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A Report of the 53rd Northeast Regional Stock Assessment Workshop

53rd Northeast Regional Stock Assessment Workshop (53rd SAW)

Assessment Summary Report

U.S DEPARTMENT OF COMMERCE
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SAW-53 ASSESSMENT SUMMARY REPORT

Introduction

The 53rd SAW Assessment Summary Report contains summary and detailed technical information on two stock assessments reviewed during November 29 to December 2, 2011 at the Stock Assessment Workshop (SAW) by the 53rd Stock Assessment Review Committee (SARC-53): Gulf of Maine Atlantic cod (*Gadus morhua*) and black sea bass (*Centropristis striata*). The SARC-53 consisted of 3 external, independent reviewers appointed by the Center for Independent Experts [CIE], and an external SARC chairman from the MAFMC 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-53 are available at website: http://www.nefsc.noaa.gov/nefsc/saw/ under the heading "SARC 53 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 scientific and management uncertainty 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 53 Panelist Reports"), the SARC review panel concluded that the results of the **Gulf of Maine cod** assessment can serve as a scientific basis for fishery management of this stock. All terms of reference for this stock assessment were fully met. Both catch and survey data were fully and adequately summarized. The newly developed statistical catch at age model (ASAP) was appropriately applied to the data and the time series of abundance and fishing mortality estimated from the model represent the best scientific estimates available for this stock. In particular, the Panel agrees that the 2005 cod year class in the Gulf of Maine was less strong than suggested by analyses conducted for a prior assessment. The Panel did not accept the proposed revision of the reference points from $F_{40\%}$ to $F_{35\%}$ that were recommended during the assessment review, but rather recommended the continued use of $F_{40\%}$ as the basis for biological reference point proxies. However, regardless of which reference point is selected, results indicate that the Gulf of Maine cod stock is overfished and is experiencing overfishing. Stock projections provided at the SARC-53 meeting indicate that the stock will not be rebuilt by 2014.

The Review Panel unanimously rejected the newly proposed statistical catch at age stock assessment model (ASAP) for **black sea bass** and concluded that it did not provide a suitable scientific basis for management of this stock. The Panel identified substantial concerns over the potential for spatial structure and incomplete mixing within the stock area that compromised the ability of the forward projecting catch at age model to index abundance and fishing mortality reliably based on the data available. Based on the biological reference points and assessment as approved at the Data Poor Species Workshop in 2007, black sea bass is not overfished and overfishing is not occurring. The SARC-53 panel suggested that the assessment team continue to consider alternative methods for assessing the black sea bass stock, perhaps continuing with age-based methods, although achieving a new framework should not be expected in the short term.

Glossary

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

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

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

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

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

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

Mortality rates. Populations of animals decline exponentially. This means that the number of animals that die in an "instant" is at all times proportional to the number present. The decline is defined by survival curves such as: $N_{t+1} = N_t e^{-z}$

where N_t is the number of animals in the population at time t and N_{t+1} is the number present in the next time period; Z is the total instantaneous mortality rate which can be separated into deaths due to fishing (fishing mortality or F) and deaths due to all other causes (natural mortality or M) and e is the base of the natural logarithm (2.71828).To better understand the concept of an instantaneous mortality rate, consider the following example. Suppose the instantaneous total mortality rate is 2 (i.e., Z = 2) and we want to know how many animals out of an initial population of 1 million fish will be alive at the end of one year. If the year is apportioned into 365 days (that is, the 'instant' of time is one day), then 2/365 or 0.548% of the population will die each day. On the first day of the year, 5,480 fish will die (1,000,000 x 0.00548), leaving 994,520 alive. On day 2, another 5,450 fish die (994,520 x 0.00548) leaving 989,070 alive. At the end of the year, 134,593 fish $[1{,}000{,}000 \times (1 - 0.00548)^{365}]$ remain alive. If, we had instead selected a smaller 'instant' of time, say an hour, 0.0228% of the population would have died by the end of the first time interval (an hour), leaving 135,304 fish alive at the end of the year $[1{,}000{,}000 \times (1 - 0.00228)^{8760}]$. As the instant of time becomes shorter and shorter, the exact answer to the number of animals surviving is given by the survival curve mentioned above, or, in this example:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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.

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.

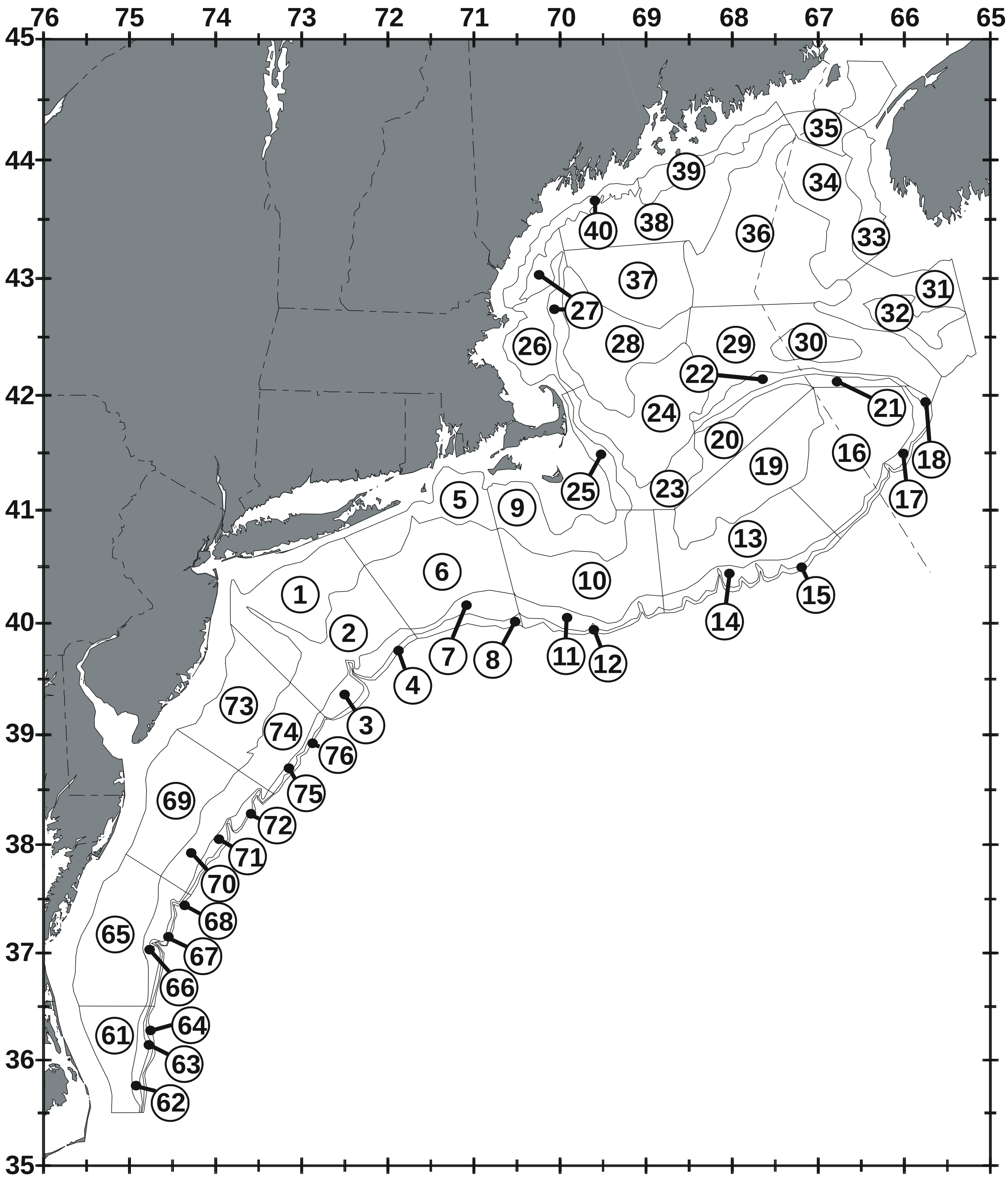


Figure 1. Offshore depth strata that have been sampled during Northeast Fisheries Science Center bottom trawl research surveys. Some of these may not be sampled presently.

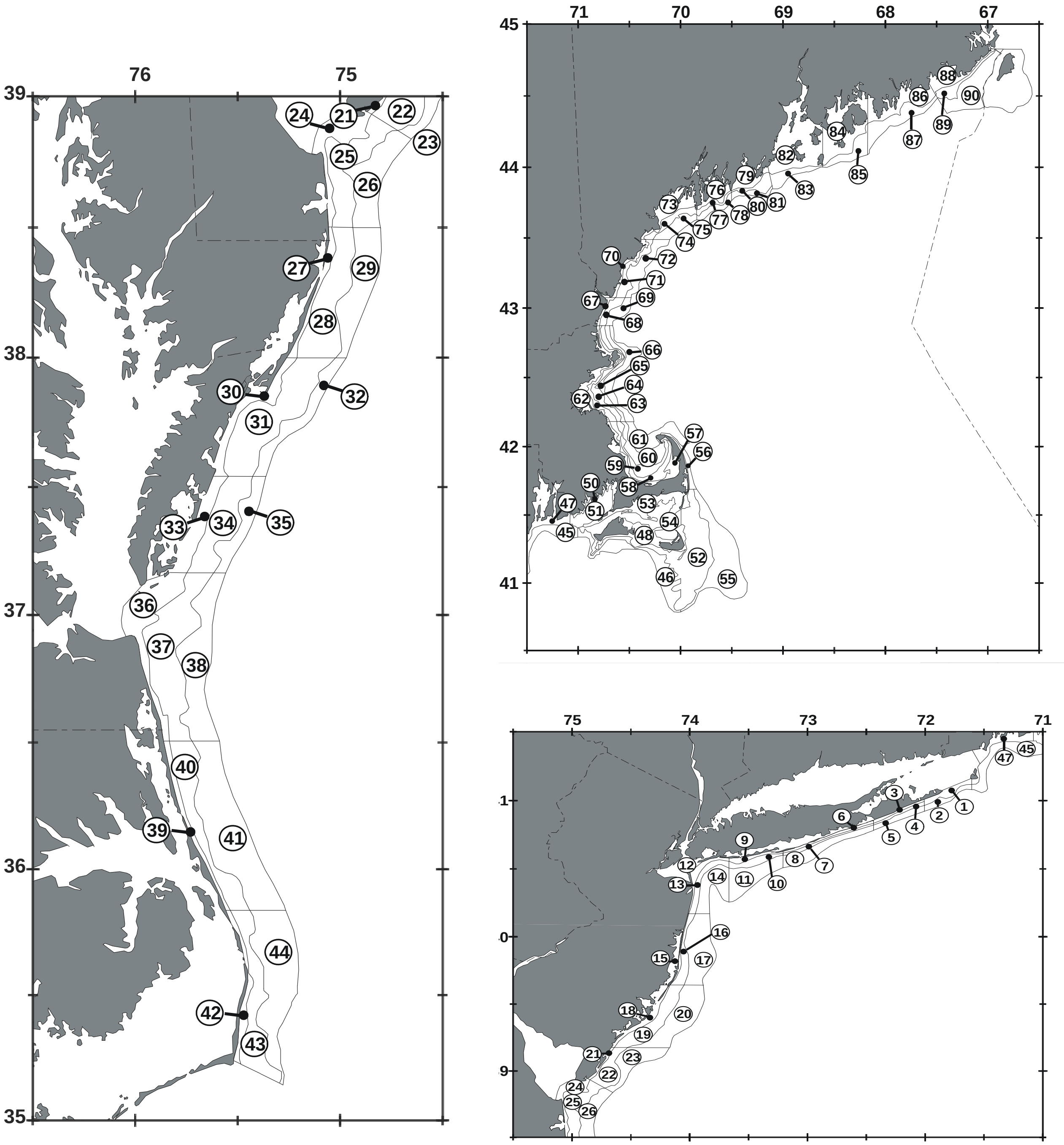
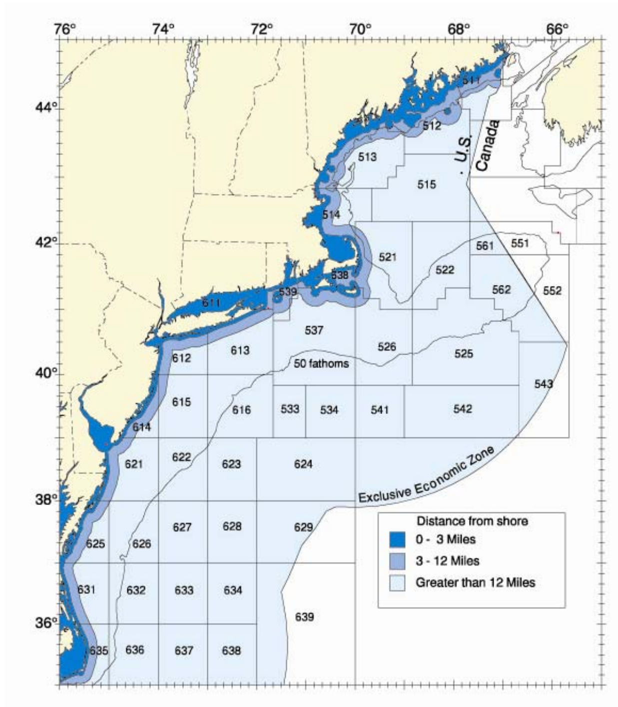


Figure 2. Inshore depth strata that have been sampled during Northeast Fisheries Science Center bottom trawl research surveys. Some of these may not be sampled presently.



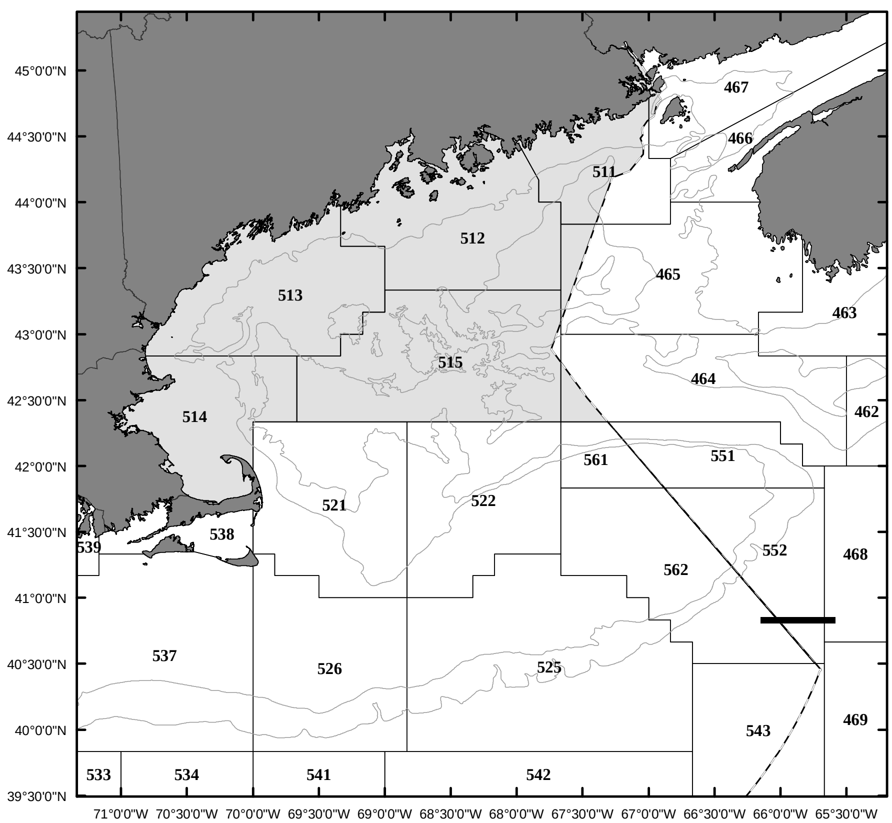


Figure 3. Statistical areas used for reporting commercial catches.

A. GULF OF MAINE COD ASSESSMENT SUMMARY FOR 2011

State of Stock: A new stock assessment model (ASAP) is proposed as the best scientific information available for determining stock status for Gulf of Maine Atlantic cod (*Gadus morhua*). Spawning stock biomass (SSB) in 2010 is estimated to be 11,868 mt and the fully recruited fishing mortality (F_{full}) is estimated to be 1.14 (Figure A1, Figure A2, Figure A3).

An MSY could not be derived directly from the ASAP model; therefore an MSY proxy must be used for reference points. $F_{40\%}$ is recommended as the proxy for F_{MSY} (the overfishing threshold). $F_{40\%}$, estimated on the fully selected F is 0.20. SSB_{MSY} (the biomass target) is calculated from projections at $F_{40\%}$ and is estimated to be 61,218 mt.

Comparing the current 2010 ASAP model estimates of SSB and fully recruited F to the newly accepted reference points, the Gulf of Maine cod stock is overfished and overfishing is occurring (Figure A1).

By the convention developed in GARM III, because the point estimate of current stock status with a five-year peel was within the confidence intervals of the base model (Figure A1), no correction for a retrospective pattern was used for stock status determination or applied in the stock projections.

All alternative parameterizations of the ASAP model led to the same conclusions regarding stock status. Moreover, all versions of the previously used VPA model also led to the same conclusions that the stock is overfished and overfishing is occurring.

Projections: The ASAP model results indicate that the stock is overfished and overfishing is occurring (Figure A1), and there was a moderate retrospective pattern. Projections were made for three constant F scenarios: F = 0 (no fishing), $F = 0.75*F_{MSY\ Proxy}$, and $F = F_{MSY\ Proxy}$ (Table A1). Based on the recommendations of the SARC-53 Review Panel, a revised method was used to conduct short term projections relative to the methods used in the previous GARM III assessment. Similar to the previous method, the revised projection model samples from a cumulative density function derived from ASAP estimated age-1 recruitment between 1982 and 2008. Recruitment in 2009 and 2010 was not included due to general uncertainty in terminal estimates of recruitment. Unlike, the previous method, the revised approach adjusts projected recruitment when SSB falls below some specified SSB threshold based on a linear function that declines to zero when SSB = 0 mt. This revised method provides a better representation of the risk associated with alternative management policies. Under all projection scenarios, the stock does not rebuild by the current rebuilding date of 2014.

Catch and Status Table: Gulf of Maine Atlantic cod (weights in 000s mt, recruitment in millions, arithmetic means)

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Max[1]	Min[1]	Mean[1]
Commercial landings	4.3	3.6	3.9	3.8	3.6	3.0	4.0	5.4	6.0	5.4	18.0	1.4	7.5
Commercial discards	2.0	1.8	1.0	0.9	0.4	0.5	0.3	0.5	1.0	0.2	2.2	<0.1	0.9
Recreational landings	2.7	1.7	2.2	1.6	1.8	0.8	1.1	1.6	1.7	3.5	4.8	0.3	1.9
Recreational discards	1.0	1.3	1.2	0.8	1.1	0.6	1.1	1.3	1.2	2.3	2.3	<0.1	0.6
Catch used in assessment	10.0	8.4	8.3	7.1	6.8	5.0	6.4	8.8	9.9	11.4	22.3	3.9	10.9
Spawning stock biomass	14.9	15.1	12.4	10.4	8.9	8.4	10.8	12.6	13.6	11.9	23.7	7.3	12.5
Recruitment (age 1)	1.7	7.4	2.8	8.6	5.4	9.0	6.7	6.7	5.3	4.3	33.1	1.7	8.7
F_{5-7}	0.69	0.59	0.72	0.70	0.84	0.62	0.59	0.74	0.77	1.10	1.44	0.49	0.85
F_{mult}	0.72	0.61	0.75	0.72	0.87	0.64	0.62	0.77	0.80	1.14	1.49	0.51	0.90

[1]Over the period 1982-2010

Stock Distribution and Identification: Within the Gulf of Maine the US EEZ splits statistical areas 464, 465 and 467. Prior to implementation of the Hague line in October 1984, United States (US) landings of fish from these statistical areas could have been either Gulf of Maine or Scotian Shelf cod. The operational definition of the stock area was changed for this assessment to be consistent with the management boundaries. Current management of Gulf of Maine cod includes catch from these areas against the fisheries ACLs. Since 1985, landings from these statistical areas have averaged less than 2% of total commercial landings. While previous assessments have not included these catches, their impact on the updated assessment is negligible.

Catches: Since 1964, catch of Gulf of Maine Atlantic cod has ranged from 3,242 mt to 22,272 mt. Recent catches over the past five years have ranged from approximately 5,000 mt to 11,000 mt. Catch estimates prior to 1981 do not include commercial discards or estimates of recreational removals. Since 1982, commercial landings have been the largest source of fishery removals, comprising 40-90% of the total catch. Commercial discards constituted a large proportion of the catch during the 1998 – 2003 period when trip limits ranged from 30-500 lb/day (13.6 – 226.8 kg/day). In the most recent five years, commercial discards have accounted for <10% of the catch (Figure A4).

Commercial discards were estimated for 1989 to 2010, and were hindcasted from 1988 back to 1982. Discard estimates ranged from 2% to 36% of catch, with an average of 9% for all years. The fleets that account for nearly all cod discards were longline, shrimp otter trawl, small-mesh otter trawl, large-mesh otter trawl, large-mesh gillnet, and extra-large mesh gillnet. Discards could not be estimated for any other commercial gear types.

Recreational catch has varied annually from a low of 574 mt in 1997 to a high of 5,795 mt in 2010. Recreational catches have constituted between 8 and 51% of total annual removals, averaging 25% over the period 1982-2010. Numerical estimates of recreational discards have increased from approximately 10% of recreational landings at the beginning of the time series to more than 200% of the recreational landings currently.

Discard mortality in all fleets was assumed to be 100%. The determination of stock status was not sensitive to this assumption.

Data and assessment: The previous assessment of Gulf of Maine cod was conducted with a VPA that accounted for total commercial landings, some commercial discards, and recreational landings. A new assessment model (ASAP) was developed that incorporated updated estimates of the length-weight equation, maturity at age, and weights at age. Commercial and recreational discards in all years were also included as inputs to the model.

The commercial fleet catch includes catch by all gear types, though Gulf of Maine cod are primarily caught using otter trawl and gillnet (with minor contributions from hook and line gear). Recreational catch was included for 1982 to 2010. These data were entered as a single time series of catch and catch-at-age.

Abundances (number/tow) from the NEFSC spring and fall surveys, and the MADMF spring survey (1982-2010) were used in the ASAP model along with estimated CV and annual age composition. The MADMF fall survey and the commercial landings per unit effort (LPUE) index were not included in this assessment.

Natural mortality rate was assumed to be 0.2 for all ages and years. Maturity at age was assumed constant for all years.

The assessment model was evaluated across a wide range of alternative assumptions regarding data inputs and was found to be robust to these different assumptions. In this assessment, inclusion of the discard weights at age into the overall weight at age estimates had a substantial impact on estimated model outputs. The estimated 2010 SSB ranged from 9,479 – 16,301 mt and F_{full} from 0.79 – 1.54.

Biological Reference Points: No basis was found to change the foundation of the biological reference points from the previous GARM III Assessment. $F_{40\%}$ is recommended as the proxy for the overfishing threshold (F_{MSY}). A deterministic value of $F_{40\%}$ was estimated from a spawner per recruit analysis using 2008-2010 average SSB weights, catch weights, maturity and selectivity at age. Expressed as a fully recruited fishing mortality, $F_{40\%}$ is 0.20.

Stochastic projections at $F_{40\%}$ were used to determine new recommended biomass-related reference points (SSB_{MSY} and MSY proxies). The projection methodology used to determine SSB_{MSY} and MSY proxies was identical to that used for short-term projections. The proxy for SSB_{MSY}, the B_{TARGET}, is estimated at 61,218 mt, with 5th and 95th percentiles spanning 46,905 - 81,089 mt. One half of SSB_{MSY} is proposed for $B_{THRESHOLD}$ (30,609 mt).

The proxy for MSY is 10,392 mt, with 5th and 95th percentiles spanning 7,825 - 14,146 mt. The median recruitment was 7.4 million age 1 fish, with 5th and 95th percentiles ranging from 2.9 to 17.5 million fish.

The biological reference points that had been used previously were F_{MSY}=$F_{40\%}$=0.237, SSB_{MSY}=58,248 mt, and MSY=10,014 mt.

Fishing Mortality: In 1982, the fully recruited F was 0.9, and over the next decade fishing mortality (F_{full}) mostly increased, peaking in the early 1990s (1.10-1.49). It subsequently decreased through 1999, but has since increased to 1.14 in 2010 (Figure A5).

Biomass: The ASAP model estimates a 1982 spawning stock biomass (SSB) of 23,675 mt. Spawning biomass decreased to the time series low (7,270 mt) in 1998 (Figure A6). Spawning biomass then increased steadily through 2002, but has been fluctuating around 8,000-14,000 mt for the last eight years. Spawning biomass in 2010 is estimated to be 11,868 mt.

Total population biomass (January 1) follows the same trend as SSB (Figure A6). It has ranged from 41,575 mt in 1982 to a low of 11,885 mt in 1998. The current estimate of total biomass in 2010 is 20,589 mt.

Recruitment: Mean recruitment (age 1) was around 8.7 million fish. Strong year classes were produced in 1982, 1983, 1985, 1986, and 1987 with below average recruitment in recent years (Figure A7). The 2005 year class was believed to be very strong based on survey estimates in 2007 and 2008 (NEFSC 2008). However, as this year class recruited to the fishery and to the fishery-independent surveys, data through 2010 indicate that this year class was not as strong as previously believed, but still above the time series average.

Special Comments:

- The addition of three years of catch and survey data since the last assessment has altered the perception of the 2005 year class. Two anomalously large tows in the spring survey (2007 and 2008) produced an estimate of this year class of 23.9 million fish in the previous assessment. The additional recent observations of this year class in the surveys, and now in the catch, have revised this estimate downwards to 8.9 million fish. This has reduced estimates of stock biomass substantially.

- Previous estimates of fish weights at age were biased high as a result of their being derived only from landed catch. The current assessment re-estimated weights at age based on both the landed and discarded catch, and this has resulted in lower weights at age and lower stock biomasses.

- Based on the previous assessment (NEFSC 2008), the stock was predicted to be rebuilt by 2009-2010. The current re-evaluation of the stock indicates that this expectation was incorrect.

References:

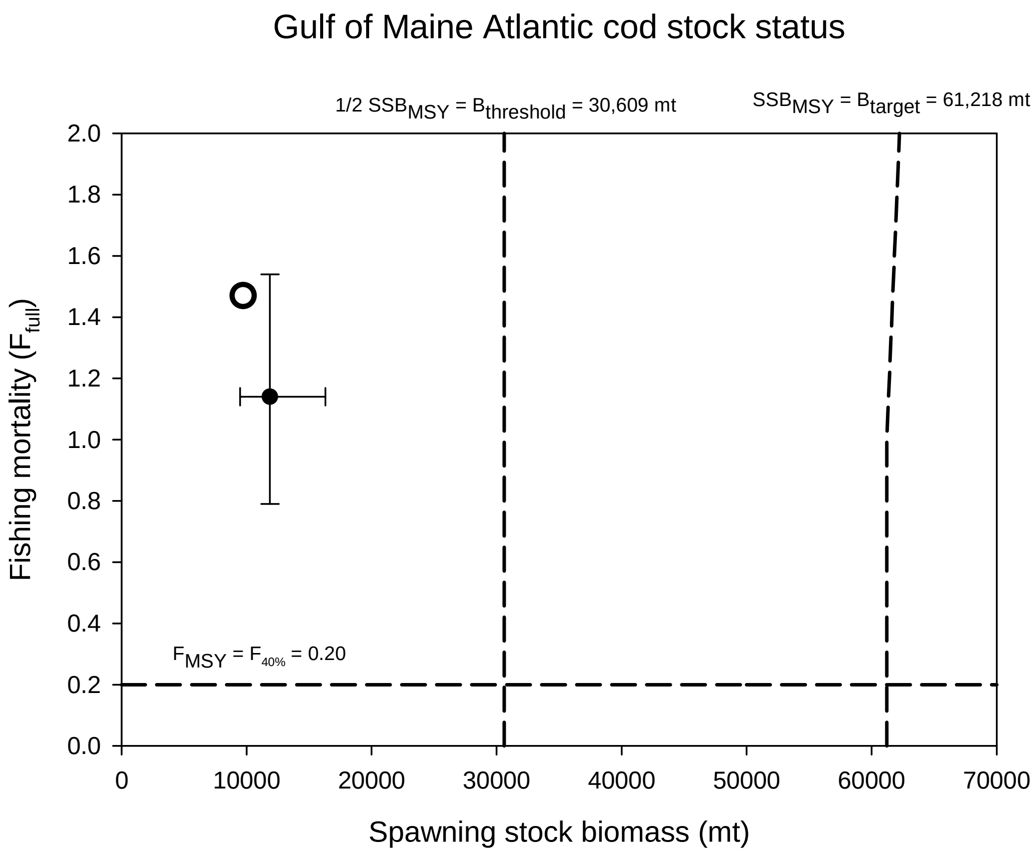
Northeast Fisheries Science Center. 2008. Assessment of 19 Northeast Groundfish Stocks through 2007: Report of the 3rd Groundfish Assessment Review Meeting (GARM III), Northeast Fisheries Science Center, Woods Hole, Massachusetts, August 4-8, 2008. US Dep Commer, NOAA Fisheries, Northeast Fish Sci Cent Ref Doc. 08-15; 884 p + xvii.

Northeast Fisheries Science Center (NEFSC). (in prep. for 2012.) 53rd Northeast Regional Stock Assessment Workshop (53rd SAW) Assessment Report. US Dept Commer, Northeast Fish Sci Cent Ref Doc.

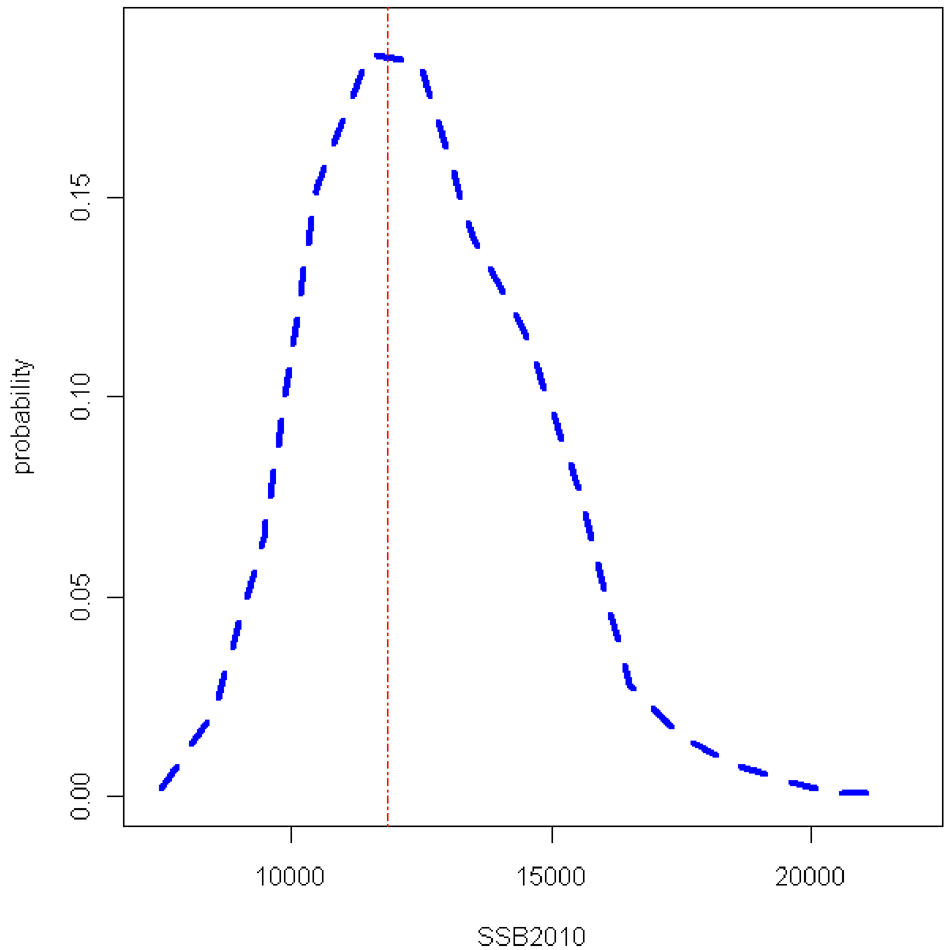
Table A1. Short term projections of total fishery yield and spawning stock biomass for Gulf of Maine Atlantic cod based on three different harvest scenarios: no fishing (F_0), fishing at 75% F_{MSY}, and fishing at F_{MSY}. The 'Unadjusted' notation indicates that these projections have not been adjusted to account for a retrospective pattern.

Total fishery yield (mt)			
	F_0	75% F_{MSY} (0.15)	F_{MSY} ($F_{40\%}$ = 0.20)
Year	*Unadjusted*	*Unadjusted*	*Unadjusted*
2011	11,392	11,392	11,392
2012	0	1,001	1,313
2013	0	1,746	2,232
2014	0	2,780	3,482
2015	0	3,740	4,584
2016	0	4,629	5,562
2017	0	5,526	6,541
2018	0	6,399	7,469
2019	0	7,115	8,213
2020	0	7,682	8,777
2021	0	8,133	9,202
2022	0	8,508	9,560
2023	0	8,781	9,811
2024	0	8,972	9,981
2025	0	9,116	10,100

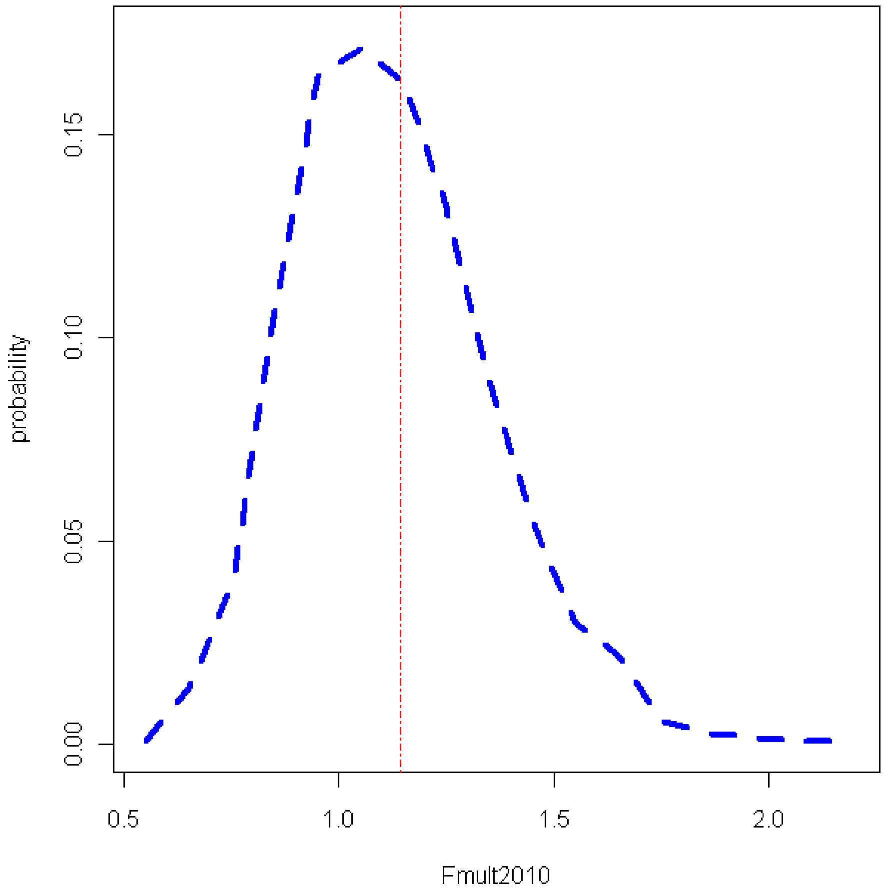
Spawning stock biomass (mt)			
	F_0	75% F_{MSY} (0.15)	F_{MSY} ($F_{40\%}$ = 0.20)
Year	*Unadjusted*	*Unadjusted*	*Unadjusted*
2011	8,178	8,178	8,178
2012	7,069	6,894	6,834
2013	13,073	11,838	11,463
2014	21,656	18,311	17,363
2015	31,565	24,809	23,014
2016	42,701	31,286	28,405
2017	55,765	38,067	33,884
2018	70,054	44,968	39,337
2019	85,801	51,811	44,599
2020	99,450	57,382	48,761
2021	110,811	61,576	51,821
2022	121,689	65,347	54,534
2023	130,611	68,136	56,370
2024	138,032	70,219	57,820
2025	144,000	71,759	58,819



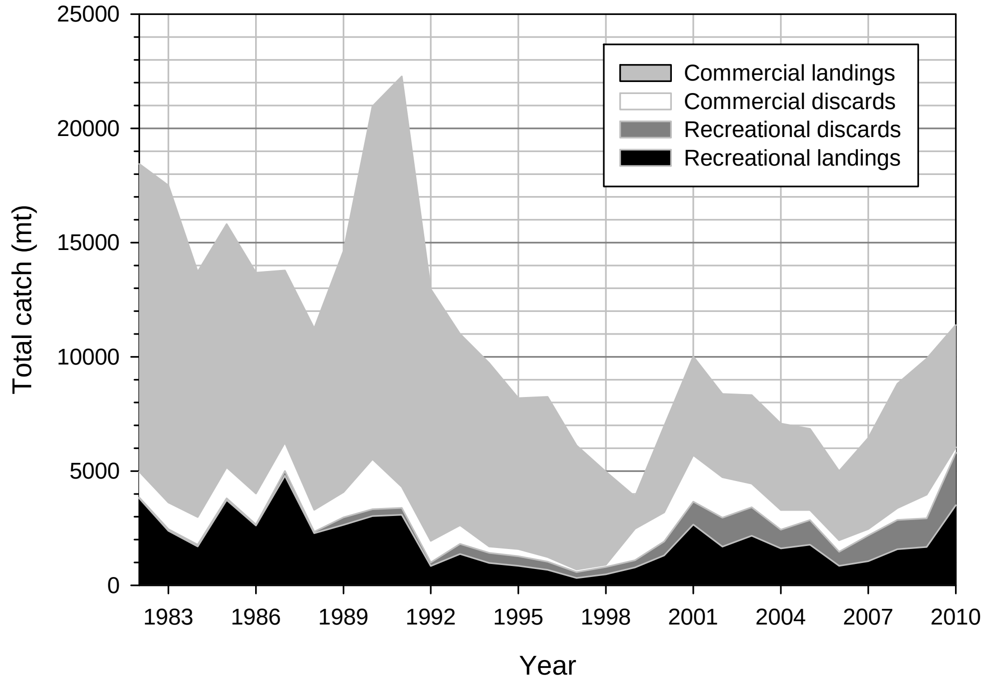
A1. Stock status based on estimates of F and SSB for 2010 for Gulf of Maine Atlantic cod with respect to biological reference points (solid circle); error bars represent 90% confidence intervals. The figure also shows fishing mortality and spawning stock biomass estimates that have been adjusted to account for retrospective pattern (open circle).



A2. MCMC distribution of the estimate of the 2010 spawning stock biomass (SSB2010) for Gulf of Maine Atlantic cod. The final year point estimate is indicated by the dashed vertical red line.

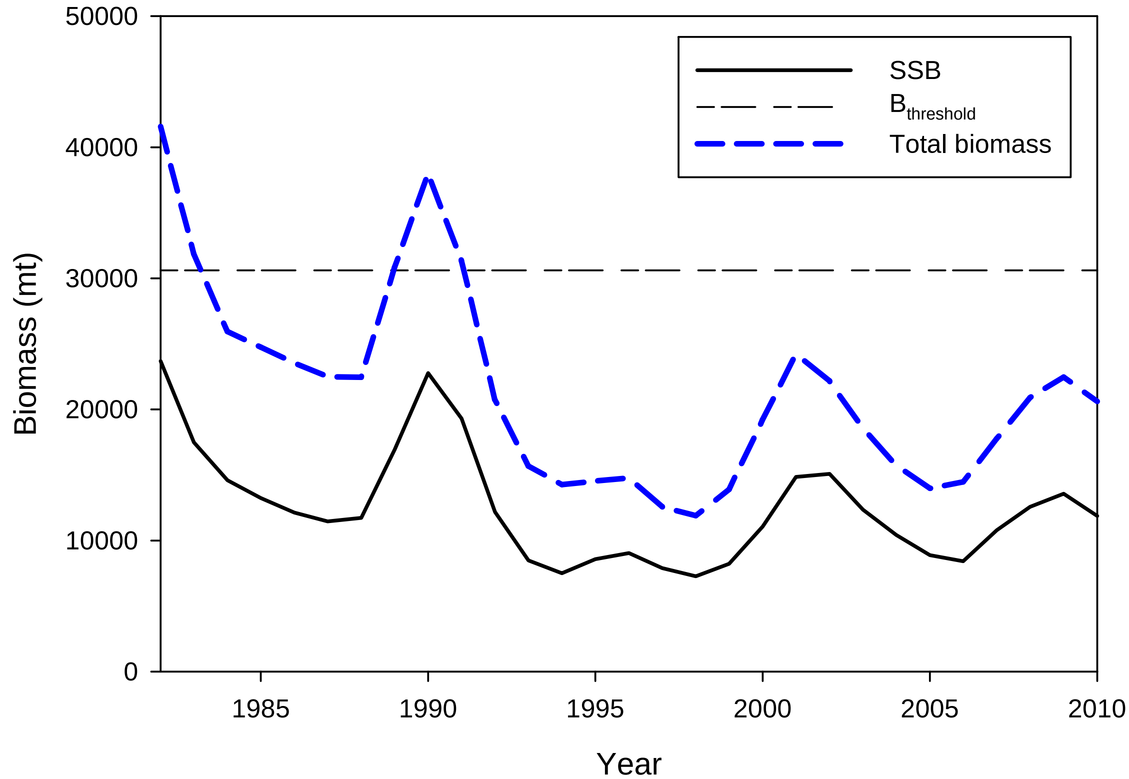


A3. MCMC distribution of the estimate of the 2010 fishing mortality for Gulf of Maine Atlantic cod (Fmult2010). The final year point estimate is indicated by the dashed vertical red line.

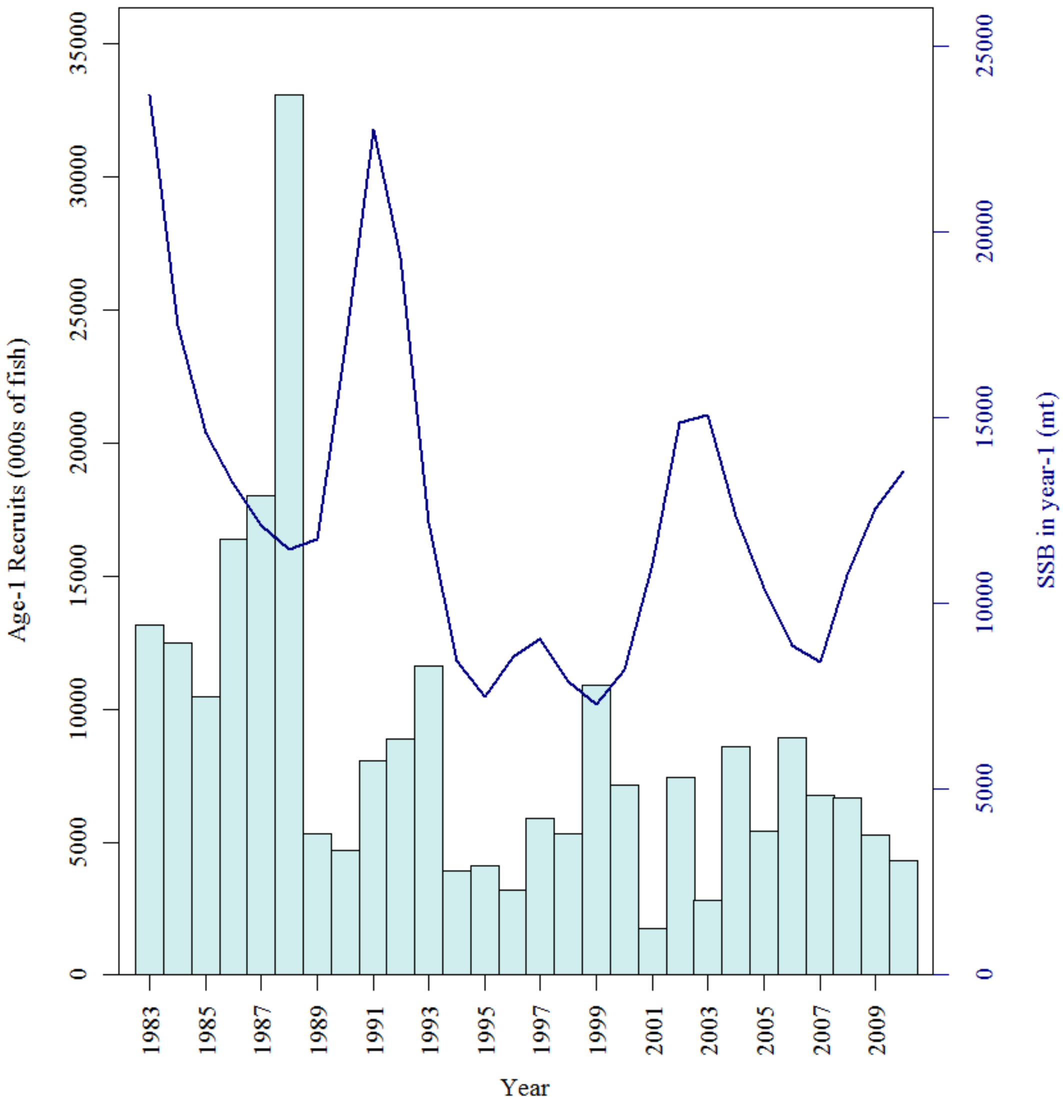


A4. Total catch of the Gulf of Maine Atlantic cod between 1982 and 2010 by fleet (commercial and recreational) and disposition (landings and discards).

A5. Estimated trends in fishing mortality (F_{Full}) of Gulf of Maine Atlantic cod and associated overfishing level, $F_{Threshold}$.



A6. Estimated trends in total biomass and spawning stock biomass (SSB) of Gulf of Maine Atlantic cod and the associated overfished level, $SSB_{threshold}$.



A7. Time series plot of Gulf of Maine Atlantic cod spawning stock biomass in year t-1 (SSB, solid line) and recruitment of age-1 fish in year t (solid bars).

B. BLACK SEA BASS ASSESSMENT SUMMARY FOR 2011

State of Stock:

The SARC-53 Review Panel did not believe that the new statistical catch at age model (ASAP) for black sea bass (*Centropristis striata*) brought forward to SARC-53 provided a sound scientific basis for management.

The last approved stock assessment model – a statistical catch at length (SCALE) model was approved at the Data Poor Working Group meeting in December 2008 (NEFSC 2009a, 2009b) and has been updated annually in support of management. The SCALE model was most recently used in June and July 2011 (MAFMC 2011; NEFSC 2011) to estimate the status of the stock compared to previously accepted reference points. Based on that analysis, a comparison of 2010 estimates of the spawning stock biomass and fishing mortality rate to existing biological reference points (SSB_{MSY} proxy estimate = 12,537 mt [27.6 million lbs] and F_{MSY} proxy estimate = 0.42) indicated that black sea bass was not overfished and overfishing was not occurring. SSB in 2010 was estimated to be 13,926 mt (30.7 million lbs) and the fully selected F was estimated to be 0.41. The 2010 stock was at 111% of the SSB_{MSY} proxy. Based on deterministic projections for 2012 at the F_{MSY} proxy (0.42), the resulting catch would be 3,551 mt (7.8 million lbs) with landings equal to 2,841 mt (6.3 million lbs) (assuming the release mortality rate that was used in June 2011).

Catch and Status Table: Black Sea Bass (mt)

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Min	Max	Mean
Commercial landings1	1,299	1,587	1,359	1,405	1,298	1,285	1,037	875	523	751	523	1,635	1,221
Commercial discard1	187	24	58	370	29	16	57	37	165	110	16	483	103
Recreational landings1	1,545	1,983	1,498	762	852	898	1,011	713	1,049	1,351	519	2,815	1,341
Recreational discards1	309	391	314	142	150	173	220	252	228	231	33	391	147
Catch used in assessment1	3,340	3,985	3,230	2,679	2,330	2,372	2,326	1,877	1,965	2,444	1,877	3,985	2,812
Commercial quota (mt)	1,372	1,511	1,511	1,778	1,823	1,778	1,111	938	511	1,066	511	1,823	1,347
Recreational harvest limit (mt)	1,428	1,573	1,573	1,851	1,897	1,851	1,157	975	975	830	830	1,897	1,415

1: Over the period 1984-2010

Stock Distribution and Identification:

The Mid-Atlantic Fishery Management Council (MAFMC) and Atlantic States Marine Fisheries Commission (ASMFC) Fishery Management Plan for black sea bass defines the management unit as all black sea bass from Cape Hatteras, North Carolina northeast to the US-Canada border (MAFMC 1999).

Catch:

The principal gears used in commercial fishing for black sea bass are fish pots, otter trawl and hand-line. After peaking at 9,900 mt (21.8 million lbs) in 1952, commercial landings markedly decreased during the 1960s, and have since ranged between about 600 (1.3 million lbs) and 2,000 mt (4.4 million lbs) (Figure B1). Commercial landings averaged 1,300 mt (2.9 million lbs) annually during 1988-1997. Commercial fishery quotas were implemented in 1998, and landings then ranged between 1,300 mt (2.9 million lbs) and 1,600 mt (3.5 million lbs) during 1998-2007. Recent quota restrictions resulted in declining commercial landings of 523 (1.2 million lbs) and 751 mt (1.7 million lbs) in 2009 and 2010, respectively. The recreational rod-and-reel fishery for black sea bass harvests a significant proportion of the total catch. After peaking in 1986, recreational landings averaged 1,700 mt (3.7 million lbs) annually during

1988-1997. Recreational fishery harvest limits were implemented in 1998, and landings then ranged between 500 mt (1.1 million lbs) and 2,000 mt (4.4 million lbs) during 1998-2010. Landings in 2010 were 1,350 mt (3.0 million lbs). Commercial fishery discards, although poorly estimated, appear to be a minor part of the total fishery removals from the stock, generally less than 200 mt (0.4 million lbs) per year. Recreational discards, assuming 15% hook and release mortality, are similar ranging from 30 (0.01 million lbs) to 390 mt (0.9 million lbs) per year.

Data and Assessment:

The age-structured model presented to the SARC-53 Review Panel was rejected. The last previously approved peer reviewed assessment model was a statistical catch at length model.

Biological Reference Points:

The 2008 DPSWG Peer Review Panel (NEFSC 2009a) recommended that F40% be used as a proxy for the FMSY overfishing threshold reference point and spawning stock biomass at F40% (SSB40%) be used as the proxy for the stock biomass target reference point. Estimates of the BRPs are F40% = 0.42, SSB40% = 12,537 mt (27.6 million lbs), and MSY = 3,903 mt (8.6 million lbs).

Ecosystem Considerations:

Black sea bass are a temperate reef fish utilizing natural habitats such as sponges and other soft bottom habitats, mussel beds, rocky habitats, shipwrecks and artificial reefs. Sea bass prey on small prey fishes and invertebrates and are preyed upon by sharks, skates and other predatory fishes such as weakfish, bluefish and summer flounder.

Special Comments:

The Review Panel endorses a switch to the use of an arithmetic survey index as opposed to a logarithmic survey index for use in future assessments.

Black sea bass is the only known protogynous hermaphroditic species north of Cape Hatteras, NC which is targeted by a fishery. The response of this species, as well as other hermaphroditic species, to exploitation is not fully understood.

The Review Panel notes that the work completed in preparing the ASAP model represents a considerable improvement in summarizing the information in the data.

The Review Panel felt that an age-structured approach has the potential to present a robust assessment approach for this species, even though the model brought forward in SARC-53 was not accepted. In particular, the Panel notes

- Inherent deficiencies in the data collection programs for this species limit the information available for the assessment; these issues include this species' strong association with structure during times when it is distributed in inshore regions
- There seems to be a degree of spatial structure within the managed stock that compromised the ability to fit a single age-structured model throughout the stock area.

The Review Panel recommends continuation and expansion of the current sampling programs that collect data on catch, abundance and biological characteristics of the stock including age.

The Review Panel suggests that new data, such as a species-specific survey, improved information on operational sex-ratios and information on mixing among population sub-units will likely be required to produce an assessment that provides an improved scientific basis for management.

The Review Panel notes that concerns regarding these issues will affect all black sea bass stock assessment approaches.

In considering all of these issues, the Review Panel suggest that development of an effective model is likely to require a considerable investment of additional effort and will not be achieved in the short term.

References:

Mid-Atlantic Fishery Management Council. (MAFMC). 1999. Amendment 12 to the Summer flounder, scup and black sea bass fishery management plan. Dover, DE. 398 p + appendix.

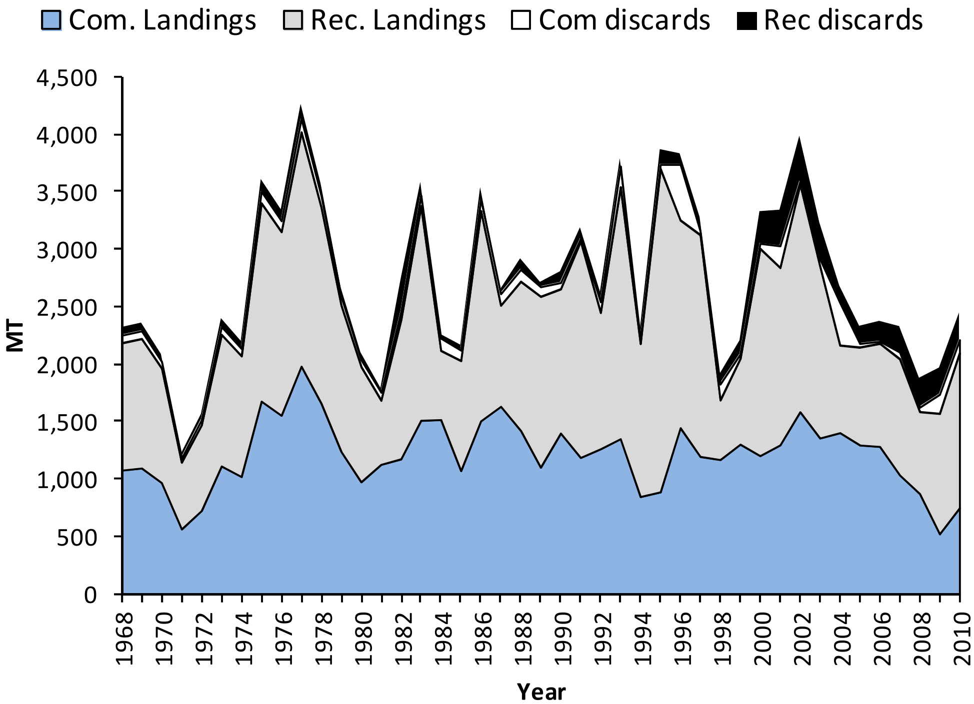
Mid-Atlantic Fishery Management Council. (MAFMC). 2011. Black Sea Bass Management Measures for 2012. MAFMC staff memorandum from Jessica Coakley to Chris Moore, dated 27 June 2011.

Northeast Fisheries Science Center (NEFSC) 2009a. Report by the Peer Review Panel for the Northeast Data Poor Stocks Working Group, 20 January 2009. 34 p.

Northeast Fisheries Science Center (NEFSC) 2009b. The Northeast Data Poor Stocks Working Group Report, December 8-12, 2008 Meeting. Part A. Skate species complex, Deep sea red crab, Atlantic wolfish, and Black sea bass. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 09-02; 496 p.

Northeast Fisheries Science Center (NEFSC) 2011. Black sea bass 2012 projection update. Unpublished manuscript by Gary Shepherd. 12 pp.

Steimle, F.W., C.A. Zetlin, P.L. Berrien and S. Chang. 1999. Essential Fish Habitat Source Document: Black Sea Bass, *Centropristis striata*, Life History and Habitat Characteristics. NOAA Technical Memorandum NMFS-NE-143. 50 pp.



B1. Components of total black sea bass catch (mt) (Commercial and Recreational).

Appendix: Assessment Terms of Reference
TORs for SAW/SARC53 (Nov. 29 – Dec. 2, 2011) (file vers.: 5/20/11-b)

A. Cod (Gulf of Maine Stock)

1. Estimate catch from all sources including landings and discards. Characterize the uncertainty in these sources of data. Evaluate available information on discard mortality and, if appropriate, update mortality rates applied to discard components of the catch.

2. Present the survey data being used in the assessment (e.g., indices of abundance, recruitment, state surveys, age-length data, etc.). Investigate the utility of commercial or recreational LPUE as a measure of relative abundance. Characterize the uncertainty and any bias in these sources of data.

3. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series, and estimate their uncertainty. Include a historical retrospective analysis to allow a comparison with previous assessment results. Review the performance of historical projections with respect to stock size, catch recruitment and fishing mortality.

4. Perform a sensitivity analysis which examines the impact of allocation of catch to stock areas on model performance (TOR-3).

5. If time permits, consider the small-scale distribution of cod (e.g., spawning sites, resource distribution, fishing effort) in the Gulf of Maine and advise on its management implications.

6. State the existing stock status definitions for "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, F_{MSY} , and MSY) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the appropriateness of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

7. Evaluate stock status with respect to the existing model (from the most recent accepted peer reviewed assessment) and with respect to a new model developed for this peer review. In both cases, evaluate whether the stock is rebuilt.
   a. When working with the existing model, update it with new data and evaluate stock status (overfished and overfishing) with respect to the existing BRP estimates.
   b. Then use the newly proposed model and evaluate stock status with respect to "new" BRPs (from Cod TOR-6).

8. Develop and apply analytical approaches to conduct single and multi-year stock projections to compute the pdf (probability density function) of the OFL (overfishing level) and candidate ABCs (Acceptable Biological Catch; see Appendix to the SAW TORs).
   a. Provide numerical annual projections (3-5 years). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. Use a sensitivity analysis approach in which a range of assumptions about the most important uncertainties in the assessment are considered (e.g., terminal year abundance, variability in recruitment).
   b. Comment on which projections seem most realistic. Consider the major uncertainties in the assessment as well as sensitivity of the projections to various assumptions.
   c. Describe this stock's vulnerability (see "Appendix to the SAW TORs") 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. Black sea bass

1. Estimate catch from all sources including landings and discards. Characterize the uncertainty in these sources of data. Evaluate available information on discard mortality and, if appropriate, update mortality rates applied to discard components of the catch. Describe the spatial and temporal distribution of fishing effort.

2. Present the survey data being used in the assessment (e.g., indices of abundance, recruitment, state surveys, age-length data, etc.). Investigate the utility of commercial or recreational LPUE as a measure of relative abundance. Characterize the uncertainty and any bias in these sources of data.

3. Consider known aspects of seasonal migration and availability of black sea bass, and investigate ways to incorporate these into the stock assessment. Based on the known aspects, evaluate whether more than one management unit should be used for black sea bass from Cape Hatteras north and, if so, propose unit delineations that could be considered by the Mid-Atlantic Fishery Management Council and for use in future stock assessments.

4. Investigate estimates of natural mortality rate, M, and if possible incorporate the results into TOR-5. Consider including sex- and age-specific rate estimates, if they can be supported by the data.

5. Estimate annual fishing mortality, recruitment and appropriate measures of stock biomass (both total and spawning stock) for the time series (integrating results from TOR-4), and estimate their uncertainty. Include a historical retrospective analysis to allow a comparison with most recent assessment results.

6. State the existing stock status definitions for “overfished” and “overfishing”. Then update or redefine biological reference points (BRPs; point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, F_{MSY}, and MSY) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the appropriateness of existing BRPs and the “new” (i.e., updated, redefined, or alternative) BRPs.

7. Evaluate stock status with respect to the existing model (from the most recent accepted peer reviewed assessment) and with respect to a new model developed for this peer review.
    a. When working with the existing model, update it with new data and evaluate stock status (overfished and overfishing) with respect to the existing BRP estimates.
    b. Then use the newly proposed model and evaluate stock status with respect to “new” BRPs (from black sea bass TOR 6).

8. Develop and apply analytical approaches to conduct single and multi-year stock projections to compute the pdf (probability density function) of the OFL (overfishing level) and candidate ABCs (Acceptable Biological Catch; see Appendix to the SAW TORs).
    a. Provide numerical annual projections (3-5 years). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. Use a sensitivity analysis approach in which a range of assumptions about the most important uncertainties in the assessment are considered

(e.g., terminal year abundance, variability in recruitment, and definition of BRPs for black sea bass).

b. Comment on which projections seem most realistic. Consider major uncertainties in the assessment as well as the sensitivity of the projections to various assumptions.
c. Describe this stock's vulnerability (see "Appendix to the SAW TORs") 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.

Appendix to the SAW TORs:

Explanation of "Acceptable Biological Catch" (DOC Natl. Standard Guidelines, Fed. Reg., vol. 74, no. 11, 1/16/2009):

> *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)

Explanation of "Vulnerability" (DOC Natl. Standard Guidelines, Fed. Reg., vol. 74, no. 11, 1/16/2009):

> *''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)

Rules of Engagement among members of a SAW Assessment Working Group:

> Anyone participating in SAW assessment working group meetings that will be running or presenting results from an assessment model is expected to supply the source code, a compiled executable, an input file with the proposed configuration, and a detailed model description in advance of the model meeting. Source code for NOAA Toolbox programs is available on request. These measures allow transparency and a fair evaluation of differences that emerge between models.

Appendix to the SAW TORs (cont.):

ABC Control Rule Methods Proposed by the Mid-Atlantic Fishery Management Council:

A multi-level approach will be used for setting an ABC for each Mid-Atlantic stock, based on the overall level of scientific uncertainty associated with its assessment. The stock assessment will be required to provide estimates of the maximum fishing mortality threshold (MFMT) and future biomass, the probability distributions of these estimates, the probability distribution of the overfishing limit (OFL; level of catch that would achieve MFMT given the current or future biomass), and a description of factors considered and methods used to estimate their distributions. The multi-level approach defines four levels of overall assessment uncertainty defined by characteristics of the stock assessment and determination by the SSC that the uncertainty in the probability distribution of OFL adequately represents best available science. The procedure used to determine ABCs is different in each level of the methods framework. The SSC will determine to which level the assessment for a particular stock belongs when setting single or multi-year ABC specifications and a description of the justification for assignment to a level will be provided with the ABC recommendation. The ABC recommendations should be more precautionary as an assessment moves from level 1 to level 4. Recommendations for ABC may be made for up to 3 years for all of the managed resources except spiny dogfish which may be specified for up to 5 years. The rationale for assigning an assessment to a level will be reviewed each time an ABC determination is made.

Levels of stock assessments, characteristics, and procedures for determining ABCs are defined as follows:

Level 1: Level 1 represents the highest level to which an assessment can be assigned. Assignment of a stock to this level implies that all important sources of uncertainty are fully and formally captured in the stock assessment model and the probability distribution of the OFL calculated within the assessment provides an adequate description of uncertainty of OFL. Accordingly, the OFL distribution will be estimated directly from the stock assessment. In addition, for a stock assessment to be assigned to Level 1, the SSC must determine that the OFL probability distribution represents best available science. Examples of attributes of the stock assessment that would lead to inclusion in Level 1 are:

- Assessment model structure and any treatment of the data prior to inclusion in the model includes appropriate and necessary details of the biology of the stock, the fisheries that exploit the stock, and the data collection methods;
- Estimation of stock status and reference points integrated in the same framework such that the OFL calculations promulgate all uncertainties (stock status and reference points) throughout estimation and forecasting;
- Assessment estimates relevant quantities including F_{MSY}[1], OFL, biomass reference points, stock status, and their respective uncertainties; and
- No substantial retrospective patterns in the estimates of fishing mortality (F), biomass (B), and recruitment (R) are present in the stock assessment estimates.

1 With justification, F_{MSY} may be replaced with an alternative maximum fishing mortality threshold to define the OFL.

Appendix to the SAW TORs (cont.):

The important part of Level 1 is that the precision estimated using a purely statistical routine will define the OFL probability distribution. Thus, all of the important sources of uncertainty are formally captured in the stock assessment model. When a Level 1 assessment is achieved, the assessment results are likely unbiased and fully consider uncertainty in the precision of estimates. Under Level 1, the ABC will be determined solely on the basis of an acceptable probability of overfishing (P*), determined by the Council's risk policy (see alternatives in section 5.2.2), and the probability distribution of the OFL.

Level 2: Level 2 indicates that an assessment has greater uncertainty than Level 1. Specifically, the estimation of the probability distribution of the OFL directly from the stock assessment model fails to include some important sources of uncertainty, necessitating expert judgment during the preparation of the stock assessment, and the OFL probability distribution is deemed best available science by the SSC. Examples of attributes of the stock assessment that would lead to inclusion in Level 2 are:

- Key features of the biology of the stock, the fisheries that exploit it, or the data collection methods are missing from the stock assessment;
- Assessment estimates relevant quantities, including reference points (which may be proxies) and stock status, together with their respective uncertainties, but the uncertainty is not fully promulgated through the model or some important sources may be lacking;
- Estimates of the precision of biomass, fishing mortality rates, and their respective reference points are provided in the stock assessment; and
- Accuracy of the MFMT and future biomass is estimated in the stock assessment by using *ad hoc* methods.

In this level, ABC will be determined by using the Council's risk policy (see alternatives in section 5.2.2), as with a Level 1 assessment, but with the OFL probability distribution based on the specified distribution in the stock assessment.

Level 3: Attributes of a stock assessment that would lead to inclusion in Level 3 are the same as Level 2, except that

- The assessment does not contain estimates of the probability distribution of the OFL or the probability distribution provided does not, in the opinion of the SSC, adequately reflect uncertainty in the OFL estimate.

Assessments in this level are judged to over- or underestimate the accuracy of the OFL. The SSC will adjust the distribution of the OFL and develop an ABC recommendation by applying the Council's risk policy (see alternatives in section 5.2.2) to the modified OFL probability distribution. The SSC will develop a set of default levels of uncertainty in the OFL probability distribution for this level based on literature review and a planned evaluation of ABC control rules. A control rule of 75 percent of F_{MSY} may be applied as a default if an OFL distribution cannot be developed.

Appendix to the SAW TORs (cont.):

Level 4: Stock assessments in Level 4 are deemed to have reliable estimates of trends in abundance and catch, but absolute abundance, fishing mortality rates, and reference points are suspect or absent. Additionally, there are limited circumstances that may not fit the standard approaches to specification of reference points and management measures set forth in these guidelines (i.e., ABC determination). In these circumstances, the SSC may propose alternative approaches for satisfying the NS1 requirements of the Magnuson-Stevens Act than those set forth in the NS1 guidelines. In particular, stocks in this level do not have point estimates of the OFL or probability distributions of the OFL that are considered best available science. In most cases, stock assessments that fail peer review or are deemed highly uncertain by the SSC will be assigned to this level. Examples of potential attributes for inclusion in this category are:

- Assessment approach is missing essential features of the biology of the stock, characteristics of data collection, and the fisheries that exploit it;
- Stock status and reference points are estimated, but are not considered reliable;
- Assessment may estimate some relevant quantities including biomass, fishing mortality or relative abundance, but only trends are deemed reliable;
- Large retrospective patterns usually present; and
- Uncertainty may or may not be considered, but estimates of uncertainty are probably substantially underestimated.

In this level, a simple control rule will be used based on biomass and catch history and the Council's risk policy.

The SSC will determine, based on the assessment level to which a stock is classified, the specifics of the control rule to specify ABC that would be expected to attain the probability of overfishing specified in the Council's risk policy. The SSC may deviate from the above control rule methods framework or level criteria and recommend an ABC that differs from the result of the ABC control rule calculation, but must provide justification for doing so.