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A Report of the 48th Northeast Regional Stock Assessment Workshop

48th Northeast Regional Stock Assessment Workshop (48th SAW)

Assessment Summary Report

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Table of Contents

Introduction **1**
Outcome of Stock Assessment Review Meeting **2**
A. GOLDEN TILEFISH ASSESSMENT SUMMARY FOR 2009 ..... **12**
State of Stock 12
Projections for 2009-2011 12
Stock Distribution and Identification 15
Catches 15
Data and Assessment 15
Biological Reference Points 16
Fishing Mortality 16
Biomass 17
Recruitment 17
Special Comments 17
References 18
Figures 19
B. OCEAN QUAHOG ASSESSMENT SUMMARY FOR 2009 ..... **26**
State of the Stock 26
Projections 26
Stock Distribution and Identification 27
Catches 27
Data and Assessment 28
Biological Reference Points 28
Fishing Mortality 29
Recruitment 29
Stock Biomass 29
Special Comments 29
References 31
Tables 32
Figures 33
C. WEAKFISH ASSESSMENT SUMMARY FOR 2009 ..... **41**
State of Stock 41
Projections 41
Stock Distribution and Identification 41
Catches 42
Data and Assessment: 42
Biological Reference Points 42
Fishing Mortality 43
Spawning Stock Biomass 43
Recruitment 43
Special Comments 43
References 43
Figures 44
Appendix: Terms of Reference **47**

SAW-48 ASSESSMENT SUMMARY REPORT

Introduction

The 48th SAW Assessment Summary Report contains summary and detailed technical information on three stock assessments reviewed in June 2009 at the Stock Assessment Workshop (SAW) by the 48th Stock Assessment Review Committee (SARC-48): golden tilefish (*Lopholatilus chamaeleonticeps*), ocean quahog (*Arctica islandica*), and weakfish (*Cynoscion regalis*). The SARC-48 consisted of three external, independent reviewers appointed by the Center for Independent Experts (CIE) and an external SARC chairman from the New England Fishery Management Council Science and Statistics Committee (NEFMC SSC). The SARC evaluated whether each Term of Reference (listed in the Appendix) was completed successfully based on whether the work provided a scientifically credible basis for developing fishery management advice. The reviewers' reports for SAW/SARC-48 are available at website: http://www.nefsc.noaa.gov/nefsc/saw/ under the heading "SARC 48 Panelist Reports".

An important aspect of any assessment is the determination of current stock status. The status of the stock relates to both the rate of removal of fish from the population – the exploitation rate – and the current stock size. The exploitation rate is the proportion of the stock alive at the beginning of the year that is caught during the year. When that proportion exceeds the amount specified in an overfishing definition, overfishing is occurring. Fishery removal rates are usually expressed in terms of the instantaneous fishing mortality rate, F, and the maximum removal rate is denoted as $F_{THRESHOLD}$.

Another important factor for classifying the status of a resource is the current stock level, for example, spawning stock biomass (SSB) or total stock biomass (TSB). Overfishing definitions, therefore, characteristically include specification of a minimum biomass threshold as well as a maximum fishing threshold. If the biomass of a stock falls below the biomass threshold ($B_{THRESHOLD}$) the stock is in an overfished condition. The Sustainable Fisheries Act mandates that a stock rebuilding plan be developed should this situation arise.

Since there are two dimensions to stock status – the rate of removal and the biomass level – it is possible that a stock not currently subject to overfishing in terms of exploitation rates is in an overfished condition, that is, has a biomass level less than the threshold level. This may be due to heavy exploitation in the past, or a result of other factors such as unfavorable environmental conditions. In this case, future recruitment to the stock is very important and the probability of improvement may increase greatly by increasing the stock size. Conversely, fishing down a stock that is at a high biomass level should generally increase the long-term sustainable yield. Stocks under federal jurisdiction are managed on the basis of maximum sustainable yield (MSY). The biomass that produces this yield is called B_{MSY} and the fishing mortality rate that produces MSY is called F_{MSY}.

Given this, federally managed stocks under review are classified with respect to current overfishing definitions. A stock is overfished if its current biomass is below $B_{THRESHOLD}$ and overfishing is occurring if current F is greater than $F_{THRESHOLD}$. The table below depicts status criteria.

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

Fisheries management may take into account the precautionary approach, 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

Based on the Review Panel reports (available at http://www.nefsc.noaa.gov/nefsc/saw/ under the heading "SARC 48 Panelist Reports"), the SARC review committee concluded that the assessment terms of reference were satisfied for each of the three stocks.

For tilefish, neither of the two assessment models presented (an ASPIC surplus production model and a statistical, age-and-length-structured model fit to the CPUE and length-frequency data) fit the data well. However, because both models and their uncertainty were adequately investigated, the SARC was able to conclude that stock is not overfished and that overfishing is not occurring. The ASPIC model results suggested a recent increase in abundance; however, the commercial CPUE index has been declining in recent years in a manner consistent with the passage of a strong cohort through the stock, lack of age-structure in the population, and nonequilibrium stock conditions. Based on these considerations and some additional factors, the SARC review committee was not convinced that the stock had rebuilt to B_{TARGET}. They concluded that the tilefish projections are useful for displaying the extent of uncertainty in future stock size, but not for predicting future stock size. They also concluded that for the most recent years the biomass estimates from the ASPIC model are likely overestimates.

For ocean quahogs, the SARC felt commercial landings and fishing effort were well characterized, and the analyses were very thorough. As a whole, the stock is slowly being fished down to its B_{MSY} proxy reference point (1/2 of the virgin biomass), the stock is not overfished and overfishing is not occurring. The unique biology of ocean quahogs (slow growth, low levels of recruitment and very long-lived) creates time lags that are outside the planning horizons for most managed activities and presents unique challenges for the assessment of this stock.

For weakfish, multiple analyses were presented to provide estimates of abundance, total mortality and fishing mortality, including an ADAPT VPA, an analysis of survey data as abundance indices, and a Steele-Henderson production model including predation effects. While there are technical issues with some of the modeling, taken as a whole the analyses indicate that abundance has declined markedly, total mortality is high, non-fishing mortality has recently increased and that the stock is currently in a depleted state.

Glossary

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

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

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

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

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

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

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

Biomass Dynamics Model. A simple stock assessment model that tracks changes in stock

using assumptions about growth and can be tuned to abundance data such as commercial catch rates, research survey trends or biomass estimates.

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

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

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

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

Mortality rates. Populations of animals decline exponentially. This means that the number of animals that die in an "instant" is at all times proportional to the number present. The decline is defined by survival curves such as:

$$N_{t+1} = N_t e^{-z}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Spawning stock biomass per recruit (SSB/R or SBR). The expected lifetime contribution to the spawning stock biomass for each

recruit. SSB/R is calculated assuming that F is constant over the life span of a year class. The calculated value is also dependent on the exploitation pattern and rates of growth and natural mortality, all of which are also assumed to be constant.

Stock Synthesis 2 (SS2). This application provides a statistical framework for calibration of a population dynamics model using a diversity of fishery and survey data. SS2 is designed to accommodate both age and size structure and with multiple stock sub-areas. Selectivity can be cast as age specific only, size-specific in the observations only, or size-specific with the ability to capture the major effect of size-specific survivorship. The overall model contains subcomponents which simulate the population dynamics of the stock and fisheries, derive the expected values for the various observed data, and quantify the magnitude of difference between observed and expected data. Parameters are searched for which will maximize the goodness-of-fit. A management layer is also included in the model allowing uncertainty in estimated parameters to be propagated to the management quantities, thus facilitating a description of the risk of various possible management scenarios. The structure of SS2 allows for building of simple to complex models depending upon the data available.

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

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

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

Uncertainty. Uncertainty results from a lack of perfect knowledge of many factors that affect stock assessments, estimation of reference points, and management. Rosenberg and Restrepo (1994) identify 5 types: measurement error (in observed quantities), process error (or natural population variability), model error (mis-specification of assumed values or model structure), estimation error (in population parameters or reference points, due to any of the preceding types of errors), and implementation error (or the inability to achieve targets exactly for whatever reason)

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

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

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

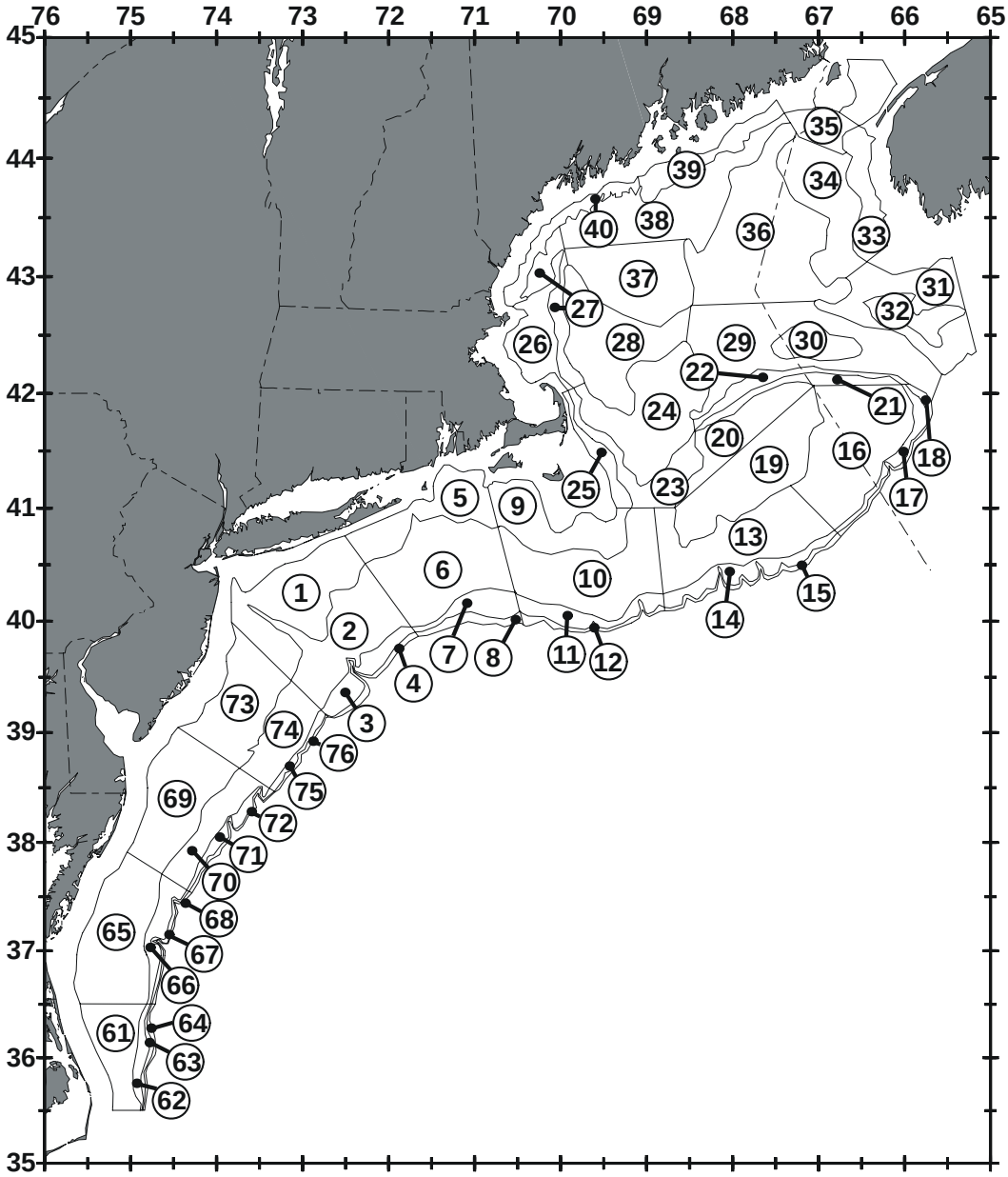

Figure 1. Offshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys.

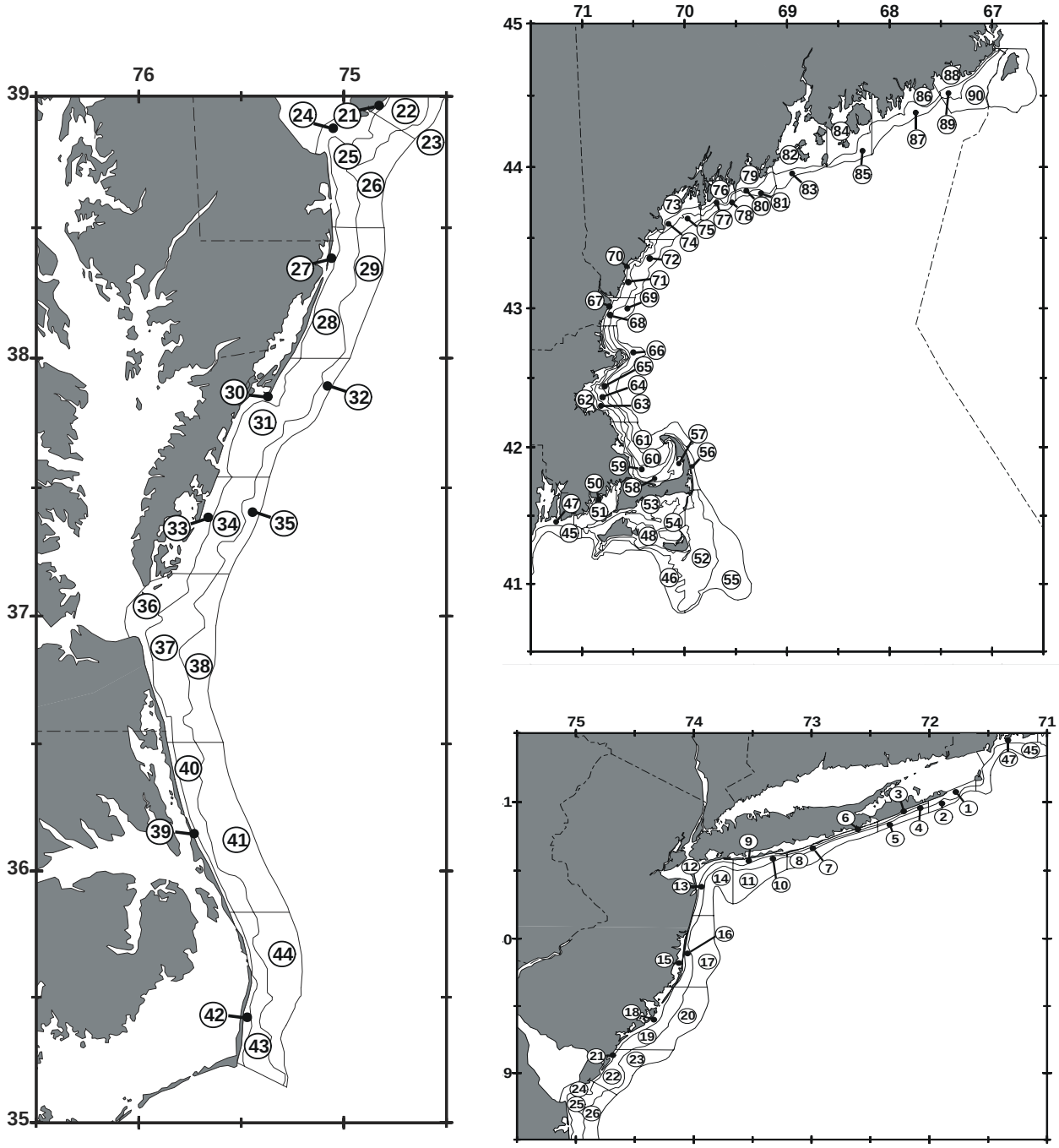

Figure 2. Inshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys.

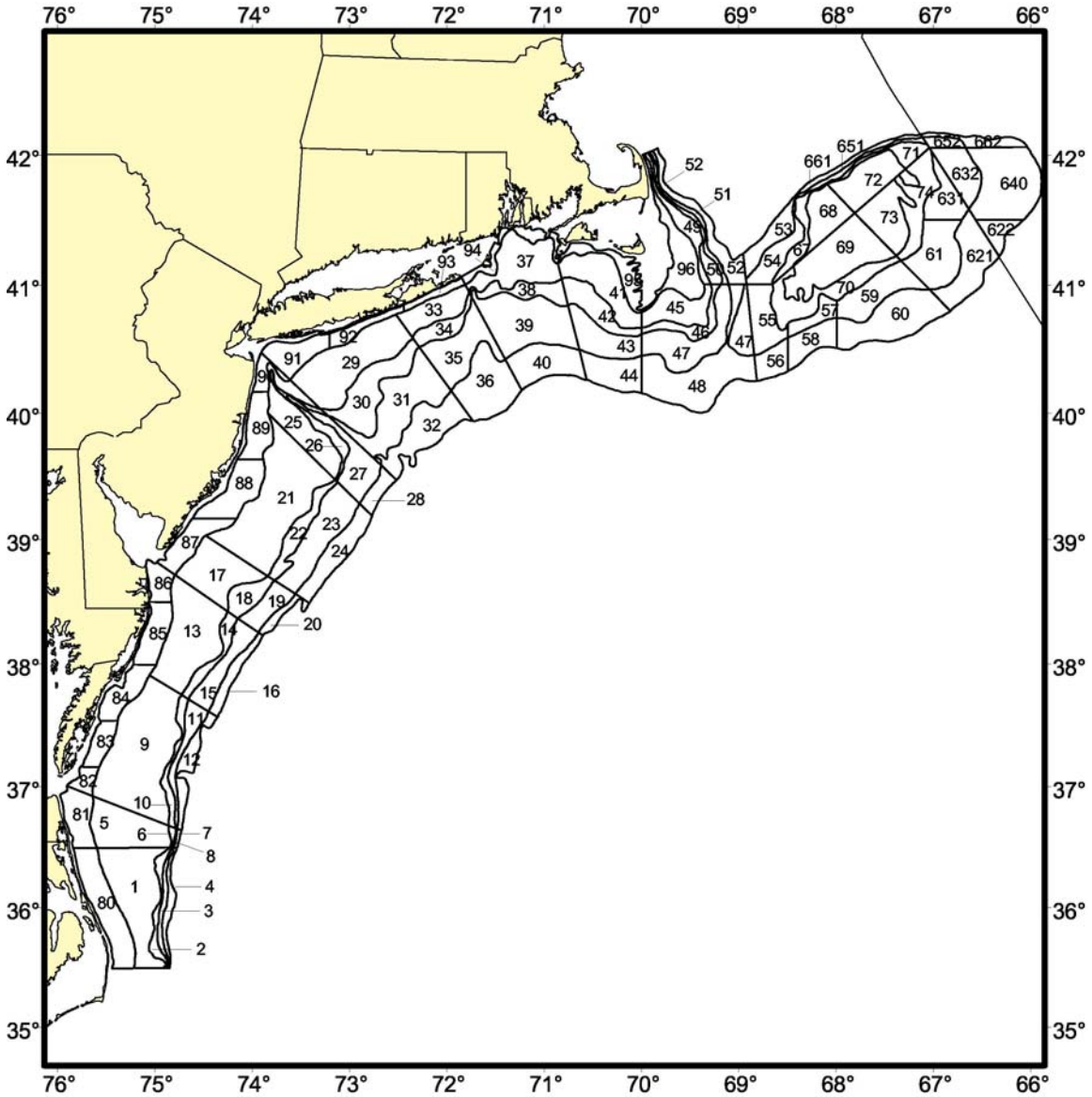

Figure 3. Northeast Fisheries Science Center clam resource survey strata, along the east coast of the US.

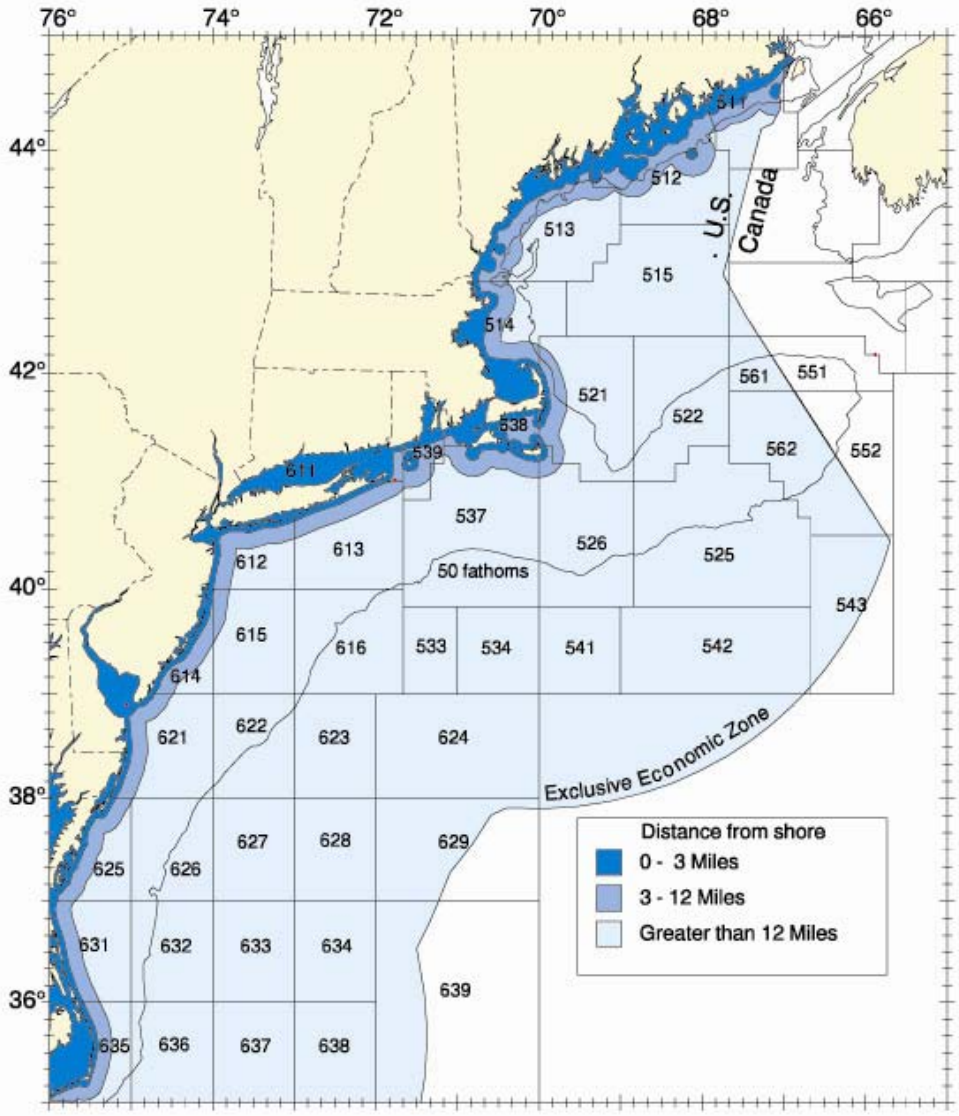

Figure 4. Statistical areas used for reporting commercial catches.

A. GOLDEN TILEFISH ASSESSMENT SUMMARY FOR 2009

State of Stock

The Golden Tilefish stock is not overfished and overfishing is not occurring (Figures A1 and A2). Fishing mortality in 2008 was estimated to be 0.06, 38% of the updated F_{MSY} = 0.16. Total biomass in 2008 was estimated to be 11,910 mt, 104% of the updated B_{MSY} = 11,400 mt (Figure A1). The 50% confidence interval (25%ile to 75%ile) for F in 2008 is between 0.05 and 0.07 (Figure A3). The 50% confidence interval (25%ile to 75%ile) for total biomass in 2008 is between 9,550 mt and 13,538 mt (Figure A4). The biomass estimates for recent years from the ASPIC model are likely over-optimistic because trends in commercial VTR CPUE declined recently in a manner consistent with the passage of the strong 1999 cohort through the population (an interpretation further supported by the length frequency data). The current assessment model (ASPIC) does not account for those factors. Much of the confidence interval around the 2008 biomass estimate falls below the updated B_{MSY} listed above. Based on these considerations there is no convincing evidence that the stock has rebuilt to levels above B_{TARGET}.

Projections for 2009-2011

Two types of projections were made using the ASPIC model results: one type conditioned on fishery yield or F, and the other type incorporating assumptions about future trend of the commercial fishery VTR CPUE index of abundance.

> ***NOTE FROM SAW CHAIRMAN: The SARC48 Review Panel concluded that the tilefish projections are useful for displaying the extent of uncertainty in future stock size, but not for predicting future stock size. They noted that the projections were highly variable depending on both the assumed future trend in commercial CPUE and to small changes in the magnitude of the assumed CPUE values. They also concluded that for the most recent years (e.g., 2008) the biomass estimates from the ASPIC model are likely overestimates and that the estimates are more uncertain than the model suggests. (SARC reports are available at http://www.nefsc.noaa.gov/nefsc/saw/ under the heading "SARC 48 Panelist Reports")***

Tilefish Projections conditioned on Yield or F:

Projections were made assuming constant catch (C) or F in 2009-2011 for three scenarios: A) at the 2008 TAC = 905 mt, B) at MSY = 1,868 mt, and C) at F_{MSY} = 0.16. The projected estimate is the 50%ile of catch and biomass for constant catch (C) or F; landings and total biomass (B) in metric tons. The projections condition on the current assessment start off with population levels that are likely to be overestimates and the projections from this method, while they can be used to explore the uncertainty in the projections, will not adequately represent likely stock levels over the next few years.

A) C = 2008 TAC = 905 mt

Year	C (mt)	F	F25%ile	F75%ile	P > FMSY	B (mt)	B25%ile	B75%ile	P < BMSY	P < 1/2 BMSY
2009	905	0.07	0.06	0.08	0%	13,030	10,480	14,210	35%	<1%
2010	905	0.06	0.06	0.08	0%	13,930	11,420	14,720	25%	0%
2011	905	0.06	0.06	0.07	0%	14,760	12,200	15,260	15%	0%

B) C = MSY = 1,868 mt

Year	C (mt)	F	F25%ile	F75%ile	P > FMSY	B (mt)	B25%ile	B75%ile	P < BMSY	P < 1/2 BMSY
2009	1,868	0.14	0.13	0.18	36%	13,030	10,480	14,210	35%	<1%
2010	1,868	0.14	0.14	0.18	38%	12,990	10,480	13,810	37%	<1%
2011	1,868	0.14	0.14	0.18	40%	12,950	10,470	13,590	39%	<1%

C) F = FMSY = 0.16

Year	C (mt)	F	F25%ile	F75%ile	P > FMSY	B (mt)	B25%ile	B75%ile	P < BMSY	P < 1/2 BMSY
2009	2,112	0.16	0.15	0.21	50%	13,030	10,480	14,210	35%	<1%
2010	2,071	0.16	0.15	0.21	50%	12,750	10,230	13,660	39%	<1%
2011	2,038	0.16	0.15	0.21	50%	12,530	9,995	13,290	45%	<1%

Tilefish projections based on assumptions about future trends in commercial CPUE: Projections were made assuming constant catch at the 2008 TAC = 905 mt and five scenarios for the future trend in the VTR CPUE index of abundance in 2009-2011: A) constant at the 1995-2008 time series average value, B) constant at the 2001-2008 average value (since FMP implementation), C) a 25% annual increase, D) a 25% annual decrease, E) constant at the 2008 value and F) constant at the 2008 value rounded to one decimal place. The projected estimate is the 50%ile of catch and biomass for fixed yield (C) or F; landings and total biomass (B) in metric tons. Note that projections constructed in this fashion provide alternative assessment models and so can also substantially change the reference points (note **bold** font) and status determination which makes the use of these reference points highly uncertain for short term interpretation of stock status.

A) CPUE = 1995-2008 FMSY = 0.165 BMSY = 9,853 mt MSY = 1,627 mt

Year	C (mt)	F	F25%ile	F75%ile	P > FMSY	B (mt)	B25%ile	B75%ile	P < BMSY	P < 1/2 BMSY
2009	905	0.070	0.065	0.079	0%	12,836	11,259	13,844	16%	<1%
2010	905	0.069	0.064	0.077	0%	13,082	11,595	14,134	13%	<1%
2011	905	0.067	0.062	0.075	0%	13,322	11,896	14,349	10%	0%

B) CPUE = 2001-2008 FMSY = 0.168 BMSY = 9,759 mt MSY = 1,643 mt

Year	C (mt)	F	F25%ile	F75%ile	P > FMSY	B (mt)	B25%ile	B75%ile	P < BMSY	P < 1/2 BMSY
2009	905	0.071	0.066	0.082	0%	12,496	10,768	13,502	17%	<1%
2010	905	0.069	0.065	0.077	0%	12,874	11,412	13,843	13%	<1%
2011	905	0.068	0.063	0.075	0%	13,210	11,913	14,142	9%	0%

C) CPUE = +25% FMSY = 0.158 BMSY = 10,070 mt MSY = 1,590 mt

Year	C (mt)	F	F25%ile	F75%ile	P > FMSY	B (mt)	B25%ile	B75%ile	P < BMSY	P < 1/2 BMSY
2009	905	0.071	0.065	0.082	0%	12,598	10,751	13,820	20%	0%
2010	905	0.069	0.064	0.078	0%	12,936	11,348	14,087	15%	0%
2011	905	0.067	0.063	0.075	0%	13,255	11,780	14,342	12%	0%

D) CPUE = -25% FMSY = 0.060 BMSY = 15,000 mt MSY = 897 mt

Year	C (mt)	F	F25%ile	F75%ile	P > FMSY	B (mt)	B25%ile	B75%ile	P < BMSY	P < 1/2 BMSY
2009	905	0.139	0.084	0.213	84%	6,620	4,357	10,981	84%	57%
2010	905	0.143	0.085	0.223	85%	6,440	4,157	10,741	84%	59%
2011	905	0.148	0.087	0.238	86%	6,211	3,924	10,523	85%	60%

E) CPUE = 2008 FMSY = 0.197 BMSY = 8,989 mt MSY = 1,774 mt

Year	C (mt)	F	F25%ile	F75%ile	P > FMSY	B (mt)	B25%ile	B75%ile	P < BMSY	P < 1/2 BMSY
2009	905	0.069	0.064	0.075	0%	12,980	12,022	14,038	<1%	6%
2010	905	0.068	0.063	0.074	0%	13,081	12,074	14,233	<1%	0%
2011	905	0.068	0.063	0.074	0%	13,174	12,124	14,398	<1%	0%

F) CPUE = 2008 round FMSY = 0.104 BMSY = 12,060 mt MSY = 1,254 mt

Year	C (mt)	F	F25%ile	F75%ile	P > FMSY	B (mt)	B25%ile	B75%ile	P < BMSY	P < 1/2 BMSY
2009	905	0.088	0.066	0.130	38%	10,125	6,789	13,436	64%	18%
2010	905	0.084	0.065	0.125	36%	10,505	7,115	13,840	63%	15%
2011	905	0.083	0.063	0.119	34%	10,844	7,454	14,156	61%	12%

Landings and Status Table (weights in '000 mt live): Golden Tilefish

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Max[1]	Min[1]	Mean[1]
Commercial landings	0.5	0.5	0.9	0.8	1.1	1.2	0.9	0.9	0.8	0.7	4.0	0.4	1.5
B/B_{msy} ratios	0.4	0.5	0.6	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.4	0.3	0.7
F/F_{msy} ratios	0.6	0.5	0.8	0.7	0.9	0.9	0.6	0.5	0.4	0.4	4.0	0.2	1.3
Total biomass	4.7	5.4	6.3	7.0	7.8	8.4	8.9	9.9	10.8	11.9	15.7	3.7	8.1
Total fishing mortality	0.10	0.09	0.13	0.12	0.14	0.14	0.09	0.09	0.07	0.06	0.65	0.03	0.21

[1] Over period 1973-2008. No recruitment index exists.

Stock Distribution and Identification

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

Catches:

Total commercial landings (live weight) increased from less than 125 mt during 1967-1972 to more than 3,900 mt in 1979 and 1980 (Figure A5). Landings stabilized at about 2,000 mt during 1982-1986. An increase in landings occurred in 1987 to 3,200 mt but subsequently declined to 450 mt in 1989. Annual landings have ranged between 454 and 1,838 mt from 1988 to 1998. Landings from 1999 to 2002 were below 900 mt, ranging from 506 to 874 mt. An annual commercial TAC of 905 mt was implemented in November of 2001 (MAFMC 2000). Landings in 2003 and 2004 exceeded the TAC at 1,130 and 1,182 mt respectively, but have been at or below the TAC during 2005-2008. Commercial landings in 2008 landings were 736 mt, 19% below the TAC of 905 mt. The longline fishery currently lands about 95% of the TAC. Discards in the longline fishery are negligible. The trawl fishery currently lands about 5% of the TAC. Observer data indicate that discard rates in the trawl fishery are low. Recreational catches have been low for the last 25 years (i.e., less than 1 mt caught annually).

Data and Assessment

The Northeast Regional (NER) Stock Assessment Workshop (SAW) last reviewed the Golden tilefish assessment in 2005 at SAW 41 (NEFSC 2005). A surplus production model (ASPIC) was the basis for the 2005 SAW 41 assessment and existing biological reference points.

The current assessment uses the ASPIC surplus production model with three commercial fishery CPUE series (Turner 1973-1982, NEFSC weighout 1982-1993, and VTR 1995-2008) (Figure A6). The VTR CPUE estimate tripled from 2001 to a peak in 2005, and has since steadily declined to about the same value in 2008 as estimated for 2001. The trends in fishing mortality were very similar in the 2005 SAW 41 assessment and in the current model through 2004. The 2005 SAW 41 F estimates generally followed the 75%ile of the current estimates of F (i.e., were generally somewhat higher), while the 2005 SAW 41 biomass estimates followed the 25%ile of the current estimates of biomass (i.e., were generally somewhat lower).

The current assessment indicates that the tilefish stock biomass has continued to increase since the 2005 SAW 41 assessment. However, the trend in commercial fleet VTR CPUE index of stock biomass since 2005 is modeled with a relatively high degree of uncertainty in the ASPIC surplus production model, due to an inability to account for cohort effects (e.g., 1993 and 1999 year classes). As a result, the statistical fit to the recent VTR CPUE has deteriorated

significantly (lower correlation coefficient) since the last assessment, making interpretation of the recent trend in stock biomass and status compared to reference points relatively uncertain. The uncertainty about stock size and F is likely higher than that provided by the model bootstrap results.

An assessment of tilefish status was also attempted using the SCALE (statistical catch-at-length) model, although these estimates were not adopted as the basis for assessment for the reasons described below. SCALE is a flexible statistical model that was able to incorporate historic and contemporary length samples and growth rate information for tilefish, in addition to the commercial fishery landings and aggregate CPUE indices of stock biomass. The SCALE model estimates followed the declining trend in observed CPUE since 2005 more closely than the ASPIC model, due mainly to the ability to incorporate length and growth data, and therefore track cohort effects in the CPUE index. However, the SCALE model estimates of F during the late 1990s were judged to be unrealistically high (over ten times FMSY), while estimates of biomass in that period were correspondingly unrealistically low. In addition, due to a lack of statistical fit for some of the input data, the SCALE model does not provide a working framework for estimation of uncertainty in current and projected status (i.e., the MCMC did not work reliably, and therefore the ability to perform stochastic projections is limited to recruitment uncertainty).

Biological Reference Points

Estimates of biological reference points using the ASPIC model from the 1998 assessment were B_{MSY}= 8,448 mt, F_{MSY} = 0.22, and MSY = 1,888 mt (Nitschke et al. 1998). The previously existing biological reference points using the ASPIC model from the 2005 SAW 41 assessment were B_{MSY} = 9,384 mt, F_{MSY} = 0.21, and MSY = 1,988 mt. With respect to the previously existing reference points from the 2005 SAW 41 assessment, fishing mortality in 2008 was estimated to be 0.06, 29% of F_{MSY} = 0.21, and total biomass in 2008 was estimated to be 11,910 mt, 127% of B_{MSY} = 9,384 mt. The ASPIC model seems to be adequate for interpretation of stock productivity on a decadal basis, but not for shorter term analysis, and in particular it can not capture the dynamics associated with passage of the strong 1999 year class through the population.

The 2009 SARC48 assessment using the ASPIC model provides the following updated reference points: B_{MSY} = 11,400 mt, F_{MSY} = 0.16 and MSY = 1,868 mt. The 2009 SARC48 updated biomass reference points (B_{MSY} and K) increased by 21% from the 2005 SAW 41 estimates, while updated F_{MSY} decreased by 24% and updated MSY decreased by 6%. The current 2009 assessment provides a more optimistic evaluation of stock status in 2004 than did the 2005 SAW 41 assessment (e.g., the B2004/B_{MSY} ratio). Based on the 2009 assessment model results and updated reference points, fishing mortality (F) in 2008 is estimated to be 0.06, 38% of F_{MSY} and stock biomass (B) in 2008 is estimated to be 11,910 mt, 4% above B_{MSY} (but see State of Stock section).

Fishing Mortality

Fishing mortality (F) was often above F_{MSY} during 1978-1998. Since 1999, F has been below F_{MSY} (Figures A1 and A2). The 2008 F to F_{MSY} ratio was 0.38 (F_{2008} = 0.06, F_{MSY} = 0.16). Bootstrap estimates of the 2008 F were 0.05 (25%ile) to 0.07 (75%ile), with a median (50%ile) of 0.06 (Figure A3).

Biomass

During 1974-1980, stock biomass was above B_{MSY}. Biomass has been below B_{MSY} since 1981, and below ½ B_{MSY} from 1988-2000, but has increased to 104% of B_{MSY} in 2008 (B_{2008} = 11,910 mt, B_{MSY} = 11,400 mt; Figures A1 and A2). Bootstrap estimates of the 2008 stock biomass were 9,550 mt (25%ile) to 13,538 mt (75%ile), with a median (50%ile) of 11,767 mt (Figure A4). The estimate of 2009 stock biomass was 13,030 mt (median), which is larger than the biomass estimate for 2008.

Recruitment

Estimates of recruitment do not exist. However, strong recruitment events can be seen tracking through the commercial market categories landings and length frequency samples. Most of the catch between 2002 and 2007 appears to have come from the 1998/1999 year class with no subsequent indication of strong recruitment (Figure A7).

Special Comments:

* The partial recruitment pattern is uncertain for the tilefish longline fishery because targeting of year classes to increase catch rates and market conditions will influence the size of fish landed. The inability to characterize the actual partial recruitment pattern, the possibility of unknown refuge effects due to conflicts with lobster and trawl gear, the possibility of unknown effects on tilefish CPUE due to competition/interference from an increased abundance of dogfish, the unknown effects of bait type on tilefish CPUE (e.g., substitutes for the preferred squid) and the effects of targeting incoming year classes introduce uncertainty in interpreting CPUE from this fishery as a reliable measure of stock size. Trends in CPUE and catch length frequency data in this fishery may reflect changes in fishing practices and the spatial distribution of tilefish in addition to real changes in stock biomass. The current VTR CPUE data and GLM standardization model are unable to reflect most of these effects.
* The current tilefish fishery is conducted by a relatively small (<10) number of vessels. A few of those vessels (<6) contribute information to the VTR CPUE index of stock biomass. Even though they account for >75% of the tilefish landings, there is concern that the small scale of the fleet may not provide a synoptic index of abundance for tilefish.
* The ASPIC surplus production model results used as the basis for status evaluation indicate that the point estimate of the stock is above B_{MSY} and F is well below F_{MSY}. However, as noted in the "Data and Assessment" section, the trend in the commercial fleet VTR CPUE index of stock biomass since 2005 (Figure A6) is not fit well by the model, due to an inability to account for cohort effects (e.g., 1993 and 1999 year classes). As a result, the statistical fit to the recent VTR CPUE has deteriorated significantly (lower correlation coefficient) since the last assessment, making interpretation of the recent trend in stock biomass and status compared to reference points relatively uncertain. The uncertainty about stock size and F is likely higher than that provided by the model bootstrap results.
* The index projection scenario (E) assuming the future value of VTR CPUE index will remain at the 2008 value is considered most realistic. Note that projections constructed in this fashion provide alternative assessment models and so can also substantially change the reference points and status determination. A lack of recent strong recruitment, as evidenced by the commercial fishery length samples and SCALE model results, indicated that it is unlikely that the CPUE index will increase substantially in the short term. Likewise, a substantial amount of landings in the "Large" market category and in larger sizes of the commercial fishery length samples indicates an accumulated biomass that should prevent further substantial declines in the

CPUE index. This *status quo* index projection indicates a stock with estimated B_{MSY} about 20% lower and F_{MSY} about 20% higher than the updated reference points. This projection scenario indicates a low probability that overfishing will occur or that the stock will be classified as "overfished" (below the threshold ½ B_{MSY}) if the catch remains near the *status quo* TAC.

* The index projection scenario (D) assuming a future 25% decrease per year in the fishery VTR CPUE index (decreasing CPUE) re-scales the stock size and the reference points by a larger amount than the other scenarios considered and is particularly relevant to assessment TOR5d. This projection indicates a stock with lower resilience and productivity when compared to the other scenarios, in that the *status quo* TAC = 905 mt is above the estimated MSY, and a greater than 75% chance that fishing mortality will be above F_{MSY} and biomass will be below the target B_{MSY} by 2011, and a greater then 50% chance that biomass will be below the threshold ½ B_{MSY} by 2011. This projection scenario illustrates that the stock is vulnerable to being classified as "overfished" (below the threshold ½ B_{MSY}) if the VTR CPUE continues to decrease during 2009-2011 even as the catch remains near the recent *status quo*.

* An immediate increase in the commercial landings from the *status quo* TAC = 905 mt to the updated MSY = 1,868 mt would be risky considering the uncertainty of the assessment and stock status determination.

References:

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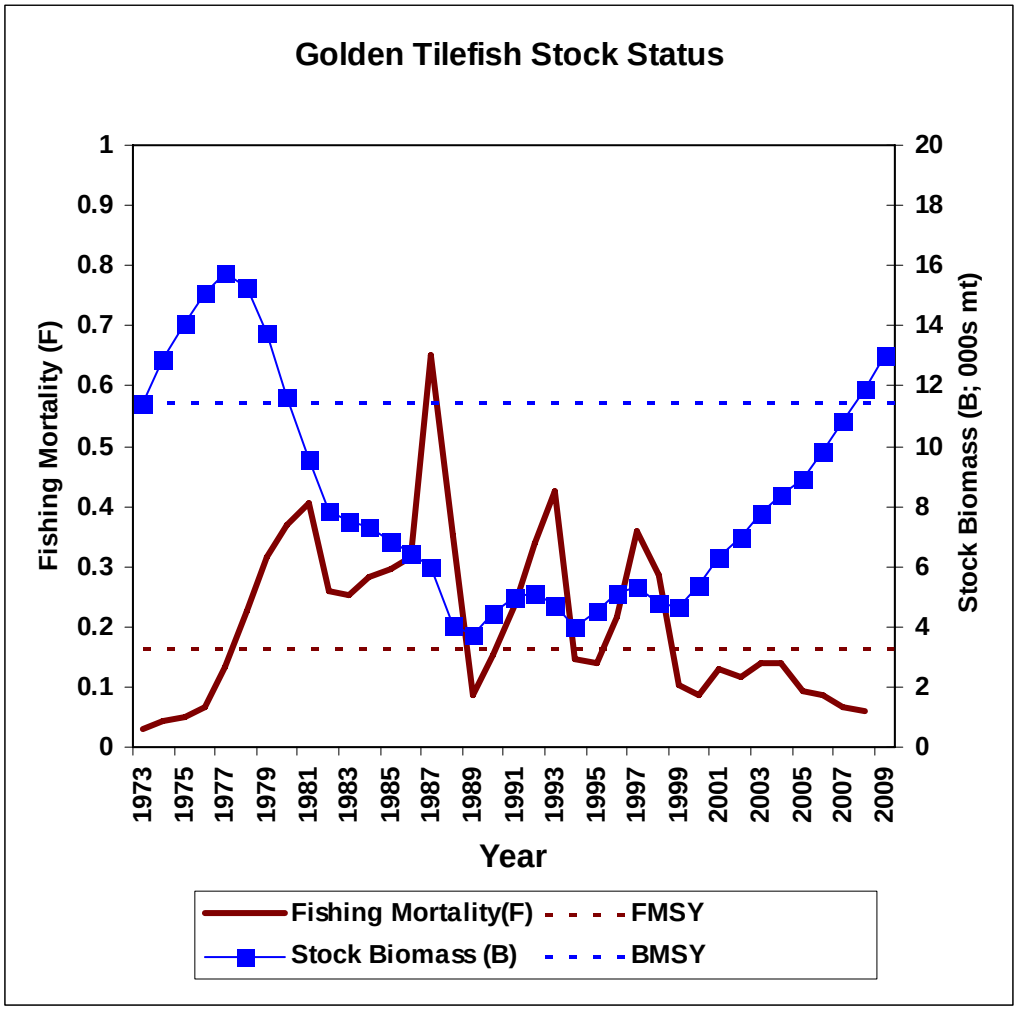
Mid-Atlantic Fishery Management Council. 2000. Tilefish fishery management plan. NOAA award No. NA57FC0002.

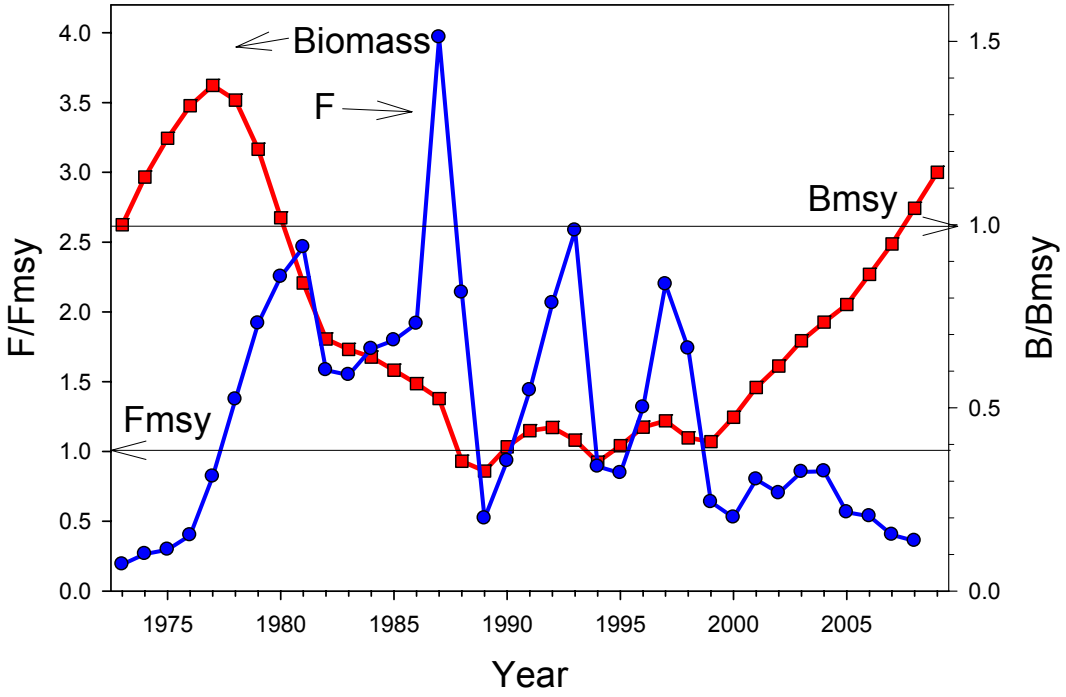
Nitschke P, Shepherd G, Terceiro M. 1998. Assessment of tilefish in the middle Atlantic – southern New England region. NEFSC. 1-12.

Turner SC. 1986. Population dynamics of and, impact of fishing on tilefish, (*Lopholatilus chamaeleonticeps)*, in the Middle Atlantic-Southern New England region during the 1970's and early 1980's. New Brunswick, N.J.: Rutgers University. Ph.D. dissertation.

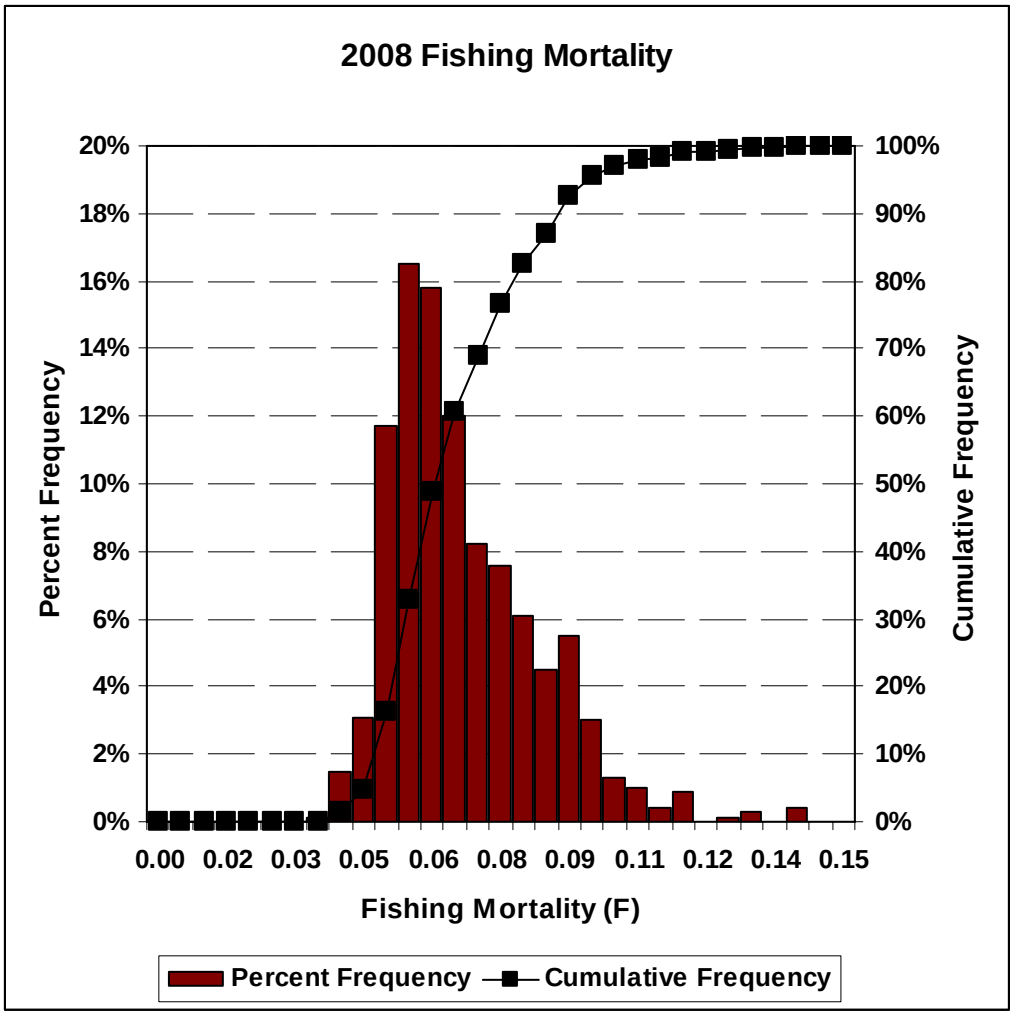
Figures:



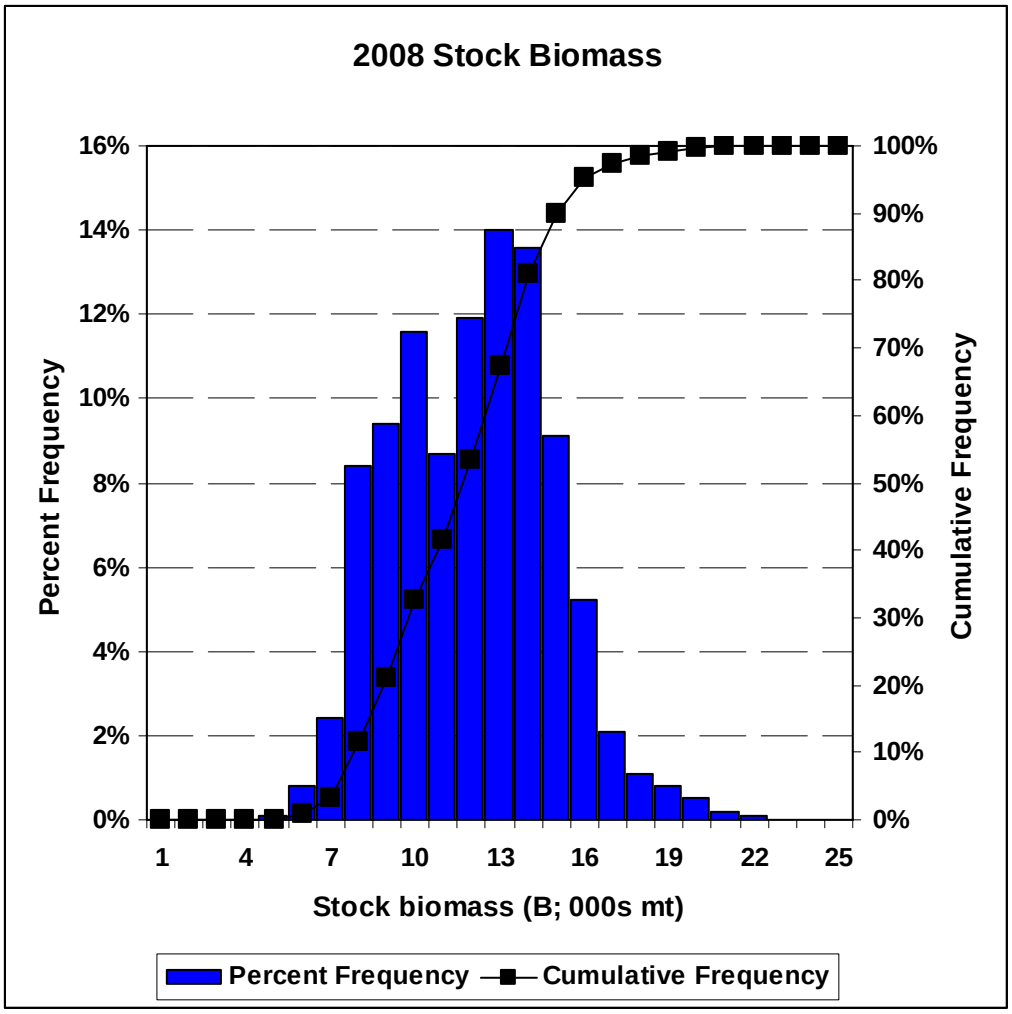
A1. Estimates of tilefish stock biomass (1973-2009) and fishing mortality rate (1973-2008) derived from the ASPIC model. The two horizontal dashed lines represent the Biological Reference Points for the overfishing threshold (F_{MSY}, lower red line) and biomass target (B_{MSY}, upper blue line).



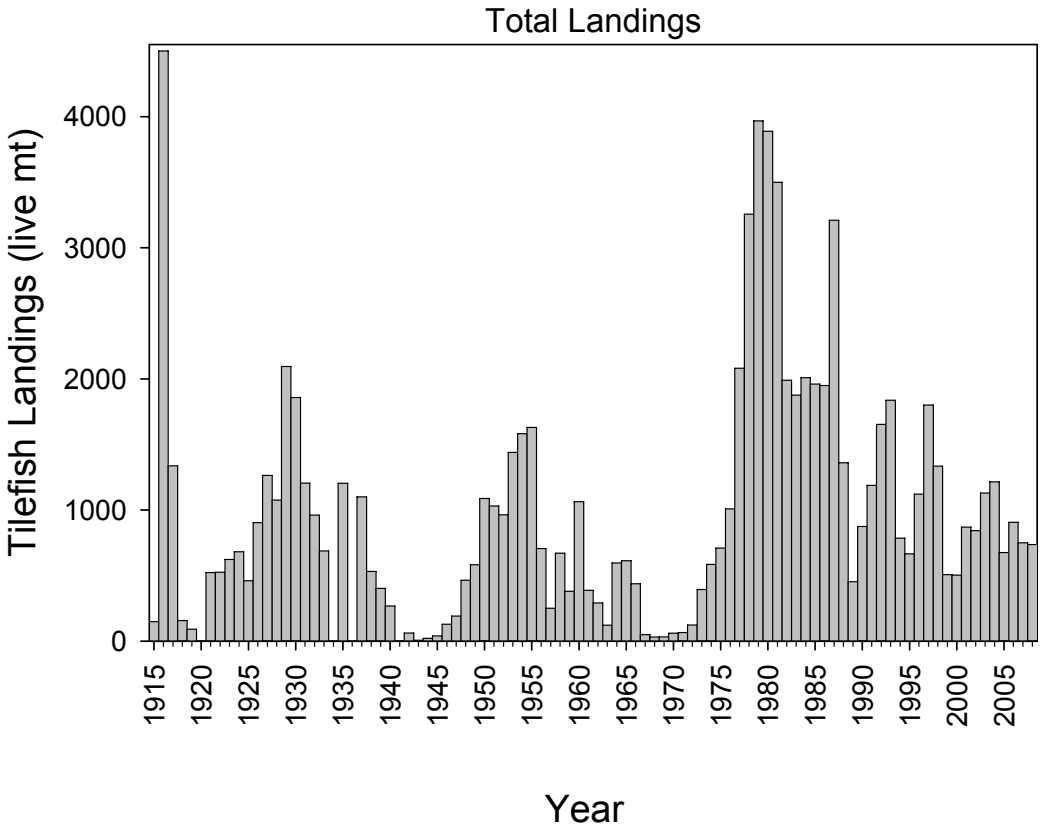
A2. Estimates of tilefish B/ Bmsy ratios (1973-2009) and F/Fmsy ratios (1973-2008). Estimates are from the 'base' ASPIC run which fixed the B1/K ratio at 0.5 and used three CPUE series (Turner, Weighout, and VTR) for tilefish.



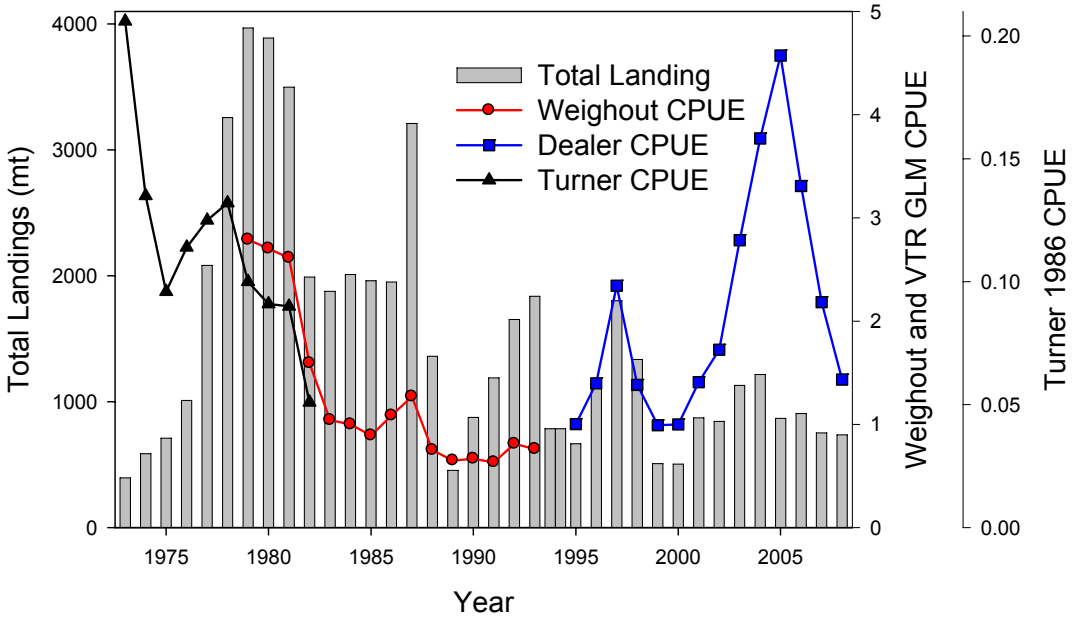
A3. Bootstrap estimates (1000 iterations) of the precision of 2008 fishing mortality on tilefish. Vertical bars display the range of the bootstrap estimates; the percent confidence intervals can be taken from the cumulative frequency. The 2008 point estimate of fishing mortality = 0.06.



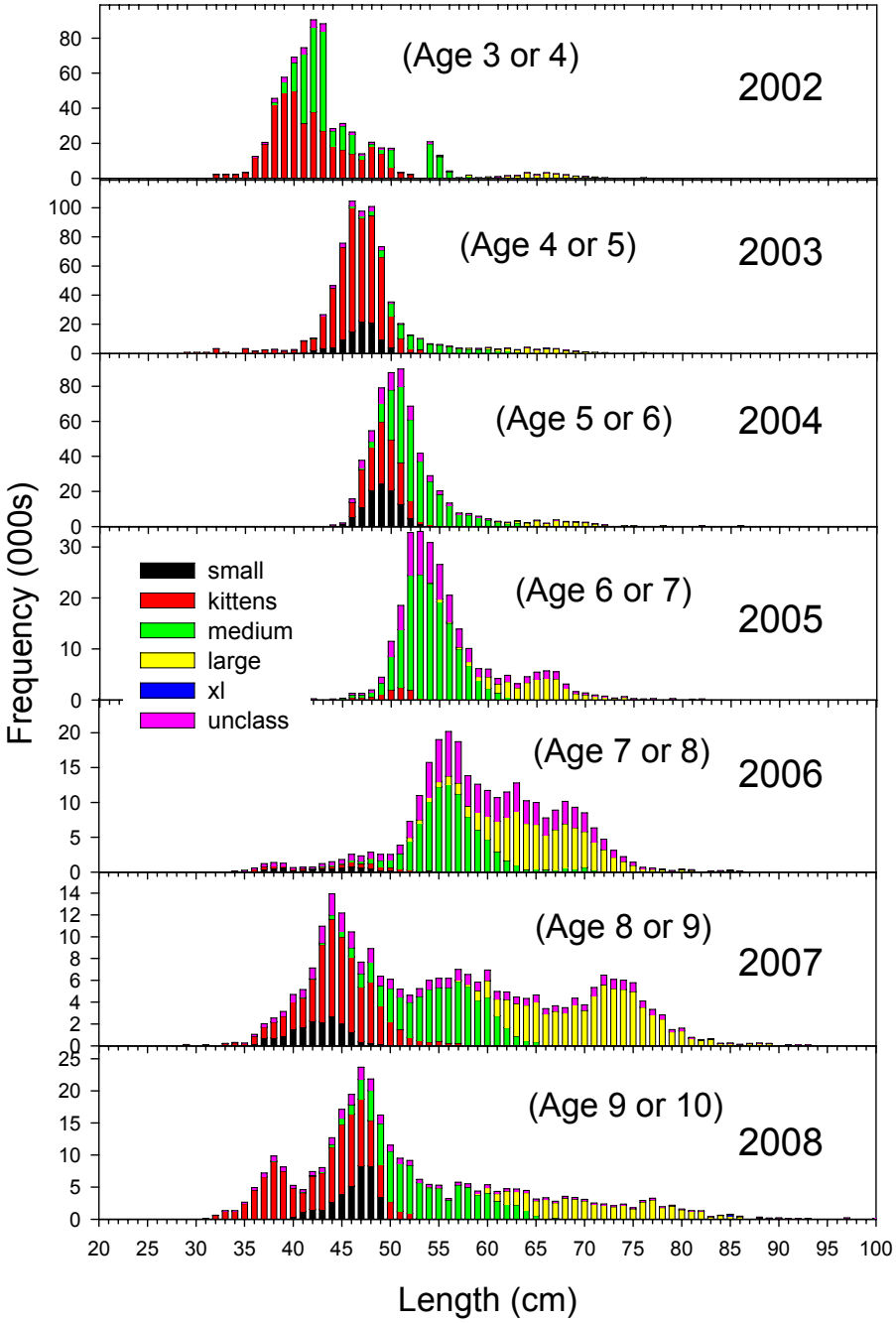
A4. Bootstrap estimates (1000 iterations) of the precision of 2008 tilefish stock biomass. Vertical bars display the range of the bootstrap estimates; the percent confidence intervals can be taken from the cumulative frequency. The 2008 point estimate of stock biomass = 11.910 thousand mt.



A5. Landings of tilefish in metric tons from 1915-2004. Landings in 1915-1972 are from Freeman and Turner (1977), 1973-1989 are from the general canvas data, 1990-1993 are from the weighout system, 1994-2003 are from the dealer reported data, and 2004-2008 is from dealer electronic reporting.



A6. GLM CPUE for the Weighout and VTR data split into two series for tilefish. Four years of overlap between Turner's and the Weighout CPUE series can be seen. Estimated total landings are also shown. Landings were based on Dealer data, except for 2005 when they were IVR-based.



A7. Expanded tilefish commercial length frequency distributions by year. Y-axis is allowed to rescale. A strong 1998 and/or 1999 year class can be seen tracking through the landings, with the age of that year class given in parentheses.

B. OCEAN QUAHOG ASSESSMENT SUMMARY FOR 2009

State of the Stock:

The ocean quahog stock is not overfished and overfishing is not occurring (Figure B4). Estimated fishable (based on fishery selectivity curve) whole stock biomass during 2008 was 2.905 million mt of meats, which is above the SARC48 recommended management target of ½ of the 1978 pre-fishery biomass = 1.790 million mt. Estimated fishing mortality during 2008 for the exploited region (all areas but Georges Bank, Figure B1) was $F = 0.0102\ y^{-1}$, and for the whole stock $F = 0.0056\ y^{-1}$. Both F estimates are less than the new SARC48 recommended fishing mortality threshold ($F_{45\%} = 0.0219\ y^{-1}$) and the current fishing mortality threshold ($F_{25\%} = 0.0517\ y^{-1}$). These estimates for ocean quahog in the US Exclusive Economic Zone (EEZ) do not include the Maine fishing grounds, which were assessed separately (see below). However, biomass and landings for Maine waters are minor and would have no appreciable effect on estimates for the stock as a whole.

In this report, "fishable" quahogs are large enough to be available to the commercial fishery, based on a size selectivity curve for commercial fishing gear. The "exploited region" is used to describe the geographic area over which the fishery currently takes place and is a portion of the "whole stock". The whole stock is not currently exploited, as the Georges Bank area (which contains an estimated 45% of the quahogs in the EEZ) has been closed to ocean quahog fishing due to PSP concerns. At this time the exploited region consists of the Southern Virginia/North Carolina, Delmarva, New Jersey, Long Island and Southern New England areas (Figure B1). Currently, the fishing mortality reference points are compared to the fishing mortality levels in the exploited region only (see Special Comments). Industry sources report that fishing may occur on Georges Bank in the future (see Special Comments).

Projections:

Table B1 shows a summary of stochastic projection results for ocean quahog stock biomass and fishing mortality in 2015 assuming natural mortality M=0.02 and a variety of harvest policies. Projection results indicate that overfished (low biomass) stock conditions are not likely to occur by 2015 under any of the states of nature or management policies considered in projections. Overfishing (F too high) is unlikely to occur in 2015 at status-quo (3.8 million bu) or at the current FMP minimum (4 million bu) landings levels. However, there is some probability of overfishing in 2015 for landings as high as the current quota (5.33 million bu) or current FMP maximum level (6 million bu, Table B1), particularly when F is calculated for just the exploited stock. The probability of overfishing occurring in 2015 is high under many of the policies where constant quotas are based on an initial F, including the current target $F = F_{0.1}$ (Table B1).

More generally, KLAMZ model projections were run with varying "states of nature" that include a range of possible values for natural mortality (M=0.015, 0.02 and 0.025) and a distribution of possible 2008 biomass levels. The projections included runs with four landings-based policies (status quo landings, FMP minimum quota level, FMP maximum quota level, and FMP current quota) and five policies where the constant quota was based on an initial fishing mortality rate ($F_{0.1}$, $F_{25\%}$, $F_{40\%}$, $F_{45\%}$ and $F_{50\%}$). Both stochastic and deterministic projections were carried out (deterministic projections are not shown but approximate median values from stochastic projections). In Table B1 (bottom 6 rows), constant annual quotas from 2010-2015 were determined from particular F's applied to the 2008 biomass estimate. The results are

presented for both the exploited region and for the whole stock.

Catch and Status Table: Ocean Quahog

Year:	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Min[1]	Max[1]	Mean[1]
Quotas:[2]													
EEZ	20.4	20.4	20.4	20.4	20.4	22.7	24.2	24.2	24.2	24.2	13.6	27.2	21.5
Maine	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Landings:[2,5]													
Maine	0.28	0.36	0.33	0.39	0.36	0.31	0.30	0.37	0.31	0.2	0.003	0.39	0.21
EEZ	17.4	14.7	17.1	17.9	18.8	17.7	13.6	14.3	15.6	15.5	10.4	22.4	18.0
Total	17.7	15.1	17.4	18.3	19.2	18.0	13.9	14.7	15.9	15.7	10.4	22.5	18.1
Biomass: [3,5]	3,209	3,173	3,141	3,107	3,071	3,035	3,000	2,969	2,938	2,905	2,905	3,580	3,343
Fishing mortality (exploited stock)[5]:	0.0094	0.0081	0.0096	0.0103	0.0110	0.0106	0.0083	0.0089	0.0100	0.0102	0.0045	0.0110	0.0090
Fishing mortality (whole stock)[5]:	0.0056	0.0048	0.0056	0.0060	0.0063	0.0060	0.0047	0.0049	0.0055	0.0056	0.0031	0.0068	0.0056
Recruitment:[4,5]	16.1 (all years)												

[1] Min, max and means for 1978-2008 (EEZ landings, biomass and fishing mortality), 1979-2008 (EEZ quota), 1990-2008 (Maine landings and quota.
[2] Landings and quotas (1000 mt meats) not adjusted for incidental mortality, which is assumed to be 5% of landings. Discards are very low.
[3] Biomass (1000 mt meats) for entire stock.
[4] Recruitment (1000 mt meats per year) is an estimated average assuming zero recruitment in SVA and DMV.
[5] See assessment for regional estimates.

Stock Distribution and Identification:

Ocean quahogs occur in the eastern Atlantic Ocean from Spain to Norway, intermittently across the North Atlantic, around Iceland, and down the North American coast to Cape Hatteras. Commercial concentrations occur in US waters on the continental shelf off the coast of Maine and from Georges Bank and the Delmarva Peninsula (Figure B1) relatively cool water from 25 to 95 meters in depth.

All ocean quahogs in US waters are assessed and managed as a single stock. The EEZ portion of the ocean quahog stock includes federal waters (between 3 and 200 nm from shore) off southern Virginia, Delmarva, New Jersey, Long Island, Southern New England, and on Georges Bank (excluding Maine). The EEZ is used to characterize the condition of the ocean quahog stock as a whole because almost all of the stock (>99% of fishable biomass) is in EEZ waters.

Catches:

EEZ quotas have been set on an annual basis since 1979. EEZ landings (Figure B2) increased from 0 in 1975 to about 14,000 mt of meats in 1979, peaked at 22,000 mt in 1992, declined to about 15,000 mt during 2000, and have averaged about 16,000 mt since 2000. EEZ landings account for about 95% of total US landings on average. The EEZ quota has not been filled in recent years due to low market demand, according to Industry sources. Ocean quahogs landed in the EEZ range from 50 to120 mm SL and are marketed primarily as meats for use in the manufacture of commercial chowders and sauces.

Catch is assumed to be 5% greater than landings in stock assessment calculations for ocean quahogs in EEZ and Maine waters to account for incidental mortality during fishing. Incidental mortality may occur when ocean quahogs contact fishing equipment (i.e. dredge and

sorting equipment) without being landed.

Fishing effort for ocean quahogs in the EEZ increased from about 23,000 mt during 1983 to a peak of about 46,000 hours during 1991 and then declined to about 25,000 hours in 2008 (Figure B3). Fishing effort in the EEZ shifted offshore and north during the last two decades as traditional fishing grounds in the south were fished down, catch rates dropped, and as processing plants were relocated to the north (Figure B3). The fishery was concentrated off Delmarva and Southern New Jersey from the 1970s to mid-1980s. During the late 1980s and early 1990s, the fishery expanded northward into the Northern New Jersey and Long Island regions. In 1995, it expanded to the Southern New England region which accounted for the bulk of landings during 1997. Since then the fishery has been concentrated mostly off Long Island.

There are two principal fishing grounds for ocean quahogs in Maine waters, the east bed and the west bed, which cover about 60 nm^2 in total. Total annual landings in Maine waters reached a peak of 387 mt in 2002, since then landings have declined to 201 mt in 2008. Fishing effort in Maine waters peaked during 2004 at about 19,000 hours per year and then declined to about 11,000 hours per year during 2008. Ocean quahogs harvested from Maine waters are small in size compared to those harvested in the EEZ. Ocean quahogs in the Maine fishery range from 35 to 70 mm SL, and are marketed in the fresh and half-shell market at relatively high prices.

Data and Assessment:

Ocean quahogs were last assessed in 2006 (SAW-44), after the 2005 NEFSC clam survey (NEFSC 2007). The 2009 assessment uses new data from the 2008 NEFSC and cooperative Industry clam surveys. A new survey of the Maine fishing grounds by the Maine Department of Natural Resources was also conducted in 2008 and also used in this assessment.

EEZ:

NEFSC clam survey data for 1982-2008, fishery data for 1978-2008, and new information about survey dredge efficiency from cooperative depletion studies were used to estimate fishable biomass during 1978-2008. Estimates for most regions (all but Southern Virginia) were from a delay-difference model (KLAMZ). A cumulative catch ("VPA") model was used in place of KLAMZ to estimate biomass and fishing mortality for Southern Virginia because data were insufficient for complicated approaches.

Maine:

Landings, surveys carried out by the State of Maine, and survey dredge efficiency estimates were used to estimate biomass and fishing mortality of ocean quahogs in Maine waters during 2005 through 2008. The estimates for Maine apply only to the area surveyed, which includes the primary fishing grounds.

Biological Reference Points:

Target and threshold reference points were reconsidered during this assessment because of the unique life history of ocean quahogs. The previously accepted (i.e. current) management targets are B_{MSY} = one-half of virgin biomass and the F_{MSY} proxy $F_{0.1}$ = 0.0277 y^{-1} in the exploited region, which excludes Georges Bank. The previously accepted (i.e. current) management thresholds are $B_{Threshold}$ = 25% of virgin biomass (1/2 B_{MSY}) for the whole stock, and $F_{Threshold} = F_{25\%}$ (0.0517 y^{-1}) in the exploited region only.

Based on a review of F_{MSY} reference points of long-lived West Coast groundfish species, the new SARC48 recommended $F_{Threshold}$ is $F_{45\%} = 0.0219\ y^{-1}$ (see Special Comments). The new recommended reference points are not referred to as MSY reference points because the potential productivity of the ocean quahog stock under fishing is unknown (see Special Comments). The new SARC48 recommended biomass target of 1.790 million mt is one-half of the 1978 pre-fishery biomass (virgin biomass is not used because it probably fluctuated and is hard to estimate). The new SARC48 recommended $B_{Threshold}$ is 40% of the 1978 pre-fishery biomass (1.432 million mt). This recommended $B_{threshold}$ is *ad hoc*, but it is probably better than the current biomass reference point both in relation to $F_{45\%}$ and in maintaining a productive stock for the long term.

Fishing Mortality:

$F = 0.0100\ y^{-1}$ during 2008 for the exploited region of the EEZ (excluding GBK). For the whole stock during 2008, F=0.0056 y^{-1} (Figures B4 and B5).

Recruitment:

Mean annual recruitment to the fishable stock was low (<1% per year during 2008). A pulse of recruitment in LI has finished growing to fishable size, based on survey data collected during 2008. Survey size frequency data in 2008 indicate an increasing number of pre-recruits in parts of SNE and GBK. Recruitment of these individuals to the fishable stock is expected to occur over the next decade.

Stock Biomass:

Fishable stock biomass during 2008 was 2.905 million mt of meats for the whole stock. Estimated fishable biomass in 1978 was 3.580 million mt. The ocean quahog population is an unproductive stock that is being fished down from its pre-fishery level. After several decades of relatively low fishing mortality, the stock is still above the current and newly recommended biomass target reference points (Figure B4).

Based on current survey data, LPUE data and biomass estimates from 1977-2008, declines in stock biomass are most pronounced in southern regions (Figures B6 and B7). In particular, stock biomass is below one-half of the 1978 level in the Southern Virginia, Delmarva, and New Jersey regions.

The LI, SNE and GBK regions in the north contained about 67% of total fishable biomass during 1978 and contained about 84% of the total fishable biomass during 2008. The GBK region, which is currently not fished due to risk of PSP contamination, contained about 33% of total fishable biomass during 1978 and about 45% during 2008. The proportion of the stock resident in high density areas has been reduced over time by fishing. Density levels are highest on GBK, where no fishing is currently allowed and lowest in southern areas (DMV and NJ) where the fishery began in the 1980s (Figure B6).

Fishable biomass in Maine waters was estimated to be 16,574 mt and fishing mortality was estimated to be F=0.021 y^{-1}during 2004. Logbook data show that fishing effort has declined since the peak of 19,000 hrs in 2002 to about 11,000 hours in 2008. Since 2000, LPUE for Maine waters has fluctuated without an overall trend (Figure B8).

Special Comments:

* Industry sources report progress in developing reliable, inexpensive and quick tests for possible PSP contamination and are negotiating with the Food and Drug Administration to potentially begin fishing on Georges Bank, possibly beginning in 2009.
* Ocean quahogs (including Georges Bank) may or may not have the potential for supporting sustainable catches in the long term. Some recruitment and growth occurs each year but at low levels. Much depends on the response of the stock on Georges Bank to fishing, where growth and potential recruitment rates are relatively high. It is probably not possible to maintain a sustainable fishery on the currently exploited region where recruitment and growth rates are very low.
* It is technically valid and probably constructive to view the ocean quahog fishery and fishing on Georges Bank is as an adaptive management experiment. The stock (including Georges Bank) may or may not support a sustainable fishery. The answer to the question of sustainability might be determined after a decade or two of fishing on Georges Bank, and managers should be prepared to react in either case. Policy and management actions in the event the fishery is not sustainable should be considered carefully beforehand. One obvious option would be to discontinue fishing, for ocean quahogs, potentially for a decade or more, if stock biomass reaches its biomass threshold.
* In conducting the adaptive management experiment, it is important that removal rates are low enough to provide one or two decades for increased recruitment following fishing because the lag time between spawning and recruitment to the fishery is relatively long. At high fishing mortality rates, it would be theoretically be possible to eliminate the spawning biomass before recruitment has a chance to occur.
* Academic, industry and NEFSC personnel have devoted considerable effort to estimating efficiency of the NEFSC clam survey dredge during the 1997-2008 surveys. Considerable progress was made since the last assessment but survey dredge efficiency remains a chief source of uncertainty. Collaborative depletion studies designed to measure dredge efficiency should continue to be part of each clam survey.
* The current fishing mortality thresholds are compared to the fishable stock which excludes GBK. The assessment makes no recommendation as to whether the recommended fishing mortality threshold should be compared to the fishable stock or the whole stock because this is a policy question. However, from a technical point of view, mortality rates calculated for the whole stock including Georges Bank do not describe conditions on either the exploited portion or unexploited portions of the stock. In particular, fishing mortality may be higher than desired on the exploited portion (resulting in foregone yield and relatively low biomass conditions) and zero on the unexploited portion (resulting in foregone yield). Levels of sustainable catch are lower than MSY for stocks with large areas where no fishing occurs. Regardless of stock structure, regional and spatially explicit management practices will tend to maximize yield and maintain adequate stock biomass levels for sessile stocks like ocean quahogs.
* Information about indirect mortality due to fishing (currently assumed to be 5% of landings) is uncertain. Indirect mortality may be significant in Maine waters where fishing effort levels per unit area are high.
* This species is potentially vulnerable to overfishing due to its low productivity. Due to its low productivity and slow dynamics, the response in recruitment to current (and historical) fishing pressure will not be detectable for at least several decades.
* At current catch levels (which are <70% of the quota) there is a low probability that the

fishing mortality would exceed the SARC48 recommended $F_{Threshold}$ by 2015 for the exploited portion or whole stock and low probability that whole stock biomass would fall below the recommended $B_{Threshold}$. At other fishing mortality levels, such as the current F_{Target} (= $F_{0.1}$), there is a high probability of overfishing in the currently exploited stock by 2015. Some of the policies considered in simulations (e.g. the current $F_{Threshold} = F_{25\%}$) virtually guarantee that fishing mortality for the exploited and whole stock would exceed the recommended $F_{Threshold}$ by 2015.

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Dahlgren T, Weinberg J, Halanych K. 2002. Phylogeography of the ocean quahog (*Arctica islandica*): influences of paleoclimate on genetic diversity and species range. Mar Biol. 137: 487-495.

Murawski SA, Ropes JW, Serchuk FM. 1982. Growth of the ocean quahog, (*Arctica islandica)*, in the Middle Atlantic Bight. Fish Bull. 80: 21-34.

NEFSC. 2007. Ocean quahog assessment. *In*: 44th Northeast Regional Stock Assessment Workshop (44th SAW): 44th SAW assessment report. NEFSC Ref Doc. 07-10. (Available online at : http://www.nefsc.noaa.gov/nefsc/publications/crd/crd0710/)

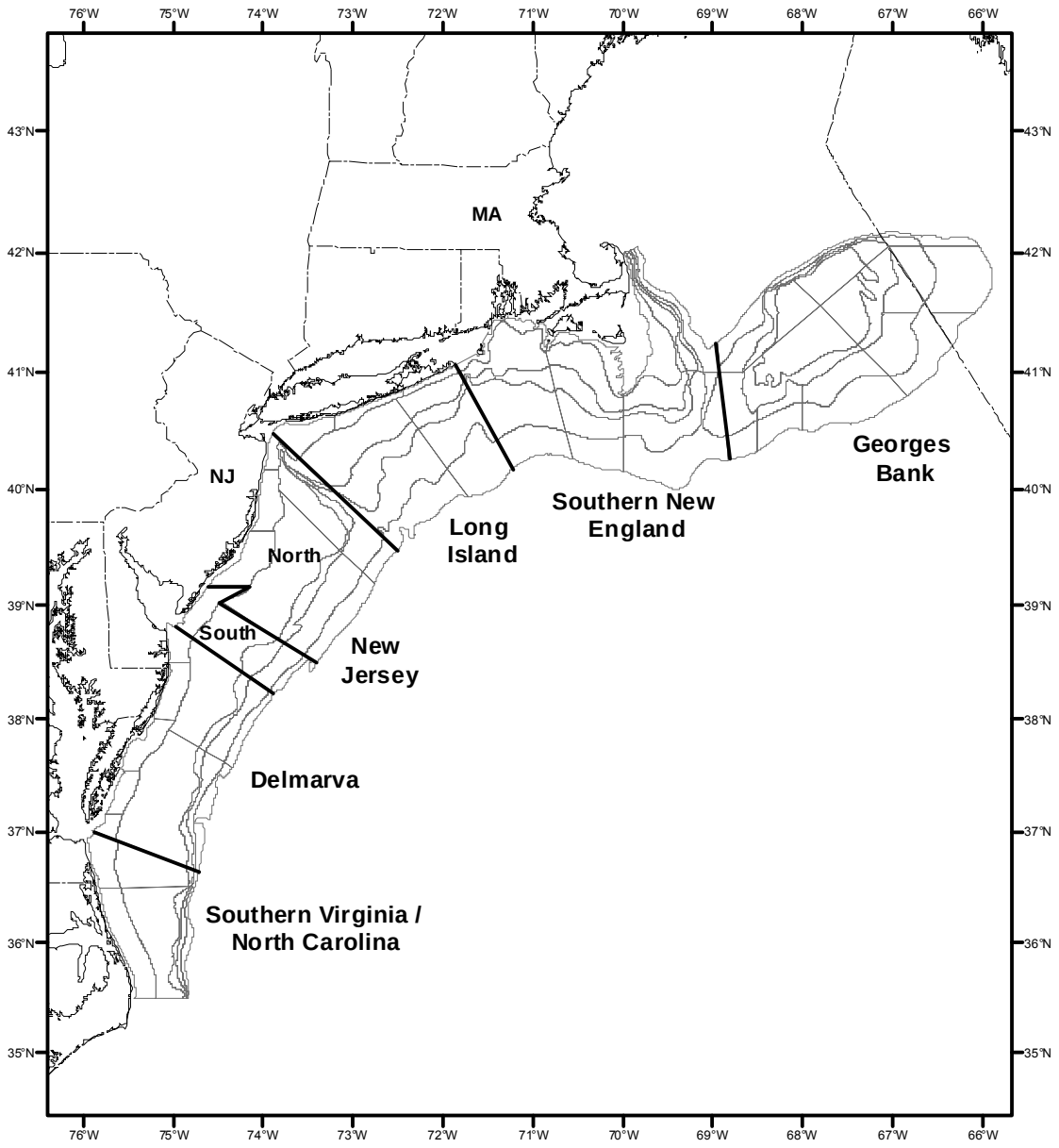
Powell E, Mann R. 2005. Evidence of recent recruitment in the ocean quahog (*Arctica islandica*) in the Mid-Atlantic Bight. J Shellfish Res. 24: 517-530.

Tables

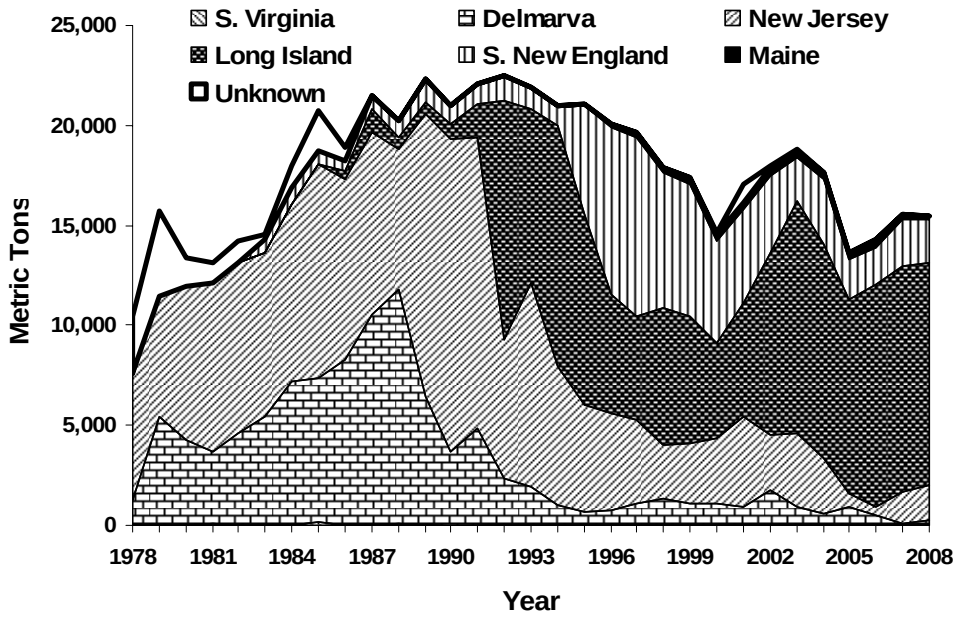
Table B1. Stochastic projection results for ocean quahogs in 2015 with natural mortality M=0.02 under various constant annual quotas during 2010-2015. Starting biomass levels in 2008 are from a bootstrap analysis with the KLAMZ model for ocean quahogs in the exploited area. Biomass on GBK was assumed constant at the 2008 estimate. Actual landings were used in simulations for 2008 and expected landings (3.8 million bushels or 17.2 mt meats) were used for 2009. For 2010-2015, there is a constant level of annual landings (quota) for each harvest policy, calculated by multiplying the target fishing mortality times the current best estimate of biomass during 2008, where the biomass estimate is for either the exploited or entire stock area. Simulated catches were equal to the quota plus 5% to account for incidental mortality. Probabilities of overfished stock conditions ($B_{2015} \leq$ the recommended $B_{Threshold}$) and probabilities of overfishing ($F_{2015} \geq$ the recommended fishing mortality threshold $F_{45\%}$) in 2015 are shown in the last three columns. The probability of overfishing is for either the exploited stock (F_{2015} for exploited stock $\geq F_{45\%}$) or the entire stock (F_{2015} for entire stock $\geq F_{45\%}$).

How are the landings calculated? (alternative management actions, under constant annual removal)	Annual landings 2010-2015 (million bushels)	Annual landings 2010-2015 (1000 mt meats)	Probability overfished in 2015 ($B_{2015} \leq B_{Threshold}$)	Probability of overfishing for exploited stock in 2015 (F_{2015} for exploited stock $\geq F_{45\%}$)	Probability of overfishing for entire stock in 2015 (F_{2015} for entire stock $\geq F_{45\%}$)
Status quo landings	3.8	17.2	0	0.00	0.00
Current quota	5.3	24.2	0	0.19	0.00
FMP min landings	4.0	18.1	0	0.00	0.00
FMP max landings	6.0	27.2	0	0.54	0.00
Recommended F threshold ($F_{45\%}$) x 2008 biomass in exploited area	7.7	34.8	0	0.90	0.00
Current F target ($F_{0.1}$) x 2008 biomass in exploited area	9.7	44.0	0	0.99	0.00
Current F threshold ($F_{25\%}$) x 2008 biomass in exploited area	18.1	82.2	0	1.00	1.00
Recommended F threshold ($F_{45\%}$) x biomass in entire area	14.0	63.7	0	1.00	0.97
Current F target ($F_{0.1}$) x biomass in entire area	17.8	80.6	0	1.00	1.00
Current F threshold ($F_{25\%}$) x biomass in entire area	33.1	150.4	0	1.00	1.00

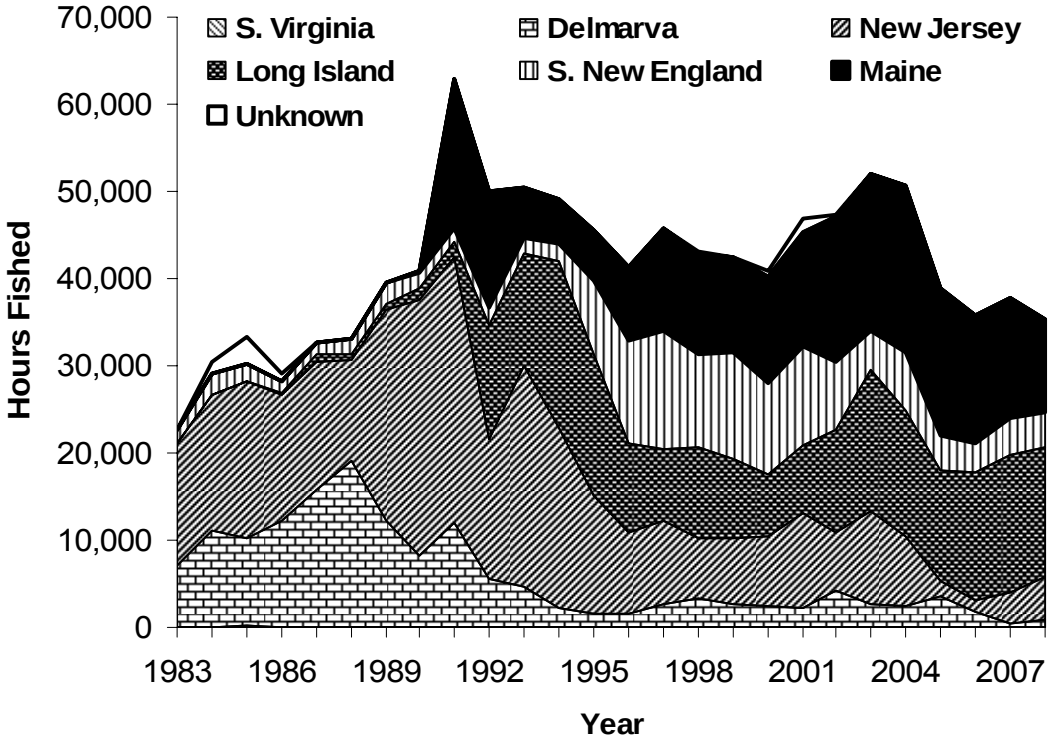
Figures



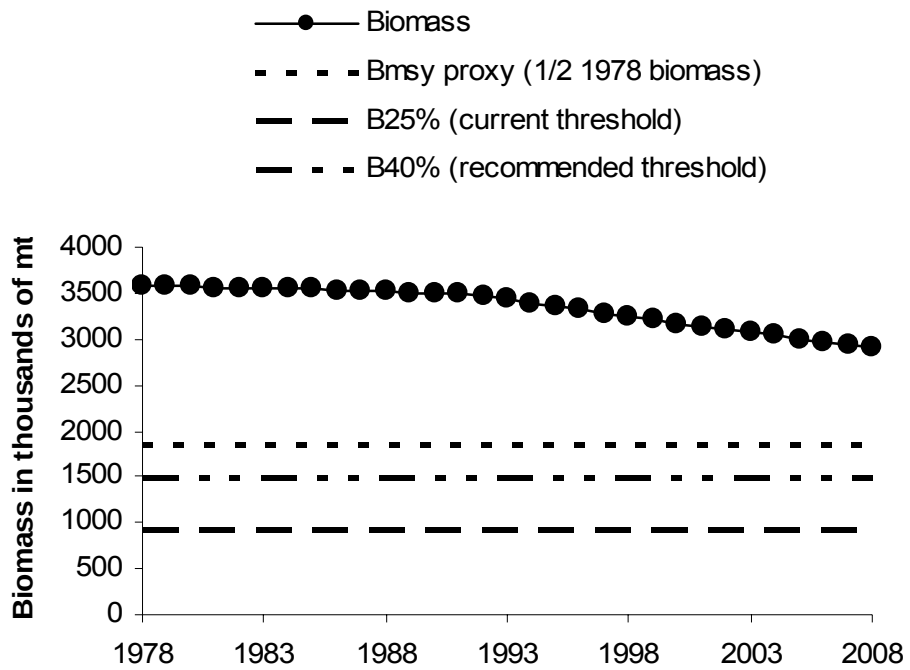
B1. Stock assessment regions for ocean quahogs in the US EEZ, with survey strata and stock assessment regions. For ocean quahogs, the southern and northern portions of the New Jersey region are combined. The Maine fishing area is off the Maine coast north of 43° 50' N.

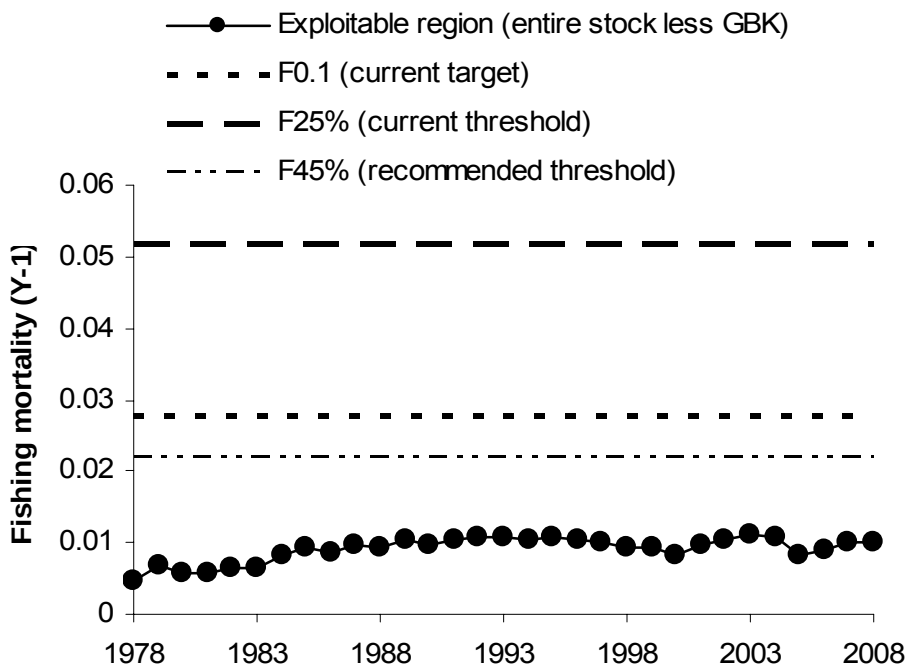


B2. Ocean quahog landings (mt meats) in the EEZ by region during 1978-2008. Figures for SVA are near zero and do not show clearly in plots.

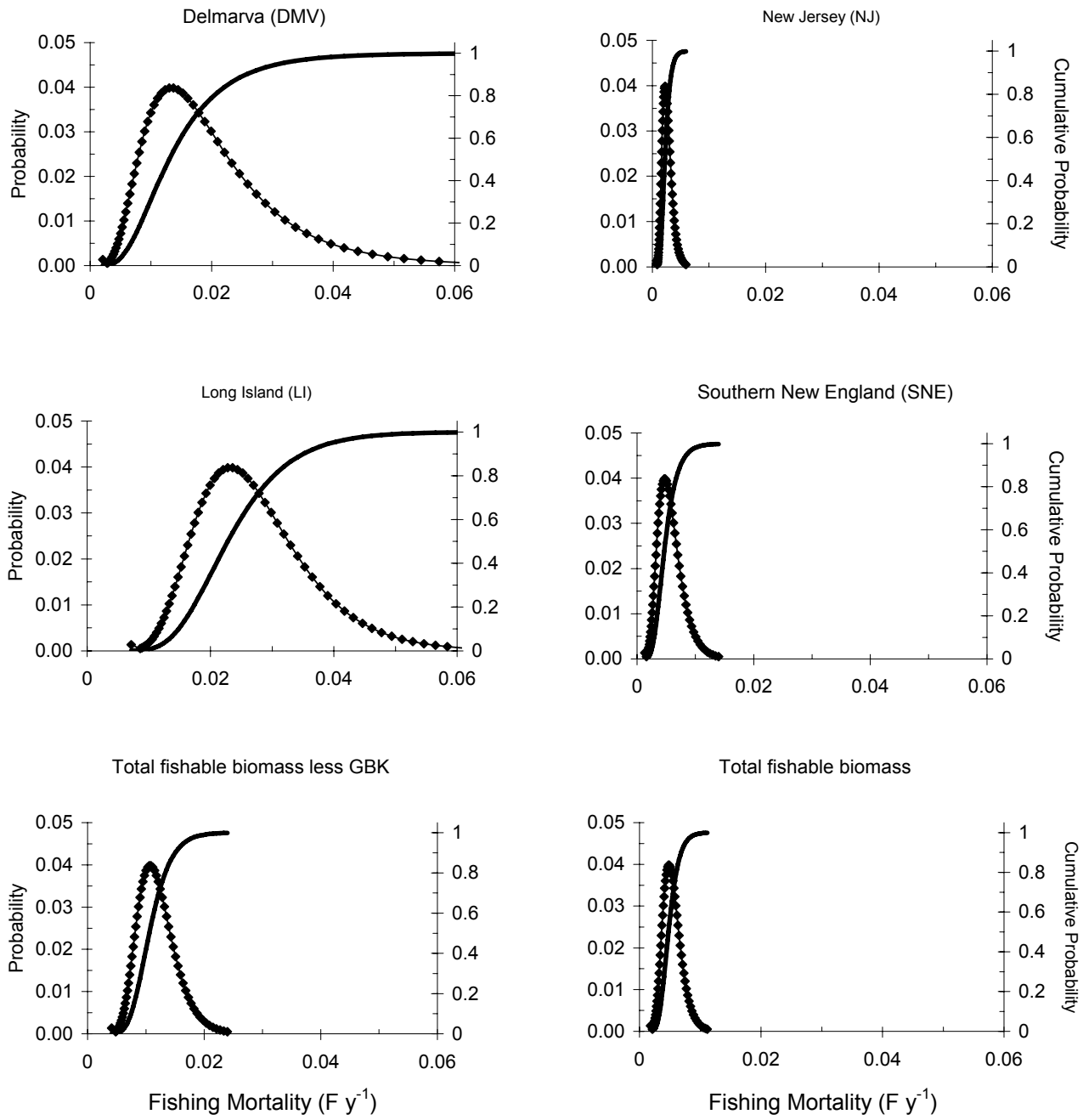


B3.Fishing effort (hours fished per year) for ocean quahog in EEZ and Maine waters during 1983-2008 calculated from mandatory logbook data. Figures for SVA are near zero and do not show clearly in plots.

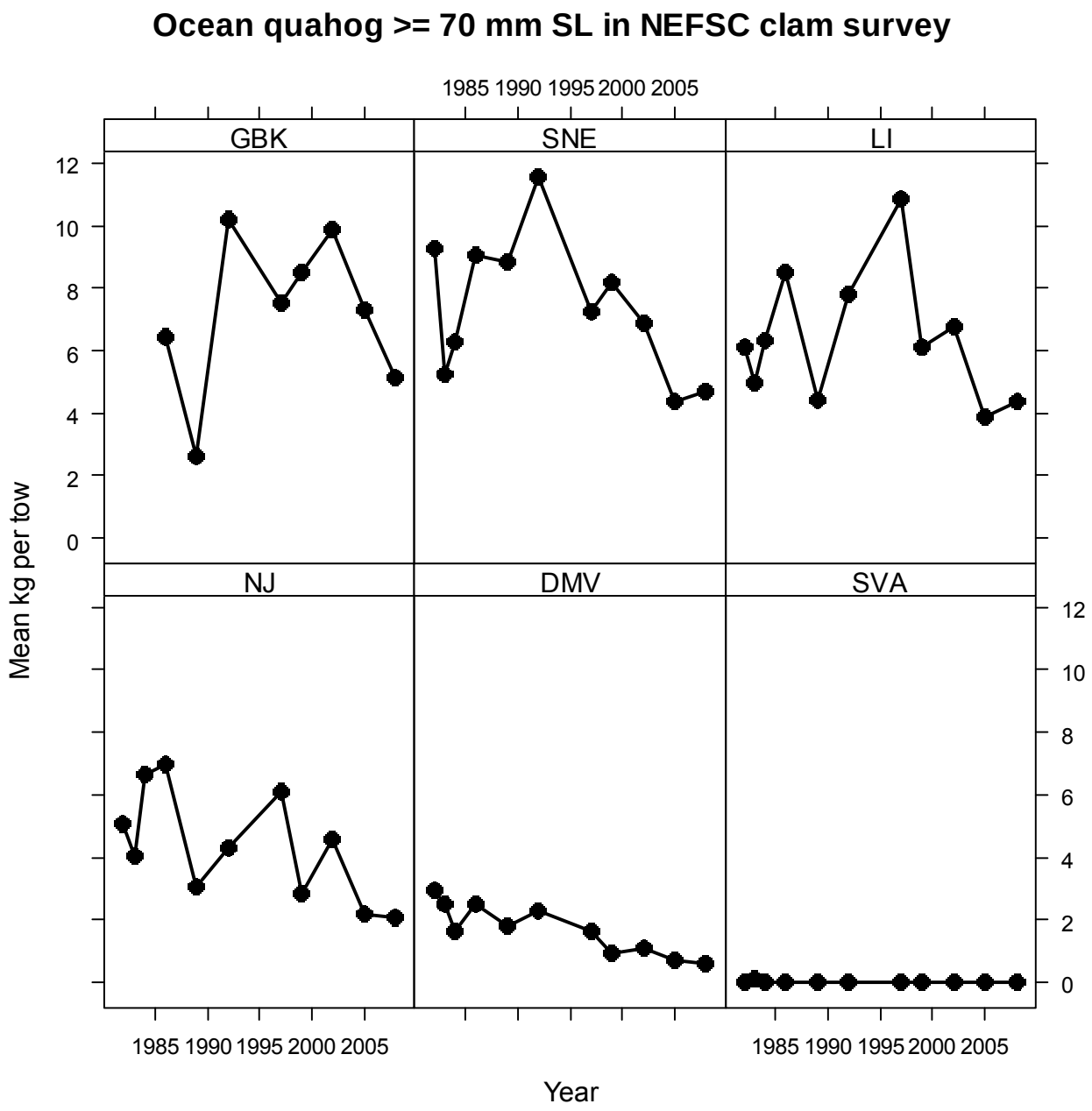




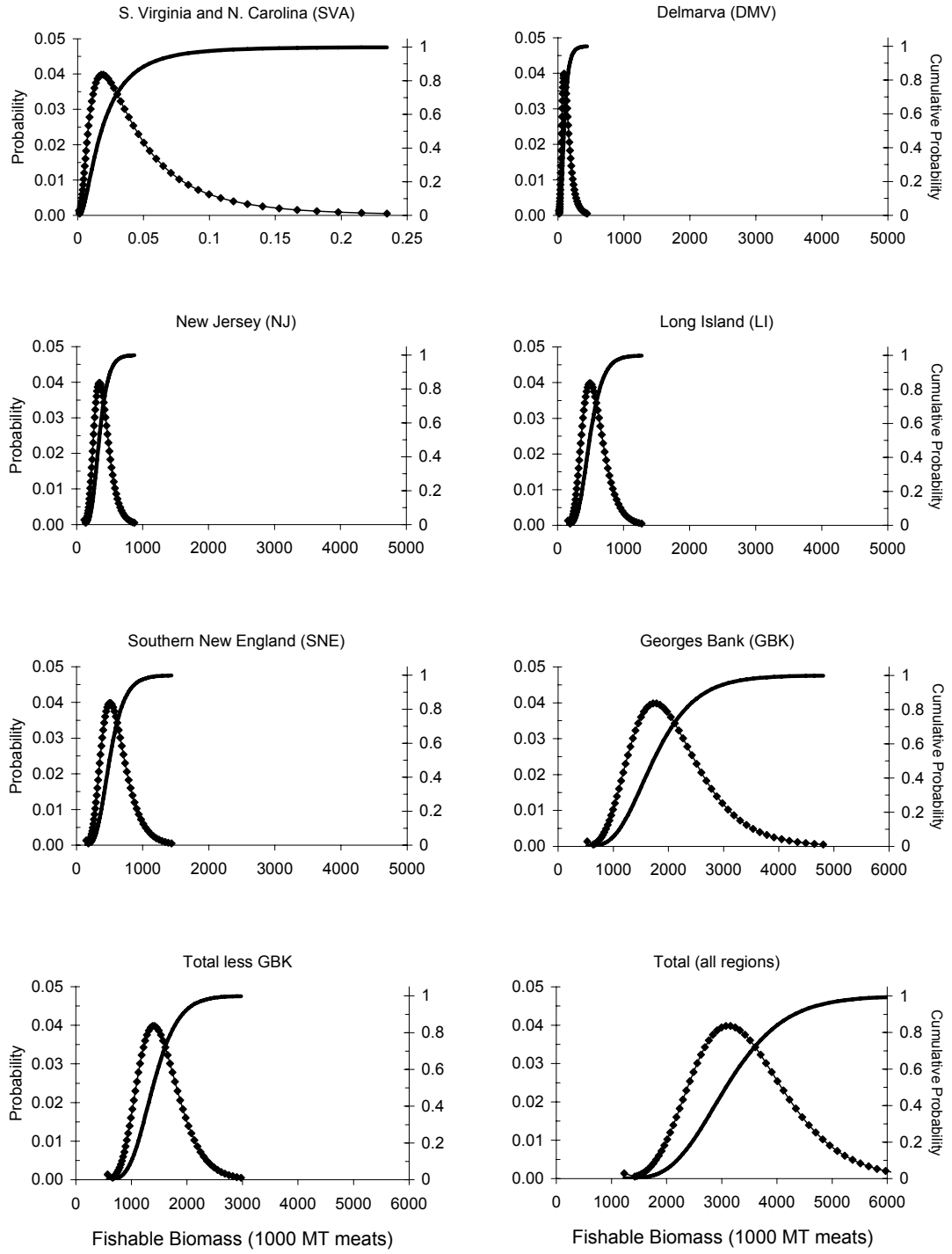
B4. Top: Estimated ocean quahog fishable biomass since 1978, based on sum of "best" regional estimates. Bottom: Estimated fishing mortality on the exploited portion of the stock since 1978. Both current and new SARC48 recommended reference points are shown as horizontal lines.



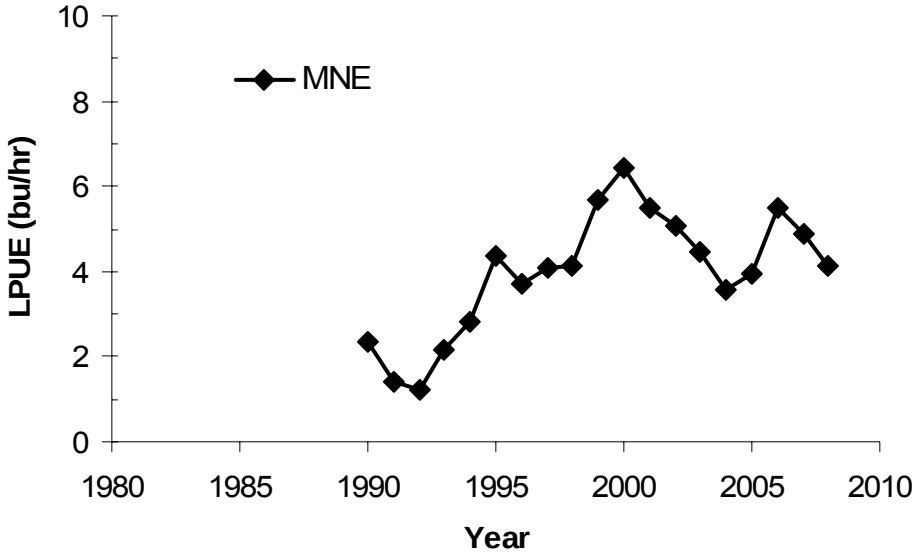
B5. Uncertainty in fishing mortality estimates for ocean quahog by region during 2008 based on catch data and efficiency corrected swept-area biomass. X-axes are scaled to the same maximum to facilitate comparisons.



B6. Trends in survey mean biomass per tow for large (≥70 mm SL) ocean quahogs, 1982-2008. Data from the 1994 survey are not shown because of voltage problems that affected catchability of the survey dredge. Sampling was relatively poor and estimate are less reliable for GBK during 1982-1984, 1989, 2002 and 2005; SNE during 1984 and 2005; LI during 1984; NJ during 1984; DMV during 2008; and in SVA during 1999 and 2008.



B7. Uncertainty in efficiency corrected swept area biomass (ESB) estimates by region for fishable ocean quahogs during 2008. Note that the x-axis differs in the panel for SVA but is the same in all other panels to facilitate comparisons.



B8. Ocean quahog LPUE (kg meats hr^{-1}) in Maine waters during 1990-2008.

C. WEAKFISH ASSESSMENT SUMMARY FOR 2009

State of Stock:

The stock is currently depleted. The biomass based reference point threshold is SSB20% = 10,179 mt assuming a constant natural mortality rate of M = 0.25 (see Biological Reference Point section below). The mid-year 2008 biomass level as estimated by the index-based method is 1,333 mt. There were 850 mt removed in 2007 and 811 mt in 2008 (including landings and discard mortality). This level of removals is unsustainable under current stock conditions. In terms of biomass the F in 2008 is estimated to be 0.61. In terms of abundance the F level in 2008 is estimated to be 0.07, due to the high number of partially selected recruits.

Natural mortality, M, within this population was approximately 0.25 prior to 1995, but M has risen substantially since then. At this higher level of natural mortality the stock is unlikely to recover in six years to any biomass reference level even under a scenario of no directed fishing (see Projections section).

Several models were used to explore likely scenarios of increasing M. All models investigated indicate that weakfish spawning stock biomass is below the overfished biomass threshold. The analyses found that factors such as predation, competition and changes in the environment may have had a stronger influence on recent weakfish stock dynamics than fishing mortality.

The Atlantic States Marine Fisheries Commission describes the weakfish stock as "depleted" because stock biomass is below the biomass threshold, and fishing mortality is not considered to be the primary cause.

Catch and Status Table ('000 MT): Weakfish

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	max[1]	min[1]	mean[1]
Catch weight	5.35	4.96	4.70	3.66	1.56	1.35	1.45	1.13	0.97	0.81	20.20	0.81	6.78
Stock numbers[2,3]	76.47	63.39	37.65	26.33	19.16	33.66	34.70	23.56	21.27	19.26	96.55	17.38	53.06
Stock biomass[2,3]	9.34	9.25	7.18	4.51	2.68	3.29	3.01	2.35	1.71	1.33	28.54	1.33	9.06
N weighted F[2,4]	0.13	0.14	0.26	0.34	0.15	0.10	0.11	0.12	0.12	0.07	1.06	0.07	0.36
B weighted F[2,4]	0.57	0.54	0.65	0.81	0.58	0.41	0.48	0.48	0.56	0.61	1.37	0.35	0.74

1: Based on 1981 - 2008 time series; includes commercial and recreational harvest and discards
2: Estimated from the index-based approach detailed in Section C8.0 of the Stock Assessment Report
3: Stock size estimates are mid-year values. Numbers are in millions; biomass is thousands of metric tons.
4: F estimates are for ages 1+

Projections:

A stock projection was conducted using a model (i.e., an extended surplus production model with Steele-Henderson predator response) that differs from the index-based model used for the assessment. In this projection (Figure C1), stock biomass and the biomass reference point are scaled to each other (i.e., relative) and are not in absolute units. They provide a reasonable indication of future trends. The projection suggests that little stock growth is possible with current high mortality levels, even under a harvest moratorium. This is because current fishing mortality represents a small component of total mortality, thus reducing the management "leverage" considerably.

Stock Distribution and Identification:

The range of weakfish extends along the Atlantic coast from Massachusetts to southern Florida, but they are occasionally found as far as Nova Scotia, Canada. Primary abundance occurs between New York and North Carolina. Within their range there is evidence of multiple

stocks based on life history patterns but not genetics. These conclusions result in disparate recommendations on how the stock should be managed. Based on available information, the ASMFC Weakfish Fishery Management Plan (FMP) treats Atlantic coast weakfish as a single stock.

Catches:

Since 1982, total removals have been dominated by commercial and recreational harvest (Figures C2 and C3). Removals were greatest during the early portion of the time series, averaging 13,500 mt between 1981 and 1988. Between 1989 and 1993, removals dropped off quickly to 4,000 mt. The next few years showed a slight rebound to a peak of 6,500 mt in 1998 under a concerted effort to reduce F under the auspices of the FMP. Since then, removals have declined continuously to the time series minimum of only 850 mt in 2007. Combined commercial and recreational discard losses were generally less than 5% of total removals prior to 1993. Discarding increased rapidly following implementation of management measures due to minimum size regulations. Regardless, discard losses have averaged less than 20% of total removals since 1994 (Figure C2).

Data and Assessment:

This is the first update to the weakfish stock assessment since 2006 when the assessment was peer reviewed through the ASMFC External Peer Review process (ASMFC 2006). The current assessment includes harvest data and survey indices through 2007. As recommended by SARC 26 (NEFSC 1998), an ADAPT VPA was used to evaluate trends in population parameters. However, while the ADAPT VPA method provided reasonable estimates of biomass and fishing mortality in the early part of the time series (when such models readily converge) the model exhibited a significant retrospective pattern for the most recent years' estimates making them unusable for assessing current stock conditions. In an attempt to remedy this situation, an index-based method was used that was scaled to the biomass estimates taken from the first four years of the converged estimates from the ADAPT VPA. The estimates and reference points used in this report are based on the index-based method.

Biological Reference Points:

When there is a trend in M then, generally speaking, the use of equilibrium reference points for setting management objectives is not appropriate. The current management plan uses reference points that assume constant natural mortality. To create a means for assessing stock status a biomass reference level is proposed that establishes a biomass threshold (SSB20%) under the assumption of constant M=0.25. SSB20% is estimated to be 10,179 mt. Under current conditions of high natural mortality the stock has negative productivity. For the population to pass through this period of negative productivity, total mortality needs to be reduced to levels that would allow biomass to be at least SSB20% and preferably higher. Even in the absence of fishing this will not likely occur until natural mortality decreases to previous low levels.

Due to the changes in M over time and the current negative productivity of the stock, F reference points are also not currently meaningful. However, should M return to some constant level, then F reference points could again be calculated recognizing that if M remains high an equilibrium yield would likely be low and there would be a significant risk to the stock. If M were to drop back down to previous low levels, a harvest rate could be determined that would allow an appropriate rebuilding schedule.

Fishing Mortality:

Fishing mortality estimated using the index-based approach scaled to the converged portion of the ADAPT VPA biomass while accounting for the estimated trend in M has varied between 0.7 and 1.1 over the years 1981 and 1987. From 1988 through 1990, biomass-weighted F values generally varied around F = 1.3 before dropping rapidly to the time series low of F = 0.35 in 1995. Since that time biomass-weighted F has varied between 0.4 and 0.8, but M has risen substantially. Note that F values given in this assessment are not comparable to F's or F-reference points provided in previous assessments. Values presented in this assessment are for ages 1+ and therefore are affected by partial recruitment of younger ages, while previous assessments provided estimates for fully-recruited ages only.

Spawning Stock Biomass:

Between 1981 and 1990, spawning stock biomass estimated by the approved index-based method dropped from 28,000 to 3,920 mt, then increased to approximately 14,000 mt in 1996, then dropped again to low levels of 2,000 – 4,000 mt in the early 2000s and is now calculated to be less than 2,000 mt in 2008 (Figure C3).

Recruitment:

Recruitment was not estimated from the index-based method. The juvenile abundance surveys indicate that young-of-year weakfish continued to be present in numbers similar to previous years, suggesting that recruitment at this point has not been severely limited in spite of the low stock size.

Special Comments:

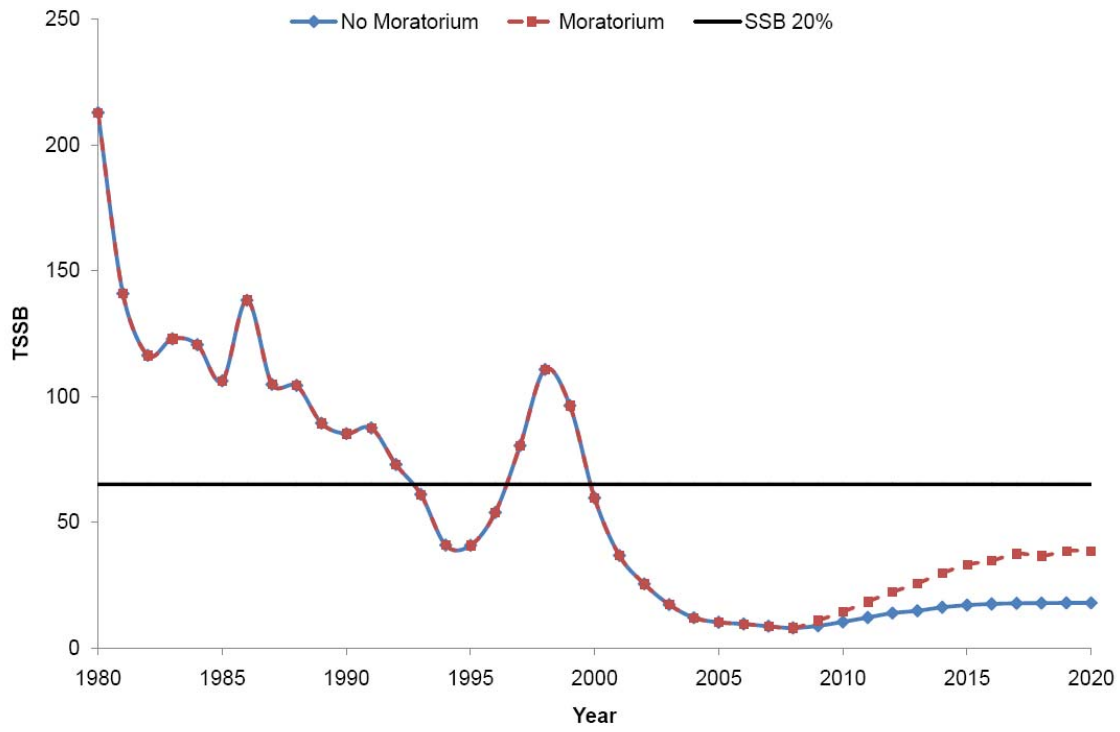
* ADAPT VPA was recommended by the 26th SAW as a modeling framework for weakfish; however, concerns regarding some of the underlying assumptions (such as error-free catch at age and constant natural mortality), prominent retrospective patterns, and anomalous results have prompted the ASMFC Weakfish Technical Committee to investigate alternative models.
* A key question is the reason for the unexpected decline in abundance in the late 1990s at harvest levels that had previously resulted in stock growth. A suite of analyses was conducted that provide evidence that factors other than fishing mortality resulted in decreased stock size over the last decade.
* All models investigated indicate that weakfish biomass is at a low level.

References:

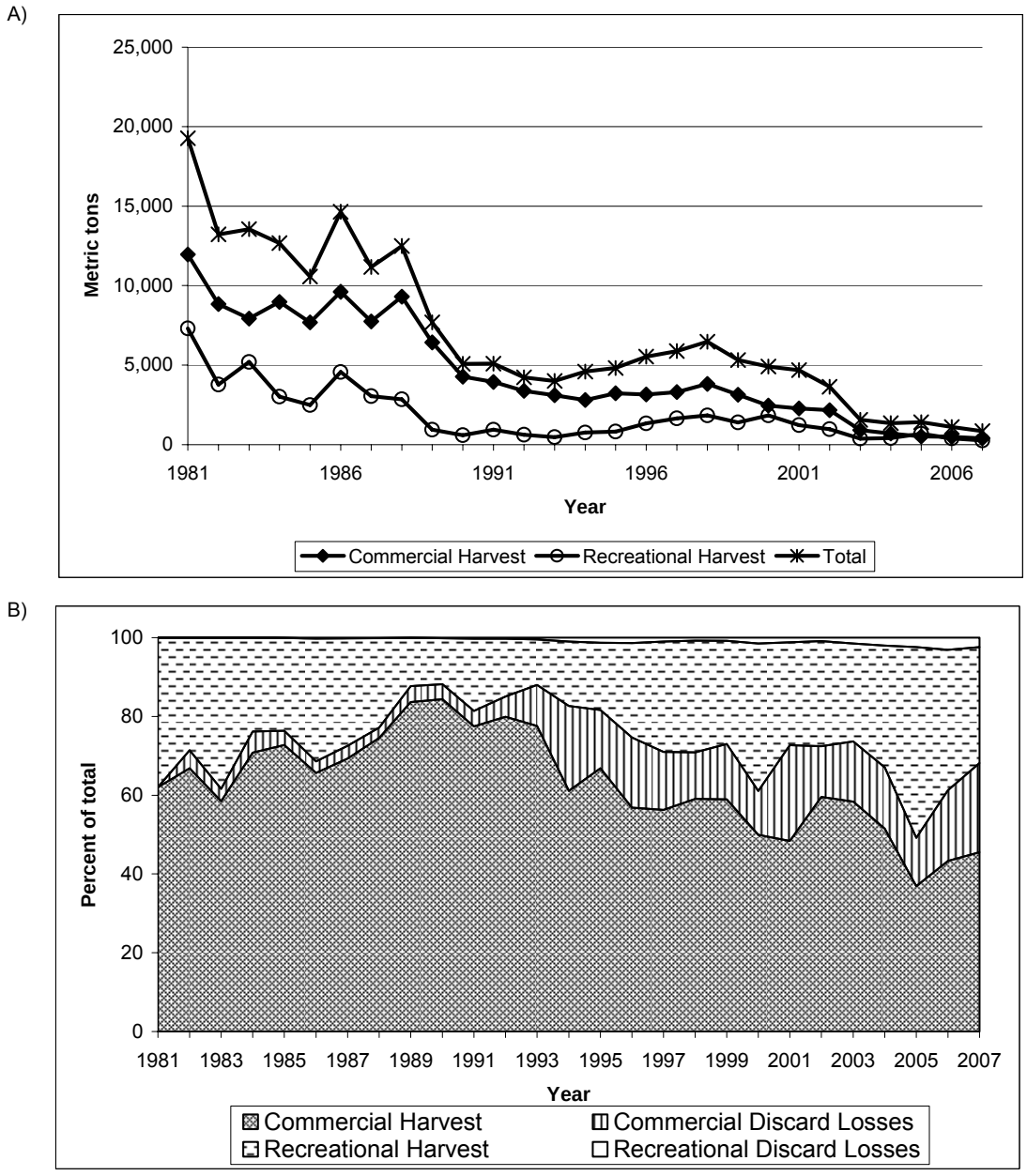
ASMFC. 2006. 2006 Weakfish Stock Assessment: Weakfish Stock Assessment Report, Terms of Reference and Advisory Report, and Technical Committee Supplemental Material. Washington (DC): ASMFC. 315 p.

NEFSC. 1998. Report of the 26th Northeast Regional Stock Assessment Workshop (26th SAW): Stock Assessment Review Committee (SARC) Consensus Summary of Assessments. Woods Hole (MA): National Marine Fisheries Service. NEFSC Ref Doc. 98-03; p 10-50.

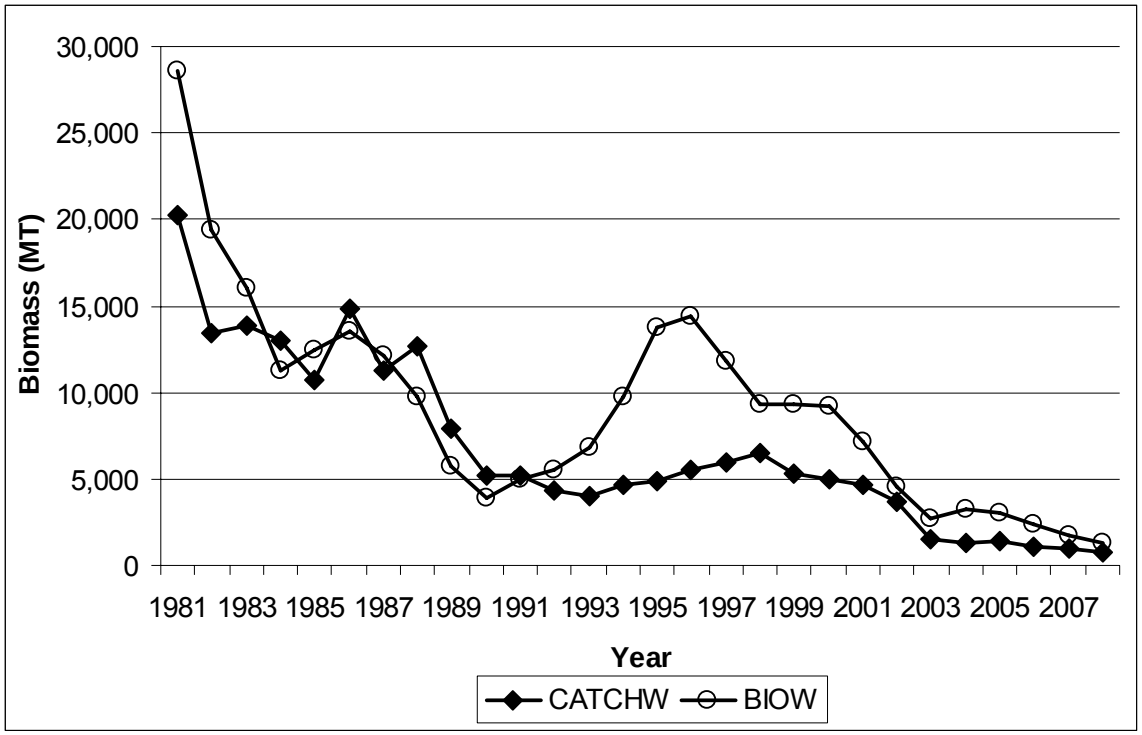
Figures



C1. A projection through 2020 of total weakfish spawning stock biomass (TSSB) which simulates no moratorium as well as a harvest moratorium (F=0) beginning in 2009. The projection is based on the assumption that M = 0.25 from 1981-1998, followed by a rise to M=0.65 thereafter. All values in the figure, including SSB20% have been scaled, so they are indicative of relative trends in biomass in relation to SSB20%., and not absolute biomass. SSB20% was estimated assuming constant natural mortality of M = 0.25. Projections were conducted based on results of the Steele-Henderson model described in section C9.0 of the stock assessment report.



C2. Total weakfish fishery removals. A) Harvest weight (metric tons) for the two principal sectors and all four sectors combined; B) Percent of total biomass removals by sector.



C3. Weakfish fishery catch biomass (mt) and estimates of stock biomass (mt) estimated by the SARC48 approved, 'index-based' approach. Recent biomass is well below the current estimate of SSB20% (10,179 mt) which the SARC felt could be used as an interim biomass threshold until a future assessment.

Appendix: Terms of Reference

Assessment Terms of Reference for SAW/SARC-48, June 1-4, 2009
(file: 4/27/09)

A. Tilefish

1. Characterize the commercial catch including landings, effort and discards. Characterize recreational landings. Evaluate utility of study fleet results as improved measures of CPUE.
2. Estimate fishing mortality and total stock biomass for the current year, and for previous years if possible, and characterize the uncertainty of those estimates. Incorporate results of new age and growth studies.
3. Update or redefine biological reference points (BRPs; estimates or proxies for BMSY, BTHRESHOLD, and F_{MSY}). Comment on the scientific adequacy of existing and redefined BRPs.
4. Evaluate stock status with respect to the existing BRPs, as well as with respect to updated or redefined BRPs (from TOR 3).
5. Develop and apply analytical approaches and data that can be used for conducting single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs).
    a. Provide numerical short-term projections (2-3 years). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions about the most important uncertainties in the assessment (alternate states of nature).
    b. If possible, comment on the relative probability of the alternate states of nature and on which projections seem most realistic.
    c. For a range of candidate ABCs, compute the probabilities of rebuilding the stock by November 1, 2011.
    d. Describe this stock's vulnerability to becoming overfished, and how this could affect the choice of ABC.
6. Review, evaluate and report on the status of the research recommendations offered in recent SARC reviewed assessments. Identify new research recommendations, including recruitment estimation.

B. Ocean quahog

1. Characterize commercial catch including landings, effort, and discards.
2. Estimate fishing mortality, spawning stock biomass, and stock biomass for the current and previous years. Characterize uncertainty of the estimates.
3. Update or redefine biological reference points (BRPs; estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, and F_{MSY}). Comment on the scientific adequacy of existing and redefined BRPs.
4. Evaluate stock status with respect to the existing BRPs, as well as with respect to updated or redefined BRPs (from TOR 3).
5. Develop and apply analytical approaches and data that can be used for conducting single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs).
    a. Provide numerical short-term projections (3-4 years). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions about the most important uncertainties in the assessment (alternate states of nature).
    b. If possible, comment on the relative probability of the alternate states of nature and on which projections seem most realistic.
    c. Describe this stock's vulnerability to becoming overfished, and how this could affect the choice of ABC.
6. Review, evaluate and report on the status of SARC/Working Group research recommendations listed in recent SARC reviewed assessments. Identify new research recommendations.

C. Weakfish

(Final weakfish TORs approved by Weakfish Management Board 4-24-09)

1. Evaluate biases, precision, uncertainty, and sampling methodology of the commercial and recreational catch (including landings and discards) and effort.
2. Evaluate precision, geographical coverage, representation of stock structure, and relative accuracy of the fisheries independent and dependent indices of abundance. Review preliminary work on standardization of abundance indices.
3. Evaluate the ADAPT VPA catch at age modeling methods and the estimates of F, Z, spawning stock biomass, and total abundance of weakfish produced, along with the uncertainty and potential bias of those estimates. Review the severity of retrospective pattern.
4. Evaluate the index-based methods and the estimates of F, ages 1+ stock biomass, surplus production, and time-varying natural mortality of weakfish produced, along with the uncertainty of those estimates. Determine whether these techniques could complement or substitute for age-based modeling for management advice.
5. Evaluate testing of fishing and additional trophic and environmental covariates and modeling of hypotheses using biomass dynamic models featuring multiple indices blended into a single index with and without a Steele-Henderson (Type III) predator-prey extension. Evaluate biomass dynamic model estimates of F, ages 1+ stock biomass, surplus production, time-varying natural mortality, and biological reference points along with uncertainty of those estimates. Advise on burden of proof necessary for acceptance of alternatives to constant M and whether these biomass dynamic techniques could complement or substitute for age-based modeling for management advice.
6. Evaluate AIC-based hypothesis testing of fishing and additional predation-competition effects using multi-index biomass dynamic models with and without prey-based, predator-based, or ratio dependent predator-prey extensions. Evaluate biomass dynamic model estimates of F, ages 1+ stock biomass, surplus production, time-varying natural mortality, and biological reference points along with uncertainty of those estimates. Advise on burden of proof necessary for acceptance of alternatives to constant M and whether these biomass dynamic techniques could complement or substitute for age-based modeling for management advice.
7. Review evidence for constant or recent systematic changes in natural mortality, productivity, and/or unreported removals.
8. Estimate biological reference points using equilibrium and non-equilibrium assumptions and evaluate stock status relative to these BRPs.
9. Review stock projections and impacts on the stock under different assumptions of fishing and natural mortality.
10. Make research recommendations for improving data collection and assessment.

Appendix to the TORs:

Clarification of Terms used in the SAW/8SARC Terms of Reference

(The text below is from DOC National Standard Guidelines, Federal Register, vol. 74, no. 11, January 16, 2009)

On "Acceptable Biological Catch":
Acceptable biological catch (ABC) is a level of a stock or stock complex's annual catch that accounts for the scientific uncertainty in the estimate of [overfishing limit] OFL and any other scientific uncertainty…" *(p. 3208) [In other words, OFL ≥ ABC.]*

ABC for overfished stocks. For overfished stocks and stock complexes, a rebuilding ABC must be set to reflect the annual catch that is consistent with the schedule of fishing mortality rates in the rebuilding plan. *(p. 3209)*

NMFS expects that in most cases ABC will be reduced from OFL to reduce the probability that overfishing might occur in a year. (p. 3180)

ABC refers to a level of ''catch'' that is ''acceptable'' given the ''biological'' characteristics of the stock or stock complex. As such, [optimal yield] OY does not equate with ABC. The specification of OY is required to consider a variety of factors, including social and economic factors, and the protection of marine ecosystems, which are not part of the ABC concept. (p. 3189)

On "Vulnerability":
"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)

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