Northeast Fisheries Science Center Reference Document 10-09

# 50th Northeast Regional Stock Assessment Workshop (50th SAW):

## Assessment Summary Report

by Northeast Fisheries Science Center

July 2010

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10-08 In preparation.

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**US DEPARTMENT OF COMMERCE**
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
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## Northeast Fisheries Science Center Reference Documents

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**Editorial Treatment:** To distribute this report quickly, it has not undergone the normal technical and copy editing by the Northeast Fisheries Science Center's (NEFSC's) Editorial Office as have most other issues in the NOAA Technical Memorandum NMFS-NE series. Other than the four covers and first two preliminary pages, all writing and editing have been performed by the authors listed within. This report was reviewed by the Stock Assessment Review Committee, a panel of assessment experts from the Center for Independent Experts (CIE), University of Miami.

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# SAW-50 ASSESSMENT SUMMARY REPORT

## Introduction

The 50th SAW Assessment Summary Report contains summary and detailed technical information on three stock assessments reviewed in June 2010 at the Stock Assessment Workshop (SAW) by the 50th Stock Assessment Review Committee (SARC-50): monkfish (also called goosefish; *Lophius americanus*), sea scallop (*Placopecten magellanicus*), and pollock (*Pollachius virens*). The SARC-50 consisted of 4 external, independent reviewers (3 appointed by the Center for Independent Experts [CIE] and one by the New England Fishery Management Council Science and Statistics Committee (NEFMC SSC), and an external SARC chairman from the NEFMC 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-50 are available at website: http://www.nefsc.noaa.gov/nefsc/saw/ under the heading "SARC 50 Panelist 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.

As 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 under federal jurisdiction are 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, federally managed 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.

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

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.

### Outcome of Stock Assessment Review Meeting

Based on the Review Panel reports (available at http://www.nefsc.noaa.gov/nefsc/saw/ under the heading "SARC 50 Panelist Reports"), the SARC review committee accepted the monkfish assessment, but expressed serious concerns regarding the high levels of uncertainty throughout the assessment. There is considerable uncertainty in estimates of stock size, recruitment, fishing mortality, biological reference points, stock status determination, and stock projections. There is a large retrospective pattern in the model for the northern management area. It is possible that similar uncertainties exist in the southern management area. Sources of uncertainty in the assessment are neither well characterized nor documented. The scientific basis of the redefined reference points is adequate, but they are uncertain given their dependence upon the uncertain assessment model. Under both the unadjusted and adjusted retrospective scenarios, monkfish in both the northern and southern management areas are not overfished and overfishing is not occurring. The causes of the retrospective patterns in the models need to be determined.

The Panel accepted the sea scallop assessment. The assessment was rigorous and it was well supported by the available information. Strong analytical frameworks were defined for estimating fishing mortality, stock biomass and recruitment (CASA model), for defining biological reference points (SYM model) and for performing stock projections to inform ABC decisions (SAMS model). An innovative approach was developed for quantifying uncertainties around BRPs relative to exploitation levels, facilitating the incorporation of risk assessment into fishery management decisions. The stock is not overfished, and overfishing is not occurring, although the probability of overfishing is only marginally less than 50%. The SAMS model allows complex spatial management scenarios to be addressed. The principal uncertainty in the assessment concerns whether the current high productivity levels will continue in the future.

The Panel accepted the pollock assessment. The new assessment method (ASAP) is a significant improvement over the previous method (AIM). There is significant concern over the presumed large and as of yet unobserved adult biomass (i.e. cryptic biomass) and its implications for fishery management. For the future, the Panel recommends a risk analysis approach to determine the consequences to management of different assumptions about exploitable biomass. The Panel emphasizes the need for field evidence to document whether the cryptic biomass exists. Based on the assessment the stock is not overfished and overfishing is not occurring. This conclusion is robust to the assumptions about the shape of the survey selectivity curve. However, the Biological Reference Points (BRPs) are sensitive to the assumed shape of the selectivity curve, which has consequences for the projection results.

## Glossary

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

**AGEPRO**. The Age Structured Projection Model (AGEPRO) is an age-structured projection model designed to evaluate the likely population consequences of complex harvest scenarios under alternative hypotheses about the stock-recruitment relationship. Uncertainty in initial population size at age is incorporated into the model. AGEPRO uses Monte Carlo simulation to evaluate probabilities of achieving targets for fishing mortality or stock size and the expected age structure of landings and the population.

**AIM**. (An Index Method) An analysis that allows the user to fit a relationship between the time series of relative stock abundance indices and catch data. AIM can be used to estimate the level of relative fishing mortality at which the population is likely to be stable. The index methodology can be used to develop Biological Reference Points.

**ASAP**. (Age Structured Assessment Program) An age-structured model that uses forward computations assuming separability of fishing mortality into year and age components to estimate population sizes given observed catches, catch-at-age, and indices of abundance. Discards can be treated explicitly. The separability assumption is relaxed by allowing for fleet-specific computations and by allowing the selectivity at age to change smoothly over time or in blocks of years. The software can also allow the catchability associated with each abundance index to vary smoothly with time. The problem's dimensions (number of ages, years, fleets and abundance indices) are defined at input and limited by hardware only. The input is arranged assuming data is available for most years, but missing years are allowed. The model currently does not allow use of length data nor indices of survival rates. Diagnostics include index fits, residuals in catch and catch-at-age, and effective sample size calculations. Weights are input for different components of the objective function and allow for relatively simple age-structured production model type models up to fully parameterized models.

**ASPM**. (Age-structured production models) Also known as statistical catch-at-age (SCAA) models. A technique of stock assessment that integrates 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. ASPM is similar to the NOAA Fishery Toolbox applications ASAP (Age Structured Assessment Program) and SS2 (Stock Synthesis 2)

**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.

**CASA**. (Catch-At-Size-Analysis) A stock assessment model that tracks numbers of individuals by size group (rather than age group) to estimate abundance, biomass and mortality rates in each year.

**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 x $(1 - 0.00548)^{365}$] 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 x $(1 - 0.00228)^{8760}$]. 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: $N_{t+1} = 1{,}000{,}000e^{-2} = 135{,}335$ 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) ½$B_{MSY}$, 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).

**SAMS**. (Scallop Area Management Simulator). A size-based forecasting model that tracks scallop populations in a number of subregional areas in order to take into account area management options as well as differences in life history parameters.

**SCALE.** The Statistical Catch At Length (SCALE) model is a forward projecting age-structured model tuned with total catch (mt), catch at length or proportional catch at length, recruitment at a specified age (usually estimated from first length mode in the survey), survey indices of abundance of the larger/older fish and survey length frequency distributions. Model parameter estimates are fishing mortality and recruitment in each year, fishing mortality to produce the initial population (Fstart), logistic selectivity parameters for each year or blocks of years and Qs for each survey index.

**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.

**Stock Synthesis (SS).** This application provides a statistical framework for calibration of a population dynamics model using a diversity of fishery and survey data. SS is designed to accommodate both age and size structure and with multiple stock sub-areas. Selectivity can be cast as age specific only, size-specific in the observations only, or size-specific with the ability to capture the major effect of size-specific survivorship. The overall model contains subcomponents which simulate the population dynamics of the stock and fisheries, derive the expected values for the various observed data, and quantify the magnitude of difference between observed and expected data. Parameters are searched for which will maximize the goodness-of-fit. A management layer is also included in the model allowing uncertainty in estimated parameters to be propagated to the management quantities, thus facilitating a description of the risk of various possible management scenarios. The structure of SS allows for building of simple to complex models depending upon the data available.

**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).

**SYM**. (Stochastic Yield Model) A computer model for estimating reference points that uses stochastic Monte-Carlo simulations to take into account uncertaintyin parameters.

**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.

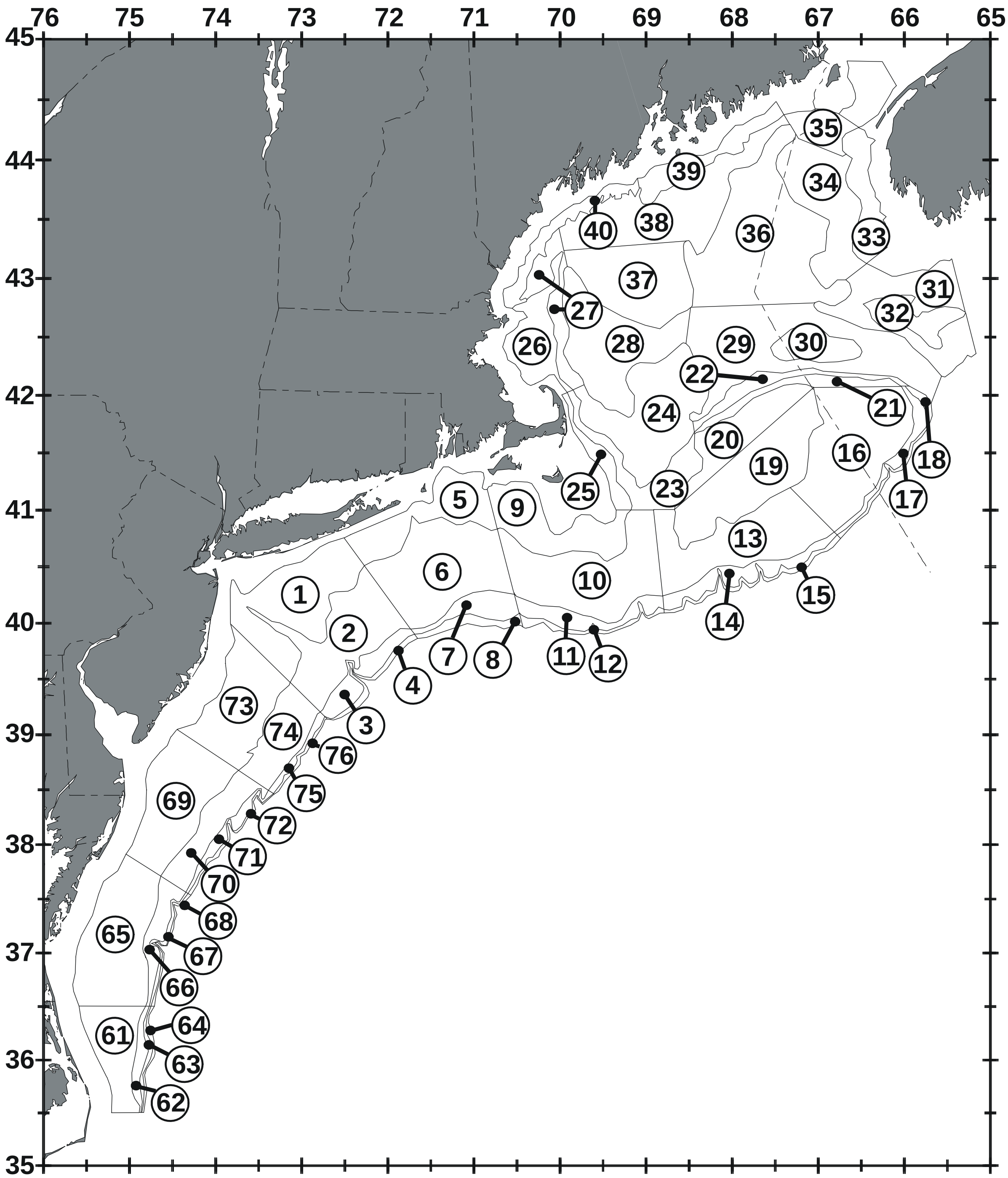


Figure 1. Offshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys.

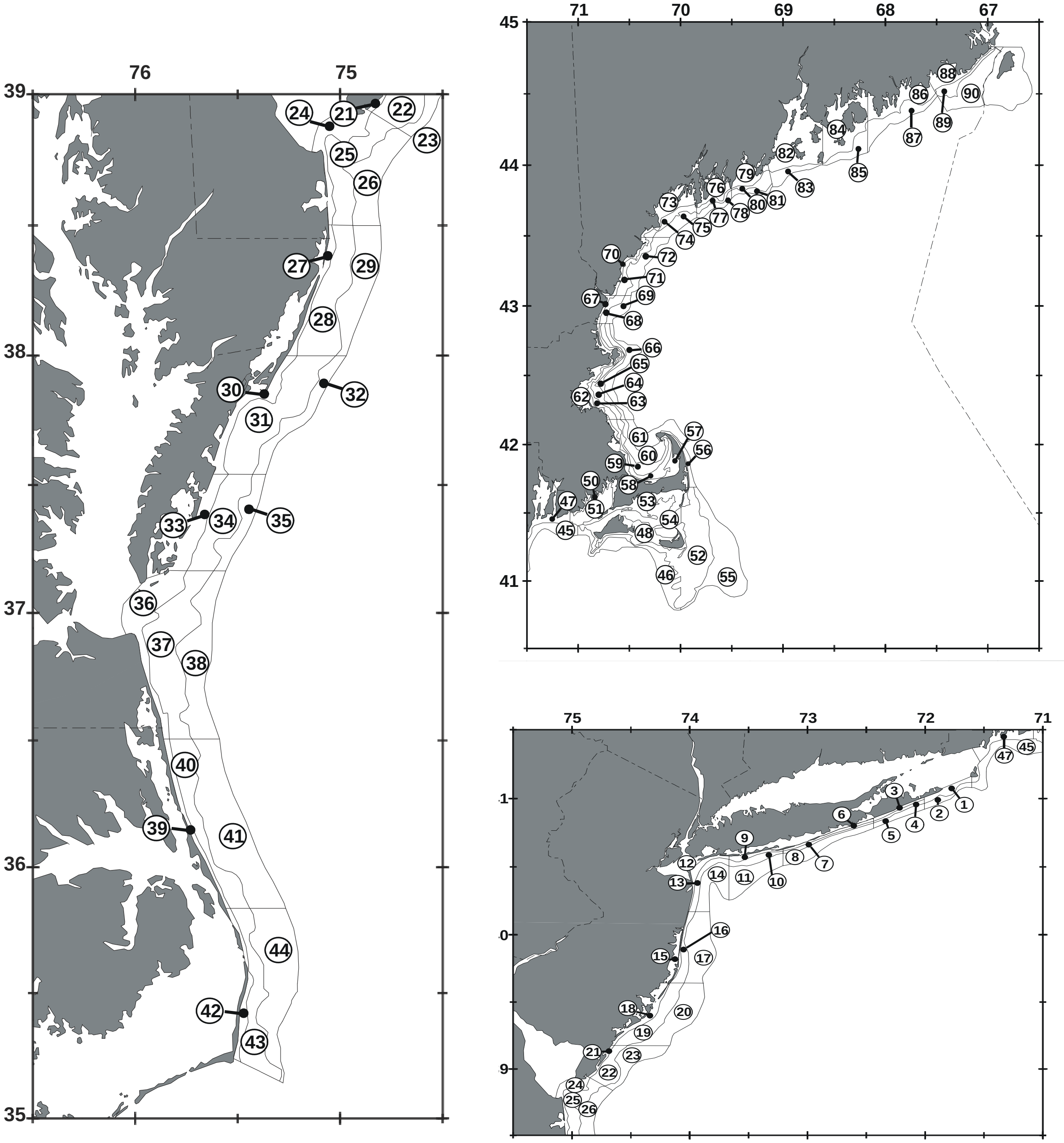


Figure 2. Inshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys.

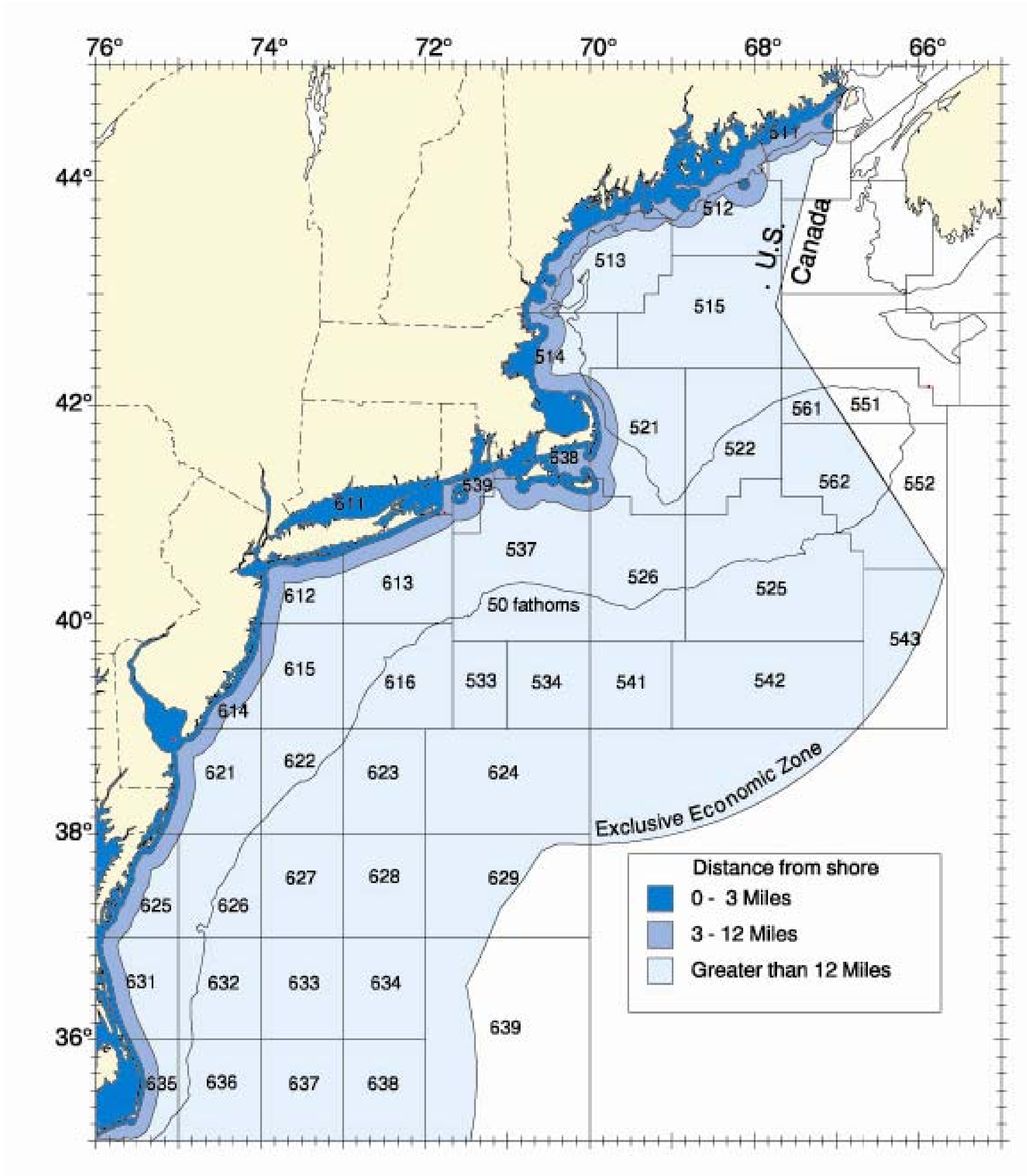


Figure 3. Statistical areas used for reporting commercial catches.

## A: MONKFISH (GOOSEFISH) ASSESSMENT SUMMARY FOR 2010

### State of Stock

The new 2010 assessment has updated the biological reference points based on an updated yield-per-recruit analysis and the results of the SCALE length-tuned population model that incorporates multiple survey indices and catch data. Based on accepted reference points from these updated analyses, monkfish in both the northern and southern management areas are not overfished and overfishing is not occurring (Figures A1 and A2).

The existing overfishing threshold is based on Fmax, and this was retained in the 2010 assessment. The updated estimates of Fmax are 0.43 per year in the northern area and 0.46 per year in the southern area. Estimates of current F (2009) are 0.10 per year in the northern area and 0.07 per year in the southern area, both less than the respective overfishing thresholds.

The new recommended estimates of Btarget are 52,930 mt in the northern area and 74,490 mt in the southern area, and estimates of Bthreshold are 26,465 mt in the northern area and 37,245 mt in the southern area. The current (2009) estimates of total biomass are 66,062 mt in the northern area and 131,218 mt in the southern area. The total catch produced from the long-term Btarget at the respective values of Fmax (i.e., proxy for Fmsy), is 10,745 mt for the northern area and 15,279 mt for the southern area. These updated biomass reference points are based upon a new methodology.

If the previous assessment reference points had been used, both resources would have been declared not overfished and overfishing not occurring (Figure A1).

This represents our current best scientific understanding of the monkfish stock status; however, the SARC-50 panel expressed serious concerns regarding the high levels of uncertainty throughout this assessment. The assessment results continue to be uncertain due to cumulative effects of under-reported landings, unknown discards during the 1980s, uncertainty in survey indices, and incomplete understanding of key biological parameters such as age and growth, longevity, natural mortality and stock structure contributing to retrospective patterns primarily in the northern management area [see Special Comments].

### Projections

Uncertainty in the current state for the northern management area makes it difficult to predict stock dynamics in that area. Keeping this in mind, SCALE model results and AGEPRO projections were used to evaluate stock trends during 2011-2016. Projections were done using Fthreshold and NEFMC-proposed Annual Catch Targets (ACTs) and Acceptable Biological Catches (ABCs). Stochastic long-term recruitment was assumed. Projections also assumed that F in 2010 would equal the estimated F in 2009 from the SCALE model.

Projections for the northern management area (NMA) are more likely to be unrealistic than for the southern area, given the relatively strong retrospective pattern in the model observed since 2002. The projections indicate that the northern area is more likely than the southern area to experience overfishing during 2011-2016 if total catches approach the proposed ABC.

## Projection Tables

### Northern Management Area Projection Table

**Annual P relative to BRP** **Catch and Biomass in Metric tons**

**Basis for Projection = Proposed ACT**

| Year | F | Total Catch | Total Biomass | P < 0.5*Bmax | P > Fmax |
|---|---|---|---|---|---|
| 2010 | 0.10 | 4,447 | 74,102 | 0% | 0% |
| 2011 | 0.22 | 10,750 | 81,907 | 0% | 0% |
| 2012 | 0.22 | 10,750 | 81,204 | 0% | 0% |
| 2013 | 0.22 | 10,750 | 80,225 | 0% | 0% |
| 2014 | 0.23 | 10,750 | 78,944 | 0% | 0% |
| 2015 | 0.24 | 10,750 | 77,548 | 0% | 0% |
| 2016 | 0.24 | 10,750 | 76,383 | 0% | 0% |

**Basis for Projection = Proposed ABC**

| Year | F | Total Catch | Total Biomass | P < 0.5*Bmax | P > Fmax |
|---|---|---|---|---|---|
| 2010 | 0.10 | 4,447 | 74,102 | 0% | 0% |
| 2011 | 0.38 | 17,485 | 81,907 | 0% | 4% |
| 2012 | 0.44 | 17,485 | 73,769 | 0% | 52% |
| 2013 | 0.54 | 17,485 | 64,796 | 0% | 94% |
| 2014 | 0.71 | 17,485 | 55,815 | 0% | 99% |
| 2015 | 1.01 | 17,485 | 46,871 | 0% | 100% |
| 2016 | 1.69 | 17,485 | 37,631 | 12% | 100% |

**Basis for Projection = Fthreshold** **n/a = not applicable**

| Year | F | Total Catch | Total Biomass | P < 0.5*Bmax | P > Fmax |
|---|---|---|---|---|---|
| 2010 | 0.10 | 4,447 | 74,102 | 0% | 0% |
| 2011 | 0.43 | 19,557 | 81,907 | 0% | n/a |
| 2012 | 0.43 | 16,553 | 70,831 | 0% | n/a |
| 2013 | 0.43 | 14,120 | 62,846 | 0% | n/a |
| 2014 | 0.43 | 12,402 | 57,627 | 0% | n/a |
| 2015 | 0.43 | 11,384 | 54,619 | 0% | n/a |
| 2016 | 0.43 | 10,883 | 53,298 | 0% | n/a |

## Southern Management Area Projection Table

**Annual P relative to BRP** **Catch and Biomass in Metric tons**

**Basis for Projection = Proposed ACT**

| Year | F | Total Catch | Total Biomass | P < 0.5*Bmax | P > Fmax |
|---|---|---|---|---|---|
| 2010 | 0.07 | 6,235 | 131,344 | 0% | 0% |
| 2011 | 0.13 | 11,469 | 132,243 | 0% | 0% |
| 2012 | 0.14 | 11,469 | 126,295 | 0% | 0% |
| 2013 | 0.15 | 11,469 | 121,055 | 0% | 0% |
| 2014 | 0.16 | 11,469 | 116,674 | 0% | 0% |
| 2015 | 0.17 | 11,469 | 113,979 | 0% | 0% |
| 2016 | 0.17 | 11,469 | 113,777 | 0% | 0% |

**Basis for Projection = Proposed ABC**

| Year | F | Total Catch | Total Biomass | P < 0.5*Bmax | P > Fmax |
|---|---|---|---|---|---|
| 2010 | 0.07 | 6,235 | 131,344 | 0% | 0% |
| 2011 | 0.15 | 13,326 | 132,243 | 0% | 0% |
| 2012 | 0.16 | 13,326 | 124,255 | 0% | 0% |
| 2013 | 0.18 | 13,326 | 114,149 | 0% | 0% |
| 2014 | 0.20 | 13,326 | 111,160 | 0% | 0% |
| 2015 | 0.22 | 13,326 | 107,047 | 0% | 0% |
| 2016 | 0.23 | 13,326 | 105,443 | 0% | 0% |

**Basis for Projection = Fthreshold** **n/a = not applicable**

| Year | F | Total Catch | Total Biomass | P < 0.5*Bmax | P > Fmax |
|---|---|---|---|---|---|
| 2010 | 0.07 | 6,235 | 131,344 | 0% | 0% |
| 2011 | 0.46 | 36,245 | 132,243 | 0% | n/a |
| 2012 | 0.46 | 25,171 | 99,182 | 0% | n/a |
| 2013 | 0.46 | 18,484 | 80,735 | 0% | n/a |
| 2014 | 0.46 | 15,033 | 72,167 | 0% | n/a |
| 2015 | 0.46 | 13,857 | 69,597 | 0% | n/a |
| 2016 | 0.46 | 13,878 | 69,949 | 0% | n/a |

**Catches**

Reported total landings (live weight) increased from an average of 2,500 mt in the 1970s to 8,700 mt in the 1980s, 23,000 mt in the 1990s, 22,000 mt from 2000-2005 and 11,600 mt during 2006-2009 (Figure A5). Total landings have declined since 2003 due to management regulations including TACs during 2007-2009 of 5,000 mt in the northern region and 5,100 mt in the southern region. Landings in 2009 were 3,255 mt in the northern region and 5,302 mt in the southern region. Landings in the early part of the time series are thought to be under-reported. The accuracy of landings data has likely improved with mandatory reporting beginning in 1994.

During 1990-1999, 53% of USA monkfish landings were taken in otter trawls, 28% in scallop dredges, and 18% in gill nets (Figure A6). During 2000-2009, 50% of USA monkfish landings were taken in otter trawls, 6% in scallop dredges, 36% in gill nets, and 8% other gear. While trawl gear accounts for most of the landings in the northern area (75% during 2000-2009), gillnets now account for the majority of the landings in the southern area (54% during 2000-2009).

Estimated total discards of monkfish have ranged between 1,600 mt (1992) and 7,500 mt (2001) per year, with a long-term discard/kept ratio of 0.15 (1989-2009, northern and southern areas combined). Discard rates have been highest in the scallop dredge fisheries in the southern area, and lowest in gillnets in both areas. Discard ratios and discard levels (mt) increased in both areas after 2000, and have since declined somewhat (overall discard/kept ratio for 2000-2004 =0.20; for 2005-2009=0.17).

## Catch and Status Table (weights in '000 mt): Monkfish (Goosefish)

| Year | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | Max[1] | Min[1] | Mean[1] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| USA Commercial landings | | | | | | | | | | | | | |
| Northern area | 10.7 | 13.3 | 14.0 | 15.0 | 13.2 | 10.3 | 6.7 | 4.9 | 4.0 | 3.3 | 15.0 | 3.2 | 7.6 |
| Southern area | 10.1 | 10.0 | 8.9 | 11.1 | 8.0 | 8.8 | 7.9 | 7.3 | 6.9 | 5.3 | 19.3 | 3.7 | 9.1 |
| Total | 20.9 | 23.3 | 22.9 | 26.1 | 21.2 | 19.1 | 14.6 | 12.1 | 11.0 | 8.6 | 28.2 | 7.3 | 16.7 |
| USA Commercial discards | | | | | | | | | | | | | |
| Northern area | 1.0 | 2.9 | 1.4 | 1.3 | 0.9 | 0.9 | 0.5 | 0.4 | 0.4 | 0.5 | 2.9 | 0.4 | 1.0 |
| Southern area | 1.5 | 4.6 | 3.4 | 3.2 | 2.7 | 2.5 | 1.8 | 1.8 | 1.1 | 0.8 | 4.6 | 0.6 | 2.0 |
| Total | 2.5 | 7.5 | 4.8 | 4.5 | 3.6 | 3.4 | 2.3 | 1.2 | 1.5 | 1.3 | 7.5 | 1.6 | 3.0 |
| Foreign landings[2] | 0.2 | 0.1 | 0.3 | 0.3 | 0.2 | 0.2 | 0.3 | 0 | 0 | 0 | 0.3 | <0.1 | 0.4 |
| Total Catch | 23.6 | 30.9 | 28.0 | 30.9 | 24.9 | 22.7 | 17.2 | 13.3 | 12.5 | 9.9 | 31.0 | 9.9 | 24.1 |
| | | | | | | | | | | | | | |
| Northern area | | | | | | | | | | | | | |
| Total Biomass[3] | 56.0 | 63.2 | 65.5 | 65.5 | 57.1 | 50.6 | 47.9 | 51.4 | 58.2 | 66.1 | 100.4 | 41.2 | 62.0 |
| F | 0.46 | 0.68 | 0.82 | 1.13 | 0.96 | 0.71 | 0.38 | 0.22 | 0.14 | 0.10 | 1.13 | 0.10 | 0.56 |
| Age-1 recruitment[4] | 44,137 | 29,071 | 18,412 | 18,771 | 19,798 | 14,750 | 25,032 | 18,373 | 17,459 | 16,147 | 44,137 | 14,750 | 22,195 |
| | | | | | | | | | | | | | |
| Southern area | | | | | | | | | | | | | |
| Total Biomass[3] | 102.2 | 108.5 | 111.9 | 117.1 | 119.2 | 123.0 | 125.7 | 129.2 | 131.1 | 131.2 | 146.7 | 99.2 | 121.3 |
| F | 0.17 | 0.21 | 0.20 | 0.22 | 0.16 | 0.16 | 0.13 | 0.12 | 0.10 | 0.07 | 0.22 | 0.07 | 0.15 |
| Age-1 recruitment[4] | 33,286 | 16,235 | 32,177 | 41,825 | 24,292 | 16,460 | 14,451 | 13,113 | 17,880 | 18,988 | 41,825 | 13,113 | 22,871 |

[1]Landings data based on 1980-2009 ('000 mt). Commercial fishery discard means from 1989-2009.

[2] Foreign landings are for NAFO Areas 5 and 6.

[3] Estimates from SCALE model ('000 mt)

[4] Estimates from SCALE model (thousands of fish)

## Stock Distribution and Identification

The monkfish resource in US waters is distributed from the Gulf of Maine through Cape Hatteras, NC. Current management practice divides US waters into two areas north and south of Georges Bank to accommodate differences in fishery practices. Information on growth, maturity, and genetics tends to support the hypothesis of a single biological stock. Information from recent and ongoing tagging studies is equivocal, but indicates limited movement of fish from the northern management area to the southern area. Patterns in recruitment tend to support the hypothesis of two biological stocks. In the past, fishing practices and estimated fishery selectivity also tended to support management and assessment for two areas; however, the current mix of removals by gear provides model estimates indicating very similar average fishery selectivity in the two areas.

## Data and Assessment

Data used in the 2010 assessment include data from NEFSC surveys, ME/NH surveys, and cooperative monkfish surveys conducted in 2001, 2004 and 2009 (see below) as well as commercial fishery data from vessel trip reports, dealer landings records and on-board fishery observers through 2009. The assessment assumed a natural mortality rate (M) = 0.3. Fishing mortality rates and stock sizes were estimated using the SCALE statistical catch-at-length model.

A cooperative monkfish survey was conducted during February-April 2009 using two industry trawlers and 3 nets (2 flat, 1 rockhopper). The survey design differed slightly from previous cooperative surveys (in 2001, 2004) because sampling effort was allocated proportional to stratum area (with extra sampling in strata designated by industry) rather than proportional to spatial patterns of fishing effort. A total of 204 successful survey tows and 91 gear experiment tows were completed in USA waters from Cape Hatteras through the Gulf of Maine. Absolute estimates of biomass, abundance and length composition were developed using catch and area swept by each tow and net efficiency estimates from depletion experiments. Proportion at length from the cooperative surveys was used in the SCALE model; however, the estimates of absolute population biomass and abundance were not included in the final model runs due to poor model fit.

The model for the northern area exhibited retrospective patterns in fishing mortality and stock size that were strongest for the 2002-2006 terminal years and weaker for the 2007-2008 terminal years (Figure A3). The retrospective underestimation of fishing mortality averaged -66% for the 2002-2008 terminal years, ranging from -21% for the 2008 terminal year to -84% for the 2003 terminal year. The retrospective overestimation of total biomass averaged +108% for the 2002-2008 terminal years, ranging from +17% for the 2008 terminal year to +163% for the 2003 terminal year. The retrospective estimation error in recruitment at age 1 averaged +36% for the 2002-2008 terminal years, ranging from -2% for the 2008 terminal year to +89% for the 2003 terminal year.

The model for the southern area exhibited moderate retrospective patterns in fishing mortality and stock size since 2002 (Figure A4). The retrospective underestimation of fishing mortality averaged -13% for the 2002-2008 terminal years, ranging from -9% for the 2008 terminal year to -21% for the 2006 terminal year. The retrospective overestimation of total biomass averaged +16% for the 2002-2008 terminal years, ranging from +8% for the 2008 terminal year to +22% for the 2006 terminal year. The retrospective overestimation of recruitment at age 1 averaged +48% for the 2002-2008 terminal years, ranging from +12% for the 2008 terminal year to +130% for the 2006 terminal year.

## Biological Reference Points

Previous monkfish biomass targets and thresholds (NEFSC 2007) were based on long-term average biomass and a low point in the biomass time series from which the stock recovered, respectively. The current assessment recommends using a different approach that is used for New England groundfish stocks based on the long-term projected biomass corresponding to Fmsy or its proxy. For monkfish this proxy is Fmax. Based on the new approach, total biomass targets (i.e., Bmax at Fmax) and thresholds (0.5*Bmax) were calculated for monkfish for the northern and southern management areas. Btarget is 52,930 mt in the northern area and 74,490 mt in the southern area, and Bthreshold is 26,465 mt in the northern area and 37,245 mt in the southern area. The total catch produced from the long-term Btarget at the respective values of

Fmax (i.e., proxy for Fmsy), is 10,745 mt for the northern management area and 15,279 mt for the southern management area.

The existing overfishing threshold is based on Fmax, and this was retained in the 2010 assessment, with updated estimates of Fmax = 0.43 per year in the northern area and Fmax = 0.46 per year in the southern area.

The following table summarizes biological reference points for monkfish from the 2007 and 2010 assessments. These were calculated using different methods as indicated in the 'Basis' column.

| **Management Area** | | **Biomass BRPs in metric tons** | | |
|---|---|---|---|---|
| **North** | **BRP** | **Basis** | **NEFSC 2007** | **SAW 2010** |
| | Fmax | YPR | 0.31 | 0.43 |
| | Bthreshold | Bloss 1980-2006 | 65,200 | |
| | Bthreshold | Bloss 1980-2009 | | 41,238 |
| | Bthreshold | 0.5*Bmax Projected | | 26,465 |
| | Btarget | Bavg 1980-2006 | 92,200 | 62,371 |
| | Btarget | Bavg 1980-2009 | | 61,991 |
| | Btarget | Bmax Projected | | 52,930 |
| | MSY | Fmax Projected | | 10,745 |
| **South** | **BRP** | **Basis** | **NEFSC 2007** | **SAW 2010** |
| | Fmax | YPR | 0.40 | 0.46 |
| | Bthreshold | Bloss 1980-2006 | 96,400 | |
| | Bthreshold | Bloss 1980-2009 | | 99,181 |
| | Bthreshold | 0.5*Bmax Projected | | 37,245 |
| | Btarget | Bavg 1980-2006 | 122,500 | 120,292 |
| | Btarget | Bavg 1980-2009 | | 121,313 |
| | Btarget | Bmax Projected | | 74,490 |
| | MSY | Fmax Projected | | 15,279 |

## Fishing Mortality

Fishing mortality estimated for 2009 from the SCALE model (assuming M=0.3 per year) was F = 0.10 per year in the northern area, and F = 0.07 per year in the southern area (Figure A1). Fishing mortality has declined in both areas since 2003.

## Recruitment

Northern area SCALE model results (Figure A3) indicate that the strongest year classes were produced in 1997-1999. Recruitment was generally below average in the 1980s, and has been about average since 2001. The time series average recruitment is about 20 million age 1 fish. Southern area results (Figure A4) indicate that the strongest year classes were produced in 1992, 1997, and 2002, with the weakest year class produced in 1987. Recruitment has been below average since 2004. The time series average recruitment is about 23 million age 1 fish.

## Stock Biomass

Total stock biomass in the northern area declined steadily from the early 1980s through the early 1990s, remained at a relatively low level during the 1990s and then began to increase after 1999 (Figure A2). Biomass in the northern area has been relatively stable since 2003, and was estimated to be 66,062 mt in 2009. In the southern area, total biomass increased until the late 1980s and then declined throughout the 1990s. Biomass has increased in the southern area since 1999, and was estimated to be 131,218 mt in 2009 (Figure A2).

## Ecosystem Considerations

Monkfish is potentially one of the dominant piscivores in the ecosystem. The amount of food consumed by monkfish is 0.005-0.02% of all energy flows in the ecosystem, and monkfish account for 2-6% of the total consumption by all finfish in the ecosystem (1-4 % in the northern area, 2-8% in the southern area). The amount of food eaten and per capita consumption peaked in the early 1980s for both stocks, driven by larger fish. Monkfish consumption of mackerel and herring is equivalent to 20-50% of landings, and they consume the same magnitude of squid as the landings of squid, and potentially consume more than the landings of silver hake and skates.

## Special Comments

- Without knowing the reason(s) for the retrospective pattern in the model, it is not possible to know if the 2010 assessment is biased. In the north, if the 2010 assessment suffers from a retrospective bias equal to that seen on average over the past 7 years, a projection at the proposed ACT = 10,750 mt using retrospective adjusted 2009 stock sizes indicates a 65% chance that total biomass will fall below the adjusted Bthreshold by 2016. This is a very different result from the unadjusted analyses (see Projections).
- The assessment is uncertain for a number of reasons, including uncertainty due to cumulative effects of under-reported landings, unknown discards during the 1980s, uncertainty in survey indices, distribution of monkfish outside the survey areas, and incomplete understanding of key biological parameters such as age and growth, longevity, natural mortality and stock structure contributing to retrospective patterns primarily in the northern management area. The model results are sensitive to the assumed value of natural mortality (M) of 0.3 per year, adopted by NEFSC (2007). This value was adjusted in 2007 as a compromise between the observed longevity of males (~7 yr) and females (at least age 13); however, both sexes may potentially have longer lifespans. Uncertainties in key life history parameters and historical catches are unlikely to be resolved in the short term.
- The SCALE model allows integration of a wide variety of input information and facilitates estimation of uncertainty of fishery selectivity and stock sizes; these estimates can then be used in stochastic projections to provide measures of uncertainty of future trends of the monkfish populations in the management areas. However, these projections are subject to the same uncertainties that are of concern regarding the assessment model.
- The higher monkfish catch efficiency of the new NOAA vessel *Henry Bigelow* is expected to improve our ability to monitor trends in abundance.

**References**

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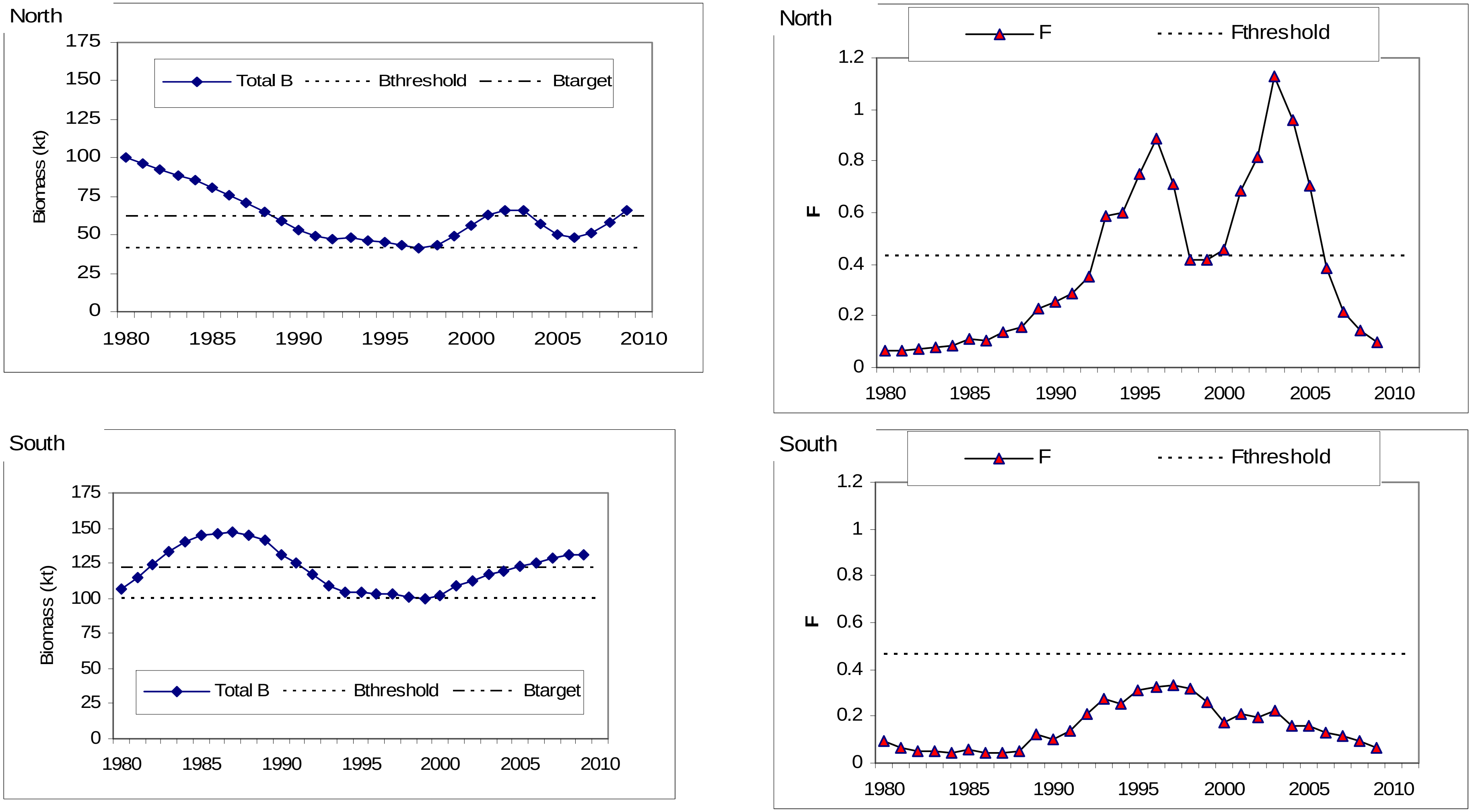
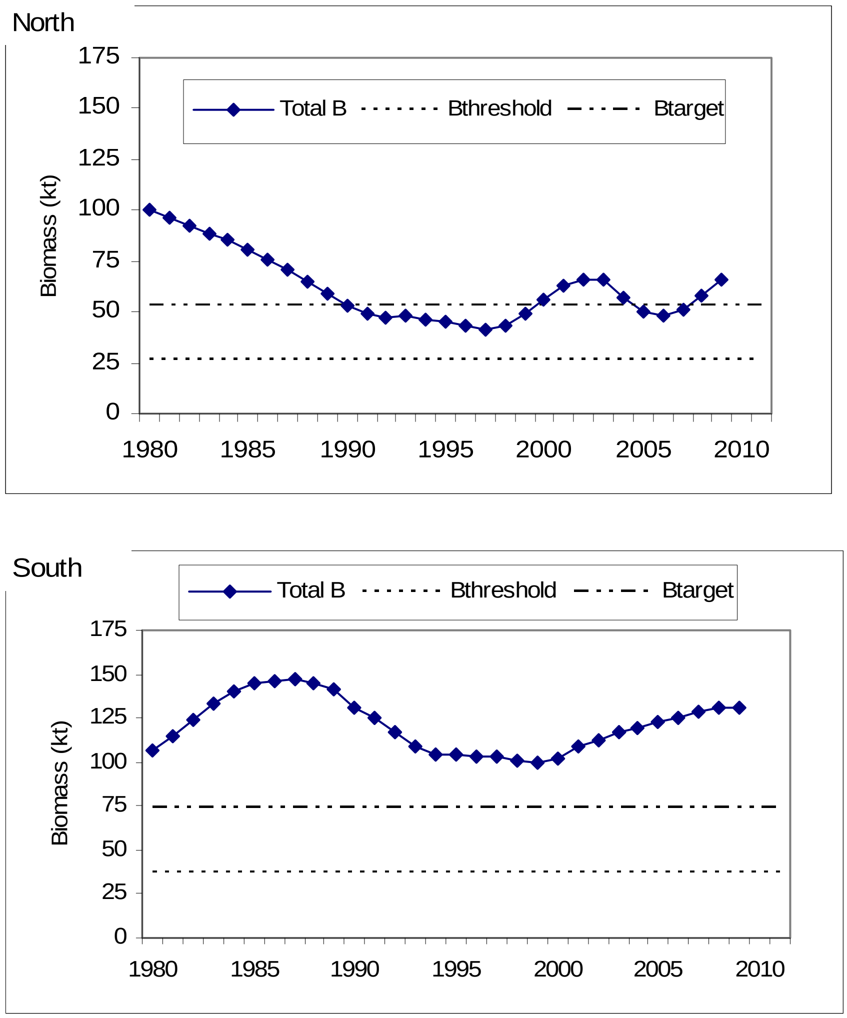
Richards RA, Nitschke P, Sosebee K. 2008. Population biology of monkfish *Lophius americanus*. ICES J Mar Sci. 65: 1291-1305.

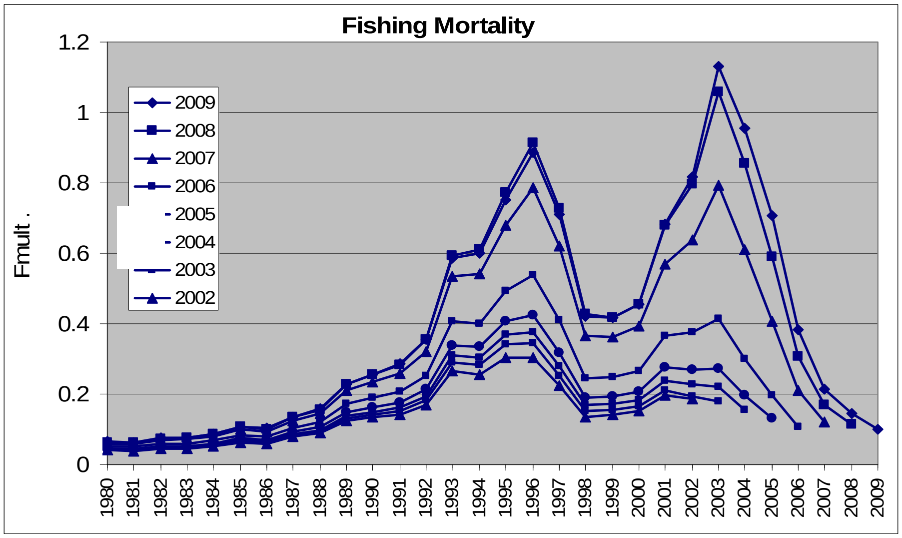
**Figures:**

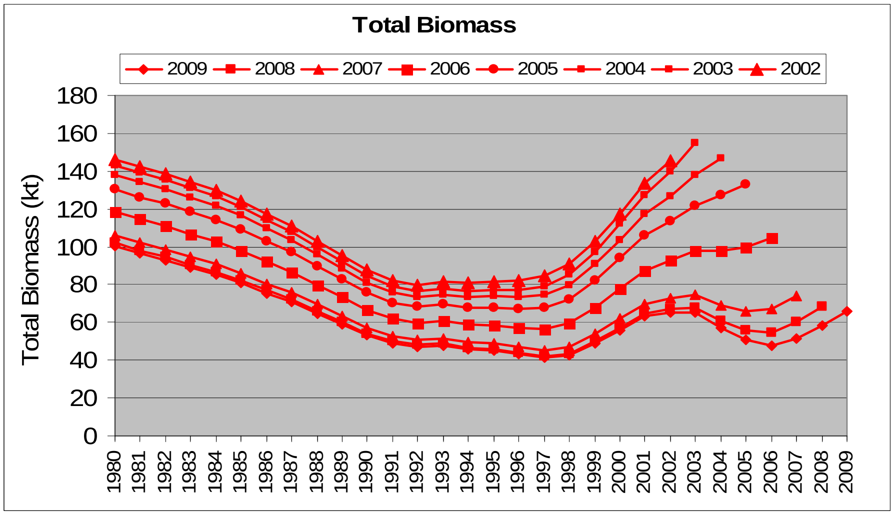


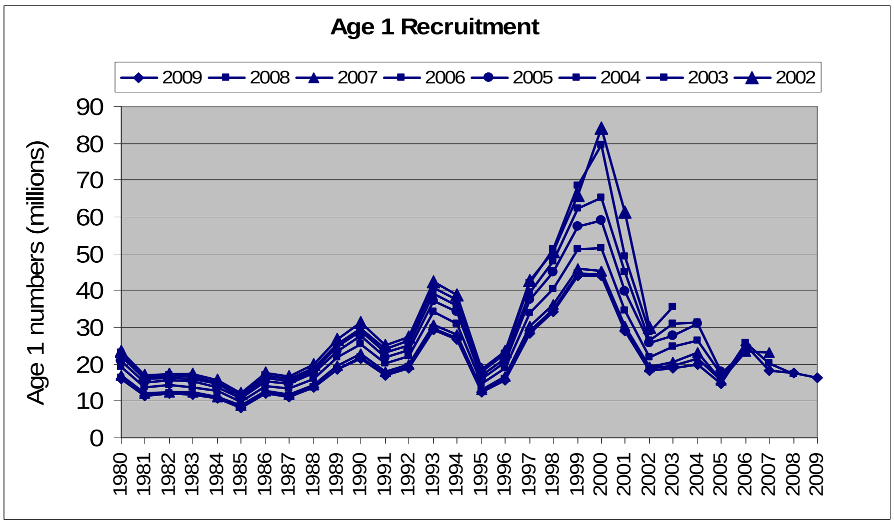

**A1.** Trends in total biomass and fishing mortality rate (F) from the 2010 assessment model (SCALE) relative to updated biological reference points using previous (NEFSC 2007) definitions in the monkfish fishery management plan for northern and southern areas. Panels on the right can be used to determine status with respect to overfishing.



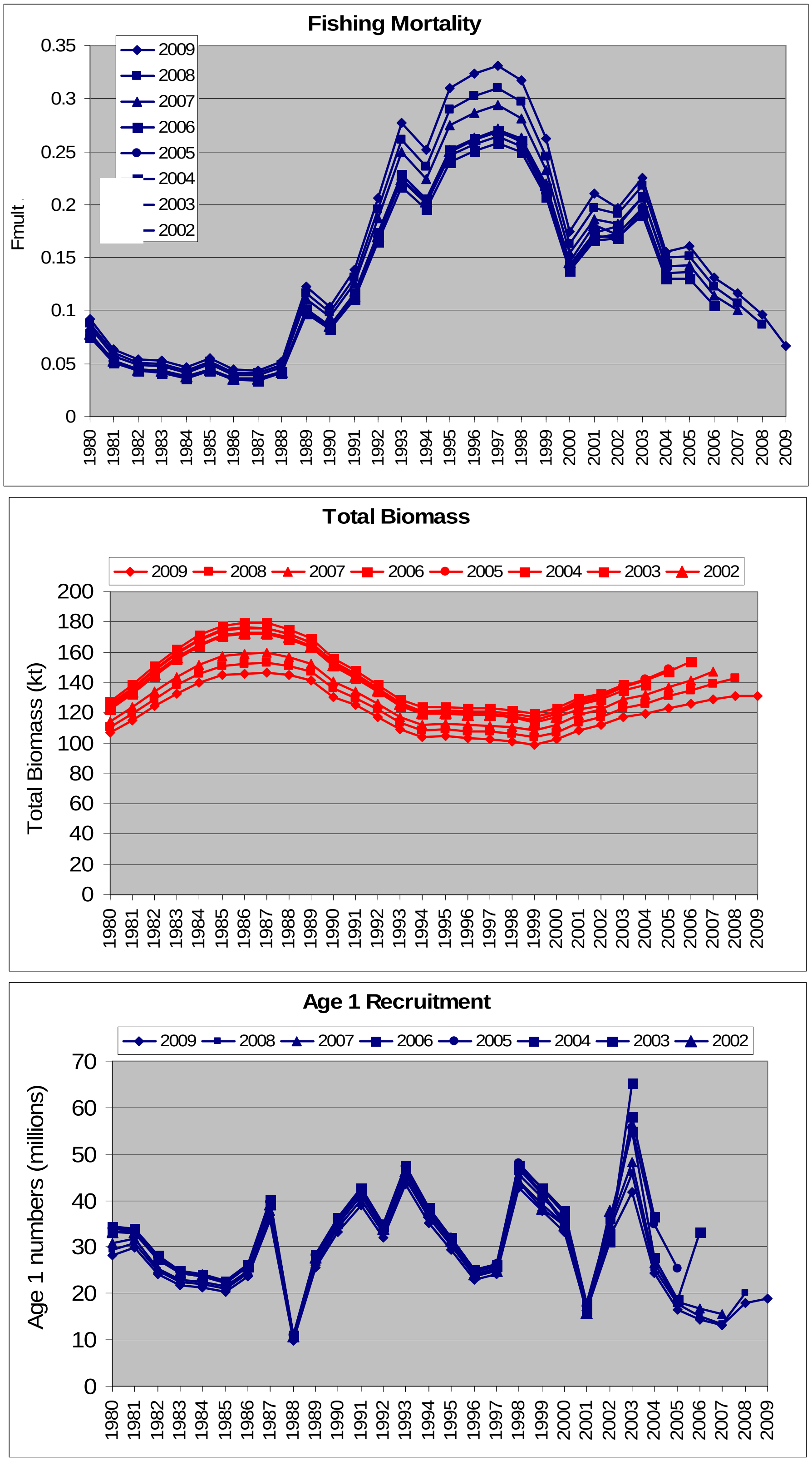

**A2.** Trends in total biomass from the assessment model (SCALE) relative to new recommended biomass reference points for the northern and southern management areas. This figure can be used to determine status with respect to whether stocks are overfished.



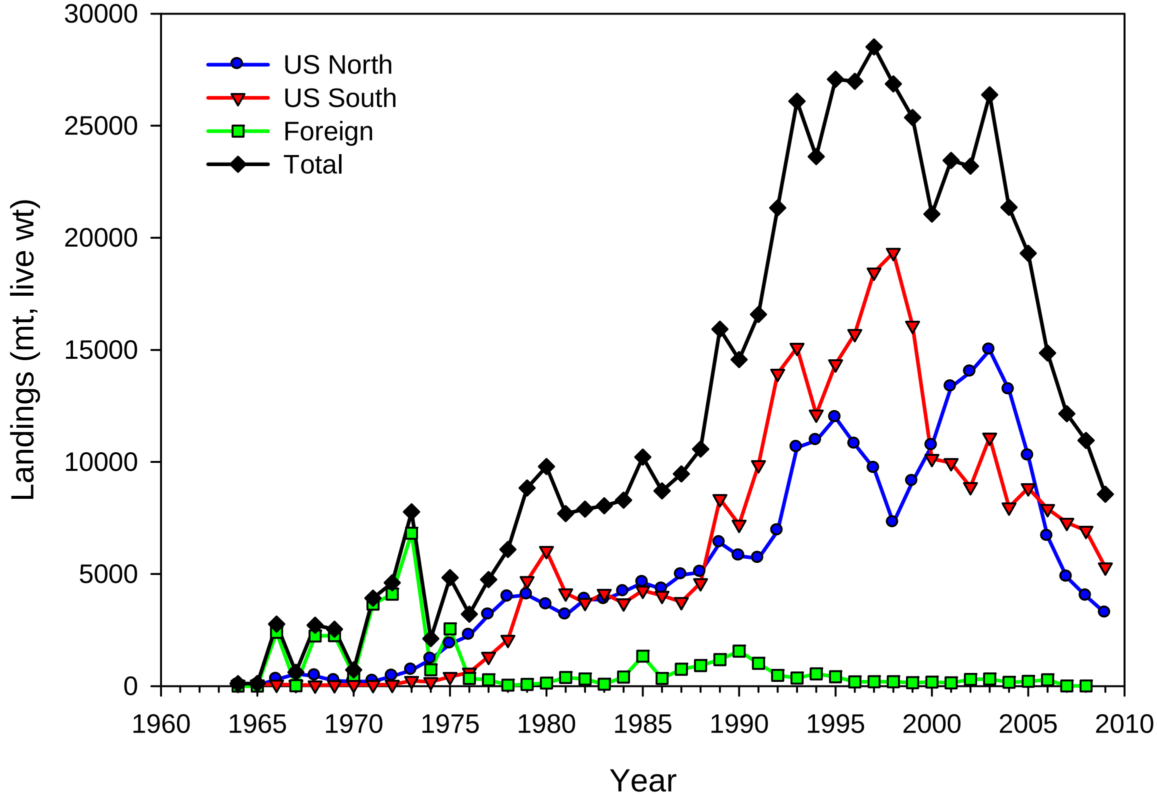



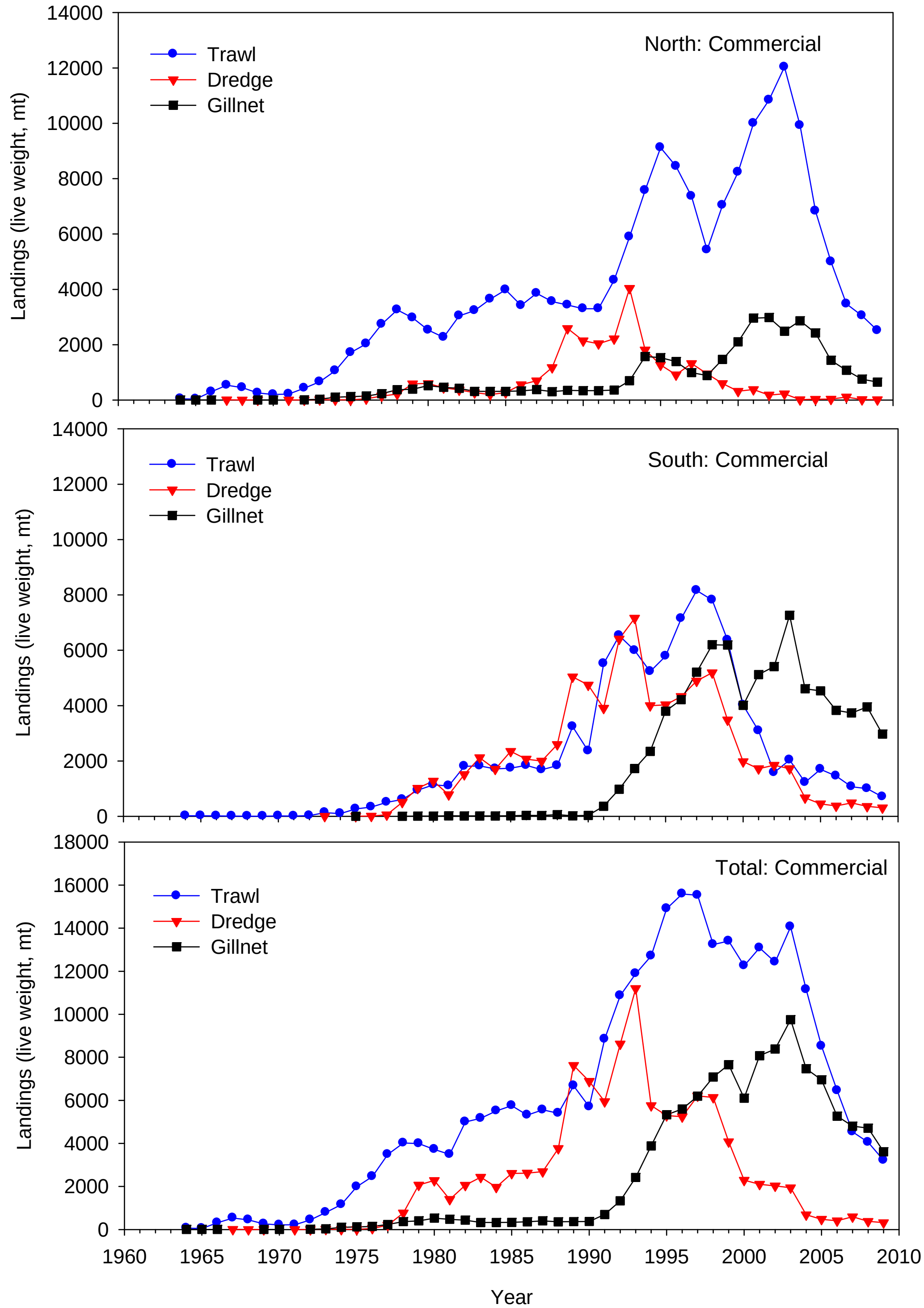

**A3.** Retrospective patterns in estimated monkfish fishing mortality, biomass and recruitment from the SCALE model for the **northern** management region.




**A4.** Retrospective patterns in estimated monkfish fishing mortality, biomass and recruitment from the SCALE model for the **southern** management region.




**A5.** Monkfish commercial fishery landings, by management region and total, 1964-2009.




**A6.** Monkfish commercial fishery landings by major gear type, northern, southern and combined management regions.

## B. SEA SCALLOP ASSESSMENT SUMMARY FOR 2010

### State of Stock

During 2009, the sea scallop stock was not overfished and overfishing was not occurring. Using the new recommended reference point approach, estimated biomass (40+ mm SH) on July 1, 2009 was 129.7 thousand mt meats (Figure B1), which is above $B_{TARGET}$=$B_{MSY}$=125 thousand mt meats, and the $B_{THRESHOLD}$=½$B_{MSY}$=62.6 thousand mt meats.
The estimated fishing mortality rate during 2009 was $F$=0.378 (Figure B2). Based on the new recommended overfishing threshold reference point, the stock was near its mortality threshold but overfishing did not occur because the estimated fishing mortality is slightly lower than $F_{Threshold}$=$F_{MSY}$=0.38. The probability that overfishing occurred during 2009 is slightly less than 50%.

### Projections

Projections are carried out by the Sea Scallop Fishery Management Plan Development Team (PDT) using a spatially structured model (SAMS) that accommodates variability in recruitment, vital rates and fishing among regions. Scallop management approaches are complex because they are spatially explicit and dependent on regional recruitment levels and other factors. SAMS was used in this assessment to provide example projection results (Figures B4 and B5). These example projections indicate that stock biomass would increase slightly during 2009-2012 under a management strategy of F = 0.24.

### Stock Distribution and Identification

Sea scallops are distributed from Cape Hatteras to Newfoundland. Populations are found on Georges Bank (GBK), including the Canadian portion, the Gulf of Maine (GOM), and Mid Atlantic Bight (MAB). Sea scallops in US waters were assessed based on two main stock assessment regions - GBK and MAB. Results for GBK and MAB were combined to characterize the entire (i.e. total) EEZ stock. A component of the stock occurs in the GOM but landings and biomass there are small relative to the stock as a whole. Overfishing and overfished status was evaluated for the entire stock (GBK and MAB), as specified by the current Sea Scallop Fishery Management Plan (New England Fisheries Management Council 2010). Overfishing and overfished status were not evaluated for the GOM region.

### Catch

Annual landings increased from about 8000 mt meats in the mid-1980s to over 17,000 mt meats in 1990-1991, then fell to between 5000 and 8000 mt meats during the 1993-1998 (Figure B6). Landings increased considerably from 1998-2003 and have remained at high and relatively stable levels since then. US landings during 2003-2009 exceeded 24,000 mt (meats) during each year, and were roughly twice the long-term mean.

Discarding occurs due to catch of undersized scallops and some highgrading (in Special Access Areas). Discards averaged about 2300 mt during 2002 – 2004 and 800 mt since 2005 (see “Catch and Status Table”). Although discards are not included in the CASA assessment model, some compensation for this is considered through use of an estimate of incidental mortality.

## Catch and Status Table: Sea scallops

**U.S Landings (mt meats)**

| *Year* | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | Min[1] | Max[1] | Mean[1] | Median[1] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *GBK* | 5,044 | 5,008 | 6,043 | 4,940 | 5,398 | 9,940 | 17,807 | 9,842 | 6,765 | 6,695 | 1,040 | 17,807 | 5,654 | 5,261 |
| *MAB* | 9,351 | 15,703 | 17,443 | 20,276 | 23,533 | 15,566 | 8,772 | 16,634 | 17,388 | 19,350 | 731 | 23,533 | 7,650 | 5,124 |
| *GOM* | 226 | 343 | 405 | 201 | 177 | 187 | 155 | 117 | 120 | 84 | 84 | 1,614 | 483 | 407 |
| *SNE*[6] | 89 | 65 | 32 | 57 | 992 | 898 | 2,047 | 360 | 325 | 220 | 7 | 2,047 | 206 | 79 |
| *Total* | 14,710 | 21,119 | 23,923 | 25,474 | 30,100 | 26,591 | 28,781 | 26,953 | 24,598 | 26,349 | 14,710 | 30,100 | 24,860 | 25,912 |

**U.S. Discards (mt meats)**

| *Year* | 2000[2] | 2001[2] | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | Min[3] | Max[3] | Mean[3] | Median[3] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *GBK* | -- | -- | 103 | 181 | 103 | 421 | 868 | 240 | 259 | 289 | 103 | 868 | 308 | 250 |
| *MAB* | -- | -- | 1,673 | 2,386 | 2,482 | 473 | 254 | 162 | 372 | 748 | 162 | 2,482 | 1,069 | 611 |
| *Total* | -- | -- | 1,776 | 2,567 | 2,585 | 894 | 1,122 | 402 | 631 | 1,037 | 402 | 2,585 | 1,377 | 1,080 |

**Estimated abundance (July 1, 40+ mm SH, millions, from CASA model)**

| *Year* | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | Min | Max | Mean | Median |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *GBK* | 3,129 | 3,294 | 2,819 | 2,945 | 2,708 | 2,571 | 2,128 | 2,364 | 2,769 | 3,453 | 531 | 3,453 | 1,579 | 1,260 |
| *MAB* | 3,523 | 3,766 | 3,427 | 4,174 | 3,703 | 3,609 | 3,805 | 3,853 | 4,509 | 3,993 | 343 | 4,509 | 1,713 | 977 |
| *Combined* | 6,652 | 7,061 | 6,246 | 7,119 | 6,411 | 6,180 | 5,933 | 6,217 | 7,278 | 7,446 | 1,070 | 7,446 | 3,292 | 2,191 |

**Estimated biomass for status determination (July 1, 40+ mm SH, thousand mt meats, from CASA model)**

| *Year* | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | Min | Max | Mean | Median |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *GBK* | 41,066 | 53,064 | 62,370 | 69,416 | 74,629 | 73,828 | 62,769 | 53,650 | 55,508 | 62,470 | 4,868 | 74,629 | 27,679 | 17,822 |
| *MAB* | 37,324 | 45,796 | 48,798 | 48,756 | 50,029 | 49,027 | 56,405 | 61,784 | 63,983 | 67,233 | 5,426 | 67,233 | 21,321 | 9,340 |
| *Combined* | 78,389 | 98,859 | 111,167 | 118,171 | 124,658 | 122,855 | 119,174 | 115,434 | 119,492 | 129,703 | 10,502 | 129,703 | 49,001 | 25,500 |

**Recruitment, (millions, approximate age 2 y, from CASA model)**

| *Year* | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | Min | Max | Mean | Median |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *GBK* | 2,015 | 915 | 239 | 882 | 316 | 512 | 389 | 1,075 | 1,062 | 1,425 | 126 | 2,015 | 679 | 619 |
| *MAB* | 1,678 | 1,722 | 969 | 3,073 | 651 | 1,868 | 1,306 | 1,356 | 2,561 | 412 | 93 | 3,073 | 878 | 648 |
| *Combined* | 3,693 | 2,637 | 1,207 | 3,955 | 968 | 2,379 | 1,695 | 2,431 | 3,624 | 1,837 | 219 | 3,955 | 1,557 | 1,400 |

**Estimated fully recruited fishing mortality for status determination (from CASA model)[4]**

| *Year* | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | Min | Max | Mean | Median |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *GBK* | 0.48 | 0.26 | 0.23 | 0.17 | 0.10 | 0.18 | 0.38 | 0.25 | 0.19 | 0.18 | 0.10 | 1.72 | 0.52 | 0.39 |
| *MAB* | 0.48 | 0.54 | 0.61 | 0.68 | 0.87 | 0.84 | 0.35 | 0.55 | 0.54 | 0.60 | 0.13 | 1.37 | 0.73 | 0.68 |
| *Combined* | 0.48 | 0.43 | 0.41 | 0.42 | 0.38 | 0.37 | 0.37 | 0.40 | 0.37 | 0.38 | 0.21 | 1.47 | 0.60 | 0.51 |

**Exploitation index (catch number/ abundance 80+mm on January 1)[5]**

| *Year* | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | Min | Max | Mean | Median |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *GBK* | 0.11 | 0.09 | 0.10 | 0.08 | 0.07 | 0.12 | 0.23 | 0.16 | 0.10 | 0.09 | 0.07 | 0.79 | 0.31 | 0.26 |
| *MAB* | 0.21 | 0.26 | 0.24 | 0.29 | 0.27 | 0.20 | 0.11 | 0.18 | 0.18 | 0.18 | 0.11 | 0.71 | 0.38 | 0.37 |
| *Combined* | 0.17 | 0.18 | 0.17 | 0.19 | 0.18 | 0.16 | 0.17 | 0.17 | 0.15 | 0.14 | 0.14 | 0.72 | 0.35 | 0.33 |

[1] 1975-2009
[2] Missing discard estimates due to small sample size
[3] Summary statistics for years shown in the table (2002-2009)
[4] Values for 2009 comparable to reference points; values for other years not comparable due to changes in fishery size selectivity.
[5] Values from different years are comparable
[6] Region abbreviations: Georges Bank (GBK), Mid-Atlantic Bight (MAB), Gulf of Maine (GOM), Southern New England (SNE).
Note: For assessment modeling purposes, SNE landings are lumped with the GBK region.

**Data and Assessment**

The NEFSC sea scallop survey transitioned from the *R/V Albatross IV*, which conducted the surveys through 2007 to the *R/V Hugh Sharp,* which conducted the NEFSC survey in 2008-2009. Comparison of paired tows between these two vessels, as well as comparisons of both research vessels to a commercial vessel towing lined survey dredges indicated no statistical difference between the catches of the vessels. However, dredge sensors indicated that the tow path of the *Sharp* was about 5% longer than that of the *Albatross*. Survey dredge efficiency was estimated based on about 140 paired tows between the survey research vessels and the HabCam towed camera system. Analysis of these data gave estimated dredge efficiency of 0.38 in strata containing substantial proportions of gravel/cobble/rock substrate (e.g., portions of Georges Bank), and 0.44 in other strata with mostly sand substrate (e.g., the Mid-Atlantic Bight). These efficiency estimates were similar to previous estimates based on NEFSC and SMAST comparisons and depletion experiments. Scallop biomass lying outside the standard NEFSC sea scallop strata set was estimated and include in the assessment. Additionally, the effective area sampled by the SMAST drop large camera was re-estimated to provide more accurate scallop density estimates.

A size-structured forward projecting stock assessment model (CASA) used in previous assessments (NEFSC 2007; NEFMC 2010) was also used in this assessment. Data sources used in the CASA model include the NEFSC sea scallop dredge and winter trawl surveys, the SMAST large camera video survey, commercial landings, commercial kept and discarded shell heights from port and sea sampling, and growth increment data inferred from analysis of shell growth rings. Biomass estimates from the model are similar to swept area biomass estimates from the NEFSC surveys. There is uncertainty in recent estimates for the stock that are reflected in retrospective patterns that are most apparent for Mid Atlantic Bight and appear to be due in part to conflicting data on the strength of the 2001 year class.

In this assessment, July 1st rather than January 1st biomass is used to determine overfished status and stock trends. July 1st estimates are more representative because growth parameters are estimated from mid-year surveys and because the CASA model does not consider seasonal growth. Moreover, July 1st biomass estimates are comparable to survey swept-area biomass. This date change does not change the estimated F or affect the definition of overfishing.

For the first time, this assessment includes information about the northern Gulf of Maine (NGOM) federal management area from a special University of Maine/Maine Department of Marine Resources dredge survey during 2008. NGOM is managed under a special TAC although it is part of the stock managed under the FMP. Survey results indicate that the biomass of NGOM sea scallops targeted by the fishery (101+ mm shell height) was approximately 100 mt of meats during 2008 with a 95% confidence interval ranging from about 60 to 250 mt. Exploitation rate (reported landings in weight / estimated biomass) during 2008 was 0.065, with a 95% confidence interval ranging from 0.035 to 0.12. The assessment also includes information about sea scallops and the fishery in Maine state waters, but estimates of total biomass and exploitation rates are not available.

## Biological Reference Points

| Reference point | SARC-45, whole Stock | Updated | | |
|---|---|---|---|---|
| | | GBK | MAB | Whole stock |
| $F_{MSY}$ | -- | 0.21 | 0.47 | 0.38 |
| $B_{TARGET}=B_{MSY}$ (July 1, 40+ mm SH) | 108,628[1] | 41,468 | 86,330 | 125,358 |
| $B_{THRESHOLD}$=1/2 $B_{MSY}$ | 54,314[1] | 20,734 | 43,165 | 62,679 |
| MSY | -- | 6,410 | 19,040 | 24,975 |
| $F_{MAX}$ | 0.29 | 0.295 | 0.835 | 0.48 |

1. Jan 1 biomass based on median recruitment * BPR at $F_{MAX}$ (proxy for $F_{MSY}$)

In the last sea scallop assessment (NEFSC 2007, SARC-45), $F_{MAX}$ was used as a proxy for $F_{MSY}$, and the biomass target ($B_{TARGET}$) was calculated by multiplying biomass per recruit at $F_{MAX}$ by median recruitment. Both $F_{MAX}$ and median recruitment were estimated by the CASA model. The biomass threshold was set at ½ the biomass target.

Selectivity in the sea scallop fishery has shifted towards larger sea scallops. Although this had positive effects on the stock and fishery, it caused flattening of yield per recruit curves so that $F_{MAX}$ estimates are now uncertain and questionable as a proxy for $F_{MSY}$.

The new recommended biological reference points in the current 2010 assessment are direct $F_{MSY}$ (0.38) and $B_{MSY}$ (125,358 mt) estimates (with uncertainty characterized in Figure B8) from the new Stochastic Yield Model (SYM). The biomass threshold is ½ the biomass target. SYM includes spawner-recruit relationships, per recruit calculations, uncertainty in all parameters and is similar to approaches that are increasingly used in other stock assessments. SYM is a separate model but is configured to be consistent with assumptions and calculations of the CASA model. In particular, selectivity, spawning biomass and recruitment estimates in SYM are obtained from the CASA model.

To inform ABC decisions, a new method is recommended which takes into account uncertainty in both current fishing mortality and the reference point. This method quantifies risk of overfishing and loss of yield at a specified fishing mortality (Figure B9 and see Special Comments).

## Fishing Mortality

Fully recruited fishing mortality rates for the whole stock ranged 0.37 to 0.4 during 2005-2009 and averaged 0.38. Fully-recruited fishing mortalities prior to 2006 cannot be directly compared to the $F_{MSY}$ estimate (Figure B2) due to changes in fishery size-selectivity over time. The estimated fishing mortality rate during 2009 was $F$=0.378. The standard errors for whole stock fishing mortality were estimated by the CASA model to be 0.04 for 2009 and 0.03 for 2005-2008. These standard errors likely underestimate the true uncertainty because they assume that input parameters to CASA and model equations are exact.

A simple exploitation index indicates that fishing pressure has been relatively low since 1994, when closed area management was initiated (Figure B3). The exploitation index is calculated as the ratio of total catch number and January 1 abundance for sea scallops 80+ mm SH estimated in the CASA model. The exploitation rate index is useful for showing annual trends in the proportion harvested.

## Recruitment

Recruitment on Georges Bank was relatively low during 2002-2006, but appears to be above average during 2007-2009 (Figure B7). Recruitment in the Mid-Atlantic was above average during 1998-2008 but below average in 2009. For the combined stock, recruitment has been above average since 2005.

## Stock and Spawning Stock Biomass

Total and spawning stock biomass are approximately equivalent. Stock biomass rapidly increased during 1995 – 2003 and has been relatively stable since then (Figure B1). Coincident with initial area closures (1994 on Georges Bank and 1998 in Mid Atlantic Bight), stock biomass increased rapidly between 1995 and 2000 on Georges Bank and between 1998 and 2003 in the Mid Atlantic Bight. Estimated biomass (40+ mm shell height) on July 1, 2009 was 129.7 thousand mt meats. Current biomass is approximately the same in both regions (slightly over 60,000 mt in each region). Biomass standard errors for 2009 are slightly lower for Georges Bank (5341 mt) than in the Mid-Atlantic (6460 mt). These standard errors likely underestimate the true uncertainty.

## Special Comments

- The new method used to facilitate ABC decisions was developed based on $F_{\mathrm{MSY}}$ and can be employed to characterize risk of overfishing for other levels of fishing mortality (e.g. $F_{\mathrm{TARGET}}$). Here, $F_{\mathrm{MSY}}$ is directly estimated and is not a proxy as has been used in the past (Figure B9).
- Area management plays an important role in sea scallop stock dynamics, with much of the biomass located in long-term or rotational closures, or are in reopened closed areas under special management. Under such area management, the calculated fishing mortalities will underestimate fishing mortalities in areas where fishing occurs (Hart 2001; 2003).
- Historically, Georges Bank was the dominant component of the US sea scallop resource. In recent years, the Mid-Atlantic Bight has become more productive which is unprecedented. Recent recruitment in this area is an order of magnitude higher than during 1975 – 1984 (Figure B7) and may not persist.

## References

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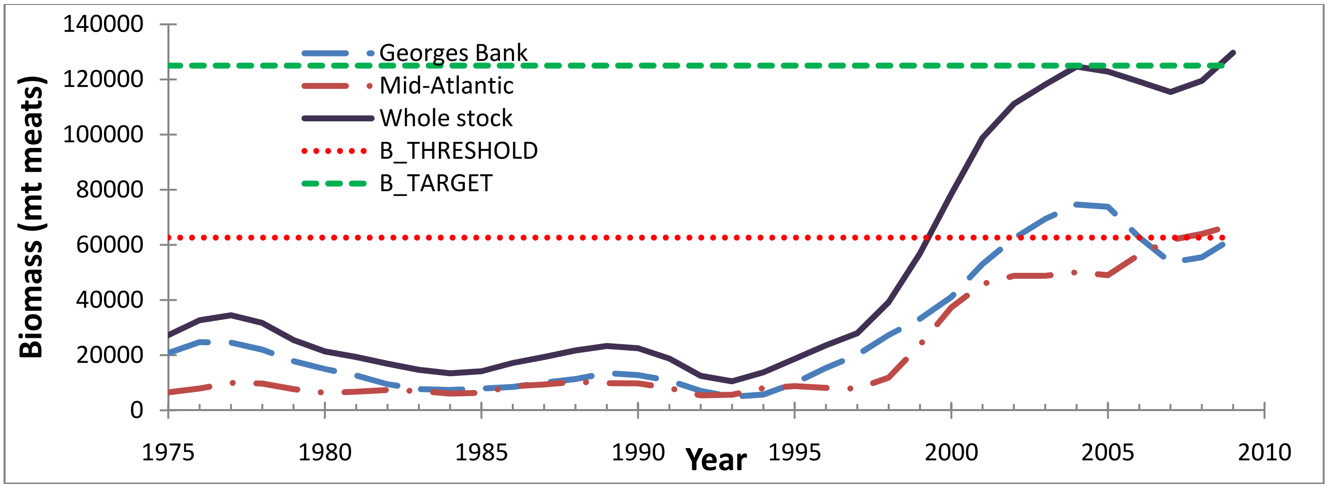
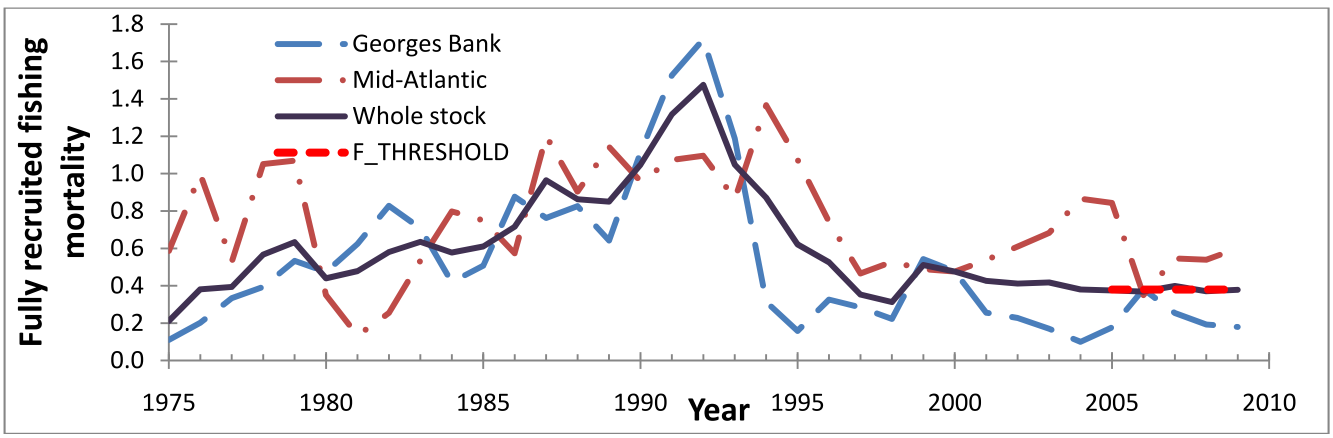
Northeast Fisheries Science Center. 2007. NEFSC. 2007. 45th Northeast Regional Stock Assessment Workshop (45th SAW): 45th SAW assessment report. NEFSC Ref Doc. 07-16.

New England Fishery Management Council. 2010. Framework adjustment 21 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.

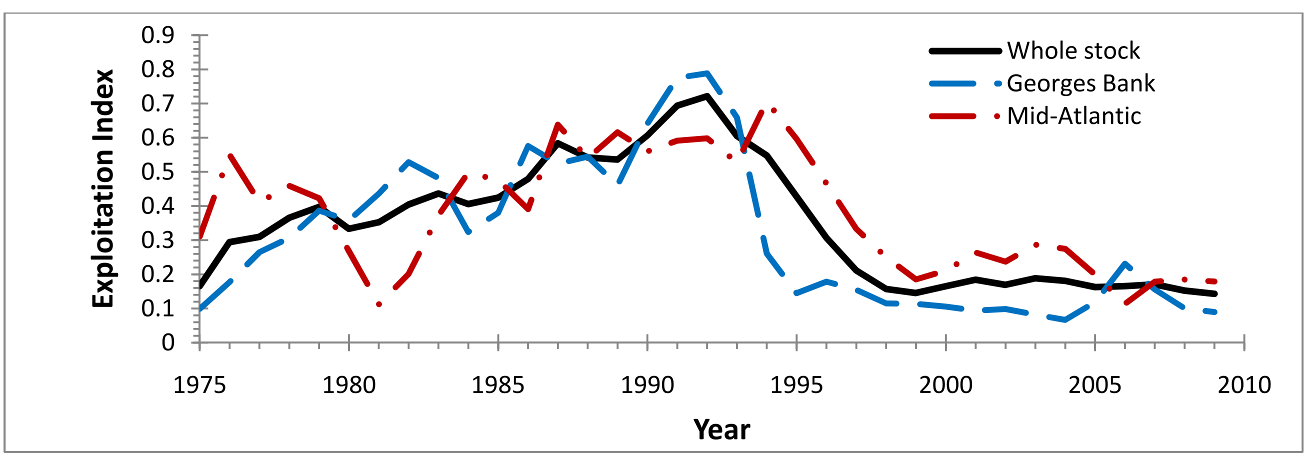
**Figures**



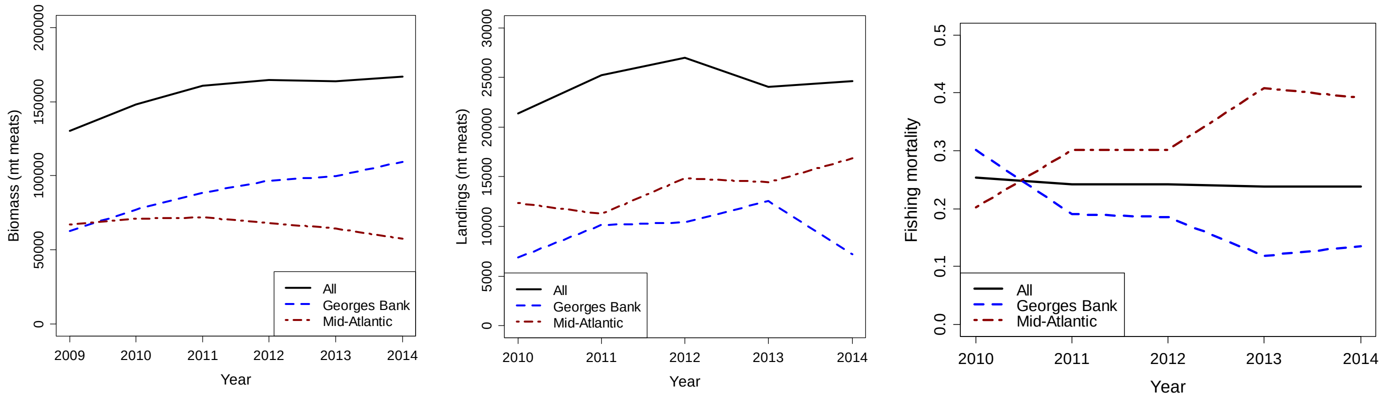

**B1.** Sea scallop biomass (40+ mm SH), on July 1 during 1975-2009.



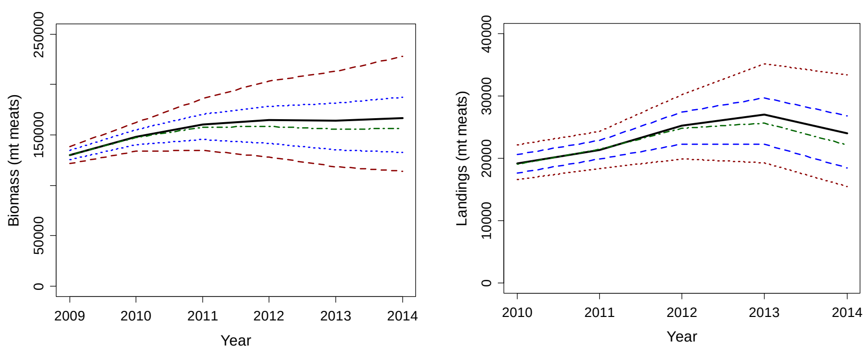

**B2**. Fully recruited annual fishing mortality rate for sea scallops during 1995-2009. Trends are difficult to interpret because of changes in commercial size-selectivity.



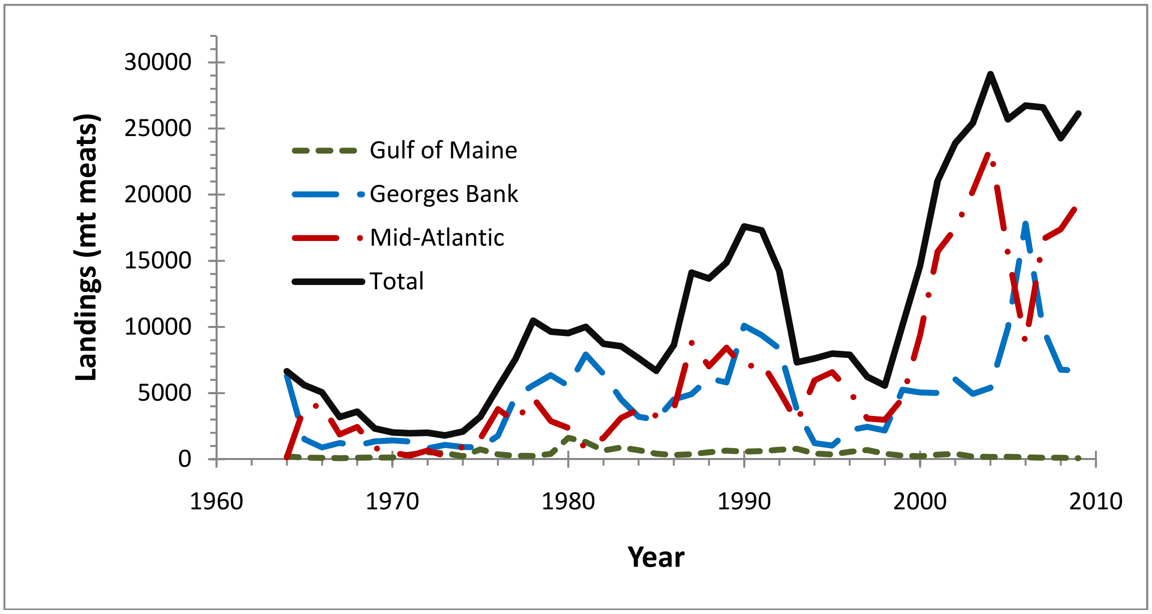

**B3**. Simple exploitation index for sea scallops during 1975-2009.



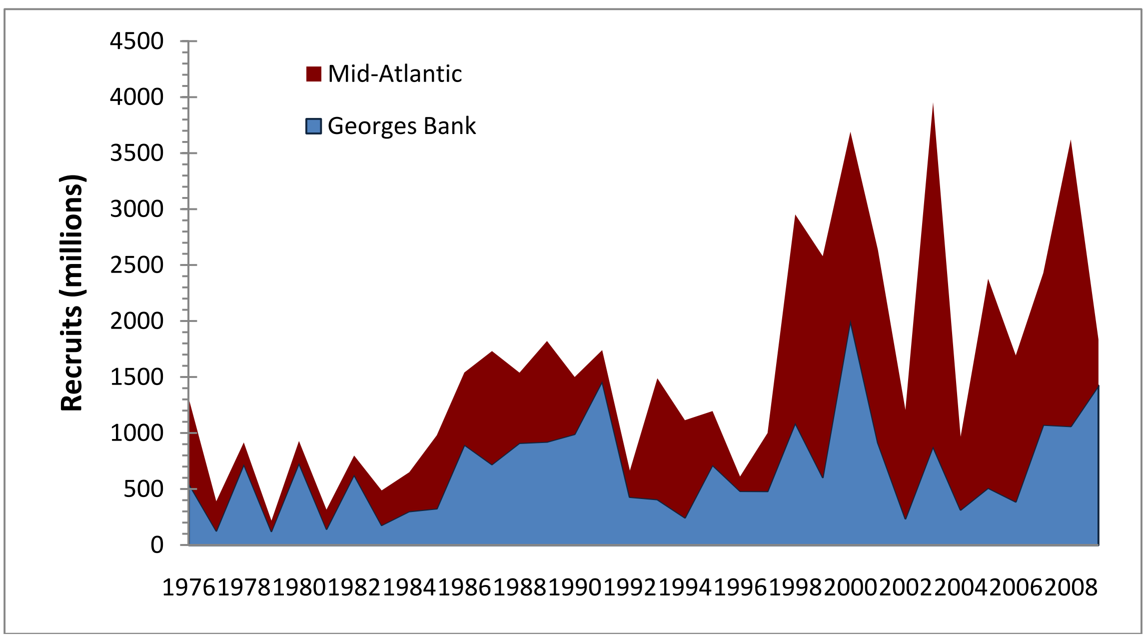

**B4.** Projected sea scallop biomass, landings and fully recruited fishing mortality for GBK, MAB and the entire (i.e., total) stock under an example management scenario during 2010-2014.



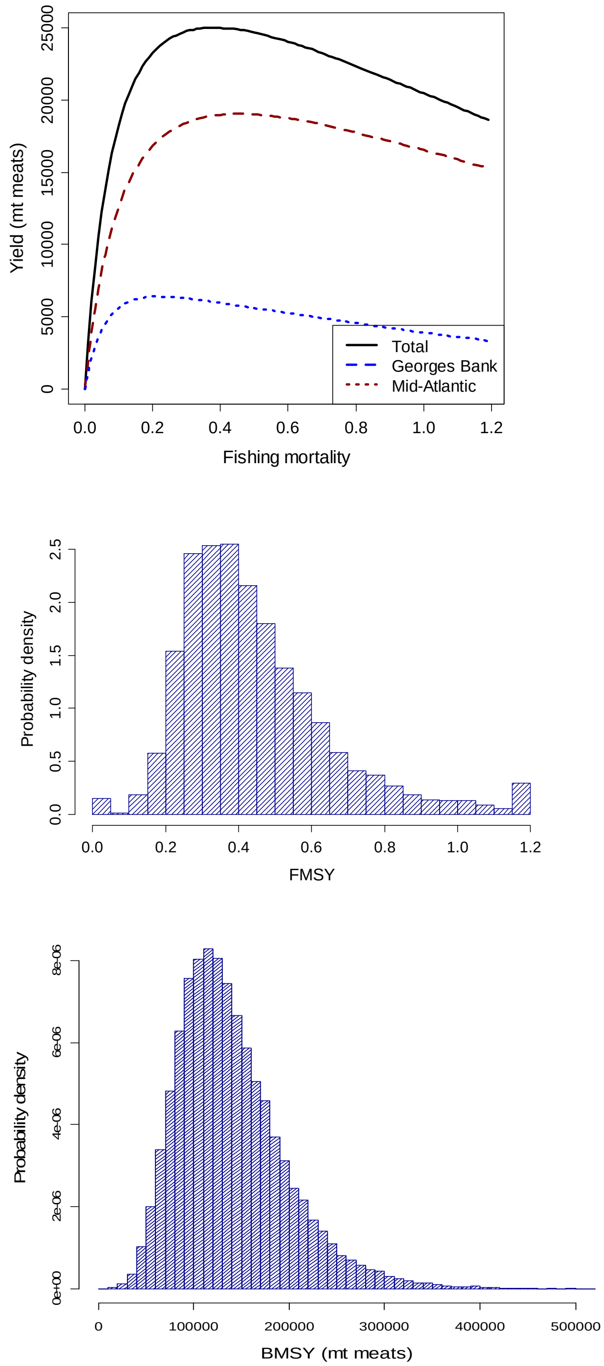

**B5.** Mean (black solid line) and median (green dashed-dotted line) projected sea scallop biomass and landings for the entire (i.e., total) stock during 2010-2014 under an example management scenario during 2010-2014. The 10th and 90th percentiles are red dashed lines. The 25th and 75th percentiles are dotted blue lines.



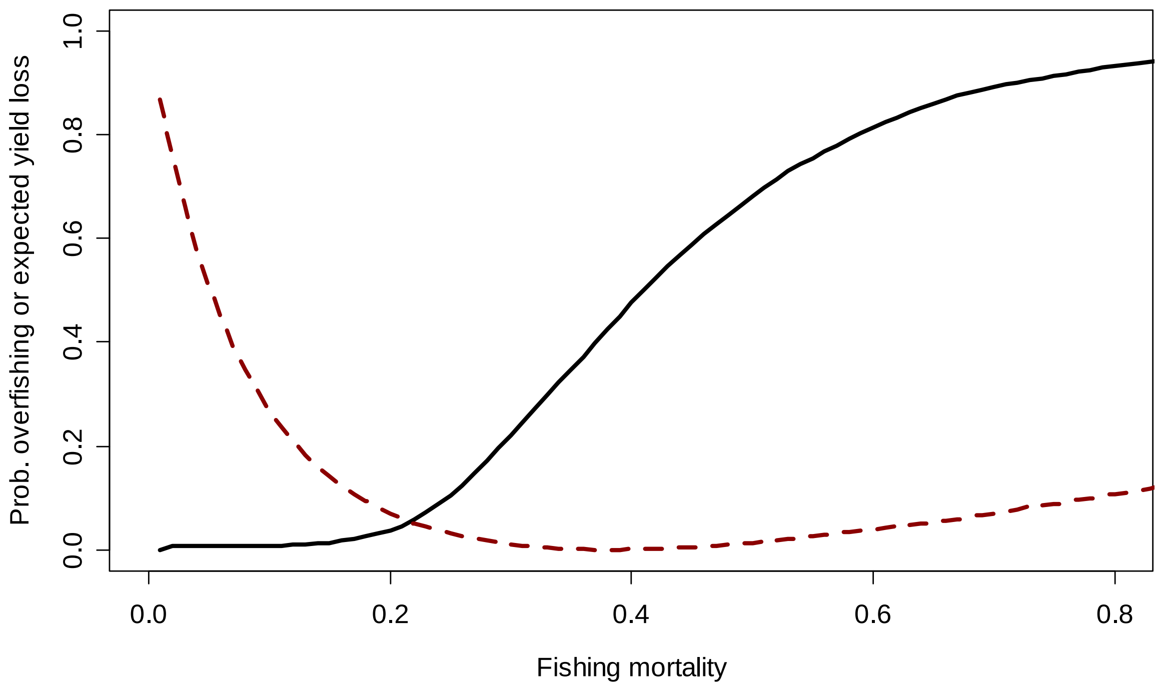

**B6**. Sea scallop landings during 1975-2009.




**B7.** Sea scallop recruitment (millions, approximate age 2) during 1975-2009.




**B8.** *Top*: Median yield curves for Georges Bank, the Mid-Atlantic Bight, and total sea scallop stock from the SYM model. *Middle*: Probability density function for total-stock $F_{MSY}$ calculated in the SYM model. *Bottom*: Probability density function for total-stock $B_{MSY}$ calculated in the SYM model.




**B9.** The probability of overfishing sea scallops as a function of realized fishing mortality (black solid line) and the loss of expected yield relative to that obtained at $F_{MSY}$.

## C. POLLOCK ASSESSMENT SUMMARY FOR 2010

### State of Stock

Comparing the current 2009 estimates of spawning stock biomass (SSB) and fishing mortality rate (F) to the newly accepted reference points, the pollock stock is not overfished and overfishing is not occurring. A new assessment model (ASAP) is accepted as the best scientific information available for determining stock status for pollock (*Pollachius virens*). SSB in 2009 is estimated to be 196,000 mt and the average F on ages 5-7 ($F_{5-7}$) is estimated to be 0.07 (Figure C3 and Figure C8).

$F_{40\%}$ is recommended as the new proxy for $F_{MSY}$ (the overfishing threshold). The average fishing mortality on ages 5 to 7 is chosen as the basis of indicator and reference point estimation in order to account for temporal changes in fishery age-specific selectivity.

$F_{40\%}$ , measured as F on the fully selected age (age-7) in the most recent period (2005 – 2009) is 0.41, which is equivalent to an average fishing mortality on ages 5-7 ($F_{5-7}$) of 0.25.

$SSB_{MSY}$ (the biomass target) is calculated from projections at $F_{40\%}$ and is estimated to be 91,000 mt.

If the previously used AIM model had been used to determine stock status, the resource would have been judged to be overfished and overfishing to be occurring. In contrast to the previously used AIM model, ASAP uses age structure, additional surveys, more comprehensive catch information, changes in selectivity and uncertainty in the input data (see Special Comments).

### Projections

The ASAP model estimates that the stock is not overfished, so no rebuilding projections were conducted. For the purposes of informing ABC decisions, projections were made for three constant F scenarios: $F=F_{statusquo}=F_{2009}$, $F=0.75*F_{40\%}$, and $F=F_{40\%}$. Under all three scenarios (Table C1a), spawning biomass declines from $SSB_{2009}$=196,000 mt until it approaches equilibrium at the projected F. Under $F_{40\%}$ the median SSB equilibrates at 91,000 mt (the proxy for $SSB_{MSY}$). Projected median recruitment does not vary by F scenario, because the same time series of recruitments (1970-2007) was resampled in all projections. The median recruitment was 19.3 million age 1 fish, with $5^{th}$ and $95^{th}$ percentiles ranging from 8.4 to 42 million fish.

Projected median catch (which includes both commercial and recreational fleets) under $F_{status\text{-}quo}$ decreases from 8,100 mt in 2010 to 7,200 mt in 2012, then gradually increases until equilibrating around 8,400 mt in 2017 (Table C1b). Projecting at $0.75*F_{40\%}$, the median catch fluctuates from 19,800 mt in 2010 to 15,400 mt in 2012, and continues to oscillate in this range until equilibrating at 14,500 mt. Projecting at $F_{40\%}$, median catch declines from 25,700 mt in 2010 to 17,500 mt in 2017 with minor fluctuations until equilibrating at 16,200 mt (the proxy for MSY). Note that a projected 2010 catch of 25,700 mt would exceed MSY, be more than double recent catch, and has not been observed since the 1980s.

## Catch and Status Table: Pollock in US Waters of Areas 5&6

| Year | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | Min | Max | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Comm Lands (mt) | 4043 | 4109 | 3580 | 4794 | 5070 | 6509 | 6067 | 8372 | 9965 | 7477 | 2962 | 24994 | 10723 |
| Comm Disc (mt) | 117 | 73 | 68 | 45 | 103 | 100 | 69 | 147 | 362 | 362 | 45 | 473 | 164 |
| Rec Lands (mt) | 243 | 471 | 547 | 499 | 669 | 520 | 571 | 533 | 941 | 468 | 50 | 941 | 355 |
| Rec Disc (mt) | 356 | 875 | 613 | 472 | 241 | 272 | 252 | 227 | 926 | 428 | 34 | 926 | 327 |
| Total Catch (mt) | 4759 | 5528 | 4808 | 5810 | 6083 | 7401 | 6959 | 9278 | 12194 | 8735 | 3754 | 25170 | 11920 |
| SSB (000s mt) | 130 | 148 | 166 | 199 | 214 | 222 | 236 | 224 | 227 | 196 | 69 | 327 | 176 |
| Exploitable Biomass (000s mt) | 74 | 87 | 95 | 114 | 113 | 133 | 138 | 125 | 105 | 86 | 37 | 168 | 92 |
| Ave F on ages 5-7 | 0.062 | 0.061 | 0.047 | 0.047 | 0.037 | 0.038 | 0.034 | 0.051 | 0.082 | 0.070 | 0.034 | 0.486 | 0.157 |
| Full F | 0.073 | 0.072 | 0.057 | 0.057 | 0.060 | 0.062 | 0.057 | 0.084 | 0.134 | 0.117 | 0.057 | 0.508 | 0.177 |
| Recr (000s) | 50260 | 22385 | 34708 | 13792 | 18057 | 11891 | 13982 | 16355 | 20812 | 20804 | 7244 | 57510 | 21360 |

[1]The value for commercial discards in 2009 was assumed to be equal to the value in 2008.
[2]Recreational discards were calculated assuming 100% discard mortality.

### Stock Distribution and Identification

Pollock move widely throughout the Gulf of Maine and into Canadian waters. Previous assessments of pollock assumed a variety of stock definitions. Recent assessments of pollock in US waters are for "the portion of the unit stock of pollock primarily within the USA EEZ (NAFO Subareas 5&6) including a portion of eastern Georges Bank (Subdivision 5Zc) that is under Canadian management jurisdiction". Canadian stock assessments treat the management unit within the Canadian EEZ separately. Given uncertainties in stock structure and management implications, a refined assessment unit that reflects US jurisdictional waters was used (see Special Comments).

### Catches

Pollock were traditionally landed as bycatch in various demersal otter trawl fisheries, but directed otter trawl effort increased during the 1980s, peaking in 1986 and 1987. Directed effort by US trawlers declined in the 1990s and early 2000's, but there have been recent increases in landings that may reflect increased targeting of pollock (Figure C1). Similar trends have also occurred in the U.S. winter gillnet fishery.

U.S. commercial landings increased from approximately 4,000 mt per year in the late 1960s to a peak of 24,000 mt in 1986. Landings rapidly decreased to 4,000 mt in 1996, and generally increased to 10,000 mt in 2008. Historical landings were primarily from trawl fisheries, but contributions from gillnet fisheries generally increased, and the recent fishery is composed of 60% trawl and 40% gillnet landings.

Commercial discards were estimated for 1989 to 2008 (data were not available for 2009, so an assumed value equal to 2008 discards was used). Discards were assumed to be negligible prior to 1989. Discard estimates ranged from 1% to 8% of US commercial landings, with an average of 3% for all years. The four fleets that account for nearly all pollock discards were small-mesh otter trawl, large-mesh otter trawl, large-mesh gillnet, and extra-large mesh gillnet.

Recreational catch is highly variable from year to year. Recreational catch peaked at 1867mt in 2008, which is consistent with fishermen's accounts of encountering large numbers of pollock in that year. However, recreational catch decreased in 2009 to 896 mt. Recreational catch is small relative to commercial landings and has generally been 10% or less. However, during 2000-2004, recreational catch is estimated to have contributed 15-24% of total catch (commercial catch was near the lowest values in the time series for these same years, Figure C1).

Discard mortality in the recreational catch is assumed to be 100%, consistent with the 100% discard mortality assumed for commercial discards.

Recreational catch was assumed to be negligible prior to 1981 and there is no agreed method upon which to base hindcasted estimates.

**Data and assessment**

The previous assessment of pollock was conducted with an index-based model (AIM) that used total commercial landings and mean kg/tow from the NEFSC fall survey. A new assessment model (ASAP) was developed which incorporates age structure, additional surveys, more comprehensive catch information, changes in selectivity and uncertainty in the input data.

Catch at age for 1970-2009 are used for two fleets: a composite commercial and a recreational fleet. The commercial fleet includes US catch by otter trawl and gillnet (with minor contributions from hook and line gear), as well as landings by distant water fleets (1970-1976) and Canadian fleets (1970-1985). Total discards for the commercial fleet are estimated for 1989-2008 from observer data. Recreational catch was included for 1981 to 2009.

NEFSC Spring and Fall surveys (1970-2009) number/tow were used in the ASAP model along with estimated CV and annual age composition.

Natural mortality was assumed to be 0.2 for all ages and years, corresponding to 1% survival to age 24 (the maximum age observed). Maturity at age was assumed constant for all years.

**Biological Reference Points**

$F_{40\%}$ is recommended as the new proxy for the overfishing threshold ($F_{MSY}$). A deterministic value of $F_{40\%}$ was estimated from a yield per recruit analysis using 2005-2009 average SSB weights, catch weights, maturity and selectivity at age. Expressed as the average F experienced at ages 5-7 for 2005-2009, the estimate is $F_{40\%,\ 5\text{-}7}$ = 0.25 (Figure C3), which corresponds to a fully selected F of 0.41 at age 7.

Stochastic projections at $F_{40\%}$ were used to determine new recommended biomass related reference points ($SSB_{MSY}$ and MSY proxies). The proxy for $SSB_{MSY}$, the $B_{TARGET}$, is estimated at 91,000 mt, with 5$^{th}$ and 95$^{th}$ percentiles spanning 71,000 to 118,000 mt. One half of $SSB_{MSY}$ is proposed for $B_{THRESHOLD}$ (45,500 mt).

The proxy for MSY is 16,200 mt, with 5$^{th}$ and 95$^{th}$ percentiles spanning 11,800 to 23,200 mt. The median recruitment was 19.2 million age 1 fish, with 5$^{th}$ and 95$^{th}$ percentiles ranging from 8.3 to 42 million fish. Distributions for $SSB_{MSY}$ and MSY are given in Figure C2.

The biological reference points that had been used previously were based upon the AIM model, which is no longer the recommended model for assessing this stock.

**Fishing Mortality**

Since 1970, there has been a shift in fishery selectivity towards older ages. To provide a consistent metric for expressing F over the time series, an unweighted average F for ages 5-7 ($F_{5\text{-}7}$) was used. In 1970, $F_{5\text{-}7}$ was 0.11, increased to 0.48 by 1986, and then steadily decreased to 2006, when it reached the time series low of 0.03. During 2007 – 2009, $F_{5\text{-}7}$ was 0.05, 0.08, and

0.07, respectively (Figure C3). The uncertainty in the estimate of $F_{5-7}$ in 2009 is described in Figure C4.

To provide a historical perspective on fishing mortality, a time series of $F_{40\%}$ corresponding to ages 5 through 7 is plotted along with the ASAP model estimate of $F_{5-7}$ (Figure C3). This year-specific $F_{40\%}$ accounts for selectivity at age which has changed substantially through time. The fishing mortality reference point has increased significantly since the mid 1990s with the shift of fishing pressure towards older age groups (Figure C5). Overfishing was occurring during the period 1980-1990.

**Biomass**

The ASAP model estimates a 1970 spawning stock biomass (SSB) of 297,000 mt. Spawning biomass decreased to the time series low (68,600 mt) in 1990 (Figure C6). Spawning biomass then increased steadily through 2006, with a slight decline during 2007 - 2009. Spawning biomass in 2009 is 196,000 mt (the uncertainty in the estimate of SSB in 2009 is provided in Figure C7).

Total population biomass follows the same trend as SSB (Figure C6). Exploitable biomass ranges from 35% to 70% of spawning biomass over the time series. This substantial difference is due to the estimated dome-shaped fishery selectivities (see Special Comments).

In order to provide an historical picture of biomass status, year-specific $SSB_{MSY}$ proxies were calculated using five year averages of selectivity and weights at age. The year-specific $F_{40\%}$ values were used to make stochastic projections for determining the median equilibrium $SSB_{MSY}$. The full time series of model estimated recruitments was used in all projections. The estimated year specific $SSB_{MSY}$ proxies range from 91,000 mt to 122,000 mt, and the model estimates of SSB were below $SSB_{MSY}$ during the period 1987-1998 (Figure C8).

**Recruitment**

Mean recruitment (age 1) was around 21 million fish. Strong year classes were produced in 1971, 1979, 1997, 1998, 1999, and 2001 with about average recruitment in recent years (Figure C9).

**Ecosystem Considerations**

Pollock is an important but not a dominant piscivore in the ecosystem. The amount of food consumed by pollock is 0.001-0.007% of all energy flows in the Gulf of Maine/Georges Bank ecosystem, and pollock account for 0.5-5% of the total consumption by all finfish in this ecosystem. The abundance, amount of food eaten and per capita consumption peaked in the late 1990s to early 2000s. Pollock probably do not consume a significant amount of most prey species (relative to those spp. biomass, production, or fisheries landings), except for pandalid shrimp and in some years herring.

**Special Comments:**

- The ASAP model with dome-shaped survey and fishery selectivity implies the existence of a large biomass (35 – 70% of total) of pollock (i.e. cryptic biomass) that neither current surveys nor the fishery can confirm. Assuming full survey selectivity for ages 6 and above reduces stock biomass and associated biomass reference points by 20 – 50%. Notwithstanding this, the stock did not appear to be overfished in either case. Under the full selectivity assumption, long-term catches can be expected to be reduced by approximately 30%.

- The spatial assessment unit is based on jurisdictional boundaries and may not reflect a single self-sustaining resource.
- There is considerable uncertainty in indices of pollock abundance from trawl surveys. The new NOAA survey vessel *Bigelow* appears to have lower catchability of pollock than the *Albatross*, implying that precision of the survey time series is not likely to improve.

**References:**

Northern Demersal Working Group. 2010. Stock Assessment of Pollock in US Waters for 2010 50th Northeast Stock Assessment Workshop. NEFSC Ref. Doc. (in prep.)

## Tables

Table C1a. Percentiles of pollock spawning stock biomass (000s mt) for projections at $F_{status\ quo}$, 0.75*F40%, and F40%.

| | **F-status-quo = 0.07 (average F on ages 5-7)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| YEAR | 1% | 5% | 10% | 25% | 50% | 75% | 90% | 95% | 99% |
| 2010 | 138.5 | 153.8 | 160.8 | 175.9 | 194.3 | 213.5 | 233.0 | 249.5 | 270.7 |
| 2011 | 130.7 | 143.5 | 149.5 | 163.2 | 179.8 | 196.6 | 215.6 | 229.8 | 250.1 |
| 2012 | 127.1 | 137.6 | 143.6 | 156.4 | 171.6 | 187.0 | 204.5 | 218.0 | 237.6 |
| 2013 | 123.6 | 133.9 | 140.5 | 152.5 | 166.6 | 181.4 | 198.0 | 209.4 | 228.6 |
| 2014 | 124.1 | 134.0 | 140.2 | 151.9 | 165.0 | 179.2 | 194.9 | 205.0 | 223.8 |
| 2015 | 125.5 | 135.2 | 141.4 | 152.4 | 164.9 | 178.8 | 193.7 | 202.8 | 221.3 |
| 2016 | 126.5 | 136.7 | 142.6 | 153.2 | 165.8 | 179.8 | 194.1 | 203.1 | 221.0 |
| 2017 | 126.5 | 136.8 | 142.7 | 153.3 | 166.2 | 180.5 | 194.9 | 204.1 | 221.8 |

| | **0.75*F40% = 0.19 (average F on ages 5-7)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| YEAR | 1% | 5% | 10% | 25% | 50% | 75% | 90% | 95% | 99% |
| 2010 | 138.5 | 153.8 | 160.8 | 175.9 | 194.3 | 213.5 | 233.0 | 249.5 | 270.7 |
| 2011 | 122.5 | 134.2 | 139.9 | 152.8 | 168.3 | 184.3 | 202.2 | 214.8 | 234.0 |
| 2012 | 112.3 | 121.1 | 126.6 | 138.0 | 151.2 | 165.1 | 180.7 | 191.7 | 209.8 |
| 2013 | 104.1 | 112.8 | 118.1 | 128.5 | 140.0 | 152.6 | 166.5 | 176.2 | 192.7 |
| 2014 | 100.1 | 108.0 | 113.0 | 122.4 | 132.8 | 144.3 | 156.8 | 165.0 | 180.8 |
| 2015 | 96.9 | 104.7 | 109.3 | 117.8 | 127.6 | 138.5 | 149.8 | 157.1 | 171.4 |
| 2016 | 93.7 | 101.4 | 105.8 | 113.9 | 123.5 | 134.4 | 145.5 | 152.6 | 166.1 |
| 2017 | 90.2 | 97.8 | 102.2 | 110.1 | 120.0 | 131.2 | 142.5 | 149.7 | 163.6 |

| | **F40% = 0.25 (average F on ages 5-7)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| YEAR | 1% | 5% | 10% | 25% | 50% | 75% | 90% | 95% | 99% |
| 2010 | 138.5 | 153.8 | 160.8 | 175.9 | 194.3 | 213.5 | 233.0 | 249.5 | 270.7 |
| 2011 | 118.5 | 129.6 | 135.2 | 147.7 | 162.6 | 178.0 | 195.5 | 207.6 | 226.2 |
| 2012 | 105.3 | 113.4 | 118.9 | 129.7 | 142.0 | 155.0 | 169.6 | 180.0 | 197.1 |
| 2013 | 95.7 | 103.4 | 108.4 | 117.9 | 128.5 | 140.0 | 152.8 | 161.4 | 177.0 |
| 2014 | 90.0 | 97.1 | 101.7 | 110.0 | 119.4 | 129.8 | 141.0 | 148.4 | 162.8 |
| 2015 | 85.4 | 92.4 | 96.5 | 103.9 | 112.6 | 122.4 | 132.4 | 138.9 | 151.5 |
| 2016 | 81.0 | 87.7 | 91.6 | 98.6 | 107.3 | 117.0 | 127.0 | 133.5 | 145.7 |
| 2017 | 76.6 | 83.2 | 86.9 | 93.9 | 102.8 | 112.8 | 123.2 | 129.7 | 142.4 |

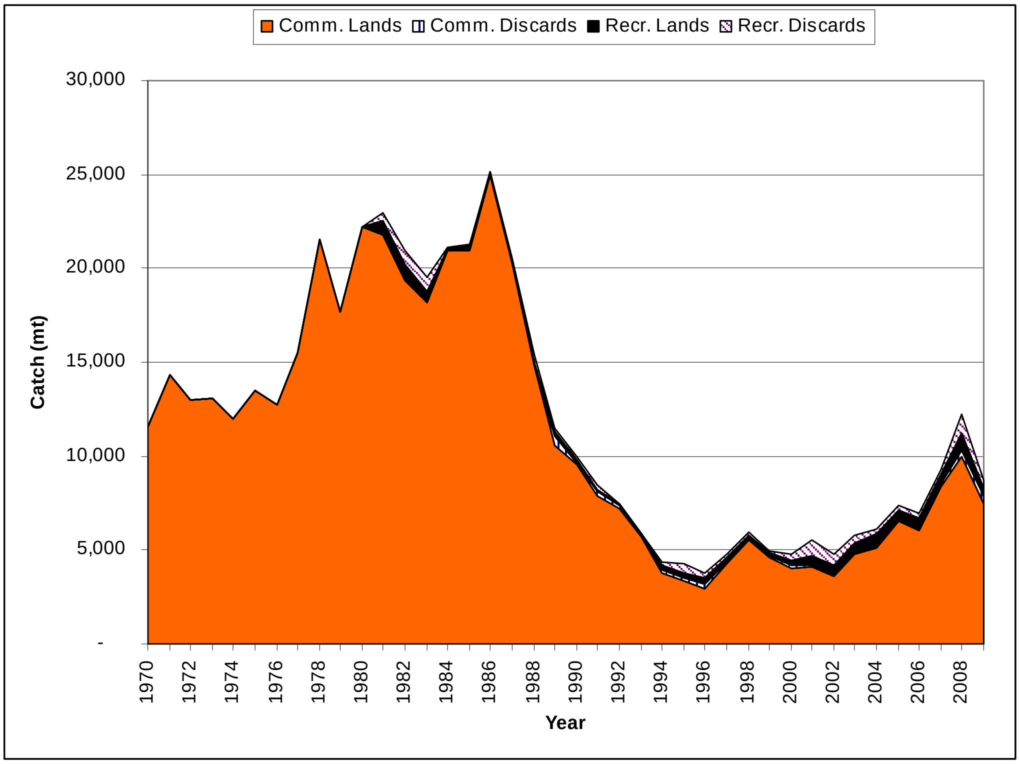
Table C1b. Percentiles of catch (000s mt) of pollock for projections at $F_{status\ quo}$, 0.75*F40%, and F40%.

| | **F-status-quo = 0.07 (average F on ages 5-7)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| YEAR | 1% | 5% | 10% | 25% | 50% | 75% | 90% | 95% | 99% |
| 2010 | 5.8 | 6.4 | 6.7 | 7.3 | 8.1 | 8.7 | 9.6 | 10.2 | 11.2 |
| 2011 | 5.5 | 6.0 | 6.2 | 6.8 | 7.5 | 8.1 | 8.8 | 9.4 | 10.4 |
| 2012 | 5.3 | 5.7 | 6.0 | 6.6 | 7.2 | 7.8 | 8.5 | 9.0 | 9.8 |
| 2013 | 5.5 | 6.1 | 6.3 | 6.9 | 7.5 | 8.2 | 9.0 | 9.4 | 10.3 |
| 2014 | 5.9 | 6.5 | 6.8 | 7.3 | 8.0 | 8.8 | 9.6 | 10.1 | 11.1 |
| 2015 | 6.3 | 6.8 | 7.1 | 7.7 | 8.4 | 9.2 | 10.0 | 10.5 | 11.6 |
| 2016 | 6.4 | 7.0 | 7.3 | 7.8 | 8.5 | 9.3 | 10.2 | 10.7 | 11.7 |
| 2017 | 6.1 | 6.6 | 7.0 | 7.6 | 8.4 | 9.3 | 10.5 | 11.3 | 12.6 |

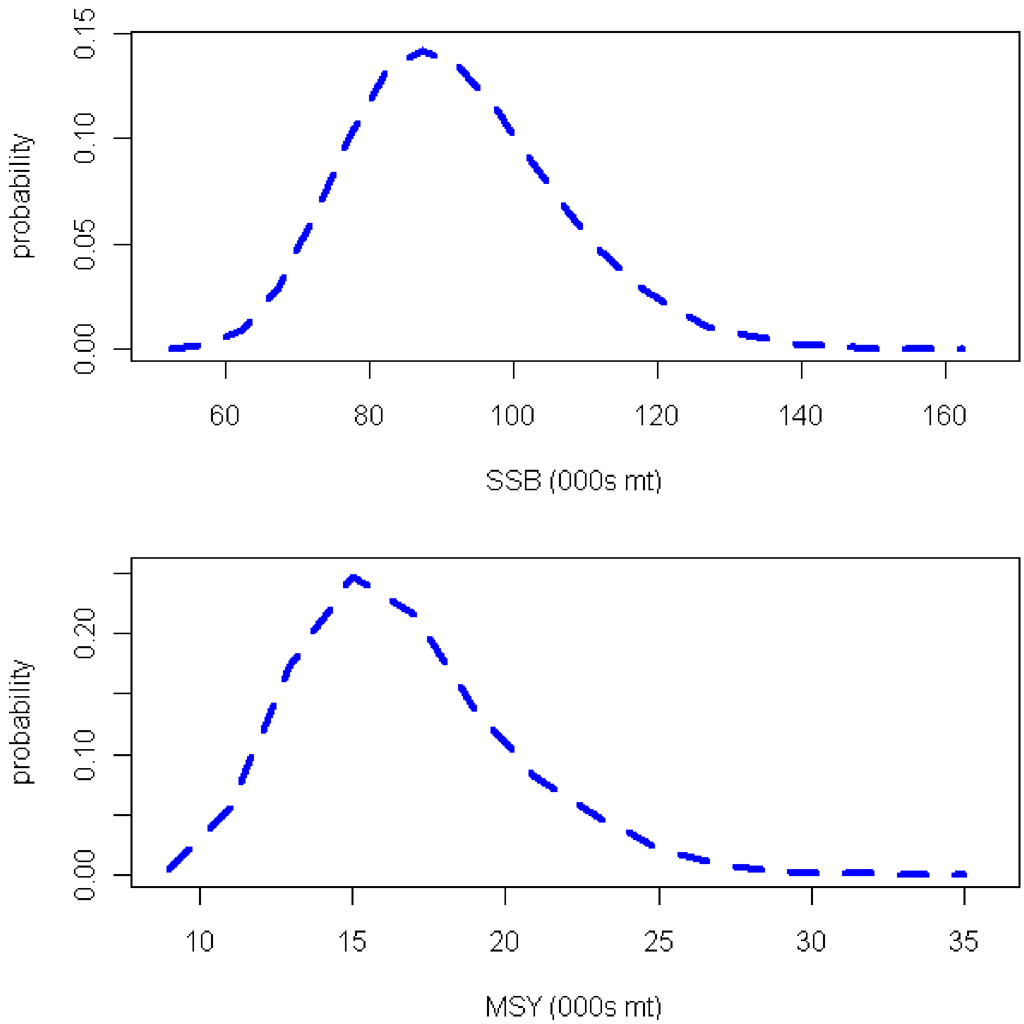
| | **0.75*F40% = 0.19 (average F on ages 5-7)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| YEAR | 1% | 5% | 10% | 25% | 50% | 75% | 90% | 95% | 99% |
| 2010 | 14.3 | 15.8 | 16.5 | 17.9 | 19.8 | 21.5 | 23.6 | 25.0 | 27.6 |
| 2011 | 12.4 | 13.5 | 14.1 | 15.3 | 16.9 | 18.4 | 20.0 | 21.2 | 23.4 |
| 2012 | 11.4 | 12.3 | 12.9 | 14.1 | 15.4 | 16.8 | 18.3 | 19.4 | 21.0 |
| 2013 | 11.4 | 12.5 | 13.1 | 14.2 | 15.6 | 17.0 | 18.5 | 19.5 | 21.3 |
| 2014 | 11.8 | 12.9 | 13.5 | 14.6 | 16.0 | 17.6 | 19.2 | 20.2 | 22.3 |
| 2015 | 12.2 | 13.3 | 13.9 | 15.0 | 16.3 | 17.9 | 19.4 | 20.4 | 22.5 |
| 2016 | 12.1 | 13.1 | 13.7 | 14.8 | 16.1 | 17.7 | 19.4 | 20.6 | 22.7 |
| 2017 | 11.0 | 12.1 | 12.7 | 14.0 | 15.6 | 17.5 | 19.8 | 21.4 | 24.0 |

| | **F40% = 0.25 (average F on ages 5-7)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| YEAR | 1% | 5% | 10% | 25% | 50% | 75% | 90% | 95% | 99% |
| 2010 | 18.6 | 20.4 | 21.3 | 23.2 | 25.7 | 27.9 | 30.5 | 32.4 | 35.8 |
| 2011 | 15.3 | 16.7 | 17.5 | 19.0 | 21.0 | 22.8 | 24.8 | 26.3 | 29.0 |
| 2012 | 13.8 | 14.9 | 15.6 | 17.1 | 18.6 | 20.3 | 22.2 | 23.4 | 25.4 |
| 2013 | 13.5 | 14.9 | 15.5 | 16.9 | 18.4 | 20.1 | 22.0 | 23.1 | 25.3 |
| 2014 | 13.7 | 15.0 | 15.7 | 17.0 | 18.6 | 20.5 | 22.4 | 23.5 | 26.0 |
| 2015 | 14.1 | 15.3 | 16.0 | 17.2 | 18.7 | 20.6 | 22.3 | 23.5 | 25.9 |
| 2016 | 13.7 | 14.9 | 15.6 | 16.8 | 18.3 | 20.2 | 22.2 | 23.6 | 26.2 |
| 2017 | 12.3 | 13.5 | 14.2 | 15.7 | 17.5 | 19.8 | 22.6 | 24.4 | 27.4 |

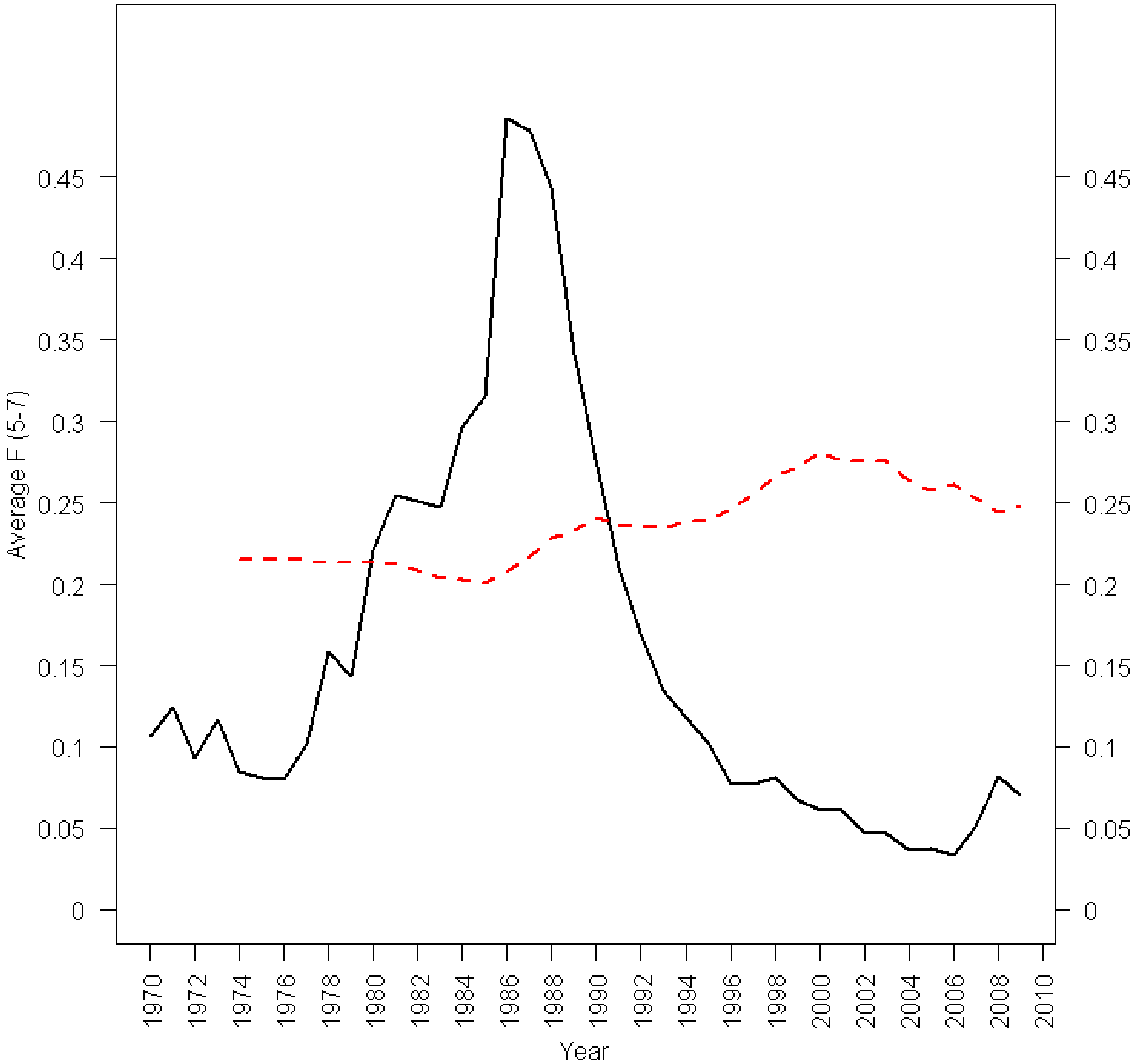
## Figures



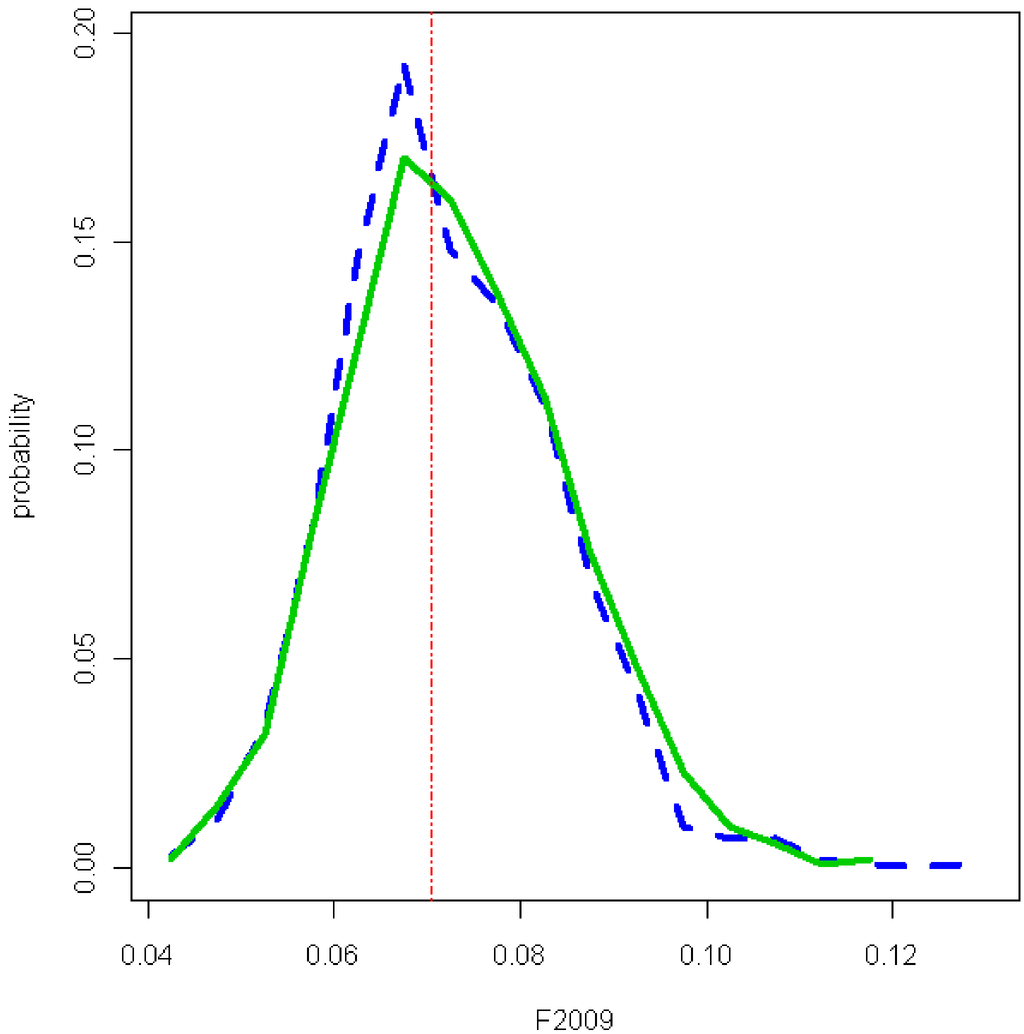

**C1.** Components of total pollock catch by fleet (Commercial and Recreational).



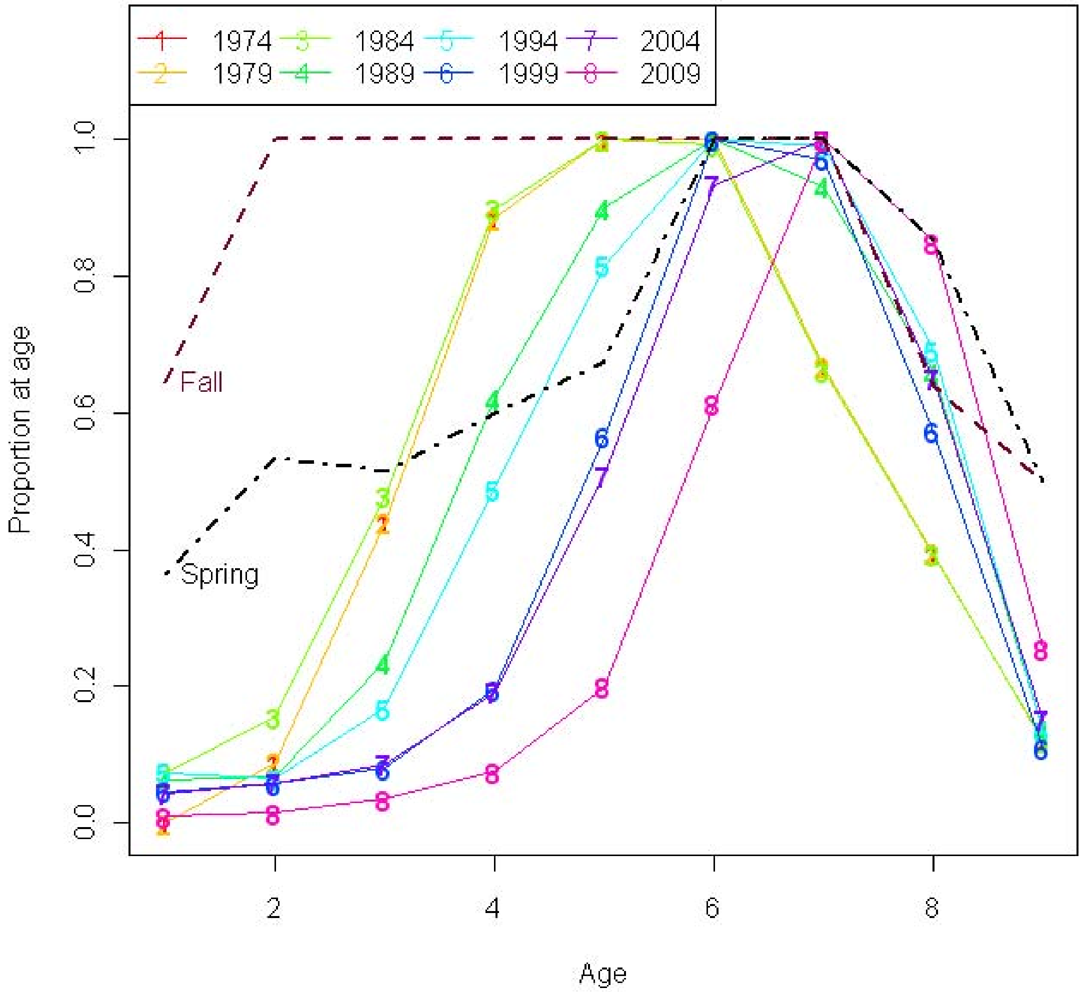

**C2.** Distributions of $SSB_{MSY}$ and MSY for pollock based on stochastic projections at $F_{40\%}$. The median estimates are 91,000 mt for $SSB_{MSY}$ and 16,200 mt for MSY, based on projections that used $F_{40\%}$ as a proxy for $F_{MSY}$. The MSY amount includes both commercial and recreational landings and discards.




**C3.** ASAP model estimated time series of average F on ages 5-7 for pollock. The dashed red line is $F_{40\%}$ on ages 5-7, calculated for years 1974-2009 with a 5 year moving average of weights at age, selectivity at age, and maturity at age. The $F_{40\%}$ in 1974 used years (1970-1974) while the final $F_{40\%}$ used years (2005-2009).

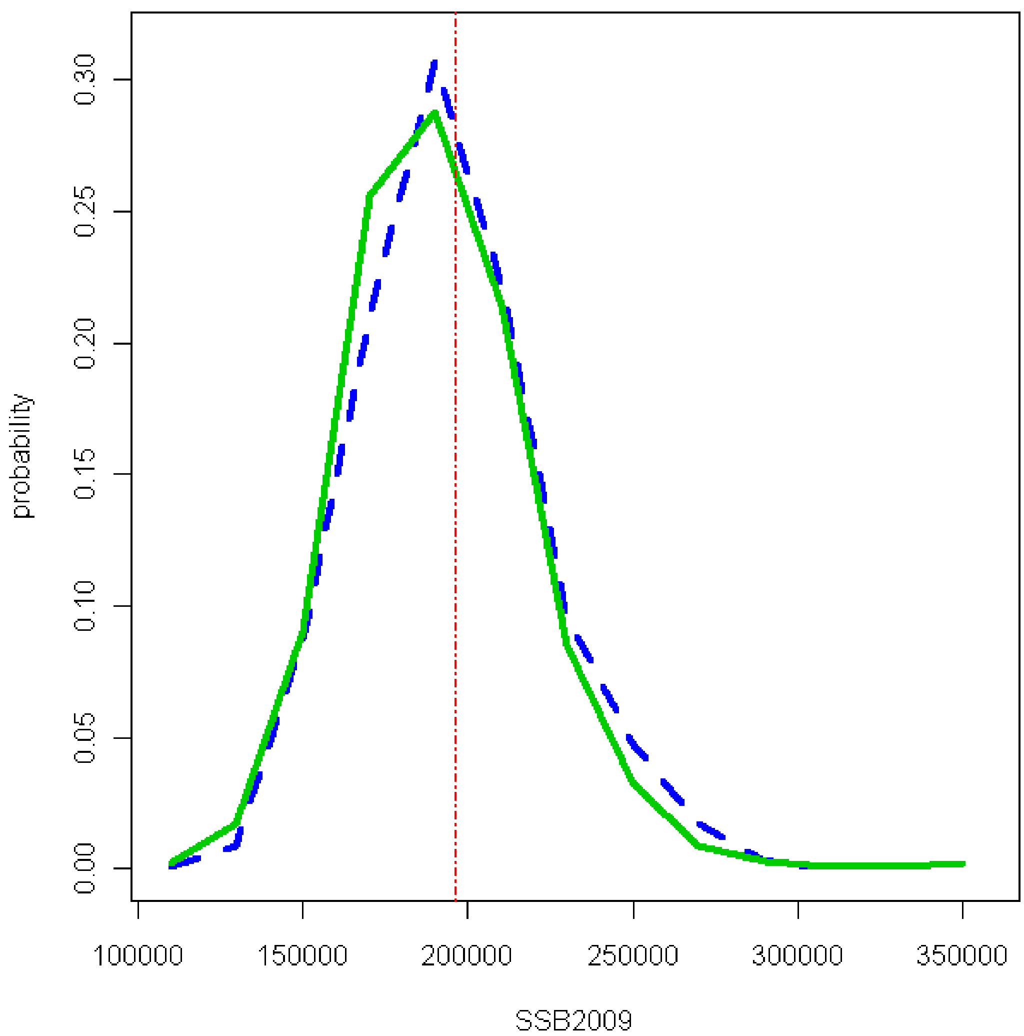



**C4.** Uncertainty in average F on ages 5-7 ($F_{5\text{-}7}$) pollock in 2009 for two MCMC chains (dotted blue and solid green lines). The vertical dashed red line indicates the point estimate.

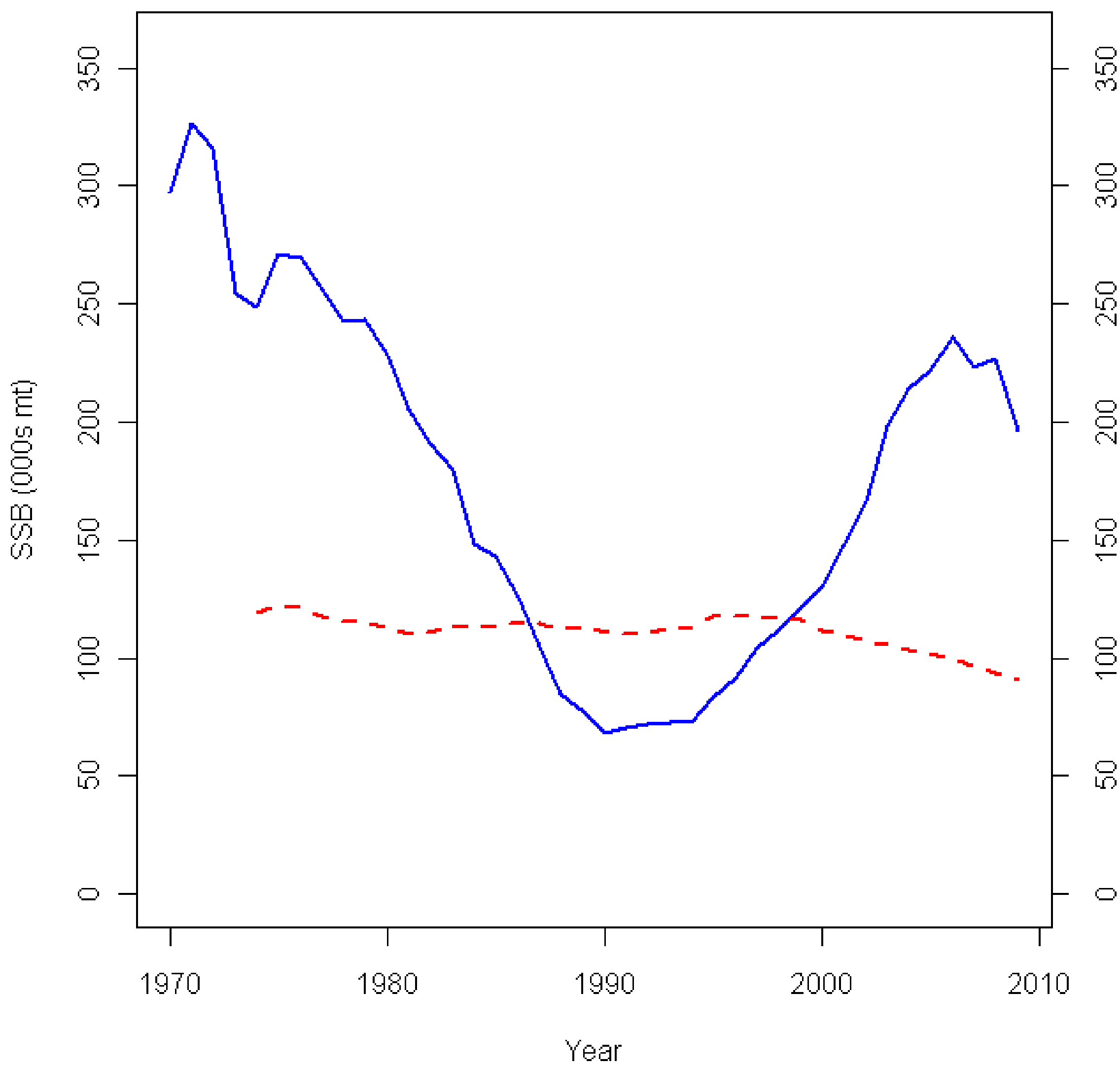



**C5.** ASAP model estimates for NEFSC Fall and Spring index selectivities for pollock (dashed, and dot-dash, respectively) compared to 5-year average fleet selectivities. Average selectivity at age for the 1st 5-year period includes estimates from 1970-1974 (line with '1' for point symbols) while the last 5-year average includes estimates from 2005-2009 (line with '8' for point symbols).

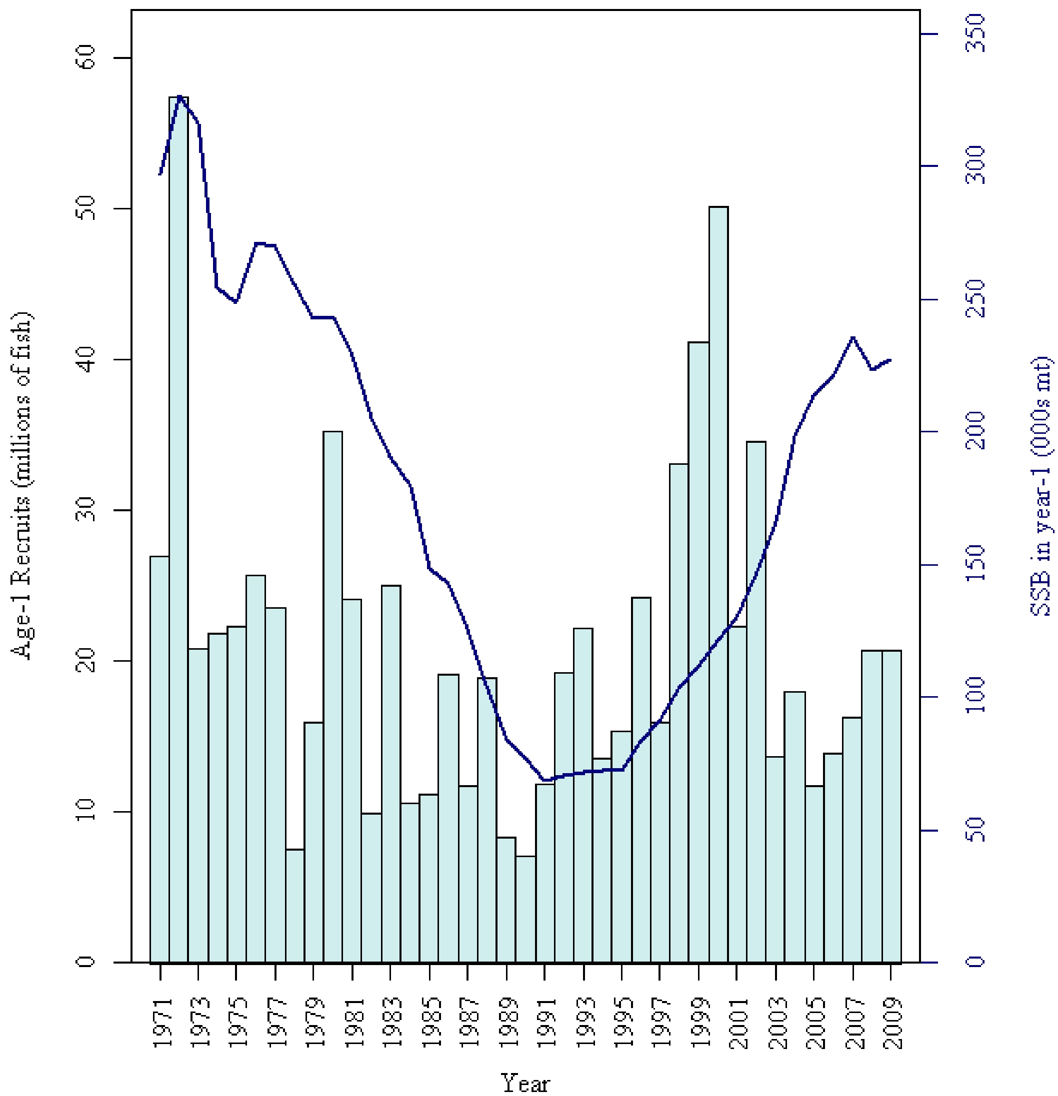

**C6.** Annual estimates of three biomass measures (total biomass, spawning stock biomass, and exploitable biomass in mt) for pollock based on the ASAP model.




**C7.** Posterior distribution for pollock spawning stock biomass (SSB) in 2009 for two MCMC chains (dotted blue and solid green lines). The vertical dashed red line indicates the point estimate.




**C8.** ASAP model estimated time series of pollock spawning stock biomass (solid line). The dashed red line is the corresponding $SSB_{MSY}$ proxy calculated from stochastic projections at year-specific F40% with a 5 year moving average of weights at age, selectivity at age, and maturity at age. $SSB_{MSY}$ in 1974 used years (1970-1974) while the final $SSB_{MSY}$ used years (2005-2009).




**C9.** Time series plot of pollock spawning stock biomass in year t-1 (solid line) and recruitment of age-1 fish in year t (solid bars).

**Appendix: Terms of Reference**

## *Assessment Terms of Reference for SAW/SARC50 (June 2010)*

(file vers.: 12/22/09-c)

**A. Monkfish**

1. Characterize the commercial catch including landings, effort, LPUE and discards. Describe the uncertainty in these sources of data.

2. Report results of 2009 cooperative monkfish survey and describe sources of uncertainty in the data and results.

3. Characterize other survey data that are being used in the assessment (e.g., regional indices of abundance, recruitment, length data, state surveys). Describe the uncertainty in these sources of data.

4. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series, and characterize the uncertainty of those estimates.

5. Update or redefine biological reference points (BRPs; estimates or proxies for $B_{MSY}$, $B_{THRESHOLD}$, and $F_{MSY;}$ and estimates of their uncertainty). Comment on the scientific adequacy of existing and redefined BRPs.

6. Evaluate stock status with respect to the existing BRPs, as well as with respect to updated or redefined BRPs (from TOR 5).

7. Evaluate monkfish diet composition data and its implications for population level consumption by monkfish.

8. Develop and apply analytical approaches and data that can be used for conducting single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs).
    a. Provide numerical short-term projections (through 2016). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions to examine important sources of uncertainty in the assessment.
    b. Comment on which projections seem most realistic, taking into consideration uncertainties in the assessment.
    c. Describe this stock's vulnerability to becoming overfished, and how this could affect the choice of ABC.

9. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.

**B. Sea scallop**

1. Characterize the commercial catch including landings, effort, LPUE and discards. Describe the uncertainty in these sources of data.

2. Characterize the survey data that are being used in the assessment (e.g., regional indices of abundance, recruitment, state surveys, length data, etc.). Describe the uncertainty in these sources of data. Document the transition between the survey vessels and their calibration. If other survey data are used in the assessment, describe those data as they relate to the current assessment (Exclude consideration of future survey designs and methods).

3. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series, and characterize the uncertainty of those estimates.

4. Update or redefine biological reference points (BRPs; estimates or proxies for $B_{MSY}$, $B_{THRESHOLD}$, and $F_{MSY;}$ and estimates of their uncertainty). Comment on the scientific adequacy of existing and redefined BRPs.

5. Evaluate stock status with respect to the existing BRPs, as well as with respect to updated or redefined BRPs (from TOR 4).

6. Develop and apply analytical approaches and data that can be used for conducting single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs).
    a. Provide numerical short-term projections (through 2014). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions to examine important sources of uncertainty in the assessment.
    b. Comment on which projections seem most realistic, taking into consideration uncertainties in the assessment.
    c. Describe this stock's vulnerability to becoming overfished, and how this could affect the choice of ABC.

7. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.

**C. Pollock**

1. Characterize the commercial and recreational catch including landings, effort, LPUE and discards. Describe the uncertainty in these sources of data, including consideration of stock definition.

2. Characterize the survey data that are being used in the assessment (e.g., regional indices of abundance, recruitment, state surveys, age-length data, etc.). Describe the uncertainty in these sources of data, including consideration of stock definition.

3. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series, and characterize the uncertainty of those estimates.

4. Update or redefine biological reference points (BRPs; estimates or proxies for $B_{MSY}$, $B_{THRESHOLD}$, and $F_{MSY;}$ and estimates of their uncertainty). Comment on the scientific adequacy of existing and redefined BRPs.

5. Evaluate stock status with respect to the existing BRPs, as well as with respect to updated or redefined BRPs (from TOR 4).

6. Evaluate pollock diet composition data and its implications for population level consumption by pollock.

7. Develop and apply analytical approaches and data that can be used for conducting single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs).
    a. Provide numerical short-term projections (through 2017). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions to examine important sources of uncertainty in the assessment.
    b. Comment on which projections seem most realistic, taking into consideration uncertainties in the assessment.
    c. For a range of candidate ABC scenarios, compute probabilities of rebuilding the stock by 2017.
    d. Describe this stock's vulnerability to becoming overfished, and how this could affect the choice of ABC.

8. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.

***Appendix to the SAW TORs:***

## Clarification of Terms
## used in the SAW/SARC Assessment Terms of Reference

(The text below is from DOC National Standard Guidelines, Federal Register, vol. 74, no. 11, January 16, 2009)

**On "Acceptable Biological Catch":**

*Acceptable biological catch (ABC)* is a level of a stock or stock complex's annual catch that accounts for the scientific uncertainty in the estimate of [overfishing limit] OFL and any other scientific uncertainty…" *(p. 3208) [In other words, OFL ≥ ABC.]*

*ABC for overfished stocks.* For overfished stocks and stock complexes, a rebuilding ABC must be set to reflect the annual catch that is consistent with the schedule of fishing mortality rates in the rebuilding plan. *(p. 3209)*

NMFS expects that in most cases ABC will be reduced from OFL to reduce the probability that overfishing might occur in a year. (p. 3180)

ABC refers to a level of ''catch'' that is ''acceptable'' given the ''biological'' characteristics of the stock or stock complex. As such, [optimal yield] OY does not equate with ABC. The specification of OY is required to consider a variety of factors, including social and economic factors, and the protection of marine ecosystems, which are not part of the ABC concept. (p. 3189)

**On "Vulnerability":**

*''Vulnerability.* A stock's vulnerability is a combination of its productivity, which depends upon its life history characteristics, and its susceptibility to the fishery. Productivity refers to the capacity of the stock to produce MSY and to recover if the population is depleted, and susceptibility is the potential for the stock to be impacted by the fishery, which includes direct captures, as well as indirect impacts to the fishery (e.g., loss of habitat quality)." (p. 3205)

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The mission of NOAA's National Marine Fisheries Service (NMFS) is "stewardship of living marine resources for the benefit of the nation through their science-based conservation and management and promotion of the health of their environment." As the research arm of the NMFS's Northeast Region, the Northeast Fisheries Science Center (NEFSC) supports the NMFS mission by "conducting ecosystem-based research and assessments of living marine resources, with a focus on the Northeast Shelf, to promote the recovery and long-term sustainability of these resources and to generate social and economic opportunities and benefits from their use." Results of NEFSC research are largely reported in primary scientific media (*e.g.*, anonymously-peer-reviewed scientific journals). However, to assist itself in providing data, information, and advice to its constituents, the NEFSC occasionally releases its results in its own media. Currently, there are three such media:

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