

Northeast Fisheries Science Center Reference Document 17-09

# 63<sup>rd</sup> Northeast Regional Stock Assessment Workshop (63<sup>rd</sup> SAW)

## Assessment Summary Report

by the Northeast Fisheries Science Center

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Stock Assessment Workshop  
(63<sup>rd</sup> SAW)  
Assessment Summary Report

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**U.S. DEPARTMENT OF COMMERCE**  
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## Northeast Fisheries Science Center Reference Documents

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# SAW-63 ASSESSMENT SUMMARY REPORT

## Introduction

The 63rd SAW Assessment Summary Report contains summary and detailed technical information on one stock assessment reviewed during February 19-21, 2017 at the Stock Assessment Workshop (SAW) by the 63rd Stock Assessment Review Committee (SARC-63): Ocean quahog. The SARC-63 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-63 are available at website: <http://www.nefsc.noaa.gov/nefsc/saw/> under the heading "SARC 63 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  $B_{\text{MSY}}$  and the fishing mortality rate that produces MSY is called  $F_{\text{MSY}}$ .

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.

		<b>BIOMASS</b>		
		$B < B_{\text{THRESHOLD}}$	$B_{\text{THRESHOLD}} < B < B_{\text{MSY}}$	$B > B_{\text{MSY}}$
<b>EXPLOITATION RATE</b>	$F > F_{\text{THRESHOLD}}$	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-63 Review Panel reports (available at <http://www.nefsc.noaa.gov/nefsc/saw/> under the heading “SARC-63 Panelist Reports”).

SARC 63 concluded that the ocean quahog stock is neither overfished nor did it experience overfishing in 2012-2016, the period since the last benchmark assessment. Outcomes based on the new SS3 model, the previous KLAMZ model, and empirical analyses all supported the conclusion. The Panel agreed that the focus on trends and ratios, especially for assessing stock status, was appropriate. The Panel also concluded that the SAW WG had reasonably and satisfactorily completed all tasks specified in the ToRs.

Fishery-independent survey results indicate that the northward shift in ocean quahog landings probably is a response of the fishery to declining abundance in the southern subregions. These declines in the south were indicated by decreasing commercial effort and LPUE. The fishery is now concentrated off Long Island where 70-80% of landings were recorded during 2005-2015. Commercial LPUE indices were not used in the assessment, and the Panel agreed that this was appropriate because of the small proportion of the stock area fished. The Panel noted the mismatch between the broad spatial scale of the stock assessment for status determination vs the smaller spatial scales at which demographic differences likely occur, and encourages more research on this topic.

## 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<sub>MAX</sub>**. The rate of fishing mortality that produces the maximum level of yield per recruit. This is the point beyond which growth overfishing begins.

**F<sub>0.1</sub>**. 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<sub>0.1</sub> rate is only one-tenth the slope of the curve at its origin).

**F<sub>10%</sub>**. 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<sub>x%</sub>, is the fishing mortality rate that reduces the SSB/R to x% of the level that would exist in the absence of fishing.

**F<sub>MSY</sub>**. 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<sub>MAX</sub> 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<sub>THRESHOLD</sub>)**. 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<sub>THRESHOLD</sub>, overfishing is occurring.

**Minimum Stock Size Threshold (MSST, B<sub>THRESHOLD</sub>)**. Another of the Status Determination Criteria. The greater of (a)  $\frac{1}{2}B_{MSY}$ , or (b) the minimum stock size at which rebuilding to B<sub>MSY</sub> 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<sub>THRESHOLD</sub>, 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.

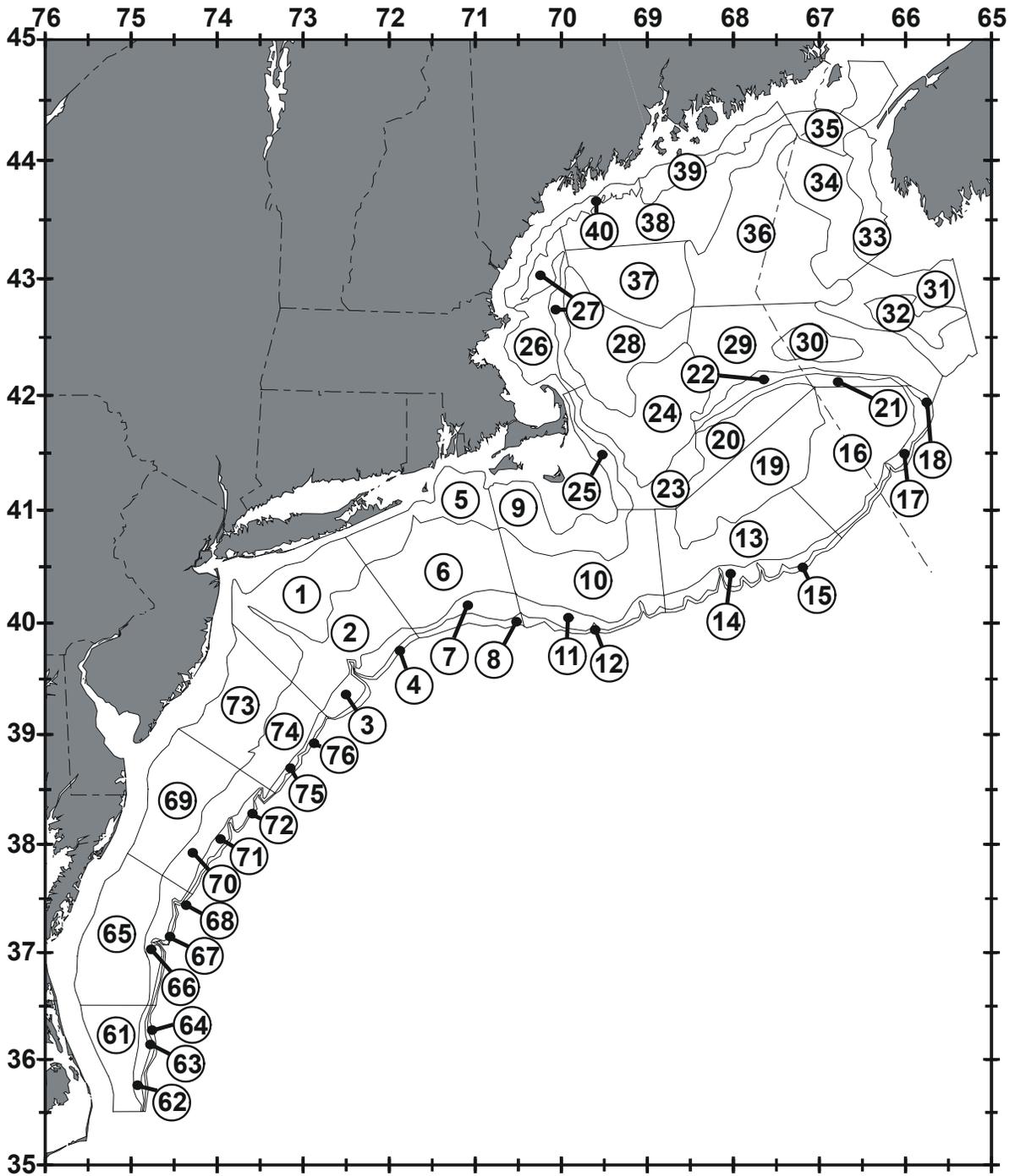


Figure 1. Offshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys. Some of these may not be sampled presently.

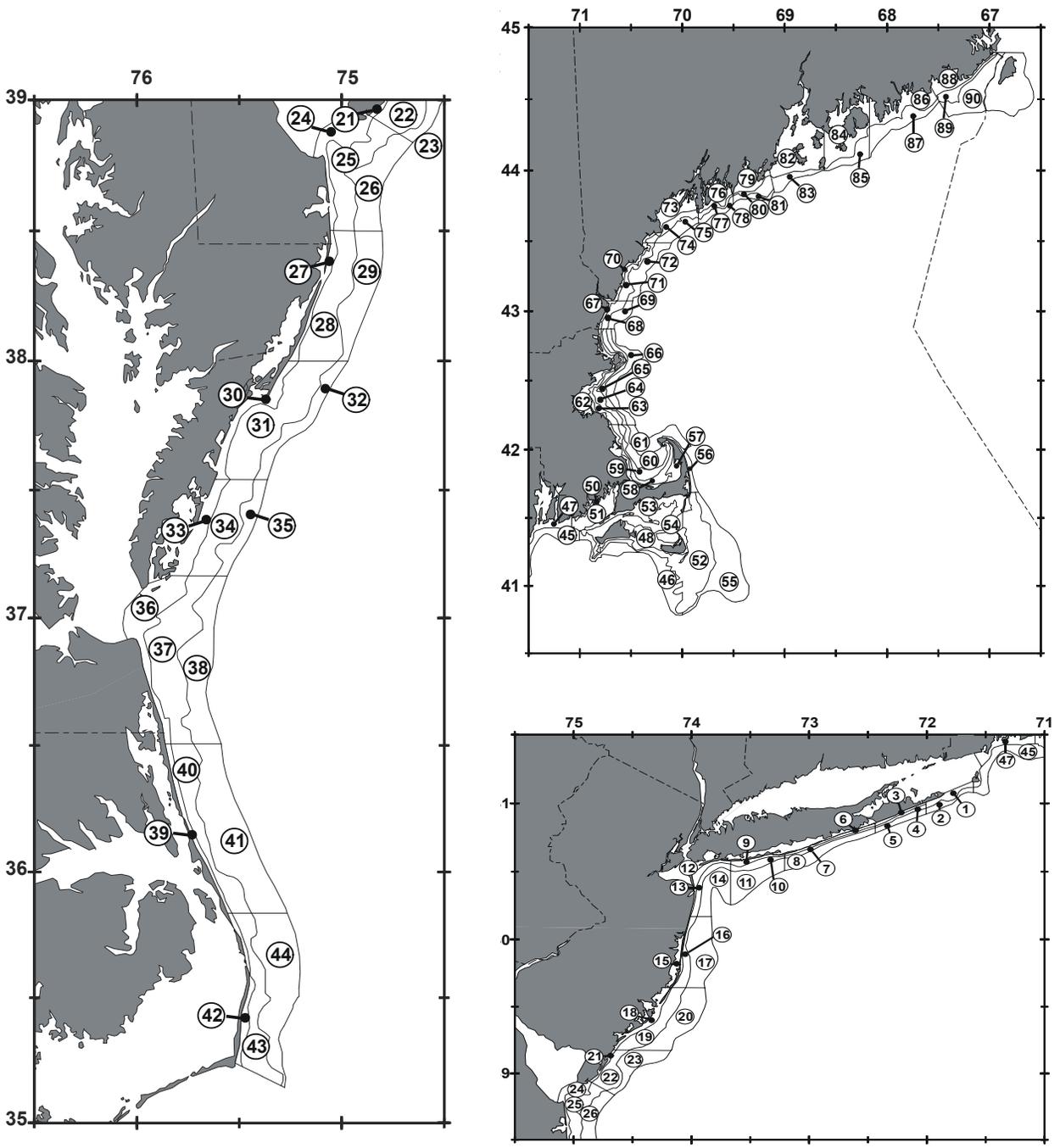


Figure 2. Inshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys. Some of these may not be sampled presently.

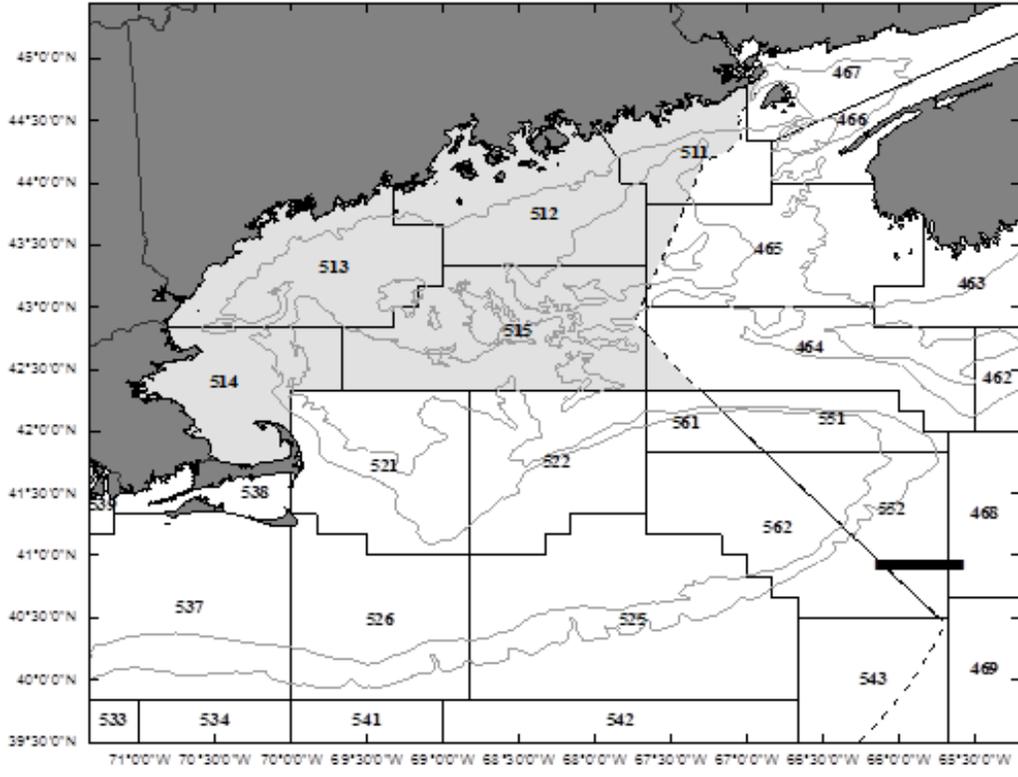
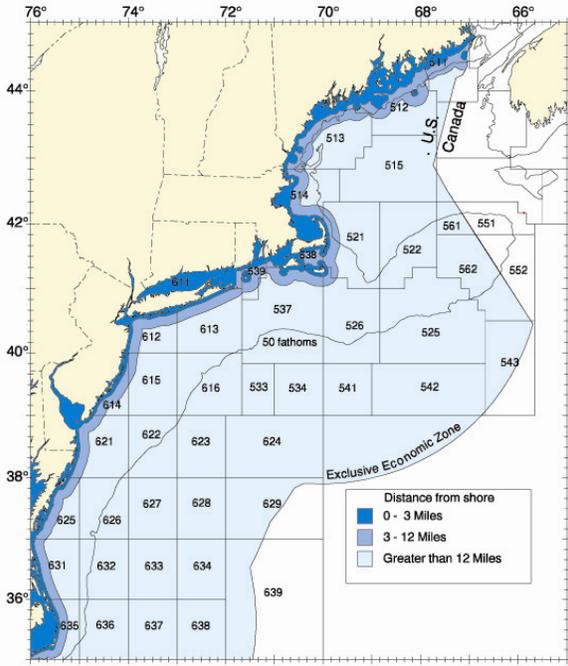


Figure 3. Statistical areas used for reporting commercial catches.

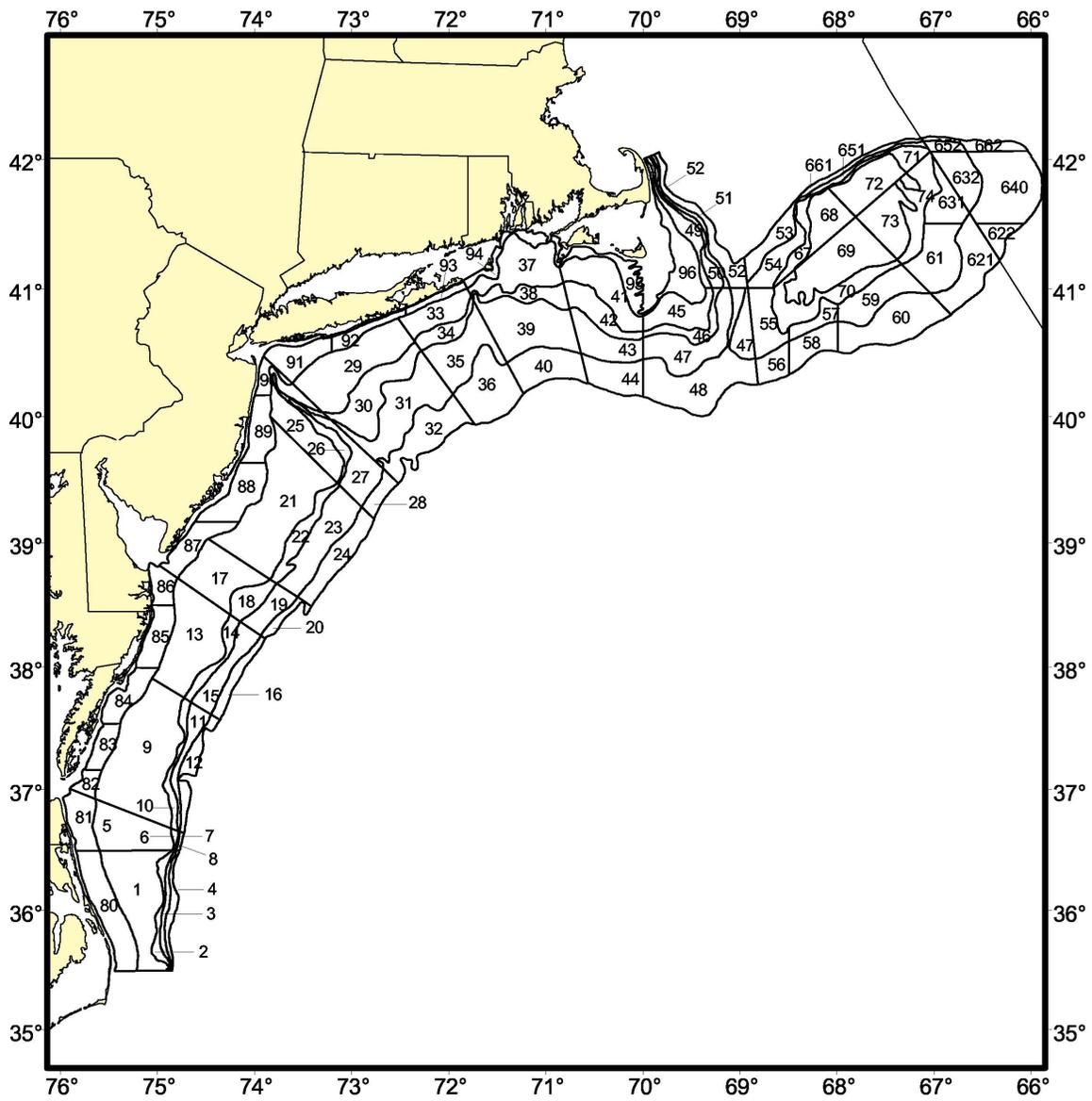


Figure 4. Northeast Fisheries Science Center clam resource survey strata, along the east coast of the US.

## A. OCEAN QUAHOG ASSESSMENT SUMMARY FOR 2017

**Status of the Stock:** The ocean quahog (*Arctica islandica*) stock was not overfished in 2016. Based on SAW/SARC-63 reference points from the 2017 assessment for the stock, estimated  $SSB_{2016}/SSB_{Threshold} = 2.04$  (probability overfished  $< 0.01$ ; Table A1 and Figure A1), where SSB is spawning stock biomass. The US EEZ stock extends from the US/Canadian border to Cape Hatteras and is modeled as two areas (northern and southern, defined below).

Overfishing did not occur in 2016. Based on SAW/SARC-63 reference points, estimated  $F_{2016}/F_{Threshold} = 0.246$  (probability overfishing  $< 0.01$ ; Table A1 and Figure A2), where F is fishing mortality rate.

Model results and empirical analyses indicated that SSB was high and F's rates were low relative to the reference points. Sensitivity analyses indicate that trends in SSB and F were estimated with acceptable precision. Exploitation rates from catch and swept-area biomass were consistent with model results and also indicated that stock biomass was high and fishing mortality rates were low. There is no indication that overfishing or overfished stock conditions occurred during 1982-2016.

Based on the previous reference points from SAW/SARC-48 (2009),  $SSB_{2016}/SSB_{Threshold} = 2.33$  (probability overfished  $< 0.01$ ), and  $F_{2016}/F_{Threshold} = 0.207$  (probability overfishing  $< 0.01$ ).

**Projections:** Recruitment in the projections was assumed equal to recruitment in the two areas in the last year of the assessment model when total recruitment was representative of the historical average. Confidence intervals were based on uncertainty in both recruitment and the stock size in 2016. Results indicate overfishing is unlikely during 2017-2067 at status quo or quota catch levels. Overfished conditions did not result during 2017-2067 under any of the projection scenarios (Table A2). Additional projection runs in the assessment report that assume lower recruitment also indicate that overfishing and overfished stock conditions are unlikely to occur even if recruitment declines to negligible levels during the projection period.

**Stock Distribution:** In the western Atlantic, ocean quahog is found from Cape Hatteras to Newfoundland from depths of 20 to 100 m or more. The federal ocean quahog resource in the US EEZ is assessed in two areas, northern and southern. The northern area is Georges Bank. The southern area is Southern New England to Cape Hatteras. Ocean quahog in the Gulf of Maine is not included in the assessment model, but stock assessment results for that area are presented in the assessment report.

**Landings:** Fisheries data for 1982-2016 were from mandatory logbook reports and are considered accurate (Table A1 and Figure A3). Except for 1996-1998 landings have not reached the quota (current quota = 24,190 mt) because of limited markets. EEZ landings peaked during 1989-1992 at 22 thousand mt, fell to 17 thousand mt during 1998-2004, and dropped to about 15 thousand mt during 2006-2016. Landings in the small Maine fishery ranged from 387 mt in 2002 to 125 mt in 2015.

Ocean quahog landings and fishing effort have shifted north through time as catch rates in the south declined (Figure A3). Landings were mostly from the Delmarva and New Jersey regions during 1980-1991 and then shifted to Long Island and Southern New England. The Long Island

region provided 70-80% of ocean quahog landings during the last three years. There were no landings from Georges Bank in most years during 1990-2012 and they remain low, despite the reopening in 2013 of areas that were closed previously because of the risk of paralytic shellfish poison (PSP). Despite declines in the southernmost regions, landings per unit effort (LPUE) for the fishery as a whole has been relatively constant.

**Data and assessment:** A Stock Synthesis model was used for the first time in an ocean quahog assessment to estimate biomass and fishing mortality based on commercial catch and size composition data, fishery independent abundance indices, and size and biological data from NEFSC clam surveys. The Stock Synthesis model used data starting in 1982 (Figures A1-A2 and A4). The model treated recruitment, selectivity, and catchability separately in the northern and southern areas. The model had two areas because of differences in biological parameters, fishing history, recruitment patterns, and survey timing. The model was informed by estimates of capture efficiency and size selectivity from cooperative field experiments. Abundance indices were derived from two resource surveys. A new survey using a commercial fishing vessel and modified commercial dredge replaced the previous survey which was carried out during 1982-2011 using a smaller dredge. The new survey was conducted in the southern area during 2012 and 2015 and in the northern area (Georges Bank) during 2013 and 2016. 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:** Relative SSB ( $SSB/SSB_{\text{Threshold}}$ ) has been stable and above the threshold level (Table A1, Figure A1). Estimated total  $SSB_{2016} = 3.3$  million mt (95% confidence interval = 2.5 to 4.3 million mt) and the  $SSB_{2016}/SSB_{\text{Threshold}} = 2.04$ .

**Fishing mortality:** Relative F ( $F/F_{\text{Threshold}}$ ) has been stable and is below the threshold (Table A1, Figure A2). Estimated  $F_{2016} = 0.005$  (95% confidence interval = 0.003 to 0.006) and the  $F_{2016}/F_{\text{Threshold}} = 0.246$ .

**Recruitment:** There is little information about annual recruitment variability for ocean quahog. Model estimated recruitment has been stable and near unfished recruitment levels since 2000 (Figure A4, see Special Comment).

**Biological reference points:** New reference points were developed in this assessment based on management strategy evaluation (MSE; Table A3). They are presented as ratios. For example, the ratio  $SSB_{2016}/SSB_{\text{Threshold}} = 2.04$  in Table A3 means that spawning stock biomass in 2016 was 2.04 times the  $SSB_{\text{Threshold}}$ . Ratios are more robust to uncertainty in estimating biomass.

According to the reference points in the 2017 assessment, the stock would be considered overfished if  $SSB_{\text{current}}/SSB_{\text{Threshold}}$  was less than 1. The new  $B_{\text{MSY}}$  proxy is  $SSB_{\text{Target}} = 0.5 * SSB_0$  and the new biomass threshold is  $SSB_{\text{Threshold}} = 0.4 * SSB_0$ , where  $SSB_0$  is mean unfished spawning biomass estimated by assessment models. The stock would be considered overfished if SSB fell below  $0.4 * SSB_0$ . See Table A3 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 proxy  $F_{\text{MSY}} = 0.019$  is the new  $F_{\text{Threshold}}$  reference point for the stock. It is based on a

management strategy evaluation analysis, rather than a proxy used for long-lived rockfish (Table A3). MSY proxy, based on applying the  $F_{MSY}$  proxy to the  $B_{msy}$  proxy, was 73,298 mt (Table A3).

## Special Comments

The broad conclusions of the assessment model (Stock Synthesis) were supported by empirical analyses and the previous assessment model (KLAMZ).

Estimates of absolute biomass for the entire time series were similar to earlier assessments. Despite uncertainty about scale, no retrospective adjustments were required for spawning stock biomass or fishing mortality trends.

Initial work with tree models and environmental variables to predict ocean quahog locations and density were promising. However, more work is required to determine the spatial precision of these predictions and how they might be used in future assessments, or surveys.

True recruitment is difficult to estimate in the ocean quahog assessment because there is no age composition data and growth is highly variable. The model estimates a strong peak in recruitment in the mid-1990s because of the abundance of small quahogs in recent length compositions. However, the estimate is uncertain and the actual year class strength will not be known for several decades (Figure A4). Periodic, large recruitment events are common in bivalves,

There are substantial opportunities to improve the clam/quahog survey that would improve its precision and utility in the stock assessment. Work is underway to examine this issue.

It is recognized that the assessment considers the stock at large spatial scales and there is scope for better understanding of demographic processes at smaller spatial scales not now captured in the model. Considerable value may be added to the assessment through research that addresses these mismatches between the spatial scale of the assessment and that of population processes and fishery operations.

## References

Northeast Fisheries Science Center. 2009. 48th Northeast Regional Stock Assessment Workshop (48th SAW) Assessment Report. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 09-15; 834 p.

**Table A1.** Catch and status table for ocean quahog.

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Min <sup>1,2</sup>	Max <sup>1,2</sup>	Mean <sup>1,2</sup>
	<i>Whole stock</i>												
Landings <sup>3</sup>	15,564	15,727	15,710	16,289	14,332	15,864	14,721	14,498	13,639	9,542	9,542	22,477	17,250
w/discard & incidental <sup>3,4</sup>	16,342	16,513	16,496	17,103	15,049	16,657	15,457	15,223	14,321	10,019	10,019	23,601	18,112
SSB <sup>5</sup>	3,140	3,154	3,170	3,188	3,205	3,224	3,241	3,257	3,273	3,287	3,123	4,027	3,304
SSB/SSB <sub>Threshold</sub> <sup>6</sup>	1.95	1.96	1.97	1.98	1.99	2.00	2.01	2.02	2.03	2.04	1.94	2.19	2.04
F	0.005	0.005	0.005	0.005	0.004	0.005	0.005	0.005	0.004	0.005	0.004	0.006	0.005
F/F <sub>Threshold</sub> <sup>7</sup>	0.25	0.26	0.26	0.27	0.24	0.27	0.25	0.25	0.23	0.25	0.20	0.33	0.27
Recruitment (R/R <sub>0</sub> ) <sup>8</sup>	0.97	0.98	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	0.69	2.73	1.07

<sup>1</sup>Summary statistics for landings and catch: 1980-2016

<sup>2</sup>Summary statistics for SSB, F and recruitment during 1980-2016

<sup>3</sup>Landings, discards, incidental and catch are mt meats (2016 landings are partial)

<sup>4</sup>Incidental = landings + 5%; Discards zero

<sup>5</sup>SSB in thousand mt meats

<sup>6</sup>SSB<sub>Threshold</sub>=0.4\*SSB<sub>0</sub>

<sup>7</sup>F<sub>Threshold</sub>= F<sub>MSY</sub> proxy= 0.01855

<sup>8</sup>R<sub>0</sub> is mean recruitment for an unfished stock

**Table A2.** Projections for ocean quahog based on “status quo” catches (catch = landings + 5% = 13,807 mt per year), “quota” (catch = 24,190 mt quota + 5% = 25,400 mt per year) and OFL (Catch at  $F \approx F_{\text{Threshold}}$  harvest levels) during 2017-2067.  $SSB/SSB_{\text{Threshold}} < 1$  indicates overfished and  $F/F_{\text{Threshold}} > 1$  indicates overfishing. Each simulation started in 2016 at SSB listed in Table A3. Biomass units are in mt meats.

Year	Status Quo	Quota	OFL	Status Quo	Quota	OFL	Status Quo	Quota	OFL
	SSB			SSB/SSB <sub>Threshold</sub>			F/F <sub>Threshold</sub>		
2017	3299930	3299930	3299930	2.049	2.049	2.049	0.251	0.416	1.027
2018	3310860	3302630	3270880	2.055	2.050	2.031	0.249	0.415	1.027
2019	3320590	3304210	3241460	2.061	2.051	2.012	0.248	0.413	1.026
2020	3329230	3304800	3211770	2.067	2.052	1.994	0.246	0.412	1.025
2021	3336870	3304480	3181920	2.071	2.051	1.975	0.245	0.410	1.024
2022	3343620	3303360	3152030	2.076	2.051	1.957	0.243	0.409	1.023
2023	3349560	3301530	3122190	2.079	2.050	1.938	0.242	0.407	1.021
2024	3354780	3299070	3092500	2.083	2.048	1.920	0.240	0.406	1.019
2025	3359330	3296060	3063050	2.085	2.046	1.901	0.239	0.404	1.016
2026	3363300	3292570	3033920	2.088	2.044	1.883	0.237	0.402	1.010
2027	3366730	3288660	3005160	2.090	2.042	1.866	0.235	0.400	1.004
2028	3369690	3284380	2976850	2.092	2.039	1.848	0.233	0.398	0.997
2029	3372210	3279790	2949030	2.093	2.036	1.831	0.233	0.398	0.997
2030	3374350	3274920	2921730	2.095	2.033	1.814	0.233	0.400	0.998
2031	3376150	3269820	2895010	2.096	2.030	1.797	0.234	0.401	1.000
2032	3377630	3264530	2868870	2.097	2.027	1.781	0.234	0.403	1.002
2033	3378840	3259070	2843350	2.098	2.023	1.765	0.234	0.404	1.004
2034	3379790	3253480	2818470	2.098	2.020	1.750	0.234	0.405	1.006
2035	3380530	3247780	2794230	2.099	2.016	1.735	0.234	0.406	1.007
2036	3381060	3242000	2770640	2.099	2.013	1.720	0.234	0.406	1.008
2037	3381430	3236160	2747710	2.099	2.009	1.706	0.234	0.407	1.009
2038	3381630	3230270	2725440	2.099	2.005	1.692	0.234	0.407	1.010
2039	3381700	3224360	2703830	2.099	2.002	1.678	0.234	0.408	1.010
2040	3381650	3218430	2682860	2.099	1.998	1.665	0.234	0.408	1.011
2041	3381490	3212500	2662550	2.099	1.994	1.653	0.233	0.408	1.011
2042	3381230	3206580	2642870	2.099	1.991	1.641	0.233	0.409	1.011
2043	3380890	3200690	2623820	2.099	1.987	1.629	0.233	0.409	1.011
2044	3380480	3194820	2605390	2.099	1.983	1.617	0.233	0.409	1.011
2045	3380010	3188990	2587560	2.098	1.980	1.606	0.233	0.410	1.011
2046	3379480	3183210	2570320	2.098	1.976	1.596	0.233	0.410	1.011
2047	3378900	3177470	2553670	2.098	1.973	1.585	0.232	0.410	1.011
2048	3378280	3171780	2537580	2.097	1.969	1.575	0.232	0.411	1.011
2049	3377620	3166160	2522040	2.097	1.966	1.566	0.232	0.411	1.011
2050	3376940	3160590	2507040	2.096	1.962	1.556	0.232	0.411	1.011
2051	3376230	3155090	2492560	2.096	1.959	1.547	0.232	0.411	1.011
2052	3375500	3149660	2478580	2.095	1.955	1.539	0.232	0.412	1.011
2053	3374750	3144290	2465100	2.095	1.952	1.530	0.232	0.412	1.010
2054	3373990	3138990	2452090	2.095	1.949	1.522	0.231	0.412	1.010
2055	3373210	3133760	2439550	2.094	1.945	1.514	0.231	0.412	1.010
2056	3372430	3128600	2427450	2.094	1.942	1.507	0.231	0.412	1.010
2057	3371640	3123520	2415790	2.093	1.939	1.500	0.231	0.413	1.010
2058	3370850	3118500	2404550	2.093	1.936	1.493	0.231	0.413	1.010
2059	3370050	3113560	2393710	2.092	1.933	1.486	0.231	0.413	1.009

Year	Status Quo	Quota	OFL	Status Quo	Quota	OFL	Status Quo	Quota	OFL
	SSB			SSB/SSB <sub>Threshold</sub>			F/F <sub>Threshold</sub>		
2060	3369260	3108690	2383260	2.092	1.930	1.479	0.231	0.413	1.009
2061	3368460	3103890	2373200	2.091	1.927	1.473	0.230	0.413	1.009
2062	3367660	3099160	2363500	2.091	1.924	1.467	0.230	0.413	1.009
2063	3366870	3094490	2354150	2.090	1.921	1.461	0.230	0.413	1.009
2064	3366080	3089900	2345140	2.090	1.918	1.456	0.230	0.413	1.008
2065	3365290	3085380	2336460	2.089	1.915	1.450	0.230	0.413	1.008
2066	3364510	3080920	2328100	2.089	1.913	1.445	0.230	0.413	1.008

**Table A2 continued.** Projections for ocean quahog based on “status quo” catches (catch = landings + 5% = 13,807 mt per year), “quota” (catch = 24,190 mt quota + 5% = 25,400 mt per year) and OFL (Catch at  $F \approx F_{\text{Threshold}}$  harvest levels) during 2017-2067.  $SSB/SSB_{\text{Threshold}} < 1$  indicates overfished and  $F/F_{\text{Threshold}} > 1$  indicates overfishing. Each simulation started in 2016 at SSB listed in Table A3. Biomass units are in mt meats.

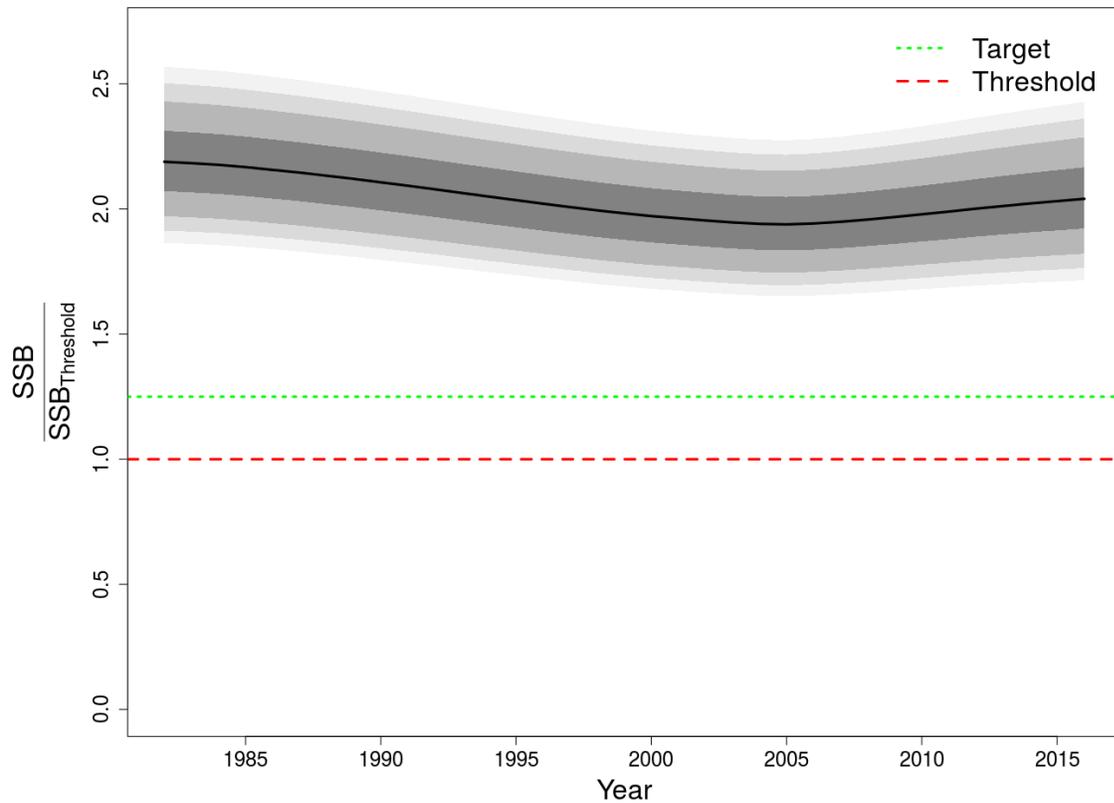
**Table A3.** Ocean quahog. Comparison of SAW-48 (NEFSC 2009) and SAW-63 (this 2017 assessment) biological reference points and reference point calculations for 2016. This comparison uses the current model for both columns, but the different reference point definitions from SAW-48 and SAW-63. Biomass units are mt meats.

Reference point	SAW48 (2013 computed values)	SAW48 (2017 computed values)	New SAW63 (2017 computed values)
<i>Definitions</i>			
$F_{MSY}$	$F_{MSY} \text{ proxy} = F_{45\%}$	$F_{MSY} \text{ proxy} = F_{45\%}$	$F_{MSY} \text{ proxy} = 0.019$ (from MSE)
$F_{Threshold}$	Same as $F_{MSY}$	Same as $F_{MSY}$	Same as $F_{MSY}$
$B_{Target}$	$B_{1978} / 2$	$SSB_{1982} / 2$	$SSB_0 / 2$
$B_{Threshold}$	$B_{1978} * 0.4$	$SSB_{1982} * 0.4$	$SSB_0 * 0.4$
<i>Values</i>			
$MSY_{proxy}$			73,298
$F_{MSY}$	0.022	0.022	0.019
$F_{Threshold}$			
$F_{terminal}$	0.005	0.005	0.005
$F_{terminal}/F_{Threshold}$	0.227	0.207	0.246
Overfishing?	No	No	No
$B_0$	3,460,000	3,525,900	4,027,200
$B_{Target}$	1,730,000	1,762,950	2,013,585
$B_{Threshold}$	1,384,000	1,410,360	1,610,868
$B_{terminal}$	2,960,000	3,287,300	3,287,300
$B_{terminal}/B_{Threshold}$	2.14	2.33	2.04
Overfished?	No	No	No

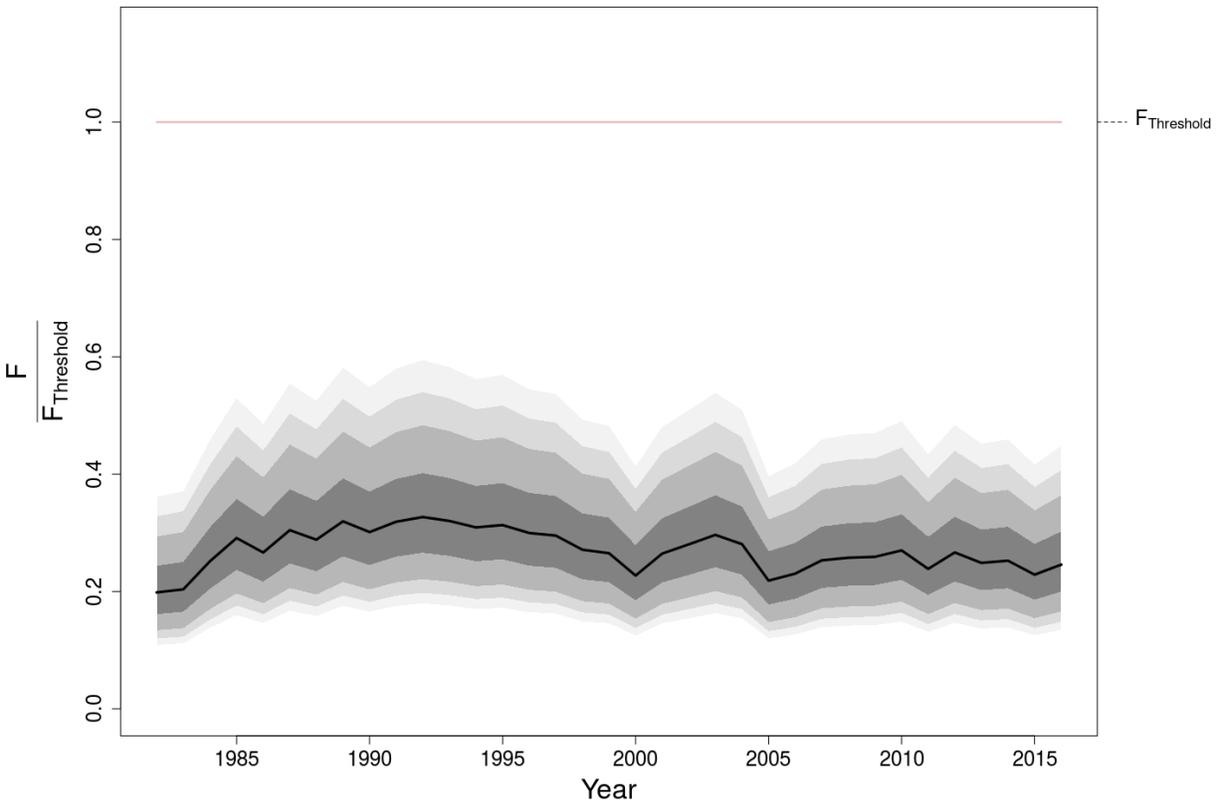
Note: The SAW-48 reference points were originally defined in terms of fishable biomass while those for SAW-63 in 2017 are defined in SSB. Here both columns are SSB to allow for direct comparison.

**Table A4.** Projected ocean quahog catch (landings + incidental mortality) at the over fishing limit in selected years, with mean, median, coefficient of variation (CV), and approximate upper and lower 95% lognormal confidence limits (UCI, LCI).

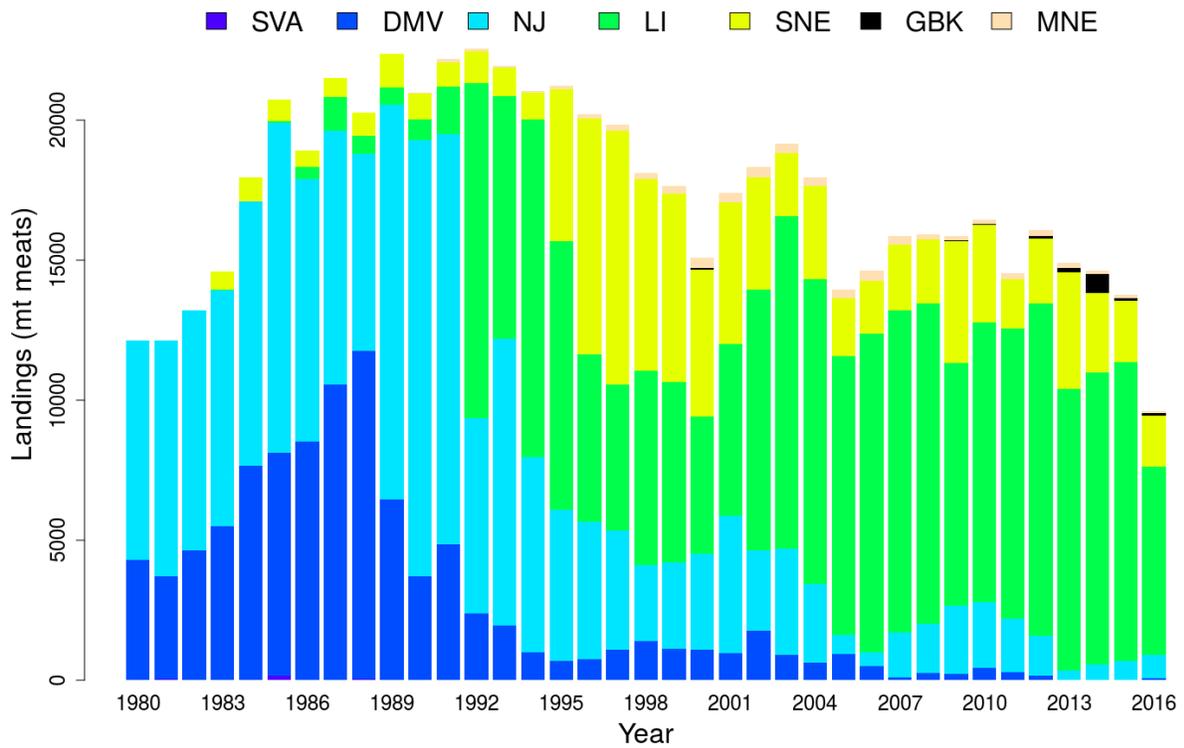
Year	Mean	Median	CV	LCI	UCI
2017	65293	64702	0.135	50173	84969
2018	64755	64167	0.135	49760	84269
2019	64225	63642	0.135	49352	83580
2020	63693	63116	0.136	48849	83048
2021	63138	62573	0.136	48423	82324
2026	60410	59846	0.138	46152	79072
2041	52689	52202	0.136	40410	68700
2066	45066	44785	0.113	36138	56199



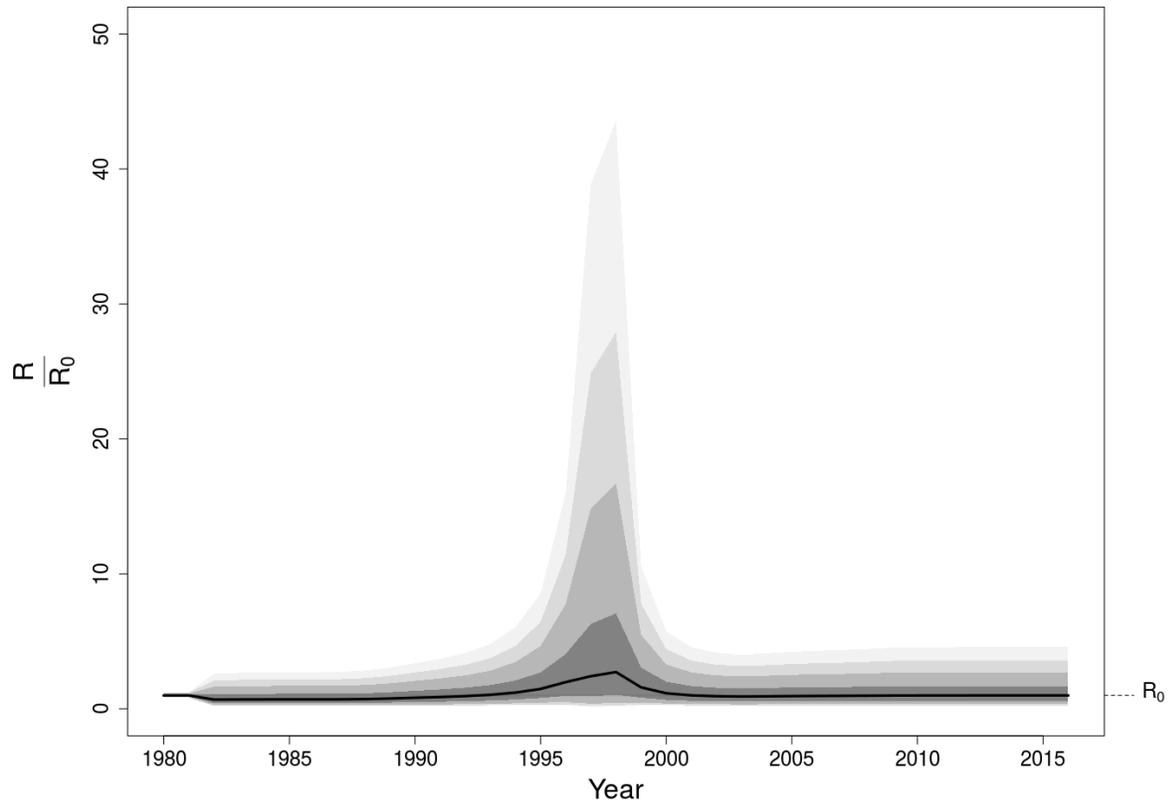
**Figure A1.** Trends in relative spawning stock biomass ( $SSB/SSB_{Threshold}$ ) for the whole ocean quahog stock during 1982-2016. The solid line shows estimates from this assessment with approximate 50, 80, 90, and 95<sup>th</sup> percentile lognormal confidence intervals in shades of grey. The green short-dash line at  $SSB/SSB_{Threshold} = 1.25$  is the management target. The red long-dash line at  $SSB/SSB_{Threshold} = 1$  is the level that defines an overfished stock.



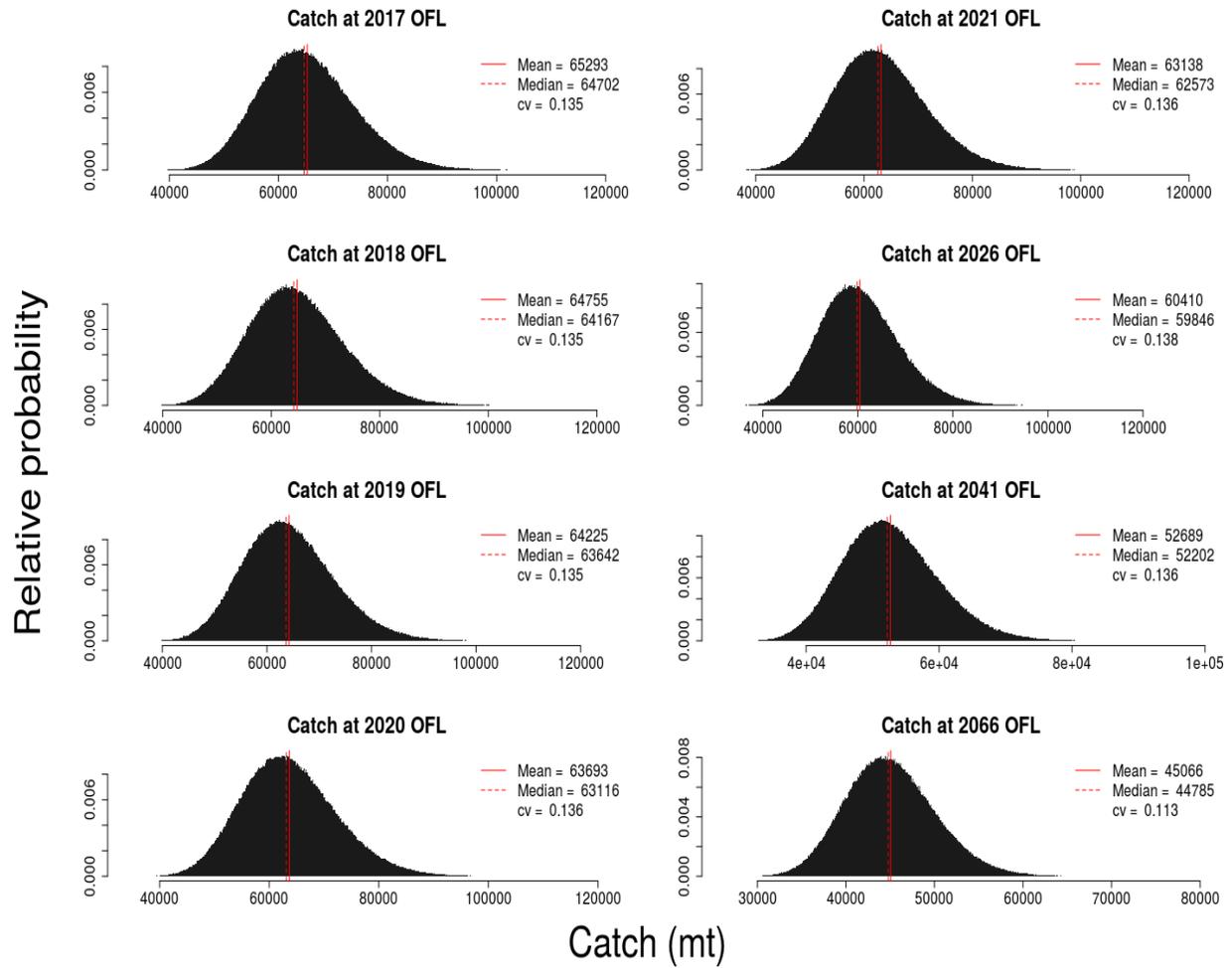
**Figure A2.** Trends in relative fishing mortality  $F/F_{\text{Threshold}}$  for ocean quahog stock 1982-2016. The solid line shows estimates from this assessment with approximate 50, 80, 90, and 95<sup>th</sup> percentile lognormal confidence intervals in shades of grey. The solid line at  $F/F_{\text{Threshold}} = 1$  is the new fishing mortality threshold reference point.



**Figure A3.** Landings for ocean quahogs by region during 1980-2016. Regions from north to south are abbreviated with MNE for Maine, 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 ocean quahog stock during 1982-2016. The solid line shows estimates from this assessment with approximate 50, 80, 90, and 95<sup>th</sup> percentile lognormal confidence intervals in shades of grey. The horizontal line is mean recruitment in the unfished stock ( $R_0$ ). The recruitment time series is probably not reflective of true recruitment to the stock (see Special Comments).



**Figure A5.** Distribution of projected catch (landings + incidental mortality) at the Overfishing Limit (OFL) from 2017-2066 for ocean quahog in eight example years.

## **Appendix: Stock Assessment Terms of Reference for SAW/SARC-63, Feb. 19-21, 2017**

### **A. Ocean quahog**

1. Estimate catch from all sources including landings and discards. Map the spatial and temporal distribution of landings, discards, and fishing effort, 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, 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. Describe the relationship between habitat characteristics (e.g., benthic, pelagic, and climate), survey data, and ocean quahog distribution, and report on any changes in this relationship.
4. Evaluate age determination methods and available data for ocean quahogs to potentially estimate growth, productivity, and recruitment. Review changes over time in biological parameters such as length, width, and condition.
5. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series (integrating results from TOR 4, 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.
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-6).
8. Develop approaches and apply them to conduct stock projections.
  - a. Provide numerical annual projections (5 – 50 years) and the statistical distribution (e.g., probability density function) of the OFL (overfishing level), including model estimated and other uncertainties. 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. 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 "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 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 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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## **Publications and Reports of the Northeast Fisheries Science Center**

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:

*NOAA Technical Memorandum NMFS-NE* -- This series is issued irregularly. The series typically includes: data reports of long-term field or lab studies of important species or habitats; synthesis reports for important species or habitats; annual reports of overall assessment or monitoring programs; manuals describing program-wide surveying or experimental techniques; literature surveys of important species or habitat topics; proceedings and collected papers of scientific meetings; and indexed and/or annotated bibliographies. All issues receive internal scientific review and most issues receive technical and copy editing.

*Northeast Fisheries Science Center Reference Document* -- This series is issued irregularly. The series typically includes: data reports on field and lab studies; progress reports on experiments, monitoring, and assessments; background papers for, collected abstracts of, and/or summary reports of scientific meetings; and simple bibliographies. Issues receive internal scientific review and most issues receive copy editing.

*Resource Survey Report* (formerly *Fishermen's Report*) -- This information report is a regularly-issued, quick-turnaround report on the distribution and relative abundance of selected living marine resources as derived from each of the NEFSC's periodic research vessel surveys of the Northeast's continental shelf. This report undergoes internal review, but receives no technical or copy editing.

**TO OBTAIN A COPY** of a *NOAA Technical Memorandum NMFS-NE* or a *Northeast Fisheries Science Center Reference Document*, either contact the NEFSC Editorial Office (166 Water St., Woods Hole, MA 02543-1026; 508-495-2350) or consult the NEFSC webpage on "Reports and Publications" (<http://www.nefsc.noaa.gov/nefsc/publications/>). To access *Resource Survey Report*, consult the Ecosystem Surveys Branch webpage (<http://www.nefsc.noaa.gov/femad/ecosurvey/mainpage/>).

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