Northeast Fisheries Science Center Reference Document 06-14

43rd Northeast Regional

Stock Assessment Workshop (43rd SAW)

43rd SAW Assessment Summary Report

July 2006

Recent Issues in This Series

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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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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SAW-43 ASSESSMENT SUMMARY REPORT
INTRODUCTION

The 43rd SAW Assessment Summary Report contains summary and detailed technical information on three assessments reviewed in June 2006 at the Stock Assessment Workshop (SAW) by the 43rd Stock Assessment Review Committee (SARC-43): spiny dogfish (*Squalus acanthias*), black sea bass (*Centropristis striata*), and deep sea red crab (*Chaceon quinquedens*). An ocean quahog (*Arctica islandica*) assessment was also reviewed, but it was withdrawn because it did not include all available data and a formula used in the assessment was used incorrectly.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 Regional Coordinating Council (NRCC). The SARC-43 consisted of two external, independent reviewers and an external SARC chairman, all appointed by the Center for Independent Experts (CIE). The SARC evaluated whether each Term of Reference (listed in the Appendix) was completed successfully based on scientific criteria and whether the work provided a scientifically credible basis for developing fishery management advice. The reviewers' report for SAW/SARC-43 is available at website: http://www.nefsc.noaa.gov/nefsc/saw/ under the heading "Recent Reports".

An important aspect of any assessment is the determination of current stock status. The status of the stock relates to both the rate of removal of fish from the population – the exploitation rate – and the current stock size. The exploitation rate is the proportion of the stock alive at the beginning of the year that is caught during the year. When that proportion exceeds the amount specified in an overfishing definition, overfishing is occurring. Fishery removal rates are usually expressed in terms of the instantaneous fishing mortality rate, F, and the maximum removal rate is denoted as $F_{THRESHOLD.}$

Another important factor for classifying the status of a resource is the current stock level, for example, spawning stock biomass (SSB) or total stock biomass (TSB). Overfishing definitions, therefore, characteristically include specification of a minimum biomass threshold as well as a maximum fishing threshold. If the biomass of a stock falls below the biomass threshold ($B_{THRESHOLD}$) the stock is in an overfished condition. The Sustainable Fisheries Act mandates that a stock rebuilding plan be developed should this situation arise.

Since there are two dimensions to stock status – the rate of removal and the biomass level – it is possible that a stock not currently subject to overfishing in terms of exploitation rates is in an overfished condition, that is, has a biomass level less than the threshold level. This may be due to heavy exploitation in the past, or a result of other factors such as unfavorable environmental conditions. In this case, future recruitment to the stock is very important and the probability of improvement may increase greatly by increasing the stock size. Conversely, fishing down a stock that is at a high biomass level should generally increase the long-term sustainable yield. This philosophy is embodied in the Sustainable Fisheries Act — stocks should be managed on the basis of maximum sustainable yield (MSY). The biomass that produces this yield is called B_{MSY} and the fishing mortality rate that produces MSY is called F_{MSY}.

Given this, stocks under review are classified with respect to current overfishing definitions. A stock is overfished if its current biomass is below $B_{THRESHOLD}$ and overfishing is occurring if current F is greater than $F_{THRESHOLD}$. The schematic below depicts how status criteria are interpreted in this context.

Fisheries management takes into account the precautionary approach, and overfishing guidelines often include a control rule in the overfishing definition. Generically, the control rules suggest actions at various levels of stock biomass and incorporate an assessment of risk, in that F targets are set so as to avoid exceeding F thresholds.

		BIOMASS		
		$B < B_{THRESHOLD}$	$B_{THRESHOLD} < B < B_{MSY}$	$B > B_{MSY}$
EXPLOITATION	$F > F_{THRESHOLD}$	Overfished, overfishing is occurring; reduce F, adopt and follow rebuilding plan	Not overfished, overfishing is occurring; reduce F, rebuild stock	$F = F_{TARGET} <= F_{MSY}$
RATE	$F < F_{THRESHOLD}$	Overfished, overfishing is not occurring; adopt and follow rebuilding plan	Not overfished, overfishing is not occurring; rebuild stock	$F = F_{TARGET} <= F_{MSY}$

Outcome of Stock Assessment Review Meeting

The volume of results on spiny dogfish made parts of that assessment hard for the SARC to evaluate. The SARC felt that the very large 2006 survey estimate probably overestimates the current stock size, and that stock projections based on it may be overly optimistic. Major concerns of the SARC about the spiny dogfish stock are the long term reduction in female biomass, imbalance in the sex ratio, and the 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 to larger fish in recent years. The SARC felt that $B_{threshold}$ was adequate, but that there was substantial uncertainty about 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 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 the confidence intervals are large, the SARC felt that it was questionable 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 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 provided adequate estimates of biomass and fishing mortality rate, but that the biomass reference point established in the 1970s is not reliable. Therefore, current stock status could not be evaluated.

GLOSSARY

ADAPT. A commonly used form of computer program used to optimally fit a Virtual Population Assessment (VPA) to abundance data.

ASPM. Age-structured production models, also known as statistical catch-at-age (SCAA) models, are a technique of stock assessment that integrate fishery catch and fishery-independent sampling information. The procedures are flexible, allowing for uncertainty in the absolute magnitudes of catches as part of the estimation. Unlike virtual population analysis (VPA) that tracks the cumulative catches of various year classes as they age, ASPM is a forward projection simulation of the exploited population.

Availability. Refers to the distribution of fish of different ages or sizes relative to that taken in the fishery.

Biological reference points. Specific values for the variables that describe the state of a fishery system which are used to evaluate its status. Reference points are most often specified in terms of fishing mortality rate and/or spawning stock biomass. The reference points may indicate 1) a desired state of the fishery, such as a fishing mortality rate that will achieve a high level of sustainable yield, or 2) a state of the fishery that should be avoided, such as a high fishing mortality rate which risks a stock collapse and long-term loss of potential yield. The former type of reference points are referred to as "target reference points" and the latter are referred to as "limit reference points" or "thresholds". Some common examples of reference points are $F_{0.1}$, F_{MAX}, and F_{MSY}, which are defined later in this glossary.

B_0. Virgin stock biomass, i.e., the long-term average biomass value expected in the absence of fishing mortality.

B_{MSY}. Long-term average biomass that would be achieved if fishing at a constant fishing mortality rate equal to F_{MSY}.

Biomass Dynamics Model. A simple stock assessment model that tracks changes in stock using assumptions about growth and can be tuned to abundance data such as commercial catch rates, research survey trends or biomass estimates.

Catchability. Proportion of the stock removed by one unit of effective fishing effort (typically age-specific due to differences in selectivity and availability by age).

Control Rule. Describes a plan for pre-agreed management actions as a function of variables related to the status of the stock. For example, a control rule can specify how F or yield should vary with biomass. In the National Standard Guidelines (NSG), the "MSY control rule" is used to determine the limit fishing mortality, or Maximum Fishing Mortality Threshold (MFMT). Control rules are also known as "decision rules" or "harvest control laws."

Catch per Unit of Effort (CPUE). Measures the relative success of fishing operations, but also can be used as a proxy for relative abundance based on the assumption that CPUE is linearly related to stock size. The use of CPUE that has not been properly standardized for temporal-spatial changes in catchability should be avoided.

Exploitation pattern. The fishing mortality on each age (or group of adjacent ages) of a stock relative to the highest mortality on any age. The exploitation pattern is expressed as a series of values ranging from 0.0 to 1.0. The pattern is referred to as "flat-topped" when the values for all the oldest ages are about 1.0, and "dome-shaped" when the values for some intermediate ages are about 1.0 and those for the oldest ages are significantly lower. This pattern often varies by type of fishing gear, area, and seasonal distribution of fishing, and the growth and migration of the fish. The pattern can be changed by modifications to fishing gear, for example, increasing mesh or hook size, or by changing the proportion of harvest by gear type.

Mortality rates. Populations of animals decline exponentially. This means that the number of animals that die in an "instant" is at all times proportional to the number present. The decline is defined by survival curves such as:

$$N_{t+1} = N_t e^{-z}$$

where N_t is the number of animals in the population at time t and N_{t+1} is the number present in the next time period; Z is the total instantaneous mortality rate which can be separated into deaths due to fishing (fishing mortality or F) and deaths due to all other causes (natural mortality or M) and e is the base of the natural logarithm (2.71828).

To better understand the concept of an instantaneous mortality rate, consider the following example. Suppose the instantaneous total mortality rate is 2 (i.e., Z = 2) and we want to know how many animals out of an initial population of 1 million fish will be alive at the end of one year. If the year is apportioned into 365 days (that is, the 'instant' of time is one day), then 2/365 or 0.548% of the population will die each day. On the first day of the year, 5,480 fish will die (1,000,000 x 0.00548), leaving 994,520 alive. On day 2, another 5,450 fish die (994,520 x 0.00548) leaving 989,070 alive. At the end of the year, 134,593 fish $[1{,}000{,}000 \times (1 - 0.00548)^{365}]$ remain alive. If, we had instead selected a smaller 'instant' of time, say an hour, 0.0228% of the population would have died by the end of the first time interval (an hour), leaving 135,304 fish alive at the end of the year $[1{,}000{,}000 \times (1 - 0.00228)^{8760}]$. As the instant of time becomes shorter and shorter, the exact answer to the number of animals surviving is given by the survival curve mentioned above, or, in this example:

$$N_{t+1} = 1{,}000{,}000e^{-2} = 135{,}335 \text{ fish}$$

Exploitation rate. The proportion of a population alive at the beginning of the year that is caught during the year. That is, if 1 million fish were alive on January 1 and 200,000 were caught during the year, the exploitation rate is 0.20 (200,000 / 1,000,000) or 20%.

F_{MAX}. The rate of fishing mortality that produces the maximum level of yield per recruit. This is the point beyond which growth overfishing begins.

$F_{0.1}$. The fishing mortality rate where the increase in yield per recruit for an increase in a unit of effort is only 10% of the yield per recruit produced by the first unit of effort on the unexploited stock (i.e., the slope of the yield-per-recruit curve for the $F_{0.1}$ rate is only one-tenth the slope of the curve at its origin).

$F_{10\%}$. The fishing mortality rate which reduces the spawning stock biomass per recruit (SSB/R) to 10% of the amount present in the absence of fishing. More generally, Fx%, is the fishing mortality rate that reduces the SSB/R to x% of the level that would exist in the absence of fishing.

F_{MSY}. The fishing mortality rate that produces the maximum sustainable yield.

F**ishery Management Plan (FMP)**. Plan containing conservation and management measures for fishery resources, and other provisions required by the MSFCMA, developed by Fishery Management Councils or the Secretary of Commerce.

Generation Time. In the context of the National Standard Guidelines, generation time is a measure of the time required for a female to produce a reproductively-active female offspring for use in setting maximum allowable rebuilding time periods.

Growth overfishing. The situation existing when the rate of fishing mortality is above F_{MAX} and when fish are harvested before they reach their growth potential.

Limit Reference Points. Benchmarks used to indicate when harvests should be constrained substantially so that the stock remains within safe biological limits. The probability of exceeding limits should be low. In the National Standard Guidelines, limits are referred to as thresholds. In much of the international literature (e.g., FAO documents), "thresholds" are used as buffer points that signal when a limit is being approached.

Landings per Unit of Effort (LPUE). Analogous to CPUE and measures the relative success of fishing operations, but is also sometimes used a proxy for relative abundance based on the assumption that CPUE is linearly related to stock size.

MSFCMA. (Magnuson-Stevens Fishery Conservation and Management Act). U.S. Public Law 94-265, as amended through October 11, 1996. Available as NOAA Technical Memorandum NMFS-F/SPO-23, 1996.

Maximum Fishing Mortality Threshold (MFMT, $F_{THRESHOLD}$). One of the Status Determination Criteria (SDC) for determining if overfishing is occurring. It will usually be equivalent to the F corresponding to the MSY Control Rule. If current fishing mortality rates are above $F_{threshold,}$ overfishing is occurring.

Minimum Stock Size Threshold (MSST, $B_{threshold}$). Another of the Status Determination Criteria. The greater of (a) ½B_{MSY}, or (b) the minimum stock size at which rebuilding to B_{MSY} will occur within 10 years of fishing at the MFMT. MSST should be measured in terms of spawning biomass or other appropriate measures of productive capacity. If current stock size is below $B_{THRESHOLD}$, the stock is overfished.

Maximum Spawning Potential (MSP). This type of reference point is used in some fishery management plans to define overfishing. The MSP is the spawning stock biomass per recruit (SSB/ R) when fishing mortality is zero. The degree to which fishing reduces the SSB/R is expressed as a percentage of the MSP (i.e., %MSP). A stock is considered overfished when the fishery reduces the %MSP below the level specified in the overfishing definition. The values of %MSP used to define overfishing can be derived from stock-recruitment data or chosen by analogy using available information on the level required to sustain the stock.

Maximum Sustainable Yield (MSY). The largest average catch that can be taken from a stock under existing environmental conditions.

Overfishing. According to the National Standard Guidelines, "overfishing occurs whenever a stock or stock complex is subjected to a rate or level of fishing mortality that jeopardizes the capacity of a stock or stock complex to produce MSY on a continuing basis." Overfishing is occurring if the MFMT is exceeded for 1 year or more.

Optimum Yield (OY). The amount of fish that will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities and taking into account the protection of marine ecosystems. MSY constitutes a "ceiling" for OY. OY may be lower than MSY, depending on relevant economic, social, or ecological factors. In the case of an overfished fishery, OY should provide for rebuilding to B_{MSY}.

Partial Recruitment. Patterns of relative vulnerability of fish of different sizes or ages due to the combined effects of selectivity and availability.

Rebuilding Plan. A plan that must be designed to recover stocks to the B_{MSY} level within 10 years when they are overfished (i.e. when B < MSST). Normally, the 10 years would refer to an expected time to rebuilding in a probabilistic sense.

Recruitment. This is the number of young fish that survive (from birth) to a specific age or grow to a specific size. The specific age or size at which recruitment is measured may correspond to when the young fish become vulnerable to capture in a fishery or when the number of fish in a cohort can be reliably estimated by a stock assessment.

Recruitment overfishing. The situation existing when the fishing mortality rate is so high as to cause a reduction in spawning stock which causes recruitment to become impaired.

Recruitment per spawning stock biomass (R/SSB). The number of fishery recruits (usually age 1 or 2) produced from a given weight of spawners, usually expressed as numbers of recruits per kilogram of mature fish in the stock. This ratio can be computed for each year class and is often used as an index of pre-recruit survival, since a high R/SSB ratio in one year indicates above-average numbers resulting from a given spawning biomass for a particular year class, and vice versa.

Reference Points. Values of parameters (e.g. B_{MSY}, F_{MSY}, $F_{0.1}$) that are useful benchmarks for guiding management decisions. Biological reference points are typically limits that should not be exceeded with significant probability (e.g., MSST) or targets for management (e.g., OY).

Risk. The probability of an event times the cost associated with the event (loss function). Sometimes "risk" is simply used to denote the probability of an undesirable result (e.g. the risk of biomass falling below MSST).

Status Determination Criteria (SDC). Objective and measurable criteria used to determine if a stock is being overfished or is in an overfished state according to the National Standard Guidelines.

Selectivity. Measures the relative vulnerability of different age (size) classes to the fishing gears(s).

Spawning Stock Biomass (SSB). The total weight of all sexually mature fish in a stock.

Spawning stock biomass per recruit (SSB/R or SBR). The expected lifetime contribution to the spawning stock biomass for each recruit. SSB/R is calculated assuming that F is constant over the life span of a year class. The calculated value is also dependent on the exploitation pattern and rates of growth and natural mortality, all of which are also assumed to be constant.

Survival Ratios. Ratios of recruits to spawners (or spawning biomass) in a stock-recruitment analysis. The same as the recruitment per spawning stock biomass (R/SSB), see above.

TAC. Total allowable catch is the total regulated catch from a stock in a given time period, usually a year.

Target Reference Points. Benchmarks used to guide management objectives for achieving a desirable outcome (e.g., OY). Target reference points should not be exceeded on average.

Uncertainty. Uncertainty results from a lack of perfect knowledge of many factors that affect stock assessments, estimation of reference points, and management. Rosenberg and Restrepo (1994) identify 5 types: measurement error (in observed quantities), process error (or natural population variability), model error (mis-specification of assumed values or model structure), estimation error (in population parameters or reference points, due to any of the preceding types of errors), and implementation error (or the inability to achieve targets exactly for whatever reason).

Virtual population analysis (VPA) (or cohort analysis). A retrospective analysis of the catches from a given year class which provides estimates of fishing mortality and stock size at each age over its life in the fishery. This technique is used extensively in fishery assessments.

Year class (or cohort). Fish born in a given year. For example, the 1987 year class of cod includes all cod born in 1987. This year class would be age 1 in 1988, age 2 in 1989, and so on.

Yield per recruit (Y/R or YPR). The average expected yield in weight from a single recruit. Y/R is calculated assuming that F is constant over the life span of a year class. The calculated value is also dependent on the exploitation pattern, rate of growth, and natural mortality rate, all of which are assumed to be constant.

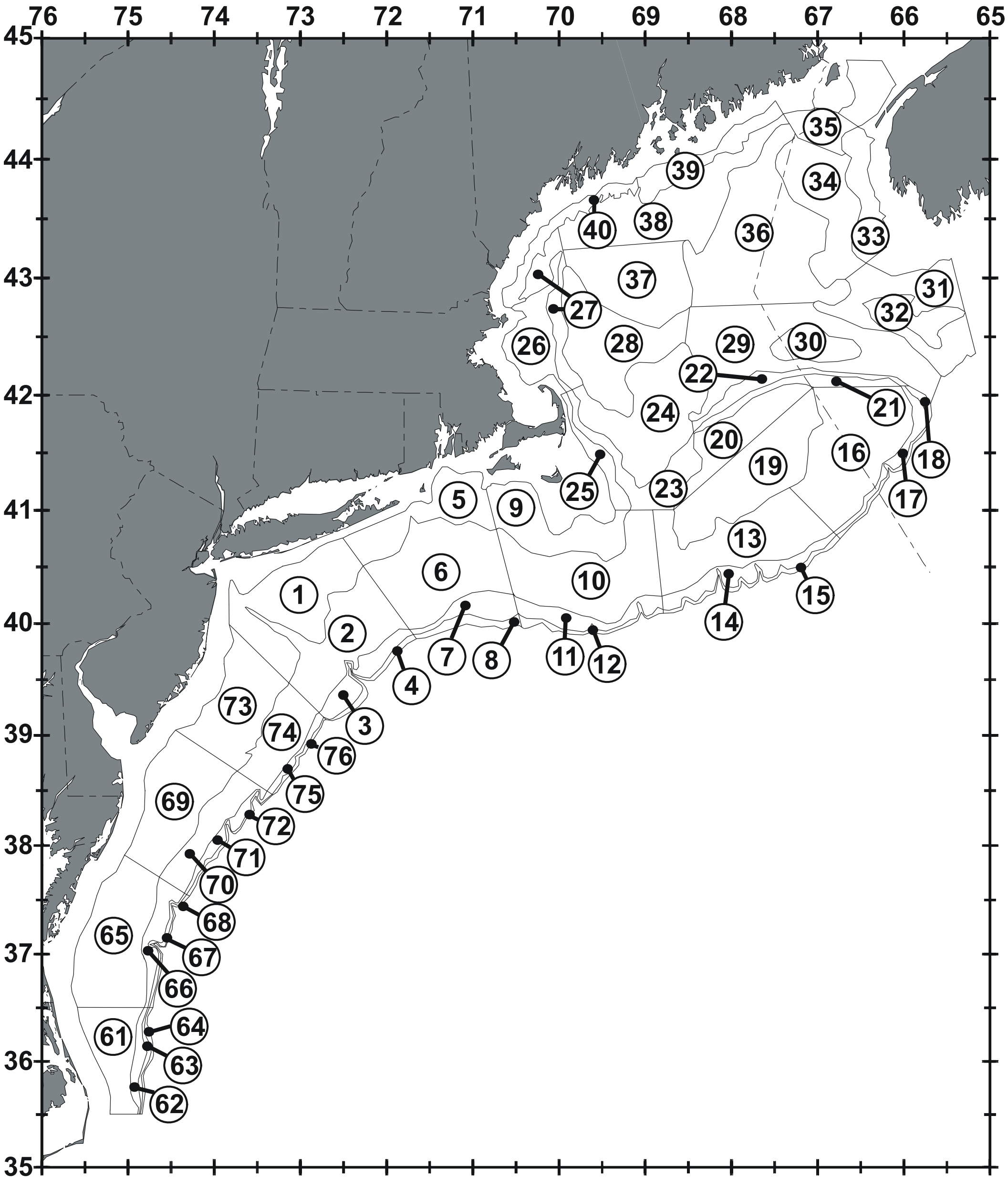

Figure 1. Offshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys.

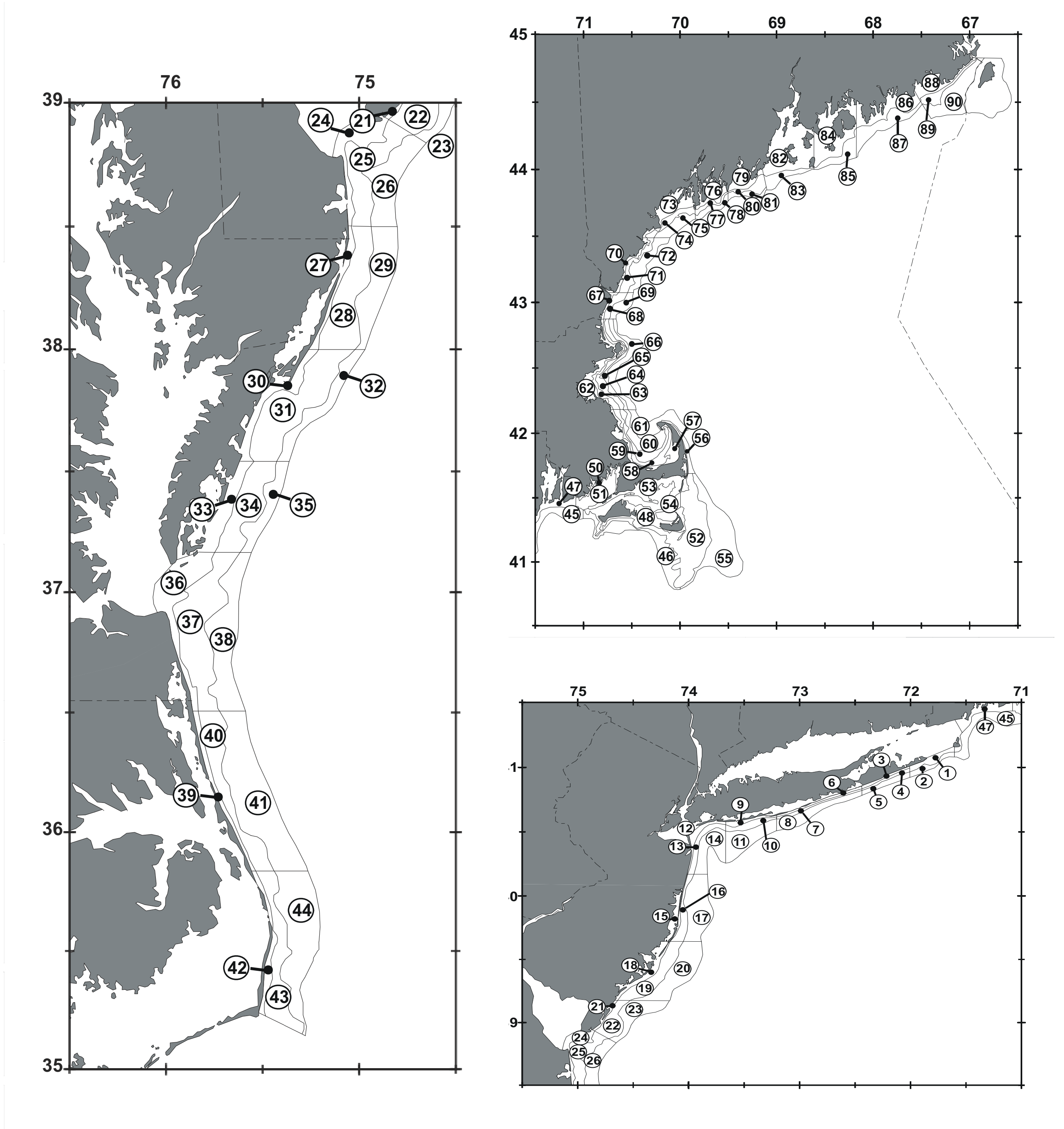

Figure 2. Inshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys.

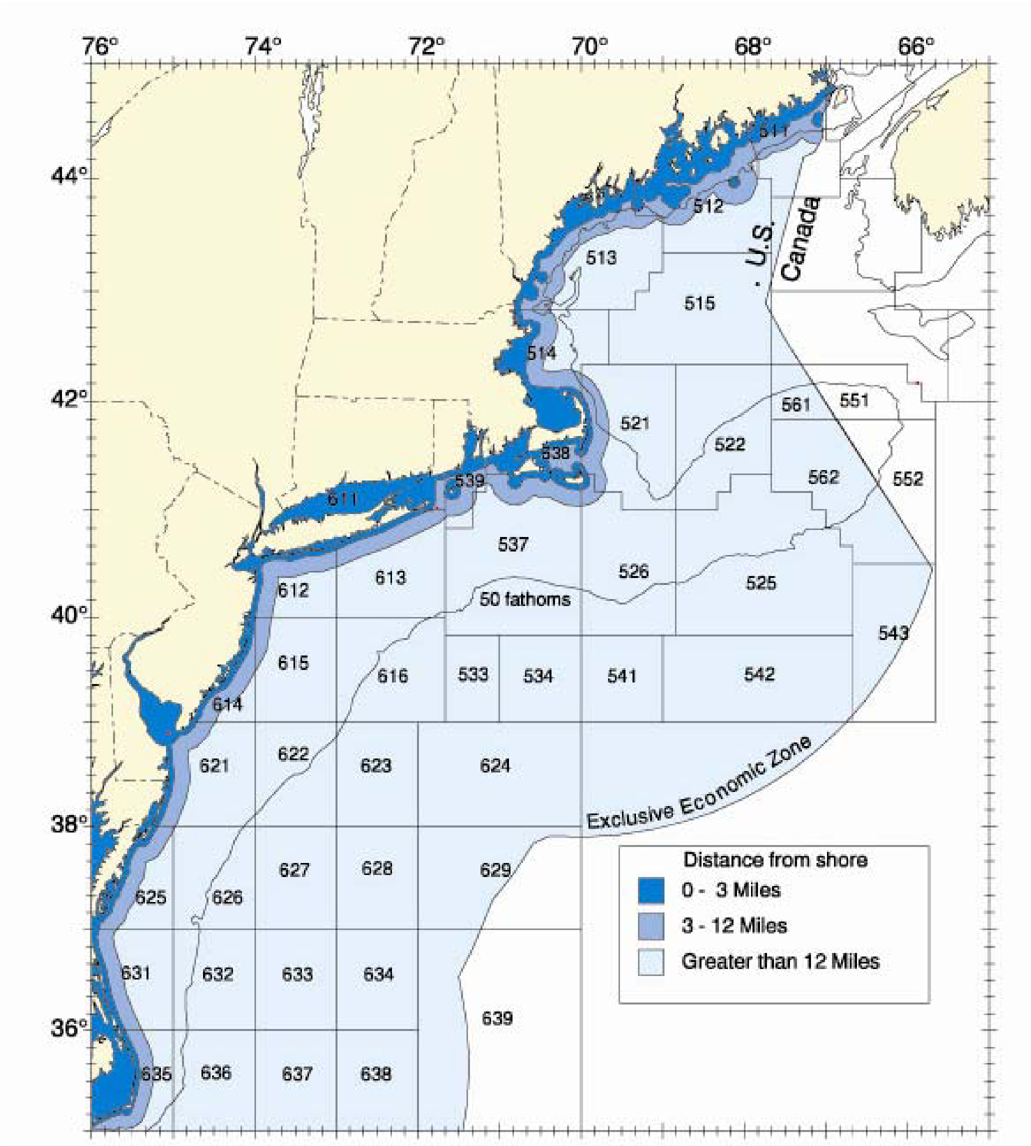

Figure 3. Statistical areas used for reporting commercial catches.

A. OCEAN QUAHOG SUMMARY FOR 2006

******The ocean quahog assessment was 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 assessment was made before the SARC43 reviews were available. This decision was approved by the Northeast Regional Coordinating Council (NRCC). The ocean quahog assessment will be reviewed at a future SARC. (This note was written by James Weinberg, NEFSC SAW Chairman, July 11, 2006.)*

B. SPINY DOGFISH ASSESSMENT SUMMARY FOR 2006

State of Stock: 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) (Figure B1), 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 (See Biological Reference Points and Special Comments sections).

The estimate for 2005 of F on fully recruited females is 0.128 (0.09-0.17; 80% confidence interval) (Figure B1). This fishing mortality rate exceeds the existing overfishing threshold ($F_{threshold}$=0.11) and the existing rebuilding target ($F_{rebuild}$=0.03). The overfishing threshold was updated in the current assessment ($F_{threshold}$=0.39). Based on the updated estimate, overfishing is not occurring (Figure B2). (See Biological Reference Points and Special Comments sections.) Despite the much lower level of landings since 2001, fishing mortality rates on fully recruited females have remained above the rebuilding F (0.03).

Spawning female biomass decreased from about 260,000 mt in 1989 to about 50,000 mt in 1998, and remained below 100,000 mt until 2005 (Figures B1 and B8). NEFSC spring survey indices rose sharply in 2006.

Annual pup production per female is low (4-9 pups per litter every two years) and total pup production is directly related to the number and size structure of spawning females. Recruitment estimates from 1997 to 2003 represent the seven lowest values in the entire series.

Projections: 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. These oscillations are expected to occur whether or not there is fishing (Figure B3). 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.

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

Catch and Status Table (weights in '000 t, recruitment in millions): Spiny Dogfish

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Max	Min	Mean
USA commercial landings	27.2	18.4	20.6	14.9	9.3	2.3	2.2	1.2	1.0	1.2		27.2	0.1	5.9[1]
Foreign commercial landings	0.7	0.7	1.7	3.0	3.2	3.5	4.1	1.9	2.7	1.8[2]		24.5	<0.1	11.1
USA recreational catch[5]	0.1	0.2	0.2	0.2	0.1	0.5	0.6	0.6	0.8	0.7		1.6	0.1	0.4
Total Landings	28.0	19.2	22.5	18.0	12.6	6.2	6.8	3.8	4.4	3.6		28.0	0.2	10.6
Discards, commercial[3,4]	6.0	4.2	3.3	4.5	2.9	4.6	4.8	3.7	5.7	5.0		22.8	2.9	11.4
Total catch in assessment	34.0	23.5	25.8	22.6	15.5	10.9	11.7	7.4	10.2	8.7				
Spring survey females[6]	60.5	44.9	15.5	32.5	29.2	19.8	32.2	29.7	14.4	17.8	60.0	89.2	14.4	44.6
F on female exploitable stock[7]	0.35	0.23	0.31	0.29	0.15	0.11	0.16	0.17	0.47	0.13		0.47	0.08	0.25
Swept Area Biomass Estimates[8]														
Total Stock (male+female)	521	489	406	358	344	338	371	347	338	454		665	338	456
Exploitable stock (male+female)	316	320	186	168	287	292	278	242	238	327		570	168	315
Female SSB[9]	114	92	52	53	62	65	58	54	48	106		270	48	117
Recruitment Index[10]	34	2	3	1	3	1	2	6	28	13	4	127	1	29

[1]Summary statistics based on data from 1962-2005.
[2]Landings assumed to be 1500 mt for Canada and status quo for other foreign.
[3]Total discard mortality in trawl, gillnet, scallop dredge and hook fisheries, 1989-2005. assuming 30% gillnet, 50% trawl, 75% scallop dredge and 10% hook discard mortality.
[4]Estimated discard mortality in trawl and gillnet fisheries, 1981-1988 using the ratio of dogfish discards to total landings of all species in 1989 with above discard mortalities.
[5]Includes all landed and released recreational catch (assuming 20% discard mortality), 1981-2005.
[6]NEFSC Spring survey average weight per tow, 1982-2006.
[7]Stochastic estimator of F on female exploitable stock, 1990-2005, minimum footprint assumption.
[8]Stochastic estimates of biomass, 1990-2005, for total, exploitable and female spawning stock, minimum foot print assumption.
[9]Individuals > 80 cm.
[10]NEFSC spring survey, expanded number of individuals < 35 cm (millions).

Stock Distribution and Identification: Spiny dogfish are distributed in the Northwest Atlantic between Labrador and Florida. They are most abundant between Nova Scotia and Cape Hatteras, and are considered to be a unit stock in NAFO Subareas 2-6. Seasonal migrations occur northward in the spring/summer and southward in the autumn/winter. Analysis of spatial and temporal abundance patterns from NEFSC spring and autumn and Canadian summer research vessel surveys suggests that the spring survey provides a valid abundance measure for the entire stock.

Tagging studies and research surveys conducted in North Carolina waters by East Carolina University (ECU) suggest that spiny dogfish found south of Cape Hatteras during the winter constitute a minor component of the stock north of Cape Hatteras, as defined above. Tag returns from the ECU studies were mainly from North Carolina waters in winter and Massachusetts waters in summer. Few ECU tags were recovered in Canadian waters. Further study of dogfish stock structure is needed.

Catches: Dogfish landings were dominated by foreign catches from 1966 to 1977, peaking in 1974 at about 25,000 mt (Figure B4). US commercial landings dominated the catch from 1979 to 2000, peaking in 1996 at about 27,000 mt. Total landings have declined steadily from 22,500 mt in 1998 to around 3,000 - 4,000 mt during 2003-2005.

Quantitative estimates of discards are available for 1989-2005 (Figure B5) along with imputed values for 1981-1988 (using the ratio of dogfish discards to total landings of all species). Total discards (live + dead) have ranged from 7,400 mt to 47,300 mt. Estimated annual discard mortalities ranged from 2,900 mt to 22,800 mt, assuming various mortality rates. Discards were estimated by size and sex for gill net and trawl fisheries. Coefficients of variation for annual discard estimates have improved with increasing observer coverage. In recent years, CVs have been below 15% for both otter trawls and gill nets.

Median body size of female dogfish in commercial landings decreased by more than 10 cm between 1989 and 1999; median average weight declined by more than half in this same period (Figure B6). Since 2000, median size of landed females has been stable at about 83 cm and 2.5 kg.

Data and Assessment: The current assessment updates the findings of SAW 18 (June 1994), SAW 26 (May 1998), and SAW 37 (June 2003). It updates annual estimates of stock biomass and fishing mortality and re-estimates $F_{threshold}$. Estimates of means and variances of discarded catch and its size composition were included in the assessment analyses. Because age compositions of the landings and discards are not available, the analytical models used were length-based. Indices of abundance were derived from research vessel survey catch per tow data. Biological data on the relationship between maternal size, and numbers and size of pups were incorporated. Natural mortality (M) was estimated to be 0.092 based on an assumed longevity of 50 years. Selectivity patterns for exploited female and male dogfish were developed from data on landings and discards.

Primary estimates of biomass and fishing mortality were derived from a stochastic length-based, survey swept-area method using data from the commercial fishery and the NEFSC spring trawl survey. The model incorporated uncertainty in the survey indices, the footprint of the NEFSC survey trawl, discards, and recreational landings plus discards. A size- and sex-structured equilibrium life history model incorporating known biological parameters was used to estimate yield per recruit and female pups per recruit corresponding to various levels of F and minimum size at entry to the fishery. A stochastic, length-based projection model was developed to predict yield, population sizes and rebuilding times under alternative management scenarios.

Some other models that were explored included a Beverton-Holt model, a Length Tuned Model (LTM) and a simple depletion model of NEFSC spring survey data.

Biological Reference Points: Reference points established in the MAFMC/NEFMC Spiny Dogfish Fishery Management Plan (1999) include B_{target} of 180,000 mt and $B_{threshold}$ of 100,000 mt, (both expressed in terms of adult ($\geq$ 80 cm) female biomass), and $F_{threshold}$ of F= 0.11 and F_{target} of F=0.08. These threshold and target fishing mortality rates represent fully recruited F, and were calculated assuming a knife edge fishery selectivity pattern with a minimum size of 70 cm. $F_{threshold}$ corresponds to a lifetime female pup production of 1.0; F_{target} corresponds to lifetime female pup production of 1.5.

The B_{target} reference point in the FMP was subsequently disapproved because it did not correspond to the biomass associated with maximum recruitment (~200,000 mt) in a Ricker stock-recruitment function. The biomass target in the ASMFC FMP (SSB_{max} = 167,000 mt) was derived by applying a Ricker model to the swept area estimates of SSB and recruits in the NEFSC spring trawl survey.

Biomass reference points were re-estimated for the current assessment using the Ricker model with data through 2006. However, these results were considered unreasonable and were rejected by the Southern Demersal Subcommittee. (See Special Comments.)

The overfishing threshold was updated in this assessment using the same life history model as in the previous assessment, but using the current (2005) size selectivity of the fishery. The revised estimate of $F_{threshold}$ is 0.39, and it reflects a shift in size selectivity to larger individuals in the landings and discards. $F_{threshold}$ is also affected by life history parameters. Using the newly estimated annual size selectivity patterns for the fishery (landings + discards), the derived reference points can be compared to F estimates during 1989-2005 (Figure B2). (See Special Comments.)

Fishing Mortality: Full F on the female exploitable stock varied between 0.08 and 0.47 between 1990 and 2005 (Figure B1, bottom panel). 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). Total mortality, expressed in terms of its consequences for projected pups per recruit, has been low enough in recent years to allow the population to grow (Figure B1 middle panel). This conclusion assumes the first year pup survival rate given in Rago et al. (1998).

Recruitment: Annual pup production per female is low (4-9 pups per litter every two years) and total pup production is directly related to the number and size structure of spawning females. Recruitment during 1997 to 2003 encompassed the seven lowest values in the entire series (Figure B7). Recruitment rebounded slightly in 2004, but declined in 2005 and 2006. Reduced recruitment in 2006 may be indicative of higher first year mortality rates for spiny dogfish pups.

Stock Biomass: Total biomass increased three-fold from the early 1970s through 1992 (Figure B8 top), and then declined by 33% during 1992-2002 (~600,000 mt to ~400,000 mt). Most of this change decline was due to the harvest of dogfish greater than 80 cm (Figure B8 bottom). Smoothed swept-area estimates of the spawning (female) biomass (defined as >= 80 cm fish) increased from about 150,000 mt in 1980 to 260,000 mt in 1989. 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 (Figure B8). The extremely high estimate in 2006 raised the 3-yr average female SSB estimate to 106,000 mt.

NEFSC spring survey indices increased sharply in 2006, indicating a near two fold increase in total stock size between 2005 and 2006. 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 (Figure B9). 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.

Observed stock size estimates for 2006 are within the range forecasted at SARC 37 (NEFSC 2003). The stochastic estimate of median spawning stock size in 2006 (based on 2004-2006 data), exceeded the threshold SSB (100,000 mt) for the first time since 1996.

Special Comments: Length-frequency data from both the US commercial landings and six separate research vessel survey catches indicate a pronounced and consistent decrease in average length of mature females in recent years (Figure B10). Changes in the size composition of the female stock component since the onset of the intensive US fishery in the early 1990s (Figure B11) may have impacted reproductive potential. Examination of the size composition for 2006 suggests some rebuilding of the population size structure, but dogfish less than 60 cm were rare for both males and females (Figure B11).

Average size of pups in the survey has declined, consistent with the decline in body size of spawning females. Recent poor recruitment poses a substantial risk to the long-term spawning stock of spiny dogfish. Short term increases in stock size are expected to continue for several more years until the reduced recruitment that has been observed acts to lower SSB.

An updated Ricker stock recruitment analysis in which data from 1997-2006 were added to the 1968-1996 time series, suggested that SSB_{max} increased from 215,000 mt to 304,000 mt (Figure B12). This revised estimate is not biologically meaningful because the underlying stock structure has changed significantly over time. The relationship between spawning stock and recruitment appears to be influenced by both a decrease in average maternal size and an increase in male to female ratio in the last decade. Analyses of model residuals suggested the odds of having recruitment below the model prediction was 4.5 times greater when the maternal size was below its median value of 87 cm. Average maternal size in 2006 was less than 85 cm.

The sex ratio of mature males (>60 cm) to females (>80 cm) began to increase in 1993, rising nearly 3-fold by 2000 (Figure B13). The skewed sex ratio may affect reproductive output of the stock. Negative implications of skewed sex ratios have been observed in other elasmobranches, but there are no direct observations of these effects in *Squalus acanthias*.

Biomass reference points for spiny dogfish are complicated by both technical and regulatory issues. Stock-recruitment analyses were conducted in 1999 to support development of the Fishery Management Plan. These analyses were reviewed by a joint meeting of the Statistical and Scientific Committee (SSC) of the New England and Mid-Atlantic Fishery Management Councils. The SSC recommended the use of an SSBmax of 200,000 mt and a threshold biomass of one-half this value, i.e., 100,000 mt. The exact value of SSB_{max} was actually slightly greater (214,000 mt) but the difference was considered negligible given the uncertainty of estimation. The New England Fishery Management Council (NEFMC) rejected the 200,000 mt estimate and instead approved an estimate of 90% of SSB_{max} (180,000 mt). This latter value was rejected by NMFS, so an official biomass reference point does not exist for spiny dogfish in federal waters. An interjurisdictional fishery management plan for spiny dogfish in state waters was developed in 2002 (ASMFC 2002). This plan utilized revised information from the swept-area method about uncertainty of the tow footprint of the trawl. Using this new information, SSB_{max} was estimated to be 167,000 mt (ASMFC 2002). Regardless of which trawl footprint estimate is used, the NEFSC spring survey estimate of mature female dogfish corresponding to B_{target} and SSB_{max} is 31 kg/tow. The threshold biomass ($B_{threshold}$), is defined as ½ B_{target} and expressed in catch per tow is 16.5 kg/tow.

Fishing mortality rate reference points have been improved by incorporating length specific patterns of fishing mortality into a measure of reproductive potential. However, temporal variation in the value of $F_{threshold}$, caused by annual changes in selectivity, may be problematic for determining whether overfishing is occurring.

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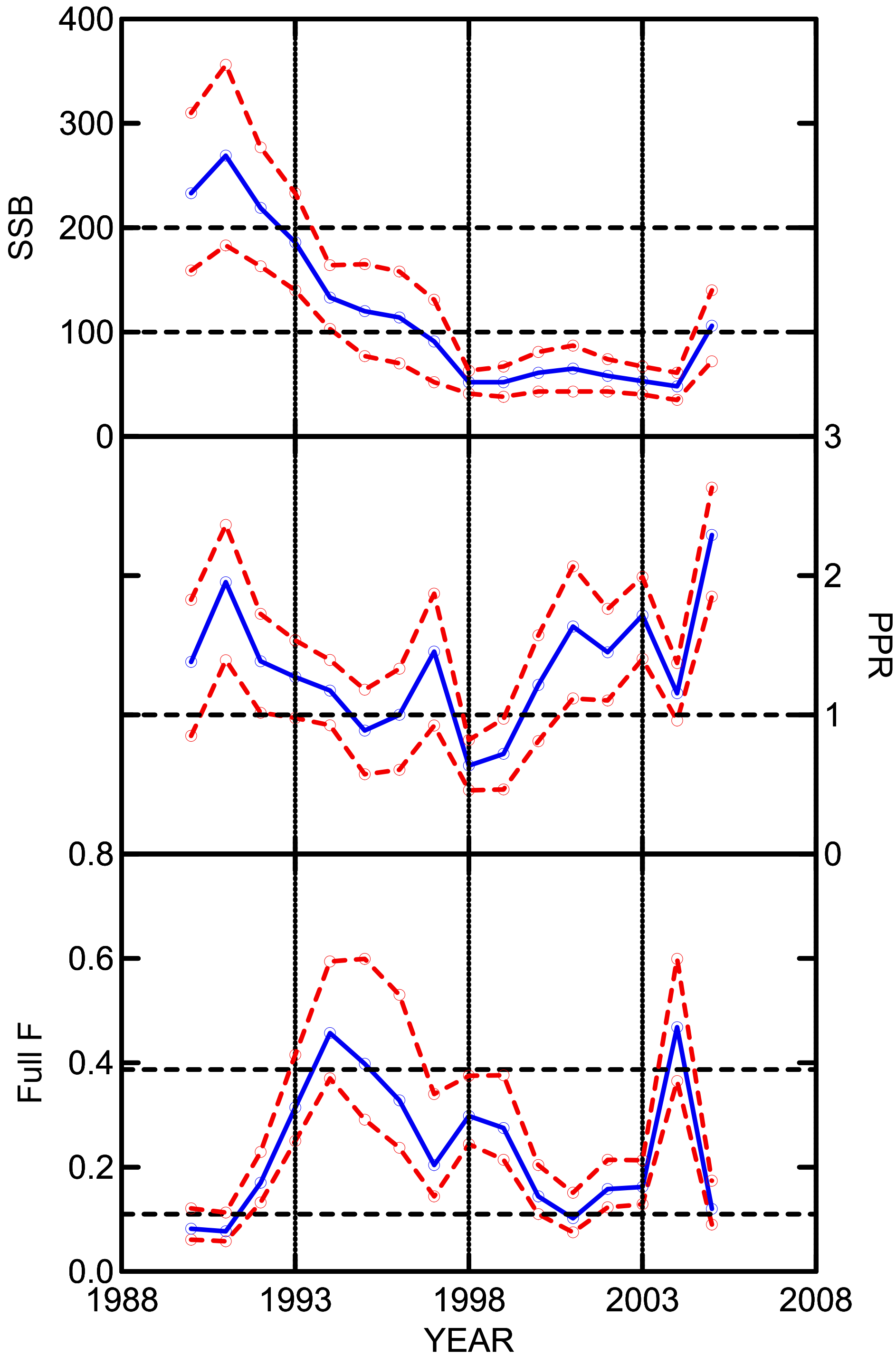
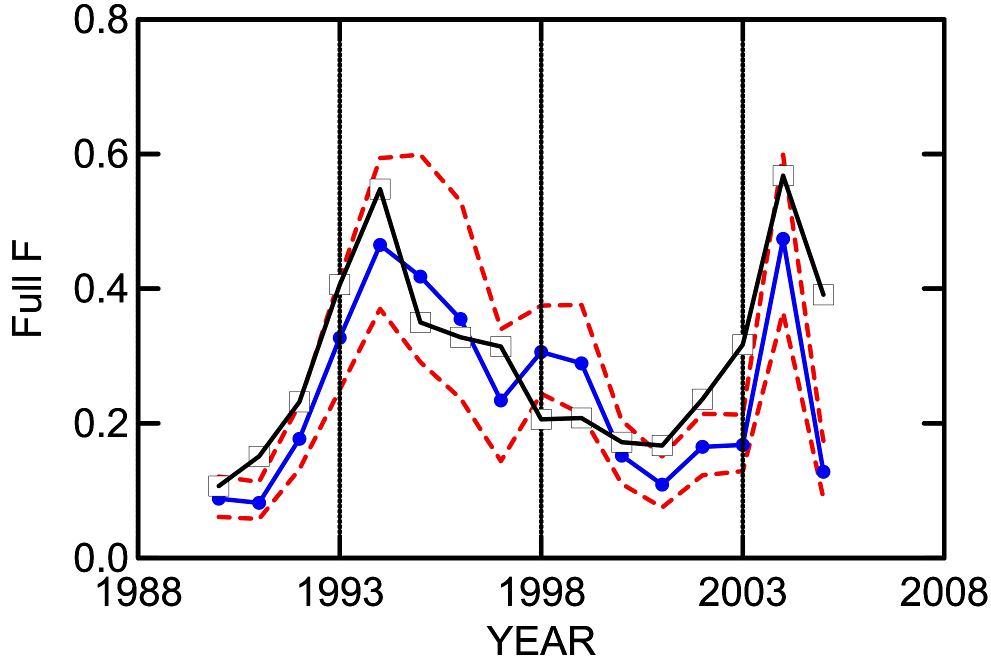
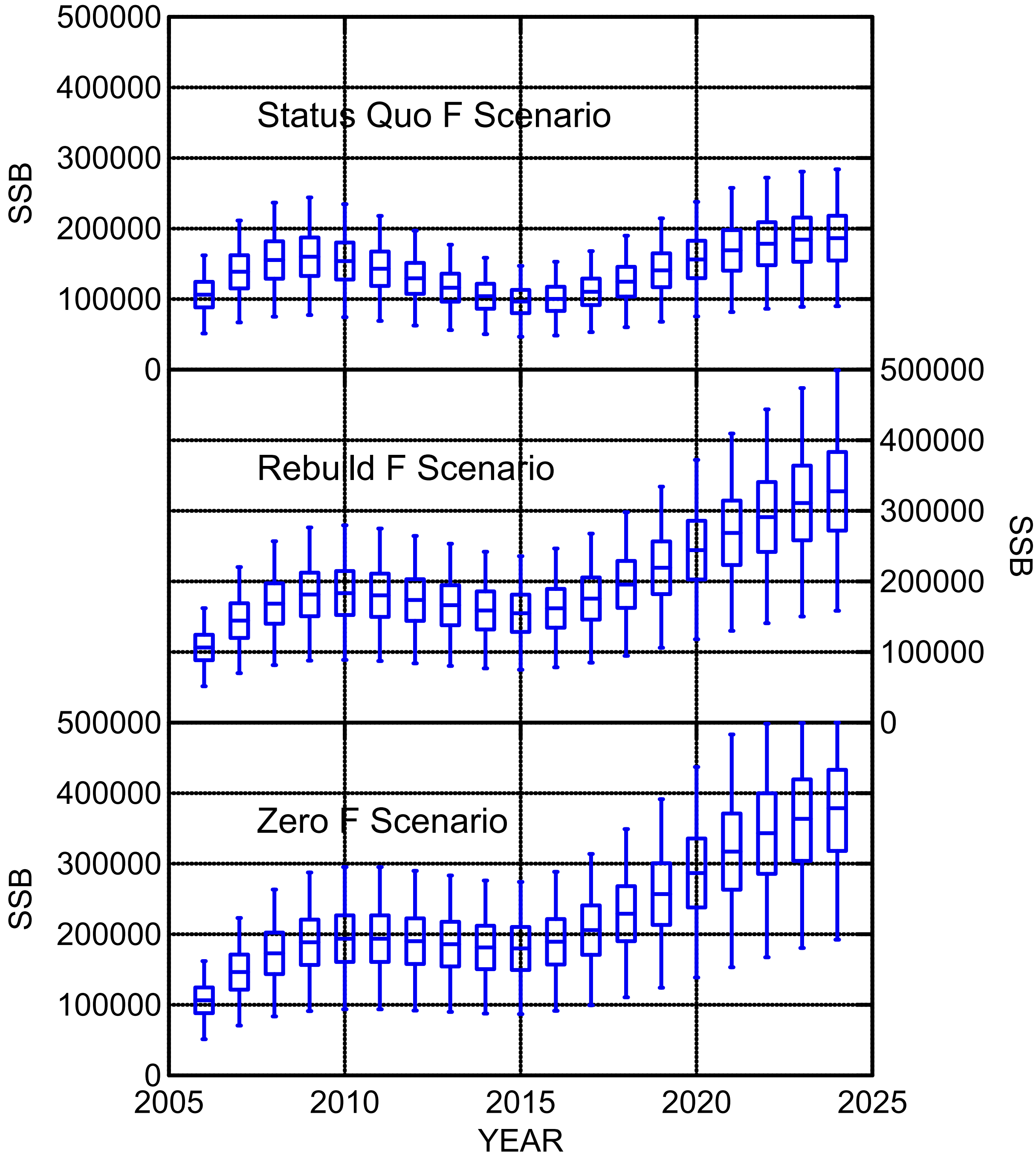


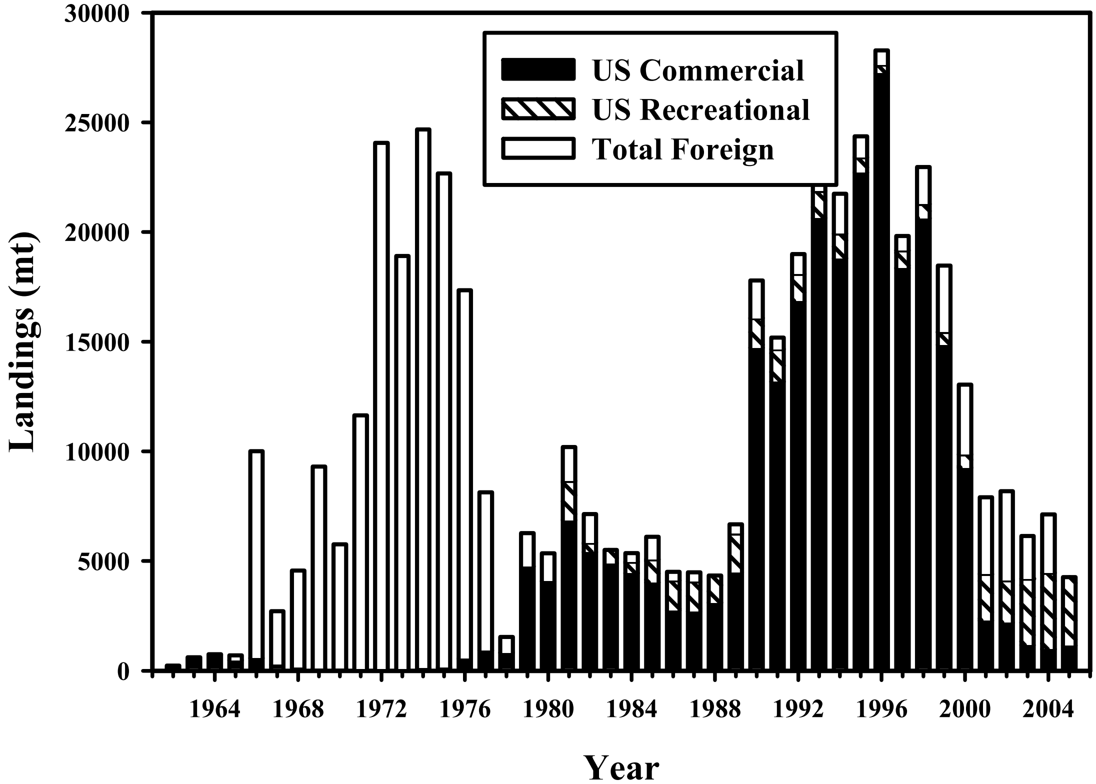
B1. Spawning female biomass, predicted pups per recruit, and full F on the female exploitable stock for spiny dogfish, 1990-2005. Swept area biomass estimates are based on minimum footprint assumption. Dashed lines represent 90% confidence intervals. Approximate SSB target (200 kmt) and threshold (100 kmt) levels are shown in top panel. The full $F_{threshold}$ used in previous assessment (SAW 37) was 0.11. The revised estimate of $F_{threshold}$ is 0.39.



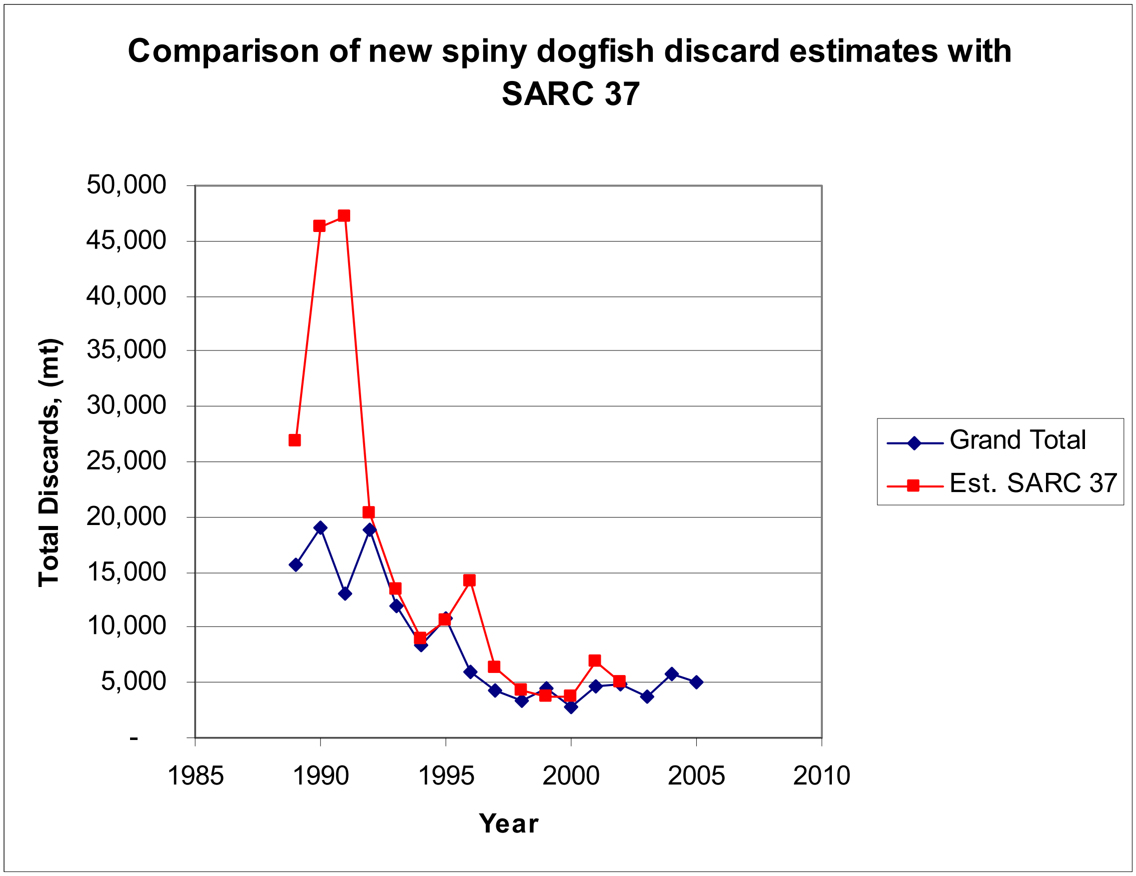
B2. Comparison of $F_{threshold}$ (squares) with estimates of full F on females (circles) and 90% confidence interval (dashed lines). $F_{threshold}$ corresponds to the fishing mortality rate where net reproductive rate (or lifetime female pups per recruit) equals one.



B3. 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.

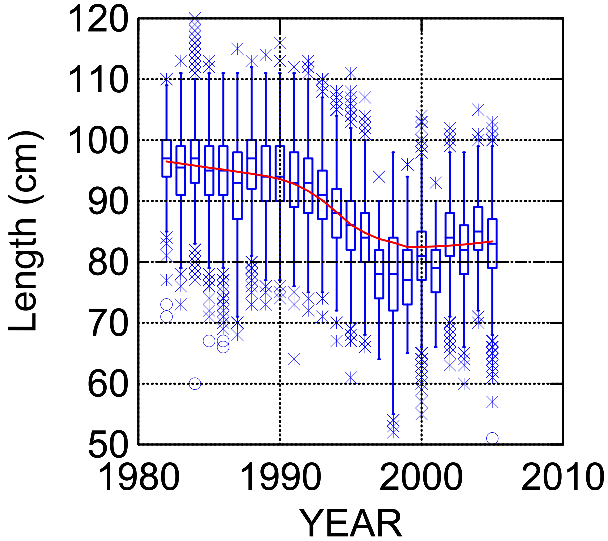


B4. Commercial dogfish landings (mt) and total recreational catch, 1962-2005. Landings in 2005 assumed to be 1500 mt for Canada and 330 mt for other foreign fisheries. Commercial landings are taken in NAFO areas 2-6. Canadian estimates of landings for 2005 not included.

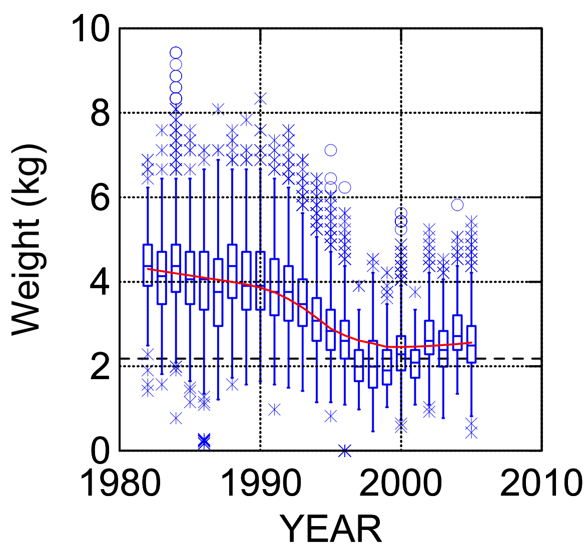


B5. Comparison of total dead discard estimates for spiny dogfish, using the methodology developed in this report, with estimates derived for SARC 37 in 2003.

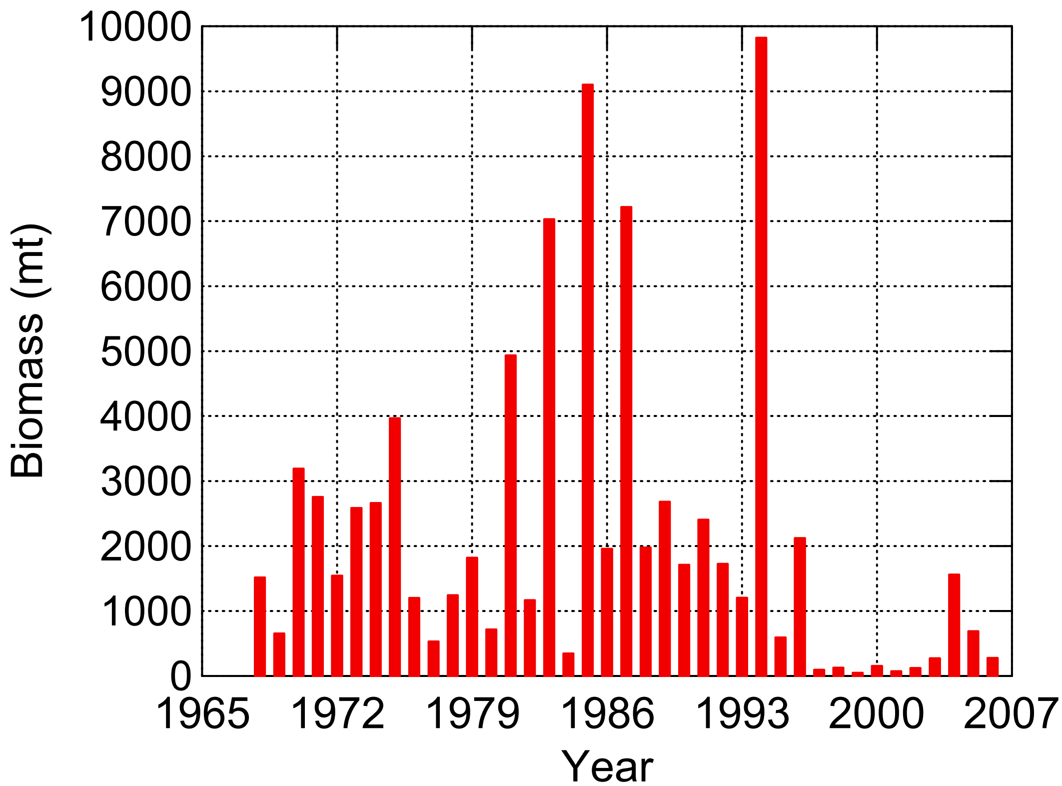
Comm Lengths: Females 1982-2005



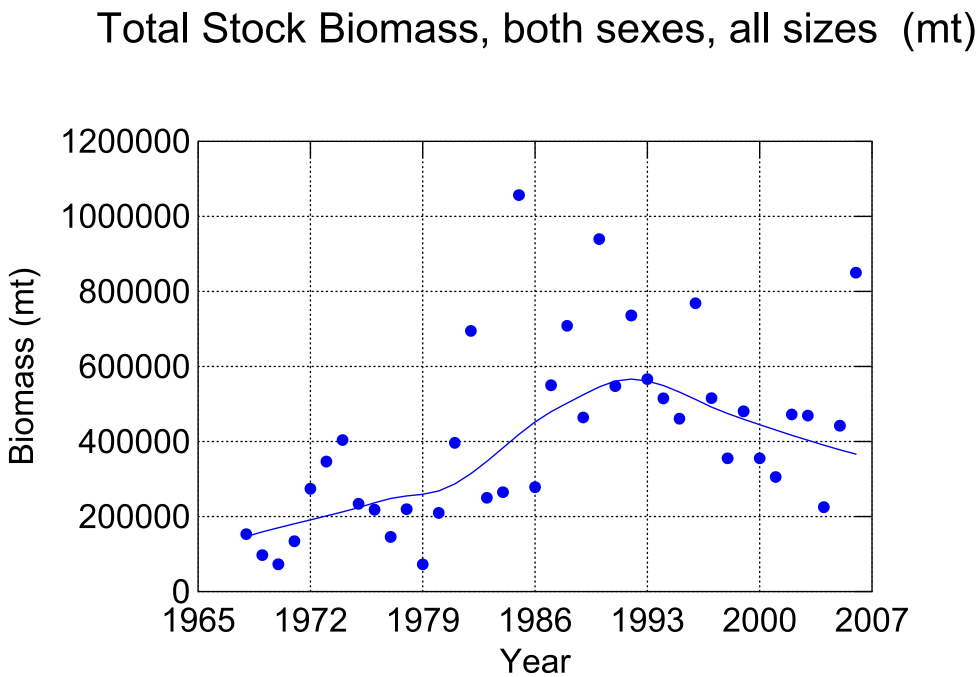
Comm Ave Wt: Females 1982-2005

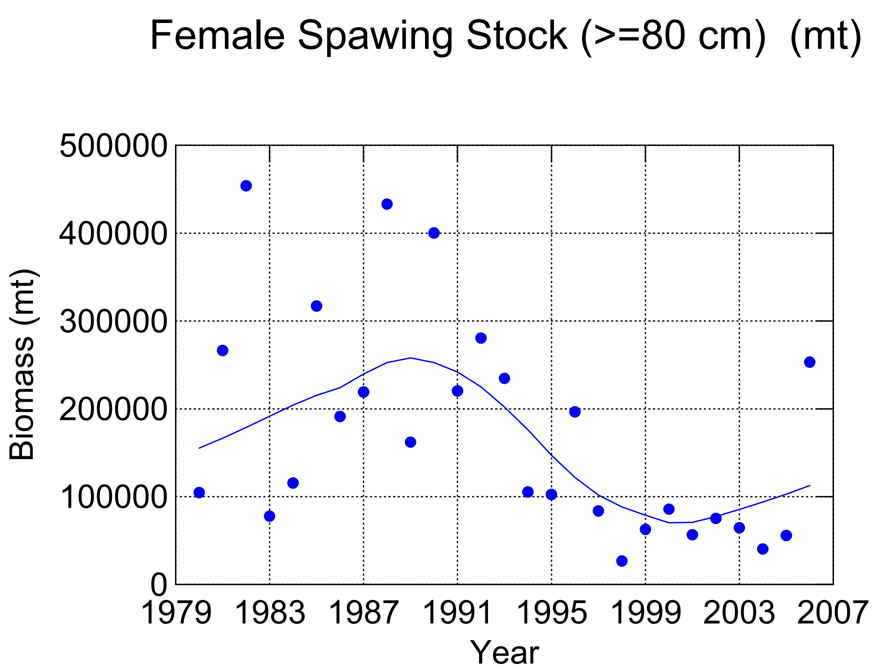


B6. Plots of length (cm) and weight (kg) frequencies for female dogfish in commercial fishery samples.

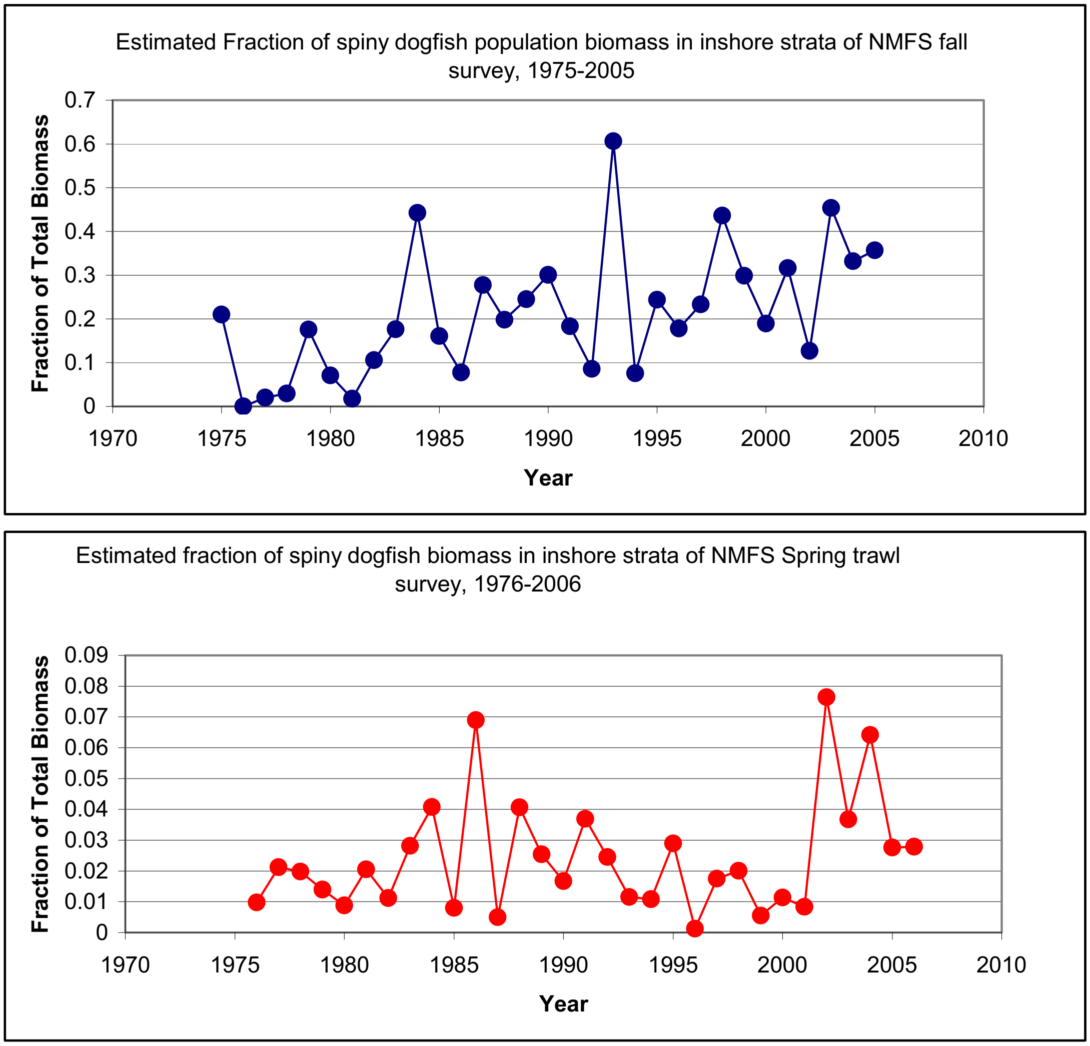


B7. Swept area estimates of dogfish recruit biomass in NEFSC spring R/V trawl surveys, 1968-2006. Recruits defined as individuals less than 36 cm.

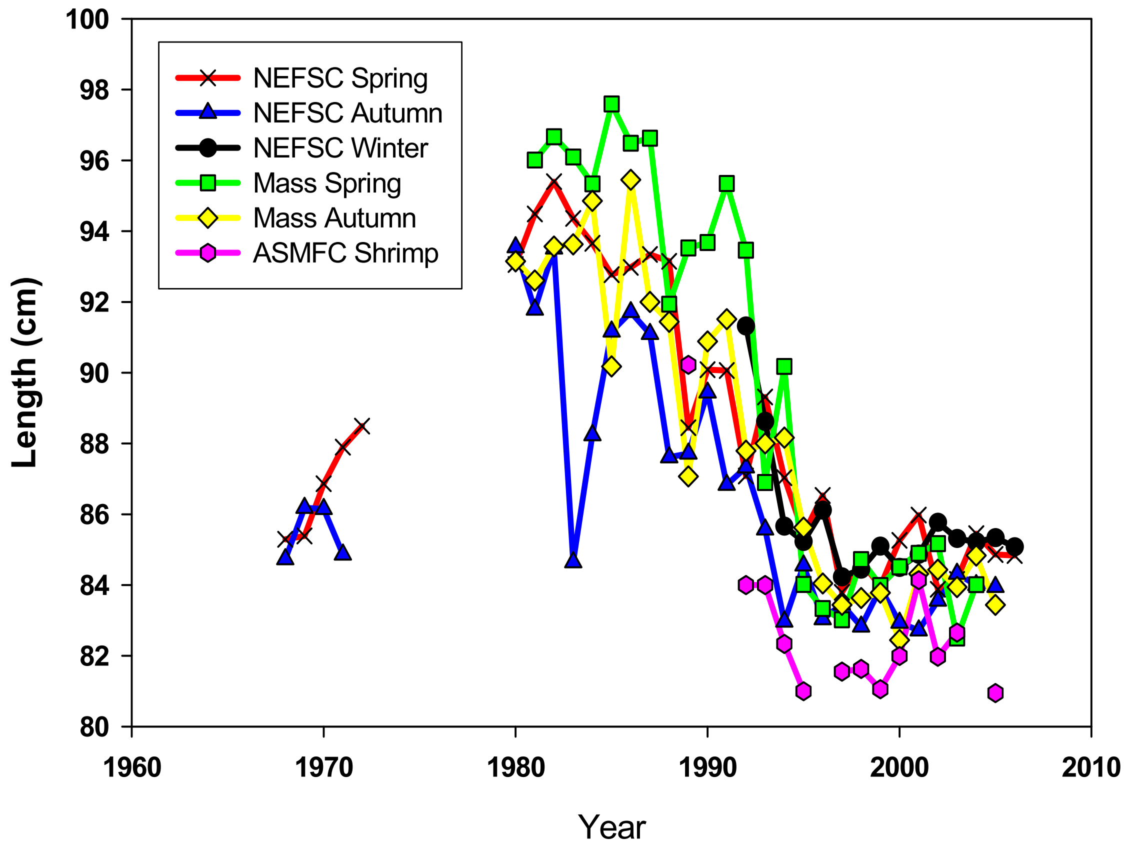




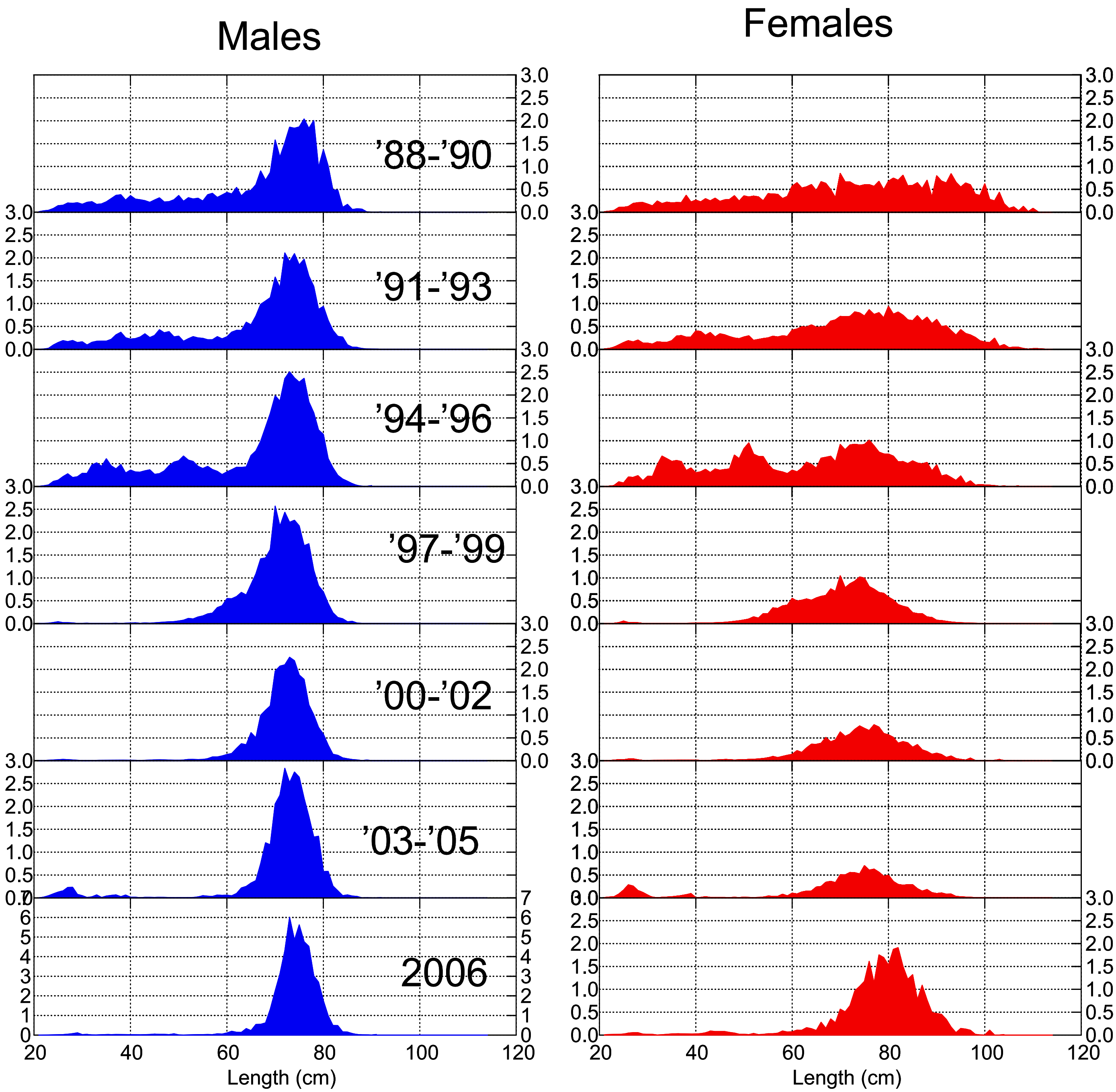
B8. Swept area estimates of total dogfish biomass (mt), 1968-2006 (top), and for mature females only (bottom), 1980-2006 in NEFSC spring R/V trawl surveys. Line represents Lowess smooth with tension factor = 0.5. Spiny dogfish sex in R/V survey unavailable prior to 1980.



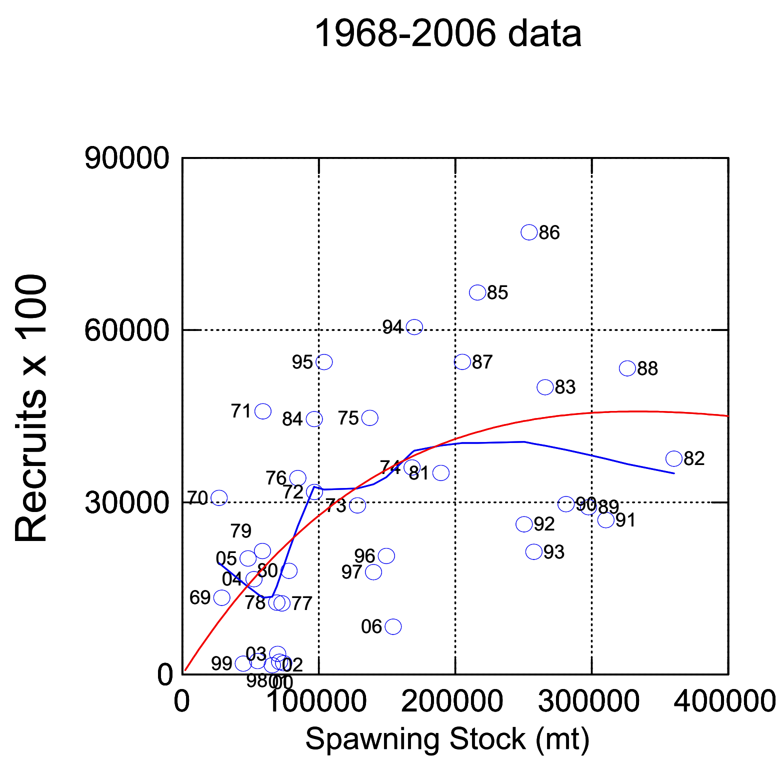
B9. Fraction of spiny dogfish biomass in inshore strata based on Fall (top) and Spring (bottom) NEFSC surveys.

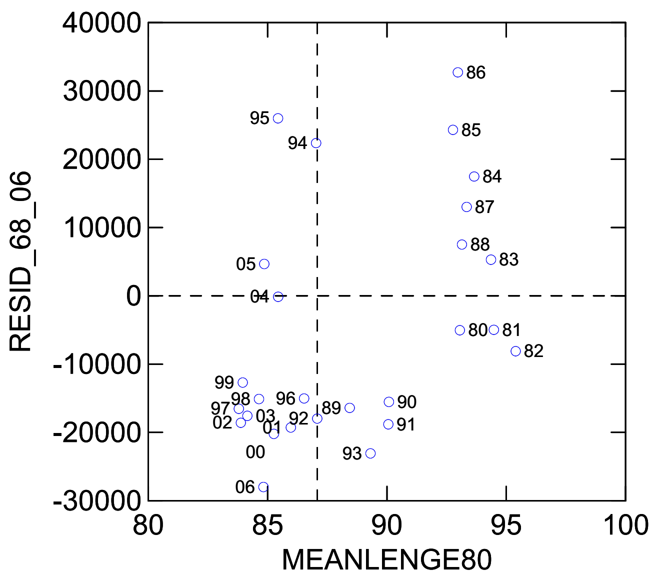


B10. Mean length (cm) of mature (>80 cm) spiny dogfish females from NEFSC, Massachusetts and ASMFC surveys.

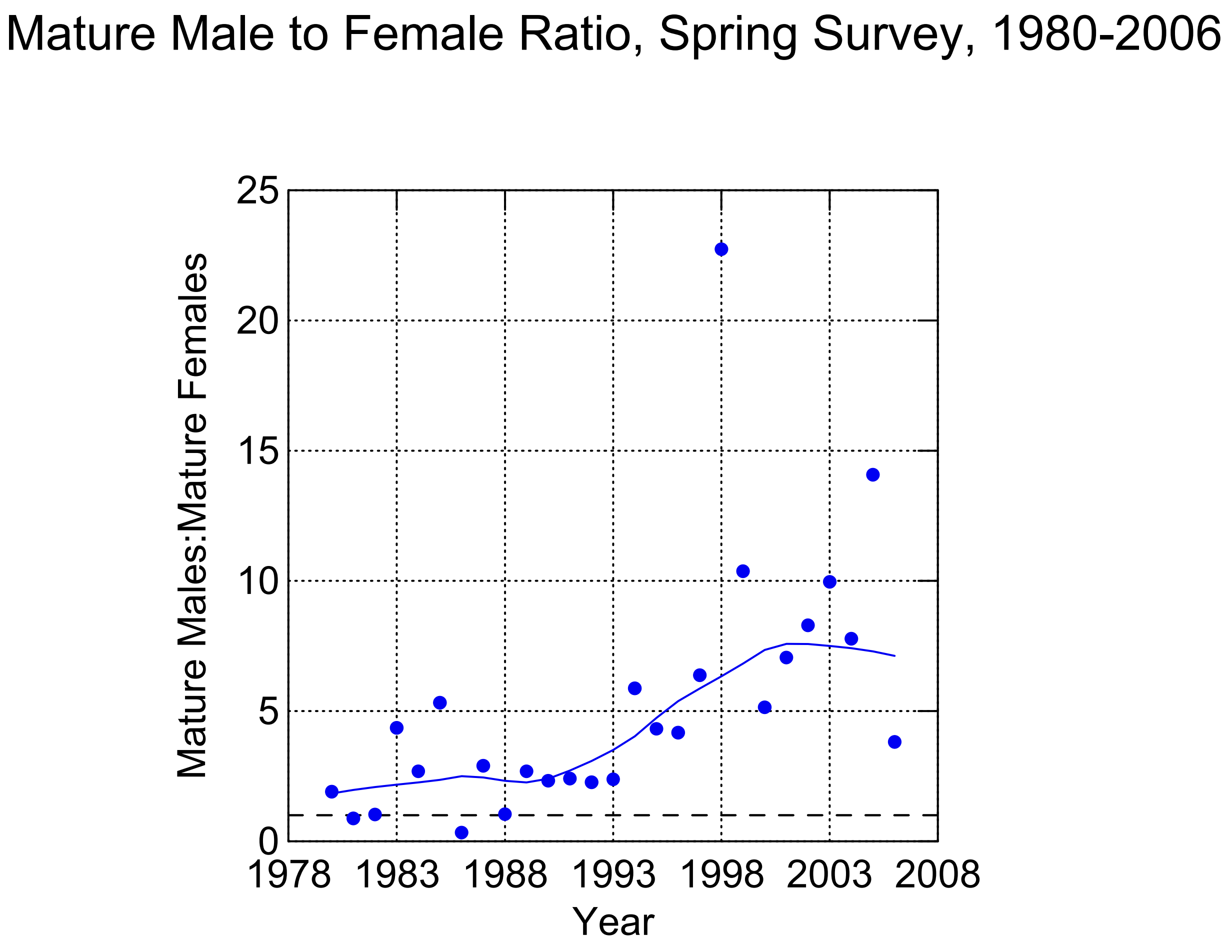


B11. Number of spiny dogfish per tow by 1 cm length class for males (left) and females (right) in NEFSC spring surveys by 3-yr period 1988-2005 and for 2006. Note the scale change for males in 2006.





B12. Comparison of parametric and non-parametric stock-recruitment model fits for spiny dogfish in NEFSC spring surveys (top). Nonparametric model fit is based on Lowess smooth with tension=0.6. For 1968-1996, estimated SSB_{max}, of 215 k mt, corresponded to average catch of 33.2 kg mature females/tow. Estimated SSB_{max} for the 1968-2006 period increases to 304 k mt or 46.8 k mt. Model residuals from Ricker model vs mean length of mature female spiny dogfish(bottom) Odds ratio test statistic suggests that odds of recruitment less than model prediction is 4.5 times greater when females are below median size of 87 cm.



B13. Ratio of number of spiny dogfish mature males (>60cm) to mature females (>80 cm) per tow in NEFSC spring trawl surveys, 1980-2006. Line represents Lowess smooth with tension =0.5.

C. BLACK SEA BASS ASSESSMENT SUMMARY FOR 2006

State of Stock: The overfishing status of this stock is currently unknown because the estimates of fishing mortality rate were not accepted by the SARC-43. In the previous black sea bass assessment (SAW-39), F_{2003} was estimated to be < 0.26, and it was concluded that overfishing was not occurring at that time (NEFSC 2004).

The current proxy for the biomass threshold is the 3-year average weight per tow of black sea bass (≥22 cm) in the NEFSC spring trawl survey during 1977-1979 (NEFSC 1998). Based on this biomass reference point (0.98 kg/tow), the stock is considered overfished because the average biomass index for 2004-2006 (0.80 kg/tow, with 80% CI from 0.301 to 1.307 kg/tow) is lower than biomass threshold (Figure C2). The SARC-43 panel did not endorse using the existing biomass reference point as a basis for management. At this time, no alternative biomass reference point exists. Hence, it is unknown whether the stock is now overfished.

Exploitable biomass indices (fish ≥ 22 cm) declined from the peak in 2003 of 2.15 kg/tow to 0.55 kg/tow in 2006 (Figure C2). Although the recruitment indices (fish ≤ 14 cm) from 2000 and 2002 were the highest in the time series (Figure C3), the recruitment indices in 2004 and 2006 were below average.

Forecast: No forecasts were performed.

Catch and Status Table (weights in '000 mt): Black Sea Bass

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Max[1]	Min[1]	Mean
Commercial landings	1.2	1.2	1.3	1.2	1.3	1.6	1.4	1.4	1.3		9.9	0.6	2.3
Recreational landings	1.9	0.5	0.7	1.8	1.6	2.0	1.5	0.8	0.8		5.6	0.5	1.7
Fishing mortality	(Estimates were not accepted by CIE panel)												
Biomass index[2]	0.30	0.11	0.42	0.16	0.47	1.12	2.15	0.94	0.93	0.55	2.15	0.03	0.44
Recruitment index[3]	0.02	0.00	0.35	0.66	0.08	0.55	0.15	0.08	0.22	0.05	0.66	0.00	0.14

[1]Over period 1950-2005 for commercial landings; 1981-2005 for recreational landings; 1968-2006 for survey indices.
[2]Units in kg/tow of fish ≥22cm in length from NEFSC spring survey. Exploitable biomass.
[3]Units in #/tow of fish ≤14 cm in length from NEFSC spring survey. Data were backtransformed after taking natural logs.

Stock Distribution and Identification: Studies have indicated two stocks, one between Florida and Cape Hatteras, NC and another north of Cape Hatteras to Cape Cod , MA (Musick and Mercer, 1977, Shepherd 1991). The Mid-Atlantic Fishery Management Council and the Atlantic States Marine Fisheries Commission jointly manage the northern stock.

Landings: Commercial landings increased from around 2,600 mt prior to 1948 to a peak of 9,900 mt in 1952, but declined to about 1,000 mt per year in the early 1970s. Commercial landings increased moderately during 1975-1979, varying between 1,700 and 2,400 mt per year, and since 1997 have remained relatively stable (Figure C1). Recreational landings have been below average since 2003. Commercial landings are limited by a quota.

Data and Assessment: The Southern Demersal Working Group concluded that data were adequate to conduct an assessment of the stock. The status of the stock biomass was evaluated from NEFSC spring survey indices. Fishing mortality rates were derived with a Brownie tag recapture model and a Petersen model for tags recovered over the period October 2002 to April 2006. A Length Tuned Model (LTM; P.

Nitschke pers. com) incorporating growth information, landings estimates, fishery length frequencies, and survey length frequencies was used to get preliminary estimates of biomass and fishing mortality rates.

Biological Reference Points: Yield per recruit reference points were not updated. Values from SAW-39 (NEFSC 2004) are $F_{0.1}$ = 0.19 (15.7 % exploitation) and F_{max} = 0.33 (25.6 % exploitation). F_{max} is a proxy for F_{msy}. MSY and Bmsy were not estimated. A 3-point moving average of NEFSC spring survey biomass per tow from 1977 to 1979, for fish greater than or equal to 22 cm, is the current proxy for the biomass threshold. The value of the biomass proxy is 0.98 kg/tow.

Fishing Mortality: Fishing mortality estimates are not presented because they were not accepted by the SARC-43 panel.

Recruitment: The NEFSC spring survey recruitment index (ln re-transformed mean number per tow) in 2006 (0. 05 fish per tow) was below the average for the last decade (0.218 fish per tow) (Figure C3).

Stock Biomass: Exploitable biomass indices (fish $\geq$ 22 cm) declined from the peak in 2003 of 2.15 kg/tow to 0.55 kg/tow in 2006 (Figure C2). A spawning stock biomass index (derived from the maturity at length converted to biomass) from the spring survey reached a peak in 2002 (0.85 kg/tow) and declined in the 2006 survey (0.29 kg/tow), however remained above average for the 1986-2004 period (0.19 kg/tow) (Figure C4).

Special Comments: The magnitude of the discard losses in the commercial fisheries remains an uncertain component of the assessment. In light of the estimated confidence intervals around the biomass indices, the Working Group recommends caution in interpreting the point estimates of current stock status.

Sources of Information:

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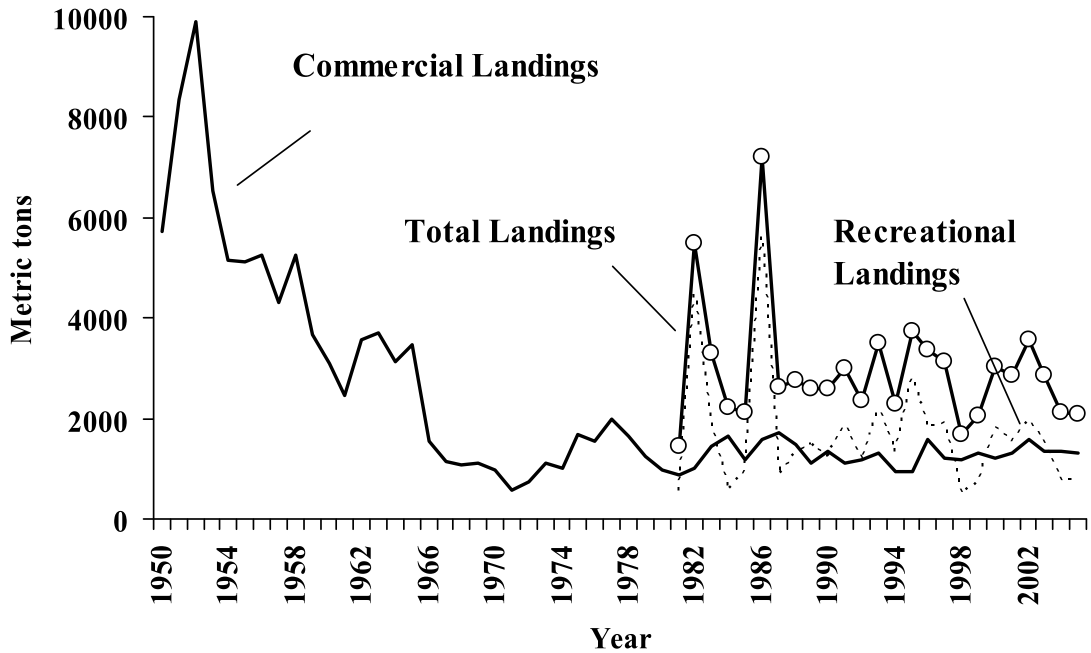
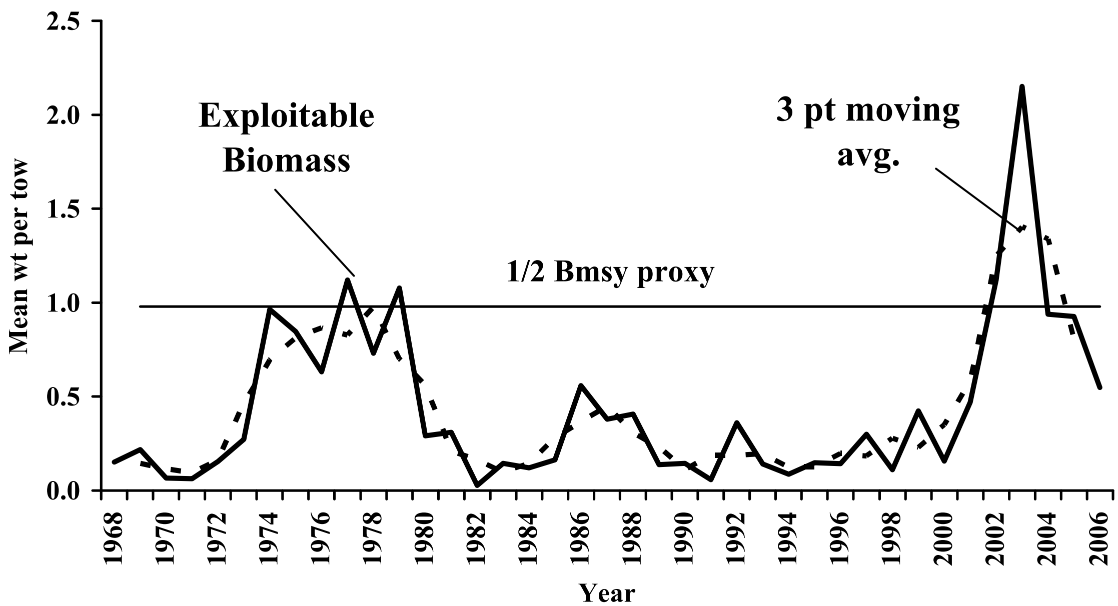
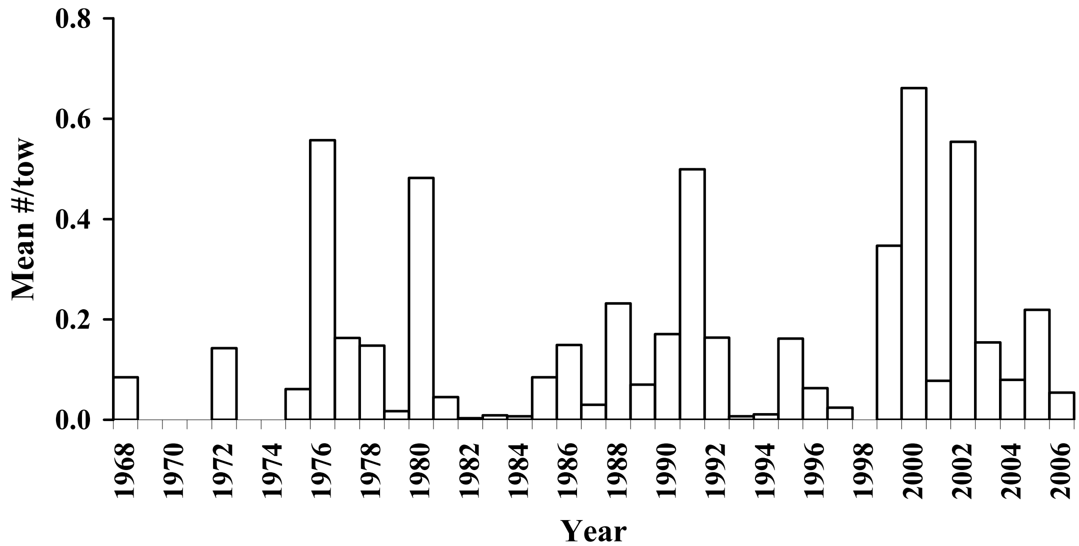
C1. Landings of black sea bass.



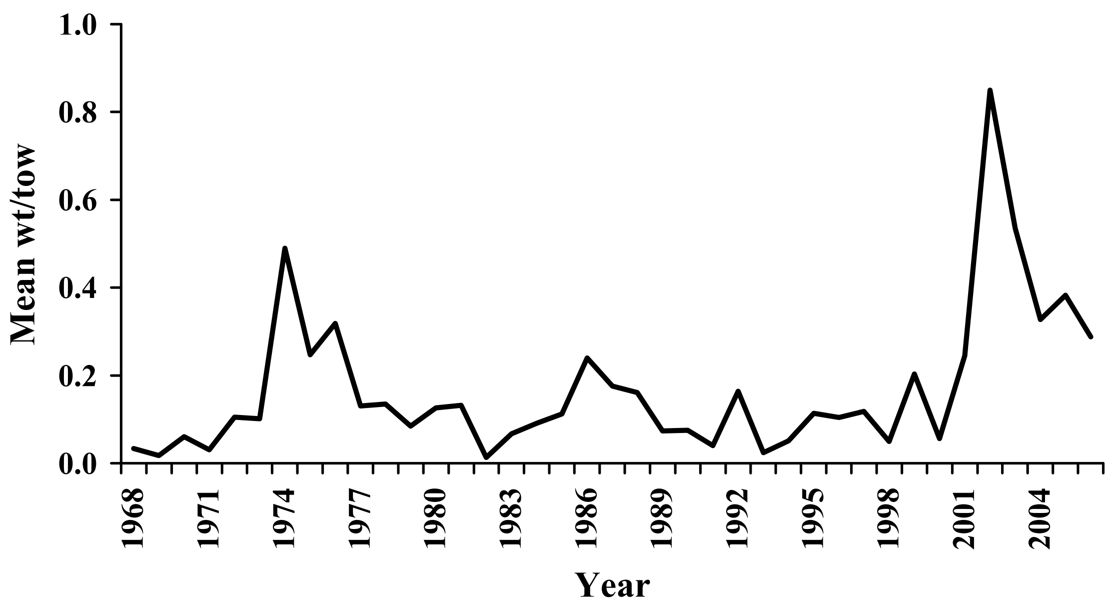
C2. Exploitable Biomass (Spring Survey) of black sea bass.



C3. Recruitment Indices (Spring survey) for black sea bass.



C4. Spawning stock biomass of black sea bass.



D. DEEP SEA RED CRAB ASSESSMENT SUMMARY FOR 2006

State of Stock: According to the Deep Sea Red Crab FMP (NEFMC 2002), overfishing occurs when male landings exceed MSY. Landings during 2005 were 2,013 mt, which is less than the estimate of MSY=2,830 mt (6.24 million lbs) in the FMP and less than the estimate of MSY=2,494 mt (5.5 million lbs) from the last assessment in 1977 (Figure D1). Based on the SARC-43 evaluation, neither estimate of MSY is reliable because the estimates are derived from a model that may not apply to red crabs (MSY=1/2 M B_o) and the natural mortality rate (M=0.15 or 2.0) is too uncertain. Therefore, the status of red crab with regard to overfishing is unknown.

Average fishing mortality rate on males ($\pm$1SE) is estimated to be 0.055 $\pm$ 0.008 y^{-1} during 2003-2005. The estimate is based on the ratio of landings to fishable biomass. This rate may be an underestimate because it does not consider potential mortality due to discarding of undersized crabs. Discard mortality rates are uncertain.

The FMP defines the red crab stock as overfished when the biomass is below ½ B_{MSY}. It is not known whether the red crab stock is overfished because the value of ½ B_{MSY} is uncertain. Although the estimate of male biomass in 1974 has been used as an indicator of virgin biomass, no formal estimates of B_{MSY} (or ½ B_{MSY}) are given in the FMP. If one were to assume that ¼ of the 1974 estimate of male biomass (114+ mm CW) of 23,800 mt, which is 5,950 mt, represents the overfished threshold value, then the stock would not currently be considered overfished (biomass of male crabs 114+mm in 2003-2005 was estimated to be 13,800 mt) . This metric (i.e., 114+ mm) may have little applicability now because the current fishery lands smaller crabs.

During 1974, male red crabs with a minimum carapace width (CW) of 114+ mm were considered marketable size. Biomass of male red crabs 114+ mm was estimated to be 23,800 mt (52.5 million lbs) in 1974, compared to 13,800 $\pm$ 1,334 mt (30.4 $\pm$ 2.9 million lbs) in 2003-2005, a -42% reduction. The current fishery lands smaller red crabs, with a mean size of about 105 mm CW (Figure D2). Fishable male biomass (including all sizes available to the recent fishery) was estimated to be 34,300 mt (75.5 million lbs) in 1974, compared to 36,300 $\pm$ 5,459 mt (79.9 $\pm$ 12.0 million lbs) in 2003-2005, a 5% increase.

Projections: Stock projections were not conducted.

Landings and Status Table (landings in mt; biomass in 000s mt): Deep Sea Red Crab

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Max	Min	Mean
Landings (live weight)[1]	466		1501	1870	3130	4004	2143	1920	2041	2014	4004	466	2102
LPUE (kg per haul)[1,2]						8.1	9.4	6.8	6.3	7.5	9.4	6.3	7.6
Fishable male biomass [3,4]								36.3	36.3	36.3	36.3	36.3	36.3
Mature female biomass (70+mm CW)[3]								67.9	67.9	67.9	67.9	67.9	67.9
Mature male biomass (75+mm CW)[3]								47.8	47.8	47.8	47.8	47.8	47.8
Fishing Mortality (*F*)[5]								0.05	0.05	0.05	0.05	0.05	0.05

[1] Discards not included or estimated. Maximum, minimum and mean landings for 1982-2005 exclude 1994 when no targeted red crab fishing occurred.
[2] LPUE from VTR logbooks, standardized for vessel and season effects.
[3] Biomass estimates for 2003-2005 are an average value from camera/bottom trawl surveys during the same years.
[4] Fishable biomass is male biomass fully available to the current fishery based on a selectivity curve created using 2004-2005 fishery data.
[5] *F* estimated by ratio of landings to fishable biomass (males only) averaged over 2003-2005.

Stock Distribution and Identification: Deep sea red crabs are distributed between the Scotian Shelf and Gulf of Mexico along the edge of the continental shelf, on the continental slope and in canyons at depths ranging from 200 to 1800+ meters. In the Gulf of Maine red crabs are found at depths as shallow as 75 m. The US fishery occurs along the shelf/slope edge from Georges Bank to Cape Hatteras. The red crab population in US north Atlantic waters between Georges Bank and Cape Hatteras is managed as a single stock.

Male and juvenile red crabs are generally found in deeper water than females. Red crabs in the Gulf of Maine are relatively small in size.

Landings: Deep sea red crab landings since 1982 (excluding 1994) varied from a low of 466 mt (1 million pounds) in 1996 to a high of 4,000 mt (8.9 million lbs) in 2001 (Figure D1). No targeted red crab fishing occurred during 1994. Record landings in 2001 may have been due to vessels attempting to establish a history in the fishery before the implementation of the FMP and limited entry in 2002. Since 2002, landings have been stable at about 2000 mt (4.4 million pounds). Four vessels are currently active in the red crab fishery. LPUE declined after 2002, and has been stable during 2003-20052 (Figure D5).

The current fishery harvests smaller red crabs than the fishery operating in 1974. Marketable red crabs were 114+ mm CW during the 1970's, but red crabs 70-114 mm CW are common in recent landings (Figure D2). Fishery selectivity curves estimated in this assessment indicate that 50% of red crabs are fully available to the fishery by 92 mm CW.

Discards: Discards consist of female crabs (which cannot be landed by regulation) and male crabs too small to sell. Discards have not been precisely quantified but are likely substantial for both males and females. Comparison of port sample length data and sea sample length data from one vessel during 2004-2005 suggest average discard levels are 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 crabs are unknown.

Data and Assessment: Fishery data were derived from landings, logbooks (Vessel Trip Reports), at-sea samples, and port samples. Abundance and biomass estimates were derived from trawl/camera surveys conducted during 2003-2005 and in 1974. Average relative fishing mortality rates during 2003-2005 were calculated from the ratio of landings to fishable biomass.

Biological Reference Points: The previous assessment estimated MSY for deep sea red crabs (males only) at 1/2 M B_o = 2,494 mt (5.5 million lbs.) assuming natural mortality M=0.2 y^{-1}, a minimum market size of 4.5 inches (114 mm), and an estimate of biomass from the 1974 survey when the stock may have been near the virgin level (B_o). The 2002 FMP has an 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, the SARC-43 panel did not consider these estimates to be reliable. No other estimates were used in this assessment due to lack of information about growth, longevity and trends in abundance.

Fishing Mortality: Based on the ratio of landings to fishable biomass (males only), average fishing mortality ($\pm$1SE) during 2003-2005 was F=0.055 $\pm$ 0.008 y^{-1}. Only male red crabs are landed by regulation. These estimates do not consider discards of undersized male or female crabs. The fishing mortality estimate for 2003-2005 underestimates fishing impacts if discard mortality is significant.

Stock Biomass: During 1974, male red crabs with a minimum carapace width (CW) of 114+ mm were marketable. Biomass of male red crab 114+ mm was estimated to be 23,800 mt (52.5 million lbs) during 1974. The estimate for 2003-2005, using the same size group of crabs, was 42% lower (13,800 $\pm$ 1,334 mt or 30.4 $\pm$ 2.9 million lbs).

The current fishery lands smaller red 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, using the same size group of crabs, was 5% higher (36,300 $\pm$ 5,459 mt or 79.9 $\pm$ 12.0 million lbs).

The abundance and size structure of the red crab population has changed over time (Figure D4). Small crabs were relatively abundant during 2003-2005. The average male crab is smaller in size while the average female size is the same as in 1974.

Recruitment: There is currently no information about trends in red crab recruitment. However, small red crabs appear to have been more abundant in 2003-2005 surveys than in the 1974 survey.

Spawning Stock Biomass: Estimated spawning biomass during 2003-2005 appears relatively high in comparison to estimates for 1974. Red crab reach maturity at relatively small size, however, and ability to detect small mature crabs may have been lower during the 1974 survey so that spawning biomass during 1974 may have been underestimated. The estimated biomass of mature female red crabs (70+ mm CW) was 67,900 mt (149.7 million lbs) during 2003-2005, compared to 19,700 mt (43.4 million lbs) in 1974. Mature male biomass (75+ mm) was estimated to be 47,800 mt (105.4 million lbs) during 2003-2005 and 37,200 mt (82.0 million lbs) during 1974. These estimates suggest increases of 244% for females and 29% for males.

Special Comments:
The definition of "overfished" in the FMP involves one of three conditions being true. The first is B_{msy} based and the second and third are CPUE based. The CPUE based conditions were not

considered due to uncertainty about what to use as a baseline value, and the limited number of years (5) of reliable CPUE data.

Fishery and survey length composition data show reductions in large males that are probably due to fishing. The stock may be vulnerable to sperm limitation if the abundance of large males is reduced.

Sea sampling by crab fishermen would be a way to provide valuable data about recruitment and size structure on an ongoing basis. A pilot program of this type provided catch data for this assessment.

The red crab stock is data poor. Basic biological information about growth, longevity and maturity is required.

Current fishing mortality rates for males are relatively low (average $F=0.055\ y^{-1}$ during 2003-2005) but these estimates do not include mortality due to discard of males and females. Target and threshold BRP's for fishing mortality should include discard mortality. Information about the quantity of discards, discard mortality, and scientifically valid biological reference points are needed to determine if current fishing mortality levels are appropriate for maximizing long-term yield.

It would be useful to continue tagging studies to accumulate information on growth.

Comparisons of stock biomass estimated from camera/trawl surveys in 1974 with those from 2003-2005 are complicated by differences in camera sled methodology that may have increased detectability of crabs in 2003-2005. It would be useful to repeat camera/bottom trawl surveys at some interval (perhaps 10 years) to monitor trends in abundance of deep sea red crab.

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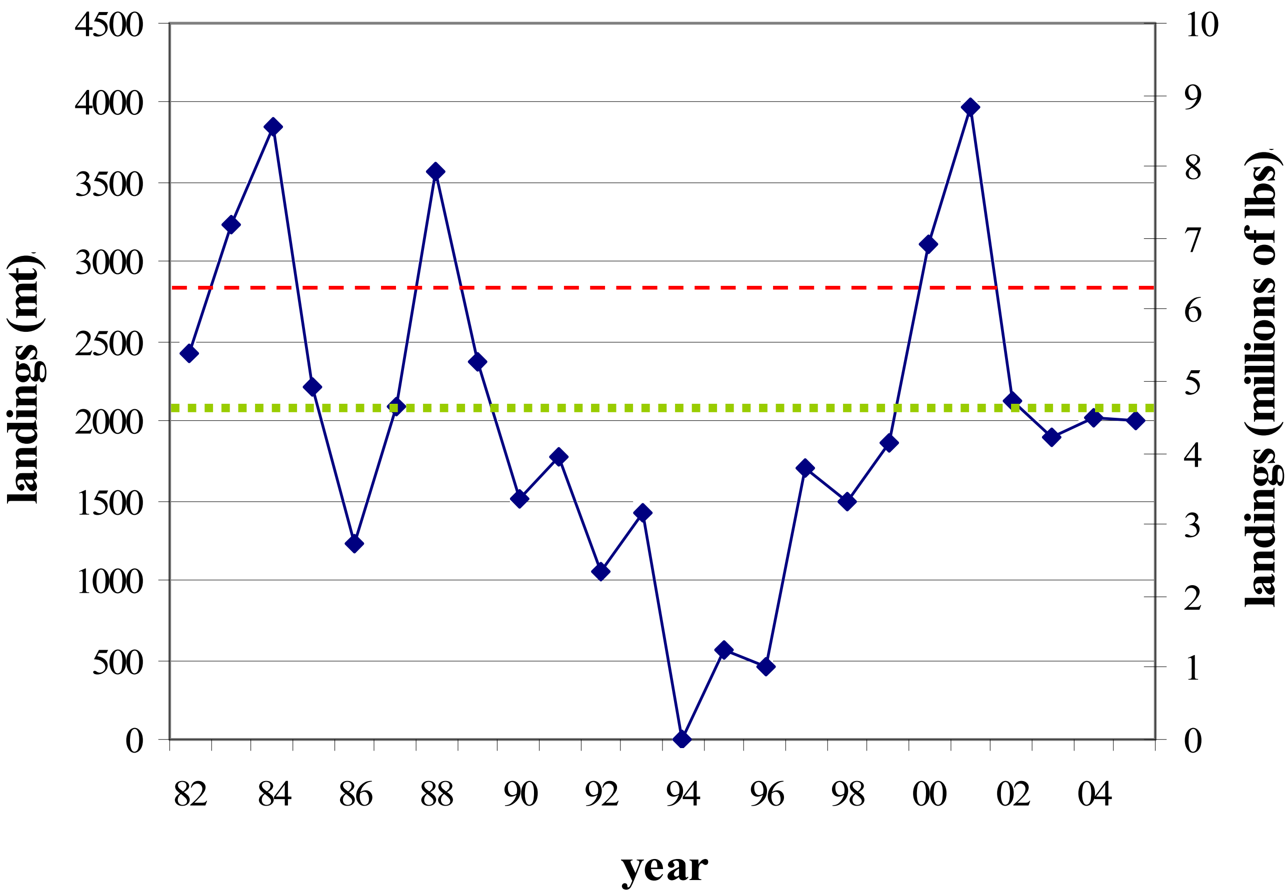
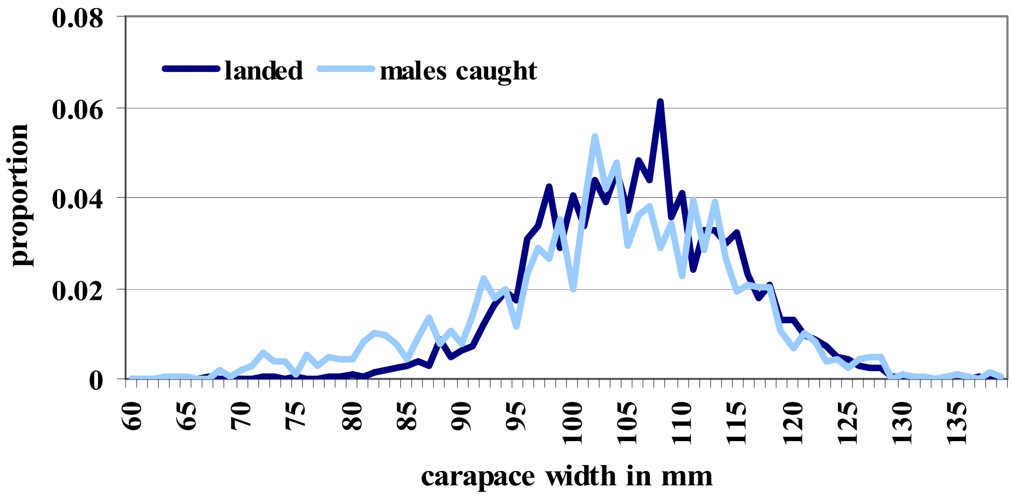
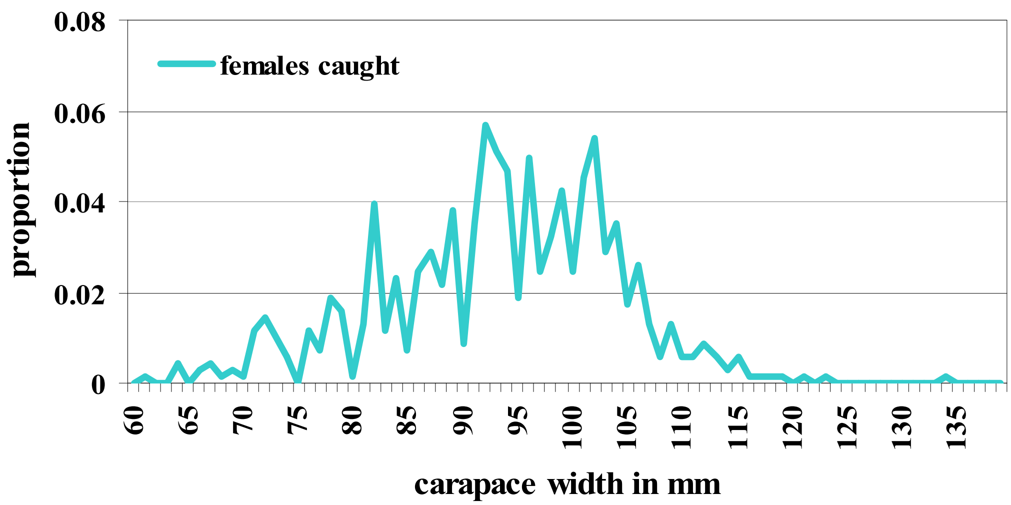
Wigley, R.L , R.B. Theroux and H.E. Murray. 1975. Deep-Sea Red Crab, *Geryon quinquedens*, Survey off Northeastern United States. Mar. Fish. Rev., 37:1-21.

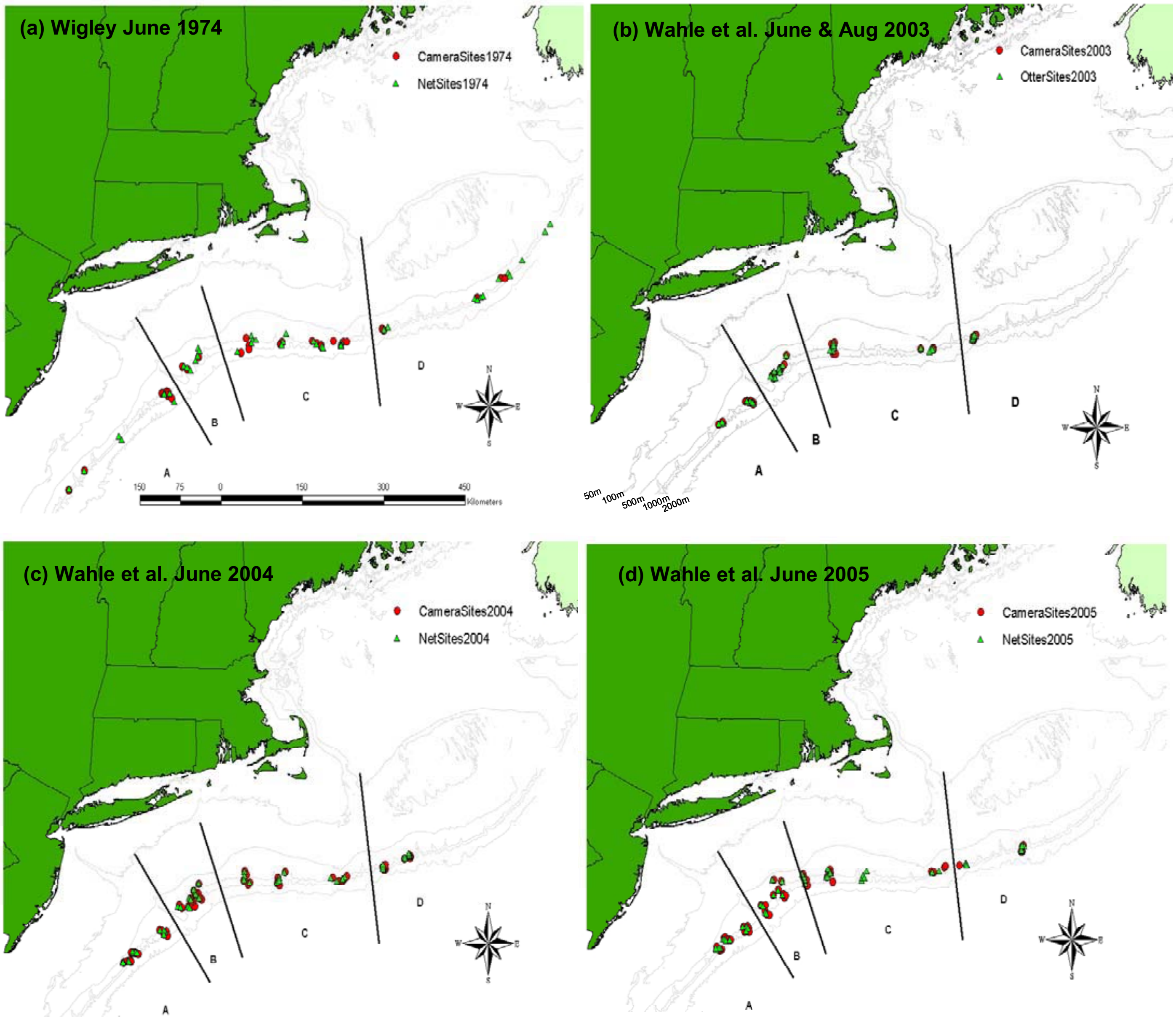


D1. Reported landings of deep sea red crab 1982-2005. The dashed line indicates the current FMP MSY of 2830 mt (6.24 million lbs) which was based on the previous assessment (Serchuk 1977). The dotted line represents the mean annual landings 1982-2005, excluding 1994 when there was no red crab fishery.

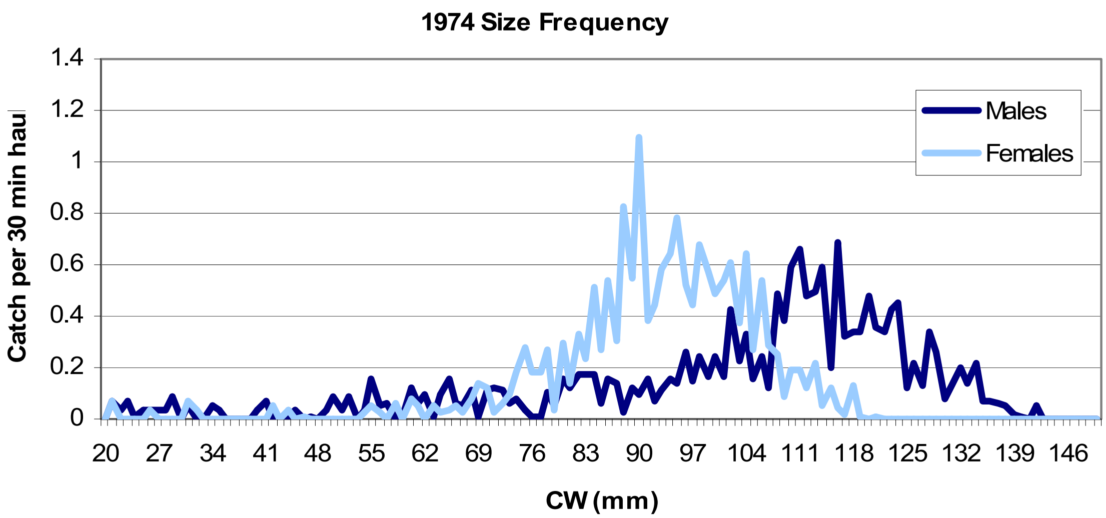


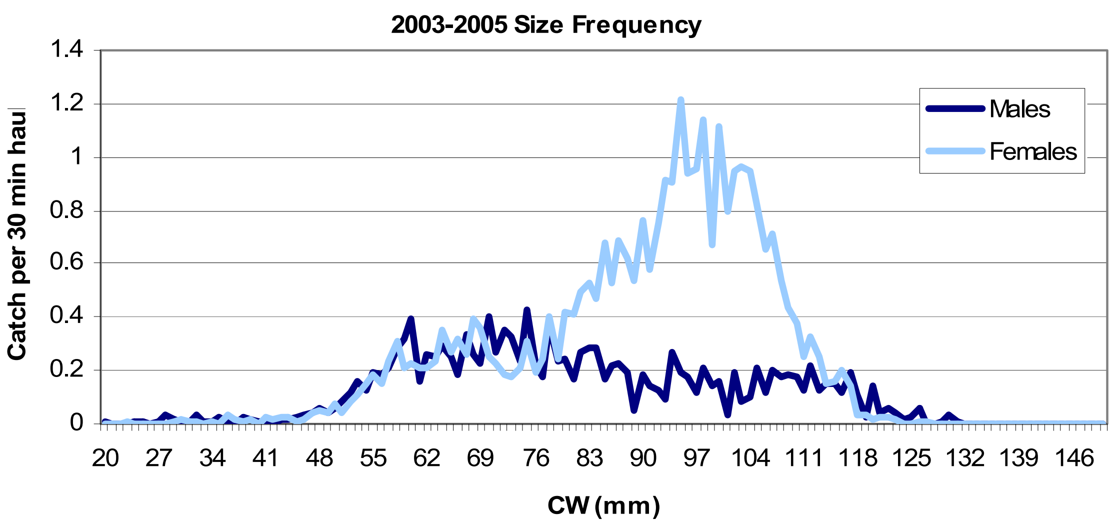


D2. Length composition from the commercial fishery. A) Red crab length composition data from port samples (only males are landed) and sea samples (males only). B) Length composition data from sea samples, females only. All crabs were caught during 2004-2005 in survey strata A, C and D (Figure D3) over a range of seasons.

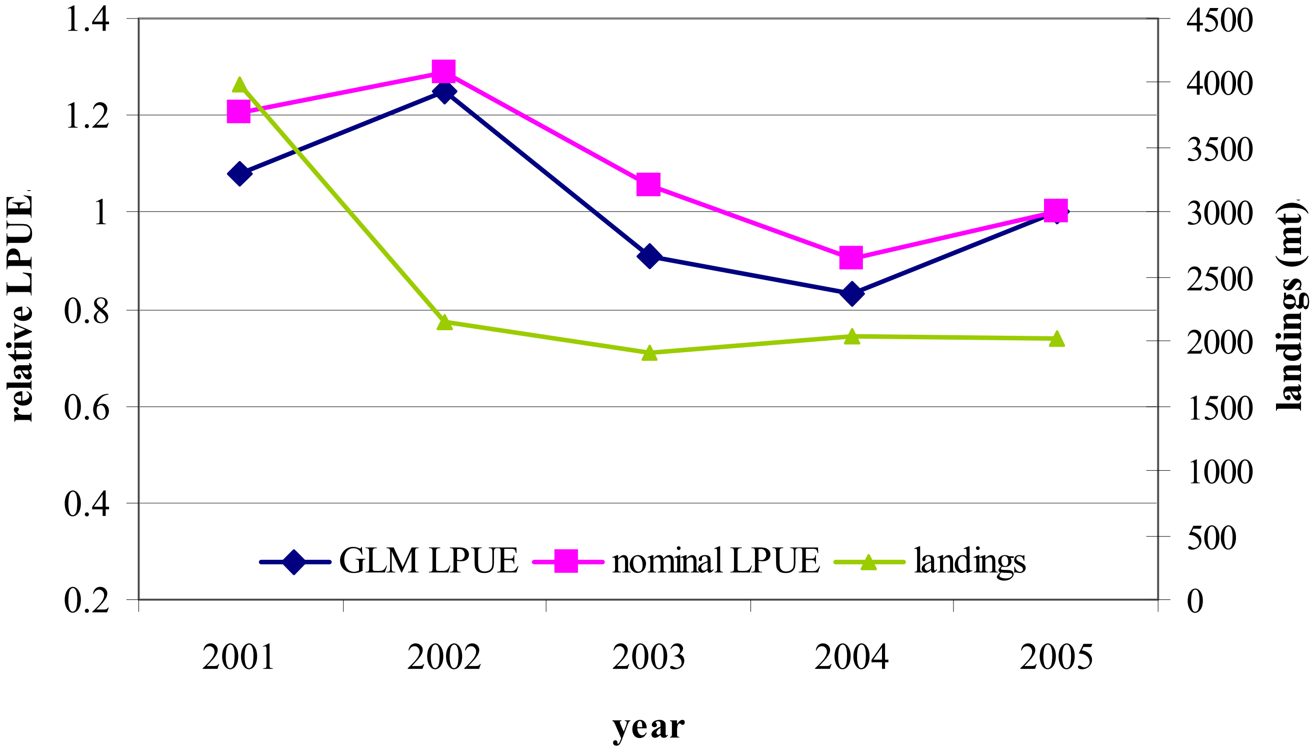


D3. Locations of net and camera tows during the (a) Wigley et al. survey conducted in 1974 and (b-d) surveys conducted by Wahle et al. in 2003-2005.





D4. Red crab size and sex composition in 1974 and 2003-2005 otter trawl samples during camera/trawl surveys. “CW” = carapace width.



D5. GLM standardized LPUE and nominal LPUE (both relative to 2005), with reported red crab landings during 2001-2005.

Appendix. Terms of Reference.

Terms of Reference for the 43rd Northeast Regional Stock Assessment Workshop

Meeting Dates: June 6-12, 2006

(Draft 4/15/2006)
*Note: This ordering does not necessarily reflect the order on the SARC Agenda

Ocean quahog - (Invertebrate Working Group)

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. Recommend what modeling approaches and data should be used for conducting single and multi-year stock 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.

Spiny dogfish - (Southern Demersal Working Group)

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.

Deep-sea red crab - (Invertebrate Working Group)

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. Recommend what modeling approaches and data should be used for conducting single and multi-year stock 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.

Black sea bass - (Southern Demersal Working Group)

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

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

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 the previous SARC-reviewed assessment.

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