

Northeast Fisheries Science Center Reference Document 16-13

61st Northeast Regional
Stock Assessment Workshop
(61st SAW)
Assessment Summary Report

by the Northeast Fisheries Science Center

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Table of Contents

Introduction.....	1
Outcome of the Stock Assessment Review Meeting.....	2
Glossary.....	3
A. SURFCLAM ASSESSMENT SUMMARY FOR 2015.....	12
Status of the Stock.....	12
Projections.....	12
Catches.....	12
Stock Distribution.....	13
Landings.....	13
Data and Assessment.....	13
Spawning Stock Biomass.....	13
Fishing Mortality.....	14
Recruitment.....	14
Biological Reference Points.....	14
Special Comments.....	15
References.....	15
Tables.....	16
Figures.....	20
Appendix: Terms of Reference.....	24

SAW-61 ASSESSMENT SUMMARY REPORT

Introduction

The 61st SAW Assessment Summary Report contains summary and detailed technical information on one stock assessment reviewed during July 19-21, 2016 at the Stock Assessment Workshop (SAW) by the 61st Stock Assessment Review Committee (SARC-61): Atlantic surfclam (*Spisula solidissima*). The SARC-61 consisted of three external, independent reviewers appointed by the Center for Independent Experts [CIE], and an external SARC chairman from the MAFMC SSC. The SARC evaluated whether each Term of Reference (listed in the Appendix) was completed successfully based on whether the work provided a scientifically credible basis for developing fishery management advice. The reviewers' reports for SAW/SARC-61 are available at website: <http://www.nefsc.noaa.gov/nefsc/saw/> under the heading "SARC 61 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 $F_{\text{THRESHOLD}}$.

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 ($B_{\text{THRESHOLD}}$) 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 $B_{\text{THRESHOLD}}$ and overfishing is occurring if current F is greater than $F_{\text{THRESHOLD}}$. The table below depicts status criteria.

		BIOMASS		
		$B < B_{\text{THRESHOLD}}$	$B_{\text{THRESHOLD}} < B < B_{\text{MSY}}$	$B > B_{\text{MSY}}$
EXPLOITATION RATE	$F > F_{\text{THRESHOLD}}$	Overfished, overfishing is occurring; reduce F, adopt and follow rebuilding plan	Not overfished, overfishing is occurring; reduce F, rebuild stock	$F = F_{\text{TARGET}} \leq F_{\text{MSY}}$
	$F < F_{\text{THRESHOLD}}$	Overfished, overfishing is not occurring; adopt and follow rebuilding plan	Not overfished, overfishing is not occurring; rebuild stock	$F = F_{\text{TARGET}} \leq F_{\text{MSY}}$

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-61 Review Panel reports (available at <http://www.nefsc.noaa.gov/nefsc/saw/> under the heading “SARC-61 Panelist Reports”).

The Atlantic surfclam stock assessment was accepted by the SARC-61 panel. In 2015 overfishing was not occurring and the stock was not overfished. Population projections suggest that the population is unlikely to become overfished and that overfishing is unlikely to occur by 2025. Nine of the ten assessment Terms of Reference were met. The assessment was based on the Stock Synthesis III model (SS3). Commercial LPUE values show mostly declining trends, appearing to contradict increasing survey trends. Stock depletion may be real at a local level, but the limited coverage of the fishery suggests that the LPUE trends are not indicative of the stock as a whole.

The Panel endorsed the redefinition of the BRPs based on relative stock status. The new BRPs can be used to provide catch limit advice. The Panel noted that the fishing mortality threshold calculation uses an estimate of F_{MSY} . This value was derived from a simulation study, the details of which were not discussed by the Panel at the review meeting.

The assessment did not determine whether the surfclam resource should be considered as one unit stock throughout the species’ range in US federal waters or if regional stocks should be recognized. However, not meeting this ToR did not impact the overall acceptability of the assessment.

Due to the importance of the clam survey in this assessment, the Panel recommends caution in making any changes to the gear and survey vessel.

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 ($1,000,000 \times 0.00548$), leaving 994,520 alive. On day 2, another 5,450 fish die ($994,520 \times 0.00548$) 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:

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

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, F_{x%}, is the fishing mortality rate that reduces the SSB/R to x% of the level that would exist in the absence of fishing.

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

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

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

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

Limit Reference Points. Benchmarks used to indicate when harvests should be constrained substantially so that the stock remains within safe biological limits. The probability of exceeding limits should be low. In the National Standard Guidelines,

limits are referred to as thresholds. In much of the international literature (e.g., FAO documents), “thresholds” are used as buffer points that signal when a limit is being approached.

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

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

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

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

Maximum Spawning Potential (MSP). This type of reference point is used in some fishery management plans to define overfishing. The MSP is the spawning stock biomass per recruit (SSB/R) when fishing mortality is zero. The degree to which fishing reduces the SSB/R is expressed as a percentage of the MSP (i.e., %MSP). A stock is considered overfished when the

fishery reduces the %MSP below the level specified in the overfishing definition. The values of %MSP used to define overfishing can be derived from stock-recruitment data or chosen by analogy using available information on the level required to sustain the stock.

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

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

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

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

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

Recruitment. This is the number of young fish that survive (from birth) to a specific age or grow to a specific size. The specific

age or size at which recruitment is measured may correspond to when the young fish become vulnerable to capture in a fishery or when the number of fish in a cohort can be reliably estimated by a stock assessment.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

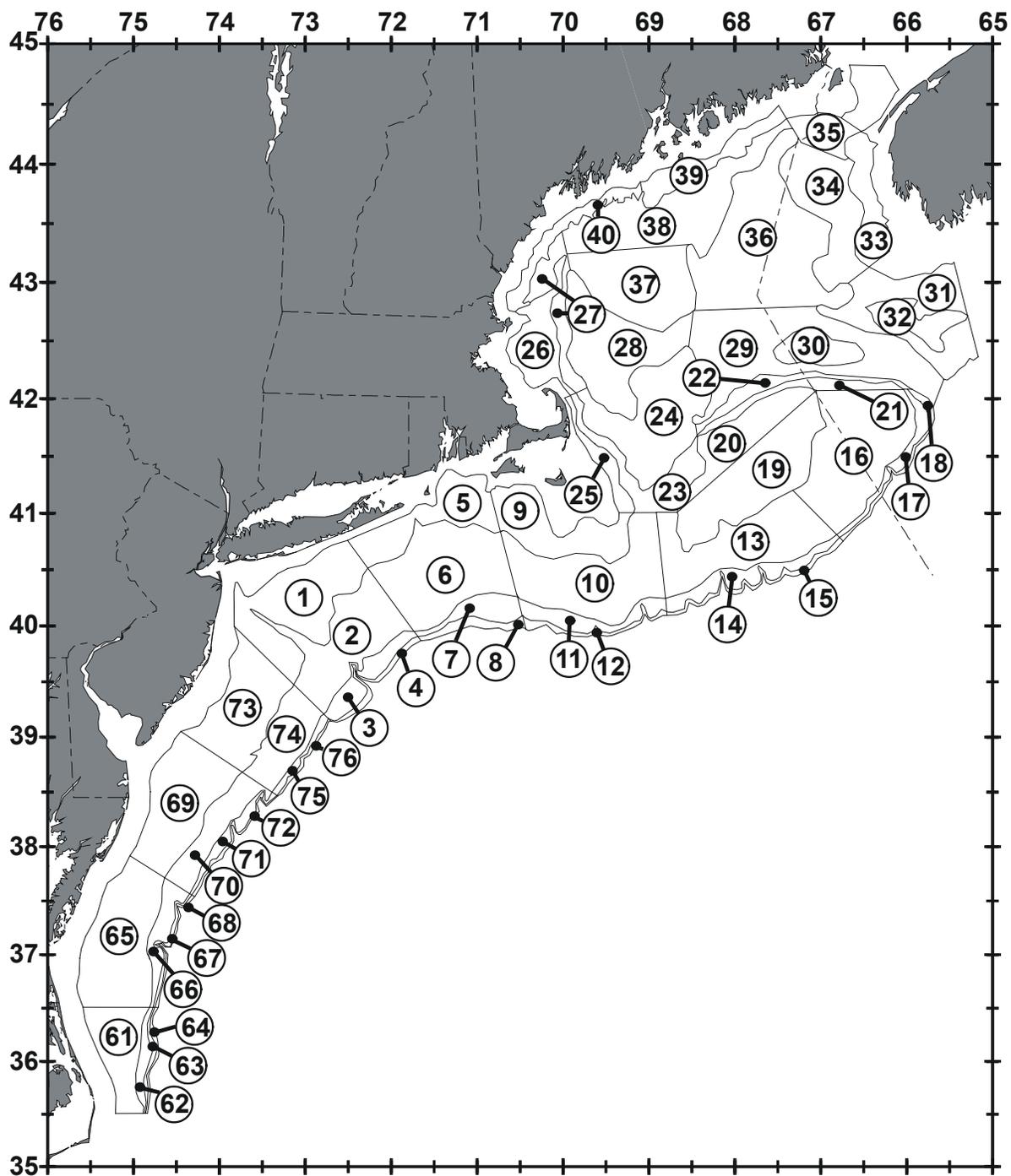


Figure 1. Offshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys. Some of these may not be sampled presently.

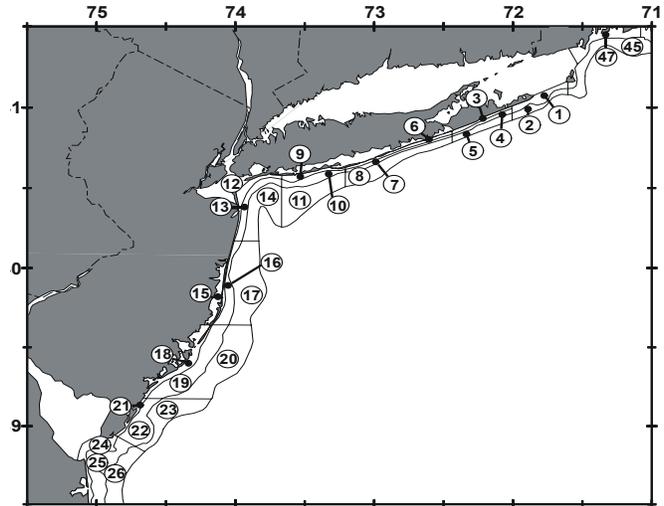
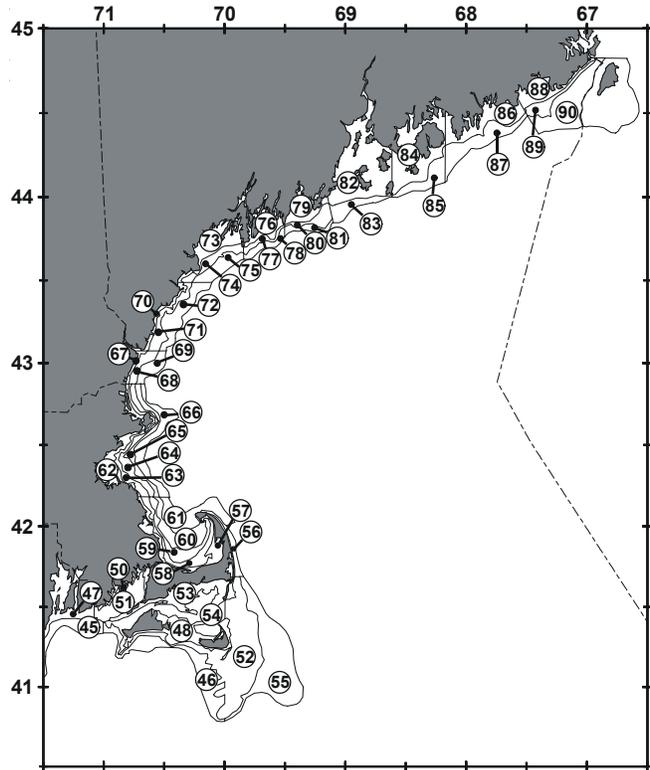
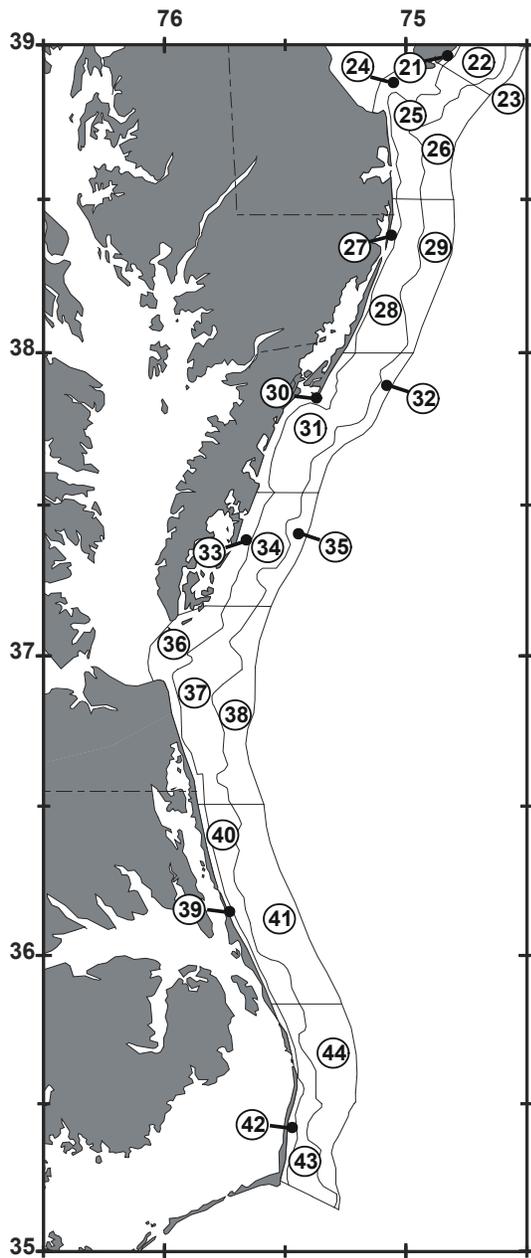


Figure 2. Inshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys. Some of these may not be sampled presently.

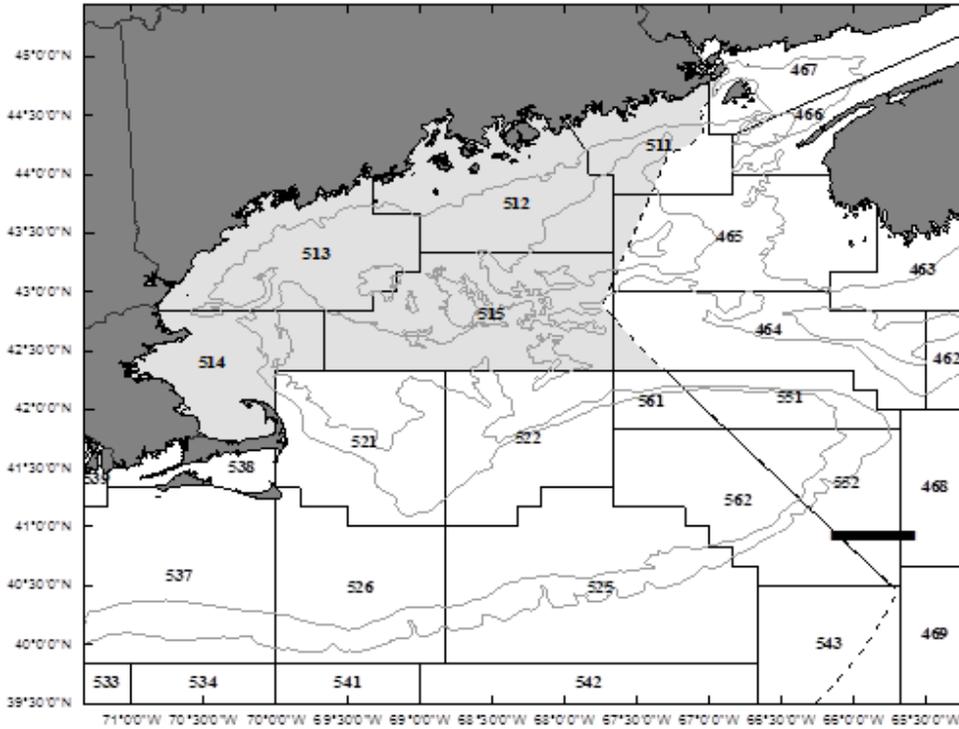
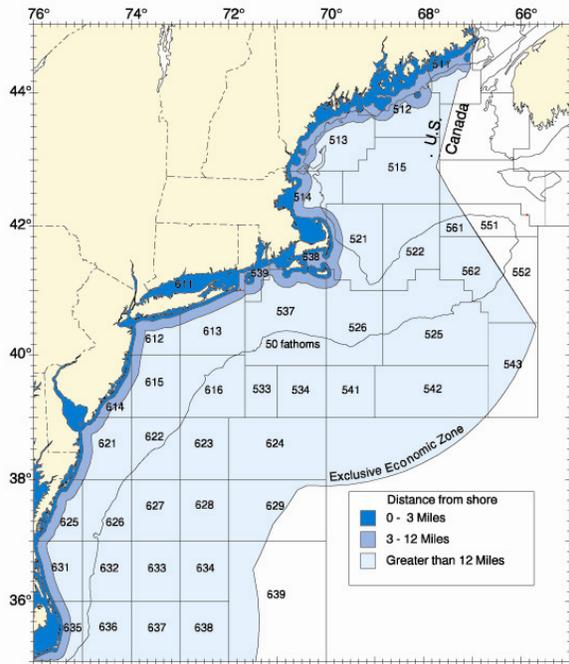


Figure 3. Statistical areas used for reporting commercial catches.

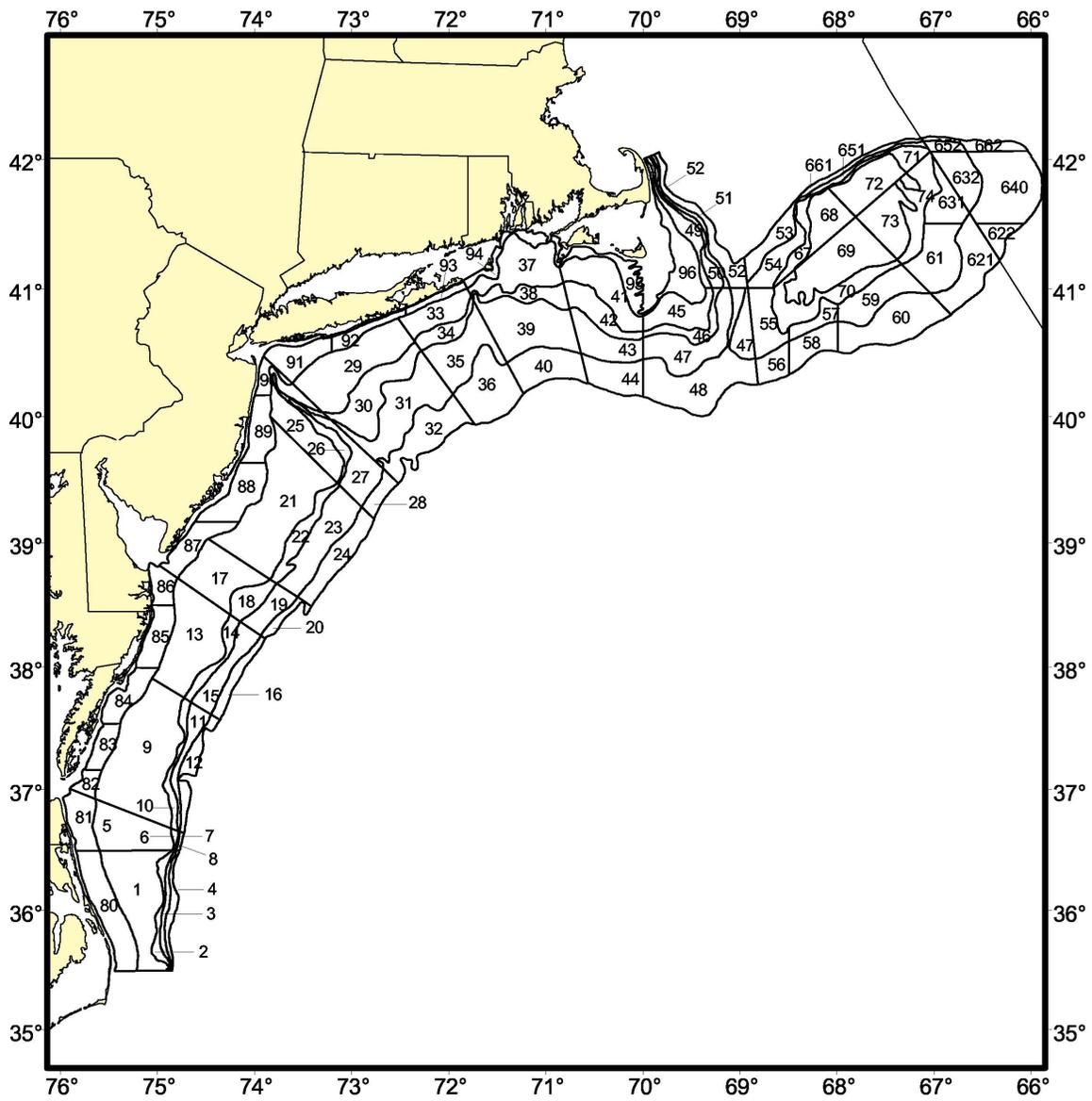


Figure 4. Northeast Fisheries Science Center clam resource survey strata, along the east coast of the US.

A. ATLANTIC SURFLAM ASSESSMENT SUMMARY FOR 2016

Status of the Stock: The Atlantic surfclam (*Spisula solidissima*) stock was not overfished in 2015. Based on recommended reference points for the whole stock, estimated $SSB_{2015}/SSB_{Threshold} = 2.54$ (probability overfished < 0.01 , Table A1 and Figure A1). For surfclams, spawning stock biomass (SSB) is almost equal to total biomass.

Overfishing did not occur in 2015. Based on new recommended reference points, estimated $F_{2015}/F_{Threshold} = 0.295$ (probability overfished < 0.01 , Table A1 and Figure A1).

Model and supplemental results indicate that spawning stock biomass (SSB) is high and fishing mortality (F) rates for surfclam are low relative to the new biological reference points. Point estimates are uncertain, but sensitivity and other analyses show that trends in SSB and F in the northern (Georges Bank) and southern areas (S. New England to Virginia) are estimated with acceptable precision. Estimates for the whole stock (northern area + southern area) are more uncertain, but are sufficient for determining stock status. Supplemental analyses such as catch curves, exploitation rates from catch and swept-area biomass, and the total area fished were consistent with model results and also indicate that stock biomass is high and fishing mortality rates are low. There is no indication that overfishing or overfished conditions occurred on the whole stock during 1984-2015.

Based on the previous reference points from SAW-56 (2013), $SSB_{2015}/SSB_{Threshold} = 2.4$ (probability overfished < 0.01). Based on the previous reference points, $F_{2015}/F_{Threshold} = 0.06$ (probability overfishing < 0.01).

Projections: Projections for the whole stock are from separate deterministic projections for the northern and southern areas that are combined. Recruitment estimates in the projections are from the spawner-recruit relationship in the assessment model for each area. Confidence intervals are based on uncertainty in recruitment and the stock size in 2015. Results suggest overfishing and overfished stock conditions are unlikely during 2016-2025 at status-quo or quota catch levels (Table A2). Additional projection runs in the assessment report assuming lower recruitment also indicate that overfishing and overfished stock conditions are unlikely to occur. Catch levels at the $F_{Threshold}$ exploitation level are summarized below.

Projected catches (landings + 12%) at the OFL fishing level (details in Table A2).					
Year	Mean ¹	Median ¹	CV	Low ² 95%	High ² 95%
2016	87,892	75,126	0.61	29,278	263,854
2017	88,243	75,432	0.61	29,394	264,908
2018	87,709	74,832	0.61	29,081	264,532
2019	87,316	74,281	0.62	28,639	266,210
2020	87,511	74,110	0.63	28,309	270,519

¹ Medians not exactly equal to values in Table A2 due to statistical assumptions in calculating confidence intervals.

² Bounds on 95% lognormal Confidence Interval

Stock Distribution: The federal surfclam resource in the EEZ (3-200 nm from shore) covered by this assessment is composed of the northern (Georges Bank) and southern (Southern New England to Virginia) areas. Surfclams are also found in state waters including the Gulf of Maine. They occur from the intertidal zone out to about 70 m depth. The southern area is further broken down into regions of particular interest: Southern New England, Long Island, New Jersey, Delmarva, and Southern Virginia, from north to south.

Landings: Fisheries data for 1982-2015 are from mandatory logbook reports and considered relatively accurate (Table A1 and Figure A3). Landings have not reached the current quota (26,218 mt) since it was set in 2004 because of limited markets. EEZ landings peaked during 1973-1974 at about 33 thousand mt, fell substantially to about 14 thousand mt during 1978-1979, increased and then varied between 18 and 25 thousand mt during 1985-2015.

Surfclam landings and fishing effort shifted north after 1979 as catch rates in the south declined. Landings were mostly from the Delmarva region during 1979-1980 and mostly from the New Jersey region since 1981. Long Island region landings were modest but increased after 2000. Southern New England landings increased substantially after 2008. There were no landings from Georges Bank during 1981-1982 and 1990-2008 but they increased to appreciable levels during 2009-2015 with the reopening of areas closed because of PSP (paralytic shellfish poisoning) risk. Landings per unit effort (LPUE) in the Delmarva and New Jersey regions are at all-time lows and catches there are composed of relatively small clams that are not favored by processors (see Special Comments).

Data and assessment: Stock Synthesis assessment model SSB and F estimates for the northern and southern areas were combined. Stock Synthesis model estimates for each region were based on commercial catch and size composition data as well as abundance indices, age, size and biological data from NEFSC clam surveys. The Stock Synthesis model for the northern area started in 1984 while the model for the southern area started in 1982. Estimates for the entire stock unit start in 1984 (Figures A1-A2 and A4). The two areas are modeled separately because of differences in survey data availability over time, fishing history, recruitment patterns and biological parameters. Cooperative field experiments to estimate capture efficiency and size selectivity are used as prior information in modeling and in supplementary analyses. A new NEFSC survey using a commercial fishing vessel and modified commercial dredge replaced the previous survey which was carried out during 1982-2011. The new survey was carried out in the southern area during 2012 and 2015 and in the northern area (Georges Bank) during 2013. Although earlier NEFSC clam surveys began in the 1960s, they were not considered in this stock assessment due to differences in survey methods.

Spawning stock biomass: Trends expressed as the ratio $SSB/SSB_{\text{Threshold}}$ are more reliably estimated than SSB. For the whole stock, relative SSB ($SSB/SSB_{\text{Threshold}}$) declined during the last fifteen years but is still above the target (Table A1, Figure A1 and see Special Comments). Although absolute model estimates of SSB are highly uncertain and should not be used, estimated total $SSB_{2015} = 46,355$ thousand mt (95% confidence interval = 14,822 to 144,974 thousand mt). Relative SSB for the whole stock is measured as the geometric mean of the $SSB/SSB_{\text{Threshold}}$ in the north and south (Table A1 and Figure A1; see Special Comments).

Fishing mortality: Trends expressed as the ratio $F/F_{\text{Threshold}}$ are more reliably estimated than absolute fishing mortality rates. For the whole stock the trend in relative F ($F/F_{\text{Threshold}}$) generally increased during the last fifteen years (despite recent declines in the south) but is still below the threshold (Table A1, Figure A2 and see Special Comments). Although absolute model estimates of F are highly uncertain and should not be used, estimated $F_{2015}=0.0091$ (95% confidence interval = 0.003 to 0.029).

Recruitment: Trends expressed as the ratio of recruitment (R) and mean recruitment in an unfished stock (R_0) are more reliably estimated than absolute recruitment (Table A1 and Figure A4). The trend in relative recruitment is measured using the ratio R/R_0 . Recruitment generally increased over the last decade, and in 2015 R/R_0 was 0.57 in the north, 0.97 in the south and 0.75 for the stock as a whole, indicating recruitment in 2015 was about 57%, 97% and 75% of the maximum long term average in the three regions. These recruitment patterns are probably normal in a surfclam stock at relatively high biomass and with low fishing mortality. Recruitment for the whole stock is measured as the geometric mean of R/R_0 in the northern and southern areas and is more uncertain than estimates for either area.

Biological reference points: New reference points were developed in this assessment which are more justified scientifically (Tables A3 and A4). The new biomass reference points and measures of stock biomass are ratios rather than absolute biomass values in mt. For example, the ratio $SSB_{2015}/SSB_{\text{Threshold}}=2.54$ in Tables A3 and A4 means that spawning stock biomass in 2015 was 2.54 times the $SSB_{\text{Threshold}}$. This approach allows for conclusions about the status of the surfclam stock despite substantial uncertainty in the actual biomass of the stock.

According to the new reference points, the stock would be considered overfished if $SSB_{\text{current}}/SSB_{\text{Threshold}}$ was less than one. The new B_{MSY} proxy is $SSB_{\text{Target}} = \frac{1}{2} SSB_0$ and the new biomass threshold is $SSB_{\text{Threshold}} = SSB_{\text{Target}}/2 = SSB_0/4$, where SSB_0 is mean unfished spawning biomass estimated by assessment models. The stock would be considered overfished if SSB fell below $SSB_0/4$. See Table A4 for details.

According to the new reference points, overfishing would be occurring if fishing mortality was larger than the threshold fishing mortality rate ($F_{\text{Threshold}}$) producing an $F_{\text{current}}/F_{\text{Threshold}}$ ratio greater than 1.0. The new $F_{\text{Threshold}}$ reference point for the whole stock is trend based and calculated as 4.136 times the average F during 1982-2015 for the whole stock where the years included in calculating the average are fixed (Table A3 and A4; see assessment report for details). See Table A4 for details.

MSY is unknown. The proxy $F_{\text{MSY}}=0.12$ was estimated based on management strategy evaluation (MSE) analysis but not used directly for status determination due to problems estimating F.

Special Comments:

There is additional uncertainty about stock size measured as $SSB/SSB_{\text{Threshold}}$, recruitment (R/R_0) and projected trends for the whole stock due to combining uncertain biomass or recruitment estimates for the northern and southern areas. However, stock status conclusions for biomass in this assessment were robust because stock size was relatively high and the stock would not have been overfished based on trends from either area.

There is also uncertainty in $F/F_{\text{Threshold}}$ due to combining results from different models for the northern and southern areas. However, the determination that $F < F_{\text{Threshold}}$ is relatively certain because supplemental analyses show that F is low in both areas and overfishing would not have occurred using trends from either area.

No retrospective pattern or adjustments were required for spawning stock biomass or fishing mortality trends. There were changes in estimates of absolute biomass for the entire time series compared with earlier assessments, but no retrospective patterns in trends.

Landings per unit effort (LPUE) are low for the fishery as a whole and in the important southern area where fishing is concentrated, but relatively high in the northern area on Georges Bank. Survey and other data indicate that the LPUE trend is not indicative of the trend in the resource as a whole. The fishery operates in a small portion of the total stock area (approximately 1%). Surfclam density is relatively high on the fishing grounds, but most of the stock biomass is located outside in areas that are not fished.

Ecosystem analyses suggest that surfclam habitat is decreasing in shallow coastal portions of the Delmarva region (Weinberg 2005) and possibly increasing in the New Jersey and Long Island regions. The net effects on total habitat area and carrying capacity are unknown. Co-occurrence of surfclams and ocean quahogs in deep water habitat has increased in recent years.

Stock structure was considered in the current and last assessments but consensus was not reached on whether or not to split the current stock between the northern and southern areas. However, stock definitions are unlikely to affect management, yield, or biological risk in the near term as long as fishing mortality rates remain low and biomass is high.

References

Northeast Fisheries Science Center. 2013. 56th Northeast Regional Stock Assessment Workshop (56th SAW) Assessment Report. NEFSC Ref. Doc. 13-10.
<http://www.nefsc.noaa.gov/nefsc/publications/>.

Weinberg, J. R. 2005. Bathymetric shift in the distribution of Atlantic surfclams: response to warmer ocean temperature. *ICES Journal of Marine Science*. 62: 1444-1453.

Table A1. Catch and status table for Atlantic surfclam. MSY is unknown.

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Min ^{1,2}	Max ^{1,2}	Mean ^{1,2}
Whole stock													
Landings ³	23,573	24,915	22,510	20,065	17,984	18,839	18,054	18,551	18,227	18,154	6,396	33,761	19,847
w/discard & incidental ^{3,4}	26,401	27,905	25,210	22,473	20,142	21,100	20,221	20,777	20,415	20,334	7,164	37,812	23,169
SSB/SSB _{Threshold} ⁵	2.9	2.8	2.7	2.7	2.8	2.8	2.6	2.5	2.5	2.5	2.5	6.4	4.0
F/F _{Threshold} ⁶	0.26	0.31	0.31	0.30	0.29	0.32	0.32	0.32	0.31	0.30	0.15	0.32	0.24
Recruitment (R/R ₀) ⁷	0.66	0.56	0.60	0.63	0.43	0.33	0.54	0.59	0.65	0.75	0.16	2.37	0.81
North													
Landings ³	0	0	0	11	1,311	2,388	3,580	4,403	3,236	4,074	7	4,403	2,002
w/discard & incidental ^{3,4}	0	0	0	12	1,468	2,675	4,010	4,931	3,624	4,563	8	4,931	2,242
SSB/SSB _{Threshold} ⁵	3.5	3.4	3.2	2.9	2.7	2.4	2.1	2.0	2.0	2.0	2.0	6.7	4.0
F/F _{Threshold} ⁶	0.00	0.00	0.00	0.00	0.10	0.19	0.31	0.41	0.33	0.45	0.00	0.45	0.08
Recruitment (R/R ₀) ⁷	0.77	0.38	0.30	0.31	0.14	0.20	0.29	0.52	0.55	0.57	0.14	3.10	0.92
South													
Landings ³	23,573	24,915	22,510	20,053	16,672	16,450	14,474	14,148	14,992	14,081	13,186	24,994	19,812
w/discard & incidental ^{3,4}	26,401	27,905	25,210	22,461	18,674	18,425	16,211	15,846	16,791	15,771	7,164	37,812	22,553
SSB/SSB _{Threshold} ⁵	2.3	2.3	2.3	2.6	2.9	3.2	3.3	3.2	3.2	3.2	2.3	7.4	4.2
F/F _{Threshold} ⁶	0.33	0.39	0.39	0.38	0.35	0.36	0.32	0.30	0.30	0.27	0.17	0.39	0.27
Recruitment (R/R ₀) ⁷	0.56	0.82	1.19	1.26	1.34	0.54	1.02	0.67	0.78	0.97	0.17	5.31	0.94

¹ Summary statistics for landings and catch during 1965-2015 (Whole stock and South) or 1984-1990 & 2009-2015 (North, excluding years with no fishing)

² Summary statistics for SSB, F and recruitment during 1984-2015

³ Landings, discards, incidental and catch are mt meats

⁴ Incidental = landings + 12%; Discards zero except 1979-1993 in south

⁵ SSB_{Threshold} = mean unfished SSB / 4 (separate values for the North, South and Whole stock)

⁶ F_{Threshold} = mean F during 1982-2015 x 4.136 (same reference point used for all areas, always calculated using 1982-2015 mean)

⁷ R₀ is mean recruitment for an unfished stock in each area

Table A2. Projections for Atlantic surfclams based on “status quo” catches (catch = landings + 12% = 20,333 mt per year during 2015), “quota” (catch = 26,218 mt quota + 12% = 29,363 mt per year) and $F=F_{\text{Threshold}}$ harvest levels during 2016-2025. $F_{\text{Threshold}}$ was not calculated for the northern area because the limited exploitation history prevents calculation of $F_{\text{Threshold}}$. Each simulation started in 2015 at SSB levels listed in Table A4.

Year	South			North			Whole stock		
	Status Quo	Quota	$F=F_{\text{Threshold}}$	Status Quo	Quota	$F=F_{\text{Threshold}}$	Status Quo	Quota	$F=F_{\text{Threshold}}$
<i>SSB/SSB_{Threshold}</i>									
2016	3.2	3.2	3.2	2.0	2.0	2.0	2.6	2.6	2.6
2017	3.3	3.3	3.3	2.3	2.3	2.3	2.8	2.8	2.8
2018	3.4	3.4	3.4	2.5	2.5	2.5	2.9	2.9	2.9
2019	3.5	3.5	3.4	2.7	2.7	2.7	3.1	3.1	3.0
2020	3.5	3.5	3.5	2.9	2.9	2.9	3.2	3.2	3.2
2021	3.6	3.6	3.5	3.0	3.0	3.0	3.3	3.3	3.2
2022	3.7	3.6	3.5	3.1	3.1	3.1	3.4	3.4	3.3
2023	3.7	3.7	3.6	3.2	3.2	3.2	3.5	3.4	3.4
2024	3.7	3.7	3.6	3.3	3.3	3.3	3.5	3.5	3.5
2025	3.8	3.7	3.6	3.4	3.4	3.4	3.6	3.6	3.5
<i>F/F_{Threshold}</i>									
2016	0.23	0.33	1.00				0.36	0.53	0.90
2017	0.22	0.32	1.00				0.37	0.55	0.90
2018	0.22	0.32	1.00				0.38	0.56	0.90
2019	0.22	0.31	1.00				0.39	0.57	0.90
2020	0.22	0.31	1.00				0.39	0.58	0.90
2021	0.21	0.31	1.00		NA		0.38	0.57	0.90
2022	0.21	0.30	1.00				0.37	0.55	0.90
2023	0.20	0.30	1.00				0.36	0.54	0.90
2024	0.20	0.29	1.00				0.35	0.52	0.90
2025	0.20	0.29	1.00				0.34	0.50	0.90
<i>Catch (Landings + 12%)</i>									
2016	15,771	22,610	68,725	4,562	6,753	6,444	20,333	29,363	75,169
2017	15,771	22,610	69,447	4,562	6,753	5,917	20,333	29,363	75,364
2018	15,771	22,610	69,332	4,562	6,753	5,527	20,333	29,363	74,859
2019	15,771	22,610	68,981	4,562	6,753	5,279	20,333	29,363	74,260
2020	15,771	22,610	68,931	4,562	6,753	5,201	20,333	29,363	74,131
2021	15,771	22,610	69,328	4,562	6,753	5,288	20,333	29,363	74,615
2022	15,771	22,610	70,044	4,562	6,753	5,503	20,333	29,363	75,547
2023	15,771	22,610	70,914	4,562	6,753	5,793	20,333	29,363	76,707
2024	15,771	22,610	71,818	4,562	6,753	6,113	20,333	29,363	77,931
2025	15,771	22,610	72,684	4,562	6,753	6,431	20,333	29,363	79,115

Table A3. Atlantic surfclam. Comparison of SAW56 (NEFSC 2013) and SAW61 (this 2016 assessment) biological reference points and reference point calculations for 2015. Note, that point estimates of 2015 biomass and fishing mortality rate are not reliable, but the ratios relative to the thresholds are sufficiently reliable. See Table A4 for additional details.

Reference point	SAW56 (2013)	New SAW61 (2016)
Definitions		
$F_{\text{Threshold}}$	M (proxy = natural mortality rate)	4.136 times the mean F during 1982-2015
B_{Target}	$B_{1999} / 2$	$SSB_0 / 2$
$B_{\text{Threshold}}$	$B_{1999} / 4$	$SSB_0 / 4$
Values in this 2016 assessment		
$F_{\text{Threshold}}^1$	0.15	See Table A4
F_{2015}^1	0.009	See Table A4
$F_{2015}/F_{\text{Threshold}}$	0.06	0.295
Overfishing?	No	No
SSB_{Target}^2	38,153	2.00
$SSB_{\text{Threshold}}^2$	19,076	1.00
SSB_{2015}^2	46,356	--
$SSB_{2015}/SSB_{\text{Threshold}}^2$	2.43	2.54
Overfished?	No	No

¹ Fishing mortality for fully recruited size groups.

² Biomass (SSB) measured in thousand mt for SAW56 (2013) overfishing definition and as $SSB/SSB_{\text{Threshold}}$ for new SAW61 (2016) overfishing definition.

Table A4. Detailed calculations for surfclam 2015 status determination using new reference points.

Estimate	North	South	Whole stock
<i>Biomass details</i>			
Absolute estimates (not reliable) ¹			
SSB ₂₀₁₅ (1000 MT)	4,816	41,539	--
Mean recruitment unfished stock (SSB ₀ , 1000 MT)	9,549	52,003	--
SSB _{Threshold} = SSB ₀ /4 (1000 MT)	2,387	13,000	--
Biomass ratios to measure trends (more reliable)			
SSB ₂₀₁₅ /SSB _{Threshold} ratio ²	2.02	3.20	2.54
SSB _{Threshold} ratio	1.00	1.00	1.00
SSB _{Target} ratio	2.00	2.00	2.00
Overfished (SSB ₂₀₁₅ ratio < 1)?	No	No	No
At or above target (SSB ₂₀₁₅ ratio >= 2)?	Yes	Yes	Yes
<i>Fishing mortality details</i>			
Absolute estimates (not reliable) ^{3,4}			
F ₂₀₁₅ (y ⁻¹) ⁵	0.014	0.008	0.0091
Mean 1982-2015 F (y ⁻¹)	--	--	0.00744
F _{threshold} ⁶	0.0308		
Trend estimates expressed as F/F _{Threshold} (more reliable)			
F/F _{Threshold}	0.45	0.27	0.295
Overfishing (F > F _{Threshold})?	No	No	No

¹ Estimates in MT from assessment models only to show calculations

² "Whole stock" is the geometric mean of estimates on same line for north and south

³ F estimates only to show calculations

⁴ North and south from assessment model

⁵ North and south from assessment model; "whole stock" from catch/mean available abundance

⁶ Mean 1982-2015 F for entire stock x 4.136

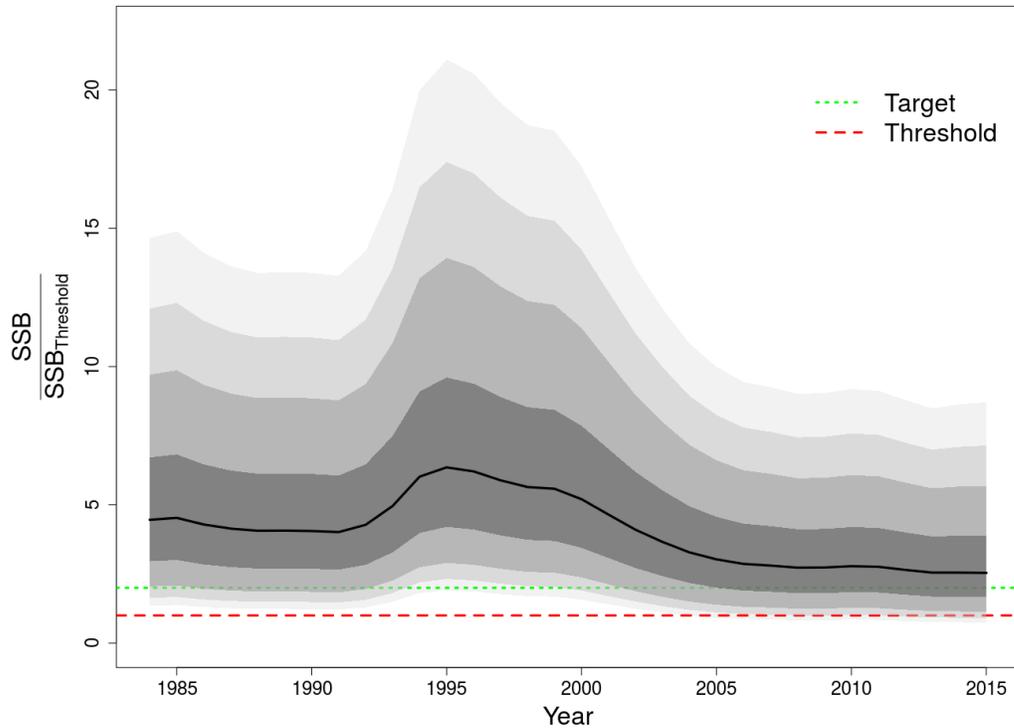


Figure A1. Trends in relative spawning stock biomass ($SSB/SSB_{Threshold}$) for the whole Atlantic surfclam stock during 1984-2015. The solid line shows estimates from this assessment with approximate 50, 80, 90, and 95th percentile lognormal confidence intervals in shades of grey. The green short-dash line at $SSB/SSB_{Threshold} = 2$ is the management target. The red long-dash line at $SSB/SSB_{Threshold} = 1$ is the level that defines an overfished stock.

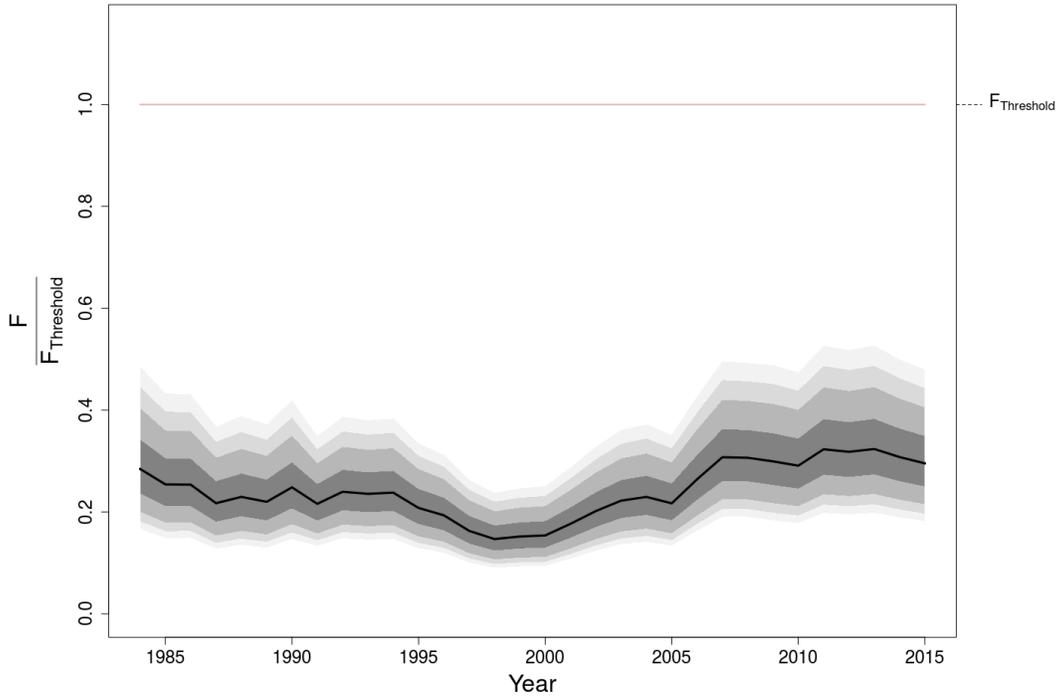


Figure A2. Trends in relative fishing mortality $F/F_{\text{Threshold}}$ for the whole Atlantic surfclam stock 1984-2015. The solid line shows estimates from this assessment with approximate 50, 80, 90, and 95th percentile lognormal confidence intervals in shades of grey. The solid line at $F/F_{\text{Threshold}} = 1$ is the new fishing mortality threshold reference point.

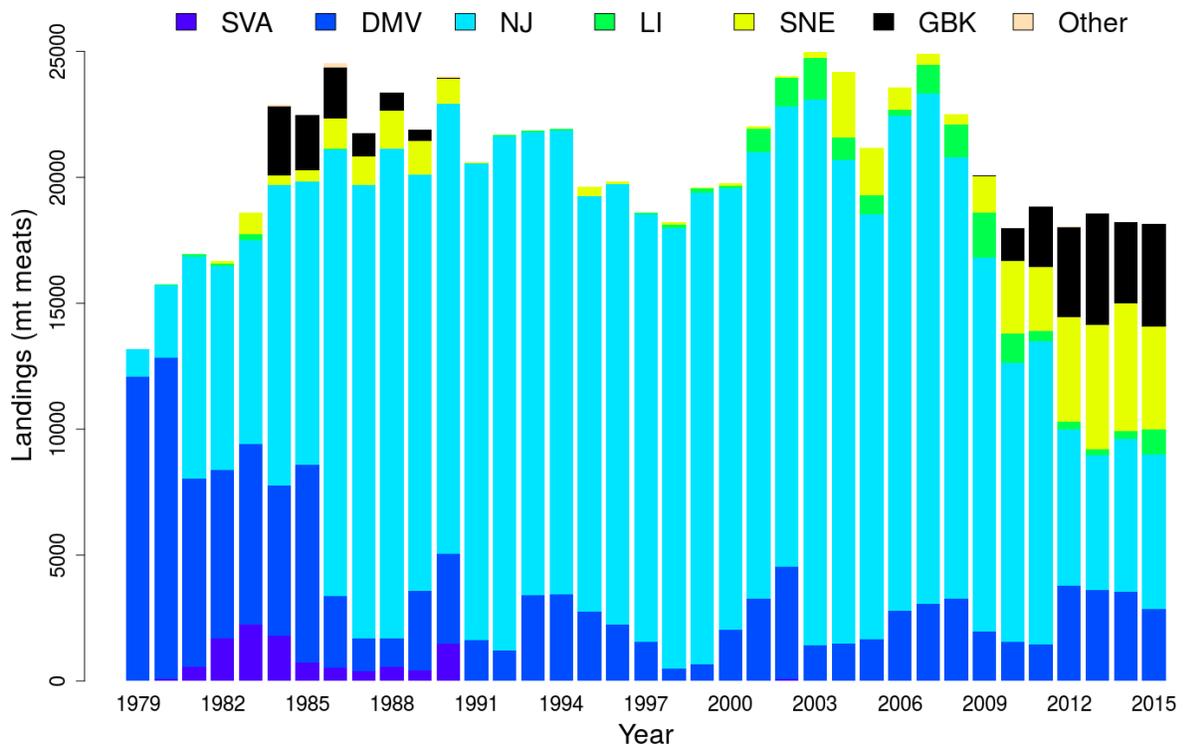


Figure A3. Landings for Atlantic surfclams by region during 1979-2015. Regions from north to south are abbreviated with GBK for Georges Bank, SNE for Southern New England, LI for Long Island, NJ for New Jersey, DMV for Delmarva, and SVA for Southern Virginia.

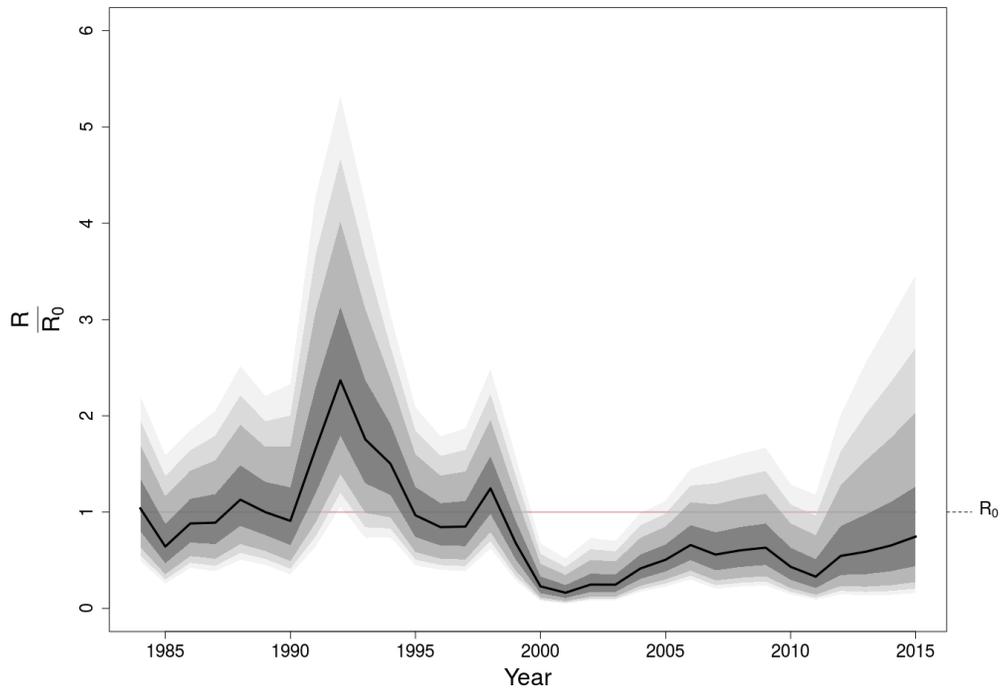


Figure A4. Trends in relative recruitment (R/R_0 for age zero recruits) for the whole Atlantic surfclam stock during 1984-2015. The solid line shows estimates from this assessment with approximate 50, 80, 90, and 95th percentile lognormal confidence intervals in shades of grey. The horizontal line is mean recruitment in an unfished stock.

Appendix: Stock Assessment Terms of Reference for SAW/SARC-61, July 19-21, 2016
(File version: 12/18/2015)

A. Atlantic surfclams

1. Estimate catch from all sources including landings and discards. Map the spatial and temporal distribution of landings, discards, fishing effort, and gross revenue, as appropriate. Characterize the uncertainty in these sources of data.
2. Present the survey data being used in the assessment (e.g., indices of relative or absolute abundance, recruitment, state surveys, age-length data, etc.). Use logbook data to investigate regional changes in LPUE, catch and effort. Characterize the uncertainty and any bias in these sources of data. Evaluate the spatial coverage, precision, and accuracy of the new clam survey.
3. Determine the extent and relative quality of benthic habitat for surfclams in the Georges Bank ecosystem to refine estimates of stock size based on swept area calculations.
4. Quantify changes in the depth distribution of surfclams over time. Review changes over time in surfclam biological parameters such as length, width, and growth.
5. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series (integrating results from TOR 3, as appropriate) and estimate their uncertainty. Include a historical retrospective analysis 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, particularly as they relate to stock assumptions.
7. Evaluate stock status with respect to the existing model (from previous peer reviewed accepted assessment) and with respect to any new model or models developed for this peer review.
 - a. When working with the existing model, update it with new data and evaluate stock status (overfished and overfishing) with respect to the existing BRP estimates.
 - b. Then use the newly proposed model and evaluate stock status with respect to “new” BRPs and their estimates (from TOR-5).
8. Develop approaches and apply them to conduct stock projections.
 - a. Provide numerical annual projections (five years) and the statistical distribution (e.g., probability density function) of the OFL (overfishing level) (see Appendix to the SAW TORs). Consider cases using nominal as well as potential levels of uncertainty in the model. Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F , and probabilities of falling below threshold BRPs for biomass. Use a sensitivity analysis approach in which a range of assumptions about the most important uncertainties in the assessment are considered (e.g., terminal year abundance, variability in recruitment).
 - b. Comment on which projections seem most realistic. Consider the major uncertainties in the assessment as well as sensitivity of the projections to various assumptions.
 - c. Describe this stock’s vulnerability (see “Appendix to the SAW TORs”) to becoming overfished, and how this could affect the choice of ABC.

9. Evaluate the validity of the current stock definition. Determine whether current stock definitions may mask reductions in sustainable catch on regional spatial scales. Make a recommendation about whether there is a need to modify the current stock definition.
10. 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.

Appendix to the SAW Assessment TORs: **Clarification of Terms used in the SAW/SARC Terms of Reference**

On “Overfishing Limit” and “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, $OFL \geq ABC$.]

ABC for overfished stocks. For overfished stocks and stock complexes, a rebuilding ABC must be set to reflect annual catch that is consistent with 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)

Interactions 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.

One model or alternative models:

The preferred outcome of the SAW/SARC is to identify a single “best” model and an accompanying set of assessment results and a stock status determination. 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.

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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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