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62nd Northeast Regional Stock Assessment Workshop (62nd SAW)

Assessment Summary Report

by the Northeast Fisheries Science Center

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SAW-62 ASSESSMENT SUMMARY REPORT

Introduction

The 62nd SAW Assessment Summary Report contains summary and detailed technical information on two stock assessments reviewed during November 29 – December 2, 2016 at the Stock Assessment Workshop (SAW) by the 62nd Stock Assessment Review Committee (SARC-62): Black sea bass and Witch flounder. The SARC-62 consisted of three external, independent reviewers appointed by the Center for Independent Experts [CIE], 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-62 are available at website: http://www.nefsc.noaa.gov/nefsc/saw/ under the heading "SARC 62 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

Text in this section is based on SARC-62 Review Panel reports (available at http://www.nefsc.noaa.gov/nefsc/saw/ under the heading "SARC-62 Panelist Reports.")

The **black sea bass** assessment was accepted by the SARC-62 panel. It was effective in determining stock status, biological reference points (BRPs) and proxies, and in projecting probable short-term trends. The black sea bass stock north of Cape Hatteras, NC is not overfished and overfishing is not occurring. An assessment model (ASAP) by north and south spatial sub-units is accepted as the best scientific information available for determining stock status. $F_{40\%}$ is still recommended as the proxy for F_{MSY} (the overfishing threshold). Although the two-area model had a major retrospective pattern in each area sub-unit, it provided reasonable estimates considering sensitivity runs and other models. Even though projections are conducted for each sub-unit, the combined projections should only be used, because of the major retrospective issues seen within each sub-unit.

The **witch flounder** age-structured assessment model, while scientifically well thought out, had major retrospective patterns in the estimates. Those model results are not recommended for management purposes. The status of the witch flounder stock is currently unknown relative to biological reference points. The panel believes that the previously accepted VPA model is not an acceptable alternative to the rejected ASAP application because it exhibits a similar major retrospective pattern. An empirical swept area approach may be useful for setting catch advice, although the Panel did not have time to fully review it in the context of the ToR of the meeting. As an F_{MSY} proxy, the Panel supports using a relative exploitation rate derived from the average exploitation (recent catch divided by recent swept area exploitable biomass estimates) in the near term, where other alternatives are unavailable. The spring and autumn NEFSC surveys are regarded as providing the best available fishery independent indices for this species and they show broadly similar patterns of a decline from the early 1960s to record low levels in the late 1980s and early 1990s, an increase to early 2000s followed by a declining trend. The empirical area swept method does not provide a biomass threshold, but does indicate that the stock is at low historical levels.

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 rebuild 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 sought 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).

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 five 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.

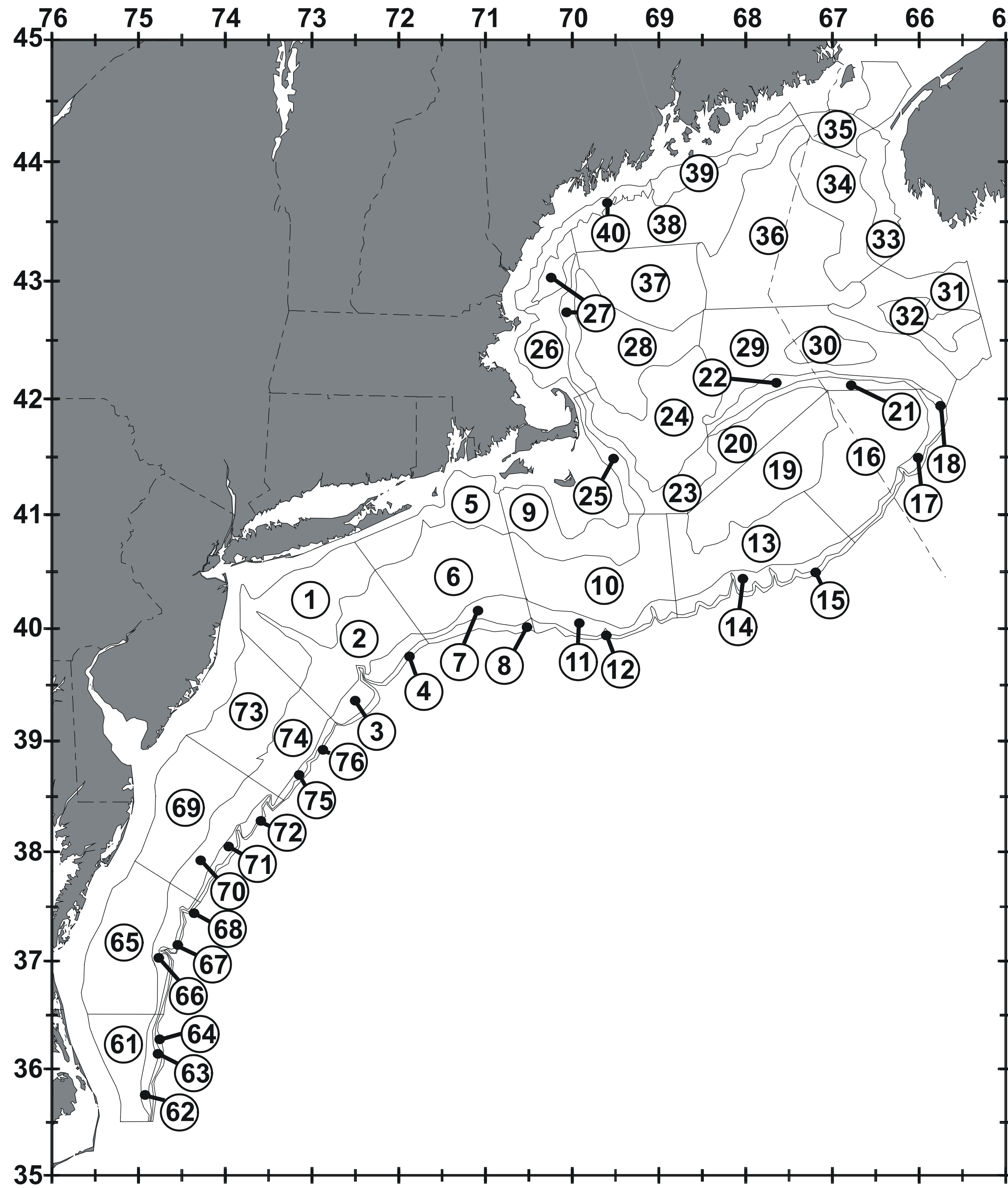

Figure 1. Offshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys. Some of these may not be sampled presently.

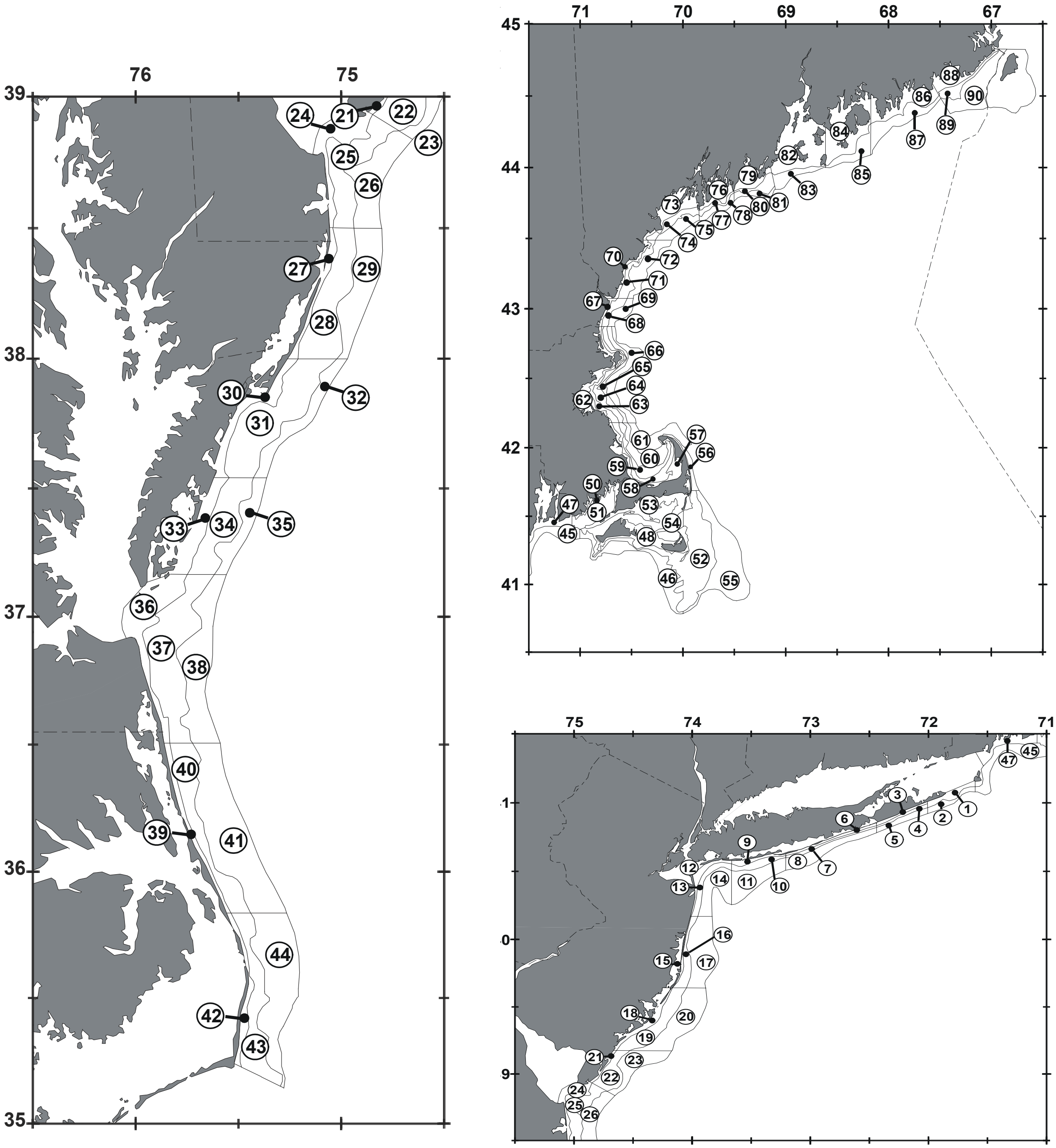

Figure 2. Inshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys. Some of these may not be sampled presently.

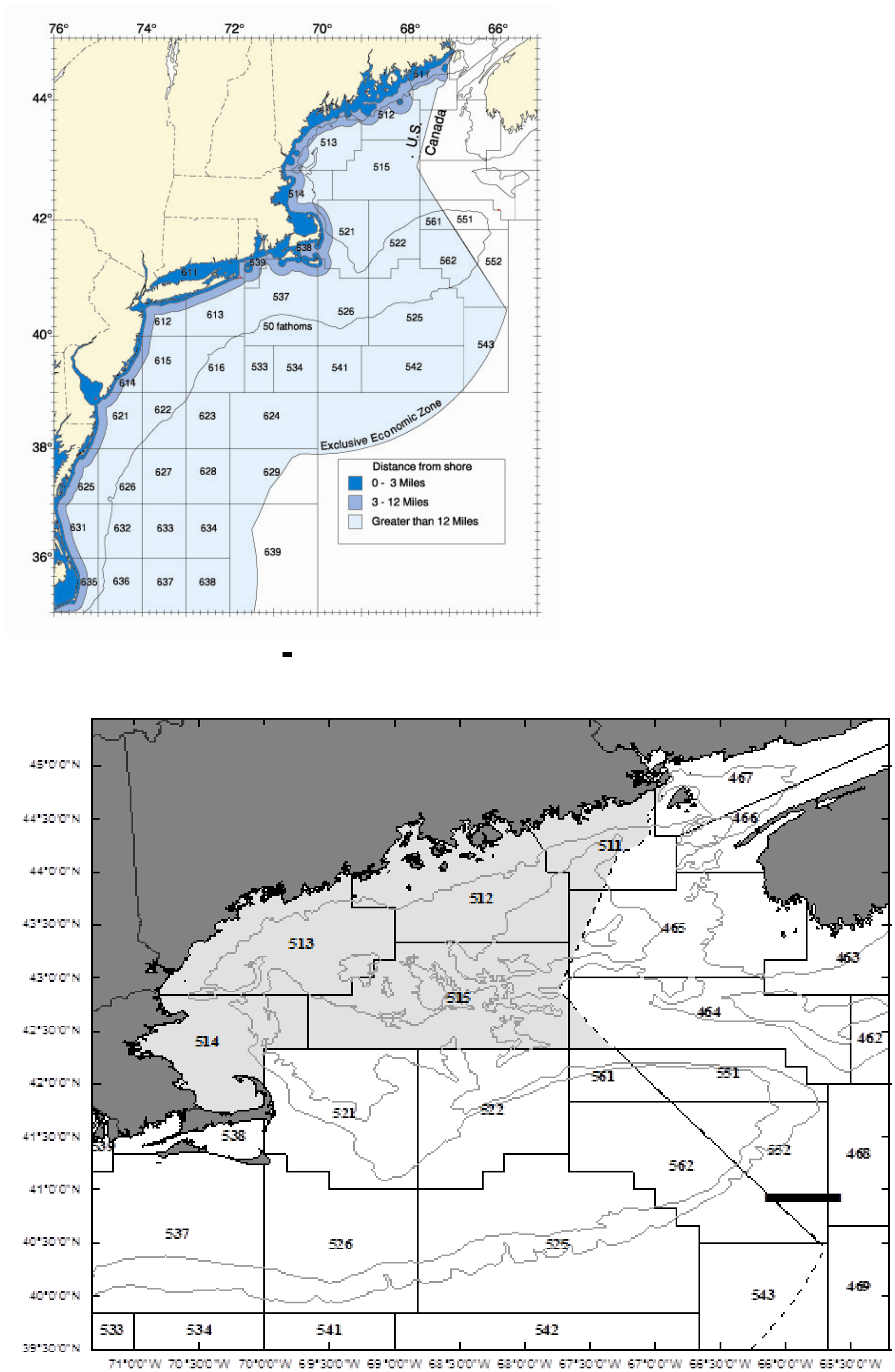

Figure 3. Statistical areas used for reporting commercial catches.

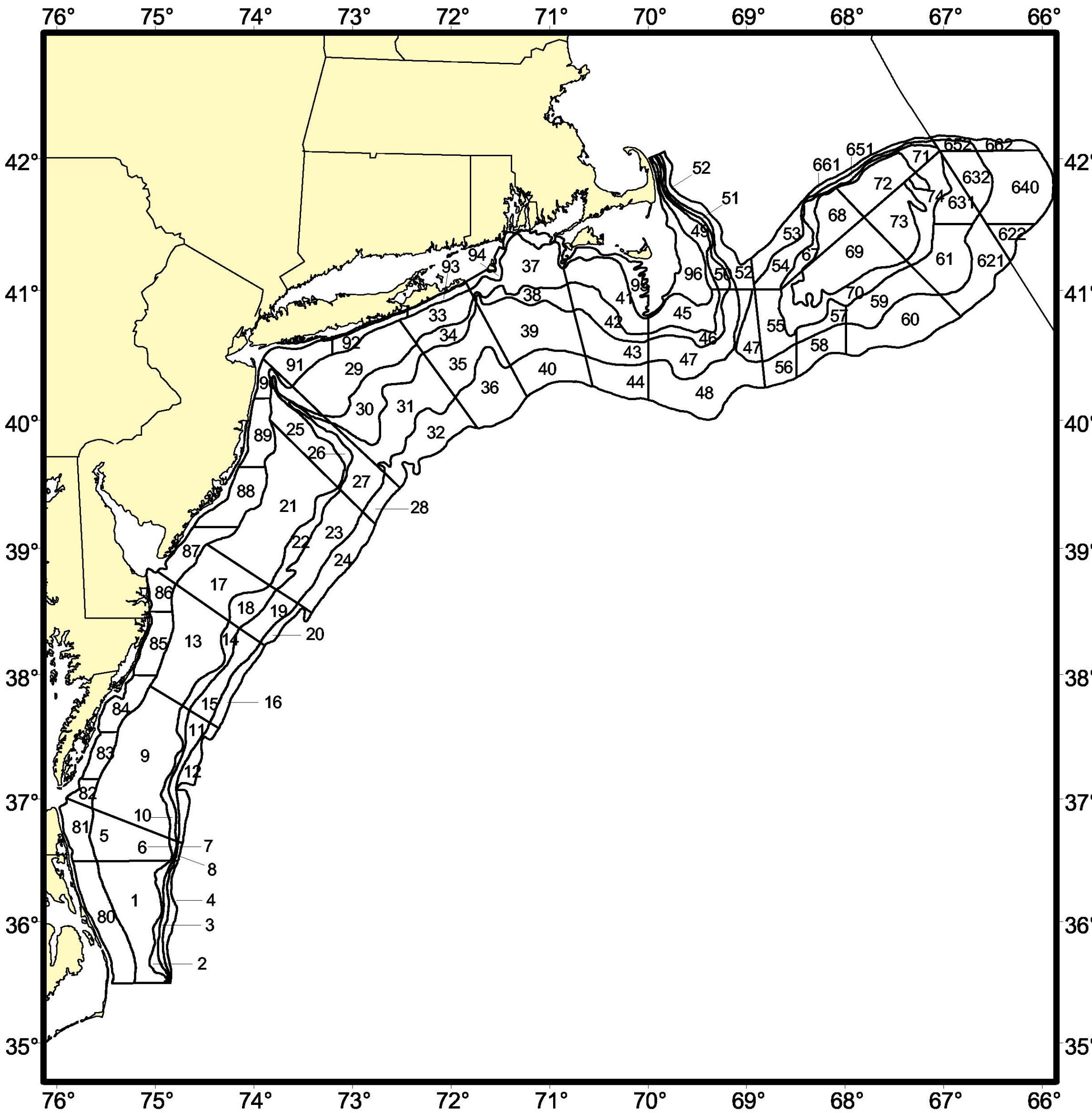

Figure 4. Northeast Fisheries Science Center clam resource survey strata, along the east coast of the US.

A. BLACK SEA BASS ASSESSMENT SUMMARY FOR 2016

State of Stock

The stock of black sea bass (*Centropristis striata*) north of Cape Hatteras, NC is not overfished and overfishing is not occurring. An assessment model (ASAP) by north and south spatial sub-units is accepted as the best scientific information available for determining stock status for black sea bass. The 2015 SSB, retrospectively adjusted by area, is estimated to be 22,176 mt (48.9 million lbs) and the average adjusted F on ages 4-7 ($F_{4\text{-}7}$) is estimated to be 0.27.

$F_{40\%}$ is recommended as the proxy for F_{MSY} (the overfishing threshold). The estimate of $F_{40\%}$ from an average of north and south sub-units equaled 0.36. SSB_{MSY} proxy (the biomass target) is calculated from projections at $F_{40\%}$ and is estimated to be 9,667 mt (21.3 million lbs) ($\pm$ 2 std. dev. of 4,150 mt (9.1 million lbs)). Spawning stock biomass in 2015 was estimated to be 2.3 times the SSB_{MSY} proxy (Figure A1). No previously accepted model results are available for comparison.

Projections

Short-term projections were conducted by sub-unit and combined into the total stock. Projections by sub-unit used historical age-1 recruitment between 2000 and 2015. A retrospective adjustment was applied in the projections that increased 2016 starting stock size by 24% (Table A1). The projection was run under assumptions of 2016 black sea bass catch equal to the Allowable Biological Catch of 3,024 mt and harvest at F_{MSY} proxy (0.36). The projection indicates OFLs of 5,467 mt (12.1 million lbs.) in 2017, 4,494 (9.9 million lbs.) in 2018, and 3,901 mt (8.6 million lbs.) in 2019.

Catch and Status Table: Black Sea Bass

(weights in mt, recruitment in millions, arithmetic means; the 2015 retrospectively adjusted values for F_{full} and SSB are 0.27 and 22,176 mt respectively)

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Min[1]	Max[1]	Mean[1]
Commercial landings	1,285	1,037	875	523	751	765	782	1,027	1,088	1,113	523	1,564	1,128
Commercial discard	30	164	66	209	142	157	103	211	416	335	25	650	161
Recreational landings	802	947	909	1,159	1,421	507	1,480	1,198	1,745	1,864	473	2,119	1,310
Recreational discards	203	200	257	241	273	232	364	296	382	371	46	771	262
Catch used in assessment	2,320	2,349	2,107	2,132	2,587	1,662	2,729	2,733	3,631	3,683	1,662	4,346	2,861
Spawning stock biomass	4,551	4,072	5,594	6,460	8,215	8,258	9,878	12,833	17,158	16,552	2,485	17,158	6,354
Recruitment (age 1, millions)	19.7	22.2	27.5	22.4	22.6	22.1	68.9	27.6	17.8	24.9	11.9	68.9	24.3
F full[2]	0.66	0.78	0.57	0.50	0.45	0.30	0.35	0.33	0.29	0.24	0.24	1.34	0.69

[1] Years 1989-2015

[2] F on fully selected ages 4-7. Note that table values are not retro adjusted.

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). The stock was partitioned into two sub-units to account for spatial differences in the assessment model. The sub-units are not considered to be separate stocks (see Special Comments below).

Catches

Commercial landings averaged 1,300 mt (2.9 million lbs) from the late 1980s through the 1990s (Figure A2). Commercial fishery quotas were implemented in 1998 and commercial landings remained stable between 1,300 mt (2.9 million lbs.) and 1,600 mt (3.5 million lbs.) until 2007. Commercial landings declined to 523 mt (1.2 million lbs.) and 751 mt (1.7 million lbs.) in 2009 and 2010, respectively then increased to 1,027 mt (2.3 million lbs.) in 2013 and have since remained above 1,000 mt (1,113 MT (2.5 million lbs.) in 2015). The recreational rod-and-reel fishery for black sea bass harvests a significant proportion of the total catch. Recreational landings averaged 1,700 mt (3.7 million lbs.) annually until 1997. Recreational fishery harvest limits were implemented in 1998 and recreational landings have since ranged between 500 mt (1.1 million lbs.) and 2,000 mt (4.4 million lbs). Recreational landings in 2015 were 1,864 mt (4.1 million lbs.). Commercial fishery discards represent a relatively small fraction of the total fishery removals from the stock. Commercial discards were generally less than 200 mt per year, but increased to 416 mt (0.9 million lbs.) and 335 mt (0.7 million lbs.) in 2014 and 2015, respectively. Recreational discard losses, assuming 15% hook and release mortality, are similar, generally less than 500 mt per year. Estimated mortality from recreational discards was 371 mt (0.8 million lbs.) in 2015.

Data and Assessment

For the first time, the black sea bass stock was modeled as two separate sub-units divided at approximately Hudson Canyon using an age-based statistical catch at age model, with data beginning in 1989. The fishery catch was modeled as trawl and non-trawl fleets with indices of stock abundance from NEFSC winter and spring surveys, NEAMAP surveys, recreational catch per effort, as well as state survey indices from MA, RI, CT, NY, NJ, DE, MD and VA. There is retrospective bias in SSB and F by sub-unit but not when combined. The biomass is underestimated in the north and overestimated in the south and conversely for F. The terminal year estimates from each sub-unit were bias-adjusted to account for the retrospective patterns. The average F and the sum of the biomass across sub-units were used to determine stock status.

Biological Reference Points

$F_{40\%}$ was chosen as a proxy for the F_{MSY} reference point and spawning stock biomass at $F_{40\%}$ ($SSB_{40\%}$) as the proxy for the stock biomass target reference point. Proxies are used when the stock recruitment relationship is not well determined, as for black sea bass. Spawning stock biomass is calculated using both males and females. The estimate of F_{MSY} proxy = $F_{40\%}$ = 0.36 was the average between the north (0.355) and south (0.365). The biomass reference point (SSB_{MSY} proxy = $SSB_{40\%}$ = 9,667 mt (21.3 million lbs) with 95% CI between 5,517 mt and 13,816 mt) was estimated from a long term projection at F=0.36. The stock biomass threshold of ½ SSB_{MSY} proxy = ½ $SSB_{40\%}$ = 4,834 mt (10.7 million lbs) (95% CI between 2,759 mt and 6,908 mt). Maximum sustainable yield (MSY) equaled 3,097 mt (6.8 million lbs) (95% CI between 1,797 mt and 4,396 mt).

Fishing Mortality

Fishing mortality varied between 0.88 and 1.34 prior to implementation of the FMP in 1997 (Figure A3). Fishing mortality remained between 0.51 and 0.78 until 2007 when it steadily decreased, reaching a low in 2015 of 0.24 (95% CI between 0.13 and 0.34) A retrospective adjustment of the 2015 F increased the estimate to 0.27 (95% CI between 0.15 and 0.39).

Biomass

Spawning stock biomass (SSB) increased from about 2,789 mt (6.1 million lbs) in 1989 to about 8,500 mt (18.7 million lbs) in 2002, then decreased to about 4,072 mt (9.0 million lbs) by 2007. With improved recruitment and declining fishing mortality rates since 2007, SSB has steadily increased since to 17,158 mt (37.8 million lbs) in 2014 (Figure A4). The 2015 SSB estimate was 16,552 mt (36.5 million lbs) (95% CI between 11,747 mt and 21,357 mt) and the retrospective adjustment further increased the 2015 SSB estimate to 22,176 mt (48.9 million lbs.) with a 95% CI between 15,984 mt and 28,369 mt. Total Jan. 1 biomass followed a similar trajectory, increasing to 16,205 mt (35.7 million lbs.) in 2002, declining for several years then steadily increasing from 9,777 mt (21.6 million lbs.) in 2006 to 27,125 mt (59.8 million lbs.) in 2014 (Figure A5). The 2015 total biomass estimate equaled 24,143 mt (53.2 million lbs.) (95% CI between 18,031 mt and 30,256 mt) with the retrospective adjusted value equal to 32,010 mt (70.6 million lbs.) with a 95% CI between 24,173 mt and 39,846 mt.

Recruitment

Recruitment at age 1 averaged 24.3 million fish from 1989 to 2015, with peaks in 2000 (1999 cohort) at 37.3 million and extremely high in 2012 (2011 cohort) estimated at 68.9 million (Figure A6). Since 2012, recruitment has been average with a 2014 cohort estimated at 24.9 million fish.

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 fishes and invertebrates and are preyed upon by sharks, skates and other predatory fishes such as weakfish, bluefish and summer flounder.

Special Comments

Several variations of the final ASAP age-based assessment model were examined (an overall model, a model accounting for migration, a Stock-synthesis model) and all provided the same trends in fishing mortality and biomass.

Since black sea bass is a protogynous hermaphrodite, spawning stock biomass was defined as the total of male and female mature biomass which accounts for changes in sex ratio. A recent study (Blaylock and Shepherd 2016) suggests that the vulnerability of this stock to exploitation is a function of the number of dominant males and the contribution of smaller males during spawning. A study by Brooks et al. (2008) showed that when adequate information about sex composition is unavailable, it is prudent to characterize spawning stock biomass (SSB) as the combined male and female mature biomass.

The assessment accounted for differences in sub-units north and south of Hudson Canyon. The large 2011 cohort was dominant in the northern area and less so in the south. The 2011 cohort is moving through the fishery. The distribution of black sea bass continues to expand northward into the Gulf of Maine.

Although this stock was assessed by sub-units, the combined results are put forth and recommended to be used for reference points and OFL and ABC specifications.

References

Blaylock, J. and G.R. Shepherd. 2016. Evaluating the vulnerability of an atypical protogynous hermaphrodite to fishery exploitation: results from a population model for black sea bass (*Centropristis striata*). *Fishery Bulletin* 114(4): 476-489.

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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.

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.

Table A1. A projection of black sea bass fished at F_{MSY} proxy = 0.36 and assuming recruitment is comparable to 2000-2015. Projection assumes 2016 catch equals quota of 3,024 mt.

Total Area Combined	**Rho adjusted** at F_{MSY}	- 2 STD DEV	Average	+ 2 STD DEV
SSB (mt)	2015		22,176	
	2016	11,950	18,670	25,391
	2017	10,270	15,918	21,565
	2018	8,914	13,407	17,900
	2019	6,706	11,849	16,991
Recruits (000s)	2015		18,002	
	2016	2,025	25,081	57,593
	2017	1,987	25,126	57,664
	2018	1,998	25,096	57,597
	2019	2,012	25,133	57,846
Jan 1 biomass	2015		32,010	
(mt)	2016	20,322	29,350	38,379
	2017	18,461	27,540	36,619
	2018	15,255	23,315	31,375
	2019	11,725	20,788	29,851
Catch	2015		3,683	
(mt)	2016		3,024	
	2017	3,484	5,467	7,451
	2018	3,037	4,494	5,950
	2019	2,398	3,901	5,403

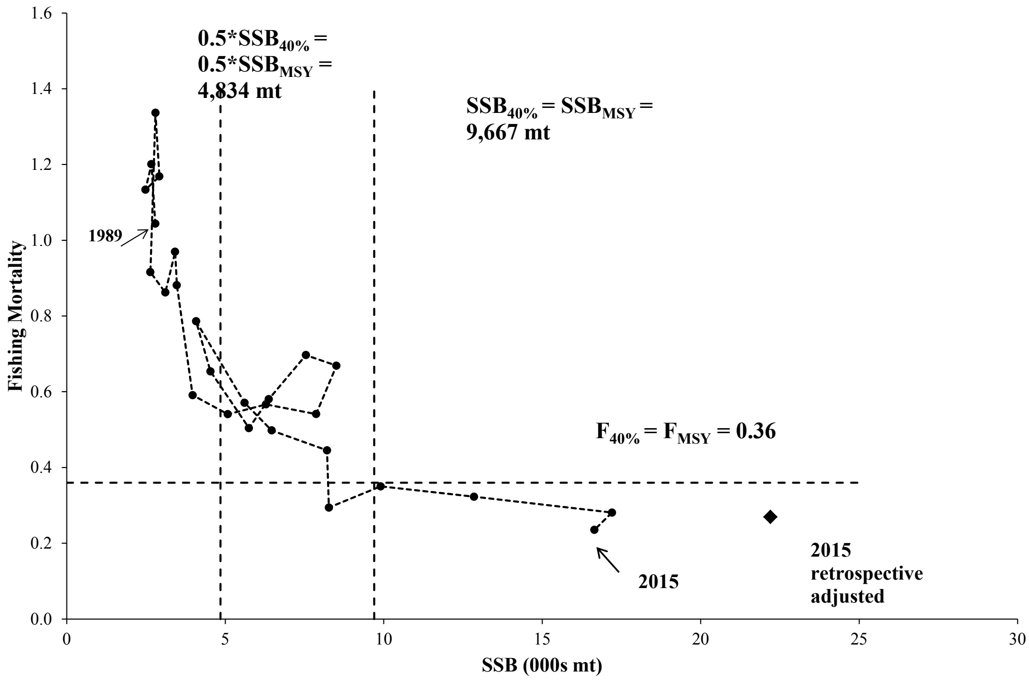

Figure A1. Time series plot of black sea bass fully selected fishing mortality relative to spawning stock biomass based on the 2016 assessment model (two area ASAP model). Biological reference points and retro-adjusted 2015 point estimate also shown.

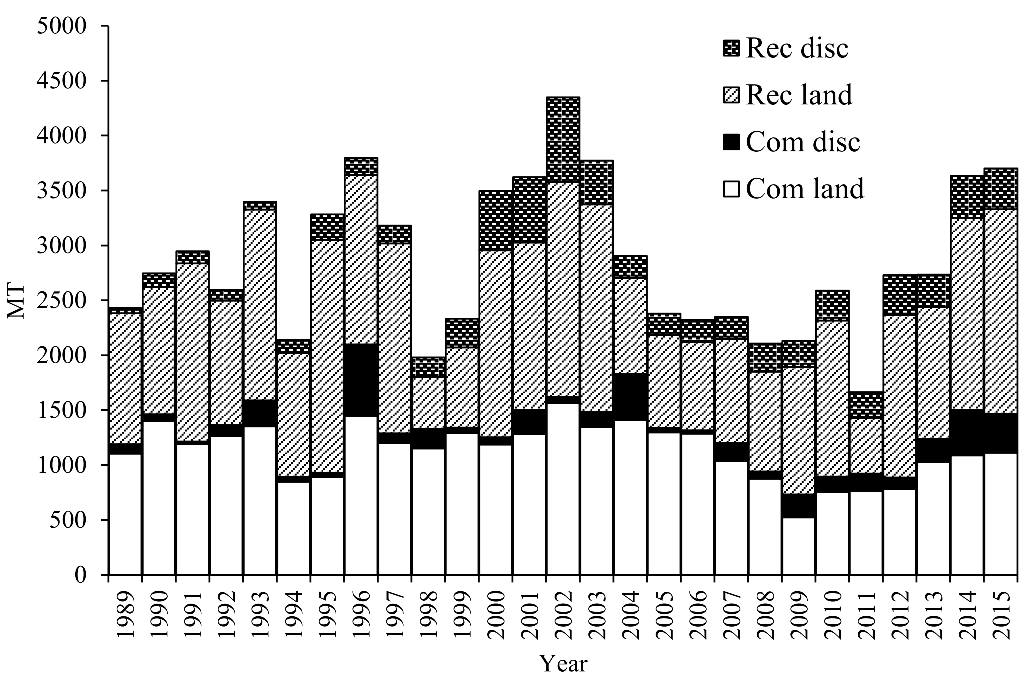

Figure A2. Components of total black sea bass catch (mt) (Commercial and Recreational).

Figure A3. ASAP model results of fishing mortality on black sea bass ages 4-7 with F_{MSY} proxy. Retrospective adjusted value indicated with black diamond.

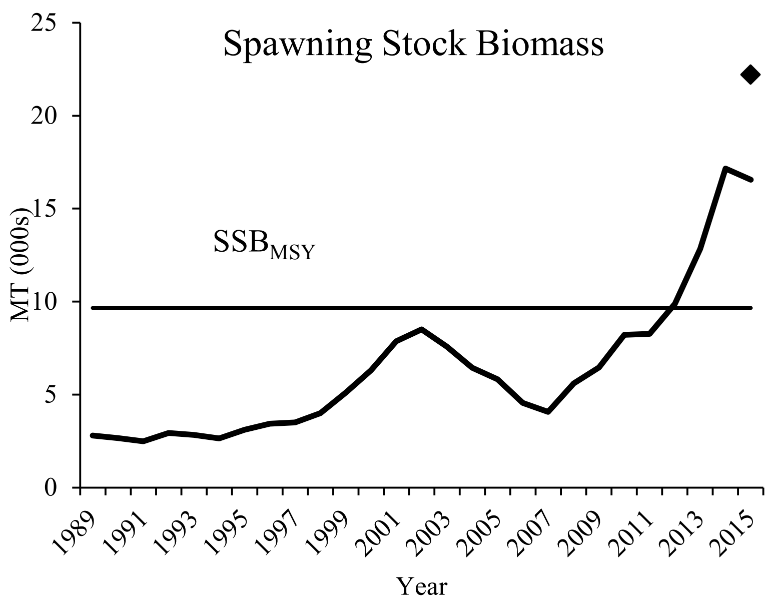

Figure A4. ASAP model results of black sea bass spawning stock biomass (mt, sexes combined) with SSB_{MSY}. Retrospective adjusted value indicated with black diamond.

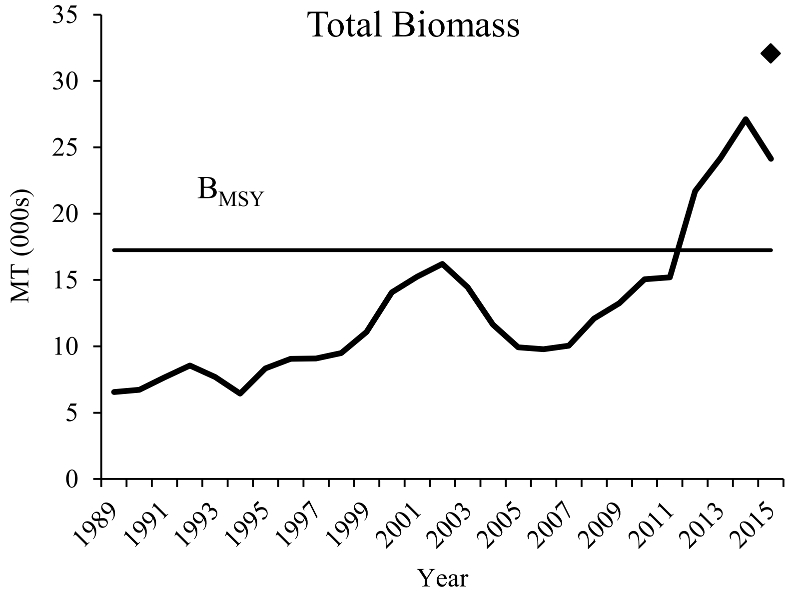

Figure A5. Total biomass (mt) for black sea bass with B_{MSY} proxy. Retrospective adjusted value indicated with black diamond.

Figure A6. ASAP model results of black sea bass age 1 recruits (millions). Retrospective adjusted value indicated with black diamond.

B. WITCH FLOUNDER ASSESSMENT SUMMARY FOR 2016

State of Stock: The status of the witch flounder (*Glyptocephalus cynoglossus*) stock is unknown with regards to biological reference points. The age-structured models applied to data for the witch flounder fishery from 1982-2015 were found to have major retrospective patterns that prevented their use for status evaluation and determination of catch advice.

Based on an empirical analysis (referred to as "empirical area swept method") conducted by the SAW and examined at the SARC, stock biomass has declined since 2002 and appears to be 16,181 mt Jan-1 surveyable biomass in 2016 and 14,563 mt exploitable biomass in 2016 (Figure B1). The relative exploitation rate corresponding to the recent observed catch is approximately 0.05 (Figure B2). The fishery landings and survey catch by age indicate truncation of age structure and a reduction in the number of old fish in the population (Figures B3-B6).

Projections: The empirical area swept method was used to estimate an overfishing limit (OFL) for 2017 of 728 mt assuming a relative exploitation rate of 0.05. This rate is close to the recent average, and it took place during a period when the stock has been relatively stable.

Catch and Model Results Table: Witch flounder (weights in 000s mt, arithmetic means)

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Min[1]	Max[1]	Mean[1]
Commercial landings	1.86	1.08	1.01	0.95	0.76	0.87	1.04	0.69	0.57	0.49	0.49	6.66	2.49
Commercial discards	0.21	0.13	0.13	0.20	0.15	0.20	0.22	0.12	0.11	0.09	0.09	0.77	0.30
Recreational landings	-	-	-	-	-	-	-	-	-	-	-	-	-
Recreational discards	-	-	-	-	-	-	-	-	-	-	-	-	-
Catch used in assessment	2.07	1.21	1.14	1.16	0.91	1.07	1.26	0.81	0.68	0.58	0.58	6.94	2.79
Empirical area swept method Jan-1 survey biomass	20.09	18.59	35.18	20.84	18.20	16.48	18.69	11.80	14.98	17.62	10.67	90.82	29.65
Exploitable biomass	18.08	16.73	31.66	18.76	16.38	14.83	16.82	10.62	13.49	15.86	9.61	81.74	26.69
Relative exploitation rate	0.10	0.07	0.03	0.06	0.05	0.06	0.07	0.07	0.05	0.03	0.03	0.26	0.10

[1] Years 1982-2015

Stock Distribution and Identification: Witch flounder is a deep water boreal flatfish whose range within United States (US) waters extends from the Canadian border southward in the continental slope waters to Cape Hatteras, NC. Within the United States Exclusive Economic Zone (EEZ) witch flounder is predominately in the Gulf of Maine and Georges Bank region and, in the absence of any stock structure information, is assessed as a unit stock (Figure B7). There are no genetic or tagging data for witch flounder to further inform stock structure.

Catches: Since 1982, fishery removals of witch flounder have ranged from 585 mt (2015) to 6,937 mt (1984). Prior to 1989 there are no direct estimates of commercial discards but discards were hindcast back to 1982 by gear. Over the assessment time series, commercial landings have been the dominant source of fishery removals, constituting 70-97% of the total catch (Figure B8). There is no recreational fishery for witch flounder.

Data and assessment: The previous benchmark assessment (i.e., NEFSC 2008) of witch flounder was conducted using a virtual population analysis model (ADAPT-VPA) that incorporated commercial landings and discards. For the current assessment, catch-at-age was re-estimated as the result of minor modifications to the commercial catch associated with refinements to the discard estimation methods, refinements of spatial extent to include the entire stock area, and additional gear types. The updates had only minor impacts on the estimated catch-at-age. For SAW/SARC62 in 2016, the assessment was attempted using the statistical catch-at-age model, ASAP. The catch inputs included landings and discards from the commercial fleet. Commercial discards were assumed to have 100% mortality. Fishery removals were modeled as a single fleet.

Swept-area estimates of abundance from the NEFSC spring and autumn surveys (1982-2015; Figure B9, subplots on the left), Atlantic States Marine Fishery Commission (ASMFC) summer shrimp survey (1984-2015) and Maine-New Hampshire (ME-NH) inshore bottom trawl survey (2000-2015) were used in the ASAP models along with associated estimates of uncertainty and annual age composition. Based on the August 2016 cooperative research survey catchability study for witch flounder, swept area estimates for the NEFSC spring and autumn surveys were derived using an Albatross survey efficiency of 0.056. With the exception of ASMFC summer survey, current survey abundance indices (number per tow) are near time series means.

The 2016 ASAP model used three fishery selectivity time blocks (1982-1992; 1993-2004; 2015-2015) with a flat-top fishery selectivity in which ages 7+ were fully selected in time blocks 1 and 3 and ages 8+ in time block 2. External analyses indicated that there was little evidence for doming in either the fishery or survey selectivities. The NEFSC survey spring and autumn selectivities were estimated to be flat-top at ages 7+. The ASMFC and ME-NH survey selectivities were domed to account for their near shore location and catch at age.

Five model sensitivity runs were made to evaluate (1) the impact of domed fishery selectivity, (2) domed survey selectivity in the NEFSC surveys, (3) including LPUE 40% trips as an additional tuning index, (4) fixed q = 1 for NEFSC spring and autumn indices, (5) reducing the importance of the catch at age information, i.e., adjusting to the effective sample size downward. Model results were robust to fishery and NEFSC survey selectivity (negligible difference in F and SSB). When the effective sample size was adjusted downward to reduce the importance of the catch at age information, F was slightly lower and SSB was slightly higher than the base run but both F and SSB generally remained within 2 standard deviations of the base run. When the LPUE 40% index was included, F was slightly higher than the base run between 1982 – 1999 and lower than the base run between 2000 and 2015 but remained within 2 standard deviations of F in the base run, except for years 2010-2015. The SSB of LPUE 40% sensitivity run was lower than the base run early in the time series and higher than the base run in later years but remained within the 2 standard deviations of SSB in the base run for all years except 1983-1987 and 2005-2015. When the survey catchability (q) for the NEFSC survey SWAN indices were held fixed at 1 (calculated assuming an ALB efficiency of 0.056, providing freely estimated model q of approximately 4) results were, as expected, significantly different from ASAP Run 9_5_v2, with F scaled significantly lower over the entire series and SSB, age 1 recruitment, and total stock numbers scaled higher, especially over the terminal 10 years. This difference in scaling, combined with the presence of the major retrospective pattern, led to further explorations of the response of the model to possible sources of missing mortality.

However, the VPA, ASAP, and SCAA age-structured models applied to data for the witch flounder fishery were found to have major retrospective patterns that prevented their use for status evaluation and determination of catch advice.

Based on an empirical area swept method (that includes the results of the NEFSC survey efficiency experiment) conducted by the SAW and examined at the SARC, stock biomass has declined since 2002 and appears to be 16,181 mt Jan-1 surveyable biomass in 2016 and 14,563 mt exploitable biomass in 2016. The relative exploitation rate associated with the recent observed catch is approximately 0.05 (Figures B1 and B2).

Biological Reference Points: The age-structured models applied to data for the witch flounder fishery from 1982-2015 were found to have major retrospective patterns that prevented their use for status evaluation and determination of catch advice. Therefore biological reference points are not available.

Fishing Mortality: The 2015 relative exploitation rate is estimated to be 0.03. The average relative exploitation rate during the most recent nine years is approximately 0.05 (range 0.03-0.07), and survey indices were relatively stable during this period. The SARC panel does not recommend using the $F_{40\%}$ approach for catch advice because the basis for that value has been rejected.

Biomass: The 2016 estimate of Jan-1 surveyable biomass from the empirical area swept method is 16,181 mt. The 2016 estimate of exploitable biomass is 14,563 mt. Survey population biomass was converted to exploitable biomass using a factor of 0.90 based on examination of survey and fishery selectivity patterns from the base ASAP assessment. The fishery landings and survey catch by age indicate truncation of age structure and a reduction in the number of old fish in the population (Figures B2-B5).

Recruitment: The time series of recruitment is not available from the empirical area swept method. All the surveys indicate the 2013 year class is relatively strong. However, this year class is not expected to fully recruit to the directed fishery until 2020 at age 7 and should start to appear in the large mesh otter trawl discards in 2017 at age 4. The absolute size of the 2013 year class is uncertain given that the estimate is based on only two years of survey observations.

Special Comments:

- An important source of uncertainty in the current witch flounder assessment is the major retrospective pattern wherein fishing mortality is underestimated and spawning stock biomass and recruitment are overestimated. This problem led to rejection of the age-structured models as the basis of status evaluation.

- The 7-year Mohn's rho, relative to SSB, was 0.51 in the 2015 VPA assessment and was 0.64 in this year's ASAP assessment. The 7-year Mohn's rho, relative to F, was -0.38 in the 2015 assessment and was -0.46 in this assessment. The rho adjusted estimates for 2015 SSB and 2015 F were outside the approximate 90% confidence region around the SSB and F point estimates. This was considered to be a major retrospective pattern for this assessment and led to rejection of the age-structured models as the basis of status evaluation.

- Increasing the catch or M in the ASAP model was effective in reducing the retrospective error in the model. The magnitude of the increase in catch (3.0 to 5.0 times) or M (2.5 to 3.0 times) needed to reduce the retrospective error to a small amount also improved the residual diagnostics for the fishery catch components and marginally improved the residual diagnostics for all surveys, and reduced the NEFSC survey qs. The timing of the "step-increase" in fishery catch informed by large changes in model diagnostics in the early 2000s was coincident with a change in catch reporting in 2004. Uncertainty in the catch of witch flounder has increased due to recent allegations of catch misreporting currently under litigation. Other than this information, the witch flounder SAW Working Group does not currently have any publicly available independent evidence or justification for such a large unaccounted fishery catch or large increase in M over the last decade. Large removals could alias other unknown sources of mortality.

- The empirical area swept method was performed with swept area biomass that used a NEFSC Albatross survey efficiency for witch flounder of 0.056 (CV=0.05) based on a cooperative research experiment ("Sweep Study") conducted in August 2016 (working paper by Hare et al. 2016).

- The biological reference points estimated in the last assessment (NEFSC 2015) were F_{MSY} proxy $=F_{40\%}=0.28$, $SSB_{MSY}=9{,}473$ mt, and MSY=1,957 mt. Although the estimates of biomass and relative exploitation rate from the empirical area swept method appear different from those based on other approaches, the approaches result in similar OFLs.

- The SARC recommends that witch flounder be put on a research track to address survey catchability and retrospective problems. Such an examination should include other stocks in the region exhibiting major retrospective patterns and survey catchability issues.

References:

Hare J, Hoey J, Manderson J, Martin M, Politis P, Richardson D, Roebuck C. 2016. Empirical estimates of maximum catchability of Witch Flounder *Glyptocephalus cynoglossus L.* on the Northeast Fisheries Science Center Fall bottom trawl survey. SAW/SARC 62 Working Paper, 27 p.

NEFSC. 2015. Operational Assessment of 20 Northeast Groundfish Stocks, Updated Through 2014. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 15-24; 251 p.

Northeast Fisheries Science Center (NEFSC). In prep. Stock Assessment of Witch flounder. 62nd Northeast Stock Assessment Workshop.

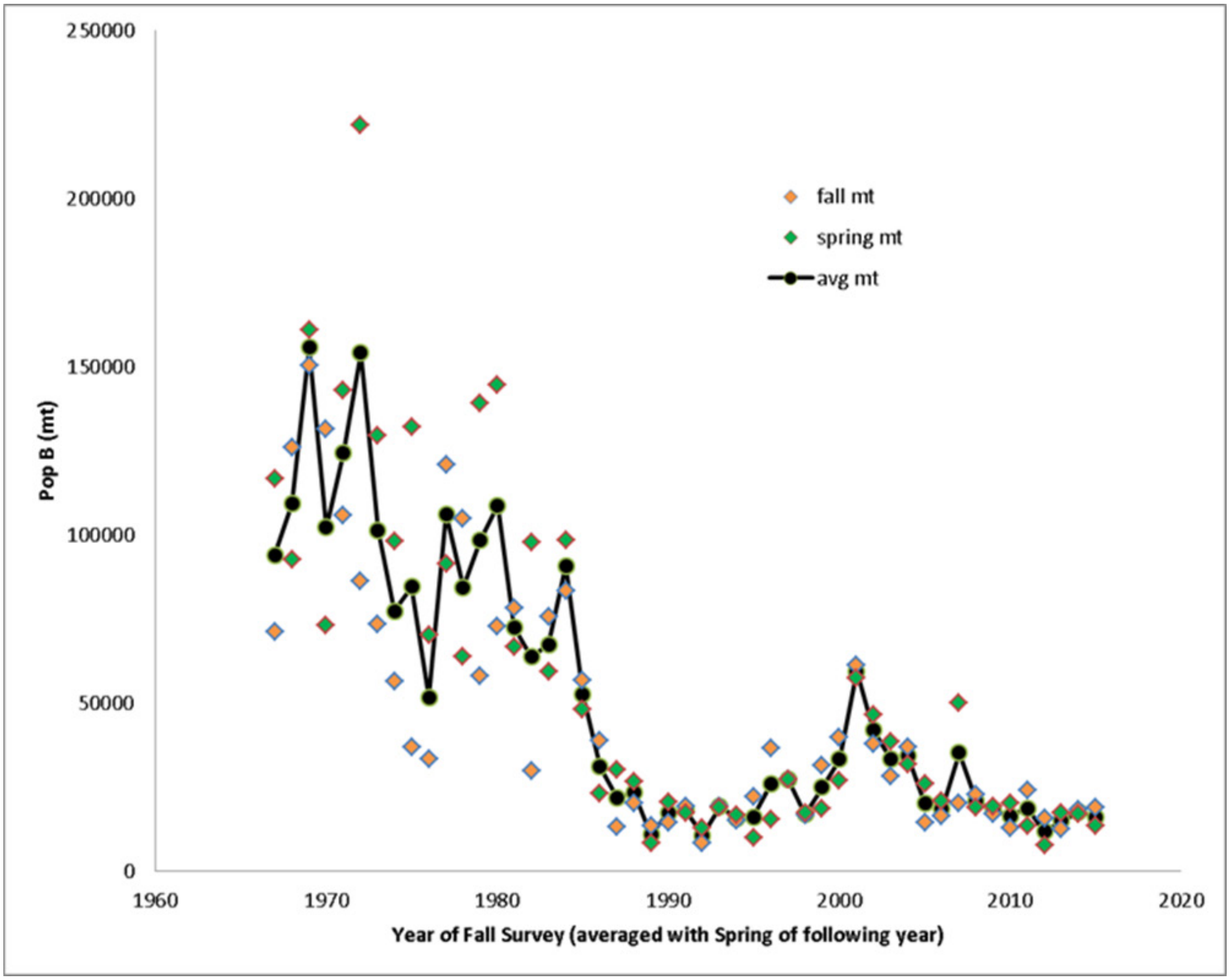

Figure B1. Trends in Northeast Fisheries Science Center witch flounder autumn (pink diamond) and spring (green diamond) population biomass estimates (mt) and the average population biomass (mt; representing beginning year biomass; black line with solid circles), 1969 – 2016.

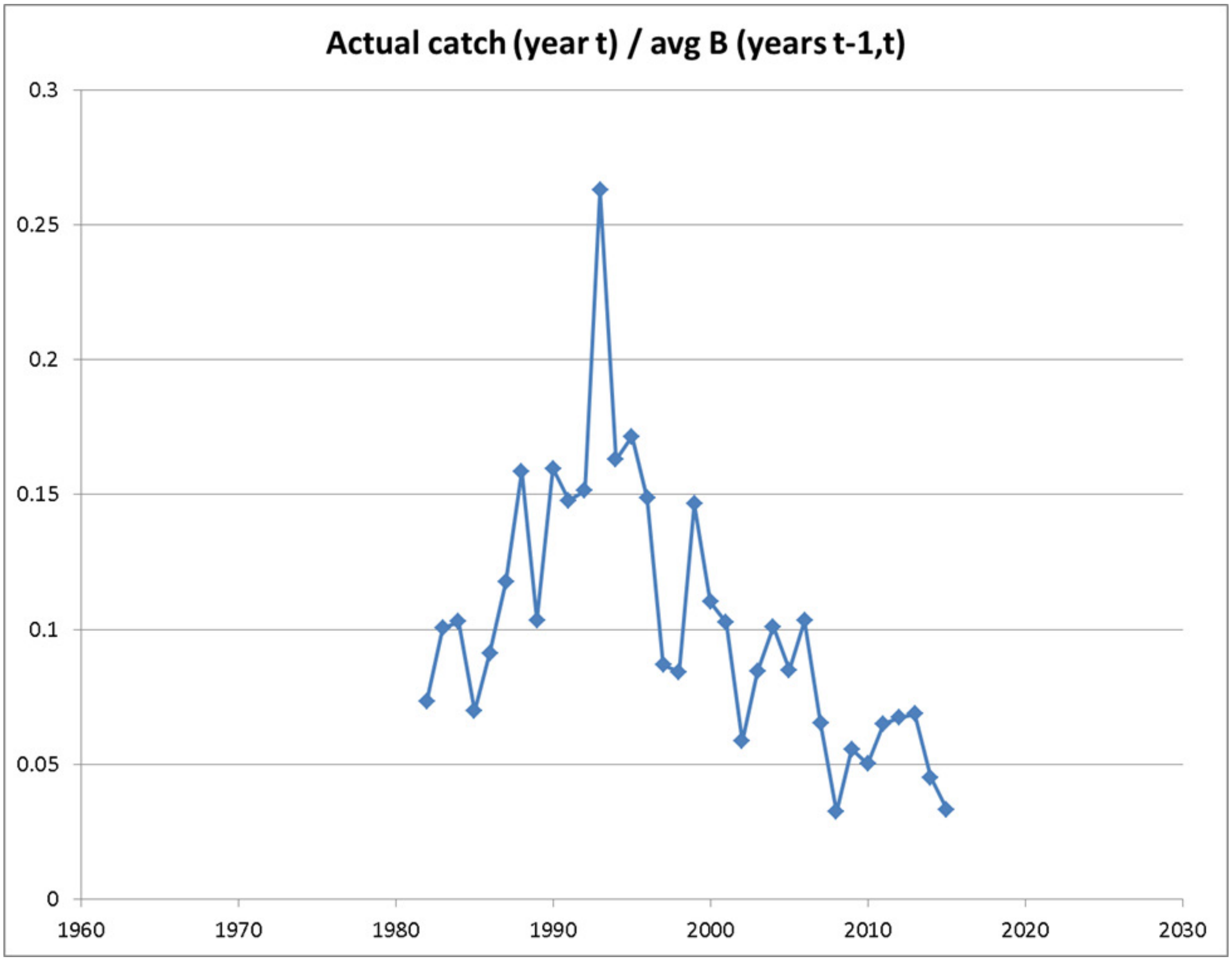

Figure B2. Historical exploitation rates of witch flounder derived from actual catch (year t) divided by average population biomass (years t-1 Autumn and t Spring), 1982 – 2015.

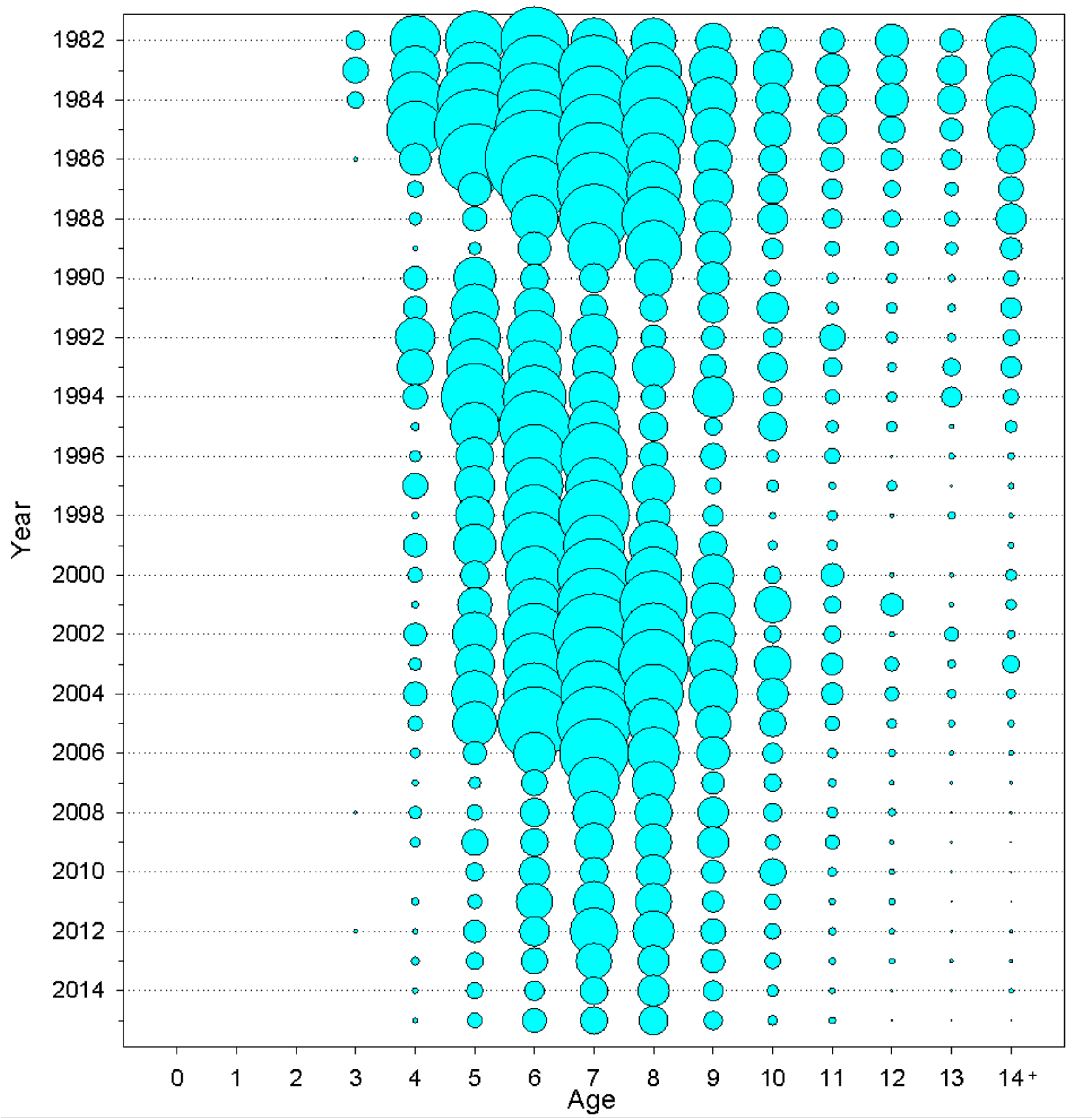

Figure B3. Witch flounder commercial landings at age (in numbers) ages 0 to 14 plus, 1982 to 2015.

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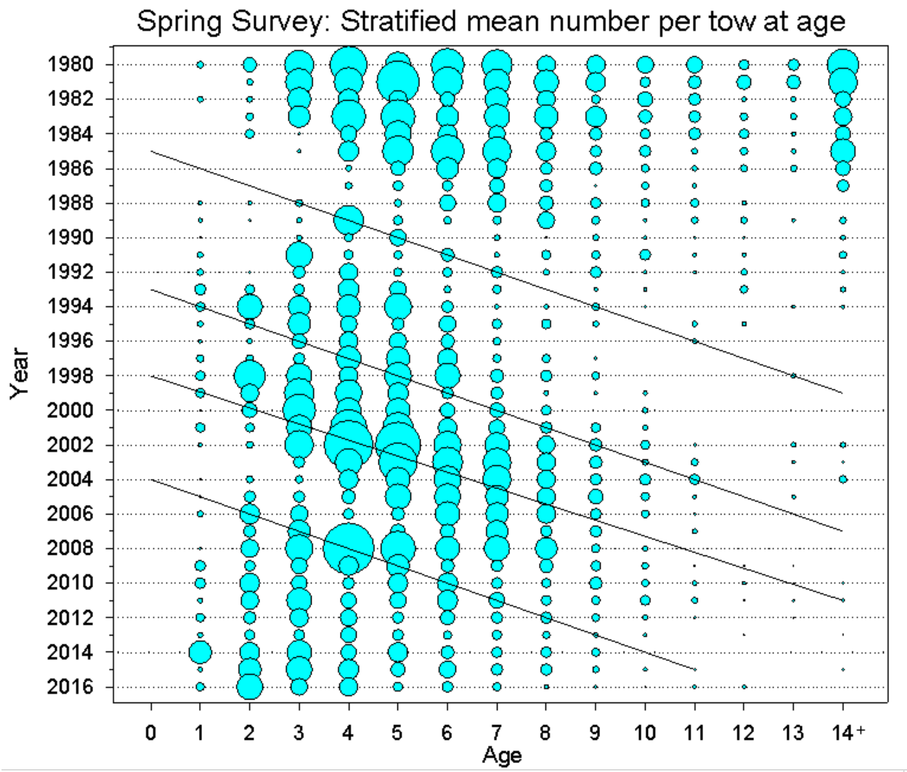

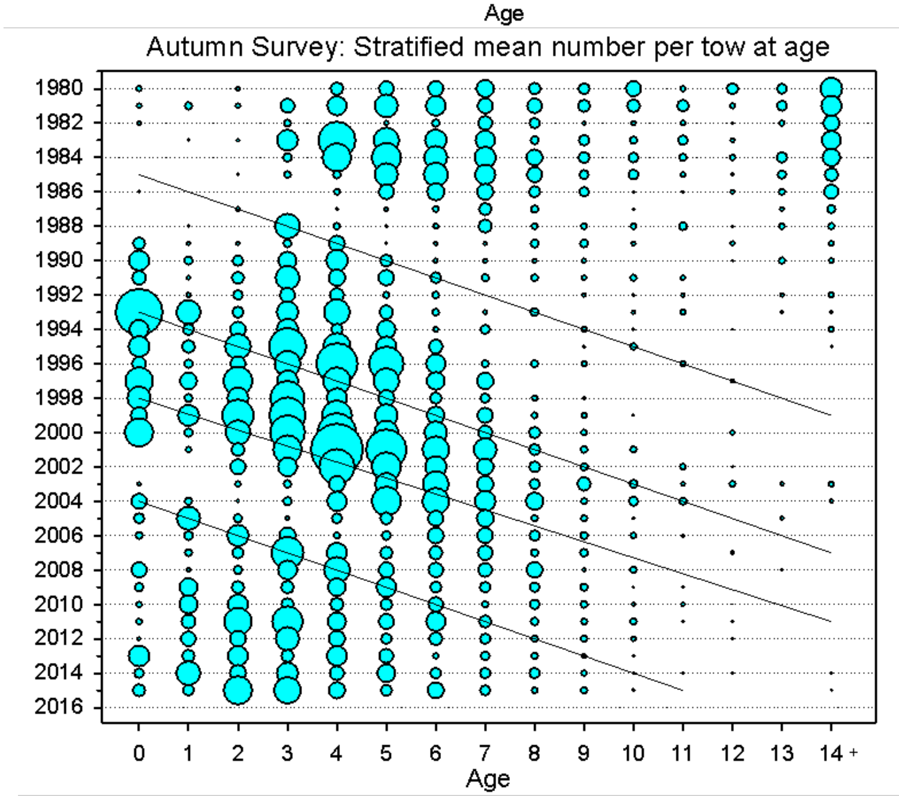

Figure B4. Stratified mean number of witch flounder per tow at age from Northeast Fisheries Science Center spring (top) and autumn (bottom) surveys, 1980 – 2015; spring 2016. Selected cohorts (1985, 1993, 1998, and 2004 year classes) are indicated with diagonal lines.

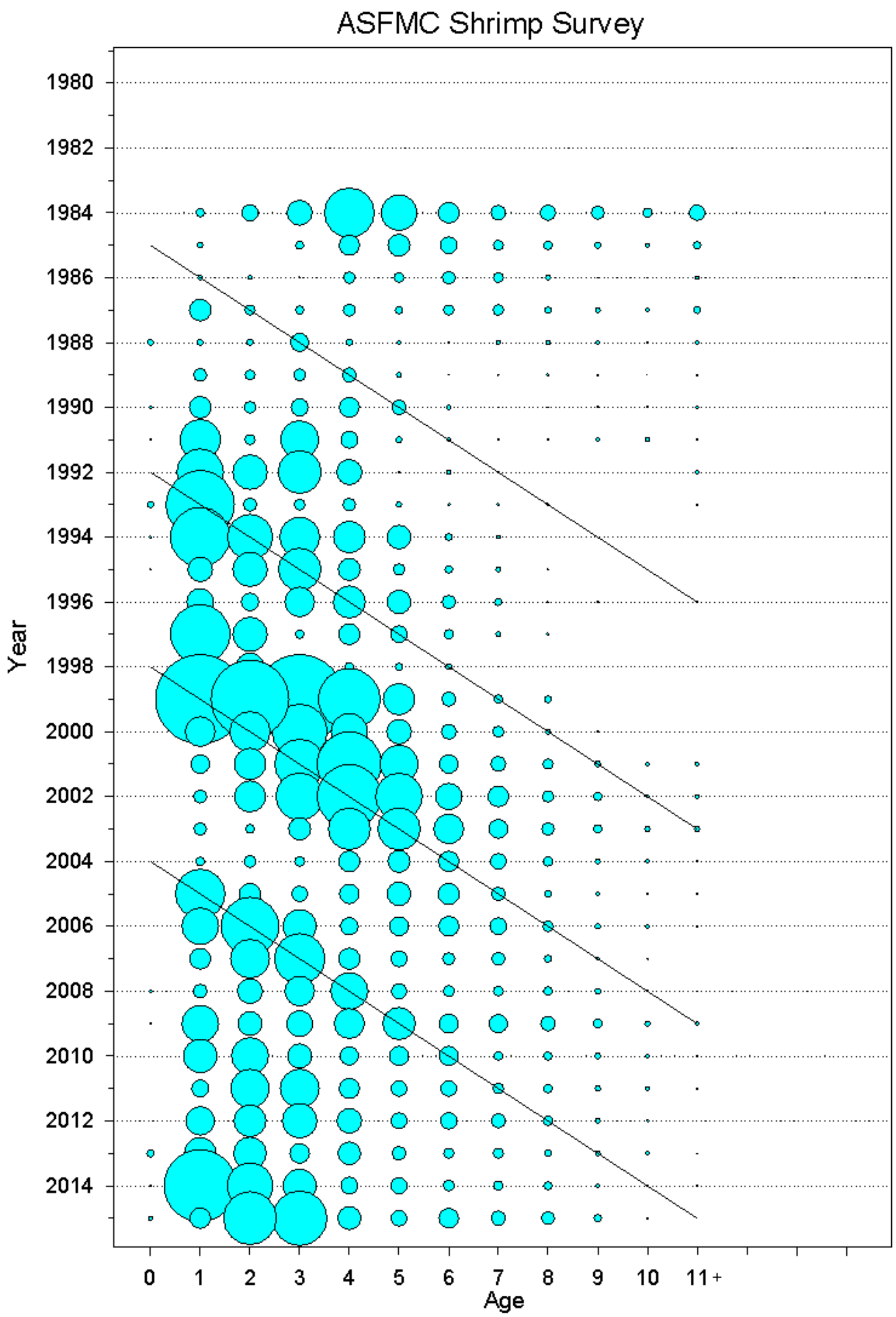

Figure B5. Stratified mean number per tow at age of witch flounder in the Atlantic States Marine Fisheries Commission summer shrimp survey (strata set 1, 3, 6, 8), 1984 - 2015. Selected cohorts (1985, 1992, 1998, and 2004 year classes) are indicated with diagonal lines.

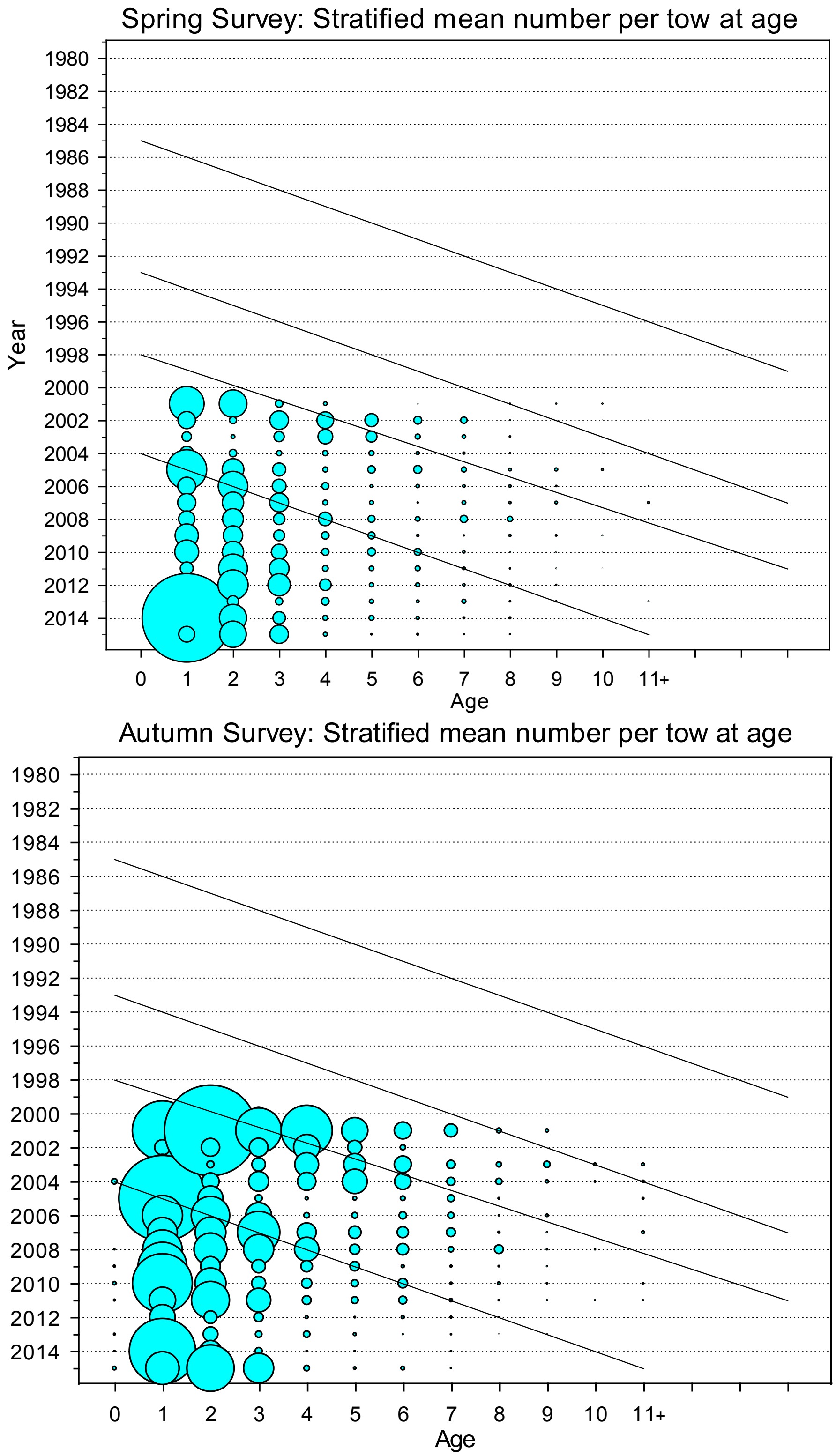

Figure B6. Stratified mean number of fish at age for witch flounder from the 2000-2015 spring (top) and autumn (bottom) Maine-New Hampshire inshore trawl survey (regions 1 through 5; strata 1 through 4). Indices for 2000-2002 were re-stratified; fixed stations are not included; seasonal Northeast Fisheries Science Center survey age/length keys used.

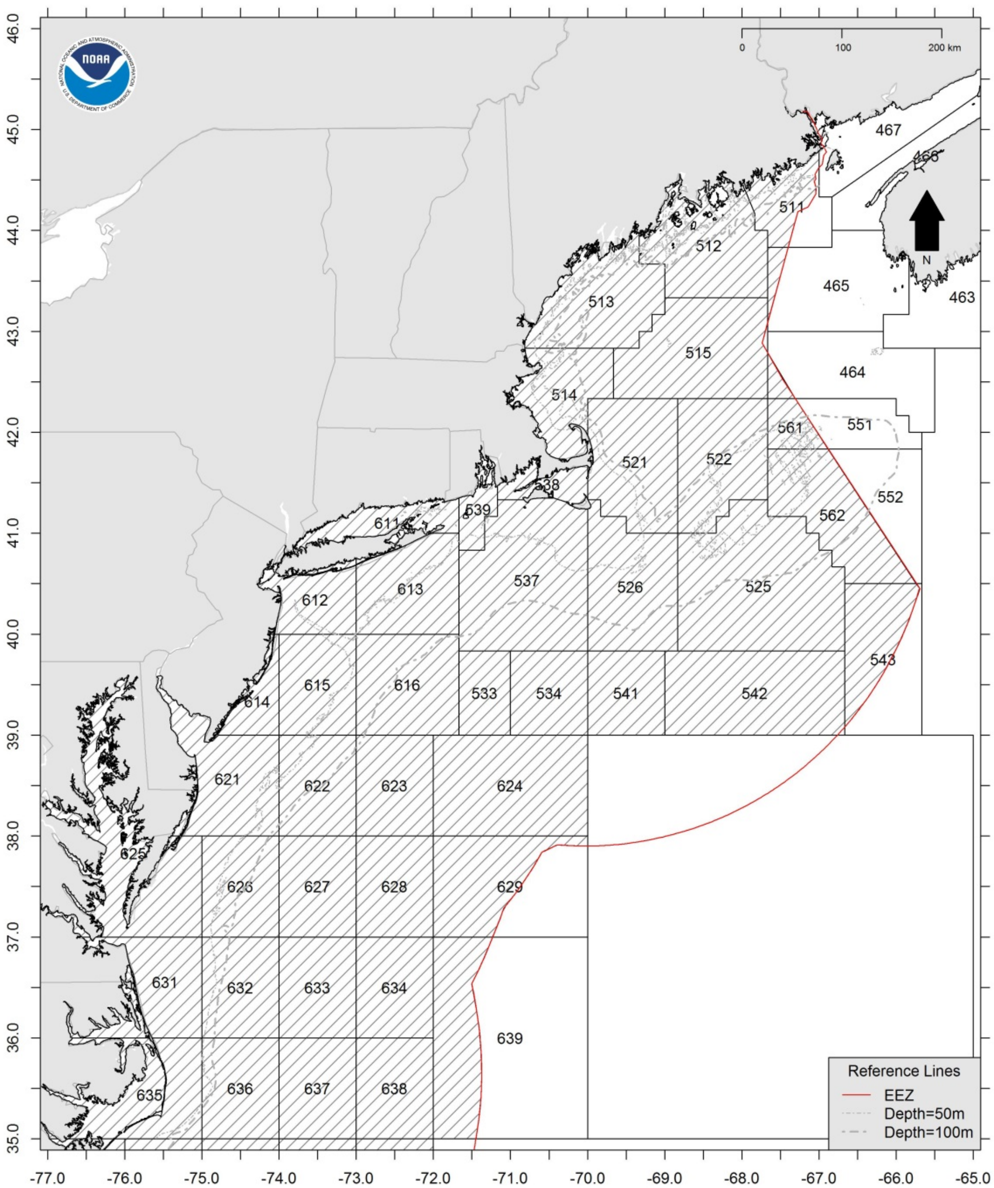

Figure B7. Map of the witch flounder management and assessment area (shaded). The United States exclusive ecomonic zone (EEZ) is defined by the red line.

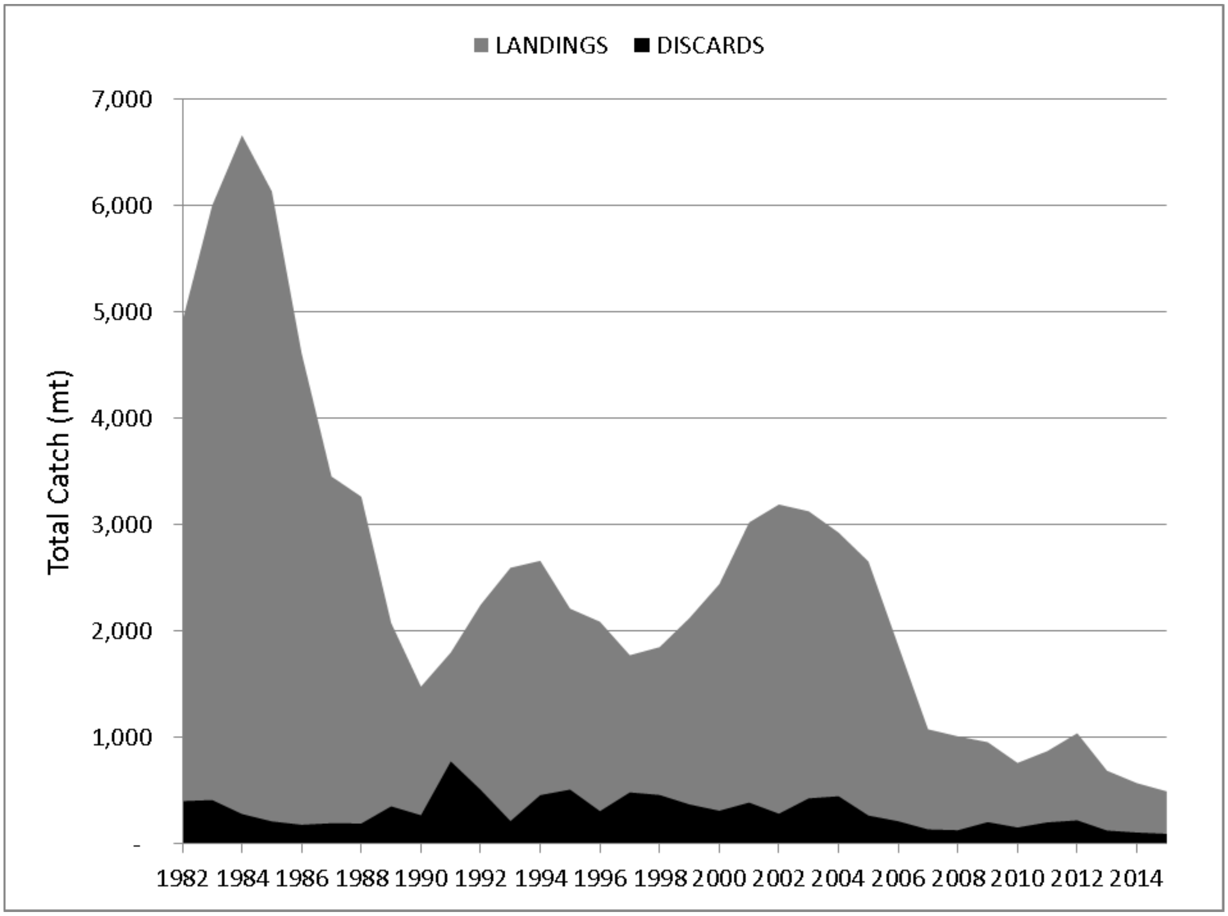

Figure B8. Total catch (landed, discarded) of witch flounder from 1982 to 2015.

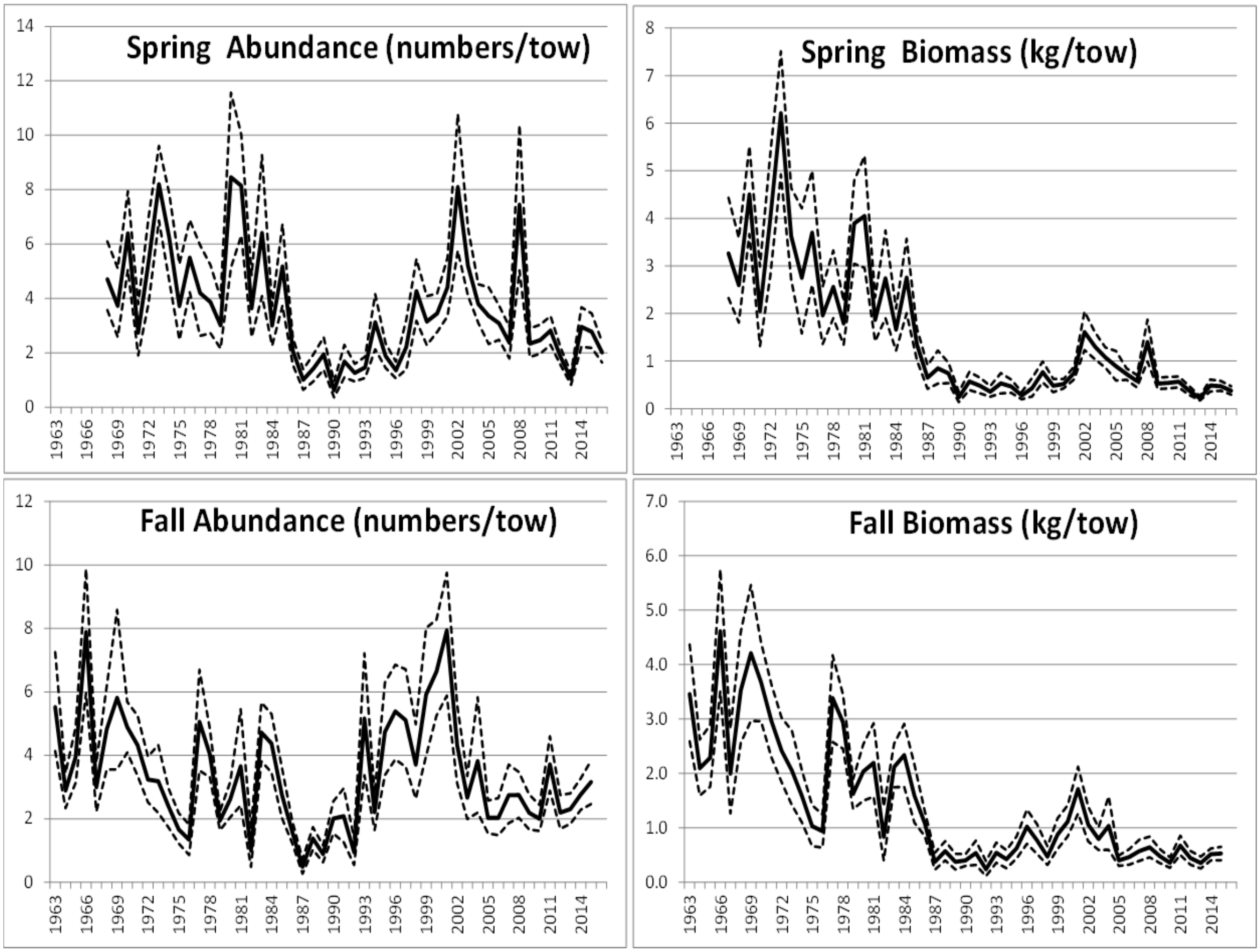

Figure B9. Stratified mean number (left) and weight (kg; right) per tow of witch flounder in the Northeast Fisheries Science Center autumn (bottom) and spring (top) bottom trawl surveys, 1963-2015, spring 2016. Survey indices are in Albatross units.

Appendix: Stock Assessment Terms of Reference for SAW/SARC-62, Nov. 29 – Dec. 2, 2016

A. Black sea bass

1. Summarize the conclusions of the February 2016 SSC peer review regarding the potential for spatial partitioning of the black sea bass stock. The consequences for the stock assessment will be addressed in TOR-6.)

2. 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.

3. 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 fishery dependent indices as a measure of relative abundance. Characterize the uncertainty and any bias in these sources of data.

4. Consider the consequences of environmental factors on the estimates of abundance or relative indices derived from surveys.

5. Investigate implications of hermaphroditic life history on stock assessment model. If possible, incorporate parameters to account for hermaphroditism.

6. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock), using measures that are appropriate to the assessment model, for the time series (integrating results from TORs-1,-4, & -5 as appropriate), and estimate their uncertainty. Include a historical retrospective analysis and past projection performance evaluation to allow a comparison with most recent assessment results.

7. Estimate biological reference points (BRPs; point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, F_{MSY}, and MSY), including defining BRPs for spatially explicit areas if appropriate, 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.

8. Evaluate overall stock status with respect to a new model or new models that considered spatial units developed for this peer review.

9. Develop approaches and apply them to conduct stock projections.
    a. Provide numerical annual projections (3-5 years) and the statistical distribution (e.g., probability density function) of the OFL (overfishing level) that fully incorporates observation, process and model uncertainty (see Appendix to the SAW TORs). 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.

10. 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. Witch flounder

1. Estimate catch from all sources including landings and discards. Describe the spatial and temporal distribution of landings, discards, and fishing effort. Characterize the uncertainty in these sources of data.

2. Present available federal, state, and other survey data, indices of relative or absolute abundance, recruitment, etc. Characterize the uncertainty and any bias in these sources of data and compare survey coverage to locations of fishery catches. Select the surveys and indices for use in the assessment.

3. Investigate effects of environmental factors and climate change on recruitment, growth and natural mortality of witch flounder. If quantifiable relationships are identified, consider incorporating these into the stock assessment.

4. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series (integrating results from TOR-3 if appropriate), and estimate their uncertainty. Include a historical retrospective analysis to allow a comparison with previous assessment results and previous projections. Compare F's and SSB's that were projected during the previous assessment to their realized values.

5. 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 scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

6. Evaluate stock status with respect to the existing model (from previous peer reviewed accepted assessment) and with respect to a new model (or possibly models, in accord with guidance in attached "Appendix to the SAW Assessment TORs") 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 updated BRP estimates.
   b. Then use the newly proposed model (or possibly models, in accord with guidance in "Appendix to the SAW Assessment TORs") and evaluate stock status with respect to "new" BRPs and their estimates (from TOR-5).

7. Develop approaches and apply them to conduct stock projections.
   a. Provide numerical annual projections (3 years) and the statistical distribution (e.g., probability density function) of the catch at F_{MSY} or an F_{MSY} proxy (i.e. the overfishing level, OFL) (see Appendix). 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, magnitude and 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. Identify reasonable projection parameters (recruitment, weight-at-age, retrospective adjustments, etc.) to use when setting specifications.
   c. Describe this stock's vulnerability to becoming overfished, and how this could affect the choice of ABC. The choice takes scientific uncertainty into account (see Appendix).

8. Evaluate the validity of the current stock definition, taking into account what is known about migration, and make a recommendation about whether there is a need to modify the current stock definition for future stock assessments.

9. Review, evaluate and report on the status of research recommendations from the last peer reviewed benchmark stock assessment. Identify new research recommendations.

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

Guidance to SAW WG about "Number of Models to include in the Assessment Report":

In general, for any TOR in which one or more models are explored by the WG, give a detailed presentation of the "best" model, including inputs, outputs, diagnostics of model adequacy, and sensitivity analyses that evaluate robustness of model results to the assumptions. In less detail, describe other models that were evaluated by the WG and explain their strengths, weaknesses and results in relation to the "best" model. If selection of a "best" model is not possible, present alternative models in detail, and summarize the relative utility each model, including a comparison of results. It should be highlighted whether any models represent a minority opinion.

On "Acceptable Biological Catch" (DOC Nat. Stand. Guidel. Fed. Reg., v. 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)

On "Vulnerability" (DOC Natl. Stand. Guidelines. Fed. Reg., v. 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 Maximum Sustainable Yield (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)

Participation among members of a Stock Assessment Working Group:

Anyone participating in SAW 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.

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