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A Report of the 46th Northeast Regional Stock Assessment Workshop

46th Northeast Regional Stock Assessment Workshop (46th SAW)

Assessment Summary Report

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Introduction

The 46[th] SAW Assessment Summary Report contains summary and detailed technical information on one assessment reviewed in November 2007 at the Stock Assessment Workshop (SAW) by the 46th Stock Assessment Review Committee (SARC-46): striped bass (*Morone saxatilis*). The SARC-46 consisted of three external, independent reviewers appointed by the Center for Independent Experts (CIE) and an external SARC chairman from the state of Florida's Fish and Wildlife Conservation Commission. The SARC evaluated whether each Term of Reference (listed in the Appendix) was completed successfully based on whether the work provided a scientifically credible basis for developing fishery management advice. The reviewers' reports for SAW/SARC-46 are available at website: http://www.nefsc.noaa.gov/nefsc/saw/ under the heading "Recent Reports."

An important aspect of any assessment is the determination of current stock status. The status of the stock relates to both the rate of removal of fish from the population – the exploitation rate – and the current stock size. The exploitation rate is the proportion of 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); the maximum removal rate is denoted as $F_{THRESHOLD}$.

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

Since there are two dimensions to stock status – the rate of removal and the biomass level – it is possible that a stock not currently subject to overfishing in terms of exploitation rates is in an overfished condition; that is, the stock has a biomass level less than the threshold level. This may be due to heavy exploitation in the past, or a result of other factors such as unfavorable environmental conditions. In this case, future recruitment to the stock is very important and the probability of improvement may increase greatly by increasing the stock size. Conversely, fishing down a stock that is at a high biomass level should generally increase the long-term sustainable yield. Stocks 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 these considerations, stocks under review are classified with respect to current overfishing definitions. A stock is overfished if its current biomass is below $B_{THRESHOLD}$, and overfishing is occurring if current F is greater than $F_{THRESHOLD}$. The table below depicts status criteria.

		BIOMASS		
		$B < B_{THRESHOLD}$	$B_{THRESHOLD} < B < B_{MSY}$	$B > B_{MSY}$
EXPLOITATION	$F > F_{THRESHOLD}$	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	$F = F_{TARGET} <= F_{MSY}$

Fisheries management may take into account the precautionary approach, and overfishing guidelines often include a control rule in the overfishing definition. Generically, the control rules suggest actions at various levels of stock biomass and incorporate an assessment of risk, in that F targets are set to avoid exceeding F thresholds.

Outcome of Stock Assessment Review Meeting

The SARC review committee concluded that the assessment team successfully met all of its terms of reference. The extensive data available for the assessment appeared to be correctly compiled and used in the assessment, and the analyses were made in accordance with good scientific practice.

The review committee found that, of the candidate assessment models, the statistical catch-at-age model (SCA) best estimated parameters that could be judged against the current biological benchmarks: 1995 spawning stock biomass and fully recruited fishing mortality rate at maximum sustainable yield. Based on these, the SARC agreed with the assessment team's stock status determination that striped bass is not currently overfished and overfishing is not occurring. Fishing mortality has increased in recent years and is currently (data up to and including 2006) at or very near the target level.

The review committee was impressed with the amount of detailed spatial data that was available. They suggested that this data has the potential to be used more fully, which might reduce the difficulties encountered in the current global assessment model (e.g., conflicting abundance indices).

In addition, the SARC identified topics that deserve special attention or could be improved in future assessments. These topics include: examining sensitivity of assessment results to discard estimates and improving those estimates; age determination for striped bass older than about age 10; extracting more information out of the young-of-year indices; employing better methods of averaging multiple survey indices; using regional surveys to get direct information about differences in recruitment levels for the sub-stocks of the fishery; and better standardization of state surveys.

Glossary

ADAPT. A form of computer program commonly 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. 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, 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}, 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 by 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. 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, by increasing mesh or hook size or changing the proportion of harvest by gear type.

Mortality rates. Populations of animals decline exponentially, which 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.

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

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

Growth overfishing. When the rate of fishing mortality is above F_{MAX} and 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, usually 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, $B_{threshold}$). One of the Status Determination Criteria (SDC). 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 NSG, "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 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. 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. 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 gear(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.

Total allowable catch (TAC). 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. 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 (the inability to achieve targets exactly for whatever reason)

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

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

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

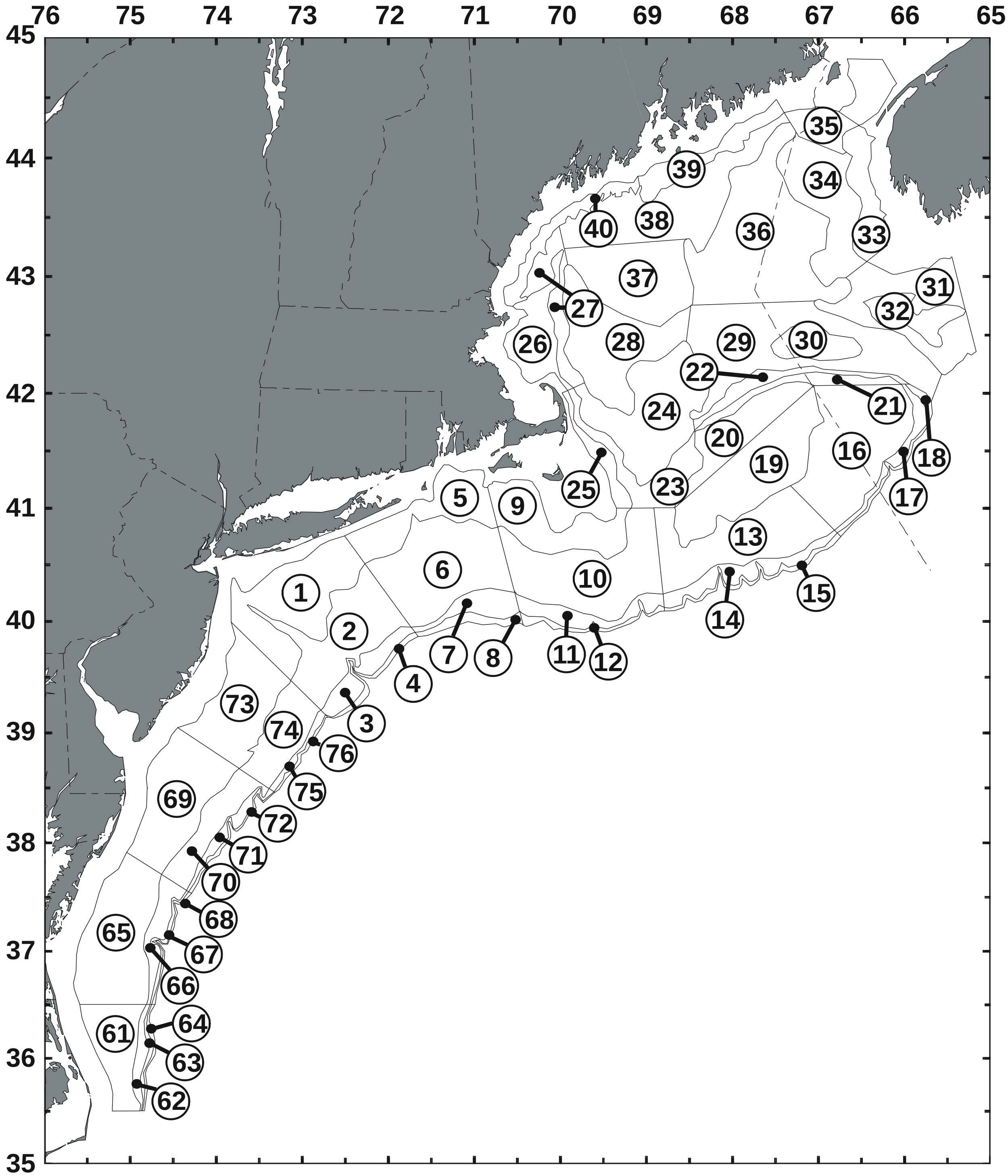

Figure 1. Offshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys.

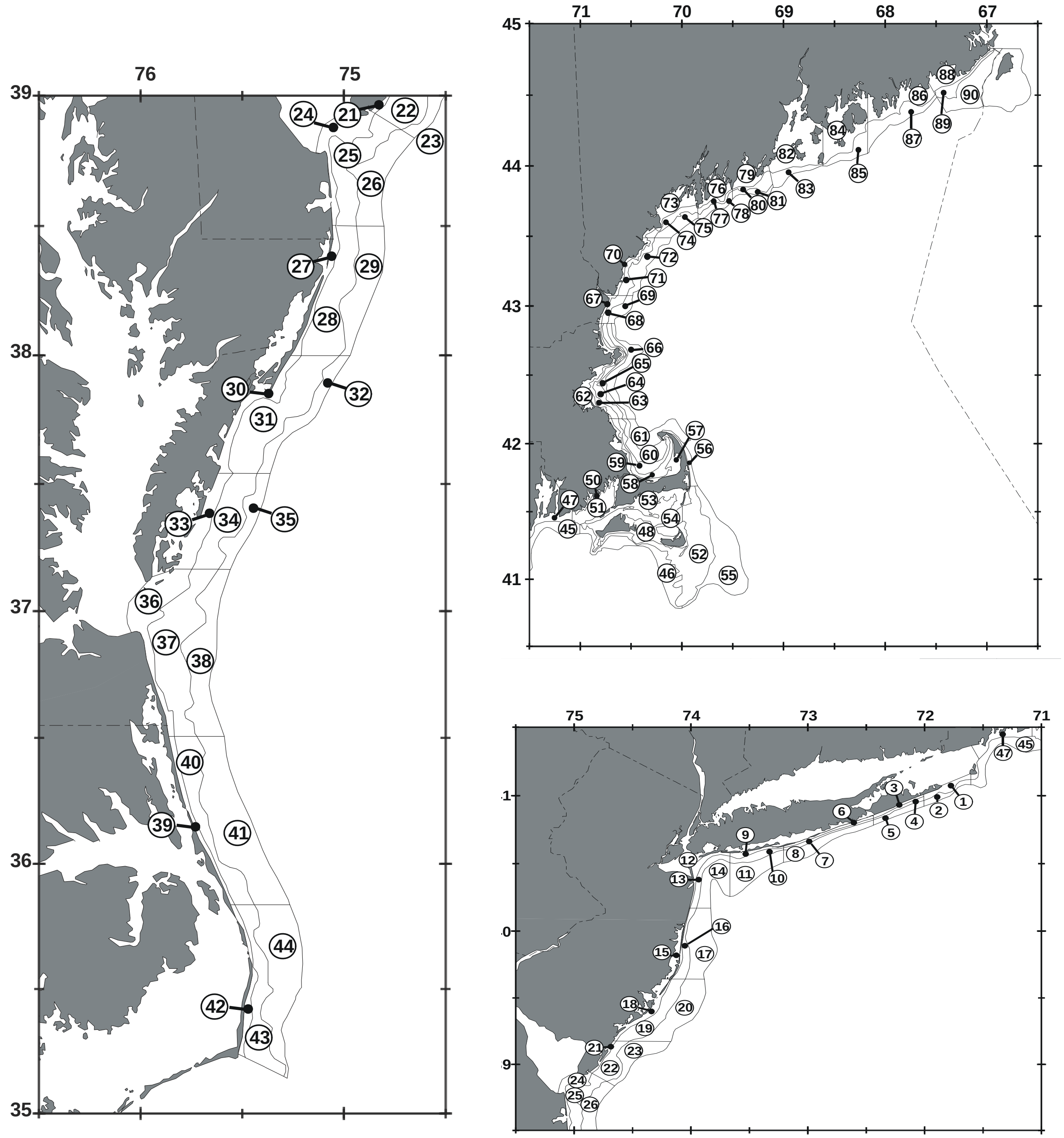

Figure 2. Inshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys.

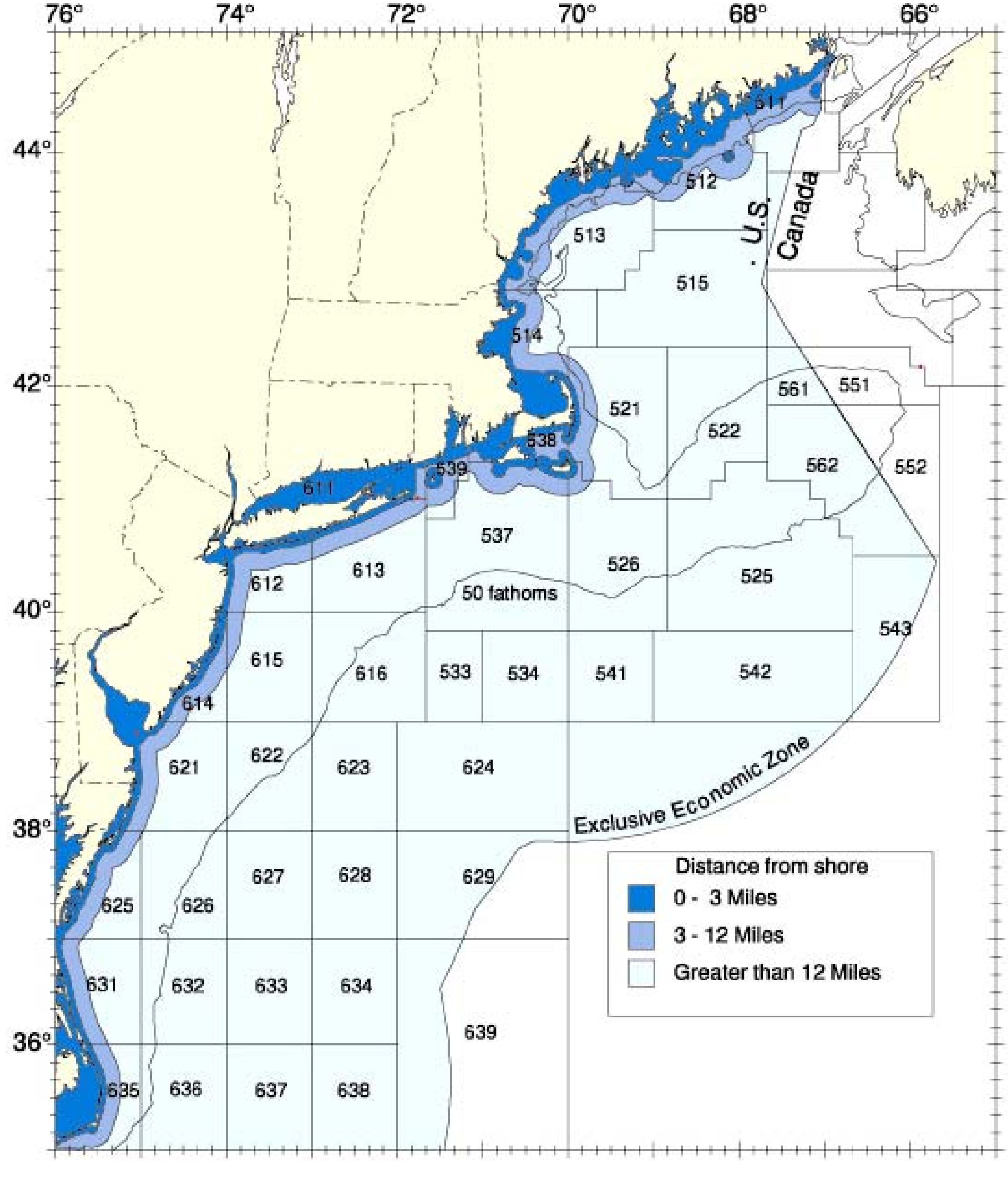

Figure 3. Statistical areas used for reporting commercial catches.

A. STRIPED BASS ASSESSMENT SUMMARY FOR 2007

Status of Stock: The target values and biological reference point thresholds of Atlantic striped bass for fishing mortality (average F of ages 8-11) and spawning stock biomass are F_{target}=0.30 and female spawning stock biomass (SSB_{target})=17,500 mt, and F_{msy}=0.41 and $SSB_{threshold}$=14,000 mt, respectively (ASMFC 2003). The forward projecting statistical catch at age model (SCA) estimated that the fishing mortality rate in 2006 was F=0.31 and the female SSB in 2006 was 24,979 mt (Figure A1). Based on the catch equation method (CEM) using tagging data, fishing mortality rate in 2006 was estimated to be F=0.16 (see Special Comments). Based on the 2006 estimates, Atlantic striped bass are not overfished and overfishing is not occurring.

Female SSB grew steadily through 2003 but has since declined. Fishing mortality estimates from the SCA and CEM models show similar increasing trends from the late 1980s to the late 1990s followed by declines through 2002 (Figure A2). After 2002, Fs from the SCA model increased (see Special Comments) while Fs from the CEM remained relatively flat. Results from retrospective analysis in the SCA suggest that the 2006 F estimate is likely over-estimated and the SSB estimate is likely under-estimated; therefore, F could decrease and SSB could increase with the addition of future years of data.

Forecast for 2007: No forecast was made.

Catch and Status Table (millions of fish): Striped Bass

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Max[1]	Min[2]	Mean[3]
Commercial Landings	1.06	1.22	1.10	1.06	0.94	0.65	0.87	0.91	0.97	1.05	1.22	0.01	0.57
Commercial Discards	0.22	0.33	0.24	0.67	0.31	0.17	0.26	0.52	0.78	0.22	0.78	0.04	0.30
Recreational Harvest	1.65	1.46	1.45	2.03	2.09	1.97	2.55	2.62	2.34	2.78	2.78	0.04	1.04
Recreational Discards	1.27	1.21	1.02	1.36	1.08	1.10	1.19	1.38	1.52	2.07	2.07	0.03	0.68
Catch Used in Assessment	4.19	4.22	3.81	5.10	4.42	3.90	4.86	5.43	5.60	6.11	6.11	0.24	2.58
Female SSB[4]	23.89	21.68	22.83	26.9	28.8	32.2	33.0	30.7	28.1	25.0	33.0	1.4	15.6
Total stock size[5]	65.44	61.94	58.83	54.64	55.19	58.63	54.58	64.82	59.18	55.84	65.44	7.13	39.56
Recruitment (Age 1)[5]	16.49	9.84	9.33	7.42	12.79	15.12	7.70	22.28	8.24	10.04	22.28	1.79	9.44
$F_{age8-11}$ (from SCA)	0.23	0.19	0.16	0.22	0.19	0.18	0.23	0.26	0.28	0.31	0.45	0.08	0.20
$F_{28"+}$ (from CEM)[6]	0.31	0.29	0.29	0.20	0.17	0.18	0.18	0.16	0.17	0.16	0.31	0.04	0.18

1-maximum value from 1982 - 2006
2-minimum value from 1982 - 2006
3-mean value from 1982 - 2006
4-female spawning stock biomass (SSB) from SCA model in metric tons (thousands)
5-millions of fish
6-fully recruited fish (≥28 inches)

Stock Distribution and Identification: Atlantic coast migratory striped bass, *Morone saxatilis*, live along the eastern coast of North America from the St. Lawrence River in Canada to the Roanoke River and other tributaries of Albemarle Sound in North Carolina (ASMFC 1990). The anadromous populations of the Atlantic coast are primarily the product of four distinct spawning stocks: a Roanoke River/Albemarle Sound stock, a Chesapeake Bay stock, a Delaware River stock, and a Hudson River stock (ASMFC 1998). The Atlantic coast fisheries, however, rely primarily on production from the spawning populations in the Hudson and Delaware rivers and in tributaries of Chesapeake Bay. Therefore, the inside fisheries of the Albemarle Sound and Roanoke River are managed separately from the Atlantic coastal management unit, which includes all other migratory stocks occurring in coastal and estuarine areas of all states and jurisdictions from Maine through North Carolina.

From Cape Hatteras, North Carolina (NC), to New England, striped bass coastal migrations are generally northward in summer and southward in winter. Results from tagging 6,679 fish from New Brunswick, Canada to the Chesapeake Bay, during 1959–1963, suggest that substantial numbers of striped bass leave their birthplaces when they are three or more years old and thereafter migrate in groups along the open coast (Nichols and Miller 1967). These fish are often referred to collectively as the "coastal migratory stock," suggesting they form one homogeneous group, but this group is probably, in itself, heterogeneous, consisting of many migratory contingents of diverse origin (Clark 1968).

Coastal migrations may be quite extensive; striped bass tagged in Chesapeake Bay have been recaptured in the Bay of Fundy. They are also quite variable, with the extent of the migration varying between sexes and populations (Hill et al. 1989). Larger bass, typically females, tend to migrate farther; however, striped bass are not usually found more than 6 to 8 km offshore (Bain and Bain 1982). The inshore zones between Cape Henry, Virginia (VA), and Cape Lookout, NC, serve as the wintering grounds for the migratory segment of the Atlantic coast striped bass population (Setzler-Hamilton et al. 1980).

Catch: Total annual removals of striped bass have been dominated by recreational harvest and discard mortality since the early 1990s (Figure A3). Annual catches (both harvested and released fish) by recreational anglers increased rapidly through the early to mid 1990s. From 1998 to 2002, catches fluctuated without trend before undergoing another rapid increase to a peak of more than 27 million fish in 2006 (Figure A4). Due to large size limits and conservation ethics, 85–90% of the fish caught have been released. Since the turn of the century, recreational harvest of striped bass has ranged from roughly 2.0 to 2.8 million fish while discard mortality from released fish has ranged from roughly 1.1 to 2.1 million fish.

Commercial harvesters have been under a quota management system since 1990. Annual coastwide landings experienced similar trends to recreational catch in the 1990s, with a steady increase to a peak in 1998 of 1.2 million fish (Figure A5). Since then, annual landings have ranged from 650,000 to 1.1 million fish. Estimates of commercial discard mortality have fluctuated greatly since the early 1990s, ranging from roughly 200,000 to over 700,000 fish, annually (Figure A5).

Data and Assessment: Recreational landings data, length data, and discard estimates were obtained from the National Marine Fisheries Service's Marine Recreational Fisheries Statistics Survey (MRFSS) for waves 2-6 (Mar–Dec). Estimates of recreational discard mortality were derived by applying an 8% discard mortality rate to the MRFSS estimates of live releases (B2s).

Anecdotal evidence suggests that NC and VA had sizeable wave-1 (January–February) fisheries for striped bass beginning in 1996. To account for landings during these months, NC began conducting MRFSS interviews and phone surveys during wave 1 in 2004. Estimates of wave-1 harvest from 1996 to 2003 in NC and 1996 to 2006 in VA were developed using observed relationships between landings and tag returns.

Discard lengths were obtained from various state volunteer angler surveys and lengths of tagged fish released by anglers participating in the American Littoral Society tagging program. Age structures were collected from recreational catches in Massachusetts, New York, New Jersey, and Maryland to develop age-length keys and recreational catch-at-age matrices. Other states used the age-length keys from nearby states or age and length data from state commercial hook and line fisheries to develop catch-at-age matrices for recreational harvest and discard mortality estimates.

Strict quota monitoring is conducted by states through various state and federal dealer and fishermen reporting systems, and landings are compiled annually from those sources by state biologists. Biological data (e.g., length, weight) and age structures from commercial harvest are collected from a variety of gear types through state-specific port sampling programs. Harvest numbers are apportioned to age classes using length frequencies and age-length keys derived from biological sampling.

Direct measurements of commercial discards of striped bass are generally only available for fisheries in the Hudson River Estuary. Discard estimates for fisheries in Chesapeake Bay and coastal locations since 1982 are based on the ratio of tags reported from discarded fish in the commercial fishery to tags reported from discarded fish in the recreational fishery, scaled by total recreational discards. To account for differential tag reporting rates between commercial and recreational harvesters, a correction factor is calculated by dividing the three-year mean of ratios of commercial to recreational landings by the three-year mean of ratios of tags returned by the two fisheries. Estimates of discard mortality were derived by applying gear specific estimates of discard mortality rates to discard estimates.

Atlantic striped bass have historically been assessed using tag data from a coastwide tagging program via estimates of survival from program MARK (Brownie et al. 1985; Smith et al. 2000) and estimates of exploitation rates from mark recapture (R/M) as well as the age-based ADAPT VPA model. In the 2005 assessment, the CEM was first used to develop estimates of F without the assumption of a constant annual value of natural mortality (M=0.15) that is used with program MARK to estimate F and in the ADAPT VPA.

For this assessment, the Striped Bass Technical Committee selected the SCA and CEM as the preferred assessment methods. The SCA was selected as the age-based assessment method for several reasons: the number and form of the selectivity patterns were chosen based on analytical methods and were estimated in the model; estimates of F were robust to the inclusion/exclusion of tuning indices (which was not the case with this years run of ADAPT); and it lacks the assumption the catch-at age is measured without error that is associated with ADAPT. Finally, because SCA is a forward-projecting model, the estimates of F and population size from the catch at age analyses at the beginning of the time series are the most uncertain estimates, not the terminal year as in ADAPT. The CEM was chosen for use with the tagging data because of its ability to estimate F without the assumption of a constant value of M.

In addition, results from several additional models and methods (ADAPT, ASAP, relative F, and catch curves) provide supporting evidence for the trends in F and SSB shown in the SCA and CEM. Further, preliminary runs were presented of two new assessment models: an Instantaneous Rates Tag Return Model Incorporating Catch-Release Data, and a Forward-Projecting Statistical Catch-At-Age Model Incorporating Age-Independent Instantaneous Rates Tag Return Model.

Biological Reference Points: Reference points apply to the entire assessed population. F_{msy} (0.41), estimated using a Shepherd/Sissenwine model, was adopted as $F_{threshold}$ for Amendment 6. An exploitation rate of 24%, or F=0.30 was chosen as F_{target}. Female $SSB_{threshold}$ (14,000 mt) was chosen to be slightly greater than the female spawning stock biomass in 1995 when the population was declared recovered. Female SSB_{target} (17,500 mt) was set 25% greater than $SSB_{threshold}$.

Target F for the producer area, Chesapeake Bay, was set at 0.27 to compensate for the 18-inch size limit that is lower than preferred size limit for Chesapeake Bay under Amendment 6. No biomass targets were chosen specifically for Chesapeake Bay.

Fishing Mortality: Fishing mortality (F) was estimated using the preferred SCA (average F of ages 8-11) and CEM (F on 28 inch plus fish) models as well as with several supporting models. The 2006 estimate of F from the SCA was 0.31 (95% C.I.: 0.23-0.40), while it was 0.16 from CEM. Only the terminal estimate of F from the SCA model (and the supporting ADAPT model) exceeded the target F of 0.30. Results from retrospective analysis in the SCA suggest that the 2006 F estimate is likely overestimated and could therefore decrease with the addition of future data.

Proportional estimates of F by fishery component indicate that recreational harvest is by far the largest component of F for fish age 6 and older followed by commercial harvest (Figure A6). Recreational discards dominate the F on fish age 3 and younger while all four fishery components contribute somewhat equally to the F on age 4 and 5 fish.

Fishing mortality estimates from the SCA and CEM models show similar increasing trends from the late 1980s to the late 1990s, followed by declines through 2002 (Figure A2). After 2002, Fs from the SCA increase while Fs from the CEM remain relatively flat.

In Chesapeake Bay, the 2006 estimate of F using the CEM is 0.14. F estimates from the CEM have ranged from 0.0 to 0.16 throughout the time series and have remained below the Chesapeake Bay target F of 0.27.

Recruitment: Estimates of abundance from SCA show strong recruitment at age 1 in 1994, 1997, 2002, and 2004, with the 2003 cohort being the strongest in the time series (Figure A7). Since 1990, age 1 abundance has ranged from 7.4 to 22.3 million fish, with the four dominant year-classes mentioned above, all in excess of 15.1 million fish.

The strong year-classes were evident in the Chesapeake Bay (Maryland and Virginia) young-of-the-year surveys during 1993, 1996, 2001, and 2003 (Figure A8). Strong recruitment was also evident in 1993, 1995, 1999, and 2003 in the Delaware Bay juvenile survey and in 1997, 1999, and 2001 in the Hudson River juvenile survey. Striped bass recruitment in the Hudson River has been below the 75^{th} percentile of the survey time series for the past three years (2004-2006).

Spawning Stock Biomass: Female SSB increased from a time series low of less than 1,500 mt in 1984 to a peak of roughly 33,000 mt in 2003 (Figure A1). Female SSB has been in excess of 20,000 mt since 1996, with 2006 estimated at 24,979 mt (95% C.I.: 18,563–32,169).

Stock Abundance: Estimates of age 1+ abundance from the SCA showed a continuous increase from 7.1 million fish in 1982 to a peak of more than 65 million fish in 1997. In subsequent years, abundance declined for a short period before increasing once again to just under 65 million fish in 2004. The 2006 estimate of age 1+ abundance is 55.8 million fish.

Estimates of abundance are also available from the CEM for fish $\geq$28 inches (assumed age 7+) and $\geq$18 inches (assumed age 3+). Abundance of assumed age 7+ fish rose from roughly 2 million fish in the late 1980's to a peak of 14.7 million fish in 2004 before declining slightly in recent years. The SCA shows a similar trend for age 7+ fish with a peak of 12.4 million fish a year in 2003. CEM estimates of assumed age 3+ abundance rose from a low of 7.7 million fish in 1992 to a time series high of 47.9 million fish in 2006.

Special Comments: Fishing in the EEZ was closed in 1990 and has remained closed to harvest and possession by both commercial and recreational fishermen.

Several new models were developed for use in this assessment, including the Forward Projecting Statistical Catch At Age (SCA) model, the Catch Equation Method (CEM), the Instantaneous Rates Tag Return Model Incorporating Catch-Release Data (IRCR), and a Forward-Projecting Statistical Catch-At-Age Model Incorporating Age-Independent Instantaneous Rates Tag Return Model (SCATAG). For this assessment, the ASMFC Striped Bass Technical Committee selected the SCA and the CEM as the preferred assessment methods.

The SARC review panel found that, of the candidate assessment models, the SCA model best estimated parameters that could be judged against the current biological benchmarks, 1995 spawning stock biomass, and fully recruited fishing mortality rate at maximum sustainable yield. With the CEM analysis, the review committee was concerned that fully recruited F was approximated using only tagged fish that were greater than or equal to 28 inches and not all striped bass of these sizes are fully recruited, i.e.; selectivity for striped bass may not be flat-topped. Based on these peer review comments, the SCA model is the preferred model at this time for determining stock status.

The assessment benefits greatly from the large tagging database with extensive spatial and temporal coverage. In addition, fisheries independent and dependent surveys used in the assessment contribute greatly to determining the status of the population.

The CEM uses both the recovery matrix for the entire time series (calculation of survival rates) and the most recent year's recovery vector (calculation of exploitation). Concern has been expressed about the use of two different time scales of the recovery data in the same equation.

While the catch equation provides reasonable estimates of F, there is considerable variation and some nonsensical values in the estimates of M.

The assignment of age from scale samples becomes less certain with increasing fish age ($\geq$ age 10).

Lack of MRFSS estimates from Wave 1 in Virginia and other mid-Atlantic states as well as the lack of coverage in freshwater areas of estuaries adds to the uncertainty in the estimates of recreational harvest and live release.

Retrospective bias was evident in estimates of fully-recruited F and abundance estimates from SCA. It is likely that the 2006 estimate of F is overestimated and female SSB is underestimated.

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Figures

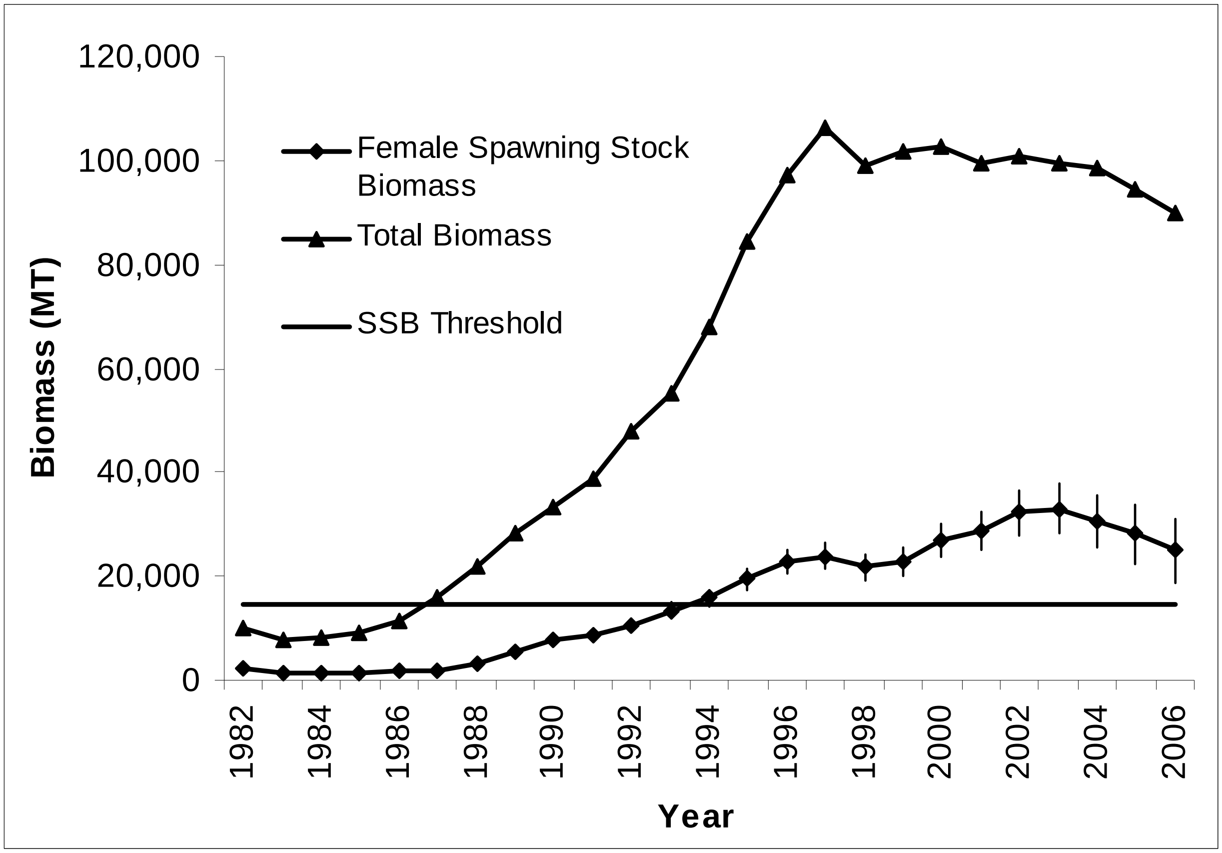


Figure A1. Estimates of Atlantic striped bass female spawning stock biomass (mt) with 95% confidence intervals and January-1 total biomass (mt) from statistical catch at age model (SCA).

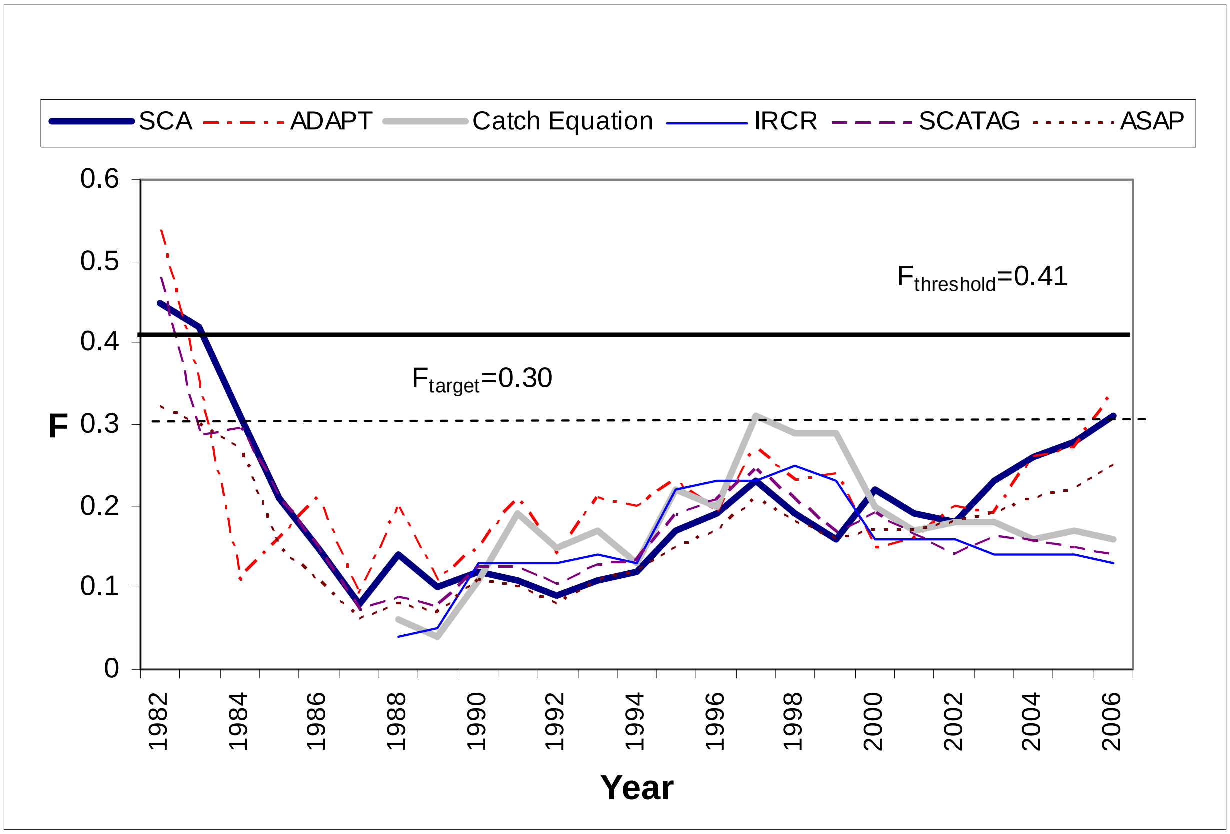


Figure A2. Estimates of instantaneous annual fishing mortality rates (F) for Atlantic striped bass from the catch equation method (CEM), the statistical catch at age model (SCA), and supporting models.

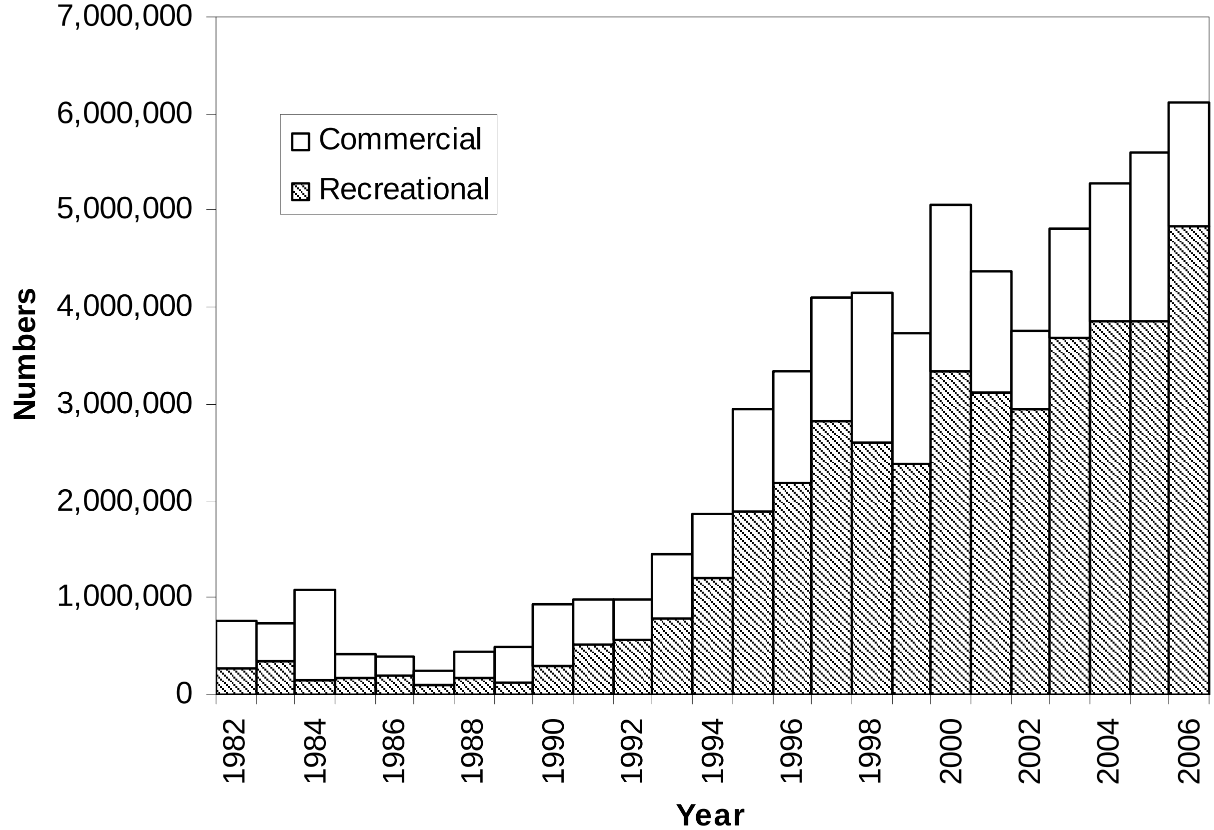


Figure A3. Total removals of Atlantic striped bass partitioned into commercial and recreational contributions, 1982-2006.

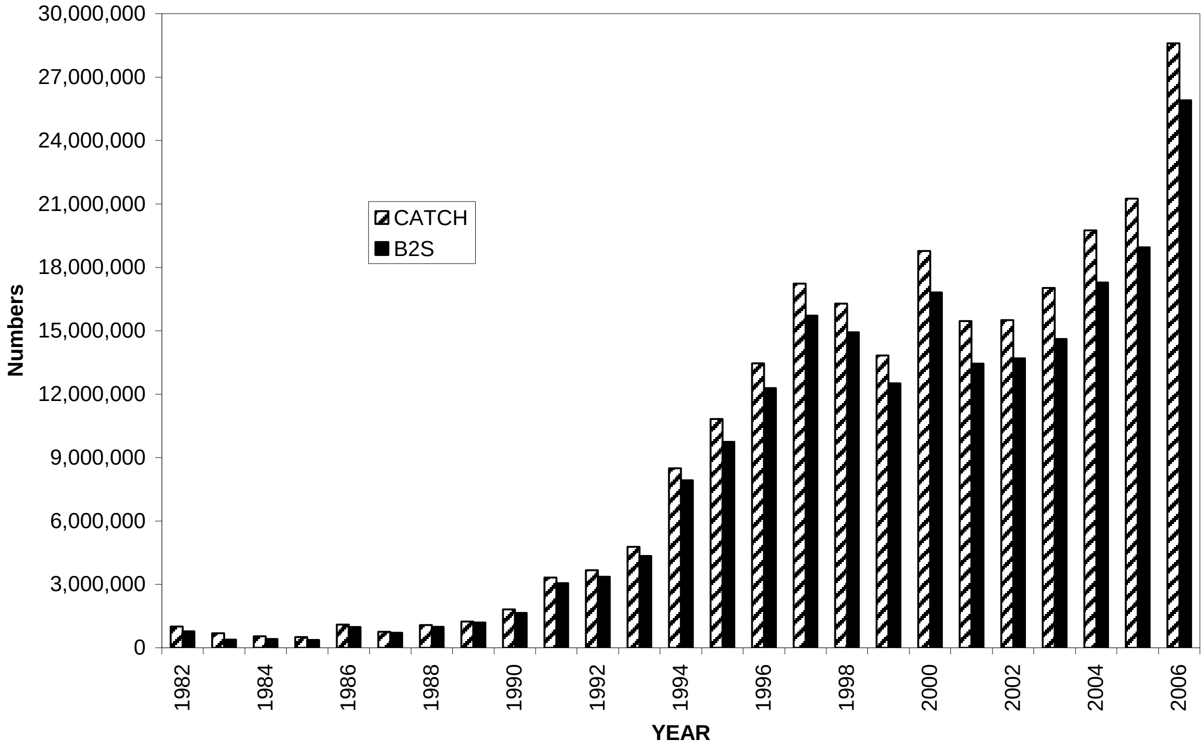


Figure A4. MRFSS estimates of total catch and live releases (B2) of Atlantic striped bass for the US Atlantic coast (ME-NC), 1982-2006.

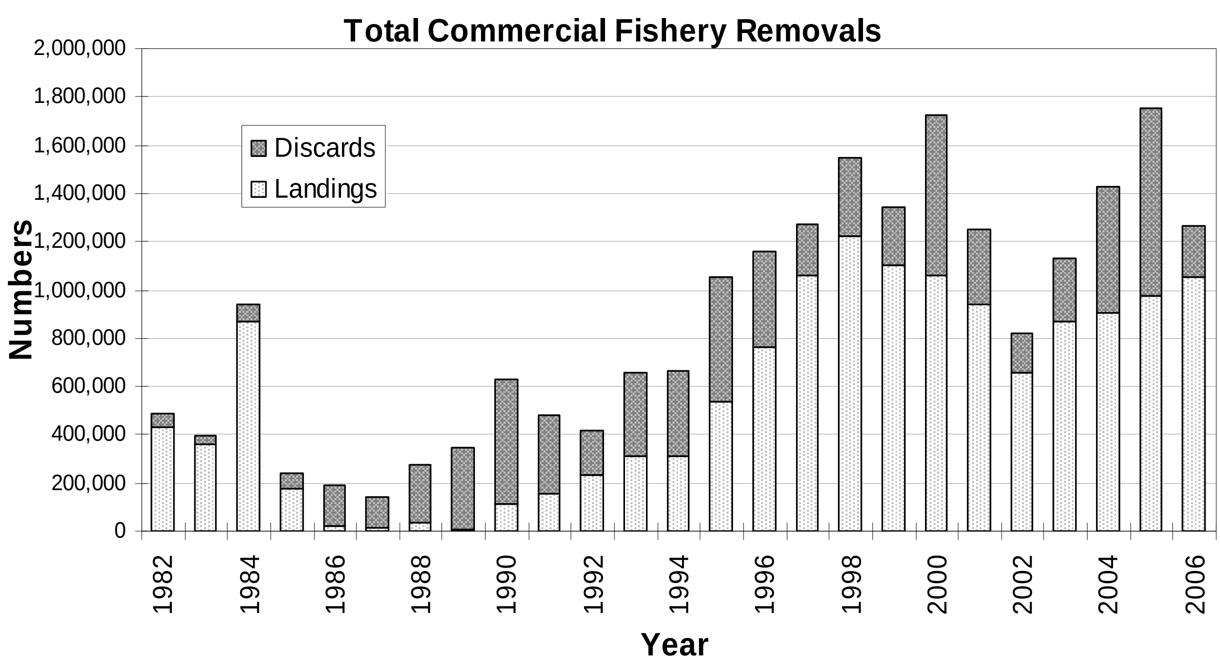
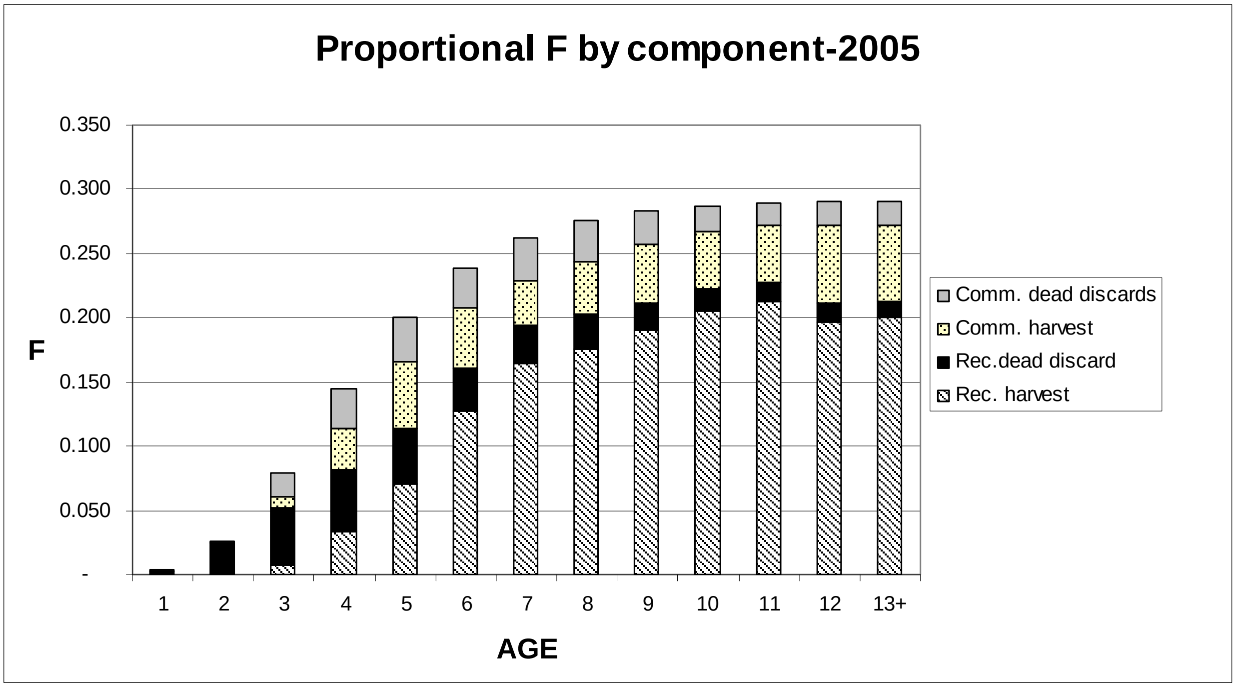


Figure A5. Total commercial removals (landings and dead discards) of Atlantic striped bass, 1982-2006.



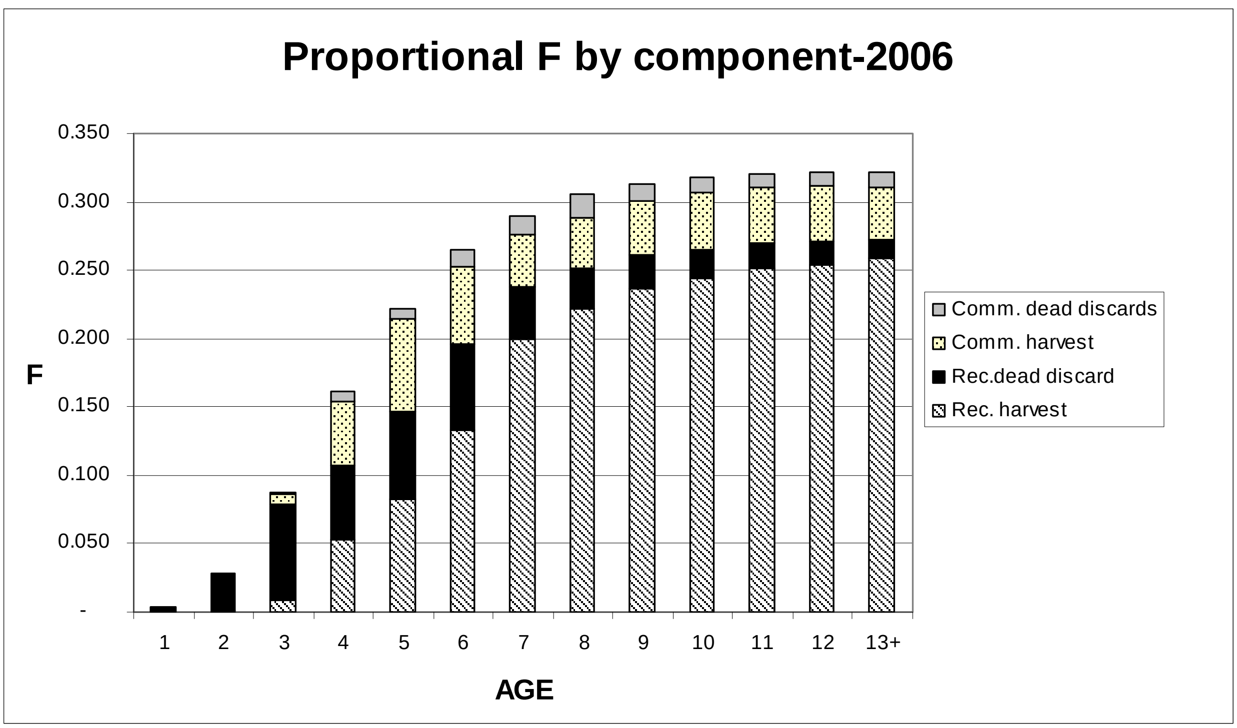


Figure A6. Proportional F at age by fishery component for Atlantic striped bass in 2005 and 2006 as derived from the statistical catch at age model (SCA).

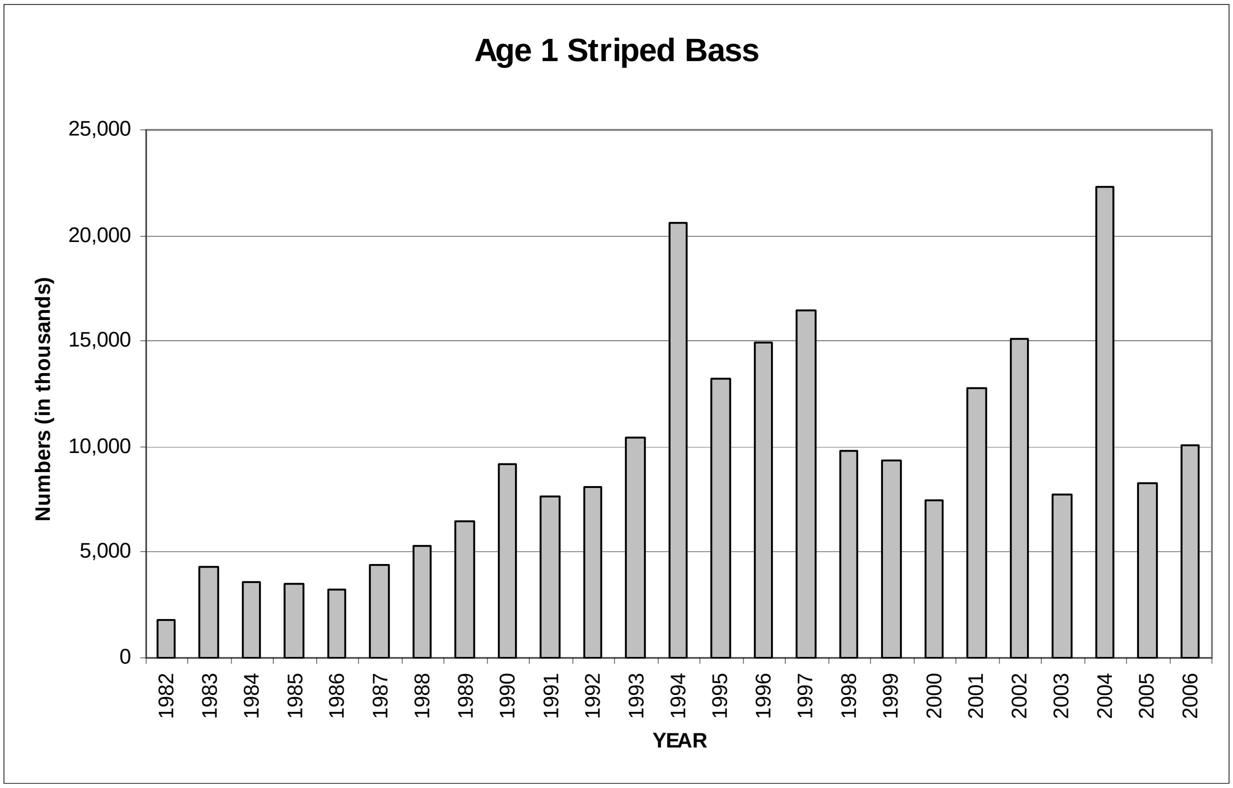


Figure A7. Estimates of age 1 abundance of Atlantic striped bass from the statistical catch at age model (SCA), 1982-2006.

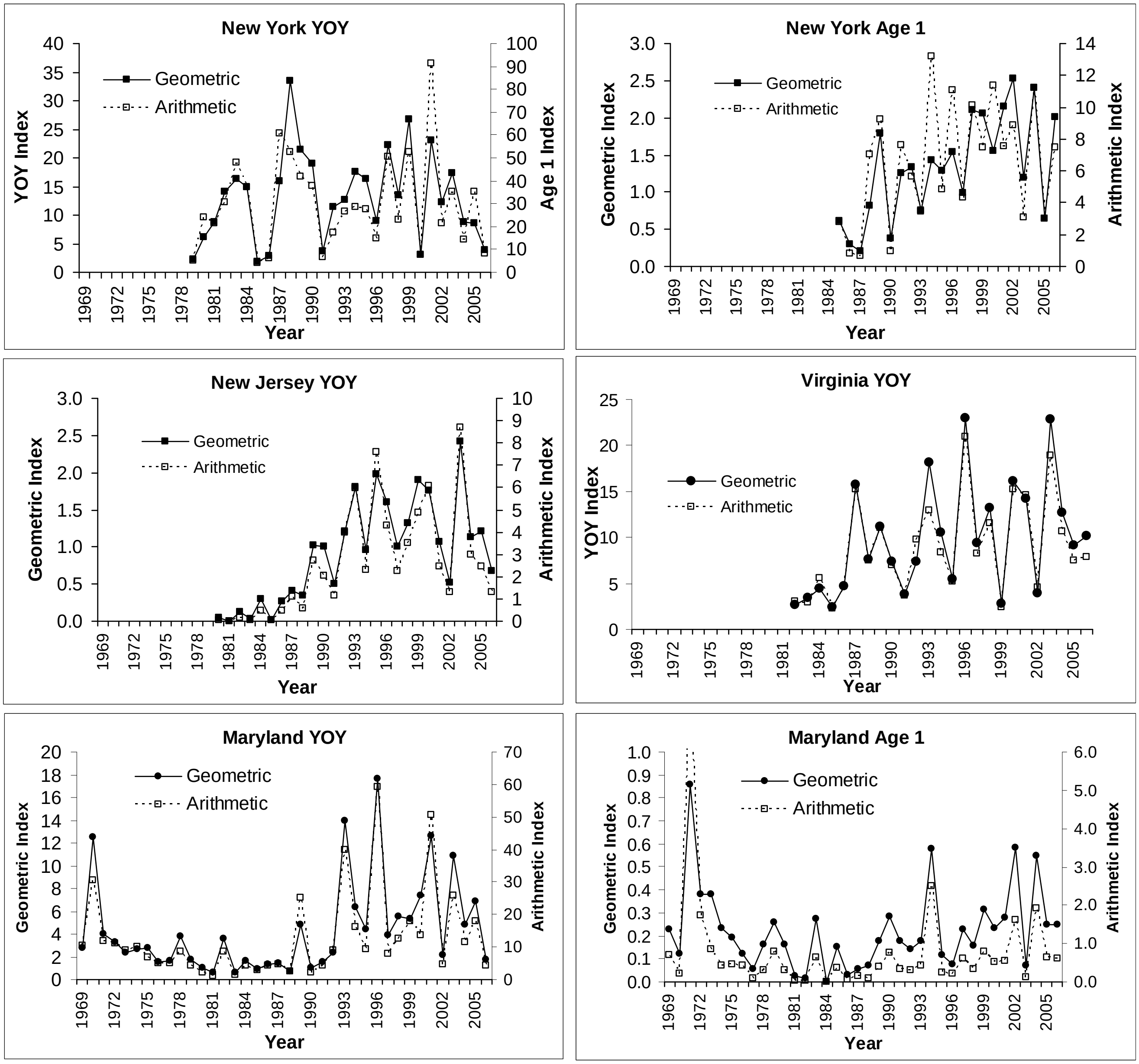


Figure A8. Young-of-the-year and age 1 indices of Atlantic striped bass relative abundance.

Appendix: Terms of Reference

TORs for SAW/SARC-46, Fall 2007 Assessment

A. Striped Bass

1. Characterize the commercial and recreational catch including landings and discards.
2. Characterize the fisheries independent and dependent indices of abundance.
3. Evaluate the Statistical Catch at Age (SCA) model and its estimates of F, spawning stock biomass, and total abundance of Atlantic striped bass, along with the uncertainty of those estimates.
4. Evaluate the Baranov's catch equation method and associated model components applied to the Atlantic striped bass tagging data. Evaluate estimates of F and abundance from coastwide and Chesapeake Bay specific programs along with the uncertainty of those estimates.
5. Review the Instantaneous Rates Tag Return Model Incorporating Catch-Release Data (IRCR) and estimates of F on Atlantic striped bass. Provide suggestions for further development of this model for future use in striped bass stock assessments.
6. Review the Forward-Projecting Statistical Catch-At-Age Model Incorporating the Age-Independent Instantaneous Rates Tag Return Model (SCATAG) and estimates of F, spawning stock biomass, and total abundance of striped bass. Provide suggestions for further development of this model for future use in striped bass stock assessments.
7. Evaluate the current biological reference points for Atlantic striped bass from Amendment 6 and determine stock status based on those reference points.

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