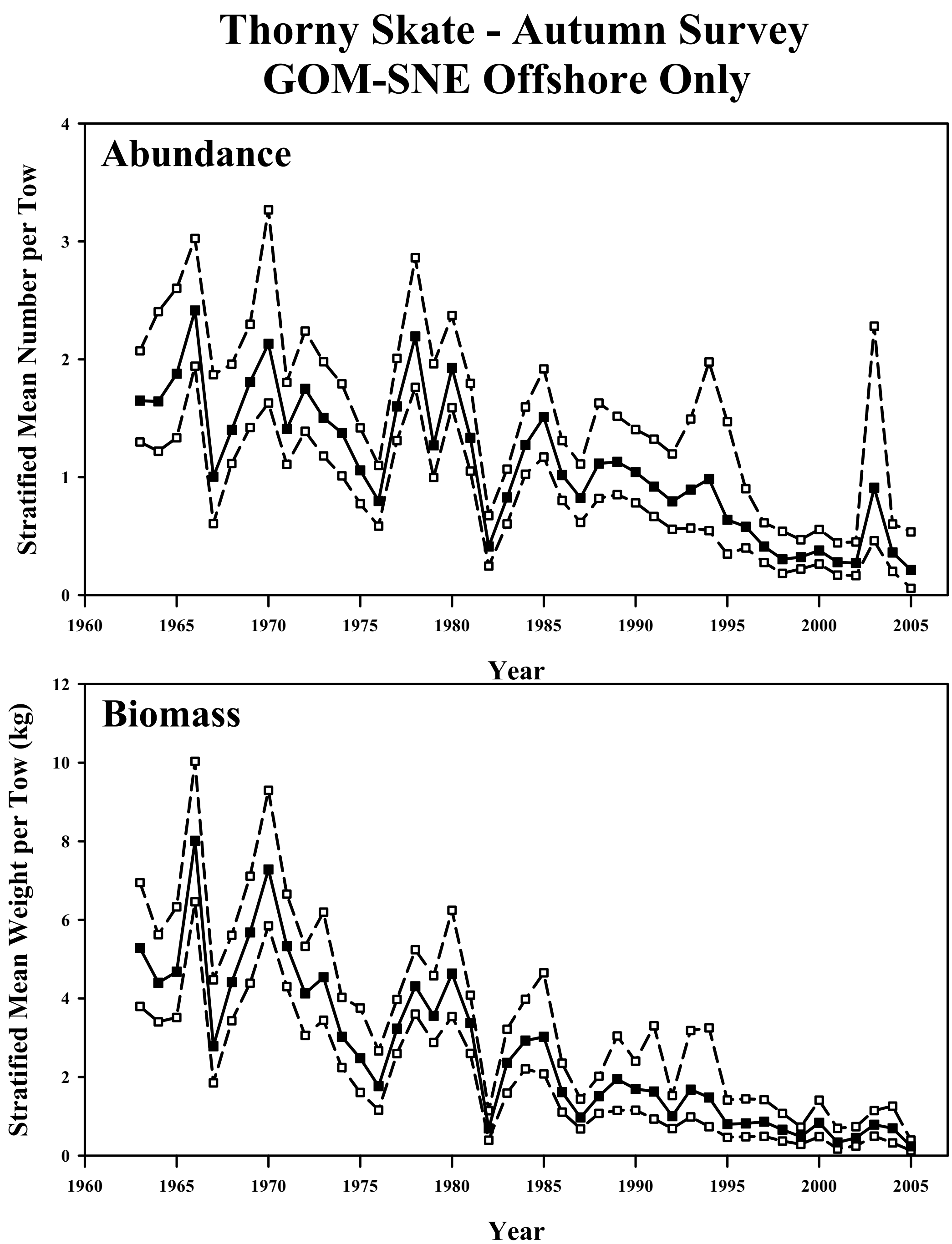
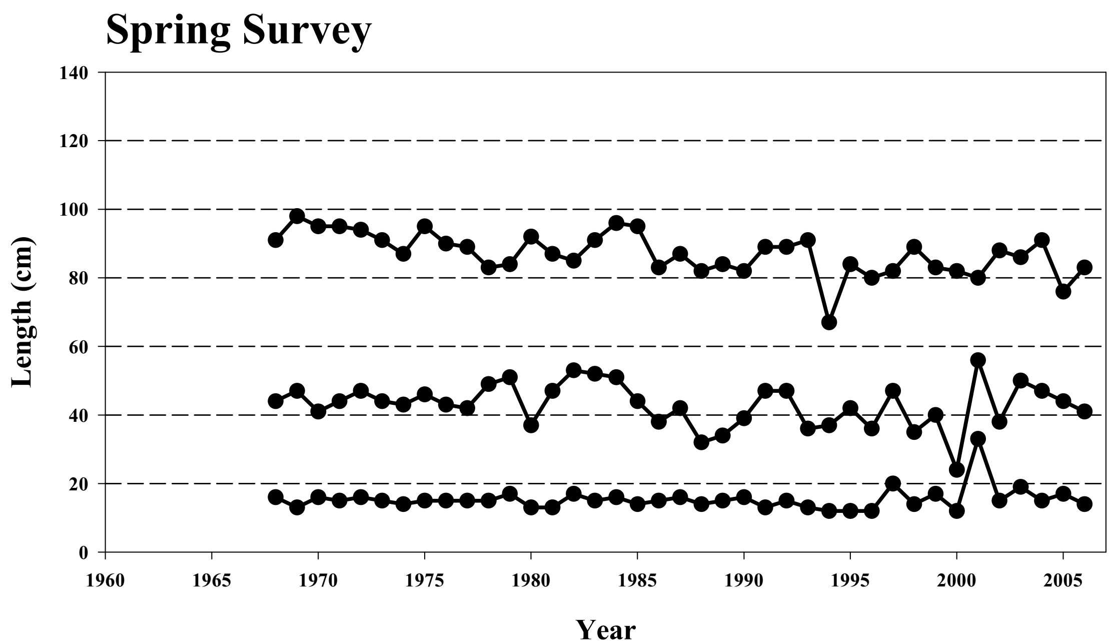


Figure B2.71. Bootstrapped abundance and biomass of thorny skate from the NESFC autumn bottom trawl survey in the Gulf of Maine to Southern New England offshore region. Mean index in solid squares, 95% confidence interval in open squares.

Thorny Skate: GOM-SNE Offshore
Percentiles of Length Composition



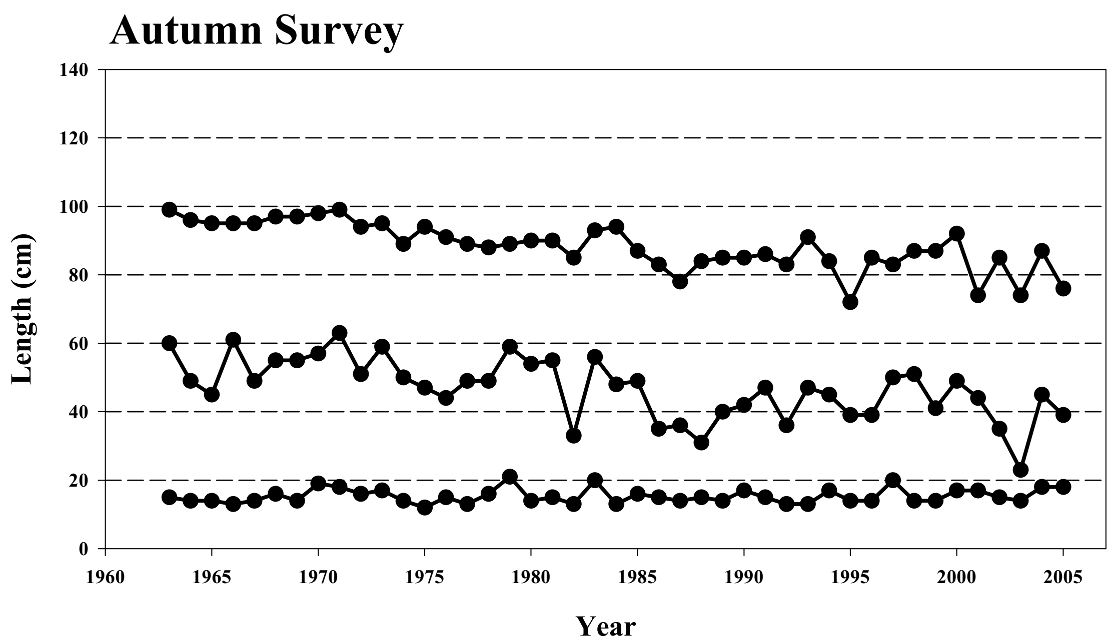


Figure B2.72. Percentiles of length composition (5, 50, and 95) of thorny skate from the NESFC spring and autumn bottom trawl surveys from 1963-2006 in the Gulf of Maine to Southern New England offshore region.

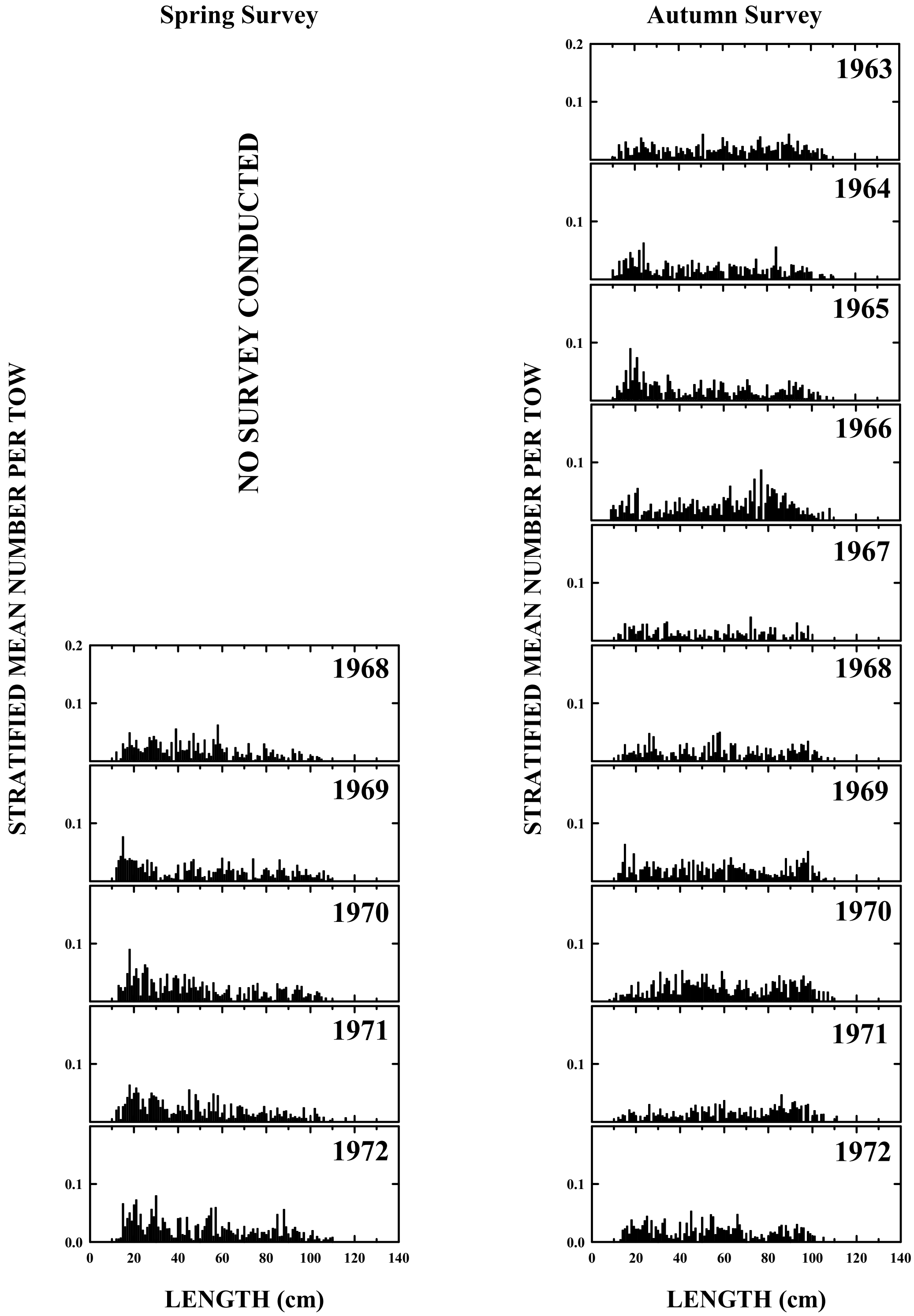


Figure B2.73. Thorny skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England offshore region, 1963-1972.

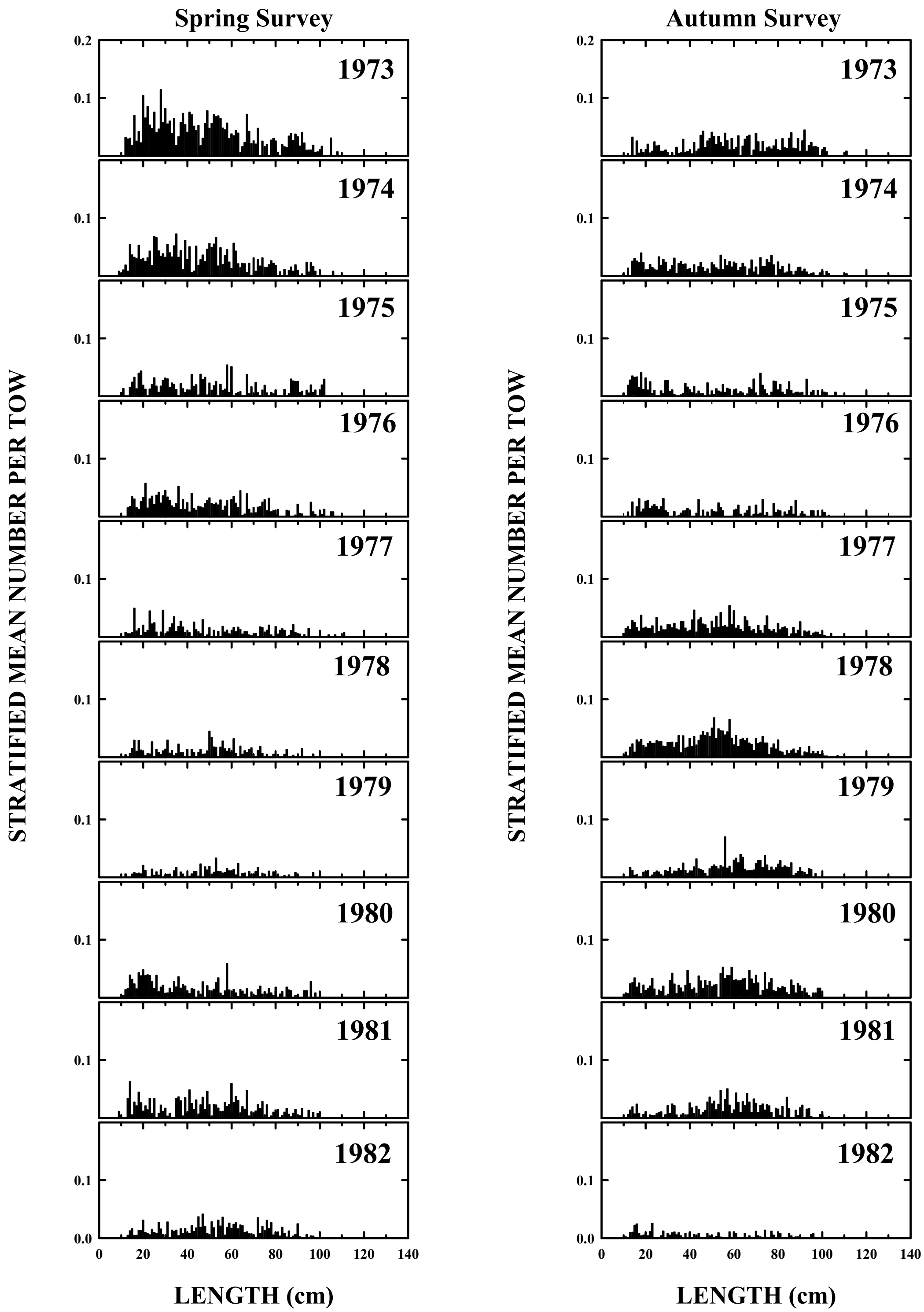


Figure B2.74. Thorny skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England offshore region, 1973-1982.

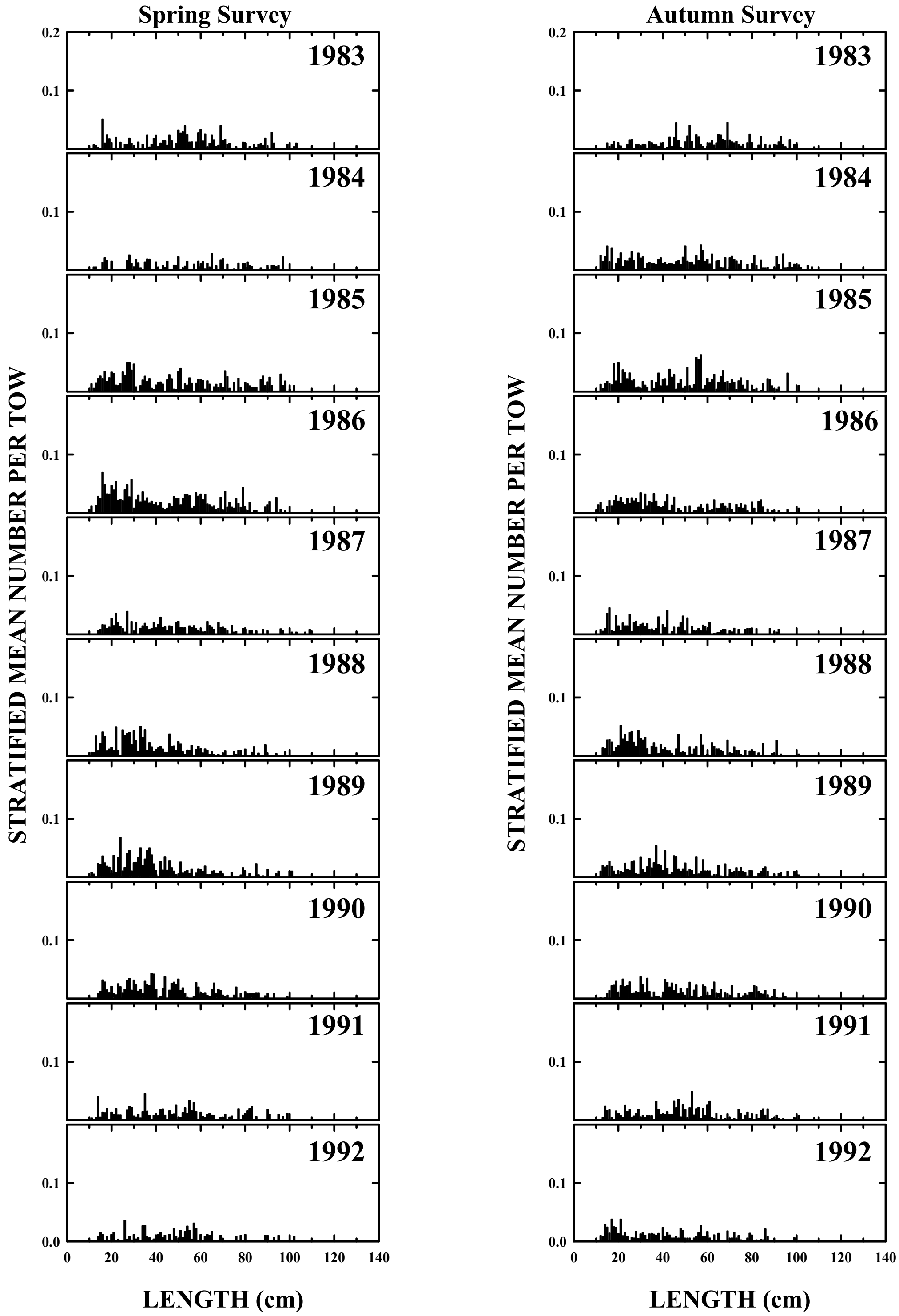


Figure B2.75. Thorny skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England offshore region, 1983-1992.

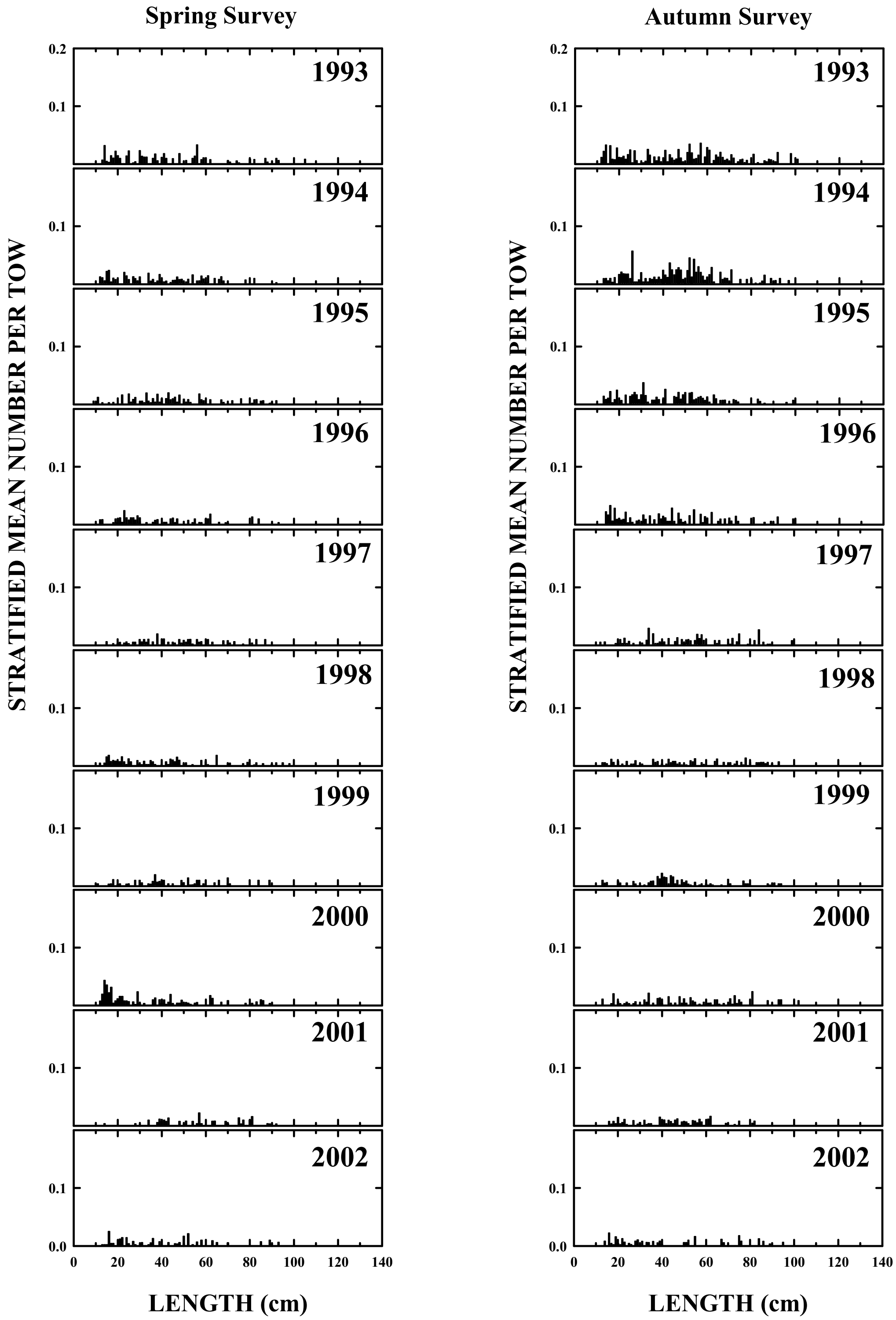


Figure B2.76. Thorny skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England offshore region, 1993-2002.

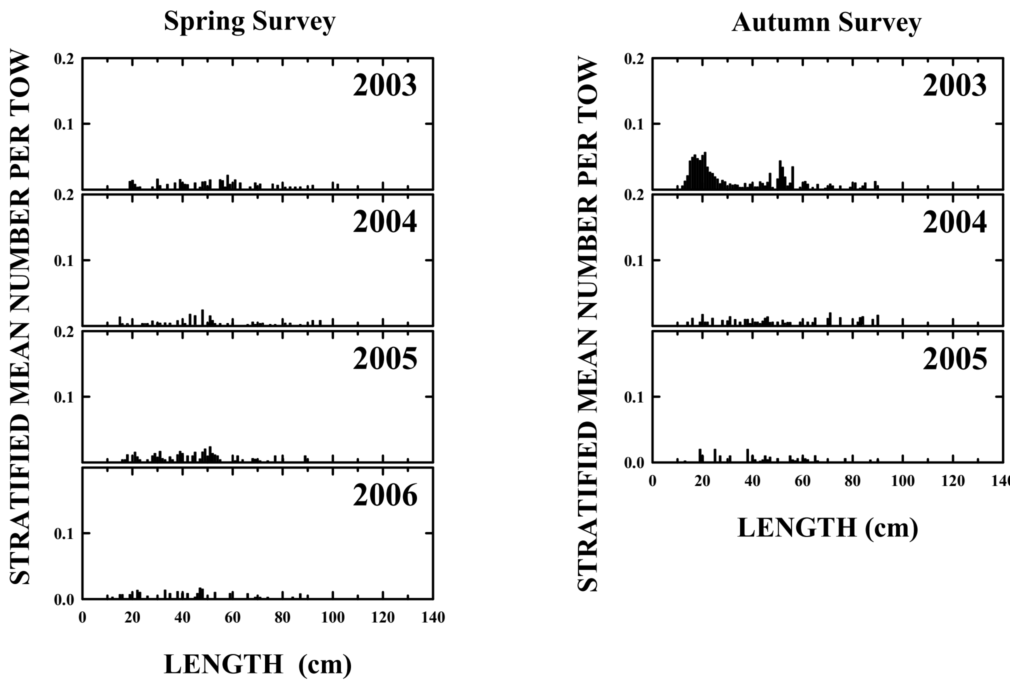


Figure B2.77. Thorny skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England offshore region, 2003-2006.

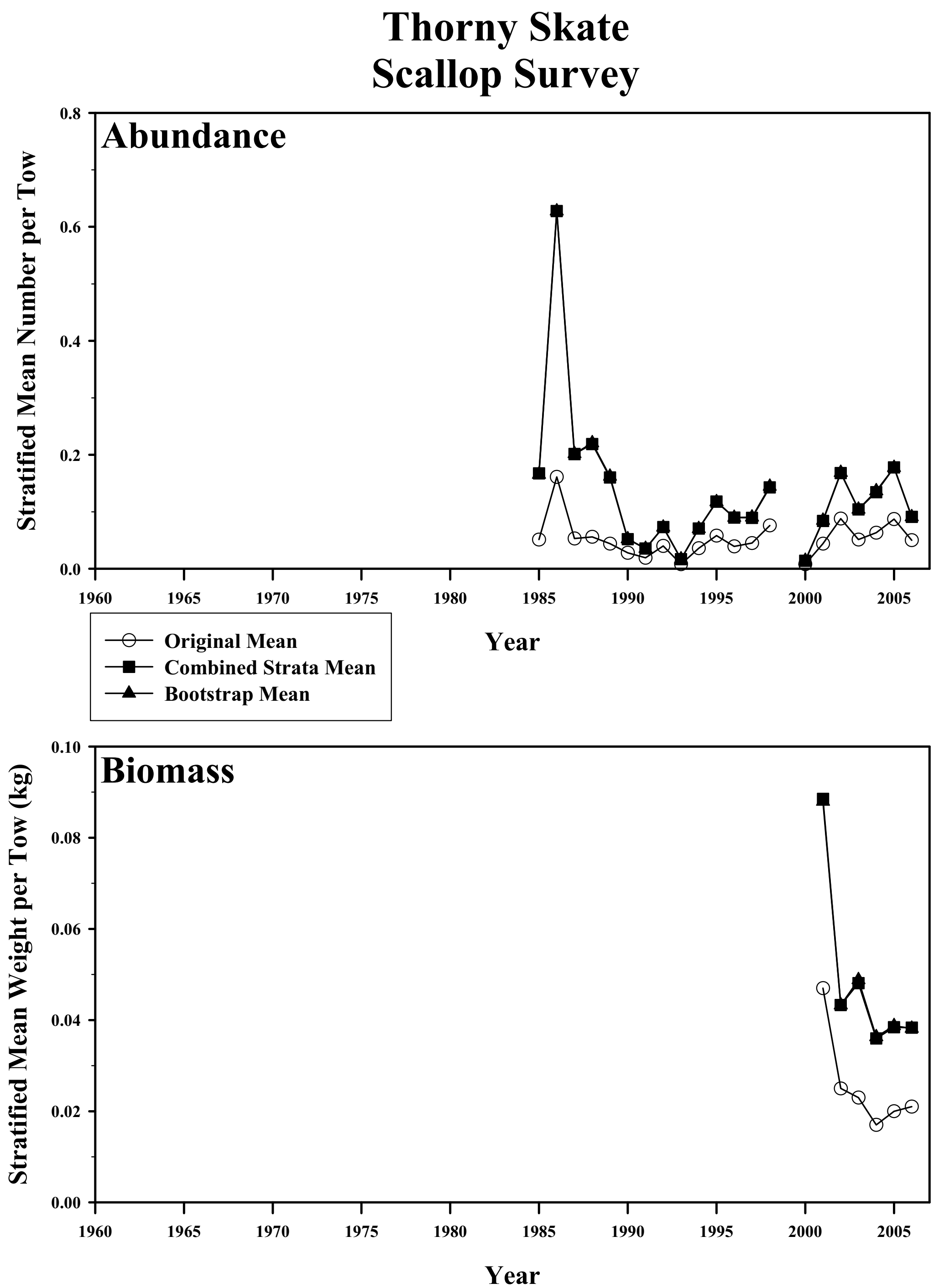


Figure B2.78. Abundance and biomass of thorny skate from the NESFC scallop surveys from 1985-2006. The circles represent the original stratified mean, the squares represent the mean combining strata for bootstrapping, and the triangles represent the bootstrapped mean.

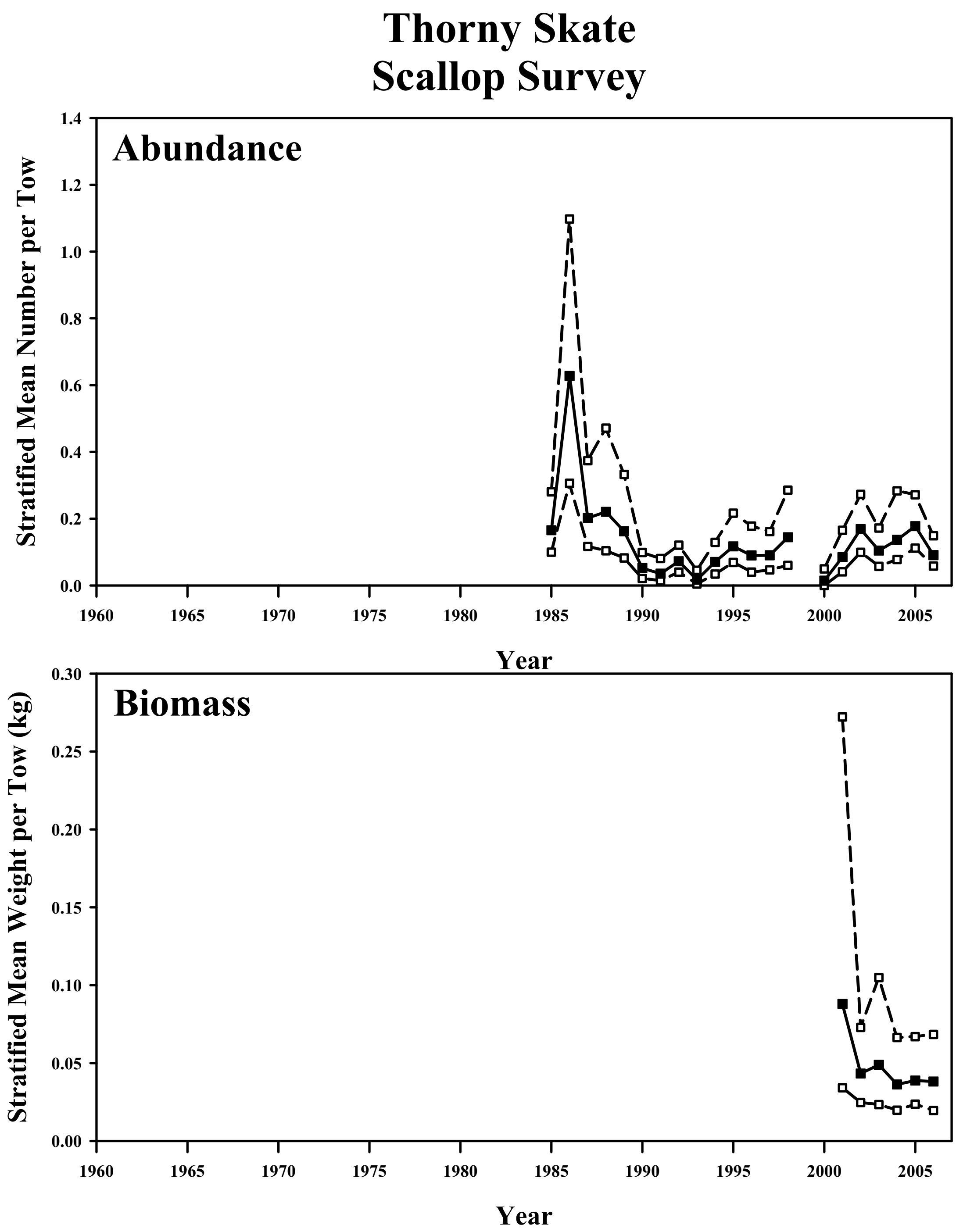


Figure B2.79. Bootstrapped abundance and biomass of thorny skate from the NESFC scallop survey. Mean index in solid squares, 95% confidence interval in open squares.

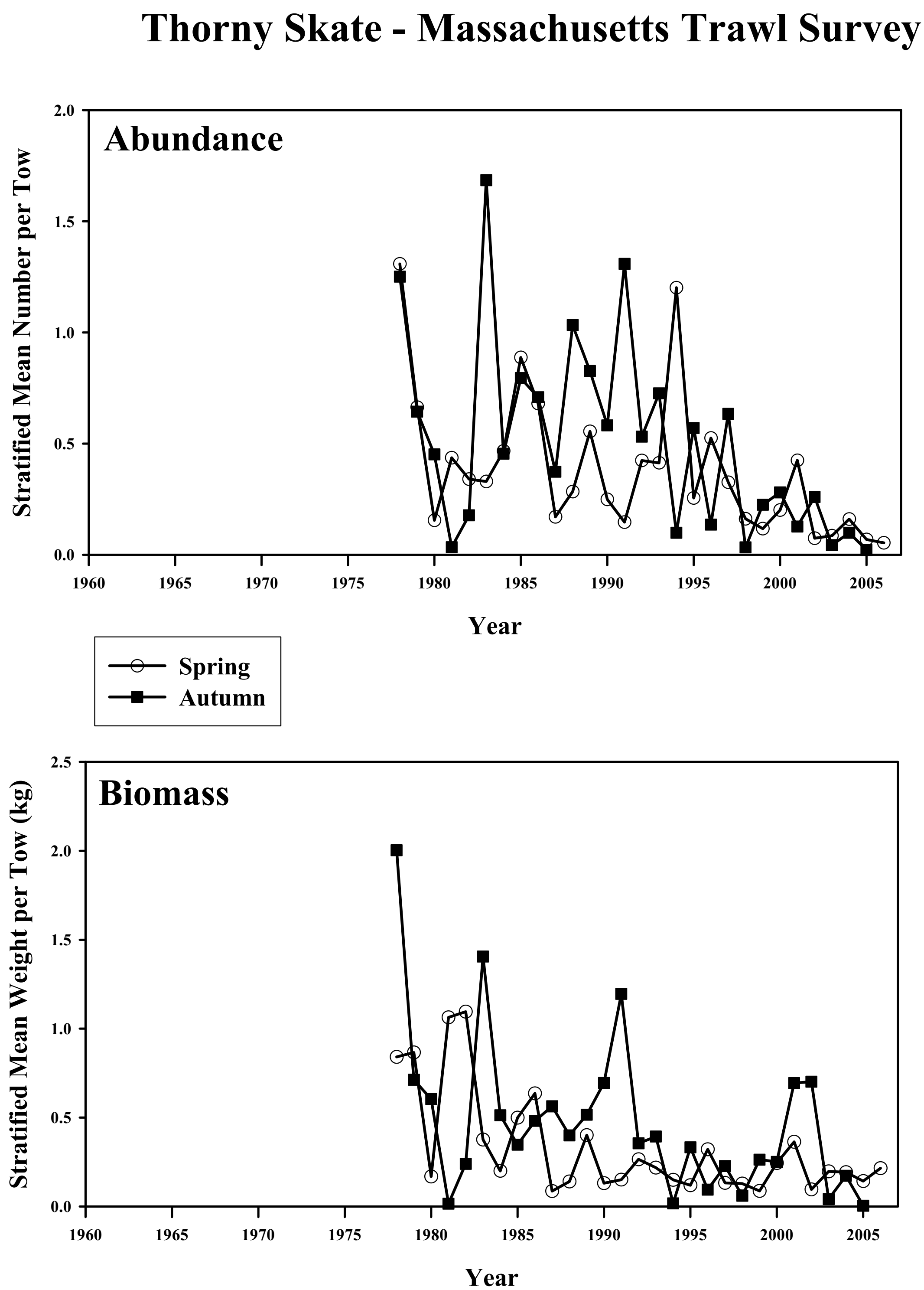
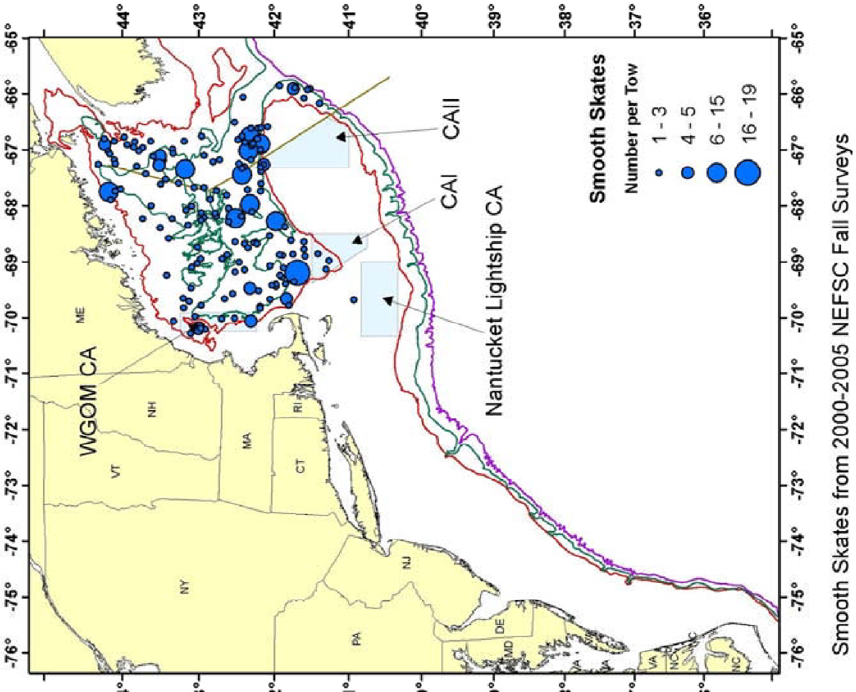


Figure B2.80. Abundance and biomass of thorny skate from the Massachusetts spring and autumn finfish bottom trawl survey in state waters (strata 25-36).



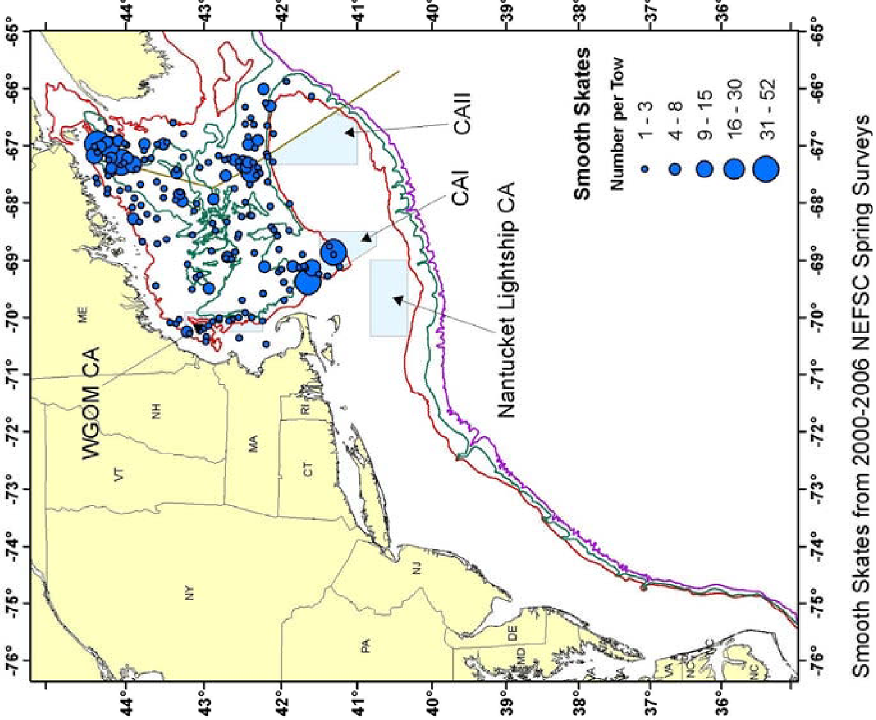


Figure B2.81. Distribution of smooth skate from the spring and autumn NEFSC surveys from 2000-2006.

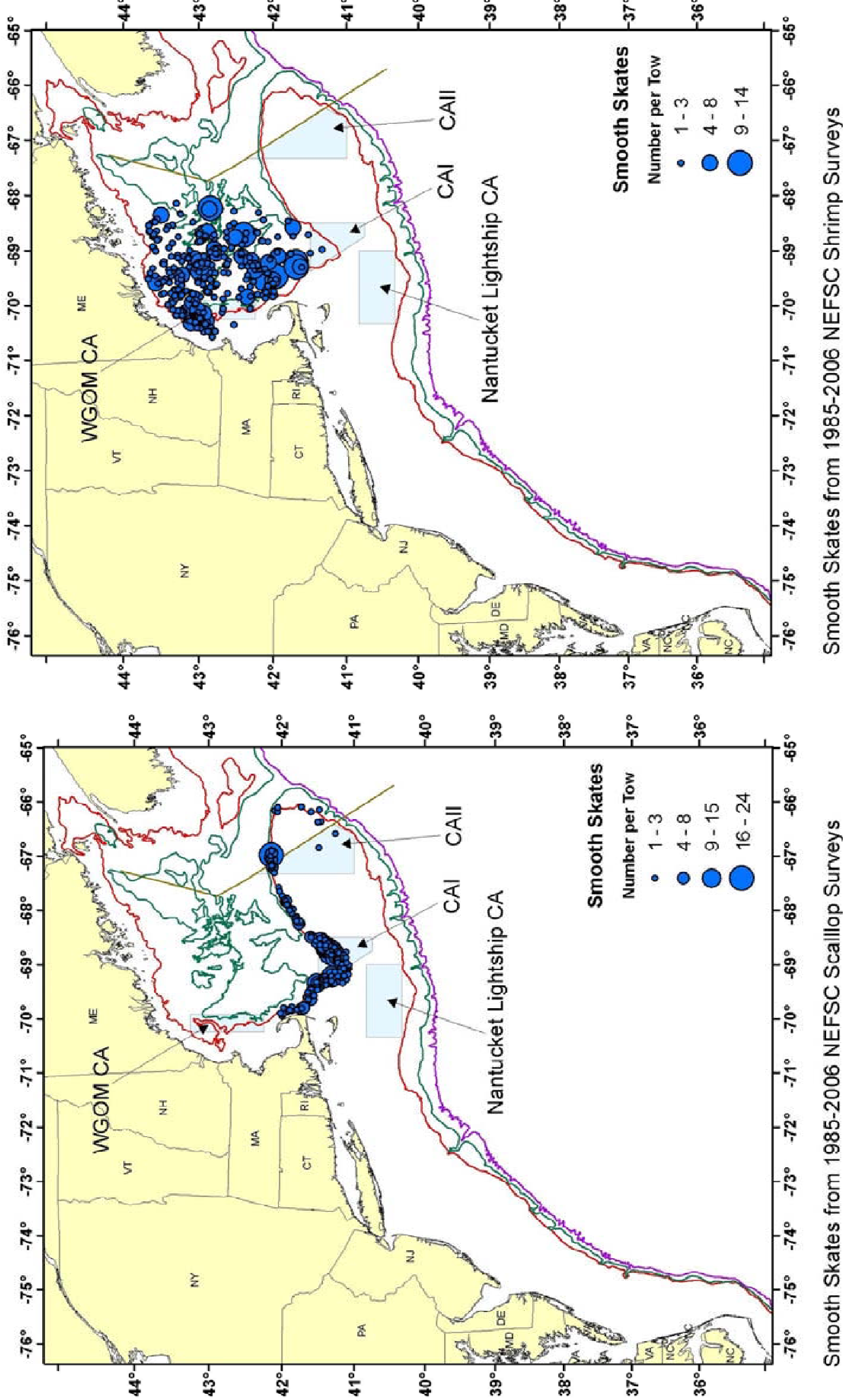


Figure B2.82. Distribution of smooth skate from the NEFSC scallop and shrimp surveys from 1985-2006.

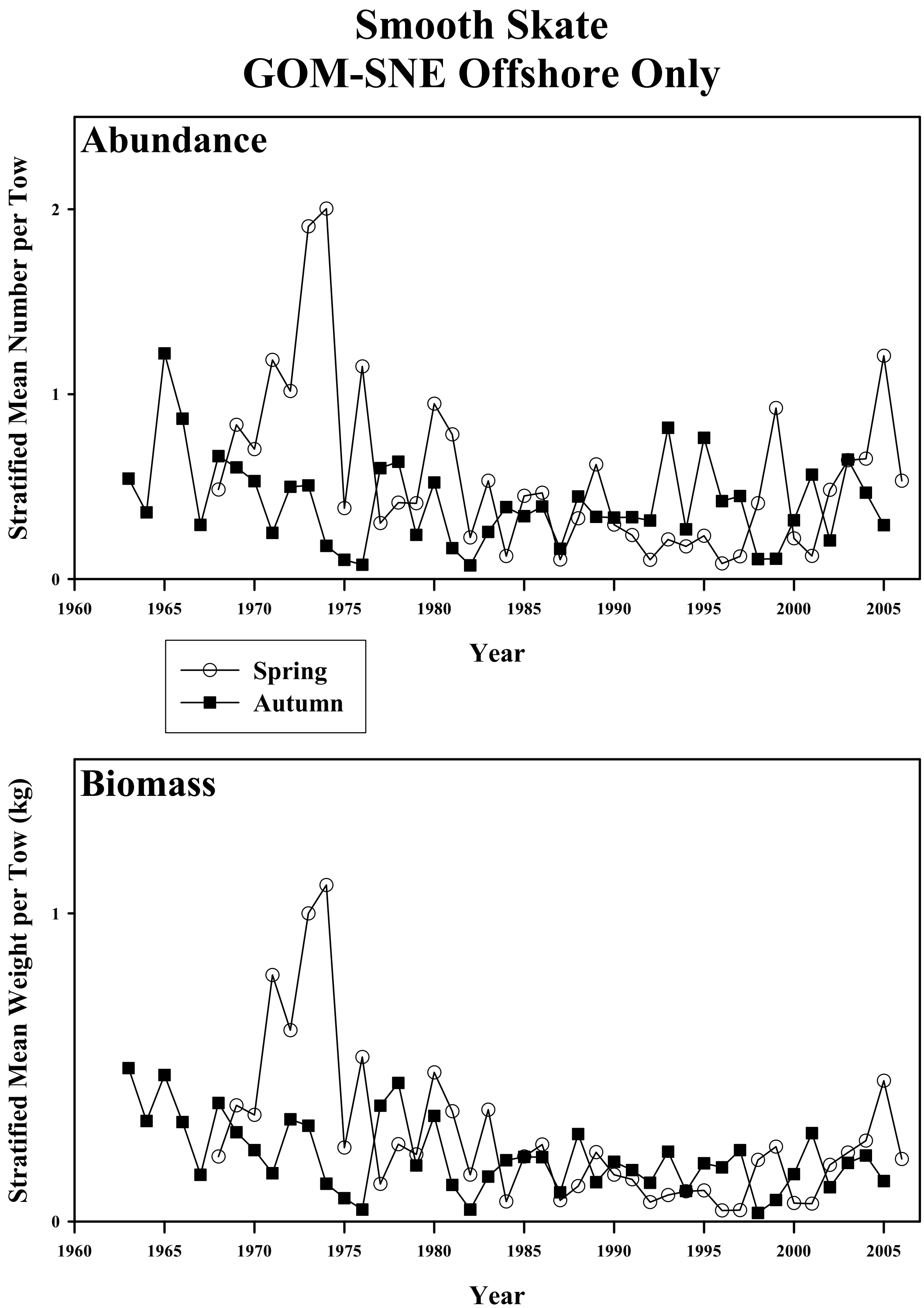


Figure B2.83. Abundance and biomass of smooth skate from the NESFC spring (circles) and autumn (squares) bottom trawl surveys from 1963-2006 in the Gulf of Maine to Southern New England offshore region.

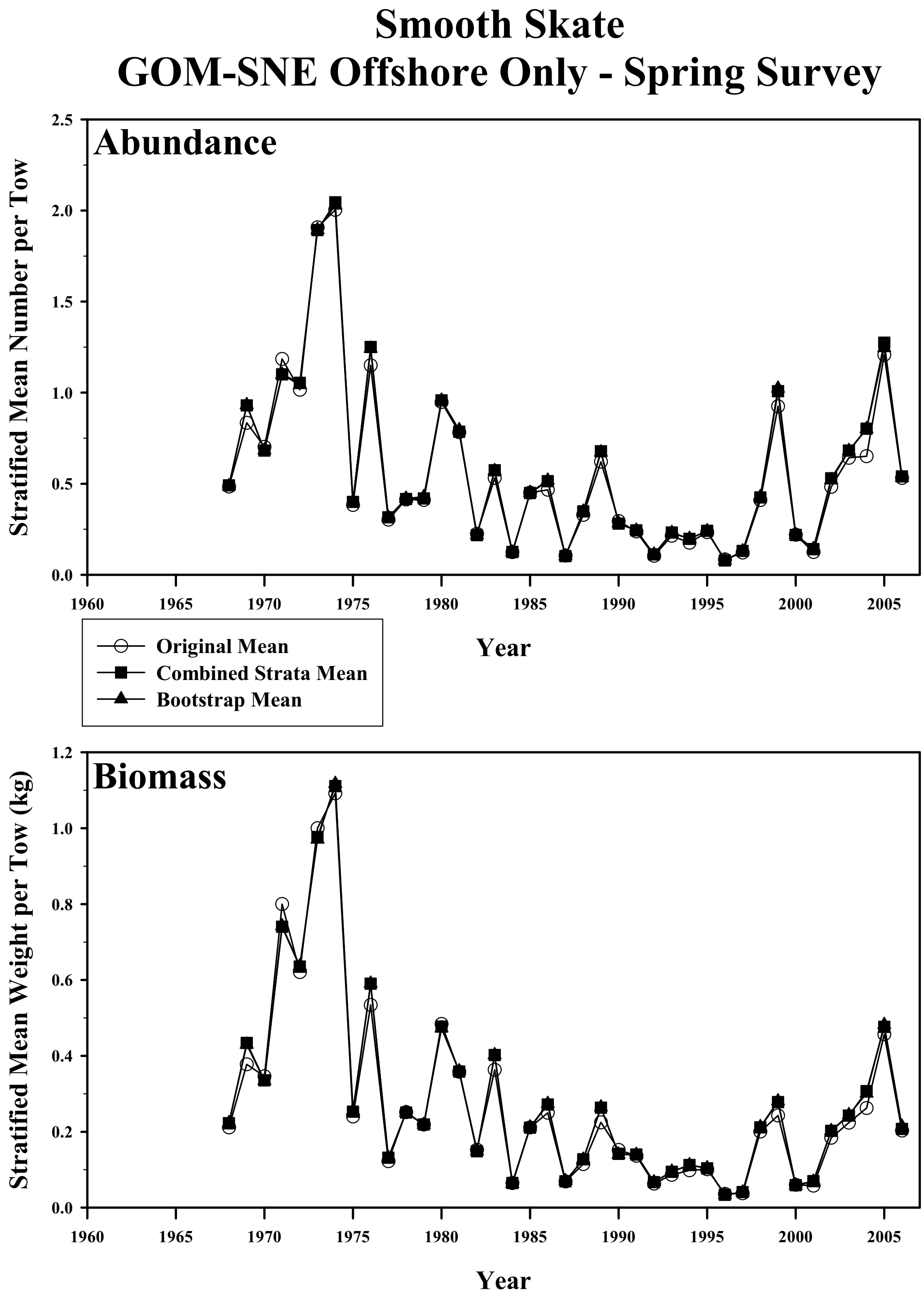


Figure B2.84. Abundance and biomass of smooth skate from the NESFC spring bottom trawl surveys from 1968-2006 in the Gulf of Maine to Southern New England offshore region. The circles represent the original stratified mean, the squares represent the mean combining strata for bootstrapping, and the triangles represent the bootstrapped mean.

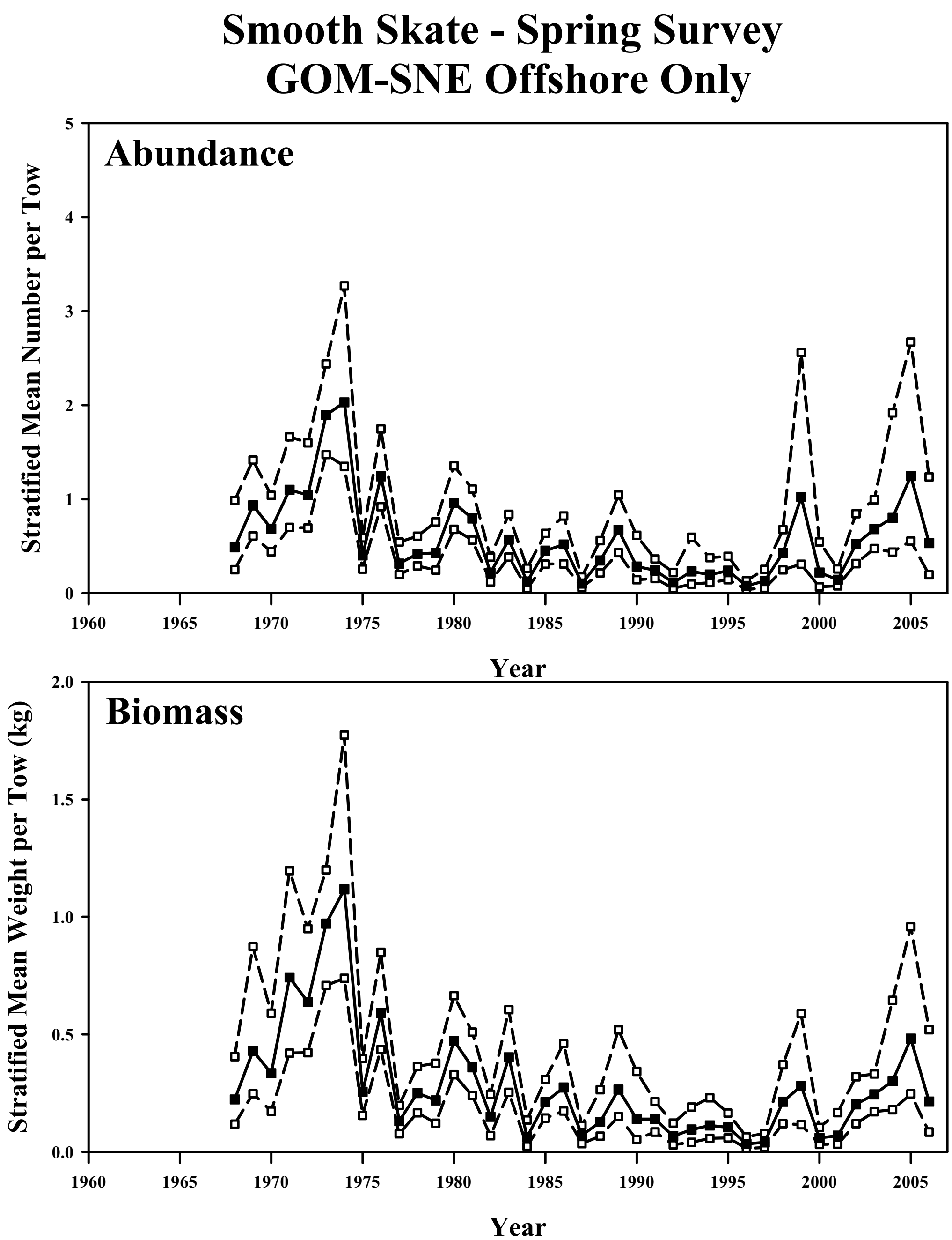


Figure B2.85. Bootstrapped abundance and biomass of smooth skate from the NESFC spring bottom trawl survey in the Gulf of Maine to Southern New England offshore region. Mean index in solid squares, 95% confidence interval in open squares.

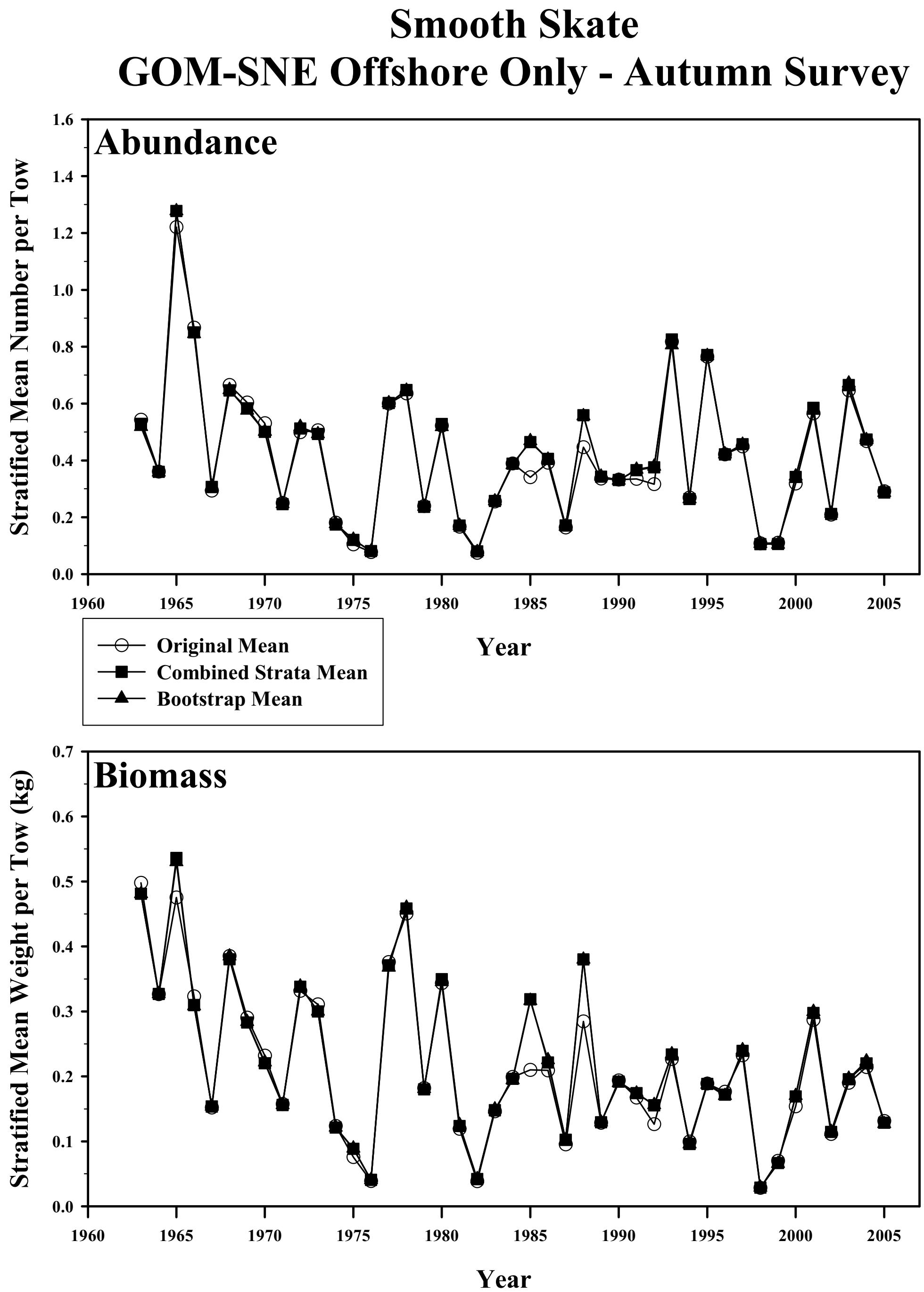


Figure B2.86. Abundance and biomass of smooth skate from the NESFC autumn bottom trawl surveys from 1968-2006 in the Gulf of Maine to Southern New England offshore region. The circles represent the original stratified mean, the squares represent the mean combining strata for bootstrapping, and the triangles represent the bootstrapped mean.

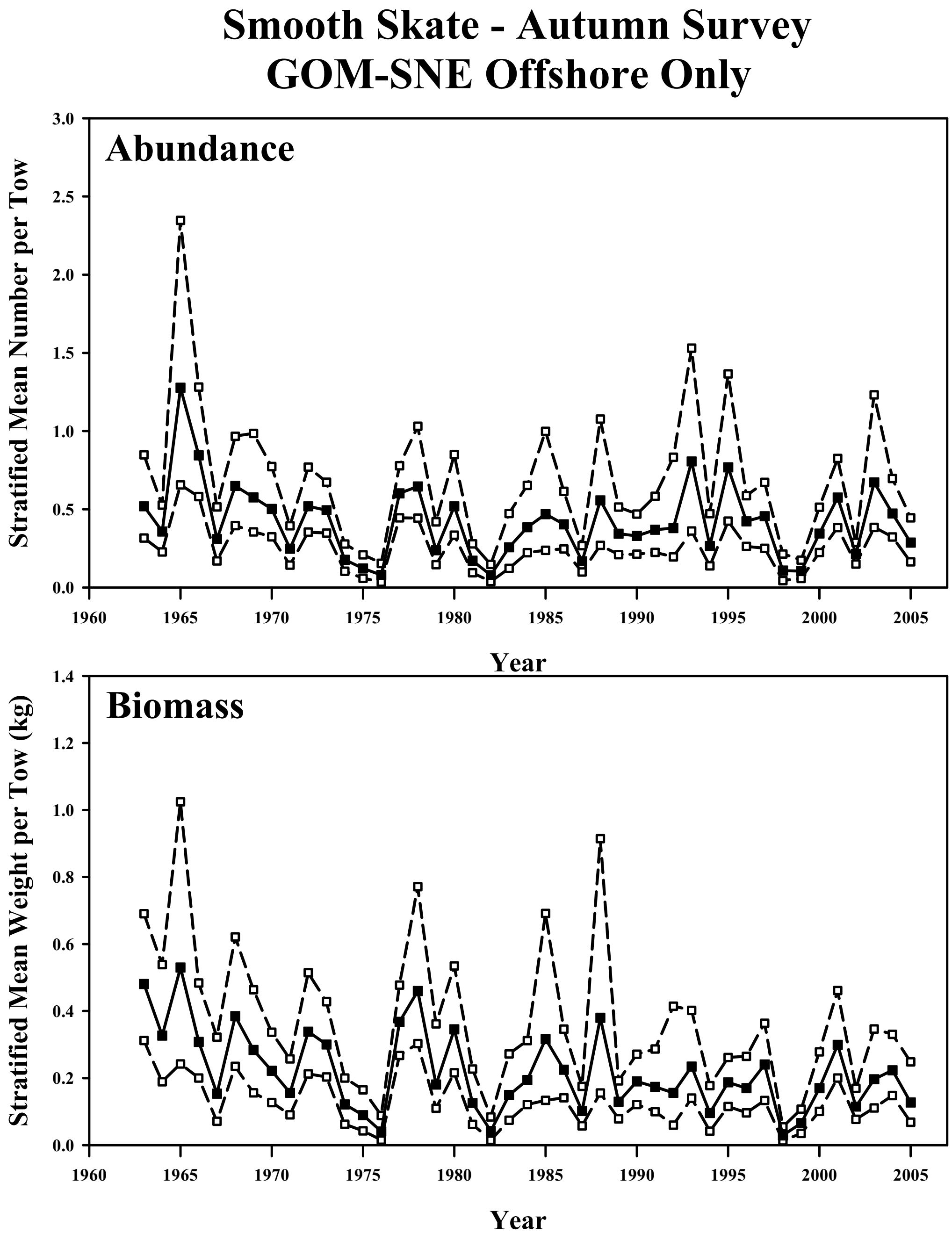


Figure B2.87. Bootstrapped abundance and biomass of smooth skate from the NESFC autumn bottom trawl survey in the Gulf of Maine to Southern New England offshore region. Mean index in solid squares, 95% confidence interval in open squares.

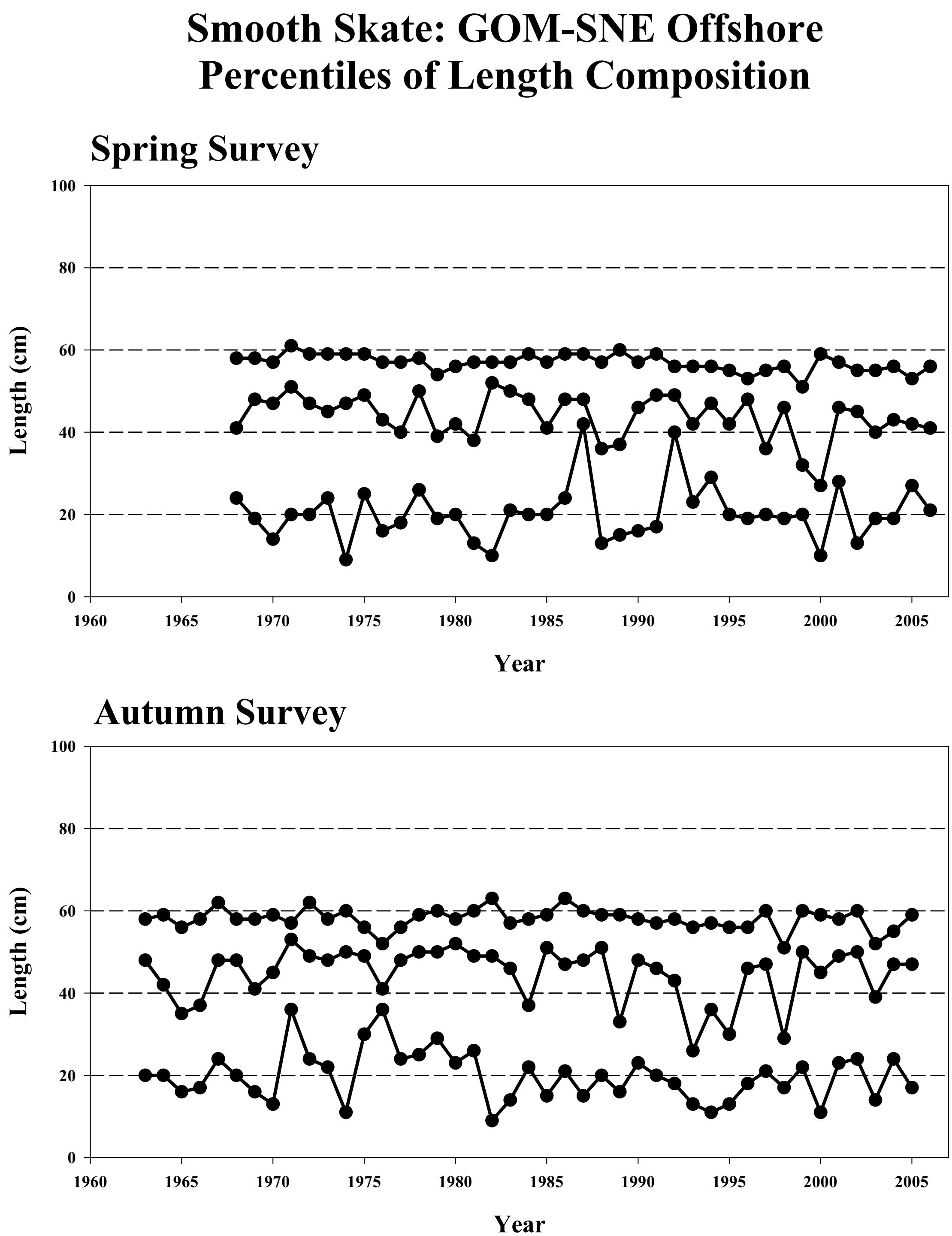


Figure B2.88. Percentiles of length composition (5, 50, and 95) of smooth skate from the NESFC spring and autumn bottom trawl surveys from 1963-2006 in the Gulf of Maine to Southern New England offshore region.

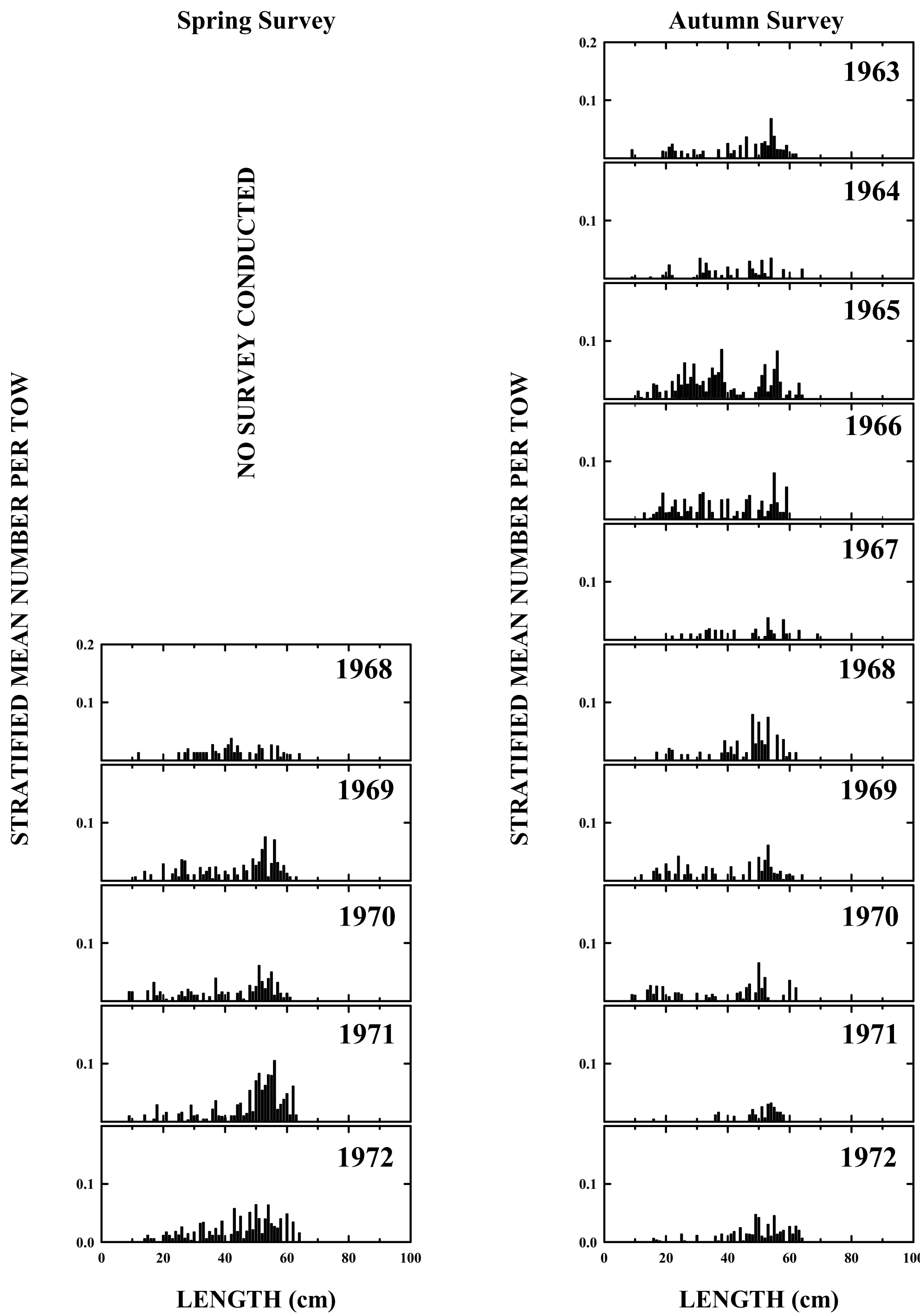


Figure B2.89. Smooth skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England offshore region, 1963-1972.

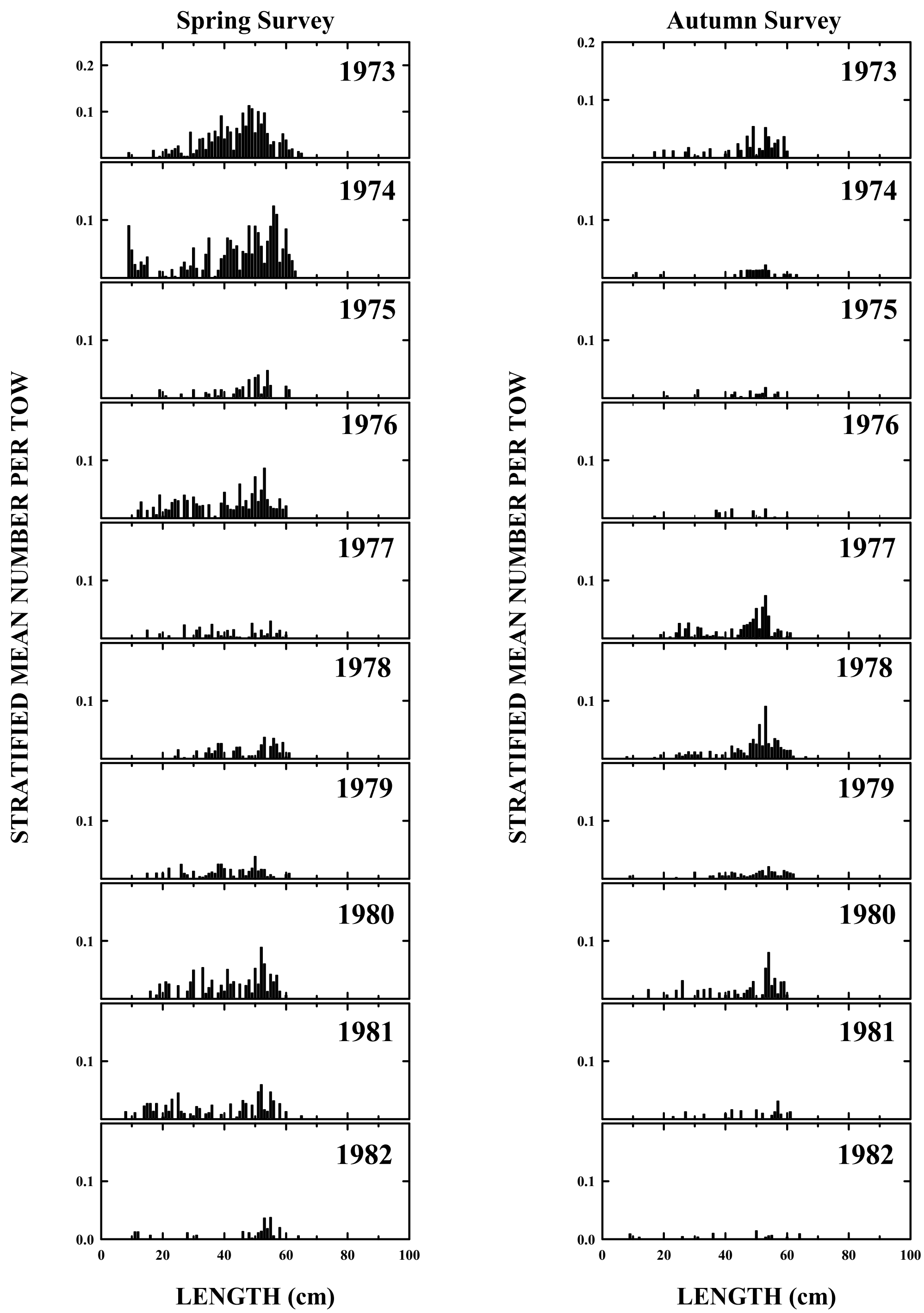


Figure B2.90. Smooth skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England offshore region, 1973-1982.

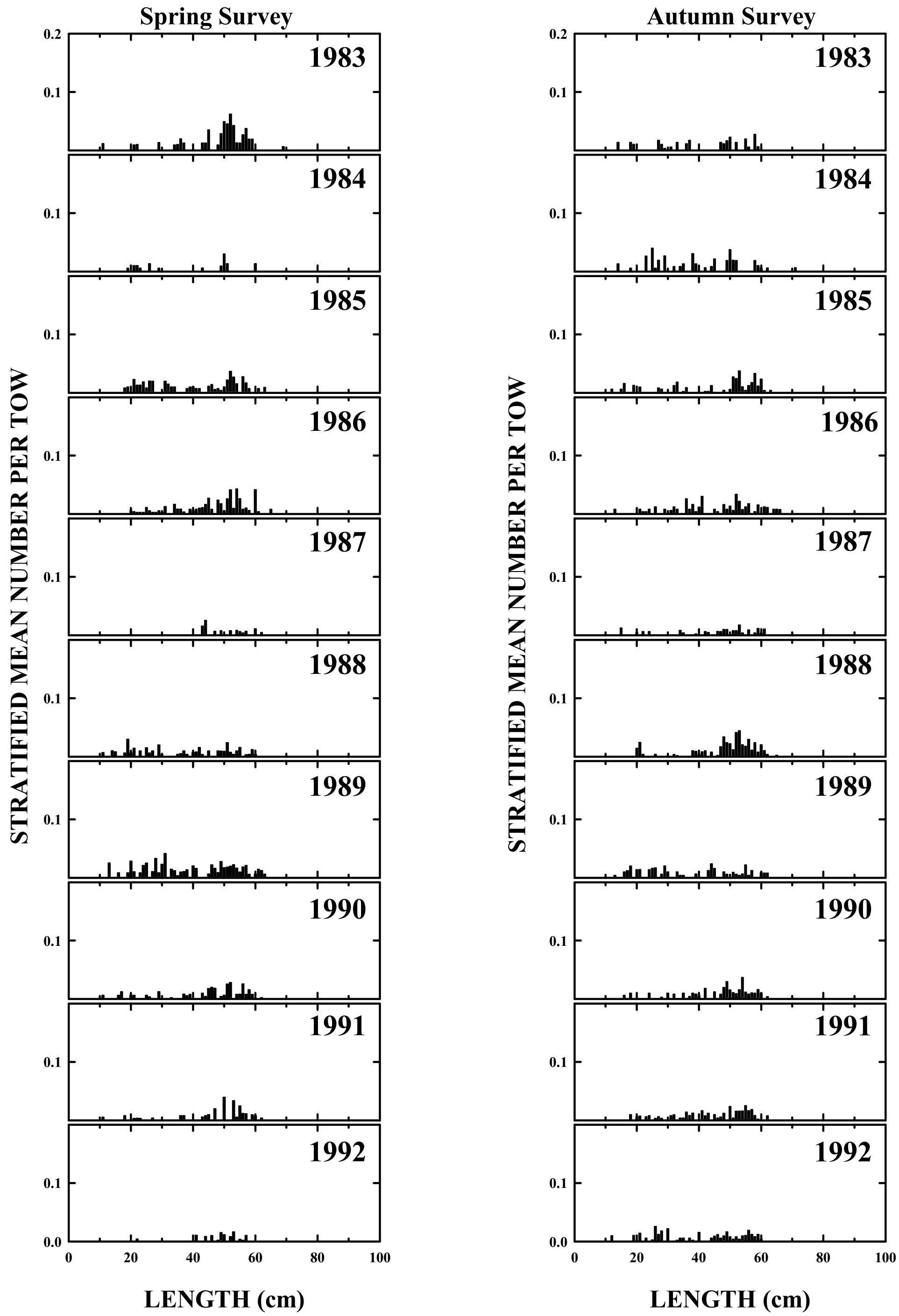


Figure B2.91. Smooth skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England offshore region, 1983-1992.

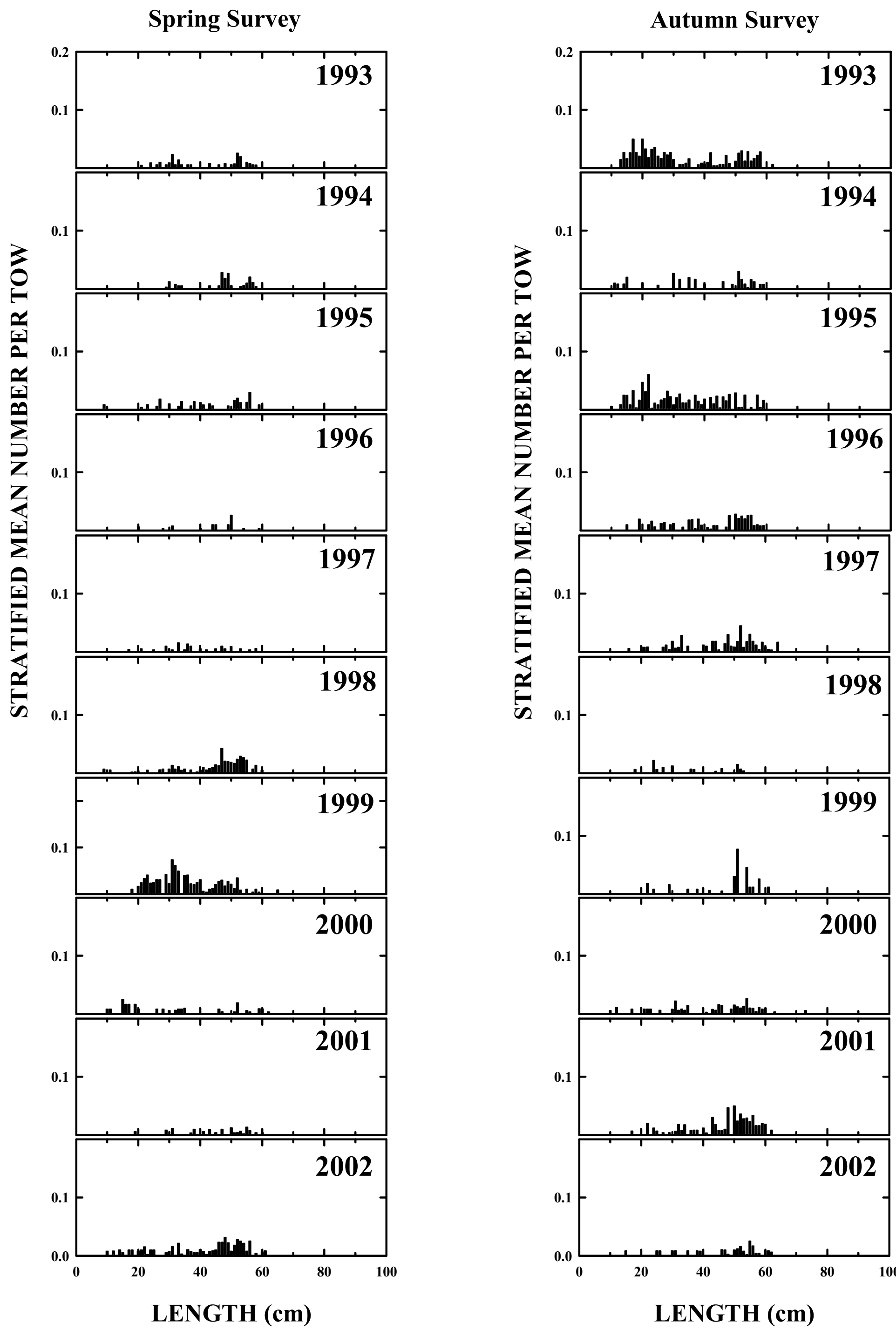


Figure B2.92. Smooth skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England offshore region, 1993-2002.

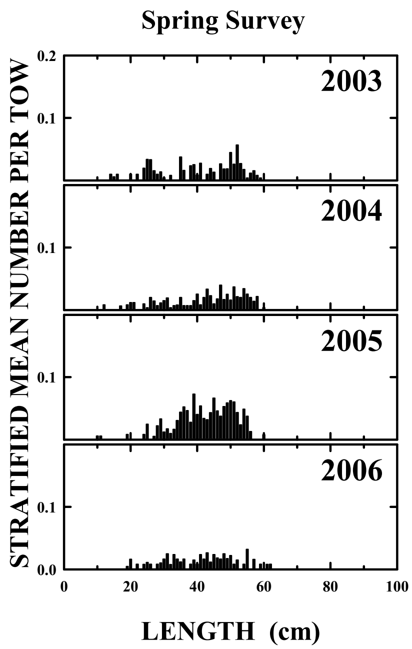


Figure B2.93. Smooth skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Gulf of Maine to Southern New England offshore region, 2003-2006.

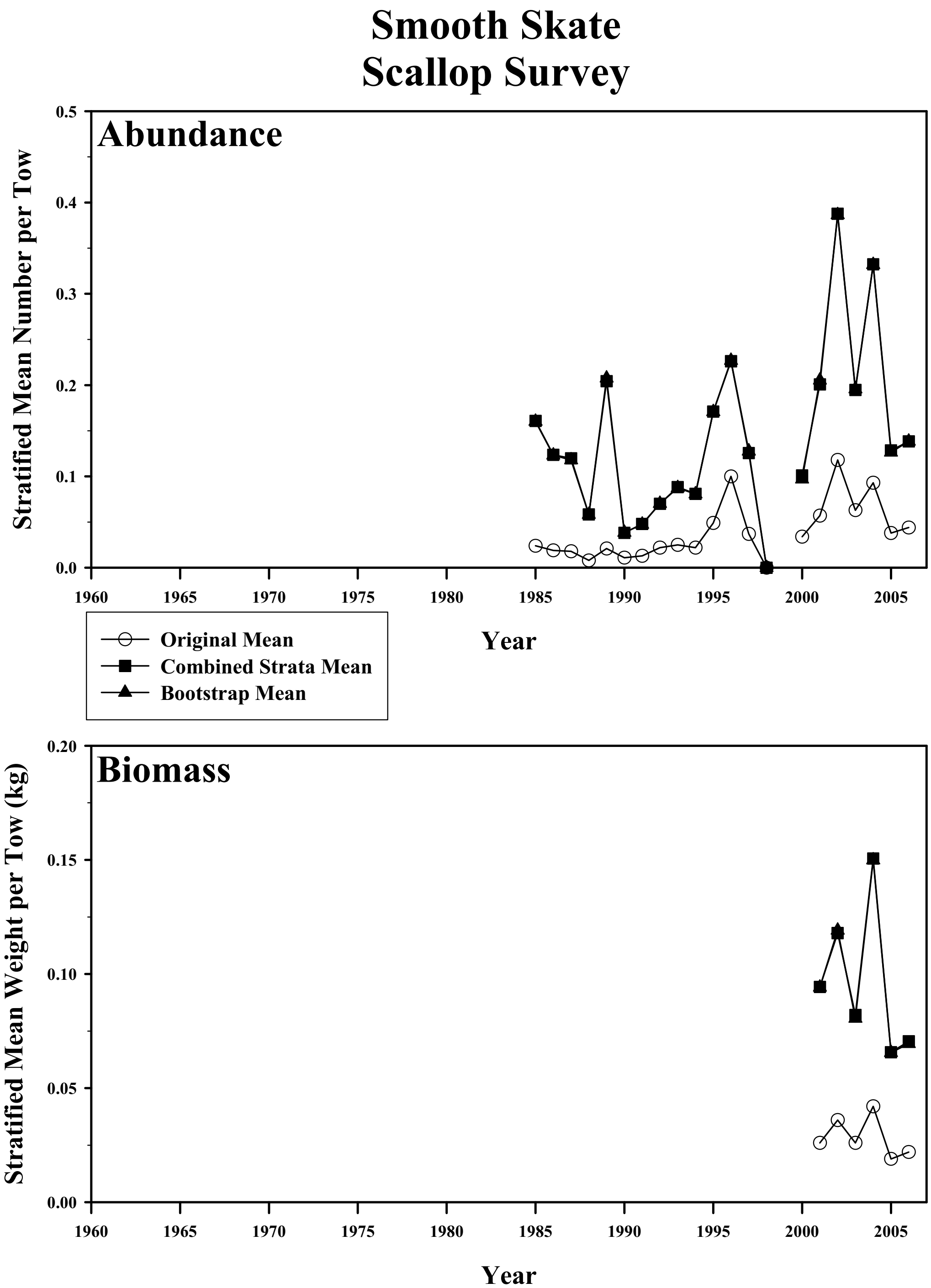


Figure B2.94. Abundance and biomass of smooth skate from the NESFC scallop surveys from 1985-2006. The circles represent the original stratified mean, the squares represent the mean combining strata for bootstrapping, and the triangles represent the bootstrapped mean.

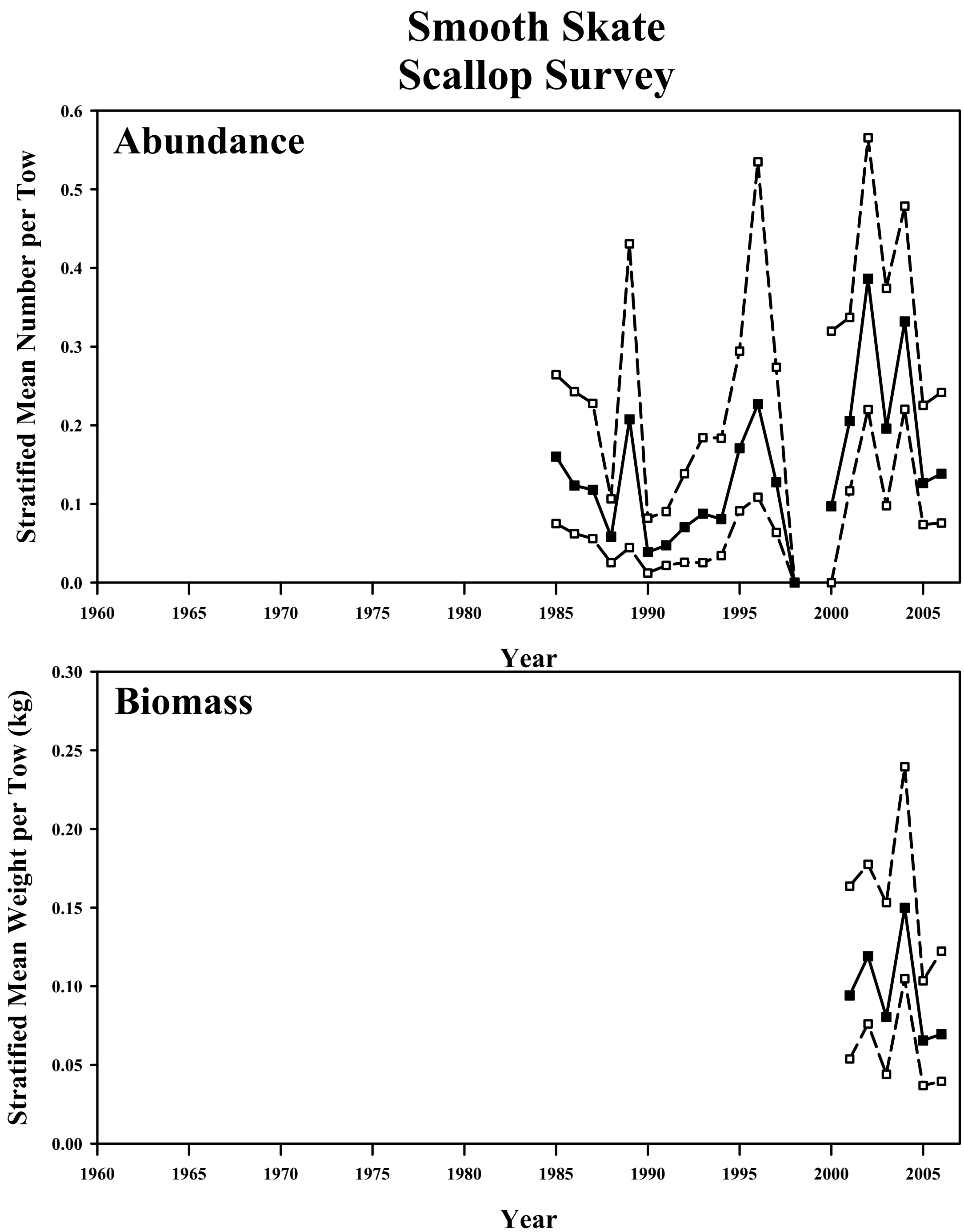


Figure B2.95. Bootstrapped abundance and biomass of smooth skate from the NESFC scallop survey. Mean index in solid squares, 95% confidence interval in open squares.

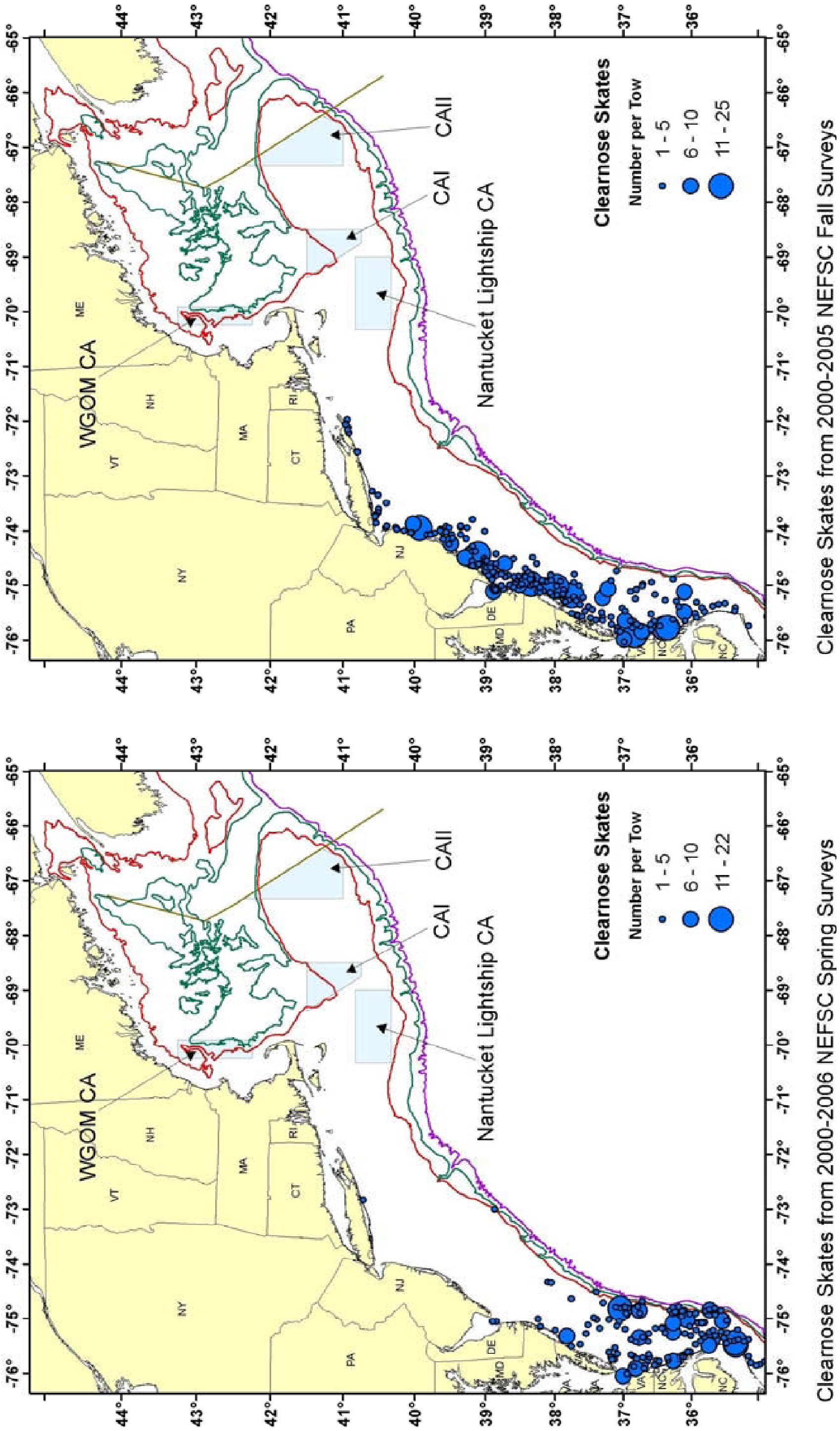


Figure B2.96. Distribution of clearnose skate from the spring and autumn NEFSC surveys from 2000-2006.

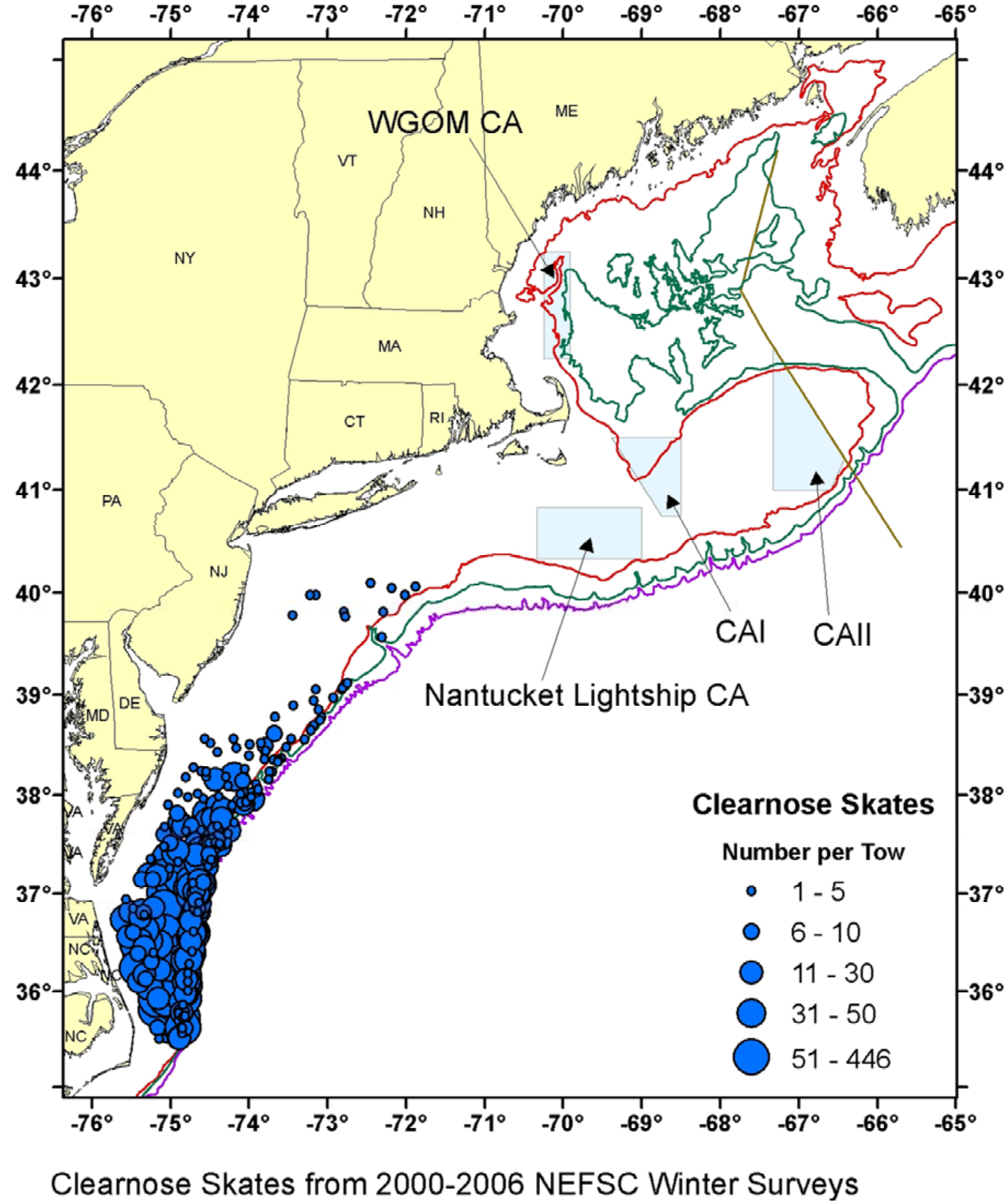


Figure B2.97. Distribution of clearnose skate from the winter NEFSC surveys from 2000-2006.

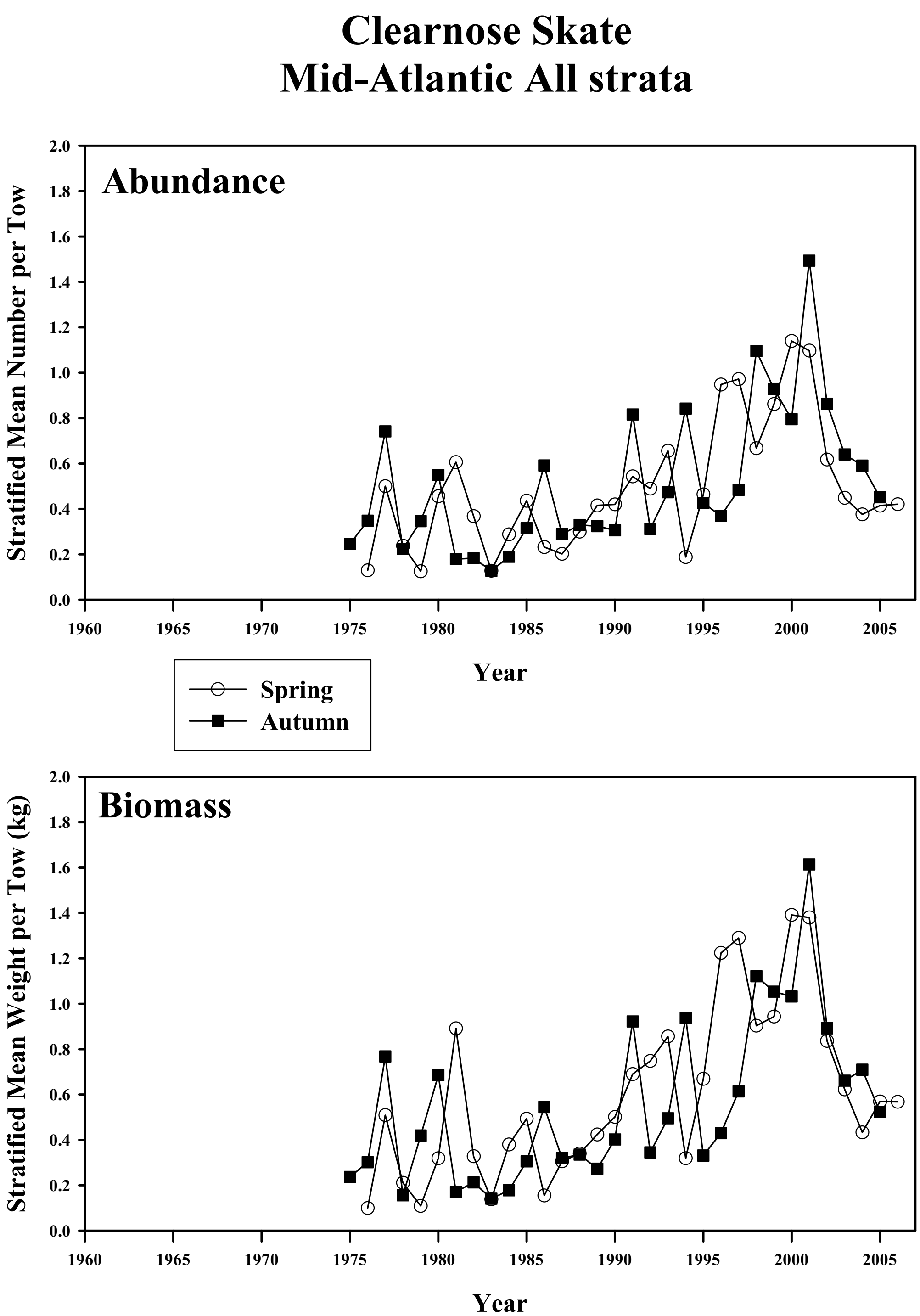


Figure B2.98. Abundance and biomass of clearnose skate from the NESFC spring (circles) and autumn (squares) bottom trawl surveys from 1975-2006 in the Mid-Atlantic (all strata).

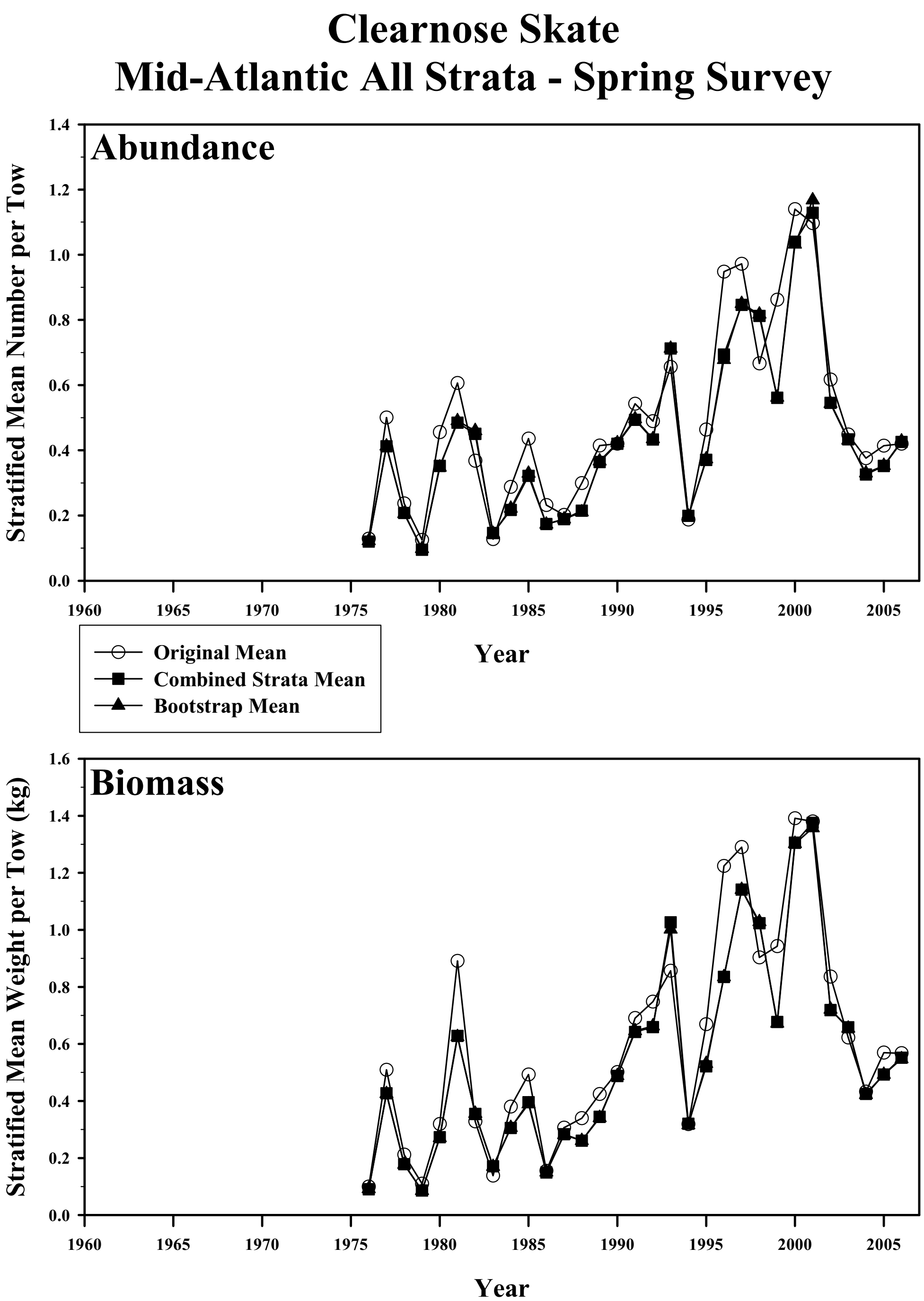


Figure B2.99. Abundance and biomass of clearnose skate from the NESFC spring bottom trawl surveys from 1976-2006 in the Mid-Atlantic (all strata). The circles represent the original stratified mean, the squares represent the mean combining strata for bootstrapping, and the triangles represent the bootstrapped mean.

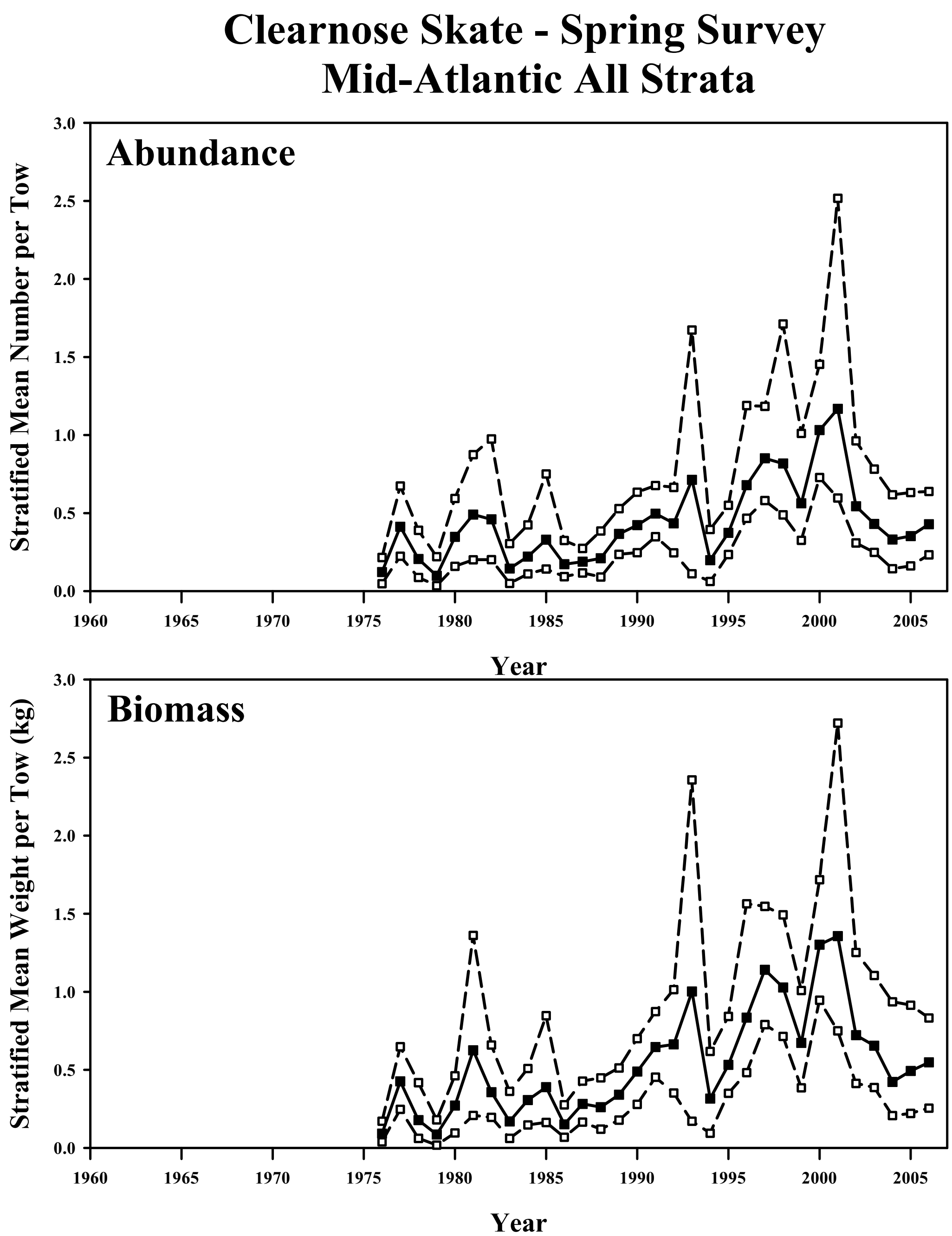


Figure B2.100. Bootstrapped abundance and biomass of clearnose skate from the NESFC spring bottom trawl survey in the Mid-Atlantic region (all strata). Mean index in solid squares, 95% confidence interval in open squares.

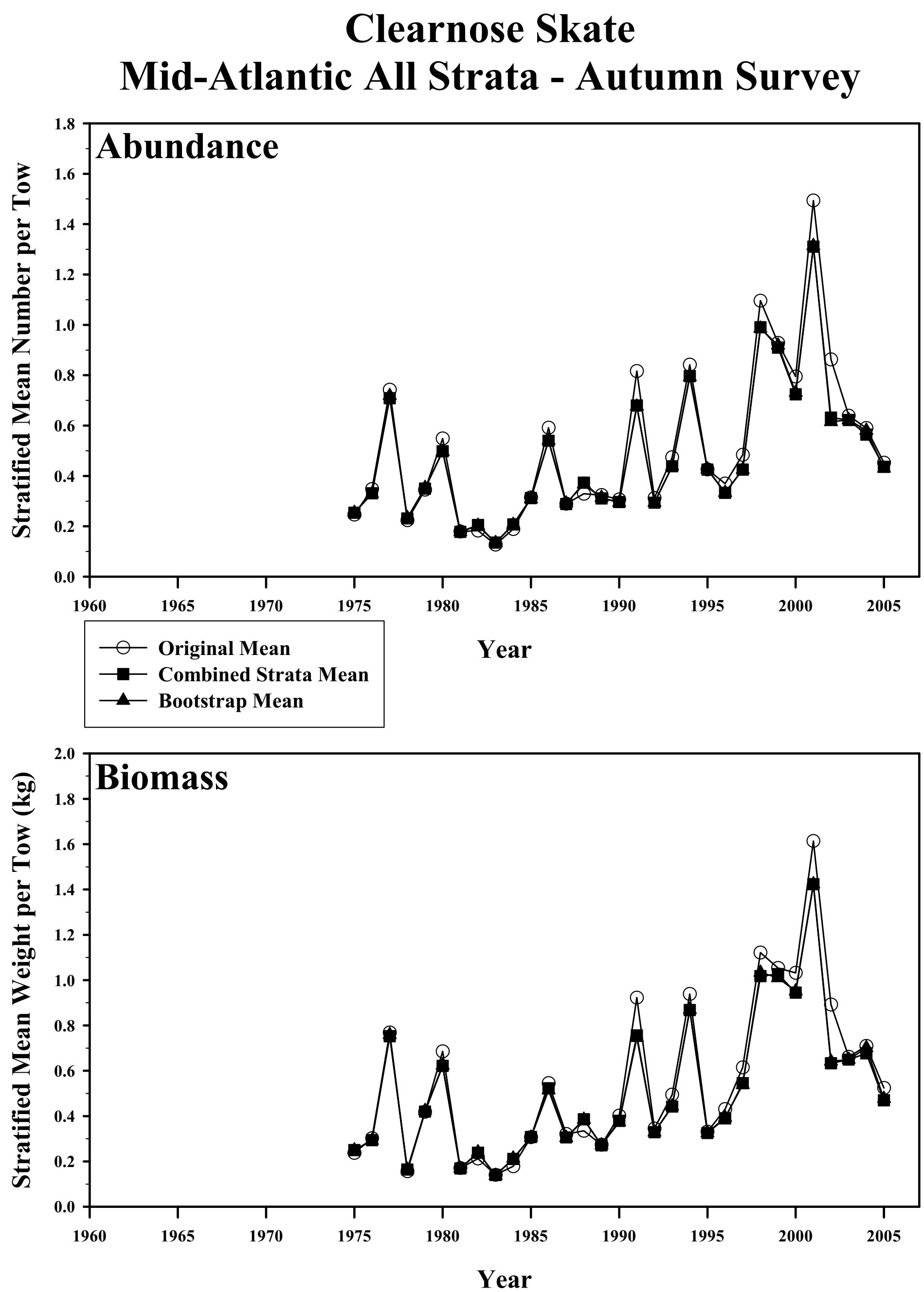


Figure B2.101. Abundance and biomass of clearnose skate from the NESFC autumn bottom trawl surveys from 1976-2006 in the Mid-Atlantic (all strata). The circles represent the original stratified mean, the squares represent the mean combining strata for bootstrapping, and the triangles represent the bootstrapped mean.

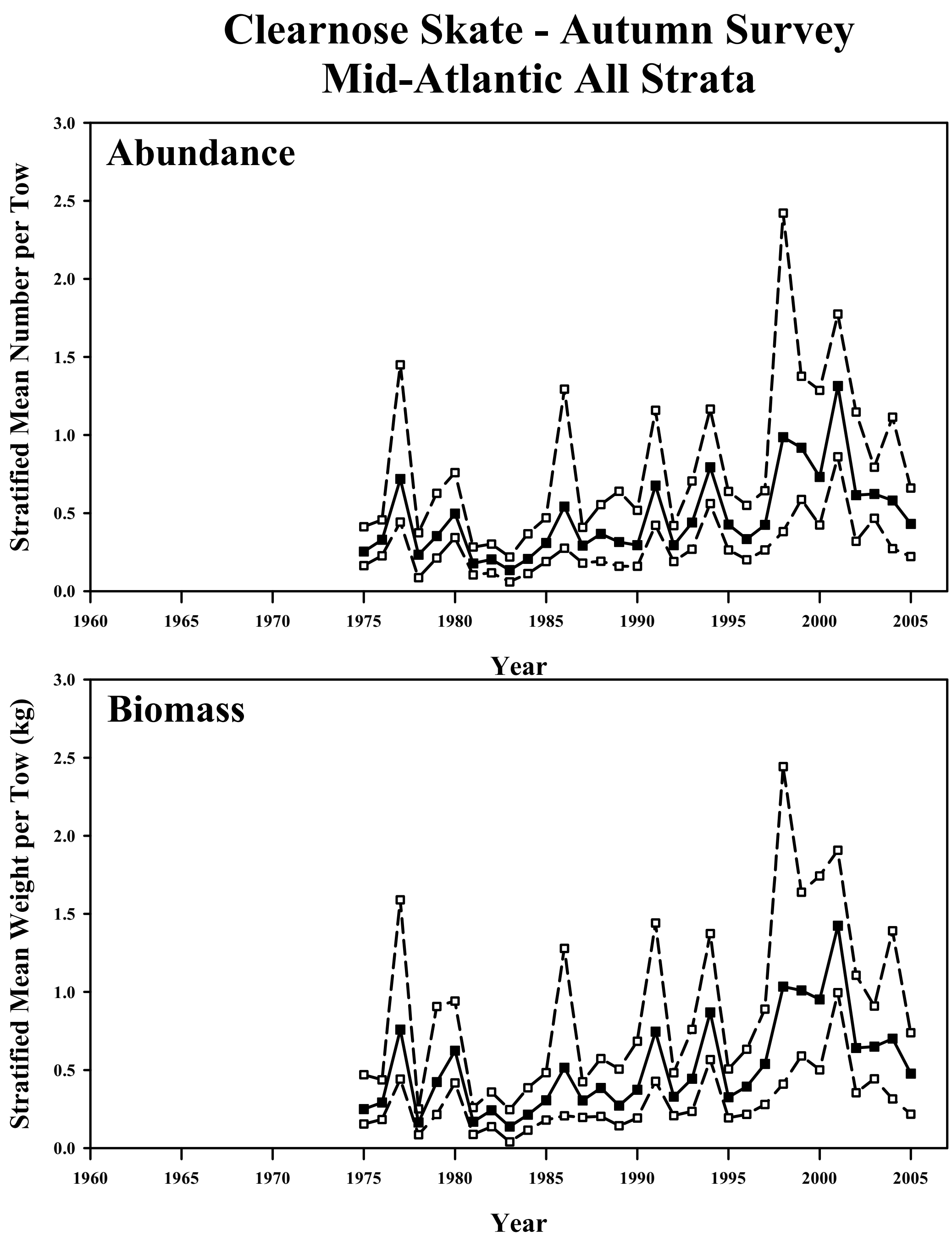
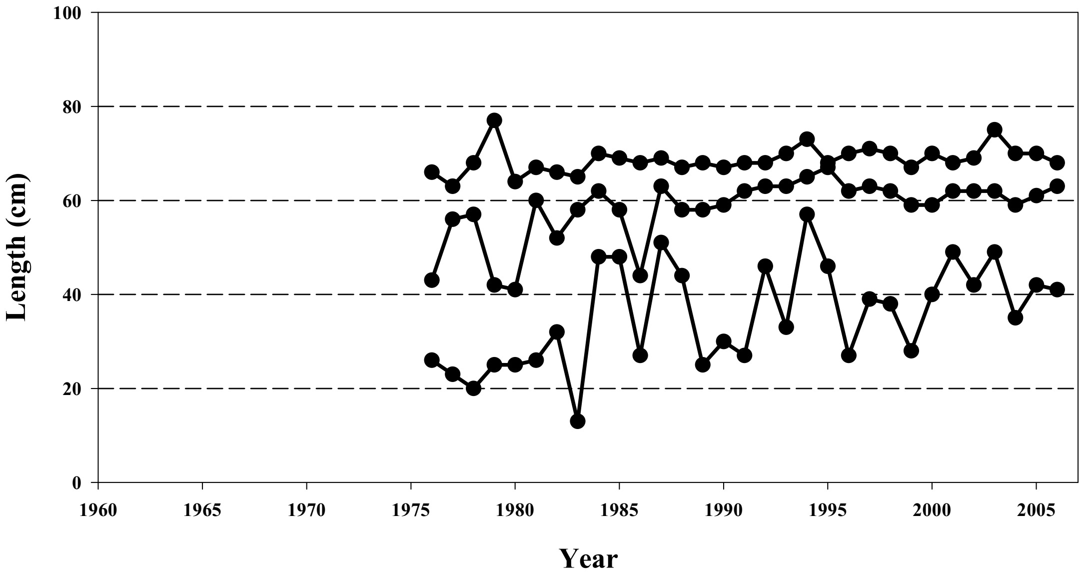


Figure B2.102. Bootstrapped abundance and biomass of clearnose skate from the NESFC autumn bottom trawl survey in the Mid-Atlantic region (all strata). Mean index in solid squares, 95% confidence interval in open squares.

Clearnose Skate
Percentiles of Length Composition

Spring Survey



Autumn Survey

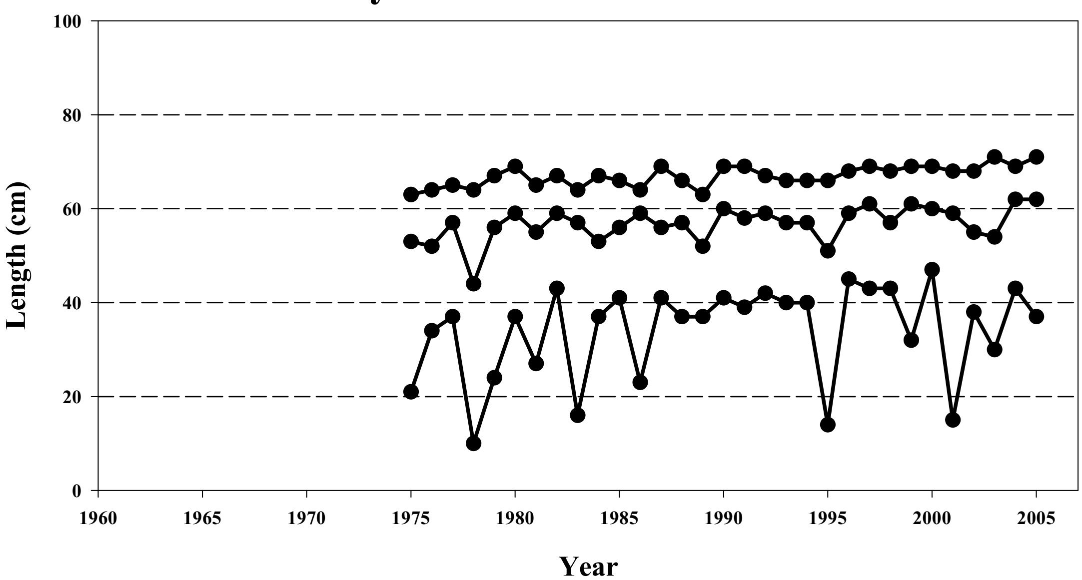


Figure B2.103. Percentiles of length composition (5, 50, and 95) of clearnose skate from the NESFC spring and autumn bottom trawl surveys from 1975-2006 in the Mid-Atlantic region (all strata).

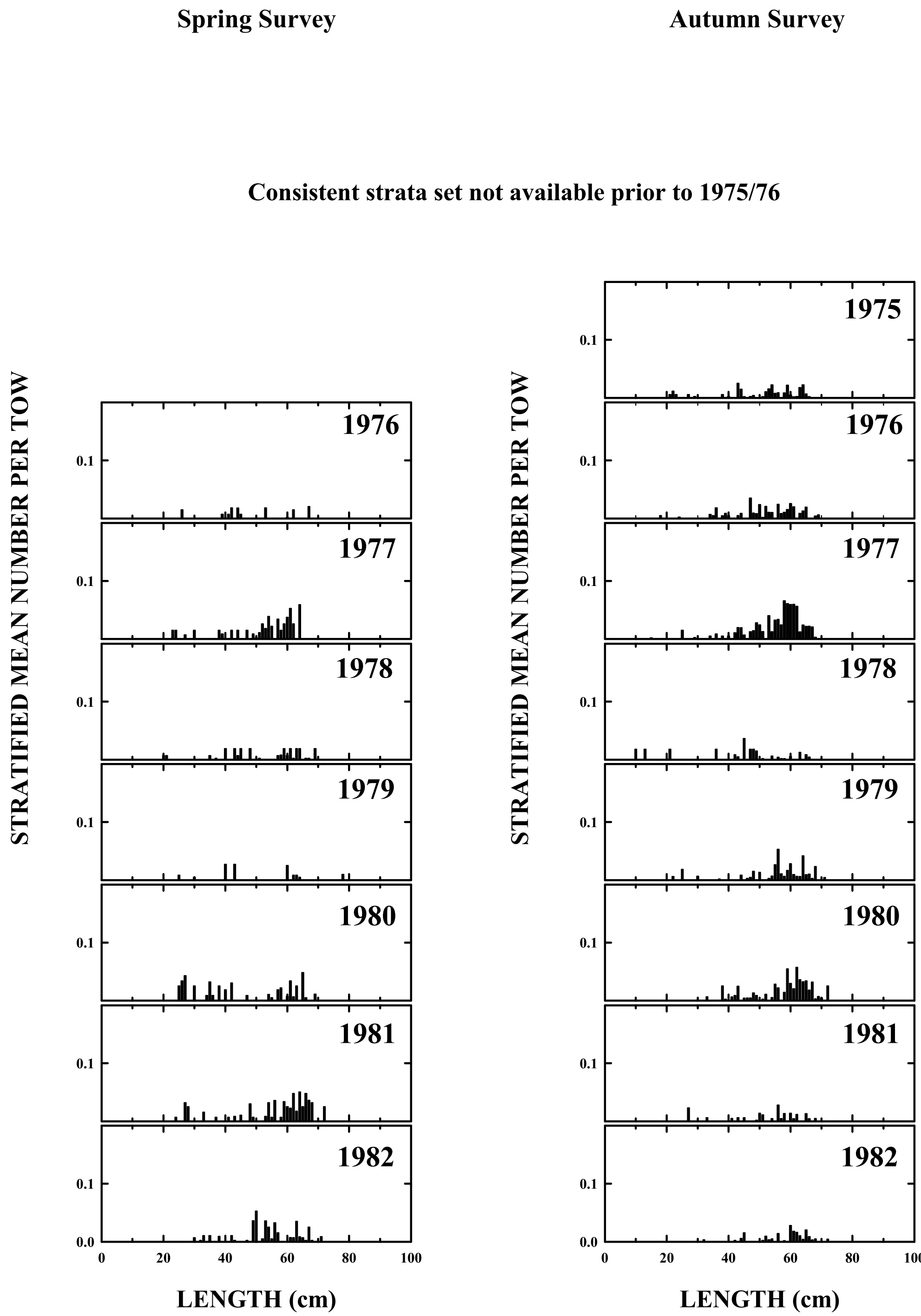


Figure B2.104. Clearnose skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Mid-Atlantic (all strata), 1975-1982.

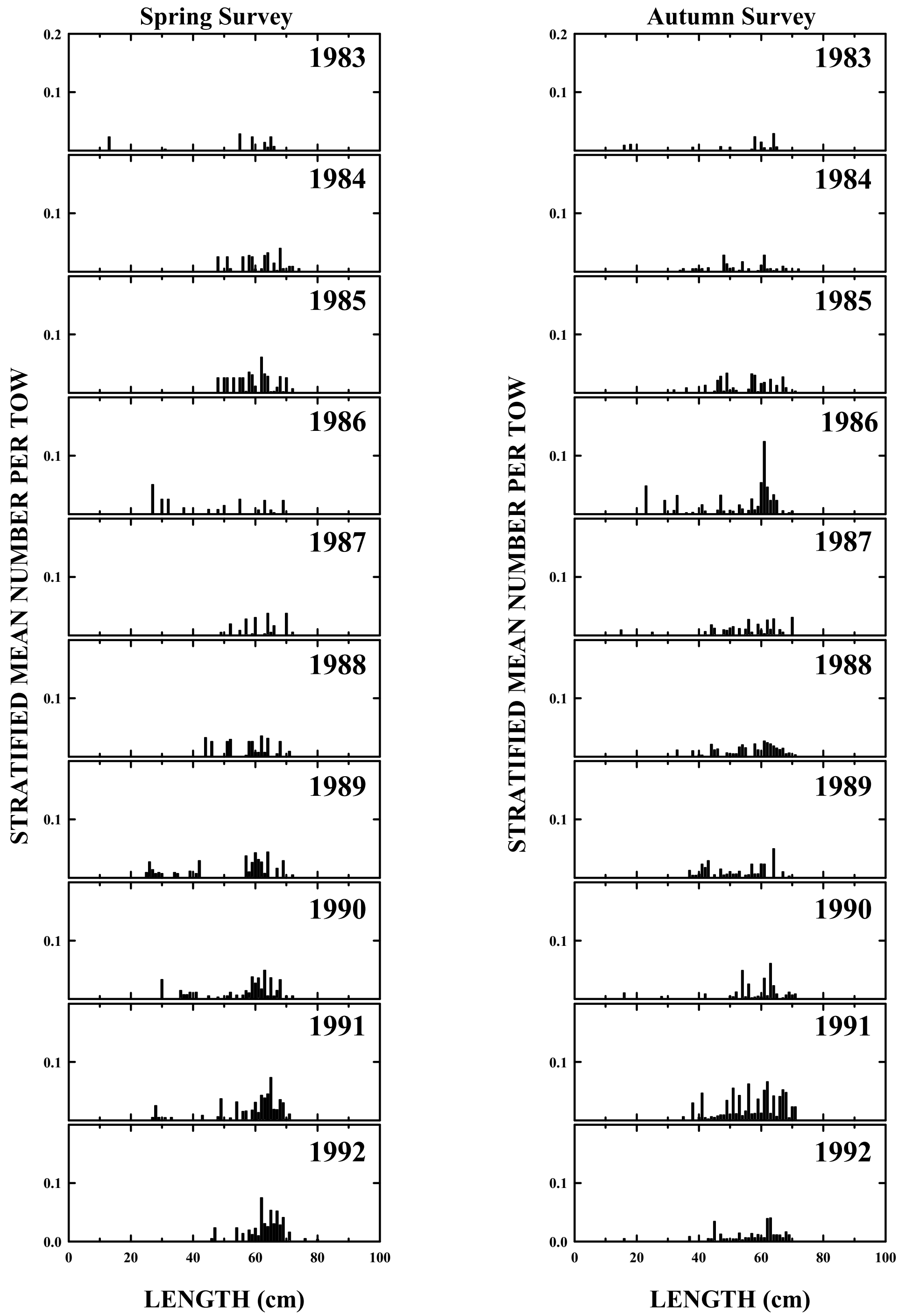


Figure B2.105. Clearnose skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Mid-Atlantic (all strata), 1983-1992.

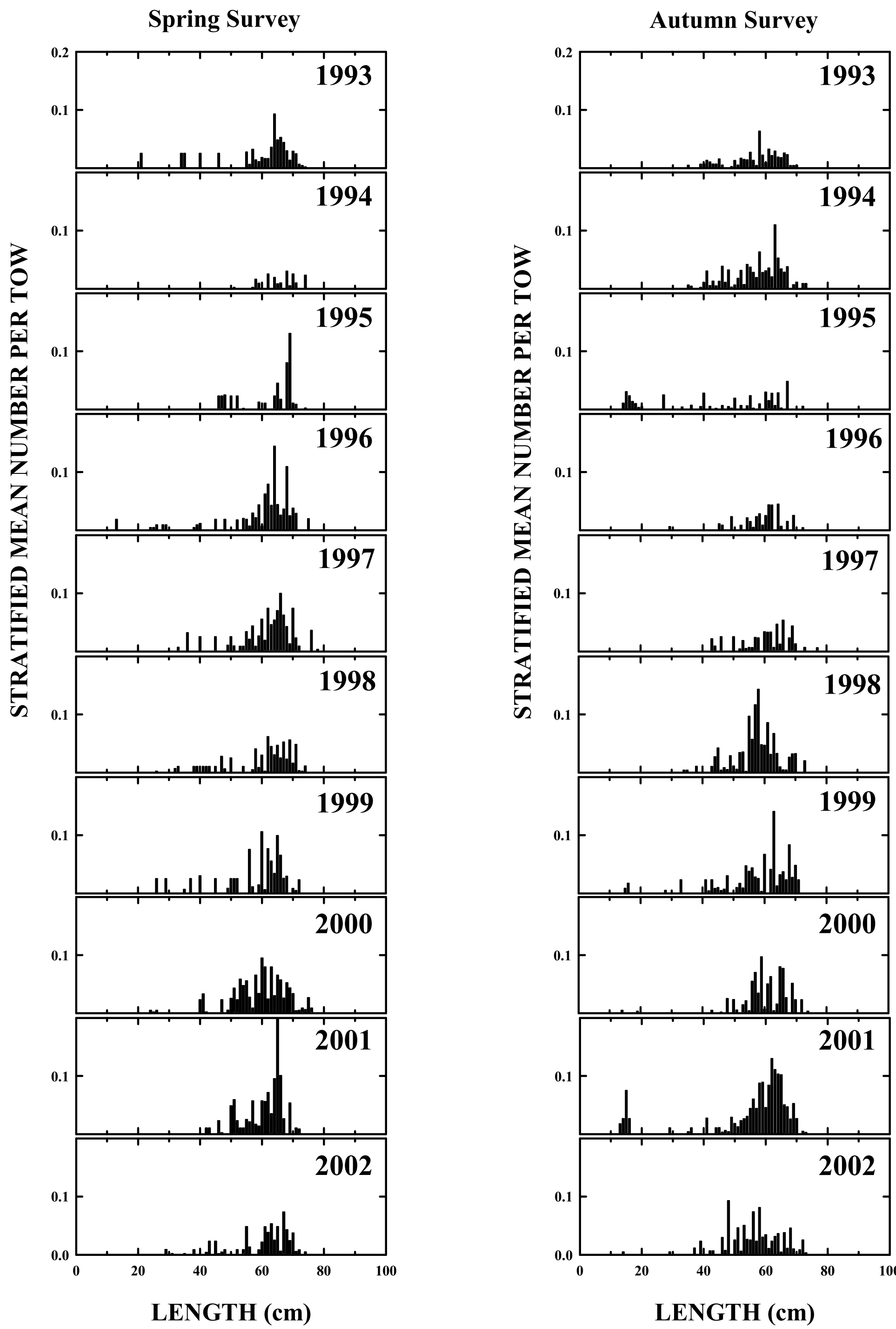


Figure B2.106. Clearnose skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Mid-Atlantic (all strata), 1993-2002.

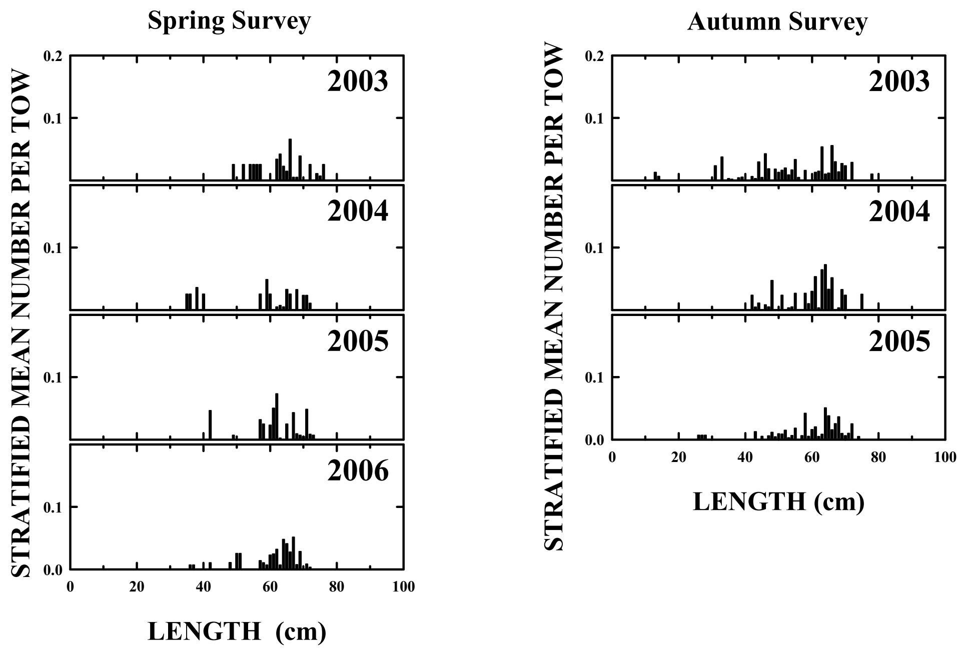


Figure B2.107. Clearnose skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Mid-Atlantic (all strata), 2003-2006.

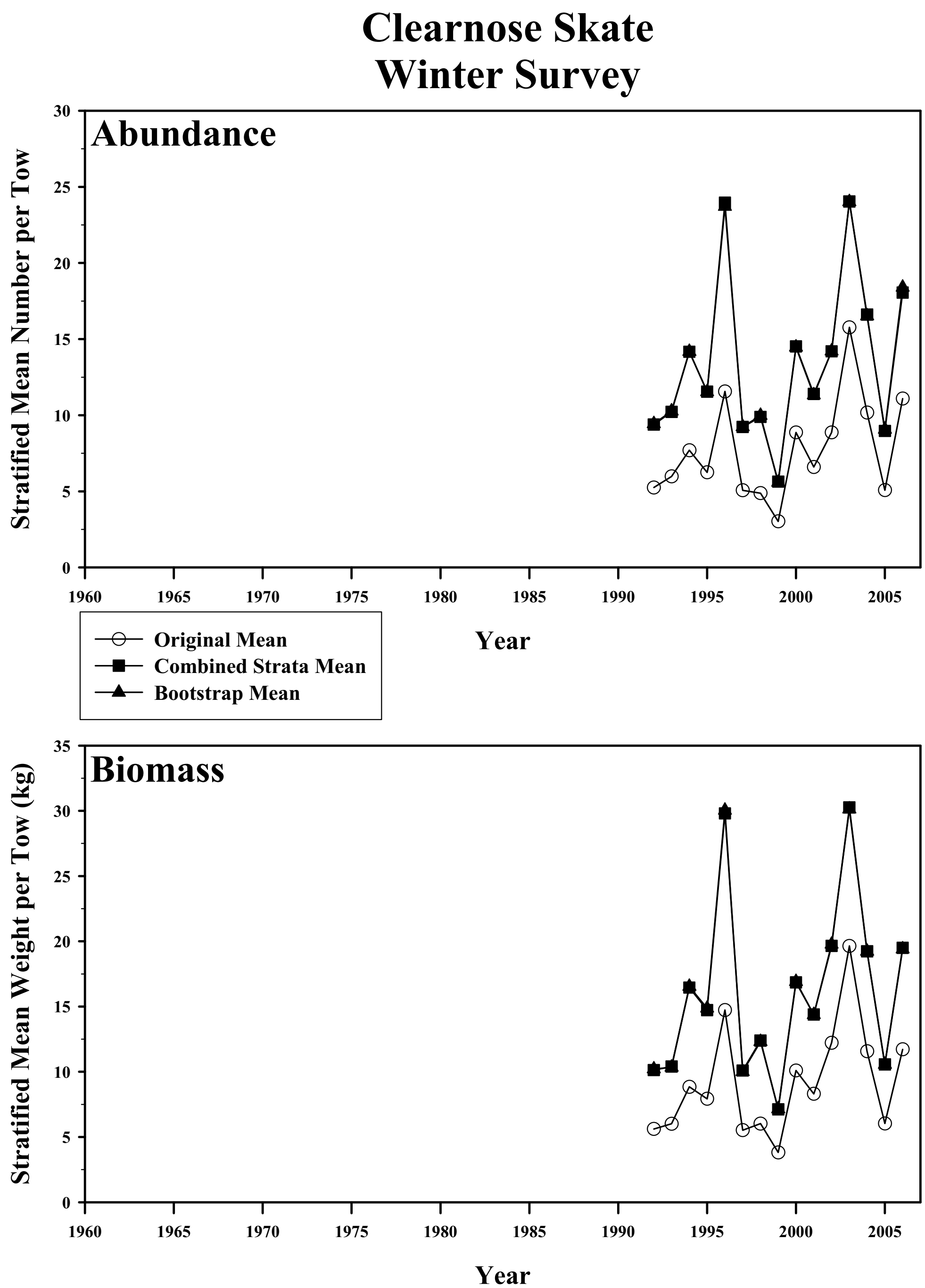


Figure B2.108. Abundance and biomass of clearnose skate from the NESFC winter bottom trawl surveys from 1992-2006. The circles represent the original stratified mean, the squares represent the mean combining strata for bootstrapping, and the triangles represent the bootstrapped mean.

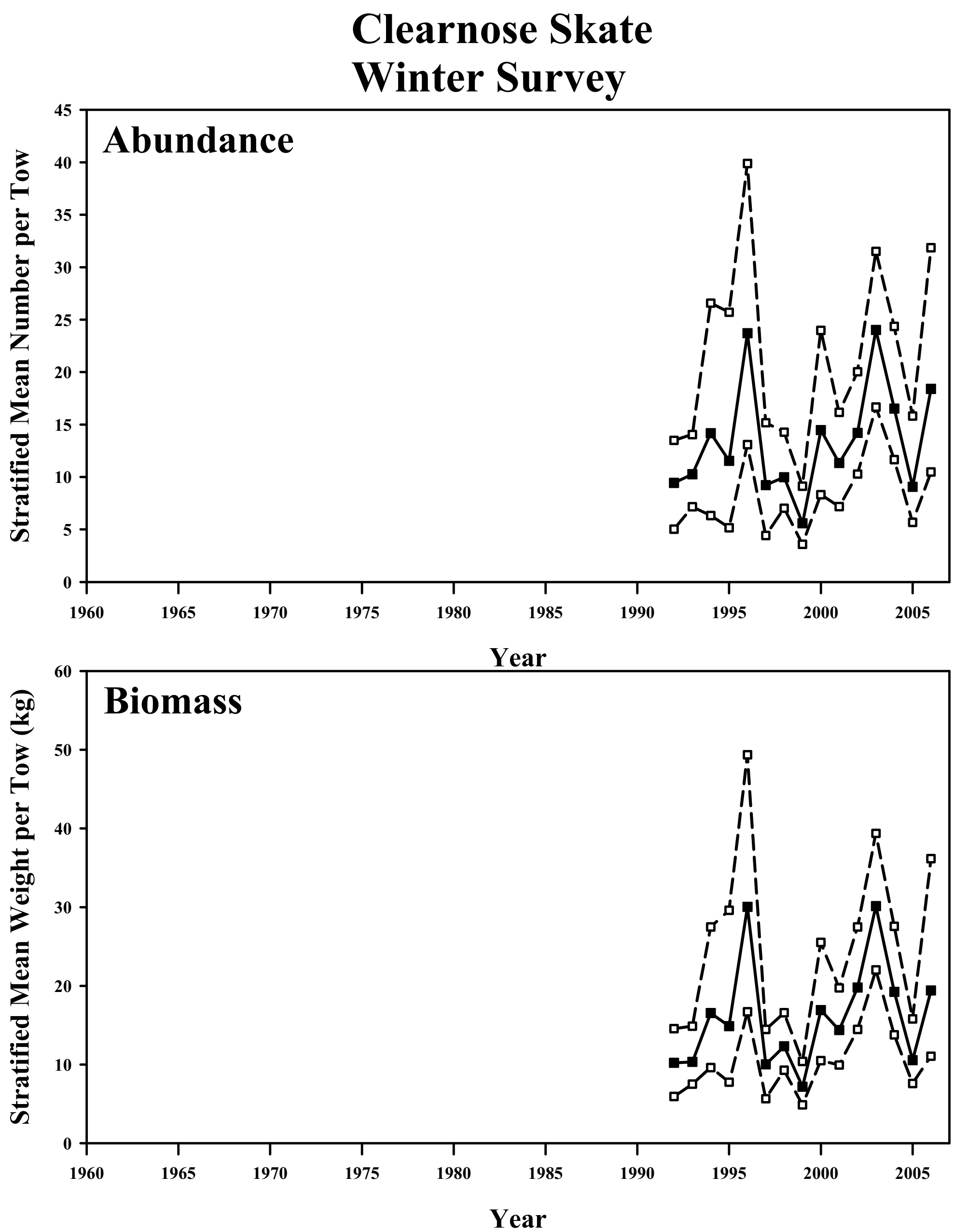


Figure B2.109. Bootstrapped abundance and biomass of clearnose skate from the NESFC winter bottom trawl survey. Mean index in solid squares, 95% confidence interval in open squares.

Clearnose Skate - CTDEP Finfish Survey

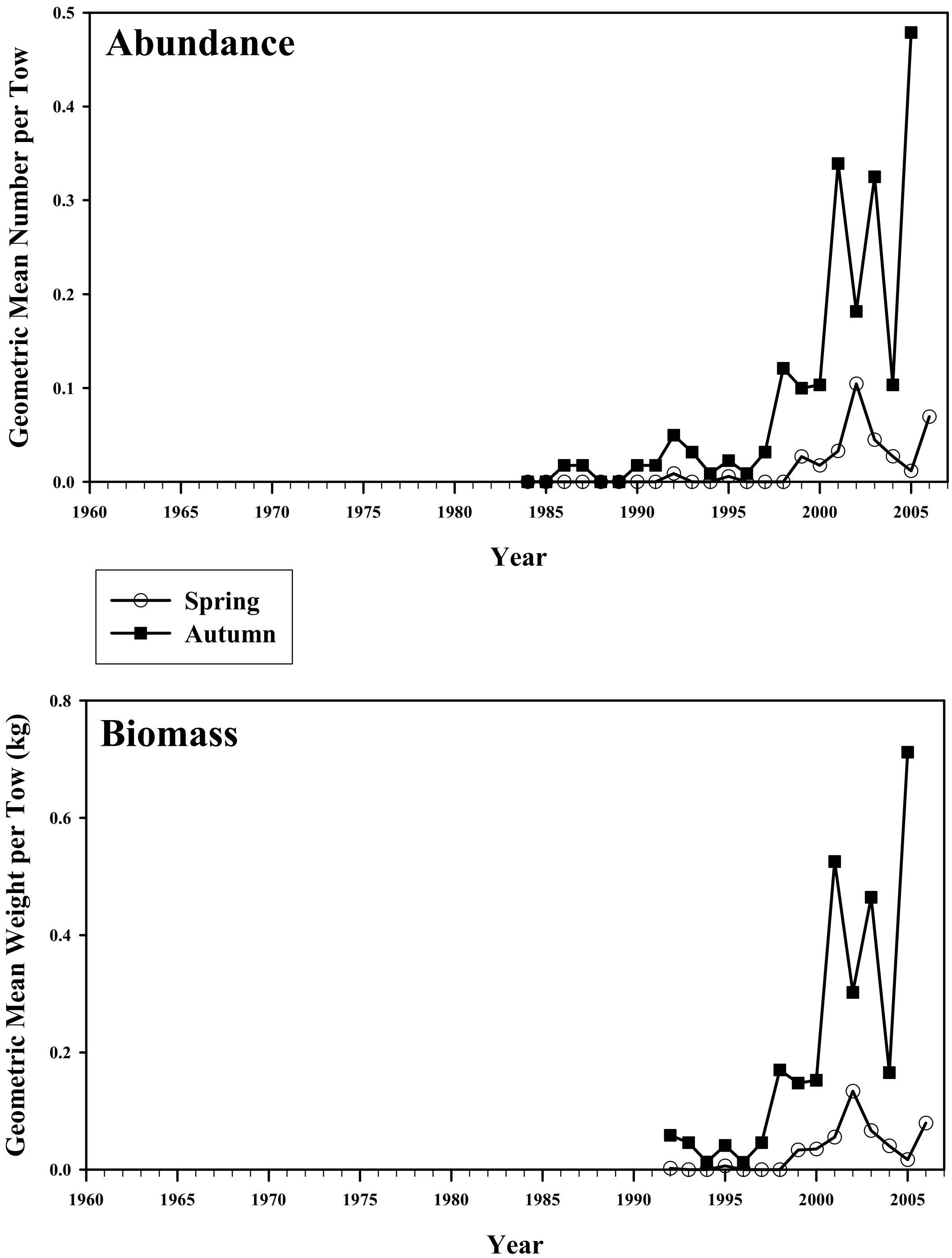


Figure B2.110. Abundance and biomass of clearnose skate from the CTDEP spring and autumn finfish bottom trawl survey in Connecticut state waters, 1984-2006.

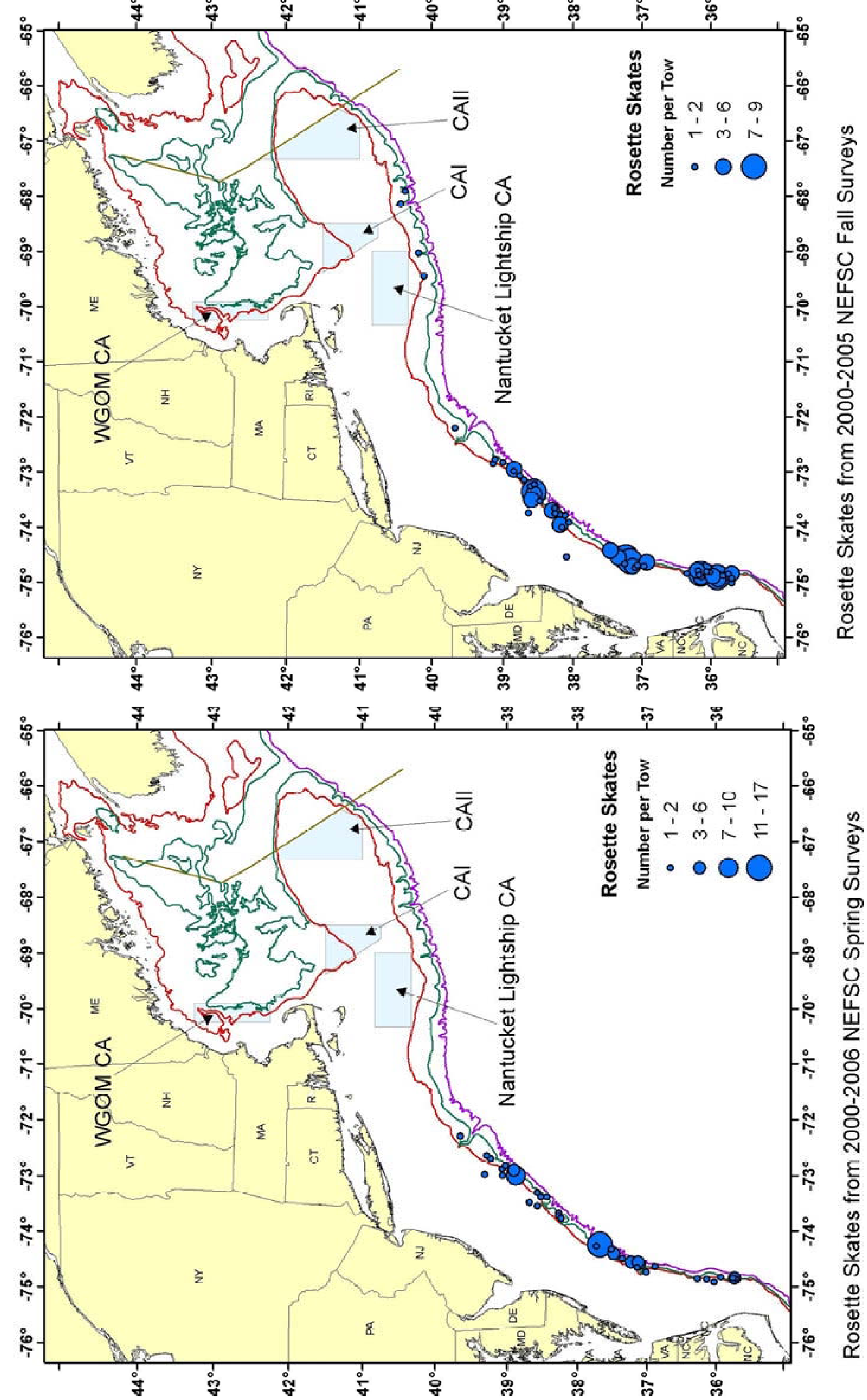


Figure B2.111. Distribution of rosette skate from the spring and autumn NEFSC surveys from 2000-2006.

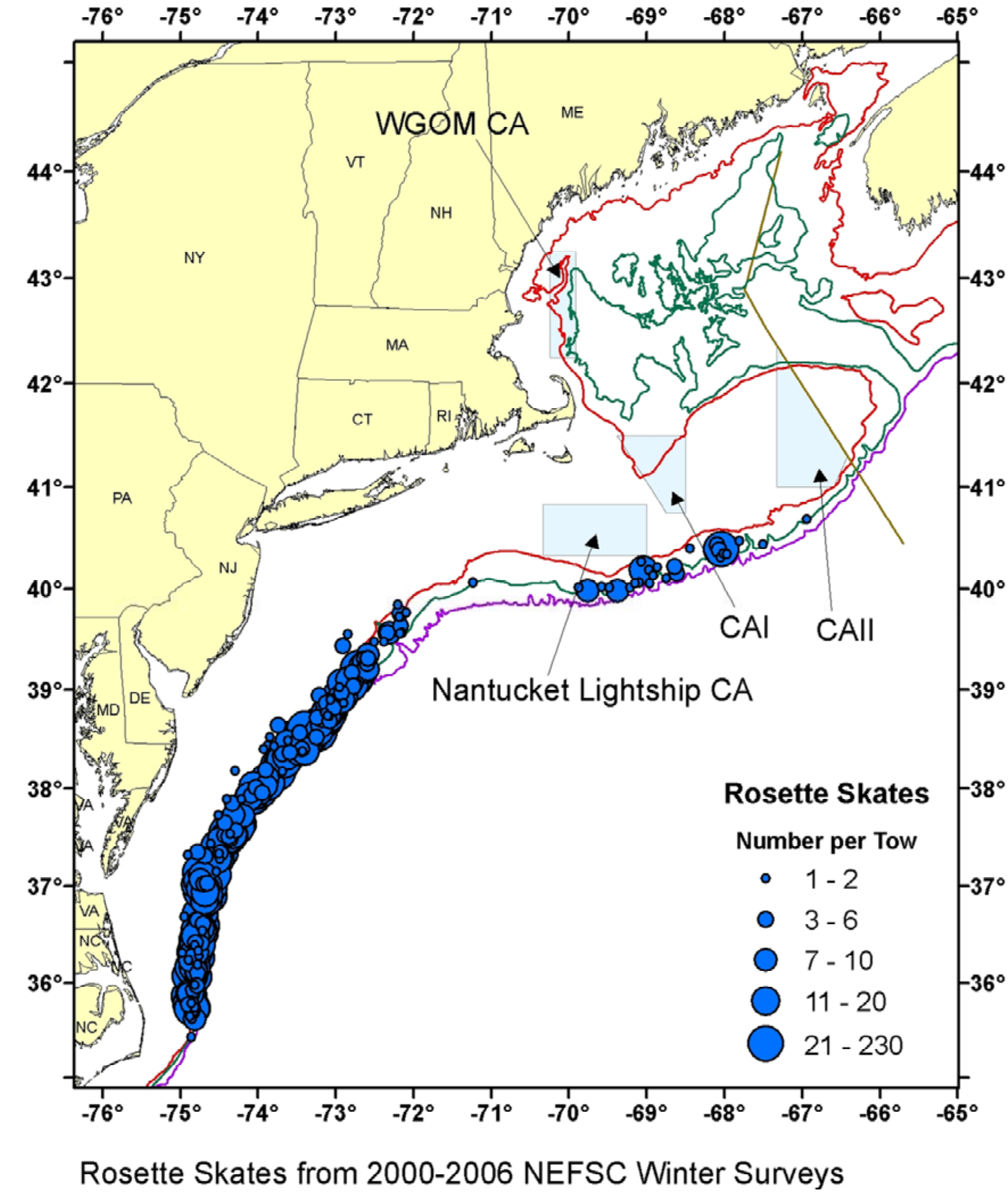


Figure B2.112. Distribution of rosette skate from the winter NEFSC surveys from 2000-2006.

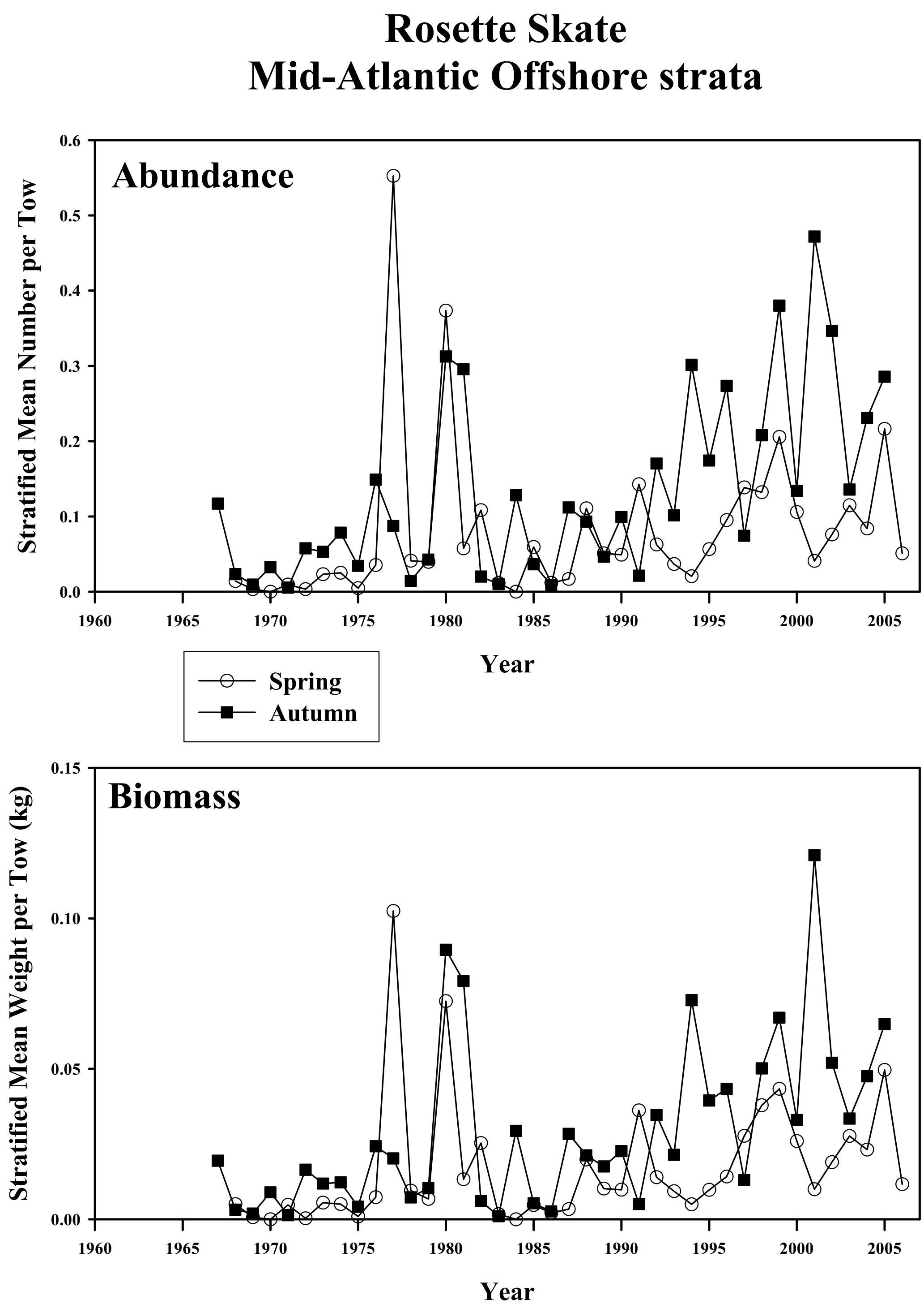


Figure B2.113. Abundance and biomass of rosette skate from the NESFC spring (circles) and autumn (squares) bottom trawl surveys from 1967-2006 in the Mid-Atlantic offshore region.

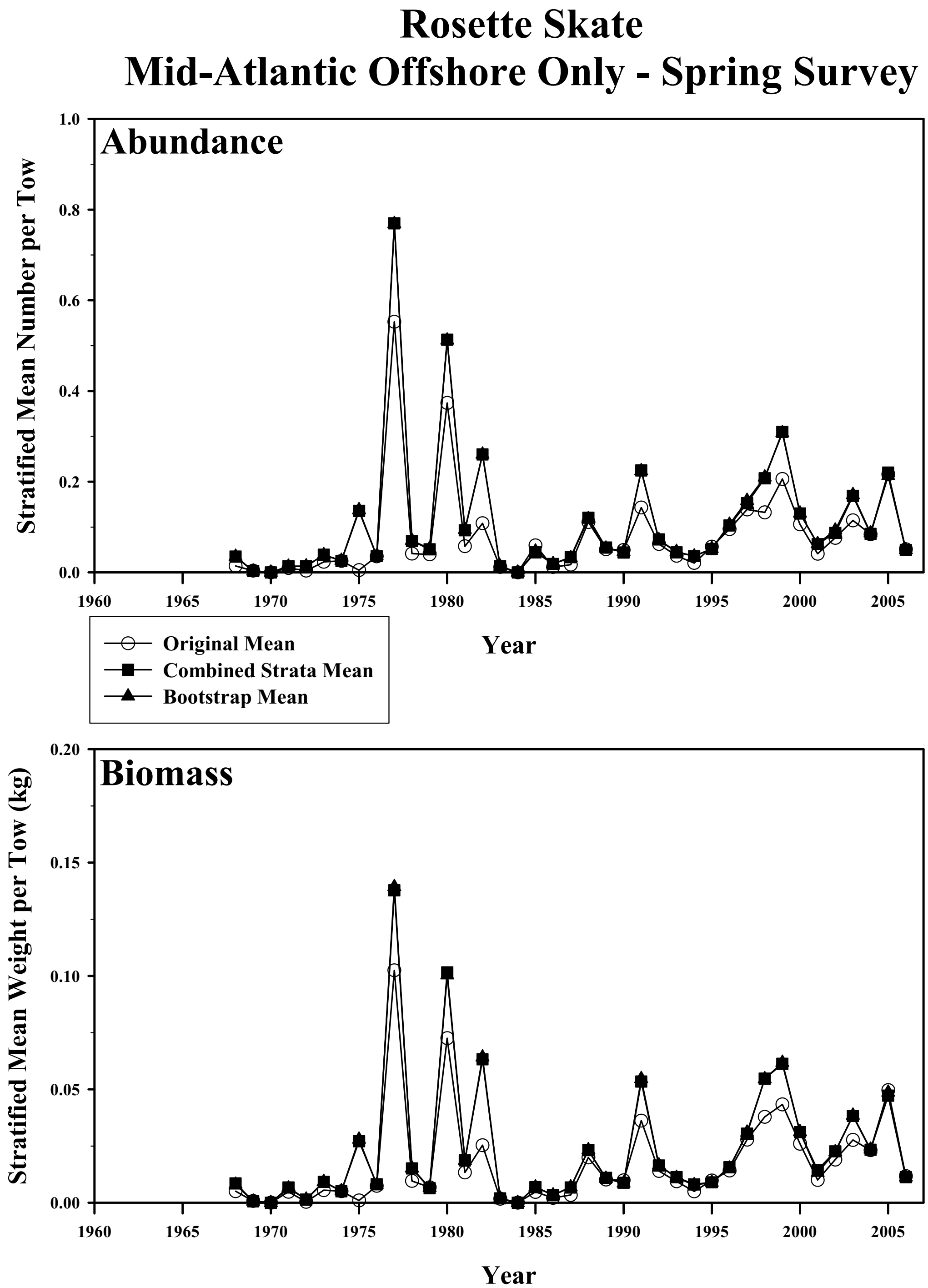


Figure B2.114. Abundance and biomass of rosette skate from the NESFC spring bottom trawl surveys from 1968-2006 in the Mid-Atlantic offshore region. The circles represent the original stratified mean, the squares represent the mean combining strata for bootstrapping, and the triangles represent the bootstrapped mean.

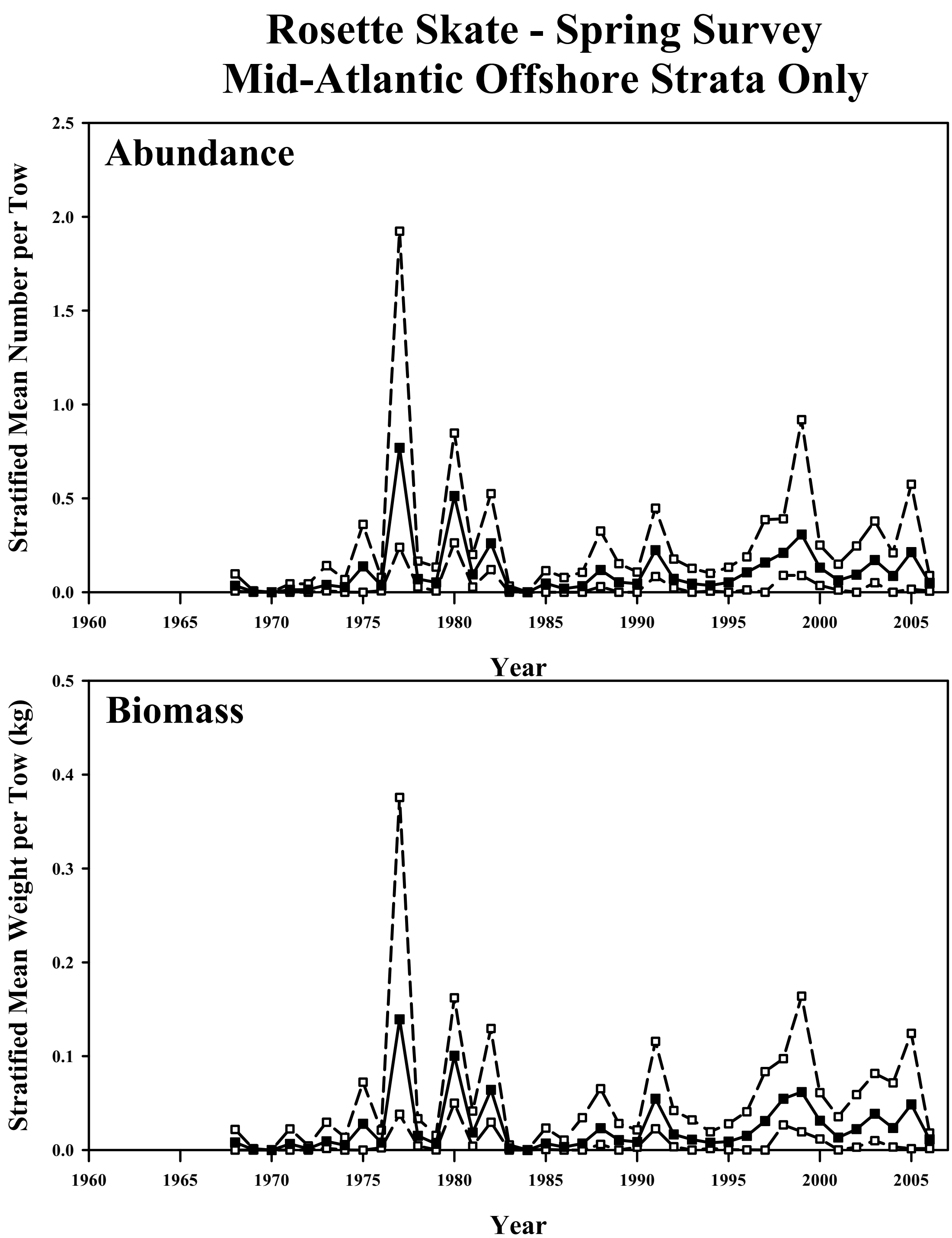


Figure B2.115. Bootstrapped abundance and biomass of rosette skate from the NESFC spring bottom trawl survey in the Mid-Atlantic offshore region. Mean index in solid squares, 95% confidence interval in open squares.

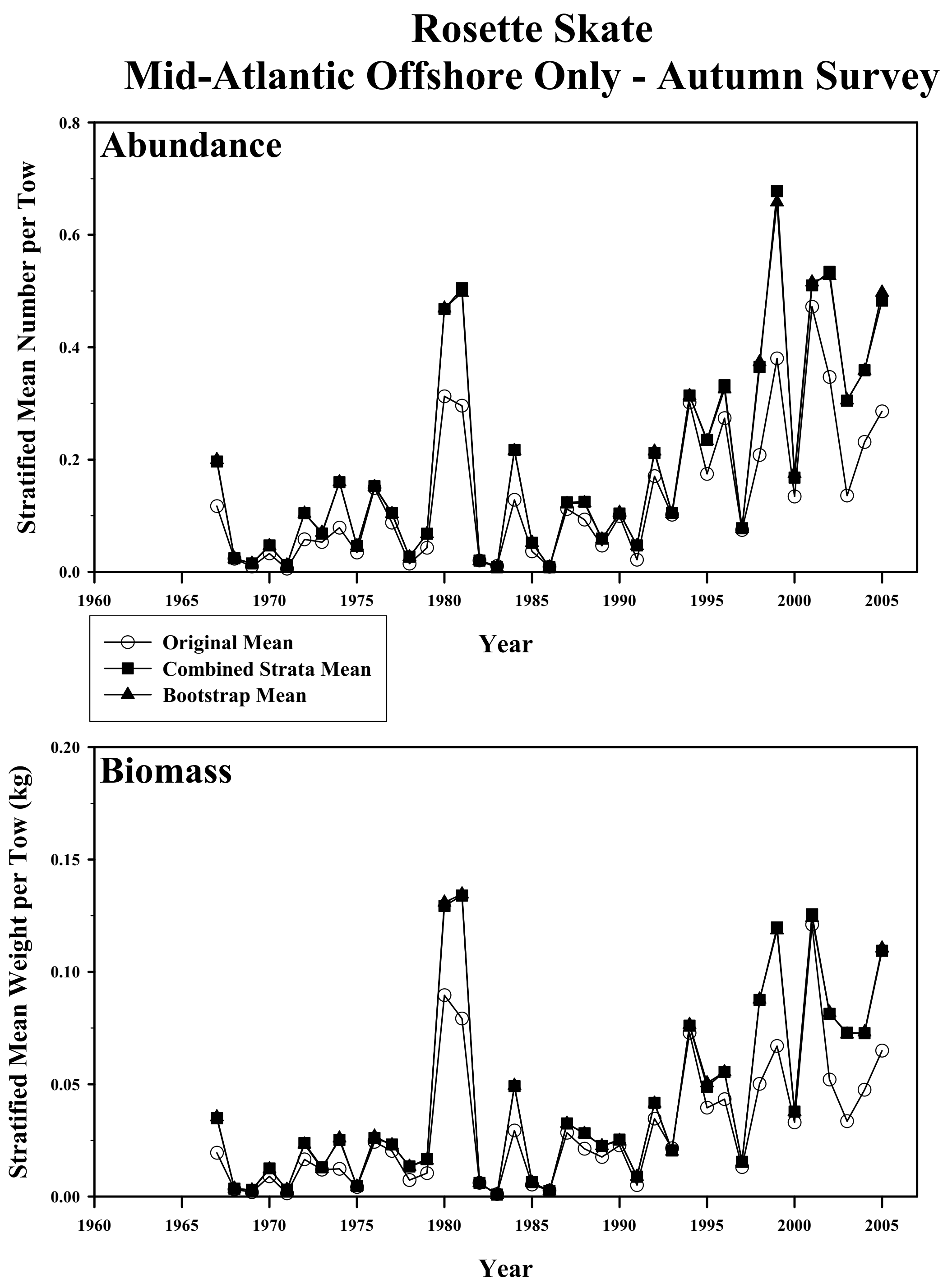
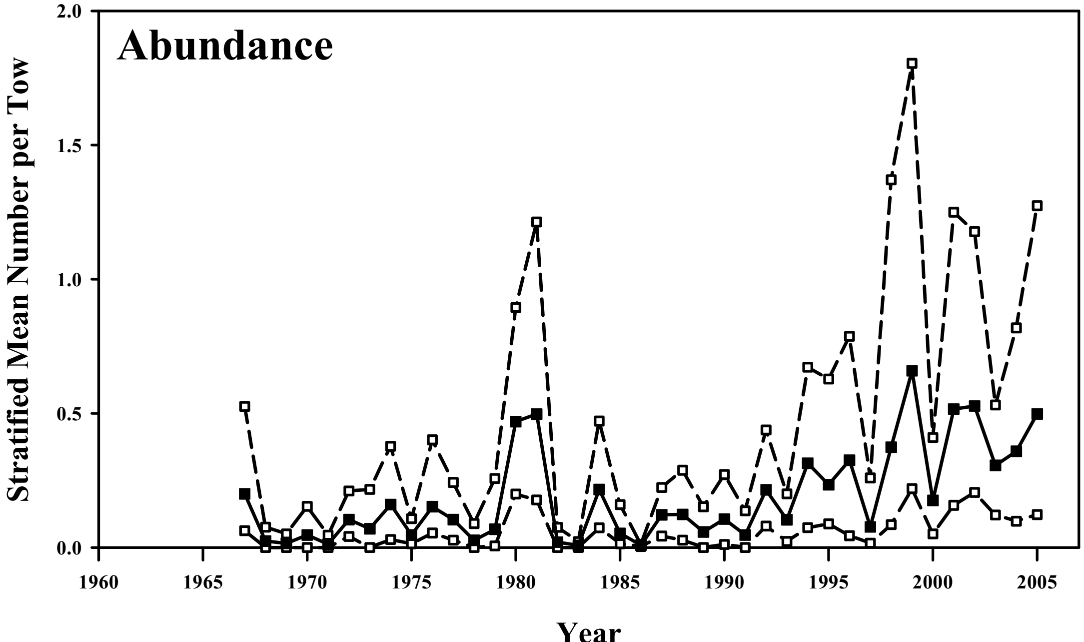


Figure B2.116. Abundance and biomass of rosette skate from the NESFC autumn bottom trawl surveys from 1967-2005 in the Mid-Atlantic offshore region. The circles represent the original stratified mean, the squares represent the mean combining strata for bootstrapping, and the triangles represent the bootstrapped mean.

Rosette Skate - Autumn Survey
Mid-Atlantic Offshore Strata Only



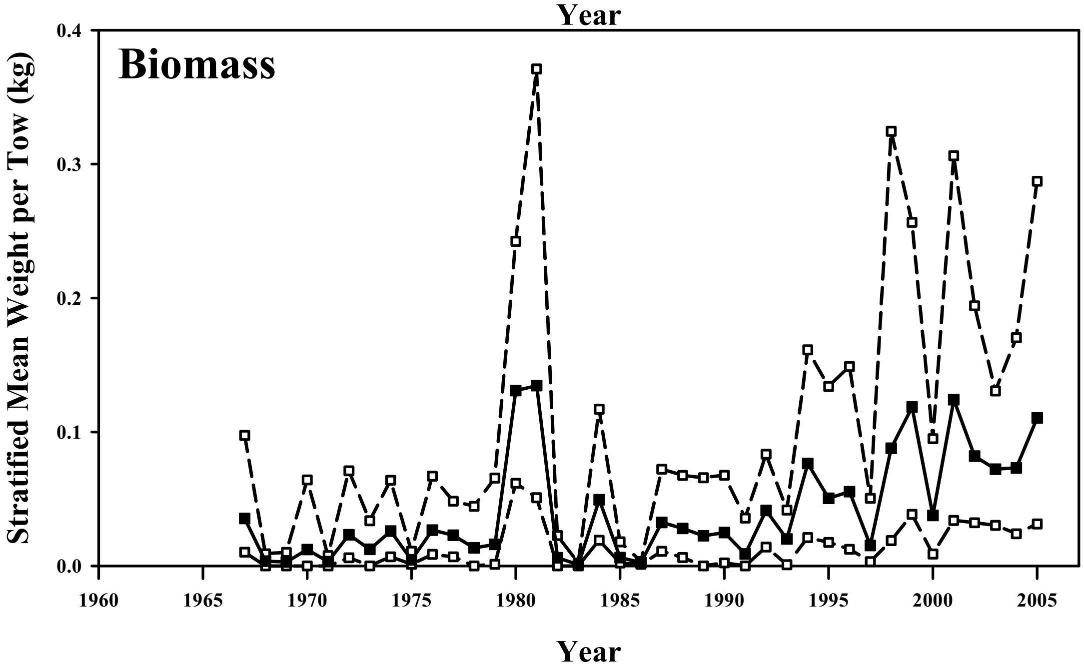
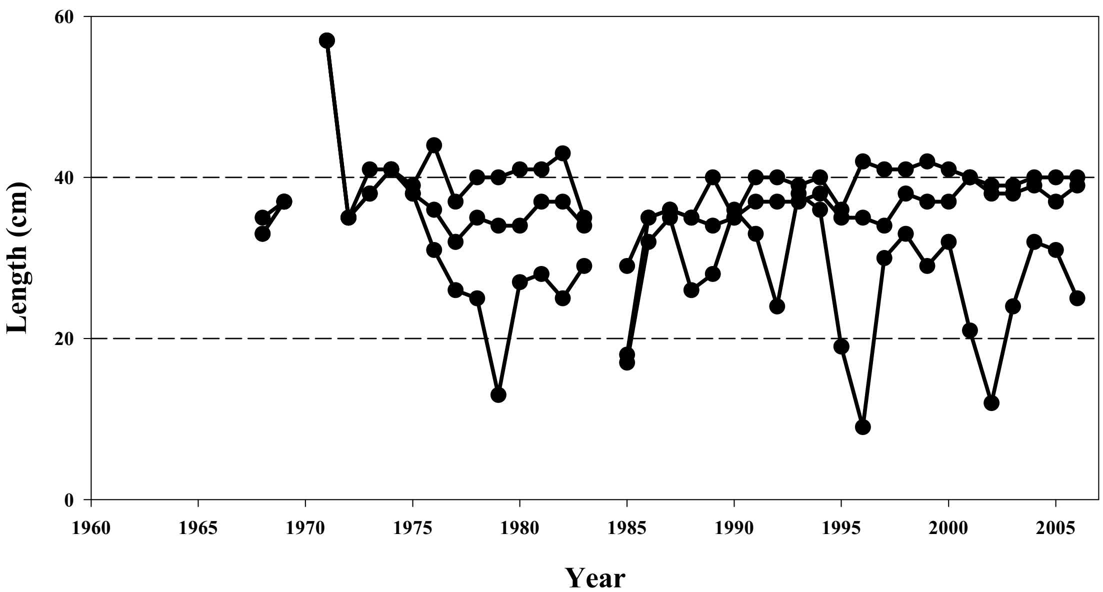


Figure B2.117. Bootstrapped abundance and biomass of rosette skate from the NESFC autumn bottom trawl survey in the Mid-Atlantic offshore region. Mean index in solid squares, 95% confidence interval in open squares.

Rosette Skate
Percentiles of Length Composition

Spring Survey



Autumn Survey

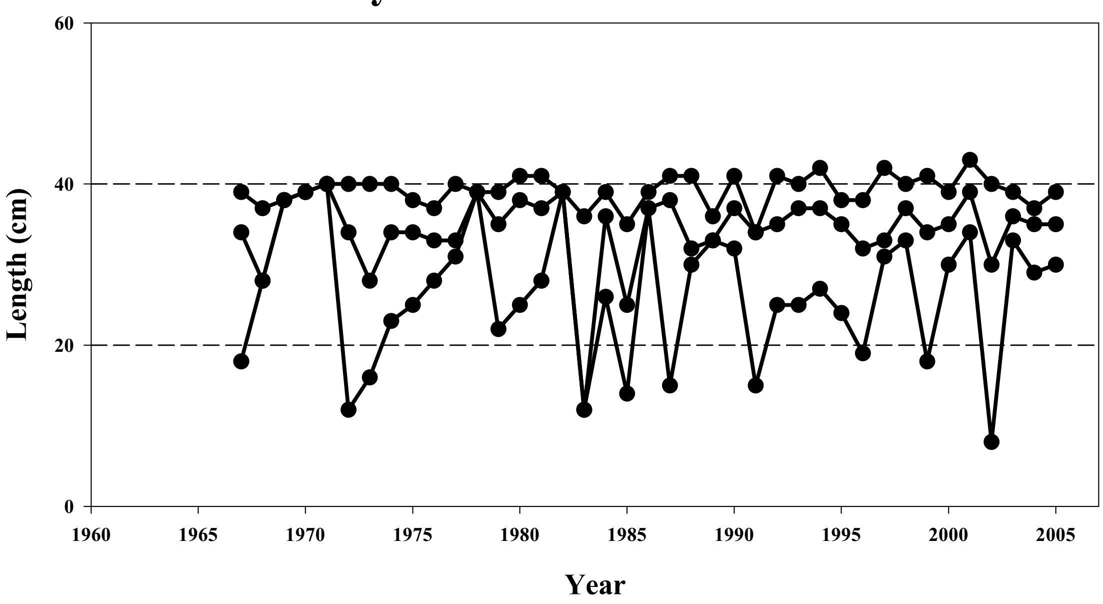


Figure B2.118. Percentiles of length composition (5, 50, and 95) of rosette skate from the NESFC spring and autumn bottom trawl surveys from 1967-2006 in the Mid-Atlantic offshore region.

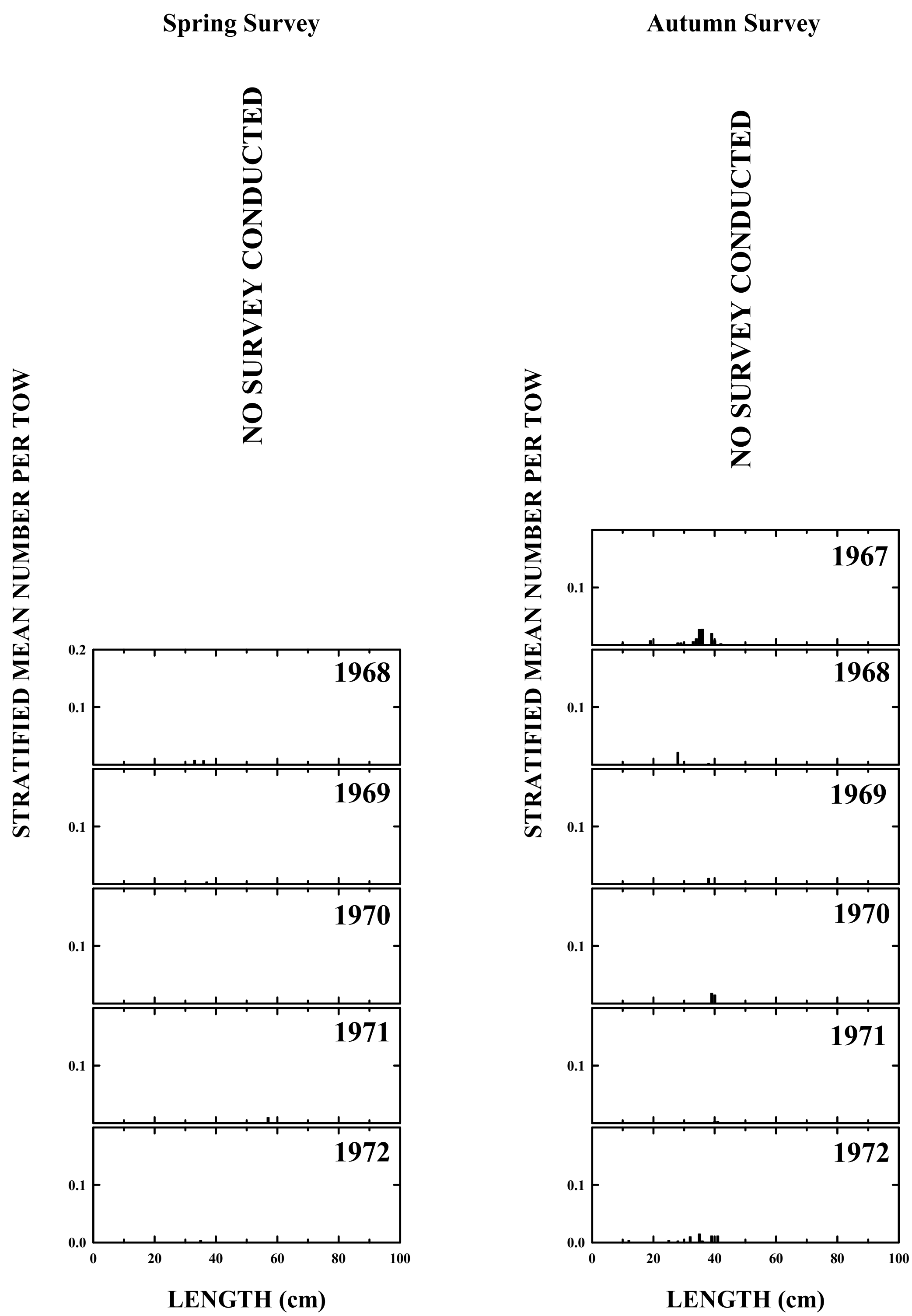


Figure B2.119. Rosette skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Mid-Atlantic offshore region, 1967-1972.

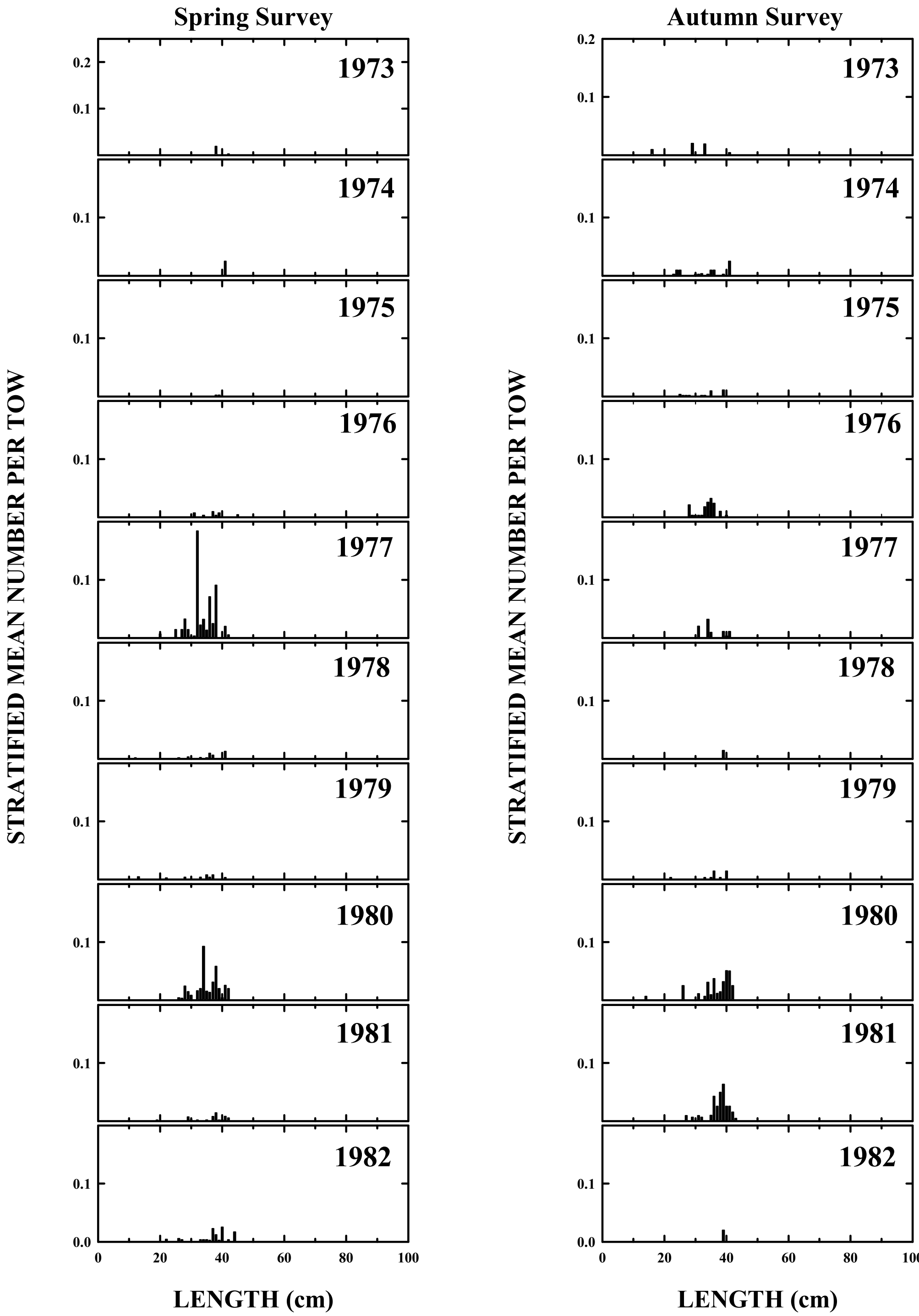


Figure B2.120. Rosette skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Mid-Atlantic offshore region, 1973-1982.

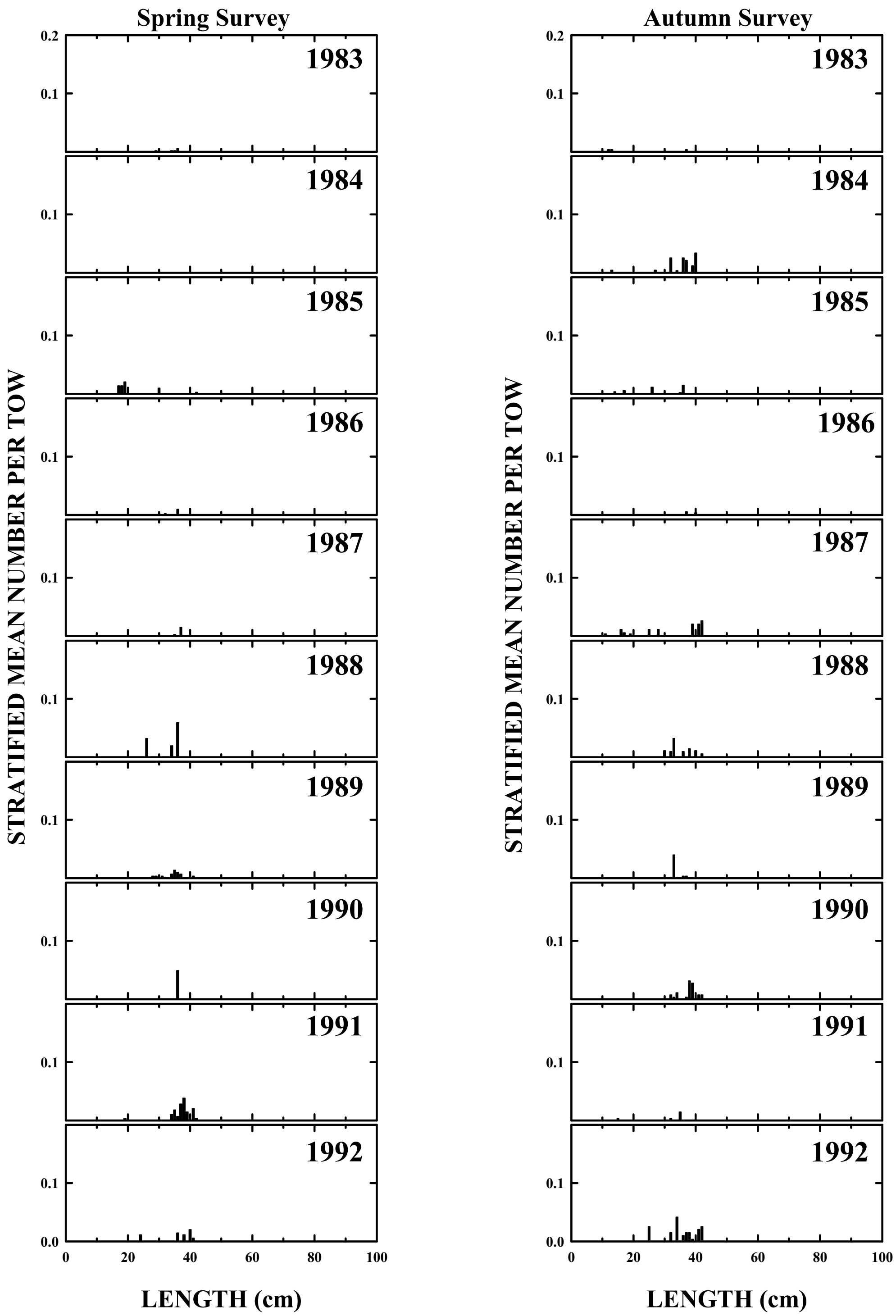


Figure B2.121. Rosette skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Mid-Atlantic offshore region, 1983-1992.

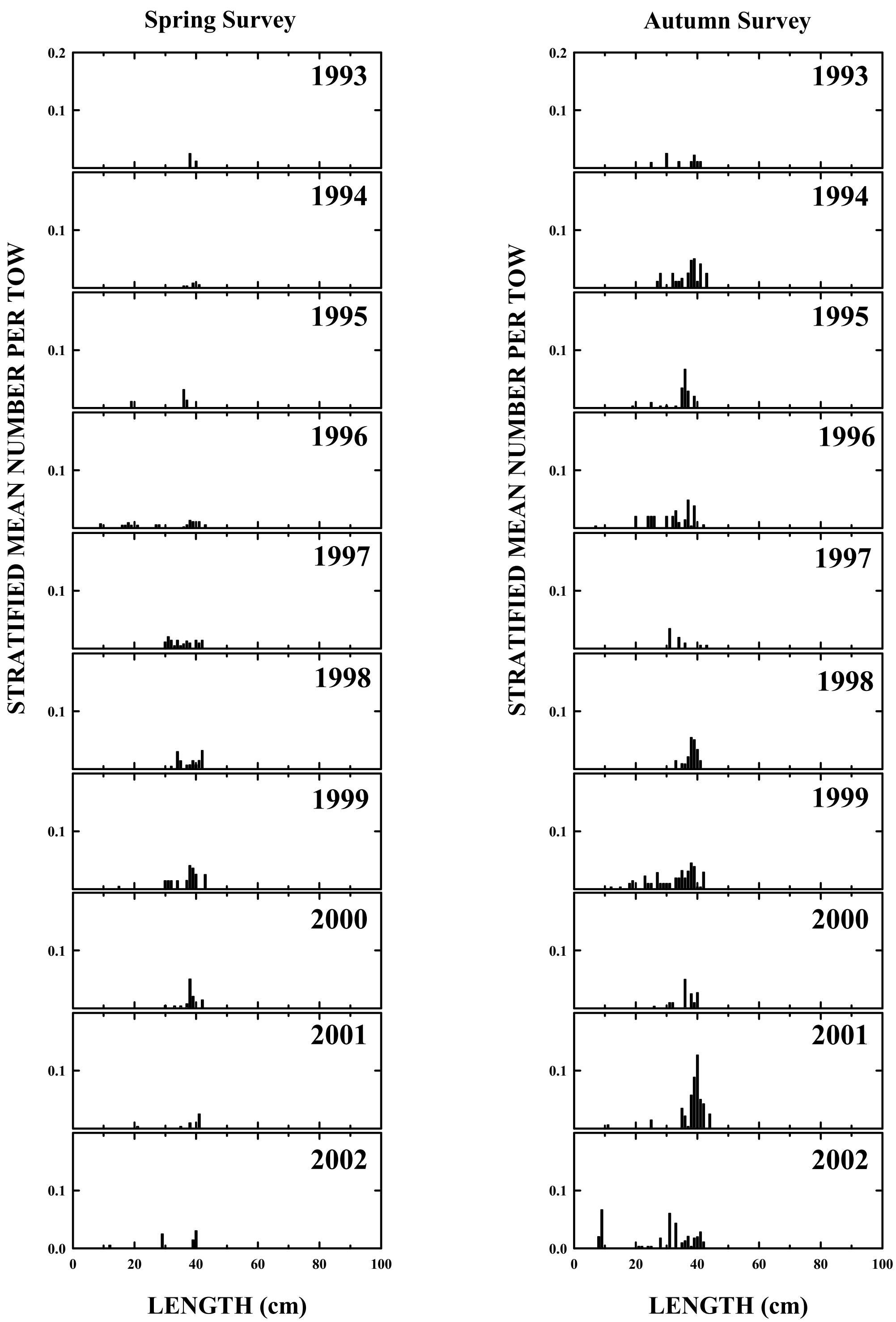


Figure B2.122. Rosette skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Mid-Atlantic offshore region, 1993-2002.

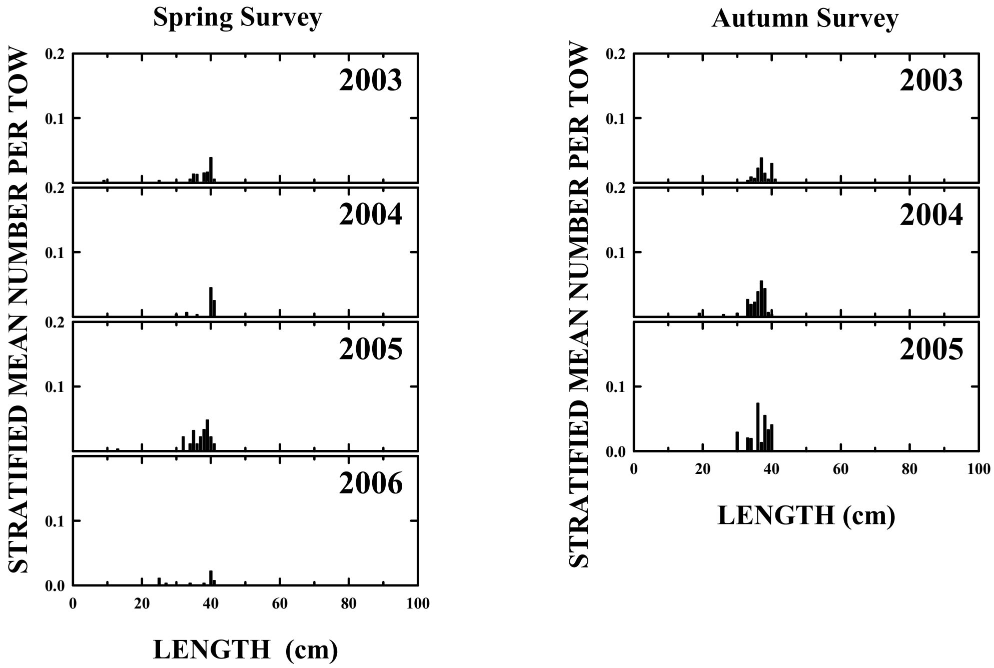


Figure B2.123. Rosette skate length composition from the NEFSC spring and autumn bottom trawl surveys in the Mid-Atlantic offshore region, 2003-2006.

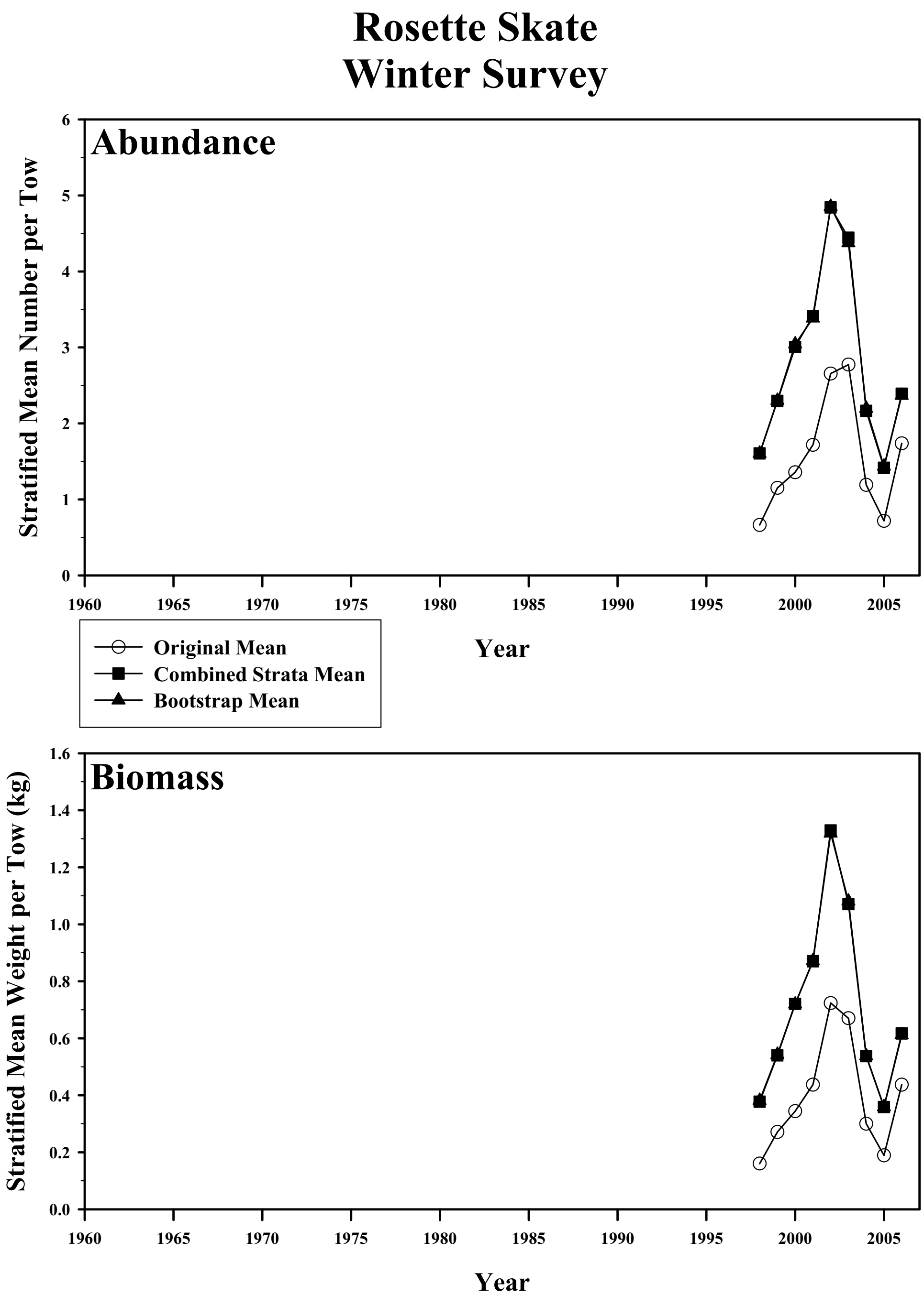


Figure B2.124. Abundance and biomass of rosette skate from the NESFC winter bottom trawl surveys from 1998-2006. The circles represent the original stratified mean, the squares represent the mean combining strata for bootstrapping, and the triangles represent the bootstrapped mean.

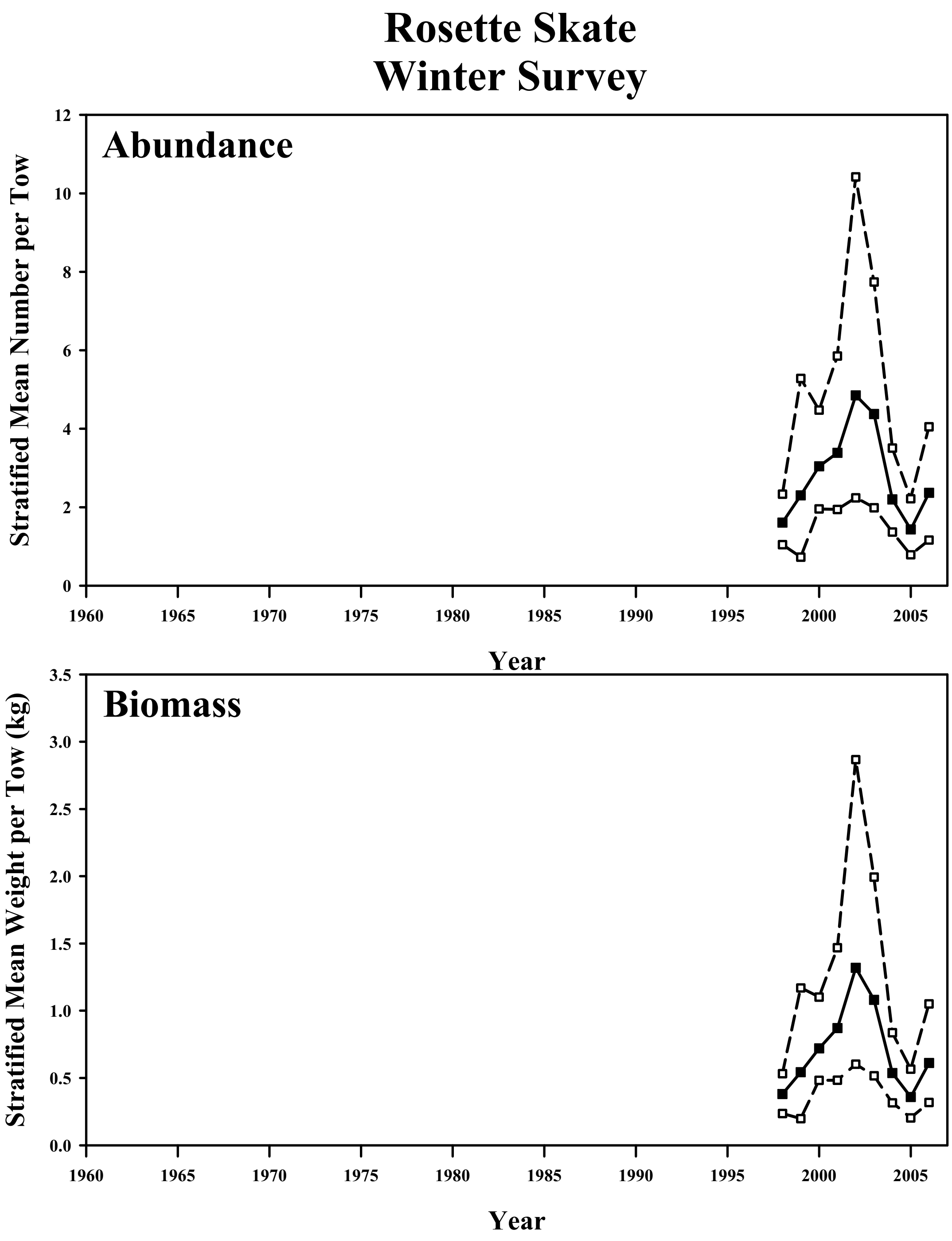


Figure B2.125. Bootstrapped abundance and biomass of rosette skate from the NESFC winter bottom trawl survey. Mean index in solid squares, 95% confidence interval in open squares.

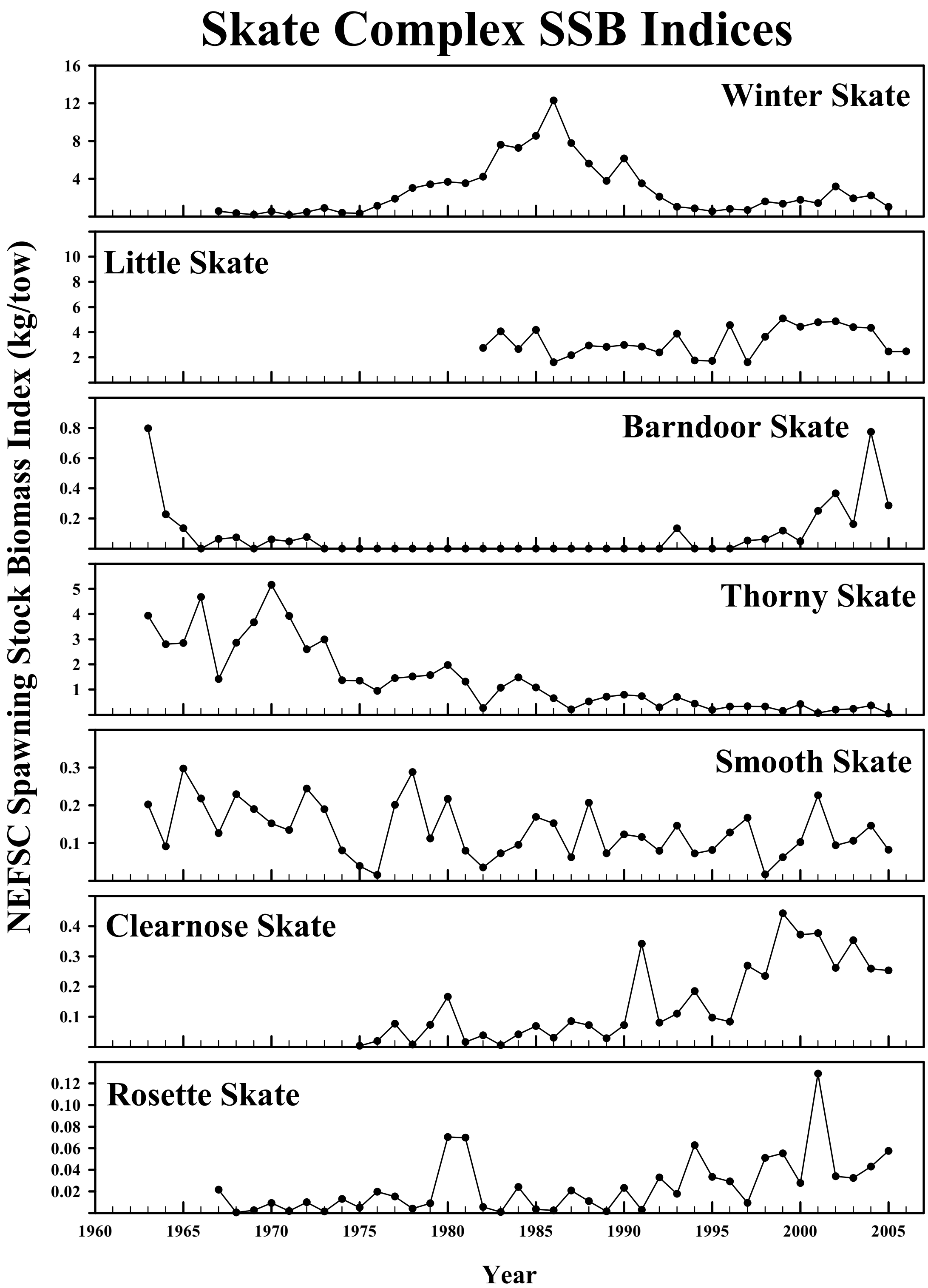


Figure B2.126. Trends in spawning stock biomass indices for seven species of skates.

FIGURES B2.127-B2.141.

(EDITOR'S NOTE: BASED ON THE REVIEWER'S COMMENTS, THESE FIGURES WERE NOT INCLUDED IN THIS REPORT. THE FIGURES DEALT WITH ESTIMATES OF FISHING MORTALITY RATE.)

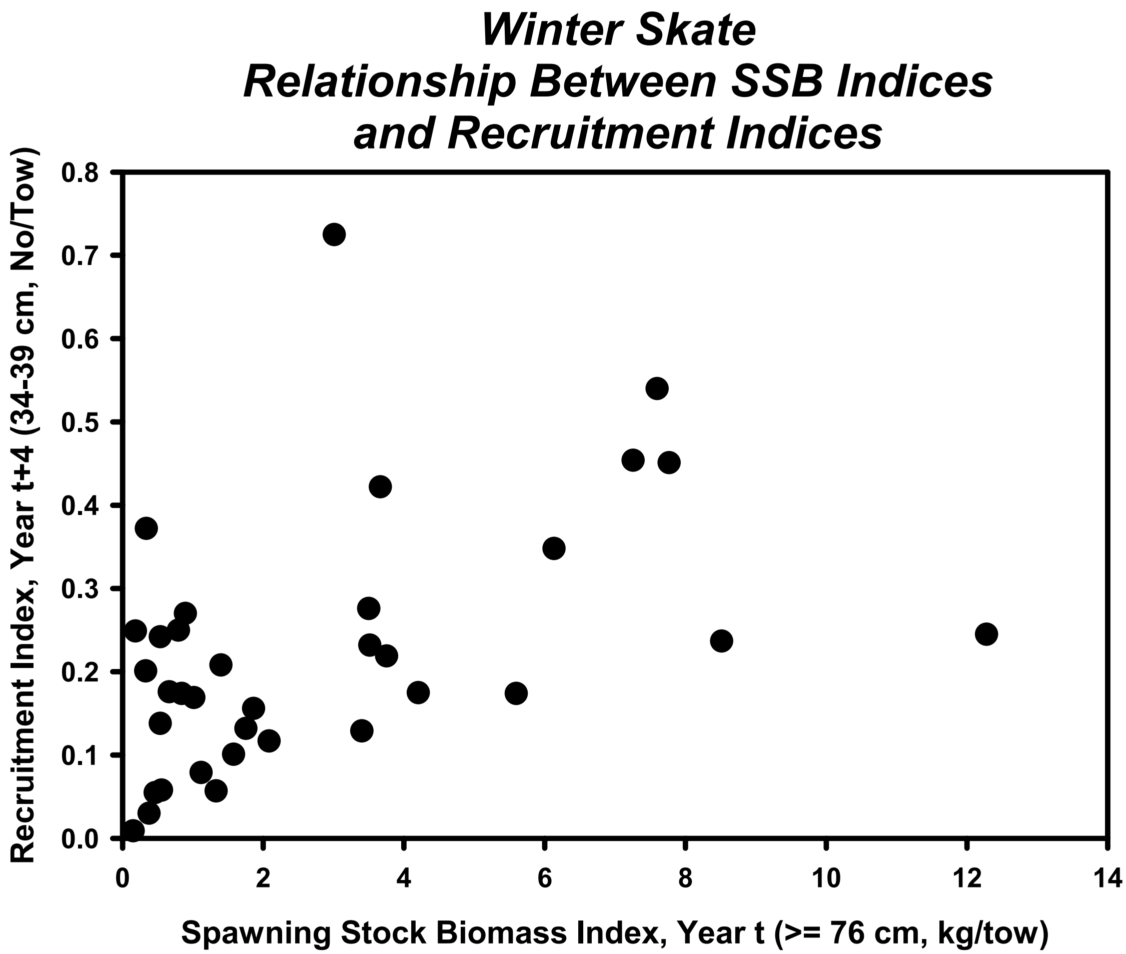
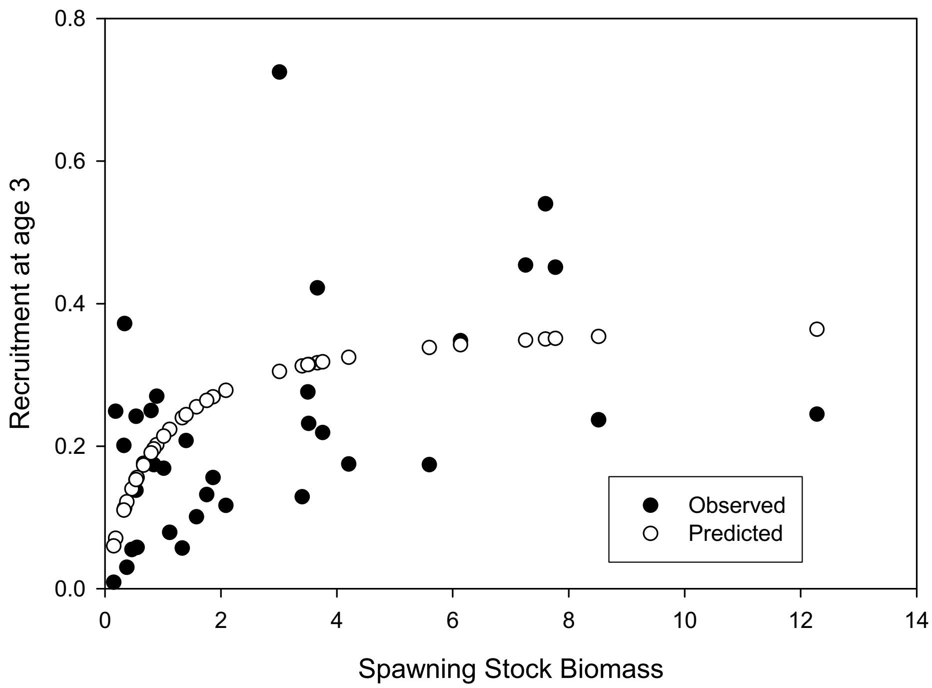


Figure B3.1. Relationship between spawning stock biomass indices (>= 76 cm) and recruitment indices (no/tow, 34-39 cm) for winter skate. The time lag between SSB and recruitment accounts for the assumed age 3 at recruitment plus one year for hatching time.

Winter Skate



Barndoor Skate

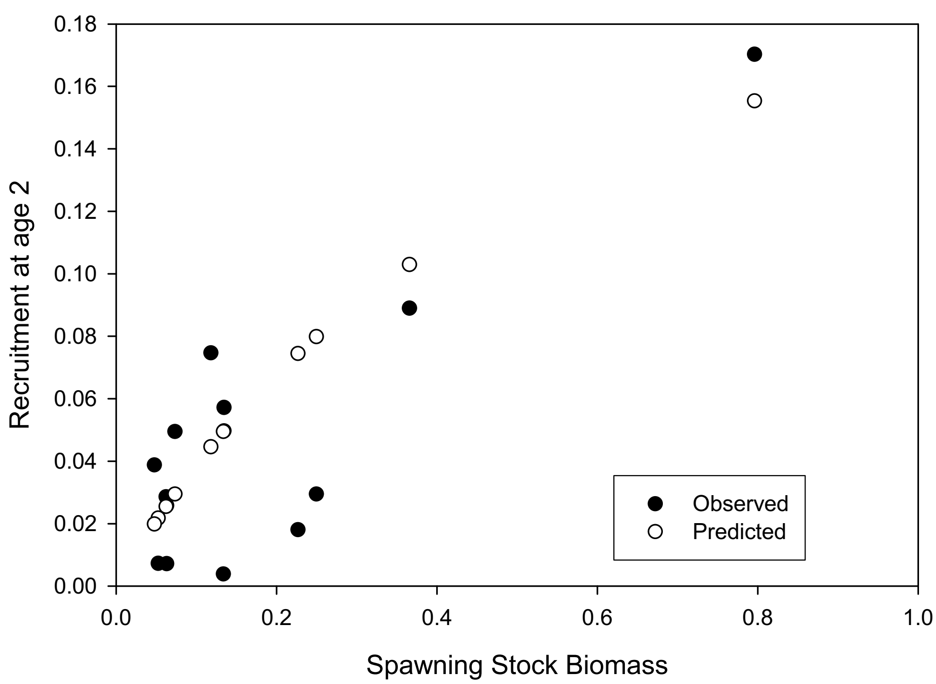


Figure B3.2. Stock-recruitment plots for winter skate and barndoor skate with the Beverton-Holt function plotted.

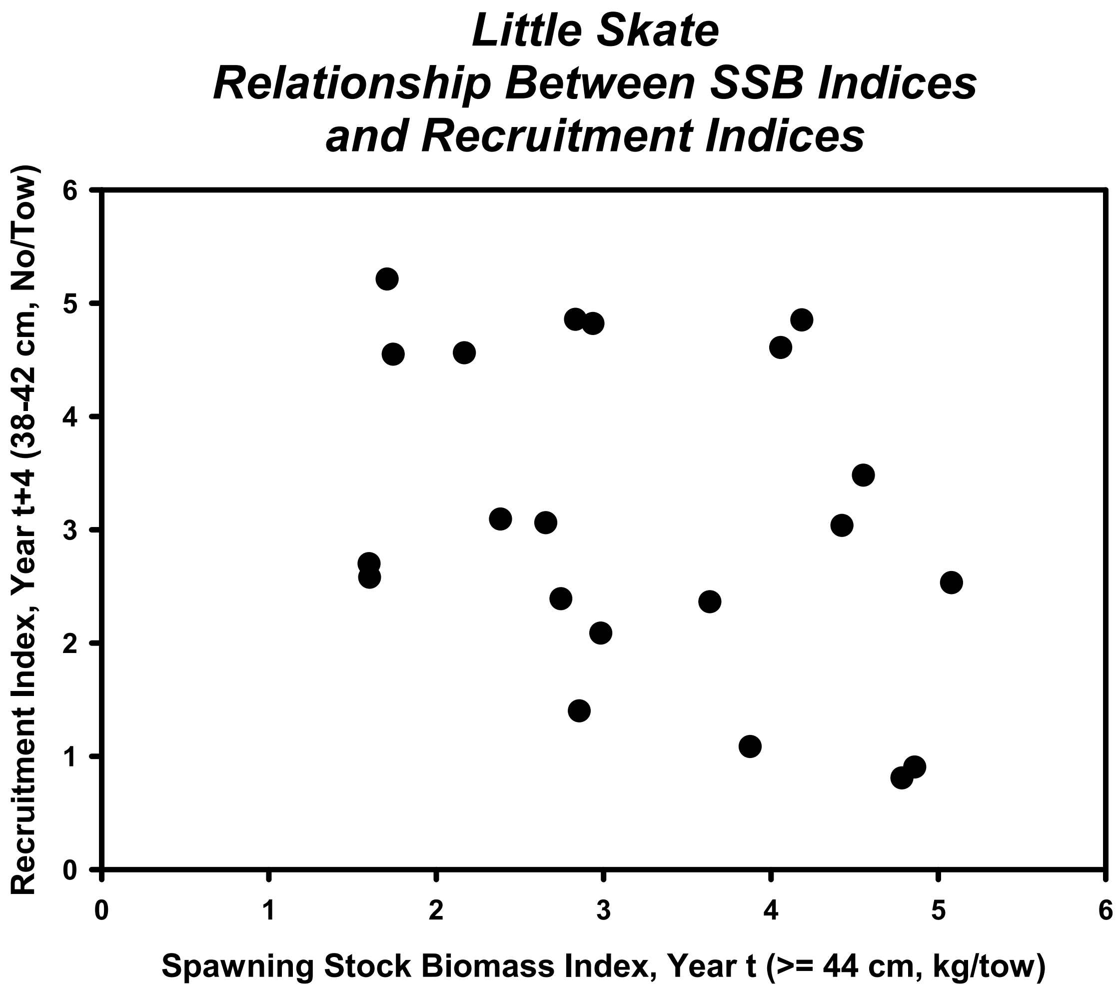


Figure B.3.3. Relationship between spawning stock biomass indices (>= 44 cm) and recruitment indices (no/tow, 38-42 cm) for little skate. The time lag between SSB and recruitment accounts for the assumed age 3 at recruitment plus one year for hatching time.

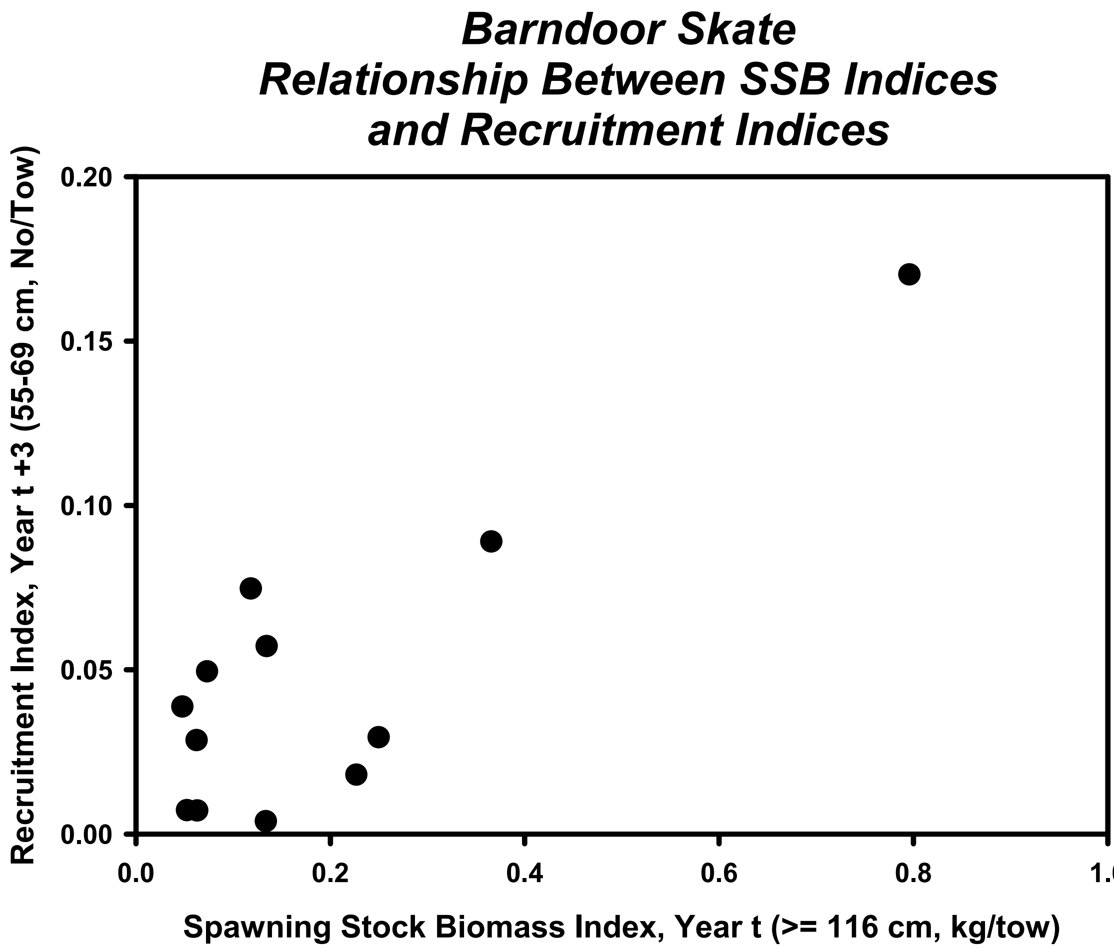


Figure B3.4. Relationship between spawning stock biomass indices (>= 116 cm) and recruitment indices (no/tow, 55-69 cm) for barndoor skate. The time lag between SSB and recruitment accounts for the assumed age 2 at recruitment plus one year for hatching time.

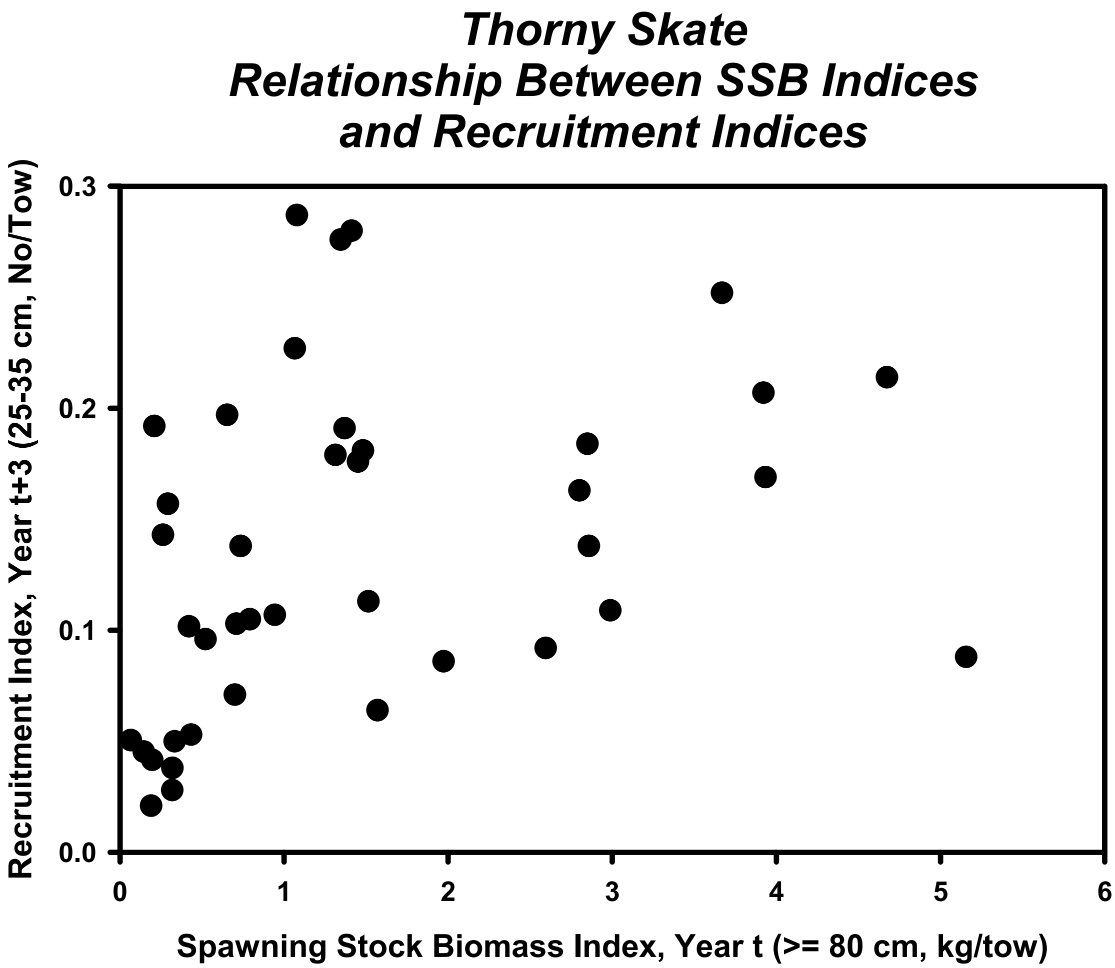
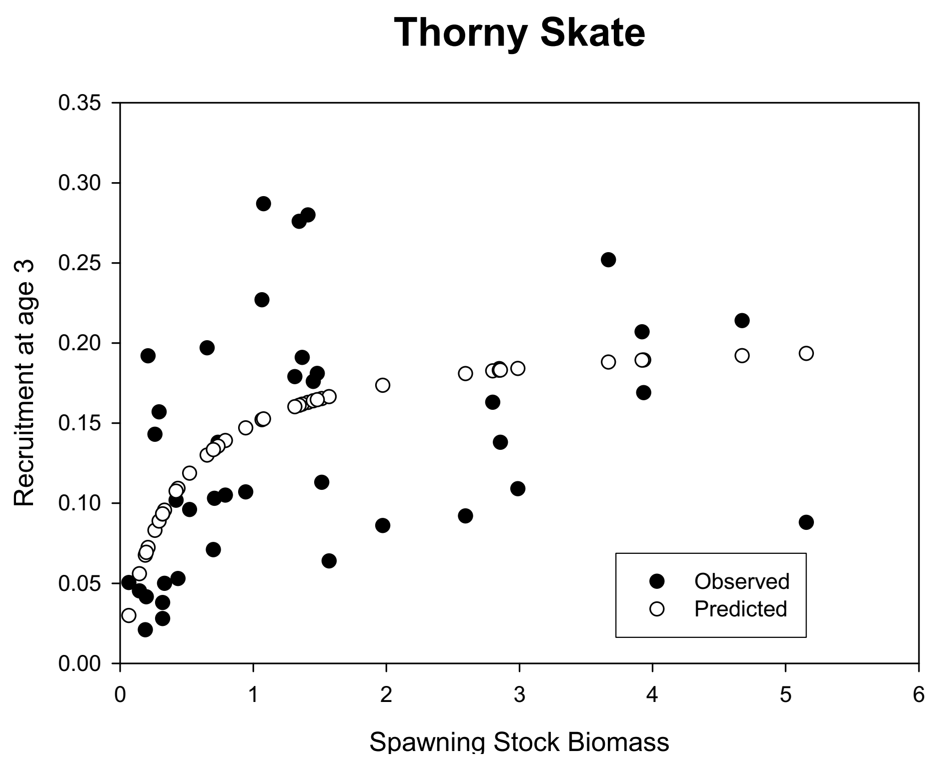


Figure B3.5. Relationship between spawning stock biomass indices (>= 80 cm) and recruitment indices (no/tow, 25-35 cm) for thorny skate. The time lag between SSB and recruitment accounts for the assumed age 2 at recruitment plus one year for hatching time.



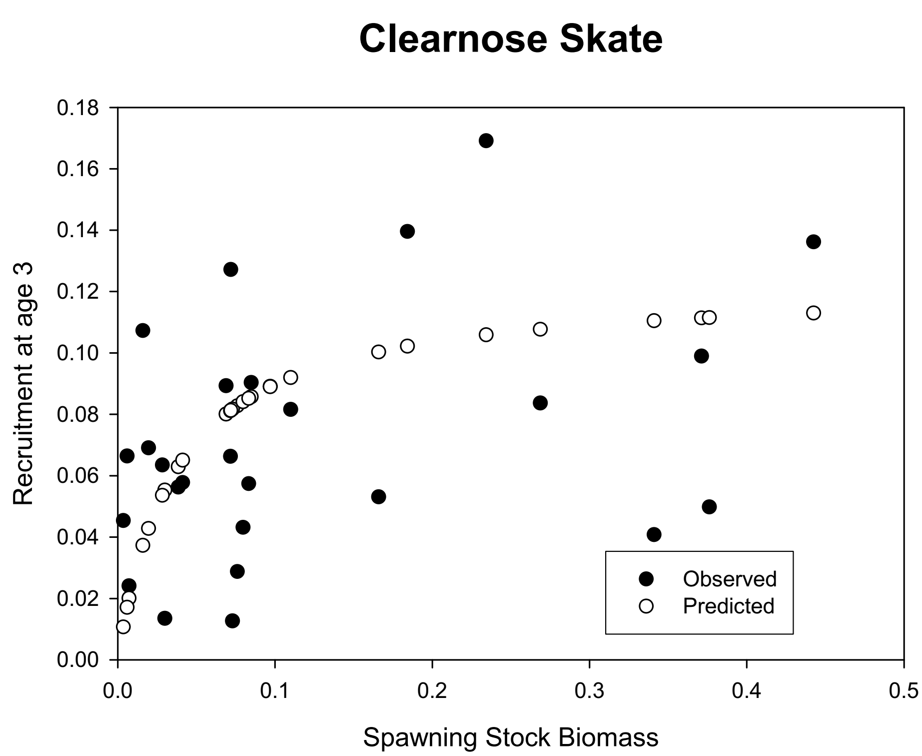


Figure B3.6. Stock-recruitment plots for thorny skate and clearnose skate with the Beverton-Holt function plotted.

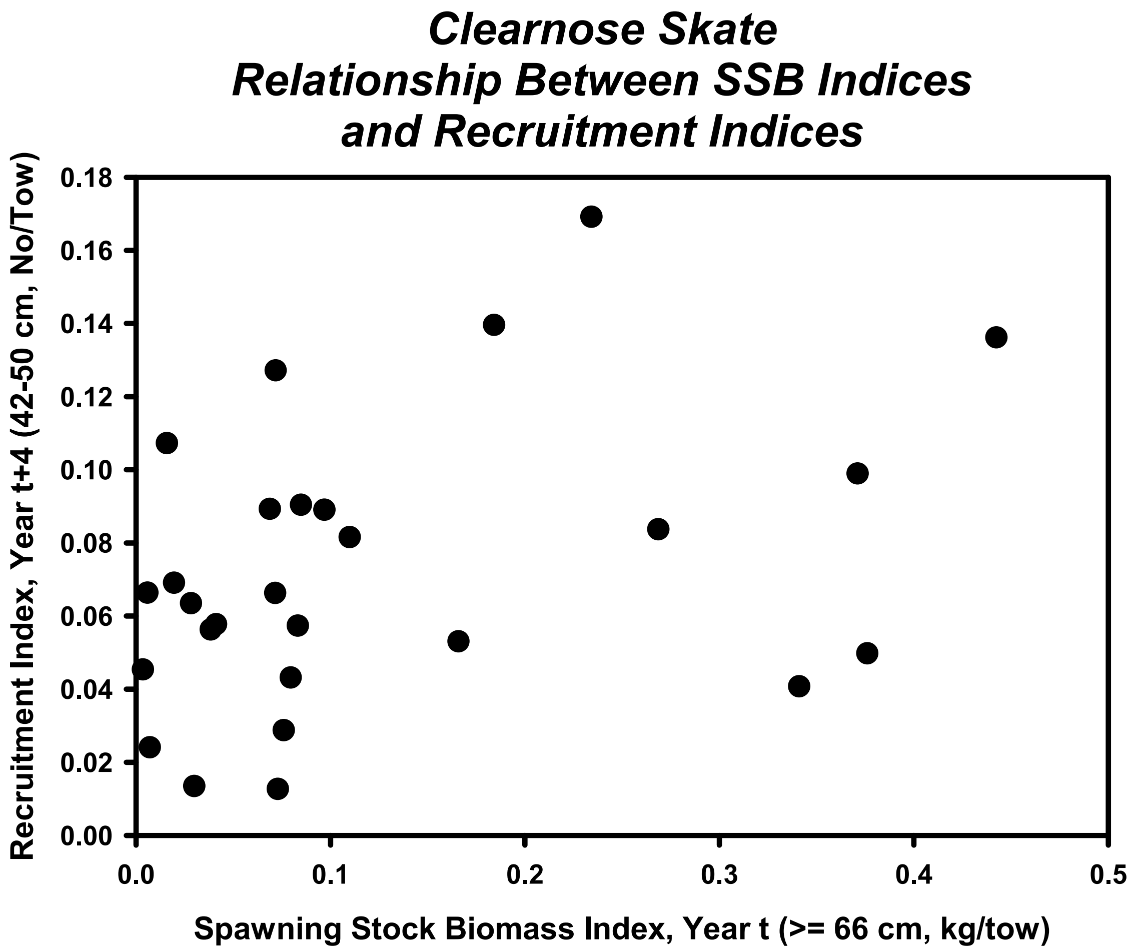


Figure B3.7. Relationship between spawning stock biomass indices (>= 66 cm) and recruitment indices (no/tow, 42-50 cm) for clearnose skate. The time lag between SSB and recruitment accounts for the assumed age 3 at recruitment plus one year for hatching time.

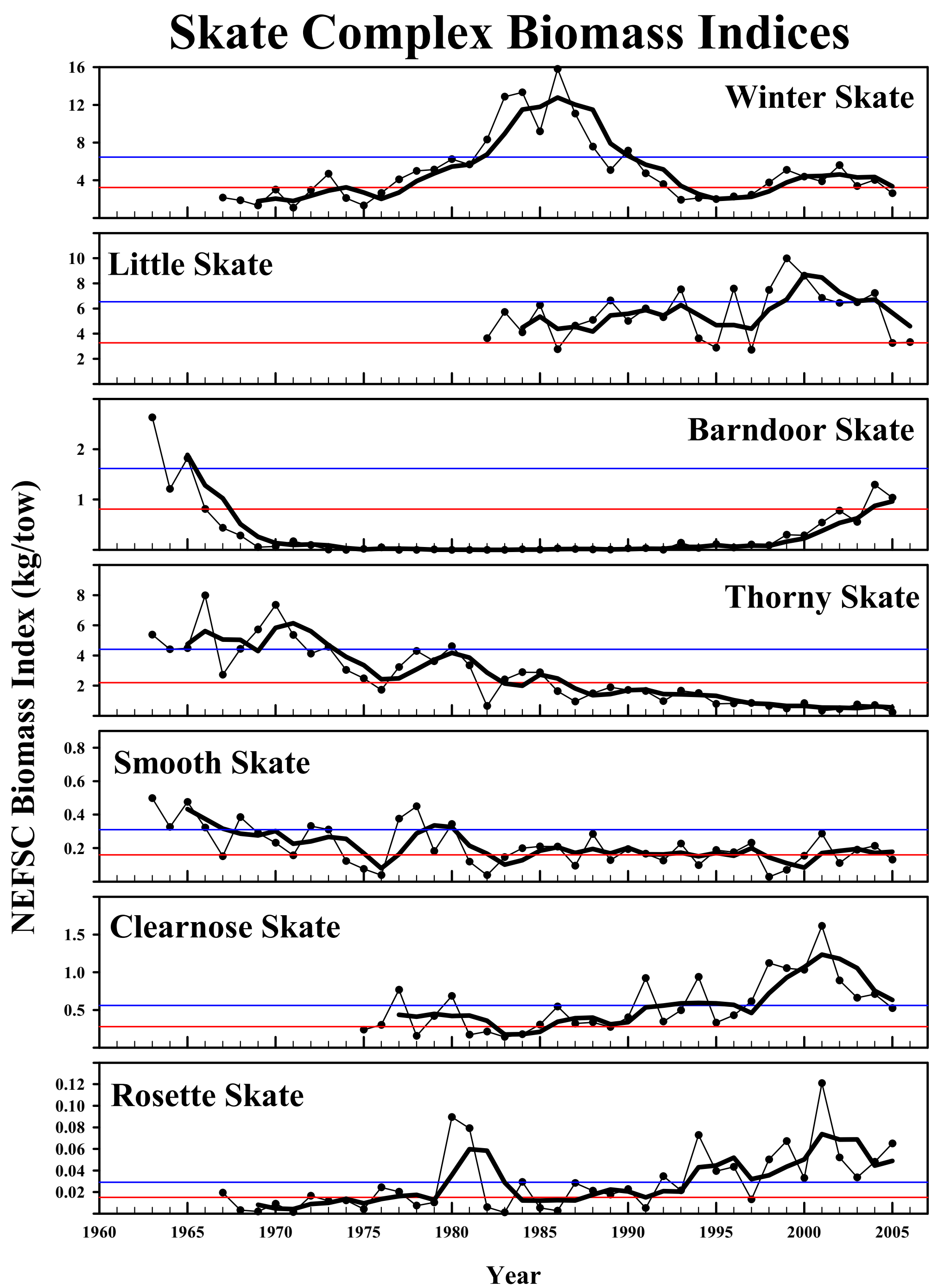


Figure B4.1. NEFSC survey biomass indices (kg/tow). Thin lines with symbols are annual indices, thick lines are 3-year moving averages, the thin horizontal lines are the current biomass targets and thresholds.

FIGURES B4.2 – B4.21.

(EDITOR'S NOTE: BASED ON THE REVIEWER'S COMMENTS, THESE FIGURES WERE NOT INCLUDED IN THIS REPORT. THE FIGURES DEALT WITH ESTIMATES OF ALTERNATIVE BIOLOGICAL REFERENCE POINTS FOR SKATES.)

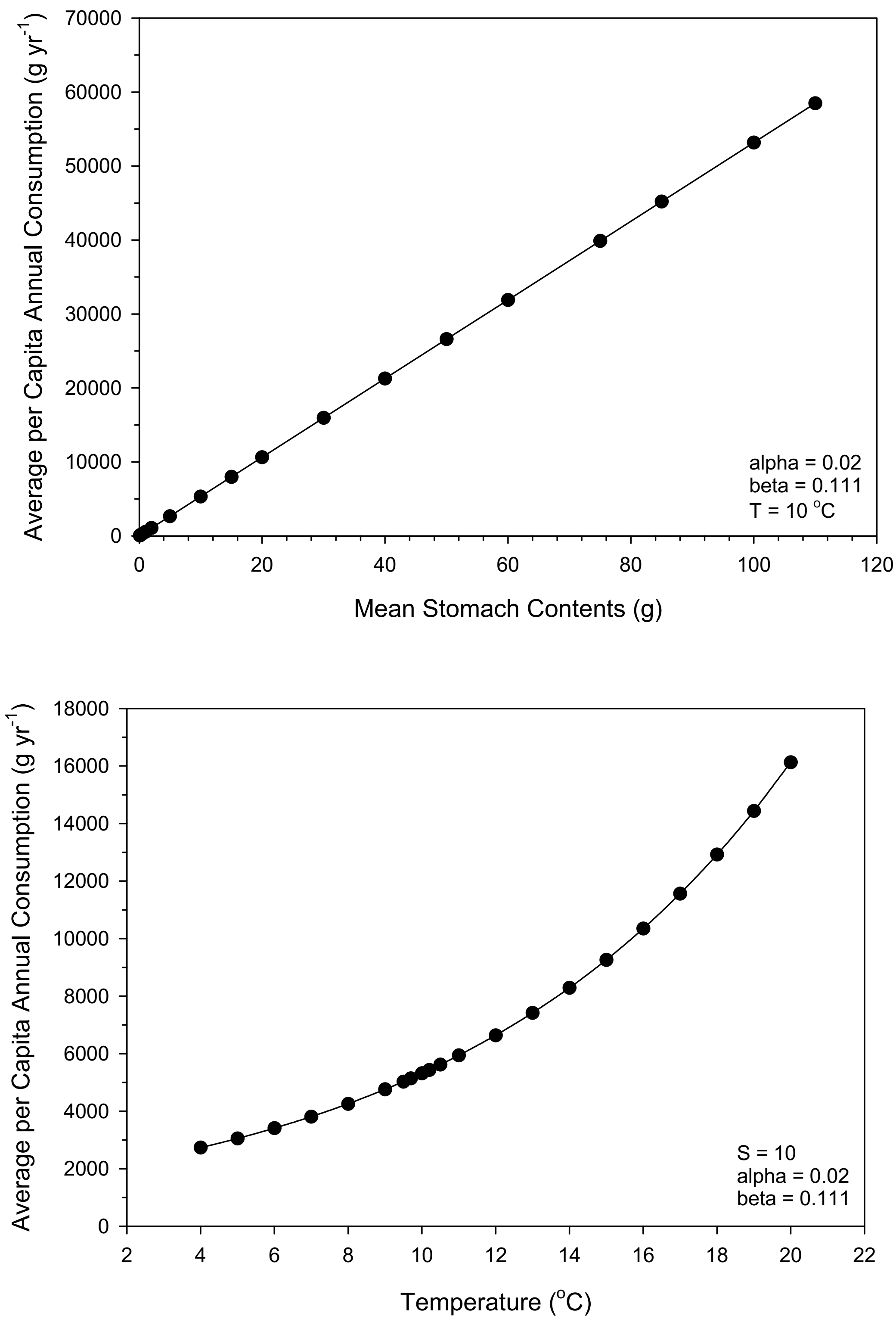


Figure B6.1. Sensitivity of Average per Capita Annual Consumption to a) mean stomach contents and b) temperature.

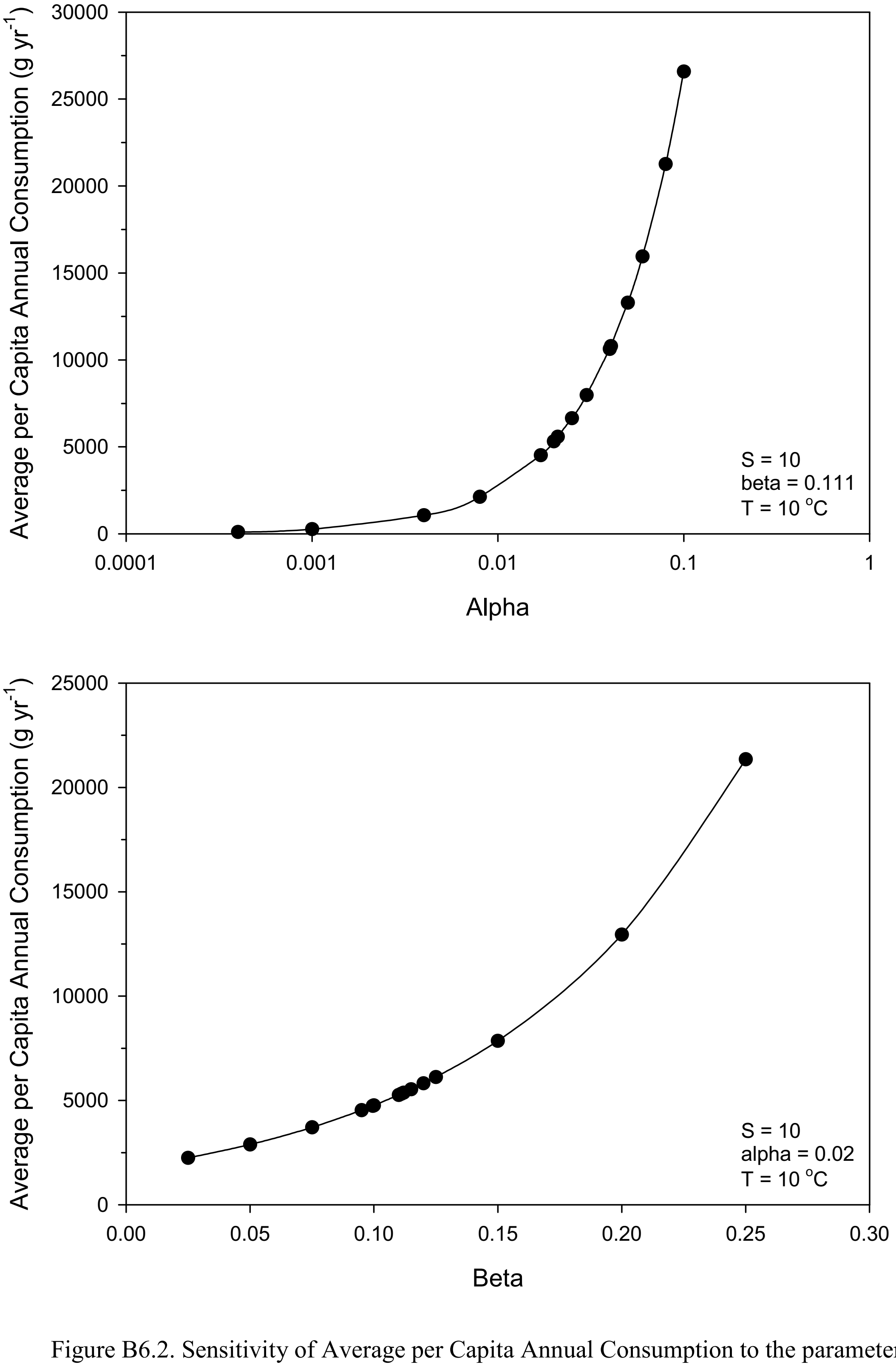


Figure B6.2. Sensitivity of Average per Capita Annual Consumption to the parameters a) alpha and b) beta.

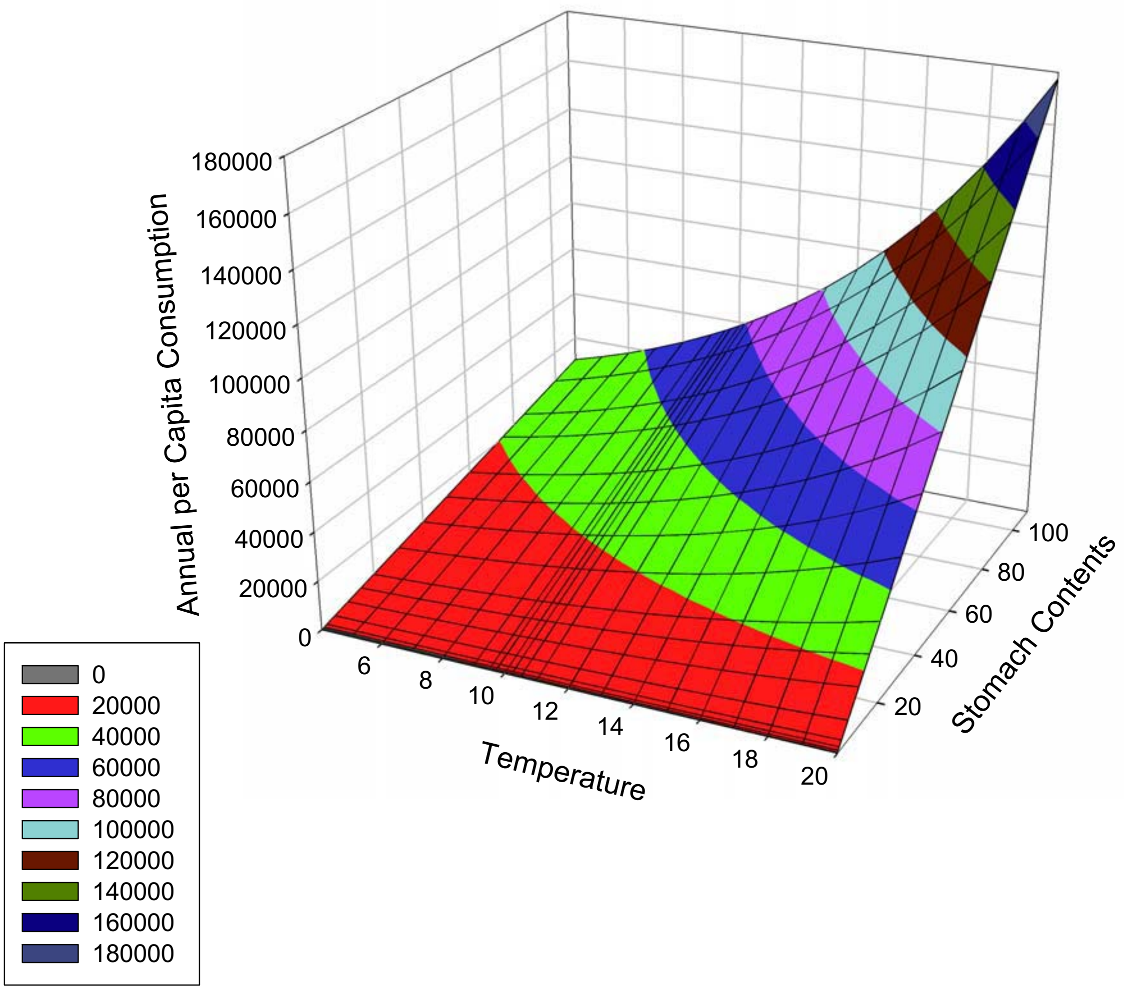


Figure 6.3. Sensitivity of Annual per Capita Consumption variation in both temperature and mean stomach contents.

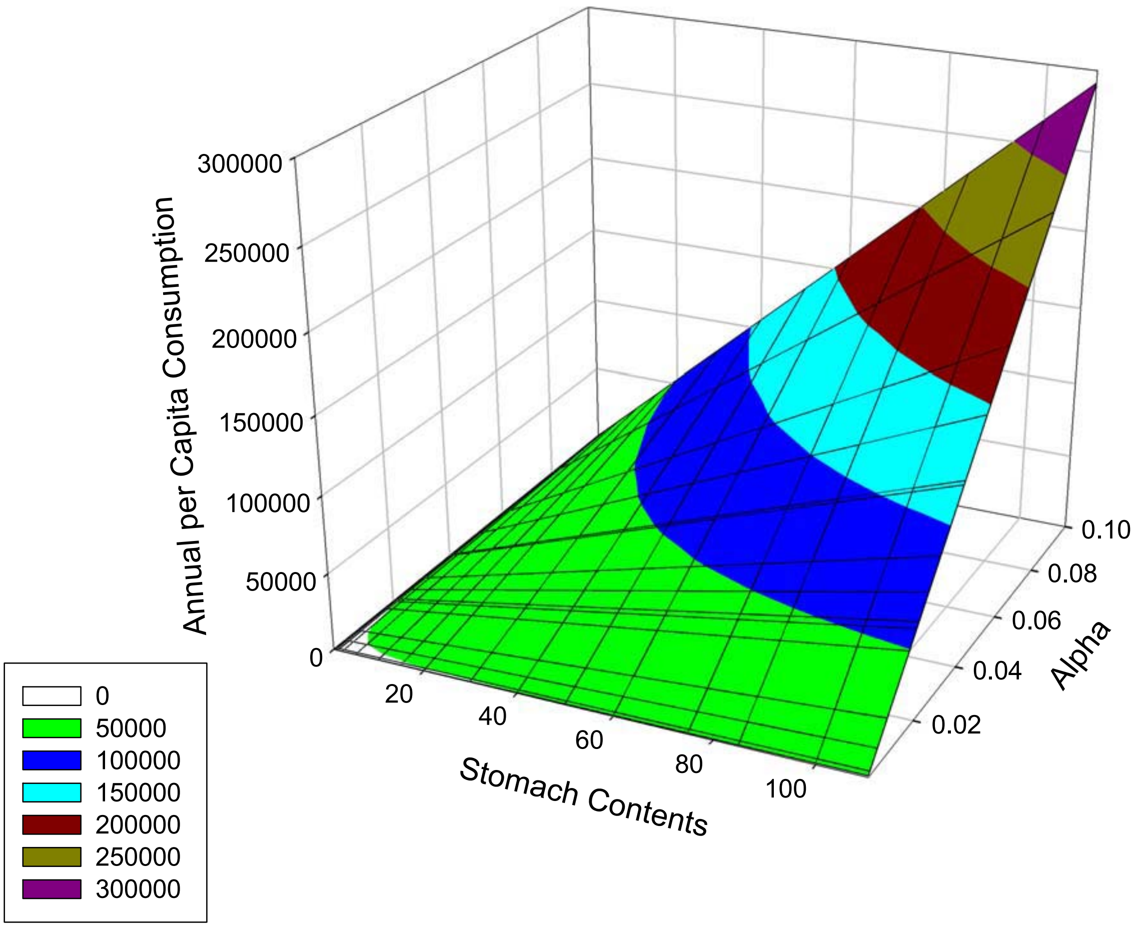


Figure 6.4. Sensitivity of Annual per Capita Consumption variation in both alpha and mean stomach contents.

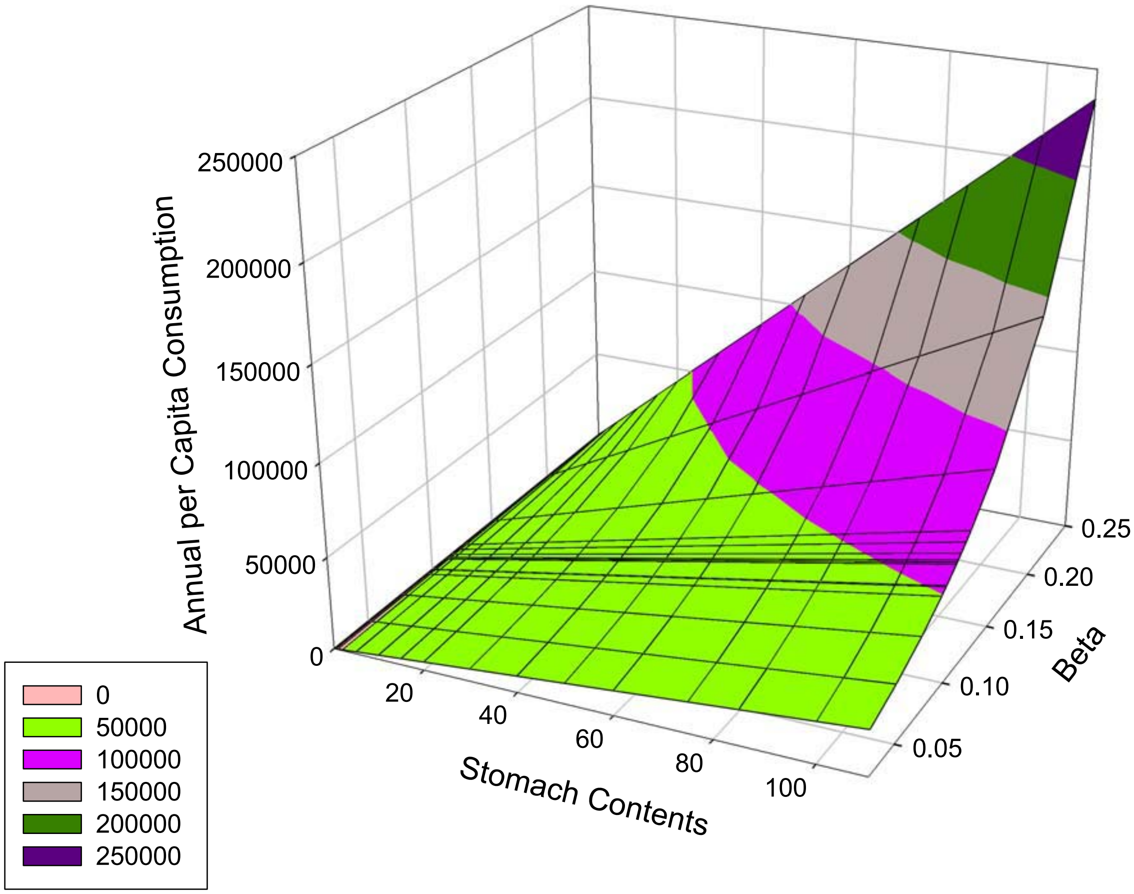


Figure 6.5. Sensitivity of Annual per Capita Consumption variation in both beta and mean stomach contents.

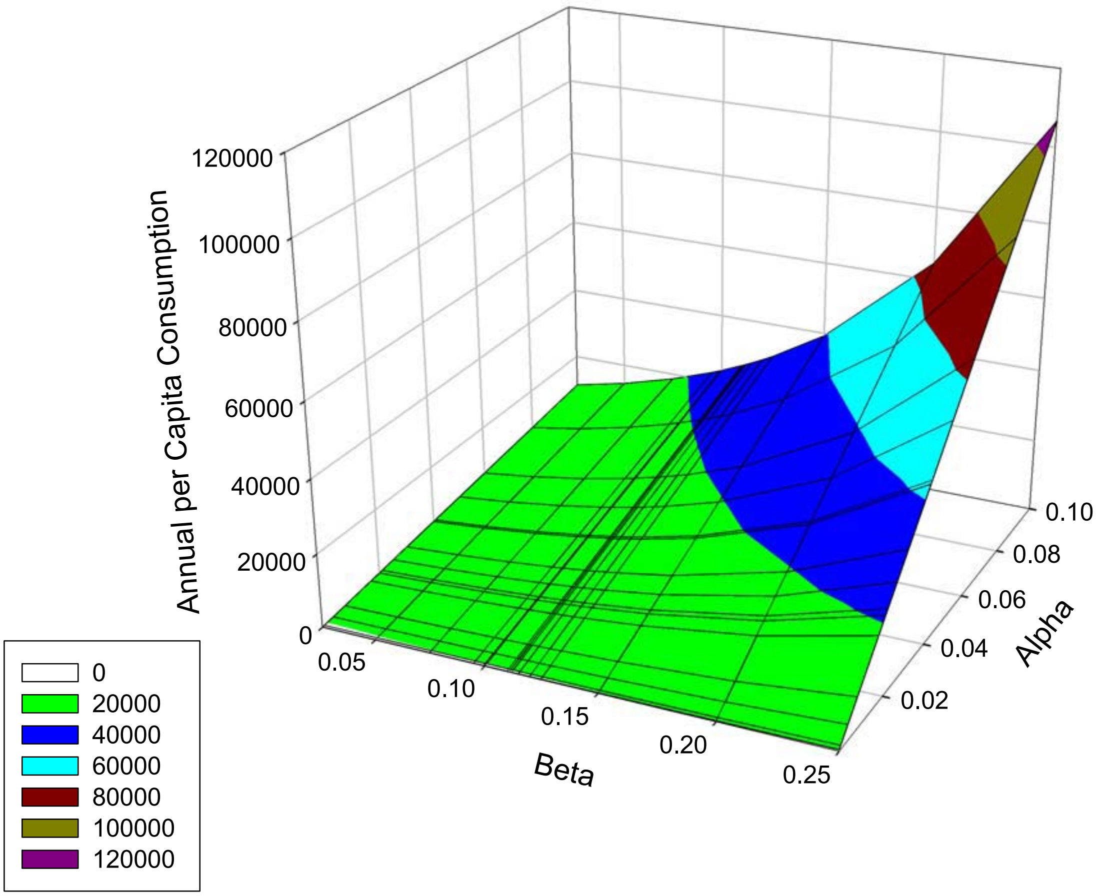


Figure 6.6. Sensitivity of Annual per Capita Consumption variation in both beta and alpha.

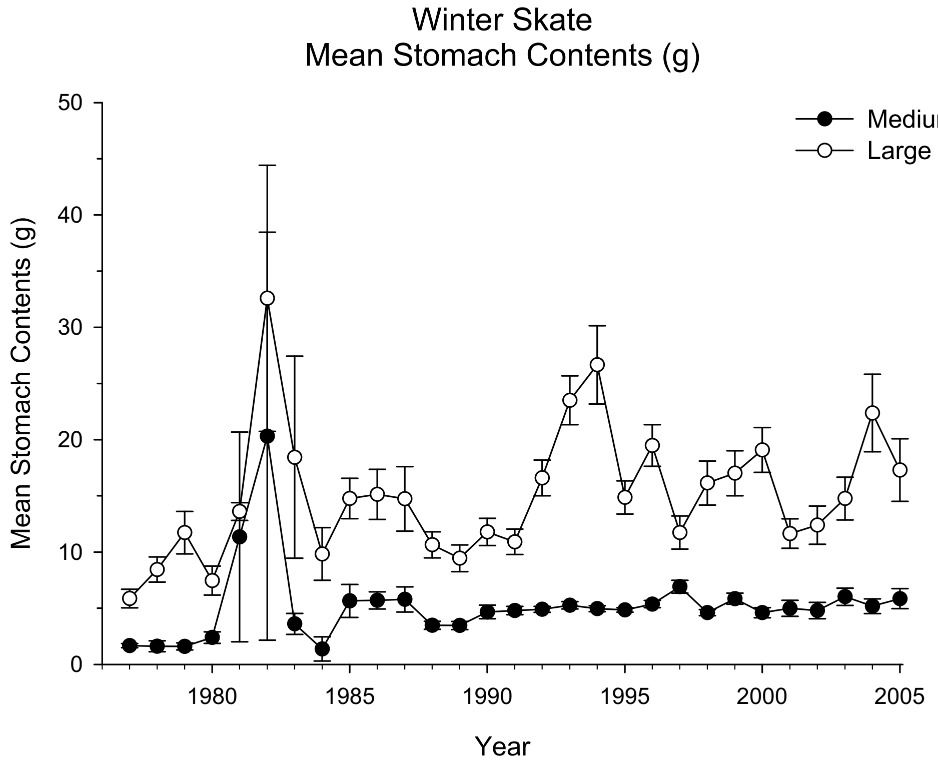


Figure B6.7a. The annual mean stomach contents (0.1 g) of winter skate for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

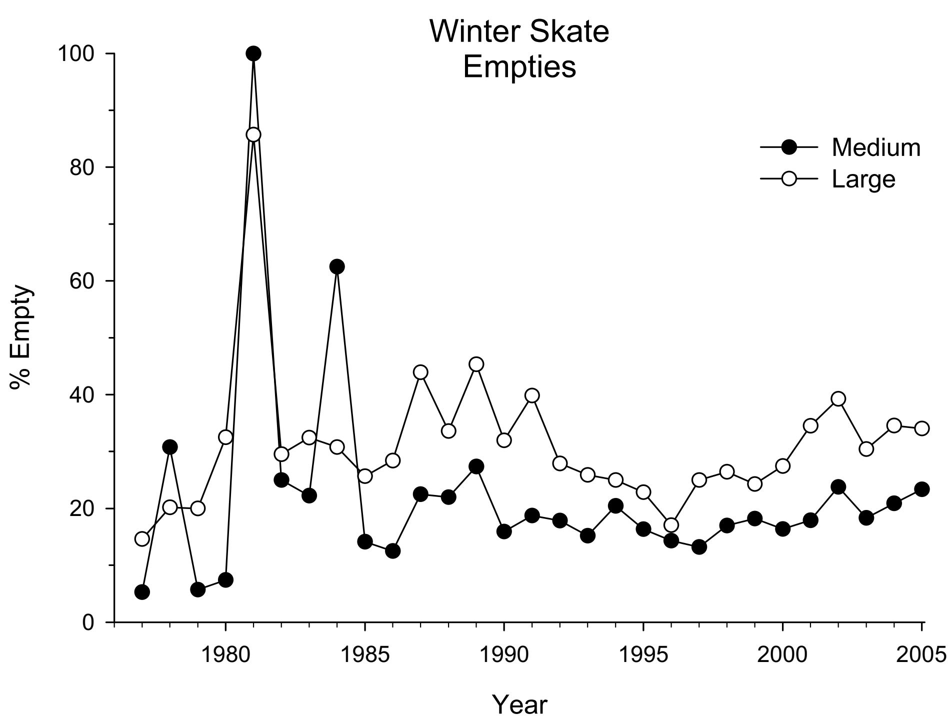


Figure B6.7b. The percentage of stomachs that were empty (i.e., containing no prey) of Winter skate for the strata set and time period noted. Each size class is noted

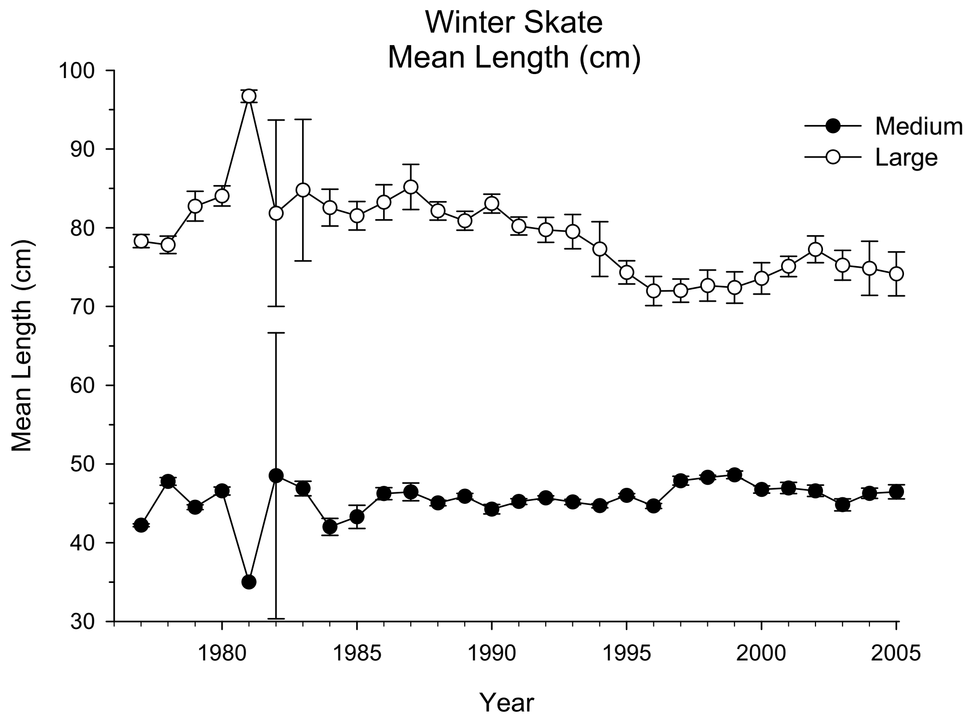


Figure B6.8a. The mean length (1 cm) of Winter skate from which stomach samples were collected, for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

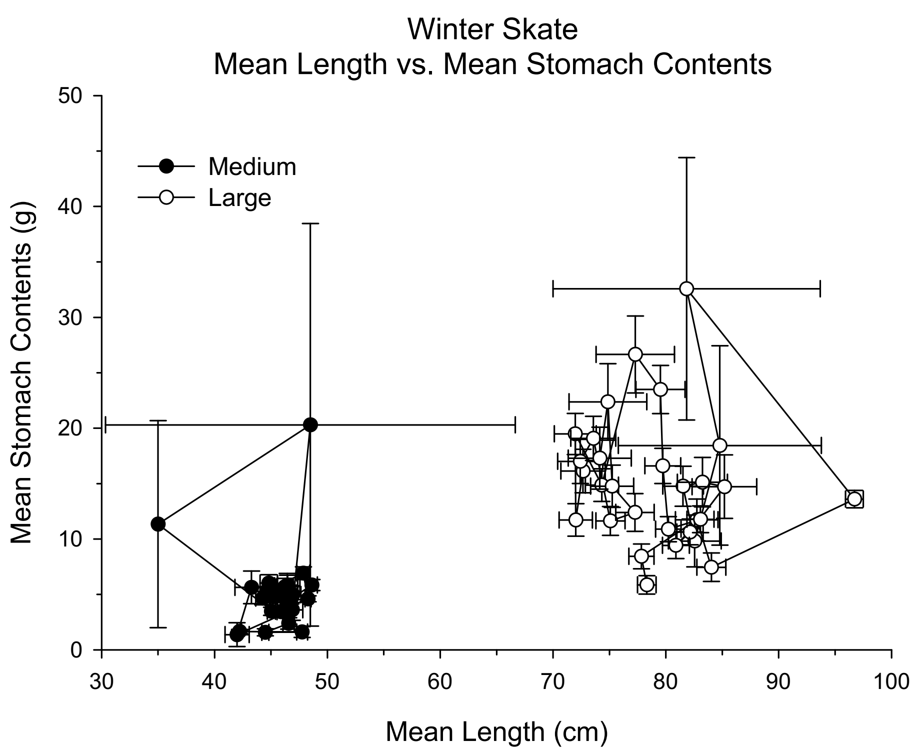


Figure B6.8b. The annual mean stomach contents (0.1 g) and the mean length (1 cm) of Winter skate for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

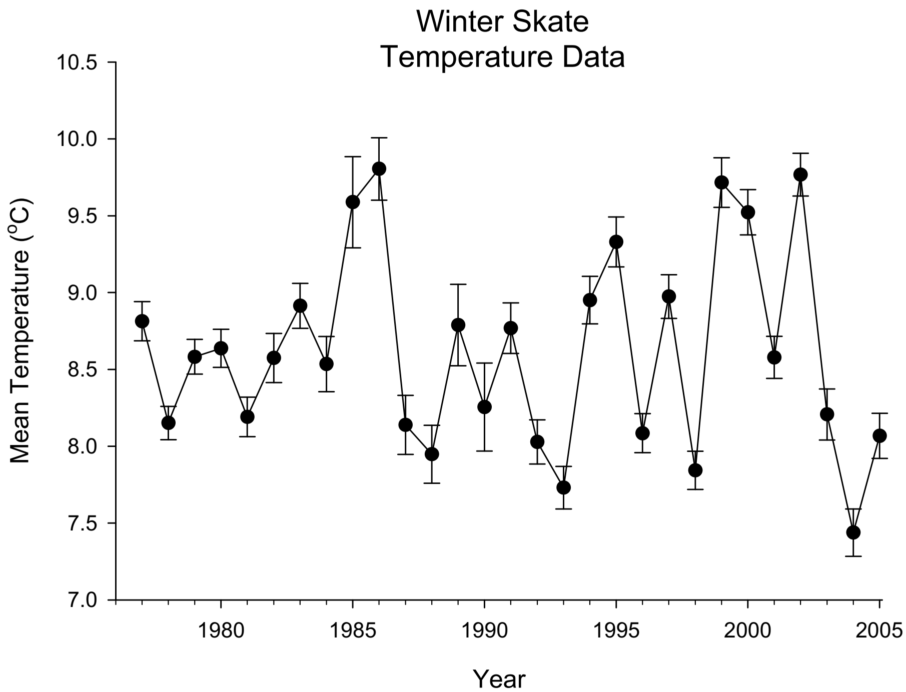


Figure B6.9a. The annual mean bottom temperature (0.1 ^{o}C) for the selected strata set, as taken from the bottom trawl survey over the time period noted. Error bars are ± 1 S.E.

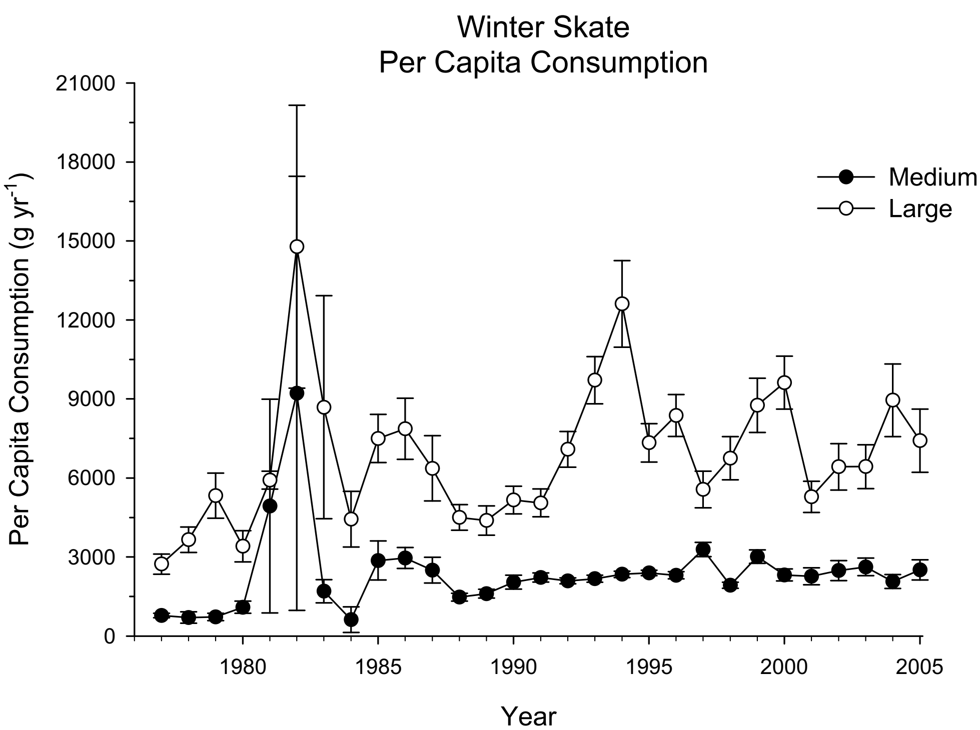


Figure B6.9b. The annual per capita consumption (g yr^{-1}) of Winter skate for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

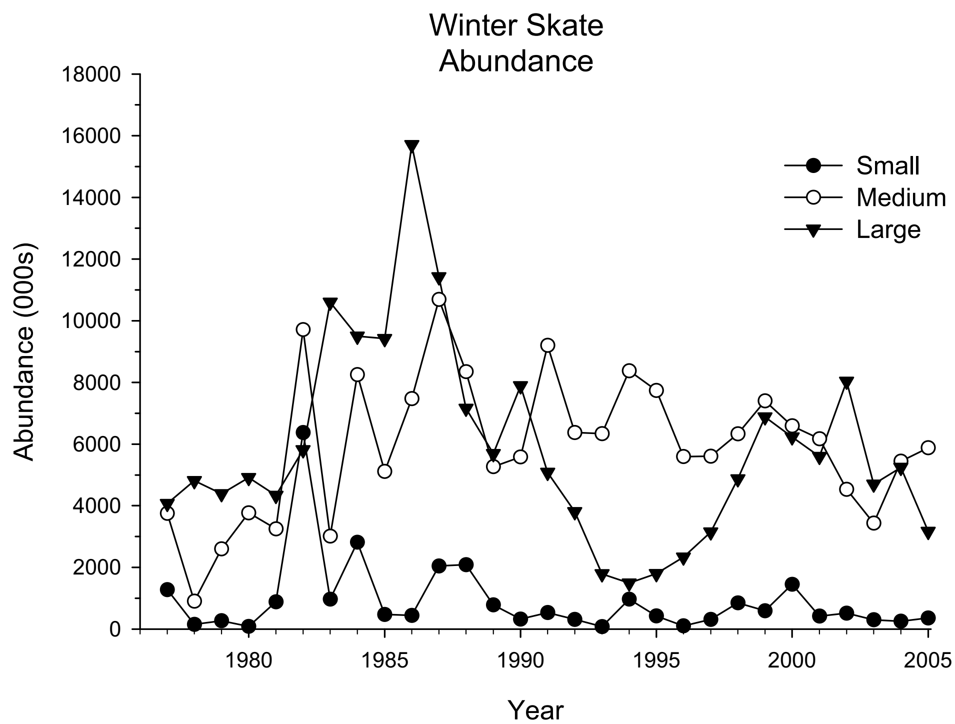


Figure B6.10a. The annual mean swept area abundance of winter skate for the strata set and time period noted. Each size class is noted.

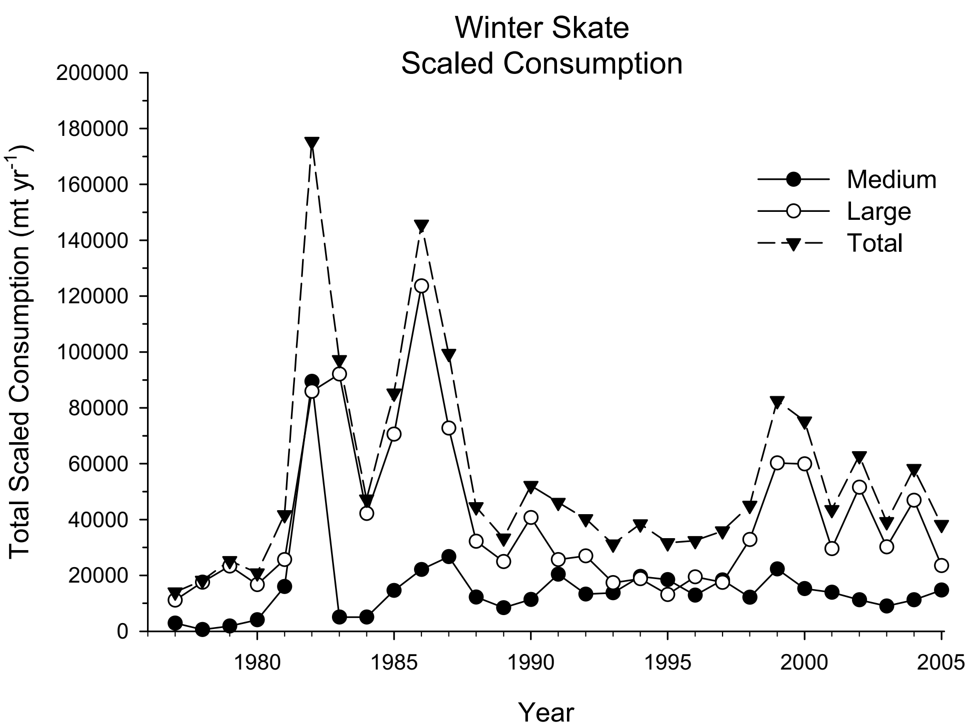


Figure B6.10b. The annual total consumption (MT yr-1) of Winter skate for the strata set and time period noted.

WINTER SKATE PREY REMOVAL

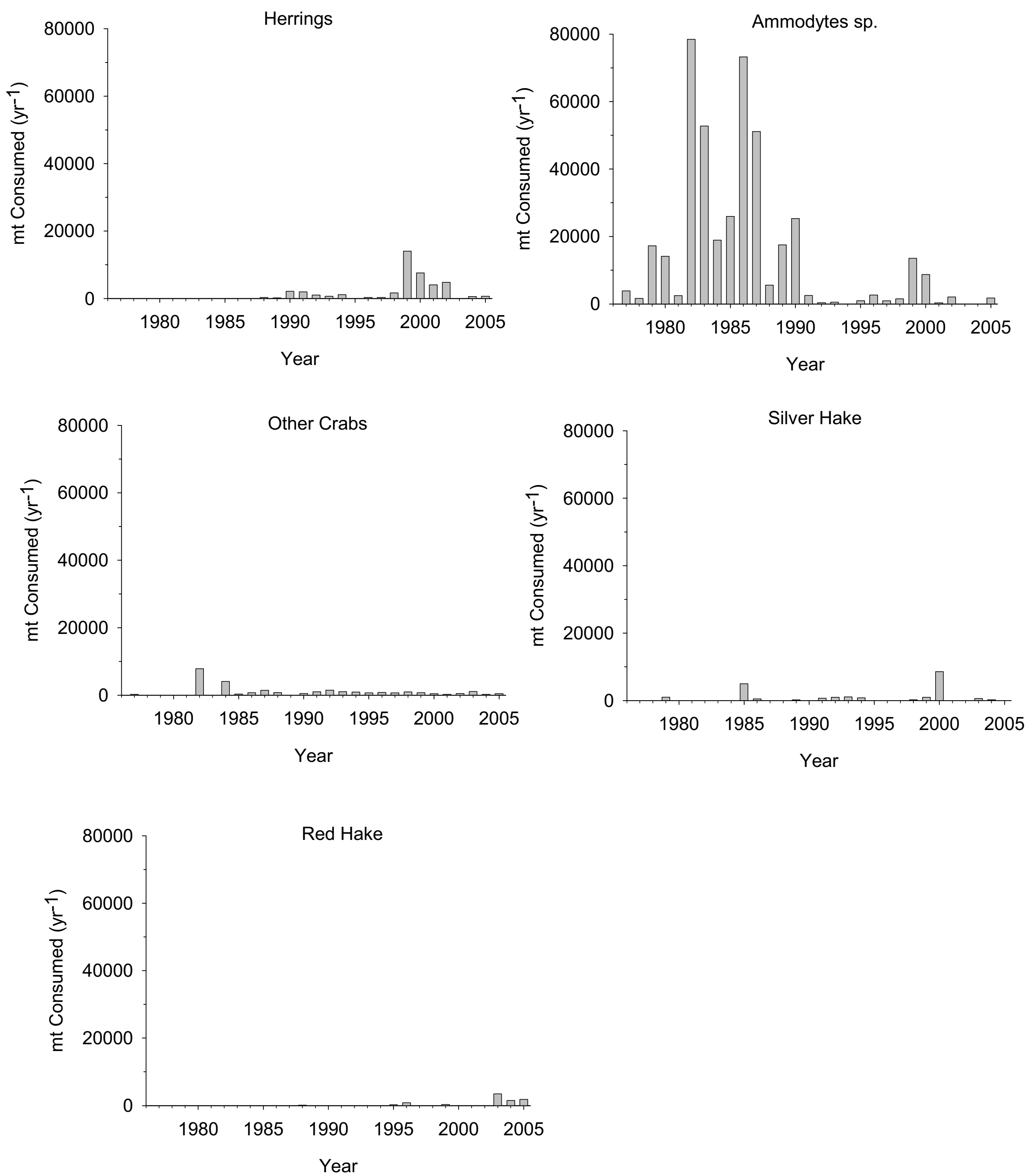


Figure B6.11. The amount of prey consumed (MT yr^{-1}) by Winter skate for the strata set and time period noted. These estimates represent the combination of total annual total consumption and the diet compositions of Winter skate. These prey were selected as some of the major prey (>>5 % of diet composition) of Winter skate.

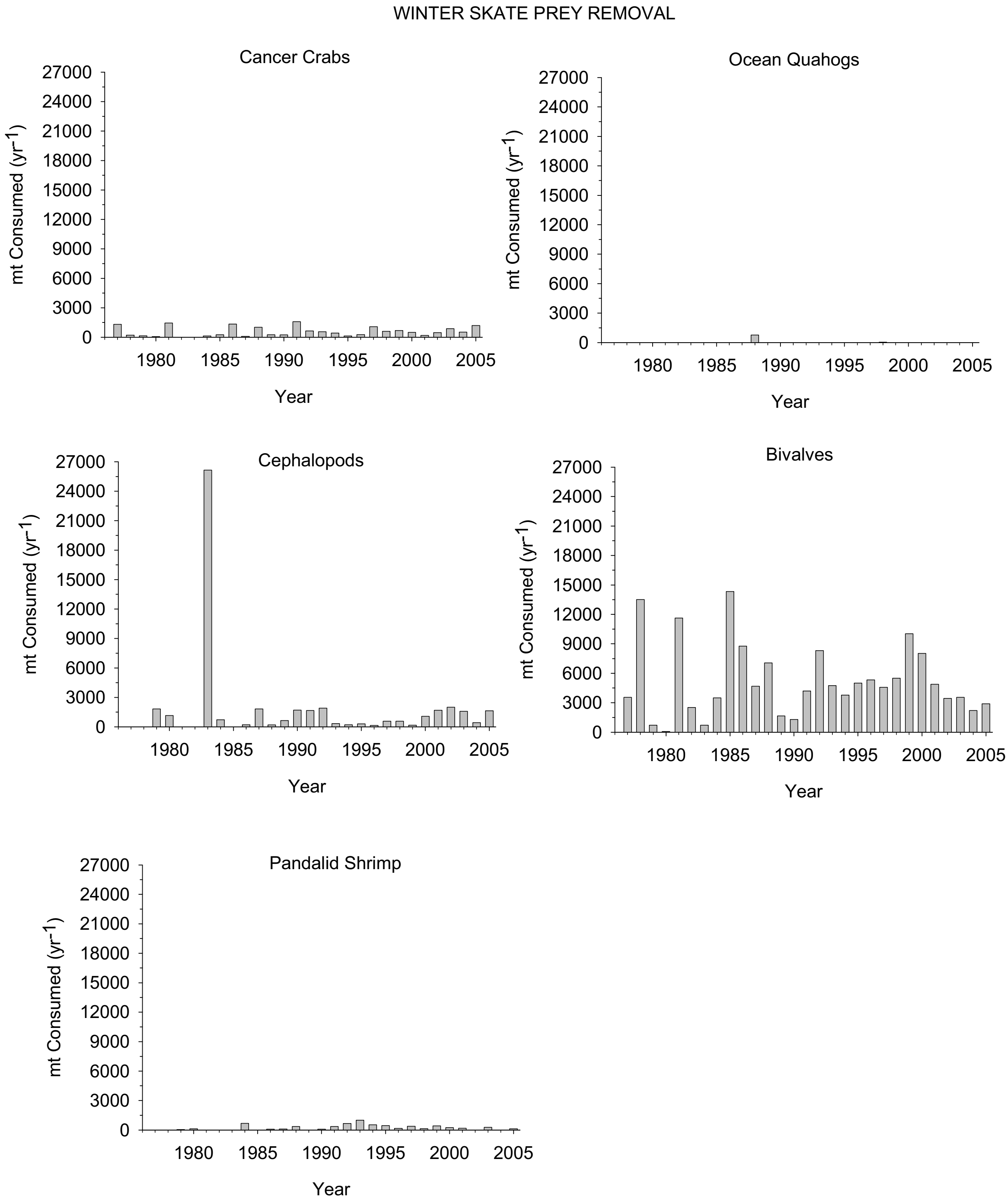


Figure B6.12. The amount of prey consumed (MT yr^{-1}) by Winter skate for the strata set and time period noted. These estimates represent the combination of total annual total consumption and the diet compositions of Winter skate. These prey were selected as some of the major prey (>>5 % of diet composition) of Winter skate.

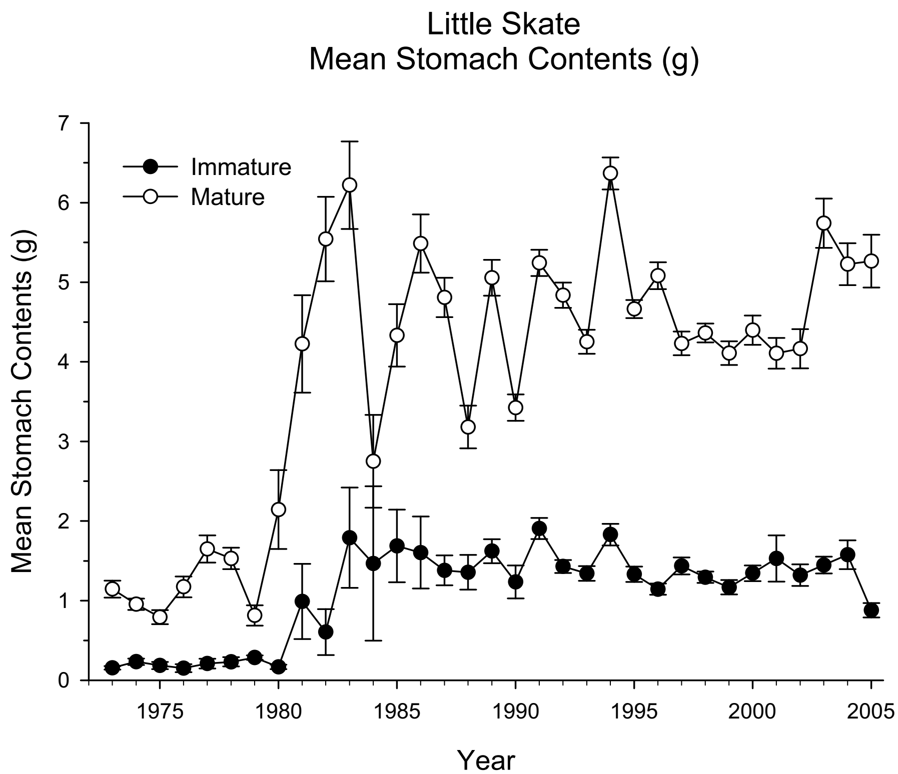


Figure B6.13a. The annual mean stomach contents (0.1 g) of Little skate for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

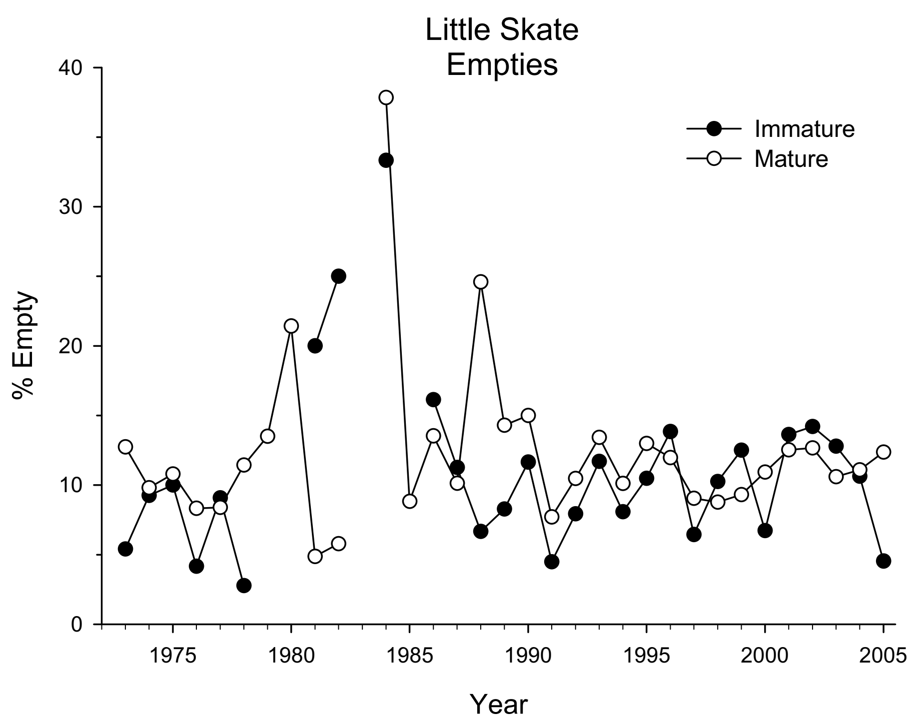


Figure B6.13b. The percentage of stomachs that were empty (i.e., containing no prey) of Little skate for the strata set and time period noted. Each size class is noted.

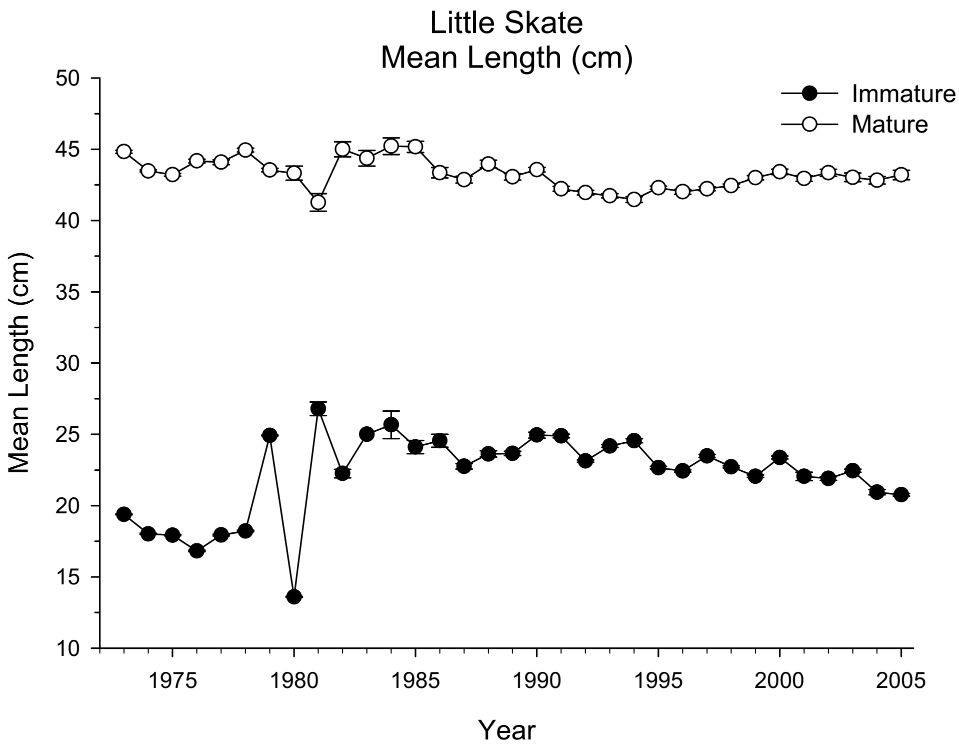


Figure B6.14a. The mean length (1 cm) of Little skate from which stomach samples were collected, for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

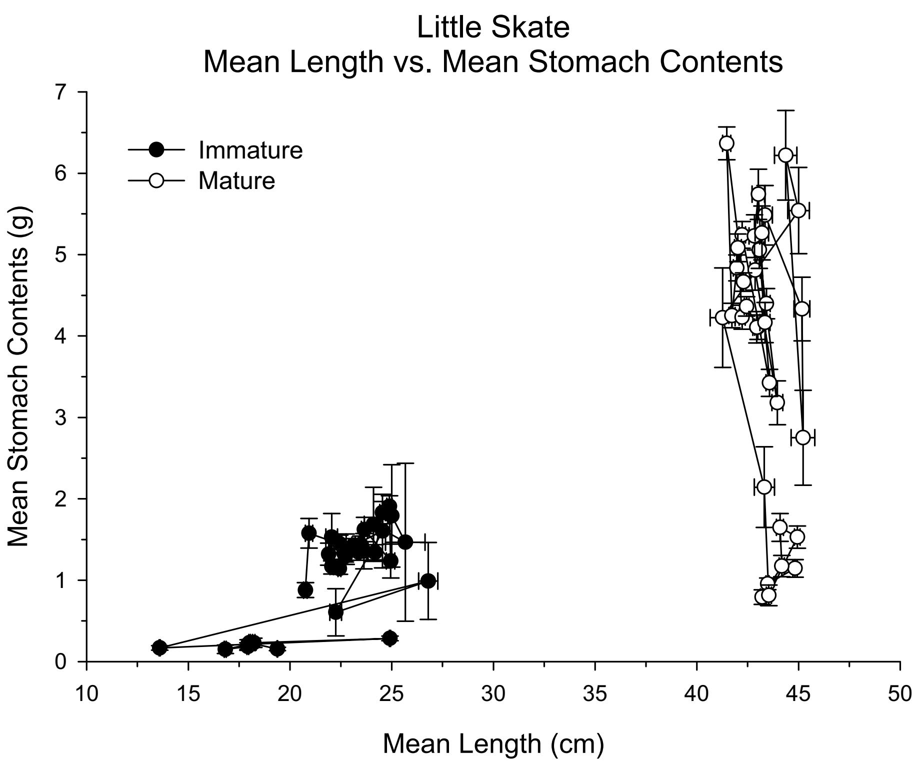


Figure B6.14b. The annual mean stomach contents (0.1 g) and the mean length (1 cm) of Little skate for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

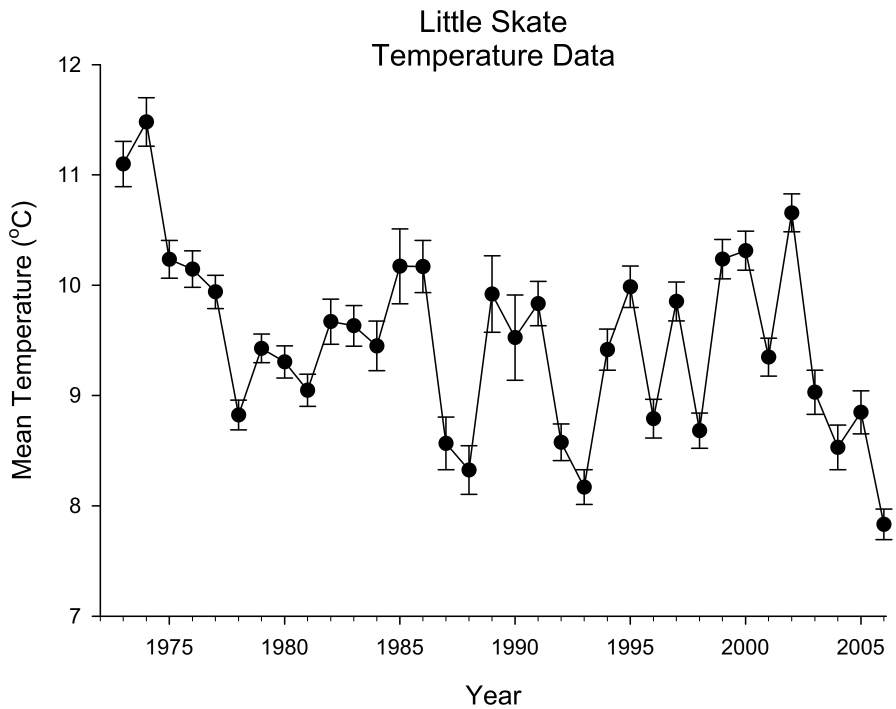


Figure B6.15a. The annual mean bottom temperature (0.1 oC) for the selected strata set, as taken from the bottom trawl survey over the time period noted. Error bars are ± 1 S.E.

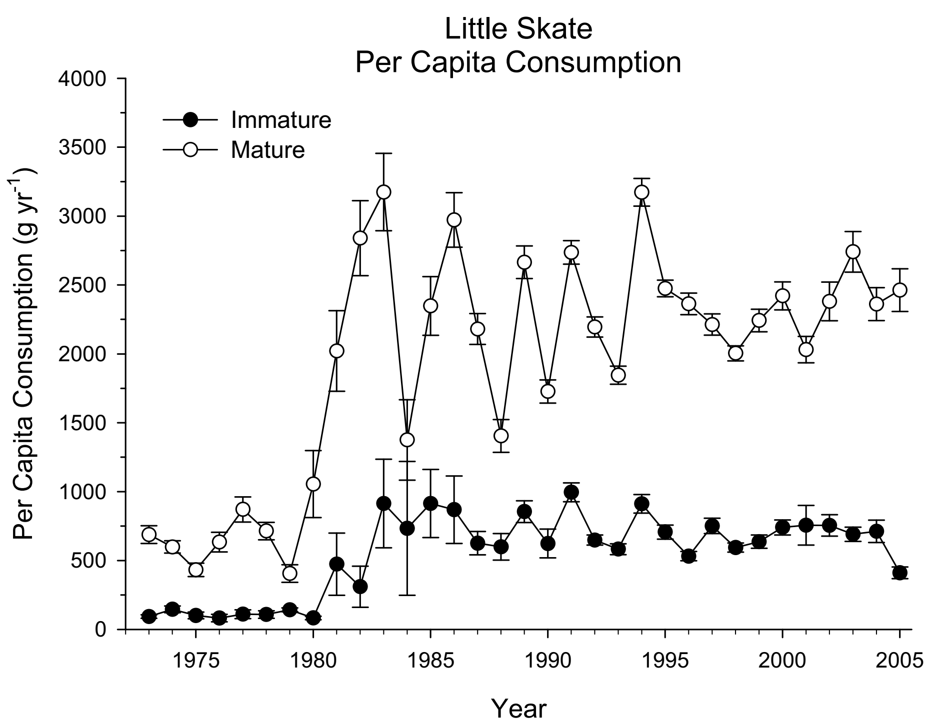


Figure B6.15b. The annual per capita consumption (g yr^{-1}) of Little skate for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

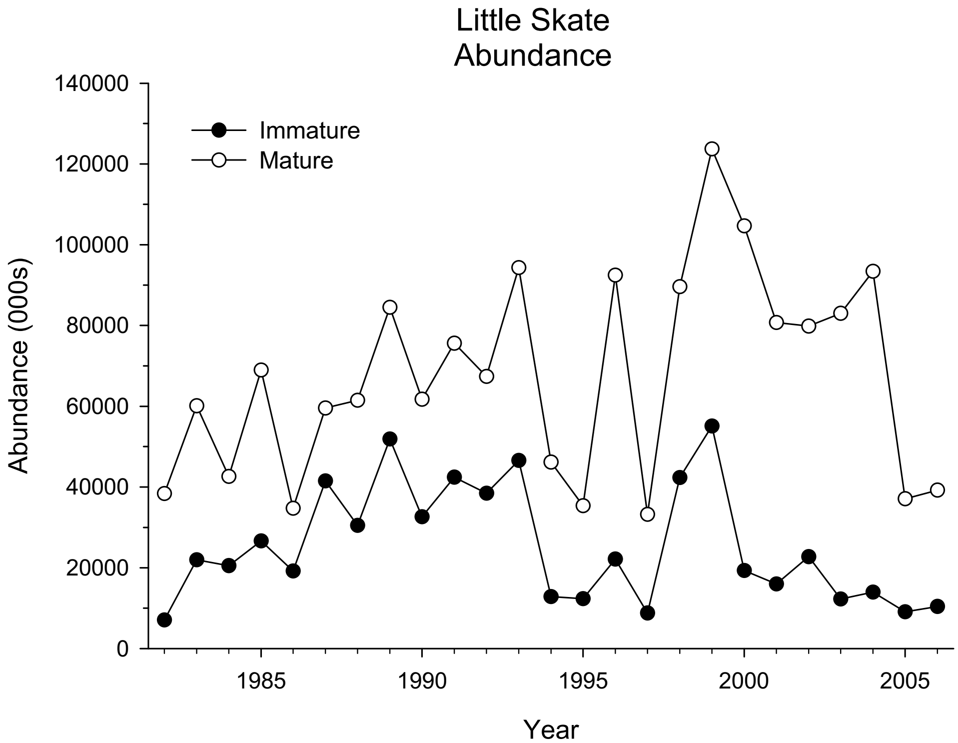


Figure B6.16a. The annual mean swept area abundance of Little skate for the strata set and time period noted. Each size class is noted.

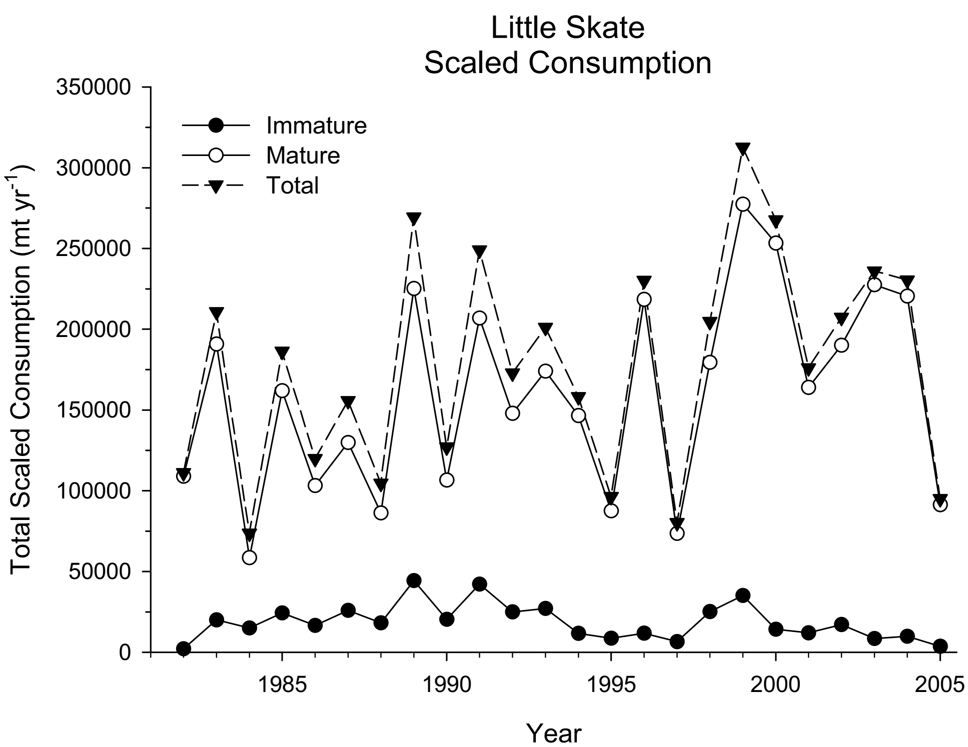


Figure B6.16b. The annual total consumption (MT yr^{-1}) of Little skate for the strata set and time period noted.

LITTLE SKATE PREY REMOVAL

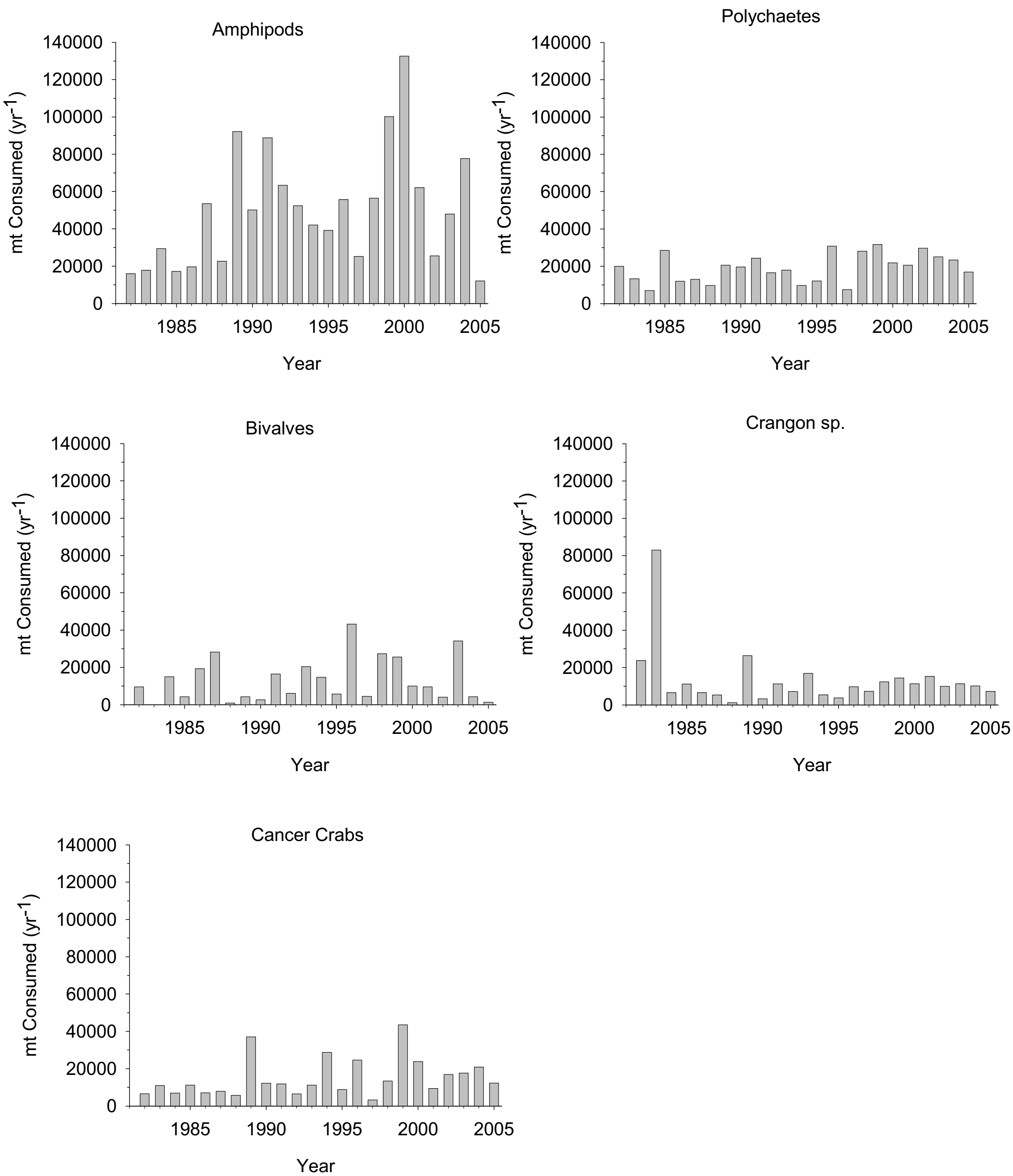


Figure B6.17. The amount of prey consumed (MT yr-1) by Little skate for the strata set and time period noted. These estimates represent the combination of total annual total consumption and the diet compositions of Little skate. These prey were selected as some of the major prey (>>5 % of diet composition) of Little skate.

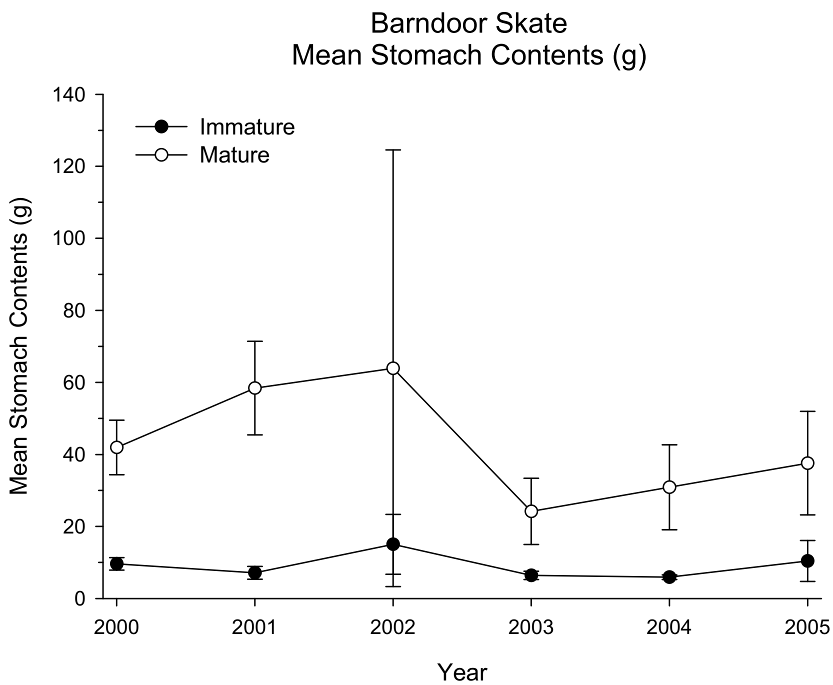


Figure B6.18a. The annual mean stomach contents (0.1 g) of barndoor skate for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

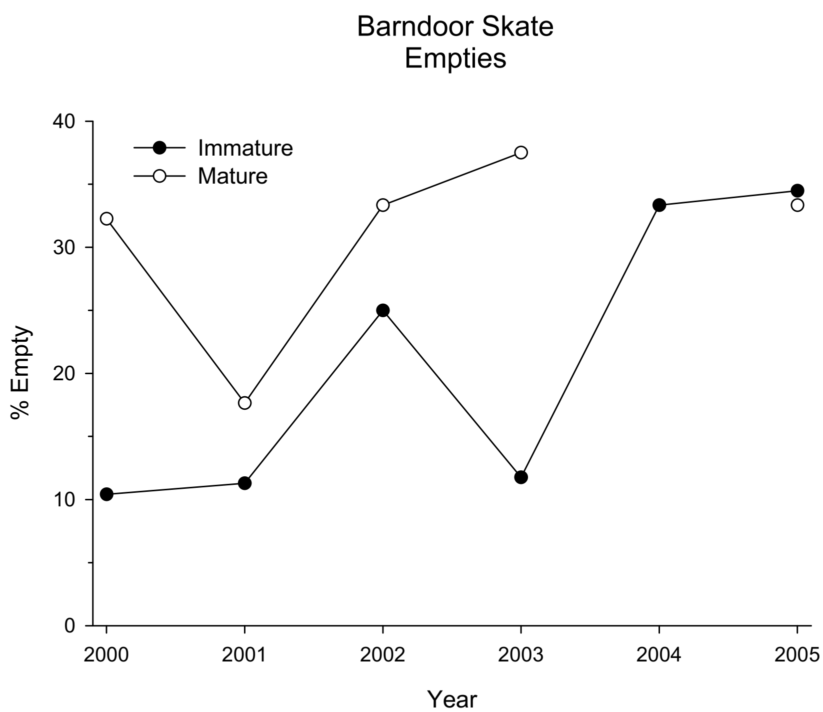


Figure B6.18b. The percent of barndoor skates that had empty stomachs, by year and size class.

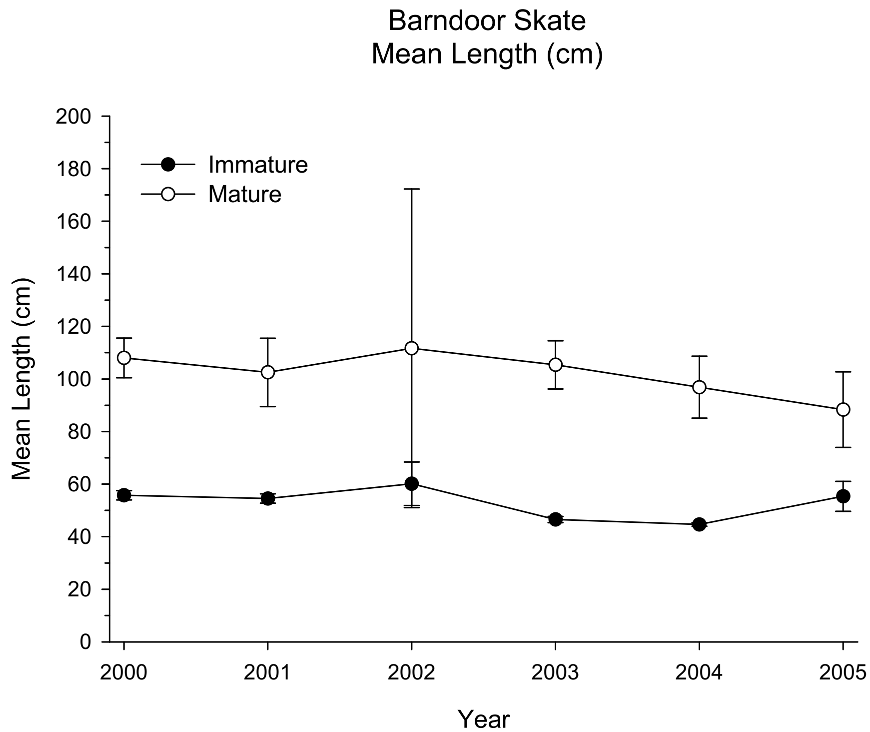


Figure B6.19a. The mean length (1 cm) of Barndoor skate from which stomach samples were collected, for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

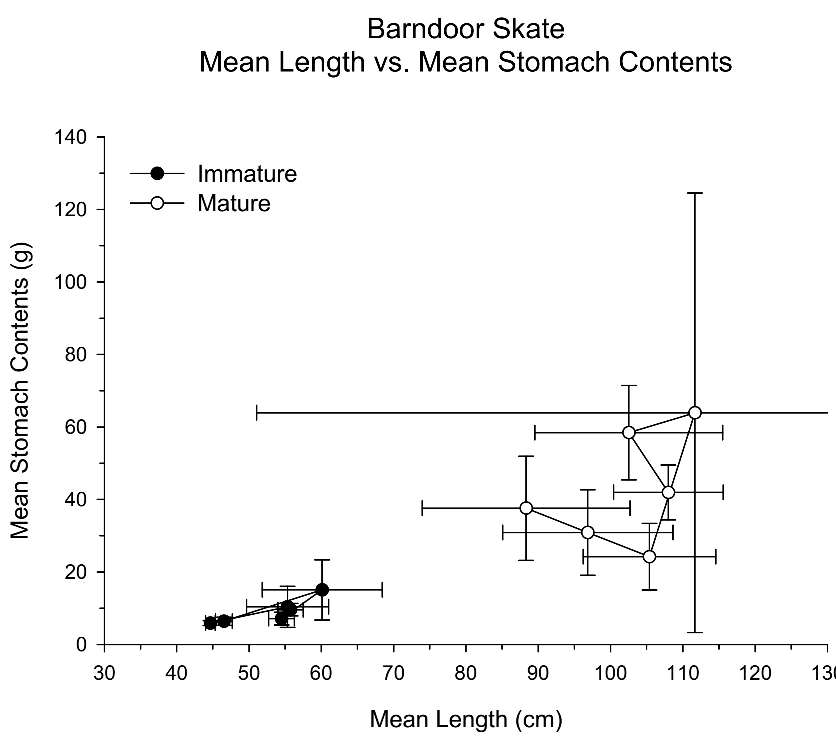


Figure B6.19b. The annual mean stomach contents (0.1 g) and the mean length (1 cm) of Barndoor skate for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

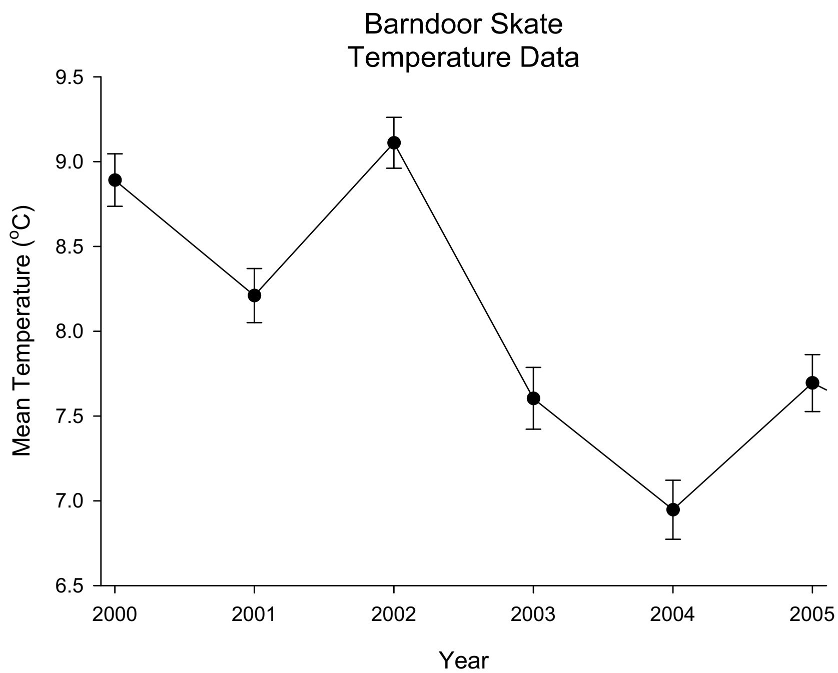


Figure B6.20a. The annual mean bottom temperature (0.1 °C) for the selected strata set, as taken from the bottom trawl survey over the time period noted. Error bars are ± 1 S.E.

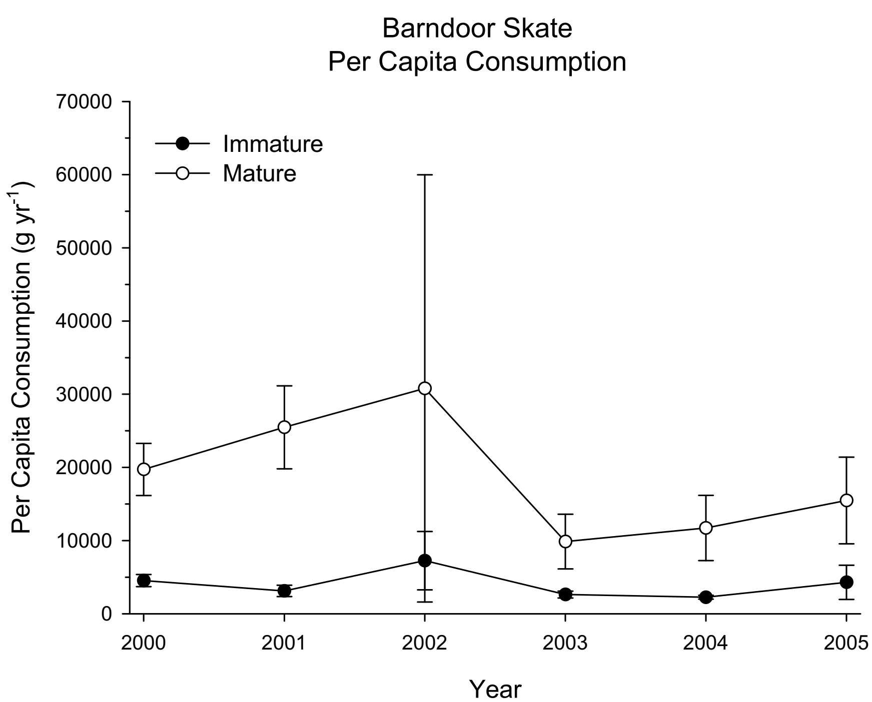


Figure B6.20b. The annual per capita consumption (g yr^{-1}) of Barndoor skate for the strata set and time period noted. Each size class is noted.

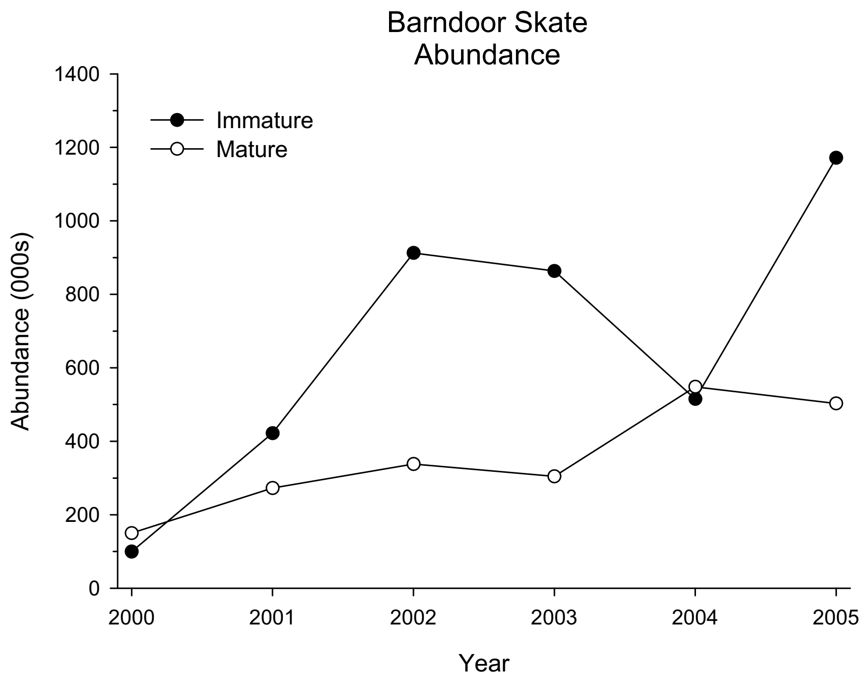


Figure B6.21a. The annual mean swept area abundance of Barndoor skate for the strata set and time period noted. Each size class is noted.

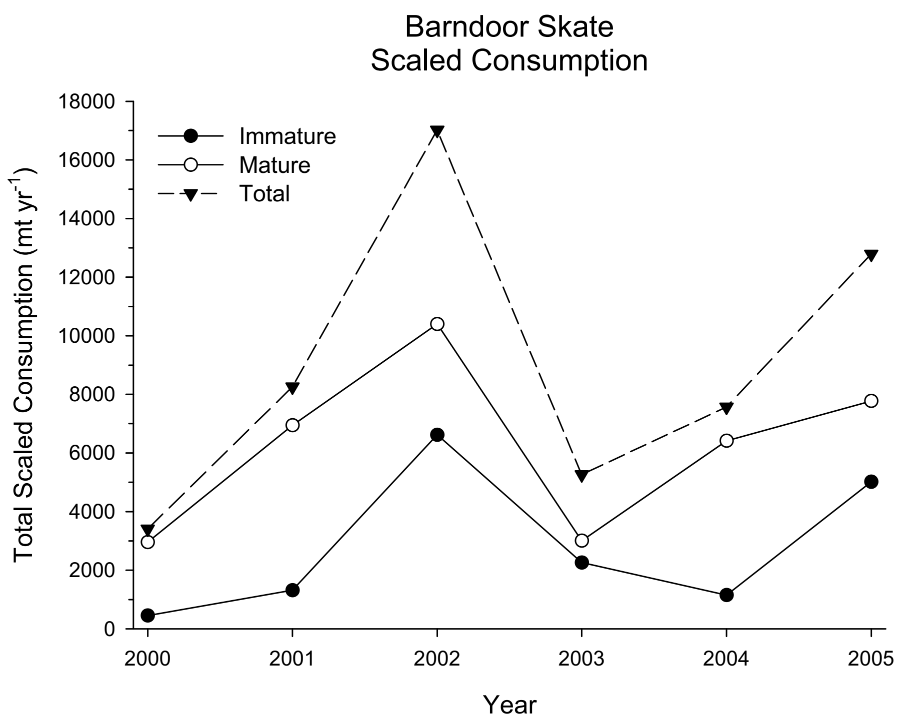


Figure B6.21b. The annual total consumption (MT yr^{-1}) of Barndoor skate for the strata set and time period noted.

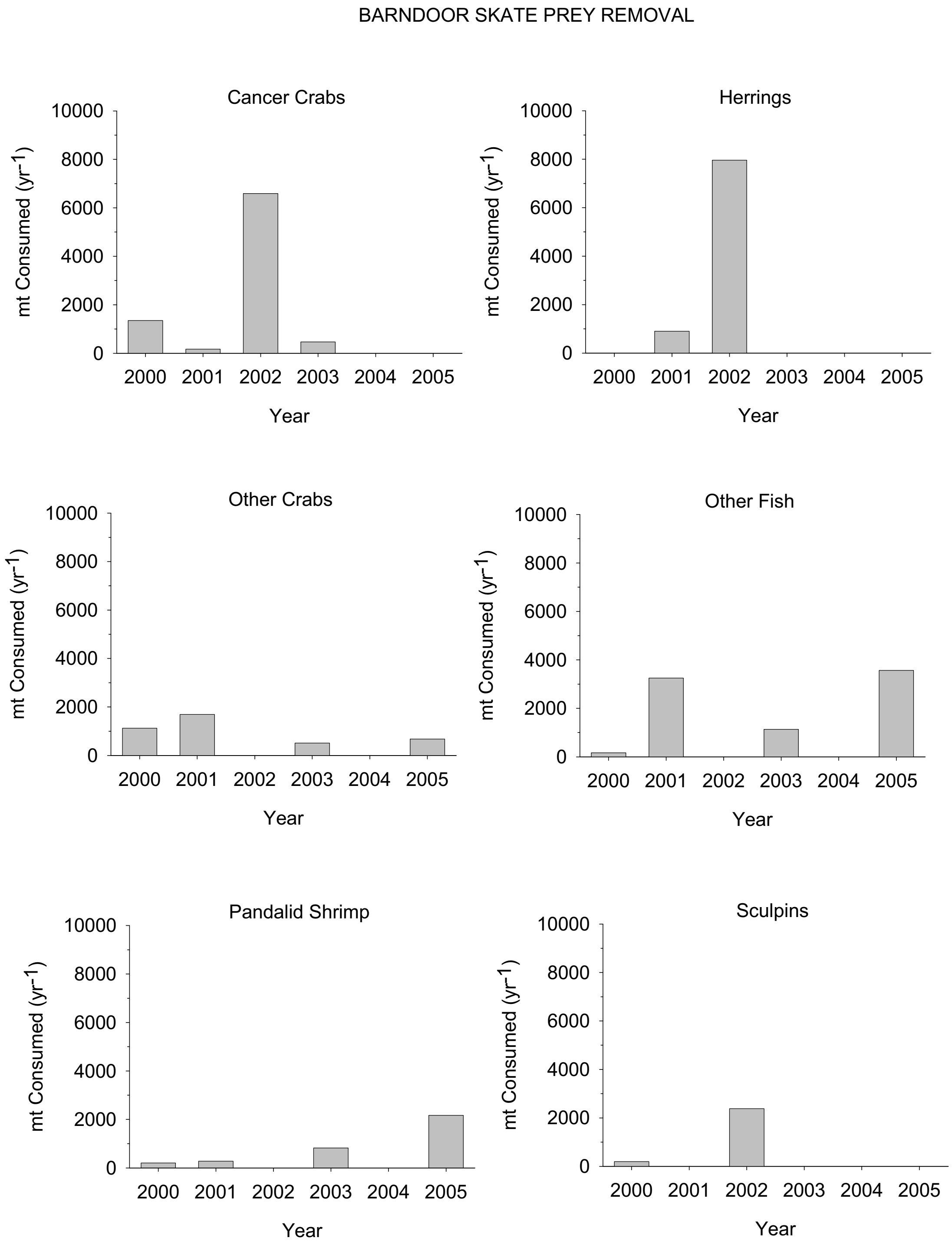


Figure B6.22. The amount of prey consumed (MT yr^{-1}) by Barndoor skate for the strata set and time period noted. These estimates represent the combination of total annual total consumption and the diet compositions of Barndoor skate. These prey were selected as some of the major prey (>>5 % of diet composition) of Barndoor skate.

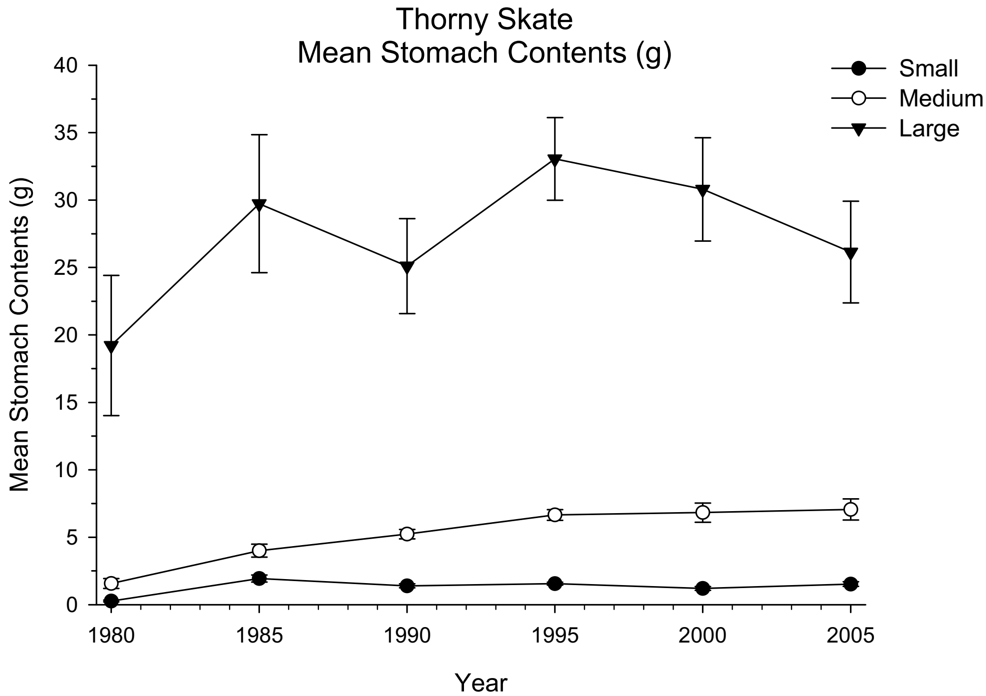


Figure B6.23a. The annual mean stomach contents (0.1 g) of Thorny skate for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

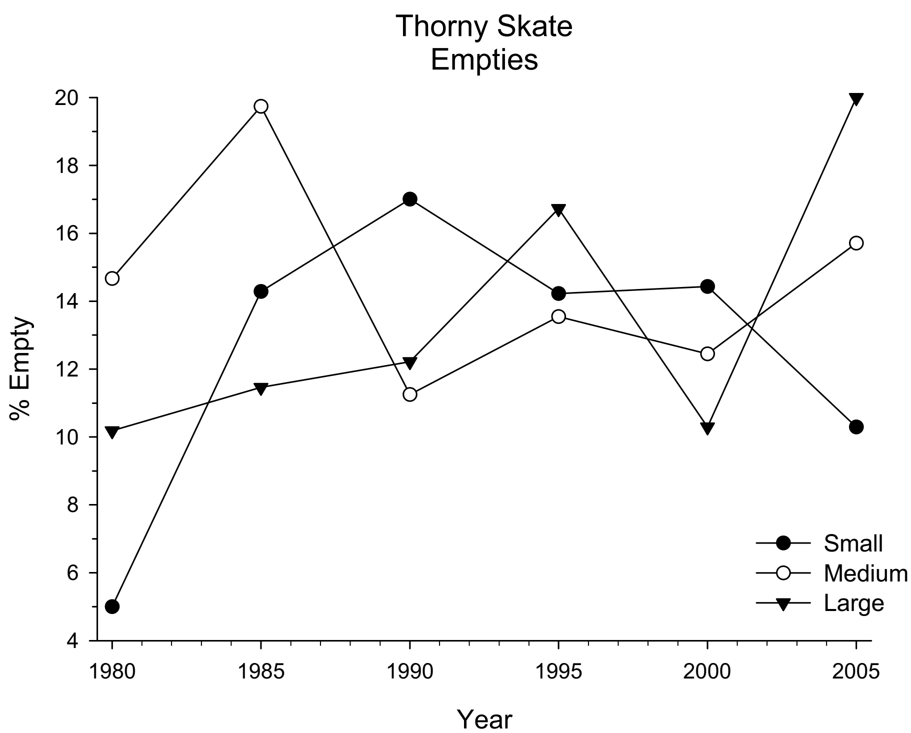


Figure B6.23b. The percentage of stomachs that were empty (i.e., containing no prey) of Thorny skate for the strata set and time period noted. Each size class is noted

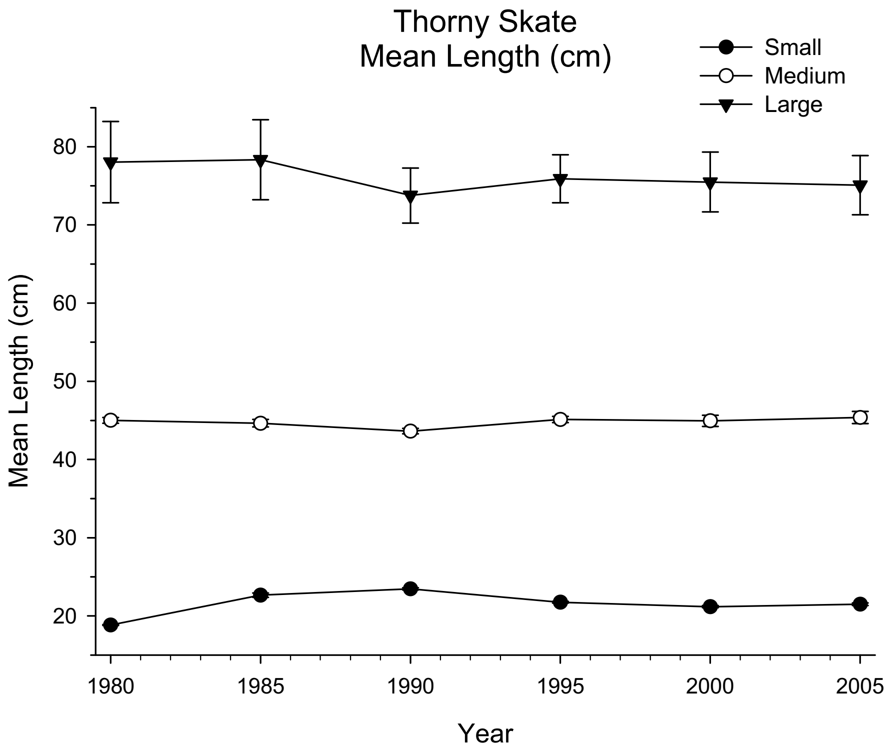


Figure B6.24a. The mean length (1 cm) of Thorny skate from which stomach samples were collected, for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

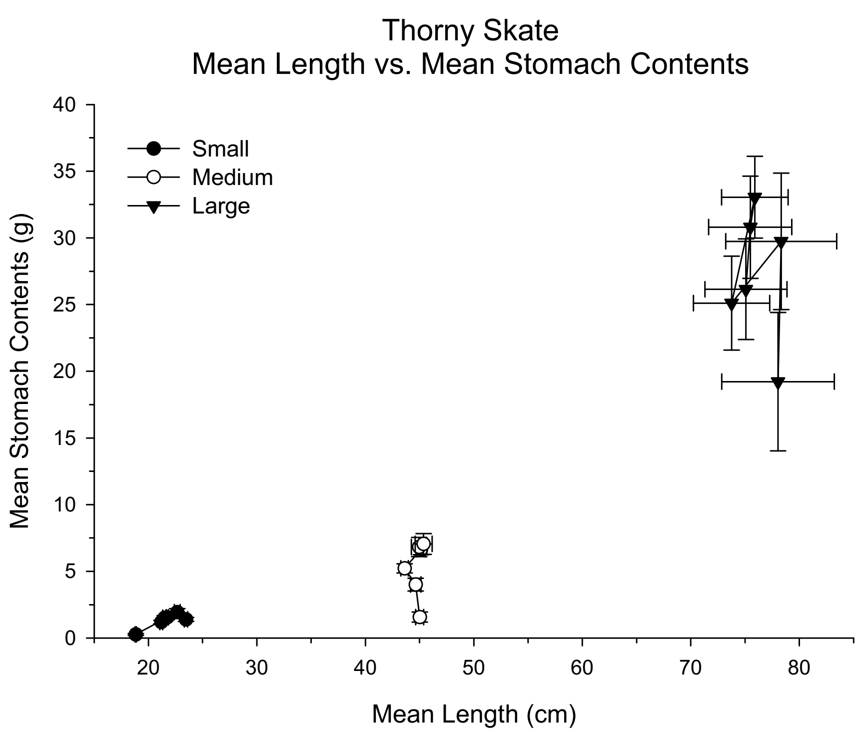


Figure B6.24b. The annual mean stomach contents (0.1 g) and the mean length (1 cm) of Thorny skate for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

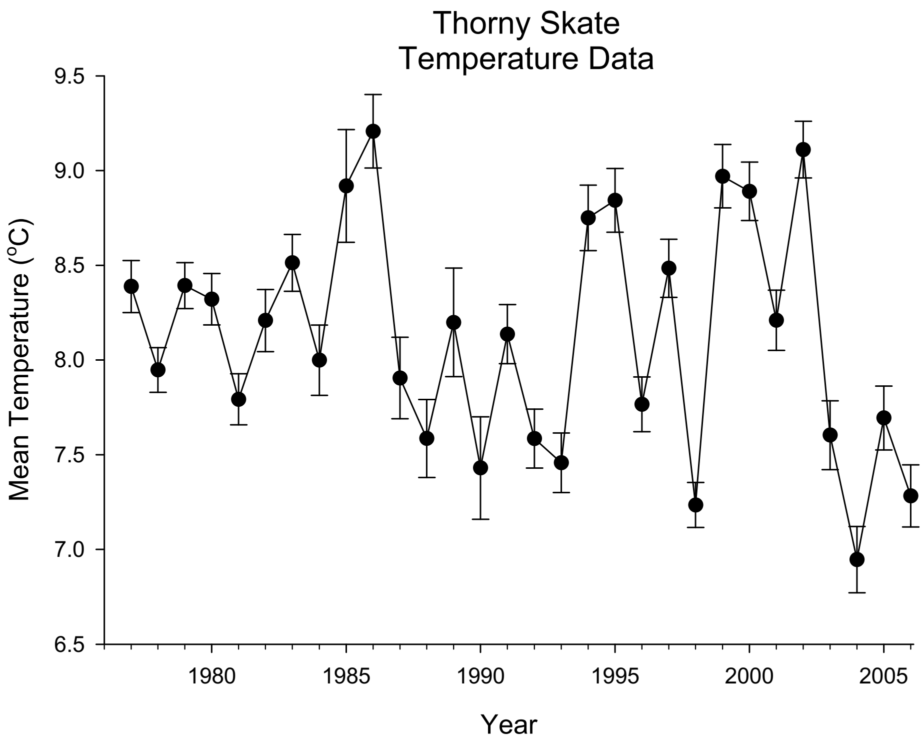


Figure B6.25a. The annual mean bottom temperature (0.1 ^{O}C) for the selected strata set, as taken from the bottom trawl survey over the time period noted. Error bars are ± 1 S.E.

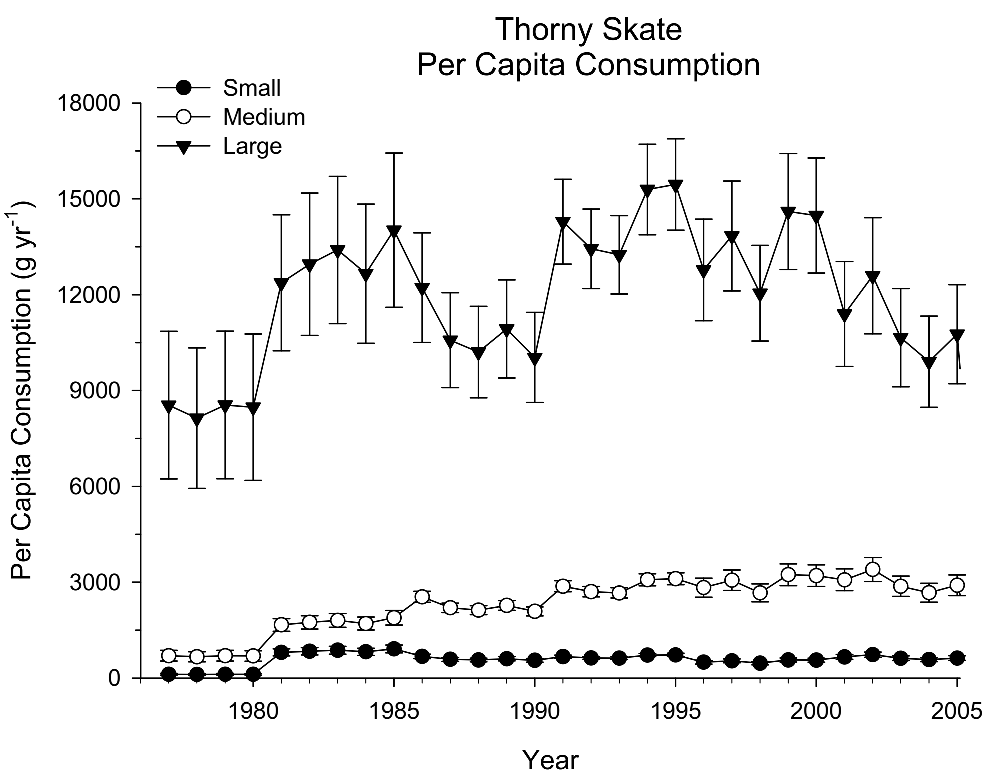


Figure B6.25b. The annual per capita consumption (g yr^{-1}) of Thorny skate for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

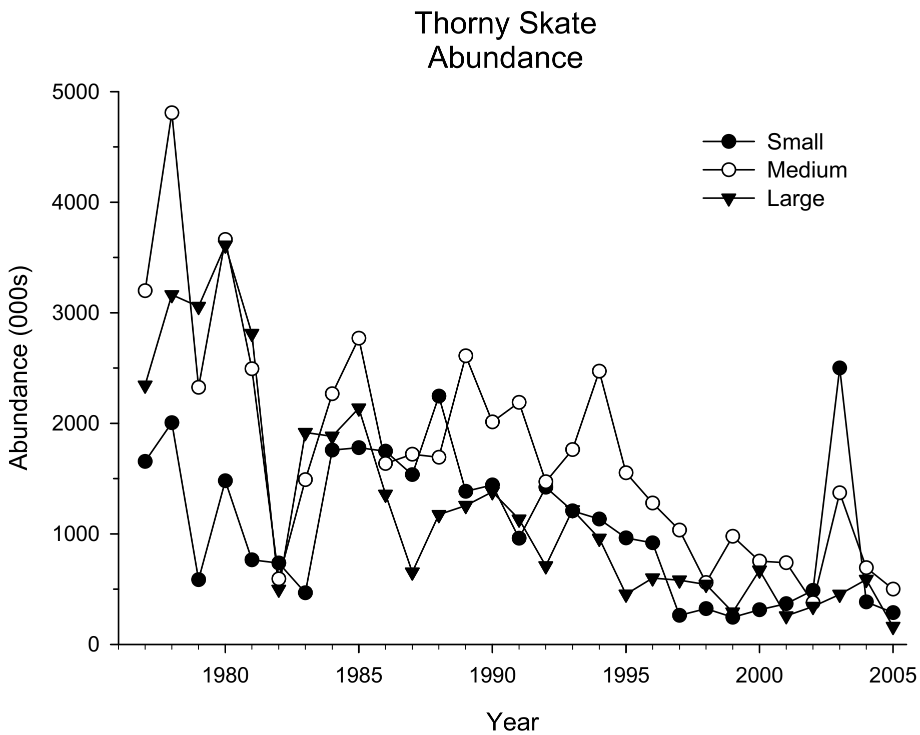


Figure B6.26a. The annual mean swept area abundance of Thorny skate for the strata set and time period noted. Each size class is noted.

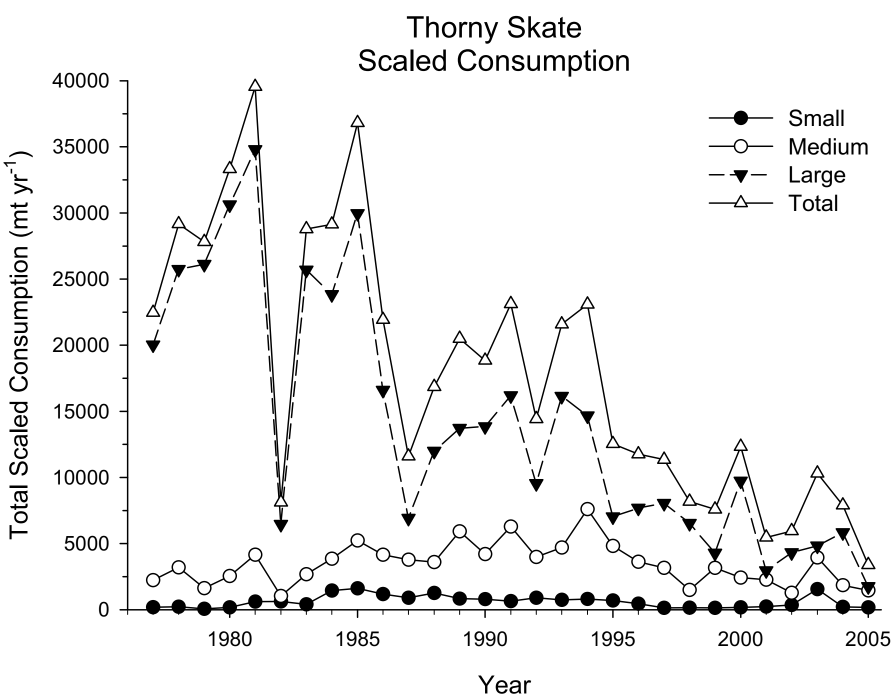


Figure B6.26b. The annual total consumption (MT yr^{-1}) of Thorny skate for the strata set and time period noted.

THORNY SKATE PREY REMOVAL

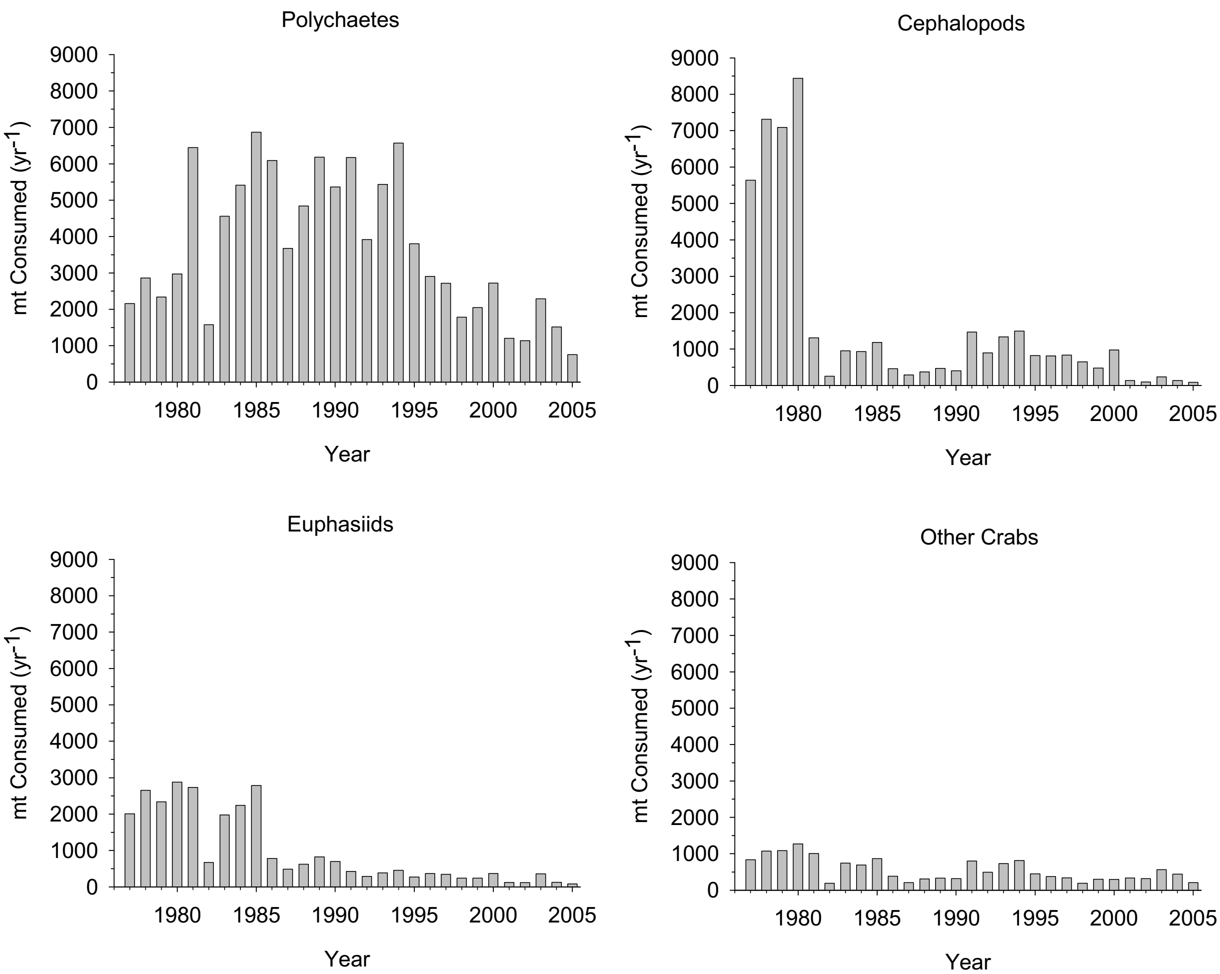


Figure B6.27. The amount of prey consumed (MT yr-1) by Thorny skate for the strata set and time period noted. These estimates represent the combination of total annual total consumption and the diet compositions of Thorny skate. These prey were selected as some of the major prey (>>5 % of diet composition) of Thorny skate.

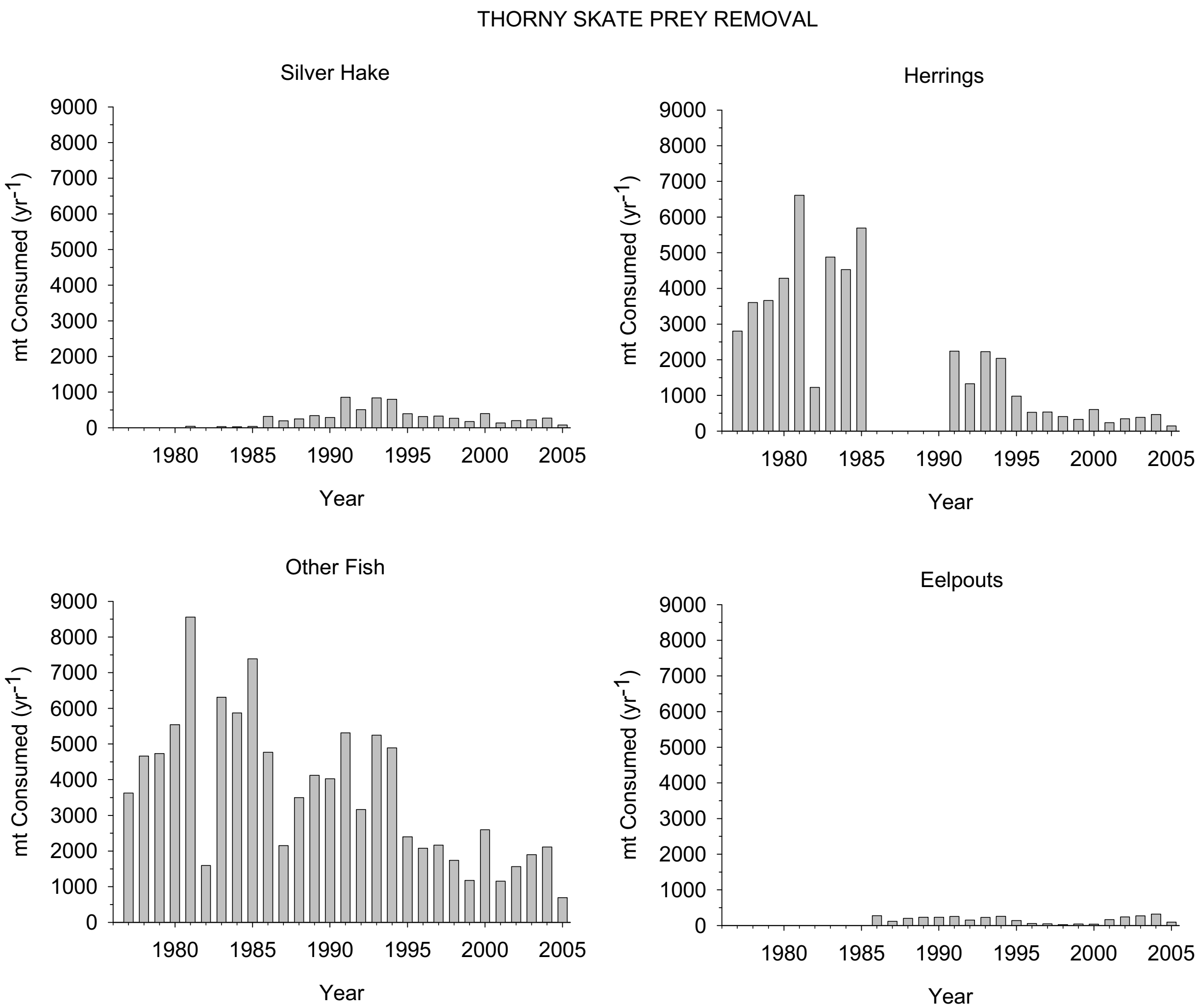


Figure B6.28. The amount of prey consumed (MT yr-1) by Thorny skate for the strata set and time period noted. These estimates represent the combination of total annual total consumption and the diet compositions of Thorny skate. These prey were selected as some of the major prey (>>5 % of diet composition) of Thorny skate.

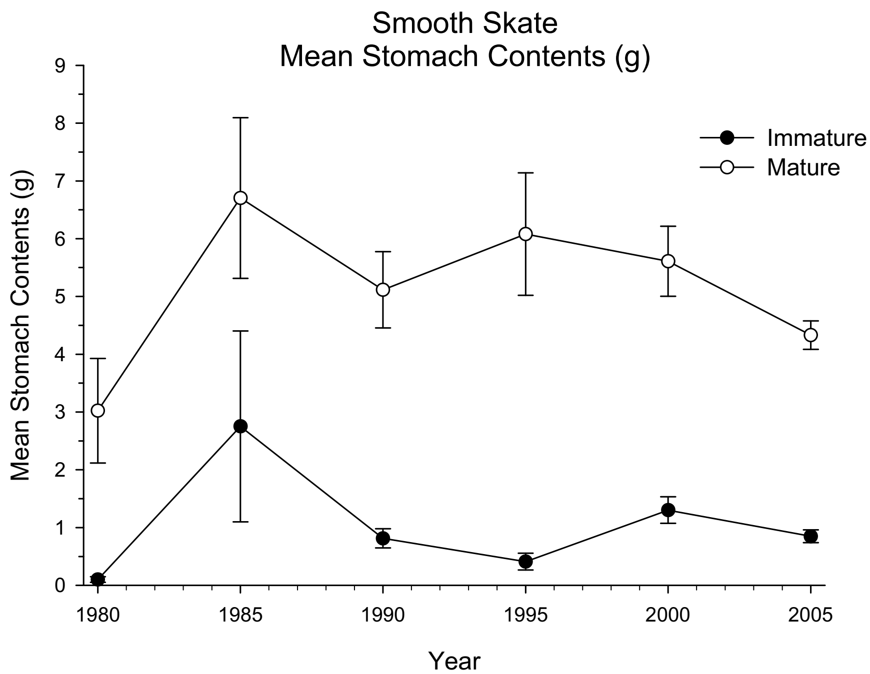


Figure B6.29a. The annual mean stomach contents (0.1 g) of Smooth skate for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

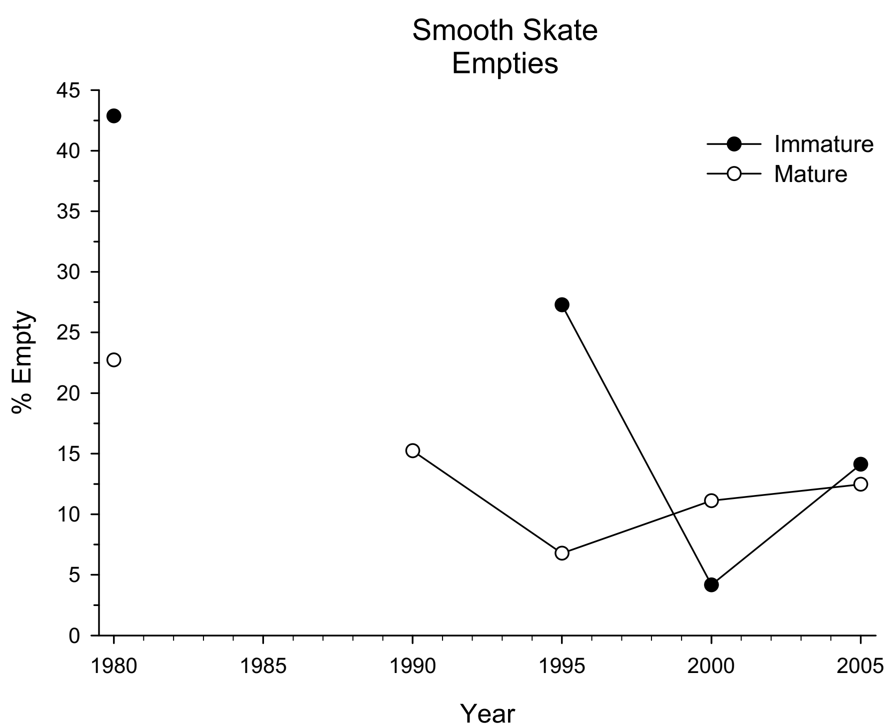


Figure B6.29b. The percentage of stomachs that were empty (i.e., containing no prey) of smooth skate for the strata set and time period noted. Each size class is noted

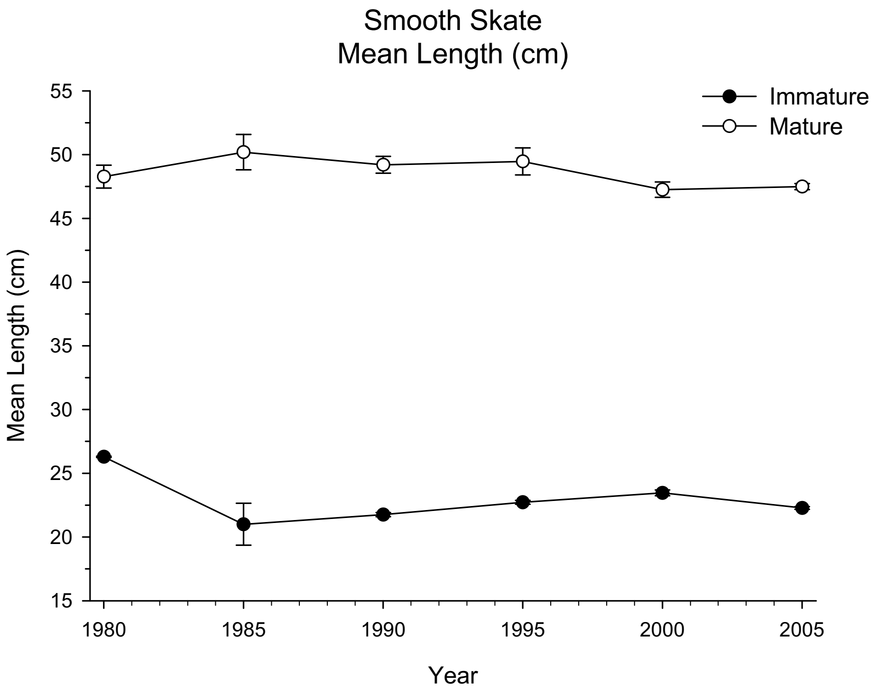


Figure B6.30a. The mean length (1 cm) of Smooth skate from which stomach samples were collected, for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

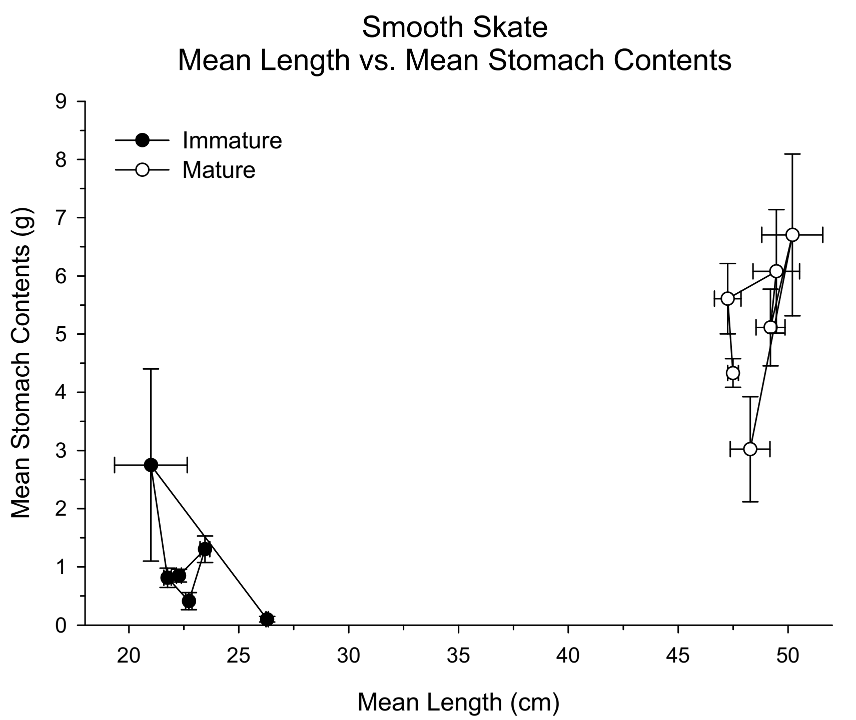


Figure B6.30b. The annual mean stomach contents (0.1 g) and the mean length (1 cm) of Smooth skate for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

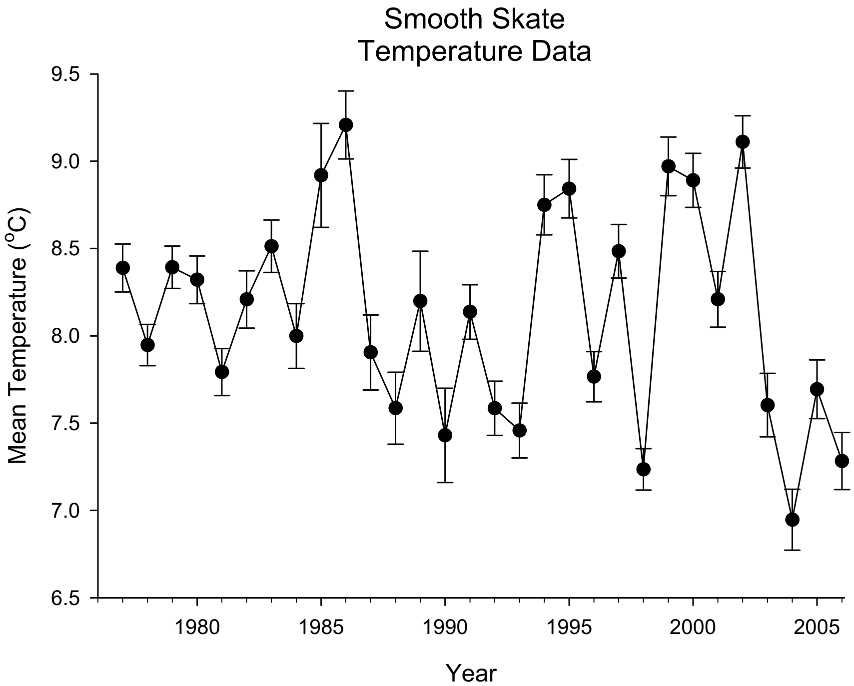


Figure B6.31a. The annual mean bottom temperature (0.1 ^{O}C) for the selected strata set, as taken from the bottom trawl survey over the time period noted. Error bars are ± 1 S.E.

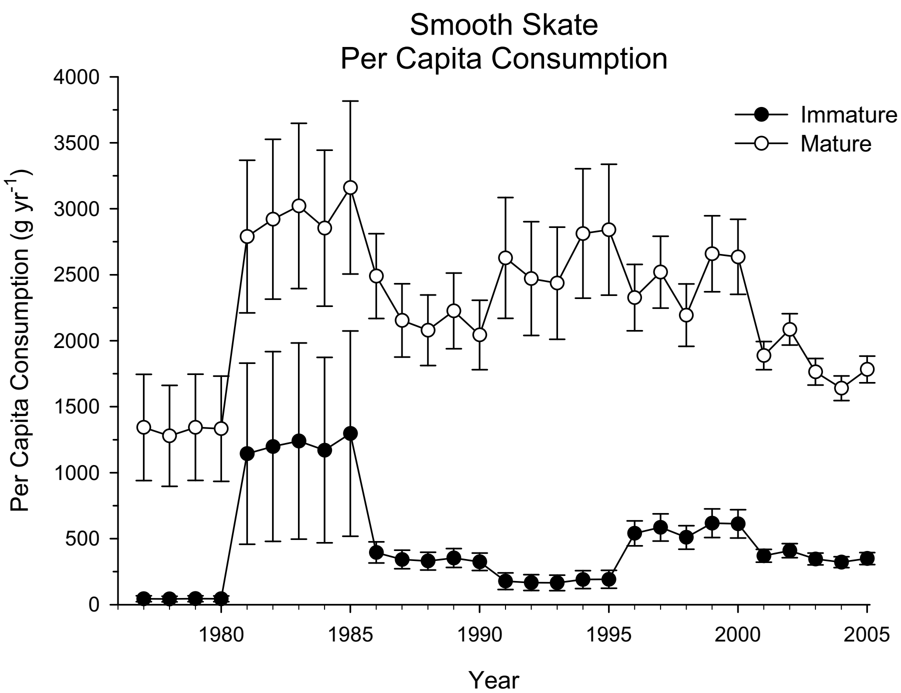


Figure B6.31b. The annual per capita consumption (g yr^{-1}) of Smooth skate for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

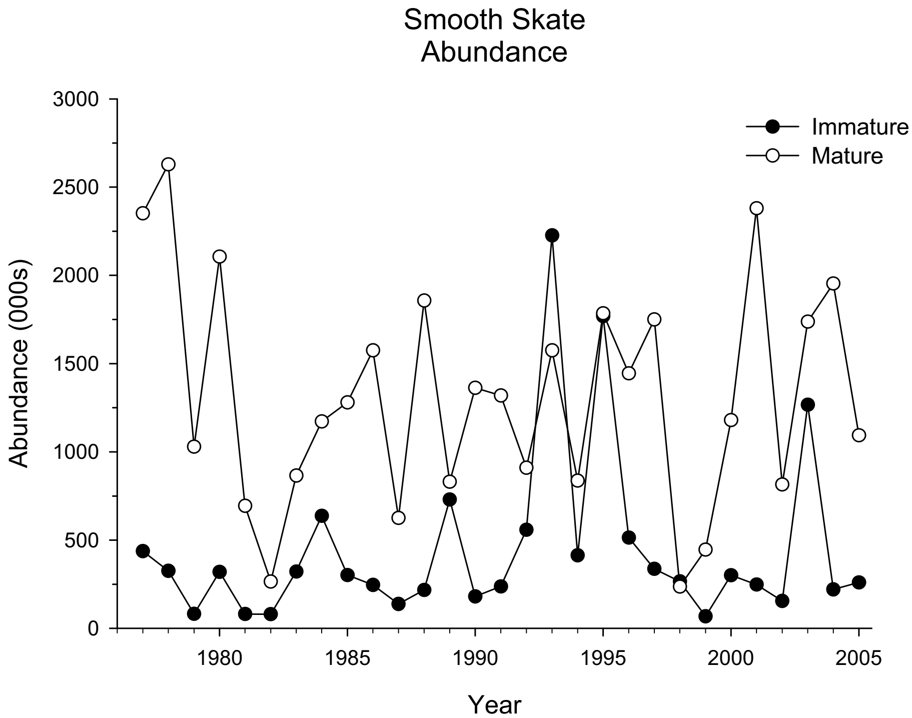


Figure B6.32a. The annual mean swept area abundance of Smooth skate for the strata set and time period noted. Each size class is noted.

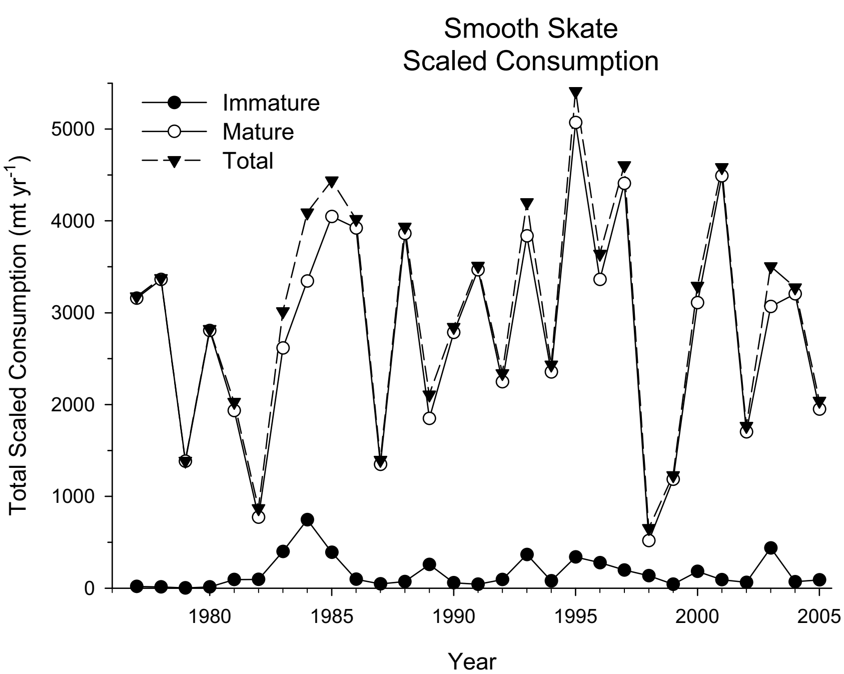


Figure B6.32b. The annual total consumption (MT yr^{-1}) of Smooth skate for the strata set and time period noted.

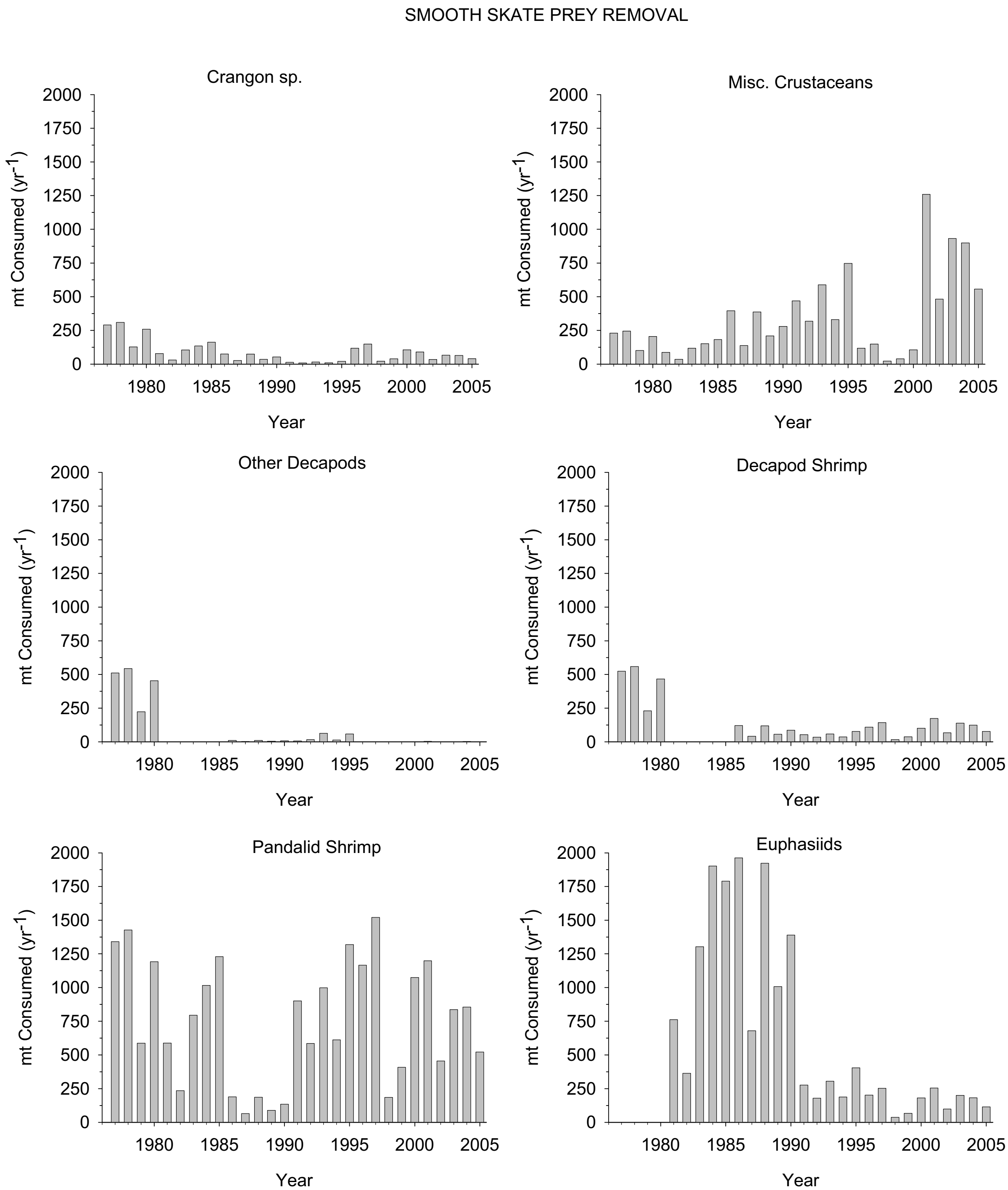


Figure B6.33. The amount of prey consumed (MT yr-1) by Smooth skate for the strata set and time period noted. These estimates represent the combination of total annual total consumption and the diet compositions of Smooth skate. These prey were selected as some of the major prey (>>5 % of diet com osition of Smooth skate.

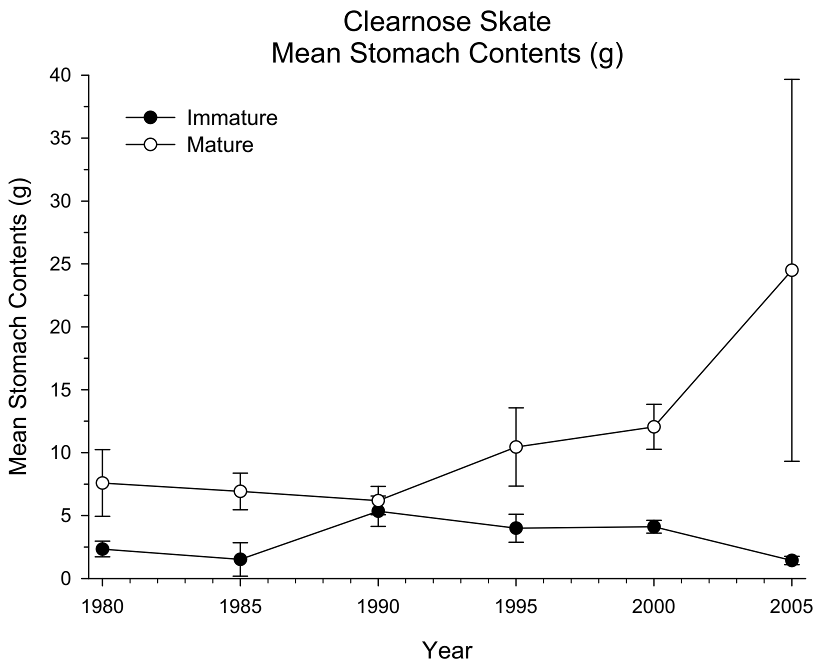


Figure B6.34a. The annual mean stomach contents (0.1 g) of Clearnose skate for the strata and time period noted. Each size class is noted. Error bars are ± 1 S.E.

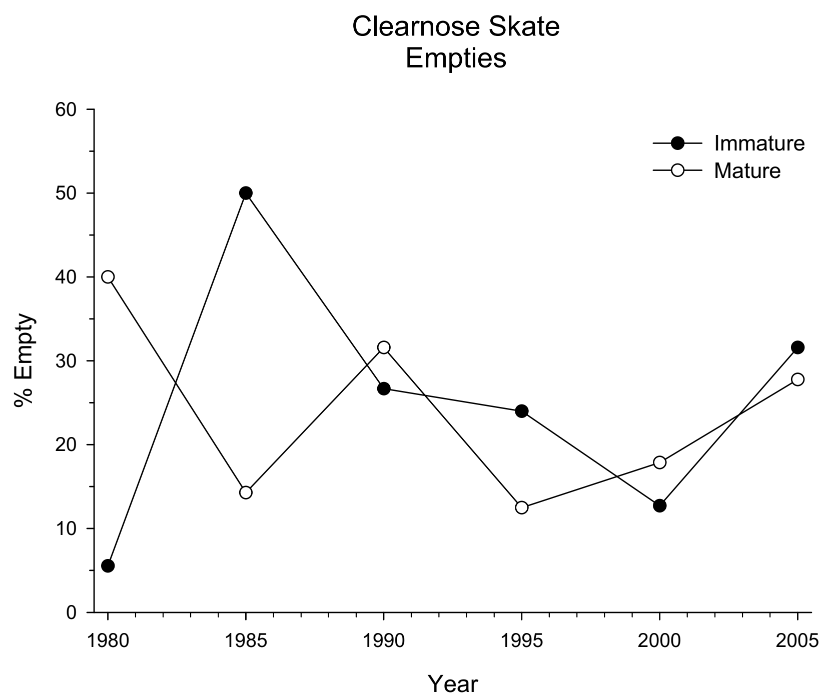


Figure B6.34b. The percentage of stomachs that were empty (i.e., containing no prey) of Clearnose skate for the strata set and time period noted. Each size class is noted

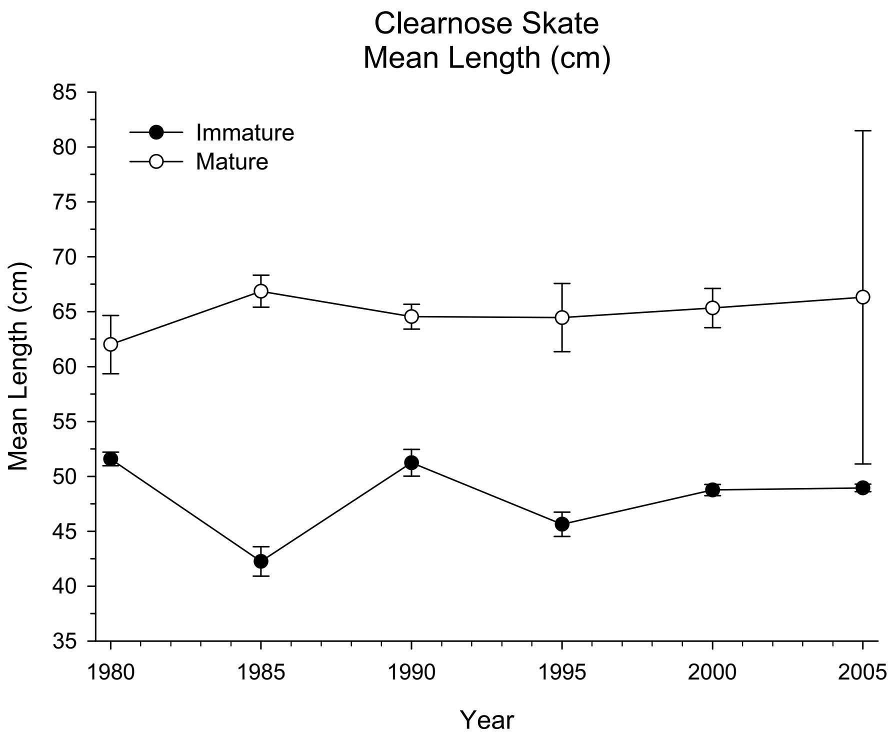


Figure B6.35a. The mean length (1 cm) of Clearnose skate from which stomach sample were collected, for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

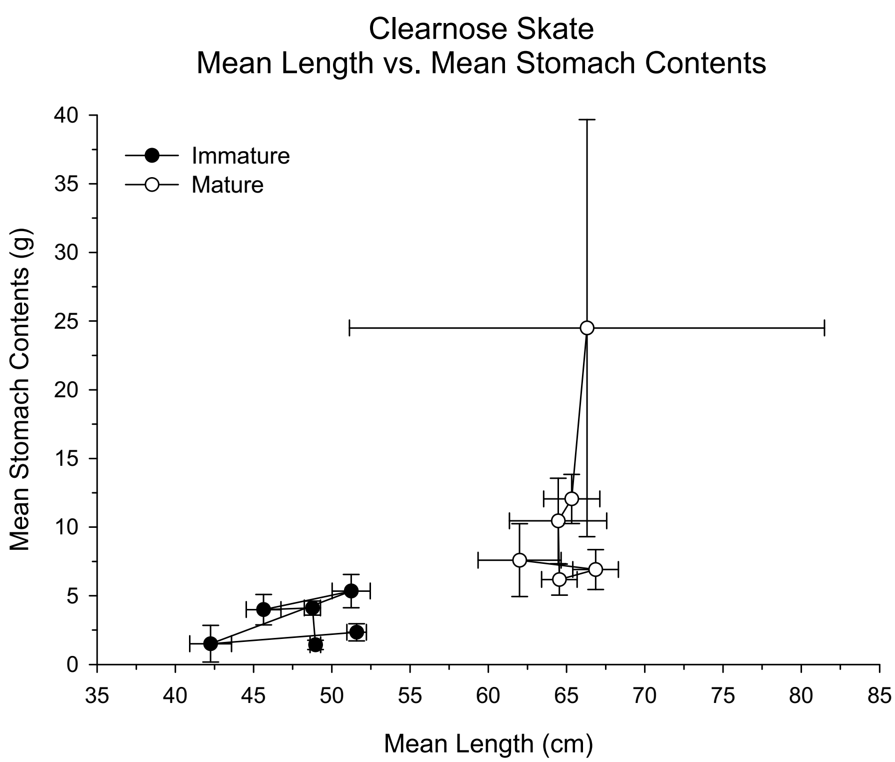


Figure B6.35b. The annual mean stomach contents (0.1 g) and the mean length (1 cm) of Clearnose skate for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

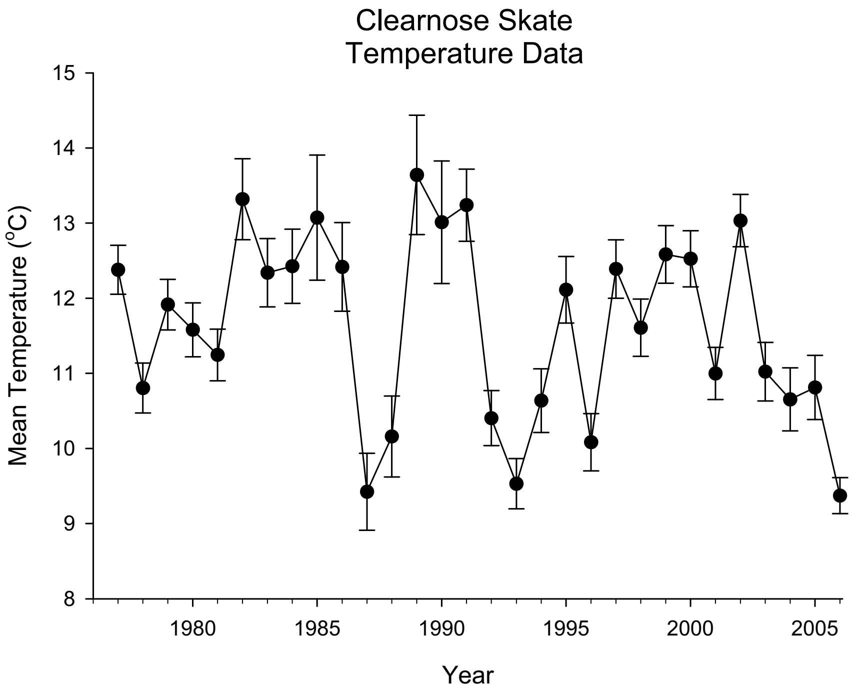


Figure B6.36a. The annual mean bottom temperature (0.1 ^{o}C) for the selected strata set as taken from the bottom trawl survey over the time period noted. Error bars are ± 1 S.E.

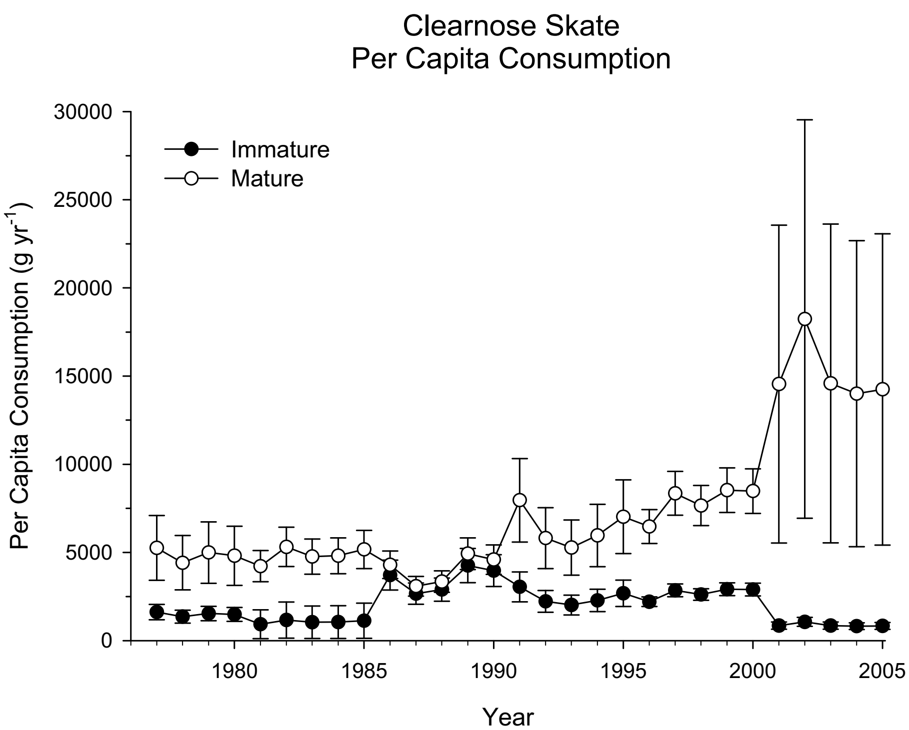


Figure B6.36b. The annual per capita consumption (g yr^{-1}) of Clearnose skate for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

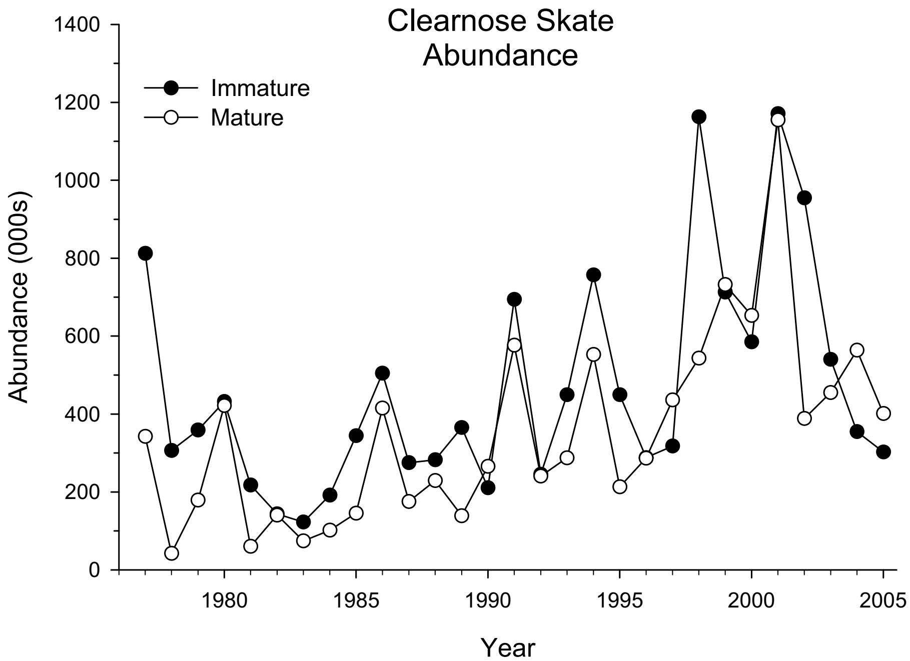


Figure B6.37a. The annual mean swept area abundance of Clearnose skate for the strata set and time period noted. Each size class is noted.

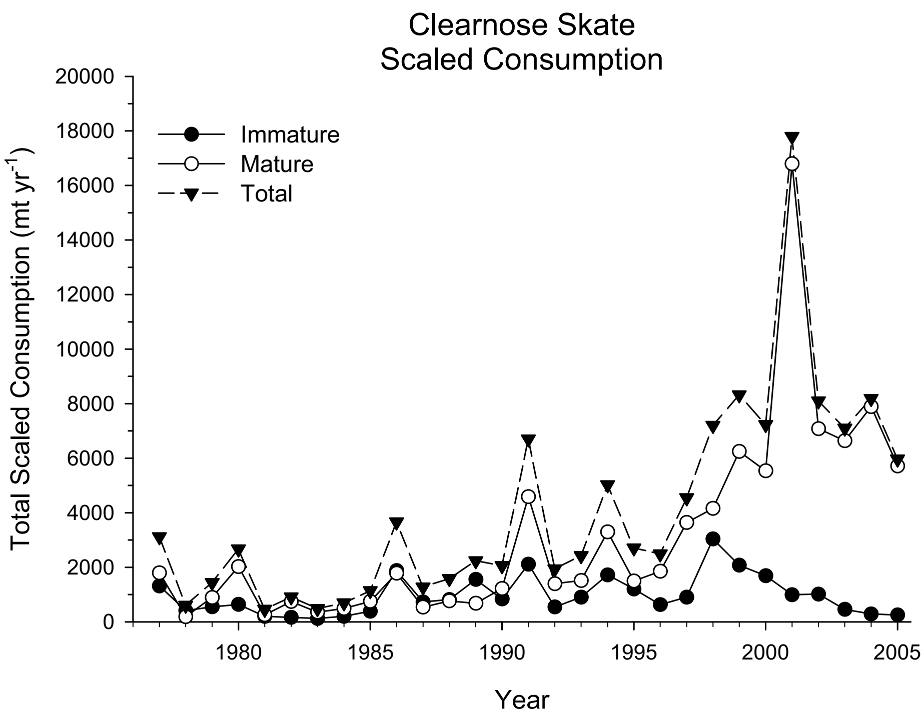


Figure B6.37b. The annual total consumption (MT yr^{-1}) of Clearnose skate for the stra set and time period noted.

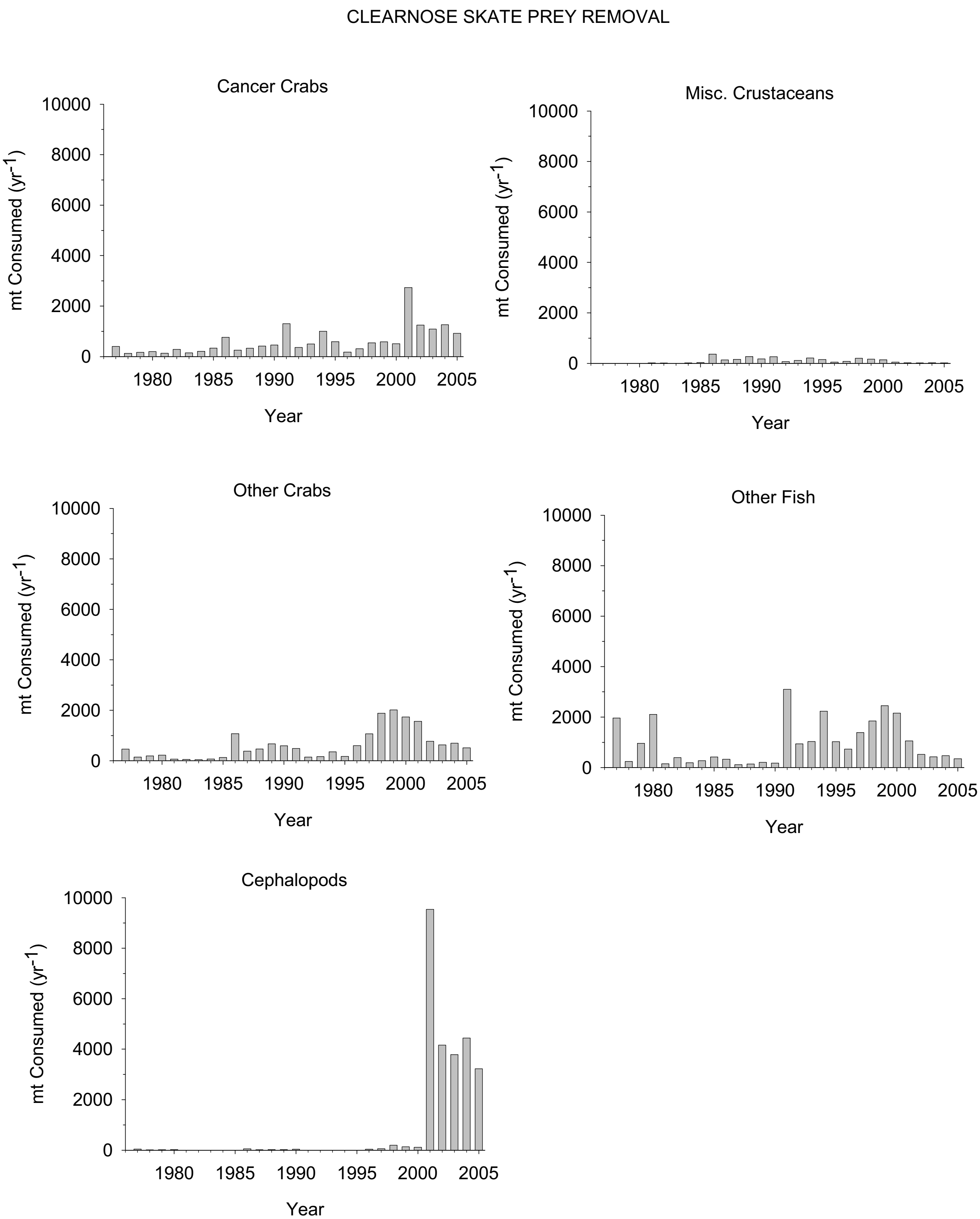


Figure B6.38. The amount of prey consumed (MT yr-1) by Clearnose skate for the strata set and time period noted. These estimates represent the combination of total annual total consumption and the diet compositions of Clearnose skate. These prey were selected as some of the major prey (>>5 % of diet composition) of Clearnose skate.

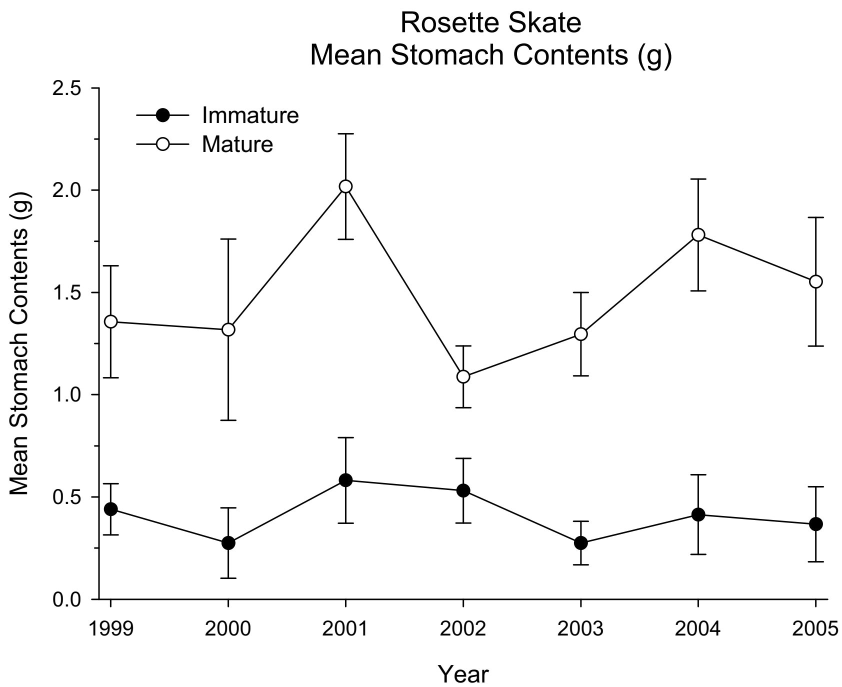


Figure B6.39a. The annual mean stomach contents (0.1 g) of Rosette skate for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

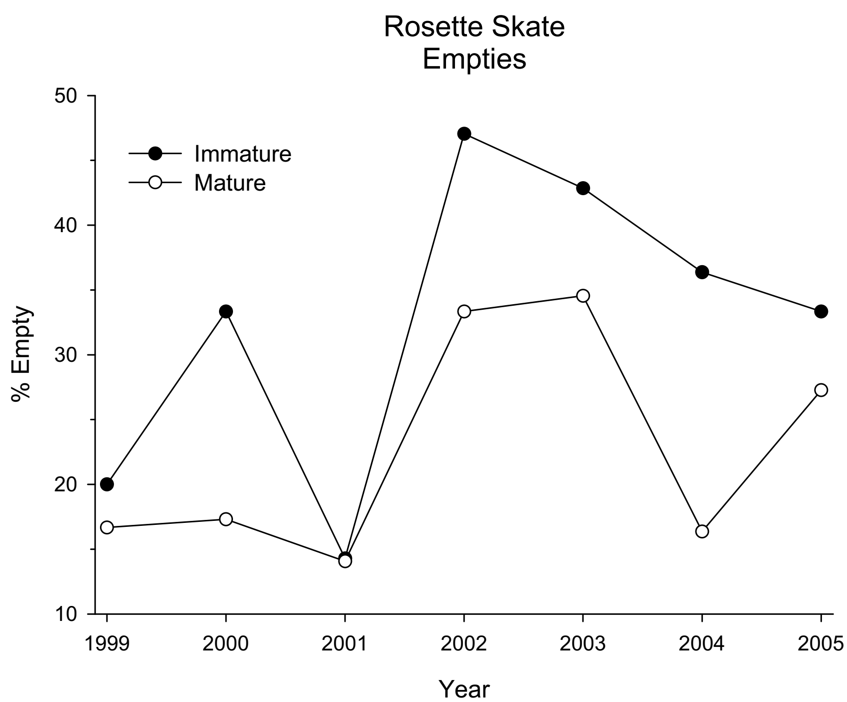


Figure B6.39b. The percentage of stomachs that were empty (i.e., containing no prey) of Rosette skate for the strata set and time period noted. Each size class is noted

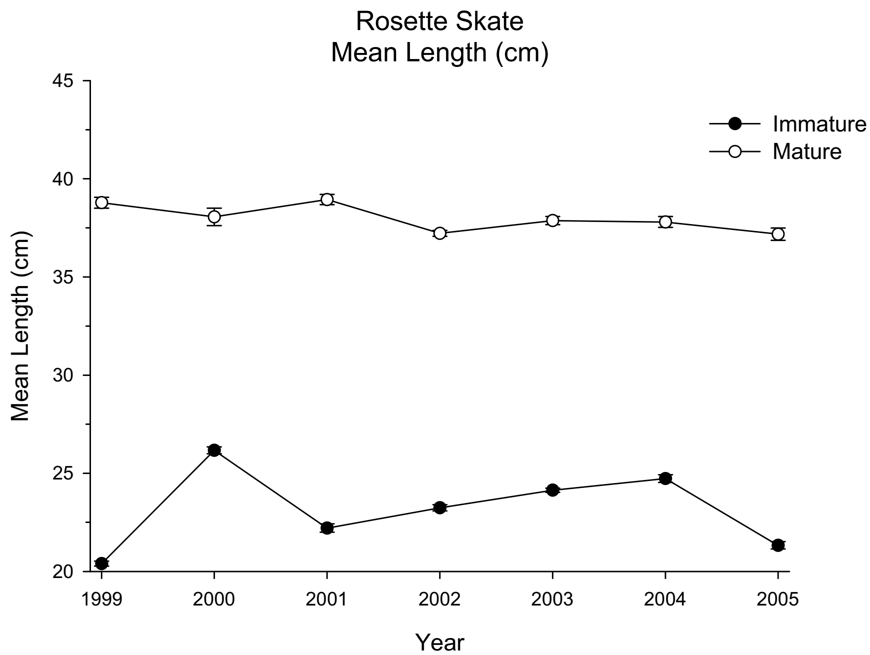


Figure B6.40a. The mean length (1 cm) of Rosette skate from which stomach samples were collected, for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

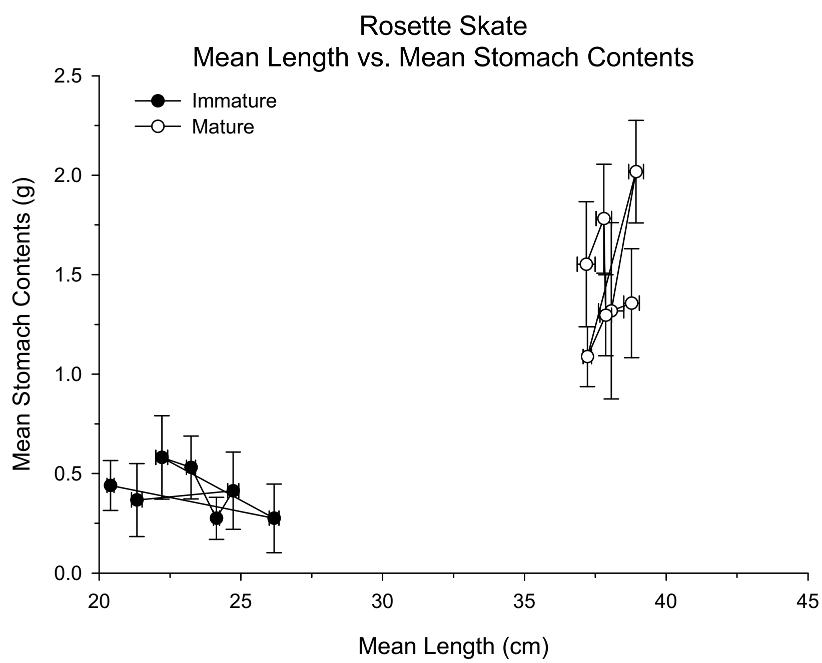


Figure B6.40b. The annual mean stomach contents (0.1 g) and the mean length (1 cm) of Rosette skate for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

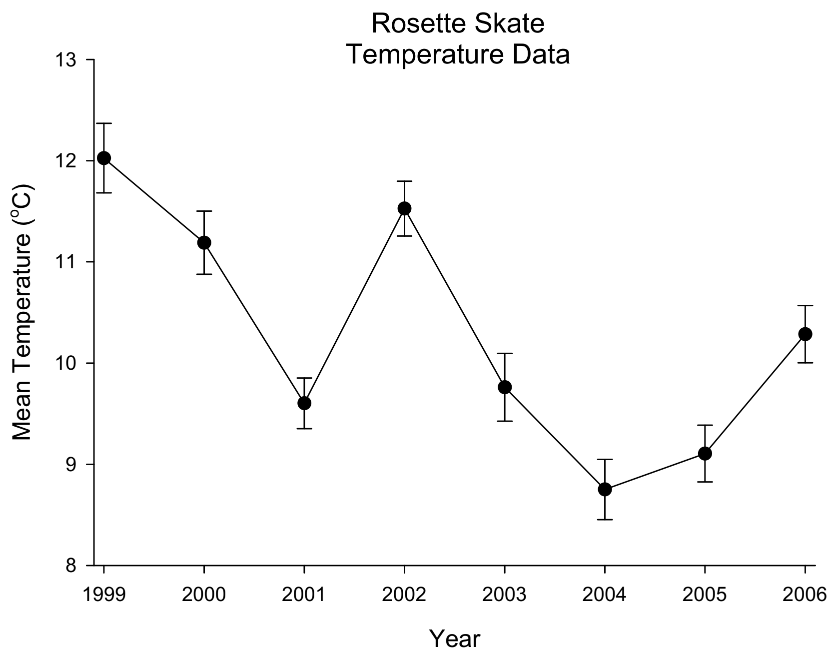


Figure B6.41a. The annual mean bottom temperature (0.1 ^{o}C) for the selected strata set, as taken from the bottom trawl survey over the time period noted. Error bars are ± 1 S.E.

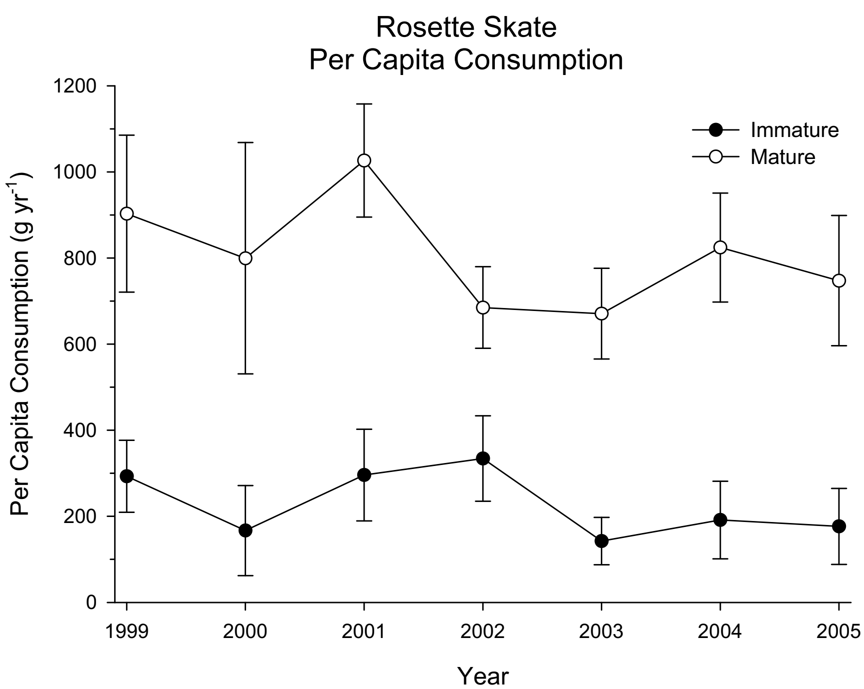


Figure B6.41b. The annual per capita consumption (g yr^{-1}) of Rosette skate for the strata set and time period noted. Each size class is noted. Error bars are ± 1 S.E.

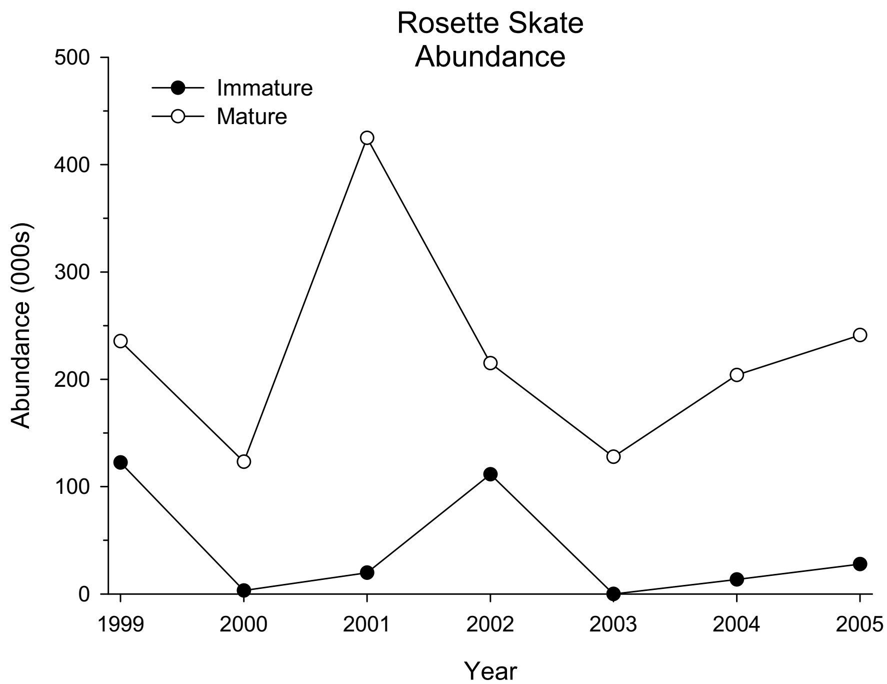


Figure B6.42a. The annual mean swept area abundance of Rosette skate for the strata set and time period noted. Each size class is noted.

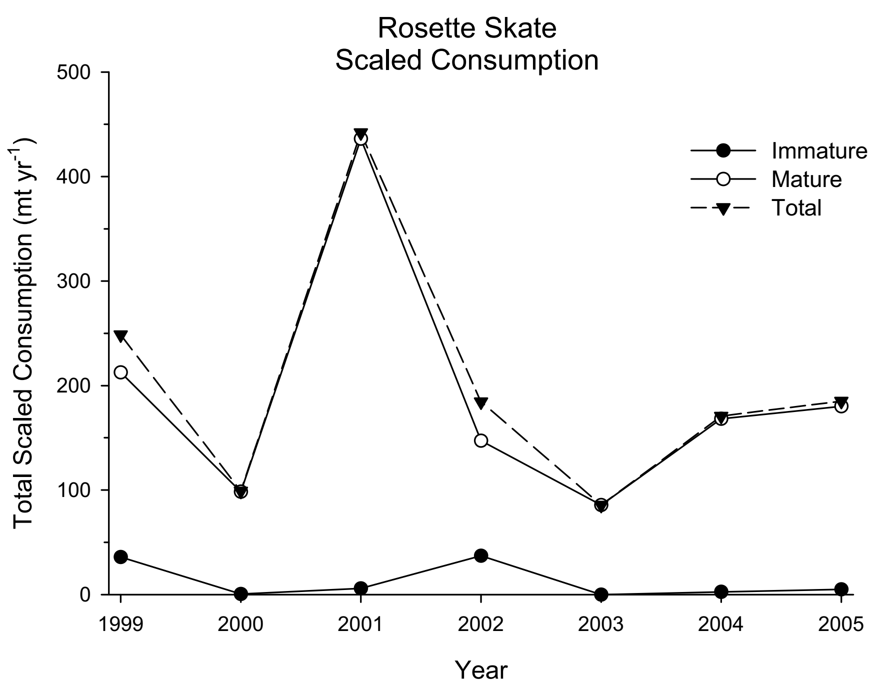


Figure B6.42b. The annual total consumption (MT yr^{-1}) of Rosette skate for the strata set and time period noted.

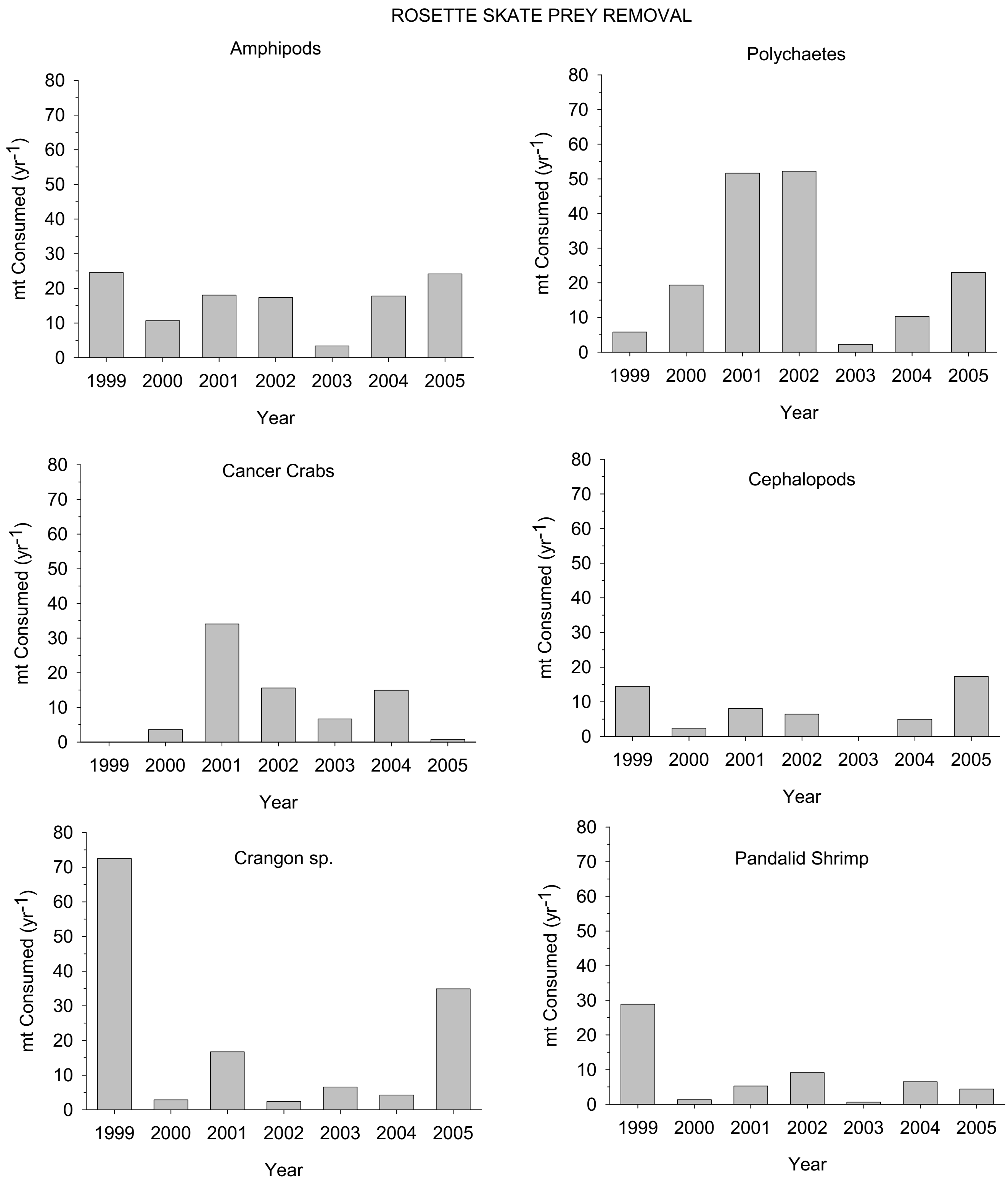


Figure B6.43. The amount of prey consumed (MT yr^{-1}) by Rosette skate for the strata set and time period noted. These estimates represent the combination of total annual total consumption and the diet compositions of Rosette skate. These prey were selected as some of the major prey (>>5 % of diet composition) of Rosette skate.

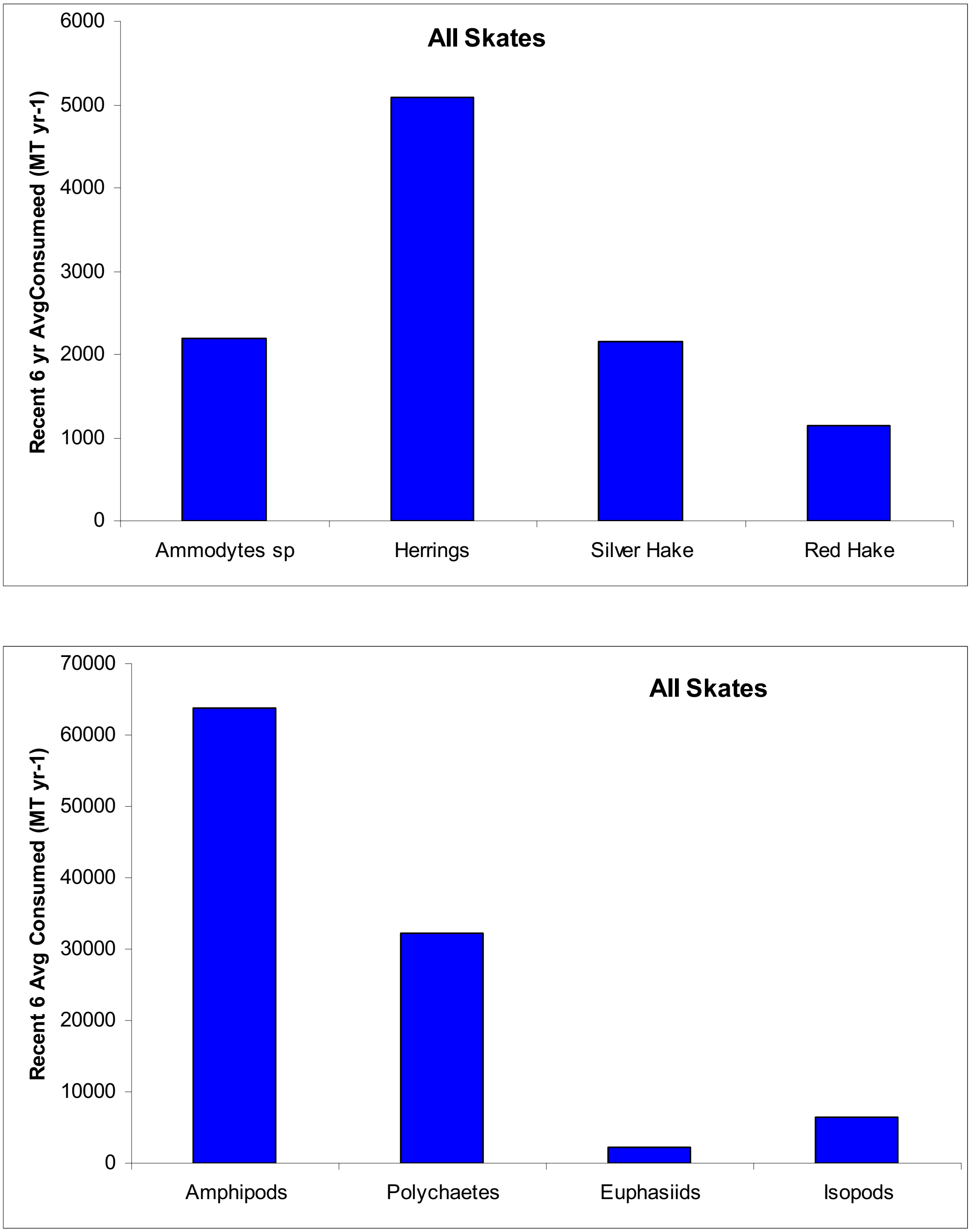


Figure B6.44. Average amount of major prey consumed by all skates from 2000-2005. A. fish prey. B. invertebrate prey.

C. ASSESSMENT OF ATLANTIC SURFCLAM

Report of the Invertebrate Subcommittee (see Appendix C1 for membership)

1.0 TERMS OF REFERENCE (TOR) AND SUMMARY

1. Characterize the commercial and recreational catch including landings and discards. *Completed, see Section C3.*

2. Estimate fishing mortality, spawning stock biomass, and total stock biomass for the current year and characterize the uncertainty of those estimates. If possible, also include estimates for earlier years. *Completed, see Section C5.*

3. Either update or redefine biological reference points (BRPs; proxies for B_{MSY} and F_{MSY}), as appropriate. Comment on the scientific adequacy of existing and redefined BRPs. *Completed, see section C6. Biomass reference points were updated based on new estimates of historical biomass levels and criteria in the Surfclam and Ocean Quahog Fisheries Management Plan. Fishing mortality reference points did not require updating. Current reference points were adequate for this assessment because stock biomass is relatively high and fishing mortality rates are low. However, it was noted that implicit assumptions about* B_{MSY} *and biomass during 1999 may not be valid and should be reevaluated.*

4. Evaluate current stock status with respect to the existing BRPs, as well as with respect to updated or redefined BRPs (from TOR 3). *Completed, see section C7. The stock is not overfished and overfishing is not occurring.*

5. Recommend what modeling approaches and data should be used for conducting single and multi-year stock projections, and for computing TACs or TALs. *Completed, see Section C8. A consistent set of stock assessment modeling, integrated bootstrap and stochastic projection software is now available that can deal with auto correlated recruitment patterns in surfclam. It is not necessary to describe approaches for setting TAC or TAL levels because the fishery is managed with constant quota levels.*

6. If possible:

    a. Provide numerical examples of short term projections (2-3 years) of biomass and fishing mortality rate, and characterize their uncertainty, under various TAC/F strategies. *Completed, see Section C9. Example projections under a wide range of scenarios indicate that surfclam biomass will decline over the next 2-3 years to levels near the* B_{MSY} *proxy level that used is used by managers as a target. The recent and expected declines are due to poor recruitment and slow growth. There is no indication that the stock will become overfished or that overfishing will occur. Uncertainty is very high, particularly for longer term projections.*

b. Compare projected stock status to existing rebuilding or recovery schedules, as appropriate. *Not relevant. surfclam are not overfished and no rebuilding schedule exists.*

7. Review, evaluate and report on the status of the SARC/Working Group Research Recommendations offered in recent SARC reviewed assessments. *Completed, see Section C10.*

<u>Plain terms summary</u>

1) The following abbreviations are used to identify stock assessment and fishing regions for surfclam (Figure C1).

Region (south to north)	Abbreviation
Southern Virginia	SVA
Delmarva	DMV
New Jersey	NJ
Long Island	LI
Southern New England	SNE
Georges Bank	GBK

2) Overall, total surfclam biomass has declined during recent years due to slow growth and poor recruitment, particularly in southern regions. Despite declines, total stock biomass is still at a relatively high level. Fishing mortality is low in all regions.

3) Stock conditions are relatively good in northern regions such as LI, SNE and GBK where the bulk of the stock was found during 2005 and little fishing occurs. Stock conditions are poorer in southern regions, DMV and SVA in particular, where fishing has occurred since the 1980's and a relatively small fraction of the stock was found during 2005. Conditions in NJ, where most of the fishing and a large fraction of the stock occur, are intermediate.

4) The surfclam stock is not overfished and overfishing is not occurring. Overfishing and overfished stock conditions are not likely to occur in the near future.

5) Total landings from the EEZ stock during 2005 were less than the quota due, based on industry sources, to market factors.

6) The majority of landings during recent years were from the NJ region although some landings were also taken from DMV in the south. Landings in the northern SNE and LI regions increased during recent years were minor. No fishing occurs on GBK due to risk of paralytic shellfish poisoning (PSP).

7) Over time, surfclam biomass has shifted towards the north. During 2005, the largest fraction of stock biomass was in GBK, rather than in NJ or DMV.

8) Fishing effort and catch have shifted north during recent years as catch rates in the south have declined.

9) Total fishing effort increased during recent years while landings per unit effort (LPUE) decreased for the fishery as a whole.

10) LPUE has declined in NJ and drastically in DMV. LPUE in the LI region appears to be increasing.

11) Growth rates for surfclam in NJ, and particularly in DMV, have slowed in recent years so that the age at recruitment to the fishery has increased by 1-2 years. Delayed recruitment and slower growth after reaching fishable size reduce potential fishery yield by a substantial amount. Slower growth is due to environmental factors.

12) Recruitment has declined during recent years for the stock as a whole and is at or near record low levels in most regions.

13) Stock biomass for the entire stock was at record high levels during the late 1990s. Since then stock biomass has declined. In 2005, total stock biomass was about the same as before the peak.

14) Biomass trends for NJ were similar to trends for the entire stock. Biomass trends for DMV indicate steeper and continuous declines since the record high levels for DMV during the early 1980s.

15) Recent declines in biomass are due to negative surplus production. This means that factors that increase stock biomass including growth and recruitment have not been large enough to offset natural (not related to fishing) losses.

16) Fishing mortality rates are low in all regions. The environment, rather than fishing, apparently caused the recent declines in biomass.

2.0 INTRODUCTION

This stock assessment for the offshore subspecies of Atlantic surfclam (*Spisula solidissima solidissima*) was prepared for SAW/SARC-44 along with a stock assessment for ocean quahog (*Arctica islandica*). No information is provided about the smaller coastal form (*S. s. similis*) that occupies relatively southern inshore habitats (Hare and Weinberg 2005). The geographic distributions of the two subspecies overlap to a limited extent in the south and in some inshore waters to the north. However, *S. s. similis* is reproductively isolated from *S. s. solidissima* and not important to the commercial fishery.

The same methods were used in the assessments for surfclam and ocean quahog although the surfclam assessment was completed after the ocean quahog assessment and incorporates a number of improvements. Interested persons and reviewers should read the ocean quahog assessment (i.e., Assessment A in this volume) first because the methods used for both species are described there in detail. Improvements to methods for surfclam and other details relevant only to surfclam are described below.

Distribution and biology

Atlantic surfclam is a relatively large fast growing bivalve distributed in the western North Atlantic Ocean, along the coast of North American from the southern Gulf of St. Lawrence to Cape Hatteras (Figure C1). Individuals larger than 16 cm shell length (SL) are relatively common in NEFSC surveys. Commercial concentrations are found primarily off New Jersey, the Delmarva Peninsula, and on Georges Bank. Surfclam are found from the intertidal zone to a depth of about 60 m but densities are low at depths greater than 40 m. See Cargnelli et al. (1999) for a complete review of life history and distributional information. The distribution of Atlantic surfclam and the distribution of a related species (*S. similis*) overlap in the south and some inshore waters to the north (Hare and Weinberg 2005).

It is likely that all Atlantic surfclam along the northeast coast belong to the same biological population. Surfclam are common in both inshore state (≤ 3 mi from shore) and offshore federal waters. Federal waters consist of the Exclusive Economic Zone (EEZ), between 3 and 200 mi from shore. The stock assessment applies only to the EEZ segment of the surfclam population in federal waters, however, because the EEZ is the management unit specified in the Fishery Management Plan for the Atlantic Surfclam and Ocean Quahog Fisheries (FMP). Surfclam in New Jersey and New York state waters support valuable fisheries that are managed by state authorities.

Surfclam in the EEZ are managed as a unit stock but there is substantial regional variability in exploitation rates and biological characteristics. A variety of calculations and estimates in this assessment are presented for smaller stock assessment regions which are defined below (Figure C1). Previous assessments separated the New Jersey (NJ) region into Northern New Jersey (NNJ) and Southern New Jersey (SNJ) components. In this assessment, the NJ region is treated as a single entity. SNJ and NNJ were combined to simplify the assessment and because data for SNJ were too limited and variable to be analyzed separately.

There is uncertainty about the timing of annual mark (annulus) formation in surfclam chondrophores, which are cut from shells and used to age surfclams taken in NEFSC clam surveys. There is additional uncertainty about indentifying the first annual mark (Jacobson et al. 2006). Despite these questions of interpretation, surfclam annual rings are relatively easy to count. In this assessment, the number of annual marks and age are assumed to be the same and the assumed birth date is January 1 so that, for example, a member of the 2004 year class taken during the 2005 NEFSC clam survey would be age 1 at the time of capture and expected to show one ring. Ages for surfclams taken in the commercial fishery that operates year round are more uncertain. Surfclams age 20+ are relatively common and the maximum observed age exceeds 35. See Jacobson et al. (2006) for information about procedures used to estimate surfclam age.

Surfclams are capable of reproduction at age 1, although full maturity may not be reached until age 2. Spawning occurs during late summer and early fall. Eggs and sperm are shed directly into the water column. Recruitment to the bottom occurs after a planktonic larval period of about three weeks.

Weinberg (1998) and Weinberg and Helser (1996) show that growth rates vary among regions, over time and in response to surfclam density levels. Based on NEFSC clam survey data (Figure C2), growth rates appear to have declined for surfclams in the southern DMV region and to a lesser extent in the NJ region since 1993. Slower growth in surfclams in DMV during recent years coincides with mortality in near shore areas off DMV probably due to warm water (Weinberg 2005) and lower occurrence of surfclams with 25+ annual marks in survey data (Figure C2).

Length-weight parameters used in this assessment to convert numbers of surfclams of different shell lengths in surveys to meat weight equivalents are region specific and based on fresh (unfrozen) material (Table C1). Length-weight parameters vary among locations and over time. Although length-weight data are collected periodically during NEFSC clam surveys, recent assessments used the same length-weight relationship for the sake of simplicity and consistency (NEFSC 2003). A simple and consistent approach is used because length-weight data are not available for the commercial catch (which targets clams with high meat yield) and because length-weight information for early surveys was based on frozen material.

Management

The fishery for Atlantic surfclams and ocean quahogs in the EEZ are unique in being the first US fishery managed under an individual transferable quota (ITQ) system. ITQ management was established during 1990 by the Mid-Atlantic Fishery Management Council under Amendment 8 to the Fishery Management Plan for the Atlantic Surfclam and Ocean Quahog Fisheries (FMP). Management measures include an annual quota for EEZ waters, which was 26.2 thousand mt meats per year during 2001-2005, and mandatory logbooks that describe each fishing trip. See Murawski and Serchuk (1989) and Serchuk and Murawski (1997) for detailed information about history, management and fishery operations. MAFMC (2006) describes recent fishery conditions and management for both surfclams and ocean quahogs.

Previous assessments

Stock assessments are generally done after NMFS clam surveys, which are conducted every 2-3 years. In the most recent stock assessment for surfclam, NEFSC (2003) concluded that the stock was above the management target level (the stock was not overfished) and that fishing mortality was below the management threshold value (overfishing was not occurring). The stock was characterized as declining from a relatively high biomass level at the rate of about 5% per year due to negative surplus production and, in particular, relatively low recruitment. Conclusions from this stock assessment are similar. See NEFSC (1993; 1995; 1998; 2000) for earlier surfclam stock assessments.

Beginning with NEFSC (1998), the primary emphasis in surfclam stock assessments was: 1) use of sensors to evaluate survey dredge performance; 2) estimating survey dredge efficiency via cooperative “depletion studies”; and 3) calculation of efficiency corrected swept-area biomass. Previous stock assessments used stock assessment models with variable results. In this assessment, data from all available depletion studies are analyzed using consistent and improved methods. The updated information is used in a stock assessment model that is successfully applied to the stock as a whole and to the important DMV and NJ regions.

3.0 COMMERCIAL CATCH (TOR-1)

In using landings data for surfclams, 1 industry standard bushel (1.88 ft^3) was assumed to produce 17 lbs or 7.711 kg of useable meats. Fishery landings in this assessment are reported as meat weights for ease in comparison to survey data and in calculations but were originally recorded in units of cages (1 cage = 32 industry bu). LPUE data, however, are reported in this assessment as landings in bushels per hour fished.

As in previous assessments (NEFSC 2003), catch in all stock assessment analyses is the sum of landings plus a 12% upper bound for incidental mortality that may occur during fishing operations (i.e. assumed catch = 1.12 times landings). It is important to realize that the 12% figure is an upper bound and that actual incidental mortality is likely to be lower. Incidental mortality in the surfclam and ocean quahog fisheries is likely lower than might be expected because the total area fished is modest. The total area fished is relatively low because fishermen operate efficiently under ITQ management and target only areas of highest density. Moreover, the ITQ fishery operates with little or no regulation induced inefficiency (e.g. inefficiency due to area closures, trip limits, size limits, etc.). Discard of small surfclams occurred during 1982-1990 when size limits were used to regulate the surfclam fishery (Table C2) but are currently near zero. Recreational catch is near zero.

Size selectivity of commercial clam dredges and harvesting equipment has not been characterized quantitatively in detail. Based on commercial length data and experimental results, NEFSC (2003) assumed that surfclams in NJ were fully available to the commercial fishery at 120 mm SL and that surfclams in other regions were fully available to the commercial fishery at 110 SL.

In this assessment, surfclams 120+ mm SL are assumed to be the fishable stock in all regions. In contrast, that NEFSC (2003) used 120+ mm for NJ and 110+ mm SL for other regions. Fishing mortality estimates in this assessment, for example, compare total catch (landings plus an assumed 12% upper bound for incidental mortality) to the fishable stock 120+ SL. The bulk of the fishery and much of the stock occurs in NJ, where NEFSC (2003) assumed recruitment at 120 mm SL. Based on commercial length data in NEFSC (2003) and shown below, there is no strong evidence that size at recruitment differs among regions. Consistent use of 120 mm SL simplifies the assessment and makes biomass and fishing mortality estimates for combined regions easier to interpret.

Age at recruitment

Age at recruitment to the surfclam fishery depends on growth rates and, in particular, the ages at which surfclams reach 120 mm SL. Growth curves used in stock assessment modeling (described later) fit to survey age data indicate that surfclam recruited to the DMV fishery at about age 5 ½ y during 1982-1992 and at about age 7 ½ y during 1994-2005. Growth curves for NJ show that surfclams reached 120 mm SL and recruited to the fishery at about age 5 y during 1982-1992 and at about age 6 y during 1994-2005. Changes in age at recruitment should have substantial effect on potential fishery yield. Assuming a natural mortality rate of M=0.15 y^{-1}, for example, numbers of recruits to the fishery per surviving larvae would be decreased by about 26% due to natural mortality during the two additional years prior to recruitment. This effect is likely compounded by other reductions in productivity due to slower growth after recruitment to the fishery occurs.

Landings, fishing effort and prices

Landings and fishing effort data for 1982-2005 were from mandatory logbooks. Data for earlier years were from NEFSC (2003) and MAFMC (2006).

Landings data for surfclams are relatively accurate in comparison to other fisheries because of a comprehensive system for tracking landings in the ITQ fishery. Effort data are, however not reliable for 1985-1990, due to regulations that restricted the duration of fishing to 6 hr. Effort data are relatively reliable during later years.

Surfclam landings were primarily from the US EEZ during 1965-2002 (Table C3 and Figure C3). EEZ landings peaked during 1973-1974 at about 33 thousand mt. EEZ landings were relatively high during 2001-2005 and varied between 21 and 25 thousand mt. Landings reached the quota in most years but were less than the quota during 2005 because of limited markets (according to industry sources).

The bulk of EEZ landings were from DMV during 1979-1980 and from NJ during every year since 1981 (Table C4 and Figure C4). During 2001-2005 DMV landings were modest with relatively small amounts reported from the LI and SNE regions. Trends in fishing effort were similar (Table C5 and Figure C5).

Nominal exvessel prices for the inshore and EEZ fisheries increased from about \$8 bu^{-1} during 1982 to \$10 bu^{-1} during 1994 and then declined to about \$9.50 bu^{-1} during 2000-2005 (Figure C6). Using 1980-1982 as a basis, prices declined in real terms from about \$9 bu^{-1} during 1982 to about \$5 bu^{-1} during 2005. Based on industry sources (D. Wallace, pers. comm.), the "break-even" price for surfclams during 2005 (i.e. price necessary to cover variable costs such as fuel, crew shares, food, etc.) was about \$4-\$5 bu^{-1} (nominal, 2005 dollars).

Landings per unit effort

Nominal landings per unit effort (LPUE) based on logbooks was computed as total landings divided by total fishing effort for all vessels and all trips (Table C6 and Figure C7). In addition, standardized LPUE indices (Table C7 and Figure C7) were computed from a log-linear GLM model with year, month and vessel effects for each region (see Assessment A. Ocean quahog, in this Report). GLM models were fit to tow by tow logbook data for vessels in size class 3 and 4 (51-150 and 151-500 GRT) which are the bulk of the EEZ fishery. There were no records with zero catch and it was not necessary to add a constant before applying the log transformation to the data. Year effects were used as the index of LPUE after they were adjusted to the average of June catch rates for a single vessel that fished in all regions.

For surfclams, year, vessel and month effects were statistically significant for all regions. Although month effects were statistically significant, they were small, of little practical importance and because they did not show meaningful seasonal trends.

Trends in nominal and standardized LPUE were similar (Figure C7). In particular, LPUE declined steadily from peak levels during 1994 to relatively low levels during 2005 in the DMV region. LPUE declined slowly but steadily in the NJ region during 1991-1995 and in LI after 2000. LPUE levels during 2005 were at or near record lows. In contrast to other regions, LPUE levels in SNE increased rapidly after 1998 as the small fishery in SNE developed.

LPUE is not an ideal measure of fishable biomass trends for sessile and patchy stocks like surfclam because fishermen target high density beds and change their operations to maintain relatively high catch rates as stock biomass declines (Hilborn and Walters 1992). However, trends in LPUE and fishable biomass based on the NEFSC clam survey were similar during recent years for DMV and NJ where fishing has been heaviest and fishing grounds are widespread (Figure C29). In contrast, LPUE and survey trends were not similar for LI and SNE where less fishing has occurred and the fishery is not as widespread. The correlation in trends for DMV and NJ was likely due to reduced surfclam densities in many habitat areas where significant densities occurred. Previous assessments noted that the fishery in DMV and NJ and surfclam stock overlap relatively completely.

Spatial patterns in fishery data

Average landings, fishing effort and LPUE per year from logbooks were calculated for ten-minute squares (TNMS) during 1981-1990, 1991-1995, 1996-2000, and 2001-2005. For plots, data for TNMS with very low levels of landings and data for TNMS outside the range of the fishery (obvious errors) were omitted.

Spatial patterns in fishery data (Figure C8 to C9) show relatively high landings and fishing effort in the south mostly offshore in DMV and SVA during 1981-1990 with some activity near shore in NJ and in northern regions of SNE south of Cape Cod. In later years, fishing activity was mostly in NJ. During 1991-1995, there were no landings or effort in SVA or SNE, reduced activity in DMV, and increased activity in NJ with expansion to offshore regions. During 1996-2000, activity in DMV decreased and the fishery moved north with some activity off southern LI. During 2001-2005, landings and effort increased in DMV and SNE with some activity SNE southeast of Cape Cod.

TNMS with relatively high LPUE levels (Figure C10) were mostly off NJ and DMV in all years. During 2001-2005, LPUE levels were high in offshore NJ, with several areas of high LPUE in DMV and SNE southeast of Cape Cod.

Important TNMS

TNMS "important" to the fishery were identified by choosing the twenty TNMS with the highest mean landings per year during 1981-1990, 1991-1995, 1996-2000 and 2001-2005 (see Assessment A. Ocean quahog, in this Report). Trends in landings, effort and LPUE were plotted (Figures C11-C13) for each to show changes in conditions within individual TNMS. Compared to less productive ocean quahog, landings, effort and LPUE were relatively high for some TNMS after many years of fishing activity.

Fishery length composition

Taken together, port sample length data for DMV and NJ in the south indicate that the surfclam stock consisted of a wider range of sizes during the early 1980s (Figure C14 to C3-15). As expected, the port sample data for both regions appear to reflect the relatively strong 1991 year class which would have recruited to the fishery during the early and mid-1990s (see below). Although sampling levels are low and the data are difficult to interpret, smaller surfclam in landings from DMV and NJ during 2005 might be due to recruitment of the 1998 year class at age 7 (see below).

Port samplers routinely collected shell length measurements for 30 randomly selected surfclams from landings after selected fishing trips. Numbers of trips sampled and numbers measured were low (Table C8), particularly during recent years and care is required in interpreting trends. Numbers of trips sampled is probably the best measure of the potential information in port sample length data because lengths tend to be similar for individuals from the same trip (Pennington et al., 2002).

Commercial length composition data for DMV indicate that surfclams landed during 1982-2005 were mostly 120+ mm SL during most years although smaller individuals were evident during 1992-1994 and 2005 (Figure C14). The apparent reduction in shell length during 2005 is difficult to interpret due to modest sampling (Table C8). Relatively large surfclams were landed in DMV during 1982-1985 indicating that large surfclams were more common in DMV at that time.

There were more port samples from NJ than DMV during most years (Table C8). Commercial length composition data for NJ indicate that most of the surfclams landed during 1982-2005 were at least 120 mm SL, although smaller individuals were evident during 1982-1985, 1993-1998 and 2005 (Figure C15).

Port sample data for LI are limited to 1983, 1993 and 2005 (Figure C16) and samples sizes are modest (Table C8). The data for 2005 show substantial numbers of small individuals. However, the data suggest that most of the landings in LI are at least 120+ mm SL.

Port sample data for SNE are limited to 1982-1990 (Figure C17) and samples sizes are modest (Table C8). The data suggest that most of the landings in SNE are at least 120+ mm SL.

Fishery age composition

Fishery age composition data for DMV and NJ during 2005 (Figure C18) from port sample lengths and survey age-length keys indicate that most of the 2005 landings were ages 5+ y. The strong 1992 (age 13 y in 2005) and 1998 (age 7 in 2005) year classes were important to the fishery during 2005.

Apparently strong year classes in the fishery length and age composition data for DMV and NJ may have due to low port sampling in some years and lack of age data for the commercial catch. However, survey age composition data (described later) suggest the same recruitment patterns.

Fishery age composition data for DMV and NJ do not show evidence of strong incoming year classes that would recruit to the fishery prior to 2010 (Figure C18). However, small surfclam are not selected by commercial dredges.

4.0 NEFSC CLAM SURVEY TREND DATA

NEFSC survey strata used to track surfclam trends (Table C9) are different than used for ocean quahog because surfclams live in relatively shallow water where ocean quahog are usually not found. After borrowing to fill holes (survey strata with no tows, see Assessment A. Ocean quahog, in this Report) a few holes remained (Table C9). Remaining holes were filled for swept-area biomass calculations but not for trend analysis using a model described below. As pointed out earlier (i.e., see Assessment A. Ocean quahog, in this Report NEFSC), NEFSC survey data are used only from surveys during 1986-2002 because of limited sampling during other years.

A cooperative surfclam survey was conducted in SVA, DMV and NJ during 2004 (Weinberg et al. 2005). It is used in calculation of swept area biomass but not for trend analysis.

Tows with poor survey dredge performance

NEFSC developed a set of objective criteria based on sensor data used to identify NEFSC clam survey tows with poor dredge performance (see Assessment A. of this Report). These criteria were used in this assessment to identify tows in the 2005 survey with poor dredge performance.

Dredge performance during the 2002 survey

Sensor data from the 2002 survey review were reviewed to see if dredge performance problems during 2005 also occurred during 2002. If so, the dredge performance issues might occur during most surveys.

Because of time constraints the review for 2002 was limited to a visual inspection of sensor data plots for a sample (213 out of 556) of stations. Details are available in Appendix C2 but the visual criteria used to judge dredge performance were the same as used in a preliminary analysis of the 2005 SSP data. In particular, manifold pressure and angle of attach were reviewed for significant deviations from "normal" values.

In general, results showed that poor dredge performance problems are likely to arise due to a number of factors that affect either manifold pressure or the angle of attack for the dredge while in operation on the bottom. The main reason for a poor dredge performance differed during 2002 and 2005 (Appendix C3). Compared to the survey during 2002, the 2005 survey had a high number of poor incidents due to manifold blockage that occurred when a screen over the pumps water intake failed and allowed small stones to lodge in the manifold nozzles. In 2002 the main problem was the dredge pump being shut off early.

It is important to realize that most of the tows with poor dredge performance would have been excluded from stock assessment analyses anyway due to haul and tow data routinely collected by the survey watch chief or chief scientist at each station. After tows with haul or gear problems were omitted, many of the remaining tows with poor dredge performance would be excluded from trend and swept area biomass calculations because they were nonrandom (Figures C19-C20).

Based on rates of occurrence during the 2002 and 2005 surveys, it was hypothesized that poor dredge performance occurs regularly during NEFSC clam surveys. Random stations during the 2002 and 2005 surveys with poor dredge performance and not otherwise were therefore used in estimation of survey trends for surfclam. In practical terms, it would have been impossible to exclude such tows consistently in all years because sensors were not used prior to 1997. As shown below, tows with poor dredge performance during 2002 and 2005 had an imperceptible effect on survey trend indices and swept area biomass estimates with the exception of the LI area during 2005.

Survey dredge performance during depletion studies

Based on data for 2002 and 2005 surveys, the frequency of tows with poor dredge performance[29] was relatively high during depletion experiments by the *R/V Delaware II*, probably because repeated tows in the same area loosened sediments which obstructed

[29] During the 2005 survey, tows with poor dredge performance occurred at survey stations: 1, 2, 14, 17, 20-26, 28, 29-34, 45, 48, 56, 58, 67, 75, 76, 108, 218, 225, 262, 282, 405, 411, 413, 414, 417, and 422-424. Based on a sample from the 2002 survey, tows with poor dredge performance occurred at survey stations: 4, 32, 42, 44, 45, 52, 76, 82, 90, 101, 103, 105, 106, 111, 118, 125, 137, 140, 141, 218, 250, 254, 278, 360, 368, 382, 386, 394, 458, 496, 498, and 506.

the intake and exhaust nozzles on the survey dredge. Surfclam depletion experiments by the *R/V Delaware II* during the 1997, 1999 and 2002 surveys were therefore not used in this stock assessment.

Based on the sampled tows and visual analysis, the frequency of tows with poor dredge performance (Table C10) during 2002 was about 15%, almost twice as high as in 2005 (8%). In both cases, roughly 30% of the tows with poor dredge performance were made during depletion experiments.

In contrast to trend analysis, 2005 survey stations with poor dredge performance and not otherwise were excluded from swept-area biomass calculations. The goal of swept-area biomass calculations was to obtain the best biomass estimate possible and consistency from year to year was not as important. No stations with poor dredge performance were omitted from the 2002 survey because not all stations were examined and the determination was subjective.

Imputed survey data for remaining holes

Negative binomial GLM models were fit to survey catch data for surfclam to impute survey data for remaining holes (Table C9). Imputed data were used only in swept area biomass calculations and were not used in trend analysis due to lack of time and because the approach was experimental. Effects of imputed values on survey trends and swept-area biomass were minor because most holes had already been filled by borrowing (Table C12). Residual plots for SVA, GBK, and SNE (Figures C21-C23 suggest that the model was a reasonable approach that performed acceptably. Pending further evaluation, imputed survey data might be used in place of borrowing for future surfclam assessments.

Models used to impute missing survey data were fit in Splus using the glm.negbin() function available in the MASS library of functions for Splus and R statistical analysis software (Venables and Ripley 1997). The linear predictor had categorical year and stratum effects and the log link was employed so that year and stratum effects were multiplicative. Parameters were estimated by maximum likelihood assuming that the observed survey data were drawn from a negative binomial distribution with mean estimated by the model and a variance parameter common to all observations. The primary advantage of the negative binomial model was that it accommodated noisy data and tows with zero catch in a natural manner without adding constants and taking logs or otherwise changing the data.

A separate model was fit to tow by tow mean kg/tow (standardized using Doppler tow distances) for surfclam 120+ mm SL in each stock assessment region. All data for successful random tows during 1982-2002 were used. The imputed values used to fill remaining holes were predictions from the model for year and strata combinations missing in the original survey data.

2005 survey results

Based on CVs for means in stratified random sampling, the 2005 NEFSC clam survey was reasonably precise for well sampled regions (Table C11). Of particular interest, small recruit surfclams (50 to 119 mm SL) were taken from near shore strata in southern DMV (Figure C4.6) where warm water probably caused extensive mortality during 1999-2004 (Weinberg 2005; Weinberg et al. 2005). However, no large fishable surfclams (120+ mm) were found in near shore strata off southern DMV (Figures C24-

C25). See NEFSC (2005) for a summary of survey station locations and catches during the 2005 NEFSC clam survey.

Survey trends

Survey trend data (Figures C26–C28) were more variable for small surfclams than for large surfclams. Based on survey trend data, fishable biomass (120+ SL) declined in southern regions SVA, DMV and NJ. The decline in SVA was gradual beginning in the mid-1980s. The declines in DMV and NJ were relatively rapid beginning in the mid-1990s. Fishable biomass in LI may have increased gradually after 1982 but the survey data are variable and difficult to interpret.

Recruitment indices 2005 were at or near record lows for all regions surveyed with the exception of LI and GBK which was not surveyed in 2005 (Figures C26-C27). During the 2002 survey, recruitment in GBK was relatively high.

With the exception of LI during 2005, tows with poor dredge performance during 2002 and 2005 had an imperceptible effect on estimated trends in fishable biomass (Figure C28).

Year effects and the 1994 survey

Trends in NEFSC survey data (Table C11) for small recruit surfclams (mean n tow-1, 50-119 mm SL) and large fishable surfclams (mean kg tow, 120+ mm SL) showed some evidence of year effects when estimates for the same year and region increased or decreased together (Figure C26). Year effects in NEFSC clam survey may be due to changes in survey dredge equipment or protocols between surveys (NEFSC 2003).

Based on survey trend data, it was decided to include the 1994 survey in all analyses for surfclam. In contrast, previous surfclam assessments (NEFSC 1998; 2000; 2003) included 1994 survey data in graphics but excluded the data from swept area biomass and other analyses because of hypothesized year effects that may have increased catch rates. In particular, the voltage supplied to the pump on the dredge was reportedly set at 480 V, rather than 460 V as specified and higher voltage during the 1994 survey may have increased catch rates (NEFSC 2003). However, based on additional survey data there is insufficient evidence of a year effect during the 1994 survey for surfclam. Moreover, field tests with the survey dredge operating with 460 and 480 V were inconclusive (J. Weinberg, pers. comm.). Additionally, a comparison of tows during the 2002 and 2005 survey with good and poor dredge efficiency suggested that surfclam catches were not sensitive to dredge performance (Appendix C3).

The decision to use 1994 survey data for surfclams in stock assessment analyses does not apply to ocean quahogs. Evidence for a strong year effect due to high voltage appears stronger for ocean quahogs (see Assessment A. in this Report).

Survey length and age data

Survey length composition data show a wide range of lengths for surfclam in SNE, LI, and NJ with relatively few large surfclam in DMV and a relatively narrow range of lengths in GBK (Figures C30-C34). Survey length data for LI during 2005 was too variable to be interpreted. It may be possible to track a recruitment event in the survey length data for LI beginning in 1983. Length data for SVA are scant.

Survey age composition data for NJ and DMV show the strong 1992 and 1998 year classes relatively consistently and clearly (Figure C34b). During 2005 these two year classes dominated the population as 7 and 13 year-olds. There is some evidence of a recruitment event in the age composition data for age 2 surfclams in DMV during 2005.

5.0 STOCK BIOMASS AND FISHING MORTALITY (TOR-2)

Efficiency corrected swept area biomass estimates were based on NEFSC and cooperative clam survey data for 1997, 1999, 2002, 2004 and 2005 and cooperative depletion experiments. They are a key source of information about the scale (magnitude, thousand mt) of surfclam biomass during recent years in this assessment.

Efficiency corrected swept area estimates are relatively direct, model-free and independent estimates of biomass and fishing mortality. Surfclams have proven difficult to model in some cases (e.g. NEFSC 2003) and it is useful to have another method available for estimating recent biomass and fishing mortality. Fishing mortality, in particular, can be estimated on a regional basis as the ratio of catch and efficiency corrected swept area biomass. Fishing mortality rates are low for surfclams and the June survey occurs when the stock is near the average annual level so that the ratio of catch and biomass gives nearly the same result as solving the catch equation exactly. Swept area biomass and fishing mortality estimates were not made for years with surveys prior to 1997 because no sensor-based tow distance data were available.

NEFSC clam survey trend data are the main source of information about trends in fishable biomass and recruitment since 1982. Survey data (mean kg/tow, based on sensor tow distances) for trend and swept area analyses were from random stations with no problems recorded on standard survey logs. Some survey stations with poor dredge performance identified using sensors during 2005 were omitted from swept area biomass calculations. As described above, negative binomial GLM models were used to impute missing survey data used to fill remaining holes in NEFSC data.

The KLAMZ delay-difference stock assessment model was used to make estimates for surfclams in DMV, NNJ and for the entire stock. The assessment model is advantageous because it estimates long term biomass and fishing mortality levels during 1982-2005, “balances the books” to ensure that all assumptions can be reconciled, and smoothes out measurement errors in swept area biomass and survey trend data. The KLAMZ model was not applied to SNE, LI and GBK in this assessment because the survey data are difficult to interpret and very little fishing has occurred in northern regions.

In the previous assessment (NEFSC 2003), the KLAMZ model was used only for DMV because it did not give reasonable results for southern and northern New Jersey (which were modeled separately). The KLAMZ model and data used in this assessment involve improvements that enhance model performance. In particular, the southern and northern New Jersey regions are combined in this assessment to form the NJ region with relatively precise survey data. Additional survey data for 2004 and 2005 are available and show clear trends over the last decade.

All of the methods for estimating surfclam biomass and fishing mortality levels and calculating variances are described in Assessment A. Ocean Quahogs, in this same Report. A few differences in methodology for surfclams are described below where relevant.

Survey and commercial dredge efficiency

As for ocean quahogs (in Assessment A. Ocean Quahogs of this Report), the best estimate of survey dredge efficiency for surfclams in this assessment was the median of estimates from all available depletion studies (Table C13). In particular, the best estimate of efficiency for commercial dredges was the median E=0.765 (mean 0.704, CV=0.081, n=19) and the best estimate for the NEFSC survey dredge was e=0.226 (mean=0.262, CV=0.17, n=16).

All commercial efficiency estimates for surfclam in this assessment were from Rago et al.'s (2006) "Patch" model fit to data from depletion studies by commercial vessels. Survey dredge efficiencies were estimated for depletion experiments with setup tows by *R/V Delaware II* during NEFSC clam surveys. In contrast to ocean quahog and as described above, depletion studies carried out entirely by the *R/V Delaware II* were not used because of problems with survey dredge performance during repeated tows in the same location. A variety of *ad-hoc* estimators for survey dredge efficiency used by NEFSC (2003) for surfclams were not used in this assessment because they have unknown statistical characteristics and were not necessary.

Eight new depletion studies have been carried out since the last assessment, three during 2004 and five during 2005 (Table C14). Additionally, it was necessary to reanalyze depletion experiment data from fourteen depletion experiments during 1997-1999 so that consistent methodology and corrected estimators were used in all cases.

Assumed length at full recruitment

The most important difference in estimating dredge efficiencies for surfclam in this assessment and in the previous assessment was the assumed length at full recruitment to the commercial gear used in each depletion experiment. Surfclams were assumed in this assessment to be fully recruited to commercial gear used in depletion experiments at 150 mm SL.[30] Elsewhere, in mortality and biomass calculations for this assessment, surfclams are assumed to recruit to the commercial fishery and become fishable at about 120 mm SL. However, full recruitment is likely to occur at some larger size.

Depletion experiments for surfclams included vessels that specialize in surfclam (e.g. *F/V Jersey Girl* in Table C14) and vessels that specialize in ocean quahog (e.g. *F/V Lisa Kim*). Gear on quahog vessels is designed to catch relatively small ocean quahog efficiently. Thus, surfclams likely recruit to gear on ocean quahog vessels at a smaller size than gear used on surfclam vessels. However, it was important too choose an assumed length at full recruitment that was high enough to assure full recruitment to both types of gear in all experiments. A single length criterion was important for the sake of efficient data processing and consistency of surfclam density estimates.

NEFSC (2005) used 90 mm SL as the assumed size at full recruitment for ocean quahog because commercial selectivity at that size was at least 85% at 90 mm SL based on a commercial fishery selectivity curve. No directly estimated selectivity curves are available for surfclams. However, a "relative" selectivity curve that relates catches in commercial surfclam gear to catches in the NEFSC survey dredge indicates that 85% relative selectivity occurs at 145-150 mm SL (Figure C30 in NEFSC 2004). A review of

[30] Surfclam appear to recruit to the NEFSC survey dredge by about 120 mm SL. Surfclam recruit to the NEFSC survey dredge at smaller sizes that to commercial dredges because the survey dredge is made with closely spaced bars and a wire mesh liner. Moreover, survey catches are not sorted mechanically on a shaker table to remove trash and undersized objects.

length data from surfclam depletion experiments with setup tows indicated that 150 mm SL would suffice as the assumed size of full selectivity in all experiments.

The disadvantage in choosing a relatively large assumed size at full recruitment was that data from the SC2002-4, SC2004-3 and SC2005-6 depletion experiments were not useable. In these experiments, catches of surfclams 150+ mm SL were either zero or too low and variable.

Relationships between efficiency and other variables

There were no clear relationships between Patch model estimates and environmental variables such as depth and sediment size (Figure C35 and C36). With one exception, there were no clear relationships among Patch model estimates themselves (Figure C35 and C36).

The apparent negative relationship between estimates of efficiency and initial surfclam density from the Patch is potentially important (Figure C36). However, the pattern is readily explained as an artifact of the natural statistical correlation between the two parameters in the Patch model. Sites for depletion experiments are chosen to have relatively high surfclam densities. If efficiency decreases at high surfclam densities and experiments are conducted at sites with high density, then mean efficiency for the stock as a whole (in areas of high and low density) might be underestimated. If efficiency is underestimated, then stock biomass might be overestimated and fishing mortality under estimated.

As described in Rago et al. (2006) and illustrated by a typical bivariate likelihood profile for density and efficiency estimates from the Patch model (Figure C37), uncertainty in initial density and efficiency estimates take the form of an elongated "banana" shaped region so that lower estimates of initial density are associated with higher estimate of efficiency and *vice-versa*. In other words, sets of parameters with density low and efficiency high tend to fit the data from a depletion experiment as well as sets with density high and efficiency low. This type of statistical correlation is common in nonlinear parameter estimation (Bard 1974). In linear regression modeling, it takes the form familiar statistical correlation between estimates of the slope and intercept of the regression line.

A simple simulation analysis using linear regression and a simulated Leslie-Davis depletion experiment showed the same relationship between efficiency and density estimates, although no relationship was included in the simulation scenario. The Patch model is quite similar to a linear regression problem because, in effect, it is the result of applying Leslie-Davis depletion models to a number of depletion experiments sites simultaneously (Rago et al. 2006). Leslie-Davis depletion models were fit originally by simple linear regression (Ricker 1975).

Sensitivity of Patch model estimates to smoothing position data

As described in Assessment A. Ocean quahogs, in this Report, position data from depletion experiments was smoothed and interpolated prior to use in the Patch model. NEFSC (2006) carried out a number of analyses to determine the sensitivity of Patch estimates to assumptions and procedures but did not consider smoothing.

Procedures and equipment improved steadily in each survey. Precision of position data was relatively low for 1997 depletion experiments because Loran was used to measure location (accuracy 30-40 ft) and position data were recorded at relatively long time intervals (e.g. 1 minute). In later years, more precise differential GPS was used to measure location to a precision of about 6-9 ft and at shorter intervals of 1-6 seconds.

To accommodate differences in precision of location data among depletion experiments, the Patch model was fit with and without smoothing to data from one surfclam depletion experiment in each survey year. Results (Table C15) show that smoothed data produces higher estimates of initial density and lower estimates of dredge efficiency than unsmoothed data. Area swept during each depletion tow decreased by 1-20% when using smoothed data (Table C15).

Building a bridge

Assessment A. Ocean quahogs, of this Report (see Tables A14-A15) evaluated effects of the many changes made in estimation of dredge efficiency for ocean quahog. Results from those analyses for ocean quahog are probably also applicable to surfclam.

As with ocean quahog and with the exception of experiments in 2002, revised efficiency estimates for surfclam were lower and more precise (lower CVs) than estimates previous estimates (Table C16). However, care is required in making comparisons with efficiency estimates in NEFSC (2003) because previous estimates were from a variety of estimation procedures. In addition, previous estimates from the Patch model were usually made under different assumptions, data for different sizes of surfclam were included and less accurate formulas may have been used.

Efficiency corrected swept area biomass

The best estimate of survey dredge efficiency (e=0.226) was used to estimate efficiency corrected swept area biomass (Table C17) and fishing mortality (Table C18) for surfclams 120 mm SL is 1997, 1999, 2002 and 2005.

2004 Cooperative Survey

Additional information was available from a cooperative survey carried out during 2004 by the *F/V Lisa Kim* in SVA, DMV and NJ (Weinberg et al. 2005). Swept-area biomass estimates in Weinberg et al. (2005) were recalculated using the median commercial dredge efficiency (E=0.714, Table C19) from six depletion experiments by the *FV Lisa Kim* during 2004-2005 (Table C14). The updated calculations excluded some nonrandom tows that may have been used inadvertently by NEFSC (2003).

Cooperative 2004 survey analyses in this assessment used catch data for surfclams 120+ mm SL (all sizes in the fishable biomass) because the *F/V Lisa Kim* normally targets ocean quahog and is equipped to catch relatively small commercial size ocean quahog, which are smaller than commercial size surfclam. As described above, the assumed size at full recruitment was 150 mm SL in other analyses because commercial vessels were used in some experiments that target surfclams use gear that retains larger clams. Survey length composition data from the depletion experiments indicated that surfclams probably recruited to the dredge on the *F/V Lisa Kim* at about 120 mm SL.

Results from the 2004 survey (Table C20) confirmed downward trends in biomass evident in biomass estimates for DMV and NJ based on NEFSC surveys during 1997-2005 (Table C21; Figure C38). In particular, the 2004 estimates from the cooperative survey were nearly intermediate between biomass estimates from the 2002 and 2005 NEFSC surveys. The 2004 survey did not cover all strata in SVA and catch rates for SVA were too variable to be used in estimating biomass (Figure C38).

KLAMZ modeling

KLAMZ delay-difference models for surfclam biomass dynamics were similar to those used by in the Ocean quahog Assessment (see Assessment A. of this Report) for ocean quahog.[31] A few changes were made to model surfclams more realistically. These changes involved configuration of survey trend data, assumptions about recruitment, growth patterns that changed over time, and application to the stock as whole as well as to individual regions. Surfclams require slightly different modeling approaches because more data are available, surfclams are inherently more productive and their population dynamics are more variable, surfclams grow relatively quickly, growth varies over time, surfclams have a higher assumed natural mortality rate (M=0.15 y^{-1} instead of 0.02 y^{-1}), and recruitment patterns are substantially different. Many of these factors appear to be influenced by density dependent factors (Weinberg 1998), oceanographic conditions and bottom temperatures in particular (Weinberg 2005).

The most important challenges in modeling surfclams stem from variability in NEFSC clam survey data for recruits and fishable sizes, and lack of survey data between triennial NEFSC clam surveys. In a nutshell, recruitment trend data change too rapidly to be readily tracked by the triennial survey data. LPUE trend data are available and can be compared to model results but were not used in fitting KLAMZ models for surfclams due to well known problems relating commercial catch rates and trends in stock biomass (Hilborn and Walters 1992). Catch data used in KLAMZ models for surfclams included discards that occurred prior to 1993 when size limits were used to manage the fishery (Table C2).

Despite problems, a number of factors enhance the utility of the KLAMZ model for surfclam. Most importantly, direct estimates of stock biomass based on depletion studies and swept area estimates are easily incorporated in the assessment model. The KLAMZ model is flexible and has a number of features that can be used to take advantage of various aspects of surfclam biology. Landings data for surfclams are relatively accurate because of accounting procedures inherent in the ITQ fishery management program. Survey data for surfclams include CVs that characterize sampling variability and that can be used to determine when the model fits the survey data "too well" (i.e. better than could be expected based on the inherent precision of the data). Auxiliary information is available for many important parameters (e.g. survey dredge efficiency and swept area biomass and growth). Surfclams are relatively long lived (~35 y) and expected rates of change in fishable stock biomass are lower for relatively long-lived organisms.

Year effects and correlated measurement errors (the same year effect in survey data for recruits and fishable size groups in the same year) are a concern in using survey data for surfclams. Simulation analyses have not been carried out using the KLAMZ model, but detailed simulation analyses with the abundance-based Collie Sissenwine model (ASMFC 2006) which is similar to KLAMZ showed that model performance (mean squared error, bias and variance) actually improved when survey data for recruits and fishable size groups had strong correlated year effects.

[31] See Appendix A5 of the ocean quahog assessment (NEFSC 2007) for a complete technical description of the KLAMZ model.

Growth curves

Growth is a key part of biomass dynamics in the KLAMZ delay-difference model. Survey data for surfclams in KLAMZ models (particularly for new recruits) are calculated based on assumptions about growth.

The Schnute-Deriso delay difference equation in the KLAMZ model (Schnute 1985) uses a version of the von Bertalanffy model for growth in weight with two parameters. In particular, $\rho = e^K$ where K is from a von Bertalanffy model for weight, and $J_t = W_{k-1,t} / W_{k,t}$, where $W_{k,t}$ is predicted weight at age k when recruitment occurs based on the growth curve for year t. The von Bertlanffy parameters W_{max} and t_0 are implicit in J_t. In delay-difference model calculations (Schnute 1985), the parameters J_t may change over time but K is constant in all years.

Survey mean length at age data for NJ and DMV in each survey (Figure C2) were converted to mean weights at age in each survey by applying region specific length-weight relationships (Table C1). The growth curves used different W_{max} and t_0 parameters for 1982-1992 and 1994-2005, but used the same K parameter in all years (Table C22). Growth parameters for NJ were used also in modeling the whole stock.

Survey indices

NEFSC clam survey data in the KLAMZ model were for recruit (Table C23) and fishable size groups (Table C11). The recruit index was mean kg/tow for surfclam in the survey that were 120 to L_{k+1} mm SL, where L_{k+1} is the predicted size at age k+1 and k is the predicted age at recruitment (L_k = 120 mm SL) based on a growth curve. The fishable index was survey mean kg/tow for surfclams 120+ mm SL. Recruit trend data were assumed to track trends in the biomass of new recruits. Trend data for fishable surfclams were assumed to track trends in total fishable biomass (new recruits plus survivors from the previous year). Surveys were assumed to occur in the middle of the year because the NEFSC clam survey is carried out during late May-early July.

As described above, survey data for surfclams 120 to L_{k+1} mm SL were used in both the recruit and fishable biomass trend indices. This strategy was intentional and meant to link the relatively noisy recruit and more stable fishable survey data indices in the model, to reduce potential problems stemming from uncertainty about where to split the index for fishable biomass, and to help insure that the survey scaling factor for both recruit and fishable indices would be about the same. In practical terms, it had little effect on the survey data themselves because recruit kg/tow was small relative to kg/tow for the remaining fishable size groups.

NEFSC (2003) used a more complicated system of survey trend data for prerecruits, recruits and remaining fishable size groups. Fishable sizes were 100+ or 120+ mm SL, depending on area. Prerecruit size groups were L_{k-1} to either 100 or 120 mm SL based on region specific von Bertalanffy growth curves. The prerecruit index was lagged in the model by one year so that data collected in year t would be used in the model to estimate recruitment in year t+1. The prerecruit index was not used in this assessment because it is highly variable for surfclams with noisy trends that are difficult to resolve given the rest of the survey and catch data in the model.

For convenience in interpreting model results, survey mean kg/tow data for fishable surfclams in the entire stock were scaled up to approximate efficiency corrected swept area biomass before use in the KLAMZ model. The scaling factor was the average ratio of the survey data and efficiency corrected swept area biomass during 1995-2005 surveys (see below and Table C25). With this adjustment, the survey scaling factors for fishable biomass trends estimated in the KLAMZ model are expected to be close to one. The adjustment to the survey data did not affect biomass or fishing mortality estimates.

Survey dredge efficiency and swept-area biomass

Following NEFSC (2003), efficiency corrected swept area biomass estimates were included in the assessment model as a measure of scale but not as measures of trend. In fitting the model, the likelihood of the estimated scaling parameter for swept area biomass was calculated based on a lognormal prior distribution with mean 1.0 and arithmetic CV = 0.5. The relatively large CV means that the prior information about the scaling parameter was relatively "weak". However, experience shows that the prior information tends to have a strong impact when survey data are limited and there is little other information in the model data about biomass scale.

Recruitment assumptions

Following NEFSC (2003) surfclam recruits were estimated in the KLAMZ model as a random walk with steps constrained by a variance parameter. A smooth, random walk process is probably not ideal from a biological perspective because of the possibility of strong year classes in surfclams but the approach was necessary because of the lack of annual recruitment data. The random walk approach keeps the recruitment estimate in year *t* at the same level as in year *t-1*, unless there is a good reason in terms of goodness of fit to change it. For surfclams in the KLAMZ model, the random walk approach was used primarily to fill gaps in information due to not having a recruit index for each year, to avoid excessive variation in recruitment and to ensure that some recruitment was estimated for each year.

In modeling surfclam population dynamics with random walk recruitment, it is important to control the "random walk recruitment variance" σ_R^2 (NEFSC 2003) which measures variability in the size of successive steps taken during the random walk (i.e. variance in [$\ln(R_1/R_2)$, $\ln(R_2/R_3)$, $\ln(R_3/R_4)$, etc.], where R_t is the recruitment estimate for year t) . As σ_R^2 approaches zero, recruitment estimates become smooth and tend towards a constant value with no changes from year to year. As σ_R^2 becomes large, estimated recruitments will change randomly and more widely from one year to next.

Following NEFSC (2003), initial KLAMZ model runs assumed a 20% CV for steps in the random walk so that $\ln(\sigma_R^2) = \ln(0.2^2)$. The constraint was relaxed gradually in subsequent runs until the model was just able to fit the survey data without pattern in residuals. In final runs, $\ln(\sigma_R^2) = \ln(0.3^2)$ for NJ and the entire stock, and $\ln(\sigma_R^2) = \ln(0.35^2)$ for DMV. In each case, the CV for fit to the survey data (residual CV) was compared to CVs for the actual survey data to determine if σ_R^2 was too large and the model was fitting the survey data more closely than could be expected based on the precision of the survey data. The goal was basically to find the simplest model (fewest effective recruitment parameters) that would adequately explain the survey data for surfclam. Choices were subjective but had only modest effects on biomass and fishing mortality estimates for surfclam, because many different recruitment patterns imply similar biomass and recruitment levels.

Results-whole stock

Survey data for the entire stock in the KLAMZ model were filled as described above. However, no provision was made for filling remaining holes that could not be filled by borrowing (Table C9). Mean surfclam densities for strata with data (original or filled) were used to compute the weighted mean density for the stock as a whole (i.e. strata with no data were ignored in computing the mean density for the stock as a whole). However, the mean density for the stock as a whole was applied to the entire stock area, which included the area of strata with no data. The effects of remaining wholes were reduced in whole stock runs because remaining wholes were a relatively small proportion of the total number of strata and total area of the stock.

The KLAMZ model fit survey biomass trend data reasonably well although the fishable biomass trend datum for 1994 was not completely reconciled in the model fit (Figure C40). The model fit the recruit index better than the fishable biomass index, although the latter was more precise based on survey CVs. LPUE and swept area biomass trends did not affect model estimates, but estimated biomass trends from the model were similar to trends in LPUE after 1999 and to trends in swept area biomass for in all years.

The survey scaling parameter for the scaled fishable biomass index was Q=1.26 and reasonably close to one. The survey scaling parameter for efficiency corrected swept area biomass was Q=0.99 indicating that the trend data, landings and model estimates were compatible with the prior information about Q for efficiency corrected swept area biomass estimates.

Model results suggest that surfclam biomass increased from 1981-1997 to record high levels due to high surplus production (relatively good recruitment and fast growth rates) which occurred during the mid 1980s and early 1990s (Table C24 and Figure C41). Surplus production declined steadily after 1993 as recruitment declined, the stock aged and growth rates slowed. Surplus production was negative after 1997 while stock biomass declined steadily. By 2005, stock biomass had declined to about the same level as in 1986-1992 but was still relatively high in historical terms. Fishing mortality rates were much lower than natural mortality and probably inconsequential during 1981-2005.

Bootstrap analysis (2000 iterations) indicated a tendency towards negative bias in biomass and fishing mortality estimates during peak recruitment years, but good model performance and little bias overall. CVs and confidence intervals from bootstrapping indicate that biomass and fishing mortality estimates were reasonable precise, particularly for recent years (Table C24; Figures C42-C43), probably due to the swept area biomass data for 1997-2005. Recruitment was estimated less precisely than biomass and fishing mortality (Table C24; Figure C44). The model did not completely converge during a substantial fraction of bootstrap runs (roughly 50%), due to uncertainty in estimated recruitments (Table C24). In other words, a range of recruitment patterns probably explained the survey data equal well.

Results-DMV and NJ

The KLAMZ model for DMV fit survey index data quite well (Figure C45). The model for NJ fit reasonably well although the fishable biomass indices for NJ during 1994 and 1997 were not reconciled (Figure C46). Survey scaling factors for scaled fishable biomass trends and efficiency corrected swept area biomass were reasonably close to one in all cases.

Model results for DMV indicate that biomass declined continuously from relatively high levels during the early 1980s due to declining recruitment, slow growth, and surplus production levels that were usually negative (Figure C47). Model results for NJ were similar to results for the whole stock but biomass declined more steeply during recent years to lower levels during 2005 (Figure C48). Fishing mortality appears to have been a minor factor in both areas during 1981-2005 (Figures C47-C48).

<u>Stock biomass by region</u>

Average ratios for survey data (Doppler standardized) and efficiency corrected swept area biomass were calculated for each region (Table C25) and used to rescale survey trend data to approximate swept area biomass levels (Table C23). The proportions of swept area biomass in each region were used to prorate fishable biomass estimates from the KLAMZ model for the entire stock during years with NEFSC clam surveys into regional components. Results clearly show the shift over time in biomass from southern to northern regions (Figures C49 to C50).

Recruitment parameters

Recruitment estimates for surfclam from the KLAMZ model were made with limited survey data and are complicated to interpret. Under these conditions, recruitment estimates for surfclam should probably be regarded as "nuisance" parameters of less interest than biomass and fishing mortality estimates. As nuisance parameters, recruitment estimates basically amount to adjustments in the KLAMZ model that implicitly account for model misspecification, survey noise, survey year effects, changes in recruitment, natural mortality and variability in growth not explicitly included in the modeling framework.

Proportions of total fishable biomass at various density levels

As described in the first assessment in this Report (A. Ocean quahogs), best biomass estimates and survey data were combined to partition best biomass estimates into components found in areas with relatively high and low biomass density levels. Biomass density is important to profitability of the ocean quahog fishery because it determines commercial catch rates. Biomass density was measured as survey catch per tow (fishable kg/tow) because commercial catch rate data for random locations and the entire stock area were not available.

Results (Table C26) show reductions in stock within high density areas in the southern DMV and SVA regions. During 2005 (Table C27), the largest component (29% or 47 thousand mt meats) of total fishable stock biomass was on GBK in the highest (25+ kg/tow) biomass density category. In contrast, stock biomass levels in density categories larger than 10 kg/tow were low for other regions.

6.0 BIOLOGICAL REFERENCE POINTS (TOR-3)

According to the Surfclam and Ocean Quahog FMP, overfishing occurs whenever the fishing mortality rate on the entire stock is larger than F_{MSY}. The stock is overfished if total biomass falls below $B_{Threshold}$ (estimated as ½ B_{MSY}). When stock biomass is less than the biomass threshold, the fishing mortality rate threshold is reduced from F_{MSY} in a linear fashion to zero.

The current best proxy for F_{MSY} is $F = M = 0.15$ y^{-1}. The proxy for B_{MSY} is one-half of the estimated fishable biomass during 1999 which was estimated to be 1,460 thousand mt in this assessment based on KLAMZ model results for the entire stock. Revised biomass reference points are higher than previous values (see table below) because of new information about the efficiency of the dredge used in NEFSC clam surveys.

Reference Point	Last assessment	Revised
F_{MSY}	M=0.15 y^{-1}	Same
B_{1999}	1,460 thousand mt meats	1,799 thousand mt meats
B_{MSY} =½B_{1999} (target)	730 thousand mt meats	900 thousand mt meats
$B_{Threshold}$ = ½ B_{MSY}	365 thousand mt meats	490 thousand mt meats

Status determinations by comparisons of biomass estimates and biomass reference points are almost unaffected by new information about dredge efficiency because the changes in biomass estimates and the B_{MSY} proxy "cancel out" when current biomass is compared to or divided by the B_{MSY} proxy (Figure C51). Comparison of fishing mortality estimates and the F_{MSY} proxy are more sensitive because fishing mortality estimates depends on dredge efficiency but the F_{MSY} proxy does not (Figure C52).

Fortunately, conclusions in this assessment about fishing mortality and reference points are robust because fishing mortality rates for the stock are relatively low. In particular, conclusions about stock status would not change unless either the mortality estimate or threshold was changed by 7 fold (Figure C52).

Critique

Current reference points for surfclams suffice for use in this assessment because surfclam biomass is relatively high (at near average levels) and fishing mortality is low. However, biomass referenced points should be reconsidered the next time the stock is assessed.

Use of ½ B_{1999} as a proxy for B_{MSY} implicitly assumes that the stock was at carrying capacity during 1999. The carrying capacity assumption should be reevaluated based on the longer time series of data that are currently available. In addition, it may be useful to consider possible climate change effects on B_{MSY} and F_{MSY} proxies as evidenced by loss of surfclams in the south near the coast of the Delmarva Peninsula (Weinberg 2005).

7.0 STOCK STATUS (TOR-4)

The Atlantic surfclam stock is not overfished and overfishing is not occurring. Estimated fishable stock biomass during 2005 (120+ mm shell length, SL) was 1,170 thousand mt meats, which is above the management target of ½ 1999 biomass = 900 thousand mt meats (Figure C51). Estimated fishing mortality during 2005 was F= 0.0192 y^{-1}, which is below the management threshold $F_{MSY} \cong M = 0.15$ y^{-1} (Figure C52).

8.0 PROJECTION METHODS (TOR-5)

For the first time, a fully integrated assessment model, variance estimation and stochastic projection approach was used to provide example projections for surfclam stock biomass and fishing mortality. In particular, simulation runs for projection analysis were carried out using the same delay difference equation as used in the KLAMZ model and were initialized exactly as in the last year of each bootstrap run.

Projections can be made for assumed levels of constant fishing mortality or assumed constant catch levels, and can be carried out for time periods of any length. In projections for surfclams with assumed levels of catch, likely levels of incidental mortality should be considered and probably included. For example, constant quota levels can be increased by 12% to accommodate incidental mortality and to obtain a more realistic estimate of fishery impacts. A large number of individual stochastic simulation runs (e.g. 1000) should be carried out in projection analysis. Normally, the number of simulation runs is the same as the number of bootstrap runs because bootstrap results are saved for later use by the projection software. It is possible, however, to make more than one projection from each bootstrap run.

Each simulation run in the projection analysis starts with the terminal conditions estimated in one bootstrap run. Thus, uncertainty about current stock biomass, age structure, recent recruitments and other factors is included in the projection analysis.

Uncertainty in future conditions is included by simulating random future recruitments. For surfclams, random recruitments (R_t) were chosen to mimic a random walk with user specified mean and lag-1 autocorrelation. Projected recruitments were modeled as a random walk to match assumptions in the stock assessment model. As described above, the random walk recruitment assumption in the stock assessment model was pragmatic and may not be ideal from a biological perspective. The algorithm for surfclams in this assessment was:

$$
\begin{aligned}
&\sigma = \sqrt{\ln\left(CV^2 + 1\right)} \\
&b = \frac{\sigma^2}{2} \\
&s = \sqrt{1 - \rho^2} \\
&j_t \sim N(0,1) \\
&\delta_t = s j_t \\
&\gamma_t = \rho \gamma_{t-1} + \delta \\
&R_t = \overline{\mathrm{R}} \mathrm{e}^{\gamma_t \sigma - b}
\end{aligned}
$$

where j_t is drawn from the standard normal distribution, ρ is the lag-1 autocorrelation for successive log scale recruitments [i.e. the correlation of $\ln(R_t)$ and $\ln(R_{t+1})$, specified by the user], σ is the standard deviation of log scale recruitments based on an arithmetic scale CV (specified by the user), $\overline{R}$ is the mean arithmetic recruitment (specified by the user), and b is a bias correction factor. The term γ_t is normally distributed with mean zero, standard deviation 1.0 and lag-1 autocorrelation ρ. At the end of the projection analysis, the model calculates the means and CVs for biomass, recruitment, catch and fishing mortality at the beginning of each year.

Based on the KLAMZ model run for the entire stock, ρ=0.72, CV=0.53, and $\overline{R}$ = 121 thousand mt in example projection calculations. The simulation runs were for 2005-2015 (10 y beyond the last year in the KLAMZ model).

<u>Procedures for setting TAL and TAC levels</u>

It is not necessary to describe approaches for setting TAC or TAL levels in the surfclam fishery because it is managed using constant quota levels.

9.0 EXAMPLE PROJECTIONS (TOR-6)

Example projections were carried out assuming the following conditions during 2006-2015: i) constant fishing mortality = 0.15; ii) constant landings at the minimum quota level = 1.85 million bu; iii) constant landings at mean level during 2003-2005; and iv) constant landings at the maximum quota level = 3.4 million bu. In each case, landings in bushels were converted to meat weights and increased by 12% to account for potential incidental mortality during fishing.

Results (Table C28 and Figure C53) indicate that current downward trends in biomass will persist during the next few years because of the tendency for runs of good and bad recruitment in surfclams. Declines are largest for the F=0.15 scenario. Results for the status quo and maximum quota scenarios are very similar.

Projected biomass levels out by about 2015 in all scenarios. However, CVs are very large in all years and, in particular, larger than 250% after 2008. The high CV levels indicate very high uncertainty in projected results, particularly after 2008.

10.0 RESEARCH RECOMMENDATIONS (TOR-7)

Research recommendations from the previous assessments are listed below (not in priority order).

i) Consider using year-, region- or episodic natural mortality rates. *This was discussed in the working group but deferred until a later assessment when the necessity for incorporating this feature might be more pressing.*

ii) Develop a forward casting age-structured, numbers-based stock assessment model. *This work is in progress for sea scallop, ocean quahog and surfclam. In the interim, the KLAMZ model is implicitly age structured and numbers based, although it does not make full use of survey and fishery age or length data. NEFSC convened an age readers workshop during 2006 (Jacobson et al. 2006) to address questions about age data and results will be useful in formulating the new model. NEFSC has begun to characterize variability in survey length data and the results are expected to be useful in modeling as well.*

iii) Reconcile survey trends for pre- and new- recruits relative to trends in survey data for older recruits. *Pre-recruit survey indices were not used for modeling in this assessment because they are too variable. Survey data procedures for modeling were redesigned to ease interpretation.*

iv) Reconcile survey data with consistently declining trends in LPUE during the last decade. *Recent trends in survey and LPUE data were similar in this assessment for southern regions, where fishing is heaviest, and for the stock as a whole.*

v) Focus on analysis of declining LPUE trends and examine new approached for describing fishing power among commercial clam vessels. *This issue was addressed by standardizing LPUE data in models that included individual vessel effects. Thus, it was not necessary to characterize fishing power based on GRT, horsepower, etc.*

vi) Collect commercial age and length data to monitor and predict recruitment and for use in length and age structured models. *Length data but no age data are currently being collected from port samples. Sampling rates for length data should be increased particularly for new northern fishing grounds. All available survey age, length and commercial length data were used at least qualitatively in this assessment to characterize and predict recruitment.*

vii) Reexamine coefficients used to convert commercial catches in bushels to meat weights. *No progress.*

viii) Consider using a sensor that tracks dredge position, rather than the ships position, during surveys and depletion studies. *New acoustic sensor equipment was tried experimentally during the 2005 survey but with poor results.*

ix) Conduct surveys more frequently than every three years in critical areas. *A cooperative survey in the SVA, DMV and NJ areas was carried out during 2004, in the interim between the 2002 and 2005 NEFSC clam surveys.*

x) Select a new set of fixed stations in unfished areas to monitor dredge efficiency changes between surveys. *Fixed station analysis was abandoned in this assessment due to variable environmental conditions that may affect density in unfished areas.*

xi) Consider new technological methods that rely less heavily on estimating dredge efficiency. *No progress.*

xii) Consider new methods to estimate variability in the spatial distribution of biomass. *All depletion studies were reanalyzed for this assessment producing estimates of the negative binomial parameter k, which measures spatial patchiness in the density of surfclams within depletion study areas. However, this topic is of relatively low importance.*

xiii) Continue to bring outside experts to Invertebrate Working Group meetings. *One outside expert was included in each of the meetings for this assessment.*

The following are new research recommendations (not in priority order).

a) Refine logbook data collection, focusing on spatial details. Resolve apparent problems with locations for some records. Can recent data show patterns on finer spatial scales (e.g. for 1-minute rather than 10-minute squares)?
b) Improve collection and use of port sample data form the commercial fishery.
c) Characterize relationships between shell height, width and length for potential use in understanding the size selectivity of commercial and survey dredges and commercial sorting gear.

d) Test the Patch model for depletion experiments with simulations focusing on potential effects of uncertainty about position data and including all effects of cell size and smoothing.
e) Determine the size selectivity of survey and commercial fishing equipment experimentally.
f) Improve procedures for filling holes in the survey data using statistical models with year and spatial effects. Determine if filling holes is preferable to borrowing data from previous and subsequent surveys.
g) Review survey age data carefully to determine if strong year classes can be used to estimate mortality rates outside of a stock assessment model (e.g. "empirical" *Z* estimates).
h) Further investigate spatial trends in survey data.
i) Devote sufficient time and resources to fully develop and improve dynamic population models.
j) Review the technical basis of the current B_{MSY} proxy given new data and possible climate effects.
k) Utilize New Jersey and New York inshore clam survey data more fully in the EEZ surfclam assessment.

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SURFCLAM TABLES

Table C1. Length-weight parameters for Atlantic surfclam, by region. Parameters are for the relationship $W=e^{a}L^{b}$, where W is meat weight in grams, L is shell length in mm, and a and b are parameters in the table.

Region	a	b
SVA	-7.05830	2.30330
DMV	-9.48913	2.86018
NJ	-9.31210	2.86371
LI	-7.98370	2.58020
SNE	-7.98370	2.58020
GBK	-8.27443	2.65422

Table C2. Discard estimates for surfclam in the commercial fishery during 1982-1994 from Table D4 in NEFSC (1995).

Year	Discard (mt meats)					Landings (mt meats)	Discards / Landings	Catch	Size limit (mm)
	NNJ	SNJ	NJ	DMV	Total				
1982	3,684	215	3,899	2,295	6,194	16,688	37%	22,882	140
1983	2,122	385	2,507	2,127	4,634	18,592	25%	23,226	140
1984	2,266	458	2,724	2,015	4,739	22,888	21%	27,627	133
1985	1,938	248	2,186	1,725	3,911	22,480	17%	26,391	127
1986	2,328	233	2,561	239	2,800	24,520	11%	27,320	127
1987	1,414	61	1,475	415	1,890	21,744	9%	23,634	127
1988	1,317	13	1,330	106	1,436	23,377	6%	24,813	127
1989	1,048	6	1,054	258	1,312	21,887	6%	23,199	127
1990	1,089	57	1,146	123	1,269	24,018	5%	25,287	127
1991	495	36	531	5	536	20,615	3%	21,151	--
1992	918	102	1,020	4	1,024	21,685	5%	22,709	--
1993	0	0	0	0	0	21,859	0%	21,859	--
1994	0	0	0	0	0	21,942	0%	21,942	--

Table C3. Atlantic surfclam landings in state waters and the EEZ with EEZ surfclam quotas (mt meat weights). Total landings for 2002-2005 from dealer records. EEZ landings for 2002-2005 from MAFMC (2006). Other figures from logbooks or NEFSC (2003). Landings for state waters + unknown areas were estimated as total landings - EEZ landings.

Year	Total Landings	EEZ Landings	State Waters + Unknown Area Landings	Percent from EEZ	EEZ Quota
1965	19,998	14,968	5,030	75	
1966	20,463	14,696	5,767	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	1,125	95	
1972	28,744	25,071	3,673	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	2,973	87	
1977	23,149	19,490	3,659	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	3,963	81	13,882
1982	22,552	16,688	5,864	74	18,506
1983	25,373	18,592	6,781	73	18,892
1984	31,862	22,888	8,974	72	18,892
1985	32,894	22,480	10,414	68	21,205
1986	35,720	24,520	11,200	69	24,290
1987	27,553	21,744	5,809	79	24,290
1988	28,824	23,377	5,447	81	24,290
1989	30,424	21,887	8,537	72	25,184
1990	32,556	24,018	8,538	74	24,282
1991	30,037	20,615	9,422	69	21,976
1992	33,831	21,685	12,146	64	21,976
1993	33,527	21,859	11,668	65	21,976
1994	31,048	21,942	9,106	71	21,976
1995	28,733	19,627	9,106	68	19,779
1996	28,775	19,771	9,004	69	19,779
1997	26,298	18,611	7,687	71	19,779
1998	24,509	18,240	6,269	74	19,779
1999	26,685	19,570	7,115	73	19,779
2000	31,093	19,749	11,344	64	19,779
2001	31,237	22,017	9,220	70	21,976
2002	32,645	24,006	8,639	99	24,174
2003	31,526	25,017	6,509	100	25,061
2004	28,327	24,197	4,130	92	26,218
2005	26,911	21,163	5,748	81	26,218
Min	15,836	6,396	1,125	21	13,880
Max	43,595	33,761	24,139	100	26,218
Mean	27,635	19,787	7,848	73	20,914

Table C4. EEZ surfclam landings (mt meats) by stock assessment area and year based on NEFSC (2003) for 1979 and logbook data for 1980-2005. Logbook landings from unknown areas in each year were prorated to known areas based on proportions of landings in known areas.

Year	SVA	DMV	NJ	LI	SNE	Other	Total EEZ
1979	0	11,836	1,350	0	0	0	13,186
1980	64	12,788	2,878	17	0	0	15,748
1981	568	7,472	8,820	88	0	0	16,947
1982	1,705	6,679	8,086	94	125	0	16,688
1983	2,225	7,173	8,095	264	836	0	18,592
1984	1,796	5,978	11,904	7	382	2,819	22,888
1985	741	7,856	11,246	0	452	2,185	22,480
1986	529	2,853	17,730	17	1,223	2,168	24,520
1987	378	1,302	18,017	0	1,140	907	21,744
1988	557	1,149	19,420	0	1,512	739	23,377
1989	439	3,123	16,531	0	1,361	433	21,887
1990	1,502	3,546	17,887	0	998	86	24,018
1991	0	1,634	18,913	15	33	21	20,615
1992	0	1,221	20,398	61	5	0	21,685
1993	0	3,414	18,365	62	3	14	21,859
1994	0	3,454	18,417	71	0	0	21,942
1995	0	2,752	16,497	0	378	0	19,627
1996	0	2,233	17,430	26	82	0	19,771
1997	0	1,540	16,998	73	0	0	18,611
1998	0	484	17,517	117	121	0	18,240
1999	0	648	18,749	157	16	0	19,570
2000	0	2,039	17,487	121	102	0	19,749
2001	0	3,282	17,719	935	81	0	22,017
2002	64	4,489	18,271	1,130	52	0	24,006
2003	0	1,432	21,693	1,625	267	0	25,017
2004	0	1,482	19,197	906	2,612	0	24,197
2005	0	1,668	16,850	759	1,885	0	21,163
Min	0	484	1,350	0	0	0	13,186
Max	2,225	12,788	21,693	1,625	2,612	2,819	25,017
Mean	391	3,834	15,425	242	506	347	20,746

Table C5. EEZ fishing effort (all vessels, hours fished) for surfclam by stock assessment area and year based on logbook data. The fraction of logbook effort from unknown areas in each year was prorated to known areas based on fishing effort in known areas.

Year	SVA	DMV	NJ	LI	SNE	Other	Total EEZ
1991	0	1,254	17,243	21	107	293	18,917
1992	0	797	21,379	67	0	0	22,243
1993	0	2,423	18,232	57	15	5	20,732
1994	0	1,930	21,494	70	0	0	23,494
1995	0	1,560	18,625	0	1,059	0	21,244
1996	0	1,577	20,995	40	287	0	22,899
1997	0	1,098	20,383	77	0	0	21,558
1998	0	289	19,609	134	518	0	20,550
1999	0	734	18,146	151	149	0	19,179
2000	0	1,859	16,787	115	368	0	19,128
2001	0	2,536	18,462	962	148	0	22,108
2002	112	5,505	19,825	1,241	62	0	26,746
2003	0	2,367	25,071	1,827	176	0	29,441
2004	0	3,161	26,453	1,267	1,108	0	31,989
2005	0	2,654	24,335	1,206	1,340	0	29,534
Min	0	289	16,787	0	0	0	18,917
Max	112	5,505	26,453	1,827	1,340	293	31,989
Mean	7	1,983	20,469	482	356	20	23,317

Table C6. Nominal landings per unit effort (LPUE, bushels h^{-1}) for surfclam fishing (all vessels) in the US EEZ based on logbooks. Nominal LPUE is the ratio of total reported landings and total hours fished. Landings and fishing effort from unknown areas were prorated to area before LPUE was calculated.

Year	SVA	DMV	NJ	LI	SNE	Other	All areas
1991			142	95	40	9	141
1992		199	124	119			126
1993		183	131	143	28	390	137
1994		232	111	132			121
1995		229	115		46		120
1996		184	108	85	37		112
1997		182	108	122			112
1998		217	116	114	30		115
1999		115	134	135	14		132
2000		142	135	137	36		134
2001		168	124	126	71		129
2002	74	106	120	118	108		116
2003		78	112	115	197		110
2004		61	94	93	306		98
2005		82	90	82	183		93
Min	74	61	90	82	14	9	93
Max	74	232	142	143	306	390	141
Mean	74	155	118	115	91	199	120

Table C7. Standardized annual LPUE (bushels per hour) based on log-linear GLM models. Results are scaled to LPUE during June for an arbitrary vessel that fished in all areas.

	DMV		NJ		LI		SNE	
Year	LPUE	CV	LPUE	CV	LPUE	CV	LPUE	CV
1990	241	0.69	138	0.05				
1991	206	0.69	107	0.05				
1992	232	0.69	101	0.05				
1993	237	0.69	110	0.05				
1994	322	0.69	98	0.05				
1995	287	0.69	96	0.05			8	0.59
1996	215	0.69	91	0.05			6	0.66
1997	202	0.69	88	0.05	157	0.49		
1998	210	0.70	97	0.05	105	0.50	24	0.83
1999	185	0.69	101	0.05	119	0.48	39	0.99
2000	185	0.69	93	0.05	130	0.49	28	0.97
2001	200	0.69	78	0.05	116	0.47	44	0.62
2002	119	0.69	85	0.05	104	0.47	83	0.64
2003	86	0.69	75	0.05	91	0.47	109	0.56
2004	69	0.69	63	0.05	71	0.47	72	0.54
2005	85	0.69	54	0.04	60	0.46	81	0.53
Min	69	0.69	54	0.04	60	0.46	6	0.53
Max	322	0.70	138	0.05	157	0.50	109	0.99
Average	193	0.69	92	0.05	106	0.48	50	0.69

Table C8. Numbers of commercial trips sampled and numbers of surfclam measured in port samples from landings during 1982-2005, by region. Numbers of measurements for 1982-1999 are from NEFSC (2003, Table C5) and numbers of trips during 1982-1999 were estimated assuming 30 individuals sampled per trip, as specified in port sample instructions.

Year	DMV		NJ		LI		SNE	
	Trips	Lengths	Trips	Lengths	Trips	Lengths	Trips	Lengths
1982	259	7,756	249	7,477			1	30
1983	197	5,923	375	11,253			1	30
1984	102	3,066	425	12,751			3	90
1985	61	1,832	256	7,674			5	150
1986	42	1,260	171	5,130			11	330
1987	24	730	30	900			19	569
1988	14	420	30	900			27	810
1989	29	866	31	919			15	449
1990	30	892	30	901			7	209
1991	36	1,080	76	2,272				
1992	39	1,170	57	1,710				
1993	46	1,392	31	928				
1994	4	119	30	900				
1995	24	720	17	510				
1996	38	1,154	37	1,117				
1997	54	1,622	32	957				
1998	52	1,560	23	690				
1999	57	1,720	29	856				
2000	20	600	111	3,315	1	30		
2001	33	970	42	1,260				
2002	7	210	37	1,111				
2003	2	60	80	2,455	5	150		
2004			36	1,080	2	60		
2005	19	581	61	1,834	11	330		
Min	2	60	17	510	1	30	1	30
Max	259	7,756	425	12,751	11	330	27	810
Mean	52	1,552	96	2,871	5	143	10	296

Table C9. Numbers of random survey stations in NEFSC and cooperative clam surveys by stratum, region and survey year. The 2004 survey was cooperative and carried out on a commercial vessel. All others were NEFSC clam surveys carried out on the *R/V Delaware II*. Numbers of NEFSC clam survey stations for 2005 include a few tows with poor dredge performance used to trends but not for swept area biomass. For NEFSC surveys, figures in plain text are the number of original random tows (without borrowing). Bold and outlined figures are for NEFSC survey data are "holes" (strata in with no stations), which where filled by borrowing data from the same stratum during previous and/or subsequent cruises. Black cells are remaining zeroes for NEFSC survey data that could not be filled by borrowing. Only SVA, DMV and NJ were sampled during 2004 (cells for strata not sampled are crosshatched). Survey data for GBK during 1982-1984 and 2005 (stippled) should not be used in most analyses due to limited sampling.

		Survey Year											
Region	*Stratum*	*1982*	*1983*	*1984*	*1986*	*1989*	*1992*	*1994*	*1997*	*1999*	*2002*	2004	2005
SVA	1	**10**	10	14	7	10	10	11	10	**10**			
	2				**1**	1	2	1	1	**1**			
	5	4	9	13	8	8	8	7	8	**16**	8	8	8
	6	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	**3**	*2*	2	*1*
	80	**6**	6	9	3	7	7	8	7	**7**			
	81	**4**	4	7	3	5	5	5	5	**5**	5		**5**
DMV	*9*	*30*	*26*	*35*	*29*	*37*	*37*	*39*	*39*	*38*	*39*	37	*36*
	10	*2*	*2*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	3	*3*
	13	*19*	*18*	*25*	*20*	*20*	*20*	*21*	*22*	*19*	*20*	20	*18*
	14	*2*	*2*	*3*	*3*	*3*	*3*	*5*	*3*	*3*	*3*	3	*3*
	82	1	1	1	1	1	1	1	1	2	2	2	**2**
	83	2	2	2	2	2	2	2	2	2	2	2	2
	84	4	3	3	4	4	4	4	4	3	4	4	4
	85	6	5	4	5	5	5	5	5	5	5	3	3
	86	2	2	3	3	3	2	3	3	3	3	3	3
NJ	*17*	11	11	18	12	12	12	12	14	12	12	12	12
	18	3	3	**6**	3	3	3	3	3	3	3	3	3
	21	18	18	22	19	20	20	23	26	39	29	27	20
	22	3	3	**6**	3	3	3	5	3	3	3	3	3
	25	9	9	13	8	9	9	9	12	8	9	9	9
	26	2	2	**5**	3	3	3	3	3	3	3	3	3
	87	8	7	10	9	9	9	9	9	9	16	14	8
	88	15	15	24	17	20	20	20	21	23	20	20	17
	89	15	15	21	15	18	17	17	19	18	18	17	15
	90	2	2	3	2	2	2	2	2	2	2	2	2
LI	*29*	11	10	**20**	10	10	10	10	10	11	10		10
	30	7	8	**14**	6	6	6	6	6	7	6		7
	33	4	4	**8**	4	4	4	5	4	4	4		4
	34	2	2	**4**	2	2	2	5	2	2	2		2
	91	3	2	4	4	3	3	3	3	3	3		3
	92	2	2	3	2	2	2	2	2	2	2		2
	93	1	1	2	1	1	1	1	1	1	2		1

Table C9. (continued)

Region	Stratum	Survey Year 1982	1983	1984	1986	1989	1992	1994	1997	1999	2002	2004	2005
SNE	*37*	7	4	**7**	3	**6**	3	5	4	4	3		**3**
	38	3	2	**5**	3	3	3	5	3	3	3		2
	41	6	5	7	5	6	6	6	6	5	6		6
	45	3	7	9	4	4	4	4	4	4	3		3
	46	2	5	5	3	2	3	5	3	3	2		3
	47	4	3	4	2	2	4	5	4	3	1		7
	94	1	2	**2**		**1**	1	2	2	**4**	2		**2**
	95	4	14	11	4	4	4	4	4	4	4		**4**
	96	**12**	12	**13**	1	1	3	2	4	**4**			
GBK	*54*		**3**	3	3	**6**	3	3	3	**3**			
	55	3	**3**	**3**	3	1	3	3	3	2	2		**2**
	57			**2**	2	1	2	5	2	2	2		**2**
	59	1	4	**5**	1	2	6	5	5	4	5		**5**
	61	8	1	**6**	5	**12**	7	6	6	6	6		**6**
	65			**3**	3	**5**	2	4	3	**4**	1		**1**
	67		**5**	5	5	7	7	7	7	**7**			
	68	**1**	**8**	7	3	6	6	5	5	**5**			
	69	2	5	**11**	6	6	6	7	6	8	**8**		
	70	1	2	**6**	4	**8**	4	4	4	3	2		**2**
	71		**2**	2	3	1	2	3	3	1	2		**2**
	72	2	**10**	8	1	8	8	8	8	6	**6**		
	73	1	1	**4**	3	6	6	6	6	5	6		**6**
	74	3	**4**	1	3	**7**	4	4	4	3	3		**3**

Table C10. Bad tows identified using objective criteria in the 2005 survey and by eye in the 2002 survey using sensor data.

Statistic	2005	2002
All tows		
Total	433	556
N examined	399	213
% examined	92%	38%
Number w/poor dredge performance	33	32
Proportion w/poor dredge perfomance	0.08	0.15
Depletion tows only		
Total	*30*	*75*
N examined (estimate)	28	29
Number bad	8	10
Proportion w/poor dredge perfomance		
Assuming 100% examined*	27%	13%
Expanded based on % reviewed	29%	35%

* Minimal estimate assuming that all depletion tows were examined

Table C11. NEFSC clam survey data for surfclam abundance (mean N/tow) and biomass (mean KG/tow). Data are for two size groups: small recruits (50-119 mm SL) and large fishable (120+ mm SL). Survey holes (strata with no sampling) were filled by borrowing but no imputed survey data were used.

Region	Year	Small recruits (50-119 mm SL) N / Tow	CV	KG / Tow	CV	Large fishable (120+ mm SL) N / Tow	CV	KG / Tow	CV	N Tows	N Positive Tows	N Strata Sampled
SVA	1982	3.529	0.88	0.134	0.91	0.920	1.00	0.257	0.87	25	5	5
SVA	1983	6.600	0.62	0.249	0.64	0.620	1.00	0.405	0.60	30	9	5
SVA	1984	7.849	0.37	0.303	0.40	0.310	1.00	1.609	0.30	44	16	5
SVA	1986	1.498	0.35	0.058	0.41	0.750	1.00	1.553	0.74	23	11	6
SVA	1989	3.109	0.75	0.083	0.71	0.830	1.00	0.758	0.82	32	10	6
SVA	1992	18.151	0.86	0.760	0.90	0.770	1.00	0.812	0.79	33	17	6
SVA	1994	43.379	0.46	0.784	0.31	0.440	1.00	0.427	0.38	33	19	6
SVA	1997	10.309	0.44	0.294	0.46	0.460	1.00	0.030	0.44	32	14	6
SVA	1999	9.317	0.41	0.234	0.35	0.460	1.00	0.084	0.47	47	19	6
SVA	2002	13.693	0.61	0.360	0.62	0.550	1.00	0.399	0.55	15	5	3
SVA	2005	3.646	0.66	0.051	0.57	.	0.00	0.000	.	14	4	3
DMV	1982	157.134	0.46	6.621	0.44	21.360	0.23	2.687	0.29	68	37	9
DMV	1983	30.679	0.54	1.534	0.61	31.205	0.46	3.168	0.35	61	30	9
DMV	1984	184.102	0.74	5.247	0.61	34.911	0.28	3.555	0.28	79	47	9
DMV	1986	58.771	0.43	3.120	0.46	74.792	0.38	6.703	0.32	70	44	9
DMV	1989	16.705	0.54	0.813	0.55	31.237	0.26	3.065	0.24	78	37	9
DMV	1992	13.494	0.28	0.580	0.38	28.855	0.29	2.918	0.24	77	52	9
DMV	1994	68.704	0.33	2.787	0.43	60.964	0.21	5.958	0.20	83	63	9
DMV	1997	77.184	0.17	3.346	0.20	54.528	0.24	4.928	0.22	82	61	9
DMV	1999	29.612	0.28	1.543	0.28	26.363	0.22	2.406	0.20	78	44	9
DMV	2002	16.467	0.28	0.594	0.28	20.698	0.21	2.235	0.19	81	50	9
DMV	2005	6.437	0.42	0.252	0.43	4.757	0.26	0.508	0.28	74	40	9
NJ	1982	33.102	0.30	1.787	0.31	32.777	0.22	4.084	0.20	85	50	10
NJ	1983	27.780	0.51	1.627	0.55	25.382	0.22	3.147	0.20	85	54	10
NJ	1984	15.932	0.23	0.714	0.22	29.970	0.20	3.731	0.18	126	68	10
NJ	1986	10.335	0.21	0.493	0.20	29.677	0.18	4.172	0.18	91	59	10
NJ	1989	9.877	0.29	0.489	0.31	31.527	0.15	4.160	0.13	99	60	10
NJ	1992	16.462	0.33	0.849	0.42	23.221	0.16	3.193	0.15	98	62	10
NJ	1994	67.394	0.20	2.664	0.18	82.766	0.17	11.014	0.16	103	84	10
NJ	1997	17.910	0.16	1.012	0.17	83.720	0.13	11.442	0.12	112	83	10
NJ	1999	8.021	0.25	0.389	0.28	50.578	0.21	6.903	0.17	120	77	10
NJ	2002	10.678	0.16	0.464	0.16	35.035	0.17	5.503	0.17	115	94	10
NJ	2005	7.808	0.20	0.397	0.22	19.090	0.18	2.818	0.17	92	60	10
LI	1982	0.032	1.00	0.002	1.00	3.994	0.61	0.641	0.62	29	1	7
LI	1983	0.175	0.61	0.005	0.60	0.407	0.72	0.055	0.72	29	3	7
LI	1984	0.561	0.30	0.021	0.36	1.635	0.34	0.248	0.34	55	12	7
LI	1986	0.581	0.39	0.022	0.40	1.715	0.61	0.285	0.61	29	7	7
LI	1989	2.237	0.87	0.089	0.88	3.484	0.72	0.475	0.74	28	4	7
LI	1992	5.733	0.44	0.301	0.47	2.544	0.33	0.275	0.32	28	9	7
LI	1994	4.232	0.17	0.213	0.20	7.243	0.19	0.901	0.21	32	11	7
LI	1997	1.444	0.49	0.082	0.53	4.171	0.64	0.563	0.63	28	6	7
LI	1999	1.608	0.64	0.047	0.50	10.710	0.65	1.433	0.61	30	8	7
LI	2002	0.854	0.45	0.034	0.44	1.944	0.67	0.304	0.67	29	7	7
LI	2005	1.415	0.34	0.060	0.38	12.624	0.50	1.658	0.47	29	7	7
SNE	1982	2.584	0.29	0.112	0.35	12.402	0.41	1.776	0.42	42	14	9
SNE	1983	0.839	0.40	0.040	0.44	7.883	0.39	1.267	0.39	54	18	9
SNE	1984	0.810	0.36	0.034	0.43	10.838	0.34	1.676	0.34	63	18	9
SNE	1986	1.115	0.14	0.027	0.26	4.125	0.68	0.644	0.69	25	8	8
SNE	1989	1.178	0.43	0.044	0.44	4.569	0.33	0.687	0.33	29	10	9
SNE	1992	1.147	0.56	0.032	0.51	2.491	0.58	0.399	0.58	31	9	9
SNE	1994	1.265	0.52	0.061	0.58	1.693	0.53	0.265	0.54	38	10	9
SNE	1997	2.947	0.31	0.120	0.35	12.279	0.30	1.913	0.30	34	13	9
SNE	1999	2.601	0.42	0.089	0.47	4.296	0.66	0.725	0.66	34	15	9
SNE	2002	1.006	0.69	0.057	0.72	3.852	0.27	0.601	0.22	24	5	8
SNE	2005	0.261	0.49	0.008	0.51	1.986	0.19	0.355	0.19	30	6	8
GBK	1986	19.998	0.79	0.719	0.78	4.967	0.52	0.708	0.55	44	20	14
GBK	1989	5.214	0.34	0.285	0.42	24.858	0.73	3.004	0.73	75	36	14
GBK	1992	15.535	0.40	0.706	0.46	7.894	0.33	0.956	0.34	66	43	14
GBK	1994	30.010	0.33	1.610	0.34	45.843	0.39	5.853	0.41	70	47	14
GBK	1997	58.550	0.31	3.002	0.33	23.517	0.25	2.730	0.25	65	45	14
GBK	1999	24.014	0.41	1.340	0.41	29.590	0.31	3.385	0.30	59	34	14
GBK	2002	22.093	0.52	1.163	0.54	27.052	0.43	3.250	0.41	43	21	11

C:\Assessments\Surfclam2006\Surveys\Trends\[SurveyTrends-20.xls]Table 1.

Table C12. Original mean kg/tow for surfclam in regions that had strata with remaining holes and mean kg/tow with remaining holes filled. Remaining holes were filled with imputed values from a negative binomial GLM model. Estimates of mean kg/tow for swept area biomass were computed from estimates for trends using the mean ratio of doppler and sensor distances during 1997-2005 for each region.

Cruise	Region	Mean kg/tow for trends		Mean kg/tow for swept-area biomass		CV for trends	
		Imputed	Original	Imputed	Original	Imputed	Original
198204	GBK	0.059				0.219	
198204	SVA	0.243	0.257			0.874	0.870
198305	GBK	0.485				0.678	
198305	SVA	0.383	0.405			0.597	0.600
198403	SVA	1.522	1.609			0.296	0.300
198604	SNE	0.609	0.680			0.688	0.690
200206	GBK	3.411	3.250	1.847	1.890	0.349	0.410
200206	SNE	0.715	0.601	0.418	0.396	0.264	0.220
200206	SVA	0.263	0.399	0.157	0.268	0.517	0.550
200507	SNE	0.317	0.355	0.185	0.224	0.190	0.190
200507	SVA	0.000	0.000	0.000	0.000	310	

Table C13. Summary of commercial dredge efficiency, population density and negative binomial parameter *k* estimates from the Patch model, setup tow densities and NEFSC survey dredge efficiency estimates from setup tows, by year. All estimates are for surfclam 150+ mm SL.

Statistic	N successful experiments	Population Density ($N\ ft^{-2}$)	Depletion Vessel Efficiency	*k*	Setup Density ($N\ ft^{-2}$)	NEFSC Dredge Efficiency
			1997			
Mean		0.023	0.79	4.758	0.0061	0.317
Median		0.017	0.89	3.261	0.0069	0.27
Lower 80% bound		0.012	0.613	3.134	0.0049	0.225
Upper 80% bound		0.033	0.967	6.382	0.0072	0.409
SE		0.007	0.115	1.059	0.0008	0.06
CV (SE / Mean)	5	0.296	0.146	0.223	0.1281	0.189
			1999			
Mean		0.035	0.652	20.534	0.0061	0.189
Median	6	0.025	0.726	12.841	0.0058	0.199
Lower 80% bound	commercial	0.024	0.469	10.137	0.0051	0.13
Upper 80% bound	depletion, 5	0.046	0.835	30.93	0.007	0.248
SE	with setup	0.007	0.124	7.044	0.0006	0.039
CV (SE / Mean)	tows	0.211	0.19	0.343	0.1012	0.205
			2002			
Mean		0.014	0.584	16.792	0.007	0.516
Median		0.014	0.584	16.792	0.007	0.516
Lower 80% bound		0.012	-0.268	-26.157	-0.0032	-0.282
Upper 80% bound		0.016	1.437	59.74	0.0173	1.313
SE		0.001	0.277	13.955	0.0033	0.259
CV (SE / Mean)	2	0.038	0.474	0.831	0.474	0.503
			2004			
Mean		0.024	0.736	5.939	NA	NA
Median		0.024	0.736	5.939	NA	NA
Lower 80% bound	2	0.004	0.517	0.22	NA	NA
Upper 80% bound	commercial	0.043	0.955	11.658	NA	NA
SE	depletion	0.006	0.071	1.858	NA	NA
CV (SE / Mean)	experiments	0.268	0.097	0.313	NA	NA
			2005			
Mean		0.037	0.717	4.078	0.005	0.158
Median		0.034	0.676	4.593	0.005	0.158
Lower 80% bound		0.023	0.551	3.121	0.004	0.105
Upper 80% bound		0.051	0.882	5.035	0.006	0.21
SE		0.008	0.101	0.584	0	0.032
CV (SE / Mean)	4	0.229	0.141	0.143	0.084	0.203
			All years			
Mean		0.029	0.704	10.988	0.006	0.262
Median		0.025	0.765	5.676	0.006	0.226
Lower 80% bound	19	0.024	0.628	7.073	0.005	0.203
Upper 80% bound	commercial	0.033	0.779	14.903	0.007	0.32
SE	depletion,	0.004	0.057	2.943	0	0.044
CV (SE / Mean)	16 with setup tows	0.128	0.081	0.268	0.076	0.168

Table C14. Summary of depletion experiments, setup tows, Patch model estimates, and survey dredge efficiency estimates for surfclam. All depletion results are for surfclam 150+ mm SL. Depletion experiments *by R/V Delaware II* are not shown.

Experiment and Study Area							Depletion Tows					Patch Model						Survey setu p tows				
Experiment Name	Original Name	Region	Approx. latitude (decimal degrees)	Approx. longitude (decimal degrees)	Depth (m)	Mean Sediment Size (microns)	Depletion Study Vessel	Depletion Date	Ship Position Data (source / nominal accuracy / time interval)	Depletion tows: N used, [N with bushel count and length samples]	Depletion vessel blade width (ft)	Cell size (ft)	Population Density (*D*, >=150 mm SL, N ft^{-2})	Depletion vessel efficiency (*E*, fully recruited, >= 150 mm SL)	Negative binomial parameter (*K*)	Gamma (indirect effects, γ)	Goodness of fit (-log likelihood)	Survey id, [station id] (N tows) {N tows with length data}	Catch density (*d*, >= 150 mm SL, N ft^{-2})	CV for catch density (se / mean)	NEFSC survey dredge efficiency (*e*, fully recruited)	Notes
SC1997-2	PP-1	NNJ (Pt. Pleasant)	40.05317	73.83917	26		Sherri Ann	6/9/1997	Loran / 9-12 M / 1 Minute	39 [9]	8.33	16.67	0.0492	0.3540	7.5313	0.5	210.3	199703 [183-190] (8) {4}	0.0081	0.1498	0.1645	Forty depletion tows total but tow 1 (and samples) omitted. Setup tows during calibration survey 199703 prior to 199704 clam survey.
SC1997-3	AC2-1	NNJ (Atlantic City)	39.39317	73.91033	30		Jersey Girl	6/10/1997	Loran / 9-12 M / 1 Minute	13 [4]	10.83	21.67	0.0172	0.7646	2.6272	0.5	66.1	199703 [169, 175-181] (8) {8}	0.0042	0.1011	0.2463	Setup tows during calibration survey 199703 prior to 199704 clam survey.
SC1997-4	AC2-2	NNJ (Atlantic City)	39.39317	73.91033	30		Jersey Girl	6/10/1997	Loran / 9-12 M / 1 Minute	31 [4]	10.83	21.67	0.0157	0.9900	3.2368	0.5	95.8	Same as SC1997-2	0.0042	0.1011	0.2698	Setup tows during calibration survey 199703 prior to 199704 clam survey.
SC1997-5	AC1-1	NNJ (Atlantic City)	31.36500	73.89833	30		Judy Marie	6/11/1997	Loran / 9-12 M / 1 Minute	17 [4]	8.33	16.67	0.0137	0.9500	3.2606	0.5055	86.9	199703 [166-168, 170-174] (8) {8}	0.0069	0.1173	0.5016	Same as above plus -> Previous analyses at SAW-26 (NEFSC 1998) omitted depletion tow 10, which was included here
SC1997-6	AC1-2	NNJ (Atlantic City)	39.36500	73.89833	30		Judy Marie	6/11/1997	Loran / 9-12 M / 1 Minute	19 [4]	8.33	16.67	0.0171	0.8902	7.1339	0.5	99.2	Same as SC1997-5}	0.0069	0.1173	0.4022	Same as above plus -> Previous analyses at SAW-26 (NEFSC 1998) omitted depletion tows 17 and 19, which were included here
SC1999-2	JG-1 (S99 5)	NNJ	39.68133	73.74667	24	0.88	Jersey Girl	9/14/1999	Loran / 9-12 M / 1 Minute	4 [1]	10.83	21.67	0.0249	0.8453	10.2855	0.5	21.5	199903 [105-108] (4) {4}	0.0075	0.2273	0.3004	
SC1999-3	JG-2 (s99-5)	NNJ	39.68133	73.74667	24	0.88	Jersey Girl	9/14/1999	Loran / 9-12 M / 1 Minute	5 [2]	10.83	21.67	0.0631	0.4625	9.3468	0.5	30.0	Same as SC1999-2	0.0075	0.2273	0.1186	
SC1999-4	JG-3 (S99 6)	NNJ	39.52133	73.77867	26	0.67	Jersey Girl	9/14/1999	Loran / 9-12 M / 1 Minute	6 [2]	10.83	21.67	0.0251	0.9900	15.3974	0.5	31.5	199903 [112-115] (4) {4}	0.0050	0.1398	0.1990	
SC1999-5	CH-1 (S99 DEII)	DMV	36.90200	74.97583	35	1.13	Christy	9/25/1999	Loran / 9-12 M / 1 Minute	28 [6]	10.83	21.67	0.0193	0.1641	5.6765	0.5	92.8	19903 [367-370] (4) {0}				No length data for setup tows
SC1999-6	MJ-1 (s99-3, NJ Inshore Site 1)	NNJ	39.56333	73.91167	26	1.08	Melissa J	9/28/1999	Loran / 9-12 M / 1 Minute	4 [1]	10.83	21.67	0.0245	0.8357	32.4987	0.5	18.7	199903 [82-85] (4) {4}	0.0058	0.4363	0.2374	Sarc31 list Blade at 13
SC1999-7	MJ-1 (s99-3, NJ Inshore Site 2)	NNJ	39.76800	73.91633	24	3.85	Melissa J	9/28/1999	Loran / 9-12 M / 1 Minute	10 [2]	10.83	21.67	0.0513	0.6164	49.9988	0.5	52.2	199903 [88-90] (3) {3}	0.0046	0.1742	0.0888	Sarc31 list Blade at 13
SC2002-2	SC02-2	NNJ	40.10908	73.84423	38	0.43	Jersey Girl	8/20/2002	GPS-D/3M/2 sec.	16 [3]	10.83	21.67	0.0144	0.8610	30.7464	0.5	74.1	200206 [87-91] (5) {1}	0.0037	0.2774	0.2563	
SC2002-3	SC02-3	SNJ	39.26923	73.78116	31	1.12	Jersey Girl	8/19/2002	GPS-D/3M/2 sec.	19 [see footnote]	10.83	21.67	0.0134	0.3071	2.8366	0.5	88.3	200206 [202-206] (5) {4}	0.0104	0.6116	0.7748	Depletion tows: 1) bushel count for tow 1 only (tows 2-19 had catch < 1 bu); 2) clams counted for all tows because catches were low; and 3) lengths measured for 10 for tows. Setup tows: zero clams caught at setup tow (station 206); only two clams measured at station 205
SC2002-4	SC02-4	DMV	38.85791	74.40888	31	0.48	Jersey Girl	8/20/2002	GPS-D/3M/2 sec.	18 [4]	10.83	21.67						200206 [335-339] (5) {1}				Zero clams >= 150 mm in tows 1-3, very low and variable catches in other tows.
SC2004-1	SC04-1	NJ	39.28611	73.87778	35		Lisa Kim	4/8/2004	GPS-D/3M/2 sec.	24 [5] (see note)	10	20.00	0.0301241	0.8072	4.0810	0.5000	130.753					200416 Cooperative Survey (shakedown leg) stations 15-38
SC2004-2	SC04-2	NJ	39.58278	74.02778	21		Lisa Kim	4/8/2004	GPS-D/3M/2 sec.	20 [4] (see note)	10	20.00	0.017376	0.6646	7.7973	0.5000	102.320					200416 Cooperative Survey (shakedown leg) stations 49-68
SC2004-3	SC04-3	DMV	38.27075	74.37920	38		Lisa Kim	7/3/2004	GPS-D/3M/10 sec.	20 [4] (see note)	10	20.00										200416 Cooperative Survey stations146-165; zero clams >= 150 mm in tow 1, very low and variable catches in other tows.
SC2005-2	SC05-02	NNJ	39.56383	73.90364	24	0.29	Lisa Kim	9/7/2005	GPS / 6 ft / 6 sec	17 [3]	10.00	20.00	0.0407	0.7633	4.7110	0.5	98.5	200507 [137, 377-381] (6) {5}	0.004	0.3635	0.1035	
SC2005-3	SC05-03	NNJ	39.89733	73.90591	38	0.24	Lisa Kim	9/8/2005	GPS / 6 ft / 6 sec	20 [4]	10.00	20.00	0.0590	0.5879	4.7883	0.5	120.6	200507 [21, 384-387] (5) {3?}	0.006	0.2999	0.1008	
SC2005-4	SC05-04	DMV	39.56972	73.54946	41	0.20	Lisa Kim	9/9/2005	GPS / 6 ft / 6 sec	20 [4]	10.00	20.00	0.0264	0.5341	4.4756	0.5	104.5	200507 [41, 391-393, 395] (5) {3}	0.006	0.2597	0.2143	
SC2005-5	SC05-05	NNJ	39.43615	73.37320	33	0.28	Lisa Kim	9/10/2005	GPS / 6 ft / 6 sec	17 [4]	10.00	20.00	0.0212	0.9823	2.3360	0.5	96.1	200507 [143, 397-402] (7) {5}	0.004	0.1809	0.2119	
SC2005-6	SC05-01	NNJ	38.26530	74.37947	26	0.19	Lisa Kim	9/7/2005	GPS / 6 ft / 6 sec	20 [4]	10.00	20.00						200507 [123-127, 354] (6) {6}				Low catches >= 150 mm SL in setup and depletion tows (less than 6% of total).

Table C15. Sensitivity analysis to determine effects of smoothing position data on Patch model estimates for surfclam 150+ mm SL. Model runs were preliminary.

Smoothing	Density	Efficiency	K	Gamma	Goodness of fit to catch data (-log-likelihood)	Area swept (ft^2)	Effective area swept (ft^2)	Number stations	Number position observations	Mean Observations per station	Shape of tow tracks based on original position data	Type Smooth
SC1997-4												
No	0.0147	0.99	3.42	0.50	95.38	296,196	134,886	18	107	5.9	Curved, stair step	Linear or cubic polynomial
Yes	0.0157	0.99	3.24	0.50	95.82	288,202	133,535					
% Difference	-7%	0%	6%	0%	0%	3%	1%					
SC1999-2												
No	0.0206	0.95	21.53	0.50	20.22	53,854	35,480	4	46	11.5	Linear, stair step	Quadratic polynomial
Yes	0.0249	0.85	10.29	0.50	21.54	52,268	30,236					
% Difference	-17%	12%	109%	0%	-6%	3%	17%					
SC2002-2												
No	0.0134	0.94	30.21	0.50	74.42	279,668	162,865	16	2664	166.5	Linear or curved,	Spline
Yes	0.0144	0.86	30.75	0.50	74.13	276,021	152,182					
% Difference	-7%	9%	-2%	0%	0%	1%	7%					
SC2005-2												
No	0.0350	0.93	5.35	0.50	97.55	287,369	117,195	17	905	53.2	Curved, wavy	Spline
Yes	0.0407	0.76	4.71	0.50	98.55	283,682	100,759					
% Difference	-14%	22%	14%	0%	-1%	1%	16%					

Table C16. NEFSC survey dredge efficiency estimates for surfclam in the 1997-2005 NEFSC clam surveys (revised and values used in the last assessment). CVs are the standard error / mean. "NA" means not available. Efficiency estimates shown in the table are averages, not medians.

Survey year	Revised (Patch model & setup tows)			From previous assessment (various types of estimates, NEFSC 2003)		
	Efficiency	CV	N	Efficiency	CV	N
1997	0.317	0.19	5	0.460	0.471	4
1999	0.189	0.20	5	0.276	0.349	5
2002	0.516	0.50	3	0.389	0.523	6
2005	0.158	0.20	5	NA	NA	NA
All	0.262	0.17	18	0.370	0.492	15

Table C17. Efficiency corrected swept-area biomass estimates (1000 mt) and CVs for the fishable stock of surfclam during 1997-2005 by stock assessment region. Figures for SVA and GBK during 2005 were taken from 2003 because no data were available for 2005.

	Estimate	CV
INPUT: Nominal tow distance (d_n, *nm*)	0.15	
INPUT: Dredge width (nm)	0.0008225	
Area swept per standard tow (a, nm^2)	1.23375E-04	10%

Area of assessment region (A, nm^2) - no correction for stations with unsuitable clam habitat

	Estimate	CV
S. Virginia and N. Carolina (SVA)	3,119	10%
Delmarva (DMV)	4,660	10%
New Jersey (NJ)	5,078	10%
Long Island (LI)	2,917	10%
Southern New England (SNE)	4,321	10%
Georges Bank (GBK)	5,772	10%
Total	25,867	

INPUT: Fraction suitable habitat (u)

	Estimate	CV
S. Virginia and N. Carolina (SVA)	100%	10%
Delmarva (DMV)	100%	10%
New Jersey (NJ)	100%	10%
Long Island (LI)	100%	10%
Southern New England (SNE)	100%	10%
Georges Bank (GBK)	88%	10%

Habitat area in assessment region (A', nm2)

	Estimate	CV
S. Virginia and N. Carolina (SVA)	3,119	14%
Delmarva (DMV)	4,660	14%
New Jersey (NJ)	5,078	14%
Long Island (LI)	2,917	14%
Southern New England (SNE)	4,321	14%
Georges Bank (GBK)	5,079	14%

INPUT: Biomass fraction in unsurveyd deep water

	Estimate	CV
S. Virginia and N. Carolina (SVA)	0%	10%
Delmarva (DMV)	0%	10%
New Jersey (NJ)	0%	10%
Long Island (LI)	0%	10%
Southern New England (SNE)	0%	10%
Georges Bank (GBK)	0%	10%

INPUT: Original survey mean catch from fishable stock (kg/tow, for tows adjusted to nominal tow distance using sensors)

	Estimates for 1997	CV	Estimates for 1999	CV	Estimates for 2002	CV	Estimates for 2005	CV
S. Virginia and N. Carolina (SVA) 120+ mm	0.0142	43%	0.0532	52%	0.2676	58%	0.2676	58%
Delmarva (DMV) 120+ mm	2.3751	22%	1.4130	20%	2.2406	20%	0.4038	30%
New Jersey (NJ) 120+ mm	5.8453	12%	4.0036	17%	3.5823	16%	2.1776	17%
Long Island (LI) 120+ mm	0.3179	66%	0.7895	53%	0.1849	64%	1.9644	37%
Southern New England (SNE) 120+ mm	0.8868	32%	0.4839	67%	0.4180	26%	0.1851	***19%***
Georges Bank (GBK) 120+ mm	1.5228	25%	2.0445	31%	1.8469	35%	1.8469	35%

Swept-area biomass without efficiency correction (B', 1000 mt):

	1997	CV	1999	CV	2002	CV	2005	CV
S. Virginia and N. Carolina (SVA) 120+ mm	0.3597	47%	1.3447	56%	6.7651	61%	6.7651	61%
Delmarva (DMV) 120+ mm	89.7081	30%	53.3720	28%	84.6301	28%	15.2519	36%
New Jersey (NJ) 120+ mm	240.5850	23%	164.7861	26%	147.4441	26%	89.6280	26%
Long Island (LI) 120+ mm	7.5155	69%	18.6664	57%	4.3707	67%	46.4441	42%
Southern New England (SNE) 120+ mm	31.0590	38%	16.9471	70%	14.6411	33%	6.4817	28%
Georges Bank (GBK) 120+ mm	62.6950	32%	84.1714	37%	76.0380	40%	76.0380	40%
Total fishable biomass less GBK	369	17%	255	19%	258	18%	165	19%
Total fishable biomass	432	15%	339	17%	334	16%	241	18%

	1997	CV	1999	CV	2002	CV	2005	CV
INPUT: Survey dredge efficiency (e)	0.226	17%	0.226	17%	0.226	17%	0.226	17%

Efficiency adjusted swept area fishable biomass (B, 1000 mt)

	1997	CV	1999	CV	2002	CV	2005	CV
S. Virginia and N. Carolina (SVA) 120+ mm	1.593	50%	5.955	58%	29.961	64%	29.961	64%
Delmarva (DMV) 120+ mm	397	34%	236	33%	375	33%	68	40%
New Jersey (NJ) 120+ mm	1,065	29%	730	31%	653	31%	397	31%
Long Island (LI) 120+ mm	33	71%	83	59%	19	69%	206	45%
Southern New England (SNE) 120+ mm	138	41%	75	72%	65	37%	29	32%
Georges Bank (GBK) 120+ mm	278	36%	373	41%	337	44%	337	44%
Total fishable biomass less GBK	1,635	24%	1,130	25%	1,142	24%	729	25%
Total fishable biomass	1,913	23%	1,503	24%	1,479	23%	1,066	25%

Lower bound for 80% confidence intervals on fishable biomass (1000 mt, for lognormal distribution with no bias correction)

	Estimates for 1997	Estimates for 1999	Estimates for 2002	Estimates for 2005
S. Virginia and N. Carolina (SVA) 120+ mm	0.867	2.983	14.208	14.208
Delmarva (DMV) 120+ mm	260	157	249	41
New Jersey (NJ) 120+ mm	743	494	445	269
Long Island (LI) 120+ mm	15	41	9	118
Southern New England (SNE) 120+ mm	83	33	41	19
Georges Bank (GBK) 120+ mm	177	226	197	197
Total fishable biomass less GBK	1,207	821	840	529
Total fishable biomass	1,434	1,112	1,100	780

Upperbound for 80% confidence intervals on fishable biomass (1000 mt, for lognormal distribution with no bias correction)

	1997	1999	2002	2005
S. Virginia and N. Carolina (SVA) 120+ mm	2.926	11.888	63.180	63.180
Delmarva (DMV) 120+ mm	608	356	565	110
New Jersey (NJ) 120+ mm	1,528	1,078	958	586
Long Island (LI) 120+ mm	75	167	43	358
Southern New England (SNE) 120+ mm	229	172	103	43
Georges Bank (GBK) 120+ mm	435	614	574	574
Total fishable biomass less GBK	2,215	1,555	1,552	1,004
Total fishable biomass	2,551	2,031	1,988	1,456

Table C18. Fishing mortality estimates for surfclams based on catch and efficiency corrected swept-area biomass for fishable surfclams during 1997, 1999, 2002 and 2005.

INPUT: Upper bound incidental mortality allowance	12%			
INPUT: Assumed CV for catch	10%			

INPUT: Landings (1000 mt, discard ~ 0)	**Estimates for 1997**	**Estimates for 1999**	**Estimates for 2002**	**Estimates for 2005**
S. Virginia and N. Carolina (SVA)	0.000	0.000	0.064	0.000
Delmarva (DMV)	1.540	0.648	4.489	1.668
New Jersey (NJ)	16.998	18.749	18.271	16.850
Long Island (LI)	0.073	0.157	1.130	0.759
Southern New England (SNE)	0.000	0.016	0.052	1.885
Georges Bank (GBK)	0.000	0.000	0.000	0.000
Total	18.611	19.570	24.006	21.163

Catch (1000 mt, landings + upper bound incidental mortality allowance)				
S. Virginia and N. Carolina (SVA)	0.000	0.000	0.072	0.000
Delmarva (DMV)	1.725	0.726	5.028	1.868
New Jersey (NJ)	19.038	20.999	20.463	18.872
Long Island (LI)	0.081	0.176	1.265	0.850
Southern New England (SNE)	0.000	0.018	0.058	2.112
Georges Bank (GBK)	0.000	0.000	0.000	0.000
Total	20.844	21.919	26.886	23.702

INPUT: Efficiency Corrected Swept Area Biomass for Fishable Stock (1000 mt)	**Estimates for 1997**	**CV**	**Estimates for 1999**	**CV**	**Estimates for 2002**	**CV**	**Estimates for 2005**	**CV**
S. Virginia and N. Carolina (SVA) 120+ mm	2	50%	6	58%	30	64%	30	64%
Delmarva (DMV) 120+ mm	397	34%	236	33%	375	33%	68	40%
New Jersey (NJ) 120+ mm	1,065	29%	730	31%	653	31%	397	31%
Long Island (LI) 120+ mm	33	71%	83	59%	19	69%	206	45%
Southern New England (SNE) 120+ mm	138	41%	75	72%	65	37%	29	32%
Georges Bank (GBK) 120+ mm	278	36%	373	41%	337	44%	337	44%
Total fishable biomass less GBK	1,635	24%	1,130	25%	1,142	24%	729	25%
Total fishable biomass	1,913	23%	1,503	24%	1,479	23%	1,066	25%

Fishing mortality (y^{-1})								
S. Virginia and N. Carolina (SVA) 120+ mm	0.0000	51%	0.0000	59%	0.0024	64%	0.0000	64%
Delmarva (DMV) 120+ mm	0.0043	36%	0.0031	34%	0.0134	34%	0.0277	41%
New Jersey (NJ) 120+ mm	0.0179	30%	0.0288	33%	0.0313	32%	0.0475	33%
Long Island (LI) 120+ mm	0.0024	72%	0.0021	60%	0.0654	70%	0.0041	46%
Southern New England (SNE) 120+ mm	0.0000	42%	0.0002	73%	0.0009	38%	0.0736	34%
Georges Bank (GBK) 120+ mm	0.0000	NA	0.0000	NA	0.0000	NA	0.0000	NA
Total fishable biomass less GBK	0.0127	26%	0.0194	27%	0.0235	26%	0.0325	27%
Total fishable biomass	0.0109	25%	0.0146	26%	0.0182	25%	0.0222	27%

Lower bound for 80% confidence intervals for fishing mortality (y^{-1}, for lognormal distribution with no bias correction)	**Estimates for 1997**	**Estimates for 1999**	**Estimates for 2002**	**Estimates for 2005**
S. Virginia and N. Carolina (SVA) 120+ mm	NA	NA	0.0011	NA
Delmarva (DMV) 120+ mm	0.0028	0.0020	0.0087	0.0167
New Jersey (NJ) 120+ mm	0.0122	0.0191	0.0210	0.0316
Long Island (LI) 120+ mm	0.0011	0.0010	0.0292	0.0023
Southern New England (SNE) 120+ mm	NA	0.0001	0.0006	0.0483
Georges Bank (GBK) 120+ mm	NA	NA	NA	NA
Total fishable biomass less GBK	0.0092	0.0138	0.0169	0.0231
Total fishable biomass	0.0080	0.0105	0.0132	0.0159

Upper bound for 80% confidence intervals for fishing mortality (y^{-1}, for lognormal distribution with no bias correction)				
S. Virginia and N. Carolina (SVA) 120+ mm	NA	NA	0.0051	NA
Delmarva (DMV) 120+ mm	0.0068	0.0047	0.0206	0.0458
New Jersey (NJ) 120+ mm	0.0262	0.0433	0.0469	0.0715
Long Island (LI) 120+ mm	0.0056	0.0043	0.1465	0.0073
Southern New England (SNE) 120+ mm	NA	0.0006	0.0014	0.1121
Georges Bank (GBK) 120+ mm	NA	NA	NA	NA
Total fishable biomass less GBK	0.0177	0.0273	0.0328	0.0458
Total fishable biomass	0.0149	0.0202	0.0251	0.0311

Table C19. Patch model estimates for surfclam depletion experiments carried out by the F/V Lisa Kim during 2004-2005.

Statistic	N successful experiments	Population Density (N ft^{-2})	Depletion Vessel Efficiency	*k*	Setup Density (N ft^{-2})	NEFSC Dredge Efficiency
F/V Lisa Kim (2004-2005)						
Mean	6 commercial depletion, 4 with setup tows	0.032	0.723	4.698	0.0051	0.158
Median		0.028	0.714	4.593	0.0051	0.158
Lower 80% bound		0.023	0.625	3.633	0.0044	0.1051
Upper 80% bound		0.042	0.822	5.763	0.0058	0.2101
SE		0.006	0.067	0.722	0.0004	0.032
CV (SE / Mean)		0.192	0.092	0.154	0.0839	0.203

Table C20. Revised surfclam efficiency corrected swept-area abundance and biomass estimates (120+ SL) from the cooperative 2004 clam survey and assuming dredge efficiency *E*=0.714. Estimates from Weinberg et al. (2005) assuming *E*=0.792 are shown for comparison.

Statistics	SVA	DMV	NJ
Revised			
N tows	15	77	110
Mean n/tow	0.143	23.253	71.079
Var	0.012	35.412	82.763
CV	0.78	0.26	0.13
Mean kg/tow	0.011	2.365	10.863
Var	0.000	0.348	1.907
CV	0.81	0.25	0.13
Area (sq nm)	1,074	4,660	5,078
Efficiency	0.714	0.714	0.714
Swept area abundance (10^6 clams)	1.7	1230.3	4098.1
Swept area biomass (mt)	128	125,139	626,302
Weinberg et al. (2005)			
Swept area biomass (mt)	300	143,000	535,000

Table C21. Efficiency corrected swept-area biomass estimates (1,000 mt) for SVA, DMV and NJ, which were covered during the 2004 cooperative surfclam survey.

Region	1997	1999	2002	2004	2005
SVA	1.59	5.96	29.96	0.13	29.96
DMV	397	236	375	125	68
NJ	1,065	730	653	626	397
Total	1,464	972	1,058	752	494

Table C22. Von Bertalanffy growth model parameters for surfclam weight at age in the DMV and NJ regions during 1982-1992 and 1994-2005 based on NEFSC survey data with estimates of meat weight (*W*, grams) and shell length (*L*, mm) at the age of recruitment (*k*), one year before recruitment (*k*-1) and one year after recruitment (*k*+1). The parameters for NJ were also used for the whole stock.

Parameter	NJ		DMV	
	1982-1992	1994-2005	1982-1992	1994-2005
$K\ (y^{-1})$	0.1449		0.1258	
r	0.8651		0.8818	
$t0\ (y)$	1.5365	1.6919	1.5176	1.6026
W_{max}	240.5	206.8	197.4	138.0
Age at recruitment *k* (y)	4.4	5.1	4.8	6.9
W_{k-1}	56.4	61.7	49.5	57.4
W_k	81.3	81.3	66.9	66.9
W_{k+1}	102.8	98.2	82.4	75.3
L_{k-1}	105.7	109.0	107.9	113.7
L_k	120.0	120.0	120.0	120.0
L_{k+1}	130.2	128.2	129.0	125.1
J	0.6945	0.7592	0.7388	0.8578

Table C23. NEFSC survey index trend data (doppler tow distance measurements) used in KLAMZ models for surfclam recruits and for fishable biomass in the whole stock..

	DMV recruit index			NJ recruit index			Whole stock recruit index			Whole stock fishable biomass index			
	Kg/Tow	CV	Size groups (mm SL)	Kg/Tow	CV	Size groups (mm SL)	Kg/Tow	CV	Size groups (mm SL)	Mean kg/tow	Approx. swept area biomass (mt)	CV	Size groups (mm SL)
1982	0.598	0.34	120-129	0.976	0.24	120-129	0.350	0.19	120-129	1.756	1,069	0.15	120+
1983	1.177	0.78	120-129	0.882	0.34	120-129	0.448	0.45	120-129	1.615	983	0.18	120+
1984	0.846	0.3	120-129	0.776	0.27	120-129	0.396	0.18	120-129	2.149	1,308	0.13	120+
1986	3.165	0.53	120-129	0.493	0.29	120-129	0.815	0.43	120-129	2.695	1,641	0.19	120+
1989	0.745	0.31	120-129	0.508	0.2	120-129	0.352	0.22	120-129	2.290	1,395	0.22	120+
1992	0.730	0.57	120-129	0.399	0.28	120-129	0.313	0.3	120-129	1.601	975	0.14	120+
1994	1.328	0.33	120-125	1.536	0.23	120-129	0.792	0.16	120-129	4.613	2,809	0.14	120+
1997	1.933	0.34	120-125	1.060	0.22	120-129	0.790	0.19	120-129	3.989	2,429	0.09	120+
1999	0.989	0.29	120-125	0.707	0.58	120-129	0.550	0.21	120-129	2.717	1,654	0.13	120+
2002	0.380	0.34	120-125	0.242	0.24	120-129	0.296	0.28	120-129	2.481	1,510	0.14	120+
2005	0.075	0.26	120-125	0.193	0.24	120-129	0.101	0.24	120-129	1.339	815	0.17	120+

Table C24. Estimated biomass, recruitment biomass and fishing mortality for the entire surfclam stock from the KLAMZ model. CVs are from 1000 bootstrap iterations.

Year	Biomass (1000 mt)	CV	Recruitment (1000 mt)	CV	Fishing mortality (y^{-1})	CV
1981	1,020	0.26	NA		0.0173	0.25
1982	1,036	0.23	96	0.17	0.0231	0.22
1983	1,059	0.20	110	0.20	0.0229	0.19
1984	1,083	0.18	109	0.17	0.0266	0.17
1985	1,141	0.16	147	0.26	0.0241	0.15
1986	1,225	0.15	170	0.20	0.0231	0.15
1987	1,271	0.14	130	0.30	0.0193	0.15
1988	1,290	0.15	106	0.28	0.0200	0.15
1989	1,289	0.14	93	0.15	0.0187	0.15
1990	1,285	0.15	96	0.31	0.0205	0.15
1991	1,283	0.15	102	0.32	0.0172	0.15
1992	1,290	0.15	109	0.15	0.0184	0.15
1993	1,476	0.13	289	0.30	0.0153	0.14
1994	1,613	0.12	231	0.13	0.0141	0.13
1995	1,709	0.09	201	0.33	0.0119	0.09
1996	1,780	0.07	185	0.32	0.0115	0.08
1997	1,842	0.07	189	0.14	0.0105	0.07
1998	1,824	0.05	116	0.35	0.0104	0.05
1999	1,799	0.04	121	0.17	0.0114	0.04
2000	1,723	0.04	76	0.36	0.0120	0.04
2001	1,628	0.04	62	0.36	0.0142	0.04
2002	1,531	0.04	63	0.18	0.0166	0.04
2003	1,415	0.05	43	0.24	0.0187	0.05
2004	1,292	0.05	32	0.22	0.0199	0.05
2005	1,170	0.06	27	0.16	0.0192	0.06

Table C25. Factors used to scale NEFSC survey trend data (mean kg/tow, 120+ mm, doppler tow distances) to approximate efficiency corrected swept-area biomass (based on sensor distance data and efficiency estimates.

SVA	*DMV*	*NJ*
68.462	119.917	114.584
LI	*SNE*	*GBK*
76.107	89.164	103.414

Table C26. Proportions of total fishable surfclam biomass during 1980-2005 at a range of survey biomass density levels, by region.

Years	Fishable biomass density levels (kg/tow) from survey data: 0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25+	Sum of Proportions (check)	Total Number of Tows	Total Number of Surveys
Proportions of tows (and stock area) at each survey catch rate level:									
			Southern Virgina (SVA)						
1980-1989	0.94	0.03	0.01	0.02	0.01		1.00	154	5
1990-1999	0.99			0.01			1.00	107	3
2000-2005	1.00						1.00	29	2
			Delmarva (DMV)						
1980-1989	0.81	0.10	0.03	0.01	0.01	0.04	1.00	355	5
1990-1999	0.78	0.11	0.05	0.03	0.02	0.02	1.00	237	3
2000-2005	0.90	0.05	0.03	0.01		0.01	1.00	152	2
			New Jersy (NJ)						
1980-1989	0.71	0.12	0.06	0.04	0.02	0.05	1.00	484	5
1990-1999	0.56	0.13	0.10	0.05	0.05	0.11	1.00	330	3
2000-2005	0.69	0.11	0.11	0.03	0.01	0.04	1.00	206	2
			Long Island (LI)						
1980-1989	0.97	0.02	0.01				1.00	170	5
1990-1999	0.95	0.02	0.01		0.01		1.00	86	3
2000-2005	0.93	0.02	0.02	0.04			1.00	57	2
			Southern New England (SNE)						
1980-1989	0.87	0.03	0.05	0.02	0.01	0.02	1.00	202	5
1990-1999	0.90	0.02	0.04		0.01	0.02	1.00	90	3
2000-2005	0.96	0.04					1.00	48	2
			Georges Bank (GBK)						
1986-1992	0.87	0.05	0.03	0.02	0.01	0.02	1.00	126	3
1997-2002	0.79	0.04	0.04	0.02	0.01	0.10	1.00	119	3
All years	0.83	0.04	0.04	0.02	0.01	0.06	1.00	245	6
Mean survey catch rate (kg/tow) at each survey catch rate level (p_L):									
			Southern Virgina (SVA)						
1980-1989	0.267	6.206	11.779	16.929	21.086				
1990-1999	0.119			17.468					
2000-2005	0.171								
			Delmarva (DMV)						
1980-1989	0.853	7.528	11.999	16.412	21.738	50.956			
1990-1999	0.820	7.348	12.039	17.431	22.697	50.709			
2000-2005	0.518	6.800	11.471	17.350		25.869			
			New Jersy (NJ)						
1980-1989	1.018	7.559	12.270	17.662	22.426	52.603			
1990-1999	0.939	7.343	12.017	17.518	22.016	45.320			
2000-2005	1.216	7.215	12.195	15.867	22.468	32.093			
			Long Island (LI)						
1980-1989	0.095	6.554	13.132						
1990-1999	0.240	6.216	11.010		23.237				
2000-2005	0.121	7.404	10.151	17.446					
			Southern New England (SNE)						
1980-1989	0.311	8.573	11.768	18.272	22.628	43.811			
1990-1999	0.118	7.898	12.033		20.543	30.708			
2000-2005	0.640	6.301							
			Georges Bank (GBK)						
1986-1992	0.223	8.360	10.987	17.530	21.017	85.534			
1997-2002	0.500	7.110	10.928	17.167	22.838	40.544			
All years	0.351	7.792	10.954	17.385	21.927	46.971			
Proportions of stock biomass at each survey catch rate level (X_L):									
			Southern Virgina (SVA)						
1980-1989	0.242	0.156	0.148	0.320	0.133		1.00		
1990-1999	0.431			0.569			1.00		
2000-2005	1.000						1.00		
			Delmarva (DMV)						
1980-1989	0.164	0.187	0.072	0.055	0.044	0.478	1.00		
1990-1999	0.162	0.197	0.142	0.131	0.097	0.271	1.00		
2000-2005	0.311	0.233	0.197	0.149		0.111	1.00		
			New Jersy (NJ)						
1980-1989	0.118	0.146	0.119	0.100	0.060	0.457	1.00		
1990-1999	0.055	0.102	0.129	0.094	0.104	0.516	1.00		
2000-2005	0.168	0.161	0.272	0.108	0.044	0.249	1.00		
			Long Island (LI)						
1980-1989	0.255	0.319	0.426				1.00		
1990-1999	0.296	0.187	0.166		0.350		1.00		
2000-2005	0.109	0.126	0.172	0.593			1.00		
			Southern New England (SNE)						
1980-1989	0.101	0.095	0.218	0.135	0.126	0.325	1.00		
1990-1999	0.062	0.102	0.310		0.132	0.395	1.00		
2000-2005	0.700	0.300					1.00		
			Georges Bank (GBK)						
1986-1992	0.067	0.138	0.121	0.145	0.058	0.471	1.00		
1997-2002	0.069	0.052	0.080	0.050	0.034	0.715	1.00		
All years	0.068	0.082	0.094	0.083	0.042	0.630	1.00		

Table C27. Proportions of total 2005 stock biomass at a range of survey density levels, by region.

Region	Survey catch rate level (kg/tow)						
	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25+	Total
	Total 2005 biomass (mt meats)						
Southern Virginia (SVA)	36	0	0	0	0	0	36
Delmarva (DMV)	29	21	18	14	0	10	92
New Jersey (NJ)	61	59	99	39	16	91	365
Long Island (LI)	18	21	29	99	0	0	167
Southern New England (SNE)	28	12	0	0	0	0	40
Georges Bank (GBK)	33	25	38	24	16	336	471
Total	205	138	184	176	32	437	1,170
	Total 2005 biomass (bushels)						
Southern Virginia (SVA)	4,678	0	0	0	0	0	4,678
Delmarva (DMV)	3,713	2,786	2,350	1,777	0	1,325	11,951
New Jersey (NJ)	7,959	7,598	12,843	5,085	2,058	11,755	47,299
Long Island (LI)	2,354	2,721	3,731	12,823	0	0	21,628
Southern New England (SNE)	3,615	1,548	0	0	0	0	5,162
Georges Bank (GBK)	4,218	3,188	4,900	3,079	2,048	43,632	61,065
Total	26,537	17,841	23,823	22,764	4,106	56,712	151,783
	Percent of total 2005 biomass						
Southern Virginia (SVA)	3.082%	0.000%	0.000%	0.000%	0.000%	0.000%	3.082%
Delmarva (DMV)	2.45%	1.84%	1.55%	1.17%	0.00%	0.87%	7.87%
New Jersey (NJ)	5.24%	5.01%	8.46%	3.35%	1.36%	7.74%	31.16%
Long Island (LI)	1.55%	1.79%	2.46%	8.45%	0.00%	0.00%	14.25%
Southern New England (SNE)	2.38%	1.02%	0.00%	0.00%	0.00%	0.00%	3.40%
Georges Bank (GBK)	2.78%	2.10%	3.23%	2.03%	1.35%	28.75%	40.23%
Total	17.48%	11.75%	15.70%	15.00%	2.70%	37.36%	100.00%

Table C28. Example projection results for surfclam showing projected average biomass, and fishing mortality during 2006-2015 under three possible scenarios: i) constant landings at the minimum quota; ii) status-quo landings (i.e. mean landings during 2003 to 2005); iii) constant landings at the maximum quota; and iv) constant fishing mortality at the F_{MSY} proxy = M= 0.15 y^{-1}. CVs measure variability between simulation runs in the projection analysis for a scenario. CVs were similar for each scenario in the same year and the CVs shown in the table are averages for simplicity in presentation.

Year	Landings = min quota = 1.85 million bu	Status quo landings = mean 2003-2005 = 3.042 million bu	Landings = max quota = 3.4 million bu	$F = F_{MSY} = M =$ 0.15	CV
		Catch (landings + 12%, 1000 mt)			
All	16.0	49.7	49.7	variable	NA
		Biomass (1000 mt)			
2005	1,198	1,198	1,198	1,198	251%
2006	1,093	1,093	1,093	1,093	275%
2007	1,010	1,001	998	889	322%
2008	944	925	920	739	417%
2009	892	866	858	632	560%
2010	856	823	813	559	744%
2011	832	793	781	512	944%
2012	820	776	762	485	1150%
2013	819	769	754	472	1350%
2014	826	772	755	470	1532%
2015	839	781	763	474	1679%
		Fishing mortality (annual rate)			
2005	0.0188	0.0188	0.0188	0.0188	255%
2006	0.0156	0.0258	0.0288	0.1500	279%
2007	0.0169	0.0282	0.0317	0.1500	327%
2008	0.0181	0.0306	0.0345	0.1500	412%
2009	0.0193	0.0329	0.0372	0.1500	531%
2010	0.0202	0.0349	0.0396	0.1500	676%
2011	0.0210	0.0367	0.0418	0.1500	836%
2012	0.0216	0.0381	0.0435	0.1500	1009%
2013	0.0220	0.0392	0.0449	0.1500	1187%
2014	0.0222	0.0399	0.0458	0.1500	1369%
2015	0.0223	0.0403	0.0465	0.1500	1551%

SURFCLAM FIGURES

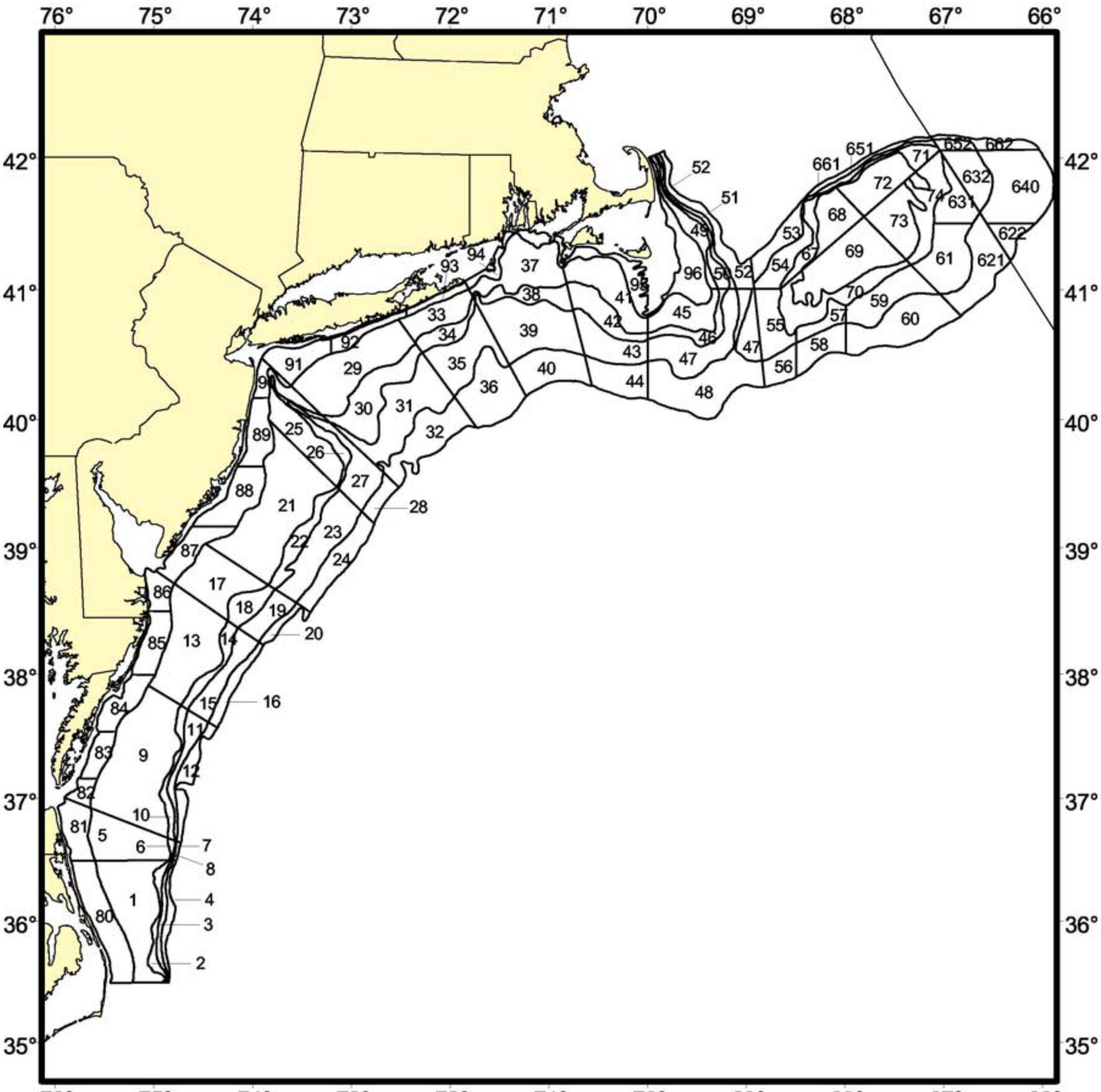
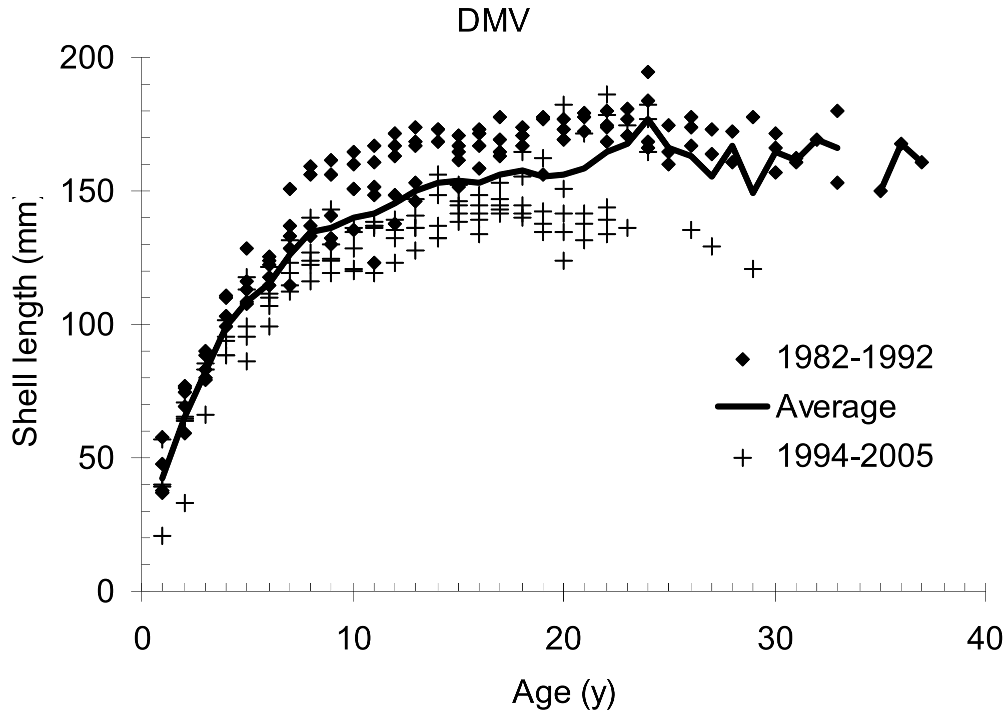


Figure C1. Surfclam stock assessment regions and NEFSC clam survey strata. Northern and southern New Jersey is combined to form the larger New Jersey (NJ) assessment region.



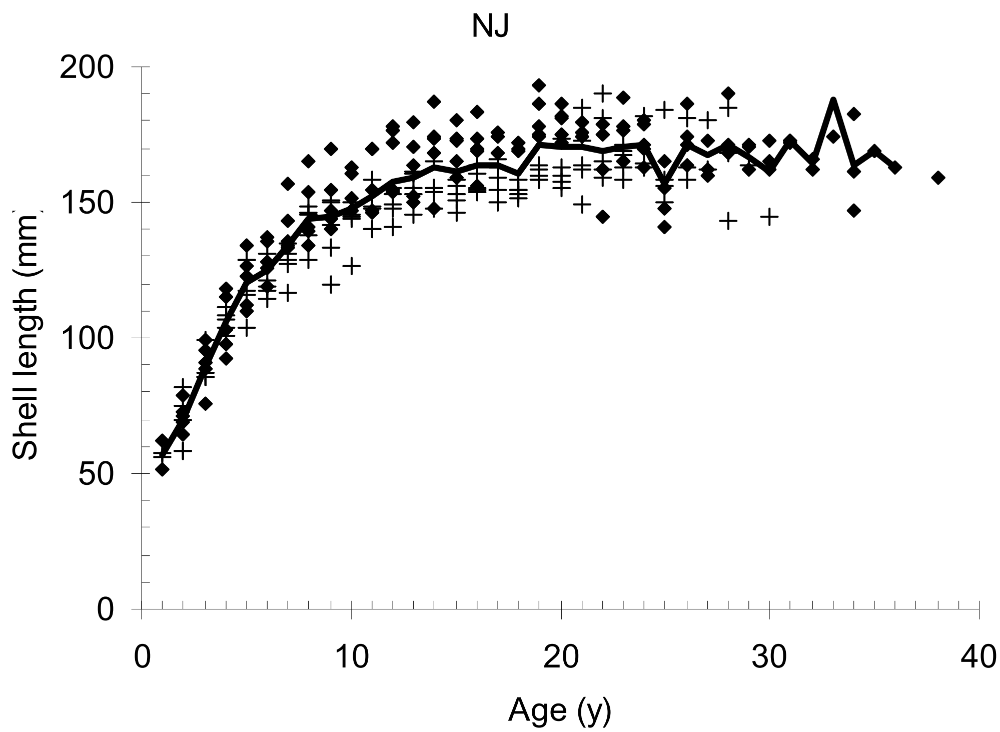


Figure C2. Size at age data for surfclam in DMV and NJ from NEFSC clam surveys during 1982-1992 and 1994-2005. The dark line shows average size at age in all years.

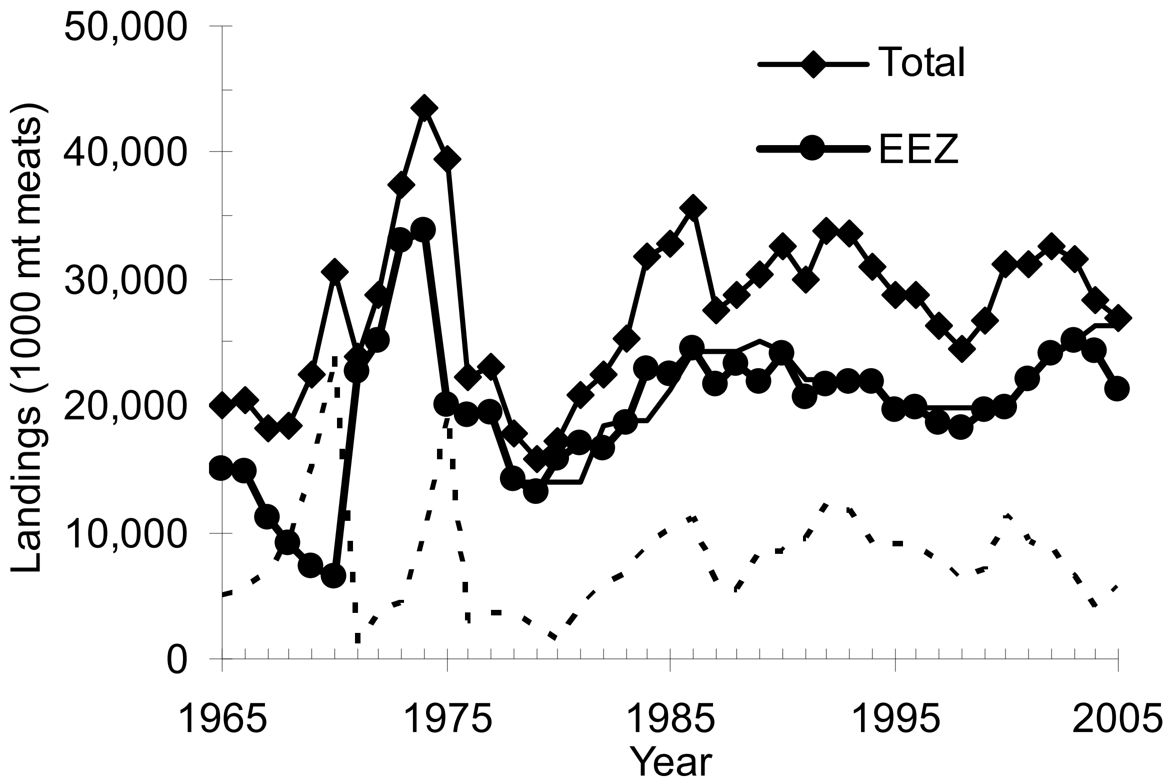


Figure C3. Atlantic surfclam landings and EEZ surfclam quotas (all converted to mt meats).

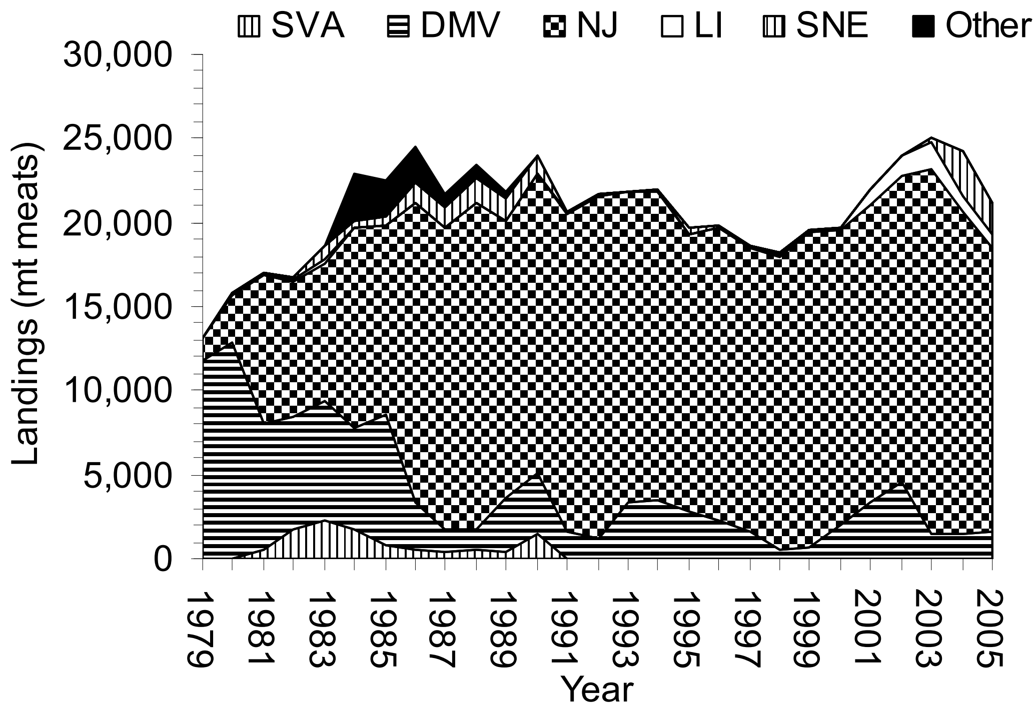


Figure C4. Surfclam landings from the US EEZ during 1979-2005 by stock assessment region.

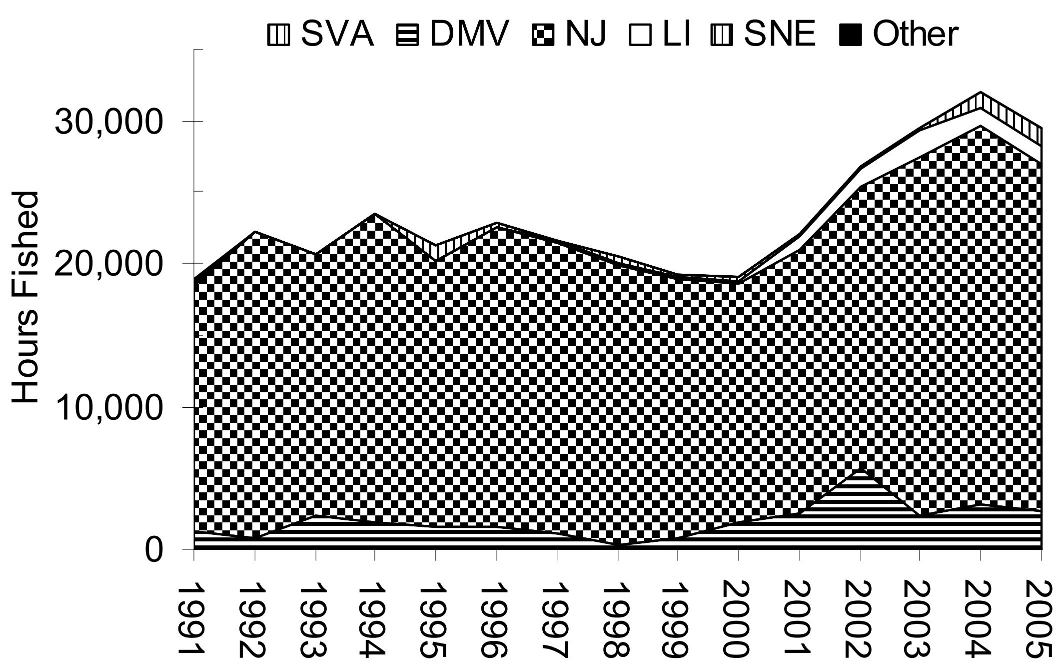


Figure C5. Total fishing effort (hours fished, all trips and all vessels) in the US EEZ during 1991-2005 by stock assessment region.

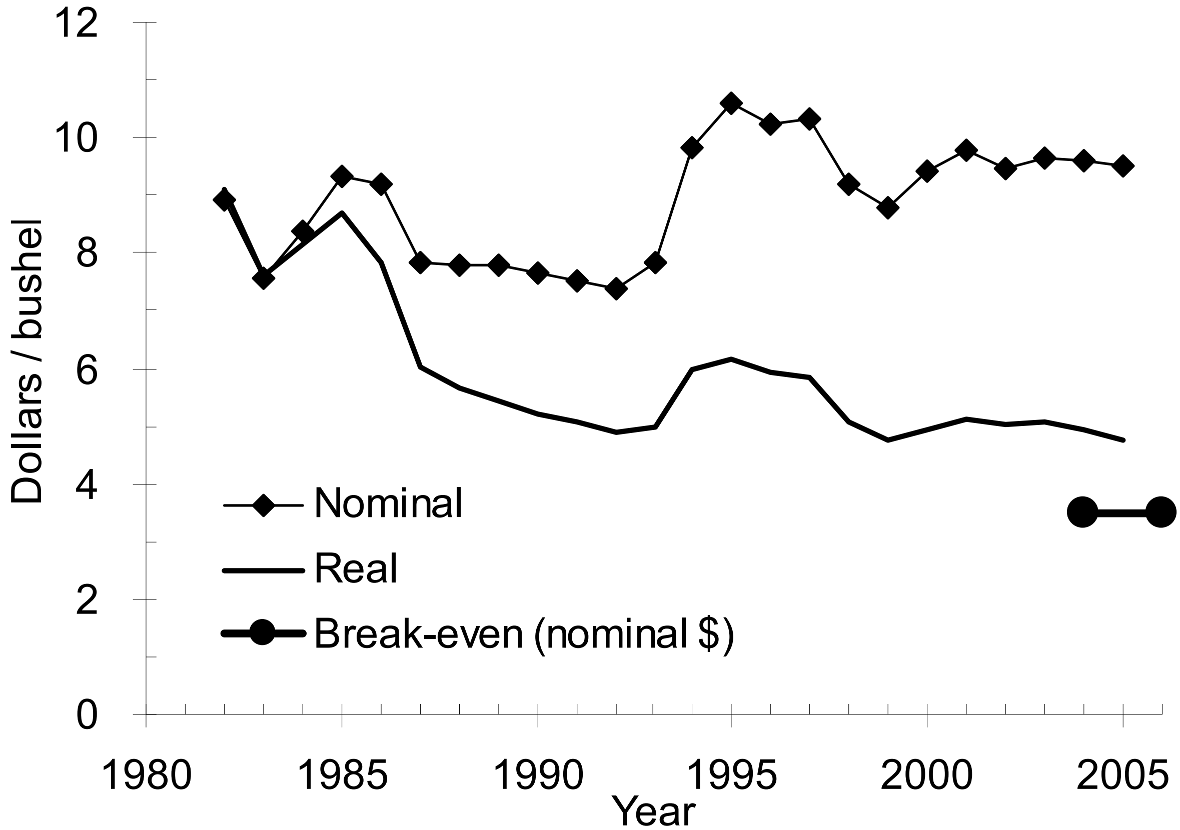


Figure C6. Real and nominal exvessel prices (US$ per bushel) for surfclam landed (EEZ and state waters) during 1982-2005. Real prices use 1980-1982 as the base year. The current "break-even" price (to meet variable costs) is about 3-4 $ bu-1 (nominal, in 2005 dollars) and shown for comparison.

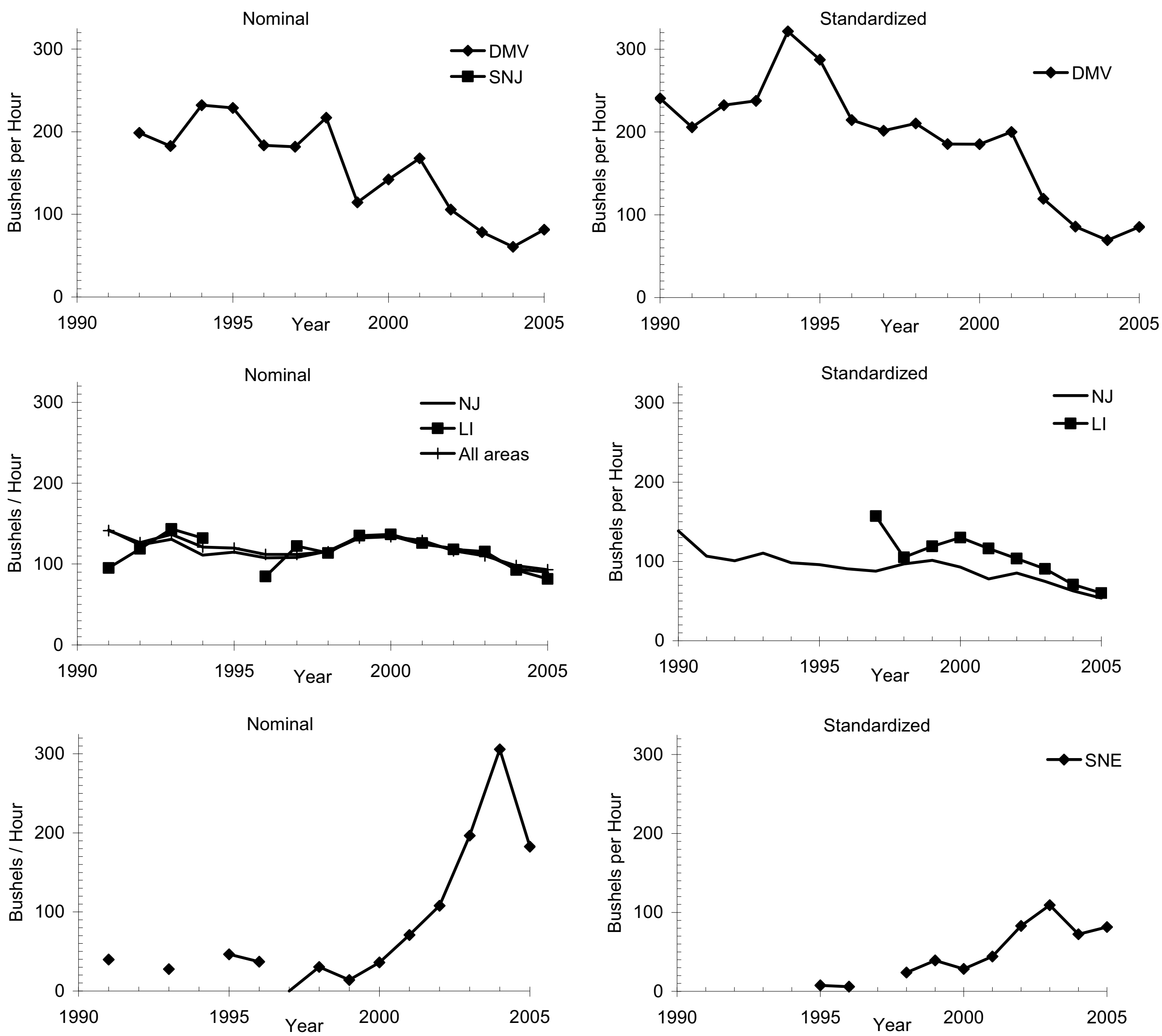


Figure C7. Nominal and standardized LPUE for surfclam in the EEZ, by region. Regions with similar trends are plotted together.

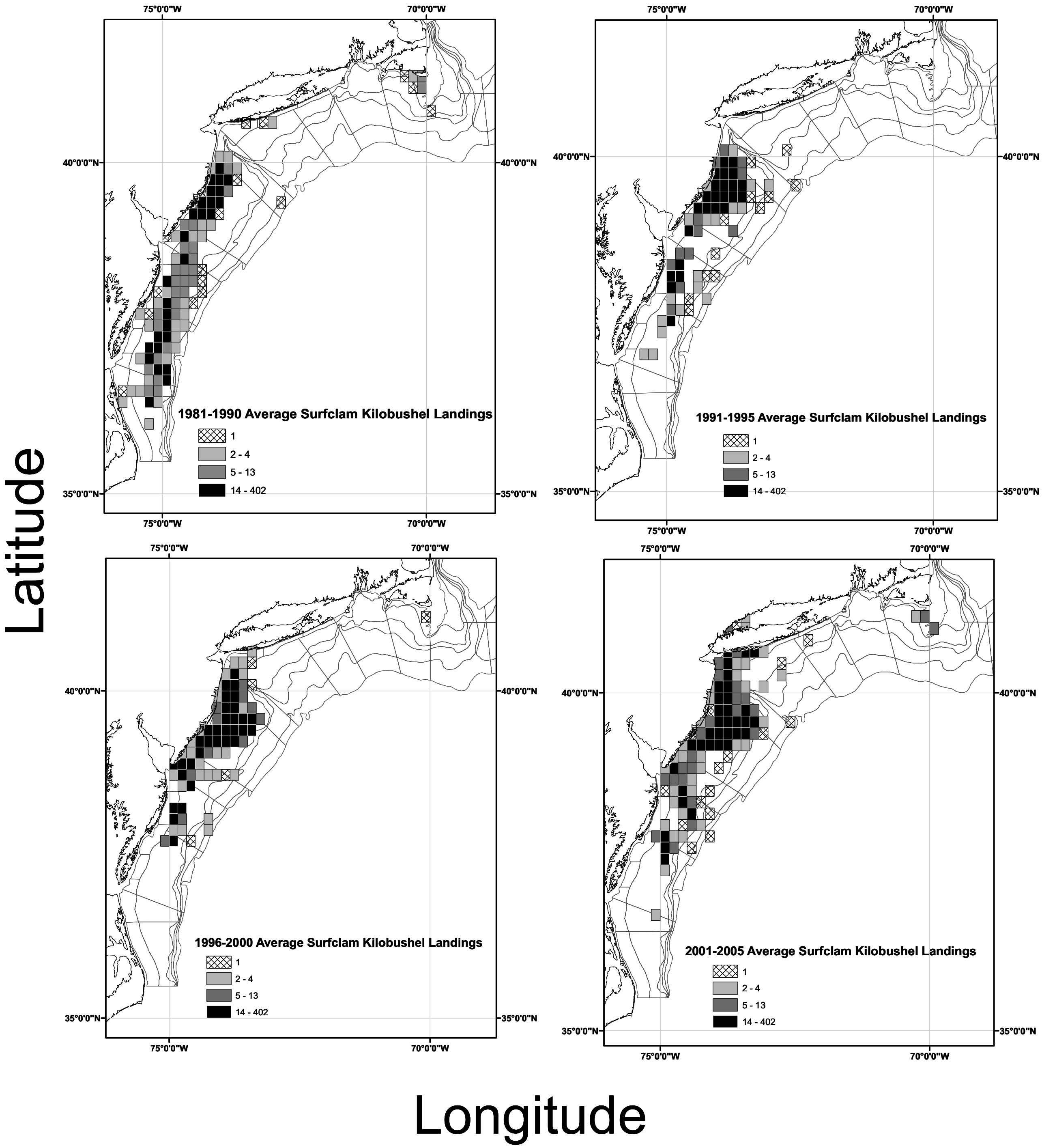


Figure C8. Spatial distribution of surfclam landings (annual means, 1 kilobushel = 1000 bu y-1) during 1981-1990, 1991-1995, 1996-2000 and 2001-2005 based on logbook data and ten-minute squares. Categories correspond approximately with quartiles during 1981-1990.

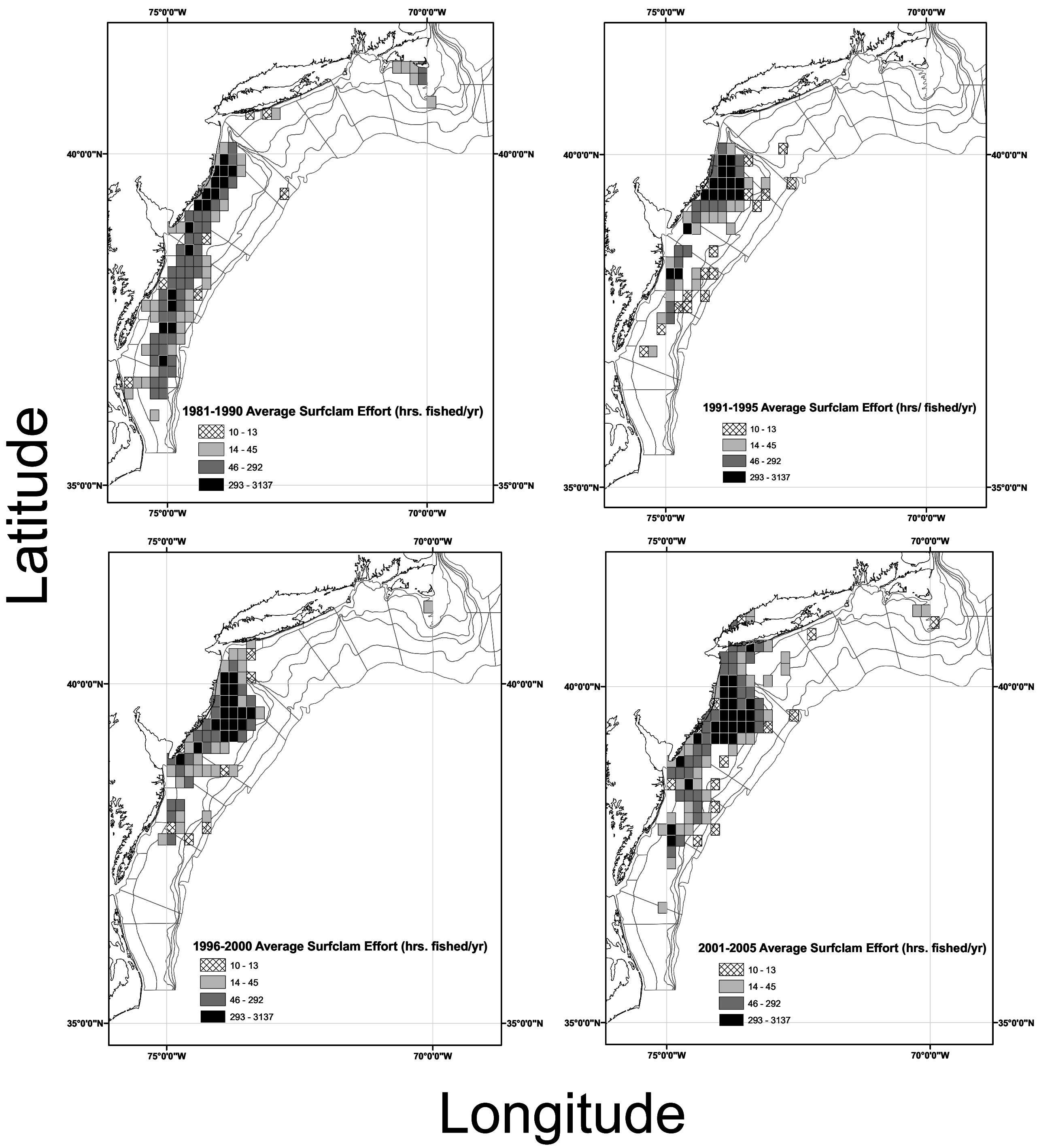


Figure C9. Spatial distribution of surfclam fishing effort (annual means, h y^{-1}) during 1981-1990, 1991-1995, 1996-2000 and 2001-2005 based on logbook data and ten-minute squares. Categories correspond approximately with quartiles during 1981-1990.

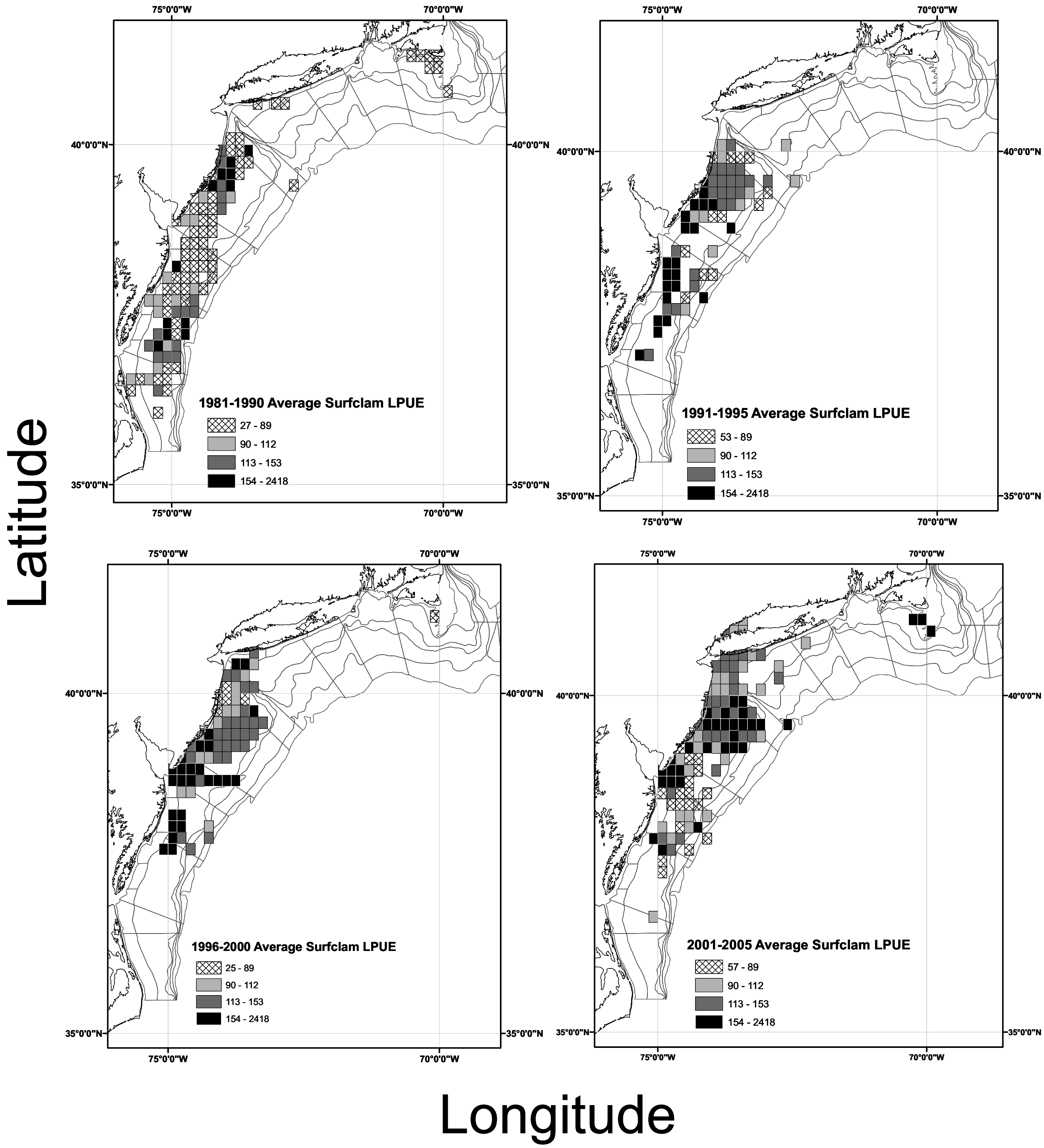


Figure C10. Spatial distribution of surfclam LPUE (annual means, bu h^{-1} y^{-1}) during 1981-1990, 1991-1995, 1996-2000 and 2001-2005 based on logbook data and ten-minute squares. Categories correspond approximately with quartiles during 1981-1990.

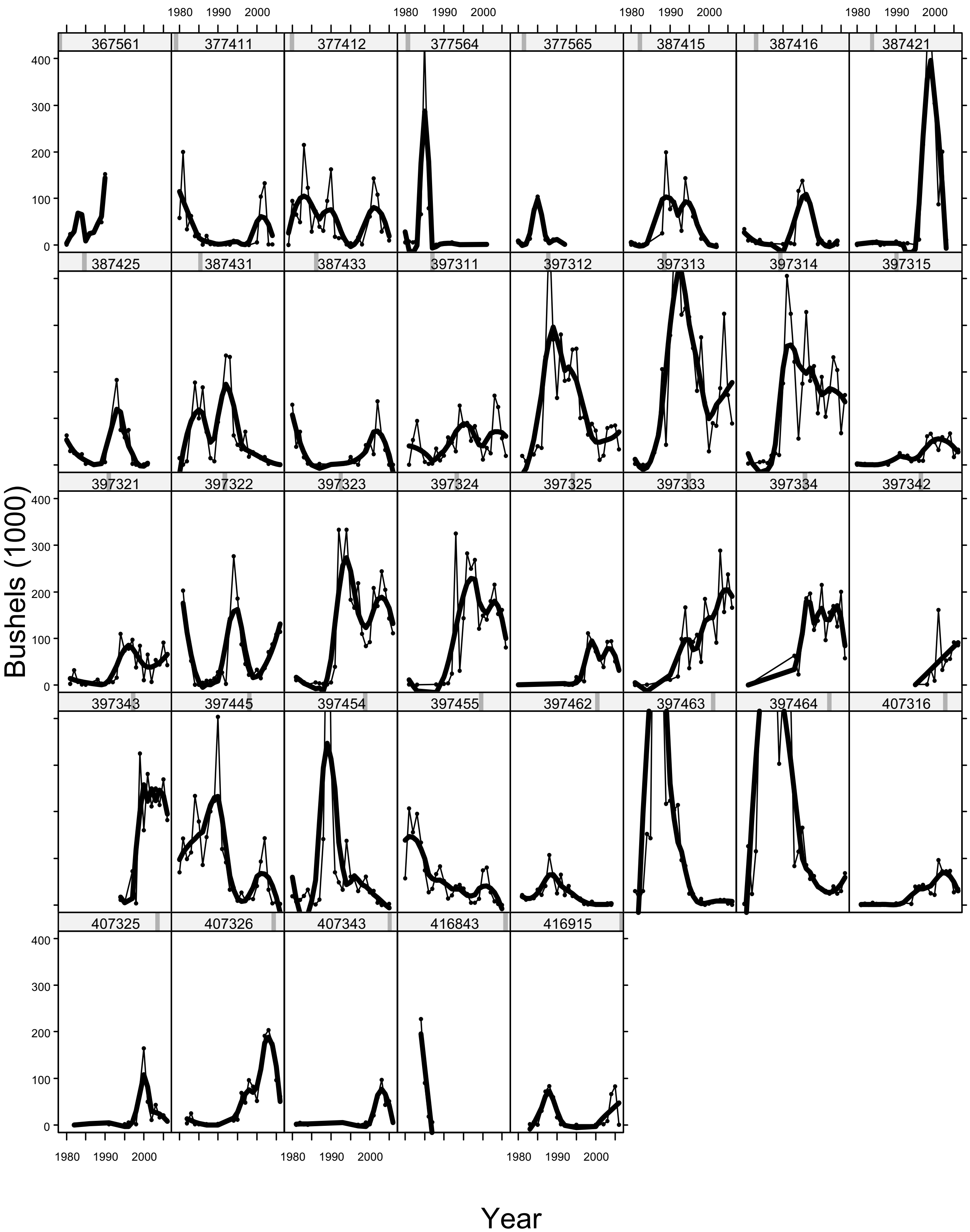


Figure C11. Annual surfclam landings (1000 bushels per year) for important ten-minute squares during 1980-2005 based on logbook data. The smooth dark line is a spline intended to show general trends.

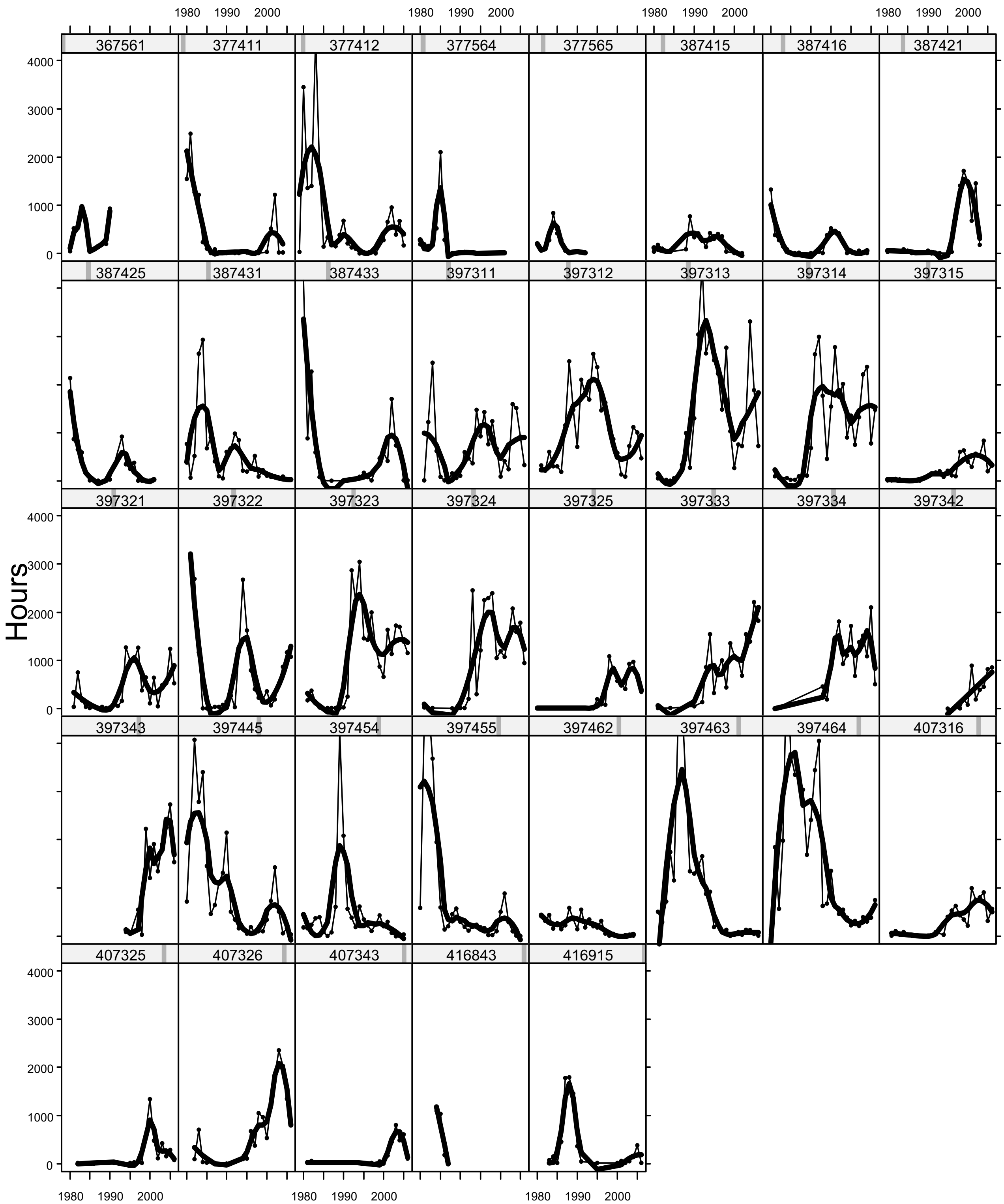


Figure C12. Annual surfclam fishing effort (hours of fishing per year) for important ten-minute squares during 1980-2005 based on logbook data. The smooth dark line is a spline intended to show general trends.

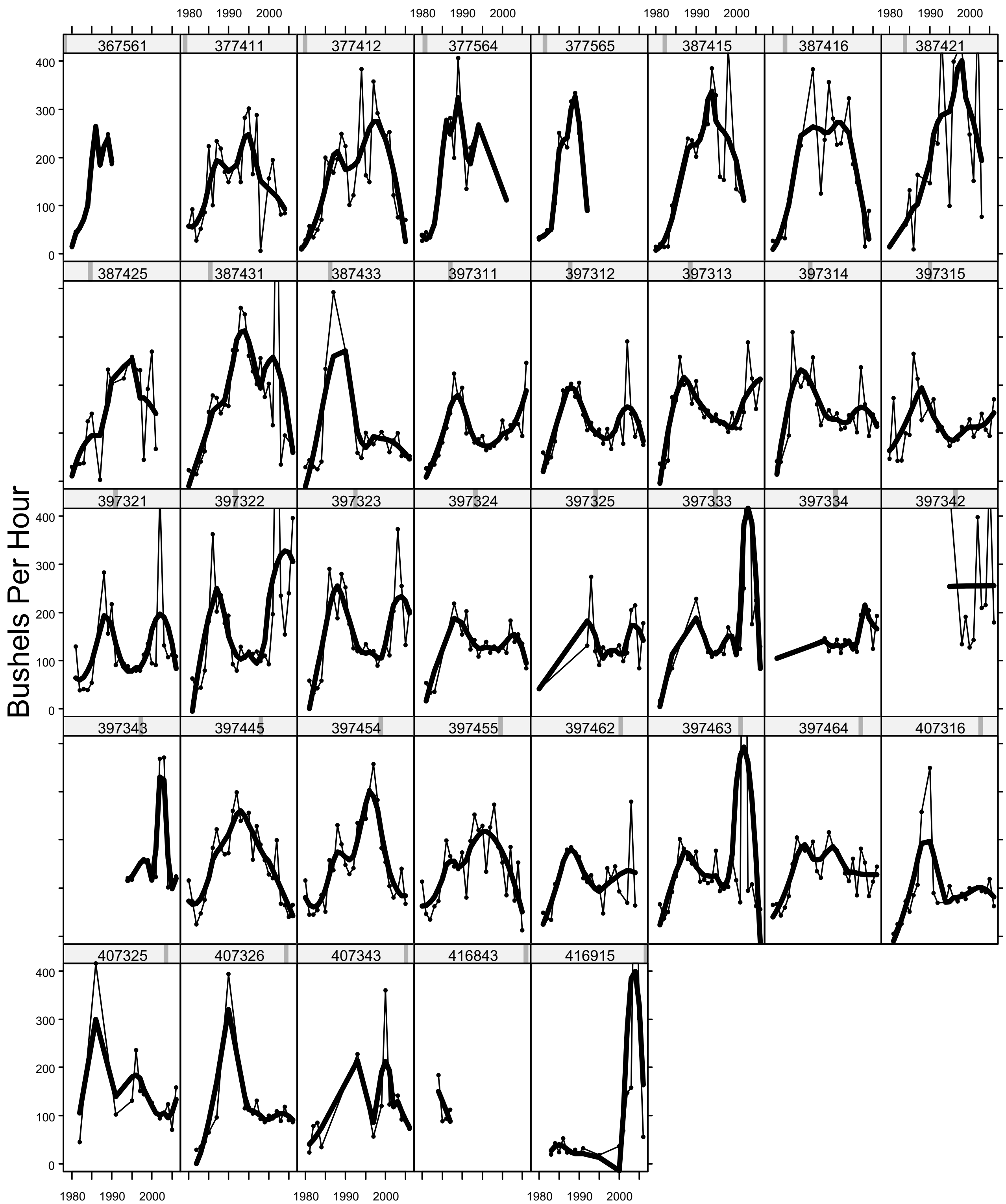


Figure C13. Annual surfclam landings per unit of fishing effort (LPUE, mean h^{-1}) for important ten-minute squares during 1980-2005 based on logbook data. The smooth dark line is a spline intended to show general trends.

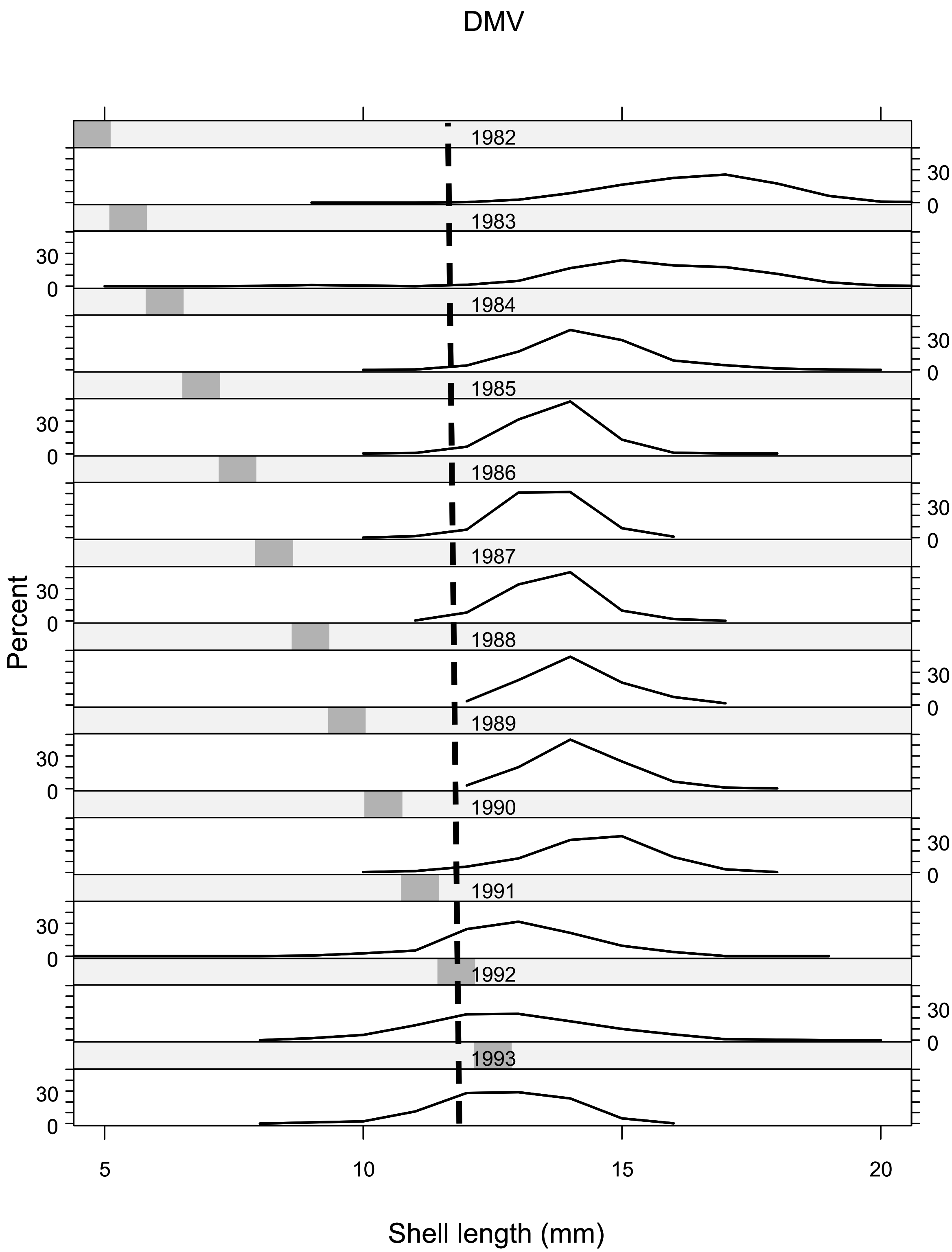


Figure C14. Commercial length composition data for surfclam caught in the DMV area, based on port samples. The dashed vertical line is at 120 mm SL.

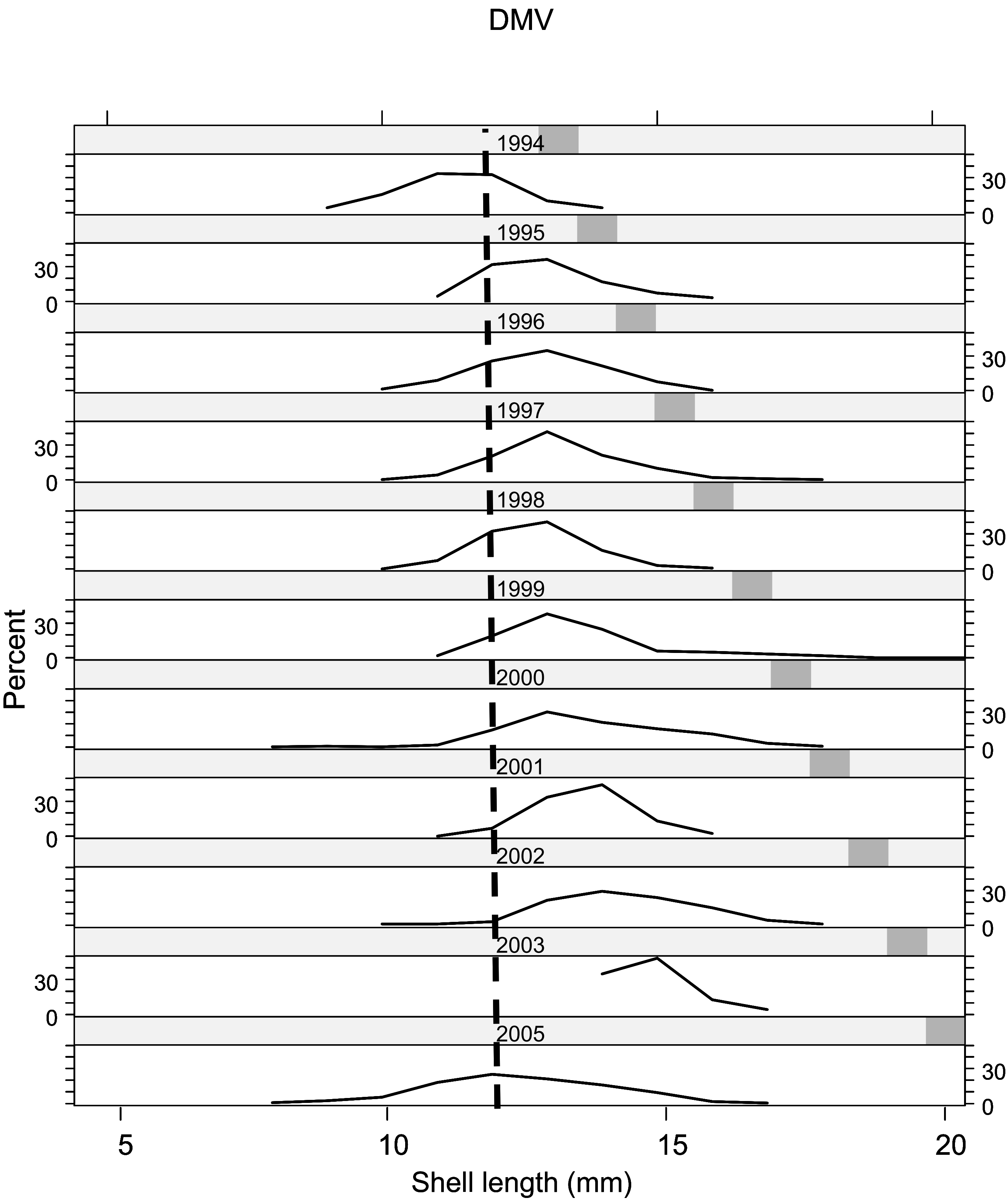
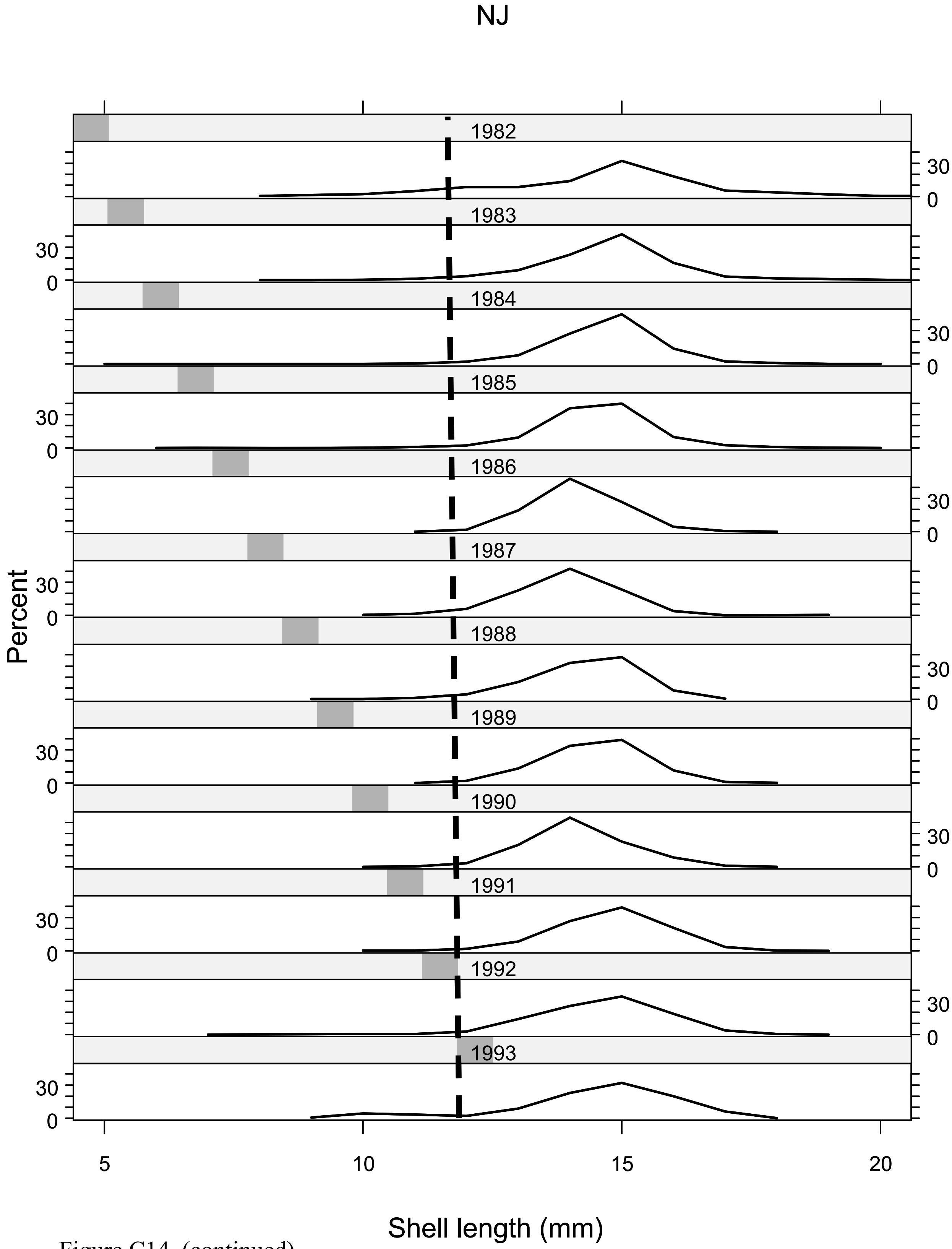


Figure C14. (continued)



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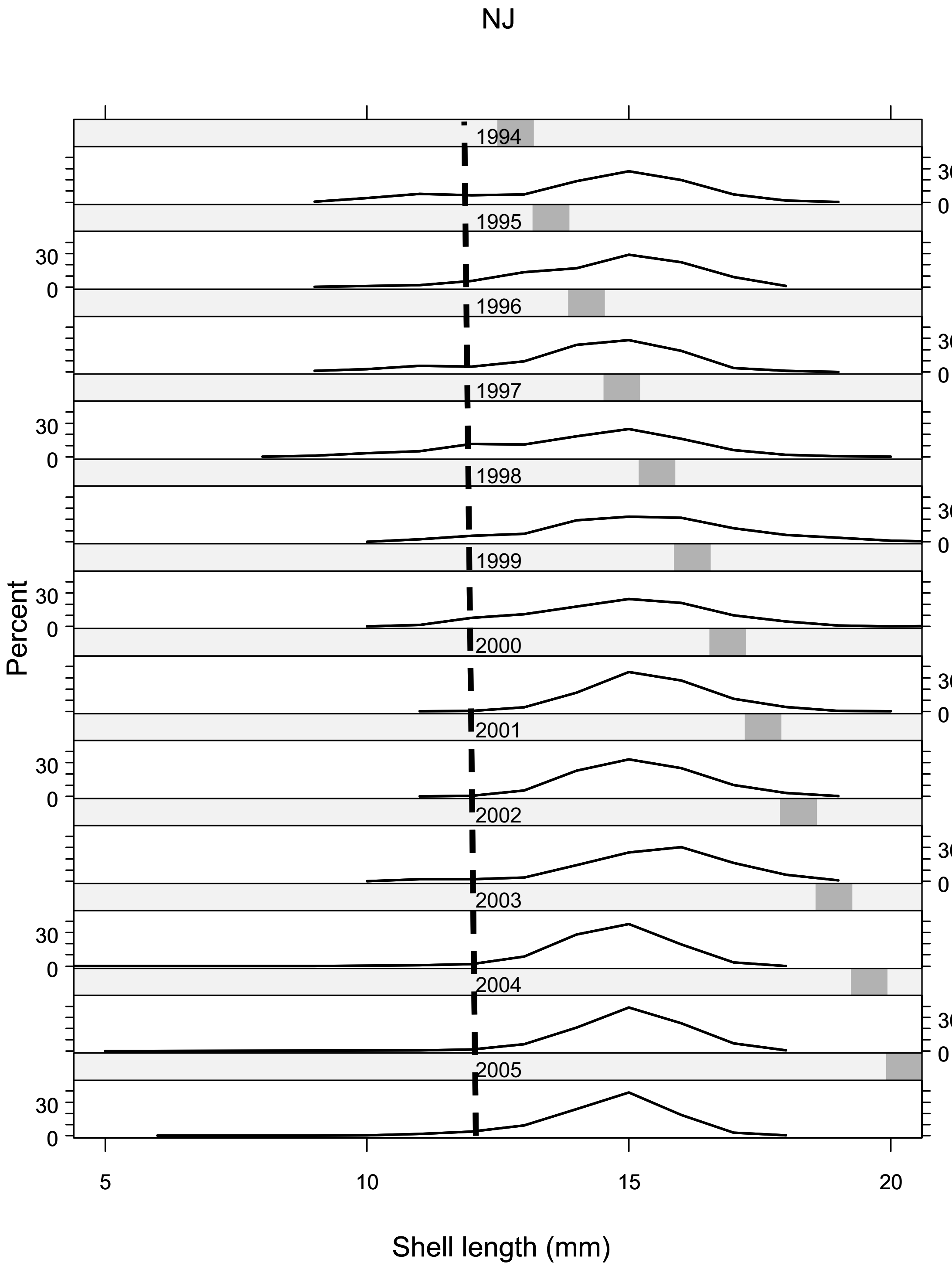


Figure C15. Commercial length composition data for surfclam caught in the NJ area, based on port samples. The dashed vertical line is at 120 mm SL.

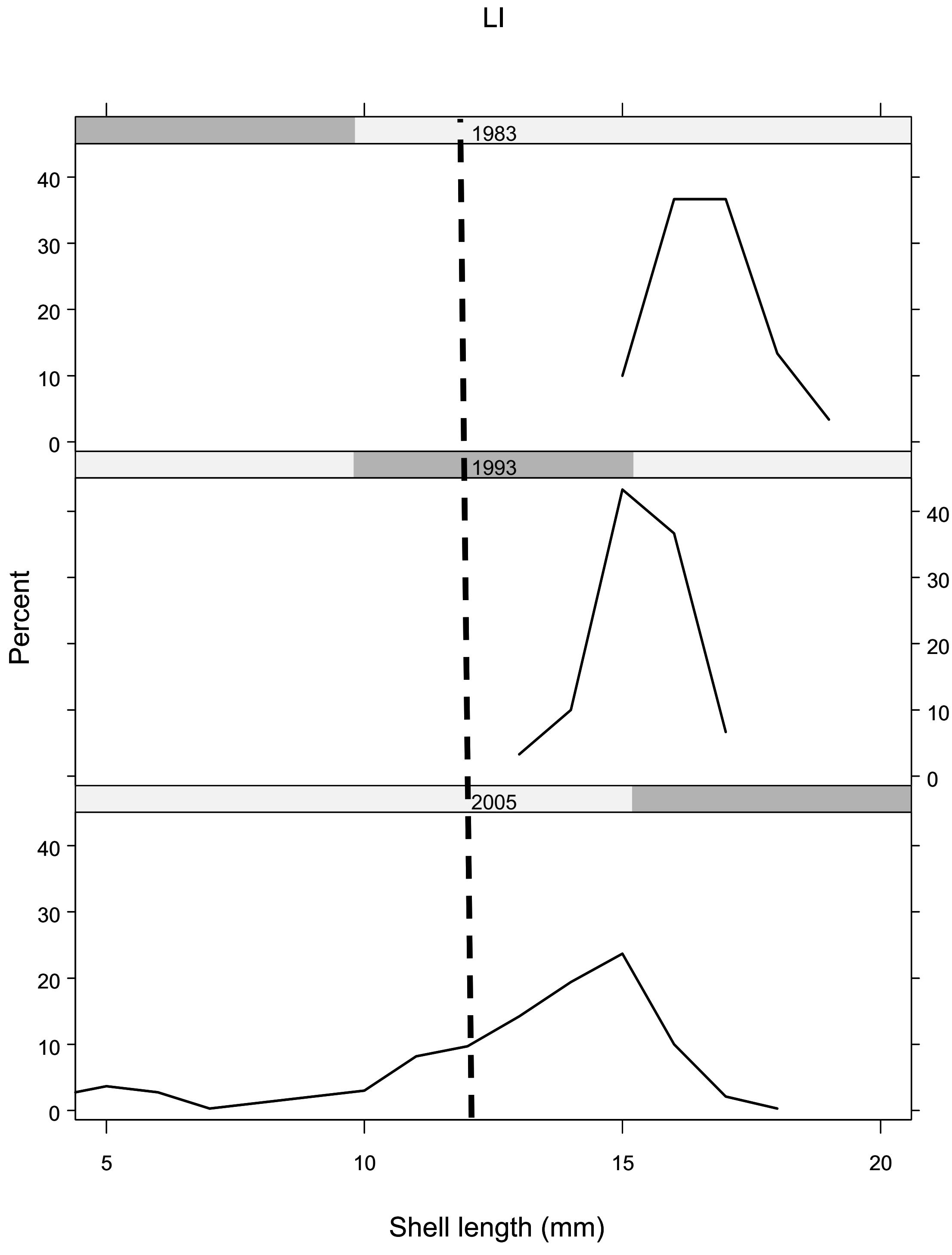


Figure C16. Commercial length composition data for surfclam caught in the LI area, based on port samples. The dashed vertical line is at 120 mm SL.

SNE

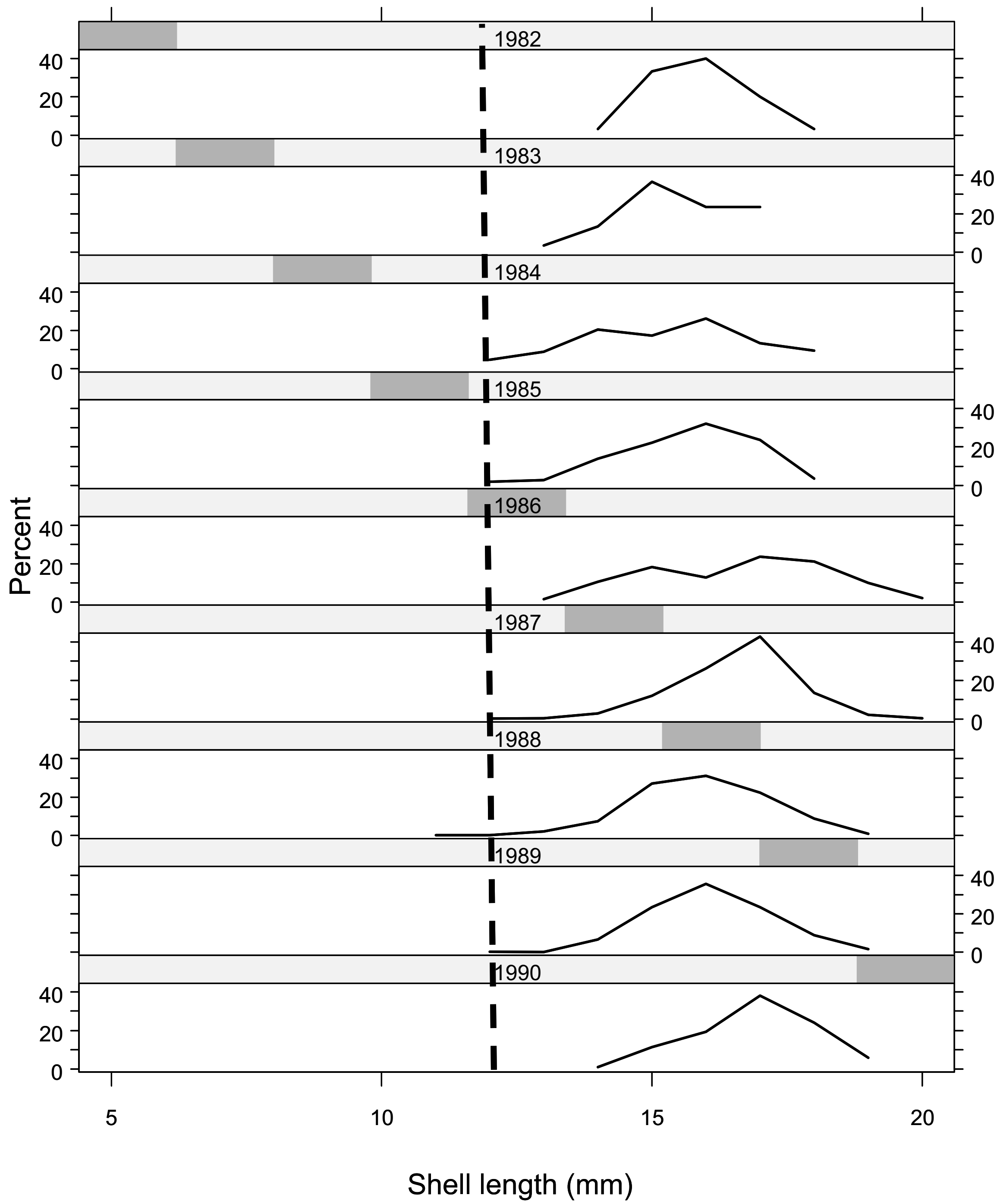


Figure C17. Commercial length composition data for surfclam caught in the SNE area, based on port samples. The dashed vertical line is at 120 mm SL.

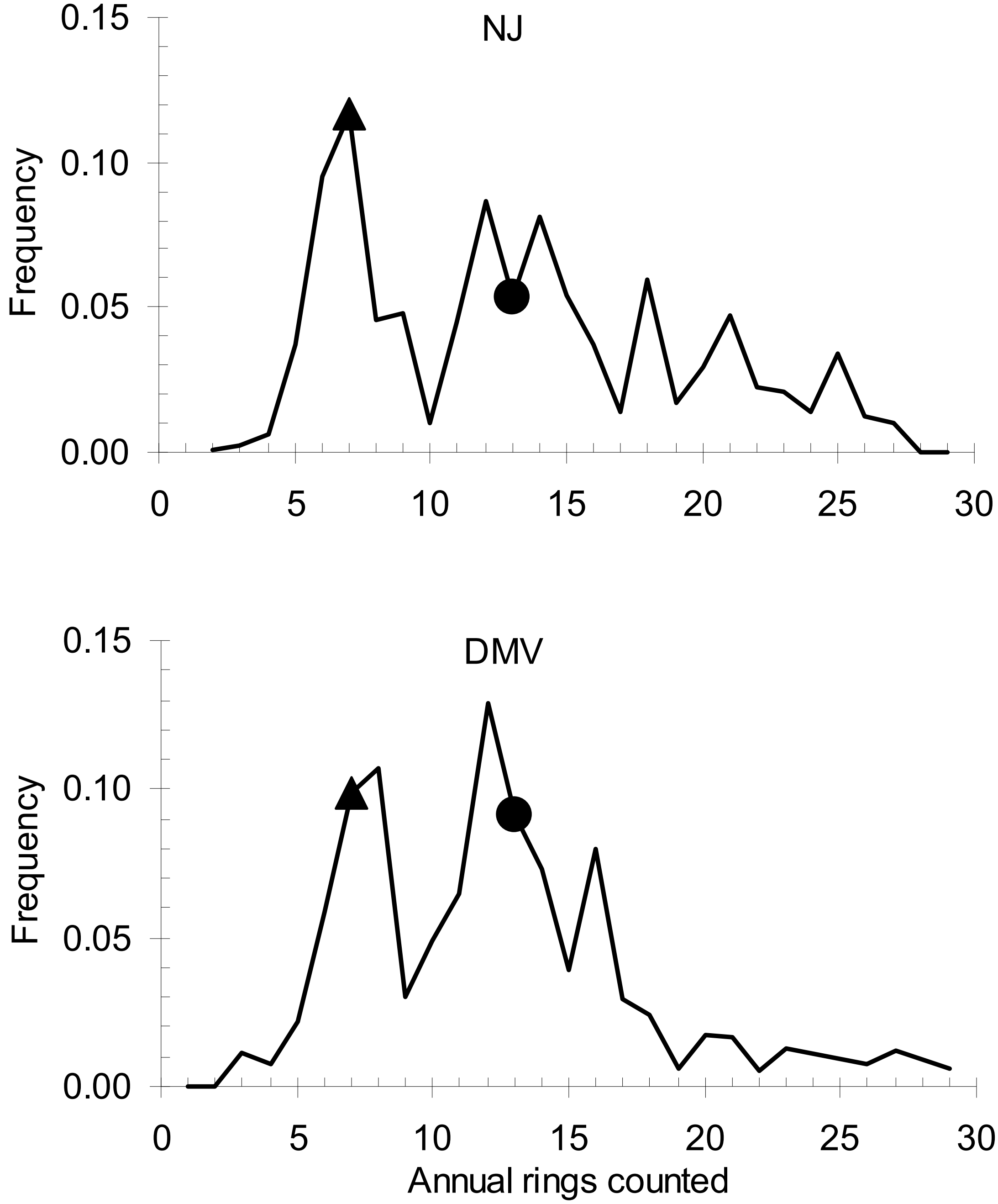


Figure C18. Commercial age composition data for surfclam in the NJ and DMV areas during 2005. There is uncertainty about timing of ring formation. Assuming rings form during the fall after the NEFSC clam survey, dark circles identify the 1992 (14 rings in 2005) year class and dark triangles identify the 1999 year class (7 rings in 2005).

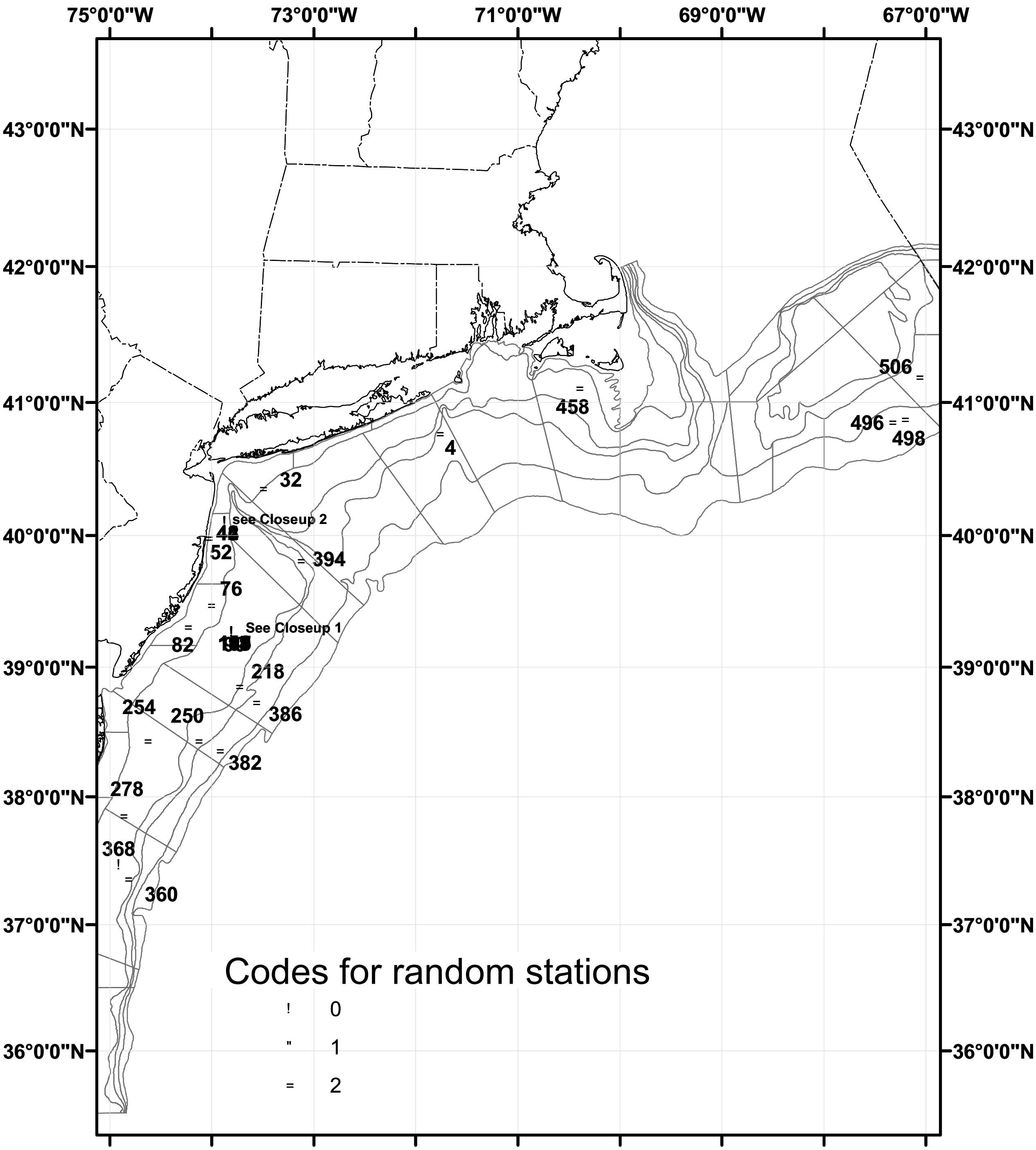


Figure C19. Locations of 2002 survey stations with poor dredge performance that would not have been excluded from trend and swept area trend analyses based on haul or gear damage codes, with station numbers. Codes 1 and 2 (dark squares and open circles) are random stations. Stations in close-up 1 are all from a depletion experiment.

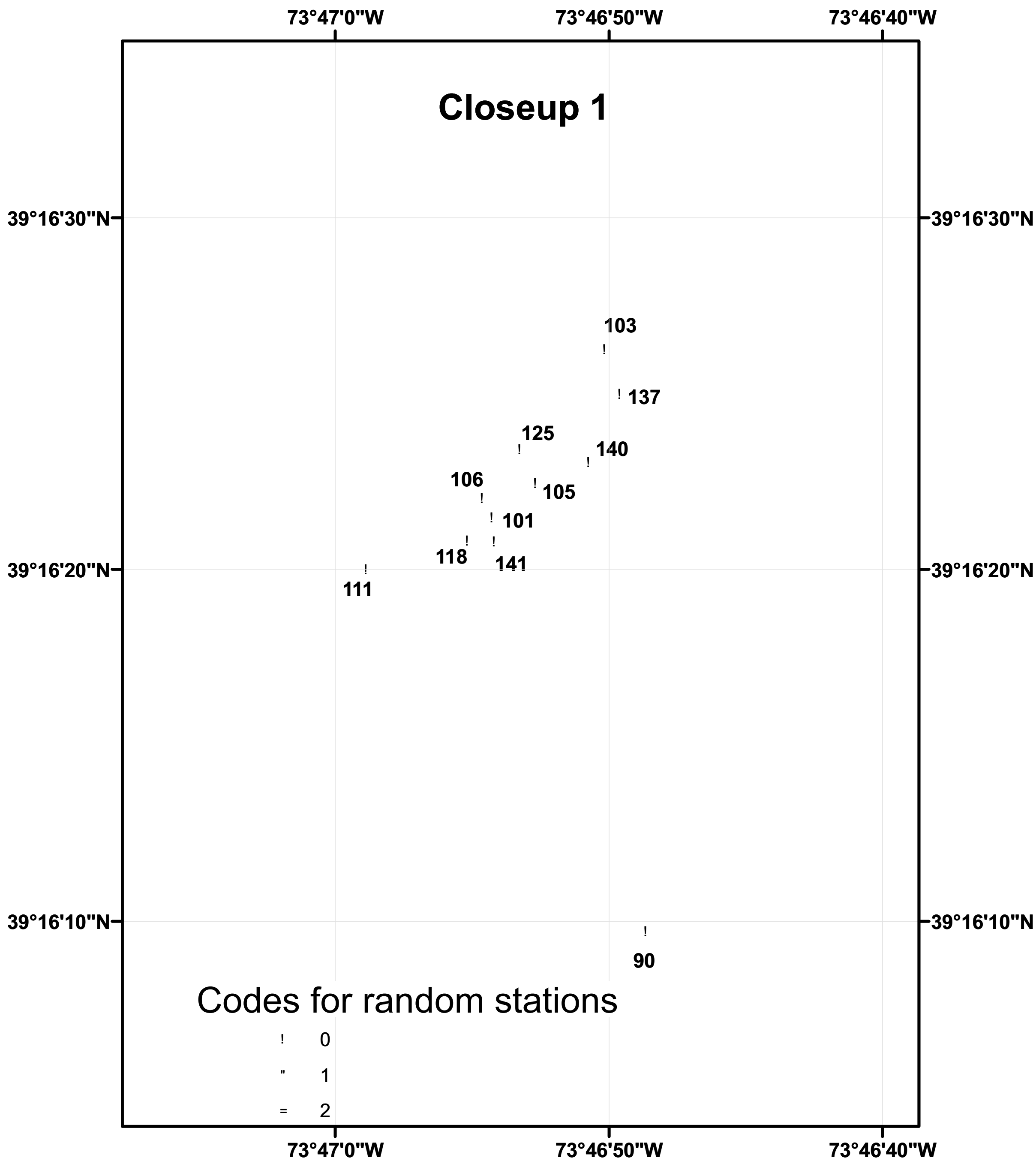


Figure C19 (continued)

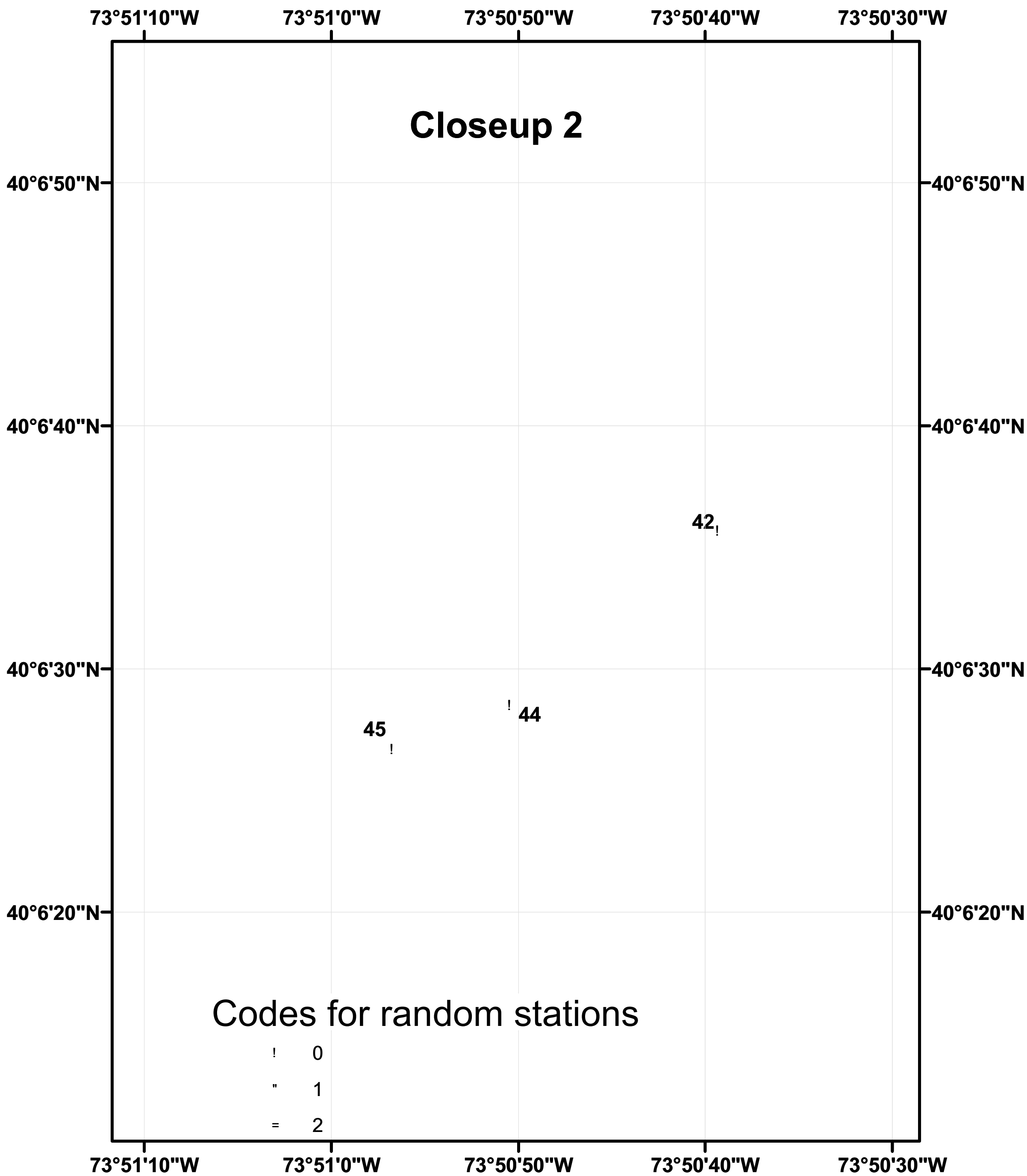


Figure C19 (continued)

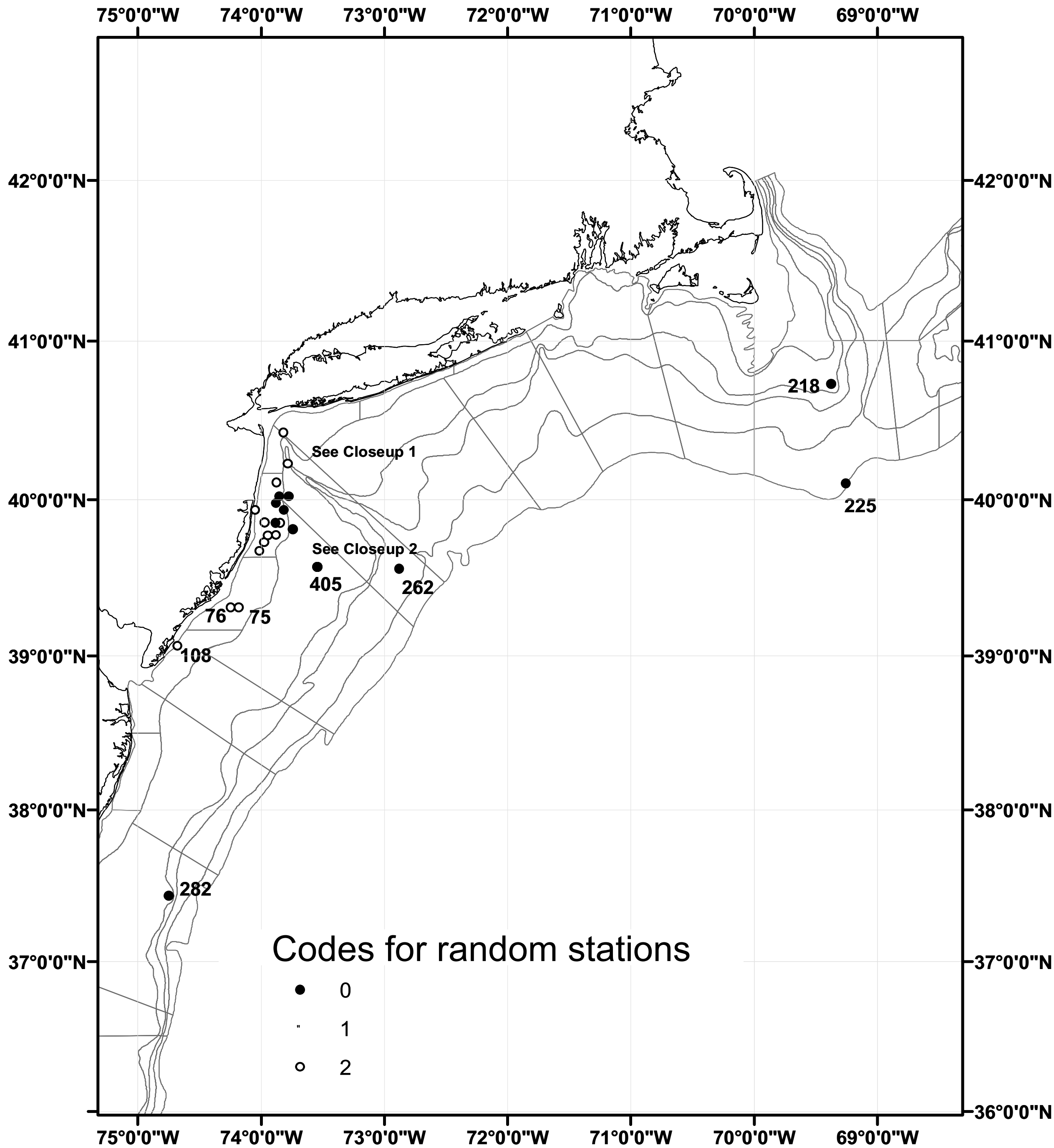


Figure C20. Locations of 2005 survey stations with poor dredge performance that would not have been excluded from trend and swept area trend analyses based on haul or gear damage codes, with station numbers. Codes 1 and 2 (dark squares and open circles) are random stations. Stations in close-up 2 are all from a depletion experiment.

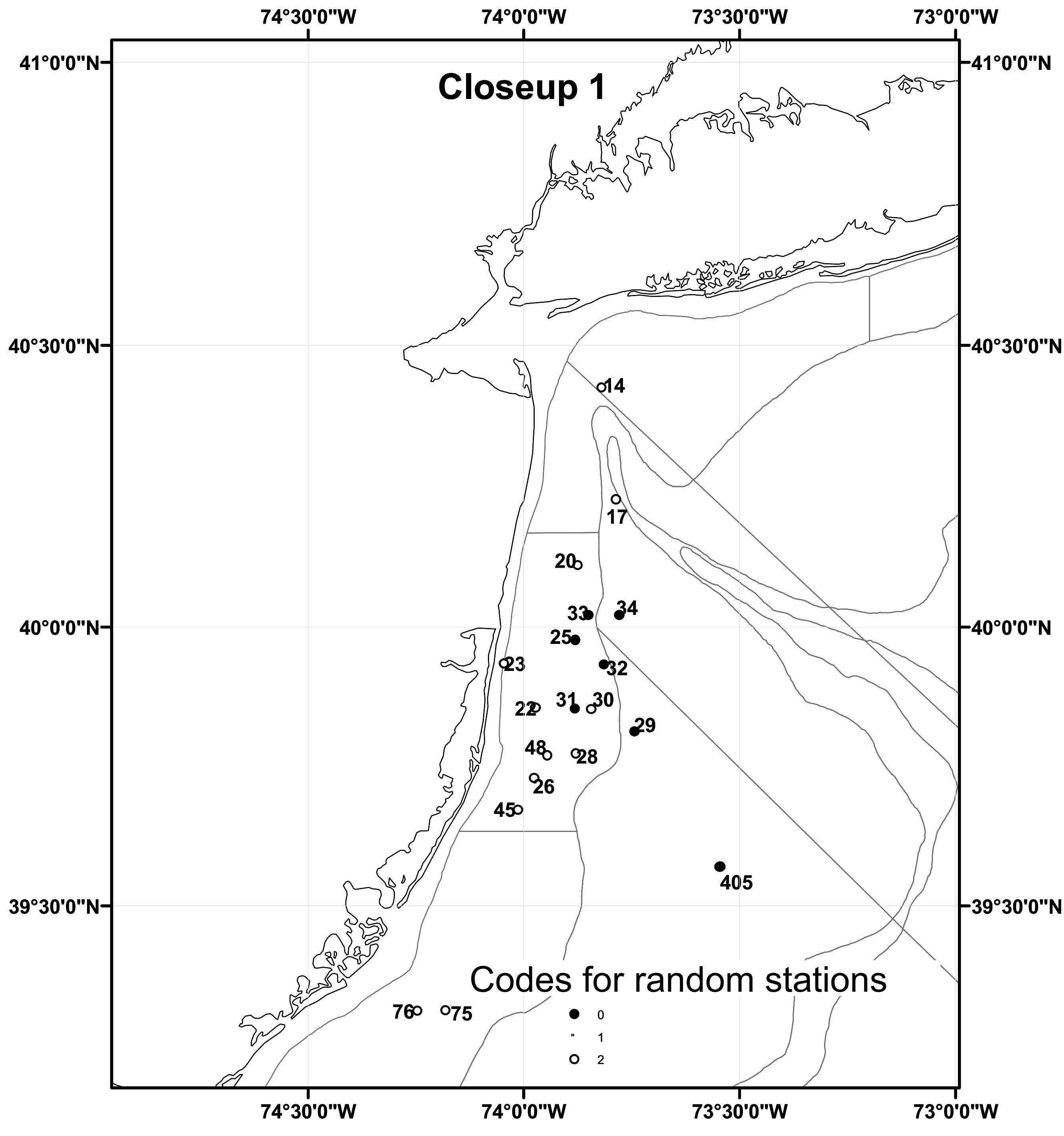
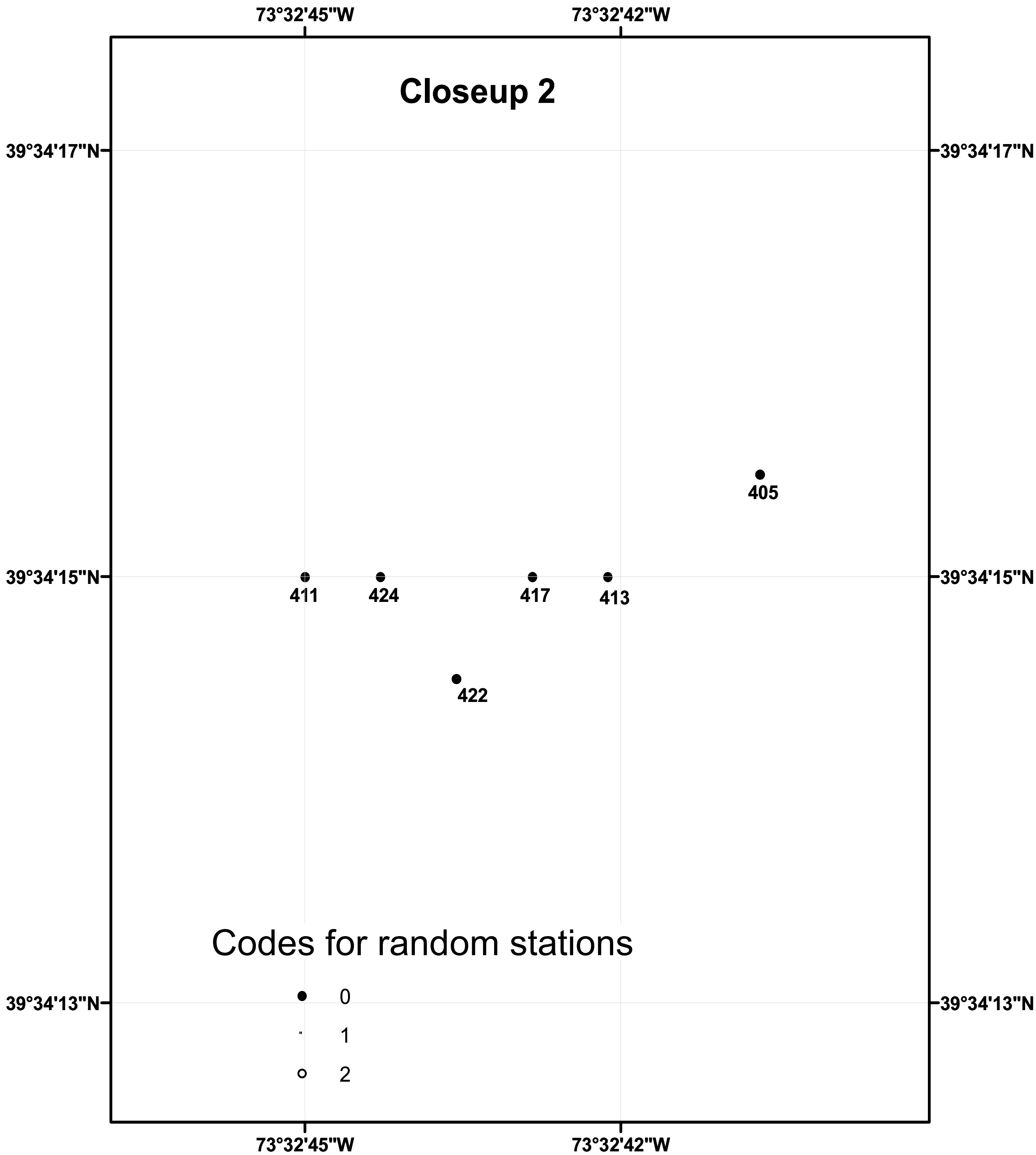


Figure C20 (continued)



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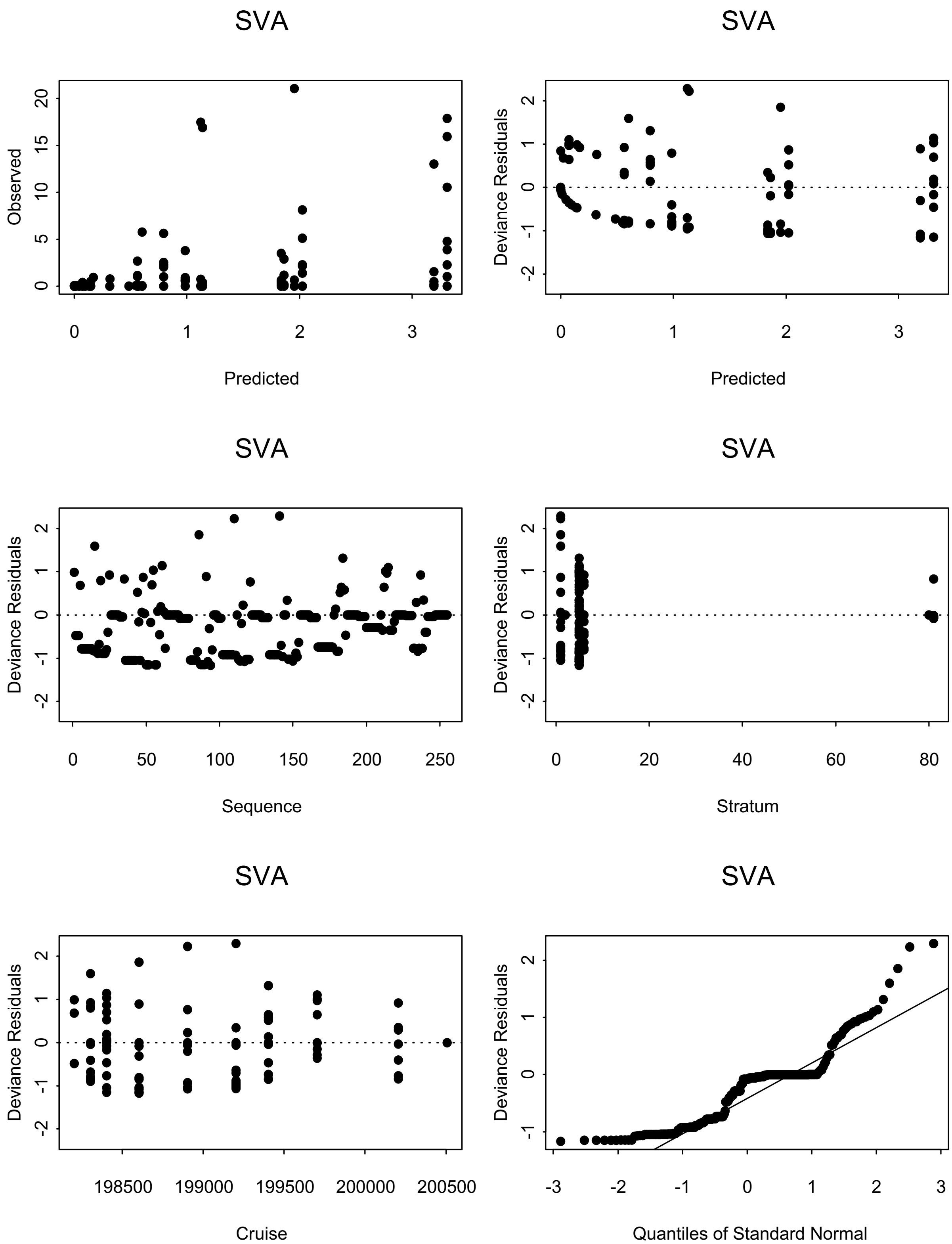


Figure C21. Residuals and diagnostics for negative binomial GLM model used to impute missing survey data for surfclam in SVA.

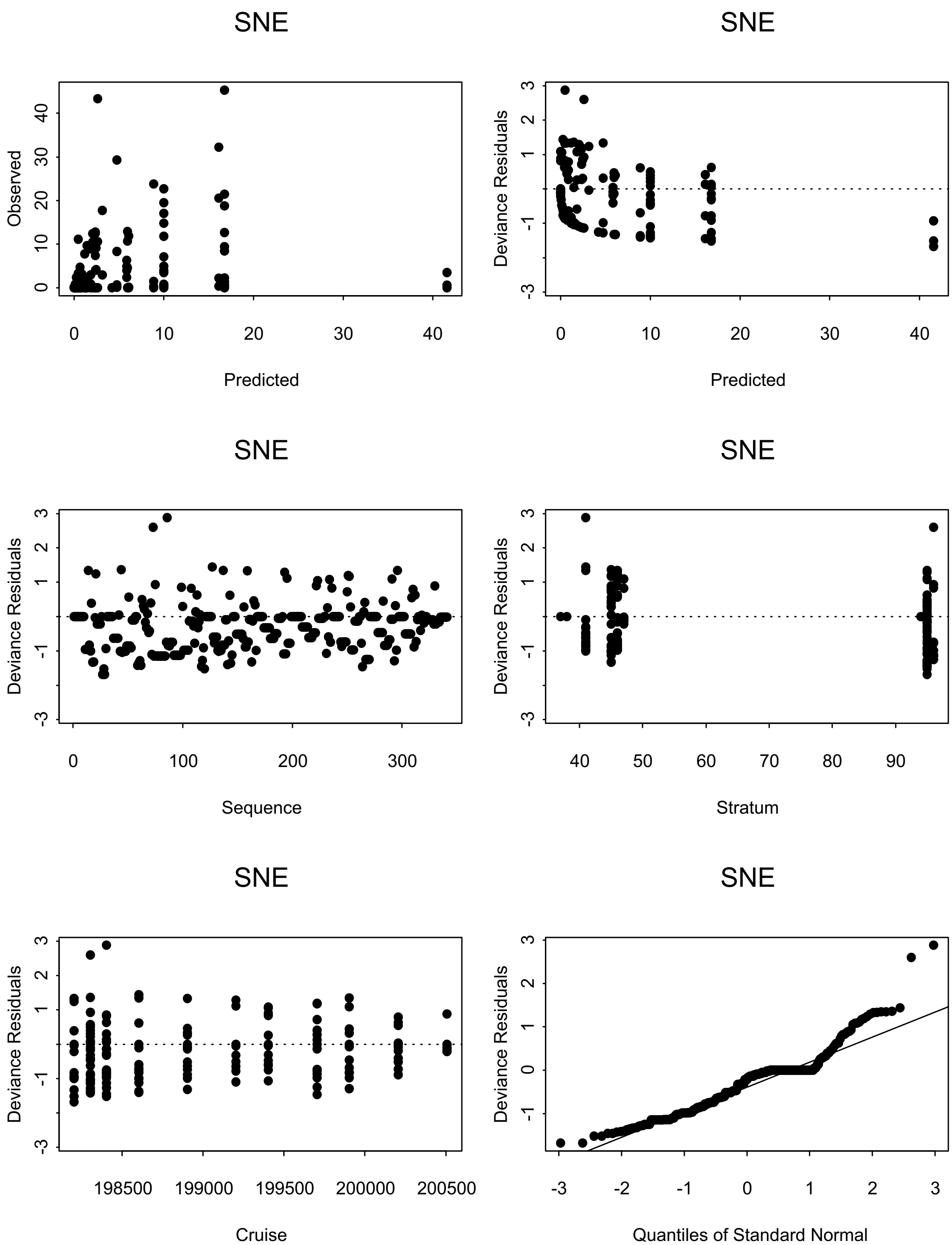


Figure C22. Residuals and diagnostics for negative binomial GLM model used to impute missing survey data for surfclam in SNE.

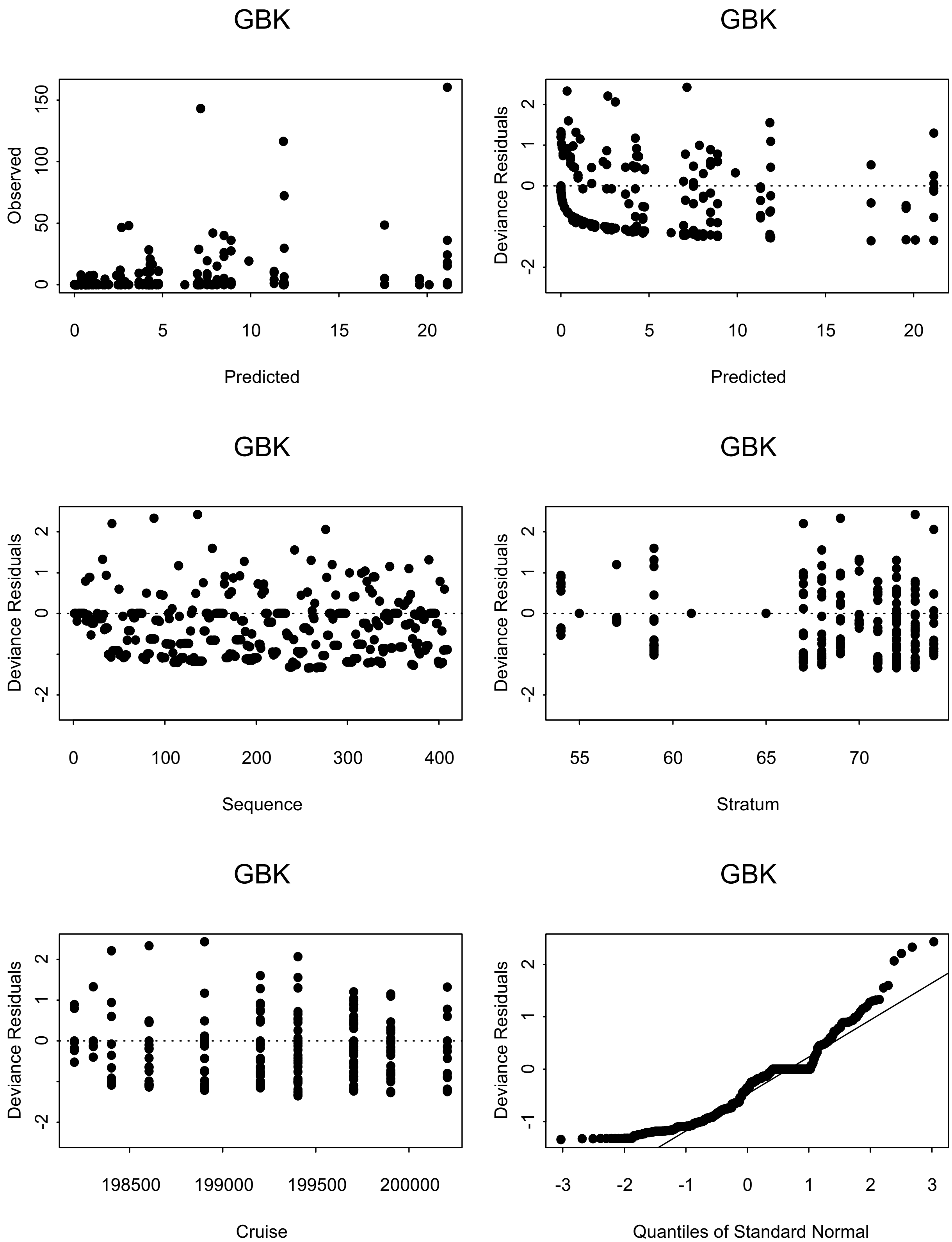


Figure C23. Residuals and diagnostics for negative binomial GLM model used to impute missing survey data for surfclam in GBK.

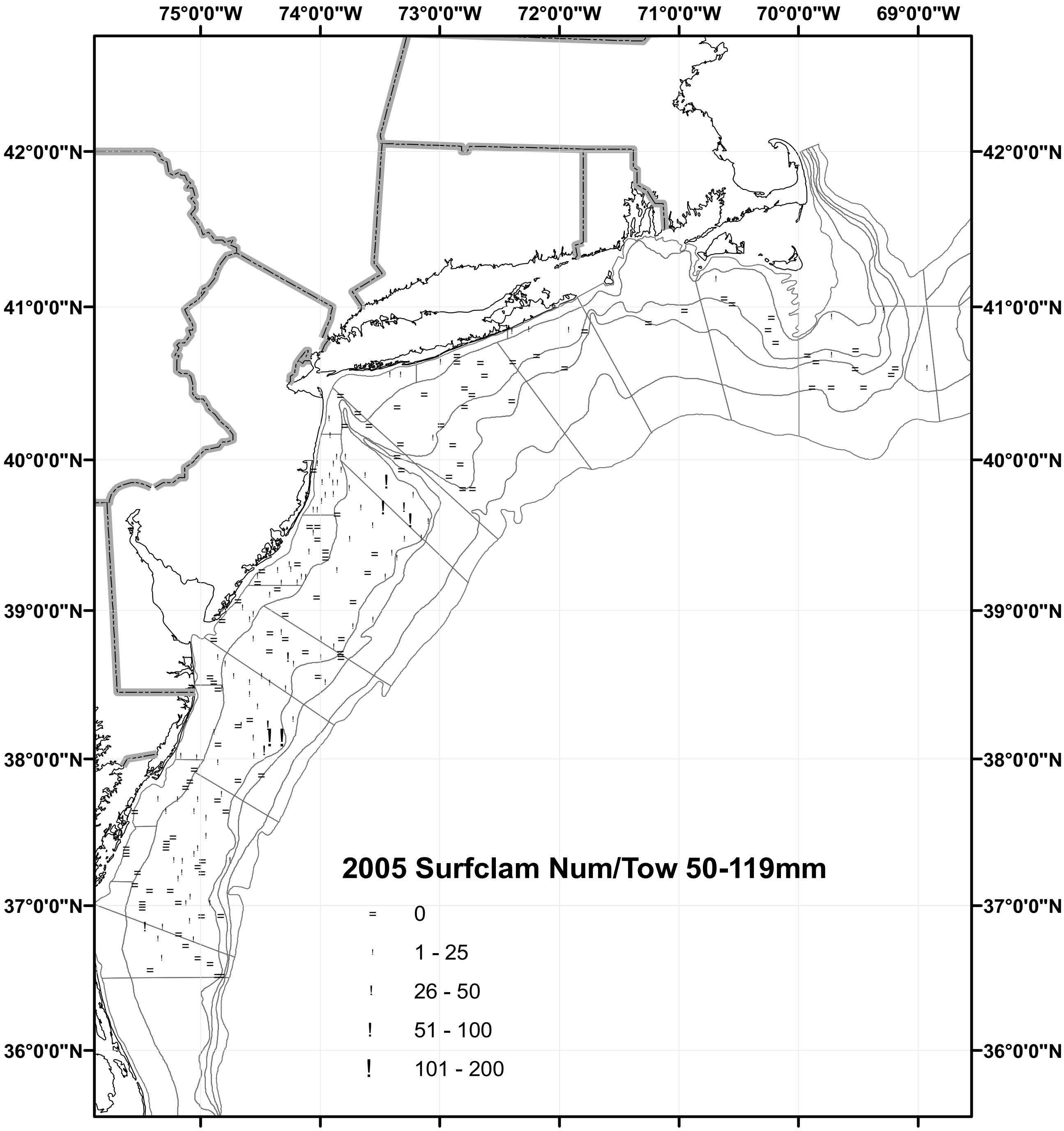


Figure C24. Location of successful random survey stations during the 2005 NEFSC clam survey with catches for small recruit surfclam 80-119 mm SL. Catches are numbers per tow, standardized by doppler distance with no borrowing.

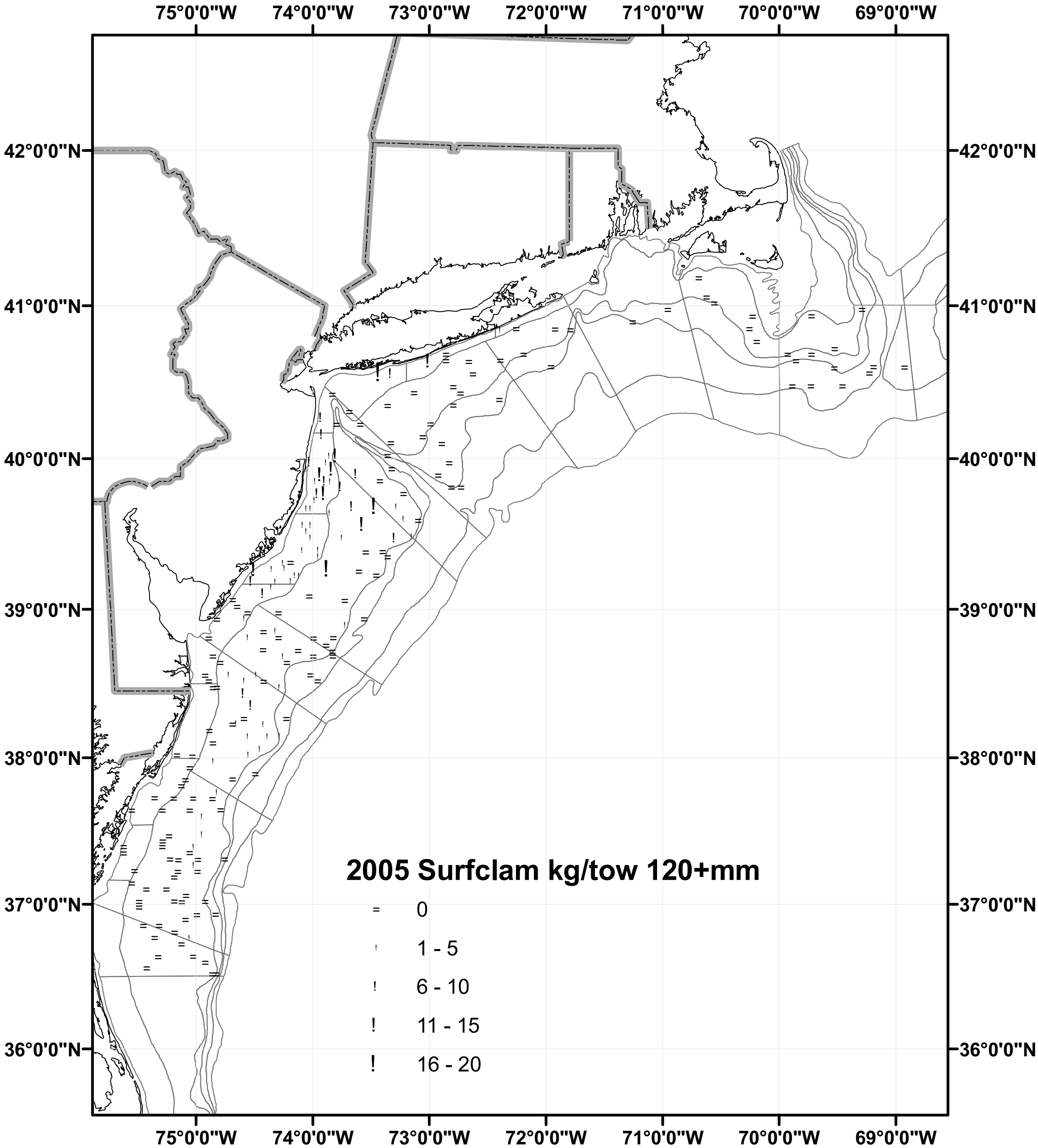


Figure C25. Location of successful random survey stations during the 2005 NEFSC clam survey with catches for large fishable surfclam 120+ mm SL. Catches are numbers per tow, standardized by doppler distance with no borrowing.

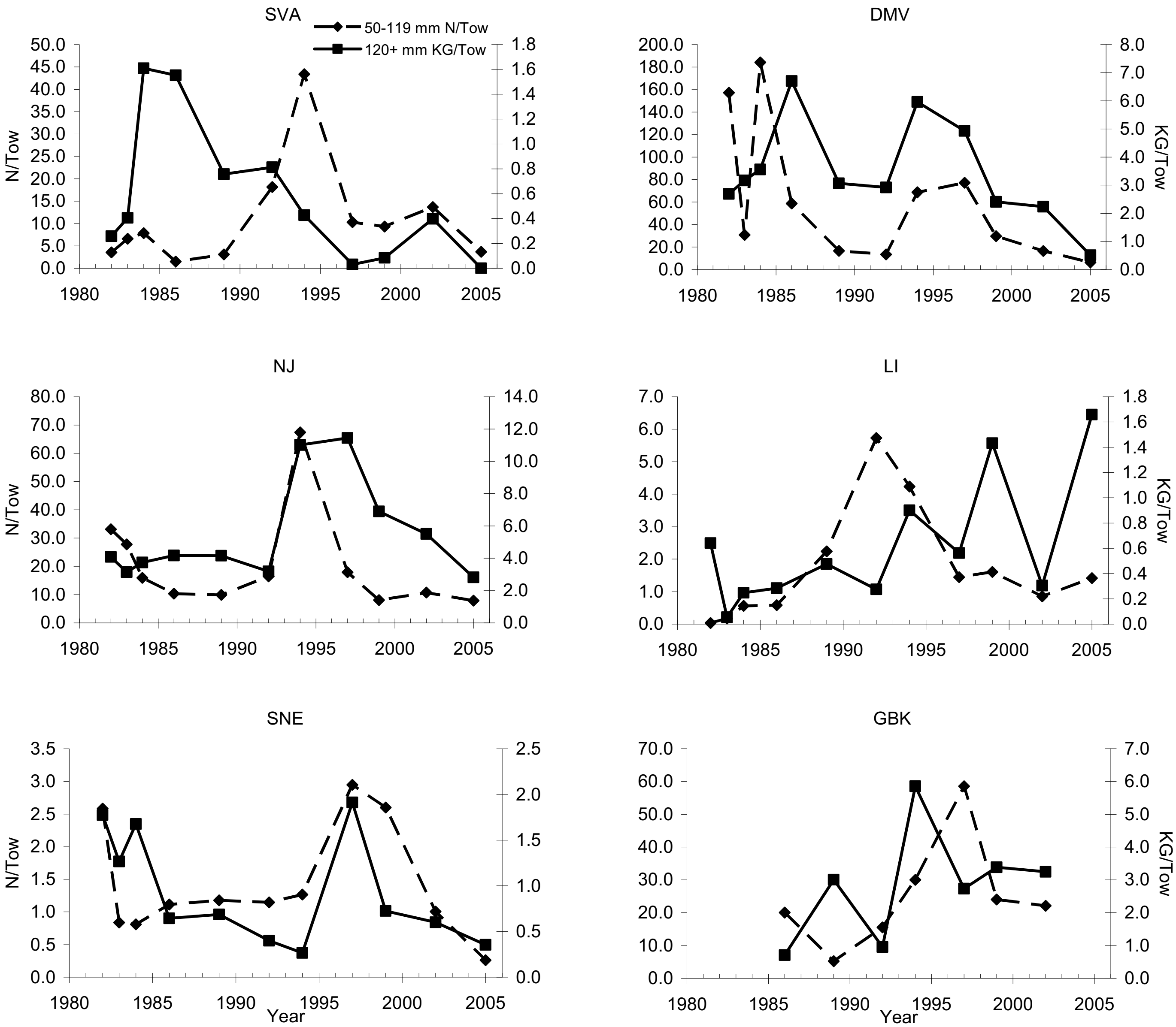


Figure C26. Trends in abundance (mean n tow^{-1}) for small recruit surfclam (50-119 mm) and trends in biomass (mean kg tow^{-1}) for large fishable (120+ mm) surfclam based on NEFSC clam surveys, by region.

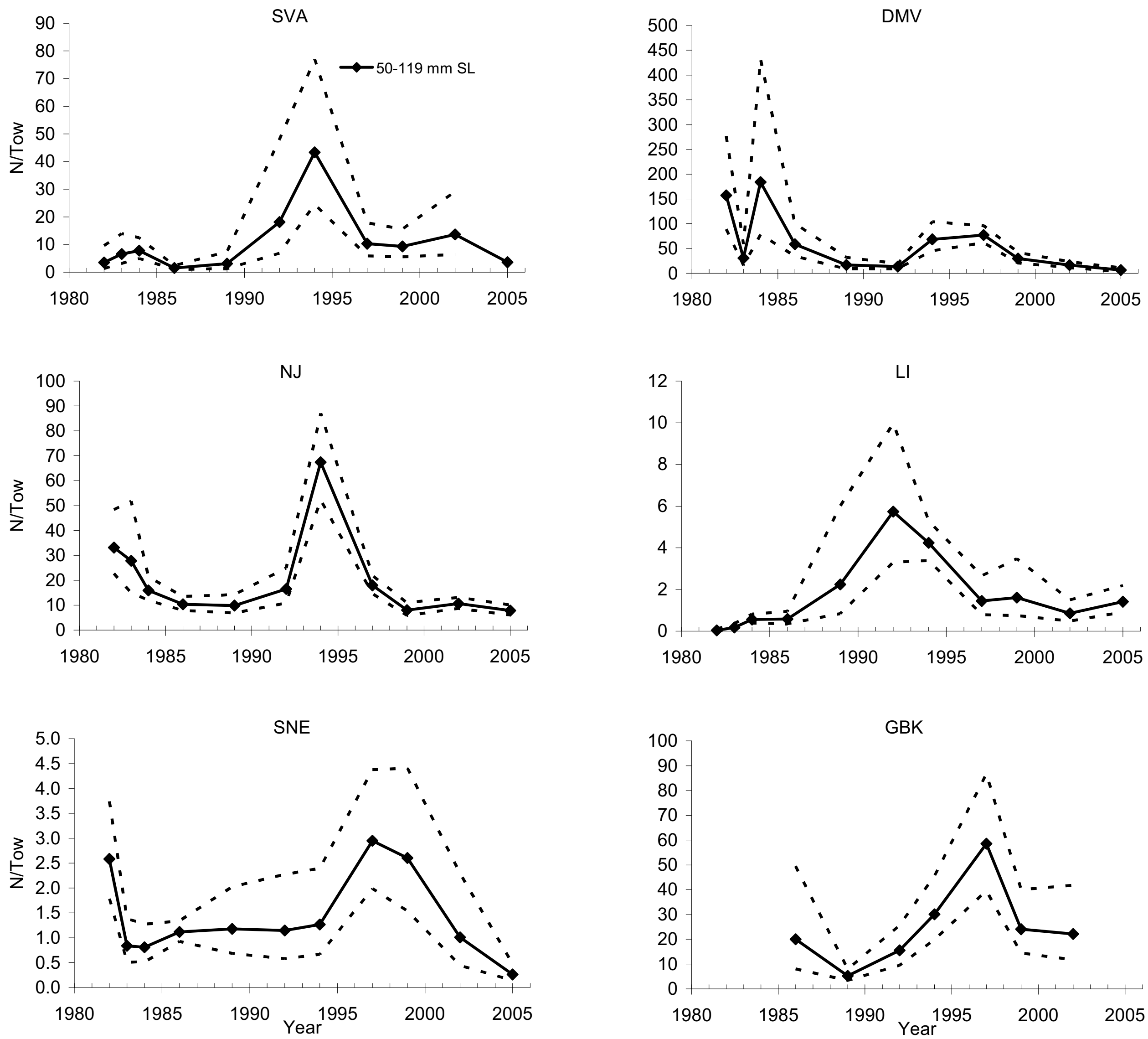


Figure C27. Trends in abundance indices (mean n tow^{-1}) for small recruit surfclam (50-119 mm SL) in NEFSC clam surveys, with 80% confidence intervals assuming lognormal measurement errors and arithmetic CVs for stratified random sampling based on Students-*t* distribution with the number of tows as degrees of freedom.

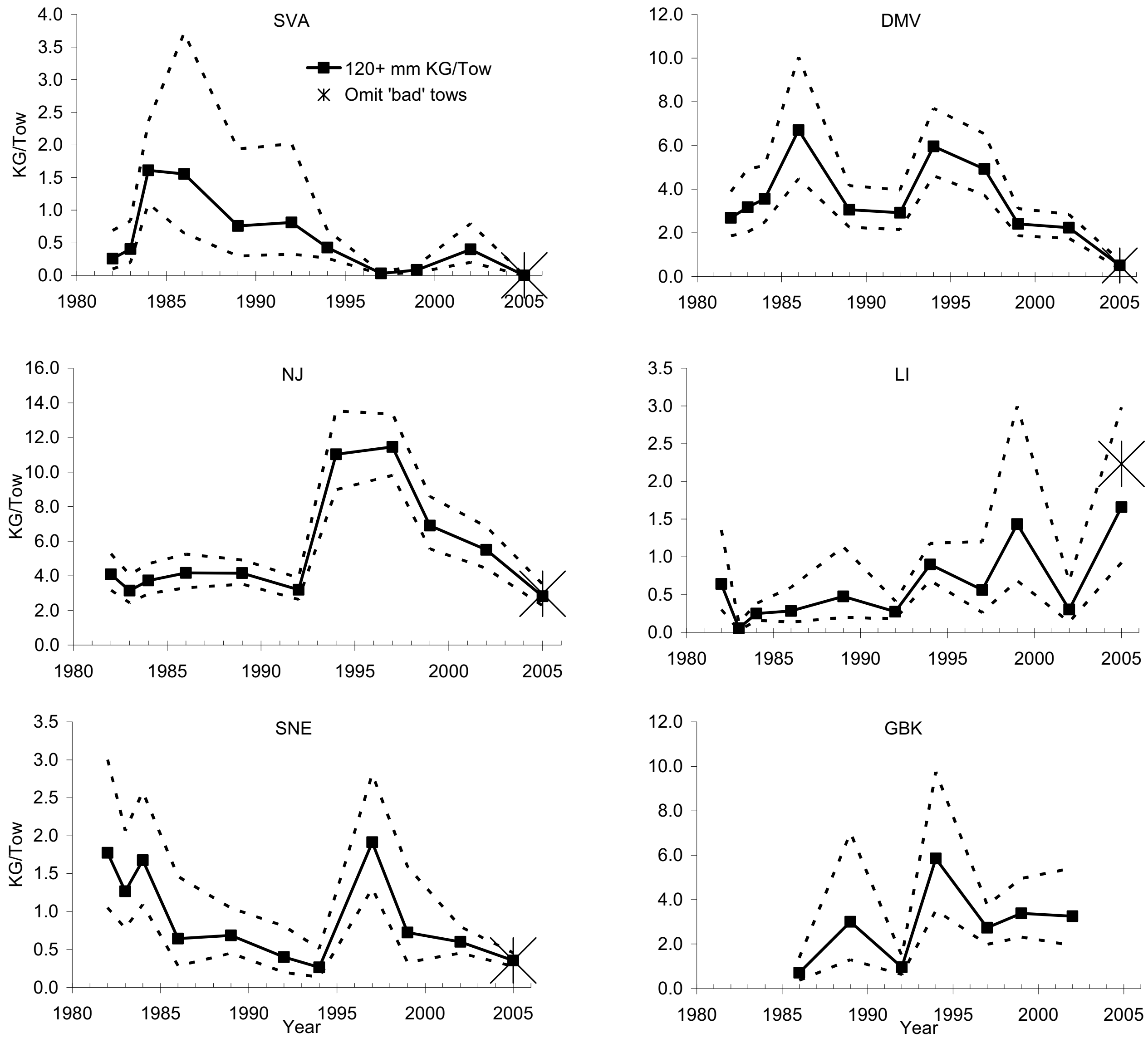


Figure C28. Trends in biomass indices (mean kg tow^{-1}) for large fishable surfclam (120+ mm SL) in NEFSC clam surveys, with 80% confidence intervals assuming lognormal measurement errors and arithmetic CVs for stratified random sampling based on Students-*t* distribution with the number of tows as degrees of freedom. Different symbols show effects of omitting tows with poor gear performance during 2005.

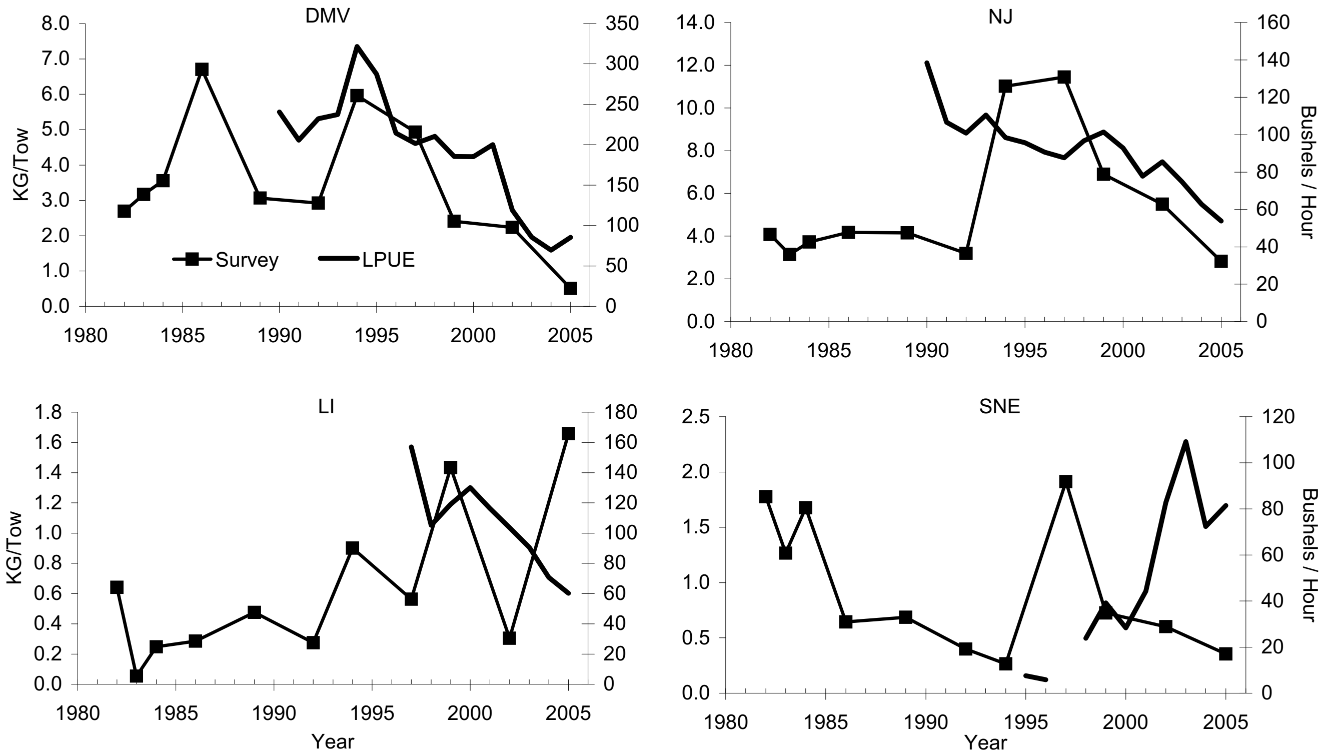


Figure C29. Trends in biomass indices for large fully large surfclam (mean kg tow^{-1}, 120+ mm SL) in NEFSC clam surveys and standardized LPUE in the commercial fishery.

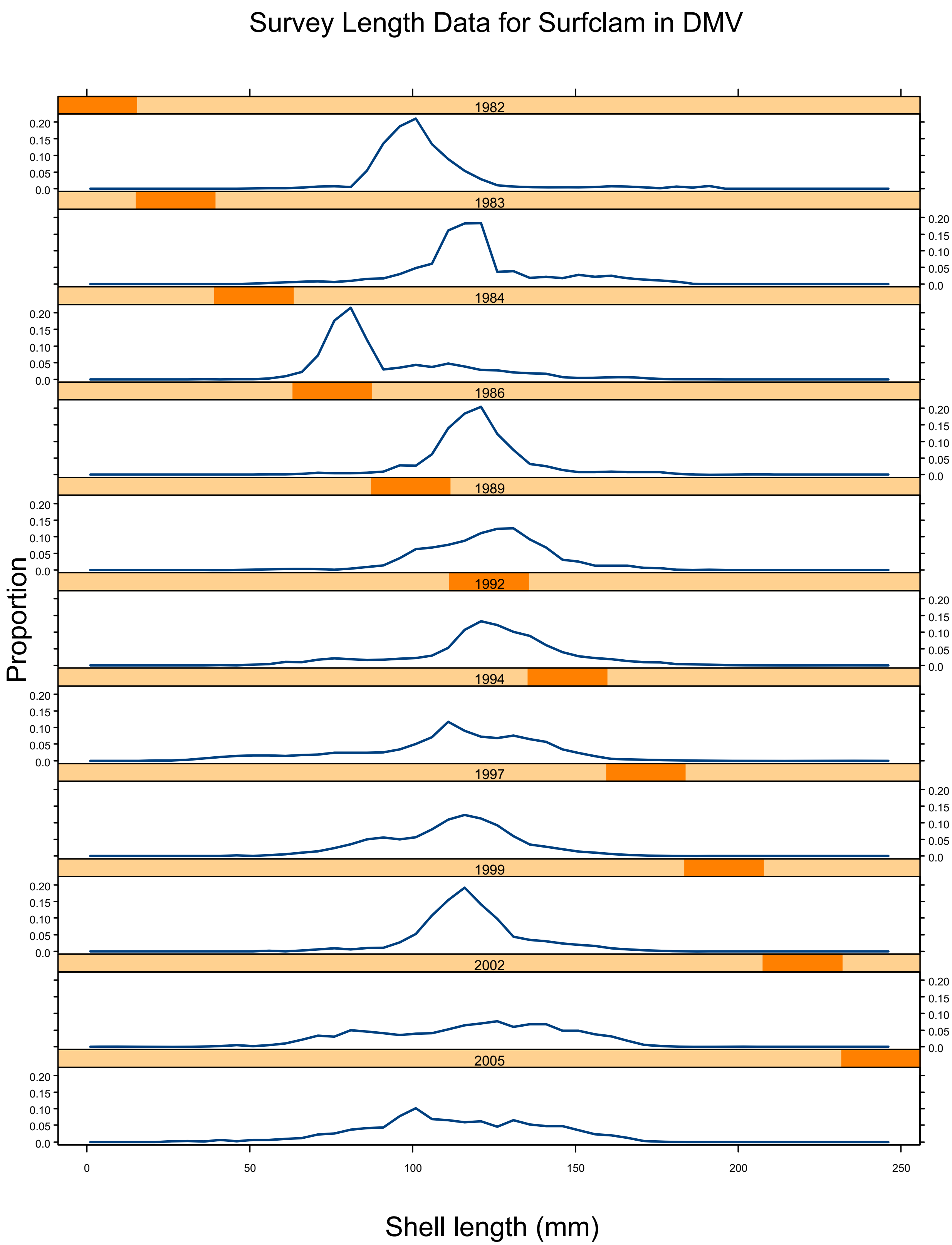


Figure C30. Survey length composition data for surfclam in the DMV region.

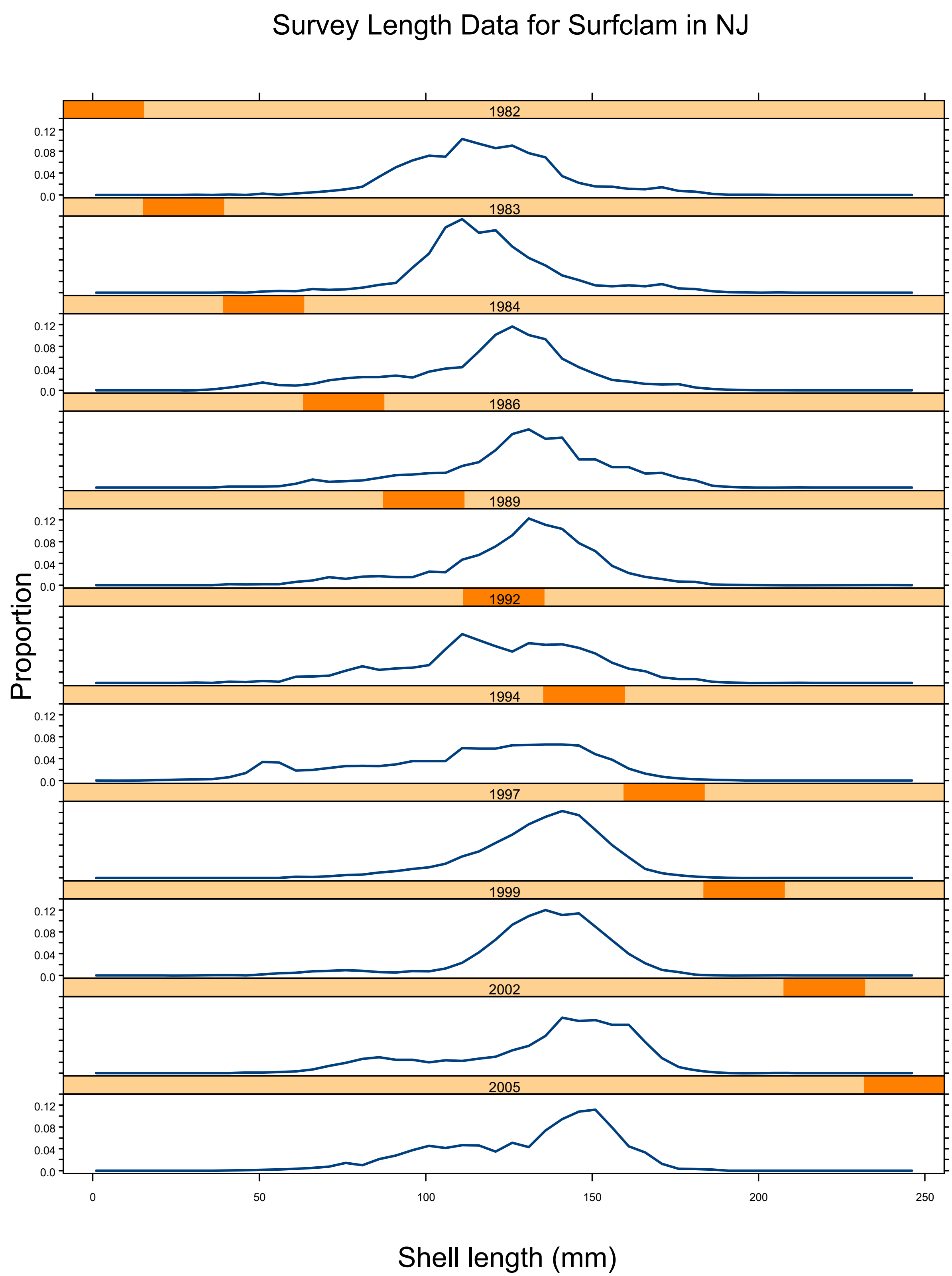


Figure C31. Survey length composition data for surfclam in the NJ region.

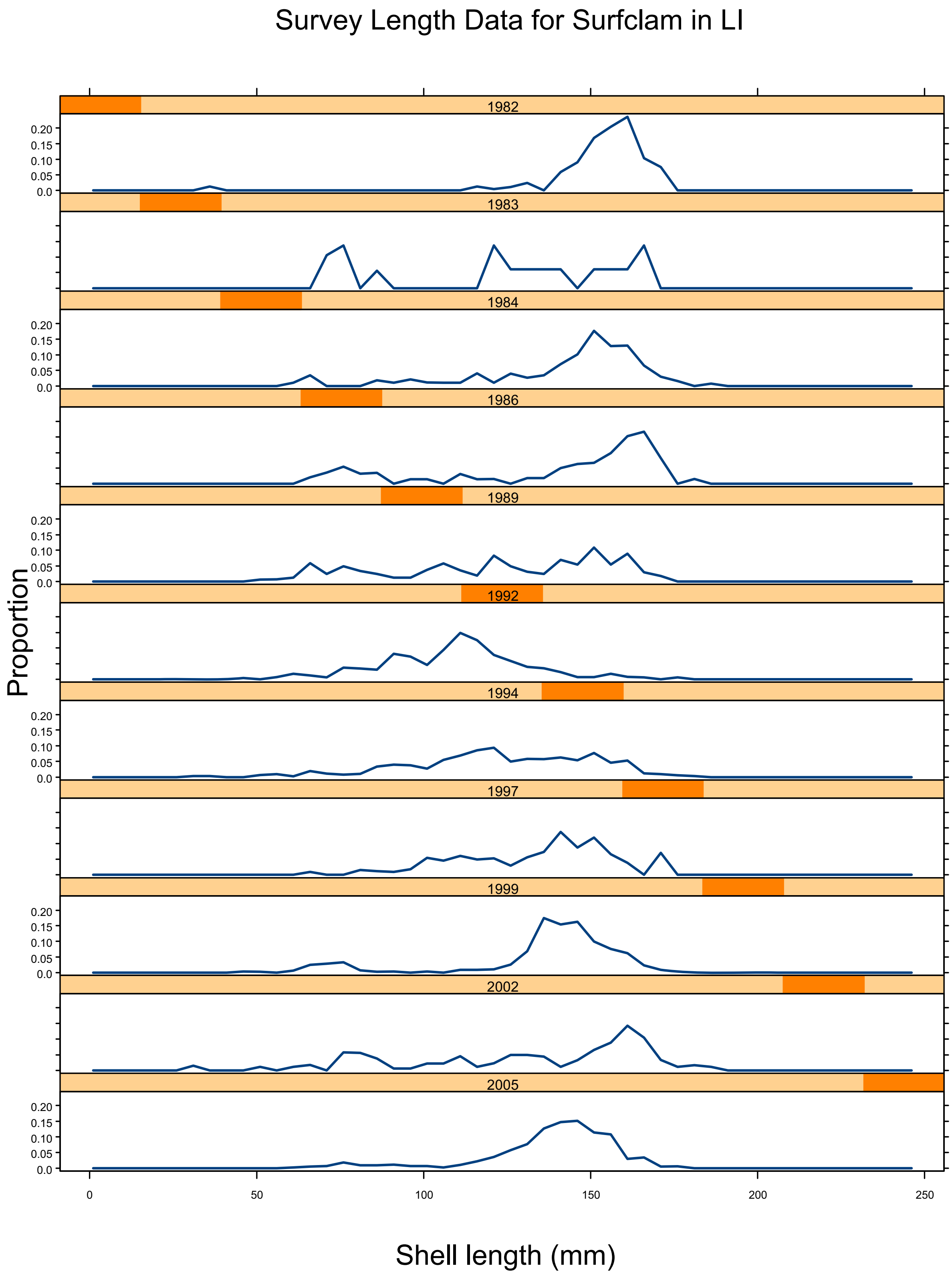


Figure C32. Survey length composition data for surfclam in the LI region.

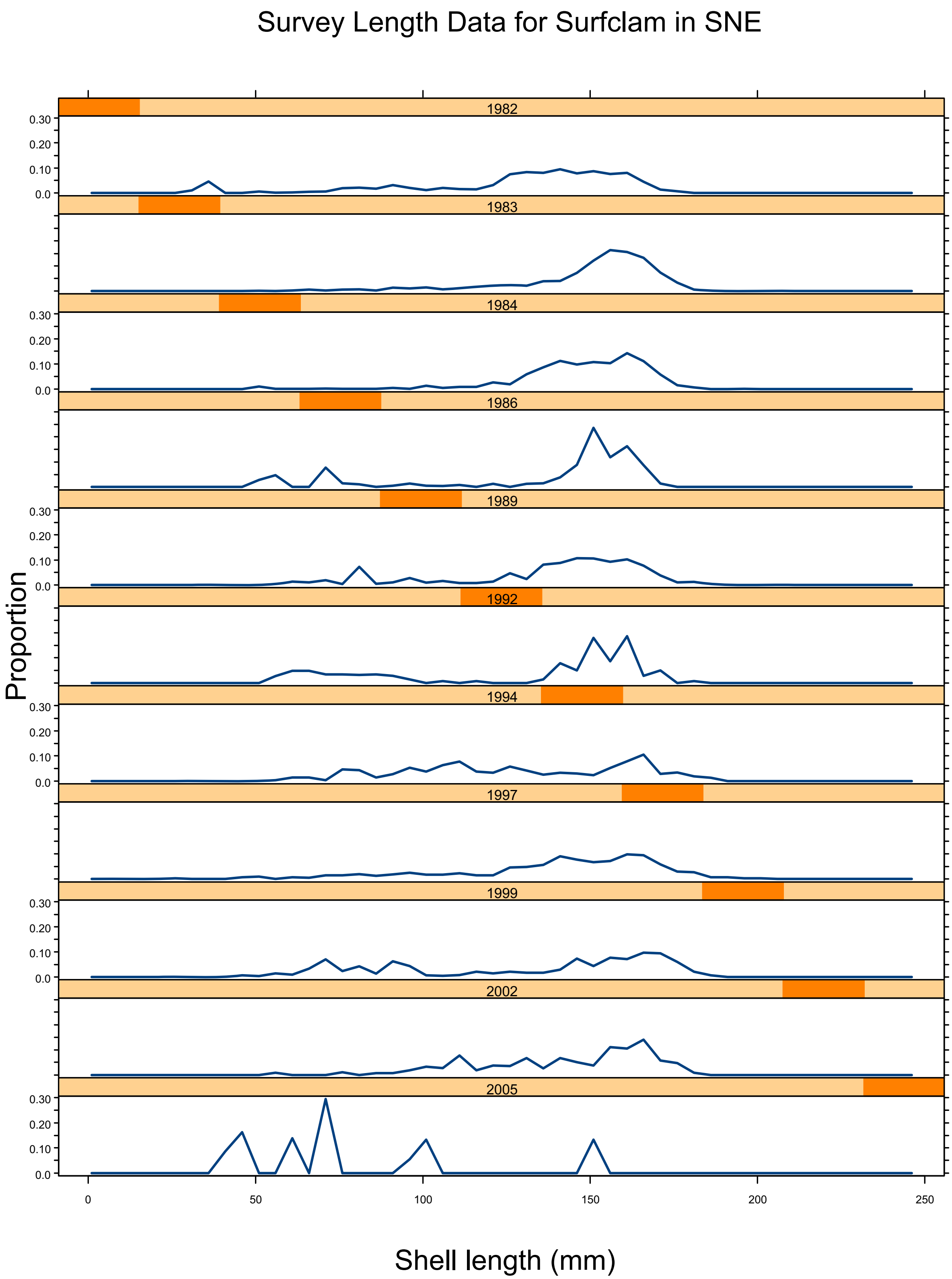


Figure C33. Survey length composition data for surfclam in the SNE region.

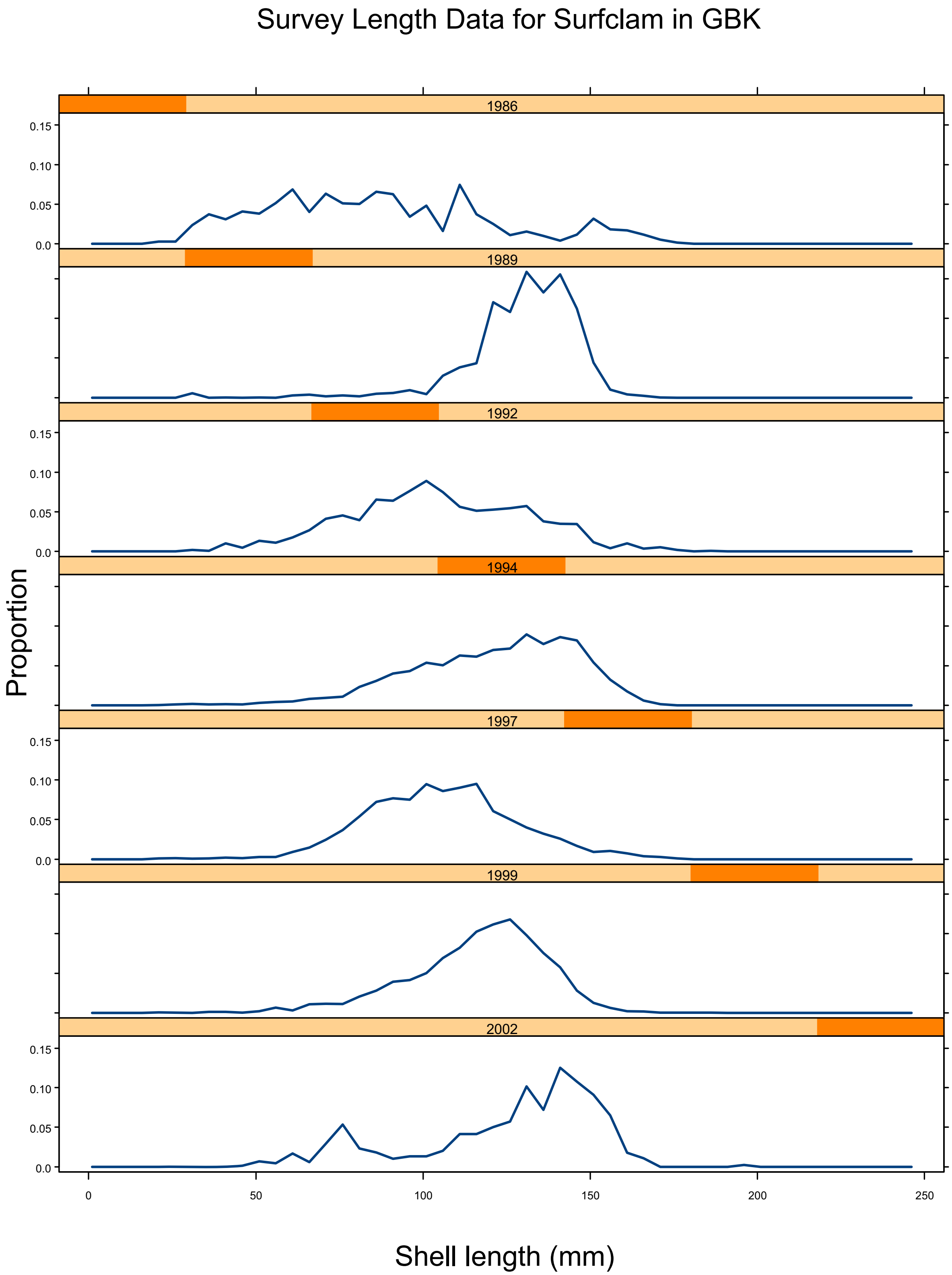


Figure C34a. Survey length composition data for surfclam in the GBK region.

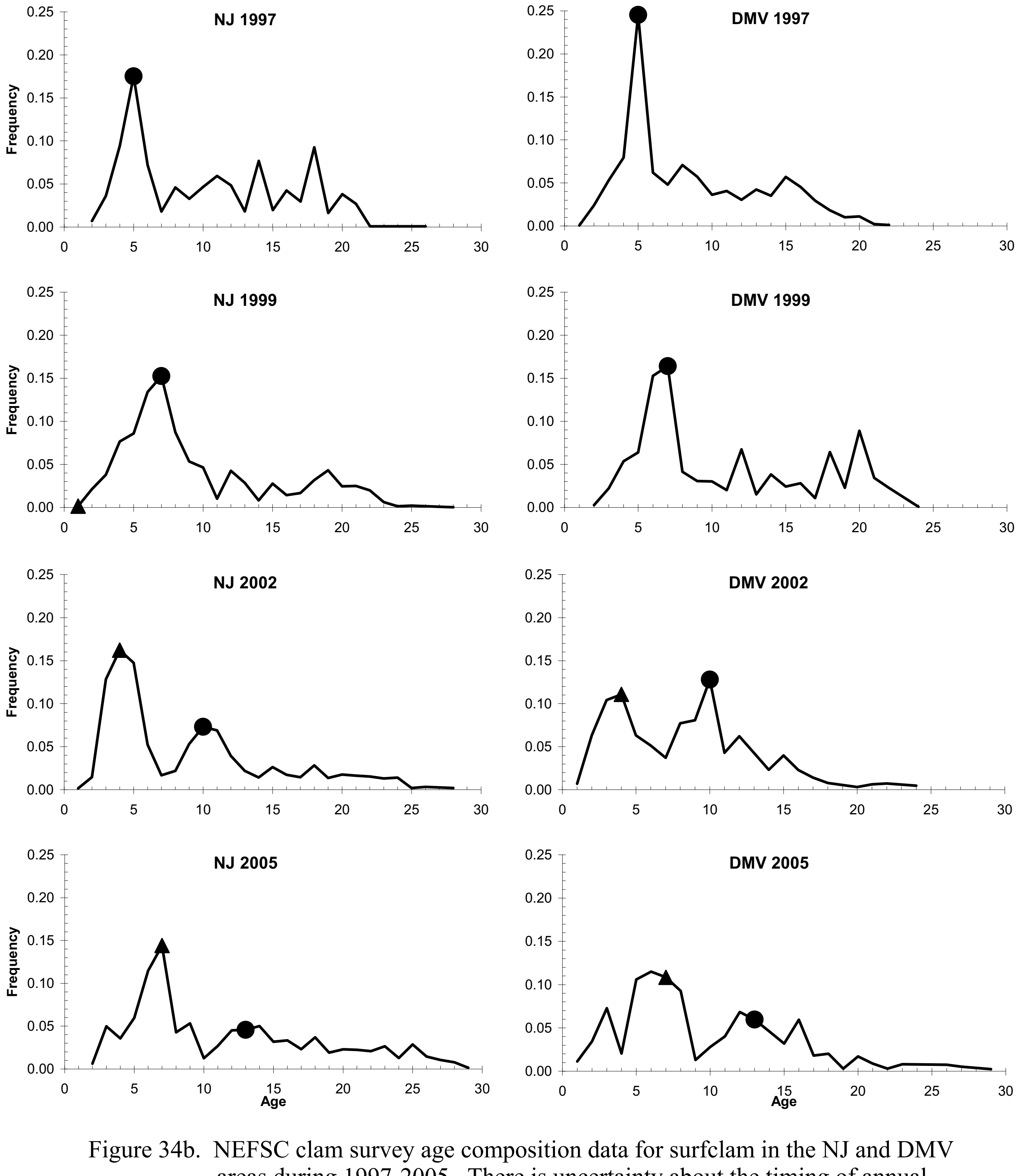


Figure 34b. NEFSC clam survey age composition data for surfclam in the NJ and DMV areas during 1997-2005. There is uncertainty about the timing of annual ring formation. Assuming rings form during the fall after the NEFSC clam survey, dark circles identify the 1992 year class (14 rings in 2005) and dark triangles identify the 1999 year class (7 rings in 2005).

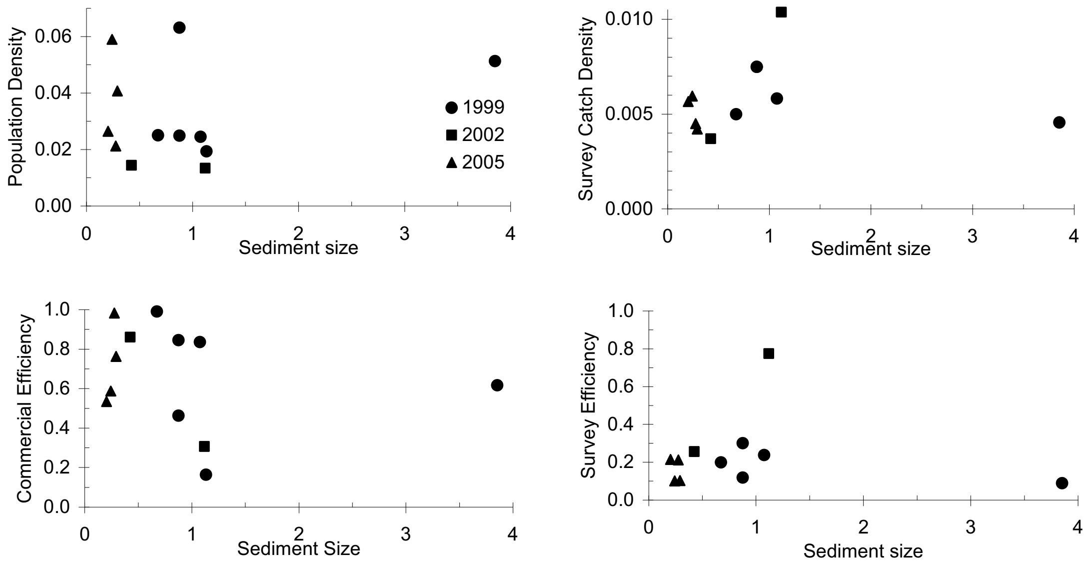


Figure C35. Relationships between depletion study variables and sediment grain size based on depletion studies during 1999, 2002 and 2005. Sediment data were not collected during 1997 and 2004.

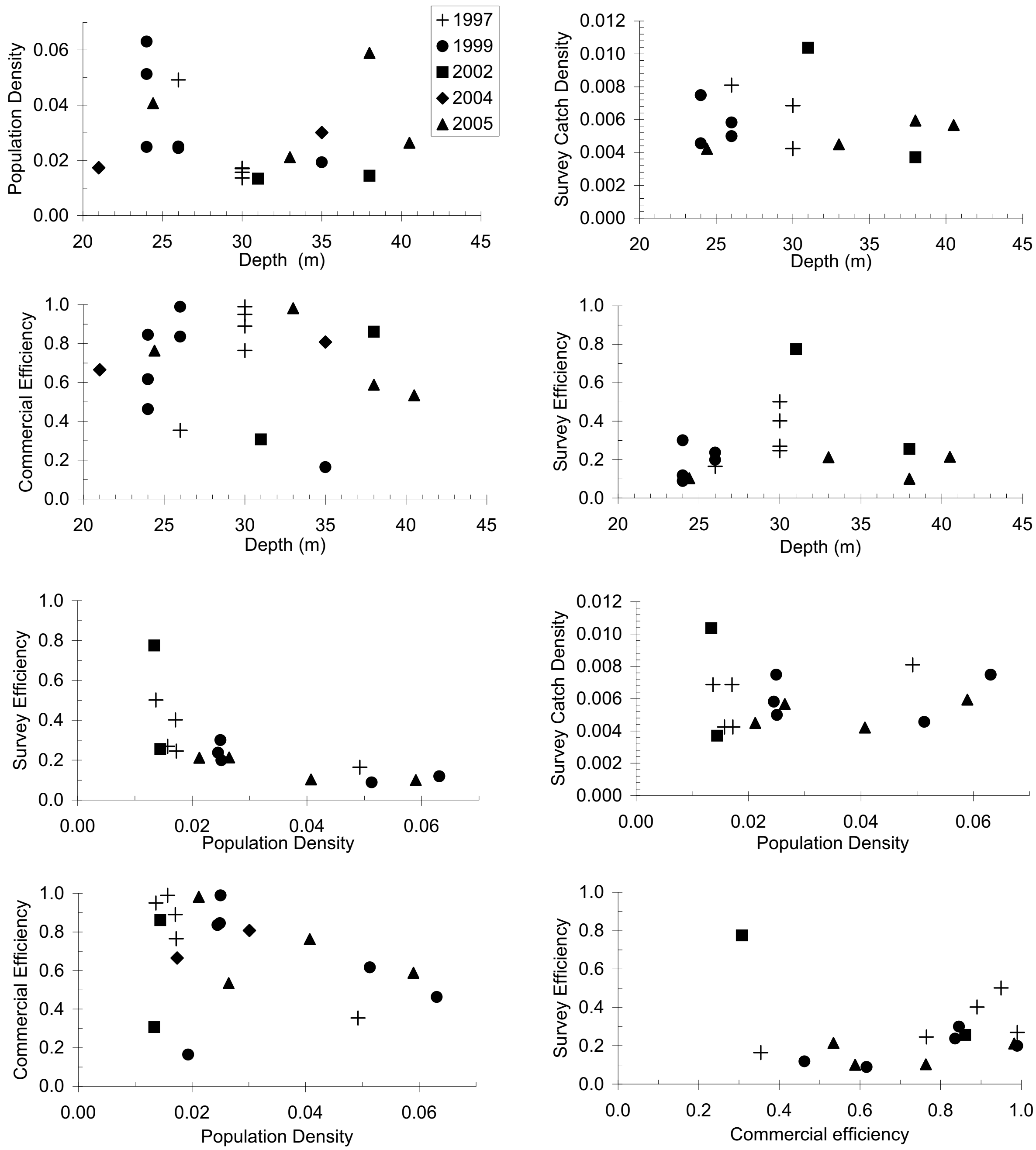


Figure C36. Relationships between depletion study variables based on all depletion studies during 1997- 2005.

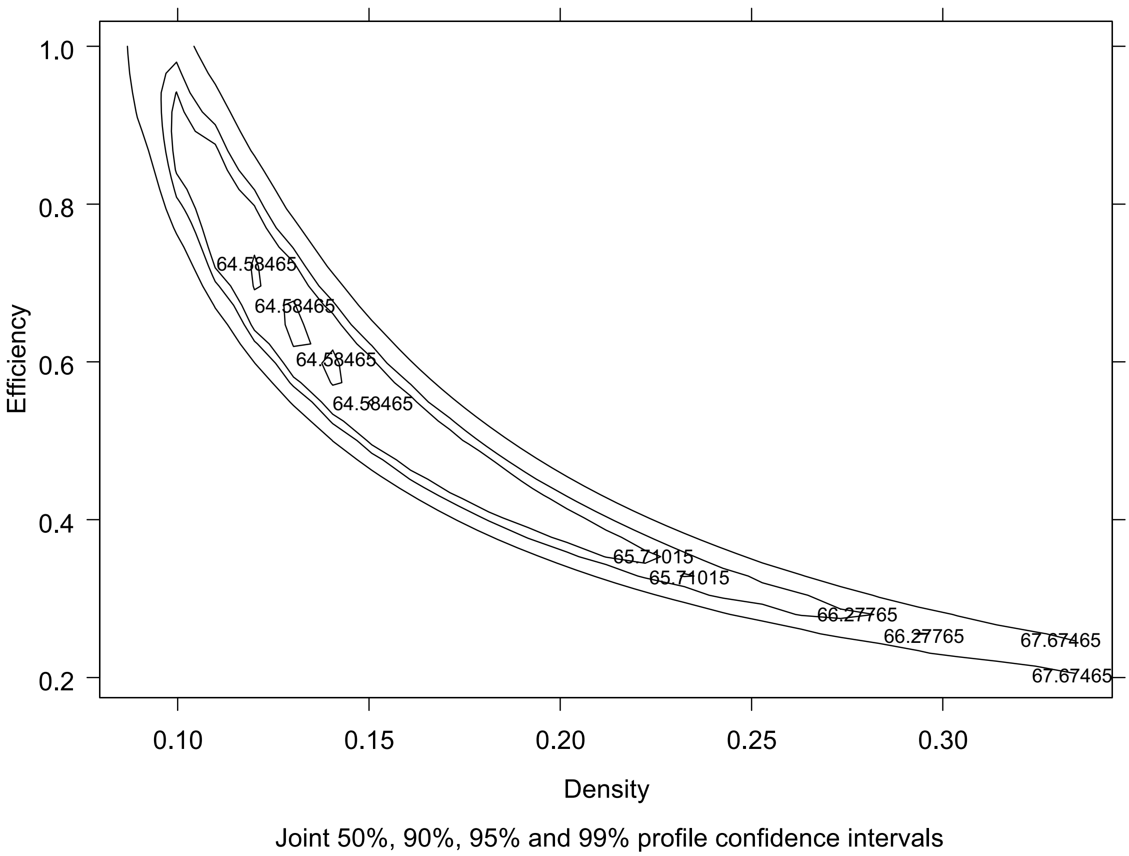


Figure C37. Likelihood profile analysis for efficiency and density estimates from the Patch model for the SC1999-7 surfclam depletion experiment. The joint 50% confidence interval for efficiency and density is the area within the outermost contour. The joint 99% confidence interval is the area inside the innermost contour lines. Contour lines for the joint 90% and 95% confidence intervals lie between.

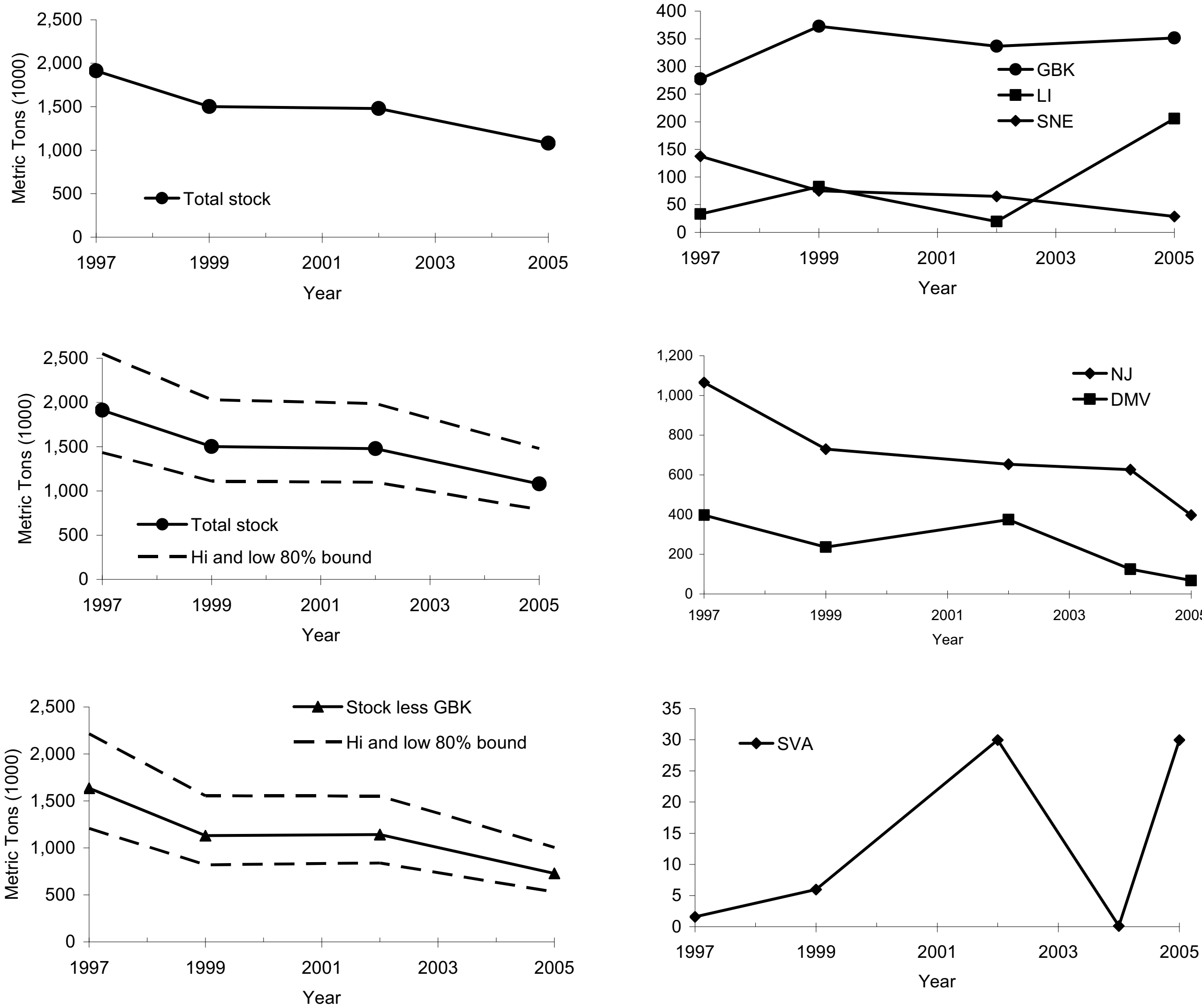


Figure C38. Efficiency corrected swept-area biomass estimates for surfclam 120+ mm SL, including estimates from the 2004 cooperative survey and NEFSC clam surveys during 1997, 1999, 2002 and 2005.

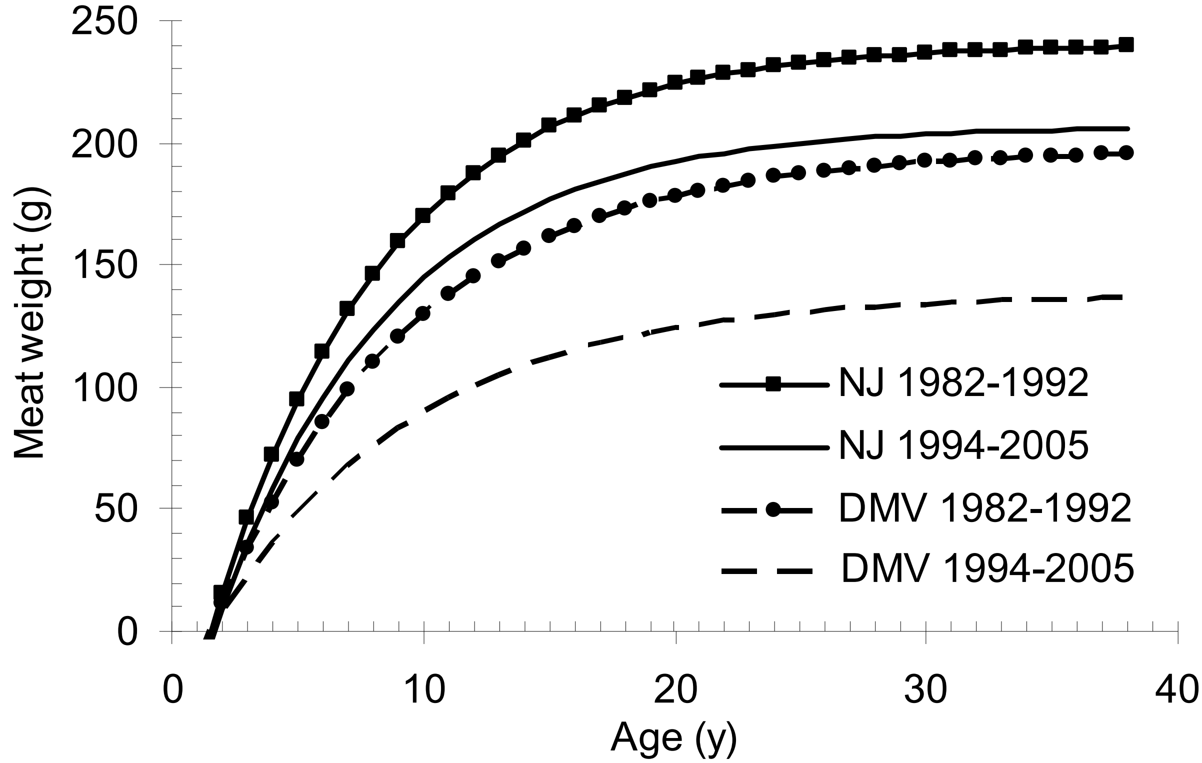


Figure C39. Von Bertlanffy curves for size (meat weight) at age of surfclam during 1982-1992 and 1994-2005 in the NNJ and DMV regions, based on NEFSC clam survey data for 1982-2005.

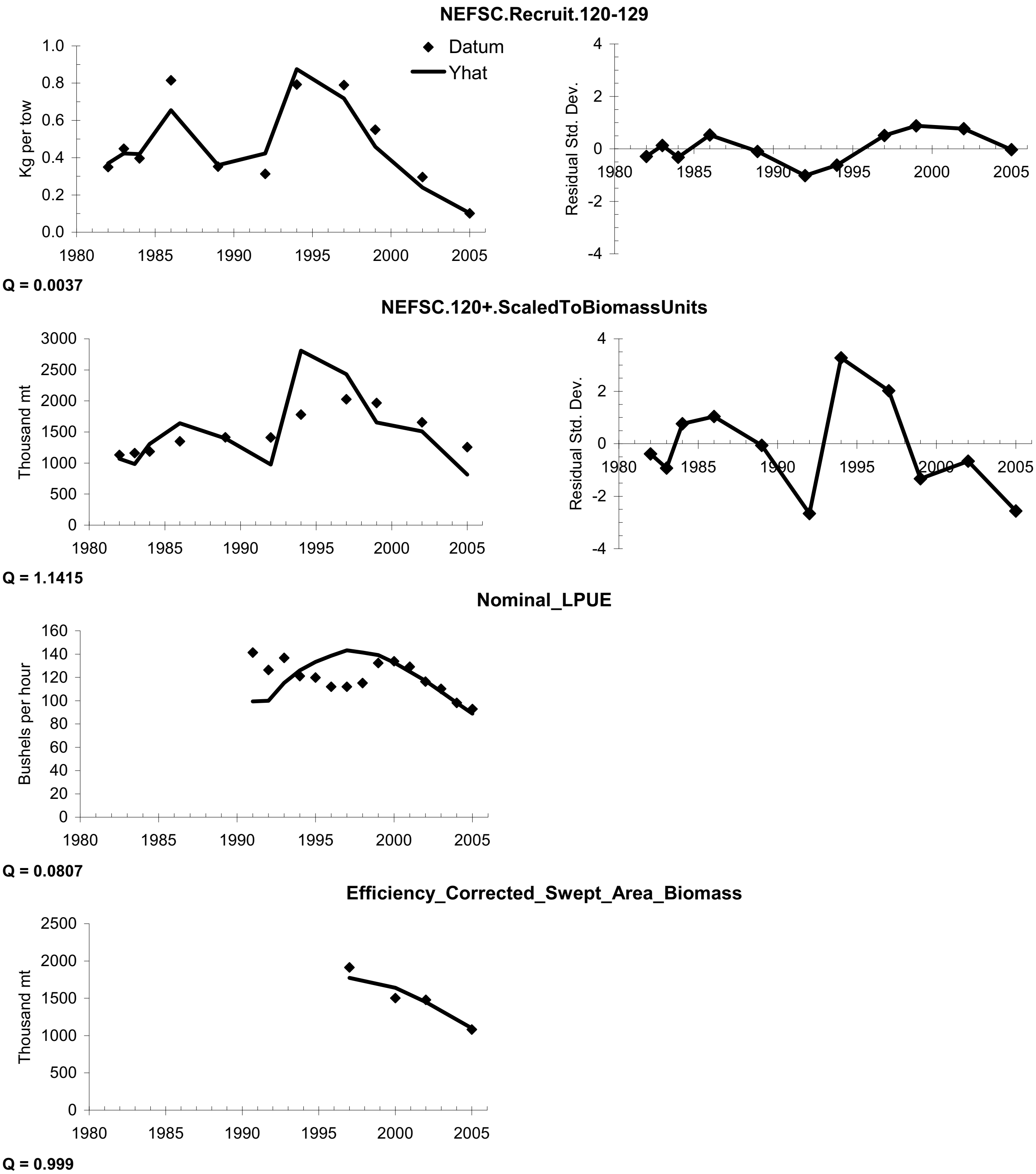


Figure C40. Model diagnostics for the KLAMZ model for the entire stock of surfclam. Trends in nominal LPUE and efficiency corrected swept area biomass are shown with predicted trends from the model for comparison, but trends in these indices did not affect model estimates. Survey scaling parameter (*Q*) estimates are shown below plots for each set of data.

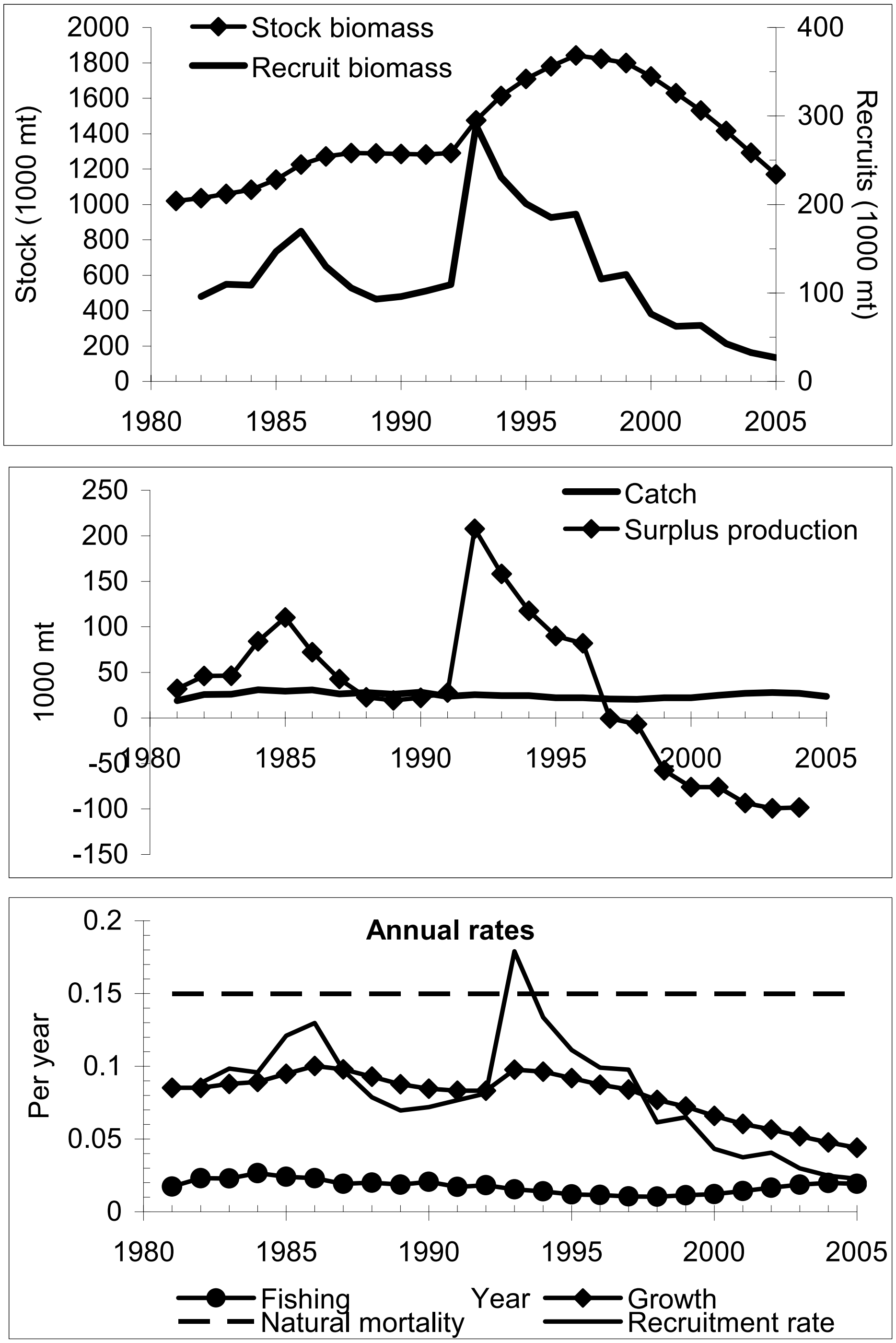


Figure C41. Population dynamics estimates from the KLAMZ model for the entire surfclam stock.

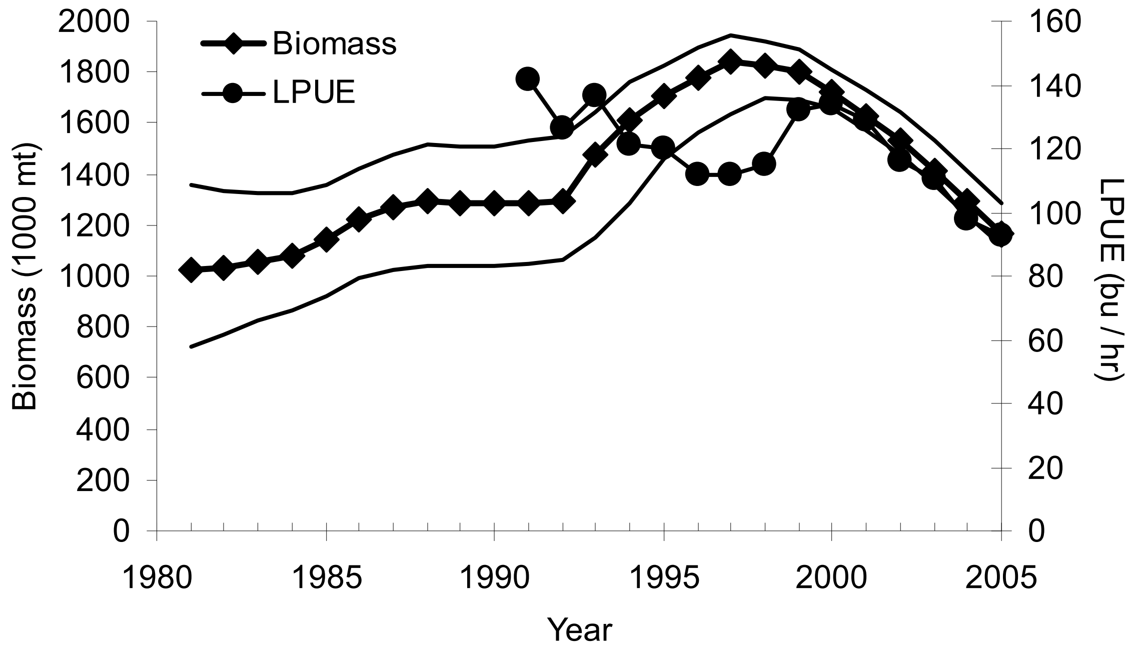


Figure C42. Fishable biomass estimates with 80% empirical confidence intervals from bootstrapping for the entire surfclam stock. Nominal LPUE from logbooks (total reported landings / total reported hours fished, all vessels and all trips) for the entire fishery is shown for comparison. LPUE data were not used in estimating biomass.

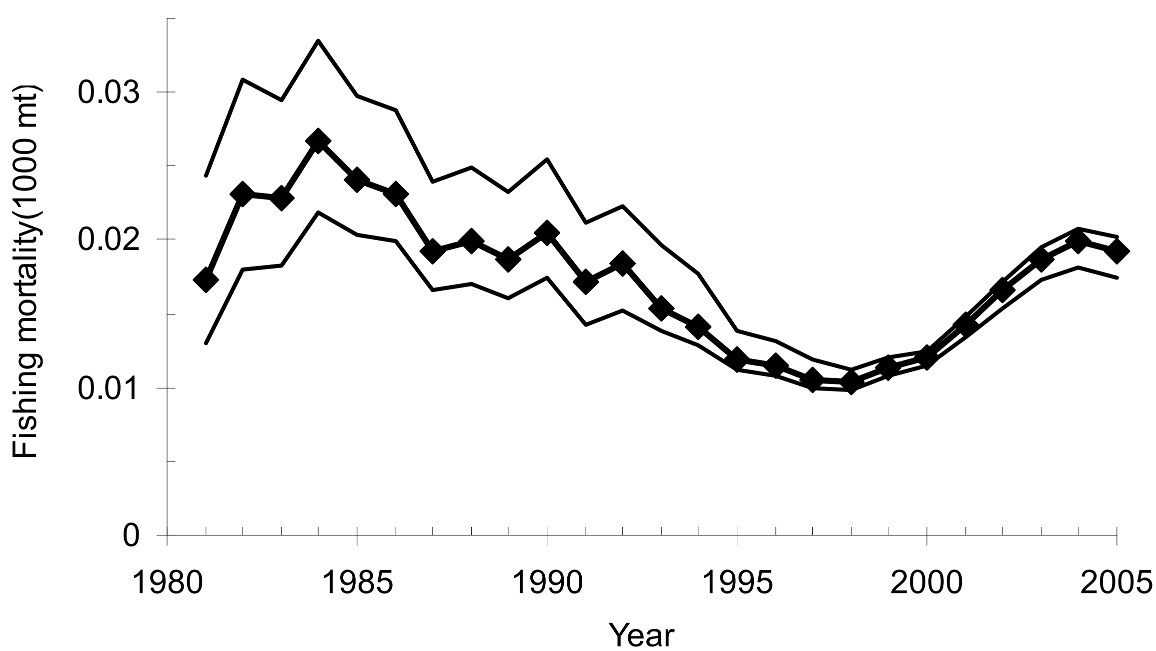


Figure C43. Fishing mortality estimates for the entire surfclam stock with 80% confidence intervals from bootstrapping.

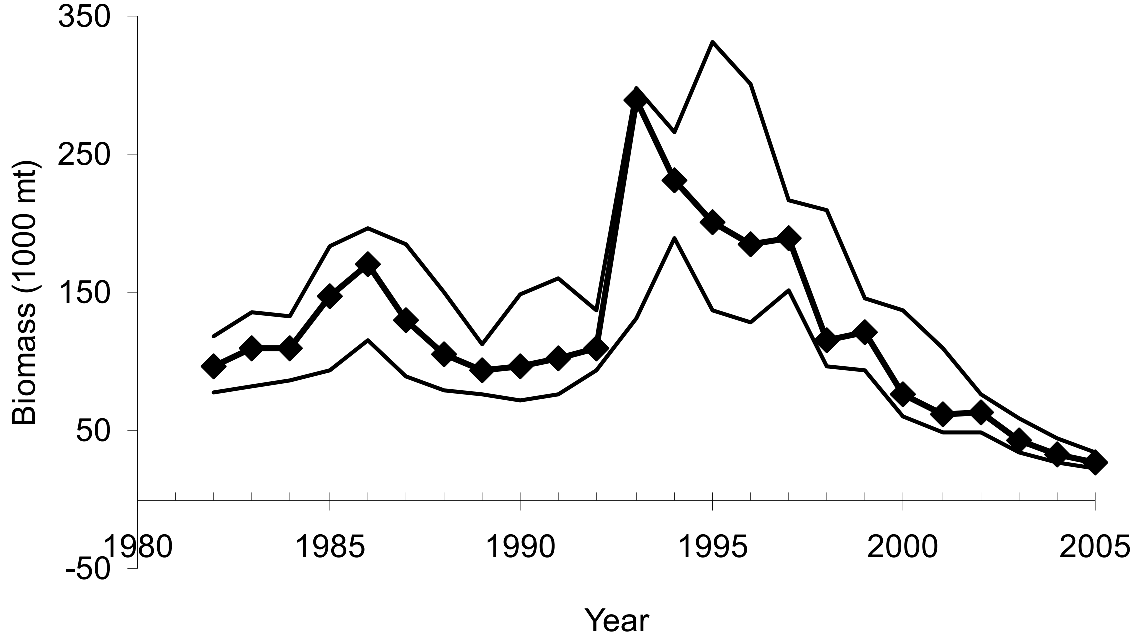
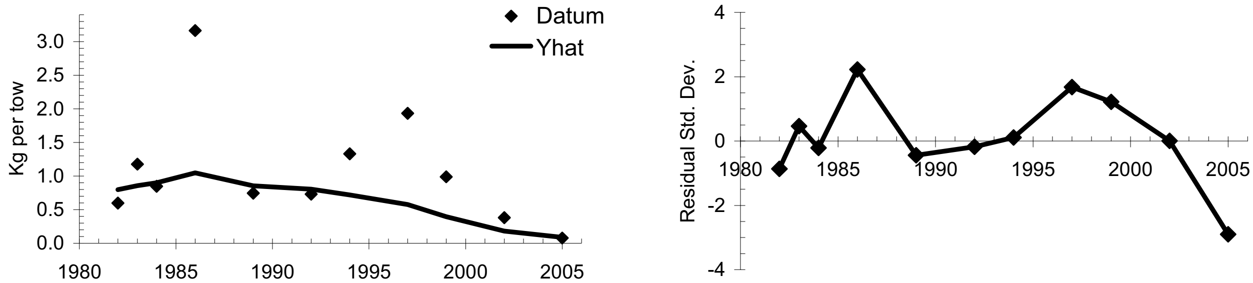


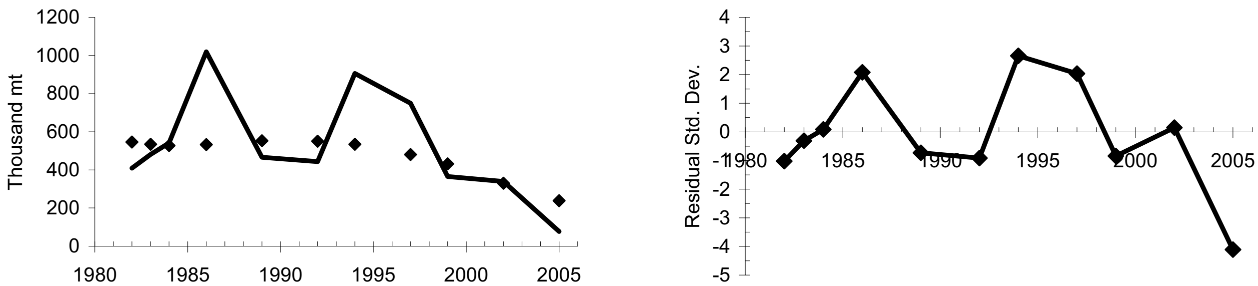
Figure C44. Recruitment for the entire surfclam stock with 80% empirical confidence intervals from bootstrapping.

NEFSC.Recruit.120-129



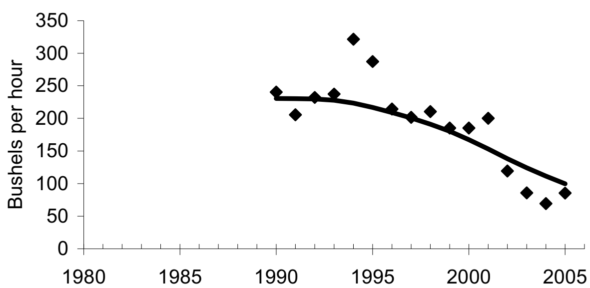
Q = 0.0288

NEFSC.120+.ScaledToBiomassUnits



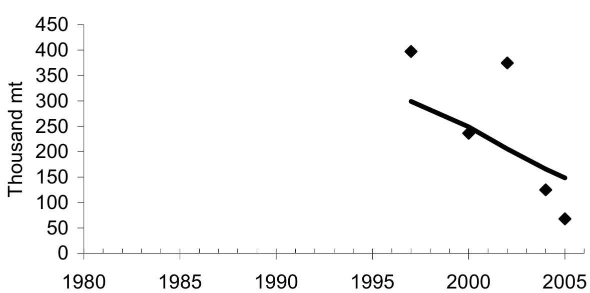
Q = 1.603

Standardized_LPUE



Q = 0.6697

Efficiency_Corrected_Swept_Area_Biomass



Q = 0.9961

Figure C45. Model diagnostics for the KLAMZ model surfclam in DMV. Trends in nominal LPUE and efficiency corrected swept area biomass are shown with predicted trends from the model for comparison, but trends in these indices did not affect model estimates. Survey scaling parameter (*Q*) estimates are shown below plots for each set of data.

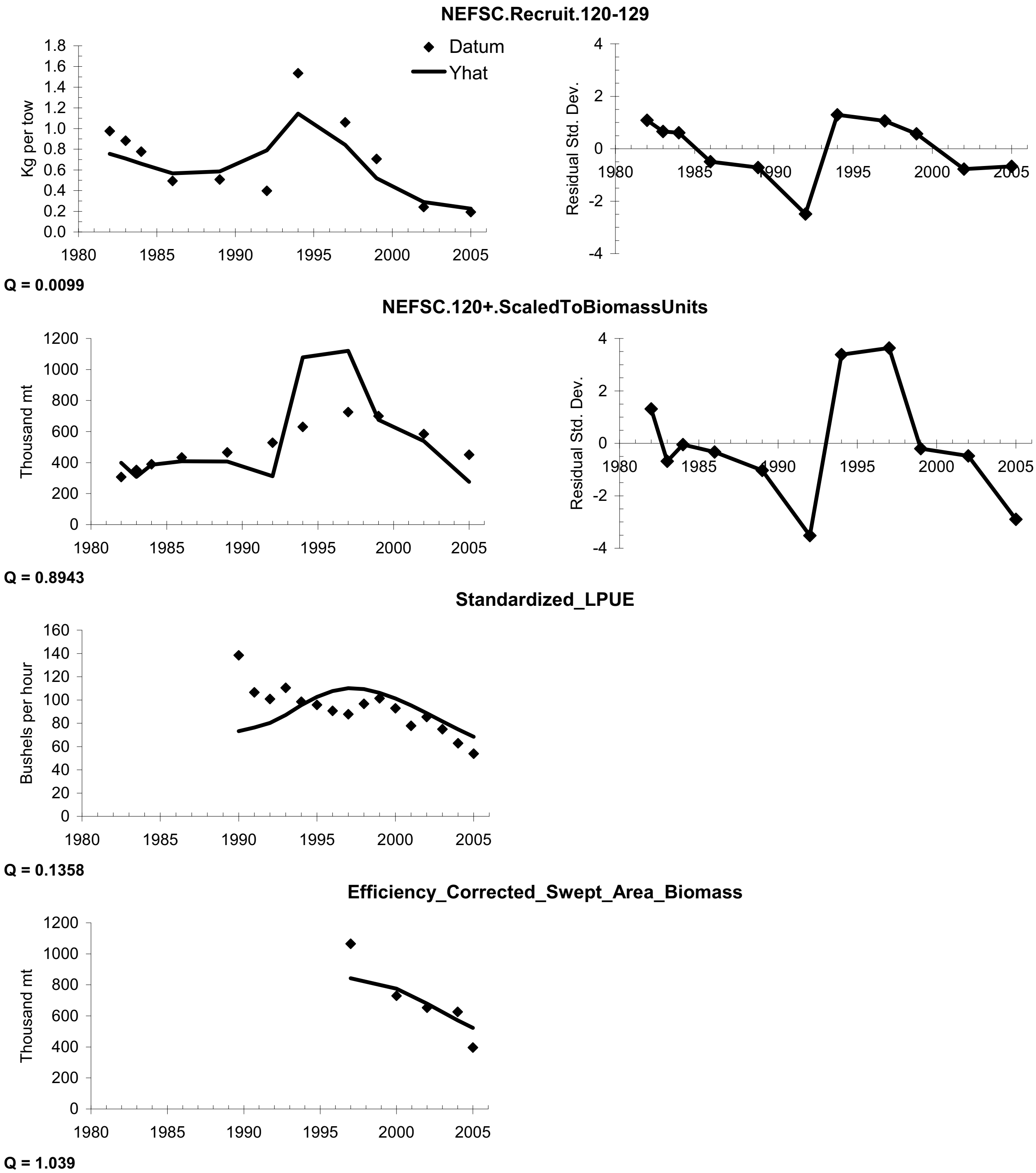


Figure C46. Model diagnostics for the KLAMZ model surfclam in NJ. Trends in nominal LPUE and efficiency corrected swept area biomass are shown with predicted trends from the model for comparison, but trends in these indices did not affect model estimates. Survey scaling parameter (*Q*) estimates are shown below plots for each set of data.

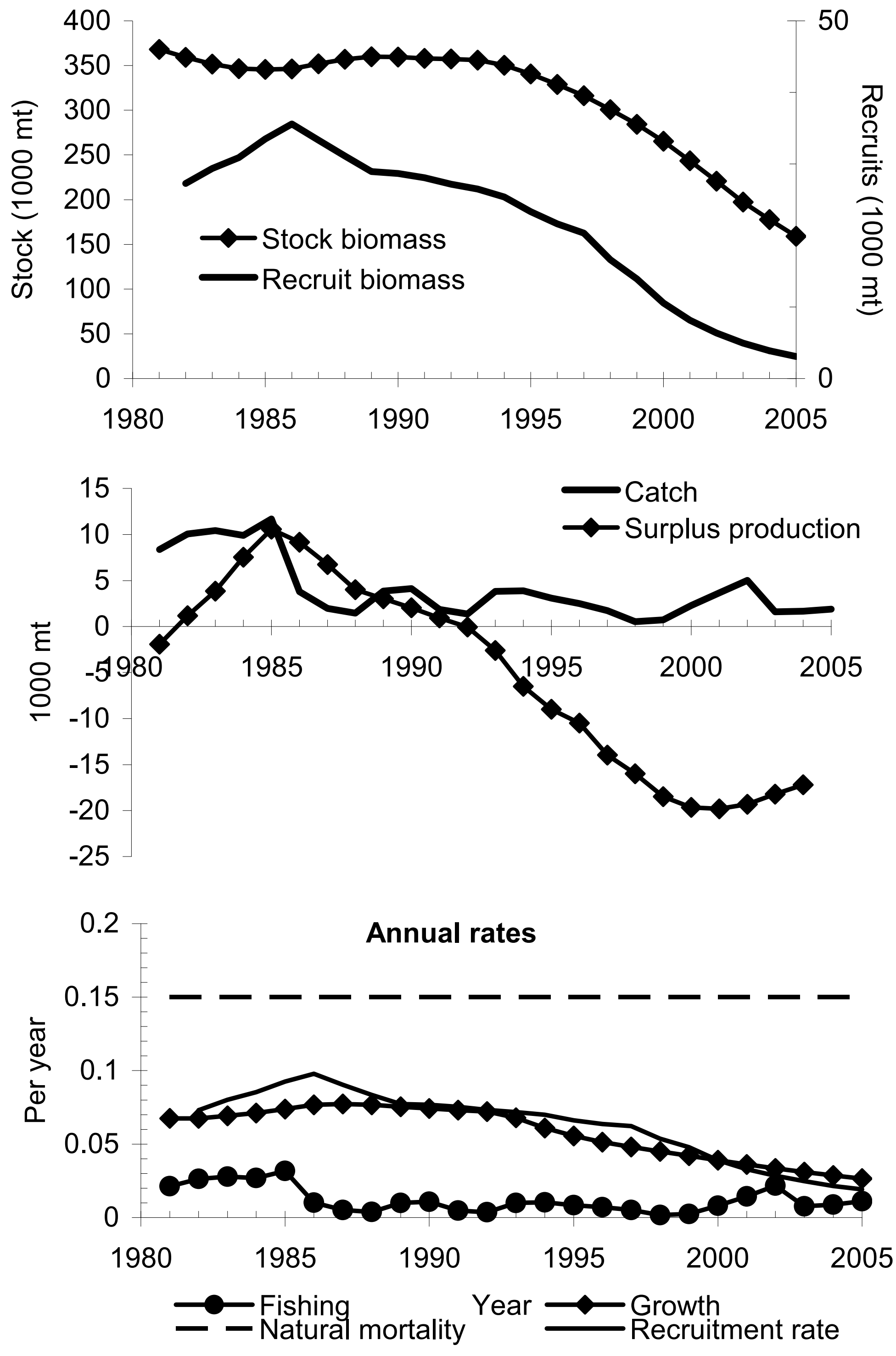


Figure C47. Population dynamics estimates from the KLAMZ model for surfclam in DMV region.

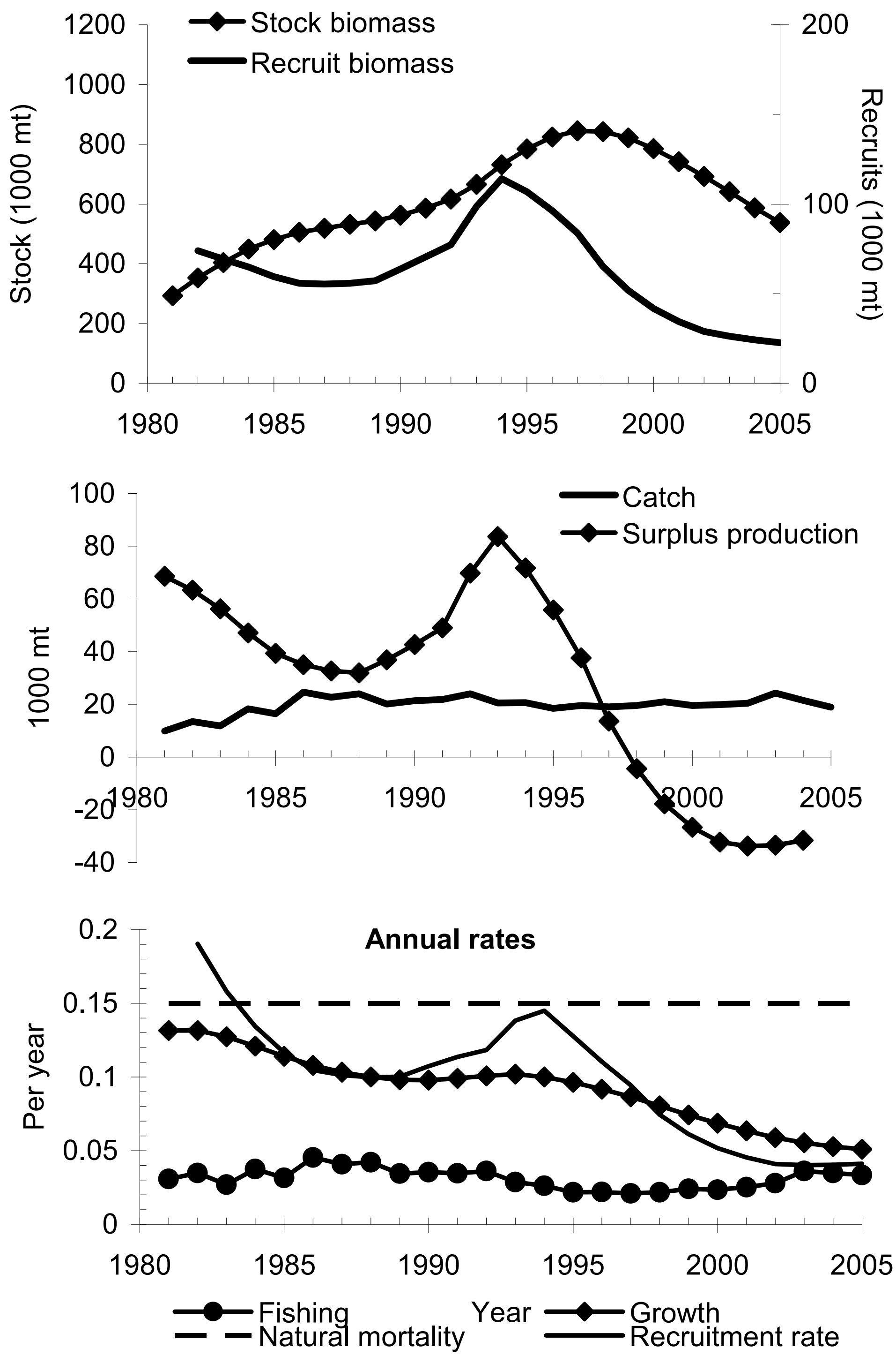
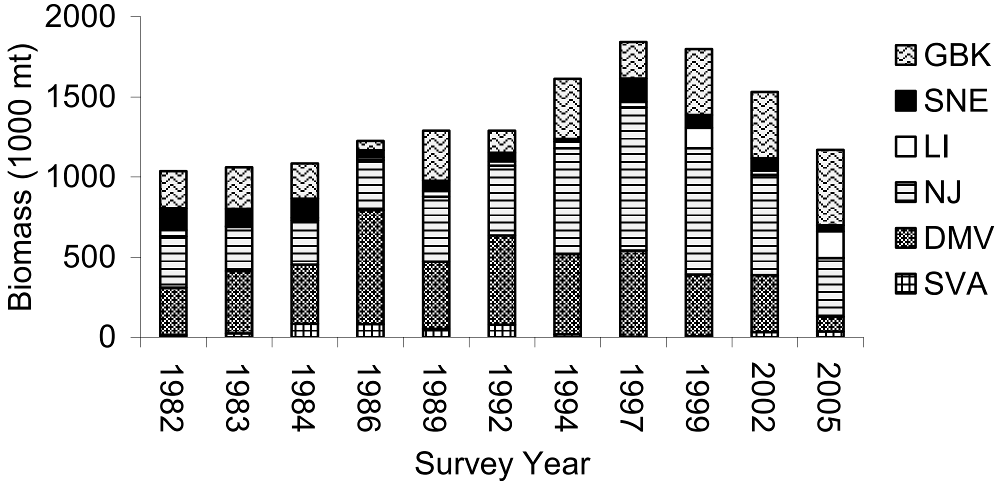


Figure C48. Population dynamics estimates from the KLAMZ model for surfclam in NJ region.



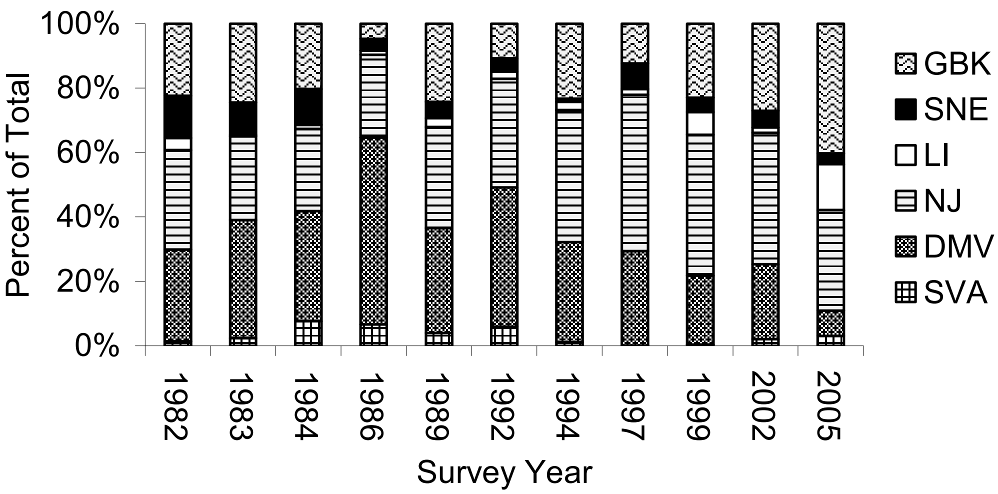
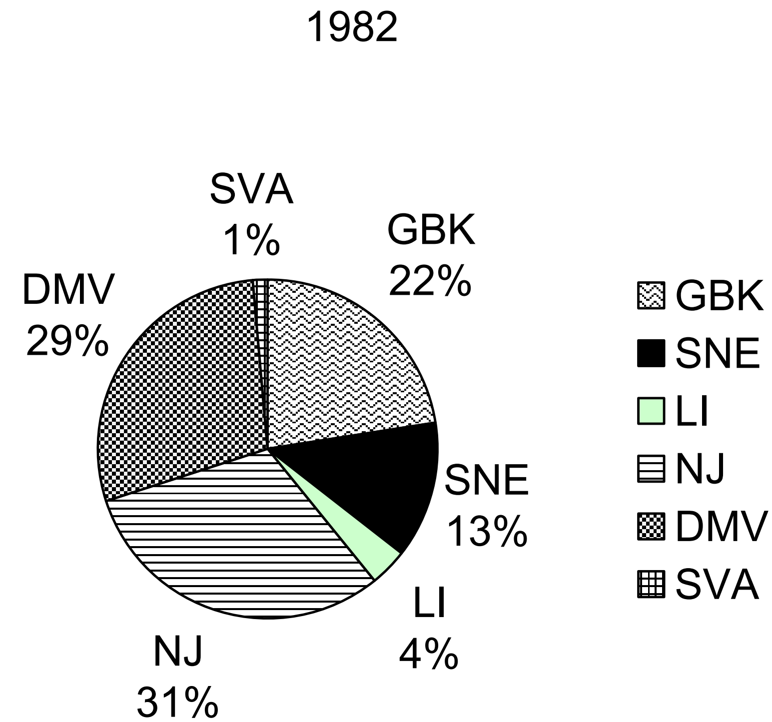


Figure C49. Surfclam biomass for the whole stock prorated into regional components based on rescaled regional survey trend data.



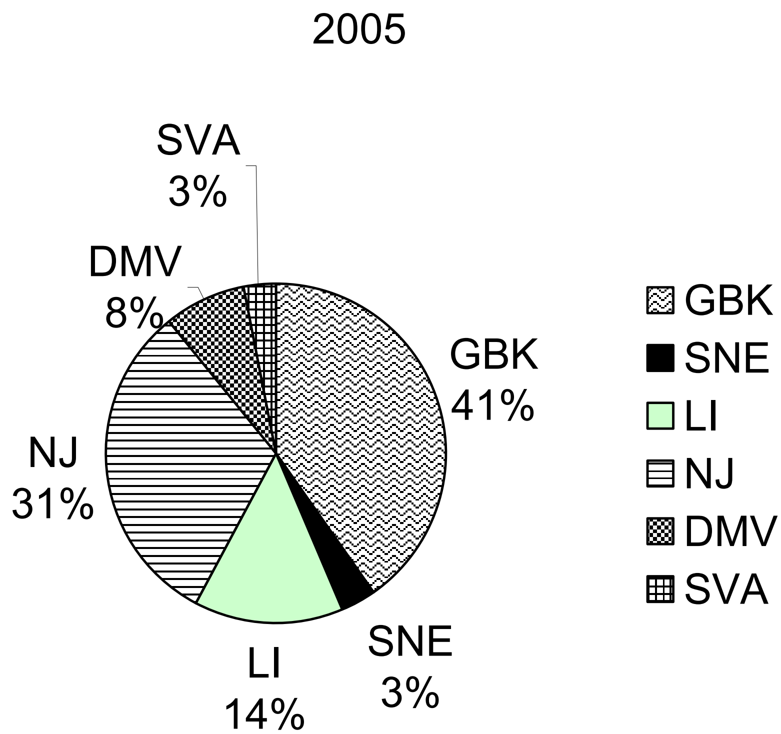


Figure C50. Proportions of total surfclam biomass by region during 1982 and 2005.

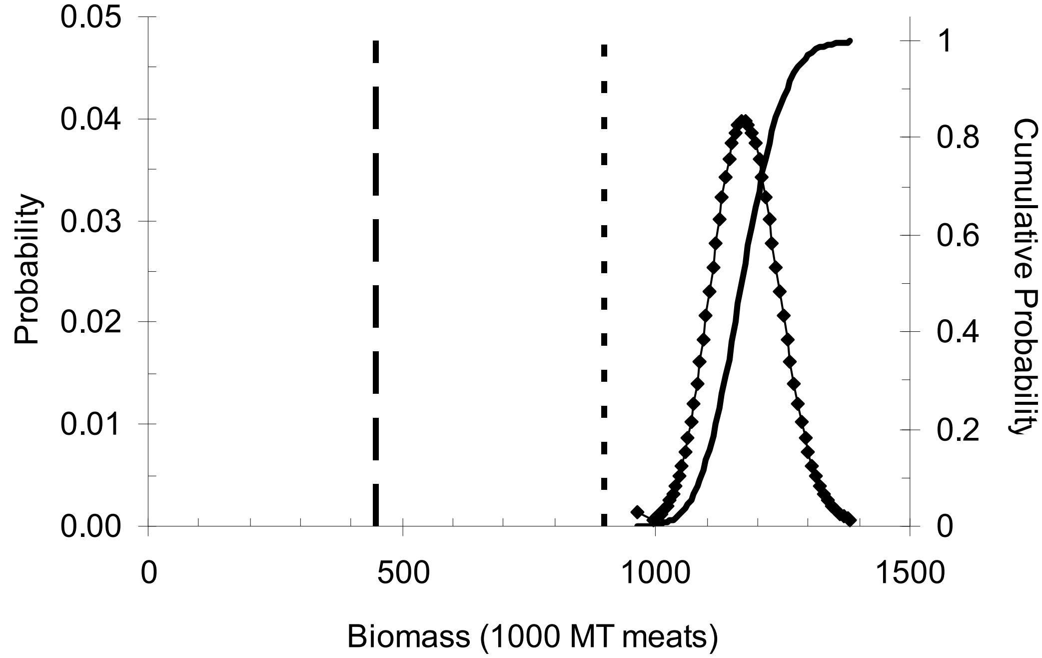


Figure C51. Fishable surfclam biomass during 2005 with probability distributions to characterize uncertainty. The long dash vertical line on the left is the biomass threshold. The short dash vertical line on the right is the biomass target.

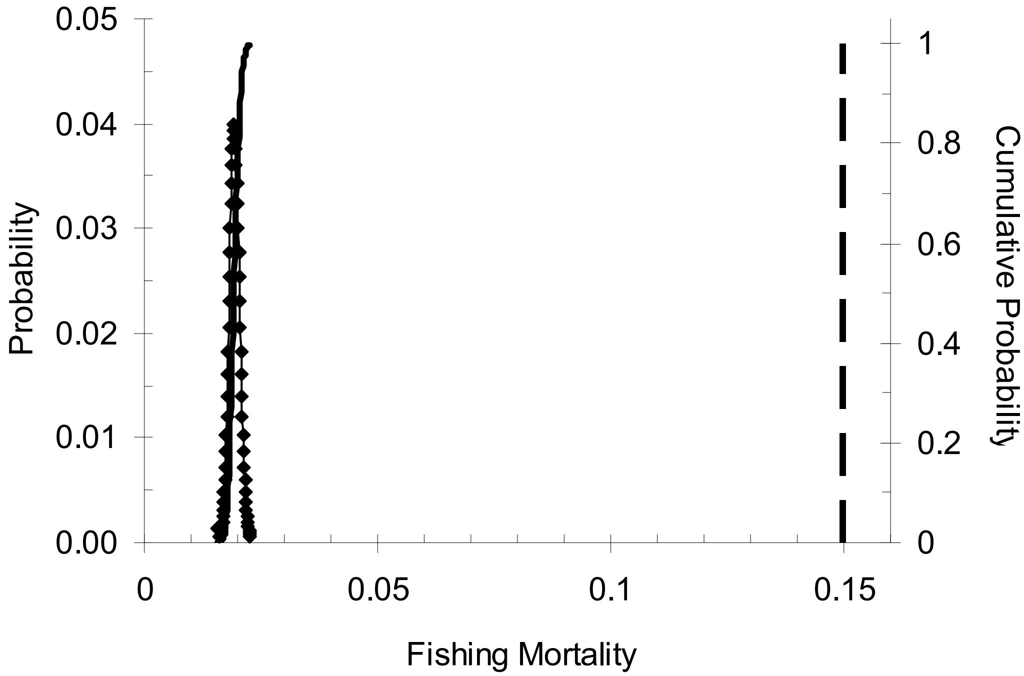


Figure C52. Fishing mortality for surfclam during 2005 with probability distributions to characterize uncertainty. The dash vertical line on the right is the fishing mortality threshold reference point.

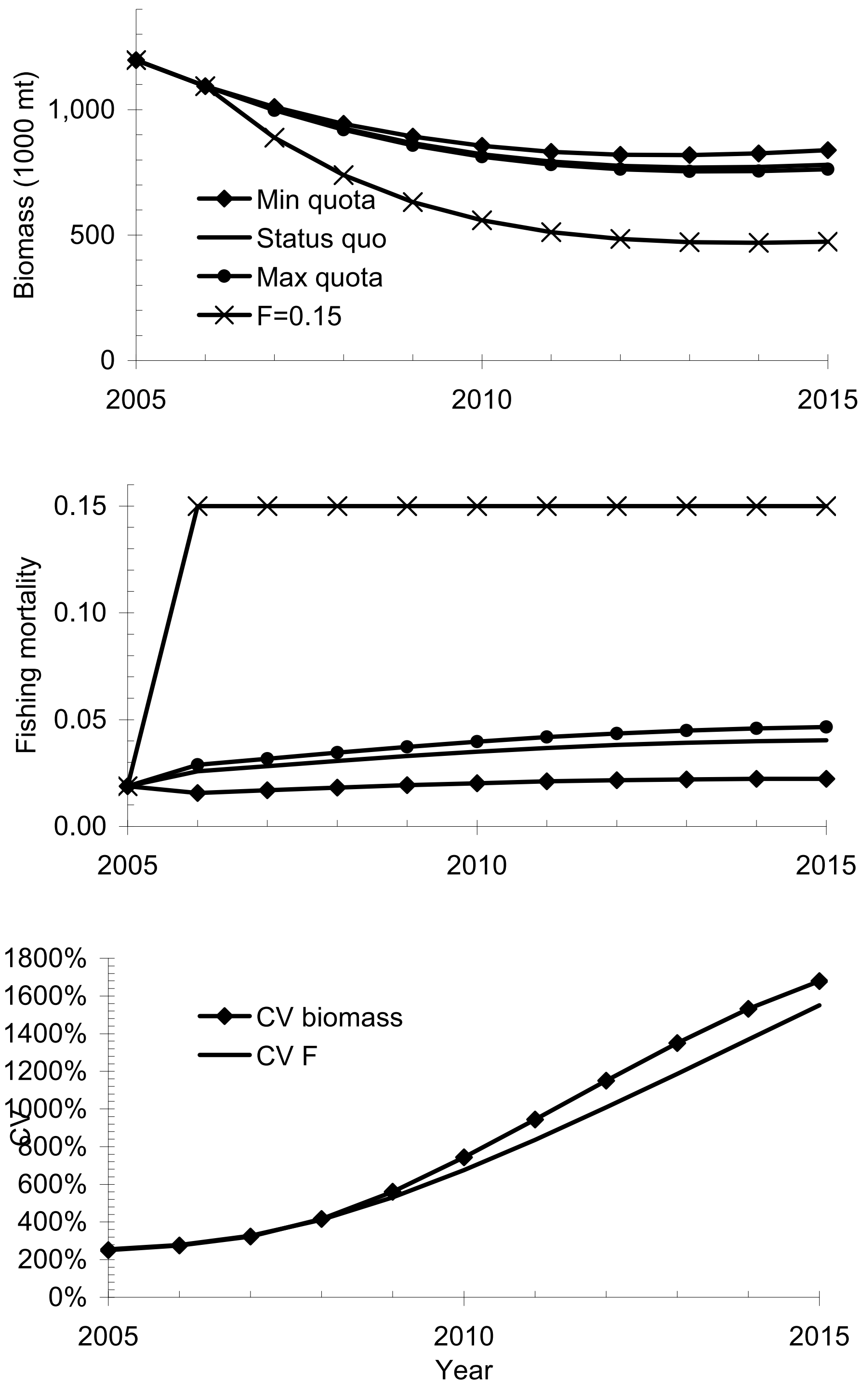


Figure C53. Average biomass and fishing mortality during 2005-2015 based on stochastic projection analysis under four assumed scenarios for constant landings of constant fishing mortality. CVs are for the variability between simulation runs in the same scenario.

APPENDIX C1. Invertebrate Subcommittee

Persons who attended Invertebrate Subcommittee meetings (September 25-26, October 16-17, and October 30-November 1, 2006) and contributed to this report are:

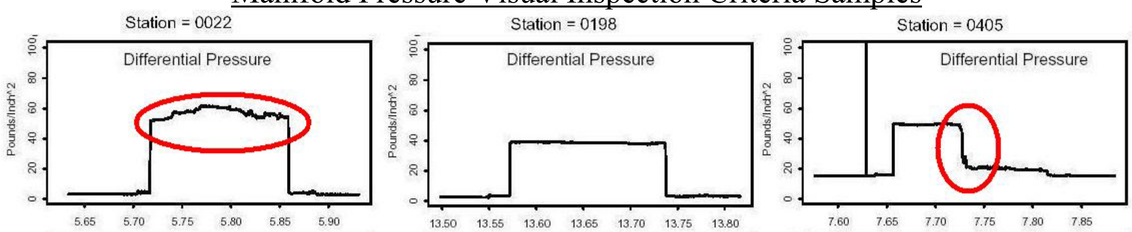
T. Alspach (Sea Watch International, Ltd.)
M. Bell (Invited external participant, Lowestoft, Suffolk, UK)
A. Chute (NEFSC)
H. Dobby (Invited external participant, FRS Marine Laboratory, Aberdeen, Scotland)
C. Heaton (Mid-Atlantic Fishery Management Council, MAFMC)
J. Heifitz (Invited external participant, NMFS, AKFSC)
T. Hoff (MAFMC)
L. Jacobson (Northeast Fisheries Science Center, NEFSC) – assessment lead
C. Pickett (NEFSC)
E. Powell (Haskin Shellfish Laboratory, Rutgers University)
D. Wallace (Wallace & Associates, Inc.)
J. Womack (Wallace & Associates, Inc.)
R. Mayo (NEFSC) – Subcommittee Chair
J. Weinberg (NEFSC)

APPENDIX C2. Analyses of tows with poor dredge performance in the 2002 NEFSC clam survey.

The review of the Survey Sensor Pack (SSP) data from the 2005 clam survey showed a significant number survey tows with anomalies that would likely affect the performance of the survey dredge. These anomalies in 2005 were mostly with problems in the manifold pressure in addition to several tows that had erratic towing angles. The number of 2005 survey tows deemed to have poor dredge performance by the proposed evaluation criteria (see Appendix C3) was approximately 8% of the total number of survey stations reviewed.

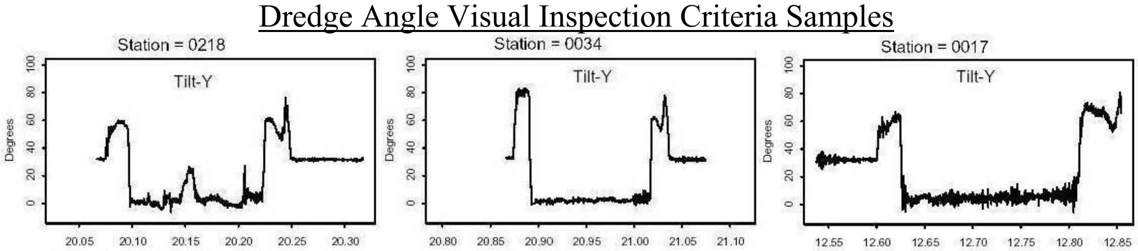
To see if the anomalies present in the 2005 survey were a unique situation or a continuation of an inherit inconsistency with the NMFS survey dredge, a review of the SSP data from the 2002 clam survey was undertaken. Because of time constraints and the limited number of survey station data plots available, this review was limited to a visual inspection of the data plots. The visual criteria used to judge a tow to have either “good” or “poor” dredge performance is the same as was used to perform a preliminary grading of the 2005 SSP data. In general the manifold pressure and fore/aft tilt angle plots were the parameters reviewed for significant deviations from normal values. Sample plots are shown below.

<u>Manifold Pressure Visual Inspection Criteria Samples</u>



Poor Manifold Blocked | Good Normal | Poor Intake Blocked

<u>Dredge Angle Visual Inspection Criteria Samples</u>



Poor High Spikes | Good Normal | Poor Erratic Over Tow

Summary of Results (for APPENDIX C2.)

The review of 2002 survey SSP data showed that similar anomalies found in 2005 survey were also found in the 2002 survey in addition to a problem with early shutoff of the dredge pump before the completion of the tow. The summary of the anomalies is shown below for both the 2002 and 2005 surveys.

Description	2002 Survey	2005 Survey
Total # of DE2 Survey Stations	556	433
Total # of Stations Tows Reviewed	213	399
Total # of Stations Labeled Good	181	366
% of Total Stations Reviewed	85.0%	91.7%
Total # of Stations Labeled Poor for Any Reason	32	33
% of Total Stations Reviewed	15.0%	8.3%
Total # of Stations Labeled for Intake Blockage	11	22
% of total Stations Reviewed	5.2%	5.5%
Total # of Stations Labeled Poor for Manifold Blockage	1	10
% of total Stations Reviewed	0.5%	2.5%
Total # of Stations Labeled Poor for Dredge Angle	0	2
% of total Stations Reviewed	0.0%	0.5%
Total # of Stations Labeled Poor for Early Pump Shutoff	20	0
% of total Stations Reviewed	9.4%	0.0%

In general the results show that the NMFS survey dredge is likely to experience a significant number of poor tows during any given survey from a number of possible reasons that affect either manifold pressure or fore and aft dredge running angle. From survey to survey, however, the predominate reason for a poor tow can vary. For example, the 2005 survey had a high number of poor tows due to manifold blockage compared to the 2002 survey. This was from an intake screen failure in 2005 on the dredge pump which allowed small stones to lodge in the manifold nozzles. In 2002, the predominate problem was the dredge pump being shutoff early which did not happen in 2005.

The list of poor tows for the 2002 tows from the tows reviewed is below. As pointed out elsewhere, many of the tows with poor gear performance would have been omitted from use in the stock assessment due to standard haul or gear condition criteria or were nonrandom tows used for special purposes.

2002 Clam Survey Bad Tow List

32					Bad Tow Reason			
STATION	STRATUM	Surfclam Region	Catch N Surfclams	Catch N Quahogs	Manifold Blockage	Intake Blockage	Excessive Dredge Angle	Early Pump Shutoff
4	35	OTH	0	30		X		
32	29	LI	0	11				X
42	89	NNJ	187	0		X		
44	89	NNJ	149	0		X		
45	89	NNJ	83	1		X		
52	89	NNJ	93	0				X
76	88	NNJ	133	0		X		
82	88	NNJ	24	0				X
90	21	NNJ	0	0				X
101	21	NNJ	0	0				X
103	21	NNJ	0	0				X
105	21	NNJ	0	0				X
106	21	NNJ	0	0				X
111	21	NNJ	0	0				X
118	21	NNJ	0	0				X
125	21	NNJ	0	0				X
137	21	NNJ	0	0				X
140	21	NNJ	0	0				X
141	21	NNJ	0	0				X
218	22	OTH	2	39		X		
250	18	OTH	0	2		X		
254	13	DMV	38	0				X
278	13	DMV	60	0		X		
360	9	DMV	35	2				X
368	9	DMV	108	0				X
382	19	OTH	0	28	X			
386	23	OTH	0	66		X		
394	26	OTH	0	16		X		
458	41	SNE	0	301		X		
496	60	OTH	0	416				X
498	60	OTH	0	107				X
506	61	GBK	0	1039				X

APPENDIX C3. Comparison of surfclam and ocean quahog catches in tows with poor dredge performance during the 2002 and 2005 NEFSC clam surveys and 2002 cooperative survey tows (prepared by John Womack, Wallace and Associates, Ltd.)

<u>2002 Stock Assessment Survey Results</u>

- Total # of DE2 Survey Stations = 556
- Total # of Stations Reviewed = 213
- Total # of Stations Labeled Good = 181
  - % of total Stations Reviewed = 85.0%
- Total # of Stations Labeled Poor = 32 (Any Reason, Visual Inspection of Plots)
  - % of total Stations Reviewed = 15.0%
  - Total # of Stations Labeled Poor = 11 (Intake Blockage)
    - % of total Stations Reviewed = 5.2%
  - Total # of Stations Labeled Poor = 1 (Manifold Blockage)
    - % of total Stations Reviewed = 0.5%
  - Total # of Stations Labeled Poor = 0 (Dredge Angle)
    - % of total Stations Reviewed = 0.0%
  - Total # of Stations Labeled Poor = 20 (Early Pump Shutoff)
    - % of total Stations Reviewed = 9.4%
- Average # of Surfclam per Good Tow - 24.2
- Average # of Surfclam per Poor Tow - 28.5
- Average # of Quahogs per Good Tow - 69.3
- Average # of Quahogs per Poor Tow - 64.3

Poor Stations, Intake Blockage - 4, 52, 76, 218, 250, 386, 394, 458
Poor Stations, Manifold Blockage - 382
Poor Stations, Early Pump Shutoff - 32, 42, 44, 45, 82, 90, 101, 103, 104, 106, 111, 118, 125, 137, 140, 141, 254, 278, 360, 368, 496, 498, 506

<u>Comments on Review of Pump Manifold Pressure (See Figure 1)</u>

For initial portion of the cruise, station 0-230, the pump voltage was about 388 VAC. During this part of the cruise the pump manifold pressure followed a similar value and decrease in pressure pattern, i.e. normal wear, as was seen in the 2005 survey.

After about station 230 the pump voltage suddenly rises to about 400 VAC till about station 300. The pump manifold pressure also showed a small increase over the first portion of the cruise from about 34 PSI to about 35-36 PSI.

After station 300 this rise can not be tracked as voltage data is lost from around station 300 till around station 400.

At around station 400 the pump voltage suddenly rises to about 417 VAC This voltage rise lasted till the survey end. The pump manifold pressure also showed a significant increase over the first portion of the cruise from about 34 PSI to about 40 PSI.

The total voltage rise from cruise start to end is about 7.5%. The power the pump was drawing also showed a similar increase from 11.87 to 12.79.

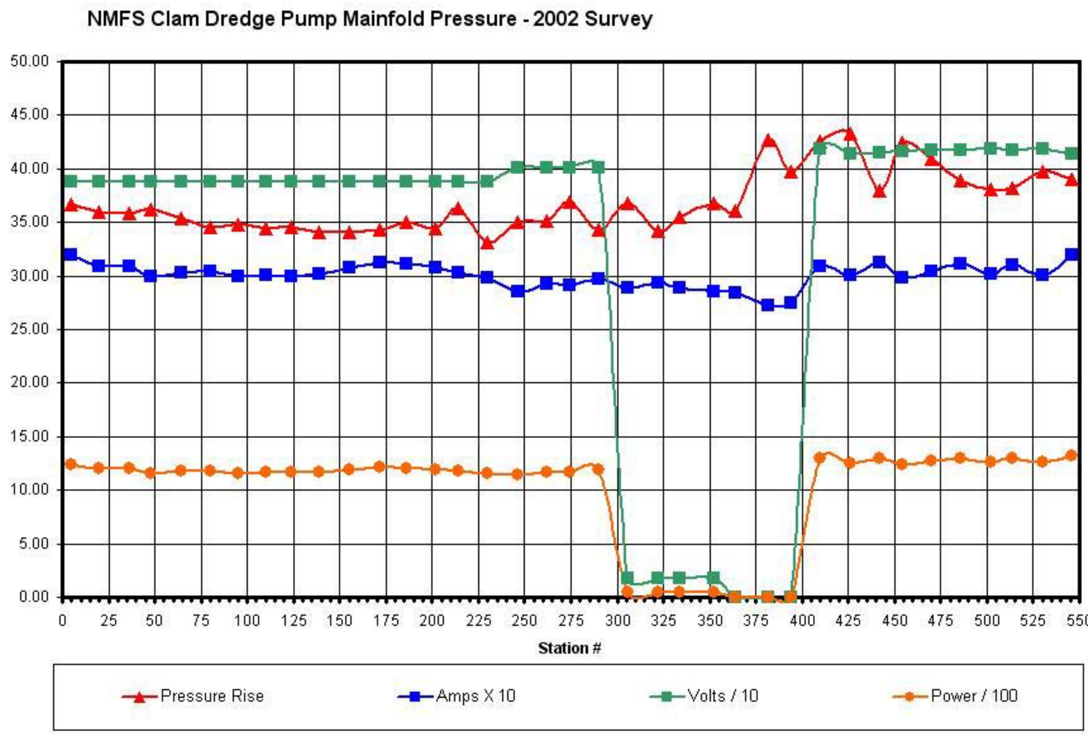


Figure 1 (Appendix C3)

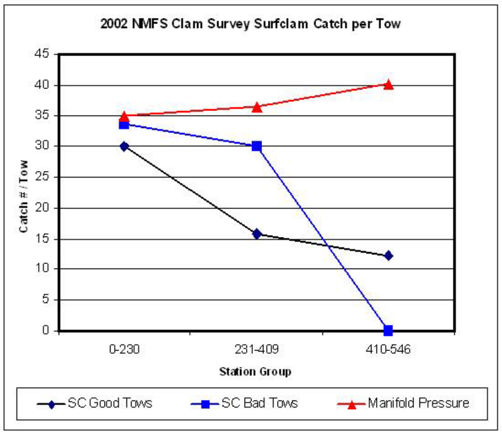
Station Number	All	0-230	231-409	410-546
Avg # of Surfclam per Good Tow -	24.2	30.1	15.8	12.3
Avg # of Surfclam per Poor Tow -	28.5	33.6	30.1	0.0
Avg # of Quahogs per Good Tow -	69.3	34.3	45.0	232.5
Avg # of Quahogs per Poor Tow -	64.3	4.1	14.3	465.8
Total # Of Good Tows	181	114	37	30
Total # Of Poor Tows	32	20	8	4

For all stations and 0-230 and 231-409 groups, the NMFS dredge appears to fish surfclam better during a poor tow, generally which was a loss of manifold pressure, than a good tow. The last group, 410-546, did not show this pattern but this could be due to the fact that it appears to be primarily composed of quahog habitat stations.

The manifold may have seen some blockage in the stations around 375 to 400 as the pressure is higher but the amps draw has dropped.

For all groups as the manifold pressure rises, the surfclam catch per tow falls significantly, over 50%. See Figure 2. Caveat, limited number of stations in last two groups and last group was likely in quahog habitat.

For all groups as the manifold pressure rises, the quahog catch per tow increases significantly. See Figure 3. Caveat, limited number of stations in last two groups and last group was likely in quahog habitat.



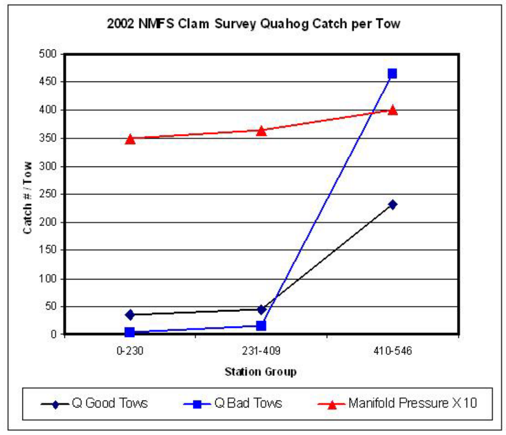


Figure 2 and Figure 3 (Appendix C3)

<u>2005 Stock Assessment Survey Results</u>

Total # of DE2 Survey Stations = 433	82 = 556
Total # of Stations Reviewed = 399	82 = 213
Total # of Stations Labeled Good = 366	82 = 181
% of total Stations Reviewed = 91.7%	82 = 85.0%
Total # of Stations Labeled Poor = 33 (Any Reason)	82 = 32
% of total Stations Reviewed = 8.3%	82 = 15.0%
Total # of Stations Labeled Poor = 22 (Intake Blockage)	82 = 11
% of total Stations Reviewed = 5.5%	82 = 5.2%
Total # of Stations Labeled Poor = 10 (Manifold Blockage)	82 = 1
% of total Stations Reviewed = 2.5%	82 = 0.5%
Total # of Stations Labeled Poor = 2 (Dredge Angle)	82 = 0
% of total Stations Reviewed = 0.5%	82 = 0.0%
Total # of Stations Labeled Poor = 0 (Early Pump Shutoff)	82 = 20
% of total Stations Reviewed = 0.0%	82 = 9.4%
Average # of Surfclam per Good Tow - 18.20	82 = 24.2
Average # of Surfclam per Poor Tow - 28.68	82 = 28.5
Average # of Quahogs per Good Tow - 42.91	82 = 69.3
Average # of Quahogs per Poor Tow - 1.19	82 = 64.3

<u>General Comments on 2002/2005 Survey Tows</u>

2002 Speed fairly smooth and consistent as opposed to 2205 survey which had more variation and steeper spikes and dips.

2002 Dredge angle relatively smooth even when pump intake was blocked or pump was shutoff early. (i.e. may have continued to fish effectively)

2002 Survey had significant changes in the dredge pump voltage and thus a significant increase in manifold pressure during the survey cruise.

NMFS Dredge fished surfclam better on poor tows then good tows for both 2002 and 2005 surveys.

2002 F/V Lisa Kim & F/V Jersey Girl Depletion Tows Review

F/V Lisa Kim Poor Tows
Station 12 - Dredge angle high. Odd as angle is about 5 degrees above normal and basically smooth throughout the tow.
Station 72 - Dredge angle very erratic varying from 0 to 25 degrees.

F/V Lisa Kim Tows with Blips, Not severe enough for a poor tow.
Station 95 - Very brief bump up in dredge angle.

F/V Jersey Girl had no Poor tows or tows with blips.

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The mission of NOAA's National Marine Fisheries Service (NMFS) is "stewardship of living marine resources for the benefit of the nation through their science-based conservation and management and promotion of the health of their environment." As the research arm of the NMFS's Northeast Region, the Northeast Fisheries Science Center (NEFSC) supports the NMFS mission by "conducting ecosystem-based research and assessments of living marine resources, with a focus on the Northeast Shelf, to promote the recovery and long-term sustainability of these resources and to generate social and economic opportunities and benefits from their use." Results of NEFSC research are largely reported in primary scientific media (*e.g.*, anonymously-peer-reviewed scientific journals). However, to assist itself in providing data, information, and advice to its constituents, the NEFSC occasionally releases its results in its own media. Currently, there are three such media:

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