Northeast Fisheries Science Center Reference Document 04-04

38th Northeast Regional Stock Assessment Workshop (38th SAW)

Advisory Report

January 2004

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Northeast Fisheries Science Center Reference Document 04-04

A Report of the 38th Northeast Regional Stock Assessment Workshop

38th Northeast Regional Stock Assessment Workshop (38th SAW)

Advisory Report

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
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Northeast Fisheries Science Center Reference Documents

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ADVISORY REPORT ON STOCK STATUS

INTRODUCTION

The *Advisory Report on Stock Status* is one of two reports produced by the Northeast Regional Stock Assessment Workshop process. The *Advisory Report* summarizes the technical information contained in the other report produced by the SAW process, the *Stock Assessment Review Committee (SARC) Consensus Summary of Assessments* and is intended to serve as scientific advice for fishery managers on resource status.

An important aspect of scientific advice on fishery resources 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 simply 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 a stock's biomass falls below the biomass threshold ($B_{THRESHOLD}$) the stock is in an overfished condition. The Sustainable Fisheries Act mandates plans for rebuilding the stock should this situation arise.

Since there are two dimensions to the status of the stock– the rate of removal and the biomass -- 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 less than the threshold . 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 is increased greatly by increasing the stock size. Conversely, fishing down a stock whose biomass is high because of low exploitation should generally increase the long-term sustainable yield. This philosophy is embodied in the Sustainable Fisheries Act — stocks should be 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, 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 schematic below depicts how status criteria are interpreted in this context.

Overfishing guidelines are based on the precautionary approach to fisheries management and encourage the inclusion of a control rule in the overfishing definition. Control rules, when they exist, are discussed in the Advisory Report chapter for the stock under consideration. 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.

BIOMASS

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

GLOSSARY OF TERMS

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

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.

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 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 $\mathbf{F_{0.1}}$, $\mathbf{F_{MAX}}$, and $\mathbf{F_{MSY}}$, which are defined later in this glossary.

$\mathbf{B_0}$**.** Virgin stock biomass, i.e., the long-term average biomass value expected in the absence of fishing mortality.

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

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 yield per recruit. This is the point beyond which **growth overfishing** begins.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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 $\mathbf{B_{MSY}}$ 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. $\mathbf{B_{MSY}}$, $\mathbf{F_{MSY}}$, $\mathbf{F_{0.1}}$) 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. 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.

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.

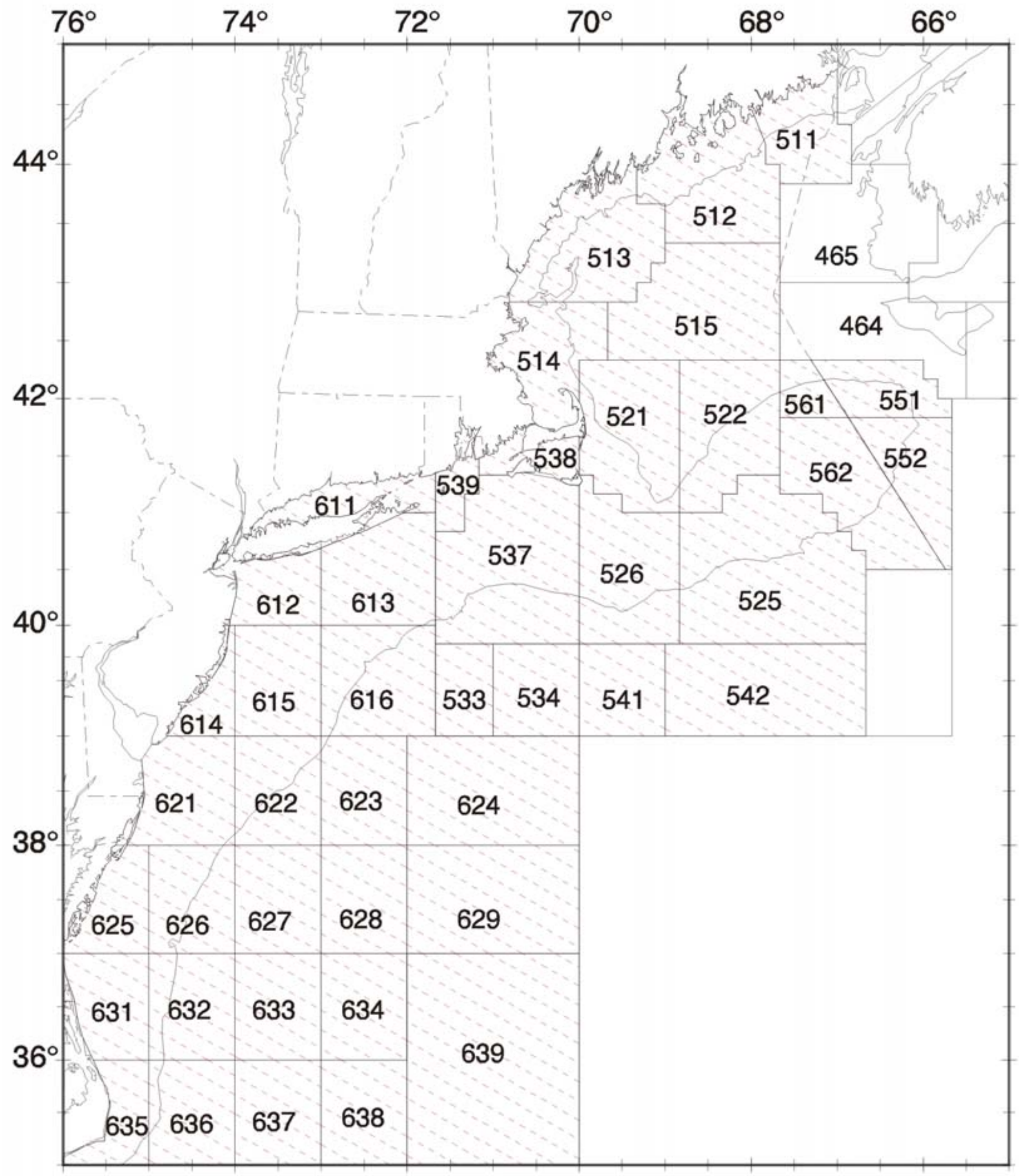


Figure 1. Statistical areas used for catch reporting

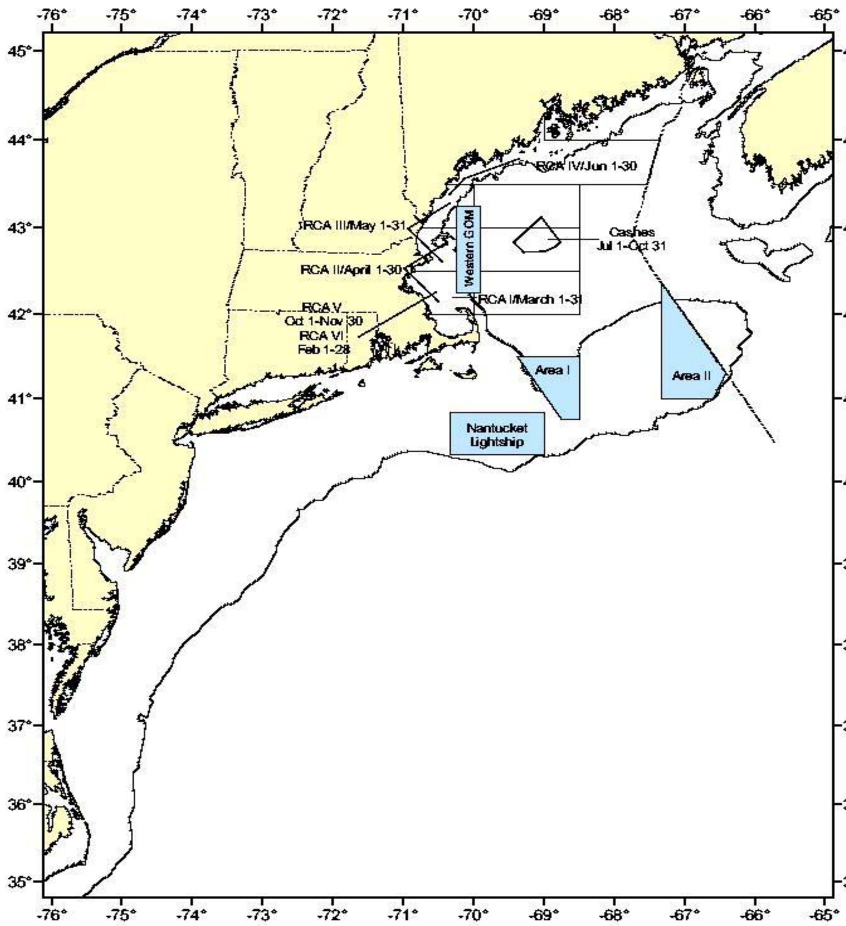


Figure 2. Year-around area closures (shaded polygons) and seasonal rolling closures (open polygons).

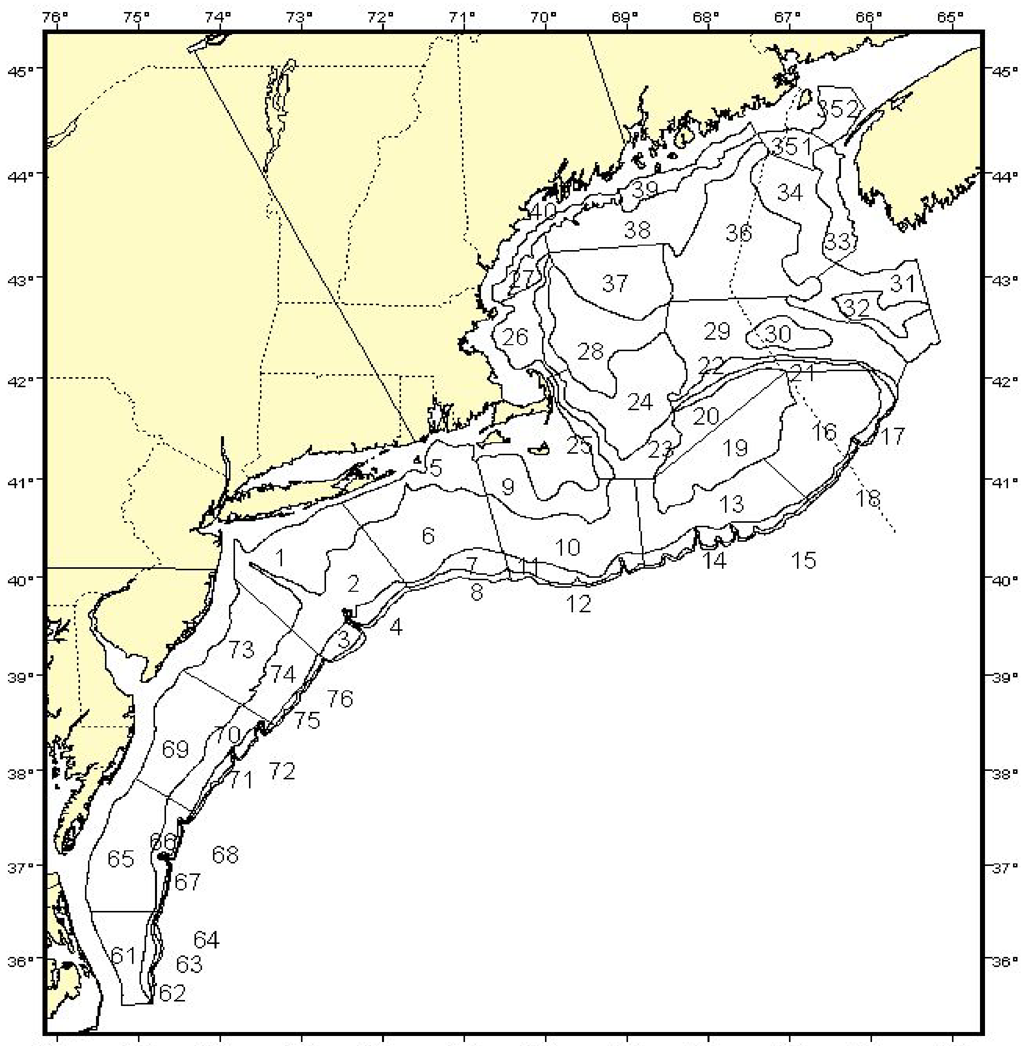


Figure 3. NEFSC bottom trawl survey sampling strata.

A. OCEAN QUAHOG ADVISORY REPORT

State of Stock: The ocean quahog resource in EEZ waters from Southern New England (SNE) to Southern Virginia (SVA) is not overfished and overfishing is not occurring. The current biomass is high (Figures A1, A2), current fishing mortality (F= 0.014 for the exploited area, Efficiency-Corrected Swept Area Biomass (ESB) Model) is 50% of the target ($F_{0.1}$= 0.028; note: the value of $F_{0.1}$, the target F, was recalculated for this assessment). Unlike in most marine populations, which may show large and variable recruitment, annual recruitment is approximately 0-2% of stock biomass. Since the fishery began in the late 1970s, biomass has declined slowly (Figures A1, A2, A5). The percentage of the 1977 biomass remaining in 2002 in the assessed area is 80% (all regions) and 72% (exploited regions only; i.e. all regions except Georges Bank). Biomass and exploitation status of ocean quahog in the Gulf of Maine are unknown because the efficiency of the dredge used to do the Maine survey has not been determined. Stock status relative to Biological Reference Points is shown in Figure A5.

Management Advice: Maintaining status quo exploitation rates should result in a sustainable biomass approximately equal to the BMSY. In addition, because ocean quahogs are sedentary and fishing in concentrated in relatively small areas, it may be advantageous to avoid localized depletion.

Projections: At current catch and F (based on KLAMZ time series table), biomass is projected to decline gradually over the next decade.

Stock projections for ocean quahog during 2003-2007 based on assumptions about *F* or landings. Projected landings do not include a 5% allowance for incidental mortality used in calculations.

Year	Biomass All Regions (1000 mt)	Biomass less GBK (1000 mt)	Landings (1000 mt)	*F* All Regions (y^{-1})	*F* less GBK (y^{-1})
	Status-quo Catch				
2003	1,825	1,182	18	0.010	0.016
2004	1,794	1,164	18	0.010	0.016
2005	1,764	1,146	18	0.010	0.016
2006	1,733	1,128	18	0.011	0.016
2007	1,704	1,110	18	0.011	0.017
	Status-quo F				
2003	1,826	1,183	16	0.009	0.015
2004	1,796	1,167	16	0.009	0.015
2005	1,767	1,150	16	0.009	0.015
2006	1,739	1,134	15	0.009	0.015
2007	1,711	1,118	15	0.009	0.015
	Catch = Quota				
2003	1,825	1,182	18	0.010	0.016
2004	1,791	1,161	20	0.012	0.018
2005	1,755	1,138	23	0.014	0.021
2006	1,720	1,114	23	0.014	0.021
2007	1,684	1,091	23	0.014	0.022
	$F = F_{0.1}$ in exploited regions (F=0 for GBK)				
2003	1,811	1,168	30	0.018	0.028
2004	1,767	1,137	29	0.018	0.028
2005	1,724	1,106	29	0.018	0.028
2006	1,682	1,077	28	0.018	0.028
2007	1,641	1,048	27	0.018	0.028

Catch and Status Table (weights in '000 mt meats): Ocean Quahogs

[1]1980-2002. [2]Values are reported landings not adjusted for indirect mortality.

Year :	1994	1995	1996	1997	1998	1999	2000	2001	2002	[1]Max	[1]Min	[1]Mean
Quota:												
EEZ	24.5	22.2	20.2	19.6	18.1	20.4	20.4	20.4	20.4	--	--	--
[2]Landings:												
SVA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	<0.1
DMV	1.0	0.7	0.7	1.1	1.4	1.1	1.0	0.9	1.7	11.7	0.7	4.0
NJ	7.0	5.4	4.9	4.2	2.7	3.0	3.3	4.5	2.8	15.6	2.7	7.7
LI	12.0	9.5	5.9	5.1	6.6	6.3	4.7	5.7	9.1	12.0	0.0	3.9
SNE	1.0	5.4	8.3	9.0	6.4	6.6	5.1	4.7	3.9	9.0	0.0	2.6
GBK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other (in EEZ)	0.1	0.2	0.3	0.3	1.0	0.4	0.7	1.4	0.6	2.0	0.0	0.6
EEZ	21.0	21.2	20.1	19.7	18.0	17.5	14.9	17.2	18.1	22.5	13.1	18.8

Biomass and Mortality Estimates, Efficiency-Corrected Swept Area Biomass (ESB)

Year :	1997	1998	1999	2000	2001	2002
Biomass, '000 mt (ESB):						
SVA	<0.1	--	<0.1	--	--	<0.1
DMV	65	--	58	--	--	71
NJ	277	--	194	--	--	330
LI	505	--	422	--	--	454
SNE	249	--	416	--	--	428
GBK	447	--	686	--	--	833
EEZ Less GBK	1097	--	1090	--	--	1283
EEZ	1544	--	1776	--	--	2116
[1]Annual Fishing Mortality Rate (ESB):						
SVA	0.000	--	0.000	--	--	0.000
DMV	0.017	--	0.020	--	--	0.026
NJ	0.016	--	0.016	--	--	0.009
LI	0.011	--	0.016	--	--	0.021
SNE	0.038	--	0.017	--	--	0.010
GBK	0.000	--	0.000	--	--	0.000
EEZ Less GBK	0.019	--	0.016	--	--	0.014
EEZ	0.013	--	0.010	--	--	0.009

KLAMZ time series table

Year	SVA	DMV	NJ	LI	SNE	GBK	Total less GBK	Total
		[1] Model (scenario #)						
	VPA	KLAMZ 5	KLAMZ 3	VPA	KLAMZ 3	Aver. ESB	NA	NA
	Biomass ('000s mt)							
1977	0.297	298	455	534	386	655	1,674	2,329
1978	0.297	289	448	534	387	655	1,659	2,315
1979	0.297	281	442	534	388	655	1,645	2,300
1980	0.297	268	436	534	388	655	1,626	2,282
1981	0.297	257	428	534	389	655	1,608	2,264
1982	0.241	247	419	534	390	655	1,590	2,246
1983	0.235	236	411	534	391	655	1,572	2,227
1984	0.235	225	403	534	391	655	1,552	2,208
1985	0.229	212	394	534	390	655	1,531	2,186
1986	0.069	200	384	534	390	655	1,508	2,163
1987	0.069	187	375	534	390	655	1,486	2,141
1988	0.069	172	367	532	390	655	1,461	2,117
1989	0.027	156	361	532	390	655	1,438	2,094
1990	0.027	146	347	531	390	655	1,414	2,069
1991	0.013	138	333	530	389	655	1,391	2,046
1992	0.013	130	319	529	389	655	1,367	2,023
1993	0.013	125	314	517	389	655	1,344	1,999
1994	0.013	120	305	508	388	655	1,321	1,976
1995	0.013	116	300	496	388	655	1,299	1,955
1996	0.013	112	296	487	383	655	1,278	1,933
1997	0.013	109	293	481	376	655	1,258	1,913
1998	0.013	105	290	476	367	655	1,238	1,893
1999	0.013	101	289	469	362	655	1,221	1,876
2000	0.013	97	288	463	356	655	1,204	1,860
2001	0.013	94	286	468	352	655	1,201	1,856
2002	0.013	91	284	478	349	655	1,201	1,856
	Fishing Mortality (y^{-1})							
1977	0.000	0.003	0.014	0.000	0.000	0.000	0.004	0.003
1978	0.000	0.005	0.014	0.000	0.000	0.000	0.005	0.003
1979	0.000	0.020	0.014	0.000	0.000	0.000	0.007	0.005
1980	0.188	0.016	0.018	0.000	0.000	0.000	0.008	0.005
1981	0.021	0.014	0.020	0.000	0.000	0.000	0.008	0.005
1982	0.000	0.019	0.021	0.000	0.000	0.000	0.008	0.006
1983	0.026	0.023	0.020	0.000	0.002	0.000	0.009	0.007
1984	0.690	0.033	0.022	0.000	0.002	0.000	0.011	0.008
1985	0.000	0.035	0.028	0.000	0.002	0.000	0.012	0.009
1986	0.000	0.042	0.024	0.001	0.001	0.000	0.012	0.009
1987	0.608	0.059	0.025	0.002	0.002	0.000	0.015	0.010
1988	0.000	0.071	0.019	0.001	0.002	0.000	0.014	0.010
1989	0.501	0.043	0.040	0.001	0.003	0.000	0.016	0.011
1990	0.000	0.026	0.046	0.001	0.002	0.000	0.015	0.010
1991	0.000	0.036	0.045	0.003	0.002	0.000	0.016	0.011
1992	0.000	0.019	0.022	0.023	0.003	0.000	0.017	0.011
1993	0.000	0.016	0.033	0.017	0.003	0.000	0.016	0.011
1994	0.000	0.008	0.023	0.024	0.002	0.000	0.016	0.011
1995	0.000	0.006	0.018	0.019	0.014	0.000	0.016	0.011
1996	0.000	0.007	0.017	0.012	0.022	0.000	0.016	0.010
1997	0.000	0.010	0.015	0.011	0.024	0.000	0.016	0.010
1998	0.000	0.013	0.009	0.014	0.018	0.000	0.014	0.009
1999	0.000	0.011	0.011	0.014	0.019	0.000	0.014	0.009
2000	0.000	0.011	0.012	0.010	0.014	0.000	0.012	0.008
2001	0.000	0.010	0.016	0.012	0.013	0.000	0.013	0.009
2002	0.000	0.019	0.010	0.019	0.011	0.000	0.015	0.009

[1]From KLAMZ delay-difference model (for quahog 70+mm length), ESB, and VPA models, as indicated in table. The VPA is a cumulative catch model. “Aver. ESB” for GBK based on 1997, 1999, 2002. For DMV, KLAMZ3 and KLAMZ5 result were the same.

Stock Distribution and Identification: Ocean quahogs are distributed on both sides of the North Atlantic. They occur from Norway to Spain, intermittently across the North Atlantic and southward along the North American coast to Cape Hatteras. Commercial concentrations occur on the continental shelf off the coast of Maine and between Georges Bank and the Delmarva Peninsula (Figure A4), to at least 90 m. The assessment and management regime assumes a unit stock off the northeast US coast.

Catches: EEZ landings generally account for about 95-100% of total US landings. Annual EEZ quotas have been set since 1978. EEZ landings increased from 0 in 1975 to 14 thousand mt (meats) in 1979, and peaked at 23 thousand mt in 1992 (Figure A3). The spatial distribution of fishing effort has changed markedly over last two decades (Figure A3) in response to a variety of factors, including reductions in local catch rates and relocation of processing plants. 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. In 2001 and 2002, landings from Long Island fishery predominated, accounting for 33 and 50%, respectively of the landings from the EEZ. Total annual landings off the coast of Maine ranged from 92,000-129,000 “Maine” bushels (= 1 US Standard bushel = 1.2448 cu ft).

Data and Assessment: Ocean quahogs were last assessed in 2000 (SAW-31). The present assessment uses efficiency-corrected swept area biomass (ESB) estimates for the EEZ from the 1997, 1999 and 2002 surveys. The catch-swept area assessment model estimates fishing mortality rates by dividing landings by biomass. The Delay-difference model (KLAMZ) used efficiency-corrected swept area biomass estimates from 1997, 1999, 2002, a von Bertalanffy growth curve, shell length-meat weight relationships, and long-term research survey data to estimate ocean quahog biomass, mean annual recruitment biomass and fishing mortality rates during 1977-2002. Discards were assumed to be zero in all analyses. Indirect mortality from commercial dredging was assumed equal to 5% of the landings by weight. A cumulative catch model was also used in some cases to estimate historical biomass.

Biological Reference Points: Reference points were recalculated for this assessment to be consistent with the assumed 70mm knife-edge selection used in the KLAMZ model. The new estimates are F_{MAX}= 0.18 y^{-1}, $F_{0.1}$= 0.028 y^{-1} and $F_{25\%MSP}$ = 0.08 y^{-1}(Figure A5). These estimates assumed M = 0.02 y^{-1}, recruitment to the fishery occurred at 70mm (Age 26), and all fully recruited animals are considered to be sexually mature.

The present management “targets” are one-half of the virgin biomass and the $F_{0.1}$ fishing mortality in the exploited region (which excludes Georges Bank). The present “thresholds” are one quarter of the total virgin biomass and $F_{25\%MSP}$.

Based on the F_{MSY} proxy ($F_{25\%MSP}$ = 0.08 y^{-1}) and the revised estimate of one-half virgin biomass (1.2 million mt), the MSY catch would be about 96,000 mt meats y^{-1} for the whole stock (see Special Comments).

Fishing Mortality: Based on the ESB Model, F for 2002 was estimated to be 0.014 y^{-1} for the EEZ excluding GBK and the Gulf of Maine (Figure A5) (80% confidence interval 0.009 - 0.022 y^{-1}). The stockwide estimate (excluding Gulf of Maine) of F is 0.009 (80% confidence interval 0.006 - 0.013 y^{-1}). Recent observed Fs do not exceed the overfishing threshold ($F_{25\%MSP}$ = 0. 08y^{-1}) or target ($F_{0.1}$ = 0.028). Uncertainty in estimated fishing mortality rates is shown in Figure A6. Fishing mortality estimates from the KLAMZ model were similar (Figure A5).

Recruitment: Mean annual recruitment to the whole stock was small, 0-2% of stock biomass depending on the region. In the 2002 NMFS survey, the greatest numbers of small (<70mm shell length) ocean quahogs per tow were collected in the GBK and LI regions. For projections regional recruitment was assumed to be 0-1.7% of biomass in 2002.

Stock Biomass: Biomass for 2002 was estimated to be 1.3 million mt (ESB model) for the EEZ excluding GBK and the Gulf of Maine (Figure A5) (80% confidence interval 0.8 – 2.0 million mt). Stockwide estimate of biomass, (including Georges Bank but excluding the Gulf of Maine) is 2.1 million mt (80% confidence interval 1.4 – 3.1 million mt). Uncertainty in ESB biomass estimates is shown in Figure A7. Biomass estimates from the KLAMZ model were similar (Figure A5).

In the previous quahog assessment (NEFSC 2000a, b), stock biomass in 1976 (unfished stock) was 1.5 million mt (excluding GBK), and 2.1 million mt (including GBK). New estimates of the prefished stock biomass in 1977 were computed in the present assessment. They are 1.7 million mt (excluding GBK), and 2.3 million mt (including GBK)

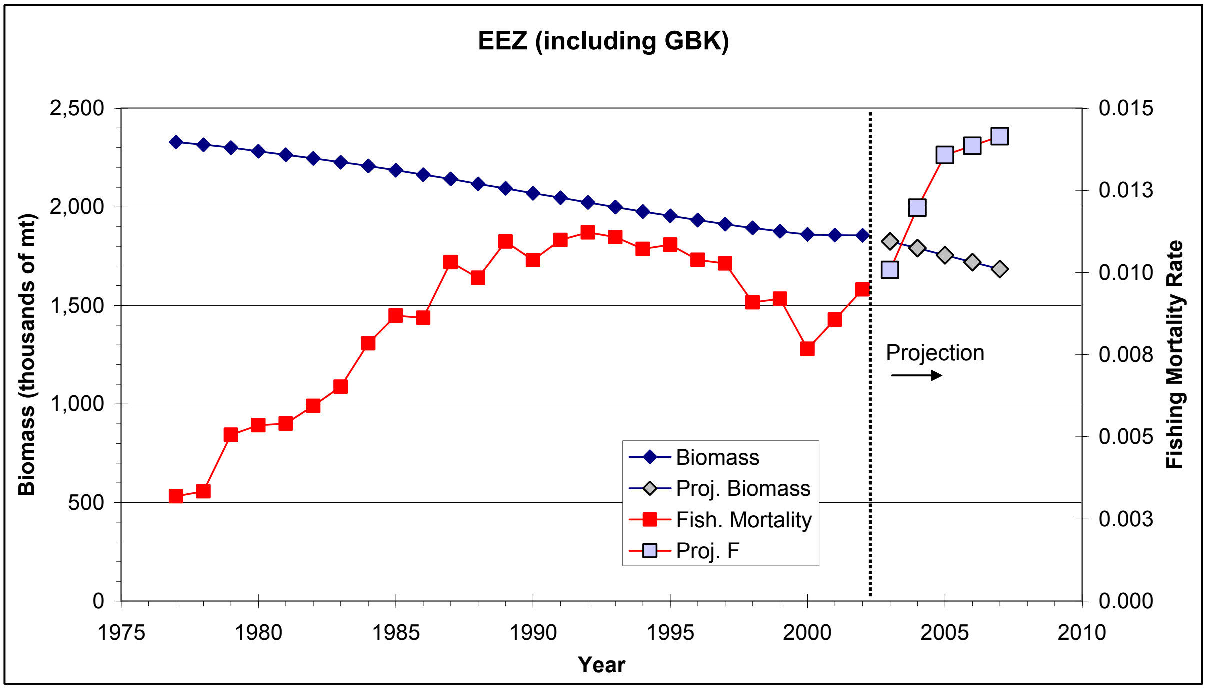
Special Comments: A major effort was made by NMFS, academia and industry collaborators from 1997-2002 to estimate the efficiency of the NMFS survey clam dredge. Nevertheless, a key source of uncertainty in the assessment is the survey dredge efficiency. The assumption that indirect mortality due to fishing is 5% is also a source of uncertainty.

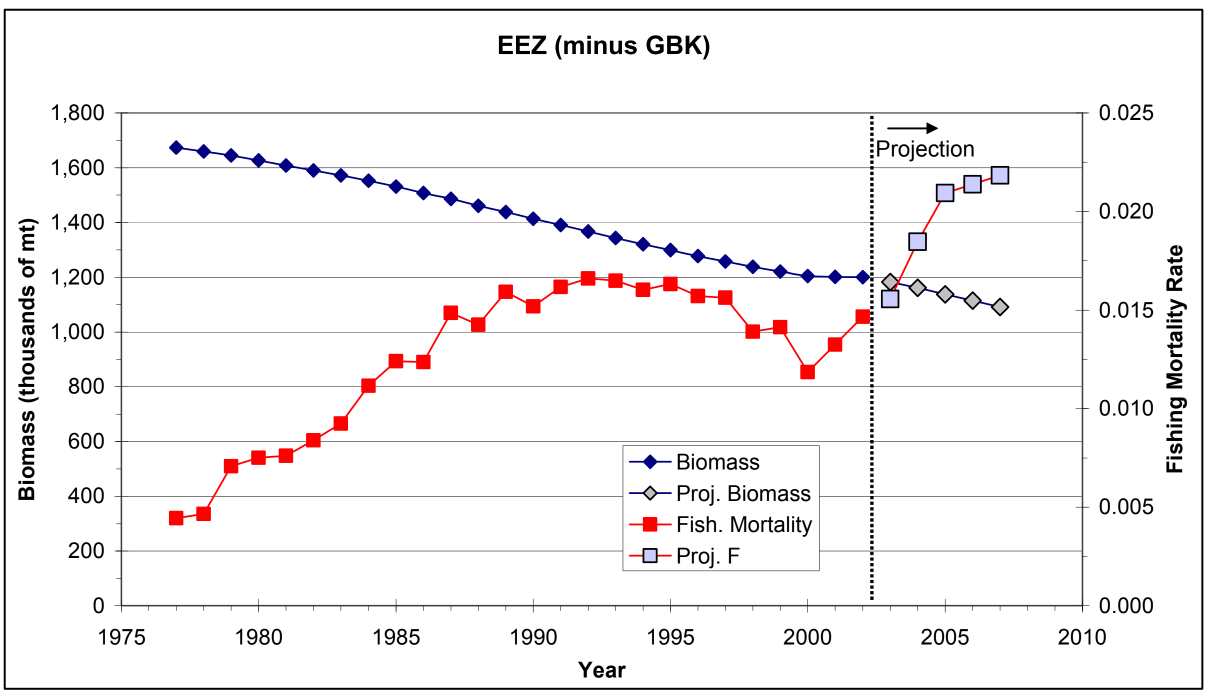
The results of a recent genetic study (Dahlgren *et al*., 2000) are consistent with the assumption that ocean quahogs throughout the EEZ are a single population.

The Surfclam-Ocean Quahog FMP currently utilizes a maximum fishing mortality threshold for ocean quahog based on the fishing mortality rate that generates 25% of the maximum spawning stock potential ($F_{25\%\ MSP}$). Based on more recent research on the use of such proxies for other resources, and concerns regarding the long term sustainability of the quahog resource, it is recommended that proxy MSP values be re-evaluated when this assessment is next updated.

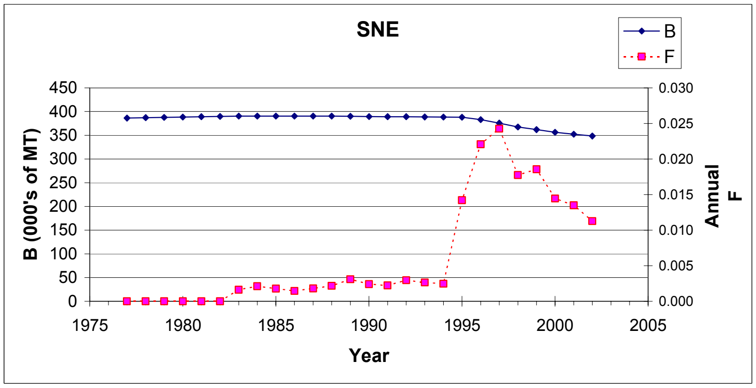
Sources of Information: Murawski, S.A., J.W. Ropes and F.M. Serchuk. 1982. Growth of the ocean quahog, *Arctica islandica*, in the Middle Atlantic Bight. Fishery Bulletin 80(1):21-34.
Dahlgren, T, J. Weinberg, and K. Halanych. 2002. Phylogeography of the ocean quahog (*Arctica islandica*): influences of paleoclimate on genetic diversity and species range. Mar. Biol. 137: 487-495.
NEFSC, 2000a. 31st Northeast Regional Stock Assessment Workshop (31st SAW). Public Review Workshop. C. Ocean quahog Advisory Report pp 24-32.
NEFSC Ref. Doc. 00-14. NEFSC, 2000b. 31st Northeast Regional Stock Assessment Workshop (31st SAW). Consensus Summary of Assessments. C. Ocean quahog. pp 172-304. NEFSC Ref. Doc. 00-15.

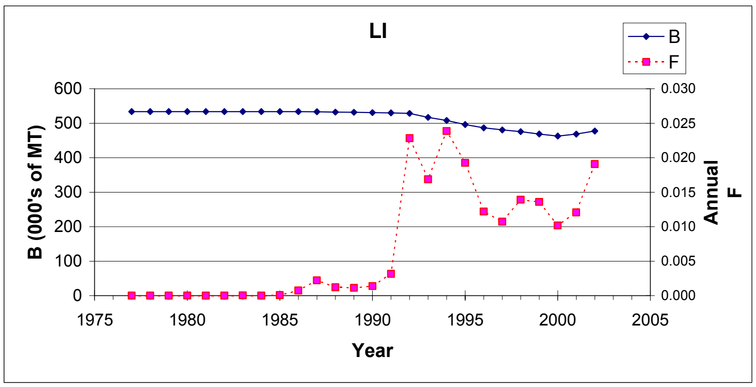
A1. Estimated and projected ocean quahog biomass and fishing mortality rate over time. Projections assume future catches = annual quotas.

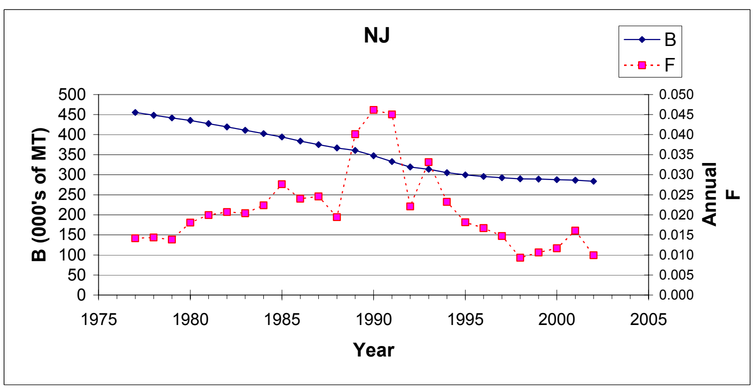


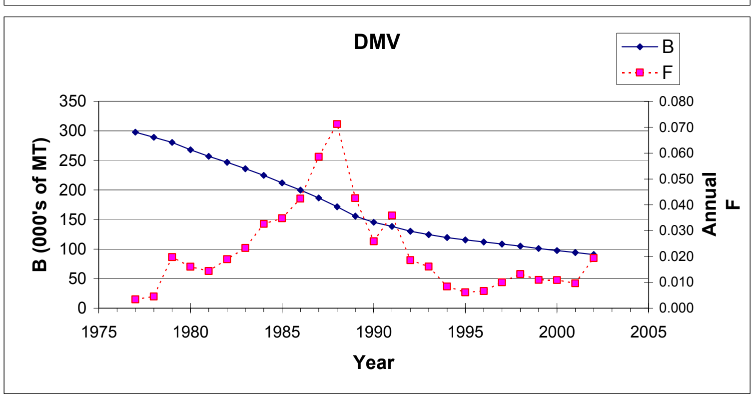


A2. Ocean quahog biomass and fishing mortality rate over time, by region.

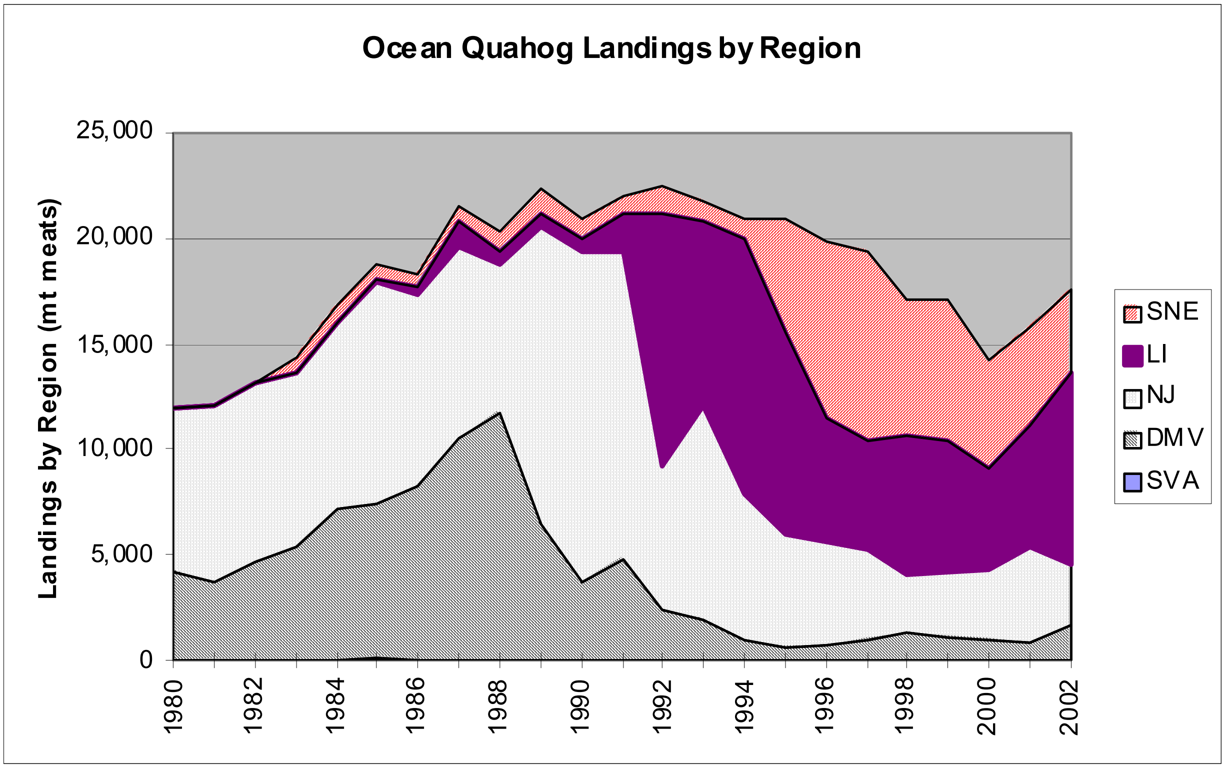




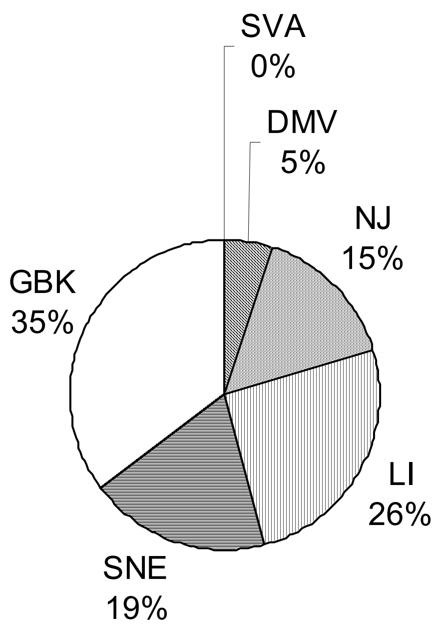




A3. Ocean Quahog landings by region, 1980-2002.

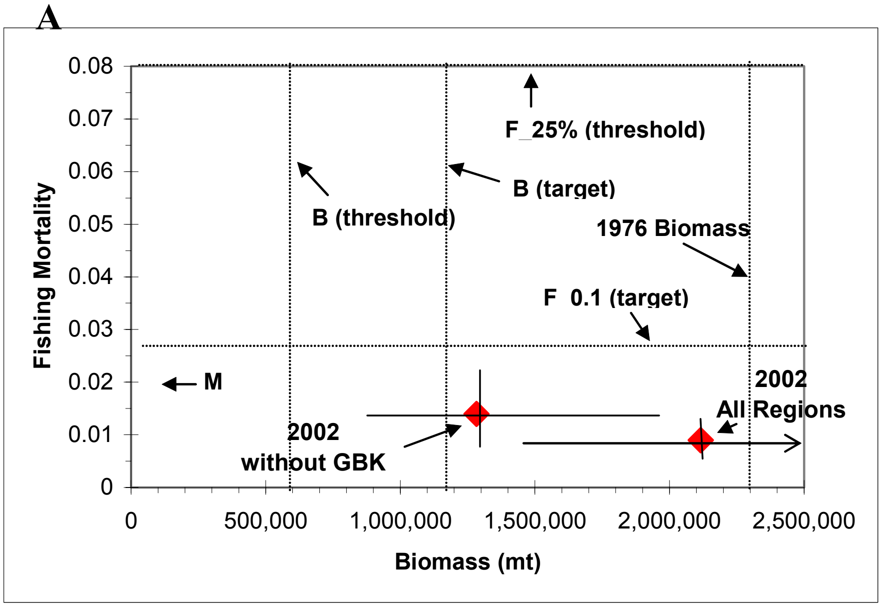


A4. Percentage of ocean quahog biomass by region, 2002.

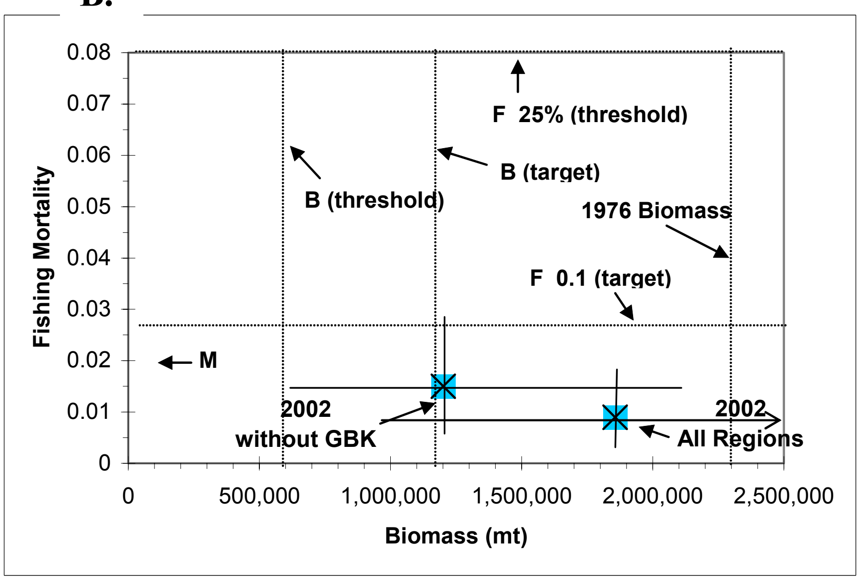


A5. Biological reference points for ocean quahogs, and estimates with 80% confidence intervals of recent biomass and annual fishing mortality rate. A ESB model or B KLAMZ model .

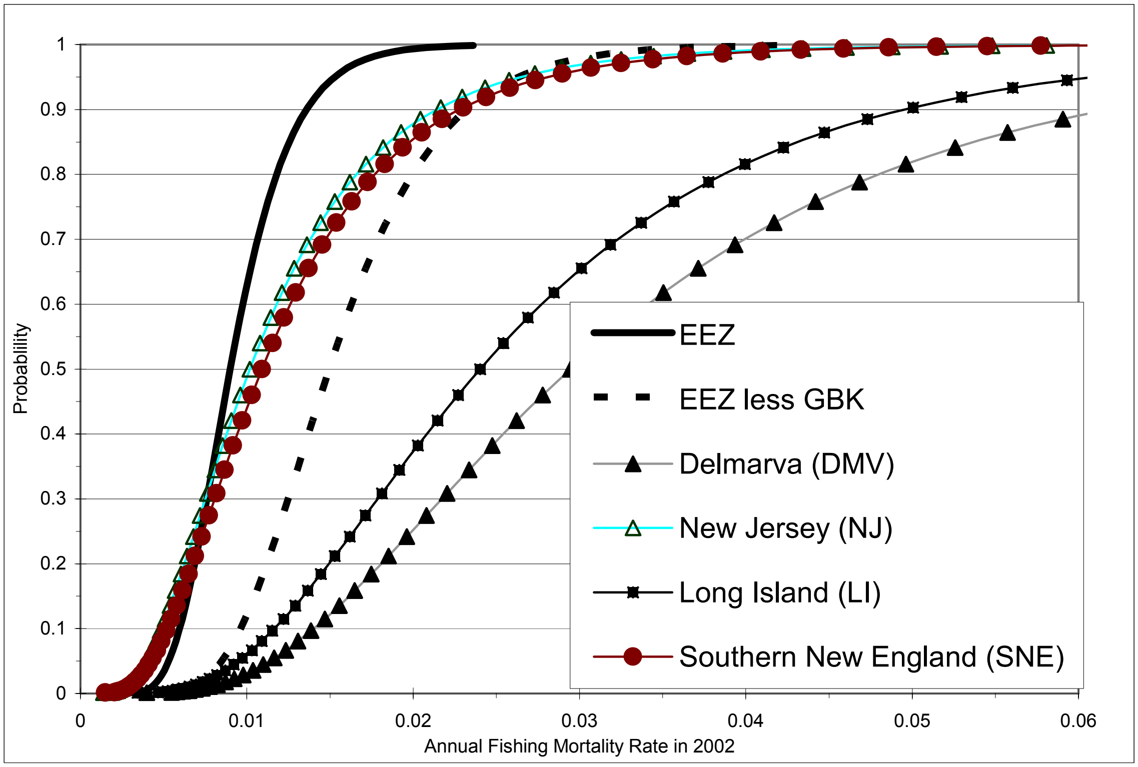
A



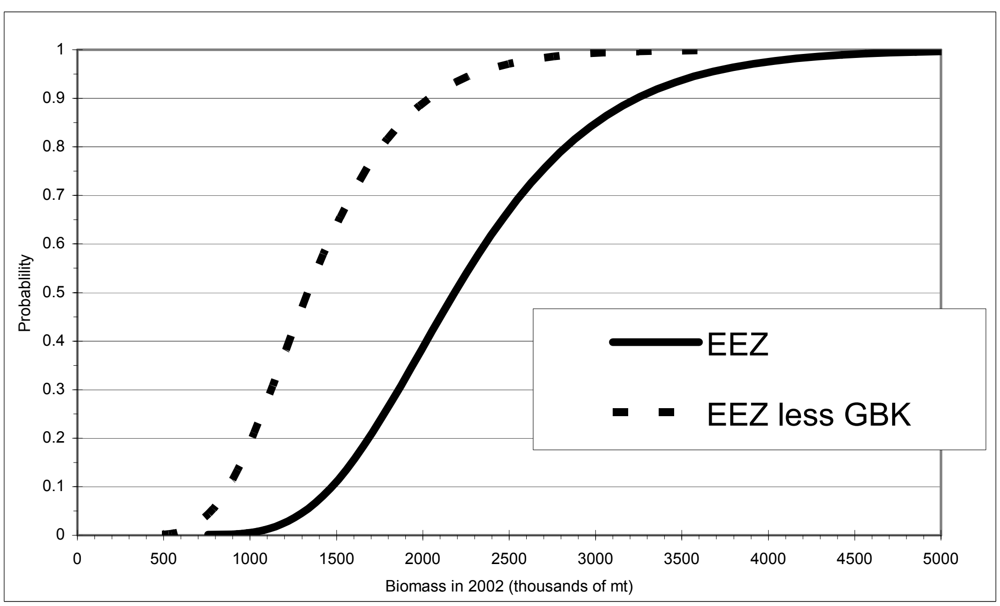
B.



A6. Uncertainty in ocean quahog fishing mortality estimates for 2002.



A7. Uncertainty in ocean quahog biomass estimates for 2002.



B. ATLANTIC BUTTERFISH

State of Stock: According to the existing status determination criterion for this stock, which is a F_{MSY} proxy ($F_{0.1}$=1.01), overfishing is not occurring. There is no biomass reference point in the Fishery Management Plan. New biological refenence points estimated for Atlantic butterfish are F_{MSY}=0.38 and B_{MSY}=22,798 mt. According to these estimates, fishing mortality in 2002 was near the overfishing definition, and stock biomass in 2002 was 8,700 mt, less than half of B_{MSY}, but the estimates of F and biomass are highly uncertain. Recruitment has declined since 1995 and was poor in 2001 and 2002. The last two NMFS autumn survey biomass per tow indices were among the lowest in the series, and the spring 2003 index was also low. Discards are estimated to be more than twice the landings.

Management Advice: Conservation and management measures should be implemented to reduce discards and discard mortality. The TAL setting-process currently ignores discards and should be revised to take this source of mortality into account.

Forecast for 2003: No forecasts were performed.

Landings and Status Table (weights in'000 mt): Butterfish

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	Max[1]	Min[1]	Mean[1]
US Comm landings	3.6	2.1	3.5	2.8	2.0	2.1	1.4	4.4	0.9	12.0	0.8	3.2
Foreign landings	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.7	0.0	3.9
USA Discards	3.7	8.6	6.8	3.9	3.3	4.1	2.4	7.3	1.8	19.0	0.3	4.4
Catch used in Assessment	7.3	10.7	10.4	6.6	5.2	6.2	3.8	11.7	2.7	34.3	2.7	11.5
Spawning Stock Biomass (age 1+)	22.3	31.3	12.4	10.8	8.2	7.8	24.5	24.1	8.7	62.9[2]	7.8[2]	23.2[2]
Average Biomass (mid-year)	41.2	21.4	18.0	13.2	12.0	31.6	31.6	16.7	7.8	77.2	7.8	33.4
Recruitment Biomass (age 0)	31.2	2.8	16.0	9.4	9.6	32.4	16.3	4.7	3.0	61.1	2.8	23.2
Fishing Mortality	0.18	0.50	0.58	0.50	0.43	0.20	0.12	0.7	0.34	0.93	0.09	0.40

[1] 1965-2002
[2] 1968-2002

Catches: From 1965 to 2002, US commercial landings averaged 3,200 mt per year, peaking at 12,000 mt in 1984 (Figure B1). Foreign landings began in the mid-1960s and averaged 6,800 mt during 1965-1986 with a peak of 31,700 mt in 1973. Estimates of discards in the USA fishery increased from a few hundred mt in 1965 to a peak of 19,000 mt in 1984, and ranged between 1,000-8,600 mt thereafter. Total catch peaked in 1973 at 34,300 mt, declined, then increased again to 31,500 mt in 1984 (Figure Bl). Since 1985, catches have averaged 8,100 mt, with discards averaging 5,100 mt. Butterfish catches in 2001 and 2002 were 11,700 mt (7,300 mt discards) and 2,700 mt (1,800 mt), respectively.

Data and Assessment: Atlantic butterfish were last assessed in August 1993 (SAW 17). The current assessment relies on NMFS survey biomass indices (wt/tow) [from NEFSC Winter, Spring, and Autumn research vessel surveys] (Figure B6), USA landings from the NMFS dealer database, USA discard estimates from the NMFS observer program, and foreign catch (Murawski and Waring 1979). The abundance and catch data provide a very noisy signal, due to the variable availability of butterfish to the survey and because 2/3rd of the catch is from imprecisely estimated discards. A delay-difference model was developed as a basis for stock assessment.

Fishing Mortality: Fishing mortality estimates averaged about 0.5 during 1967-1977 and then declined to an average of about 0.3 thereafter (Figure B2). Fishing mortality increased to 0.58 in 1996 and then declined to 0.12 in 2000. The average F during 2000-2002 was 0.39 and the F in 2002 was 0.34. There is an 80% probability that F in 2002 was between 0.25-1.02 (Figure B8).

Recruitment: Recruitment biomass (Age 0) has been highly variable over a range of spawning biomass between 10,000 mt - 50,000 mt. Average recruitment biomass during 1968-2002 was 23,200 mt. Recruitment for this stock averaged 26,600 mt during 1968-1994 and more recently has declined to 5,000 mt and 3,000 mt in 2001 and 2002, respectively (Figure B3).

Spawning Stock Biomass: Butterfish spawning stock biomass (Age 0) has been variable during 1968-2002 (Figure B3), fluctuating between 7,800-62,900 mt and averaging 23,200 mt. Spawning stock biomass in 2002 was estimated to be 8,700 mt, one of the lowest in the time series.

Average Biomass: Average biomass fluctuated between 7,800 -77,200 mt during 1969-2002 (Figure B4), averaged 34,000 mt, and declined to 7,800 mt in 2002. There is an 80% probability that average biomass in 2002 was between 2,600-10,900 mt (Figure B7).

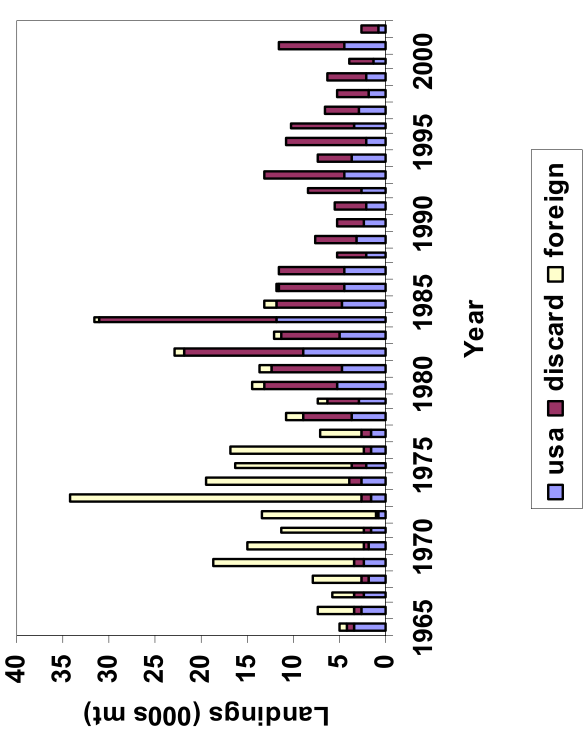
Biological Reference Points: Stock status determination is currently based on a F_{MSY} proxy ($F_{0.1}$=1.01) (Figure B5), and M = 0.8. B_{MSY} has not been previously estimated. New biological reference points were estimated in the delay-difference model for butterfish. A Fox model of surplus production for 1965-2002 produced an MSY=12,200 mt (including discards), B_{MSY}=22,800 mt, and F_{MSY}=0.38. However, there is considerable uncertainty in these estimates.

Special Comments: Further examination of existing the NEFSC Sea Sampling data is needed to evaluate butterfish discards. Other approaches to estimating discards could be explored and alternate sources of information should also be evaluated.

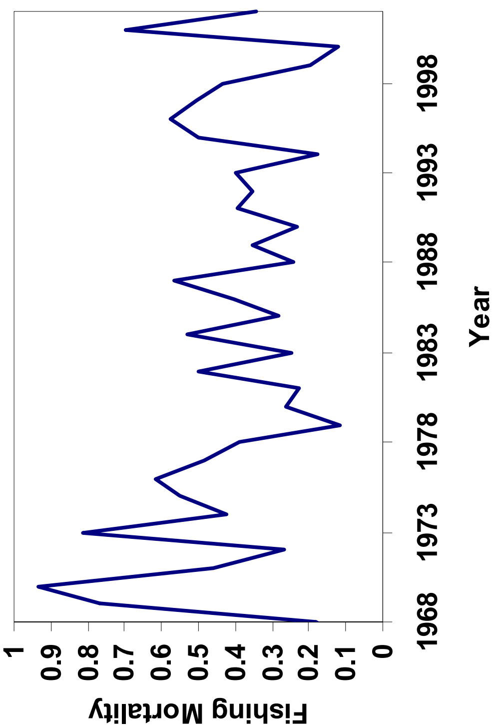
Butterfish are a major prey item for many finfish and marine mammal species. This should be considered for multispecies and ecosystem management.

Sources of Information: Murawski, S. A. and G. T. Waring. 1979. A population assessment of butterfish, *Peprilus triacanthus*, in the northwestern Atlantic Ocean. Trans. Am.Fish. Soc. 108:427-439.

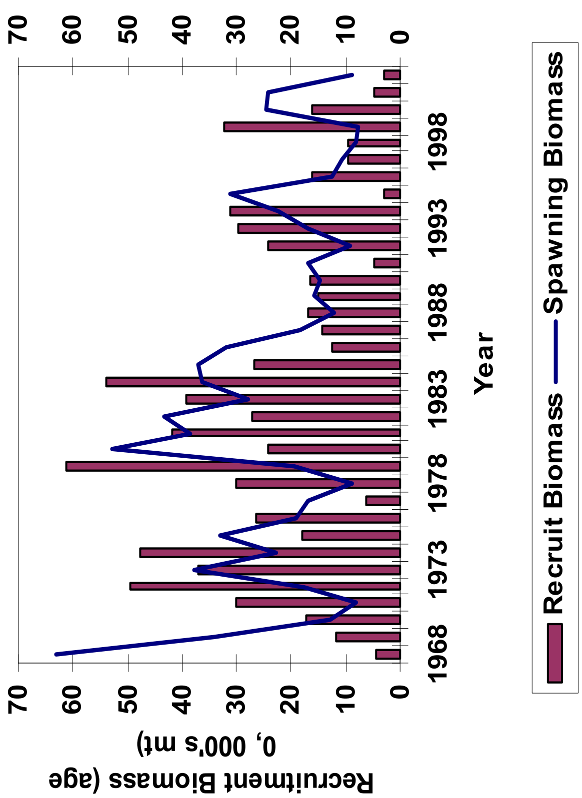
B1. Landings and Discards



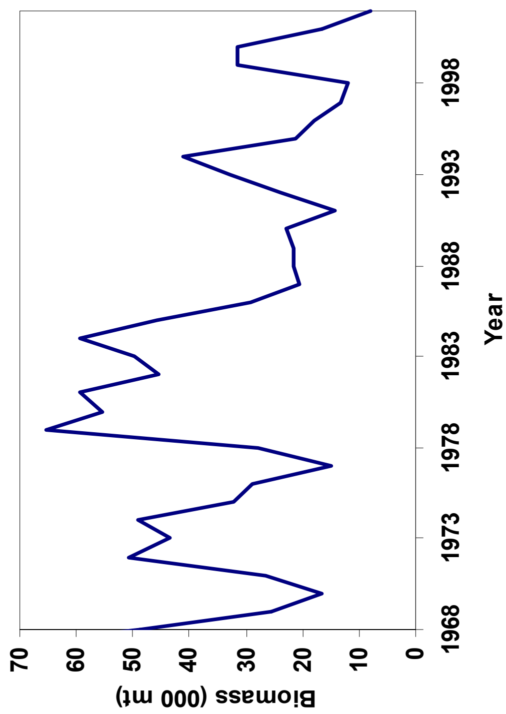
B2. Fishing Mortality



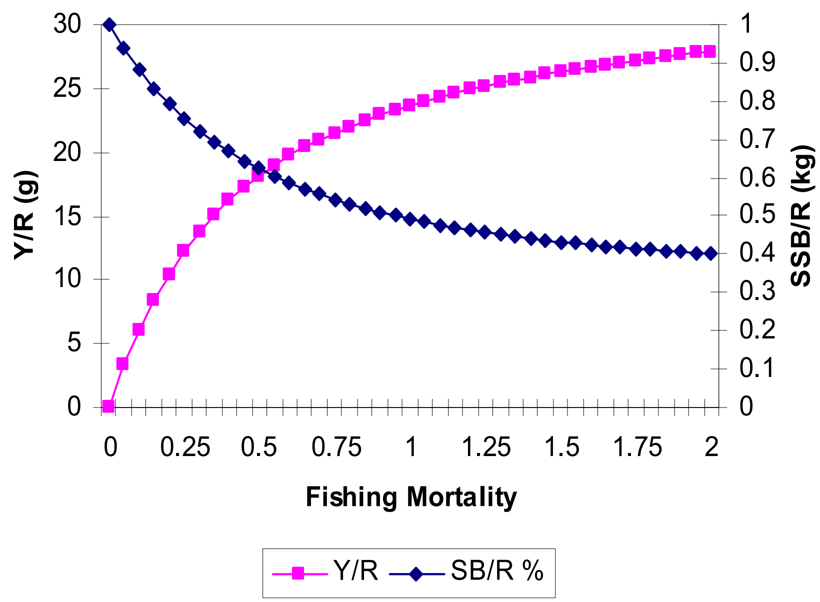
B3. Recruitment and Spawning Biomass



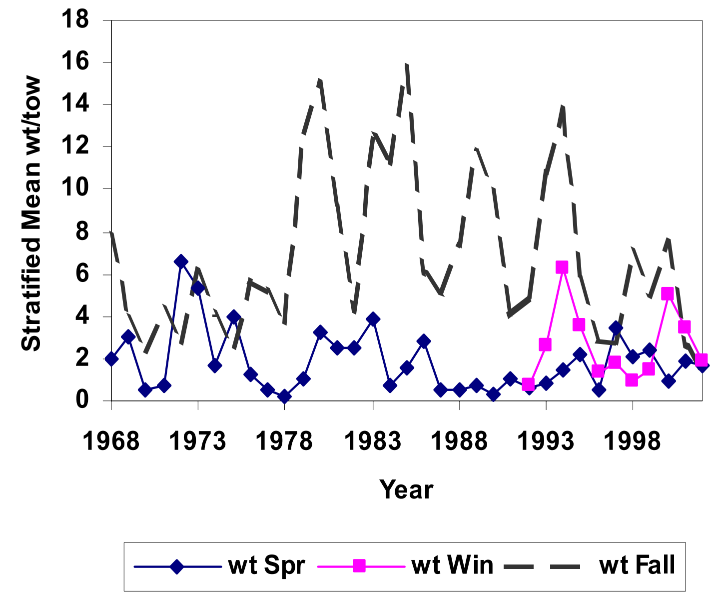
B4. Average Biomass (mid-year)



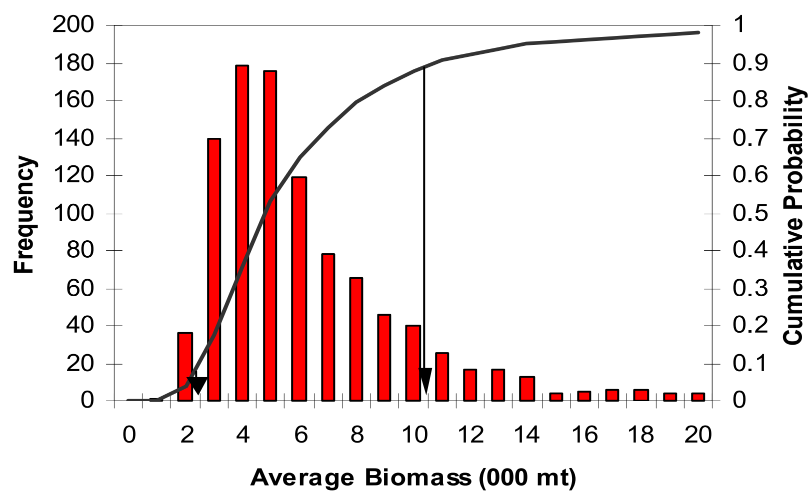
B5. Yield and SSB per Recruit



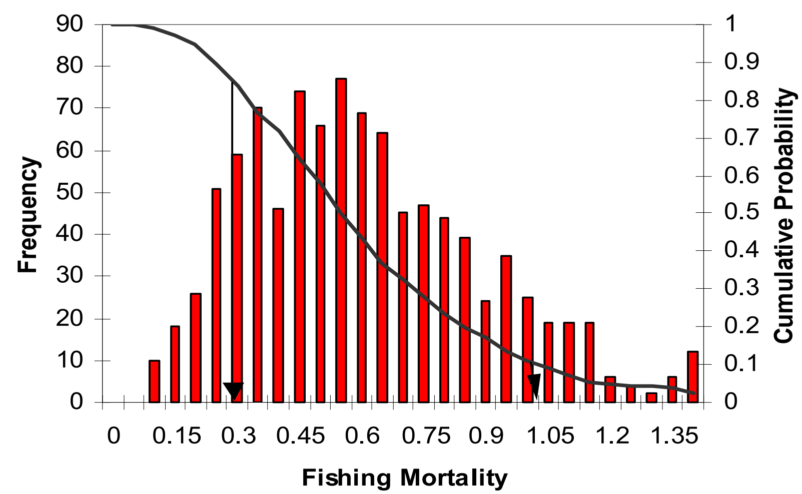
B6. NEFSC Survey wt/tow



B7. Precision of 2002 Average Biomass Estimate



B8. Precision of 2002 Fishing Mortality Estimate



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Publications and Reports of the Northeast Fisheries Science Center

The mission of NOAA's National Marine Fisheries Service (NMFS) is "stewardship of living marine resources for the benefit of the nation through their science-based conservation and management and promotion of the health of their environment." As the research arm of the NMFS's Northeast Region, the Northeast Fisheries Science Center (NEFSC) supports the NMFS mission by "planning, developing, and managing multidisciplinary programs of basic and applied research to: 1) better understand the living marine resources (including marine mammals) of the Northwest Atlantic, and the environmental quality essential for their existence and continued productivity; and 2) describe and provide to management, industry, and the public, options for the utilization and conservation of living marine resources and maintenance of environmental quality which are consistent with national and regional goals and needs, and with international commitments." Results of NEFSC research are largely reported in primary scientific media (*e.g.*, anonymously-peer-reviewed scientific journals). However, to assist itself in providing data, information, and advice to its constituents, the NEFSC occasionally releases its results in its own media. Currently, there are three such media:

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