Northeast Fisheries Science Center Reference Document 18-08

65th Northeast Regional Stock Assessment Workshop (65th SAW) Assessment Summary Report

by the Northeast Fisheries Science Center

August 2018

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U.S. DEPARTMENT OF COMMERCE
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Table of Contents

SAW-65 ASSESSMENT SUMMARY REPORT

Introduction

The 65th SAW Assessment Summary Report contains summary and detailed technical information on stock assessments reviewed during June 26-29, 2018 at the Stock Assessment Workshop (SAW) by the 65th Stock Assessment Review Committee (SARC-65): Sea scallop and Atlantic herring. The SARC-65 consisted of three external, independent reviewers appointed by the Center for Independent Experts [CIE], and an external SARC chairman from the NEFMC SSC. The SARC evaluated whether each Term of Reference (listed in the Appendix) was completed successfully based on whether the work provided a scientifically credible basis for developing fishery management advice. The reviewers' reports for SAW/SARC-65 are available at the NEFSC Stock Assessment Reports website under the heading "SARC 65 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-65 Review Panel reports (available at the NEFSC Stock Assessment Report website under the heading "SARC-65 Panelist Reports").

SARC 65 concluded that the sea scallop stock is neither overfished nor did it experience overfishing in 2017. The Panel concluded that all tasks specified in the SAW ToRs had been reasonably and satisfactorily completed. A gonad-based SSB and related reference points were developed and presented. But the panel recommended that in the interim meat weight-based reference points continue to be used. The method of using gonad weight to calculate spawning stock size seems promising, but additional work is needed to fully develop the approach.

SARC 65 concluded that the Atlantic herring stock is neither overfished nor did it experience overfishing in 2017. The Panel concluded that all tasks specified in the SAW ToRs had been reasonably and satisfactorily completed. The key changes in the ASAP model used from the last assessment were in assumptions about M and selectivity, in the introduction of new index time series (including an acoustic survey series for the first time). The sensitivity analyses successfully explained the observed assessment scale difference from 2015. The recruitment estimates from the most recent five years were among the lowest in the time series. This suggests that the short-to-medium term prognosis for the stock is likely to be relatively poor.

Glossary

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

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

ASPM. Age-structured production models, also known as statistical catch-at-age (SCAA) models, are a technique of stock assessment that integrate fishery catch and fishery-independent sampling information. The procedures are flexible, allowing for uncertainty in the absolute magnitudes of catches as part of the estimation. Unlike virtual population analysis (VPA) that tracks the cumulative catches of various year classes as they age, ASPM is a forward projection simulation of the exploited population. ASPM is similar to the NOAA Fishery Toolbox applications ASAP (Age Structured Assessment Program) and SS2 (Stock Synthesis 2).

Availability. Refers to the distribution of fish of different ages or sizes relative to that taken in the fishery.

Biological reference points. Specific values for the variables that describe the state of a fishery system which are used to evaluate its status. Reference points are most often specified in terms of fishing mortality rate and/or spawning stock biomass. The reference points may indicate 1) a desired state of the fishery, such as a fishing mortality rate that will achieve a high level of sustainable yield, or 2) a state of the fishery that should be avoided, such as a high fishing mortality rate which risks a stock collapse and long-term loss of potential yield. The former type of reference points are referred to as "target reference points" and the latter are referred to as "limit reference points" or "thresholds." Some common examples of reference points are $F_{0.1}$, F_{MAX}, and F_{MSY}, which are defined later in this glossary.

B_0. Virgin stock biomass, i.e., the long-term average biomass value expected in the absence of fishing mortality.

B_{MSY}. Long-term average biomass that would be achieved if fishing at a constant fishing mortality rate equal to F_{MSY}.

Biomass Dynamics Model. A simple stock assessment model that tracks changes in stock using assumptions about growth and can be tuned to abundance data such as commercial catch rates, research survey trends or biomass estimates.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Survival Ratios. Ratios of recruits to spawners (or spawning biomass) in a stock-recruitment analysis. The same as the recruitment per spawning stock biomass (R/SSB).

TAC. Total allowable catch is the total regulated catch from a stock in a given time period, usually a year.

Target Reference Points. Benchmarks used to guide management objectives for achieving a desirable outcome (e.g., OY). Target reference points should not be exceeded on average.

Uncertainty. Uncertainty results from a lack of perfect knowledge of many factors that affect stock assessments, estimation of reference points, and management. Rosenberg and Restrepo (1994) identify five types: measurement error (in observed quantities), process error (or natural population variability), model error (mis-specification of assumed values or model structure), estimation error (in population parameters or reference points, due to any of the preceding types of errors), and implementation error (or the inability to achieve targets exactly for whatever reason)

Virtual Population Analysis (VPA) (or cohort analysis). A retrospective analysis of the catches from a given year class which provides estimates of fishing mortality and stock size at each age over its life in the fishery. This technique is used extensively in fishery assessments.

Year class (or cohort). Fish born in a given year. For example, the 1987 year class of cod includes all cod born in 1987. This year class would be age 1 in 1988, age 2 in 1989, and so on.

Yield per recruit (Y/R or YPR). The average expected yield in weight from a single recruit. Y/R is calculated assuming that F is constant over the life span of a year class. The calculated value is also dependent on the exploitation pattern, rate of growth, and natural mortality rate, all of which are assumed to be constant.

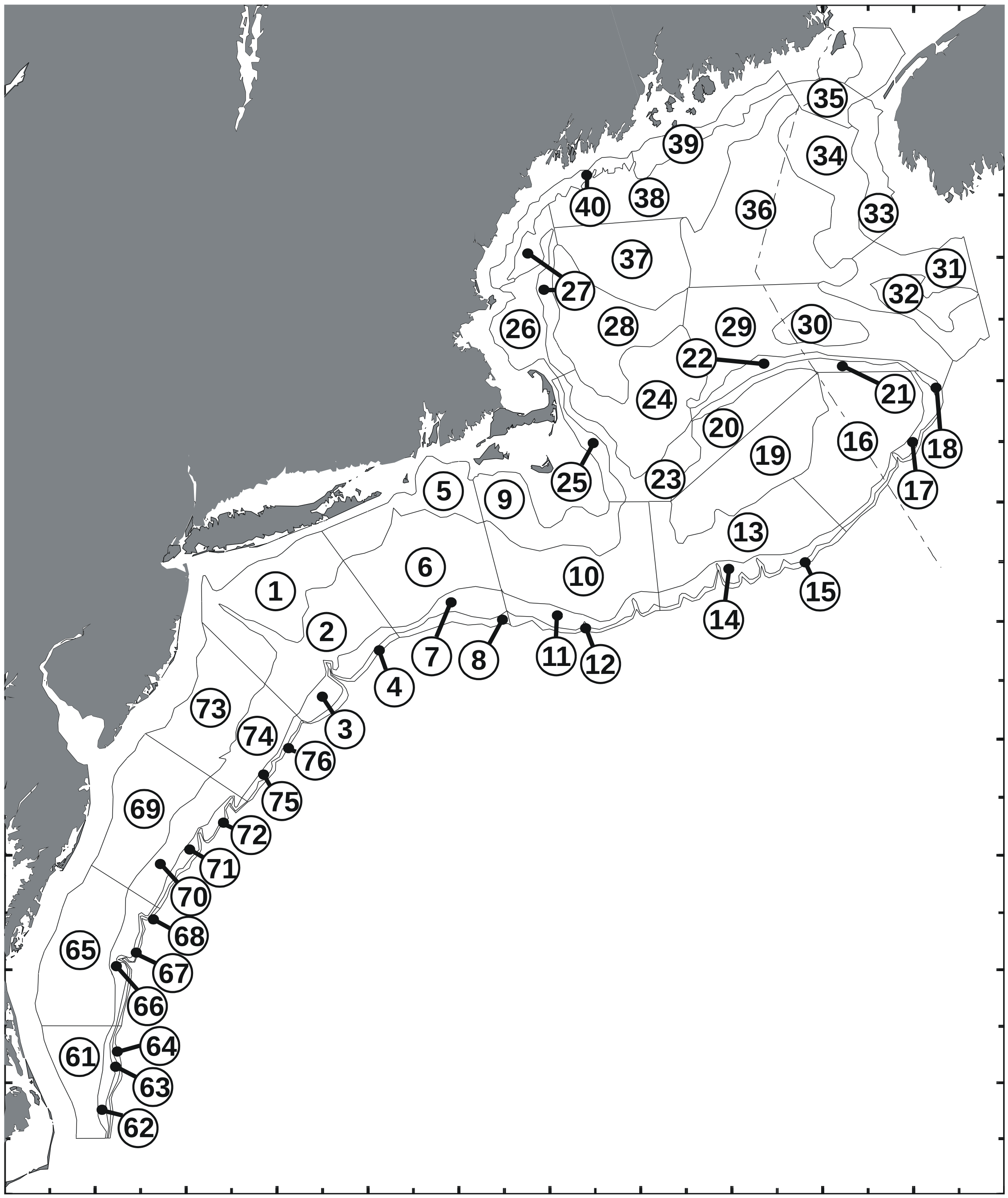


Figure 1. Offshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys. Some of these may not be sampled presently.

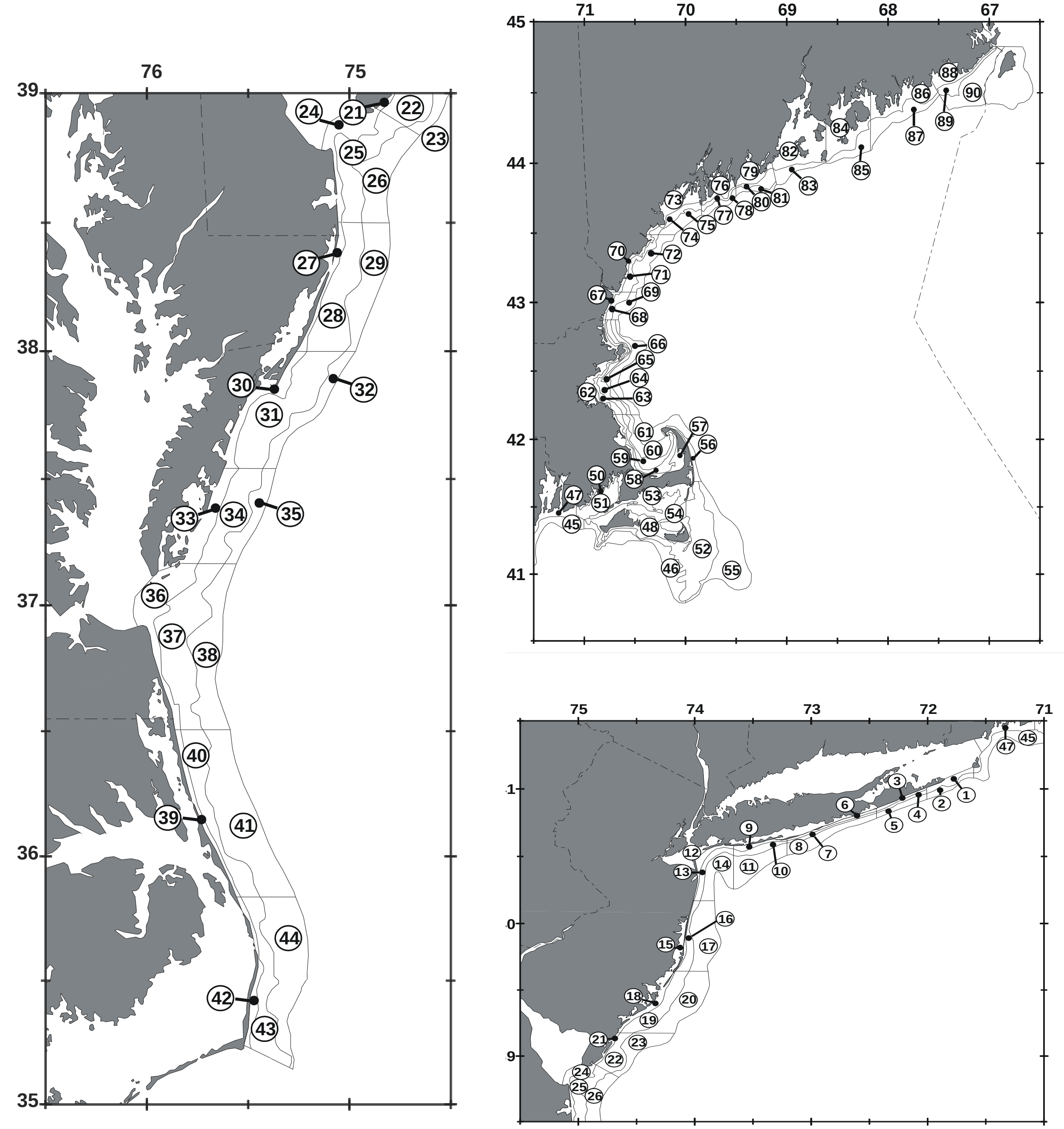
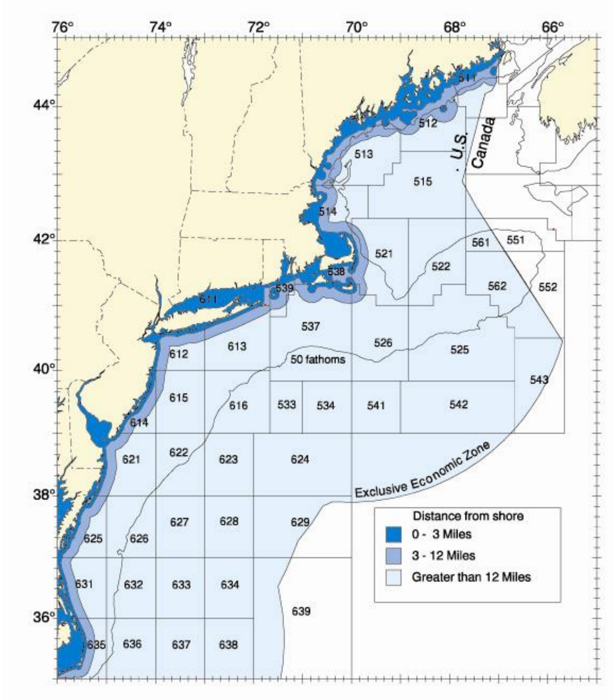


Figure 2. Inshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys. Some of these may not be sampled presently.



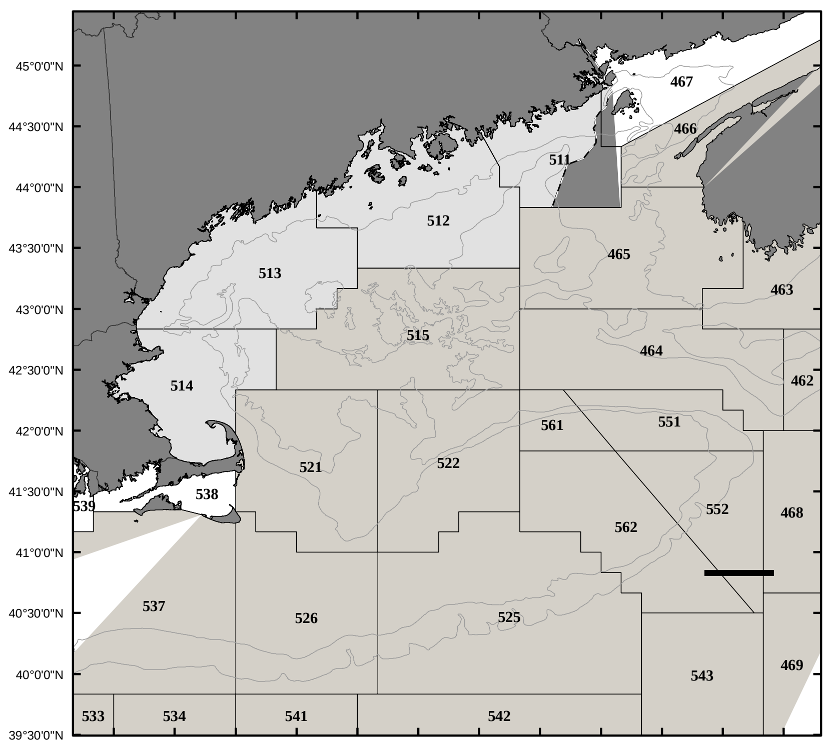


Figure 3. Statistical areas used for reporting commercial catches.

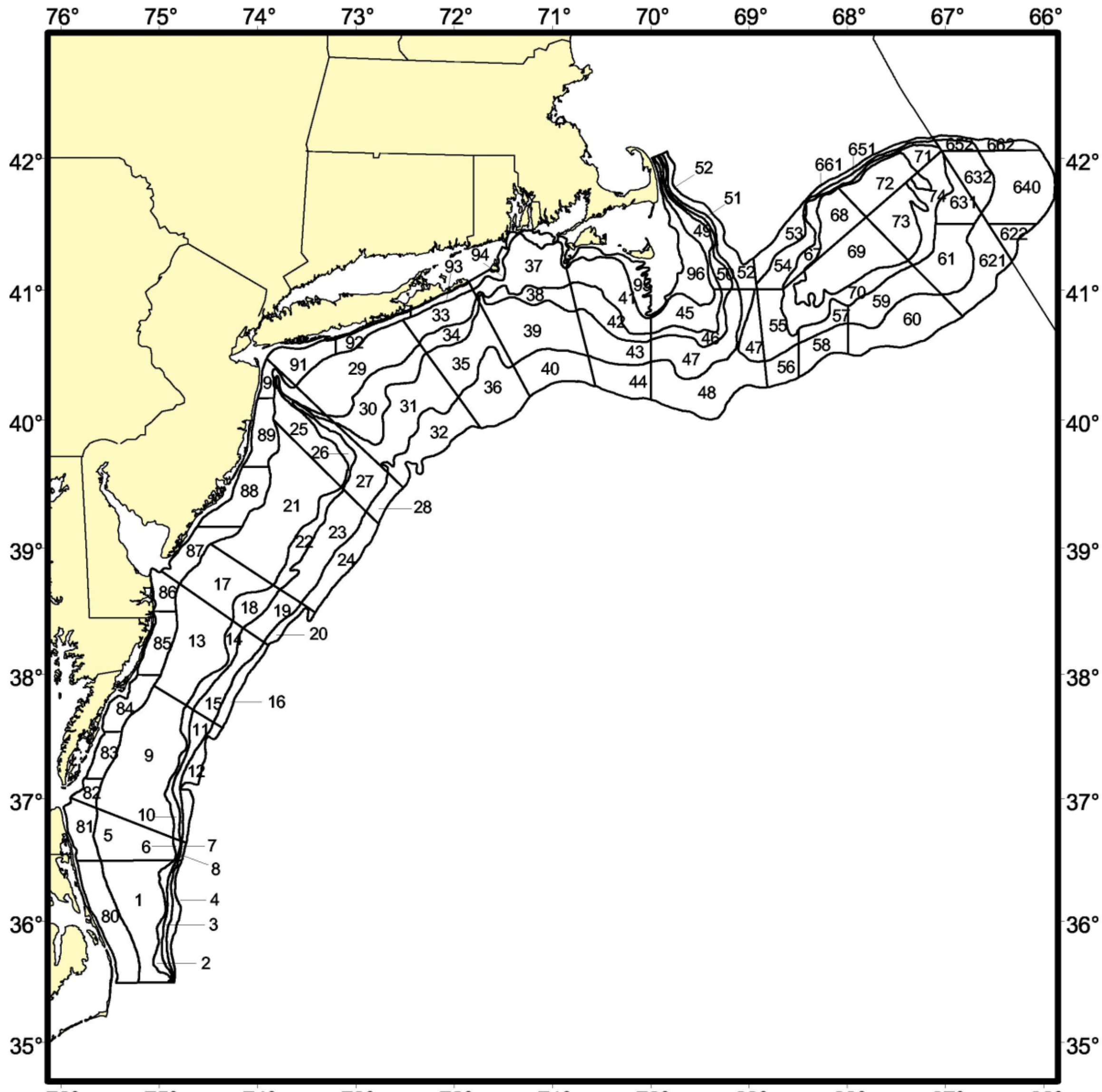


Figure 4. Northeast Fisheries Science Center shellfish resource survey strata, along the east coast of the US.

A. SEA SCALLOP ASSESSMENT SUMMARY FOR 2018

State of Stock

The SARC concluded that during 2017 the sea scallop stock was not overfished and overfishing was not occurring. Estimated biomass (40+ mm shell height; SH) in 2017 was 317,334 mt meats (Figure A1). Using the new recommended reference points, biomass was about 2.7 times B_{TARGET} (B_{MSY}) of 116,766 mt meats, and over five times the $B_{THRESHOLD}$ (½B_{MSY}) of 58,383 mt meats. The probability that the stock was overfished in 2017 is very close to zero based on the recommended reference points. Using the models from the previous assessment (NEFSC 2014), the estimated 2017 biomass of 395,610 mt meats was also well above the B_{TARGET} (B_{MSY}) of 96,480 mt meats, and the $B_{THRESHOLD}$ (½B_{MSY}) of 48,240 mt meats. These biomass estimates do not include the scallops located in the deep water southeast portion of Nantucket Lightship Area.

The estimated fishing mortality rate during 2017 was F of 0.12 (CV of 0.07; Figure A2). Based on the new recommended overfishing threshold reference point F_{MSY} of 0.64, the SARC concluded that overfishing was not occurring in 2017. The probability that overfishing occurred during 2017 was nearly zero based on the recommended reference points (Figure A6).

Projections

Projections are carried out by the Sea Scallop Plan Development Team (PDT) using a spatially-structured model (SAMS) that accommodates variability in recruitment, vital rates and fishing among sub-areas. Scallop management approaches are complex because they are spatially explicit and dependent on sub-area recruitment levels and other factors. SAMS was used in this assessment to provide example projection results where all areas are uniformly fished at F of 0.58 (Figure A3). Sensitivity analysis and a projection with more realistic assumptions regarding fishing mortality are provided in the full report. Stock biomass is likely to decline from record high levels during 2018-2020. However, biomass is expected to stay well above B_{MSY} and landings are expected to be well above average during that period.

Catch and Status Table: Sea Scallop

Catch, landings, discards, and biomass are in mt meats; recruitment is in millions.

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Commercial landings	22,273	26,129	25,927	26,653	25,915	18,664	15,343	16,207	18,439	23,458
Commercial discards	798	1,492	1,450	1,084	1,168	525	319	766	2,196	1,447
Catch used in assessment	22,273	26,129	25,927	26,653	25,915	18,664	15,343	16,207	18,439	23,458
Biomass	125,025	130,493	127,542	112,971	102,703	108,199	151,369	222,660	285,114	317,334
Recruitment (age 1)	2,853	2,475	2,249	5,099	3,494	30,195	16,596	6,519	3,281	NA
Fully selected F	0.40	0.40	0.34	0.36	0.43	0.35	0.21	0.19	0.14	0.12

Catch and Status Table (cont.): Sea Scallop.

Catch, landings, discards, and biomass are in mt meats; recruitment is in millions.

Year	Min	Max	Mean
Commercial landings[1]	1,793	28,997	12,807
Commercial discards[2]	9	2,661	950
Catch used in assessment[3]	3,212	28,997	15,240
Biomass[3]	16,680	317,334	88,035
Recruitment (age 1)[4]	479	30,195	3,850
Fully selected F[3]	0.12	1.28	0.46

[1]1965-2017
[2]1989-2017
[3]1975-2017
[4]1976-2016

Stock Distribution and Identification

Sea scallops are distributed from Cape Hatteras to Newfoundland, and are found in US waters of the Gulf of Maine, Georges Bank, Southern New England, and the Mid-Atlantic. Sea scallops in US waters were assessed based on two main stock regions – Georges Bank, including Southern New England, and the Mid-Atlantic. Results for Georges Bank and Mid-Atlantic were combined to characterize the core stock. Overfishing and overfished status was evaluated for the core stock, as specified by the current Sea Scallop Fishery Management Plan (NEFMC 2010). The small component of the stock that occurs in the Gulf of Maine was not included in the assessment of overfishing or overfished status although an evaluation for sea scallops in federal waters of Gulf of Maine was completed (Appendix A4 in assessment report). Sea scallops and their fishery in Canadian waters were not included in this assessment.

In 2012, a large cohort of scallops settled in the deep water, southeastern corner of the Nantucket Lightship Closed Area where historically they were of low density, and this area has been closely monitored since 2013. Scallops in this area are at high densities, growing slowly, and have not yet reached fishable size. Because of their unusual characteristics, these scallops were not included in the estimation models or the Catch and Status Table above, but their abundances and biomasses were estimated empirically using surveys.

Catches

Annual landings increased from about 8,000 mt meats in the mid-1980s to over 17,000 mt meats in 1990-1991, and then fell to between 5,000 and 8,000 mt meats during 1993-1998 (Figure A4). Landings increased considerably from 1998-2003, and stabilized at high levels during 2003-2012. Landings declined about 33% during 2013-2016, but rebounded in 2017. Annual landings during 2008-2017 averaged 22,101 mt meats, almost twice the long-term mean. Discarding occurs mainly due to catch of undersized scallops; high-grading may also occur, mainly in rotational access areas that are managed under trip limits. Discards averaged about 950 mt meats during 1992–2017, with an assumed discard mortality rate of approximately 20%. Discards were the highest during 2000-2004, peaking at 2,500 mt meats, but have generally been lower since, likely due to changes in gear regulations. However, large year classes can still induce elevated discard rates when they are below commercial size, as occurred in 2016. Although discards are not explicitly included in the CASA assessment model, they are minor relative to catch, and are implicitly taken into account as part of the non-landed (incidental) fishing mortality term that is included in the CASA model.

Data and Assessment

Three main survey time series were used in this assessment: dredge, drop camera and Habcam (Figure A7). Sea scallop dredge surveys have been conducted since 1975 and with the same lined gear since 1979. Currently, this survey is conducted partially by the Virginia Institute of Marine Science (VIMS) on commercial vessels, and partially by the NEFSC on a research vessel. The other two surveys are conducted with cameras: drop camera surveys from 2003-2012, 2014-2015 and 2017, and towed digital camera surveys (Habcam) from 2011-2017 (Georges Bank) and 2012-2017 (Mid-Atlantic). Biomass and abundance estimates from these three independent sources are generally similar (Figure A7), except the most recent years, where the dredge survey is below the two optical surveys that recorded extremely high densities of scallops in some areas. This is likely because the dredge survey gear has reduced efficiency when scallop density is high. The dredge survey index was adjusted in the model for areas of high density based on examination of independent empirical data to account for this reduced efficiency in the last three years.

A size-structured, forward-projecting stock assessment model (CASA) used in previous assessments (NEFSC 2007; NEFSC 2010; NEFSC 2014) was also used in this assessment. Model input data included the three main surveys listed above, the NEFSC winter bottom trawl (Mid-Atlantic), commercial landings, shell heights from port and at-sea sampling of commercial landings, and growth increment data from analysis of shell growth rings. Separate CASA models were used for Mid-Atlantic and the open and closed portions of Georges Bank. For the first time in this assessment, natural mortality was estimated by year within the models. For the closed portion of Georges Bank, natural mortality was assumed constant across sizes, but varied by year. The other two CASA models estimated size-specific natural mortality by year.

Fishing Mortality

Fully-recruited fishing mortality generally increased from 1975 to the early 1990s, peaking at 1.28 in 1991 (Figure A2). Fishing mortality then rapidly declined, and remained fairly steady from 1999-2012 averaging around 0.35. Fishing mortality rates for the whole stock declined from 0.21 in 2014 to 0.12 (SE of 0.01) in 2017, the minimum for the entire 1975-2017 time series.

Biomass

Sea scallop biomass is measured in terms of meat weight. Biomass declined from 1975 through the early eighties and remained low through the mid-1990s (Figure A1). Biomass increased rapidly from 1994-2003, due to the implementation of closed areas, gear regulations, and effort reduction measures. Biomass declined about 40% during the next decade before rapidly increasing due to large year classes in both Georges Bank and the Mid-Atlantic. Biomass in 2017 was estimated at 317,334 mt meats (SE of 19,040), the maximum for the time series and over four times B_{MSY}.

Recruitment

Age-1 recruitment has generally been higher in the most recent 20 years (Figure A5). The 2012 year class on Georges Bank and the 2013 year class in the Mid-Atlantic were both the highest in their regions.

Biological Reference Points

Reference points were calculated using the SYM model (Hart 2013), which includes spawner-recruit relationships, per recruit calculations, and uncertainty in all parameters, as in the last two benchmark assessments. SYM was configured to be consistent with assumptions and calculations of the CASA model. In particular, selectivity, spawning biomass and recruitment estimates in SYM were obtained from the CASA model. The biological reference points for the whole stock recommended by the SARC-65 in 2018 are F_{MSY} = 0.64, B_{MSY} = 116,766 mt meats, $B_{Threshold}$ = ½ B_{MSY} = 58,383 mt meats, and MSY = 46,531 mt meats (Figure A6). The basis for the increase in F_{MSY} from 0.48 in the previous assessment is detailed in the full report, but is primarily due to increases in estimated adult natural mortality.

Special Comments

- Estimates of spawning stock biomass based on gonad weights and stock biomass based on meat weights were presented at this meeting and biological reference points and stock status recommendations were developed for both times series. While using spawning stock biomass to develop reference points makes strong sense biologically, a number of practical aspects of this approach still need to be considered before full implementation. The SARC-65 panel recommends that both time series be reported in the present assessment, but that stock biomass based on meat weights be used as the criterion for determining stock status within this 2018 assessment. The panel recommends further development of the gonad-based spawning stock biomass metrics.
- Area management plays an important role in sea scallop stock dynamics, with much of the biomass during some periods located in long-term and/or rotational closures. Under area management, the reported fishing mortality calculated across all areas underestimates fishing mortality in areas where fishing occurs. Such spatial heterogeneity in fishing mortality may reduce yield compared to fishing uniformly across areas (Hart 2001, Truesdell et al. 2015). It is possible that the areas open to fishing could be depleted even if overfishing is not occurring on the whole-stock (Hart 2003). As long-term closures have reopened, differences between whole stock and open areas fishing mortality will be reduced while overall fishing mortality is likely to increase.
- Sea scallop population dynamics in recent years have been dominated by two very large cohorts. These have been the 2012 year class on Georges Bank, primarily located in the

Nantucket Lightship Area, and the 2013 year class in the Mid-Atlantic, much of which is in the Elephant Trunk rotational area off of Delaware Bay. Such high densities of scallops have rarely been observed. For this reason, forecasts of the future of these large year classes are highly uncertain.

- In this assessment three models were used. The CASA model estimated historical biomass and fishing mortality rates at a regional scale. The SYM model estimated biological reference points based on CASA outputs. The SAMS model forecasted future abundance, biomass, and landings at a finer spatial scale to address management needs. While the structure of each model is similar, they are used to address distinct questions for assessment and management.
- The SARC-65 panel notes that projections developed by the PDT use the most current survey information as a starting point for SAMS projections because the surveys are more up-to-date than the CASA output.
- The CASA model calculates annual estimates of additional mortality that cannot directly be accounted for by fishery landings. Most of this mortality is due to natural causes (principally predation and disease), but there remains a small proportion that may be due to unaccounted fishing-related mortality. For brevity, the additional mortality is included in the natural mortality calculations.
- There are periods when the model biomass estimates are below the survey observations, particularly in the Mid-Atlantic and Georges Bank Open. The main reason for this is that observation error, natural mortality, and fishing mortality can be confounded in the model. Generally the model allows the survey indices to have high levels of observation error but in some years the correlated deviations suggest some component of mortality is missing from the model for these years. It is unclear whether this is due to underestimation of natural mortality, fishing mortality, or both.
- Fully-recruited fishing mortalities prior to 2005 cannot be directly compared to the SARC-65 recommended F_{MSY} estimate of 0.64 due to changes in fishery size-selectivity over time.

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Figures

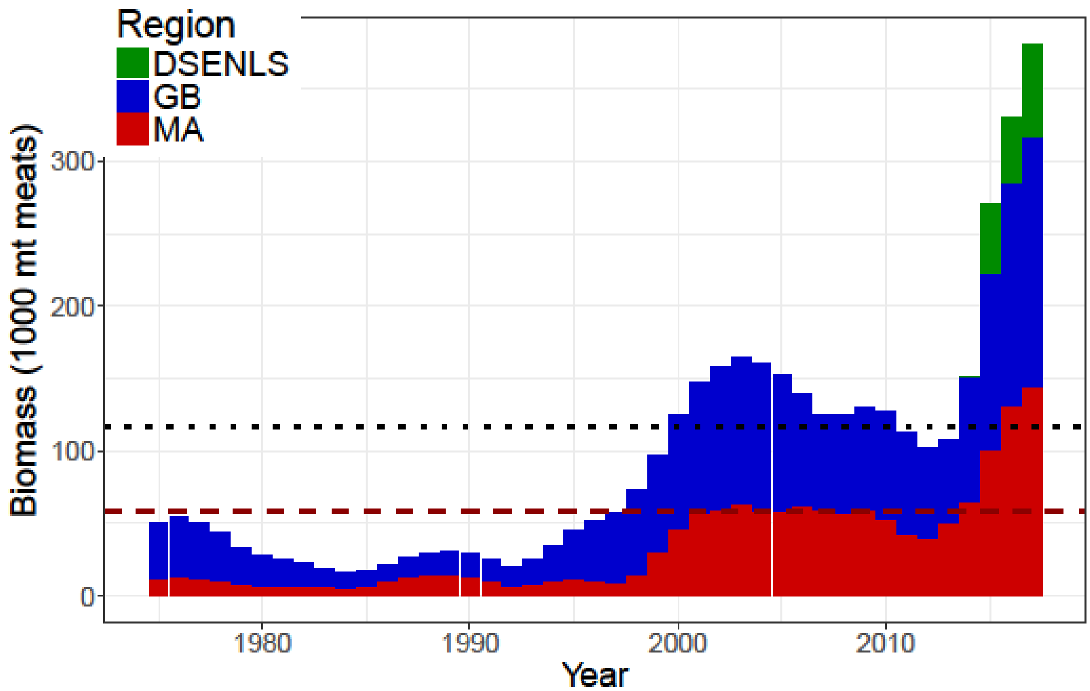

Figure A1. Sea scallop biomass (40+ mm SH) during 1975-2017, in Mid-Atlantic (MA, red), Georges Bank (GB, blue), and in the deep-water, southeast corner of Nantucket Lightship (DSENLS, green) compared to whole stock biomass reference points: The biomass target B_{MSY} is the black dotted line, and the overfished biomass threshold $B_{MSY}/2$ is the red dashed line.

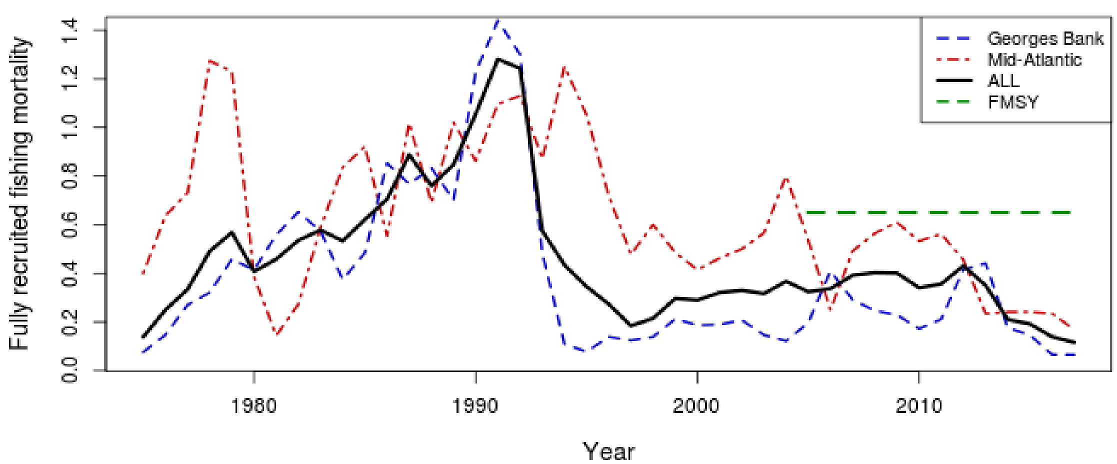

Figure A2. Fully-recruited annual fishing mortality rate for sea scallops during 1975-2017. Trends are different for partially recruited scallops because of changes in commercial size-selectivity over time. The overfishing threshold F_{MSY} is shown only for the most current selectivity period; it would have been less in earlier periods when the selectivity was different.

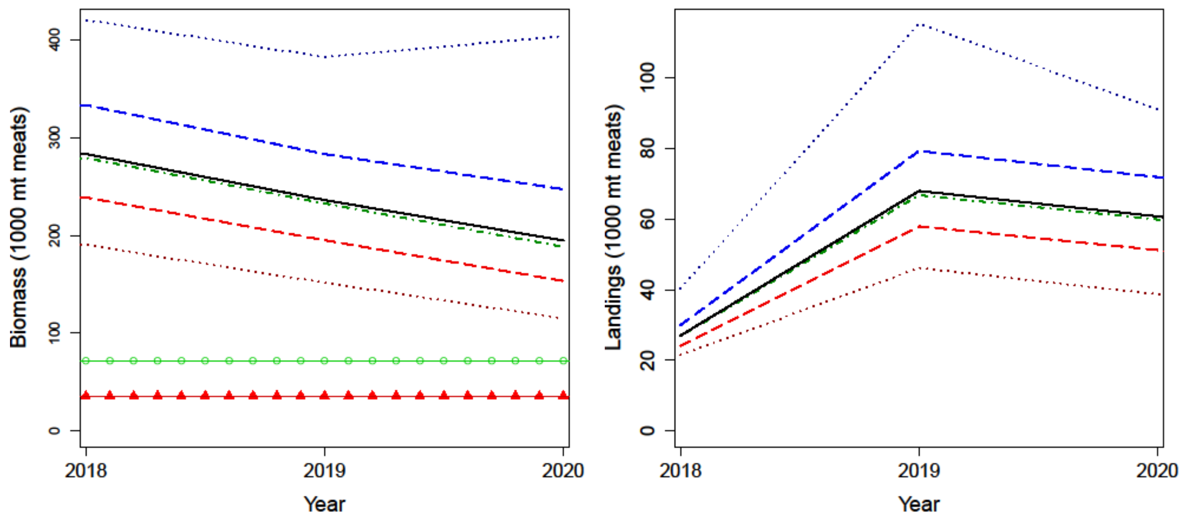

Figure A3. Projected sea scallop biomass (left) and landings (right) assuming fishing mortality is equal to F = 0.58 in all areas. The dotted lines are the minimum and maximum of the 1000 model runs, the dashed lines are the 10th and 90th percentiles, the solid line is the mean and the dashed dotted line is the median of the runs. The biomass plot also shows B_{MSY} (green line with circles) and the overfished threshold of $B_{MSY}/2$ (red line with triangles).

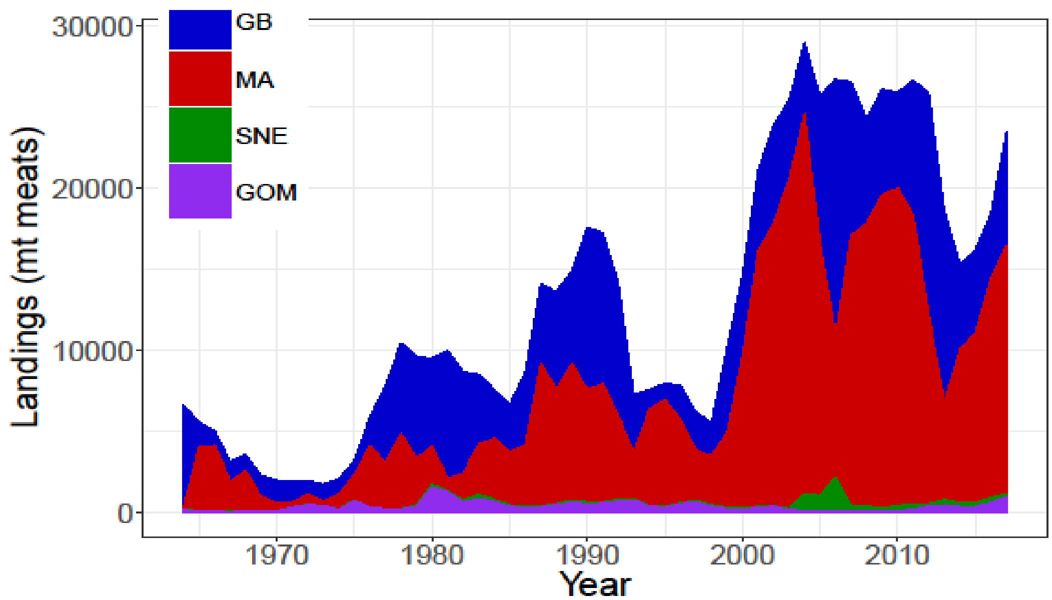

Figure A4. Scallop landings by region (Georges Bank [GB], Mid-Atlantic [MA], Southern New England [SNE], Gulf of Maine [GOM]), 1965-2017.

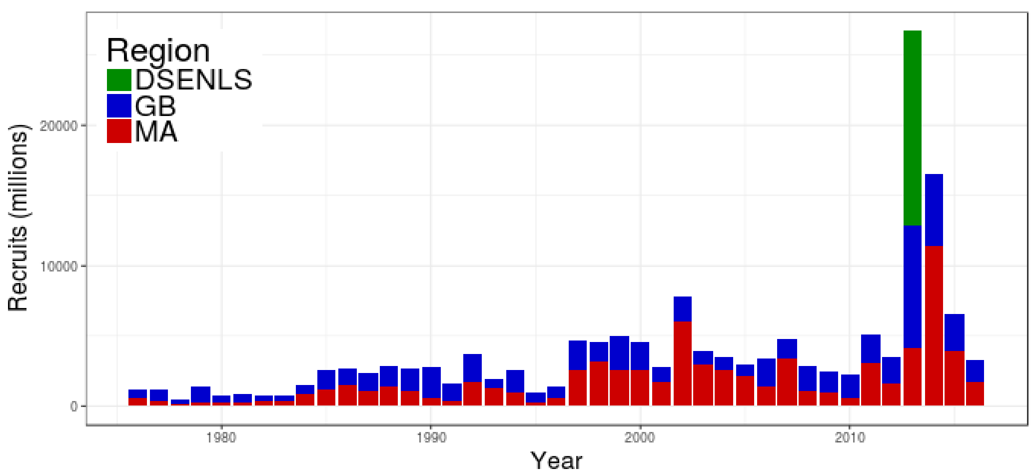

Figure A5. Sea scallop recruitment (age 1) by region, 1975-2016. Regions are: Mid-Atlantic (MA, red), Georges Bank (GB, blue) and the deep-water, southeast corner of Nantucket Lightship Closed Area (DSENLS, green).

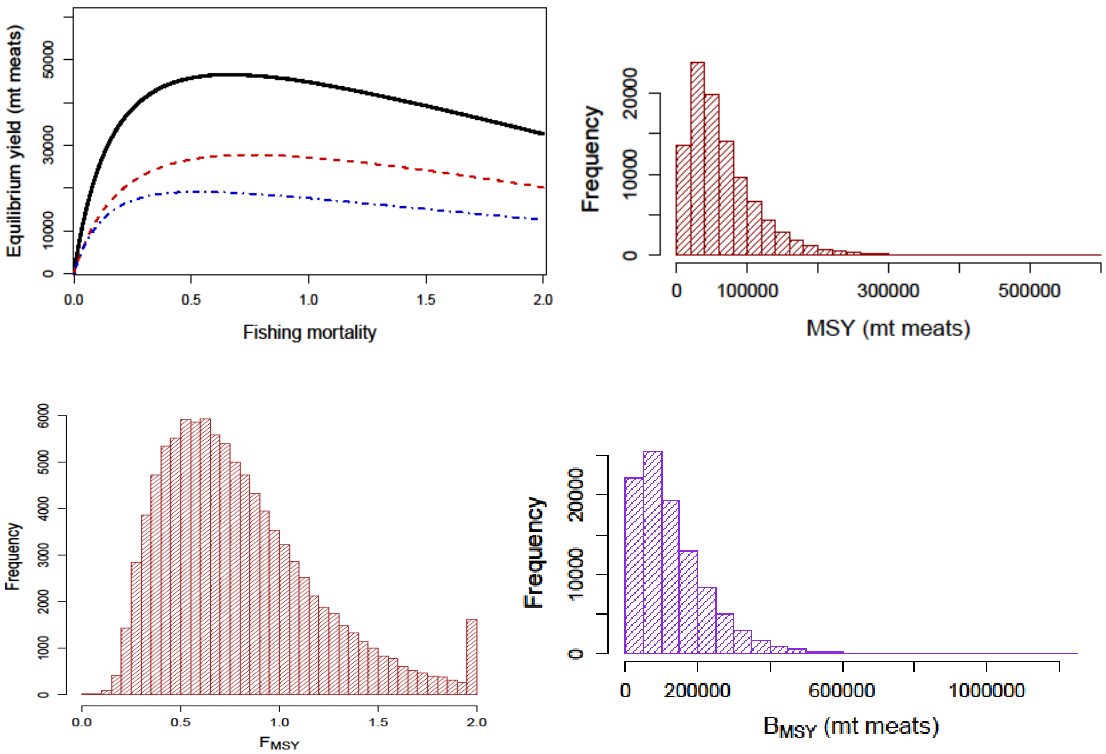

Figure A6. SYM reference point results for sea scallop. Top left: Median yield curves for Georges Bank (dashed-dotted blue line), Mid-Atlantic (dashed red line), and total (solid black line). Distribution of estimated MSY (top right), F_{MSY} (bottom left), and B_{MSY} (bottom right) out of 100,000 model runs.

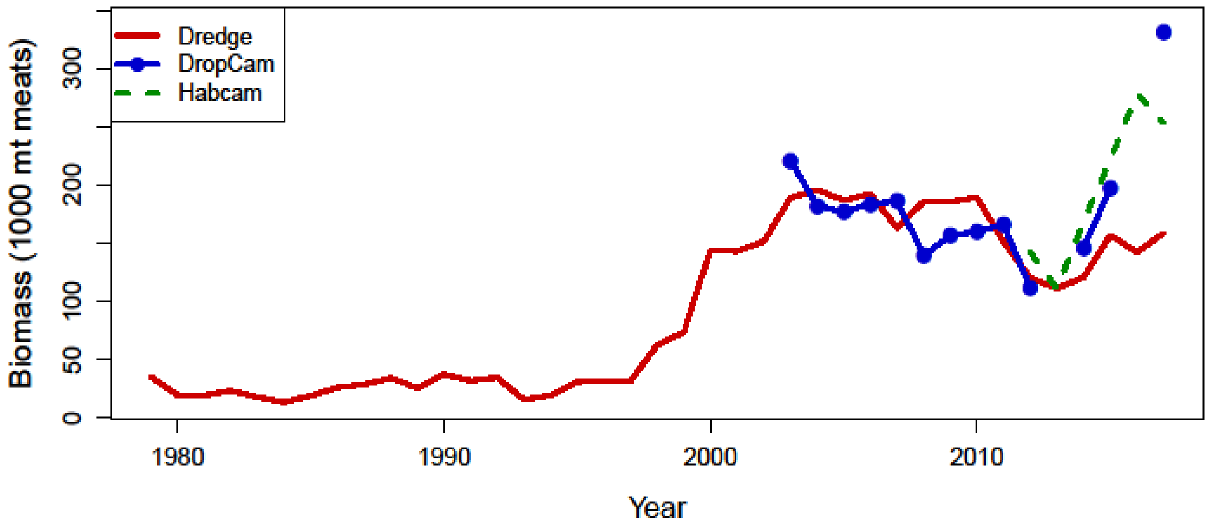

Figure A7. Total biomass (mt meats) estimates of sea scallop from the three survey time series, not including the deep water southeast portion of Nantucket Lightship Closed Area 1979-2017.

B. ATLANTIC HERRING ASSESSMENT SUMMARY FOR 2018

State of Stock

Spawning stock biomass (SSB) was estimated to be 141,473mt in 2017 and average fishing mortality rate over ages 7-8 (F) was estimated to be 0.45 (Figure B1). These estimates are derived from an age-structured model proposed as the best scientific information available for determining the stock status for Atlantic herring.

Maximum sustainable yield (MSY) reference points were estimated based on a proxy overfishing threshold of $F_{40\%}$. $F_{MSY\ proxy}$ = 0.51, $SSB_{MSY\ proxy}$ = 189,000 mt (½ $SSB_{MSY\ proxy}$ = 94,500 mt), and MSY_{proxy} = 112,000 mt. Based on a comparison of these MSY_{proxy} reference points with the estimates of F and SSB for 2017, the SARC concluded that the stock is not overfished and overfishing is not occurring (the probability of overfishing P(F>Fmsy) is 24% and the probability of being overfished P(SSB<½ $SSB_{MSY\ proxy}$) is 2%, Figure B3).

Projections

Short-term projections of future stock status were conducted based on results of the Age Structured Assessment Model (ASAP, Legault and Restrepo 1999). It was not necessary to correct projections for retrospective patterns. Uncertainty in the starting conditions for projections was derived from the results of the assessment model. Age 1 recruitment for 2018 was derived from the estimated recruitments for 2013-2017, whereas that for 2019-2021 was drawn from 1965-2015. The estimates of recruitment from 2016-2017 were excluded from the latter calculations because they were highly uncertain. Selectivity at age equaled the catch-weighted selectivities at age from the mobile and fixed fleets over the last five years. These selectivities were generally similar to that for the mobile fleet. Weights at age and maturity at age were the averages over years 2013-2017.

It is unlikely the 2018 Acceptable Biological Catch (ABC) will be fully utilized. Consequently, two example projections were conducted to address two catch scenarios in 2018 (Table B1): 1) assumed catch equal to the 2018 ABC (i.e., 111,000 mt), and 2) assumed catch equal to half the 2018 ABC (i.e., 55,000 mt). In both scenarios $F_{7\text{-}8}$ was fixed at the overfishing threshold (0.51) during 2019-2021. Projected catch and SSB were higher in Scenario 2 than Scenario 1. Likewise, the probability of overfishing in 2018 and the probability of the stock being overfished in each year were less in Scenario 2 than Scenario 1.

Table B1. Results of short-term projection under two scenarios differing in assumed 2018 catch.

Scenario 1	**2018**	**2019**	**2020**	**2021**
Catch (mt)	111,000	13,700	31,000	55,700
$F_{7\text{-}8}$	1.7	0.51	0.51	0.51
SSB (mt)	32,900	19,700	31,700	85,800
P(overfishing)	0.95	--	--	--
P(overfished)	0.96	0.94	0.93	0.58

Scenario 2	**2018**	**2019**	**2020**	**2021**
Catch (mt)	55,000	28,900	38,000	59,400
$F_{7\text{-}8}$	0.58	0.51	0.51	0.51
SSB (mt)	75,300	43,500	42,600	91,000
P(overfishing)	0.69	--	--	--
P(overfished)	0.76	0.92	0.91	0.53

As estimates of recent recruitments have been below average, a projection was also developed using age 1 recruitment estimated at half the average recruitment for the period 1965-2015. This projection gave somewhat more pessimistic results in terms of short-term fishery performance and stock status (see Appendix B8 in full herring assessment report of SAW65).

Catch and Status Table: Atlantic herring

(Weights in mt, recruitment in millions, arithmetic means; minimum, maximum and mean values for years 1965-2017)

Year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
US mobile catch	84,650	103,458	67,191	82,022	87,162	95,182	92,566	80,465	62,307	47,889
US fixed catch	31	98	1,263	422	9	9	518	738	1,208	258
New Brunswick weir catch	6,448	4,031	10,958	3,711	504	6,431	2,149	146	4,060	2,103
Total catch	91,129	107,587	79,413	86,155	87,675	101,622	95,233	81,350	67,574	50,250
Spawning stock biomass	207,711	139,353	121,661	185,013	243,767	210,106	330,492	264,982	175,698	141,473
Recruitment (age 1)	2712	10580	2364	2110	6942	1370	1608	776	175	392
Fully selected F	0.58	0.94	0.72	0.61	0.60	0.65	0.51	0.47	0.47	0.45

Catch and status table, Atlantic herring, cont'd:

Year	Min	Max	Mean
US mobile catch	26,883	421,091	111,496
US fixed catch	6	58,739	8,631
New Brunswick weir catch	146	44,112	20,125
Total catch	44,613	477,767	140,252
Spawning stock biomass	53,084	1,352,730	312,736
Recruitment (age 1)	175	14035	4163
Fully selected F	0.13	1.04	0.57

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 (Correia 2012).

Catches

US catch data were reported for two aggregate gear types, fixed and mobile gears, during 1965-2017. The reported catch is a sum of landings and self-reported discards, but discard estimates have only been available since 1996 and were assumed to be zero prior to 1996. Available discard estimates, however, are generally less than 1% of landings and do not represent a significant source of mortality (Wigley et al. 2011).

New Brunswick, Canada weir catches were provided for the years 1965-2017 and were combined with US fixed gear catches for the purposes of the assessment.

Catch in the mobile gear fishery peaked in the late 1960s and early 1970s, largely due to foreign fleets (Figure B4). Catch in the US fixed gear fishery has been variable, but has been relatively low since the mid-1980s (Figure B4). Catch in the New Brunswick weir fishery has also declined since the 1980s (Figure B4).

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

Data and Assessment

In the 2012 stock assessment (NEFSC 2012), the natural mortality rates during 1996-2011 were increased by 50% to resolve a retrospective pattern and to ensure that this additional mortality was consistent with observed increases in estimated consumption of herring by predators. In the 2015 assessment (Deroba 2015), a retrospective pattern re-emerged and the additional mortality was no longer consistent with estimated consumption. Consequently, M was reevaluated in this 2018 assessment, and M was set equal to 0.35 for all years and ages.

Similar to the previous assessment, maturity-at-age varied through time. The time variation in maturity was based on observed proportions mature-at-age from commercial fishery samples in quarter three (July-September) of each year. This represents a change from the previous assessment when predictions of maturity-at-age from annual fits of generalized additive models (GAM) were used instead of the empirical observations. The GAMs were used previously to reduce the effect of sampling noise, but sampling intensity was considered sufficient to make the empirical observations representative of temporal changes in maturity and unlikely to be affected by sampling noise, making the GAMs unnecessary.

Abundances (i.e., arithmetic mean numbers per tow) from the NMFS summer shrimp survey and the spring and fall multispecies bottom trawl surveys were used in the assessment model along with annual coefficients of variation and age composition when they were available. The spring and fall surveys had three time stanzas: 1965-1984, 1985-2008, 2009-2017 to account for the changes in vessel and gear type.

An acoustic time series collected during the NMFS fall bottom trawl survey was also used as an index of age 3+ herring abundance.

Fishing Mortality

The average F between ages 7 and 8 was used for reporting results related to fishing mortality ($F_{7\text{-}8}$) because these ages are fully selected by the mobile gear fishery, which has accounted for most of the landings since 1986. $F_{7\text{-}8}$ in 2017 equaled 0.45 (80% probability interval: 0.32-0.57), and ranged from 0.13 in 1965 to 1.04 in 1975 (Figure B1).

Biomass

The 2017 SSB was 141,473 mt (80% probability interval: 114,281-182,138), and ranged from 53,084 mt in 1982 to 1,352,700 mt in 1967 (Figure B1). Total biomass in 2017 was 239,470 mt, and ranged from 169,860 mt in 1982 to 2,035,800 mt in 1967.

Recruitment

Age-1 recruitment has been below average since 2013 (Figure B2). The time series high of 1.4 billion age-1 fish was estimated in 1971. The estimates for 2009 and 2012 are of relatively strong cohorts, as in previous assessments. The time series low of 1.7 million fish occurred in 2016, and the second lowest of 3.9 million fish occurred in 2017, although this estimate is highly uncertain. Four of the six lowest annual recruitment estimates have occurred since 2013 (2013, 2015, 2016, and 2017).

Biological Reference Points

MSY reference points from the previous assessment (Deroba 2015) were based on the fit of a Beverton-Holt stock-recruitment curve. The ability to estimate the stock-recruit curve deteriorated in this 2018 assessment. Proposed reference points from SARC65 in 2018 no longer rely on a stock-recruit relationship; thus MSY reference points were estimated based on a proxy of $F_{40\%}$. $F_{MSYproxy} = 0.51$, $SSB_{MSYproxy} = 189{,}000$ mt (½ $SSB_{MSYproxy} = 94{,}500$), and $MSY_{proxy} = 112{,}000$ mt.

Special Comments

- Note that based on the recent run of below average estimated annual recruitments and the assumed catch in 2018 in both example projection scenarios (Table B1), the projected status would change to the stock being overfished and overfishing occurring in 2018 and likely overfished in years 2019-2021.
- If the recent estimates (since 2013) of poor recruitment are confirmed and continue into the future, then projected stock status will continue to decline.
- The model's reduced ability to estimate the stock-recruit relationship is likely related to changes in M and various likelihood penalties.
- Selectivity, natural mortality, and the lack of a stock-recruitment curve have changed from the previous assessment, thus preventing comparison of the F_{MSY} between this assessment and the previous assessment.

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Figures

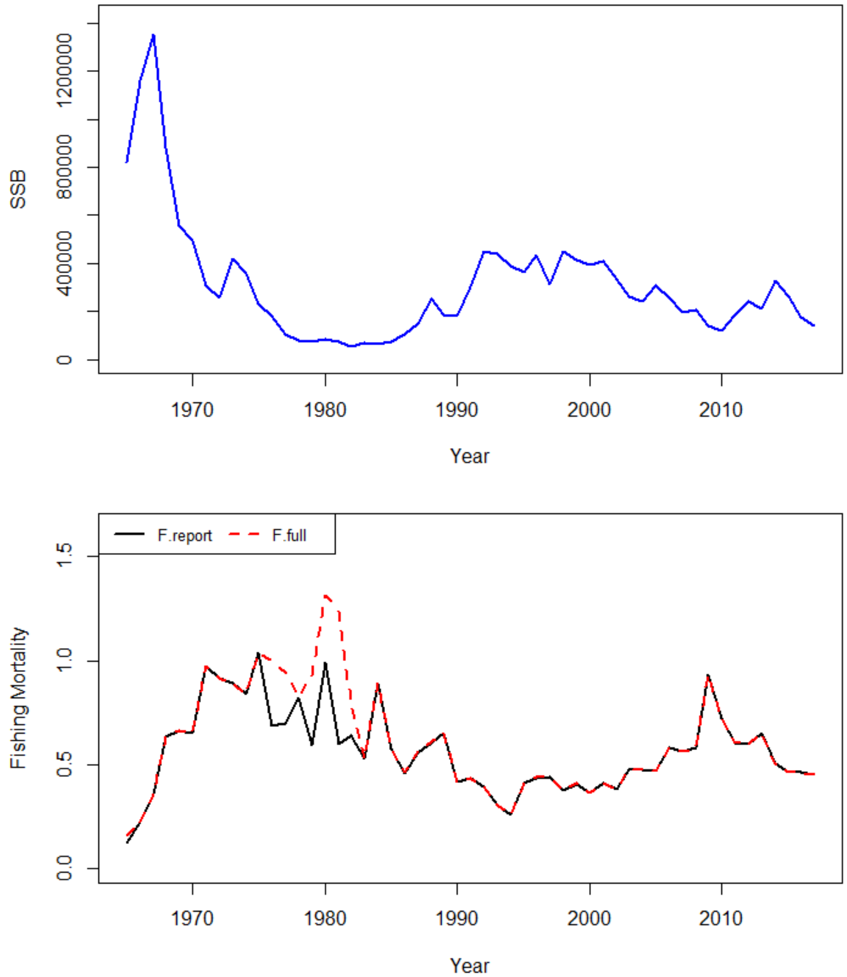

Figure B1. Atlantic herring spawning stock biomass (mt) and fishing mortality (F.report averaged over ages 7 and 8; F.full is fully selected) time series from the ASAP model for 1965-2017

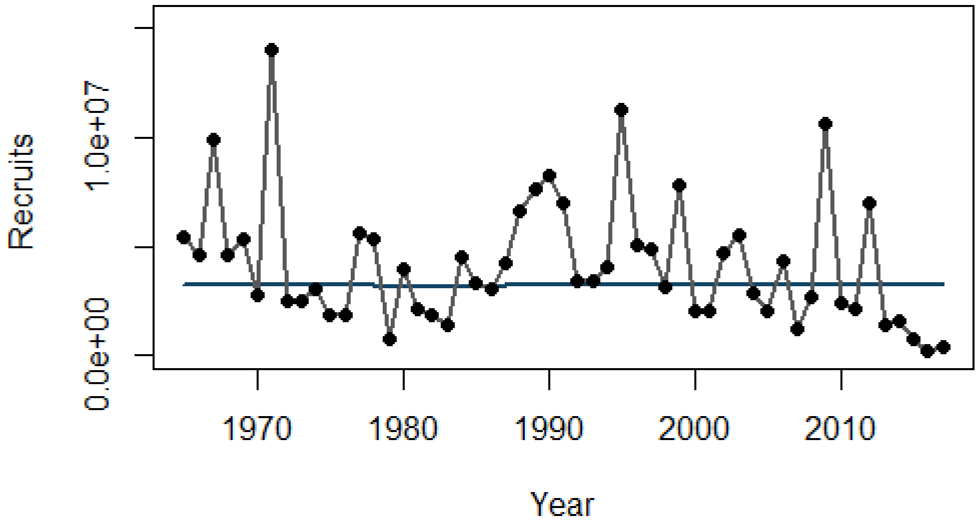

Figure B2. Atlantic herring annual recruit (000s) time series, 1965-2017. The horizontal line is the average over the time series.

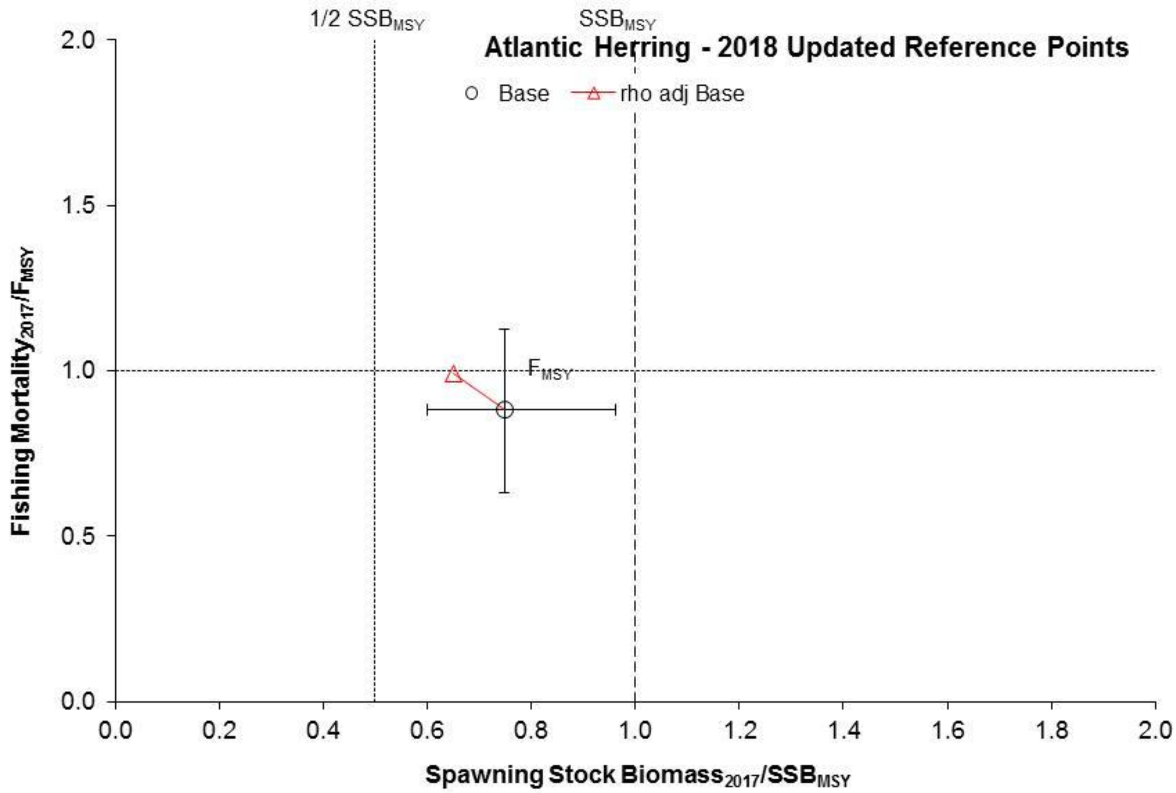

Figure B3. Atlantic herring stock status based on the ASAP model. Error bars represent the 80% probability intervals. The red triangle represents the model result if an adjustment were to be made for the retrospective pattern.

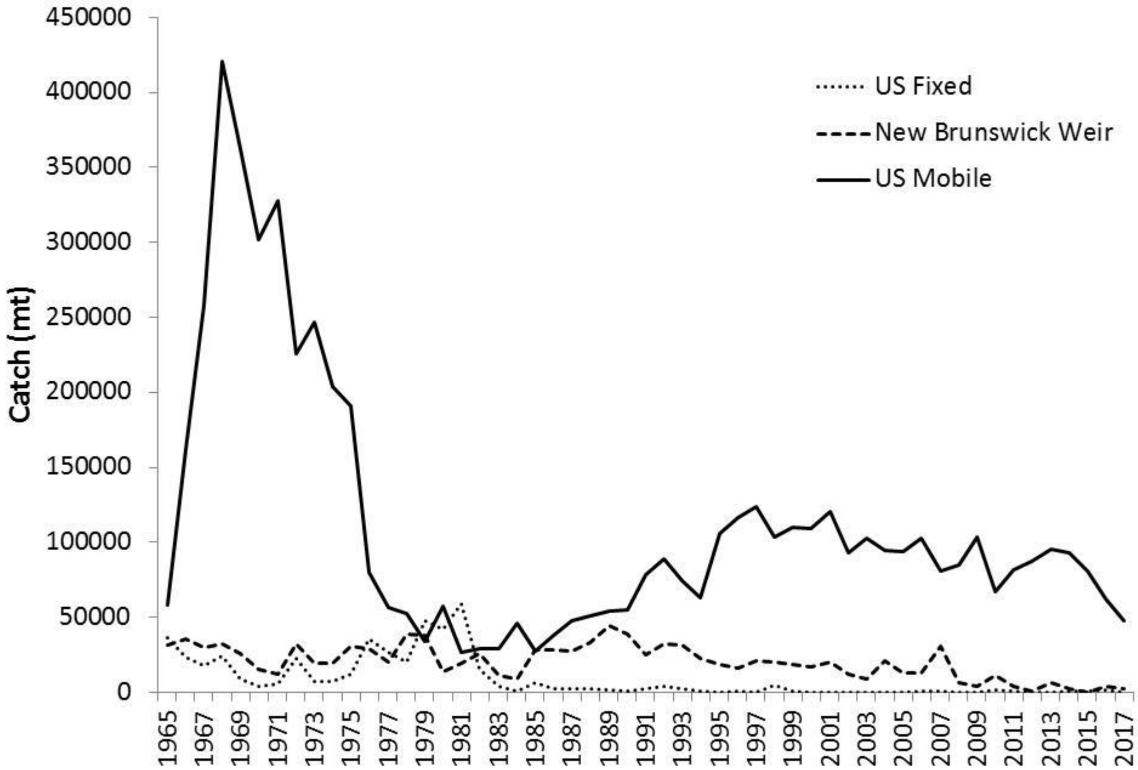

Figure B4. Atlantic herring catch for the US mobile fleet, US fixed fleet, and New Brunswick, Canada, weirs, for 1965-2017

Appendix: Stock Assessment Terms of Reference for SAW/SARC-65, June 26-29, 2018

A. Sea scallop

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

2. a. Present the survey data being used in the assessment (e.g., regional indices of relative or absolute abundance, recruitment, size data, etc.). Characterize the uncertainty and any bias in these sources of data.

3. Summarize existing data, and characterize trends if possible, and define what data should be collected from the Gulf of Maine area to describe the condition and status of that resource. If possible provide a basis for developing catch advice for this area.

4. Investigate the role of environmental and ecological factors in determining stock distribution and recruitment success. If possible, integrate the results into the stock assessment.

5. Estimate annual fishing mortality, recruitment and stock biomass for the time series, and estimate their uncertainty. Report these elements for both the combined resource and by sub-region. Include retrospective analyses (historical, and within-model) to allow a comparison with previous assessment results and previous projections.

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. Make a recommendation[a] about what stock status appears to be based on the existing model (from previous peer reviewed accepted assessment) and based on a new model or model formulation developed for this peer review.
    a. Update the existing model 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-5).
    c. Include descriptions of stock status based on simple indicators/metrics.

8. Develop approaches and apply them to conduct stock projections.
    a. Provide numerical annual projections (through 2020) and the statistical distribution (i.e., probability density function) of the catch at F_{MSY} or an F_{MSY} proxy (i.e. the overfishing level, OFL) (see Appendix to the SAW TORs). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. Use a

sensitivity analysis approach in which a range of assumptions about the most important uncertainties in the assessment are considered (e.g., terminal year abundance, variability in recruitment).

b. Comment on which projections seem most realistic. Consider the major uncertainties in the assessment as well as sensitivity of the projections to various assumptions. Identify reasonable projection parameters (recruitment, weight-at-age, retrospective adjustments, etc.) to use when setting specifications.
c. Describe this stock's vulnerability (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.

[a]NOAA Fisheries has final responsibility for making the stock status determination based on best available scientific information.

B. Atlantic herring

1. Estimate catch from all sources including landings and discards. Describe the spatial and temporal distribution of landings, discards, and fishing effort. Characterize uncertainty in these sources of data. Comment on other data sources that were considered but were not included.

2. Present the survey data being used in the assessment (e.g., regional indices of abundance, recruitment, state surveys, age-length data, food habits, etc.). Characterize the uncertainty and any bias in these sources of data.

3. Estimate consumption of herring, at various life stages. Characterize the uncertainty of the consumption estimates. Address whether herring distribution has been affected by environmental changes.

4. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series, and estimate their uncertainty. Incorporate ecosystem information from TOR-3 into the assessment model, as appropriate. Include retrospective analyses (both historical and within-model) to allow a comparison with previous assessment results and projections, and to examine model fit.

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

6. Make a recommendation[a] about what stock status appears to be based on the existing model (from previous peer reviewed accepted assessment) and based on a new model or model formulation developed for this peer review.
    a. Update the existing model 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-5).
    c. Include descriptions of stock status based on simple indicators/metrics.

7. Develop approaches and apply them to conduct stock projections.
    a. Provide numerical annual projections (through 2021) and the statistical distribution (i.e., probability density function) of the catch at F_{MSY} or an F_{MSY} proxy (i.e. the overfishing level, OFL) (see Appendix to the SAW TORs). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. Use a sensitivity analysis approach in which a range of assumptions about the most important uncertainties in the assessment are considered (e.g., terminal year abundance, variability in recruitment).
    b. Comment on which projections seem most realistic. Consider the major uncertainties in the assessment as well as sensitivity of the projections to various assumptions. Identify reasonable projection parameters (recruitment, weight-at-age, retrospective adjustments, etc.) to use when setting specifications.
    c. Describe this stock's vulnerability (see "Appendix to the SAW TORs") to becoming overfished, and how this could affect the choice of ABC.

8. If possible, make a recommendation about whether there is a need to modify the current stock definition for future assessments.

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

[a]NOAA Fisheries has final responsibility for making the stock status determination based on best available scientific information.

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)

Participation among members of a SAW Stock 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.

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

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

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

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