Northeast Fisheries Science Center Reference Document 12-14

54th Northeast Regional Stock Assessment Workshop (54th SAW)

Assessment Summary Report

by the Northeast Fisheries Science Center

July 2012

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by the Northeast Fisheries Science Center
NOAA National Marine Fisheries Service
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US DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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Northeast Fisheries Science Center Reference Documents

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Table of Contents

SAW-54 ASSESSMENT SUMMARY REPORT

Introduction

The 54th SAW Assessment Summary Report contains summary and detailed technical information on two stock assessments reviewed during June 5-9, 2012 at the Stock Assessment Workshop (SAW) by the 54th Stock Assessment Review Committee (SARC-54): Atlantic herring (*Clupea harengus*) and Southern New England Mid-Atlantic yellowtail flounder (*Pleuronectes ferrugineus*). The SARC-54 consisted of 3 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-54 are available at website: http://www.nefsc.noaa.gov/nefsc/saw/ under the heading "SARC 54 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-54 Review Panel reports (available at http://www.nefsc.noaa.gov/nefsc/saw/ under the heading "SARC-54 Panelist Reports"). For **Atlantic herring**, the Panel accepted the new ASAP assessment model. A feature of this new model is the 50% increase in natural mortality rate (M) during 1996-2011. This new M estimate is consistent with data on consumption of herring by predators and it largely resolves the retrospective pattern which has been a prominent feature of previous assessment models. The biological reference points were derived assuming that the 50% increase in M due to herring consumption will continue over the next 3 – 5 years. This assumption about the future is a source of uncertainty. The new biomass reference points (B_{TARGET} and MSY) are much lower than those from the previous assessment. A source of uncertainty in the stock projections is the size of the 2009 age-1 recruitment, which has been estimated to be almost twice as large as the next largest recruitment (1994). The 2009 age-1 fish contribute to the recent increase in stock biomass, and are a significant component of projected yield to the fishery in the future. It will be important to monitor the size of this year-class. Overall, the Panel concluded that the Atlantic herring stock is not overfished and that overfishing is not occurring.

For **Southern New England Mid-Atlantic yellowtail flounder** the Panel accepted a new stock assessment model (ASAP). There was a significant revision of most of the assessment's data sets. The new model assumed a higher natural mortality rate (M). There has been a marked decline in recruitment since 1990. Two stock–recruitment scenarios were developed which account for this decline, and the two scenarios lead to very different conclusions about biomass stock status. A "recent recruitment" scenario assumes that incoming year-classes since 1990 have been weak, perhaps due to a reduction in stock productivity, and not related to SSB. Alternatively, a "two-stanza" scenario assumes that recruitment over the entire time series is a function of spawning stock biomass (SSB) and that below about 4300 mt SSB average recruitment is very low. While neither scenario could be ruled out, the Panel concluded that the evidence was 60:40 in favor of the "recent recruitment" scenario (i.e., productivity change). Overall, the fishing mortality (F_{MSY}) reference point is relatively certain, and overfishing is likely not occurring. However, the reference points associated with biomass ($B_{MSY,}$ MSY) are uncertain due to the productivity change issue and require further exploration. There is considerable uncertainty as to whether or not the stock is overfished. Under the "recent recruitment" scenario the stock would not be considered overfished and it would be considered rebuilt to a new, much lower biomass target. In contrast, under the "two-stanza" scenario the stock would still be considered overfished.

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.

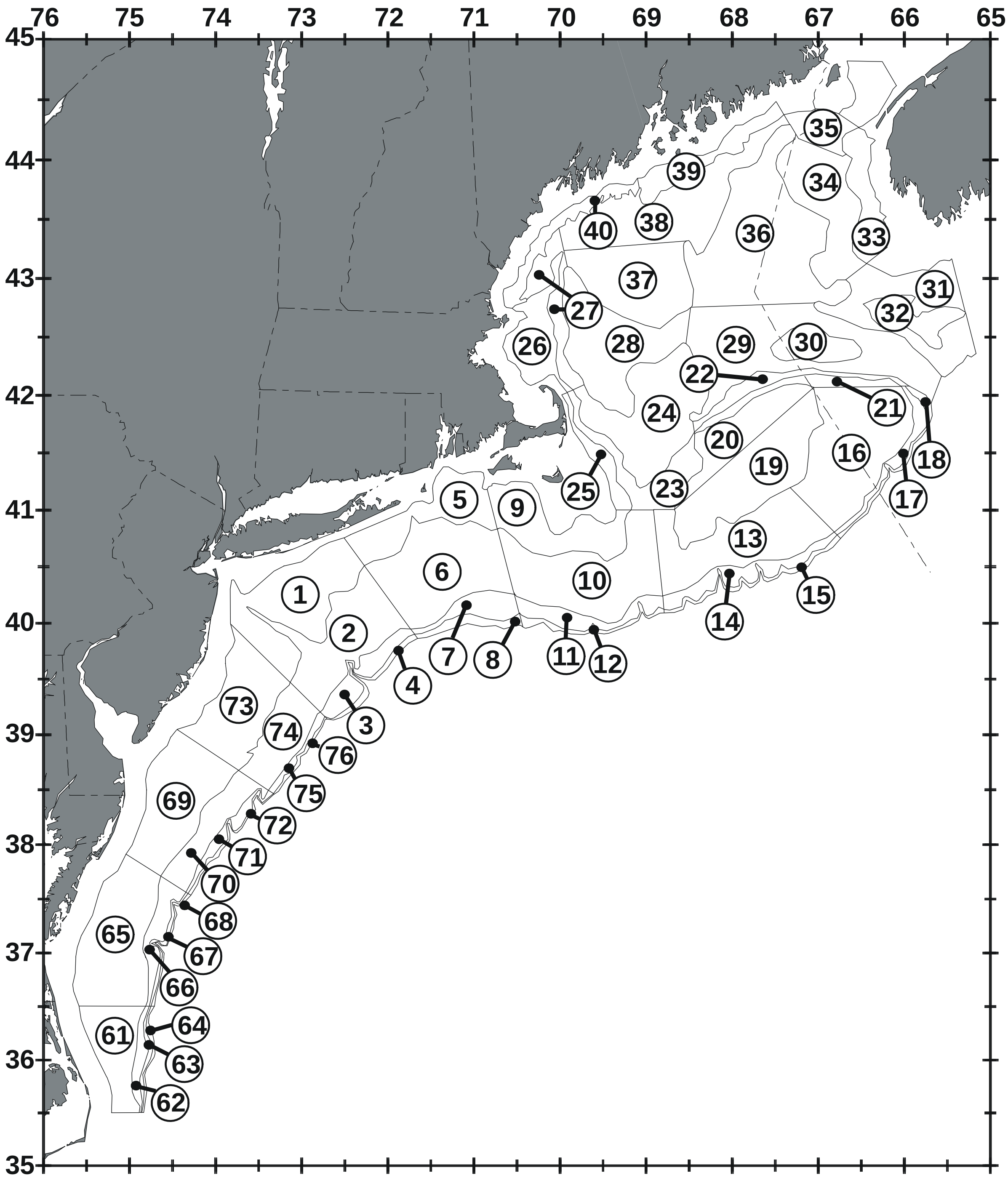


Figure 1. Offshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys. Some of these may not be sampled presently.

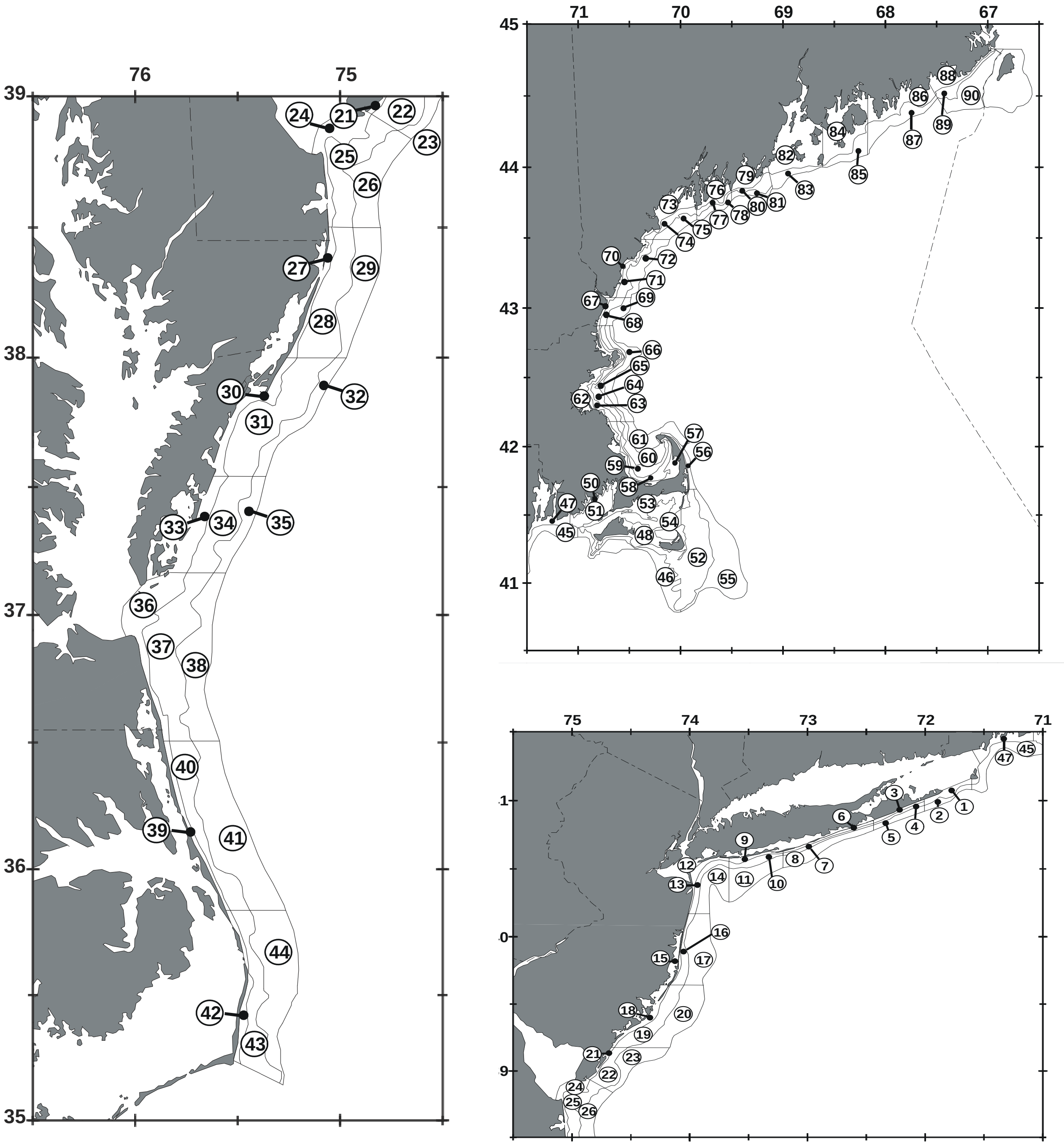
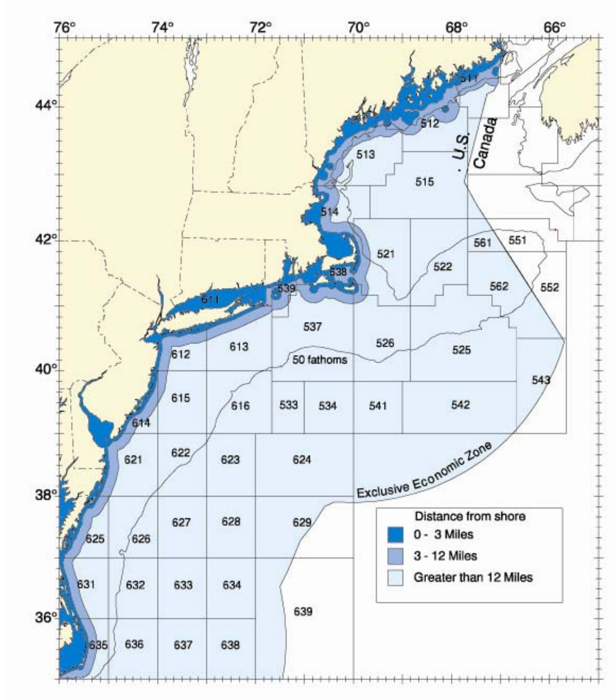


Figure 2. Inshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys. Some of these may not be sampled presently.



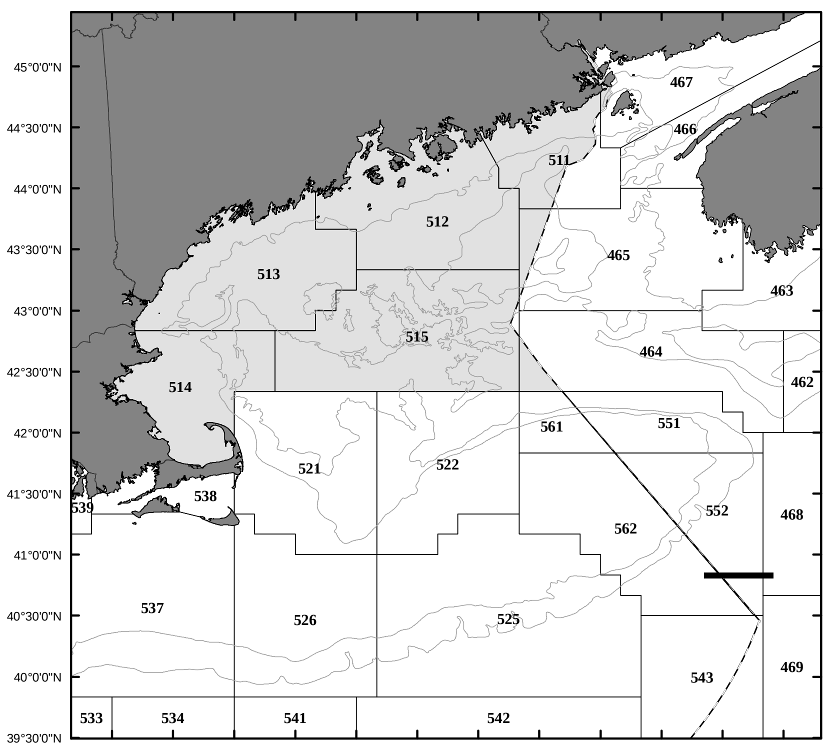


Figure 3. Statistical areas used for reporting commercial catches.

A. ATLANTIC HERRING ASSESSMENT SUMMARY FOR 2012

State of Stock: A statistical catch-at-age model, ASAP (Legault and Restrepo 1999), is proposed as the best scientific information available for determining the stock status for Atlantic herring. Spawning stock biomass (SSB) was estimated to be 517,930 mt in 2011 and fishing mortality rate at age 5 (F) was estimated to be 0.14 (Figure A1). Age 5 was used as the reference age for reporting fishing mortality rates because that age is fully selected in the mobile gear fleet, which accounted for most of the catches in recent years (see Catch and Status Table).

Maximum sustainable yield (MSY) reference points were estimated based on the fit of a Beverton-Holt stock-recruitment curve, which was estimated internally to ASAP. Steepness of the Beverton-Holt curve = 0.53, F_{MSY} = 0.27, SSB_{MSY} = 157,000 mt (½ SSB_{MSY} = 78,500), and MSY = 53,000 mt. Based on a comparison of the MSY reference points with the estimates of F and SSB for 2011, overfishing is not occurring and the stock is not overfished.

Projections: Short-term projections of future stock status were conducted based on the results of the ASAP model. The degree of retrospective error was sufficiently small, and did not warrant adjustment in the projections. Numbers-at-age in 2012 were drawn from 1000 vectors of numbers-at-age produced from MCMC simulations of the ASAP model. The projections assumed that catch in 2012 equaled the annual catch limit. Age-1 recruitment was based on the Beverton-Holt relationship estimated within ASAP. In general, results from several harvest scenarios suggested that overfishing will not occur and the stock will not become overfished through 2015. Results from the status quo catch projection were a notable exception because they resulted in small probabilities that overfishing could occur (Table A1).

Catch and Status Table: Atlantic herring

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Min[1]	Max[1]	Mean[1]
US Mobile Landings (000s mt)	93	102	94	93	103	81	84	103	67	81	67	124	99
US Fixed Landings (000s mt)	0.05	0.15	0.09	0.07	1.01	0.40	0.03	0.10	1.23	0.42	0.02	4.89	0.63
New Brunswick Weir Landings (000s mt)	12	9	21	13	13	31	6	4	11	4	4	31	15
Discards (000s mt)	0.04	0.03	0.49	0.30	0.20	0.06	0.53	0.46	0.26	0.17	0.03	0.55	0.25
Total Catch (000s mt)	105	111	115	107	117	112	91	108	79	85	79	145	115
Spawning Stock Biomass (000s mt)	433	371	371	410	376	367	385	301	313	518	301	840	468
Recruitment (millions age 1)	17,356	21,101	10,011	7,331	17,023	5,273	13,839	59,412	7,314	5,919	5,273	59,412	15,782
F	0.21	0.24	0.23	0.22	0.25	0.23	0.23	0.32	0.18	0.14	0.14	0.32	0.21

[1]Over the period 1996-2011, which is when natural mortality was increased.

Stock Distribution and Identification: The Gulf of Maine/Georges Bank Atlantic herring complex is composed of several spawning aggregations. Fisheries and research surveys, however, catch fish from a mix of the spawning aggregations and methods to distinguish fish from each aggregation are not yet well established. Consequently, recent assessments have combined data from all areas and conducted a single assessment of the entire complex. Although this approach poses a challenge to optimally managing each stock component and can create retrospective patterns within an assessment, the mixing of the spawning components in the fishery and surveys precludes separate assessments. Atlantic herring caught in the New Brunswick, Canada, weir fishery were considered part of the Gulf of Maine/Georges Bank complex because tagging studies suggested mixing. Herring from the Canadian Scotian Shelf stock also likely mix with the Gulf of Maine/Georges Bank complex, but the degree of mixing is unknown and methods to distinguish fish from each stock are not yet developed. Catches from the Scotian shelf were not considered part of the Gulf of Maine/Georges Bank complex. Despite a single assessment for the entire complex, catch limits are allocated to spatial management areas and catch allocations are based on estimates of stock composition and relative biomass among areas (Correia 2012).

Catches: US catch data were separated into two aggregate gear types, fixed and mobile gears, during 1964-2011. The reported catch is a sum of landings and self-reported discards, but discard estimates have only been available since 1996. Discards, however, were generally less than 1% of landings and do not represent a significant source of mortality (Wigley et al. 2011). Consequently, a lack of historical estimates of discards is not considered problematic to the assessment.

New Brunswick, Canada weir catches were provided for the years 1965-2011. Catches from this fishery were combined with US fixed gear catches for this assessment.

Catch in the US mobile gear fishery peaked in the late 1960s and early 70s, largely due to efforts from foreign fleets (Figure A2). Catch in this fishery has been relatively stable since about 2000 and has accounted for most of the Atlantic herring catches in recent years. Catch in the US fixed gear fishery has been variable, but has been relatively low since the mid-1980s (Figure A2). Catch in the NB weir fishery has also declined since the 1980s (Figure A2).

Total catches during 1964-2011 ranged from 44,613 mt in 1983 to 477,767 mt in 1968. Total catches during the past five years ranged from 79,413 mt in 2010 to 112,462 mt in 2007 and averaged 95,081 mt.

The US mobile gear fishery catches a relatively broad range of ages and some strong cohorts can be seen for several years. In contrast, the US fixed gear fishery and the NB weir fishery harvest almost exclusively age 2 herring.

Data and Assessment: The previous assessment of Atlantic herring used the statistical catch-at-age model ASAP and had a severe retrospective pattern (TRAC 2009). The new 2012 assessment also uses ASAP, but nearly all data inputs and model settings were reconsidered during development. Major changes to the input data are summarized here. Natural mortality during the 2009 TRAC was assumed to equal 0.2 for all ages and years. For this assessment, natural mortality was based on a combination of the Hoenig and Lorenzen methods, with the Hoenig method providing the scale of natural mortality and the Lorenzen method defining how natural mortality declined with age (Hoenig 1983; Lorenzen 1996). The natural mortality rates during 1996-2011 were increased by 50% to resolve a retrospective pattern and to ensure that the implied levels of consumption were consistent with observed increases in estimated consumption of herring. Consumption estimates were based on food habits data primarily for groundfish, but also informed by consumption estimates from marine mammals, highly migratory species, and seabirds. The 2009 TRAC also used catch data combined among all fishing gears and assumed selectivity equaled 1.0 for all ages. This assessment included separate catches and estimated selectivity separately for two aggregate gear types: fixed and mobile gears. This assessment also estimated selectivity for any survey with age composition data, which is in contrast to the 2009 TRAC which used age-specific indices. Finally, maturity at age varied through time in this assessment, but was constant among years in the 2009 TRAC. The time variation in maturity in this assessment was based on annual fits of general additive models to maturity data from males and females collected from commercial catches during July to September.

Abundances (i.e., arithmetic mean numbers per tow) from the NMFS spring, fall, and summer shrimp bottom trawl surveys were used in the assessment model along with annual coefficients of variation and age composition when they were available. The trawl door used on the spring and fall surveys changed in 1985 and likely altered the catchability of the survey gear. Consequently, the spring and fall surveys were split into two time series between 1984 and 1985, and these were treated as separate indices in assessment models. Calibrations were applied to the spring and fall surveys to account for changes in survey methods, including changes in research vessels.

Five other indices of abundance were considered, but not used in the final assessment model. These indices included: NMFS winter survey, NMFS herring acoustic survey, Massachusetts state surveys (spring and fall), joint Maine/New Hampshire state surveys (spring and fall), and a larval index of abundance.

Biological Reference Points (BRPs): Updated MSY reference points were estimated based on the fit to a Beverton-Holt stock-recruitment curve, which was estimated internally to the ASAP model. Steepness of the Beverton-Holt curve = 0.53. For calculating MSY reference points, ASAP used the inputs (e.g., weights at age, M) from the terminal year of the assessment (i.e., 2011). Using inputs from the terminal year of the assessment had the consequence of using natural mortality rates from the period when these rates were increased by 50% (see Data and Assessment). Estimates of MSY BRPs were: F_{MSY} = 0.27, SSB_{MSY} = 157,000 mt (½ SSB_{MSY} = 78,500), and MSY = 53,000 mt.

MSY reference points from the previous assessment (TRAC 2009) were based on the fit of a Fox surplus production model (TRAC 2009), and F_{MSY} = 0.27, SSB_{MSY} = 670,600 mt (½ SSB_{MSY} = 335,300 mt) and MSY = 178,000 mt.

BRPs changed since the previous assessment primarily because the Fox model had been used during the 2009 TRAC and assumed natural mortality rates were revised.

Fishing Mortality: F at age-5 equaled 0.14 in 2011, and was near the all-time low of 0.13 (1994) (Figure A3). F in 2011, however, was not representative of fishing mortality rates in recent years, which averaged 0.23 during 2000-2009 and also showed an increasing trend during those years (Figure A3). Fishing mortality rates in 2010 and 2011 were relatively low due to the presence of a strong cohort which increased the stock biomass (see below). The maximum F over the time series was 0.80 in 1980 (Figure A3).

Biomass: Based on the ASAP model, SSB = 517,930 mt in 2011. Over the entire time series, SSB ranged 53,349 mt in 1978 to 839,710 mt in 1997 (Figure A4). SSB declined during 1997-

2010, but increased in 2011 (Figure A4). Estimated total January 1 biomass was 1,322,446 mt in 2011, and ranged from a minimum of 180,527 mt in 1982 to a maximum of 1,936,769 mt in 2009 (Figure A4). Total biomass and SSB showed similar trends over time, but with 1-2 year lags caused by total biomass being more reflective of immature recruits than SSB. Spawning stock and total biomass increased after 2009, mostly due to the presence of a strong cohort (see below).

Recruitment: With the exception of 2009, age-1 recruitment since 2006 has been below the 1996-2011 average of 15.8 billion fish (Figure A5). The 2009 age-1 recruitment, however, was the largest in the time series at 59.4 billion fish. This large 2009 age-1 cohort consistently appeared in all sources of data that contain age composition.

Special Comments:

- This assessment represents a significant change from previous assessments. Unlike previous assessments, the catch at age was partitioned into mobile and fixed gear fleets and treated separately in a new formulation of the ASAP model. Age-specific and time-varying natural mortality rates were developed. Estimates of herring consumption by a representative suite of predators justified a 50% increase in natural mortality beginning in 1996, which implies a decrease in sustainable yield.
- The assessment was evaluated for uncertainty and robustness to various parameters. The justification for the 50% increase in natural mortality (M) beginning in 1996 was further evaluated using alternative increases of 0%, 30%, 40%, 60%, 70%, and a reduction in the average M among ages in each year from 0.3 (as in the base model) to 0.2. Based on fits to data, degree of retrospective pattern, and general similarity between levels of implied consumption to estimates of consumption, the 50% increase used in the base model was considered appropriate.
- The steepness parameter of the stock-recruitment model was also profiled across a range of values. This profile suggested that the data did not contain much information about the appropriate value for steepness and that subsequent biological reference points were also highly uncertain. For example, over approximate 95% confidence intervals for steepness (0.35-0.85), MSY ranged from 40,000 to 78,000 mt, SSB_{msy} ranged from 73,000 to 277,000 mt, and F_{msy} ranged from 0.12 to 0.7. Stock status in 2011, however, was robust to this uncertainty, with a broad range of comparisons resulting in the conclusion of not overfished and no overfishing ($SSB > ½ SSB_{MSY}$ and $F < F_{msy}$). Only in the extreme case of steepness equal to 0.35, which was considered implausible, would overfishing be occurring. Similarly, sensitivity runs of projections through 2015 based inputs and results of the current assessment, mostly over a range of assumptions about natural mortality, suggested that the probability of the stock being overfished or for overfishing to occur using commonly applied harvest scenarios (e.g., F_{MSY}, MSY) was generally zero.
- The robust nature of stock status was likely driven by the age-1 cohort in 2009, which was estimated to be the largest on record. To test the sensitivity of stock status to the presence of this cohort, projections through 2015 at F_{MSY} were conducted with the size of that cohort cut in half, which made the age-1 2009 cohort approximately equal to previous high recruitments. The probability of the stock being overfished or for overfishing to occur remained at zero. Furthermore, a sensitivity run was conducted with

the variation of the annual recruitments from the underlying Beverton-Holt relationship being more restricted than in the base model (CV in base =1, CV in sensitivity = 0.67). This sensitivity suggested that even with these additional restrictions on recruitment variation, the age-1 2009 cohort would still be the largest on record.

- Natural mortality is an uncertainty in this assessment. Of particular importance is acceptance of the scale of the herring consumption estimates (Figure A6). The 50% increase in natural mortality from the original natural mortality values during 1996-2011 used in the ASAP model was employed to reduce retrospective patterns in SSB and to make implied biomass removals from input natural mortality rates and the consumption data more consistent.
- The reference points and projections were based on the assumption that prevailing conditions would persist, including the relatively high natural mortality rates of 1996-2011. If life history traits such as natural mortality change rapidly, and prevailing conditions become altered, the associated biological reference points and projections would likewise need to be reexamined.
- In the short-term, the 2009 age-1 cohort (2008 year class) may reduce the vulnerability of this stock to overfishing. The strength of large cohorts, however, is often overestimated in the short-term. Consequently, the strength of this cohort should be interpreted cautiously and decisions based on this assessment should consider this uncertainty.
- Recent annual catches have been well above MSY. Consistent with this observation, SSB has declined since 1996 with the exception of recent increases driven by the 2009 age-1 cohort. The reference points (e.g., MSY), however, are uncertain.

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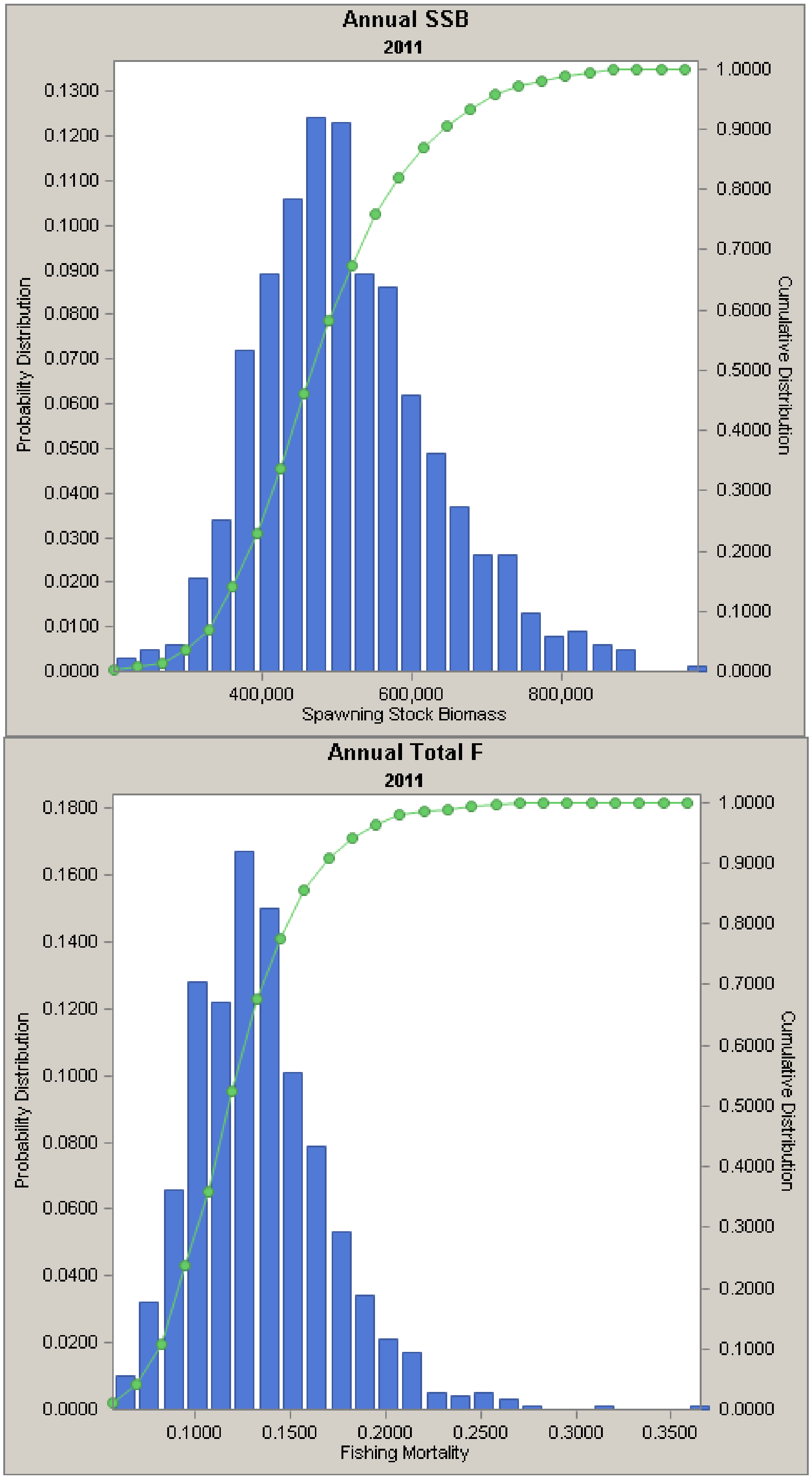
A. Atlantic Herring – Tables

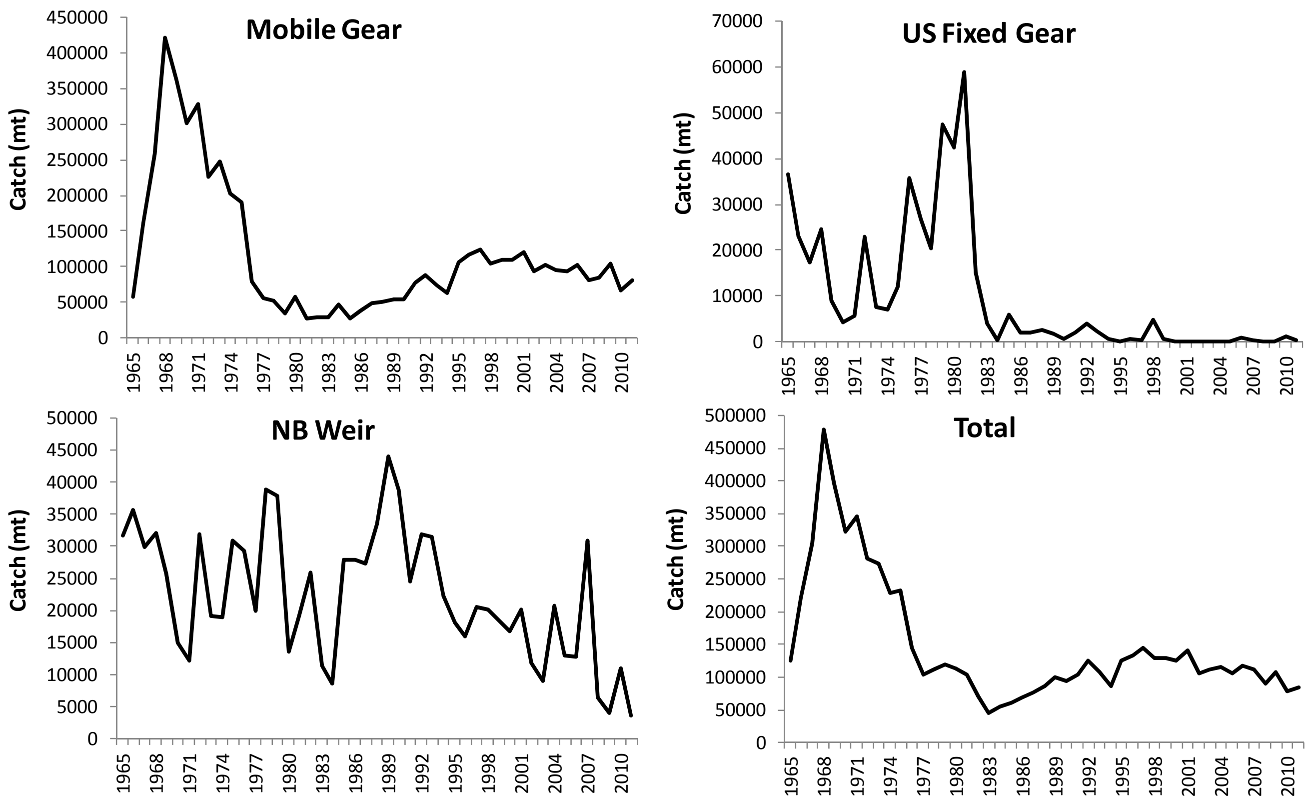
Table A1. Results of three-year Atlantic herring projections for the base ASAP model.

Fmsy = 0.267	SSBmsy = 157,000 mt	steepness = 0.53	MSY = 53,000 mt
2011 F (age 5)	SSB 2011		2011 catch
0.14	518,000 mt		85,000 mt
2012 catch = 87,683 mt (quota)			
	2013	**2014**	**2015**
	F_{msy}		
F	0.267	0.267	0.267
SSB	496,064 mt	368,501 mt	308,949 mt
80% CI	362,965 - 688,585 mt	275,695 - 517-815 mt	237,755 - 411,808 mt
Prob < SSBmsy/2	0	0	0
catch	168,775 mt	126,589 mt	104,430 mt
80% CI	124,868 - 230,764 mt	95,835 - 171,145 mt	79,505 - 139,925 mt
	$F_{75\%\ msy}$		
F	0.2	0.2	0.2
SSB	523,243 mt	409,309 mt	354,559 mt
80% CI	382,573 - 723,975 mt	306,011 - 574,128 mt	272,751 - 473,021 mt
Prob < SSBmsy/2	0	0	0
catch	130,025 mt	102,470 mt	87,574 mt
80% CI	96,216 - 177,894 mt	77,476 - 138,665 mt	66,739 - 117,318 mt
	$F_{status\ quo}$		
F	0.14	0.14	0.14
SSB	548,788 mt	450,496 mt	402,551 mt
80% CI	401,571 - 760,028 mt	336,594 - 631,502 mt	309,334 - 537,414 mt
Prob < SSBmsy/2	0	0	0
catch	93,159 mt	76,823 mt	67,912 mt
80% CI	68,954 - 127,518 mt	58,022 - 104,055 mt	51,752 - 91,001 mt
	MSY		
F	0.08	0.09	0.1
80% CI	0.06 - 0.11	0.07 - 0.12	0.07 - 0.14
Prob > Fmsy	0	0	0
SSB	576,092 mt	492,162 mt	448,725 mt
80% CI	413,046 - 813,298 mt	351,530 - 716,931 mt	321,209 - 633,132 mt
Prob < SSBmsy/2	0	0	0
catch	53,000 mt	53,000 mt	53,000 mt
	Status quo catch		
F	0.13	0.16	0.19
80% CI	0.1 - 0.18	0.11 - 0.23	0.13 - 0.27
Prob > Fmsy	1%	4%	10%
SSB	551,686 mt	446,496 mt	385,995 mt
80% CI	388,989 - 789,568 mt	306,349 - 669,721 mt	259,178 - 569,560 mt
Prob < SSBmsy/2	0	0	0
2012 quota	87,683 mt	87,683 mt	87,683 mt

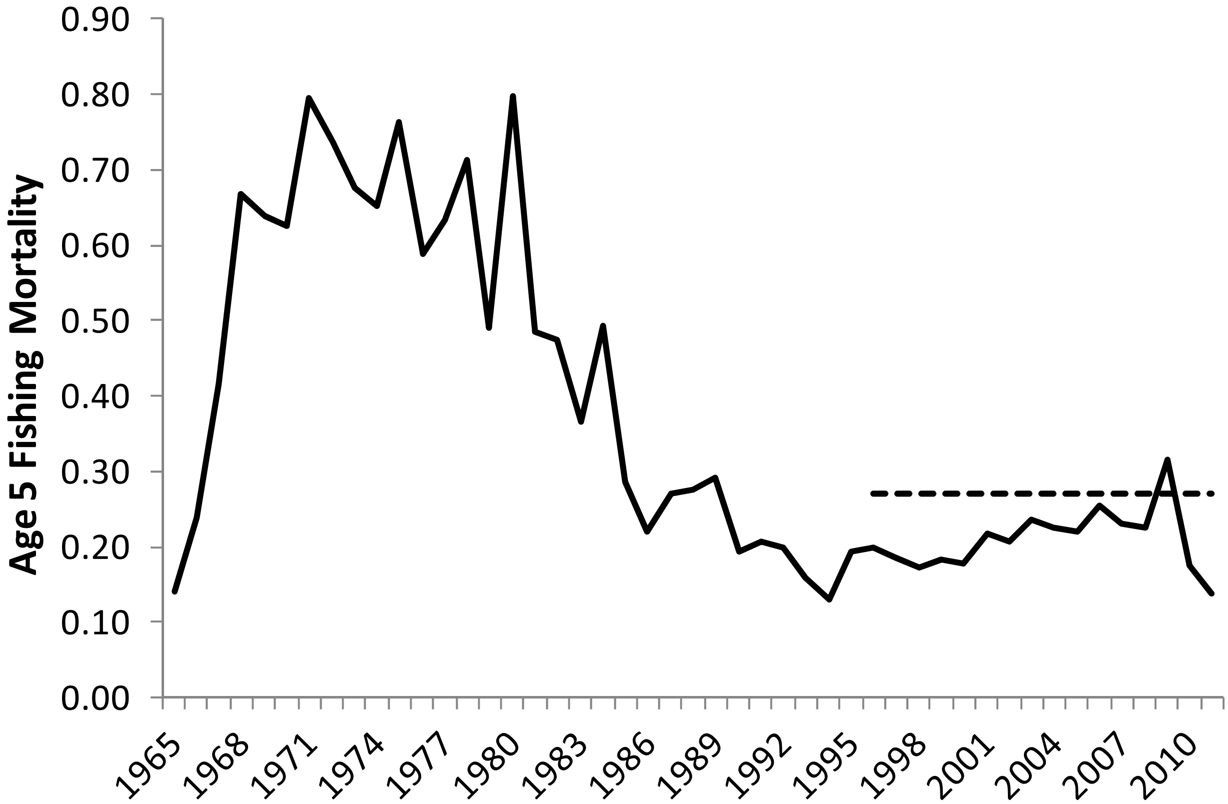
A. Atlantic Herring – Figures



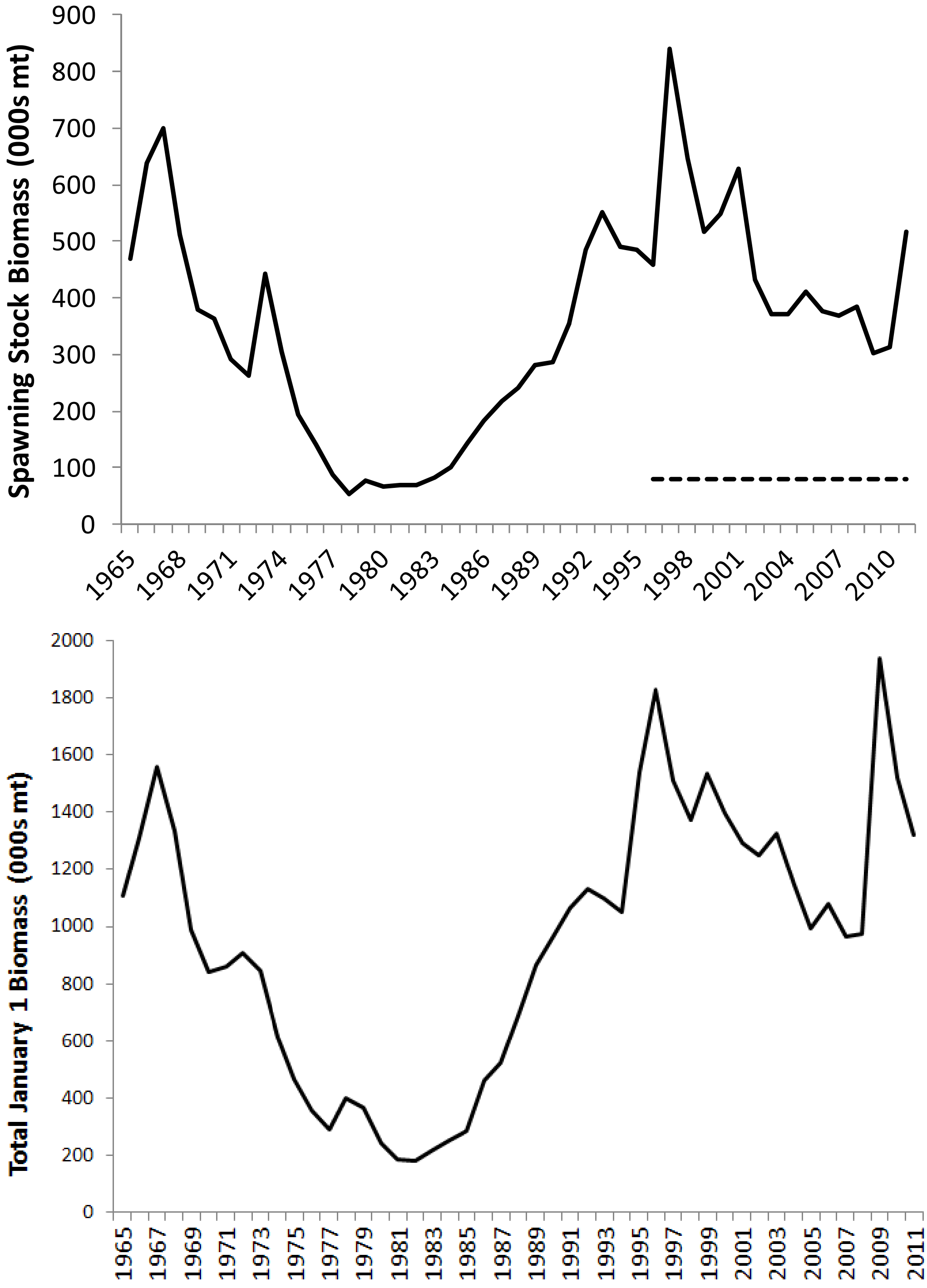
A1. Posterior densities of Atlantic herring SSB and F in 2011 from the ASAP base run.



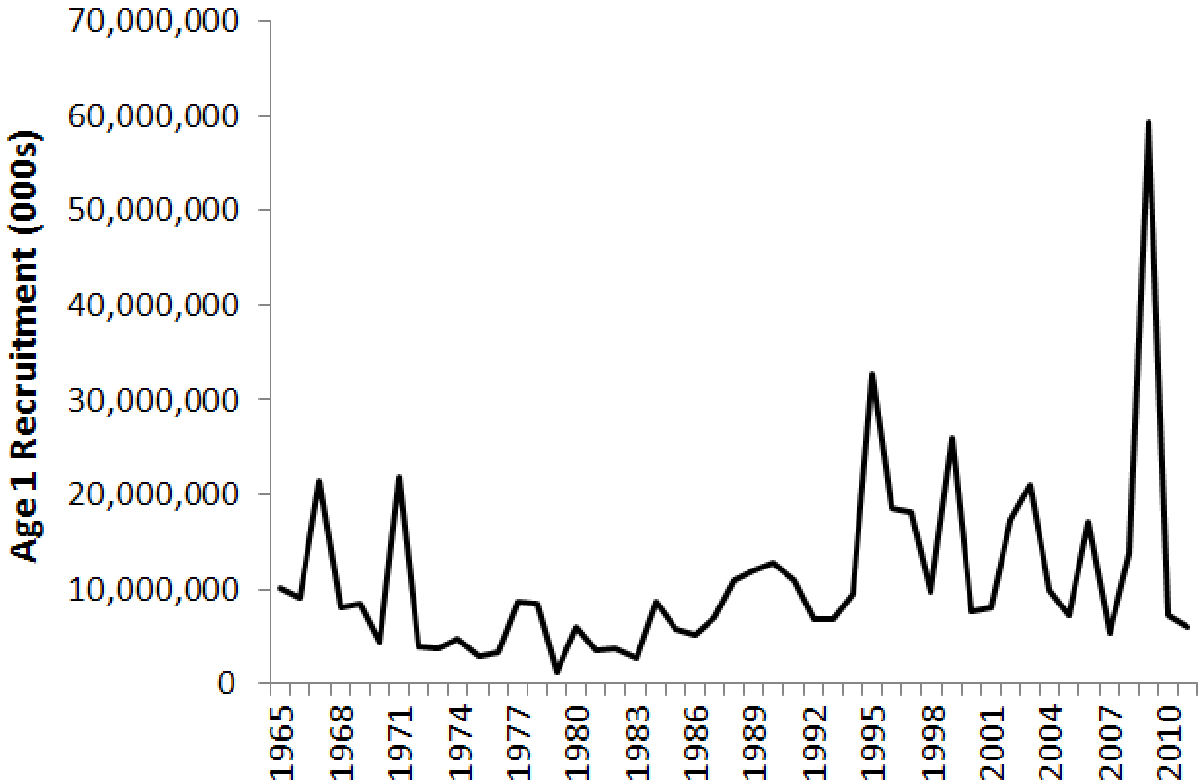
A2. Atlantic herring catch (mt) during 1965-2011 for US mobile gears, US fixed gears, NB weir fishery, and total catch. Discards estimates were only available since 1996.



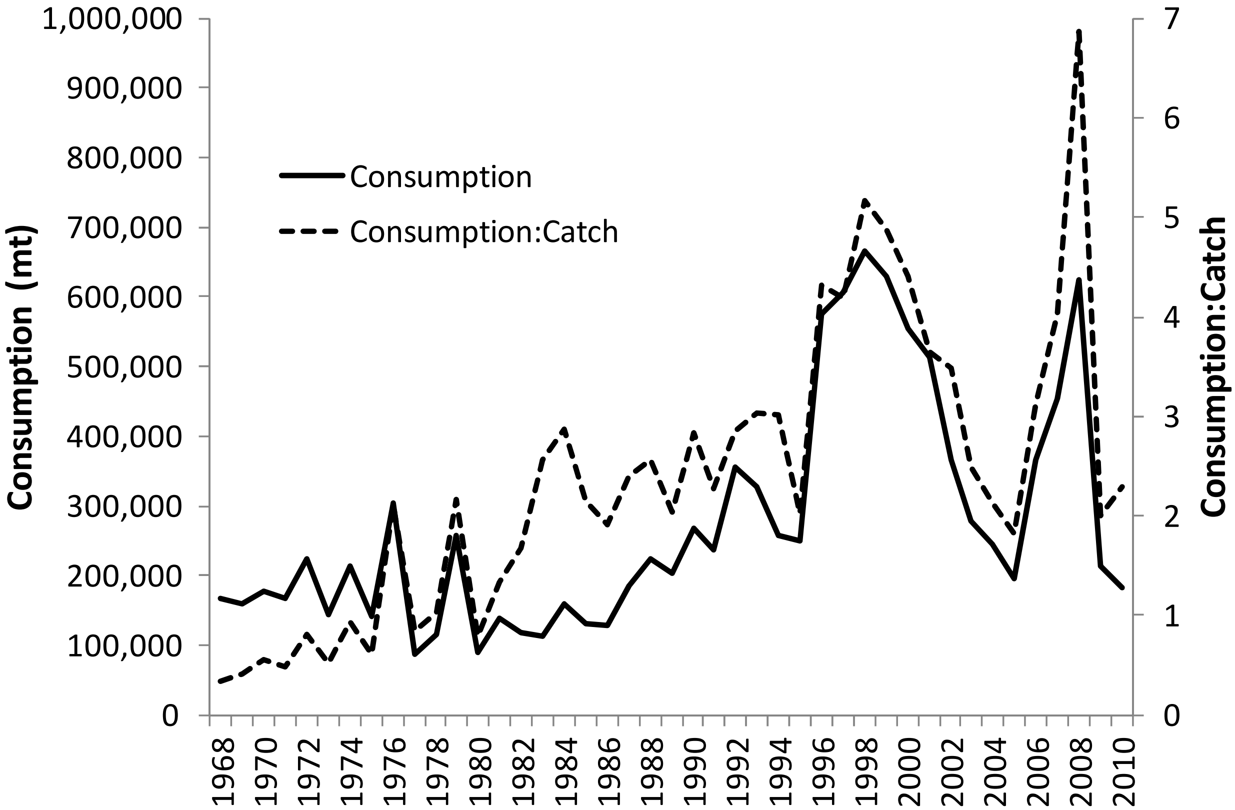
A3. Atlantic herring age-5 fishing mortality (solid line) and F_{MSY} (dashed line) estimated from the ASAP model base run. The F_{MSY} reference line is only provided during 1996-2011 because the reference point from this assessment is only for this time period.



A4. Atlantic herring spawning stock biomass (000s MT; solid line; top panel), ½ SSB_{MSY} (dashed line; top panel), and total biomass (000s MT; bottom panel) time series estimated from the ASAP base run. The ½ SSB_{MSY} reference line is shown for 1996-2011 because the reference point from this assessment is only for this time period.



A5. Atlantic herring age-1 recruitment (000s) over time, estimated from the ASAP model base run.



A6. Consumption of Atlantic herring by groundfish species, marine mammals, highly migratory species and seabirds (solid line). Also shown, the ratio of consumption to fishery catch (dashed line), 1968-2010.

B. SOUTHERN NEW ENGLAND MID-ATLANTIC YELLOWTAIL FLOUNDER ASSESSMENT SUMMARY FOR 2012

State of Stock: A statistical catch-at-age model, ASAP (Legault and Restrepo 1999), is the best scientific information available for determining stock status for Southern New England Mid-Atlantic yellowtail flounder. For 2011, model-based estimates of spawning stock biomass (SSB) = 3,873 mt and average fishing mortality for ages 4-5 ($F_{4\text{-}5}$) = 0.12 (Figures B1 and B2).

Biological Reference Points (BRP's) were computed using $F_{40\%}$, a proxy for F_{MSY}, and a corresponding SSB_{MSY} proxy derived by sampling age-1 recruitment from an empirical cumulative distribution function (CDF) with two alternative recruitment scenarios. One scenario is based only on age-1 recruitment from a "recent" time period, 1990-2010, recognizing a potential reduction in stock productivity since about 1990. The other scenario uses the entire age-1 recruitment time series from 1973-2010, with "two stanzas" of recruitment determined by whether SSB is either above or below 4,319 mt. The SSB threshold of 4,319 mt was derived from a minimum residual variance analysis relating SSB to age-1 recruitment, which allowed recruitment to be sampled from the appropriate stanza depending on the value of SSB.

For both scenarios the overfishing threshold $F_{40\%}$ = 0.316, which implies that overfishing is not occurring in this stock (Figures B3 and B6). Stochastic projections at $F_{40\%}$ were used to determine biomass reference point proxies (i.e., for SSB_{MSY} and MSY). Conclusions about whether the stock is overfished depend on which recruitment scenario is used. Under the "recent" recruitment scenario, SSB_{MSY} = 2,995 mt (2,219-3,820 mt; a 90% confidence interval) and MSY = 773 mt (573-984 mt), which leads to the conclusion that the stock is not overfished (Figures B3 and B7). Because this stock is under a rebuilding plan with a rebuilding date set for 2014, the stock would be considered rebuilt under the scenario of "recent" low recruitment. Under the "two stanza" recruitment scenario, SSB_{MSY} = 22,615 mt (13,164 - 36,897 mt) and MSY = 5,834 mt (3,415-9,463 mt), which leads to the conclusion that the stock is still overfished (Figures B3 and B7). Neither scenario could be ruled out, but the SARC concluded that the evidence was 60:40 in favor of the "recent" recruitment scenario (i.e., productivity change). There is considerable uncertainty as to whether or not the stock is overfished.

Projections: Short-term projections of future stock status were conducted based on the results of the ASAP model. The projections did not account for retrospective error because the retrospective errors were considered minimal. Retrospective Mohn's Rho statistics based on 7-year peel resulted in retrospective error of -0.16 and 0.14 for average fishing mortality and spawning stock biomass respectively. The projections assumed that catch in 2012 equaled the Annual Catch Limit for 2012. Age-1 recruitment was sampled from a CDF for both the "recent" and "two stanza" recruitment scenarios. Under the more likely scenario of "recent" low recruitment, the stock is projected to be above the SSB_{MSY} associated with that scenario, with median annual catches averaging approximately 1,000 mt in 2013 - 2015 when fishing at F_{MSY} (Table B1). However, under the "two stanza" recruitment, the stock is not expected to rebuild even if the fishing mortality rate (F) were held at zero during 2013 – 2015 (Table B1).

Catch and Status Table: Southern New England Mid-Atlantic yellowtail flounder (Weights in 000's mt, recruitment in millions, arithmetic means)

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Max[1]	Min[1]	Mean[1]
Commercial Landings	0.8	0.5	0.5	0.2	0.2	0.2	0.2	0.2	0.1	0.2	18.5	0.1	3.2
Foreign Catch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
Commercial discards	0.2	0.2	0.1	0.1	0.2	0.3	0.4	0.3	0.2	0.1	9.7	0.1	1.7
Catch used in the assessment	0.9	0.7	0.6	0.3	0.4	0.5	0.6	0.5	0.3	0.4	22.2	0.3	4.9
Spawning Stock Biomass	1.3	1.0	0.7	0.7	1.1	1.9	2.3	2.6	3.3	3.9	21.8	0.6	4.8
Recruitment (Age-1)	2.1	1.9	3.2	9.5	8.0	4.2	7.5	7.9	5.2	8.2	190.5	1.9	28.7
F4-5	1.2	0.9	1.0	0.7	0.6	0.4	0.3	0.2	0.1	0.1	3.1	0.1	1.1

[1]Over the period 1973-2011, the period of the assessment.

Stock Distribution and Identification: Yellowtail flounder inhabit relatively shallow waters (20-100 m) of the continental shelf of the Northwest Atlantic from Labrador to Chesapeake Bay. An evaluation of yellowtail flounder stock structure indicates that, in Southern New England and Mid-Atlantic waters, yellowtail flounder constitute a single stock. The stock area is defined as the continental shelf from Nantucket Shoals to the southern extent of the species range (U.S. statistical reporting areas 526, 537, 538, 539, and division 6). There has been a reduction in the stock over time in the Southern New England – Mid-Atlantic region (Figure B4).

Catches: In the assessment period (1973-2011), total catch has ranged from approximately 22,000 mt to 290 mt. Prior to 2005, landings constituted roughly 70-80% of the total catch, but recently landings have only contributed approximately 40-50% of the total catch. The magnitude of landings has been very low, averaging about 400 mt in the last 5 years, due to a combination of low biomass and regulatory restrictions on commercial landings that lead to an increase in commercial discards in the fishery.

Starting in 2005, commercial discards became a significant component, accounting for over 50% of the overall catch. Increases in discards were partly the result of restrictive trip limits that were in effect from 2003 through 2008. The scallop fleet has been a primary contributor of yellowtail discarding for market reasons and despite efforts to gradually relax the trip limits, discards of yellowtail remain approximately 60% of the total catch (Figure B5).

Discard mortality of yellowtail flounder in the previous assessment was assumed to be 100%. However, based on a recent study (Barkley and Cadrin 2012), this new assessment assumed a 90% discard mortality rate in the commercial catch.

Data and Assessment: The previous assessment of Southern New England Mid-Atlantic yellowtail flounder was conducted with a Virtual Population Analyses (VPA) model that used total commercial landings, discards and survey data from 1973-2007 (NEFSC, 2008). The new assessment model (ASAP) includes revised biological data (length-weight relationship, maturity at age, and natural mortality), survey input data (i.e. winter survey) and fishery input data (i.e., fishery catch weights and numbers from 1994-2011).

Catch at age from 1973-2011 was aggregated into a single fleet. The commercial fleet catch includes US catch by otter trawl and the scallop dredge with minor contributions from the scallop trawl in the recent years.

NEFSC spring and fall surveys (1973-2011) and the NEFSC winter survey (1992-2007), expressed as minimum swept area values, were used in the ASAP model along with estimated CVs and annual age composition. Conversion factors for the fall and spring NEFSC surveys were applied to account for any changes in the door, gear and vessel operations.

Natural mortality in previous assessments was based on the traditional longevity approach as described in Hoenig (1983) and was assumed to equal 0.2 for all ages and years. For this assessment, natural mortality was based on the Lorenzen method, with alternative life history approaches (i.e. Gonadosomatic index approach, average maximum size in the population approach and Hoenig's method) providing the scale of natural mortality and the Lorenzen method defining how natural mortality declined with age (Lorenzen 1986, Gunderson and Dygert 1988, Gunderson 1997, McElroy et al. 2012). Recognizing the potential uncertainties associated with the Lorenzen approach (i.e. non-species specific parameters and the anomalous shift in age-1 weights at age during the mid-1990's), the assessment used a time series average of age-specific natural mortality from the rescaled Lorenzen method.

Biological Reference Points: This assessment updated F40%, the overfishing threshold proxy for F_{MSY}. A deterministic value of F40% was estimated from a yield per recruit analyses using the most recent five year average from 2007-2011of SSB weights, catch weights and fishery selectivity at age. Maturity at age and natural mortality at age were both time invariant. Expressed as fully recruited fishing mortality ($F_{ages4-5}$), F40% was estimated to equal 0.316.

Stochastic projections at $F_{40\%}$ were used to determine biomass reference point proxies (i.e., for SSB_{MSY} and MSY) under two recruitment scenarios. Under the more likely scenario of recent low recruitment, SSB_{MSY} proxy = 2,995 mt, with 5th and 95th percentiles ranging from 2,219 – 3,820 mt. Under the scenario of two stanza recruitment, SSB_{MSY} proxy = 22,615 mt, with 5th and 95th percentiles spanning 13,164 - 36,897 mt.

Under the recent low recruitment scenario, MSY proxy = 773 mt with 5th and 95th percentiles of 573 – 984 mt . Under the two-stanza recruitment scenario, MSY proxy = 5,834 mt, with 5th and 95th percentiles of 3,415 – 9,463 mt.

Under the recent low recruitment scenario, median age-1recruitment = 5.8 million fish with 5th and 95th percentiles of 2.1million to 10.1 million. Under the two stanza recruitment scenario, age-1 recruitment = 37.7 million age 1 fish, with 5th and 95th percentiles ranging from 8.5 to 127.8 million fish.

The biological reference points that had been used previously were F_{MSY} proxy = $F_{40\%}$ = 0.254, SSB_{MSY} proxy = 27,400 mt, and MSY proxy = 6,100 mt.

Fishing Mortality: The fishing mortality rate (F) has been greater than the overfishing reference points for most years since 1973. F has ranged from 0.12 to 3.1. Fishing mortality generally increased in the 1980s and early 1990s to peak at 3.1 in 1990, averaged 1.6 during the 1990s, but decreased in the 2000's to 0.12 in 2011 with a 90% confidence interval of 0.08-0.16 (Figure B6).

Biomass: Spawning stock biomass was high in the early 1970s, decreased in the late 1970s, and increased in the 1980s, with the recruitment of the 1980 and 1987 cohorts. SSB decreased to a record low 621 mt in 1994, increased briefly to 1,670 mt in 2000, but then decreased to 686 mt in 2005, the second lowest value in the time series. Since 2006, SSB has increased steadily due to moderate 2004 and 2005 year classes. In 2011, SSB = 3,873 mt, with a 90% confidence interval of 3,077-4,960 mt (Figure B7).

Total January 1 biomass in 2011 was 5,305 mt. Over the entire time series, total biomass ranged from 399 mt in 2004 to 62,098 mt in 1988 (Figure B7). Generally, the trends in total biomass are similar to trends in SSB.

Recruitment: Age-1 **r**ecruitment was generally strong in the 1970s, and moderate during the 1980s, with two relatively strong year classes in 1980 and 1987 (Figure B8). For the last two decades, recruitment has been consistently low.

Special Comments:

- Causal mechanisms for the recent low recruitment were not identified. However, a suite of environmental processes may be involved. To address this uncertainty, two scenarios were identified: "recent" low recruitment and "two stanza" recruitment. In consideration of the likelihood of the two scenarios the term "more likely" is used in this report. This is meant to be interpreted as 60% in favor of the "recent" low recruitment scenario and 40% in favor of the "two stanza" recruitment scenario.

- The cause of the recent low recruitment was considered the largest uncertainty in this assessment. As a possible mechanism for reduced recent recruitment, the cold pool (i.e. remnant winter water under the summer thermocline) was investigated and modeled explicitly in ASAP. However, it could not fully explain the recent low productivity. The cold pool analyses did show that SSB_{MSY} and MSY tend to decrease in recent years as cold pools have gotten smaller and warmer. Environmental changes may be responsible for some of the changes in the stock which no longer exhibits the abundance throughout its range that was associated with the large recruitments of the 1970's and 1980's. If weak recruitment continues, the stock will not be able return to historically observed levels.

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B. Southern New England Mid-Atlantic Yellowtail Flounder- Tables

Table B1. Summary of median short-term spawning stock biomass (SSB) and yield projections for Southern New England Mid-Atlantic yellowtail flounder assuming three different F's, and under the two different recruitment scenarios: "two stanza" (top tables; Age-1 recruitment based on 1973-2010) and low "recent" (bottom tables; Age-1 recruitment based on 1990-2010).

SSB (mt) - Two Stanza Recruitment

	F_0			$F_{75\%MSY}$			F_{MSY}		
Year	5% CI	Median	95% CI	5% CI	Median	95% CI	5% CI	Median	95% CI
2012	3,140	4,013	4,988	3,140	4,013	4,988	3,140	4,013	4,988
2013	3,468	4,476	5,791	3,201	4,122	5,365	3,118	4,011	5,230
2014	4,130	5,681	11,632	3,212	4,542	10,224	2,963	4,229	9,814
2015	4,705	8,654	22,492	3,205	5,595	18,904	2,848	4,927	17,943

SSB (mt) - Recent Recruitment

	F_0			$F_{75\%MSY}$			F_{MSY}		
Year	5% CI	Median	95% CI	5% CI	Median	95% CI	5% CI	Median	95% CI
2012	3,140	4,013	4,988	3,140	4,013	4,988	3,140	4,013	4,988
2013	3,466	4,468	5,758	3,192	4,117	5,344	3,109	4,008	5,205
2014	4,030	5,248	7,130	3,131	4,122	5,733	2,885	3,815	5,353
2015	4,493	5,809	7,658	3,030	4,007	5,354	2,679	3,579	4,803

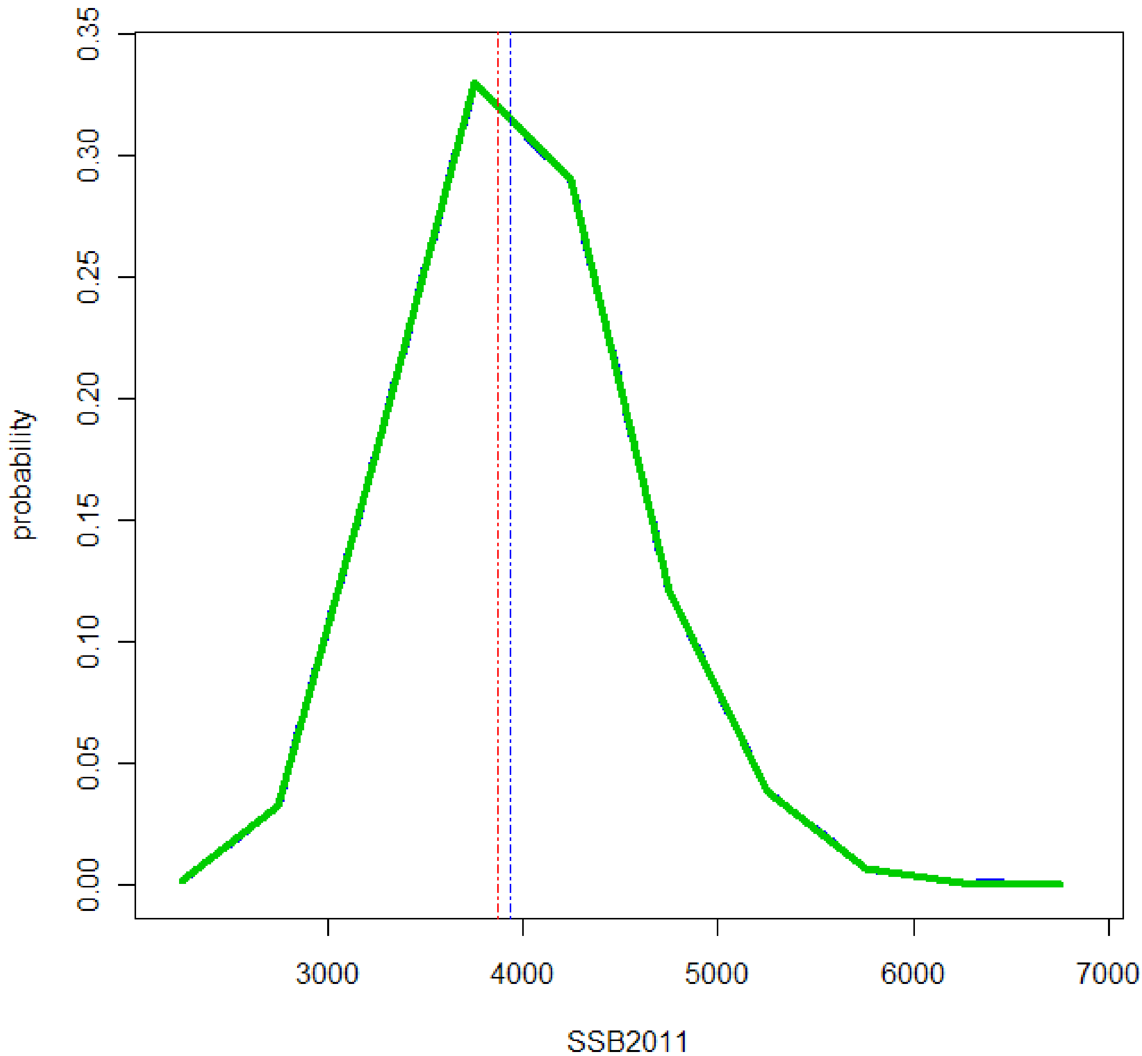
Yield (mt) - Two Stanza Recruitment

	F_0			$F_{75\%MSY}$			F_{MSY}		
Year	5% CI	Median	95% CI	5% CI	Median	95% CI	5% CI	Median	95% CI
2012	390	390	390	390	390	390	390	390	390
2013	0	0	0	659	840	1,078	850	1,085	1,393
2014	0	0	0	652	876	1,496	794	1,071	1,873
2015	0	0	0	645	1,032	2,881	752	1,199	3,601

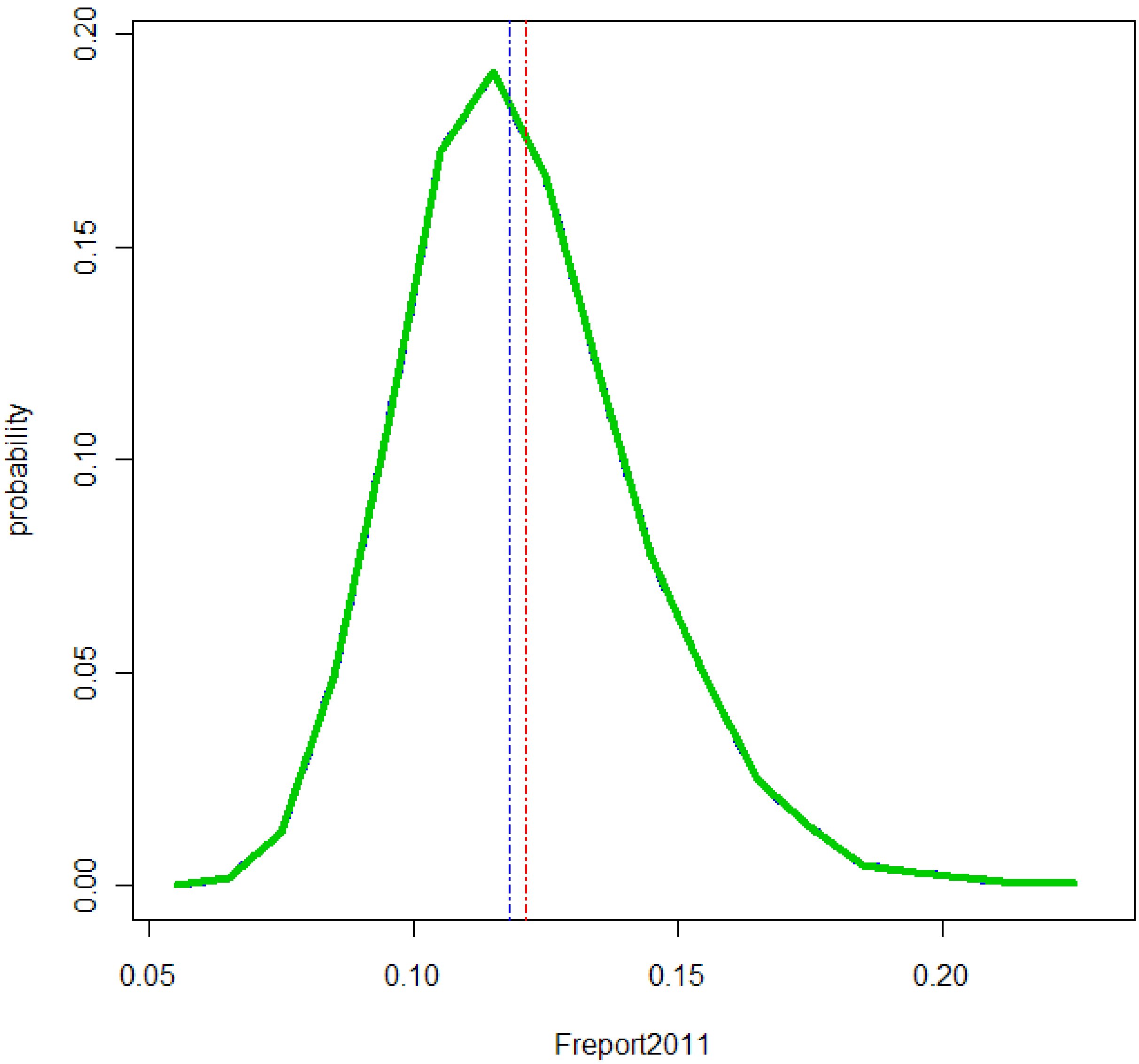
Yield (mt) - Recent Recruitment

	F_0			$F_{75\%MSY}$			F_{MSY}		
Year	5% CI	Median	95% CI	5% CI	Median	95% CI	5% CI	Median	95% CI
2012	390	390	390	390	390	390	390	390	390
2013	0	0	0	655	837	1,061	845	1,080	1,369
2014	0	0	0	637	824	1,107	775	1,004	1,357
2015	0	0	0	615	810	1,113	715	946	1,306

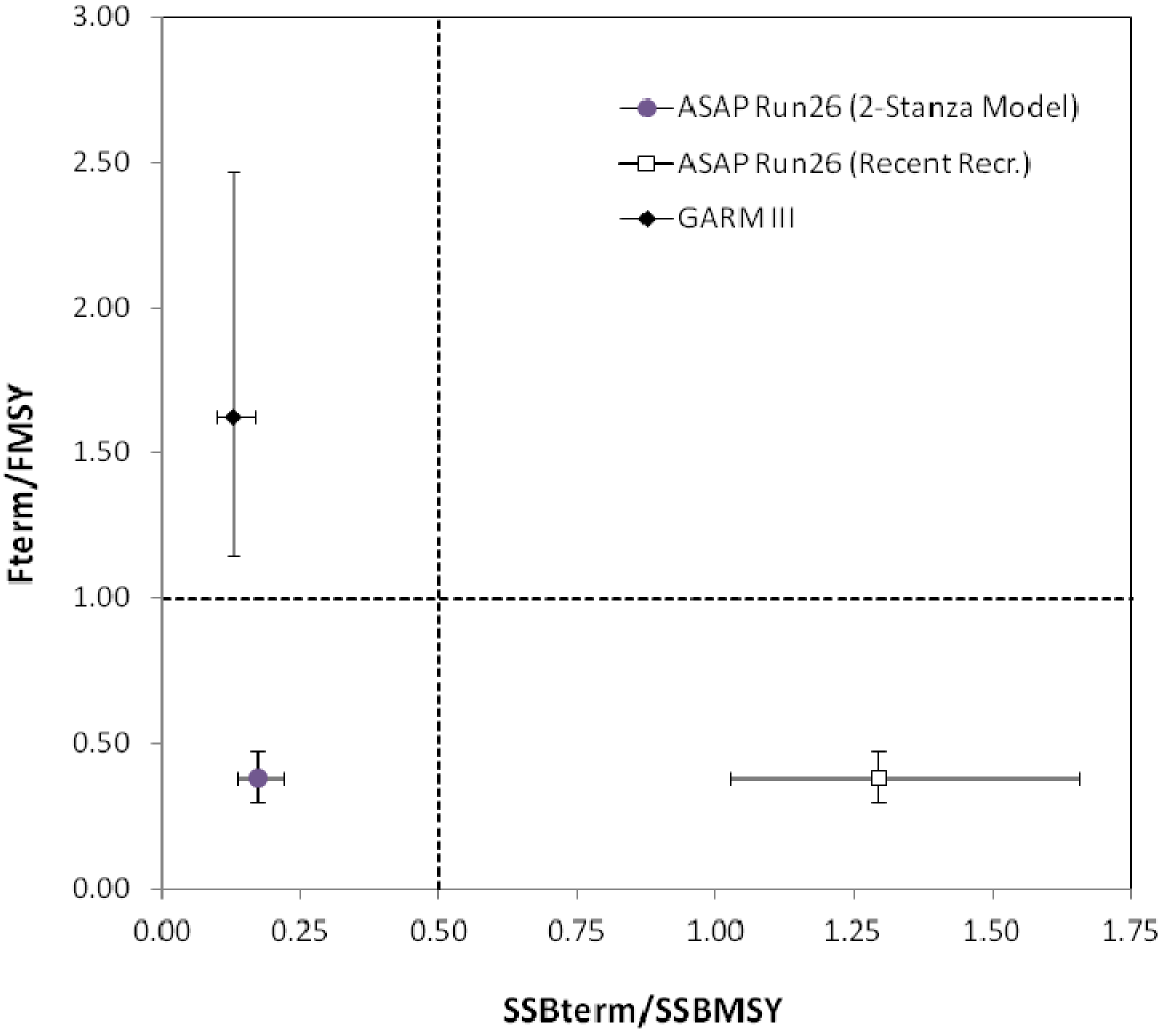
B. Southern New England Mid-Atlantic Yellowtail Flounder - Figures



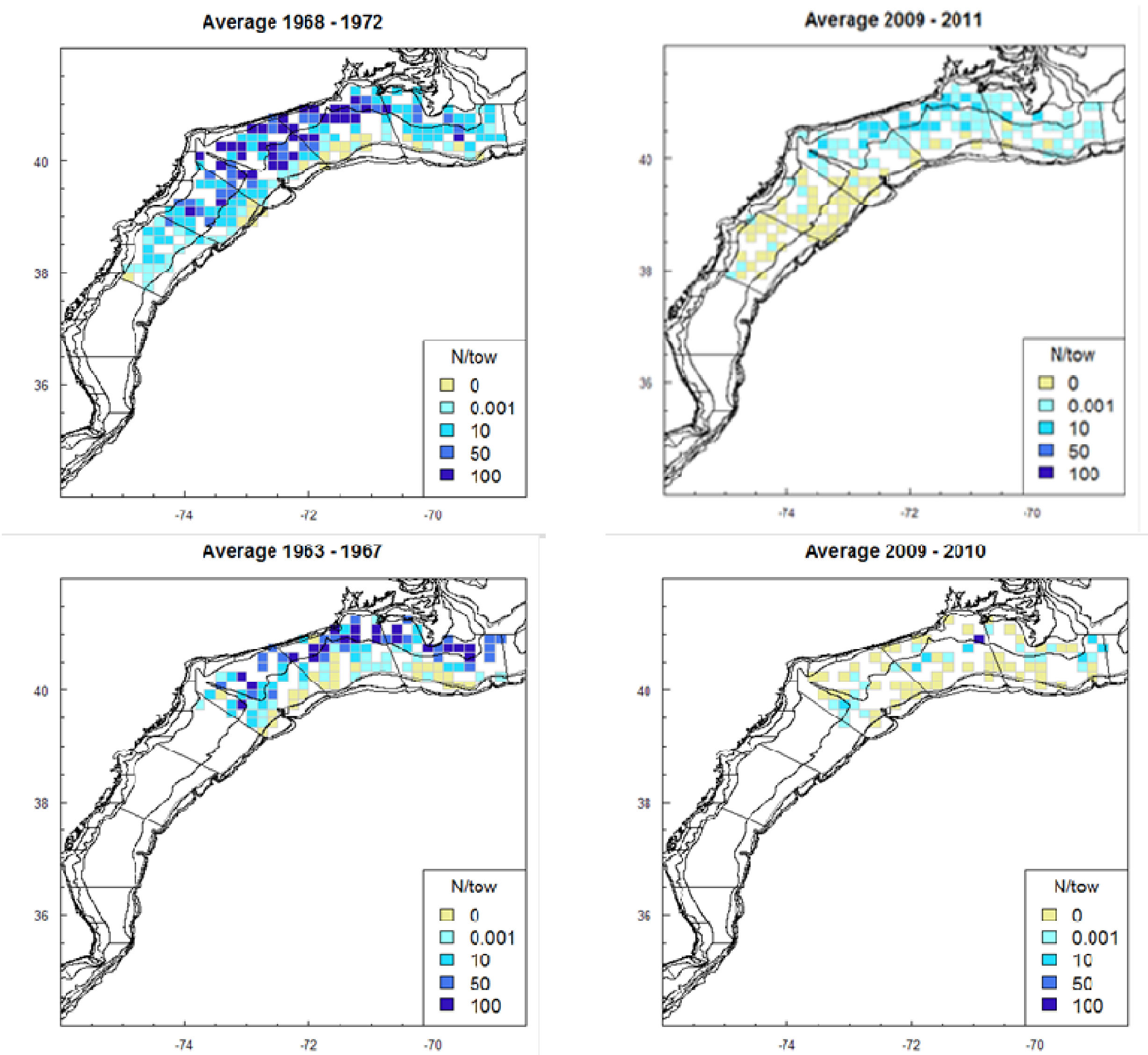
B1. MCMC distribution of the estimate of the 2011 Spawning Stock Biomass (SSB) for Southern New England Mid-Atlantic yellowtail flounder. The vertical red line represents the ASAP 2011 SSB point estimate (3,873 mt) while the blue vertical line to the right represents median 2011 SSB (3,938 mt) from the MCMC distribution.



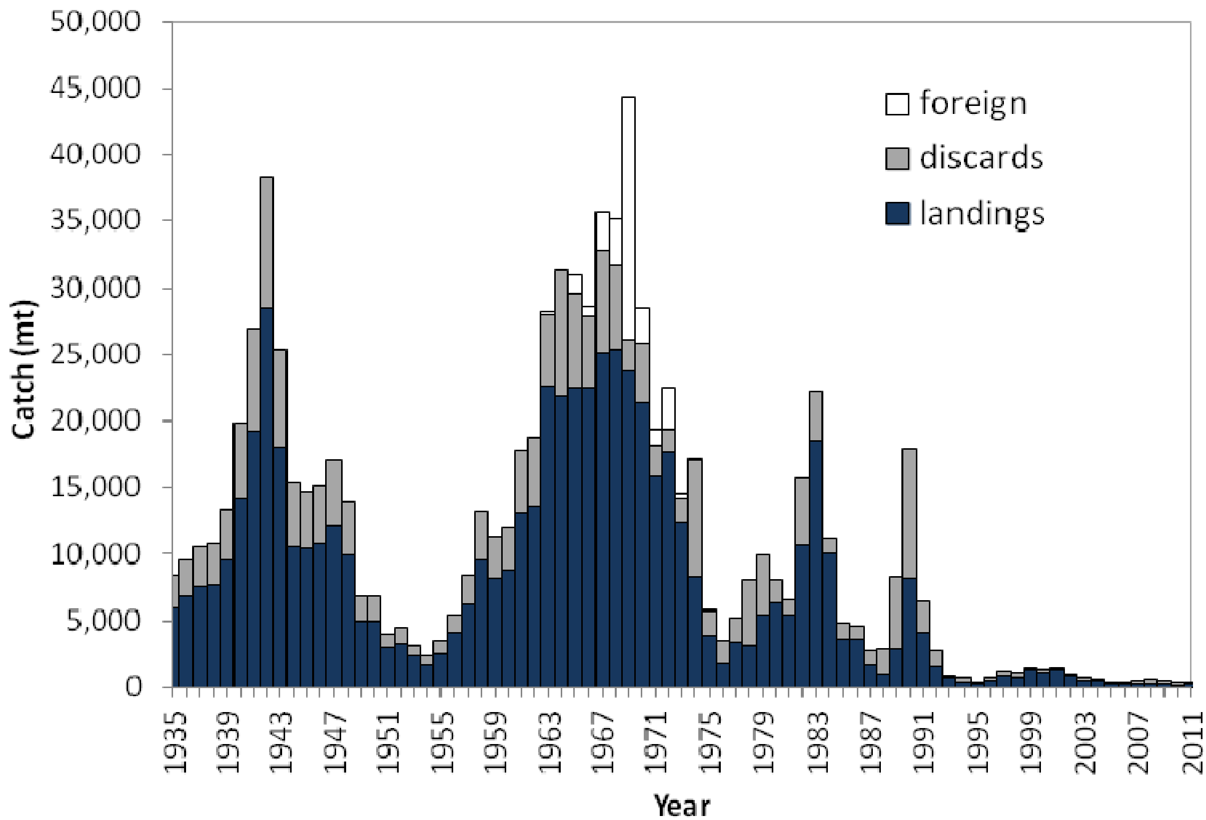
B2. MCMC distribution of the estimate of 2011 fishing mortality rate for Southern New England Mid-Atlantic yellowtail flounder. The vertical red line represents the ASAP 2011 average fishing mortality estimate (0.121) while the blue vertical line to the left represents median 2011 fishing mortality (0.118) from the MCMC distribution.



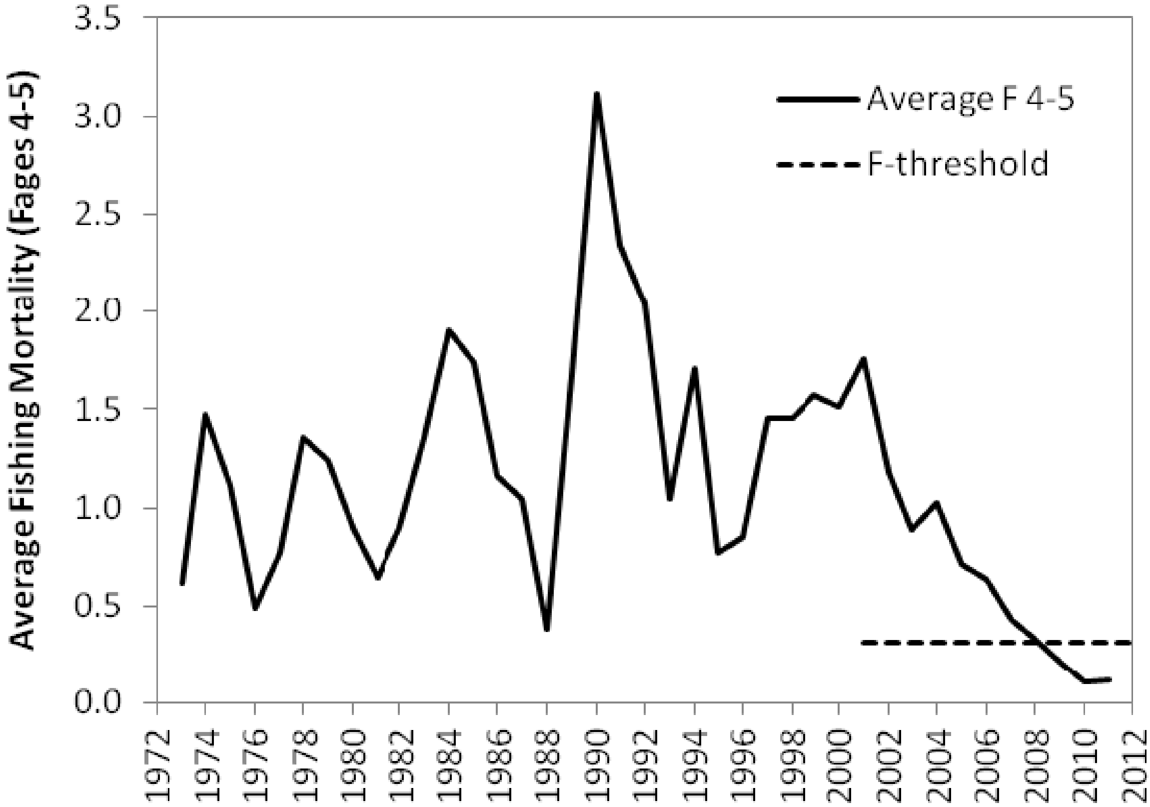
B3. Stock Status based on 2011 estimates for Southern New England Mid-Atlantic yellowtail flounder with respect to biological reference points under both the “two stanza” recruitment scenario (circle) and “recent” recruitment scenario (square). Error bars represent 90% confidence intervals. GARM III (NEFSC 2008) results are also shown (diamond). Note status change from overfishing (NEFSC 2008) to NOT overfishing based on this new SARC54 assessment.



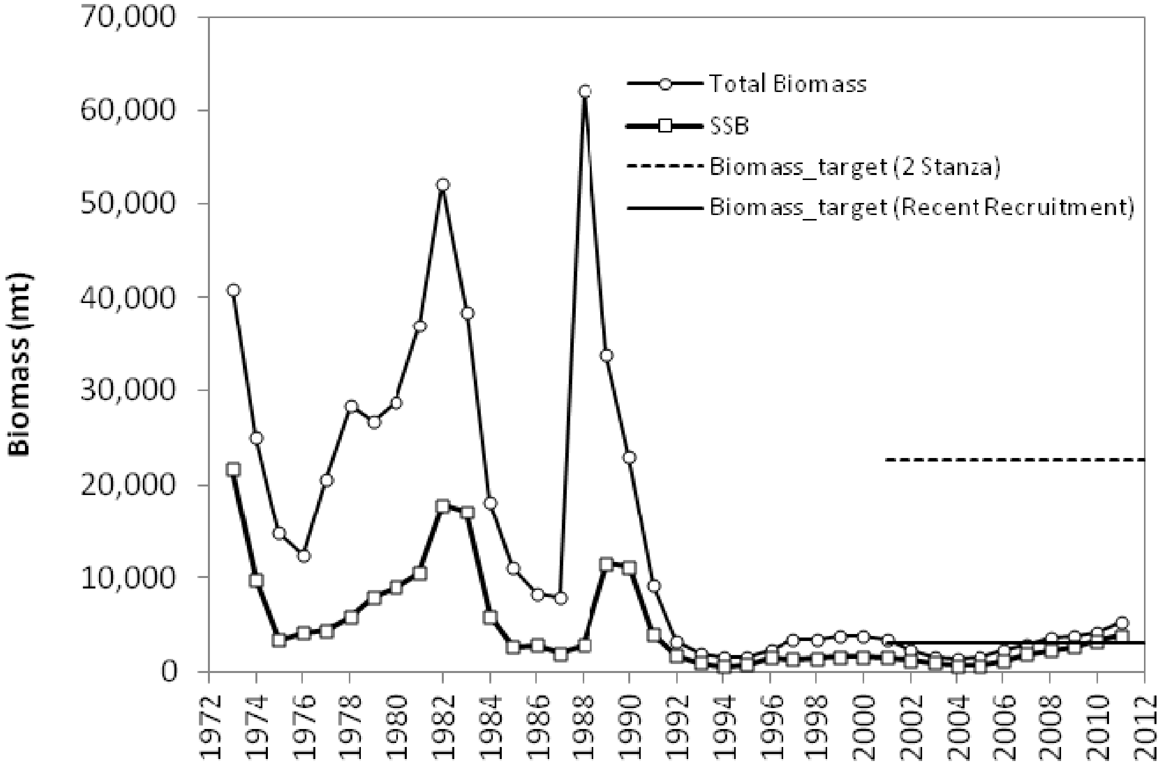
B4. Geographic distribution and abundance of yellowtail flounder in the 1960's (left) and in the recent time period (right) based on Northeast Fisheries Science Center Spring (top) and Fall (bottom) bottom trawl surveys.



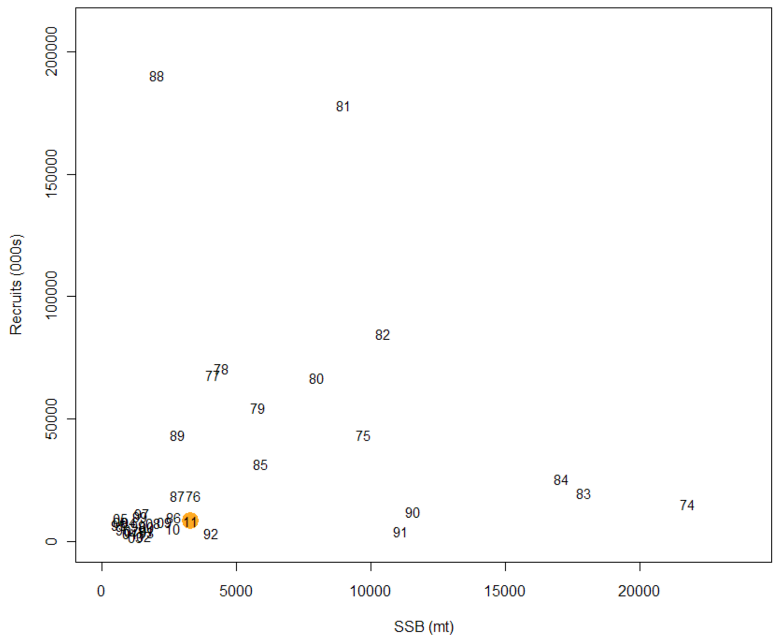
B5. Southern New England Mid-Atlantic yellowtail flounder catch, separated into landings, discards, and foreign components.

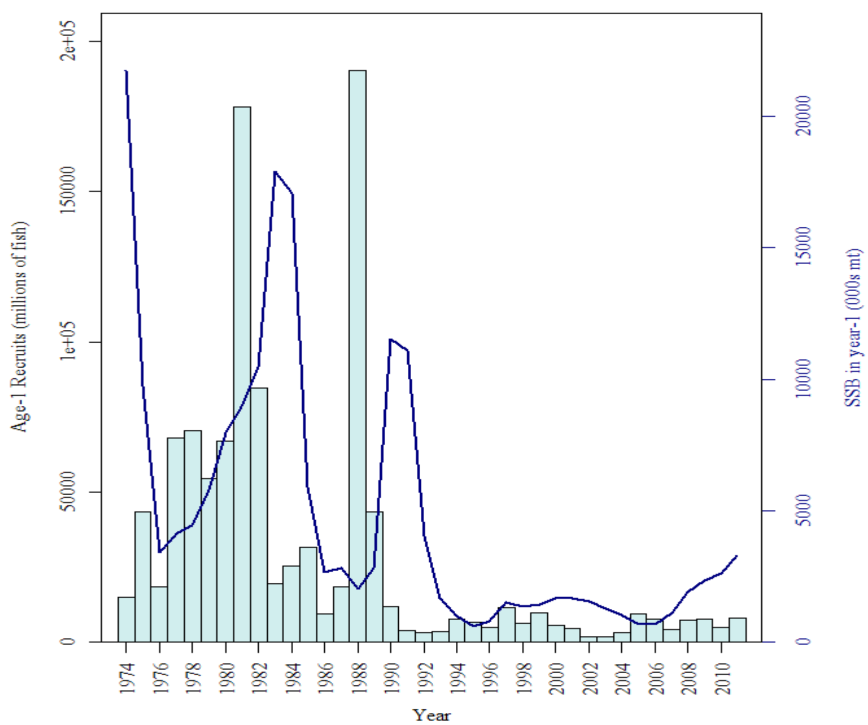


B6. Trends in fishing mortality rate for ages 4-5 (solid line) estimated from ASAP model for Southern New England Mid-Atlantic yellowtail flounder. F-threshold (dashed line) is only shown for 2002-2011 to reflect the selectivity time block for which the reference point was derived.



B7. Trends in total biomass (solid line with circles) and spawning stock biomass (solid line with squares) of Southern New England Mid-Atlantic yellowtail flounder and associated overfished threshold under the “two stanza” and “recent” low recruitment scenarios. SSB targets for the “two stanza” (horizontal dash line) and the “recent” recruitment (horizontal solid line) apply to 2002-2011, as explained in Figure B6.





B8: (Top) ASAP model estimates of Southern New England-Mid Atlantic yellowtail flounder SSB versus age-1 recruitment. The symbol for each observation is the last two digits of the year (e.g. "88" indicates age-1 estimates of the 1987 year class). The most recent recruitment estimate is highlighted (orange circle). (Bottom) ASAP base Model 26 time series of SSB (blue line) and age1 recruitment (vertical bars).

Appendix: Stock Assessment Terms of Reference for SAW/SARC54 (June 5-9, 2012)

(file vers.: 10/21/11b)

A. Atlantic herring

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

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

3. Evaluate the utility of the NEFSC fall acoustic survey to the stock assessment of herring. Consider degree of spatial and temporal overlap between the survey and the stock. Compare acoustic survey results with measures derived from bottom trawl surveys.

4. Evaluate the validity of the current stock definition, and determine whether it should be changed. Take into account what is known about migration among stock areas.

5. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series (integrating results from TOR-6), and estimate their uncertainty. Include a historical retrospective analysis to allow a comparison with previous assessment results and previous projections.

6. Consider the implications of consumption of herring, at various life stages, for use in estimating herring natural mortality rate (M) and to inform the herring stock-recruitment relationship. Characterize the uncertainty of the consumption estimates. If possible integrate the results into the stock assessment.

7. 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.

8. Evaluate stock status with respect to the existing model (from previous peer reviewed accepted assessment) and with respect to a new model, should one be developed for this peer review. In both cases, evaluate whether the stock is rebuilt (if in a rebuilding plan).
   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-7).

9. Using simulation/estimation methods, evaluate consequences of alternative harvest policies in light of uncertainties in model formulation, presence of retrospective patterns, and incomplete information on magnitude and variability in M.

10. Develop approaches and apply them to conduct stock projections and to compute the pdf (probability density function) of the OFL (overfishing level) and candidate ABCs (Acceptable Biological Catch; see Appendix to the SAW TORs).
    a. Provide numerical annual projections (3 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.

11. For any research recommendations listed in recent peer reviewed assessment and review panel reports, review, evaluate and report on the status of those research recommendations. Identify new research recommendations.

B. SNE/Mid-Atlantic Yellowtail Flounder

1. Estimate landings and discards by gear type and where possible by fleet, from all sources. Describe the spatial distribution of fishing effort. Characterize uncertainty in these sources of data.

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

3. Evaluate the validity of the current stock definition, and determine whether it should be changed. Take into account what is known about migration among stock areas.

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

5. Investigate causes of annual recruitment variability, particularly the effect of temperature. If possible, integrate the results into the stock assessment (TOR-4).

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

7. Evaluate stock status with respect to the existing model (from previous peer reviewed accepted assessment) and with respect to a new model, should one be developed for this peer review. In both cases, evaluate whether the stock is rebuilt (if in a rebuilding plan).
    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-6).

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

9. Review, evaluate and report on the status of research recommendations listed in most recent peer reviewed assessment and review panel reports. Identify new research recommendations.

Appendix to the SAW Assessment TORs:

Clarification of Terms
used in the SAW/SARC 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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