Northeast Fisheries Science Center Reference Document 06-25

43rd Northeast Regional
Stock Assessment Workshop (43rd SAW)

43rd SAW Stock Assessment Report

November 2006

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06-23 **Tenth Flatfish Biology Conference, November 29-30, 2006, Water's Edge Resort, Westbrook, Connecticut**, by R Mercaldo-Allen (chair), A Calabrese, DJ Danila, MS Dixon, A Jearld, TA Munroe, DJ Pacileo, C Powell, SJ Sutherland, steering committee members. October 2006.

06-24 **Analysis of Virginia fisheries effort as a component in the development of a fisheries sampling plan to investigate the causes of sea turtle strandings**, by CM Legault and KD Bisack. October 2006.

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43rd Northeast Regional Stock Assessment Workshop (43rd SAW)

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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

November 2006

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*.

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INTRODUCTION TO SAW-43 ASSESSMENT REPORT

The Northeast 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 Regions managers.

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 43rd SARC was convened in Woods Hole at the Northeast Fisheries Science Center, June 6 – 12, 2006 to review four assessments (ocean quahog *Arctica islandica,* spiny dogfish *Squalus acanthias*, black sea bass *Centropristis striata*, and deep sea red crab *Chaceon quinquedens*. The ocean quahog assessment (A.) has been withdrawn because it did not include all available data and a formula used in the assessment was used incorrectly. The decision by the NEFSC to withdraw the ocean quahog assessment was made before the SARC-43 reviews were available, and this decision was approved by the Northeast Region Coordinating Council (NRCC). CIE reviews for SARC43 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, meeting agenda, 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 - 4).

Outcome of Stock Assessment Review Meeting:

(The ocean quahog assessment (A.) has been withdrawn.)

The large quantity of results on spiny dogfish (B.) made parts of that assessment difficult for the SARC to evaluate. The SARC felt that the very high 2006 survey estimate probably overestimates the current stock size, and that stock projections based on it were probably overly optimistic. Major concerns of the SARC about the spiny dogfish stock included: the long term reduction in female biomass, a significant imbalance in the sex ratio, and low recent recruitment. The SARC felt that $F_{threshold}$ needed to be interpreted with care because the value of this metric is sensitive to the selectivity pattern, which has shifted in recent years. The SARC felt that $B_{threshold}$ was adequate, but that there was substantial uncertainty regarding B_{target}. While the SARC agreed that the 2005 biomass point estimate was slightly above $B_{threshold}$, it cautioned against over interpreting that result because of the uncertainty in the biomass estimate.

The black sea bass assessment (C.) provided updated commercial and recreational landings, with a breakdown by gear type, as well as temporal trends in abundance and size-structure based on NEFSC surveys. The SARC noted inconsistencies in the methods of characterizing survey indices and their uncertainty. Because confidence intervals were large, the SARC questioned whether the trends represented stock status. The SARC felt that the tagging program made a substantial contribution to understanding migration. The SARC rejected estimates of fishing mortality from the tagging studies, did not feel that the biological reference points were technically sound, and did not feel that the assessment provided an adequate basis to evaluate stock status.

The SARC felt that the deep sea red crab assessment (D.) provided adequate estimates of biomass and fishing mortality rate, but that the MSY biomass reference point established in the 1970s was not reliable. Therefore, current stock status could not be evaluated.

Sections of the Working Group reports that were not completed successfully, based on the opinion of the independent CIE review panel, have been omitted from this report (The CIE report can be found at: http://www.nefsc.noaa.gov/nefsc/saw/). In those places where text has been omitted, a note has been inserted by the SAW Chairman informing the reader of this. The CIE's decision to accept or reject assessment results was based on scientific criteria such as the quality of the input data that were available, quality of the data analysis and modeling, and whether the conclusions of the Working Group held up during the independent peer review SARC meeting. The CIE panel also considered whether the results were technically sufficient to serve as a basis for developing fishery management measures and advice.

Table 1. 43rd Stock Assessment Review Committee Panel.

43rd Northeast Regional Stock Assessment Workshop (SAW 43)
Stock Assessment Review Committee (SARC) Meeting

June 6 – 12, 2006
Woods Hole MA

SARC Chairman (CIE):

Dr. Robin Cook
FRS Marine Laboratory
PO Box 101
375 Victoria Rd.
Aberdeen AB11 9DB
United Kingdom

SARC Panelists (CIE):

Dr. Mark Maunder
Inter-American Tropical Tuna Commission
8604 La Jolla Shores Drive
La Jolla, CA, 92037-1508, USA

Dr. Michael Armstrong
The Centre for Environment, Fisheries and Aquaculture Science
Pakefield Road
Lowestoft
Suffolk NR33 0HT United Kingdom

Table 2. Agenda, 43rd Stock Assessment Review Committee Meeting.

43rd Northeast Regional Stock Assessment Workshop (SAW 43)
Stock Assessment Review Committee (SARC) Meeting

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

June 6 – 12, 2006

AGENDA (Revised 6/5/06)

TOPIC	PRESENTER	SARC LEADER	RAPPORTEUR
Tuesday, 6 June (9:00 – 12:15 PM)…………………………………………………			
Opening			
Welcome	**James Weinberg**, SAW Chairman		
Introduction	**Robin Cook**, SARC Chairman		
Agenda			
Conduct of Meeting			
Ocean quahog (A)	**L. Jacobson/R. Russell**	**Mark Maunder**	**Laurel Col**
SARC Discussion	**Robin Cook**		
Tuesday, 6 June (1:30 – 5:00 PM)…………………………………………………			
Spiny dogfish (B)	**Paul Rago**	**Mark Maunder**	**Kathy Sosebee**
SARC Discussion	**Robin Cook**		
Wednesday, 7 June (8:30 AM -12:00)…………………………………………………			
Black sea bass (C)	**Gary Shepherd**	**Michael Armstrong**	**Michelle Traver**
SARC Discussion	**Robin Cook**		

Wednesday, 7 June (1:15 – 5:00 PM) ………………………………………………

Revisit Assessments (A – C), as needed.

Thursday, 8 June (8:30 AM – 12:00) ………………………………………………

Deep sea red crab (D)	**Rick Wahle**	**Michael Armstrong**	**Toni Chute**
SARC Discussion	**Robin Cook**		

Thursday, 8 June (1:15 – 5:00 PM) ………………………………………………

Revisit Assessments (D, and A – C), as needed.

Friday, 9 June (8:30 AM –) ………………………………………………

Revisit Assessments, if needed.

SARC Report writing (closed)

Friday, 9 June (1:00 PM –) – 12 June …………………………………………

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			
	Mark Terceiro, NMFS NEFSC		
		Spiny Dogfish	May 10-12, 2006 Woods Hole

Jim Armstrong	Mid-Atlantic Fishery Management Council
Greg DiDomenico	GSSA
Eric Powell	Rutgers
Paul Rago	NMFS NEFSC
Kelly Register	East Carolina University
Roger Rulifson	East Carolina University
Katherine Sosebee	NMFS NEFSC
Mark Terceiro (chair)	NMFS NEFSC
Victor Vecchio	NY DEC
Jim Weinberg	NMFS NEFSC

Assessment Group	Chair	Species	Meeting Date/Place
SAW Southern Demersal Working Group			
	Mark Terceiro, NMFS NEFSC		
		Black Sea Bass	May 8-9, 2006 Woods Hole

Mark Terceiro (Chair)	NEFSC	Toni Kerns	ASMFC
Victor Vecchio	NY DEC	(not present but contributed text concerning management history)	
Paul Nitschke	NEFSC		
Paul Caruso	MA DMF		
Katherine Sosebee	NEFSC		
Gary Shepherd	NEFSC		
Jessica Coakley	MAFMC		
Joshua Moser	NEFSC		
Christopher Legault	NEFSC		
Laurel Col	NEFSC		
Brian Murphy	RI DEM		

Invertebrate Working Group

Mark Terceiro, NMFS NEFSC

Deep Sea Red Crab — March 20-21, 2006; April 27-28, 2006; Woods Hole

Richard Allen	Red Crab Harvesters Association
Andy Applegate	NEFMC
Charlene Bergeron	Bigelow Laboratory for Ocean Sciences
Yong Chen	University of Maine, Orono
Toni Chute	NMFS NEFSC
Peter Cooke	F/V Frank H. Wetmore
Bob Glenn	Mass. DMF
Neal Goff	F/V Frank H. Wetmore
Larry Jacobson	NMFS NEFSC
Peter Lawsing	F/V Frank H. Wetmore
Bruce Medeiros	Benthic Fishing
Barbara Rountree	NMFS NEFSC
Mike Ruccio	NMFS NERO
Fred Serchuk	NMFS NEFSC
Jim Stone	F/V Krystal James
Shelly Tallack	GMRI
Mark Terceiro	NMFS NEFSC (Chair)
Richard Wahle	Bigelow Laboratory for Ocean Sciences (Assessment Lead)
Jon Williams	Benthic Fishing

Table 4. 43rd SAW/SARC, List of Attendees

K. Sosebee	NEFSC
J. Quiroz	IFOP Chile
J. Womack	Wallace and Assoc.
T. Hoff	MAFMC
P. Nitschke	NEFSC
C. Pickett	NEFSC
D. Wallace	Wallace and Assoc.
C. Keith	NEFSC
S. Rowe	NEFSC
E. Dolan	NOAA/NERO
T. Curtis	NOAA/NERO
J. Coakley	MAFMC
T. Kerns	ASMFC
J. Fletcher	UNFA
G. DiDomenico	Industry
L. Col	NEFSC
B. Rountree	NEFSC
R. Mayo	NEFSC
M. Terceiro	NEFSC
M. Palmer	NEFSC
L. Jacobson	NEFSC
R. Russell	Maine DMR

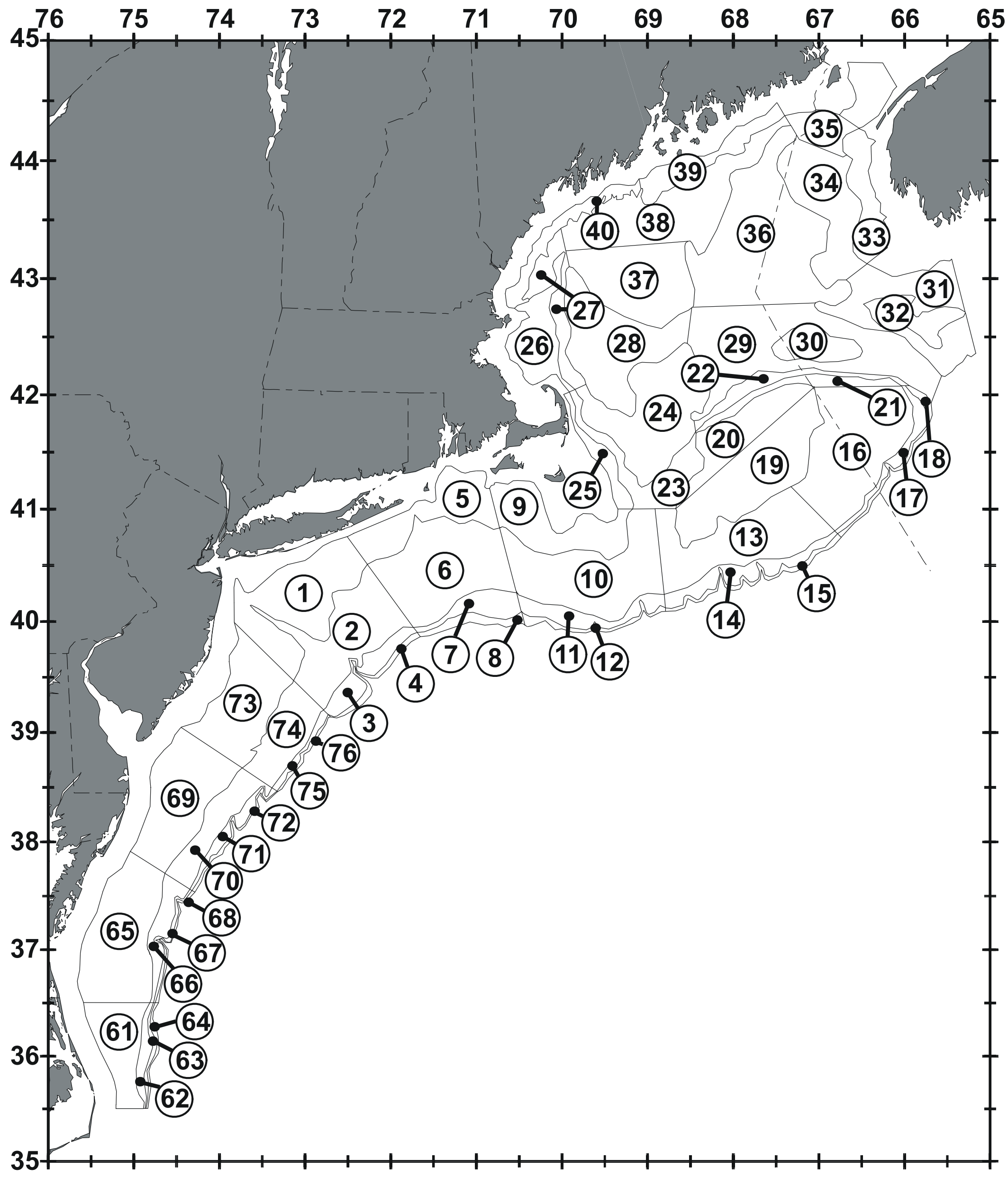

Figure 1. Offshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys.

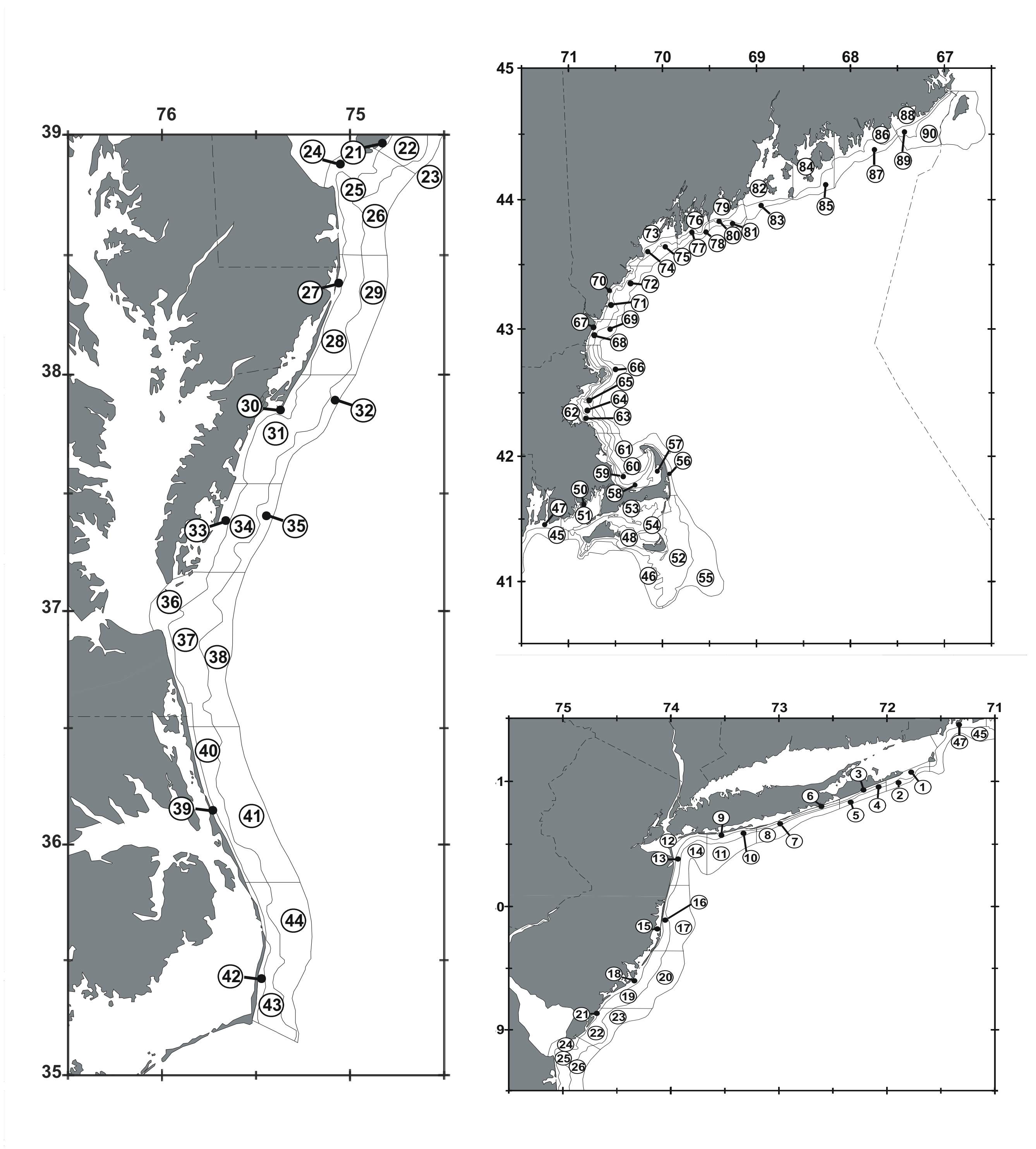

Figure 2. Inshore depth strata sampled during research surveys.

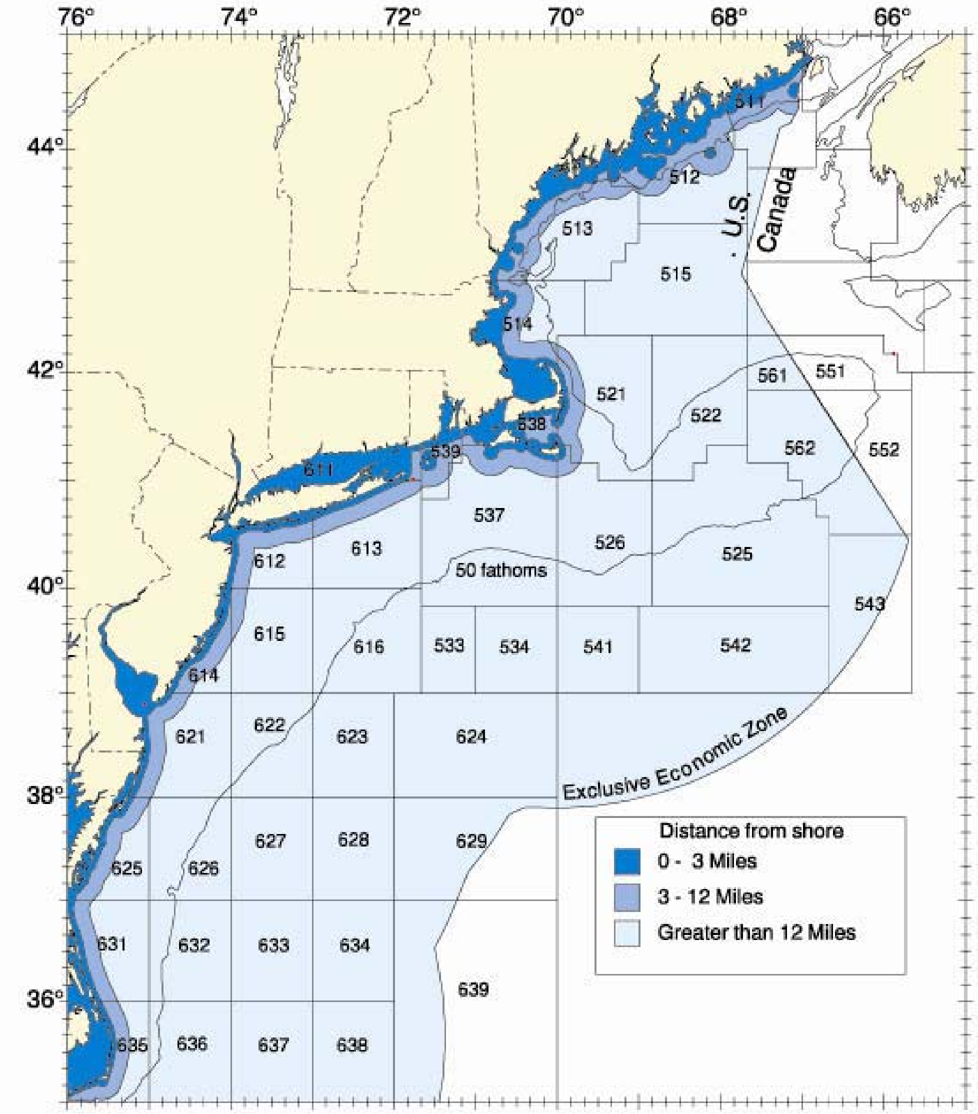

Figure 3. Statistical areas used for reporting commercial catches.

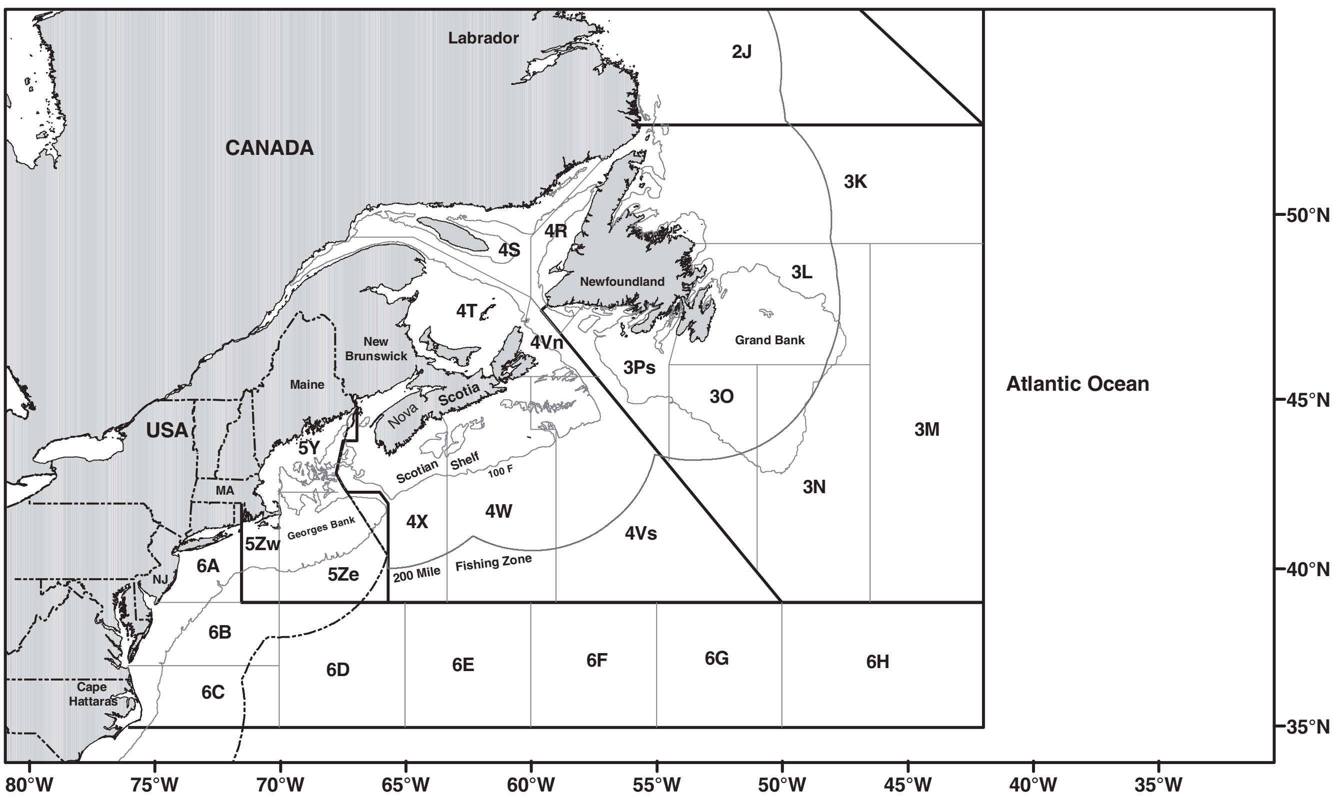

Figure 4. Catch reporting areas of the Northwest Atlantic Fisheries Organization (NAFO) for Subareas 3-6.

A: ASSESSMENT OF OCEAN QUAHOG

(ASSESSMENT WITHDRAWN; SEE INTRODUCTION)

B: ASSESSMENT OF SPINY DOGFISH

Report of the Southern Demersal Subcommittee

and the

Atlantic States Marine Fisheries Commission
Spiny Dogfish Technical Committee

1.0 TERMS OF REFERENCE

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

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.

3. Either update or re-estimate biological reference points (BRPs), as appropriate.

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).

5. Perform sensitivity analyses to determine the impact of uncertainty in the recreational data on the assessment results.

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

7. 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 or recovery schedules, as appropriate.

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

2.0 EXECUTIVE SUMMARY

TOR 1: *Characterize the commercial and recreational catch including landings and discards.*

The Working Group completed this term of reference. Discards were estimated with a new approach, mortality rates of discarded dogfish were updated, and the length and sex composition of the discards were estimated (see Dogfish Section 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.*

The stochastic estimator of F and B, used in SARC 37 was updated to include uncertainty in recreational catch, and discards by gear type. This was the primary model used in the assessment. Full F on the female exploitable stock varied between 0.08 and 0.47 between 1990 and 2005. Even with the lower landings since 2001, fishing mortality rates on the fully recruited female stock component have remained above the rebuilding target (0.03). The current estimate of full F on dogfish in 2005 is 0.128 (0.09-0.174; 80% confidence interval). Female spawning stock size dropped to below 100,000 mt in 1997, declined to about 50,000 mt in 1998 and remained below 100,000 mt through 2004. The extremely high estimate in 2006 raised the 3-yr average female SSB estimate to 106,000 mt. The Working Group also developed an analytical model (LTM) to express survey indices of biomass in absolute scale and in turn to provide estimates of fishing mortality rates (see Dogfish Appendix B3).

TOR 3: *Either update or re-estimate biological reference points (BRPs), as appropriate.*

The Working Group estimated new biological reference points for spawning stock biomass based on the Ricker Stock-Recruitment model (Dogfish Section 8.0, Table 8.2). However, recent patterns of recruitment do not conform to the Ricker model, suggesting that more detailed consideration of reproductive biology may be necessary. Therefore, the Working Group recommended retaining the existing F and B reference points.

TOR 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).*

Based on the existing biomass threshold from SAW-37 (NEFSC 2003), the spiny dogfish stock is not currently overfished. The current estimated stock size of mature females (>80 cm) is 106,000 mt (72,000-140,000; 80% confidence interval), and this value exceeds $B_{threshold}$ (100,000 mt mature females, P=0.724). The biomass target in the spiny dogfish FMP (180,000 mt) was subsequently disapproved by NMFS; currently there is no approved biomass target in place.

The estimate for 2005 of F on fully recruited females is 0.128 (0.09-0.17; 80% confidence interval). This fishing mortality rate exceeds the existing overfishing threshold ($F_{threshold}$=0.11) and the existing rebuilding target ($F_{rebuild}$=0.03). However, the overfishing threshold was updated in the current assessment ($F_{threshold}$=0.39). Based on the updated estimate, overfishing is not occurring.

TOR 5: *Perform sensitivity analyses to determine the impact of uncertainty in the recreational data on the assessment results.*

Due to the small magnitude of recreational catch found it had little effect on the assessment. Moreover, the coefficient of variation of the discarded component of recreational landings is low (~10%) in recent years. Recreational removals are a minor source of uncertainty in the assessment.

TOR 6: *Recommend what modeling approaches and data should be used for conducting single and multi-year stock projections, and for computing TACs or TALs.*

The Working Group recommends using the approach from SAW37. (See Dogfish Section 10.0)

TOR 7: *If possible,*

c. *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*

d. *compare projected stock status to existing rebuilding or recovery schedules, as appropriate.*

Short term forecasts of spiny dogfish biomass (mt) are influenced by the current biomass and size structure of the population. Biomass of mature female spiny dogfish is expected to continue increasing through 2008 and 2009 as fish <80cm grow into mature size ranges (Figure B3). Subsequently, the biomass should decline due to the low number of recruits that were born during 1997-2003. If recruitment returns to levels consistent with expected size-specific reproduction, the biomass should begin to rebound again by 2015. (See Dogfish Section 10.0)

TOR 8: *Review, evaluate and report on the status of the SARC/Working Group Research Recommendations offered in recent SARC-reviewed assessments.*

This was addressed in Dogfish Section 11.

3.0 OVERVIEW

Spiny dogfish (*Squalus acanthias*) are distributed in Northwest Atlantic waters between Labrador and Florida, are considered to be a unit stock in NAFO Subareas 2-6, but are most abundant from Nova Scotia to Cape Hatteras. Seasonal migrations occur northward in the spring and summer and southward in the fall and winter and preferred temperatures range from 7.2° to 12.8°C (Jensen 1965). In the winter and spring, spiny dogfish are located primarily in Mid-Atlantic waters but also extending onto southern Georges Bank on the shelf break. In the summer, they are located further north in Canadian waters and move inshore into bays and estuaries. By autumn, dogfish have migrated north with high concentrations in Southern New England, on Georges Bank, and in the Gulf of Maine. They remain in northern waters throughout the autumn until water temperatures begin to cool and then return to the Mid-Atlantic.

Dogfish tend to school by size and, for large mature individuals, by sex. Dogfish prey on some commercially important species, mainly herring, Atlantic mackerel, and squid, and to a much lesser extent, on haddock and cod. Maximum reported ages for males and females in the Northwest Atlantic were estimated by Nammack (1982) to be 35 and 40 years, respectively, whereas ages as old as 70 years have been determined for spiny dogfish off British Columbia (McFarlane and Beamish 1987). In this paper, a maximum age of 50 years was assumed. Sexual maturity occurs at a length of about 60 cm (~8-10 yr) for males and 75 cm (~12-15 yr) for females (Jensen 1965). Reproduction occurs offshore in the winter (Bigelow and Schroeder 1953), and female dogfish bear live offspring. The gestation period ranges from 18 to 22 months with 2 to 15 pups (average of 6) produced. Females attain a greater size than males, reaching maximum lengths and weights up to 125 cm and 10 kg, respectively.

4.0 FISHERY-DEPENDENT INFORMATION

4.1 Commercial landings

Commercial landings data and biological information were obtained from the NEFSC commercial fisheries database. The sex of commercial landings was not recorded routinely until 1982. The commercial landings sampling program is described in Burns et al. (1983). Historical records dating back to 1931 indicate levels of US commercial landings of dogfish in Subareas 5 and 6 of less than 100 mt in most years prior to 1960 (NEFC 1990). Total landings of spiny dogfish in NAFO Subareas 2-6 by all fisheries climbed rapidly from the late 1960s to a peak of about 25,000 mt in 1974 (Table 4.1). Substantial harvests of dogfish by foreign trawling fleets began in 1966 in Subareas 5 and 6 and continued through 1977. Since 1978 landings by foreign fleets have been curtailed, and landings by US and Canadian vessels have increased markedly. A sharp intensification of the US commercial fishery began in 1990; estimated landings in 1996, in excess of 28,000 mt, were about five times greater than the 1980-1989 average. Landings between 1997 and 1999 averaged about 20,000 mt. Landings in 2001 and 2002 dropped dramatically with the large landings reductions imposed by federal and ASMFC management plans.

4.1.1 US landings

US commercial landings of dogfish from NAFO Subareas 2-6 were around 500 metric tons (mt) in the early 1960s (Table 4.1), dropped to levels as low as 70 mt during 1963-1975 while averaging about 90 mt, and remained below 1,000 mt until the late 1970s. Landings increased to about 4,800 mt in 1979 and remained fairly steady for the next ten years at an annual average of about 4,500 mt. Landings increased sharply to 14,900 mt in 1990, dropped slightly in 1991, but continued a rapid expansion from 18,987 mt in 1992 to over 28,000 mt in 1996. Landings in 1996 were the highest recorded since 1962, exceeding previous peak years during the early 1970's when the fishing fleet was dominated by foreign vessels (Fig. 4.1). Landings declined in 1997 and 1998 to around 20,000 mt. In 1999, the last full year unaffected by regulations, the landings declined to 14,860 mt. US landings dropped to about 2200 mt in 2001 and 2002 and then dropped further to around 1000 mt in response to quota restrictions.

4.1.2 Foreign landings

A substantial foreign harvest of dogfish occurred mainly during 1966-1977 in Subareas 5 and 6. Landings, the bulk of which were taken by the former USSR, averaged 13,000 mt per year and reached a peak of about 24,000 mt in 1972 and 1974 (Table 4.1). In addition to the former USSR, other countries which reported significant amounts of landings include Poland, the former German Democratic Republic, Japan, and Canada. Since 1978, landings have averaged only about 900 mt annually and, except for those taken by Japan and Poland, have come primarily from Subareas 4 and 3. Canadian landings, insignificant until 1979 when 1,300 mt were landed, have been sporadic, but again totaled about 1,300 mt in 1990. Canadian landings increased about nine-fold between 1996 and 2001 with landings of 3,755 mt in 2001. Landings in 2005 have not been finalized but should be around 1500 mt (Steve Campana, DFO personal comm.). and the other foreign landings were assumed to be the same as in 2004.

4.1.3 Gear types

The primary gear used by US fishermen to catch spiny dogfish has been otter trawls and sink gill nets (Table 4. 2, Fig. 4.2). The latter accounted for over 50% of the total US landings during the 1960s, while the former was the predominant gear through the 1970s and into the early 1980s. During the peak period of exploitation in the 1990s sink gill nets were the dominant gear. Landings in otter trawls ranged around 3000-5000 during this period. Both otter trawl and gill net landings decreased markedly in 2001, coincident with the rise in landings by hook gear. Landings of dogfish in drift gillnets peaked in 1998 with over 1300 mt but have since declined to near zero. Spiny dogfish taken by the distant water fleets were caught almost entirely by otter trawl. Recent Canadian landings have been mainly by gill nets and longlines.

4.1.4 Temporal and spatial distribution

The temporal and spatial pattern of dogfish landings are closely tied to the north-south migration patterns of the stock. Peak landings from May through October coincide with residency of dogfish along the southern flank of Georges Bank, the Gulf of Maine and the near shore waters around Massachusetts. At the population migrates to the south in late fall and early winter, landings increase in the southern states, especially North Carolina. US dogfish landings have been reported in all months of the year, but most have traditionally occurred from June through September (Table 4.3). During the peak years of the domestic fishery substantial quantities were also taken during autumn and winter months.

In most years since 1979, the bulk of the landings occurred in Massachusetts (Table 4.4). Other states with significant landings include New Jersey, Maryland, and Virginia. Landings in North Carolina peaked in 1996 at 6200 mt , about half of the Massachusetts landings, but dropped sharply to about 1300 mt between 1997 and 2000. North Carolina landings in 2001-02 were negligible. In 2001 and 2002, virtually all of the landings were taken north of Rhode Island.

Landings by statistical area (Fig 4.3) were updated for this assessment. As reported in SARC 19 (NEFSC 1994) most landings during the 1980's originated from statistical area 514 (Massachusetts Bay) and continue to occur in this statistical area (Table 4.5). Following the intensification of the fishery in 1990, statistical areas 537 (Southern New England) and 621 (off Delmarva and southern New Jersey) produced substantial quantities. In 1992 and 1993, large landings were reported from statistical areas 631 and 635 (North Carolina). However, in recent years, these have declined.

4.2 Recreational landings

Estimates of recreational catch of dogfish were obtained from the NMFS Marine Recreational Fishery Statistics Survey MRFSS (see Van Voorhees et al. 1992 for details). Recreational catch data have been collected consistently since 1979 but sex is not recorded. Methodological differences between the current survey and intermittent surveys before 1979 preclude the use of the earlier data. The MRFSS consists of two complementary surveys of anglers via on-site interviews and households via telephone. The angler-intercept survey provides catch data and biological samples, while the telephone survey provides a measure of overall effort. Surveys are stratified by state, type of fishing (mode), and sequential two-month periods (waves). For the purposes of this paper, annual catches pooled over all waves and modes and grouped by subregion (ME to CT, NY to VA, and NC to FL) were examined.

The MFRSS estimates are partitioned into three categories of numbers caught and landed: A, B1, and B2. Type A catches represent landed fish enumerated by the interviewer, while B1 are landed catches reported by the angler. Type B2 catches are those fish caught and returned to the water. Inasmuch as dogfish are generally caught with live bait and are often mishandled by anglers, the higher end of the estimated finfish discard mortality rates of 20% was assumed. The MRFSS provides estimates of landings in terms of numbers of fish. Biological information on dogfish is generally scanty, resulting in wide annual fluctuations in mean weights. To compute total catch in mt, an average weight of 2.5 kg per fish was assumed for all years.

Total recreational catches increased from an average of about 350 mt per year in 1979-1980 to about 1,700 mt in 1989-1991 (Table 4.1). Since 1991 recreational landings have decreased continuously from nearly 1500 mt to less than 400 mt in 1996. Landings by number (Fig. 4.4) suggest a similar but less pronounced decline. During the 1990s recreational landings represented a small fraction of the total fishing mortality on spiny dogfish. Even if all of the Type B2 catch died after release, recreational catches have comprised only about 8% of the total landings during this period. In 2001 and 2002 estimated B2 catches increased sharply. Total recreational catches represent about 25% of the landings in those years. In recent years, the precision of the discard estimates in the recreational fishery have been about 10% (Fig. 4.5). Precision of the estimates for the much smaller landed component has average about 28% over the 1981 to 2005 period.

As most of the recreational landings are discarded and is unlikely to be size or sex selective, recreational landings were added to the total discard estimates in this assessment. Average size composition of the recreational catch was assumed to be similar to the size compositions derived from at-sea observers in the otter trawl fishery. Size frequencies from a 2005 survey of recreational charter boat vessels (Fig. 4.6) was similar to the size composition of the NMFS trawl survey and the commercial fishery.

4.3 Size and sex composition of commercial landings

The seasonal distribution of biological sampling of the landings generally coincided with the seasonal pattern of landings (Table 4.6). Most samples were taken in June through November with much lower effort from January to May. In addition to the samples listed in Table 4.6, port samples obtained by MADMF in 2000 (15) and 2002(8), (provided by Brian Kelly, MADMF) were incorporated in into the analyses. These samples provided a substantial increase to the total number of measured fish in these years. The biological characteristics of the landings are driven primarily by the market place, particularly the acceptance of small dogfish. The major increase of small males in the 1996 landings probably reflects their acceptance by export markets as well as the availability of processing equipment for smaller dogfish. The estimated size and sex composition of the landings are based on pooled samples over the entire year.

From 1982 to 1995, over 95% of the sampled landings of spiny dogfish were females greater than 84 cm. Males comprised a small fraction of the landings and were rarely observed above 90 cm in length. In 1996 landings of male dogfish increased dramatically, both in numbers and total weight (Table 4.7). The increased fraction of male dogfish in the landings continued through 1999 but dropped markedly from 2000 through 2002. Presumably the drop in total quota resulted in a return to the remaining large females in the population.

Shifts in length frequencies toward smaller sizes reflect the marked increase in landings since 1989. The average size of landed females appears to have decreased by more than 15 cm since 1988 (Fig. 4.7, top). The average size of males dropped about 5 cm between1994 and 2000 (Fig. 4.8 top). Reductions in average weight of females (Fig. 4.7 bottom) are dramatic with a decline of average individual weight greater than 2 kg per fish since 1992. Again, the decline for males in 1996 is evident (Fig. 4.8 bottom) but the drop is about 25% for males in contrast to the 50% decrease for females. Decreases in average size are consistent with increased fishing mortality, but could also be due to changes in the mix of otter trawl and sink gill net catches.

Corroboration of these trends in observer program (Fig. 4.9) and in the research surveys (later section) suggests that these trends are the result of increased fishing mortality.

Mean sizes in the commercial fishery have declined to the extent that the increase in total landings of 14,731 mt in 1990 to 27, 241 mt in 1996 (an increase of 85%) was accompanied by a 311% increase in numbers landed. Percentage of males in the landed jumped dramatically in 1996 to 17% by weight and 25% by numbers. Commercial landings by weight in 1999 (17327 mt) were about equal to those in 1992 (17687 mt) but the decrease in average weight resulted in the removal of almost twice as many dogfish (9.3 M vs 4.6 M).

4.4 Discards

Methods

Owing to their ubiquitous distribution, dogfish are caught in a wide variety of fisheries. Owing to their low price per pound and need for special handling procedures onboard, dogfish is often discarded if more valuable species are present. Hence, high rates of dogfish bycatch and discards are expected. Previous assessments of spiny dogfish in the Northeast US have emphasized the need to estimate discard rates in other fisheries. In NEFSC (1994), preliminary estimates suggested that total discards were about the same order of magnitude at the commercial fishery. SARC 19 accepted provisional estimates of discard morality rates of 0.75 in gillnets and 0.5 in otter trawls but noted considerable uncertainty in these estimates. Preliminary information from discard mortality studies (Roger Rulifson, East Carolina State University, pers. comm.; Marianne Farrington and John Mandelman, New England Aquarium, pers. comm..) indicates that the mortality from gillnets may be much lower than previously assumed so an estimate of 0.3 was assumed in this assessment. The information from otter trawls also indicated a much lower mortality. However, the dogfish in various unpublished studies were all captured in relatively small tows. It was decided by the Working Group that these may not be representative of the otter trawl fishery in all areas, especially when very large tows are encountered. Therefore, the value of 50% was retained for otter trawls.

The primary database for discard estimates in the Northeast began in 1989 with the advent of a large-scale fisheries observer program for commercial vessels (Murawski et al. 1995, Anderson 1992). Species catch, effort, and associated biological and fishery data are collected for each trip. Previous estimates of dogfish discards used a ratio estimator to expand the sample discard rates to the total population. A primary component of this expansion was the reliance on the skipper's characterization of "primary species sought". Total estimates of dogfish discards were expanded by multiplying the discard/ton ratio by the total tonnage of landings of the target species. Previous estimates of dogfish discards were hampered by low sample sizes in major gear/area/target species cells.

A modified ratio estimator for discards developed for SARC 37 resulted in improved estimates of total discards and relative precision. The estimator relied on a post stratification of the observed data set into a groups defined by a primary species group landed. Instead of relying on a discard to kept (d/k) ratio based on a single species or effort, the method developed for SARC 37 was a more precise estimator of the d/k ratio. However, the method was subsequently shown to generate biased estimates of total discards. The difficulty arose because the expansion factor used to estimate total discards was based on the total landings of the primary species group. Since the total landings of the primary species groups also occurred in fishing trips where the not the dominant catch, the method could lead to extreme overestimates of dogfish discards in poorly sampled fisheries.

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, mesh, 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:

$$\hat{R}_h = \frac{\sum_{i=1}^{n_h} d_{ih}}{\sum_{i=1}^{n_h} k_{ih}} \tag{1}$$

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:

$$\hat{R} = \sum_{h=1}^{H} \left(\frac{N_h}{\sum_{h=1}^{H} N_h} \right) \hat{R}_h \tag{2}$$

The total discard within a strata is simply the product of the estimate discard ratio R and the total landings for the fishery defined as stratum h, i.e., $D_h = R_h K_h$

The approximate variance of the estimate of R_{jh} is obtained from a first order Taylor series expansion about the mean (Cochran 1963):

$$V\left(\hat{R}_{jh}\right) = \frac{1}{(n_{jh}-1)n_{jh}\bar{k}_{jh}^2}\left[\left(\sum_{i=1}^{n_{jh}} d_{ijh}\right)^2 + \hat{R}_{jh}^2\left(\sum_{i=1}^{n_{jh}} k_{ijh}\right)^2 - 2\hat{R}_{jh}\left(\sum_{i=1}^{n_{jh}} d_{ijh}\right)\left(\sum_{i=1}^{n_{jh}} k_{ijh}\right)\right] \tag{3}$$

where d_{ih} is the total discard weight of dog fish in trip i within stratum h, k_{ih} is the total kept weight of species in trip i within stratum h, n_h is the sample size (number of trips) in stratum h, and k_h bar is the sum of kept landings of all species within stratum h. Note that in this formulation of the variance, the finite population correction factor (fpc), i.e., one minus the sampling fraction within the stratum, has been omitted. This has been done to improve readability. The fpc is included however, in Eq. 4 for the total variance of the d/k ratio.

The variance of the d/k ratio for species group j over the entire set of strata is estimated using standard sampling theory methodology for a stratified random design as

$$V\left(\hat{R}_j\right) = \sum_{h=1}^{H}\left(\frac{N_h - n_{jh}}{N_h}\right)\left(\frac{N_h}{\sum_{h=1}^{H} N_h}\right)^2 V\left(\hat{R}_{jh}\right) \tag{4}$$

The overall coefficient of variation for the discard/kept ratio is defined as

$$CV_j = \frac{\sqrt{V(\hat{R}_j)}}{\hat{R}_j} \tag{5}$$

Under the assumption that the landings (K_h) are measured without error, the variance of the total discard estimate can be written as a linear combination of the stratum specific variances of d/k.

One of the key assumptions of ratio estimators is that the predictor variable (i.e., primary species group) should be positively correlated with the dependent variable (i.e., dogfish discards). In the gill net fishery, the correlation between dogfish discard and total landings was 0.851 (Fig. 4.10). In the otter trawl fishery, the correlation was 0.321 (Fig. 4.11) and statistically significant. For other fisheries examined (e.g., the scallop dredge fishery, Fig. 4.12) it was not possible to develop a statistically reliable estimator due to a lack of historical observer coverage. Precision of discard estimates decreases as one move toward inferences at finer temporal or spatial scales. This occurs no only because the reduction in sample size within strata but also because the estimate of the variance itself becomes less precise. The variability of the d/k ratio at a quarterly level is about twice as high as the derived annual estimate (Fig. 4.10-4.12).

Annual estimated discards for gill net and trawl fisheries for 1989-2005 are summarized in Table 4.8. Total discards peaked in 1990 with about estimates of about 40,000 mt. Most of this came from the otter trawl fishery. Relative precision of the estimates overall was reasonable, with highest levels of about 25% corresponding low numbers of observed trips. The overall effect of increased observer coverage can be seen in Fig. 4.13-4.15. Levels of observer coverage in past 2 years appear to be sufficient to generate annual discard estimates with CV<15% for all regions combined. Precision at finer spatial or temporal scales is much lower as shown in Fig. 4.10-4.12. A much greater source of uncertainty is the fate of the discarded dogfish, as discussed below.

Dogfish appear to be hardy animals and have a high post capture survival rate. Many factors influence this rate but one common feature appears to be the size of the total catch. Survival in very large tows appears to be low owing to compression, wounding, and delays in processing large catches. As noted above, the Subcommittee endorsed retaining the previously used survival rate of 0.50 for dogfish taken in trawl fisheries. Application of these survival rates to the total discard estimates by gear type and year are summarized in Tables 4.9 and 4.10. Discard estimates in fisheries other than otter trawls and gill nets appear to be an order of magnitude lower. Historical coverage for many of these fisheries has been sporadic and instances of high discard mortality cannot be denied or confirmed. In 2004 and 2005, when coverage has been high, estimated dead discards in scallop dredge, hook gear, midwater trawls and shrimp trawls appears to less than 5% of the total discard mortality (Table 4.10) .

Estimates of dead discards, using the method described above, compare favorably to values obtained at SARC 37 (Fig. 4.16) for 1992 onward. The very high levels in 1989-1991 in the previous report (e.g., greater than 45,000 mt) may have been a manifestation of the potential bias of the “primary species group” approach used at SARC 37.

In contrast to the previous assessment, the discard information on size and sex of retained and kept spiny dogfish was analyzed. Estimates of total discard weight by sex were obtained by multiplying the total discard weight by the ratio of sampled weights of males or females to the total sampled weight of discarded dogfish. Analyses of the size composition of the discarded dogfish could then be used to obtain a mean weight of the discarded dogfish. Dividing this value into the estimated total discards by sex allows for an estimate of total numbers discarded (Tables 4.11 and 4.12). Finally, the discard estimates by size can be estimated by redistributing the total numbers over the proportions at size from the observer data. Between 1989 and 2005 over 250,000 spiny dogfish were measured, with over 100,000 of these in the last 3 years.

Changes in size composition in the kept fraction of the catch on observed trips (Fig. 4.9) mirror the changes in median sizes found by port agents (Fig. 4.7). More detailed examination of the trends for males and female dogfish by gill net and trawl fisheries over time reveal a general decline in average size landed for females (Fig. 4.17 top). Large male dogfish appeared to decline quickly in the trawl fishery (Fig. 4.18 top) but there was no apparent change in average size of males retained in the gill net fishery. The effect of management measures on the discarded dogfish can be seen in Fig. 4.17 (bottom) where the average size has increased steadily since 2000 for both trawl and gill nets. No changes in average size of discarded male dogfish are evident for either gill nets or trawl (Fig. 4.18).

Estimates of discards for the 1981 to 1988 period were based on hindcast approach that relied on the observed ratio of discarded dogfish to landings of all species in 1989. For the otter trawl fishery this ratio was 0.21; for gill nets 0.28. Discards for 1981 to 1988 were estimated as the product of these ratios and the total landings within these fisheries (Table 4.13). Estimates of the size and sex composition of for this 1981 to 1990 period required another layer of imputation. Biological attributes of dogfish were irregularly collected in the early years of the at-sea observer program. Samples from 1991 to 1994 were pooled to obtain sufficient samples for a suitable size frequency distribution for discards. The composite sex and size frequency information was applied to actual total discard estimates for 1989 and 1990, and to the imputed discards for the period 1981-1989. As a consequence, the discard estimates for the1981-1990 are considerably less precise than those since then. The resulting composite size frequencies for female spiny dogfish landings and dead discards by year are presented in Fig. 4.19 to 4.21. The strong mode at about 70 cm reflects the assumptions associated with the use of the pooled biological attributes from 1991-1994.

5.0 FISHERY-INDEPENDENT DATA

5.1 Research vessel abundance indices

5.1.1 NEFSC surveys

The Northeast Fisheries Science Center (NEFSC) has conducted both spring and autumn trawl surveys of the USA continental shelf annually since 1968. The surveys extend from the Gulf of Maine to Cape Hatteras. Details on the stratified random survey design and biological sampling methodology may be found in Grosslein (1969), Azarovitz (1981) and NEFSC (1995). Sex of spiny dogfish was not entered into the database until 1980.

Indices of relative stock biomass and abundance for spiny dogfish were calculated from NEFSC spring and autumn bottom trawl survey data. Overall indices were determined using only the offshore strata (1-30, 33-40, and 61-76) (Fig. 5.1) in order to obtain longer time series (i.e., 1967-1993 for the autumn survey and 1968-1994 for the spring survey). The autumn survey could not be extended back to 1963 because sampling of the Mid-Atlantic strata (61-76) did not begin until 1967. Estimates of dogfish density in inshore strata (Fig. 5.2) were also computed.

In both the spring and the autumn surveys, there was considerable variability in the indices (Table 5.1 ,5.2, Fig. 5.3). Both sets of indices indicate an overall increase in abundance and biomass from the early 1970s through the early 90s. Since that time, total index biomass has begun to decline, with greatest change occurring with females in the spring survey. The rate of change in the autumn survey has generally been less than observed for spring. At SARC 18 it was determined that the higher variability in the fall survey is attributable to variable fraction of the population present in Canadian waters during the NEFSC fall survey. The NEFSC winter survey utilizes a flat net without the large rock-hopper rollers present on Yankee 36 trawl used in the spring survey. Average catches in the winter survey are generally 3 to 5 times greater than the other NEFSC surveys (Table 5.3)

5.1.2 Canada R/V survey

The Canadian Department of Fisheries and Oceans conducts a survey from the Bay of Fundy eastward to Georges Bank and northeast to the boundary of the Laurentian Channel in NAFO Divisions 4VWX. Average station densities for the 1980-2001 period (Fig. 5.4) reveal the distribution of dogfish to be low east of 62.5 deg W. Male dogfish are much more abundant than female dogfish in Canadian waters in the summer. Over the entire time series estimated male dogfish biomasses were 2.8 times greater than female biomass.

5.1.3 State surveys

Abundance indices for spiny dogfish from Massachusetts spring and autumn inshore bottom trawl surveys in 1978-2005 reveal two different facets of dogfish abundance. The spring survey usually occurs before the major influx of dogfish to Massachusetts waters. Catches are low but variable. In the fall, catches tend to be an order of magnitude larger, as much of the dogfish stock is concentrated near the Massachusetts coast (Table 5.4, 5.5, Fig. 5.5). Wide variations in availability result in highly variable survey indices. High variability in this survey is also a reflection of the seasonal use by dogfish of the area surveyed by the State of Massachusetts.

5.2 Size and sex compositions

Size frequency distributions of spiny dogfish (sexes combined) from the spring and autumn NEFSC surveys were examined (Fig. 5.6 a-d). The spring survey length frequencies have three modes corresponding to new recruits (≤40 cm), mature males (70-80 cm), and mature females 95 cm. Large numbers of recruits have appeared periodically in the time series, especially in the early 1970s. The length frequency patterns in the autumn survey catches are much less consistent and there is no apparent tracking of modal lengths over time. Since 1997 both the spring and fall surveys are characterized by a single mode (Fig. 5.6d). NEFSC spring survey indices increased sharply in 2006 (Fig. 5.6d), and catches are shown in maps (Fig. 5.6 e-f).

Male and female size frequencies distributions are summarized by year for the spring (Fig. 5.7 a-c) and fall surveys (Fig. 5.8a-c). Male length frequencies are strongly skewed with an accumulation near the asymptotic size limit.

Qualitatively similar size frequency patterns for both sexes combined can be seen in the Massachusetts survey data (Fig. 5.9 a-c) autumn survey.

Further insight into the changes in abundance and size composition may be obtained by examining the average size frequency compositions over multi-year periods (Fig. 5.10). The size composition changed as the fishery progressed. The 1988-90 length frequencies approximate the expected female size composition in a stable population under a low rate of fishing mortality. A large number of adults greater than 80 cm are present with a peak near the asymptotic size. Concomitantly, a relatively large number of juveniles less than 35 cm are also present. Reductions in maximum sizes occurred rapidly such that by 1996 the population of mature females had been reduced roughly by half. Beginning in 1997 incidence of pups in the survey was almost non existent, a pattern that has continued until 2006. A slight increase in pup production was observed in 2004 but not since. The absence of pups during this period is similarly confirmed in the 1997-2005 fall survey (Fig. 5.6c-d)

The cumulative effects of reductions in the spawning stocks and the near absence of pups in the surveys since 1997 are evident in the size frequency of both male and female spiny dogfish. The progressive loss of smaller dogfish less than 70 cm is evident and is consistent with the expected growth of dogfish. These reductions support the hypothesis that the absence of recruits beginning in 1997 is real, since dogfish in this size range are expected to be about 4-7 years old. While the reduction in dogfish size groups below 70 cm is consistent for both males and females, no truncation of male dogfish is evident for males. This observation is again consistent with the observed low rates of landings of males.

Size frequencies of male and female dogfish in the DFO summer survey (Fig. 5.11) do not show major reductions in either large females or immature males or females during the period of the intense size selective fishery on female dogfish in the US. The apparent absence of these smaller dogfish over the entire time series suggests that pups are not present in 4VWX in appreciable numbers. This would support the argument that the adults present in Canadian waters of the Gulf of Maine and Scotian shelf are born elsewhere.

Changes in average size of mature female dogfish is a consistent property of NEFSC spring, fall, and winter surveys, the Massachusetts Division of Marine Fisheries survey, and the ASMFC shrimp survey (Fig. 5.11a). All of these surveys have shown declines in average size of 10 cm or more between 1990 and 2000. A SeaMap Survey (not shown) conducted off North Carolina has a similar current average size for mature females. The average average length of mature females in the DFO survey is about a cm smaller than in the US (Fig. 5.11b). While the average size of female dogfish has also declined about 10 cm, the decline commenced slightly earlier (~1980) than in the US.

Spiny dogfish are known to school by size and sex and a viable hypothesis for the scarcity of pups in the 1997 to 2006 period is that the surveys “missed” the few tows that define a peak. Due to intracluster correlation, (Pennington et al. 2002) the effective sample size of a trawl tows is close to one. To examine these hypotheses, each tow of the 24,000+ tows taken in the NMFS spring and fall surveys since 1982 were assigned a value related to the fraction of females present (0-1) and average size of individuals in the tow. A bivariate bubble plot of these variables was used to illustrate the effect of tows on the derivation of changes in size and sex composition of the population structure. Bivariate nonparametric kernel densities were used to define the loci of nearly pure male and female schools and the mixed schools of immature fish. It is hypothesized that the all male and all female schools represent sexually mature fish while the mixed schools are immature fish. Marginal kernel distributions in each plot reveal the overall sex ratios and size frequencies.

The changes in size and sex composition since 1982 are marked and consistent for both the spring and fall surveys (Fig. 5.12 and 5.13). The frequency of large female schools decreased between 1982 and 2006 concomitant with a reduction in average length of fish in the schools. Densities of mixed schools with average sizes less than 60 cm declined markedly as the abundance of large female dominated schools dropped. For both the fall and spring surveys, the bivariate distribution of average size vs sex ratio that resembled a “Y” in 1982-1986 had been transformed to a long “dash”, with little distinction in average size.

Marked changes in the ratio of numbers of mature male spiny dogfish to female spiny dogfish have occurred since 1980. Sex ratios of mature males (>60 cm) to mature females (i.e. >80 cm) averaged about 2:1 before 1992 but increased rapidly to about 7:1 in 2001 (Fig.5.13a). Since then it has been varied about the 7:1 ratio. The importance of the sex ratio for successful reproduction of spiny dogfish is unknown. Spatial segregation of shark populations by sex has been reported in the lesser spotted dogfish, *Scyliorhinus canicula* by Sims et al. (2001) and appears to be a general behavior of sharks (Springer 1967, cited by Sims et al.). Sims et al. hypothesized that the spatial segregation may be related to a “need for females to conserve energy by limiting multiple matings during a time when mating coincides with a peak in egg production and laying.” Parturition and fertilization in spiny dogfish (*Squalus acanthias*) overlap in time (~October-January, Jones and Ugland, 2001). Therefore, a similar behavioral mechanism for spatial segregation by school may be present in spiny dogfish.

5.3 Analysis of survey variability

Wide swings in spiny dogfish abundance are common in all of the survey indices for spiny dogfish. In most instances the variations are greater than expected or possible for a slowly growing, low fecundity species like spiny dogfish. Much of the variation can be attributed to the schooling behavior of dogfish and a hypothesized herding response to trawl doors. Many teleost species herd (Ramm and Xiao 1995), a process which increases the effective footprint of the trawl. When herding occurs, but not accounted for, population sizes will be overestimated and fishing mortality will be underestimated. Schooling and herding effects both contribute to the overdispersion of catch data. Exploratory analyses of the relationship between the mean and variance of each stratum reveal that the standard deviation of stratum numbers per tow increases linearly with the mean in both the spring (Fig 5.14) and fall (Fig. 5.15) surveys. This property is consistent with the variances increasing with the square of the mean, an expected property of the negative binomial distribution where $\sigma^2=\mu+\mu^2/k$. Since the variance is increasing faster than the mean, the ability to detect moderate true changes will decrease as population size increases (and vice versa). Thus the variability of a single realization of a sampling program is also expected to increase with overall density. This property manifested itself in the 2006 NEFSC spring survey wherein average weight per tow increased by two fold, after more than a decade of consistent declines or no appreciable increases (Fig. 5.3). This change, and its implications for stock rebuilding, mandated a more intensive investigation of the variability of the survey data and a consideration of alternative hypotheses. The remainder of this section and section 5.3 are devoted to this line of investigation.

The sampling properties of finfish surveys have been investigated by many authors (see Smith 1997 as a starting point). It has been noted that the variability induced by availability to the survey area and changes in gear efficiency can exceed variations associated with sample selection within a stratified design. Analyses were conducted to address the following questions:

- Is the current stratified sampling design an improvement over simple random sampling for dogfish?
- Has the proportion of positive tows or excessively large tows masked true changes in abundance?
- Does the use of an untransformed response variable (numbers or weight) an appropriate measure of central tendency and dispersion?
- Has the population changed its distributional patterns?
- If distributional changes have occurred, can they be associated with an environmental change?

The design efficiency was evaluated using the methodology of Gavaris and Smith (1987) and Cochran (1963) and using Splus software written by Stephen Smith, DFO, Halifax. Design efficiency can be decomposed into components associated with stratification and allocation of samples to strata. Stratification effects alone are always neutral or positive, i.e., they will always improve the precision of an estimate relative to a simple random sample or leave it unchanged. Allocation effects can be positive or negative such that a stratified design can have lower precision than a simple random sample. Analyses of the spring and fall surveys, using female weight per tow as the response variable, suggests a small positive effect (~ 10%) due to stratification (Fig. 5.16) and a small, usually negative allocation effect. Effects of stratification and allocation appear to be less variable for the spring survey than the fall survey. Neither survey represents a significant improvement over a simple random sample for spiny dogfish. This conclusion however cannot be generalized since the survey stratification is designed to accommodate many species. A theoretical analysis of optimal allocation of sampling effort for these surveys suggested that sampling effort would have to be redirected almost entirely to the strata with the highest densities. Since the strata with highest concentrations of dogfish can change over time, an allocation strategy based on the previous year's distribution could be seriously in error, especially since it would diminish sampling effort in strata important for other species.

The fraction of positive tows in the spring survey for decreased from about 50 to 30% between 1970 and 1980 and has fluctuated at about 40% since then (Fig. 5.17). An arbitrary total catch weight of 1000 kg was used to define "large" tows. "Large" tows have increased in the fall survey to about 2.5% of the tows. These tows represent about 50% of the total dogfish catch taken by the survey in a given year (Fig. 5.17 bottom, Table 5.6). In the spring survey (Fig. 5.18, Table 5.7) the fraction of positive tows exhibited no trend, nor has the fraction tows with "large" catches. The contribution of large tows to the spring survey appears to fluctuate about 30% of the total survey catch. Thus the fall survey is more variable over time and thought to be less useful as a measure of the closed population.

A variety of method have been proposed to deal with overdispersed catch data including transformations (Pennington 1996), trimming (Kappenman 1999), and bootstrapping (Smith 1997). Bootstrap methods per Smith (1997) were used to examine the sampling distribution of the survey estimates of mean density. Bootstrap estimates of mean weight per tow for female and male dogfish in the spring survey are reported in Fig. 5.19. Bootstrap confidence intervals increase in length as density increases. With respect to the 2006 value however, little overlap with the 2005 estimate is evident. Confidence regions for 2006 do appear to overlap with survey values in 2002. The length of the nominal confidence interval (=upper percentile value – lower percentile) is generally smaller for the bootstrap method than the parametric method (Fig. 5.20). It appears that the bootstrap interval is an improvement over the conventional parametric confidence intervals, especially since it ensures that the lower bound predicted confidence interval will always exceed zero and it does not require the uncertain implications of the back transformation to the arithmetic scale.

The 2006 spring survey index for mature females of 39.4 kg/tow was the 5th highest in the 39 year time series. The swept area estimate of spawning stock was 4.5 times greater than that observed in 2005. A map of the survey catches in 2006 did not reveal any extraordinary outliers (Fig. 5.20.1). Two major concentrations were evident from in a band directly east of Gloucester into the Gulf of Maine, and in the Mid Atlantic south of Long Island. Relatively lower concentrations were found in along the shelf break from Southern New England to the southern flank of Georges Bank. Over the entire time series, this zone was generally in the upper quintile of densities. The high concentration in the central Gulf of Maine is anomalous with the long term patterns of use for this region (lower 40% of station densities) but appears consistent with patterns in the last 5 years (2001-2005). A comparison of the mean variance relationship for 2006 with the 1993-2005 period suggested a newly equivalent relationship (Fig. 5.20.2) .

5.4 Analysis of environmental factors

Over the past few years, numerous fishermen have complained about the increased densities of dogfish in the inshore waters, particularly in the fall. A comparison of swept area estimates for the inshore and offshore strata in spring and fall supports these claims (Fig. 5.21, Table 5.8). In the fall survey the inshore strata constituted about 10% of the population; in the last 5 years this fraction has been greater than 30%. The spring survey typically indicates about 1-2% in the inshore strata, but since 2001 this has been about 5%.

The movement toward shore was quantified by computing the distance to shore for each station and computing catch weighted average distances. Catch-weighted distances were compared to the average distance from shore for sample stations. This approach is similar to that used by Perry and Smith 1994 to identify important environmental factors. In the present context, we are simply using this approach to describe trends. This methodology was applied to a number of other factors including latitude, longitude, bottom temperature, average depth, and salinity. (Fig. 5.22 to 5.27) Computations were performed for each year by sex for both spring and fall surveys.

Analyses of distance to shore reveal a striking inshore movement by males (fall survey) of nearly 60 km between the mid 1980s and the last decade (Fig. 5.22). Females also moved closer to shore, from 60 km offshore to 40 km. In the spring survey, males moved about 50 km closer to shore but females showed no consistent trend. Historically, the locus of male abundance was about150 km offshore. Currently the locus for males is about 100 km offshore and more coincident with the distribution of females. This increased overlap during this period immediately after dogfish have released their pups may be important ecologically.

Survey catches from 2006 are mapped in Fig. 5.6 e-f. Stock size of mature females increased nearly five-fold compared to the previous years. Such rapid changes in the true abundance of dogfish are implausible owing to the slow growth rate of the species. Changes in distribution and availability of dogfish to the Spring survey in 2006 can partly explain the major change in the survey index. The high index in 2006 was not due to one or two exceptionally large tows. Rather, the dogfish distribution shifted into large strata with higher weighting factors. In 2006, five strata had average survey catches that were the highest since 1980. Strata 65 and 66, east of Delmarva, had female catch rates that ranked second and first, respectively over their time series. Stratum 73, off New Jersey, also recorded its highest ever female dogfish survey catch. The high average in stratum 73 was attributable to a large catch on the boundary with stratum 74, a much smaller stratum.

Changes in catch-weighted latitude (Fig. 5.23) and longitudes (Fig. 5.24) suggest that dogfish are north of the average station in the fall survey and south of the average station in the spring. In particular, the locus for male dogfish is almost 2 degrees farther south than during the 1990's. Males in the spring have moved farther west (~ 2 degrees).

Analyses of temperature (Fig. 5.25), average depth (Fig. 5.26) and salinity (Fig. 5.27) did not appear to have any significant trends. However, males and females are found at cooler temperatures in the fall (~10 deg) than the standard survey station and higher temperatures in the spring. In the fall these temperatures are found in more shallow depths whereas in the spring males are found at deeper depths than the average over all tows.

6.0 ANALYSIS OF INDEX TRENDS

In this section we further examine the changes in the survey indices and consider changes in swept area biomass for various size groups by sex. A summary of the research on changes in the average size of mature females and interrelationships with numbers and average size of pups may be found in NEFSC (2003, SARC 37)

6.1 Swept-area biomass estimates

Estimates of minimum stock biomass were determined from the NEFSC spring survey catches. Mean numbers per tow by sex and 1-cm length class were converted to average weights using a length-weight regression (females: $W = \exp(-15.0251) * L^{3.606935}$; males: $W = \exp(-13.002) * L^{3.097787}$). These average weights were then multiplied by the total survey area (64,207 n mi^2) and divided by the average area swept by a 30-minute trawl haul (0.01 n mi^2). Three size categories were defined ($\leq$35 cm, 36-79 cm, and $\geq$80 cm) which approximately correspond to new recruits, males and immature females, and mature females, respectively (Table 6.1).

One of the critical assumptions of the swept area computation is the size of the trawl footprint. The nominal footprint is based on the area swept by the net traveling at an average speed of 3.5 knots for 30 minutes. The effective capture zone is the distance between the wings of the net. Recent information (unpublished net mensuration data, Ecosystem Survey Branch, NEFSC) on variations in vessel speed and the increased contact time during haulback suggest that the effective area swept is expected area swept is greater than the nominal footprint. Additional details on this are provided in section 7 of this report. To illustrate the effect of this factor, the swept area biomass estimates are computed with a nominal footprint of 0.012 n mi^2 (Table 6.2).

Swept area biomass estimates, using the 0.01 n mi^2 footprint were partitioned into size groups <36 cm, 36-79 cm, and $\geq$80 cm. For females, these size ranges roughly correspond to dogfish less than one year old, immature individuals and mature adults, respectively. For males, the intermediate size range represents both adolescent and mature individuals. Male dogfish >80 cm are mature, but relatively uncommon as the average asymptotic size is about 80 cm.

Swept-area estimates of stock biomass exhibit annual variation that exceeds biologically realistic changes for such a long-lived species. Therefore, LOWESS smoothed (tension=0.5) estimates of biomass were considered to be better measures of population trends. Overall biomass estimates increased steadily from 1968 through 1992 to about 600 k mt but have declined to about 400 k mt, about the same level as observed in 1985 (Fig. 6.1). The changes in total biomass mask significant changes that have occurred within size and sex groups. The pool of male and female dogfish between 36 and 79 cm has remained relatively stable over the past decade (Fig. 6.1 bottom) at about 350 k mt. From 1980 onward dogfish sex was recorded in the NEFSC database, allowing examination of the trends by sex as well. Figure 6.2 reveals the marked change in female spawner biomass (top) and evidence of reductions in the large males as well (bottom). Biomass changes in the intermediate size range of females are now evident (Fig. 6.3 top) as the fishery has continued to accept smaller sized dogfish. Male 36-79 cm dogfish biomass has increased steadily since the early 1980's (Fig. 6.3 bottom). The effects of the increased catch rates for the 2006 survey do not seem to have much influence on the predicted abundance in the terminal year.

Dogfish less than 36 cm represent individuals less than one year old at the time of the survey and are considered as recruits to the population. Recruitment generally has been stable through most of the time series with a number of strong year classes in the 1980's (Fig. 6.4). Number of recruits between 1997 and 2003 were the 7 lowest in the 41 year series. Coincident with the change in abundance, the average size of dogfish in this size range has also declined by about 3 cm (Fig. 6.5). The trend in abundance of recruits is consistent with the reduction in spawning stock but the magnitude of the change is unexpected. The decline in the average size of mature females appears to have attenuated in the last 3 years. Average pup size has stabilized and may have increased by about 1 cm. No additional work on this topic was reviewed by the Subcommittee. See Section 6.2 of NEFSC (2003) for a summary of previous work.

7.0 FISHING MORTALITY AND BIOMASS ESTIMATION

7.1 Beverton-Holt estimator

Instantaneous total mortality rates (Z) for female dogfish were estimated using the length based method of Beverton and Holt (1956)

$$Z = \frac{K(L_\infty - \bar{L})}{\bar{L} - L'}$$

where K and $L\infty$ are from the von Bertalanffy growth model and L is the stratified mean length of individuals in the spring survey greater than the critical length L'. L' is the 25%-ile of length in the commercial landings. Parameters for female growth were K=0.1128, Lmax=105 cm. Fishing mortality rate is obtained as the difference between Z and natural mortality M. The Beverton-Holt estimator was evaluated over a range of sizes at entry to the fishery and natural mortality rates (M=0.092; 50-yr lifespan, M=0.06; 100-yr lifespan) to explore the sensitivity to these assumptions.

Mortality rates averaged about 0.06 during 1980's when landings averaged about 6000 mt. Landings nearly tripled between 1989 and 1990, increased since then to over 28,000 mt in 1997 and have subsequently decreased (Table 4.1). The increase in fishing mortality rates reflects the increase in landings to levels above 0.4 in the late 1990's. Regardless of the underlying parameter assumptions, the estimates of F exceed the biological reference points of 0.08 (target) and 0.11 (threshold) (Fig. 7.1). The Beverton-Holt estimator is expected to lag the true rate of fishing mortality when fishing mortality is increasing. Conversely, since it is dependent on the growth and assumes an equilibrium size structure, it is subject to transient conditions. Thus the mortality estimates for the female population in the last 3 years, when fishing mortality rates have declined are likely to reflect the history of the fishery rather than the contemporary status. During the course of various meetings related to the development of the federal and ASMFC management plans, it was noted that additional analyses would be required to assess contemporary fishing mortality rates. Those analyses are presented below.

7.2. Selectivity of fishery: landings and discards

The changes in average size of dogfish are consistent with the targeted removal of large females. However, the changes in size selectivity over time also have important implications for the total force of fishing mortality on the population. High rates of mortality over a broad range of size groups have greater biological implications than an equivalent fishing mortality rate over a narrow range of size classes. The magnitude of these changes is important for estimation of fishing mortality, for evaluation of reference points and for population projections under various management scenarios. The first step in developing an estimator of F which incorporates both landings and survey information is to estimate a size specific selectivity function.

The selectivity of the fishery was approximated by assuming that proportion of stock available to the commercial fishery could be expressed as a logistic function of the size frequency distribution of the survey. Let $p_s(l)$ represent the proportion at length l in the survey and let $p_c(l)$ represent the proportion at length l in the commercial landings. The statistical model to relate these quantities can be written as

$$p_c(\ell) = \frac{p_s(\ell)\left(\dfrac{1}{1+e^{a+b\ell}}\right)}{\sum_{\ell=50}^{L_\infty} p_s(\ell)\left(\dfrac{1}{1+e^{a+b\ell}}\right)}$$

where a and b represent the parameters to be estimated. In general this model fit the data very well. Details on the application of this model to data from 1990-2002 by sex are provided in Appendix 1. Appendix 1 deals with the selectivity of the commercial fishery, in the absence of data on the discarded length classes. Appendix 2 examines the derived selectivity function for composite size frequencies in Fig. 4.19-4.21. The selectivity model tends to fit the composite landed + discard data more poorly. Owing to the mixture of component fleets constituting this composite size frequency distribution, and the extreme uncertainty of the size compositions for 1994 and earlier, a more complicated selection function may be warranted.

7.3 Stochastic estimation of fishing mortality and biomass

7.3.1 Methods

A stochastic estimator of fishing mortality was developed to improve the estimation of contemporary estimates of fishing mortality. The estimator developed below incorporates a greater degree of mechanistic detail and uncertainty in the data. Several different measures of fishing mortality are of interest. First we are interested in the total rate of mortality on the exploitable stock of male and female dogfish (F_1).

Second, we are interested in the mortality generated by the removals of discards (F_2). This quantity is differentiated from F_1 because it acts non-selectively over the entire stock, not just the exploitable stock. The weighted average of F_1 and F_2, called F_{bar}, represents the force of mortality acting on the entire stock. (i.e., a biomass-weighted F). In terms of evaluating the fishing mortality rate with respect to a biological reference point, we are interested in have a metric commensurate with the pup-per-recruit analyses (Section 8.0).

Define

F_1 = F generated by female landings and discards acting on the exploitable biomass of female dogfish

F_2 = F generated by male landings and discards acting on the exploitable biomass of male dogfish

F_3 = F generated by female landings acting on the spawning biomass of female dogfish (>80 cm)

F_4 = F generated by male landings acting on the exploitable biomass of male dogfish

Using the catch equation, it is possible to define the various F metrics as follows

<u>Variable Definitions</u>

L = Total landings (mt) of USA plus Canadian commercial landings
L_f = Landings (mt) of female dogfish in USA plus Canadian commercial landings
L_m = Landings (mt) of female dogfish in USA plus Canadian commercial landings

$B(\ell)$ = Total biomass(mt) of male plus female dogfish at length ℓ. $B(\ell)=B_f(\ell) + B_m(\ell)$
$B_f(\ell)$ = Total biomass(mt) of female dogfish at length ℓ.

$B_m(\ell)$ = Total biomass(mt) of male dogfish at length ℓ.

$B_{expl}(\ell)$ =Exploitable biomass(mt) of male plus female dogfish at length ℓ.
$B_{expl}(\ell)=B_{expl,f}(\ell) + B_{expl,m}(\ell)$
$B_{expl,f}(\ell)$ = Exploitable biomass(mt) of female dogfish at length ℓ.
$B_{expl,m}(\ell)$ = Exploitable biomass(mt) of male dogfish at length ℓ.

D = Total discards (mt)

D_{G_f} = Dead discards of females in the gill net fishery
D_{T_f} =Dead discards of females in the otter trawl fishery
D_{R_f} = Discards of females in the recreational fishery

D_{G_m} = Dead discards of males in the gill net fishery
D_{T_m} =Dead discards of males in the otter trawl fishery
D_{R_m} = Discards of males in the recreational fishery

$N(\ell)$ = Number of dogfish in population at length ℓ.
$I(\ell)$ = Index number of dogfish in population at length ℓ.
$p(\ell)$= proportion of dogfish in population of length class ℓ

$sel_f(\ell)$ = Selectivity fraction for females of length ℓ.
$sel_m(\ell)$ = Selectivity fraction for males of length ℓ.

$W_f(\ell)$ = Average weight (kg) of females of length ℓ.
$W_m(\ell)$ = Average weight (kg) of males of length ℓ.

A= Total domain of offshore survey strata (nm^2)
a= Area swept by standard trawl tow (nm^2).

Xbar,t = Average number of dogfish caught per tow in NMFS spring survey in year t.
S^2_t = Estimated variance of mean catch per tow in NMFS spring survey in year t.

$$L_f + D_{Gf} + D_{Tf} + D_{Rf} = \sum_{l=l_{\min}}^{l_{\max}} F_1\left(sel_f(l)B_f(l)\right) \qquad 1)$$

$$L_m + D_{Gm} + D_{Tm} + D_{Rm} = \sum_{l=l_{\min}}^{l_{\max}} F_2\left(sel_m(l)B_m(l)\right) \qquad (2)$$

$$L_f = \sum_{l=80}^{l_{\max}} F_3 B_f(l) \tag{3}$$

$$L_m = \sum_{l=l_{\min}}^{l_{\max}} F_4 sel_f(l) B_m(l) \tag{4}$$

The estimates of F can be obtained by rearranging Eq. 1 to 4, simply dividing the left hand side by the non-F terms on the right hand side equation.

The biomass variables can be written as the product of survey numbers at length and average weight at length and a scaling factor equal to the ratio of the total survey area divided by the footprint of the average tow.

$$B(l) = B_f(l) + B_m(l)$$

$$where,$$

$$B_f(l) = N_f(l)W(l) = I_f(l)\left(\frac{A}{a}\right)W_f(l)$$

$$B_m(l) = N_m(l)W(l) = I_m(l)\left(\frac{A}{a}\right)W_m(l)$$

The index number at length by sex can be further generalized to express it as the average number per tow X_{bar} times the fraction of the population at length p(ℓ). The proportion at length is derived from the survey.

$$I_f(l) = \overline{X}_f p(l)$$

$$I_m(l) = \overline{X}_m p(l)$$

All of the quantities in Eq.1 to 5 are measured with error but for this assessment it is assumed that the errors in the estimates of landings by sex and length class are negligible. Much greater variation is likely for survey abundance measures and total discards. To capture the effects of these sources of variation, stochastic versions of Eq. 1 to 5 were computed by convolving distributions of survey abundance, discards and trawl footprints.

Substantial variation in survey based estimates of dogfish abundance occurs across years. For some years the variation exceeds what would be expected in terms of possible biological changes. To accommodate such variation, we use a simple 3yr moving average smooth of the overall abundance estimates. The composite averages by sex are estimated as

$$\bar{\bar{X}}_{f,t} = \frac{\sum_{j=t-1}^{j=t+1} \bar{X}_{f,j}}{3}$$

$$\bar{\bar{X}}_{m,t} = \frac{\sum_{j=t-1}^{j=t+1} \bar{X}_{m,j}}{3}$$

The associated variances are estimated as

$$\bar{S}^2_{f,t} = \frac{\sum_{j=t-1}^{j=t+1} \bar{S}^2_{f,j}}{3}$$

$$\bar{S}^2_{m,t} = \frac{\sum_{j=t-1}^{j=t+1} \bar{S}^2_{m,j}}{3}$$

Sampling theory suggests that the survey mean should be asymptotically normal. We exploit this feature to simplify the estimation of the stochastic distribution of the Fs. A summary of the 3-yr moving average and its composite variation is provided in Table 7.1.

The survey footprint is also measured with error. One source of error is the magnitude of variation in the length of the tow. The effective time on the bottom can exceed the nominal tow duration owing to delays in lifting the net off the bottom during haulback. As the net is moving forward with the combined forward velocity of the vessel plus the forward speed of the cable, the effective area swept will exceed the nominal target. To account for this variation in footprint size, preliminary data collected aboard the R/V Albatross IV in 2002 were used to estimate the possible variation in tow lengths. See Table 7.2

Variation in discards was estimated using the method described in Section 4.4.

Evaluation Method

Let Φ = Normal cumulative distribution function. The inverse of Φ, denoted as Φ^{-1} allows the evaluation of a set of values over a specified range, say α_{min} and α_{max}, over equal probability intervals.

$$X'_{t,\alpha} = \Phi^{-1}(\alpha \mid \overline{\overline{X}}, \overline{S}_t^2)$$

The step size between successive values of α was set as 1/500 (0.975-0.025), where α_{min} =0.025 and α_{max}=0.975. An equivalent approach was used for evaluation of the footprint parameter a where a~N(μ_a , σ_a^2) and the discard estimate D~N(μ_D , σ_D^2). Discard means and variances were estimated for each gear and sex and incorporated into Eq. 1 and 2. For both of these parameters the sample mean and variance estimates were used to estimate the normal distribution parameters.

The sampling distribution of each of the Fs described above was evaluated by integrating over each of the normal distributions for X, a, and D_G, D_T, and D_R. The density X and footprint a parameters were evaluated over 500 equal probability intervals, while the sampling distribution D_G , D_T, and D_R were evaluated over 20 intervals. This brute force approach to the multidimensional integration provides reasonable assurance that the sampling distributions of the Fs will be appropriately estimated.

7.3.2 Results

Biomass Estimates

Stochastic estimates of total, exploitable, and female spawning stock biomass are summarized in Fig. 7.2. Trends in SSB are comparable to Tables 6.1 and 6.2. Incorporation of the uncertainty in the survey mean numbers per tow and footprint variation suggests relatively precise estimates. The exploitable biomass quantities vary as a function of the selectivity functions derived in Section 7.2 (Appendix 2). These quantities are more erratic as they reflect the joint action of a temporally varying selectivity pattern and changes in underlying total biomass. The derived sampling distributions of the exploitable male and female biomasses and spawning stock biomass estimates are depicted in Fig. 7.3a-b. Estimates of male biomass are much less precise than those for females.

Swept area (minimum footprint) spawning stock biomass in for the 3 yr average 2004-2006 was estimated to be 106, 000 mt (Fig. 7.2). This estimate rose sharply from 2003-2005 owing to the large increase in the point estimate for 2006 spring survey (Fig. 5.19, Table 6.1). The sampling distribution of SSB for 2004-06 was much broader than the 2003-05 distribution (Fig. 7.3b). The sampling distributions of SSB suggest that the probability of SSB exceeding 200,000 mt was about 65-80% in 1990-1992 but rapidly declined to zero by 1997 and has remained there since.

Estimates of exploitable biomass for males and females are driven by the size selective pattern of the fishery and the size distribution of the dead discards. These components have varied greatly in the past 15 years. As a consequence the estimates of exploitable biomass have different bases across years (Fig. 7.3a-b).

Fishing Mortality Estimates

Stochastic estimates of the fully recruited F for exploitable female and SSB are presented Fig. 7.4 (with table). Estimated F on the exploitable female stock peaked in 1994 at 0.465, remained high through 1999, and has declined to about 0.13 in recent years. The ratio of landings to SSB showed a rapid rise from 0.06 to more than 0.4 by 1998. Since then however, it has declined sharply (Fig. 7.4).

The sampling distribution of fully recruited F (Fig. 7.5a-b) shows the progression of fishing mortality on the exploitable male and female biomasses and on female SSB. Estimates of higher rates of F tend to be much less precise. Estimated F's on males, even when discarding was included, was well below 0.05 during the 1990-2005 period. The ratio of female landings to SSB (F_3, Eq. 3) was much greater than the F on the fully exploited female stock (F_1 Eq. 1).

The incorporation of the size frequency of discards into the estimate of total mortality alters the force of mortality on the population such that the various estimates of F given in Eq. 1 to 4 are difficult to interpret. The patterns of increasing F from 1990 to 1999 and a decline since then are consistent with patterns observed in SARC 37. For this assessment (SARC 43) the force of mortality is distributed over a greater range of length classes such that the full Fs are not strictly comparable among year or with the biological reference points for target F (0.08), threshold F (0.11) and rebuild F (0.03).

The changing force of mortality on the female spiny dogfish motivated a need for a more synthetic approach. The varying force of mortality can be expressed as its net effect on reproductive value. This concept was employed in Rago et al. (1998) as pups per recruit (see their Eq. 8) and more recently by Gallucci et al (2006). Both approaches are measures of net reproductive rate and express an integration of the force of mortality on the expected reproductive output. If net reproductive value is expressed as number of female offspring per female spawner, then values below one imply a declining population; values above one imply that the population has the ability to increase.

Pups per recuit were modeled as a function of length specific growth, maturation and fecundity. The average duration Δt (yrs) of a length interval ΔL was computed by inverting the von Bertalanffy growth model

$$\Delta t_j = t_{j+1} - t_j$$

where

$$t_{j+1} = \frac{-\ln\left(1 - \frac{L_j}{L_\infty}\right)}{K} + t_o$$

$$t_j = \frac{-\ln\left(1 - \frac{L_{j+1}}{L_\infty}\right)}{K} + t_o$$

$$L_{j+1} = L_{j+1} + \Delta L$$

The von Bertalanffy parameters used for spiny dogfish were K=0.1128, to=-2.552, and L_∞=110 cm.

Reproduction at length class j (R_j) is computed as the expected annual number of female pups per female by length class. It is necessary to consider the fraction of the population mature, the average gestation period, the number of pups per female and the expected fraction of pups that are female as follows:

$$R_j = \left(\frac{f_{mature,L_j}}{t_{gestation}}\right) f_{female,L_j}\, x\ Pups_{L_j}$$

Size specific survival was modeled as a function of size specific selectivity, full F and natural mortality as

$$S_j = e^{-\left(Sel_{L_j} F + M\right)\Delta t_j}$$

The expected pups per recruit is given as

$$PPR = S_o\left(R_1 + \sum_{j=2}^{J}\prod_{i=1}^{j-1}\frac{S_i R_j}{\lambda^{T_j}}\right)$$

where (5)

$$T_j = \sum_{i=1}^{j} t_i$$

The variable S_o defined as the first year survival rate of pups (0.72) , was derived by Rago et al. (1998) for the finite rate of increase λ =1.09.

Evaluation of Eq. 5 vs F for the selectivity functions in Appendix 2 demonstrated that the full F cannot be easily interpreted across years (Fig. 7.6). A full F corresponding to a PPR=1 (i.e., equilibrium) can vary between 0.11 when selectivity occurs over the entire length structure to 0.6 when the full F only applies to the largest size class.

The frequency distributions of full F in Fig. 7.5a-b were mapped to frequency distributions of Pups per recruit in Fig. 7.7a-b using the selectivity functions defined in Fig. 7.5.

8.0. LIFE HISTORY MODEL AND STOCK RECRUITMENT

The life history model used to estimate biological F reference points for spiny dogfish are summarized in Rago et al. (1998) and in SARC 26. No additional work on this particular aspect of the assessment has been conducted.

The application of the Ricker stock-recruitment relationship to spiny dogfish has been reviewed the Joint Statistical and Scientific Committee of the New England and Mid-Atlantic Fishery Management Councils in 1999. On the basis of these meetings an estimate of the SSB necessary to produce the maximum recruitment, denoted as SSB_{max} , was set at 200,000 mt. It should be noted that the estimate of 200,000 mt "roughly" corresponds to a swept area biomass estimate based on a nominal trawl footprint of 0.01 nm^2. The modifier "roughly" is used because the estimate was taken from a graph of the Ricker function plot. The stock and recruitment data for spiny dogfish are summarized in Table 8.1. The actual point estimate corresponding to the peak value of the Ricker function for the 1968-1996 data is 215,024 mt. The data used in this relationship were two year averages of recruitment, and SSB.

It is important to note that the estimate of SSB_{max} scales directly with the NEFSC spring research trawl survey. The abundance index, in kg/tow, for female dogfish greater than 80 cm is converted to total biomass by multiplying the average by the ratio of the total survey area (~64207 nm^2) and the footprint of the trawl. Evidence presented in section 6.3 suggests that the actual footprint exceeds the nominal footprint of 0.01 nm^2

by about 10 to 20%. For example, since SARC 26 updated information on vessel speed and contact time suggested that the average footprint corresponded to a contact time of 33 minutes (rather than 30) and a vessel speed of 3.8 knots (rather than 3.5). These changes increase the nominal footprint to 0.012206 nm^2 or about 20% greater. Increasing the footprint reduces the swept area biomass estimate, leading to an alternative estimate of the SSB_{max} of 167,000 (i.e., 200,000 mt *(0.01/0.12) = 166,667 mt).

The important conclusion from this example is that the trawl footprint simply scales the abundance index for both recruitment and SSB. The underlying relationship between recruits and SSB is unaffected, such that estimates can be derived from analyses of the survey data alone (recruits expressed in numbers per tow, SSB expressed in kg/tow). The results of alternative model formulations are summarized in Table 8.2. The estimate of SSB_{max} of 214,024 mt corresponds to an average weight per tow of 33.2 kg. If unsmoothed data, rather than a 2 point moving average, are used, the estimate of SSB_{max} becomes 35.9 kg but its variance increases significantly.

Inclusion of the data from 1997 to 2006 illustrates another important property of the SSB_{max} estimate. Recruitments since 1997-2003 represented the seven lowest values in the 1968-2006 time series. Incorporation of these values into the Ricker model estimate has no effect on the R_{max} estimate, but the estimate of SSB_{max} increases by 41% to 304,000 mt (Table 8.2). A Lowess smooth of the SR data (Fig. 8.1) is much less sensitive to the additional years of data with an approximate SSBmax slightly less than 200,000 mt (using the 0.01nm^2 footprint). Discussion of the scaling problems at the SARC 37 led to the general recommendation that the smoothed estimate for the entire data series would be a more appropriate measure of SSB_{max}, if an empirical model of the SR function were used to provide a biomass reference point.

The Ricker model assumes that the total female biomass is an adequate measure of spawning potential. As described in NEFSC (2003 Section 6.3) the reproductive output of dogfish declines with maternal size. Declines in maternal size decrease both numbers and size of pups. The information on decline in pup size in smaller females is an important conclusion in this assessment as it provides a possible explanatory mechanism for the lower than expected pup production since 1997. The temporal trajectory of recruits and SSB in Fig 8.2 illustrates that most of the negative residuals have occurred since 1989. Notably, a dense cluster of negative residuals has occurred when the spawning stock size has been below 100,000 mt in the 1997-2003 period. Model residuals, plotted against mean maternal length (Fig. 8.3), revealed a strong clustering when maternal size was below the 1968-2006 median of 87 cm. An odds ratio test suggested that the odds of having a negative residual were 4.5 times greater when the mean length of spawners fell below 87 cm. The clustering of negative residuals is also consistent with the increase in male to female ratio (Fig. 5.13a).

Our analyses of the Ricker model suggest that additional biological processes may be necessary to explain the lack of fit in recent years. Clearly, a model based only on accumulated stock biomass may be inadequate to predict recruitment for a population which is currently experiencing a strongly truncated size distribution (Fig. 5.10), reduced average size of females (Fig.5.11a and 6.5), smaller than average size pups (Fig. 6.5), and a skewed sex ratio (Fig.5.13a). Some consideration might be given to a proxy value for B_{MSY} that would be based on the product of average recruitment and the biomass per recruit wherein the force of mortality was sufficient to ensure that pups per recruit exceeded 1.0. The current sex ratio dominated by males is more problematic because this is a long term transient condition. It is not known if biological mechanisms alone are sufficient to shift the balance toward the sex ratio observed before 1992(Fig. 5.13a).

9.0 SIMPLE MASS BALANCE MODELS

SARC37 expressed concerns regarding the utility of the nominal footprint (0.01 nm^2) analyses of survey data as an adequate measure of true stock abundance. It was suggested that model- based approaches would be an alternative means of estimating the likely magnitude of q and therefore, efficiency, defined as the probability of capture given encounter. To test this concept two alternative mass balance models were applied. A simple Leslie-Davis model, based on a closed population was applied, primarily as a means of circumscribing the possible value of q. The second model was based on a simplified catch survey analysis, similar to the process model of Collie and Sissenwine.

Swept area estimates of mature female dogfish, based on a footprint of 0.012 (Table 6.2) were used as an index of abundance and compared with cumulative landings of females (Table 4.7). A 3-yr moving average of swept area biomass was used . This tends to dampen interannual changes, and is consistent with time-series approaches (e.g. Pennington 1986) for estimating abundance from surveys.

Leslie-Davis model results (Fig. 9.1) suggest that the initial SSB size in 1989, prior to the start of the fishery, was ~250,000 mt (R^2=0.91) and that the q was 0.943. This would imply that the effective footprint for the tow would be 0.943* 0.012 nm^2 = 0.011 nm^2. In terms of the capture process, this could occur if, on the average, spiny dogfish were herded by the trawl doors (footprint ~ 0.02325, Table 7.2) and 48.6% of these were caught by the trawl. Since the 3-yr average measures of CPUE are autocorrelated, the Leslie-Davis model was refit to a reduced number of points, such that the CPUE terms were not used twice (i.e, 1988-1991, 1992-1994, etc was regressed against cumulative landings. Results for this model suggested an initial abundance of 238,000 mt and a q=0.837. Under this model the effective footprint is 0.837 * 0.012=0.01, which is equivalent to the nominal footprint of the survey and implies an efficiency of 0.432 for the area swept by the doors. These results are consistent with Harley and Myers (2001) who reported rapidly increasing catchabilities for a variety of fish exceeding 80 cm.

The Leslie Davis model makes strong, and perhaps untenable, assumptions about constancy of recruitment and offsetting effects of growth and natural mortality. To address these concerns a (slightly) more complicated mass balance model was devised. The model is similar to that proposed by Collie and Sissenwine (1983), except in this instance, it was assumed that all of the error is process error, rather than observation error. Thus the model boils down to one parameter as follows.

Define recruits R_t as the biomass of dogfish in the 79 cm range that will grow into the 80 cm range in the next time step. The biomass of 80+ cm dogfish will change between time steps in response to the growth of individuals (G), losses through natural mortality (M), and biomass removals by the fishery C_t. Basing the expanded values of B and R on a nominal footprint of 0.01, the model can thus be defined as

$$B_{t+1} = B_t\, e^{G-M} + R_t - C_t$$

The G and M parameters are not separably estimable but their difference can be estimated as a single parameter, say ϕ. The model estimate of ϕ was -0.06 which corresponds well with the assumed natural mortality rate of 0.092 and a very slow adult growth rate (Fig. 9.2) Results of the model fit are summarized in Fig. 9.2. The model fits well with no aberrant residual patterns. The model now adequately tracks the recent change in abundance, a small upturn in the last 3 yrs. This appears to be due to a decrease landings, since the difference between the recruitment and the landings becomes positive in 2001 and 2002. (Fig. 9.2, bottom panel). An independent estimate of the average G parameter for 1980-2006 suggests a continuous increase since 1980 as the population size structure has been truncated. Since 1995 the average G, defined as follows:

$$G = \ln\left(\sum_L \hat{W}_{L+\Delta L,t+1} N_{L+\Delta L,t+1}\right) - \left(\sum_L W_{L,t} N_{L,t}\right)$$

where the predicted value of weight in time t+1 is based on the von Bertalanffy growth model.

The fit of mass balance model declined slightly when the model was used to describe the population back to 1980 (Fig. 9.3). Model fit declined precipitously when unsmoothed data were used (Fig. 9.4). All three applications of the model suggest that landings exceeded recruitment to the spawning biomass between 1990 and 2001.

Both the Leslie-Davis and simple mass-balance models support the concept that the nominal footprint assumption adequately characterizes the true size of the population. The rapid change in the size-structure, and paucity of pups in recent years also provide evidence that the removals in the directed fishery were sufficient to exert a relative large mortality on the adult stock.

10.0 STOCHASTIC PROJECTION MODEL

This section describes the stochastic projection model for spiny dogfish. Examples are provided with initial conditions based on the 2004 -2006 population size structure.

10.1 Overview

A length-based stochastic projection model was developed to evaluate effects of alternative fishing mortality scenarios. The model incorporates sex specific rates of growth and fishing mortality. Discard mortality is assumed to act equally all size ranges of both sexes. Reproduction in the model is assumed to be proportional to stock abundance. The basic model can be written in terms of two matrix equations as

$$N_{f,t+1} = S_{f,Z,t} P_f S_{D,t} N_{f,t} + S_{D,t} N_{f,t}^T Pup\, S_o \varphi R_f^o$$

$$N_{m,t+1} = S_{m,Z,t} P_m S_{D,t} N_{m,t} + S_{D,t} N_{f,t}^T Pup\, S_o (1-\varphi) R_m^o$$

where

$\mathbf{N_{f,t}}$= Vector of female population abundance at length. Dimension = (ℓ_{max}- ℓ_{min}+1)

$\mathbf{N_{m,t}}$= Vector of male population abundance at length. Dimension = (ℓ_{max}- ℓ_{min}+1)

$\mathbf{S_{D,t}}$= Diagonal matrix of discard survival rates at time t. Dimensions = (ℓ_{max}- ℓ_{min}+1, ℓ_{max}- ℓ_{min}+1)

$\mathbf{S_{f,Z,t}}$=Diagonal matrix of composite survival from instantaneous fishing and natural mortality rates for females at time t. Dimensions = (ℓ_{max}- ℓ_{min}+1, ℓ_{max}- ℓ_{min}+1)

$\mathbf{S_{m,Z,t}}$=Diagonal matrix of composite survival from instantaneous fishing and natural mortality rates for males at time t. Dimensions = (ℓ_{max}- ℓ_{min}+1, ℓ_{max}- ℓ_{min}+1)

$\mathbf{R^o}$=Vector of proportions at length of new recruits. Dimension = (ℓ_{max}- ℓ_{min}+1)

$\mathbf{P_f}$= Growth projection matrix for females. Dimensions = (ℓ_{max}- ℓ_{min}+1, ℓ_{max}- ℓ_{min}+1)

$\mathbf{P_m}$= Growth projection matrix for males. Dimensions = (ℓ_{max}- ℓ_{min}+1, ℓ_{max}- ℓ_{min}+1)

Pup= Vector of length specific pup production rates for mature females. Dimension = (ℓ_{max}- ℓ_{min}+1)

S_o= Scalar first year survival rate of newborn pups. Derived from analysis of life history model

T = Transpose operator

φ = proportion of female pups at birth; 0.5 implies an equal sex ratio.

Note that the projection equation for males is a function of the numbers of recruits. produced by females.

Notation Footnote Vector quantities and operations will be denoted in bold font. As examples, let **X** denote a matrix with k x k elements, and **Y** denote a vector with k elements. Then **XY** would define the matrix multiplication of the vector **Y** by matrix **X** yielding a vector quantity, say **Z**. Similarly, $\mathbf{Y}^{\mathbf{T}}\mathbf{Y}$, read as **Y** *transpose* **Y,** represents the dot product of the elements of **Y** with itself, yielding a scalar quantity. Scalar multiplication of a vector is denoted as c**Y** where c is an arbitrary constant. By convention, matrix operators proceed from left to right and in general, operations are not commutable. The elements of a matrix are denoted by appending the appropriate number of identifiers within parentheses following the variable name. Thus, X(i,j) represents the scalar quantity in the i^{th} row and j^{th} column of the matrix **X** and Y(i) represents the i^{th} element of the vector **Y**.

The component processes of the matrix model and quantities derived from the population states are described below. The Fortran computer code used to implement the model is provided in Appendix 3.

10.2 Processes

10.2.1 Growth

Growth in length at age is modeled by the von Bertalanffy equation applied separately to each sex. The model parameters are taken from Nammack et al. (1985). The projection matrices, $\mathbf{P_f}$ and $\mathbf{P_m}$ for females and males, respectively are defined as square matrices consisting of 0, 1 elements. The non-zero elements in cell i, j indicate the growth of individuals from cell i to cell j. The growth of individual dogfish from length i to length j is modeled by first inverting the von Bertalanffy equation to obtain the age of individuals of length i to obtain age_i. The projected length at age_{i+1} is then obtained substituting age_i+1 back into the von Bertalanffy equation to obtain length j. The projection matrix algorithm for females can be summarized as follows:

$$Step\ 1.\ Find\ age\ for\ L_i$$

$$a_{f,i} = \frac{\log\left(1 - \frac{L_{f,i}}{L_{f,\infty}}\right)}{K_f} + t_{f,o}$$

$$Step\ 2. Compute\ L\ in\ next\ time\ step$$

$$L_{f,j} = L_{f,\infty}(1 - e^{-K_f(a_{f,i}+1-t_{f,o})})$$

$$Step\ 3.\quad Compute\ element\ of\ projection\ matrix$$

$$P_f(\text{int}(L_{f,j}), \text{int}(L_{f,i})) = 1$$

The same algorithm is defined for males by substituting the m for f in the subscript terms of the above equation.

10.2.2. Fishing and natural mortality

Natural mortality is assumed equal to 0.092 and to be constant over all length classes. Fishing mortality in year t, defined as F_t , is multiplied by sex-specific selectivity functions (Sec. 7) to estimate the sex- and length-specific fishing mortality rates. The diagonal matrices that decrement the populations for fishing and natural mortality are defined as $\mathbf{S_{f,Z,t}}$ and $\mathbf{S_{m,Z,t}}$ with elements defined by

$$S_{f,Z,t}(\ell,\ell) = e^{-(sel_f(\ell)F_t + M)}$$

$$S_{m,Z,t}(\ell,\ell) = e^{-(sel_m(\ell)F_t + M)}$$

In some scenarios it is desirable to evaluate the effects of a quota rather than a fishing mortality rate. For these scenarios it is necessary to iteratively solve for F_t sufficient to generate a quota of magnitude Q_t. A Newton-Ralphson algorithm (function rtsafe, p 359 in Press et al. 1992) was used to find the value of F. The application to this length-based model is patterned after the approach used in Brodziak et al. 1998. When a quota was too large for the estimated exploitable biomass to support, a default F=3.0 was set as an upper bound.

10.2.3 Discard mortality

Instantaneous discard mortality rates for the entire population were estimated using methodology described in Section 7.. The discard matrix in Eq. 9.1 is a diagonal matrix with principal diagonal elements estimated as

$$S_{D,t}(\ell,\ell) = e^{F_{discard,t}}$$

For all scenarios considered in this report, the discard rate was set equal to the estimate for 2002 (i.e. $F_{discard} \sim 0.02$). Note that the discard rate is assumed to be equal for all length classes. In the model, it is assumed that discard acts as a Ricker Type I Fishery in which the discard is assumed to occur before the fishing and natural mortality. This approximation results in a small overestimate of the numbers discarded. Assuming a discard rate of 0.02, the effect on discard numbers would be 4% higher when F=0 and 8% when F=0.11 when comparing a type I and II fishery.

The survivors, after discard mortality has occurred, is written as

$$N_{f,t+\Delta t} = S_{D,t} N_{f,t}$$
$$N_{m,t+\Delta t} = S_{D,t} N_{m,t}$$

The numbers of discards at length by sex, $\mathbf{D_{f,t}}$ and $\mathbf{D_{m,t}}$, for females and males, respectively, is defined as

$$D_{f,t} = N_{f,t} - N_{f,t+\Delta t}$$
$$D_{m,t} = N_{m,t} - N_{m,t+\Delta t}$$

10.2.4 Reproduction

The total number of pups produced is written at the product of the length-specific pup production rates and the number of females alive in year t.

$$Pup_{TOT,t} = S_o N^T_{f,t+\Delta t} Pup$$

The numbers of pups produced by length and size category are estimated by splitting the total pup number by sex and multiplying by the observed proportion of dogfish at length for lengths assumed to be less than one year old at the time of the survey. The resulting numbers of pups produced is written as:

$$female\ pups = \varphi Pup_{TOT,t} R^o_f$$
$$male\ pups = (1-\varphi) Pup_{TOT,t} R^o_m$$

The $\mathbf{R_f}$ and $\mathbf{R_m}$ vectors representing the proportions by length class consist of (ℓ_{max}- ℓ_{min}+1) elements of which only elements 1 to k are non-zero. The male and female vectors have equivalent proportions but differ with respect to vector length, owing to the larger maximum size attained by females.

10.2.5 Biomass outputs: yield, discards SSB, exploitable biomass, total biomass

Yield is estimated by applying the catch equation to the number of individuals alive after discarding has occurred. The catch at length by sex is estimated as

$$C_{f,t}(\ell) = \left(\frac{F_t sel_f(\ell)}{F_t sel_f(\ell) + M} \right) \left[1 - e^{-\left(F_t sel_f(\ell) + M\right)} \right] N_{f,t+\Delta t}(\ell)$$

$$C_{m,t}(\ell) = \left(\frac{F_t sel_m(\ell)}{F_t sel_m(\ell) + M} \right) \left[1 - e^{-\left(F_t sel_m(\ell) + M\right)} \right] N_{m,t+\Delta t}(\ell)$$

The total yield by sex is computed as the sum of the products of the numbers caught and their average weight . In matrix notation this is written as:

$$Y_{f,t} = C_{f,t}^T W_f$$
$$Y_{m,t} = C_{m,t}^T W_m$$
$$and$$
$$Y_t = Y_{f,t} + Y_{m,t}$$

Discards in weight, $D_{B,t}$ are estimated in a similar fashion such that:

$$D_{B,f,t} = D_{f,t}^T W_f$$
$$D_{B,m,t} = D_{m,t}^T W_m$$
$$and$$
$$D_{B,t} = D_{B,f,t} + D_{B,m,t}$$

The total biomass of the population by sex $B_{f,t}$ and $B_{m,t}$, is estimated as the total number alive at the start of the year multiplied by the average weight at length.

$$B_{f,t} = N_{f,t}^T W_f$$
$$B_{m,t} = N_{m,t}^T W_m$$
$$and$$
$$B_t = B_{f,t} + B_{m,t}$$

Exploitable biomass is defined as the fraction of the population biomass available to the fishery given the prevailing selectivity pattern. The commercial selectivity pattern by sex is defined in Section 7.2.   Exploitable biomass will always be less than total biomass and is computed as follows:

$$B_{Expl,f,t} = \sum_{j=\ell_{\min}}^{\ell_{\max}} sel_f(j) N_{f,t}(j) W_f(j)$$

$$B_{Expl,m,t} = \sum_{j=\ell_{\min}}^{\ell_{\max}} sel_m(j) N_{m,t}(j) W_m(j)$$

and

$$B_{Expl,t} = B_{Expl,f,t} + B_{Expl,m,t}$$

Finally, the spawning stock biomass is expressed in terms of female biomass only and is defined at the sum of mature females. In the projection model, females are assumed to be mature at 80 cm such that the spawning stock biomass can be written as

$$SSB_t = \sum_{j=80}^{\ell_{\max}} N_{f,t}(j) W_f(j)$$

10.3. Initial conditions

The initial condition of the population was defined as the 3-yr average (2004-2006) of dogfish abundance in the NEFSC spring R/V trawl survey. Unlike the stochastic estimator of fishing mortality and biomass, the projection model does not incorporate uncertainty in the estimates of discard mortality or the footprint of the survey. Instead, the projection model incorporates the variation in abundance defined by survey abundance. Variation in mean abundance is used to scale the index numbers at length by generating values of mean abundance over 500 equally-spaced probability intervals.

10.4 Scenarios

A projection based on the 2004-06 initial condition and the 2004-2006 selectivity parameters is shown in Table 10.1 and in Figure 10.1. Short term forecasts of spiny dogfish biomass (mt) are influenced by the current biomass and size structure of the population. Biomass of mature female spiny dogfish is expected to continue increasing through 2008 and 2009 as fish <80cm grow into mature size range. Subsequently, the biomass should decline due to the low number of recruits that were born during 1997-2003. If recruitment returns to levels consistent with expected size-specific reproduction, the biomass should begin to rebound again by 2015. These oscillations are expected to occur whether or not there is fishing (Figure 10.1). With the “rebuild F” strategy (F=0.03), female SSB will rise through 2010, then decrease slightly through 2015, and then rise to approximately 200,000 mt in 2018. Higher levels of fishing mortality will increase the amplitude of the oscillation and take longer to reach 200,000 mt. Potential negative influences of low birth weight and male-dominated sex ratio are not included in these projections.

11.0 SPINY DOGFISH RESEARCH RECOMMENDATIONS

1) Attempt to allocate landings to statistical area (i.e. attempt proration) using Vessel Trip Report data for 1994 and later years.

The Working group successfully completed work to address this RR.

2) Evaluate the utility of length frequency for spiny dogfish sampled in the NEFSC Observer Program in the most recent years (2001 and later).

The Working group successfully completed work to address this RR.

3) Ensure the inclusion of recent (2000 and later) MADMF Observer sample data for spiny dogfish in the NEFSC database, for more efficient use in future assessments.

The Working group successfully completed work to address this RR.

4) Conduct tagging and genetic studies of spiny dogfish in U.S. and Canadian waters to clarify current assumptions about stock structure.

The Working Group reviewed an ongoing streamer tag project conducted by East Carolina University.

5) Conduct discard mortality studies for spiny dogfish, with consideration of the differences in mortality rates among seasons, areas, and gear types.

The Working Group reviewed a discard mortality study in North Carolina near-shore trawl and gillnet fisheries conducted by East Carolina University, and took these results into consideration in updating assumed discard mortality rates for the coast-wide trawl, gillnet, and hook fisheries.

6) Conduct experimental work on NEFSC trawl survey gear performance, with focus on video work to study the fish herding properties of the gear for species like dogfish and other demersal roundfish.

The Working Group made no progress on this RR.

7) Investigate the distribution of spiny dogfish beyond the depth range of current NEFSC trawl surveys, possibly using experimental research or supplemental surveys.

The Working Group made no progress on this RR.

8) Initiate aging studies for spiny dogfish age structures (e.g., fin spines) obtained from NEFSC trawl surveys and other sampling programs. These studies should include additional age validation and age structure exchanges. The WG notes that other aging methodologies (e.g., Canadian studies on radiometry) are also in dev*elopment.*

The Working Group reviewed preliminary results of NEFSC aging work for spiny dogfish. Preliminary results agree more with validated ages for Pacific dogfish, then with current estimates used for Northwest Atlantic dogfish.

9) Additional analyses of the effects of environmental conditions on survey catch rates should be conducted.

The Working Group investigated the associations of temperature and depth with trawl survey densities. Examination of dogfish distributions in trawl surveys indicates greater concentrations closer to shore over the last five years.

10) Additional work on the stock-recruitment relationship should also be conducted with an eye toward estimation of the intrinsic rate of population increase.

The Working Group used the results from a new analytical model (LTM) to estimate parameters of a stock-recruitment relationship.

11) The SARC noted that the increased biological sampling of dogfish should be conducted and research trawl surveys. Maturation and fecundity estimates by length class will be particularly important to update. Additional work on the survey database to recover and encode information on the sex composition prior to 1980.

The Working group notes that a sampling program to collect aging structures (2003) and maturity data (1998) for dogfish has been implemented on NEFSC surveys. The WG examined sex composition data from NEFSC spring and fall surveys from 1968 to 1972, and this historical information has been included in this assessment.

New:

1) Incorporate Canadian commercial fishery sample data into the assessment when it is made available (expected in 2007).

2) Conduct an aging workshop for spiny dogfish, encouraging participation by NEFSC, NCDMF, Canada DFO, other interested state agencies, academia, and other international investigators with an interest in dogfish aging (US and Canada Pacific Coast, ICES).

3) Examine observer data to calculate a weighted average discard mortality rate based on an assumption that the rate increases with catch size.

4) Develop experimental estimates of discard mortality in the New England and Mid-Atlantic commercial fisheries.

5) Develop experimental estimates of discard mortality in the New England and Mid-Atlantic recreational fisheries.

6) Conduct a coast-wide tagging study for spiny dogfish to explore stock structure, migration patterns, and mixing rates.

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DOGFISH TABLES

Table B4.1. Total spiny dogfish landings (mt, live).

Year	Canada	US	USSR	Other Foreign	US Recreational Landed	US Recreational Discards	Total
1962	0	235	0	0		NA	235
1963	0	610	0	1		NA	611
1964	0	730	0	16		NA	746
1965	9	488	188	10		NA	695
1966	39	578	9389	0		NA	10006
1967	0	278	2436	0		NA	2714
1968	0	158	4404	0		NA	4562
1969	0	113	8827	363		NA	9303
1970	19	106	4924	716		NA	5765
1971	4	73	10802	764		NA	11643
1972	3	69	23302	689		NA	24063
1973	20	89	14219	4574		NA	18902
1974	36	127	20444	4069		NA	24676
1975	1	147	22331	192		NA	22671
1976	3	550	16681	107		NA	17341
1977	1	931	6942	257		NA	8131
1978	84	828	577	45		NA	1534
1979	1331	4753	105	82		NA	6271
1980	670	4085	351	248		NA	5354
1981	564	6865	516	458	1493	296	10192
1982	953	5411	27	337	70	349	7147
1983		4897	359	105	67	540	5968
1984	4	4450	291	100	91	424	5361
1985	13	4028	694	318	89	964	6107
1986	21	2748	214	154	182	1187	4506
1987	280	2703	116	23	306	1056	4484
1988		3105	574	73	359	876	4987
1989	166	4492	169	87	418	1344	6676
1990	1316	14731	383	10	179	1170	17788
1991	292	13177	218	16	131	1350	15183
1992	829	16858	26	41	215	1019	18987
1993	1411	20643	0	27	120	1110	23311
1994	1819	18800	0	2	154	969	21744
1995	948	22711	0	14	64	628	24365
1996	416	27241	0	236	34	353	28279
1997	446	18352		214	64	749	19825
1998	1079	20628		607	39	610	22962
1999	2467	14860		554	53	532	18466
2000	2777	9257		402	5	604	13044
2001	2820	2294		677	28	2090	7908
2002	3589	2199		474	225	1698	8185
2003	1304	1170		643	40	2987	6144
2004	2339	981		330	109	3368	7127
2005	1500	1150		330	36	3083	6098
	A	B	C	D	E	F	

red = from NAFO STATLANT21A including unclassified dogfishes
blue = from DFO website

Table B4.2. Spiny dogfish landings (mt, live) by gear type.

	Gear Type					
Year	Line Trawl	Otter Trawl	Sink Gill Net	Drift Gill Net	Other Gear	Total
1962	18.7	78.3	0.0	129.4	8.4	234.9
1963	49.8	85.5	297.2	138.3	38.8	609.6
1964	12.5	75.4	89.5	529.5	23.4	730.4
1965	55.1	52.3	129.8	228.6	22.2	488.0
1966	84.7	95.2	173.2	184.8	40.1	578.1
1967	23.9	110.8	54.9	43.1	44.9	277.5
1968	2.5	78.0	0.0	54.3	23.2	158.0
1969	1.9	88.4	0.5	5.9	16.7	113.4
1970	1.8	80.5	9.6	2.8	11.0	105.7
1971	0.0	53.0	0.6	3.5	16.2	73.3
1972	0.6	53.5	0.6	0.1	14.4	69.2
1973	0.5	76.7	1.3	5.0	5.8	89.4
1974	1.9	79.2	1.1	10.2	34.9	127.3
1975	0.3	89.4	4.1	10.3	42.8	146.9
1976	5.2	71.6	432.9	5.4	34.5	549.6
1977	2.8	102.6	796.1	2.8	27.2	931.4
1978	3.4	121.4	680.8	6.3	16.6	828.4
1979	17.7	3517.6	1198.3	1.5	17.6	4752.7
1980	12.1	3370.1	634.2	4.0	64.7	4085.1
1981	1.0	6287.1	560.8	7.3	8.7	6865.0
1982	2.9	5065.6	310.7	9.4	22.0	5410.6
1983	0.2	3367.5	1517.1	6.6	5.1	4896.5
1984	0.9	2486.0	1949.5	6.1	7.9	4450.4
1985	158.7	2844.4	1007.6	9.8	7.6	4028.0
1986	2.6	1258.1	1467.2	3.1	16.7	2747.6
1987	7.8	1848.1	811.7	2.9	32.8	2703.4
1988	4.7	1589.5	1489.5	12.6	9.0	3105.2
1989	138.2	486.5	3839.0	7.5	20.8	4492.0
1990	16.8	7010.8	7685.2	14.7	3.1	14730.6
1991	31.1	5208.7	7805.8	107.6	23.6	13176.7
1992	9.8	4785.5	11639.7	171.5	251.4	16857.9
1993	250.8	5100.2	15764.9	77.3	22.7	21215.9
1994	482.4	3056.1	15097.7	27.1	134.1	18797.5
1995	1494.3	2817.8	17654.2	340.9	270.7	22577.8
1996	1313.0	3398.0	21061.8	1263.8	99.0	27135.6
1997	1084.6	1800.6	14357.1	1026.4	84.1	18352.9
1998	1410.0	2709.2	15071.4	1315.4	121.6	20627.6
1999	1610.8	2212.5	10462.8	325.4	248.5	14860.0
2000	1776.1	3146.8	4297.6	15.9	20.3	9256.7
2001	1276.3	254.4	749.0	0.7	13.1	2293.6
2002	1044.1	251.7	896.0	0.5	6.5	2198.9
2003	652.3	38.0	409.8	0.4	69.5	1170.0
2004	18.0	133.7	744.0	0.0	85.4	981.1
2005	26.5	211.7	713.8	0.0	197.9	1150.0

Table B4.3. Spiny dogfish landings (mt, live) by month,1964-2002.

Year	Month													Total
	Unk	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1964	627.9	7.3	1.4	1.2	-	12.9	31.7	-	4.8	35.9	-	-	7.4	730.3
1965	308.5	0.1	4.1	-	14.9	4.9	34.4	23.1	27.2	30.8	11.9	22.6	5.6	488.1
1966	318.4	1.5	1.8	7.8	7.1	2.1	68.7	82.0	48.9	26.6	5.5	7.6	-	578.1
1967	188.3	-	3.9	-	4.3	6.0	15.9	42.7	5.3	7.2	0.9	2.5	0.8	277.5
1968	157.6	-	-	-	-	0.1	-	-	0.2	-	-	-	-	158.0
1969	113.4	-	-	-	-	-	-	-	-	-	-	-	-	113.4
1970	102.8	-	-	-	-	-	-	0.3	1.0	0.2	0.9	0.4	<0.1	105.6
1971	72.9	<0.1	-	-	-	0.4	-	-	-	-	-	-	-	73.3
1972	60.2	-	-	-	0.1	0.4	0.3	-	-	-	1.8	4.7	1.7	69.2
1973	73.7	2.7	<0.1	-	0.7	2.4	4.3	2.4	0.3	-	1.6	0.8	0.4	89.3
1974	122.6	0.1	-	0.9	-	0.8	0.3	1.1	0.2	0.6	0.4	0.2	0.1	127.3
1975	136.0	0.2	0.1	0.4	2.6	0.3	0.2	0.2	0.1	-	0.1	3.6	2.9	146.9
1976	116.2	0.1	0.5	-	-	-	24.1	126.2	70.9	119.7	91.8	0.1	0.1	549.7
1977	95.4	0.0	-	-	-	30.0	259.9	120.4	169.4	136.7	98.3	4.1	17.3	931.4
1978	140.8	0.1	0.8	5.9	0.1	0.5	85.0	294.5	102.2	54.2	133.0	9.1	2.3	828.5
1979	344.3	-	-	-	-	16.7	292.4	637.0	502.3	1043.1	1137.5	389.8	389.5	4752.7
1980	406.7	26.9	3.3	81.5	0.4	112.3	803.0	540.5	818.9	1087.4	52.2	91.4	60.7	4085.1
1981	1729.4	1.2	0.4	-	0.8	107.6	945.4	1121.0	1156.8	1005.2	698.6	98.0	0.7	6865.0
1982	65.8	143.1	369.6	1287.8	219.4	134.1	830.4	819.7	411.6	517.6	256.4	235.7	119.4	5410.6
1983	45.9	3.7	3.6	-	0.3	55.8	140.8	710.0	963.2	744.5	402.5	169.2	1656.9	4896.5
1984	46.8	-	-	-	0.3	1.4	559.5	2077.1	1111.6	357.8	168.2	103.1	24.5	4450.4
1985	71.1	-	-	0.8	1.9	275.5	690.6	753.2	785.6	588.1	642.6	175.4	43.0	4027.9
1986	13.1	1.0	5.8	2.5	11.8	145.5	483.1	468.0	473.7	622.8	376.9	93.8	49.9	2747.6
1987	6.0	4.8	1.5	4.0	8.6	17.6	397.1	555.8	384.6	440.5	703.6	175.5	3.9	2703.4
1988	49.8	0.6	116.0	27.5	4.4	384.8	566.3	532.4	502.6	508.8	401.1	9.9	0.9	3105.1
1989	15.5	0.2	-	2.0	21.2	296.9	1134.1	713.5	961.4	924.5	374.2	41.7	6.8	4492.0
1990	49.5	290.0	207.8	283.2	318.6	494.2	1137.9	2881.6	2819.3	2079.5	1166.8	959.8	2042.6	14730.6
1991	213.7	1609.9	1105.1	661.4	1298.9	1136.8	624.5	1421.6	962.8	840.1	353.7	965.7	1982.6	13176.7
1992	320.8	2117.3	1620.3	1402.6	703.7	787.5	1083.4	2327.4	1549.7	808.9	1362.7	1887.9	885.8	16858.0
1993	281.7	1867.2	1641.7	860.9	279.5	559.1	2004.8	3423.6	3227.9	2587.4	1983.8	1127.3	1371.0	21215.8
1994	77.1	1276.5	1438.2	1234.9	628.9	653.1	1975.1	3391.2	4202.8	1508.1	878.2	409.5	1123.9	18797.5
1995	28.7	1692.5	1432.8	1140.9	871.8	926.4	3381.4	4148.8	2200.8	1831.7	1887.1	1492.2	1542.8	22577.8
1996	0.2	2596.0	2329.8	2532.1	1693.6	534.5	2218.9	3615.8	2460.8	2141.6	2473.0	2055.8	2483.5	27135.6
1997	0.0	2304.0	1543.4	1468.0	724.0	1419.6	2122.0	2684.4	1917.8	1055.3	1129.3	1070.9	914.2	18352.9
1998	0.0	1652.6	1304.4	1113.9	571.6	572.2	1415.7	2272.8	2983.1	2620.1	2922.1	1965.8	1233.2	20627.6
1999	0.0	1732.1	1701.1	1478.7	869.4	850.5	1761.3	1209.4	995.7	1085.5	1372.3	829.1	974.9	14860.0
2000	0.0	1215.6	1885.1	1771.1	698.1	61.6	595.7	1326.1	1029.7	267.3	222.0	110.1	74.1	9256.7
2001	0.0	5.4	0.0	0.2	17.0	144.6	1048.2	2.2	3.3	1.5	1.0	1070.1	0.1	2293.6
2002	0.0	0.2	0.1	1.2	40.7	490.1	892.1	3.2	3.1	1.0	0.5	726.4	40.3	2198.9
2003	0.0	6.3	0.1	0.0	3.1	94.9	10.8	1.0	233.4	375.6	384.1	13.9	46.9	1170.0
2004	0.0	165.4	57.2	40.6	42.0	16.1	63.2	95.6	92.1	126.9	103.9	98.6	77.9	979.6
2005	0.0	20.3	0.6	0.5	1.3	39.9	130.5	189.0	195.1	188.0	196.3	105.0	83.4	1150.0

Table B4.4. Landings of spiny dogfish (mt, live) by state (Includes 100% unclassified dogfish).

	State											
Year	Connecticut	Delaware	Maine	Maryland	Massachusetts	New Hampshire	New Jersey	New York	North Carolina	Rhode Island	Virginia	Total
1962	2.6	0.0	21.6	17.4	0.0	0.0	1.6	25.2	0.0	0.1	166.3	234.9
1963	0.1	0.0	343.5	16.5	0.0	0.0	1.9	35.4	0.0	0.1	212.2	609.6
1964	4.7	0.0	102.1	12.4	0.0	0.0	0.2	33.1	0.0	0.4	577.5	730.3
1965	6.9	0.0	171.3	7.2	7.6	0.0	0.7	43.9	0.0	0.7	249.7	488.1
1966	4.9	0.2	259.6	6.7	0.0	0.0	1.5	81.7	0.0	0.1	223.4	578.1
1967	1.6	0.0	82.1	6.5	6.6	0.0	0.1	89.0	0.0	0.5	91.1	277.5
1968	22.8	0.0	0.0	7.2	0.3	0.0	3.3	61.8	0.0	0.1	62.5	158.0
1969	2.2	0.0	0.0	7.9	0.0	0.0	6.1	65.6	0.0	0.1	31.6	113.4
1970	8.0	0.0	0.0	6.1	2.4	0.0	0.6	54.1	0.0	0.7	33.8	105.7
1971	4.1	0.0	0.0	1.5	0.4	0.0	5.6	50.5	0.0	0.1	11.1	73.3
1972	0.0	0.0	0.0	2.4	0.7	0.0	0.1	51.4	0.0	8.3	6.4	69.2
1973	0.1	0.0	0.0	4.5	5.4	0.0	2.5	44.4	0.0	10.4	22.2	89.3
1974	0.0	0.6	0.0	6.5	3.2	0.0	0.3	79.8	0.0	2.2	34.6	127.3
1975	0.0	1.8	0.0	2.6	1.8	0.0	0.9	101.1	0.0	9.1	29.5	146.9
1976	1.1	0.0	428.3	3.1	3.1	0.0	1.7	93.4	0.0	1.7	17.2	549.7
1977	1.0	0.1	792.8	3.6	17.4	0.0	4.7	78.1	0.0	26.4	7.4	931.4
1978	2.2	0.4	647.0	7.5	31.5	31.6	6.4	88.1	0.0	2.8	30.3	847.7
1979	4.1	0.1	1049.6	5.4	2964.9	140.6	392.4	96.7	0.0	1.6	97.6	4752.7
1980	0.1	0.1	619.1	5.0	2794.4	6.7	263.0	104.1	1.3	0.6	290.6	4085.1
1981	2.0	3.8	516.2	695.4	4523.3	0.0	92.5	50.1	2.0	1.7	978.1	6865.0
1982	1.2	1.2	282.6	895.2	2885.3	0.0	2.5	47.4	3.0	1.3	1291.0	5410.6
1983	4.3	2.0	225.0	96.5	4529.9	0.3	0.3	25.8	0.0	0.0	12.4	4896.5
1984	2.4	2.7	565.4	117.6	3703.2	0.1	4.1	35.0	0.0	11.1	8.8	4450.4
1985	4.5	0.0	409.8	76.9	3463.7	0.0	3.8	61.9	0.5	0.7	6.3	4028.0
1986	8.7	0.0	349.1	58.6	2165.6	0.0	24.0	133.9	0.0	2.2	5.5	2747.6
1987	2.9	0.0	271.0	3.5	2335.2	0.0	1.7	70.6	0.0	13.9	4.6	2703.4
1988	42.8	0.0	218.4	10.7	2643.6	0.2	4.6	39.2	136.9	0.3	8.6	3105.1
1989	0.4	0.0	2213.4	1.6	2233.8	0.0	10.3	21.9	0.0	2.0	8.7	4492.0
1990	11.0	0.0	2887.6	989.7	8077.0	84.0	2061.2	8.2	18.8	590.1	3.0	14730.6
1991	4.0	2.6	914.5	2240.4	6572.2	0.0	1231.8	35.0	663.7	1433.5	78.9	13176.7
1992	10.1	0.0	779.9	1389.5	8335.2	182.4	1149.7	70.6	3916.8	919.7	103.9	16857.9
1993	6.8	0.0	1598.9	814.6	12170.4	744.6	349.3	43.3	3994.4	872.9	620.7	21215.9
1994	77.1	0.0	822.5	648.0	10527.9	1178.4	512.5	107.5	4480.5	240.1	203.0	18797.5
1995	133.2	28.5	754.6	1414.1	12989.5	955.4	1079.6	423.5	4244.3	259.9	295.3	22577.8
1996	320.2	0.0	413.2	3243.7	12161.9	489.7	2101.1	565.1	6202.4	511.9	1126.3	27135.6
1997	157.6	0.0	203.5	1917.6	9827.0	457.6	1791.7	221.7	1376.6	460.6	1939.1	18352.9
1998	121.2	0.9	124.2	1088.2	11299.7	858.9	2860.1	660.7	1364.3	802.4	1447.1	20627.6
1999	39.9	0.2	15.8	968.0	6765.5	561.8	1780.2	659.0	1186.9	606.7	2276.1	14860.1
2000	13.7	0.1	3.5	204.0	2613.5	1058.9	2368.8	864.6	1290.4	138.7	700.7	9256.7
2001	3.4	0.0	0.1	0.1	1774.7	243.1	7.8	28.4	0.0	178.7	57.3	2293.6
2002	2.6	0.0	0.3	1.1	1723.1	158.2	0.4	22.6	1.2	200.3	89.1	2198.9
2003	0.3	0.0	0.0	0.2	909.8	79.3	0.0	17.4	0.0	55.8	107.2	1170.0
2004	22.8	0.0	1.5	2.5	549.3	0.1	3.2	23.9	191.7	67.7	118.4	981.1
2005	37.0	0.1	17.0	2.4	915.2	69.4	0.4	21.5	0.4	66.7	19.7	1150.0

Table B4.5. Proportion of Spiny Dogfish landings by statistical area from Vessel Trip Reports.

	Statistical Area																					
year	464	465	500	510	511	512	513	514	515	520	521	522	524	525	526	530	533	534	537	538	539	541
1994	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.38	0.00	0.00	0.23	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.07	0.00	0.01	0.00
1995	0.00	0.00	0.00	0.00	0.00	0.01	0.11	0.35	0.01	0.00	0.24	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.01	0.00
1996	0.00	0.00	0.02	0.00	0.00	0.00	0.04	0.35	0.01	0.00	0.21	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.04	0.01	0.02	0.00
1997	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.45	0.02	0.00	0.20	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.03	0.00	0.02	0.00
1998	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.42	0.01	0.00	0.20	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.03	0.00	0.03	0.00
1999	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.36	0.01	0.00	0.25	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.03	0.00	0.03	0.00
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.10	0.00	0.00	0.24	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.00
2001	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.17	0.00	0.00	0.63	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.06	0.00
2002	0.00	0.00	0.00	0.00	0.00	0.03	0.09	0.32	0.00	0.00	0.33	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.02	0.16	0.00
2003	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.14	0.00	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.16	0.00
2004	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.34	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.05	0.00
2005	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.46	0.00	0.00	0.23	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.04	0.01

	Statistical Area																					
year	542	551	561	562	600	610	611	612	613	614	615	616	620	621	622	623	624	625	626	627	628	629
1994	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1995	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.01	0.01	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
1996	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.00	0.02	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00
1997	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.01	0.00	0.04	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00
1998	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.03	0.00	0.05	0.00	0.00	0.04	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00
1999	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.04	0.00	0.03	0.00	0.00	0.02	0.00	0.00	0.00	0.03	0.04	0.00	0.00	0.00
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.08	0.01	0.06	0.05	0.00	0.02	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00
2001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.03	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.03	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00
2005	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Statistical Area													
year	630	631	632	633	635	636	637	638	639	700	701	702	703	704
1994	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1995	0.00	0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1996	0.00	0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1997	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1998	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000	0.00	0.02	0.01	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	0.00	0.04	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table B4.6 Number of samples collected and number of individual spiny dogfish measured for length, by sex (U= unspecified; M-male; F=female), from USA commercial landings, by month, year and quarter, 1982-2005.

Year		Sex	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Q1	Q2	Q3	Q4	Total
1982	# of Samples		2	1	2									1	6	5	0	0	1	6
		U													0	0	0	0	0	0
		M	2		22										24	24	0	0	0	24
		F	198	101	281									100	680	580	0	0	100	680
1983	# of Samples							1		1	1	1	1		5	0	1	2	2	5
		U													0	0	0	0	0	0
		M													0	0	0	0	0	0
		F						104		118	121	133	134		610	0	104	239	267	610
1984	# of Samples							3	6	3	1				13	0	3	10	0	13
		U													0	0	0	0	0	0
		M						1	3	4	1				9	0	1	8	0	9
		F						286	745	351	117				1499	0	286	1213	0	1499
1985	# of Samples							2	1	3	3	2	2		13	0	2	7	4	13
		U													0	0	0	0	0	0
		M							1	1	14	1	4		21	0	0	16	5	21
		F						267	135	389	368	252	246		1657	0	267	892	498	1657
1986	# of Samples							3	1	4	3	2			13	0	3	8	2	13
		U						232							232	0	232	0	0	232
		M							45	1	10	8			64	0	0	56	8	64
		F						130	129	521	168	217			1165	0	130	818	217	1165
1987	# of Samples							3	6	2	1	2	1		15	0	3	9	3	15
		U													0	0	0	0	0	0
		M						16	4		1	1	9		31	0	16	5	10	31
		F						457	800	257	128	243	115		2000	0	457	1185	358	2000
1988	# of Samples						3	3	2	1	2	4			15	0	6	5	4	15
		U													0	0	0	0	0	0
		M							1	1		5			7	0	0	2	5	7
		F					371	364	238	128	230	433			1764	0	735	596	433	1764
1989	# of Samples							3	1	1	3	3			11	0	3	5	3	11
		U													0	0	0	0	0	0
		M								6	6	23			35	0	0	12	23	35
		F						352	127	137	390	369			1375	0	352	654	369	1375
1990	# of Samples							5	6	3	1	1	1	1	18	0	5	10	3	18
		U													0	0	0	0	0	0
		M							4			1	14		19	0	0	4	15	19
		F						593	775	358	135	111	123	135	2230	0	593	1268	369	2230
1991	# of Samples				1	1		2	4	2		1	1	2	14	1	3	6	4	14
		U							108			109			217	0	0	108	109	217
		M						11	127	12			8	3	161	0	11	139	11	161
		F			101	125		226	396	272			116	282	1518	101	351	668	398	1518
1992	# of Samples					1	2	4	6	4	1	2	4	1	25	0	7	11	7	25
		U						123							123	0	123	0	0	123
		M						2	1				8	1	12	0	2	1	9	12
		F				109	219	409	829	503	124	296	556	142	3187	0	737	1456	994	3187
1993	# of Samples						1	3	5	5	3	4			21	0	4	13	4	21
		U					133								133	0	133	0	0	133
		M								4	19	19			42	0	0	23	19	42
		F						400	683	776	369	545			2773	0	400	1828	545	2773
1994	# of Samples							3	6	4	2				15	0	3	12	0	15
		U							134						134	0	0	134	0	134
		M						2	31	14					47	0	2	45	0	47
		F						423	758	649	262				2092	0	423	1669	0	2092
1995	# of Samples						1	2	7	4					14	0	3	11	0	14
		U													0	0	0	0	0	0
		M					5	3	4	13					25	0	8	17	0	25
		F					158	373	1124	611					2266	0	531	1735	0	2266
1996	# of Samples							1	5	3		1	1	2	13	0	1	8	4	13
		U													0	0	0	0	0	0
		M						1	96	30		157	127	158	569	0	1	126	442	569
		F						142	784	504		96	118	18	1662	0	142	1288	232	1662

Table B4.6 cont. Number of samples collected and number of individual spiny dogfish measured for length, by sex (U= unspecified; M-male; F=female), from USA commercial landings, by month, year and quarter, 1982-2005.

Year		Sex	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Q1	Q2	Q3	Q4	Total
1997	# of Samples							4					1		5	0	4	0	1	5
		U						234							234	0	234	0	0	234
		M						278					25		303	0	278	0	25	303
		F						288					94		382	0	288	0	94	382
1998	# of Samples						1		1		1	2		1	6	0	1	2	3	6
		U													0	0	0	0	0	0
		M							24		18	14		12	68	0	0	42	26	68
		F					101		230		86	195		71	683	0	101	316	266	683
1999	# of Samples		2		1				1						4	3	0	1	0	4
		U													0	0	0	0	0	0
		M	47		46										93	93	0	0	0	93
		F	152		55				104						311	207	0	104	0	311
2000	# of Samples		4	5		1	1	3	8	1						9	5	9	0	23
		U	100	151			83	100	99							251	183	99	0	533
		M	108	107				69	58	3						215	69	61	0	345
		F	254	180		125		281	879	202						434	406	1081	0	1921
2001	# of Samples						2	2					2		6	0	4	0	2	6
		U					142	103					177		422	0	245	0	177	422
		M						12							12	0	12	0	0	12
		F						215							215	0	215	0	0	215
2002	# of Samples						2	1					2		5	0	3	0	2	5
		U											119		119	0	0	0	119	119
		M						1	65						66	0	1	65	0	66
		F					213								213	0	213	0	0	213
2003	# of Samples									5	6	1			12	0	0	11	1	12
		U								102	210				312	0	0	312	0	312
		M								11	10	13			34	0	0	21	13	34
		F								482	396	88			966	0	0	878	88	966
2004	# of Samples						1	5		1			5	7	19	0	6	1	12	19
		U											68		68	0	0	0	68	68
		M						8		5				2	15	0	8	5	2	15
		F					108	357		113			209	393	1180	0	465	113	602	1180
2005	# of Samples							8	4	4	3	4	3	7	33	0	8	11	14	33
		U						87							87	0	87	0	0	87
		M							324	280	48	72	11	10	745	0	0	652	93	745
		F						548	184	175	261	273	250	374	2065	0	548	620	897	2065

Table B4.7. Summary of estimated landings of US and Canada commercial fisheries by sex. Port samples from NMFS and MADMF were pooled. Estimated total weights based on summation of estimated weights from sampled length frequency distributions. Estimated weights computed from length-weight regressions.
Females W =exp(-15.025)*L ^3.606935, Males W=exp(-13.002)*L^3.097787 with weight in kg, length in cm. "Samples"= number of measured dogfish.

	Composite (NMFS and MADMF) Biological Samples from Ports							Commercial Landings			Prorated Landings By Sex				
year	Total Samples Males	Est Tot Wt (kg) Males	Ave Wt (kg) Males	Total Samples (females)	EstTot Wt (kg) females	Est Avg Wt (kg) females	Fraction Females by weight	US Commercial Landings (mt)	Canada Landings (mt)	Total Comm Landings (mt)	Est Landings (mt) of Males	Est. Landings (mt) of females	Number of Males Landed (000)	Number of Females Landed (000)	Total Numbers Landed (000)
1982	24	52.0	2.167	680	3016.0	4.435	0.9830	5410.565	1317	6727.565	114.1	6613.5	52.6	1491.1	1543.7
1983	0	0.0		610	2514.2	4.122	1.0000	4896.51	464	5360.51	0.0	5360.5		1300.6	1300.6
1984	9	15.8	1.760	1499	6626.6	4.421	0.9976	4450.39	395	4845.39	11.6	4833.8	6.6	1093.5	1100.0
1985	21	35.2	1.678	1657	6799.9	4.104	0.9948	4028.017	1025	5053.017	26.1	5027.0	15.5	1225.0	1240.5
1986	64	104.1	1.626	1165	4669.4	4.008	0.9782	2747.61	389	3136.61	68.4	3068.2	42.1	765.5	807.6
1987	31	52.7	1.700	2000	7550.9	3.775	0.9931	2703.35	419	3122.35	21.6	3100.7	12.7	821.3	834.0
1988	7	14.8	2.114	1764	7561.4	4.287	0.9980	3105	647	3752	7.3	3744.7	3.5	873.6	877.1
1989	35	67.5	1.927	1375	5528.6	4.021	0.9879	4492	422	4914	59.2	4854.8	30.7	1207.4	1238.2
1990	19	33.7	1.772	2230	8917.5	3.999	0.9962	14731	1709	16440	61.9	16378.1	34.9	4095.7	4130.6
1991	161	379.2	2.356	1518	5924.5	3.903	0.9398	13177	526	13703	824.4	12878.6	350.0	3299.8	3649.8
1992	12	22.3	1.861	3187	12181.9	3.822	0.9982	16858	896	17754	32.5	17721.5	17.5	4636.3	4653.7
1993	42	78.4	1.866	2772	9923.1	3.580	0.9922	20643	1438	22081	173.0	21908.0	92.7	6119.9	6212.7
1994	47	86.6	1.843	2091	6619.5	3.166	0.9871	18800	1821	20621	266.3	20354.7	144.5	6429.8	6574.3
1995	25	38.9	1.555	2266	6677.3	2.947	0.9942	22711	962	23673	137.0	23536.0	88.1	7987.2	8075.3
1996	569	886.7	1.558	1662	4398.0	2.646	0.8322	27241	652	27893	4679.8	23213.2	3003.2	8772.2	11775.4
1997	303	449.1	1.482	382	780.9	2.044	0.6349	18352	660	19012	6941.6	12070.4	4683.2	5904.2	10587.5
1998	68	85.4	1.257	683	1434.6	2.100	0.9438	20628	1686	22314	1254.4	21059.6	998.2	10026.1	11024.3
1999	93	130.3	1.401	311	625.6	2.011	0.8276	14860	3021	17881	3082.3	14798.7	2200.0	7357.1	9557.1
2000	405	561.2	1.386	5144	12168.5	2.366	0.9559	9257	3079	12336	543.8	11792.2	392.5	4984.9	5377.4
2001	12	17.1	1.422	215	456.5	2.123	0.9640	2294	4432	6726	242.3	6483.7	170.4	3053.5	3223.9
2002	65	97.6	1.501	1893	5065.8	2.676	0.9811	2195	3874	6069	114.7	5954.3	76.4	2225.0	2301.4
2003	34	48.3	1.421	966	2338.6	2.421	0.9798	1170	1947	3117	63.1	3053.9	44.4	1261.4	1305.8
2004	15	23.9	1.593	1180	3297.2	2.794	0.9928	981	2669	3650	26.3	3623.7	16.5	1296.8	1313.3
2005	745	1018.7	1.367	2065	5196.5	2.516	0.8361	1150	1830	2980	488.4	2491.6	357.2	990.1	1347.3
formula	*A*	*B*	*C=B/A*	*D*	*E*	*F=E/D*	*G=E/(E+B)*	*H*	*I*	*J=H+I*	*K=(1-G)*J*	*L=G*J*	*M=K/C*	*N=L/F*	*O=M+N*

Table B4.8. Summary of total observed trips, observer day, total discards and coefficient of variation for otter trawl and gill net fisheries, 1989-2005.

year	Gear Name	Number of Observed Trips	Total Observer Days	Total Discard (lb)	Variance of Total Discards	CV of total Discard	Total Discard (mt)
1989	Trawl and Gill Net	280	772	74,176,356	3.728E+14	0.260	33,646
1990	Trawl and Gill Net	270	676	88,856,064	3.71273E+14	0.217	40,304
1991	Trawl and Gill Net	1203	2028	66,913,746	7.76355E+13	0.132	30,352
1992	Trawl and Gill Net	1357	2161	85,032,889	3.81572E+14	0.230	38,570
1993	Trawl and Gill Net	870	1397	59,741,372	1.1307E+14	0.178	27,098
1994	Trawl and Gill Net	465	956	37,027,860	6.41411E+13	0.216	16,796
1995	Trawl and Gill Net	592	1280	52,309,703	7.75735E+13	0.168	23,727
1996	Trawl and Gill Net	609	1101	29,302,659	3.97162E+13	0.215	13,291
1997	Trawl and Gill Net	490	874	19,908,326	2.54107E+13	0.253	9,030
1998	Trawl and Gill Net	473	754	15,945,518	1.69785E+13	0.258	7,233
1999	Trawl and Gill Net	321	677	21,362,521	3.59401E+13	0.281	9,690
2000	Trawl and Gill Net	477	1036	16,339,852	1.12486E+13	0.205	7,412
2001	Trawl and Gill Net	487	1061	26,726,550	2.60376E+13	0.191	12,123
2002	Trawl and Gill Net	521	1238	23,230,426	2.06506E+13	0.196	10,537
2003	Trawl and Gill Net	1010	2618	20,429,293	5.14154E+12	0.111	9,267
2004	Trawl and Gill Net	1963	4385	27,183,459	9.2326E+12	0.112	12,330
2005	Trawl and Gill Net	2633	8703	23,926,709	4.33002E+12	0.087	10,853

year	Gear Name	Number of Observed Trips	Total Observer Days	Total Discard (lb)	Variance of Total Discards	CV of total Discard	Total Discard (mt)
1989	otter trawl	176	638	62,359,933	3.66447E+14	0.307	28,286
1990	otter trawl	126	453	75,491,469	3.59712E+14	0.251	34,242
1991	otter trawl	245	818	42,596,724	6.95288E+13	0.196	19,322
1992	otter trawl	173	718	71,908,104	3.79989E+14	0.271	32,617
1993	otter trawl	101	477	38,105,353	9.63872E+13	0.258	17,284
1994	otter trawl	84	523	30,662,599	6.0461E+13	0.254	13,908
1995	otter trawl	228	835	37,471,035	5.37199E+13	0.196	16,997
1996	otter trawl	202	640	20,727,372	3.29486E+13	0.277	9,402
1997	otter trawl	108	462	14,780,801	2.38154E+13	0.330	6,704
1998	otter trawl	68	261	11,614,289	1.53784E+13	0.338	5,268
1999	otter trawl	115	388	16,942,573	3.45467E+13	0.347	7,685
2000	otter trawl	242	766	6,014,125	2.13144E+12	0.243	2,728
2001	otter trawl	319	880	10,844,410	3.03332E+12	0.161	4,919
2002	otter trawl	385	1091	12,214,536	1.49713E+13	0.317	5,540
2003	otter trawl	554	2113	8,495,095	2.71363E+12	0.194	3,853
2004	otter trawl	1084	3360	18,295,848	8.54019E+12	0.160	8,299
2005	otter trawl	1829	7712	16,567,239	3.46821E+12	0.112	7,515

year	Gear Name	Number of Observed Trips	Total Observer Days	Total Discard (lb)	Variance of Total Discards	CV of total Discard	Total Discard (mt)
1989	gill net	104	134	11,816,422	6.35354E+12	0.213	5,360
1990	gill net	144	223	13,364,595	1.15603E+13	0.254	6,062
1991	gill net	958	1210	24,317,022	8.10668E+12	0.117	11,030
1992	gill net	1184	1443	13,124,785	1.58266E+12	0.096	5,953
1993	gill net	769	920	21,636,019	1.66827E+13	0.189	9,814
1994	gill net	381	433	6,365,261	3.68017E+12	0.301	2,887
1995	gill net	364	445	14,838,667	2.38536E+13	0.329	6,731
1996	gill net	407	461	8,575,287	6.76758E+12	0.303	3,890
1997	gill net	382	412	5,127,525	1.59526E+12	0.246	2,326
1998	gill net	405	493	4,331,228	1.60012E+12	0.292	1,965
1999	gill net	206	289	4,419,948	1.39339E+12	0.267	2,005
2000	gill net	235	270	10,325,727	9.11719E+12	0.292	4,684
2001	gill net	168	181	15,882,139	2.30043E+13	0.302	7,204
2002	gill net	136	147	11,015,890	5.67928E+12	0.216	4,997
2003	gill net	456	505	11,934,198	2.42791E+12	0.131	5,413
2004	gill net	879	1025	8,887,611	6.9241E+11	0.094	4,031
2005	gill net	804	991	7,359,470	8.61812E+11	0.126	3,338

Table B4.9. Total Discard estimates (mt) by gear type, 1989-2005 using expansion based on discard to kept. Zero values mean that no trips were observed.

Year	gill net	line trawl	longline	midwater trawl	otter trawl	pair trawl	purse seine	scallop dredge	scallop trawl	shrimp trawl	Grand Total
1989	5,360	-	-	-	28,286	-	-	-	-	6	33,652
1990	6,062	-	-	-	34,243	-	-	-	-	-	40,305
1991	11,030	97	-	1	19,322	-	-	32	-	2	30,484
1992	5,953	650	-	-	32,618	-	-	827	-	0	40,048
1993	9,814	-	44	-	17,285	235	-	209	-	-	27,587
1994	2,887	-	-	-	13,909	-	-	723	-	-	17,519
1995	6,731	-	-	6	16,997	-	-	378	-	-	24,112
1996	3,890	-	-	-	9,402	-	-	121	-	-	13,413
1997	2,326	-	-	-	6,705	-	-	198	-	-	9,228
1998	1,965	-	-	-	5,268	-	-	120	-	-	7,353
1999	2,005	-	-	-	7,685	-	-	41	-	-	9,731
2000	4,684	-	-	155	2,728	-	-	14	-	-	7,580
2001	7,204	-	-	-	4,919	-	-	30	-	-	12,153
2002	4,997	4,015	-	147	5,541	-	-	58	-	-	14,757
2003	5,413	2	-	150	3,853	-	0	103	-	0	9,521
2004	4,031	497	-	481	8,299	-	65	53	32	0	13,457
2005	3,338	1,175	-	217	7,515	-	3	15	3	-	12,266

Table B4.10. Total discard mortality estimates (mt), 1989-2005, given constant gear specific mortality rates.

original "estimates" per SARC 37	*0.75*	*0.25*	*0.25*	*0.50*	*0.50*	*0.50*	*0.50*	*0.75*	*0.50*	*0.50*
	gill net	**line trawl**	**longline**	**midwater trawl**	**otter trawl**	**pair trawl**	**purse seine**	**scallop dredge**	**scallop trawl**	**shrimp trawl**
Discard Mort. Value per SARC 43 discussions	*0.30*	*0.10*	*0.25*	*0.50*	*0.50*	*0.50*	*0.50*	*0.75*	*0.50*	*0.50*

Year	gill net	line trawl	longline	midwater trawl	otter trawl	pair trawl	purse seine	scallop dredge	scallop trawl	shrimp trawl	Grand Total
1989	1,608	-	-	-	14,143	-	-	-	-	3	15,754
1990	1,819	-	-	-	17,121	-	-	-	-	-	18,940
1991	3,309	10	-	0	9,661	-	-	24	-	1	13,005
1992	1,786	65	-	-	16,309	-	-	620	-	0	18,780
1993	2,944	-	11	-	8,642	118	-	157	-	-	11,872
1994	866	-	-	-	6,954	-	-	542	-	-	8,363
1995	2,019	-	-	3	8,498	-	-	283	-	-	10,804
1996	1,167	-	-	-	4,701	-	-	91	-	-	5,959
1997	698	-	-	-	3,352	-	-	149	-	-	4,199
1998	589	-	-	-	2,634	-	-	90	-	-	3,313
1999	601	-	-	-	3,843	-	-	31	-	-	4,475
2000	1,405	-	-	77	1,364	-	-	10	-	-	2,857
2001	2,161	-	-	-	2,460	-	-	22	-	-	4,643
2002	1,499	402	-	73	2,770	-	-	43	-	-	4,788
2003	1,624	0	-	75	1,927	-	0	77	-	0	3,703
2004	1,209	50	-	240	4,149	-	32	40	16	0	5,737
2005	1,001	117	-	108	3,757	-	1	11	2	-	4,999

Table B4.11. Female total discard mortality estimates by numbers(000's) and weight, 1989-2005,given constant gear specific mortality rates. Based on all size classes

	gill net			otter trawl			Female total (gillnet	
Year	***Numbers (000)***	***Weight (mt)***		***Numbers (000)***	***Weight (mt)***		***Numbers (000)***	***Weight (mt)***
1989	476	1,397		7,084	7,913		7,560	9,310
1990	538	1,580		8,576	9,579		9,114	11,159
1991	979	2,875		4,839	5,405		5,818	8,280
1992	934	1,406		4,025	9,145		4,958	10,551
1993	804	2,561		2,151	4,769		2,955	7,330
1994	413	764		1,948	2,934		2,360	3,697
1995	855	1,062		4,345	6,224		5,200	7,286
1996	327	568		3,351	3,018		3,678	3,587
1997	276	478		1,461	1,637		1,737	2,115
1998	262	351		1,250	1,558		1,513	1,908
1999	213	485		5,797	2,860		6,010	3,345
2000	523	1,256		760	720		1,283	1,976
2001	787	1,977		953	2,031		1,740	4,008
2002	562	1,392		988	2,237		1,549	3,629
2003	636	1,452		796	1,402		1,431	2,855
2004	455	1,083		1,422	2,888		1,878	3,971
2005	319	809		1,365	2,763		1,684	3,572

Table B4.12 Male Total discard mortality estimates by numbers(000's) and weight, 1989-2005,given constant gear specific mortality rates. Based on all size classes

	gill net			otter trawl			Male total (gillnet	
Year	***Numbers (000)***	***Weight (mt)***		***Numbers (000)***	***Weight (mt)***		***Numbers (000)***	***Weight (mt)***
1989	156	211		6,152	6,231		6,308	6,441
1990	177	238		7,448	7,543		7,624	7,781
1991	322	434		4,202	4,256		4,524	4,690
1992	376	380		5,970	7,164		6,346	7,544
1993	353	384		3,304	3,873		3,657	4,257
1994	102	103		4,313	4,021		4,415	4,123
1995	861	957		2,775	2,275		3,636	3,232
1996	464	599		2,955	1,683		3,419	2,281
1997	178	220		1,897	1,716		2,075	1,935
1998	235	239		965	1,077		1,200	1,315
1999	101	117		4,882	982		4,983	1,099
2000	100	149		551	644		651	793
2001	124	185		382	428		506	613
2002	67	107		402	533		469	641
2003	157	172		467	524		624	696
2004	93	127		989	1,261		1,082	1,388
2005	138	193		840	994		978	1,187

Table B4.13 Imputed discards of spiny dogfish in otter trawl and gill net fisheries, 1981-1988 based on observed ratio of dogfish discard to total landings in 1989. Discard mortality rates are assumed to 0.50 for otter trawls and 0.30 for gill nets.

	Otter Trawl Fishery				Gill Net Fishery			
Year	Total Landings (mt)	Discard:Kept Ratio	Imputed Dogfish Discards (mt)	Imputed Dead Dogfish Discards (mt)	Total Landings (mt)	Discard:Kept Ratio	Imputed Dogfish Discards (mt)	Imputed Dead Dogfish Discards (mt)
1981	175,220	0.2075	36,360	18,180	19,028	0.2817	5,360	1,608
1982	206,785	0.2075	42,910	21,455	15,814	0.2817	4,454	1,336
1983	203,307	0.2075	42,188	21,094	14,349	0.2817	4,042	1,213
1984	190,954	0.2075	39,625	19,813	17,460	0.2817	4,918	1,475
1985	160,733	0.2075	33,354	16,677	16,115	0.2817	4,539	1,362
1986	152,978	0.2075	31,745	15,872	17,336	0.2817	4,883	1,465
1987	139,995	0.2075	29,050	14,525	17,267	0.2817	4,864	1,459
1988	139,517	0.2075	28,951	14,476	18,220	0.2817	5,132	1,540

Table B4.14 Imputed dogfish discards in otter trawl and gill net fisheries, 1981-1988. Estimated fractions by sex and average weights are based on 1991-1994 observer sampling

Fraction Female		Fraction Male	
Otter Trawl	Gill Net	Otter Trawl	Gill Net
0.55946	*0.868781*	0.44054	0.131219

	Total (mt)		Female (mt)		Male (mt)	
year	Otter Trawl	Gill Net	Otter Trawl	Gill Net	Otter Trawl	Gill Net
1981	18,180	1,608	10,171	1,397	8,009	211
1982	21,455	1,336	12,003	1,161	9,452	175
1983	21,094	1,213	11,801	1,053	9,293	159
1984	19,813	1,475	11,084	1,282	8,728	194
1985	16,677	1,362	9,330	1,183	7,347	179
1986	15,872	1,465	8,880	1,273	6,992	192
1987	14,525	1,459	8,126	1,268	6,399	191
1988	14,476	1,540	8,099	1,338	6,377	202

Female Ave Wt (kg)		Male Ave Wt (kg)	
Otter Trawl	Gill Net	Otter Trawl	Gill Net
2.355	*2.256*	1.529	1.143

Dogfish discard mortality (NUMBERS) (000)

	Total (000)		Female (000)		Male (000)	
year	Otter Trawl	Gill Net	Otter Trawl	Gill Net	Otter Trawl	Gill Net
1981	9,555.1	804.0	4,318	619	5,237	185
1982	11,276.4	668.2	5,096	515	6,180	153
1983	11,086.8	606.3	5,011	467	6,076	139
1984	10,413.2	737.7	4,706	568	5,707	169
1985	8,765.1	680.9	3,961	525	4,804	156
1986	8,342.3	732.5	3,770	564	4,572	168
1987	7,634.2	729.6	3,450	562	4,184	168
1988	7,608.2	769.8	3,438	593	4,170	177

Table B5.1. Stratified mean number per tow indices for spiny dogfish from NEFSC spring (1968-2006) and autumn (1967-2005) bottom trawl surveys (offshore strata 1-30, 33-40, 61-76; Footnotes A-D).

	Spring				Autumn			
	Unsexed	Male	Female	Total	Unsexed	Male	Female	Total
1967					34.0			34.0
1968	24.3			24.3	19.7			19.7
1969	13.3			13.3	27.7			27.7
1970	15.3			15.3	16.6			16.6
1971	15.9			15.9	12.9			12.9
1972	27.6			27.6	10.5			10.5
1973	35.6			35.6	15.0			15.0
1974	39.1			39.1	4.7			4.7
1975	35.4			35.4	17.7			17.7
1976	23.1			23.1	14.9			14.9
1977	13.1			13.1	6.8			6.8
1978	22.5			22.5	26.0			26.0
1979	10.1			10.1	22.0			22.0
1980	6.1	12.9	10.0	29.0	0.0	1.4	3.8	5.1
1981	0.5	18.2	23.0	41.7	0.0	36.0	39.7	75.7
1982		23.7	27.8	51.6		6.9	6.8	13.7
1983	0.0	23.6	18.1	41.7	0.0	14.3	18.0	32.4
1984		13.3	9.2	22.5		10.6	11.9	22.5
1985	0.0	80.2	37.1	117.3	0.0	19.0	19.7	38.7
1986		9.5	19.3	28.7		12.3	15.2	27.4
1987		39.3	25.8	65.1		16.5	16.3	32.8
1988	0.0	29.5	35.1	64.6		15.5	19.9	35.3
1989		29.6	27.1	56.7		6.7	6.0	12.8
1990		47.8	44.0	91.8		14.7	11.5	26.1
1991		32.3	30.0	62.3		20.9	17.4	38.4
1992		38.2	41.3	79.5		12.9	26.2	39.1
1993		32.6	28.3	60.9		4.5	2.4	6.9
1994		53.4	38.1	91.5		16.6	14.2	30.9
1995		25.8	25.0	50.8		16.9	13.7	30.6
1996		52.6	44.6	97.3		12.8	20.1	32.8
1997		29.6	29.1	58.7		17.6	10.4	27.9
1998		32.4	11.1	43.5		8.8	13.2	22.0
1999		35.4	21.4	56.8		9.2	8.7	17.9
2000	0.3	22.2	15.4	37.9		17.1	5.7	22.8
2001		20.3	10.9	31.2		16.5	18.5	35.0
2002		32.2	18.7	50.9		15.8	15.4	31.2
2003		32.5	17.5	49.9		5.2	6.5	11.7
2004		18.3	10.0	28.3		16.1	11.8	27.9
2005		38.0	10.3	48.3		24.8	7.6	32.4
2006		50.3	28.5	78.8				

A. During 1963-1984, BMV oval doors were used in the spring and autumn surveys; since 1985, Portuguese polyvalent doors have been used in both surveys. No adjustments have been made because no significant difference was found between the two types of doors for spiny dogfish (NEFSC 1991)

B. Spring surveys from 1973-1981 were accomplished with a '41 Yankee' trawl; in all other years, spring surveys were accomplished with a '36 Yankee' trawl. A factor of 0.71 was applied to all tows in these years (Sissenwine and Bowman, 1978).

C. During the fall of 1970, 1975, 1978, 1979, 1980, 1981, 1985, 1986, 1988, 1989 1990, 1991, and 1993 and the springs of 1973, 1976, 1977, 1979, 1980, 1981, 1982, 1987, 1989, 1990, 1991, and 1994 the Delaware II was used entirely or in part to conduct the survey. All other years, the Albatross IV was the only vessel used for the survey. A factor of 0.79 was applied to all Delaware II tows (NEFSC 1991).

D. During the spring of 2003, the Delaware II was used to conduct the survey. Since the vessel was remodeled in 1995, it was unclear whether the conversion factors applied in earlier years were still appropriate. Therefore no conversion factor was applied.

Table B5.2. Stratified mean weight per tow (kg) indices for spiny dogfish from NEFSC spring (1968-2006) and autumn (1967-2005) bottom trawl surveys (offshore strata 1-30, 33-40, 61-76; Footnotes A-E).

	Spring				Autumn			
	Unsexed	Male	Female	Total	Unsexed	Male	Female	Total
1967					34.9			34.9
1968	25.8			25.8	22.4			22.4
1969	16.1			16.1	55.3			55.3
1970	13.3			13.3	23.8			23.8
1971	24.0			24.0	15.5			15.5
1972	49.0			49.0	16.1			16.1
1973	57.1			57.1	21.7			21.7
1974	67.0			67.0	8.1			8.1
1975	45.6			45.6	20.9			20.9
1976	37.0			37.0	19.8			19.8
1977	24.1			24.1	16.1			16.1
1978	36.3			36.3	19.3			19.3
1979	13.4			13.4	26.6			26.6
1980	13.4	34.2	1.6	49.1	0.0	4.0	15.1	19.1
1981	0.6	20.4	48.2	69.2	0.0	12.7	34.9	47.6
1982		31.1	86.0	117.0		5.2	9.7	14.9
1983	0.0	21.1	17.7	38.9	0.0	13.7	22.1	35.8
1984		19.3	23.0	42.4		8.7	13.9	22.5
1985	0.0	100.4	66.7	167.1	0.0	14.6	25.0	39.7
1986		5.8	39.0	44.9		13.4	23.7	37.1
1987		40.6	61.7	102.3		10.6	11.2	21.8
1988	0.0	26.9	77.4	104.4		15.3	24.3	39.6
1989		34.8	43.1	77.8		6.1	5.5	11.5
1990		60.6	89.2	149.8		14.9	14.9	29.8
1991		36.5	53.0	89.5		24.6	26.7	51.3
1992		44.8	70.1	114.9		14.1	41.6	55.7
1993		35.7	52.2	87.9		5.1	2.1	7.2
1994		49.9	35.3	85.1		18.5	14.2	32.8
1995		34.8	40.0	74.8		16.7	11.4	28.0
1996		59.0	60.5	119.5		14.4	26.7	41.1
1997		37.5	44.9	82.4		19.9	10.0	29.9
1998		43.4	15.5	58.9		10.7	21.6	32.3
1999		46.3	32.5	78.8		12.3	12.7	25.1
2000	0.4	29.7	29.2	59.4		25.5	9.2	34.7
2001		29.5	19.8	49.3		20.8	27.0	47.8
2002		42.9	32.2	75.0		22.2	25.2	47.4
2003		45.2	29.7	74.8		7.4	13.1	20.5
2004		23.2	14.4	37.5		20.7	18.4	39.0
2005		50.1	17.8	67.9		36.8	13.2	49.9
2006		70.4	60.0	130.4				

A. During 1963-1984, BMV oval doors were used in the spring and autumn surveys; since 1985, Portuguese polyvalent doors have been used in both surveys. No adjustments have been made because no significant difference was found between the two types of doors for spiny dogfish (NEFSC 1991)

B. Spring surveys from 1973-1981 were conducted with a '41 Yankee' trawl; in all other years, spring surveys were conducted with a '36 Yankee' trawl. A factor of 0.69 was applied to all tows in these years (Sissenwine and Bowman, 1978).

C. In 1980, dogfish were often measured and counted by sex but only one weight recorded. This weight was always recorded under males.

D. During the fall of 1970, 1975, 1978, 1979, 1980, 1981, 1985, 1986, 1988, 1989, 1990, 1991, and 1993 and the springs of 1973, 1976, 1977, 1979, 1980, 1981, 1982, 1987, 1989, 1990, 1991, and 1994 the Delaware II was was used entirely or in part to conduct the survey. All other years, the Albatross IV was the only vessel used for the survey. A factor of 0.81 was applied to all Delaware II tows (NEFSC 1991).

E. During the spring of 2003, the Delaware II was used to conduct the survey. Since the vessel was remodeled in 1995, it was unclear whether the conversion factors applied in the earlier years were still appropriate. Therefore no conversion factor was applied.

E. In 1980, dogfish were often measured and counted by sex but only one weight recorded. This weight was always recorded under males.

Table B5.3. Indices for spiny dogfish from NEFSC winter (1992-2002)
(offshore strata 1-3, 5-7, 9-11, 13-14, 16, 61-63, 65-67, 69-71,73-75).

	Number/Tow			Weight/Tow		
	Male	Female	Total	Male	Female	Total
1992	123.9	74.7	198.7	168.3	172.6	340.9
1993	225.2	103.1	328.2	274.8	145.1	419.9
1994	154.9	153.1	308.1	169.8	219.7	389.5
1995	198.3	124.6	322.8	195.9	103.2	299.1
1996	87.6	48.3	135.9	116.2	76.1	192.2
1997	75.3	69.1	144.3	91.9	107.7	199.6
1998	76.1	43.5	119.6	101.6	62.8	164.4
1999	193.0	110.8	303.8	203.0	120.6	323.5
2000	102.1	39.6	141.7	129.8	53.6	183.4
2001	76.4	47.2	123.5	102.1	66.4	168.5
2002	144.3	65.4	209.7	192.7	115.3	308.1
2003	87.8	56.6	144.4	122.8	112.6	235.4
2004	87.7	33.5	121.2	121.8	53.4	175.2
2005	84.3	35.4	119.7	133.8	60.2	194.0
2006	77.0	37.8	114.9	108.2	77.3	185.5

Table B5.4. Number per tow indices for spiny dogfish from the state of Massachusetts spring and autumn inshore bottom trawl surveys.

	Spring				Autumn			
	Unsexed	Male	Female	Total	Unsexed	Male	Female	Total
1978	10.9			10.9	10.5			10.5
1979	1.9			1.9	12.6			12.6
1980	1.7			1.7	0.0	0.1	4.7	4.8
1981	0.5		1.0	1.6	11.2	0.1	0.3	11.6
1982		0.0	2.0	2.0		8.2	45.9	54.1
1983		0.0	0.8	0.8		3.1	11.5	14.7
1984		1.4	5.5	6.9		14.0	11.9	25.9
1985		0.1	0.8	0.8		12.5	116.6	129.1
1986		0.1	2.2	2.3		30.7	36.7	67.4
1987		0.0	0.2	0.2		13.9	28.6	42.6
1988		1.5	11.5	12.9		6.8	168.3	175.1
1989		9.2	16.4	25.6		256.7	764.6	1021.3
1990		0.0	2.3	2.3		16.3	41.5	57.8
1991		0.0	0.9	0.9		2.8	25.6	28.4
1992		0.0	2.2	2.2		51.4	67.6	119.1
1993		9.4	10.5	19.8		15.8	93.9	109.7
1994		0.0	0.2	0.2		18.7	1.3	20.0
1995		7.5	21.2	28.6		40.0	33.1	73.1
1996		0.0	0.0	0.0		14.2	21.1	35.3
1997		2.1	11.1	13.2		9.5	46.4	55.9
1998		0.8	3.0	3.8		3.4	19.4	22.9
1999		0.3	4.1	4.3		8.4	55.8	64.2
2000		0.1	1.0	1.1		7.7	361.4	369.1
2001		1.5	4.1	5.6		26.6	87.2	113.8
2002		0.0	4.4	4.5		68.1	243.7	311.8
2003		0.7	14.8	15.6		162.5	51.8	214.4
2004		0.3	5.3	5.6		258.0	178.9	436.9
2005		0.1	3.0	3.1		376.8	107.7	484.4

Table B5.5. Weight per tow (kg) indices for spiny dogfish from the state of Massachusetts spring and autumn inshore bottom trawl surveys.

	Spring				Autumn			
	Unsexed	Male	Female	Total	Unsexed	Male	Female	Total
1978	22.9			22.9	22.6			22.6
1979	6.4			6.4	40.2			40.2
1980	6.1			6.1	0.1	0.1	17.8	18.1
1981	2.6		4.3	6.9	44.9	0.2	1.3	46.4
1982		0.1	9.2	9.3		14.2	166.2	180.4
1983		0.0	3.2	3.3		5.0	35.6	40.6
1984		1.6	10.8	12.4		21.8	35.8	57.5
1985		0.1	3.4	3.5		18.0	297.5	315.5
1986		0.1	9.9	10.0		47.0	93.1	140.1
1987		0.0	0.9	0.9		20.8	76.8	97.6
1988		1.9	39.3	41.2		8.6	537.7	546.3
1989		4.8	14.0	18.9		328.9	1546.2	1875.1
1990		0.0	9.4	9.4		22.6	95.0	117.6
1991		0.0	4.5	4.5		3.4	80.7	84.1
1992		0.0	8.5	8.5		68.6	107.0	175.6
1993		10.4	19.5	29.9		23.3	211.7	235.0
1994		0.0	0.8	0.8		30.8	2.8	33.6
1995		9.5	34.1	43.7		59.6	63.6	123.2
1996		0.0	0.1	0.1		20.8	44.4	65.2
1997		2.4	20.5	22.9		13.5	87.2	100.7
1998		1.0	5.8	6.8		4.5	41.9	46.4
1999		0.4	8.5	8.8		12.9	116.0	128.9
2000		0.1	2.7	2.9		11.1	738.2	749.3
2001		2.4	9.3	11.7		36.7	180.8	217.5
2002		0.0	11.5	11.6		105.6	448.0	553.6
2003		1.0	29.5	30.5		254.0	96.8	350.8
2004		0.4	11.5	11.9		400.3	376.8	777.2
2005		0.1	6.9	7.1		542.9	225.5	768.4

Table B5.6. Summary of positive tows and fraction exceeding 1000 kg/tow for spiny dogfish in NMFS fall trawl survey

Survey	Year	Total Tows	Fraction Positive Tows females	Fraction Positive Tows males	Fraction Positive Tows both	Fraction >Threshold	Total Catch for tows exceeding threshold	Fraction of total survey catch
Fall	1967	252	0.000	0.000	0.472	0.000	0	0.000
Fall	1968	254	0.441	0.496	0.555	0.000	0	0.000
Fall	1969	254	0.358	0.429	0.484	0.008	6584	0.588
Fall	1970	257	0.370	0.440	0.510	0.000	0	0.000
Fall	1971	266	0.286	0.338	0.444	0.000	0	0.000
Fall	1972	256	0.000	0.000	0.457	0.000	0	0.000
Fall	1973	249	0.000	0.000	0.402	0.000	0	0.000
Fall	1974	254	0.000	0.000	0.362	0.000	0	0.000
Fall	1975	361	0.000	0.000	0.429	0.000	0	0.000
Fall	1976	328	0.000	0.000	0.293	0.000	0	0.000
Fall	1977	375	0.000	0.000	0.371	0.000	0	0.000
Fall	1978	500	0.000	0.000	0.366	0.000	0	0.000
Fall	1979	508	0.000	0.000	0.406	0.000	0	0.000
Fall	1980	348	0.155	0.129	0.195	0.003	2760	0.568
Fall	1981	328	0.277	0.229	0.317	0.009	7560	0.570
Fall	1982	328	0.201	0.216	0.317	0.006	2702	0.472
Fall	1983	320	0.238	0.272	0.378	0.009	6396	0.541
Fall	1984	324	0.235	0.265	0.367	0.009	8621	0.585
Fall	1985	321	0.299	0.327	0.427	0.016	6178	0.624
Fall	1986	326	0.261	0.245	0.301	0.006	4447	0.431
Fall	1987	302	0.315	0.301	0.364	0.007	3061	0.300
Fall	1988	294	0.401	0.361	0.469	0.010	5524	0.408
Fall	1989	307	0.293	0.264	0.332	0.000	0	0.000
Fall	1990	320	0.263	0.269	0.334	0.019	19535	0.837
Fall	1991	316	0.190	0.215	0.247	0.019	16389	0.754
Fall	1992	311	0.244	0.264	0.312	0.016	14670	0.803
Fall	1993	313	0.227	0.224	0.268	0.006	4369	0.542
Fall	1994	320	0.266	0.238	0.306	0.006	2653	0.285
Fall	1995	314	0.242	0.258	0.290	0.010	8822	0.620
Fall	1996	311	0.322	0.302	0.389	0.010	8387	0.591
Fall	1997	315	0.397	0.343	0.425	0.010	6603	0.499
Fall	1998	332	0.395	0.346	0.440	0.018	15581	0.689
Fall	1999	332	0.419	0.398	0.476	0.009	4874	0.317
Fall	2000	316	0.320	0.282	0.351	0.013	6931	0.478
Fall	2001	316	0.326	0.342	0.386	0.019	11737	0.561
Fall	2002	311	0.373	0.347	0.405	0.010	5387	0.358
Fall	2003	310	0.290	0.297	0.368	0.010	7838	0.544
Fall	2004	307	0.309	0.300	0.355	0.026	13810	0.538
Fall	2005	313	0.348	0.361	0.409	0.029	23307	0.701
Total	0	12369	0.225	0.225	0.376	0.008	224724	0.467

Table B5.7. Summary of positive tows and fraction exceeding 1000 kg/tow for spiny dogfish in NMFS spring trawl survey

Survey	Year	Total Tows	Fraction Positive Tows females	Fraction Positive Tows males	Fraction Positive Tows both	Fraction >Threshold	Total Catch for tows exceeding threshold	Fraction of total survey catch
Spring	1968	240	0.308	0.267	0.413	0.013	3672	0.416
Spring	1969	244	0.467	0.389	0.586	0.000	0	0.000
Spring	1970	261	0.410	0.268	0.487	0.004	1504	0.353
Spring	1971	260	0.477	0.346	0.558	0.008	5697	0.523
Spring	1972	265	0.174	0.091	0.611	0.008	3266	0.199
Spring	1973	278	0.000	0.000	0.712	0.000	0	0.000
Spring	1974	219	0.000	0.000	0.667	0.000	0	0.000
Spring	1975	221	0.000	0.000	0.679	0.000	0	0.000
Spring	1976	339	0.000	0.000	0.611	0.000	0	0.000
Spring	1977	341	0.000	0.000	0.560	0.000	0	0.000
Spring	1978	349	0.000	0.000	0.501	0.000	0	0.000
Spring	1979	426	0.000	0.000	0.413	0.000	0	0.000
Spring	1980	391	0.391	0.292	0.512	0.008	3525	0.187
Spring	1981	320	0.506	0.388	0.581	0.013	6432	0.317
Spring	1982	334	0.440	0.281	0.473	0.018	20803	0.702
Spring	1983	331	0.372	0.284	0.408	0.009	6273	0.415
Spring	1984	327	0.330	0.217	0.367	0.003	1944	0.172
Spring	1985	319	0.408	0.276	0.433	0.022	23629	0.645
Spring	1986	332	0.530	0.307	0.536	0.006	2299	0.174
Spring	1987	312	0.571	0.353	0.583	0.022	22848	0.652
Spring	1988	300	0.470	0.230	0.503	0.013	16375	0.606
Spring	1989	281	0.520	0.320	0.530	0.011	12673	0.533
Spring	1990	296	0.551	0.358	0.564	0.014	22979	0.642
Spring	1991	312	0.542	0.337	0.571	0.010	6362	0.308
Spring	1992	297	0.495	0.279	0.512	0.020	12877	0.463
Spring	1993	312	0.474	0.304	0.484	0.006	6995	0.333
Spring	1994	315	0.451	0.330	0.470	0.013	6797	0.295
Spring	1995	313	0.518	0.479	0.581	0.006	2550	0.155
Spring	1996	335	0.481	0.355	0.513	0.024	15369	0.526
Spring	1997	315	0.578	0.394	0.606	0.006	2340	0.125
Spring	1998	348	0.471	0.431	0.566	0.006	4240	0.302
Spring	1999	310	0.526	0.423	0.590	0.010	3700	0.224
Spring	2000	312	0.506	0.343	0.561	0.006	3421	0.300
Spring	2001	317	0.410	0.382	0.492	0.009	5022	0.421
Spring	2002	317	0.593	0.451	0.669	0.009	7926	0.353
Spring	2003	310	0.471	0.390	0.516	0.013	11473	0.552
Spring	2004	314	0.379	0.347	0.455	0.006	3843	0.266
Spring	2005	316	0.402	0.291	0.437	0.009	10851	0.556
Spring	2006	327	0.532	0.462	0.612	0.024	15060	0.498
Total	0	12056	0.379	0.275	0.533	0.009	272744	0.390

Table B5.8. Swept area biomass estimates (thousands of metric tons) from NEFSC spring and autumn surveys for offshore areas (Offshore strata1-30, 33-40, 61-76) and inshore areas (inshore strata 1-66). Note inshore strata 46-66 not sampled until 1979.

	Spring Survey					Autumn Survey			
year	offshore	inshore	total	Fraction Inshore		offshore	inshore	total	Fraction Inshore
1975						134.6	35.8	170.4	0.210187
1976	239.8	2.4	242.2	0.009752		127.7	0.0	127.7	0
1977	156.0	3.4	159.4	0.021244		104.1	2.1	106.2	0.01982
1978	235.3	4.8	240.0	0.019832		125.6	3.8	129.4	0.029223
1979	86.2	1.2	87.4	0.013923		169.4	36.1	205.5	0.17557
1980	318.0	2.8	320.9	0.008807		123.3	9.4	132.7	0.070893
1981	446.8	9.4	456.2	0.020542		308.0	5.5	313.5	0.017388
1982	758.0	8.6	766.6	0.011155		96.7	11.5	108.1	0.105914
1983	251.7	7.3	259.0	0.02814		227.9	48.9	276.8	0.176537
1984	274.3	11.7	286.0	0.040755		145.6	115.5	261.0	0.442401
1985	1082.2	8.7	1090.9	0.008008		247.9	47.4	295.3	0.160527
1986	284.9	21.1	306.1	0.069003		236.6	19.9	256.5	0.077643
1987	656.5	3.3	659.8	0.004944		139.8	53.7	193.5	0.277597
1988	668.9	28.3	697.3	0.040631		225.9	55.8	281.6	0.198024
1989	493.0	12.8	505.8	0.025383		73.7	23.9	97.6	0.24504
1990	959.2	16.2	975.4	0.016655		191.1	82.1	273.2	0.300499
1991	574.8	22.0	596.8	0.03692		321.8	72.1	393.9	0.183033
1992	719.0	18.0	737.1	0.024487		355.5	33.4	388.9	0.08582
1993	562.3	6.5	568.8	0.011496		46.0	70.9	116.9	0.606506
1994	545.1	6.0	551.0	0.01086		178.5	14.7	193.2	0.075927
1995	472.3	14.1	486.4	0.028939		179.7	57.9	237.7	0.243791
1996	765.8	0.9	766.7	0.001215		262.8	57.0	319.8	0.178307
1997	526.8	9.4	536.2	0.017483		188.7	57.3	246.0	0.232826
1998	377.7	7.7	385.4	0.020078		205.4	158.7	364.1	0.43594
1999	494.7	2.7	497.5	0.005521		150.4	64.0	214.4	0.298458
2000	381.2	4.4	385.6	0.011395		222.2	51.8	274.0	0.189175
2001	316.3	2.7	319.0	0.008373		259.4	119.9	379.3	0.316138
2002	482.7	39.9	522.6	0.07641		299.9	43.6	343.5	0.126885
2003	482.7	18.4	501.1	0.036773		130.5	108.5	239.0	0.453853
2004	241.0	16.5	257.6	0.064163		248.4	123.2	371.6	0.331592
2005	436.1	12.4	448.4	0.027583		315.0	175.0	490.0	0.35712
2006	837.0	24.0	861.0	0.02787					

Table B6.1. Biomass estimates for spiny dogfish (thousands of metric tons) based on area swept by NEFSC trawl during spring surveys, 1968-2006.

Year	Lengths >= 80 cm			Lengths 36 to 79 cm			Length <= 35 cm			All Lengths
	Females	Males	Total	Females	Males	Total	Females	Males	Total	
1968			41.4			110.4			1.52	153.3
1969			27.4			69.3			0.66	97.3
1970			36.7			33.0			3.19	72.9
1971			103.8			27.6			2.76	134.2
1972			126.6			145.9			1.55	274.1
1973			178.7			165.3			2.58	346.5
1974			221.9			179.6			2.66	404.1
1975			105.1			125.0			3.97	234.0
1976			96.3			120.8			1.20	218.3
1977			77.3			68.0			0.53	145.9
1978			87.4			131.2			1.24	219.8
1979			52.3			18.6			1.82	72.7
1980	104.7	15.3	168.1	16.8	72.2	123.5	0.32	0.39	0.84	292.4
1981	266.5	24.4	293.8	25.5	75.1	100.6	2.14	2.80	5.06	399.5
1982	454.0	34.6	488.6	61.6	143.3	204.9	0.48	0.69	1.17	694.6
1983	77.7	30.1	107.8	36.7	98.5	135.3	3.09	3.95	7.03	250.1
1984	115.6	27.5	143.1	33.4	88.0	121.4	0.14	0.21	0.35	264.9
1985	317.0	125.5	442.6	102.5	502.5	605.0	4.01	5.10	9.10	1056.7
1986	191.3	3.5	194.8	51.9	29.6	81.5	0.84	1.11	1.96	278.2
1987	219.1	90.5	309.6	61.5	171.7	233.1	2.46	4.76	7.22	550.0
1988	433.1	26.2	459.4	93.3	153.6	247.0	0.89	1.09	1.98	708.4
1989	162.1	40.5	202.6	100.4	158.2	258.6	1.14	1.54	2.68	463.9
1990	400.3	70.7	471.0	163.5	303.1	466.6	0.68	1.03	1.71	939.3
1991	220.4	30.0	250.3	108.4	186.3	294.7	0.98	1.43	2.41	547.4
1992	280.5	41.9	322.4	179.9	231.9	411.8	0.73	1.00	1.73	735.9
1993	234.6	27.8	262.5	104.1	198.5	302.6	0.55	0.65	1.21	566.3
1994	105.3	37.1	142.4	108.3	254.2	362.5	4.28	5.54	9.82	514.8
1995	102.4	29.5	131.9	154.0	174.5	328.5	0.25	0.35	0.59	460.9
1996	196.5	33.4	229.9	201.7	334.8	536.4	0.98	1.14	2.12	768.5
1997	83.7	17.5	101.2	205.2	209.1	414.3	0.05	0.05	0.10	515.5
1998	26.7	22.9	49.7	69.0	236.4	305.4	0.05	0.08	0.13	355.2
1999	62.7	20.4	83.1	140.8	256.4	397.2	0.02	0.03	0.05	480.4
2000	85.8	11.7	97.5	91.5	166.2	257.7	0.07	0.09	0.16	355.4
2001	56.7	16.7	73.4	71.4	160.5	231.9	0.04	0.03	0.07	305.4
2002	75.2	19.0	94.2	131.5	246.3	377.8	0.06	0.06	0.12	472.1
2003	64.5	22.5	87.1	125.5	256.3	381.8	0.13	0.14	0.27	469.1
2004	40.4	10.0	50.3	46.9	126.2	173.1	0.66	0.91	1.56	225.0
2005	55.8	30.8	86.6	59.8	294.7	354.5	0.28	0.42	0.69	441.9
2006	253.2	49.9	303.1	141.5	405.1	546.6	0.10	0.18	0.28	849.9

Notes: Total equals sum of males and females plus unsexed dogfish. Data for dogfish prior to 1980 are currently not available by sex.

Table B6.2 Biomass estimates for spiny dogfish (thousands of metric tons) based on area swept by NEFSC trawl during spring surveys, 1968-2006, adjusted for 0.012 nm sqr footprint.

Year	Lengths >= 80 cm			Lengths 36 to 79 cm			Length <= 35 cm			All Lengths
	Females	Males	Total	Females	Males	Total	Females	Males	Total	
1968			34.5			92.0			1.26	127.8
1969			22.8			57.8			0.55	81.1
1970			30.6			27.5			2.66	60.8
1971			86.5			23.0			2.30	111.8
1972			105.5			121.6			1.29	228.4
1973			148.9			137.7			2.15	288.8
1974			184.9			149.7			2.22	336.8
1975			87.6			104.1			3.31	195.0
1976			80.3			100.7			1.00	181.9
1977			64.4			56.7			0.44	121.6
1978			72.8			109.3			1.04	183.2
1979			43.6			15.5			1.52	60.6
1980	87.2	12.7	140.1	14.0	60.2	102.9	0.27	0.33	0.70	243.7
1981	222.1	20.3	244.8	21.2	62.6	83.9	1.78	2.33	4.21	332.9
1982	378.3	28.8	407.1	51.3	119.4	170.7	0.40	0.57	0.97	578.8
1983	64.8	25.1	89.8	30.6	82.1	112.7	2.57	3.29	5.86	208.4
1984	96.3	22.9	119.3	27.9	73.3	101.2	0.11	0.18	0.29	220.7
1985	264.2	104.6	368.8	85.4	418.8	504.2	3.34	4.25	7.58	880.6
1986	159.4	3.0	162.3	43.2	24.6	67.9	0.70	0.93	1.63	231.8
1987	182.6	75.4	258.0	51.2	143.0	194.3	2.05	3.97	6.02	458.3
1988	361.0	21.8	382.9	77.8	128.0	205.8	0.74	0.91	1.65	590.4
1989	135.1	33.7	168.8	83.7	131.9	215.5	0.95	1.28	2.24	386.6
1990	333.6	58.9	392.5	136.2	252.6	388.8	0.57	0.86	1.43	782.7
1991	183.6	25.0	208.6	90.4	155.2	245.6	0.81	1.19	2.00	456.2
1992	233.8	34.9	268.6	149.9	193.2	343.2	0.61	0.83	1.44	613.2
1993	195.5	23.2	218.7	86.8	165.4	252.2	0.46	0.54	1.00	471.9
1994	87.8	30.9	118.7	90.2	211.9	302.1	3.57	4.62	8.19	429.0
1995	85.4	24.5	109.9	128.3	145.4	273.7	0.21	0.29	0.49	384.1
1996	163.7	27.8	191.6	168.1	279.0	447.0	0.82	0.95	1.77	640.4
1997	69.7	14.6	84.3	171.0	174.2	345.2	0.04	0.04	0.08	429.6
1998	22.3	19.1	41.4	57.5	197.0	254.5	0.04	0.06	0.11	296.0
1999	52.2	17.0	69.3	117.4	213.6	331.0	0.01	0.03	0.04	400.3
2000	71.5	9.7	85.9	76.2	138.5	214.8	0.06	0.07	0.13	300.9
2001	47.2	14.0	61.2	59.5	133.7	193.3	0.04	0.03	0.06	254.5
2002	62.6	15.8	78.5	109.5	205.3	314.8	0.05	0.05	0.10	393.4
2003	53.8	18.8	72.5	104.6	213.6	318.1	0.11	0.12	0.23	390.9
2004	33.6	8.3	42.0	39.1	105.1	144.2	0.55	0.75	1.30	187.5
2005	46.5	25.7	72.2	49.8	245.6	295.4	0.23	0.35	0.58	368.2
2006	211.0	41.6	252.6	117.9	337.6	455.5	0.08	0.15	0.23	708.3

Notes: Total equals sum of males and females plus unsexed dogfish. Data for dogfish prior to 1980 are currently not available by sex.

Table B7.1 Summary of 3yr moving average survey mean numbers per tow and SE for female and male dogfish caught in the NEFSC spring survey. All offshore strata included.

<<<<<FEMALES>>>>>

Spring data All offshore strata

Sex	***year***	***mean***	***variance***	***SE***	***CV***	***Pop Var***	***Pop***	***Var(pop)***	***Low CI***	***High CI***	***3-yrMean***	***3-yrVar***	***3-yr SE***	***3-yrCV***
Females	1980	10.015	5.04E+00	2.25E+00	22.40	2.00E+03	6.49E+07	2.11E+14	5.615	14.415				
Females	1981	22.993	2.24E+01	4.74E+00	20.60	1.81E+04	1.49E+08	9.36E+14	13.71	32.275				
Females	1982	27.845	8.65E+01	9.30E+00	33.40	2.83E+04	1.80E+08	3.63E+15	9.617	46.074	20.28	3.80E+01	6.163497	30.39
Females	1983	18.075	1.70E+01	4.13E+00	22.80	1.34E+04	1.17E+08	7.15E+14	9.986	26.164	22.97	4.20E+01	6.479686	28.21
Females	1984	9.155	3.13E+00	1.77E+00	19.30	1.19E+03	5.93E+07	1.31E+14	5.689	12.62	18.36	3.56E+01	5.962519	32.48
Females	1985	37.114	1.21E+02	1.10E+01	29.60	3.37E+04	2.40E+08	5.08E+15	15.552	58.675	21.45	4.71E+01	6.860002	31.98
Females	1986	19.256	9.12E+00	3.02E+00	15.70	5.16E+03	1.25E+08	3.83E+14	13.335	25.176	21.84	4.44E+01	6.665103	30.52
Females	1987	25.824	4.15E+01	6.44E+00	24.90	1.27E+04	1.66E+08	1.71E+15	13.203	38.444	27.40	5.72E+01	7.563198	27.60
Females	1988	35.095	1.06E+02	1.03E+01	29.40	3.01E+04	2.25E+08	4.36E+15	14.905	55.286	26.73	5.22E+01	7.227399	27.04
Females	1989	27.115	2.77E+01	5.26E+00	19.40	2.36E+04	1.72E+08	1.11E+15	16.801	37.429	29.34	5.84E+01	7.643559	26.05
Females	1990	44.008	1.93E+02	1.39E+01	31.60	6.94E+04	2.82E+08	7.91E+15	16.781	71.234	35.41	1.09E+02	10.43665	29.48
Females	1991	29.994	3.07E+01	5.54E+00	18.50	1.05E+04	1.93E+08	1.26E+15	19.141	40.848	33.71	8.38E+01	9.152686	27.15
Females	1992	41.305	1.01E+02	1.01E+01	24.40	2.44E+04	2.58E+08	3.96E+15	21.583	61.027	38.44	1.08E+02	10.40631	27.07
Females	1993	28.33	2.22E+01	4.72E+00	16.60	7.01E+03	1.81E+08	9.10E+14	19.087	37.573	33.21	5.14E+01	7.168263	21.58
Females	1994	38.115	4.39E+01	6.63E+00	17.40	3.54E+04	2.44E+08	1.80E+15	25.124	51.105	35.92	5.58E+01	7.470252	20.80
Females	1995	25.032	3.29E+01	5.73E+00	22.90	7.88E+03	1.61E+08	1.36E+15	13.794	36.27	30.49	3.30E+01	5.745723	18.84
Females	1996	44.625	2.86E+02	1.69E+01	37.90	9.13E+04	2.87E+08	1.18E+16	11.466	77.785	35.92	1.21E+02	11.00033	30.62
Females	1997	29.058	2.22E+01	4.72E+00	16.20	6.06E+03	1.86E+08	9.09E+14	19.815	38.3	32.91	1.14E+02	10.66666	32.42
Females	1998	11.143	5.45E+00	2.33E+00	20.90	1.41E+03	7.15E+07	2.24E+14	6.569	15.717	28.28	1.05E+02	10.22909	36.18
Females	1999	21.351	1.10E+01	3.32E+00	15.60	3.37E+03	1.34E+08	4.35E+14	14.839	27.862	20.52	1.29E+01	3.592585	17.51
Females	2000	15.421	2.42E+01	4.92E+00	31.90	5.20E+03	9.90E+07	9.99E+14	5.771	25.07	15.97	1.36E+01	3.684291	23.07
Females	2001	10.884	1.39E+01	3.73E+00	34.20	3.18E+03	6.99E+07	5.73E+14	3.578	18.19	15.89	1.64E+01	4.048456	25.49
Females	2002	18.769	1.54E+01	3.92E+00	20.90	9.28E+03	1.21E+08	6.34E+14	11.084	26.454	15.02	1.78E+01	4.223269	28.11
Females	2003	17.474	5.86E+00	2.42E+00	13.90	9.30E+03	1.12E+08	2.42E+14	12.73	22.218	15.71	1.17E+01	3.421905	21.78
Females	2004	10.0074	7.92028	2.8143	28.12	2803.61	64254400	3.27E+14	4.49	15.52343	15.42	9.72E+00	3.117402	20.22
Females	2005	10.348	1.03E+01	3.20E+00	31.00	3114.2	66440000	4.23E+14	4.067	16.629	12.61	8.02E+00	2.831288	22.45
Females	2006	28.51	3.89E+01	6.23E+00	21.87	1.22E+04	1.83E+08	1.60E+15	16.289	40.72	16.29	1.90E+01	4.360668	26.77

Table B7.1 (cont.)

Sex	*year*	***mean***	***variance***	***SE***	***CV***	***Pop Var***	***Pop***	***Var(pop)***	***Low CI***	***High CI***	***3-yrMean***	***3-yrVar***	***3-yr SE***	***3-yrCV***
Males	1980	12.859	9.87E+00	3.14E+00	24.4	4.05E+03	8.33E+07	4.14E+14	6.7	19.017				
Males	1981	18.249	1.61E+01	4.01E+00	22.0	1.37E+04	1.18E+08	6.71E+14	10.391	26.108				
Males	1982	23.705	4.25E+01	6.52E+00	27.5	1.67E+04	1.54E+08	1.78E+15	10.93	36.48	18.27	2.28E+01	4.775971	26.14
Males	1983	23.622	1.81E+01	4.26E+00	18.0	7.94E+03	1.53E+08	7.60E+14	15.279	31.965	21.86	2.56E+01	5.055525	23.13
Males	1984	13.338	2.34E+01	4.84E+00	36.3	8.51E+03	8.64E+07	9.83E+14	3.85	22.826	20.22	2.80E+01	5.292542	26.17
Males	1985	80.175	7.34E+02	2.71E+01	33.8	1.82E+05	5.19E+08	3.08E+16	27.073	133.277	39.05	2.59E+02	16.07877	41.18
Males	1986	9.457	7.33E+00	2.71E+00	28.6	3.52E+03	6.13E+07	3.08E+14	4.151	14.764	34.32	2.55E+02	15.96656	46.52
Males	1987	39.298	2.19E+02	1.48E+01	37.7	5.66E+04	2.52E+08	9.04E+15	10.269	68.326	42.98	3.20E+02	17.89516	41.64
Males	1988	29.467	1.28E+02	1.13E+01	38.4	7.16E+04	1.89E+08	5.25E+15	7.302	51.632	26.07	1.18E+02	10.87153	41.69
Males	1989	29.574	7.58E+01	8.71E+00	29.4	2.05E+04	1.87E+08	3.04E+15	12.505	46.642	32.78	1.41E+02	11.87541	36.23
Males	1990	47.791	6.32E+02	2.51E+01	52.6	2.38E+05	3.06E+08	2.59E+16	-1.484	97.066	35.61	2.79E+02	16.69088	46.87
Males	1991	32.294	8.47E+01	9.21E+00	28.5	2.70E+04	2.07E+08	3.49E+15	14.251	50.337	36.55	2.64E+02	16.25431	44.47
Males	1992	38.223	6.45E+01	8.03E+00	21.0	2.76E+04	2.39E+08	2.52E+15	22.487	53.958	39.44	2.60E+02	16.1372	40.92
Males	1993	32.57	2.23E+02	1.49E+01	45.9	6.04E+04	2.08E+08	9.13E+15	3.297	61.843	34.36	1.24E+02	11.13954	32.42
Males	1994	53.391	7.91E+01	8.89E+00	16.7	4.23E+04	3.42E+08	3.24E+15	35.961	70.821	41.39	1.22E+02	11.05459	26.71
Males	1995	25.754	2.46E+01	4.96E+00	19.3	5.68E+03	1.65E+08	1.02E+15	16.029	35.48	37.24	1.09E+02	10.43676	28.03
Males	1996	52.633	1.94E+02	1.39E+01	26.4	6.09E+04	3.38E+08	7.98E+15	25.362	79.904	43.93	9.91E+01	9.954865	22.66
Males	1997	29.594	2.89E+01	5.37E+00	18.2	6.69E+03	1.89E+08	1.18E+15	19.065	40.123	35.99	8.24E+01	9.075057	25.21
Males	1998	32.353	6.71E+01	8.19E+00	25.3	2.13E+04	2.08E+08	2.76E+15	16.293	48.413	38.19	9.65E+01	9.824951	25.72
Males	1999	35.452	4.09E+01	6.40E+00	18.0	1.38E+04	2.23E+08	1.61E+15	22.915	47.989	32.47	4.56E+01	6.75559	20.81
Males	2000	22.24	3.49E+01	5.91E+00	26.6	7.24E+03	1.43E+08	1.44E+15	10.657	33.824	30.02	4.77E+01	6.903767	23.00
Males	2001	20.345	3.11E+01	5.57E+00	27.4	1.02E+04	1.31E+08	1.28E+15	9.418	31.272	26.01	3.56E+01	5.970036	22.95
Males	2002	32.174	3.76E+01	6.13E+00	19.0	1.83E+04	2.07E+08	1.55E+15	20.162	44.186	24.92	3.45E+01	5.875656	23.58
Males	2003	32.45	2.51E+01	5.01E+00	15.4	7.09E+04	2.08E+08	1.03E+15	22.637	42.262	28.32	3.12E+01	5.588798	19.73
Males	2004	18.3176	24.5928	4.95911	27.1	9720.55	1.18E+08	1.01E+15	8.597744	28.03746	27.65	29.0726	5.391901	19.50
Males	2005	37.973	346.14	18.605	49.0	103580	2.44E+08	1.43E+16	1.507	74.439	29.58	131.9323	11.48618	38.83
Males	2006	50.2729	214.159	14.6342	29.1	46653.2	3.23E+08	8.83E+15	21.58987	78.95593	35.52	194.9639	13.96295	39.31

Table B7.2 Summary of input values for swept area scenarios.

(These estimates of wing spread, door spread, and tow length are provisional and subject to change per further analysis)

(The data are incorporated as part of this assessment complements of Henry Milliken, NEFSC)

	door spread(m)	***wing spread (m)***	***mid range (m)***
ave Albatross	22.98	11.07	17.02
sd Albatross	1.34	0.64	0.99
CV Albatross	0.06	0.06	0.06

Distance per tow	***nautical mile***
mean	1.874
std dev	0.112
CV	0.060

Conversion Factor	1m =	0.000539957	nautical miles

Estimated area swept per tow

Area per tow (nm^2)	***Max (based on Door)***	***Min(based on wing spread)***	***Midrange***	***Max/min***
mean	0.02325	0.01120	0.01722	2.076455081
std dev= (CV*mean)	0.00140	0.00067	0.00103	
CV(fixed at 0.06 per above)	0.06	0.06	0.06	

Table B8.1 Summary of input data for stock recruitment analyses of spiny dogfish.

	Survey Data				Survey Data Scaled to Nominal Footprint (0.01 nm^2)	
	Raw Data		2-Pt Moving Average		2 -yr moving average	
Year	*Recruits (Num/Tow)*	*SSB (kg/tow)*	*Recruits (Num/tow)*	*SSB (kg/tow)*	*Recruits (000's)*	*SSB (mt)*
1968	2.881	5.37	.	.	.	.
1969	1.248	3.55	2.065	4.46	13,374	28,884
1970	8.250	4.76	4.749	4.16	30,760	26,916
1971	5.905	13.47	7.077	9.11	45,841	59,034
1972	3.909	16.43	4.907	14.95	31,785	96,814
1973	5.183	23.18	4.546	19.81	29,445	128,278
1974	5.948	28.78	5.565	25.98	36,046	168,294
1975	7.851	13.63	6.899	21.21	44,686	137,366
1976	2.718	12.49	5.285	13.06	34,229	84,616
1977	1.110	10.03	1.914	11.26	12,399	72,952
1978	2.759	11.34	1.934	10.69	12,530	69,205
1979	3.883	6.79	3.321	9.06	21,510	58,688
1980	1.356	16.16	2.620	11.47	18,069	78,154
1981	8.853	41.25	5.104	28.71	35,110	189,423
1982	2.459	70.09	5.656	55.67	37,580	360,246
1983	12.990	12.00	7.725	41.05	50,033	265,861
1984	0.744	17.84	6.867	14.92	44,478	96,647
1985	19.799	48.95	10.272	33.40	66,530	216,304
1986	3.982	29.53	11.891	39.24	77,017	254,141
1987	12.942	34.13	8.462	31.83	54,443	205,196
1988	3.671	67.57	8.306	50.85	53,313	326,141
1989	5.482	25.59	4.576	46.58	29,128	297,611
1990	3.841	62.51	4.661	44.05	29,661	281,184
1991	4.548	34.32	4.195	48.42	26,899	310,322
1992	3.663	44.41	4.105	39.36	26,170	250,438
1993	3.060	36.68	3.362	40.54	21,357	257,578
1994	15.840	16.45	9.450	26.56	60,501	169,975
1995	1.151	15.95	8.496	16.20	54,408	103,872
1996	5.276	30.60	3.214	23.28	20,634	149,461
1997	0.281	13.09	2.778	21.85	17,835	140,080
1998	0.454	4.16	0.367	8.63	2,353	55,188
1999	0.143	9.98	0.299	7.07	1,907	44,692
2000	0.479	13.36	0.311	11.67	1,990	74,239
2001	0.208	8.83	0.344	11.10	2,207	71,235
2002	0.297	11.71	0.253	10.27	1,622	65,921
2003	0.825	10.05	0.561	10.88	3,602	69,860
2004	4.346	6.29	2.585	8.17	16,599	52,458
2005	1.951	8.70	3.148	7.493	20,213	48,112
2006	0.644	39.44	1.297	24.067	8,330	154,529

Table B8.2. Summary of parameter estimates for Ricker stock-recruitment model

Years Included	Data	Units	Parameter	Estimate	Asymptotic SE	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1968-96	Swept Area 2-yr avg.		A	0.541578	0.109155	0.31761	0.765546
			B	-0.000005	0.000001	-0.000007	-0.000003
		thousands	RMAX (000')	42,839	3,517	35,622	50,055
		mt	SSBMAX (mt)	215,014	43,749	125,249	304,780
			R-sqr	0.172			
			MSE	7.925 E+9			
	Raw (2-yr avg.)		A	0.543445	0.108853	0.320097	0.766793
			B	-0.030141	0.006055	-0.042565	-0.017717
		num/tow	RMAX	6.632914	0.542621	5.519549	7.74628
		kg/tow	SSBMAX	33.177455	6.665081	19.501838	46.853071
			R-sqr	0.178			
			MSE	190.97			
	Raw		A	0.521389	0.16949	0.174204	0.868574
			B	-0.027862	0.009425	-0.047169	-0.008555
		num/tow	RMAX	6.884334	1.118478	4.593236	9.175431
		kg/tow	SSBMAX	35.891764	12.141952	11.020103	60.763425
			R-sqr	0.055			
			MSE	625.76			
1968-2006	Swept Area 2-yr avg.		A	0.373678	0.080375	4.64919	0.21067
			B	-0.00003	0.000001	-0.000005	-0.000001
		thousands	RMAX	41,812	5,565	30,524	53,100
		mt	SSBMAX	304,158	90,354	120,912	487,405
			R-sqr	3.06E-01			
			MSE	7.34E+07			
	Raw (2-yr avg.)		A	0.37464	0.080409	0.211564	0.537716
			B	-0.021384	0.006276	-0.034112	-0.008657
		num/tow	RMAX	6.445057	0.844803	4.731716	8.158398
		kg/tow	SSBMAX	46.763476	13.723467	18.930994	74.595957
			R-sqr	0.327			
			MSE	339.75			
	Raw		A	0.414183	0.128034	0.154762	0.673605
			B	-0.024286	0.008786	-0.042088	-0.006483
		num/tow	RMAX	6.274074	1.109566	4.02588	8.522269
		kg/tow	SSBMAX	41.176671	14.896883	10.992719	71.360623
			R-sqr	0.098455			
			MSE	771.27			

Table B10.1. Projections of spiny dogfish spawning stock biomass (mt) under three scenarios.

Scenario	F	Year	SSB (mean)	P(SSB>thresh)	P(SSB>Target)
Status Quo	0.128	2006	106,385	0.72	0.00
		2007	138,758	0.93	0.09
		2008	155,394	0.96	0.24
		2018	124,652	0.87	0.02
		2028	184,104	1.00	0.51
Rebuild F	0.030	2006	106,385	0.72	0.00
		2007	144,560	0.94	0.14
		2008	168,616	0.98	0.37
		2018	195,685	1.00	0.60
		2028	383,756	1.00	1.00
Zero F	0.0	2006	106,385	0.72	0.00
		2007	146,391	0.95	0.16
		2008	172,918	0.99	0.41
		2018	229,182	1.00	0.79
		2028	490,464	1.00	1.00

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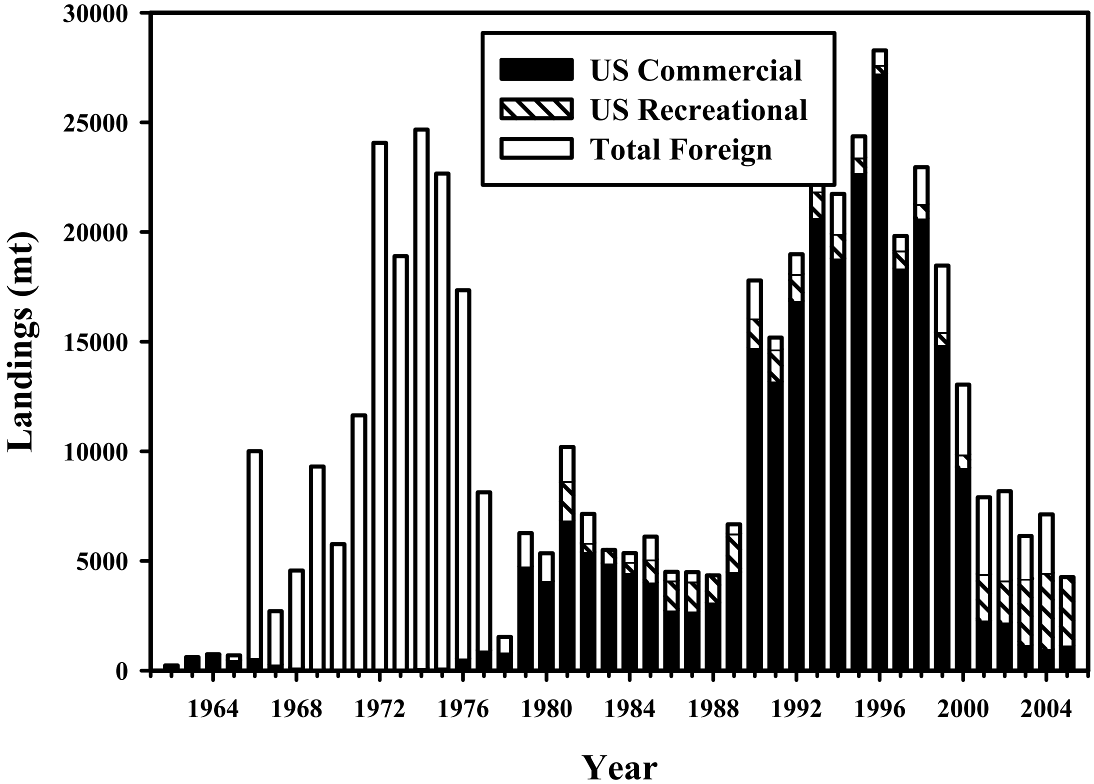


Figure B4.1. Commercial landings (metric tons) and total recreational catch, 1962-2005.

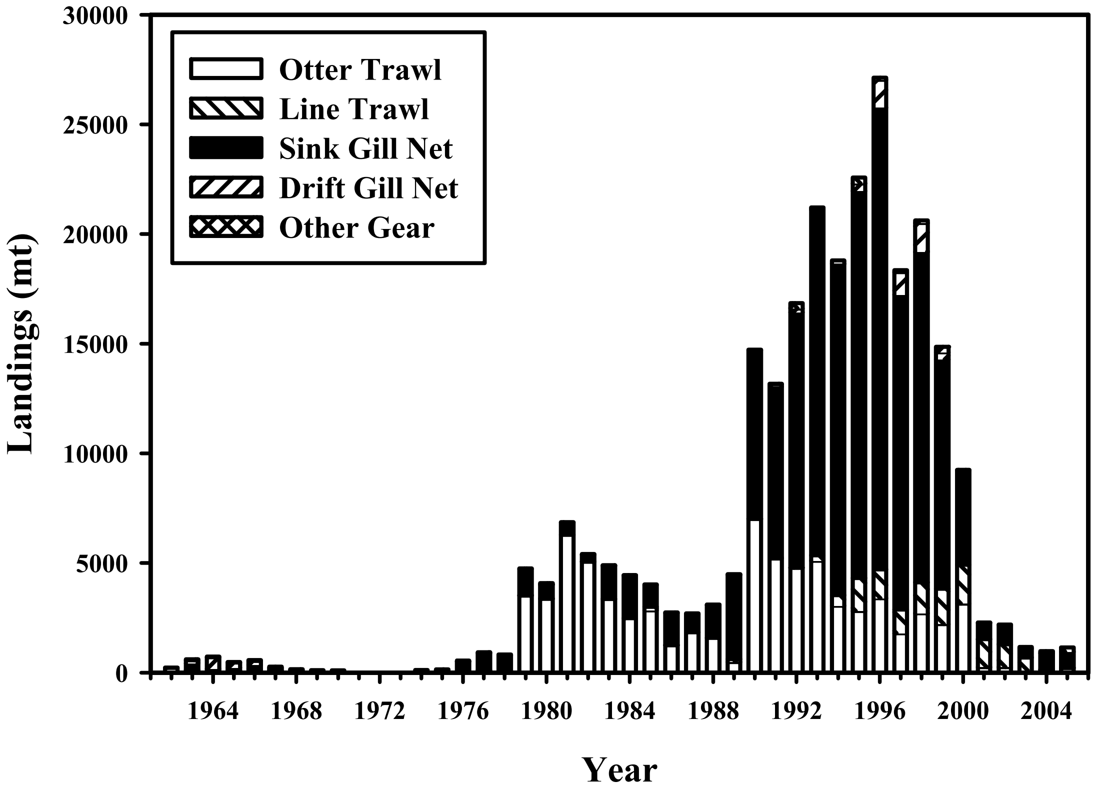


Figure B4.2. U.S. landings (metric tons) of spiny dogfish from NAFO subareas 2-6 by gear type, 1962-2005.

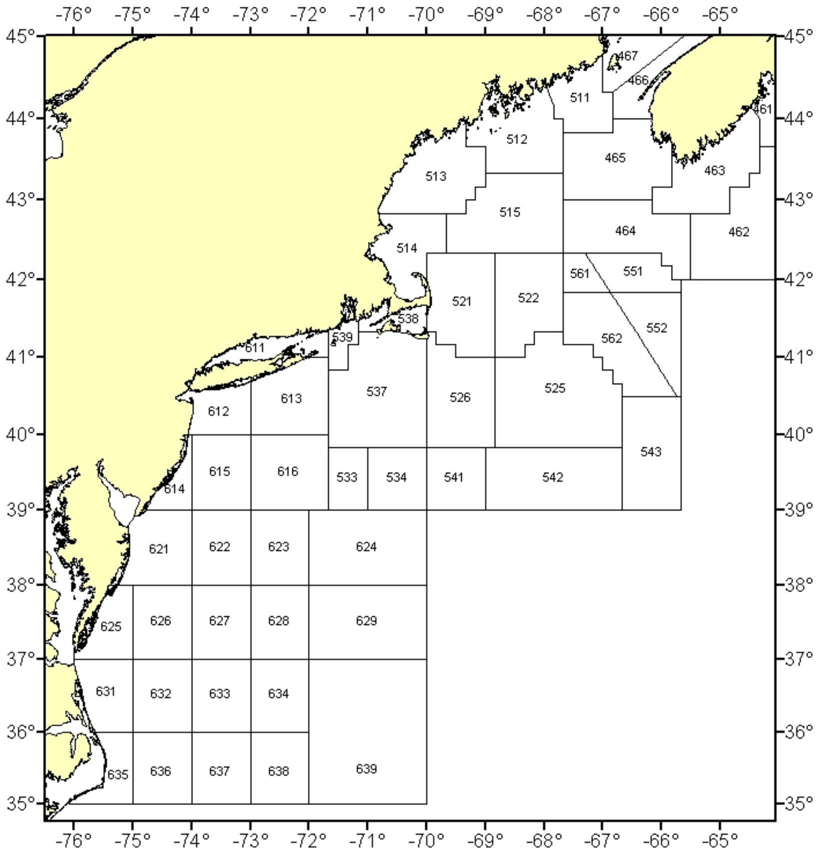


Fig. B4.3. Statistical areas for Canada and USA.

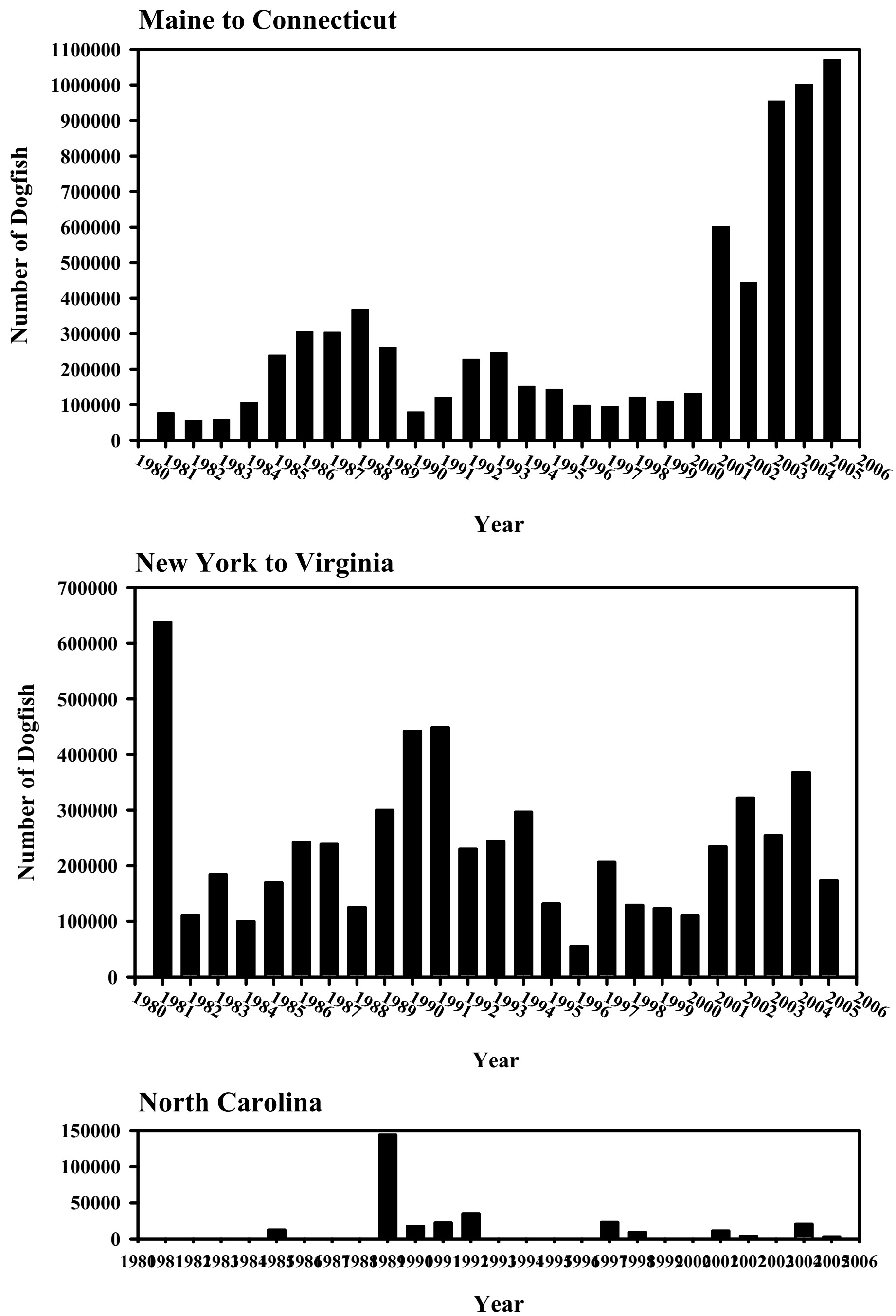


Figure B4.4. Estimated total recreational catch of spiny dogfish (numbers of fish) by geographical area, 1981-2005.

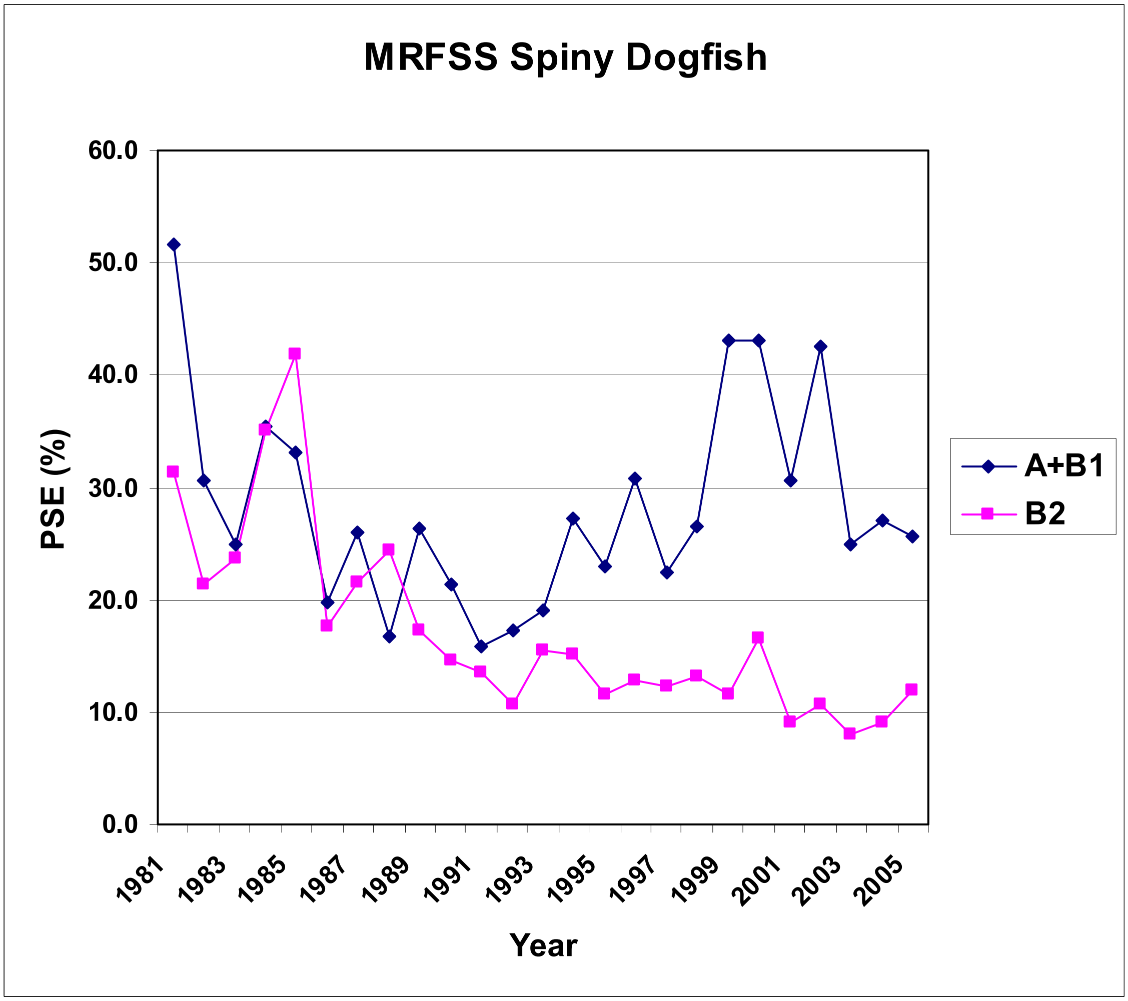


Fig. B4. 5. Estimate proportional standard errors (PSE) for spiny dogfish landings (A+B1) and discards (B2), 1981-2005, in Marine Recreational Fisheries Statistical Survey for Northeast US.

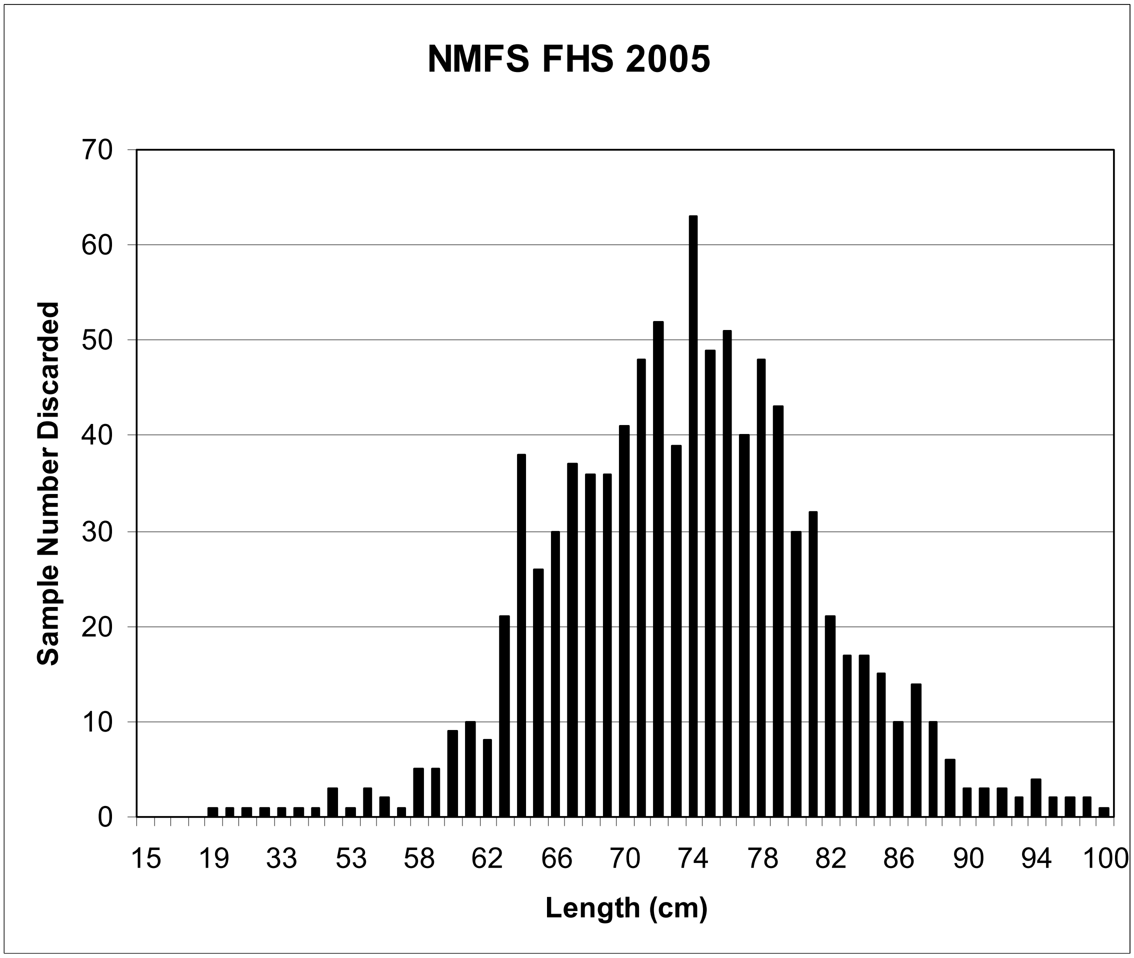
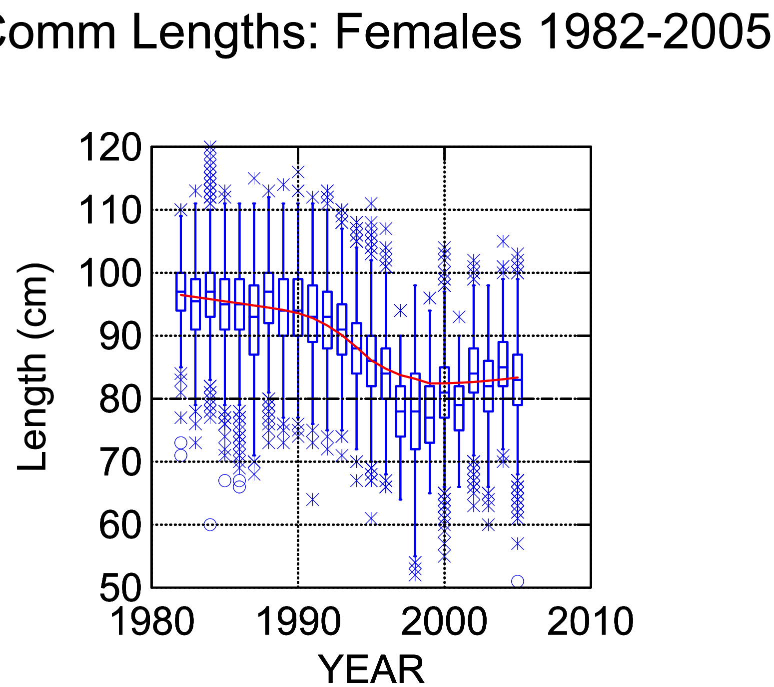


Fig. B4.6 Length frequency distribution of discarded spiny dogfish measured (n=946) during 2005 survey of recreational charter boat vessels.



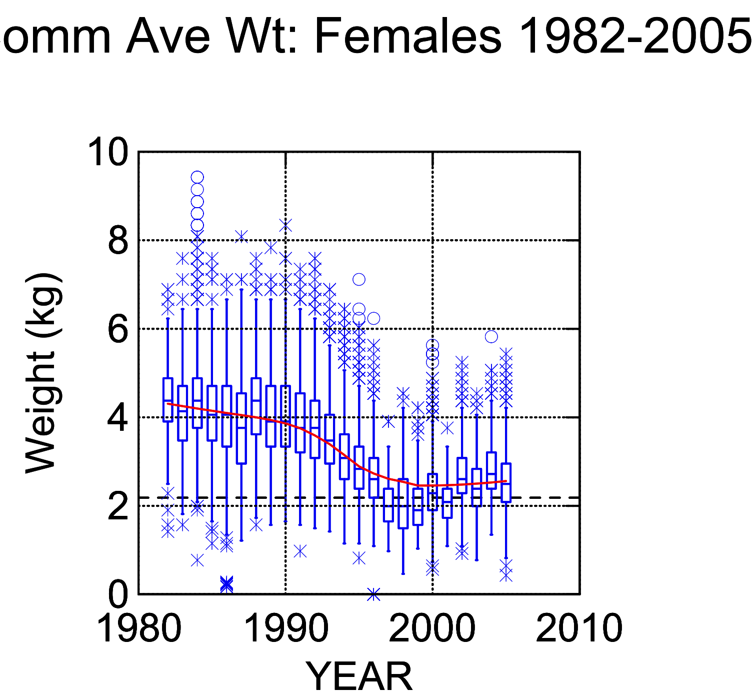


Fig. B4.7 Box plots of length (cm) and weight (kg) frequencies of female dogfish in commercial fishery samples.

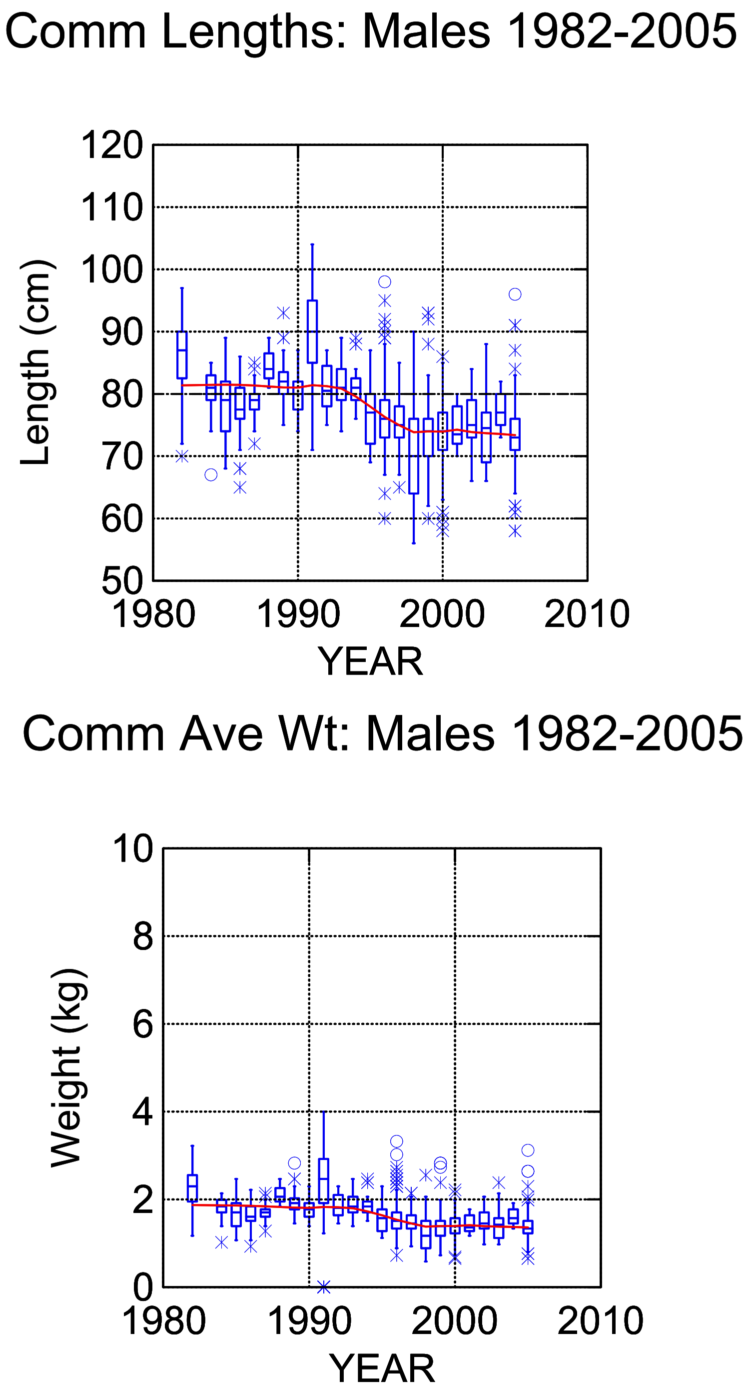
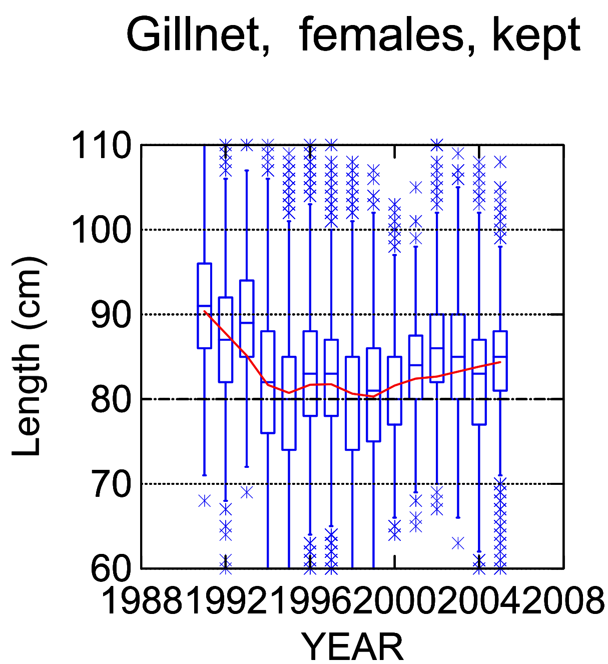


Fig. B4.8 Box plots of length (cm) and weight (kg) frequencies of male dogfish in commercial fishery samples.



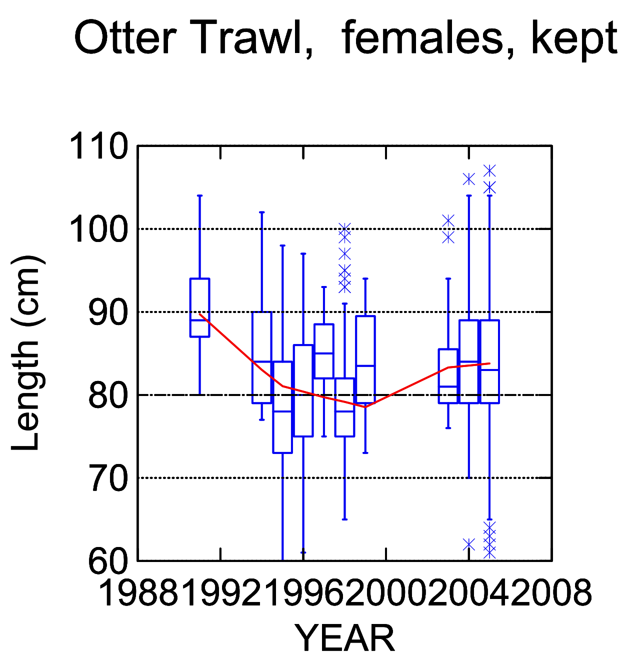


Fig.B4.9 Comparison of trends in size distribution of kept of female spiny dogfish by at-sea observers in gill nets (top) and otter trawl gear (bottom), 1989-2005. Lines represent lowess smoothes (tension=0.5) of composite annual size frequencies. Boxes represent medians and interquartile range of lengths.

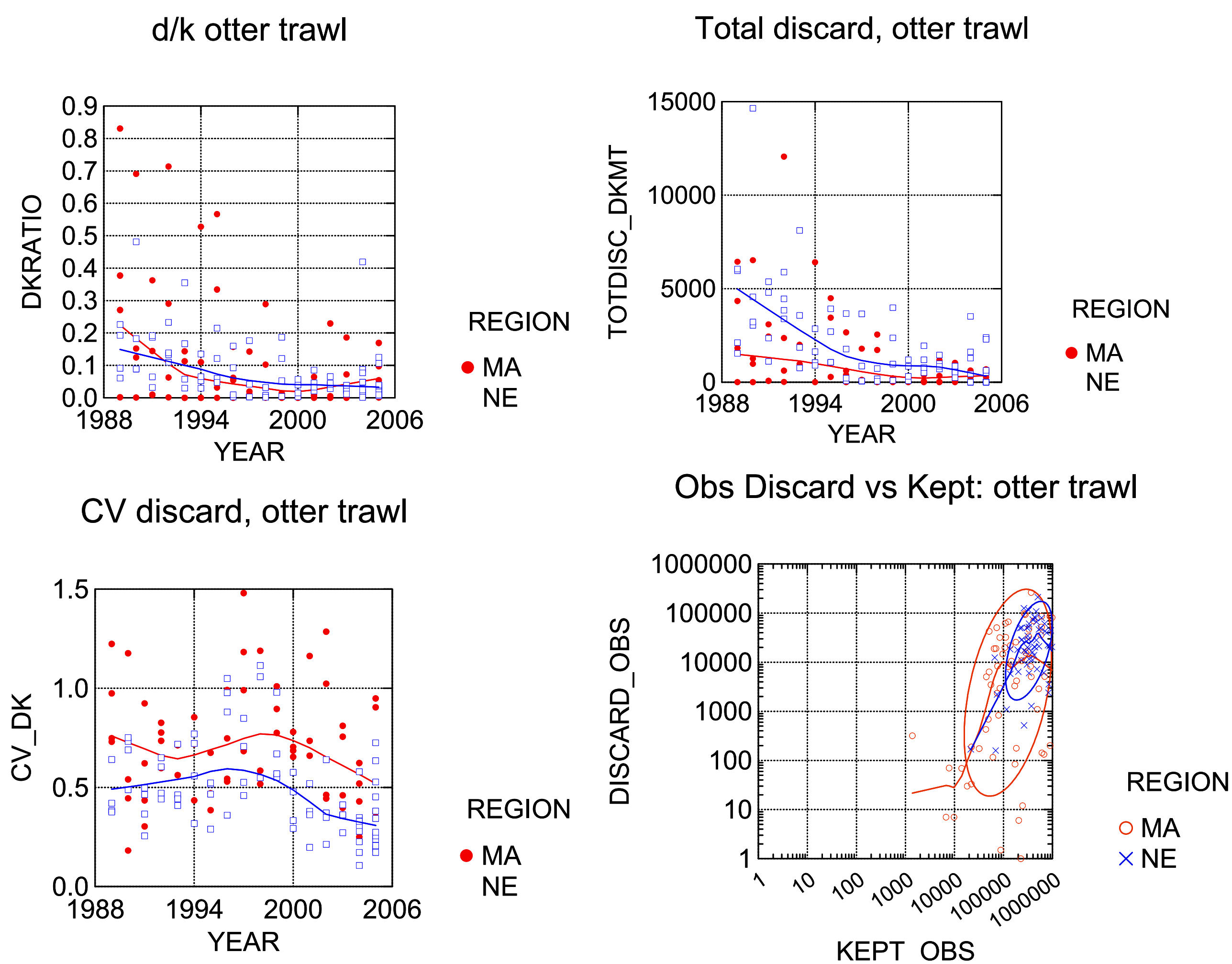


Fig. B4.10 Quarterly estimates of d/k ratios, total discards, coefficients of variation for spiny dogfish discards in otter trawl fisheries in the Mid Atlantic and New England, 1989-2005. The lower right panel depicts the association between dogfish discards discards and total weight of all kept species.

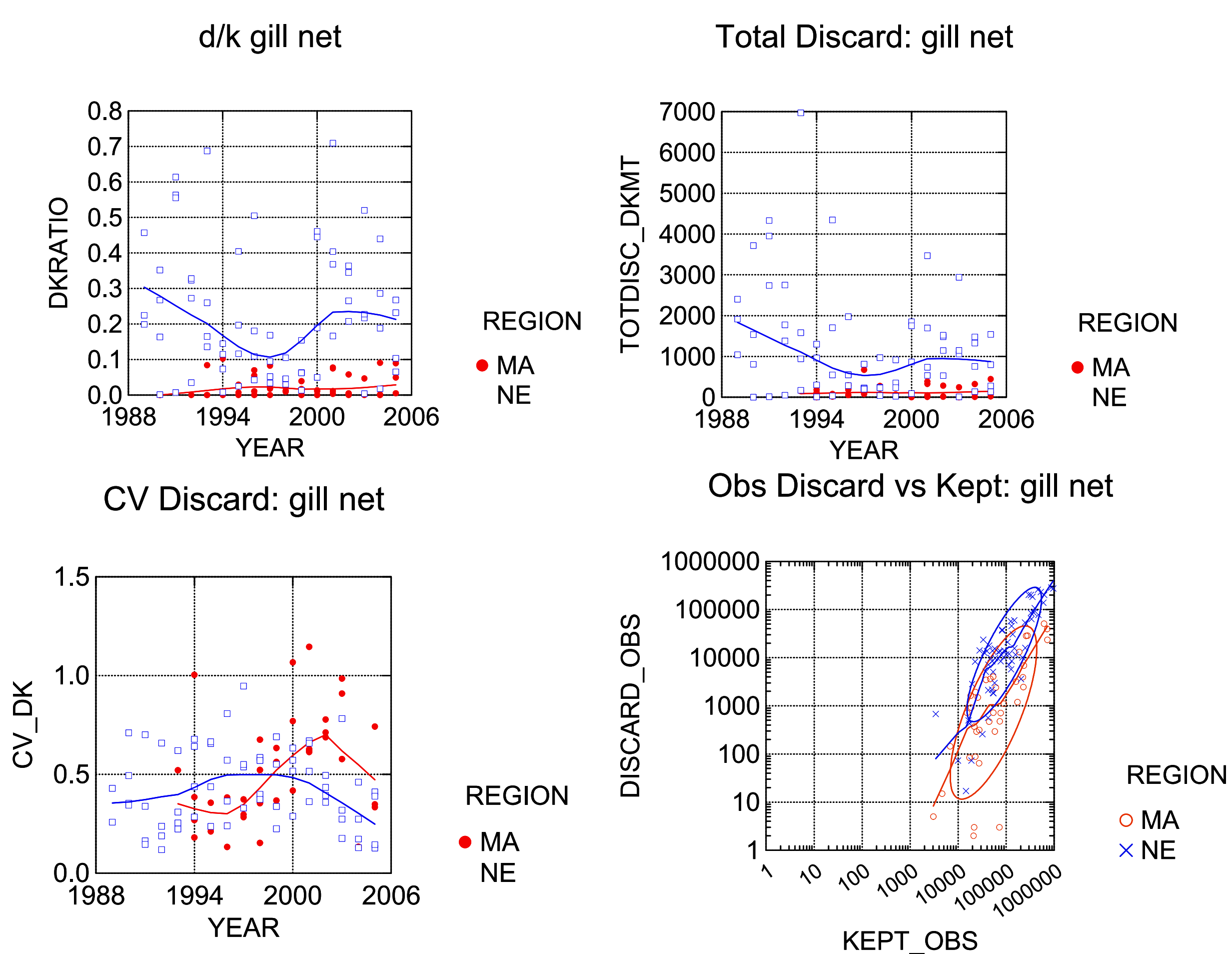


Fig. B4.11 Quarterly estimates of d/k ratios, total discards, coefficients of variation for spiny dogfish discards in gill net fisheries in the Mid Atlantic and New England, 1989-2005. The lower right panel depicts the association between dogfish discards discards and total weight of all kept species.

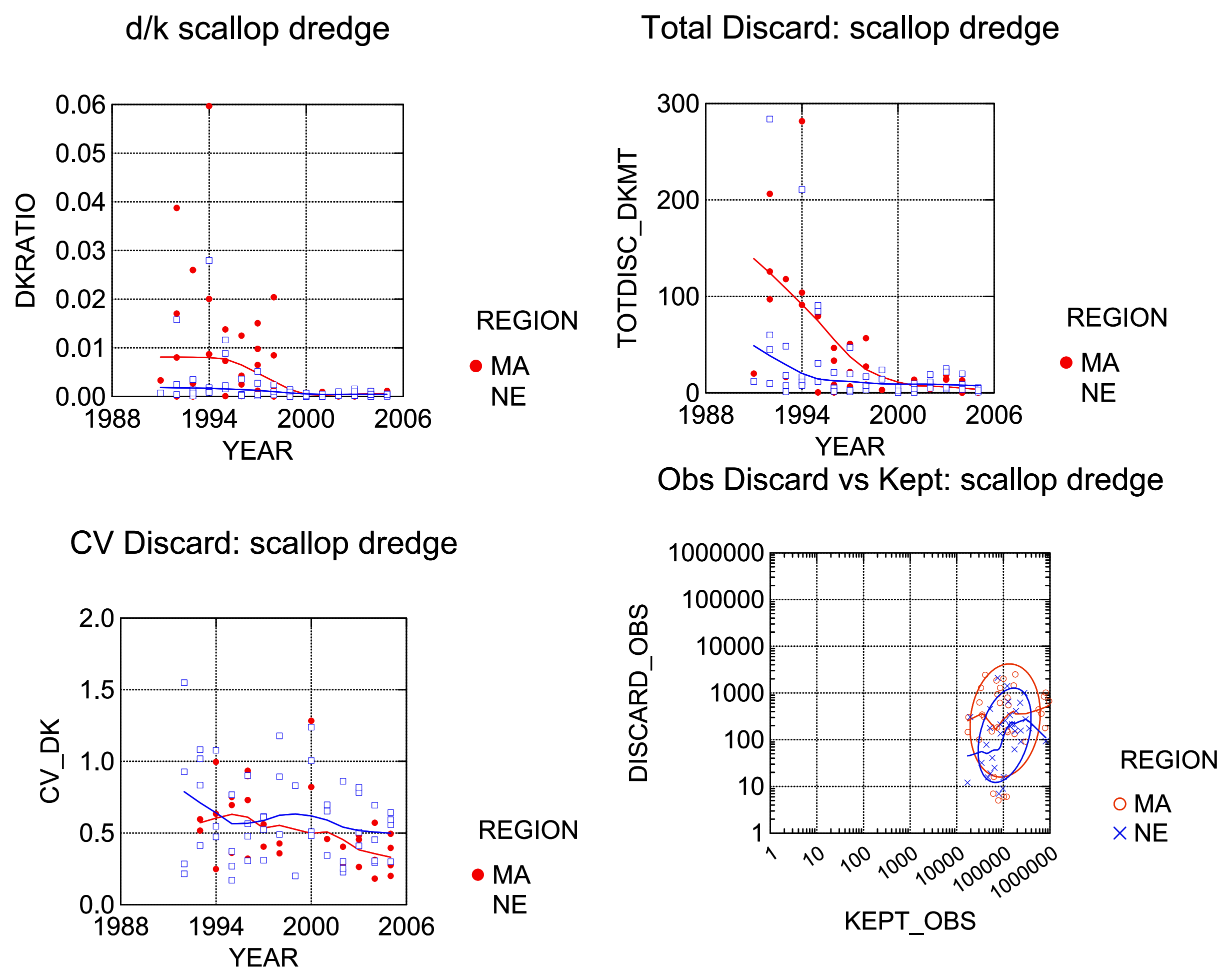


Fig. B4.12 Quarterly estimates of d/k ratios, total discards, coefficients of variation for spiny dogfish discards in scallop dredge fisheries in the Mid Atlantic and New England, 1989-2005. The lower right panel depicts the association between dogfish discards discards and total weight of all kept species.

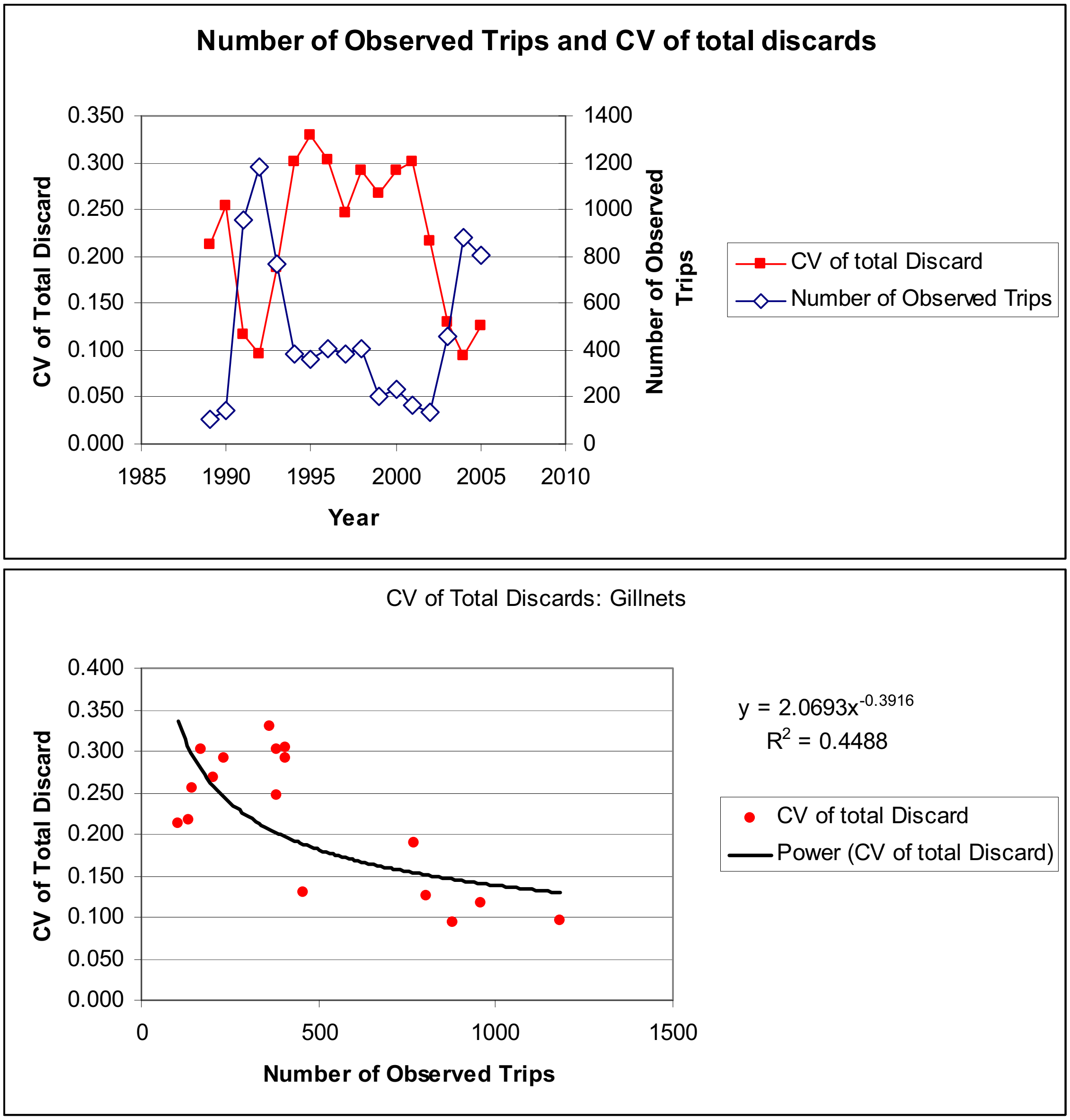
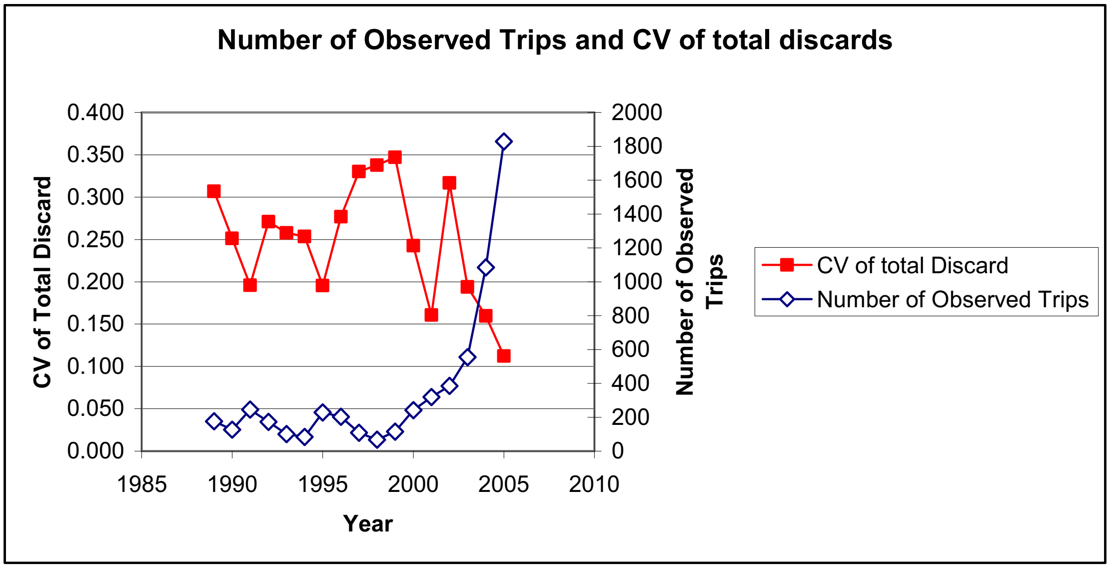


Fig. B4.13. Trends in relative precision of discard estimates for spiny dogfish discards in gill net fisheries (top) and the the effects of increased trips on coefficient of variation (bottom).



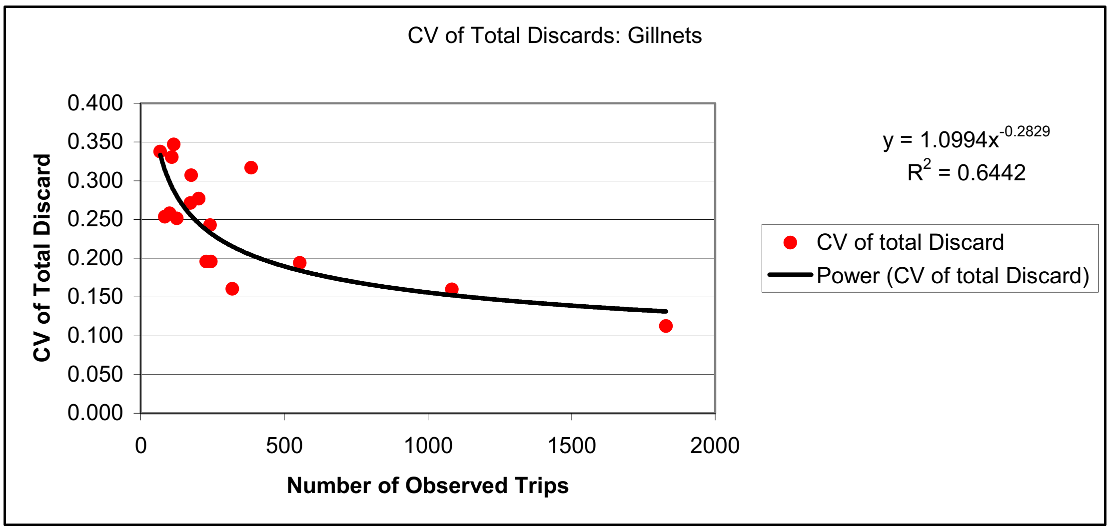
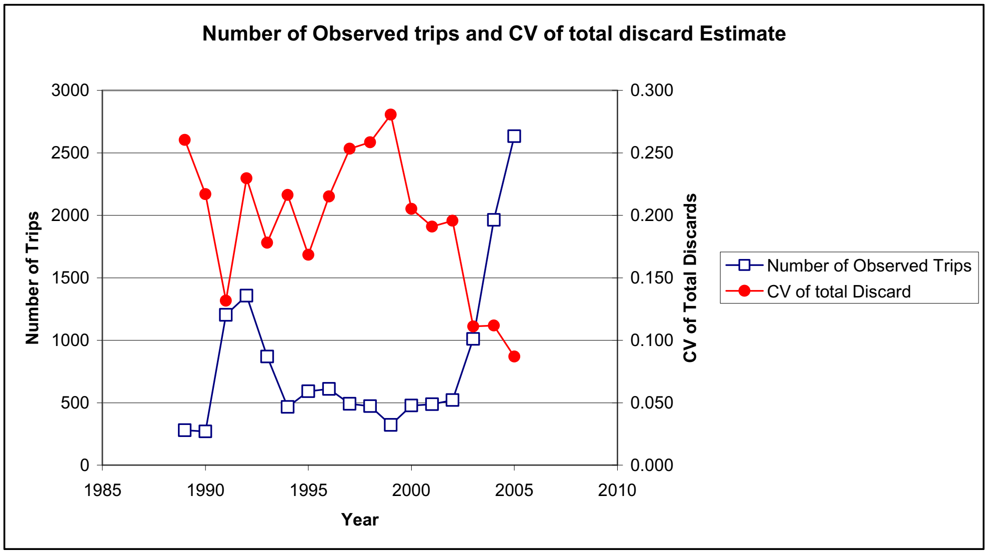


Fig. B4.14. Trends in relative precision of discard estimates for spiny dogfish discards in otter trawl fisheries (top) and the the effects of increased trips on coefficient of variation (bottom).



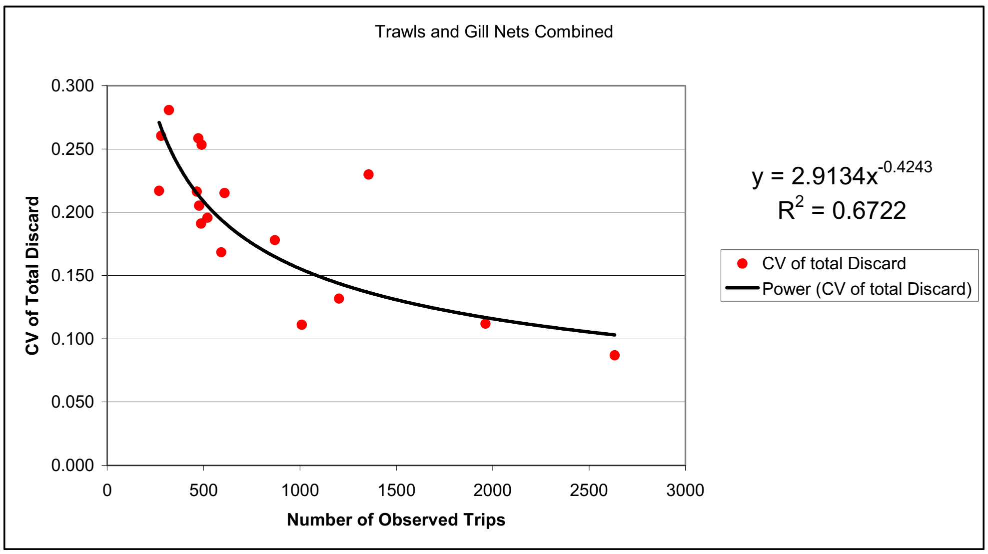


Fig. B4.15. Trends in relative precision of discard estimates for spiny dogfish discards in trawl and gill net fisheries combined (top) and the the effects of increased trips on coefficient of variation (bottom).

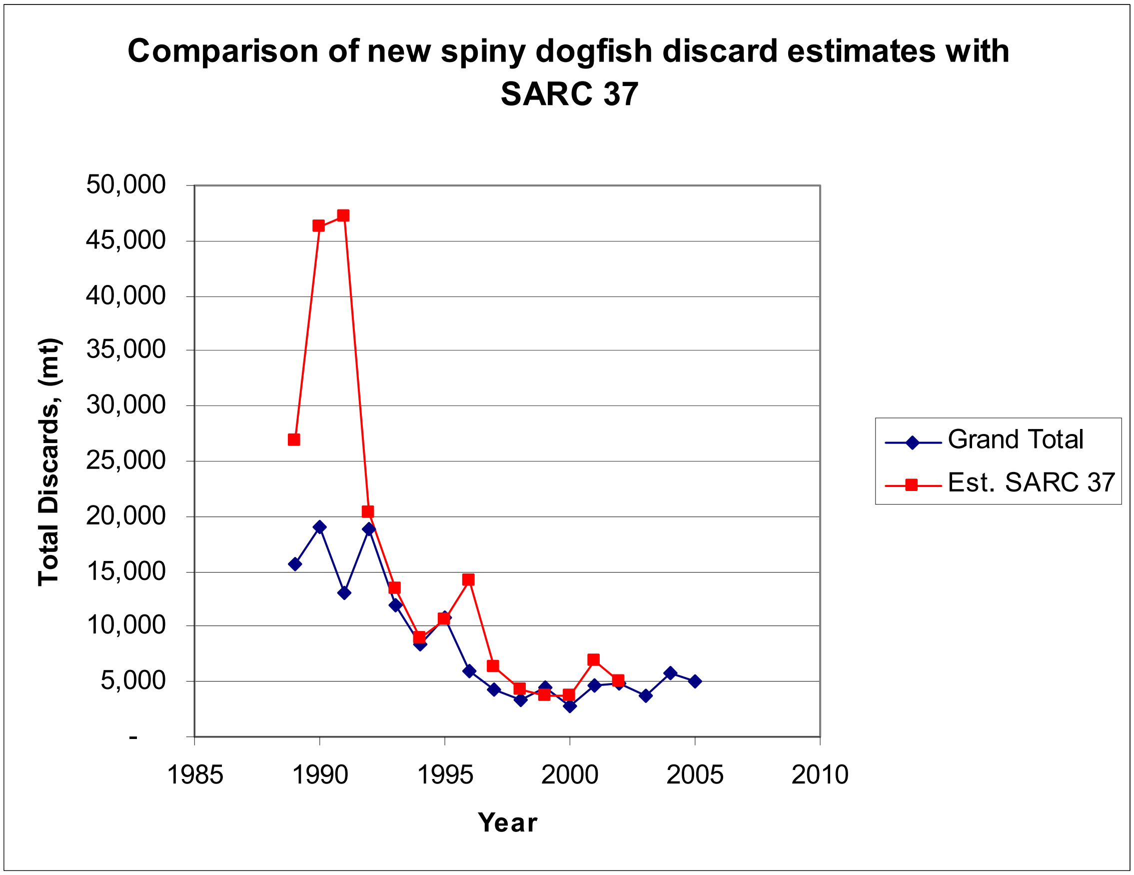
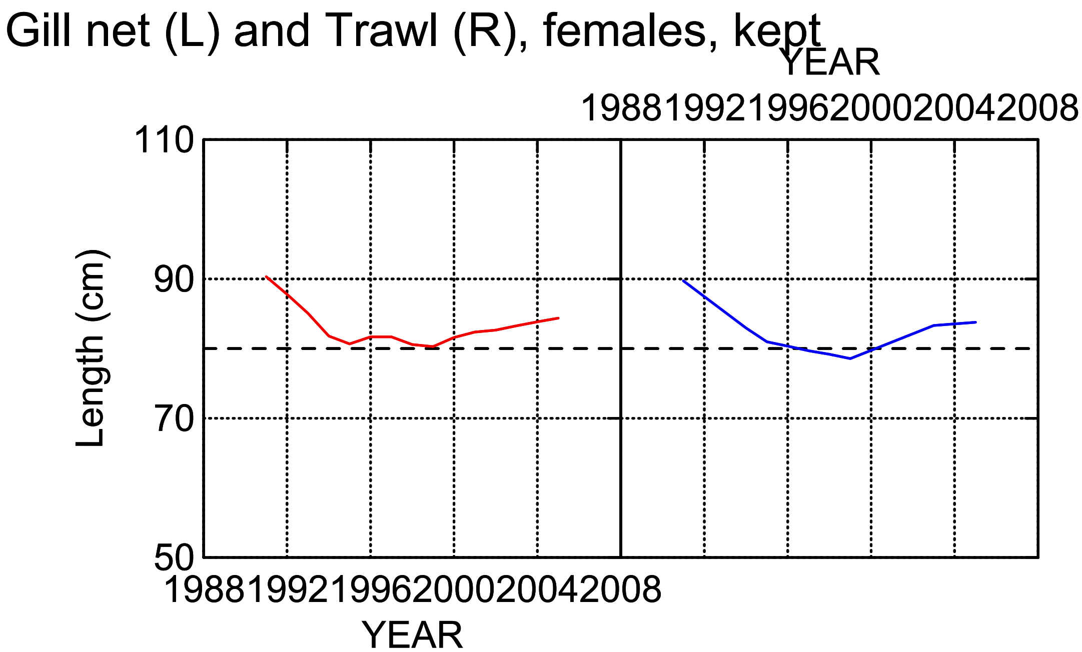


Fig. B4.16. Comparison of total discard estimates for spiny dogfish using the methodology developed in this report with estimates derived for SARC 37 in 2003.



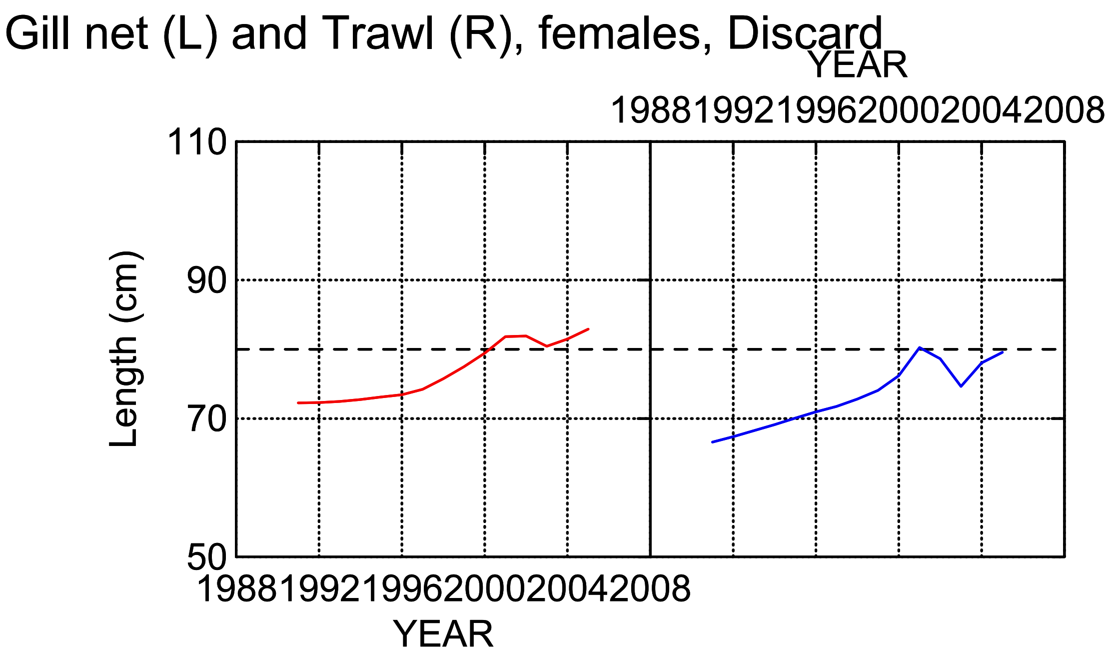
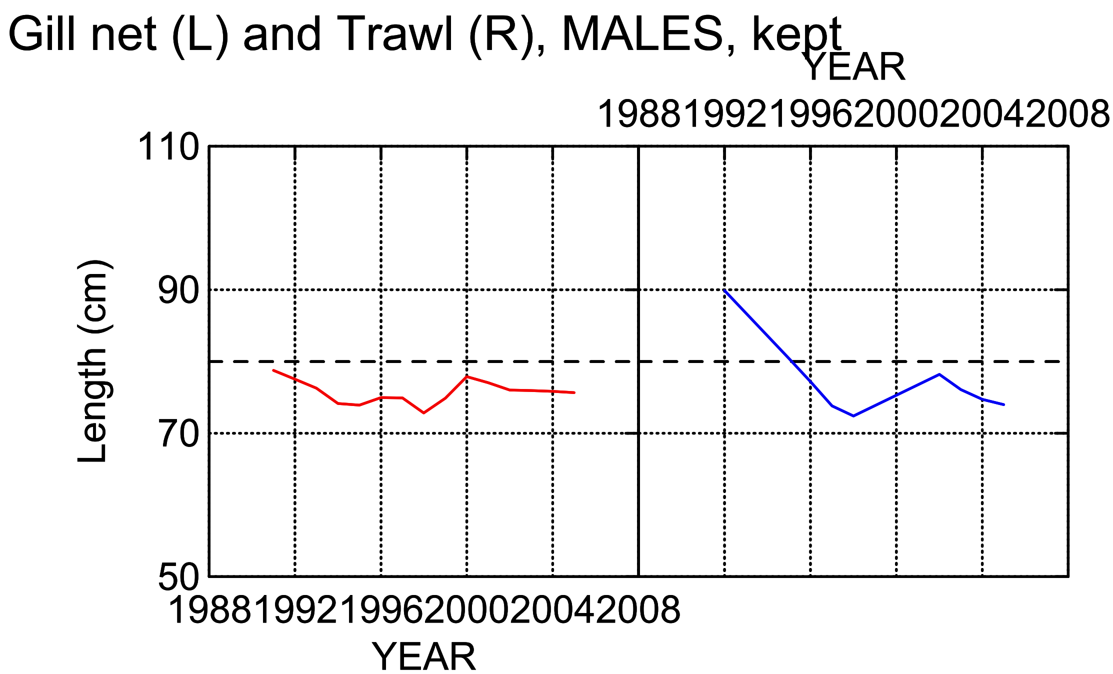


Fig.B4.17 Comparison of trends in discard and kept of female spiny dogfish by at-sea observers in gill nets (left) and otter trawl gear, 1989-2005. Lines represent lowess smoothes of composite annual size frequencies.



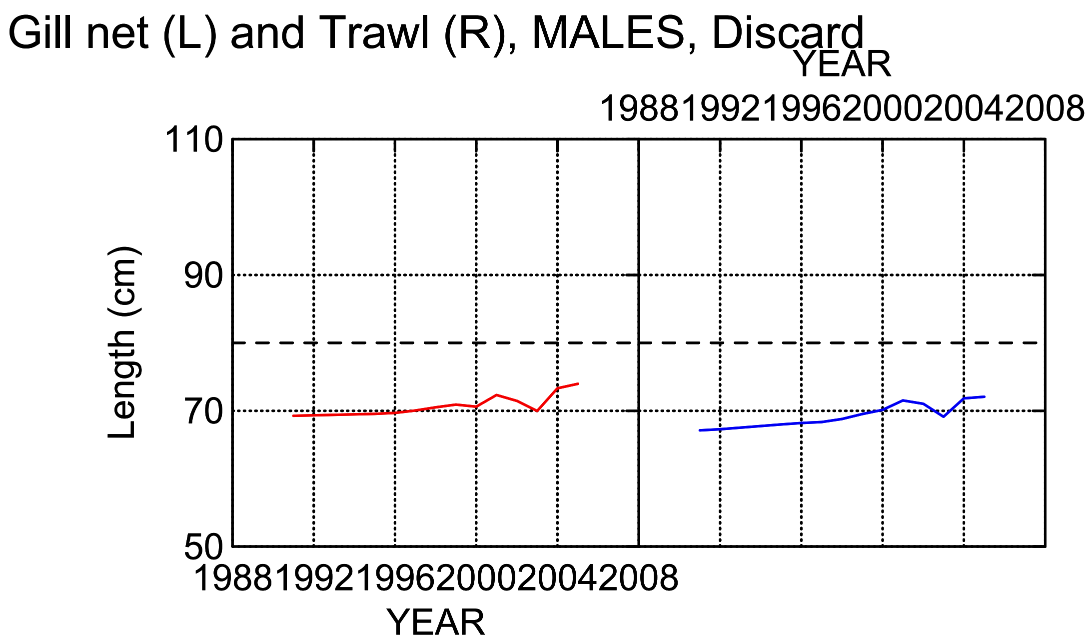


Fig. B4.18. Comparison of trends in discard and kept of MALE spiny dogfish by at-sea observers in gill nets (left) and otter trawl gear, 1989-2005. Lines represent lowess smoothes of composite annual size frequencies.

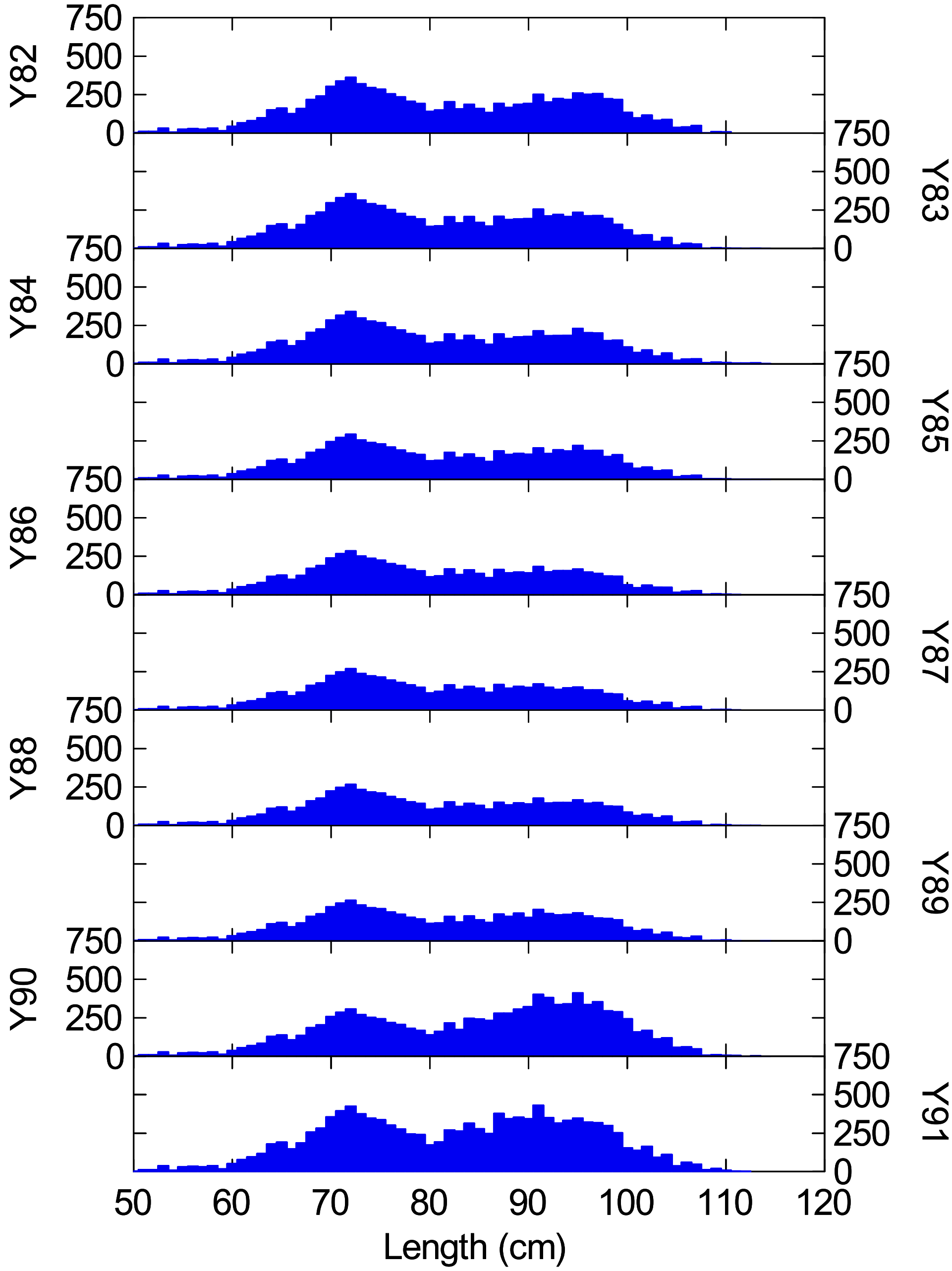


Fig. B4.19. Size frequency distribution of female spiny dogfish landed or assumed to be dead discard in gill net, otter trawl, and recreational fisheries, 1982-1991.

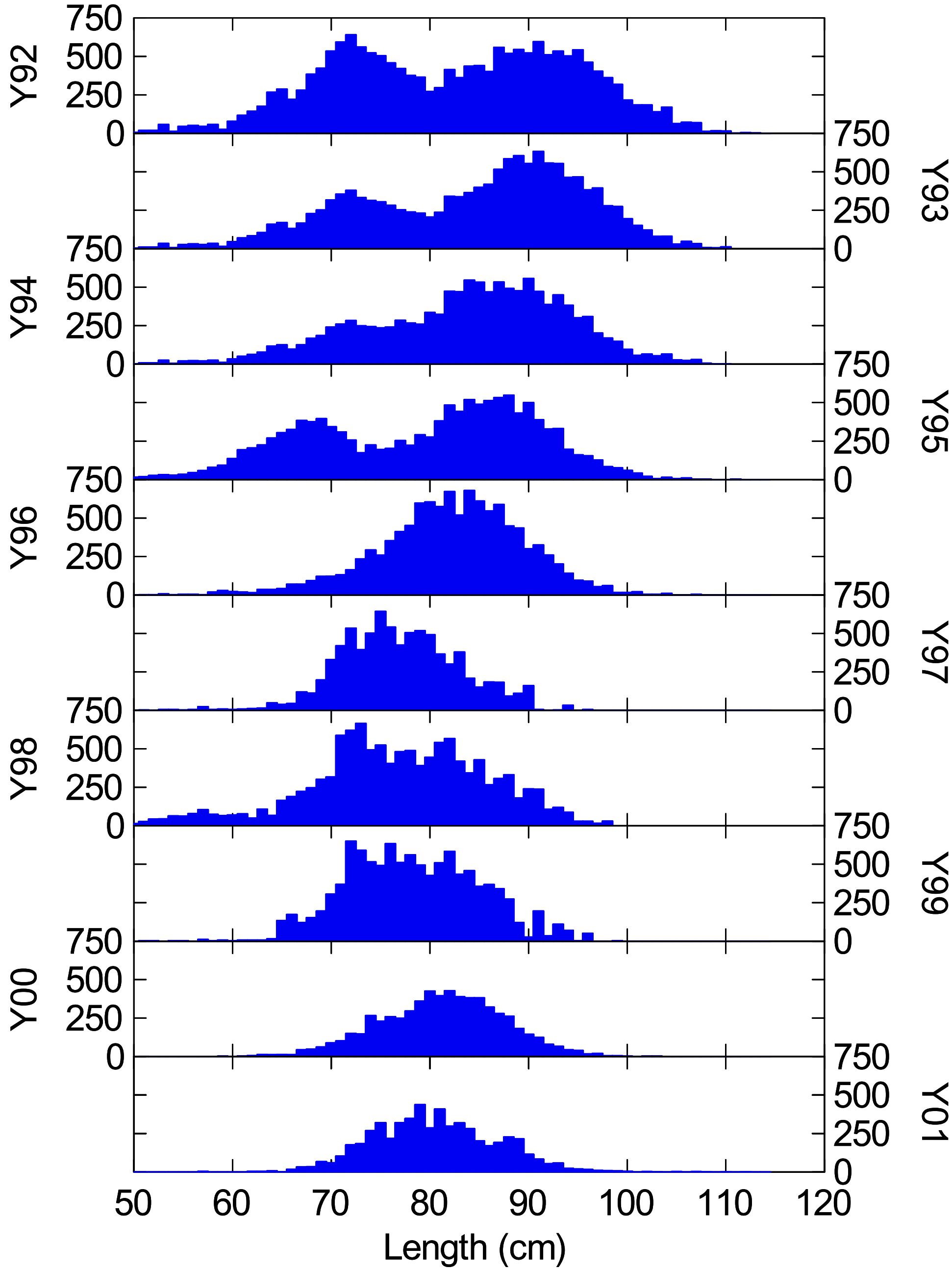


Fig. B4.20. Size frequency distribution of female spiny dogfish landed or assumed to be dead discard in gill net, otter trawl, and recreational fisheries, 1992-2001.

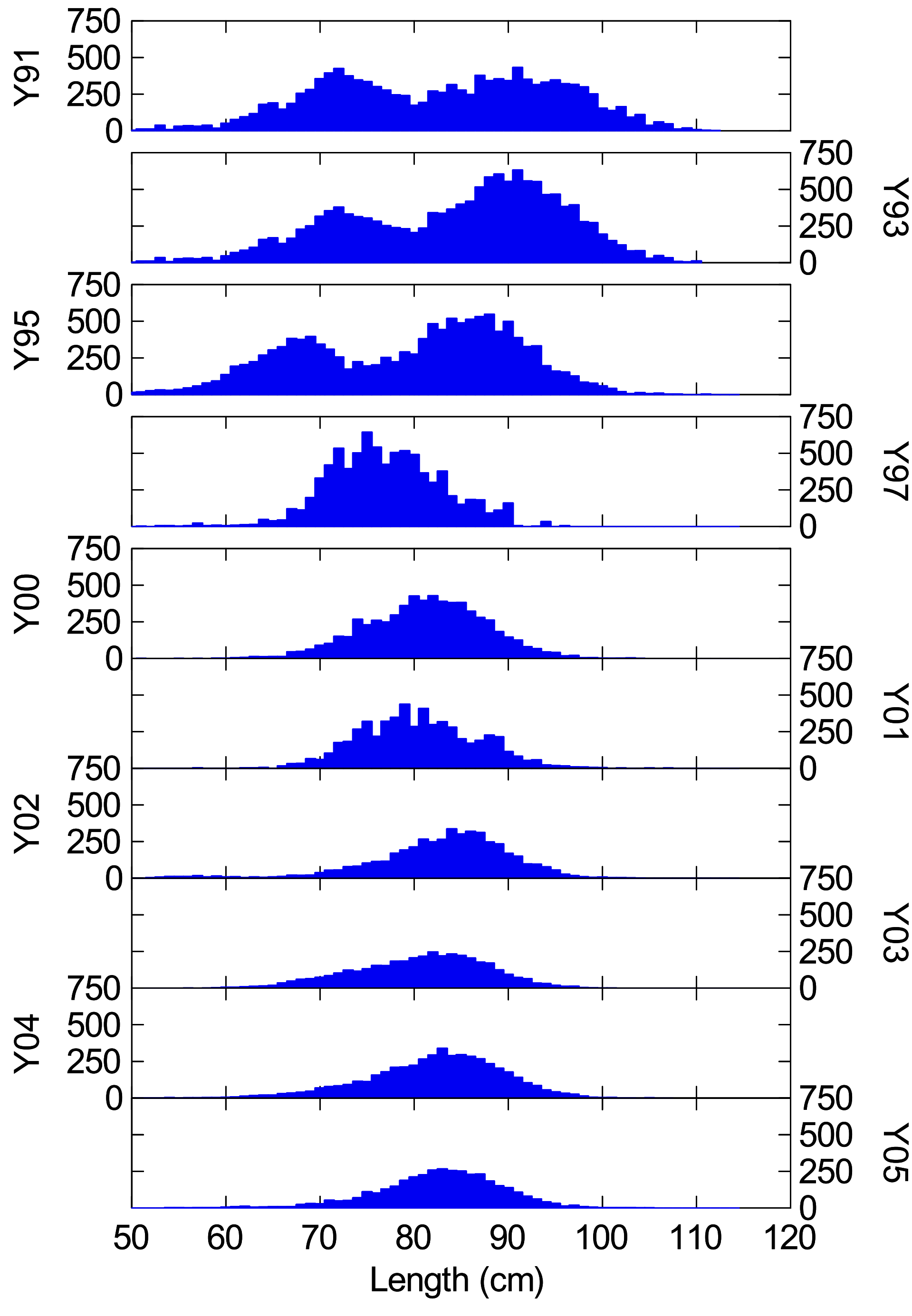


Fig. B4.21. Size frequency distribution of female spiny dogfish landed or assumed to be dead discard in gill net, otter trawl, and recreational fisheries, 1991, 1993, 1995, 1997, 2000-2005.

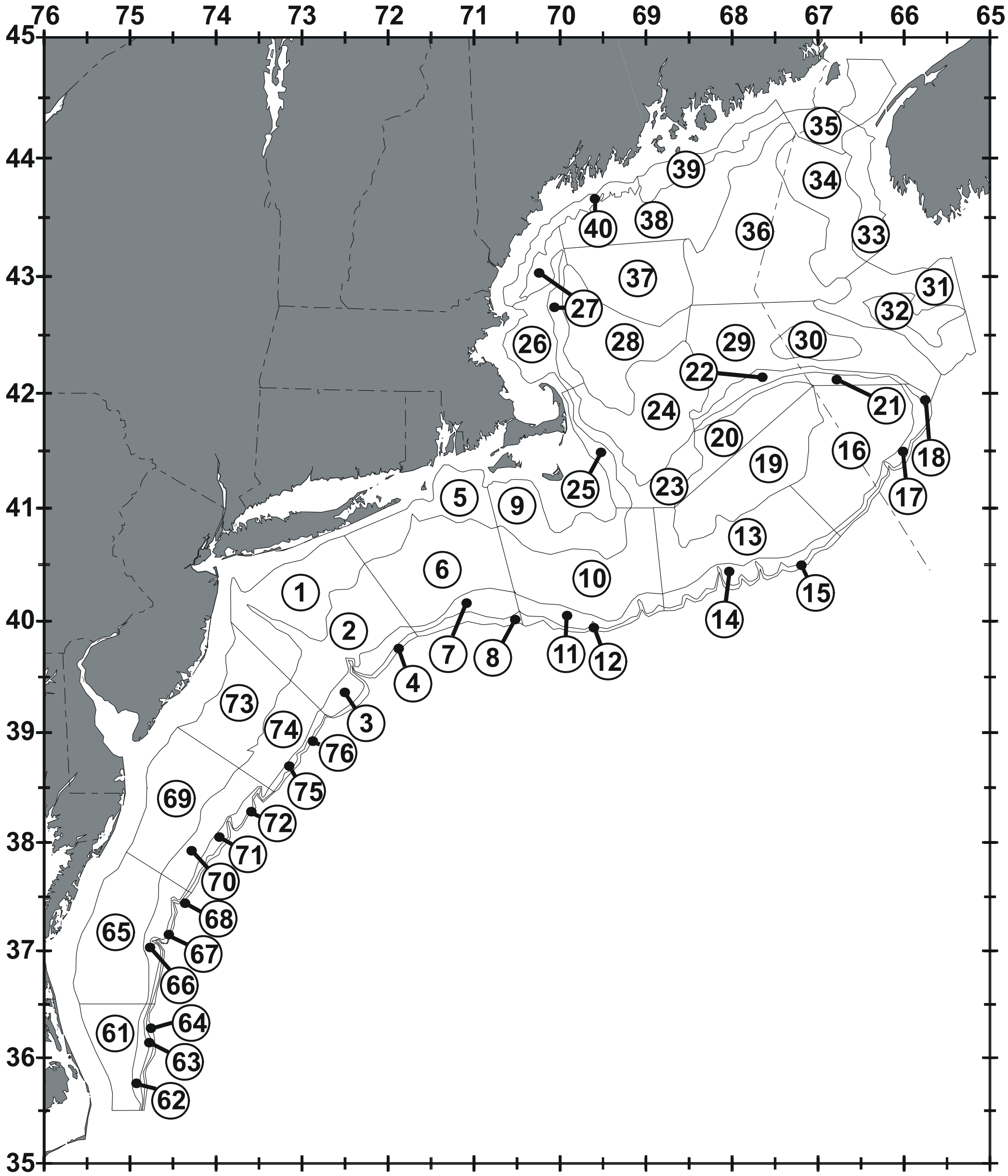


Fig. B5.1. Offshore Sampling strata for NMFS research trawl finfish surveys.

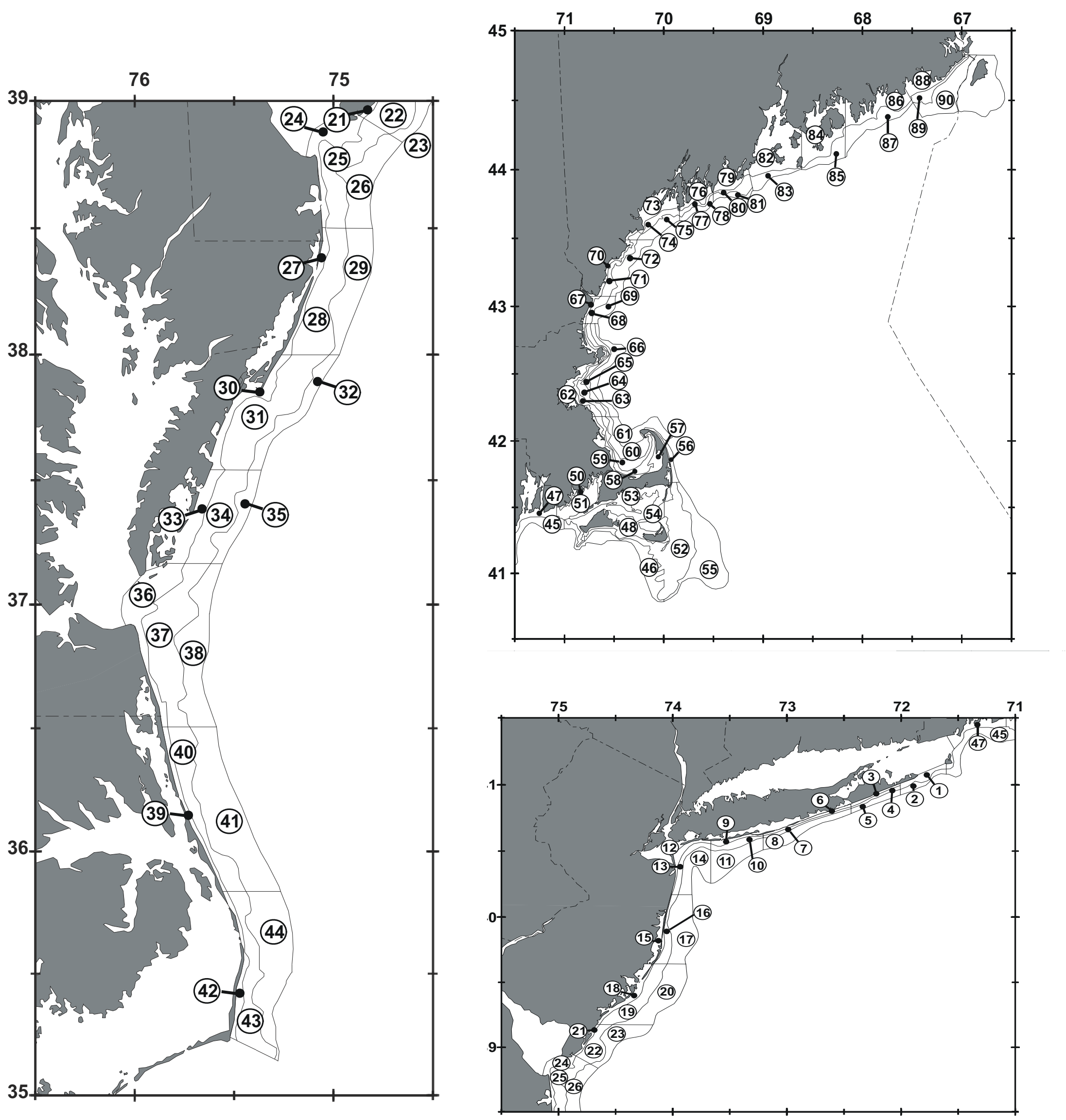


Fig. B5.2. Inshore strata used in NEFSC R/V trawl surveys.

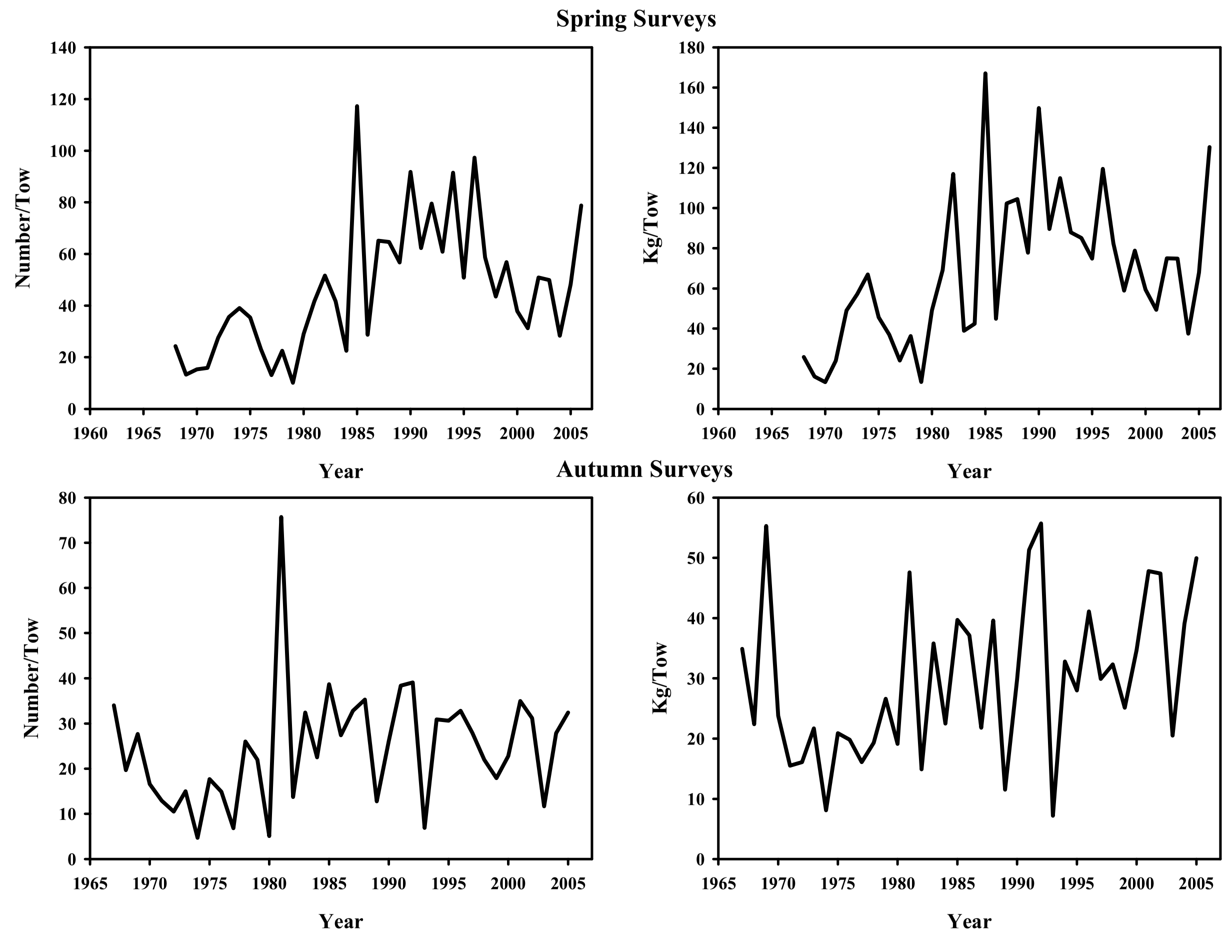


Figure B5.3 Abundance (stratified mean catch per tow in numbers) and biomass (stratified mean catch per tow in kilograms) indices of spiny dogfish from the NEFSC spring survey, 1968-2006, and autumn survey, 1967-2005 (Offshore strata 1-30, 33-40, 61-76).

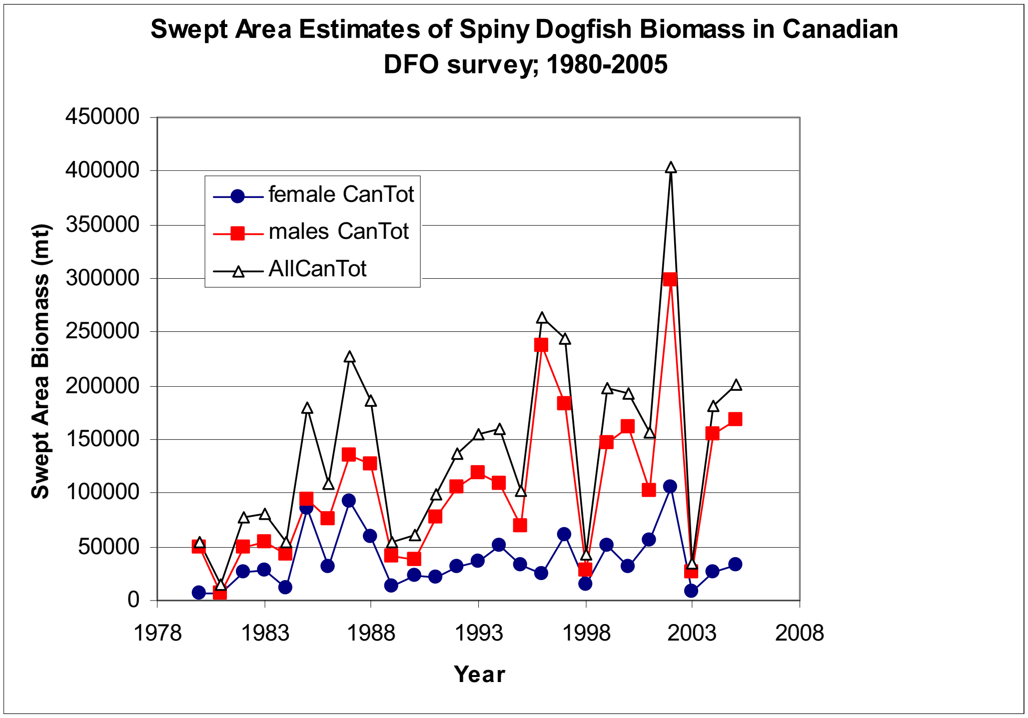
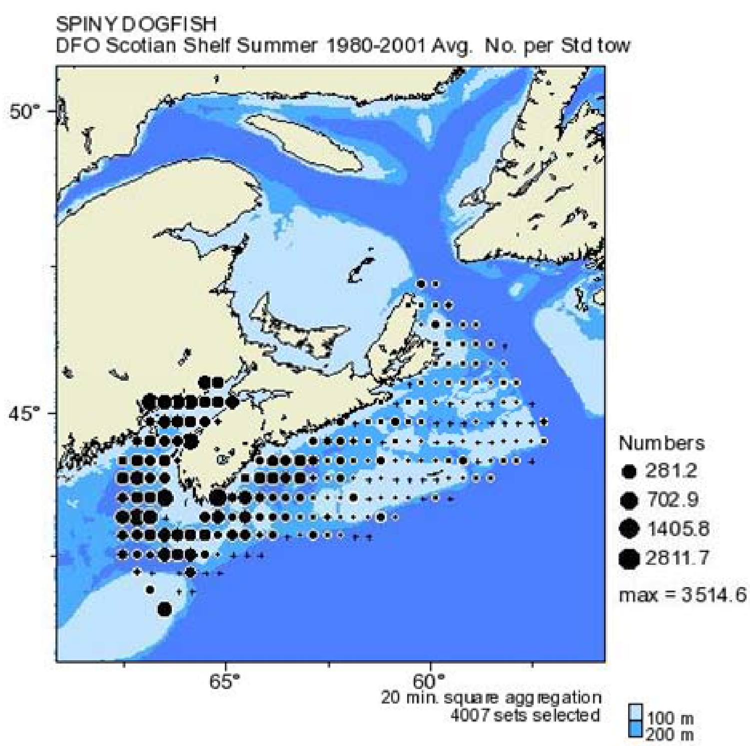


Fig B5.4 Summary of DFO Canadian R/V trawl survey swept area survey estimates (mt), 1980-2005 for males, females and total. Map data express average densities per standard tow, binned at a 20 minute square aggregation. Survey estimates provide courtesy of Bette Hatt and Stratis Gavaris, DFO.



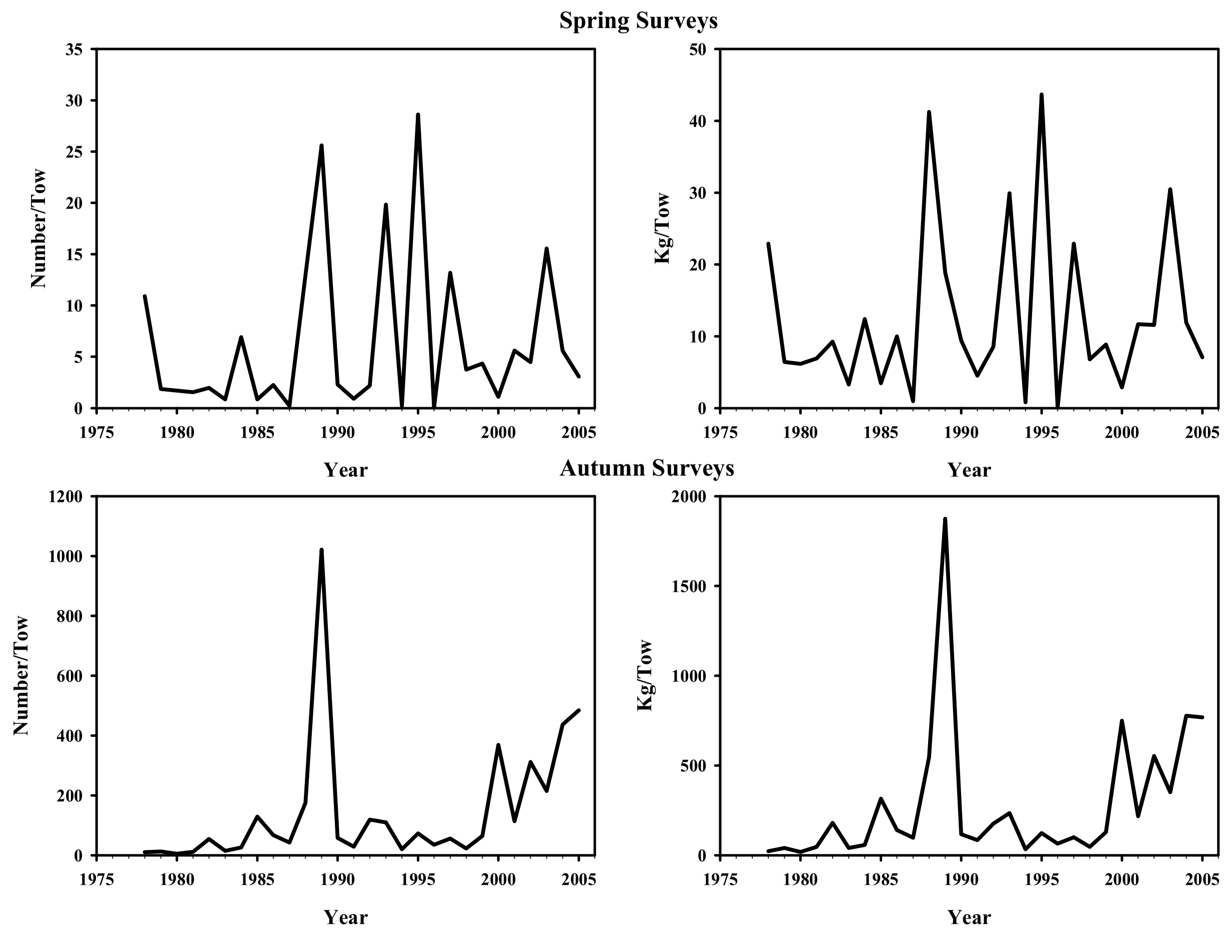


Figure B5.5. Abundance (stratified mean catch per tow in numbers) and biomass (stratified mean catch per tow in kilograms) indices of spiny dogfish from the Massachusetts spring and autumn surveys, 1978-2005.

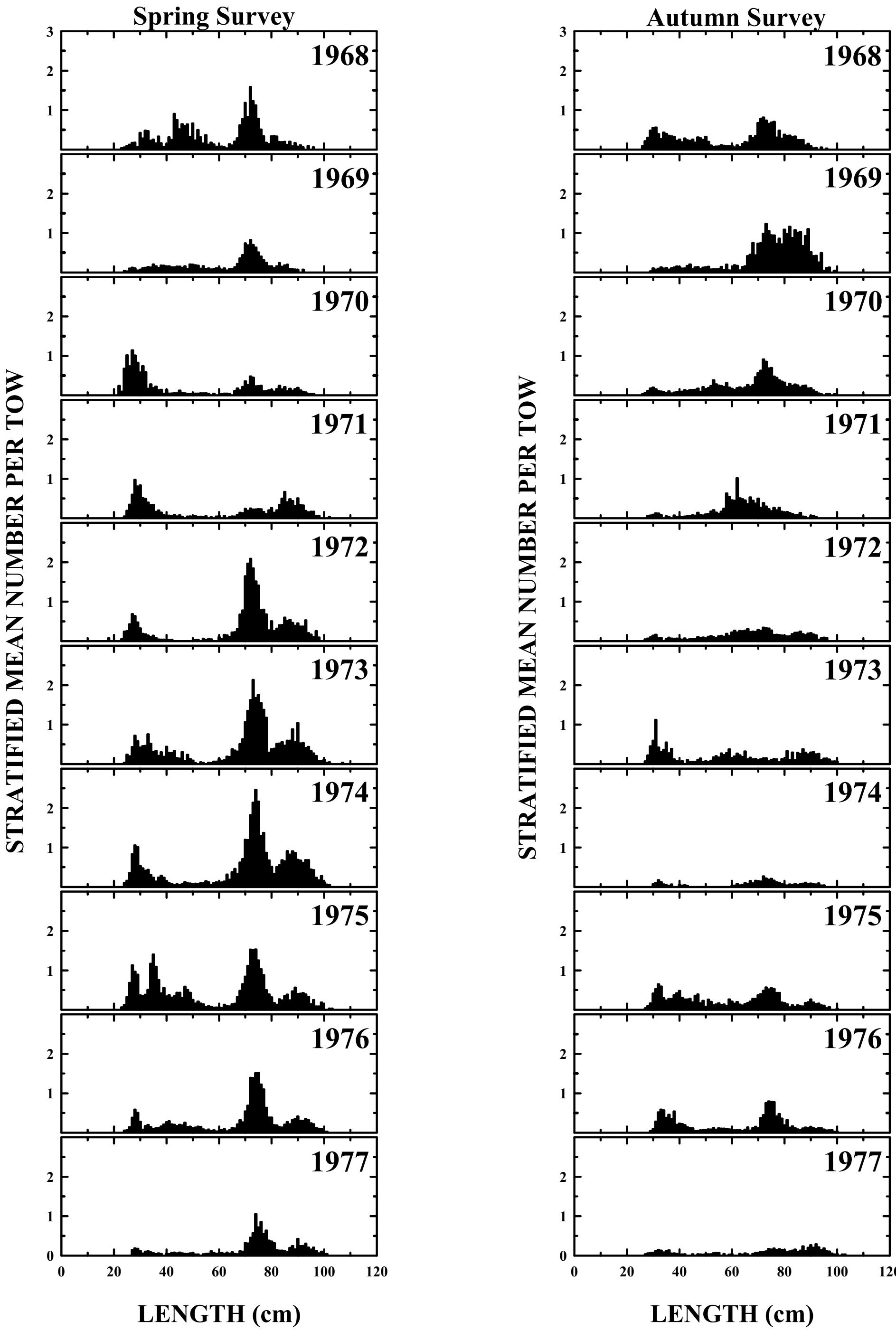


Figure B5.6a. Length composition of spiny dogfish from the NEFSC spring and autumn bottom trawl surveys, 1968-1977 (Offshore strata 1-30, 33-40, 61-76).

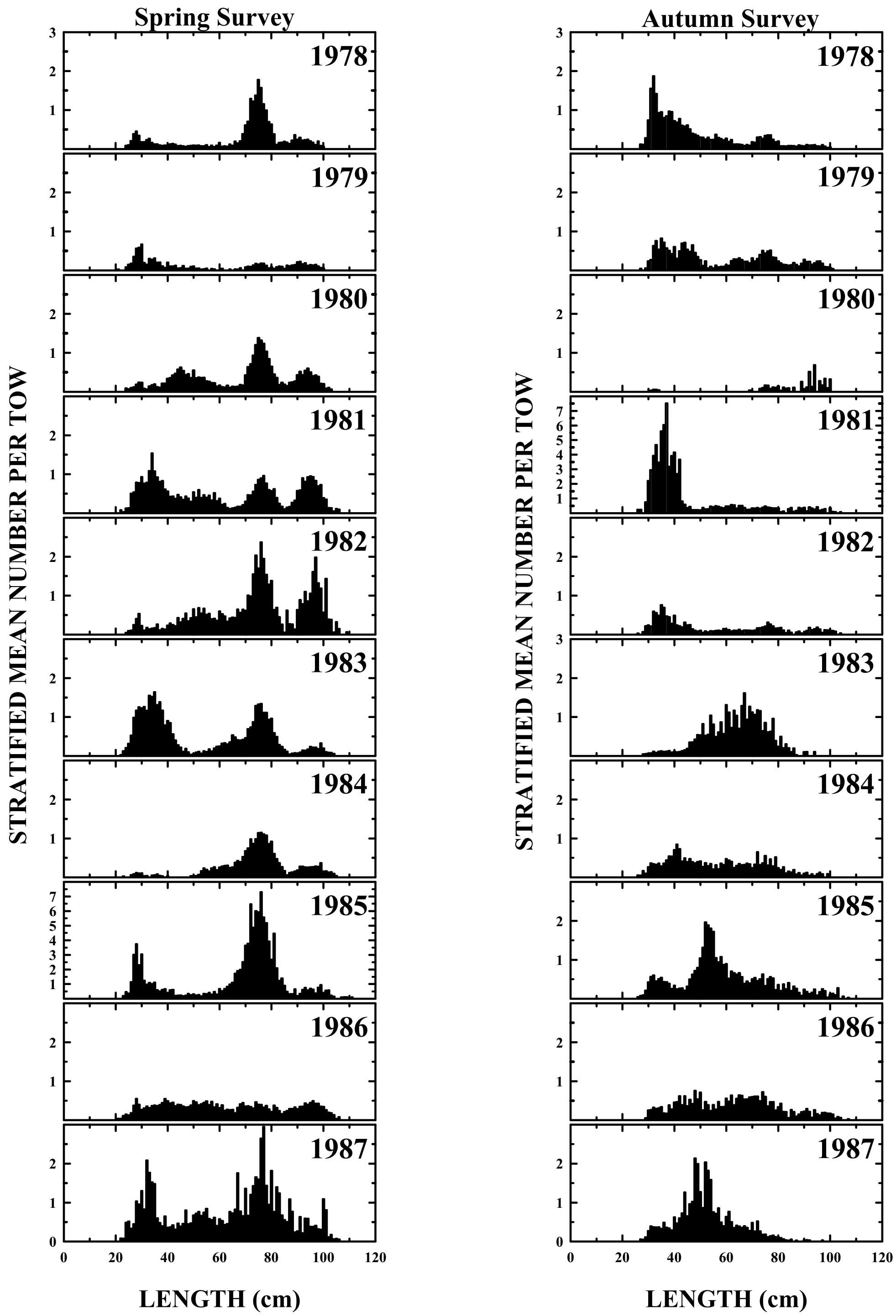


Fig. B5.6b. Length composition of spiny dogfish from the NEFSC spring and autumn bottom trawl surveys, 1978-1987 (Offshore strata 1-30, 33-40, 61-76). Note the scale for spring 1985 and autumn 1981 are higher.

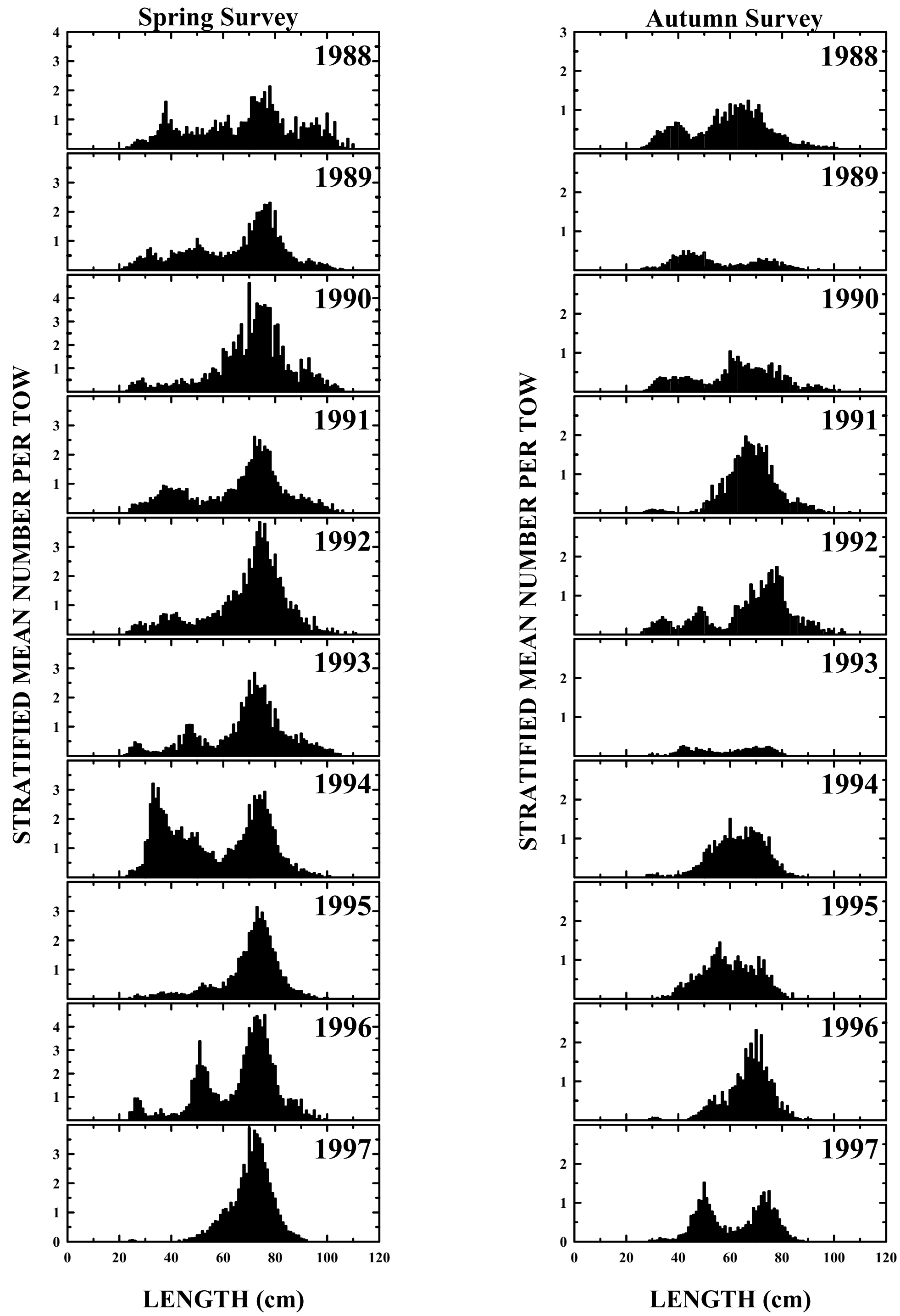


Fig. B5.6c. Length composition of spiny dogfish from the NEFSC spring and autumn bottom trawl surveys, 1988-1997 (Offshore strata 1-30, 33-40, 61-76). Note the scale for spring and autumn differ and spring 1990 and 1996 are also higher.

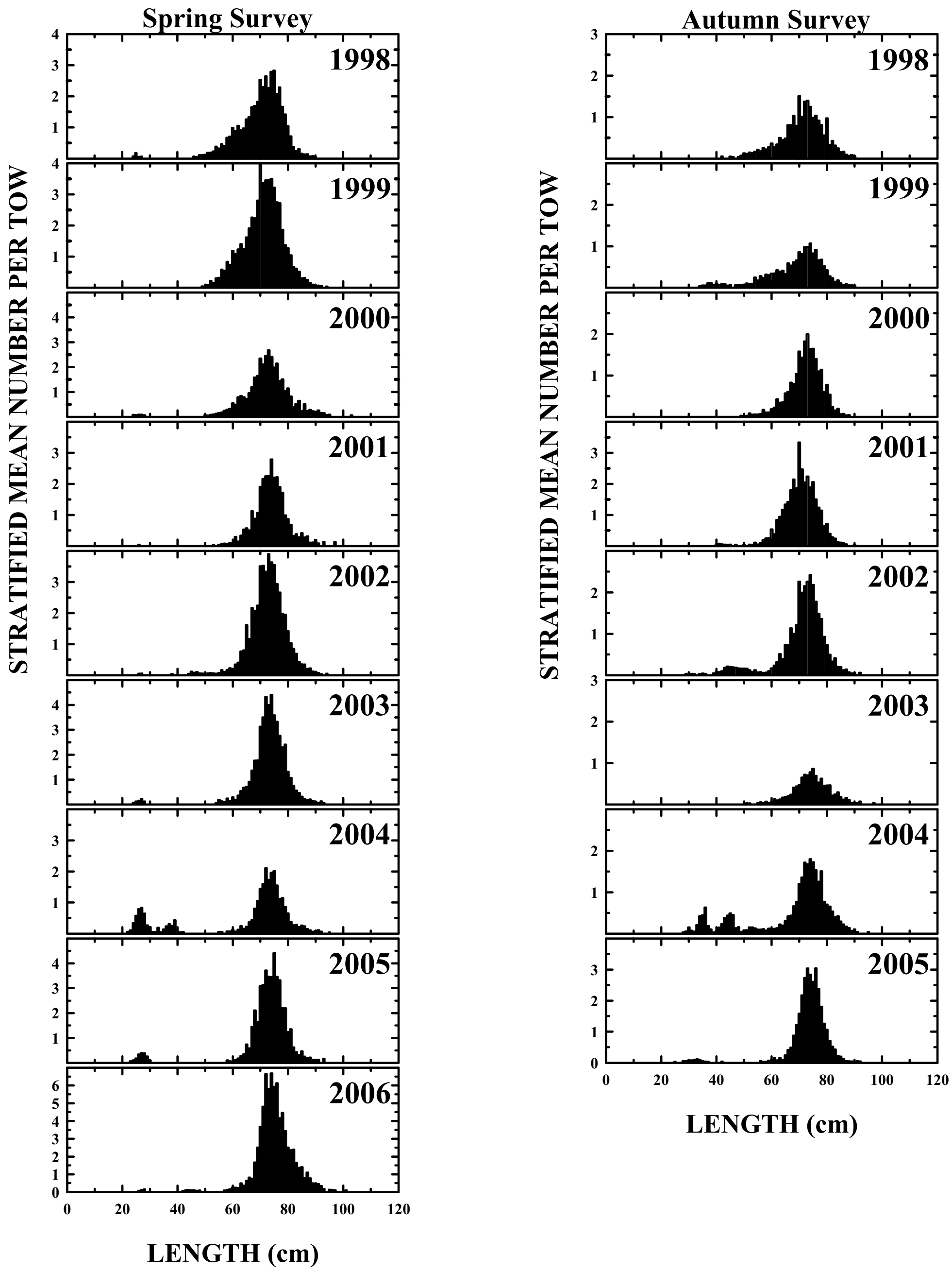


Fig. B5.6d. Length composition of spiny dogfish from the NEFSC spring and autumn bottom trawl surveys, 1998-2006 (Offshore strata 1-30, 33-40, 61-76). Note the scale for spring and autumn differ and spring 2002, 2005, and 2006 and autumn 2001 and 2005 are also different.

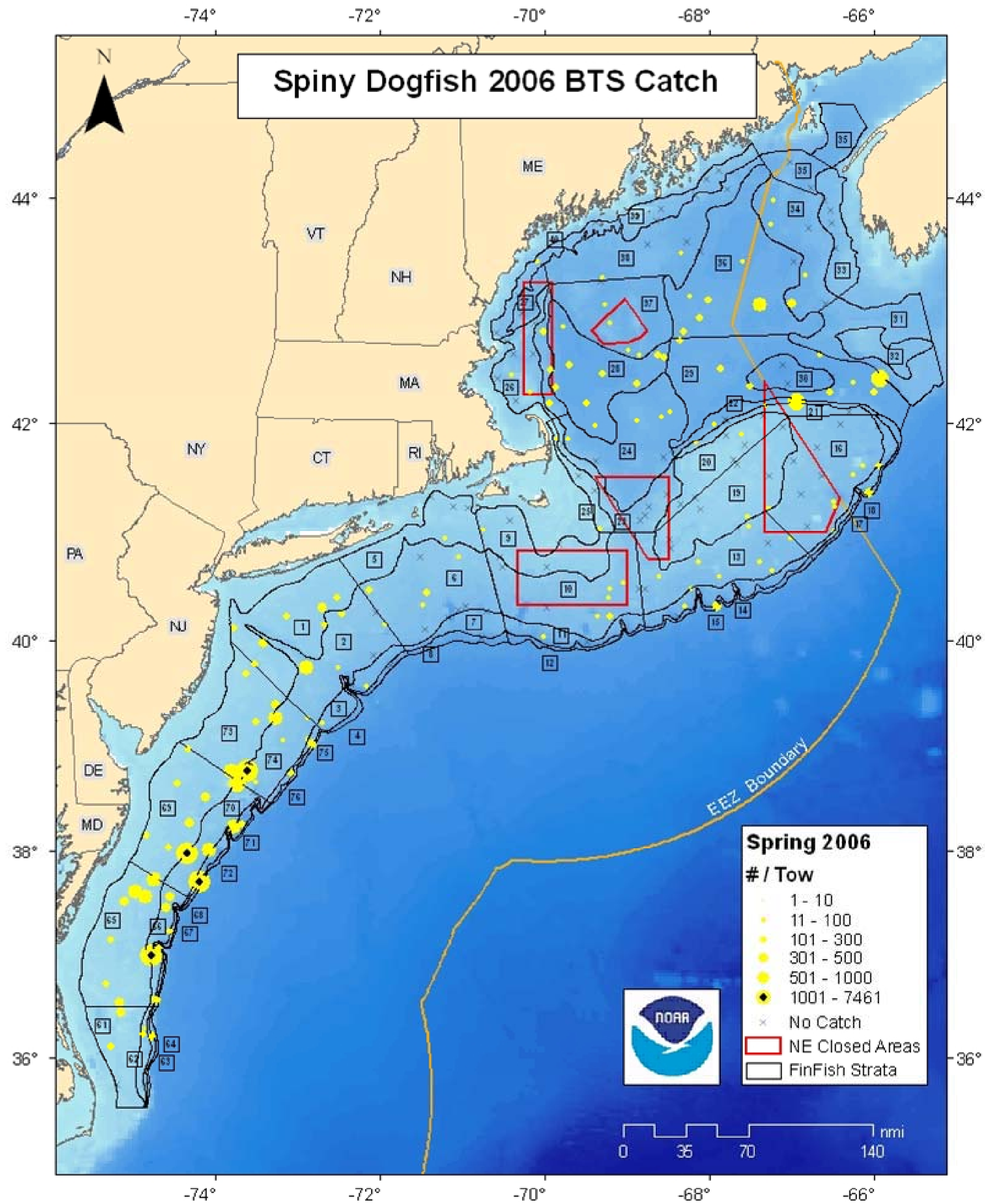


Figure B5.6e. Catch per tow of spiny dogfish, 2006 NEFSC Spring survey.

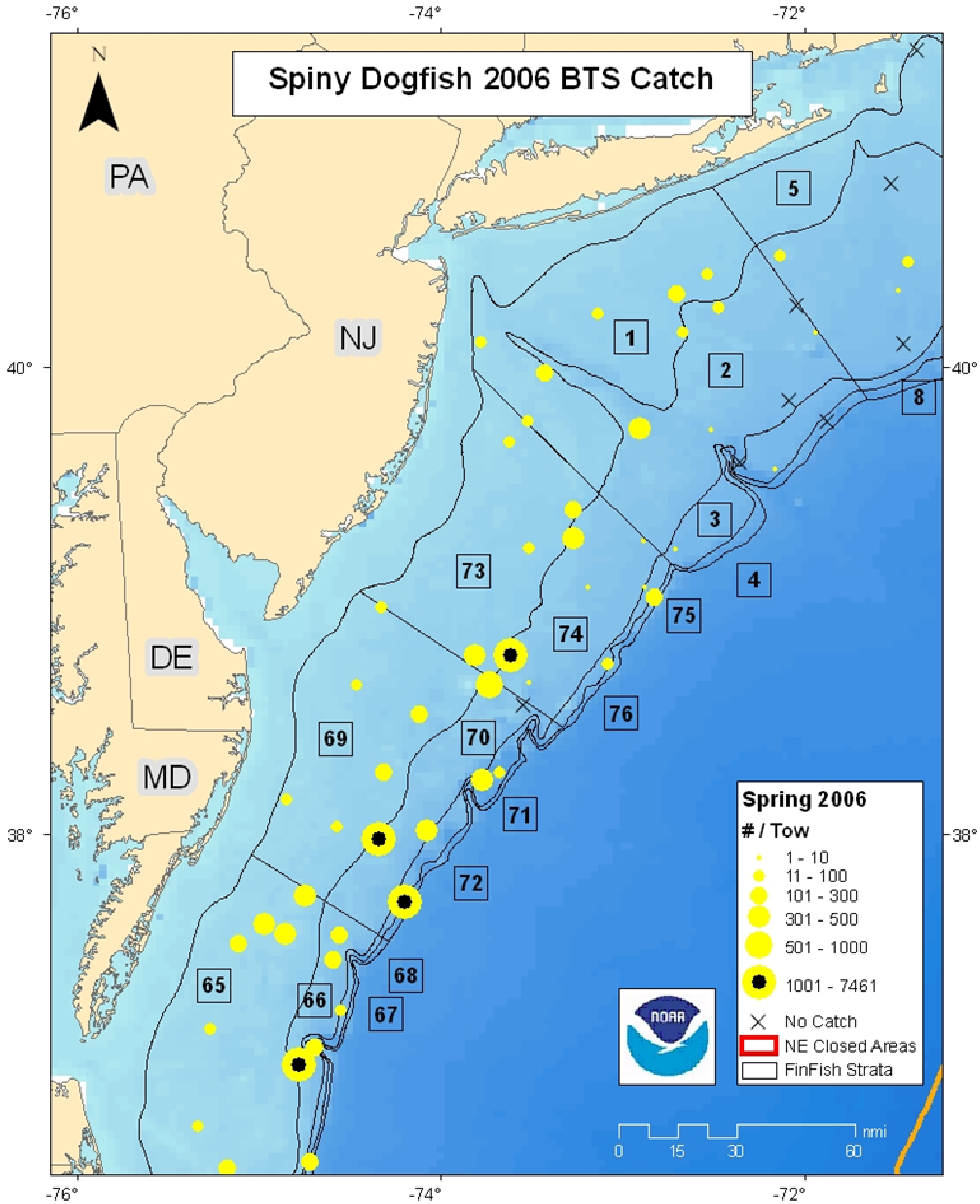


Figure B5.6f. Catch per tow of spiny dogfish, 2006 NEFSC Spring survey.

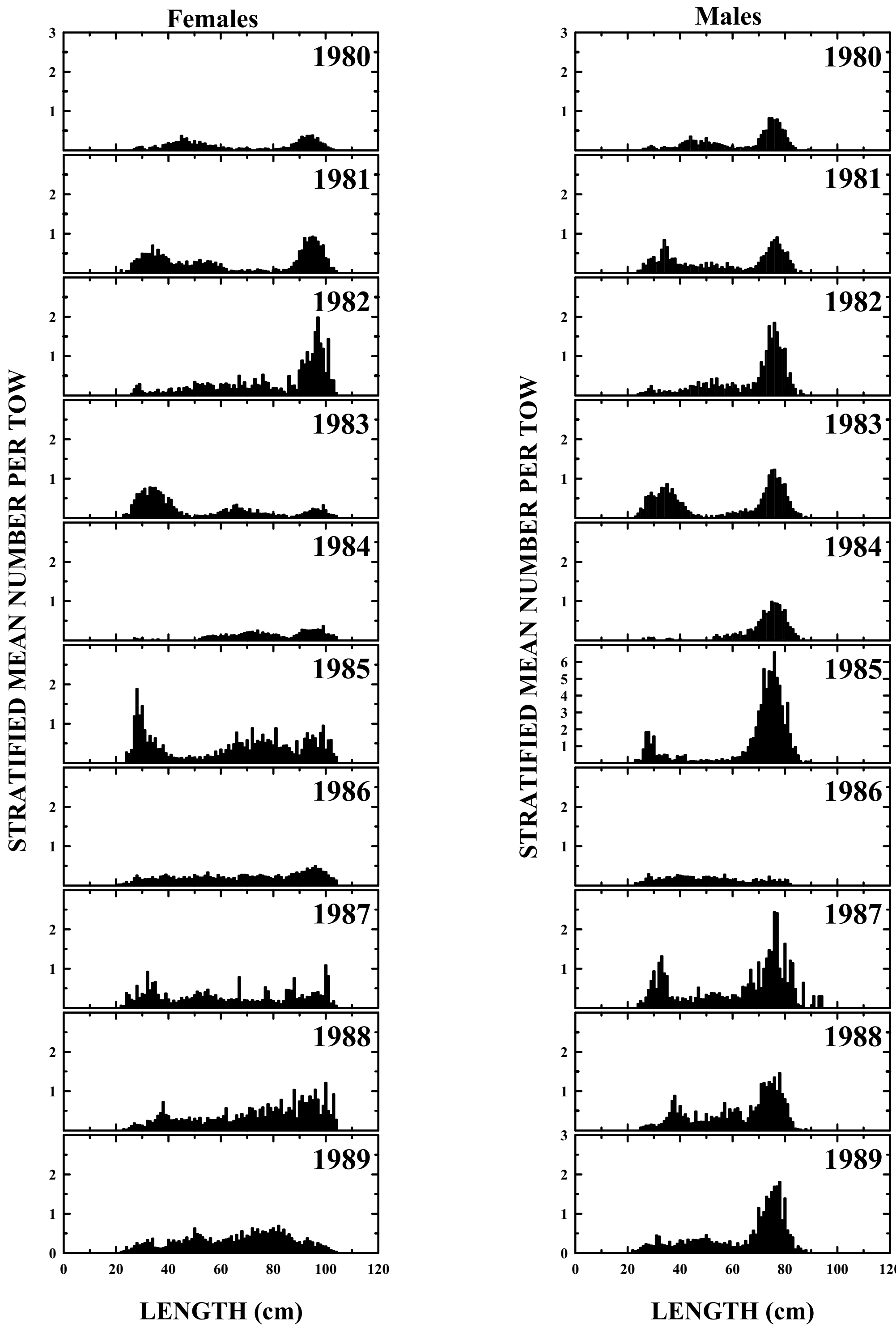


Fig. B5.7a.. Length composition of male and female spiny dogfish from the NEFSC spring bottom trawl surveys, 1980-1989 (Offshore Strata 1-30, 33-40, 61-76). Note the scale for males in 1985 is larger.

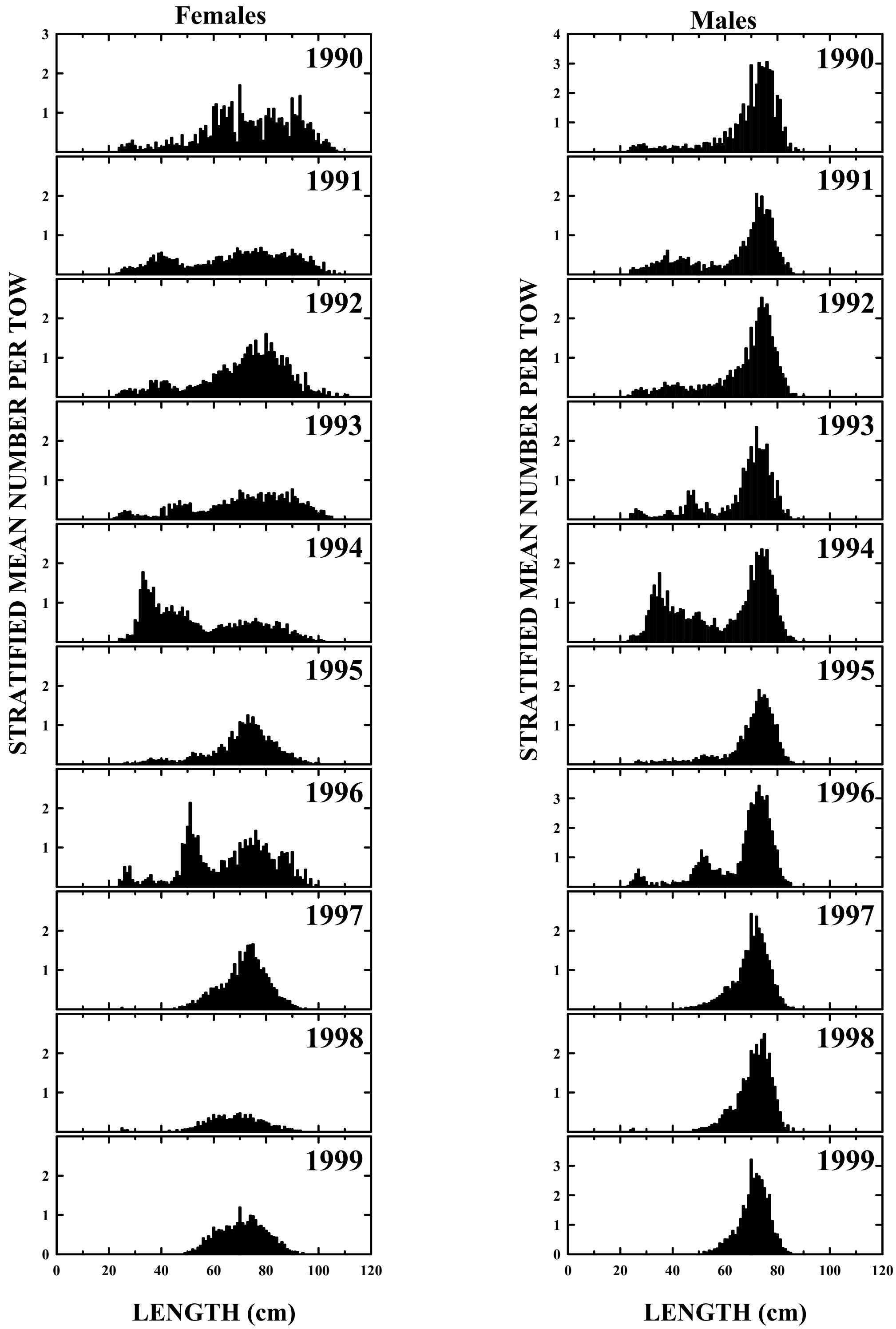


Fig. B5.7b. Length composition of male and female spiny dogfish from the NEFSC spring bottom trawl surveys, 1990-1999 (Offshore Strata 1-30, 33-40, 61-76). Note the scales for males in 1990, 1996, and 1999 are different.

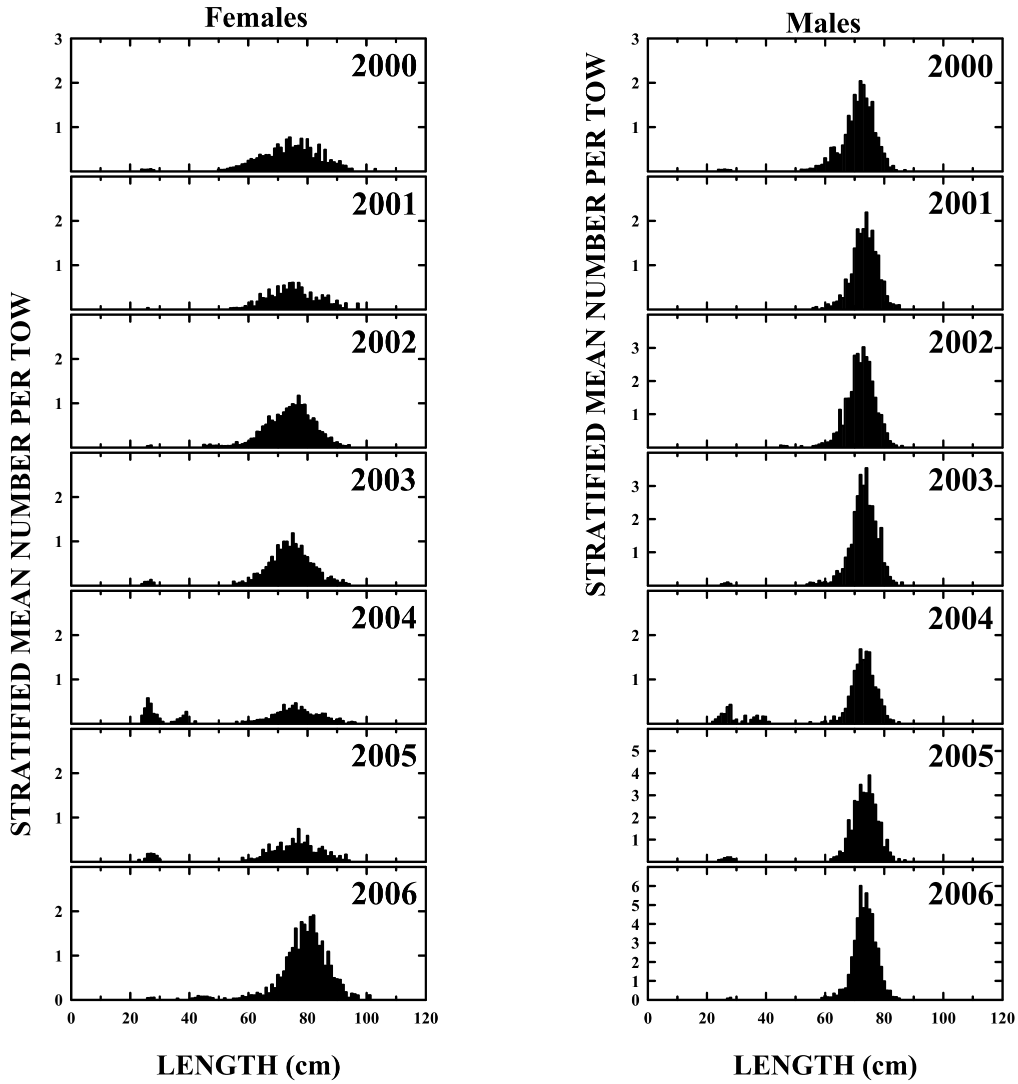


Fig. B5.7c. Length composition of male and female spiny dogfish from the NEFSC spring bottom trawl surveys, 2000-2006 (Offshore Strata 1-30, 33-40, 61-76). Note the scales for males in 2002, 2003, 2005, and 2006 are different.

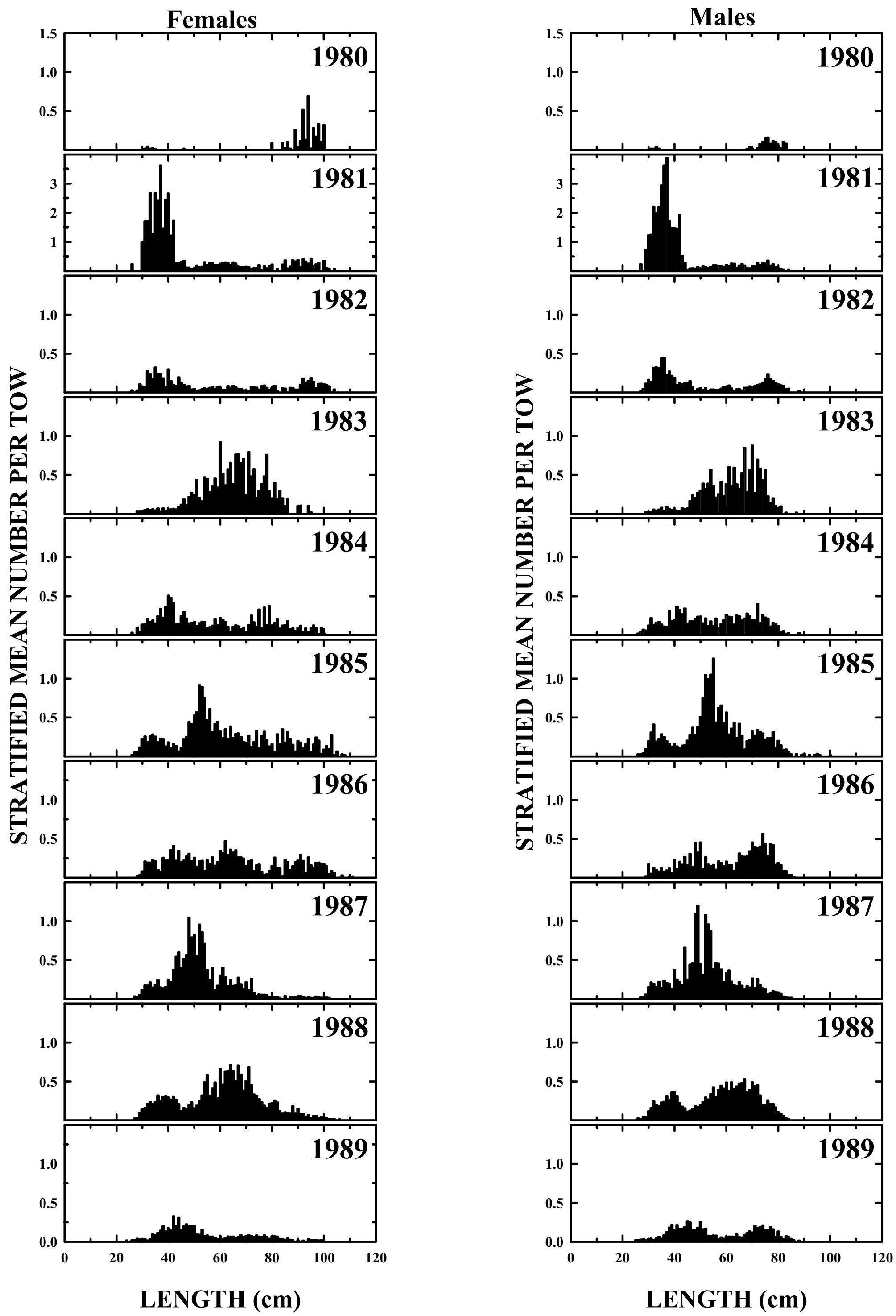


Fig. B5.8a. Length composition of male and female spiny dogfish from the NEFSC autumn bottom trawl surveys, 1980-1989 (Offshore Strata 1-30, 33-40, 61-76). Note the scales in 1981 are larger.

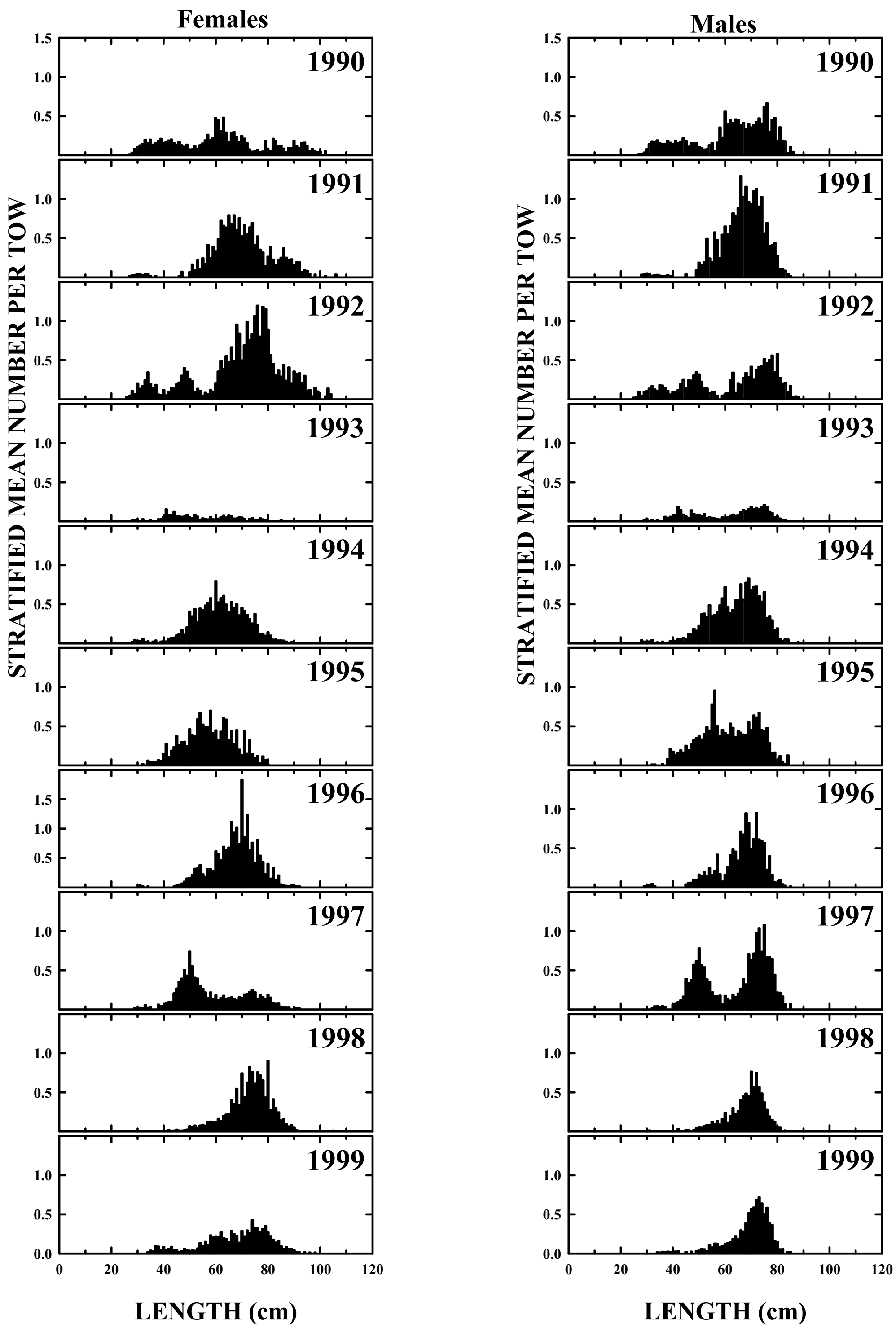


Fig. B5.8b. Length composition of male and female spiny dogfish from the NEFSC autumn bottom trawl surveys, 1990-1999 (Offshore Strata 1-30, 33-40, 61-76). Note the scale for females in 1996 is larger.

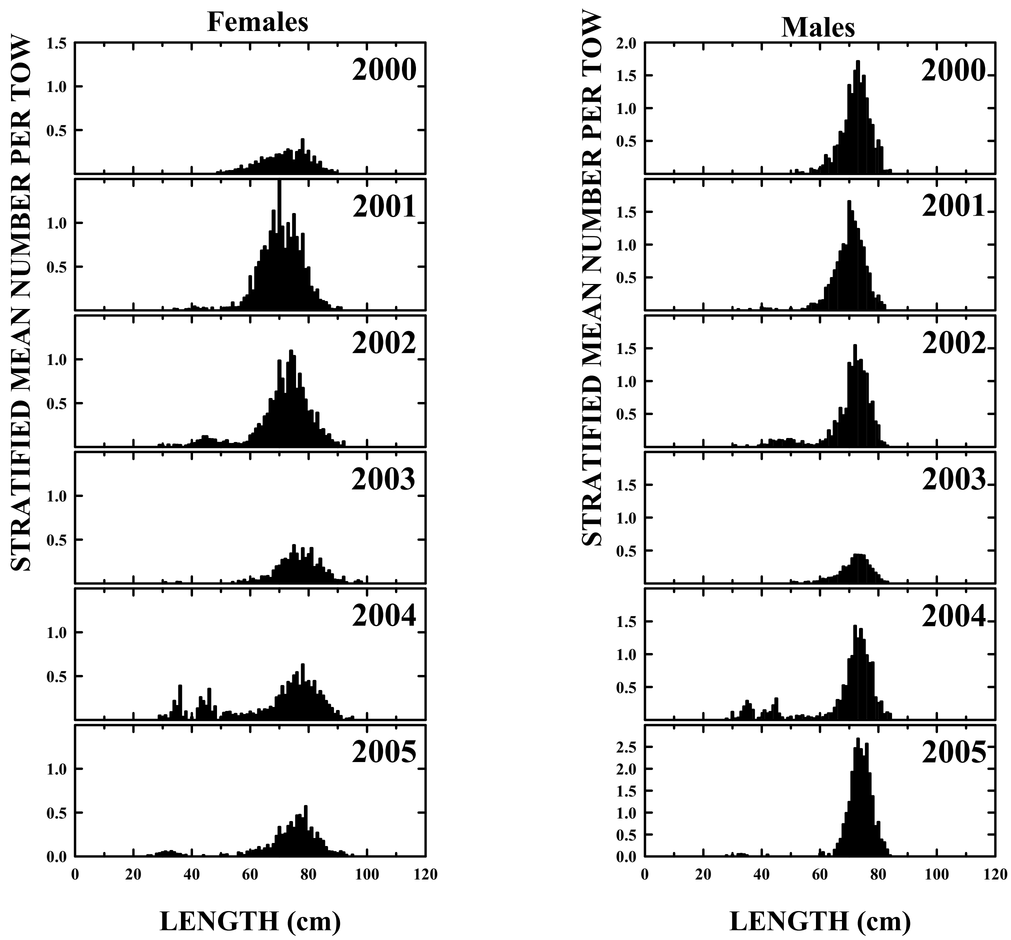


Fig. B5.8c. Length composition of male and female spiny dogfish from the NEFSC spring bottom trawl surveys, 2000-2005 (Offshore Strata 1-30, 33-40, 61-76). Note the scale for males in 2000-2004 is different from previous figures and the scale for males in 2005 is larger.

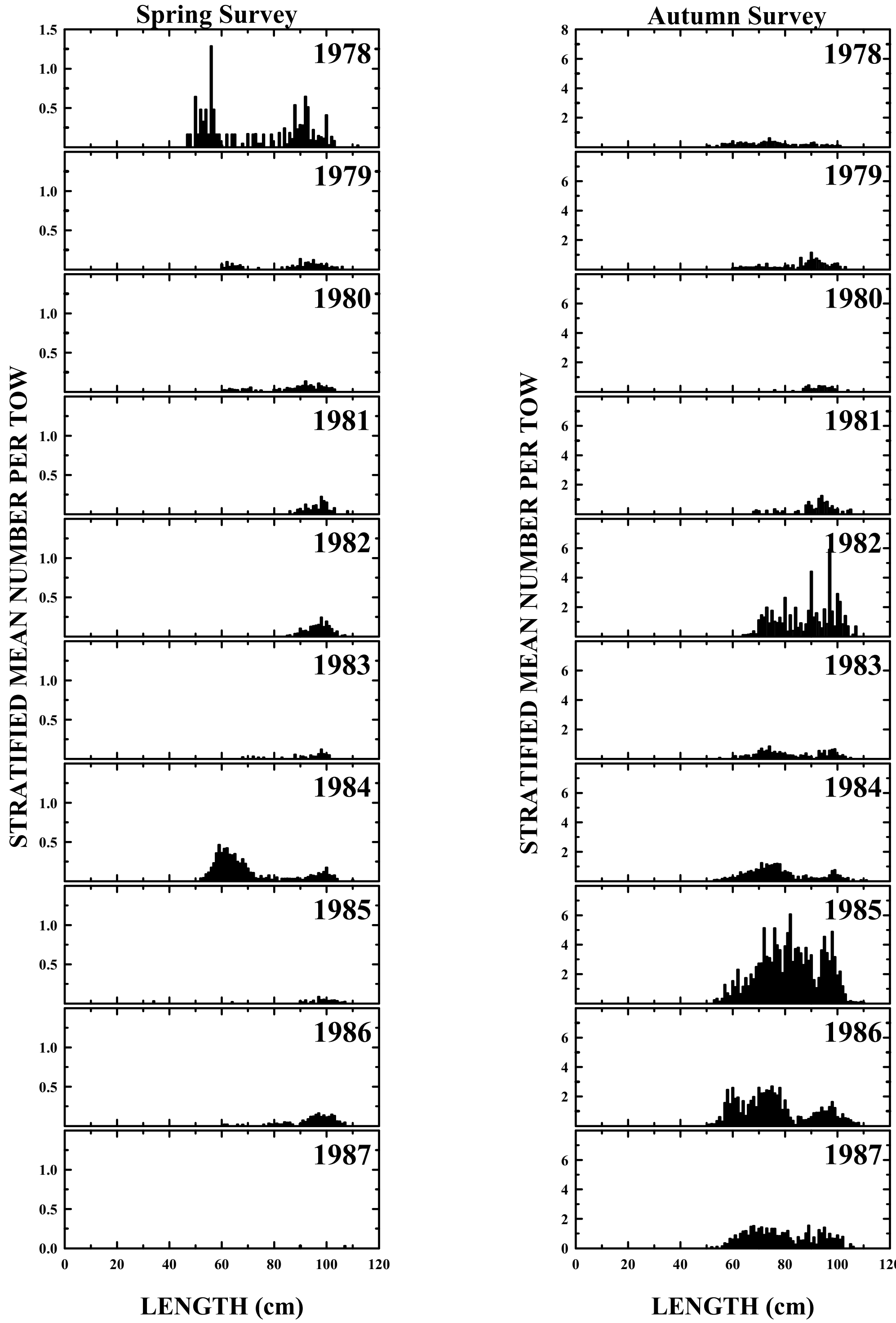


Fig. B5.9a. Length composition of spiny dogfish from the Massachusetts spring and autumn bottom trawl surveys, 1978-1987 Note the scales for Spring and autumn differ.

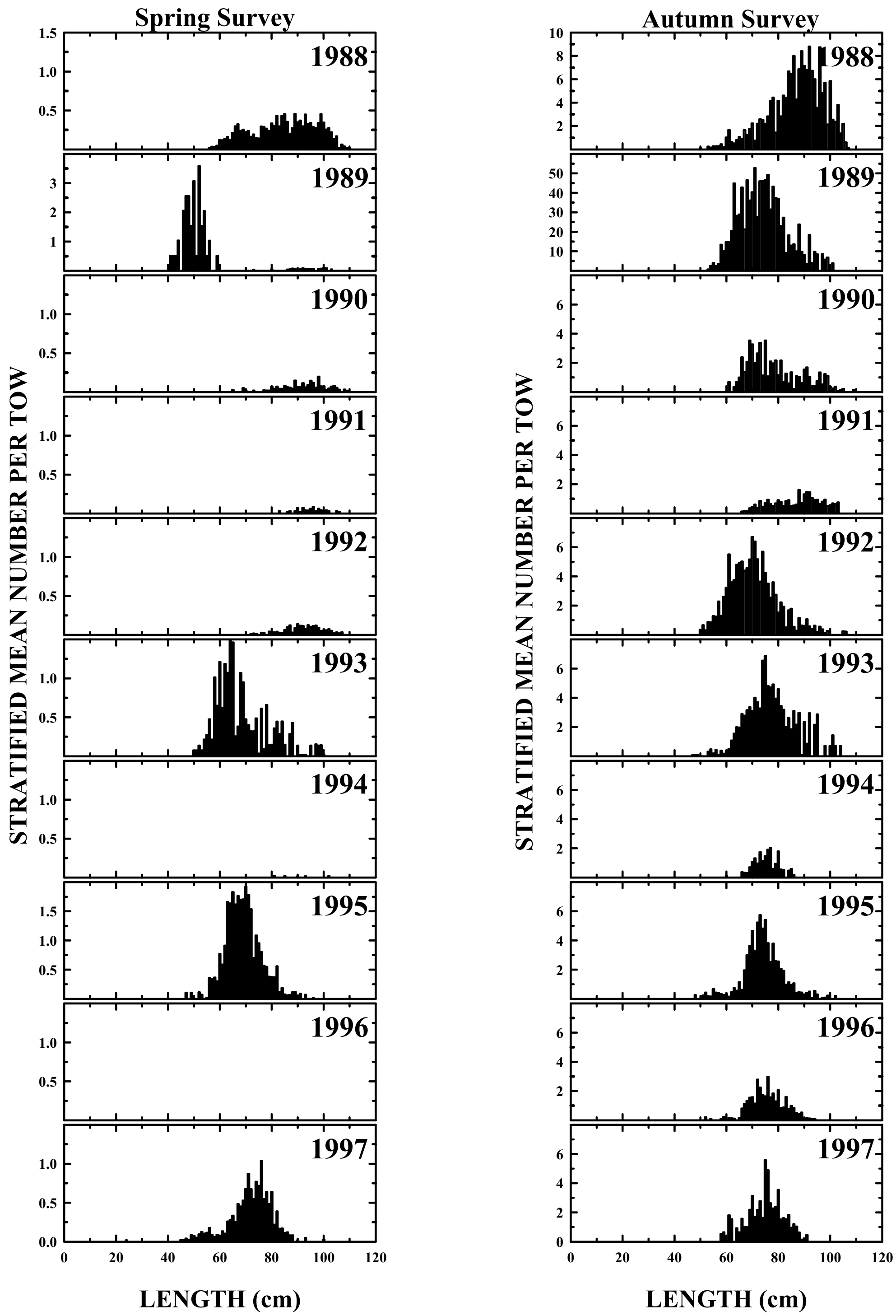


Fig. B5.9b. Length composition of spiny dogfish from the Massachusetts spring and autumn bottom trawl surveys, 1988-1997 Note the scales for spring and autumn differ and spring (1989,1995) and autumn (1988,1989) are also different.

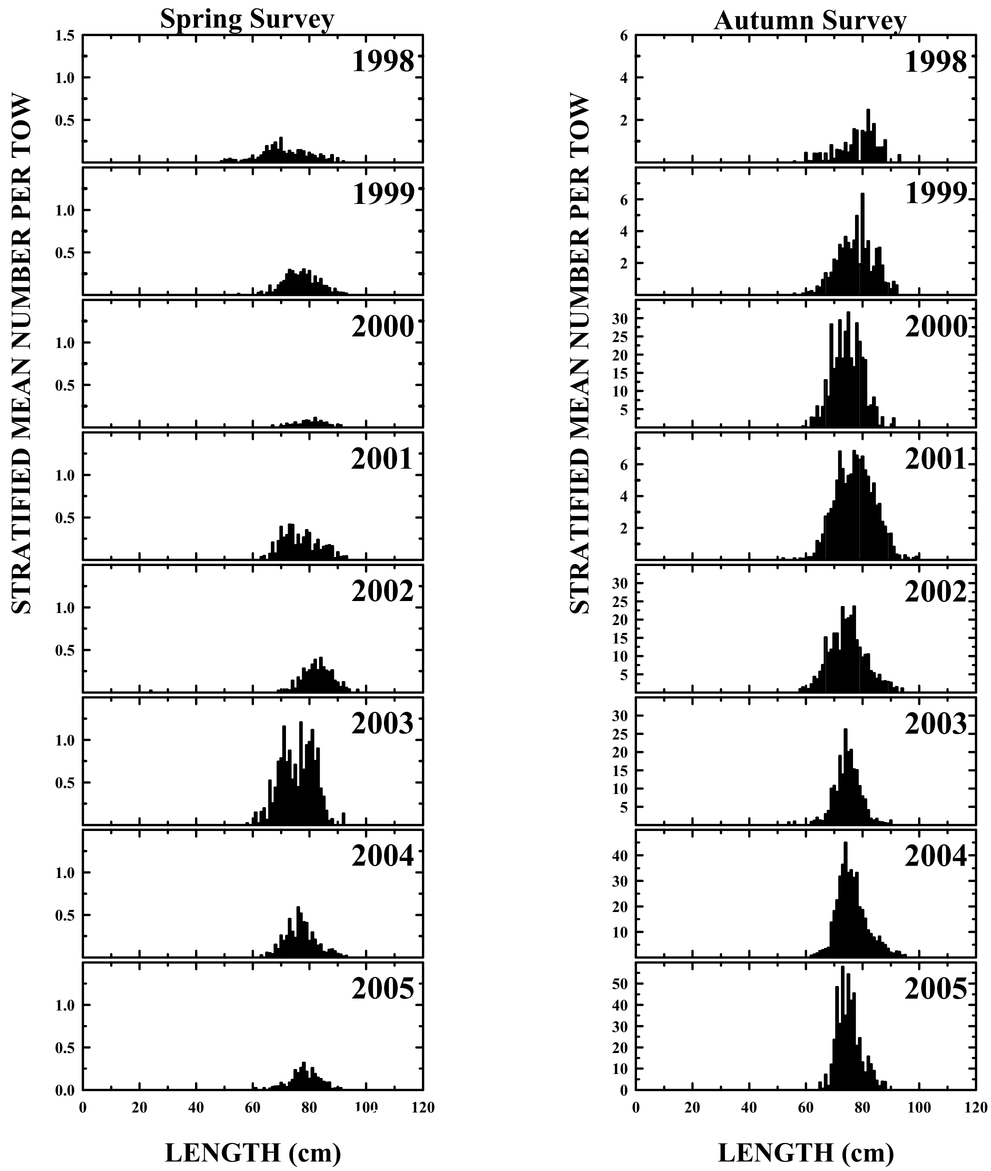


Fig. B5.9c. Length composition of spiny dogfish from the Massachusetts spring and autumn bottom trawl surveys, 1998-2005. Note the scales for spring and autumn differ and note the scale change in autumn 2000 and 2002-2005.

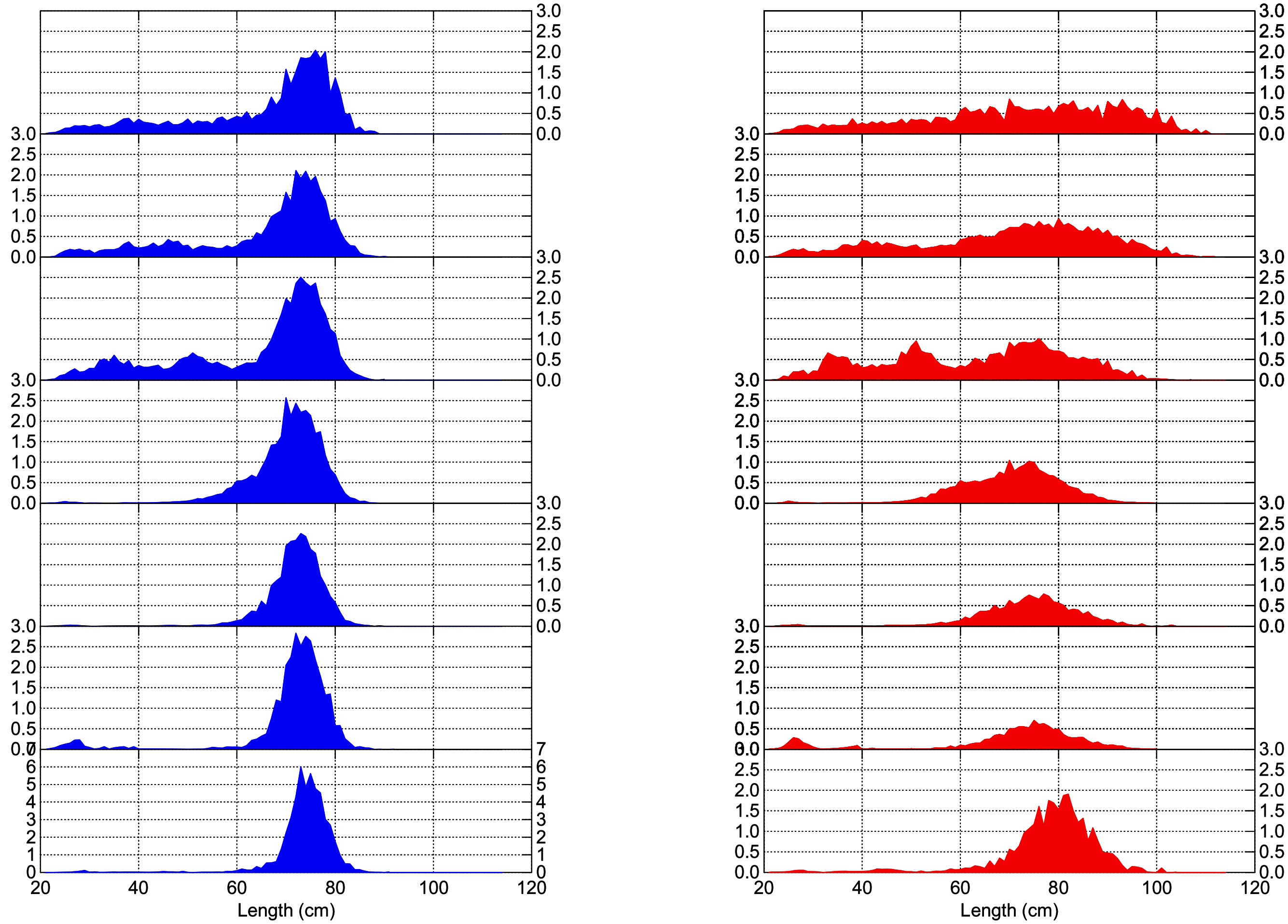


Fig. B5.10 Number of spiny dogfish per tow by 1 cm length class for male (left) and females (right) in NEFSC spring survey by 3-yr period 1988-2005 and for 2006 separately. Note the scale change for males in 2006.

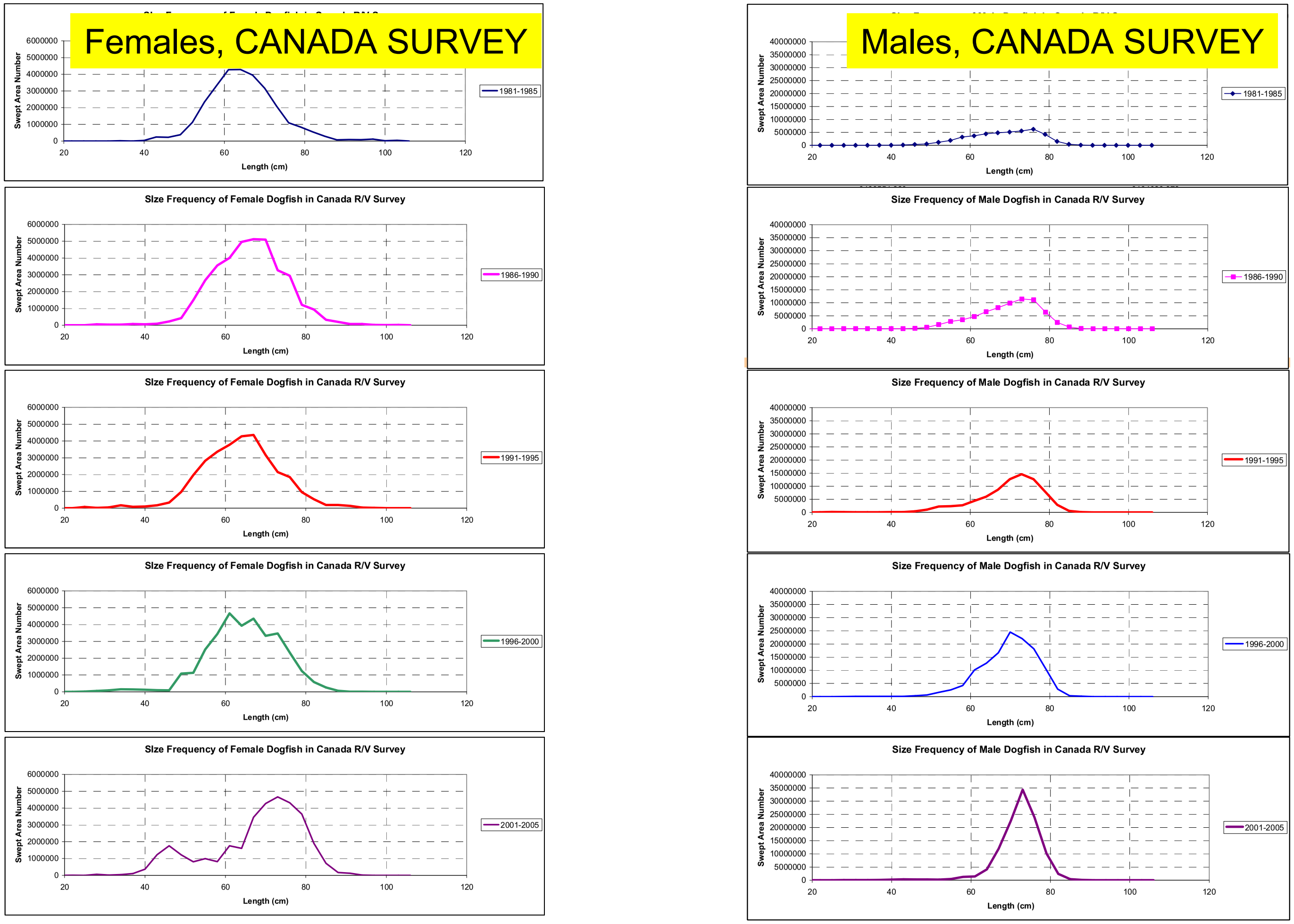


Fig. B5.11 Number of spiny dogfish per tow by 3 cm length class for female (left) and males (right) in DFO summer survey by 5-yr period, 1981-2005.

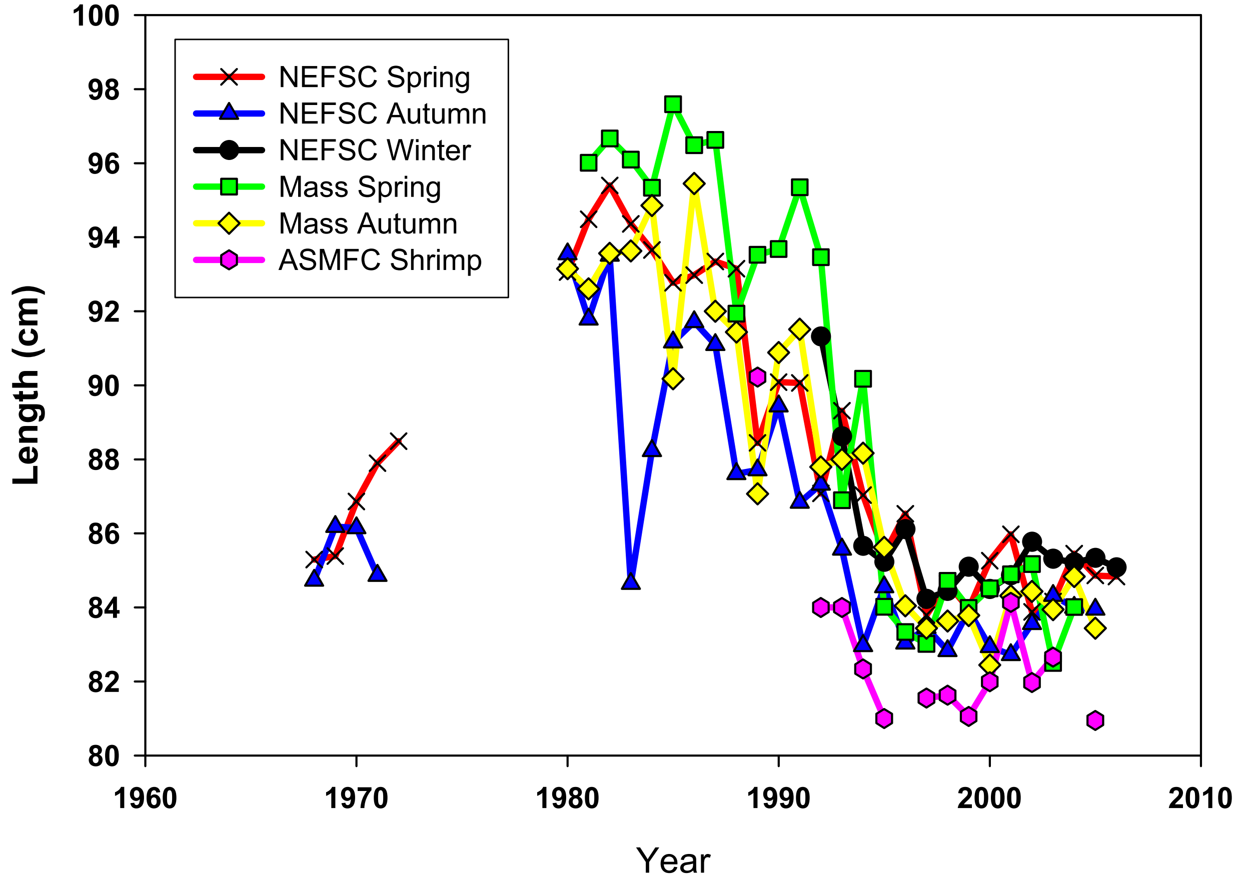


Figure B5.11a. Mean length (cm) of mature spiny dogfish females from NEFSC, Massachusetts and ASMFS shrimp surveys.

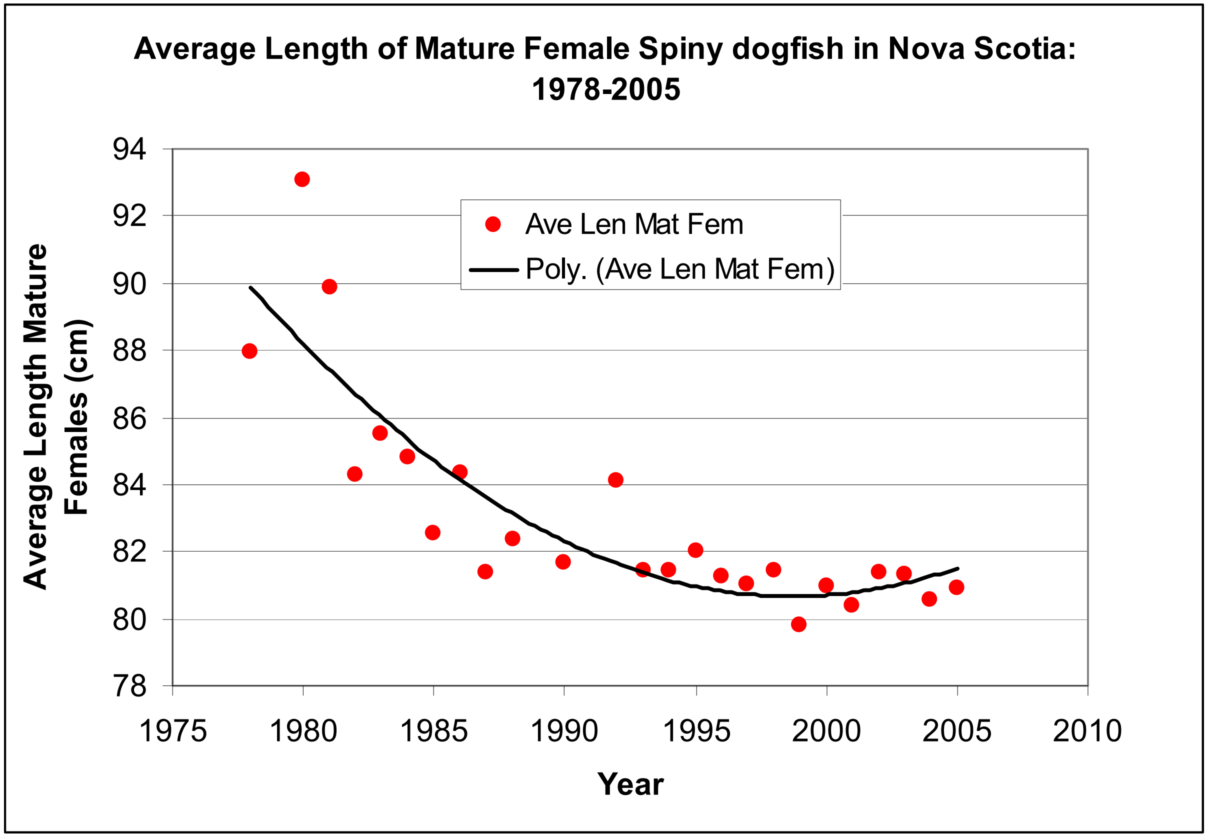


Figure B5.11b. Mean length (cm) of mature spiny dogfish females in DFO Summer R/V trawl survey in NAFO areas 4VWX.

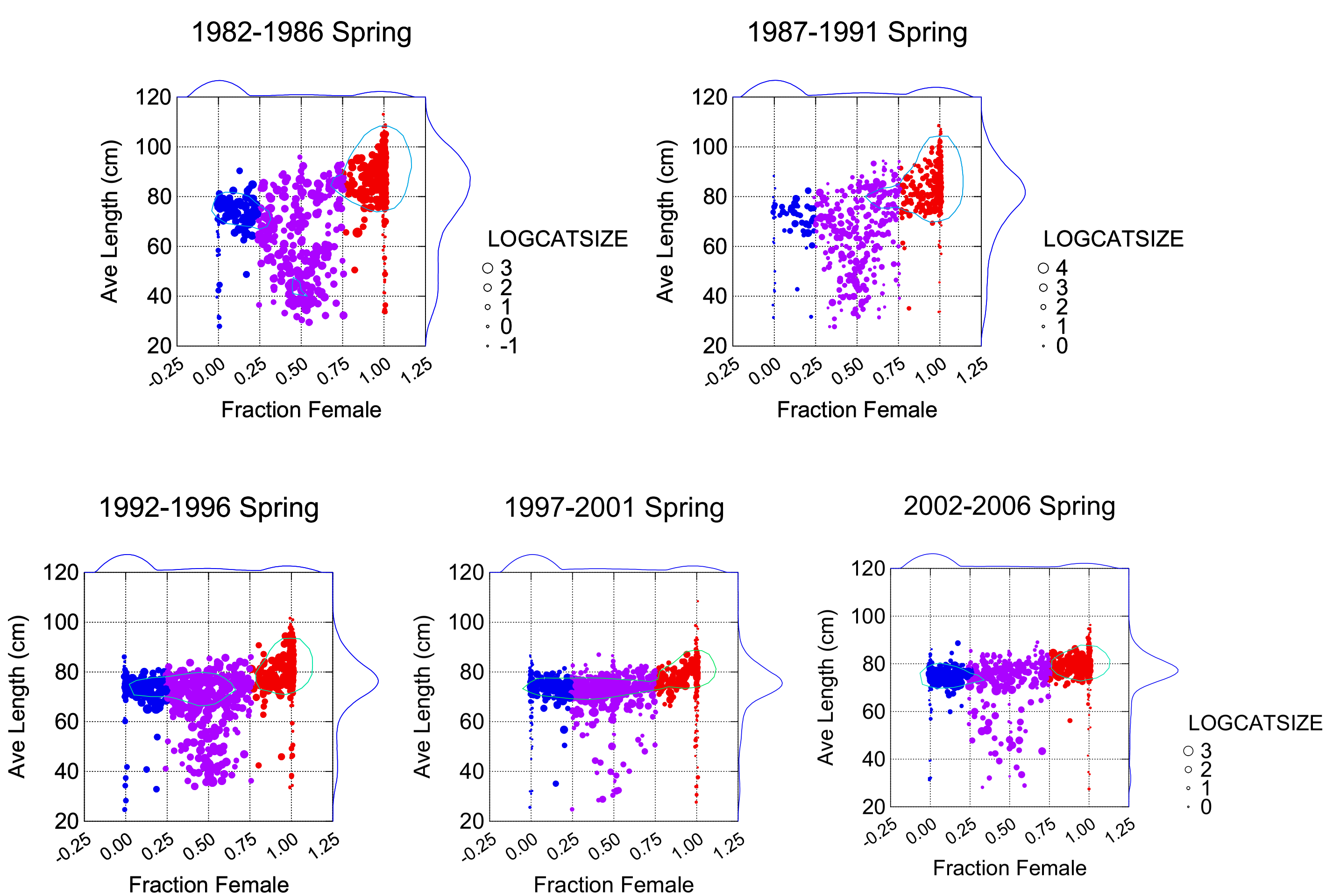


Fig B5.12. Trend in average size and sex ratio of dogfish caught in NEFSC spring trawl survey, 1982-2006. Dots represent individual tows and are scaled relative to total catch weight. Nonparametric kernels are used to describe the marginal and joint densities. Inshore and offshore strata are combined.

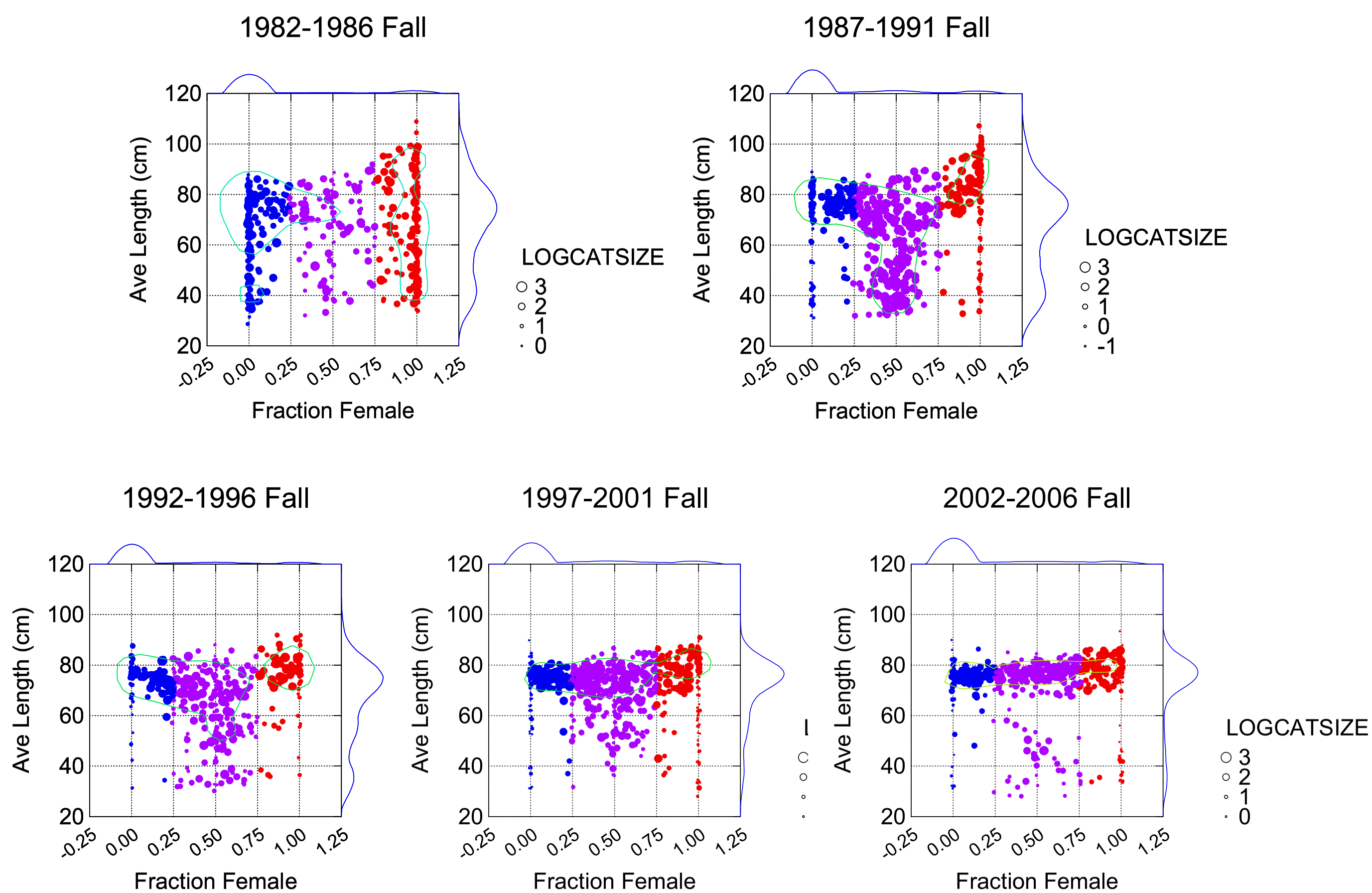


Fig B5.13 Trend in average size and sex ratio of dogfish caught in NEFSC fall trawl survey, 1982-2005. Dots represent individual tows and are scaled relative to total catch weight. Nonparametric kernels are used to describe the marginal and joint densities. Inshore and offshore strata are combined.

Mature Male to Female Ratio, Spring Survey, 1980-2006

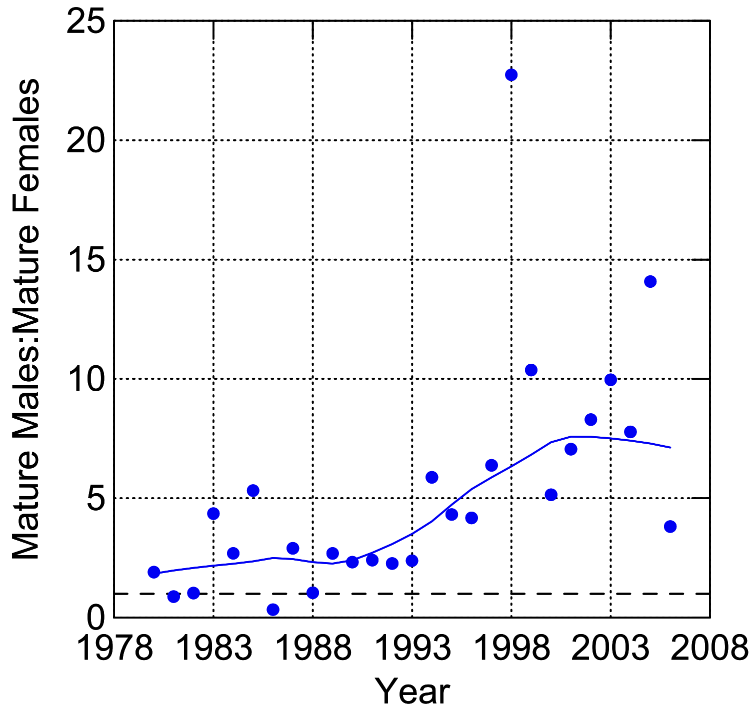
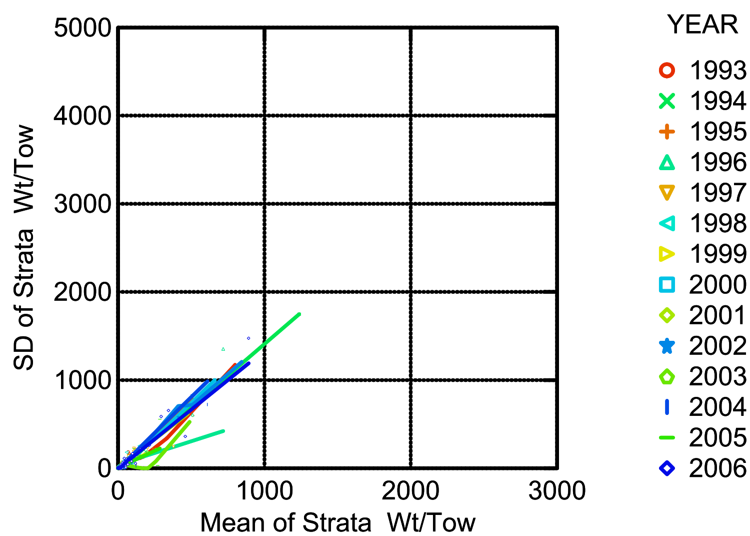


Fig. B5.13a Ratio of numbers per tow of mature males (>60cm) to mature females (>80 cm) spiny dogfish in NEFSC spring trawl survey, 1980-2006. Line represents Lowess smooth with tension =0.5.

SD vs Means by strata, Spring Survey: 1993-2006



SD vs Means by strata, Spring Survey: 1980-1992

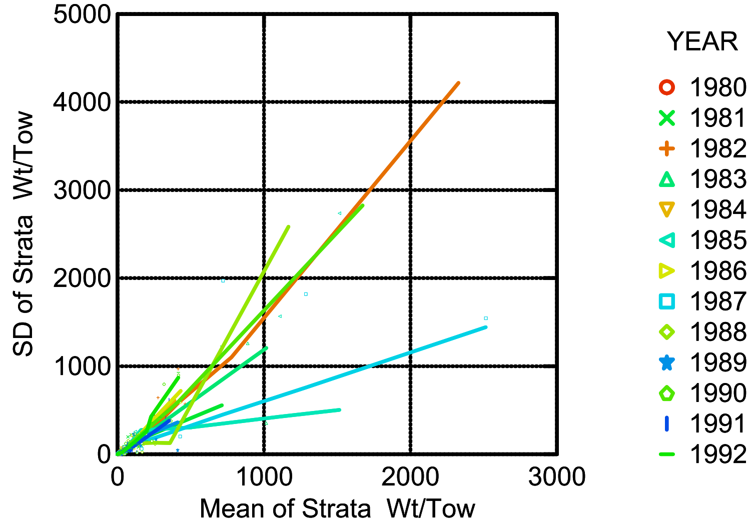
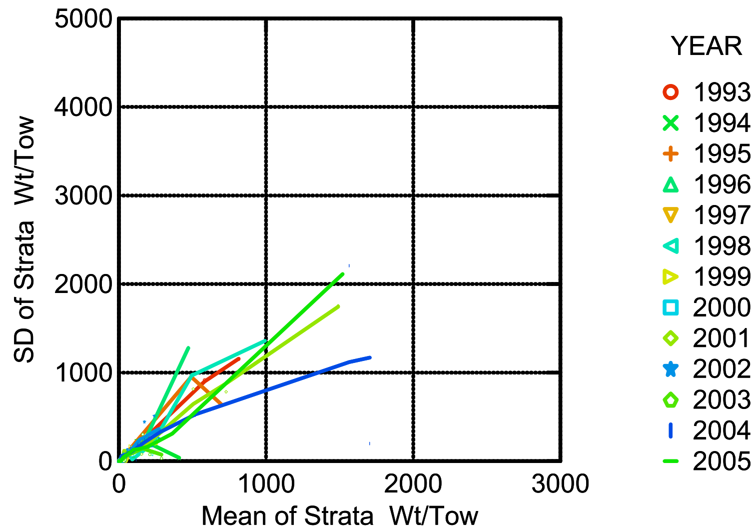


Fig. B5.14 Comparison of SD of strata vs Mean of strata for female spiny dogfish in NMFS Spring survey, 1993 to 2005 (top) and 1980 to 1992 (bottom). Lines represent lowess smooth with tension = 0.50.

SD vs Means by strata, Fall Survey: 1993-2006



SD vs Means by strata, Fall Survey: 1980-1992

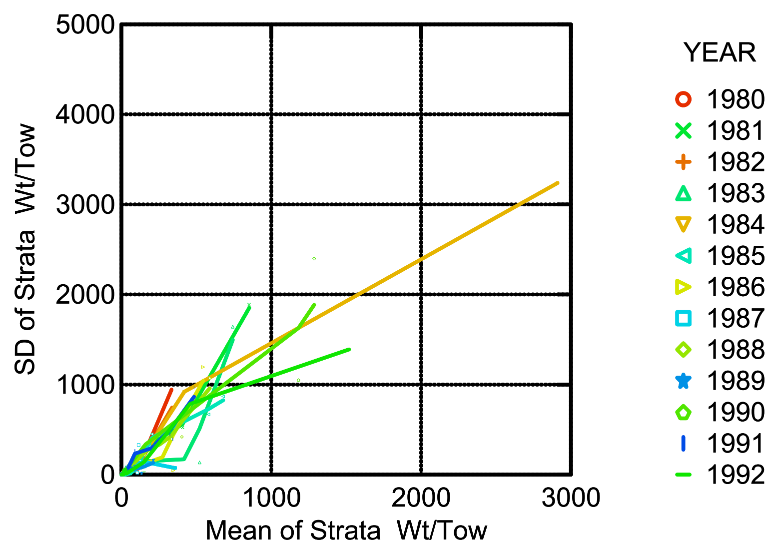


Fig. B5.15. Comparison of SD of strata vs Mean of strata for female spiny dogfish in NMFS Fall survey, 1993 to 2005 (top) and 1980 to 1992 (bottom). Lines represent lowess smooth with tension = 0.50.

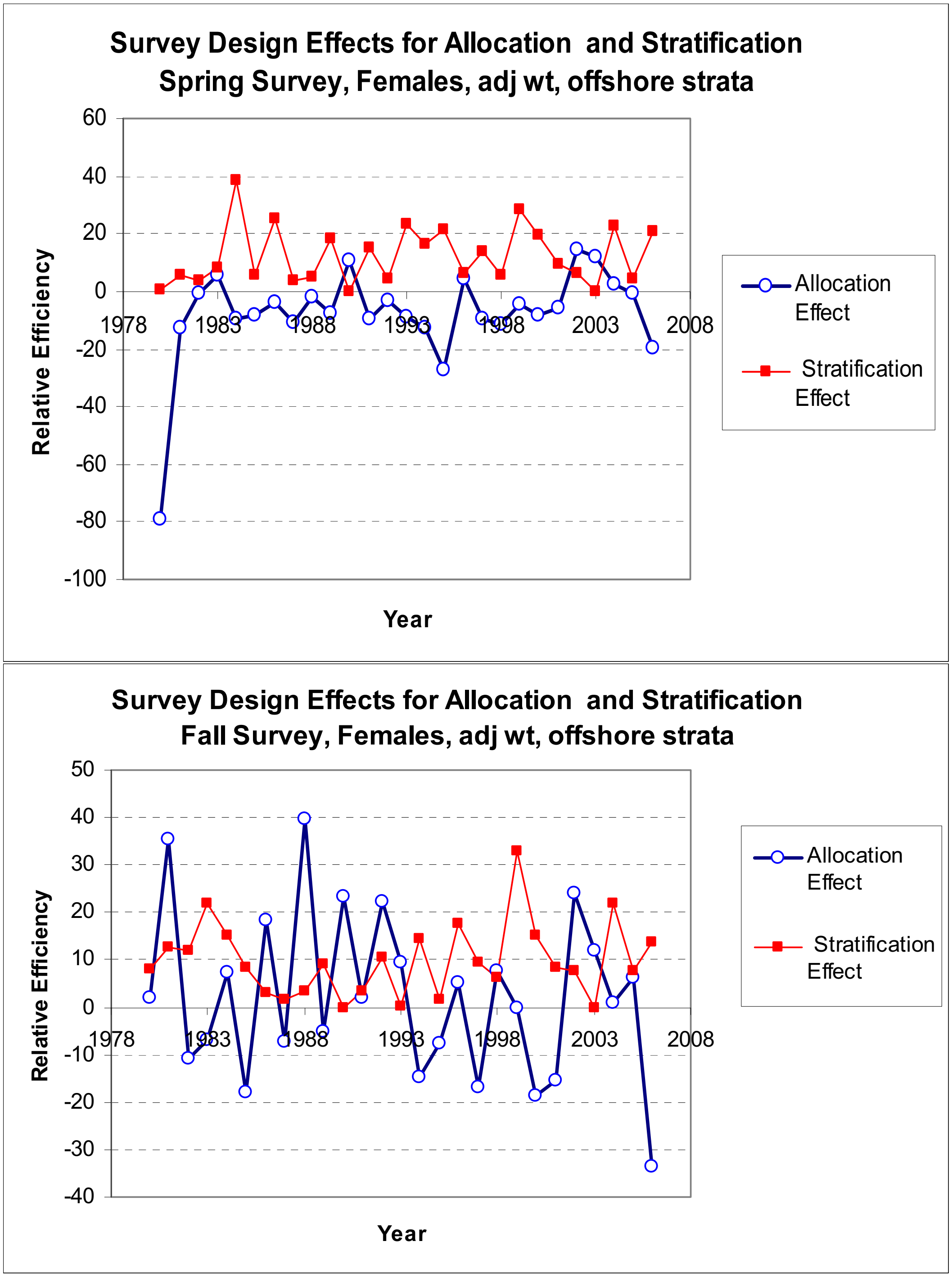
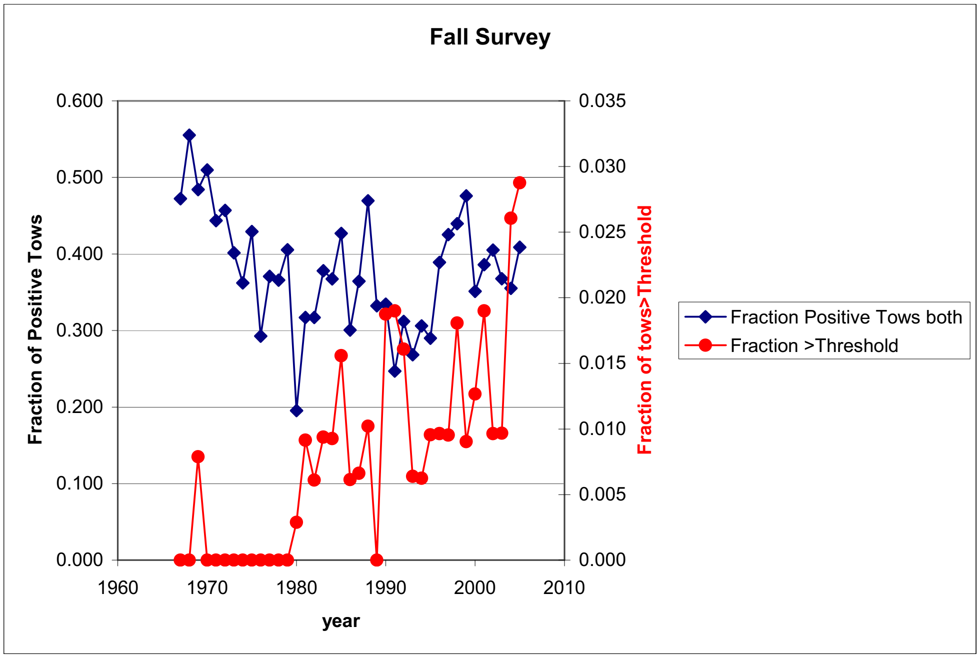


Fig. B5.16. Evaluation of survey design efficiency for NEFSC spring and fall R/V surveys for female spiny dogfish, 1980-2006. Design efficiency is the sum of two effects: stratification and allocation. A design efficiency of zero is equivalent to a simple random sample.



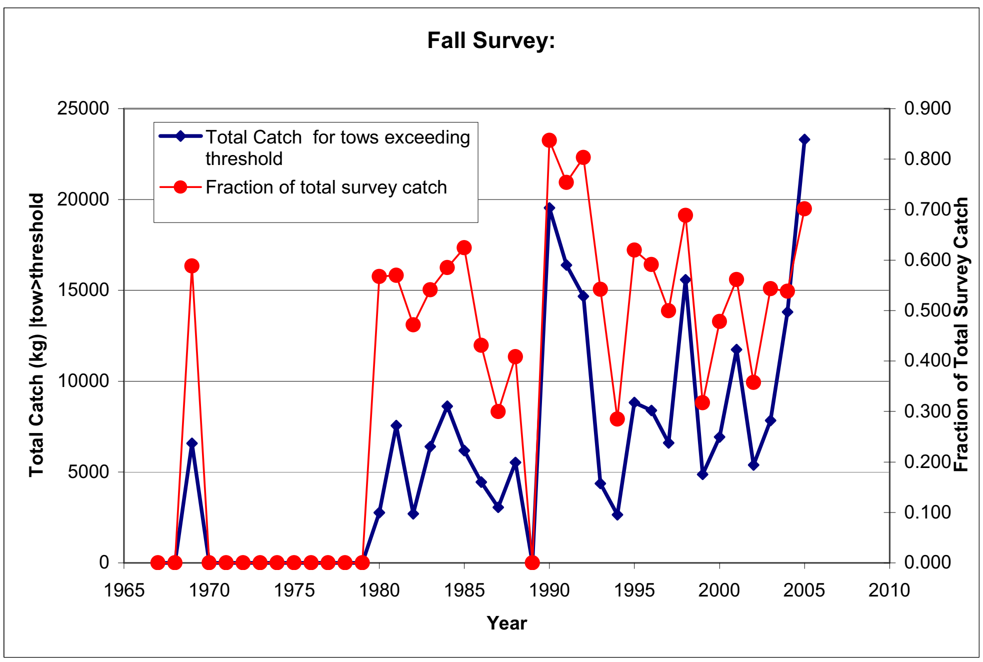


Fig. B5.17. Trends in fraction of positive tows and tows exceeding 1000 kg/tow for female spiny dogfish in fall survey (top) through 2005. Bottom panel depicts total catch taken in large tows and their fraction of total catch in the NMFS survey 1967-2005. Dogfish sex information prior to 1980 is incomplete.

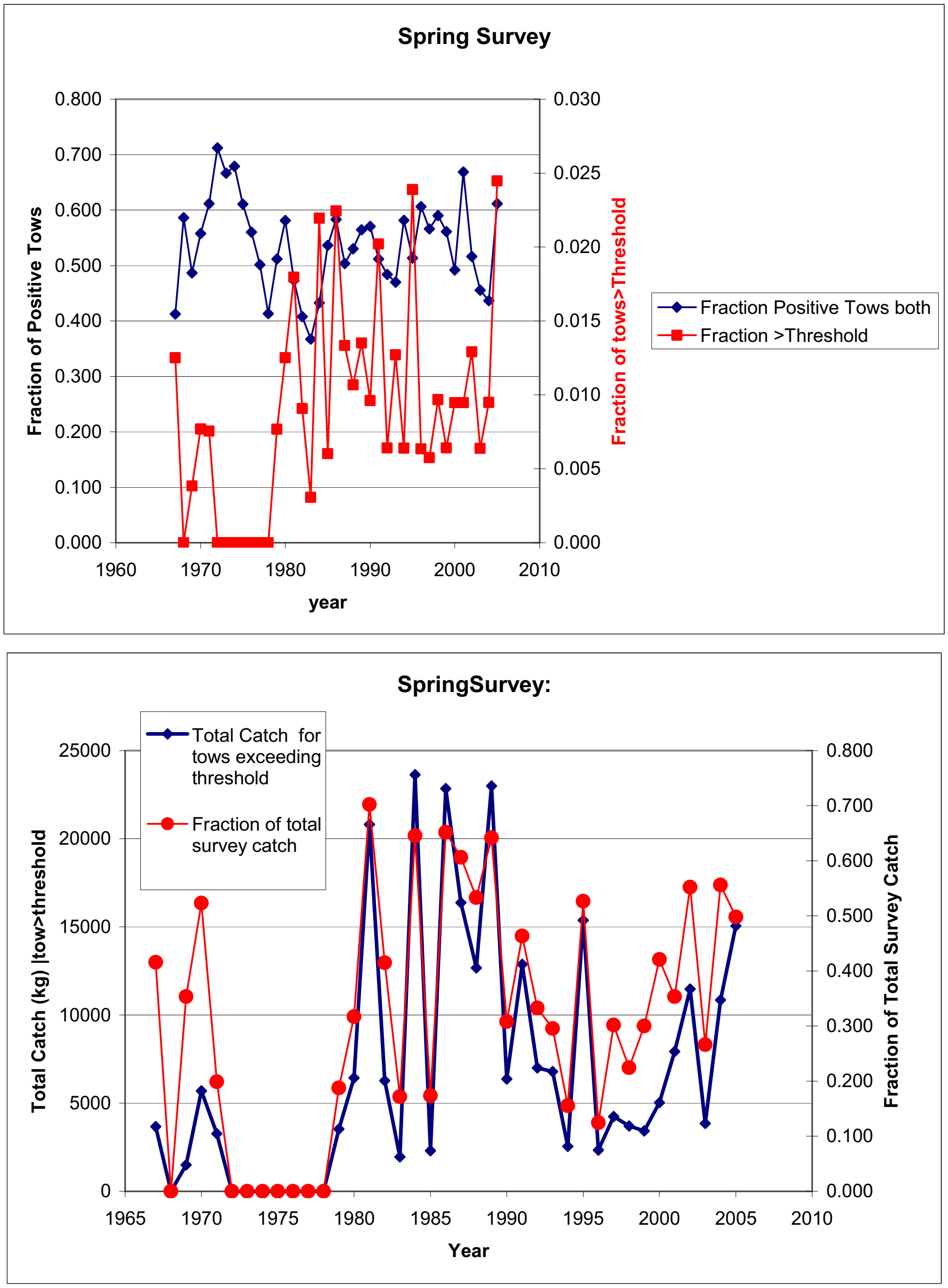


Fig. B5.18. Trends in fraction of positive tows and tows exceeding 1000 kg/tow for female spiny dogfish in spring survey (top) through 2005. Bottom panel depicts total catch taken in large tows and their fraction of total catch in the NMFS survey 1967-2005. Dogfish sex information prior to 1980 is incomplete.

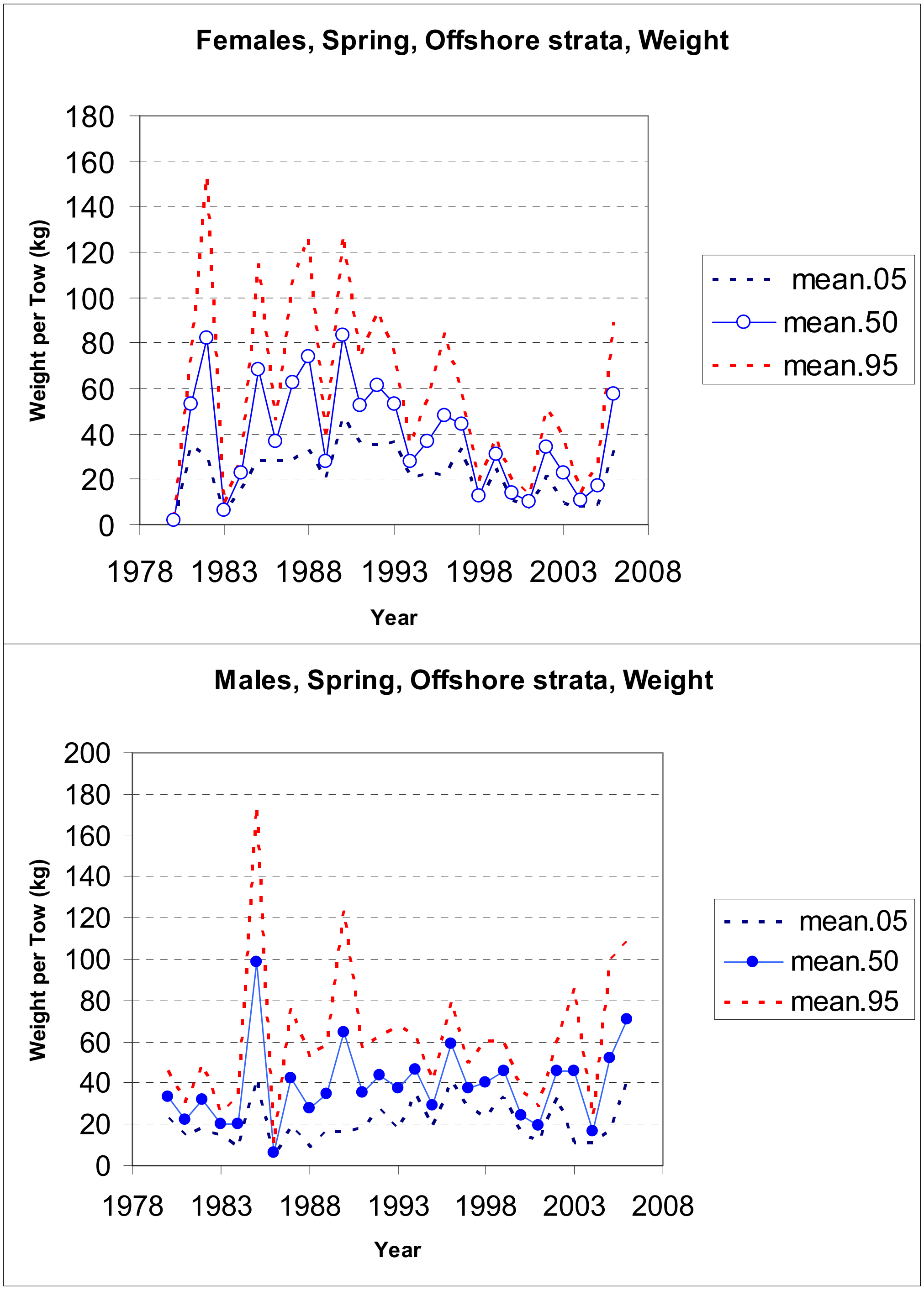


Fig. B5.19. Bootstrap sampling distributions of mean weight per tow for female and male spiny dogfish taken in the spring survey for offshore strata. Confidence intervals are based on the percentile method and represent 90% of the realized values. Number of bootstrap realizations per year =2000.

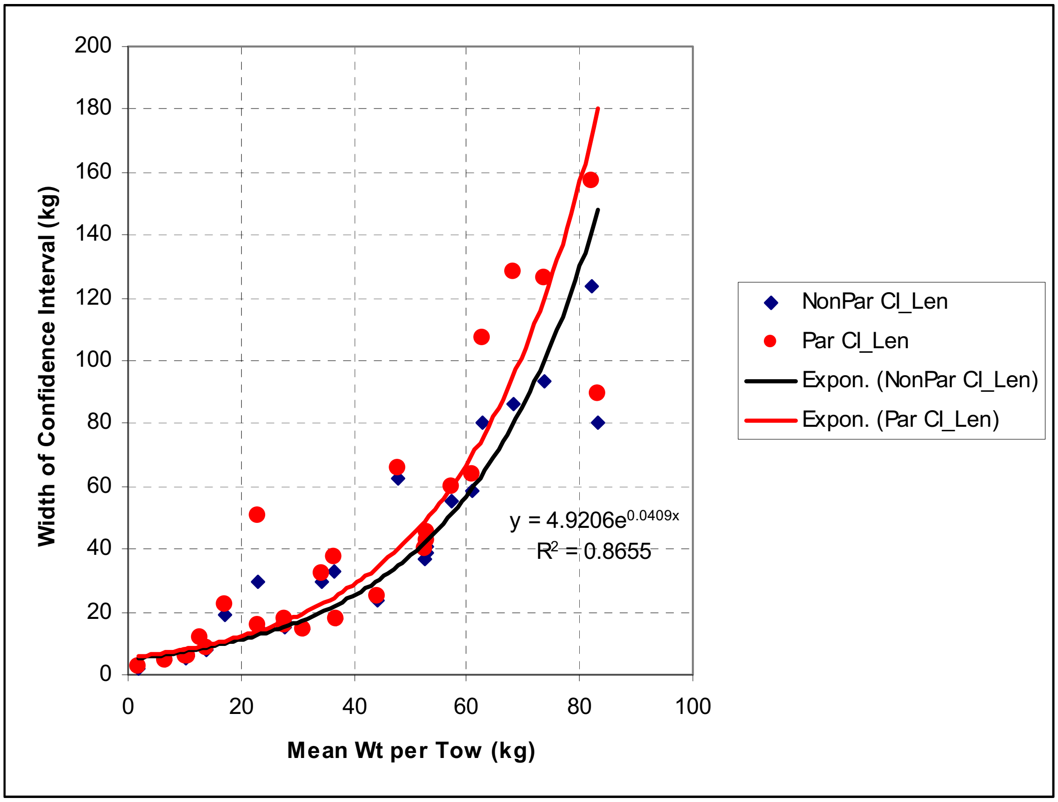


Fig. B5.20 Comparison of parametric and bootstrap 90% confidence interval widths of female weight per tow for spring survey, 1980-2006.

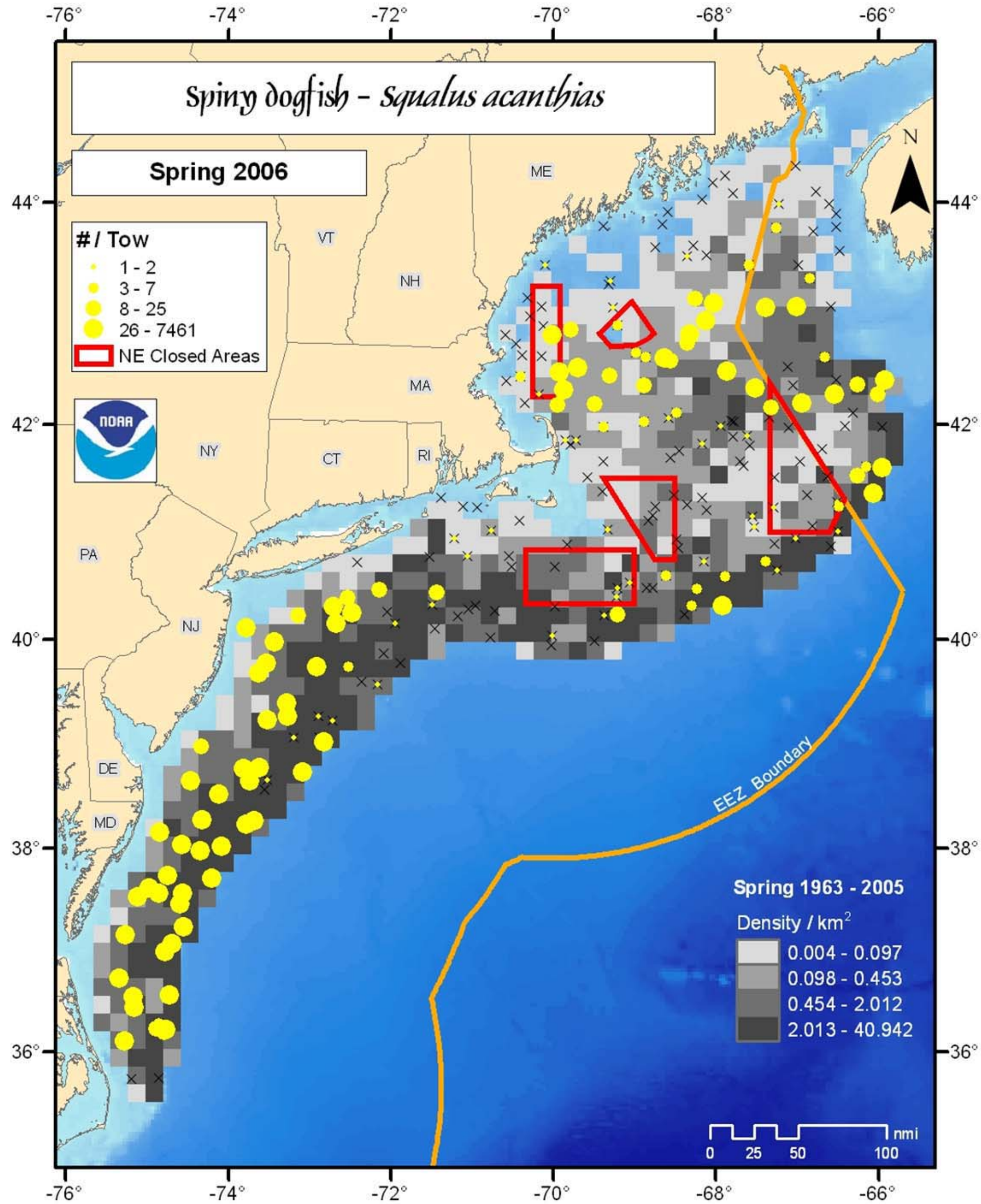


Fig. B5.20.1. Distribution of spiny dogfish in 2006 NEFSC spring research trawl survey. Yellow dots represent number per tow. Shaded 10 minute squares represent relative habitat utilization in March-April, 1963-2005

Spring Survey: comparison of 2006 vs 1993-2005

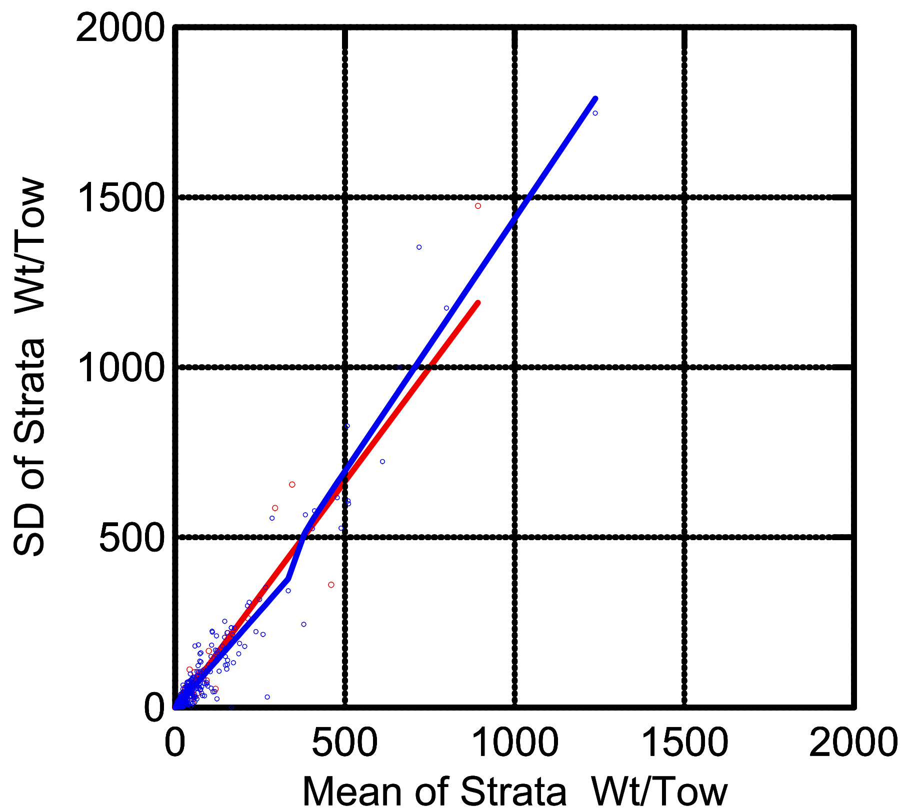
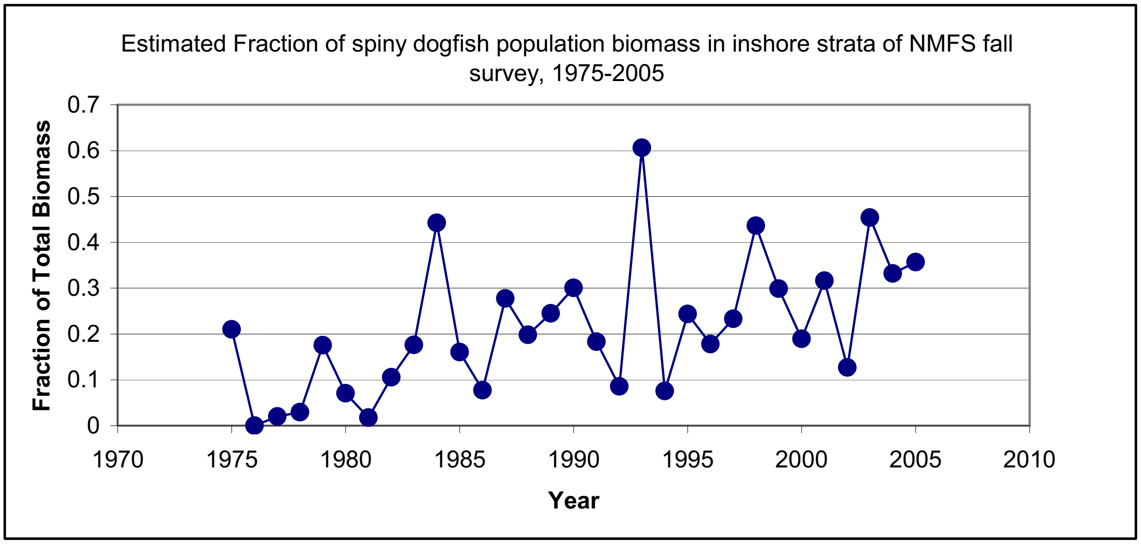


Fig. B5.20.2. Comparison of SD of strata vs Mean of strata for female spiny dogfish spring in NMFS spring survey, 2006 with 1993 to 2005 pooled. Lines represent lowess smooth with tension = 0.50.



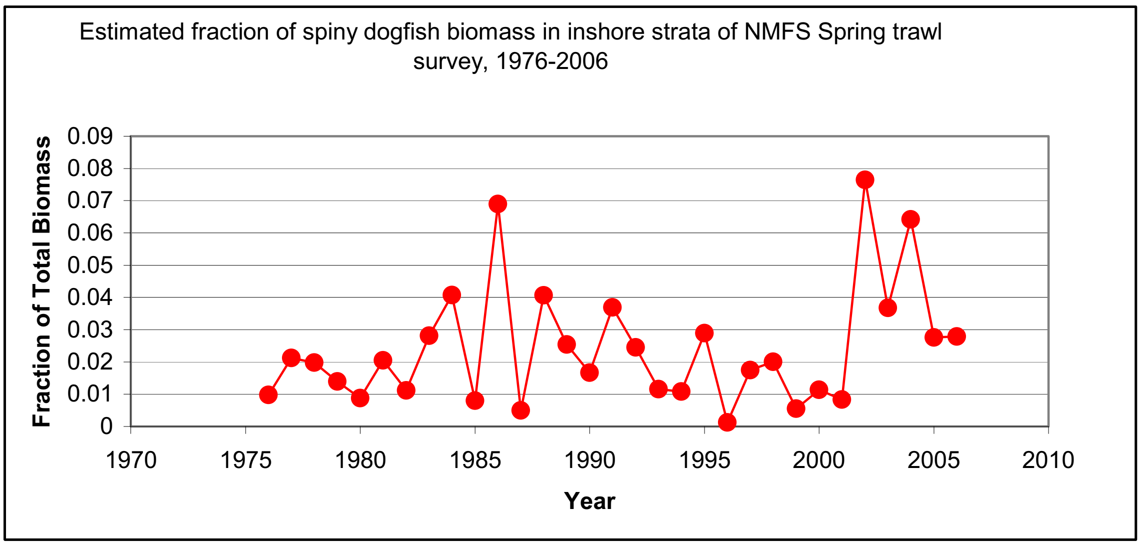


Fig. B5.21. Fraction of total spiny dogfish swept-area estimates of population biomass in inshore strata in NMFS fall (top panel) and spring (bottom) bottom trawl survey.

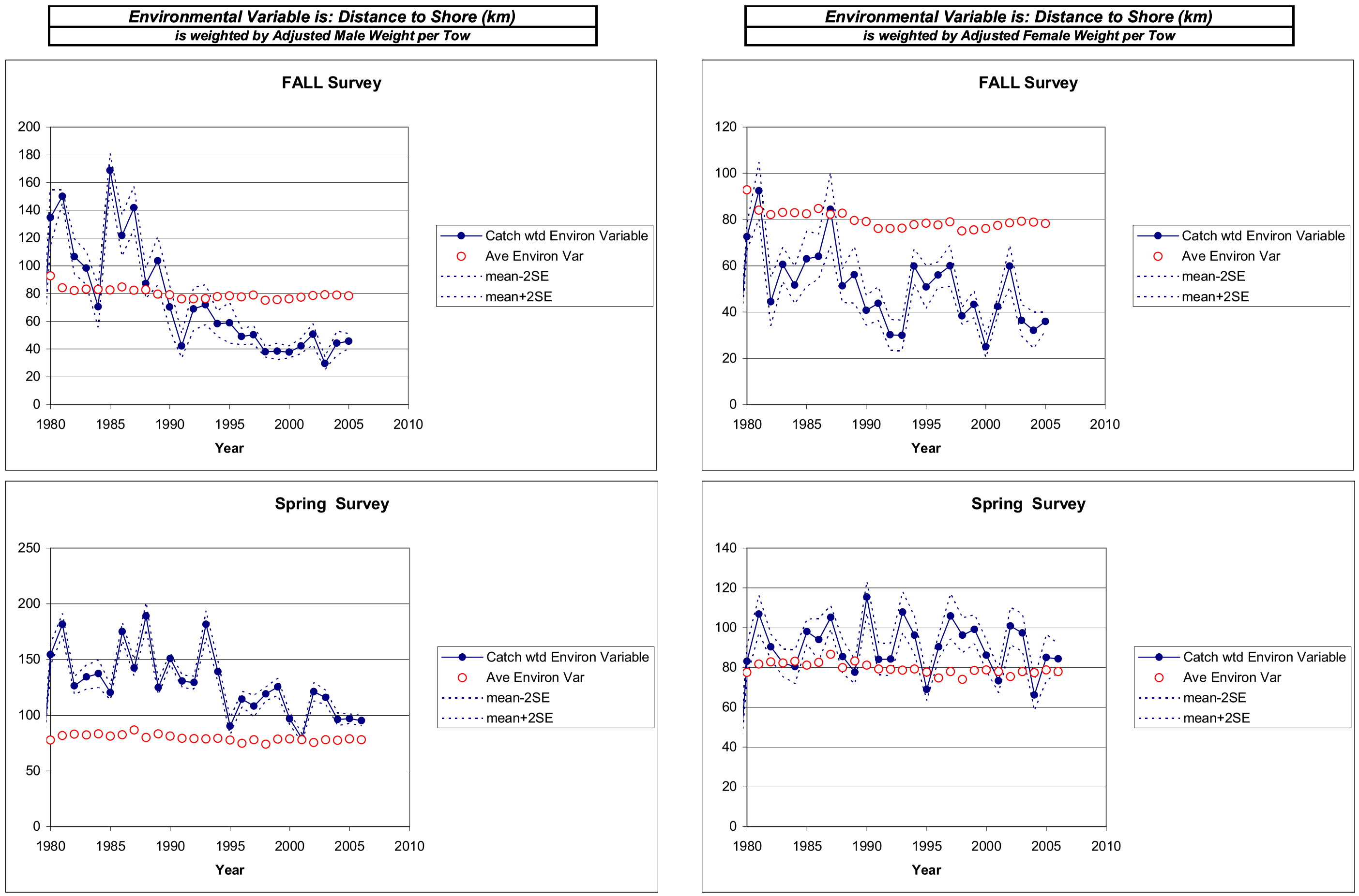


Fig. B5.22 Comparison of average distance from shore (km) for samples taken in NMFS fall (open dots) and spring surveys with distances weighted by male (left) and female (right) spiny dogfish adjusted weight per tow (kg) (closed dots). Adjustments account for effect of gear and vessel changes. Distance to shore represent closest distance from sample station to shore.

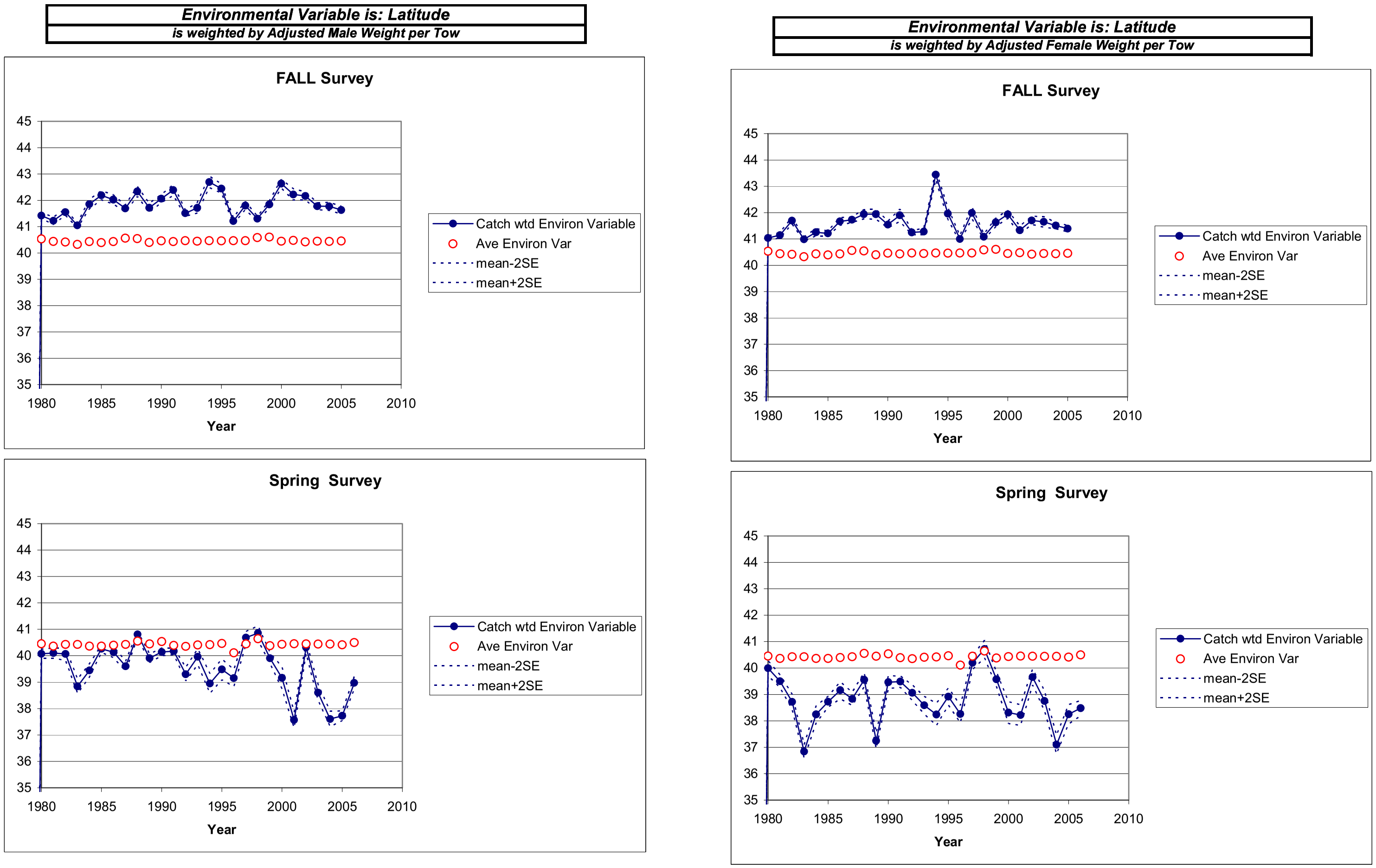


Fig. B5.23 Comparison of average latitude (degrees) for samples taken in NMFS fall (open dots) and spring surveys with latitudes weighted by male (left) and female (right) spiny dogfish adjusted weight per tow (kg) (closed dots). Adjustments account for effect of gear and vessel changes.

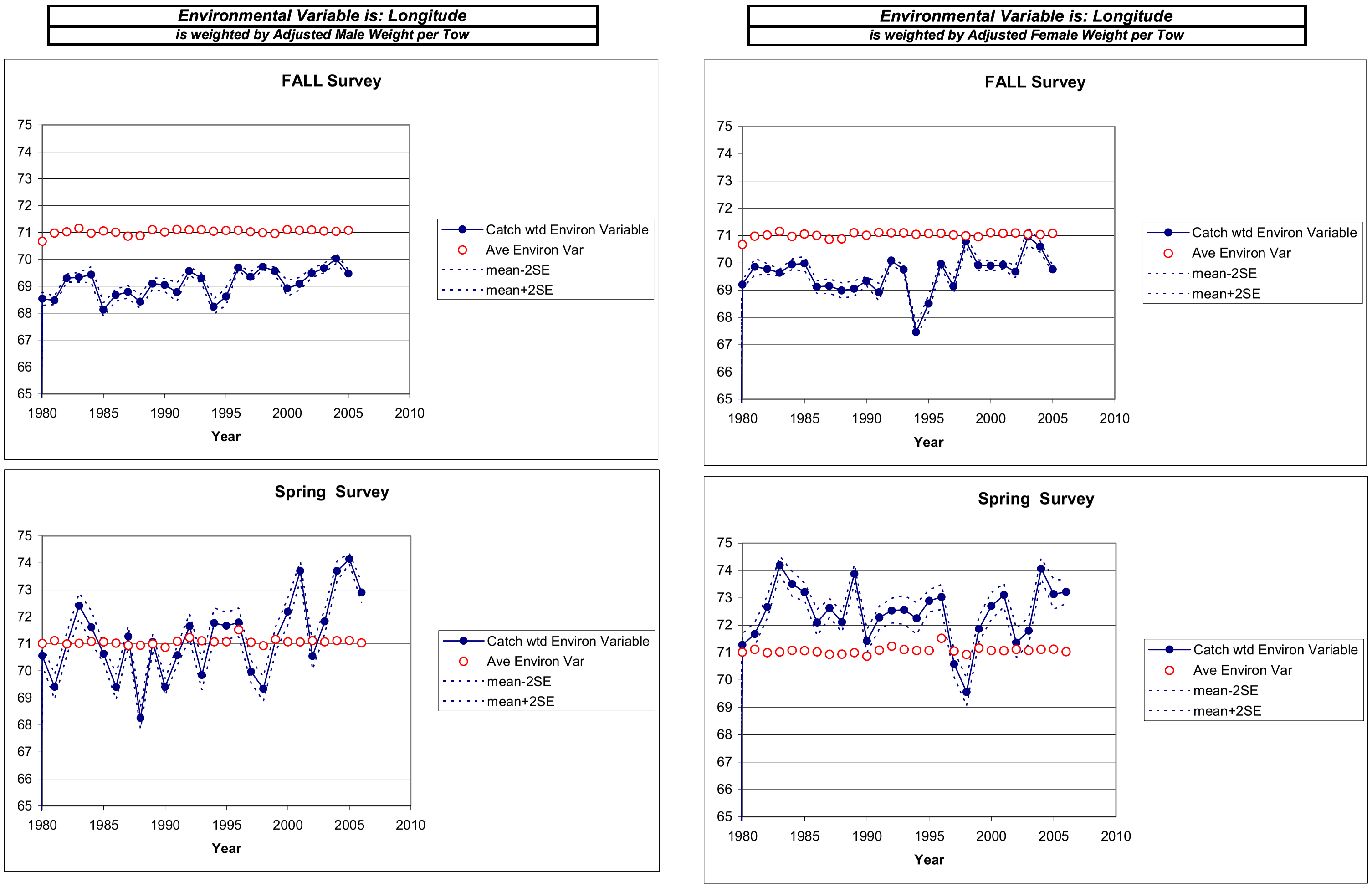


Fig. B5.24 Comparison of average longitude (degrees) for samples taken in NMFS fall (open dots) and spring surveys with longitudes weighted by male (left) and female(right) spiny dogfish adjusted weight per tow (kg) (closed dots). Adjustments account for effect of gear and vessel changes.

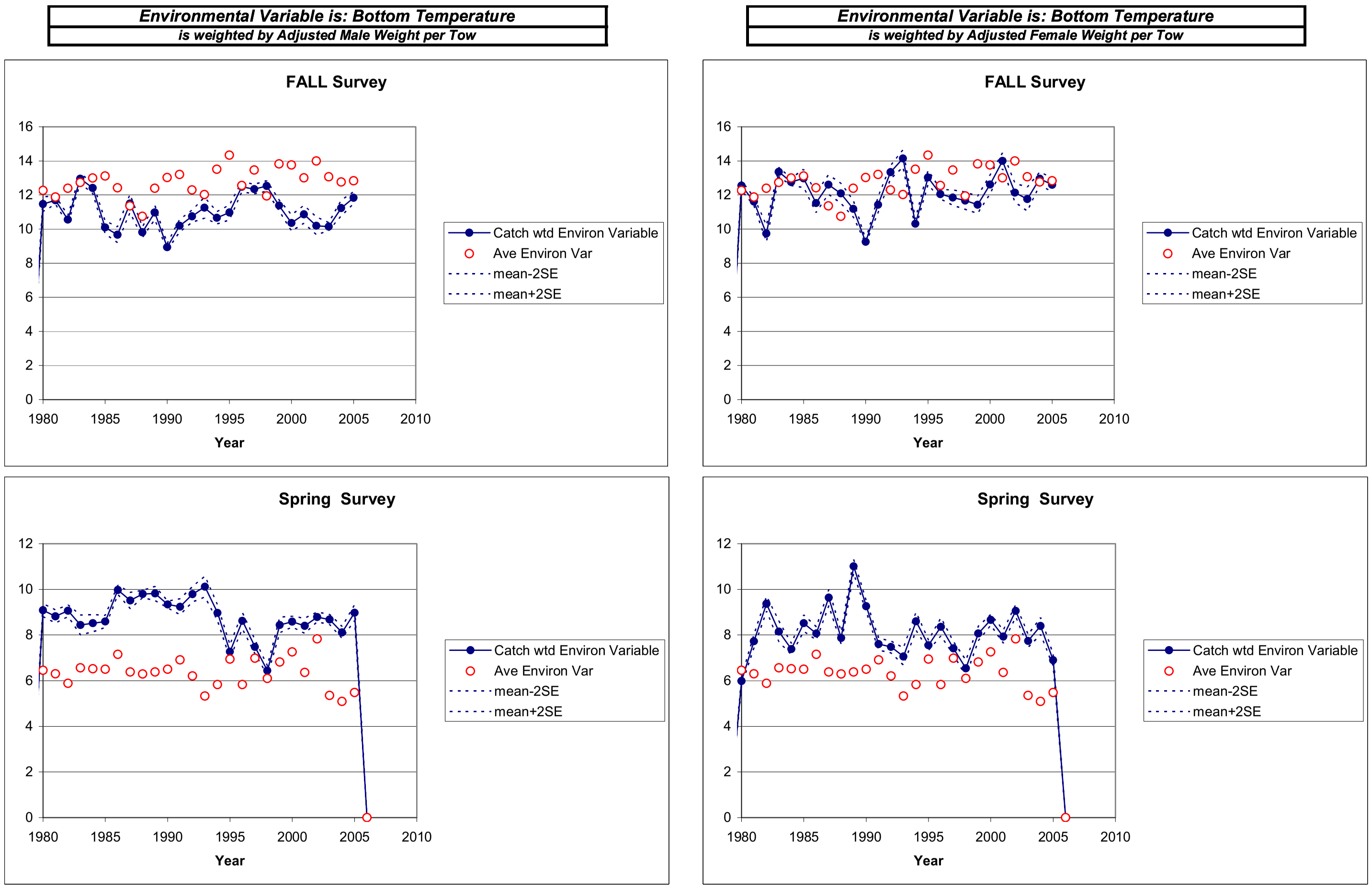


Fig. B5.25 Comparison of average bottom temperature (degrees C) for samples taken in NMFS fall (open dots) and spring surveys with temperatures weighted by male (left) and female (right) spiny dogfish adjusted weight per tow (kg) (closed dots). Adjustments account for effect of gear and vessel changes.

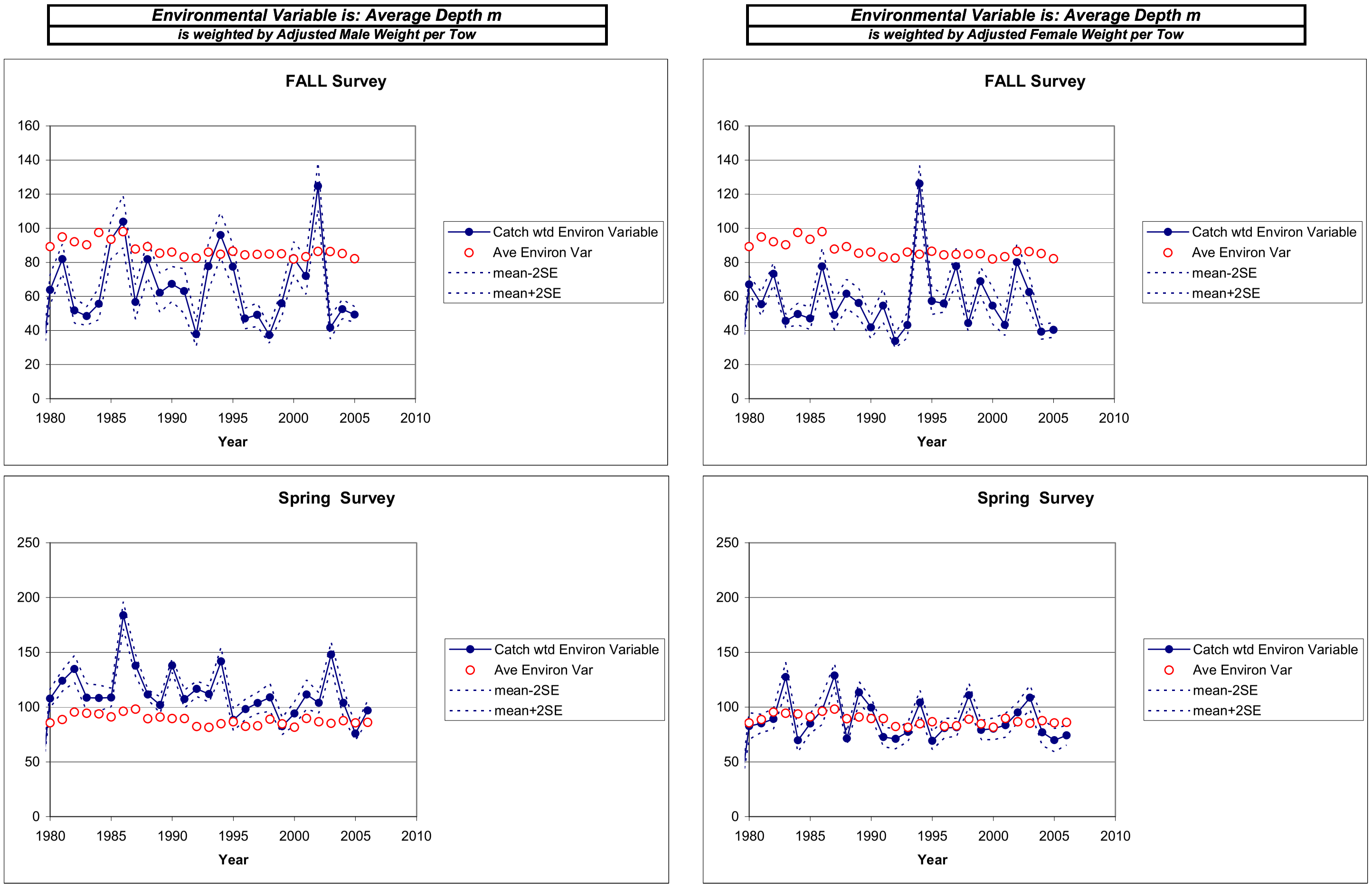


Fig. B5.26 Comparison of average depth (m) for samples taken in NMFS fall (open dots) and spring surveys with depths weighted by male(left) and female(right) spiny dogfish adjusted weight per tow (kg) (closed dots). Adjustments account for effect of gear and vessel changes.

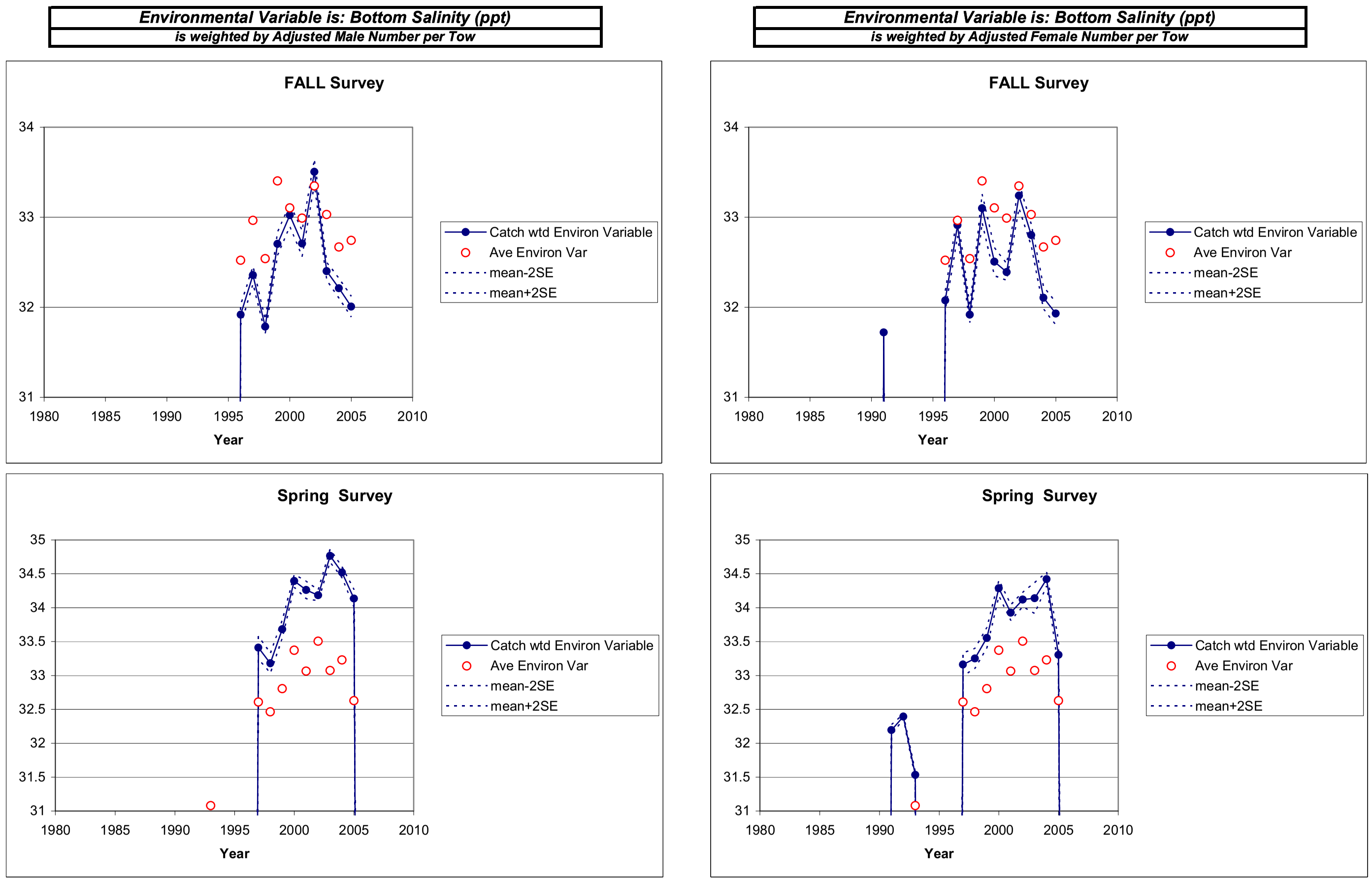
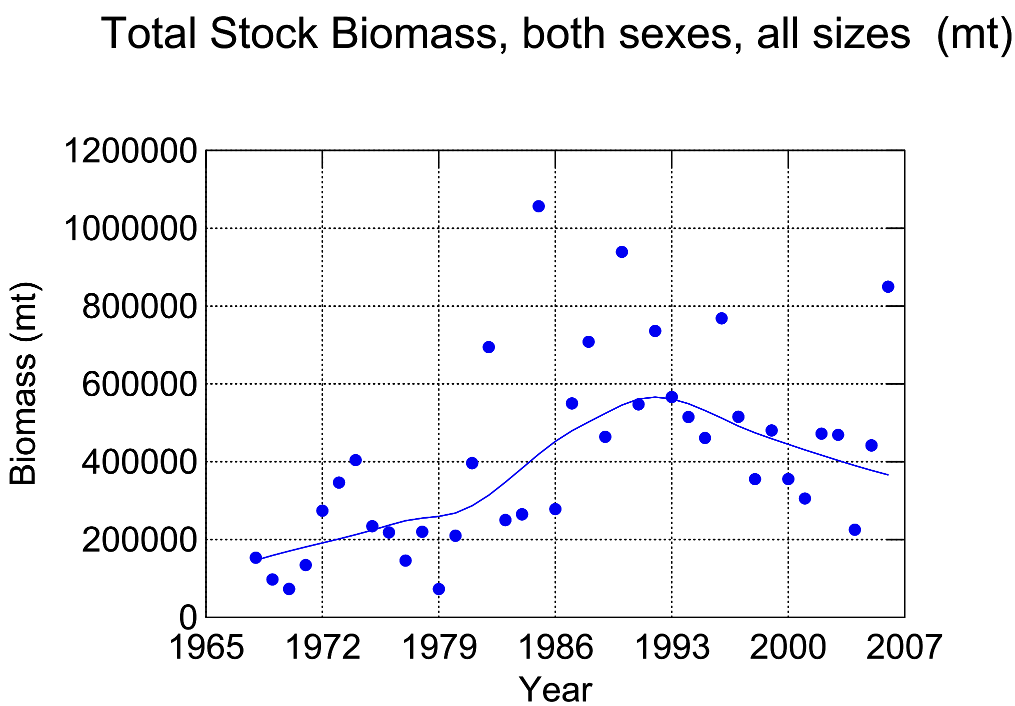


Fig. B5.27 Comparison of average salinity (ppt) for samples taken in NMFS fall (open dots) and spring surveys with salinities weighted by male (left) and female (right) spiny dogfish adjusted weight per tow (kg) (closed dots). Adjustments account for effect of gear and vessel changes. Bottom salinities are not available for all stations.



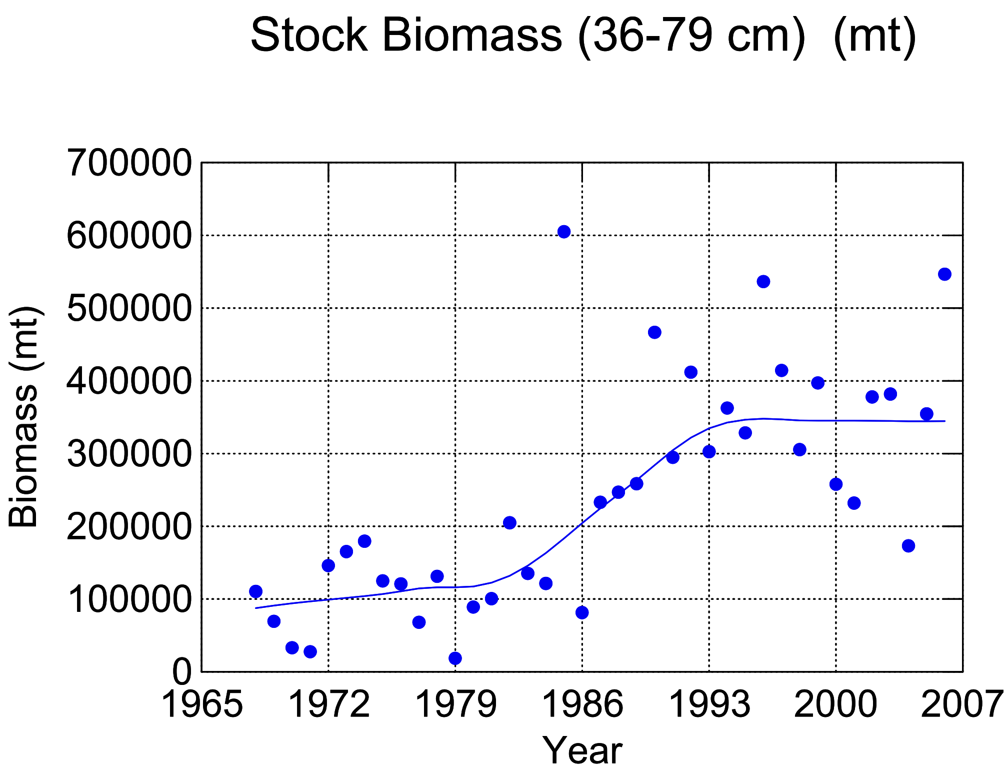


Fig. B6.1 Swept area estimate of total dogfish biomass (000 mt) (top) and biomass of individuals between 36 and 79 cm in spring R/V trawl survey, 1968-2006. Lines represents Lowess smooth with tension factor = 0.5.

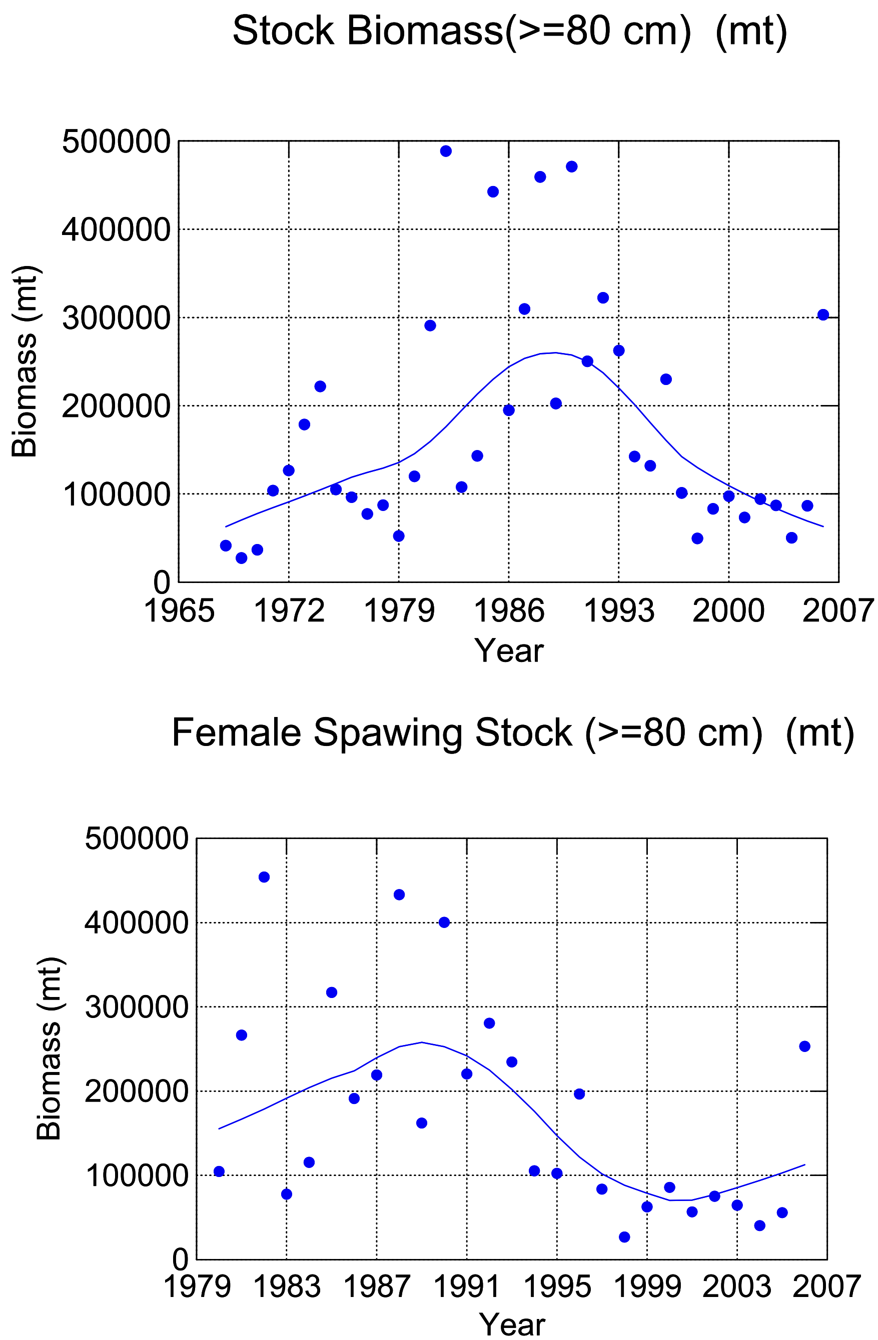
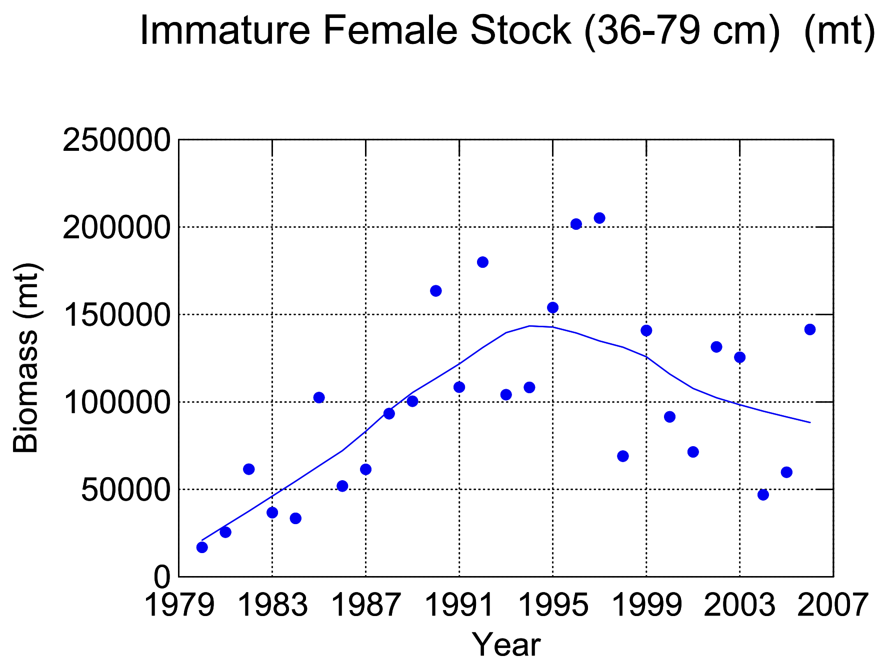


Fig. B6.2 Swept area estimate of dogfish biomass (000 mt) greater than 80 cm, 1968-2006 (top) and for mature females only (bottom), 1980-2006 in spring R/V trawl survey. Line represents Lowess smooth with tension factor = 0.5. Spiny dogfish sex in R/V survey unavailable prior to 1980.



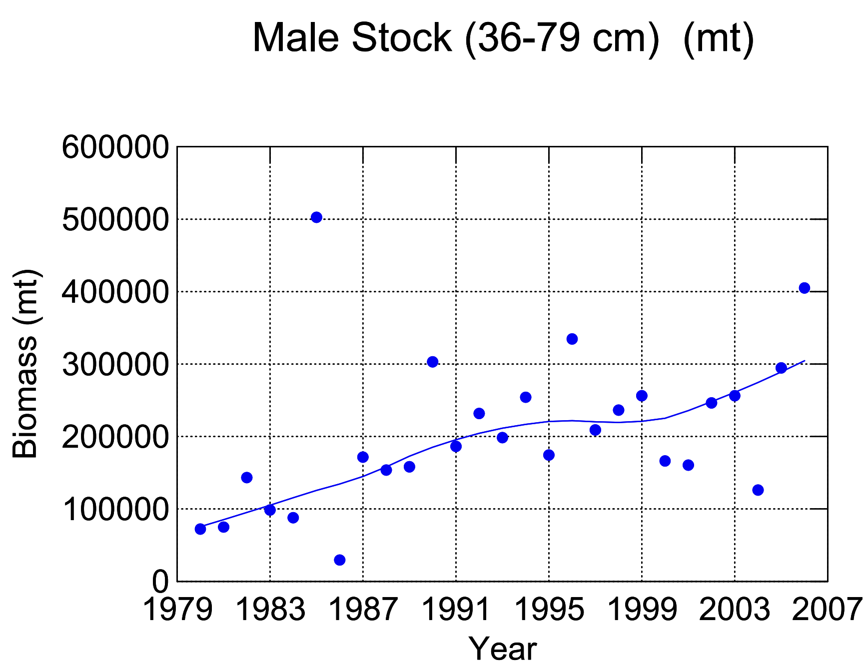


Fig. B6.3 Swept area estimate of female (top) and male (bottom) spiny dogfish biomass (000 mt) 36-79, 1980-2006 in spring R/V trawl survey. Line represents Lowess smooth with tension factor = 0.5. Spiny dogfish sex in R/V survey unavailable prior to 1980.

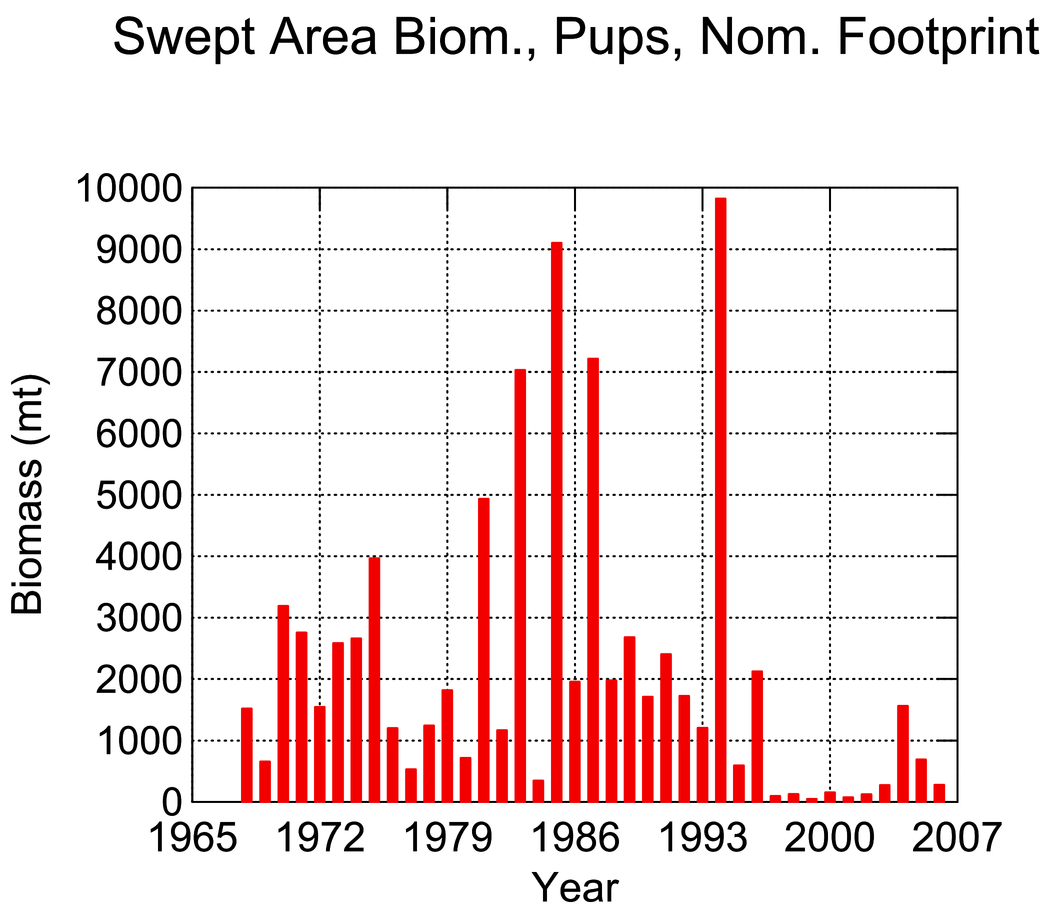


Fig. B6.4 Swept area estimate of dogfish biomass recruits in spring R/V trawl survey, 1968-2006. Recruits defined as individuals less than 36 cm.

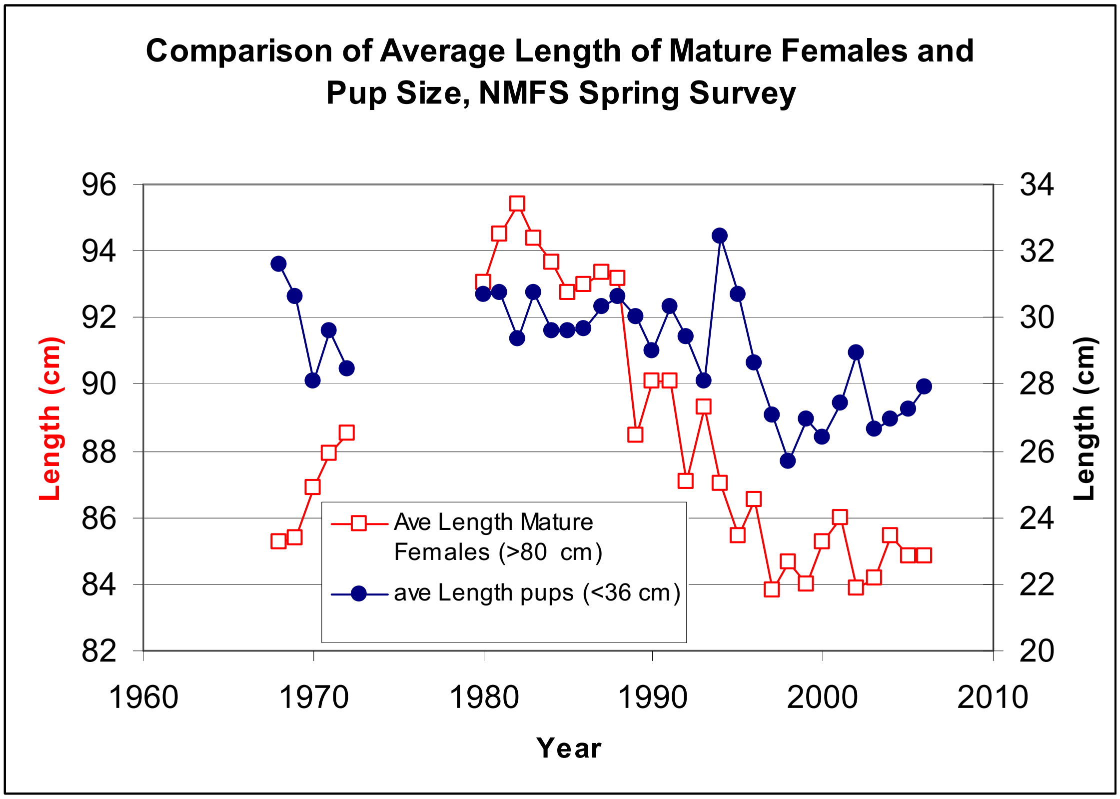


Fig. B6.5 Comparison of average length of mature female spiny dogfish caught in NMFS spring survey and female juvenile dogfish caught in the same year.

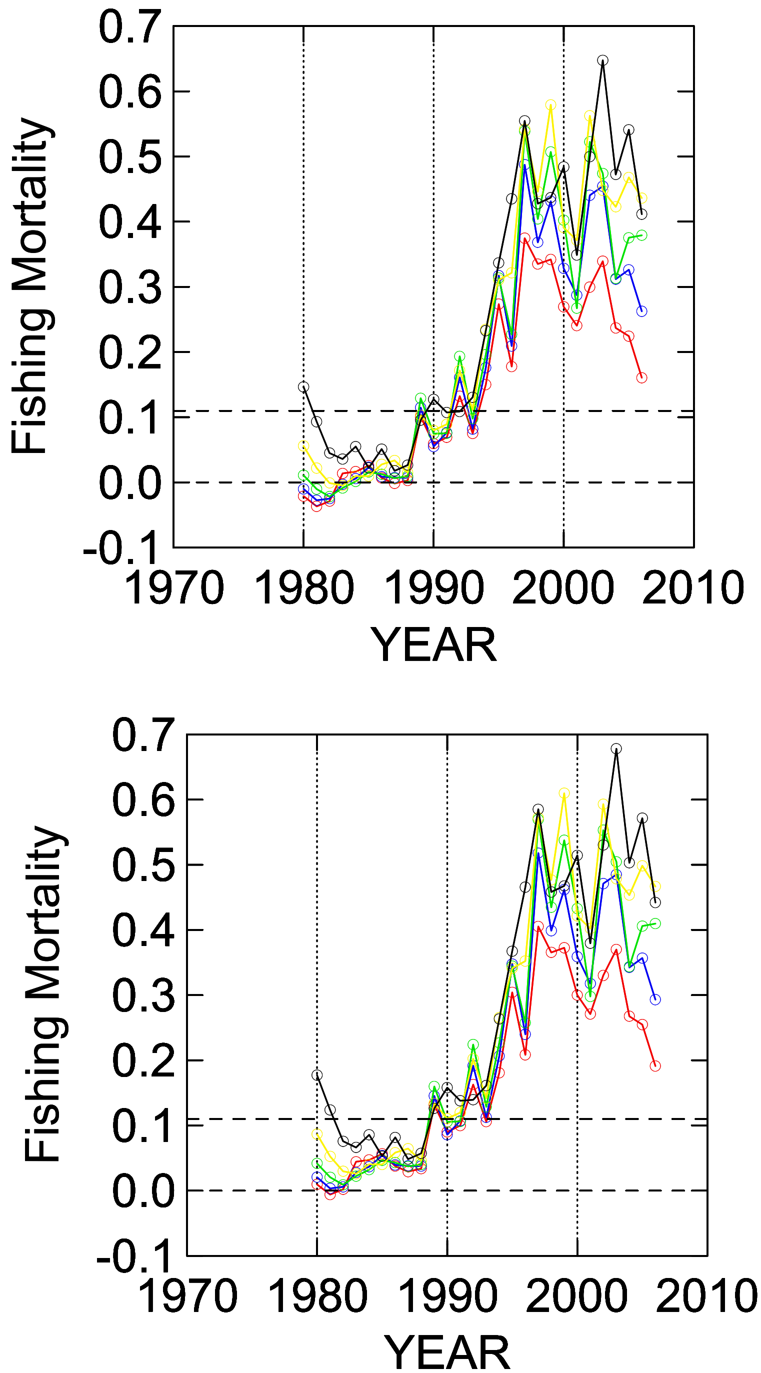


Fig. B7.1. Estimates of F based on Beverton-Holt model for two assumed levels of M and 5 assumed levels of size at entry into the fishery. Estimates are based on a 3-yr moving average of size composition of the NEFSC spring survey, 1980-2006

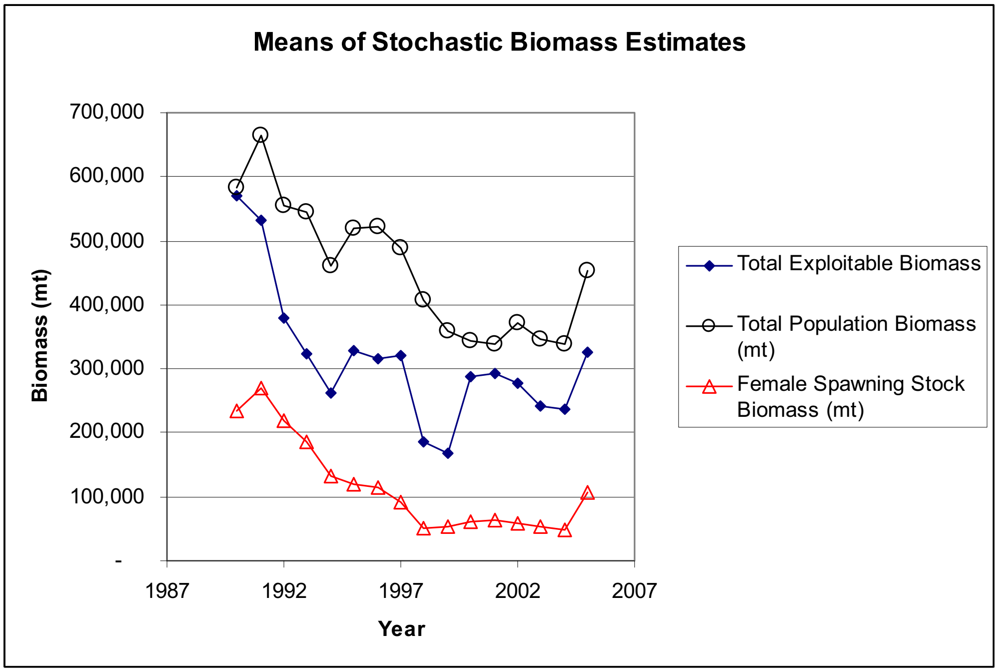


Fig. 7.2. Mean estimates of total, exploitable and mature female biomass from stochastic model. Assumes minimum trawl footprint = 0.01 nm^2.

Mean estimates of biomass from stochastic model. Assumes minimum trawl footprint = 0.01 nm^2. SSB target is 200,000 mt.

Year	Total Exploitable Biomass	Exploitable Female Biomass (mt)	Exploitable Male Biomass (mt)	Total Population Biomass (mt)	Female Spawning Stock Biomass (mt)	Fraction > SSB target
1990	570,113	339,405	230,208	582,274	234,229	0.706344
1991	532,641	278,419	253,722	664,850	269,624	0.840524
1992	379,501	169,227	209,773	553,731	220,002	0.658844
1993	322,345	93,716	228,128	544,415	186,132	0.347196
1994	261,387	55,102	205,785	460,932	133,264	0.000284
1995	329,048	77,600	250,948	519,920	120,664	0.00324
1996	316,075	81,413	234,162	520,782	114,091	0.000788
1997	319,828	69,005	250,323	489,233	91,458	0
1998	185,468	77,142	107,825	406,287	51,821	0
1999	167,483	66,023	100,960	358,185	52,562	0
2000	286,458	96,233	189,725	343,602	61,552	0
2001	291,695	107,026	184,169	337,686	64,844	0
2002	278,283	63,794	213,989	371,200	58,376	0
2003	241,697	39,745	201,452	347,176	53,625	0
2004	237,536	17,432	219,604	338,170	47,719	0
2005	327,077	54,587	271,991	453,881	106,180	0

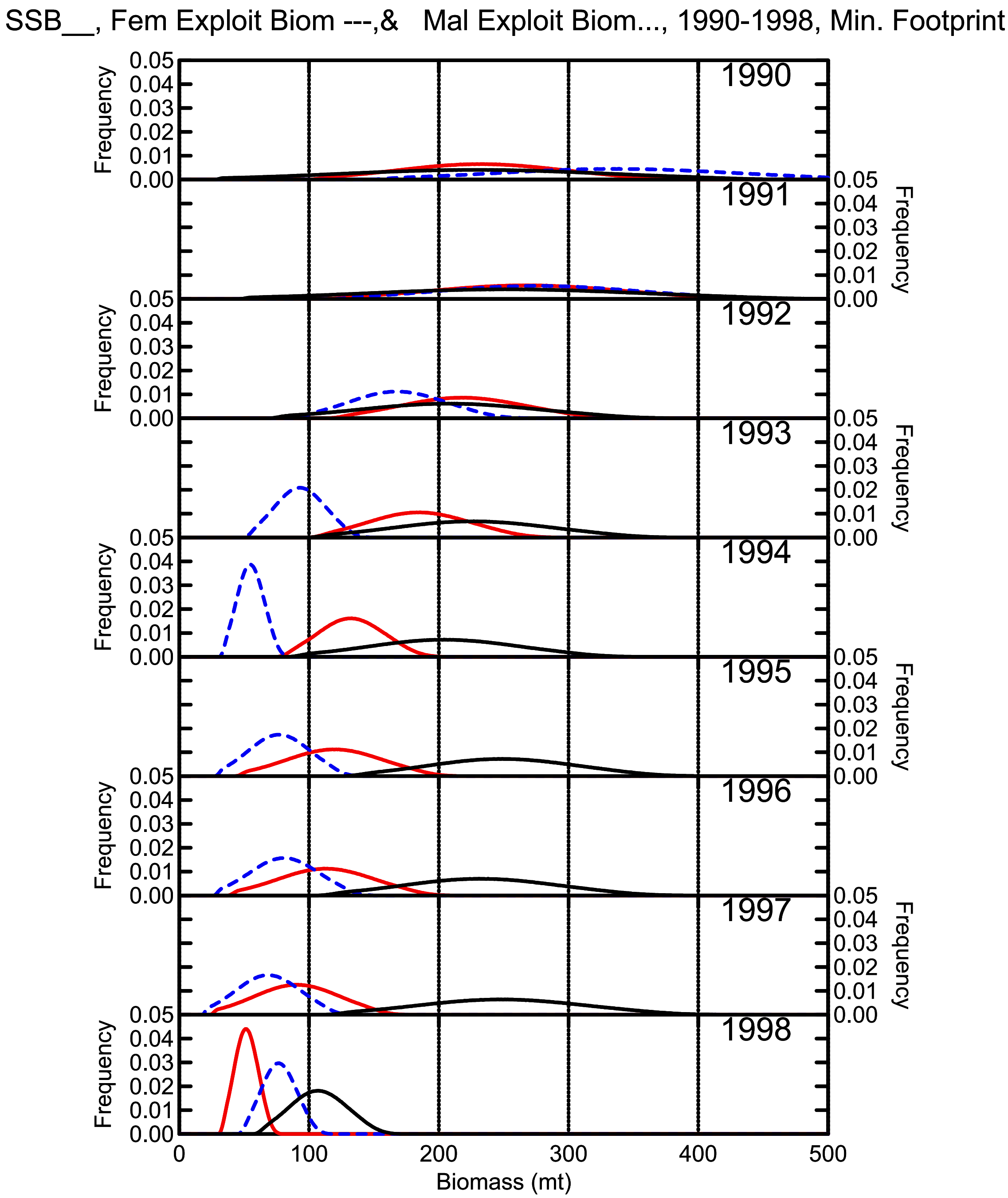


Fig. B7.3a. Sampling distribution of population biomass for mature females (red), exploited female (dashed), and exploited male biomass (black), 1990-1998. Years represent midpoint of 3-yr average; i.e., 1998 is average for 1997-1999. Sampling distribution represents joint effect of sampling variability and variations in average footprint of trawl (min estimate of footprint, assumes no herding effect of doors).

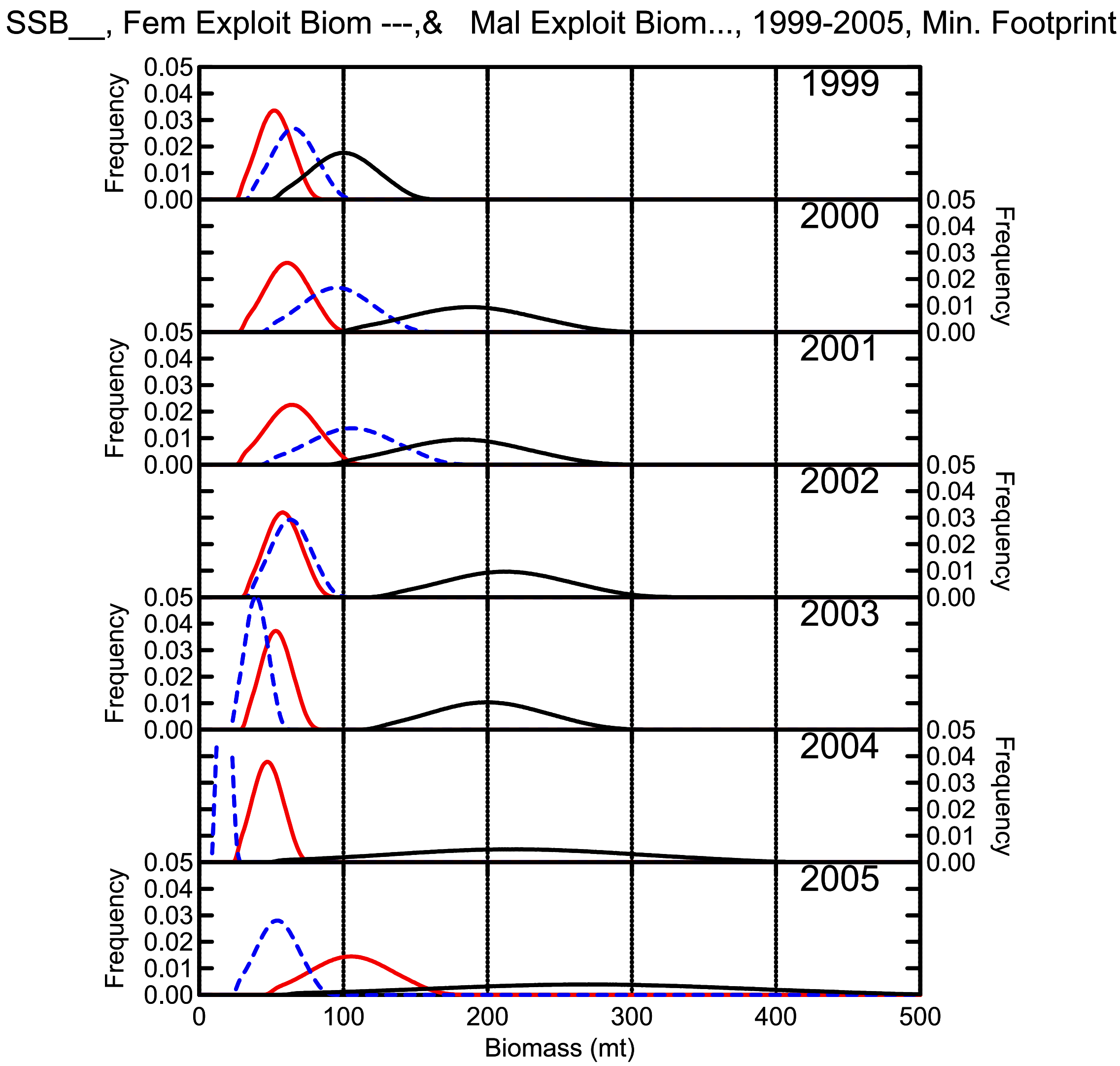


Fig. B7.3b. Sampling distribution of population biomass for mature females (red), exploited female (dashed), and exploited male biomass (black), 1990-1998. Years represent midpoint of 3-yr average; i.e., 2005 is average for 2004-2006. Sampling distribution represents joint effect of sampling variability and variations in average footprint of trawl (min estimate of footprint, assumes no herding effect of doors).

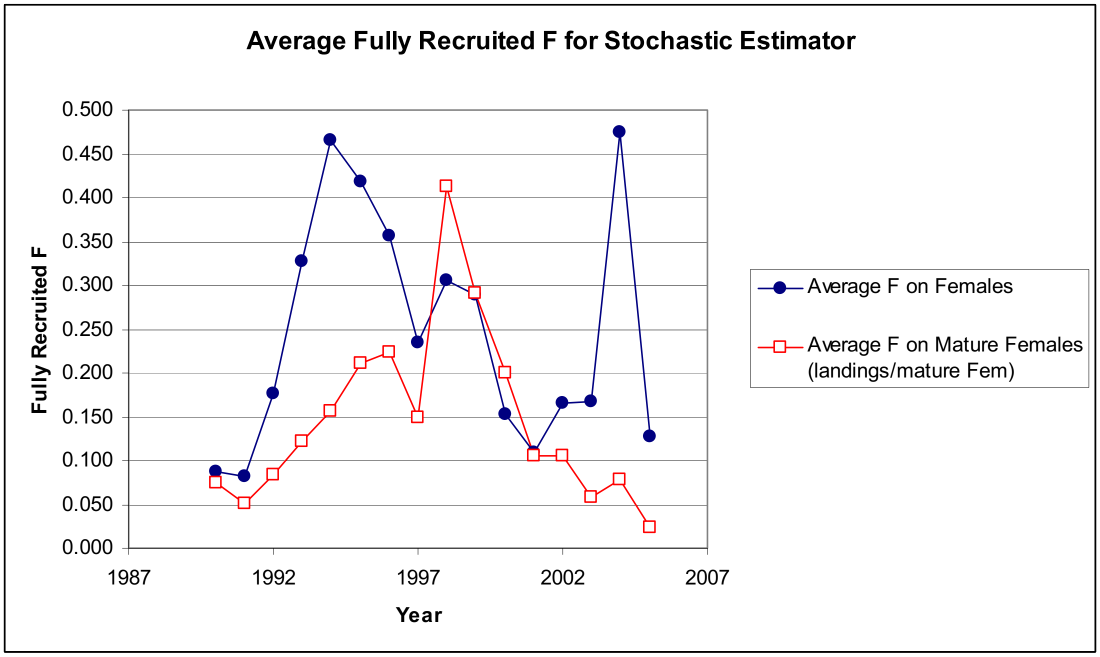


Fig. 7.4 Average fully recruited F derived from stochastic F estimator. Average F on mature females represents ratio of female landings to mature (>80 cm) spiny dogfish.

Year	Average F on Females	Average F on Mature Females (landings/mature Fem)
1990	0.088	0.074
1991	0.082	0.050
1992	0.177	0.083
1993	0.327	0.121
1994	0.465	0.156
1995	0.418	0.211
1996	0.355	0.223
1997	0.234	0.149
1998	0.306	0.413
1999	0.289	0.292
2000	0.152	0.201
2001	0.109	0.106
2002	0.165	0.105
2003	0.168	0.058
2004	0.474	0.078
2005	0.128	0.024

F female__,F on Mat Fem ---,& F Males..., 1990-1996, Min. Footprint

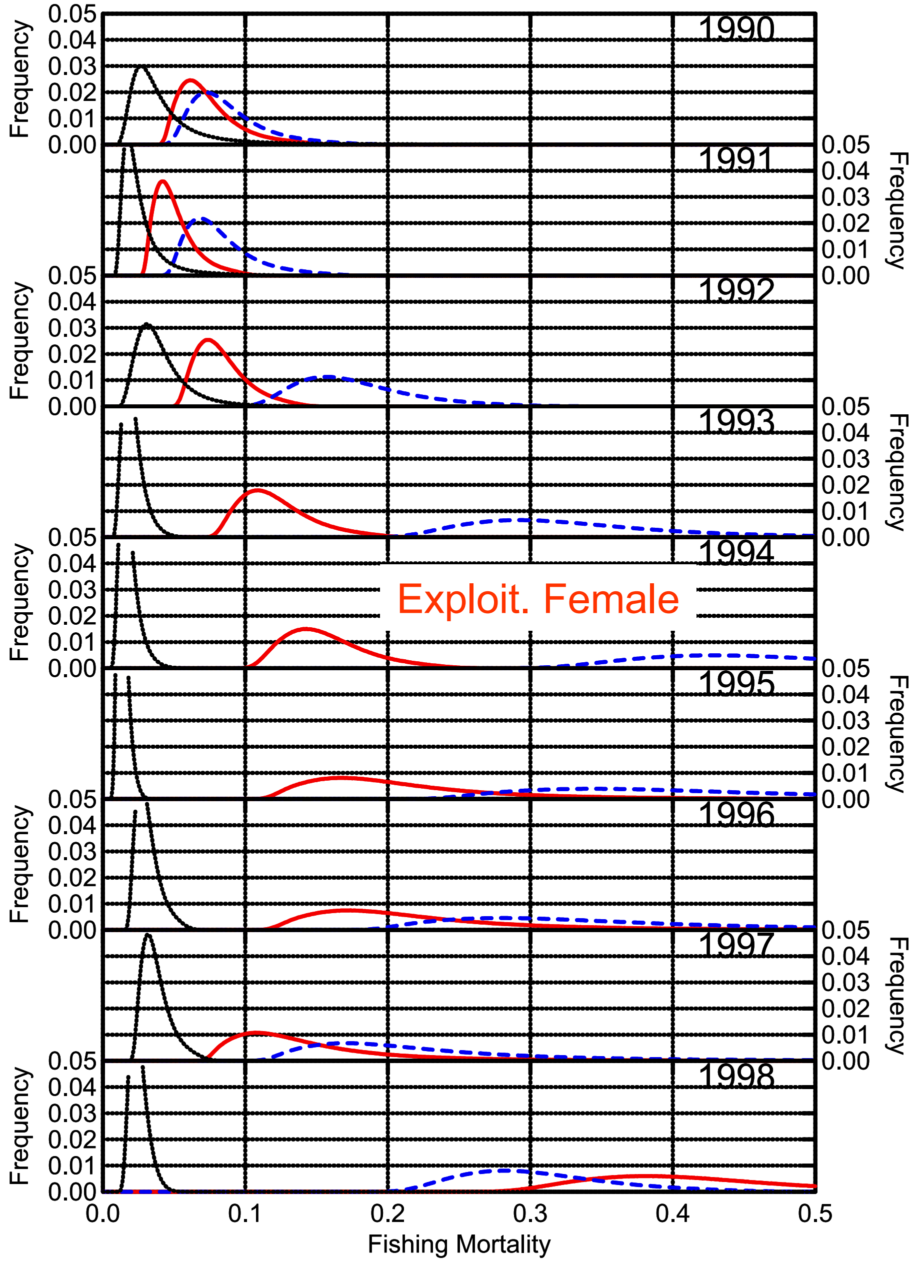


Fig.B 7.5a. Sampling distribution of F on fully recruited sizes for mature females (blue dashed), exploited female (solid red), and exploited male biomass (black dashed), 1990-1998. Years represent midpoint of 3-yr average; i.e., 1998 is average for 1997-1999. Sampling distribution represents joint effect of sampling variability and variations in average footprint of trawl (min estimate of footprint, assumes no herding effect of doors), variation in discards in trawl, gill net and recreational fisheries, and annual changes in selectivity patterns.

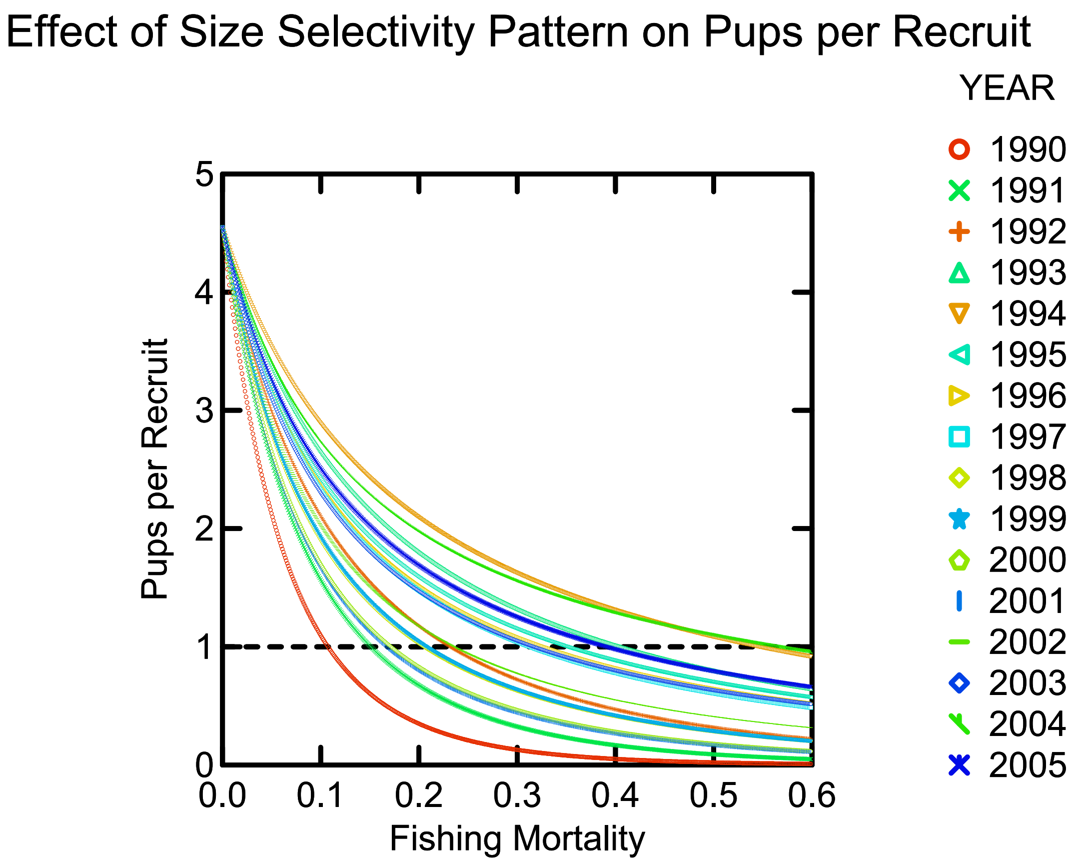


Fig. B7.6 Effect of size selectivity of fishery and F on the expected pups per recruit. Abscissa represents F on fully-recruited length classes. Selectivity changes vary across years due to changes in commercial landings patterns and varying degrees of discard mortality. Selectivity patterns are described in Appendix xx

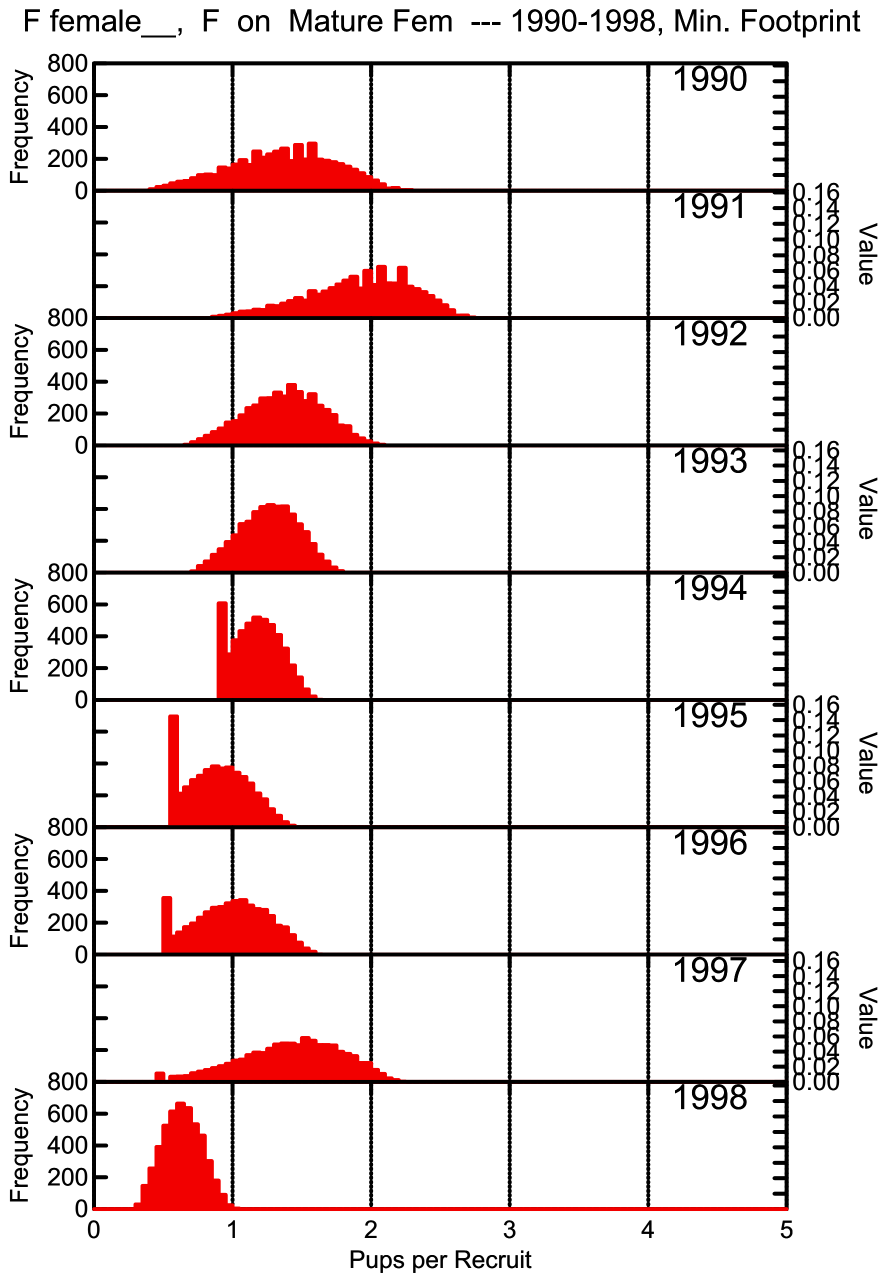


Fig. B7.7a Predicted sampling distribution for pups per recruit given variations in size selectivity and fishing mortality, 1990-1998. Pups per recruit represents integral measure of the force of mortality on longterm reproductive potential. Year represents a 3-yr average centered on the year label, i.e., 1998 is average for 1997-1999. PPR values above one suggest that the force of mortality is low enough to allow population growth. Histograms represents effect of landings plus discards on entire population of female spiny dogfish.

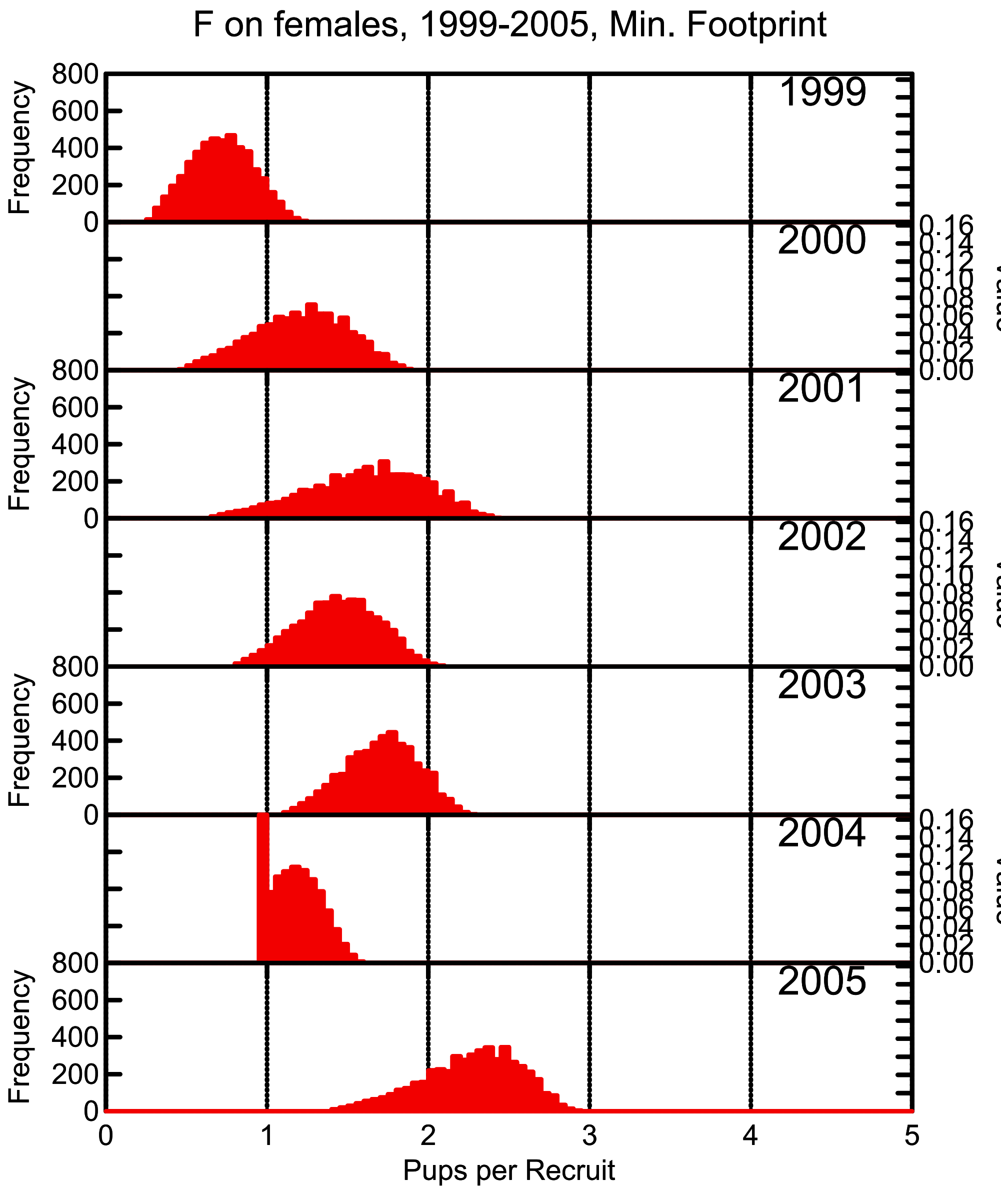
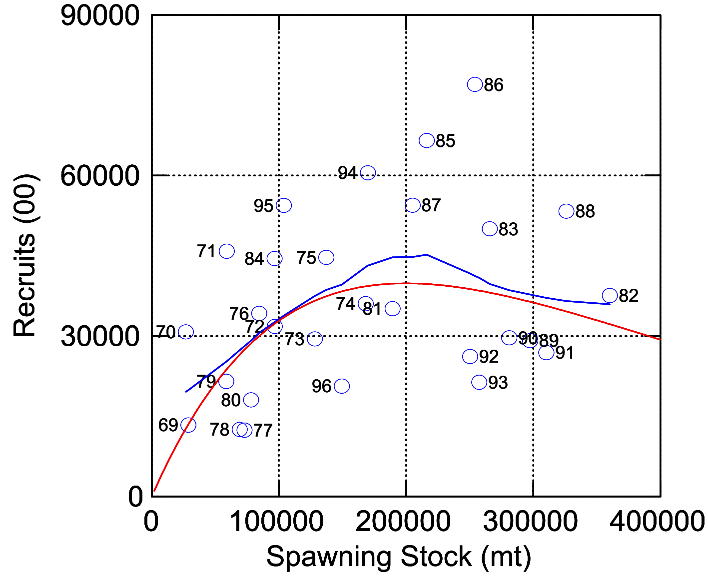


Fig. B7.7b Predicted sampling distribution for pups per recruit given variations in size selectivity and fishing mortality, 1999-2005. Pups per recruit represents integral measure of the force of mortality on longterm reproductive potential. Year represents a 3-yr average centered on the year label, i.e., 1998 is average for 1997-1999. PPR values above one suggest that the force of mortality is low enough to allow population growth. Histograms represents effect of landings plus discards on entire population of female spiny dogfish.

1968-1996 data



1968-2006 data

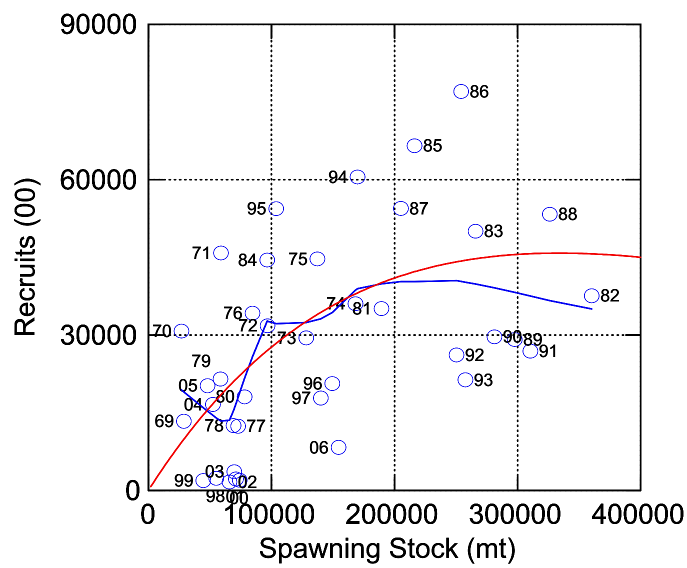


Fig. B8.1 Comparison of parametric and non-parametric stock-recruitment model fits for spiny dogfish captured in NMFS spring survey for 1968-1996 (top) and 1968-2006 (bottom). Nonparametric model fits base on lowess smoothes with tension=0.6. Estimated SSBmax, 1968-1996 of 215 k mt, corresponds to average catch of 33.2 kg mature females/tow. Estimated SSBmax for the 1968-2006 period increases to 304 k mt or 46.8 k mt.

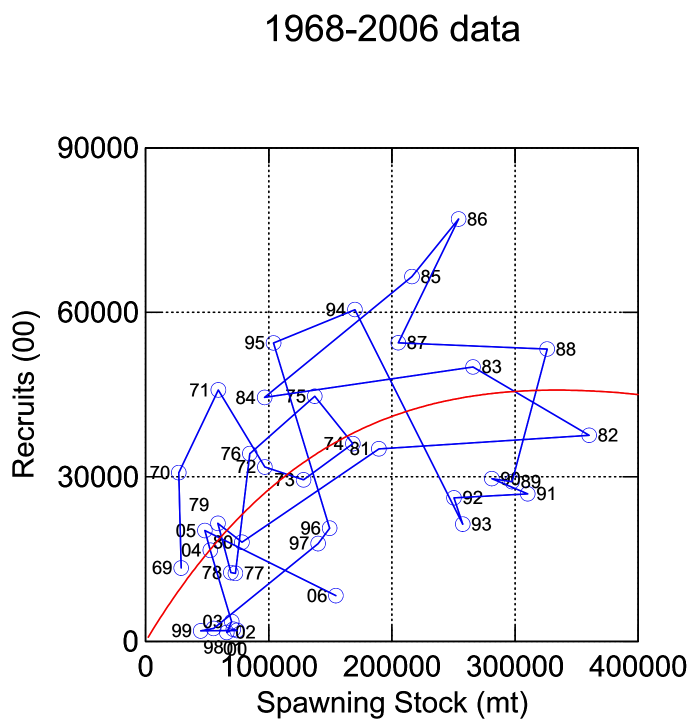


Fig. B8.2 Temporal pattern of .spawning stock and recruits for 1968-2006. Swept area estimates of abundance based on NMFS spring survey.

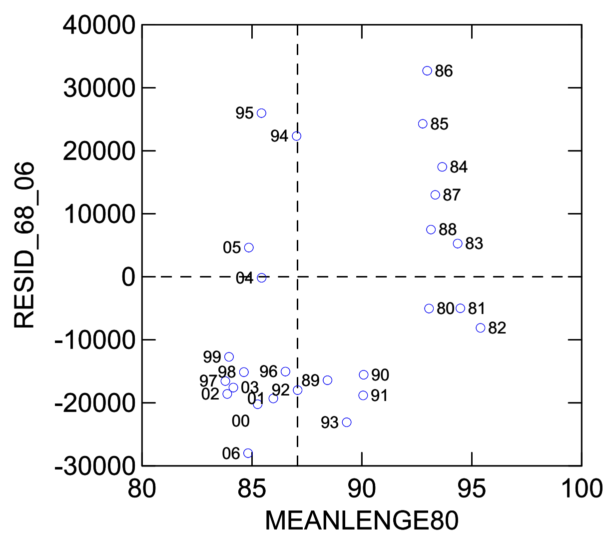


Fig. B8.3 Model residuals from Ricker model vs mean length of mature female spiny dogfish. Odds ratio test statistic suggests that odds of recruitment less than model prediction is of 4.5 times greater when females are below median size of 87 cm.

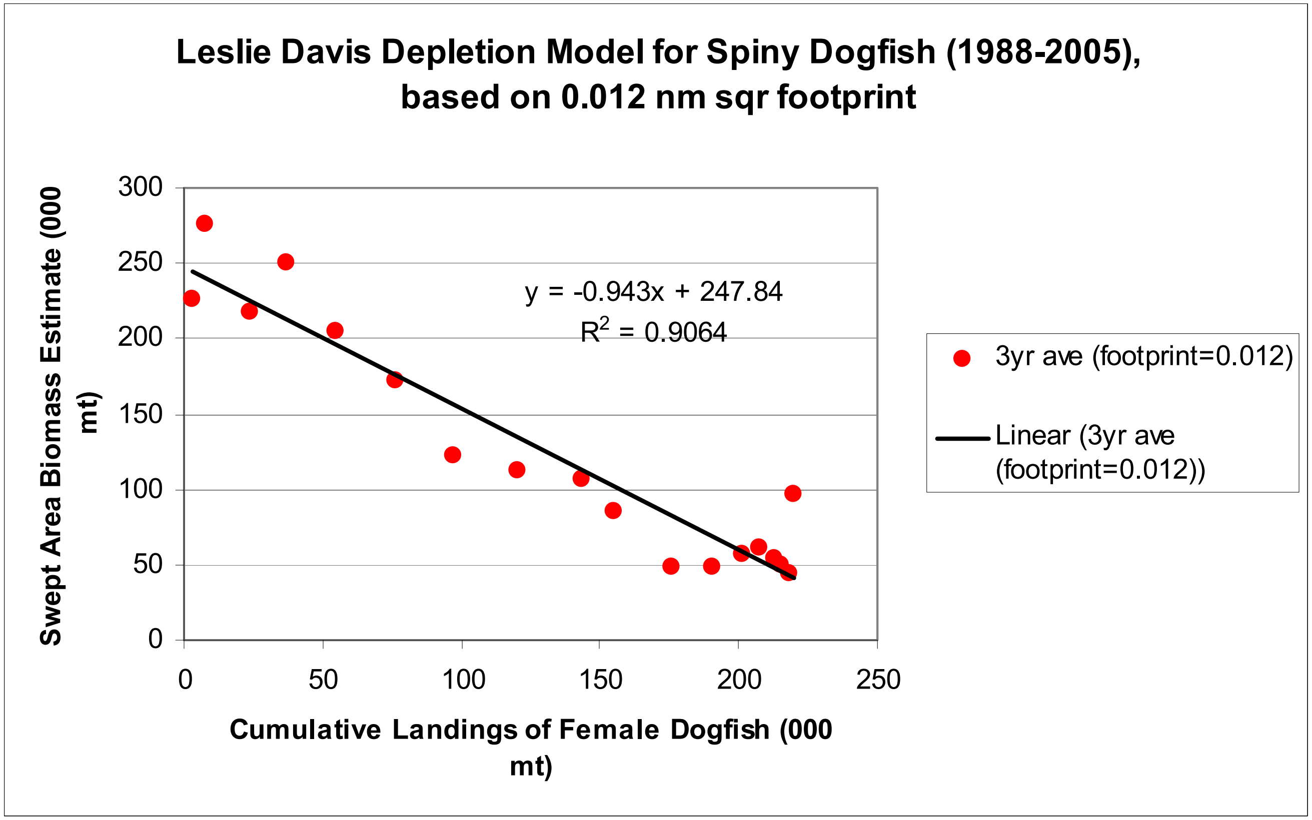


Fig. B9.1 Summary of Leslie Davis depletion model for female spiny dogfish, assuming a closed population.

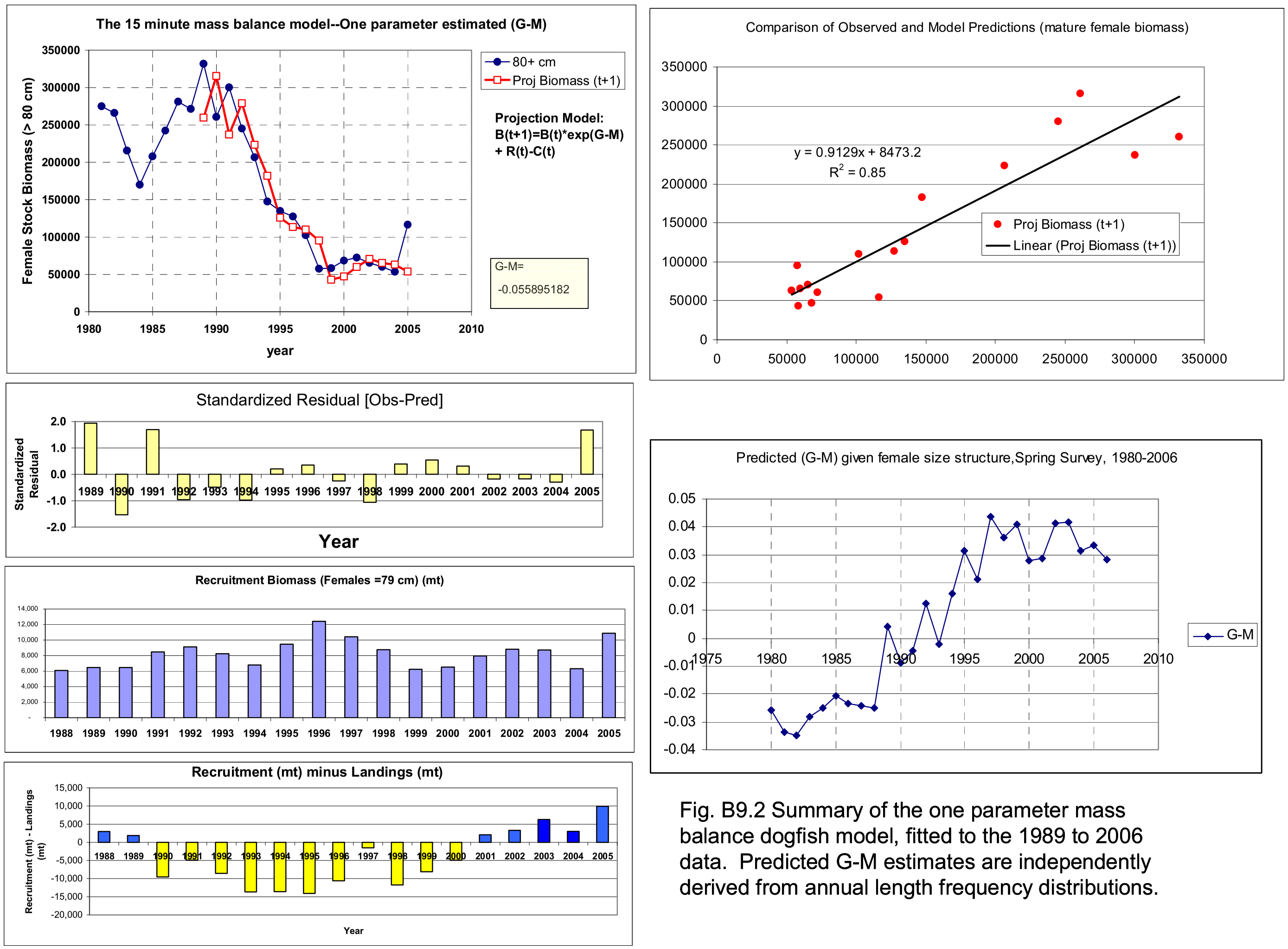


Fig. B9.2 Summary of the one parameter mass balance dogfish model, fitted to the 1989 to 2006 data. Predicted G-M estimates are independently derived from annual length frequency distributions.

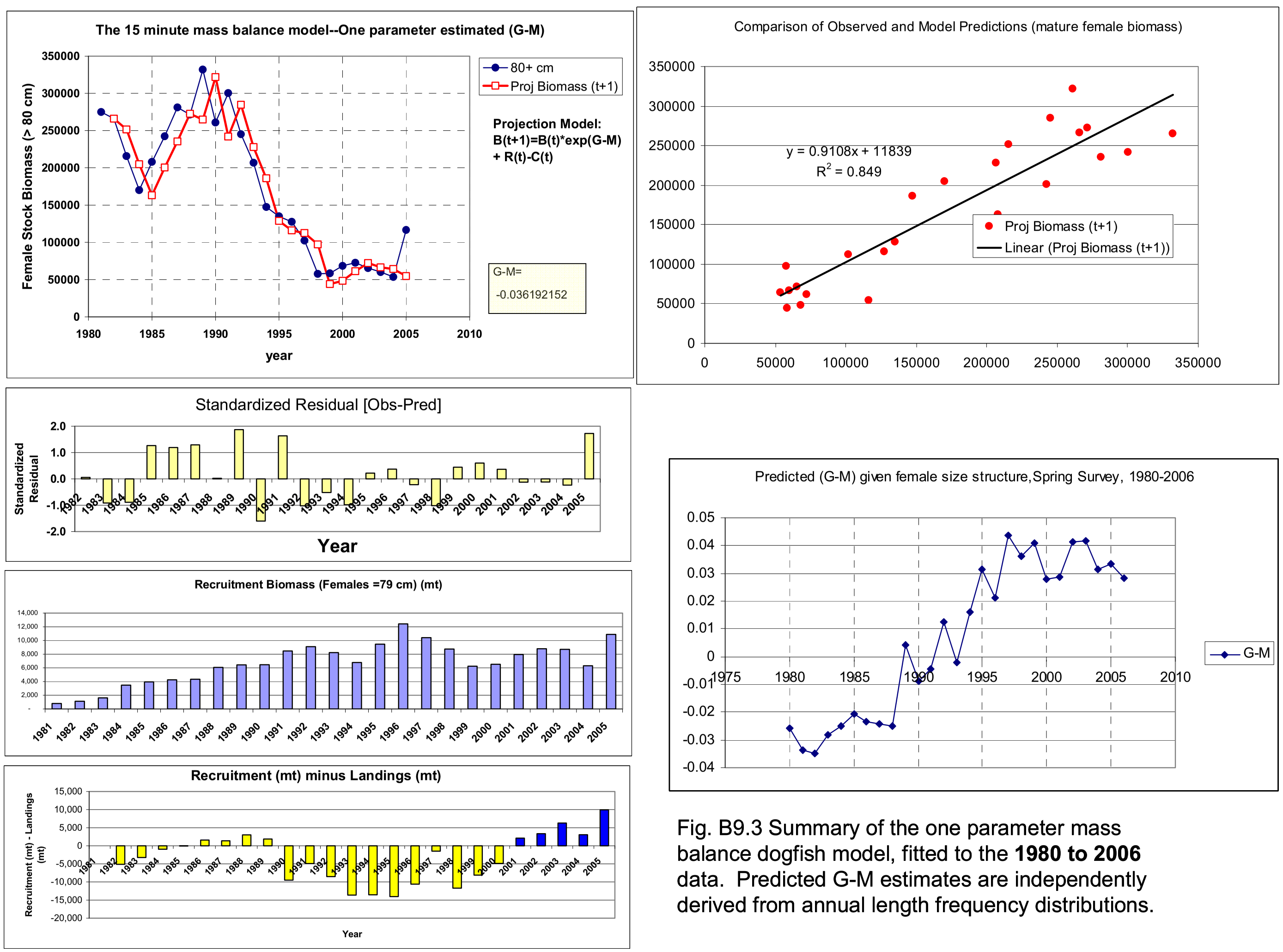


Fig. B9.3 Summary of the one parameter mass balance dogfish model, fitted to the **1980 to 2006** data. Predicted G-M estimates are independently derived from annual length frequency distributions.

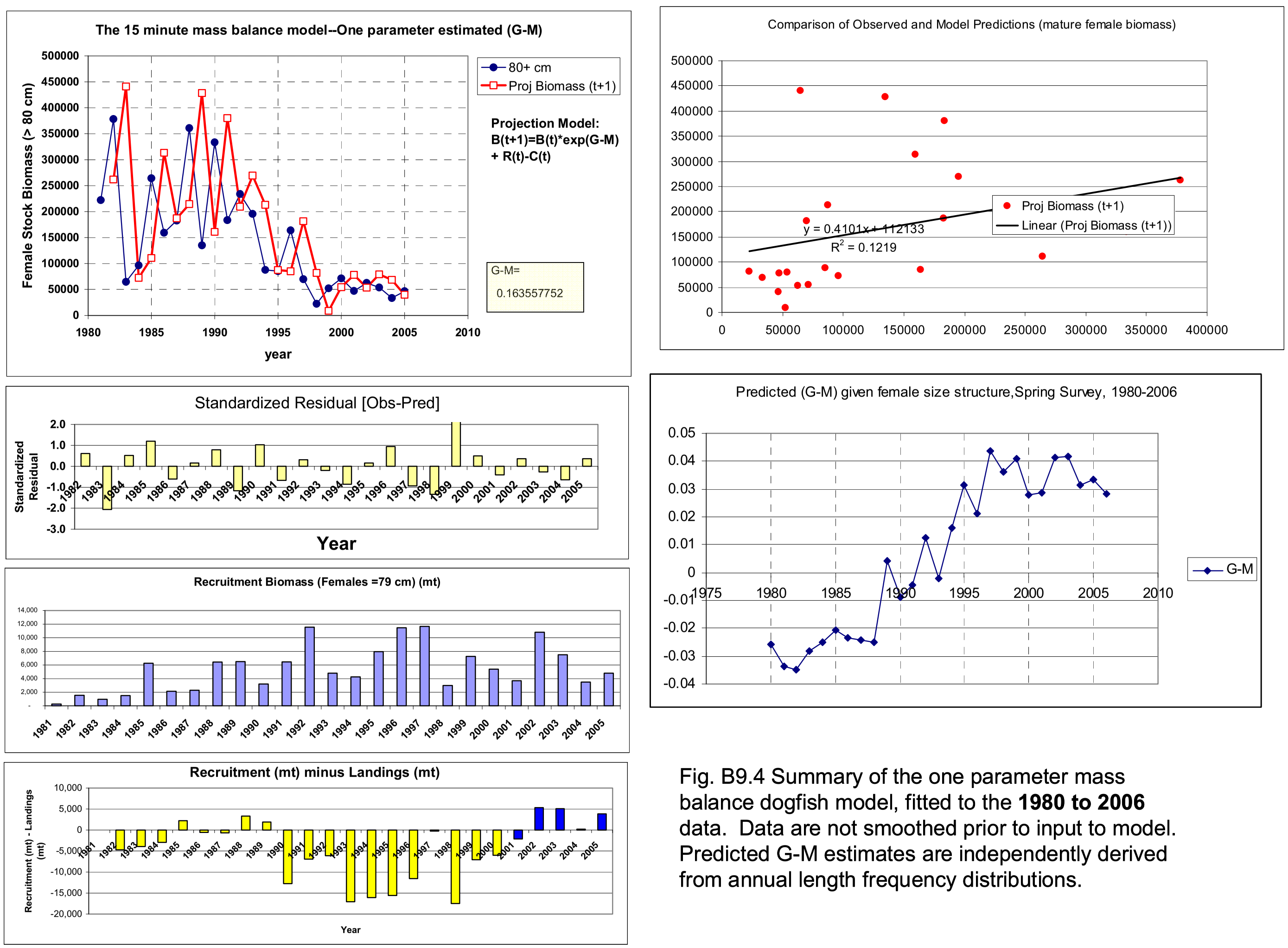


Fig. B9.4 Summary of the one parameter mass balance dogfish model, fitted to the **1980 to 2006** data. Data are not smoothed prior to input to model. Predicted G-M estimates are independently derived from annual length frequency distributions.

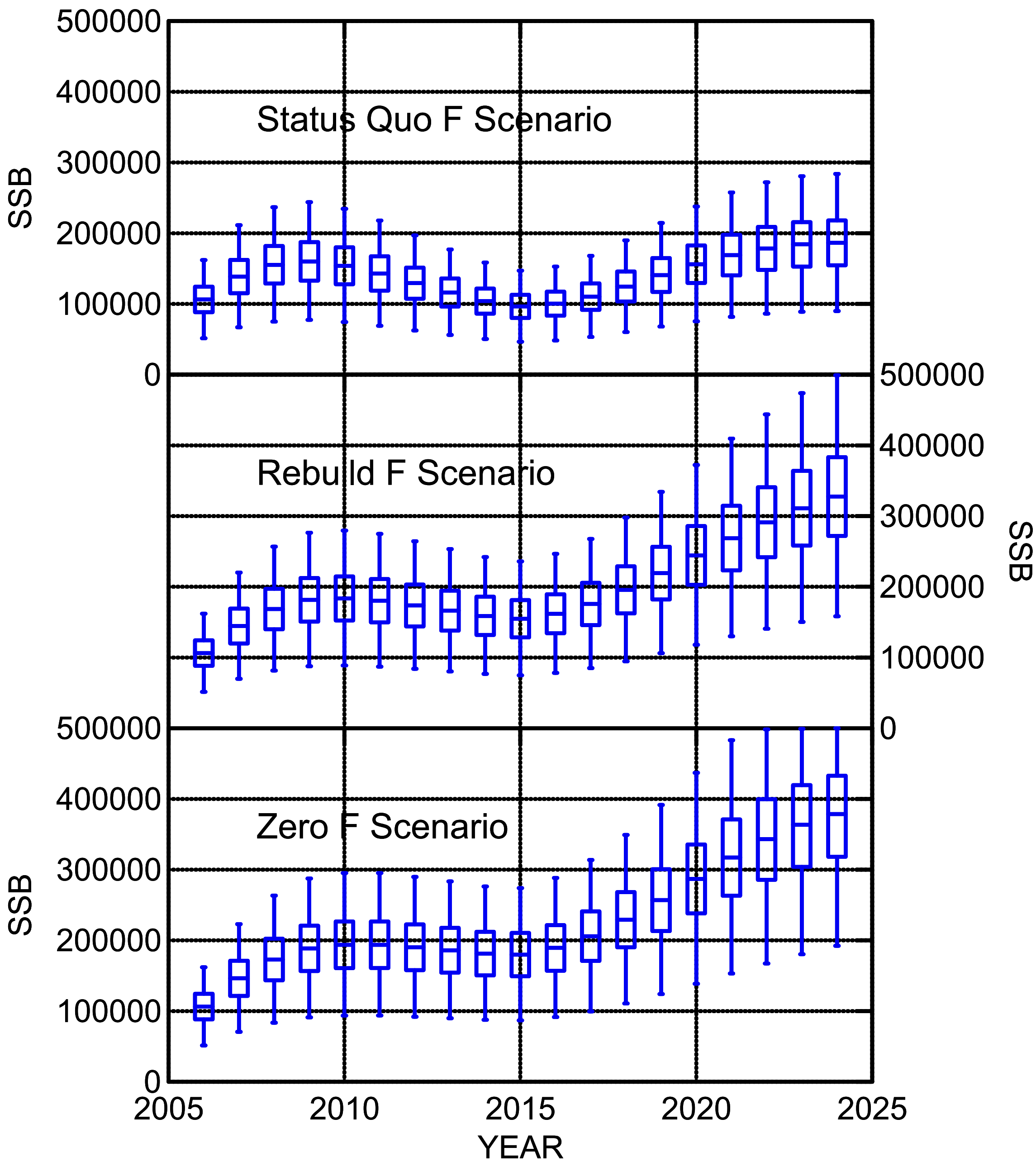


Figure B10.1. Spiny dogfish spawning stock biomass (mt) projections, 2006-2024, for three scenarios: Status quo (full F=0.128), Rebuild F(=0.03), and Zero F. Boxes represent interquartile ranges.

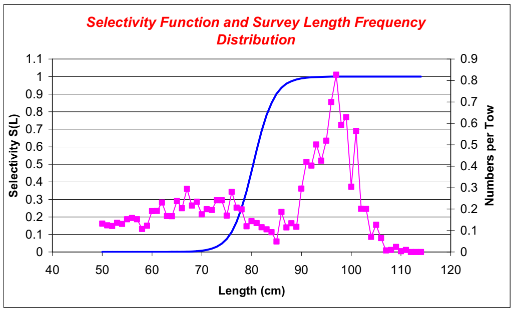
APPENDIX B1. Commercial dogfish selectivity for landings only.

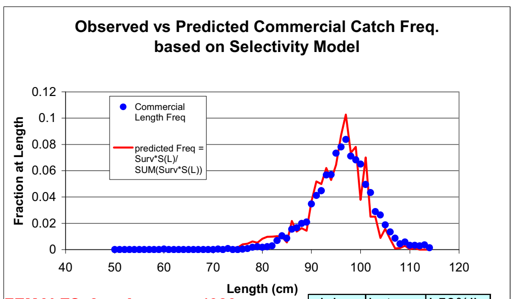
Females:

FEMALES, 3-yr Average, 1984

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
38.04	-0.474	80.318

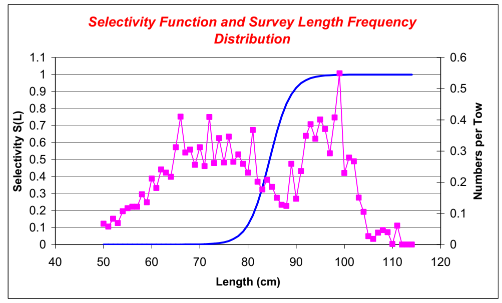


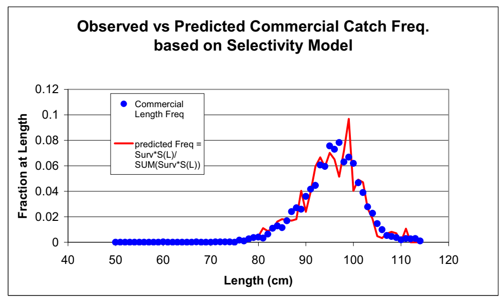


FEMALES, 3-yr Average, 1985

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
38.04	-0.45	84.501

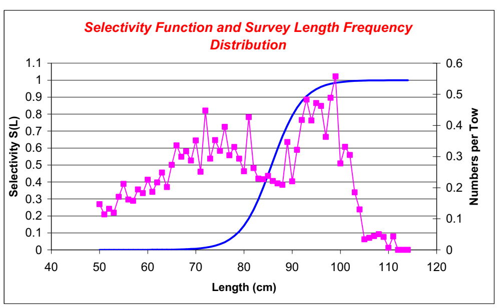


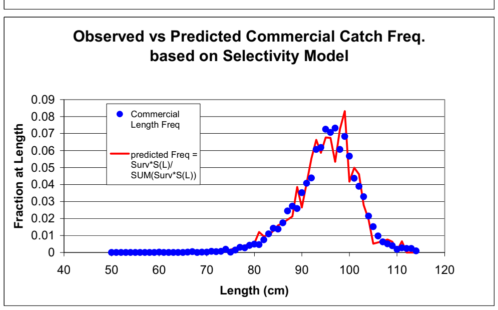


FEMALES, 3-yr Average, 1986

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
26.73	-0.312	85.74

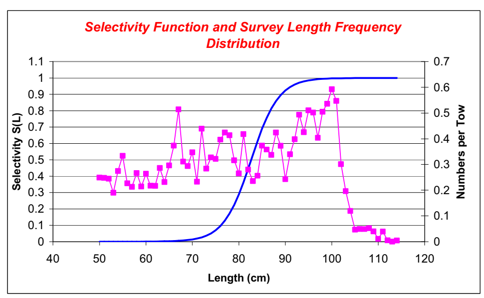


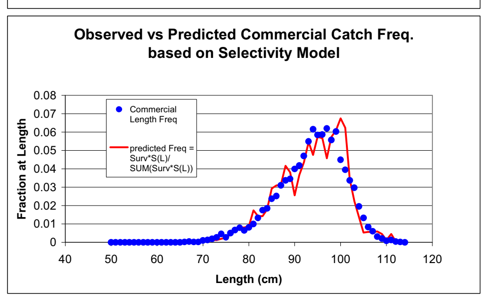


FEMALES, 3-yr Average, 1987

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
28	-0.339	82.65

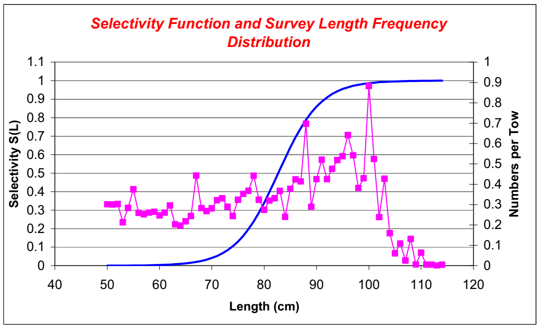


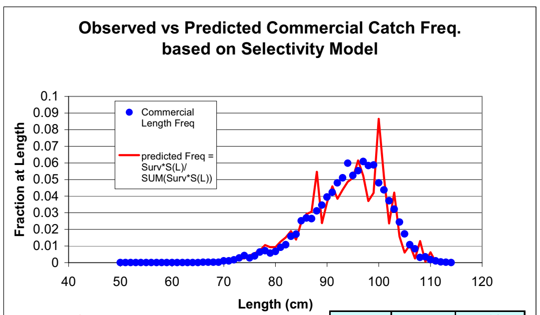


FEMALES, 3-yr Average, 1988

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
20.43	-0.247	82.68

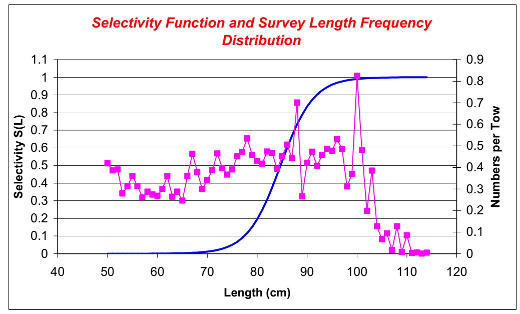


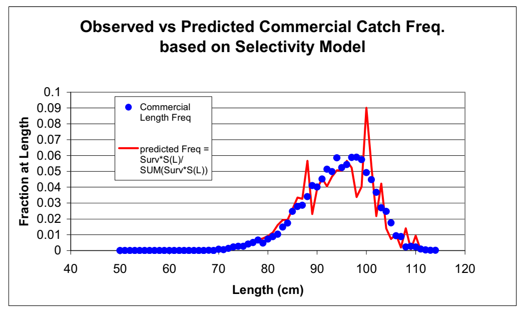


FEMALES, 3-yr Average, 1989

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
25.7	-0.304	84.675

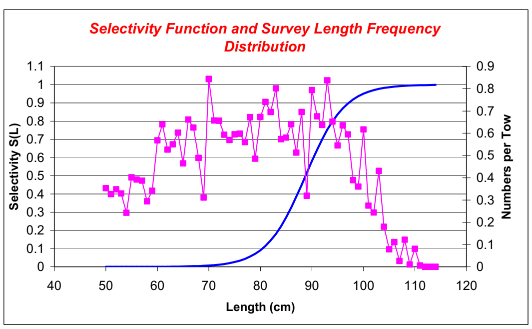


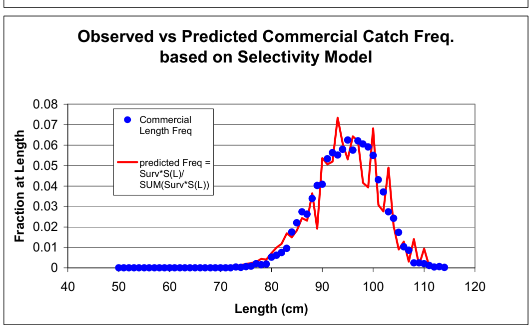


FEMALES, 3-yr Average, 1990

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
23.3	-0.263	88.754

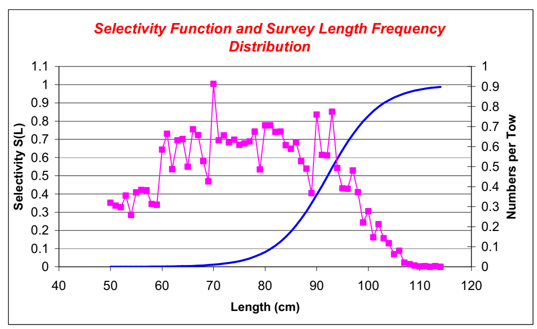


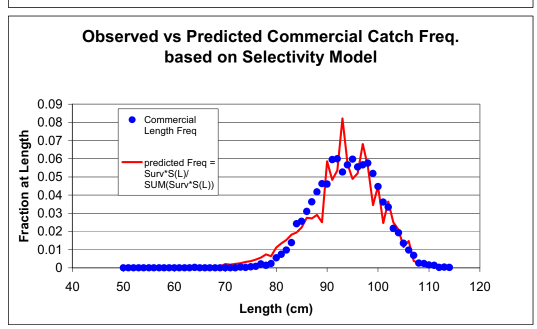


FEMALES, 3-yr Average, 1991

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
18.44	-0.2	92.118

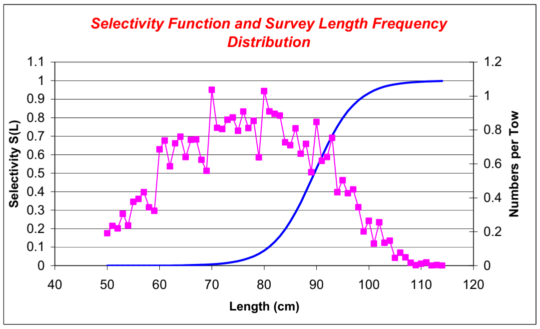


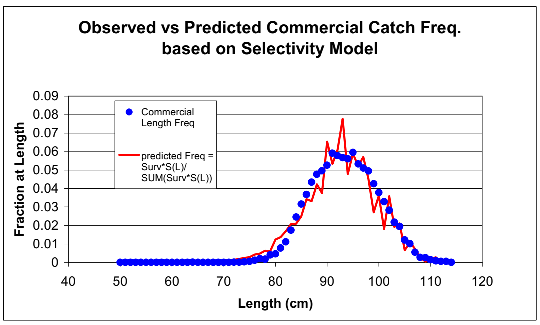


FEMALES, 3-yr Average, 1992

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
22.64	-0.253	89.582

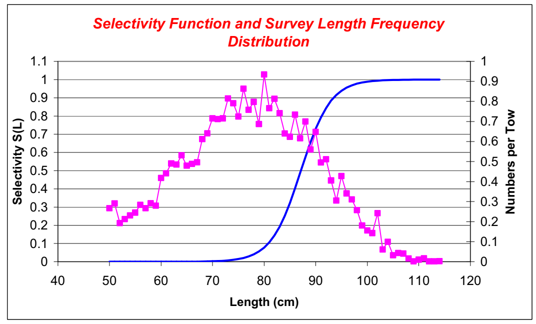


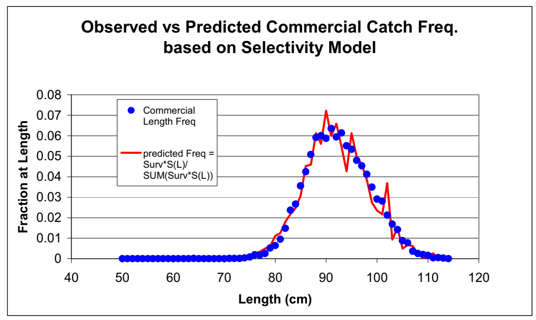


FEMALES, 3-yr Average, 1993

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
30.22	-0.347	87.129

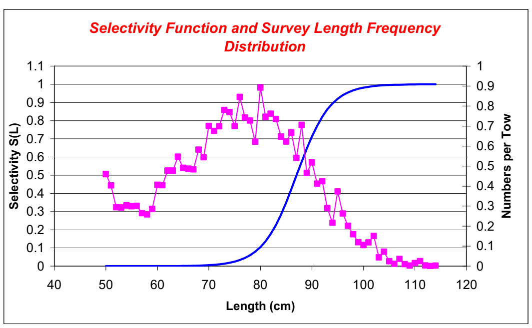


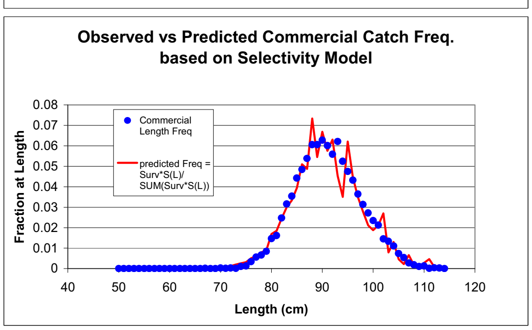


FEMALES, 3-yr Average, 1994

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
26.63	-0.306	87.023

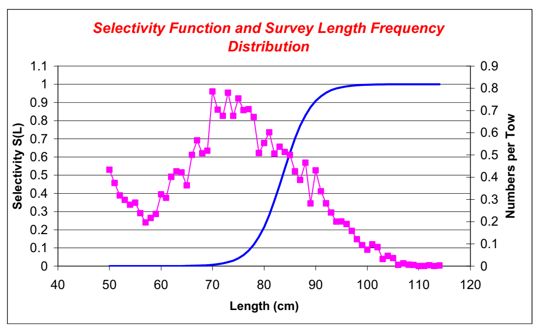


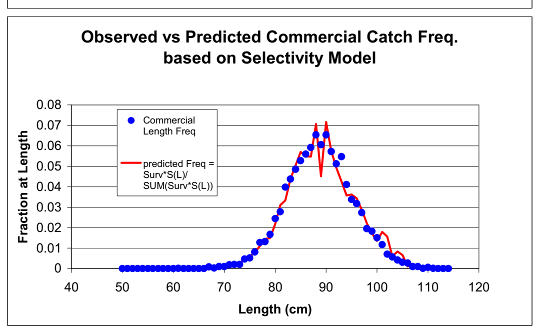


FEMALES, 3-yr Average, 1995

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
30.02	-0.359	83.603

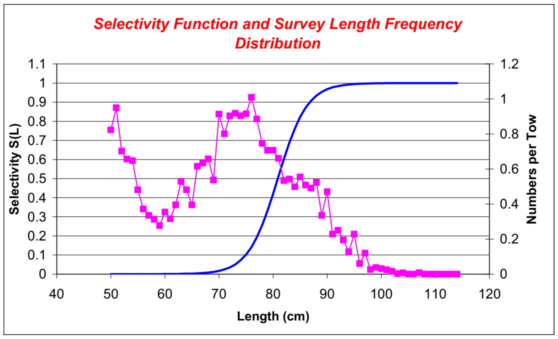


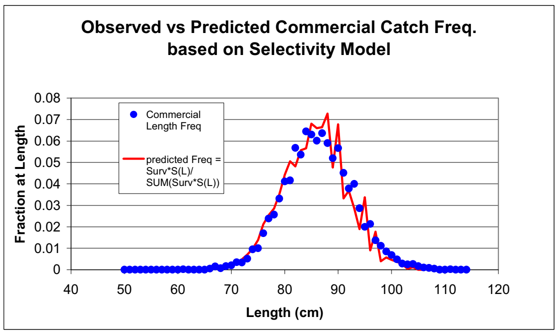


FEMALES, 3-yr Average, 1996

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
30.02	-0.371	80.861

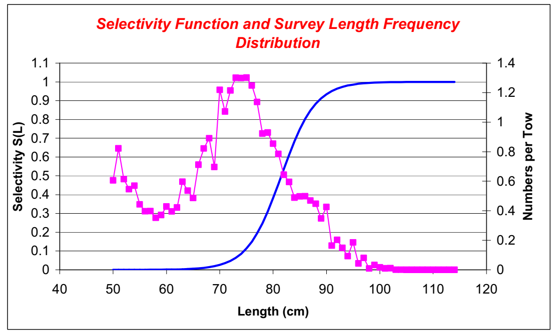


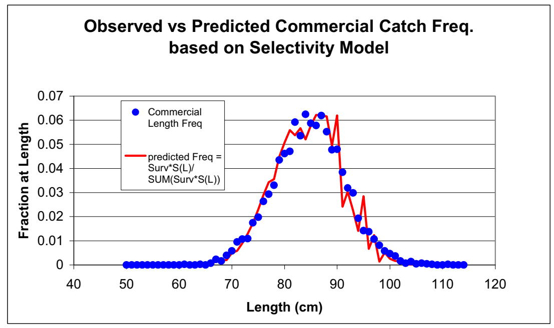


FEMALES, 3-yr Average, 1997

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
25.61	-0.314	81.54

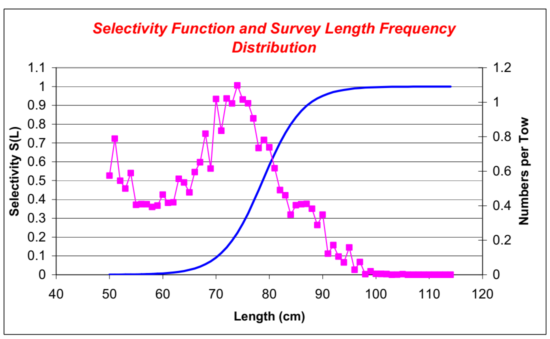


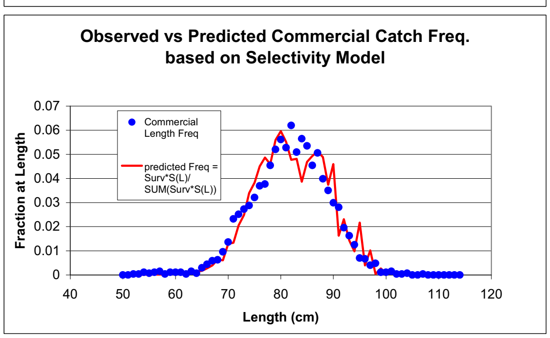


FEMALES, 3-yr Average, 1998

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
20.7	-0.263	78.756

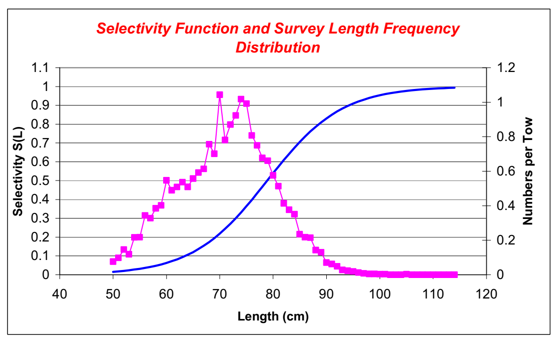


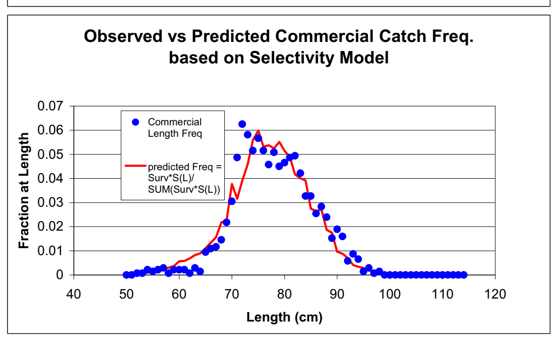


FEMALES, 3-yr Average, 1999

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
11.29	-0.143	78.9

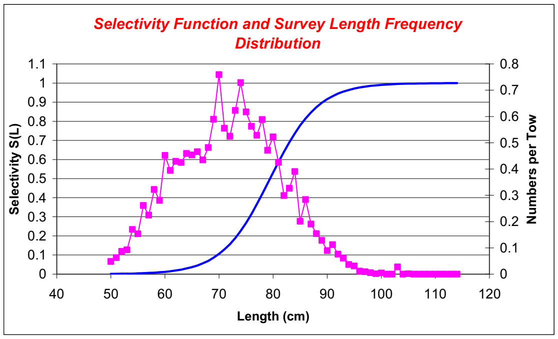


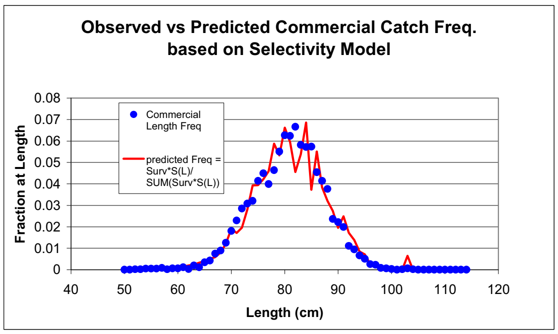


FEMALES, 3-yr Average, 2000

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
17.95	-0.226	79.442

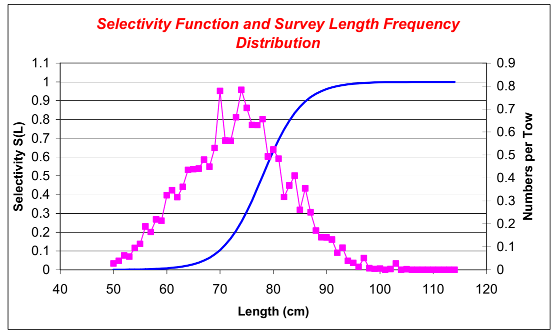


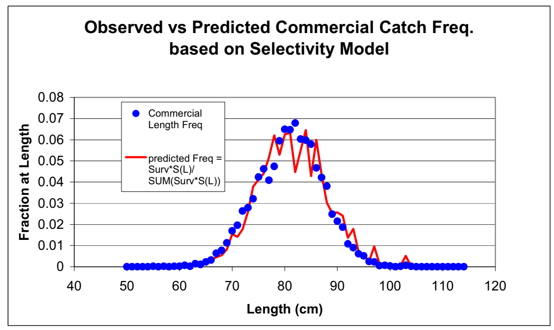


FEMALES, 3-yr Average, 2001

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
20.95	-0.269	77.983

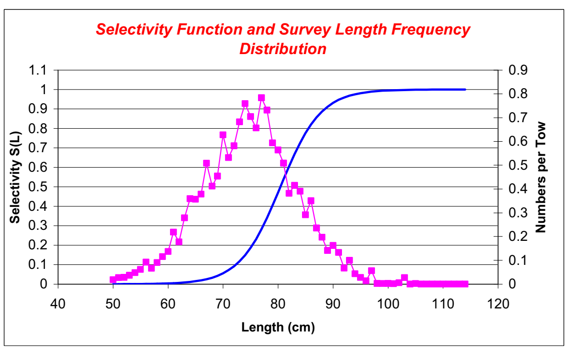


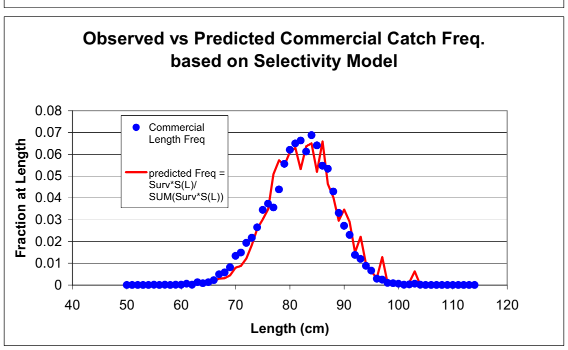


FEMALES, 3-yr Average, 2002

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
21.87	-0.272	80.422

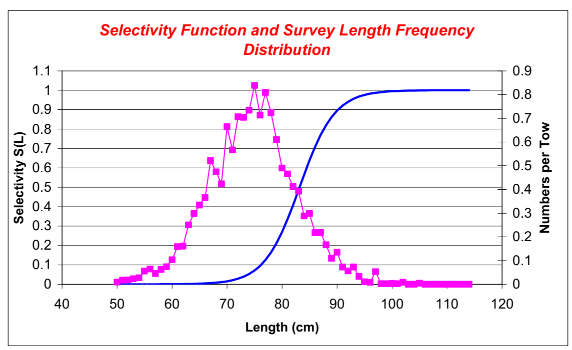


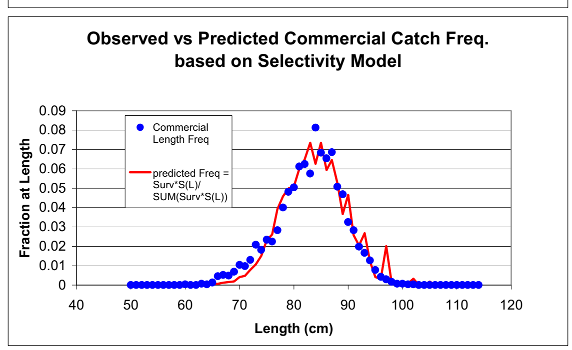


FEMALES, 3-yr Average, 2003

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
26.1	-0.314	83.178

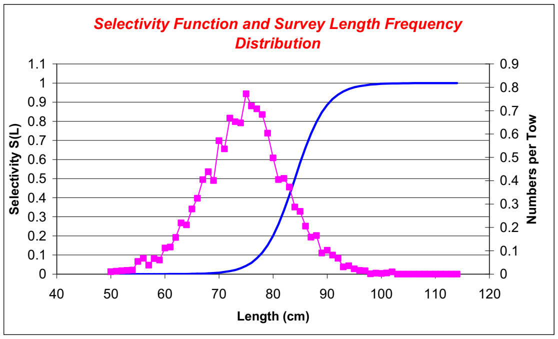


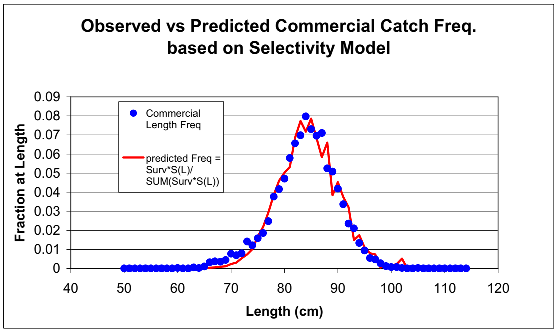


FEMALES, 3-yr Average, 2004

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
28.81	-0.343	84.021

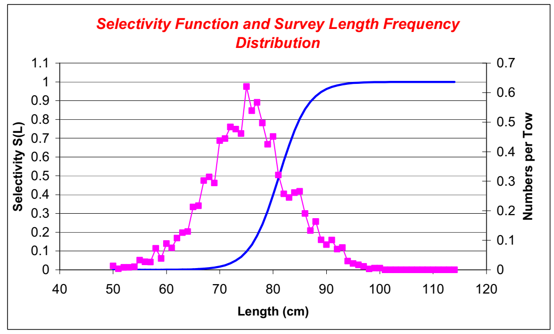


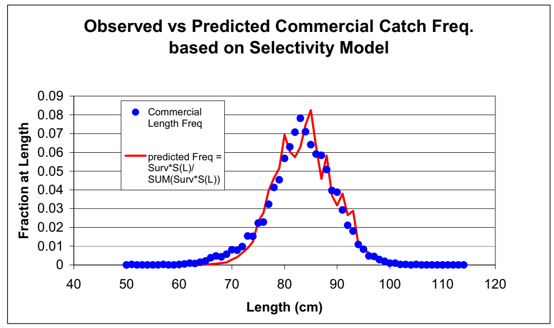


FEMALES, 3-yr Average, 2005

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
29.58	-0.365	81.134



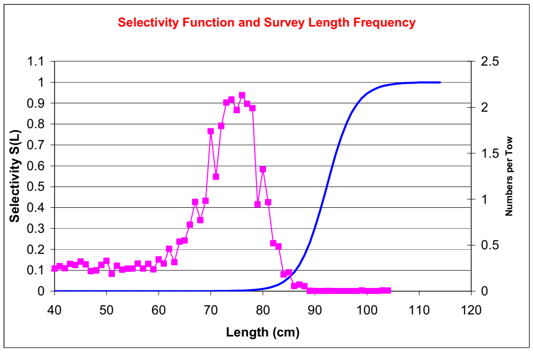


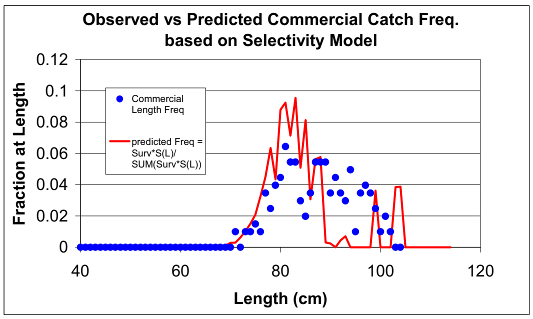
Males:

MALES, 3-yr Average, 1991

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
34.06	-0.369	92.253

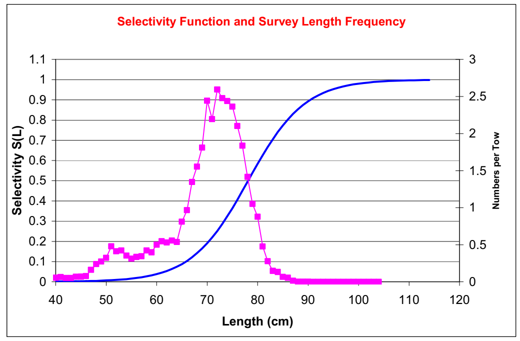


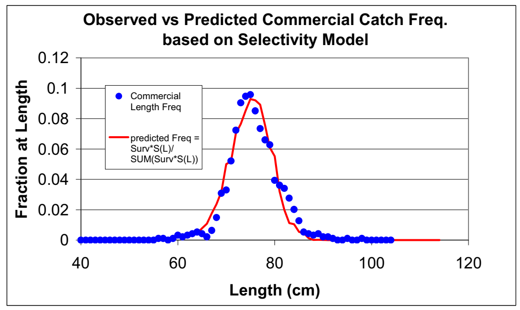


MALES, 3-yr Average, 1998

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
13.94	-0.178	78.119

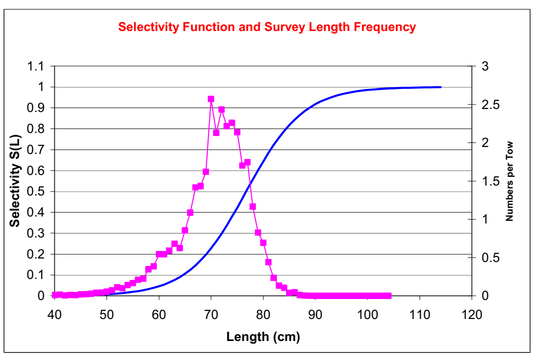


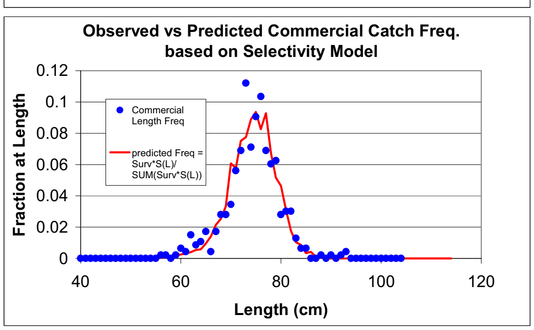


MALES, 3-yr Average, 1999

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
13.94	-0.182	76.732

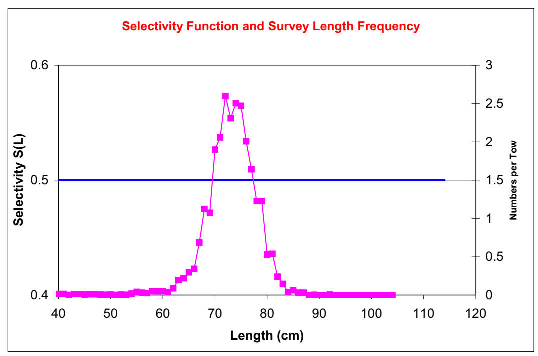


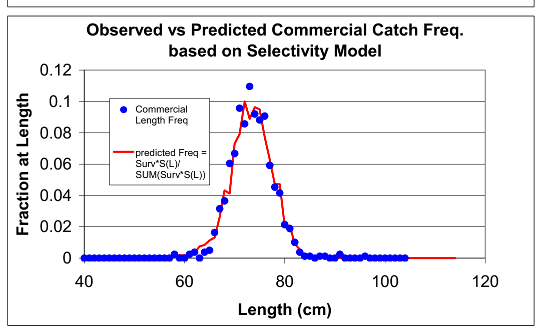


MALES, 3-yr Average, 2005

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
3E-04	-6E-06	50



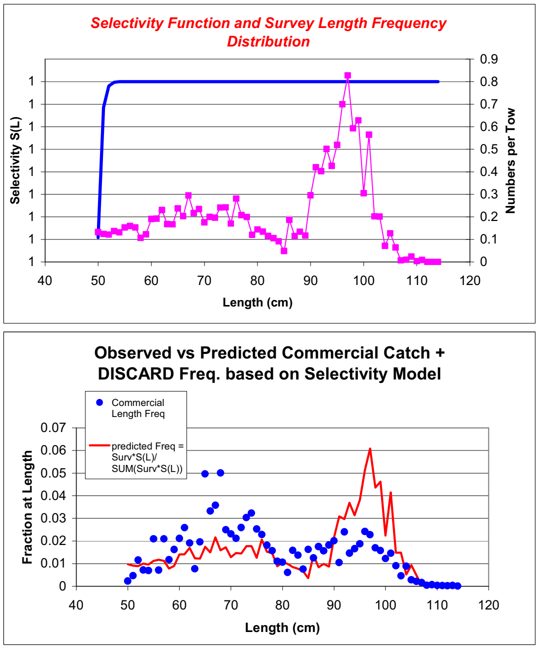


APPENDIX B2. Commercial selectivity for landings, dicards, and recreational.
Females:

FEMALES, 3-yr Average, w/Discard 1984

model: S(L) = 1/(1+exp(alpha+beta * L))

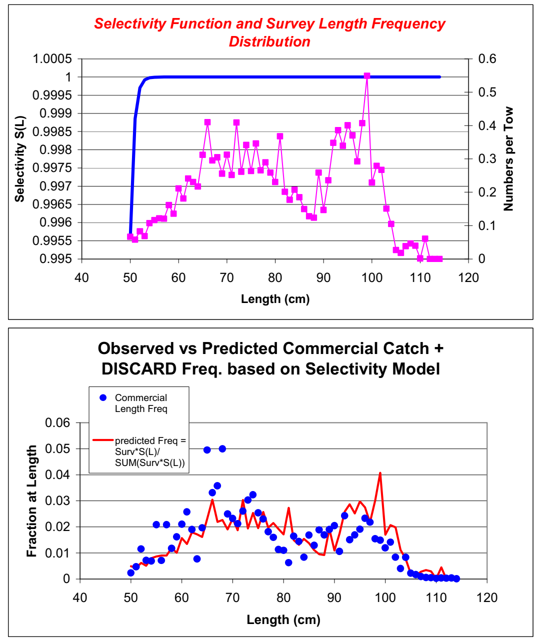
alpha	beta	L50%ile
62	-1.8	34.444



FEMALES, 3-yr Average, w/Discard 1985

model: S(L) = 1/(1+exp(alpha+beta * L))

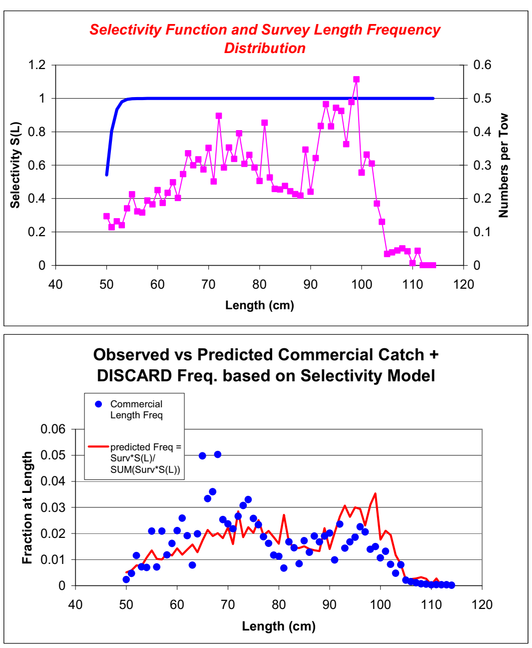
alpha	beta	L50%ile
62.14	-1.351	45.989



FEMALES, 3-yr Average, w/Discard 1986

model: S(L) = 1/(1+exp(alpha+beta * L))

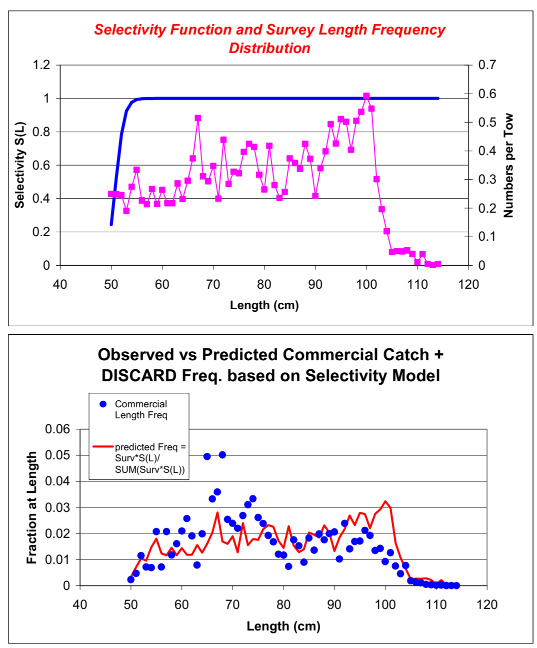
alpha	beta	L50%ile
62.14	-1.246	49.867



FEMALES, 3-yr Average, w/Discard 1987

model: S(L) = 1/(1+exp(alpha+beta * L))

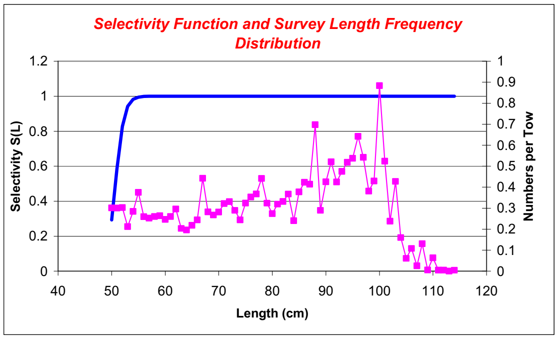
alpha	beta	L50%ile
62.14	-1.22	50.931

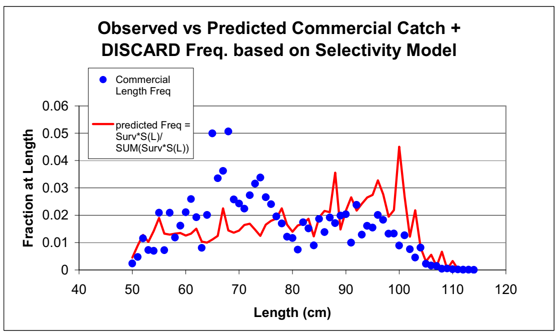


FEMALES, 3-yr Average, w/Discard 1988

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
62.14	-1.225	50.72

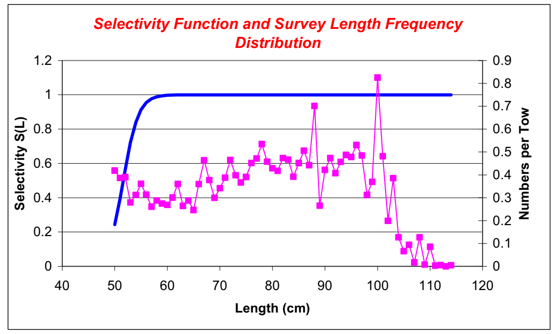


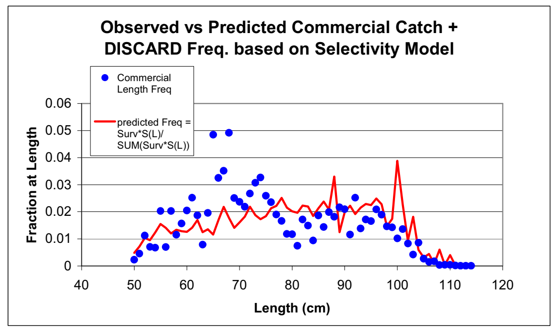


FEMALES, 3-yr Average, w/Discard 1989

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
36	-0.697	51.625

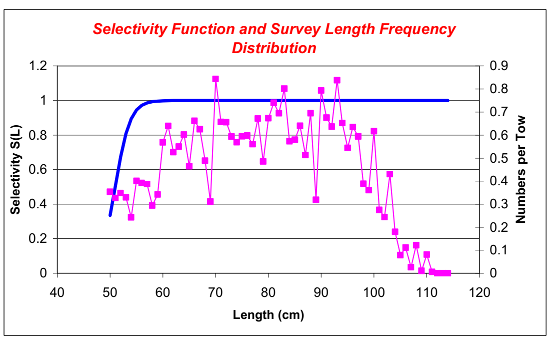


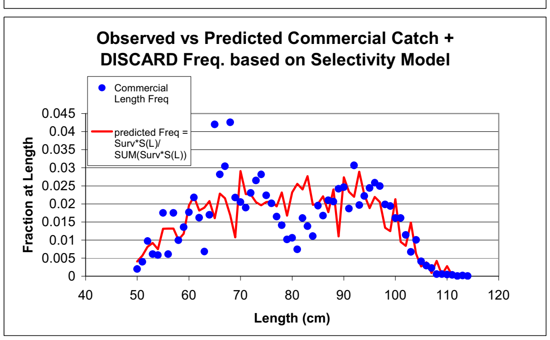


FEMALES, 3-yr Average, w/Discard 1990

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
36	-0.706	50.97

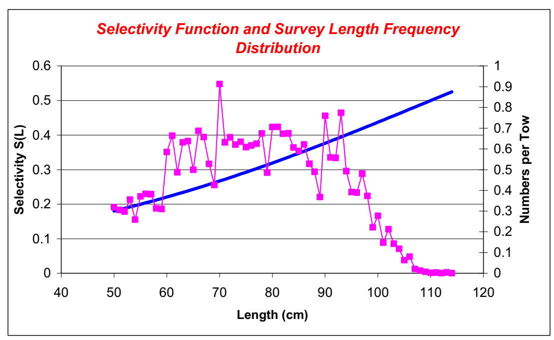


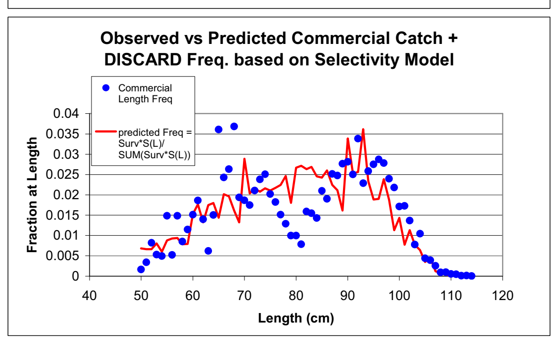


FEMALES, 3-yr Average, w/Discard 1991

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
2.777	-0.025	110

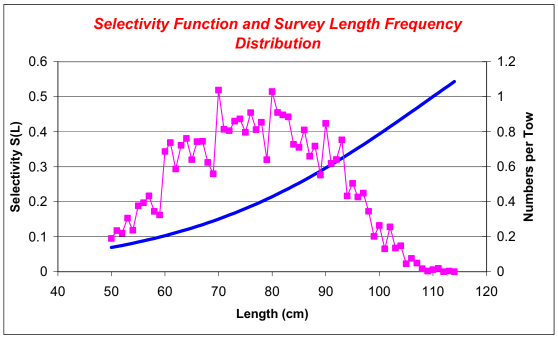


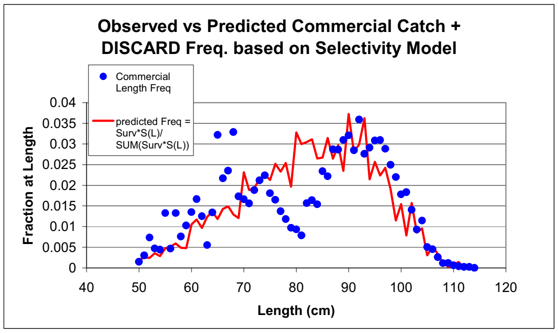


FEMALES, 3-yr Average, w/Discard 1992

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
4.762	-0.043	110

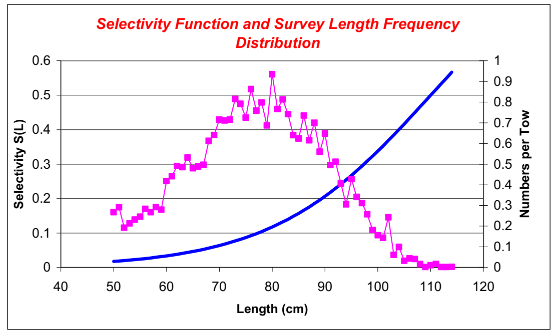


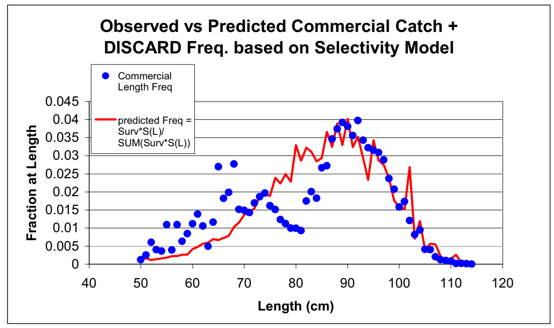


FEMALES, 3-yr Average, w/Discard 1993

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
7.397	-0.067	110

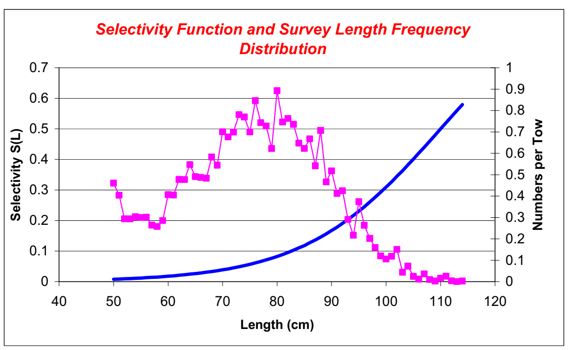


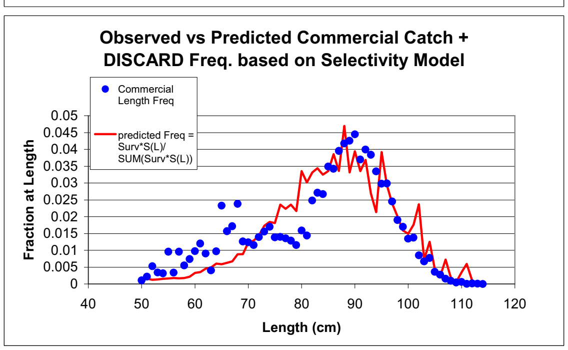


FEMALES, 3-yr Average, w/Discard 1994

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
8.831	-0.08	110

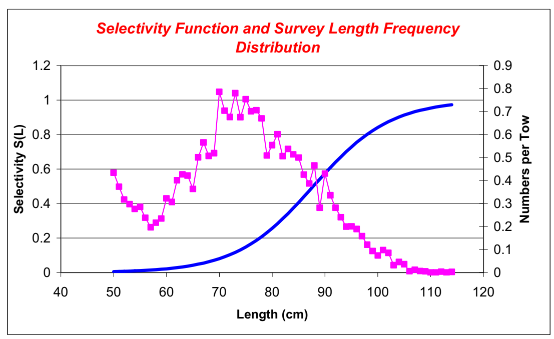


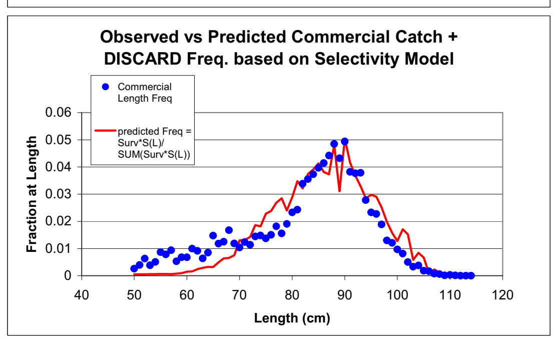


FEMALES, 3-yr Average, w/Discard 1995

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
11.99	-0.137	87.777

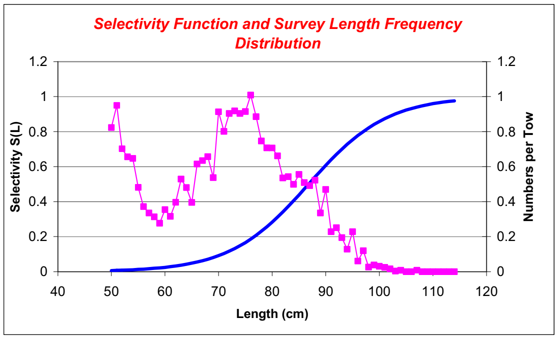


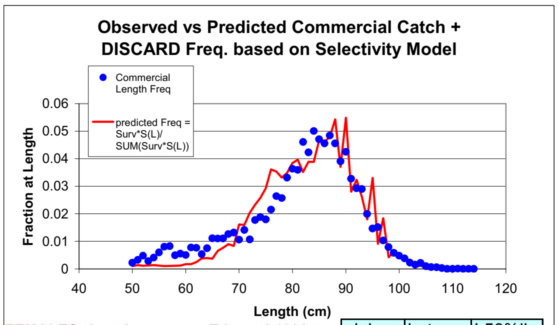


FEMALES, 3-yr Average, w/Discard 1996

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
11.85	-0.137	86.794

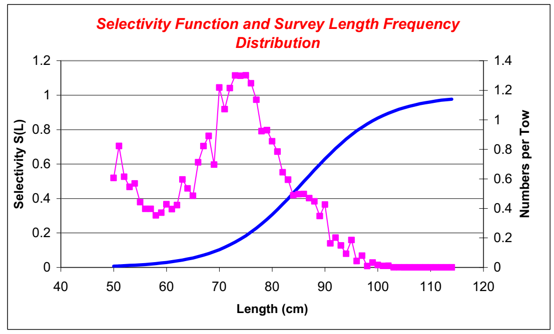


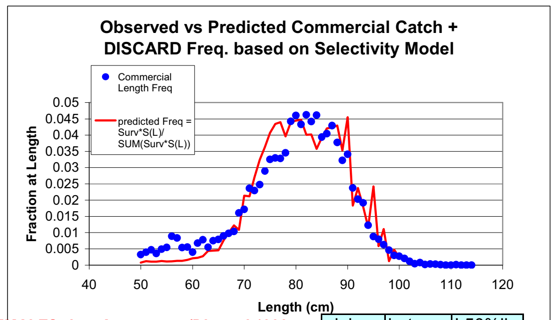


FEMALES, 3-yr Average, w/Discard 1997

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
11.59	-0.135	86.043

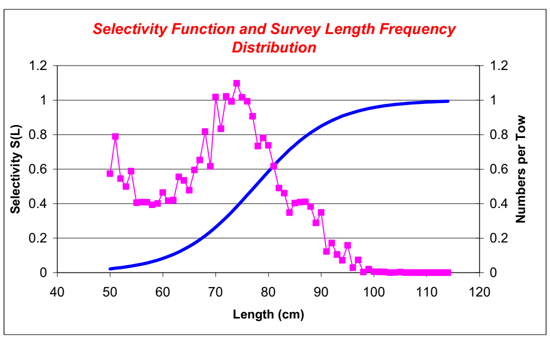


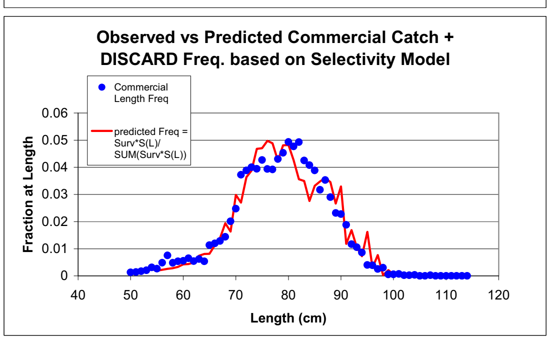


FEMALES, 3-yr Average, w/Discard 1998

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
10.69	-0.138	77.449

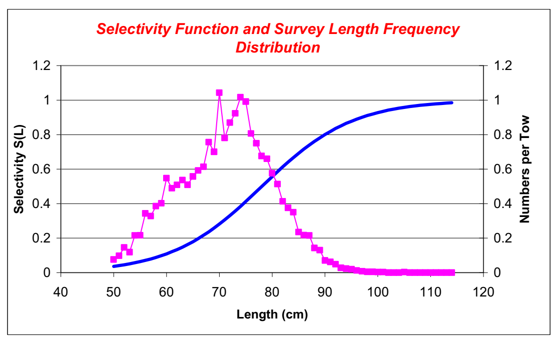


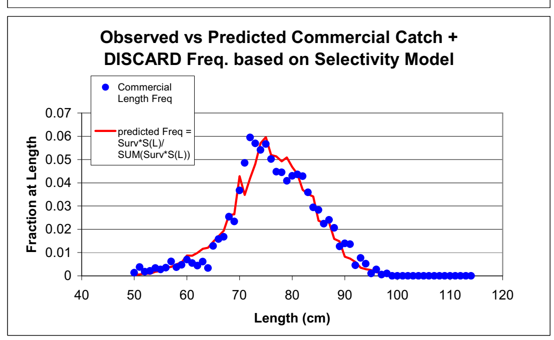


FEMALES, 3-yr Average, w/Discard 1999

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
9.083	-0.116	78.042

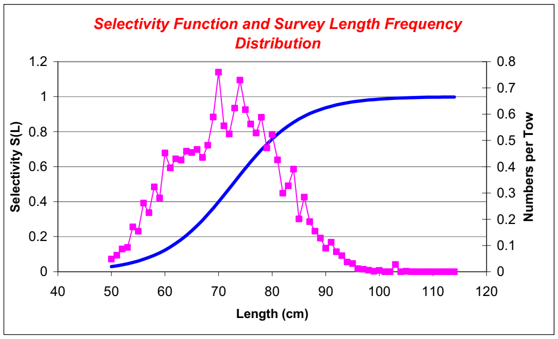


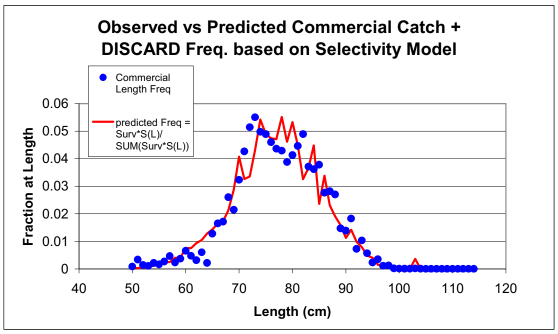


FEMALES, 3-yr Average, w/Discard 2000

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
11.27	-0.155	72.628

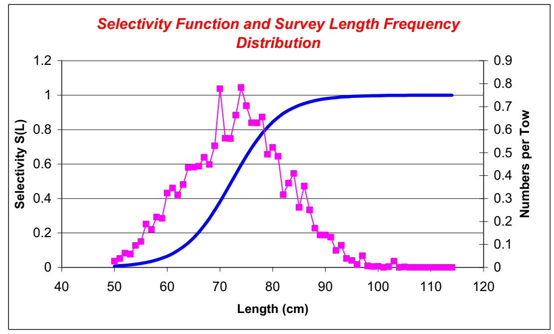


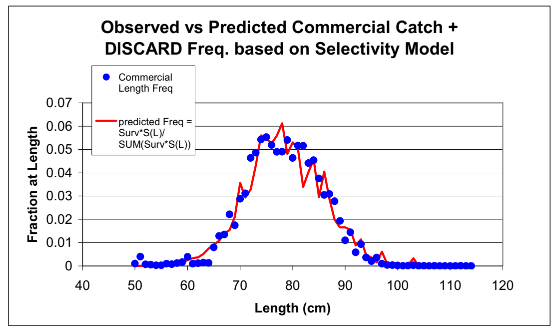


FEMALES, 3-yr Average, w/Discard 2001

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
15.72	-0.218	72.219

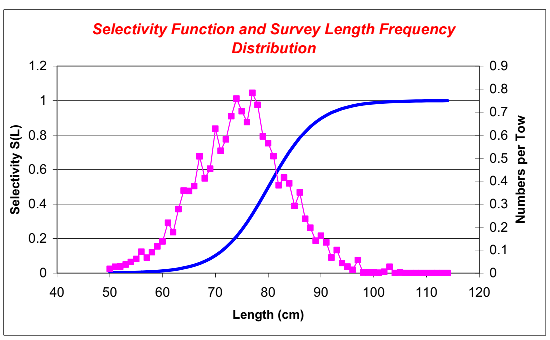


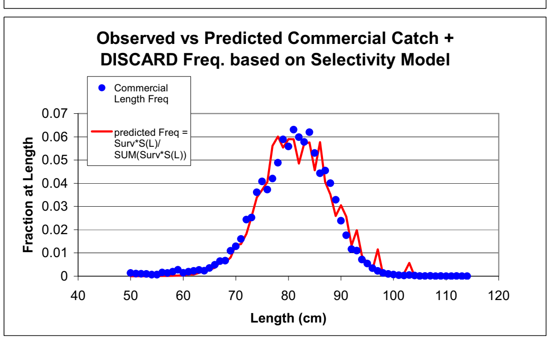


FEMALES, 3-yr Average, w/Discard 2002

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
17.34	-0.217	80.036

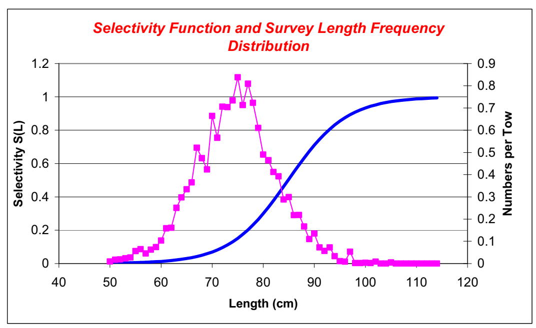


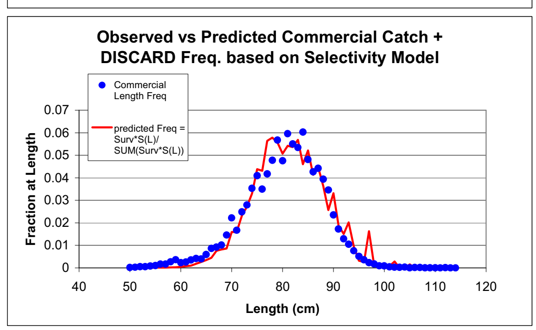


FEMALES, 3-yr Average, w/Discard 2003

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
14.83	-0.175	84.859

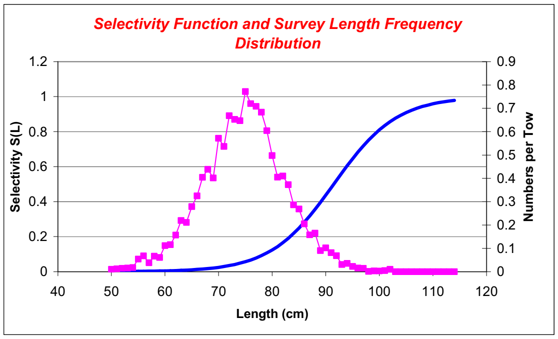


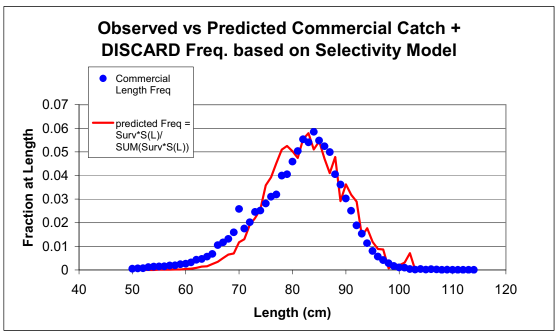


FEMALES, 3-yr Average, w/Discard 2004

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
15.57	-0.17	91.478

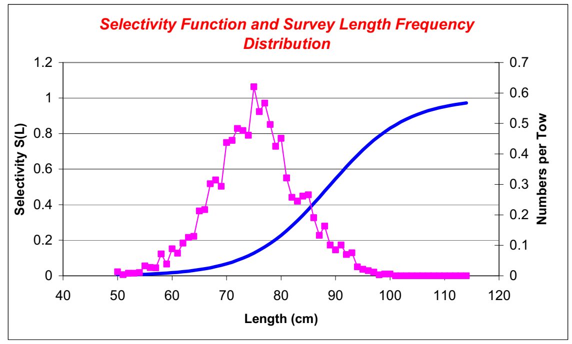


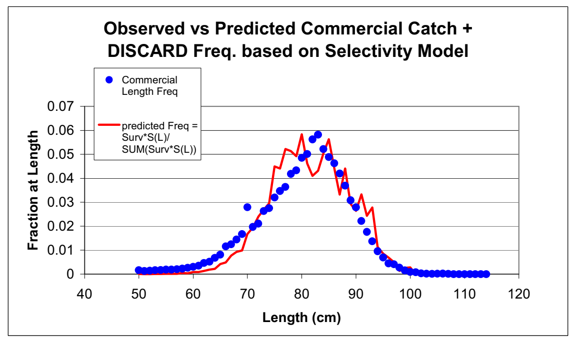


FEMALES, 3-yr Average, w/Discard 2005

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
12.45	-0.14	88.691



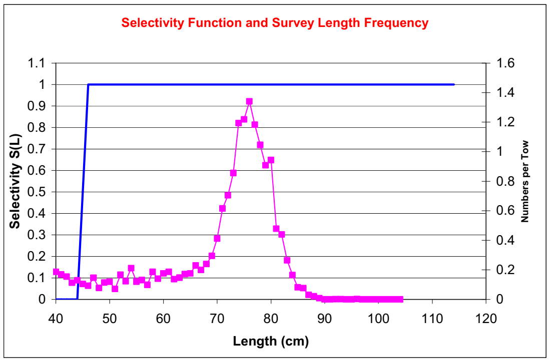


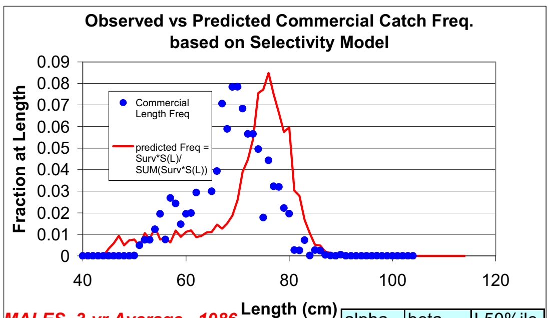
Males:

MALES, 3-yr Average, 1984

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
720.2	-16	45

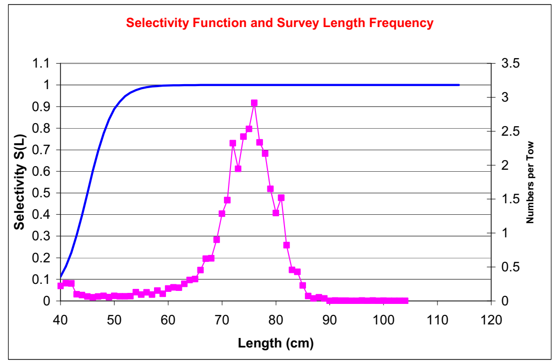


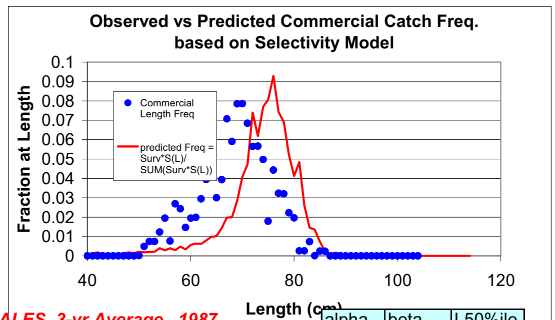


MALES, 3-yr Average, 1985

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
18.65	-0.414	45

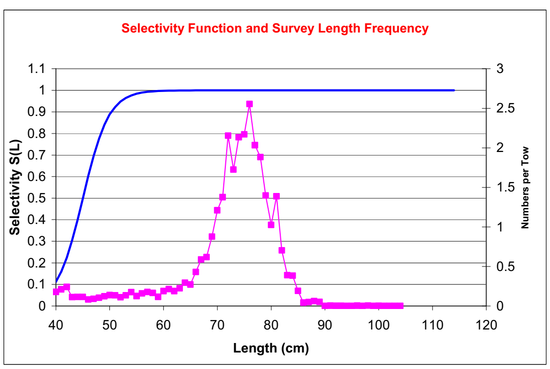


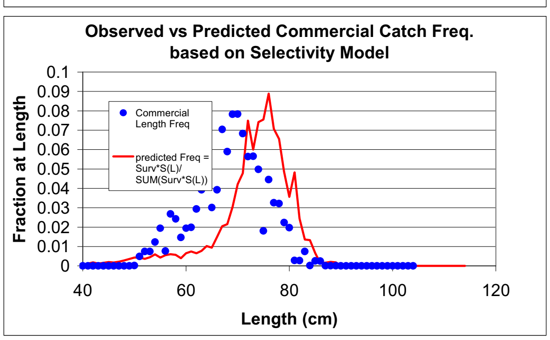


MALES, 3-yr Average, 1986

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
18.65	-0.414	45

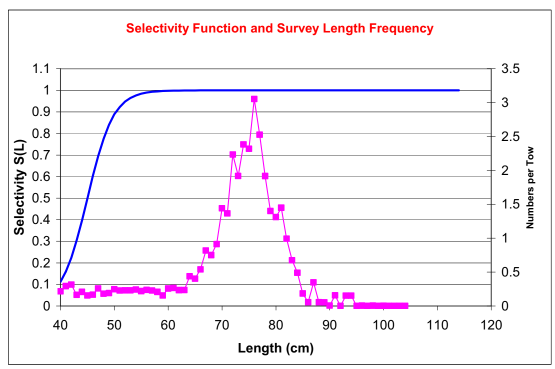


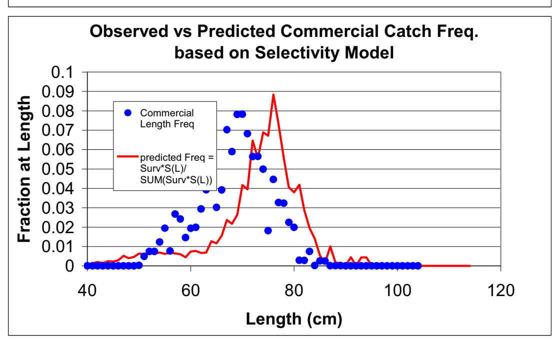


MALES, 3-yr Average, 1987

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
18.65	-0.414	45

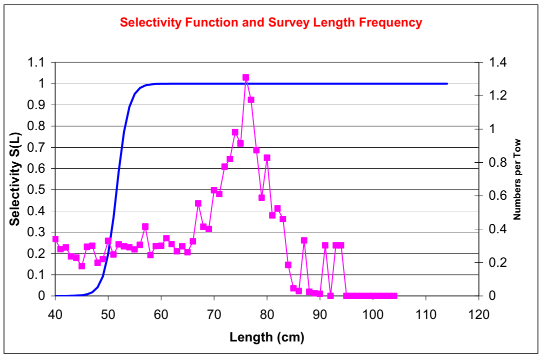


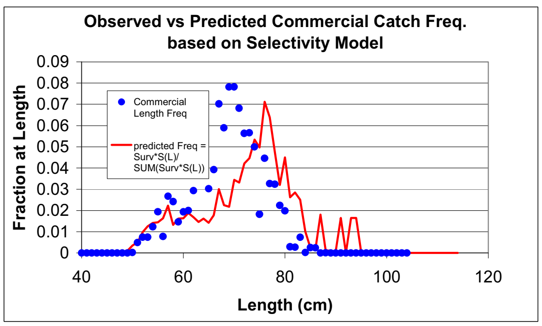


MALES, 3-yr Average, 1988

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
45.27	-0.877	51.601

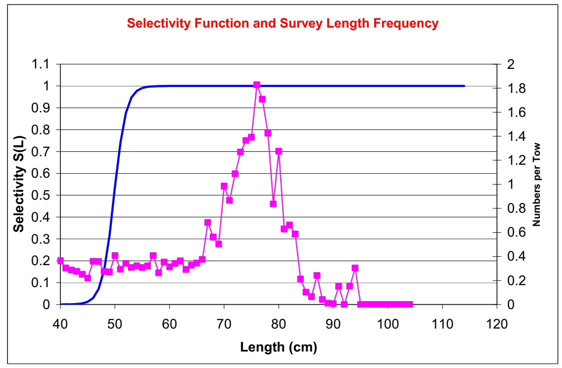


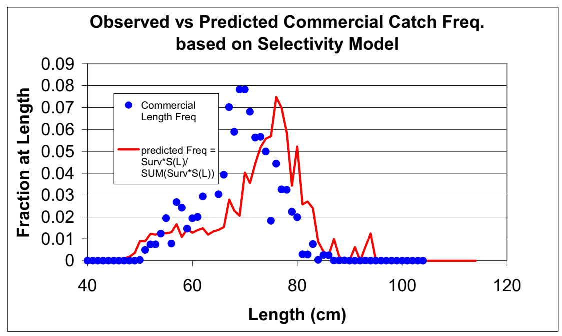


MALES, 3-yr Average, 1989

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
45.26	-0.908	49.836

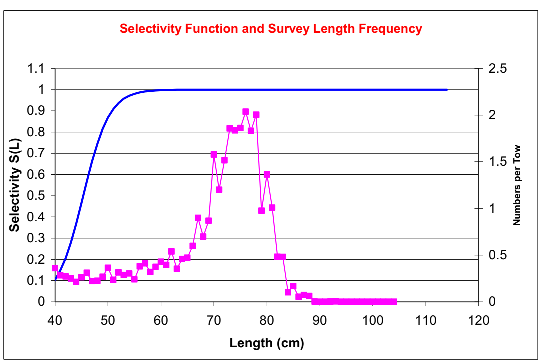


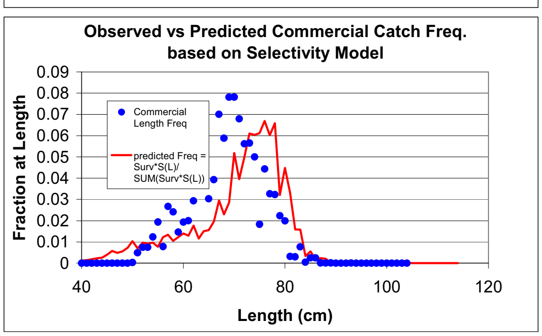


MALES, 3-yr Average, 1990

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
18.34	-0.405	45.332

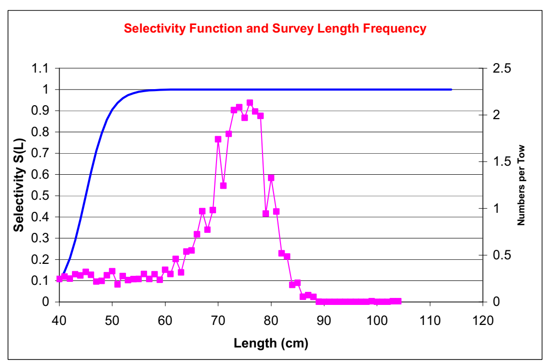


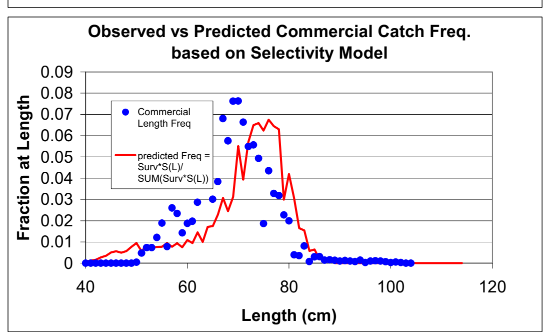


MALES, 3-yr Average, 1991

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
20.25	-0.45	45

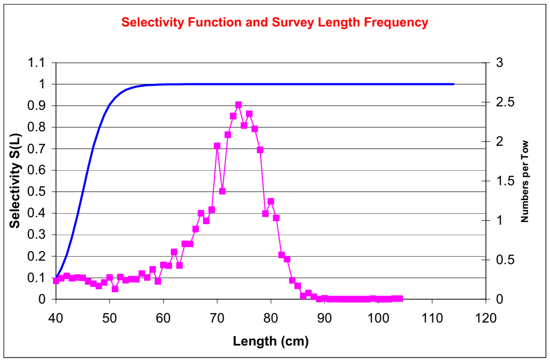


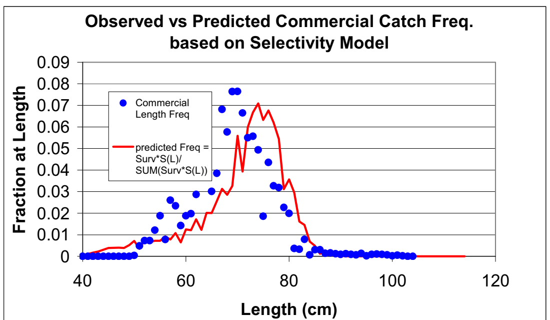


MALES, 3-yr Average, 1992

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
20.25	-0.45	45

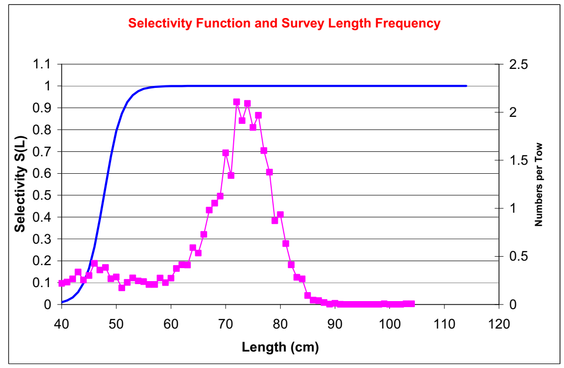


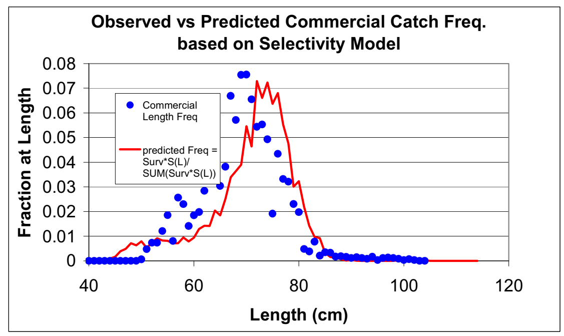


MALES, 3-yr Average, 1993

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
28.32	-0.593	47.732

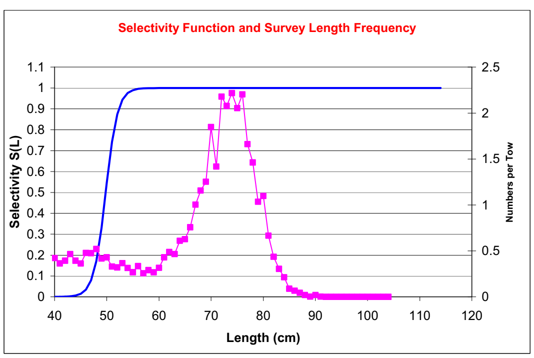


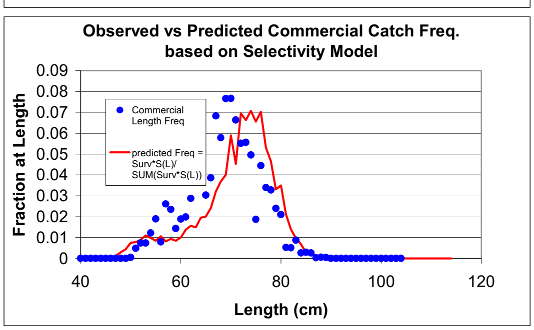


MALES, 3-yr Average, 1994

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
43.75	-0.879	49.793

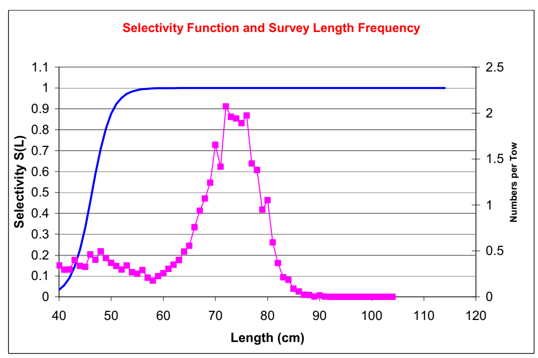


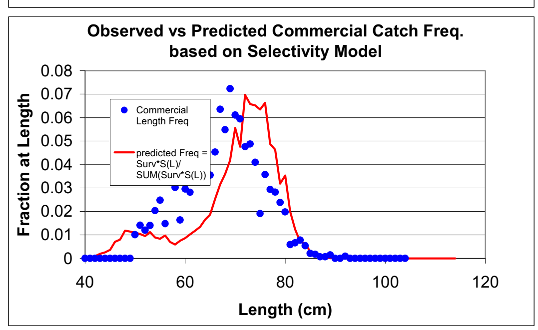


MALES, 3-yr Average, 1995

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
24.67	-0.533	46.319

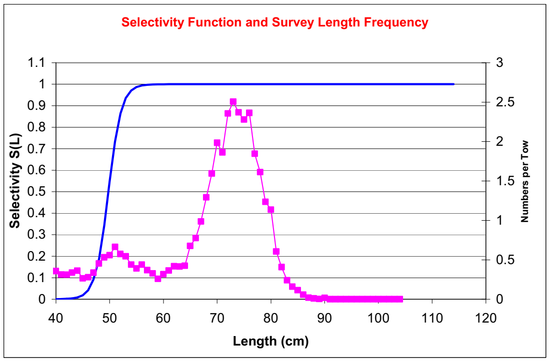


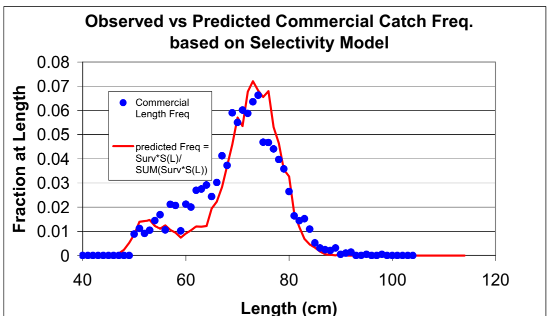


MALES, 3-yr Average, 1996

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
41.27	-0.829	49.776

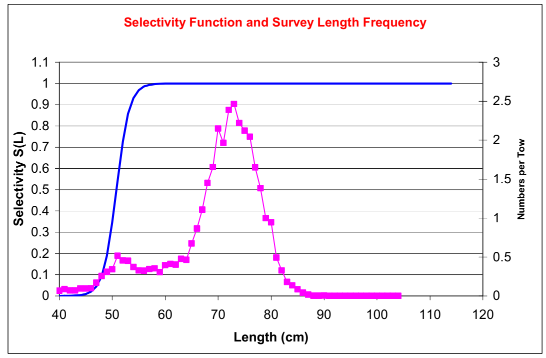


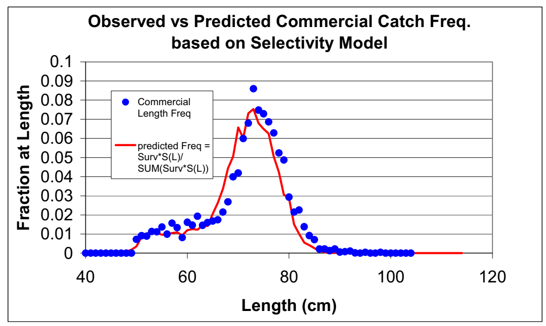


MALES, 3-yr Average, 1997

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
41.27	-0.812	50.792

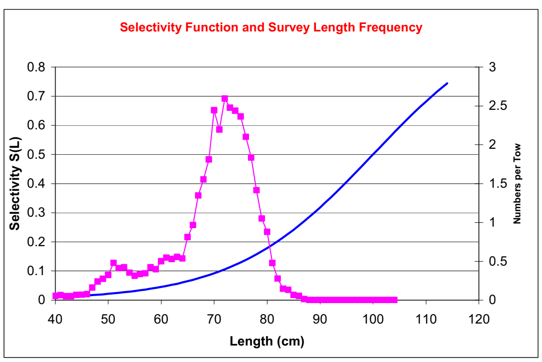


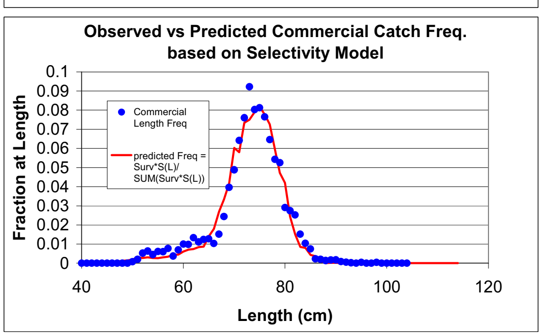


MALES, 3-yr Average, 1998

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
7.626	-0.076	100

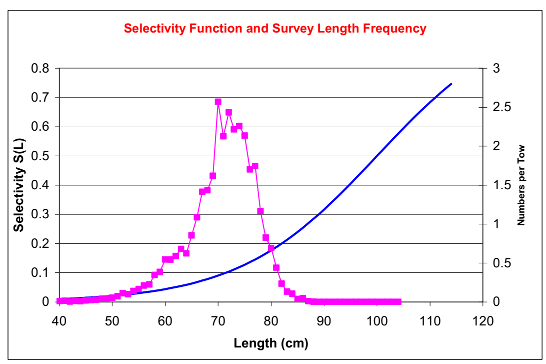


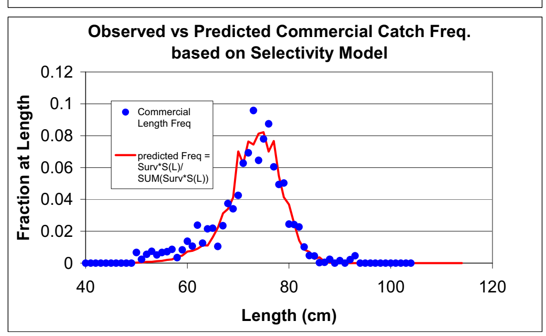


MALES, 3-yr Average, 1999

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
7.699	-0.077	100

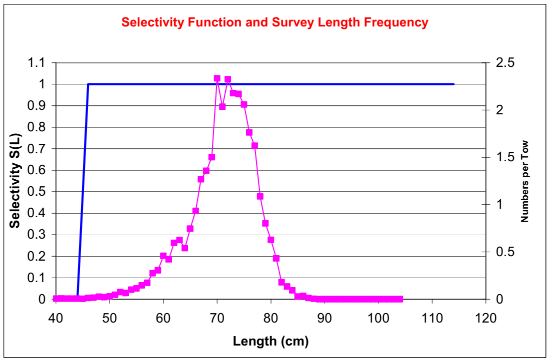


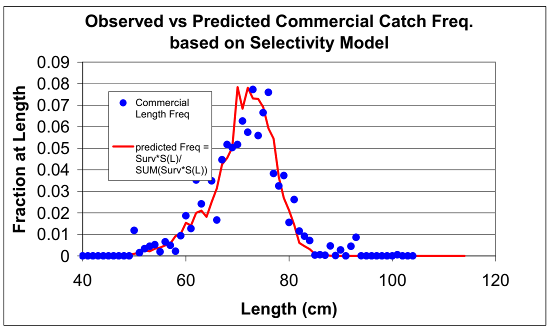


MALES, 3-yr Average, 2000

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
760.7	-16.9	45

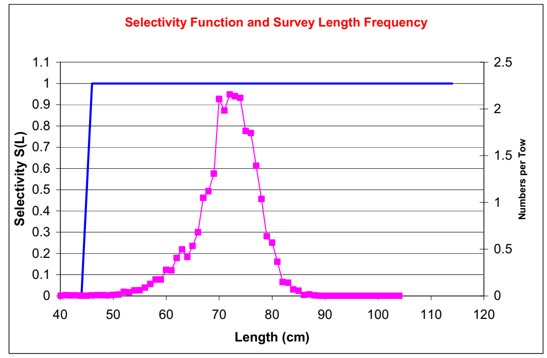


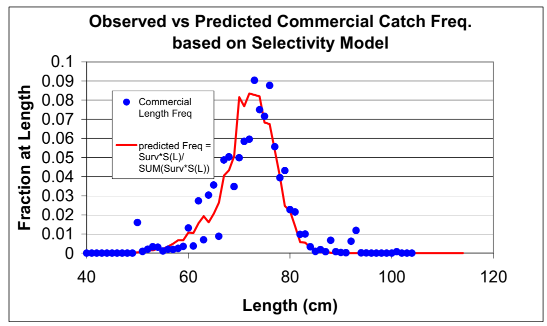


MALES, 3-yr Average, 2001

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
549.4	-12.21	45

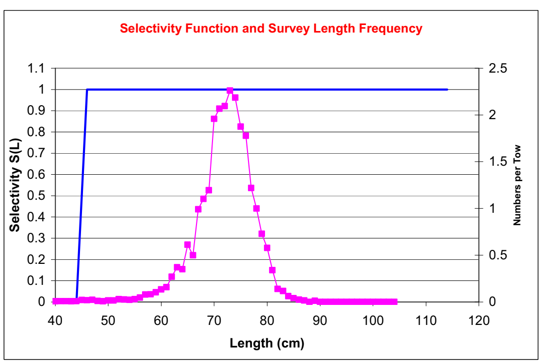


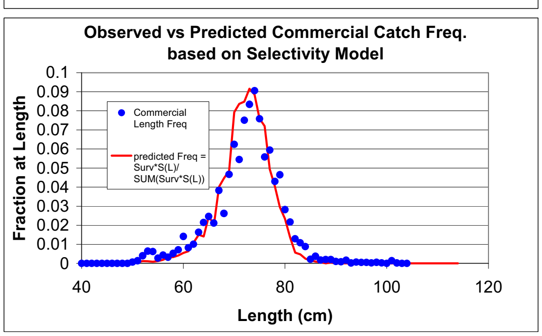


MALES, 3-yr Average, 2002

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
549.4	-12.21	45

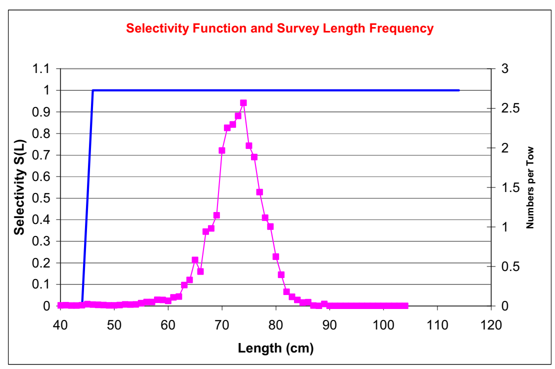


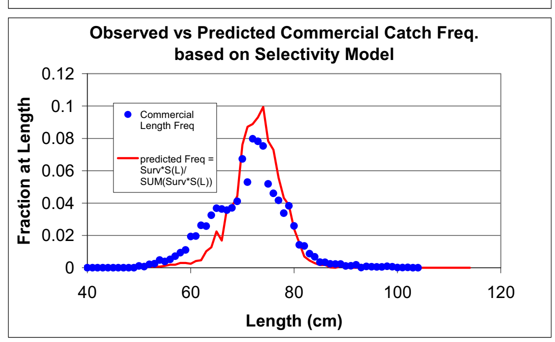


MALES, 3-yr Average, 2003

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
547.4	-12.16	45

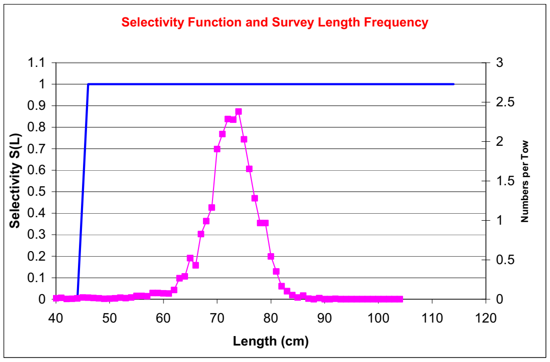


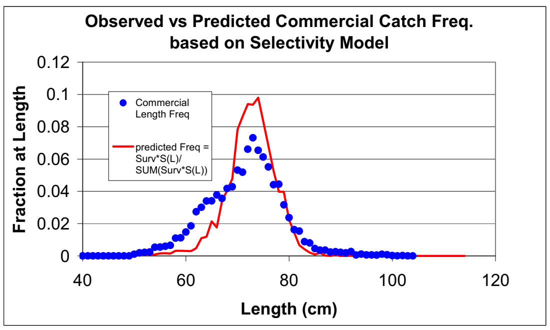


MALES, 3-yr Average, 2004

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
548	-12.18	45

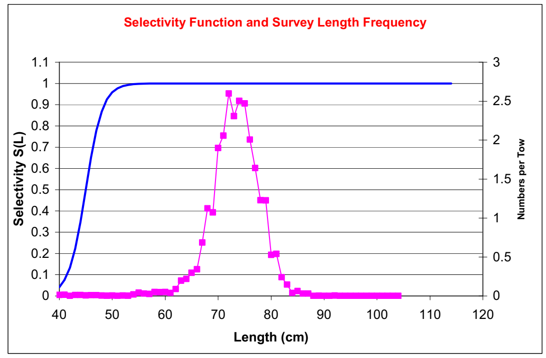


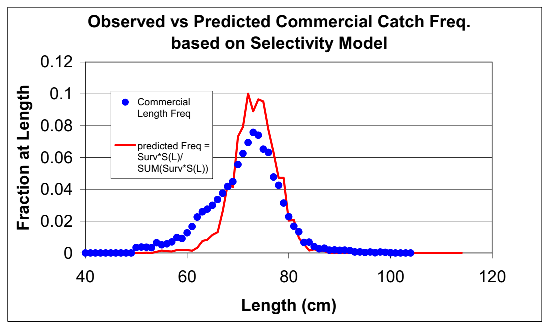


MALES, 3-yr Average, 2005

model: S(L) = 1/(1+exp(alpha+beta * L))

alpha	beta	L50%ile
28.23	-0.627	45





APPENDIX B3. Female spiny dogfish Length Tuned Model (LTM)

Introduction

Incomplete age information on catch and survey indices, often limits the application of full age-structured assessment models tuned with age specific data (e.g. Virtual Population Analysis). Knowledge of a species growth and lifespan, along with total catch data, size composition of the removals, recruitment indices and indices on numbers and size composition of the large fish in a survey can provide insights on population status using a simple model framework.

Herein we used a simple forward projecting age-based model tuned with total catch, catch at length, age-1 recruitment (estimated from first length mode in the survey), and survey numbers and length frequency of the larger fish sizes. The Length Tuned Model (LTM) was developed in the AD model builder framework. The model estimates fishing mortality and recruitment in each year, fishing mortality to produce the initial population (Fstart), and Qs for each survey index.

Methods

Model configuration

The LTM model assumes growth follows the mean input length at age with predetermined input error in length at age. Therefore a growth model or estimates of the average mean lengths at age is essential for reliable results. The LTM model uses an input partial recruitment (pr) vector at length in each year for the calculation of population and catch age-length matrices. A starting population is computed for year one in the model. First the estimated populations numbers at age starting with age-1 recruitment get normally distributed at one cm length intervals using the mean length at age with the assumed standard deviation. Next the initial population numbers at age are calculated from the previous age at length abundance using the survival equation. An estimated fishing mortality (Fstart) is also used to produce the initial population. This F can be thought of as the average fishing mortality that occurred before the first year in the model. Now the process repeats itself with the total of the estimated abundance at age getting redistributed according to the mean length at age and standard deviation in the next age (age+1).

This two step process is used to incorporate the effects of length specific selectivities and fishing mortality. The initial population length and age distribution is constructed by assuming that the population is at equilibrium with an initial value of F, say F_{start}. Length specific mortality is estimated as a two step process in which the population is first decremented for the length specific effects of mortality as follows:

$$N^*_{a,len,y_1} = N_{a-1,len,y_1} e^{-\left(PR_{len}F_{start}+M\right)}$$

In the second step, the total population of survivors is then redistributed over the lengths at age *a* by assuming that the proportions of numbers at length at age *a* follow a normal distribution with a mean length derived from the von Bertalanffy growth function.

$$N_{a,len,y_1} = \pi_{len,a} \sum_{len=0}^{L_\infty} N^*_{a,len,y_1}$$

where

$$\pi_{len,a} = \Phi\left(len+1 \mid \mu_a, \sigma_a^2\right) - \Phi\left(len \mid \mu_a, \sigma_a^2\right)$$

where

$$\mu_a = L_\infty\left(1 - e^{-K(a-t_0)}\right)$$

For spiny dogfish the variance of length at age a = σ_s^2 was obtained empirically from the Fig 5 in Nammack et al (standard deviation of 5 from ages 9+).

This model formulation does not explicitly track the dynamics of length groups across age because the consequences of differential survival at length at age a do not alter the mean length of fish at age a+1. However, it does more realistically account for the variations in age specific partial recruitment patterns by incorporating the expected distribution of lengths at age.

In the next step the population numbers at age and length for years after the calculation of the initial population use the previous age and year for the estimate of abundance. Here the calculations are done on a cohort basis. Like in the previous initial population survival equation the partial recruitment is taken from the input length vector.

$$N^*_{a,len,y} = N_{a-1,len,y-1} e^{-\left(PR_{len} F_{start} + M\right)}$$

second stage

$$N_{a,len,y} = \pi_{len,a} \sum_{len=0}^{L_\infty} N^*_{a,len,y}$$

Constant M is assumed along with an estimated length-weight relationship to convert estimated catch in numbers to landings in weight. The best available estimate of partial recruitment at length is used as input to the model from knowledge of landings size distribution, fishing practice, regulations, and discarding. The standard Baranov's catch equation is used to remove the catch from the population in estimating fishing mortality.

$$C_{y,a,len} = \frac{N_{y,a,len} F_y \left(1 - e^{-\left(F_y PR_{len} + M\right)}\right)}{(F_y \ \ PR_{len}) + M}$$

Catch is converted to yield by assuming a time invariant average weight at length

$$Y_{y,a,len} = C_{y,a,len} W_{len}$$

The LTM model results in the calculation of population and catch age-length matrices for the starting population and then for each year thereafter. The model is programmed to estimate recruitment in year 1 and estimate variation in recruitment relative to recruitment in year 1 for each year thereafter. Estimated recruitment in year one can be thought of as the estimated average long term recruitment in the population since it produces the initial population. The residual sum of squares of the variation in recruitment $\sum(\mathrm{Vrec})^2$ is than used as a component of the total objective junction. The weight on the recruitment variation component of the objective junction (Vrec) can be used to penalize the model for estimating large changes in recruitment relative to estimated recruitment in year one.

The model requires an age-1 recruitment index for tuning or the user can assume relatively constant recruitment over time by putting a high weight on Vrec. Usually there is little overlap in ages at length for fish that are one and/or two years of age in a survey of abundance. The first mode in a survey can generally index age-1 recruitment using length slicing. In addition numbers and the length frequency of the larger fish in a survey where overlap in ages at a particular length occurs can be used for tuning population abundance. The model tunes to the catch and survey length frequency data using a multinomial distribution. The user specifies the minimum size (cm) for the model to fit. Different minimum sizes can be fit for the catch and survey data length frequency.

The number of parameters estimated is equal to the number of years in estimating F and recruitment plus one for the F to produce the initial population (Fstart) and for each survey Q. The total likelihood function to be minimized is made up of 10 likelihood components:

$$\mathrm{L}_1 = \sum_{years}\left(l\,\mathrm{n}(Y_{\mathrm{obs,y}} + 1) - \ln\left(\sum_{a}\sum_{len} \mathrm{Y}_{\mathrm{pred,len,a,y}} + 1 \right)\right)^2$$

$$L_2 = -N_{eff} \sum_y \left(\sum_{len=80}^{L_\infty} \left(\left(C_{y,len} + 1\right) \ln\left(1 + \sum_a C_{pred,y,a,len}\right) - \ln\left(C_{y,len} + 1\right) \right) \right)$$

$$\mathrm{L}_3 = \sum_{y=2}^{Nyears} \left(Vrec_y\right)^2 = \sum_{y=2}^{Nyears} \left(R_1 - R_y\right)^2$$

$$L_4 = \sum_{y}^{Nyears} \left(\ln\left(I_{FALL,1,y} + 1\right) - \ln\left(1 + \sum_{len}^{L_\infty} N_{y,1,len}\right) q_{FALL} \right)^2$$

$$L_5 = \sum_{y=1992}^{Nyears} \left(\ln\left(I_{WINTER,1,y} + 1\right) - \ln\left(1 + \sum_{len}^{L_\infty} N_{y,1,len}\right) q_{WINTER} \right)^2$$

$$L_6 = \sum_{y}^{Nyears} \left(\ln\left(I_{SPRING,1,y} + 1\right) - \ln\left(1 + \sum_{len}^{L_\infty} N_{y,1,len}\right) q_{SPRING} \right)^2$$

$$L_7 = \sum_{y=1992}^{Nyears} \left(\ln\left(I_{WINTER,80+,y} + 1\right) - \ln\left(\sum_a \sum_{len=80}^{L_\infty} \ln\left(N_{pred,y,a,len} + 1\right) q_{WINTER,80+} \right) \right)^2$$

$$L_8 = -N_{eff} \sum_{y=1992}^{Nyears} \left(\sum_{len=80}^{L_\infty} \left(\left(I_{WINTER,y,len} + 1\right) \ln\left(1 + \sum_a N_{pred,y,a,len}\right) - \ln\left(I_{WINTER,y,len} + 1\right) \right) \right)$$

$$L_9 = \sum_{y}^{Nyears} \left(\ln\left(I_{SPRING,80+,y} + 1\right) - \ln\left(\sum_{a} \sum_{len=80}^{L_\infty} \ln\left(N_{pred,y,a,len} + 1\right) q_{SPRING,80+} \right) \right)^2$$

$$L_{10} = -N_{eff} \sum_{y} \left(\sum_{len=80}^{L_\infty} \left(\left(I_{SPRING,y,len} + 1\right) \ln\left(1 + \sum_{a} N_{pred,y,a,len}\right) - \ln\left(I_{SPRING,y,len} + 1\right) \right) \right)$$

In equation L_2 calculations of the sum of length is made from the user input catch length to the maximum length for fitting the catch. In equation L_7 through L_{10} the input survey length up to the maximum length is used in the calculation. For dogfish 80+ cm was used for both the catch and surveys.

$$Obj\ \ fcn = \sum_{i=1}^{10} \lambda_i L_i$$

Lambdas represent the weights to be set by the user for each likelihood component in the total objective function.

Female Dogfish LTM Model Results

The LTM model for dogfish (1981-2005) is limited to females only since there is a large difference in growth between the sexes (males L_∞ = 82.5 cm, female L_∞ = 100.5 cm) (Nammack et al). In addition most of the landings is comprised of females when the directed fishery targeted the larger fish. Eighty plus centimeter biomass indices for males and females possess very different trends with the male biomass remaining relatively constant over time. Female changes in biomass are presumably due to increases in mortality from the directed fishery. Therefore the working group assumed that female population trends are limiting for the population dynamics. Catch, surveys, and growth were limited to female fish in the LTM model.

Female growth and variation in mean lengths at age was taken from Nammack et al. (1985). Natural mortality was assumed to be 0.09 with a forty year lifespan. The catch length frequency, survey numbers and survey length frequency were fit to 80+ cm fish. Surveys were standardized by dividing each survey by its mean and multiplying by 1 million.

Preliminary runs of the LTM model assumed that landings are comprised of females in the (US, USSR, Canada, and other foreign landings). Half of the Recreation and B2 catch was assumed to be females and mortality occurred on 100 percent of the B2 releases. Preliminary runs used an approximation of the partial recruitment vector at length. Runs with different assumptions on the variation in recruitment (Vrec weight = 5, 1000, 0.1) showed little differences in F and biomass with the preliminary input data (Table 1, Fig 1-3). Adding the estimated partial recruitment at length in each year from the survey-landings analysis did not produce a large change in the results (run 7, Fig 4) (see selectivity estimation section).

Subsequent model runs used improved estimates of the female catch which included estimates of female commercial discards (runs 4-7, Fig 5-7)(See landings and estimated discard sections). Landings were prorated to female landings, the sex ratio from the fall inshore Massachusetts DMF survey (70% female) was applied to the recreational component with a 20% mortality rate on the B2 releases. Recreational catch were characterized with the discard length frequency. Adding the commercial discard catch and refined estimates of the female landings resulted in substantial changes to the preliminary catch trend with larger discard estimates early in the time series and a lower estimated B2 component later in the series. The catch length frequency also shifted to smaller fish after adding the discard information.

The working group reviewed a model run using the estimated partial recruitment pattern (survey-landings analysis) which included the discards in the catch length frequency. This partial recruitment estimation resulted in large changes in the partial recruitment during 1991 to 1997 when the directed fishery developed which landed larger fish. The estimated partial recruitment vector suggested that larger size fish were not fully selected during this period. This produced a high estimation of fishing mortality during that period. The working group chose a run using a constant selectivity given the problems of interpreting fishing mortality with the large shifts in the partial recruitment, in addition to the problems of estimating a partial recruitment pattern from catch comprised of both discard and landings. The final run used a constant partial recruitment with a L_{50} of 70 cm (alpha = 10.5, beta -.015) and Vrec weight of 1 (Figs 7). As a consequence of choosing a constant partial recruitment vector the LTM model has difficulty matching the observed catch length frequency for the larger fish in the catch when the directed fishery landed larger fish. In addition the observed and predicted total catch length frequencies do not match well in some years. However, the working group noted very similar trends in F and biomass among the different model configurations (Table 1 Fig1-7). It was also noted that decreases in recruitment after 1996 do not have a large influence on the model results because the long lifespan prevents these recruits from feeding back into the catch prior to the terminal year.

In all Dogfish model runs the LTM model estimates start F at the lower bound. The model predicts a virgin stock at the beginning of the model in 1981. All LTM model runs result in a decreasing trend to the total number of 80+ fish in both the winter and spring survey from beginning of the index to 2001. The model predicts more fish than was observed in the beginning of the spring survey (1981-1987) between the sizes of 80 and 90 cm. However the later part of the times series produced a better fit to the length frequency distributions.

After the working group meeting an error was discovered in the computation of commercial discards. LTM model runs 8 through 12 used the corrected length frequency and catch estimates (Table 3). The model runs with the corrected discards have lower catch at the beginning and a small increase in catch at the end of the time series. This resulted in an increase in F from 0.13 to 0.2 in the terminal year for the final run configuration (Tables 2 and 4). The corrected final run (run 8, Vrec=1, Fstart estimated at 0.001) results are given in Figures 8 to 13. Runs 9 through 12 are some additional sensitivity runs which compared the effects of a Vrec = 5, a fixed Fstart at 0.1 and 0.05 and a higher weight (increased from 10 to 50) on the spring 80+ index. Increasing the weight on Vrec decreased F in the terminal year from 0.2 to 0.14. However F and

Biomass trends were very similar between runs with a Vrec weight of 1 and 5. Fixing the Fstart at 0.1 and 0.05 may be more appropriate given the likely commercial discarding and the USSR landings in the 1970s. Fixing Fstart at 0.1 or 0.05 resulted in a slightly better fit to the Spring 80+ numbers. However the model had difficulty producing sufficient amounts of larger fish to match the observed length frequency data. Forcing the model to fit the Spring 80+ numbers did result in a higher estimated Fstart (0.08) but the fit to the catch suffered with lower catch being predicted during the period when discarding made up most of the catch (1981-1990) and higher predicted landing during the time of the directed fishery.

APPENDIX B3.

Table 1. Female dogfish LTM runs of residual sum of squares, input weights, estimated Qs, estimated Fstart, and age 1 recruitment in year 1.

run number	1	2	3	4	5	6	7
Catch makeup	landing+B2s	landing+B2s	landing+B2s	landing+B2s	land + discards	land + discards	land + discards
PR used	approximation	approximation	approximation	estimated	estimated	estimated	constant
total objective function	196.1	129.1	237.1	190.0	187.7	149.5	154.0
total catch	0.1	0.1	0.4	0.0	0.1	0.1	0.1
catch len freq 80+	18.7	18.2	19.1	15.1	6.2	6.5	9.7
Vrec	4.8	49.1	0.0	4.6	4.4	22.0	21.9
Fall age 1	31.1	19.7	45.8	31.4	31.8	22.0	22.9
Spring age 1	29.0	11.5	47.4	29.1	30.0	16.7	16.6
Winter age 1	7.1	6.9	10.4	7.0	7.2	6.3	6.3
Winter 80+ len freq	7.5	7.1	9.7	7.6	7.7	7.6	7.7
Winter 80+ numbers	3.3	3.4	3.2	3.3	3.5	3.6	3.5
Spring 80+ len freq	23.3	23.5	24.9	22.0	21.8	21.9	22.6
Spring 80+ numbers	5.9	5.7	5.9	5.9	7.9	7.8	7.6
wt total catch	10	10	10	10	10	10	10
effective sample size wt catch len freq 80+	200	200	200	200	200	200	200
wt Vrec	5	0.1	1000	5	5	1	1
wt Fall age 1	1	1	1	1	1	1	1
wt Spring age 1	2	2	2	2	2	2	2
wt Winter age 1	2	2	2	2	2	2	2
effective sample size wt Winter 80+ len freq	200	200	200	200	200	200	200
wt Winter 80+ numbers	2	2	2	2	2	2	2
effective sample size Spring 80+ len freq	200	200	200	200	200	200	200
wt Spring 80+ numbers	2	2	2	2	2	2	2
Q Fall age 1	0.79	0.83	0.78	0.79	0.76	0.78	0.78
Q Spring age 1	0.81	0.84	0.80	0.81	0.78	0.80	0.80
Q Winter age 1	0.84	0.91	0.82	0.84	0.82	0.85	0.85
Q Winter 80+ numbers	0.82	0.82	0.82	0.82	0.82	0.82	0.83
Q Spring 80+ numbers	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Fstart	0.001	0.001	0.001	0.001	0.001	0.001	0.001
recruitment year 1	11.7	11.4	13.9	11.5	20.1	19.0	18.7

APPENDIX B3.

Table 2. Female dogfish LTM run 7 F-mult, age 1 recruitment and 80+ population biomass.

year	F Fmult	age 1 recruitment millions	population 80+ biomass metric tons
1981	0.11	18.7	249,088
1982	0.11	27.9	226,115
1983	0.12	35.1	203,969
1984	0.12	7.0	184,298
1985	0.11	44.1	166,699
1986	0.11	26.1	152,300
1987	0.11	42.7	140,084
1988	0.12	25.1	129,440
1989	0.12	30.7	119,434
1990	0.23	18.1	111,442
1991	0.18	24.3	95,923
1992	0.30	17.8	88,054
1993	0.34	25.2	74,275
1994	0.34	26.3	62,012
1995	0.42	9.1	53,516
1996	0.44	8.4	44,778
1997	0.26	3.8	38,075
1998	0.40	4.0	38,169
1999	0.35	3.4	33,711
2000	0.28	6.1	30,763
2001	0.21	3.2	29,944
2002	0.21	3.9	31,039
2003	0.13	5.8	32,473
2004	0.20	13.6	35,969
2005	0.13	6.5	36,244

APPENDIX B3.

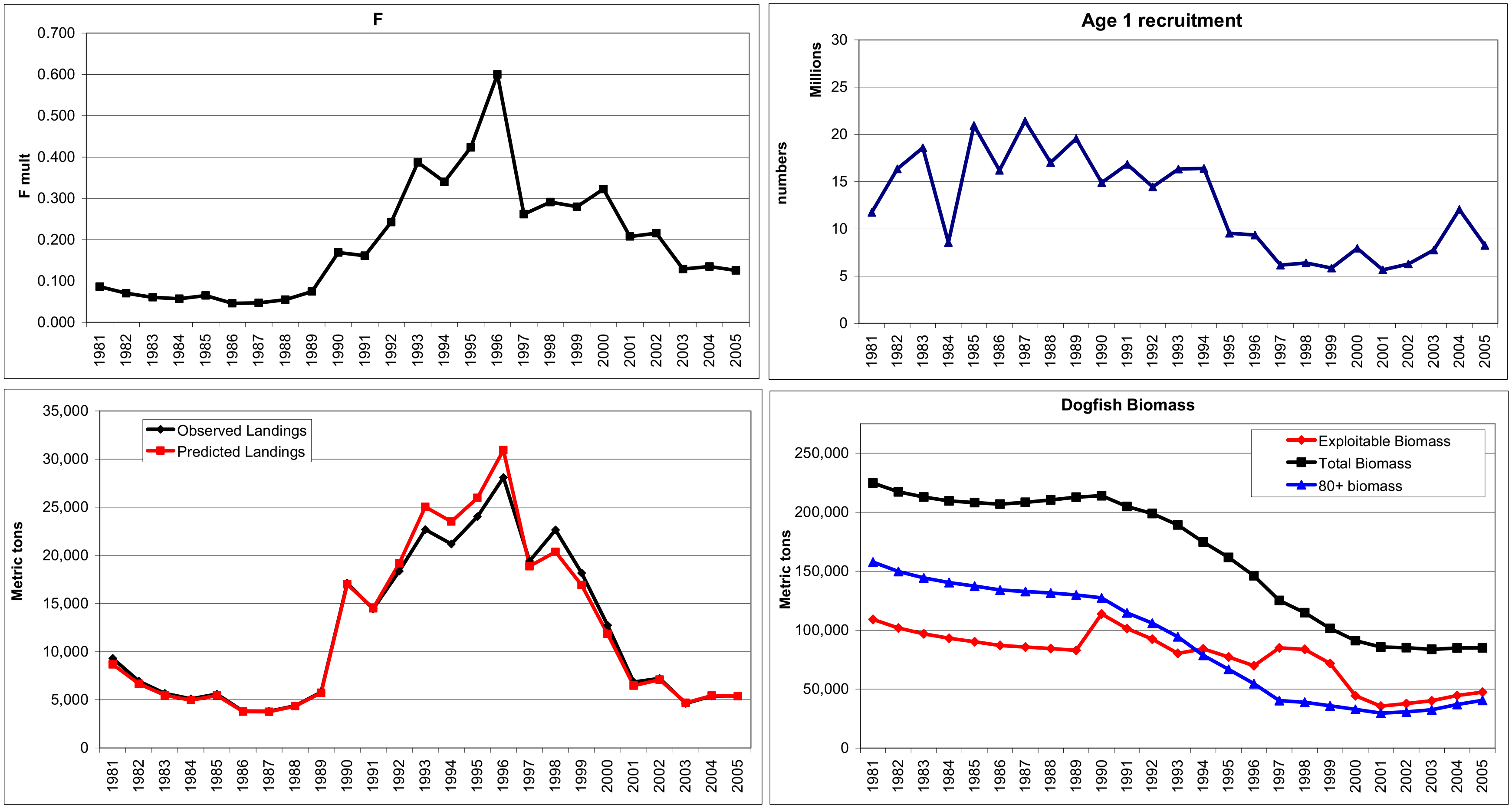
Table 3. Female dogfish LTM runs using the corrected Discard data. The residual sum of squares, input weights, estimated Qs, estimated Fstart, and age 1 recruitment in year 1 are shown.

run number	8	9	10	11	12
Description	final run	vrec = 5	fixed Fstart = 0.1	fixed Fstart = 0.05	increase spr survey wt
Catch makeup	land + discards	land + discards	land + discards	land + discards	land + discards
PR used	constant	constant	constant	constant	constant
total objective function	153.9	193.1	190.6	170.4	429.2
total catch	0.1	0.0	0.2	0.1	3.0
catch len freq 80+	13.4	13.0	26.7	19.2	24.2
Vrec	21.3	4.8	23.3	22.1	24.4
Fall age 1	22.5	31.5	24.3	23.5	21.9
Spring age 1	16.2	29.2	16.9	16.6	17.5
Winter age 1	6.2	7.1	6.4	6.3	6.5
Winter 80+ len freq	7.6	8.2	8.4	7.9	8.9
Winter 80+ numbers	3.5	3.3	3.4	3.4	3.2
Spring 80+ len freq	22.5	22.7	40.3	30.8	36.7
Spring 80+ numbers	7.1	7.1	6.0	6.4	4.6
wt total catch	10	10	10	10	10
effective sample size wt catch len freq 80+	200	200	200	200	200
wt Vrec	1	5	1	1	1
wt Fall age 1	1	1	1	1	1
wt Spring age 1	2	2	2	2	2
wt Winter age 1	2	2	2	2	2
effective sample size wt Winter 80+ len freq	200	200	200	200	200
wt Winter 80+ numbers	2	2	2	2	2
effective sample size Spring 80+ len freq	200	200	200	200	200
wt Spring 80+ numbers	2	2	2	2	50
Q Fall age 1	0.79	0.77	0.78	0.78	0.78
Q Spring age 1	0.81	0.79	0.80	0.80	0.80
Q Winter age 1	0.86	0.83	0.85	0.85	0.85
Q Winter 80+ numbers	0.83	0.83	0.83	0.83	0.83
Q Spring 80+ numbers	0.81	0.80	0.81	0.81	0.81
Fstart	0.001	0.001	0.100	0.050	0.078
recruitment year 1	15.3	16.3	21.5	20.0	21.1

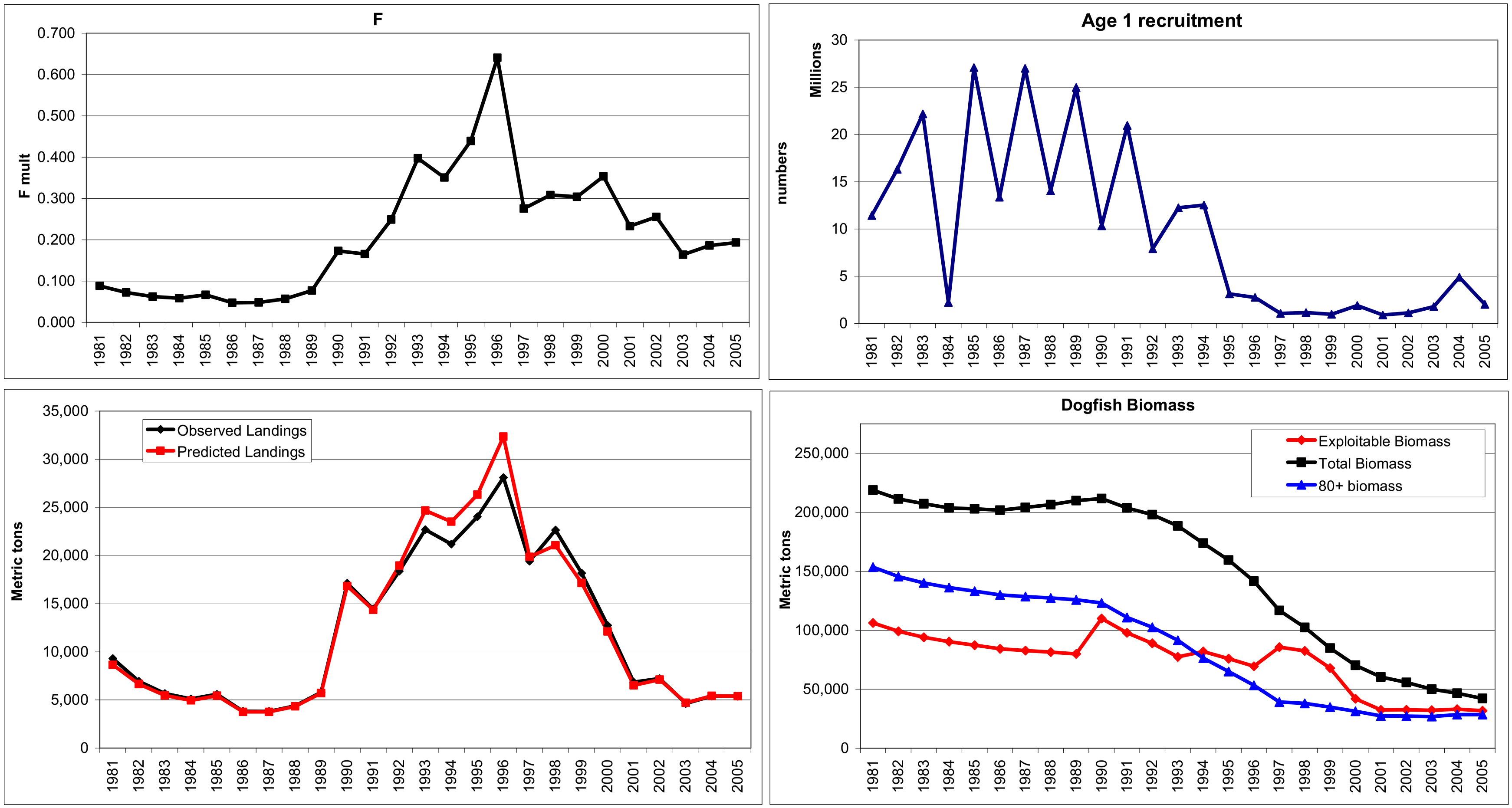
APPENDIX B3.

Table 4. Female dogfish LTM run 8 (Final run with corrected catch including commercial discards) F-mult, age 1 recruitment and 80+ population biomass.

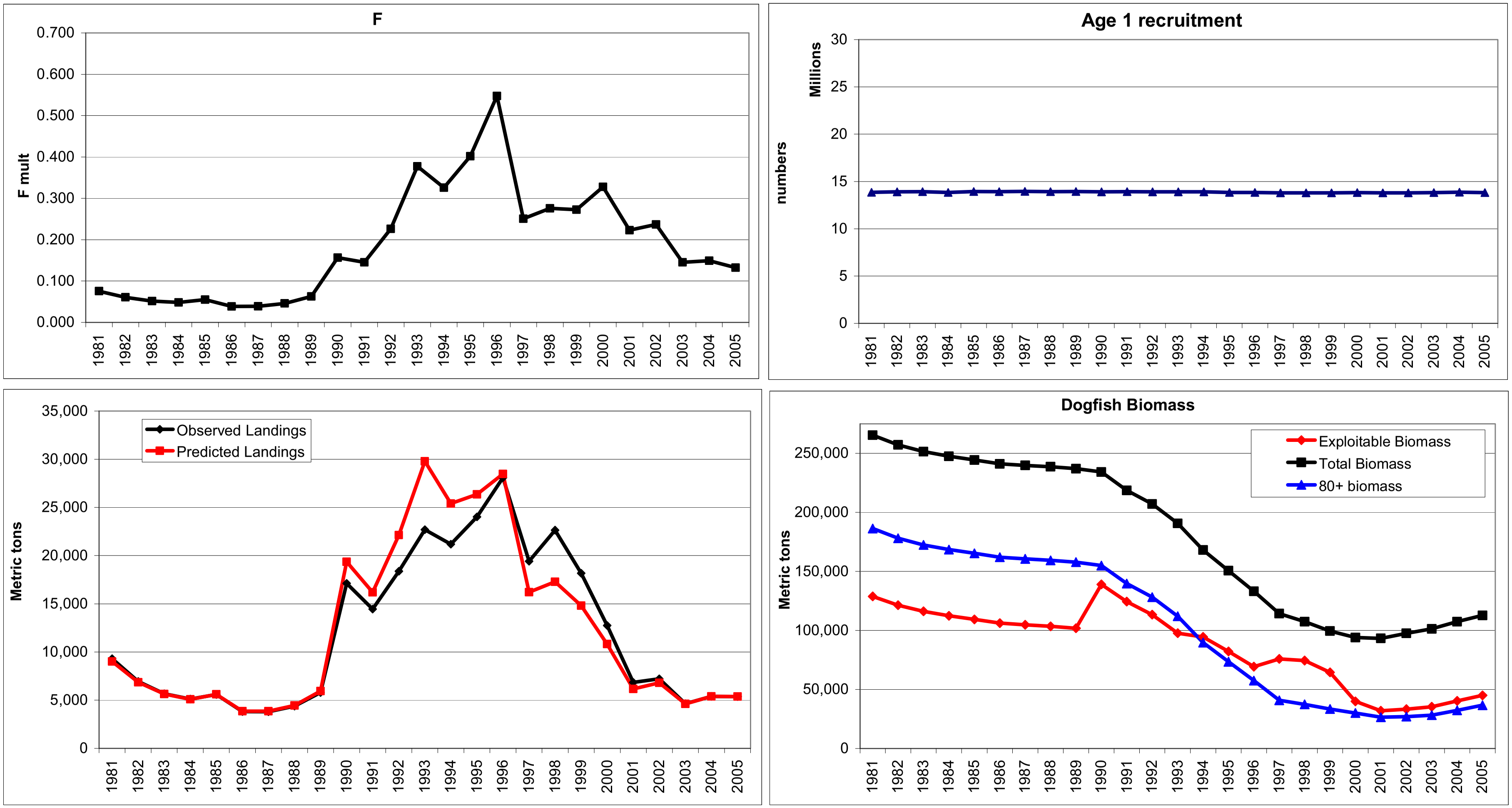
year	F Fmult	age 1 recruitment millions	population 80+ biomass metric tons
1981	0.09	15.3	203,804
1982	0.10	24.6	187,940
1983	0.10	31.5	172,256
1984	0.09	6.2	158,557
1985	0.09	40.9	146,513
1986	0.09	23.9	135,898
1987	0.09	40.7	127,651
1988	0.09	23.5	120,440
1989	0.11	29.8	113,378
1990	0.21	16.9	106,456
1991	0.18	23.4	92,054
1992	0.27	16.3	83,910
1993	0.33	23.3	72,035
1994	0.30	24.3	60,246
1995	0.44	8.1	53,251
1996	0.46	7.4	43,581
1997	0.26	3.3	36,394
1998	0.42	3.5	36,449
1999	0.37	3.0	31,702
2000	0.30	5.4	28,460
2001	0.25	2.8	27,076
2002	0.25	3.5	27,292
2003	0.17	5.1	27,766
2004	0.23	12.0	29,894
2005	0.20	5.7	29,442



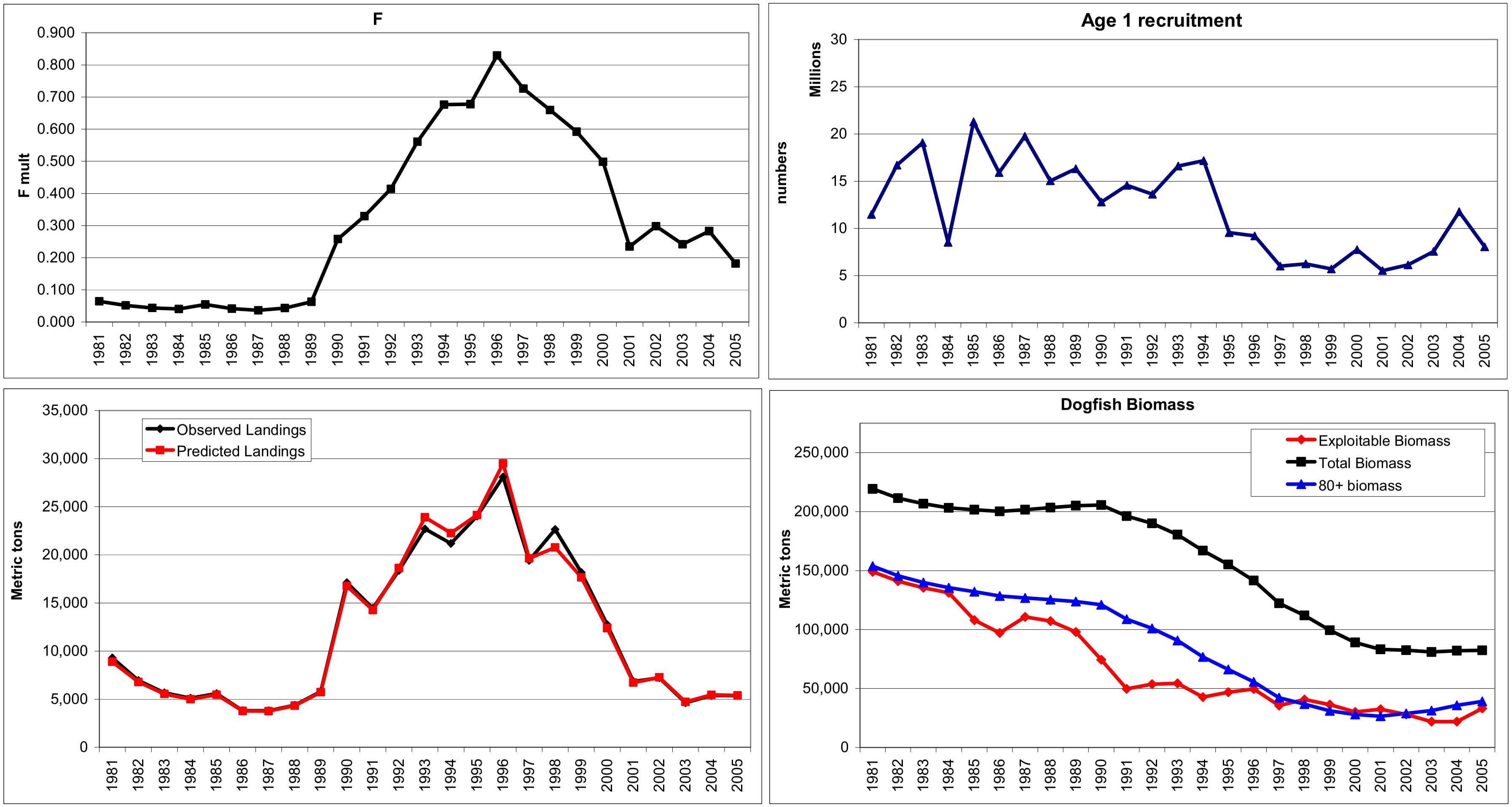
APPENDIX B3. Fig 1. Female dogfish LTM run 1 with preliminary landings and no commercial discard estimates with a Vrec weight of 5.



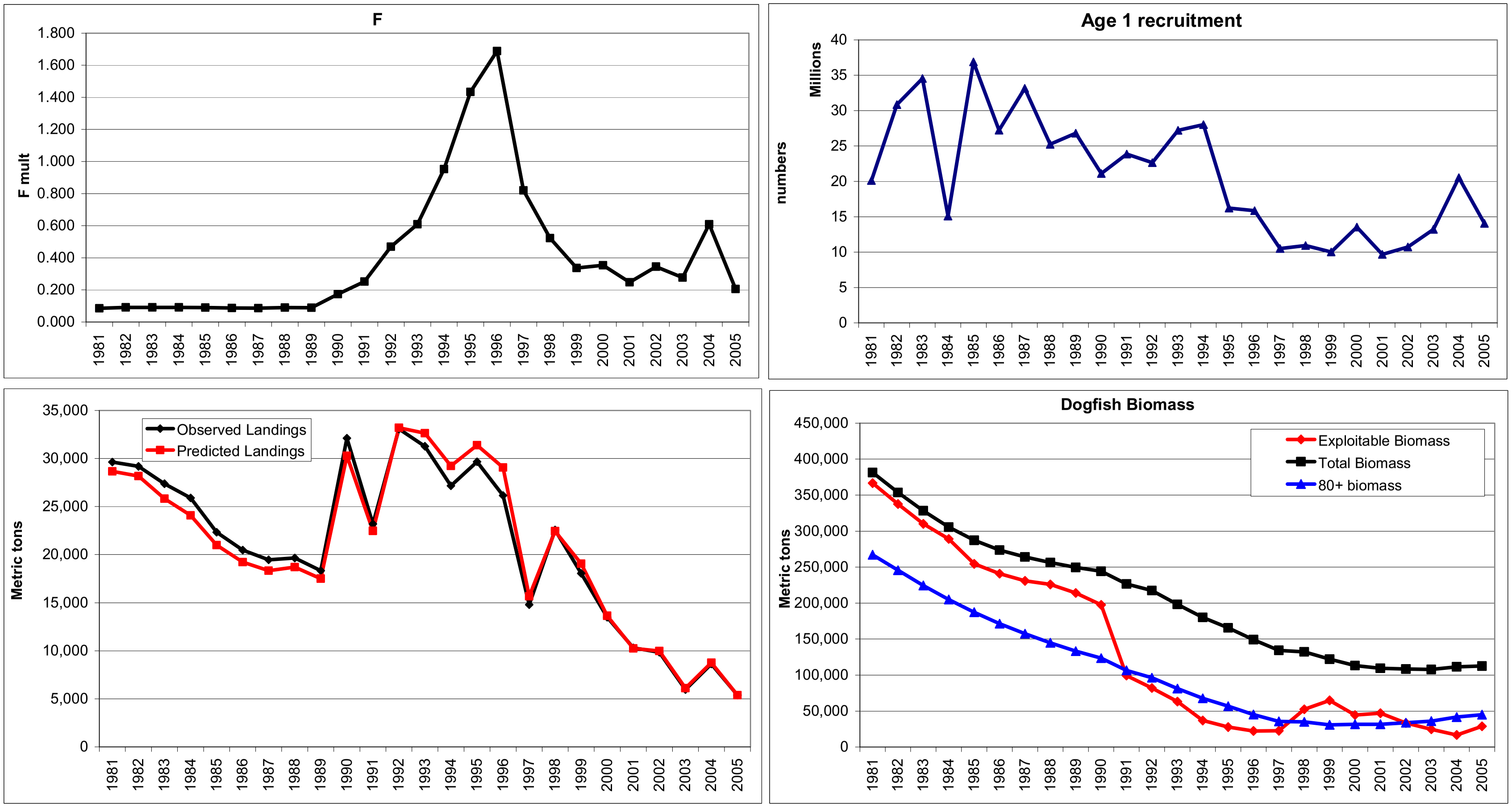
APPENDIX B3. Fig 2. Female dogfish LTM run 2 with preliminary landings and no commercial discard estimates with Vrec weight of 0.1.



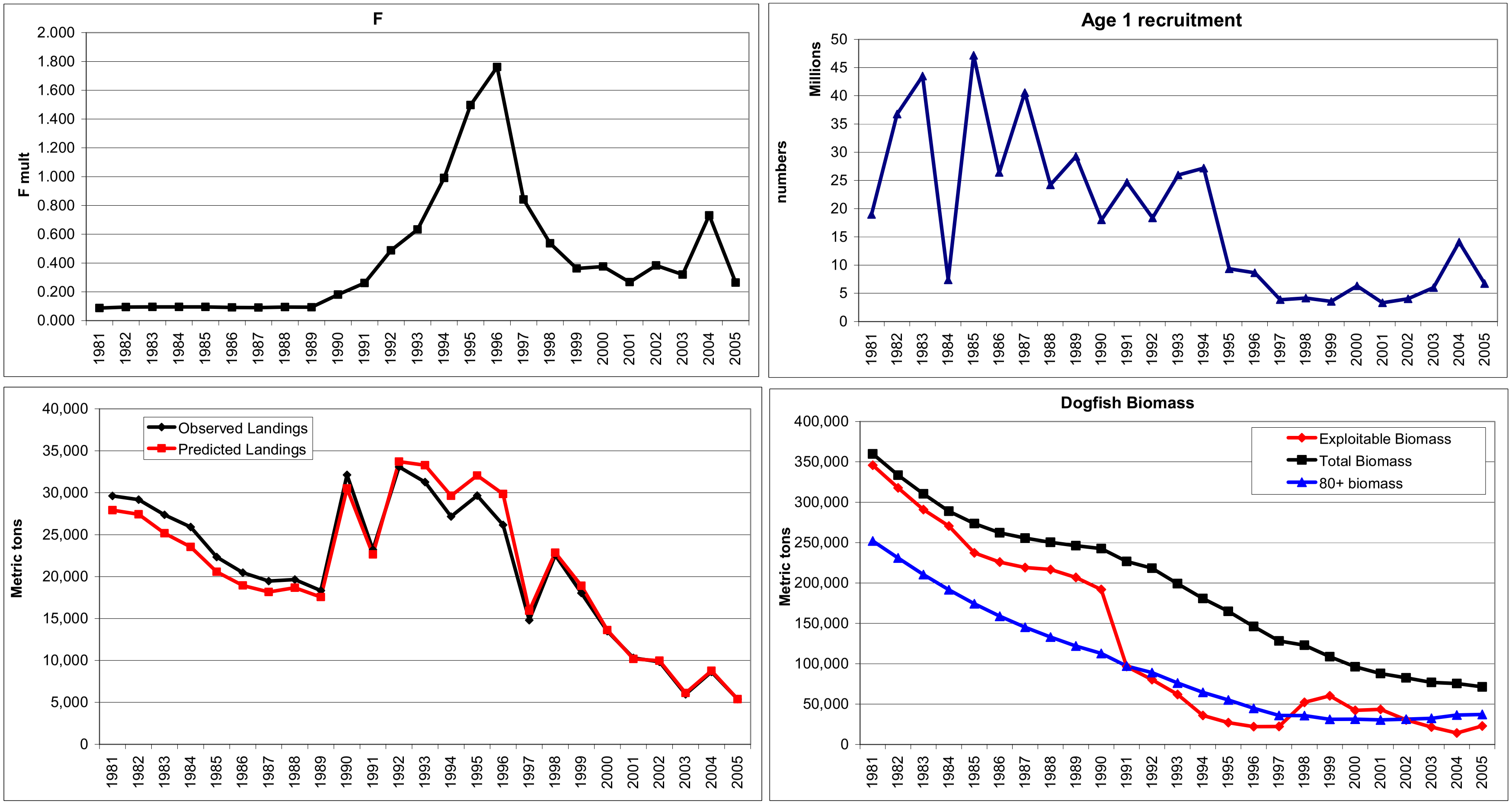
APPENDIX B3. Fig 3. Female dogfish LTM run 3 with preliminary landings and no commercial discard estimates with Vrec weight 1000.



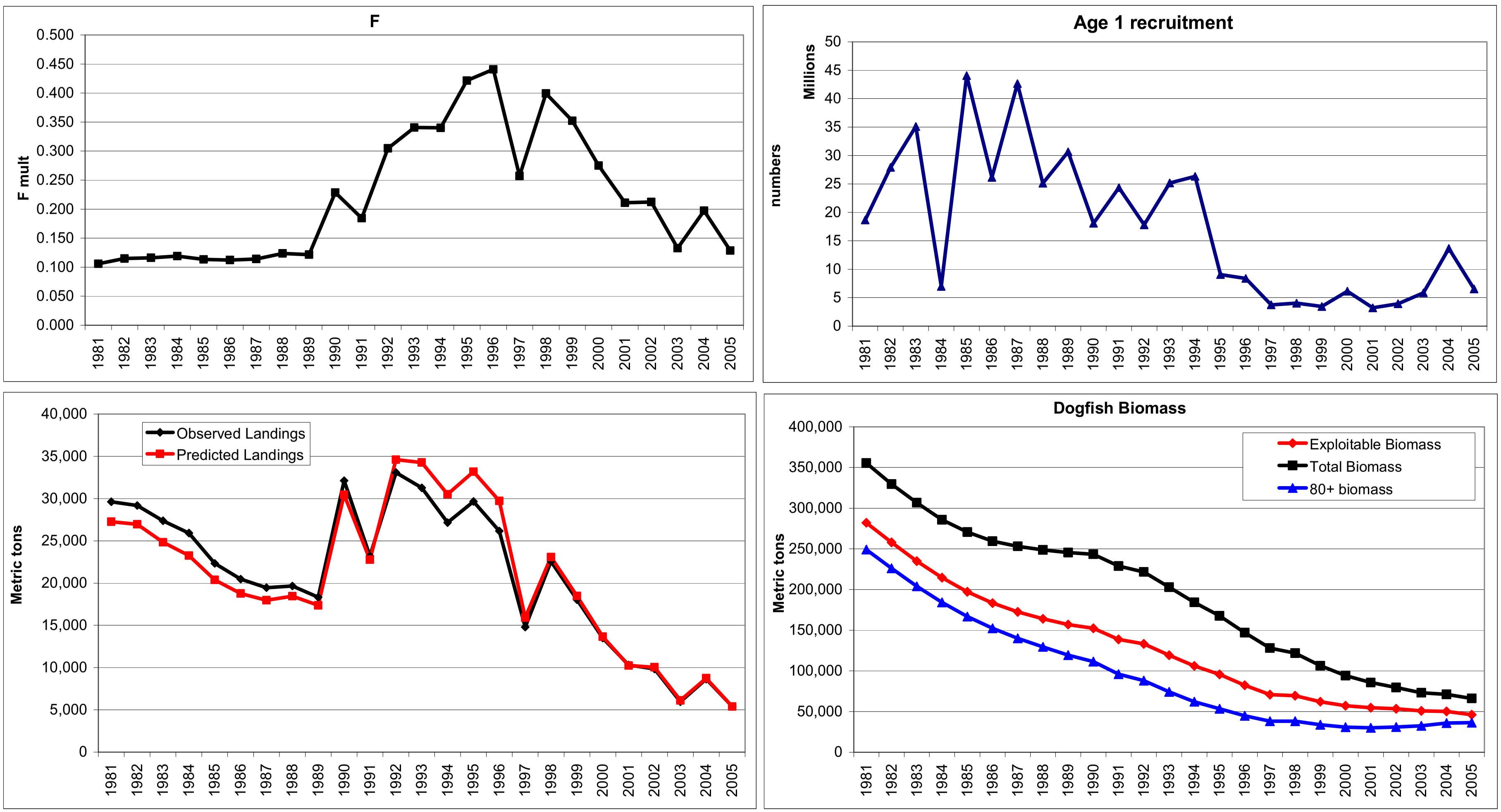
APPENDIX B3. Fig 4. Female dogfish LTM run 4 with preliminary landings, no commercial discard estimates, estimated pr, Vrec weight 5.



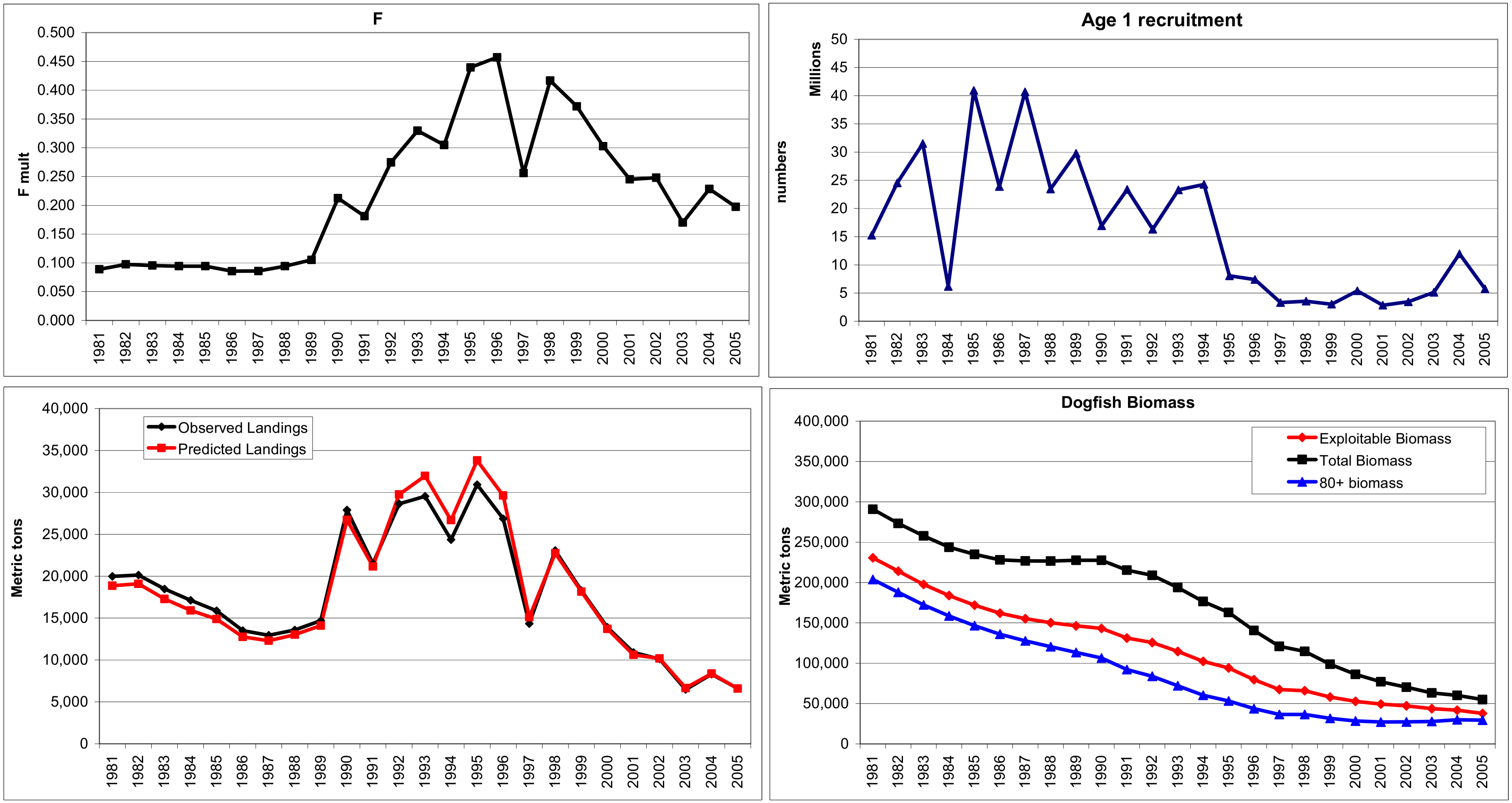
APPENDIX B3. Fig. 5. Female dogfish LTM run 5 with updated female landings and commercial discards, estimated pr, Vrec weight 5.



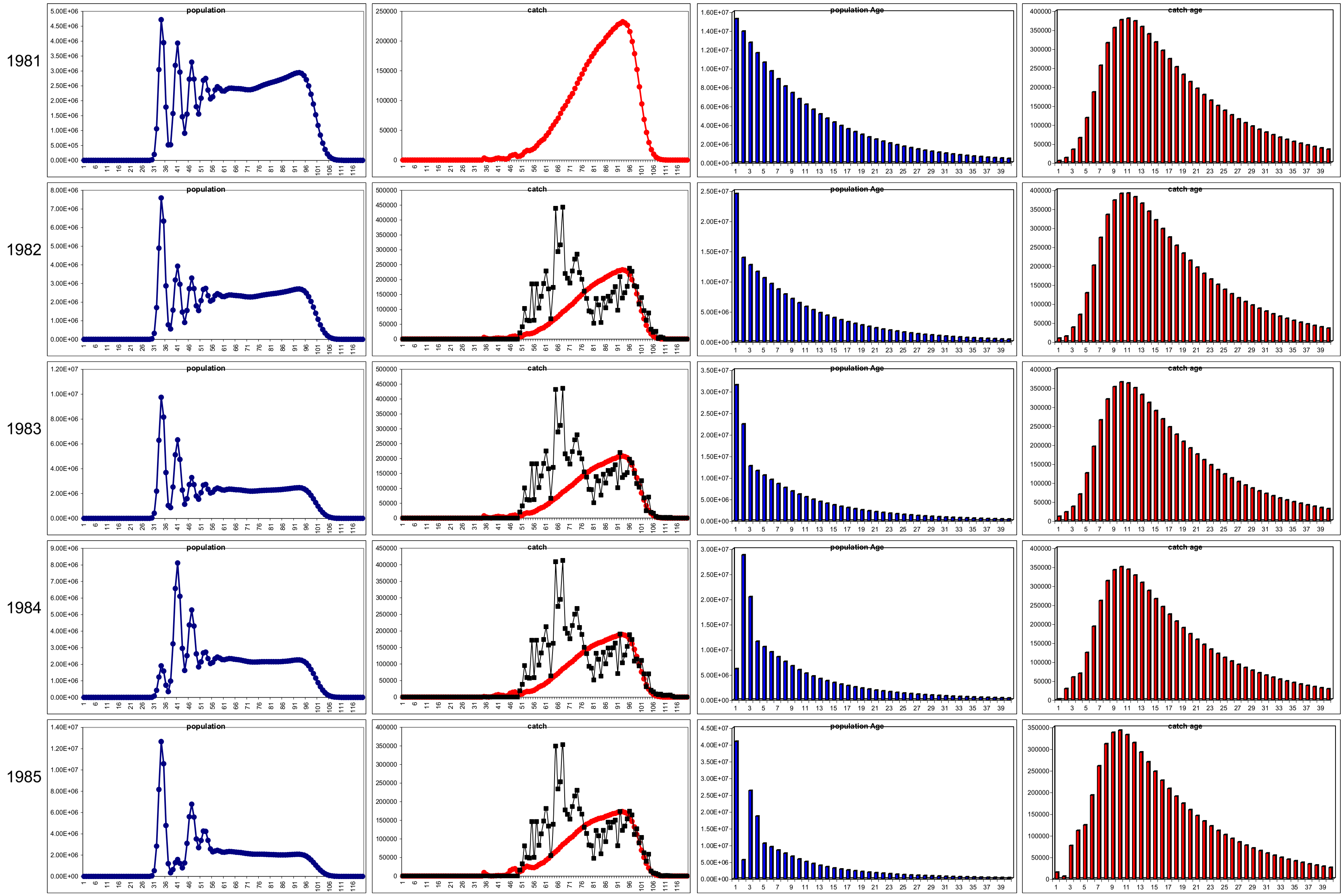
APPENDIX B3. Fig. 6. Female dogfish LTM run 6 with updated female landings and commercial discards, estimated pr and a Vrec weight 1.



APPENDIX B3. Fig. 7. Female dogfish LTM run 7 with updated female landings and commercial discard estimates, constant pr, and Vrec weight of 1.



APPENDIX B3. Fig. 8. Female dogfish Final LTM run 8 with corrected catch including commercial discards, constant pr, and Vrec weight of 1.



APPENDIX B3. Fig. 8. Female dogfish LTM run 8 population length frequency, observed (squares) and predicted (dots) catch length frequency, population age frequency and catch frequency from 1981-2005

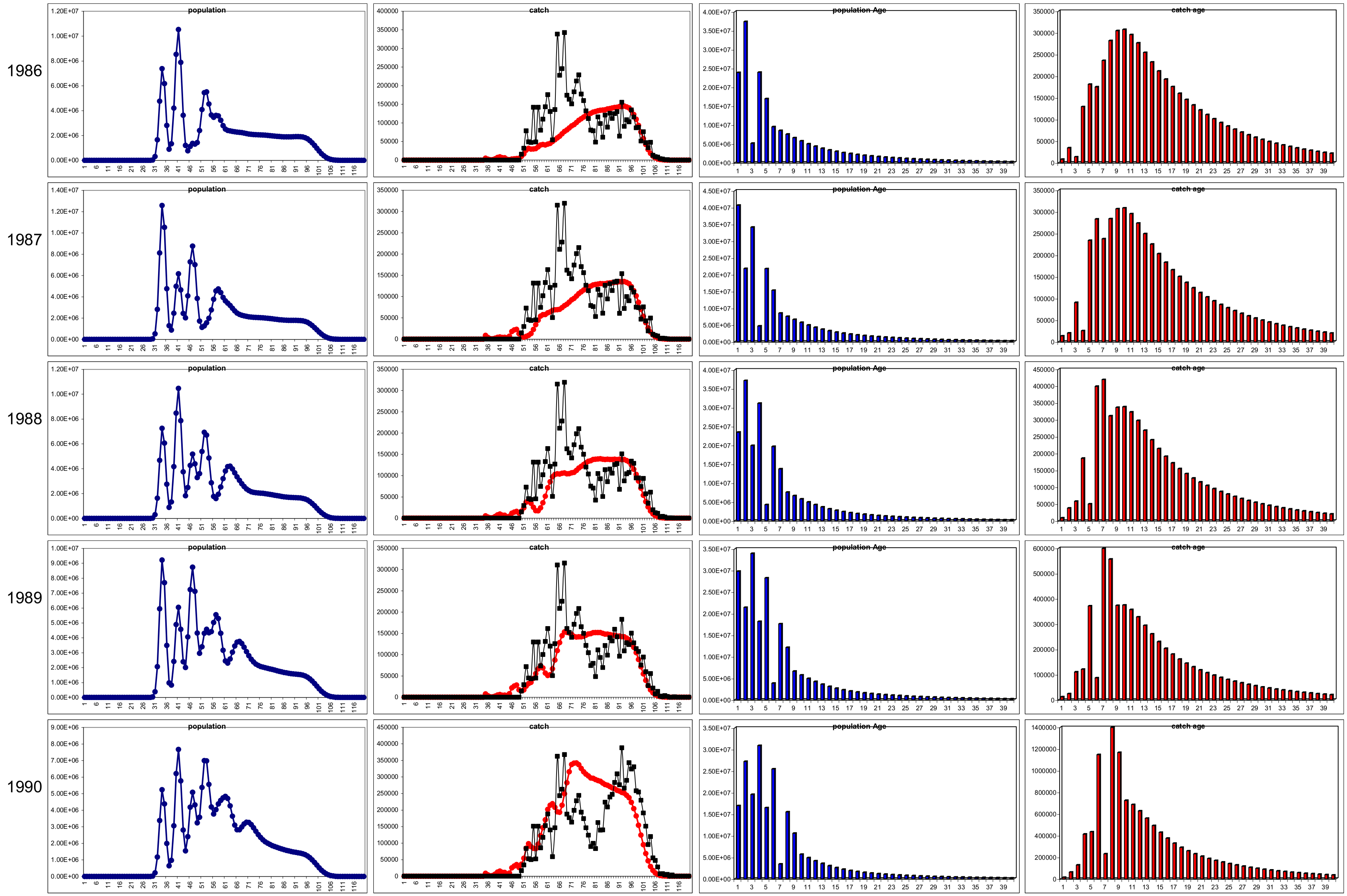

1986
1987
1988
1989
1990
population
catch
population Age
catch age

Fig. 8. cont.

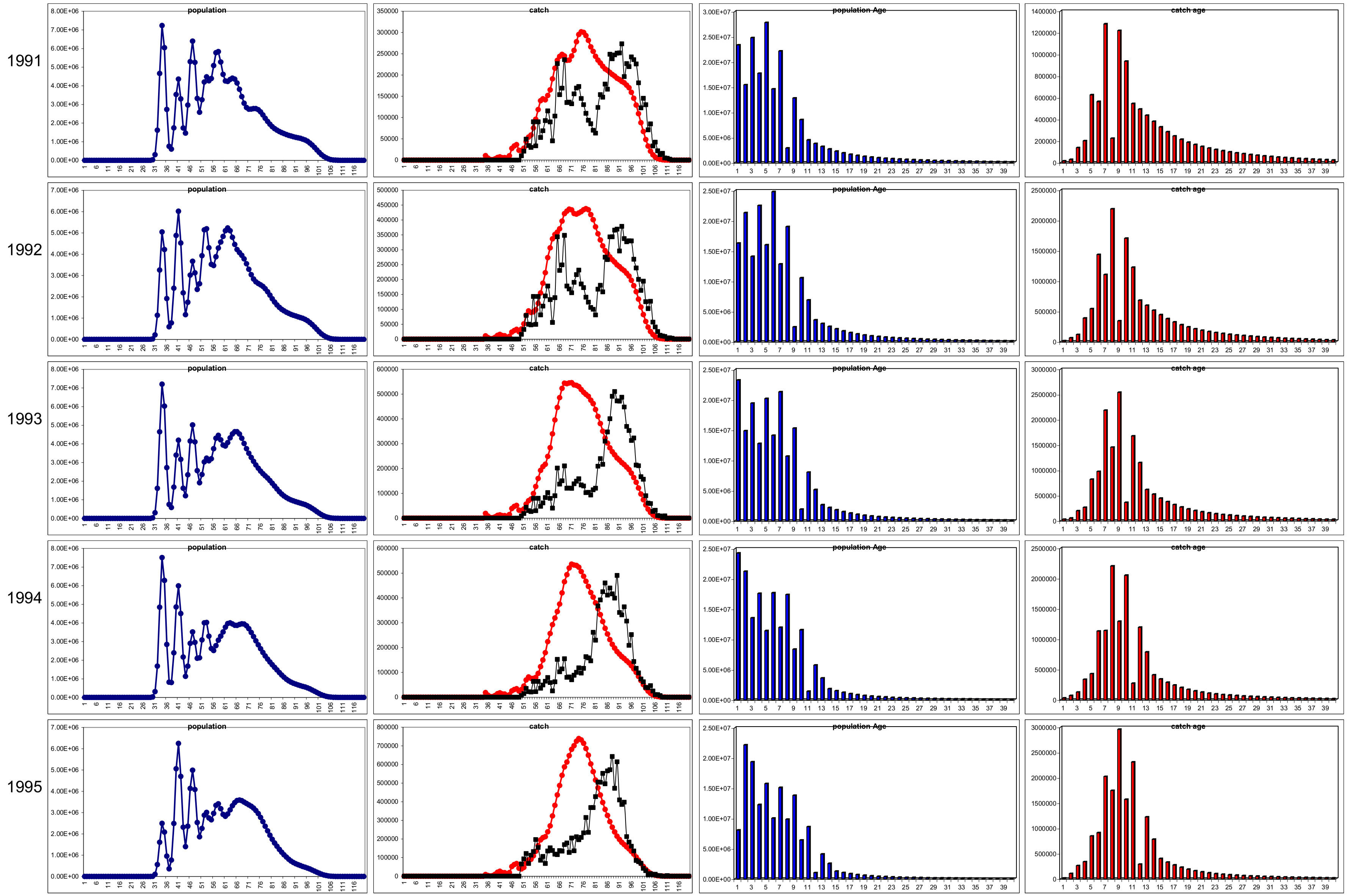

1991
1992
1993
1994
1995
population
catch
population Age
catch age

Fig. 8. cont.

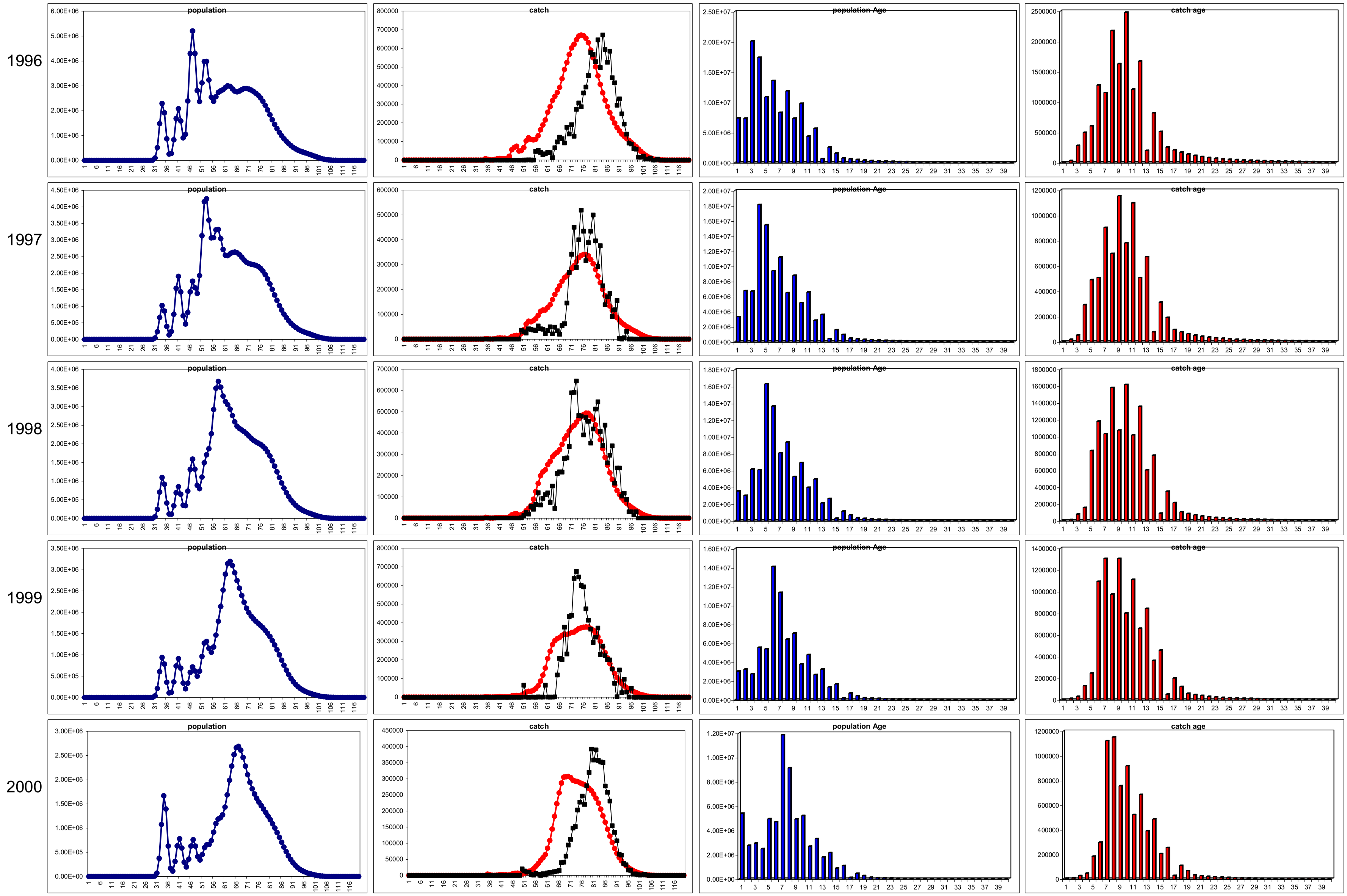
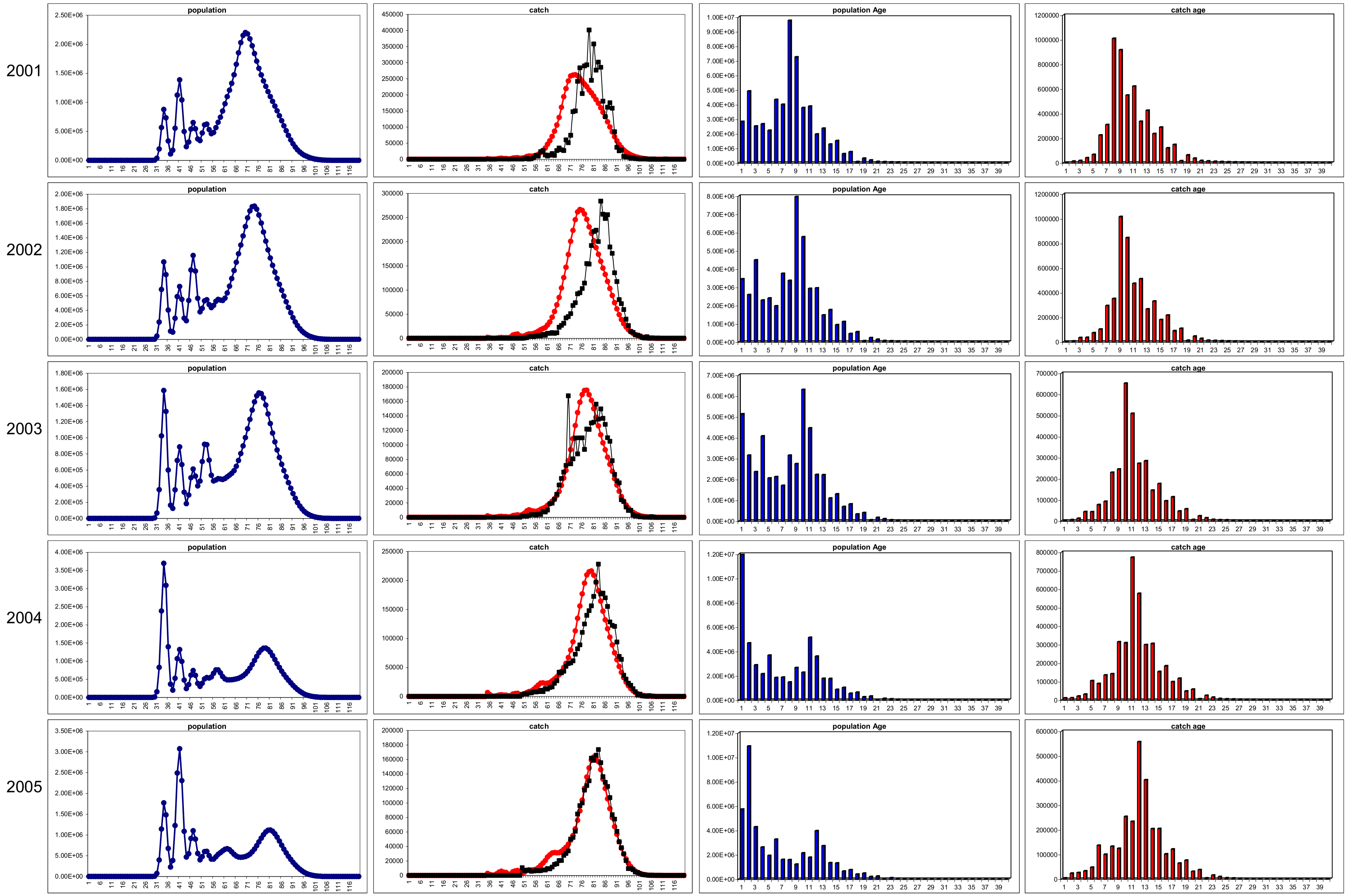
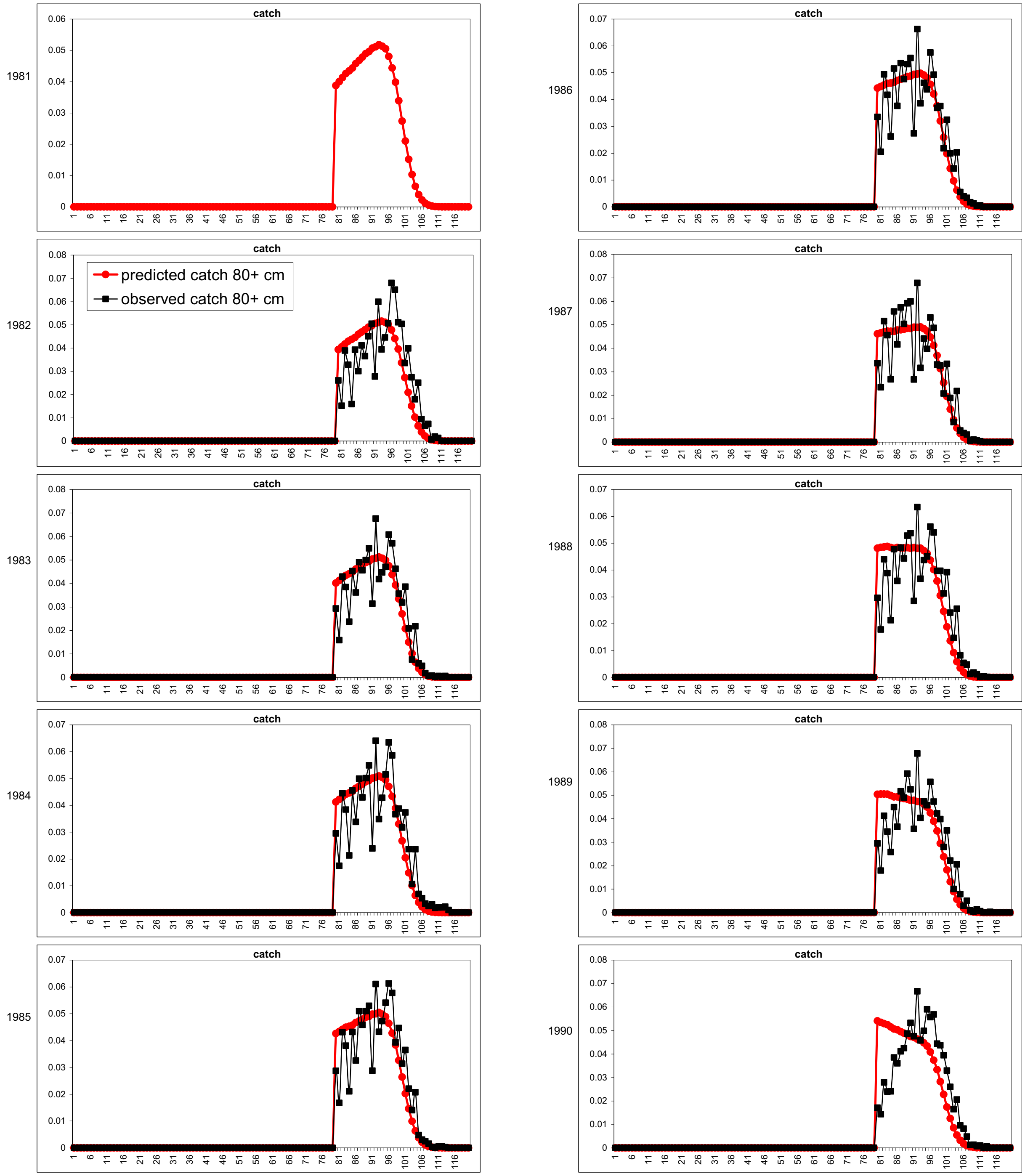

1996
1997
1998
1999
2000
population
catch
population Age
catch age

Fig. 8. cont.


2001
2002
2003
2004
2005
population
catch
population Age
catch age
Fig. 8. cont.



APPENDIX B3. Fig. 9. Female dogfish LTM run 8 observed (squares) and predicted (dots) fitted catch length frequency for 80+ cm fish from 1981-2005.

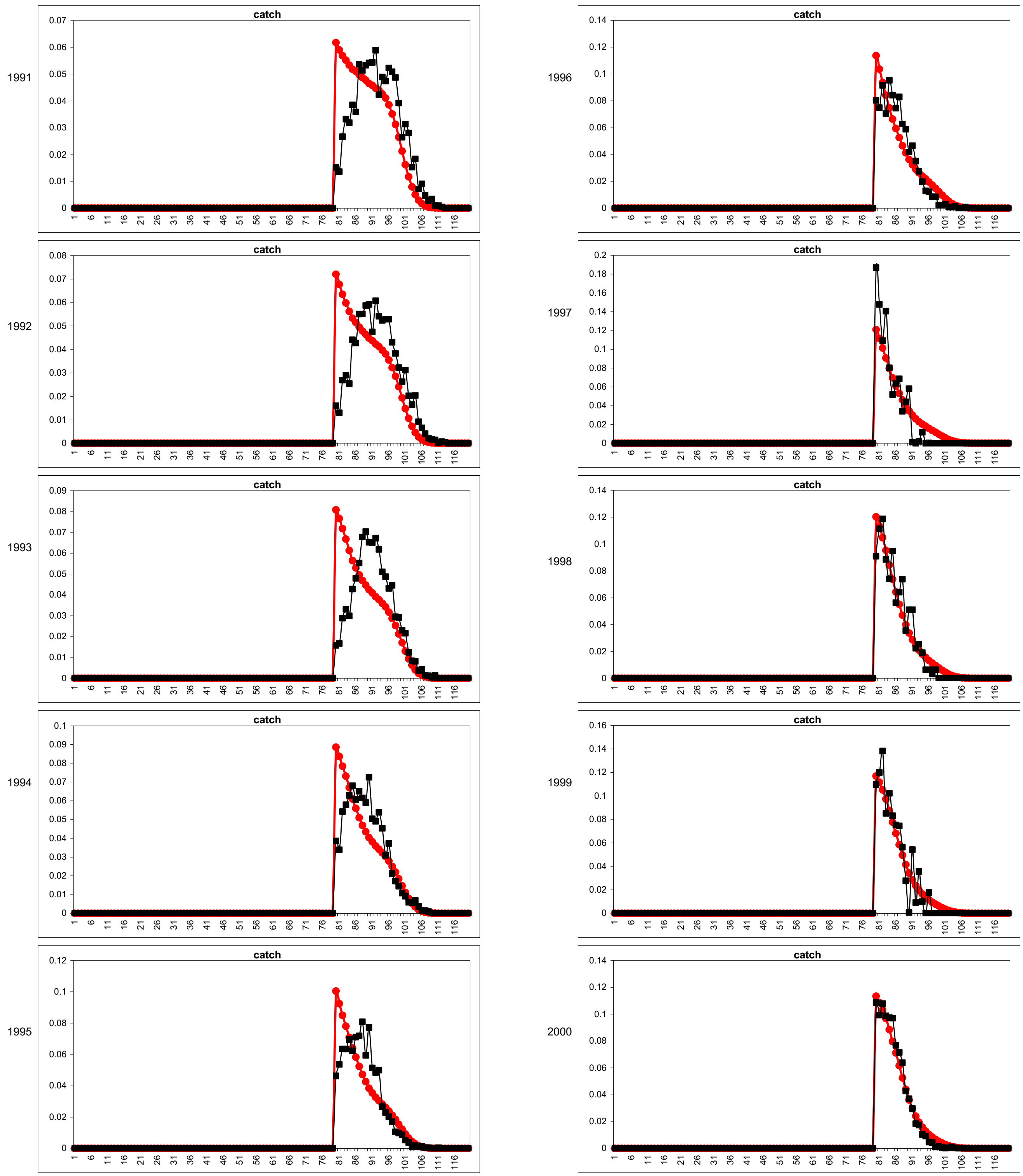

1991
catch
1992
catch
1993
catch
1994
catch
1995
catch
1996
catch
1997
catch
1998
catch
1999
catch
2000
catch

Fig. 9. cont

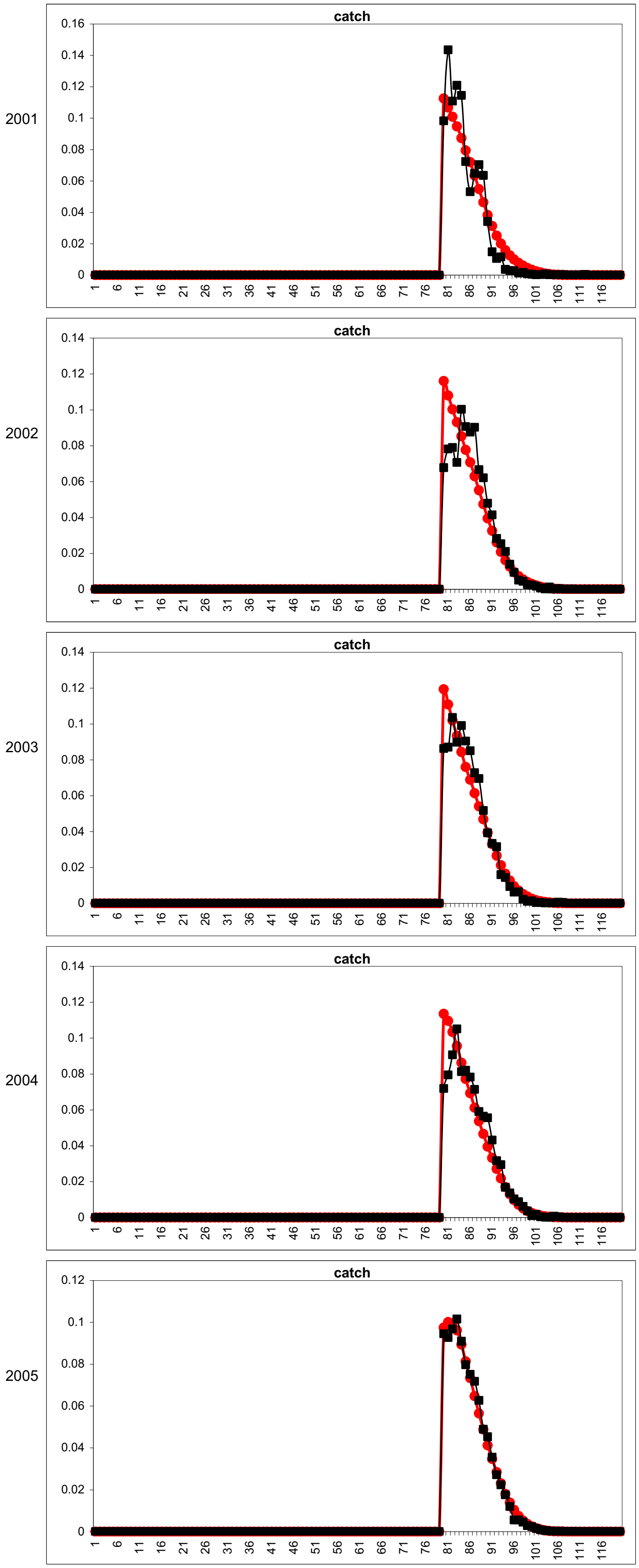
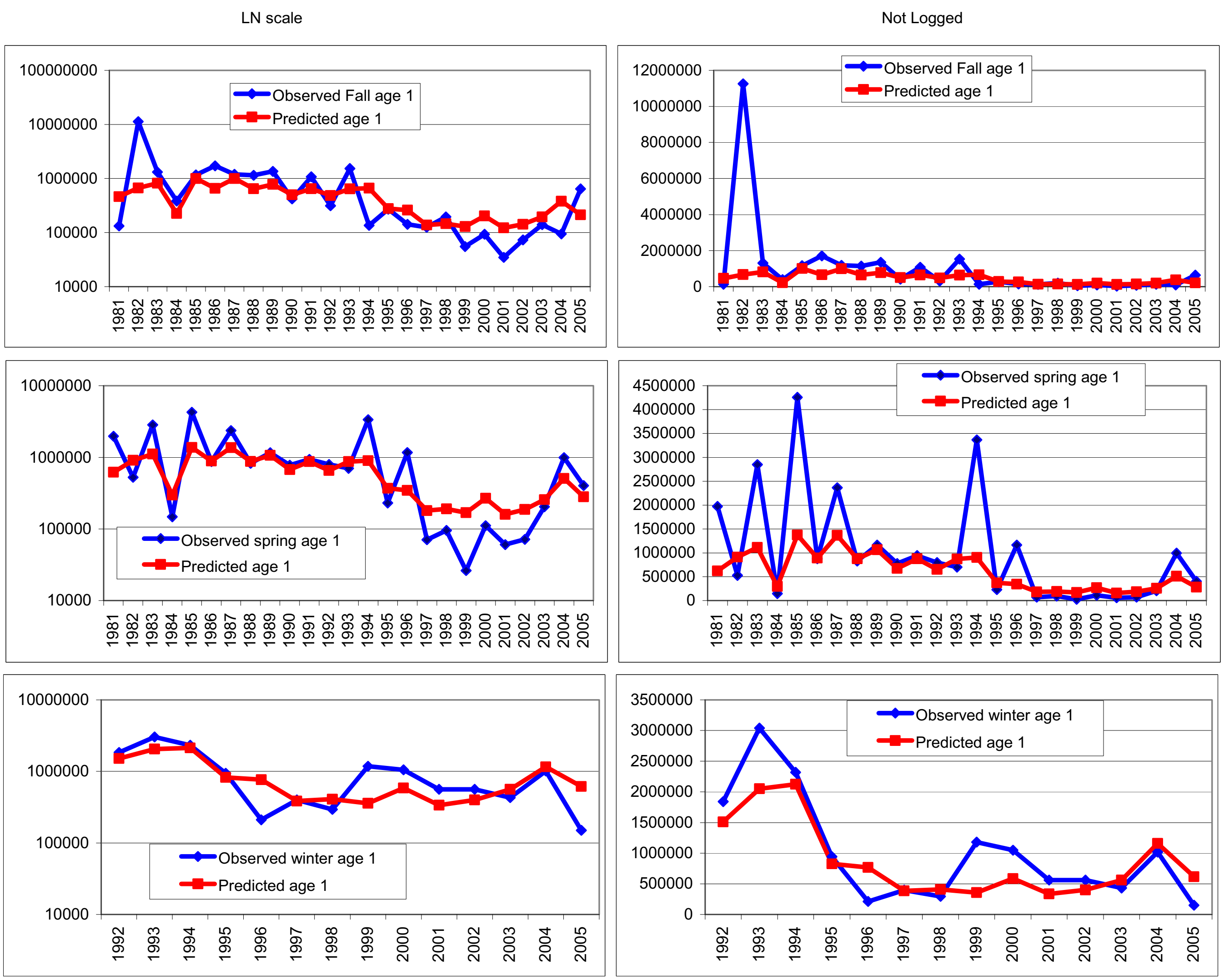
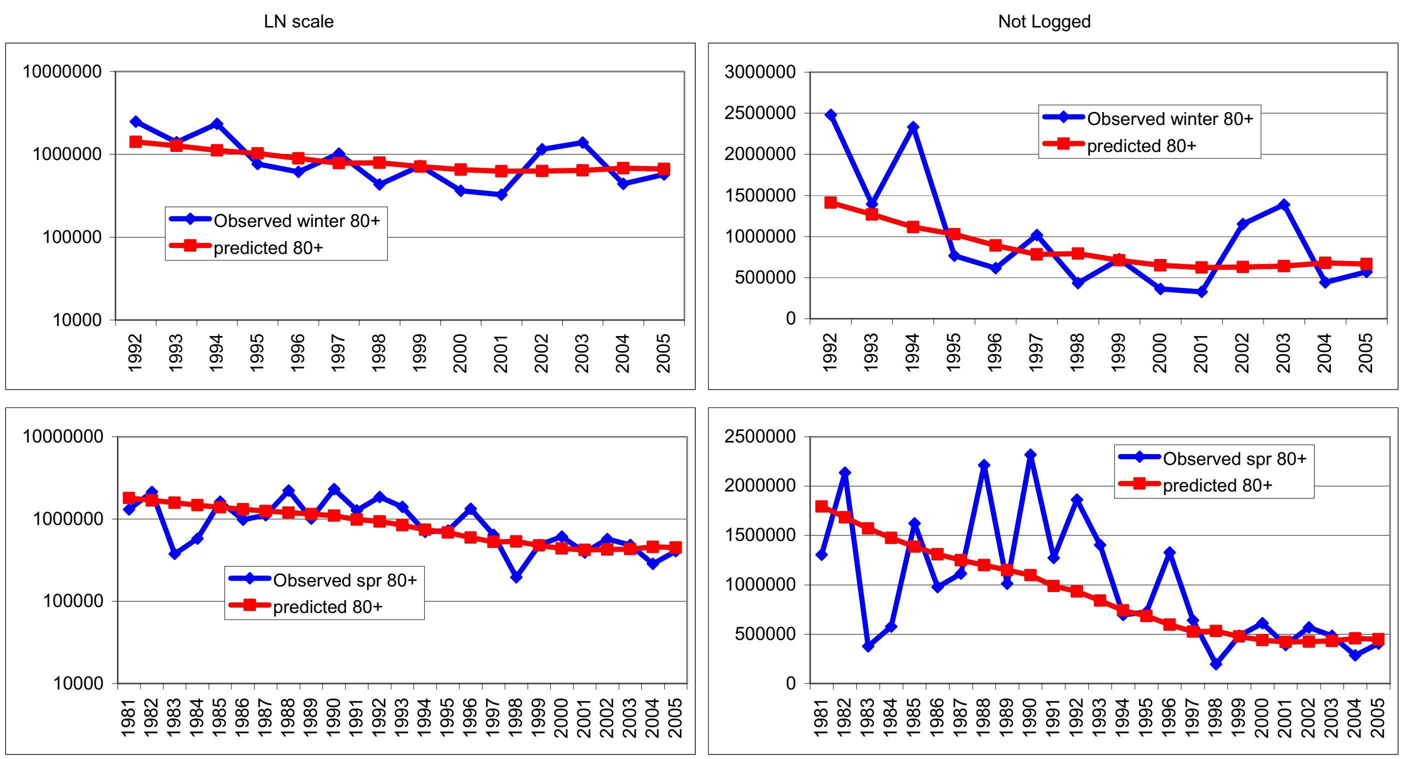


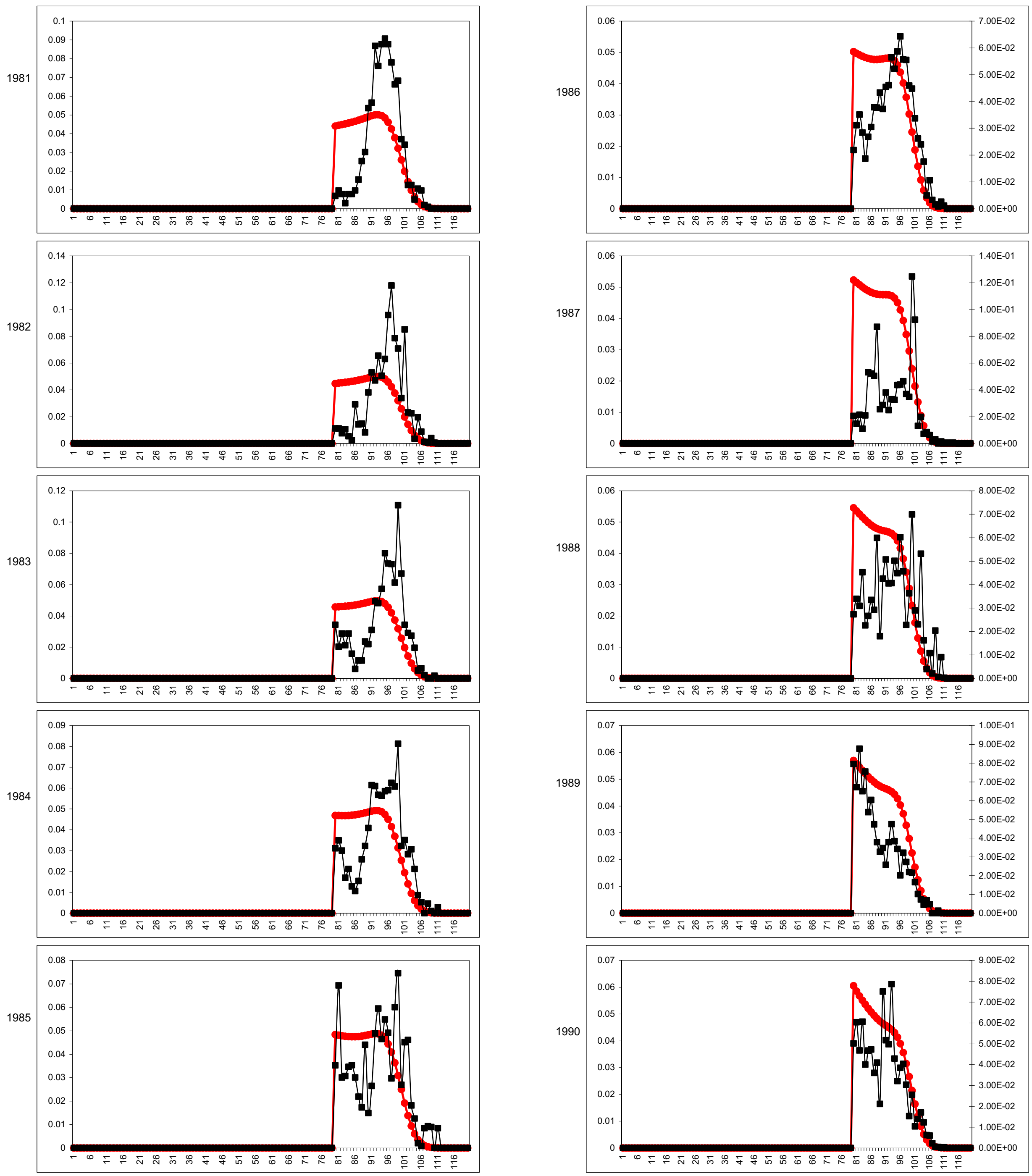
Fig. 9. cont.



APPENDIX B3. Figure 10. Female dogfish run 8 ln and nominal observed and predicted age 1 recruitment indices for the Fall, Spring, and winter NEFSC surveys.



APPENDIX B3. Figure 11. Female dogfish run 8 ln and nominal observed and predicted 80+ cm number indices for the NEFSC winter and spring surveys.



APPENDIX B3. Fig. 12. Female dogfish LTM run 8 observed (squares) and predicted (dots) fitted length frequency for 80+ cm fish for the NEFSC Spring survey from 1981-2005.

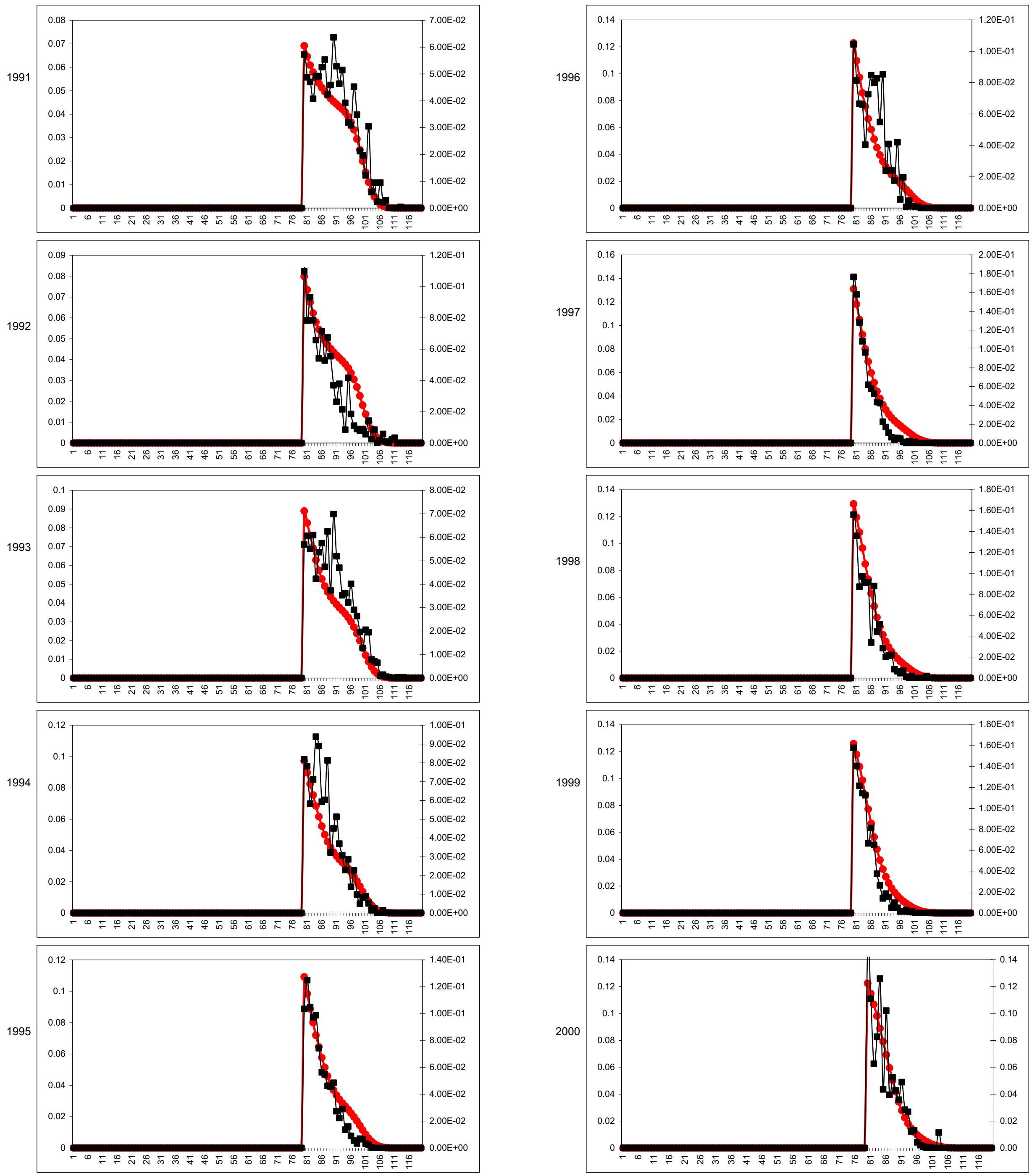


Fig. 12. cont.

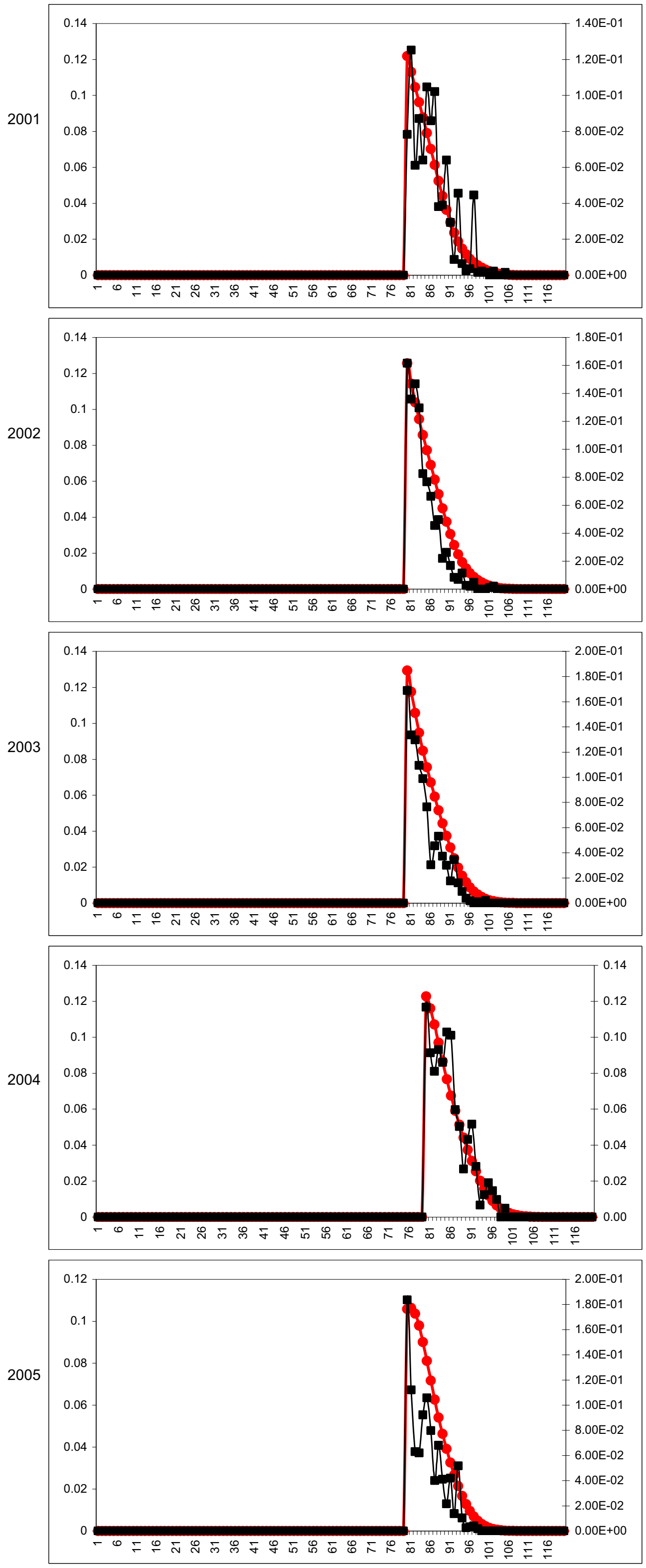
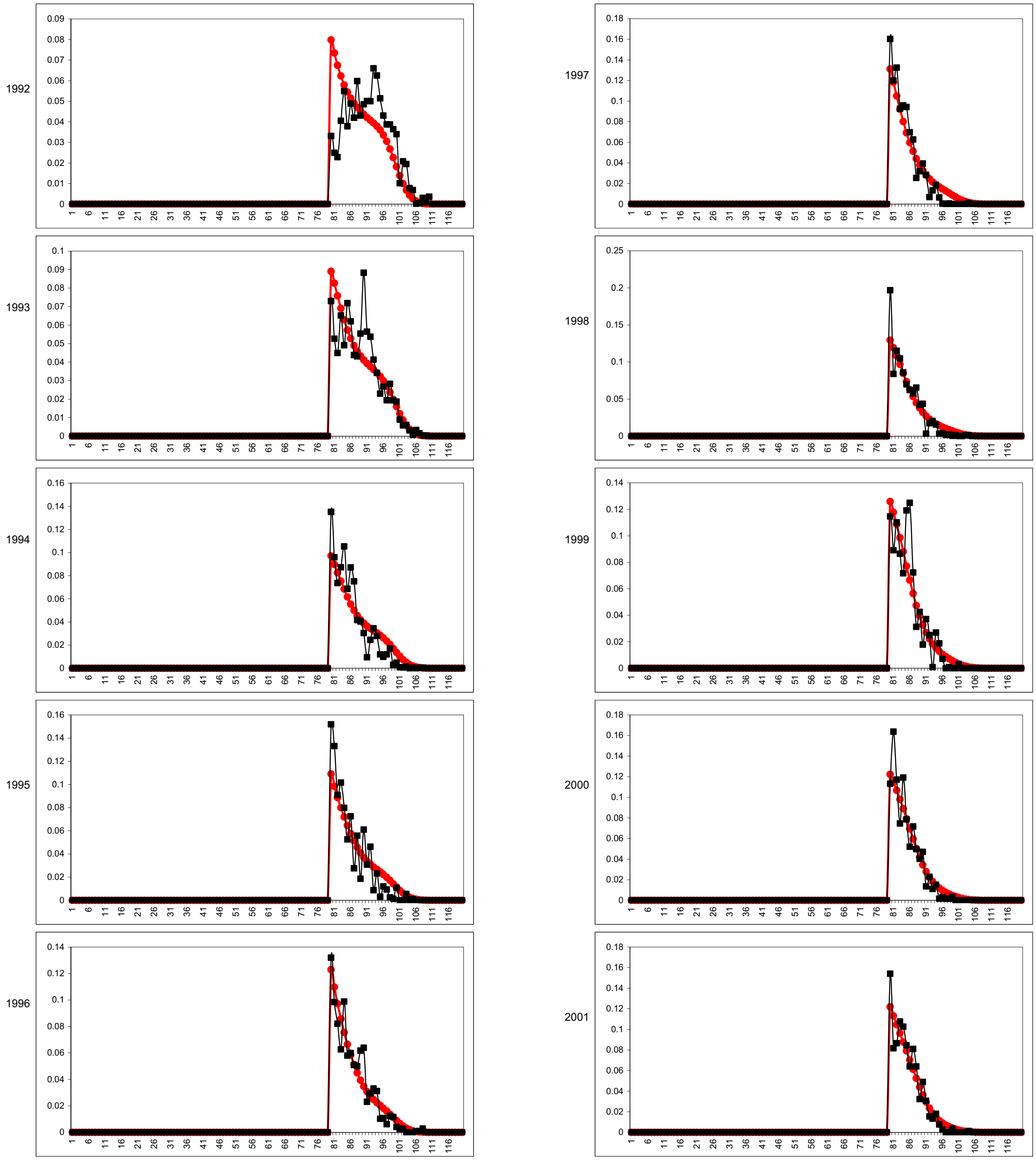


Fig. 12. cont.



APPENDIX B3. Fig. 13. Female dogfish LTM run 8 observed (squares) and predicted (dots) fitted length frequency for 80+ cm fish for the NEFSC Winter survey from 1992-2005.

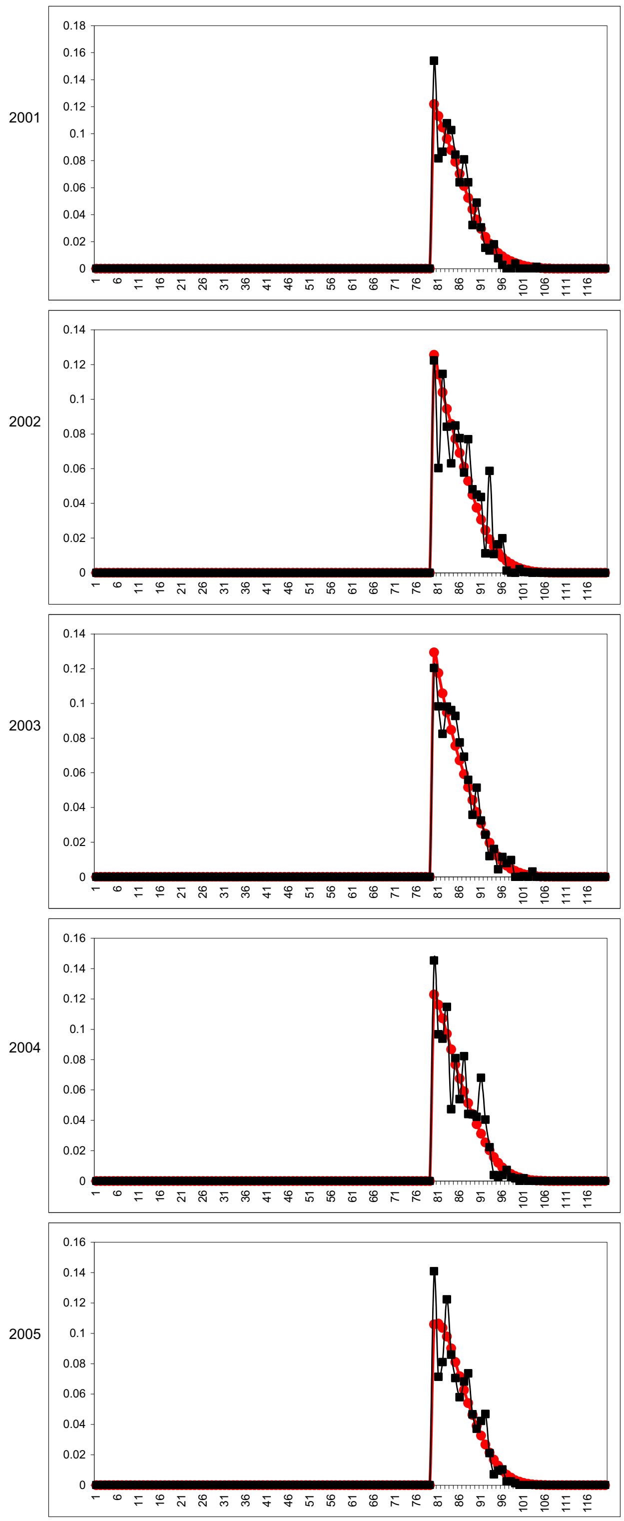
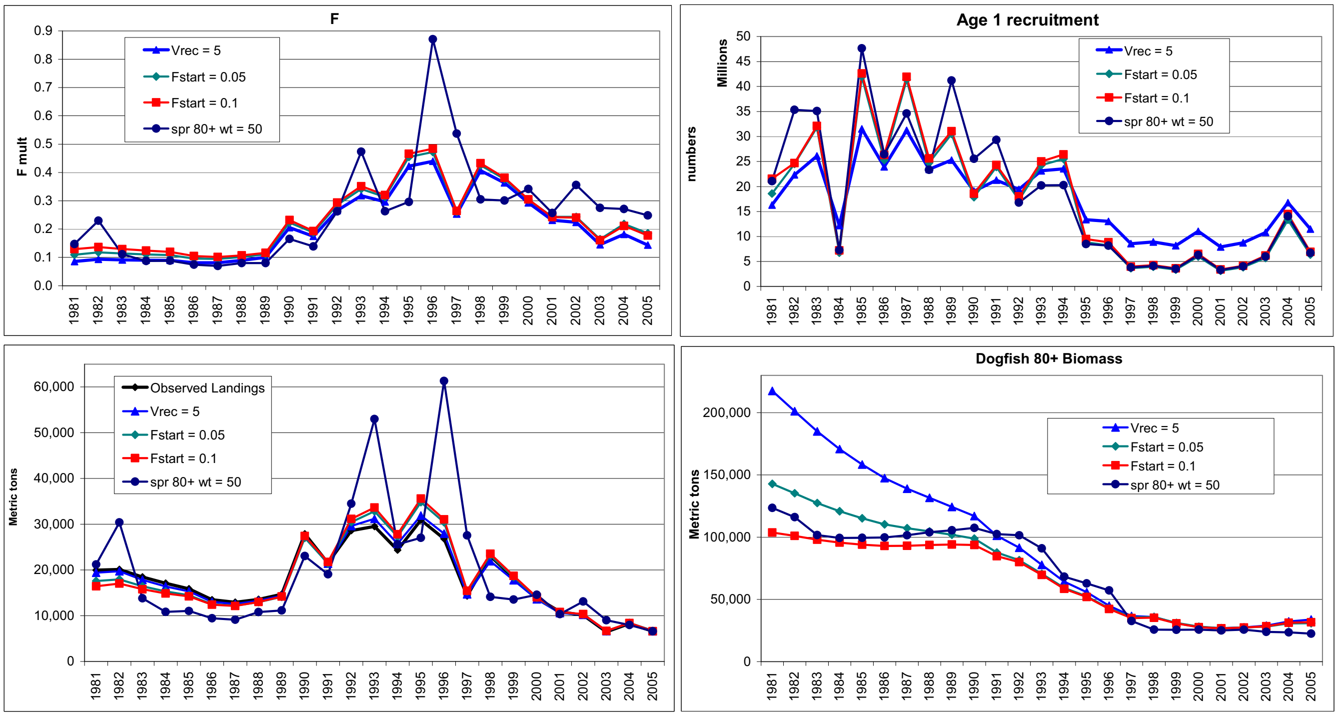

2001
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
2002
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
2003
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
2004
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
2005
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1 6 11 16 21 26 31 36 41 46 51 56 61 66 71 76 81 86 91 96 101 106 111 116

Fig. 13. cont

.



APPENDIX B3. Fig. 14. Female dogfish LTM runs 9-12 with corrected catch including commercial discards and constant pr. Runs 9-12 compare the effects of Vrec = 5, a fixed Fstart at 0.05 and 0.1, and a higher weight (50) on the spring 80+ index.

C: ASSESSMENT OF THE NORTHERN STOCK OF BLACK SEA BASS

Report of the Southern Demersal Working Group

1.0 EXECUTIVE SUMMARY

The status of the northern stock of black sea bass was evaluated. (EDITOR'S NOTE: TEXT FROM THIS PARAGRAPH HAS BEEN OMITTED BECAUSE THE REVIEW PANEL DID NOT ACCEPT THE F ESTIMATES OR THE EXISTING BIOMASS REFERENCE POINT.)

Total landings declined in 2004 and 2005 due primarily to reduced recreational landings. Commercial landings are controlled by quota and have remained relatively stable for the past decade. Discards in the recreational fishery are substantial, however only 15% of the discards are expected to be lost due to mortality. Commercial discards, based on logbook information, range from 5% to 13% of landed weight.

The NEFSC spring bottom trawl survey of offshore strata is the basis for evaluating black sea bass biomass status. Adult biomass ($\geq$ 22cm) peaked in 2002 but has since declined to the long term average. A similar pattern in biomass decline has been evident in the NEFSC winter survey. Strong juvenile abundance indices ($\leq$ 14 cm) appeared in 2000 and 2002 winter and spring surveys. However, these strong cohorts have not produced an expected increase in the adult biomass indices. State surveys index local recruitment and also suggest the 2002 year class was above average.

A tagging program for black sea bass between Massachusetts and North Carolina was initiated in September 2002. The recaptures of tagged adult sea bass show seasonal offshore migrations to the edge of the continental shelf and a return migration inshore during spring. Fish in the north (MA and RI) move south as far Virginia before returning in spring. In contrast, fish in the southern end of the range follow a simple inshore/ offshore movement of 50 to 100 miles. Site fidelity is quite strong although straying does occur, particularly for fish traveling the farthest distances.

The tag release/recapture data formed the basis for estimating exploitation rate. Two model types were used; a modified Petersen (R/M) model for exploitation that uses annual recaptures as a ratio of released tags and a Brownie band recovery model which uses the full tag recovery matrix. The WG concluded that the Brownie models as configured did not provide accurate estimates of survival. The R/M model, modified for reporting rates and tag losses, produced the best estimate of exploitation. A Monte-Carlo approach to the R/M model characterized the uncertainty in the estimates. (EDITOR'S NOTE: TEXT FROM THIS PARAGRAPH HAS BEEN OMITTED BECAUSE. THE MODEL RESULTS WERE NOT ACCEPTED BY THE REVIEW PANEL.)

Overfishing in black sea bass is defined by an F_{max} value of 0.33 which serves as a proxy for F_{msy}. The stock biomass threshold is based on a three point moving average of the NEFSC spring adult biomass index from 1977 to 1979. (EDITOR'S NOTE: TEXT HAS BEEN OMITTED BECAUSE THE REVIEW PANEL REJECTED THE F ESTIMATES AND BIOMASS REFERENCE POINT.)

A recent review of the MRFSS program prompted examination of the effect uncertainty in recreational catch data has on stock assessments. Since catch was not used in determination of black sea bass stock status, any error in the MRFSS estimates remains inconsequential to status determination at this time.

2.0 TERMS OF REFERENCE

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

2. Describe temporal trends in abundance and size-structure based on data from NEFSC surveys. When possible, characterize the uncertainty of point estimates. Describe data from other surveys, as appropriate.

3. Based on the recent tagging study, estimate annual rates of mortality due to fishing and overall. Characterize the uncertainty of those estimates.

4. Based on the recent tagging study, describe migration patterns with respect to depth, season, latitude and longitude.

5. Evaluate current stock status with respect to the existing BRPs.

6. Perform sensitivity analyses to determine the impact of uncertainty in the recreational data on the assessment results.

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

3.0 INTRODUCTION

Black sea bass (*Centropristis striata*) range from the Gulf of Maine to the Gulf of Mexico and the population is partitioned into two stocks north and south of Cape Hatteras, NC (Musick and Mercer 1977, Shepherd 1991). The management unit of the Black Sea Bass FMP includes all black sea bass in U.S. waters in the western Atlantic Ocean from Cape Hatteras, North Carolina north to the Canadian border. The initial joint ASMFC (Commission) and MAFMC (Council) Black Sea Bass FMP was completed and approved in 1996. The objectives of the FMP were to reduce fishing mortality to assure overfishing does not occur, reduce fishing mortality on immature black sea bass to increase spawning stock biomass, improve yield from the fishery, promote compatible regulations among states and between federal and state jurisdictions, promote uniform and effective enforcement, and to minimize regulations necessary to achieve the stated objectives. The original FMP defined overfishing as fishing in excess of F_{max}, or F=0.29, which represented an annual exploitation rate of 23%. The FMP was intended to reduce fishing mortality over an eight-year period starting in 1996 implementing coastwide commercial size limits and quota allocated on a quarterly basis, and a recreational harvest limit constrained through the use of minimum size, possession limit (maximum of 25 fish), and seasonal closures. The specifications were minimum requirements and states, such as Massachusetts, chose to implement more conservative measures.

	Minimum sizes	
	commercial	recreational
1996	9"	9"
1997	9"	9"
1998	10"	10"
1999	10"	10"
2000	10"	10"
2001	10"	11"
2002	11"	11.5"
2003	11"	12"
2004	11"	12"
2005	11"	12"
2006	11"	12"

Amendment 12 to the Summer Flounder, Scup, and Black Sea Bass FMP was approved by the Commission and Council in October 1998 and established revised overfishing definitions, identification and description of essential fish habitat, and defined the framework adjustment process. The updated overfishing definition defined F_{max} as a proxy for F_{msy} with F_{max} = 0.32.

Amendment 13, approved by the Commission in May 2002 and Council in June 2002, implemented increases in minimum size for commercial and recreational fisheries as well as a federal, coastwide annual quota that is managed by the Commission using a state-by-state allocation system. F_{max} was re-estimated to account for changes in minimum sizes and currently equals 0.33.

The stock status was reviewed in SARC 39 (NEFSC 2004) which concluded that the assessment, based on tagging results, was suitable for management purposes. The assessment concluded that exploitation was below the management target and biomass indices were at or above the biomass threshold, which is the three-year moving average of the NEFSC spring survey catch per tow from 1977-1979 (0.98 kg/tow)

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

Commercial sea bass landings have remained relatively stable since the mid-1960s, ranging from a low of 566 mt (1,249 thousand lbs) in 1971 to a high of 1,985 mt (4,377 thousand lbs) in 1977 (Table C1, Figure C2). Prior to 1962, landings of the northern stock from North Carolina are not reported. The 2005 quota (1,823 mt) restricted landings of 1,310 mt, which is slightly above the average for 1994-2004 (1,268 mt). Recent landings are all substantially below the peak landings of 9,883 mt estimated for 1952 (Figure C2).

Commercial black sea bass landings in 2005 were primarily from sea bass pots (32%), otter trawl (33%), hook and line (11%) and the remainder from other gear (14% from unreported gear) Figure C3. The pot and hook fisheries begin in coastal waters in May and continue until late October in MA to December in southern areas (Shepherd and Terceiro 1994) (Figure C4). Otter trawl landings generally occur offshore during the winter months in the summer flounder, scup and squid fisheries (Shepherd and Terceiro 1994). New Jersey, Massachusetts, Virginia, North Carolina, Maryland and Rhode Island accounted for 89% of commercial landings in 2005.

Biological samples collected by NMFS and North Carolina DMF were used to expand length frequencies of dealer reported commercial landings. Samples were partitioned by quarter and market category (unclassified, small, medium, large and jumbo). Jumbos accounted for 30% of landings in 2004 and 33% in 2005, while large (31% and 29%) and mediums (27% and 25%) were also a significant part of landings in both 2004 and 2005 respectively (Figure C5).

Expansion of length frequencies to total landing were based on 12,132 measurements in 2005 and 9,557 in 2004 (Table C2). Sample intensity has steadily increased from the 1998-2000 period, which averaged only 4,329 samples per year. Quarter/market categories with no length samples were expanded using samples from adjacent quarters within the same year, market category combination.

Length to weight conversions were based on length-weight equations in the form ln Wt (kg) = ln a + b ln Len (cm) derived from 1995-2005 NEFSC survey data.

	ln a	b
spring	-11.537	3.103
autumn	-11.251	3.033
winter	-11.477	3.077

Expanded length distributions are shown in figure 6. Average lengths in the commercial fisheries have increased steadily since 1996. Increasing minimum sizes have largely contributed to the increase from a 25.3 cm mean length in 1996 to the 2005 average of 35.4 cm (Table C3, Figure C7). Total estimated landings were 2.3 million fish in 2004 and 2.0 million in 2005 (Note: 2002 and 2003 preliminary numbers estimated for commercial landings in SARC 39 report are updated).

Commercial discards were estimated from commercial vessel logbook information which provides coverage of all fishermen holding federal sea bass permits. Total discards were estimated as the ratio of the sum of the reported pounds discarded per trip to weight of reported pounds kept (Table C4). The average ratio by year and gear type was expanded to total pounds discarded. Discard mortality is unknown, although hook mortality is likely similar to recreational fisheries, estimated at 15%. In addition, the fishing methods used in the pot fishery likely results in relatively low discard mortalities. Total discarded pounds peaked in 2002 at 201 mt (443,000 pounds) but declined to 63 mt (140,000 lbs) by 2005. Observer data does not adequately cover pot or hook and line trips which constitute a substantial proportion of landings and was not considered representative of discarding practices. Therefore the observer data was not used for discard estimates.

The proportion of the recreational landings has fluctuated around 50% of total black sea bass landings over the past decade (Table C1). The recreational fishery generally takes place in coastal areas from May until November and is subject to a 12" (30 cm) minimum size and a 25 fish bag limit. Landings ranged from a low of 518 mt (1.1 million pounds) in 1998 to a high of 5,621 mt (12.4 million pounds) in 1986 (Table C1, Figure C8). MRFSS estimates of black sea bass recreational landings (A + B1) in 2004 were 760 mt (1675 thousand lbs) and 787 mt (1735 thousand lbs) in 2005. The average for 1981-2005 was 1,674 mt (3690 thousand lbs.). In 2004-2005, 64.6% of the recreational landings were from the state of New Jersey. The next highest percentages per state were 10.8% from Delaware and 8.6% from Maryland. Length distributions from the recreational landings are shown in Figure C9. Average length in landings has increased from 26.5 cm in 1995 to 34.2 cm in 2005 (Figure C10). Recreational discards (B2) amounted to 5.7 million and 5.8 million fish in 2004 and 2005, respectively (Table C5). As with landings, New Jersey accounted for the largest percent with 45% of total B2 discards. A discard mortality estimate of 5% (Bugley and Shepherd 1991) was based on cage experiments conducted in relatively shallow water. However, an estimate of 15% may be more representative of conditions in deeper water fisheries such as New Jersey. A mortality rate of 15% would result in total discard losses of 851,000 and 860,000 fish in 2004 and 2005 respectively. In 2005, the MRFSS program initiated at sea sampling of party/charter vessels which resulted in 3,883 length measurements of discarded sea bass. Sea bass discards lengths had a knife edge distribution at the legal size limit of 30 cm (Figure C11). The average length of discards in 2005 was 23.2 cm.

5.0 TOR 2. Describe temporal trends in abundance and size-structure based on data from NEFSC surveys. When possible, characterize the uncertainty of point estimates. Describe data from other surveys, as appropriate.

NEFSC surveys

The NEFSC spring bottom trawl survey in offshore strata is used to represent the abundance of adult black sea bass (defined as fish $\geq$ 22 cm). The highest abundance index (log re-transformed stratified mean number per tow) occurred in 2003 (1.614 per tow with a 95% CI of 1.181 to 2.134) and was the highest value since 1974 (Table C6, Figure C12). A slight rise in abundance was evident in the late 1980s but was followed by a decade of fluctuations around low levels of abundance. Since 1999 there was a noticeable increase in the index values which peaked in 2003, followed by a steady decline in the 2006 index (preliminary) of 0.456 fish per tow (95% CI of 0.331 to 0.594), which is equal to the long-term average of 0.461 fish per tow.

The NEFSC winter survey, initiated in 1992, follows a similar pattern with a peak in the index value for 2002 (3.44 fish/tow with a 95% CI of 2.82 to 4.16) followed by declining indices to 1.06 fish/tow in 2006 (95% CI of 0.82 to 1.33) (Table C6, Figure C12). The autumn survey has also had relatively large indices in recent years but has not been considered reliable as an index of adult abundance due to potential catchability issues during sea bass residency in coastal waters.

During development of the FMP, exploitable biomass from survey results was defined as fish greater or equal to 22 cm. The working group decided to maintain this definition for evaluation of trends over the time series to maintain consistency with the definition of the biological reference point (minimum biomass threshold). Total biomass indices from the spring and winter trawl surveys indicate a significant increase between 2000 and 2003 followed by a decline. Spring survey biomass per tow peaked in 2003 at 2.151 kg/tow (95% CI of 0 to 5.00), well above the long term average of 0.435 kg/tow (Table C7, Figure C13). The preliminary 2006 index declined to 0.548 kg/tow (95% CI of 0 to 1.12). The log re-transformed biomass indices show a similar pattern although the index peaked in 2002 (0.6.17 kg/tow, 95% CI of 0.505 to 0.743) and declined to a 2006 index of 0.288 kg/tow (95% CI of 0.199 to 0.358). The winter survey peaked in 2003 at 3.123 kg/tow (95% CI of 0.430 to 5.814), well above the time series average of 0.878 kg/tow (Table C7, Figure C13). The index decreased steadily thereafter to a preliminary 2006 index of 0.568 kg/tow (95% CI of 0.282 to 0.855). Log re-transformed indices had a similar pattern although the indices peak in both 2002 and 2003 (1.327 and 1.300 kg/tow, respectively), followed by a decline to 0.378 kg/tow (95% CI of 0.282 to 0.855) in 2006.

Juvenile indices of black sea bass from the winter, spring and autumn surveys provide some insight into the cohort strength (Table C8). The juveniles appear as clearly defined modes at sizes $\leq$ 14 cm in the autumn surveys. There appears to be little growth during the winter, as the same distinct size mode appears in the winter and spring survey length frequencies. In the spring, fish $\leq$ 14 cm would be considered one year old. Log re-transformed mean #/tow of juvenile sea bass in both the winter and spring surveys suggest large 1999 and 2001 cohorts (peaks in the 2000 and 2002 surveys) (Figure C14). Both of these modes in the length frequency appear the following year as increases in a mode above 20 cm, which is consistent with known growth rates (Figures C15 and C16). The winter survey shows an above average 2002 year class, however this is not apparent in the spring survey and the spring survey shows a strong 1998 cohort that was below average in the winter survey. The autumn surveys show above average 1998-2000 year classes. In all three surveys, the 2005 cohort appears below average.

Massachusetts Division of Marine Fisheries

The Massachusetts spring bottom trawl survey, initiated in 1978, showed a recent increase in sea bass with a peak stratified mean number per tow of 4.0 in 2000 (Table C9, Figure C17). However the indices have since declined and have been at or below the time series average (1.21/tow). The 2005 index was 1.1 fish/tow. The index of spawning stock biomass also peaked in 2000 at 1.93 kg/tow and has steadily declined in 2003 to 0.93 kg/tow in 2005. The SSB index still remains well above the levels experienced in the 1990s. The MA juvenile sea bass index from the autumn survey indicated a series of strong cohorts during the early 1980s, followed by a decade and half of low values. Juvenile indices have increased steadily since 2000 and the 2005 index of 432.5 fish/tow is the series maximum (Figure C17).

Rhode Island Trawl Survey

Catches in the RI autumn bottom trawl survey, which began in 1981, are predominated by juveniles. The mean number per tow shows several strong cohorts in the early 1980s, with 1981 the largest value in the time series (Table C10). Similar to Massachusetts, the late 1980s and 1990s were below average with increased year-class strength beginning in 2000 and a very large 2005 year class.

Connecticut Long Island Sound Trawl survey

The time series of geometric mean number per tow from the CT trawl survey begins in 1984 and this survey catches very few black sea bass. The juvenile indices from the fall survey show a similar trend to the NMFS, MA and RI surveys with low abundance in the 1990s and an increased in abundance over the past several years, beginning in Long Island Sound in 2001 (Table C10) .

New Jersey Coastal Ocean Survey

The New Jersey trawl survey is conducted during January, April, June, August, and October. Mean number per tow peaked in 2002 (2.7/tow) and has since steadily declined (Table C10). Indices of juvenile abundance (<= 14 cm) were unusually large in 1997 (as well as adults that year) and also showed a strong cohort in 2002. The 2004 and 2005 year classes are below time series average.

Chesapeake Bay and Lower James River

A trawl survey conducted by the VA Institute of Marine Science provides indices of age 1 sea bass abundance within Chesapeake Bay. The indices show increasing cohort strength beginning in 1997 (1996 cohort) and peaking in 2002 (2001 cohort), followed by a steady decline to 2005 (Table C10). The 2002 index was 1.29 fish per tow compared to the 2005 index of 0.06 per tow.

The juvenile indices from all sources were standardized as a percent of the maximum value within each series, and averaged across all values (assumed equal weighting among programs). Age 0 fish in fall survey indices were advanced to the next calendar year to coincide with age 1 sea bass in spring indices. The results, presented in Figure C18, show an overall trend of good recruitment in the 1980s, low recruitment in the 1990s and improved recruitment in since 2001.

6.0 TOR 3. Describe migration patterns based on data from the recent tagging study.

The northern stock of black sea bass has distinctive seasonal movement patterns. Timing and directionality of these movements are not the same throughout the region but they experience a common offshore residence area during the winter/spring (Jan-Jun) and then return to a seasonal separation during the summer/fall (Jul-Dec) inshore residence. Movement patterns were examined on a sub-regional basis (area of release) (New England (NE) = MA, RI, CT) (Mid Atlantic Bight (MAB) = NY, NJ, DE) (Maryland/Virginia (MV) = MD, VA). Distinctive patterns emerged among the groups based on recapture data.

Maps and migration descriptions are based on the 2,415 tag recaptures reported as of 15 April 2006. Fish tagged and released in late summer or fall moved to the edge of the continental shelf for the winter months and almost always returned to the same area the following summer (Figure C19). During summer and fall months, recapture data show relatively little mixing among adjacent areas whereas winter and spring recaptures show a thorough mix of all three sub-regions along the edge of the continental shelf (Figure C20).

Timing of fish movements begin in the New England (MA, RI, CT) region during late October and progress southward as water temperature decreases. It is clear that fish released in the New England area travel much greater distances to reach the offshore area (Table C11). Mean distance traveled is twice as high during summer/fall months for the New England released fish (when compared to Mid-Atlantic Bight and the Maryland/Virginia releases) and more than 3½ times the mean distance traveled during winter/spring months. The NE releases move south-southwest, MAB fish tend to move southeast and MV fish move eastward to reach their offshore grounds.

The seasonality of movement and mixing of tag recaptures is further supported by Table C12; a matrix of recaptures by region and month, based on the region of release. During December through April, New England released fish were primarily caught in the MAB region (33 of 49 tags), approximately half as many were caught within the MV region (15 of 49) and only two tags were recaptured within that same region during that time period. Conversely, from May through November, the majority of recaptured tags were recovered within the New England region. When the Mid Atlantic Bight released tags are examined, there is much less movement to the MV region and only a single tag moved into the NE region (consequently, this tag was released near the NE/MAB boundary). Maryland and Virginia released fish showed a more random pattern of movement. Eight tags moved into North Carolina water (south of the MV boundary region) and 36 of the 1024 recaptured tags moved into the MAB region. The majority of the MV released tags were recaptured within the MV region.

A matrix of movement among the States of release is shown on Table C13. The grey boxes represent no net movement or recapture within the State of release (State fidelity). Values within the same row but outside the grey box demonstrate net movement to the north and south of the release State. Proportions of net movements are presented in the last three columns. In most States the recaptures primarily occur within the State of release ('No net Move') which suggests that the fish return to the same State in which they were originally tagged. The exception is Connecticut where all recaptures (2) occurred to the south. Fish generally moved more southward than northward, the two exception being RI → MA (the states are at equal latitude, movements are actually eastward) and DE → NJ (where tag data shows a common exchange of fish between underwater structures located off Lewes, DE and Cape May, NJ).

Archival tag (data storage tag – DST) information suggests that fish movements are cued by decreasing temperatures in late fall. Figure C21 shows the depth and temperature profiles of a tag released off RI and recovered along the edge of the continental shelf near the tip of Hudson canyon. The data show decreases in temperature related to fish movement to deeper water, apparently in search of warmer water (abrupt depth changes suggest movement perpendicular to depth contours). Once a warmer body of water is found (usually at greater depth), the fish settles at depth and remains until the temperature falls and once again the fish moves. By late January the temperature readings leveled out and the movement patterns cease.

7.0 TOR 4. Estimate annual rates of fishing mortality and total mortality, based on the recent tagging study. Characterize the uncertainty of those estimates.

The black sea bass tagging program was initiated in September of 2002, with subsequent release periods in May 2003, September 2003 and September 2004. An analysis of tag recaptures were reviewed in SARC 39 and judged to be adequate for management. At that point, tag returns were limited to one year and consequently analysis was limited to a simple R/M estimate of exploitation. Since then, we have completed three years of tag recaptures which allows us to complete a more rigorous analysis of the data. Two basic modeling approaches are presented; a modified R/M estimate with a Monte Carlo method of examining uncertainty and Brownie models under a variety of configurations.

Modified R/M Method

Tag releases were limited to fish greater than 28 cm (11 in) which were considered to be subject to full exploitation by both commercial and recreational fisheries. Subsequent tag recaptures were tallied by release cohort and year of recapture. Year of recapture was a one year period beginning with time of release (e.g. September to September) and not a calendar year. A recapture matrix is provided in Table C14.
Tag recaptures (and the associated release record) that occurred within 7 days by the same fisherman involved with the release program were discounted. Tag releases and recaptures are influenced by several external factors. The number of released tags can be reduced by tag loss and tagging induced mortality. The number of tag recaptures are a function of reporting rate, exploitation, fishery selectivity and emigration from the system. There is no indication from the geographic distribution of tag recaptures that the tagged sea bass left the tag recovery area, since there are active commercial and recreational fisheries in surrounding areas with no reported recaptures. Tag retention experiments (Table C15) have provided an estimate of tag loss (8%) and mortality (2%), as well as a range of values from the three experiments (Table 16). Reporting rate was estimated for each tagging period using the ratio of regular tag returns to returns from \$100 tags. We are assuming that \$100 tags are reported at close to 100% although there is evidence that the rate may be slightly less than 100%. Reporting rates for the four release periods were estimated as 65.8% (fall 2002-2003); 60.9% (spring 2003-2004); 68.6% (fall 2003-2004); and 55.3% (fall 2004-2005). Length frequency of tag recaptures

and fishery length frequencies are comparable, suggesting that the selectivity of the tags is representative of the fisheries (Figure C22).

The modified R/M estimate was based on the expression:

$$u = \frac{\text{\# tags recaptured /reporting rate)}}{\text{(\# tags release - \# tags lost - \# tags lost due to tag induced mortality)}}$$

Since the estimated reporting rates, tag loss and tag induced mortalities were all measured with error, possible variation around the exploitation rate was estimated using a Monte Carlo approach. A normal distribution around mean tag loss and tag induced mortality was generated with standard deviations that produced a comparable range of values as the empirical data. A normal distribution around the mean annual reporting rates was generated to produce a distribution ranging from 40% to 95% (Figure C23). A thousand values from each distribution were randomly selected to produce 1000 combinations of tag loss, tag induced mortality and reporting rate. Exploitation rates were generated for each of the 1000 combinations to produce a distribution of *u* for each tag release group. (EDITOR'S NOTE: TEXT FROM THIS PARAGRAPH HAS BEEN OMITTED. THE REVIEW PANEL DID NOT ACCEPT THE F ESTIMATES. THE PANEL CONCLUDED THAT INCOMPLETE MIXING AND MIGRATION NEED TO BE INVESTIGATED FURTHER.)

The R/M approach was further modified in an attempt to directly estimate natural mortality. The method is based on a variation of an approach described by Pollock et al. (1991). The tag release and recoveries were arranged as follows:

		Recapture year		
	M_1	$\mathbf{R_{11}}$	R_{12}	R_{13}
Release	M_2		$\mathbf{R_{21}}$	R_{22}
Year	M_3			$\mathbf{R_{31}}$

The diagonal of the recaptures represent the exploitation for the first recapture year following release of that tag cohort. The second year of recoveries ($R_{12,}$ R_{22}) should also be a function of same exploitation rate and tag reporting rate within that recapture year, except the number of tags available for recapture has been reduced by the removals in the first year (R_{i1}) and natural mortality. Since the number of tags removed the first year is known, and we assume tags recovered in the diagonal row properly estimate exploitation for that year, the difference between R_{21} and R_{12} should be equal to tags lost from natural annual mortality. Therefore:

[(R_{21} / reporting rate) / (M_2-initial tag loss)] - [(R_{12}/reporting rate) / (M_1- initial tag loss - (R_{11}/reporting rate))] = # tags removed by natural annual mortality

The natural loss percentage was translated into instantaneous natural mortality as described above using 1000 combinations of initial tag loss, tag induced mortality and reporting rates. For M in years not estimable with this approach, values were randomly selected from a uniform distribution ranging from 0.17 to 0.27. (EDITOR'S NOTE: TEXT FROM THIS PARAGRAPH HAS BEEN OMITTED. THE REVIEW PANEL DID NOT ACCEPT THE MORTALITY ESTIMATES. THEY CONCLUDED THAT INCOMPLETE MIXING AND MIGRATION NEED TO BE INVESTIGATED FURTHER.)

Brownie Method

A second modeling approach used was a class of band recovery models commonly referred to as Brownie models (Brownie et al. 1985). Survival estimates are based on the tag release-recovery matrix and the estimates of model parameters S (survival) and f (recovery rate) were developed using maximum log-likelihood estimation. A spreadsheet version of the model was developed (see appendices) and tested against known model results. Two series of models were examined; the first series used the fall annual recapture matrix of regular tags while a second series divided release and recoveries into seasonal components (June-November and December-May), which included the spring release cohort and combined regular with high reward tags to increase sample size. The spreadsheet model included parameters to allow adjustments in the recovery matrix for reporting rate (which is subsumed in the f parameter) and a term labeled dispersal rate which allowed adjustment of the first year recoveries to examine the sensitivity to the assumption of tag dispersal. The numbers of released tags in the recovery matrix were adjusted by 8% to account for initial tag loss and annual models adjusted recoveries for annual reporting rates. The seasonal tag model included 0 tags released or recovered in the second spring period and therefore no likelihood estimates were included for that row. QAIC values were calculated for each model for comparison within each series. Pearson goodness-of-fit tests were also made for each model to test for significance between observed and predicted recoveries (degrees of freedom were calculated as # cells - # of model parameters).

The first annual recapture model was a fully parameterized model:

N_1f_1	$N_1S_1f_2$	$N_1S_1S_2f_3$
	N_2f_2	$N_2S_2f_3$
		N_3f_3

The second annual model assumed constant survival and tag recovery over the 3 years and had the structure:

N_1f	N_1Sf	N_1SSf
	N_2f	N_2Sf
		N_3f

Model results are listed in Table C17. (EDITOR'S NOTE: THIS TABLE OF THE WORKING GROUP REPORT HAS BEEN OMITTED. THE ESTIMATES WERE NOT ACCEPTED BY THE REVIEW PANEL. THEY CONCLUDED THAT INCOMPLETE MIXING AND MIGRATION NEED TO BE INVESTIGATED FURTHER.)

The seasonal model increased the model structure to 5 release periods (which included the 0 releases in the 2nd spring period) and 8 recovery periods. The fully parameterized model was structured as:

N_1f_1	$N_1S_1f_2$	$N_1S_1S_2f_3$	$N_1S_1S_2S_3f_4$	$N_1S_1S_2S_3S_4f_5$	$N_1S_1S_2S_3S_4S_5f_6$	$N_1S_1S_2S_3S_4S_5S_6f_7$	$N_1S_1S_2S_3S_4S_5S_6S_7f_8$
	N_2f_2	$N_2S_2f_3$	$N_2S_2S_3f_4$	$N_2S_2S_3S_4f_5$	$N_2S_2S_3S_4S_5f_6$	$N_2S_2S_3S_4S_5S_6f_7$	$N_2S_2S_3S_4S_5S_6S_7f_8$
		N_3f_3	$N_3S_3f_4$	$N_3S_3S_4f_5$	$N_3S_3S_4S_5f_6$	$N_3S_3S_4S_5S_6f_7$	$N_3S_3S_4S_5S_6S_7f_8$
			N_4f_4	$N_4S_4f_5$	$N_4S_4S_5f_7$	$N_4S_4S_5S_6f_7$	$N_4S_4S_5S_6S_7f_8$
				N_5f_5	$N_5S_5f_7$	$N_5S_5S_6f_7$	$N_5S_5S_6S_7f_8$

Other seasonal models examined were: an assumption of constant survival within each period (S_1, S_2 and f_1, f_2) and an assumption of constant survival across periods (S and f). These model results are listed in Table C17. (EDITOR'S NOTE: THIS TABLE HAS BEEN OMITTED BECAUSE THE RESULTS WERE NOT ACCEPTED BY THE REVIEW PANEL. THEY CONCLUDED THAT INCOMPLETE MIXING AND MIGRATION NEED TO BE INVESTIGATED FURTHER.)

An alternative length tuned model (LTM) was compared to the tagging models (Appendix). The length model was able to capture the dynamics of the population with the exception of the last few years. A decrease in biomass observed in the surveys following several large cohorts since 2002 could not be explained by reported landings.

Consequently the model predicted a significant rise in biomass over the most recent 5 years. The WG concluded that there may be underestimates of removals from discarding, the recruitment index may be overestimating the strength of recent year classes, the survey biomass index was not correct or combinations of all three. The group also concluded that further model runs should be conducted to explore the sensitivity of the input data.

8.0 TOR 5. Evaluate current stock status with respect to the existing BRPs.

The present BRP for black sea bass is F_{max} as a proxy for F_{msy}. F_{max} as currently defined is equal to 0.33 based on Thompson-Bell yield per recruit model. The Working Group did not recommend any changes to the estimate. (EDITOR'S NOTE: F ESTIMATES THAT WERE IN THIS PARAGRAPH HAVE BEEN REMOVED BECAUSE THEY WERE NOT ACCEPTED BY THE REVIEW PANEL.)

A proxy for the minimum biomass threshold is based on a three point moving average of exploitable biomass ($\geq$ 22 cm) from the NEFSC spring survey 1977-1979 indices. No alternative biomass estimates are currently available. The average biomass ($\geq$22 cm) index for 2004-2006 (0.80) was below the biomass threshold proxy of 0.98 kg/tow. (EDITOR'S NOTE: TEXT ABOUT STOCK STATUS HAS BEEN OMITTED BECAUSE THE REVIEW PANEL DID NOT ACCEPT THE EXISTING BIOMASS REFERENCE POINT.)

9.0 TOR 6. Perform sensitivity analyses to determine the impact of uncertainty in the recreational data on the assessment results.

The impact of uncertainty in the recreational data was not explicitly evaluated since this assessment model does not incorporate fishery landings. Recreational landings and discards $\pm$ 2 PSE are presented in Table C19. The length based model (LTM) was run using MRFSS estimates $\pm$ 2 PSE. The changes did not affect the results.

10.0 TOR 7. Review, evaluate and report on the status of the SARC/Working Group Research Recommendations offered in the previous SARC-reviewed assessment.

SARC 39 Recommendations, followed by update in italics:

- More comprehensive evaluation of regional survey data is required to give more integrated indices of recruitment. *The WG did not make progress on this research recommendation.*

- Adequate sampling of both commercial and recreational catches should be implemented with a view to improving knowledge of discarding and what affects it, so reducing one of the uncertainties inherent in the catch series. *Commercial and recreational length sampling intensity has improved since the last assessment. However, in light of recent overall reductions in commercial observer coverage, discard sampling is expected to decline.*

- Both accuracy and completeness of catch data, particularly recreational catch, should be investigated to explain unusual inter-annual variability. *No further information was available to investigate the variability in recreational catch estimates. In the preliminary LTM model, the average of adjacent years was used to replace the aberrant 1982 and 1986 recreational landing estimates.*

- Attempts should be made to extract as much information as possible from all time-series considered appropriate using, for example, a GLM or GAM approach to combine the various surveys and gear types into a standardized index. *The Working Group made no progress on this recommendation.*

- Confidence limits for survey-based estimates of recreational catch should be derived and presented. *Estimates of proportional standard error are included with the recreational catch estimates.*

- Ageing of samples of black sea bass should be initiated as soon as possible, and survey indices need to be disaggregated by age to identify the impact of year-class variation in the biomass index and to investigate the magnitude of year effects. *No progress was made in aging the back log of age samples.*

- A standard assessment based on a population model should be developed for the stock. A catch-at-age model would seem to be the most appropriate. *A length tuned model (LTM) was applied to the fishery and survey catch information to derive preliminary estimates of population biomass and fishing mortality.*

- Clarification is needed whether the bias introduced on back-transforming from length-weight relationship has been corrected for in the assessment. If not, it should be. *No progress made on this recommendation*.

- If financially feasible, tagging studies should continue (at least sporadically), to permit return rates over longer periods and the stability of estimates of exploitation rate to be established. Further, long-term data on rates of tag loss need to be collected through the tagging program. *The tag release program for black sea bass has been completed. Recoveries continue to be collected and included in analysis. Current assessment includes recoveries through April 2006.*

- A more sophisticated analytical model such as the Brownie with a migration extension should be applied to the tagging data. *The Working Group completed analysis of tagging data with a Brownie model however a migration extension was not included due to limited data. Work continues on defining migration patterns for inclusion in the Brownie model.*

- Improved education and awareness programs should be initiated in an attempt to improve tag return rates. *The tag release program for black sea bass has been completed and no funds are available for continued outreach programs.*

- The relationship between offshore distribution patterns and environmental variables such as temperature and frontal systems should be investigated, to ensure that catchability effects are not driving trends in the spring surveys*. No further progress has been completed on this recommendation.*

Working Group Research Recommendations:

- If a new analytical assessment is available, update biological reference points as part of the assessment. The Working Group notes that a new age-based analytical assessment will be contingent on aging the backlog of age structures in storage and developing reliable estimates of fishery discards.

- Continue work on development of the length based model, or another analytical model as the basis for the assessment. The WG notes that progress is contingent on development of updated growth estimates and improved estimates of fishery discards.

- Continue work on defining migration pathways and identifying migration groups of black sea bass for use in analyzing tagging data.

- Funding should be provided for continued management of tag recoveries and outreach programs (tag rewards).

- Recommend examination of population structure of black sea bass using genetic techniques.

11.0 SUMMARY

(EDITOR'S NOTE: TEXT ABOUT STOCK STATUS HAS BEEN OMITTED BECAUSE THE REVIEW PANEL DID NOT ACCEPT THE EXISTING BIOMASS REFERENCE POINT.) Following a peak in 2002, the spring and winter indices have both followed a similar pattern of decline. The WG expressed concern about the use of biomass index for fish greater or equal to 22 cm as a proxy for exploitable biomass. When the index was developed, the minimum size for the commercial and recreational fisheries was equivalent to 22 cm but has since increased such that exploitable biomass is closer to 29 cm. The WG decided that the current definition was a reasonable compromise for use as a biomass reference point. The WG also discussed the shortcomings of a biomass reference point where the status determination can be heavily influenced by one large data point in the index. However at this time there do not appear to be any better alternatives.

The tag model using a modified tag recapture to release ratio was chosen as the best estimate of current exploitation. (EDITOR'S NOTE: TEXT ON F RATES AND OVERFISHING HAS BEEN OMITTED BECAUSE THE F ESTIMATES WERE NOT ACCEPTED BY THE REVIEW PANEL. THEY CONCLUDED THAT INCOMPLETE MIXING AND MIGRATION NEED TO BE INVESTIGATED FURTHER.)

Various configurations of the Brownie model produced a wide range of survival estimates. Sensitivity tests implied that the Brownie model results were less robust than the R/M approach. The WG also noted that since the f parameter in the model was the probability of tag recovery, adjustments of the observed tag recoveries to account for estimated reporting rate (f /reporting rate) should be equivalent to exploitation rate. Also with a year, the survival estimate and exploitation rate should be comparable. However, in all the Brownie model results, the two parameters were not comparable implying the model fit was not adequate.

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BLACK SEA BASS TABLES

Table C1. Black sea bass commercial and recreational landings, ME-NC.

Year	Commercial landings 000s lbs	Commercial landings (mt)	Recreational landings (000 lbs)	Recreational landings (mt)	Total landings (mt)
1950	12,645	5,736			
1951	18,432	8,361			
1952	21,788	9,883			
1953	14,375	6,521			
1954	11,334	5,141			
1955	11,310	5,130			
1956	11,569	5,247			
1957	9,521	4,319			
1958	11,554	5,241			
1959	8,056	3,654			
1960	6,836	3,101			
1961	5,422	2,459			
1962	8,123	3,554			
1963	8,372	3,705			
1964	7,051	3,143			
1965	7,948	3,481			
1966	3,606	1,537			
1967	2,803	1,154			
1968	2,482	1,079			
1969	2,489	1,097			
1970	2,214	970			
1971	1,349	566			
1972	1,989	727			
1973	2,746	1,115			
1974	3,320	1,023			
1975	4,650	1,680			
1976	4,135	1,557			
1977	5,014	1,985			
1978	4,267	1,662			
1979	3,152	1,241			
1980	2,325	977			
1981	2,548	868	1,245	565	2,678
1982	2,960	1,004	9,898	4,490	15,392
1983	3,692	1,437	4,106	1,862	7,405
1984	3,786	1,641	1,294	587	3,522
1985	3,341	1,178	2,116	960	4,254
1986	3,984	1,594	12,391	5,621	19,606
1987	4,263	1,729	1,942	881	4,551
1988	3,466	1,473	2,864	1,299	5,636
1989	2,758	1,105	3,292	1,493	5,890
1990	3,178	1,334	2,770	1,257	5,361
1991	2,433	1,104	4,162	1,888	7,154
1992	2,594	1,177	2,620	1,189	4,985
1993	2,896	1,314	4,835	2,193	8,341
1994	2,094	950	2,940	1,333	5,223
1995	2,069	938	6,204	2,814	9,957
1996	3,458	1,569	3,986	1,808	7,363
1997	2,642	1,198	4,262	1,933	7,394
1998	2,583	1,171	1,143	518	2,833
1999	2,881	1,307	1,651	749	3,707
2000	2,658	1,206	4,006	1,817	7,028
2001	2,862	1,298	3,429	1,556	6,283
2002	3,499	1,587	4,380	1,987	7,955
2003	2,996	1,359	3,314	1,503	6,177
2004	3,002	1,362	1,675	760	3,796
2005	2,888	1,310	1,735	787	3,833

Table C2. Summary of number of black sea bass length measurements from commercial fisheries, 1998-2005.

1998

	1	2	3	4
Unclassified		69		
Small	750	475	494	174
Medium	990	587	260	102
Large	590	111	9	
Jumbo	104	28		
				4,743

1999

	1	2	3	4
Unclassified		221		
Small	627	530	377	375
Medium	924	344	261	351
Large	278			275
Jumbo	103			
				4,666

2000

	1	2	3	4
Unclassified				
Small	252	312	513	108
Medium	809	318	64	121
Large	722	67		
Jumbo	269	24		
				3,579

2001

	1	2	3	4
Unclassified	89	80		
Small	953	178	300	200
Medium	1370	206	209	100
Large	622	310	100	27
Jumbo	3678	89	103	147
				8,761

2002

	1	2	3	4
Unclassified	906			
Small	274	199		300
Medium	1310	49		417
Large	1693	103	104	263
Jumbo	278	87	100	169
				6,252

2003

	1	2	3	4
Unclassified	103	128	50	
Small		200	99	
Medium	2552	343	204	408
Large	2625	264	101	463
Jumbo	2071	215	134	231
				10,191

2004

	1	2	3	4
Unclassified		54	168	41
Small	219		104	
Medium	2446	939	303	106
Large	1872	817	101	131
Jumbo	1322	686	18	230
				9,557

2005

	1	2	3	4
Unclassified	33	100	58	
Small	278	100		
Medium	2454	1061	399	354
Large	2885	931	419	219
Jumbo	1903	502	25	411
				12,132

Table C3. Summary of total number, total weight, mean weight and mean lengths by year and market category of commercial black sea bass, 1998-2005.

	1998	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
	number	*number*	*number*	*number*	*number*	*number*	*number*	*number*
uncl	323,967	173,127	164,069	157,495	373,279	64,935	139,376	180,419
large	360,523	488,271	519,377	545,703	640,400	873,903	752,321	693,492
jumbo	70,841	105,361	186,302	220,932	429,998	268,934	290,911	258,768
med	1,049,440	962,946	623,481	926,165	988,376	892,235	833,155	739,007
small	1,297,322	995,057	763,540	706,149	344,846	225,718	241,028	152,660
total	3,102,093	2,724,762	2,256,770	2,556,445	2,776,898	2,325,726	2,256,792	2,024,346
	wt kg	*wt kg*	*wt kg*	*wt kg*	*wt kg*	*wt kg*	*wt kg*	*wt kg*
uncl	118,204	119,993	92,564	83,264	136,135	56,228	70,286	99,727
large	249,420	364,936	372,206	379,265	518,184	436,463	420,716	380,501
jumbo	88,119	143,652	226,116	192,660	366,878	377,954	410,063	417,214
med	364,681	387,143	286,839	422,354	446,842	409,077	366,690	321,047
small	350,997	290,876	227,814	220,816	119,283	79,450	92,030	56,890
mean wt	0.38	0.48	0.53	0.51	0.57	0.58	0.60	0.63
	x wt	*x wt*	*x wt*	*x wt*	*x wt*	*x wt*	*x wt*	*x wt*
uncl	0.36	0.69	0.56	0.53	0.36	0.87	0.50	0.55
large	0.69	0.75	0.72	0.70	0.81	0.50	0.56	0.55
jumbo	1.24	1.36	1.21	0.87	0.85	1.41	1.41	1.61
med	0.35	0.40	0.46	0.46	0.45	0.46	0.44	0.43
small	0.27	0.29	0.30	0.31	0.35	0.35	0.38	0.37
	x len	*x len*	*x len*	*x len*	*x len*	*x len*	*x len*	*x len*
uncl		35.5		32.9	29.5	40.6	34.7	28.3
large	36.3	37.2	36.7	36.4	38.1	36.3	37.6	37.3
jumbo	44.0	45.2	43.7	38.6	38.3	45.6	45.5	47.5
med	28.9	30.4	31.8	31.8	31.7	31.7	31.3	31.1
small	26.8	27.4	27.7	28.1	29.1	29.2	29.8	29.6
mean length	29.3	31.4	32.6	32.4	33.6	35.1	35.3	34.9

Table C4. Summary of commercial black sea bass discards from vessel log books, prorated to total landings.

	lbs kept	lbs disc	% discard	total landings	% in VTR	total discard lbs	total discard mt
2005	2,424,560	117,439	5%	2,888,223	84%	139,898	63
2004	2,633,329	173,804	7%	3,001,888	88%	198,129	90
2003	2,484,244	209,349	8%	2,996,458	83%	252,514	115
2002	2,629,970	333,106	13%	3,499,448	75%	443,232	201
2001	2,297,375	268,104	12%	2,862,243	80%	334,024	152
2000	2,307,036	250,255	11%	2,657,944	87%	288,320	131
1999	2,521,161	205,336	8%	2,880,556	88%	234,607	106
1998	2,335,566	178,172	8%	2,582,541	90%	197,013	89
1997	2,315,661	64,185	3%	2,641,595	88%	73,219	33

Table C5. Recreational discards (B2) (000s) from 1981 to 2005 as estimated from MRFSS.

	ME	NH	MA	RI	CT	NY	NJ	DE	MD	VA	NC	Total
1981	-	-	79	3	11	79	142	12	144	1,249	41	1,760
1982	-	-	2	3	-	127	364	14	135	671	23	1,339
1983	-	-	9	-	-	166	800	26	170	1,481	370	3,023
1984	-	1	24	4	8	199	136	10	389	723	117	1,610
1985	-	-	8	1	41	227	929	26	172	1,151	96	2,651
1986	-	2	110	49	204	713	3,265	66	518	2,164	84	7,175
1987	-	-	119	42	2	247	280	62	425	879	388	2,444
1988	-	-	60	11	7	244	201	104	2,492	1,632	264	5,014
1989	-	1	18	18	20	184	584	148	442	714	107	2,235
1990	1	-	11	5	1	56	616	124	1,461	2,889	91	5,254
1991	1	-	8	5	39	230	2,019	277	1,280	1,622	131	5,610
1992	-	-	3	9	2	114	1,065	219	1,096	1,541	257	4,304
1993	-	-	9	9	2	30	956	178	546	1,256	239	3,223
1994	-	-	6	1	1	326	1,317	206	381	1,379	352	3,970
1995	-	0	16	41	10	343	2,570	314	1,832	2,012	418	7,556
1996	-	-	21	82	19	311	1,405	119	582	1,936	77	4,553
1997	-	0	29	36	18	523	2,811	272	586	1,533	207	6,015
1998	-	-	42	26	15	79	1,235	284	754	1,332	134	3,900
1999	-	0	26	121	174	731	1,728	213	1,487	1,242	29	5,751
2000	-	0	268	401	89	1,222	5,545	820	3,224	1,570	66	13,207
2001	-	0	143	151	17	641	4,371	1,003	2,324	2,180	56	10,886
2002	-	-	268	241	291	1,411	4,318	1,233	925	2,441	177	11,304
2003	-	-	197	205	55	739	4,295	832	773	1,742	38	8,877
2004	-	0	58	38	11	491	2,559	439	671	1,322	83	5,672
2005	-	-	68	50	42	967	2,536	286	767	962	89	5,767

Table C6a. Spring offshore survey mean number per tow and 95% confidence intervals of black sea bass ≥ 22 cm, 1968-2006.

Year	Spring offshore stratified mean #/tow (≥22 cm)	std. error	95% CI High	95% CI Low	ln re-transform mean #/tow	95% CI Low	95% CI High
1968	0.269	0.233	0.725	-0.187	0.070	0.045	0.096
1969	0.937	0.854	2.611	-0.737	0.103	0.076	0.13
1970	0.118	0.032	0.180	0.056	0.111	0.073	0.15
1971	0.182	0.134	0.445	-0.081	0.105	0.059	0.154
1972	0.358	0.141	0.633	0.083	0.250	0.169	0.337
1973	0.696	0.351	1.383	0.009	0.337	0.212	0.475
1974	2.332	0.941	4.176	0.488	1.229	0.786	1.78
1975	1.83	1.251	4.283	-0.623	0.513	0.42	0.612
1976	1.223	0.420	2.046	0.400	0.688	0.525	0.867
1977	4.54	4.073	12.522	-3.442	0.604	0.458	0.765
1978	2.261	1.002	4.225	0.297	0.598	0.444	0.768
1979	4.634	4.114	12.697	-3.429	0.446	0.342	0.558
1980	1.006	0.441	1.871	0.141	0.462	0.326	0.611
1981	0.686	0.196	1.070	0.302	0.360	0.288	0.436
1982	0.102	0.049	0.197	0.007	0.073	0.045	0.102
1983	0.607	0.315	1.225	-0.011	0.339	0.221	0.469
1984	0.23	0.084	0.394	0.066	0.186	0.123	0.252
1985	0.376	0.111	0.594	0.158	0.268	0.193	0.347
1986	1.981	1.148	4.230	-0.268	0.755	0.515	1.032
1987	0.959	0.274	1.496	0.422	0.514	0.389	0.65
1988	1.229	0.413	2.038	0.420	0.602	0.457	0.76
1989	0.397	0.105	0.602	0.192	0.245	0.18	0.315
1990	0.458	0.197	0.844	0.072	0.270	0.177	0.37
1991	0.221	0.109	0.434	0.008	0.186	0.101	0.277
1992	1.154	0.427	1.992	0.316	0.665	0.505	0.842
1993	0.697	0.416	1.512	-0.118	0.201	0.137	0.268
1994	0.257	0.126	0.504	0.010	0.175	0.109	0.244
1995	0.431	0.159	0.742	0.120	0.314	0.221	0.413
1996	0.317	0.131	0.573	0.061	0.203	0.149	0.258
1997	1.201	0.659	2.492	-0.090	0.542	0.396	0.702
1998	0.401	0.249	0.889	-0.087	0.189	0.137	0.244
1999	1.026	0.708	2.413	-0.361	0.537	0.344	0.759
2000	0.343	0.095	0.528	0.158	0.301	0.202	0.407
2001	1.581	0.582	2.722	0.440	0.792	0.598	1.009
2002	2.274	0.478	3.210	1.338	1.253	1.024	1.508
2003	6.885	4.569	15.839	-2.069	1.614	1.181	2.134
2004	2.081	0.837	3.721	0.441	0.711	0.561	0.874
2005	1.803	0.965	3.695	-0.089	0.727	0.571	0.898
2006	0.913	0.478	1.849	-0.023	0.456	0.331	0.594

Table C6b. Winter survey mean number per tow and 95% confidence intervals of black sea bass $\geq$ 22 cm, 1992-2006.

	Winter stratified mean #/tow	std. error	95% CI Low	95% CI High	ln re-transform mean #/tow	95% CI Low	High
Year	($\geq$22 cm)						
1968							
1969							
1970							
1971							
1972							
1973							
1974							
1975							
1976							
1977							
1978							
1979							
1980							
1981							
1982							
1983							
1984							
1985							
1986							
1987							
1988							
1989							
1990							
1991							
1992	1.913	0.496	0.941	2.885	0.991	0.808	1.193
1993	2.521	0.916	0.725	4.317	0.951	0.755	1.169
1994	0.517	0.146	0.231	0.803	0.405	0.294	0.525
1995	1.247	0.347	0.566	1.928	0.847	0.639	1.081
1996	2.036	0.550	0.957	3.115	1.058	0.819	1.330
1997	0.809	0.384	0.057	1.561	0.422	0.325	0.527
1998	2.299	0.500	1.319	3.279	0.351	0.297	0.408
1999	0.805	0.149	0.514	1.096	0.612	0.495	0.738
2000	1.790	0.547	0.717	2.863	1.082	0.843	1.352
2001	4.869	1.825	1.291	8.447	1.866	1.487	2.302
2002	5.893	1.516	2.922	8.864	3.436	2.817	4.156
2003	7.591	3.339	1.046	14.136	3.160	2.351	4.164
2004	3.207	1.090	1.070	5.344	1.213	1.007	1.440
2005	2.182	0.759	0.695	3.669	0.558	0.450	0.674
2006	1.595	0.410	0.792	2.398	1.061	0.819	1.334

Table C7a. Spring offshore survey mean weight per tow and 95% confidence intervals of black sea bass ≥ 22 cm, 1968-2006.

Year	Spring offshore stratified mean kg/tow (≥22 cm)	95% CI High	Low	ln re-transform mean kg/tow	95% CI Low	High
1968	0.152	-0.113	0.417	0.040	0.026	0.055
1969	0.217	-0.178	0.613	0.024	0.018	0.030
1970	0.066	0.030	0.102	0.062	0.041	0.084
1971	0.063	-0.030	0.155	0.036	0.020	0.053
1972	0.155	0.034	0.277	0.108	0.073	0.146
1973	0.272	-0.001	0.545	0.131	0.083	0.185
1974	0.964	0.185	1.744	0.509	0.325	0.737
1975	0.846	-0.310	2.002	0.237	0.194	0.283
1976	0.631	0.198	1.064	0.355	0.271	0.447
1977	1.120	-0.891	3.130	0.149	0.113	0.189
1978	0.730	0.083	1.378	0.193	0.143	0.248
1979	1.078	-0.835	2.990	0.104	0.080	0.130
1980	0.292	0.036	0.547	0.134	0.094	0.177
1981	0.311	0.133	0.489	0.164	0.131	0.198
1982	0.027	0.001	0.053	0.019	0.012	0.027
1983	0.145	-0.005	0.296	0.081	0.053	0.112
1984	0.122	0.034	0.209	0.097	0.064	0.132
1985	0.164	0.068	0.260	0.116	0.084	0.150
1986	0.559	-0.088	1.206	0.213	0.145	0.291
1987	0.380	0.163	0.597	0.204	0.154	0.258
1988	0.407	0.133	0.680	0.199	0.151	0.251
1989	0.138	0.066	0.211	0.085	0.062	0.109
1990	0.144	0.021	0.268	0.085	0.055	0.116
1991	0.057	0.001	0.113	0.048	0.026	0.072
1992	0.362	0.094	0.629	0.208	0.158	0.263
1993	0.141	-0.027	0.309	0.041	0.028	0.054
1994	0.086	0.002	0.171	0.059	0.037	0.082
1995	0.148	0.040	0.256	0.107	0.075	0.141
1996	0.143	0.026	0.260	0.091	0.067	0.116
1997	0.300	-0.029	0.629	0.135	0.099	0.175
1998	0.111	-0.026	0.247	0.052	0.038	0.067
1999	0.424	-0.160	1.008	0.222	0.142	0.313
2000	0.156	0.070	0.242	0.137	0.092	0.185
2001	0.470	0.124	0.815	0.235	0.178	0.300
2002	1.121	0.650	1.591	0.617	0.505	0.743
2003	2.151	-0.703	5.004	0.504	0.369	0.666
2004	0.938	0.183	1.693	0.321	0.253	0.394
2005	0.927	-0.066	1.919	0.374	0.293	0.461
2006	0.548	-0.027	1.123	0.288	0.199	0.358

Table C7b. Winter survey mean weight per tow and 95% confidence intervals of black sea bass ≥ 22 cm, 1992-2006.

Year	Winter stratified mean kg/tow (≥22 cm)	95% CI Low	High	ln re-transform mean kg/tow	95% CI Low	High
1968						
1969						
1970						
1971						
1972						
1973						
1974						
1975						
1976						
1977						
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992	0.455	0.224	0.686	0.236	0.192	0.284
1993	0.764	0.220	1.308	0.288	0.229	0.354
1994	0.139	0.062	0.217	0.109	0.079	0.142
1995	0.335	0.152	0.518	0.228	0.172	0.290
1996	0.539	0.253	0.824	0.280	0.217	0.352
1997	0.252	0.018	0.485	0.131	0.101	0.164
1998	0.602	0.346	0.859	0.092	0.078	0.107
1999	0.288	0.184	0.392	0.219	0.177	0.264
2000	0.488	0.196	0.781	0.295	0.230	0.369
2001	1.507	0.400	2.614	0.577	0.460	0.712
2002	2.276	1.128	3.423	1.327	1.088	1.605
2003	3.123	0.430	5.814	1.300	0.967	1.713
2004	1.184	0.395	1.973	0.448	0.372	0.532
2005	0.643	0.205	1.081	0.164	0.133	0.199
2006	0.568	0.282	0.855	0.378	0.292	0.476

Table C8. NEFSC Spring , Autumn and Winter survey indices of juvenile (<14 cm) black sea bass.

	Spring JI		Spring JI			Fall JI		Fall JI			Winter JI	≤ 14 cm			
	≤ 14 cm		ln re- trans	95% CI		≤ 14 cm		ln re-transform	95% CI		mean		ln re-transform	95% CI	
	#/tow	SE	mean #/tow	Low	High	#/tow	SE	mean #/tow	Low	High	#/tow	SE	mean #/tow	Low	High
1968	0.408	0.408	0.085	0.040	0.133										
1969	0.000	0.000	0.000	0.000	0.000										
1970	0.000	0.000	0.000	0.000	0.000										
1971	0.000	0.000	0.000	0.000	0.000										
1972	0.243	0.200	0.143	0.062	0.231	0.033	0.020	0.034	0.007	0.061					
1973	0.000	0.000	0.000	0.000	0.000	0.624	0.294	0.482	0.316	0.668					
1974	0.000	0.000	0.000	0.000	0.000	0.525	0.189	0.493	0.320	0.688					
1975	0.069	0.069	0.061	-0.003	0.129	4.094	3.477	1.334	0.841	1.958					
1976	0.944	0.396	0.557	0.397	0.735	2.074	1.163	1.740	1.086	2.598					
1977	0.184	0.066	0.163	0.099	0.231	15.998	5.813	1.661	1.420	1.925					
1978	0.384	0.261	0.148	0.088	0.211	0.080	0.027	0.079	0.040	0.119					
1979	0.017	0.016	0.017	-0.004	0.039	0.463	0.095	0.386	0.299	0.479					
1980	1.018	0.538	0.482	0.304	0.685	0.856	0.416	0.646	0.407	0.925					
1981	0.045	0.021	0.045	0.016	0.074	0.302	0.267	0.252	0.082	0.448					
1982	0.003	0.003	0.003	0.000	0.006	0.381	0.092	0.387	0.263	0.523					
1983	0.009	0.007	0.009	-0.001	0.018	1.425	0.263	0.724	0.612	0.844					
1984	0.007	0.007	0.007	-0.002	0.016	0.542	0.504	0.257	0.131	0.398					
1985	0.097	0.058	0.085	0.034	0.138	3.464	0.113	1.035	0.866	1.220					
1986	0.182	0.116	0.149	0.068	0.237	7.910	4.634	2.337	1.641	3.216					
1987	0.031	0.020	0.030	0.004	0.055	0.453	0.236	0.363	0.232	0.508					
1988	0.497	0.420	0.232	0.109	0.370	3.011	0.438	2.210	1.528	3.076					
1989	0.079	0.063	0.070	0.016	0.126	0.378	0.177	0.383	0.204	0.589					
1990	0.396	0.373	0.171	0.065	0.288	0.961	0.474	0.845	0.499	1.271					
1991	0.761	0.413	0.499	0.322	0.699	1.062	0.366	0.889	0.607	1.220					
1992	0.382	0.362	0.164	0.060	0.279	0.501	0.158	0.505	0.314	0.724	0.705	0.258	0.538	0.373	0.723
1993	0.007	0.007	0.007	-0.002	0.016	0.079	0.033	0.081	0.041	0.123	0.174	0.074	0.146	0.083	0.214
1994	0.011	0.008	0.011	0.000	0.022	6.488	5.869	1.058	0.818	1.329	0.223	0.109	0.199	0.098	0.309
1995	0.181	0.055	0.162	0.107	0.219	1.239	0.468	1.207	0.790	1.720	0.480	0.124	0.420	0.315	0.533
1996	0.068	0.036	0.063	0.024	0.103	0.741	0.541	0.314	0.226	0.408	1.909	0.617	1.244	0.975	1.548
1997	0.025	0.013	0.024	0.006	0.043	0.841	0.461	0.631	0.434	0.856	0.192	0.093	0.156	0.094	0.220
1998	0.000	0.000	0.000	0.000	0.000	2.888	1.312	1.974	1.400	2.685	0.261	0.062	0.247	0.171	0.328
1999	0.700	0.553	0.347	0.191	0.523	2.489	1.535	1.723	1.009	2.690	0.545	0.179	0.462	0.328	0.610
2000	2.782	2.394	0.661	0.417	0.948	9.977	2.766	2.401	1.721	3.250	3.820	1.285	2.422	1.840	3.123
2001	0.087	0.052	0.078	0.026	0.132	0.325	0.166	0.296	0.167	0.438	1.026	0.250	0.801	0.623	0.999
2002	0.718	0.264	0.554	0.397	0.729	4.394	3.980	1.233	0.801	1.770	3.954	1.072	1.998	1.636	2.411
2003	0.156	0.050	0.154	0.085	0.227	5.960	5.284	1.131	0.757	1.583	2.889	0.943	1.876	1.346	2.526
2004	0.101	0.014	0.080	0.059	0.102	1.326	0.790	0.853	0.572	1.184	0.478	0.214	0.320	0.230	0.416
2005	0.535	0.437	0.219	0.116	0.331	2.793	1.953	0.775	0.600	0.969	1.617	0.691	0.692	0.534	0.866
2006	0.057	0.026	0.054	0.022	0.087						0.896	0.307	0.647	0.465	0.851

Table C9. Massachusetts Division of Marine Fisheries autumn trawl survey stratified mean number per tow and spawning stock biomass per tow of black sea bass, 1978-2005.

Year	spring index mean # / tow	spring index mean kg / tow	fall juv index index mean # / tow	mean weight (kg) per fish	SSB index
1978	1.96	1.40	79.3	0.72	1.40
1979	0.99	0.73	73.2	0.74	0.73
1980	1.00	0.79	93.1	0.79	0.79
1981	2.23	1.26	62.9	0.56	1.26
1982	2.16	0.90	397.2	0.42	0.90
1983	4.53	1.42	185.7	0.31	1.42
1984	1.60	0.69	201.3	0.43	0.69
1985	1.21	0.57	198.5	0.47	0.57
1986	1.58	0.74	80.4	0.47	0.74
1987	0.71	0.20	35.3	0.29	0.20
1988	0.42	0.20	60.4	0.48	0.20
1989	0.55	0.23	6.5	0.42	0.23
1990	0.70	0.45	4.3	0.64	0.45
1991	0.38	0.43	9.5	1.12	0.43
1992	0.09	0.04	10.8	0.43	0.04
1993	0.11	0.08	1.1	0.72	0.08
1994	0.22	0.19	45.0	0.87	0.19
1995	0.47	0.15	32.6	0.33	0.15
1996	0.15	0.09	23.6	0.58	0.09
1997	0.45	0.18	5.3	0.40	0.18
1998	0.22	0.08	9.9	0.35	0.08
1999	1.26	0.78	22.1	0.62	0.78
2000	4.00	1.93	195.5	0.48	1.93
2001	1.75	1.04	87.9	0.59	1.04
2002	1.88	1.14	118.9	0.61	1.14
2003	0.83	0.72	178.2	0.87	0.72
2004	1.25	0.68	241.0	0.54	0.68
2005	1.10	0.93	432.5	0.85	0.93
Avg.	1.21	0.64	103.29	0.57	0.64

Table C10. Juvenile black sea bass indices from state agencies, MA to VA.

Year	MA Fall Mean #/tow age 0	RI Fall Mean #/tow age 0	CT Spring total catch age 1	CT Fall total catch age 0	NJ Fall Mean #/tow age 0	VIMS May-July Mean #/tow age 1	Lower CL	Upper CL
1978	79.3							
1979	73.2							
1980	93.1							
1981	62.9	29.15						
1982	397.2	0.20						
1983	185.7	1.38						
1984	201.3	8.68						
1985	198.5	7.97						
1986	80.4	11.72						
1987	35.3	0.41	0	2				
1988	60.4	1.50	1	0		1.58	1.08	2.20
1989	6.5	0.33	0	1	0.10	0.84	0.59	1.13
1990	4.3	0.76	1	2	0.06	2.36	1.70	3.17
1991	9.5	0.33	4	15	0.57	1.12	0.78	1.53
1992	10.8	1.14	0	0	0.50	1.28	0.91	1.72
1993	1.1	0.03	0	7	0.18	0.22	0.13	0.32
1994	45.0	0.17	0	9	0.18	1.05	0.74	1.42
1995	32.6	1.19	0	0	0.28	1.06	0.74	1.45
1996	23.6	1.15	0	2	0.44	0.50	0.33	0.69
1997	5.3	4.24	0	0	38.00	0.36	0.22	0.52
1998	9.9	0.07	0	1	3.77	0.46	0.31	0.63
1999	22.1	0.90	1	4	1.01	0.57	0.35	0.82
2000	195.5	9.40	17	1	0.98	0.58	0.41	0.77
2001	87.9	3.71	0	22	0.86	0.74	0.50	1.02
2002	118.9	2.38	48	32	4.41	1.29	0.85	1.84
2003	178.2	6.67	0	0	0.54	0.64	0.41	0.90
2004	241.0	1.74	0	67	1.34	0.12	0.06	0.18
2005	432.5	15.51	0	11	0.37	0.06	0.02	0.1

Table C11. Distance traveled for tagged black sea bass recovered since 2002. "DAL": days at large.

Region	Time	Months	Max Dist(nm)	Mean Dist(nm)	Max DAL	Mean DAL
MA, RI, CT	Sum/Fall	7-12	354	16	1088	139
	Win/Spr	1-6	387	76	1000	338
NY, NJ, DE	Sum/Fall	7-12	146	7	1144	121
	Win/Spr	1-6	212	17	1028	174
MD, VA	Sum/Fall	7-12	90	7	1079	210
	Win/Spr	1-6	180	18	1269	269

Table C12. Black sea bass movements among areas based on region of release and recaptures by region and month.

Release Area	Recapture Area	Recapture Month											
		10	**11**	**12**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
New England (NE) - MA, RI, CT	NE	227	32	1	-	-	-	1	38	69	20	44	33
	MAB	1	1	5	10	3	7	8	-	7	3	2	-
	MV	-	-	-	6	3	5	1	-	-	1	-	-
Mid Atl. Bight (MAB) - NY, NJ, DE	NE	-	-	-	-	-	-	-	-	-	1	-	-
	MAB	274	100	9	1	5	7	7	77	150	55	64	94
	MV	1	1	1	1	3	5	-	-	4	1	-	1
Maryland/Virginia (MV) - MD, VA	NE	-	-	-	-	-	-	-	-	-	-	-	-
	MAB	7	5	3	-	-	1	4	4	2	7	2	1
	MV	199	200	46	23	35	16	14	122	108	82	83	52

Table C13. Site fidelity of tagged sea bass as indicated by frequency of tagged fish returning to area of release. Recapture limited to inshore residency period.

May 15-Sept 30 Recaptures

Release State	# Released	MA	RI	CT	NY	NJ	DE	MD	VA	NC	Total Recaps	Recap North	No net Move	Recap South
MA	2607	145	10	6	9	1	-	-	1	-	172	0.0%	84.3%	15.7%
RI	963	11	31	1	3	-	-	-	-	-	46	23.9%	67.4%	8.7%
CT	31	-	-	-	2	-	-	-	-	-	2	0.0%	0.0%	100.0%
NY	532	-	1	-	16	2	-	-	-	-	19	5.3%	84.2%	10.5%
NJ	2398	-	-	-	6	265	61	4	-	-	336	1.8%	78.9%	19.3%
DE	453	-	-	-	-	12	68	1	3	-	84	14.3%	81.0%	4.8%
MD	3549	-	-	-	-	4	14	176	57	-	251	7.2%	70.1%	22.7%
VA	3155	-	-	-	-	-	-	-	165	8	173	0.0%	95.4%	4.6%

Table C14. Tag release/recapture matrix of black sea bass recaptured between September 2002 and April 2006.

Regular Reward tags

	releases	fall 2002- fall 2003	spr 2003 - spr 2004	fall 2003 - fall 2004	spr 2004 - spr 2005	fall 2004- fall 2005	spr 2005 - spr 2006
fall 2002	**3143**	289		63		23	
spr 2003	**2199**		256	60	60		18
fall 2003	**2449**			355		46	
fall 2004	**2854**					346	

High Reward tags

	releases	fall 2002- fall 2003	spr 2003 - spr 2004	fall 2003 - fall 2004	spr 2004 - spr 2005	fall 2004- fall 2005	spr 2005 - spr 2006
fall 2002	**279**	39		9		5	
spr 2003	**68**		13		4		1
fall 2003	**232**			49		3	
fall 2004	**178**					39	

Table C15. Tag retention results from experiments in MA, RI, NJ and VA.

Study Site	**# Tagged**	**# Shed**	**Initial Tag Shedding**	**Tag induced Mortality**
Sandy Hook	30	3	10%	0%
RI DEP	30	4	13%	0%
VIMS	33	1	3%	0%
Woods Hole	7	0	0%	0%
	100	8	8%	0%

Table C16. Estimates of exploitation rates by year $\pm$ 80% confidence intervals, instantaneous fishing mortalities and natural mortalities from tagging data.

(EDITOR'S NOTE: TABLE OMITTED. RESULTS NOT ACCEPTED BY THE REVIEW PANEL. PANEL FELT THAT INCOMPLETE MIXING AND MIGRATION REQUIRE FURTHER INVESTIGATION)

Table C17. Results of Brownie model estimates of survival with annual and seasonal recoveries.

(EDITOR'S NOTE: TABLE OMITTED. RESULTS NOT ACCEPTED BY THE REVIEW PANEL. PANEL FELT THAT INCOMPLETE MIXING AND MIGRATION REQUIRE FURTHER INVESTIGATION.)

Table C18. Sensitivity of the full annual Brownie model to variation in the tag release and recovery matrix. Dispersion coefficient is an adjustment in recaptures in first year, with number recaptured reduced by the coefficient. Dispersion and reporting rate apply to recoveries, tag loss rate to releases.

(EDITOR'S NOTE: TABLE OMITTED. RESULTS NOT ACCEPTED BY THE REVIEW PANEL. PANEL FELT THAT INCOMPLETE MIXING AND MIGRATION REQUIRE FURTHER INVESTIGATION.)

Table C19. MRFSS estimated of recreational landings (AB1) and discards (B2) from Maine to Virginia, with ± 2 PSE.

	Total # AB1 (000s)	Confidence Intervals lower 95%	upper 95%	Total # B2 (000s)	Confidence Intervals lower 95%	upper 95%
1981	1,808	1,252	2,363	1,719	739	2,699
1982	10,030	3,046	17,013	1,316	856	1,777
1983	4,457	2,925	5,989	2,653	1,577	3,729
1984	1,592	1,189	1,996	1,493	888	2,099
1985	3,336	2,567	4,105	2,555	1,975	3,136
1986	21,723	12,531	30,915	7,091	5,300	8,881
1987	2,841	2,068	3,614	2,056	1,508	2,605
1988	3,048	2,136	3,959	4,750	3,759	5,741
1989	4,221	3,679	4,763	2,129	1,824	2,433
1990	3,853	3,221	4,486	5,165	4,378	5,951
1991	5,200	4,385	6,016	5,479	4,812	6,145
1992	3,507	2,987	4,027	4,048	3,354	4,741
1993	5,981	3,697	8,265	2,984	2,331	3,637
1994	3,409	2,622	4,196	3,618	3,111	4,126
1995	6,726	4,809	8,644	7,138	6,120	8,157
1996	3,610	2,840	4,379	4,476	3,749	5,202
1997	4,721	3,849	5,594	5,808	4,927	6,689
1998	1,126	850	1,402	3,766	3,125	4,407
1999	1,323	928	1,719	5,721	4,835	6,607
2000	3,608	2,853	4,363	13,142	11,573	14,711
2001	2,830	2,430	3,230	10,830	9,924	11,736
2002	3,337	2,879	3,795	11,128	9,899	12,356
2003	3,226	2,875	3,577	8,838	8,021	9,656
2004	1,637	1,344	1,930	5,589	4,836	6,343

BLACK SEA BASS FIGURES

Figure C1. Map of the east coast of the United States.

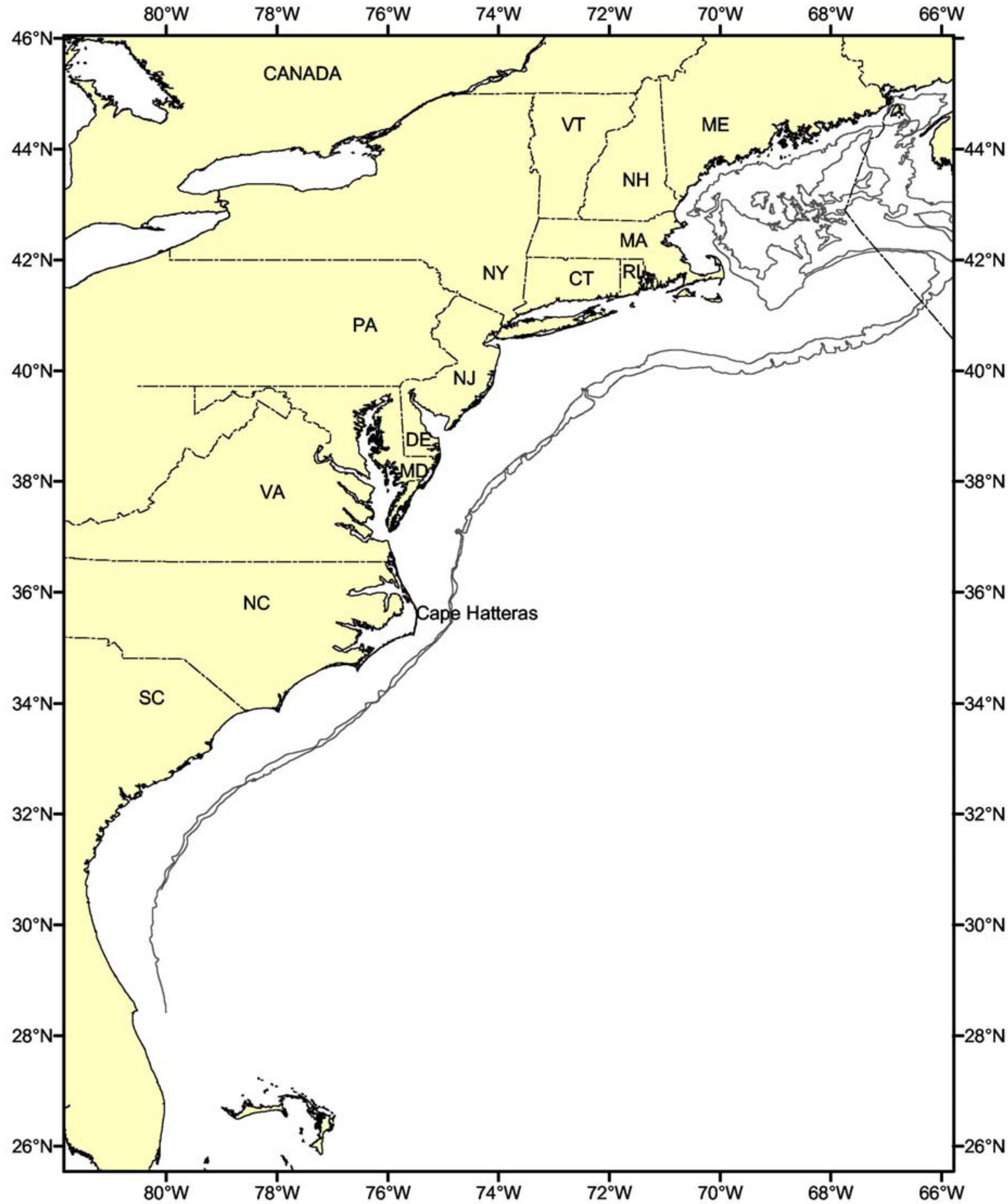


Figure C2. Time series of commercial black sea bass landings ME- Cape Hatteras, NC (note: 1950 – 1961 does not include NC landings).

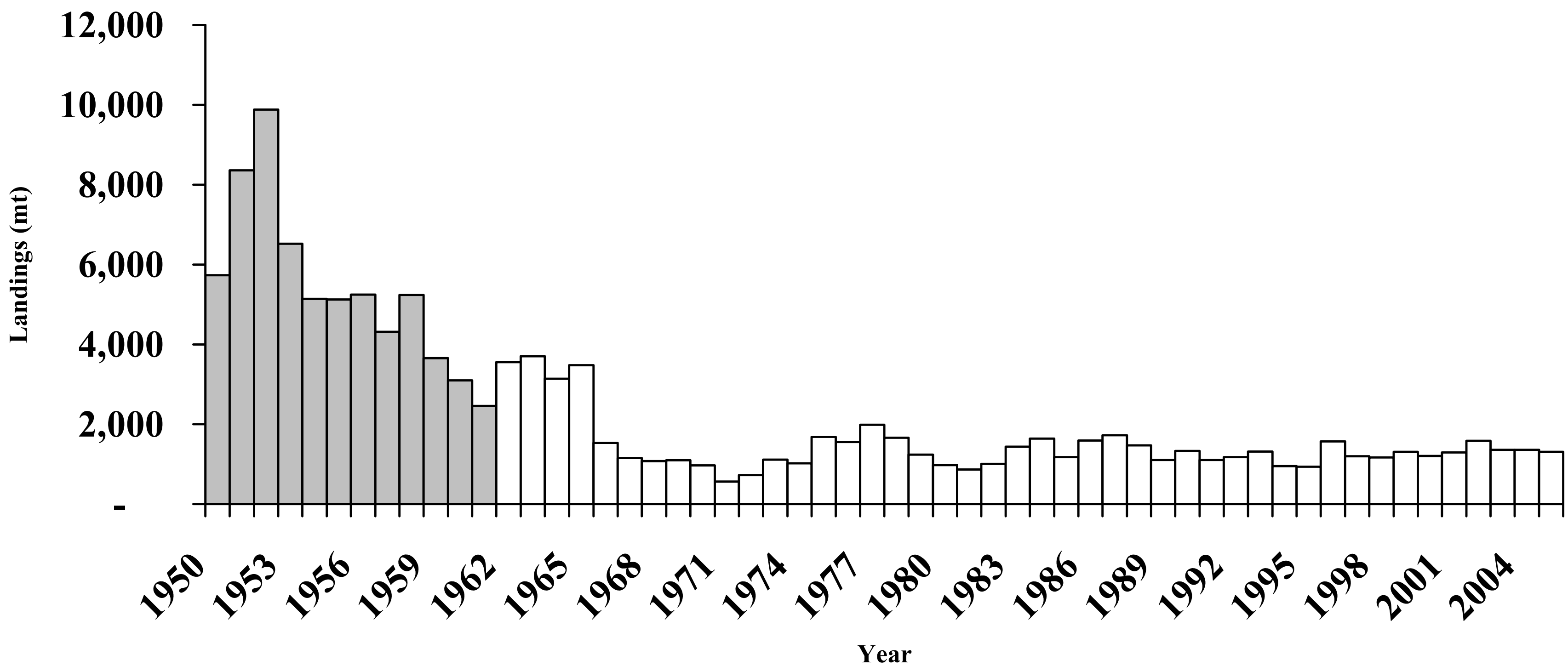


Figure C3. Percent of average black sea bass commercial landings by major gear type, 2000-2005.

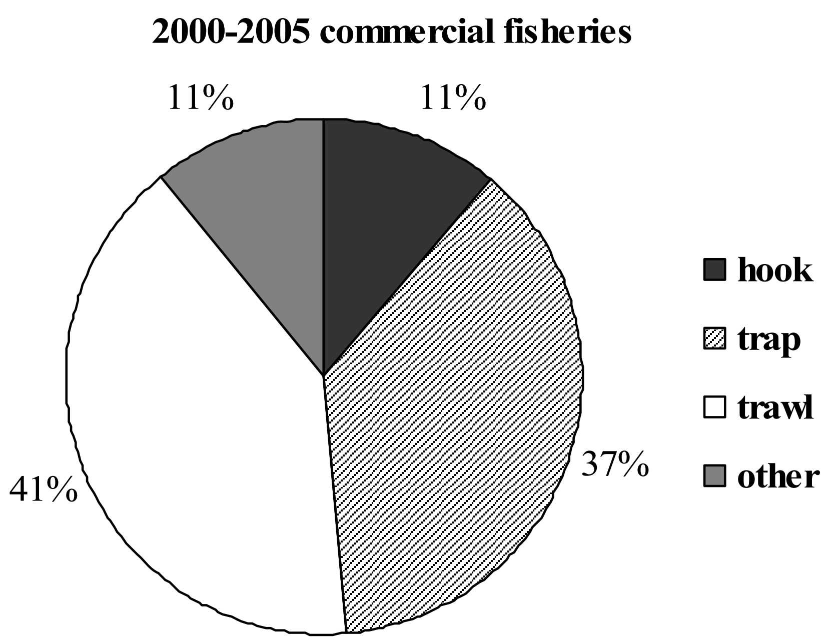


Figure C4. Average percent landings of commercial black sea bass by quarter and gear type 2000-2005.

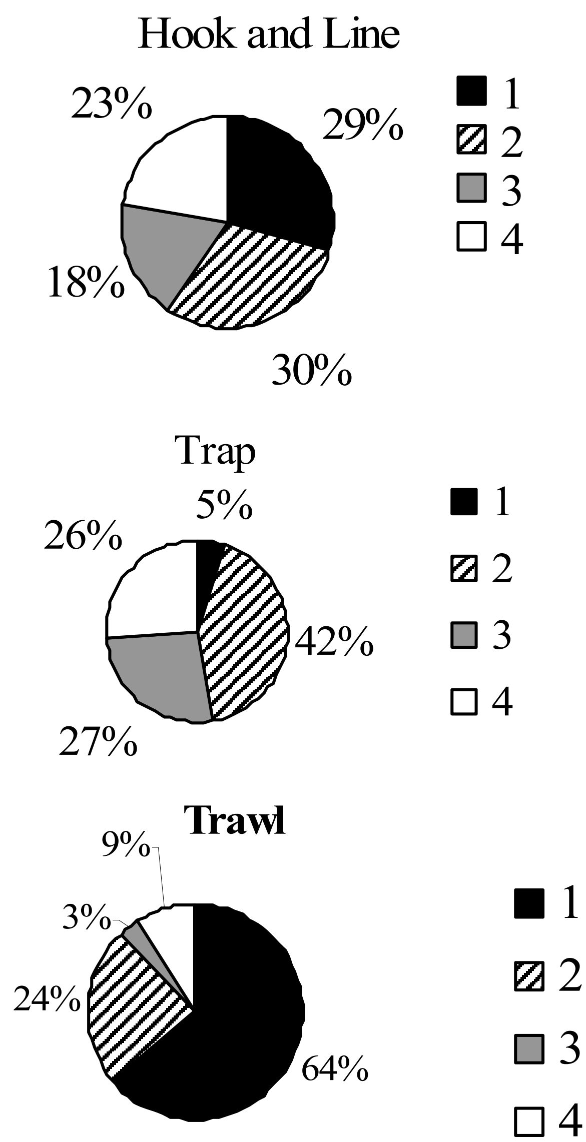
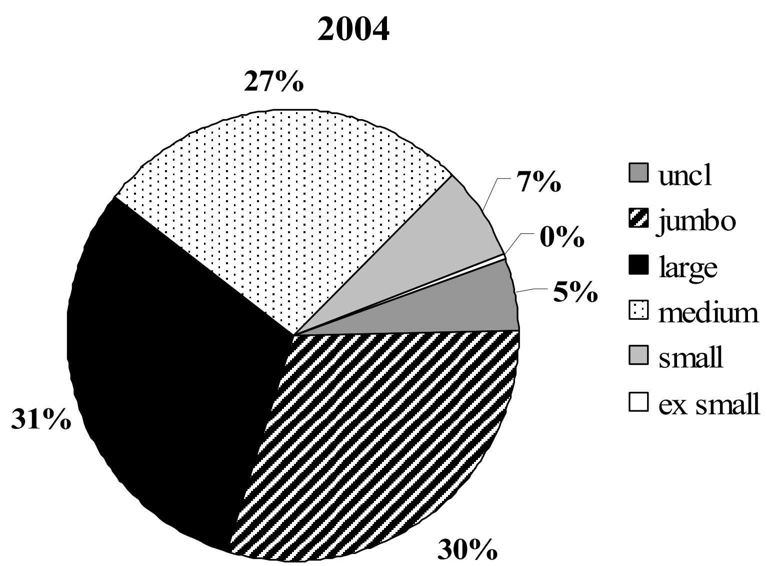


Figure C5. Landings of commercial black sea bass by market category, 2004 and 2005.



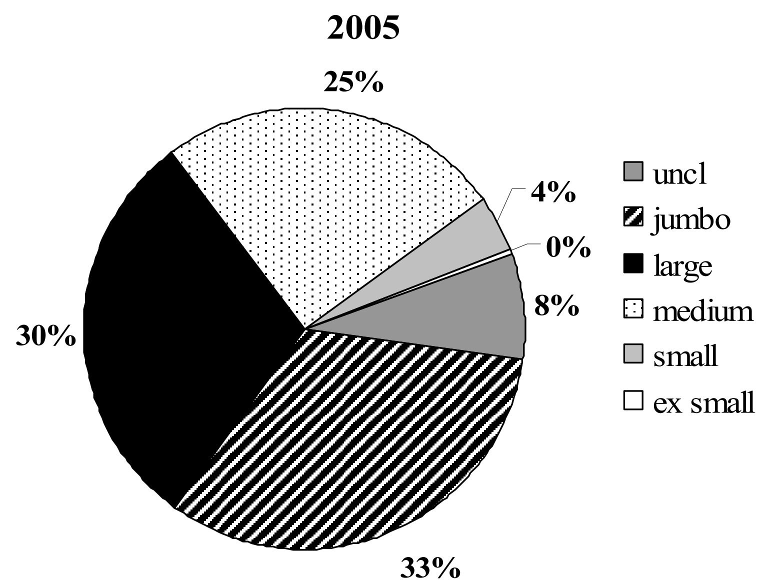


Figure C6. Expanded length frequencies of commercial landings, 1998-2005.

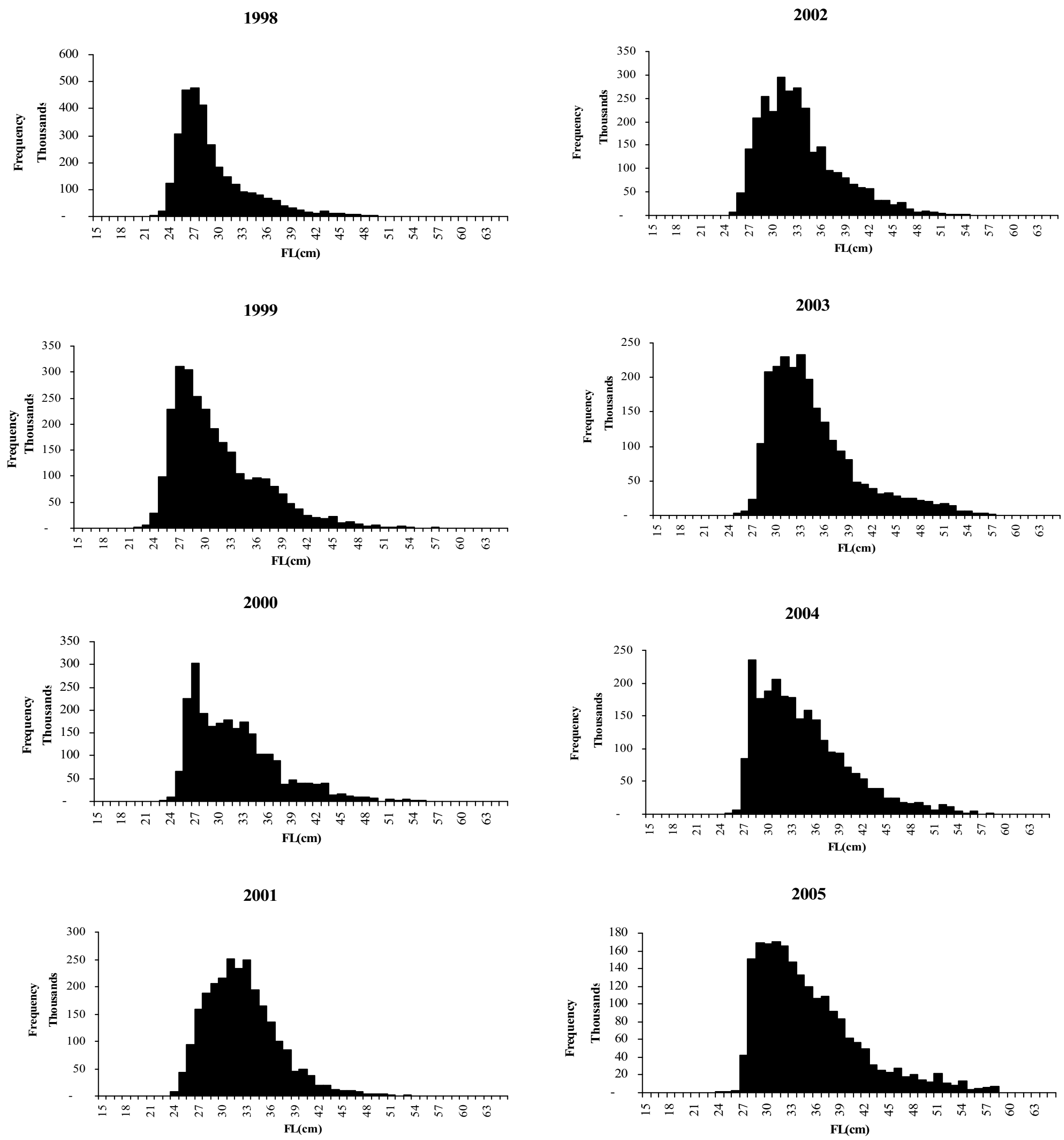


Figure C7. Average length (cm) of black sea bass in commercial landings, 1984-2005.

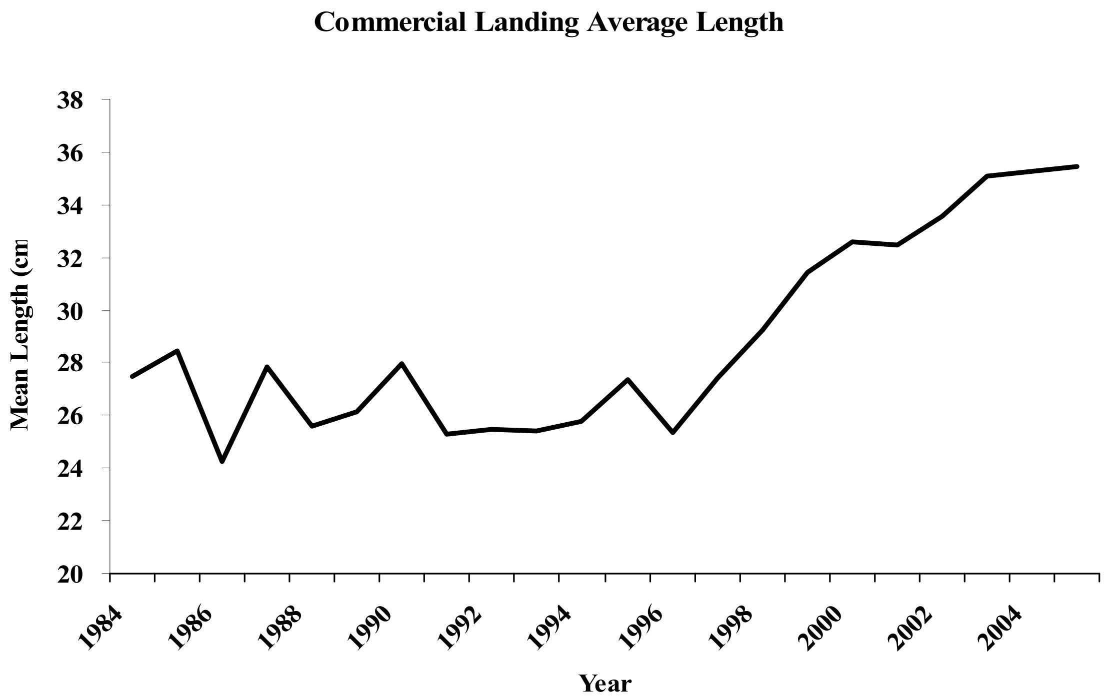


Figure C8. Recreational black sea bass landings from the northern stock, 1981-2005.

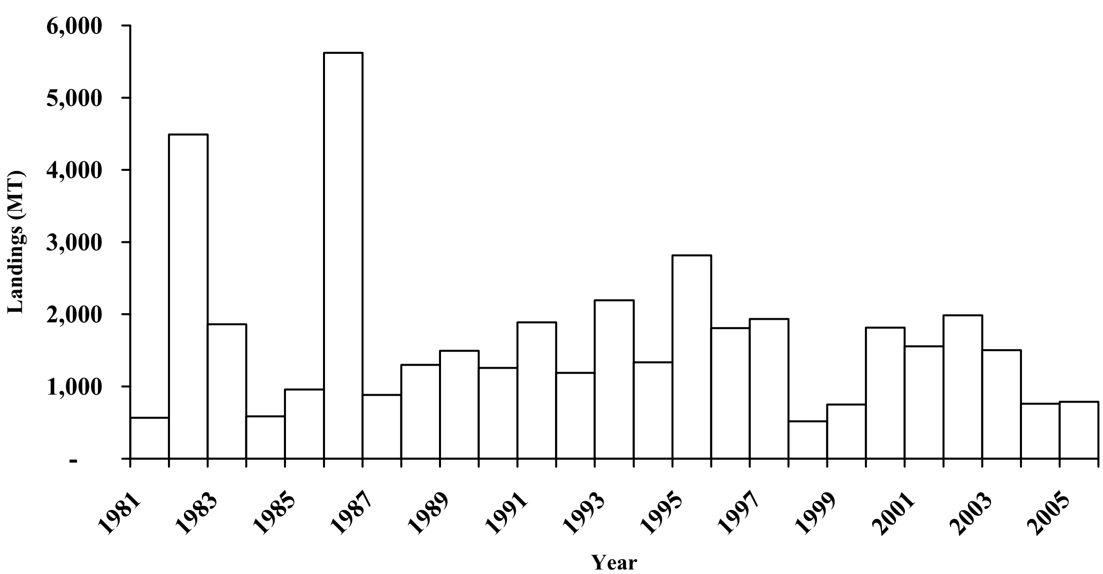


Figure C9. Expanded length distribution of recreational black sea bass landings, 1981-2005.

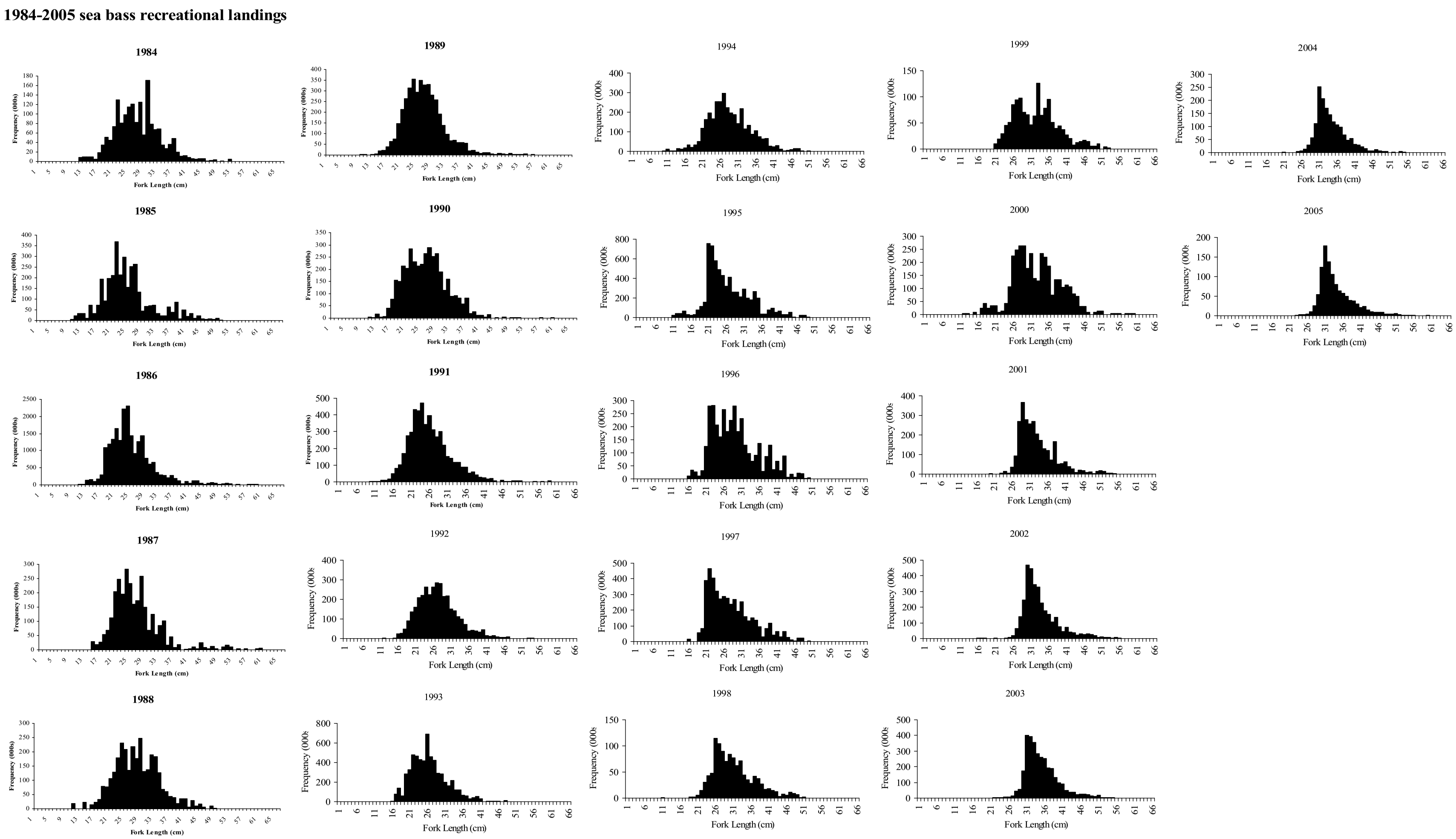


Figure C10. Average length (cm) of black sea bass recreational landings, 1981-2005.

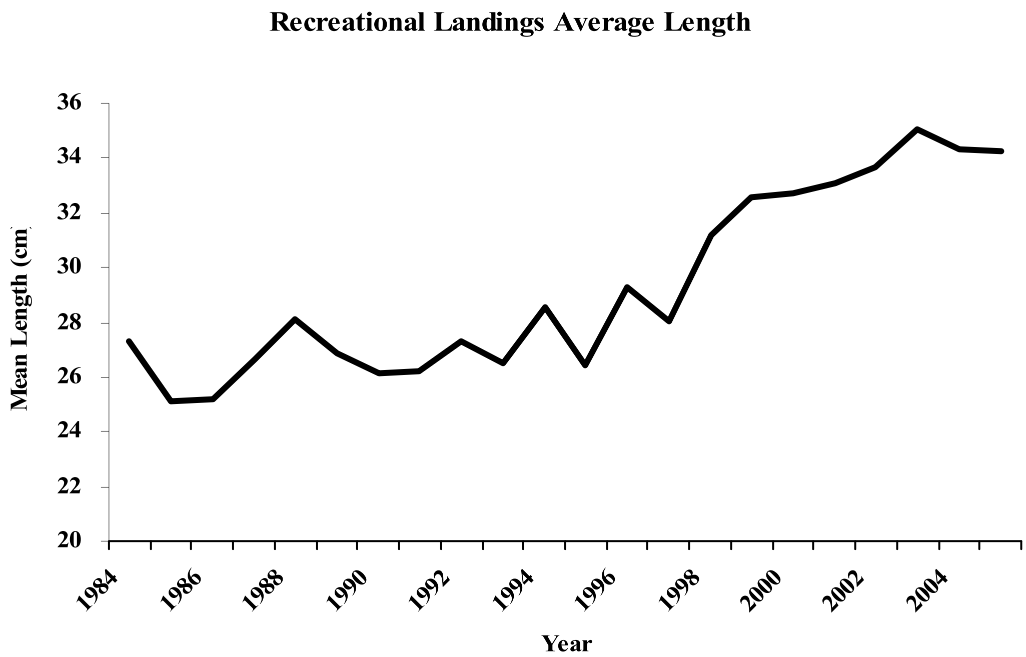


Figure C11. Length distribution of recreationally discarded black sea bass (B2) for 2005 party and charter boats. "FL": fork length.

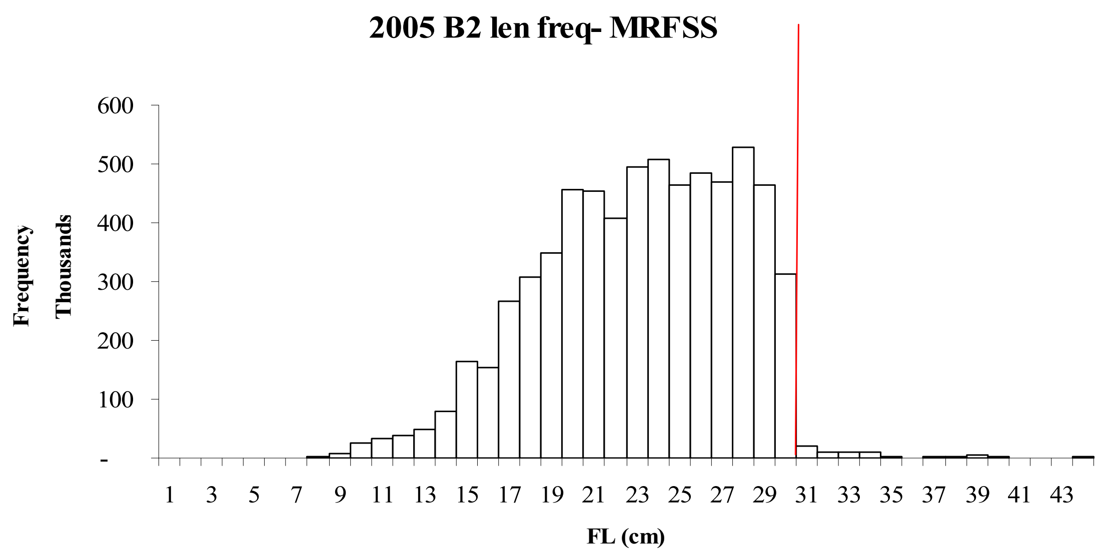
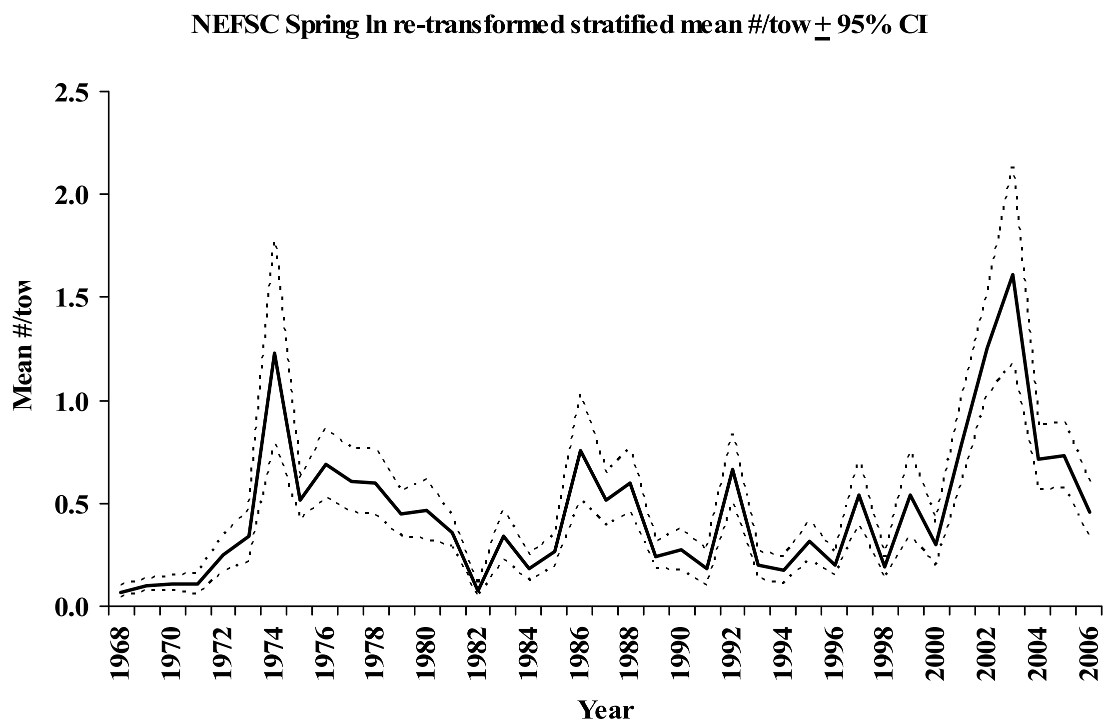


Figure C12. Adult black sea bass $\geq$ 22 cm ln re-transformed stratified mean #/tow $\pm$ 95% CI from NEFSC spring and winter bottom trawl surveys.



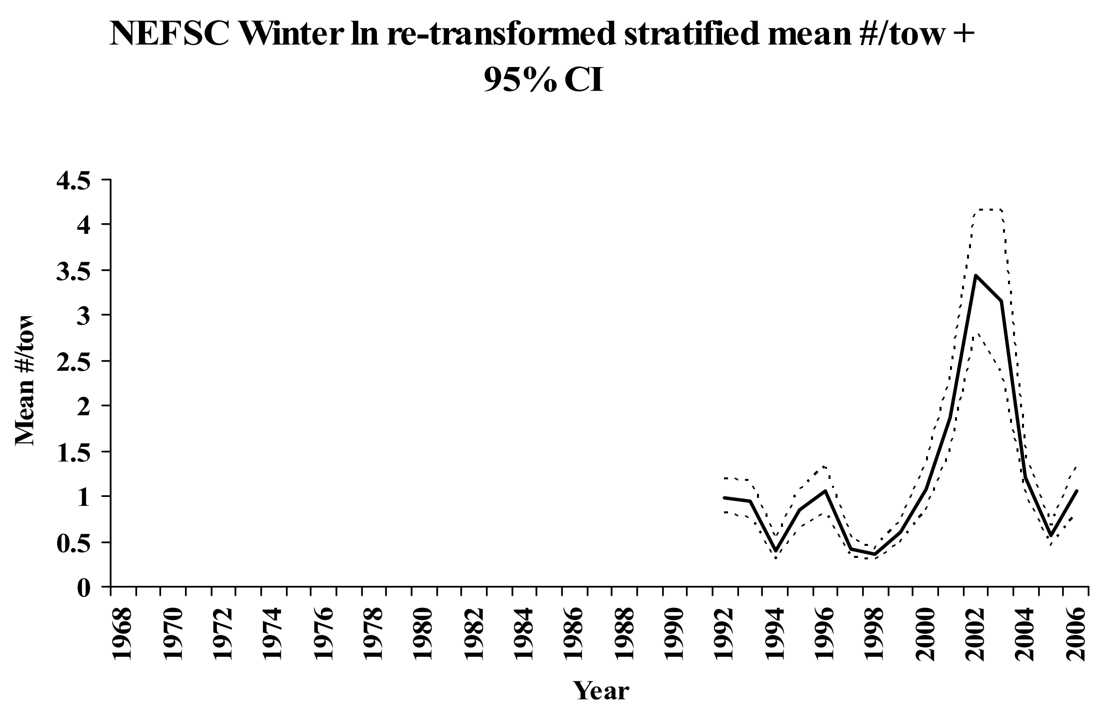
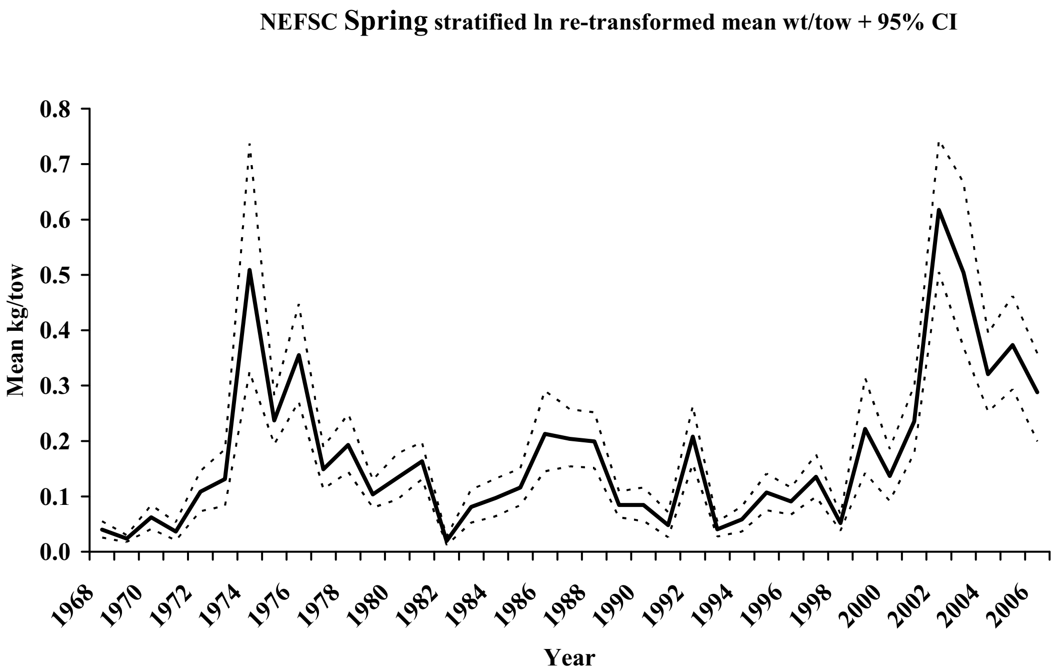


Figure C13. Adult black sea bass ≥ 22 cm stratified mean biomass per tow and 95% CI for spring and winter NEFSC bottom trawl surveys.



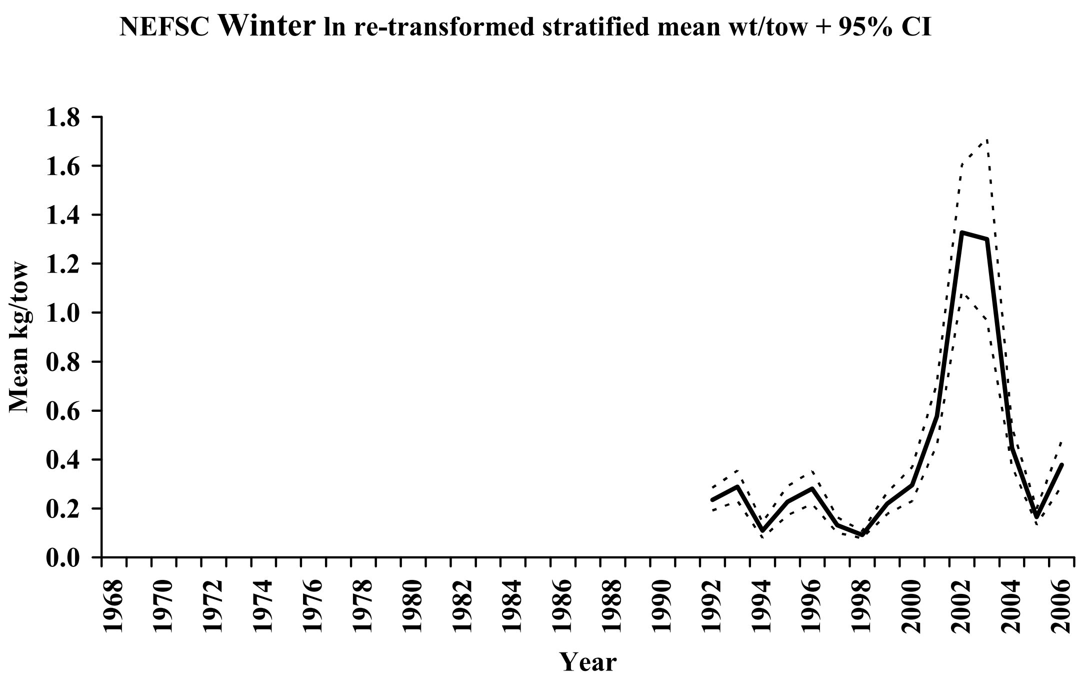
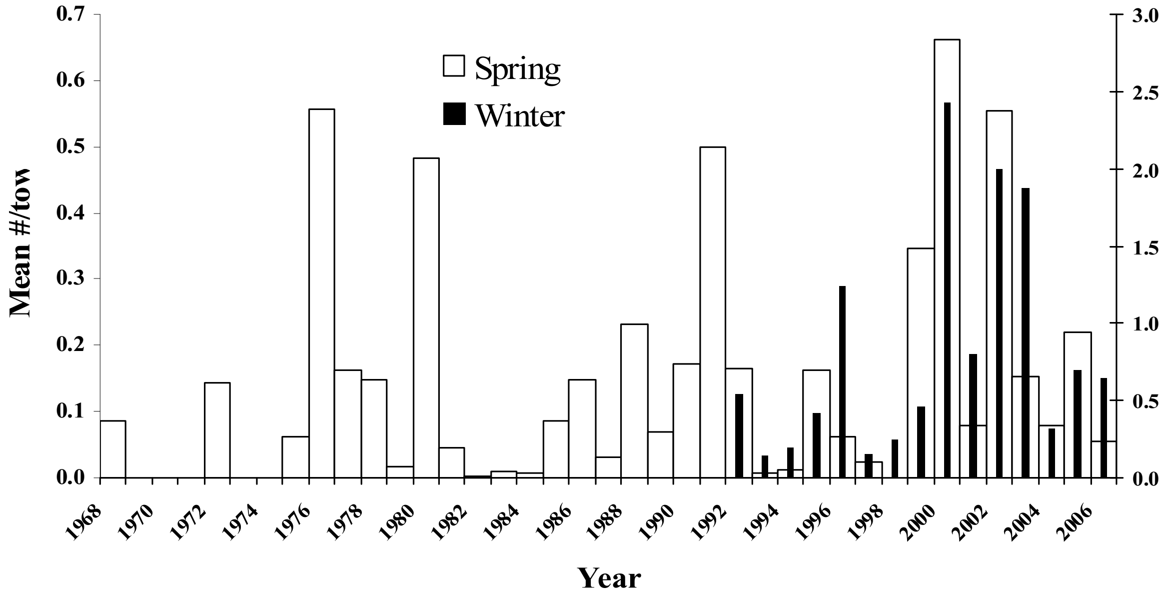


Figure C14. NEFSC black sea bass juvenile indices (≤ 14 cm) from winter, spring and autumn surveys.



Autumn

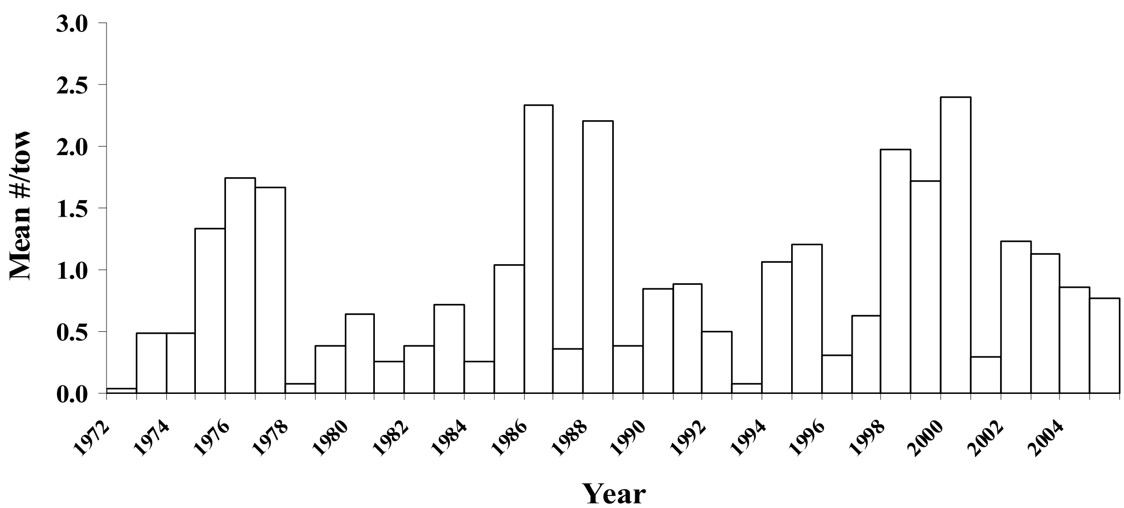


Figure C15. Length frequencies of black sea bass from NEFSC spring offshore surveys, 1981-2006.

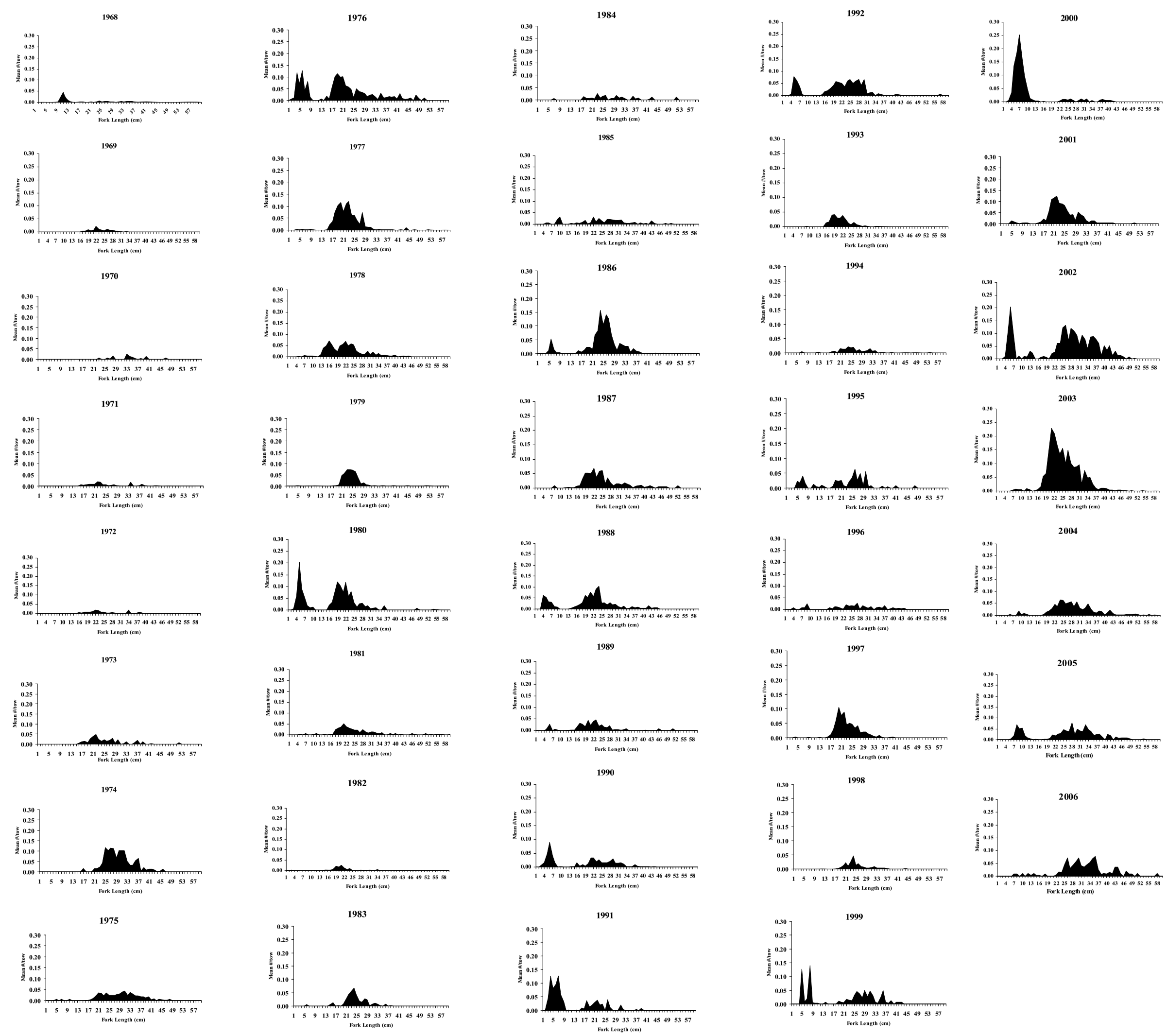


Figure C16. Length frequencies of black sea bass from NEFSC winter offshore survey, 1992-2006.

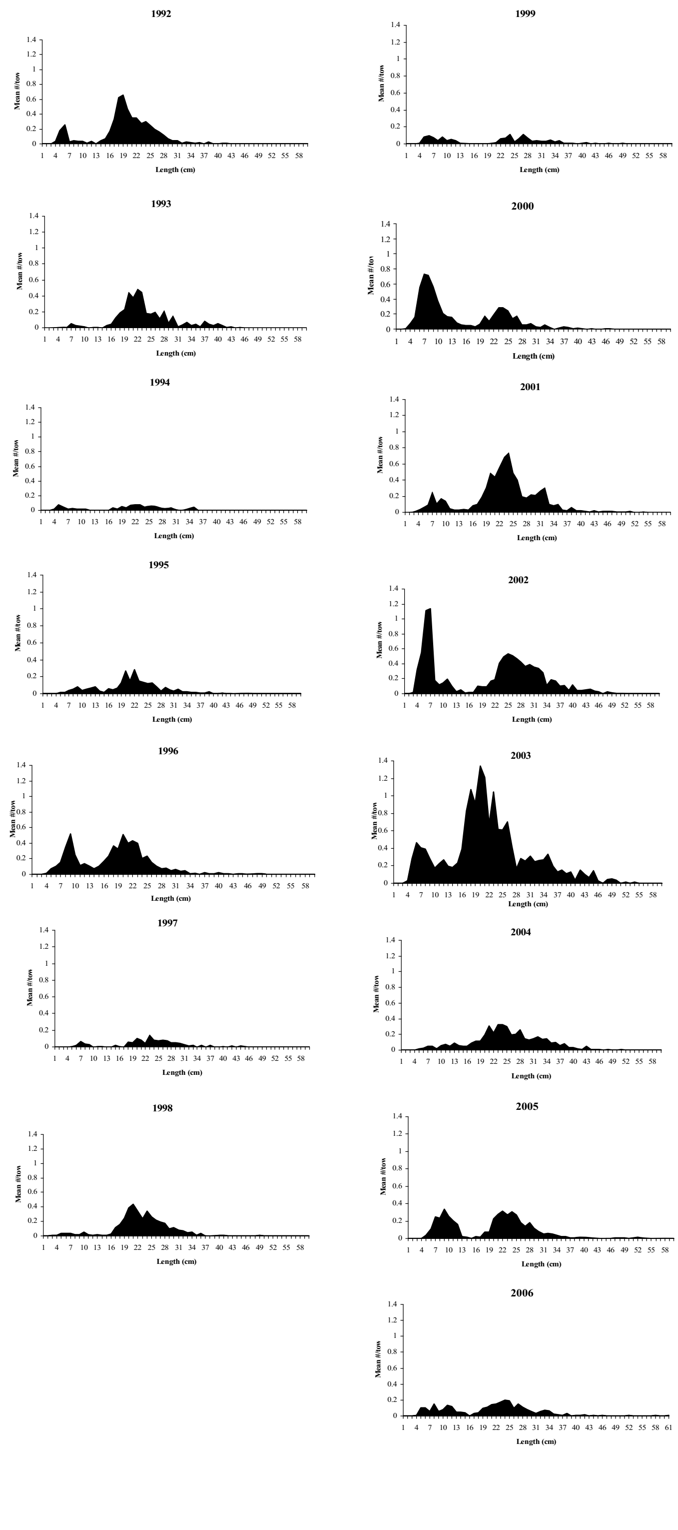


Figure C17. Massachusetts Division of Marine Fisheries spring trawl survey stratified mean number per tow and autumn juvenile number per tow of black sea bass, 1978-2005. “JI”: juvenile index.

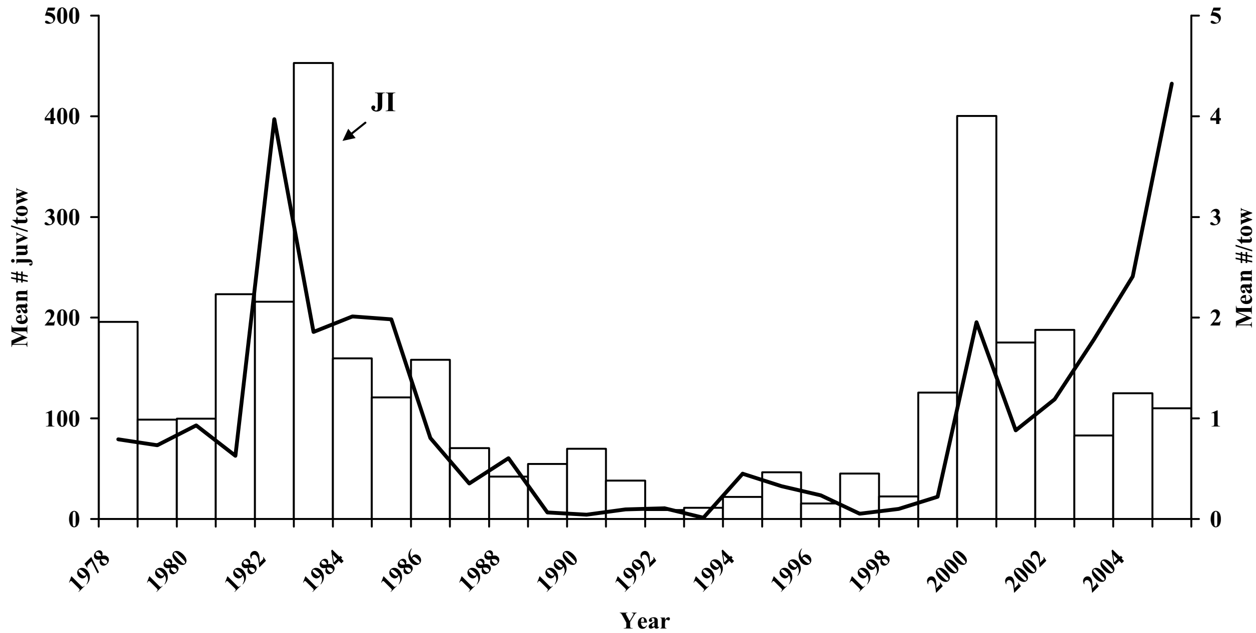


Figure C18. Sum of state survey rank indices of juvenile abundance. Age 0 fish in fall survey indices were advanced to the next calendar year to coincide with age 1 sea bass in spring indices. “JI”: juvenile index.

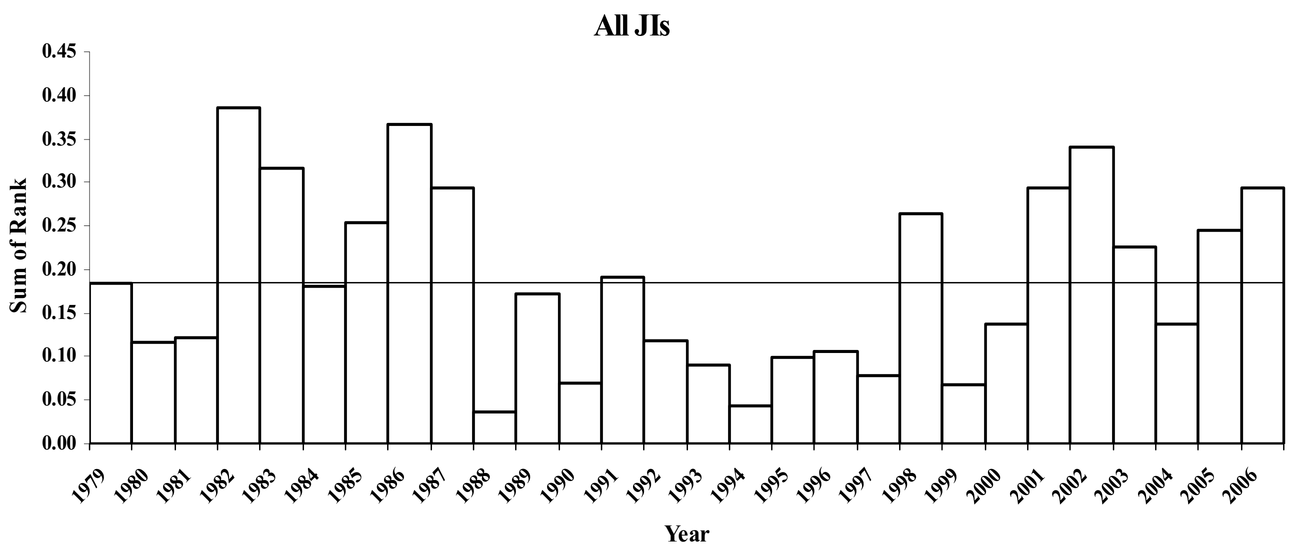


Figure C19. Tag recoveries relative to location of commercial fisheries.

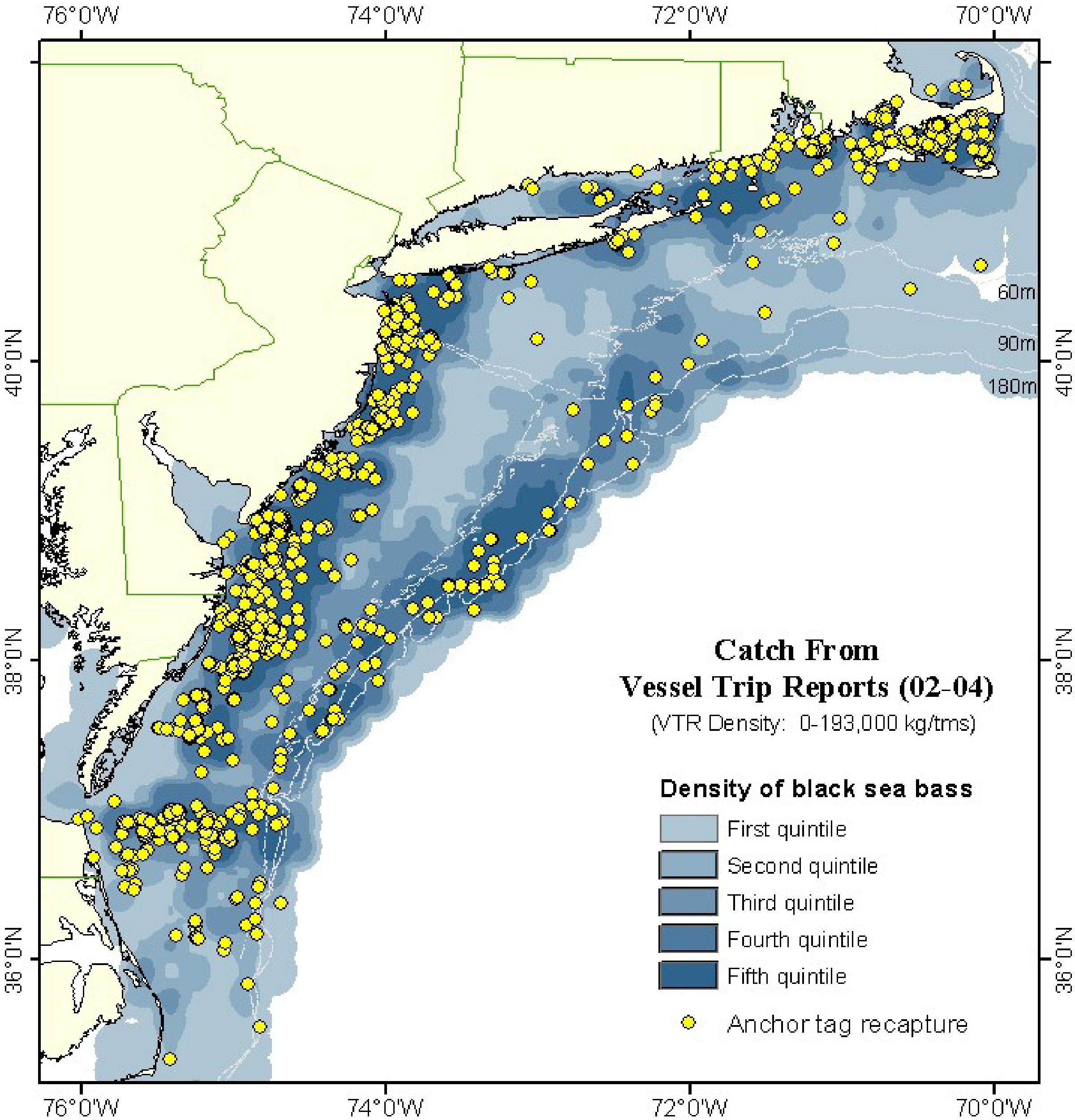


Figure C20. Tag recoveries by area of release and season.

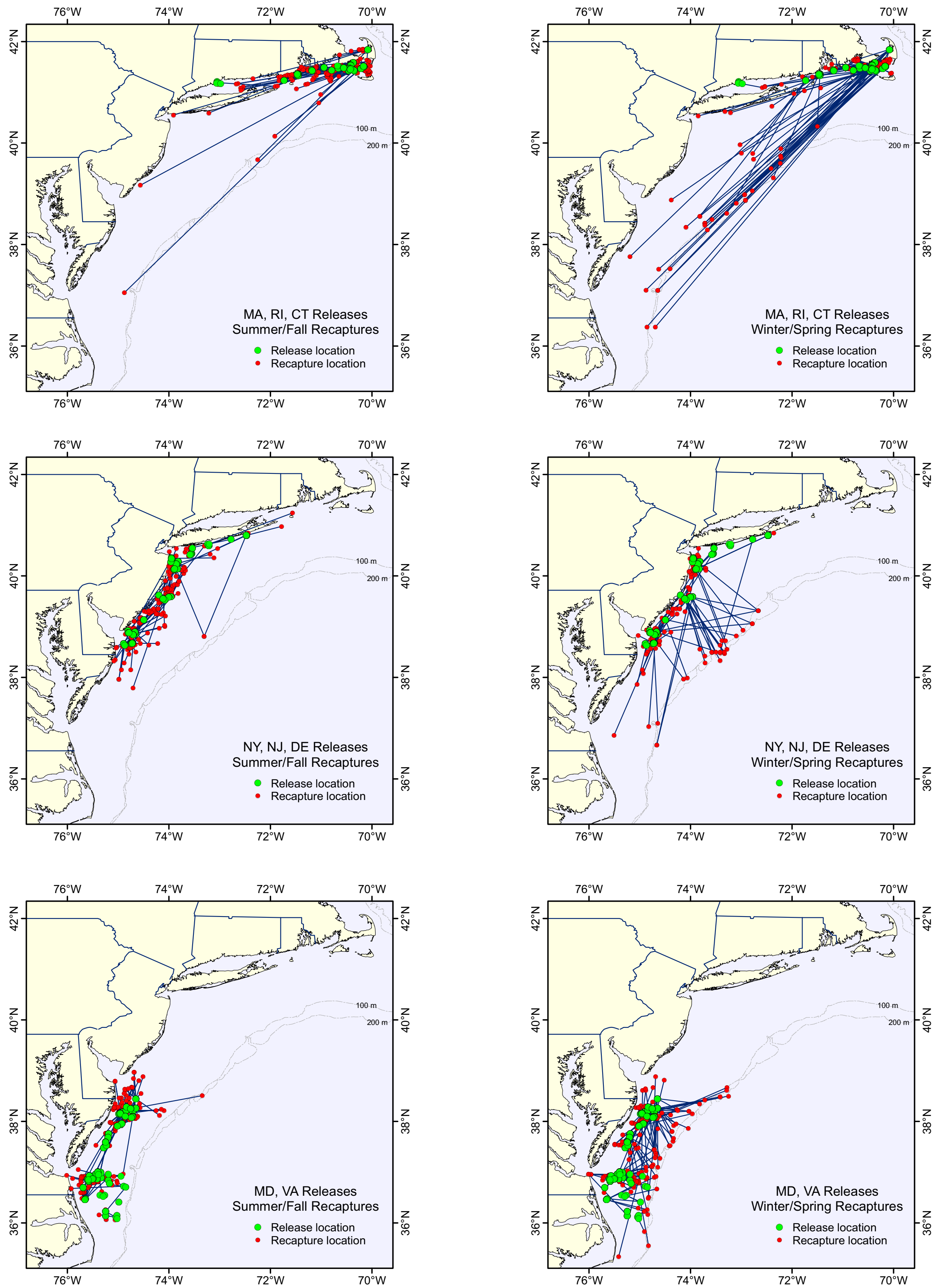


Figure C21. Data Storage Tag (DST) results of depth and temperature for black sea bass released in RI and recovered in Hudson Canyon.

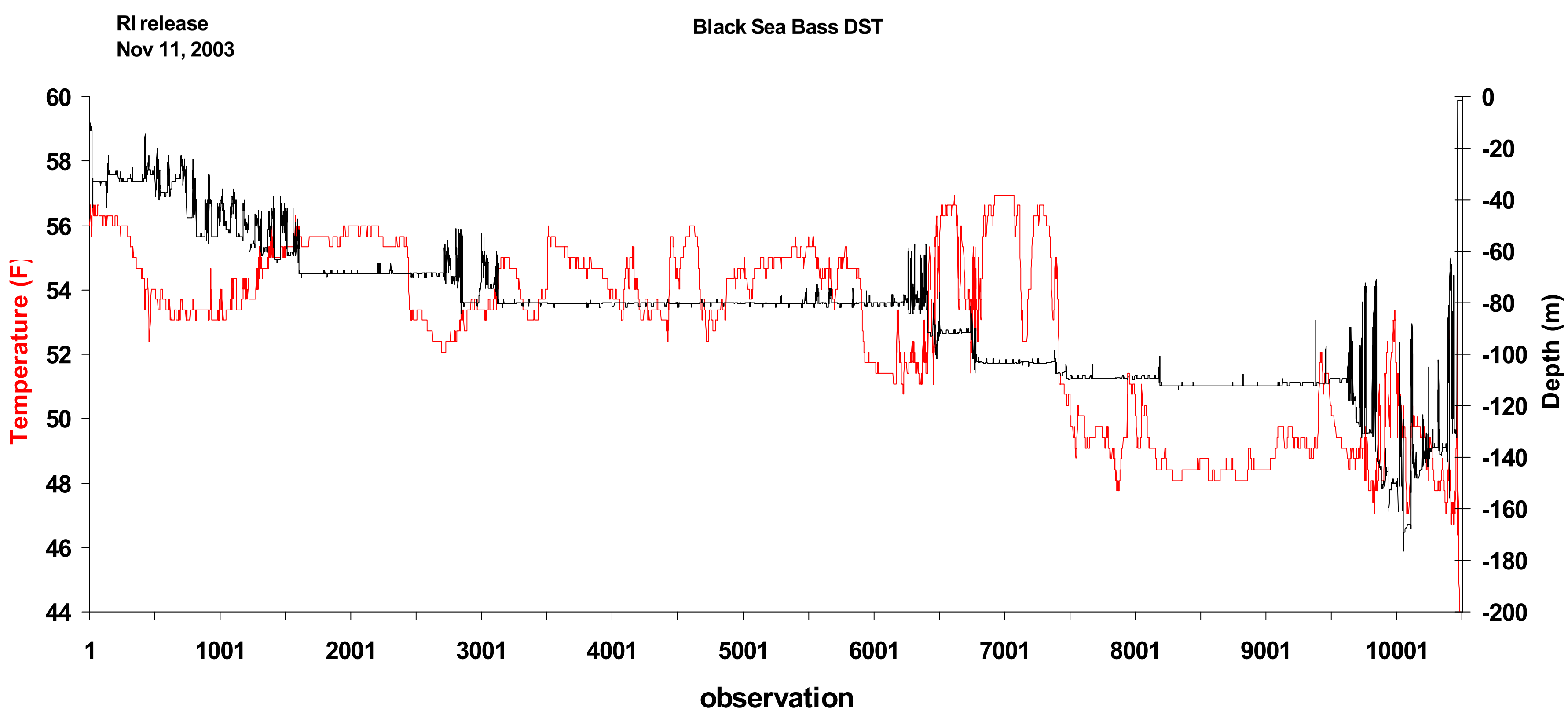
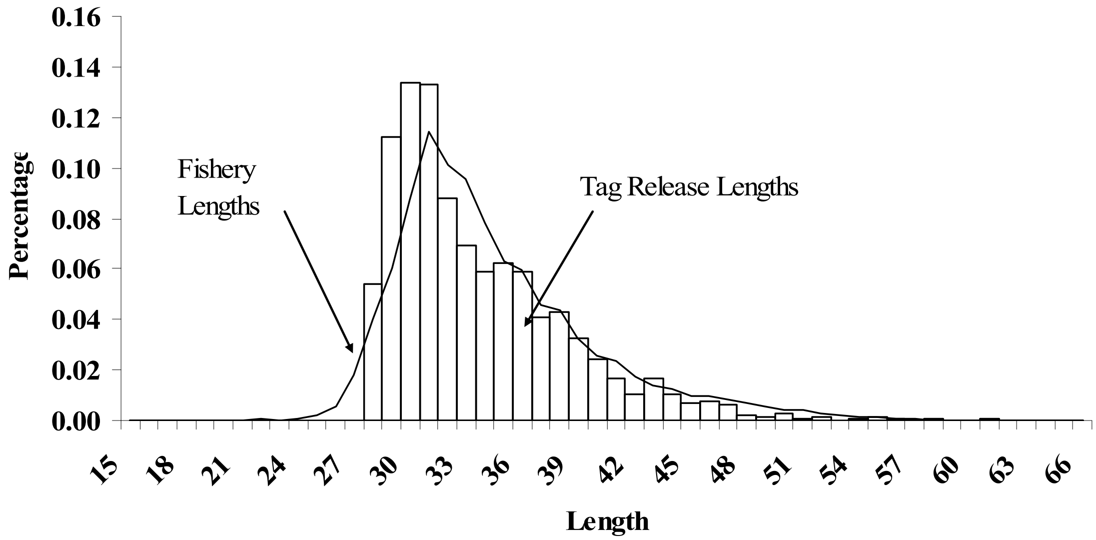


Figure C22. Tag releases and recoveries compared to average length frequency of fisheries between 2002 and 2004.



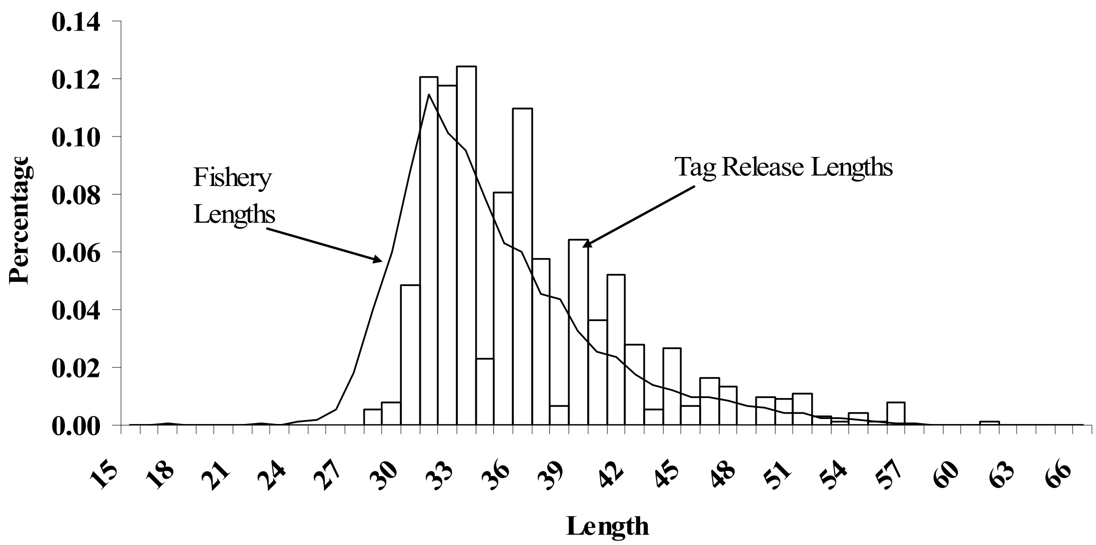


Figure C23. Distribution of tag loss, tag induced mortality and reporting rates used in estimation of exploitation rate.

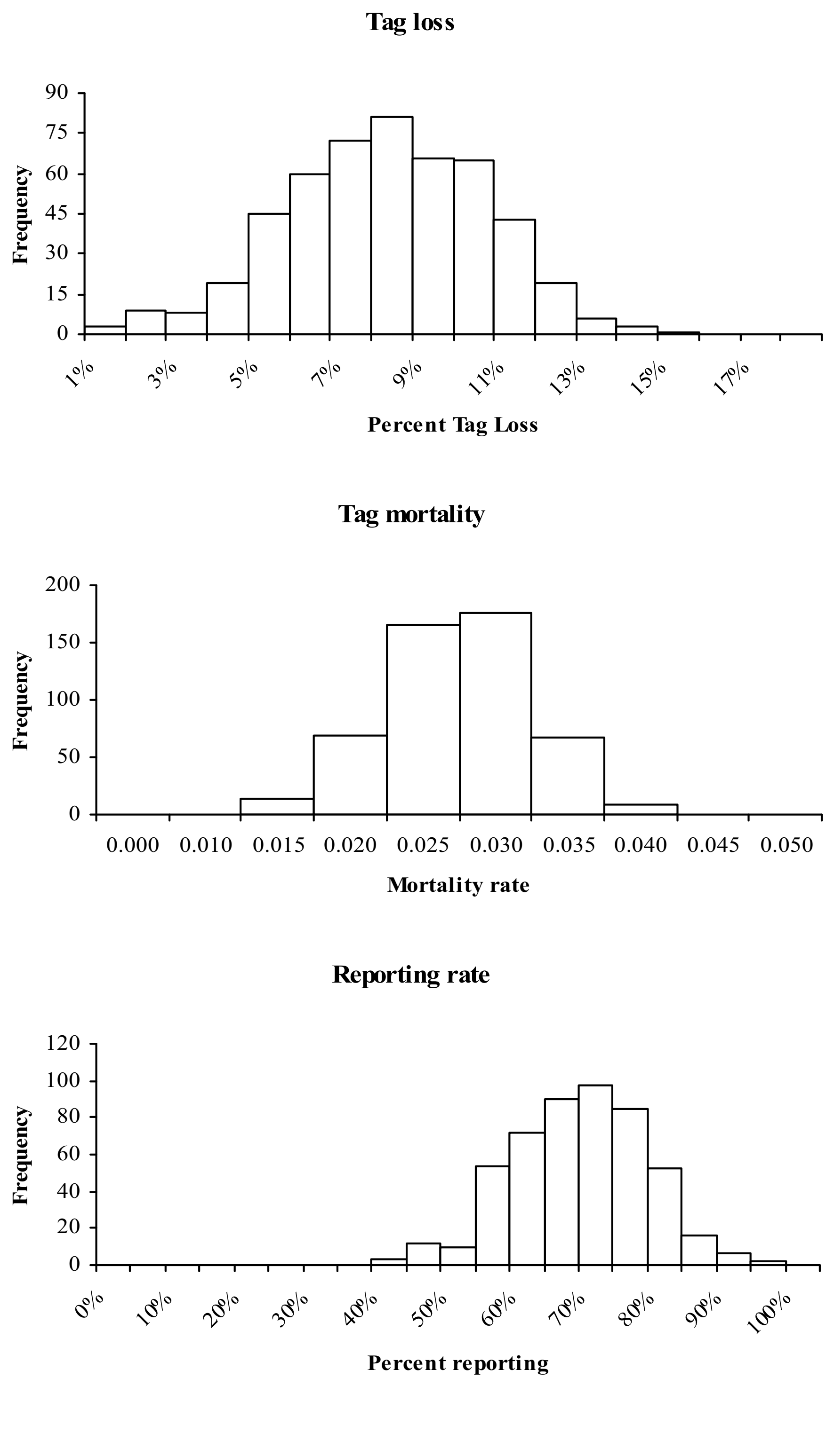


Figure C24. Frequency distribution of exploitation rate estimates and cumulative frequency based on Monte Carlo approach.

(EDITOR'S NOTE: THIS FIGURE OF THE WORKING GROUP REPORT HAS BEEN OMITTED. THE MORTALITY ESTIMATES WERE NOT ACCEPTED BY THE REVIEW PANEL.)

Figure C25. Frequency distribution and cumulative frequency of instantaneous fishing mortality rates assuming a constant M of 0.2.

(EDITOR'S NOTE: THIS FIGURE OF THE WORKING GROUP REPORT HAS BEEN OMITTED. THE MORTALITY ESTIMATES WERE NOT ACCEPTED BY THE REVIEW PANEL.)

Figure C26. Distribution of estimated natural mortalities for 2003-2004 and 2004-2005.

(EDITOR'S NOTE: THIS FIGURE OF THE WORKING GROUP REPORT HAS BEEN OMITTED. THE ESTIMATES WERE NOT ACCEPTED BY THE REVIEW PANEL.)

Figure C27. Distribution of estimated F using calculated M for 2003-2004 and 2004-2005.

(EDITOR'S NOTE: THIS FIGURE OF THE WORKING GROUP REPORT HAS BEEN OMITTED. THE ESTIMATES WERE NOT ACCEPTED BY THE REVIEW PANEL.)

APPENDIX C1: Black sea bass Length Tuned Model (LTM)

Introduction

Incomplete age information on catch and survey indices, often limits the application of full age-structured assessment models tuned with age specific data (e.g. Virtual Population Analysis). Knowledge of a species growth and lifespan, along with total catch data, size composition of the removals, recruitment indices and indices on numbers and size composition of the large fish in a survey can provide insights on population status using a simple model framework.

Herein we used a simple forward projecting age-based model tuned with total catch, catch at length, age-1 recruitment (estimated from first length mode in the survey), and survey numbers and length frequency of the larger fish sizes. The Length Tuned Model (LTM) was developed in the AD model builder framework. The model estimates fishing mortality and recruitment in each year, fishing mortality to produce the initial population (Fstart), and Qs for each survey index.

Methods

Model configuration

The LTM model assumes growth follows the mean input length at age with predetermined input error in length at age. Therefore a growth model or estimates of the average mean lengths at age is essential for reliable results. The LTM model uses an input partial recruitment (pr) vector at length in each year for the calculation of population and catch age-length matrices. A starting population is computed for year one in the model. First the estimated populations numbers at age starting with age-1 recruitment get normally distributed at one cm length intervals using the mean length at age with the assumed standard deviation. Next the initial population numbers at age are calculated from the previous age at length abundance using the survival equation. An estimated fishing mortality (Fstart) is also used to produce the initial population. This F can be thought of as the average fishing mortality that occurred before the first year in the model. Now the process repeats itself with the total of the estimated abundance at age getting redistributed according to the mean length at age and standard deviation in the next age (age+1).

This two step process is used to incorporate the effects of length specific selectivities and fishing mortality. The initial population length and age distribution is constructed by assuming that the population is at equilibrium with an initial value of F, say F_{start}. Length specific mortality is estimated as a two step process in which the population is first decremented for the length specific effects of mortality as follows:

$$N^*_{a,len,y_1} = N_{a-1,len,y_1} e^{-\left(PR_{len}F_{start}+M\right)}$$

In the second step, the total population of survivors is then redistributed over the lengths at age *a* by assuming that the proportions of numbers at length at age *a* follow a normal distribution with a mean length derived from the von Bertalanffy growth function.

$$N_{a,len,y_1} = \pi_{len,a} \sum_{len=0}^{L_\infty} N^*_{a,len,y_1}$$

where

$$\pi_{len,a} = \Phi\left(len + 1 \mid \mu_a, \sigma_a^2\right) - \Phi\left(len \mid \mu_a, \sigma_a^2\right)$$

where

$$\mu_a = L_\infty\left(1 - e^{-K(a - t_0)}\right)$$

For black sea bass the variance of length at age a = σ_s^2 was estimated from the NEFSC survey age data (standard deviation of 4.2 from ages 4+).

This model formulation does not explicitly track the dynamics of length groups across age because the consequences of differential survival at length at age a do not alter the mean length of fish at age a+1. However, it does more realistically account for the variations in age specific partial recruitment patterns by incorporating the expected distribution of lengths at age.

In the next step the population numbers at age and length for years after the calculation of the initial population use the previous age and year for the estimate of abundance. Here the calculations are done on a cohort basis. Like in the previous initial population survival equation the partial recruitment is taken from the input length vector.

$$N^*_{a,len,y} = N_{a-1,len,y-1} e^{-\left(PR_{len} F_{start} + M\right)}$$

second stage

$$N_{a,len,y} = \pi_{len,a} \sum_{len=0}^{L_\infty} N^*_{a,len,y}$$

Constant M is assumed along with an estimated length-weight relationship to convert estimated catch in numbers to landings in weight. The best available estimate of partial recruitment at length is used as input to the model from knowledge of landings size distribution, fishing practice, regulations, and discarding. The standard Baranov's catch equation is used to remove the catch from the population in estimating fishing mortality.

$$C_{y,a,len} = \frac{N_{y,a,len} F_y \left(1 - e^{-\left(F_y PR_{len} + M\right)}\right)}{(F_y \ \ PR_{len}) + M}$$

Catch is converted to yield by assuming a time invariant average weight at length

$$Y_{y,a,len} = C_{y,a,len} W_{len}$$

The LTM model results in the calculation of population and catch age-length matrices for the starting population and then for each year thereafter. The model is programmed to estimate recruitment in year 1 and estimate variation in recruitment relative to recruitment in year 1 for each year thereafter. Estimated recruitment in year one can be thought of as the estimated average long term recruitment in the population since it produces the initial population. The residual sum of squares of the variation in recruitment $\sum(\text{Vrec})^2$ is than used as a component of the total objective junction. The weight on the recruitment variation component of the objective junction (Vrec) can be used to penalize the model for estimating large changes in recruitment relative to estimated recruitment in year one.

The model requires an age-1 recruitment index for tuning or the user can assume relatively constant recruitment over time by putting a high weight on Vrec. Usually there is little overlap in ages at length for fish that are one and/or two years of age in a survey of abundance. The first mode in a survey can generally index age-1 recruitment using length slicing. In addition numbers and the length frequency of the larger fish in a survey where overlap in ages at a particular length occurs can be used for tuning population abundance. The model tunes to the catch and survey length frequency data using a multinomial distribution. The user specifies the minimum size (cm) for the model to fit. Different minimum sizes can be fit for the catch and survey data length frequency.

The number of parameters estimated is equal to the number of years in estimating F and recruitment plus one for the F to produce the initial population (Fstart) and for each survey Q. The total likelihood function to be minimized is made up of 10 likelihood components:

$$\mathrm{L}_1 = \sum_{years} \left(l\,\mathrm{n}(Y_{\mathrm{obs,y}} + 1) - \ln\left(\sum_a \sum_{len} \mathrm{Y}_{\mathrm{pred,len,a,y}} + 1 \right) \right)^2$$

$$L_2 = -N_{eff} \sum_y \left(\sum_{len=30}^{L_\infty} \left(\left(C_{y,len} + 1\right) \ln\left(1 + \sum_a C_{pred,y,a,len} \right) - \ln\left(C_{y,len} + 1\right) \right) \right)$$

$$\mathrm{L}_3 = \sum_{y=2}^{Nyears} \left(Vrec_y\right)^2 = \sum_{y=2}^{Nyears} \left(R_1 - R_y\right)^2$$

$$L_4 = \sum_{y}^{Nyears} \left(\ln\left(I_{FALL,1,y} + 1\right) - \ln\left(1 + \sum_{len}^{L_\infty} N_{y,1,len}\right) q_{FALL} \right)^2$$

$$L_5 = \sum_{y=1992}^{Nyears} \left(\ln\left(I_{WINTER,1,y} + 1\right) - \ln\left(1 + \sum_{len}^{L_\infty} N_{y,1,len}\right) q_{WINTER} \right)^2$$

$$L_6 = \sum_{y}^{Nyears} \left(\ln\left(I_{SPRING,1,y} + 1\right) - \ln\left(1 + \sum_{len}^{L_\infty} N_{y,1,len}\right) q_{SPRING} \right)^2$$

$$L_7 = \sum_{y=1992}^{Nyears} \left(\ln\left(I_{WINTER,22+,y} + 1\right) - \ln\left(\sum_{a} \sum_{len=22}^{L_\infty} \ln\left(N_{pred,y,a,len} + 1\right) q_{WINTER,22+} \right) \right)^2$$

$$L_8 = -N_{eff} \sum_{y=1992}^{Nyears} \left(\sum_{len=22}^{L_\infty} \left(\left(I_{WINTER,y,len} + 1\right) \ln\left(1 + \sum_{a} N_{pred,y,a,len}\right) - \ln\left(I_{WINTER,y,len} + 1\right) \right) \right)$$

$$L_9 = \sum_{y}^{Nyears} \left(\ln\left(I_{SPRING,22+,y} + 1\right) - \ln\left(\sum_{a} \sum_{len=22}^{L_\infty} \ln\left(N_{pred,y,a,len} + 1\right) q_{SPRING,22+} \right) \right)^2$$

$$L_{10} = -N_{eff} \sum_{y} \left(\sum_{len=22}^{L_\infty} \left(\left(I_{SPRING,y,len} + 1\right) \ln\left(1 + \sum_{a} N_{pred,y,a,len}\right) - \ln\left(I_{SPRING,y,len} + 1\right) \right) \right)$$

In equation L_2 calculations of the sum of length is made from the user input catch length to the maximum length for fitting the catch. In equation L_7 through L_{10} the survey length up to the maximum length is used in the calculation.

$$Obj\ \ fcn = \sum_{i=1}^{10} \lambda_i L_i$$

Lambdas represent the weights to be set by the user for each likelihood component in the total objective function.

Black Sea Bass LTM Model Results

Black sea bass natural mortality was assumed to be 0.2 with a fifteen year lifespan. Estimates of commercial discard were not available. B2 estimates were relatively small when reduced by a 15 % mortality rate and are not used in the model. The catch length frequency were fit to 30+ cm fish and the survey numbers and survey length frequency were fit to 22+ cm fish. Surveys were standardized by dividing each survey by its mean and multiplying by 1 million. An approximation of the partial recruitment vector at length was developed by shifting the partial recruitment curve to larger fish as minimum size limits and mesh size increases occurred in the recreational and commercial fisheries (Fig 1). The shift to larger fish can be observed in the landings length frequency.

All black sea bass LTM model runs estimated high F start values. The model predicts a truncated distribution at the beginning of the model in 1981. The fishery landings history supports the presence of an exploited population before 1981.

The working group reviewed the effects of using different growth estimates in runs 1 to 3 (Fig 2 and 3). The three different growth estimates tend to produce changes in the fishing mortality estimates in the past with the terminal year estimates being very similar among the runs. However the changes in growth resulted in a shift in the recruitment/biomass estimates among the three runs. The survey growth model was used for all subsequent model runs and comparisons.

In general all three recruitment indices showed increases in recruitment between 2000 and 2002. The recreational B2 estimates were also higher during the early 2000s which suggests higher recruitment. Runs with different assumptions on the variation in recruitment (Vrec = 1, 1000, 0.1) showed different trends in F and biomass depending on how closely the model is allowed to fit the increases in recruitment in the surveys from 2000-2002 (Table 1, Fig 4). However all the black sea bass LTM model runs could not match the decrease in the 22+ index. Given that the catch has decreased and strong recruitment occurred during the early 2000s, the effect should be reflected in both the adult index (22+) and the exploitable length frequency in the terminal year of the model. Both the winter and spring survey show a substantial decrease in numbers of 22+ fish from 2004 to 2006. The model predicts a greater amount of larger fish than observed in the catch and surveys for the terminal year especially as the model is allowed to fit the high recruitment in the surveys. The working group was not confident in the LTM model results for stock status determination given the differences in trends between the predicted and observed 22+ cm indices in the last three years. The working group could not determine if this mismatch was due to a survey availability event and/or an unaccounted source of mortality such as commercial and recreational discards.

The working group questioned the large increases in recreational catch in 1982 and 1986. These large increases were not realistic and the average of adjacent years was used for the recreational catch estimate in these two years. Results did not change greatly when the actual reported recreational landings were used in run 7 (Fig 5). All of the resulting output graphs are shown for run 3 which uses the survey growth curve and a Vrec weight of 5 in figures 6-11. Using the Lower or Upper 95% confidence intervals for the MRFSS catch did not produce different trends in the LTM model results (Table 3, Fig 12).

APPENDIX C1

Table 1. Black Sea Bass LTM runs of residual sum of squares, input weights, estimated Qs, estimated Fstart, and age 1 recruitment in year 1.

run number	1	2	3	4	5	6	7
Landings makeup	avg rec 82 & 86	avg rec 82 & 86	avg rec 82 & 86	avg rec 82 & 86	avg rec 82 & 86	avg rec 82 & 86	MRFSS landings
growth	Shepherd	Caruso	NEFSC survey	NEFSC survey	NEFSC survey	NEFSC survey	NEFSC survey
total objective function	181.00	206.14	184.28	165.93	172.80	202.53	187.24
total catch	0.04	0.23	0.14	0.14	0.13	0.17	0.18
catch len freq 80+	10.31	17.51	9.17	10.39	9.98	9.96	10.13
Vrec	1.98	1.60	1.62	12.07	5.46	0.0002	1.61
Fall age 1	11.62	13.11	13.41	12.94	12.67	16.77	13.61
Spring age 1	40.16	41.78	42.32	33.47	36.26	52.86	43.22
Winter age 1	16.75	16.45	15.83	10.00	11.84	22.35	15.55
Winter 80+ len freq	17.81	21.94	18.84	20.73	20.13	19.07	18.96
Winter 80+ numbers	6.46	6.06	5.95	5.67	5.55	7.06	5.81
Spring 80+ len freq	58.19	69.93	60.57	61.94	61.49	62.37	61.10
Spring 80+ numbers	9.37	9.04	8.69	8.22	8.08	10.17	9.04
wt total catch	10	10	10	10	10	10	10
effective sample size wt catch len freq 80+	200	200	200	200	200	200	200
wt Vrec	5	5	5	0.1	1	1000	5
wt Fall age 1	1	1	1	1	1	1	1
wt Spring age 1	1	1	1	1	1	1	1
wt Winter age 1	1	1	1	1	1	1	1
effective sample size wt Winter 80+ len freq	200	200	200	200	200	200	200
wt Winter 80+ numbers	1	1	1	1	1	1	1
effective sample size Spring 80+ len freq	200	200	200	200	200	200	200
wt Spring 80+ numbers	1	1	1	1	1	1	1
Q Fall age 1	0.80	0.83	0.82	0.81	0.82	0.82	0.82
Q Spring age 1	0.77	0.80	0.79	0.78	0.79	0.79	0.79
Q Winter age 1	0.77	0.80	0.79	0.77	0.78	0.80	0.79
Q Winter 80+ numbers	0.77	0.81	0.80	0.78	0.79	0.81	0.80
Q Spring 80+ numbers	0.79	0.82	0.81	0.80	0.81	0.82	0.81
Fstart	0.75	1.72	1.40	1.08	1.43	1.36	0.89
recruitment year 1	21.9	12.0	14.0	12.4	14.5	13.6	15.4

APPENDIX C1

Table 2. Black Sea Bass LTM run 3 F-mult, age 1 recruitment and 22+ population biomass.

year	F Fmult	age 1 recruitment millions	population 22+ biomass metric tons
1981	0.83	14.0	3,520
1982	0.78	12.4	4,589
1983	0.93	10.2	5,230
1984	0.78	10.7	4,753
1985	0.79	13.1	4,725
1986	0.96	15.1	4,885
1987	1.24	12.2	4,909
1988	1.54	18.3	4,881
1989	1.39	10.8	4,575
1990	1.23	15.0	4,846
1991	1.56	15.1	4,707
1992	1.35	16.6	4,553
1993	1.45	9.9	5,024
1994	0.77	11.8	4,650
1995	1.17	14.3	5,293
1996	1.32	13.4	4,954
1997	1.34	11.9	4,795
1998	0.57	9.8	4,492
1999	0.60	16.4	5,821
2000	0.82	24.6	7,199
2001	0.72	13.3	8,879
2002	0.80	25.2	11,567
2003	0.42	21.6	13,601
2004	0.20	15.4	17,882
2005	0.13	16.6	23,359

Table 3. Black Sea Bass LTM runs 8 and 9 which used the MRFSS 95% upper and lower CI bounds. The residual sum of squares, input weights, estimated Qs, estimated Fstart, and age 1 recruitment in year 1 are shown.

run number	8	9
Landings makeup	MRFSS lower CI landings	MRFSS upper CI landings
growth	NEFSC survey	NEFSC survey
total objective function	183.00	185.81
total catch	0.12	0.16
catch len freq 80+	8.98	9.20
Vrec	1.66	1.72
Fall age 1	13.32	13.61
Spring age 1	41.92	41.94
Winter age 1	15.74	15.93
Winter 80+ len freq	18.65	19.01
Winter 80+ numbers	5.88	6.05
Spring 80+ len freq	60.33	60.99
Spring 80+ numbers	8.67	8.90
wt total catch	10	10
effective sample size wt catch len freq 80+	200	200
wt Vrec	5	5
wt Fall age 1	1	1
wt Spring age 1	1	1
wt Winter age 1	1	1
effective sample size wt Winter 80+ len freq	200	200
wt Winter 80+ numbers	1	1
effective sample size Spring 80+ len freq	200	200
wt Spring 80+ numbers	1	1
Q Fall age 1	0.82	0.81
Q Spring age 1	0.79	0.78
Q Winter age 1	0.79	0.78
Q Winter 80+ numbers	0.80	0.79
Q Spring 80+ numbers	0.82	0.80
Fstart	1.51	1.40
recruitment year 1	13.3	17.1

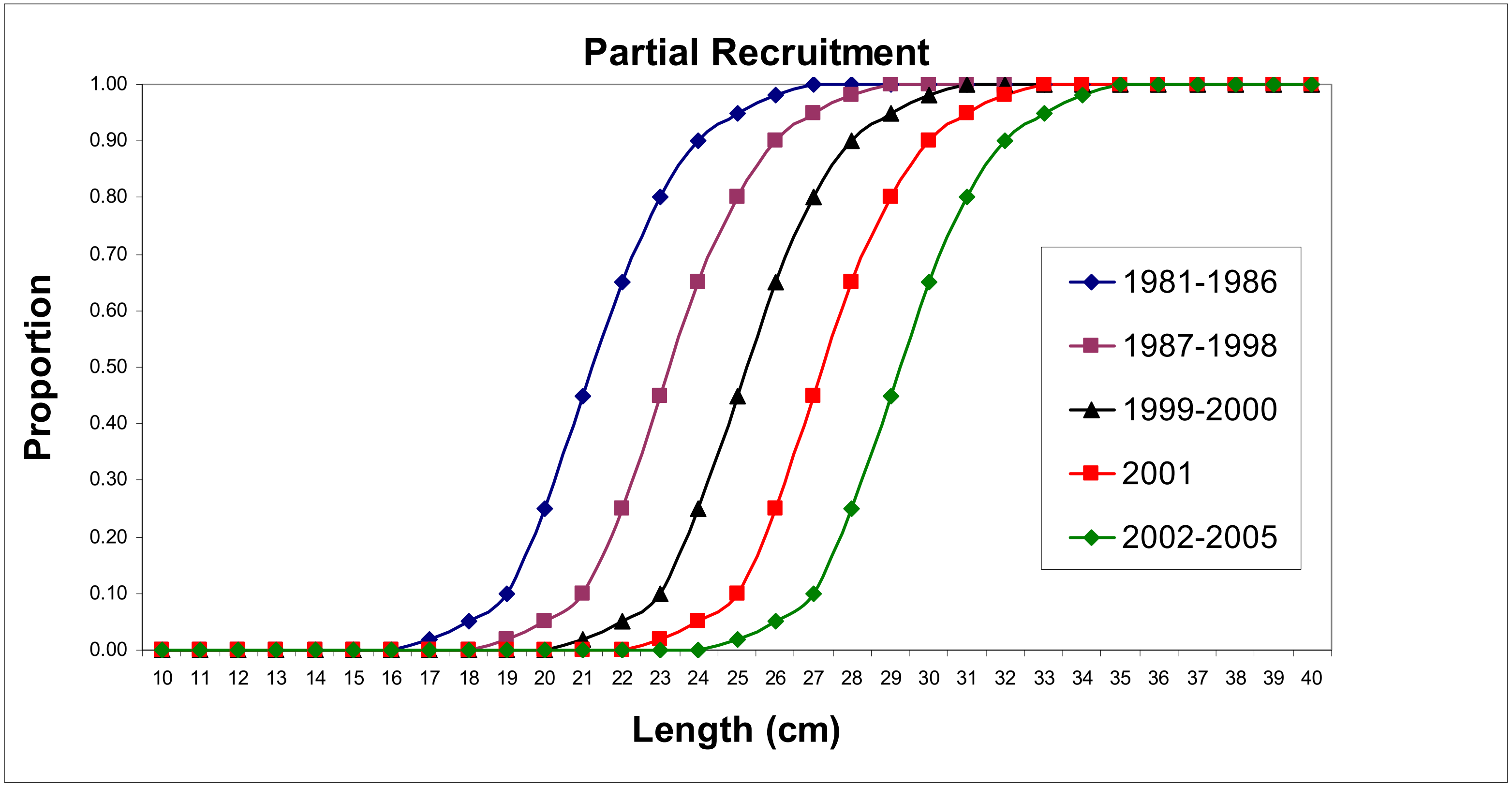


Figure 1 (Appendix C1). Input partial recruitment vector at length used in the black sea bass LTM model.

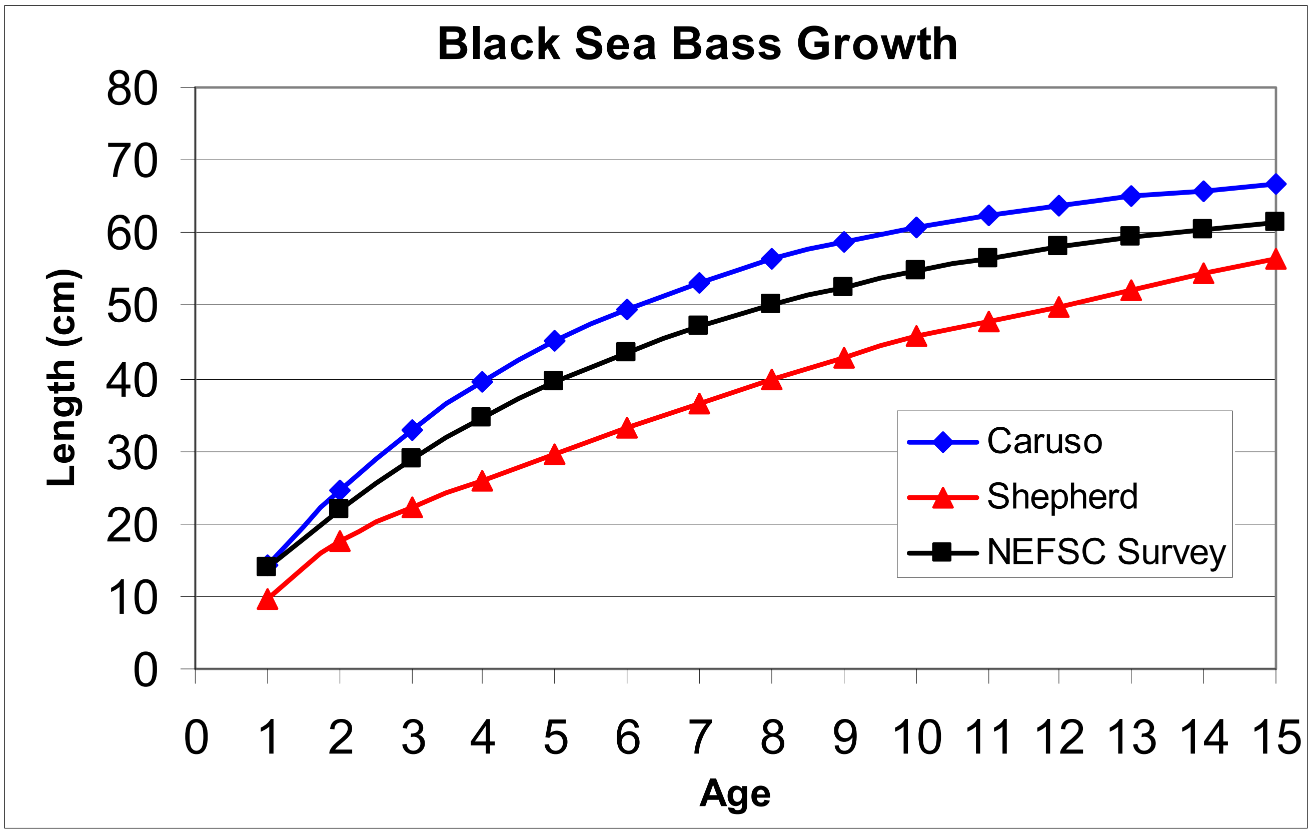


Figure 2 (Appendix C1). Three different growth models used in Black Sea Bass LTM runs 1 to 3.

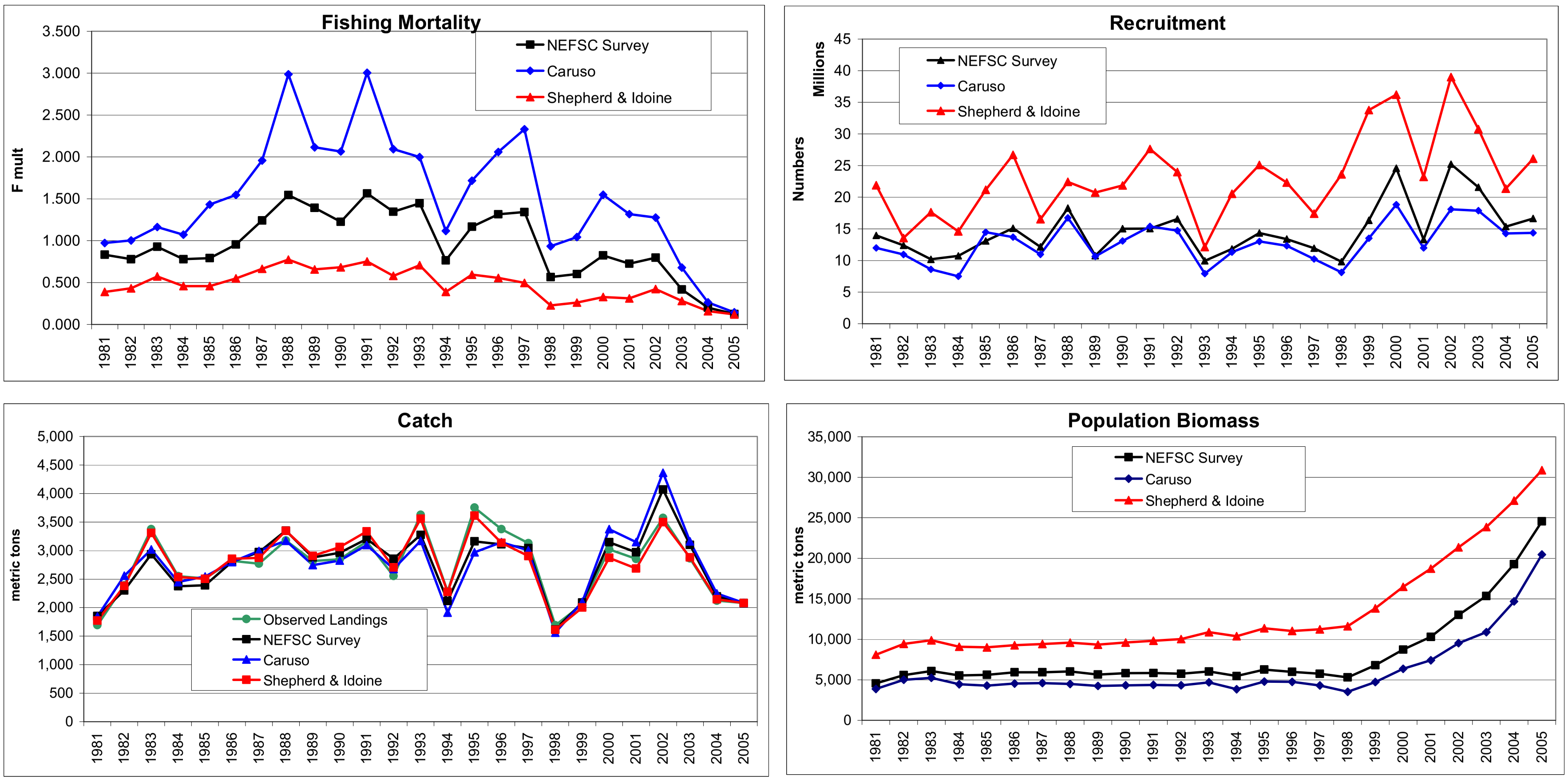


Figure 3 (Appendix C1). Black Sea Bass LTM runs 1 to 3 using three different growth models with a Vrec weight of 5 and average 82 and 86 recreational landings.

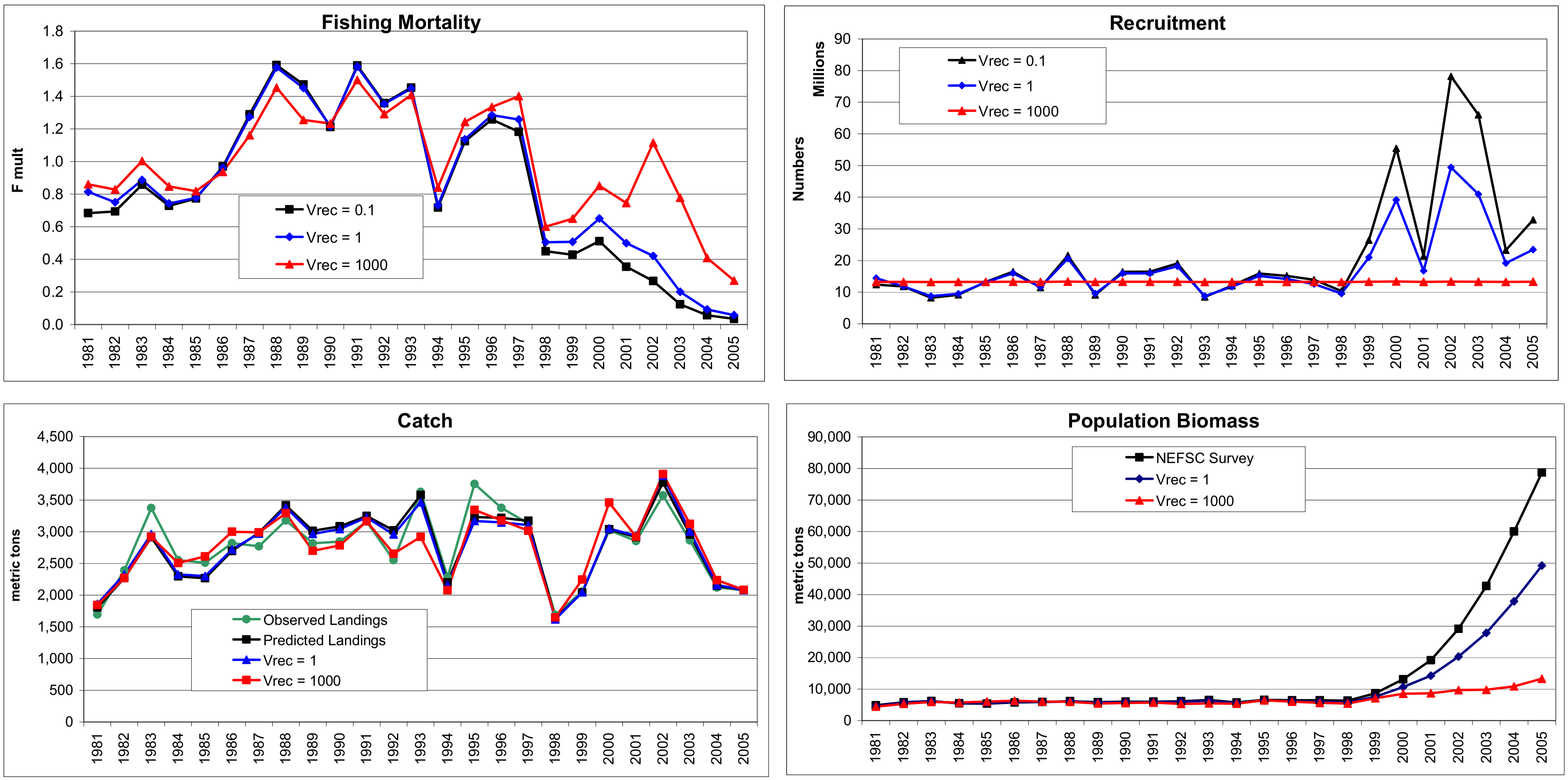


Figure 4 (Appendix C1). Black Sea Bass LTM runs 4 to 6 using three different Vrec weights (0.1,1,1000) and average 82 and 86 recreational landings.

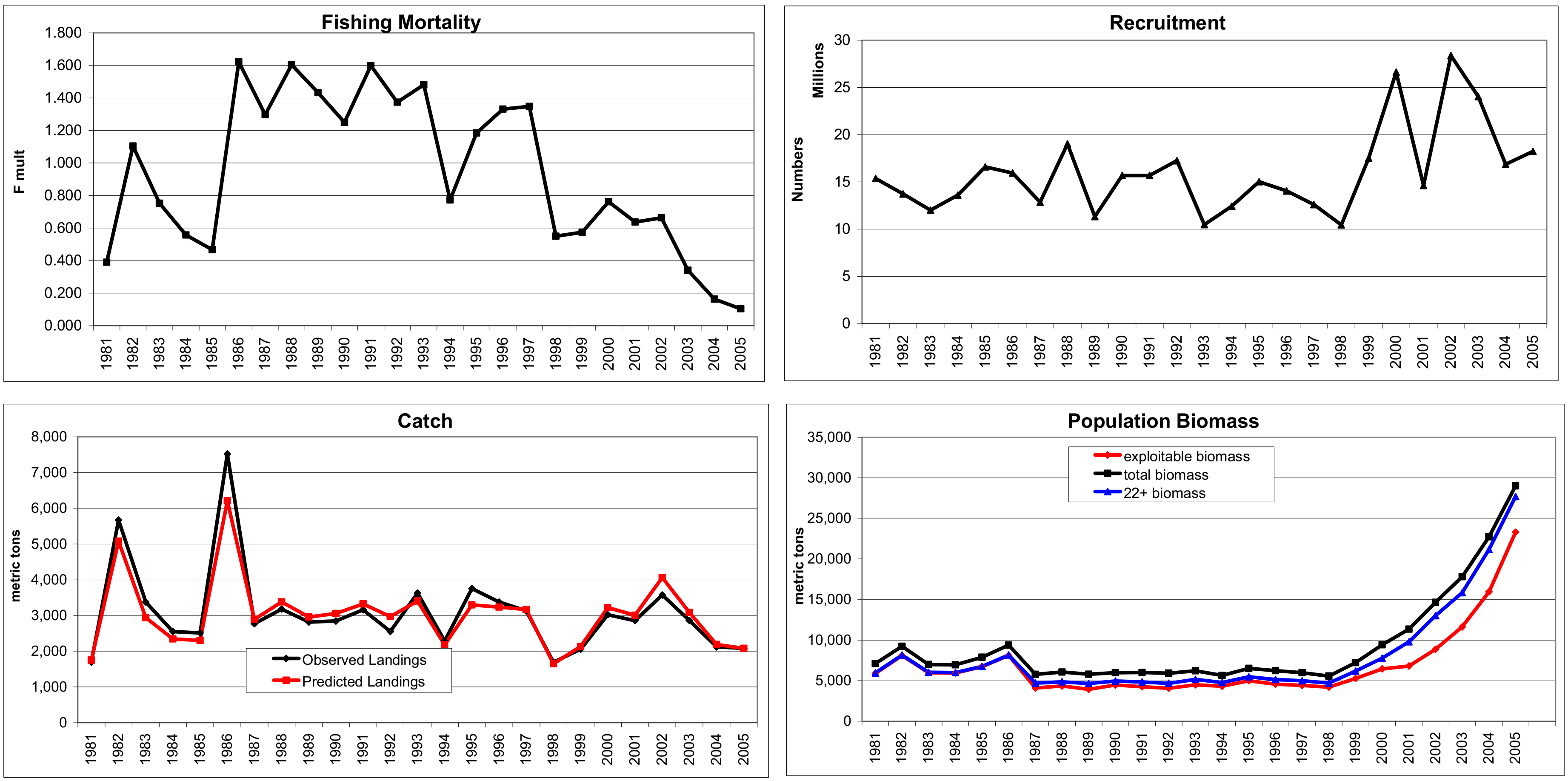


Figure 5 (Appendix C1). Black Sea Bass LTM run 7 using Vrec weight of 5 and the reported recreational landings for 1982 and 1986

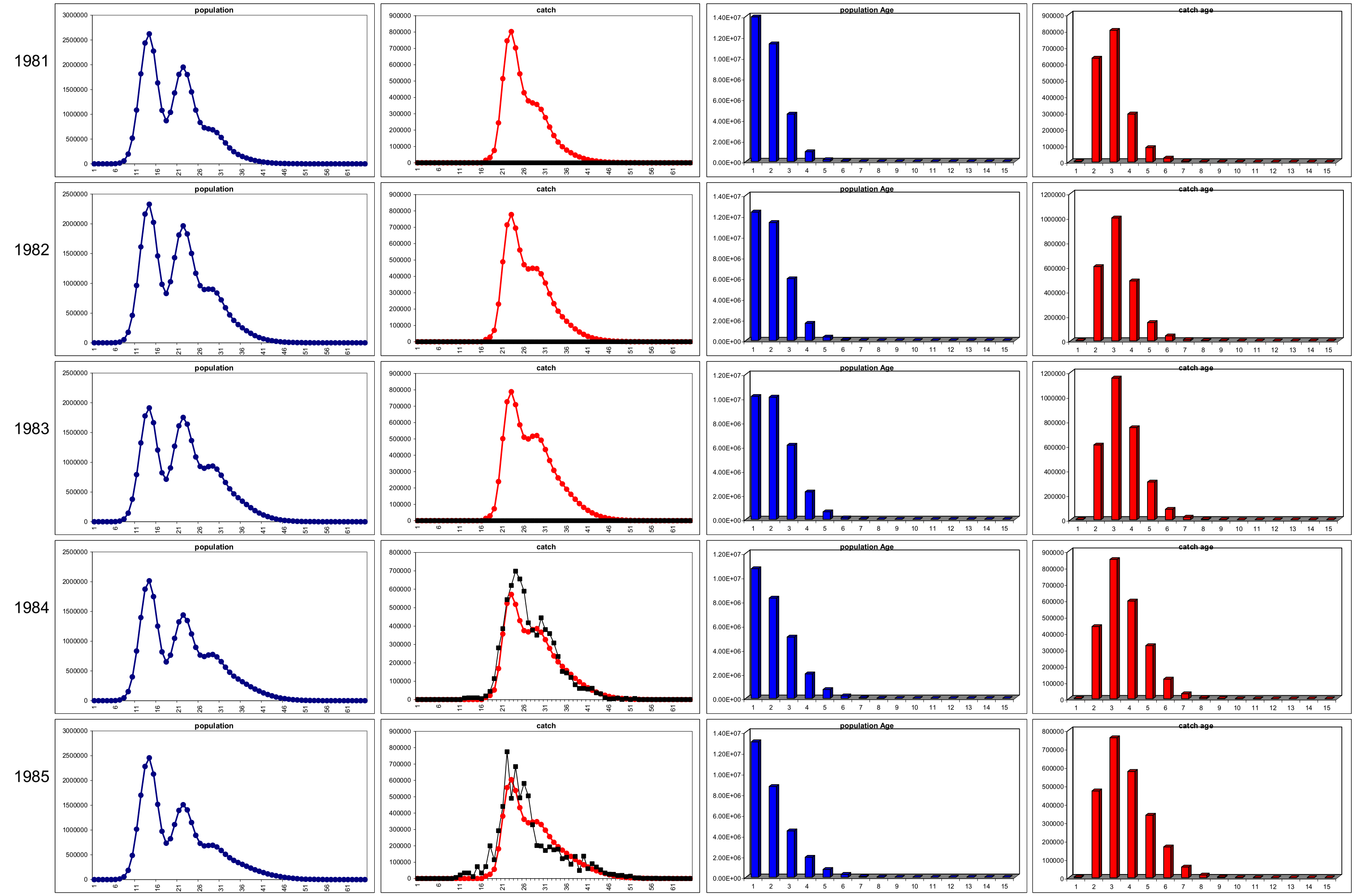


Figure 6 (Appendix C1). Black Sea Bass LTM run 3 population length frequency, observed (squares) and predicted (dots) catch length frequency, population age frequency and catch frequency from 1981-2005.

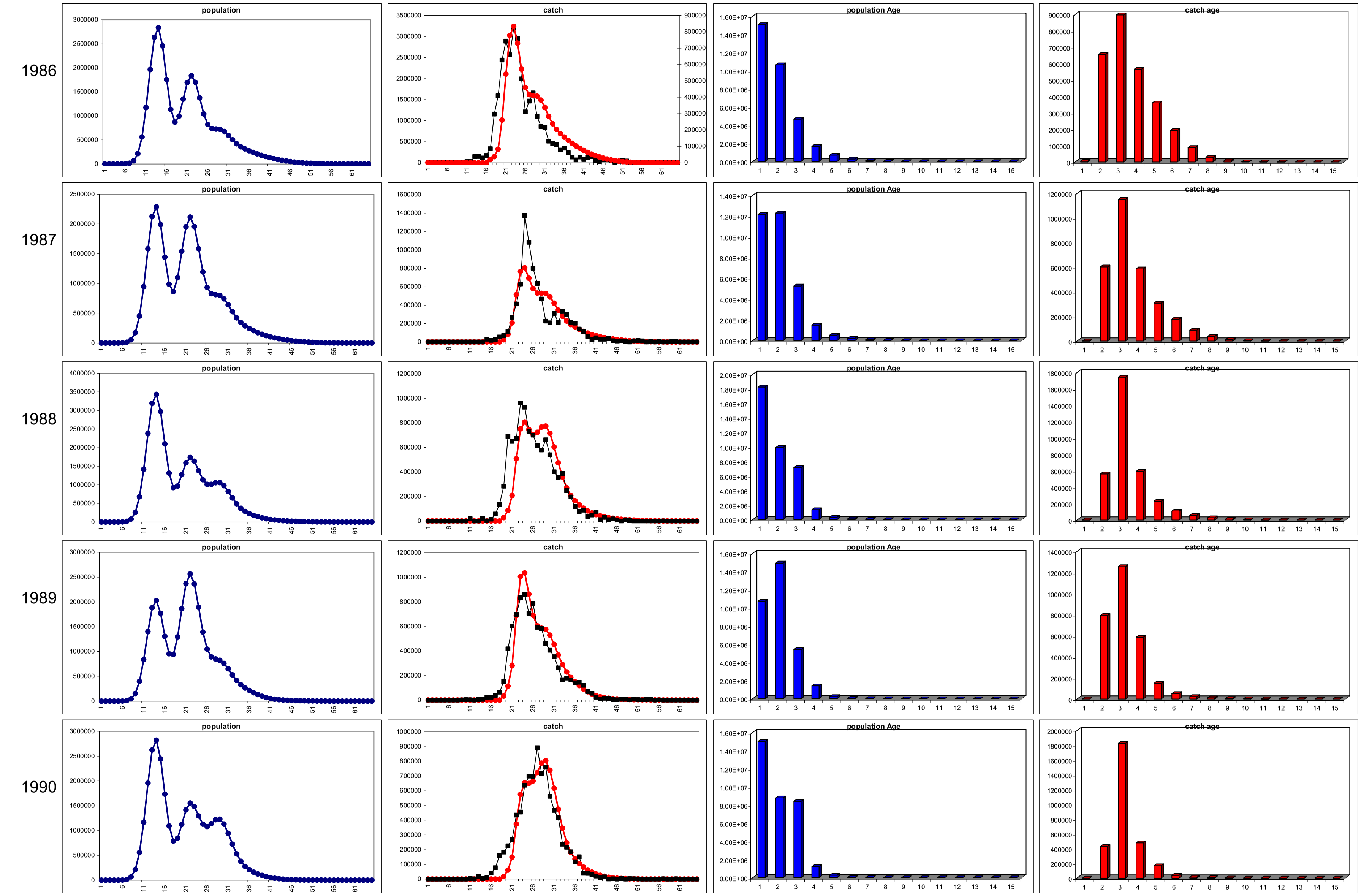
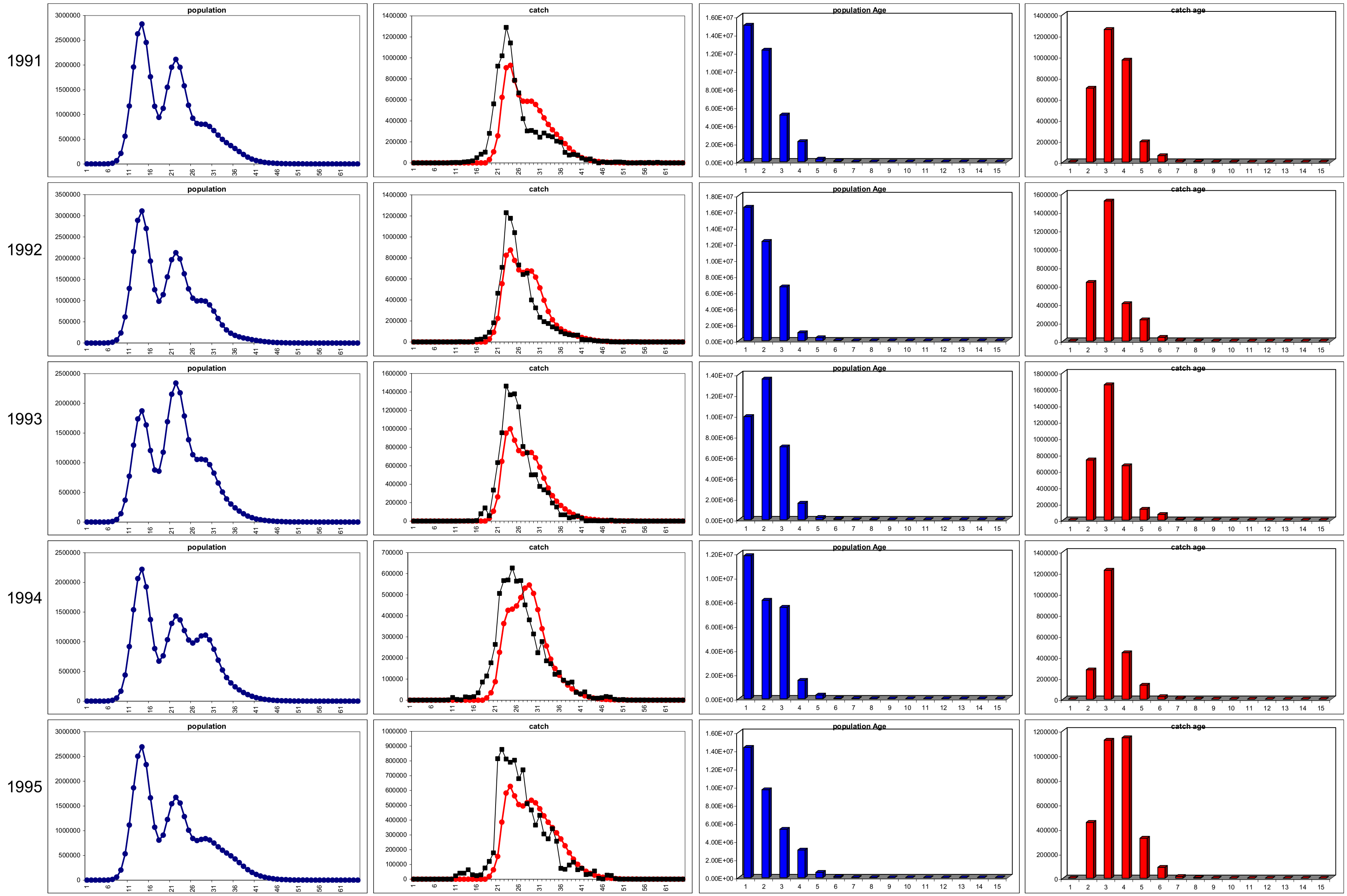
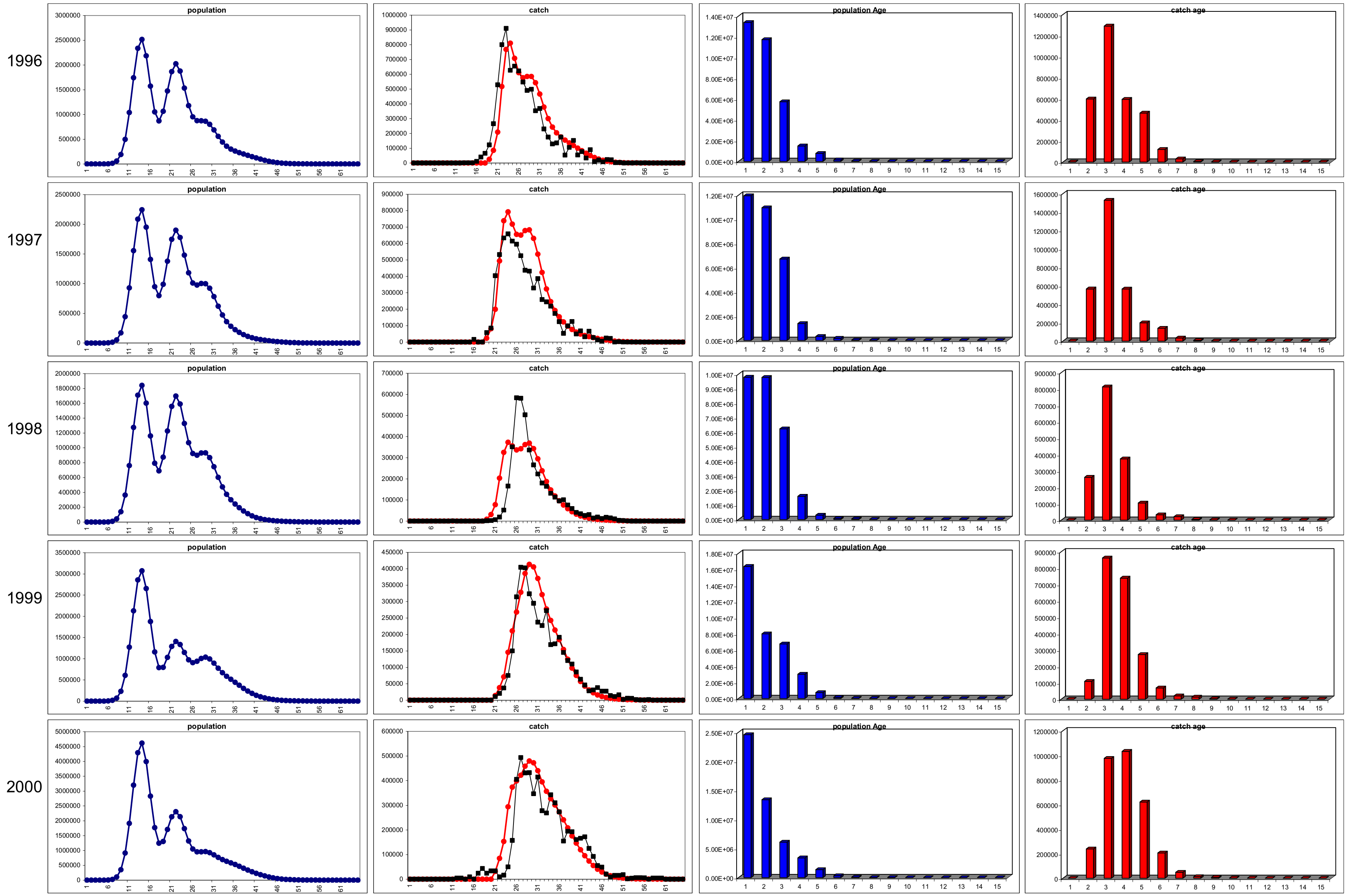

1986
1987
1988
1989
1990
population
catch
population Age
catch age

Fig. 6. cont.



1991
1992
1993
1994
1995
population
catch
population Age
catch age

Fig. 6. cont.


1996
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1998
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population
catch
population Age
catch age

Fig. 6. cont.

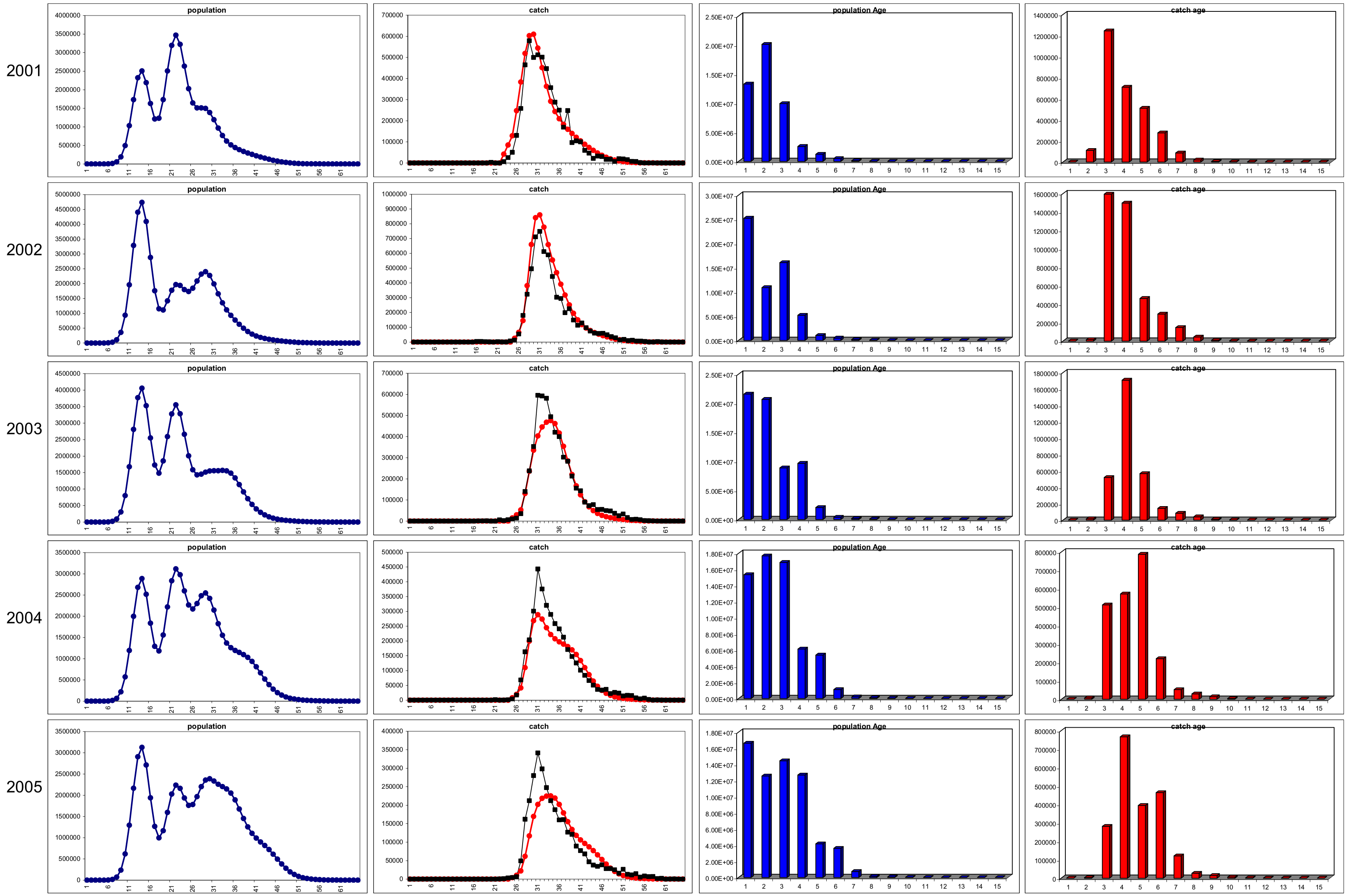

2001
2002
2003
2004
2005
population
catch
population Age
catch age

Fig. 6. cont.

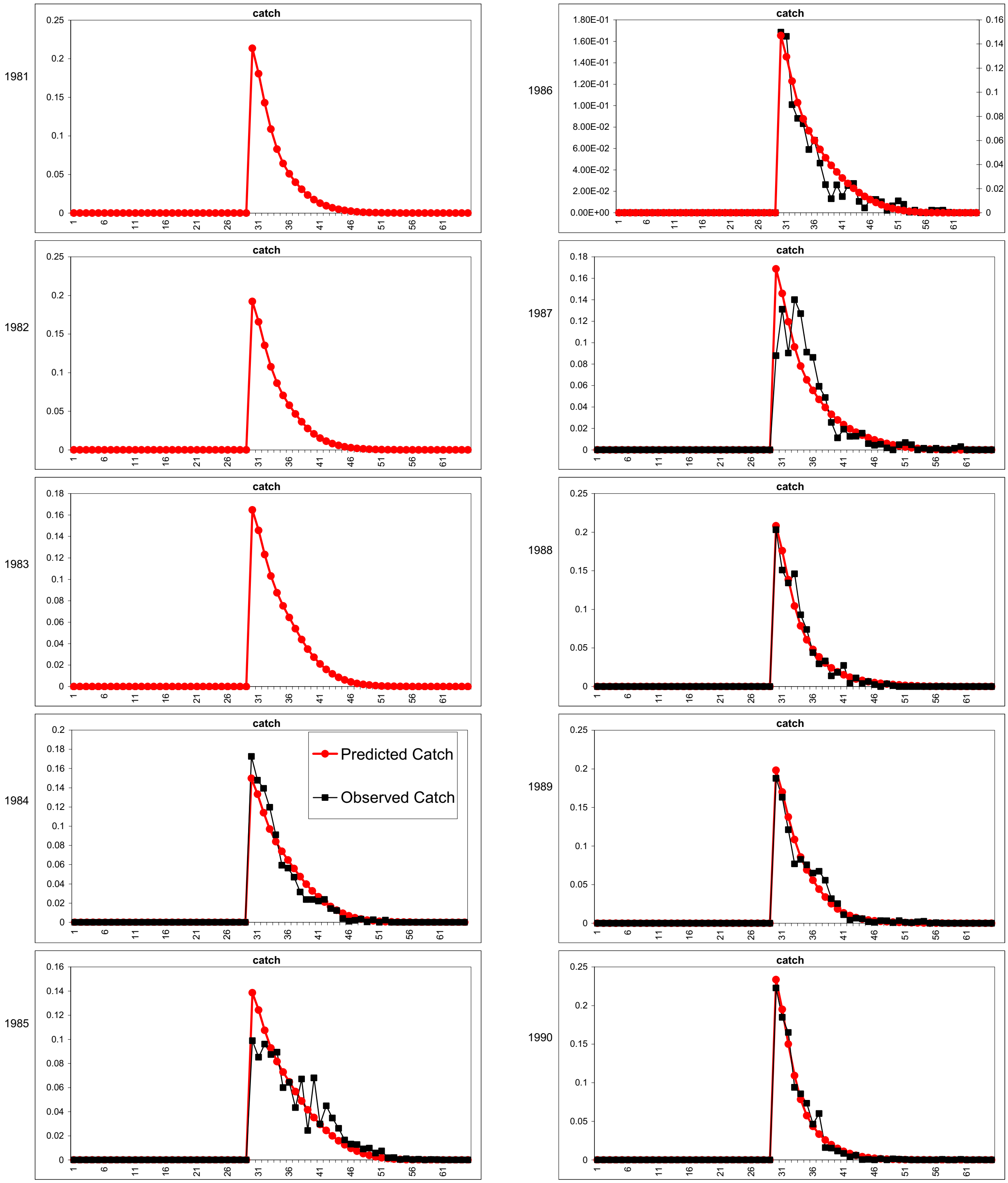
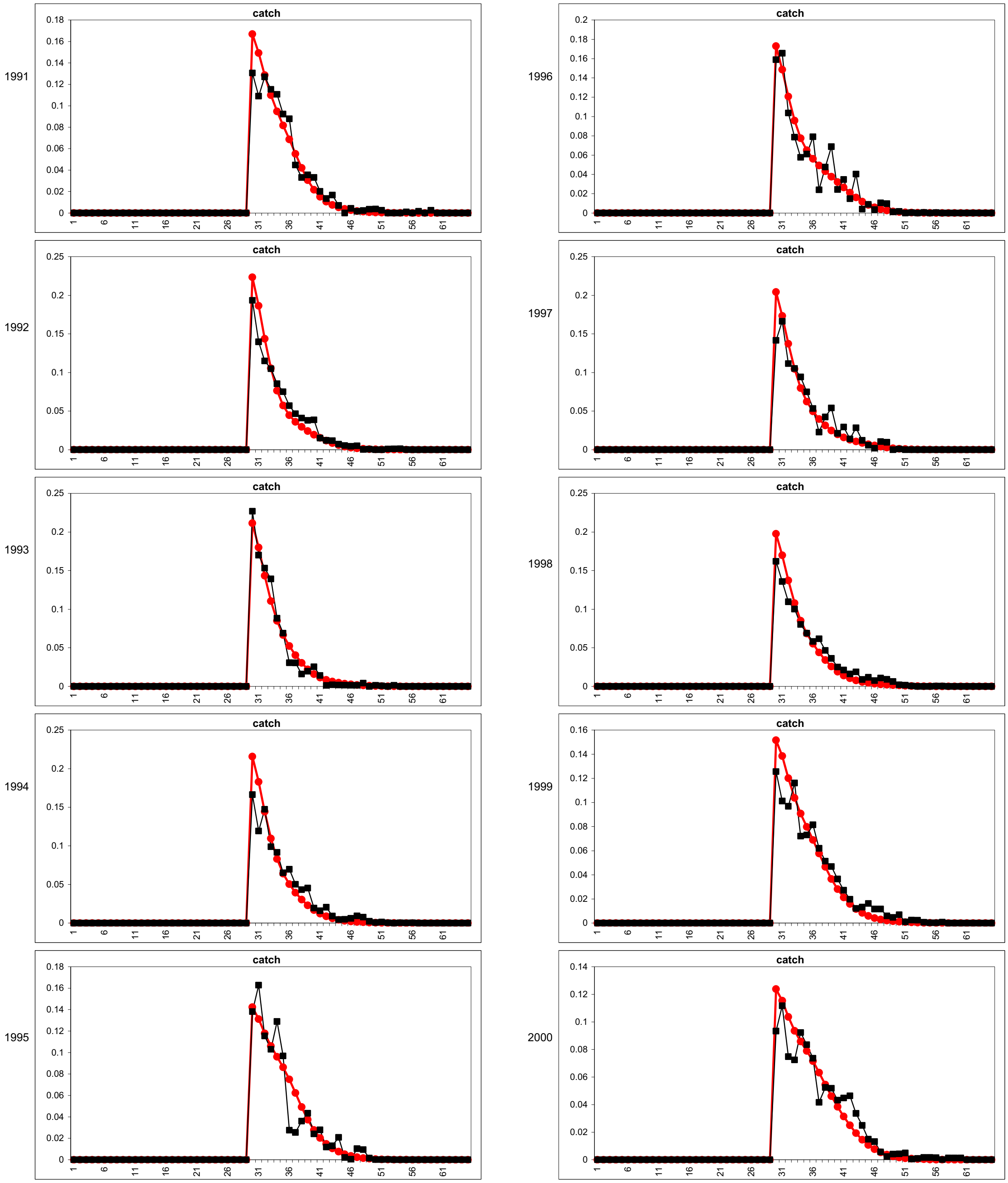


Figure 7 (Appendix C1). Black sea bass LTM run 3 observed and predicted fitted catch length frequency for 22+ cm fish from 1981-2005.


1991
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catch
2000
catch

Fig 7. cont.

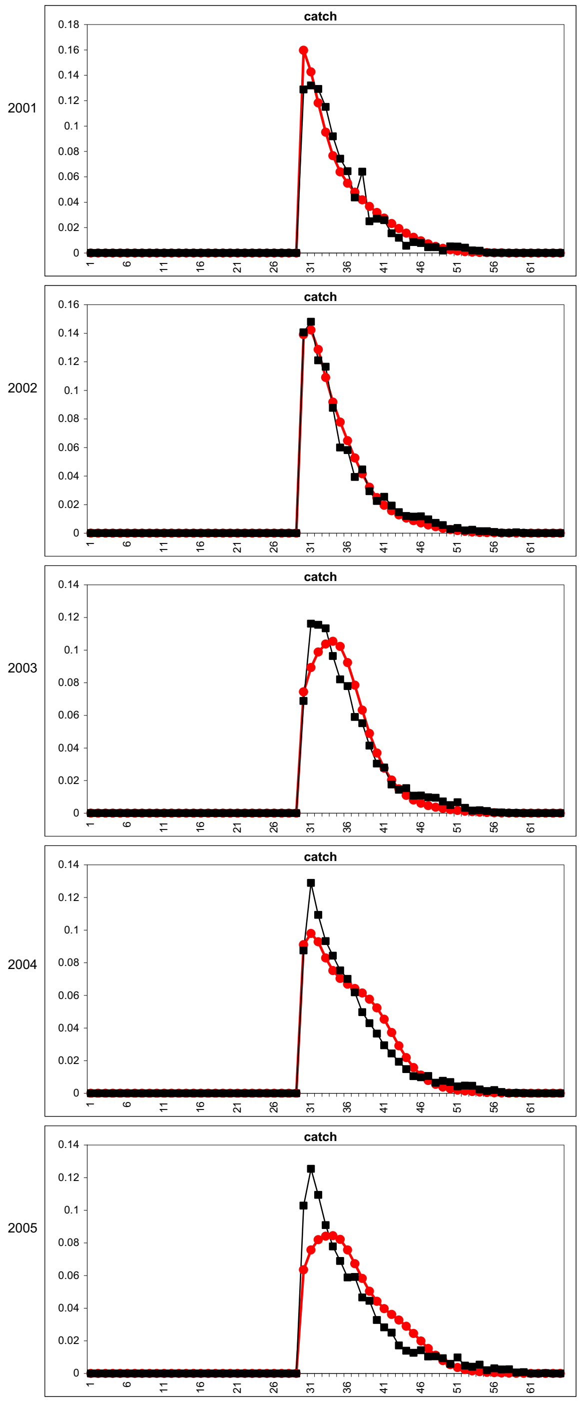


Fig 7. cont.

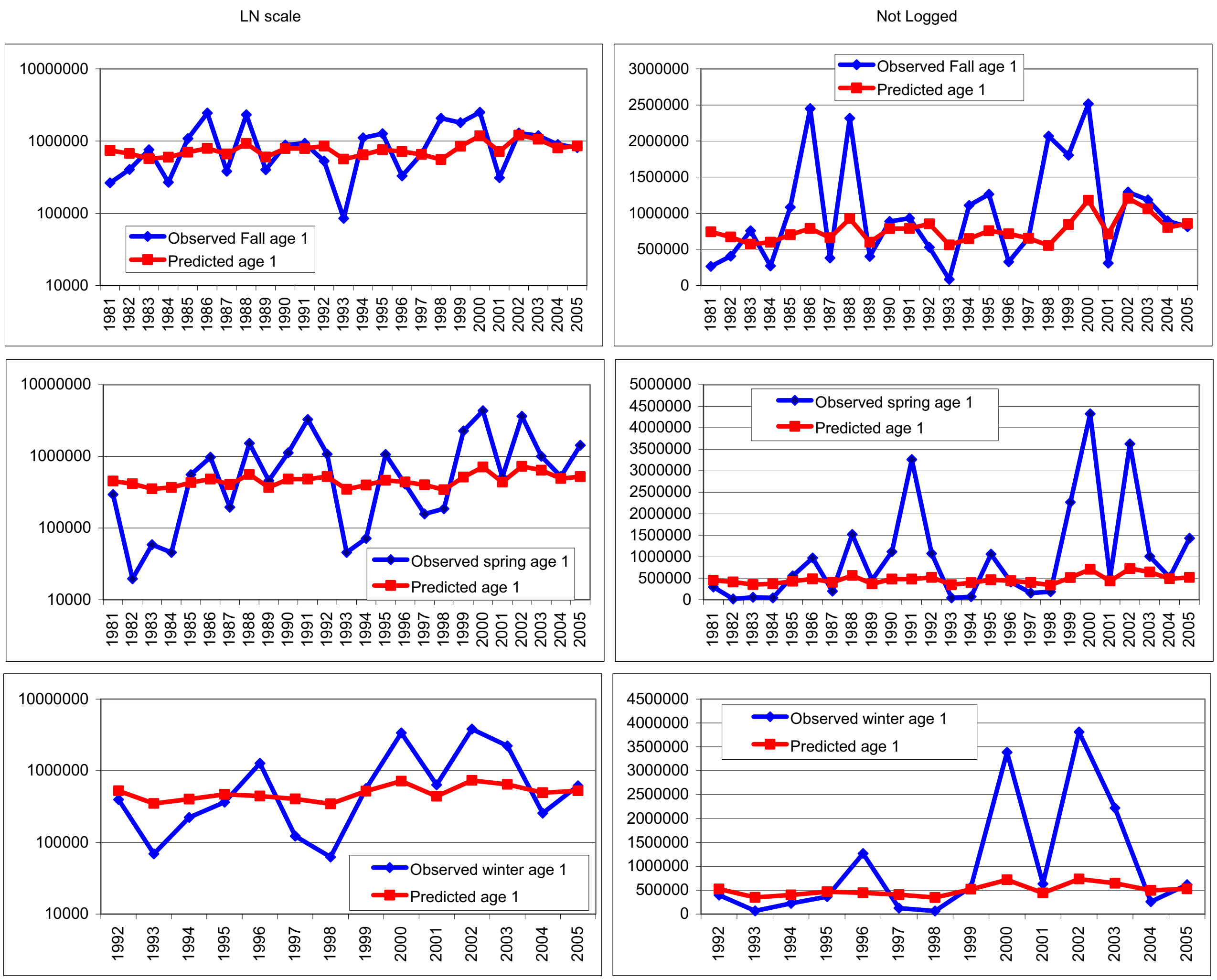


Figure 8 (Appendix C1). Black sea bass run 3 ln and nominal observed and predicted age 1 recruitment indices for the Fall, Spring, and winter NEFSC surveys.

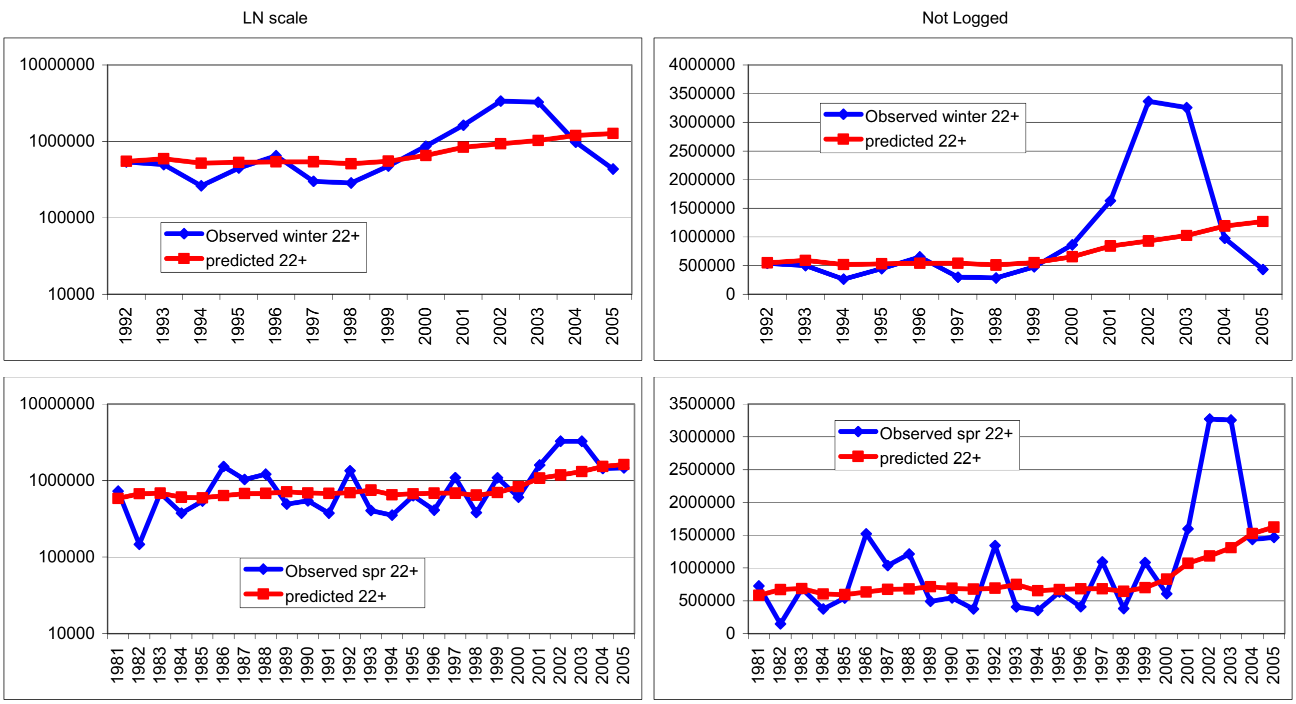


Figure 9 (Appendix C1). Black sea bass run 3 ln and nominal observed and predicted 22+ cm number indices for the NEFSC winter and spring surveys.

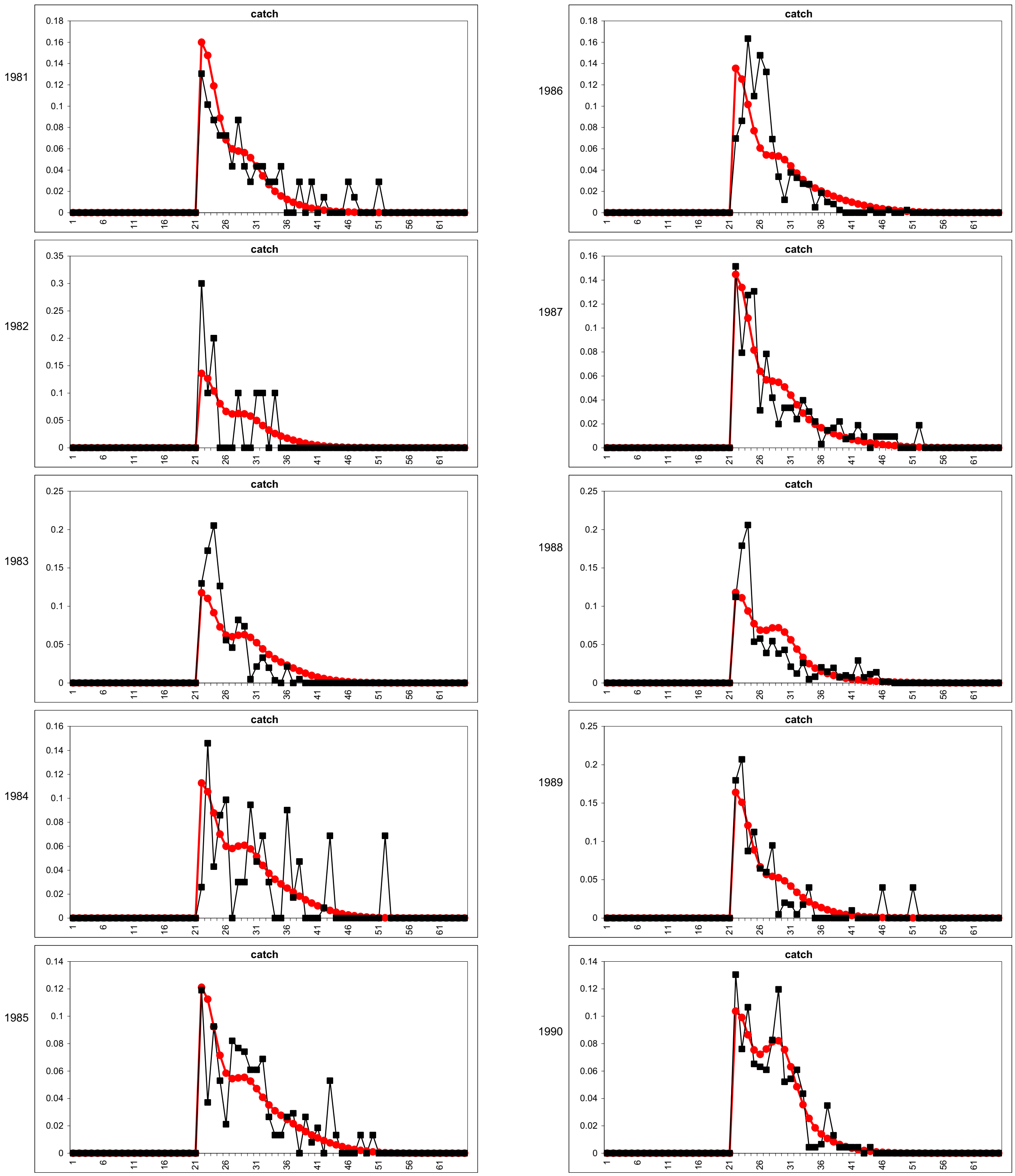
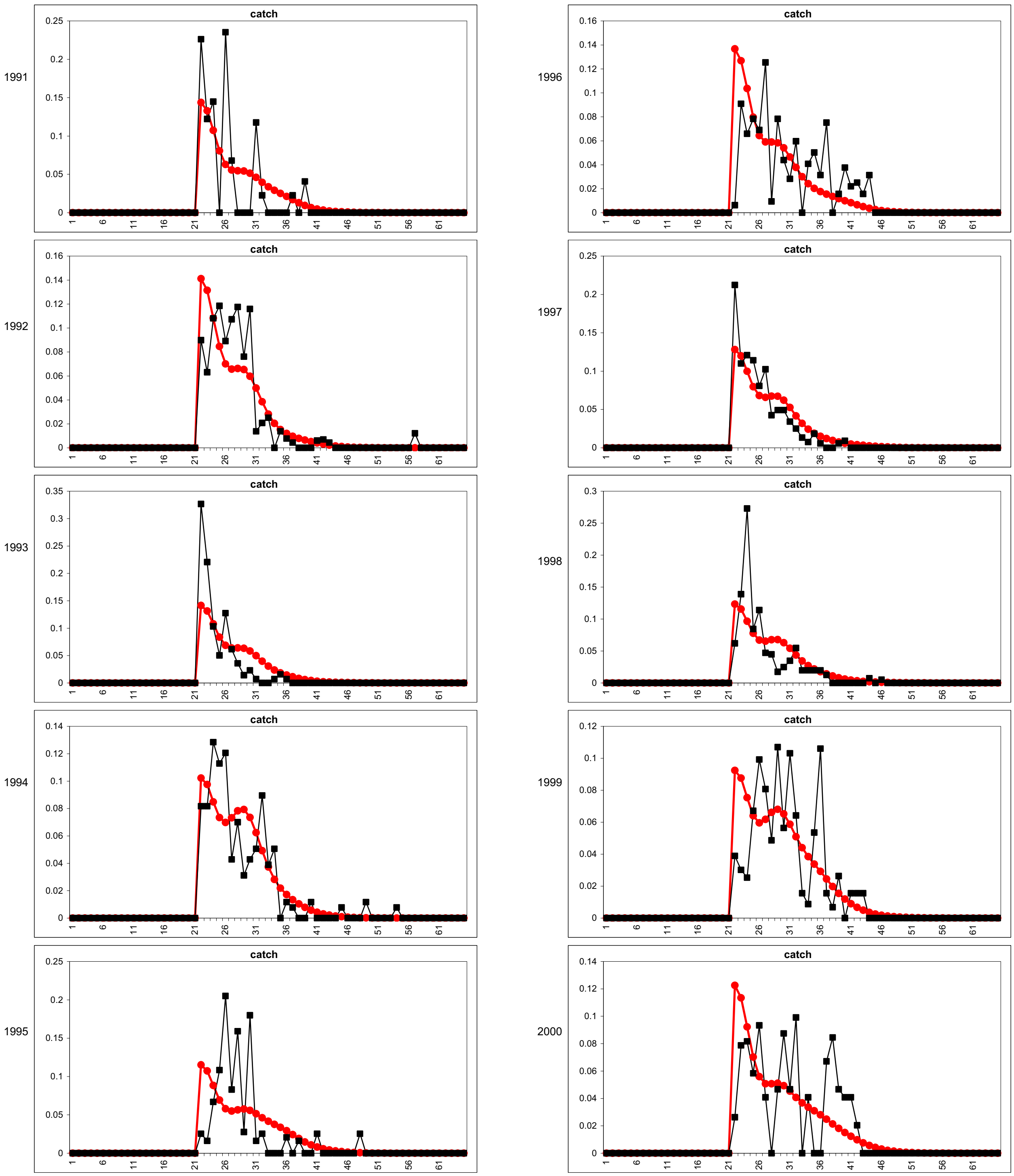


Figure 10 (Appendix C1). Black sea bass LTM run 3 observed (squares) and predicted (dots) fitted length frequency for 22+ cm fish for the NEFSC Spring survey from 1981-2005.



1991
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2000
catch

Fig 10. cont.

2001

2002

2003

2004

2005

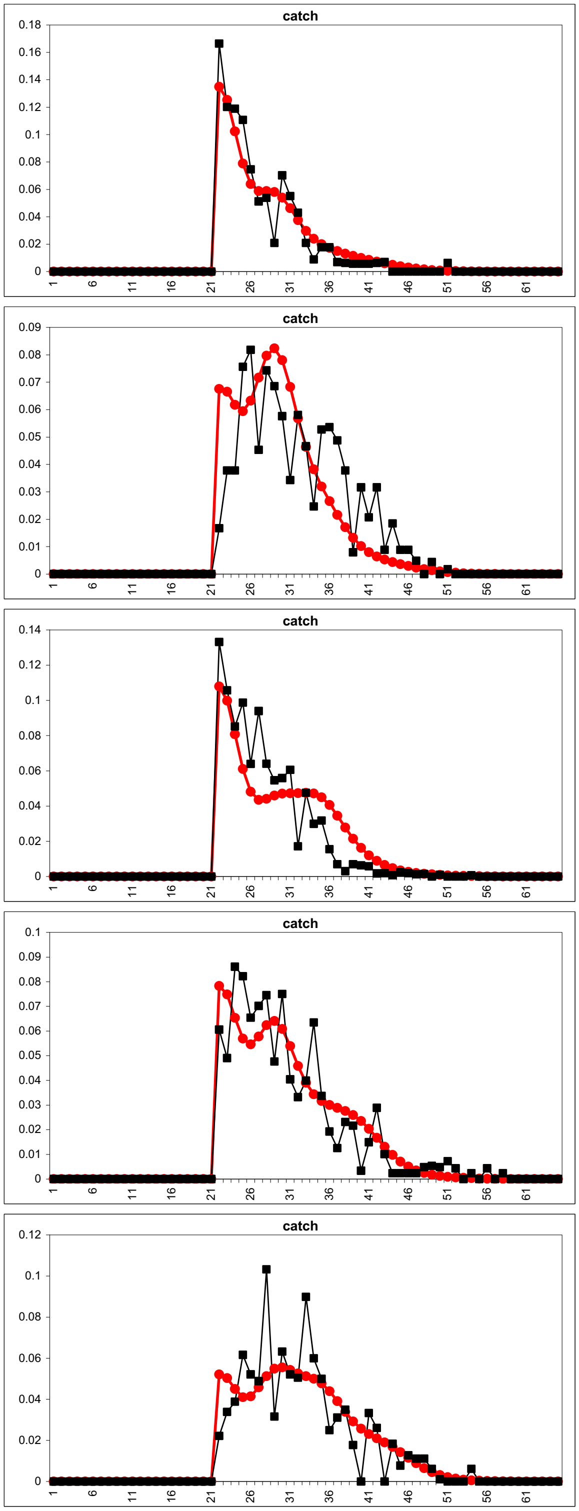

Fig 10. cont.

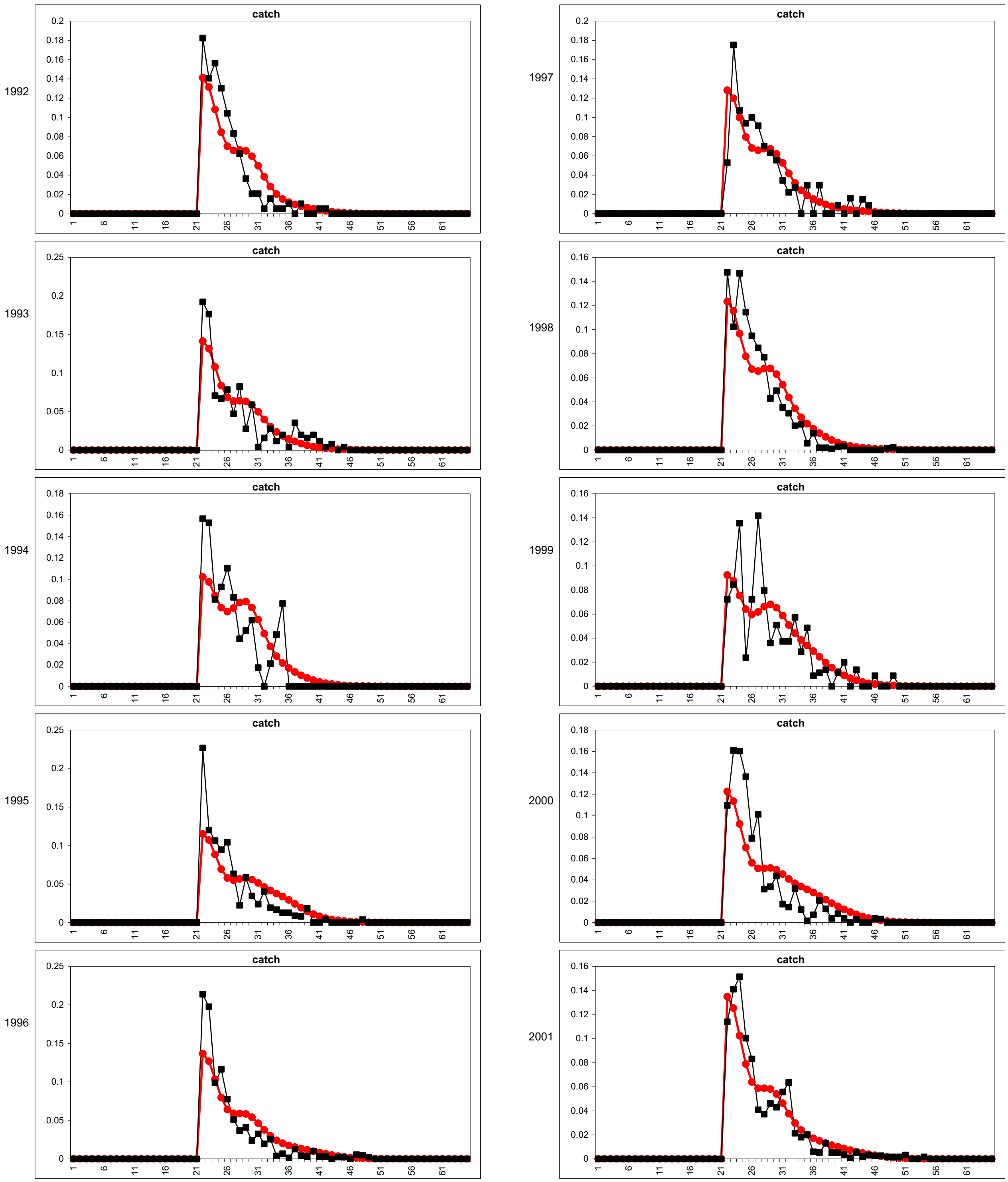

Figure 11 (Appendix C1). Black sea bass LTM run 3 observed (squares) and predicted (dots) fitted length frequency for 22+ cm fish for the NEFSC Winter survey from 1992-2005.

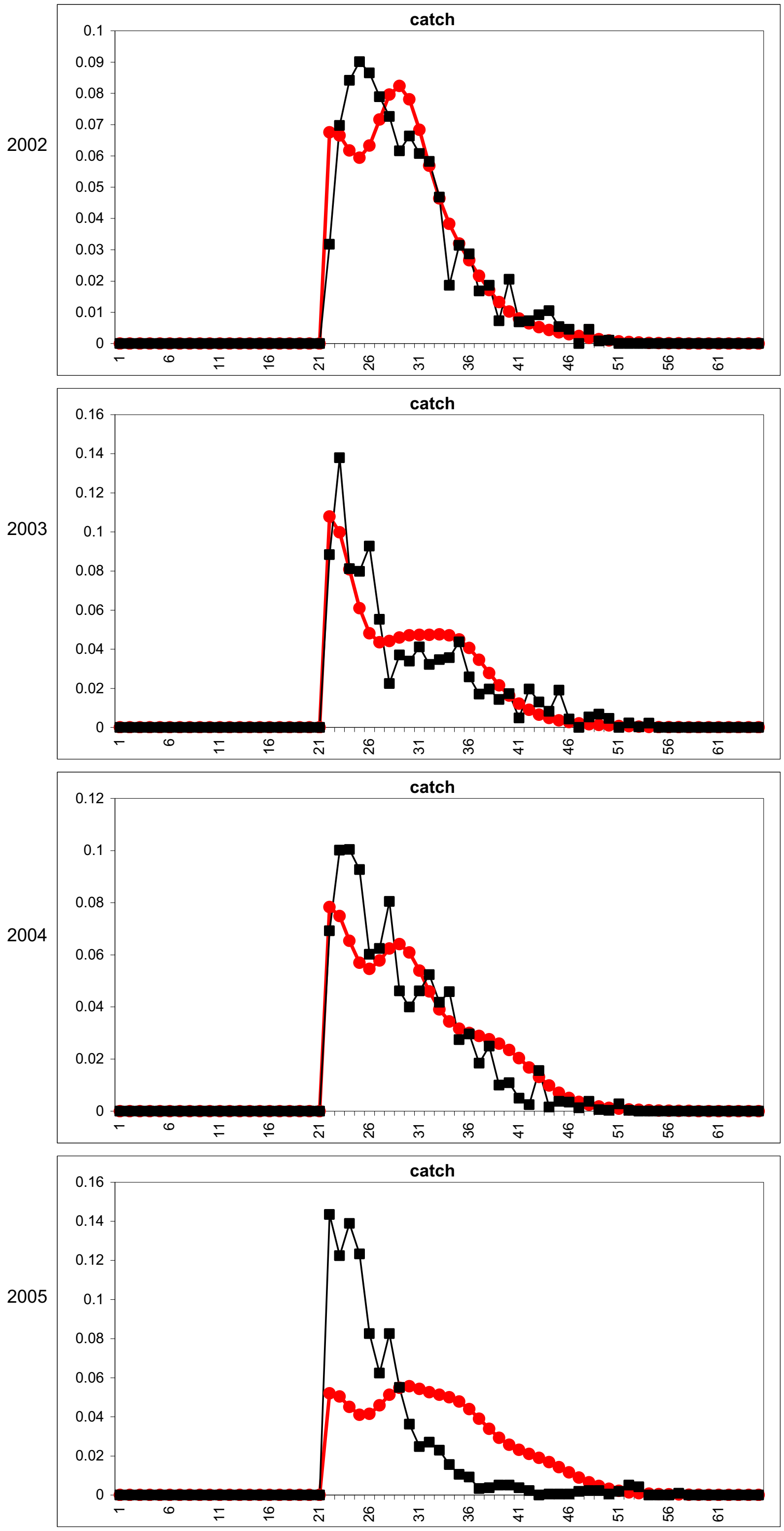

Fig 11. cont.

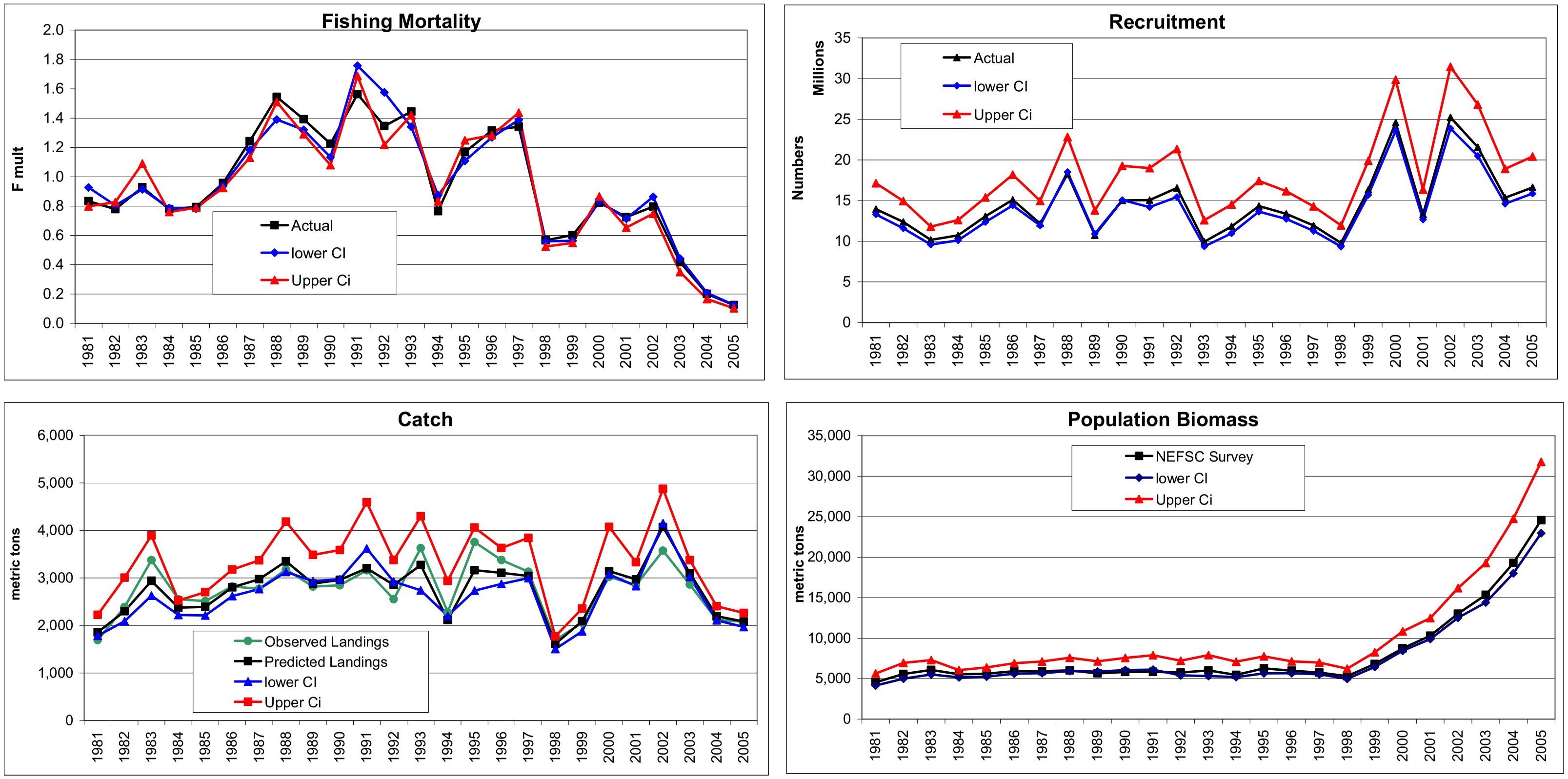

Figure 12 (Appendix C1). Black Sea Bass LTM runs 3, 8, and 9 using MRFSS median, 95% lower and upper confidence interval as the catch with a Vrec weight of 5 and average 82 and 86 recreational landings.

D. ASSESSMENT OF DEEP SEA RED CRAB

Report of the Invertebrate Working Group

1.0 TERMS OF REFERENCE

The terms-of-reference (TOR) for deep sea red crab were addressed in this assessment:

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

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

3. *Either update or re-estimate biological reference points (BRPs), as appropriate.*

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).*

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

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 or recovery schedules, as appropriate.*

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

2.0 EXECUTIVE SUMMARY

TOR 1: (*Characterize the commercial and recreational catch including landings and discards.*)

Deep sea red crab fishing, which is done with large square or conical traps, occurs year round in deep water along the continental shelf edge from the southern part of Georges Bank south to Cape Hatteras. Deep sea red crabs have been fished commercially since the 1970s, and reported landings since 1982 (excluding 1994, when there was no targeted red crab fishing) varied from a low of 466 mt (1 million pounds) in 1996 to a high of 4,000 mt (8.9 million pounds) in 2001. The number of boats participating in the fishery has varied from 3 to 22. Since the Deep Sea Red Crab Fishery Management Plan was implemented in 2002, making it a limited access fishery, landings have been stable at around 2000 mt (4.4 million pounds) and there were 4 vessels fishing in 2005. A small percentage of annual landings are bycatch from the offshore lobster fishery (section 3.2). There is no recreational fishery for deep sea red crab.

The deep sea red crab fishery is male-only, so all females and undersized males (generally < 90 mm carapace width) are discarded. Reported discards from VTR logs (from 10 to 50% percent of the catch with a mean of 32-35%) are considered somewhat unreliable because they are reported irregularly and often in units that differ from landings, but they are consistent with a mean discard rate of 29% estimated from a comparison of sea-sampled catch and landed crabs. The survival rate of discarded crabs is unknown (Section 4.5).

TOR 2: (*Estimate fishing mortality, spawning stock biomass, and total stock biomass for the current year and characterize the uncertainty in those estimates. If possible, also include estimates for earlier years*)

The main sources of deep sea red crab abundance data have been two camera/trawl surveys specifically targeting red crabs. The first survey was conducted in 1974 by the NEFSC using sled-mounted camera gear to count the crabs on the bottom and an otter trawl to catch, measure and sex the crabs (Wigley et al. 1975). A second survey, using comparable gear, was conducted between 2003 and 2005 as a cooperative research project (section 5.1).

Based on the ratio of landings and fishable biomass from the most recent survey, average (± 1SE) fishing mortality is estimated to be 0.055 + 0.008 y^{-1} during 2003-2005. These estimates do not consider potential discard mortality, which may be substantial (section 7.2).

During 1974, male red crabs with a carapace width (CW) of 114+ mm were considered the minimum marketable size. Biomass of male red crabs over 114 mm was estimated to be 23,800 mt (52.5 million lbs) at that time. The biomass estimate for these large male crabs in 2003-2005 (13,800 ± 1,334 mt or 30.4 ± 2.9 million lbs) was 42% lower, but the current fishery lands smaller crabs, with a mean size of about 105 mm CW. Fishable male biomass (including all sizes available to the recent fishery) was estimated to be 34,300 mt (75.5 million lbs) during 1974. The estimate for 2003-2005 (36,300 ± 5,459 mt or 79.9 ± 12.0 million lbs) was 5% higher. The size structure of the red crab population has changed over time, probably in response to fishing. The average male crab is smaller in size while the average female is the same size as in 1974, and young crabs of both sexes are relatively abundant (section 5.1).

The current estimated biomass of sexually mature female red crabs (70+ mm CW) is 67,900 mt (149.7 million lbs), and the estimate for sexually mature males (75+ mm) is 47,800 mt (105.4 million lbs). These estimates suggest increases of 244% for females and 29% for males since 1974 (section 5.1).

The overfishing status of red crab is unknown because no reliable estimate of F_{MSY} or its proxy (MSY) exists. According to the Deep Sea Red Crab FMP, overfishing occurs if male landings exceed MSY. Landings during 2005 were 2013 mt, which is less than the preferred estimate of MSY=2830 mt (6.24 million lbs) in the FMP.

TOR 3: (*Either update or re-estimate biological reference points (BRPs), as appropriate*)

Because very little is known about deep sea red crab biology, it is a fairly new fishery, and there have only been two red crab surveys in thirty years, it has not been possible to estimate any reliable BRPs. Until the time series of reliable landings data lengthens, and more is known about red crab growth and natural mortality, BRPs are likely to be unreliable (section 8).

TOR 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)*)

Stock status relative to a threshold for biomass was not evaluated because a reliable BRP was not available. However, the deep sea red crab stock currently appears to be at a biomass level comparable to estimates from 1974 (section 9).

TORs 5 and 6: (*Recommend what modeling approaches and data should be used for conducting single and multi-year projections, and for computing TACs or TALs*) (*If possible, 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 compare projected stock status to existing rebuilding or recovery schedules, as appropriate)*

Several model-based approaches, including length based catch curves and surplus production models, were examined for potential usefulness during this assessment. It was not possible, however, to use length based catch curves because of uncertainty about growth and longevity of red crab. Production models were not used because of insufficient surveys and commercial catch rate (LPUE) data. This is an important topic for future research (sections 6 and 7).

TOR 6: (*If possible, 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 compare projected stock status to existing rebuilding or recovery schedules, as appropriate)*

This TOR was not completed because of a lack of data on red crab growth, recruitment, and natural mortality which precludes quantitative projections (sections 6 and 7).

TOR 7: (*Review, evaluate and report on the status of the SARC/Working Group Research Recommendations offered in recent SARC- reviewed assessments*)

The previous deep sea red crab stock assessment, completed in 1977, did not include research recommendations.

3.0 INTRODUCTION

3.1 Biological characteristics

The deep-sea red crab (*Chaceon quinquedens*) is a deep-water species of brachyuran crab (family *Geryonidae*) that inhabits the edge of the continental shelf and slope off the Atlantic coast of the United States. The species is distributed between 200 and 1800 meters from Emerald Bank, Nova Scotia (and into the Gulf of Maine) and along the continental slope of the east coast of the U.S. into the Gulf of Mexico (Fig. D3.1; Pequegnat 1970; Williams and Wigley 1977; Elner et al. 1987, Duggan and Lawton 1997). Off the southeastern states and in the Gulf of Mexico the red crab co-occurs with its congener, the golden crab, *C. fenneri* (Weinberg et al. 2003). Genetic analysis suggests that the northern population of *C. quinquedens* is distinct from the Gulf of Mexico population (Weinberg et al. 2003), however the location of the boundary between these two stocks remains uncertain. Curiously, this analysis also suggests that the genetic differences between these two populations of *C. quinquedens* are greater than the differences between the two congeners, raising important questions about the designation of morphological species and the evolutionary history of these groups. For the purposes of this assessment red crab between Cape Hatteras and the Hague Line were considered a single stock.

High numbers of red crab are found on mud, sand, and hard bottom between 320 and 914 meters, and water temperatures between 5-8° C (Wigley et al. 1975). Adult red crabs are somewhat segregated by sex; adult female crabs inhabit shallower zones than adult males. Furthermore, juvenile red crabs are found in deeper waters than the adults. From this pattern, Wigley et al. (1975) suggested a deep-to-shallow migration as crabs grow and mature.

As with other large-bodied decapods, red crabs are likely to grow quickly in their early years and then molt infrequently as they approach marketable size and sexual maturity. However, information on growth in the wild is scarce. In tagging studies currently under way since 2002, over 9000 crabs between 65 and 125 mm in size have been marked with tags that are retained through the molt. Of the 180 tag returns to date, only 11 crabs, mostly smaller ones, have shown any indication of growth. While these results are consistent with previous growth studies of this and other Geryonid crabs (Melville-Smith 1989), the data are insufficient at this time to parameterize a growth model for *C. quinquedens*. On the basis of very limited, mostly laboratory-based growth data, red crab are believed to require 5-6 years to attain a desired commercial size of 114 mm carapace width (4.5 inches; Van Heukelem 1983). Juvenile crabs grow faster in warmer water, and are estimated to require 18-20 molts over some 15 years before reaching their maximum size of 180 mm carapace width (Haefner 1978, Van Heukelem 1983). Red crabs are estimated to reach a maximum size of about 180 mm carapace width, and may live for 15 years or more (Serchuk and Wigley, 1982). Prior tagging studies, while documenting movement, provided almost no information on growth because the tags used were not retained through the molt (Lux et al. 1982). However, a few crabs were captured in that study that retained their tags for more than five years, underscoring the long intermolt periods.

Male red crabs are estimated to mature at about 75 mm carapace width and can reach a size of 180 mm, a weight of nearly 1.7 kg; females begin to mature at a somewhat smaller size, and do not grow as large, reaching a maximum carapace width of about 136 mm and 0.7 kg (McElman and Elner 1982). The reported size of ovigerous female crabs varies from 80-91 mm carapace width (Haefner 1977), 80-130 mm (Wigley et al. 1975; Haefner 1977) and some as small as 61 mm (Elner et al. 1987). It is possible spawning may not occur annually if mating only occurs during molting. Mature females are estimate to have intermolt periods as long of 5-7 years (Gerrior 1981; Lux et al. 1982). On the other hand, it is possible that females store sperm and are able to fertilize more than one clutch of eggs between molts, as has been observed in lobsters (Flight et al. 2004).

Mating behavior is typical of other crabs, where the larger male crab forms a protective "cage" around the female while she molts and becomes receptive to copulation. In red crabs this protective and copulatory period may last for as long as two to three weeks, substantially longer than most other brachyuran crabs (Elner et al. 1987). Where it has been possible from camera survey to measure the relative size of the male and female in mating pairs, the males have averaged about 50% larger than the females (Bergeron and Wahle in prep.). If males are only competent to mate when they are larger than females, recent evidence that the fishery may be depleting large males (Weinberg and Keith 2003) may be reason for concern over the potential for fishery impacts on the reproductive capability of the population.

Female deep-sea red crabs brood their eggs *en masse* under the abdominal flap for up to nine months, until the larvae hatch and are released into the water column (Haefner 1978). Egg bearing females are found year-round off New England with a peak in November. The large yolky eggs hatch between January and June. As in other decapods, the fecundity and reproductive output of red crab eggs scales with female body size (Hines 1988). However, red crabs are notable for their relatively heavy investment in egg production: clutch mass as a percent of female body mass is substantially greater than in other brachyuran crabs of comparable size (Hines 1988). Red crab eggs are also among the largest of brachyuran eggs; although there is a trade-off in fecundity as a consequence (Hines 1988).

Information on the biology and distribution of red crab larvae and postlarvae is scant. Laboratory rearing studies suggest that red crab larvae may require 23-125 days to settle (Kelly et al., 1982). Larval settlement is believed to occur near the base of the continental slope (Roff et al. 1986). Recruitment to the benthos is thought to be episodic with potentially long intervals between successful cohorts (Hines 1990 cited in Hastie 1995).

There is also very little information available on the red crab habitat requirements. Nonetheless, essential fish habitat (EFH) for red crab has been defined for each life stage of this species (eggs, larvae, juvenile, adult and spawning adult) (Steimle et al. 2001). Overall, both the water column and bottom habitats above the continental shelf between depths of 200 and 1800 meters have been defined as EFH for one or more life stages of red crab (Figure D3.1). Red crab EFH is not considered to be "vulnerable" to the effects of fishing gear, and the impacts of gear used in the red crab fishery on EFH of other species is considered to be minimal and temporary in nature.

3.2 Fishery characteristics

During the 1960s and 1970s, the deep-sea red crab resource was considered underutilized, and several vessels began experimenting in the early 1970s to develop a deep-sea red crab fishery in this region. The directed red crab fishery is entirely a trap fishery. The primary fishing zone for red crab is at a depth of 400-800 meters along the continental shelf north of Cape Hatteras, NC and south of the Hague Line. Fall River, MA is the primary port for all red crab landings and all red crab are currently processed at one facility in New Brunswick, Canada. Red crabs are sold by the processor to several large food chains, primarily as generic crabmeat and cocktail claws. Landings since the Red Crab Fishery Management Plan (FMP) and limited entry were implemented in 2002 have been stable at around 2000 mt (4.4 million pounds), with four vessels currently fishing.

On the basis of a comprehensive targeted camera and trawl survey conducted by the NEFSC in 1974 (Wigley et al. 1975), Serchuk (1977) provided preliminary estimates of maximum sustainable yield for red crab at approximately 2700 metric tons (5.9 million lbs.), about ten percent of the estimated standing biomass of commercial sized crabs ($\geq$114 mm) at that time. Annual landings from the late 1990's to 2001, prior to implementation of the FMP, averaged around 3200 metric tons (7 million lbs.). If Serchuk's estimates are correct, the resource would be fully exploited at that level of fishing effort. However, these estimates are based on standing stock estimates nearly three decades old. The present stock assessment utilizes the results of comparable series of surveys conducted between 2003 and 2005 as part of a cooperative research project supported by the Northeast Consortium.

Since implementation of the FMP in October 2002, reporting of red crab landings has improved, and all vessels that land red crab are now required to report total landings by trip. Ex-vessel revenues are estimated to be about \$4-5 million dollars a year, and the four vessels involved in this fishery have a very high dependence on the red crab resource.

The average length of vessels prior to the FMP was 105 feet, ranging from 72 to 150 feet in length. Since implementation of the FMP none of the vessels have upgraded length, tonnage or horsepower. One of the four active vessels uses a rectangular wooden trap, and the other three vessels use a conical trap.

3.3 Relevant fishery management measures

The limited access program for the directed red crab fishery currently operates with a target TAC of 2688 mt (5.928 million pounds) and a 780 days-at-sea allocation. Other management measures include trip limits, limits on the number of traps permitted per vessel, a prohibition against harvesting female crabs, and other measures.

4.0 FISHERY DATA

4.1 Commercial landings

Red crab landings from dealer reports during 1982 to 2005 have varied without trend, from a low of 450 mt (1 million pounds) in 1996 to a high of 3990 mt (8.8 million pounds) in 2001 (Table D4.1). Dealers reported only 250 kg (560 pounds) of landings in 1994, however, and current industry members report that targeting red crabs temporarily stopped in 1994. Landings in 2003-2005 were between 2040 and 1900 mt (4.2 and 4.5 million pounds). Red crab landings are primarily from specially designed crab traps (Table D4.2), although some landings occur as incidental catch in offshore lobster traps. Unadjusted ex-vessel prices have risen from \$0.44-0.57 in 1982-1999 to \$0.90 in 2005.

According to dealer reports (Table D4.1), 50-150 trips landed red crab each year prior to 2003. After 2003, the number of trips declined to 63-77. Average landings per trip were between 40 and 84 thousand lbs. (18-38 mt) during 1982-1991 (Table D4.1), declined to between 7 and 22 mt (15,000 and 48,000 pounds) during 1992-1997, and varied without trend during 1998-2005 between 23 and 30 mt (51 and 67 thousand pounds). Landings since the 2002 FMP was approved are constrained to 34 mt (75,000 pounds) per trip, averaging from 25to 32 mt (56 to 70 thousand pounds), including a few trips landing red crab as incidental catch.

Vessel Trip Report (VTR) logbooks are an important source of information about the commercial fishery during 1994-2005 (Table D4.3). A small fraction of total landings was reported via VTR logbooks prior to 2002. VTR data coverage has been gradually improving, however, and included 82-85% of landings in 2004 and 2005 (Table D4.3).

Canadian landings are low compared to those in the US. Landings of 623,000 lbs (283 mt) in 1996 declined to 11 mt (25,000 pounds) by 1998, increased to 57 mt (126,000 pounds) in 2001 and then declined to 24 mt (53,000 pounds) in 2004 and 21 mt (47,000 pounds) in 2005 (D. Pezzack, Canadian Department of Fisheries and Oceans, pers. comm.).

4.2 Spatial distribution of landings

Survey strata defined by Wigley (1975) are the primary spatial unit used in this stock assessment (stratum A in the south to stratum D in the north, Figure D4.1). Most recent landings originated from the four limited access vessels that report landings via VTR logs. They include the average latitude and longitude of the area fished during each trip. Each red crab trip generally occurs in a relatively confined area, with the vessel setting roughly six trawls of around 100 traps per string. Reported latitude and longitude (with the exception of reporting mistakes) are useful for assigning landings to survey strata. Industry members report that fishing locations outside the survey strata are errors, rather than real fishing locations. Trips with mis-reported locations were assigned to the closest stratum for further use in the assessment.

US landings in 2003 and 2004 from the four limited access vessels using the VTR system are assigned to survey strata in Table D4.4. These data accounted for 55 trips in 2003 and 64 trips in 2004 (some trips had no latitude or longitude values), accounting for 1400 and 1540 mt (3.1 and 3.4 million pounds) of landings, respectively. Half of the landings on these trips were caught in Stratum C. Stratum D had the next highest reported catch and 14 trips.

Since 2001, trips were generally well distributed along the shelf break and in all four survey strata (Figure D4.1). During 2001-2005, trips in stratum D were concentrated along the southern edge of Georges Bank but fishing also occurred further east along the SE edge of Georges Bank during the late 1990s (Figure D4.2).

The names of vessels harvesting red crab are replaced in this report by codes (B-E for the four boats currently active) to enhance confidentiality. The four currently active vessels tend to fish in relatively discrete offshore areas, along a relatively narrow strip along the outer edge of the continental shelf (Figure D4.2).

Trips by Canadian vessels are generally fished on the SE part of Georges Bank, east of the Hague Line and on the southern portion of the Scotian Shelf, west of 62°30' W longitude along the 200m isobath (D. Pezzack, Canadian Department of Fisheries and Oceans, pers. comm.).

4.3 Fishing effort

Dealers provide the longest time series of fishing effort data, but it is only useful for examining the catch per trip, since the reporting of days absent by port agents was discontinued in 1994. More importantly, different sets of vessels were present in the fishery before 1994 (Figure D4.3). Changes in technology and regulations, as well as changes in vessel ownership and fishing behavior (reported to have occurred by industry members), may have also have affected catches and trip length. Industry members saw signs of these changes in vessel ownership and operation in the VTR-based LPUE data from the early to mid 1990s.

Excluding vessels that appeared to be landing red crab as incidental catch, the average catch per trip was 23-68 mt (50,000 to 150,000 pounds), depending on vessel and year. After 1994, the average catch per trip for a vessel was 23-45 mt (50,000 to 100,000 pounds) and since 2002 has averaged about 23-27 mt (50,000 to 60,000 pounds). Since the FMP implementation in 2002, the catch is limited to 34 mt (75,000 pounds) per trip by regulation, except for one vessel that qualified for a 57 mt (125,000 pound) live weight trip limit.

Although the time series is shorter than the dealer reported landings data, VTRs provide a more reliable measure of trends in LPUE. Catch per day at sea (DAS) can be derived by computing the difference between the date sailed and the date landed, which usually corresponds to when the vessel leaves the dock and when it arrives in port. Trends in landings per DAS by trip since 1995 for the four limited access vessels are shown in Figure D4.3.

Vessels also report the amount of gear fished via VTRs. The four limited access vessels in the LPUE time series typically fish 100 traps per string (trawl) and six strings per day. Some fish about 180 traps on three strings.

The VTR data were carefully reviewed to determine what gear information had been reported on each trip to calculate the number of trap hauls on a trip. VTRs contain three fields which indicate the amount of gear a vessel fishes on a trip, GEARQTY, GEARSIZE, and NHAUL. These fields can be difficult to interpret because the vessels do not report these variables in the same way and some have even changed what they report during the time series. Applying knowledge about how the vessels fish allows proper interpretation of the data and corrections where necessary. Typically, GEARQTY is reported as the number of traps on a string, but sometimes represents the total number of traps fished in a day. GEARSIZE is typically the number of strings (trawls) fished in a day. NHAULS is usually the total number of strings fished in a trip, but is sometimes reported as the number of traps fished per day. The data in these fields, while reported inconsistently, are easy to interpret for calculating the total number of trap hauls, once the type of information being reported is understood. The current vessels in the fishery typically make daily hauls of their trap strings and generally make about 2500 to 4500 individual trap hauls per trip, except for broken trips that can be identified by low landings.

4.4 Trends in nominal and standardized LPUE

Nominal LPUE

Prior to plotting trends, to enhance confidentiality, nominal landings per unit effort (LPUE) for individual vessels (either landings per DAS or landings per trap haul) were normalized to mean zero and unit standard deviation. Normalized trends in landing per DAS for each vessel were computed using data for quarters 3 (Jul – Sep) and 4 (Oct – Dec). Quarters 3 and 4 were chosen to standardize the data, because this is when the catch rates were highest and when most of the vessels targeted red crab. Vessel C tends to fish year around and has a substantial number of trips in quarters 1 and 2. The LPUE data for this vessel was standardized to the mean catch over the entire year. Outliers in the data were corrected for obvious errors or omitted if they could not be corrected and were substantially outside the normal range.

Trends in catch per DAS are shown by vessel in Figure D4.4. Catch rates per DAS in quarters 3 and 4 (the peaks in catch per DAS for vessels B, D, and E) appear to be declining slowly from 2001 to 2005. Catch per trap haul, on the other hand, declined in 2003, but then increased in 2004 and 2005 (Figure D4.5). These trends however may be deceptive if the geographic distribution of trips changes and the catch rates are more representative of localized availability than of trends in exploitable biomass.

The geographical distribution of landings per trap haul for each vessel is shown in Figure D4.6. The geographical distribution of catch per trap haul by quarter is shown in Figure D4.7. Most of the catch in strata A, B, and C is taken in quarters 3 and 4, but a large fraction is also taken in quarters 1 and 2 in Stratum D. For this reason, trends in average normalized catch rates are compared for all quarters in Stratum D, but only quarters 3 and 4 in the other strata.

The catch rates in Stratum A have generally declined since 2001 (Figure D4.8). Vessel E was the primary vessel fishing with reported trips in the stratum. Catch per DAS was lowest in 2004 and increased in 2005, whereas catch per trap haul has declined continuously from 2003 to 2005.

The catch rates in Stratum B were highest in 2002 and lowest in 2003 (Figure D4.8). The average catch rates increased in 2004 and 2005. The trends for Stratum B are based on a low number of trips, however. Vessel E reported 4 trips in 2002-2004 and Vessel B reported 6 trips in 2005.

Most trips in Stratum C are reported by Vessel D. Catch rates were lowest in 2001, reached a peak in 2002 and have since declined in 2003 and 2004. Catch rates increased in 2005.

Vessel C fished most frequently in Stratum D and has the longest time series of VTRs. Catch rates in the mid 1990s were relatively high, dropped to a low level in 2000, reached a peak in 2002 and then declined through 2004 (Figure D4.8). A small increase in catch rates was observed in 2005.

In all four strata, catch rates were generally highest in 2001 or 2002, declined in 2003 and 2004, then recovered a bit in 2005.

Standardized LPUE
Generalized Linear Model (GLM) analysis was used to standardize LPUE from VTR data for 2001-2005 because data for 2001-2005 are most complete and reliable. Log-transformed LPUE (calculated from the days absent and catch per trip information provided in the Vessel Trip Reports) were standardized in a Generalized Linear Model (GLM) using year, vessel, quarter, statistical area and quarter-vessel interaction effects. All these effects were significant (Appendix D2). The most influential variables were quarter, vessel, and year (Figure D4.9). Residual analysis (Figure D4.11) suggests good model fit.

Standardized LPUE data show some evidence of declining catch rates during 2001-2005 (starting with 2001, the average standardized catches per haul were 8.1, 9.4, 6.8, 6.3, and 7.5 kg, figure D4.10) but the time series is too short to measure trends with confidence. In subsequent years, as the time series lengthens, the standardized LPUE will become a better indicator of the stock status.

4.5 Discards

Discards reported in VTRs
Vessels generally discard female and unmarketable size male crabs. Some vessels report the amount of discards on their VTRs. The amount of discards as a proportion of the total reported catch varies greatly from vessel to vessel, and even between trips for one vessel. Some vessels report no discards in a fishery where discarding of crabs is commonly practiced. The total reported discards in Table 4.6 from VTR logs are therefore considered unreliable but may represent a minimum estimate of total discards.

Three of the limited access vessels appear to report discards fairly consistently. Based on data from these vessels, discards in the second quarter of the year appear to be somewhat higher than at other times of the year (Figure D4.12). Discards as a fraction of the catch for vessels B and C, were about 20 to 50% during the first and third quarters, with a mean value of about 32 to 35%. The proportion discarded by vessel C was about the same in quarter 4, but was only 10-30% for vessel B. This may reflect differences in discrete areas fished by individual limited access vessels (see discussion below). The proportion of crabs discarded by vessel D was lower than either vessels B and C, except during quarter 2, which may be anomalous because discards were reported on only two trips, or because discards are reported in different units than landings.

Discards based on sea- and port-sampling
Size (CW) composition data from sea samples and port samples were compared to evaluate potential discard of female and undersize male red crabs in the fishery during 2004-2005. Sea sample data were collected by a crew member on board one red crab fishing vessel that participated in a pilot program during 2004-2005. Sea samples were records of all red crabs in roughly one pot per trawl that were sexed and measured (carapace width to the nearest mm) at sea before any discard took place.

Port sample data (sex and size of landed red crabs) were collected from landings by port agents. Port samples from both years were assigned to a survey stratum based on the statistical area reported by the vessel for the location of the catch. Port sample records for statistical areas that were not from strata where sea samples were taken were excluded from the analysis.

During 2004, there were sea sample data from eight commercial trips in survey strata C and D. During 2005, there were sea sample data from six commercial trips from survey strata A, C and D. Sea sample data for 2004 were from quarters 3 and 4. Sea sample data for 2005 were from quarters 1 and 4. Port samples were from all 4 quarters in both years.

Size frequencies of all male red crabs from both sea and port samples were plotted together for comparison. Female size composition data were plotted separately (Figure D4.13). The data show that proportions of small male red crabs were higher in sea samples than in landings.

Based on visual inspection of the size composition data, male crabs smaller than 90 mm were assumed to be discarded. From 90 mm to 95 mm, half of the males in sea sample size composition data were assumed discarded. All females were assumed discarded. The potentially discarded and kept portions of the sea sample catch were converted from numbers to weight using sex-specific size-weight relationships (Farlow, 1980 cited in Steimle et al. 2001) so that discard ratios could be calculated in terms of numbers and weight. The potential discard ratios (Table D4.5) were calculated as discard divided by the total catch (males plus females).

The high level of potential discards for stratum C in 2005 is due to the large percentage of females caught there. The previous year in the same sector many unmarketable small males were caught. These data seem to illustrate the seasonality and variation in discards.

4.6 Trends in commercial size-frequency

Port agents sampled 71 trips and measured 5,954 red crabs during 2001-2005 (Table D4.6). In contrast to VTR data, port agents assigned sampled trips to three-digit statistical areas, instead of latitude and longitude. In this analysis, statistical areas for port sample data were linked to survey strata according to the following table:

Statistical areas	Survey stratum
622, 627	A
538, 616	B
526, 537	C
525, 562	D

Most of the trips and crabs sampled were caught in statistical areas associated with strata C and D. Only three trips were sampled in 2004 and 2005 from stratum A. Nine trips were sampled in 2004 and 2005 from stratum B, plus one trip sampled in 2001.

Cumulative size distributions for all areas combined (Figure D4.14), show a trend towards landing smaller red crab during 2001-2005. With the exception of 2004, crabs landed each year were generally smaller than during the year before. The apparent trend for all areas combined may have been driven by relatively few samples in the Mid-Atlantic region because no trend is evident in samples from the Georges Bank region (Figure D4.14). Changes in culling, landings of female crabs, changes in location fished, or sampling bias may also be responsible. Plots of mean size by year for each survey strata do not show trends over time during 2001-2005 (Figure D4.15).

In summary, the data provided by the fishery is extremely valuable when it comes to the management and assessment of red crab, and provides several ways of monitoring the condition of the population. Spatial distribution of fishing effort, landed crab size frequencies and LPUE are all possible to analyze on an ongoing basis through the data provided by the VTR and port sampling programs.

5.0 FISHERY INDEPENDENT DATA

This section summarizes all available fishery independent survey data for red crab. Survey data useful for red crab included those specifically targeting red crab, as well as groundfish and shrimp surveys that caught red crab incidentally.

Targeted surveys were first conducted in 1974 by NEFSC using sled-mounted camera gear and an otter trawl (Wigley et al. 1975). A comparable survey was conducted between 2003 and 2005 in a cooperative research project supported by the Northeast Consortium and led by industry-scientist partners, Jon Williams (Benthic Fishing Corp.) and Richard Wahle (Bigelow Laboratory for Ocean Sciences). The more recent surveys were conducted for the express purpose of assessing changes in crab abundance on the fishing grounds after approximately three decades of harvesting.

Non-targeted surveys include, (1) the winter, spring and fall NEFSC groundfish bottom trawl surveys, (2) the NEFSC shrimp survey, (3) the NEFSC Cooperative Monkfish survey, and (4) the Rutgers Supplemental Finfish (transect) survey.

The information presented from these surveys includes, where applicable, location of survey catches, crab densities per unit area, catch per tow, proportions of positive, and size frequency distributions. Where it is relevant to the assessment, data are presented by survey, season and sex.

5.1 Camera/otter trawl surveys

The camera and otter trawl surveys originally conducted in 1974 and repeated in 2003, 2004, and 2005 provide an opportunity to compare the red crab population before and after a period of sustained targeted exploitation for more than two decades. As much as possible an effort was made to pair camera and net tows at each survey site. Camera surveys provided estimates of population density and otter trawls provided data on sex, size, and maturity.

The 1974 surveys were conducted from the R/V *Albatross IV*, a 57 m (187 ft) research vessel operated by the National Marine Fisheries Service, Northeast Science Center. The more recent surveys were conducted from two different fishing vessels, the 96 foot F/V *Hannah Boden* and the 90 foot F/V *Krystle James*, both of which are engaged in the deep sea red crab fishery.

The locations of the camera and net tows conducted. in 1974 and in 2003-2005 are shown in Figure D5.1. The overall sampling effort spanned a segment of the continental shelf break from offshore Maryland to the eastern end of Georges Bank. Survey results are partitioned into seven depth intervals and four geographic sectors originally established by Wigley et al. (1975). The distribution of camera tow and otter trawl sampling effort by depth and sector is tabulated for all years (Table D5.1).

Specifications of the camera-sled systems and otter trawls employed in the two surveys are summarized in Table D5.2 and details of the methodology follow.

Camera-Sled System

Photographs were used to determine the density (numbers per unit area) of red crabs and associated fauna. The photographic system in both surveys was mounted on a benthic sled. The sled used in the more recent survey was somewhat smaller than that used in 1974 primarily because of constraints imposed by the smaller size of the vessels. As a result there were some unavoidable differences in the area of sea bed sampled by the two systems (Table D5.1). In both cases during preliminary trials in shallow water, a grid with known intervals was placed level on the sea floor in front of the camera to determine the area of illumination in the image. During image analysis only the best-lighted and unobscured areas of the photograph were used, and crab densities calculated for individual images were thus corrected accordingly.

The camera system used in 1974 consisted of a 70 mm Nikon film camera and stroboscopic light (see Theroux 1976, Wigley et al. 1975 for details). The camera was aimed perpendicular to the sled at a height of 1.75 m and a downward angle of 16 degrees from horizontal. In that position the camera viewed a total area of 148 m^2 although the effective area sampled (illuminated) was 31.8 m^2 (Theroux 1976, Patil et al. 1979). The system was programmed to take photographs every 10 sec; at a speed of 2 knots a photograph would be taken approximately every 10m and a 30 minute tow provided approximately 180 images.

The system used in the 2003-2005 surveys consisted of a Nikon Coolpix 990 digital still camera modified with a programmable intervalometer and computer interface software designed by Engage Technologies. The camera was housed in a deep-sea titanium housing and was coupled to a Benthos model 382 strobe (on loan from the National Undersea Research Center at the University of Connecticut). The camera was aimed perpendicular to the sled at a height of 1m with a downward angle of 35 degrees. In that position the camera viewed a total area of 10 m^2 and an effective illuminated area determined to be 6.6 m^2. This was determined using a grid subdivided into 0.01 m^2 squares placed horizontally on the sea bed in front of the camera. The system was programmed to take photographs every 15 sec; at a speed of 2 knots a photograph was taken approximately every 14m, a 30 minute tow resulting in about 120 images.

For surveys in both 1974 and 2003-2005, it was important to determine if the oblique orientation of the camera relative to the sea bed may have resulted in under-estimates of abundance because of crabs avoiding the sled in the foreground or not being detected in the background. It was only possible to evaluate this question for the 2003-2005 surveys because the photographs from the 1974 were not available. In the case of the 2003-2005 surveys, it was possible to determine if crabs were more abundant in the foreground or background areas of the photograph. A subset of 141 randomly selected photographs from the 2005 surveys was examined, all photographs containing one or more crabs. The 6.6 m^2 illuminated area of each photograph was divided into equal 3.3 m^2 foreground and background sub-areas in which crabs were counted. The null hypothesis that crabs were as likely to be present in the foreground as the background areas was tested with a simple χ^2 statistic. Crabs occurred with significantly greater frequency in the background (79% of the time) than the foreground sub-areas (34% of the time; χ^2 contingency analysis: $\chi^2 = 49.06$, df = 1, $p < 0.0001$). This result suggests crabs may have been avoiding the oncoming sled, and that the resultant density estimates may be too low.

It is possible that population estimates from the 1974 survey would be subject to the same bias, although perhaps to a lesser extent given the larger area photographed. However, it is also possible that the larger area sampled in the 1974 photographs (31.8 m^2 versus 6.6 m^2 in 2003-2005) might cause smaller red crabs to escape detection at the margins, and in turn, result in underestimates of abundance. Unfortunately, materials from the 1974 survey that might be used to evaluate this hypothesis were lost. NEFSC staff searched files and storage facilities for information about calculation of red crab densities during the 1974 camera/bottom trawl survey. Some related materials (originally the property of Roger B.Theroux) were found but no survey photos or information about processing of photo images was recovered.

Otter trawl

Net trawls were used in both surveys to collect crabs for the purpose of determining size, sex and shell condition. The nets used in the two surveys were virtually identical; specifications are listed in Table D5.2. Once the net was deployed, it was towed at 1.5- 2.0 knots for 30-45 min. The scope (wire length to depth ratio) used during the 2003-2005 surveys was consistent with that employed during the 1974 surveys (Theroux pers. comm.): it varied between 1.5 and 3 depending on depth and conditions. In the more recent surveys no net tows were conducted at depths greater than 500 fathoms (914 m) because of insufficient wire to tow successfully at those depths.

Catch numbers were standardized to catch-per-30-minute-tow. Catch-per-tow was not found to correlate strongly with the density estimate from the camera tows at the same sites ($r^2 = 0.06$); therefore catch per tow was not regarded as a reliable indicator of abundance. Otter trawl data, however, were a valuable source of information on crab size and sex composition. The sex and size composition data were used to parse density estimates from the camera survey.

Differences in results among the four surveys carried out during 2003-2005 (June, August 2003, June 2004, and June 2005) may have been due primarily to sampling errors. For use in computing recent abundance and fishing mortality, data from surveys during 2003-2005 were combined by averaging the stratum and depth specific estimates available from each individual survey. Standard errors were computed based on the four survey-specific estimates. This approach treats the individual survey estimates (rather than individual camera sled tows) as the experimental unit. Standard errors and CV's for biomass and abundance estimates calculated in this way will be relatively high because the number of observations (4) is lower than the number of camera sled tows.

Density and Abundance Estimates by Sex and Size

Figure D5.2 provides an overview of the approach whereby crab densities from camera tows and sex and size composition from net tows enabled estimates of numerical abundance and biomass. Biomass density was determined slightly differently in the two surveys. In Wigley et al. (1975), biomass density was determined by dividing the total weight of the otter trawl catch by the number of crabs in the catch to give an average weight per crab. Biomass density for a given geographic stratum is the product of numerical density and the average weight of crab in the catch.

In the 1974 survey, commercial crabs were defined as crabs of both sexes $\geq$114 mm carapace width, the marketable size at the time. Wigley et al. (1975) did not make a distinction between male and female crabs in estimating standing crop biomass. However, detailed data from otter trawl tows in the 1974 survey were available (Murray 1974) and it was possible to use the otter trawl size and sex data to prorate total abundance and biomass by size and sex.

Sex-specific size-weight relationships (Farlow 1980 cited in Steimle et al. 2001) were used in calculating biomass in the 1974 and 2003-2005 surveys:

Males: $\log W = 3.0997 \log(L) - 0.59763$

Females: $\log W = 2.75225 \log(L) - 0.34986$

where L is carapace width in cm and W is body weight in grams. Using these relationships, it was possible to convert numerical densities for any size group of crabs to biomass density.

To calculate numerical and biomass standing crop, densities were multiplied by estimates of the area of sea floor in each stratum at and depth interval. These areas in hectares (ha) were deduced from Wigley et al. (1975) by dividing the reported abundance estimate by the density estimate for each depth-sector stratum (Table D5.3).

The depth range over which densities and standing crop are estimated is 125-500 fathoms (229-914m). At greater depths net tows were unreliable and no harvestable crabs were found either in 1974 or in the more recent surveys. In strata where no tow data were available the mean value for that depth was used as a proxy value from which to calculate standing crop.

Size and Sex Composition

In 1974 a total of 795 female and 641 male crabs were collected by otter trawl. Between 2003 and 2005, 4602 female and 2209 male crabs were collected. The overall size compositions for the 1974 and 2003-2005 surveys are presented by sex in Figure D5.3. Size and sex composition differed in the two surveys in important ways. Although the overall size range and catch-per-tow of crabs from the two surveys was similar, the number of large male crabs was substantially lower in the more recent surveys than in 1974. The size composition of females differed much less dramatically, with the current size mode of female abundance falling within the same range is it did in 1974. Also apparent in the 2003-2005 size distribution is a greater proportion of crabs of both sexes in the 50 to 80 mm size range. The apparently higher abundance of these small crabs may have been due to good recruitment. It is unlikely the differences in the size composition of crabs between the earlier and more recent surveys were due to differences in the selectivity of the nets. The nets in the two surveys were virtually identical and they were towed in the same manner. Appendix D3 contains proportions at size and sex for each depth-sector stratum that contributed to estimation of density and standing crop.

Density and Abundance Estimates

Estimates of red crab biomass from the 2003-2005 surveys were compared to estimates from earlier surveys conducted in 1974. Biomass estimates are given for the following groupings of crabs: all crabs, male crabs ≥114 mm (commercial by 1974 standards), fishable crabs by current standards, as well as sexually mature crabs of both sexes. Tables provided in Appendix D4 summarize the data from which the following analysis was derived; they give numerical density, biomass density, numerical abundance, and total biomass by depth and sector for the different size and sex categories of crabs.

Total red crab biomass is estimated to have increased by two-and-a-half fold since 1974, most likely because of the larger numbers of small crabs (Figure D5.4). Despite the overall increase in crab abundance, the biomass of crabs of both sexes ≥114 mm is estimated to be down by 27% (Figure D5.4), and this decline is primarily the result of a 42% decline in large males ≥114 mm (Figure D5.4).

The red crab fishery currently harvests crabs substantially smaller than what was considered marketable in 1974 (114+ mm). Therefore estimates of the biomass of crabs 114+ mm were compared to the estimated biomass of crabs currently vulnerable to the fishery based on fishery selectivity during 2003-2005 (in Section 7 of this report). Despite the estimated decline in very large males, under the current fishery, the biomass of fishable crabs is estimated to be about 5% higher than it was in 1974, although this value falls within 1 SE of the 2003-2005 mean (Figure D5.4).

The depth distribution of red crabs during the 2003-2005 surveys (all sectors combined) was considerably different than in 1974 (Figure D5.5). In the 2003-2005 surveys, crabs of all sizes were estimated to be somewhat less abundant in the shallow zones, but considerably more abundant in the deeper zones (Figure D5.5, top). Commercially harvestable males, both by the 1974 standard (114+ mm) and currently fishable standard, were estimated to be considerably less abundant in the shallower zones while their biomass was higher in deeper zones (Figure D5.5, middle & bottom panels).

Red crab distributions by sector, combining all depths, were also somewhat different than in 1974 (Figure D5.6). In the recent surveys total crab biomass was estimated to be considerably higher in all sectors except B, relative to 1974 levels (Figure D5.6 top). The biomass of fishable males was about twice the 1974 levels in sectors A and D, but fell below 1974 levels in sectors B and C (Figure D5.6 middle). The biomass of the larger males (114+ mm) was estimated to be below 1974 levels in all sectors except in D (Figure D5.6 bottom).

The biomass and distribution of reproductive male and female red crabs also appears to have changed since 1974 (Figure D5.7). For the purposes of this assessment the size of spawning females was defined as females equal to or larger than 70 mm CW based on observations of the smallest ovigerous females. In separate surveys the minimum size of ovigerous females has ranged from 61 to 80 mm (Wigley et al. 1975, Haefner 1977, Elner et al. 1987). Male red crabs may be physiologically mature at sizes less than 40 mm (Haefner 1977), but in camera surveys males observed in copulatory embrace have averaged about 50% larger in carapace width than females. This suggests males must be considerably larger than females to mate successfully. A previous report set the size of reproductive males at 75 mm (McElman & Elner 1982). This size designation seemed reasonable for the purposes of this stock assessment because it balances the uncertainty between physiological and functional maturity and is somewhat larger than the minimum spawning size used here for females.

The depth-wise pattern of spawning male and female red crabs (all sectors combined) has changed from the 1974 pattern in similar ways (Figure D5.7). Although the biomass of spawning female and male red crabs is estimated to have declined from 1974 levels in the 175-225 fathom depth stratum, the biomass of spawning females is currently estimated to be substantially higher at greater depths (Figure D5.7).

Reproductive crabs were also compared across sectors by combining data from all depths (Figure D5.7 bottom panels). In all sectors the biomass of spawning females was estimated to be more than twice as high in 2003-2005 as it was in 1974. Differences in mature male biomass among sectors (Figure D5.7 bottom right) were similar to that for harvestable males (Figure D5.6 bottom): it was estimated to be lower than in 1974 in sectors B and C, but about twice as high in sectors A and B.

Taken together, while the targeted surveys indicate that the population of red crabs in the entire survey area is substantially greater than it was in 1974, there is evidence of depletion of large commercial size males, especially in the shallow strata and geographic sectors B and C which may be subject to most intensive harvesting.

5.2 Non-targeted surveys

Table D5.4 shows sampling intensity of the four non-targeted surveys within the red crab survey strata defined by Wigley et al. (1975). Crabs in NEFSC/NMFS trawl surveys were not reliably identified to species prior to 1999; therefore only data collected since 1999 are presented. The Cooperative Monkfish surveys and the Rutgers Supplemental Finfish surveys began after the year 2000. Crab carapace width was measured to the nearest centimeter in these surveys.

NEFSC Groundfish and Shrimp Surveys

The winter groundfish bottom trawl survey and the summer shrimp survey in the Gulf of Maine, show the most promise for tracking trends in red crab abundance along the shallow edge of the species depth range. Because of the rarity of red crabs in the catch, indices based on proportion positive tows may be more useful than indices based on numbers caught (Figures D5.8 and D5.9). Other bottom trawl surveys provide information on red crab distribution and sizes but are not likely to be useful in tracking abundance.

The winter groundfish survey covers the shelf waters of Mid-Atlantic Bight and the southern part of Georges Bank, and the spring and fall surveys cover the entirety of Georges Bank and the Gulf of Maine as well (Figure D5.10). The spring and fall surveys complete over 300 stations a year. The first survey was in 1963, and the first recorded red crab catch was in 1967. A total of 2841 red crabs were captured during NEFSC groundfish surveys during 1967-2005. Total catch (combining surveys from all seasons) averaged 36 crabs per year with the occasional larger catch mostly attributable to one or two tows. After 2000, winter survey catches increased, which may be due to an increase in sampling intensity in deeper strata initiated in 2000 (Figure D5.9).

The northern shrimp survey has taken place once a year in the summer since 1983, and covers the Gulf of Maine, using a 4-seam commercial shrimp trawl. A total of 823 red crabs (an average of 36 a year) have been identified during shrimp surveys, which generally complete between 50 and 70 stations yearly.

- ***Proportion of positive tows:*** The proportion of positive tows (tows containing red crab) in a survey can be useful for detecting trends over time for an infrequently caught species like red crab (Mangel and Smith, 1990). Sampling has been consistent in NEFSC groundfish surveys since 2001, so positive-tow data from the same survey season in different years are directly comparable. Over the last five years the proportion of positive tows for red crab from the spring and fall surveys has stayed fairly stable or decreased slightly, while positive tows have increased in the winter surveys. The number of shrimp survey tows containing red crab has been stable except for a dip in 2004 (Figure D5.9).

Independent of season, red crabs are generally taken along the Mid-Atlantic Bight and southern New England shelf break as well as in the basins of the GOM (Figures D5.11-D5.14). The largest red crabs are generally found in the southern part of the survey, while some of the smallest are found in the GOM. Males and females are caught in the same places, but females predominate numerically comprising 70% of all NEFSC crabs that were sexed.

- ***Length frequencies:*** Length frequencies of all red crabs in the NMFS database suggest a reduction in the proportion of large males resulting in a decrease in their mean size, but little change in the size of females between 1996-2000 and 2001-05 (Figures D5.15 and D5.16). Survey length data for 1991-1995 may show a recruitment event. Females caught during the winter bottom trawl survey far surpassed any other catches in number, and it appears slightly larger crabs of both sexes may be caught during the winter.

NMFS Cooperative Monkfish Surveys

The area covered by the Cooperative monkfish surveys is much the same as the spring and fall NMFS ground fish surveys, but the catches of red crab are larger and more frequent largely because the monkfish survey was designed to sample deeper areas where the heaviest commercial fishing for monkfish occurs. The shelf drops off fairly quickly, so a tow a small distance further out can be in significantly deeper water.

Two monkfish surveys were conducted in early spring (Feb/Mar to May/Jun), one in 2001 and a second in 2004. They covered all of the Gulf of Maine, Georges Bank and the mid-Atlantic Bight (Figure D5.17). Data were available for the 2001 survey from 80 stations for which data had been processed to date for an area between Delaware Bay and the Great South channel. This represents a substantially smaller area than the 304 stations for which data were available from the 2004 survey.

The mean depth of tows in which more than one red crab was caught during the 2001 monkfish surveys was 428 m, considerably deeper than the mean depth for all NMFS groundfish surveys (290 m). The shelf break north of Hudson canyon to the Great South Channel is an area where the monkfish survey tows are noticeably denser and further offshore, and the large red crab catches there contrast with the sparse catches in the same area by the bottom trawl survey (Figure D5.17). Maps of the monkfish survey red crab catch by year, size category and sex (Figures D5.17-D5.21) are similar to maps of red crab catch by NEFSC bottom trawl surveys. In particular, females outnumber males, and larger females are found in the south. Size frequencies from the 2001and 2004 Monkfish surveys (Figure D5.22) show smaller red crabs in the Gulf of Maine.

Rutgers Supplemental Finfish (Transect) Survey
These surveys sample along a transect line moving from shallower to deeper water near four offshore canyons in the Mid-Atlantic Bight, generally completing 20-30 stations per cruise. Supplementary survey data are available from eight cruises, the first March 2003 and the most recent in March 2005. All cruises took place in January, March, May or November. The surveys are meant to track the seasonal offshore, onshore and along shore movement of finfish. Since red crabs are only recorded in kilograms per tow the data are limited, but the recurring sampling in the same locations makes these surveys potentially useful for looking at trends over time. Between 2003 and 2005 the weight of crabs per haul was greatest in the deeper tows and varied without trend (Table D5.5).

In summary, although the non-targeted surveys sample red crabs at the fringe of their depth range, they have the potential to act as an index of abundance, especially those surveys with a long time series of annual catch data.

6.0 NEW ESTIMATES OF BIOLOGICAL PARAMETERS

No new estimates of growth, maturity or natural mortality were developed in this assessment. Various length based approaches were applied to survey size data for red crab to estimate growth and maturity parameters. Results were uncertain and this area is an important topic for future research.

7.0 ABUNDANCE AND MORTALITY INFORMATION AND ESTIMATES

Camera/bottom trawl estimates of fishable biomass and landings data were used to estimate fishing mortality for male red crab in this assessment. Several more sophisticated model-based approaches, including length based catch curves and surplus production models, were examined also. It was not possible, however, to use length based catch curves because of uncertainty about growth and longevity of red crab. Production models were not used because of insufficient survey and commercial catch rate (LPUE) data.

7.1 Fishery selectivity

Fishery selectivity curves estimated in this assessment measure the relative probability that red crabs of different sizes will be taken in the fishery and landed. Fishery selectivity should be low for small red crab and should increase with size because small individuals are not marketable.

Fishery selectivity curves for deep-sea red crab were estimated in this assessment by comparing length composition data from port samples during 2004-2005 to length composition data from the camera sled/bottom trawl survey during the same years. In effect, the survey length composition data were used as length composition data for the population. The survey bottom trawl had a small mesh liner that increased retention of small individual red crabs so that they might occur more frequently in survey bottom trawl catches.

Fishery length data were originally in numbers of individuals measured per 1 mm size group by trip. Fishery length data from all trips in each statistical area and year were combined by addition. Survey length data were originally in numbers caught per standard 30 minute tow and 1 mm size group. Survey length data from all tows in each survey stratum and year were combined by addition. Commercial and survey length data were then aggregated by 5 mm size groups for subsequent analyses. Five millimeters is likely the range of measurement error in commercial length data for red crab.

Survey and commercial length composition data indicate that red crabs in the north are larger than in the south. There were differences in survey length composition data for 2004 and 2005, probably due to sampling error arising from relatively few survey stations. Based on preliminary analyses, survey and commercial length data were assigned to northern and southern regions and data for 2004 and 2005 were combined. The resulting length composition data were converted to proportions at length for further analysis.

For survey data, the southern region included strata A and B while the northern region included strata C and D. Regions for commercial data were based on statistical areas used to report landings. In particular, the southern region included statistical areas 533, 613, 615, 616, 621, 622, 623, 625, 626, 627, 631, 632, 635, and 636 while the northern region included statistical areas 522, 525, 526, 534, 537, 541, 543 and 562.

The approach to estimating fishery selectivity curves for red crab was a method for limited data first used by NEFSC (2004) for ocean quahog. Fishery selectivity was modeled using ascending logistic curves:

$$\hat{s}_L = \frac{1}{1+e^{\alpha+\beta L}}$$

where $\hat{s}_L$ is predicted commercial selectivity at size L (mm, $0 < s_L < 1$), and α and β are parameters estimated in Excel by nonlinear regression and least-squares. The lengths used in the regression analysis were the midpoints of the 5 mm length groups (e.g. 92.5 for the 90-94 mm size group). Residuals minimized by least-squares were:

$$r_L = L(s_L) - L(\hat{s}_L)$$

where $L(p)$=ln(p)/ln(1-p) is the logit transformation for the proportion p. The logit transformation is commonly used in regression analyses with proportions. Only size groups with both survey and commercial data were used in the regression analysis.

The estimated selectivity curves for both areas were similar and it would be reasonable to use a single curve estimated with data from the southern and northern regions combined in analyses for the whole stock (Figure D7.1, and see below). Fishery selectivity for red crab in all regions during 2004-2005 is near 0% at sizes less than 80 mm. After 80 mm, fishery selectivity increases rapidly and is nearly 100% by 120 mm. Red crabs reach 50% selectivity at about 90-94 mm (see below). The steep ascending part of the selectivity curve occurs at the same lengths as the steep left-hand side of the fishery length composition data (Figure D7.1).

Fishery selectivity parameters for deep-sea red crab during 2004-2005.

Estimate	South	North	Combined
α	26.95	32.37	26.86
β	-0.2991	-0.3461	-0.2905
$L_{50\%}$ (mm)	90	94	92

7.2 Biomass and fishing mortality during 2003-2005

Fishable biomass for red crab is the portion of total stock biomass that is fully available to the commercial fishery. Fishable biomass is important because it can be used to calculate exploitation and fishing mortality rates. In particular, if C is catch in weight and B is average fishable biomass during the year, then the annual fishing mortality rate is $F=C/B$ (Ricker 1975). Biomass estimates for male red crab approximate average annual biomass because they are from camera/trawl surveys conducted during summer (i.e. midyear). For red crab, landings data (assumed to be 100% male) are used instead of catch data because estimates of mortality due to discard at sea are not available.

Average fishable biomass for male red crab during 2003-2005 was estimated based on fishery selectivity and average abundance at length in video/trawl surveys during the same years. Fishable biomass was calculated:

$$B = \sum_{L=1}^{150} B_L s_L$$

where B_L is average fishable biomass of red crab of size L, and s_L is commercial selectivity at size calculated using parameters for the northern and southern regions combined. Fishable biomass during 1974 was calculated for comparison based on the same fishery selectivity curve. It was not possible to compute fishing mortality during 1974, however, because the fishery in 1974 selected larger (114+ mm CW) individuals (Serchuk 1977).

Fishable biomass of male deep-sea red crabs averaged ($\pm$1SE) 36,250 $\pm$ 5,460 mt (80 million lbs) during 2003-2005, while landings averaged about 2000 mt (4.4 million lbs) per year (Table D7.1). In contrast, and based on the selectivity curve for the recent fishery, fishable biomass was about 34,000 mt (76 million lbs) during 1974 (Table D7.2). According to Serchuk (1977) landings during 1974 were about 503 mt (1.1 million lbs). Fishing mortality rates for deep sea red crab averaged 0.057, 0.031, 0.100, 0.030 in survey strata A-D, and 0.055 $\pm$ 0.008 y^{-1} for the stock as a whole during 2003-2005. The Standard Error term for fishing mortality SE_F was calculated assuming that the coefficient of variation for fishing mortality ($CV_F = SE_F/F$) is equal to the CV for recruited biomass ($CV_B = SE_B/B$). Thus CV_B = 5459/35,253 = 0.15, and SE_F = $F(CV_B)$ = 0.055(0.15) = 0.008. This further assumes no error in landings data and that the average biomass estimate is log-normally distributed. Thus, $SE_F = F\ (SE_B)$ = 0.55 (0.15) = 0.008. More detailed information about the calculation of confidence intervals for estimates of fishable biomass during 1974 and 2003-2005, and fishing mortality during 2004-2005, can be found in appendix D5.

Substantial discards of male and female red crab likely occur in the red crab fishery. Mortality due to discarding is unknown. If discards are substantial and discarded red crab often die, then fishing mortality estimates for male red crab based on landings underestimate mortality rates due to fishing. Fishing mortality rates for females are assumed to be zero in this assessment because females are relatively uncommon in landings. However, mortality of discarded females due to fishing may be substantial if discard mortality is high.

8.0 BIOLOGICAL REFERENCE POINTS

Lack of data about growth, longevity, and trends in abundance precluded estimation of new reference points in this assessment. Based on the previous assessment, MSY for deep sea red crabs 114+ mm (males only) is 1/2 M B_o = 2,494 mt (5.5 million lbs.). This estimate assumes that the natural mortality rate M is 0.2 y^{-1}, the minimum market size is 114mm, and that the estimate of exploitable biomass from the 1974 survey was made when the stock was near the virgin level (B_o). The 2002 FMP includes a preferred estimate of MSY=2,830 mt (6.24 million lbs) which was calculated using the same model but assuming a natural mortality of M=0.15, a minimum market size of 4 inches (101mm) and an expanded fishing area. Due to uncertainty about biological parameters and the model used to calculate MSY, these estimates are considered invalid. More accurate estimates were precluded in this assessment by lack of information about growth, longevity and trends in abundance.

9.0 CONCLUSIONS ABOUT STOCK STATUS

The deep sea red crab population and fishery appear to be at sustainable levels. The red crab fishery has had a noticeable impact on the stock of large male red crabs ≥114 mm carapace width which were considered marketable in 1974. Since 1974 the abundance of large males has decreased by 42%, probably in response to fishing. However, the biomass of currently marketable male crabs which includes smaller individuals has increased by 5%. Small red crabs less than about 60 mm appear to be abundant relative to 1974. Current landings during 2002-2005 averaged approximately 2000 mt (4.4 million lbs), and were comparable to average landings of about 2300 mt (5 million lbs) during 1982-2001 as the population was being fished down from the virgin state. Results of this stock assessment are consistent with the hypothesis that the red crab population has been fished down from a virgin state over the past 30 years and is currently at a productive biomass level. There are, however, several key issues that contribute uncertainty to this conclusion (i.e. lack of biological information about growth and longevity that could be used to estimate stock productivity and information about discard mortality, see below).

Camera/bottom trawl surveys directed at red crab and carried out during 1974 and 2003-2005 are the main source of information about biomass. Biomass of female red crab increased during 1974 to 2003-2005. Total biomass of male and female red crab 114+ mm CW was 25,900 mt during 1974 and declined by 27% to 18,990 ± 2160 (1SE) mt during 2003-2005. Average biomass of male red crab large enough to contribute to the fishery during 2003-2005 was more than one-half of the level observed in 1974. Biomass of male red crab 114+ mm was 23,794 mt during 1974 and declined by 42% to 13,769 ± 1334 during 2003-2005. Fishable male biomass (which includes all sizes available to the recent fishery) was 34,264 mt during 1974 and increased by 5% to 36,253 ± 5459 mt during 2003-2005. Biomass of red crab ≥ 114 mm CW decreased while fishable biomass increased because small red crabs which contribute to fishable biomass were abundant during 2003-2005. Small red crabs are abundant suggesting good recruitment, although this may be due to higher probability of detection for small red crabs in the 2003-2005 surveys.

LPUE and fishing effort were stable during 2001-2005. Landings fluctuated without trend during 1982-2005 and were stable during 2001-2005. Regulations preclude landing female red crabs but discard mortality may occur. Fishery size data show declines in the proportion of large male red crabs which are targeted by the fishery.

The fishery during 2003-2005 targeted smaller red crabs than during the 1970's when most of the landings consisted of red crabs 114+ mm CW. During 2003-2005, 50% of male red crabs were fully available to the fishery at 92 mm CW.

Fishing effort (number of vessels and total days fished) is effectively controlled by a limited entry program but latent effort exists because current days at sea allocations (DAS) have not been fully utilized. The fishery is managed under a target TAC that has not been reached in recent years.

Red crab catches have been fairly stable in bottom trawl surveys directed at groundfish and shrimp. Survey size data show evidence of reductions in the relative abundance of large male red crab.

Based on the ratio of landings and fishable biomass, average ($\pm$ 1SE) fishing mortality is estimated to be 0.055 + 0.008 y^{-1} during 2003-2005. These estimates do not consider potential mortality due to discard of undersized male or female red crabs, which are protected by regulations. Discard of undersized males and females are likely substantial but discard mortality rates are uncertain.

Discards consist of female crabs (which are not landed by regulation) and male crabs too small to sell. Comparison of port sample data and sea sample data from one vessel during 2004-2005 suggests that discard levels for males and female red crab average about 29% of total catch weight. VTR data are harder to interpret but indicate discard levels of 32 to 35%. Mortality rates for discarded red crab are unknown.

As currently defined in the FMP, overfishing is not occurring because landings of male red crab during 2003-2005 were 2013 mt, which is less than an estimate of MSY (2670 mt) from the last assessment (Serchuk 1977), and less than the FMP preferred MSY of 2830 mt. However, these MSY estimates are based on the assumption that the natural mortality rate is either 2.0 (Serchuk) or 1.5y^{-1} (FMP), which is probably unrealistic, and a stock assessment method which is more applicable to short-lived productive fish stocks. If red crabs are long-lived, then the estimated MSY level may be misleading and the stock is likely to be less productive than expected.

Stock status relative to biomass thresholds and targets is unknown because biological reference points have not been defined.

10.0 RESEARCH RECOMMENDATIONS

10.1 Commercial fishery data:

- Investigate seasonal patterns and magnitude of red crab discarding through sea sampling, and compare sea-sampled discard rates with VTR reported discard rates.

- Look into a possible industry-based sampling program for assessing size and sex of discards.

- Assess survival of discarded red crabs.

- Document in detail the configuration and features of the traps currently used by vessels in the fishery, and investigate changes in trap design that would reduce catch of unmarketable (small) red crabs.

- Consider whether there may be a way of reporting trip data that would be more readily translatable to LPUE.

10.2 Biological data:

- Develop a better understanding of the reproductive cycle, maturity schedule, fecundity of the deep sea red crab, and the potential reproductive consequences of removing large males from the population.

- Develop a better understanding of the growth rate and molt cycle of red crab.

- Examine red crab sex ratios: can they be standardized by depth so that comparisons can be made from year to year and changes in the ratio tracked?

- Information on larval supply, transport, settlement and early juvenile distributions and abundance would contribute to an understanding of recruitment processes.

- More detailed bathymetry of the continental slope would be beneficial to an understanding of this and other deepwater species.

10.3 Assessment methods:

- Evaluate the use of a size-structured and sex-specific stock assessment model compatible with the data available.

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12.0 ACKNOWLEDGMENTS

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RED CRAB TABLES

Table D4.1 Annual red crab landings during 1982-2005 from dealer/weighout reports.

YEAR	Landings, live wt., mt	Average price ($/kg)	Total trips	Average landings (mt) per trip
1982	2,446	$1.04	78	31.36
1983	3,253	$0.96	101	32.21
1984	3,876	$1.00	106	36.56
1985	2,237	$0.97	66	33.90
1986	1,249	$1.01	34	36.73
1987	2,111	$1.23	71	29.73
1988	3,593	$1.45	117	30.71
1989	2,394	$1.25	63	37.99
1990	1,527	$1.24	84	18.18
1991	1,791	$1.11	52	34.45
1992	1,061	$1.07	49	21.66
1993	1,440	$1.07	73	19.73
1994	0	$1.01	4	0.06
1995	572	$1.25	83	6.89
1996	466	$1.06	48	9.70
1997	1,726	$1.08	104	16.59
1998	1,501	$1.13	60	25.02
1999	1,870	$1.10	67	27.90
2000	3,130	$1.58	102	30.69
2001	4,004	$2.02	147	27.23
2002	2,143	$1.87	84	25.51
2003	1,920	$2.15	70	27.43
2004	2,041	$2.35	77	26.50
2005	2,014	$2.39	63	31.96

Table D4.2 Annual landings (mt) by gear type from 1982-2005 based on dealer reports.

Year	Crab traps	Lobster traps	Trawls	Other	Total	Dealers	Vessels
1982	2,422	24			2,446		3
1983	3,231	22			3,253		5
1984	3,875	1			3,876		7
1985	2,237	0			2,237		7
1986	1,247	2			1,249		8
1987	2,107	3			2,111		14
1988	3,556	37	0		3,593		22
1989	2,390	3		0	2,394		10
1990	1,517	10	0		1,527		17
1991	1,789	2	0	0	1,791		11
1992	1,058	1	0	2	1,061		12
1993	1,432	1		7	1,440		12
1994		0	0		0		3
1995	50	520	2	0	572	6	14
1996	33	426	0	7	466	6	8
1997	1,084	641	0		1,726	7	11
1998	959	542			1,501	6	4
1999	1,526	343		0	1,870	5	6
2000	2,500	630		0	3,130	5	6
2001	3,969	24	9	0	4,004	6	12
2002	2,143	0		0	2,143	4	9
2003	1,717	62	112	30	1,920	3	5
2004	2,008			33	2,041	4	7
2005	2,014				2,014	2	4

Table D4.3 Annual reported landings and discards (mt) of red crab from 1994-2005 vessel trip reports (VTR) logbooks.

year	vessels reporting	trips	landings	discards	discards as a percent of landings
1994	8	12	1	5	500%
1995	16	84	283	153	54%
1996	20	83	637	493	77%
1997	15	77	591	330	56%
1998	13	80	198	84	42%
1999	10	93	421	0	0%
2000	11	163	344	64	19%
2001	18	150	1,753	301	17%
2002	10	80	1,521	93	6%
2003	9	62	1,412	99	7%
2004	10	104	1,733	764	44%
2005	11	77	1,642	600	37%

Table D4.4 Landings (mt) by year and survey stratum from vessel trip reports, 2003 and 2004.

Zone_	2003	2004
A	277	516
B	26	54
C	724	654
D	364	326
Total	1,392	1,550

Table D4.5 Number of sea-sampled and port-sampled crabs, and proportion of catch assumed discarded by weight and numbers.

Year	Survey Stratum	N Crabs in Sea samples	N Crabs in Port Samples	Female Proportion Discard (weight)	Male Proportion Discard (weight)	Female Proportion Discard (numbers)	Male Proportion Discard (numbers)	Proportion Total Discard (weight)
2004	C	770	564	0.16	0.08	0.22	0.14	0.24
2004	D	645	227	0.06	0.05	0.11	0.09	0.12
2005	A	323	468	0.04	0.34	0.04	0.48	0.37
2005	C	456	593	0.51	0.04	0.64	0.06	0.55
2005	D	689	399	0.12	0.03	0.21	0.05	0.15
Mean	all	577	450	0.18	0.11	0.24	0.16	0.29

Table D4.6 Number of red crabs measured by port agents by year, three digit statistical area and survey stratum.

			YEAR	Data										
			2001		2002		2003		2004		2005		Total Trips sampled	Total Crabs measured
Survey stratum	Statistical area	Quarter	Trips sampled	Crabs measured	Trips sampled	Crabs measured	Trips sampled	Crabs measured	Trips sampled	Crabs measured	Trips sampled	Crabs measured		
A	622	2							1	104			1	104
		4							1	89			1	89
	627	2									1	88	1	88
A Total									2	193	1	88	3	281
B	533	3									2	191	2	191
		4									1	90	1	90
	616	1							1	81	2	180	3	261
		2	1	85									1	85
		4							1	99	2	200	3	299
B Total			1	85					2	180	7	661	10	926
C	526	3									1	77	1	77
		4							3	244			3	244
	537	1					1	85	1	77			2	162
		2			3	190	1	75	1	93			5	358
		3			2	172	4	321	1	72	2	182	9	747
		4			3	257	4	315	1	78	4	334	12	984
C Total					8	619	10	796	7	564	7	593	32	2572
D	525	1					1	79			1	77	2	156
		2			1	53	4	325	1	70	3	235	9	683
		3			2	154	1	85	2	157			5	396
		4	2	158							1	87	3	245
	562	1			1	79	2	139					3	218
D Total			2	158	4	286	8	628	3	227	5	399	22	1698
G	522	2			1	60							1	60
G Total					1	60							1	60
Unknown		1							1	72			1	72
		3			1	285	1	60					2	345
Unknown Total					1	285	1	60	1	72			3	417
Grand Total			3	243	14	1250	19	1484	15	1236	20	1741	71	5954

Table D5.1 Distribution of camera (a) and otter trawl (b) sampling effort in 1974, and in 2003-2005. Strata as defined by Wigley et al. (1975).

A. Camera Survey - Number of tows

1974 June						
Depth(fath)	Depth (m)	A	B	C	D	All
125-175	229-320	1		3	2	6
175-225	320-412	3		2	2	7
225-275	412-503	1	2	3	2	8
275-350	503-640	1	1	4	0	6
350-500	640-914	1		2		3
500-700	914-1280	1		1		2
700-900	1280-1646			1		1
2003 June						
Depth(fath)	Depth (m)	A	B	C	D	All
125-175	229-320	1	1	1	1	4
175-225	320-412			1		1
225-275	412-503	1	2	1		4
275-350	503-640		1		2	3
350-500	640-914	2	2	3	1	8
2003 August						
Depth(fath)	Depth (m)	A	B	C	D	All
125-175	229-320			1	1	2
175-225	320-412	1	1	1		3
225-275	412-503	2	2	1	1	6
275-350	503-640		1	2		3
350-500	640-914	4	2	1	2	9
2004 June						
Depth(fath)	Depth (m)	A	B	C	D	All
125-175	229-320	3	3	3		9
175-225	320-412	1		1	2	4
225-275	412-503	2	3	2	2	9
275-350	503-640	2			1	3
350-500	640-914	5	5	6	3	19
500-700	914-1280	3	3	3	2	11
2005 June						
Depth(fath)	Depth (m)	A	B	C	D	All
125-175	229-320	2	2	2	1	7
175-225	320-412	1	2			3
225-275	412-503		1	2		3
275-350	503-640	3	2	2	1	8
350-500	640-914	6	4	2	2	14
500-700	914-1280	3	3	2	1	9

B. Net Survey - Number of tows

1974 June						
Depth(fath)	Depth (m)	A	B	C	D	All
125-175	229-320	2	1	4	3	10
175-225	320-412	1	1	1	2	5
225-275	412-503	2	2	3	4	11
275-350	503-640		1	2	1	4
350-500	640-914	1	1	3	2	7
500-700	914-1280	1		2		3
700-900	1280-1646	1		2		3
2003 June						
Depth(fath)	Depth (m)	A	B	C	D	All
125-175	229-320	1		1	1	3
175-225	320-412		1			1
225-275	412-503	1	2	2		5
275-350	503-640		2	1	2	5
350-500	640-914	1		1		2
2003 August						
Depth(fath)	Depth (m)	A	B	C	D	All
125-175	229-320			1	1	2
175-225	320-412	1	1	2		4
225-275	412-503	2	1		1	4
275-350	503-640	1	2	1		4
350-500	640-914	3	2	2	2	9
2004 June						
Depth(fath)	Depth (m)	A	B	C	D	All
125-175	229-320	3	3	3	2	11
175-225	320-412			1	1	2
225-275	412-503	2	2	2	2	8
275-350	503-640	2	2	2	3	9
350-500	640-914	5	5	4	3	17

2005 June						
Depth(fath)	Depth (m)	A	B	C	D	All
125-175	229-320	2	1		1	4
175-225	320-412	1	2	2		5
225-275	412-503	3	1	2	2	8
275-350	503-640	1	3	2		6
350-500	640-914	4	4	4	2	14

Table D5.2 Specifications for sleds, cameras and nets used in the surveys conducted in 1974 and in 2003-2005.

	Wigley et al.	Wahle et al.
Sled		
Length	2.7 m	2.1 m
Width	2.1 m	1.2 m
Height	1.9 m	1.5 m
Material	6.4 cm steel tubing	10, 5, & 2.5 cm steel tubing
Weight	1225 kg	363 kg
Camera System		
Camera		
Type	Film	Digital
Manufacturer	Hydroproducts	Engage Technologies
Make	DeepSea Photo Cam	SeaSnap
Model	Model PC705	Nikon CoolPix 995, DigiSnap 2000
Strobe		
Manufacturer	Hydroproducts	Benthos
Make	DeepSea Strobe	DeepSea Strobe
Model	Model PF730	Model 382
Medium	Kodak Ectachrome EF	Digital 2048x1536 pixel
Camera Setup		
Height off bottom	1.7 m	0.92 m
Angle of camera	16 deg	35 deg
Shot interval	10 sec	15 sec.
Tow Duration	30-75 min	30-45 min
Approx. number photos	400	120-260
Total area covered by photo	148 m^2	10 m^2
Effective (illuminated) area sampled	31.8 m^2	6.6 m^2
Trawl Net		
Type	semi-balloon otter trawl	semi-balloon otter trawl
Length	4.9 m	6.2 m
ground rope	5.8 m	7.3 m
wire extension pieces	4 m	3.7 m
mesh of wings	No. 9 thread, 3.8 cm stretched measure	No. 7 thread, 3.8 cm stretched measure
mesh of body	No. 9 thread, 3.8 cm stretched measure	No. 7 thread, 3.8 cm stretched measure
mesh of cod end	No. 15 thread, 3.2 cm stretched measure	No. 15 thread, 3.2 cm stretched measure
codend liner	NA	12 mm
tow speed	1.5 - 2 knots	1.5 - 2 knots
tow duration	15 or 30 min	27 - 45 min

Table D5.3 Survey stratum areas in hectares (ha) by depth as calculated from Wigley et al. (1975).

	Area by Depth (ha)				
Depth (fath)	A	B	C	D	All
125-175	30310	17803	55000	39109	142,222
175-225	43800	26996	75300	64100	210,196
225-275	23401	17200	37300	26501	104,402
275-350	44502	28301	62600	28901	164,304
350-500	65599	47827	63703	56836	213,491
500-700	121704	60442	77995	90025	350,166
700-900	124037	54679	67523	113028	359,266

Table D5.4. Non-targeted surveys: NEFSC groundfish bottom trawl surveys (winter, spring and fall), NEFSC shrimp survey (summer), NEFSC Cooperative Monkfish survey, and Rutgers Supplemental Finfish (transect) survey. Shown are the number of tows completed in survey strata A-D, as well as the Gulf of Maine.

	125-175f 229-320m	175-225f 320-412m	225-275f 412-503m	275-350f 503-640m	350-500f 640-914m	500-700f 914-1280m	700-900f 1280-1646m
STRATUM A							
NMFS Groundfish 00-05	43	25	4	3			
Monkfish 2001	4	2					
Monkfish 2004	34	2					
Transect January	5	5					
Transect March	12	9	2				
Transect May	3	4					
Transect November	3	3					
STRATUM B							
NMFS Groundfish 00-05	6						
Monkfish 2001	4	2	1				
Monkfish 2004	4	3					
Transect January	6	5					
Transect March	6	8	3				
Transect May	4	5					
STRATUM C							
NMFS Groundfish 00-05	21	3	2				
Monkfish 2001	2	9	5	3	3		
Monkfish 2004	23	9					
Transect March	1		1				
STRATUM D							
NMFS Groundfish 00-05	8	5	2	1			
Monkfish 2001		1					
Monkfish 2004		1					
GULF OF MAINE							
NMFS Groundfish 00-05	120	14					
NMFS Shrimp surveys	8						
Monkfish 2004	13						

Table D5.5 Average red crab catch per tow (kg) from the Rutgers supplemental finfish survey cruises, in chronological order from left to right, by survey stratum and depth zone.

SECTOR A

	Mar 03	May 03	Jan 04	Mar 04	May 04	Nov 04	Jan 05	Mar 05
229-320m	0.6	7.8				1.5	9.0	15.9
320-412m	6.8	67.9	60.5	55.4	61.0	228.1	52.6	129.0
412-503m	52.0							249.1

SECTOR B

	Mar 03	May 03	Jan 04	Mar 04	May 04	Nov 04	Jan 05	Mar 05
229-320m	.06			4.0	105	7.3	5.9	15.2
320-412m	29.0	33.8	14.3	18.5	116.9	293.6	19.8	127.5
412-503m	128.2	88.7	274.3	57.7	43.5	206.9	127.2	101.7

Table D7.1 Fishable biomass (mt) and average annual fishing mortality (y-1) estimates for deep-sea read crab by survey stratum (A, B, C and D) and for the entire stock during 2003-2005 based on camera/bottom trawl survey biomass estimates, total landings from dealer data, and landings by area from logbook data. Average fishing mortality was computed as the ratio of average landings and average biomass. Standard errors for recruited biomass were computed among the four surveys that occurred between 2003-2005 as in Tables 5.4-5.7.

Average 2003-2005 male recruited biomass from video/bottom trawl survey (mt).

Depth (fath)	A	B	C	D	All
125-175	410	24	0	0	434
175-225	4,319	166	908	1	5,395
225-275	766	469	1,475	1,175	3,885
275-350	2,449	447	3,469	9,559	15,924
350-500	1,441	629	3,512	5,033	10,616
All	9,384	1,735	9,364	15,769	36,253

Standard errors for average 2003-2005 male recruited biomass (not used in calculations).

Depth (fath)	A	B	C	D	All
125-175	299	19	0	0	245
175-225	3,261	2	128	0	2,715
225-275	271	135	328	105	968
275-350	0	83	1,635	3,052	2,542
350-500	362	140	695	1,855	1,564
All					5,459

Total landings from dealer data (mt, assumed 100% male).

Year	Landings
2003	1,920
2004	2,041
2005	2,014
Average 2003-2004	1,992

Original VTR landings by survey stratum mt, assume 100% male, only 2003-2004 available).

Year	A	B	C	D	Unknown
2003	277	26	724	364	529
2004	516	54	654	326	491

Percent by area from VTR landings.

Year	A	B	C	D	Unknown	All
2003	14%	1%	38%	19%	28%	100%
2004	25%	3%	32%	16%	24%	100%
Average 2003-2004	20%	2%	35%	17%	26%	100%

Percent to prorate landings by area.

	A	B	C	D	All
Average 2003-2004	27%	3%	47%	24%	100%

Prorated total landings from dealer data (mt assumed 100% male)

	A	B	C	D	All
Average 2003-2004	533	54	936	469	1,992

Fishing mortality = landings / fishable biomass.

	A	B	C	D	All
Average 2003-2004	0.057	0.031	0.100	0.030	0.055

Table D7.2 Fishable 1974 male biomass from the camera/bottom trawl survey (mt).

Depth (fathoms)	A	B	C	D	All
125-175	177	0	715	0	892
175-225	976	1,698	7,795	4,032	14,502
225-275	610	342	1,992	1,478	4,422
275-350	2,373	2,036	3,709	1,777	9,895
350-500	481	936	2,025	1,112	4,554
All	4,617	5,012	16,236	8,399	34,265

RED CRAB FIGURES

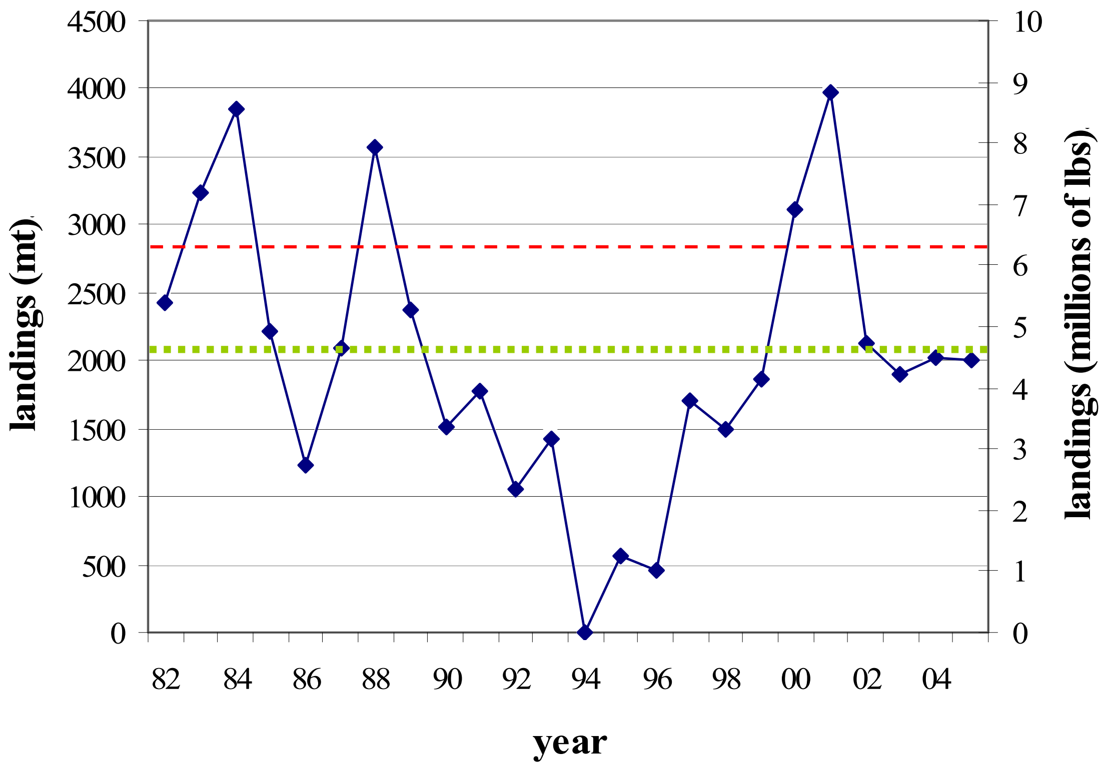

Figure D2.1 Reported landings of deep sea red crab 1982-2005. The dashed line indicates an MSY of 2714 mt (6.24 million lbs) which was based on the previous assessment (Serchuk 1977). The dotted line represents the mean annual landings 1982-2005, excluding 1994 when there was no targeted red crab fishery.

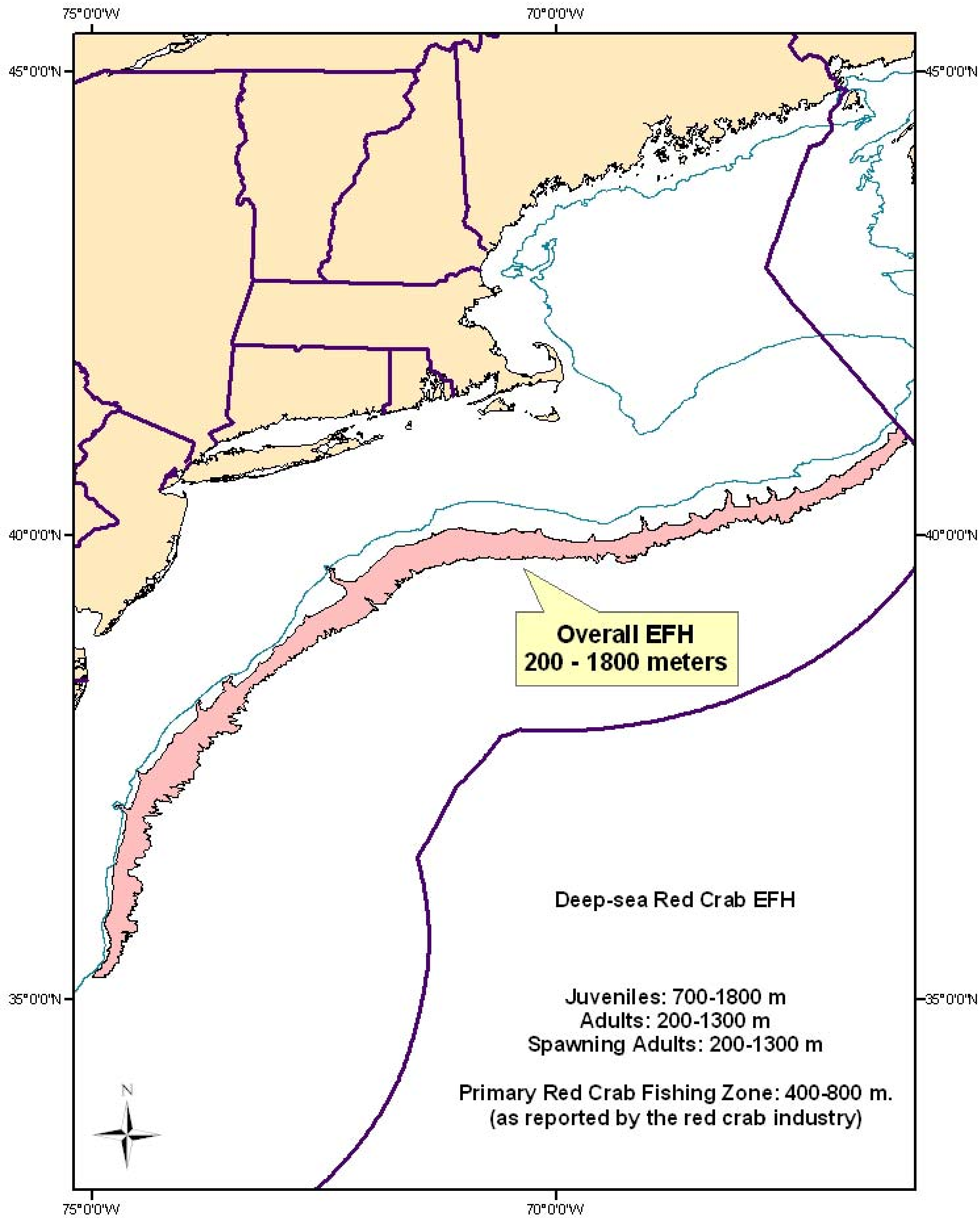

Figure D3.1 Red Crab Essential Fish Habitat by life stage (200-1800 meters).

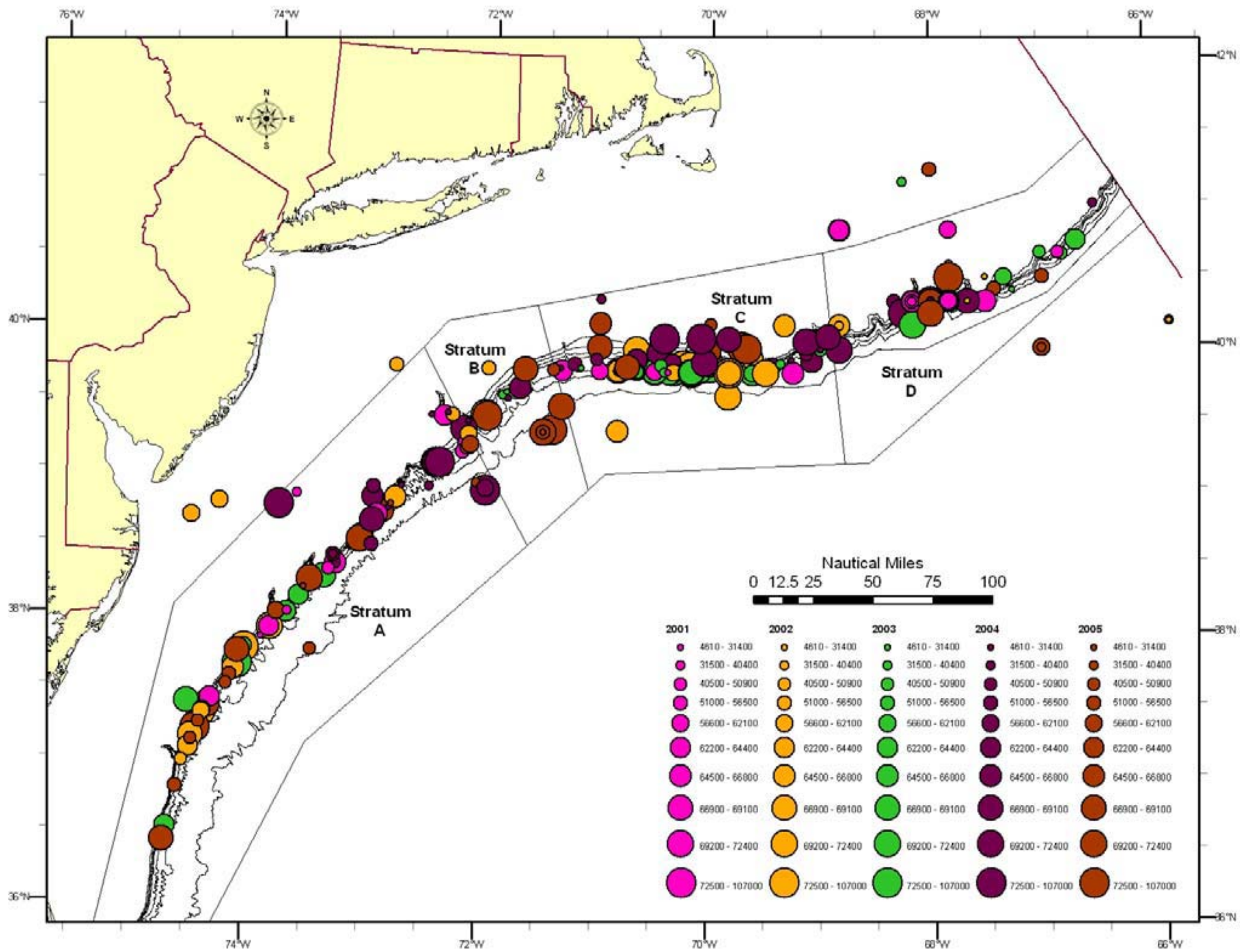

Figure D4.1 Reported VTR landings per trip in pounds for vessels targeting red crab during 2001-2005, showing boundaries of survey strata. Isobaths on the map are 200, 300, 400, 500, 900, 1300, and 2100 m. (Outlying catches probably did not occur in that location, but are a result of errors in reporting or transcription of latitude or longitude.)

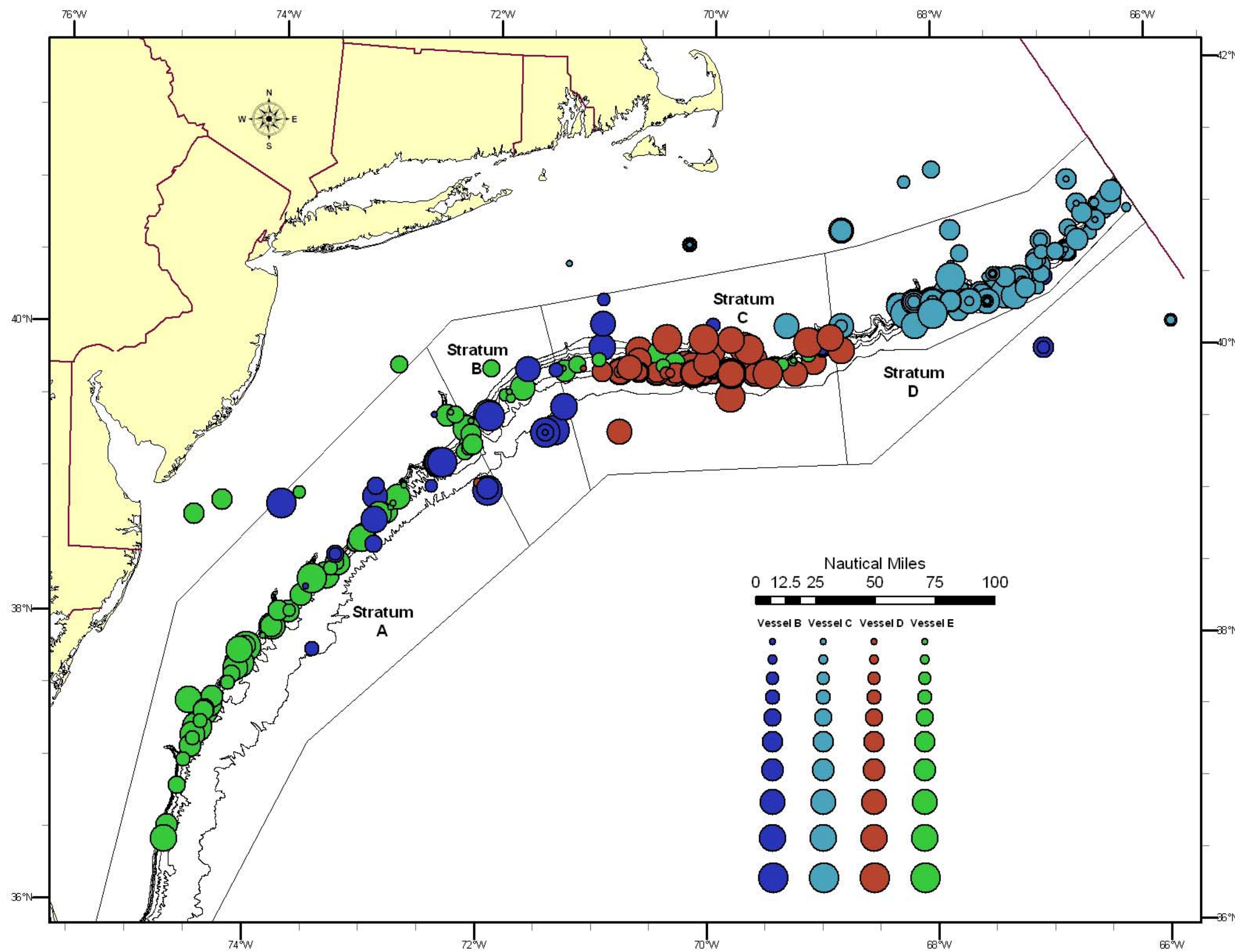

Figure D4.2 VTR landings per trip by vessel (coded A-D) for 1995-2005, showing boundaries of survey strata. The amount landed per trip is not shown for confidentiality reasons, but ranged from 0.3 to 33 mt. (Outlying catches probably did not occur in that location, but are a result of errors in reporting or transcription of latitude or longitude.)

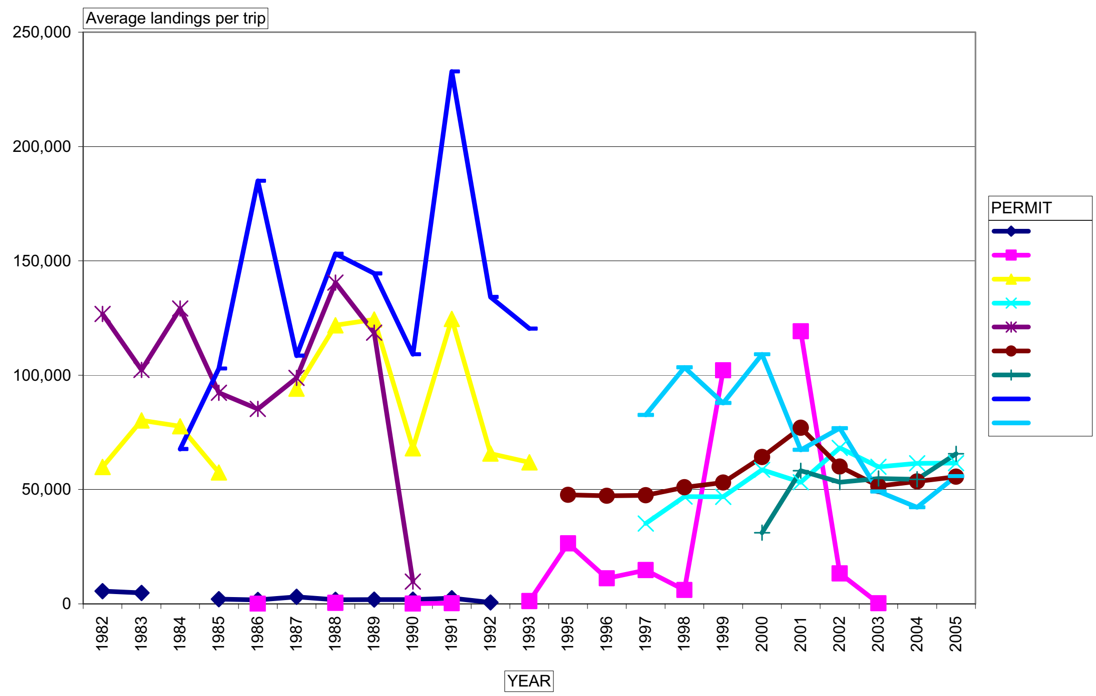

Figure D4.3 Trends in landings (lbs) per trip by vessels with large amounts of crab landings in dealer reports.

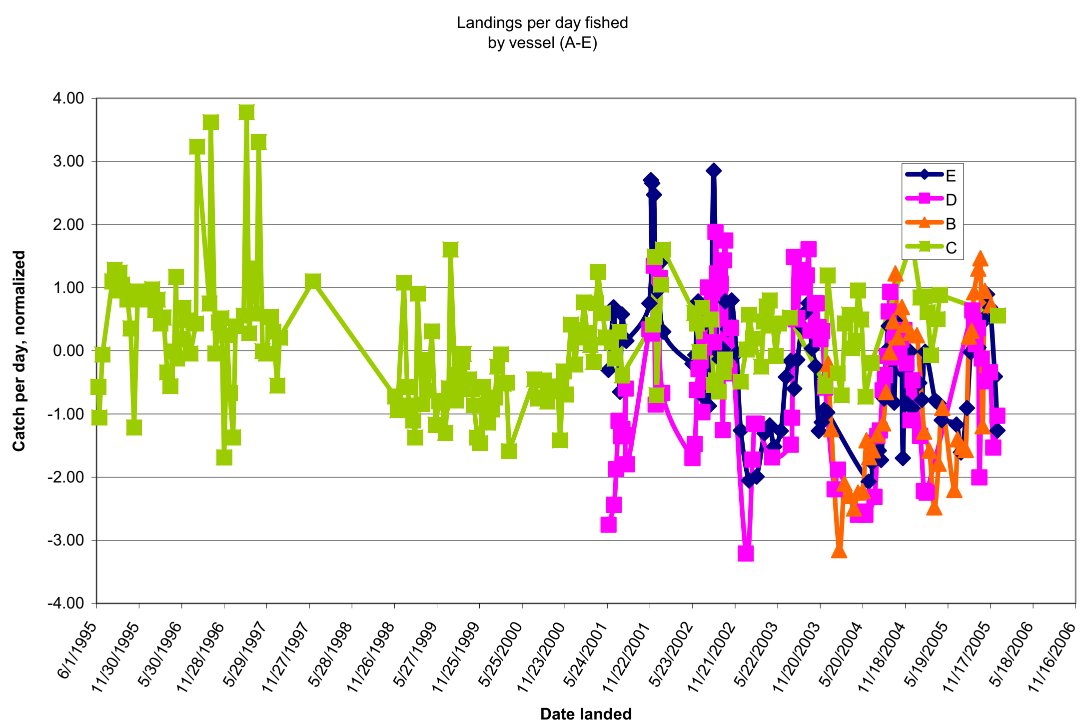

Figure D4.4 Trend in catch per day at sea for vessel trip reports from four limited access vessels recently targeting red crab. The data were normalized using each vessel's landings per day mean and standard deviation for the time series.

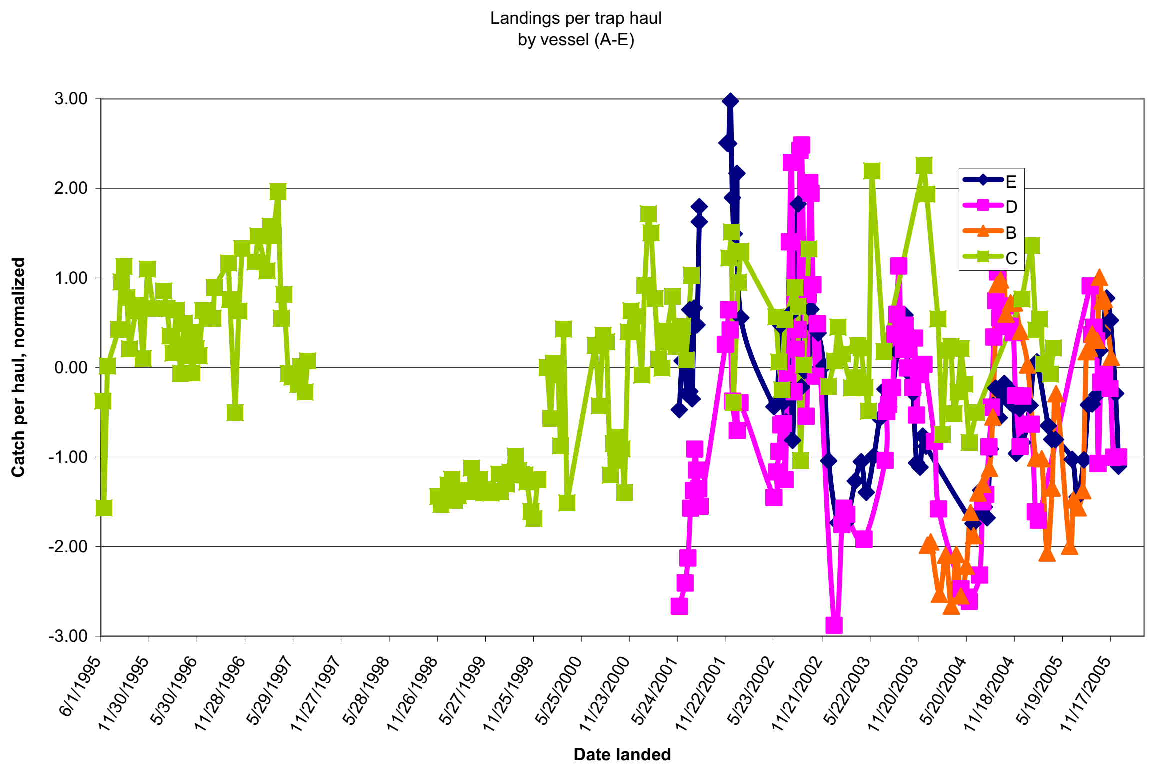

Figure D4.5 Trends in catch per trap haul for vessel trip reports from four limited access vessels targeting red crab. The data were normalized using each mean and standard deviation for the time series.

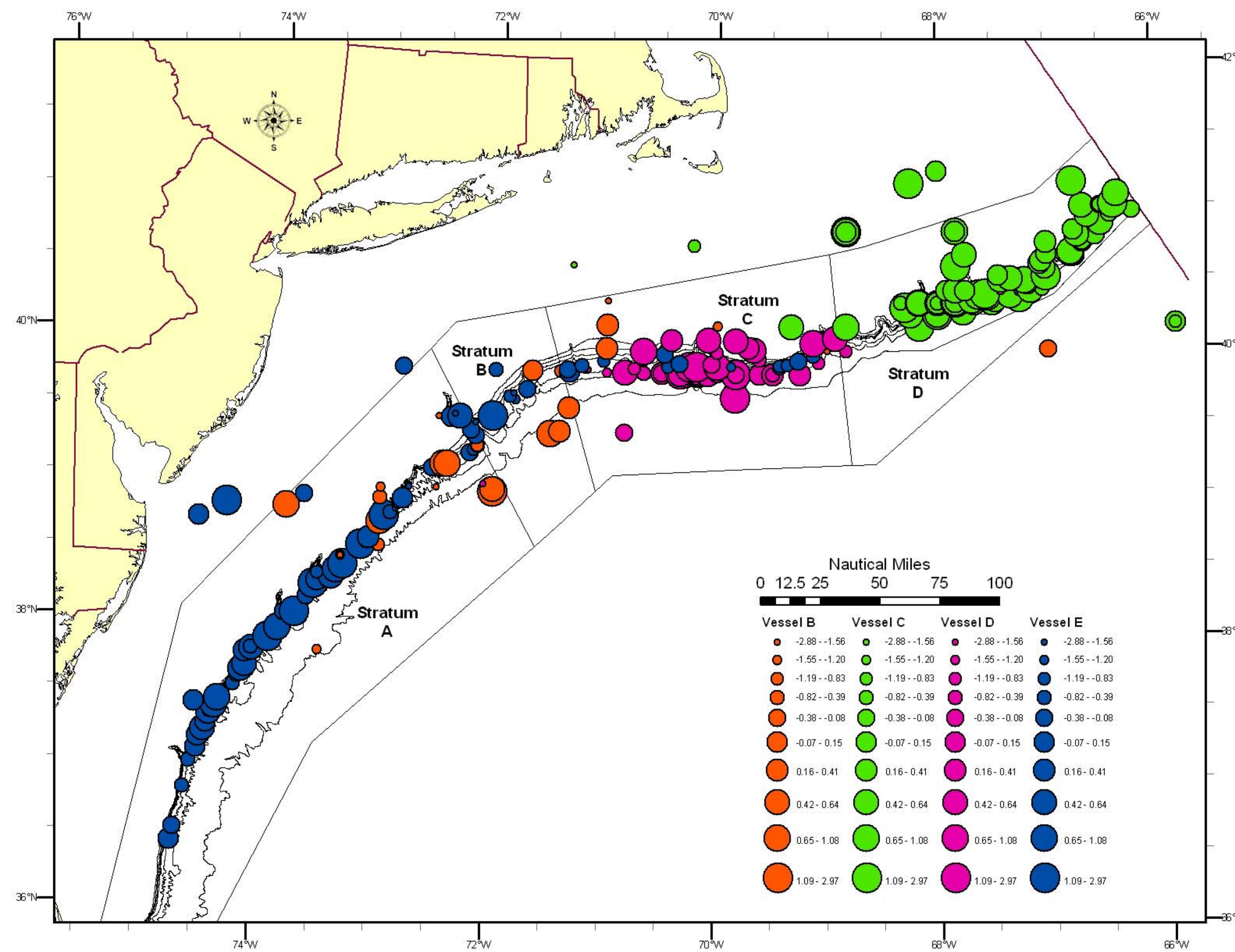

Figure D4.6 Normalized VTR reported landings per trap haul by vessel, 2001-2005. (Outlying catches probably did not occur in that location, but are a result of errors in reporting or transcription of latitude or longitude.)

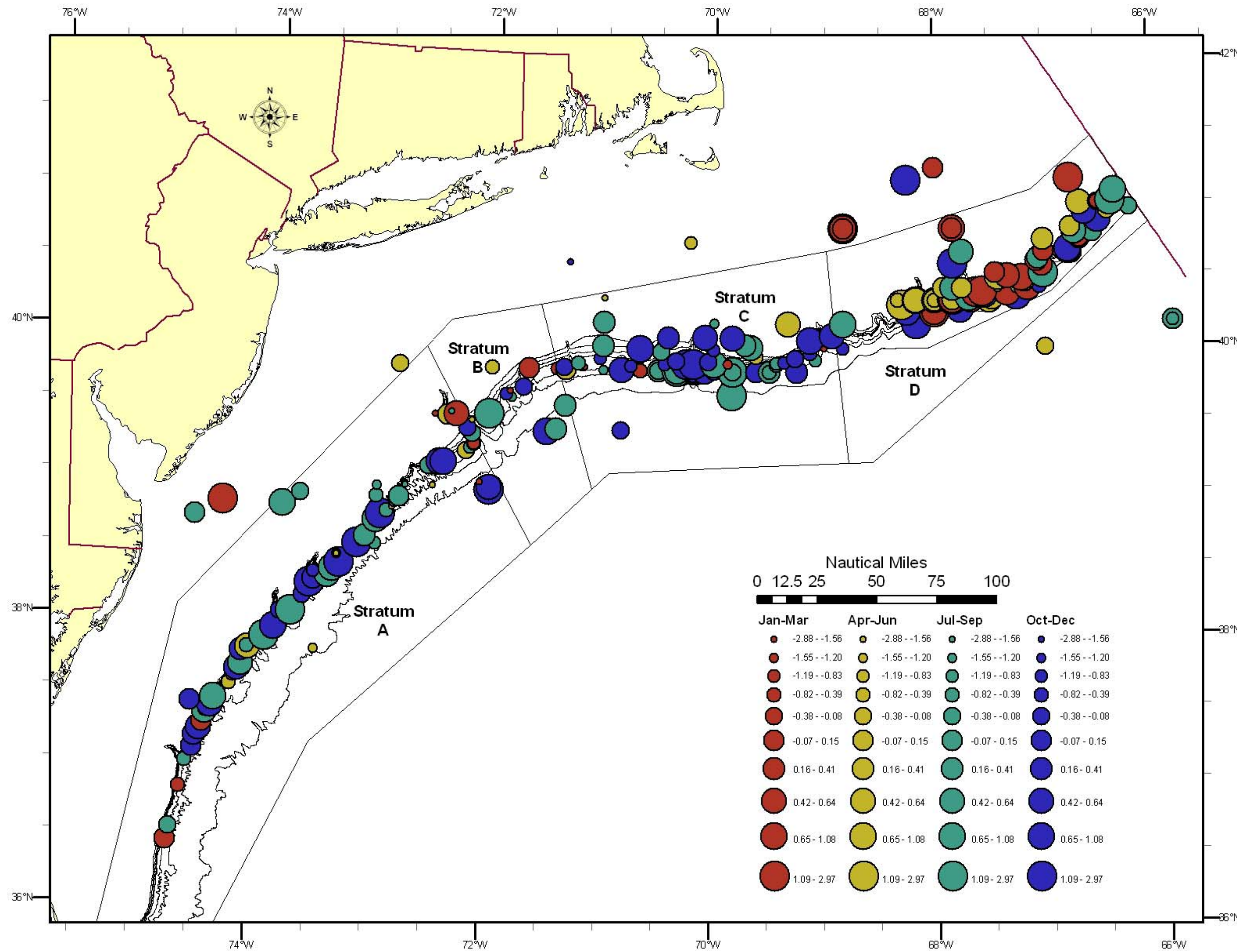

Figure D4.7 Normalized VTR reported landings per trap haul by quarter, 2001-2005. (Outlying catches probably did not occur in that location, but are a result of errors in reporting or transcription of latitude or longitude.)

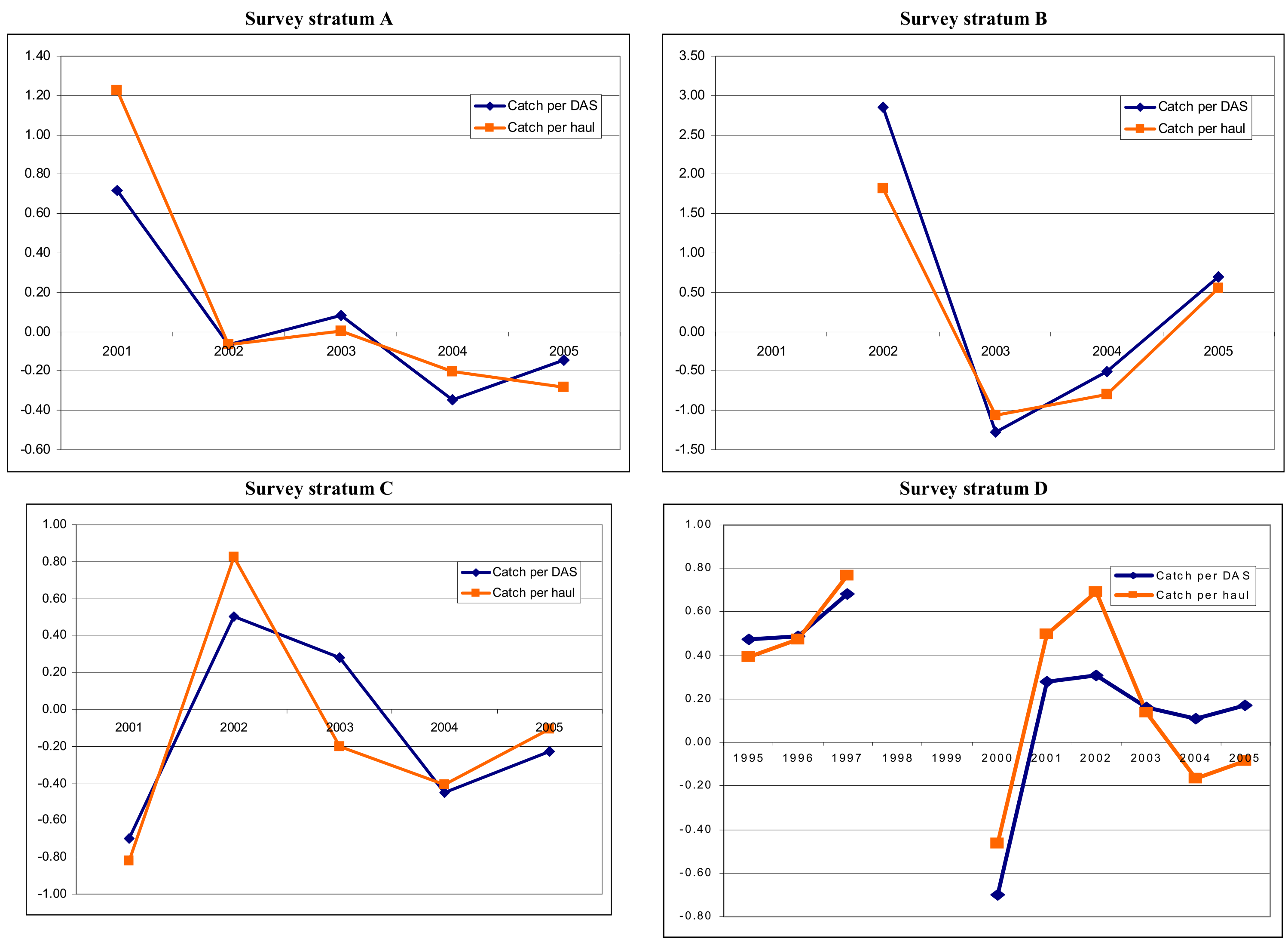

Figure D4.8 Trends in normalized landings per day and per trap haul by stratum.

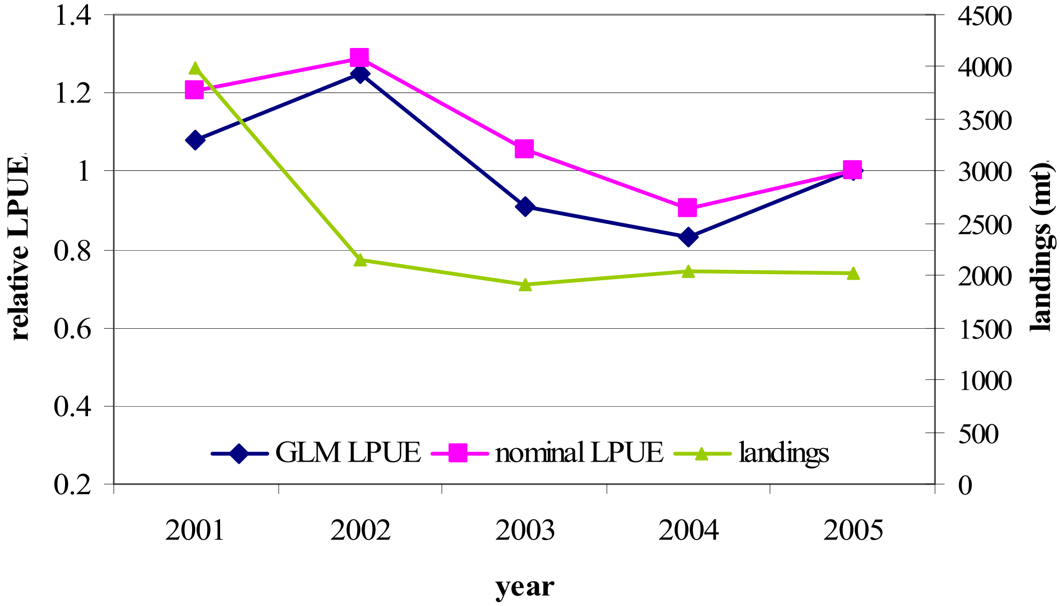

Figure D4.9 Standardized LPUE, nominal LPUE and reported red crab landings, 2001-2005.

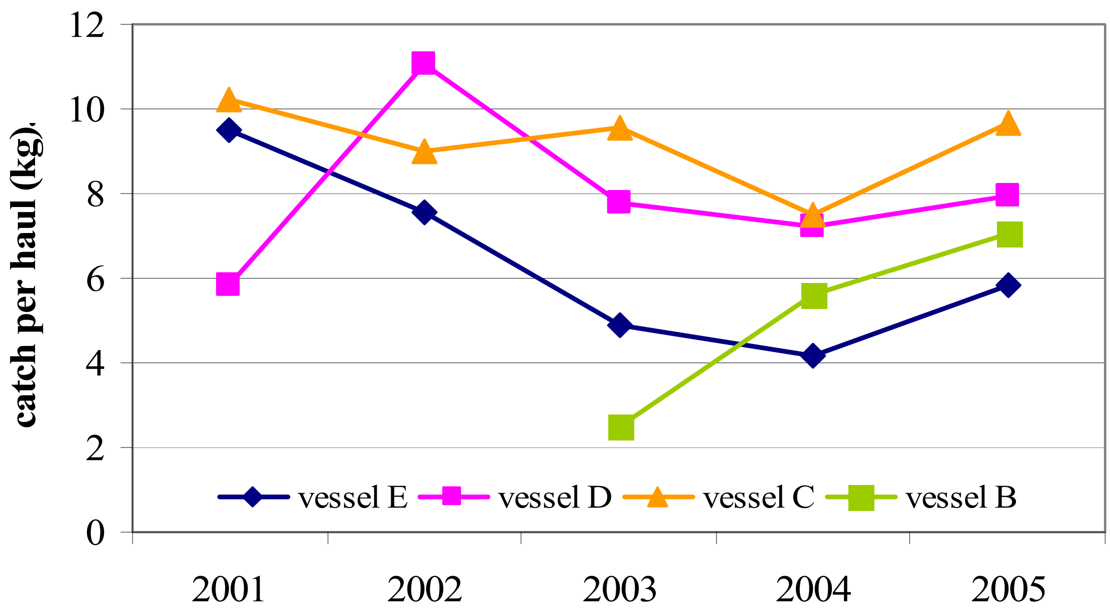

Figure D4.10 Re-transformed standardized LPUE from a GLM model for four vessels.

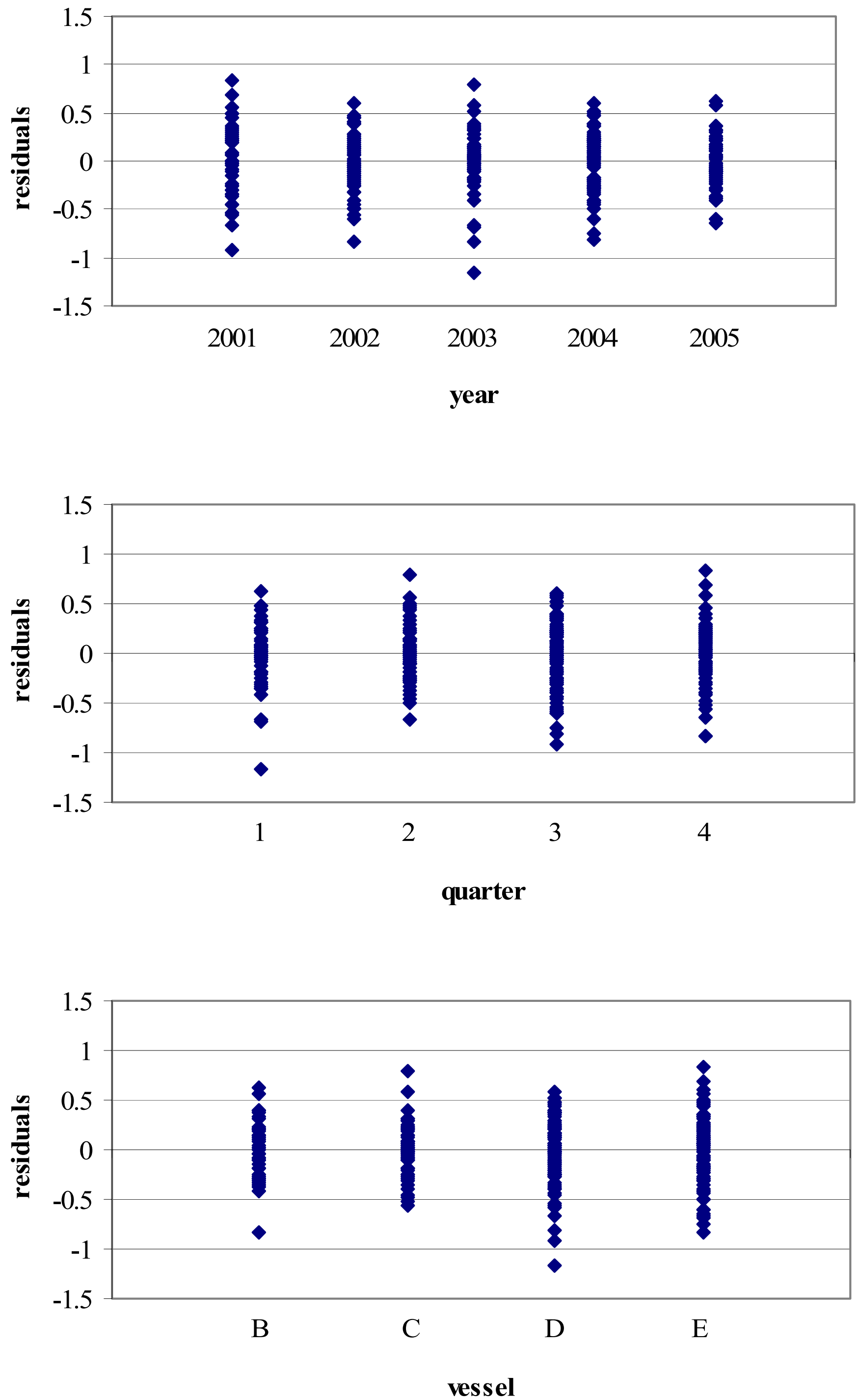

Figure D4.11 Plots of GLM model residuals vs. the three most influential variables.

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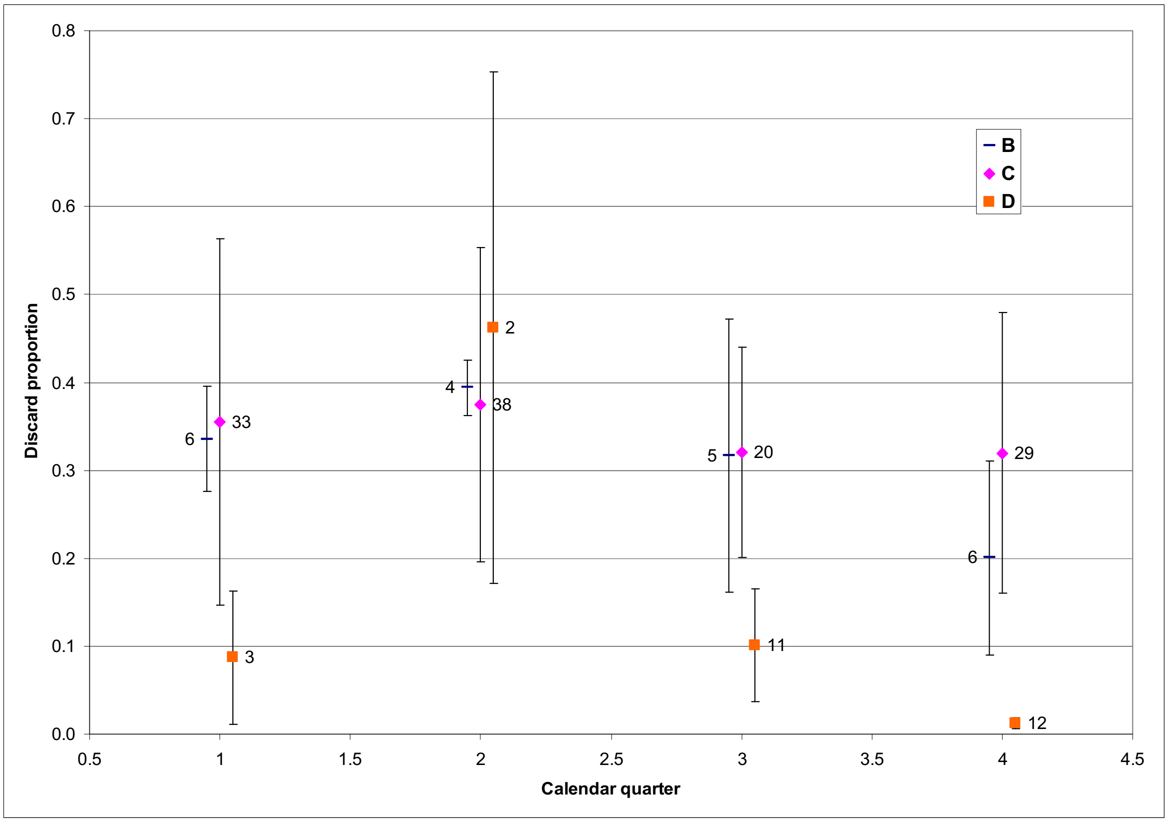


Figure D4.12 VTR reported discards as a fraction of catch by limited access vessels during 2002-2005 by calendar quarter. The mean fraction of the catch discarded is shown, +/- one standard deviation. The number of trips reporting discards is shown next to the mean point.

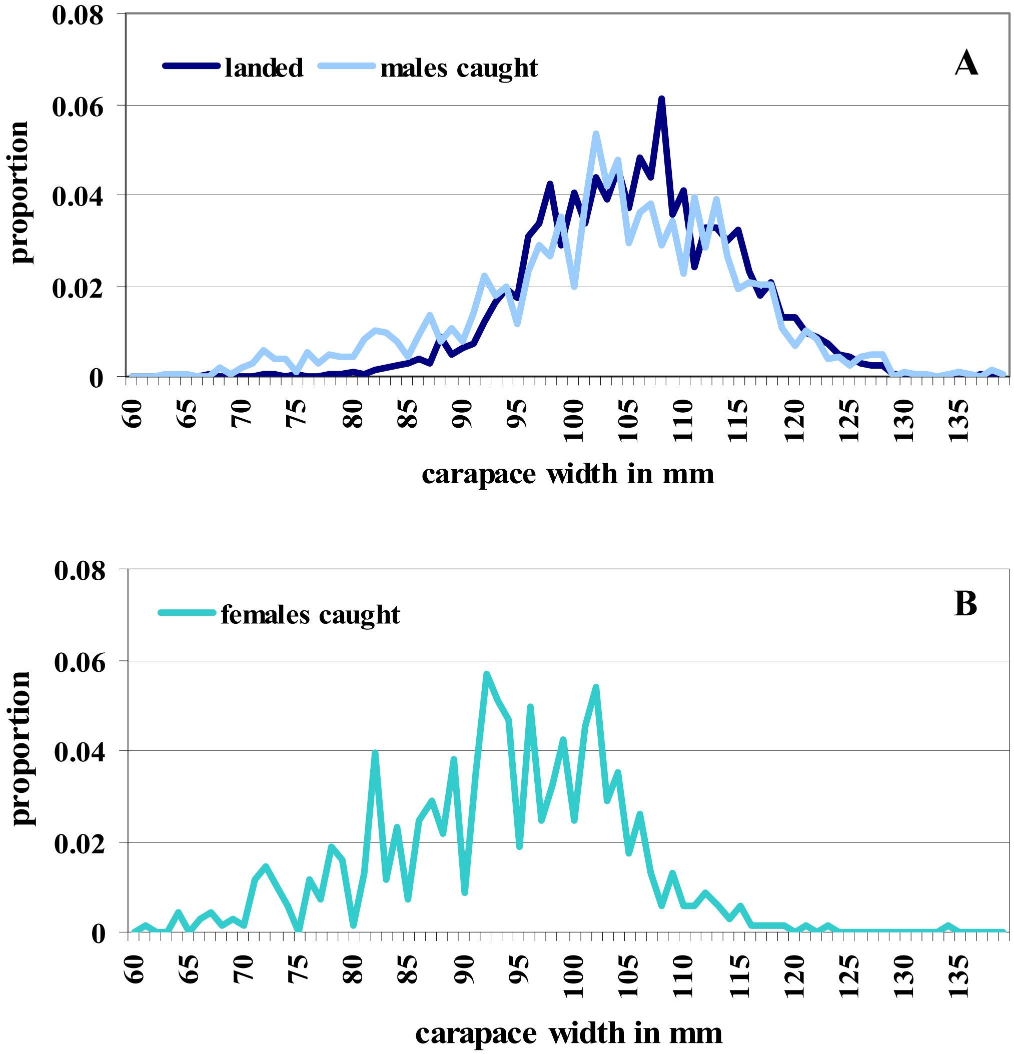
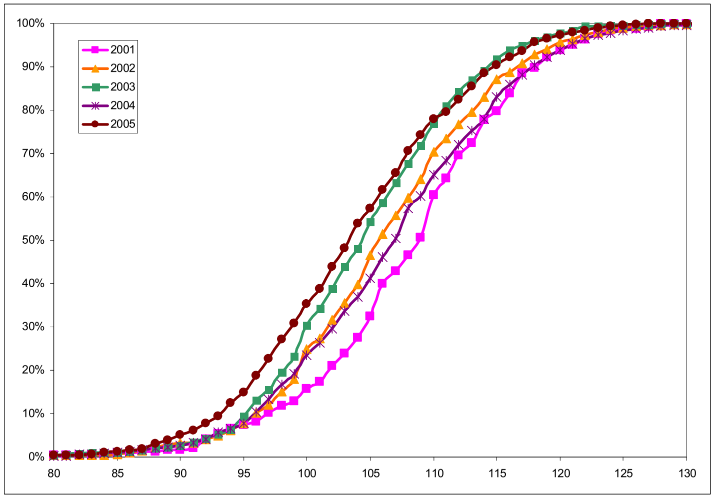
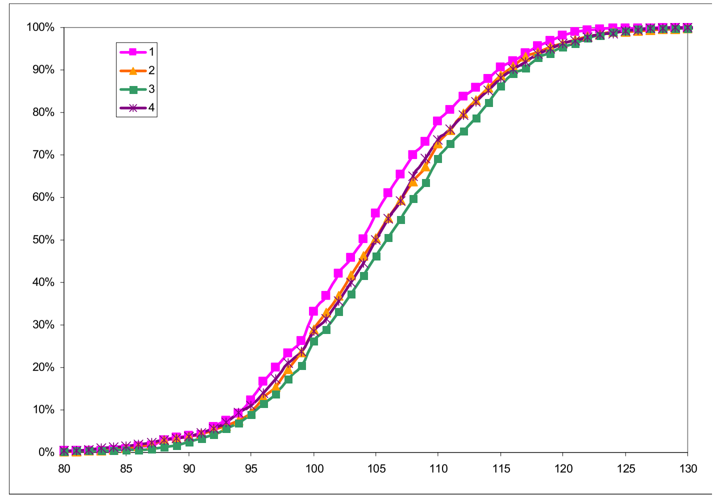


Figure D4.13 (A) Red crab length composition data from port samples (only males are landed) and sea samples (males only). (B) Length composition data from sea samples, females only. All crabs were caught during 2004-2005 in survey strata A, C and D over a range of seasons.

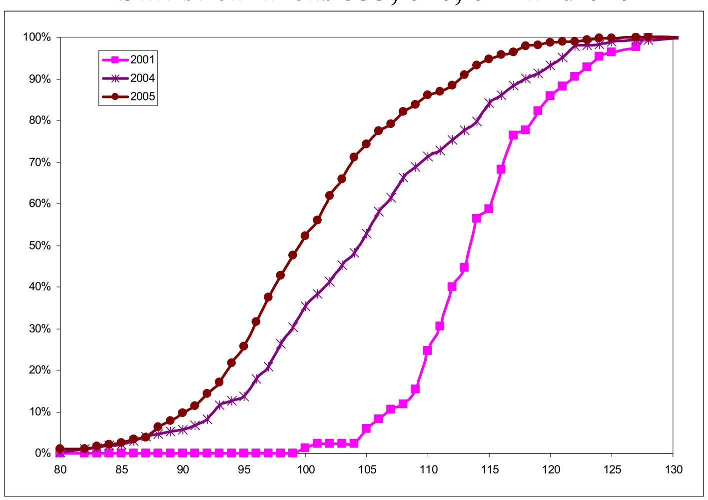
Size frequency by year, 2001-2005
All areas combined



Size frequency by calendar quarter
All areas combined



Mid-Atlantic Region
Statistical areas 533, 616, 622 and 627



Georges Bank Region
Statistical areas 525, 526, 537, and 562

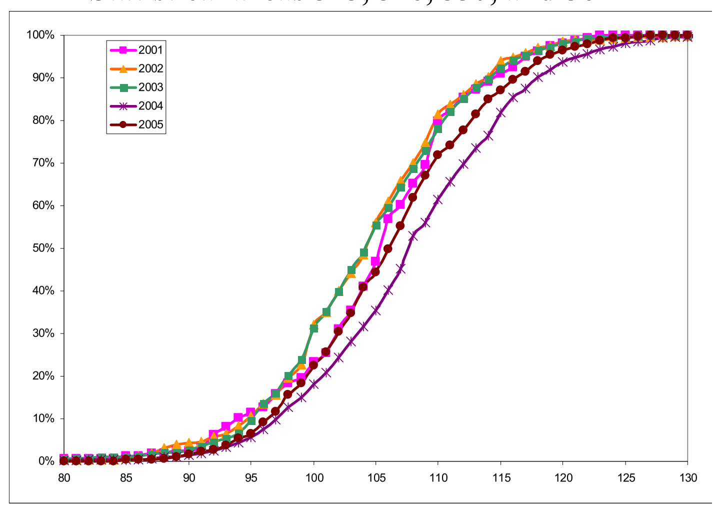
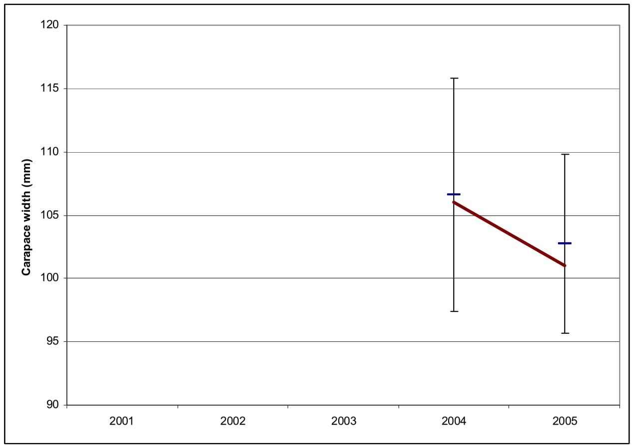
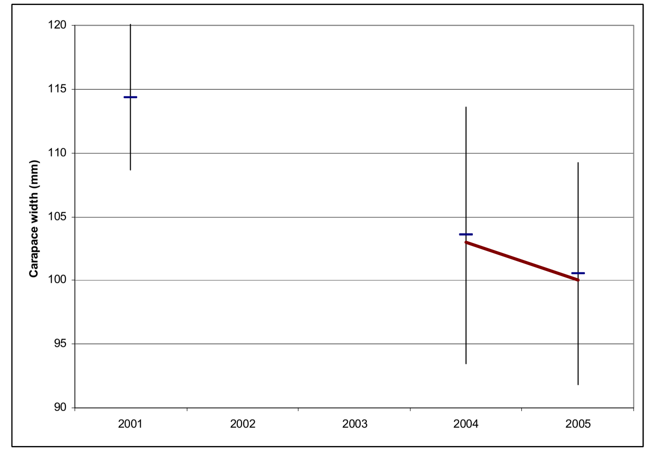


Figure D4.14 Cumulative red crab size frequency for all areas, 2001-2005. Carapace width is measured in mm.

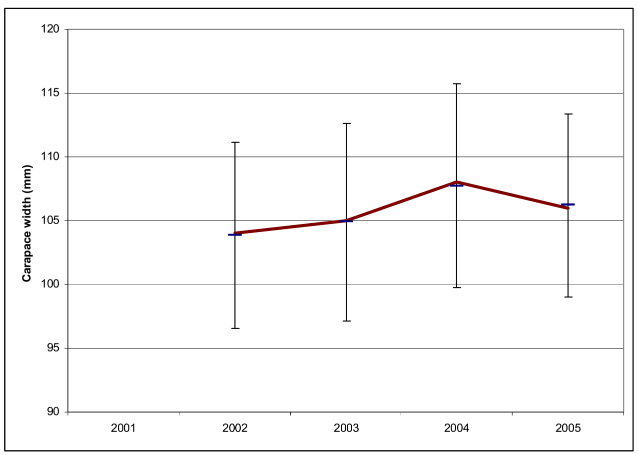
Survey stratum A
Statistical areas 622 and 627



Survey stratum B
Statistical areas 533 and 616



Survey stratum C
Statistical areas 526 and 537



Survey stratum D
Statistical areas 525 and 562

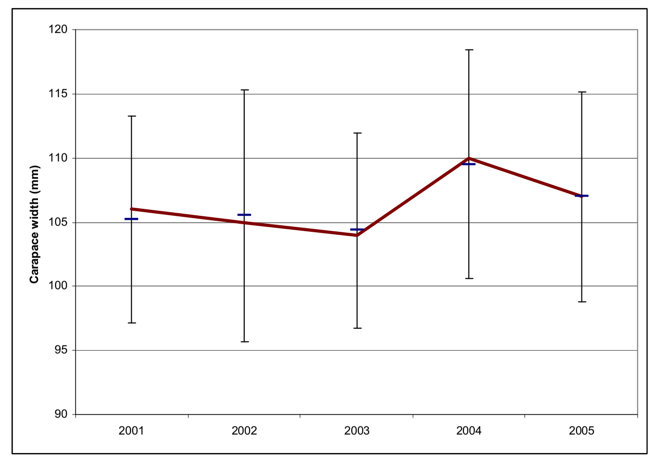


Figure D4.15 Mean (horizontal line, +/- 1 standard deviation) and median carapace width (at hatch mark) for red crabs measured by port agents from commercial catches during 2001-2005 by year and survey stratum.

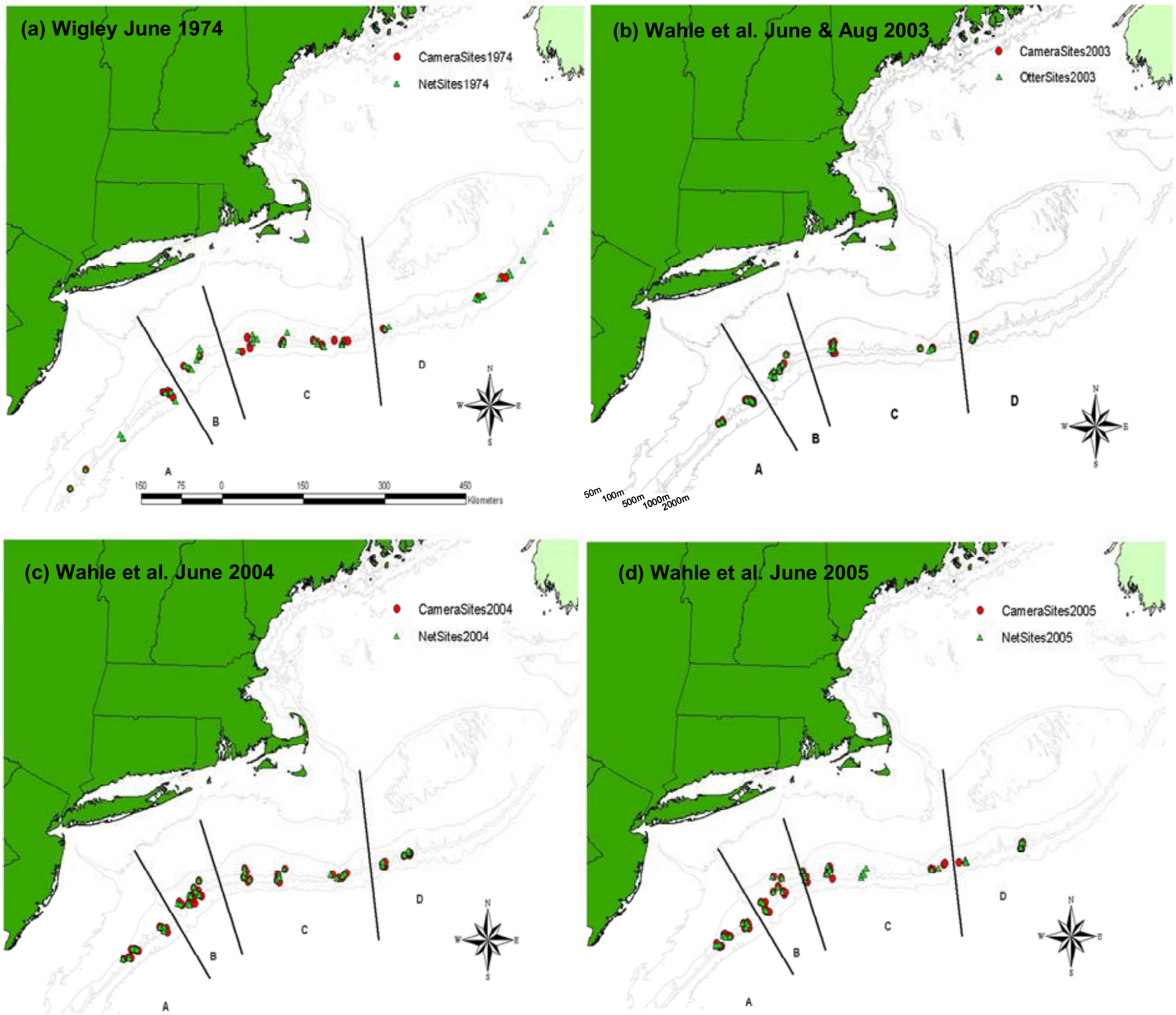


Figure D5.1 Locations of net and camera tows during the (a) camera/trawl surveys conducted in 1974 and (b-d) the camera/trawl surveys conducted in 2003-2005.

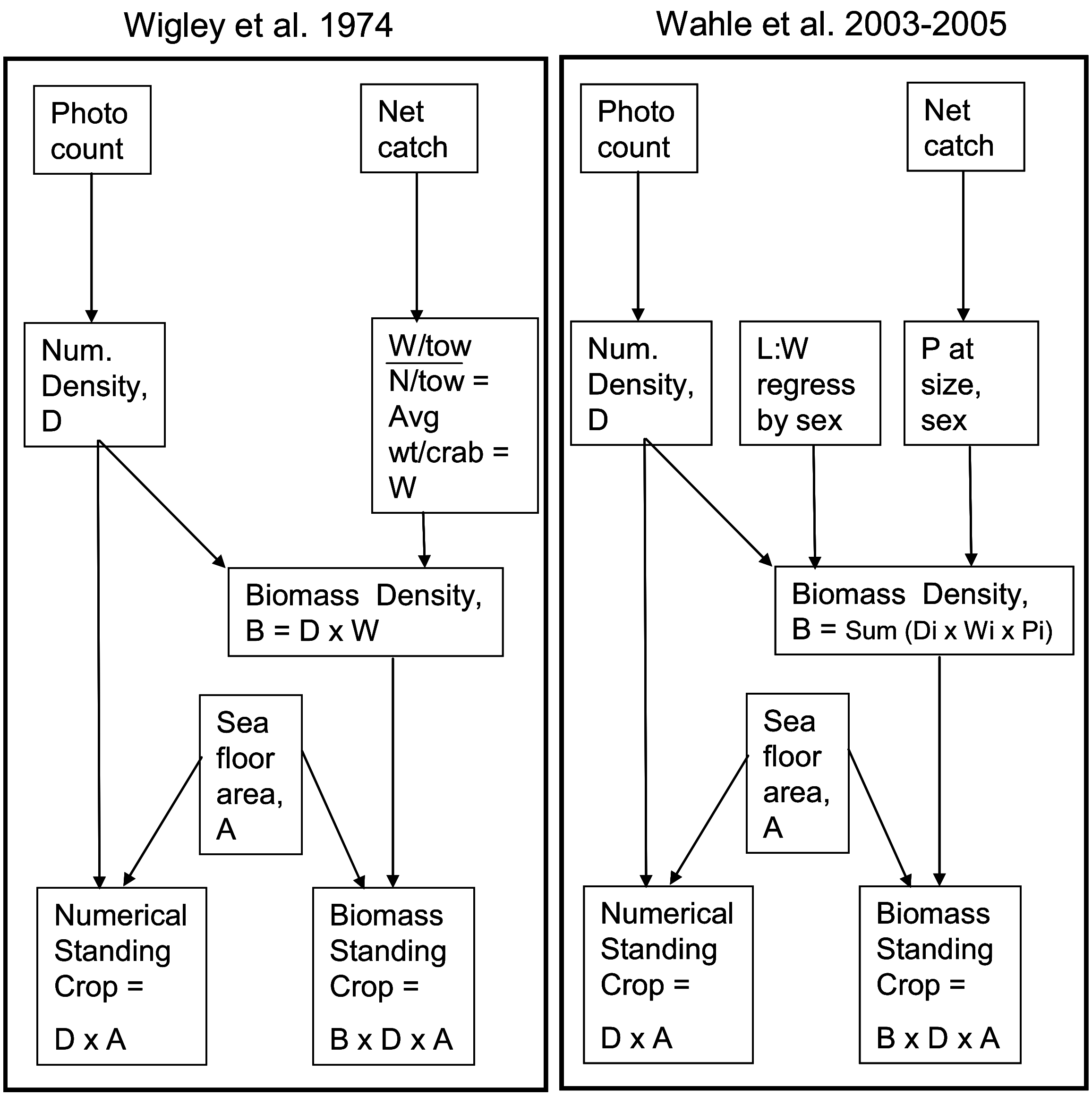
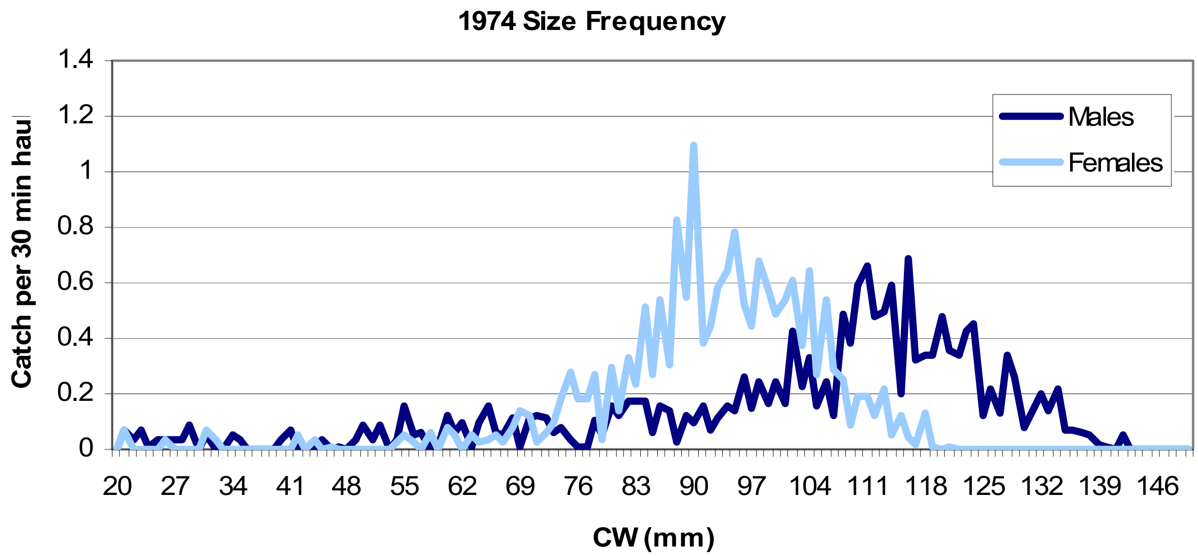


Figure D5.2 Comparative overview of the 1974 and 2003-05 camera and net survey methods to estimate standing crop.



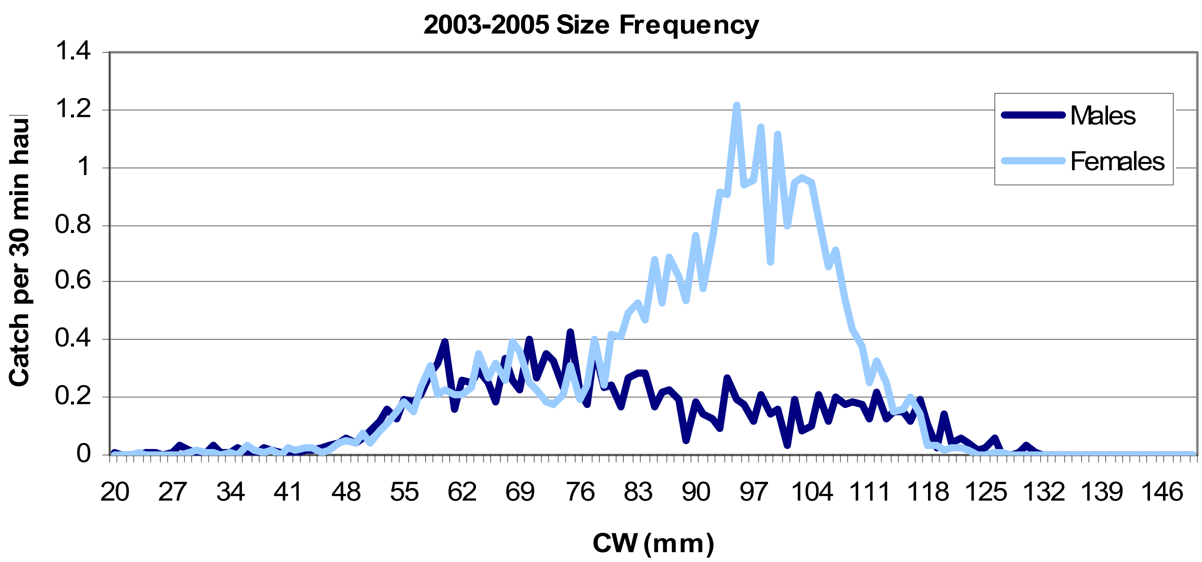


Figure D5.3 Red crab size and sex composition in the 1974 and 2003-2005 otter trawl samples during camera/trawl surveys standardized to catch-per-30-minute-tow, tows from all depths and sectors combined. Vertical line indicates "commercial" size as defined in Wigley et al. (1975): crabs ≥114 mm carapace width. The 1974 size distribution is represented by 641 male and 795 female crabs; the 2003-2005 distribution, 2209 male and 4602 female crabs. Complete size-sex composition by depth and sector is tabulated in Appendix D3.

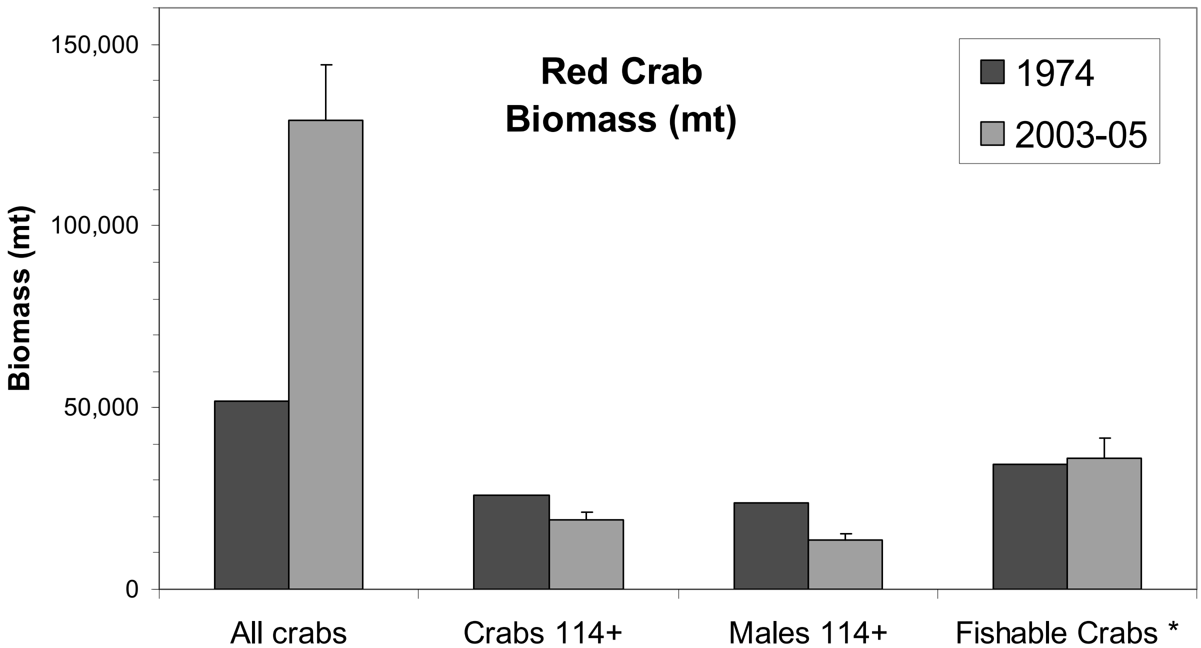


Figure D5.4 Red crab standing biomass (mt) estimates for 1974 and the mean (+1SE) of four surveys conducted between 2003 and 2005. Estimates for 2003-2005 represent the mean (+1SE) of four surveys conducted over that period. No error term is available for the 1974 estimates. * Biomass of fishable crabs determined from fishery selectivity analysis (section 7.1).

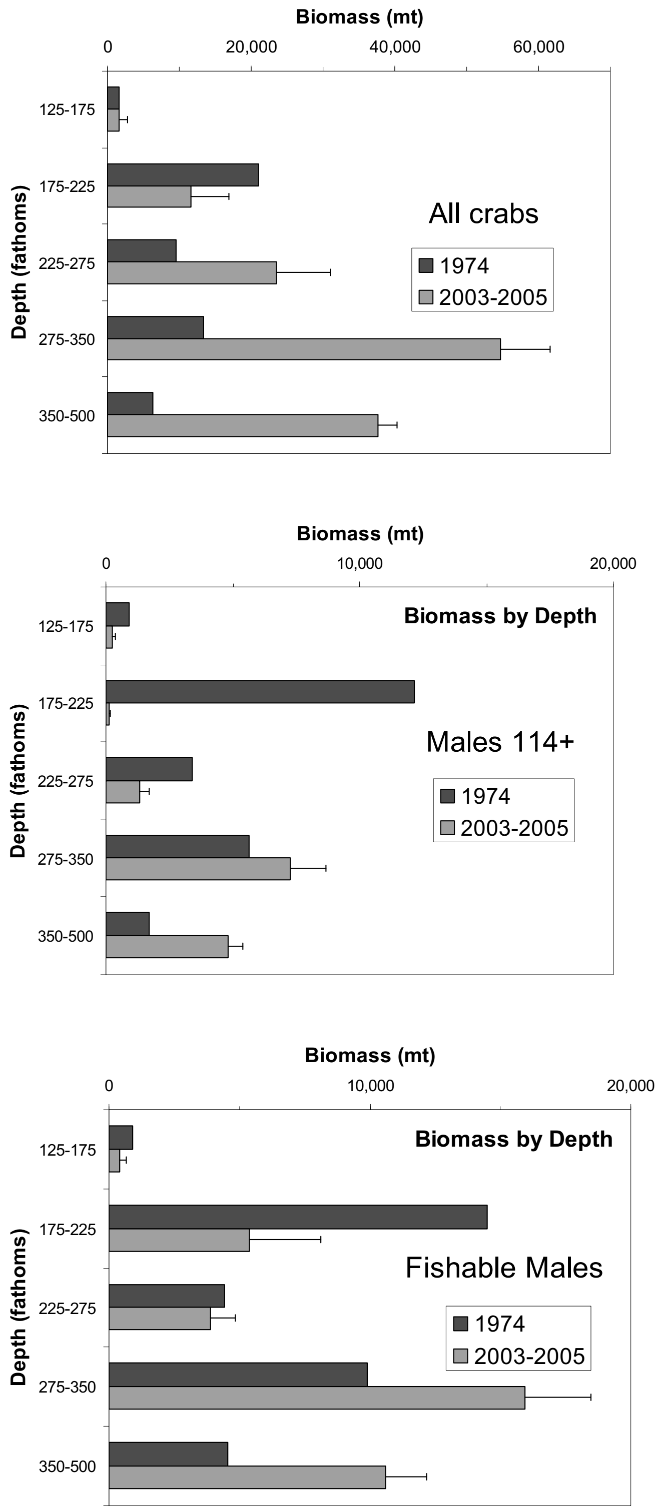


Figure D5.5. Red crab biomass by depth in 1974 and 2003-2005. All crabs (top), males 114+ mm (middle), and currently fishable males (bottom). Estimates for 2003-2005 represent the mean (+1SE) of four surveys conducted over that period. No error term is available for the 1974 estimates.

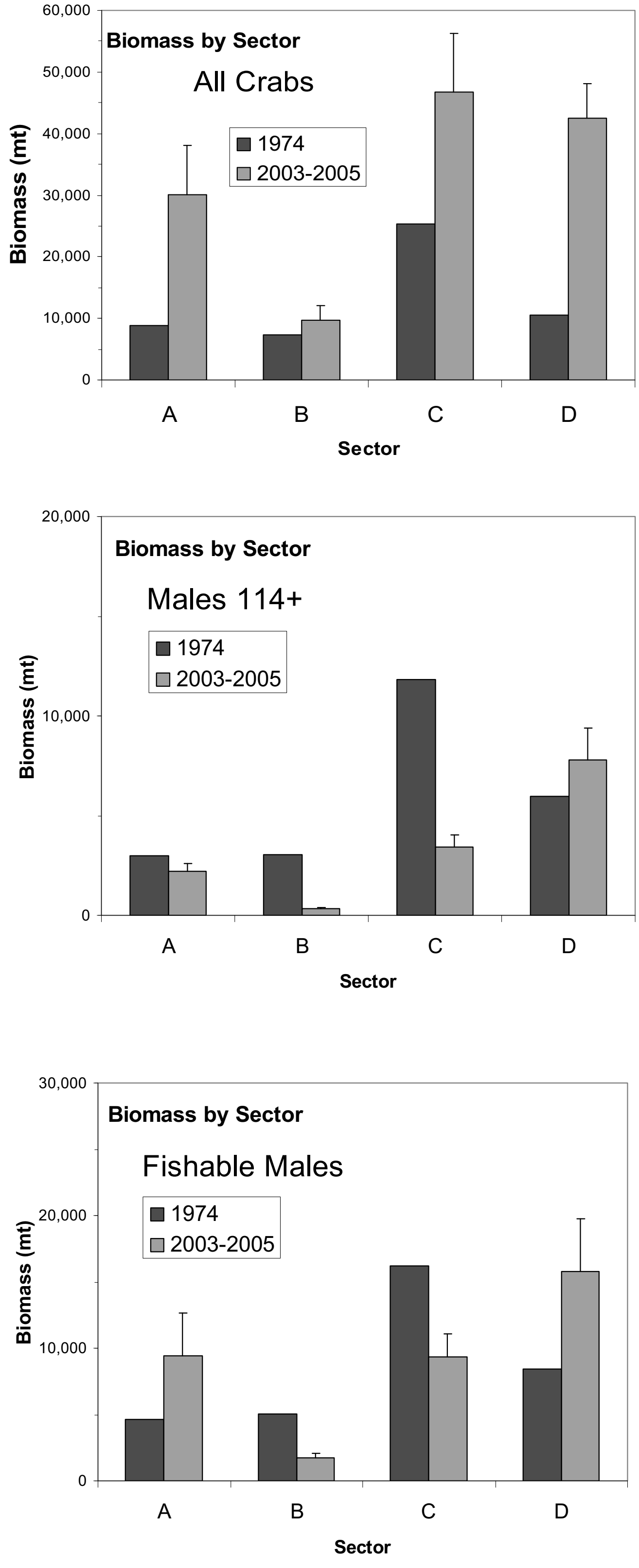


Figure D 5.6. Red crab biomass by sector in 1974 and 2003-2005. All crabs (top), males over 114+ mm (middle), and currently fishable males (bottom). Estimates for 2003-2005 represent the mean (+1 SE) of four surveys conducted over that period. No error term is available for the 1974 estimates.

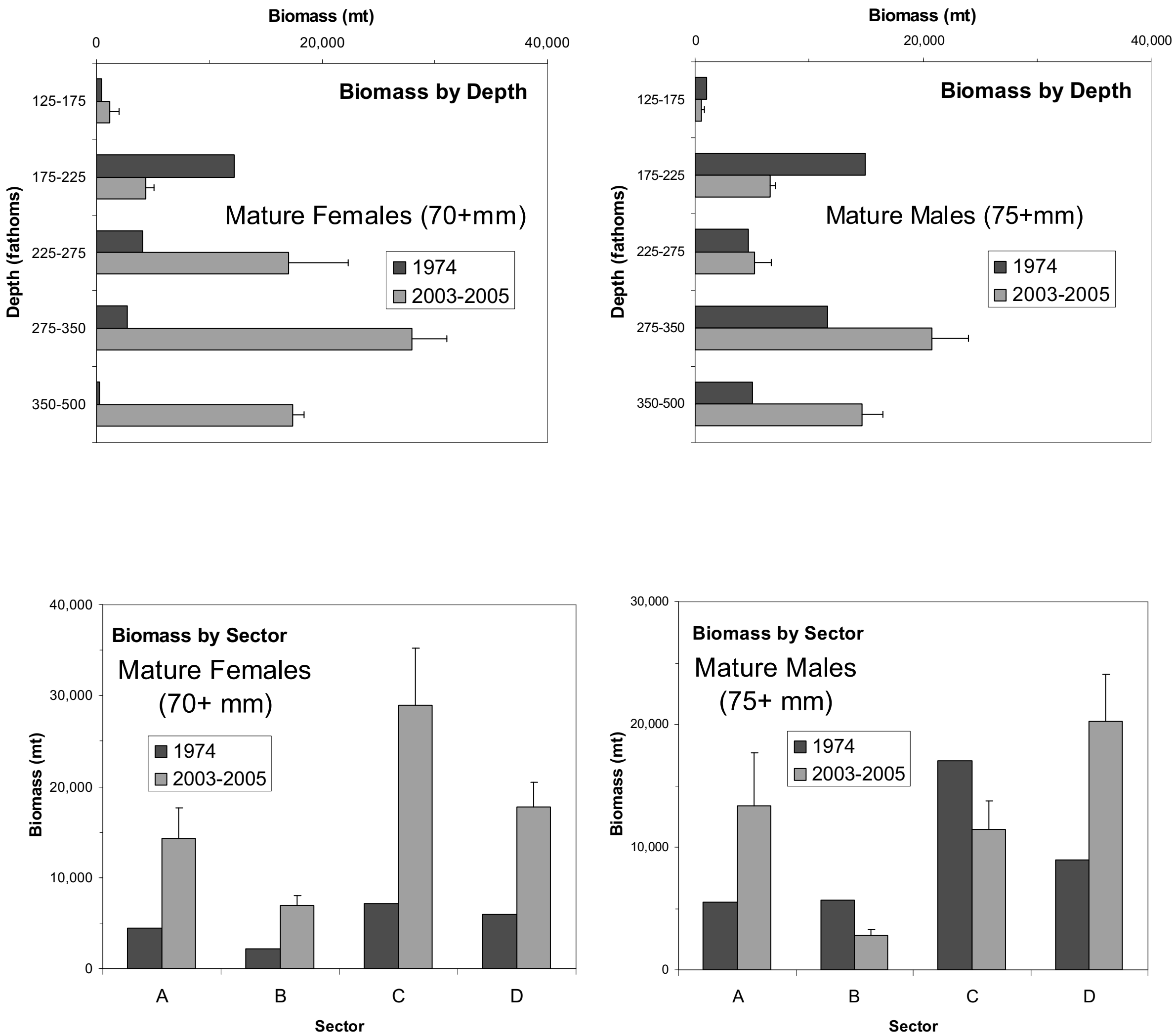


Figure D5.7. Biomass estimates of reproductive males (75+ mm) and females (70+ mm) in 1974 and 2003-2005 by depth stratum and geographic sector. Estimates for 2003-2005 represent the mean (+1 SE) of four surveys conducted over that period. No error term is available for the 1974 estimates.

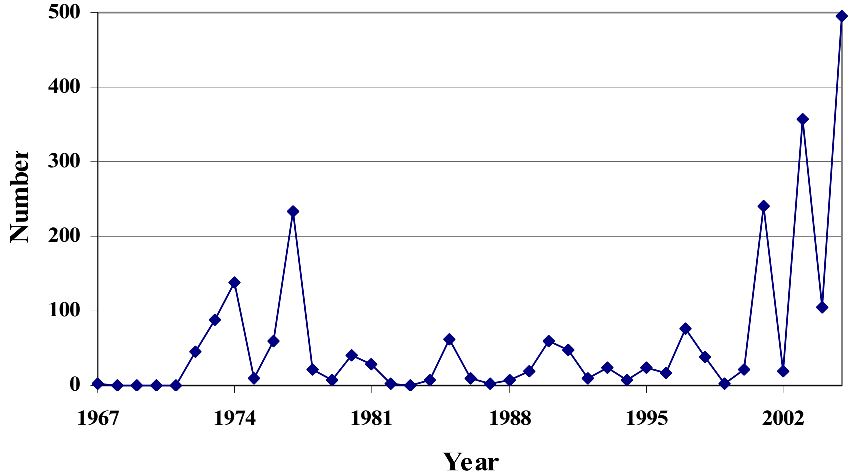


Figure D5.8. Total number of deep sea red crabs caught during the winter, spring, summer and fall NEFSC/NMFS groundfish surveys per year. Not all surveys were conducted every year. A few large tows during recent surveys account for the large numbers in those years.

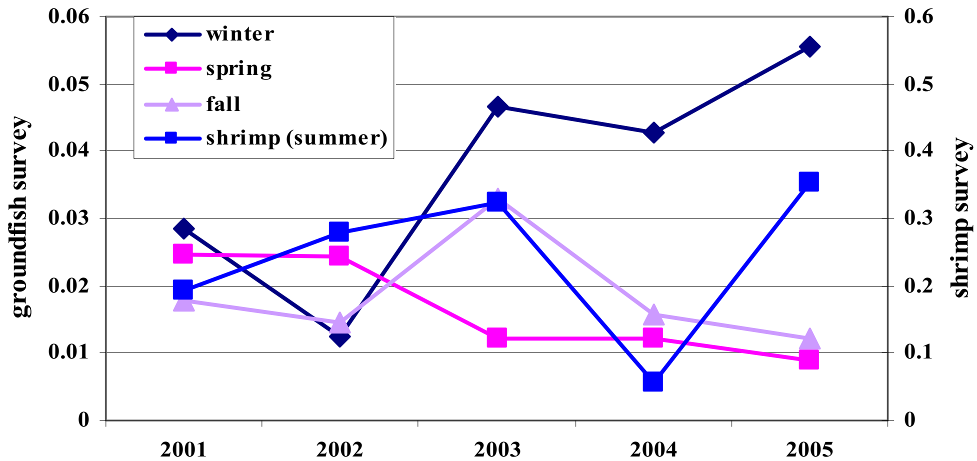


Figure D5.9. Proportion of tows containing red crab in the NEFSC/NMFS groundfish surveys (winter, spring and fall) and the NEFSC/NMFS northern shrimp survey (summer, Gulf of Maine only).

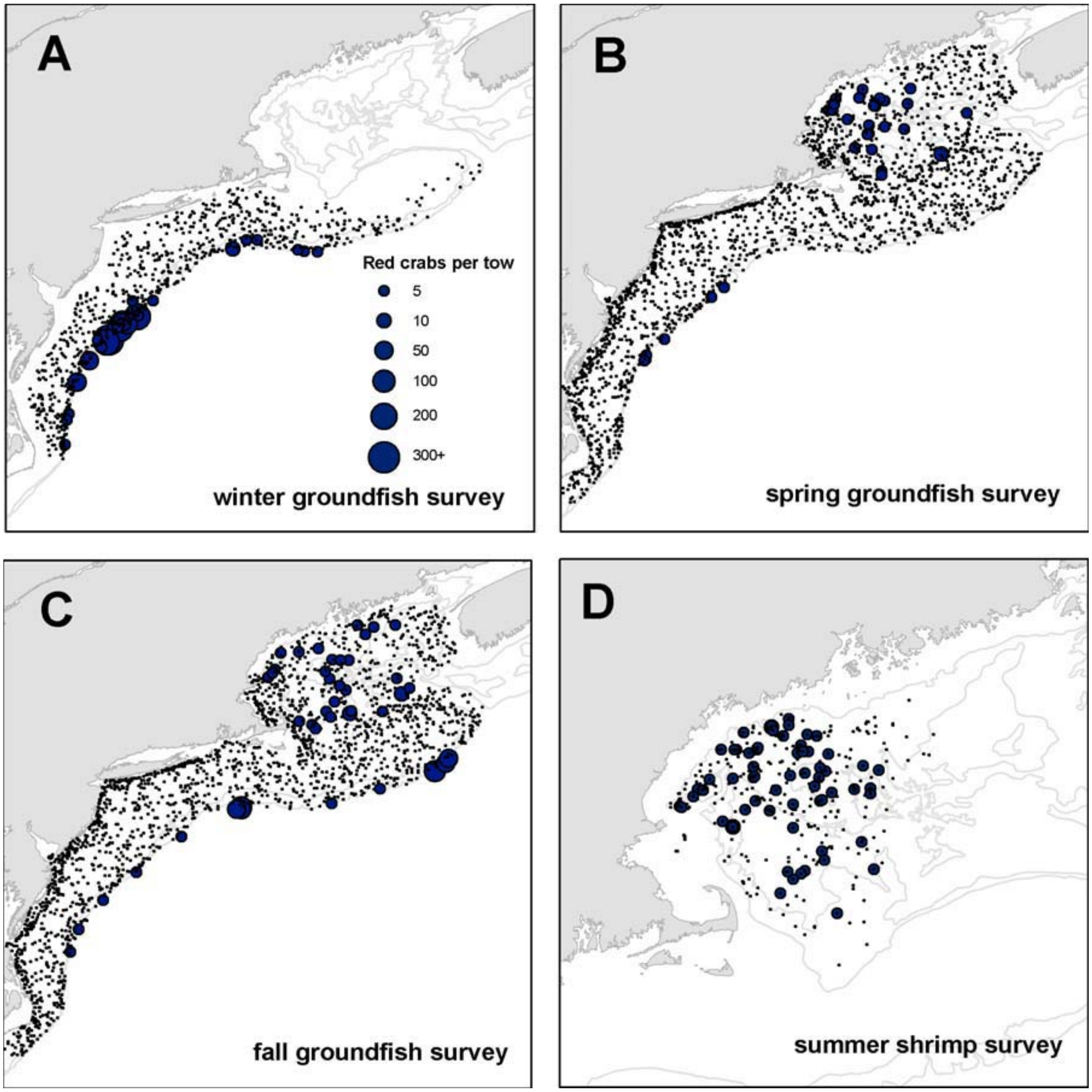


Figure D5.10. Locations of all tows made during the NEFSC/NMFS winter (A), spring (B) and fall (C) groundfish surveys and summer northern shrimp survey (D), 2000-2005. All catches of red crab during this time period are shown in larger symbols.

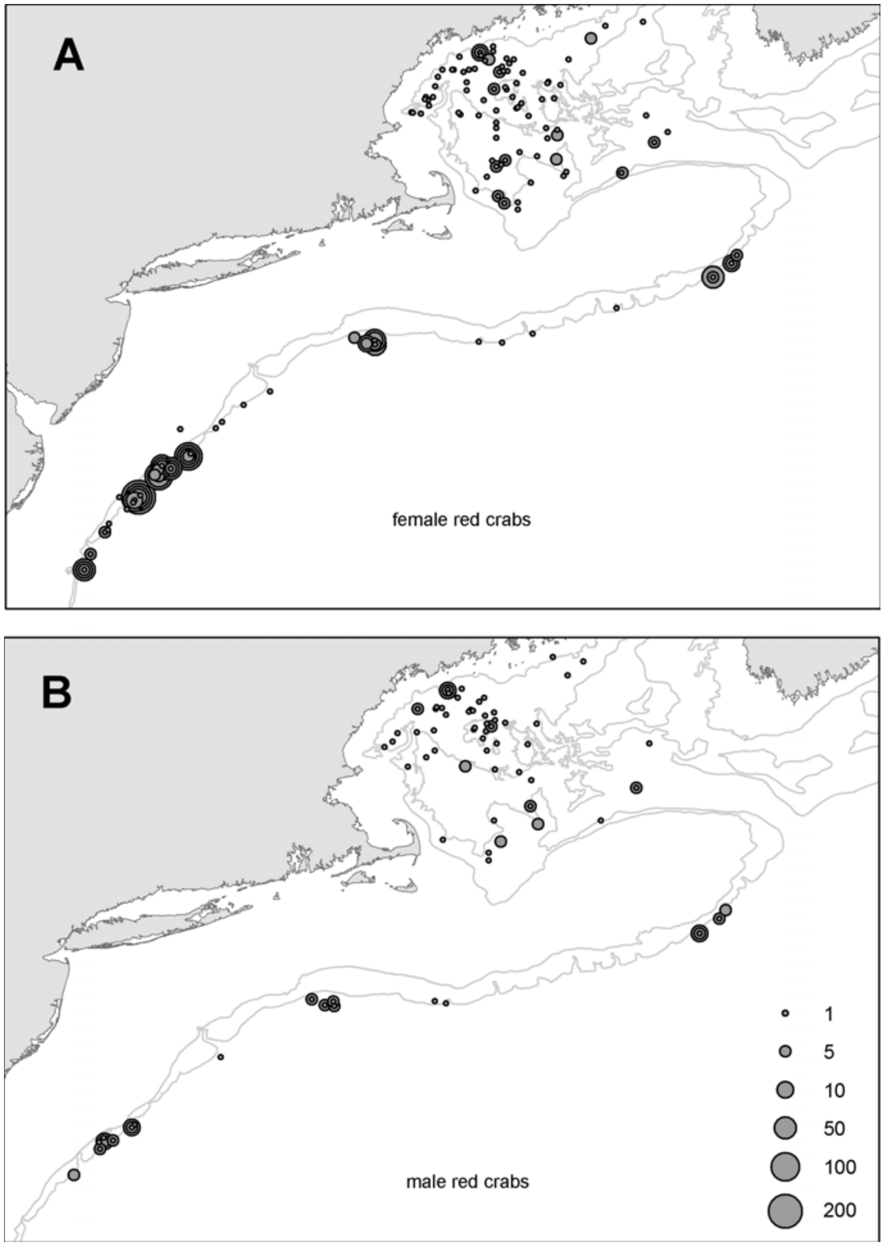


Figure D5.11. All female (A) and male (B) red crab catches from the NEFSC/NMFS winter, spring and fall groundfish and northern shrimp surveys combined, 2000-2005.

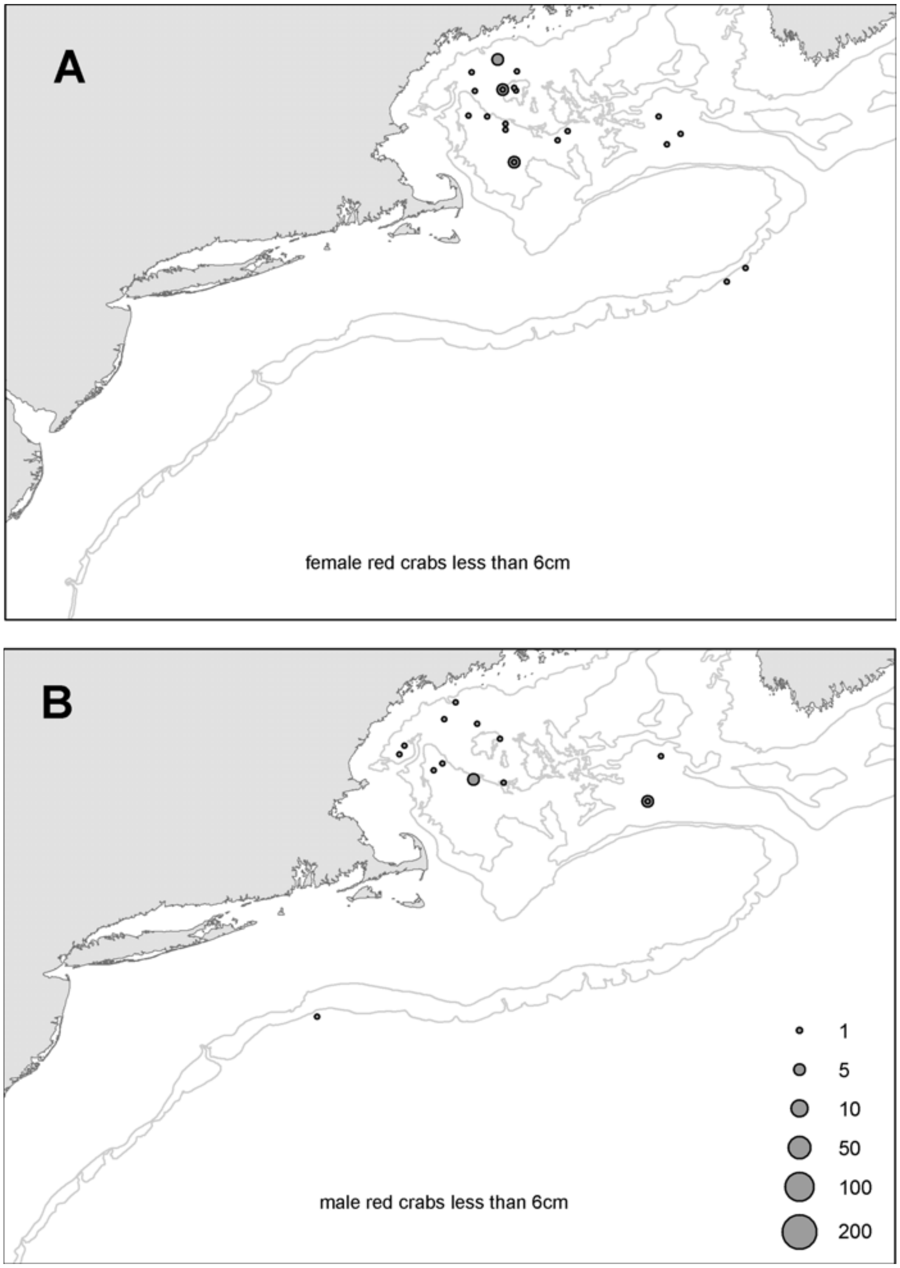
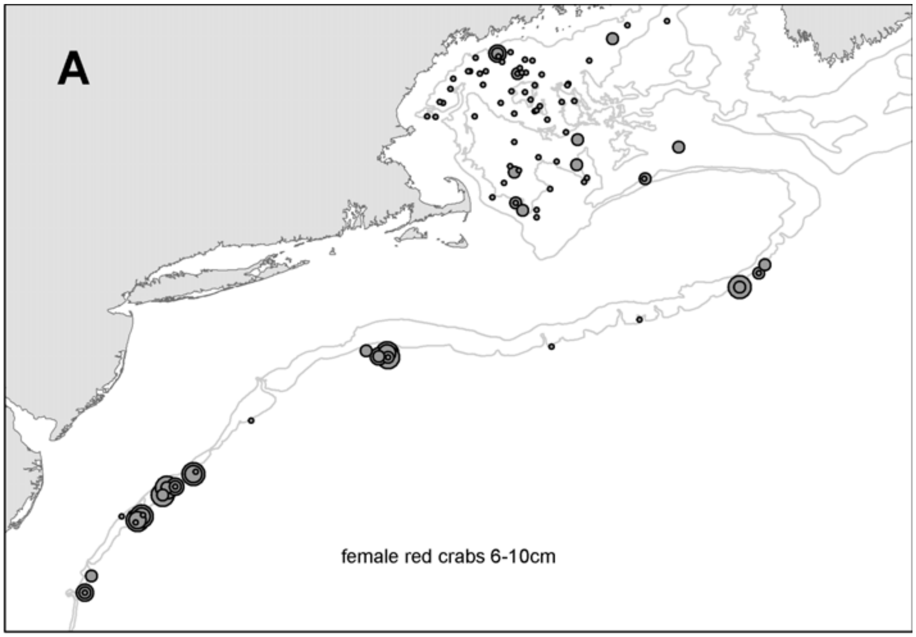


Figure D5.12. All female (A) and male (B) red crabs under 6cm carapace width (most assumed to be immature) caught during the NEFSC/NMFS winter, spring and fall groundfish and northern shrimp surveys combined, 2000-2005.



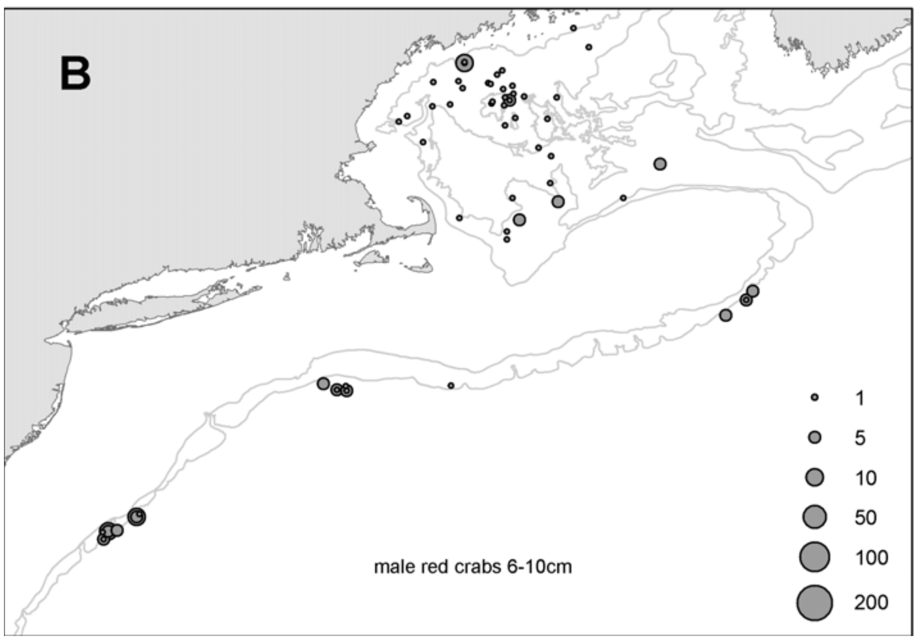


Figure D5.13. (A-B). All female (A) and male (B) red crabs 6-10cm carapace width caught during the NEFSC/NMFS winter, spring and fall groundfish and northern shrimp surveys combined, 2000-2005.

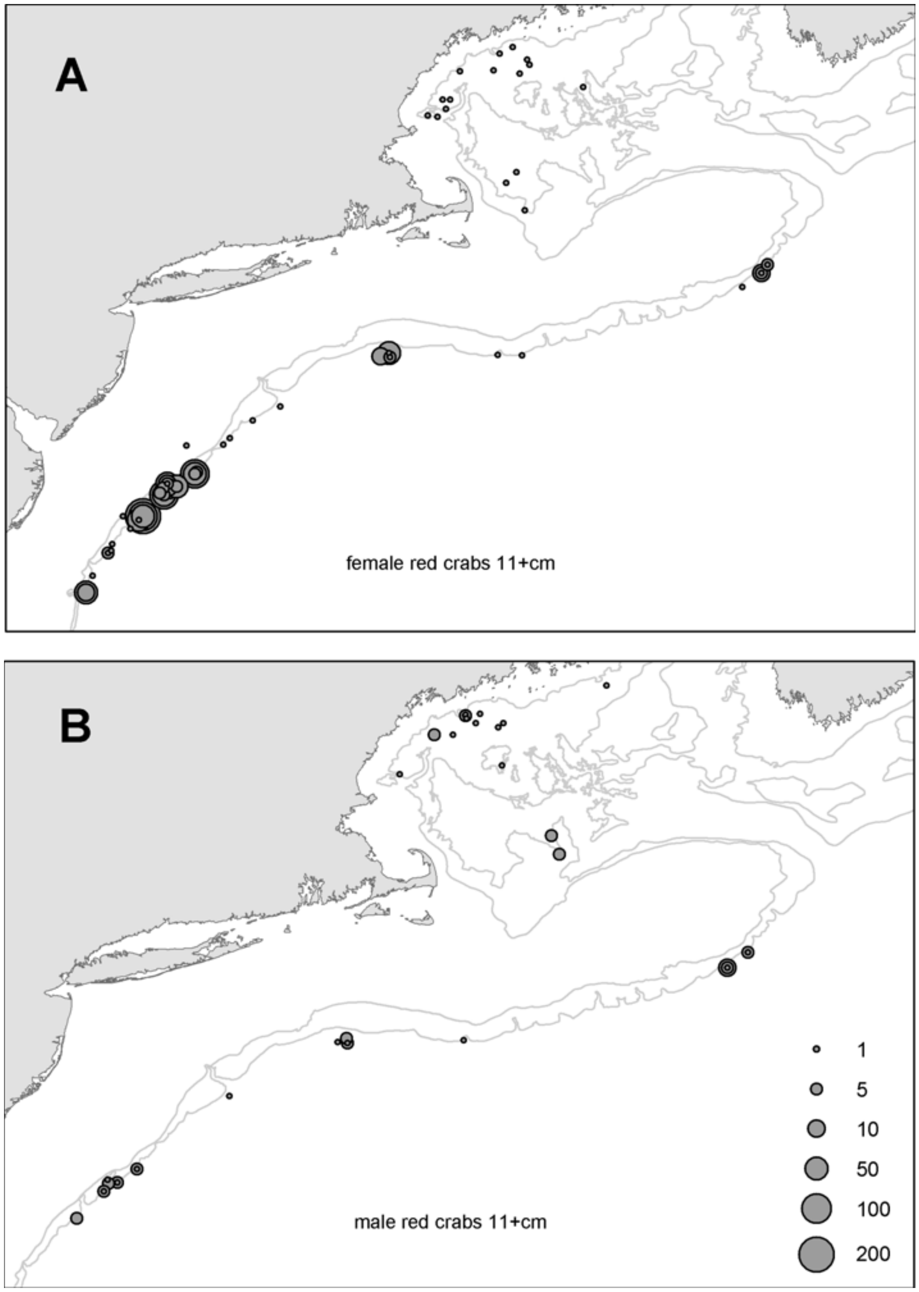


Figure D5.14. All female (A) and male (B) red crabs over 10cm carapace width (marketable size) caught during the NEFSC/NMFS winter, spring and fall groundfish and northern shrimp surveys combined, 2000-2005.

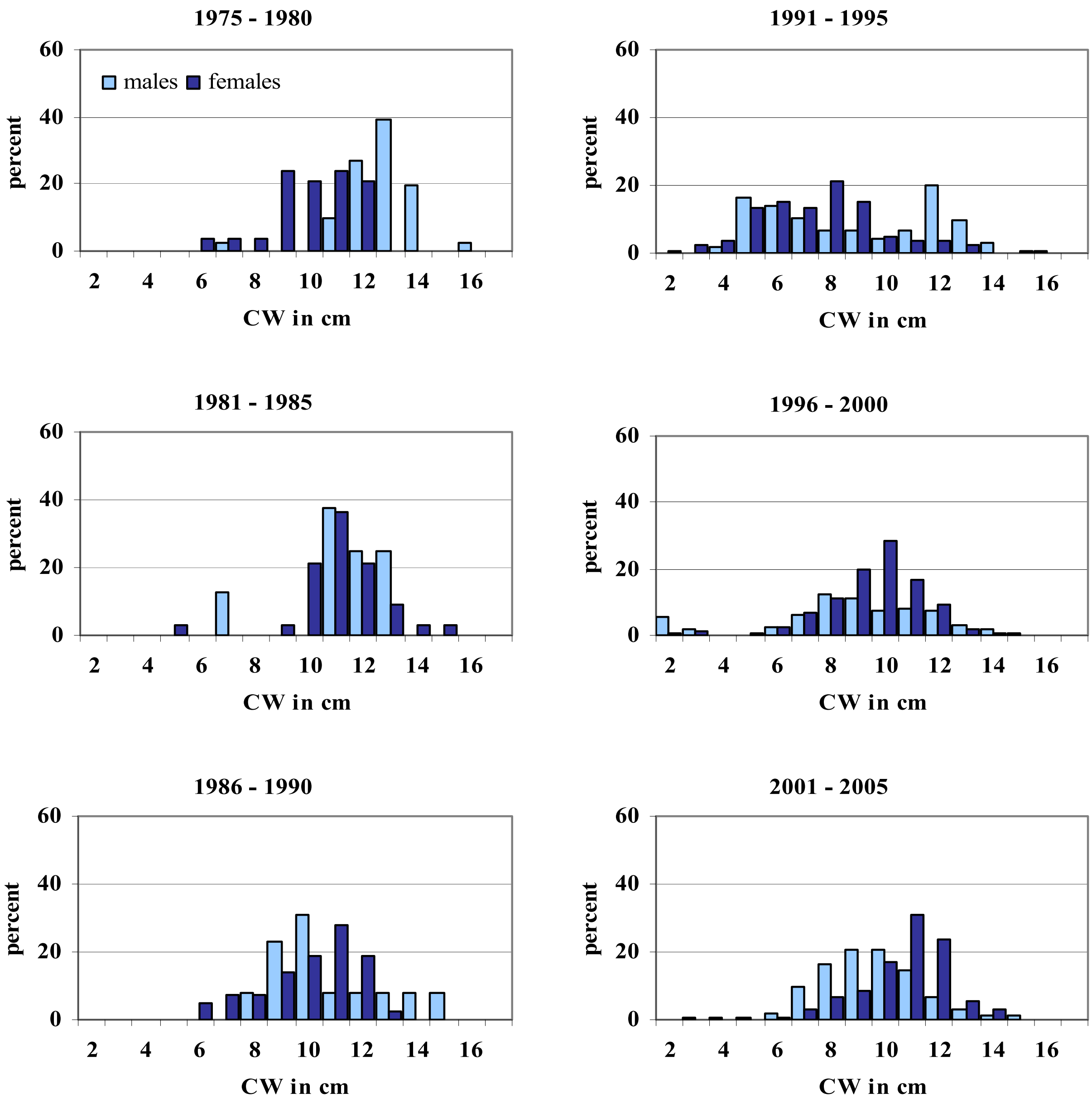


Figure D5.15. Percent at length (carapace width in cm) of all male and female red crabs caught and measured in any NEFSC/NMFS survey in 5-year bins from 1975 to 2005.

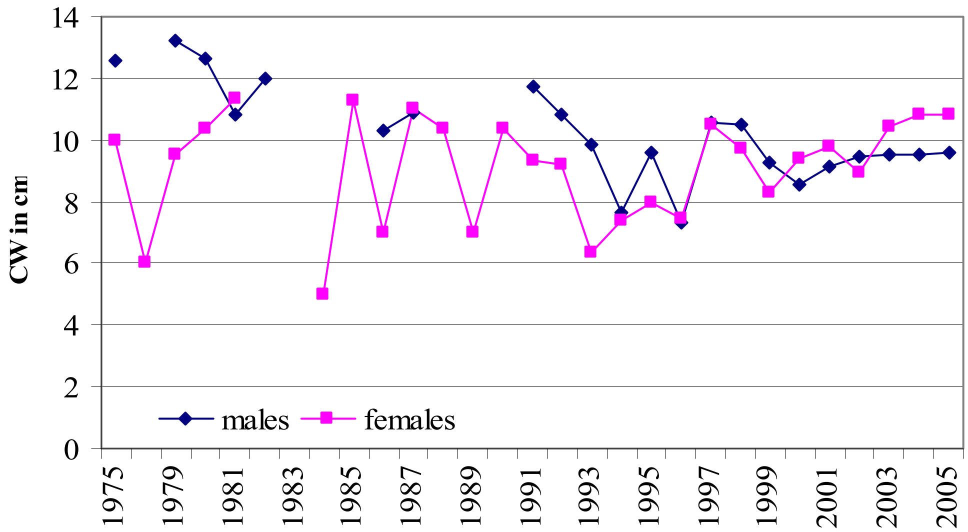
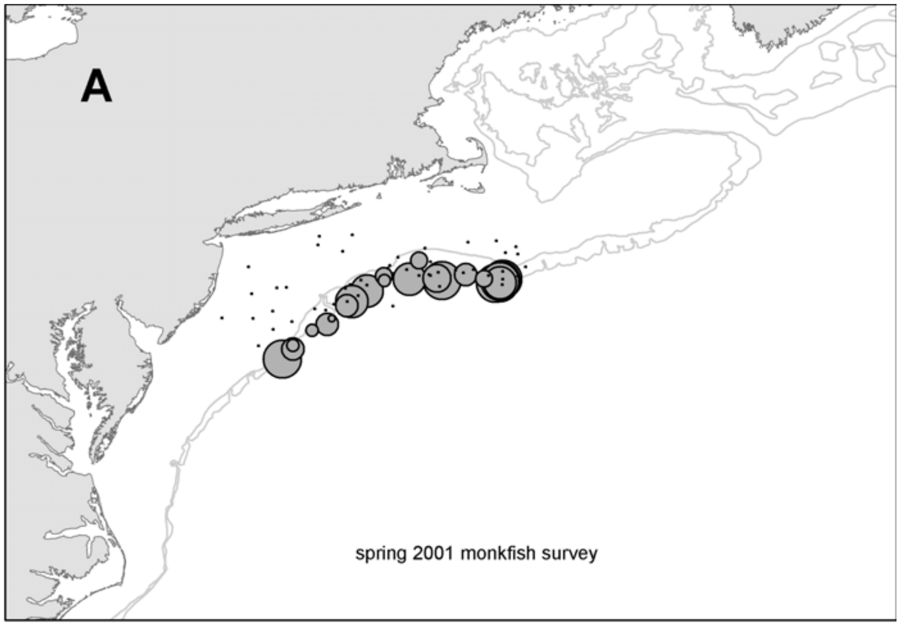


Figure D5.16. Mean male and female red crab carapace width, all NEFSC/NMFS surveys where crabs were measured, by year.



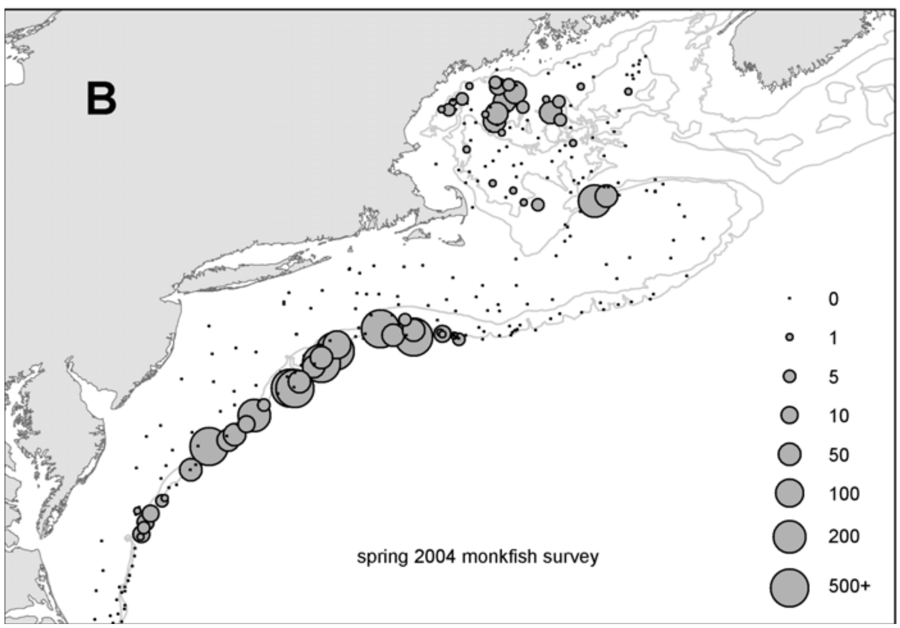
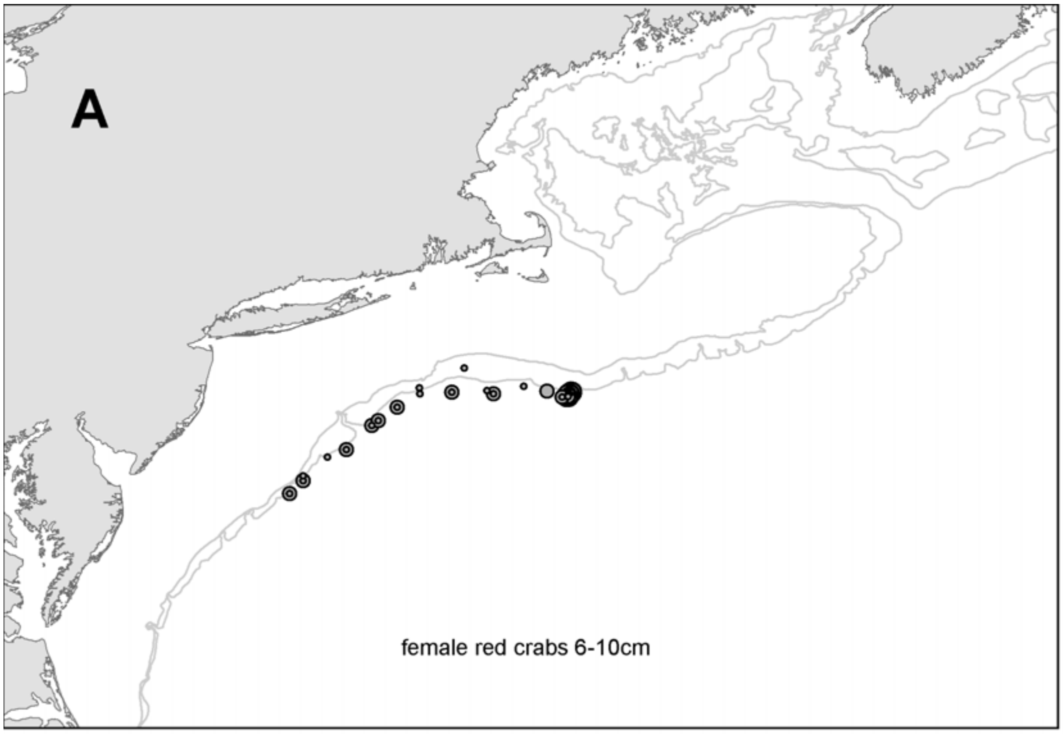


Figure D5.17. All red crab catch data from the NEFSC/NMFS cooperative monkfish surveys conducted in spring/summer 2001 (A) and 2004 (B).



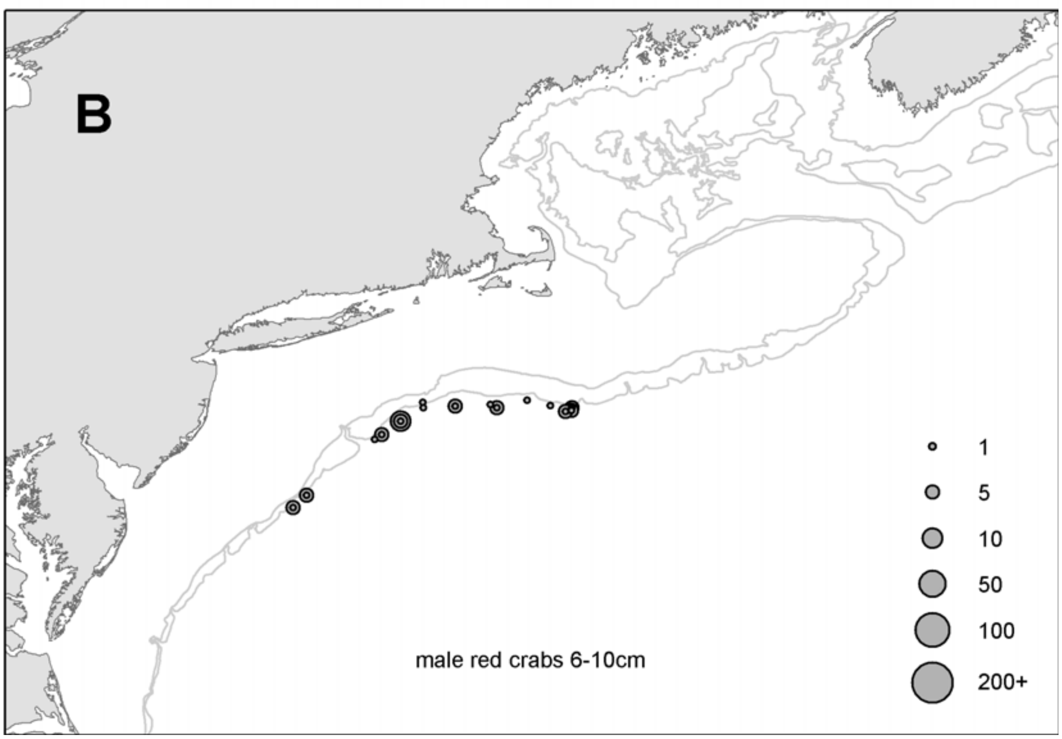


Figure D5.18. All female (A) and all male (B) red crabs 6-10cm in carapace width from the 2001 NEFSC/NMFS cooperative monkfish survey.

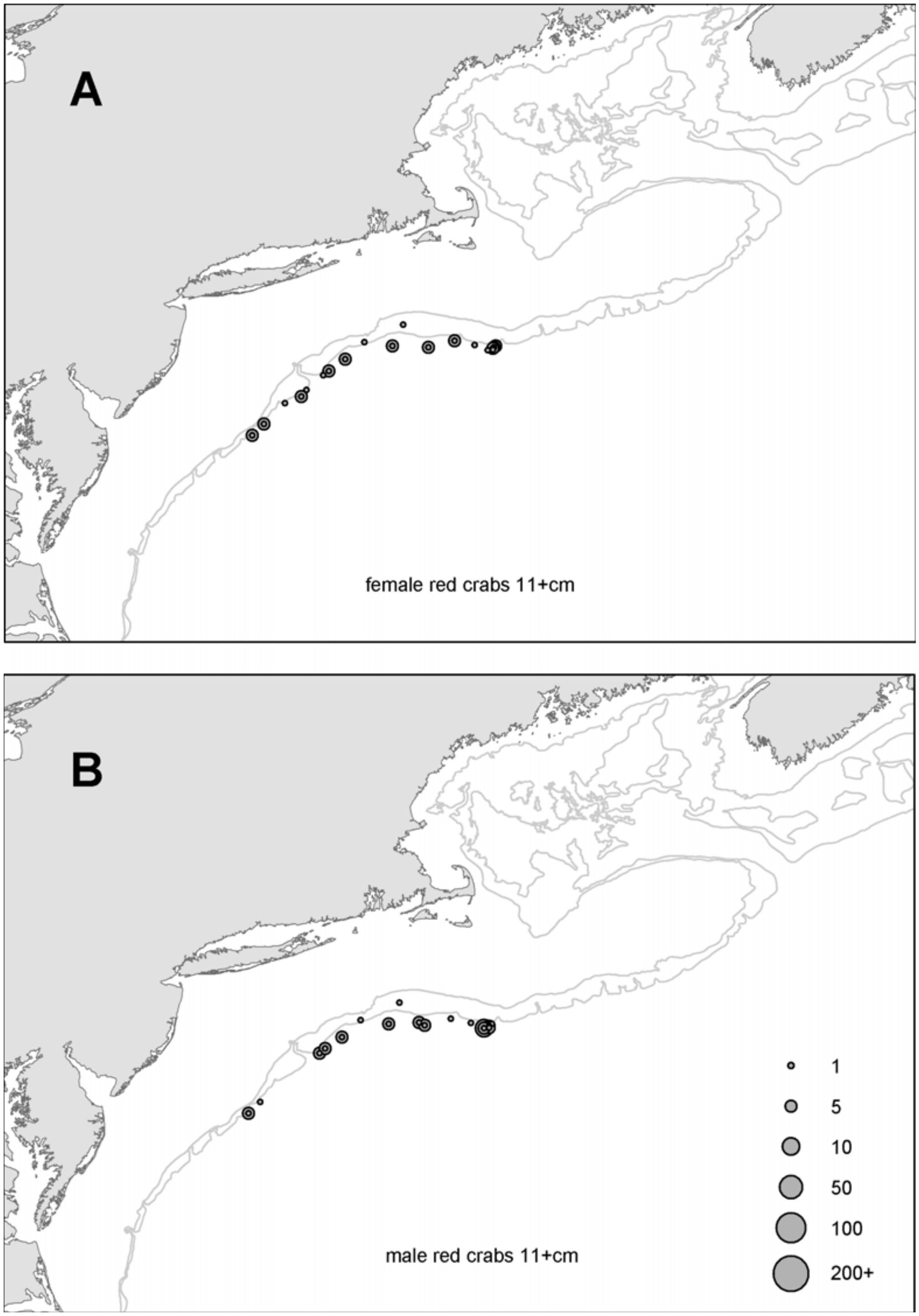
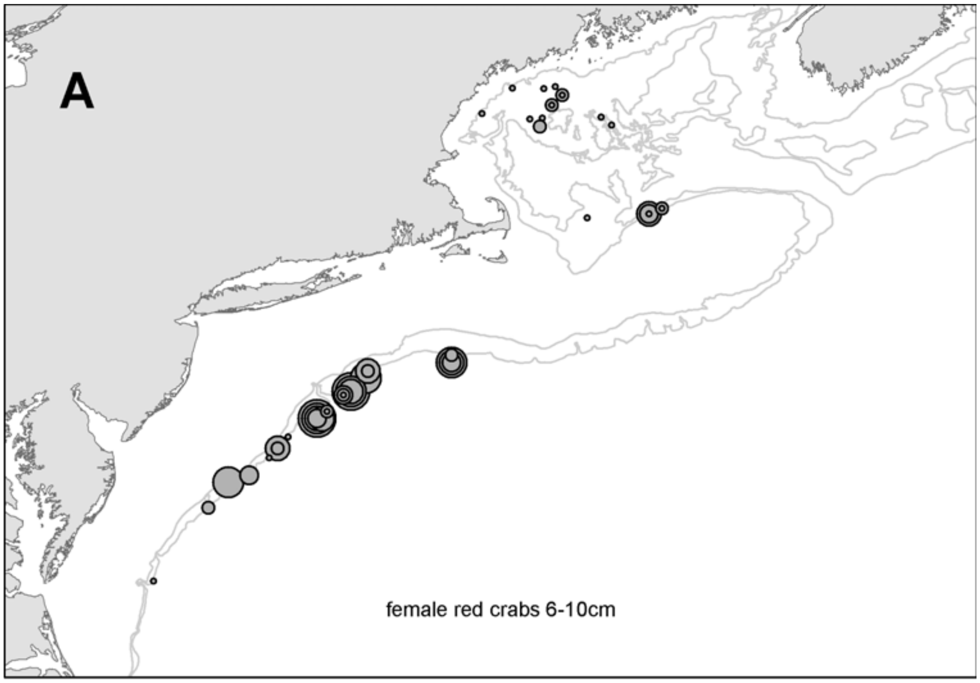


Figure D5.19. All female (A) and all male (B) red crabs over 10cm in carapace width from the 2001 NEFSC/NMFS cooperative monkfish survey.



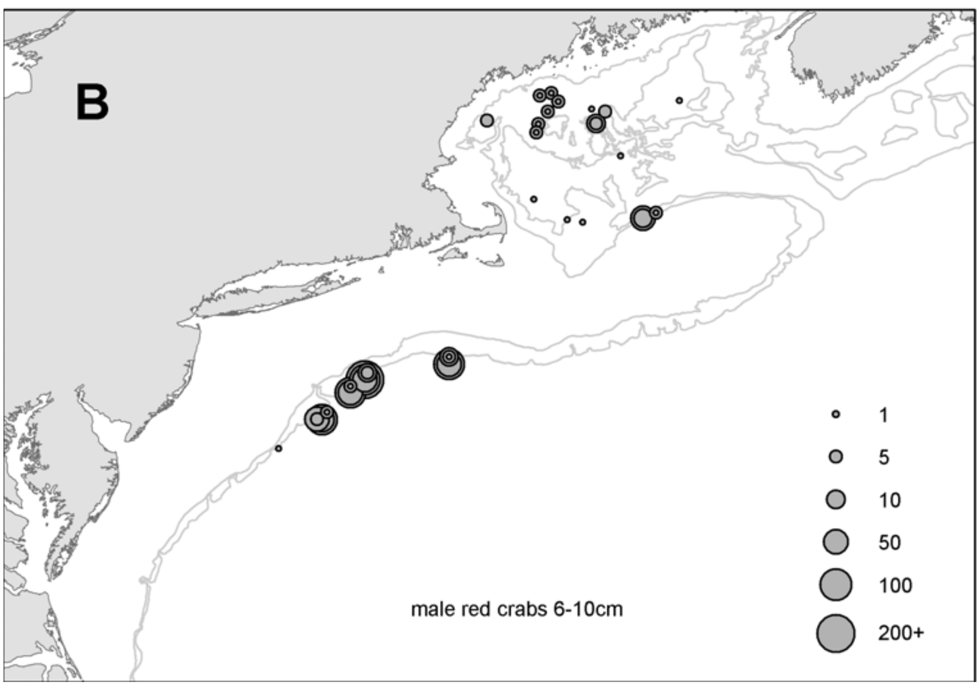


Figure D5.20. All female (A) and all male (B) red crabs 6-10cm in carapace width from the 2004 NEFSC/NMFS cooperative monkfish survey.

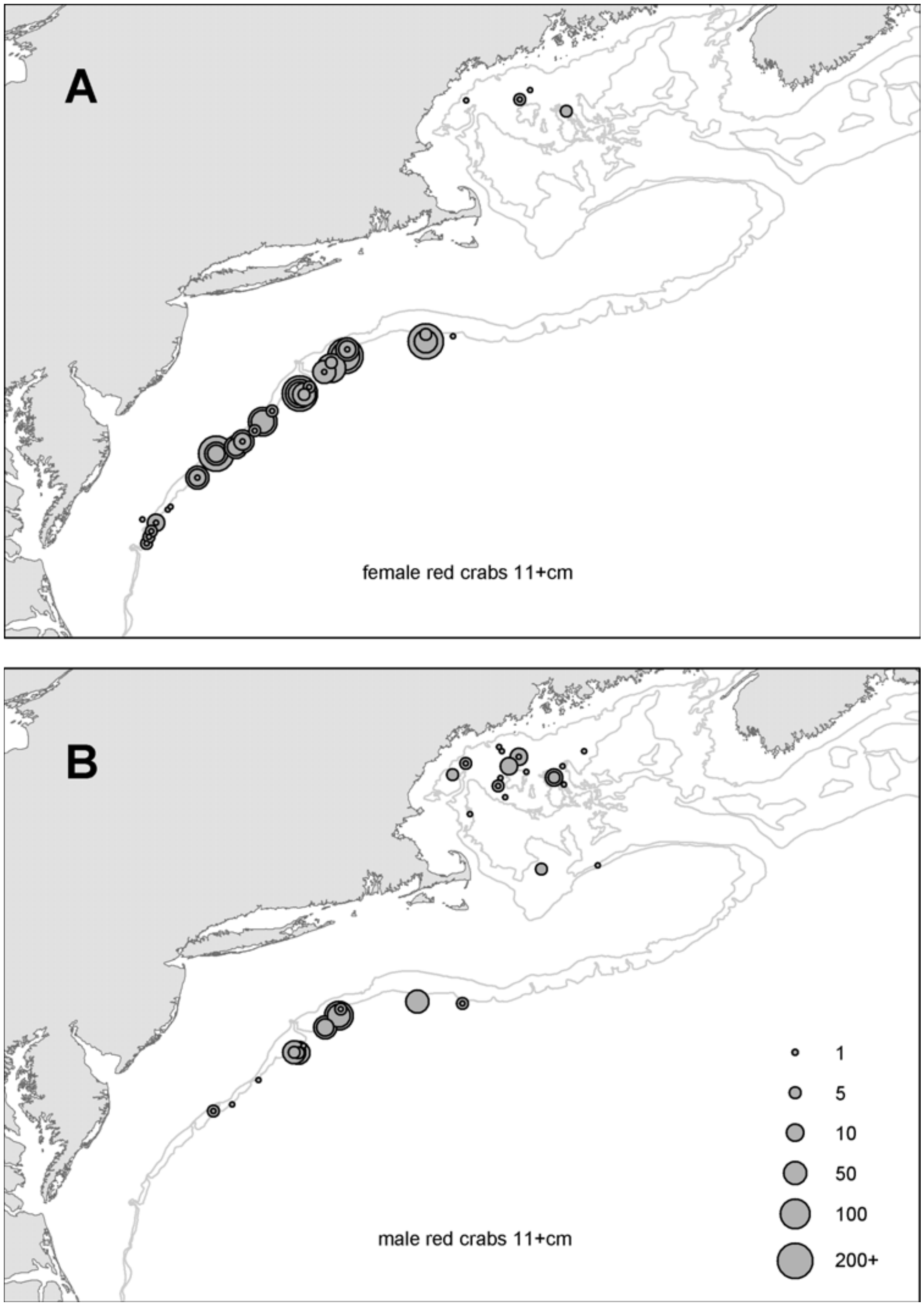


Figure D5.21. All female (A) and all male (B) red crabs over 10cm in carapace width from the 2004 NEFSC/NMFS cooperative monkfish survey.

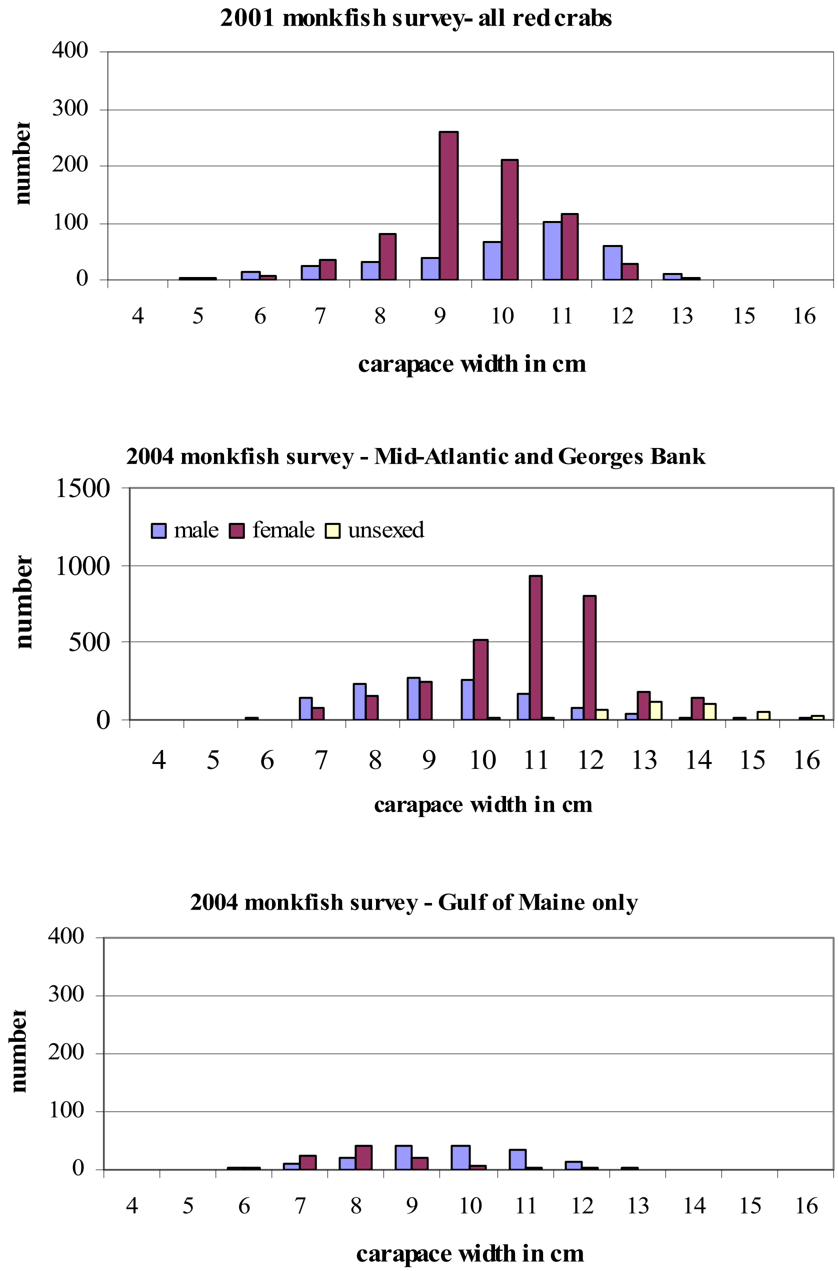


Figure D5.22. Length frequencies of red crabs from the 2001 and 2004 cooperative monkfish surveys. In 2004, the Gulf of Maine crabs are plotted separately. (Data from the Gulf of Maine portion of the 2001 monkfish survey were not available).

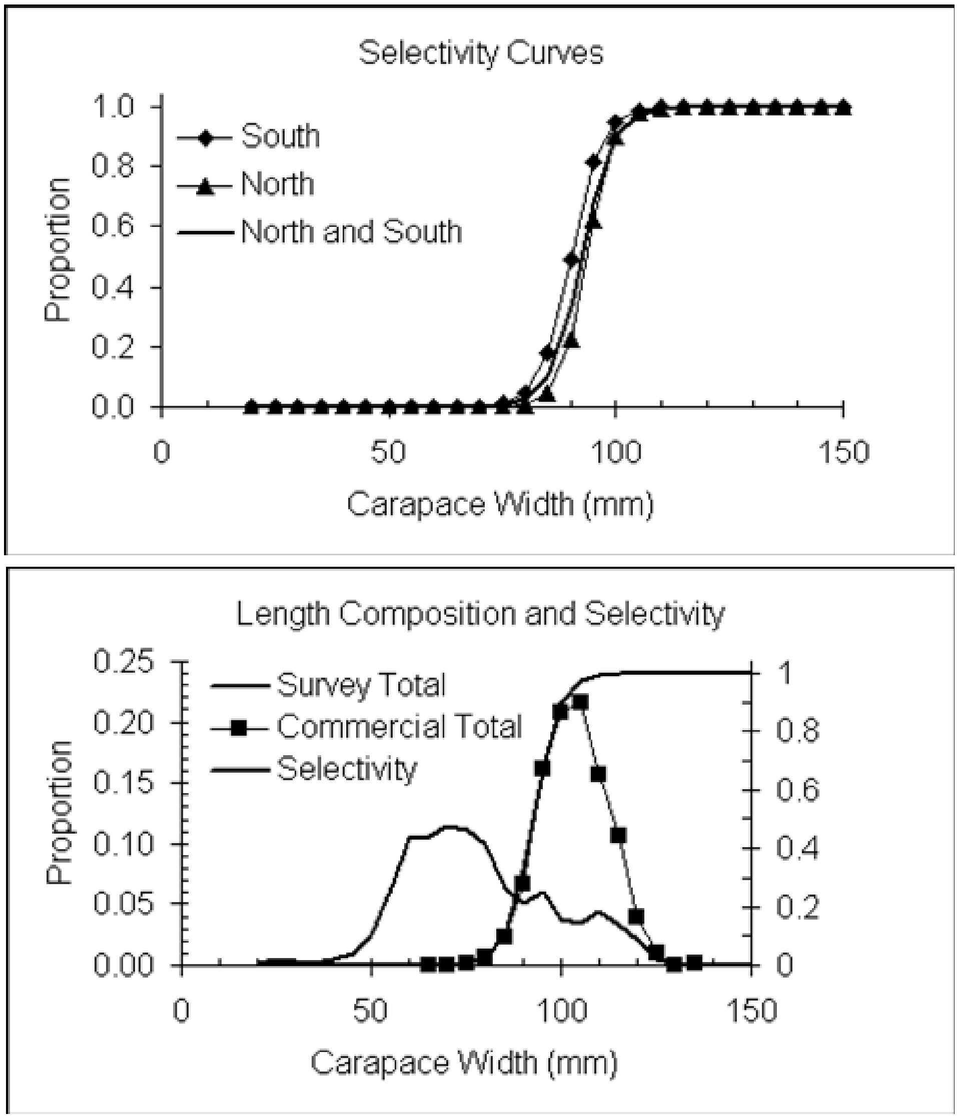


Figure D7.1. Fishery and survey length composition data with fishery selectivity curves for deep-sea red crab in the northern and southern regions during 2004-2005.

APPENDIX D1: Working Group Participants.

Richard Allen	Red Crab Harvesters Association
Andy Applegate	NEFMC
Charlene Bergeron	Bigelow Laboratory for Ocean Sciences
Yong Chen	University of Maine, Orono
Toni Chute	NMFS NEFSC
Peter Cooke	F/V Frank H. Wetmore
Bob Glenn	Mass. DMF
Neal Goff	F/V Frank H. Wetmore
Larry Jacobson	NMFS NEFSC
Peter Lawsing	F/V Frank H. Wetmore
Bruce Medeiros	Benthic Fishing
Barbara Rountree	NMFS NEFSC
Mike Ruccio	NMFS NERO
Fred Serchuk	NMFS NEFSC
Jim Stone	F/V Krystal James
Shelly Tallack	GMRI
Mark Terceiro	NMFS NEFSC (Subcommittee Chair)
Richard Wahle	Bigelow Laboratory for Ocean Sciences (Assessment Lead)
Jim Weinberg	NMFS NEFSC
Jon Williams	Benthic Fishing

APPENDIX D2: 2001-2005 VTR data GLM model

The GLM Procedure

Dependent Variable: lnhaul

Source	DF	sum of squares	mean square	F value	Pr >F
Model	36	35.80644	0.99462346	8.95	<.0001
Error	248	27.57169	0.11117617		
Corr total	284	63.37813			

R-Square	Coeff var	Root MSE	mean lnhaul
0.564965	11.67162	0.333431	2.856766

Source	DF	type 1 ss	mean sq	f val	pr>f
year	4	6.547771	1.63694278	14.72	<.0001
quarter	3	9.558456	3.18615211	28.66	<.0001
statarea	17	8.966749	0.52745583	4.74	<.0001
vessel	3	6.891198	2.29706589	20.66	<.0001
quarter*vessel	9	3.84227	0.42691892	3.84	0.0001

Source	DF	type III ss	mean sq	f val	pr>f
year	4	4.466238	1.11655942	10.04	<.0001
quarter	3	9.801626	3.26720881	29.39	<.0001
statarea	17	3.813623	0.22433078	2.02	0.011
vessel	3	3.761409	1.25380289	11.28	<.0001
quarter*vessel	9	3.84227	0.42691892	3.84	0.0001

Parameter		Estimate		SE	t val	pr>t
	Intercept	2.873772337	B	0.176259	16.3	<.0001
year	2001	0.077618397	B	0.076006	1.02	0.3081
year	2002	0.221066747	B	0.074375	2.97	0.0032
year	2003	-0.093689379	B	0.069033	-1.36	0.176
year	2004	-0.185242525	B	0.065723	-2.82	0.0052
year	2005	0	B	.	.	.
quarter	1	-0.353396096	B	0.139522	-2.53	0.0119
quarter	2	-0.397887415	B	0.108275	-3.67	0.0003
quarter	3	-0.117081704	B	0.087073	-1.34	0.18
quarter	4	0	B	.	.	.
statarea	522	0.439857962	B	0.406369	1.08	0.2801
statarea	525	-0.213436232	B	0.195365	-1.09	0.2757
statarea	526	-0.175149386	B	0.18127	-0.97	0.3349
statarea	533	-0.074899673	B	0.239637	-0.31	0.7549
statarea	534	-0.525061643	B	0.387105	-1.36	0.1762
statarea	537	-0.223868189	B	0.181407	-1.23	0.2183
statarea	541	-0.00909559	B	0.304063	-0.03	0.9762
statarea	543	-0.957907139	B	0.329457	-2.91	0.004
statarea	562	-0.493404468	B	0.282084	-1.75	0.0815
statarea	613	0.300865157	B	0.292351	1.03	0.3044
statarea	616	-0.205513637	B	0.171507	-1.2	0.232
statarea	621	0.258465223	B	0.289799	0.89	0.3733
statarea	622	-0.024290278	B	0.182154	-0.13	0.894
statarea	623	-0.261062337	B	0.20691	-1.26	0.2082

statarea		625	-0.634394698	B	0.395249	-1.61	0.1098
statarea		626	0.031341585	B	0.175323	0.18	0.8583
statarea		627	0.146379248	B	0.23959	0.61	0.5418
statarea		632	0	B	.	.	.
vessel		2	0.420734378	B	0.139729	3.01	0.0029
vessel		3	0.415537757	B	0.172311	2.41	0.0166
vessel		4	0.667723848	B	0.104842	6.37	<.0001
vessel		5	0	B	.	.	.
quarter*vessel	1	2	-0.411538151	B	0.222812	-1.85	0.0659
quarter*vessel	1	3	0.356143557	B	0.195663	1.82	0.0699
quarter*vessel	1	4	-0.271215422	B	0.182894	-1.48	0.1394
quarter*vessel	1	5	0	B	.	.	.
quarter*vessel	2	2	-0.388579031	B	0.208212	-1.87	0.0632
quarter*vessel	2	3	0.2385848	B	0.173287	1.38	0.1698
quarter*vessel	2	4	-0.574693338	B	0.160761	-3.57	0.0004
quarter*vessel	2	5	0	B	.	.	.
quarter*vessel	3	2	-0.179889877	B	0.183934	-0.98	0.329
quarter*vessel	3	3	0.035653165	B	0.200143	0.18	0.8588
quarter*vessel	3	4	-0.069219174	B	0.119102	-0.58	0.5617
quarter*vessel	3	5	0	B	.	.	.
quarter*vessel	4	2	0	B	.	.	.
quarter*vessel	4	3	0	B	.	.	.
quarter*vessel	4	4	0	B	.	.	.
quarter*vessel	4	5	0	B	.	.	.

APPENDIX D3a: Proportion at size for 1974 otter trawls by sex, depth, and sector.

	Sector A										Sector B										Sector C										Sector D									
	125-175		175-225		225-275		275-350		350-500		125-175		175-225		225-275		275-350		350-500		125-175		175-225		225-275		275-350		350-500		125-175		175-225		225-275		275-350		350-500	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No Data		0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0.045	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.014	0	0			0	0	0	0	0	0
19	0	0	0	0	0	0	0.03	0	0	0.045	0	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0.007	0	0	0	0	0			0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0.091	0.091	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0.045	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0.045	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.007	0	0	0	0	0			0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0.045	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
26	0.024	0	0	0	0	0	0	0	0	0	0	0	0	0	0.004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.014	0	0			0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0.045	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.038	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
29	0	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0.007	0	0	0	0	0			0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
31	0	0	0	0	0.005	0	0	0	0	0.045	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.007	0.007	0	0	0	0			0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0.045	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.007	0	0	0	0	0			0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0.333	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.038	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
41	0	0	0	0	0	0	0	0	0.045	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.007	0	0	0	0	0			0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.007	0	0	0	0			0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0.045	0	0	0	0	0.004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.007	0	0	0	0	0			0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
47	0	0	0	0	0.005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.038	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.014	0	0	0	0	0			0	0	0	0	0	0
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.007	0	0	0	0	0			0	0	0	0	0	0
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.014	0	0	0	0	0			0	0	0	0	0	0
53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.008	0	0	0	0	0	0	0.012	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
55	0	0	0	0	0.005	0	0.03	0	0	0	0	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0.014	0.007	0	0	0	0			0	0	0	0	0	0
56	0	0	0	0	0	0.005	0.03	0	0	0	0	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0.011	0	0	0	0
57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.007	0	0	0	0	0			0.022	0	0	0	0	0
58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.008	0	0	0	0	0	0	0	0	0	0	0	0.007	0	0	0	0			0	0	0	0	0	0
59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
60	0	0	0	0	0	0.005	0	0	0	0	0	0	0	0	0	0.004	0	0	0	0	0	0	0	0	0	0	0.007	0.007	0.027	0	0	0			0.011	0	0	0	0	0
61	0	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0.004	0	0.03	0	0	0	0	0	0	0	0	0	0	0.007	0	0	0	0			0	0	0	0	0	0
62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.014	0	0	0	0	0			0	0	0	0	0	0
63	0	0	0	0	0	0.005	0	0	0	0	0	0	0	0	0.004	0.008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0.011	0	0	0	0
64	0	0	0	0	0	0.005	0	0	0	0	0	0	0	0	0.004	0.004	0	0	0	0	0	0	0	0	0	0	0.007	0	0.014	0	0	0			0	0	0	0	0	0
65	0	0	0	0	0	0.009	0	0	0	0	0	0	0	0	0.004	0.004	0	0	0	0	0	0	0	0	0	0	0.021	0	0	0	0	0			0	0	0	0	0	0
66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.004	0	0	0	0	0	0	0	0	0	0	0	0.007	0.007	0	0	0	0			0	0	0	0	0	0
67	0	0	0	0	0.005	0	0	0	0.045	0	0	0	0	0	0	0.008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
68	0	0	0	0	0	0.005	0.03	0	0	0	0	0	0	0	0.004	0	0.03	0	0	0	0	0	0	0	0	0	0.007	0.007	0	0	0	0			0	0.011	0	0	0	0
69	0	0	0	0	0	0.019	0	0	0	0	0	0	0	0	0.004	0.004	0	0	0	0	0	0	0	0	0	0.016	0	0.007	0	0	0	0			0	0	0	0	0	0
70	0	0	0	0	0	0.028	0	0	0	0	0	0	0	0	0.004	0.016	0	0	0	0	0	0	0	0	0	0	0.014	0	0	0	0	0			0	0	0	0	0	0
71	0	0	0	0	0	0.009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.007	0	0.027	0	0	0			0	0	0	0	0	0
72	0	0	0	0	0	0.014	0	0	0	0	0	0	0	0	0.012	0.008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0.034	0	0	0	0	0
73	0	0	0	0	0	0.009	0	0	0	0.045	0	0	0	0	0.004	0.012	0	0	0	0	0	0	0	0	0.008	0	0.007	0	0	0	0	0			0	0	0	0	0	0
74	0	0	0	0	0	0.014	0	0	0	0	0	0	0	0	0.008	0.012	0	0	0	0	0	0	0	0	0.008	0	0.007	0.014	0	0	0	0			0	0.011	0	0	0	0
75	0	0	0	0	0	0.019	0	0	0	0	0	0	0	0.018	0.012	0.004	0	0	0	0	0	0	0	0	0	0.008	0	0.007	0	0	0	0			0	0.011	0	0	0	0
76	0	0	0	0	0	0.019	0	0	0	0	0	0	0	0.009	0	0.008	0	0	0	0	0	0	0	0	0.008	0	0	0	0	0.014	0	0			0	0	0	0	0	0
77	0	0	0	0	0	0.009	0	0.03	0	0	0	0	0	0	0.004	0.004	0	0.03	0	0	0	0	0	0	0	0	0	0.014	0	0	0	0			0	0	0	0	0	0
78	0	0.032	0	0.077	0.009	0.014	0	0	0	0	0	0	0	0	0.016	0.016	0	0	0	0	0	0	0	0	0.016	0.016	0	0.007	0	0.014	0	0			0	0	0	0	0	0
79	0	0	0	0	0	0.005	0	0	0	0	0	0	0	0	0.004	0.008	0	0	0	0	0	0	0	0	0	0	0.007	0	0	0	0	0			0	0	0	0	0	0
80	0	0	0	0	0.005	0.014	0	0	0	0	0	0	0	0.018	0	0.031	0	0	0.115	0	0	0	0.012	0	0	0	0	0	0	0	0	0			0	0.011	0	0	0	0
81	0	0	0	0	0.005	0.019	0	0	0	0	0	0	0.005	0	0.004	0.008	0	0	0	0	0	0	0	0	0.008	0.008	0.007	0.007	0	0	0	0			0	0	0	0	0	0
82	0	0	0	0	0	0.009	0.03	0	0	0	0	0	0.005	0.009	0.004	0.012	0.03	0	0.077	0	0	0	0	0	0	0	0	0.027	0	0	0	0			0	0	0	0	0	0
83	0	0	0	0	0	0.014	0.061	0.03	0	0	0	0	0	0.009	0.004	0.008	0.061	0.03	0	0	0	0	0.012	0	0.016	0	0	0.007	0	0	0	0			0	0	0	0	0	0
84	0	0	0	0	0	0.032	0.03	0	0	0	0	0	0	0.037	0.012	0.004	0.03	0	0	0	0	0	0.012	0	0	0.016	0	0.014	0.014	0	0	0			0.011	0	0	0	0	0
85	0	0	0	0	0	0.032	0.03	0	0	0	0	0	0	0.009	0.004	0.031	0.03	0	0	0	0	0	0	0	0	0.008	0	0	0	0	0	0			0	0	0	0	0	0
86	0	0	0	0	0	0.028	0.03	0	0	0	0	0	0	0.018	0.004	0.016	0.03	0	0	0	0	0	0	0.012	0.016	0.024	0	0.027	0.027	0	0	0			0	0	0	0	0	0
87	0	0	0	0	0	0.023	0.03	0	0	0	0	0	0	0.018	0.004	0.008	0.03	0	0	0	0	0	0	0	0	0.008	0	0.007	0.027	0	0	0			0	0.011	0	0	0	0
88	0	0	0	0	0	0.014	0	0	0	0	0	0	0	0.06	0.004	0.02	0	0	0	0	0	0	0	0	0.008	0.008	0	0.034	0	0	0	0			0	0	0	0	0	0
89	0	0	0	0	0.005	0.028	0	0	0	0	0	0	0	0.028	0.012	0.02	0	0	0	0	0	0	0.012	0.012	0	0.024	0	0.014	0.014	0.014	0	0			0	0	0	0	0	0
90	0	0.016	0	0	0	0.042	0.03	0	0	0	0	0	0	0.055	0	0.023	0.03	0	0.038	0	0	0	0	0	0.008	0.016	0	0.055	0	0	0	0			0	0.034	0	0	0	0
91	0	0.016	0	0.038	0	0.014	0	0	0	0	0	0	0.005	0.009	0.004	0.02	0	0	0	0	0	0	0	0	0	0.024	0	0.021	0.041	0	0	0			0	0	0	0	0	0
92	0.024	0	0	0	0	0.032	0	0	0	0	0	0	0	0.018	0	0.016	0	0	0	0	0	0	0	0	0.008	0.016	0.007	0.021	0	0	0	0			0	0	0	0	0	0
93	0	0	0	0	0	0.019	0	0	0	0	0	0	0	0.046	0	0.016	0	0	0.038	0	0	0.043	0	0.012	0	0.016	0.007	0	0.014	0	0	0			0	0.022	0	0	0	0
94	0.024	0.032	0	0.077	0.005	0.028	0	0	0	0	0	0	0.005	0.037	0.004	0.012	0	0	0	0	0	0	0	0.012	0	0.016	0	0	0.027	0	0	0.333			0	0.045	0	0	0	0
95	0.024	0	0	0	0	0.028	0	0	0	0	0	0	0	0.046	0	0.016	0	0	0.038	0	0	0	0	0	0	0.063	0.014	0.027	0	0	0	0			0	0	0	0	0	0
96	0	0	0	0	0	0.028	0	0	0	0	0	0	0.028	0.028	0.004	0.012	0	0	0	0	0	0	0	0.012	0	0.024	0	0.014	0.014	0	0	0			0	0.022	0	0	0	0
97	0	0.016	0	0.038	0.005	0.023	0	0	0	0	0	0	0	0.009	0	0.035	0	0	0	0	0	0	0	0.012	0	0.008	0.014	0.007	0.014	0.014	0	0			0	0.022	0	0	0	0
98	0	0	0	0	0	0.014	0	0	0	0.045	0	0	0.009	0.028	0.004	0.008	0	0	0	0	0	0	0	0.036	0	0.024	0.007	0.027	0.041	0	0	0			0	0.022	0	0	0	0
99	0.024	0.016	0.038	0.038	0.005	0.014	0.03	0	0	0	0	0	0	0.037	0	0.008	0.03	0	0	0	0	0	0	0.024	0.008	0.016	0	0	0.014	0	0	0			0	0.045	0	0	0	0
100	0	0.016	0	0.038	0.009	0.019	0	0	0	0	0	0	0	0.018	0	0.035	0	0	0.038	0	0.043	0	0.012	0	0	0.008	0.007	0.014	0.027	0	0	0			0	0.034	0	0	0	0
101	0.024	0.032	0	0.038	0	0.014	0	0	0	0	0	0	0.009	0.018	0	0.023	0	0	0	0	0	0	0	0.06	0	0.016	0	0	0.027	0	0	0			0	0.022	0	0	0	0
102	0	0	0	0	0	0.019	0.03	0	0	0	0	0	0.009	0.037	0	0.016	0.03	0	0	0	0	0	0	0.036	0.008	0.024	0.027	0	0.041	0	0	0			0	0.022	0	0.167	0	0
103	0.024	0.032	0	0.038	0	0.009	0.03	0	0.045	0	0	0	0	0.009	0	0.008	0.03	0	0	0	0	0	0	0.024	0.008	0.032	0	0	0.041	0.014	0	0			0	0.034	0	0	0	0
104	0	0.016	0	0.038	0.019	0.009	0	0	0	0	0	0	0.009	0.028	0.008	0.023	0	0	0	0	0	0	0	0.036	0.008	0.008	0.007	0.007	0.041	0	0	0			0.011	0.079	0	0	0	0
105	0	0	0	0	0	0.005	0	0	0	0	0	0	0.005	0.009	0.004	0.008	0	0	0.115	0	0	0.043	0	0.024	0	0.024	0	0	0	0	0	0			0	0.011	0	0	0	0
106	0.024	0.032	0	0.077	0.005	0.014	0	0	0	0	0	0	0	0.009	0.008	0.016	0	0	0.077	0	0	0.043	0	0.036	0.008	0.016	0	0	0.027	0	0	0			0.022	0.045	0	0.167	0	0
107	0	0	0	0	0	0.005	0	0	0	0	0	0	0	0.009	0	0.012	0	0	0	0	0	0	0	0.048	0	0.008	0.007	0	0.027	0	0	0			0	0.011	0	0	0	0
108	0	0.032	0	0.077	0	0.009	0	0	0.045	0	0	0	0.023	0.009	0.004	0.012	0	0	0	0	0	0	0	0.012	0	0.008	0.021	0	0.041	0	0	0			0	0	0	0	0	0
109	0.072	0	0	0	0.005	0.005	0	0	0	0	0	0	0.009	0	0.004	0.008	0	0	0.038	0	0	0	0	0.012	0.008	0.008	0.021	0	0.014	0	0	0			0.011	0	0	0	0	0
110	0.048	0.016	0	0.038	0.009	0	0.03	0	0.045	0	0	0	0.009	0	0	0.012	0.03	0	0.077	0	0	0.043	0.012	0.024	0.016	0.008	0.007	0	0.041	0	0	0			0.034	0.011	0	0	0	0
111	0	0.016	0	0.038	0.005	0	0.061	0	0	0	0	0	0.009	0.009	0	0	0.061	0	0	0	0	0.043	0.024	0	0.016	0.008	0.041	0	0.014	0	0	0			0.034	0.034	0	0	0	0
112	0	0.016	0.038	0.038	0	0	0.061	0	0	0	0	0	0.005	0	0	0.004	0.061	0	0.077	0	0	0	0	0.012	0.016	0.008	0.021	0	0.027	0	0	0			0	0.022	0	0	0	0
113	0.024	0	0	0	0	0.005	0	0	0	0	0	0	0.023	0.009	0.004	0.008	0	0	0	0	0.043	0	0.012	0.024	0	0.016	0.014	0	0.041	0	0	0			0	0.011	0	0	0	0
114	0.024	0	0	0	0	0	0.03	0	0	0	0	0	0.023	0	0.008	0	0.03	0	0.038	0	0.043	0	0.012	0.012	0.008	0.008	0.007	0	0.027	0	0	0			0.034	0	0	0	0	0
115	0	0.032	0	0.077	0.009	0.005	0	0	0	0	0.5	0	0.009	0	0	0.012	0	0	0	0	0	0	0	0	0	0	0	0	0.014	0	0	0			0	0	0.167	0	0	0
116	0.024	0	0	0	0.005	0.005	0.061	0	0	0	0	0	0.009	0	0.004	0	0.061	0	0.038	0	0.13	0	0.012	0	0.016	0.008	0.027	0	0.014	0	0	0.333			0.011	0	0	0	0.333	0
117	0	0	0	0	0.005	0	0.03	0	0.045	0	0	0	0	0	0.012	0	0.03	0	0.038	0	0	0	0.012	0	0	0	0.007	0	0.027	0	0	0.333			0	0	0	0	0	0
118	0.024	0.032	0	0.077	0	0.005	0	0	0	0	0	0	0.009	0	0.012	0.004	0	0	0	0	0.043	0	0	0.012	0.024	0	0.014	0	0.014	0	0	0			0	0	0	0	0	0
119	0.024	0	0	0	0	0	0	0	0	0	0	0	0.009	0	0.008	0.004	0	0	0	0	0.043	0	0.012	0	0.024	0	0.007	0	0.014	0	0	0			0.022	0	0	0	0	0
120	0.048	0	0	0	0.014	0	0	0	0	0	0	0	0.018	0	0.004	0	0	0	0.038	0	0	0	0.012	0	0.024	0	0.021	0	0	0	0	0			0	0	0	0	0	0
121	0.024	0	0	0	0.009	0	0	0	0	0	0	0	0.018	0	0	0.004	0	0	0	0	0	0	0.036	0	0.008	0	0	0	0.014	0	0	0			0.011	0	0	0	0	0
122	0	0	0	0	0.005	0	0	0	0	0	0	0	0.005	0	0.004	0	0	0	0	0	0	0	0.036	0	0.016	0	0.007	0	0.041	0	0	0			0	0	0	0	0	0
123	0	0	0	0	0.009	0	0.061	0	0.045	0	0.5	0	0.005	0	0.004	0	0.061	0	0	0	0.043	0	0	0	0.008	0	0.021	0	0	0	0	0			0	0	0	0	0	0
124	0.048	0	0	0	0.009	0	0	0	0	0	0	0	0.005	0	0.02	0	0	0	0	0	0.13	0	0.012	0	0.016	0	0.014	0	0	0	0	0			0.022	0	0	0	0	0
125	0.024	0	0.038	0	0.005	0	0	0	0	0	0	0	0	0	0.012	0	0	0	0	0	0	0	0	0	0.008	0	0	0	0	0	0	0			0	0	0	0	0	0
126	0	0	0	0	0.005	0	0	0	0	0	0	0	0	0	0.008	0	0	0	0	0	0.043	0	0.036	0	0.016	0	0	0	0	0	0	0			0.011	0	0	0	0	0
127	0	0	0	0	0.005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.024	0	0	0	0	0	0	0	0	0			0	0	0.167	0	0	0
128	0	0	0	0	0.009	0	0	0	0	0	0	0	0	0	0.008	0	0	0	0	0	0	0	0.036	0	0.016	0	0.014	0	0.014	0	0	0			0.022	0	0	0	0	0
129	0	0	0	0	0.009	0	0.03	0	0	0	0	0	0.005	0	0.008	0	0.03	0	0	0	0.13	0	0.012	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
130	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.008	0	0	0	0	0	0	0			0.011	0	0.167	0	0	0
131	0	0	0	0	0.005	0	0.03	0	0	0	0	0	0.005	0	0	0	0.03	0	0	0	0	0	0.012	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
132	0	0	0	0	0.005	0	0	0	0	0	0	0	0.005	0	0.008	0	0	0	0	0	0.087	0	0.024	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
133	0	0	0	0	0.005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.012	0	0.008	0	0	0	0	0	0	0			0.034	0	0	0	0	0
134	0	0	0.038	0	0.009	0	0	0	0	0	0	0	0	0	0.008	0	0	0	0	0	0	0	0.012	0	0.008	0	0	0	0	0	0	0			0	0	0.167	0	0.333	0
135	0	0	0	0	0.005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.012	0	0.016	0	0	0	0	0	0	0			0	0	0	0	0	0
136	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.024	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
137	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.012	0	0.016	0	0	0	0	0	0	0			0	0	0	0	0	0
138	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.004	0	0	0	0	0	0	0	0.012	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
139	0.024	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
141	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
142	0	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
143	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
144	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
145	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
146	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
147	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
148	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
149	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
	0.6	0.4	0.154	0.846	0.231	0.769	0.939	0.061	0.591	0.409	1	0	0.289	0.711	0.336	0.664	0.939	0.061	1	0	0.783	0.217	0.494	0.506	0.437	0.563	0.568	0.432	0.904	0.096	0	1			0.371	0.629	0.667	0.333	1	0

APPENDIX D3b: Proportion at size from otter trawls averaged from 2003-2005 by sex, depth, and sector

	Sector A										Sector B										Sector C										Sector D									
	125-175		175-225		225-275		275-350		350-500		125-175		175-225		225-275		275-350		350-500		125-175		175-225		225-275		275-350		350-500		125-175		175-225		225-275		275-350		350-500	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7E-04	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.007	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.002	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0.003	0	0	0	0	0	0	0	0	0	0	0	9E-04	0	0	0	0	0	0	0	0	0	4E-04	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0.006	0	0	0	0	0	0	0	8E-04	0	0	0	0	0	0	0	0	0	0.001	0	8E-04	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0.002	0.002	0	0	0	0	0	0	0.001	0	9E-04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0.002	0.002	0	0	0	0	0	0	8E-04	0	0	0	0	0	0	0	0	0	0	0	0	5E-04	0	0.068	0	0	0	0	0	0.004	0	0
31	0	0	0	0	0	0	0	0	0.002	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0.006	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.001	0	0	5E-04	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.002	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9E-04	0.003	0	0	0	0	0	0	0	0	0.001	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0.004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.002	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0.003	0.006	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0	0	0.002	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0.003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5E-04	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0.004	0	0	0	0	0	0	0	0	0	0.005	0	0	0	0	0	0	0	0	0	0	5E-04	0	0	0	0	0	0.002	0	0	0	0
39	0	0	0	0	0	0	0	0	0.004	0	0	0	0	0	0	0	0	0	0	9E-04	0	0	0	0	0	0	0	0	8E-04	5E-04	0	0	0	0	0	0	0	0	0	0.01
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9E-04	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0.003	0	0	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.002	0.001	0	0	0.068	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	9E-04	0	0	0	0	0	0	0	0	0	0.003	0	0	0	0	0	0	0	7E-04	5E-04	5E-04	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0.002	0	0	0	0	0	0	0.002	0.001	0	0	9E-04	0	0	0	0	0	0	0	0.002	0	0	0	0	0	0	0	0	0	0	0.01	0
44	0	0	0	0	0	0	0	0	0.002	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.003	0.002	0	0	0	0	0	0	0	0	0	0.01	0
45	0	0	0	0	0	0.002	0	0	0	0	0	0	0	0	0.002	0	0	0	9E-04	0	0	0	0	0	0	0.002	7E-04	0	0.002	0	0	0	0	0	0	0	0.004	0	0	0
46	0	0	0	0	0	0	0	0	9E-04	0.003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.002	0	5E-04	0	0	0	0	0	0.002	0.002	0.002	0	0	0
47	0	0	0	0	0	0	0.003	0	0.002	0.004	0	0	0	0	0	0	0.002	0	0.001	8E-04	0	0.004	0	0	0	0.002	0	0	0.001	0.001	0	0	0	0	0.002	0	0.002	0	0.01	0.01
48	0	0	0	0	0	0	0	0	0.002	0.002	0	0	0	0	0	0	0	0	0	0.003	0	0.004	0	0.005	0	0.002	0.002	0	0.004	0.001	0	0.068	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0	0.005	0.004	0	0	0	0	0	0	0	0	0.003	0.003	0	0	0	0	0	0	0	0	5E-04	0.001	0	0.068	0	0	0	0	0.006	0.004	0	0
50	0	0	0	0	0	0	0	0.004	0.006	0	0	0	0	0	0	0	0	0	0.001	0.003	0	0	0	0	0	0.002	0.003	0.005	8E-04	0.002	0	0	0	0	0	0.002	0.006	0	0	0
51	0	0	0	0	0	0	0	0	0	0.002	0	0	0	0	0.002	0	0	0	0.006	0.005	0	0	0	0	0.002	0	0.002	7E-04	0.004	5E-04	0	0	0	0	0.002	0	0	0.004	0	0.01
52	0	0	0	0	0.005	0.002	0.004	0	0.004	0.006	0	0	0	0	0	0.004	0	0	0.001	0.002	0	0	0	0	0.006	0.004	0.002	0	0.004	8E-04	0	0.068	0	0	0.002	0.002	0	0.006	0.014	0.017
53	0	0	0	0	0.002	0.002	0	0	0.006	0.008	0	0	0	0	0.004	0	0.003	0	0.007	0.004	0	0	0	0.005	0	0.004	0.002	0	0.008	0.003	0	0.068	0	0	0.002	0	0.002	0	0	0
54	0	0	0	0	0.002	0	0	0	0.012	0.006	0	0	0	0	0.002	0.006	0.003	0	0.006	0.008	0	0	0.004	0	0.002	0	0.002	0.006	0.002	0.002	0	0	0	0	0.004	0.005	0	0.012	0.007	0
55	0	0	0	0	0.002	0	0	0	0.013	0.017	0	0	0.024	0	0.004	0.008	0.003	0	0.004	0.009	0	0	0.011	0.011	0	0.005	0.006	0.005	5E-04	0.002	0	0.068	0	0	0	0	0.002	0	0.017	0
56	0	0	0	0	0.002	0	0	0	0.015	0.013	0	0	0	0	0.002	0.004	0.001	0.002	0.007	0.006	0	0	0.004	0.011	0.003	0.002	0.004	0.002	0.005	0.002	0	0	0	0	0.005	0	0	0.017	0	0
57	0	0	0	0	0.007	0	0	0.004	0.019	0.009	0	0	0	0	0.002	0.002	0.003	0.002	0.003	0.013	0	0.004	0.005	0.016	0.004	0.004	0	0.003	0.005	0.005	0	0	0	0	0.009	0.001	0.005	0.006	0.013	0.02
58	0	0.025	0	0	0.012	0	0	0.004	0.03	0.014	0	0.01	0	0	0.008	0.004	0.011	0	0.002	0.011	0	0	0	0	0.002	0.011	0.003	0	0.005	0.009	0	0.068	0	0	0.005	0.004	0.007	0.021	0.007	0.02
59	0	0	0.125	0	0	0.002	0.003	0.004	0.024	0.004	0	0	0.024	0	0.012	0.006	0.004	0	0.016	0.006	0	0.004	0.011	0.005	0.004	0.004	0.003	0	0.004	0.008	0	0	0	0	0.002	0	0.015	0.019	0.01	0
60	0	0	0	0	0.012	0	0.006	0.004	0.021	0.013	0	0.006	0	0	0.024	0.006	0.007	0.003	0.007	0.011	0	0.004	0.004	0.005	0.002	0.013	0.005	7E-04	0.009	0.004	0	0.068	0	0	0.007	0.002	0.01	0	0.007	0.01
61	0	0	0	0	0	0.002	0	0.004	0.012	0.01	0	0	0	0	0.006	0.012	0.006	0.003	0	0.011	0	0	0	0	0.002	0.007	0.006	0.007	0.004	0	0	0	0	0	0.004	0.002	0	0	0.01	0.013
62	0	0	0	0	0.007	0	0.013	0	0.009	0.014	0	0.004	0	0	0.01	0.002	0.015	0.002	0.005	0.006	0	0.004	0	0.021	0.002	0.005	0.003	0	0.003	0.009	0	0	0	0	0.007	0.005	0.008	0.004	0.023	0
63	0	0	0	0	0.007	0	0.004	0	0.02	0.01	0	0	0	0	0.014	0.014	0.009	0.005	0	0.014	0	0.012	0.009	0	0.006	0.006	0.002	0	0.004	0.01	0	0.068	0	0	0.005	0.002	0.002	0.006	0.007	0
64	0	0.025	0	0	0.01	0	0	0	0.019	0.009	0	0.01	0	0.024	0.022	0.009	0.016	0	0.003	0.011	0	0.004	0	0	0.002	0.002	0.002	0.004	0.009	0.013	0	0	0	0	0.001	0	0.01	0.024	0	0.013
65	0	0	0	0	0.005	0.004	0.007	0.004	0.021	0.017	0	0.024	0	0	0.014	0.017	0.003	0.003	0.002	0.011	0	0.004	0.005	0.016	0.002	0.007	7E-04	0.002	0.005	0.001	0	0	0	0	0.005	0.001	0.008	0	0.01	0
66	0	0	0	0	0.012	0.01	0	0	0.007	0.008	0	0.006	0.047	0	0.006	0.017	0.002	0.007	0.006	0.012	0	0.004	0.004	0.011	0	0.004	0.004	0.008	0.002	0.007	0	0	0	0	0.005	0	0.011	0	0.021	0
67	0	0	0	0	0.007	0.002	0.002	0.007	0.008	0.002	0	0	0	0	0.021	0.023	0.003	0.007	0.012	0.01	0	0	0.011	0.043	0	0	0.005	0.002	0.006	0.008	0	0	0.118	0	0.005	0	0.013	0	0.023	0
68	0	0	0	0	0.015	0.008	0.004	0.007	0.009	0.013	0	0.012	0.024	0.024	0.017	0.018	0.018	0.012	0.002	0.018	0	0	0.011	0.005	0.004	0.005	0	0.004	0.002	0.003	0	0	0	0	0.005	0.007	0.002	0	0.007	0.02
69	0	0	0	0	0.01	0.001	0.002	0.004	0.015	0.008	0	0.006	0.024	0	0.016	0.01	0.006	0.003	0.009	0.017	0	0.004	0	0.011	0.004	0.013	0	0.004	0.001	0.017	0	0	0	0	0.005	0.007	0.015	0	0.017	0
70	0	0.025	0	0	0.008	0.011	0.013	0	0.007	0.009	0	0.006	0.047	0	0.018	0.02	0.008	0.009	0.013	0.008	0	0.012	0.011	0.011	0.006	0.011	0.004	7E-04	0.006	0.004	0	0	0.118	0	0.002	0.004	0.002	0	0.01	0
71	0	0	0	0	0.005	0.003	0.004	0.008	0.011	0.01	0	0.006	0	0	0.012	0.007	0.018	0	0.005	0.012	0	0	0.004	0	0.006	0.002	0.002	0.003	0.003	0.005	0	0	0.059	0	0.004	0.003	0.002	0.008	0.007	0
72	0	0	0	0	0.017	0.006	0.007	0	0.004	0.006	0	0.018	0	0.024	0.005	0.012	0.017	0.005	0.008	0.009	0	0	0.016	0	0.002	0.005	7E-04	0.005	0.007	0.004	0	0	0	0	0.009	0	0.018	0	0.027	0
73	0	0	0	0	0.018	0.001	0.007	0	0.003	0.002	0	0.028	0	0.024	0.015	0.007	0.013	0.003	0.008	0.015	0	0.008	0	0	0.009	0.007	0.001	0	0.007	0	0	0	0.059	0	0.003	0.002	0.009	0	0.023	0.022
74	0.025	0.025	0	0	0.019	0.006	0.01	0.007	0.009	0	0	0.024	0	0	0.017	0.006	0.008	0	0.005	0.011	0	0	0	0	0.006	0.004	0.003	0.003	0.002	0.004	0	0	0	0.059	0.005	0.004	0	0	0.014	0
75	0	0.05	0	0	0.01	0.008	0.011	0.007	0.006	0	0	0.018	0.024	0	0.015	0.008	0.018	0.005	0.007	0.014	0	0	0.032	0.005	0.016	0.004	0.006	0.008	0.006	0.008	0	0	0	0	0.005	0.001	0.007	0	0.007	0
76	0	0.025	0	0	0.006	0.005	0.014	0	0.009	0.002	0	0.006	0.024	0.024	0.011	0.003	0.002	0.011	0.003	0.005	0	0.008	0	0	0	0.005	0	0.006	0.006	0.003	0	0	0	0	0	0.001	0.002	0	0.021	0
77	0	0	0	0	0.013	0.006	0.002	0.011	0	0.002	0	0.028	0	0	0.02	0.01	0.011	0	0.004	0.008	0	0.004	0	0.011	0.004	0.004	0	0.001	0.002	0.005	0	0	0	0	0.005	0.006	0.016	0	0	0
78	0	0.025	0	0	0.015	0.005	0.006	0.011	0.012	0.004	0	0.012	0	0.024	0.022	0.015	0.009	0.012	0.004	0.014	0	0.012	0	0.016	0.002	0.005	0.015	0.01	5E-04	0.009	0	0	0	0	0.005	0.003	0.025	0	0.035	0.007
79	0	0.025	0	0	0.007	0.007	0.011	0.006	0.008	0.003	0	0.012	0	0	0.008	0.007	0.01	0.003	0.003	0.013	0	0.004	0.011	0	0.006	0.009	0.001	0.011	0.005	0.001	0	0	0	0	0.003	0.008	0	0	0	0
80	0	0.05	0	0	0.016	0.019	0.015	0.017	0.007	0	0	0.012	0	0.024	0.015	0.013	0.003	0.012	0.006	0.009	0	0.016	0	0.011	0.007	0.009	0.006	0.005	0.002	0.007	0	0	0	0	0.003	0.001	0.012	0.007	0	0
81	0.025	0	0	0	0.008	0.014	0.002	0.022	0.002	8E-04	0	0.018	0	0	0.008	0.016	0.008	0.003	0	0.016	0	0	0	0	0.004	0.005	0.001	0.012	0.003	0.007	0	0	0.059	0	0.001	0.009	0.005	0	0.01	0
82	0	0.025	0	0	0.014	0.01	0.006	0.004	0.009	0.007	0	0.012	0.024	0	0.004	0	0.007	0	0.001	0.015	0	0.016	0.011	0	0	0.016	7E-04	0.019	0.008	0.017	0	0	0	0	0.004	0.012	0.006	0.004	0.027	0.007
83	0	0	0	0	0.009	0.014	0.009	0.015	0.003	0.006	0	0.006	0	0	0.009	0.002	0.008	8E-04	0.009	0.018	0	0.024	0.021	0	0	0.007	0.009	0.012	8E-04	0.02	0	0	0	0	0	0.001	0.011	0.008	0.01	0.01
84	0	0	0	0	0.011	0.023	0.01	0.007	0.012	0.002	0	0.018	0.031	0.024	0.006	0.007	0.007	0.014	0	0.018	0	0.008	0.018	0	0.004	0.004	0.008	0.015	0.002	0.006	0	0	0	0	0	0.016	0.006	0.006	0.013	0.007
85	0.025	0.025	0	0	0.007	0.016	0.016	0.019	0.003	0.01	0	0.006	0	0.024	0.005	0.009	0.006	0.012	0.001	0.009	0	0.016	0	0.011	0.002	0.01	0.004	0.018	8E-04	0.018	0	0	0	0	0.004	0.011	0	0.015	0	0.007
86	0.025	0.025	0	0	0.005	0.01	0.012	0.015	0.004	0.003	0	0.018	0.016	0.024	0.004	0.007	0.01	0.01	0.005	0.01	0	0	0.011	0.005	0.004	0.009	0	0.017	6E-04	0.015	0	0	0	0	0.004	0.019	0.005	0.004	0.007	0
87	0	0.025	0	0	0.005	0.01	0.015	0.024	0.005	0.002	0	0.031	0.016	0	0.006	0.007	0.008	0.019	0.001	0.007	0	0.024	0	0	0.006	0.012	0.004	0.022	0.006	0.024	0	0	0	0	0	0.018	0.004	0.008	0.01	0
88	0	0	0.125	0	0.011	0.014	0.015	0.002	0.007	0.004	0	0.006	0	0.047	0.004	0.012	0.007	0.017	0.002	0.02	0	0.024	0	0	0.002	0.005	0.001	0.031	0.002	0.01	0	0	0	0	0	0.013	0.006	0.008	0.015	0
89	0	0	0	0	0.01	0.01	0.002	0.011	0.002	0.002	0	0.031	0	0.024	0	0.007	0.002	0.013	0.004	0.013	0	0.024	0	0	0	0.021	0	0.023	0	0.006	0	0	0	0	0	0.027	0.006	0.006	0	0
90	0	0	0	0	0.008	0.012	0.004	0.015	0.004	0.005	0	0.012	0	0.047	0.005	0.007	0.003	0.008	0.001	0.016	0	0.036	0.011	0.026	0.003	0.021	0.004	0.021	6E-04	0.023	0	0	0	0	0.002	0.016	0.01	0.015	0.007	0
91	0	0.025	0	0	0.004	0.012	0.004	0.006	0.006	0.013	0	0.024	0	0.039	0.006	0.007	0.002	0.003	0	0.007	0	0.02	0.011	0.005	0	0.016	0	0.026	0.004	0.015	0	0	0	0	0.002	0.014	0.016	0.004	0	0
92	0	0.025	0	0	0.012	0.011	0.002	0.019	0.002	0.008	0	0.018	0.024	0.024	0.01	0.003	0	0.014	0.003	0.021	0	0.059	0	0	0.002	0.03	0.002	0.027	0.002	0.01	0	0	0	0	0	0.03	0	0.014	0.01	0
93	0	0.05	0.125	0.125	0.002	0.012	0	0.006	0.002	0.006	0	0.018	0	0	0	0.008	0.005	0.014	0.001	0.027	0	0.06	0.011	0.011	0.002	0.016	0	0.039	0.002	0.023	0	0	0	0	0	0.022	0	0.016	0	0
94	0	0.025	0	0	0.008	0.015	0.023	0.011	0.005	0.006	0	0.036	0	0	0.009	0.005	0.009	0.018	0.002	0.018	0	0.032	0	0.021	0.007	0.026	0.008	0.021	0.002	0.022	0	0	0	0	0.002	0.029	0.002	0.014	0.01	0
95	0	0	0	0	0.005	0.021	0.007	0.02	0.005	0.009	0	0.012	0.016	0	0.015	0.005	0.005	0.015	0.003	0.013	0	0.055	0	0.026	0.005	0.016	0.007	0.034	0	0.038	0	0	0	0	0	0.022	0.008	0.022	0.007	0.007
96	0	0	0	0	0.004	0.013	0.009	0.015	0.001	0.01	0.009	0.006	0	0	0.002	0.002	0.005	0.022	0.001	0.006	0	0.048	0.014	0.021	0.002	0.011	0.005	0.044	0.001	0.019	0	0	0	0.235	0.002	0.033	0	0.015	0	0.014
97	0.025	0	0	0	0.006	0.012	0.002	0.011	0.003	0.011	0	0.018	0.031	0	0.007	0.005	0.004	0.018	0.004	0.016	0	0.032	0	0.021	0	0.022	0.003	0.024	0.002	0.038	0	0	0	0	0	0.038	0.004	0.011	0	0.022
98	0	0	0	0	0.004	0.024	0.004	0.028	0.005	0.005	0	0.045	0.024	0	0.007	0.013	0.006	0.027	0.003	0.022	0	0.044	0.005	0.016	0.007	0.025	0.006	0.022	8E-04	0.032	0	0	0	0	0.002	0.028	0.024	0.022	0.017	0
99	0	0	0	0	0.005	0.021	0.004	0.013	0.006	0.005	0	0.016	0	0	0	0.002	0.001	0.012	7E-04	0.014	0	0.032	0.011	0	0.003	0.027	0.003	0.018	0.001	0.02	0	0	0	0	0	0.011	0.013	0.002	0.01	0
100	0.025	0	0.125	0	0.004	0.019	0.006	0.031	0	0.008	0	0.037	0	0	0.011	0.005	0	0.018	0.003	0.015	0	0.044	0	0.021	0.002	0.034	0.001	0.019	0.006	0.028	0	0	0	0.059	0.005	0.042	0.002	0.01	0.017	0.022
101	0.025	0	0	0	0.004	0.01	0.003	0.013	0.003	0.005	0	0.016	0	0	0	0.006	0	0.014	7E-04	0.014	0	0.028	0	0.025	0	0.016	0	0.022	0	0.019	0	0.045	0	0	0	0.034	0	0.004	0	0
102	0.05	0	0	0	0.003	0.014	0.002	0.017	0.002	0.01	0.018	0.044	0.024	0	0.009	0.005	0	0.017	0.003	0.013	0	0.028	0	0.005	0.003	0.029	0.004	0.019	0.008	0.032	0	0	0	0	0	0.029	0.008	0	0.01	0
103	0	0	0	0	0.001	0.011	0	0.017	0.002	0.013	0	0.016	0.024	0.047	0.009	0.012	0	0.034	0.005	0.013	0	0.047	0	0.019	0.003	0.033	0.001	0.027	0.003	0.018	0	0.045	0	0	0	0.046	0.004	0.008	0	0.007
104	0	0	0	0	0.006	0.012	0	0.011	0.003	0.016	0.009	0.028	0	0	0.005	0.006	0.003	0.026	0	0.012	0	0.059	0.005	0.037	0	0.03	0	0.023	6E-04	0.008	0	0	0	0	0	0.027	0.007	0.011	0.014	0.007
105	0	0.025	0	0	0.001	0.005	0.004	0.015	0.002	0.003	0	0.016	0	0.024	0.002	0.01	0.008	0.02	0.003	0.01	0	0.016	0.011	0.046	0.003	0.028	0.003	0.011	0.008	0.023	0	0	0	0.059	0	0.028	0.008	0	0	0.007
106	0	0	0	0	0.001	0.019	0.002	0.022	0.003	0.009	0	0.031	0	0	0.007	0.005	0.003	0.02	0	0.005	0	0.012	0	0.021	0.003	0.033	0.003	0.014	0.005	0.006	0	0	0	0.059	0.001	0.016	0.007	0.004	0	0.007
107	0	0	0	0	0.002	0.004	0	0.02	0.003	0.004	0	0.022	0	0	0.002	0.009	0.003	0.045	0.003	0.008	0	0.024	0.011	0.021	0.002	0.018	0.002	0.015	0.01	0.009	0	0	0	0	0	0.029	0.002	0.006	0.007	0
108	0	0	0	0	0.001	0.005	0.008	0.015	0.003	0.006	0	0.018	0	0	0.002	0.002	0.003	0.016	0	0.011	0	0.024	0.005	0.016	0	0.021	0.007	0.013	0.004	0.004	0	0	0	0	0	0.026	0.021	0.006	0	0.014
109	0	0	0.125	0	0.007	0.01	0.002	0.004	0	0.005	0	0.016	0	0	0	0.01	0.003	0.01	0.001	0.008	0	0.012	0.005	0.005	0.003	0.012	0.004	0.011	0.008	0.007	0	0	0	0	0.002	0.008	0.011	0.004	0	0.01
110	0	0	0	0	0.004	0.009	0.002	0.024	0.006	0.004	0	0.024	0	0	0.002	0	0.003	0.007	0.001	0.006	0	0.008	0.005	0.005	0.002	0.016	0.002	0.01	0.009	0.002	0	0	0	0.059	0.002	0.014	0.008	0.008	0	0
111	0	0	0.125	0	0.001	0.005	0.002	0.009	0	0.001	0	0.006	0	0	0.004	0.002	0	0.01	0	0.003	0	0.004	0	0.004	0.006	0.007	0	0.002	0.01	0.004	0	0.045	0	0	0.001	0.012	0.002	0.01	0	0.007
112	0	0	0	0	0.001	0.006	0.006	0.013	0.003	0.001	0	0.024	0	0.024	0.002	0.002	0.003	0.005	7E-04	0.005	0	0.008	0.021	0.019	0.005	0.002	0.008	0.01	0	0.004	0	0.045	0	0	0	0.009	0.021	0.004	0.017	0
113	0	0.025	0	0	0.005	0.007	0	0.013	0	0.003	0	0.024	0	0	0	0.002	0	0.012	0	0.001	0	0.008	0	0	0.006	0.005	0.013	0.001	0.002	0.001	0	0	0	0	0.005	0.013	0.004	0	0.01	0.01
114	0.075	0	0	0	0.001	0.001	0.008	0.004	0.002	0.001	0	0	0	0	0	0.004	0	0.008	0.003	0.003	0	0.008	0.011	0	0	0.002	0.006	0.001	0.002	0.003	0	0	0	0	0.004	0.007	0.008	0.008	0	0
115	0	0.025	0	0	0.002	0.006	0.002	0.004	0.003	0.002	0	0	0	0	0	0.002	0	0.003	0.005	0.001	0	0	0.004	0.004	0.002	0.003	0.003	0.002	0.007	0.001	0	0.045	0	0	0.003	0.009	0.014	0.008	0	0.007
116	0	0.025	0	0	0.003	0.006	0.004	0.006	0.001	0.002	0.009	0.006	0	0.024	0	0.002	0	0	0	0.003	0	0	0	0	0	0.006	0	7E-04	0.006	8E-04	0	0	0	0.059	0.004	0.004	0.008	0.008	0.007	0
117	0.025	0.025	0	0.125	0.006	0.008	0.002	0.004	0.001	0.005	0	0.006	0	0	0.002	0.002	0	0	0.001	0.002	0	0	0.005	0.009	0.011	0	7E-04	0	0.009	0	0	0.045	0	0	0	0.005	0.021	0	0.017	0
118	0	0.05	0	0	0.001	0.002	0.004	0	8E-04	0	0	0	0	0	0	0	0.002	0.002	0	0	0	0	0	0	0.005	0	0.008	0.001	0.002	8E-04	0	0	0	0	0.004	0.007	0.011	0	0.007	0
119	0	0	0	0	0.001	0.003	0.002	0.004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.002	0.002	0	7E-04	6E-04	0	0	0	0	0	0.002	0	0.007	0	0	0
120	0	0	0	0	0.001	0.001	0	0	0.002	0	0	0	0	0	0	0	0.003	0	0	0	0	0	0	0	0.009	0.003	0.004	0	0.005	8E-04	0	0	0	0	0	0.002	0.021	0	0	0
121	0	0	0	0	0	0.002	0.007	0.004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.003	0.002	0	7E-04	0	0	0	0	0	0	0.005	0	0.006	0	0	0
122	0	0	0	0	0	0	0.002	0	0.003	0.001	0	0.006	0	0	0	0	0.003	0.002	7E-04	0	0	0	0	0.004	0.003	0	0.001	0	8E-04	0	0	0.045	0	0	0	0	0.008	0	0	0
123	0	0	0	0	0	0	0.004	0.004	0.003	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0	0	0	0	0.002	0	8E-04	6E-04	0	0	0	0	0	0	0	0	0	0
124	0	0	0	0	0	0	0.004	0	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.001	0	0	0.007	0
125	0	0	0	0	0	0	0.002	0	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.002	0	0.001	0	0	0	0	0	0	0	0	0	0	0	0.007	0
126	0	0	0	0	0	0	0	0	0.005	0	0	0.006	0	0	0	0	0.002	0	9E-04	0	0	0	0	0	0	0	0	0	0.003	0	0	0	0	0	0	0.001	0.002	0	0	0
127	0	0	0	0	0	0	0	0	8E-04	0	0	0	0	0	0	0	0	0	0	0	0	0.004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
128	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
129	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.002	0	0	0
130	0	0	0	0	0	0	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.003	0	0	0	0	0	0	0	0	0	0	0
131	0	0	0	0	0	0	0	0	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.007	0
132	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
133	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
134	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
135	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
136	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
137	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
138	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
139	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.007	0
141	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
142	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
143	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
144	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
145	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
146	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
147	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
148	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
149	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.325	0.675	0.75	0.25	0.447	0.553	0.375	0.625	0.532	0.468	0.046	0.954	0.465	0.535	0.516	0.484	0.378	0.622	0.257	0.743	0	1	0.356	0.644	0.231	0.769	0.239	0.76	0.3	0.7	0	1	0.412	0.588	0.185	0.815	0.569	0.431	0.655	0.345

Appendix D4: Density and abundance estimates, additional tables

Appendix D4 Table 1. Red crab numerical density (N/ha) for 1974 and the mean (+1SE) of four surveys conducted between 2003 and 2005. Densities are presented by depth and sector for all crabs, those ≥114 mm carapace width ("commercial size" as defined by Wigley et al. 1975), and males ≥114 mm. Empty cells in the 1974 density table indicate no samples taken. Empty cells in the SE 2003-2005 table indicate insufficient data to calculate an error term. Standard errors computed for the four surveys in 2003-2005.

All crabs

1974

Depth (fath)	Depth (m)	A	B	C	D	Avg
125-175	229-320	22.6	13.2	28.4	20.2	21.1
175-225	320-412	270.8		376.4	127.8	258.3
225-275	412-503	256.1	199.3	282.2	355.2	273.2
275-350	503-640	197.7	266.7	381.6		282.0
350-500	640-914	70.9		111.8		91.4
Total						**185.2**

Average 2003-2005

Depth (fath)	Depth (m)	A	B	C	D	Avg
125-175	229-320	156.7	64.0	0.0	69.2	72.5
175-225	320-412	598.8	172.6	178.4	38.1	247.0
225-275	412-503	943.7	867.9	982.5	1573.3	1091.9
275-350	503-640	1127.2	587.1	1641.8	2860.3	1554.1
350-500	640-914	645.1	588.9	1058.2	1244.3	884.1
Total						**769.9**

SE 2003-2005

Depth (fath)	Depth (m)	A	B	C	D	Avg
125-175	229-320	114.4	47.2	0.0	69.2	44.0
175-225	320-412	452.1	2.2	81.3		126.8
225-275	412-503	333.7	250.4	218.4	795.9	327.5
275-350	503-640		109.0	985.9	913.0	242.8
350-500	640-914	162.0	149.0	209.3	314.0	57.9
Total						**19.7**

Crabs ≥114 mm

1974

Depth (fath)	A	B	C	D	Avg
125-175	7.4	13.2	19.8	13.5	13.5
175-225	62.5		149.7		106.1
225-275	35.6	31.1	71.7	63.9	50.6
275-350	53.9	72.7	52.3		59.6
350-500	6.4		19.9		13.2
Total					**48.6**

Average 2003-2005

Depth (fath)	A	B	C	D	Avg
125-175	35.3	2.1	0.1	9.4	11.7
175-225	74.8	4.1	6.4	2.2	21.9
225-275	42.4	10.6	51.3	88.5	48.2
275-350	77.9	15.0	52.8	380.8	131.6
350-500	23.9	13.7	48.8	81.4	41.9
Total					**51.1**

SE 2003-2005

Depth (fath)	A	B	C	D	Avg
125-175	25.7	1.6	0.1	9.4	7.1
175-225	56.5	0.1	2.9		15.0
225-275	15.0	3.1	11.4	44.8	14.8
275-350		2.8	31.7	121.5	37.3
350-500	6.0	3.5	9.6	20.6	4.5
Total					**10.5**

Male Crabs ≥114 mm

1974

Depth (fath)	A	B	C	D	Avg
125-175	6.0	13.2	19.8	0.0	9.7
175-225	20.8		140.6		80.7
225-275	32.0	26.5	67.2	63.9	47.4
275-350	53.9	72.7	52.3		59.6
350-500	6.4		19.9		13.2
Total					**42.1**

Average 2003-2005

Depth (fath)	A	B	C	D	Avg
125-175	15.7	0.6	0.0	0.0	4.1
175-225	0.0	0.0	3.5	0.0	0.9
225-275	15.0	1.8	35.1	31.4	20.8
275-350	46.6	5.9	42.7	312.9	102.0
350-500	16.4	8.1	41.3	72.2	34.5
Total					**32.4**

SE 2003-2005

Depth (fath)	A	B	C	D	Avg
125-175	11.4	0.4	0.0	0.0	2.3
175-225	0.0	0.0	1.6		0.4
225-275	5.3	0.5	7.8	15.9	5.9
275-350		1.1	25.6	99.9	29.9
350-500	4.1	2.1	8.2	18.2	4.2
Total					**6.0**

Appendix D4 Table 2 . Red crab biomass density (kg per hectare) for 1974 and the mean (+1SE) of four surveys conducted between 2003 and 2005. Densities presented by depth and sector for all crabs, those ≥114 mm carapace width ("commercial size" as defined by Wigley et al. 1975), and males ≥114 mm. Empty cells in the 1974 density table indicate no samples taken. Empty cells in the SE 2003-2005 table indicate insufficient data to calculate an error term. Standard errors computed for the four surveys in 2003-2005.

All crabs

1974						
Depth (fath)	Depth (m)	A	B	C	D	Avg
125-175	229-320	11.1	9.0	14.1	7.3	10.4
175-225	320-412	74.5		157.3	52.7	94.8
225-275	412-503	82.2	56.6	97.6	114.0	87.6
275-350	503-640	57.1	79.7	101.5		79.4
350-500	640-914	10.7		43.6		27.2
Total						**59.9**

Average 2003-2005						
Depth (fath)	Depth (m)	A	B	C	D	Avg
125-175	229-320	28.5	14.0	1.4	9.6	13.4
175-225	320-412	171.9	31.3	37.2	7.5	62.0
225-275	412-503	186.0	101.1	217.3	352.4	214.2
275-350	503-640	254.2	80.2	351.6	662.8	337.2
350-500	640-914	92.8	94.9	216.9	232.1	159.1
Total						**157.2**

SE 2003-2005						
Depth (fath)	Depth (m)	A	B	C	D	Avg
125-175	229-320	21.8	10.3	1.4	9.6	9.5
175-225	320-412	129.8	0.4	16.9		35.6
225-275	412-503	65.7	51.4	48.3	178.3	68.9
275-350	503-640		32.2	211.2	211.6	49.3
350-500	640-914	23.3	24.0	42.9	58.6	11.0
Total						**32.9**

Crabs ≥114 mm

1974					
Depth (fath)	A	B	C	D	Avg
125-175	4.1	7.2	12.1	5.2	7.1
175-225	30.8		97.3		64.1
225-275	21.8	18.4	43.9	39.4	30.9
275-350	33.4	45.1	29.5		36.0
350-500	3.6		10.8		7.2
Total					**29.1**

Average 2003-2005					
Depth (fath)	A	B	C	D	Avg
125-175	15.2	1.0	0.0	3.8	5.0
175-225	29.1	1.5	2.9	0.9	8.6
225-275	18.3	3.2	25.5	38.5	21.4
275-350	38.3	4.6	21.8	192.9	64.4
350-500	12.5	6.6	25.4	47.9	23.1
Total					**24.5**

SE 2003-2005					
Depth (fath)	A	B	C	D	Avg
125-175	9.6	0.6	0.0	3.3	2.7
175-225	19.0	0.0	1.1		5.3
225-275	5.8	1.4	5.1	16.9	5.9
275-350		1.6	8.9	53.3	17.4
350-500	2.8	1.5	4.5	10.8	2.4
Total					**4.5**

Male Crabs ≥114 mm

1974					
Depth (fath)	A	B	C	D	Avg
125-175	3.5	7.2	12.1	0.0	5.7
175-225	14.8		93.8		54.3
225-275	20.4	16.6	42.2	39.4	29.7
275-350	33.4	45.1	29.5		36.0
350-500	3.6		10.8		7.2
Total					**26.6**

Average 2003-2005					
Depth (fath)	A	B	C	D	Avg
125-175	7.6	0.3	0.0	0.0	2.0
175-225	0.0	0.0	1.7	0.0	0.4
225-275	7.7	0.9	19.2	16.4	11.0
275-350	25.8	3.4	18.6	167.7	53.9
350-500	9.6	4.5	22.5	44.5	20.2
Total					**17.5**

SE 2003-2005					
Depth (fath)	A	B	C	D	Avg
125-175	5.6	0.2	0.0	0.0	1.1
175-225	0.0	0.0	0.8		0.2
225-275	2.7	0.3	4.3	8.3	3.1
275-350		0.6	8.8	53.5	16.9
350-500	2.4	1.1	4.4	11.2	2.6
Total					**3.4**

Appendix D4 Table 3. Red crab numerical abundance estimates in thousands of individuals for 1974 and the mean (+1SE) of four surveys conducted between 2003 and 2005. Estimates presented by depth and sector for all crabs, those ≥114 mm carapace width ("commercial size" as defined by Wigley et al. 1975), and males ≥114 mm. Abundances were summed across sectors and depths for total standing crop estimate. For strata with no density information (Table 5.4), standing crop was determined by using the average density for that depth. Empty cells in the SE 2003-2005 table indicate insufficient data to calculate an error term. Standard errors computed for the four surveys in 2003-2005.

All crabs

1974						
Depth (fath)	Depth (m)	A	B	C	D	All
125-175	229-320	685.0	235.0	1562.0	790.0	3272.0
175-225	320-412	11861.0	6974.0	28343.0	8192.0	55370.0
225-275	412-503	5993.0	3428.0	10526.0	9413.0	29360.0
275-350	503-640	8798.0	7548.0	23888.0	8150.0	48384.0
350-500	640-914	4651.0	4369.0	7122.0	5192.0	21334.0
Total						**157720.0**

Average 2003-2005						
Depth (fath)	Depth (m)	A	B	C	D	All
125-175	229-320	4749.0	1139.8	0.0	2707.9	8596.7
175-225	320-412	26226.1	4660.3	13434.8	2443.3	46764.4
225-275	412-503	22084.4	14928.7	36647.2	41692.2	115352.5
275-350	503-640	50162.9	16617.0	102773.2	82664.4	252217.4
350-500	640-914	42319.5	28164.8	67411.7	70719.3	208615.3
Total						**631546.3**

SE 2003-2005						
Depth (fath)	Depth (m)	A	B	C	D	All
125-175	229-320	3467.6	839.6	0.0	2707.9	5376.8
175-225	320-412	19800.9	59.3	6120.9		19663.4
225-275	412-503	7807.8	4307.5	8147.0	21092.1	34584.1
275-350	503-640		3084.5	61717.6	26387.8	32751.0
350-500	640-914	10629.0	7127.0	13331.3	17849.4	13988.3
Total						**71465.2**

Crabs ≥114 mm

1974					
Depth (fath)	A	B	C	D	All
125-175	224.7	235.0	1086.6	526.7	2073.0
175-225	2737.2	1909.0	11268.9	4532.8	20447.9
225-275	832.4	535.6	2673.3	1692.2	5733.5
275-350	2399.5	2058.5	3272.3	1723.7	9454.0
350-500	422.8	630.2	1268.3	749.0	3070.3
Total					**40778.7**

Average 2003-2005					
Depth (fath)	A	B	C	D	All
125-175	1068.5	38.3	4.2	369.3	1480.3
175-225	3278.3	110.1	479.5	143.7	4011.5
225-275	991.7	182.8	1914.3	2346.1	5434.9
275-350	3466.2	423.6	3306.6	11004.0	18200.4
350-500	1565.3	655.2	3107.4	4628.7	9956.7
Total					**39083.8**

SE 2003-2005					
Depth (fath)	A	B	C	D	All
125-175	780.2	28.2	4.2	369.3	910.5
175-225	2475.1	1.4	218.4		2091.8
225-275	350.6	52.7	425.6	1186.9	1664.6
275-350		78.6	1985.7	3512.7	3571.6
350-500	393.2	165.8	614.5	1168.3	1052.6
Total					**5253.4**

Male Crabs ≥114 mm

1974					
Depth (fath)	A	B	C	D	All
125-175	180.8	235.0	1086.6	0.0	1502.4
175-225	912.4	1452.5	10585.9	3448.9	16399.7
225-275	749.1	455.3	2506.2	1692.2	5402.8
275-350	2399.5	2058.5	3272.3	1723.7	9454.0
350-500	422.8	630.2	1268.3	749.0	3070.3
Total					**35829.3**

Average 2003-2005					
Depth (fath)	A	B	C	D	All
125-175	474.9	10.4	0.0	0.0	485.3
175-225	0.0	0.0	263.7	0.0	263.7
225-275	352.0	30.5	1309.7	830.9	2523.1
275-350	2072.1	167.9	2670.5	9042.3	13953.0
350-500	1073.3	388.2	2629.0	4101.4	8191.8
Total					**25417.0**

SE 2003-2005					
Depth (fath)	A	B	C	D	All
125-175	272.4	6.0	0.0	0.0	278.3
175-225	0.0	0.0	107.5		107.5
225-275	124.5	8.8	291.2	362.6	706.3
275-350		31.2	1011.4	3045.7	2809.5
350-500	269.6	98.2	519.9	1035.2	969.3
Total					**2698.2**

Appendix D4 Table 4. Red crab standing biomass estimates (mt) for 1974 and the mean (+1SE) of four surveys conducted between 2003 and 2005. Estimates presented by depth and sector for all crabs, those ≥114 mm carapace width ("commercial size" as defined by Wigley et al. 1975), and males ≥114 mm. For strata with no density information (Table 5.4), standing crop was determined by using the average density for that depth. Empty cells in the SE 2003-2005 table indicate insufficient data to calculate an error term. Standard errors computed for the four surveys in 2003-2005.

All crabs

1974

Depth (fath)	Depth (m)	A	B	C	D	All
125-175	229-320	336.4	160.2	775.5	285.5	1557.7
175-225	320-412	3263.1	2560.1	11844.7	3378.1	21046.0
225-275	412-503	1923.6	973.5	3640.5	3021.1	9558.6
275-350	503-640	2541.1	2255.6	6353.9	2294.7	13445.3
350-500	640-914	701.9	1300.0	2777.5	1545.9	6325.3
Total						**51932.9**

Average 2003-2005

Depth (fath)	Depth (m)	A	B	C	D	All
125-175	229-320	864.0	248.8	77.4	375.1	1565.3
175-225	320-412	7530.9	846.1	2797.9	481.3	11656.2
225-275	412-503	4351.9	1739.2	8103.8	9339.5	23534.4
275-350	503-640	11311.7	2269.2	22013.0	19155.4	54749.3
350-500	640-914	6084.9	4538.0	13814.0	13191.4	37628.4
Total						**129133.6**

SE 2003-2005

Depth (fath)	Depth (m)	A	B	C	D	All
125-175	229-320	660.9	183.3	77.4	375.1	1155.7
175-225	320-412	5685.9	10.8	1274.7		5298.3
225-275	412-503	1538.6	884.5	1801.6	4724.9	7450.1
275-350	503-640		910.1	13219.3	6114.7	6839.3
350-500	640-914	1528.3	1148.3	2731.8	3329.5	2677.6
Total						**14954.1**

Crabs ≥114 mm

1974

Depth (fath)	A	B	C	D	All
125-175	123.8	128.5	663.8	202.5	1118.6
175-225	1350.5	1152.9	7325.4	4106.2	13935.0
225-275	509.4	317.3	1636.8	1044.5	3507.9
275-350	1488.5	1277.1	1847.9	1041.3	5654.8
350-500	236.9	345.6	690.6	410.7	1683.8
Total					**25900.2**

Average 2003-2005

Depth (fath)	A	B	C	D	All
125-175	461.2	17.0	1.7	147.3	627.2
175-225	1275.5	41.8	214.6	54.6	1586.6
225-275	429.1	72.6	951.2	1019.9	2472.8
275-350	1702.9	193.6	1366.9	5573.8	8837.1
350-500	816.9	315.3	1615.0	2722.5	5469.8
Total					**18993.5**

SE 2003-2005

Depth (fath)	A	B	C	D	All
125-175	336.7	12.5	0.0	147.3	382.5
175-225	963.1	0.5	97.8		822.2
225-275	151.7	27.7	211.5	516.0	750.1
275-350		51.8	644.3	1779.3	1646.8
350-500	205.2	79.8	319.4	687.2	629.1
Total					**2164.0**

Male Crabs ≥114 mm

1974

Depth (fath)	A	B	C	D	All
125-175	106.9	128.5	663.8	0.0	899.2
175-225	648.6	977.6	7065.7	3482.0	12173.9
225-275	477.5	285.8	1574.8	1044.5	3382.6
275-350	1488.5	1277.1	1847.9	1041.3	5654.8
350-500	236.9	345.6	690.6	410.7	1683.8
Total					**23794.4**

Average 2003-2005

Depth (fath)	A	B	C	D	All
125-175	231.2	5.3	0.0	0.0	236.5
175-225	0.0	0.0	129.3	0.0	129.3
225-275	180.6	15.7	714.8	433.5	1344.7
275-350	1150.3	97.3	1164.8	4845.8	7258.2
350-500	627.1	215.1	1431.8	2526.9	4800.9
Total					**13769.5**

SE 2003-2005

Depth (fath)	A	B	C	D	All
125-175	168.8	3.9	0.0	0.0	135.6
175-225	0.0	0.0	58.9		52.7
225-275	63.9	4.5	158.9	219.3	374.0
275-350		18.1	549.1	1546.9	1417.3
350-500	157.5	54.4	283.1	637.8	598.1
Total					**1333.6**

Appendix D4 Table 5. Numerical density as N/ha (A), and abundance in thousands (B) of reproductive size red crabs by depth and sector in 1974 and 2003-2005 (+1SE).

A.

All mature Crabs - Male + Female

1974					
Depth (fath)	A	B	C	D	Avg
125-175	22.1	13.2	28.4	20.2	21.0
175-225	270.8		371.9		321.3
225-275	238.3	175.2	273.2	319.3	251.5
275-350	161.8	218.2	282.3		220.7
350-500	22.6		101.1		61.8
Total					**175.3**

Average 2003-2005	Numerical density (N/ha)				
Depth (fath)	A	B	C	D	Avg
125-175	144.9	58.9	6.1	22.0	58.0
175-225	523.9	131.8	129.8	24.7	202.6
225-275	733.1	499.2	811.0	1338.1	845.4
275-350	973.0	451.7	1421.1	2025.4	1217.8
350-500	280.9	376.7	802.0	682.4	535.5
Total					**571.8**

SE 2003-2005	Standard Error Numerical Density (N/ha)				
Depth (fath)	A	B	C	D	Avg
125-175	105.8	43.4	6.1	22.0	34.4
175-225	395.6	1.7	59.2	#DIV/0!	108.7
225-275	259.2	144.0	180.3	676.9	255.1
275-350	#DIV/0!	83.8	853.4	646.5	188.7
350-500	70.6	95.3	158.6	172.2	31.0
Total	140.5	64.1	111.7	198.0	**95.1**

Male Crabs > 75 mm

1974					
Depth (fath)	A	B	C	D	Avg
125-175	13.0	13.2	22.2	0.0	12.1
175-225	41.7		181.4		111.5
225-275	54.5	52.9	118.7	107.8	83.5
275-350	149.8	202.0	141.1		164.3
350-500	16.1		93.4		54.8
Total					**85.2**

Average 2003-2005	Numerical Desity (N/ha)				
Depth (fath)	A	B	C	D	Avg
125-175	47.0	2.9	0.0	0.0	12.5
175-225	374.2	47.6	44.5	2.2	117.1
225-275	246.0	222.9	155.1	126.3	187.6
275-350	317.8	115.1	274.2	1149.6	464.2
350-500	117.3	61.0	183.2	430.9	198.1
Total					**195.9**

SE 2003-2005	Standard Error Numerical Density (N/ha)				
Depth (fath)	A	B	C	D	Avg
125-175	34.3	2.2	0.0	0.0	7.1
175-225	282.5	0.6	20.3	#DIV/0!	74.2
225-275	87.0	64.3	34.5	63.9	56.6
275-350	#DIV/0!	21.4	164.7	367.0	105.6
350-500	29.5	15.4	36.2	108.8	24.4
total	64.9	21.7	21.4	125.7	36.3

Female Crabs > 70 mm

1974					
Depth (fath)	A	B	C	D	Avg
125-175	9.0	0.0	6.2	20.2	8.9
175-225	229.1		190.5		209.8
225-275	183.8	122.2	154.5	211.5	168.0
275-350	12.0	16.2	141.1		56.4
350-500	6.4		7.7		7.1
Total					**90.0**

Average 2003-2005	Numerical Desity (N/ha)				
Depth (fath)	A	B	C	D	Avg
125-175	97.9	56.0	6.1	22.0	45.5
175-225	149.7	84.3	85.3	22.4	85.4
225-275	487.1	276.3	655.9	1211.8	657.8
275-350	655.2	336.6	1146.9	875.8	753.7
350-500	163.7	315.7	618.8	251.5	337.4
Total					**376.0**

SE 2003-2005	Standard Error Numerical Density (N/ha)				
Depth (fath)	A	B	C	D	Avg
125-175	71.5	41.3	6.1	22.0	27.4
175-225	113.0	1.1	38.9	#DIV/0!	35.2
225-275	172.2	79.7	145.8	613.0	201.8
275-350	#DIV/0!	62.5	688.8	279.6	146.9
350-500	41.1	79.9	122.4	63.5	17.9
total	78.9	42.7	90.6	133.0	72.2

B.

All mature Crabs - Male + Female

1974					
Depth (fath)	A	B	C	D	All1
125-175	668.6	235.0	1562.0	790.0	3255.6
175-225	11861.0	5783.2	28001.5		59377.3
225-275	5576.8	3012.9	10191.8	8461.1	27242.7
275-350	9823.7	6175.6	17670.6	6379.8	40049.6
350-500	1479.9	2956.6	6439.1	3513.6	14389.1
Total					**144314.3**

Average 2003-2005					
Depth (fath)	A	B	C	D	All1
125-175	4392.9	1049.3	333.8	861.6	6637.6
175-225	22947.8	3559.4	9776.2	1581.0	37864.4
225-275	17155.9	8586.6	30249.7	35460.4	91452.5
275-350	43300.6	12783.5	88961.0	58535.8	203580.9
350-500	18429.4	18014.4	51089.5	38787.2	126320.5
Total					**465856.0**

SE 2003-2005					
Depth (fath)	A	B	C	D	All2
125-175	3207.5	773.0	333.8	861.6	4081.3
175-225	17325.8	45.3	4454.0		16467.4
225-275	6065.4	2477.6	6724.8	17939.4	27626.4
275-350		2372.9	53423.1	18685.6	26874.3
350-500	4628.7	4558.5	10103.4	9789.8	7815.0
Total	27110.0	7377.4	37679.2	16644.2	**56554.9**

Male Crabs > 75 mm

1974					
Depth (fath)	A	B	C	D	All1
125-175	394.6	235.0	1222.4	0.0	1852.0
175-225	1824.8	2007.2	13659.3	4766.0	22257.3
225-275	1276.3	910.6	4427.6	2855.6	9470.1
275-350	7312.5	5718.2	8835.3	4748.9	26614.9
350-500	1057.0	2619.4	5951.3	3112.8	12740.5
Total					**72934.8**

Average 2003-2005					
Depth (fath)	A	B	C	D	All1
125-175	1424.7	52.2	0.0	0.0	1476.9
175-225	16391.3	1284.3	3351.5	143.7	21170.9
225-275	5756.8	3833.7	5785.7	3348.1	18724.3
275-350	14141.7	3256.4	17164.2	33223.9	67786.2
350-500	7693.4	2917.4	11667.7	24491.0	46769.5
Total					**155927.7**

SE 2003-2005					
Depth (fath)	A	B	C	D	All2
125-175	1040.3	38.4	0.0	0.0	846.9
175-225	12375.5	16.3	1527.0		10511.0
225-275	2035.3	1106.2	1286.2	1693.8	5344.5
275-350		604.5	10307.5	10605.6	10795.2
350-500	1932.3	738.2	2307.4	6181.5	5652.5
Total	13945.1	2015.5	7434.1	11336.7	**18408.0**

Female Crabs > 70 mm

1974					
Depth (fath)	A	B	C	D	All1
125-175	274.0	0.0	339.6	790.0	1403.6
175-225	10036.2	3775.9	14342.2	8965.6	37120.0
225-275	4300.5	2102.3	5764.2	5605.5	17772.6
275-350	2511.2	457.5	8835.3	1630.8	13434.7
350-500	422.8	337.3	487.8	400.8	1648.7
Total					**71379.5**

Average 2003-2005					
Depth (fath)	A	B	C	D	All1
125-175	2968.1	997.1	333.8	861.6	5160.7
175-225	6556.5	2275.1	6424.7	1437.2	16693.5
225-275	11399.1	4752.8	24464.1	32112.3	72728.2
275-350	29159.0	9527.2	71796.8	25311.8	135794.8
350-500	10735.9	15097.0	39421.9	14296.2	79551.0
Total					**309928.3**

SE 2003-2005					
Depth (fath)	A	B	C	D	All2
125-175	2167.2	734.6	333.8	861.6	3237.5
175-225	4950.2	29.0	2927.1		6079.8
225-275	4030.1	1371.4	5438.6	16245.6	22440.0
275-350		1768.5	43115.6	8079.9	21179.0
350-500	2696.5	3820.2	7796.0	3608.3	4535.7
Total	13361.3	5384.3	30285.7	11189.4	**44312.0**

Appendix D4 Table 6. Biomass density in kg/ha (A), and abundance in mt (B) of reproductive size red crabs by depth and sector in 1974 and 2003-2005 (+1SE).

A.

All mature Crabs - Male + Female

1974 **Biomass Density (kg/ha)**

Depth (fath)	A	B	C	D	Avg
125-175	8.6	7.2	14.8	6.6	9.3
175-225	87.2		159.8		123.5
225-275	62.6	49.0	93.9	110.5	79.0
275-350		85.7	88.2		86.9
350-500	8.5		36.9		22.7
Total					**64.3**

Average 2003-2005

Depth (fath)	A	B	C	D	Avg
125-175	37.0	13.6	1.4	7.6	14.9
175-225	167.3	27.9	33.5	6.1	58.7
225-275	167.6	104.8	204.6	334.9	203.0
275-350	241.6	108.7	278.5	605.3	308.5
350-500	70.1	80.3	199.6	192.2	135.5
Total					**144.1**

SE 2003-2005

Depth (fath)	A	B	C	D	Avg
125-175	23.4	8.7	1.2	6.6	8.0
175-225	109.4	0.3	13.2	#DIV/0!	30.8
225-275	53.0	27.0	40.7	146.7	54.8
275-350	#DIV/0!	18.1	113.7	167.3	45.6
350-500	15.7	18.2	35.3	43.4	8.3
Total	33.1	12.2	23.3	51.9	**21.3**

Male Crabs > 75 mm

1974

Depth (fath)	A	B	C	D	Avg
125-175	6.1	7.2	13.0	0.0	6.6
175-225	22.7		106.7		64.7
225-275	27.4	22.9	57.5	56.6	41.1
275-350		83.4	62.1		72.8
350-500	7.4		35.5		21.4
Total					**41.3**

Average 2003-2005

Depth (fath)	A	B	C	D	Avg
125-175	16.1	1.1	0.0	0.0	4.3
175-225	122.7	11.2	12.4	0.4	36.7
225-275	60.4	51.4	50.6	39.6	50.5
275-350	87.9	28.4	72.0	400.8	147.3
350-500	33.3	16.9	64.9	132.9	62.0
Total					**60.1**

SE 2003-2005

Depth (fath)	A	B	C	D	Avg
125-175	11.8	0.8	0.0	0.0	2.4
175-225	92.6	0.1	5.6	#DIV/0!	24.3
225-275	21.3	14.8	11.3	20.0	14.9
275-350	#DIV/0!	5.3	34.0	127.9	38.5
350-500	8.4	4.3	12.8	33.5	7.6
Total	19.5	5.2	6.6	43.5	**12.2**

Female Crabs > 70 mm

1974

Depth (fath)	A	B	C	D	Avg
125-175	2.5	0.0	1.8	6.6	2.7
175-225	64.4		53.1		58.8
225-275	35.2	26.2	36.4	53.9	37.9
275-350		2.2	26.1		14.2
350-500	1.1		1.4		1.3
Total					**23.0**

Average 2003-2005

Depth (fath)	A	B	C	D	Avg
125-175	20.9	12.5	1.4	7.6	10.6
175-225	44.6	16.6	21.1	5.7	22.0
225-275	107.2	53.4	154.0	295.4	152.5
275-350	153.7	80.3	206.5	204.5	161.2
350-500	36.7	63.4	134.6	59.3	73.5
Total					**84.0**

SE 2003-2005

Depth (fath)	A	B	C	D	Avg
125-175	15.3	9.2	1.4	7.6	6.5
175-225	33.7	0.2	9.6	#DIV/0!	10.2
225-275	37.9	15.4	34.2	149.4	47.2
275-350	#DIV/0!	14.9	97.3	65.3	28.2
350-500	9.2	16.0	26.6	15.0	3.8
Total	18.3	8.6	19.5	32.4	**15.7**

B.

All mature Crabs - Male + Female

1974

Depth (fath)	A	B	C	D	All1
125-175	260.0	128.5	815.9	258.6	1463.0
175-225	3817.6	3333.3	12031.9		27097.6
225-275	1464.8	843.6	3503.5	2929.6	8741.6
275-350	3868.6	2424.5	5521.1	2512.4	14326.6
350-500	559.0	1086.6	2351.7	1291.3	5288.6
total					**56917.4**

Average 2003-2005

Depth (fath)	A	B	C	D	All1
125-175	1121.7	242.0	76.2	296.9	1736.8
175-225	7328.0	752.0	2523.6	391.6	10995.1
225-275	3921.4	1802.3	7631.9	8876.1	22231.8
275-350	10751.5	3077.4	17432.9	17492.6	48754.5
350-500	4596.4	3839.1	12712.8	10921.4	32069.6
total					**115787.8**

SE 2003-2005

Depth (fath)	A	B	C	D	All1
125-175	819.0	178.3	76.2	296.9	1075.3
175-225	5532.7	9.6	1149.7	#DIV/0!	5080.9
225-275	1386.4	520.0	1696.6	4490.4	6723.5
275-350	#DIV/0!	571.2	8218.0	5583.9	4319.4
350-500	1154.4	971.5	2514.1	2756.5	2289.6
Total	7574.5	1587.1	8619.1	4996.0	**11576.2**

Male Crabs > 75 mm

1974

Depth (fath)	A	B	C	D	All1
125-175	184.3	128.5	716.9	0.0	1029.7
175-225	995.0	1746.5	8032.4	4146.9	14920.9
225-275	640.0	393.3	2144.7	1501.2	4679.3
275-350	3238.0	2361.8	3885.8	2102.9	11588.4
350-500	486.0	1025.7	2260.4	1218.9	4991.1
Total	5543.4	5655.8	17040.3	8969.9	**37209.4**

Average 2003-2005

Depth (fath)	A	B	C	D	All1
125-175	488.5	19.0	0.0	0.0	507.5
175-225	5374.3	302.8	932.7	23.8	6633.6
225-275	1412.3	883.5	1888.7	1048.7	5233.2
275-350	3913.7	803.7	4509.0	11582.1	20808.5
350-500	2186.9	808.1	4136.9	7552.6	14684.5
Total	13375.7	2817.2	11467.2	20207.1	**47867.2**

SE 2003-2005

Depth (fath)	A	B	C	D	All2
125-175	356.7	14.0	0.0	0.0	291.0
175-225	4057.7	3.9	424.9	#DIV/0!	384.7
225-275	499.3	254.9	419.9	530.5	1472.7
275-350	#DIV/0!	149.2	2125.6	3697.2	3162.2
350-500	549.3	204.5	818.1	1906.2	1754.2
Total	4323.3	496.9	2258.9	3898.6	**3453.7**

Female Crabs > 70 mm

1974

Depth (fath)	A	B	C	D	All1
125-175	75.7	0.0	99.0	258.6	433.3
175-225	2822.6	1586.8	3999.5	3767.7	12176.7
225-275	824.8	450.3	1358.8	1428.4	4062.3
275-350	630.6	62.7	1635.3	409.5	2738.2
350-500	73.0	60.9	91.3	72.3	297.4
Total	4426.7	2160.7	7183.9	5936.7	**19708.0**

Average 2003-2005

Depth (fath)	A	B	C	D	All1
125-175	633.2	223.0	76.2	296.9	1229.4
175-225	1953.6	449.1	1590.9	367.9	4361.5
225-275	2509.2	918.8	5743.3	7827.4	16998.6
275-350	6837.8	2273.7	12923.9	5910.5	27946.0
350-500	2409.4	3030.9	8575.9	3368.9	17385.1
Total	14343.3	6895.5	28910.2	17771.6	**67920.6**

SE 2003-2005

Depth (fath)	A	B	C	D	All2
125-175	462.4	164.3	76.2	296.9	785.7
175-225	1475.0	5.7	724.8	#DIV/0!	718.7
225-275	887.1	265.1	1276.8	3959.9	5287.7
275-350	#DIV/0!	422.1	6092.4	1886.7	3093.4
350-500	605.2	767.0	1696.0	850.3	992.5
Total	3294.6	1096.4	6373.6	2722.4	**8359.0**

Appendix D4 Table 7. Estimated biomass density in kg/ha (A), and standing biomass in mt (B) of fishable red crab by depth and sector in 1974 and 2003-2005 (+1SE).

A.

Fishable Males

1974	**Recruited Biomass density (kg/ha)**				
Depth (fath)	A	B	C	D	Avg
125-175	5.8	0.0	13.0	0.0	4.7
175-225	22.3		103.5		62.9
225-275	26.0	19.9	53.4	55.8	38.8
275-350	53.3	71.9	59.2		61.5
350-500	7.3		31.8		19.6
					37.5

Average 2003-2005	**Recruited Biomass density (kg/ha)**				
Depth (fath)	A	B	C	D	Avg
125-175	13.5	1.0	0.0	0.0	2.9
175-225	98.6	6.2	8.4	0.0	29.9
225-275	32.7	27.2	39.5	29.6	32.7
275-350	55.0	15.8	55.4	330.7	111.2
350-500	22.0	11.2	55.1	95.5	45.9
					44.5

SE 2003-2005	**SE Recruited Biomass density (kg/ha)**				
Depth (fath)	A	B	C	D	Avg
125-175	9.9	0.7	0.0	0.0	2.1
175-225	74.4	0.1	3.8		19.5
225-275	11.6	7.9	8.8	15.0	9.3
275-350		2.9	26.1	105.6	31.3
350-500	5.5	2.8	10.9	24.1	5.5
	14.4	2.9	5.0	35.6	**9.4**

B.

Fishable Males

1974	Recruited Biomass (mt)				
Depth (fath)	A	B	C	D	All1
125-175	177.2	0.0	714.4	0.0	891.7
175-225	976.0	1697.9	7793.9	4031.5	14499.3
225-275	609.4	341.7	1991.7	1478.2	4420.9
275-350	2372.3	2035.2	3708.6	1777.1	9893.2
350-500	481.2	935.4	2024.6	1111.6	4552.8
	4616.1	5010.2	16233.3	8398.4	**34258.0**

Average 2003-2005	Recruited Biomass (mt)				
Depth (fath)	A	B	C	D	All1
125-175	409.5	24.3	0.0	0.0	433.8
175-225	4318.2	166.3	908.0	1.0	5393.5
225-275	766.0	468.5	1474.5	1175.3	3884.3
275-350	2448.6	446.7	3468.4	9557.7	15921.4
350-500	1440.4	629.3	3511.7	5032.2	10613.5
	9382.7	1735.1	9362.6	15766.1	**36246.5**

SE 2003-2005	SE Recruited Biomass (mt)				
Depth (fath)	A	B	C	D	All1
125-175	299.0	19.3	0.0	0.0	245.4
175-225	3260.3	2.1	128.3	#DIV/0!	2714.3
225-275	270.8	135.2	327.8	104.5	967.4
275-350	#DIV/0!	82.9	1635.0	3051.0	2542.0
350-500	361.8	140.0	694.5	1855.0	1564.2
	3252.1	352.1	1736.4	4009.4	**5457.6**

Appendix D5: Variability and confidence intervals for estimates of fishable biomass.
(During 1974 and 2003-2005, and fishing mortality during 2004-2005)

Reviewers at SARC-43 requested information about the precision of fishable biomass and fishing mortality estimates from camera/bottom trawl survey and landings data. The preferred estimates in the assessment were obtained by pooling data from four camera/bottom trawl surveys during 2003-2005 and using average annual landings during the same years. The analysis described here uses data from each of the four surveys separately.

The first step in the analysis was to tabulate fishable biomass for each survey, strata and depth zone using the data available from each survey. There were a number of "holes" in these tabulations because not all strata and depths were sampled in each survey.

The second step in the analysis was to fill holes in the fishable biomass estimates for each survey with average fishable biomass in the same strata and depth. This step tends to artificially reduce the variability among the surveys but was necessary in order to simulate the preferred estimates which were made from the pooled data set with no holes.

Using the augmented data, fishable biomass for each survey in each stratum was calculated by summing across depths:

$$B_{y,s} = \sum_{d=1}^{5} B_{y,s,d}$$

where $B_{y,s}$ is fishable biomass based on augmented data for stratum s in survey y and d=1 to 5 are depth zones. The total fishable biomass for each survey was calculated by summing across strata:

$$B_y = \sum_{s=1}^{4} B_{y,s}$$

Fishing mortality based on each survey was calculated from the ratio landings and fishable biomass, in particular:

$$F_y = \frac{L}{B_y}$$

where landings L were for the same year as the survey.

The third step was to compute the mean, standard deviation, standard error and CVs for biomass and fishing mortality estimates from each survey (see below). The CV=standard deviation / mean estimates the precision of a biomass estimate from a single camera/bottom trawl survey. The data used to estimate the standard deviation was from surveys during 2003-2005 but, for lack of other information, the standard deviation was used as a measure of precision for the fishable biomass estimate from the 1974 survey. The CV = standard error / mean measures the precision of the pooled biomass and fishing mortality estimates for 2003-2005 based on all four camera/bottom trawl surveys.

	Stratum				
Year	A	B	C	D	All
	Fishable biomass (mt)				
2003 June	7,251	1,262	9,222	9,839	27,573
2003 Aug	6,634	1,911	12,850	16,449	37,844
2004	15,590	2,132	9,228	13,918	40,868
2005	8,063	1,620	6,158	22,870	38,712
Average	9,384	1,731	9,364	15,769	36,249
CV std/mean	45%	22%	29%	35%	16%
CV se/mean	22%	11%	15%	17%	8%
	Fishing mortality				
2003 June	0.0709	0.0414	0.0978	0.0459	0.0696
2003 Aug	0.0775	0.0273	0.0702	0.0275	0.0507
2004	0.0350	0.0260	0.1039	0.0345	0.0499
2005	0.0668	0.0338	0.1536	0.0207	0.0520
Average	0.0625	0.0322	0.1064	0.0322	0.0556
CV std/mean	30%	22%	33%	33%	17%
CV se/mean	15%	11%	16%	17%	8%

Fishable biomass estimates from individual surveys during 2003-2005 ranged 28-41 thousand mt while fishing mortality estimates ranged 0.05-0.07 y^{-1}. Based on the CV=8% from the standard error, average fishable biomass and fishing mortality estimates during 2003-2005 were reasonably precise for all survey strata combined. Based on the CV=16% from the standard deviation, the fishable biomass estimate for all strata combined in the 1974 survey was substantially less precise.

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