2008 Update of the Multispecies Virtual Population Analysis

A report prepared by the
ASMFC Multispecies Technical Committee
For the ISFMP Policy Board
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EXECUTIVE SUMMARY

In spring 2007, a subcommittee of the Multispecies Technical Committee was organized to 1) update the existing Multispecies Virtual Population Analysis (MSVPA-X) with the most recent available data, 2) generate new age-specific natural mortality estimates (M) for menhaden to be used in the upcoming menhaden assessment, and 3) address charges made by the ISFMP Policy Board and recommendations made by the SARC-42 review. The MSTC subcommittee assembled the majority of available input data during fall/winter 2007 and held modeling workshops in January and September 2008. The main objectives of these workshops were to 1) update the existing MSVPA-X model configuration with recent data through 2006 (continuity run), and 2) develop a new base run, which included several important changes in model input data, including new catch-at-age information for weakfish, new biomass trends for bluefish, new predator diet information, weakfish and striped bass variable size- and weight-at-age estimates, and new fishery and population estimates for non-menhaden prey species.

2006 SARC MSVPA-X base run (SARC run)

The MSVPA-X base run developed for the 2006 peer-reviewed model (referred to here as the SARC run) utilized the best available single-species assessment and diet data for important predator (striped bass, bluefish, weakfish) and prey (menhaden, other prey) species for the period 1982-2002 from the mid-Atlantic region (NEFSC 2006). The extended survival analysis (XSA) method was used for striped bass, weakfish, and menhaden as the single-species assessment model because it incorporated fishery-independent survey data as tuning indices and was consistent with the approach used in the single-species assessment models (Garrison et al. *in review*). Due to the lack of catch-at-age information from a peer reviewed stock assessment during the model reference period (1982 – 2002), bluefish was included as a “biomass predator” in the SARC run. To account for available non-menhaden prey, biomass estimates were developed for several “other prey” species groups that comprise important components of the predator species’ diets throughout their life history and range. “Other prey” items included in the SARC-run included: clupeids (Atlantic herring and threadfin herring); medium forage fish (squids and butterfish); anchovies; sciaenids (spot and croaker); macrozooplankton; benthic invertebrates; and benthic crustaceans. The diet information used in the SARC-run was based on an extensive review of available diet data for striped bass, weakfish, and bluefish. In general, the diet data lacked coast wide coverage for all ages of the predator species modeled. The most spatially and temporally comprehensive data set for all three species was the Northeast Fisheries Science Center Food Habits database. However, this survey was limited to the coastal (i.e., non-estuarine) waters, was only available during spring and fall, and generally did not have large sample sizes for older fish. For each species, there were additional regional studies providing diet information for estuarine waters and other times of the year.

Corrections made while creating the 2008 continuity run

The 2008 continuity run was created to update the 2006 SARC run to the extent possible with data through 2006. In the 2006 SARC run, weakfish age class 6 was not treated as a true plus class in the XSA; this was an oversight in model configuration the subcommittee corrected when the new continuity run was created (last age class is now 6+). Comparisons of the continuity run with and without this change did not identify any major differences in model results, likely due to the fact that there may be few old weakfish in the population. Also, the Virginia pound net index used to tune the striped bass XSA was offset incorrectly by one year; therefore, the time series for this index was adjusted accordingly. Note the original 2006 SARC run model configuration (containing data through 2002) was not updated with these corrections.

Changes made in creating new 2008 base run

Several important changes were made while creating the new base run in 2008, including 1) incorporation of new variable size- and weight-at-age estimates for striped bass and weakfish; 2) used striped bass indices from the 2008 peer reviewed assessment (i.e., dropped Virginia pound net index and added Connecticut trawl, Delaware trawl, New Jersey trawl, Delaware seine, and MRFSS); 3) used updated catch-at-age matrix (2001-2006) for weakfish (provided by J. Brust, not yet finalized by Weakfish Technical Committee); 4) added MRFSS harvest per unit effort (HPUE) and NYDEC indices in the weakfish assessment (as was recommended by the Weakfish Technical Committee); 4) used new biomass estimates for bluefish (from the peer reviewed ASAP model) and new adjusted proportion biomass for three size classes in the model; 5) used new adult index for menhaden based on lbs/days fished instead of lbs/license and included the New Jersey survey data in the coastwide index; 6) used new direct population size-at-age for Atlantic herring (from recent assessment); 7) used new length cutoff for available blue crab prey estimates; 8) used new population estimates for American lobster from 2006 assessment; 9) used average 2002-2007 seasonal biomass estimates for rock and Jonah crabs; and 10) used new prey preferences generated from the addition of ChesMMAP, NEAMAP, Overton et al.’s (2008) North Carolina striped bass diet study, and updated Food Habits Database diets.

Additional data and new parameter estimates in the MSVPA-X new base run have resulted in considerable changes in predator population size, predator consumption rate, and menhaden and other prey population size, trend, and predation mortality rate (see results in the following sections). Principal factors affecting the results appear to be 1) a significant downward trend in the weakfish population size in recent years, 2) changes in weakfish diet prey preferences (with less emphasis on menhaden for all ages of weakfish) and a possible functional response (assuming fewer large weakfish results in more small prey selected), and 3) impact on menhaden predation mortality from a three-fold increase in bluefish stock biomass from the new assessment, especially in early years of the time series. Uncertainties associated with the weakfish and bluefish population trends and magnitudes, and the lack of high-resolution diet information, continue to impact the outcome of the MSVPA-X analysis.

DATA INPUT AND MODEL PARAMETERIZATION

Unless otherwise stated, species data inputs were updated through 2006 as in the 2006 SARC run and model configuration was not changed. Below is a summary of major data sources and details of all changes made to the MSVPA-X since the 2006 SARC run.

Atlantic menhaden

Commercial Landings and Catch-at-Age (CAA)

Reduction fishery: Reduction fishery CAA was updated in the MSVPA-X through 2006. Landings from the reduction fishery have been provided to and summarized by the NMFS Beaufort Laboratory since 1955. The Beaufort Laboratory has also conducted biological sampling for the reduction fishery since 1955, based on a two-stage cluster design. This sampling is conducted over the range of the fishery, both temporally and geographically. Sampling protocols and estimation of catch at age are described in the latest updated assessment for Atlantic menhaden for ASMFC (2006b, §3.1.3).

Bait fishery: Bait fishery CAA was updated in the MSVPA-X through 2006. Landings from the bait fishery have been provided by the individual coastal states since 1985. It was noted during the 2006 update assessment for menhaden (ASMFC 2006b) that no landings were available from VA snapper vessels for 1993-97. A correction for these missing years was developed and used in the new base run. This correction was made by linearly interpolating between the average VA snapper-vessels landings before (11,157,236 pounds for 1989-1992) and average VA snapper-vessels landings after (38,795,454 pounds for 1998-2005) the missing years. To obtain VA bait landings for 1993-1997, these interpolated snapper-vessel landings were added to bait landings from other gears (e.g., gill net, pound net, haul seines). Unadjusted bait CAA was used in the continuity run. Biological sampling of bait landings has mostly been restricted to directed-bait, purse-seine vessels, who dominate the bait fishery in landings. Sampling protocols and estimation of CAA are described in the latest updated assessment for Atlantic menhaden for ASMFC (2006b, §3.2.3). Because sampling is much less intense than for the reduction fishery, estimated catch-at-age for the bait fishery is subject to greater uncertainty.

Tuning indices

Fishery-independent surveys: An aggregated juvenile abundance index was developed from six state seine surveys, namely NC, VA, MD, NJ, CT, and RI (Figure 1). The methodology for developing these individual indices and combining them into a coastwide juvenile abundance index is described in the recent update assessment for Atlantic menhaden for ASMFC (2006b, §4.16). In that menhaden update assessment, the NJ seine survey was included in the coastwide survey as an alternate run, and not in the base run. For this update of the MSVPA-X, the NJ seine survey is included in the coastwide index.

Potomac River Fisheries Commission pound net index: An improved version of this index employing pounds per days fished from the recent update assessment for Atlantic menhaden (2006b, §4.2) was used in the MSVPA-X base run (Figure 1). This version replaces an index based on Potomac River menhaden landings divided by pound net licenses. The earlier index was deemed biased subsequent to 1994 when the number of licenses was fixed at 100.

Striped bass

Catch-at-age matrix, weight-at-age, and tuning indices for striped bass used in this update of the MSVPA-X were taken from the most recent ASMFC striped bass assessment (NEFSC 2008).

Catch-at-age

Catch-at-age was estimated using standard methods (NEFSC 2008). Commercial landings-at-age were estimated by applying corresponding length-frequency distributions and age-length keys to the reported number of fish landed by the commercial fishery in each state. Length-frequencies of recreational landings were based on a combination of Marine Recreational Fisheries Statistics Survey (MRFSS) length samples and volunteer angler logbooks. State specific age-length keys were applied, where possible, to length frequencies to estimate number of fish-at-age landed by the recreational fishery. Age composition of the recreational discards was estimated using lengths available from volunteer angler logbooks and American Littoral Society data. State specific methods for estimating age composition of commercial landings, recreational landings, and recreational discards are provided in individual state compliance reports to ASMFC.

Annual weight- and size-at-age

Annual estimates of striped bass weights at age in the coast-wide population were reported in Barker (2005) and Barker and Warner (2007). The coast-wide WAA calculations were based on individual fishery elements for each state that reported landings and biological characteristics. The coast-wide WAA was calculated for each age as the weighted mean of the fish at that age in each fishery, where weights were the proportion of each fishery contribution (in numbers) to the coast-wide catch for that age.

Year specific size-at-age was calculated using year specific mean weight-at-age (Barker and Warner, 2007) and length weight relationship:

$$W_a = e^{-7.792 + 2.982 \ln L_a}$$

where W_a is mean weight (lb) at age a and L_a is mean total length (inches) at age a.

Tuning indices

Available striped bass abundance indices included both age-specific and aggregate indices from fisheries-dependent and fisheries independent surveys provided by the states and the North East Fisheries Science Center. The young of the year (age-0) indices were available from Maryland, Virginia, New Jersey, and New York and juveniles (age-1) indices are available for Maryland and New York. The Massachusetts commercial

CPUE, originally age-specific harvest-per-trip indices, were redeveloped as age-specific (ages 2–13+) total catch-per-hour indices. The New Jersey trawl, originally an aggregate index, was further apportioned into age-specific mean indices for ages 2–13+. Connecticut age-specific recreational catch indices are available for ages 2-9. Ages 10–13+ were aggregated to 10+. Maryland spawning survey index is age specific, representing ages 2 – 15+. The NEFSC spring inshore survey, originally age-specific, was reduced to an aggregate index (ages 2–9) and was truncated at 1991 due to missed sampling of inshore survey strata prior to 1991. The New York ocean haul seine survey indices for ages 8–13+ were aggregated into an 8+ index.

In the MSVPA-X continuity run, the Virginia pound net survey was updated through 2006 (data from Virginia Institute of Marine Science) and offset by one year to correct a data input mistake discovered in the SARC run. However, the Virginia pound net survey, a single fixed station, commercial pound net index, was not used in the new base run because few analyses conducted could support its continued use as an index that reflected striped bass abundance. Two new surveys used in the 2007 striped bass assessment were added to the MSVPA-X base run: age-specific (ages 2–13+) Delaware River electrofishing spawning stock indices and the coastwide MRFSS aggregate (ages 2–13+) total catch rate index. The Delaware trawl survey was mistakenly retained in this base run and will be removed when the model is rerun with updated weakfish catch data at the 2009 menhaden data workshop.

Weakfish

Catch-at-age

Catch-at-age data are supplied either individually by state, or by estimating catch-at-age from length-frequency data and applying regional length-weight and age-length relationships as appropriate (ASMFC 2006c, Part A). For the SARC-reviewed MSVPA-X model, the fishery catch-at-age matrix included commercial and recreational landings, and recreational discard estimates. Commercial discard estimates were not included at that time. The resulting catch-at-age matrix includes the period from 1982-2000 and includes age classes 1-6+. For the MSVPA-X update, the catch matrix is projected forward to include 2001 and 2002 based upon fishing mortality rates and population sizes calculated through 2000 (Table 1). For both the MSVPA-X continuity run and the new base run, the catch-at-age matrix includes removals from all four components. Regardless, there are several differences worth noting in the CAA matrix between the continuity and new base runs which are described in Table 2. Differences include new commercial discard estimation methodology, correction factors for weakfish-like species in recreational catch, updated recreational discard rates, and updated recreational discard length frequency estimation. Note that this CAA matrix is preliminary; once the ASMFC Weakfish Technical Committee approves the final matrix in preparation for the 2009 weakfish assessment, the MSVPA-X will be updated at the 2009 menhaden data workshop to reflect any changes in weakfish CAA.

Tuning indices

Four fishery-independent surveys provide age-specific indices of weakfish abundance for use in tuning the ADAPT and XSA approaches. In all three model runs (SARC, continuity, and new base run) only surveys encompassing the region between North Carolina and Delaware are used: the New Jersey coastal trawl survey, a Delaware Bay survey, the SEAMAP fall coastal survey in North Carolina waters, and the NMFS fall inshore survey. In addition, several juvenile indices based upon haul seine surveys in estuarine waters are included: the VIMS haul seine (age-1), the North Carolina DMF survey (ages-1 and -2), two surveys by Maryland DNR (both age-1), and a Delaware Bay survey age-1). For the new base run, one additional juvenile index (New York trawl) and one additional age-specific index (MRFSS HPUE, ages 3-6; ASMFC 2006c, Part A) were included. An additional sensitivity run was conducted using only the MRFSS ages 3-6 HPUE index as input for consistency with the 2006 weakfish stock assessment (ASMFC 2006c, Part A).

Annual weight- and size-at-age

Due to uncertainties in the methods (scales versus otoliths) used for length and weight analyses, the average derived weights and lengths from the 1990-1999 period were used in the MSVPA-X SARC and continuity runs. In the new base run, annual size- and weight-at-age estimates were calculated using year-specific von Bertalanffy parameters developed by Vaughan (unpublished data) for the period from 1990-1999 based upon otolith data (Kahn 2002b and D. Vaughn, SEFSC, pers. comm) and 2001 to 2006 (J. Brust, pers. comm.) (Table 3). The 1992 estimates were applied for the period from 1982 to 1991. For 2000, estimates from 1999 and 2001 were averaged.

Bluefish

In the SARC and continuity run, the time-series of bluefish stock biomass from 1982-2002 is derived from the ASPIC Biomass Dynamic model used in the ASMFC stock assessment (Lee 2003). The model uses recreational CPUE and the NEFSC inshore fall bottom trawl survey as tuning indices. Lee (2003) points out several areas of concern with this assessment model including: uncertainty as to the appropriateness of the NEFSC survey as an index of total biomass, assumptions of constant catchability in the fishery, and general concerns with the base assumptions of the simplified biomass dynamic model.

Biomass estimates for the MSVPA-X base run are derived from the 2005 ASAP age-structured model, a distinctly different method from the biomass production model used earlier. The model estimated biomass across all years at approximately three times greater than estimates resulting from the ASPIC model. Therefore, to update the MSVPA-X continuity run biomass stream, age-based biomasses were aggregated, then divided by three, for 2003-2006. The time series of total bluefish biomasses are shown in Figure 2.

An analysis of bluefish diet information based upon the NEFSC food habits database indicated significant breaks in bluefish diets in three size classes: 10-30 cm (ages 0-1), 30-60 cm (ages 2-3), and >60 cm (ages 4+). These three size classes were used in the MSPVA-X model to account for ontogenetic changes in feeding selectivity and consumption parameters. The proportion of the total biomass in each age class was estimated based upon the average size distribution from the previous age-structured assessment (NEFSC 1997). The proportion of biomass calculated for each size class was: Size 1 – 0.03; Size 2 – 0.26; Size 3 – 0.71 in the continuity run. For the new base run, these input values were adjust slightly – 0.08, 0.21, and 0.71, respectively - due to inclusion of new diet results (ChesMMAPP, NEFSC bottom trawl survey, Walter et al. 2003).

Other prey (non-menhaden)

Benthic invertebrates and macrozooplankton

The three primary benthic invertebrate taxa important in the diets of weakfish, bluefish, and striped bass are gammarid amphipods, isopods, and polychaetes. Regional density estimates for these benthic invertebrate taxa were developed from a systematic benthic sampling program of the U.S. Atlantic continental shelf described in Wigley and Theroux (1981) and Theroux et al. (1998). While these estimates of benthic invertebrate biomass are based upon several decades old data, there is not a more recent broadscale estimate of benthic biomass available over the U.S. Atlantic continental shelf. The resulting total estimated biomass of benthic invertebrates is 3,357,000 mt (NEFSC 2006). The size structure of the benthic invertebrate taxa was inferred from general descriptions of the observed size ranges in these habitats (NEFSC 2006).

Benthic crustaceans

The “other prey” group called benthic crustaceans in the MSVPA-X includes blue crab, lobster, rock crab, and Jonah crab. These species make up a small, but consistent, proportion of the diet of striped bass, bluefish, and weakfish (NEFSC 2006). In the continuity run, the average total estimated biomass for benthic crustaceans used in the last MSVPA-X was 91,471 mt (NESFC 2006). Due to the dominance of the blue crab component, the size distribution was based upon those developed for blue crabs from assessment data. The peak biomass is in the adult size classes between 13-16 cm carapace width (NESFC 2006). In the new base run, revised estimates of total annual total benthic crustacean biomass were obtained by summing results from all four species (Table 4).

<u>Blue crabs</u>: Blue crab population estimates on the Atlantic coast were available only for the largest, commercially important populations of blue crab in Delaware Bay, Chesapeake Bay and North Carolina sounds. Estimated biomass was summed across all three areas. Based on available diet data (R. Latour, VIMS ChesMMAP, pers. comm.), blue crab found in predator stomachs do not exceed the size of approximately 60 mm, so only total biomass of blue crab less than 60 mm in size was included in the analysis.

> *Chesapeake Bay.* The absolute abundance of the blue crab stock in Chesapeake Bay was estimated using the swept-area method. A winter dredge survey that utilizes stratified random design has been conducted since 1990. The survey is conducted during the winter, when crabs are dormant and "buried" in the bottom.

The catching efficiency of the survey gear is estimated from multiple depletion experiments to correct for temporal and vessel differences in catchability. Mean numbers of crabs per towed area are corrected for gear catchability and applied to the total area, thus producing the absolute abundance estimates. Details of the survey design and estimation procedure are presented in Sharov et al. (2002). Direct estimates of abundance are available for 1990-2007 period (L. Fegley, MD DNR Blue Crab Program, pers. comm.). Blue crab population estimates for the earlier period (1982- 1989) were based on absolute abundance values reported by Rugolo et al. (1998). Year specific estimates of population numbers were applied to the 1990-1999 average size frequency distributions from the winter dredge survey to produce numbers of crabs by size groups. Number of crabs per size interval was multiplied by the mean weight to estimate blue crab population biomass.

Delaware Bay. A blue crab assessment for Delaware Bay was recently completed by Richard Wong at the Delaware Division of Fish and Wildlife (Wong 2007). The assessment was based on a catch-survey model (Collie and Sissenwine 1983), incorporating observation and process error that produced annual estimates of absolute abundance, biomass, and fishing mortality rates from 1979 through 2006. Population estimates were presented for two groups of crabs, recruits (crabs with carapace width <=120 mm) and postrecruits (crabs with carapace width > 120 mm). Observations in Chesapeake Bay indicated that blue crabs have a relatively stable size frequency bimodal distribution in winter, when they stop growing. An average size frequency distribution observed in Chesapeake Bay was applied to absolute abundance estimates for crabs in Delaware Bay to obtain number of crabs per 10 mm size intervals. Biomass estimates were calculated by multiplying mean weight per size group by the number of crabs in each size category.

North Carolina estuaries. A stock assessment of blue crab in North Carolina was conducted by Eggleston et al. (2004). Collie-Sissenwine catch survey model was used to estimate absolute abundance of recruits (CW<127 mm) and postrecruits (CW=>127 mm). Total abundance estimates for 1982-2002 were distributed by 10 mm size groups using an average size frequency distribution observed in Chesapeake Bay. Finally, mean weights at size were applied to number of crabs per size group to produce biomass by size. No population estimates were available for the 2003-2006 period. A proxy of population size estimates for these years was applied by dividing the total annual harvest by the average exploitation rate observed in 1997-2002 period. Total biomass was allocated by size groups as described above.

Lobster: Estimates of lobster pre-recruit abundance by stock area (Gulf of Maine, Georges Bank, and Southern New England) were obtained from assessment results (ASMFC 2006a). Estimates selected for the 2008 MSVPA-X base run were those derived from the enhanced Collie-Sissenwine Model. This assessment spanned 1982-2003 with some exceptions. In the Southern New England stock unit, no abundance estimates were available prior to 1984, so the average abundance estimate from 1984-

1986 was used for 1982 and 1983 in the MSVPA-X update. Due to anomalous recruit catches in the 2003 NEFSC and MA surveys, the average abundance in Gulf of Maine from 2000-2002 was used for 2003 and 2004-2006. To gap-fill missing years (2004-2006) in Southern New England and Georges Bank, averages of recent years (2001-2003) were used in the MSVPA-X base run. In all three stock areas, these were the multiple-year averages used to determine stock status (ASMFC 2006a, Tables 7.1.1-7.3.1, page 45). Total abundance across all three stock areas was summed and multiplied by a mean weight of 57.38 g to obtain biomass estimates (NEFSC 2006).

Rock and Jonah Crab: For rock and Jonah crabs, there is no detailed assessment data from which to derive information on total biomass. However, the NEFSC bottom trawl survey samples and quantifies (number and weight) both species. Raw trawl survey data were obtained from 2001 – 2006 and seasonal (winter, spring and fall) catch rates (number and biomass per tow) were developed annually. Catch rates were not developed on a regional basis, as was done in 2005 – one catch rate was developed for an entire survey for a particular season. Similar to the procedure for bay anchovy, the catch rates were converted into minimum trawlable biomass estimates assuming a trawl swept-area of 0.0315 km^2 (NEFSC 2006), a total survey area of 150,382 km^2 (area includes Chesapeake Bay even though not sampled), a gear efficiency of 100%, and using the biomass data for each tow instead of a calculated mean weight (the latter was done in 2005).

Annual total biomass estimates were the most variable in the spring, greater than six-fold differences, and least variable in the winter. Average (2001 – 2006) total biomass estimates, by season, for rock and Jonah crabs combined were as follows: winter – 5,426 mt; spring – 313 mt; fall – 439 mt. These 2007 average biomass estimates are different than the average biomass estimates calculated in 2005 (Figure 3), particularly for the spring season. (Note: the spring and fall estimates from the 2005 assessment were reversed – i.e., the spring estimate was 2,220 mt and the fall estimate was 287 mt, not vice versa as was used.) Also, the winter data was not used or available during the 2005 assessment because that data was not collected until 2002, the terminal year of the 2005 assessment. Combined rock and Jonah crab biomass estimates for 2002-2007 were averaged across seasons. The 2002-2007 average of these annual biomass estimates (2015 mt) was used as the final biomass estimate for rock and Jonah crabs from 1982-2006.

Other Clupeid Data

The sum of Atlantic herring, Atlantic thread herring, Spanish sardine, and scad estimated biomasses were summed to create the “other clupeid” non-menhaden prey group (Table 5).

Atlantic herring: Recent results from an age-based assessment model, including population abundance estimates, were provided by Matt Cieri (ME, pers. comm) for use in the new base run. Formerly, reported Atlantic herring landings were divided by 0.05 (assuming F~0.05). These new estimates are more precise (and generally lower) than the previous crude estimates used in the 2005 SARC review of MSVPA-X.

Atlantic thread herring: Two sources of information were used for obtaining landings of this species along the Atlantic coast: 1) NMFS commercial landings website (http://www.st.nmfs.gov/st1/commercial/index.html), and 2) landings from the menhaden reduction fishery (Beaufort Fisheries in NC) from Joseph Smith (Beaufort Laboratory, pers. comm). Updated landings from the NMFS commercial website were obtained, but there were no landings in recent years from menhaden reduction with closure of Beaufort Fisheries after the 2004 season.

Spanish sardine and scad: The source of information for Spanish sardine and scad landings was from the NMFS commercial landings website. This site was used to update landings for these two species.

Medium forage fish – butterfish and squid

To obtain biomass estimates for butterfish, average weight per tow from the fall NEFSC survey was multiplied by a swept area of 0.0389358 km^2, divided by a total stock area of 146,324 km^2, and divided by 1,000 to convert to metric tons.

To obtain biomass estimates for *Loligo* and *Illex* squid, average weight per tow from the fall NEFSC survey was divided by a catchability of 0.45, multiplied by a swept area of 0.0389358 km^2, divided by a total stock area of 146,324 km^2, and divided by 1,000 to convert to metric tons.

Bay anchovy

Estuary Biomass Calculations**:** During a majority of the year, bay anchovy biomass in the estuary is relatively constant; however, during the late summer and fall following recruitment, anchovy biomass increases dramatically as age-0 fish undergo rapid growth (Newberger and Houde 1995). Based on survey data collected in 1993, Rilling and Houde (1999) estimated baywide (Chesapeake Bay) biomass during June and July to be approximately 23,000 metric tons. More recently, Jung and Houde (2004) estimated baywide anchovy abundance over a number of years (1995 – 2000) and seasons (spring, summer and fall) with their results showing extreme seasonal and annual variability.

The average bay anchovy estuary biomass, by season, was calculated using data from both published reports. The new data (Jung and Houde 2004) altered the seasonal estuary estimates from the 2005 MSVPA assessment (Figure 4) – new seasonal estuary estimates are as follows: winter – 10,300 mt; spring – 10,300 mt; summer – 23,400 mt; fall – 104,000.

Coastal Biomass Calculations: The New Jersey Ocean Trawl survey database was used to develop bay anchovy biomass estimates to apply to near shore coastal waters. During the survey, the total weight of each species is measured in kg and the length of all individuals, or a representative sample by weight for large catches, is measured to the nearest cm following each tow. Minimum trawlable biomass estimates were developed assuming a 100% gear efficiency using the following equation:

$$B = (cA/a) / e \qquad \text{(from Link and Almeida 2000)}$$

where: B is absolute biomass, c is mean catch per tow, A is total survey area, a is area swept per tow; e is the net efficiency. Minimum trawlable biomass estimates were developed on an annual and seasonal basis. The mean biomass estimate for the timeseries (1989 – 2006) was used to determine the total seasonal biomass estimate along the New Jersey coast. The seasonal trends for bay anchovy off the New Jersey coast are similar to those for Chesapeake Bay, although the absolute biomass values are quite different (Figure 4).

Annual estuary and coast indices: Bay anchovy data from various fishery-independent survey datasets (7 total) were used to develop annual estuary specific indices for Chesapeake Bay and Delaware Bay and a grand Estuary Index to apply to all other coastal estuaries. The data were Z-transformed to normalize and standardize all datasets. The transformed indices were then weighted in order to combine indices and create a grand index for the Chesapeake Bay and Delaware Bay. The estuary specific indices were then re-weighted and combined for a grand Estuary Index that would be applied to the other estuaries (Figure 5). Data from the NJ Ocean Trawl survey and the SEAMAP survey were used to develop the yearly Coastal bay anchovy index. As with the estuary indices, the data were Z-transformed and weighted to develop a single annual coastwide index (Figure 5).

Annual and seasonal indices: The seasonal estuary biomass estimates developed by Rilling and Houde (1999) and Jung and Houde (2004) and were determined from data collected in 1993 and 1995-2000. Since a single seasonal biomass estimate was developed, the 93/95-00 data were used as the ‘reference period’ to then scale the annual (1982 – 2006) Estuary indices to the average 93/95-00 index to determine the annual seasonal biomass estimates. First, annual seasonal densities (biomass km^{-2}) were calculated for each of the estuaries along the coast – Buzzards Bay, Long Island Sound, Hudson River Estuary, Delaware Bay, Chesapeake Bay, Neuse River and Pamlico Sound (GIS tools were used to determine estuary and coastal water area – km^{2}). The density inside Chesapeake Bay was assumed to be similar to that in other estuaries, but the appropriate scaled index value was applied to the appropriate estuary to develop the seasonal densities (ex. formula: [season biomass * scaled index value] / regional area). The calculated seasonal densities were then multiplied by the respective estuaries total area (km^{2}) to determine the annual seasonal biomass estimate for each estuary. All of the individual estuary estimates were summed to determine the total estuary bay anchovy biomass.

A similar procedure was followed with the coastal estimates. For consistency with the estuary estimates, we scaled the annual coastal estimates to the 93/95-00 reference period to determine the annual seasonal biomass estimates – note: from 1982 through 1988, coastal biomass estimates are constant and are equivalent to the 93/95-00 reference period because the coastal surveys used in this analysis has not begun until 1989. We determined the annual seasonal densities (biomass km^{-2}) for the New Jersey coast and the remaining coastal waters (out to 10 nautical miles from shore) and assumed the density along the Jersey coast was similar to that along other parts of the coast and applied the appropriate scaled index value to develop the seasonal densities. As with the estuaries estimates, the calculated densities were multiplied by the corresponding coastal total area and then all of the coastal areas were summed to get the total coastal bay anchovy biomass. The total estuary and coastal estimates were then summed to develop the overall annual seasonal bay anchovy biomass.

Sciaenids

Spot and croaker biomass estimates were updated with new landings information for 2003-2006. Total annual spot and croaker biomass estimates were summed to create the "other prey" class called "sciaenids" (Table 6).

> *Croaker*. Estimated trends in croaker biomass for 1982-2002 were obtained from assessment results (ASMFC 2005). Because biomass estimates were not available for recent years, total recreational (North, Mid, and South Atlantic MRFSS) and commercial landings (ME to NC) were summed by region (Mid and South Atlantic). Regional landings were converted to biomass using 2002 region-specific exploitation rate estimates (Mid U = 0.2, South U = 0.33) generated during the 2005 assessment. Biomass estimates from both regions was summed to generate a total croaker biomass trend in recent years.
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> *Spot*. As in the 2005 MSVPA-X, spot biomass estimates for 2003-2006 were calculated by summing total recreational (North, Mid, and South Atlantic MRFSS) and commercial landings (ME to NC). Catch was then converted to biomass using an assumed exploitation rate of 0.288 (F = 0.4, Z = 0.7).

Predator diets

Selectivity indices

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 when they are available. The strategy used to develop type indices for each predator is outlined as follows:

1) For each region, summarize available data to develop an average diet for each season and age class.
2) Calculate the seasonal biomass of each prey type in the region based upon the estimated biomass and spatial distribution of each prey type (used in the spatial overlap analyses).
3) Calculate a quantitative electivity index as the ratio between the proportion of the prey in the diet vs. the proportion of the prey biomass, and normalize so that these electivity values sum to one. This is equivalent to calculating Chesson's electivity index.
4) For each predator age and prey type, calculate the average of this quantitative index weighting by the proportion of the predator biomass in each region. Thus, the average selectivity will therefore reflect data from the region(s) containing the majority of each predator's biomass.

5) Rank the resulting overall values, and use these as the rank type-preference index in the model. The rank indices reduce the effects of poor estimation of biomasses in each region that may result in biases in the quantitative indices.

For the predators considered in this model, diet composition data were obtained from a variety of sources ranging from fairly large-scale food web dynamics programs to smaller scale studies focused on species within particular locations, seasons, and time periods. The continuity run of the model included prey preferences used in the SARC run (NEFSC 2006). New diet data incorporated into prey preferences for the new base run included updated Northeast Fisheries Science Center Food Habits database (FHDBS) and three new data sources: the Chesapeake Multispecies Monitoring and Assessment Program (ChesMMAP), the Northeast Monitoring and Assessment Program (NEAMAP), and Overton et al. (2008). The large-scale datasets used include the FHDBS, ChesMMAP, and NEAMAP. The smaller-scale studies include Hartman and Brandt (1995), Walter and Austin (2003), Buckel et al. (1999), Juanes et al. (2001), Buckel and Conover (1997), and Overton et al. (2008). A compilation of all of these data sources was used to develop overall rank indices of type preference for each predator species and age class in the new base run.

NEFSC: The food habits database (FHDBS) is based on the Northeast Fisheries Science Center's (NEFSC) standardized bottom trawl survey that is conducted twice a year (spring and fall) in the northwest Atlantic Ocean from Nova Scotia to Cape Hatteras, NC (approximately 293,000 km^2). The survey was initiated in 1963 and is based on a stratified random design, where the strata are chosen according to water depth, latitude, and historical fishing patterns. Sampling stations are allotted to each stratum in proportion to its area (approximately one station per 690 km^2), with some exceptions to ensure at least two stations are assigned to small strata (Link and Almeida 2000). Since its inception, the survey has provided a wealth of information on the diet composition (since 1973 over 250,000 stomachs have been collected) and trends in abundance and distribution of commercially important fish species (Link and Almeida 2000).

Diet summaries derived from the FHDBS are typically calculated by treating each stomach as a random sample in one of three possible statistical designs: unweighted random, stratified, or two-stage clustered (Link and Almeida 2000). From the food habits data, proportion frequency of occurrence of prey items, total stomach contents as either volume or weight, and mean proportion diet composition of prey items are estimated. For diet composition data need in the selectivity model in the MSVPA-X, the diet index mean proportion by weight following a two-stage cluster design was used.

ChesMMAP & NEAMAP: The ChesMMAP survey employs a bottom trawl designed to sample late-juvenile and adult fishes in the mainstem Chesapeake Bay (i.e., non-tributary waters). Each year, research cruises are conducted (March, May, July, September, and November) and approximately 80 to 90 sites are sampled during each cruise. Sampling locations are chosen according to a stratified random design, with strata based on water depth (3-9 m, 9-15 m, and >15 m) within five 30-latitudinal minute regions of the bay. The locations sampled in each stratum of each region are randomly selected and the number was in proportion to the surface area of that stratum. The catch from each tow is sorted and individual lengths are recorded by species or size-class if distinct classes within a particular species were evident. Stomachs are removed from a subsample of each species or size-class and immersed in preservative for diet composition analysis following each cruise.

The NEAMAP survey was recently initiated in response to an existing paucity of fisheries-independent data in the coastal waters of the mid-Atlantic Bight, and because of anticipated loss of survey area due to the NEFSC's replacement of the *R/V Albatross* with the *FSV Henry B. Bigelow* (i.e., larger vessel with deeper draft – the longstanding groundfish survey will no longer be able to sample inshore areas). The NEAMAP survey employs a bottom trawl designed to sample late-juvenile and adult fishes along the U.S. eastern coastline from Martha's Vineyard, MA to Cape Hatteras, NC. Sampling locations are chosen according to a stratified random design, with strata based on water depth (6 - 12 m and 12 -18 m) and latitude. Diet composition data for weakfish from the pilot and first official cruises (conducted in fall 2006, 2007, respectively) were incorporated into the model. The catch from each tow is sorted and individual lengths are recorded by species or size-class if distinct classes within a particular species were evident. Stomachs are removed from a subsample of each species or size-class and immersed in preservative for diet composition analysis following each cruise.

The right sagittal otolith is typically used to determine the age of fishes collected by the ChesMMAP and NEAMAP surveys. A thin transverse section is cut through the nucleus of the otolith and the resulting section is mounted on a glass slide. Annuli are counted by viewing the slide under a dissecting microscope using transmitted light (500X magnification).

The stomach contents of each predator collected by the ChesMMAP and NEAMAP surveys are removed for identification to the lowest possible taxon. Prey encountered in the esophagus and buccal cavity are included for identification (and assumed not to be the result of net feeding due to lack of retention in large mesh gear), while those in the intestines are ignored due to the difficulty associated with identifying prey items in the advanced stages of digestion. All prey items are sorted, measured (either fork or total length, as appropriate and when possible), and the wet weight (0.001 g) of each is recorded.

The proportion of each prey type to the diet by weight (W_k) is calculated from the stomach contents of fishes collected by the ChesMMAP and NEAMAP surveys using the following equation (Bogstad et al. 1995, Buckel et al. 1999):

$$W_k = \frac{\sum_{i=1}^{n} M_i q_{ik}}{\sum_{i=1}^{n} M_i}, \quad \text{where } q_{ik} = \frac{w_{ik}}{w_i},$$

and n is the number of trawls containing a specific predator, M_i is the number of predators collected at sampling site i, w_i is the total weight of all prey items encountered in the stomachs of predators collected from sampling location i, and w_{ik} is the total weight of prey type k in these stomachs.

Disparity among analyses of diet data

Unfortunately, the diet composition indices derived from the various data sources were not all based on the same underlying statistical sampling design for the collection of fish stomachs. Several of the older published studies (e.g., Hartman and Brandt 1995) assumed simple random sampling and thus used an arithmetic mean as the estimator for proportion by weight. The indices based on data from the fisheries-independent monitoring programs were calculated in accordance with a cluster sampling design and therefore utilized a cluster sampling estimator (see above equation). Since the index proportion by weight can vary considerably between the simple random and cluster sampling estimators, there is a need for consistency. Attempts were made to only utilize cluster based estimates of diet for the MSVPA-X, however, the trawl survey data alone was not comprehensive enough to yield reliable prey-type rankings. Hopefully as additional diet data become available in the future, it will be possible to base the MSVPA-X on a more uniformly analyzed diet composition database.

Temperature

Variable temperature by year and season from new buoys were updated in both the continuity and new base runs.

RESULTS

Atlantic menhaden

This section summarizes MSVPA-X model output for Atlantic menhaden from three project runs. These model project runs include: (1) SARC base run (1982-2002), (2) continuity run (1982-2006), and (3) new base run (1982-2006). Changes in model input among these project runs are described above. First, we compare four output parameters for Atlantic menhaden: (1) total population abundance (ages 1-6), (2) recruits to age-0, (3) spawning stock biomass (SSB), and (4) average-recruited fishing mortality (F2+). For output parameters (2) - (4), we also include estimates from the most recent single-species assessment for Atlantic menhaden (2006 update assessment) in our comparison. Subsequently, we describe and compare the contribution of the three modeled predators (bluefish, striped bass, and weakfish) to M2, as well as overall estimates of M2 for Atlantic menhaden.

Total population abundance (ages 1+) of Atlantic menhaden showed a decline over the study period from 1982 to 2001 for all three project runs (Figure 6). The SARC base and continuity runs were very similar, while the new base run suggested somewhat higher population abundance in the earlier years, but converged very closely in the most recent years with the other project runs. Recruitment to age-0 menhaden also showed a general decline over time for all three project runs, as did the 2006 update assessment (Figure 7). The new MSVPA-X base run suggested higher recruitment in the earliest years, probably associated with higher M2's in those years because of bluefish predation (see next section). Although there were periods of divergence, the estimated Atlantic menhaden spawning stock biomass (SSB) for the three MSVPA-X runs and the 2006 menhaden update assessment showed remarkably similar patterns (Figure 8). The 2006 update assessment did suggest an upturn in SSB in its last two years (2004-2005).

Menhaden fishing mortality rates (F2+) were calculated in two ways: (1) unweighted average of F for ages 2 and older, and (2) weighted average of F for ages 2 and older. The weighting used in method 2 is population numbers at age. Method 1 estimates were provided by the MSVPA-X program, while method 2 estimates were calculated from age specific estimates of N and F provided by the MSVPA-X program. The 2006 update assessment (and previous single-species assessments) provided estimates based on method 2. Atlantic menhaden were essentially fully recruited to the fishery by age 2 (selectivity analyses from previous single-species assessments). Only small differences were noted when comparing these two methods for the new MSVPA-X base project run (Figure 9), with only small divergence observed in some of the recent years. We first compared estimates of F2+ using method 1 among the three project runs (Figure 10). The SARC base and continuity run estimates of F (2+) lined up very closely, while the new base run suggested somewhat lower values of F (2+) in the earlier years. We next compared estimates of F2+ based on method 1 including the results from the 2006 update (Figure 11). The 2006 update assessment generally suggested lower fishing mortality and a greater decline during the study period than that suggested by the three project runs.

Estimates of predation mortality component (M2) on Atlantic menhaden by the three modeled predators (bluefish, striped bass, and weakfish) were developed by age of menhaden for each of the three project runs (SARC base run, continuity run, and the new base run). For age-0 menhaden, the SARC base run and continuity run suggests that weakfish were the dominant predator on menhaden, with bluefish being important in the early years of this study (1980s) and striped bass becoming more important subsequently (Figures 12-13). The new base run paints a different picture (Figure 14). This run suggests that bluefish was the most important predator, especially in the early years, with striped bass becoming increasingly important as that stock rebuilt. The new base run also suggested that weakfish played a relatively minor role in menhaden consumption (e.g.; smaller M2). As age of the menhaden increased, the proportion of M2 associated with weakfish declined for all three project runs (essentially zero by age 3 menhaden) (Figures 15-20). Note the increase in consumption of 2+ menhaden by striped bass concurrent with the recovery of the striped bass stock (Figures 20-24).

Estimates of total M2 (summed across the 3 modeled predators) were then compared for ages 0-2 menhaden. For age-0 menhaden, the SARC base run provided somewhat lower estimates in the 1980s, and generally intermediate values in the 1990s (Figure 25). Higher values of M2 are noted in 2001 and 2002. The continuity run generally follows the same trends as the SARC base run with somewhat higher estimated M2. The new base run suggests that estimated M2 was higher in the earlier years when bluefish were more abundant and generally smaller in the 1990s when bluefish were less abundant. Estimated M2 on age-0 menhaden gradually increased, starting in the early 1990s as striped bass populations increased (more gradually than suggested by the SARC base and continuity runs). For ages 1 and 2, lowest estimates of M2 were associated with the SARC base run, somewhat higher estimates with the continuity run, and highest estimates generally with the new base run (Figures 26-27). The change in inputted bluefish and weakfish diets on menhaden likely accounts for this pattern change, which is especially notable in the early years (1980s).

In summary, total population abundance, and recruits to age-0 are similar in trend and magnitude among the MSVPA-X project runs and the latest single-species assessment (ASMFC 2006b). Average F (2+) is generally lower from the latest singles-species assessment compared to the several MSVPA-X project runs. There has been a switch in importance of predators towards bluefish and away from weakfish when comparing the SARC base run (and continuity run) as compared to the new base run. The new base run suggests that M2 estimates are higher in the 1980s (when bluefish were more abundant) than more recently. Otherwise, M2 estimates are generally comparable among the project runs since about 1990.

Striped bass

A comparison of striped bass population estimates from the MSVPA-X SARC (data through 2002), continuity, and new base runs (data through 2006) showed similar trends in absolute population size through 1993 (Figure 28). The population size estimate in a new base run are substantially higher and show an increasing trend in striped bass abundance compared to the previous run. These differences are most likely explained by the effect of additional years of data (more years of exploitation history on a number of cohorts). Similarly, striped bass SSB is growing much more rapidly in the new base run compared to the previous results (Figure 29). Recruitment of striped bass in the updated MSVPA-X is also higher compared to the SARC run (Figure 30). Effects on fishing mortality are of the opposite nature – fishing mortality in the updated model are lower and declining compared to SARC run (Figure 31); an expected increase in F with reopening of the fishery in the early 1990s was not observed.

A comparison of MSVPA-X population estimate of striped bass with the population numbers from the 2007 peer reviewed striped bass stock assessment indicated that MSVPA-X model estimated a substantially higher (60 % difference in 2006) striped bass total abundance, while the trend in abundance is the same (Figure 32). Difference in population size estimates is attributed to the difference in structure of assessment models (XSA in MSVPA-X versus statistical catch-at-age). In the future, the MSTC subcommittee will explore alternate XSA configurations and try to reduce the discrepancies in population and F estimates between the MSVPA and the single species striped bass models.

Total consumption of menhaden by striped bass population is notably higher in new base run for most of the time series (Figures 33-34). Menhaden consumption is exponentially increasing in the most recent years.

Weakfish

The 2006 stock assessment for weakfish (ASMFC 2006c, Part A) used a combination of ADAPT VPA and production modeling with a Type III functional response for predation (i.e., Steele-Henderson). Results indicated that weakfish stock biomass was generally low throughout the 1980s into the early 1990s. Fisheries regulations put into place in the mid-1990s to restore the stock (Amendment 3 to the Interstate Fishery Management Plan for Weakfish) resulted in moderate increases in abundance and biomass through the late 1990s; however, decreases in stock size have been evident since 2000. Formal comparisons between MSVPA-X update model outputs and single species assessment results were not examined because weakfish is currently undergoing the assessment process. The MVSPA-X base run will be updated with the final weakfish CAA inputs once they are approved by the Weakfish TC and comparison of single species results will be conducted once the current assessment for weakfish is peer reviewed and approved (SARC reviewed scheduled for summer 2009).

The SARC, continuity, and new base runs of the MSVPA-X show a similar pattern in population abundance. All three runs show high population levels during the 1985-1989 time period, followed by a decline (Figure 35). All three model runs show a gradual increase in population abundance until approximately 1998. Thereafter the SARC configuration showed a much different trend in population abundance when compared to the continuity run, and the new base run. The SARC run suggested that population abundance increases, while the other two runs show a precipitous decline to historic lows. The downward turn in weakfish population estimates for more recent model runs is likely due to a recent downward correction in the NMFS survey.

Overall there were no major differences between either the continuity run or the new base run with respect to average recruited fishing mortality, both trend and pattern (Figure 36). All three model configurations show high but variable fishing mortality rates prior to 1988, varying degrees of mortality declines, followed by increasing mortality. All three configurations showed that fishing mortality is very high in recent times (close to 2.0) and in the past. This scale of fishing mortality is probably not realistic. The committee is not certain of the cause, but suspects that changes in the catch-at-age as well as the surveys utilized may have some effect. It should be noted that the MSVPA-X, as per the SARC peer reviewers' comments (NEFSC 2006), cannot and should not serve as a single species indicator over status. Managers and the public should utilize the single species assessment for status determination, rather then the outputs of the MSVPA-X.

From 1988-1995, the SARC configuration showed similar trend and pattern in fishing mortality when compared to the continuity and base runs, but scale is noticeably higher. After 1995 all three configurations seem to converge. Overall fishing mortality in the new base and continuity runs seem to indicate an increase from 2001 through the present with little difference between these two configurations noted in either scale or trend.

All three configurations again show similar trends in SSB until 1998; unlike abundance, there seems to be some differences in magnitude (Figure 37). Overall SSB seems to be lagged with abundance; however there is a peak in the 1994 to 2000 time frame that does not appear quite so prominently in the abundance trend. Since 1998, the SARC run diverged from the continuity and the new base run in a similar manner to abundance. It is interesting to note the differences in scale between SSB for the continuity and the new base run, suggesting the addition of variable weight-at-age may have played a contributing factor to these differences.

Similar to both abundance and SSB, all three configurations had similar trends in recruitment until approximately 1996, showing high recruitment until 1984-1986, followed by a decline in 1987, a steady increase until 1993 and then a rapid decline (Figure 38). In 1998, the SARC run diverged from the others, showing an increase in recruitment similar to the pattern seen in SSB and abundance. This is expected given the differences in both population abundance and SSB among the runs.

Large differences in consumption of various prey species can be seen in Figure 39 among model configurations. All three runs show a dependence of weakfish on bay anchovy, benthic invertebrates, and menhaden. However, overall consumption in the continuity and new base runs show reductions in overall consumption; as expected, declines in consumption were not seen in the SARC configuration, which had shown an increase in weakfish abundance in later years. Differences among runs are most apparent in consumption of menhaden. The continuity run showed high menhaden consumption prior to stock declines in the late 1990s, higher in fact than the SARC run. After 1998, the SARC configuration showed fairly high consumption of menhaden by weakfish, while the other runs do not. Interestingly, the new base run shows similar trends in menhaden consumption prior to 1998; but lower consumption in the 1993-present time frame when compared to the continuity configuration.

A sensitivity run, in which only the MRFSS HPUE index was used to tune the MSVPA-X, indicated no substantial differences in model performance.

Bluefish

Trends in bluefish biomass are similar among the SARC run, continuity run, and new base run. Each begins with high biomass (>225,000 mt) in the 1980s and steadily declines to a low (<100,000 mt) in the mid-1990s. Biomass then increases to a moderate level in more recent years, to levels between 100,000-150,000 metric tons (Figure 2).

Biomass levels differ three-fold across all years when comparing the three runs. This is due to different input data in the new base run following results from the most recent assessment model, an age-structured model (ASAP) that produced biomass estimates three times higher than the previous model (Biomass Dynamic Model) used in the SARC and continuity runs. A comparison of biomass trends among the three modeled predators can be found in Figure 40.

Diet composition of bluefish is very similar among all MSVPA-X runs (Figure 41). The only notable difference is the reduced proportional consumption of benthic crustaceans and increased consumption of menhaden in the largest (60+cm) size class in the new base run.

RETROSPECTIVE PATTERN ANALYSIS

When the MSVPA-X is run with a terminal year of 2003, little retrospective pattern is observed compared with 2006 estimates (see Figure 42 for striped bass XSA example). However, due to extremely large, sudden changes in many striped bass, weakfish, and menhaden tuning indices in 2004, extremely large retrospective pattern (overestimation of predator biomass and abundance) is observed when the model terminates in that year.

MODEL UTILITY FOR MANAGEMENT

The committee suggests this updated iteration of the MSVPA-X has management utility. However, the committee gives some caveats to the interpretation of the results. Similar caveats were suggested during the peer review of this model by the SARC, and what follows are the recommendations for how this model can be best utilized for management.

The committee notes this model was not designed for setting reference points or harvest limits for single species. Additionally, examination of local abundance or depletion is not possible with this model. The MSVPA-X was conceived, in part, to provide accessory information; not to replace the single species assessments already in place. This formulation employs the Extended Survivor's Analysis (XSA) method; output from the XSA may not correspond exactly to outputs from single species assessments as peer reviewed.

While the "other prey" items are included in this iteration of the MSVPA-X and represent the best estimates available, they are primarily inputs into this analysis and are not explicitly modeled. Further, they are grouped by "type" to reflect guild functions within the prey field and in their respective ecosystems. Consequently, model outputs defining consumption of prey should be used with caution. Resulting population sizes of "other prey" items in this analysis should not be used for management. Decision makers should reference single species assessments, where available, for the "other prey" items.

The MSVPA-X has the potential to improve single species assessments by providing estimates of the natural mortality (M) at age (or by year, as appropriate) for explicitly modeled prey species. This has already been accomplished for menhaden in the 2003 benchmark and the 2006 Update to the assessment (ASMFC 2004, ASMFC 2006b). However, menhaden population size was estimated using a different single species assessment model and overall natural mortality was specified within that single species assessment. The committee recommends continuation of the single species assessment and methodology concerning estimates of menhaden natural mortality

Additionally, decision makers can be shown the 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 manageable under the same body. Further analysis may allow for the management of prey using total mortality, rather than fishing mortality.

The MSVPA-X, in principle, may examine prey availability and tie that availability to both growth rates and its effects on the predator species by age class. However, 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 can examine the interactions among predators and prey, without the confounding effects of growth of predators. This is an area where more modeling research is needed, but can be included in the next peer review, if necessary.

While model projections are not provided with this update, managers are reminded such projections are readily available, and the methodology has been peer reviewed. The projection portion of the MSVPA-X provides many opportunities to explore different moderate and long-term management scenarios. For example the MSVPA-X can also provide insight on multiple species target biomasses based on trade-offs among predators and prey. The seasonal resolution in this model may provide insight as to when an explicitly modeled prey stock could be important for a given predator. The model could also provide guidance for rebuilding predator stocks and the interactions between a specific predator biomass target and availability of prey species for other stocks of concern should that target be realized.

Based on thorough review and testing of the MSVPA-X model, the committee suggests this updated formulation is capable of answering management questions about predator/prey interactions among explicitly modeled species (currently striped bass, weakfish, bluefish, and menhaden). With clear understanding of the MSVPA-X's abilities and limitations described above, the MSVPA-X approach has the potential to provide much accessory information for fisheries managers.

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Table 1. Preliminary revised weakfish catch-at-age, 2001-2006 (J. Brust, NJDEP, pers. comm.).

	Age classes					
Year	1	2	3	4	5	6+
2001	1,411	3,738	1,650	1,034	515	516
2002	580	648	2,441	816	392	417
2003	387	949	852	527	101	265
2004	1,191	2,233	949	134	61	451
2005	341	1,581	1,240	196	10	345
2006	1,236	1,979	1,244	229	40	235

Table 2. Differences in calculation of weakfish catch-at-age between the 2008 MSVPA-X continuity and base runs.

	Continuity Run	Base Run
Commercial harvest		No change
Commercial discards	Multi-year discard to harvest ratios for key gear/target species combinations	Annual discard to harvest ratios for key gear/target species combinations
Recreational harvest	MRFSS estimates	MRFSS estimates corrected for sand seatrout and seatrout-weakfish hybrids in Florida estimates
Recreational discards	MRFSS B2 estimates 20% discard mortality rate (N_{B2} * 0.20) LF of MRFSS AB1 used to characterize LF of B2	MRFSS estimates corrected for FL sand seatrout 10% discard mortality rate (N_{B2} * 0.10) NEFSC fall trawl LF distribution used to characterize LF of B2

Table 3. Variable weight- and size-at-age (WAA and SAA, respectively) for weakfish used in new base run of MSVPA-X (D. Vaughan, SEFSC, and J. Brust, NJDEP, pers. comm.). Weights measured in kg and size measured in cm.

	Age class													
	0		1		2		3		4		5		6+	
Year	WAA	SAA	WAA	SAA	WAA	SAA	WAA	SAA	WAA	SAA	WAA	SAA	WAA	SAA
1982	0.027	5.3	0.0273	14.22	0.1813	26.65	0.4770	36.73	0.8748	44.92	1.3261	51.57	1.7901	56.97
1983	0.027	5.3	0.0273	14.22	0.1813	26.65	0.4770	36.73	0.8748	44.92	1.3261	51.57	1.7901	56.97
1984	0.027	5.3	0.0273	14.22	0.1813	26.65	0.4770	36.73	0.8748	44.92	1.3261	51.57	1.7901	56.97
1985	0.027	5.3	0.0273	14.22	0.1813	26.65	0.4770	36.73	0.8748	44.92	1.3261	51.57	1.7901	56.97
1986	0.027	5.3	0.0273	14.22	0.1813	26.65	0.4770	36.73	0.8748	44.92	1.3261	51.57	1.7901	56.97
1987	0.027	5.3	0.0273	14.22	0.1813	26.65	0.4770	36.73	0.8748	44.92	1.3261	51.57	1.7901	56.97
1988	0.027	5.3	0.0273	14.22	0.1813	26.65	0.4770	36.73	0.8748	44.92	1.3261	51.57	1.7901	56.97
1989	0.027	5.3	0.0273	14.22	0.1813	26.65	0.4770	36.73	0.8748	44.92	1.3261	51.57	1.7901	56.97
1990	0.027	5.3	0.0273	14.22	0.1813	26.65	0.4770	36.73	0.8748	44.92	1.3261	51.57	1.7901	56.97
1991	0.027	5.3	0.0273	14.22	0.1813	26.65	0.4770	36.73	0.8748	44.92	1.3261	51.57	1.7901	56.97
1992	0.027	5.3	0.0273	14.22	0.1813	26.65	0.4770	36.73	0.8748	44.92	1.3261	51.57	1.7901	56.97
1993	0.027	5.3	0.0363	15.63	0.1315	23.96	0.2920	31.22	0.5092	37.54	0.7692	43.05	1.0577	47.84
1994	0.027	5.3	0.0692	19.36	0.1808	26.62	0.3460	33.02	0.5562	38.66	0.8005	43.62	1.0674	47.99
1995	0.027	5.3	0.0715	19.67	0.1525	25.30	0.2653	30.41	0.4065	35.05	0.5716	39.25	0.7555	43.07
1996	0.027	5.3	0.0659	19.14	0.1523	25.29	0.2761	30.82	0.4330	35.79	0.6171	40.26	0.8217	44.29
1997	0.027	5.3	0.1386	24.51	0.2393	29.39	0.3658	33.84	0.5145	37.90	0.6813	41.61	0.8619	44.99
1998	0.027	5.3	0.0784	20.28	0.1702	26.24	0.2979	31.61	0.4570	36.44	0.6416	40.79	0.8456	44.71
1999	0.027	5.3	0.0592	18.47	0.1660	26.02	0.3286	32.66	0.5383	38.48	0.7832	43.59	1.0515	48.07
2000	0.027	5.3	0.0486	17.57	0.1635	26.49	0.3518	34.20	0.6001	40.85	0.8916	46.59	1.2997	51.54
2001	0.027	5.3	0.0380	16.66	0.1610	26.96	0.3750	35.74	0.6620	43.22	1.0000	49.59	1.5480	55.01
2002	0.027	5.3	0.0810	19.42	0.2330	28.40	0.4570	36.18	0.7360	42.91	1.0480	48.73	1.4710	53.77
2003	0.027	5.3	0.0590	18.73	0.2200	29.27	0.4800	38.15	0.8150	45.66	1.1950	51.99	2.4050	57.33
2004	0.027	5.3	0.0590	23.13	0.2200	30.67	0.4800	37.35	0.8150	43.26	1.1950	48.49	2.4050	53.12
2005	0.027	5.3	0.0294	22.60	0.1180	29.63	0.2769	35.57	0.5023	40.60	0.7832	44.85	1.1060	48.44
2006	0.027	5.3	0.0316	23.99	0.1187	30.70	0.2591	36.22	0.4390	40.77	0.6426	44.52	0.8563	47.61

Table 4. Estimated coastal biomass (mt) of benthic crustaceans considered in the new base run of the MSVPA-X.

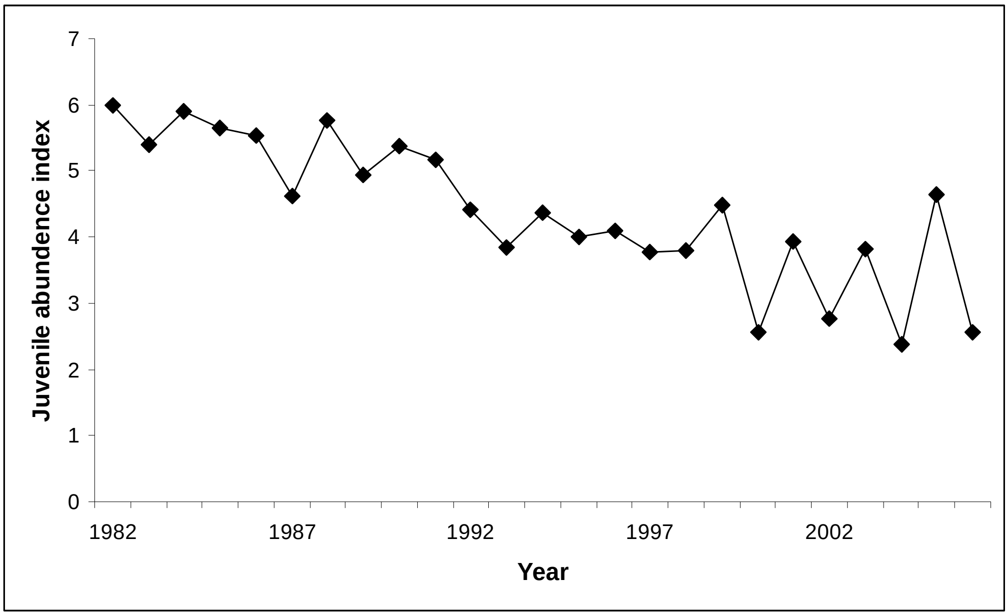
	Biomass (mt)			
	Blue crab	American lobster	Rock & Jonah crab	Total
1982	3,652.58	2,614.00	2015	8,281.57
1983	3,616.41	2,910.09	2015	8,541.50
1984	3,328.03	2,016.45	2015	7,359.47
1985	3,414.72	2,617.82	2015	8,047.55
1986	2,895.08	2,721.11	2015	7,631.19
1987	3,222.58	1,846.02	2015	7,083.59
1988	3,539.33	3,104.43	2015	8,658.76
1989	7,684.95	3,661.05	2015	13,361.00
1990	3,848.18	3,367.82	2015	9,231.00
1991	6,283.35	2,771.61	2015	11,069.96
1992	2,414.69	3,424.63	2015	7,854.32
1993	4,534.74	3,587.60	2015	10,137.33
1994	3,660.23	4,780.59	2015	10,455.82
1995	2,888.96	3,413.73	2015	8,317.68
1996	3,783.04	4,988.32	2015	10,786.36
1997	4,536.66	4,314.07	2015	10,865.73
1998	2,748.18	4,984.88	2015	9,748.06
1999	3,297.10	4,686.49	2015	9,998.58
2000	2,437.73	4,528.68	2015	8,981.41
2001	1,907.94	4,732.39	2015	8,655.33
2002	2,536.88	5,213.26	2015	9,765.15
2003	2,408.16	4,708.86	2015	9,132.02
2004	2,070.14	4,710.01	2015	8,795.15
2005	2,094.02	4,710.01	2015	8,819.03
2006	2,014.23	4,710.01	2015	8,739.24

Table 5. Estimated coastal biomass (mt) of non-menhaden clupeids considered in the new base run of the MSVPA-X (Atlantic herring and thread herring, Spanish sardine, and scads).

	Biomass (mt)
Year	Other clupeids
1982	127,488
1983	150,402
1984	197,439
1985	238,270
1986	266,832
1987	290,732
1988	339,973
1989	443,154
1990	554,061
1991	584,533
1992	701,179
1993	856,388
1994	790,154
1995	896,977
1996	942,330
1997	1,128,987
1998	1,054,489
1999	1,159,241
2000	1,198,547
2001	1,100,933
2002	1,110,397
2003	1,052,872
2004	1,056,892
2005	1,005,364
2006	1,291,222

Table 6. Estimated coastal biomass (mt) of sciaenids (spot and Atlantic croaker) used in the new base run of the MSVPA-X.

	Biomass (mt)		
Year	Spot	Atlantic croaker	Total
1982	22,795	9,908	32,703
1983	19,206	13,055	32,261
1984	12,164	19,031	31,195
1985	20,730	22,433	43,163
1986	16,367	22,691	39,058
1987	18,876	19,051	37,927
1988	14,864	15,270	30,134
1989	16,348	12,790	29,138
1990	16,033	13,557	29,590
1991	18,472	17,641	36,113
1992	17,048	24,266	41,314
1993	16,885	29,453	46,338
1994	20,734	34,961	55,695
1995	16,760	43,809	60,569
1996	12,140	48,420	60,560
1997	14,675	46,517	61,192
1998	16,362	57,206	73,568
1999	11,442	69,793	81,235
2000	14,185	76,590	90,775
2001	16,349	75,311	91,660
2002	12,257	72,408	84,665
2003	16,334	72,308	88,642
2004	17,165	66,687	83,852
2005	13,697	68,052	81,749
2006	11,577	58,489	70,066



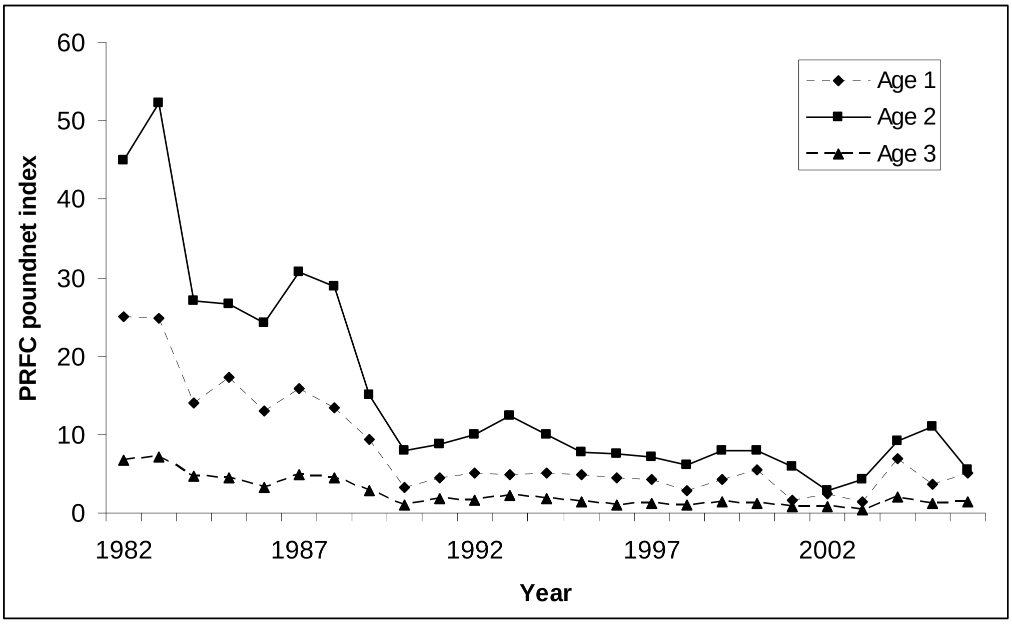


Figure 1. Indices used to tune the XSA. Top: coastwide menhaden juvenile abundance index. Bottom: Potomac River Fisheries Commission poundnet index.

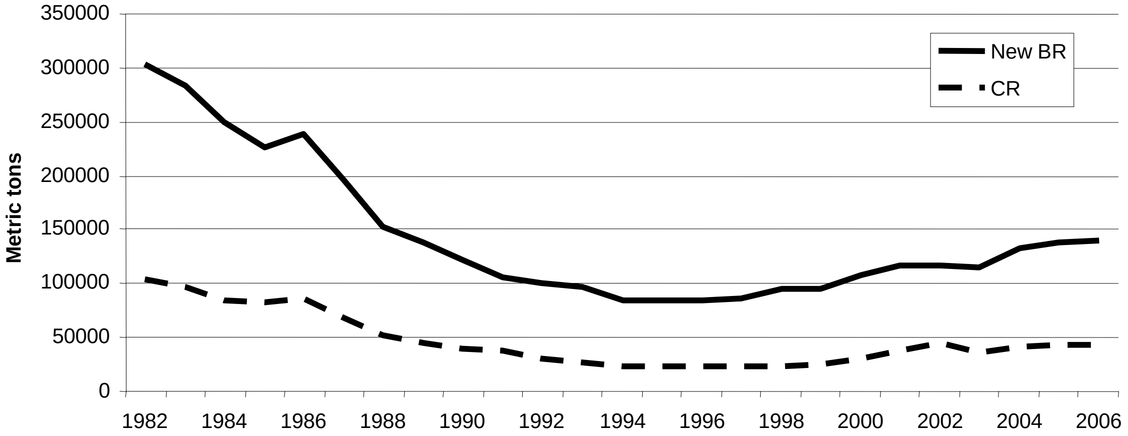
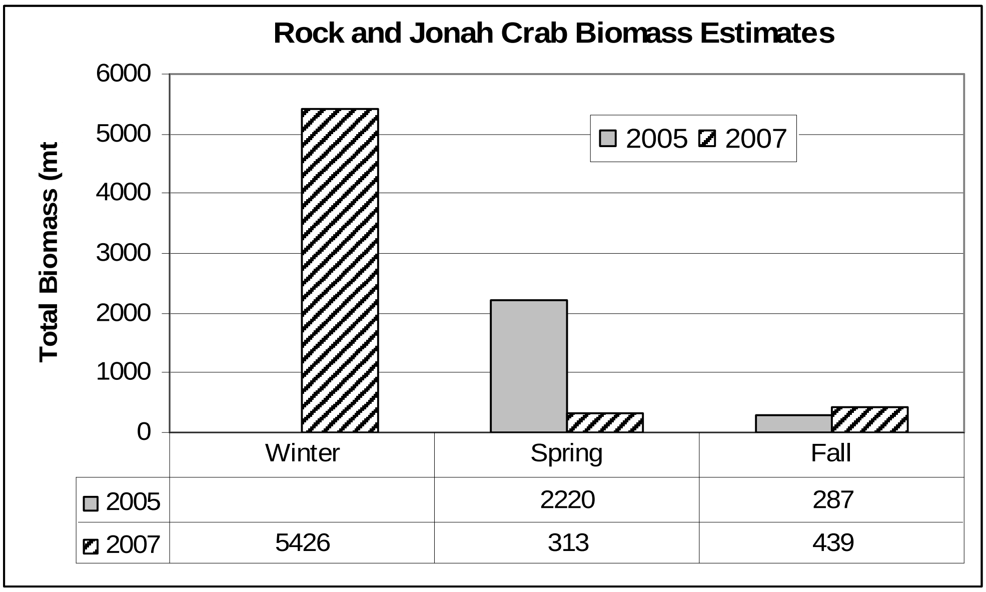
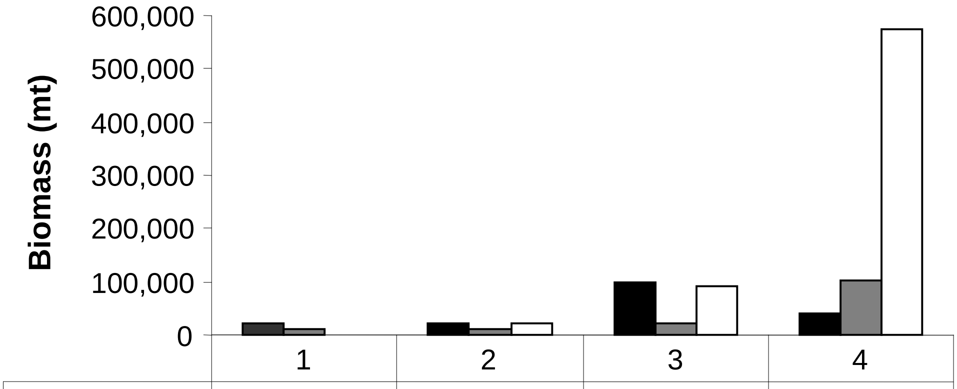


Figure 2. Bluefish biomass trends - a comparison between the Continuity Run (CR) and New Base Run (BR). The SARC run (not shown) and Continuity Run are identical through 2002 (before update).



	Winter	Spring	Fall
▢ 2005		2220	287
▨ 2007	5426	313	439

Figure 3. Comparison between the 2005 and 2007 analyses for Rock and Jonah crab coastwide biomass estimates. (Note: seasonal estimates are switched from what was reported in the 2005 assessment. Also, winter data was not used or available in 2005.)



	1	2	3	4
■ Ches. Bay 05	23,000	23,000	100,000	40,000
▨ Ches. Bay 07	10,300	10,300	23,400	104,000
☐ NJ Coast	108	23,371	91,396	573,413

Figure 4. Seasonal bay anchovy biomass (mt) estimates for the Chesapeake Bay developed for the 2005 and 2007 assessment (Rilling and Houde, 1999; Jung and Houde 2004) and the New Jersey coast.

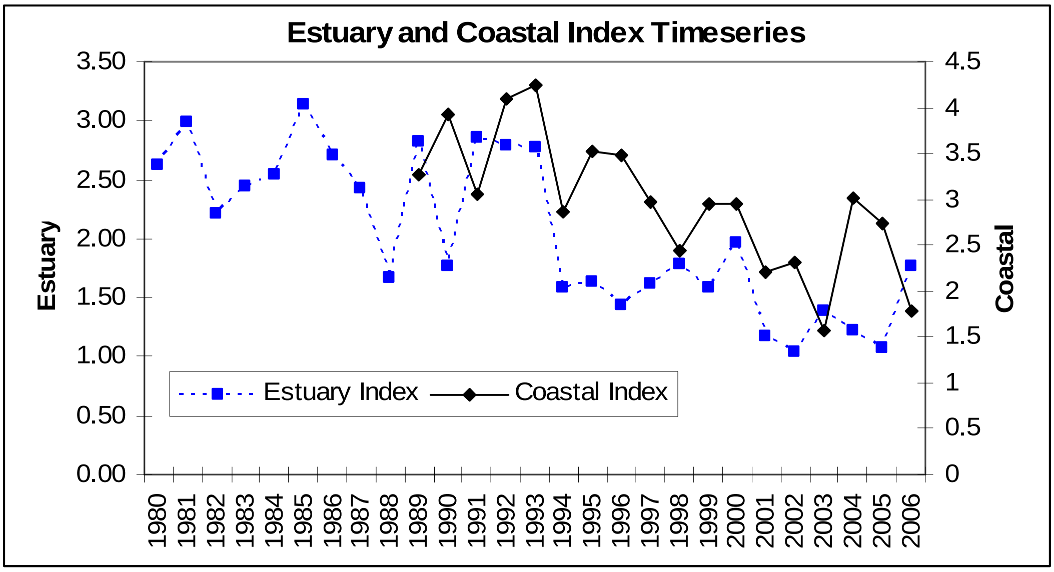


Figure 5. Z-transformed and weighted survey indices combined to create an annual grand Estuary and Coastal indices for bay anchovy.

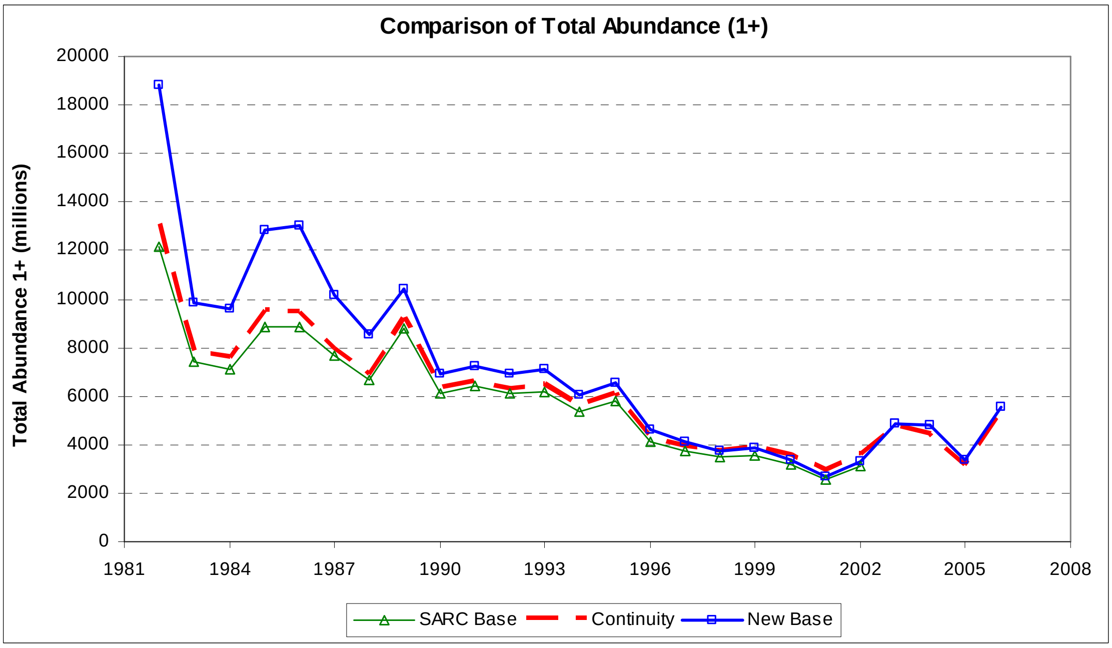


Figure 6. Comparison of estimated total abundance of menhaden among three runs of the MSVPA-X.

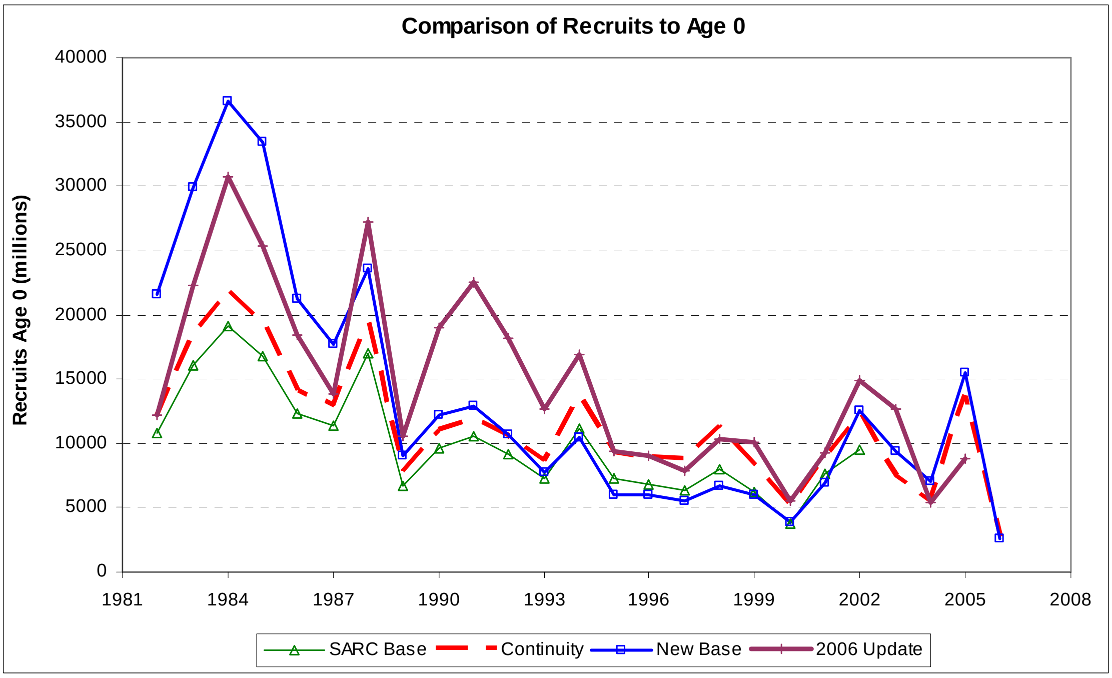


Figure 7. Comparison of estimated recruit (age 0) abundance of menhaden among three runs of the MSVPA-X.

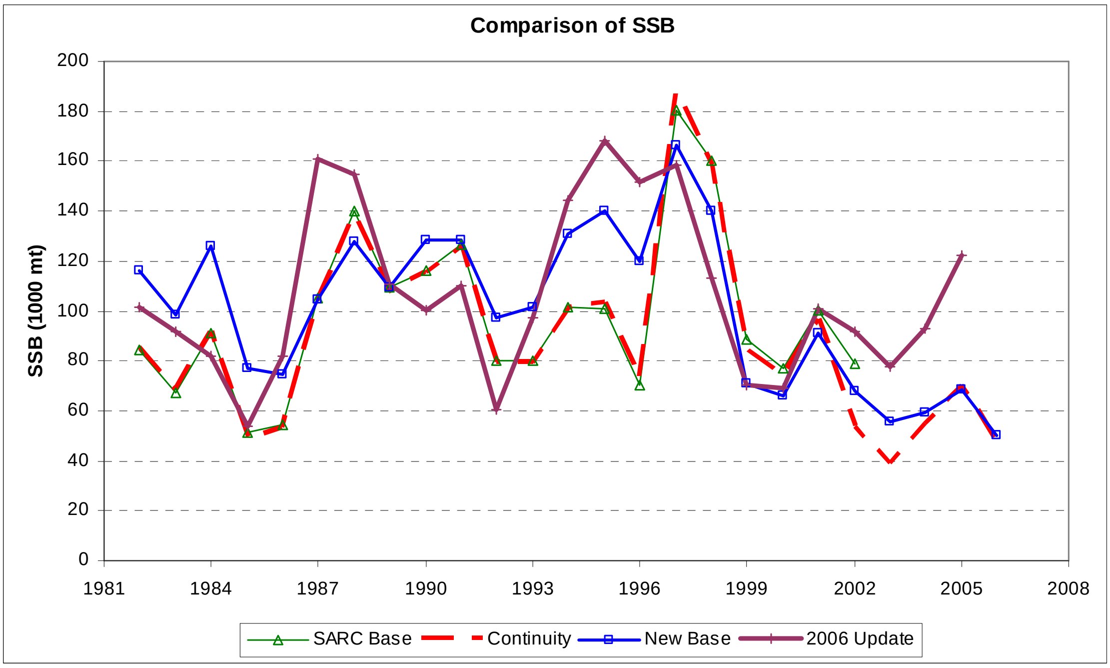


Figure 8. Comparison of estimated spawning stock biomass of menhaden among three runs of the MSVPA-X and the menhaden single species assessment update.

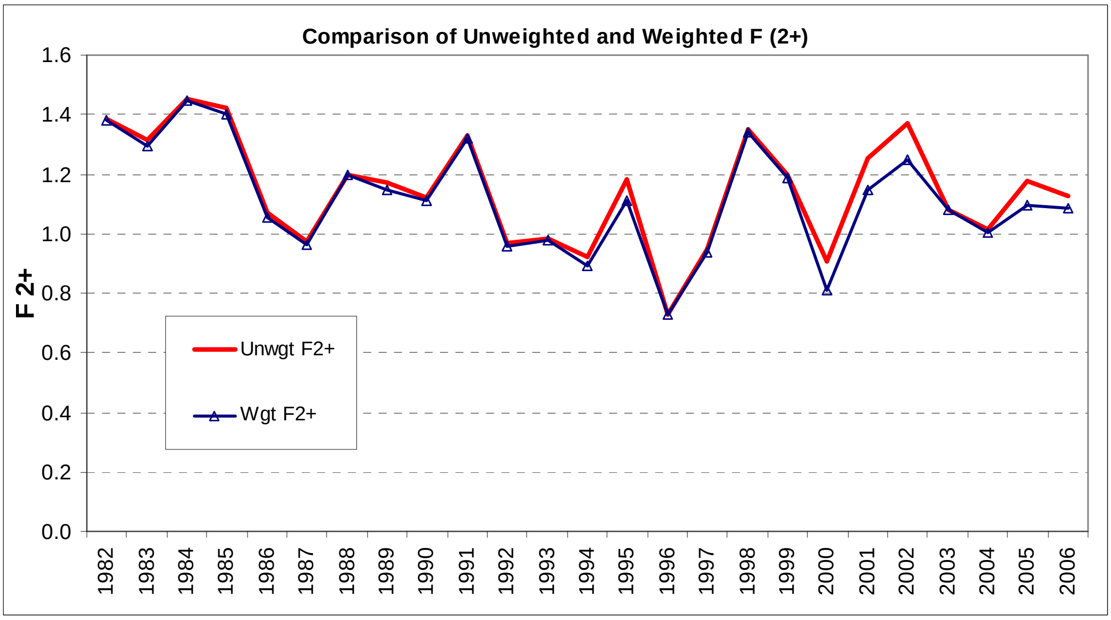


Figure 9. Comparison of two methods for estimating menhaden fishing mortality rates (F on ages 2+) from new base run of the MSVPA-X.

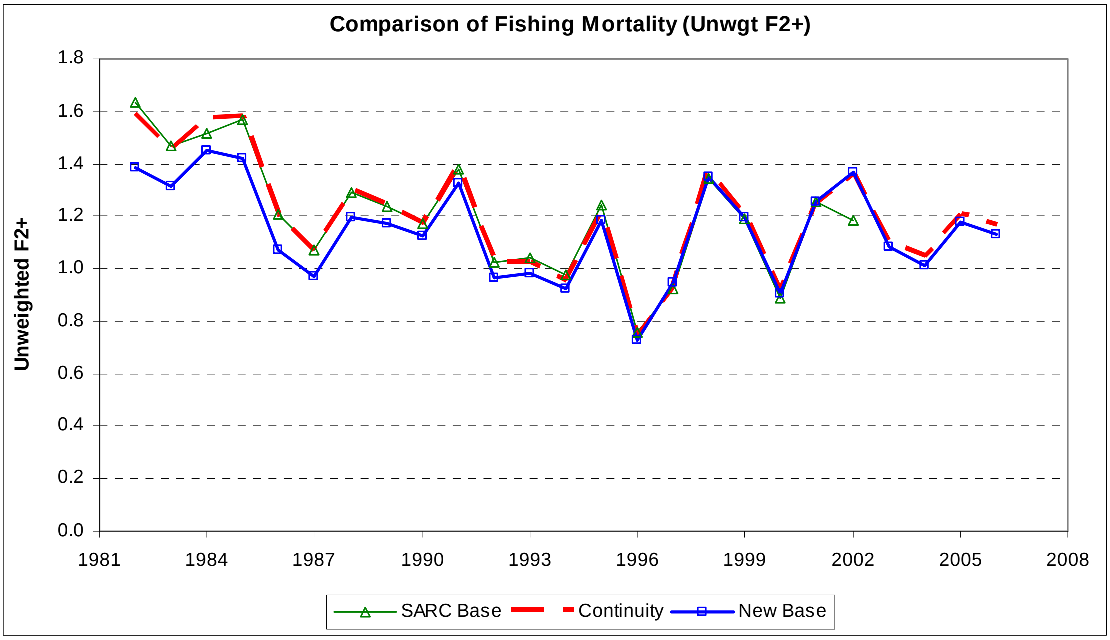


Figure 10. Comparison of estimated fishing mortality rates (ages 2+) on menhaden among three runs of the MSVPA-X using method 1 (unweighted).

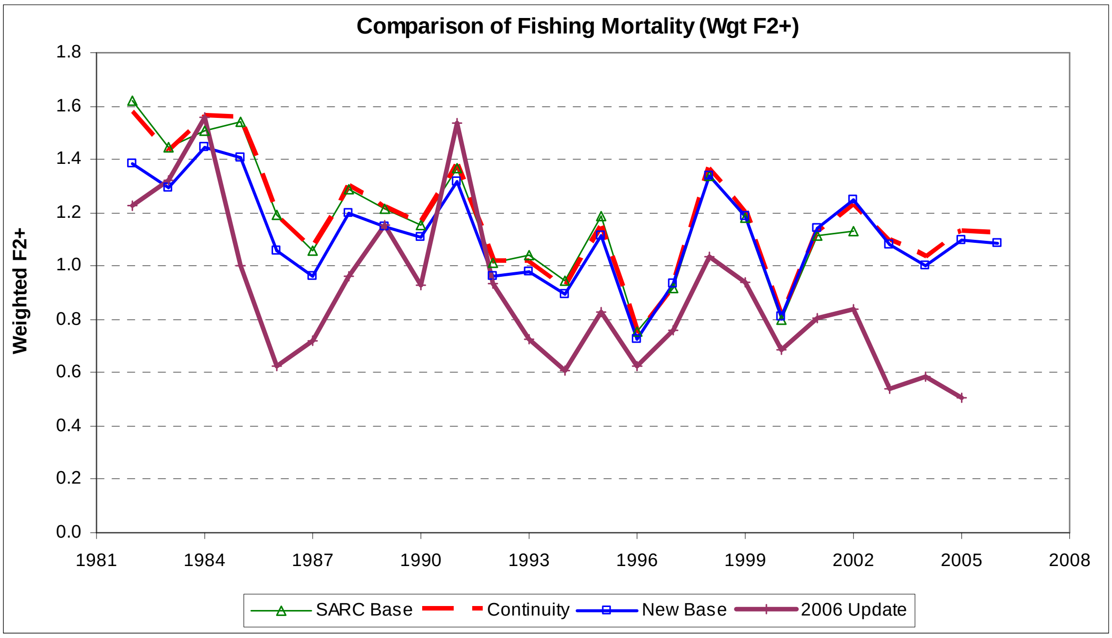


Figure 11. Comparison of estimated fishing mortality rates (ages 2+) on menhaden among three runs of the MSVPA-X and the menhaden single species update assessment using method 2 (weighted).

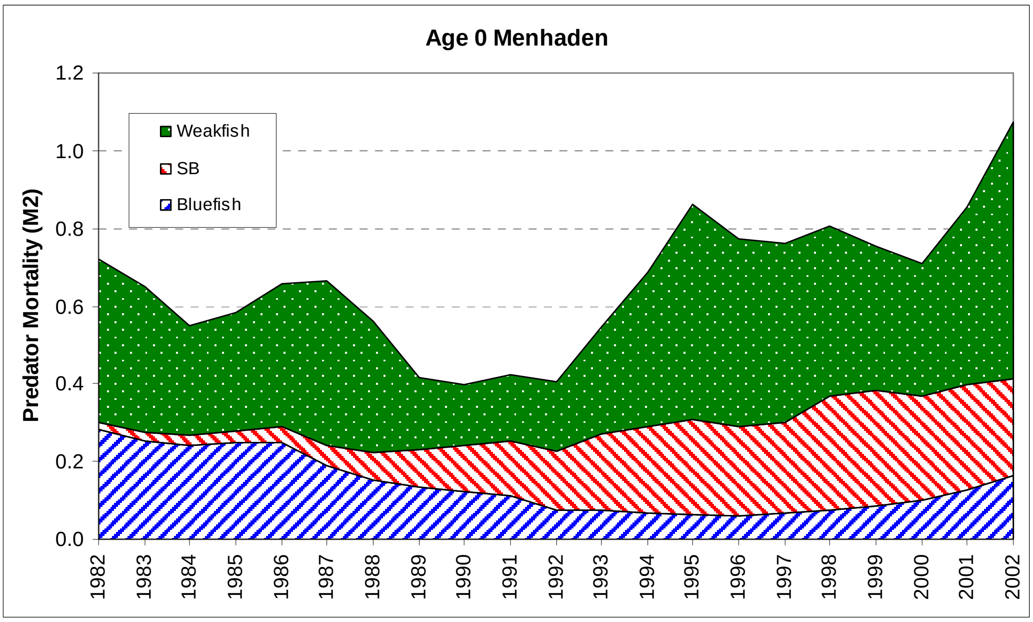


Figure 12. Estimates of predation mortality component (M2) on Atlantic menhaden by the three modeled predators (bluefish, striped bass, and weakfish) for age 0 menhaden for the SARC base run.

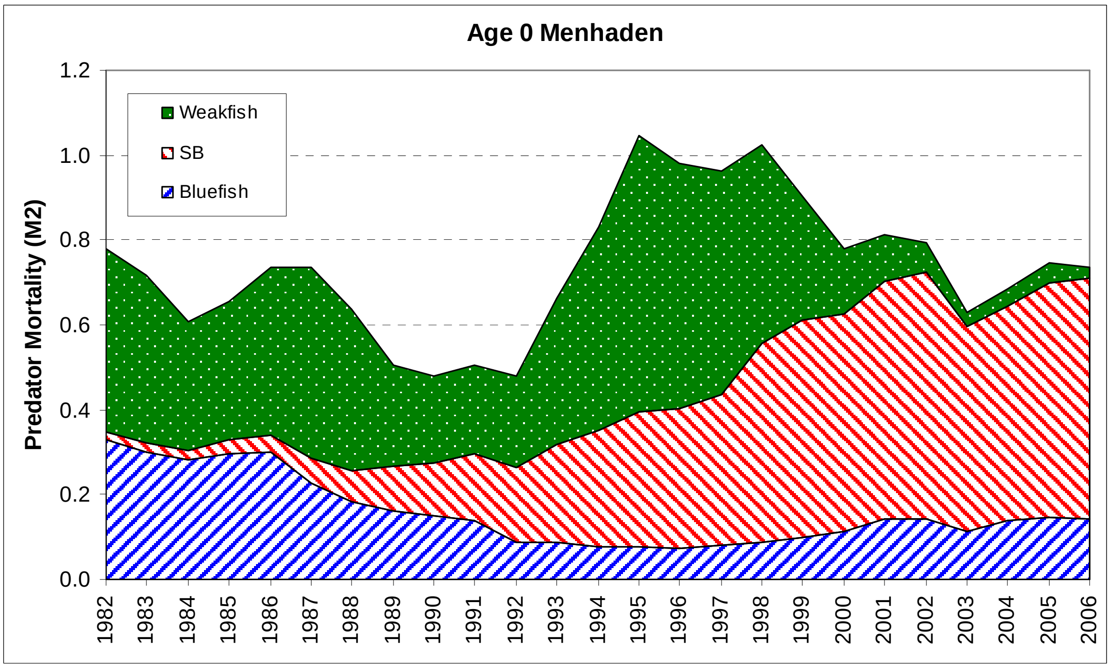


Figure 13. Estimates of predation mortality component (M2) on Atlantic menhaden by the three modeled predators (bluefish, striped bass, and weakfish) for age 0 menhaden for the continuity run.

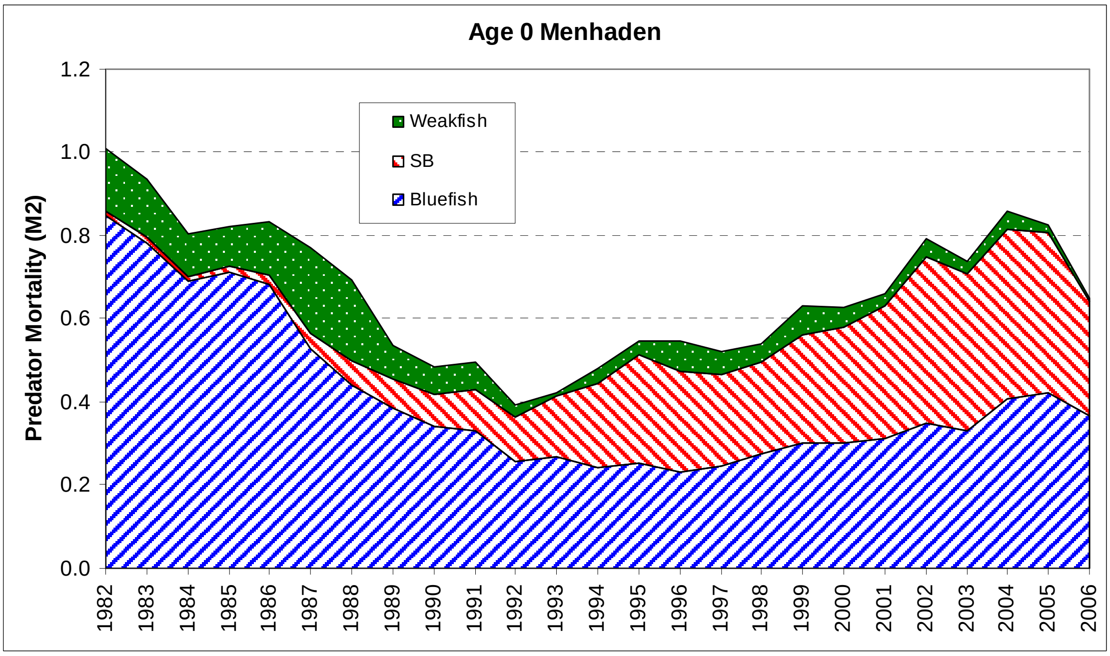


Figure 14. Estimates of predation mortality component (M2) on Atlantic menhaden by the three modeled predators (bluefish, striped bass, and weakfish) for age 0 menhaden for the new base run.

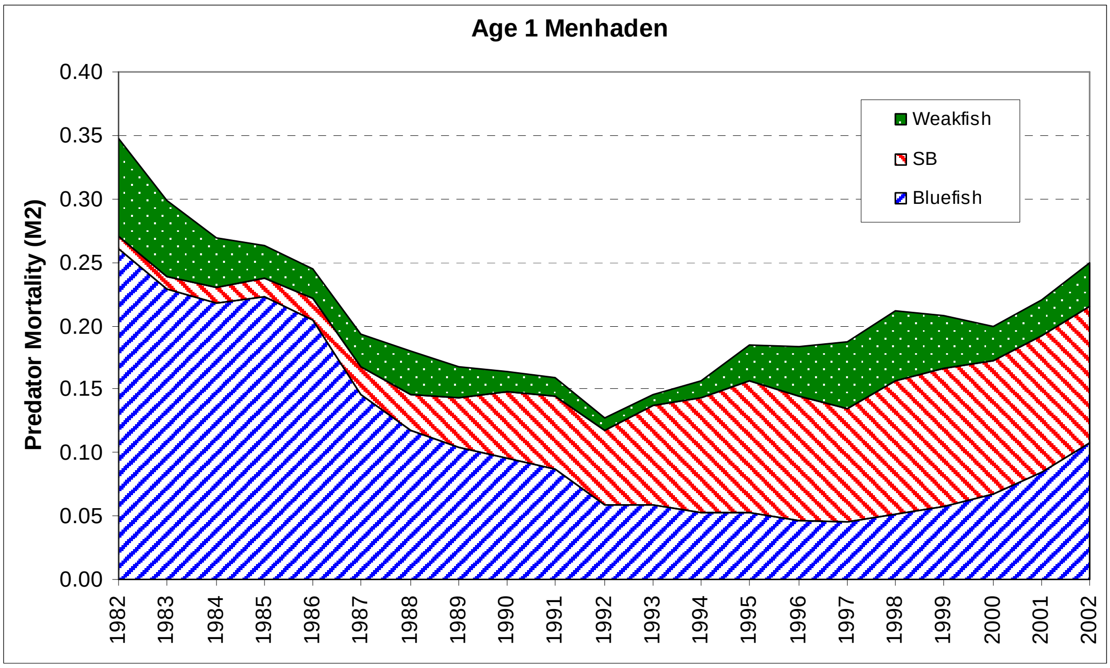


Figure 15. Estimates of predation mortality component (M2) on Atlantic menhaden by the three modeled predators (bluefish, striped bass, and weakfish) for age 1 menhaden for the SARC base run.

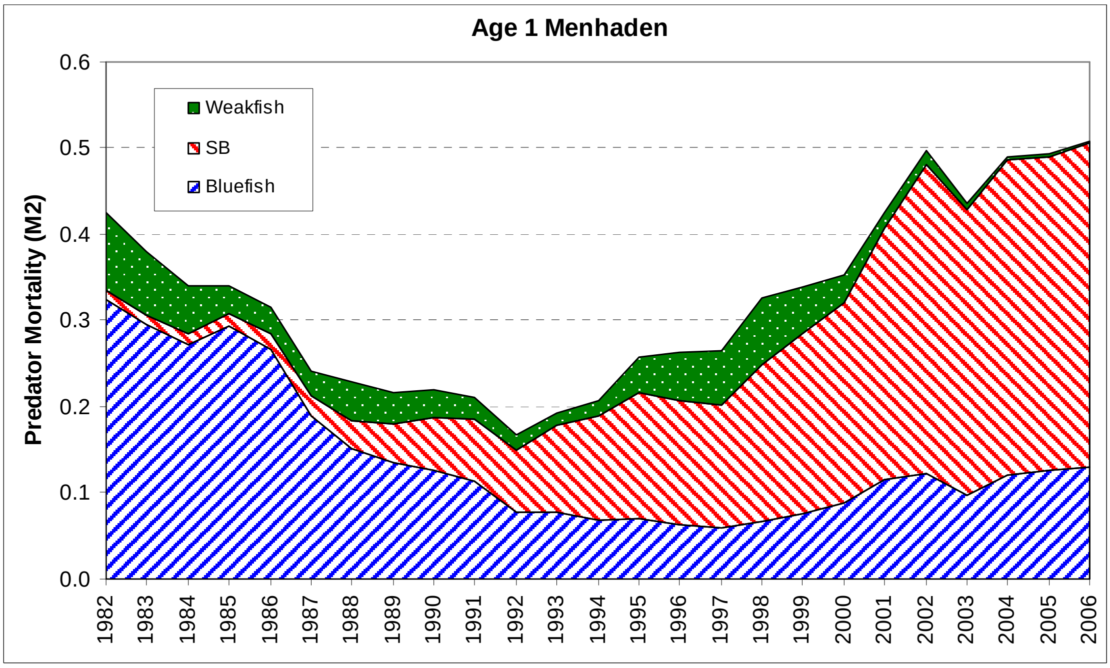


Figure 16. Estimates of predation mortality component (M2) on Atlantic menhaden by the three modeled predators (bluefish, striped bass, and weakfish) for age 1 menhaden for the continuity run.

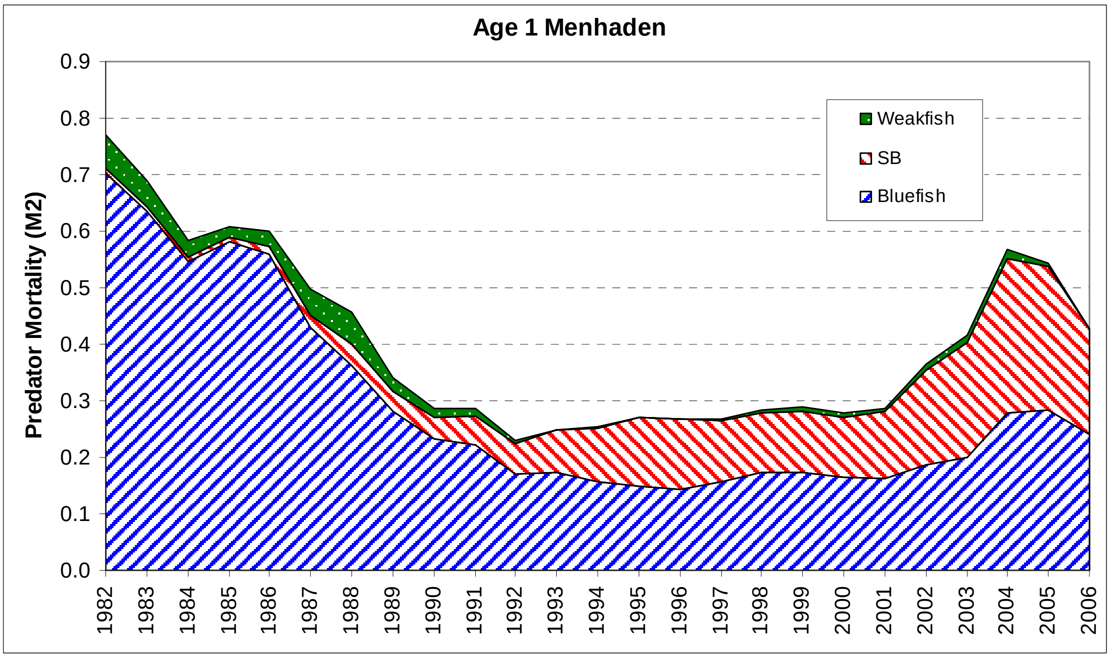


Figure 17. Estimates of predation mortality component (M2) on Atlantic menhaden by the three modeled predators (bluefish, striped bass, and weakfish) for age 1 menhaden for the new base run.

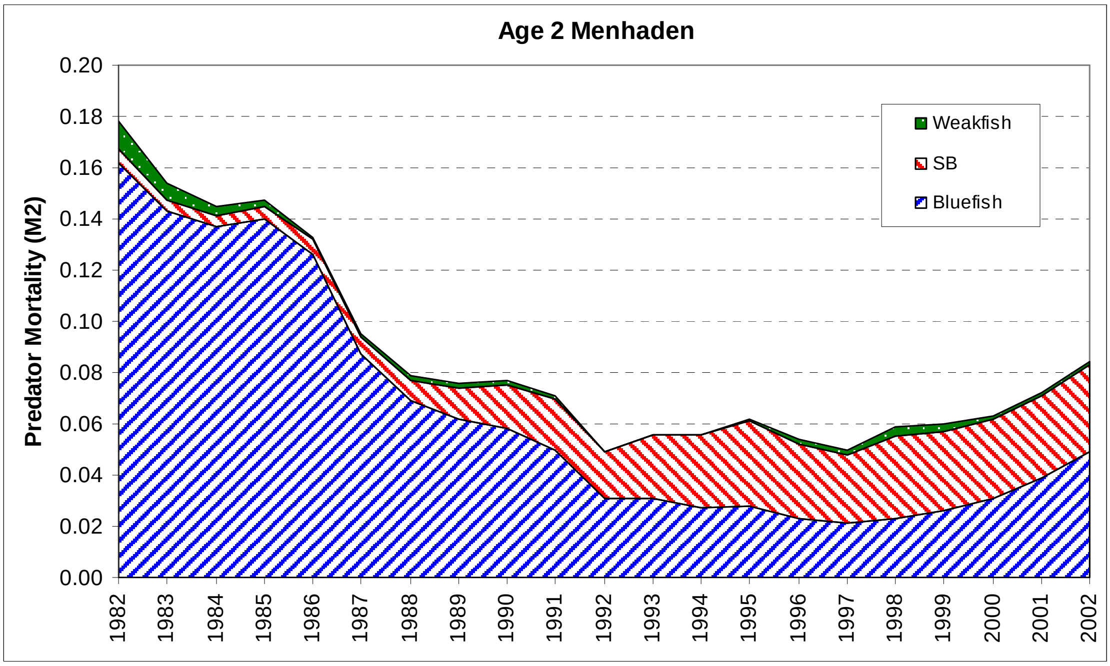


Figure 18. Estimates of predation mortality component (M2) on Atlantic menhaden by the three modeled predators (bluefish, striped bass, and weakfish) for age 2 menhaden for the SARC base run.

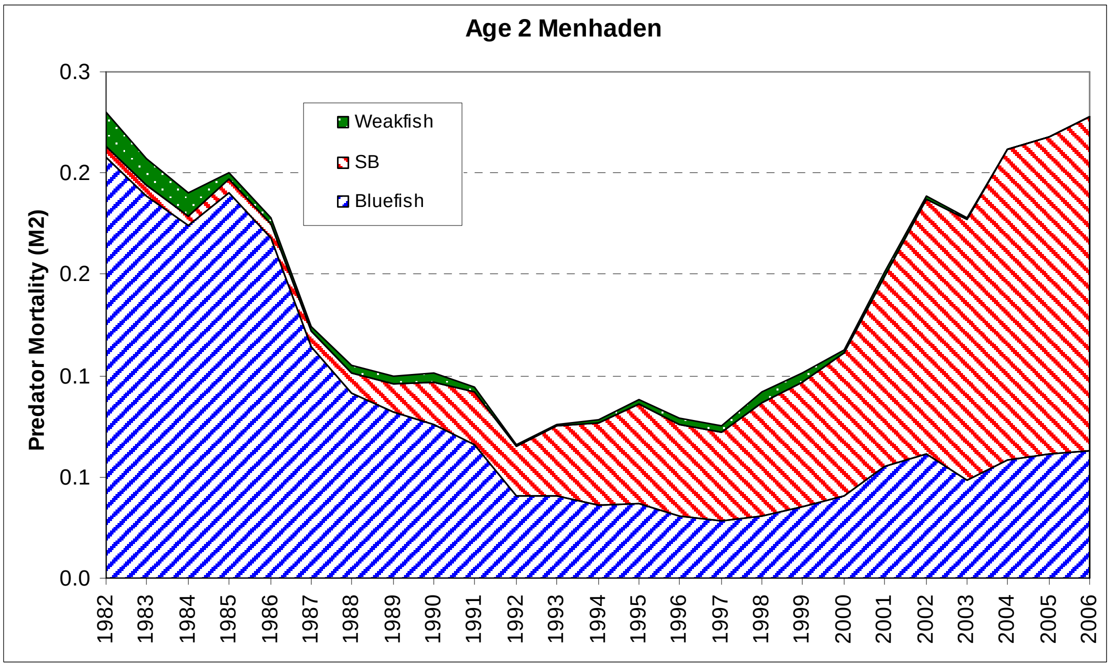


Figure 19. Estimates of predation mortality component (M2) on Atlantic menhaden by the three modeled predators (bluefish, striped bass, and weakfish) for age 2 menhaden for the continuity run.

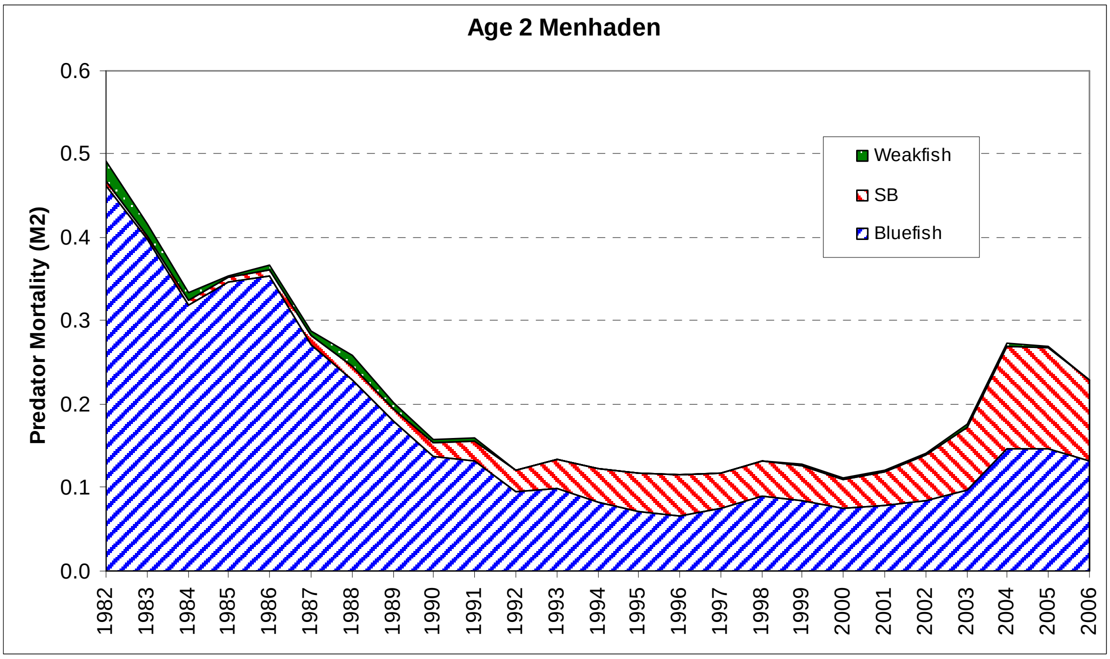


Figure 20. Estimates of predation mortality component (M2) on Atlantic menhaden by the three modeled predators (bluefish, striped bass, and weakfish) for age 2 menhaden for the new base run.

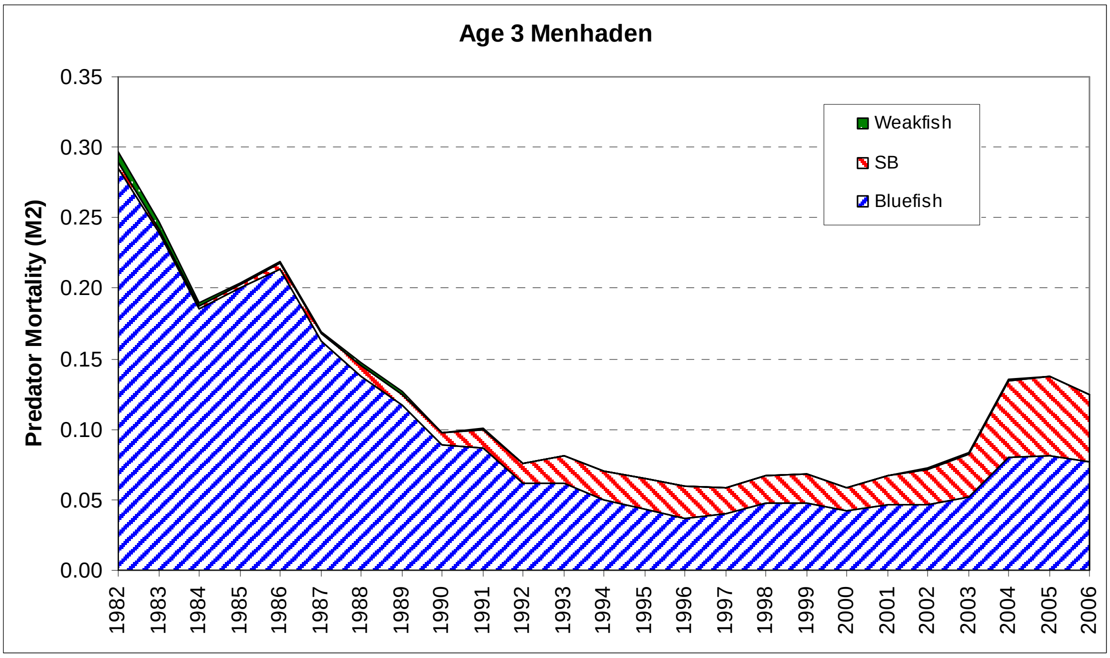


Figure 21. Estimates of predation mortality component (M2) on Atlantic menhaden by the three modeled predators (bluefish, striped bass, and weakfish) for age 3 menhaden for the new base run.

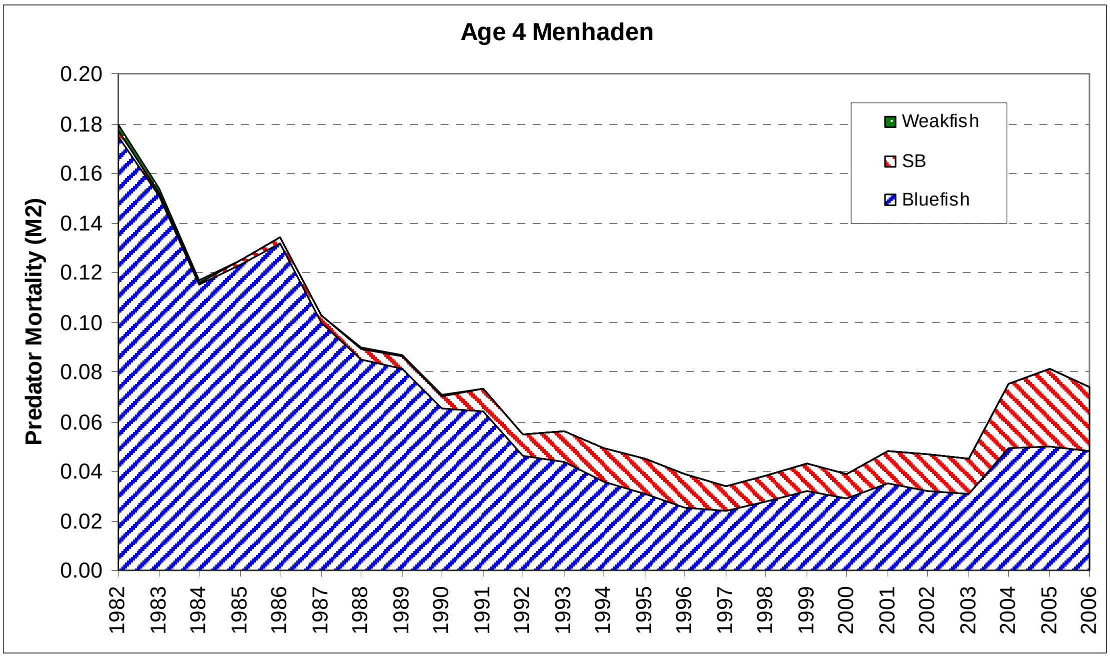


Figure 22. Estimates of predation mortality component (M2) on Atlantic menhaden by the three modeled predators (bluefish, striped bass, and weakfish) for age 4 menhaden for the new base run.

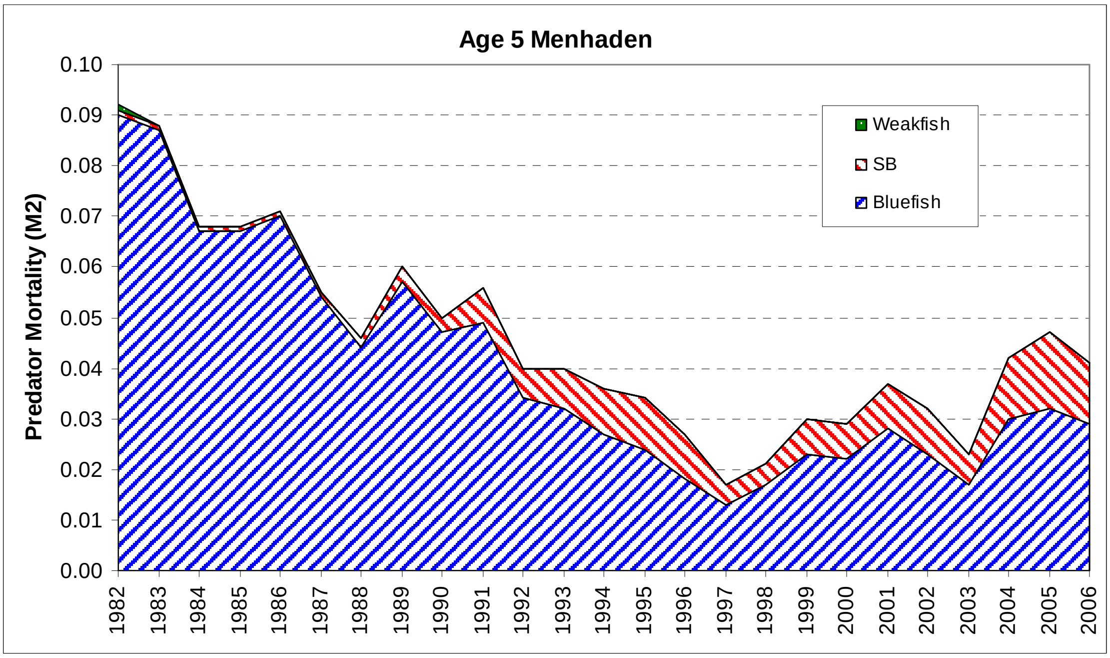


Figure 23. Estimates of predation mortality component (M2) on Atlantic menhaden by the three modeled predators (bluefish, striped bass, and weakfish) for age 5 menhaden for the new base run.

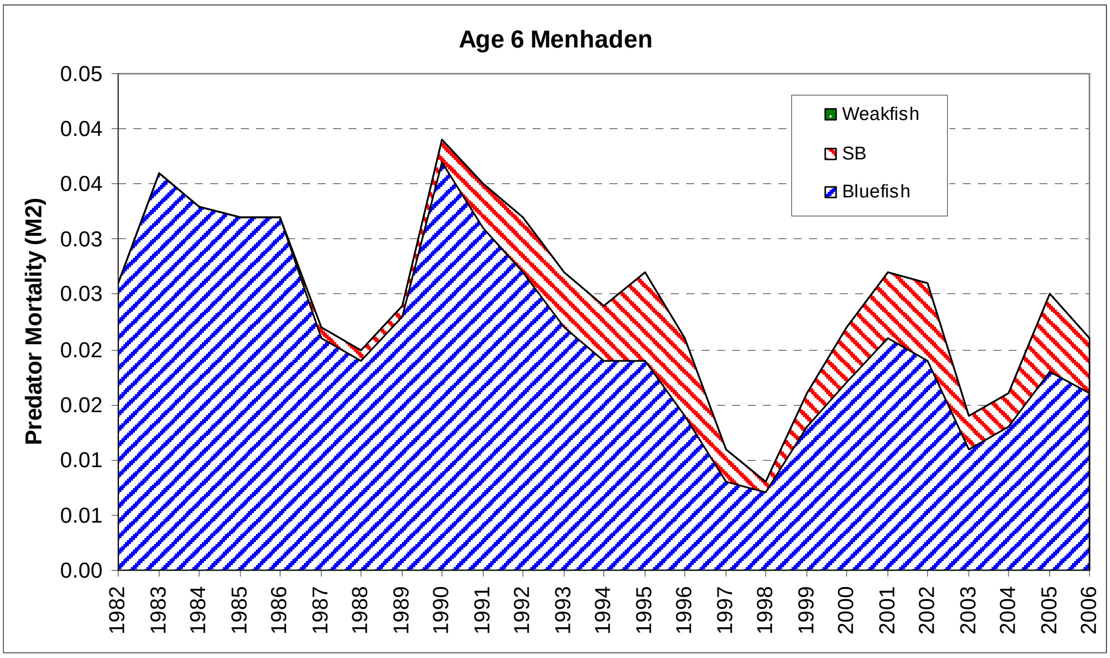


Figure 24. Estimates of predation mortality component (M2) on Atlantic menhaden by the three modeled predators (bluefish, striped bass, and weakfish) for age 6 menhaden for the new base run.

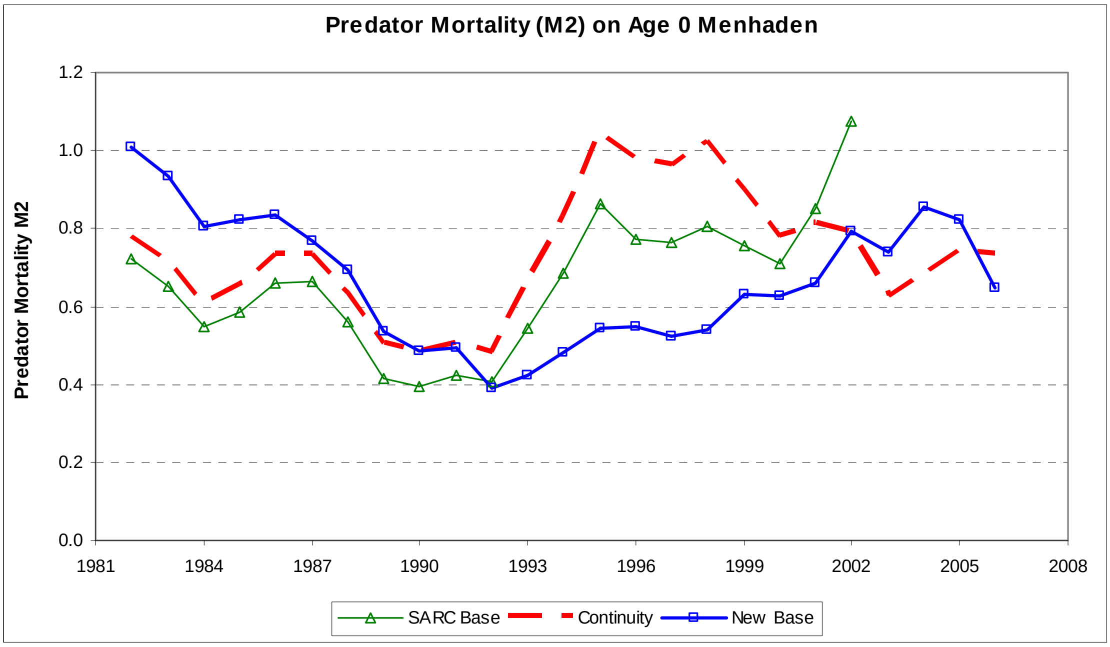


Figure 25. Estimates of total M2 (summed across the 3 modeled predators for age 0 menhaden

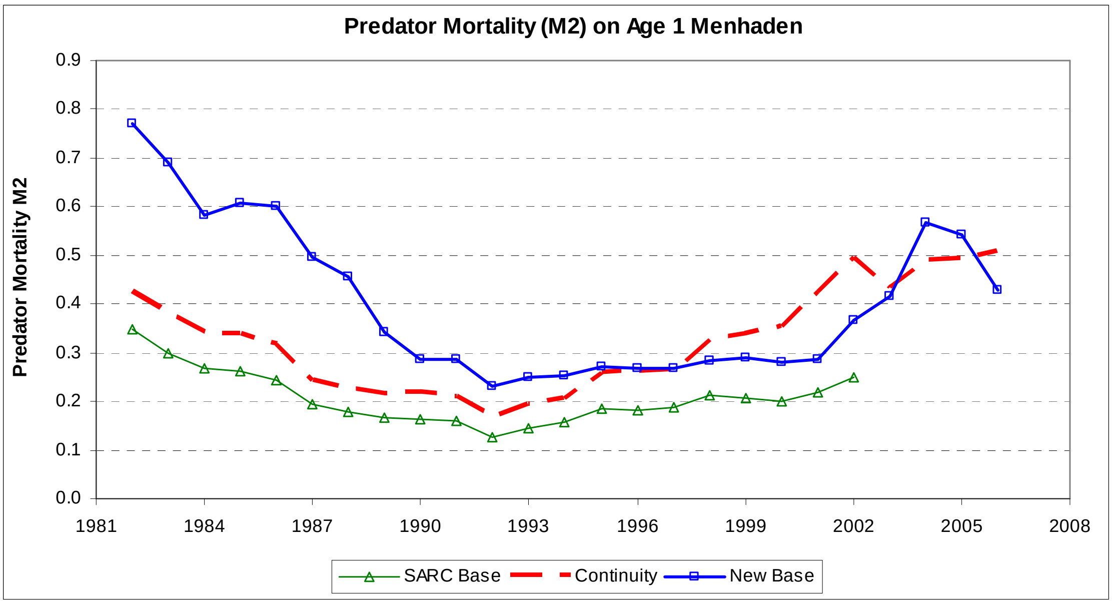


Figure 26. Estimates of total M2 (summed across the 3 modeled predators for age 1 menhaden

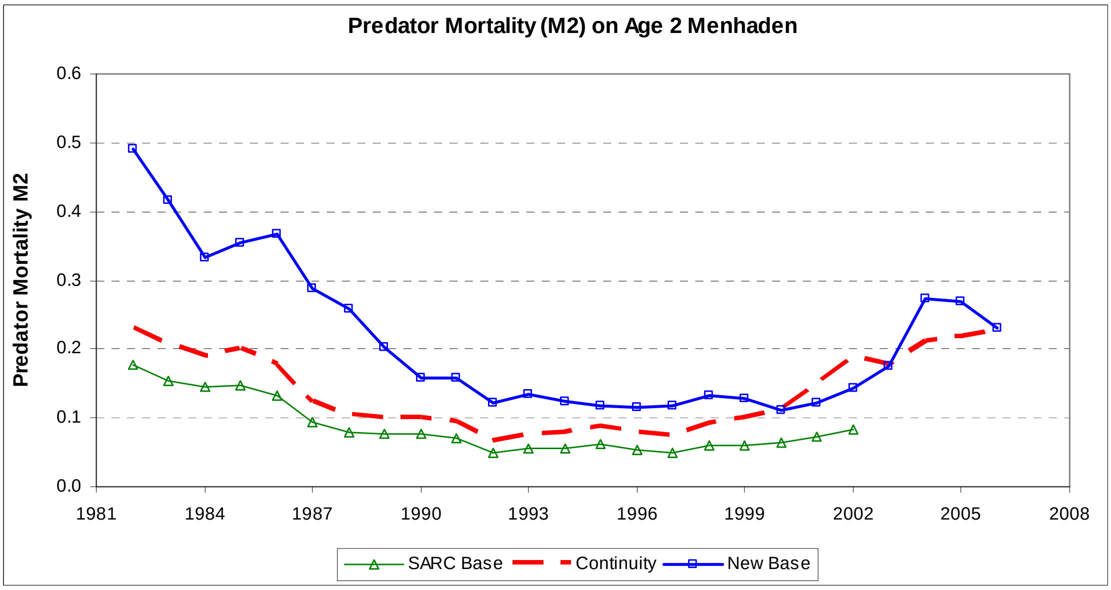


Figure 27. Estimates of total M2 (summed across the 3 modeled predators for age 2 menhaden

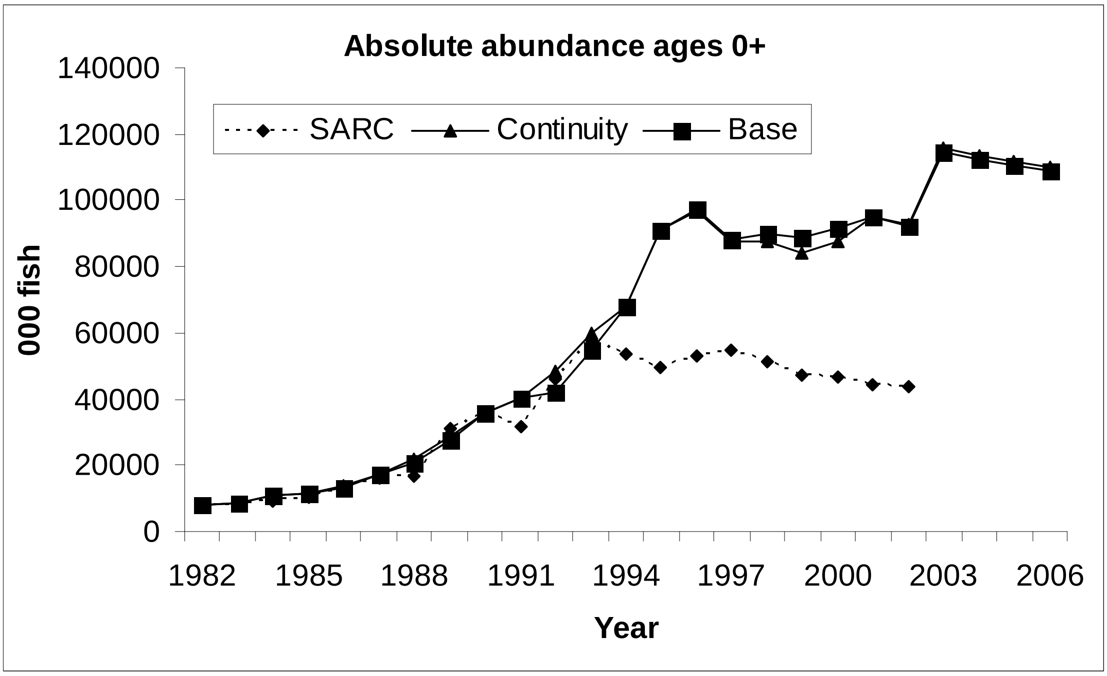


Figure 28. Abundance estimates of striped bass compared across three MSVPA-X runs.

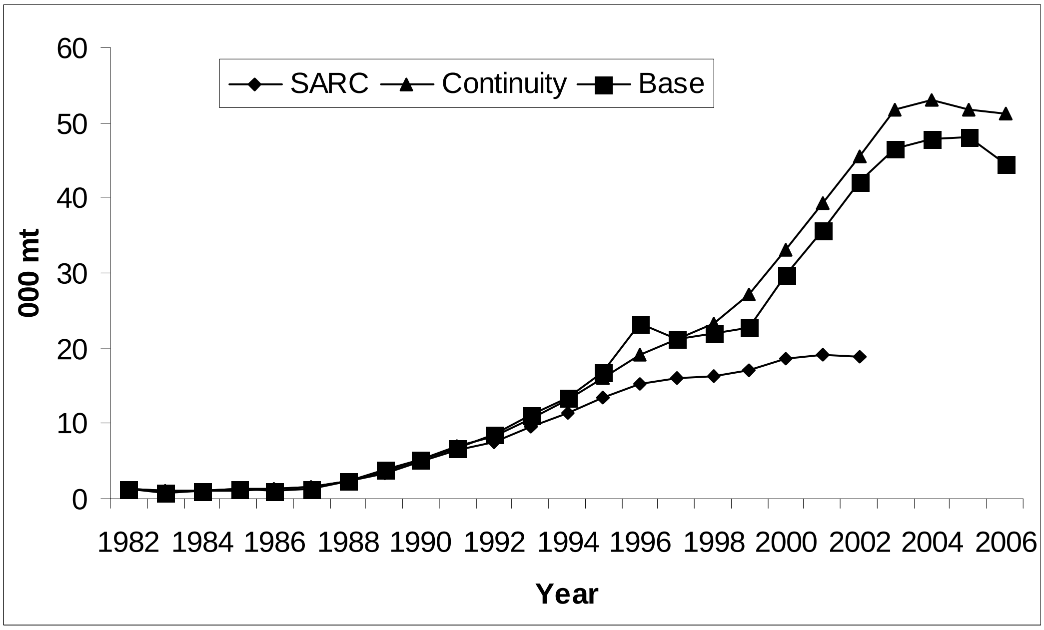


Figure 29. Spawning stock biomass estimates of striped bass compared across three MSVPA-X runs.

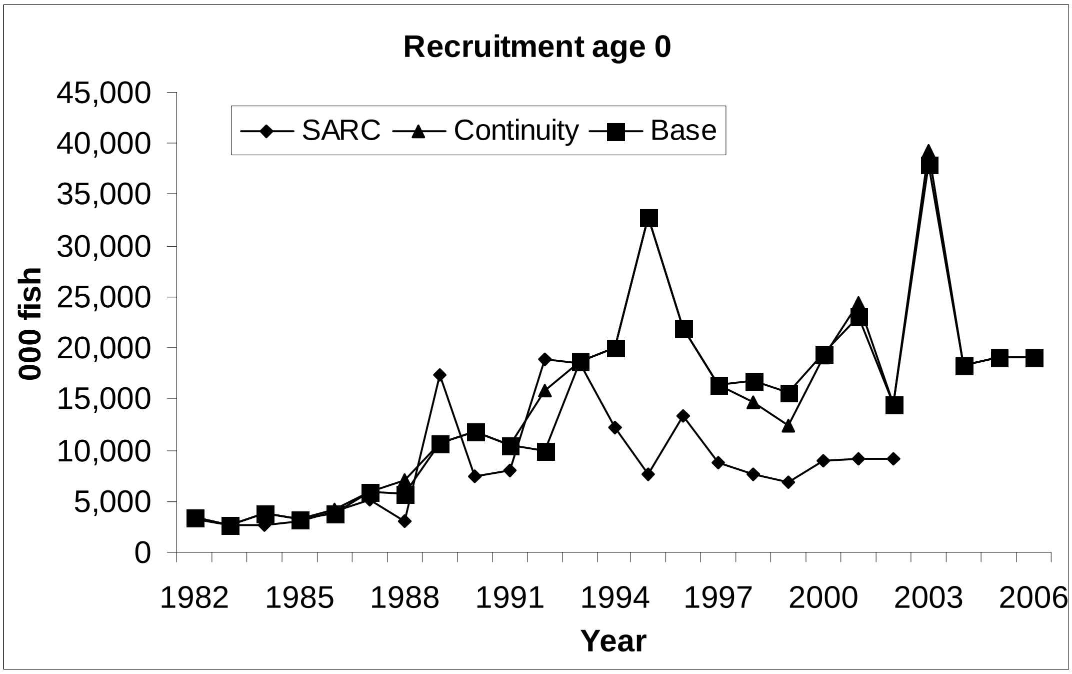


Figure 30. Recruitment estimates of striped bass compared across three MSVPA-X runs.

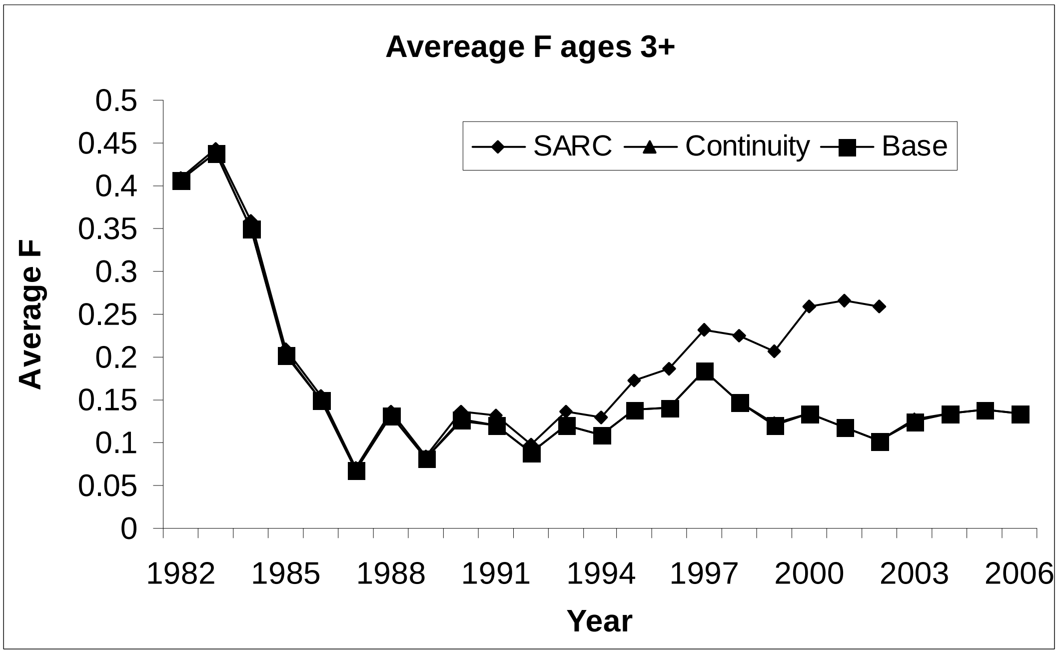


Figure 31. Average fishing mortality (F) estimates of striped bass compared across three MSVPA-X runs.

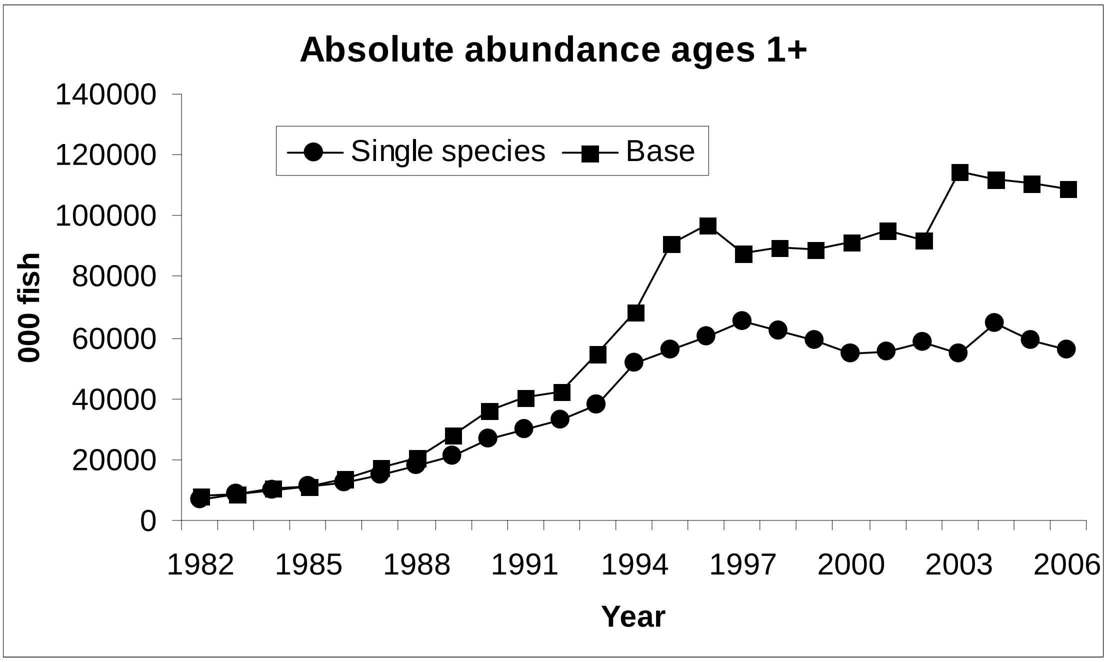
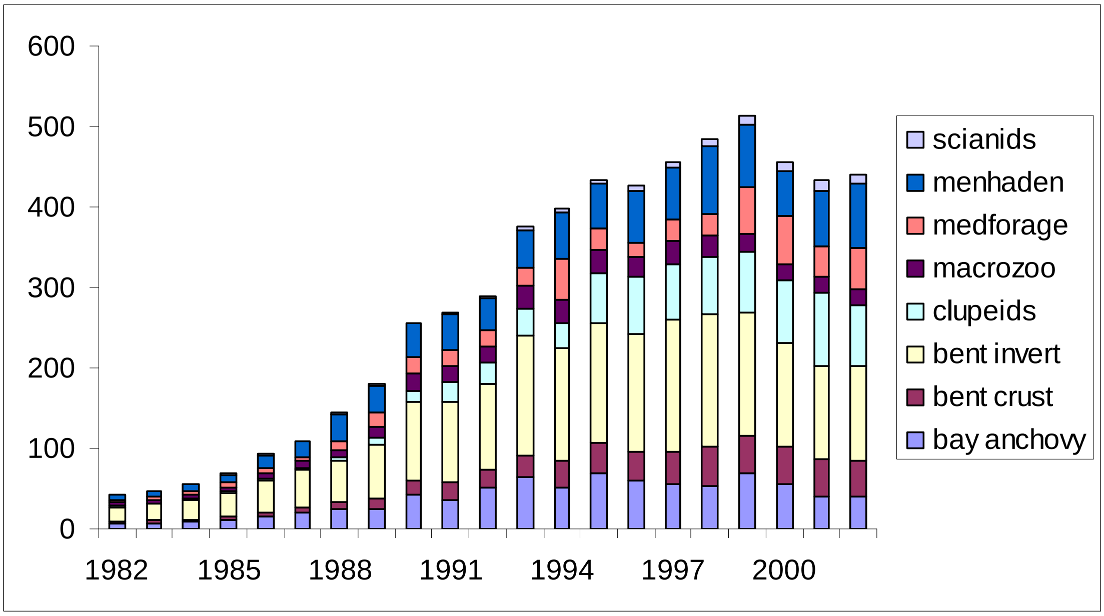


Figure 32. A comparison of MSVPA-X base run population estimates of striped bass with the population numbers from the 2007 peer reviewed single species striped bass stock assessment.



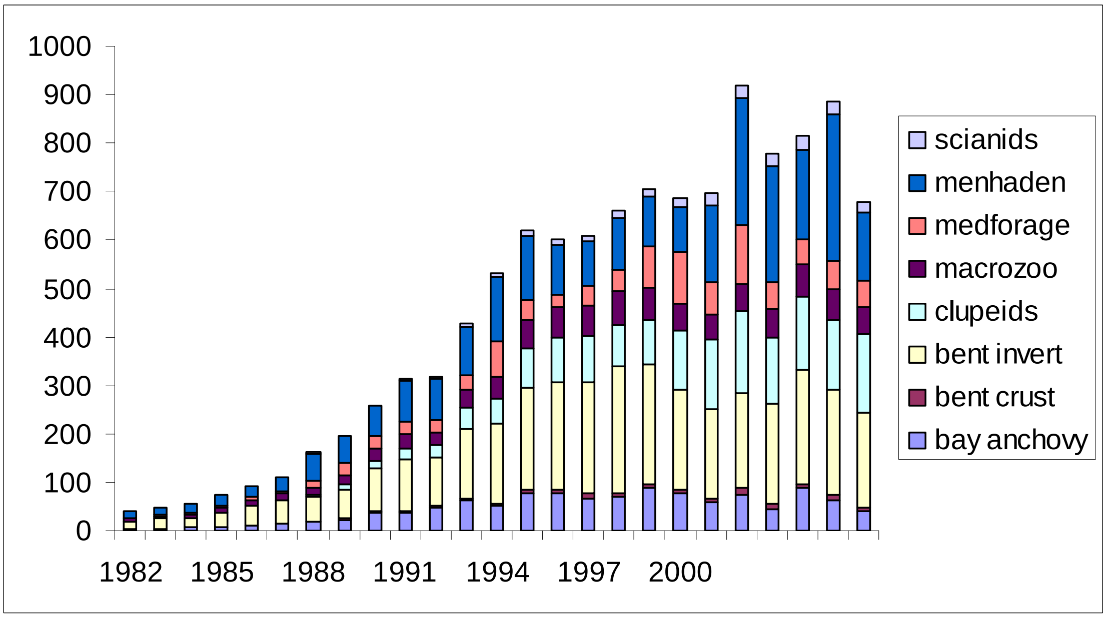


Figure 33. Comparison of prey consumption by striped bass between continuity run and new base run.

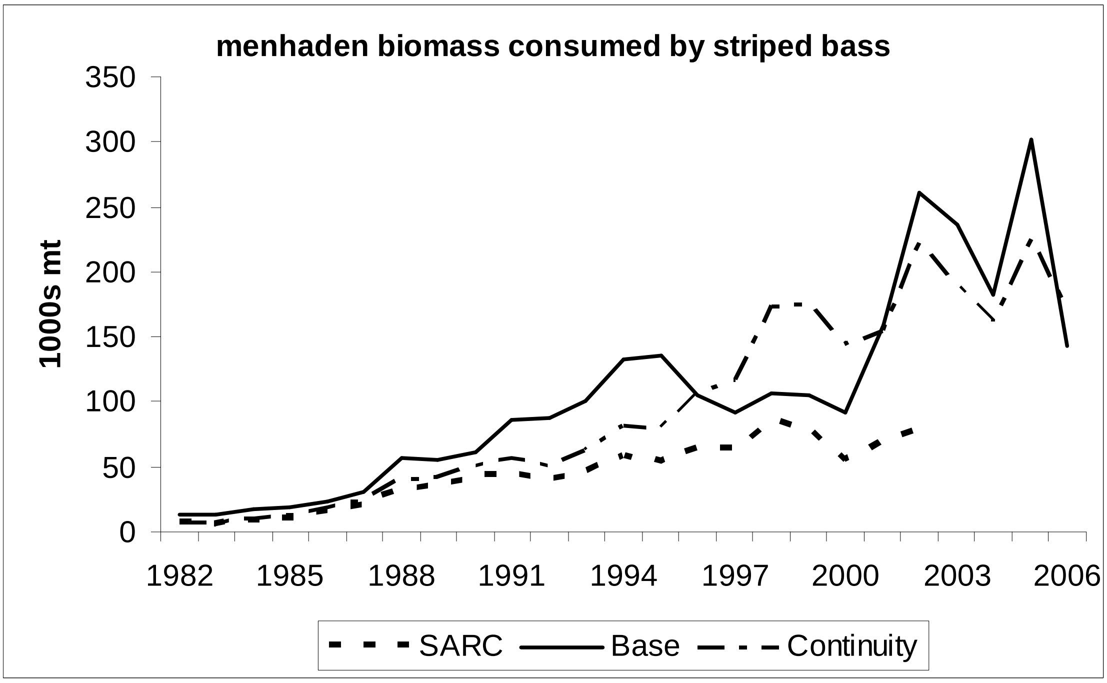


Figure 34. Total consumption of menhaden by striped bass.

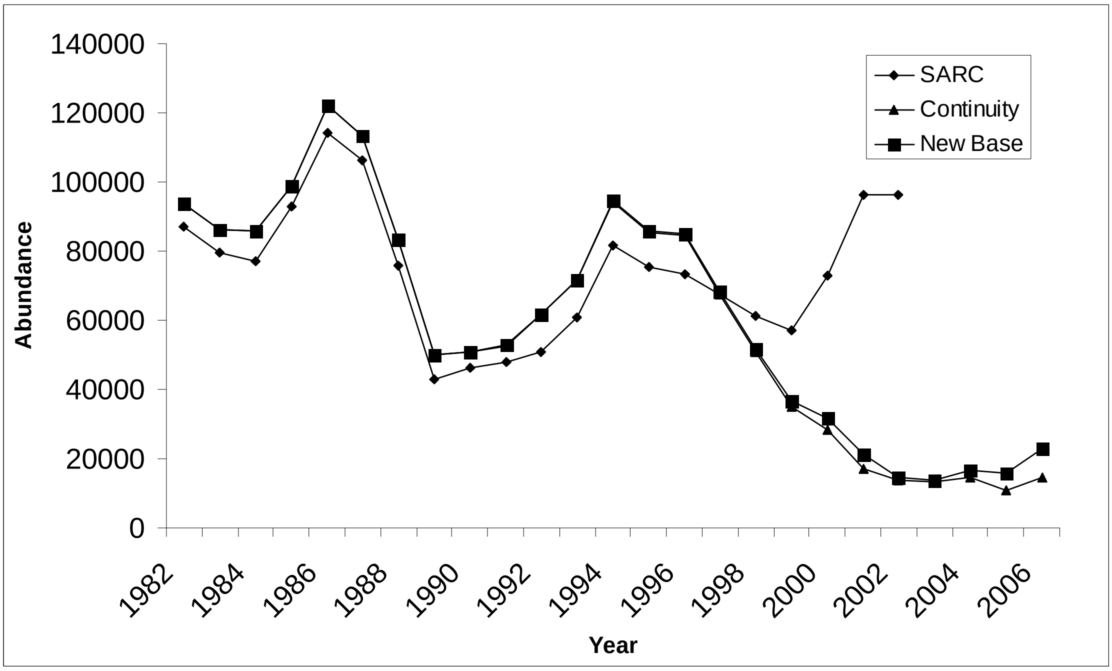


Figure 35. Abundance estimates for weakfish 1982-2006 for three configurations of the MSVPA-X.

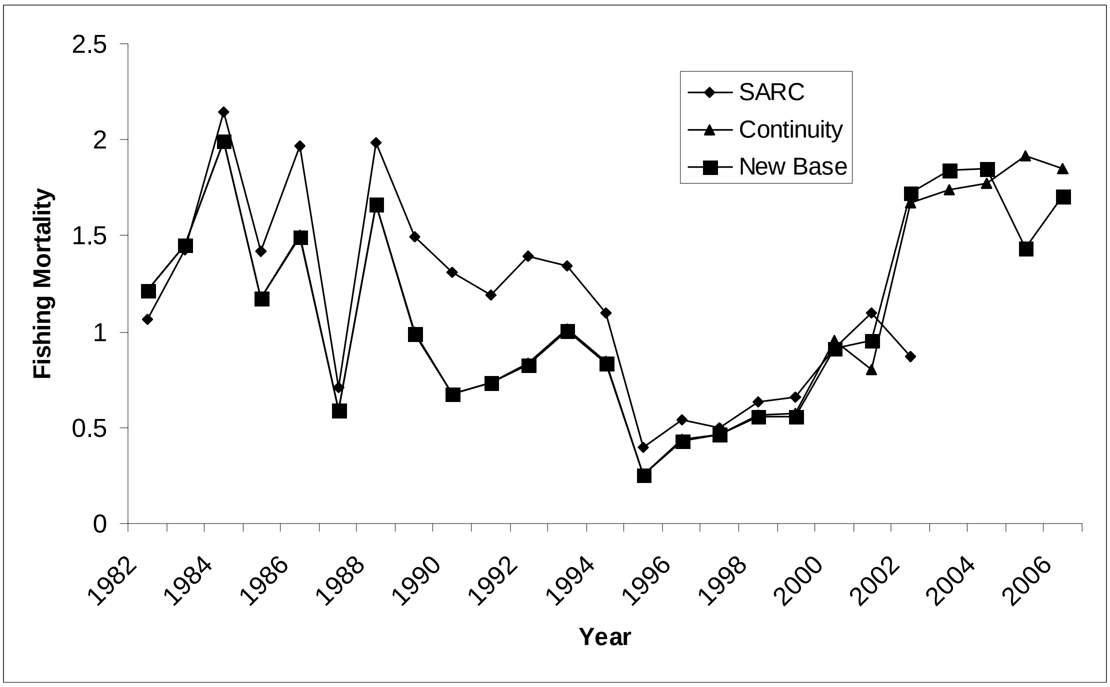


Figure 36. Fishing morality estimates for weakfish 1982-2006 for three configurations of the MSVPA-X.

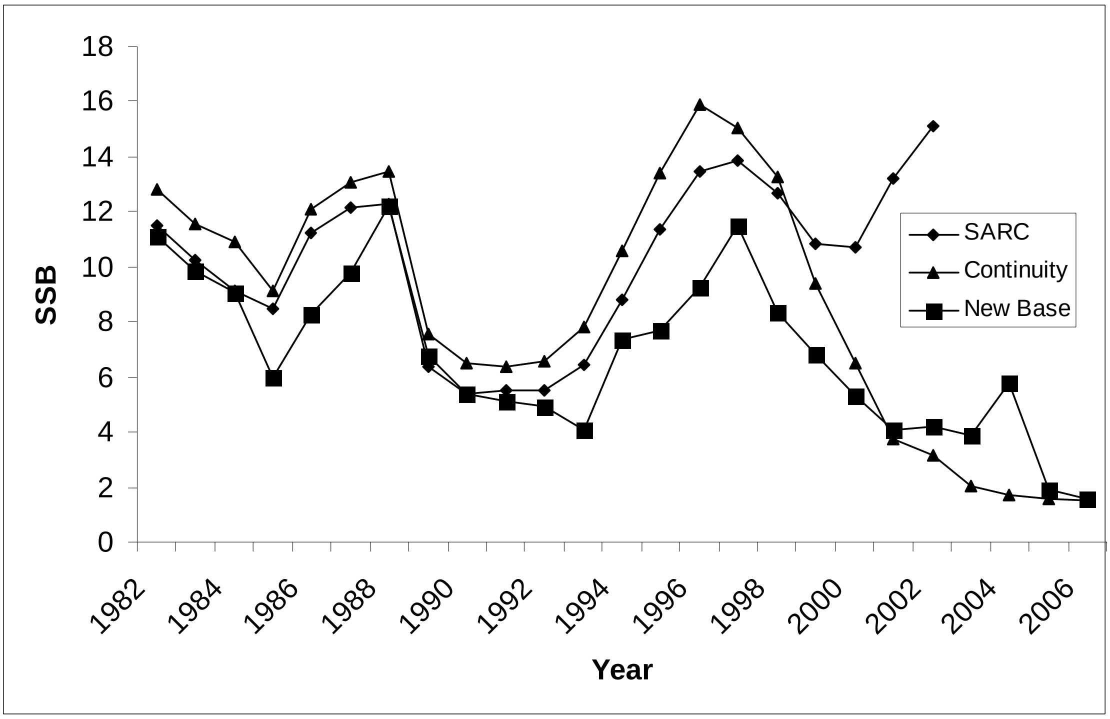


Figure 37. Spawning Stock Biomass (SSB) estimates for weakfish 1982-2006 for three configurations of the MSVPA-X.

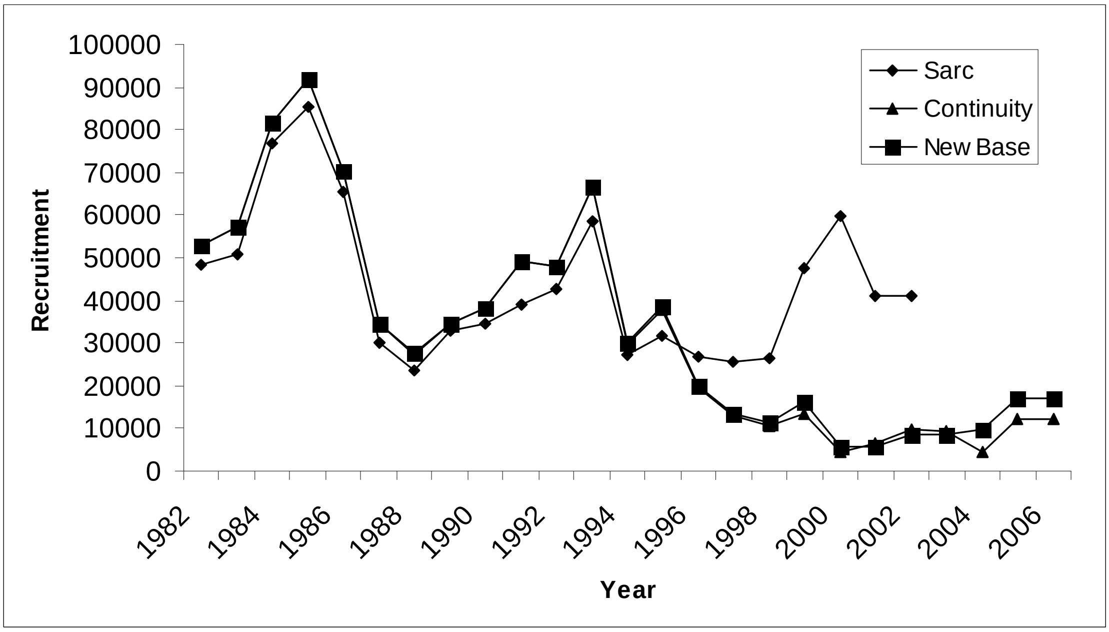
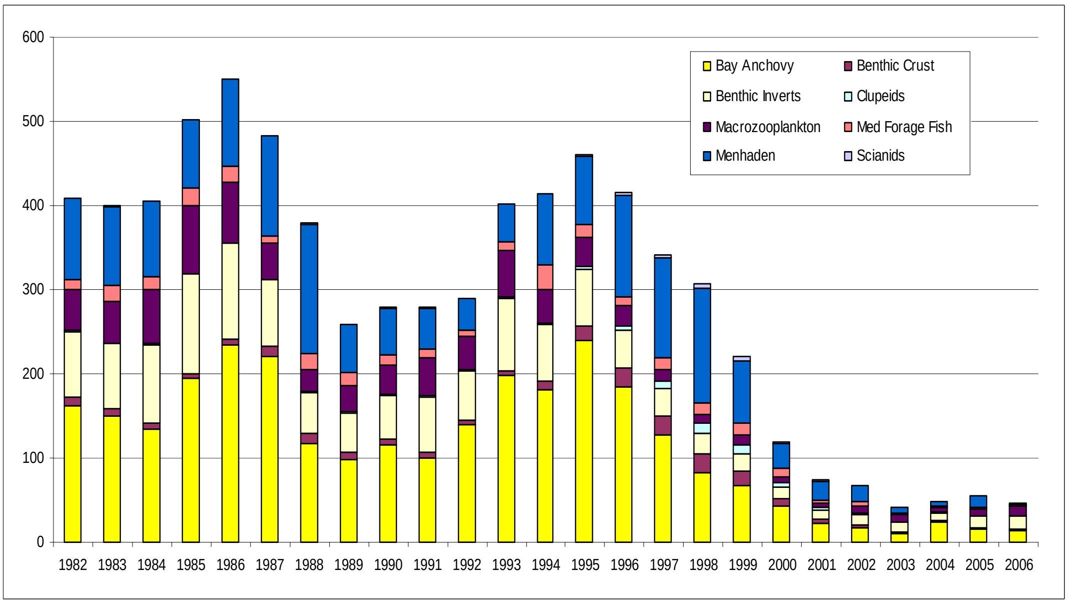


Figure 38. Estimated recruitment of weakfish 1982-2006 for three configurations of the MSVPA-X.



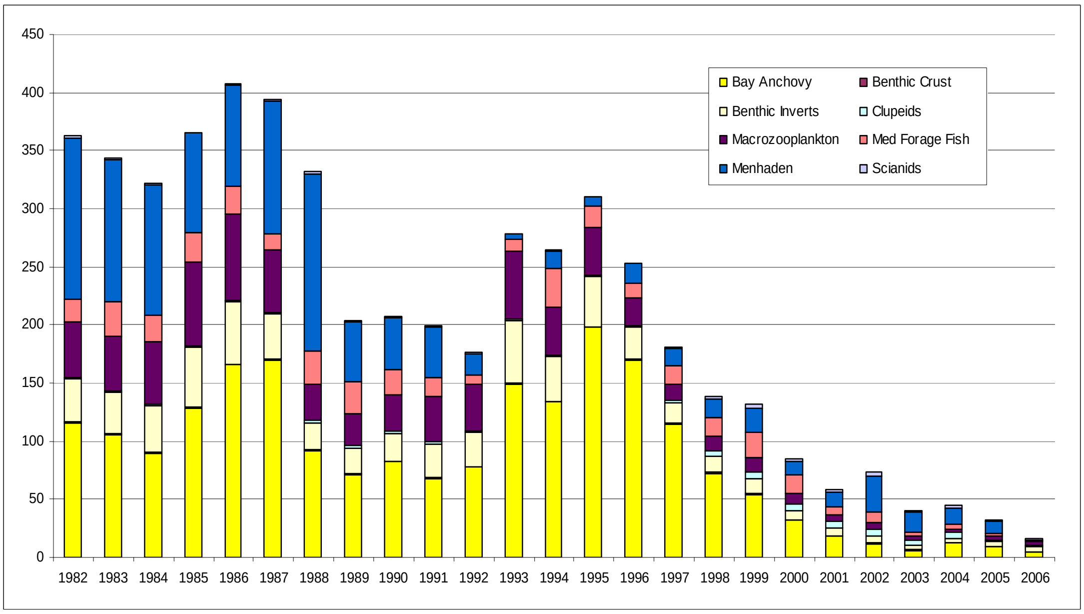


Figure 39. Consumption of various prey species by weakfish 1982-2006 for the continuity (top) and base (bottom) runs of the MSVPA-X.

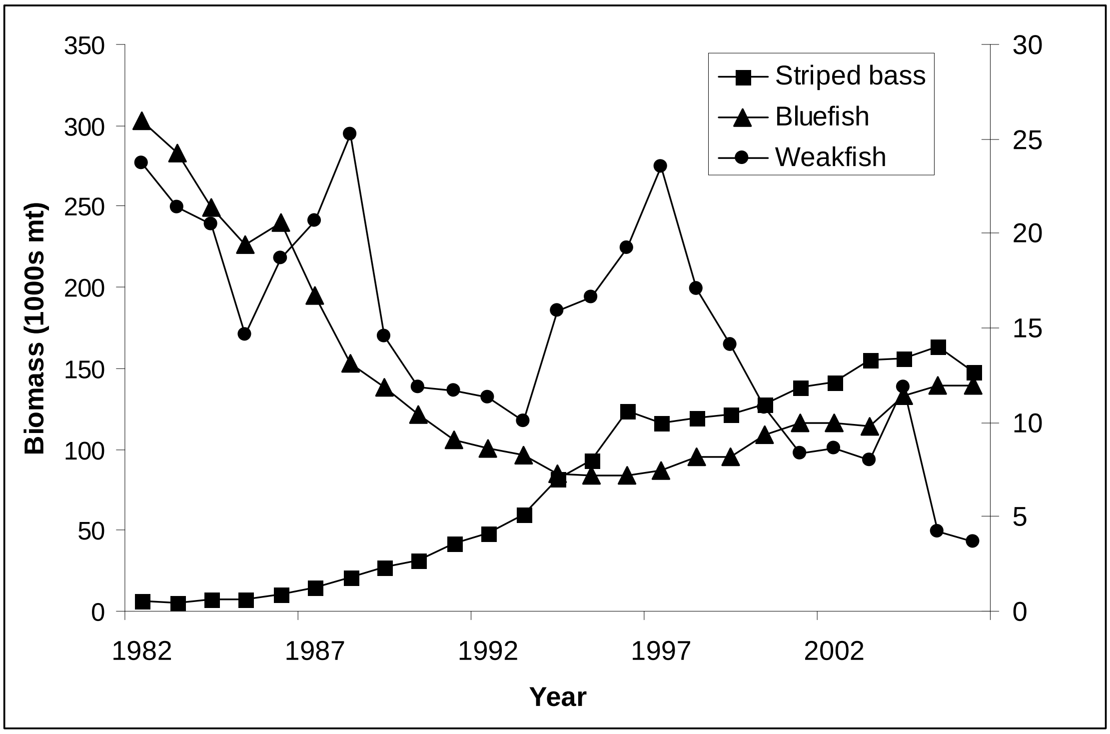


Figure 40. Comparison of biomass trends among three modeled predators. The lefthand y-axis represents biomass in 1,000s of metric tons for striped bass and bluefish. The righthand y-axis represents biomass in 1,000s of metric tons for weakfish.

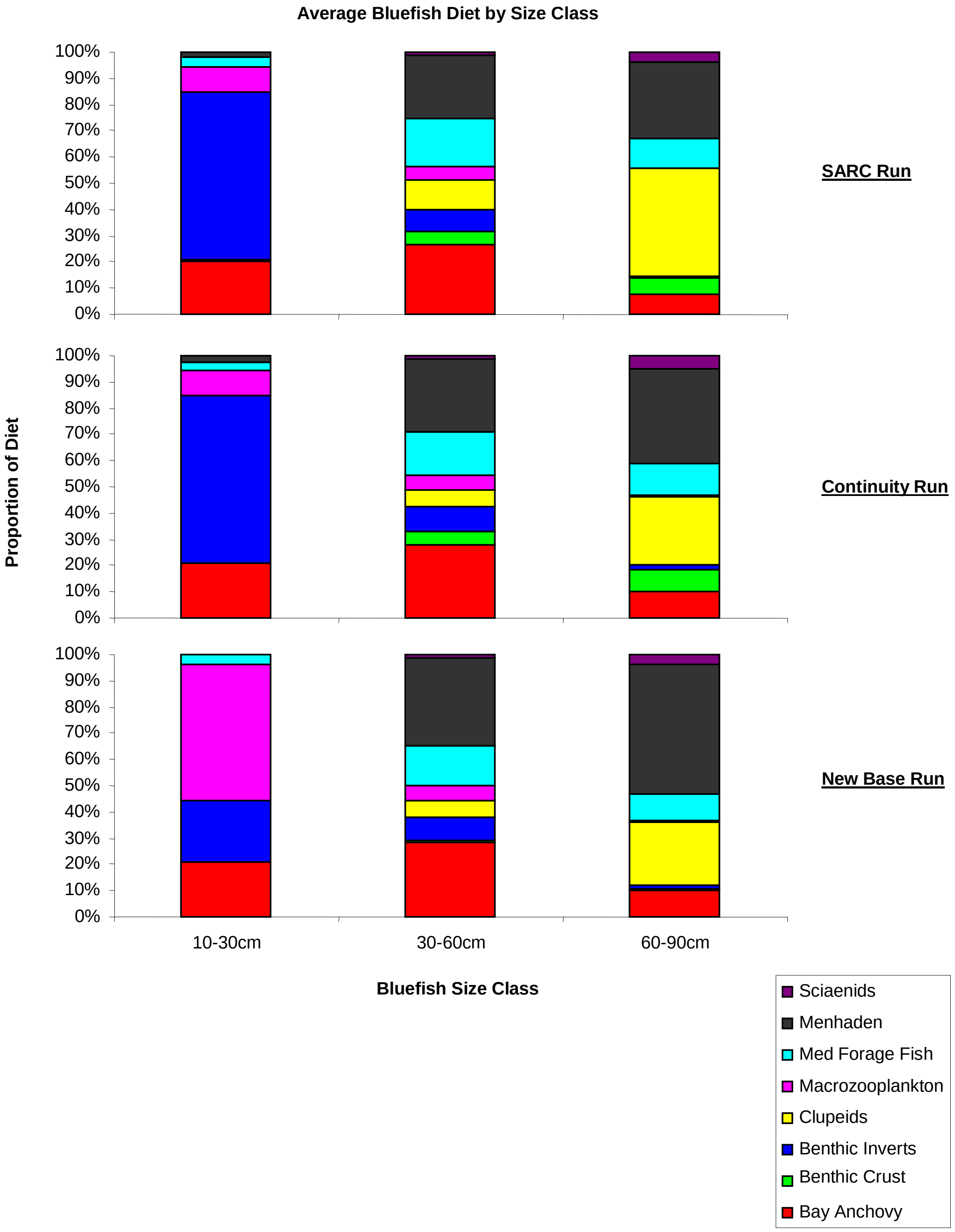


Figure 41. Bluefish diet compositions. A comparison among the SARC run (top), Continuity Run (middle) and New Base Run (bottom).

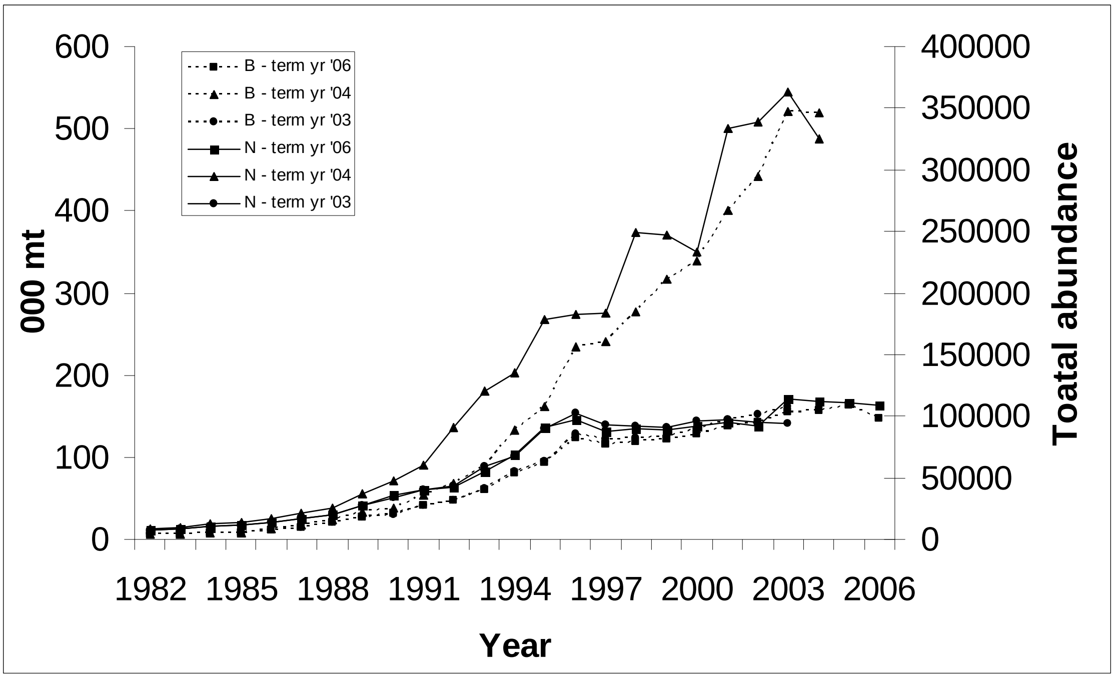


Figure 42. Retrospective pattern in both estimated biomass and abundance of striped bass is extreme when terminal year of the MSVPA-X is 2004, likely due to dramatic increases in tuning index values in that year. MSVPA-X results terminating in other years (e.g. 2003 as shown above) do not display serious retrospective pattern. Other predator models showed similar, but not as extreme, retrospective pattern (terminal year 2004) or lack thereof (terminal year other then 2004).