Northeast Fisheries Science Center Reference Document 06-01

42nd Northeast Regional Stock Assessment Workshop (42nd SAW)

42nd SAW Assessment Summary Report

January 2006

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A Report of the 42nd Northeast Regional
Stock Assessment Workshop (42nd SAW)

42nd SAW Assessment Summary Report

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts

January 2006

Northeast Fisheries Science Center Reference Documents

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This document's publication history is as follows: manuscript submitted for review -- January 9, 2006; manuscript accepted through technical review -- January 13, 2006; manuscript accepted through policy review -- January 13, 2006; and final copy submitted for publication -- January 13, 2006. This document may be cited as:

42nd Northeast Regional Stock Assessment Workshop (42nd SAW): 42nd SAW assessment summary report. *U.S. Dep. Commer., Northeast Fish. Sci. Cent. Ref. Doc.* 06-01; 61 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026.

The stock assessments which are the subject of this document were peer reviewed by a panel of assessment experts known as the Stock Assessment Review Committee (SARC). Panelists were provided by the Center for Independent Experts (CIE), University of Miami. Reports from the SARC panelists and a summary report from the SARC Chairman can be found at *http://www.nefsc.noaa.gov/nefsc/saw*.

Table of Contents

SAW-42 ASSESSMENT SUMMARY REPORT

INTRODUCTION

The 42nd SAW Assessment Summary Report contains summary and detailed technical information on the three assessments and one multispecies predator prey model reviewed in November/December 2005 at the Stock Assessment Workshop (SAW) by the 42nd Stock Assessment Review Committee (SARC-42): silver hake (*Merluccius bilinearis*), Atlantic mackerel (*Scomber scombrus*), northern shortfin squid (*Illex illecebrosus*) and the MSVPA-X model. The SARC-42 consisted of three external, independent reviewers and a SARC chairman, all appointed by the Center for Independent Experts. The SARC evaluated whether each Term of Reference (listed in the Appendix) was completed successfully based on scientific criteria and whether the work provided a scientifically credible basis for developing fishery management advice. The reviewers' report for SAW/SARC-42 is available at website: http://www.nefsc.noaa.gov/nefsc/saw/ under the heading "Recent Reports".

The SARC accepted part of the silver hake assessment. Three approaches were used in the assessment to estimate fishing mortality (F) and stock biomass. Two of these approaches were new and were designed to derive lower bounds for biomass and upper bounds for F: (1) a comparison of catches in the NEFSC survey with those in a Supplemental Finfish survey; and (2) a method based on the assumption that landings must be less than stock biomass. The third approach was the existing method which uses standard biomass and exploitation indices derived from NEFSC fall bottom trawl survey data and commercial landings. The results of the two new approaches were not accepted by the SARC because the approaches depended on key assumptions that were not well supported. Thus, the assessment was based on the existing method which was used for determining stock status. The SARC concluded that although the silver hake assessment was able to evaluate stock status, more work should be done to evaluate the appropriateness of the existing threshold criteria.

The SARC accepted the Atlantic mackerel stock assessment, and indicated that the assessment was scientifically-sound and provided a credible basis for developing management advice. It was noted that estimates of fishing mortality and biomass from the new mackerel assessment model (ASAP) model had a retrospective pattern, raising concerns about whether these quantities were estimated well. The SARC felt that a suitable description was provided regarding the transition from an earlier assessment model to the ASAP model, but that more details and documentation should have been provided in the mackerel assessment report.

The *Illex* squid assessment was not able to estimate fishing mortality rate, stock biomass, or to determine stock status. The SARC indicated that the available data on *Illex* were not adequate to estimate these quantities; nevertheless, significant advances in modeling had taken place. The SARC advocated finding a new approach for evaluating overfishing, and deemed the existing criteria inappropriate for this short-lived species.

With respect to the MSVPA-X model, the reviewers concluded that all of the Terms of Reference were met; however, they stressed that it would not be appropriate to use the present model as a basis for quantitative fishery management advice about menhaden or its predators.

Rather, they felt that the MSVPA-X model was a valuable tool for understanding predator-prey dynamics and for exploring "what if" scenarios.

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 a stock's biomass falls below the biomass threshold ($B_{THRESHOLD}$) the stock is in an overfished condition. The Sustainable Fisheries Act mandates that a plan be developed for stock rebuilding should this situation arise.

Since there are two dimensions to the status of the stock– 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 is increased 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. 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.

		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	$F = F_{TARGET} <= F_{MSY}$

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 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.

GLOSSARY

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 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.

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.

A. SILVER HAKE ASSESSMENT SUMMARY FOR 2005

State of Stock: The northern stock of silver hake (Figure A1) is not overfished and overfishing is not occurring. The three year delta mean biomass index (Figure A2), based on NEFSC fall bottom trawl survey data for 2002-2004 (6.72 kg/tow), was above the management threshold level (3.31 kg/tow) and slightly above the target level (6.63 kg/tow). The three year average exploitation index (landings divided by biomass index, Figure A3) for 2002-2004 (0.24) was below the single management threshold/target level (2.57).

The southern stock of silver hake (Figure A1) is not overfished and overfishing is not occurring. The three year delta mean biomass index (Figure A5) based on NEFSC fall bottom trawl survey data for 2002-2004 (1.37 kg/tow) was above the management threshold level (0.89 kg/tow) but below the target level (1.78 kg/tow). The three year average exploitation index (Figure A6) for 2002-2004 (4.85) was below both the management threshold (34.39) and the management target level (20.63).

Projections: Stock projections were not conducted.

Landings and Status Table (weights in '000 mt live weight): Silver Hake

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Max	Min	Mean
Northern stock area													
Commercial landings[1,5]	3.0	3.2	2.6	2.3	4.0	2.4	3.4	2.8	1.7	0.6	94.5	0.6	22.4
Biomass index (Kg/tow)[2]	9.40	9.32	8.90	11.83	13.08	15.80	11.65	10.44	8.77	6.72	15.80	2.28	8.05
Exploitation index[2]	0.53	0.49	0.37	0.32	0.30	0.21	0.29	0.30	0.30	0.24	15.75	0.21	3.43
Recruit index[3,4]	22	13	15	29	60	61	50	34	37	32	61	2	19
Southern stock area													
Commercial landings[1,5]	11.7	13.0	13.0	12.7	10.0	10.0	8.7	5.2	6.9	7.9	307.1	5.2	40.9
Biomass index (Kg/tow)[3]	1.26	0.96	0.97	0.63	0.78	0.74	1.27	1.38	1.66	1.37	2.89	0.63	1.66
Exploitation index[3]	9.9	16.7	17.6	22.0	15.8	15.2	9.6	7.3	4.2	4.9	78.7	4.2	21.3
Recruit index[3,4]	29	29	37	20	29	38	42	38	48	41	74	19	38

[1] Maximum, minimum and mean of annual values for 1955-2004

[2] Maximum, minimum and mean of 3-year running averages for 1966-2004 (first annual figure is from 1964)

[3] Maximum, minimum and mean of 3-year running averages for 1969-2004 (first annual figure is from 1967)

[4] Three year average of stratified mean number per tow for silver hake < 20 cm TL in NEFSC fall bottom trawl survey

[5] Discards are not included in this table. Discards from the North+South stock areas averaged 3,820 mt per year during 2001-2004, with at least 1,580 mt per year in the north and at least 2,142 mt per year in the south (estimates not available prior to 2001).

Stock Distribution and Identification: Silver hake range from Newfoundland to South Carolina and are most abundant from Nova Scotia to New Jersey (Figure A1). Silver hake are found over a wide range of depths, from shallow waters to greater than 400 m (219 fathoms). Larger and older silver hake tend to be found further to the north and in deeper water. There are seasonal patterns with movement inshore during the spring and summer.

Stock assessments and management are based on two stocks due to differences in morphology of silver hake in the two areas (Figure A1), population trends, and fishery patterns. The northern stock is distributed in the Gulf of Maine-northern Georges Bank region. The southern stock extends from southern Georges Bank to Cape Hatteras. Although biological differences exist, the two stocks are best viewed as management units rather than separate biological populations.

Landings: During 1955-1975, silver hake landings from the northern stock area averaged about 30,000 mt (68 million lbs) per year (Figure A4). Northern area landings declined in 1976, when the foreign fishery ceased, and continued to slowly decline thereafter slowly to less than 4,000 mt (9 million lbs) per year during 2000-2004. Landings in 2004 were a record low 600 mt.

Landings from the southern stock area (Figure A7) were less than 20,000 mt (44 million lbs) per year, except during 1963-1978 when catches by foreign fleets were relatively high. Annual landings during 2002-2004 were less than 8,000 mt (17.6 million lbs) per year.

Discards: Discards averaged about 4,000 mt (9 million lbs) per year during 2001-2004 for the combined stock areas (Figure A1).

Data and assessment: Three methods were used to estimate fishing mortality (F) and stock biomass in both stocks. Two of these methods were new (1. comparison of catches in the in the NEFSC survey with those in a Supplemental Finfish survey, and 2. a method based on the assumption that landings must be less than stock biomass) and were designed to derive lower bounds for biomass and upper bounds for F. The third method was the existing method which uses standard biomass and exploitation indices based on NEFSC fall bottom trawl survey data and commercial landings. The results of the two new approaches were not accepted by the SARC because the approaches were based on some key assumptions that were not well supported. The assessment was therefore based on the existing method and this was used for determining stock status.

Biological Reference Points: Biological reference points for silver hake are stock specific MSY proxies based on averages of NEFSC fall bottom trawl survey biomass indices (delta mean kg/tow) and exploitation indices (landings / fall survey biomass index) during a period of relative stability (1973-1982). To determine whether a stock is overfished or if overfishing is occurring, reference points are compared to the most recent three year average survey biomass or exploitation index.

For the northern stock, the biomass target is 6.63 kg/tow (a proxy for B_{MSY}), and the biomass threshold is 3.31 kg/tow (one-half of the target). The F_{MSY} proxy (2.57) is the average exploitation index during 1973-1982, which is used as both a target and threshold for fishing mortality in the northern stock.

For the southern stock, the biomass target is 1.78 kg/tow (a proxy for B_{MSY}), and the biomass threshold is 0.89 kg/tow (one-half of the target). The F_{MSY} proxy (34.39) and threshold reference point for fishing mortality is the average exploitation index during 1973-1982. The target fishing mortality in the southern stock is 20.63 (60% of the F_{MSY} proxy).

Fishing Mortality: Based on three-year running average indices and landings, exploitation on the northern silver hake stock was relatively high during 1964-1970 and declined steadily after 1970 to low levels by 1976 (Figure A3). Since 1976, exploitation has remained very low.

In the southern stock, exploitation declined after 1977 and remained relatively low until 1988 (Figure A6). Thereafter, exploitation increased slowly until 1998. Subsequently, exploitation declined to relatively low levels.

Total Stock Biomass: Survey biomass indices of the northern silver hake stock increased from relatively low levels in 1967 to relatively high current levels (Figure A2).

Survey biomass indices of the southern silver hake stock varied without trend during 1967-1990, declined during 1991-2000 and then increased to near average levels by 2004 (Figure A5).

Recruitment: The recruitment index for the northern stock increased during the 1980s and 1990s, and peaked in the late 1990s (Figure A8). In the southern stock, recruitment has varied without trend since 1980 (Figure A9).

Spawning Stock Biomass: Not estimated

Special Comments:

1) The threshold and target for fishing mortality in the northern stock are the same. From a technical point of view, it is desirable to have fishing mortality targets that are less than the fishing mortality thresholds.
2) Although the recent annual exploitation index has been relatively low in both silver hake stocks, old fish and large fish are uncommon in both stocks.
3) Information about the distribution, abundance and biomass of silver hake in deep water beyond the reach of current surveys is required to better understand the dynamics of both stocks.
4) Information about mixing and north-south movement is required to better understand population dynamics of silver hake as a whole.

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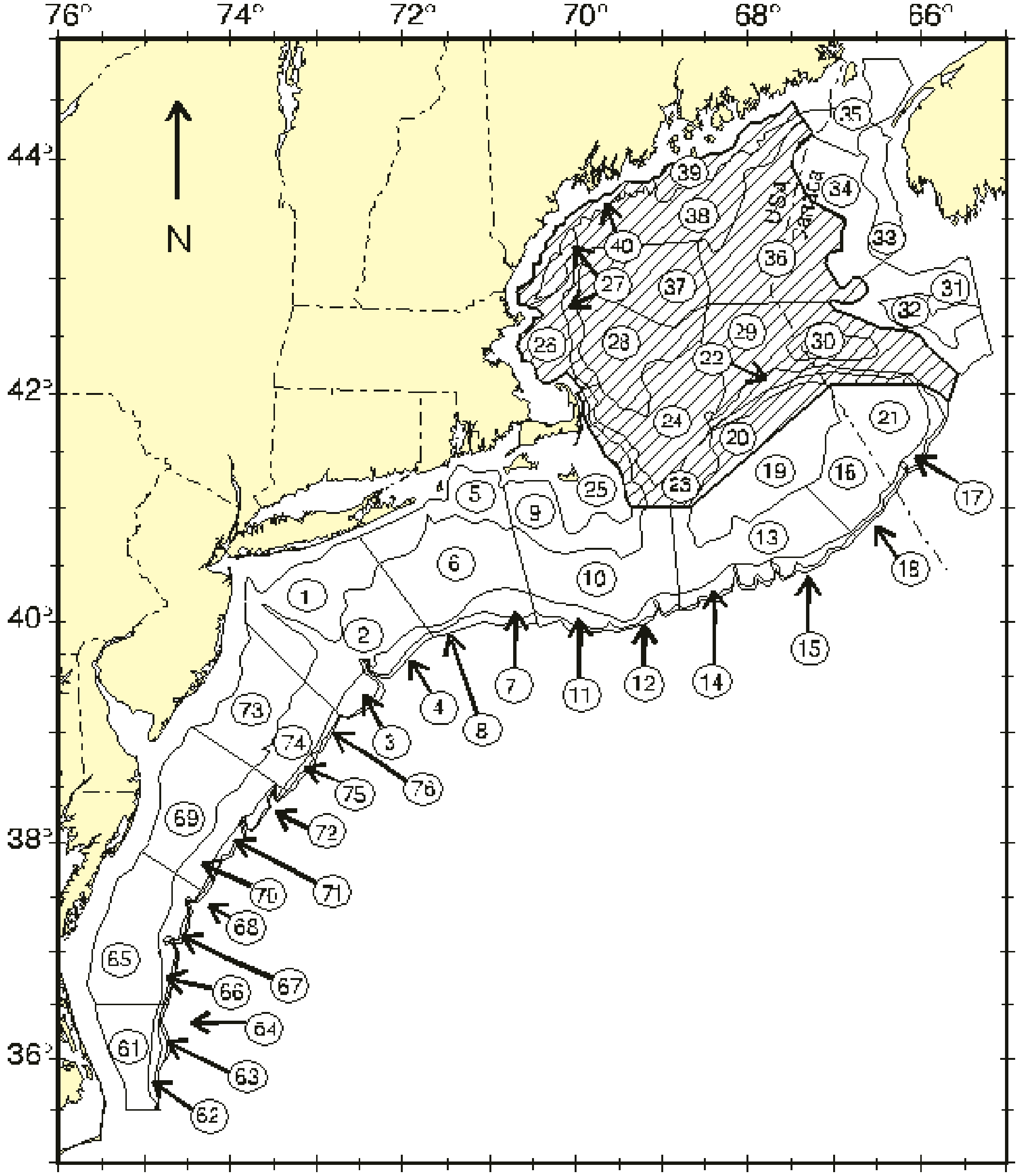
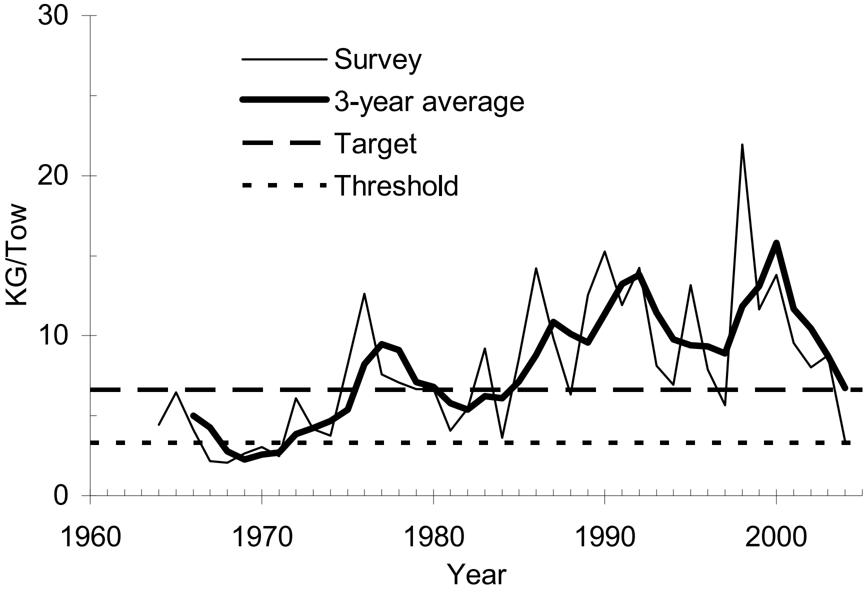
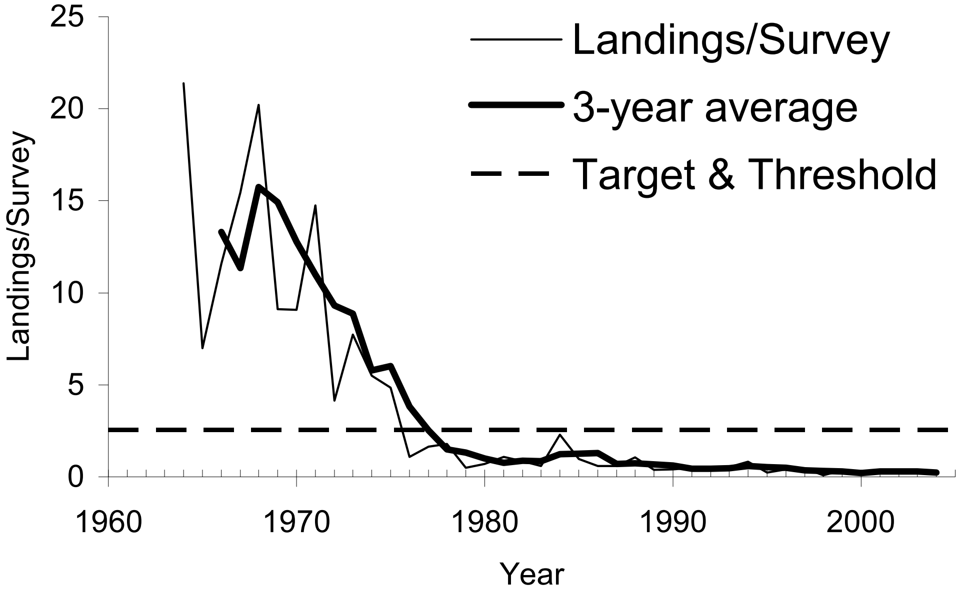


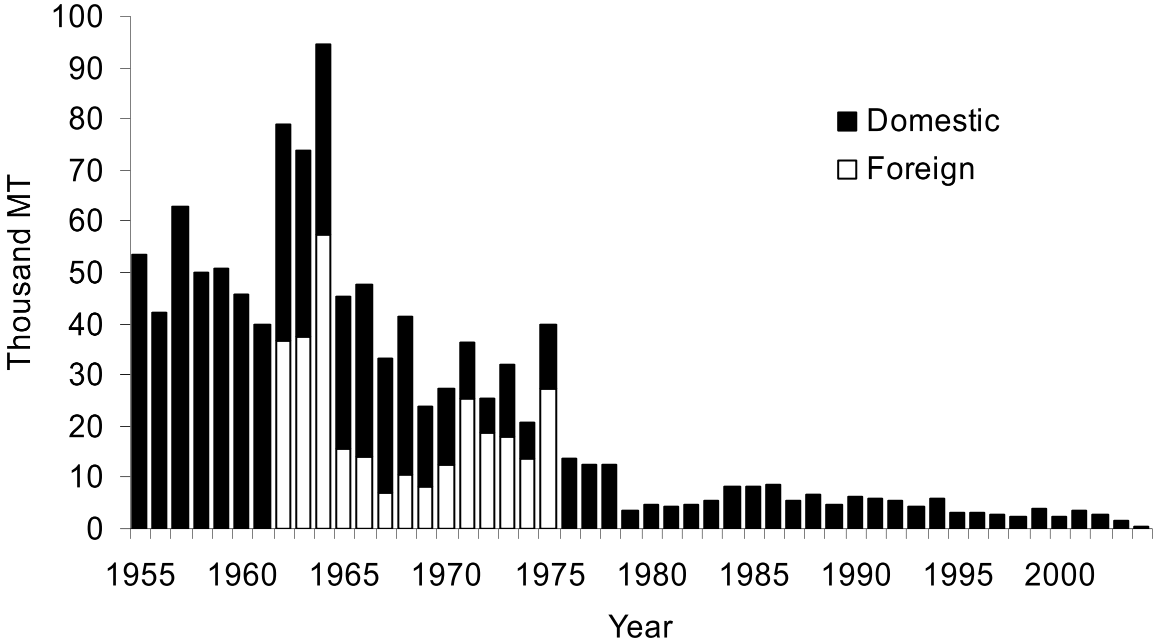
A1. The northern (hatched) and southern stock areas for silver hake with offshore NEFSC bottom trawl survey strata.



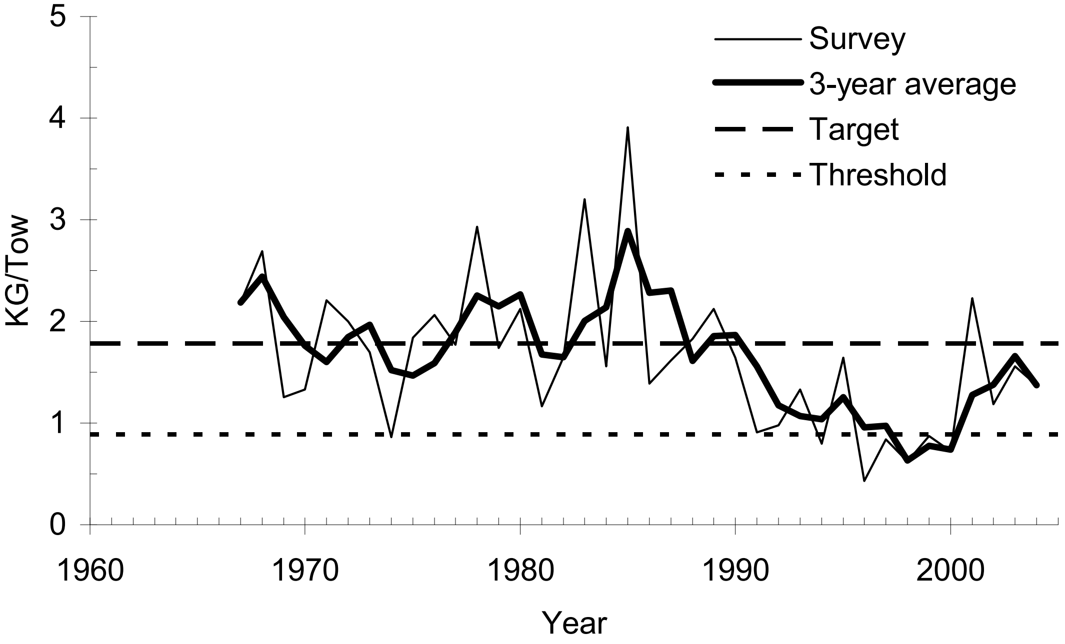
A2. NEFSC fall bottom trawl survey biomass index (delta mean kg per tow), 3-year running averages and current reference points for the northern stock of silver hake.



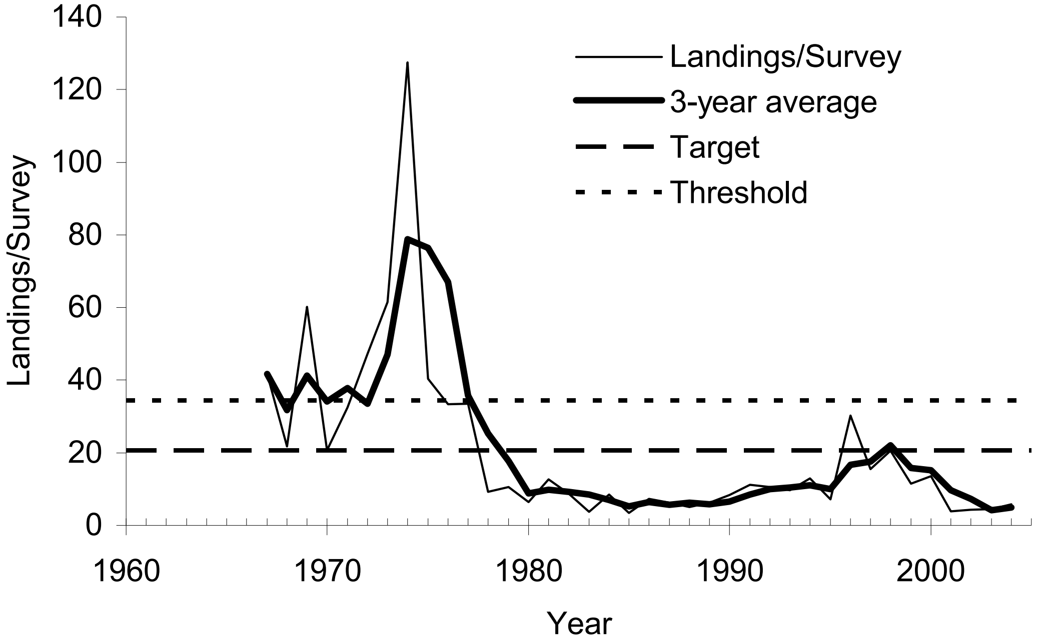
A3. Exploitation index (landings / NEFSC fall bottom trawl biomass index) and current reference points for the northern stock of silver hake.



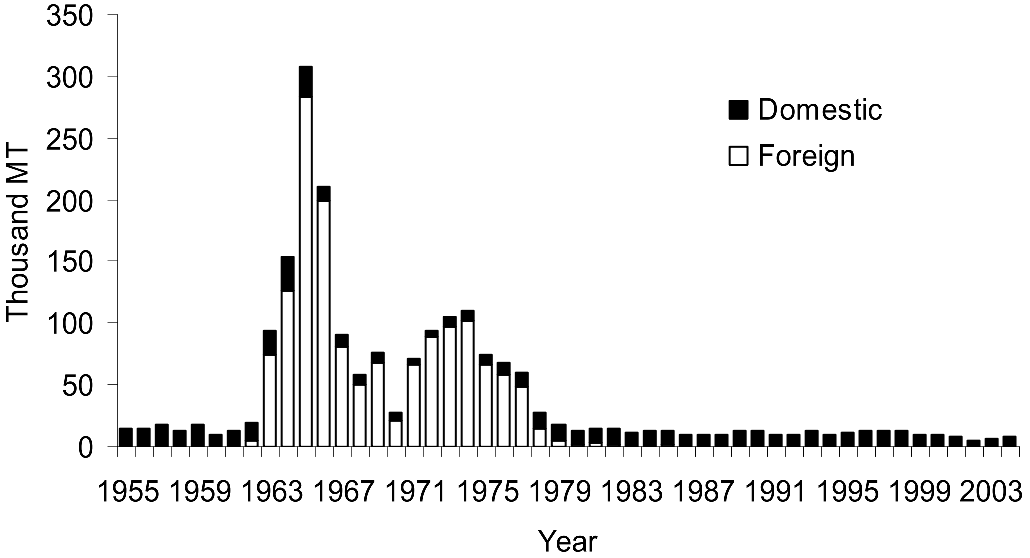
A4. Landings from the northern stock of silver hake, 1955-2004.



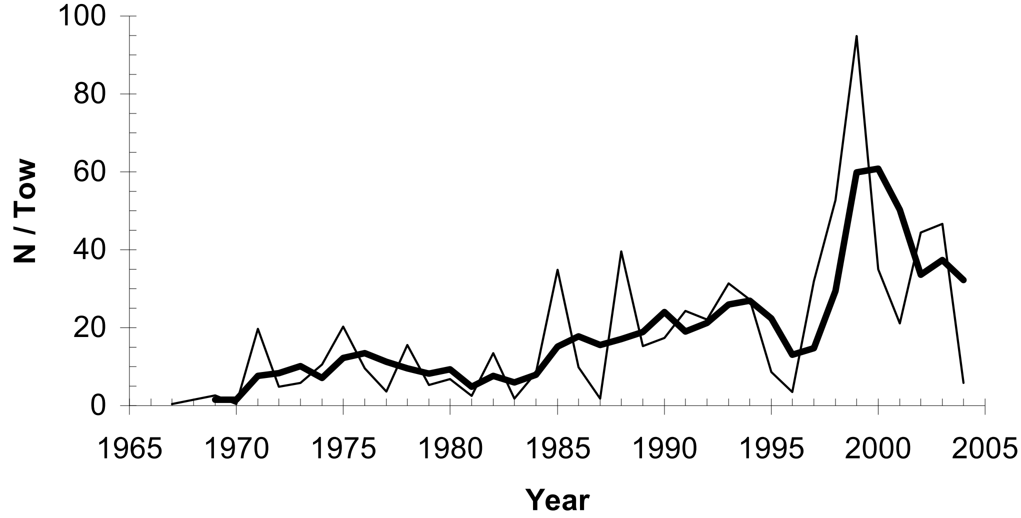
A5. NEFSC fall bottom trawl survey biomass index (delta mean kg per tow) and current reference points for the southern stock of silver hake.



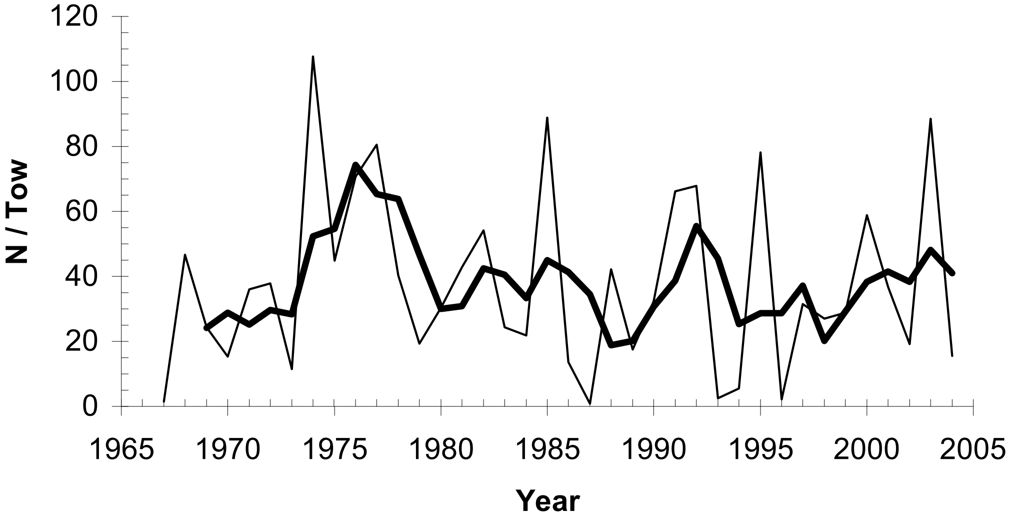
A6. Exploitation index (landings / NEFSC fall bottom trawl biomass index) and current reference points for the southern stock of silver hake.



A7. Landings of silver hake from the southern area, 1955-2004.



A8. Recruitment index (stratified mean number per tow for silver hake < 20 cm TL in NEFSC fall bottom trawl survey) for the northern stock. The thick dark line is the three year moving average.



A9. Recruitment index (stratified mean number per tow for silver hake < 20 cm TL in NEFSC fall bottom trawl survey) for the southern stock. The thick dark line is the three year moving average.

B. ATLANTIC MACKEREL ASSESSMENT SUMMARY FOR 2005

State of Stock: Biological reference points (BRP) for Atlantic mackerel listed in Amendment 8 to the Atlantic mackerel, squid and butterfish FMP, implemented in 1998, are Fmsy = 0.45 and SSBmsy = 890,000 mt (NEFMC 1998). Updated estimates of these reference points in the present assessment are Fmsy = 0.16 and SSBmsy = 644,000 mt. Based on the ASAP model used in the present assessment, fishing mortality on Atlantic mackerel in 2004 was F = 0.05 and spawning stock biomass was 2.3 million mt. Based on the new reference points the northwest Atlantic mackerel stock is not overfished and overfishing is not occurring.

Fishing mortality has remained low for the last decade, but increased slightly from 0.01 in 2000 to 0.05 in 2004 (Figure B1). The confidence interval (± 2 SD) for F in 2004 is from 0.035 to 0.063. Retrospective analysis shows that F has sometimes been underestimated in recent years (Figure B4).

Spawning stock biomass increased from 663,000 t in 1976 to 2.3 million mt in 2004 (Figure B3). The confidence interval on the 2004 SSB estimate (± 2 SD) is from 1.49 to 3.14 million mt; based on retrospective analysis, SSB has sometimes been overestimated in recent years (Figure B4).

Recruitment has been variable during 1962-2004 and there have been three very large year-classes: 1967, 1982, and 1999 (Figure B3). Recruitment during 2000-2004 averaged 2.3 billion fish, and ranged from 0.8-5.0 billion age-1 fish (Figure B3). Recruitment from the 2002 (1.8 billion fish) and 2003 (2.8 billion fish) cohorts appears promising.

Projection for 2006-2008:
Deterministic projections for 2006-2008 were conducted by assuming an estimated catch of 95,000 mt (209 million lbs) in 2005, a target fishing mortality of 0.12 (MAFMC 1998, Ftarget=0.75 x Fmsy) in 2006-2008, and annual recruitment values based on the fitted S/R curve (Figure B5). If 95,000 mt (209 million lbs) are landed in 2005, SSB in 2006 will increase to 2,640,210 mt (5.8 billion lbs). If the Ftarget F=0.12 is attained in 2006-2008, SSB will decline to 2,304,020 mt (5.1 billion lbs) in 2007 and to 2,043,440 mt (4.5 billion lbs) in 2008. Landings during 2006-2008 would be 273,290 mt (603 million lbs), 238,790 mt (527 million lbs), and 211,990 mt (467 million lbs), respectively. These landings are the result of an unusually large year-class (1999) present in 2005, and will not be sustainable in the long term. It is expected that these projected landings will decline to MSY (89,000 mt (196 million lbs)) in the future when more average recruitment conditions exist in the stock.

Projection Table: Projection for SSB (000 mt), landings (000 mt), and recruits (millions of individuals) during 2006-2008 for the northwest Atlantic stock of mackerel.

Year	SSB	F	Landings	Recruits
2005	2450	0.04	95	942
2006	2640	0.12	273	951
2007	2304	0.12	238	963
2008	2043	0.12	211	941

Catch and Status Table ('000 of mt): Atlantic Mackerel

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Max[3]	Min[4]	Mean[5]
Canada Commercial landings[1]	17.7	20.4	21.3	19.3	16.6	13.4	23.9	34.4	44.5	51.4	51.4	5.4	19.8
USA commercial landings[2]	8.5	16.1	15.4	14.4	12.0	5.6	12.3	26.5	34.3	53.7	53.7	0.9	8.9
USA Recreational landings[2]	1.2	1.4	1.7	0.7	1.3	1.4	1.5	1.3	0.7	0.5	4.0	0.3	1.9
Catch used in assessment	27.4	37.9	38.4	34.4	29.9	20.5	37.7	62.1	79.5	105.6	436.7	6.8	93.4
Spawning stock biomass	1057.1	1143.5	1171.5	1194.2	1262.6	1327.6	1847.9	2265.9	2353.7	2323.1	2353.7	298.2	1090.8
Recruitment (age 1)	766.3	651.8	938.2	647.6	806.9	5035.6	1088.0	804.3	1758.1	2794.4	5853.0	109.0	1129.7
Total stock biomass	1244.8	1334.8	1403.3	1357.3	1439.9	2294.7	2414.5	2443.8	2617.8	2902.4	2902.4	342.2	1310.3
F (ages 4-6)[6]	0.03	0.04	0.04	0.03	0.03	0.01	0.02	0.03	0.04	0.05	0.54	0.01	0.11
Exploitation rate	3%	4%	4%	3%	3%	1%	2%	3%	4%	5%	42%	1%	10%

1 Landings by Canadian commercial vessels in Canadian waters (SA 2-4)
2 Landings by USA commercial vessels or recreational sources in USA waters (SA5-6)
3 Maximum value during 1960-2004, except recreational landings during 1979-2004.
4 Minimum value during 1960-2004, except recreational landings during 1979-2004.
5 Average value during 1962-2004, except recreational landings during 1979-2004.
6 Unweighted

Stock Distribution and Identification: Atlantic mackerel in the northwest Atlantic comprise a single biological stock that ranges from North Carolina to Labrador. There are two primary spawning grounds: the Gulf of St. Lawrence and U.S. coastal waters from New Jersey to Long Island. There is no indication that these spawning groups constitute genetically discrete populations with temporal and spatial integrity. This transboundary stock is highly migratory and its seasonal distribution patterns are influenced by oceanographic thermal regimes. In the spring, the stock migrates northward in response to vernal warming, while in the fall, it migrates southward and offshore to avoid seasonal cooling of shelf waters.

Catches: Atlantic mackerel were heavily exploited by distant water fleets during the 1970's. Total landings in NAFO Subareas 2-6 averaged 347,000 mt during 1970-1976, but this level was not sustainable (Figure B1). Total annual landings decreased to less than 50,000 mt during 1978-1984. Landings by Canadian vessels remained relatively constant at approximately 20,000 mt during 1968-2000 (Figure B2) (Grégoire 2005). With the advent of a JV fishery in the Mid-Atlantic region, total landings increased during 1985-1991 to an average of 76,000 mt. More recently landings by both the USA and Canada have increased as world demand has improved. Commercial landings in the USA increased from 5,600mt in 2000 to 53,700 mt in 2004, and landings in Canada increased from 13,400 mt in 2000 to 51,000 mt in 2004. Recreational landings of mackerel in the USA averaged 1,300 mt during 1990-2000, but decreased from 1,500 mt in 2001 to only 500 mt in 2004. There are no discard estimates but they are thought to be minor based on the gear required to catch mackerel in most years.

Data and Assessment: The last Atlantic mackerel assessment was conducted in 1999 at SARC-30 (NEFSC 2000). For the present SARC-42, a trial VPA was done but the results were not used to characterize the stock because of problems of scale, recruitment overestimation, and a severe retrospective problem. Rather, an age structured forward projection model (ASAP) was used to address problems with fishery selectivity, scaling, recruitment estimation, and many other issues. The current assessment provides an update through 2004 with commercial (USA and Canada) and recreational catch-at-age data (landings) and NEFSC spring bottom trawl abundance indices. Natural mortality (M) was assumed to be 0.20.

Biological Reference Points: Biological reference points (BRP's), re-estimated for SARC-42 using the ASAP model with B-H parameters, are MSY = 89,000 mt, SSBmsy = 644,000 mt, and Fmsy = 0.16. Updated values of $F_{0.1}$ and $F_{40\%}$ are 0.25 and 0.24 respectively.

Surplus production (SP) in the mackerel stock was available sporadically during 1962-2004 (Figure B6). Periods of positive SP occurred before the ICNAF fishery in the late 1960s, during the early 1980s, and more recently in the late 1990s through 2003. The average annual surplus production available during 1962-2003 was 148,000 mt; this can serve as a proxy upper bound on MSY for the current assessment.

Stock-recruitment BRP's, estimated prior to SARC-30 using a bootstrap method, were Fmsy=0.45, F target=0.25, MSY=326,000 mt, and SSBmsy=887,000 mt (NEFMC 1998). These should be replaced with the more current values.

Fishing Mortality: Fishing mortality (F) was high during 1969-1975, peaking at 0.54 in 1975 (Figure B1). F declined to a low of 0.05 in 1978, and remained low during 1979-1986. Fishing mortality reached a small peak in 1988 at 0.09, coincident with the joint venture (JV) fishery that operated for several years, and then declined to 0.02 in 2000 (Figure B1). The average annual fishing rate during 2001-2004 was 0.04 and F in 2004 was 0.05.

Recruitment: Recruitment ranged between 0.1-5.8 billion fish during 1962-2004 and averaged 1.1 billion fish (Figure B3, Figure B5). Three large year-classes were produced during that period, the 1967, 1982, and 1999 cohorts (Figure B3). Recent recruitment (2001-2004) appears above the long-term average, but the magnitude of these cohorts is uncertain at this time.

Spawning Stock Biomass: Spawning stock biomass peaked in 1972 at 1.7 million mt, declined until 1976, and has increased thereafter (Figure B3). Spawning biomass was 1.3 million mt in 2000. SSB increased further to 2.3 million mt in 2003-2004 (Figure B3).

Special Comments: For the current assessment, the use of a VPA model was rejected due to survey variability, poor residual fits, lack of older fish in the CAA, and a large retrospective pattern in SSB. An age structured forward projection model (ASAP) was better able to address many of the problems noted, and the ASAP model was used for stock assessment. However, there is still a retrospective pattern in ASAP model outputs for F and SSB (Figure 4); this pattern should be considered in future management decisions for the stock. For recent years (2000 to 2004), the mean change in the terminal year estimate of F was 32% (range: 3% to 86%), when the model was rerun with an additional year of data. The mean change in the terminal year estimate of SSB was -21% (range: -3% to -46%).

There appears to be an absence of large fish in both the commercial catch at age (CAA) and the NEFSC spring survey in recent years. Although several possible explanations for this situation were discussed, the cause was not resolved. Increased fishery dependent sampling of size and age compositions was recommended, and enhanced age sampling during the NEFSC surveys will be implemented. Other survey methods such as hydroacoustics, egg and larval survey analysis, and mid-water trawl surveys should be explored in future.

Several more years of increased catches are likely to cause the ASAP model to stabilize further. This will result in better estimates of key rates, such as fishing mortality and SSB and allow for better estimation of management parameters.

Sources of Information:

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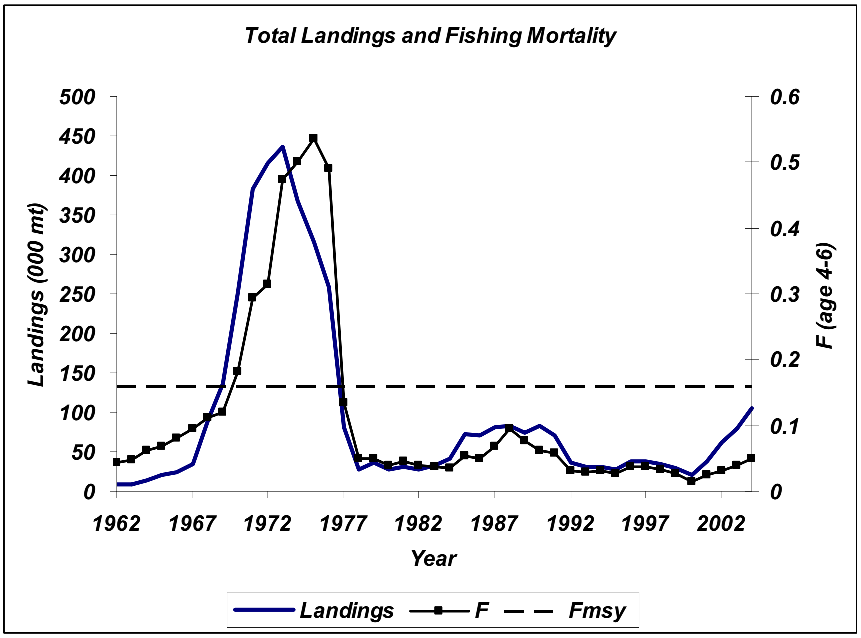
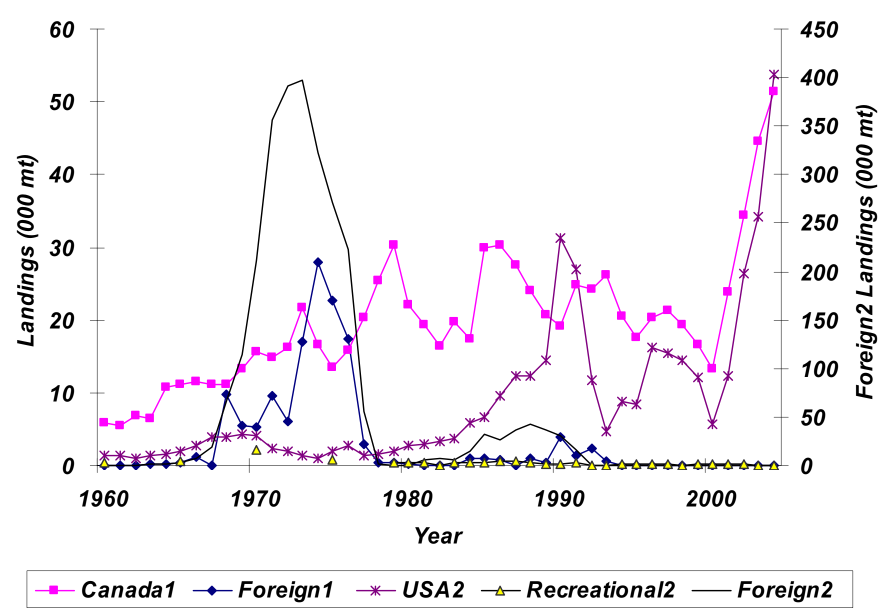
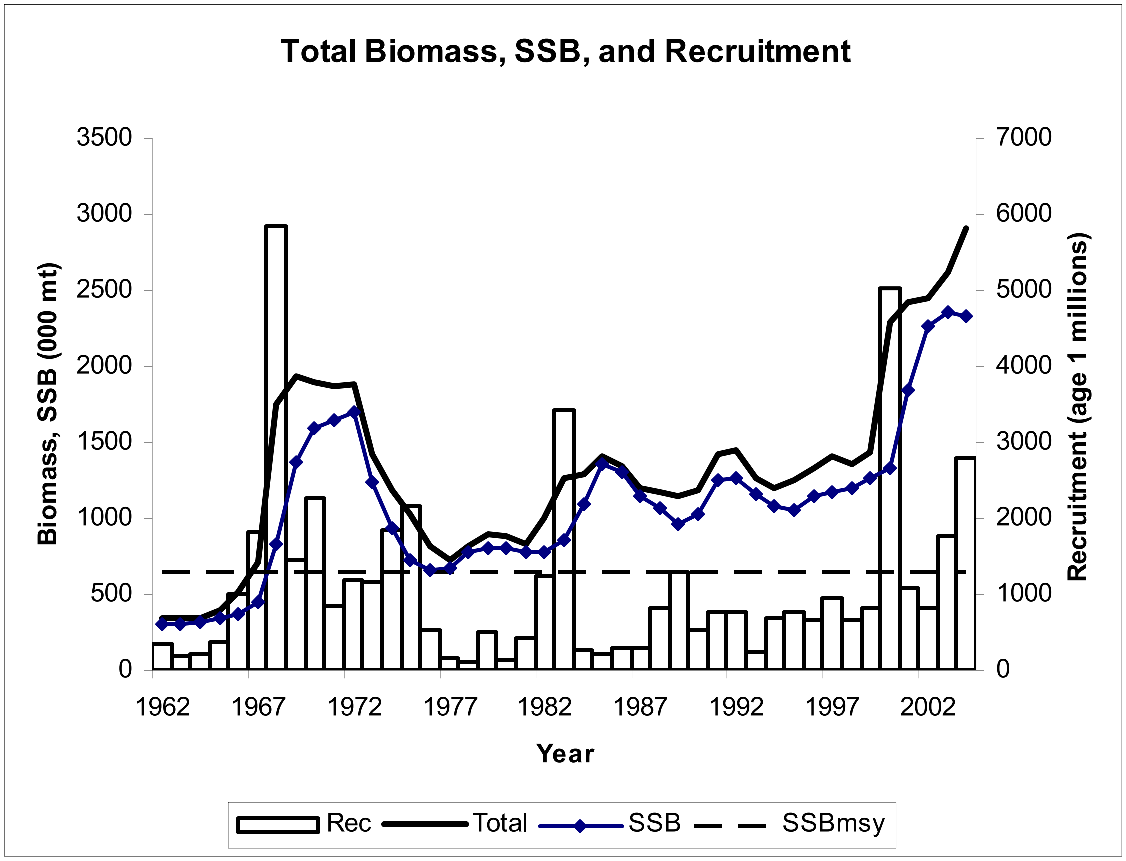
B1. Total landings (000 mt) and fishing mortality rate (ages 4-6, unweighted) for mackerel. The updated fishing mortality threshold (dashed line) for this stock is Fmsy = 0.16.



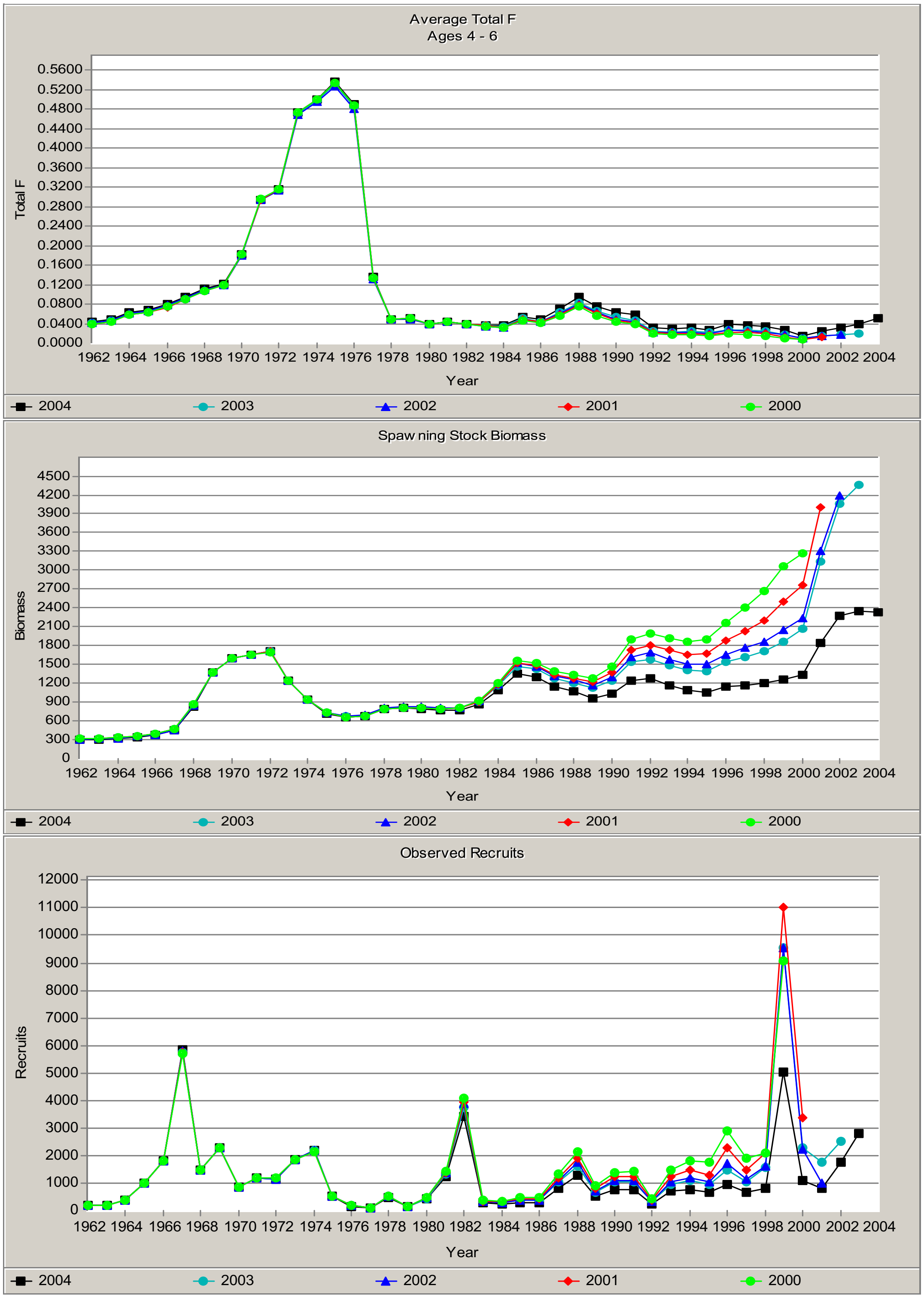
B2. Landings partitioned by where Mackerel were captured and who landed them. “Canada1” = Canadian waters, Canadian vessels; “Foreign1” = Canadian waters, Foreign vessels; “USA2” = USA waters, USA vessels; “Recreational2” = USA waters, Recreational vessels; “Foreign2” = USA waters, Foreign vessels. The second y-axis only applies to “Foreign2”.



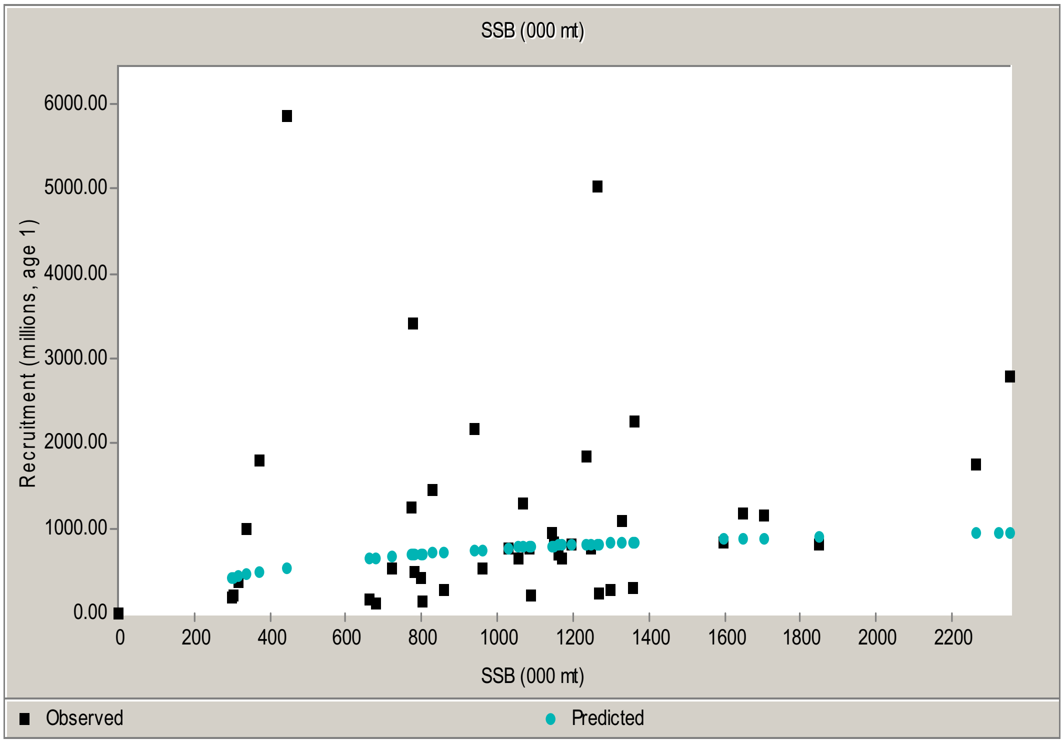
B3. Total stock biomass (000 mt), spawning stock biomass (SSB, 000 mt), and Recruitment (millions at age 1) for mackerel. The updated SSB reference point (dashed line) for this stock is SSBmsy=644,000 mt.



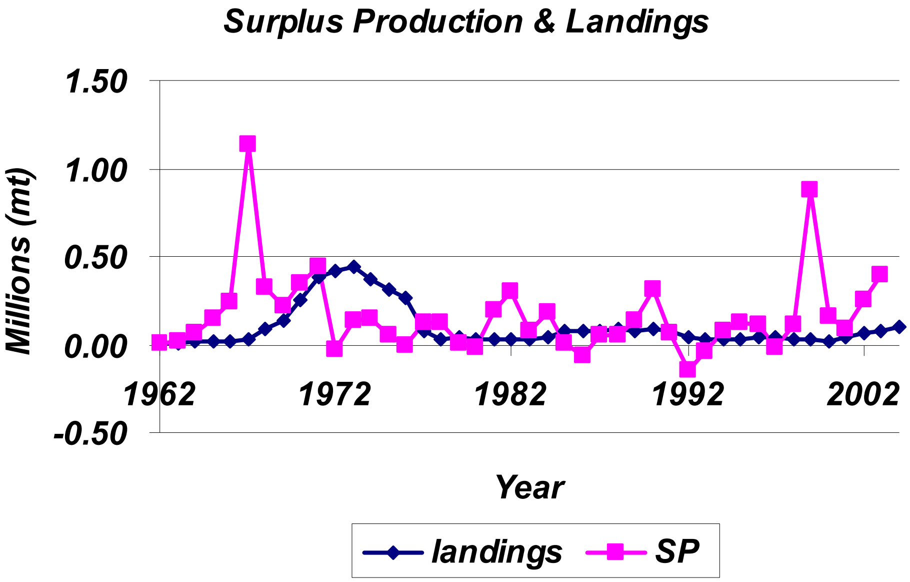
B4. Retrospective pattern in fishing mortality, SSB (000 mt), and recruitment (millions at age 1) from ASAP base case.



B5. ASAP spawning stock biomass (000 mt) and recruitment (millions, age 1) estimates for mackerel (black squares). The stock-recruitment curve is also shown (blue dots).



B6. Surplus production and landings (millions mt) for Atlantic mackerel during 1962-2004.



C. NORTHERN SHORTFIN SQUID (*Illex*) ASSESSMENT SUMMARY FOR 2005

State of Stock: It was not possible to evaluate current stock status because there are no reliable current estimates of stock biomass or fishing mortality rate.

Projection for 2005: No projection were made.

Landings and Status Table (landings in '000 mt): Northern Shortfin Squid (*Illex*)

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Max	Min	Mean
US EEZ Domestic Landings[1]	14.1	17.0	13.6	23.6	7.4	9.0	4.0	2.7	6.3	26.1	26.1	2.0	12.3
US EEZ Foreign Landings[2]	0	0	0	0	0	0	0	0	0	0	24.7	0	6.2
Total US EEZ Landings[2]	14.1	17.0	13.6	23.6	7.4	9.0	4.0	2.7	6.3	26.1	26.1	1.5	13.0
Subareas 3+4 (Canada) Landings[2]	1.0	8.7	15.6	1.9	0.3	0.4	0.1	0.3	1.1	2.0	162.1	0.1	16.3
Total Landings (All areas)[2]	15.1	25.7	29.2	25.5	7.7	9.4	4.1	3.0	7.5	28.1	179.3	1.6	29.3
Escapement Index in Numbers, NEFSC Fall Survey[3] (number/tow)	8.0	10.8	5.8	14.6	1.4	7.4	4.5	6.4	28.5	5.1	28.5	0.6	9.2
Escapement Index in Biomass, NEFSC Fall Survey[3] (kg/tow)	0.7	0.9	0.5	1.4	0.2	0.7	0.3	0.4	1.9	0.4	9.3	0.1	1.6
Average body weight (g),NEFSC Fall Survey[3]	84	87	89	94	136	94	72	70	69	82	327	69	149

[1] Min, max, mean for 1987-2004.
[2] Min, max, mean for 1968-2004.
[3] Min, max, mean for 1967-2004.

Stock Distribution and Identification: The *Illex illecebrosus* population is assumed to constitute a unit stock throughout its range of exploitation from Cape Hatteras to Newfoundland (Dawe and Hendrickson 1998; Hendrickson and Holmes 2004). Spawning occurs throughout the year (Dawe and Beck 1997; Hendrickson 2004) and stock structure is complicated by the overlap of seasonal cohorts. This highly migratory, oceanic species tends to school by size and sex and, based on age validation studies (Dawe et al. 1985: Hurley et al. 1985), is a sub-annual species. A statolith-based aging study of squid caught in a research survey conducted in U.S. waters indicated that the oldest individual was about seven months (215 days) of age (Hendrickson 2004). Spawning occurs on various places on the US shelf, including on the fishing grounds during the fishing season.

Catches: During 1973-1982, total stock landings (NAFO Subareas 3-6) averaged 71,900 mt and were predominately taken from the northern stock component in Subareas 3+4 (Hendrickson et al. 2005). Total landings (US and foreign) during this time peaked at 179,300 mt. Since 1982, total landings have been dominated by the domestic fishery, with the exception of 1997. Prior to 1967, U.S. landings of squid (*Illex* and *Loligo*) averaged about 2,000 mt per year. A directed foreign fishery for *Illex* developed in 1968 in U.S. waters, continued through 1982, and ended in 1987 (Figure C1). Domestic landings increased to 18,350 mt from 1988 to 1994, and then averaged 14,900 mt during 1995-1997. In 1997, Subarea 3+4 landings off Canada were nearly equal to US

EEZ landings and were at their highest levels since 1981. In 1998, US EEZ landings (23,600 mt) reached the highest level observed since 1977, resulting in a fishery closure because the TAC (19,000 mt) was exceeded. US landings dropped by 69% between 1998 and 1999. During 2000-2002, US landings declined from 9,011 mt to 2,723 mt; the lowest level since 1988. In 2003, US landings were 6,400 mt. In 2004, US landings reached the highest level on record (26,100 mt) and the fishery was closed near the end of the fishing season because the quota (24,000 mt) was reached. Preliminary US landings for 2005 are 11,429 mt.

Observer data for 1995-2004 indicate that discarding of *Illex* occurs primarily in the *Illex* and offshore *Loligo* fisheries and is higher in the latter. During this time period, annual discards from both fisheries combined ranged between 53 and 1,565 mt, 0.5% - 6.0% of the annual *Illex* landings by weight. Annual discards were highest during 1998 (453 mt) and 2004 (1,565 mt), when USA *Illex* landings were highest.

Data and Assessment: *Illex illecebrosus* was last assessed in 2003 at SAW 37 (NEFSC 2003). It was not possible in the current assessment to estimate fishing mortality or stock size. Although new models show promise, the results could not be accepted because required seasonal maturity and age data are lacking.

Biological Reference Points: The current FMP specifies B_{MSY} as 39,300 mt and F_{MSY} as 1.22 per year (MAFMC 1998). These reference points were based on results from a biomass dynamics model that utilized U.S. fishery data for 1982-1993 (NEFSC 1996). However, this model is now considered inappropriate to use to derive biological reference points for the *Illex* stock because the model does not address the semelparous (living for only a single season or year) life history of *Illex*.

SFA Control Rule: The Amendment 8 control rule (MAFMC 1998) states that when the stock biomass exceeds B_{MSY}, the overfishing threshold is F_{MSY}, and target F is 75% of F_{MSY}. Below B_{MSY}, target F decreases linearly and is set to zero when stock size is at the biomass threshold of 50% of B_{MSY}.

Fishing Mortality: No estimates of fishing mortality are available. Despite a shorter fishing season, fishing effort (days fished), an indicator of fishing mortality, was twice as high in 2004 as in 2003, due to a doubling in the number of vessels participating in the fishery and four times the number of trips.

Recruitment: Statolith-based age data suggest that spawning occurs throughout the year (Dawe and Beck 1997: Hendrickson 2004) and that recruitment to the fisheries is continuous. However, absolute estimates of recruitment during 2003 and 2004 are not available.

Stock Biomass: The current level of stock biomass is unknown. The NEFSC autumn bottom trawl survey occurs primarily after the U.S. *Illex* fishery and can be considered to provide a relative index of spawner escapement because the survey occurs near or after the end of the fishing season. The Autumn survey relative abundance index for *Illex* was a record high in 2003, but was very low in 2004 (Figure C2).

Special Comments: *Illex illecebrosus* is a highly migratory, transboundary species with a maximum observed age of 215 days for squid from U.S. waters. The overfishing definition currently in place for this stock, F_{MSY}, addresses yield rather than ensuring adequate spawning escapement for this sub-annual species.

Adequate escapement of spawners is needed to ensure sufficient recruitment in the subsequent year. The magnitude of escapement could be affected by increased exploitation.

Alternative approaches to managing the *Illex* fishery, including constant quota, constant effort, real-time management, and constant escapement should be investigated.

Cooperative research projects with the *Illex* fishing industry such as the collection of tow-based fisheries and biological data and electronic logbook reporting (Hendrickson et al. 2003) should continue because these high resolution data are needed to improve the assessment models. Based on promising new models, the collection of in-season maturity and age data are essential for improvement of the assessment.

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Dawe E. G. and L. C. Hendrickson. 1998. A review of the biology, population dynamics, and exploitation of short-finned squid in the Northwest Ocean in relation to the assessment and management of the resource. NAFO SCR Doc. 98/59, Ser. No. N3051. 33 p.

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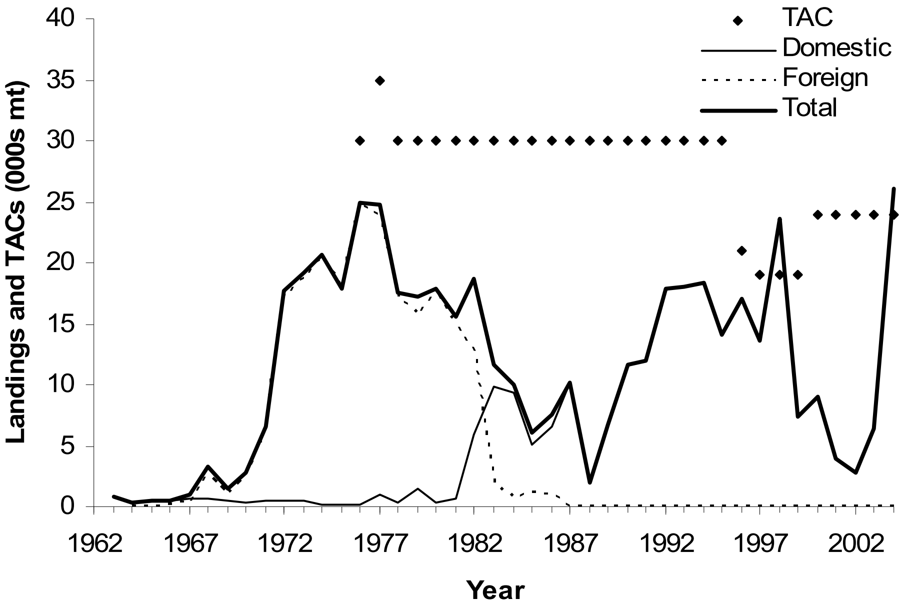
Hurley, G.V., P. Odense, R.K. O'Dor and E.G. Dawe. 1985. Strontium labelling for verifying daily growth increments in the statoliths of the short-finned squid (*Illex illecebrosus*). Can. J. Fish. Aquat. Sci. 42:380-383.

Mid-Atlantic Fishery Management Council (MAFMC). 1998. Amendment 8 to the Atlantic mackerel, squid, and butterfish management plan. Dover, DE. 351 p. plus appendices.

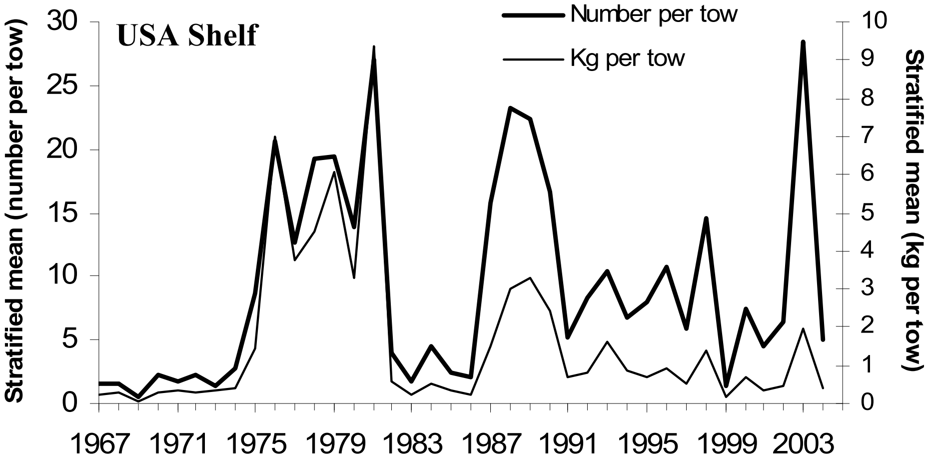
Northeast Fisheries Science Center (NEFSC). 1996. Report of the 21st Northeast Regional Stock Assessment Workshop, Stock Assessment Review Committee (SARC) Consensus Summary of Assessments. NEFSC Ref. Doc. 96-05d. 200 p.

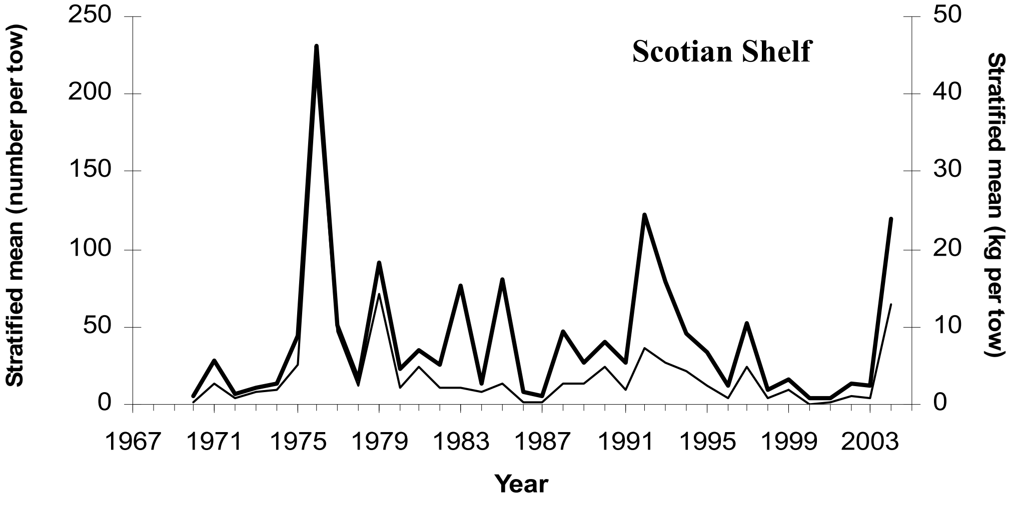
Northeast Fisheries Science Center (NEFSC). 2003. Report of the 37th Northeast Regional Stock Assessment Workshop, Stock Assessment Review Committee (SARC) Consensus Summary of Assessments. NEFSC Ref. Doc. 03-16. 597 p.

C1. Annual *Illex* landings and TACs for the USA stock component (Subareas 5+6).



C2. Annual relative abundance and biomass indices of *Illex* on the USA shelf near the end of the US fishing season (top), based on NEFSC September-October bottom trawl surveys, and on the Scotian Shelf near the start of the fishing season (bottom), based on Canadian July bottom trawl surveys. Scotian Shelf survey indices were not standardized for gear and vessel changes that occurred in 1982, 1983 and 2004.





D. MULTISPECIES PREDATOR-PREY MSVPA-X MODEL SUMMARY

In recent years many stakeholder groups, government officials, and scientists have called for an ecosystem approach to fisheries management on both local and federal levels. While managers have traditionally relied on analytical methods to help them make informed choices on a single-species basis, few analytical tools are available to evaluate decisions at the ecosystem level. The Expanded Multispecies Virtual Population Analysis (MSVPA-X) was conceived to support to fisheries management decisions made in a multispecies context.

Terms of Reference (TOR)

TOR 1. Evaluate adequacy and appropriateness of model input data, including fishery-dependent data, fishery-independent data, selectivities, etc. as configured.

Single-species assessments: This configuration of the MSVPA-X model uses data from single-species assessments to run the MSVPA-X through 2002. Since the MSVPA-X utilizes peer reviewed stock assessments, all of the best available fishery-dependent, fishery-independent, and life-history data were used in the current configuration of the MSVPA-X. The MSVPA-X depends on the quality of the underlying single species models and data, and improvements to the single species assessments will carry through to multispecies modeling efforts. Future investigations with the MSVPA-X will require using the most current assessment data.

Atlantic menhaden: Atlantic menhaden are the only explicitly modeled prey species in this configuration of the MSVPA-X.The Extended Survivors Analysis (XSA, Shepherd, 1999) is used as the single-species assessment model because it incorporates fishery independent survey data as tuning indices and is consistent with the forward-projection approach used in the current single-species assessment model. Estimated fishing mortality (F) on the last age class is sensitive to the number of age classes used to calculate terminal F (Figure D1). The XSA model estimates higher fishing mortality rates on older age classes than the forward-projection approach (Figure D2). This is likely due to the fact that the reduction (i.e., commercial menhaden) and bait fisheries cannot be separately analyzed in the XSA formulation. However, the trends in fishing mortality rates are similar in the two assessment approaches.

Striped bass: The XSA is used as the single-species virtual population analysis (VPA) model for striped bass, which is a predator species in the MSVPA-X. The XSA approach is similar to the ADAPT VPA methodology of the single species striped bass stock assessment in that it utilizes tuning indices in the estimation procedures for fishery mortality rates. The tuning index data used in the 2003 striped bass stock assessment are used in the XSA, with the exception of age-aggregated and biomass indices. As in the ADAPT assessment, a 13+ age class is used and natural mortality set at 0.15 (ASMFC, 2003). Trends in F were qualitatively similar for age classes 3-8 and 8-11 for the two approaches (Figure D3). There is a tendency for the XSA to estimate slightly higher values of F relative to the ADAPT approach for older age classes during the last years of the assessment (Figure D3). The selection curve and average F at-age, however, are comparable between the two models.

The time series of estimated recruit abundance differs significantly in the last two years of the time series with ADAPT estimating much higher age-1 abundance during 2001 and 2002 compared to XSA (Figure D4). For both assessment approaches, estimates of F and abundance for pre-recruit age classes are highly uncertain, so it is difficult to evaluate which model provides the “better” assessment. The trends and estimates of abundance for the remaining age classes are similar between the two approaches, though there is a tendency for the XSA to underestimate abundance relative to the ADAPT model (Figure D4).

Weakfish: The XSA model is used as the single-species VPA approach for weakfish, which is a predator species in this configuration of the MSVPA-X. A series of XSA evaluation runs are developed for the period from 1982-2000 for comparison to the ADAPT VPA and integrated catch-at-age (ICA) analysis used in the 2002 assessment document. The qualitative trends of fishing mortality rate estimates are similar for the ICA, XSA, and ADAPT models with the exception of the last two years of the assessment (Figure D5). The XSA tends to underestimate fishery mortality rates on older age classes through most of the time series compared to the other two models. However, in the last two years of the assessment, the ADAPT approach estimates very low fishery mortality rates for ages 3-5 compared to the other two approaches (Figure D6).

Bluefish: Because catch-at-age information from a peer reviewed stock assessment during the model reference period (1982 – 2002) was not available, bluefish is included in the MSPVA-X application as a “biomass predator.” In this formulation, the predator population dynamics are not modeled. Model input requirements include a time series of total predator biomass, limited information on predator size structure, and feeding selectivity parameters. The biomass dynamics model (ASPIC), previously used to assess the bluefish stock, utilizes commercial and recreational landings data. The recreational CPUE and NEFSC inshore fall survey are used as tuning indices in this approach.

Other prey: In addition to explicitly modeled prey species (i.e., menhaden), an additional prey type is included in the MSVPA-X formulation to account for “other prey” and the associated system biomass that is available to the predator species. Thus, the total available biomass to a predator is the sum of the suitable biomass of both explicitly modeled prey and “other prey” available to the predators. When available, the data and estimates from current stock assessments are utilized; however, for some “other prey” items, biomass estimates are derived using available fishery-independent, fishery-dependent and life-history data. As with the single-species assessments, the MSVPA-X will benefit from improved population estimates for all “other prey” items.

TOR 2. Evaluate assumptions for data gap filling when reliable data are not available (diet, biomass of prey species, feeding selectivity).

An extensive review of available diet data for striped bass, weakfish, and bluefish was conducted. There is a lack of coast wide diet data for all ages of the predator species modeled. The most spatially and temporally comprehensive data set for all three species is the Northeast Fisheries Science Center Food Habits database. However, this survey is limited to coastal non-estuarine waters, is only available during spring and fall, and generally does not have large sample sizes for older fish. For each species, there are additional regional studies that provide diet information for estuarine waters and other times of the year. The MSVPA-X utilizes the available diet data through 2002.

Predation mortalities in the standard MSVPA approach utilized by the International Council for the Exploration of the Seas (ICES) are calculated based upon a simplified feeding model. Daily prey consumption rates are expressed as a constant proportion of body weight for each predator age class. This constant daily ratio therefore does not reflect the effects of food availability or water temperature on predator feeding rates. Food consumption rates in fish can vary strongly, particularly between seasons as a function of food availability, changing temperatures, and metabolic demands. To account for these processes, a somewhat more detailed consumption model is implemented in the MSVPA-X using the Elliot and Persson (1978) evacuation rate approach and including a functional relationship between food availability and predator consumption rates.

The standard MSVPA formulation assumes that predator feeding rates are independent of prey availability, resulting in a Holling type II predator-prey feeding response (Magnusson, 1995). Type II feeding responses result in depensatory dynamics in predation mortality rates. The estimated predation mortality rate on a given prey item will increase exponentially at low prey biomasses, creating a “predation pit” that can result in unrealistic model dynamics such as prey extinction due to predation. In contrast, type III functional responses are compensatory in that the feeding rate on a particular prey item will decline at low prey abundances, and hence predation mortality pressure is released. To avoid the unrealistic dynamics resulting from the type II feeding relationship, the MSVPA-X implements a weak type III feeding response by modifying the consumption equation to incorporate a logarithmic relationship between food availability (measured as total suitable prey biomass) and the amount of prey consumed by a predator. The feeding model includes a “suitability index”, which is comprised of seasonal spatial overlap for predators and prey, prey type preference and prey size preference.

The selectivity model used in the MSVPA-X relies upon a rank index for prey type preference. These indices are derived from summaries of available diet composition data. For the predators considered here, there are multiple diet studies published in the literature; however, these are generally smaller scale studies focusing on particular places, seasons, and time periods.

While the MSVPA-X model is not fully spatially explicit, it is necessary to define a spatial domain and strata at regional scales to evaluate seasonal spatial overlap between predators and prey. The spatial resolution of these strata is primarily limited by available data on the spatial distribution of the species included in the model.

The spatial domain for the current model application is developed based upon the known spatial distribution of the four primary species. Five regional strata are defined ranging from North Carolina to the Gulf of Maine (Figure D7). Commercial and recreational landings data are used to evaluate the spatial distribution of several species. While landings data are subject to several biases, there is no comprehensive regional survey providing spatial distribution data for the larger predators. The NMFS bottom trawl survey provides some data; however, it is inefficient at catching these larger predators, does not sample nearshore waters, and does not include sampling in Chesapeake Bay and other estuaries. In addition, the bottom trawl survey is limited to primarily the fall and spring seasons. For these reasons, landings data provide the best available measure of the relative spatial distribution of the predators included in this model.

The spatial distribution of each taxon is evaluated on a seasonal basis using landings, survey, or regional density data as appropriate. These relative spatial distributions are then used to calculate the seasonal spatial overlap (using Schoener's index) between each predator age class and each prey species.

The final component of the feeding selectivity relationship is size selectivity. The original equation from the ICES MSVPA for size selectivity uses a predator-prey weight ratio to determine selection for a particular prey item. The feeding literature indicates that the relative length of the prey is the more pertinent measure, presumably due to factors such as gape width limitations and relative swimming speed. For example, predator-prey length ratios had a significant effect on prey capture probabilities for juvenile bluefish (Scharf *et al.*, 1998). In general, this effect results in a dome-shaped relationship between predator-prey length ratios and the capture success and is often reflected as a unimodal distribution of prey in the diets. To effectively model this pattern, the MSVPA-X model employs a flexible unimodal function to describe the relationship between prey size and the proportion of the prey in the diet. The size selection index for a prey of a particular size thus corresponds to the predicted proportion of prey of that size in the predator's diet.

TOR 3. Review model formulation (overall setup, data handling, VPA calculations, assessment options, sensitivity analyses, recruitment model options, and forward projection options) as configured.

The MSVPA approach was developed within ICES as a multispecies extension of cohort analysis or VPA. The approach can be viewed essentially as a series of single-species virtual population analysis (SSVPA) models that are linked by a simple feeding model to calculate natural mortality rates. The system of linked single-species models is run iteratively until the predation mortality (M2) rates converge. Predation mortality is the portion of natural mortality of a species that is the result of predation by another species. The basic model is performed in two primary iteration loops. First, all single-species VPAs are run to calculate population size at all ages for predators and prey, then predation mortality rates are calculated for all age classes of each species based upon the simple feeding model. The single-species VPAs are run again using the calculated M2 rates, and this iteration is repeated until convergence (reviewed in Magnusson, 1995).

The expanded MSVPA (MSVPA-X) approach described here builds upon the framework of the standard MSVPA by incorporating a variety of SSVPA approaches including a "tuned" VPA, modification of the consumption model, introducing a weak Type III functional feeding response, formalizing the derivation of selectivity parameters from diet data, altering the size-selectivity model, and including predators without age-structured assessment data. These additions allow for a clearer definition of the input parameters used to model predator diets and consumption rates and improve the MSVPA equations to reflect processes controlling feeding and predation rates.

Single-Species Assessment Configurations: Implementation of multiple SSVPA models allows greater flexibility in model construction to address particular data availability and the most appropriate assessment approach for each modeled species. Several forms of SSVPA are implemented in the MSVPA-X program. Some are included specifically to match previous assessment approaches for species considered in this application. However, for this application, all explicitly modeled species use the XSA method.

The XSA is a tuned VPA method that provides solutions for mortality rates in incomplete cohorts based upon multiple fishery-dependent and -independent abundance indices. The approach is related to the ADAPT VPA currently applied in many ASMFC single-species stock assessments. However, the ADAPT method requires extensive model building and minimization routines, resulting in a thorough statistical treatment that generally requires considerable analytical expertise and judgments of input parameters to develop the most appropriate model. While XSA does not reflect the full statistical approach of ADAPT methodology and does not require as intensive computational or model-building demands, it retains a similar theoretical basis and provides similar results.

Forecast module: The MSVPA-X includes a forecast model that allows one to explore potential effects of management scenarios. The forecast model includes the feeding response and consumption equations used in the historical model. A given application of a forecast model is based upon a reference MSVPA-X implemented in the project file. The forecast model is built upon the basic age-structured population model, and thus, given an initial population size (N_0), fishing mortality rate (F), and other natural mortality rate (M1) it is necessary to calculate both the individual weights at time t and M2 to project the population forward.

Predation mortality rate is a function of prey selection, predator biomass, predator weight, and prey abundance. Calculating M2 for a given season using the MSVPA-X equations requires estimates for the total mortality rate (Z), and M2 experienced during the season to find the average prey and predator biomass. The projection model is resolved to a daily time step to avoid this problem.

The model is initialized to a selected year of the reference MSVPA-X historical run. Model outputs include seasonal estimates of predation mortality, predator and prey population sizes in numbers and biomass, fisheries yields (for a given F), seasonal average predator diets, total seasonal consumption, and seasonal predator size and weight-at-age. The projection model is run for each age class of each predator and prey population on an annual basis, starting from the population abundance-at-age estimated in the initial year of the projection.

MODEL RESULTS

Results of the MSVPA-X Base run for explicitly modeled predators are given in Figures D8 (total biomass) and D9 (spawning stock biomass (SSB)). Biomass by size class for bluefish, the biomass input predator, is given in Figure D10. Total biomass and SSB of striped bass increases over the time series. Weakfish experience fluctuations in total biomass, but a general increasing trend in SSB is noted after 1990. Bluefish population biomass exhibits high abundance early in the time series (1982 – 1988), declines throughout much of the 1990s, and increases the last three to four years.

The only explicitly modeled prey species in this configuration of the MSVPA-X is menhaden. Abundance and biomass trends are shown in Figures D11 and D12. Total abundance and abundance at maturity (age-2+) decline, although overall SSB has remained stable yet somewhat variable (Figure D12). This is in part due to an increase in weight-at-age for menhaden (ASMFC, 2004).

Menhaden biomass and predation mortality (M2) by age (weights in 000 mt):

	Year	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
SSB (000 mt)		70. 8	181.7	161.1	89.0	77.8	101.4	79.6
Age-0	**Biomass**	9.6	32.9	41.8	32.4	19.7	40.0	48.8
	M2	0.76	0.75	0.79	0.74	0.69	0.84	1.05
Age-1	**Biomass**	106.0	195.5	185.6	223.4	175.8	114.2	207.9
	M2	0.18	0.19	0.22	0.21	0.21	0.23	0.26
Age-2	**Biomass**	258.2	261.1	259.5	248.6	285.9	248.2	164.5
	M2	0.06	0.06	0.07	0.07	0.08	0.09	0.11
Age-3	**Biomass**	91.2	225.7	123.1	80.7	91.2	164.2	123.4
	M2	0.03	0.03	0.03	0.03	0.04	0.05	0.06
Age-4	**Biomass**	25.5	63.2	74.7	34.3	17.4	18.0	21.1
	M2	0.02	0.02	0.02	0.02	0.02	0.03	0.04
Age-5	**Biomass**	2.0	16.2	14.1	6.1	3.7	1.6	1.6
	M2	0.02	0.01	0.01	0.02	0.02	0.02	0.02
Age-6+	**Biomass**	4.9	58.2	96.6	38.6	21.9	11.9	10.4
	M2	0.01	0.01	0.01	0.01	0.01	0.02	0.02

Average predicted diet compositions, across the available time series and seasons, are given for striped bass, weakfish, and bluefish (Figures D13-D15, respectively) by age (or size). In general, all predators are predicted to feed mainly on macrozooplankton and benthic invertebrates at younger ages or size classes. The diet composition for intermediate ages shifts to dominance by medium forage fish and anchovies. At older age classes, clupeids and menhaden dominate as many predators become more piscivorous. One exception to the overall trend above is the prevalence of benthic crustaceans in the diet of striped bass at intermediate ages (ages 5-8). Nelson *et al.* (2003) suggest that as striped bass age, they tend to move farther north during the summer feeding period.

Estimates of consumption, expressed as total biomass, for each important prey item by year are given in Figures D16-D18 for striped bass, weakfish, and bluefish, respectively. Striped bass increase consumption of all prey items during the time series, the expected result given their increasing abundance during the period modeled. Recent results suggest a decrease in benthic invertebrate consumption, which is attributed to expansion of the striped bass population to older ages (Figure D16). Recent increases in consumption of both clupeids and menhaden may be the result of the expanding in age structure seen in striped bass.

Weakfish consumption exhibits no overall trend. Consumption of menhaden, benthic invertebrates, and anchovies is highly variable, but may show signs of recent increases in consumption by this stock. Estimated consumption of fish prey by bluefish increases over time, particularity for the clupeids.

Menhaden exhibit significant changes in predation mortality for age-0 and age-1 fish (Figures D19 and D20. Age-0 menhaden M2 fluctuates, but generally increases over time as the weakfish population increases. Likewise, M2 on age-1 menhaden increases as predation by both striped bass and bluefish increases, as a result of both changes in the size- and age-structure of these predators and potential overlap with menhaden in recent years.

Several analyses are conducted to evaluate the sensitivity of the MSVPA-X to changes in input parameters. Specifically, sensitivity of the model to changes in M1 (all non-predation natural mortality), prey type selectivity, prey size selectivity, predator weight-at-age, gastric evacuation rate parameters, predator and prey spatial overlap, and the addition and deletion of 'other prey' items were conducted. An examination into the retrospective bias of the model in terminal year estimates, as well as a test of the forecast model to investigate the ability of MSVPA-X to reproduce past observations were performed.

TOR 4. Develop research recommendations for data collection, model formulation, and model results presentation.

Recommendations for data collection improvements:

- Add a bluefish age-structure/catch-at-age matrix.
- Adult index for menhaden (e.g., an aerial line transect survey) and other species.
- Obtain population weight-at-age estimates.
- Conduct a coast wide diet and abundance study (i.e., an Atlantic coast "year of the stomach").
- Collect more diet data for all four MSVPA-X species along the entire Atlantic coast.
- Conduct stomach selectivity research for predator species to improve prey ranking matrix.
- Encourage existing fishery-independent surveys to take regular gut contents.
- Evaluate if striped bass disease (mycobacteria) is correlated with natural mortality (M1) and food availability or if disease is disrupting striped bass feeding and causing starvation.
- Estimate carrying capacity for the system to evaluate what model estimates/suggests for carrying capacity.
- Improve estimates of biomass for prey species on coast wide basis.
- Conduct a parallel comparison with ICES MSVPA model on a system that has the necessary data collected (Georges Bank or the North Sea) to identify the differences in results.
- Explore the ability to add other predators to model (birds, mammals, other fish, other systems).
- Explore the utility of implementing the Williamson spatial overlap index in the model.
- Investigate type II and type III feeding responses of the MSPVPA-X species in field studies.

Recommendations for the improvement of model formulation:

- Add uncertainty to model forecast and incorporate elements of Monte Carlo simulations on recruitment curves.
- Alter biomass predator bin sizes for more flexible way to vary for projection model, if necessary after conducting sensitivity analyses or until an age-structured stock assessment is developed for bluefish.

- Add ICA and production model options to retrospective.
- Develop a similar application to the "amoeba" program that allows the user to easily vary changes to model parameters.

Recommendation for the forecast component of the MSVPA-X:

- Determine the affect sensitivity of the model to the removal of all fishing pressure from system.
- Insert recovery benchmarks.
- Explore options for adaptive management framework with stock-recruitment options.

TOR 5. Evaluate whether or not the model and associated data are of sufficient quality to develop recommendations to management.

The model was developed to better quantify and examine predator and prey interactions and to account for these effects on explicitly modeled prey populations . The MSVPA-X Assessment Committee[1] recommends that the model can be used to:

- Improve single-species assessment models for single-species population adjustments (i.e., age and year specific inclusion of M),
- Insight on multiple species benchmarks based on species trade offs,
- Investigate predation mortality versus catch for important prey species by age-class,
- Determine the trade offs among harvesting strategies when fisheries exist for both predator and prey,
- Develop short-term projections for explicitly modeled species,
- Provide guidance for rebuilding predator stocks,
- Evaluate change in predator management and its effects on prey and competing predators,
- Explore potential feedbacks between lack of prey, abundance of alternative prey, fishing mortality on the predator populations,
- Longer projections can be performed as exploratory tool to investigate linkages among species but should not be used as a management tool, and
- Examine the role of predator consumption in reduced prey recruitment to the fishery.

The MSVPA-X should not be used to address the following issues:

- Setting reference points or harvest limits for single-species from MSVPA-X,
- Estimations of absolute abundance for explicitly modeled species,
- Examining local abundance or depletion, and

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[1] SAW42 Stock Assessment Workshop Editor's note: The MSVPA-X Assessment Committee is different from the Stock Assessment Review Committee (SARC) that reviewed this model and this report. The recommendations listed here were not written by the SARC. The SARC's opinion, expressed in their report, may differ from this.

- Long-term projections are subject to the limitations of recruitment variability for the prey population and predator populations.

The MSVPA-X includes a forecast module that provides modelers the ability to explore the potential effects of variations in recruitment, fishing patterns or pressure, and the availability of "other prey" items on the changes in stock size and dynamics of explicitly modeled species. Any projections are subject to the limitations of predicting recruitment of prey species. While longer-term projections are desirable to examine management objectives for longer-lived predator stocks, the MSVPA-X relies on the modeled recruitment. Due to their short life spans and environmentally driven recruitment, forage species may depart radically from their predicted population sizes which makes long-term predictions highly variable.

The model has the potential to improve assessments in single-species assessments by suggesting the M at age (or by year, as appropriate) for explicitly modeled prey species. This has already been accomplished for menhaden in the 2003 assessment (ASMFC, 2004). An earlier iteration of MSVPA-X produced the estimates of menhaden natural mortality at age; however, menhaden population size was estimated using a separate single-species assessment model and overall natural mortality was specified within that single-species assessment.

Additionally, decision makers can be shown potential impacts of fishing and predation mortality by age class for explicitly modeled prey. Such an analysis may suggest optimum harvest strategies for both predators and prey when fisheries for both exist and are managed together. Further analyses may allow for the management of prey using total mortality, rather than fishing mortality. The model may also provide insight on multiple species target biomass based on trade offs among predators and prey. The model may provide additional guidance for rebuilding predator stocks by allowing the investigation of the interactions of specific predator biomass targets and the availability of prey species for other modeled predator stocks should that target be realized.

The seasonal resolution in this model may provide insight to when an explicitly modeled prey stock could be important for a given predator. The MSVPA-X may pinpoint specific seasons when particular prey items are important for particular predators and how different predators may affect each other. Seasonal importance is defined by specifying spatial overlap and type preference. Indirect interactions between predators can be examined in the forecast module, which is derived seasonally.

This model is not designed for setting reference points or harvest limits for individual species. Additionally, the model intentionally encompasses a broad geographic range and therefore examination of local abundance or depletion is not possible. The MSVPA-X was conceived, in part, to provide accessory information and not to replace the single-species assessments already in place. Moreover, this formulation employs the XSA method for ease of calculation. Although every effort is made to develop configurations that reflect the single-species assessment results, results for individual species in the MSVPA-X framework may not correspond exactly to the outputs from the single-species assessments.

The MSVPA-X, in principle, may examine prey availability and then link that availability to both growth rates and its effects on the predator species by age class. Until survivability of any given year-class, or predator stock, is examined relative to prey availability, such calculations are not possible. Further, the effects of prey availability on growth and recruitment of the predator species have been left out of the base run, so that this review examines the interactions among predators and prey without the confounding effect of predator growth.

The MSVPA-X may help decision makers determine appropriate size and bag limits for a given predator species. The model indicates that changing a predator's age structure may affect prey species under certain régimes. Changes in bag limits and selectivities for a predator species may therefore affect prey availability, consumption, and prey availability for other species. Such analyses will require further modeling outside of the MSVPA-X.

Based on thorough review and testing of the MSVPA-X model, the MSVPA-X Assessment Subcommittee[2] suggests that this formulation is capable of providing guidance on management questions about predator-prey interactions among explicitly modeled species. With clear understanding of the MSVPA-X's abilities and limitations, this approach has the potential to provide accessory information for fisheries managers.

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[2] SAW42 Stock Assessment Workshop Editor's note: The MSVPA-X Assessment Subcommittee did the modeling and wrote this report. The text in this paragraph is the opinion of those who wrote the report, and is not necessarily the same as the opinion of the Stock Assessment Review Committee (SARC42) that reviewed this model.

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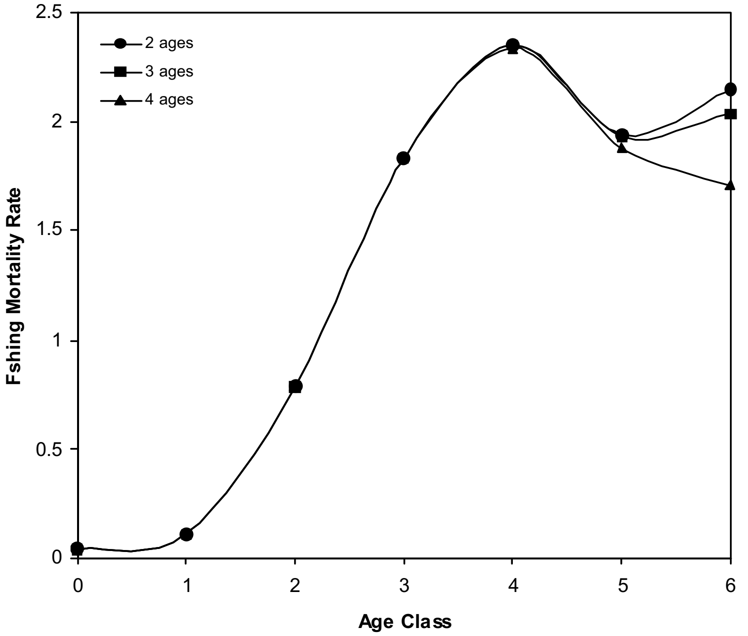
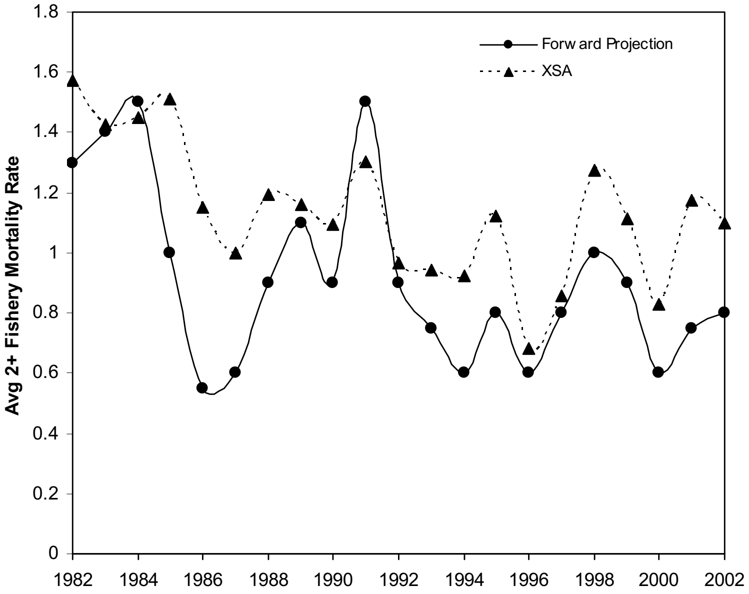
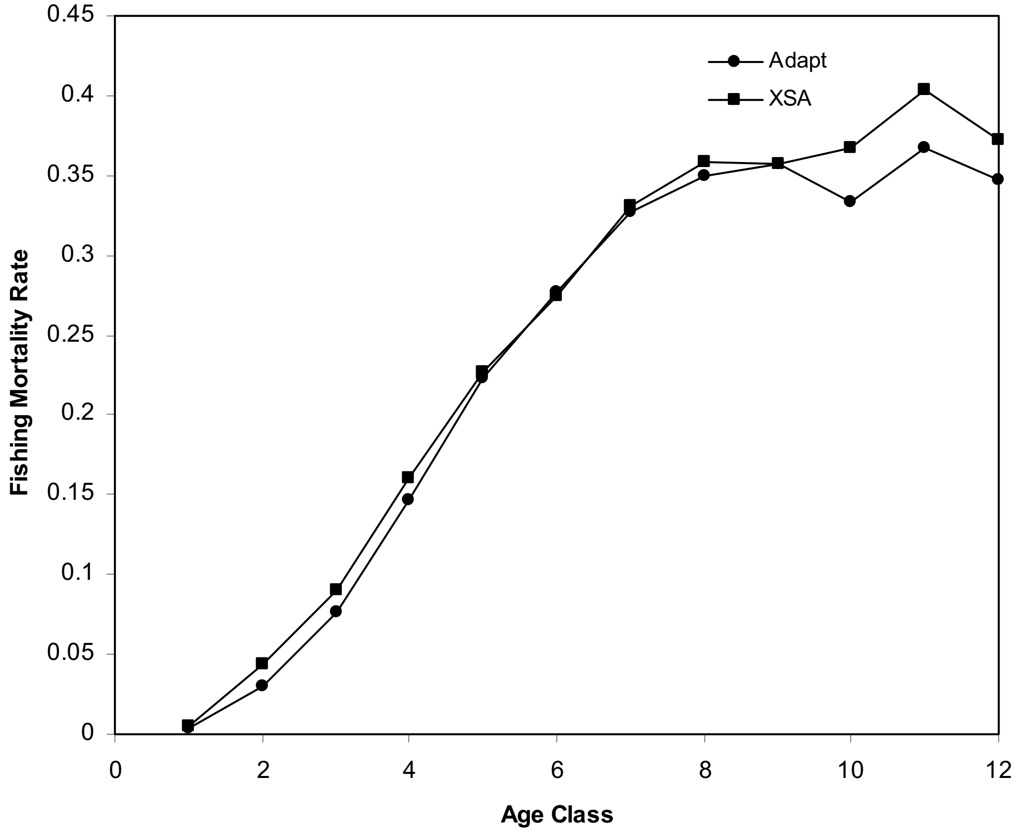
D1. Estimated average fishing mortality rate at age during 2000-2002 for Atlantic menhaden in evaluation runs assessing sensitivity to the number of age classes used to constrain the estimates of terminal fishing mortality (F) rates.



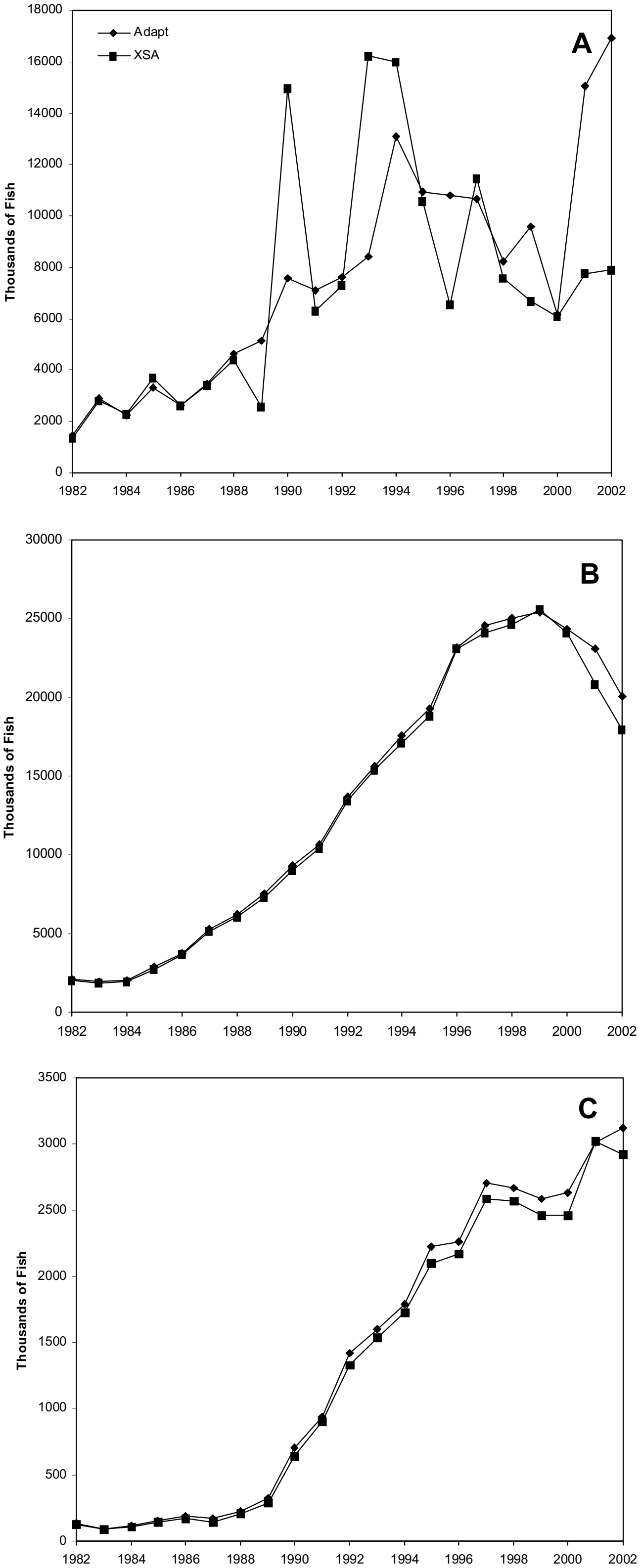
D2. Average fishery mortality rate on age classes 2+ menhaden estimated by the forward projection model and evaluation runs using Extended Survivors Analysis (XSA).



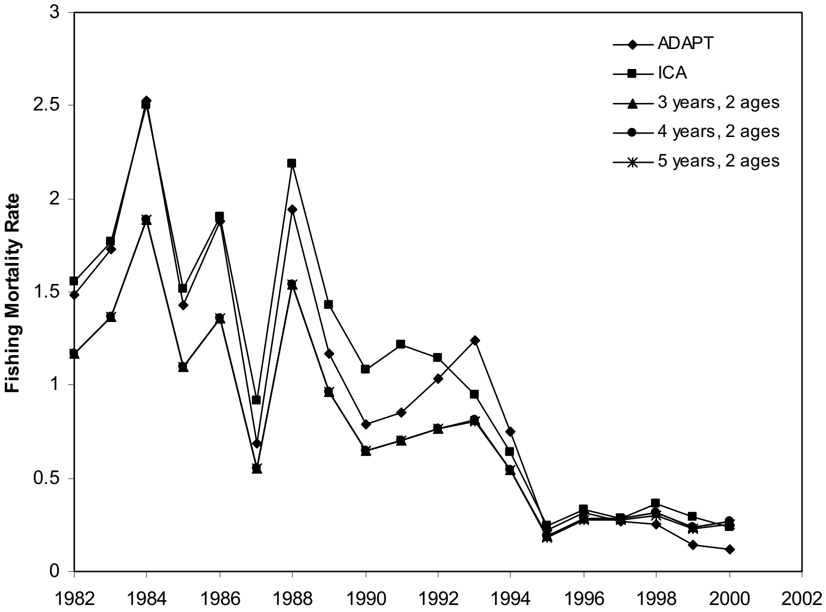
D3. Average fishery mortality rates during 2000-2002 by age class for the XSA evaluation run. The ADAPT time series represents output from the striped bass stock assessment (ASMFC, 2003).



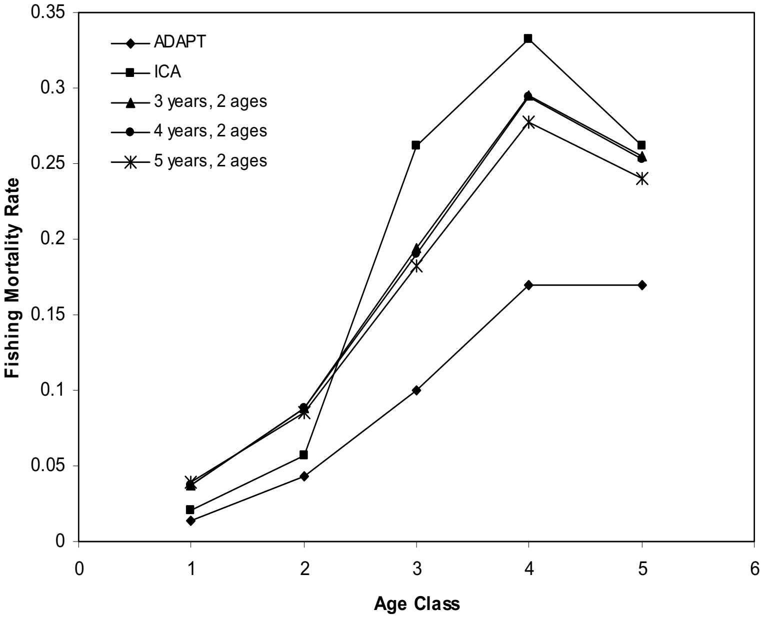
D4. Total abundance of striped bass age class 1 (A), ages 3-8 (B), and ages 8-11 (C) estimates from XSA evaluation runs. The ADAPT time series represents output from the striped bass stock assessment (ASMFC, 2003).



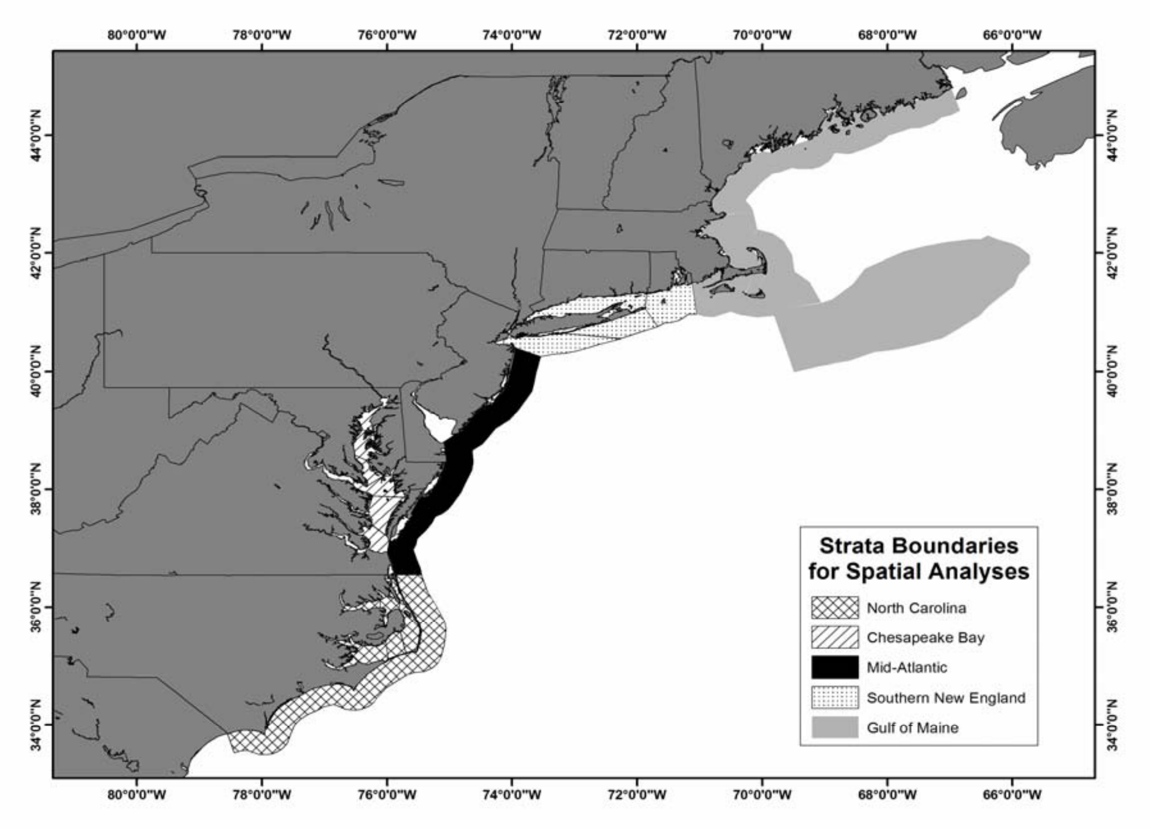
D5. Average age 4 and 5 fishing mortality rates for weakfish estimated by evaluation runs of the extended survivors analysis. Results from the ADAPT VPA assessment for weakfish (Kahn, 2002) and an integrated catch at age (ICA) analysis are shown.



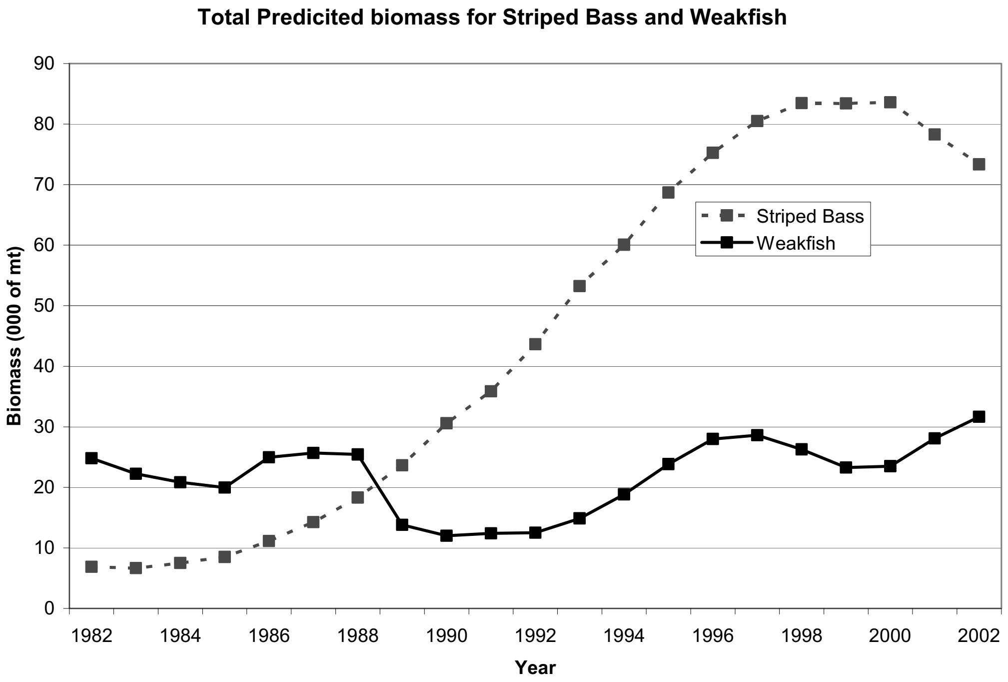
D6. Average fishing mortality rates by age class during 1998-2000 for weakfish estimated by evaluation runs of the extended survivors analysis. Results from the ADAPT VPA assessment for weakfish (Kahn, 2002) and an integrated catch-at-age (ICA) analysis are shown.



D7. Five regional strata were defined from North Carolina to the Gulf of Maine.

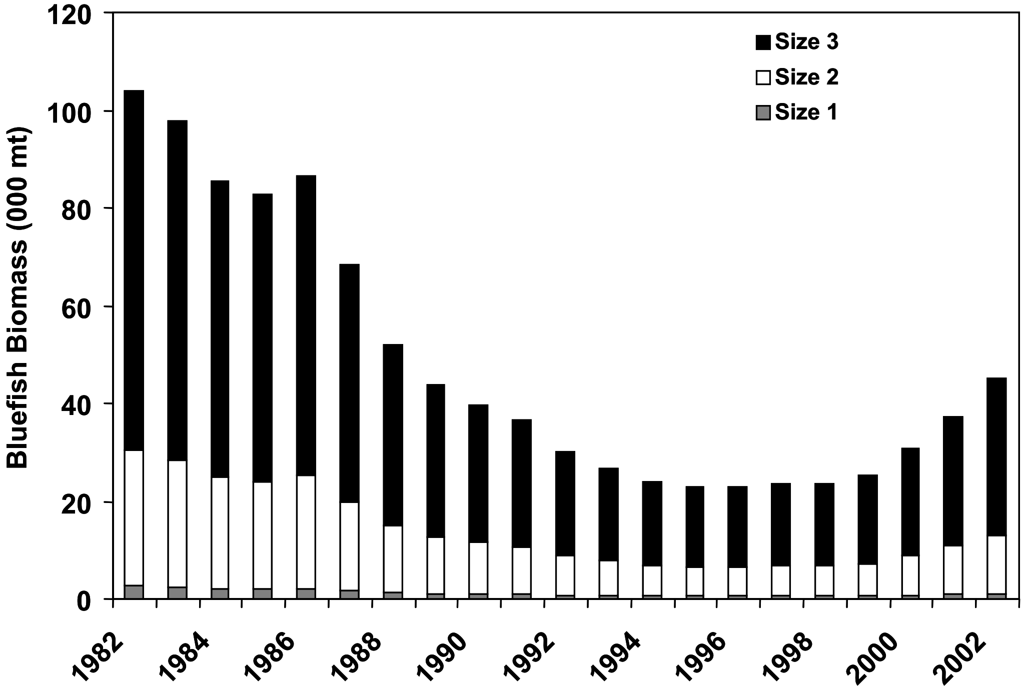


D8. Total population biomass (000 mt) for weakfish and striped bass.

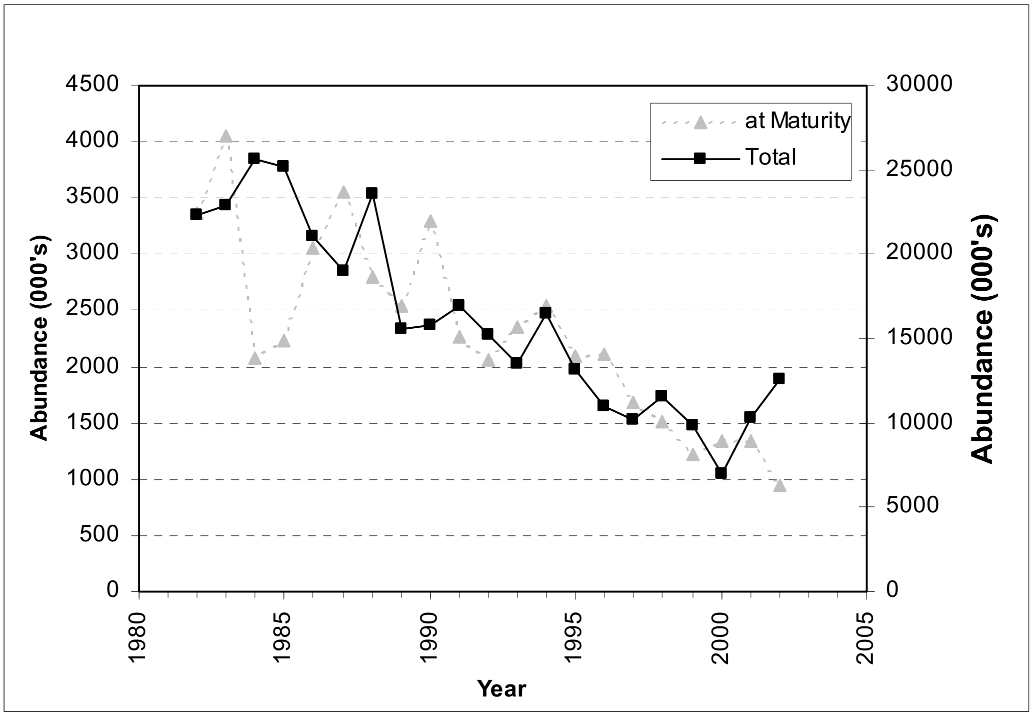


D9. Annual spawning stock biomass (SSB in 000 mt) for weakfish and striped bass.

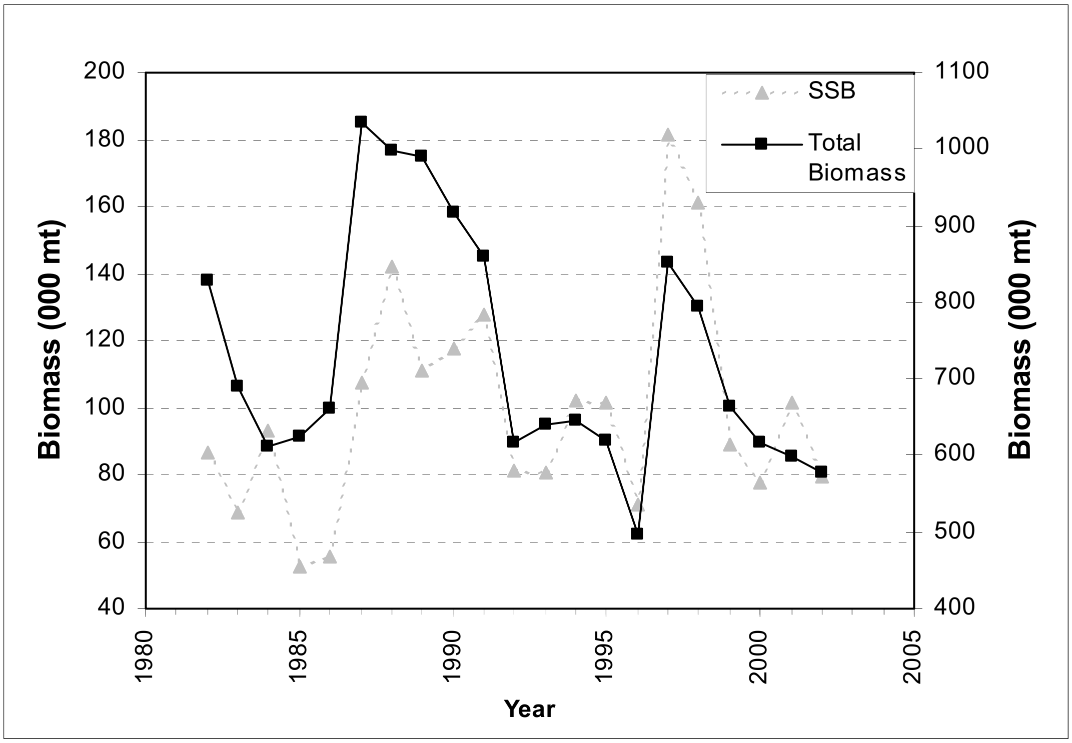
D10. Annual bluefish population biomass (000mt) by size class.



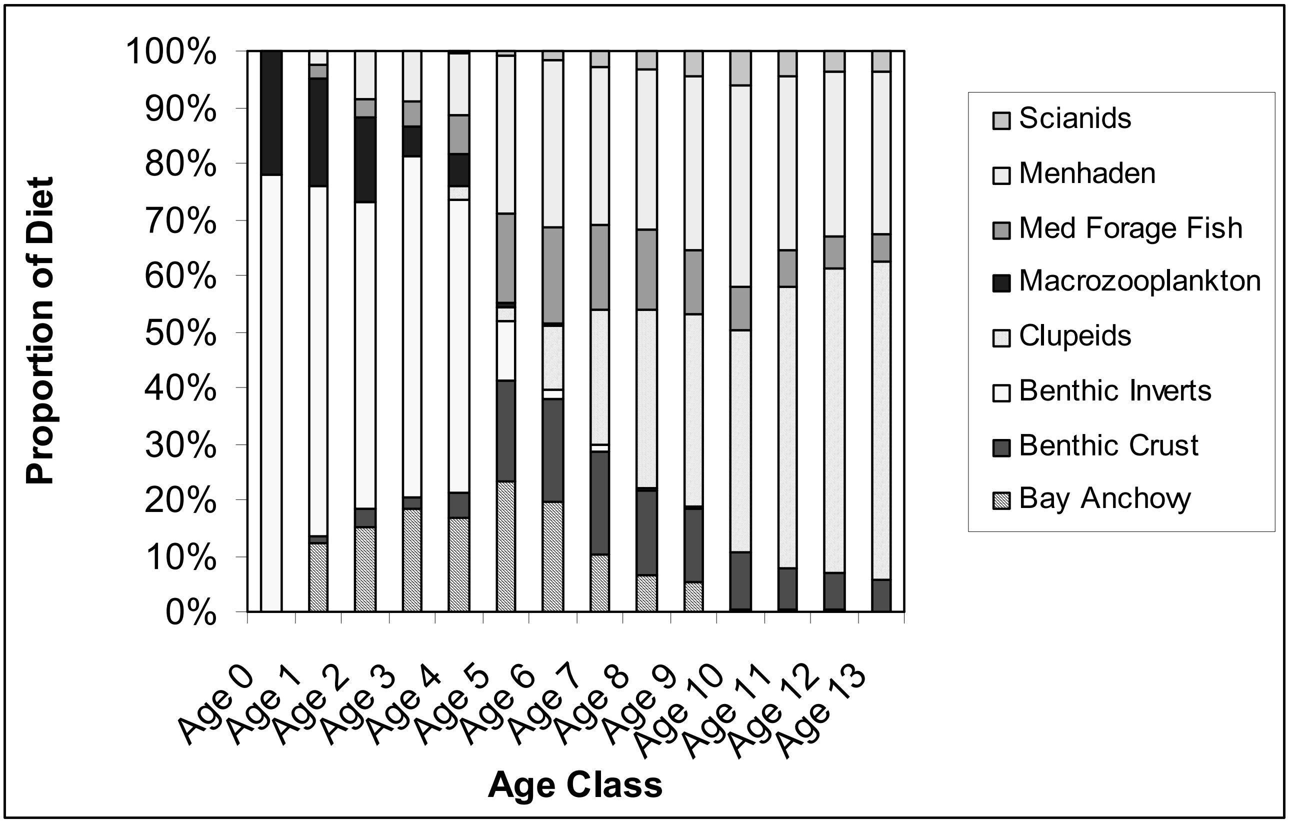
D11. Menhaden abundance at maturity (Age 2+, primary y-axis) and total menhaden abundance (secondary y-axis). Note the scale change on the secondary y-axis.



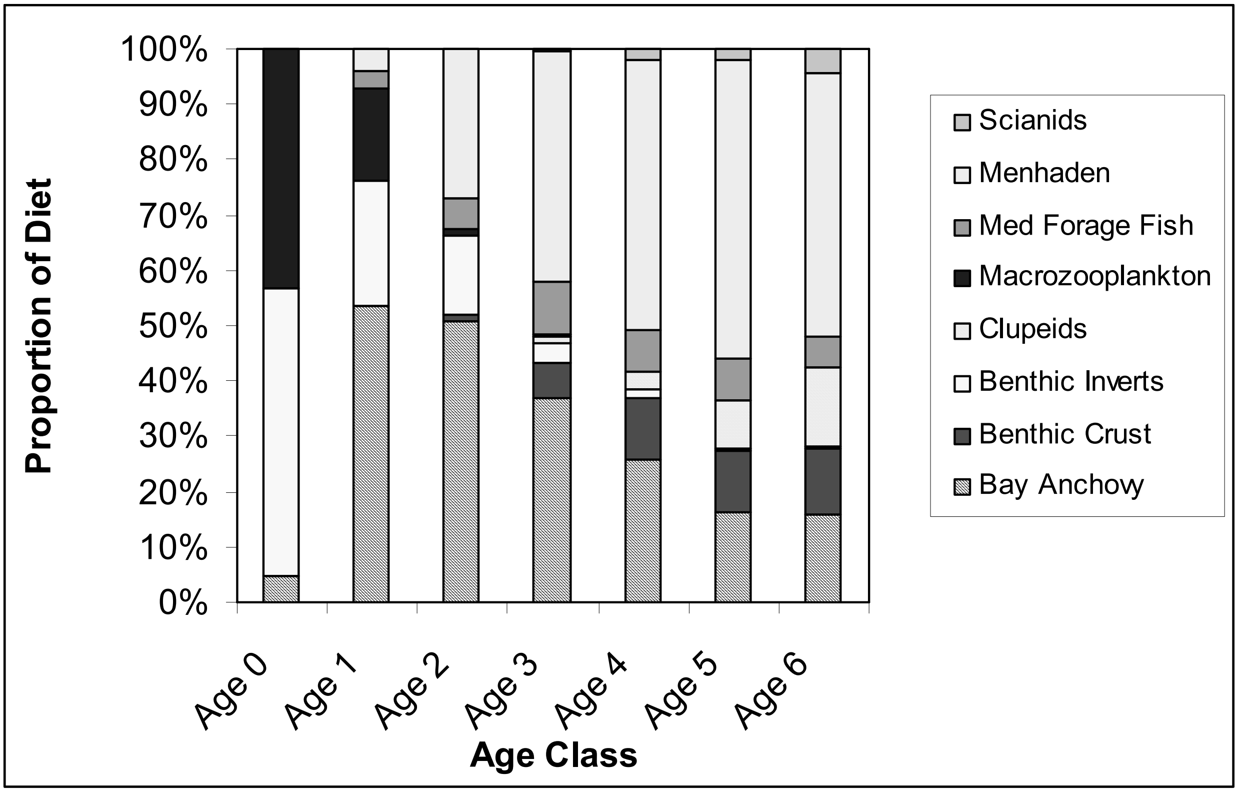
D12. Total menhaden SSB (primary y-axis) and population biomass (secondary y-axis) (000 mt). Note the scale change on the secondary y-axis.



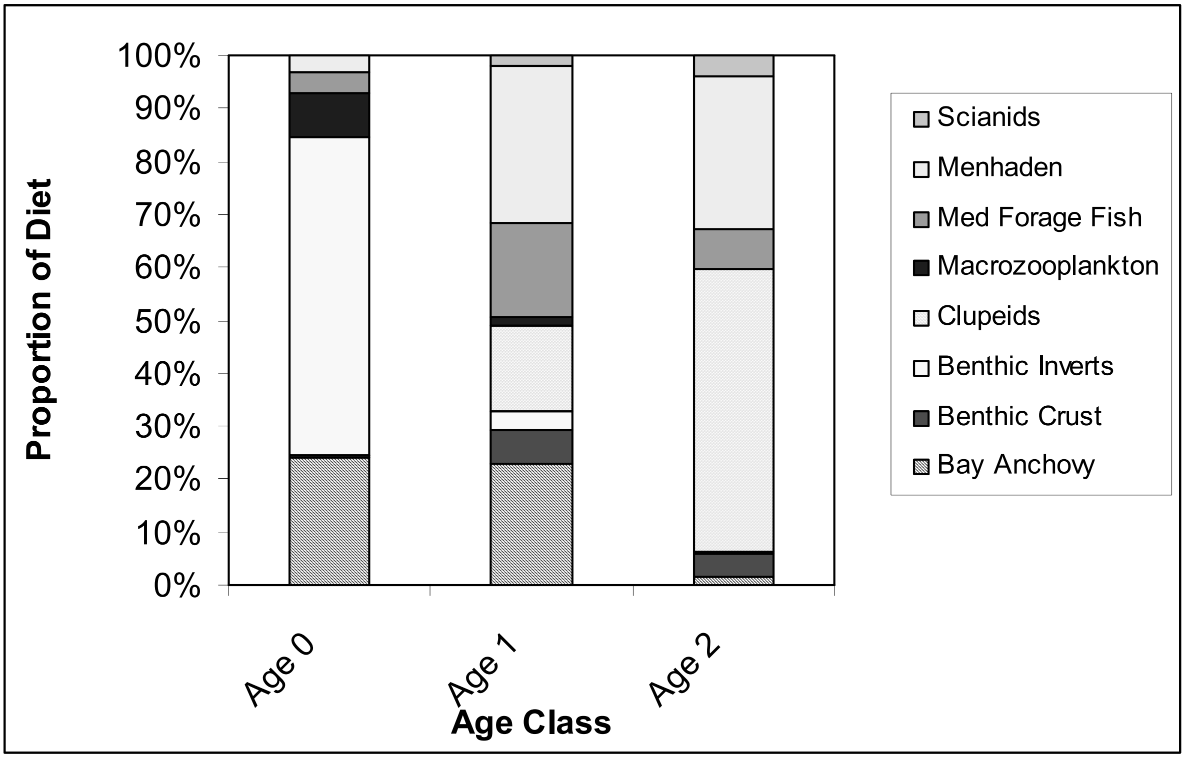
D13. Predicted average proportion of prey in striped bass diets.



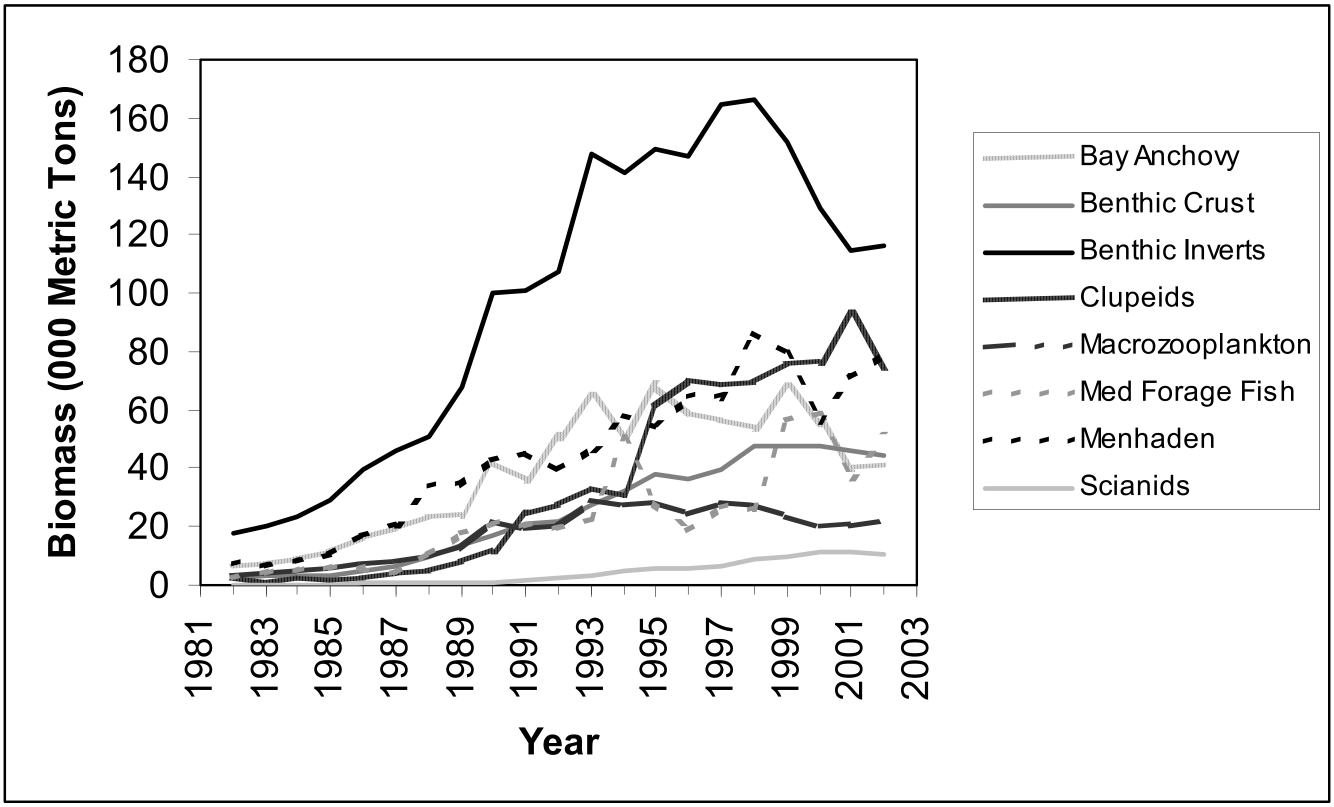
D14. Predicted average proportion of prey in weakfish diets.



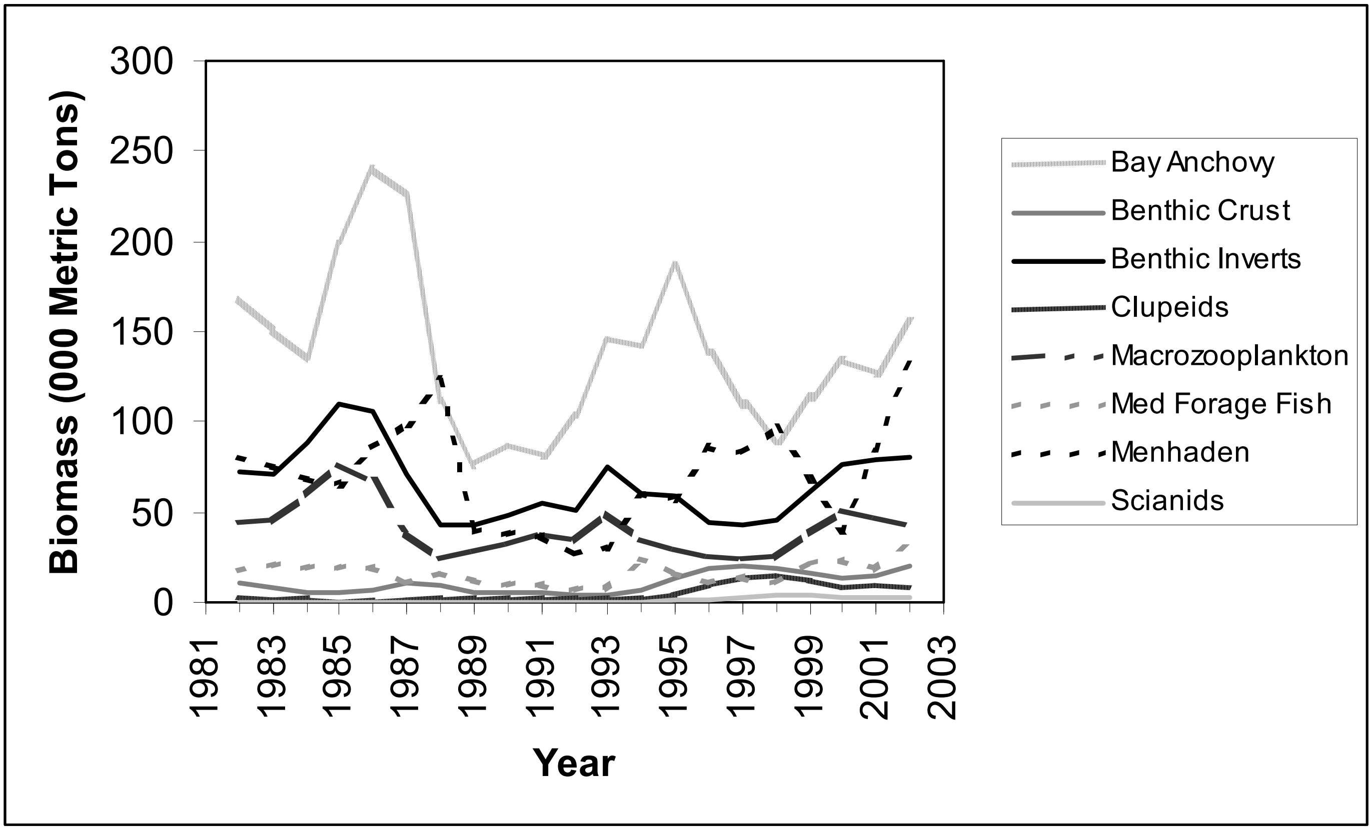
D15. Predicted average proportion of prey in bluefish diets.



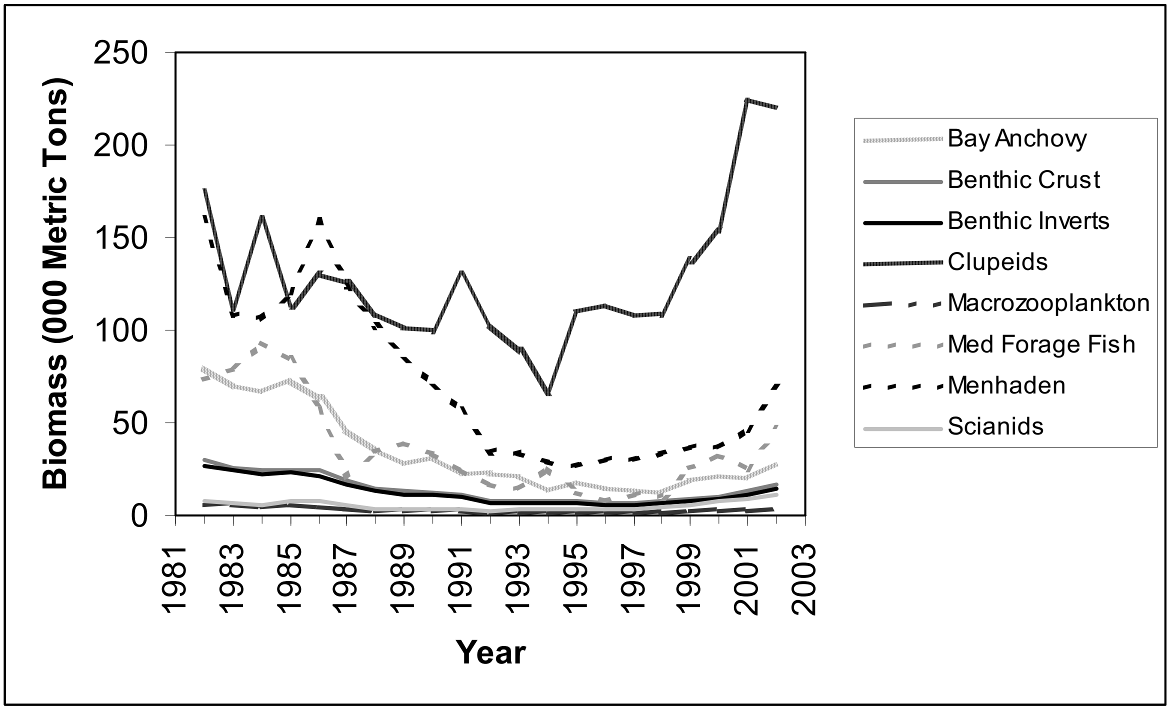
D16. Predicted total prey biomass consumed annually by all ages of striped bass.



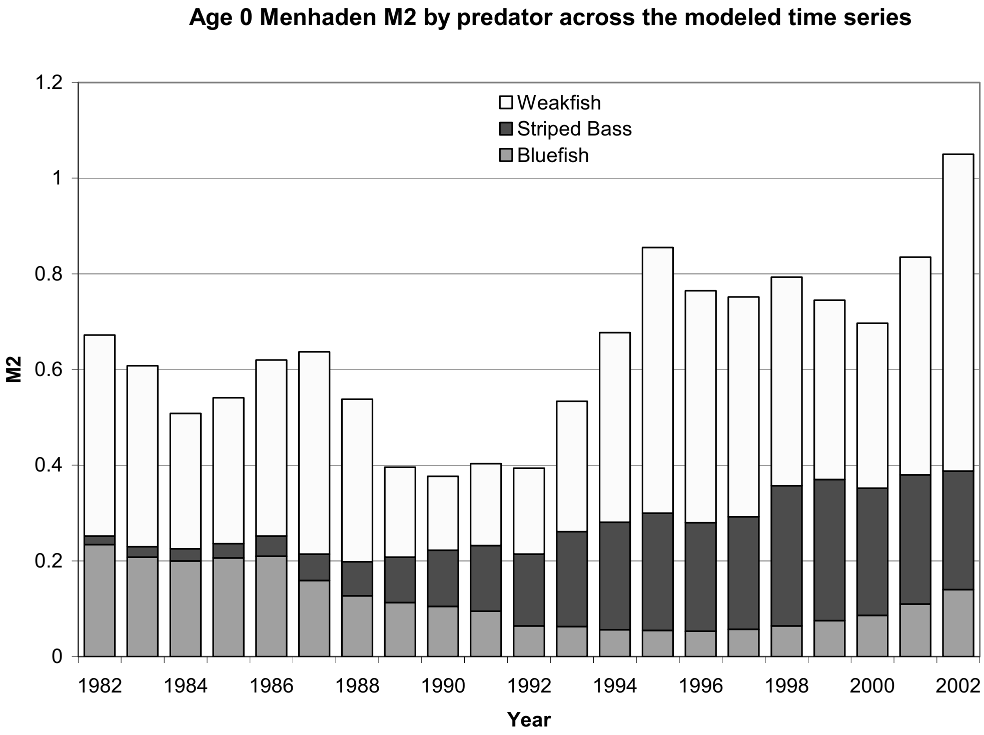
D17. Predicted total prey biomass consumed annually by all ages of weakfish.



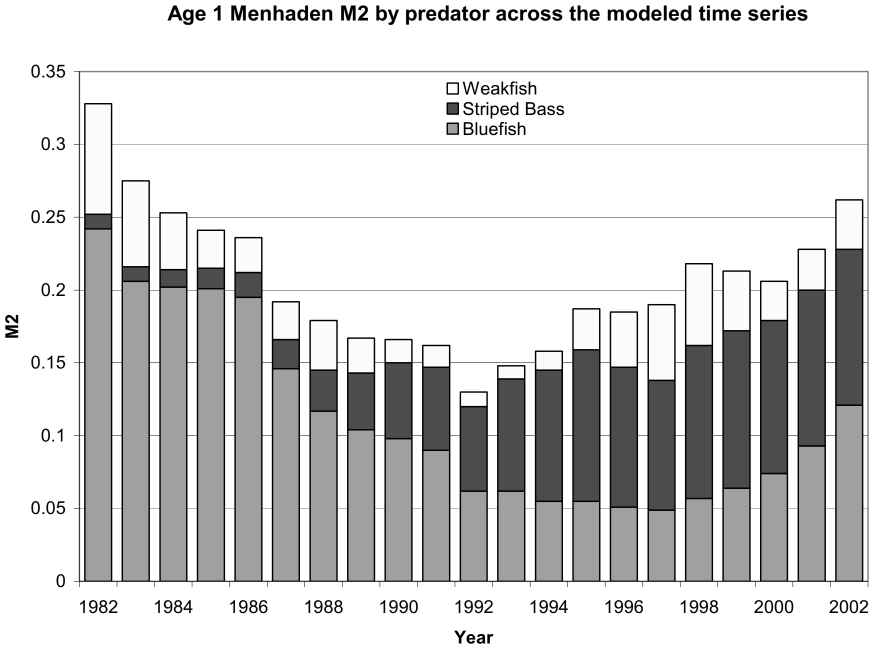
D18. Predicted total prey biomass consumed annually by all size classes of bluefish.



D19. Annual age-0 menhaden predation mortality (M2) by predator.



D20. Annual age-1 menhaden predation mortality (M2) by predator.



APPENDIX. TERMS OF REFERENCE

Terms of Reference for the 42nd Northeast Stock Assessment Workshop

(approved: (11/10/05)

SAW/SARC 42
November 28- December 2, 2005
NEFSC, Woods Hole, MA

Atlantic mackerel - Coastal and Pelagic Working Group

1. Characterize the commercial and recreational catch including landings and discards.

2. Estimate fishing mortality, spawning stock biomass, and total stock biomass for the current year and characterize the uncertainty of those estimates. If possible, also include estimates for earlier years.

3. Evaluate and either update or re-estimate biological reference points, as appropriate.

4. As needed by management, estimate a single-year or multi-year TAC and/or TAL by calendar year or fishing year, based on stock biomass and target mortality rate.

5. If possible,

    a. provide short term projections (2-3 years) of biomass and fishing mortality rate, and characterize their uncertainty, under various TAC/F strategies and

    b. evaluate current and projected stock status against existing rebuilding or recovery schedules, as appropriate.

6. Review, evaluate and report on the status of the SARC/Working Group Research Recommendations offered in previous SARC-reviewed assessments.

Silver hake - Northern Demersal Working Group

1. Characterize the commercial and recreational catch including landings and discards.

2. Estimate fishing mortality, spawning stock biomass, and total stock biomass for the current year and characterize the uncertainty of those estimates. If possible, also include estimates for earlier years.

3. Evaluate and either update or re-estimate biological reference points, as appropriate.

4. As needed by management, estimate a single-year or multi-year TAC and/or TAL by calendar year or fishing year, based on stock biomass and target mortality rate.

5. If possible,

    a. provide short term projections (2-3 years) of biomass and fishing mortality rate, and characterize their uncertainty, under various TAC/F strategies and

    b. evaluate current and projected stock status against existing rebuilding or recovery schedules, as appropriate.

6. Review, evaluate and report on the status of the SARC/Working Group Research Recommendations offered in previous SARC-reviewed assessments.

Illex squid - Invertebrate Working Group

1. Characterize the commercial and recreational catch including landings and discards.

2. Estimate fishing mortality, spawning stock biomass, and total stock biomass for the current year and characterize the uncertainty of those estimates. If possible, also include estimates for earlier years.

3. Evaluate and either update or re-estimate biological reference points, as appropriate.

4. As needed by management, estimate a single-year or multi-year TAC and/or TAL by calendar year or fishing year, based on stock biomass and target mortality rate.

5. If possible,

    a. provide short term projections (2-3 years) of biomass and fishing mortality rate, and characterize their uncertainty, under various TAC/F strategies and

    b. evaluate current and projected stock status against existing rebuilding or recovery schedules, as appropriate.

6. Review, evaluate and report on the status of the SARC/Working Group Research Recommendations offered in previous SARC-reviewed assessments.

Multispecies predator-prey MSVPA-X model – ASMFC

1. Evaluate adequacy and appropriateness of model input data, including fishery-dependent data, fishery-independent data, selectivities, etc. as configured.

2. Evaluate assumptions for data gap filling when reliable data are not available (diet, biomass of prey species, feeding selectivity).

3. Review model formulation (overall setup, data handling, VPA calculations, assessment options, sensitivity analyses, recruitment model options, and forward projection options) of model as configured.

4. Develop research recommendations for data collection, model formulation, and model results presentation.

5. Evaluate whether or not the model and associated data are of sufficient quality to develop recommendations to management.

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