Northeast Fisheries Science Center Reference Document 07-11

45th Northeast Regional Stock Assessment Workshop (45th SAW)

45th SAW Stock Assessment Summary Report

July 2007

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
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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-45 ASSESSMENT SUMMARY REPORT
INTRODUCTION

The 45th SAW Assessment Summary Report contains summary and detailed technical information on two assessments reviewed in June 2007 at the Stock Assessment Workshop (SAW) by the 45th Stock Assessment Review Committee (SARC-45): northern shrimp (*Pandalus borealis*) and Atlantic sea scallop (*Placopecten magellanicus*). The SARC-45 consisted of three external, independent reviewers appointed by the Center for Independent Experts (CIE) and an external SARC chairman from a fishery management council's Science and Statistical Committee (SSC). The SARC evaluated whether each Term of Reference (listed in the Appendix) was completed successfully based on whether the work provided a scientifically credible basis for developing fishery management advice. The reviewers' reports for SAW/SARC-45 are 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. 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 table below depicts status criteria.

Fisheries management may take 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 northern shrimp assessment was accepted by the SARC. Although the reviewers were concerned about how to interpret the unprecedented high abundance index observed in the summer 2006 Gulf of Maine shrimp survey (particularly because the sampling intensity in that survey was lower than in preceding years), evidence of high abundance was also seen in commercial catch rates. The committee concluded that abundance in 2006 was high, but perhaps not as high as indicated by the survey and CSA assessment model. The large measure of agreement between the CSA and ASPIC models reinforced the credibility of the assessment results. Despite preference for reference points that take productivity into account, the reviewers concluded that, given the current low market demand and current high stock size, there is little risk to the stock of using the current reference points in the immediate future. Consumption estimates of northern shrimp by fish predators suggested that the rate of natural mortality (*M)* is higher than the value assumed. The SARC felt that a higher value for *M* should be used in future assessments. If *M* is changed, reference points will have to be recomputed.

The Atlantic sea scallop assessment was accepted by the SARC. The reviewers noted that much had been accomplished since the last assessment to improve data collection and interpretation. The SARC supported the approach of modeling the Mid-Atlantic and Georges Bank resources separately before combining the results. The committee noted that elimination of the retrospective patterns when the CASA model results from the two areas were combined was fortuitous, and this does did not imply that the patterns have similar causes or that the patterns will cancel out in future assessments. The SARC questioned using F_{max} as a reference point because it does not explicitly ensure sufficient biomass to protect stock productivity. The SARC supported the projection model (SAMS) because it is based on fairly realistic inputs (e.g., includes spatial considerations).

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.

Fishery 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) $\frac{1}{2}B_{MSY}$, 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.

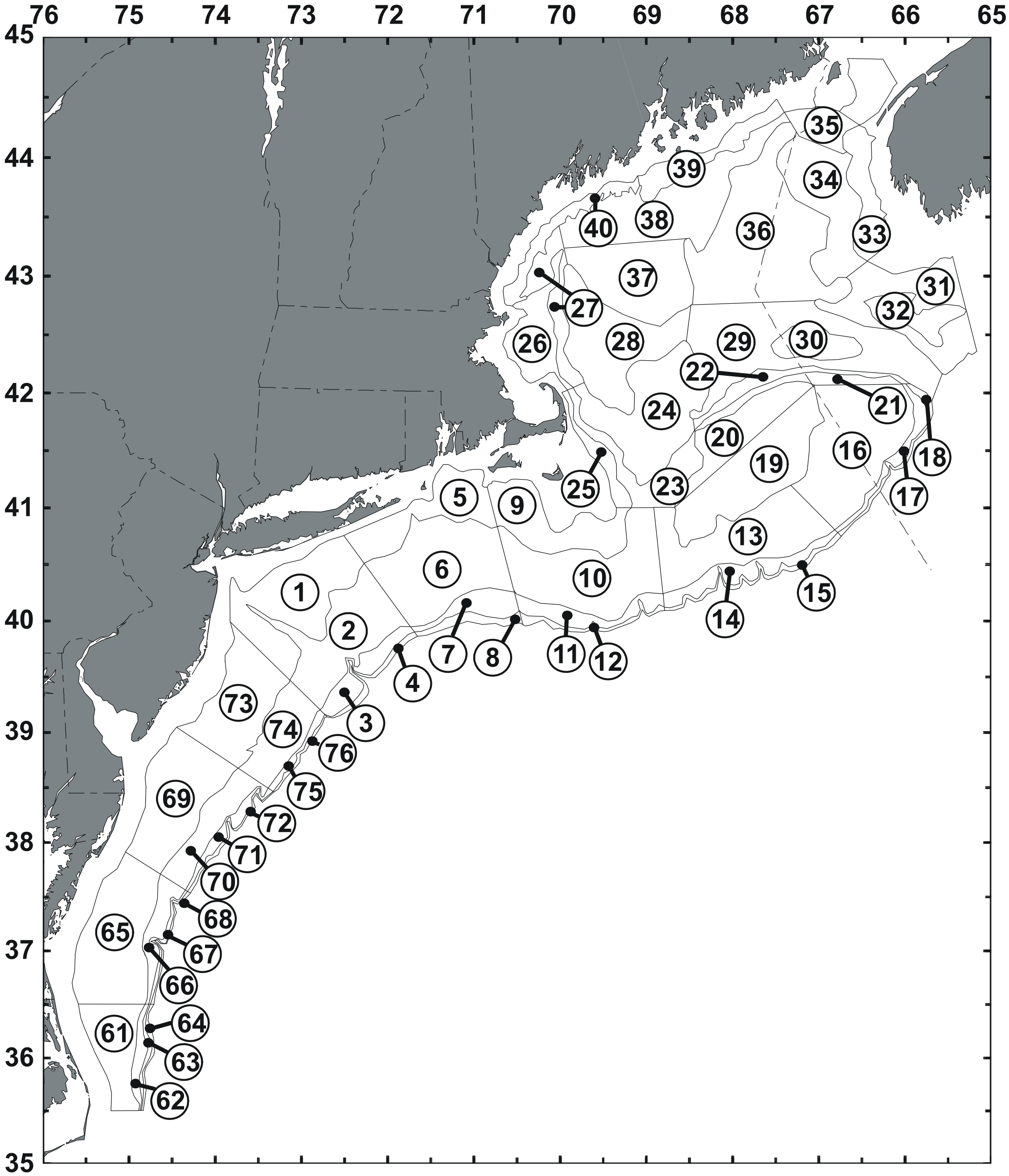

Figure 1. Offshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys.

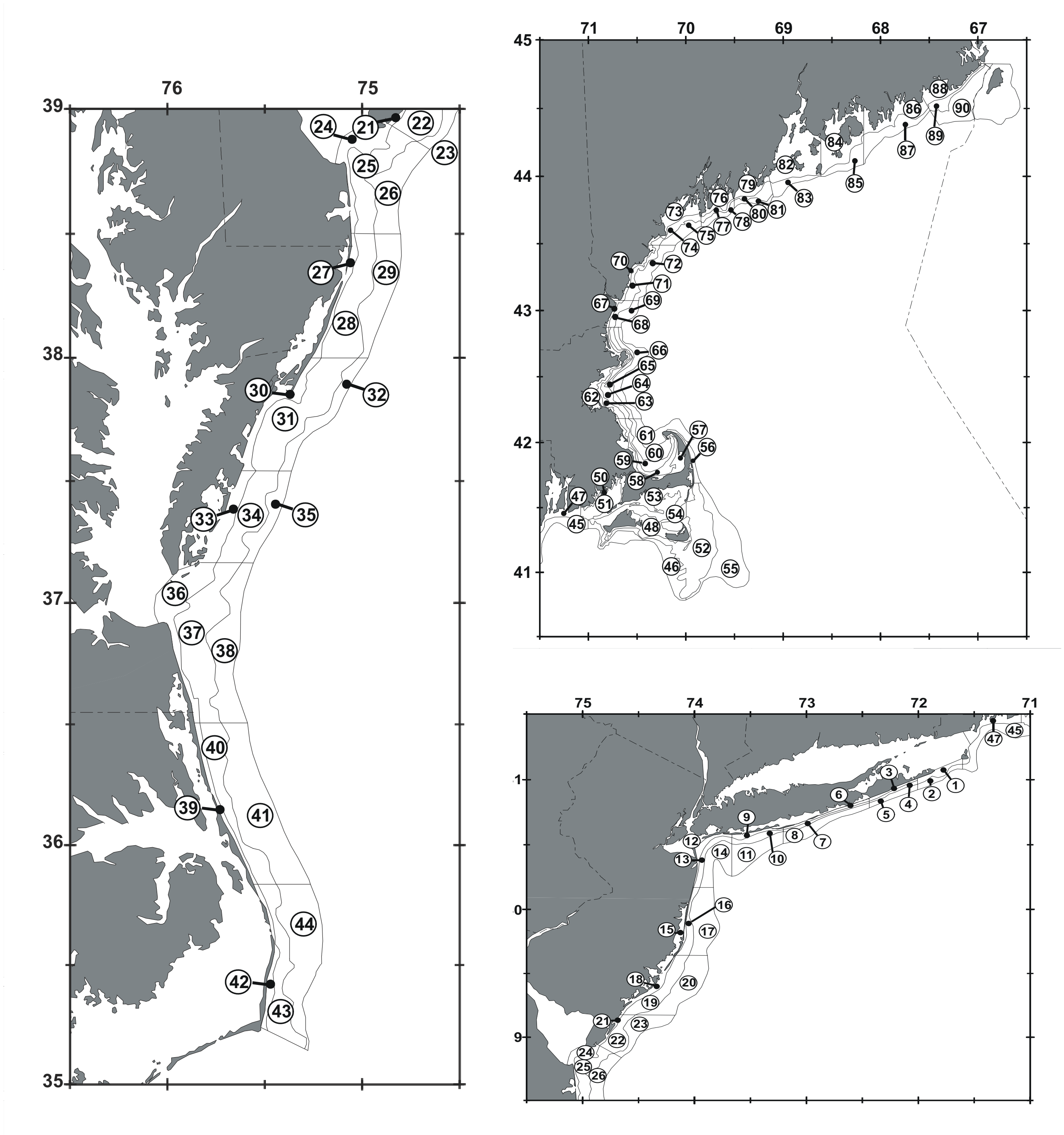

Figure 2. Inshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys.

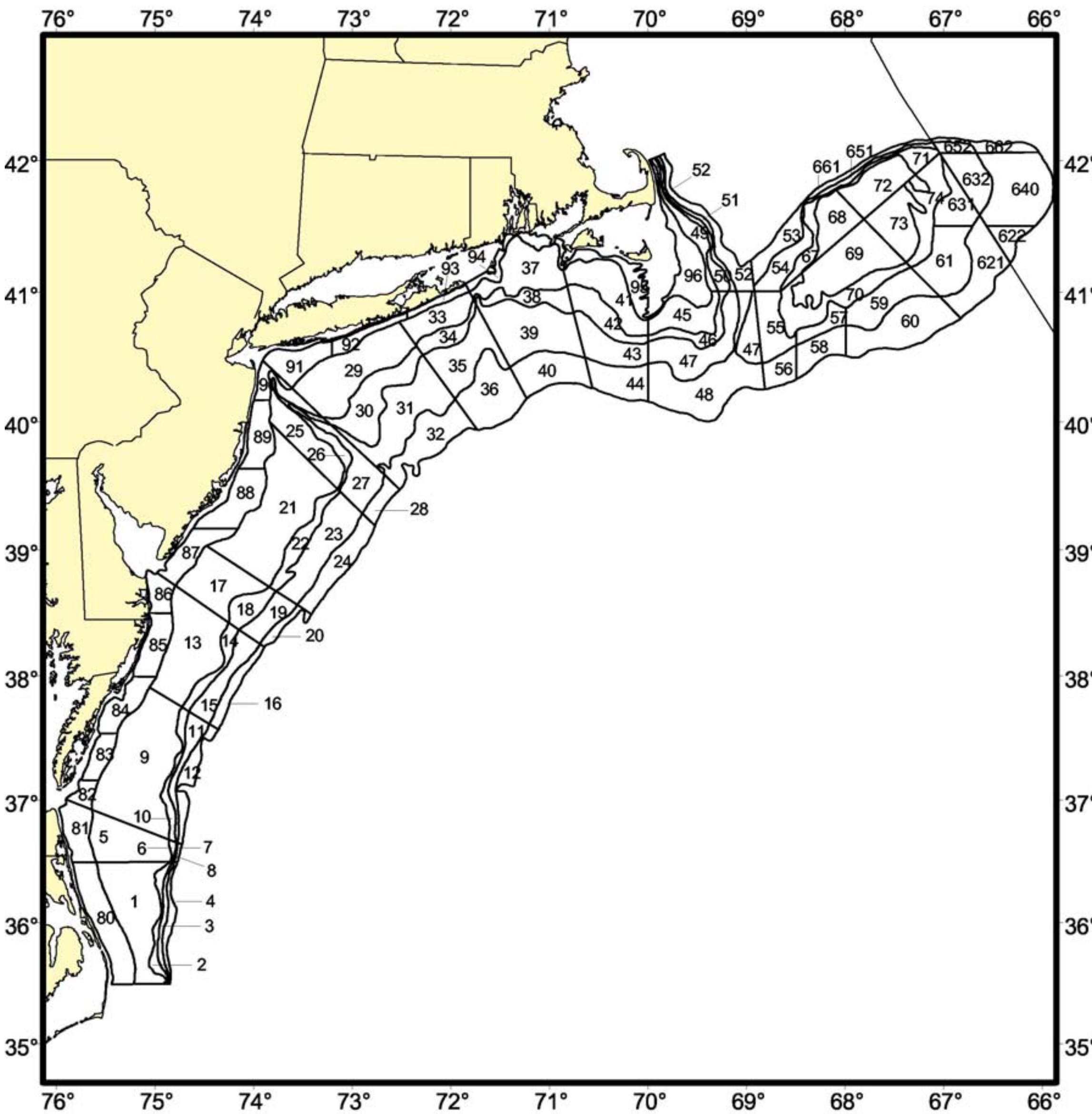

Figure 3. NEFSC clam survey strata.

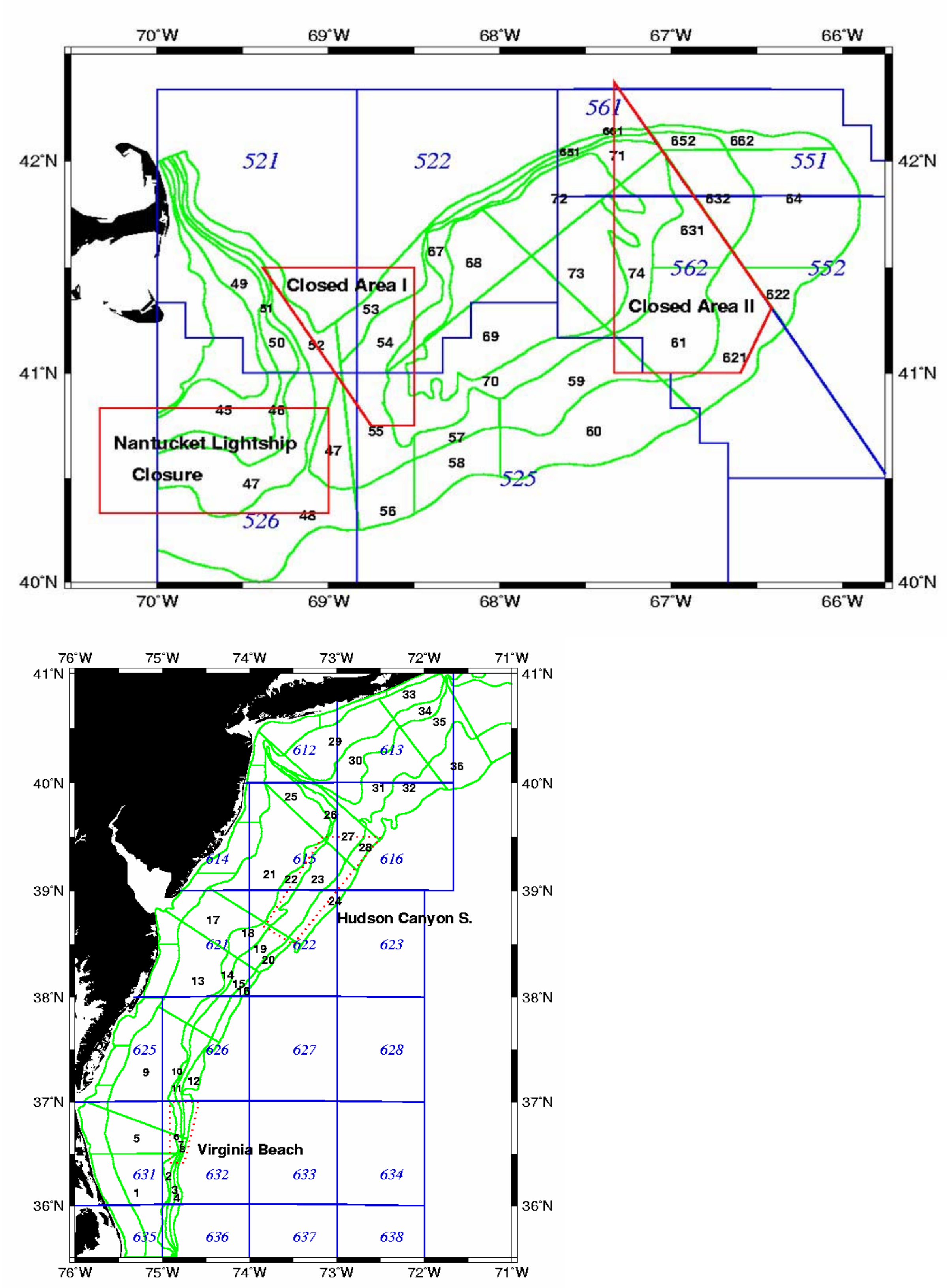

Figure 4. NEFSC sea scallop survey strata, closed areas and statistical areas.

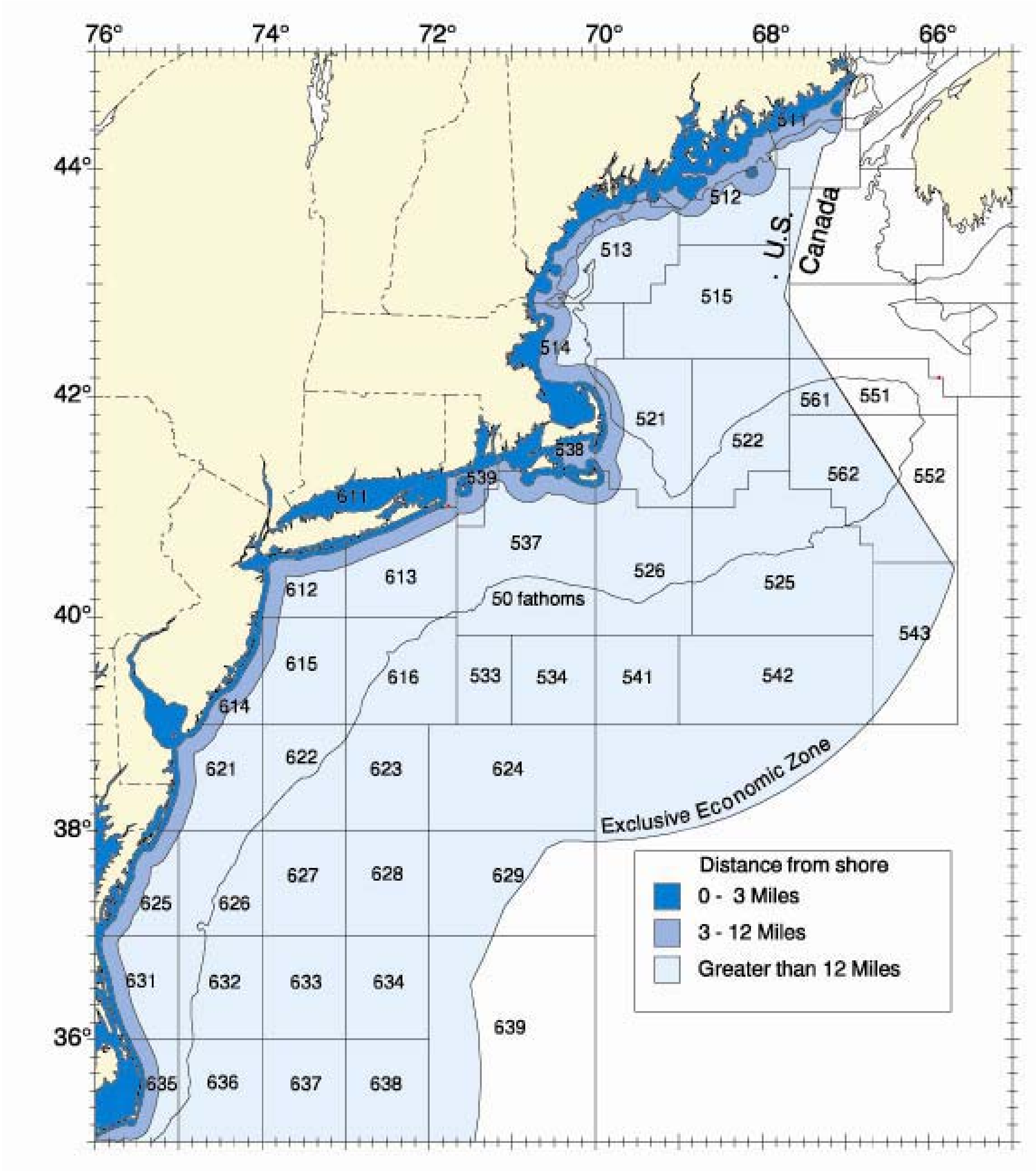

Figure 5. Statistical areas used for reporting commercial catches.

A. NORTHERN SHRIMP ASSESSMENT SUMMARY FOR 2007

State of Stock: Biological reference points (BRP) for northern shrimp listed in the Atlantic State Marine Fisheries Commission's (ASMFC) Amendment 1 to the Interstate Fishery Management Plan (FMP) for Northern Shrimp, implemented in 2004, include a target/threshold annual fishing mortality rate (F) = 0.22 and threshold biomass (B) = 9,000 mt (ASMFC 2004). Based on the Collie-Sissenwine Analysis (CSA) model used in the present assessment, fishing mortality on Northern shrimp in 2006 was F = 0.03 and biomass in 2007 was 71,500 mt. Based on these reference points the Northern shrimp stock is not overfished and overfishing is not occurring (Figure A1).

Fishing mortality rate (F) has declined from a time series high of 1.07 in 1997 to a series low of F = 0.03 in 2006 (Figure A1). The 80% confidence intervals for F were (0.81 - 1.48) in 1997 and (0.02 - 0.05) in 2006.

Fully exploited biomass has been generally increasing from 4,350 mt, a series low in 2001, to 71,500 mt, a series high in 2007 (Figure A1). The 80% confidence interval for fully exploited biomass was (3,100 - 5,800 mt) in 2001 and (52,100 - 87,700 mt) in 2007. Model results show a large increase in the most recent years (2006 and 2007).

Recruit biomass ranged from 1,700 to 6,400 mt during 1985 through 2004 (Figure A2). Recruitment has shown a large increase in recent years (2006 and 2007), similar to the overall biomass, to a series high of 39,000 mt in 2007 (See Table below). The terminal estimate of recruitment should be viewed with caution because the value is well beyond previous observed values and is based in part on the 2006 Northern Shrimp Technical Committee (NSTC) Summer Shrimp survey, which had a fairly modest number of tows in 2006 as compared to historical surveys. The 80% confidence intervals for recruit biomass were (12,900 - 34,000 mt) in 2006 and (30,200 - 44,600 mt) in 2007.

Catch and Status Table (weights in '000 mt): Northern Shrimp

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Max[1]	Min[1]	Mean[1]
Commercial Landings[2]	4.2	1.8	2.4	1.3	0.42	1.2	1.9	2.6	1.9	-	9.2	0.42	3.52
Fishing mortality (F)	0.73	0.46	0.51	0.30	0.08	0.14	0.23	0.18	0.03	-	1.06	0.03	0.34
Biomass[3]	5.6	4.7	4.7	4.4	4.7	5.8	8.0	13.0	32.1	71.5	71.5	4.4	14.1
Recruits[4]	2.5	2.2	1.7	1.8	1.8	2.5	2.7	6.5	22.9	39.0	39.0	1.7	6.1

[1] Over period 1985 – 2006 for commercial landings and F; over period 1985 – 2007 for stock biomass and recruits.
[2] Includes removals by experimental studies (2002-2006); 2005 and 2006 are preliminary.
[3] Values represent the fully-exploitable stock biomass (> 22 mm CL).
[4] Values represent shrimp biomass that will become available to the fishery in the coming fishing year.

Stock Distribution and Identification: *Pandalus borealis* is distributed throughout the North Atlantic and Arctic Oceans. In the Gulf of Maine, northern shrimp populations comprise a single stock (Clark and Anthony 1981), which is concentrated in the southwestern region of the Gulf of Maine (Haynes and Wigley 1969; Clark et al. 1999). Water temperature, salinity, depth, and substrate type are important factors governing Northern shrimp distribution in the Gulf of Maine (Haynes and Wigley 1969; Apollonio et al. 1986; Shumway et al. 1985). The Gulf marks the southern-most extent of this species' range in the Atlantic Ocean, and seasonal water temperatures in many areas regularly exceed the upper physiological limit for northern shrimp.

Landings: A directed winter fishery in coastal waters developed in the late 1930s, which landed an annual average of 63 mt (139,000 lbs) from 1938 to 1953, but no shrimp were landed from 1954 to 1957 due to low inshore availability (Wigley 1973). The fishery resumed in 1958, and landings increased steadily to a peak of 12,824 mt (28,272,000 lbs) in 1969 as an offshore, year-round fishery expanded (Figure A3). After 1972, landings declined rapidly, and the fishery was closed in 1978. The fishery reopened in 1979 and seasonal landings increased gradually to 5,253 mt (11,581,000 lbs) by 1987 and averaged 3,300 mt (7,275,000 lbs) from 1988 to 1994. Landings peaked at 9,166 mt (20,208,000 lbs) in 1996 and declined to a low in 2002 of 424 mt (935,000 lbs). The 2002 landings were the lowest northern shrimp landings since the fishery was closed in 1978, and were the result of an extremely depressed stock biomass and a very limited season. Landings increased to 2,553 mt (5,628,000 lbs) (preliminary) in 2005. Landings for 2006 were 1,877 mt (4,138,000 lbs) (preliminary) with poor market conditions.

Discards: Sea sampling observations aboard trips using a shrimp trawl from 1989 to 1997 and 2001 to 2006 in the Gulf of Maine (NMFS statistical areas 511, 512, 513, and 514) indicate that the mean weight of shrimp discards is less than 1% of total catch for all years except 1997, when it was 1.36%. From examination of the observer database for 1989 to 2006, the only other fisheries that had trips with significant shrimp discards were the small-mesh herring and whiting fisheries. This assessment does not include commercial discards in parameter estimates.

Data and Assessment: Commercial landings by state and month have been compiled by NMFS port agents from dealer reports. These data were used for annual stock assessments until 2001, when vessel trip reports (VTRs) were found to be more complete. Landings (quantity kept, not discarded) and numbers of vessels and trips have been calculated from VTRs for use in assessments since 2001. A port sampling program has been in place since the early 1980s to characterize catch at length and developmental stage, as well as to collect effort and fishing depth and location data. A Gulf of Maine summer survey from 1967 to 1983, Northeast Fishery Science Center fall trawl surveys, and Gulf of Maine state/federal summer shrimp survey from 1983 to present are used as indices of abundance. The current NSTC Gulf of Maine summer survey provides indices of recruitment and year class strength.

Primary estimates of biomass and fishing mortality were derived from the Collie Sissenwine Analysis model (CSA) using descriptive information for the Gulf of Maine shrimp fishery (total catch, port sampling, trawl selectivity, survey catches, and life history studies). The CSA estimates of abundance, biomass and fishing mortality stock status are used to provide stock status advice. A surplus production model (ASPIC) fit to three survey indices and a catch time series dating back to 1968 is used as an alternative method of estimating stock size and F. This analysis is used to corroborate results from CSA analysis and is important to provide a better historical context of potential stock size. Natural mortality (M), has been assumed to be 0.25 in the analytical assessments for Northern shrimp, and is consistent with the biological reference points in the FMP (please refer to the special comments section for further discussion).

Biological Reference Points: Biological reference points (BRPs) defined in ASMFC's Amendment 1 to the Northern Shrimp FMP (ASMFC 2004) are $B_{Threshold}$ = 9,000 mt (19.8 million lbs) and B_{Limit} = 6,000 mt (13.2 million lbs), and $F_{Target/Threshold}$ = 0.22 and F_{Limit} = 0.60.

These are the first reference points adopted for assessing the northern shrimp stock and are used in the current assessment.

A total biomass target is not defined in Amendment 1. The biomass limit is set at 2,000 mt higher than the lowest observed biomass of northern shrimp. The target/threshold of F = 0.22 is based on a level of the fishing mortality rate in the mid-1980s through mid-1990s when biomass and landings were "stable". The limit of F = 0.6 is based on the limit that was exceeded in the early to mid-1970s when the stock collapsed. The F target/threshold of 0.22 and the F limit of 0.6 correspond to Spawning Potential Ratios (SPR) of F50% and F20% respectively.

BRPs values presented in this assessment are based on biomass and fishing mortality estimates that assume M is 0.25. Given recent evidence (see Special Comments) that natural mortality is likely to be greater than 0.25, BRPs will need to be revised in the future to be consistent with the level of M used for calculating fishing mortality and biomass.

Fishing Mortality: Annual estimates of fishing mortality rate (F) ranged from 0.19 to 0.32 (average = 0.22, 19% exploitation) for the 1985 to 1994 fishing seasons, peaked at 1.06 (57% exploitation) in the 1997 season and decreased to 0.30 (22% exploitation) in the 2001 season (Figure A1). In 2002, F dropped to 0.08 (7% exploitation), due in part to a short season and poor stock conditions. Continued poor stock conditions (in terms of exploitable shrimp) resulted in F rising to 0.23 (18% exploitation) in 2004. Exceptional recruitment of the 2004 year class combined with very poor market conditions led to F dropping to 0.03 (3% exploitation) in 2006, the lowest in the time series. Recent patterns in F reflect a decline in nominal fishing effort.

Recruitment: Recruit biomass was relatively flat from 1985 through 2005, ranging from 1,700 to 6,500 mt (Figure A2). Poor recruitment was observed for the 1983, 1989, 1997, 1998, 2000, and 2002 year classes (Figure A4). Recruitment failure of the 2002 year class continues to be a concern, as is the mediocre first appearance of the 2005 year class.

Recruitment has shown a large increase in the last two years reaching a series high of 39,000 mt in 2007 due to the unprecedented 2004 year class. The terminal estimate of recruitment should be viewed with caution (see State of Stock).

Stock Biomass: Between 1985 and 1993, total stock biomass estimates averaged about 14,000 mt, with a peak at 16,000 mt before the 1991 season, and a decrease to a time series low of 4,400 mt in 2001. Total stock biomass has since increased to 71,500 mt in 2007 (32,100 mt in 2006) (Figure A1). While the absolute values of these estimates have associated larger uncertainty, the trend is reasonable because both fall and summer survey indices have been increasing since 2002.

Abundance and biomass indices (stratified mean catch per tow in numbers and weight) for the Gulf of Maine summer survey from 1984-2006 are given in Figure A5. The $\log_e$ transformed mean weight per tow averaged 15.8 kg/tow between 1984 and 1990. Beginning in 1991 this index began to decline and averaged 10.2 kg/tow between 1991 and 1996. The index then declined further, averaging 6.1 kg/tow from 1997 to 2001, and reaching a time series low of 4.3 kg/tow in 2001. In 2002 the index increased to 9.2 kg/tow, and then declined to the second lowest value in the time series (5.5 kg/tow) in 2003. Since 2003, the index has increased markedly, reaching new time series highs in both 2005 (23.3 kg/tow) and 2006 (66.0 kg/tow). The total mean number per tow had similar trends over the time series.

Special Comments: Extremely high estimates of northern shrimp biomass in 2007 are the result of unprecedented high survey indices in 2006. While all evidence suggests that the stock size of shrimp is quite large at present time, recent estimates of biomass should be viewed with caution because of the increased uncertainty of the estimates associated with the low number of tows made during the 2006 NTSC Summer Shrimp Survey. That said, there are no apparent patterns in the distribution of the 2006 survey that shed serious doubt on the validity of the 2006 index. The high abundance currently observed might not continue because the biomass estimate of the 2004 year class may not be as large in subsequent years, which would imply fewer shrimp available for the fishery.

Analyses presented in the assessment document suggest the assumed value of natural mortality rate ($M = 0.25$) is too low. The value of $M = 0.6$ is more reasonable; however, further analysis to determine the most appropriate value of M should be conducted in the next assessment. BRPs will need to be revised to reflect any changes made in M.

In the future, BRPs should be described using text as well as with specific values. For example, instead of only stating that the $F_{Threshold}$ is 0.22, it should also be described as the CSA estimate of the mean for the stable period, 1985 – 1994.

Management advice based on $M = 0.25$ does not pose a large risk to the stock given the current extremely high biomass and the nature of the current BRP's.

Sources of Information:

Apollonio, S, D.K. Stevenson and E. E. Dunton, Jr. 1986. Effects of temperature on the biology of the northern shrimp, *Pandalus borealis*, in the Gulf of Maine. NOAA Tech. Rep. NFS 42, 22 p.

Atlantic States Marine Fisheries Commission (ASMFC). 2004. Amendment 1 to the interstate fishery management plan for northern shrimp. ASMFC Fish. Man. Rpt. No. 42, 69p, http://www.asmfc.org/northernShrimp.htm

Atlantic States Marine Fisheries Commission (ASMFC). 2006. Assessment Report for Gulf of Maine Northern Shrimp – 2006. Manuscript, 57p, http://www.asmfc.org/northernShrimp.htm

Clark, S.H. and V.C. Anthony. 1981. An assessment of the Gulf of Maine northern shrimp resource. In: T. Frady, ed., Proceedings of the International Pandalid Shrimp Symposium. University of Alaska Sea Grant Report 81-3, Fairbanks. p. 207-224.

Clark, S.H., V. Silva, E. Holmes, and J.A. O'Gorman. 1999. Observations on the biology and distribution of northern shrimp, *Pandalus borealis*, in the Gulf of Maine from research vessel surveys. Poster session prepared for the International Pandalid Shrimp Symposium, Halifax, N.S. Canada, September 8-10, 1999.

Haynes, E.A. and R.L. Wigley. 1969. Biology of the northern shrimp, *Pandalus borealis*, in the Gulf of Maine. Trans. Am. Fish. Soc. 98: 60-76.

Northeast Fishery Science Center (NEFSC). 2003. Report of the 36th Northeast Regional Stock Assessment Workshop (36th SAW): Stock Assessment Review Committee (SARC) consensus summary of assessments. US Dept. Commerce NEFSC Ref. Doc 03-06, Woods Hole, MA., 453p. http://www.nefsc.noaa.gov/nefsc/publications/crd/crd0306/.

Shumway, S.E., H.C. Perkins, D.F. Schick, and A.P. Stickney. 1985. Synopsis of biological data on the pink shrimp *Pandalus borealis* Krøyer, 1838. NOAA Technical Report NMFS 30, 57 p.

Wigley, R.L. 1973. Fishery for northern shrimp, *Pandalus borealis*, in the Gulf of Maine. Mar. Fish. Rev. 35(3-4): 9-14.

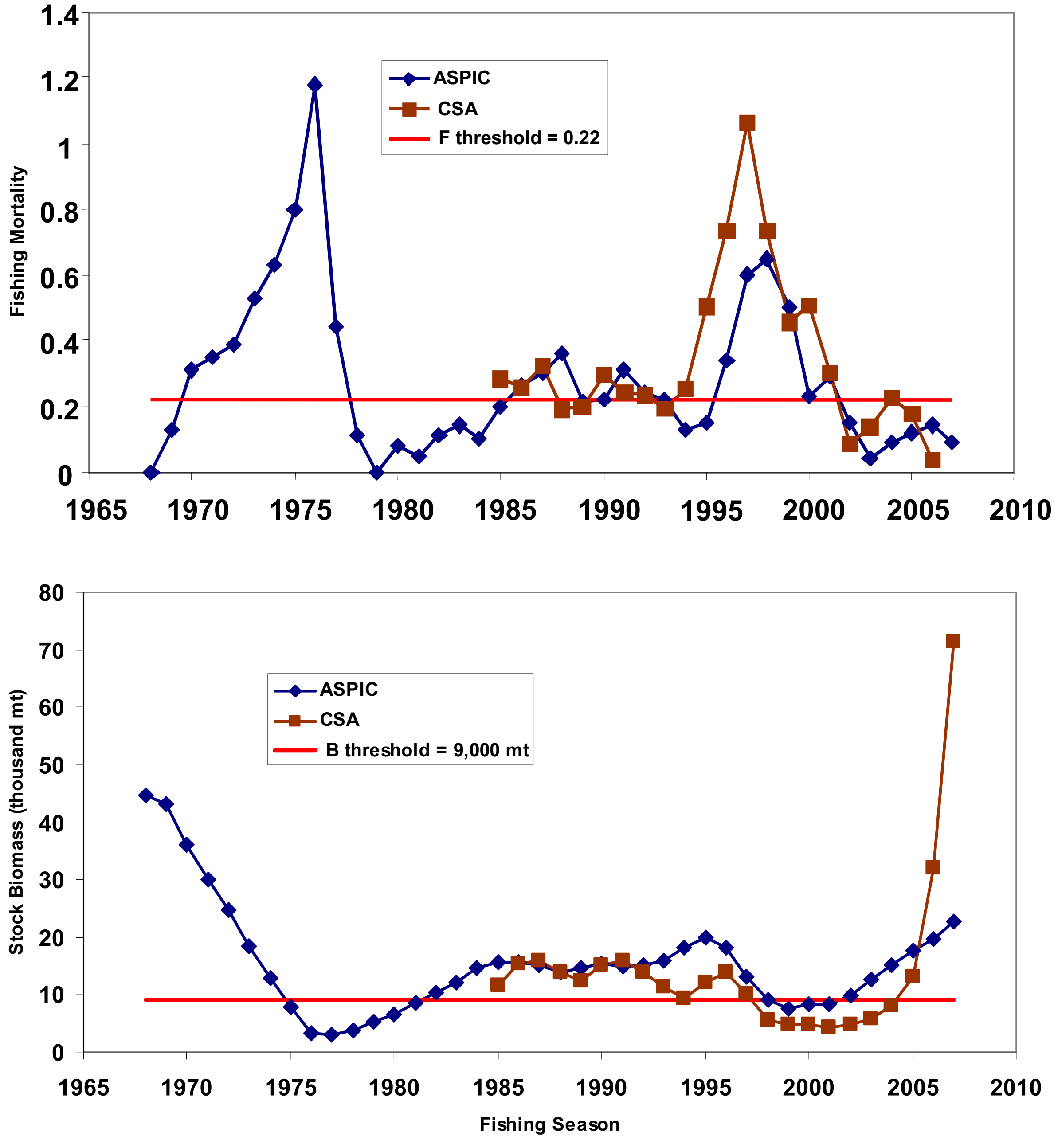

Figure A1. Annual fishing mortality rate (above) and stock biomass (below) for Gulf of Maine northern shrimp from CSA (primary assessment model) and ASPIC (used for historical context and corroboration) modeling. Thresholds are also indicated.

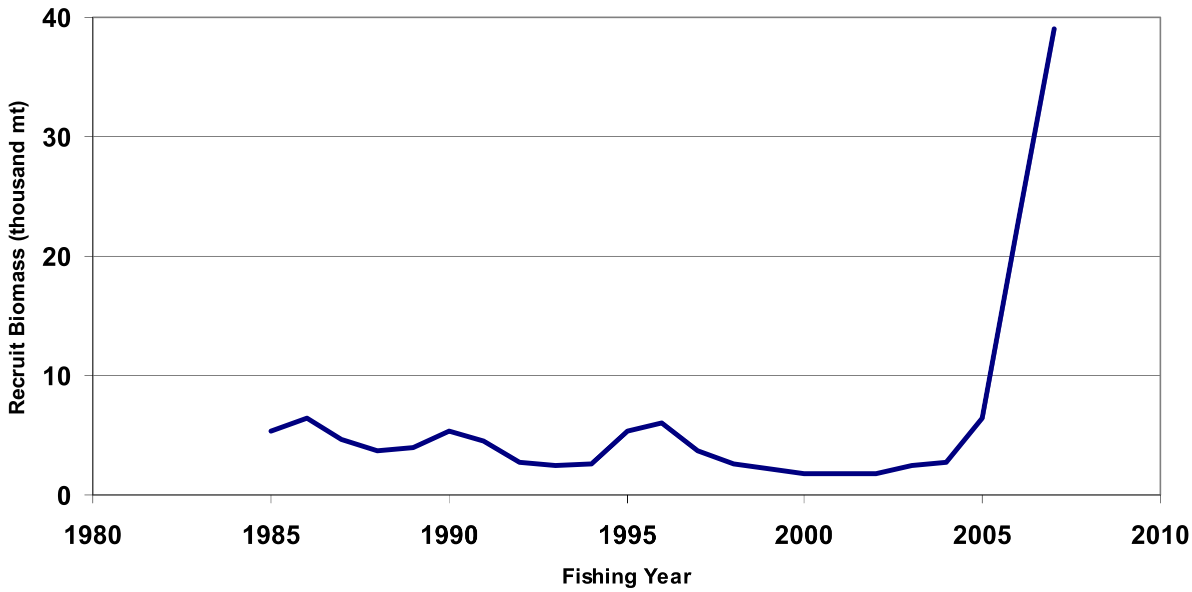

Figure A2. Annual recruit biomass (those shrimp that will recruit to the fishery in the coming fishing year) for Gulf of Maine northern shrimp from CSA analyses.

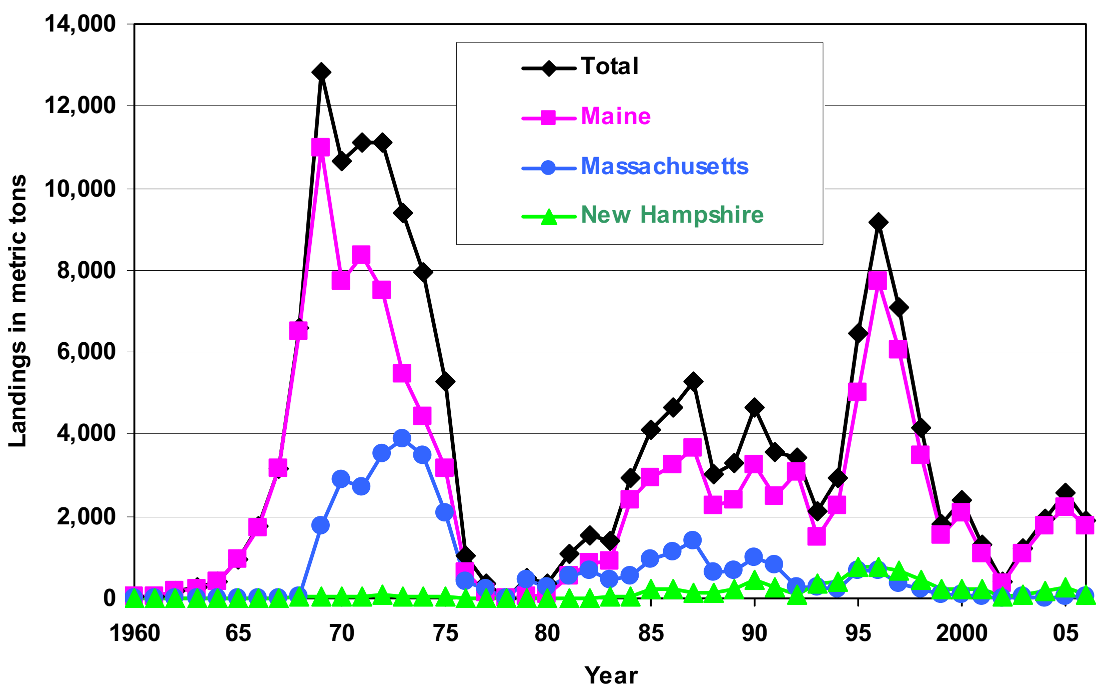

Figure A3. Gulf of Maine northern shrimp landings by year and state. (1 metric ton = 2,205 lbs)

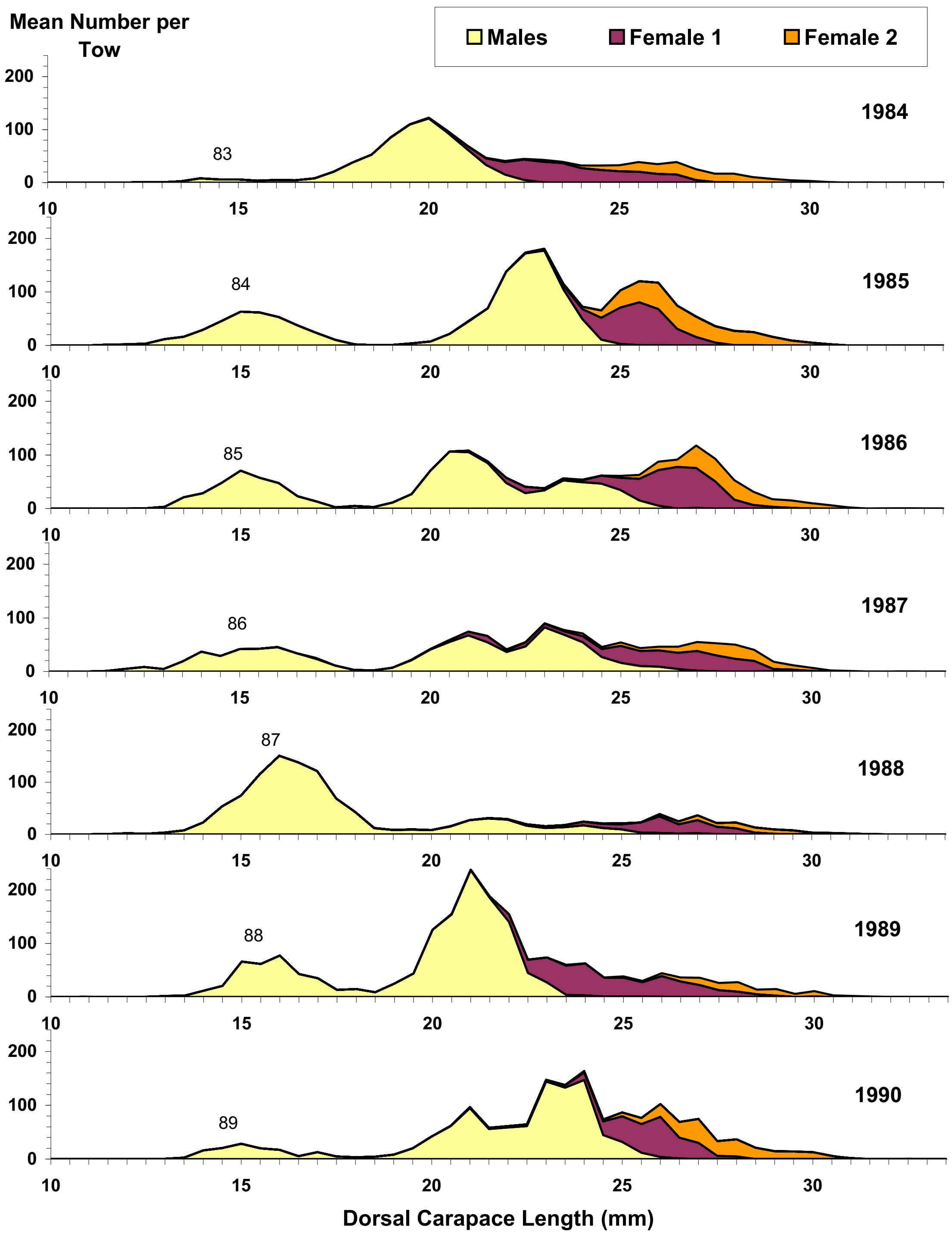

Figure A4. Mean number of shrimp per survey tow by survey year, shrimp length, and development stage for Gulf of Maine northern shrimp. Data are from the State/federal NSTC summer survey. Two-digit years indicate the year class at assumed age 1.5 years.

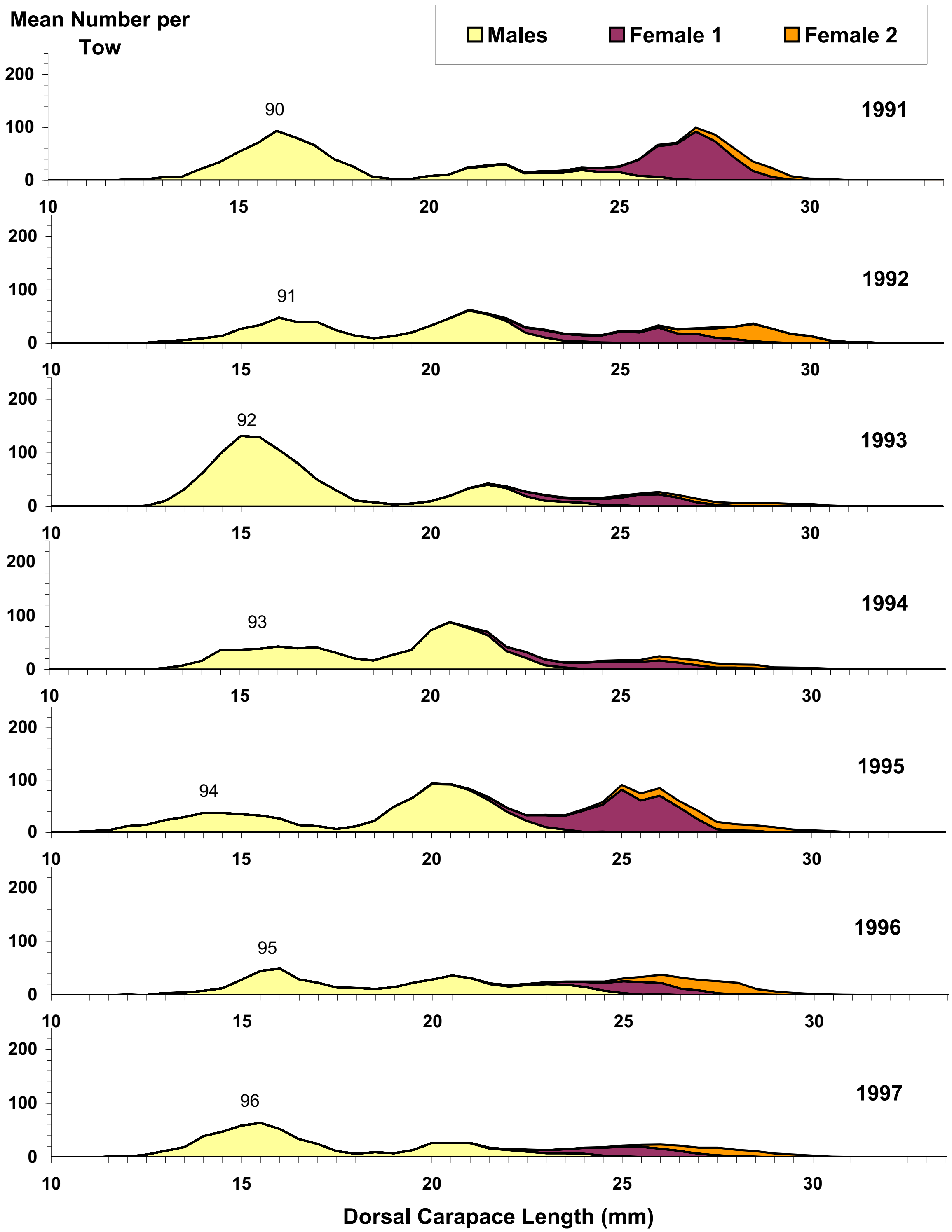

Figure A4. continued.

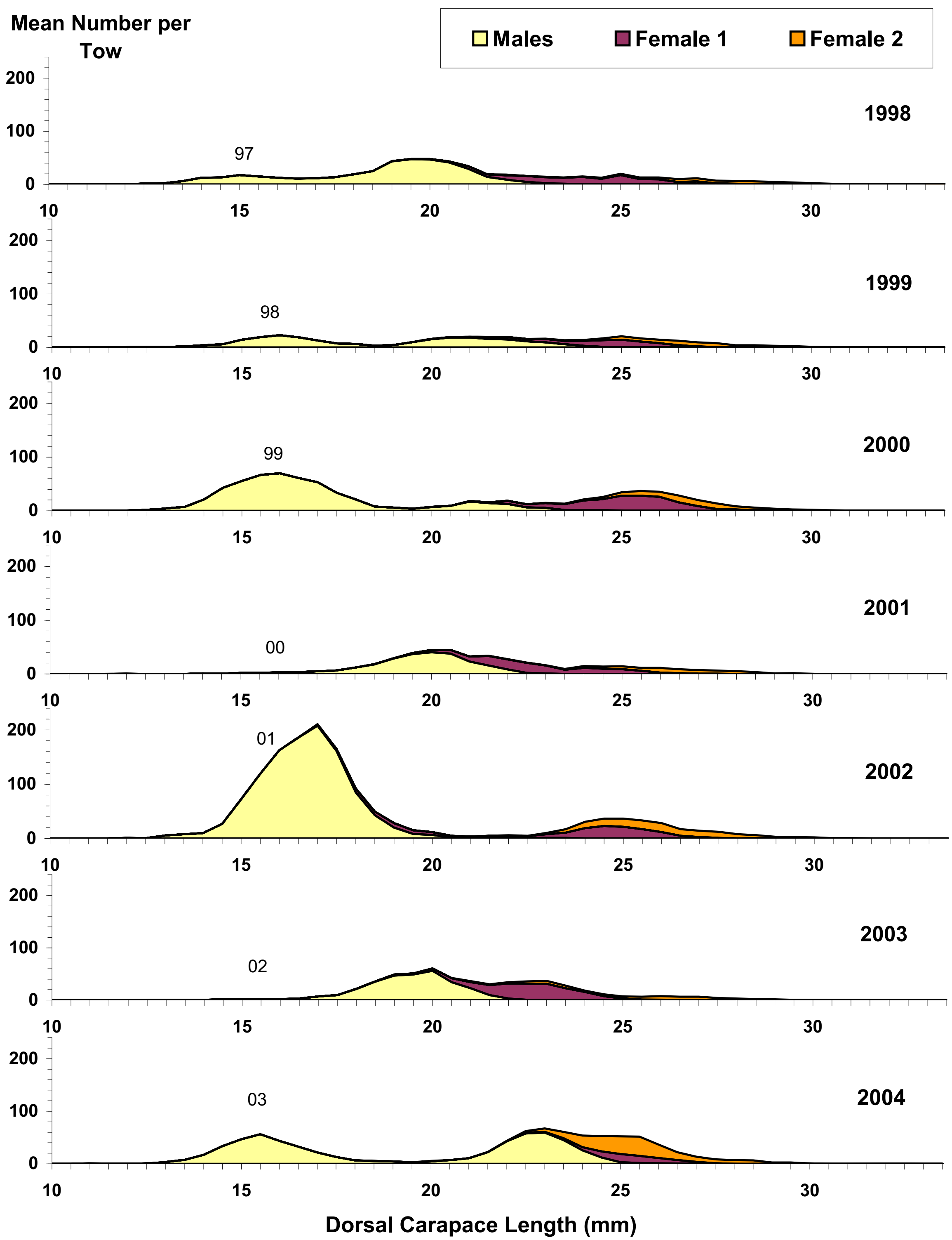

Figure A4. continued.

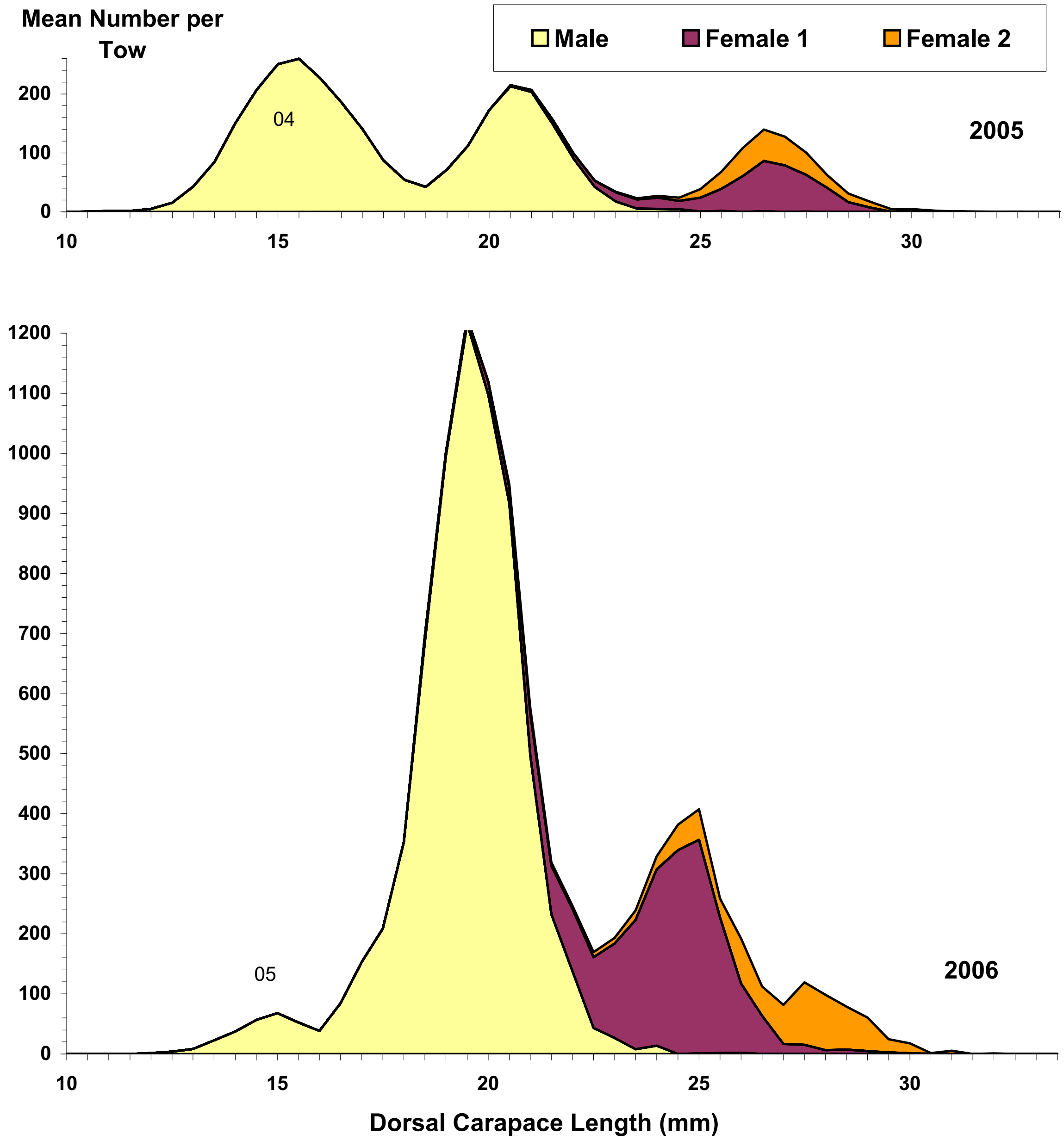

Figure A4. continued.

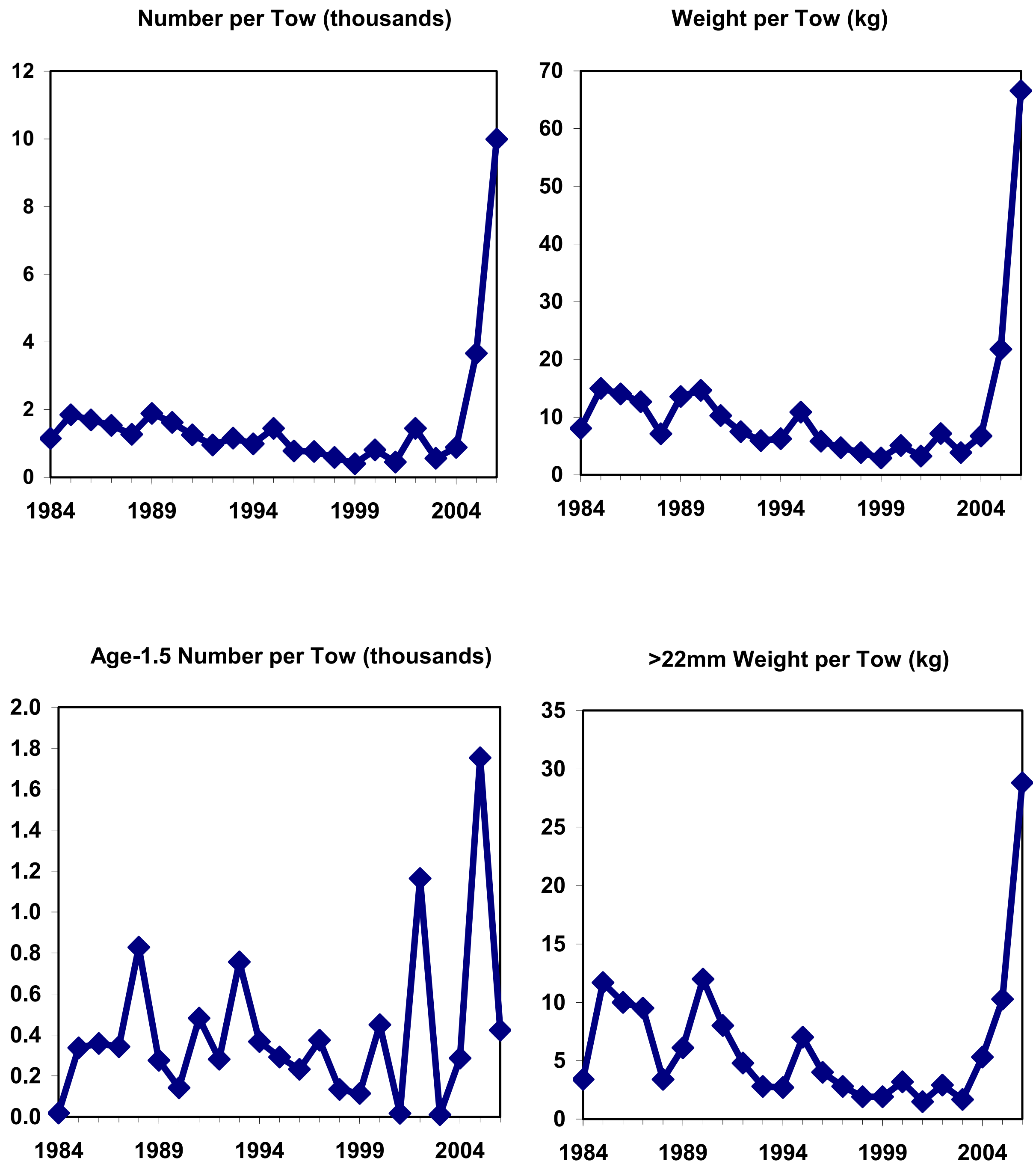

Figure A5. State/federal summer survey indices of abundance and biomass of Gulf of Maine northern shrimp. (1 kg = 2.2 lbs)

B. SEA SCALLOP ASSSESSMENT SUMMARY FOR 2007

State of Stock: Based on both the previous Biological Reference Points (BRPs) as well as the new recommended BRPs, sea scallops in the US EEZ (Figure B1) during 2006 were not overfished and overfishing was not occurring. Biomass (for scallops ≥ 40 mm shell height, SH) during 2006 was 166 thousand mt meats, which is above the new recommended biomass target (108.6 thousand mt meats), and above the new recommended biomass threshold (54.3 thousand mt meats, Figure B2). The NEFSC sea scallop survey index in 2006 was 7.3 kg/tow (adjusted for an assumed dredge survey selectivity pattern as in previous assessments, see below), which is above both the previously used biomass target (5.6 kg/tow) and biomass threshold (2.8 kg/tow, both adjusted, Figure B3).

During 2006, the fully recruited (> 120 mm SH) fishing mortality for sea scallops from the size-structured catch at size analysis (CASA) model (0.23 per year, Figure B4) was below the updated fully recruited fishing mortality threshold (0.29 per year, Figure B5). Using the rescaled *F* approach that was used in previous assessments, fishing mortality during 2006 was 0.20 per year, which is below both the current overfishing threshold (0.24 per year) and the updated estimate (0.29 per year).

Projections: Projections with fishing mortality rates of 0.20 and 0.24 per year suggest there will be modest increases in biomass and landings during 2006-2009, although projection results are uncertain (Figures B6-B7). Projected landings during 2007-2009 (25,000 – 33,000 mt meats) are similar or slightly higher than historically high 2003-2006 landings (Figures B6-B8). Example projections are based on current area-based management from sea scallop Amendment 10 and Framework 18 (NEFSC 2003, 2005), historical recruitment patterns, and on recent biological and fishery conditions.

Stock Distribution and Identification: Atlantic sea scallops are distributed from Cape Hatteras to Newfoundland. In the US EEZ, sea scallops are mainly at depths of 30 to 110 m. Sea scallops in the US EEZ are a single management unit although spatial management has been used in recent years to increase yield and prevent overfishing.

Catches: Landings increased from about 8,000 mt meats per year in the mid-1980s to over 17,000 mt meats per year during 1990-1991 (Figure B8). Landings declined during 1993-1998 to 5,000-8,000 mt meats per year and then increased rapidly during 1999-2001. Landings reached historical peaks (averaging about 26,000 mt meats per year) during 2002-2006. The Mid-Atlantic Bight accounted for three-quarters of total landings during 2000-2005. In contrast, Georges Bank accounted for two-thirds of total landings during 2006. The shift in 2006 was due to low landings in the Hudson Canyon Access Area in the Mid-Atlantic combined with high landings in the Georges Bank access areas. Landings in the Gulf of Maine ranged from 134-622 mt meats and averaged 316 mt meats per year during 1997-2006, while landings in southern New England ranged from 20-403 mt meats and averaged 139 mt meats during 1997-2006. Total discards averaged 1,000 mt meats per year during 1992-2006. Discard levels were above average during 2000-2004 but declined in 2005-2006, due in part to changes in gear regulations (4" rings). Survival of discards is probably high.

Data and Assessment: The sea scallop fishery in the U.S. E.E.Z was modeled separately for Georges Bank and the Mid-Atlantic Bight (Figure B1), and results for the two regions were combined to assess the entire stock. Overfishing and overfished status were evaluated in this assessment for the stock as a whole, as specified by Amendment 10 to the Sea Scallop Fishery Management Plan (NEFMC 2003). Other areas, such as the Gulf of Maine and Southern New England, that contribute little to landings or biomass were not included in the assessment models.

New growth data were used for the first time in this assessment. The new growth data indicate that Mid-Atlantic sea scallops do not grow as large and that they reach their maximum size faster than previously assumed. The new growth data for Georges Bank indicate that growth is similar to the previously estimated growth curve.

This assessment used new shell height/meat weight relationships for survey and commercial catches. Shell height-meat relationships for commercial catches were adjusted based on sea sampling and landings data to account for commercial shucking practices, absorption of water during storage and transport, and seasonal patterns in meat weights during each year.

The selectivity of the lined survey dredge used in the NEFSC sea scallop survey was estimated by comparison to SMAST video survey data. Results show that the lined dredge has the same selectivity (equal efficiency of catch) for all sea scallops larger than 40 mm SH. Previous assessments assumed that the lined dredge had maximum selectivity and catch efficiency for catch for sea scallops 40-60 mm SH. All calculations, other than sensitivity analysis and comparisons to existing reference points, in the current assessment used NEFSC dredge survey data assuming equal selectivity for all sea scallops greater than 40 mm SH. Because of the change in assumed selectivity, the NEFSC dredge biomass indices are about 25-30% lower than those given in previous assessments; this is a change in the relative biomass indices only and is not related to any change in the estimates of absolute biomass.

A size-structured forward projecting assessment model (CASA) was used as the primary assessment model, with additional analyses based on rescaled *F* approach used previously. The CASA model for sea scallops was introduced in the last assessment (NEFSC 2004) but was not used to determine stock status at that time because the model was relatively new and had not been tested thoroughly. Simulation modeling and sensitivity analysis in this assessment indicated that the CASA model was generally more accurate than the rescaled *F* method previously used. The CASA model results were based on a wide range of information including data from the NEFSC sea scallop, winter bottom trawl and SMAST small camera video surveys, commercial landings, shell height measurements for landed scallops from port and sea sampling, commercial landings per unit effort, and growth increment data from growth rings on scallop shells. Biomass and fishing mortality estimates from the CASA model for Georges Bank and the Mid-Atlantic Bight had mild retrospective patterns, but there was no retrospective pattern for the stock as a whole because the retrospective patterns for the two regions were in opposite directions. The estimated fishing mortality for sea scallops during 2006 from the CASA model (0.23 per year) was similar to the estimate (0.20 per year) from the rescaled *F* approach and trends in mortality estimates from the two models were similar.

Biological Reference Points: Based on the new assessment, the recommended biomass target for sea scallops is B_{TARGET} = 108.6 thousand mt meats (for scallops ≥ 40 mm shell height) and the recommended biomass threshold reference point is $B_{THRESHOLD}$ = ½ B_{TARGET} = 54.3 thousand mt meats. The recommended target biomass was calculated with CASA model estimates, by multiplying biomass per recruit at F_{MAX} (86.3 grams per recruit) times median recruitment during 1983-2006 (1,258 million sea scallops per year). Explorations of possible stock-recruitment relationships indicate that recruitment overfishing is unlikely provided that sea scallop biomass remains above the proposed reference points.

F_{MAX}, a proxy for F_{MSY}, is used as the overfishing threshold. In the new assessment, a size-based per recruit model provides an updated estimate of $F_{THRESHOLD}$ (F_{MAX} = 0.29 per year;

Figure B5) for the whole stock. The updated estimate of F_{MAX} is based on new information on growth rate and fishery selectivity patterns during 2006, and it is higher than the older value primarily due to the new estimates of growth in the Mid-Atlantic region, and the shift towards larger scallops in fishery landings.

Based on Amendment 10 (NEFMC 2003) of the sea scallop FMP, the current (i.e., older) biomass target reference point is B_{TARGET} = 5.6 kg/tow (adjusted as in the last assessment for assumed NMFS survey dredge selectivity patterns). That value was calculated as biomass per recruit at F_{MAX}, from a previous per recruit model, times the median recruitment index from NEFSC sea scallop surveys. The current biomass threshold is ½ B_{TARGET} = $B_{THRESHOLD}$ = 2.8 kg/tow (adjusted).

The current (i.e., older) estimate of the overfishing threshold (F_{MAX} = 0.24 per year) was based on an age-based yield per recruit analysis (Applegate et al. 1998). The target fishing mortality rate is 0.20 per year, and this was not revised.

Fishing Mortality: Fully-recruited fishing mortalities for sea scallops during 2006 were 0.31 per year on Georges Bank, 0.17 per year in the Mid-Atlantic, and 0.23 per year for the whole stock, based on CASA model estimates (Figure B4). Based on uncertainties in survey and commercial catch data, there is only about a 7% probability that overfishing occurred (fishing mortality above the new recommended threshold reference point) in the sea scallop stock during 2006 (Figure B9). A 95% confidence interval for 2006 whole-stock fishing mortality is (0.17, 0.32). CASA model estimates of fishing mortality are not comparable to previously estimated fishing mortality reference points because of changes in selectivity and estimates of growth.

Recruitment: Sea scallop recruits correspond roughly to two year old individuals. Recruitment was below average for sea scallops on Georges Bank during 2004-2006 based on CASA model estimates (Figure B10 and Catch and Status Table). Recruitment in the Mid-Atlantic has been above average for every year since 1998 except 2004 and 2006.

Stock Biomass: Stock biomass was 166 thousand mt meats in 2006, which is the historical high during 1982-2006 (Figure B2). Sea scallop biomass was almost equally distributed between Georges Bank (81,000 mt meats) and the Mid-Atlantic Bight (85,000 mt meats). Considering uncertainties in survey and landings data, there is less than a 1% estimated probability that the sea scallop stock biomass was below the target biomass of 108.6 mt meats during 2006 (Figure B11).

Special comments: The current recommended F_{MAX} proxy for F_{MSY} in sea scallops should be revisited in the next assessment because the recent fishery selectivity patterns that focus harvest on large sea scallops make yield-per-recruit curves flat on the top, making it difficult to estimate F_{MAX} precisely (Figure B5).

Area management plays an important role in sea scallop stock dynamics, with much of the biomass located in long-term or rotational closures, or in reopened closed areas under special management. When there is spatial variability in fishing mortality, as occurs under area management (Hart 2001), fishing mortality reference points such as the F_{MAX} proxy, calculated under the assumption of spatially uniform fishing mortality, may overestimate the fishing mortality level that would actually maximize yield per recruit. For example, if half of the scallop biomass was located in closed areas, the whole-stock fishing mortality would have to be about half of the recommended fishing mortality threshold in order to maximize yield per recruit in the areas remaining open to fishing.

Sources of Information:

Applegate, A., S. Cadrin, J. Hoenig, C. Moore, S. Murawski, and E. Pikitch. 1998. Evaluation of existing overfishing definitions and recommendations for new overfishing definitions to comply with the Sustainable Fisheries Act. Final Report, June 17, 1998. New England Fisheries Management Council, Saugus, MA, 171 p.

Hart, D.R. 2001. Individual-based yield-per-recruit analysis, with an application to the Atlantic sea scallop, *Placopecten magellanicus*. Can. J. Fish. Aquat. Sci. 58: 2351-2358.

Hart D.R. 2006. Sea Scallop Stock Assessment Update for 2005, NEFSC Ref. Doc. 06-20, 14 p.

New England Fishery Management Council (NEFMC). 2003. Final Amendment 10 to the Atlantic sea scallop fishery management plan with a supplemental environmental impact statement, regulatory impact review, and regulatory flexibility analysis. New England Fisheries Management Council, Newburyport, MA.

New England Fishery Management Council (NEFMC). 2005. Framework Adjustment 18 to the Atlantic Sea Scallop FMP including an environmental assessment, regulatory impact review, regulatory flexibility analysis and stock assessment and fishery evaluation (SAFE) report. New England Fisheries Management Council, Newburyport, MA.

Northeast Fisheries Science Center (NEFSC). 2001. 32nd Northeast Regional Stock Assessment Workshop (32nd SAW). Stock Assessment Review Committee (SARC) Consensus Summary of Assessments. NEFSC Ref. Doc. 01-05, Woods Hole, MA, 289 p.

Northeast Fisheries Science Center (NEFSC). 2004. 39th Northeast Regional Stock Assessment Workshop (39th SAW) Assessment Summary Report & Assessment Report. NEFSC Ref. Doc. 04-10a, b, Woods Hole, MA, 16 p. (a) and 211 p. (b).

Catch and Status table: Atlantic Sea Scallop

U.S. Landings (mt meats)														
Year	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*Min*[1]	*Max*[1]	*Mean*[1]	*Median*[1]
Georges Bank	2,053	2,039	5,085	5,039	4,597	5,541	4,823	4,357	9,502	17,286	982	17,286	5,341	4,710
Mid-Atlantic Bight	2,728	2,891	4,414	8,853	15,611	17,056	20,089	24,497	15,634	8,819	1,610	24,497	7,981	6,492
Gulf of Maine	622	483	243	144	260	499	403	134	143	229	134	895	475	469
Southern New England	87	100	80	74	29	20	103	120	403	370	20	403	116	82
Total	5,489	5,514	9,822	14,110	20,497	23,117	25,417	29,109	25,682	26,704	5,514	29,109	13,913	13,666
U.S. Discards (mt meats)														
Year	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*Min*[2]	*Max*[2]	*Mean*[2]	*Median*[2]
Georges Bank[3]	29	5	162	1,129	865	128	313	91	286	628	3	1,129	293	162
Mid-Atlantic Bight[3]	8	60	11	871	854	1,637	2,417	2,644	579	213	8	2,644	807	325
Total (all fisheries)	91	163	266	2,092	1,889	1,936	2,839	2,859	935	860	91	2,859	1,195	842
Trends for Stock Abundance, NEFSC sea scallop survey (numbers/tow, > 40 mm shell height)														
Year	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*Min*[1]	*Max*[1]	*Mean*[1]	*Median*[1]
Georges Bank	80.6	271.2	159.8	715.5	357.8	297.9	225.8	269.9	210.5	151	30.1	715.5	172.6	133.4
Mid-Atlantic Bight	41.3	157.6	234	283.6	306.3	301	641.3	468.8	360.1	378.1	27.7	641.3	186.6	131.2
Combined	59.6	210.5	199.4	484.8	330.3	299.6	447.7	376.1	290.4	272.4	29.7	484.8	180.0	136.7
Trends for Stock Abundance, CASA model (millions January 1, > 40 mm shell height)														
Year	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*Min*[1]	*Max*[1]	*Mean*[1]	*Median*[1]
Georges Bank	1,313	1,637	2,049	3,089	3,362	3,164	3,178	2,974	2,923	2,616	584	3,362	1,818	1,641
Mid-Atlantic Bight	881	2,257	3,599	4,418	4,825	4,657	6,014	5,563	5,360	4,833	524	6,014	2,452	1,747
Combined	2,194	3,894	5,648	7,507	8,187	7,821	9,192	8,537	8,283	7,499	1,401	9,192	4,270	3,236
Trends for Stock Biomass, NEFSC sea scallop survey (kg/tow, > 40 mm shell height)														
	1997	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*Min*[1]	*Max*[1]	*Mean*[1]	*Median*[1]
Georges Bank	1.3	3.7	2.6	6.3	5.1	6	5.4	7.1	5.7	4.5	0.4	7.1	2.4	1.1
Mid-Atlantic Bight	0.4	0.8	1.7	3.0	3.3	3.7	5.7	5.2	6.0	5.9	0.3	6.0	1.9	0.9
Combined	0.8	2.2	2.1	4.5	4.2	4.8	5.6	6.1	5.9	5.2	0.4	6.1	2.1	0.9
Trends for Stock Biomass, CASA model (thousands mt meats January 1, > 40 mm shell height)														
Year	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*Min*[1]	*Max*[1]	*Mean*[1]	*Median*[1]
Georges Bank	19	24	32	40	53	65	73	79	84	81	6	84	30	17
Mid-Atlantic Bight	10	14	27	45	59	65	71	78	78	85	8	85	29	15
Combined	30	39	59	84	112	129	143	157	162	166	17	166	58	32

Catch and Status Tables (cont.)

Recruitment (~2 year old) trends, CASA model (millions, January 1)

Year	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*Min*[1]	*Max*[1]	*Mean*[1]	*Median*[1]
Georges Bank	418	752	751	1,858	461	362	751	250	458	209	174	1,858	578	462
Mid-Atlantic Bight	500	2,048	1,695	1,451	1,444	1,121	3,211	312	1,776	370	103	3,211	866	682
Combined	918	2,800	2,446	3,310	1,905	1,483	3,962	563	2,234	579	381	3,962	1,474	1,258

Fishing Mortality (annual instantaneous rates, CASA fully-recruited *F*)

Year	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*Min*[1]	*Max*[1]	*Mean*[1]	*Median*[1]
Georges Bank	0.31	0.24	0.31	0.22	0.18	0.23	0.19	0.08	0.16	0.31	0.08	2.34	0.60	0.36
Mid-Atlantic Bight	0.50	0.51	0.48	0.45	0.51	0.60	0.61	0.73	0.41	0.17	0.17	1.20	0.70	0.70
Combined	0.38	0.34	0.39	0.36	0.38	0.43	0.43	0.38	0.29	0.23	0.23	1.30	0.64	0.61

[1] 1982-2006. [2] 1994-2006. [3] Sea scallop fishery only.

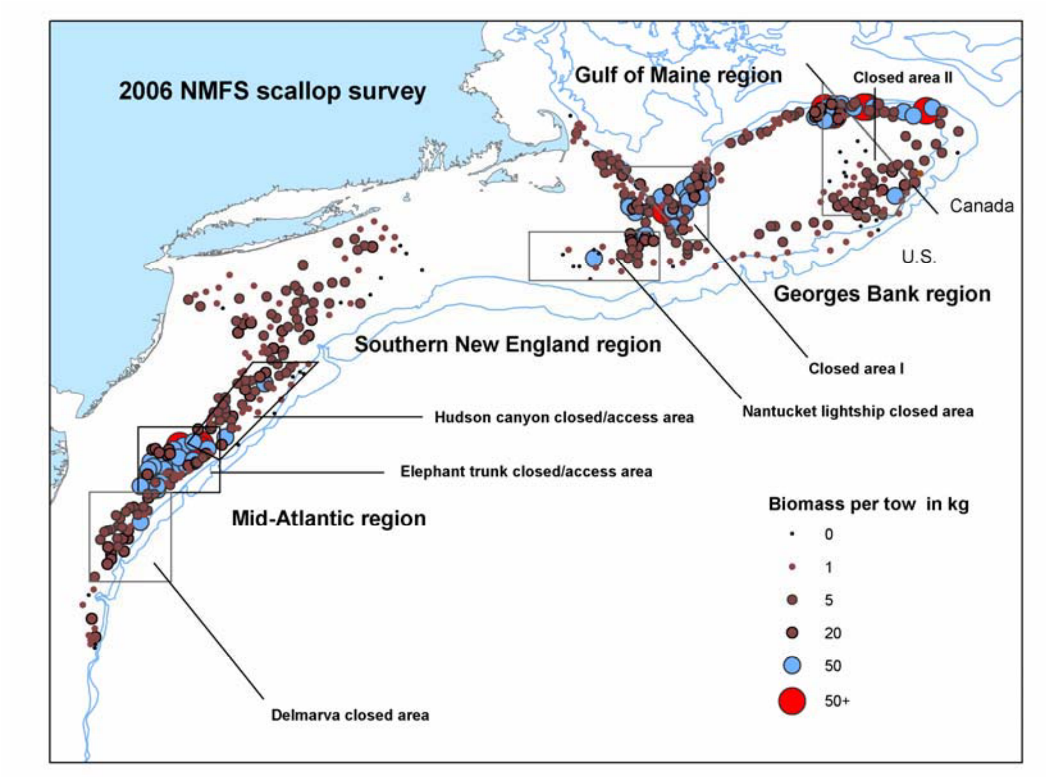

Figure B1. Sea scallop stock, with 2006 NEFSC sea scallop survey catches.

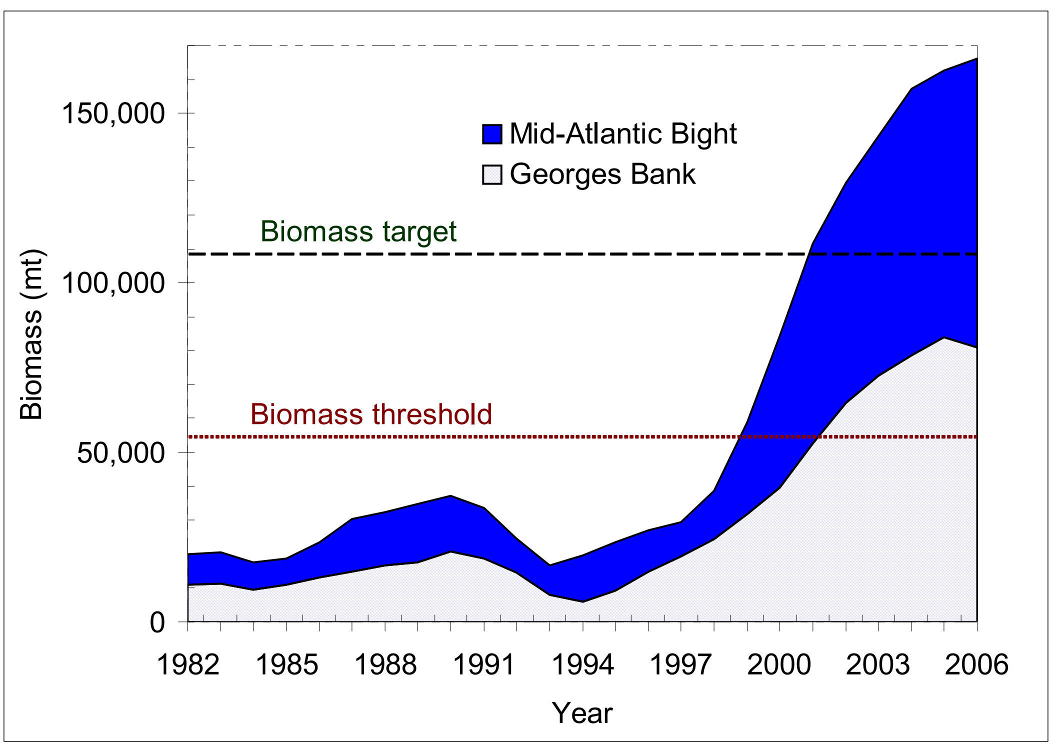

Figure B2. Sea scallop biomass estimates from CASA model, along with recommended biomass reference points.

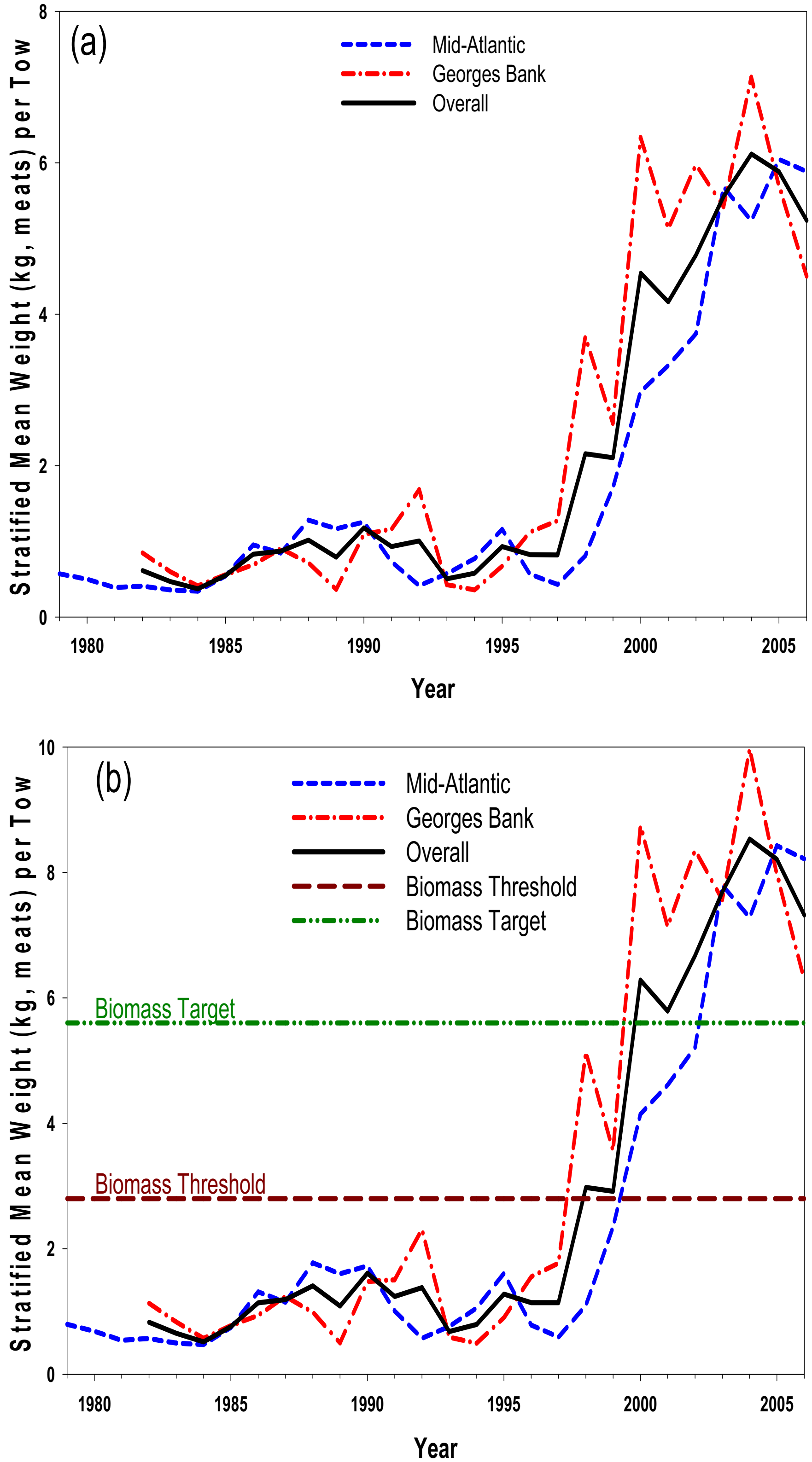

Figure B3. NEFSC sea scallop survey biomass, (a) unadjusted (b) adjusted for selectivity. Current (i.e., older) BRPs are shown (horizontal lines).

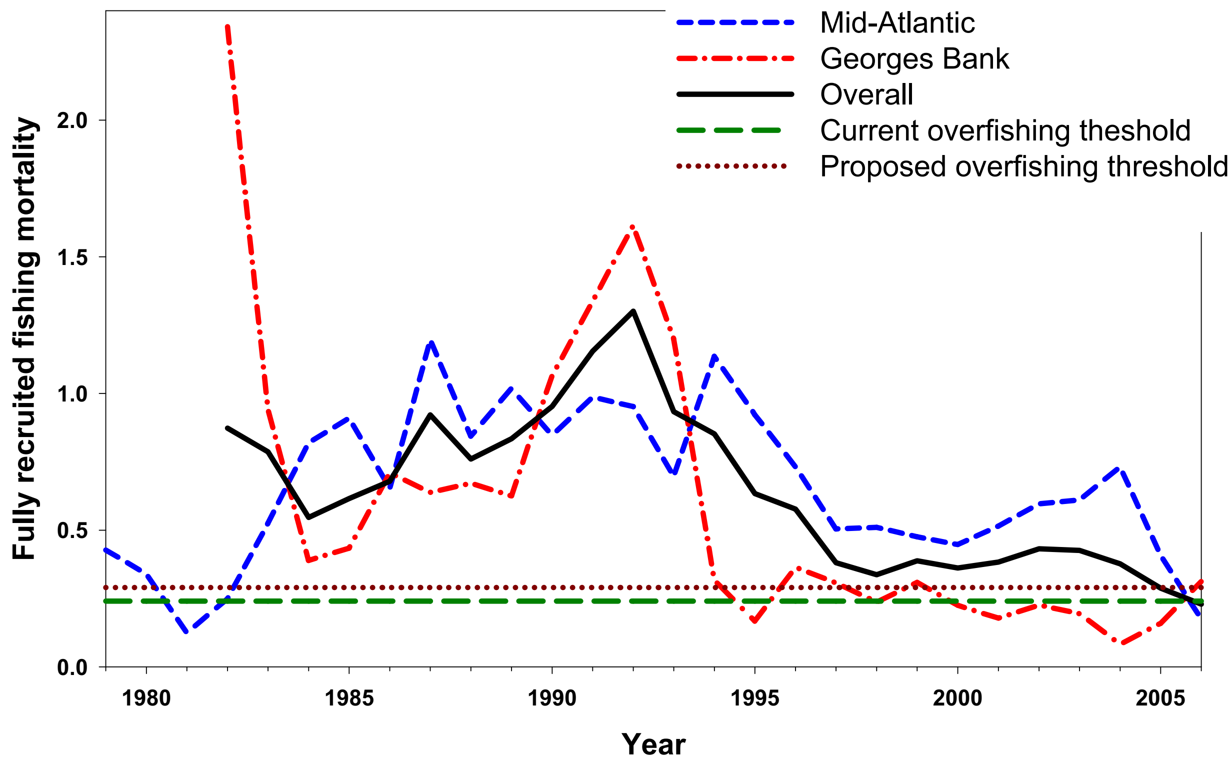

Figure B4. Fully recruited fishing mortality for sea scallops.

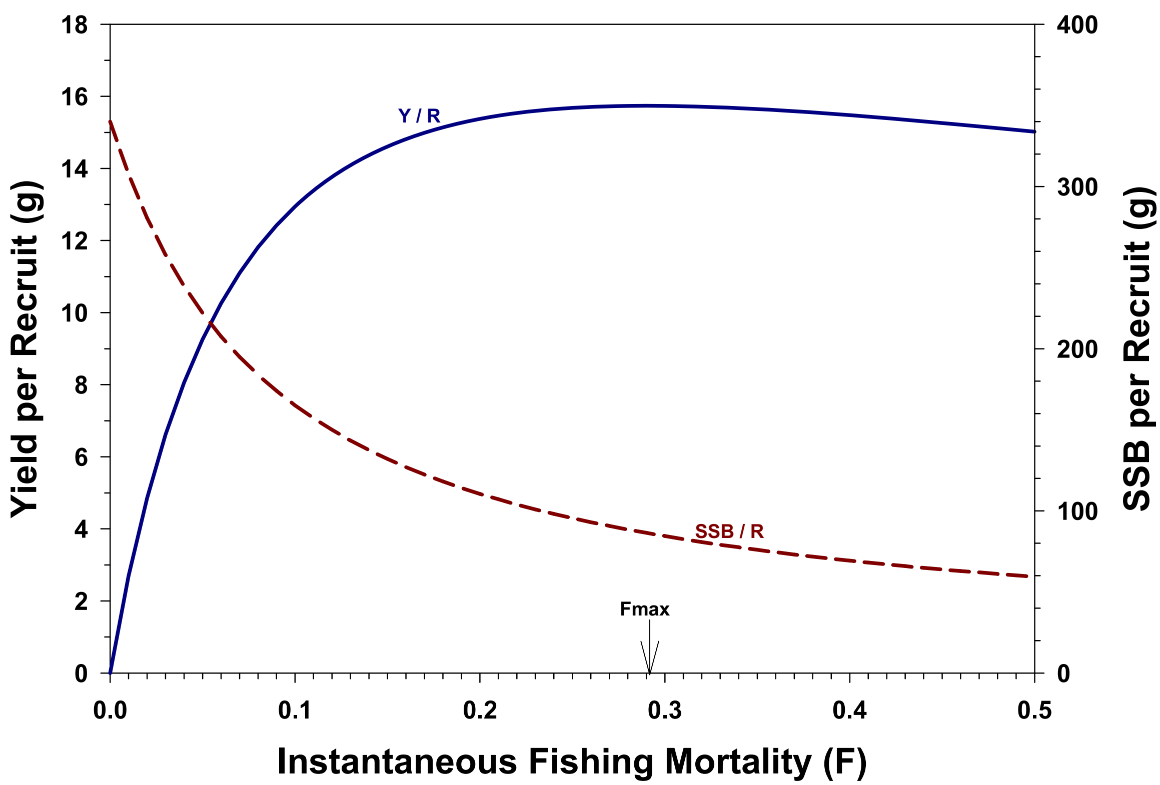

Figure B5. Sea scallop yield and biomass per recruit.

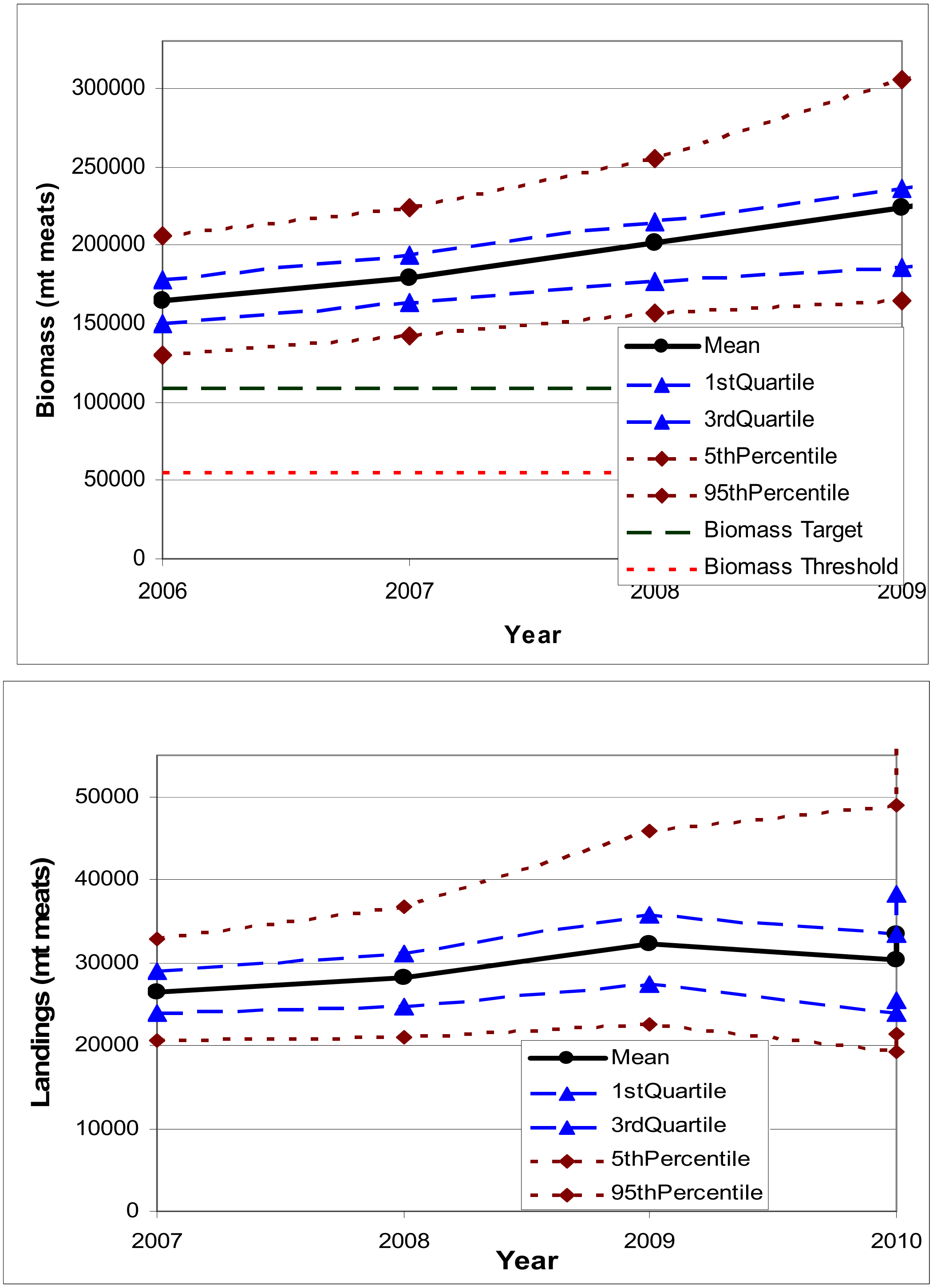

Figure B6. Example, short-term forecasts of sea scallop biomass and landings, assuming that whole-stock fishing mortality in 2007-9 is 0.20.

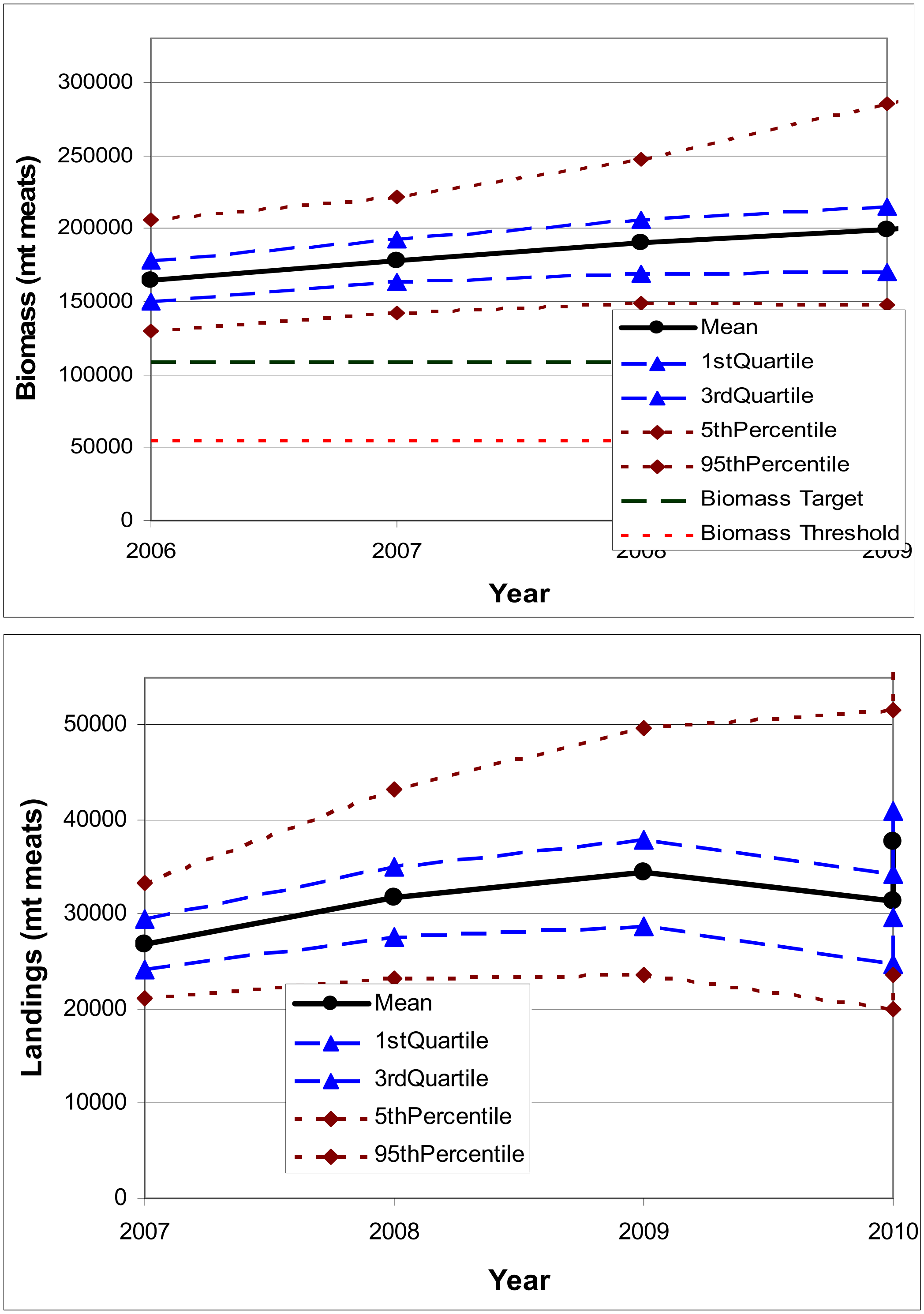

Figure B7. Example short-term forecasts of sea scallop biomass and landings, assuming that whole-stock fishing mortality in 2007-9 is 0.24.

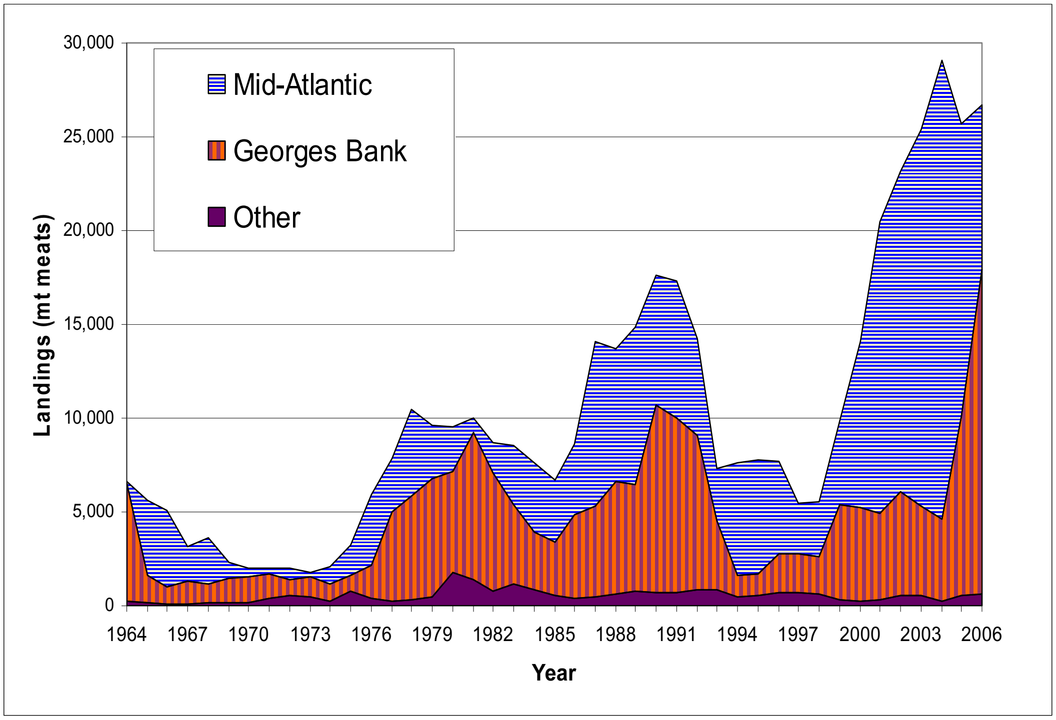

Figure B8. Sea scallop landings (MT meats), 1982-2006.

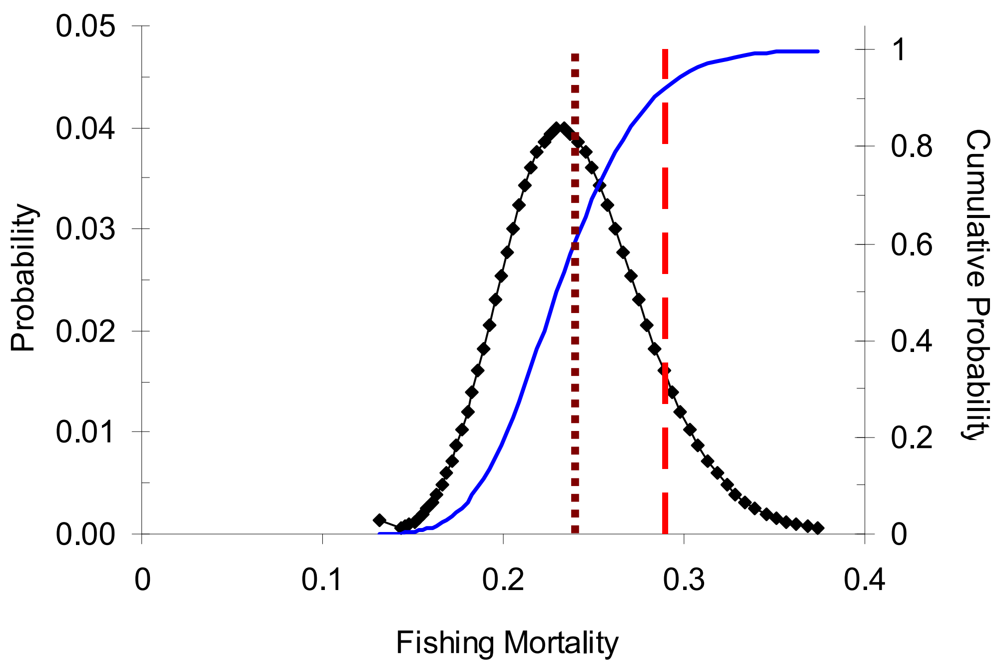

Figure B9. 2006 fishing mortality probabilities with new recommended overfishing threshold (long-dashed line) and current threshold (dotted line) for sea scallops.

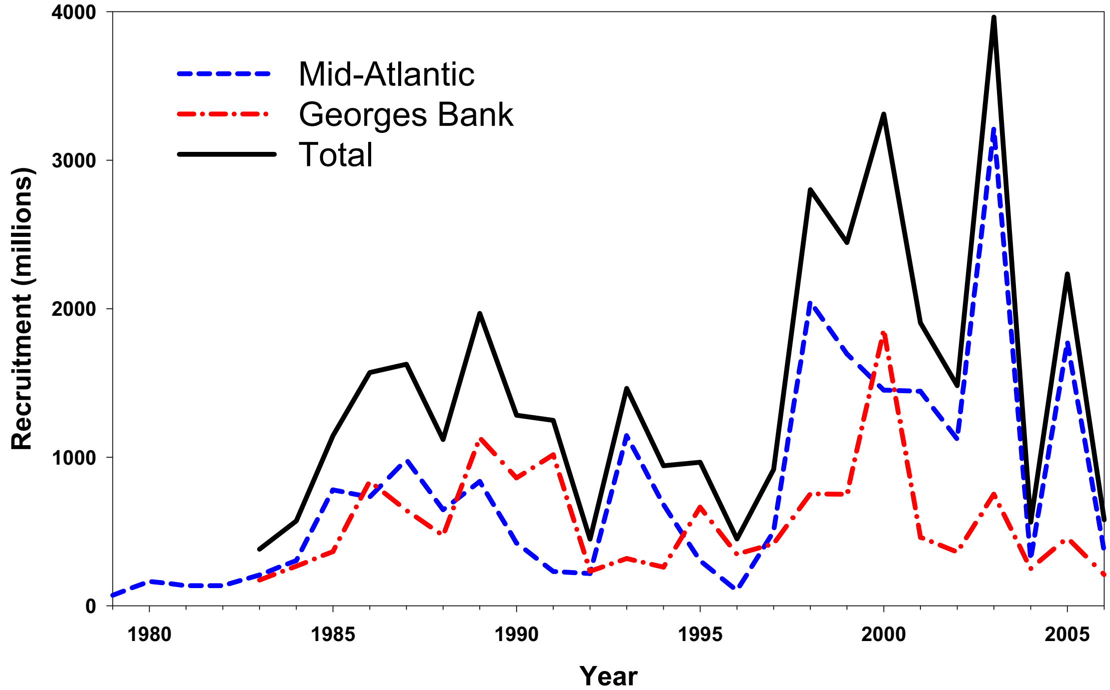

Figure B10. Trends in scallop recruitment, 1982-2006.

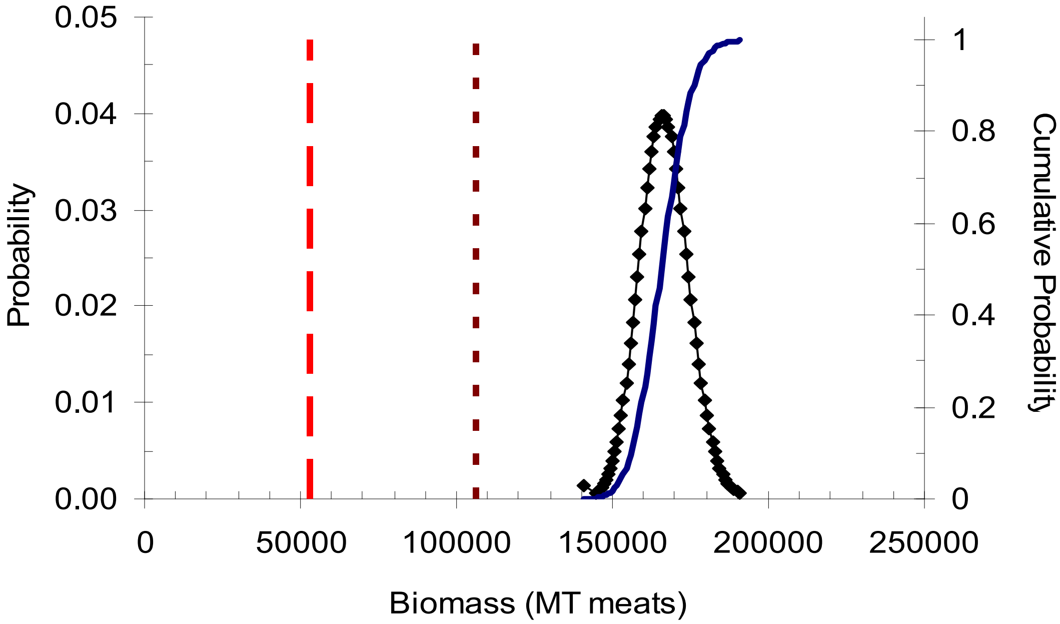

Figure B11. 2006 biomass probabilities with new recommended biomass threshold (long-dashed line) and biomass target (dotted line) for sea scallops.

APPENDIX. TERMS OF REFERENCE

TORs for SAW/SARC-45, Spring 2007 Assessments
(Last Revised: March 1, 2007)

A. Northern Shrimp

1. Characterize the Gulf of Maine northern shrimp commercial catch, effort, and CPUE, including descriptions of landings and discards of that species.
2. Estimate fishing mortality and exploitable stock biomass in 2006 and characterize the uncertainty of those estimates. Also include estimates for earlier years.
3. Comment on the scientific adequacy of existing biological reference points (BRPs).
4. Evaluate current stock status with respect to the existing BRPs.
5. Perform sensitivity analyses to determine the impact of uncertainty in the data on the assessment results.
6. Analyze food habits data and existing estimates of finfish stock biomass to estimate annual biomass of northern shrimp consumed by cod and other major predators. Compare consumption estimates with removals implied by currently assumed measures of natural mortality for shrimp.
7. Review, evaluate and report on the status of the 2002 SARC/Working Group Research Recommendations.

B. Sea Scallops

1. Characterize the commercial catch, effort and CPUE, including descriptions of landings and discards of that species.
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 redefine biological reference points (BRPs; proxies for B_{MSY} and F_{MSY}), as appropriate. Comment on the scientific adequacy of existing and redefined BRPs.
4. Evaluate current stock status with respect to the existing BRPs, as well as with respect to updated or redefined 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.

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