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58th Northeast Regional Stock Assessment Workshop (58th SAW)

Assessment Summary Report

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U.S. DEPARTMENT OF COMMERCE
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SAW-58 ASSESSMENT SUMMARY REPORT

Introduction

The 58th SAW Assessment Summary Report contains summary and detailed technical information on three stock assessments reviewed during January 27-31, 2014 at the Stock Assessment Workshop (SAW) by the 58th Stock Assessment Review Committee (SARC-58): butterfish (*Peprilus triacanthus*), golden tilefish (*Lopholatilus chamaeleonticeps*), and northern shrimp (*Pandalus borealis*). The SARC-58 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-58 are available at website: http://www.nefsc.noaa.gov/nefsc/saw/ under the heading "SARC 58 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-58 Review Panel reports (available at http://www.nefsc.noaa.gov/nefsc/saw/ under the heading "SARC-58 Panelist Reports").

For **butterfish** nearly all of the assessment Terms of Reference (ToRs) were fully met and the assessment results can be used as a basis for management. The Panel suggested that additional work could be done on consumptive removals of butterfish by predators and integration of results into the assessment. The SARC Panel felt that the work on habitat and oceanography was innovative, but the supporting document could have been clearer. The final accepted ASAP assessment model included an average measure of availability, which is a function of habitat suitability. But a temporally varying (by year) availability index was not included in the final model. In 2012, overfishing was not occurring, and the stock was not overfished. The stock is considered rebuilt.

For **golden tilefish** nearly all of the assessment ToRs were fully met and assessment results from the ASAP model can be used as a basis for management. The SARC Panel felt that the analysis of tilefish distribution in relation to temperature could be expanded by analyzing the relationship between commercial LPUE and environmental and climate variables. The Panel expressed some reservations about assuming a dome-shaped selectivity function, but noted that there appeared to be reasonable support for that assumption. In 2012, overfishing was not occurring, and the stock was not overfished. The stock is considered rebuilt.

For **northern shrimp** some key assessment ToRs were not met, and the results of the analytical assessment models should not be used as a basis for management. Three independent assessment models were presented but each model had problems. Model performance was partially related to the addition of new data, which created technical problems within the models. In lieu of an accepted assessment model, the SARC Panel recommended basing northern shrimp management on observed patterns in the northern shrimp catches, survey indices, and potentially on commercial CPUE.

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.

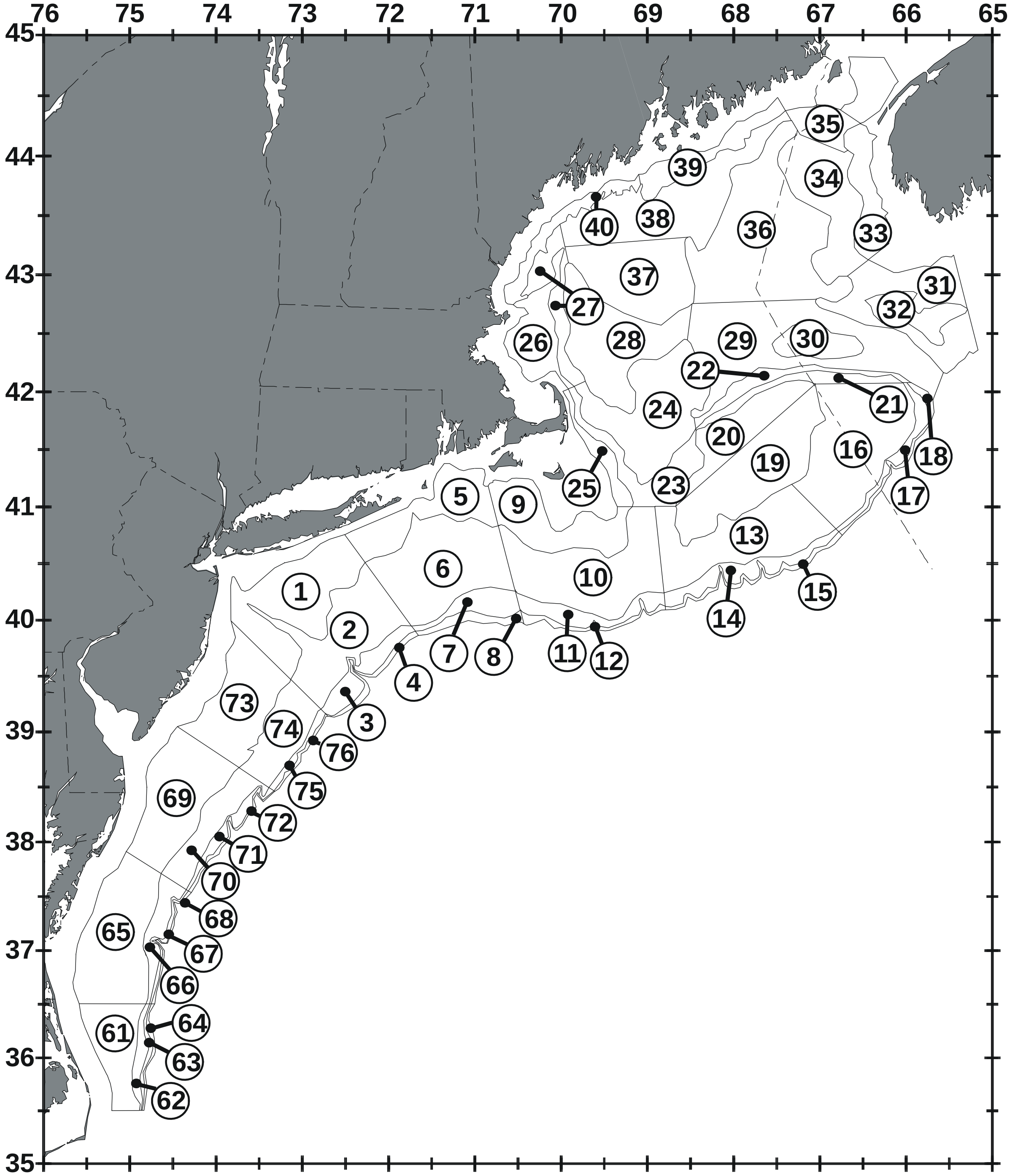

Figure 1. Offshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys. Some of these may not be sampled presently.

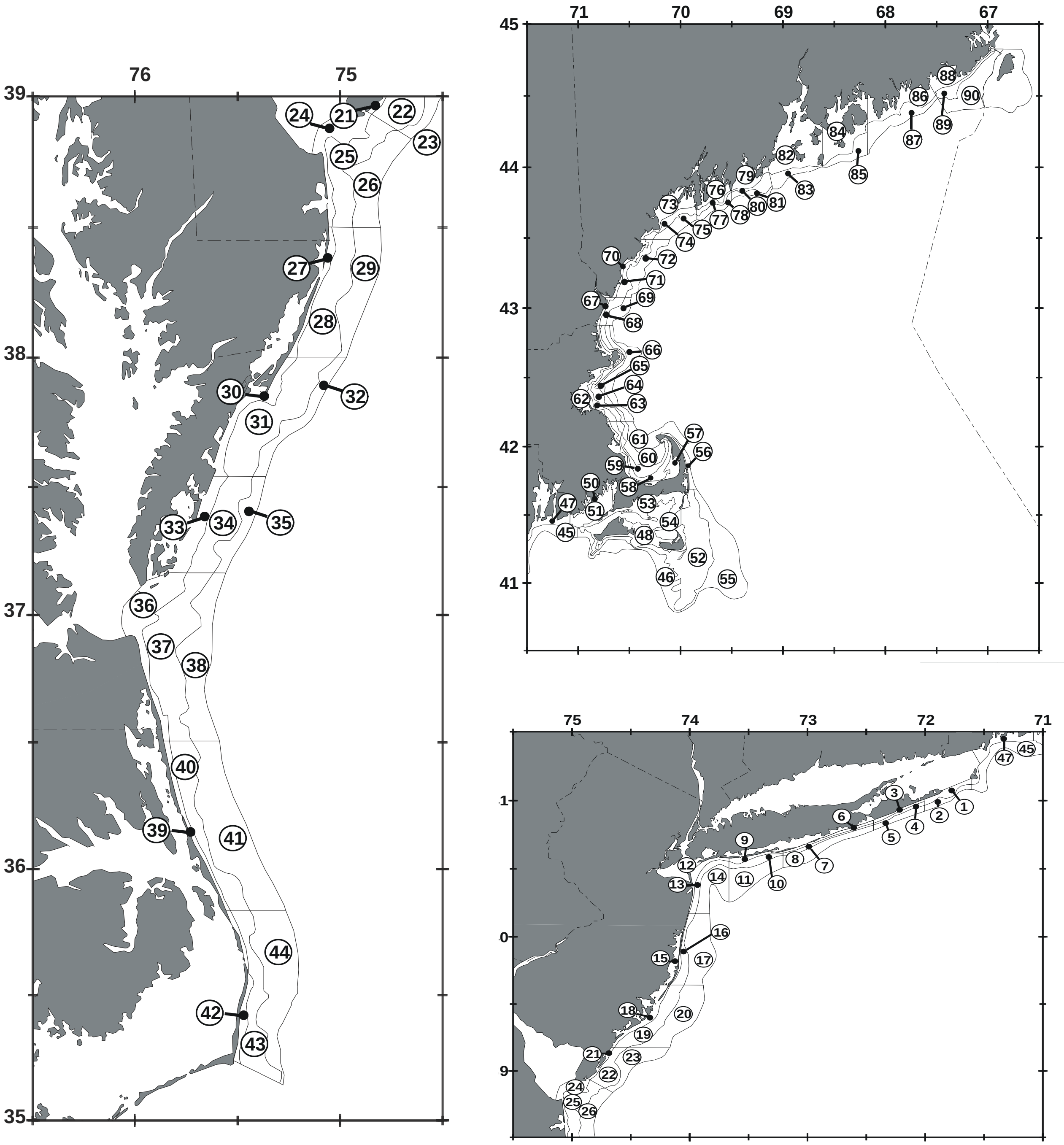

Figure 2. Inshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys. Some of these may not be sampled presently.

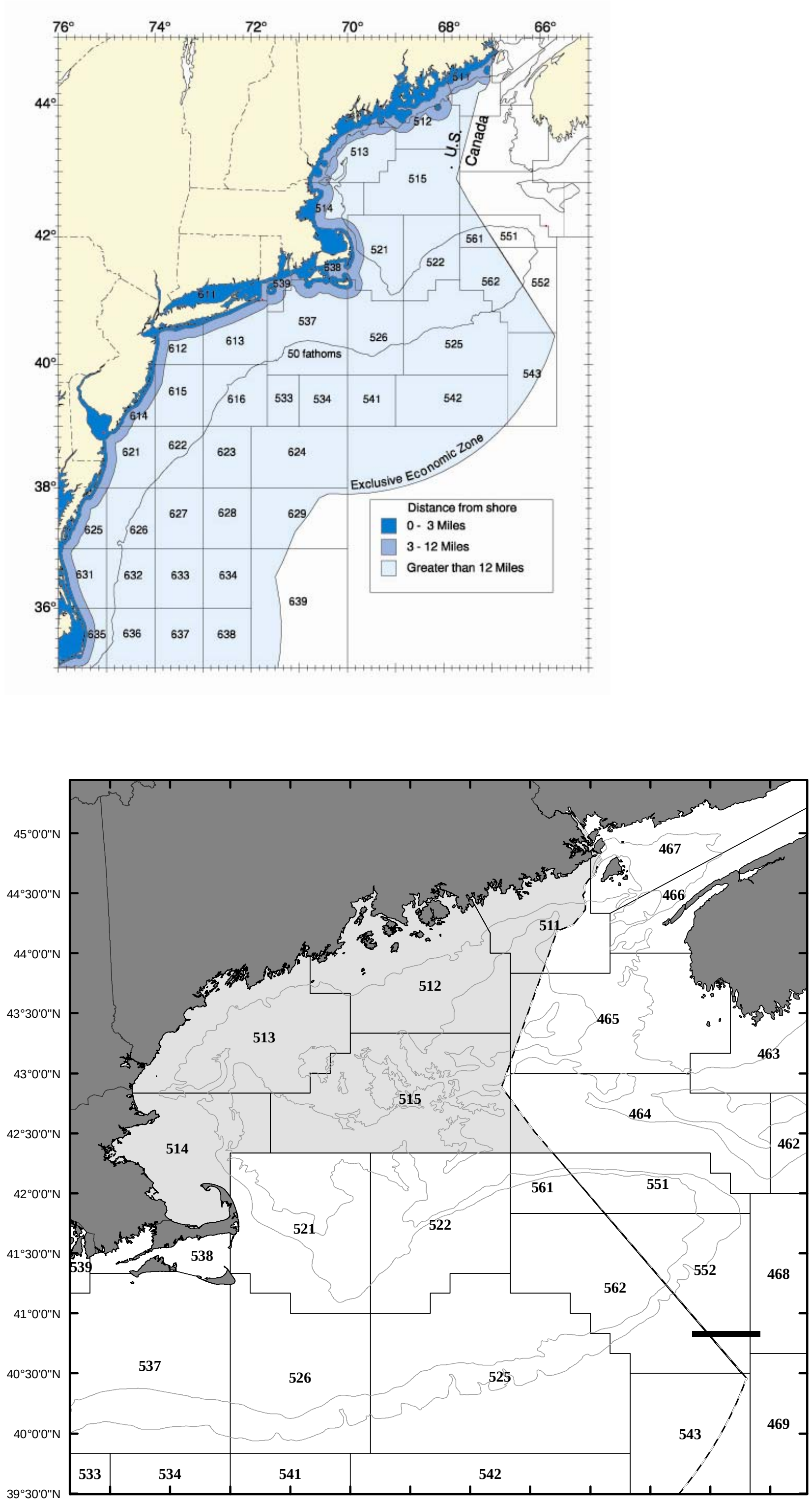

Figure 3. Statistical areas used for reporting commercial catches.

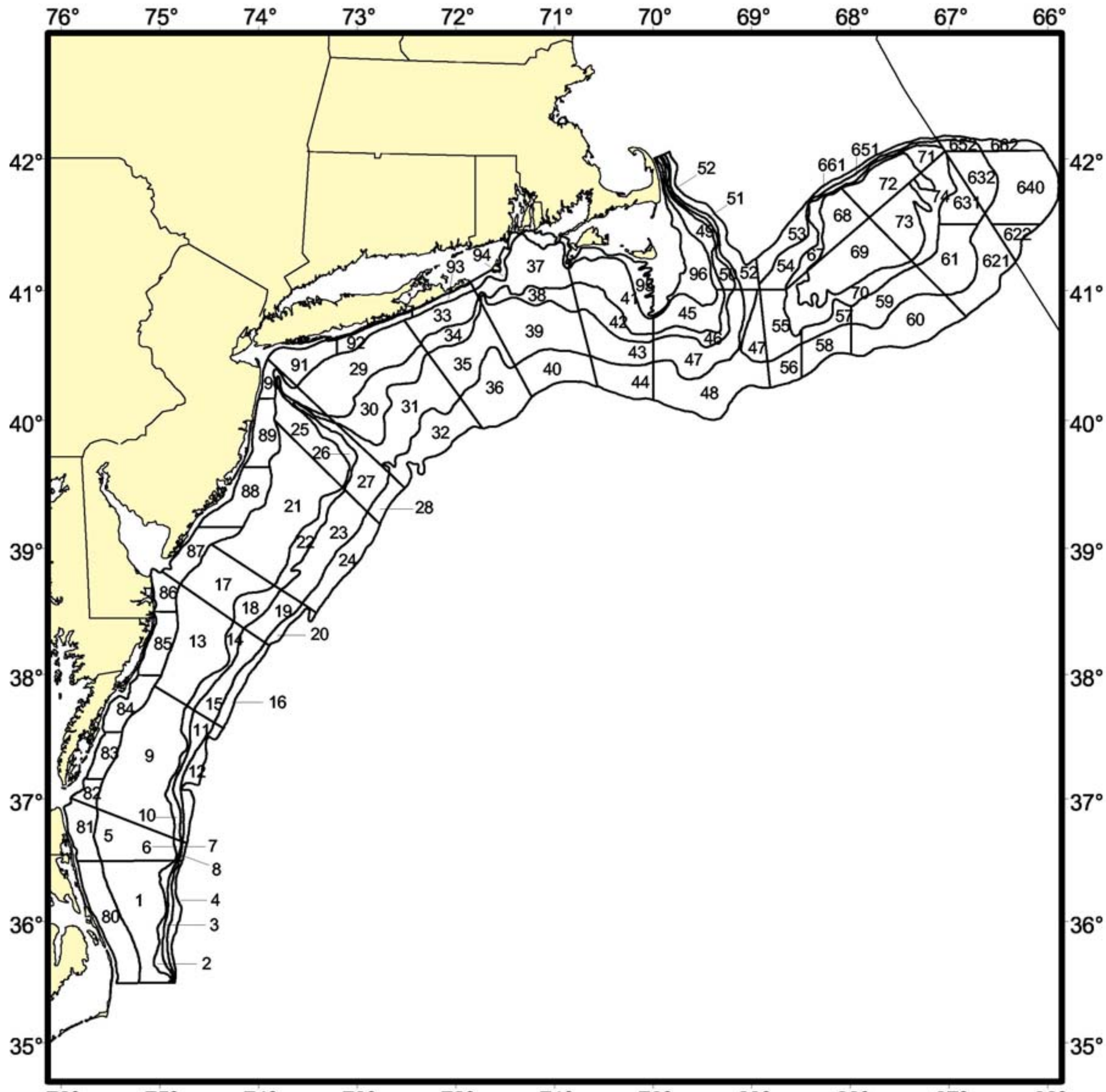

Figure 4. Northeast Fisheries Science Center clam resource survey strata, along the east coast of the US.

A. BUTTERFISH ASSESSMENT SUMMARY FOR 2014

State of Stock

Estimated fishing mortality and spawning biomass in 2012 are 0.02 (CV(F_{2012}) = 0.33) and 79,451 mt (175.2 million lb) (CV(SSB_{2012}) = 0.25), respectively. Butterfish are relatively short-lived and have a high natural mortality rate (M = 1.22) which results in the spawning stock biomass (SSB) being strongly dependent on recruitment. The current fishing mortality rate (F_{2012} = 0.02) is well below the overfishing reference point accepted by SARC 58 (2/3 M = 0.81 [CV = 0.05]; Patterson, 1992). The current SSB (79,451 mt) is well above the accepted biomass reference point 45,616 mt (100.6 million lb) (CV = 0.25). Therefore, based on the point estimates, the stock is considered rebuilt. $SSB_{threshold}$ is one half the SSB_{MSY} proxy, or 22,808 mt (50.3 million lb). Overfishing is not occurring and the stock is not overfished.

Projections

Projections of SSB and fishing mortality were made using a standard forward projection methodology sampling recruitment from the entire time series. If preliminary butterfish catch (landings plus discards) for 2013 (2,489 mt; 5.5 million lb) is used, the median projection of SSB in 2013 is 51,746 mt (114.1 million lb), with 5% and 95% confidence limits of 32,489 mt (71.6 million lb) and 81,073 mt (178.7 million lb), respectively.

If the 2014 butterfish ABC (9,100 mt; 20.1 million lb) is assumed for 2014 catch, the median projection of SSB in 2014 is 53,580 mt (118.1 million lb), with 5% and 95% confidence limits of 38,365 mt (84.6 million lb) and 73,885 mt (162.9 million lb), respectively. The probability of overfishing in 2014 associated with this catch is <1%.

Catch

Total catches of butterfish increased from 15,167 mt (33.4 million lb) in 1965 to a peak of 39,896 mt (88.0 million lb) in 1973, and were dominated by catches from the offshore foreign fleets (Figure A1). Total catches then declined to 11,863 mt (26.2 million lb) in 1977, following the implementation of the Fishery Conservation and Management Act of 1976. Foreign landings were completely phased out by 1987. A domestic fishery was developed to supply the Japanese market, leading to a peak catch of 22,401 mt (49.4 million lb) in 1984, but then declined to 2,831 mt (6.2 million lb) in 1990. During 1991-2001, catches ranged between 3,928 mt (8.7 million lb) and 12,185 mt (26.9 million lb). Catches were relatively lower during 2002-2012 due to the lack of a directed fishery and management restrictions, ranging between 918 mt (2.0 million lb) and 4,593 mt (10.1 million lb). Discards comprised a majority of the total butterfish catch, averaging 58% during 1989-2001 and 67% during 2002-2012. Total catch estimates were highly variable and imprecise, with CVs ranging from 0.07 – 1.43 due to the uncertain discard estimates.

Table A1. Catch and status table: butterfish. Weights are in 000s mt; age-0 recruitment in billions, fishing mortality for ages 2+.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Min[1]	Mean[1]	Max[1]
US landings	0.5	0.5	0.4	0.6	0.7	0.5	0.4	0.6	0.7	0.7	0.4	2.6	11.7
US discards	2.1	1.3	0.6	0.9	0.2	1.0	1.1	4.0	1.6	1.0	0.2	6.0	11.5
Foreign catch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	31.7
Total catch	2.6	1.8	1.1	1.4	0.9	1.5	1.5	4.6	2.3	1.7	0.9	11.7	39.9

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Min[2]	Mean[2]	Max[2]
Spawning biomass	80.4	85.3	56.1	67.5	79.6	62.6	57.0	77.9	71.2	79.5	56.1	79.4	106.6
Recruit numbers	9.1	5.1	7.6	7.4	5.7	7.6	11.1	6.5	9.5	2.4	2.4	8.5	14.8
Fishing mortality	0.03	0.02	0.02	0.02	0.01	0.02	0.02	0.07	0.03	0.02	0.01	0.07	0.15

[1]1965-2012 [2]1989-2012

Stock Distribution and Identification

Butterfish (*Peprilus triacanthus*) are distributed from Florida to Nova Scotia, occasionally straying as far north as Newfoundland, but are primarily found from Cape Hatteras to the Gulf of Maine, where the population is considered to be a unit stock (Collette and Klein-MacPhee, 2002). Butterfish are a fast growing species, overwintering offshore, and then moving inshore and northwards in the summer. Butterfish mature during their second summer (age 1), spawn primarily during June-July, and begin schooling around 60 mm. The diet consists primarily of urochordates (Larvacea, Ascidacea, Thaliacea) and thecosome mollusks (*Clione*). They are preyed upon by a number of commercially important fishes such as haddock, silver hake, swordfish, bluefish, weakfish, summer flounder, goosefish, and hammerhead shark. Although it is generally thought that butterfish comprise a large part of the diet of longfin squid, recent stable isotope and fatty acid work suggests this is not the case (Jensen, pers. comm.).

Data and Assessment

Butterfish were last assessed in 2009 during SAW 49 (NEFSC, 2010).

Commercial data. US landings and discard estimates, and commercial mean weights at age were used in the current assessment. Catch data prior to 1989 were not used due to uncertainty in discards, which account for a large proportion of total catch. The observer time series for calculating discards begins in 1989 as well.

Survey data. The current assessment relies on swept area abundances, and abundance indices (number/tow) by age from 1989-2012 Northeast Fisheries Science Center (NEFSC) fall surveys (inshore and offshore). Additionally, swept area abundances from the Northeast Area Monitoring and Assessment Program (NEAMAP) fall (2007-2012) survey were used. The NEFSC fall offshore bottom trawl survey (Figure A2) is considered the most reliable biomass index because most of the population is thought to be well distributed within the survey domain and coefficients of variation (CVs) were low (0.13 – 0.47).

Model. A modification of an age-structured catch at age model (ASAP) (Legault and Restrepo, 1999) was used in the current assessment. The modified model estimates natural mortality and survey vessel length-based calibration as model parameters. Other changes, relative to the last assessment, include: updated data through 2012; reassignment of survey strata into offshore and inshore series; use of NEAMAP survey data; and improvements to how catchability is determined in the ASAP model (see Special Comments).

Biological Reference Points

A proxy for F_{MSY} is based on Patterson (1992). The accepted overfishing reference point is F = 2M/3 = 2 ×1.22/3 = 0.81; CV = 0.05. The current fishing mortality (F_{2012} = 0.02, CV = 0.33) is well below the accepted overfishing reference point (Figure A3). The accepted biomass reference point SSB_{MSY} proxy (median SSB based on a 50 year projection at F_{MSY}) is 45,616 mt (100.6 million lb); CV = 0.25. SSB_{2012} is estimated to be 79,451 mt (175.2 million lb), which is well above the accepted SSB_{MSY} proxy (Figure A4). The accepted MSY proxy is 36,199 mt (79.8 million lb); CV = 0.20. $SSB_{threshold}$ is one half the SSB_{MSY} proxy, or 22,808 mt (50.3 million lb). Overfishing is not occurring and the stock is not overfished.

Fishing Mortality

The peak in fishing mortality rate on fully selected ages (ages 2+) was F = 0.15, which occurred in 1993 (Figure A3). Fishing mortality ranged between 0.04 and 0.14 during 1994-2001, but has been ≤ 0.07 since 2002 (Table A1).

Spawning Stock Biomass

Spawning stock biomass averaged 79,410 mt (175.1 million lb) during 1989-2012 (Table A1; Figures A4, A5 and A6). Spawning biomass is strongly dependent on recruitment because butterfish are relatively short-lived, mature early (A_{50} = 1 year), and have a high natural mortality rate (estimated at M = 1.22). Spawning stock biomass peaked in 2000 at 106,590 mt (235.0 million lb). Spawning stock biomass has been above the SSB_{MSY} proxy for the entire time period considered in the assessment model (Figure A4).

Recruitment

Recruitment, which can be highly variable from year to year, averaged 8.5 billion fish during 1989-2012 (Table A1; Figures A5 and A6). The 1997 year class was the largest, at 14.8 billion fish, and the 2012 year class was the smallest, at 2.4 billion fish, in the time series. The 2012 year class was estimated with more uncertainty than other year classes.

Special Comments

Relative to the previous assessment, a new modeling approach was used in this assessment. The previous assessment was based on the KLAMZ model, however it was not possible to establish BRPs in SARC 49 (NEFSC 2010) due to assessment uncertainties. The population was thought to be declining over time but fishing mortality was not considered to be the cause in the previous assessment. The current research on estimation of catchability provided an improved basis for understanding the stock history and allowed estimation of BRP.

There were three augmentations to the basic ASAP model for the base model: 1) catchability was reparameterized as the product of availability and efficiency with the former specified using the availability estimates based on bottom water temperature; 2) length-based calibration of bottom trawl survey data in 2009-2012 was performed internal to the model; and 3) estimation of natural mortality. For the NEFSC fall offshore survey, an average measure of availability based on a bottom temperature was used and the efficiency was based on relative efficiency of the FRV *Albatross IV* to the FSV *Henry B*. *Bigelow* and an assumption that the *Bigelow* was 100% efficient for daytime tows. Ability to estimate parameters within the new model framework was confirmed through simulation.

Validity of ASAP model estimates of biomass and fishing mortality was supported by the application of a simple envelope analysis method that established a feasible range for biomass. Model based estimates of stock biomass and fishing mortality rates were consistent with simple empirical interpretations of the data. The method was based on a feasible range of assumed fishing mortality rates applied to the observed catch series, and a feasible range of catchabilities applied to the NEFSC fall trawl survey catch weights per tow. Additional details are provided in Appendix 3 of the butterfish Assessment Report.

As in the previous assessment, estimates of consumption by the top six finfish predators (bluefish, *Pomatomus saltatrix*; spiny dogfish, *Squalus acanthias*; silver hake, *Merluccius bilinearis*; summer flounder, *Paralichthys dentatus*; goosefish, *Lophius americanus*; and smooth dogfish, *Mustelus canis*) of butterfish within the NEFSC food habits database appear to be very low and similar in magnitude to historic fishing mortality but well below the estimated natural mortality rate. Evidence was presented that longfin squid (*Doryteuthis pealeii*) are not a major predator on butterfish (Jensen, pers. comm.). Food habits of other potential predators, such as sharks, tuna, swordfish, marine mammals and seabirds are not adequately sampled to determine total butterfish consumption.

Continued development of the habitat model could be beneficial in other assessments or in future butterfish assessments.

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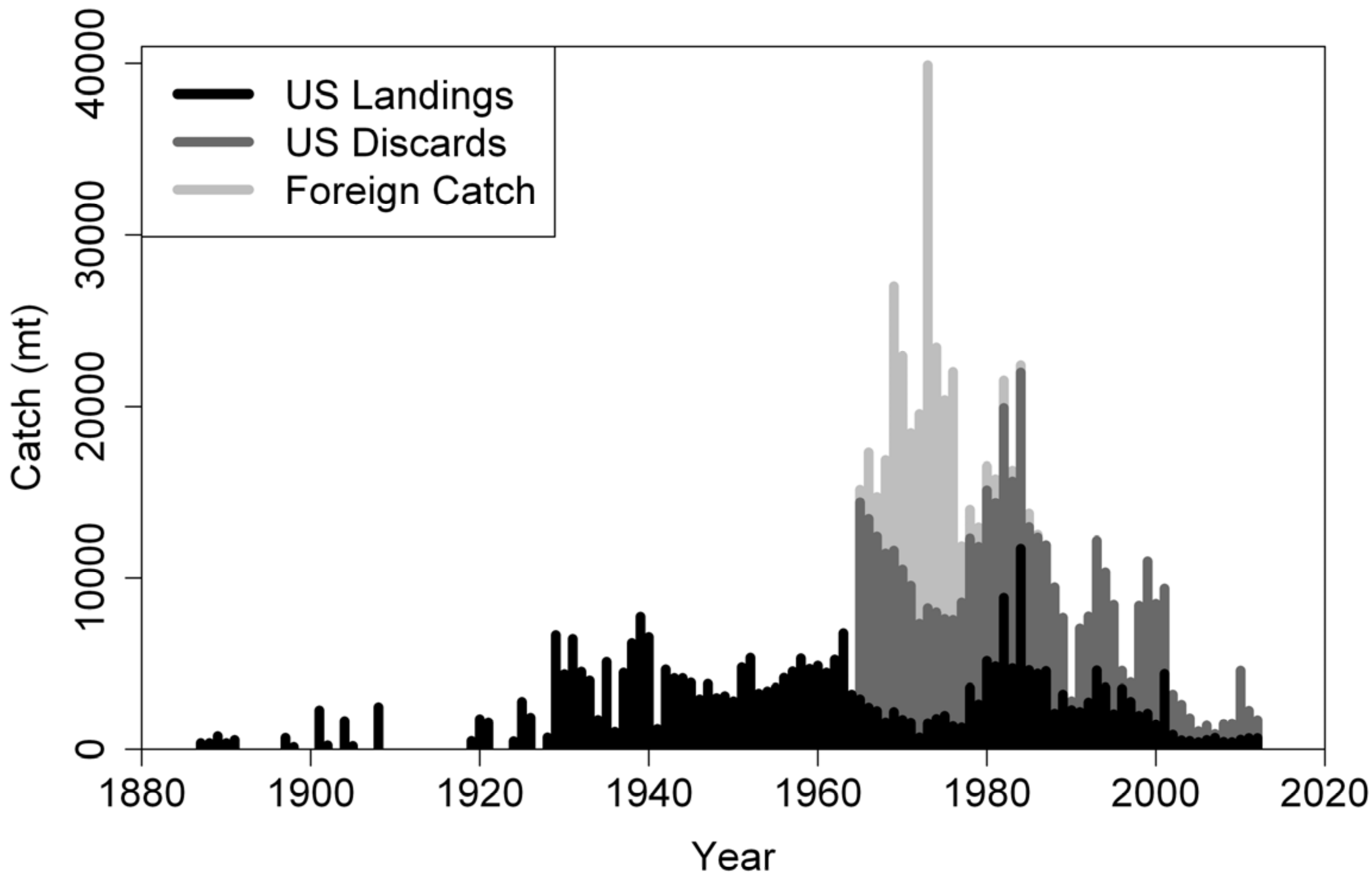

Figure A1. Butterfish total catch, 1887-2012. Annual catch data are missing for some years prior to 1930. Discards estimates are unavailable prior to 1965. Total catch from 1965-1988 includes discards estimated by applying an average of discard rates for trawl gear from 1989-1999 to annual landings of all species between 1965-1988 by trawl gear.

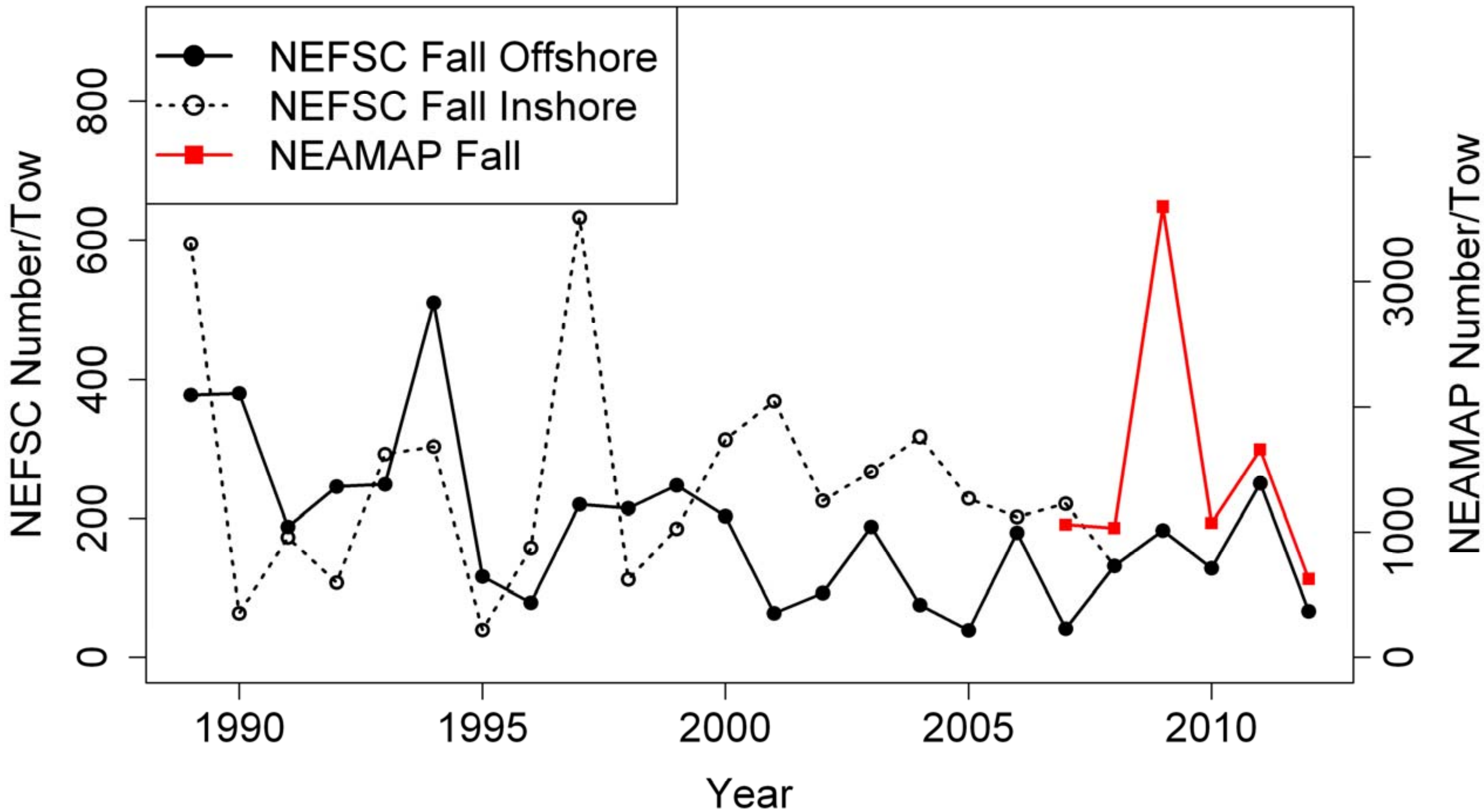

Figure A2. NEFSC and NEAMAP surveys stratified mean number of butterfish per tow. Note the NEFSC fall inshore series ends in 2008.

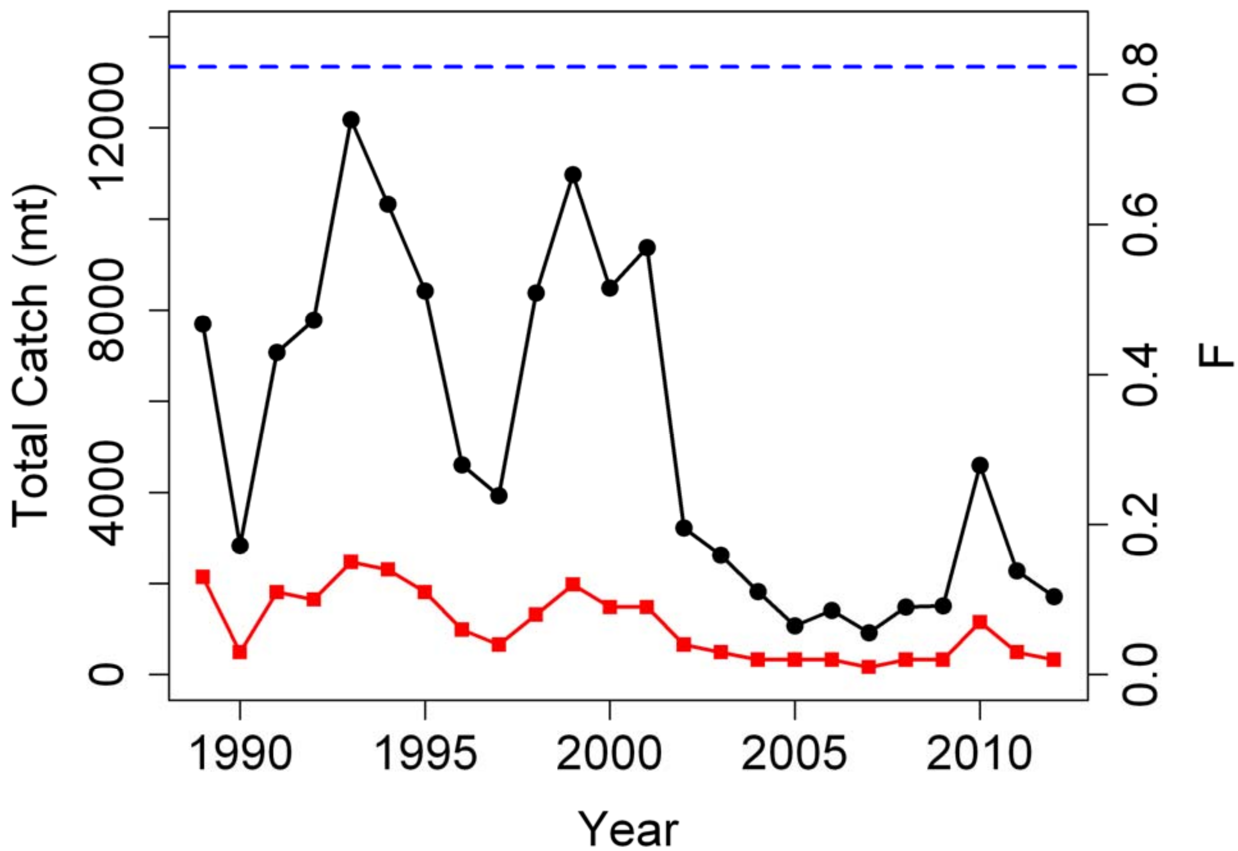

Figure A3. Butterfish total catch in mt (black circles) and fishing mortality, F (red squares). Dashed blue line is the 2014 SAW/SARC F_{MSY} proxy.

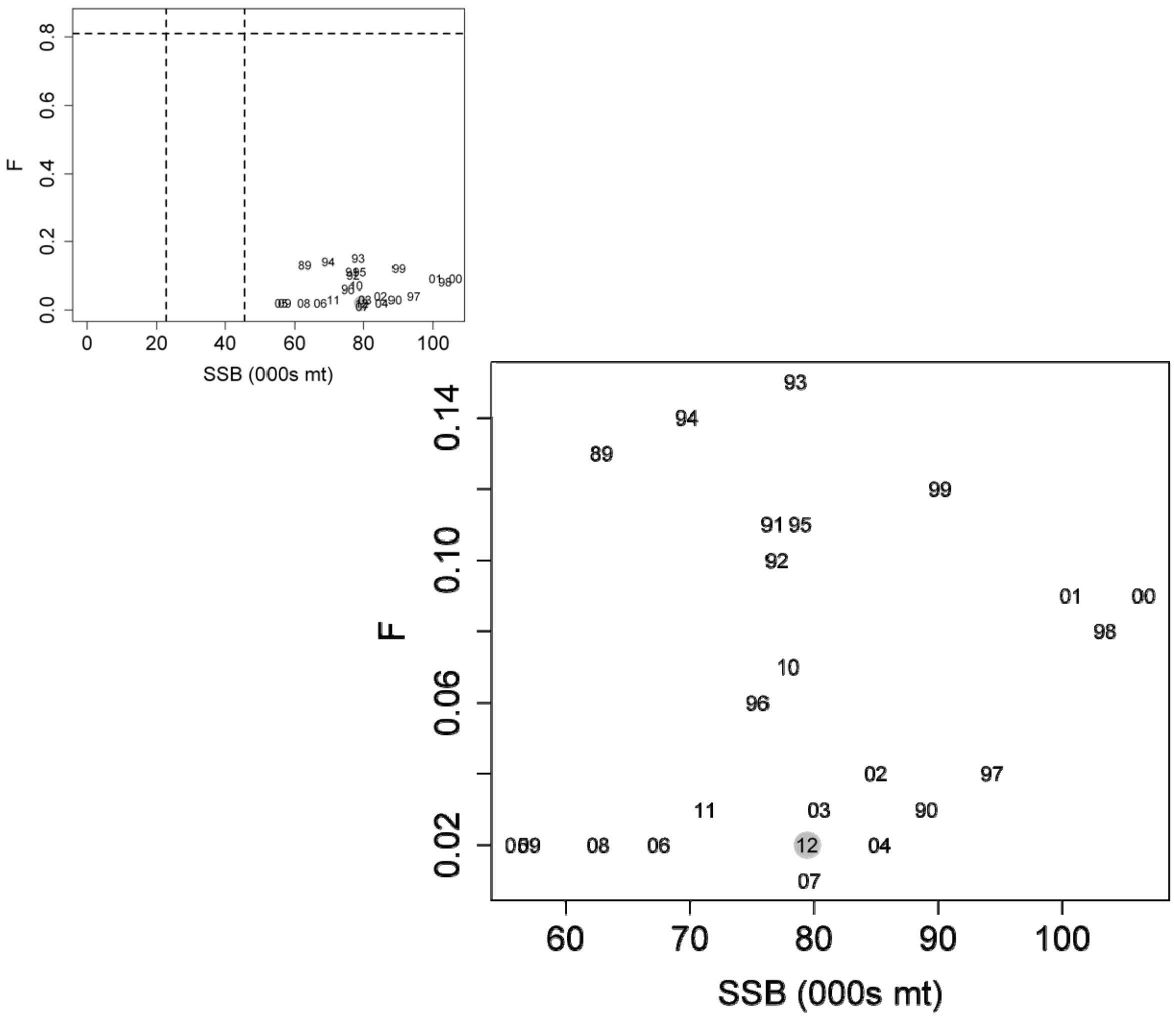

Figure A4. Butterfish spawning stock biomass (SSB) and fishing mortality (F) relative to the 2014 SAW/SARC biological reference points $SSB_{threshold}$ = 22,808 mt, SSB_{MSY} proxy = 45,616 mt, and F_{MSY} proxy = 0.81 (upper left panel). Plot is expanded for clarity in lower right panel.

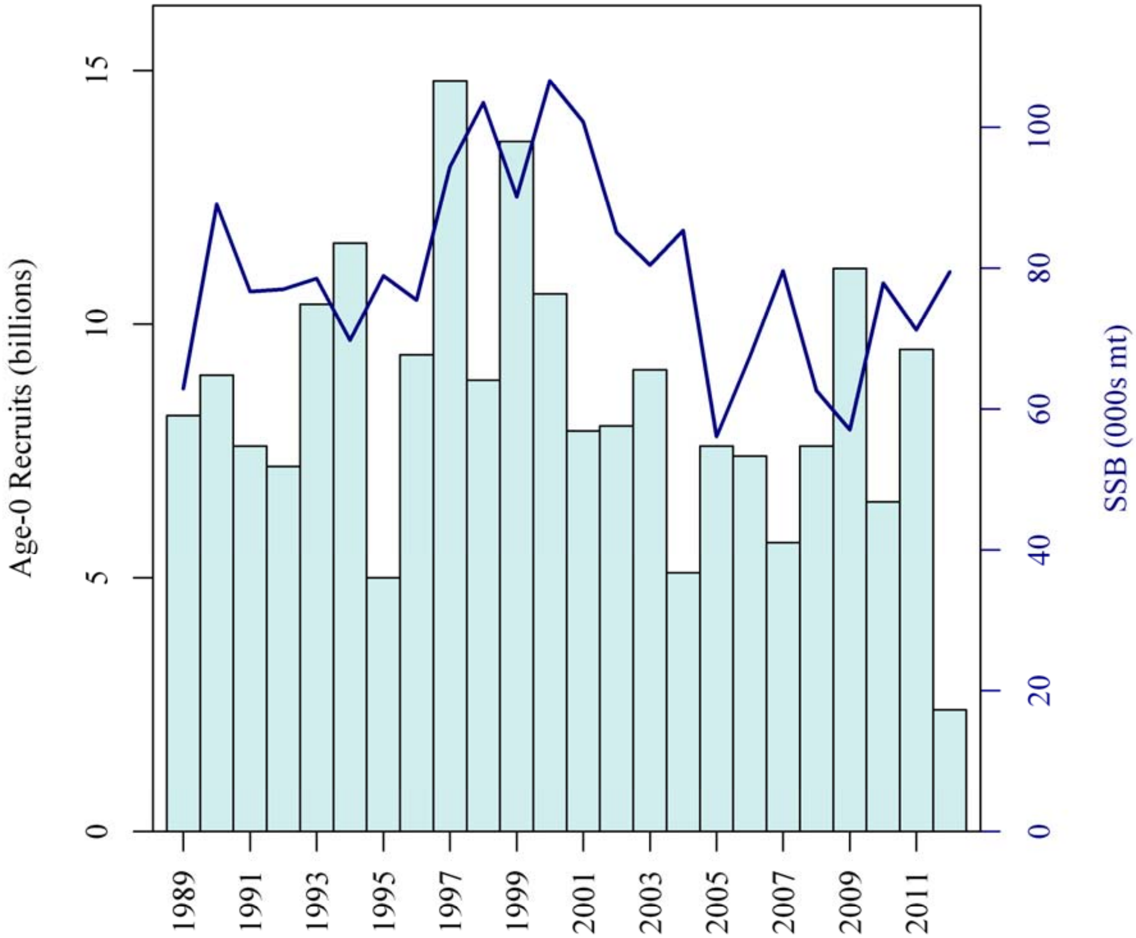

Figure A5. Butterfish recruitment (vertical bars), and the spawning stock biomass (blue line) that produced the corresponding recruitment. Year refers to spawning year.

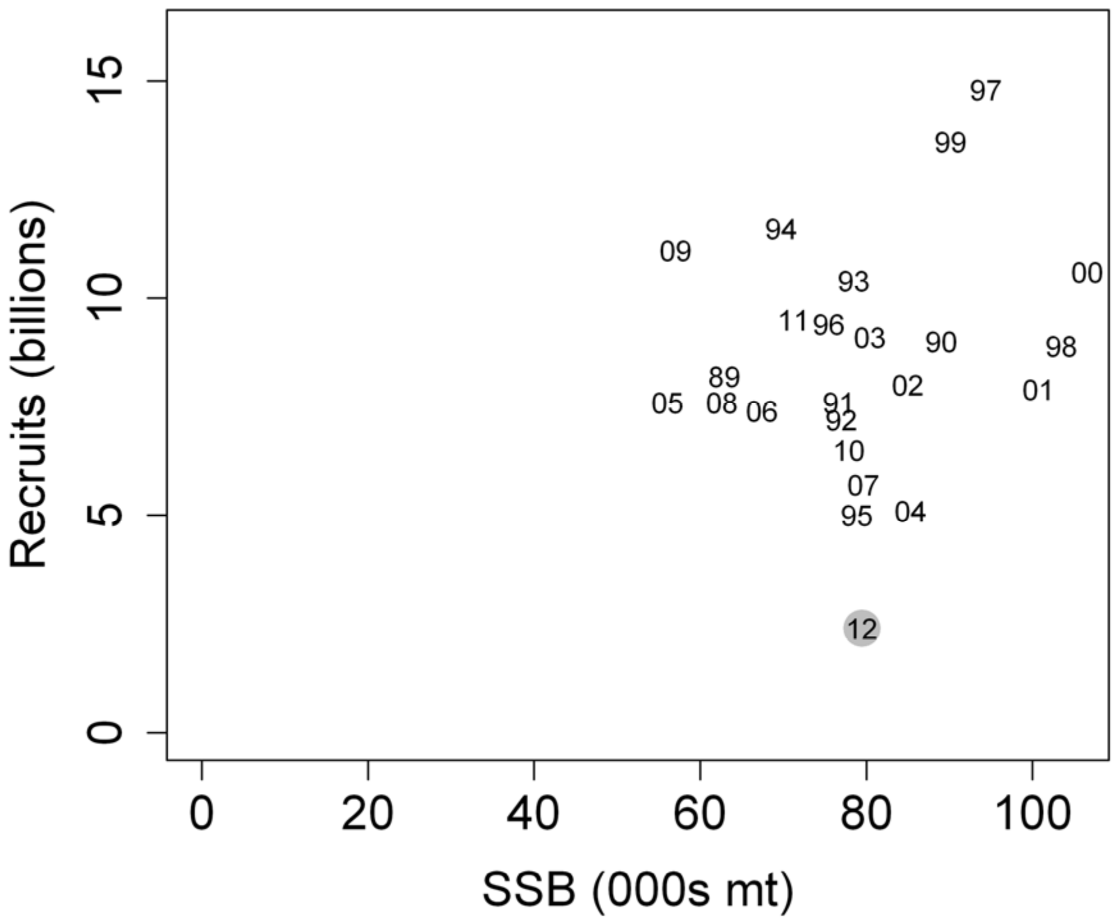

Figure A6. Butterfish stock-recruitment scatter plot, with two digit indicator of the year.

B. GOLDEN TILEFISH ASSESSMENT SUMMARY FOR 2014

State of Stock: The Golden Tilefish stock was not overfished and overfishing was not occurring in 2012 relative to the SARC 58 (2014) accepted biological reference points (Figure B1). A new model, ASAP, was used in this assessment to incorporate newly available length and age data and to better characterize the population dynamics of the stock. Based on the new model the stock was at high biomass and lightly exploited during the early 1970s. As the longline fishery developed during the late 1970s, fishing mortality rates increased and stock biomass decreased to a time series low by 1999. Since the implementation of constant landings quota of 905 mt in 2002, the stock has increased through 2012, and is near the accepted biomass target reference point (SSB_{MSY} proxy).

The fishing mortality rate was estimated to be 0.275 in 2012, below the accepted reference point F_{MSY} proxy = $F_{25\%}$ = 0.370. There is a 90% probability that the fishing mortality rate in 2012 was between 0.198 and 0.372 (Figure B2). SSB was estimated to be 5,229 mt in 2012, about 101% of the accepted biomass target reference point SSB_{MSY} proxy = $SSB_{25\%}$ = 5,153 mt (Figure B1). Therefore, based on the point estimates, the stock is considered rebuilt. There is a 90% chance that SSB in 2012 was between 3,275 and 7,244 mt (Figure B2). Average recruitment from 1971 to 2012 was 1.24 million fish at age 1. Recent large year classes occurred in 1998 (2.35 million), 1999 (2.39 million) and 2005 (1.85 million). Age-1 recruitment in 2009 was about 0.69 million fish (Figure B3).

Projections: The 2013 population estimates for ages 2-4 were adjusted in the projections to account for the apparent underestimation of recruitment in the most recent three years of the assessment model. This adjustment increased the estimated recruitment in years 2010-2012 to the geometric mean value during the assessment period. The projections are conditioned on the 2013 and 2014 Annual Catch Limit (ACL) landings being taken = 905 mt = 1.995 million lbs, and provide the following Overfishing Level (OFL) results:

OFL Landings, Fishing Mortality (F)
and Spawning Stock Biomass (SSB)
Catches and SSB in metric tons

Year	Landings	F	SSB	P(F>Fmsy)	P(SSB<SSBmsy/2)
2013	905	0.361	4,811	0.463	0.010
2014	905	0.366	4,914	0.489	0.013
2015	989	0.370	5,180	-	0.012
2016	1,027	0.370	5,246	-	0.010
2017	1,028	0.370	5,132	-	0.005

Additional projections were made assuming the current ACL landings (905 mt) are taken in all years.

Landings, Fishing Mortality (F)
and Spawning Stock Biomass (SSB)
Catches and SSB in metric tons

Year	Landings	F	SSB	P(F>Fmsy)	P(SSB<SSBmsy/2)
2013	905	0.361	4,811	0.463	0.010
2014	905	0.366	4,914	0.489	0.013
2015	905	0.335	5,219	0.371	0.017
2016	905	0.317	5,370	0.323	0.020
2017	905	0.309	5,392	0.273	0.025

Two scenarios were considered. In one, landings were determined by the F_{MSY} proxy starting in 2015. In the other, landings were held constant. In both cases, the probability of becoming overfished in any year up to 2017 is less than 3%. Under the constant landings projection, the probability of overfishing occurring in any year up to 2017 is less than 50%. The CV on the 2015 OFL is 30%.

Catch and Status Table: Golden Tilefish. Landings, SSB, Recruitment (age-1), and Fishing Mortality (F_{MULT}) (weights in '000 mt live, recruitment in millions)

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Min[1]	Mean[1]	Max[1]
Commercial landings[2]	1.1	1.2	0.7	0.9	0.7	0.7	0.9	0.9	0.9	0.8	0.1	1.4	4.0
SSB	2.3	3.0	3.9	4.4	4.2	4.2	4.5	4.5	5.0	5.2	1.2	6.9	27.0
Recruitment	0.4	0.6	1.1	1.8	1.5	1.0	0.7	NA[3]	NA[3]	NA[3]	0.4	1.3	4.5
Fishing mortality	0.43	0.39	0.29	0.38	0.43	0.42	0.37	0.30	0.26	0.27	0.01	0.54	1.27

[1]Over period 1971-2012.
[2]Estimated discards since 1989 are less than 7 mt in most years with a maximum of 41 mt in 2001.
[3]NA:Not available due to the estimates being highly uncertain.Therefore, mean recruitment is for the period 1971-2009.

Stock Distribution and Identification: Golden Tilefish, *Lopholatilus chamaeleonticeps,* inhabit the outer continental shelf from Nova Scotia to South America and are relatively abundant in the Southern New England to Mid-Atlantic region at depths of 80 to 440 m. Tilefish have a relatively narrow temperature preference of 9 to 14 °C. The Virginia-North Carolina border defines the boundary between the northern and southern Golden tilefish management units.

Catch: Total commercial landings (live weight) increased from less than 125 metric tons (mt) during 1967-1972 to more than 3,900 mt in 1979 and 1980 during the development of the directed longline fishery (Figure B4). Landings prior to the mid 1960s were landed as a bycatch through the trawl fishery. Annual landings have ranged between 666 and 1,838 mt from 1988 to 1998. Landings from 1999 to 2002 were below 900 mt (ranging from 506 to 874 mt). An annual quota of 905 mt was implemented in November of 2001. Landings in 2003 and 2004 were slightly above the quota at 1,130 mt and 1,215 mt respectively. Landing from 2005 to 2009 have been at or below the quota. Landings in 2010 were slightly above the quota at 922 mt. Landings in 2011 and 2012 were 864 mt and 834 mt respectively. During the late 1970s and early 1980s Barnegat, NJ was the principal tilefish port; since the mid-1980s Montauk, NY has accounted for most of the landings. Approximately 95% of the commercial landings are taken by the directed longline fishery. Discards in the trawl and longline fishery are negligible. Recreational catches also appear to be a minor component of the total removals.

Data and Assessment: The surplus production model ASPIC was used in the previous three assessments. The availability of length and age data facilitated application of an age-structured assessment model (ASAP) which was used in this latest stock assessment.

There are no fishery independent surveys available for this stock, so commercial catch per unit effort is relied upon for indications of population abundance changes. Over the last fifteen years, the commercial length and more recent age data indicate that increases in fishery CPUE and model estimated biomass are predominantly due to the influence of strong year classes in 1999 and 2005 (Figures B5 and B6). The 2005 year class has now passed through the fishery, and recently fishery CPUE has started to decline.

Review of commercial fishery practices and markets justified the use of a dome-shaped selectivity pattern in the assessment model.

The SCALE model was explored as a bridge between the ASPIC and the ASAP models. The ASAP model has the ability to estimate recruitment, incorporate annual fishery age compositions directly, estimate uncertainty, and model dome-shaped fishery selectivity.

Biological Reference Points (BRPs): Golden Tilefish are estimated to live about 40 years, and this information along with likelihood profiles of the ASAP model indicates that a value for instantaneous natural mortality (M) of 0.15 is appropriate. The long life span and relatively low M would suggest that a fishing mortality rate BRP of $F_{40\%}$ or higher %MSP would be appropriate. Under a management regime using a constant landings quota of 905 mt since 2002, with actual landings close to the quota each year, the stock has increased to 5,229 mt. Fishing mortality rates have averaged 0.367 since 2002, and the new yield per recruit analysis shows that this fishing rate corresponds to about $F_{25\%}$. Given these factors, the new accepted BRPs proxies are $F_{25\%}$ = 0.37 (overfishing threshold), the corresponding $SSB_{25\%}$ = 5,153 mt (biomass target), one-half $SSB_{25\%}$ = 2,577 mt (biomass threshold), and $MSY_{25\%}$ = 1,029 mt.

The reference points from the previous 2009 SAW 48 assessment are based on the ASPIC surplus production model and cannot be compared to the current assessment ASAP model results and reference points.

Fishing Mortality:

Fishing mortality on the fully selected age class (age 5) (F_{MULT}) increased with the development of the directed longline fishing from near zero in 1971 to 1.2 in 1987 (Figure B1). Fishing mortality was relatively high but fluctuated from 0.3 to 1.3 from 1987 to 1997. Fishing mortality has been decreasing since 1997 to 0.26 in 2011 and 0.275 in 2012. F_{MULT} 90% confidence intervals were 0.20 – 0.37 in 2012 (Figure B2).

Spawning Stock Biomass*:*

Spawning stock biomass declined substantially early in the time series from 27,044 mt in 1974 to 1,221 mt in 1999, lowest in the time series (Figure B1). Thereafter, SSB has increased to 5,229 mt in 2012. Spawning stock biomass 90% confidence intervals were 3,275 mt to 7,244 mt in 2012 (Figure B2).

Recruitment:

Average recruitment from 1971 to 2009 was 1.3 million fish. 2009 is the last year recruitment can be estimated accurately, with 0.69 million fish at age-1. Recent large year classes have occurred in 1998 (2.35 million), 1999 (2.39 million) and 2005 (1.85 million) (Figure B3). In the absence of empirical information to validate the uncertain estimates of recruitment in years 2010-2012, due to low selectivity for ages 1-3, estimates of these cohorts were increased in the projections. The 2013 population estimates for ages 2-4 were adjusted in the projections to account for the apparent underestimation of recruitment in the last three years of the assessment. This adjustment increased the estimated recruitment in years 2010-2012 to the geometric mean of 1.1 million fish during the assessment period.

Special Comments:

The use of fishery dependent CPUE remains a concern but is lessened by the use of age data which indicates cohort tracking and justifies the use of the dome-shaped selectivity pattern. The age data corroborate the strong year classes seen in the CPUE time series.

The current tilefish fishery is conducted by a relatively small (<10) number of vessels. A few of those vessels (<6) contribute information to the VTR CPUE index of stock biomass. Even though they account for >75% of the tilefish landings, there is concern that the small scale of the fleet may not provide a synoptic index of abundance for tilefish due to the limited spatial coverage of tilefish habitat.

Through the working group process, industry members noted an increase in the 2013 landings of small fish, data that were not available during the meeting. Industry members also noted concerns with consistency in market category reporting in the dealer reports.

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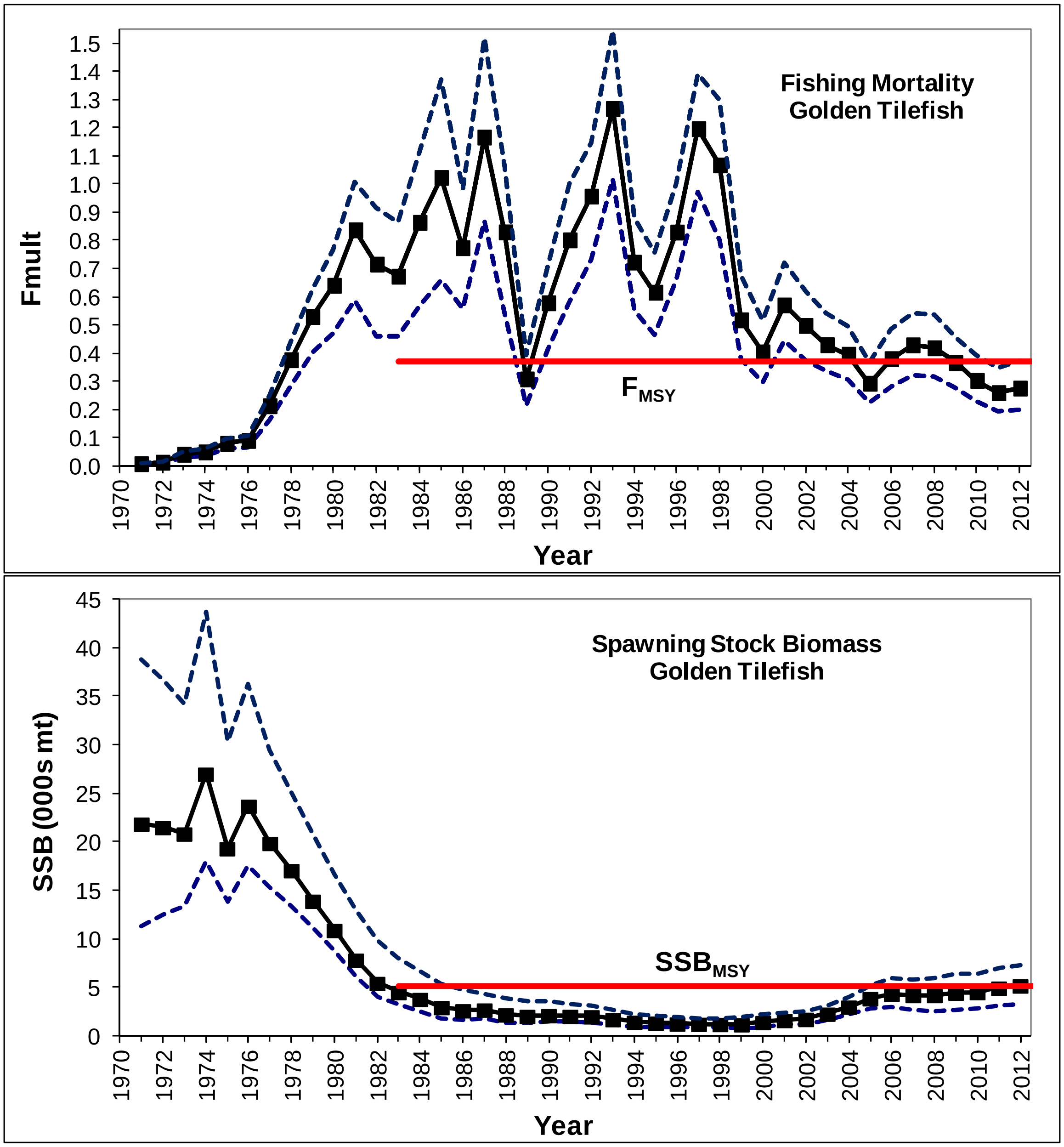

Figure B1. Tilefish. ASAP model estimated fishing mortality (F_{MULT}) and SSB with MCMC estimated 90% confidence intervals. F_{MSY} and SSB_{MSY} are shown for 1983-2012 (i.e., the second selectivity block).

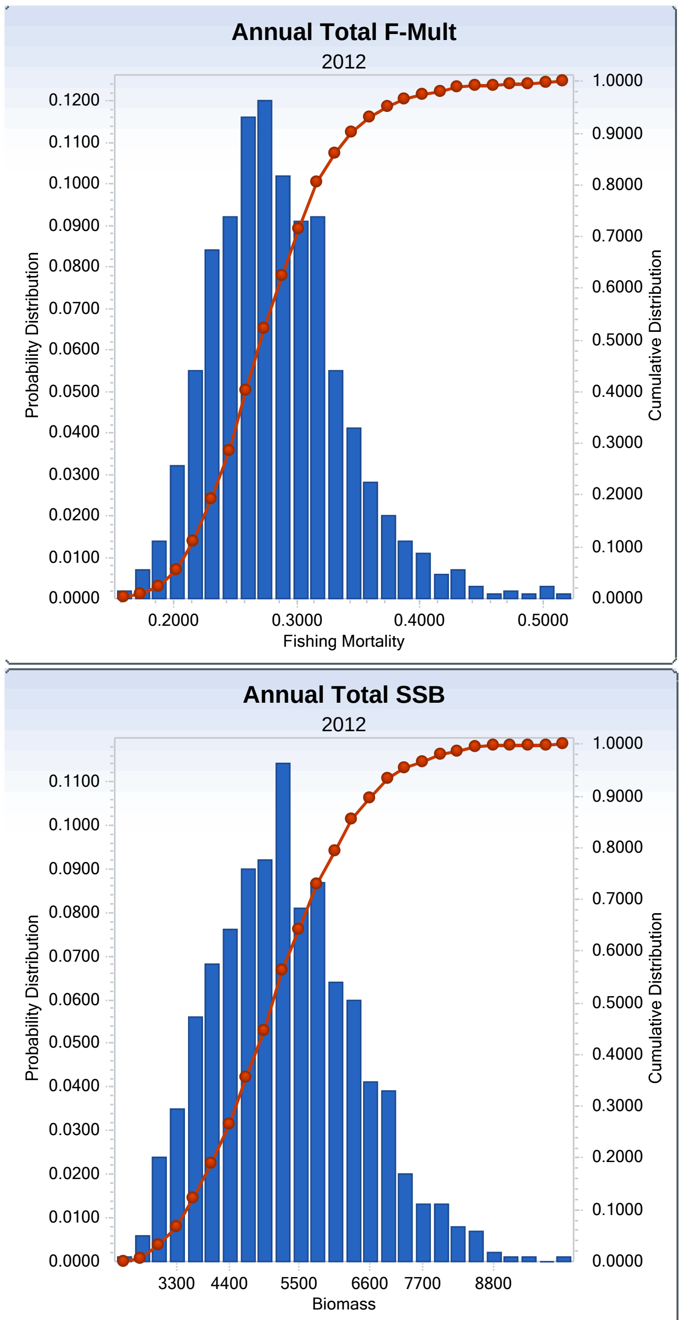

Figure B2. MCMC 2012 distributions for fishing mortality (F_{MULT}) and SSB for Golden tilefish. The percent confidence intervals can be taken from the cumulative frequency. The 2012 point estimate of fishing mortality = 0.275 and SSB = 5,229 mt.

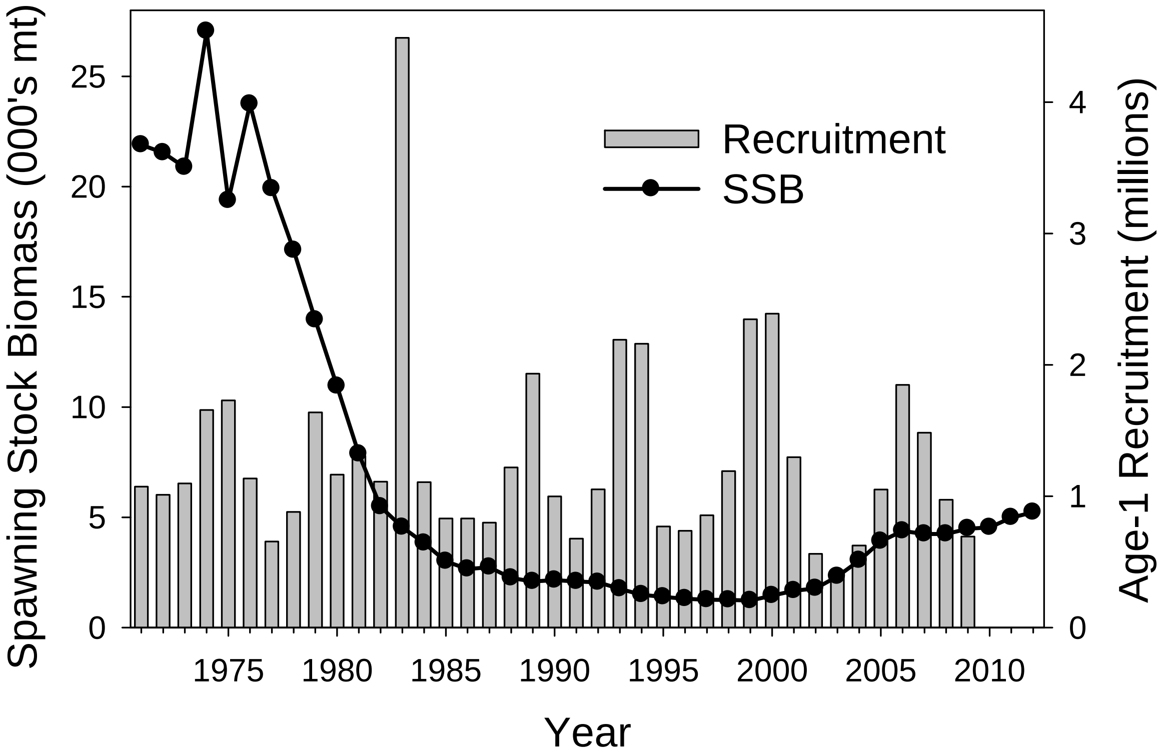

Figure B3. Comparison of age-1 recruitment and SSB for Golden tilefish from 1971-2012. Recruitments for years 2010-2012 are not shown because estimates are highly uncertain.

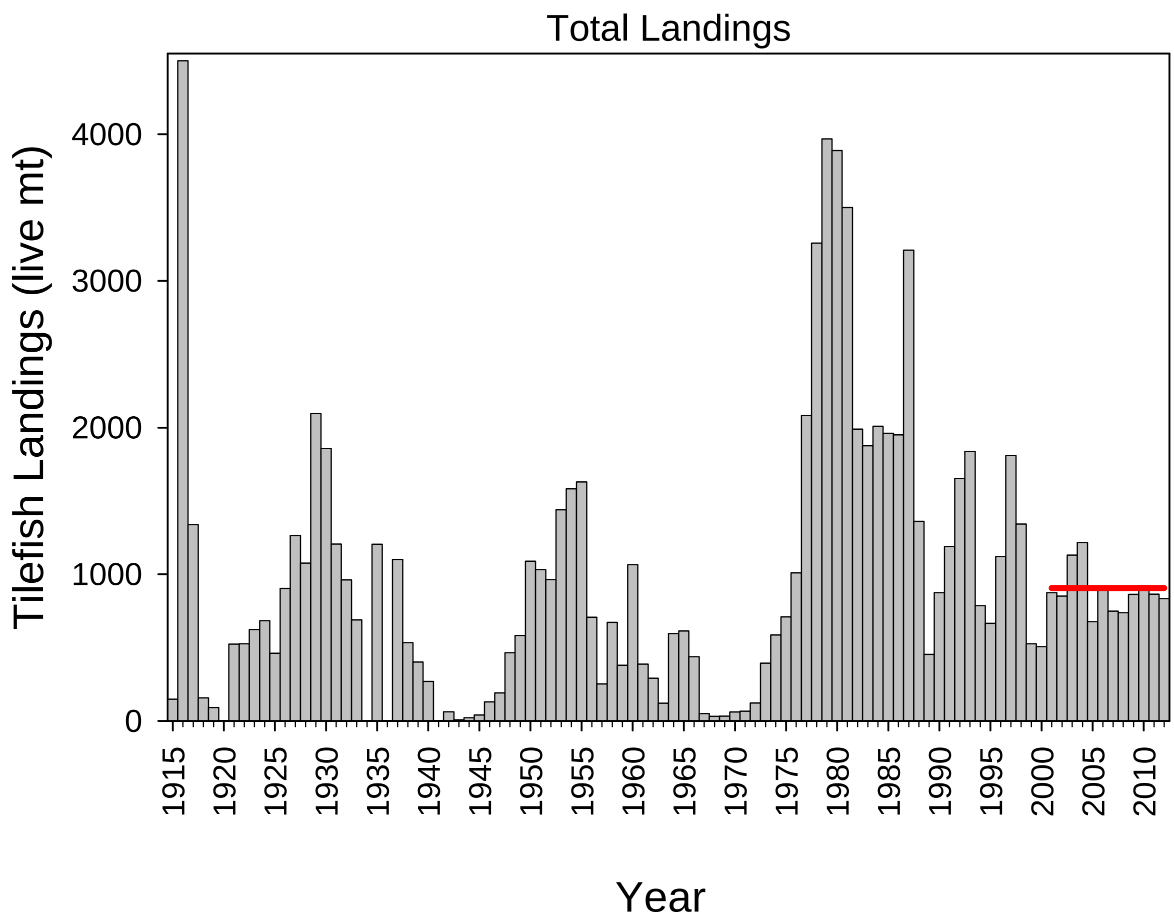

Figure B4. Landings of tilefish in metric tons from 1915-2012. Landings in 1915-1972 are from Freeman and Turner (1977), 1973-1989 are from the general canvas data, 1990-1993 are from the Weighout system, 1994-2003 are from the dealer reported data, and 2004-2012 is from dealer electronic reporting. Red line is the 905 mt quota implemented in November 2001.

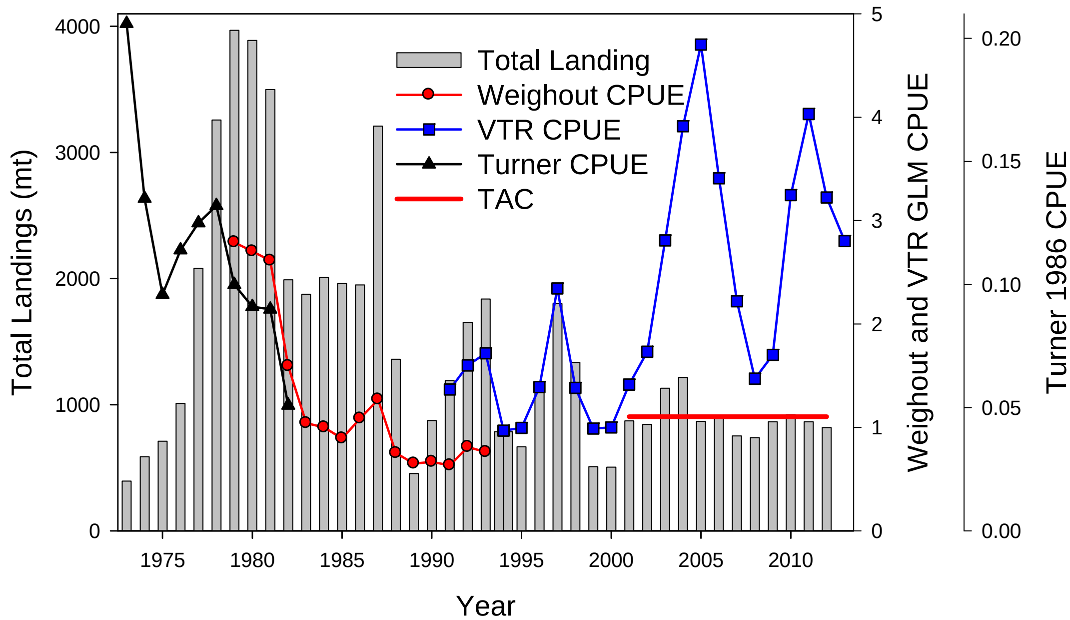

Figure B5. Tilefish. GLM CPUE for the Weighout and VTR data split into two series with additional New York logbook CPUE data from three vessels (1991-1994) added to the VTR series. Four years of overlap between Turner's and the Weighout CPUE series can be seen. Total landings are also shown. Landings in 2005 were taken from the IVR system. Fluctuations in the VTR CPUE series seem to correspond to year class effects.

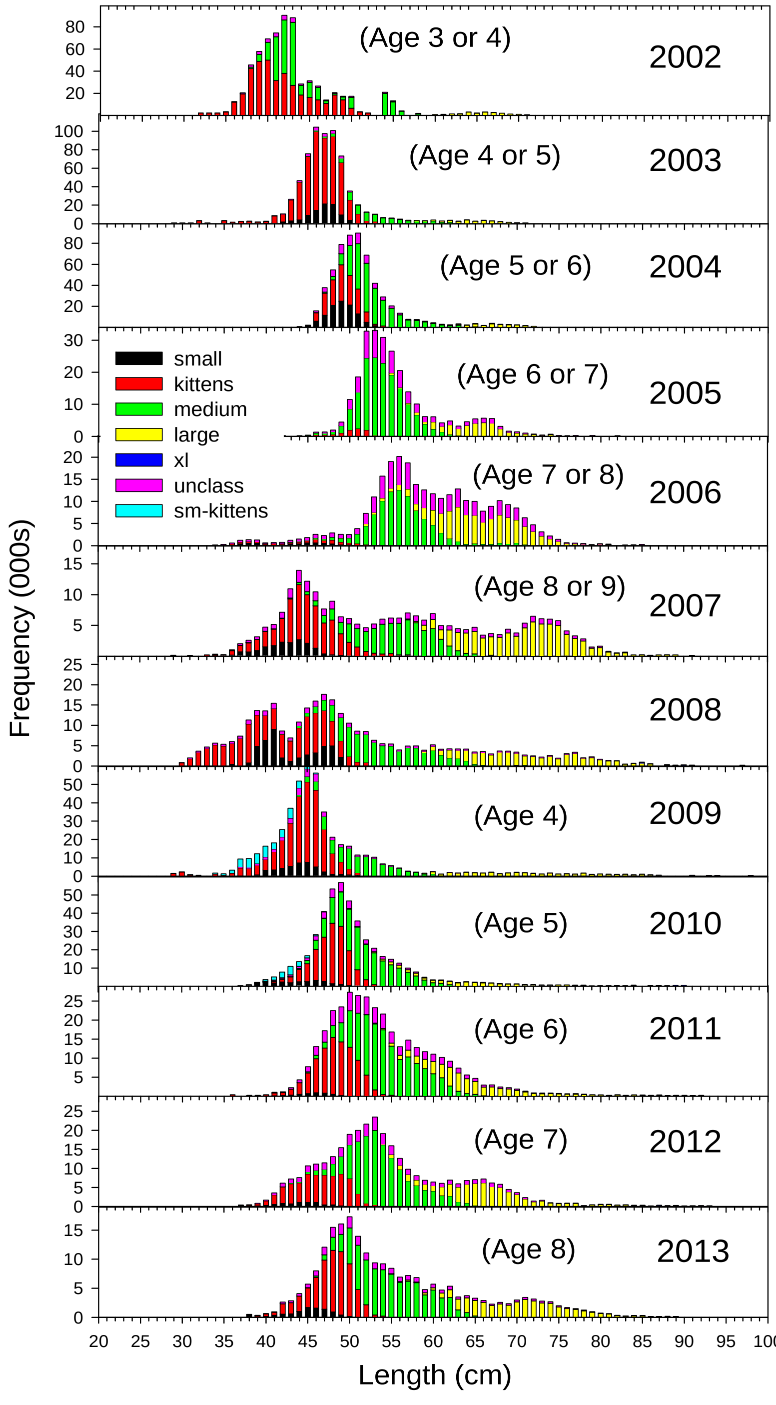

Figure B6. Expanded commercial catch length frequency distributions by year, in numbers of tilefish. Y-axis is allowed to rescale. A strong 1998 and/or 1999 and a 2005 year class can be seen tracking through the market categories and the landings at length. Sm-kittens are < 2 lbs, small & kittens = 2-2.4 lbs, medium = 3.5-5 lbs, large = 7-24 lbs, extra large > 24 lbs.

C. NORTHERN SHRIMP ASSESSMENT SUMMARY FOR 2014

State of the Stock

Overfishing and overfished status could not be determined for the northern shrimp (*Pandalus borealis*) stock in the Gulf of Maine. The ASMFC Summer Shrimp Survey biomass index is at record low levels based on data since 1984. The 2013 northern shrimp landings were 49% of the established quota, and were also the lowest since 1984. Catch-per-unit-effort (pounds per trap and trawl pounds per trip) also reflects the same trend (lowest on record since 1991).

Several key indices are at or near record lows for their respective time series (e.g., survey biomass index, survey recruitment index, commercial landings, and CPUE); this suggests that the northern shrimp stock is very low presently, and there is considerable uncertainty about when it might increase.

Projections

Projections would not be conducted for northern shrimp, as recruitment is highly variable and environmentally driven, making projections unreliable even over a short time frame. The assessment has been updated annually for management purposes.

Catches

Annual landings of Gulf of Maine northern shrimp (Figure C1) declined from an average of 11,400 mt (25.1 million pounds) during 1969-1972 to about 400 mt (0.89 million pounds) in 1977, culminating in a closure of the fishery in 1978. The fishery reopened in 1979 and landings increased steadily to over 5,000 mt (11 million pounds) by 1987. Landings ranged from 2,300 to 6,400 mt (5.1-14.1 million pounds) during 1988-1995, and then rose dramatically to 9,500 mt (21 million pounds) in 1996, the highest since 1973. Landings declined to an average of 2,000 mt (4.4 million pounds) for 1999 to 2001, and dropped further in the 25-day 2002 season to 450 mt (1 million pounds), the lowest northern shrimp landings since the fishery was closed in 1978. After 2002, landings generally increased, reaching another peak of around 6,000 mt (13.2 million pounds) in 2010 and 2011. Preliminary landings (not accounting for late reporting) in 2013 declined to 306 mt (0.67 million pounds), which was 49% of the TAC set by ASMFC for 2013. The fishery was closed before the TAC was reached to prevent an extended season that would harvest undersize males.

Limited observer coverage indicates discarding is negligible in both the directed shrimp fishery and non-directed finfish fisheries in the Gulf of Maine. Therefore, reported landings reflect total fishery removals.

Commercial CPUE of northern shrimp has declined in the last few years to near records lows for the time series (Figure C2).

Stock Distribution and Identification

Northern shrimp inhabit boreal waters of the North Atlantic and Arctic Oceans. In the Gulf of

Maine, they are at the southern extent of their range. The population in the Gulf of Maine is thought to be a single stock that does not mix with other populations further north. Northern shrimp undergo seasonal, sex-specific migration inshore and offshore. Juveniles remain in coastal waters for a year or more before migrating to deeper offshore waters, where they mature as males. The males pass through a series of transitional stages before maturing as females. Egg-bearing females move inshore in late autumn and winter, where the eggs hatch. Females are targeted in the Gulf of Maine fishery.

Data and Assessment

The northern shrimp assessment explored three different models that used total landings, catch at length, proportion female at length, and two fishery independent indices, the ASMFC summer shrimp survey and the NEFSC fall bottom trawl survey.

The proposed model for northern shrimp was a forward-projecting size-structured model (UME model) developed by the University of Maine in conjunction with the northern Shrimp Technical Committee. As a complement, a Collie-Sissenwine Analysis (CSA) and a surplus production model (ASPIC) were also run to estimate biomass and fishing mortality.

None of the proposed stock assessment models were accepted to serve as a basis for management. The UME size structured model did not fit catch and survey length composition and survey indices sufficiently well. The CSA was sensitive to the data weighting schemes resulting in inconsistent determination of overfishing status. The ASPIC model was unable to respond to the highly variable recruitment of northern shrimp, resulting in an extreme retrospective pattern and making estimates of F and B in the terminal year unreliable. Given that these models were not accepted, this report provides survey indices in lieu of model estimates for recruitment and biomass.

Biological Reference Points

Biological reference points for northern shrimp calculated in the last assessment and currently used as thresholds in management are historical proxies for F and exploitable biomass based on estimates of average F and average exploitable biomass from the CSA model during a time when both landings and biomass were considered stable (1985-1994).

For SARC 58 in 2014, new biological reference points were proposed but were not accepted.

Fishing Mortality

The estimates of fishing mortality were too sensitive to model configuration and were not accepted for use in fishery management.

Recruitment

Northern shrimp recruitment is affected by both spawning stock size and environmental conditions. Warmer waters lead to poorer recruitment. The recruitment index in 2013 was the lowest in the time series at 1 shrimp per tow, and the 2012 index was only slightly higher at 7 shrimp per tow, compared to the time series (1984-2013) mean recruitment index of 367 shrimp per tow (Figure C3). The 2011 index was also relatively low, at 44 shrimp per tow, representing three successive poor year classes.

Stock Biomass and Abundance

The biomass index from the summer shrimp survey has declined since 2008 and reached a time series (1984-2013) low (1.0 kg per tow) in 2013 relative to a time series average of 12.9 kg per tow (Figure C4). The 2012 biomass index was the second lowest in the time series (2.5 kg/tow).

Trends in the index of total abundance from the summer shrimp survey showed the same patterns, with the 2013 index being the lowest in the time-series at 27 shrimp per tow, and the 2012 index being the second lowest at 138 shrimp per tow (Figure C4). The time-series average is 1,458 shrimp per tow.

Trends in the NEFSC fall survey since 2009 have also indicated a major decline in biomass.

Special Comments

1) Gulf of Maine northern shrimp is a short-lived species with highly variable recruitment which is influenced by environmental conditions. As a result, this is a difficult species to assess. Changing environmental conditions in the Gulf of Maine may exacerbate this problem and make sustainable management more difficult.

2) CSA model: The analytical extensions to the CSA model represent a step forward, but the application to northern shrimp was not accepted because of sensitivity to weighting of data inputs and lack of robustness regarding determination of stock status. Incorporation of other data types, including effort, catch rate and environmental drivers, represent logical and promising steps for future development.

3) UME model: A size-based model like the UME model is most appropriate for difficult-to-age species. However, the application to northern shrimp needs to be further developed as it is not ready for management use.

4)ASPIC model: The high variability of recent recruitment in this stock cannot be accommodated by this model type. Given this recent variability, the ASPIC model should not be used at this time for assessment of the Gulf of Maine northern shrimp stock.

5)The SARC 58 (in 2014) review panel did not peer review previous northern shrimp assessments. The SARC 58 recommendations and comments apply solely to the models and updated data presented in this most recent northern shrimp assessment. Between SARC 45 (in 2007) and SARC 58 the northern shrimp population experienced the highest and lowest recruitment on record, which contributed to difficulties in the SARC 58 assessment.

References

45th Northeast Regional Stock Assessment Workshop (45th SAW). 2007. 45th SAW assessment summary report. US Dep Commer, Northeast Fish Sci Cent Ref Doc. 07-11; 37 p.

Total Catch of Northern Shrimp (thousands of metric tons; 1 mt = 2,205 lbs)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Min[1]	Mean[1]	Max[1]
Commercial Harvest	2.1	2.6	2.3	4.9	5.0	2.5	6.1	6.4	2.5	0.3	0.3	3.7	9.5
Commercial Discards	Assumed to be zero for this assessment.												

[1]: Minimum, mean, and maximum catch are based on 1984-2013 data.

Current Status of Northern Shrimp Based on the ASMFC Summer Shrimp Survey Indices

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Min[2]	Mean[2]	Max[2]
Biomass (kg per tow)	10.3	23.4	66.0	11.5	16.8	15.4	13.9	8.6	2.5	1.0	1.0	12.9	12.9
Total Abundance (numbers per tow)	887	3,661	9,998	887	1,737	1,627	1,373	830	138	27	27	1,458	9,998
Recruitment (numbers per tow)	286	1,752	374	28	506	555	475	44	7	1	1	367	1,752

[2]: Minimum, mean, and maximum are derived from the entire 1984-2013 time-series

	SARC 45 (2007)	
Reference Point	Definition	Value
$F_{Threshold}$	Maximum F during stable period (1985-94)	0.48[3]
F_{Target}	Average F during stable period (1985-94)	0.38[3]
$B_{Threshold}$	0.5*Average B during stable period (1985-1994)	9,000 mt
B_{Limit}	2,000 mt less than lowest value estimated by ASPIC model	6,000 mt

[3]: F reference points estimates are updated at each annual assessment update; these values are from the 2013 update.

Assessment models presented at SARC 58 (in 2014) were not accepted. For this reason, SARC 58 does not provide new reference points.

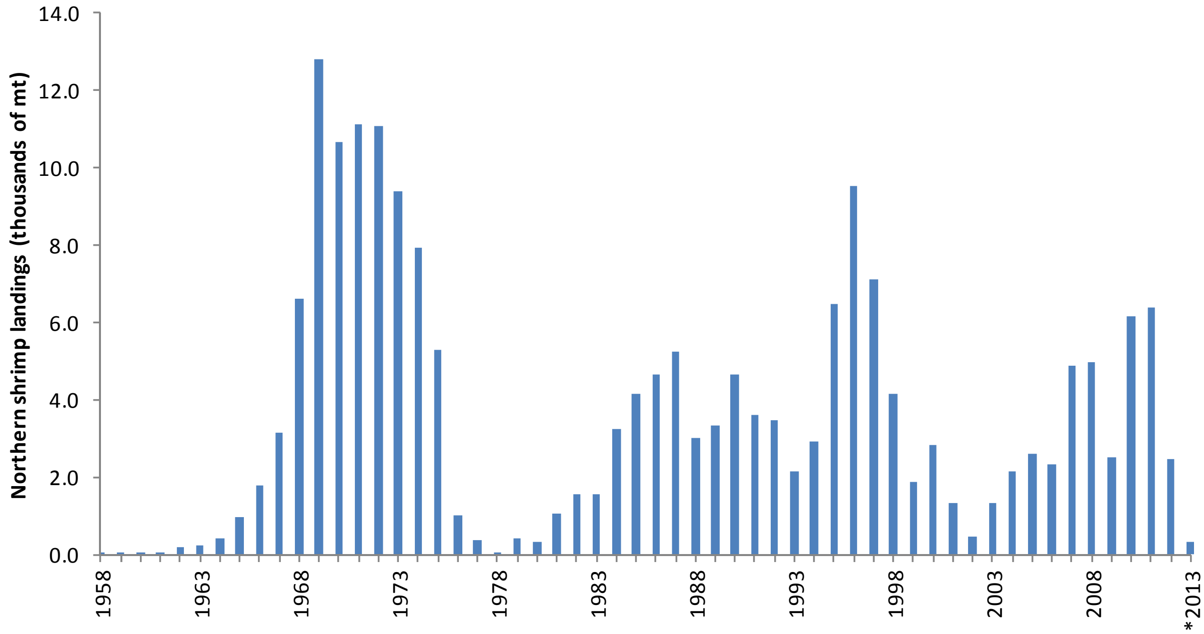

Figure C1. Commercial landings of northern shrimp in the Gulf of Maine. *: 2012 and 2013 data are preliminary and may change.

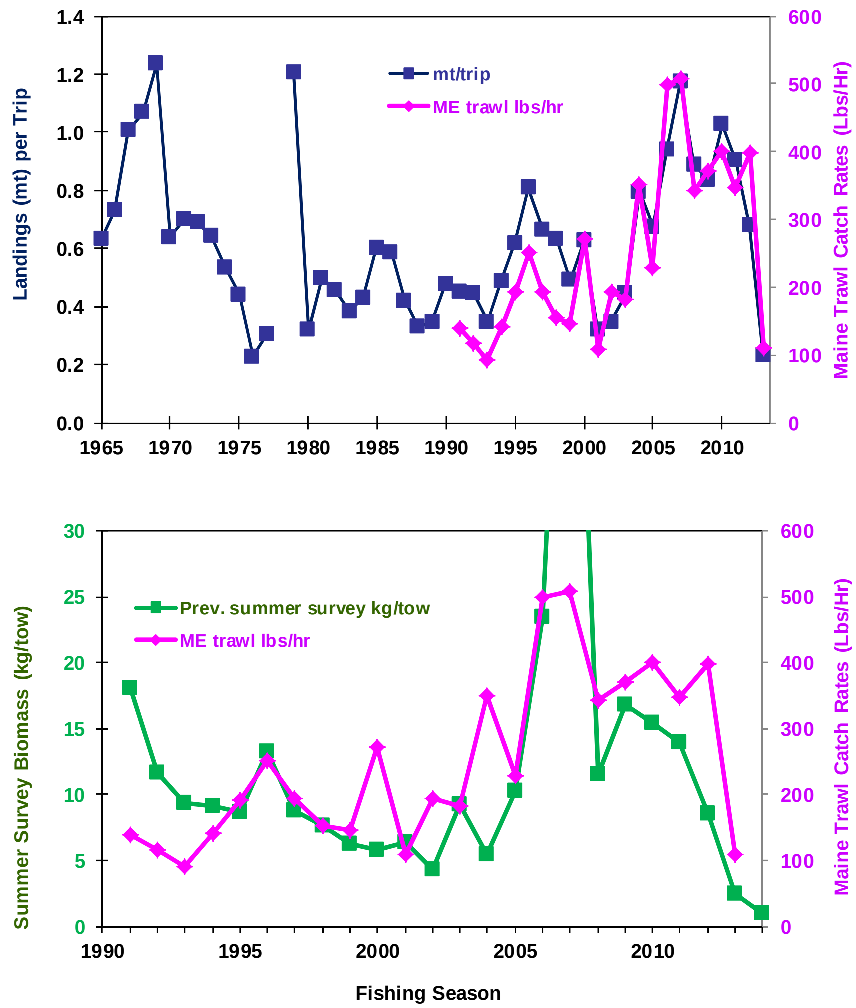

Figure C2. Commercial CPUE of northern shrimp in metric tons per trip (all states and gears combined) plotted with Maine trawl pounds per hour (top), and Maine trawl lbs/hr plotted with the summer survey index (kg/tow) for the summer prior to the fishing season (bottom). 2012 and 2013 CPUE data are preliminary.

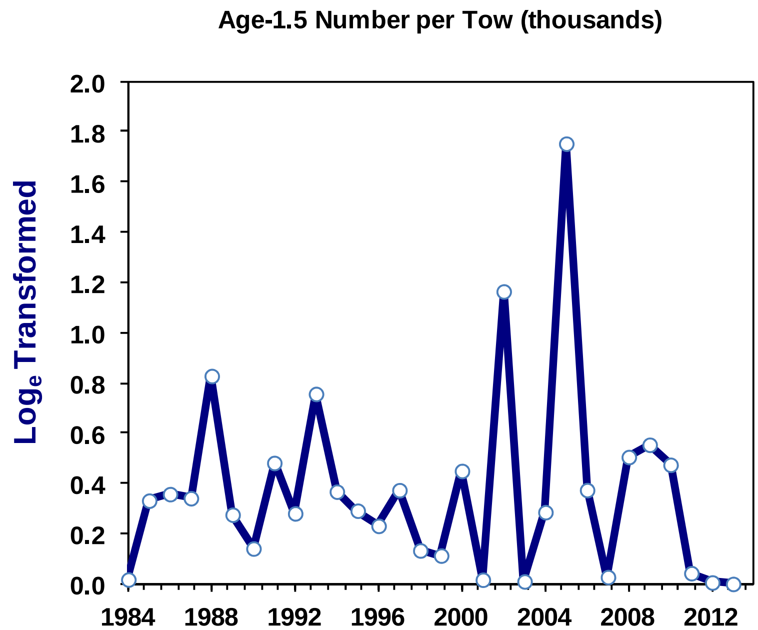

Figure C3. Recruitment index for northern shrimp from the ASMFC summer shrimp survey.

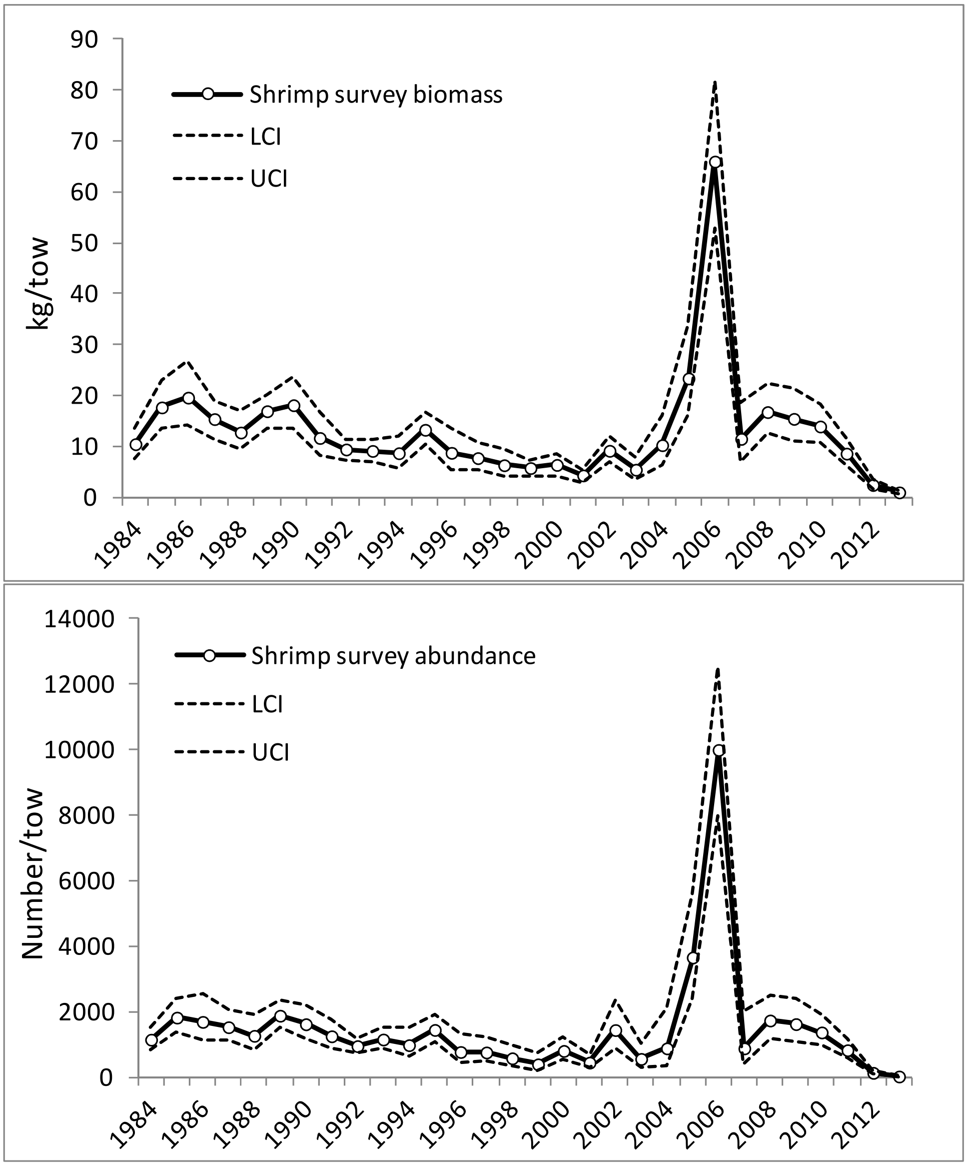

Figure C4. Northern shrimp survey indices of total biomass (top) and total abundance (bottom) with 95% confidence intervals from ASMFC summer shrimp survey.

Appendix: Stock Assessment Terms of Reference for SAW/SARC58, January 27-31, 2014
(To be carried out by SAW Working Groups) (v. 8/2/2013)

A. Butterfish

1. Characterize the commercial catch including landings, effort and discards by gear type. Describe the magnitude of uncertainty in these sources of data.

2. Characterize the survey data that are being used in the assessment. Describe the magnitude of uncertainty in these sources of data.

3. Characterize oceanographic and habitat data as it pertains to butterfish distribution and availability. If possible, integrate the results into the stock assessment (TOR-5).

4. Evaluate consumptive removals of butterfish by its predators. If possible, integrate results into the stock assessment (TOR-5).

5. Use assessment models to estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series, and estimate their uncertainty. Include a comparison with previous assessment results and previous projections.

6. State the existing stock status definitions for “overfished” and “overfishing”. Given that the stock status is currently unknown, update or redefine biological reference points (BRPs; point estimates for B_{MSY}, $B_{THRESHOLD}$, F_{MSY} and MSY, or their proxies) and provide estimates of their uncertainty. Consider effects of environmental factors on stability of reference points and implications for stock status.

7. Evaluate stock status with respect to a newly proposed model and with respect to “new” BRPs and their estimates (from TOR-6). Evaluate whether the stock is rebuilt.

8. Develop approaches and apply them to conduct stock projections and to compute the statistical distribution (e.g., 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 (2 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). Comment on which projections seem most realistic.
    b. 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 most recent SARC reviewed assessment and review panel reports. Identify new research recommendations.

B. Tilefish

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

2. Characterize commercial LPUE as a measure of relative abundance. Consider the utility of recreational data for this purpose. Characterize the uncertainty and any bias in these sources of data.

3. For the depth zone occupied by tilefish, examine the relationship between bottom temperature, tilefish distribution and thermal tolerance.

4. Use assessment models to estimate annual fishing mortality and stock size for the time series, and estimate their uncertainty. Include a historical retrospective to allow a comparison with previous assessment results.

5. State the existing stock status definitions for "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; point estimates for B_{MSY}, $B_{THRESHOLD}$, F_{MSY} and MSY or for their proxies) 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 ASPIC model (from previous peer reviewed accepted 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 and their estimates (from TOR-4).

7. Develop approaches and apply them to conduct stock projections and to compute the statistical distribution (e.g., 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 (2-3 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.

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

C. Northern shrimp

1. Present the Gulf of Maine northern shrimp landings, discards, effort, and fishery-independent data used in the assessment. Characterize the precision and accuracy of the data and justify inclusion or elimination of data sources.

2. Estimate population parameters (fishing mortality, biomass, and abundance) using assessment models. Evaluate model performance and stability through sensitivity analyses and retrospective analysis, including alternative natural mortality (M) scenarios. Include consideration of environmental effects where possible. Discuss the effects of data strengths and weaknesses on model results and performance.

3. Update or redefine biological reference points (BRPs; point estimates or proxies for B_{MSY}, SSB_{MSY}, F_{MSY}, MSY). Evaluate stock status based on BRPs.

4. Characterize uncertainty of model estimates of fishing mortality, biomass and recruitment, and biological reference points.

5. Review the methods used to calculate the annual target catch and characterize uncertainty of target catch estimates.

6. Develop detailed short and long-term prioritized lists of recommendations for future research, data collection, and assessment methodology. Highlight improvements to be made before the next benchmark assessment.

7. Based on the biology of species, and potential scientific advances, comment on the appropriate timing of the next benchmark assessment and intermediate updates.

Appendix to the SAW Assessment TORs:

Clarification of Terms
used in the SAW Terms of Reference

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 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.

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