INTRODUCTION

Background

The Expanded Multispecies Virtual Population Analysis (MSVPA-X) was developed by ASMFC and peer reviewed during SARC 42 in 2006 (Garrison et al. 2010, NEFSC 2006b). The 2006 base 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. An update assessment for the MSVPA-X occurred in 2008 during which all data source were updated through 2006 (ASMFC 2008). The MSVPA-X was partially updated in 2009 with new predator and menhaden input data through 2008 in preparation for the 2010 menhaden benchmark assessment. Major predator and prey data sources were used to update the MSVPA-X again in preparation for the 2012 menhaden update as described in this report.

Overview of changes to base run configuration

In addition to updating the model with new data, the following minor but necessary configuration changes were made to the 2012 base run: weight-at-age estimates for weakfish were revised and several striped bass indices were removed from the striped bass XSA.

DATA INPUT AND MODEL PARAMETERIZATION

Atlantic menhaden

Commercial Landings and Catch-at-Age (CAA)

Reduction fishery: Reduction fishery CAA was updated in the MSVPA-X through 2010. 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 benchmark assessment for Atlantic menhaden for ASMFC (ASMFC 2010b) and have not changed.

Bait fishery: Bait fishery CAA was updated in the MSVPA-X through 2010. Landings from the bait fishery have been provided by the individual coastal states since 1985. Landings were adjusted for missing Virginia snapper vessel landings (1993-1997) as described in the 2008 update (ASMFC 2008). Sampling protocols and estimation of CAA are described in the latest benchmark assessment for Atlantic menhaden for ASMFC (ASMFC 2010b) and have not changed. 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, NY, 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 benchmark assessment for Atlantic menhaden for ASMFC (ASMFC 2010b) and has not changed.

<u>Potomac River Fisheries Commission pound net index</u>: This index is pounds per net days fished, and the methods from the recent benchmark assessment for Atlantic menhaden (ASMFC 2010b) were used to update the index for this MSVPA-X update (Figure 2).

Striped bass

Catch-at-age, 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 update assessment (ASMFC 2011).

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. Size-at-age for 2007-2008 was not updated and was assumed the same as 2006. Size-at-age for 2009-2010 was updated.

Tuning indices

All abundance indices included in the 2011 striped bass update were included in the MSVPA-X as either age-specific or age-aggregated indices. Young of year (age-0) indices included those from Maryland, Virginia, New Jersey, and New York. Juveniles (age-1) indices were available for Maryland and New York. Adult indices included the New Jersey trawl (ages 2–13+), Delaware River electrofishing spawning stock indices (ages 2–13+), Maryland spawning survey (ages 2 – 15+), Connecticut trawl (ages 4-6), and the coastwide MRFSS aggregate (ages 2–13+) total catch rate index.

Connecticut's age-specific recreational CPUE index was not reproducible and was thus eliminated from the XSA. The NEFSC spring inshore survey was not used in the striped bass update and was thus removed from the XSA. The New York ocean haul seine survey and the Massachusetts commercial CPUE surveys ended in recent years and cannot be updated; these indices should be removed from the XSA during the next update. The Delaware trawl survey was mistakenly retained in this run as well and will be removed when the model is next updated.

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; NEFSC 2009). For the SARC-reviewed MSVPA-X model (NEFSC 2006b), the fishery catch-at-age matrix included commercial and recreational landings, and recreational discard estimates. Commercial discard estimates were not included in the catch-at-age matrix until the 2008 MSVPA-X update (ASMFC 2008). For the 2012 MSVPA-X update, catch-at-age again includes removals from all four sectors (commercial and recreational harvest and discards) covering the period 1982 to 2010 for ages 1 through 6+.

A benchmark stock assessment for weakfish in 2009 revised and updated estimates of harvest at age for the period 1981 to 2006 (Table 1; see NEFSC 2009 for details). Recent (2007-2010) recreational harvest estimates and catch-at-age were calculated as in the 2009 stock assessment; however, because of some changes in fishery regulations and data availability, commercial data were treated using slightly different methods than in the past. For the SARC review and 2008 update, commercial harvest weight was converted to numbers at size using state-year-season-gear specific biological samples where available. Recently, population declines and regulation changes have severely limited weakfish harvest, and the number of biological samples has dropped dramatically. As a result, harvest weight from 2008-2010 was converted to numbers at size using region-wide sample data (region-year-season). Commercial discards for 2008-2010 were calculated using multi-year ratios from the 2009 stock assessment for appropriate gear-species combinations, but implementation of trip limits in 2010 required calculation of additional discards for that year. The NMFS Commercial Fisheries Database System (CFDBS) was queried for trips that landed weakfish from 2005-2009. The trip limit from 2010 was applied to these trips to estimate harvest had the trip limit been in place in those years. The ratio of "restricted" 2005-2009 harvest to reported 2005-2009 harvest was calculated and applied to 2010 reported harvest to estimate harvest if the trip limits had not been in effect. The difference between 2010 reported harvest and estimated “unrestricted” harvest was added to the discard estimates developed from the multi-year gear-species combinations.

Tuning indices

The most recent weakfish stock assessment that uses VPA as the preferred method (ASMFC 2006) was tuned using fishery dependent CPUE from the federal recreational fisheries survey. A more recent weakfish assessment included additional indices for tuning the VPA, but VPA was not selected as the preferred assessment model (NEFSC 2009). The 2012 MSVPA update therefore uses only the recreational fishery dependent indices to tune the weakfish model. An age aggregated index of CPUE for ages 2+ was developed using catch (numbers) per private/rental boat trip in the Mid-Atlantic region. The Mid-Atlantic region is the center of the weakfish stock, and the private/rental sector is a highly mobile fleet, able to maintain contact with the stock throughout the season (*i.e.* the index is less likely to be biased by lack of spatial overlap during certain seasons) (ASMFC 2006c). In addition, age specific indices of harvest per unit effort (HPUE) were developed for ages 3-6+ using the same criteria (number per Mid-Atlantic private/rental boat trip).

Annual weight- and size-at-age

As with the 2008 update, annual size- and weight-at-age estimates for the 2012 update were calculated using year-specific von Bertalanffy parameters developed by Vaughan (unpublished data) for the period from 1990-1999 based upon otolith data (Kahn 2002 and D. Vaughn, SEFSC, pers. comm) and 2001 to 2010 (NEFSC 2009; J. Brust, pers. comm.). The 1992 estimates were applied for the period from 1982 to 1991. For 2000, estimates from 1999 and 2001 were averaged. When reviewing inputs from previous MSVPA-X model runs (Garrison et al. 2011, NEFSC 2006b, ASMFC 2008) several inconsistencies were noted in the weakfish weights at age. For the 2012 update, the entire time series of weight at age was updated using the estimated weight at age from the 2009 weakfish benchmark stock assessment (NEFSC 2009)(Table 2, Table 3).

Bluefish

Biomass estimates for the 2009 MSVPA-X base run were derived from the 2009 ASAP age-structured model (1982-2008 values from Table 5 in ASMFC 2009b). Biomass estimates for the 2012 update were taken from the 2011 bluefish stock assessment update (1982-2010 values from Table 11 in NEFSC 2011a). The time series of total bluefish biomasses are shown in Figure 3.

An analysis of bluefish diet information based upon the NEFSC food habits database (http://www.nefsc.noaa.gov/pbio/fwdp/databases.html#survey) indicated significant breaks in bluefish diets in three size/age classes: 10-30 cm (ages 0-1), 30-60 cm (ages 2-3), and >60 cm (ages 4+) (ASMFC 2008). These three size classes were used in the MSVPA-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 from the age-specific ASAP biomass estimates from the 2011 bluefish stock assessment update (Table 11 in NEFSC 2011a; i.e., for each of the three size classes, the sum of annual biomasses within the size class ÷ total biomass across all years and ages).

For the 2012 update, these input values were: Size 1 = 0.0451; Size 2 = 0.1553; Size 3 = 0.7996.

Other prey (non-menhaden)

Macrozooplankton

Crangonid shrimps, mysids, and other large zooplankton are primary prey items for young age classes of each predator species. However, no new estimates of macrozooplankton density have been published since Monaco and Ulanowicz (1997). Biomass estimates for macrozooplankton derived during the 2006 MSVPA-X configuration (NEFSC 2006b) were retained for this update.

Benthic invertebrates

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 2006b) and has been retained in the 2012 update. The size structure of the benthic invertebrate taxa was inferred from general descriptions of the observed size ranges in these habitats (NEFSC 2006b).

Benthic crustaceans

The "other prey" group called benthic crustaceans in the MSVPA-X includes blue crab, American 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 2006b). Revised lobster biomass estimates produced during the 2009 benchmark assessment have shifted the primary contributor to this grouping of other prey from blue crab to lobster. In the 2012 base run, revised estimates of total annual total benthic crustacean biomass were obtained by summing estimates for all four species (Table 4).

> Blue crabs: Blue crab population estimates were available only for the largest, commercially important populations of blue crab in Chesapeake Bay, Delaware Bay, and North Carolina sounds. Estimated biomass was summed across all three areas. Blue crab found in predator stomachs do not exceed the size of approximately 60 mm (R. Latour, VIMS ChesMMAP, pers. comm.); therefore, only total biomass of blue crab <=60 mm in size was included in the analysis.
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> Estimates of biomass of age 0 (<60 mm carapace width) blue crab in Chesapeake Bay were obtained from the 2011 Chesapeake Bay stock assessment (Miller et al. 2011). This assessment used a sex-specific, multiple survey model to develop integrated estimates of management reference points and stock status,

incorporating observation and process error and producing annual estimates of absolute abundance, biomass, and fishing mortality rates from 1979 through 2006.

For Delaware Bay, estimates of recruit biomass (<120 mm crabs) were obtained from the 2011 blue crab assessment for Delaware Bay (Wong 2010). This assessment was based on a catch-survey model (Collie and Sissenwine 1983), incorporating observation and process error and producing annual estimates of absolute abundance, biomass, and fishing mortality rates from 1979 through 2010. An average size frequency distribution from the Chesapeake Bay was applied to Delaware Bay recruit estimates to obtain biomass of crabs <=60 mm carapace width.

Stock assessment of blue crab in North Carolina was conducted by Eggleston et al, 2004. A Collie - Sissenwine catch survey model was used to estimate absolute abundance of recruits (CW<127 mm) and post-recruits (CW=>127 mm). Total abundance estimates for 1988-2002 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 1982-2001 period. Abundance in this time period was calculated by taking the fraction of annual harvest relative to the 2002 harvest and multiplying it by the 2002 abundance estimate. No population estimates were available for the 2003-2010 period. Population size estimates for these years was obtained by dividing the total annual harvest by the average exploitation rate observed in 1997-2002 period (0.73) and multiplying the ratio of current to 2002 biomass by the 2002 abundance estimate. Total biomass was allocated by size groups as described above.

Lobster: Abundance estimates for lobster were obtained from the 2009 American lobster stock assessment and (ASMFC 2009a). This assessment used a statistical length-, sex-, and season-structured model to estimate recruitment, abundance, and biomass of lobster 53-227 mm carapace length in each of three stock units. For each sex and season, total abundance of lobster in the 78 mm carapace length bin (≥ 78 mm and <83 mm) was multiplied by the weight of lobster by size bin, sex, and stock area. The 78 mm bin most closely corresponds with the “pre-recruit” class (i.e., the length bin from which lobsters are most likely to recruit to the fishery in a given year) used to estimate lobster biomass in the previous Collie-Sissenwine model and inform the 2008 MSVPA. Total weight of males and females in each season were summed across stock units.

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 – 20010 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 2006b), 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. Combined rock and Jonah crab biomass estimates for 2002-2010 were averaged across seasons.

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 2012 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 2006 SARC review of MSVPA-X (NEFSC 2006b).

Atlantic thread herring, Spanish sardine, and scad: As in the 2008 MSVPA model, the sardine/herring complex (Atlantic thread herring, Spanish sardine, scaled sardine, and scads) biomass estimate for was calculated by summing total recreational (north, mid, and south Atlantic from MRFSS data sets) and commercial landings from (ME to FL). The catch (88mt, an annual average for the 2008-2010 period) was then converted to biomass (1,759mt) using an assumed exploitation rate of 0.05 (F=0.1 and Z=1.2).

Medium forage fish – butterfish and squids

The biomass estimates for butterfish were taken from the most recent approved stock assessment document (NEFSC 2010; Table B26).

The biomass estimates for *Loligo* were taken from the last approved stock assessment document (NEFSC 2011b; Table B25). The biomass estimates for *Illex* squid were developed by taking the average weight per tow from the total annual tows from the NEFSC trawl survey (NEFSC, personal communication), dividing that value by a tow area of 0.0389358 km^2, multiplying that value by a total stock area of 146,324 km^2, and then dividing 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:

$$B = (cA/a) / e \qquad \text{(from Sparre and Venema 1998)}$$

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 were updated with new estimates through 2010. Total annual spot and croaker biomass estimates were summed to create the “other prey” class called “sciaenids”.

Croaker. Estimated trends in croaker biomass for 1982-1987 were obtained from assessment results (ASMFC 2005). Biomass estimates from 1988-2010 were obtained from Katie Drew (ASMFC, pers. comm.) based on an update of the most recent stock assessment (ASMFC 2010a). Note these estimates do not include shrimp bycatch.

Spot. Spot biomass estimates for 1982-2010 were calculated as in the 2008 MSVPA-X update.

Predator diets

Diet data were updated during the 2008 assessment (ASMFC 2008). The same prey preference and spatial overlap parameters were used in this 2012 update.   These parameters need to be carefully re-evaluated and updated during the next update or benchmark of the MSVPA-X.

Temperature

The same temperature data were used as in the 2008 update. Recent years were assumed to be the same as 2008. These inputs need to be updated during the next update or benchmark of the MSVPA-X.

RESULTS

Atlantic menhaden

This section compares MSVPA-X model output for Atlantic menhaden from two project runs; the 2009 run (1982-2008) and 2012 base run (1982-2010). Total population abundance (ages 1+) of Atlantic menhaden remained mostly unchanged in this update (Figure 6) with the notable exception of increased abundances in the recent period. As always, estimates in the terminal year are most uncertain.

Estimates of the predation component of natural mortality (M2) on Atlantic menhaden by year and predator averaged across ages 0 to 2 are presented in (Figure 7-Figure 9). Overall predation mortality for the overlapping years of these new and old runs was not very different with the exception of weakfish; revised weight-at-age increased the estimates of historical removals. Overall, though, the change is only slight when compared to the overall rate of predation morality on menhaden by both bluefish and striped bass.

Estimates of total M2 (summed across the 3 modeled predators) were then compared for ages 0-6+ menhaden between the 2009 and 2012 model runs (Figure 10). Despite the increase in weakfish weight at age and consumption, overall changes to the M2 were minimal between old and new runs. However, for the oldest age class (6+) large changes in the M2 were noted (Figure 11), while these differences are minor when compared to the overall magnitude of the predation mortality on younger ages, this difference could be a contributing factor to the ongoing retrospective problem found in the most recent menhaden update.

In summary, total population abundance and predation mortality are similar in trend and magnitude between old and new or updated runs. However notable differences were observed, suggesting more intensive analysis is warranted.

Striped bass

A comparison of striped bass population estimates (ages 0+) from the MSVPA-X 2009 base run (data from 1982 through 2008, inclusive) and 2012 base run (data from 1982 through 2010, inclusive) are nearly identical through 1999 (Figure 12). Trends in abundance after 1999 are similar, though between 2000 and 2004 the 2012 base run estimates are on average 10% lower than estimates from the 2009 base run, whereas between 2006 and 2008 the 2012 base run estimates are on average 15% greater than the 2009 base run estimates. The differences in total abundance coincide with differences in estimates of age 0 abundance (Figure 13) for the two runs during those same time periods. Estimates of striped bass SSB from the two configurations of the MSVPA-X are identical (or nearly so) through 1995 (Figure 14). Between 1996 and 2002 the 2012 base run estimates of SSB are on average 5% greater than those from the 2009 base run, whereas between 2003 and 2006 the 2012 base run estimates are on average 5% below estimates from the 2009 base run. Estimates of SSB in 2007 and 2008 from the two model runs trend in opposite directions (and differ by approximately 20%) – the trend in SSB for the final two years of the 2012 base run continues downward. Estimates of fishing mortality between the two configurations of the MSVPA-X are nearly identical through 2001 (Figure 15). After 2001, though both MSVPA-X configurations show an increasing trend in F, the 2012 base run consistently estimates F at levels higher than the 2008 configuration (on average, 17% higher).

Trends in age 1+ abundance between the 2012 base run and the single species 2011 striped bass update stock assessment (Table 11 from ASMFC 2011) are nearly identical (Figure 16). The 2012 MSVPA-X base run estimates are however in general lower than the single species estimates (on average 18% lower, but as much as 47% lower), with the exception of estimates from 1997 through 2003 when the 2012 base run estimates are either identical to or slightly greater than the single species estimates. Differences in population size estimates are attributed to the difference in structure of assessment models (XSA in MSVPA-X versus statistical catch-at-age).

Estimates of menhaden consumed by striped bass are similar between the two MSVPA-X configurations with the notable exception of consumption in the terminal year of the 2009 base run, in which consumption of menhaden in the 2012 configuration is twice that estimated in the 2009 configuration (Figure 17, Figure 18). Principal components of striped bass diet in the 2012 base run include: bay anchovies, benthic invertebrates, clupeids, and menhaden. Medium forage fish, a notable component of striped bass diet in the 2009 base run, are a negligible portion of striped bass diet in the 2012 base run, primarily as result of reduced medium forage fish abundances across the entire time series in the 2012 configuration.

Weakfish

Comparisons of the results for the weakfish single species analysis are made for the 2009 and 2012 base runs of the MSVPA-X model. Results of the 2009 benchmark stock assessment for weakfish (NEFSC 2009) are not included in the comparison because the Weakfish Technical Committee had concerns with the age-structured VPA model, and the VPA was not selected as the preferred model.

Weakfish abundance estimates for the 2009 and 2012 runs of the MSVPA-X are nearly identical until 2004 (Figure 19). Abundance was high in the early to mid 1980s, reaching a peak in 1985 before declining by over 50% by 1989. The population rebounded over the next five years but has exhibited a nearly exponential decline since 1996. Since 2004, results of the 2012 run are lower than those from the 2009 model run. Average abundance for the period 2006-2010 is approximately 3% of the abundance during 1982-1986.

Estimated fishing mortality rates were also similar between the 2009 and 2012 MSVPA-X model runs (Figure 20). Fishing mortality rates were variable, but generally exceeded 1.0 from 1982 to 1989, falling to between 0.5 and 1.0 for 1990 to 1994. F reached the time series minimum (F = 0.30) in 1995 before increasing rapidly to over 2.0 by 2003.

Since 2004, results from the 2012 run have been greater than F values estimated during the 2008 update. One of the concerns expressed by the Weakfish Technical Committee with the single species age structured model during the recent weakfish benchmark assessment (ASMFC 2006; NEFSC 2009) was the assumption of constant natural mortality. Increased fishing mortality rates estimated from the age-structured model during periods of increased harvest restrictions suggested that natural mortality was not constant. The trends in F from the MSVPA-X models are similar in pattern to those from the weakfish single species assessments. An alternative view proposed by the Weakfish Technical Committee would be to combine calculated F estimates with input M rates (M = 0.25) to portray a trend in total mortality, Z. Regardless, it should be noted that the MSVPA-X, as per the SARC peer reviewers' comments (NEFSC 2006b), cannot and should not serve as an indicator of single species status.

Updated weights at age are generally higher than those used during the 2008 MSVPA-X update, resulting in generally higher SSB estimates for the 2012 run (Figure 21). Regardless of the difference in scale, the temporal pattern in weakfish spawning stock biomass is similar between the 2009 and 2012 MSVPA-X model runs and generally follow the pattern of abundance. High levels of SSB during the early 1980s declined during the latter part of the decade before rebounding gradually during the early 1990s. SSB has declined since 1997 to the lowest levels on record in 2010.

As with the other parameters, estimated age-0 recruitment trends were similar between the 2009 and 2012 model runs until 2004 (Figure 22). Since 2004, recruitment from the 2012 run is lower than from the 2009 run.

The overall pattern in consumption by weakfish is similar between the 2009 and 2012 MSVPA-X model runs (Figure 23). Primary diet items include bay anchovies, benthic invertebrates, and macro-zooplankton. Menhaden has not been an appreciable component of weakfish diet since the early 1990s. The two largest differences between the 2009 and 2012 runs are that the overall scale approximately doubled for the 2012 run, and the relative absence of medium forage in the 2012 run compared to 2008. The increase in scale is largely due to using updated weight at age vectors in 2012 which greatly increased the estimated biomass of weakfish during the early part of the time series. Significant reductions in estimated availability (abundance) of medium forage are the primary driving factor behind the reduced consumption of this prey category.

After the assessment runs were completed, some potential errors were observed in the weight at age time series. Weights at age, particularly for older fish, are lower than expected based on raw data. It is likely the inconsistency is due to using fitted size and weight at age data rather than using raw data; however it is also possible that the error is due to a conversion error or other type of error. Higher weights at age would provide increased estimates of spawning stock biomass and consumption (which is driven by biomass). The impact on estimated predation mortality for menhaden, however, would be minimal since menhaden are only a small component of weakfish diet (Figure 23) and the biomass of weakfish relative to other predators is very small (Figure 24). The weakfish size and weight at age data will be thoroughly reviewed during the MSVPA-X benchmark stock assessment.

Bluefish

Trends in bluefish biomass are similar between the 2009 and 2012 base runs (Figure 3). Each begins with high biomass (>300,000 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 150,000-200,000 metric tons (Figure 3). A comparison of biomass trends among the three modeled predators can be found in Figure 24.

Diet composition of bluefish is similar between the MSVPA-X runs (Figure 25, Figure 26). The 2012 base run results suggest that size 1 bluefish (10-30 cm) are primarily consuming bay anchovies, benthic invertebrates, and macro zooplankton (Figure 25). Menhaden are important parts of size 2 and 3 bluefish diets, as are bay anchovies and clupeids (Figure 25). Total consumption of menhaden by bluefish (and other predators) is illustrated in Figure 27. Medium forage fish, a notable component of sizes 2 and 3 bluefish diet in the 2009 base run, are a negligible portion of bluefish diet in the 2012 base run, primarily as result of reduced medium forage fish abundances across the entire time series in the 2012 configuration. The 2012 base run results suggest that bluefish are consuming menhaden and bay anchovies in place of medium forage fish (Figure 25).

MODELING AND RESEARCH RECCOMMENDATIONS

Below is an abbreviated list of short (for 2015 benchmark) and long-term modeling and research needs to support upkeep and development of the MSVPA.

Short-term

- Convert MSVPA code from VB to ADMB and build associated output graphing code in R
- Carefully re-review all model input calculations and assumptions
- Modifications to MSVPA configuration:
    - Add additional explicitly modeled predators, biomass predators, and “other prey”, as necessary/possible
    - Summarize diet studies results into a synthetic view of seasonal and spatial variation in diets to both parameterize models and identify data gaps and update parameterization of prey preferences/diet ranks/spatial overlap
    - Model bluefish in MSVPA via XSA (rather than as a biomass input) and convert weakfish to a biomass predator
    - Parameterize feedback between prey and predator growth
    - Compare/contrast with ICES MSVPA results.

Long-term

- Transition to statistical MS model

- Validate diet parameters used in all these approaches by conducting a coast wide diet and abundance study (i.e., an Atlantic coast "year of the stomach") especially for nearshore sites during all seasons.

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Tables

Table 1. Weakfish catch at age (thousands of individuals).

	Age					
Year	**1**	**2**	**3**	**4**	**5**	**6+**
1982	9,914.2	12,967.0	5,473.0	2,778.2	721.6	639.5
1983	8,004.0	12,869.1	5,822.7	2,780.0	568.2	424.1
1984	10,444.2	14,736.9	6,521.1	3,045.3	484.5	254.5
1985	14,153.2	11,262.3	3,246.1	1,171.0	212.9	55.1
1986	18,610.7	15,778.4	4,942.4	1,823.7	264.1	52.1
1987	16,256.3	14,343.1	4,347.1	1,485.2	145.4	11.0
1988	8,161.9	16,140.8	10,545.3	6,092.0	1,050.5	70.7
1989	3,705.0	5,304.9	4,333.5	2,922.3	626.2	84.6
1990	9,510.1	4,890.1	2,093.6	1,204.8	591.4	89.1
1991	9,795.9	5,825.6	2,750.0	1,373.6	463.4	57.3
1992	5,179.5	6,046.0	2,211.0	1,255.0	527.8	65.0
1993	4,974.8	6,357.0	2,179.8	1,138.6	401.1	48.2
1994	3,761.9	4,347.4	3,561.0	1,563.5	204.1	39.8
1995	4,336.3	3,727.7	3,566.7	1,637.8	198.1	54.3
1996	2,498.8	2,689.5	5,033.3	3,174.2	1,379.3	100.1
1997	1,716.4	2,394.2	2,913.2	5,522.0	1,523.1	410.2
1998	1,270.6	2,138.3	3,983.1	2,019.2	2,928.8	909.5
1999	1,412.6	1,300.4	2,256.6	3,326.0	725.7	1,145.0
2000	1,377.0	1,727.1	1,985.7	1,663.7	1,528.2	403.0
2001	2,420.7	2,953.1	1,474.1	1,219.9	658.7	485.9
2002	2,591.7	1,070.5	2,695.7	823.9	388.2	231.5
2003	335.6	949.9	959.7	718.4	209.5	254.2
2004	852.3	1,511.9	667.8	115.8	49.7	38.4
2005	334.3	1,771.5	1,255.2	191.5	10.2	27.1
2006	747.3	637.3	959.2	252.9	15.5	11.9
2007	386.3	725.5	324.5	125.4	23.4	5.8
2008	599.2	670.2	247.2	80.8	6.2	1.7
2009	439.5	498.8	139.2	16.4	3.7	1.8
2010	487.1	508.3	106.3	4.8	2.0	0.4

Table 2. Variable size at age for weakfish (cm).

	Age						
Year	0	1	2	3	4	5	6+
1982	5.3	14.22	26.65	36.73	44.92	51.57	56.97
1983	5.3	14.22	26.65	36.73	44.92	51.57	56.97
1984	5.3	14.22	26.65	36.73	44.92	51.57	56.97
1985	5.3	14.22	26.65	36.73	44.92	51.57	56.97
1986	5.3	14.22	26.65	36.73	44.92	51.57	56.97
1987	5.3	14.22	26.65	36.73	44.92	51.57	56.97
1988	5.3	14.22	26.65	36.73	44.92	51.57	56.97
1989	5.3	14.22	26.65	36.73	44.92	51.57	56.97
1990	5.3	14.22	26.65	36.73	44.92	51.57	56.97
1991	5.3	14.22	26.65	36.73	44.92	51.57	56.97
1992	5.3	14.22	26.65	36.73	44.92	51.57	56.97
1993	5.3	15.63	23.96	31.22	37.54	43.05	47.84
1994	5.3	19.36	26.62	33.02	38.66	43.62	47.99
1995	5.3	19.67	25.3	30.41	35.05	39.25	43.07
1996	5.3	19.14	25.29	30.82	35.79	40.26	44.29
1997	5.3	24.51	29.39	33.84	37.9	41.61	44.99
1998	5.3	20.28	26.24	31.61	36.44	40.79	44.71
1999	5.3	18.47	26.02	32.66	38.48	43.59	48.07
2000	5.3	17.57	26.49	34.2	40.85	46.59	51.54
2001	5.3	16.66	26.96	35.74	43.22	49.59	55.01
2002	5.3	19.42	28.4	36.18	42.91	48.73	53.77
2003	5.3	18.73	29.27	38.15	45.66	51.99	57.33
2004	5.3	23.13	30.67	37.35	43.26	48.49	53.12
2005	5.3	22.6	29.63	35.57	40.6	44.85	48.44
2006	5.3	23.99	30.7	36.22	40.77	44.52	47.61
2007	5.3	23.99	30.7	36.22	40.77	44.52	47.61
2008	5.3	25.89	32.23	36.39	41.12	50.14	78.21
2009	5.3	26.34	29.60	33.88	39.95	49.99	76.67
2010	5.3	25.86	29.21	32.65	45.45	55.73	81.02

Table 3. Variable weight at age for weakfish (kg).

Year	Age 0	1	2	3	4	5	6+
1982	0.106	0.212	0.307	0.483	1.076	3.033	3.033
1983	0.078	0.19	0.368	0.885	1.4	2.86	2.862
1984	0.095	0.189	0.379	0.758	1.583	2.536	2.536
1985	0.077	0.267	0.579	1.235	1.75	3.06	3.055
1986	0.152	0.262	0.758	1.759	2.819	3.173	3.173
1987	0.087	0.236	0.524	1.234	2.127	2.536	2.536
1988	0.09	0.179	0.398	0.796	1.494	3.026	3.026
1989	0.109	0.186	0.383	0.769	1.417	3.348	3.348
1990	0.06	0.104	0.407	0.865	1.399	1.945	1.945
1991	0.036	0.215	0.543	0.971	1.446	1.925	1.925
1992	0.027	0.181	0.477	0.875	1.326	1.79	1.79
1993	0.036	0.132	0.292	0.509	0.769	1.058	1.058
1994	0.069	0.181	0.346	0.556	0.8	1.067	1.067
1995	0.071	0.153	0.265	0.407	0.572	0.755	0.755
1996	0.066	0.152	0.276	0.433	0.617	0.822	0.822
1997	0.139	0.239	0.366	0.515	0.681	0.862	0.862
1998	0.078	0.17	0.298	0.457	0.642	0.846	0.846
1999	0.059	0.166	0.329	0.538	0.783	1.051	1.051
2000	0.059	0.166	0.329	0.538	0.783	1.051	1.051
2001	0.043	0.182	0.425	0.751	1.134	1.548	1.548
2002	0.092	0.265	0.52	0.836	1.191	1.566	1.566
2003	0.067	0.249	0.544	0.924	1.356	1.809	1.809
2004	0.116	0.279	0.512	0.802	1.134	1.493	1.493
2005	0.101	0.237	0.431	0.674	0.953	1.257	1.257
2006	0.133	0.287	0.5	0.762	1.064	1.392	1.392
2007	0.174	0.388	0.675	1.015	1.388	1.776	1.776
2008	0.152	0.362	0.653	1.005	1.398	1.811	1.811
2009	0.136	0.341	0.631	0.983	1.376	1.79	1.79
2010	0.109	0.311	0.608	0.978	1.393	1.83	1.83

Table 4. Benthic crustacean biomass estimates by season (mt).

	Season 1	Season 2	Season 3	Season 4
1982	17,808	17,557	17,568	17,724
1983	14,784	14,539	15,790	16,419
1984	20,753	20,444	23,566	23,695
1985	19,850	19,487	19,368	19,684
1986	17,033	16,699	17,841	17,940
1987	19,664	19,341	20,008	20,762
1988	19,839	19,523	22,266	22,817
1989	27,728	27,365	27,509	28,351
1990	25,584	25,213	25,752	26,514
1991	25,460	25,069	24,909	25,620
1992	20,297	19,914	19,979	21,026
1993	23,154	22,760	24,355	25,339
1994	21,158	20,700	20,952	21,812
1995	21,984	21,520	21,518	22,601
1996	22,206	21,738	22,990	24,162
1997	25,532	25,011	25,719	26,742
1998	21,017	20,473	20,822	22,380
1999	24,105	23,533	24,980	25,617
2000	21,599	20,994	18,021	19,324
2001	18,714	18,212	19,385	20,260
2002	21,780	21,241	20,127	21,458
2003	18,812	18,305	19,611	20,763
2004	20,433	19,876	19,704	21,007
2005	20,924	20,366	20,395	21,238
2006	21,578	21,030	19,082	20,129
2007	18,366	17,889	18,249	19,426
2008	22,750	22,273	22,633	23,810
2009	22,444	21,968	22,327	23,504
2010	23,337	22,861	23,221	24,397

Table 5. Other clupeid biomass estimates by season (mt).

	Season 1	Season 2	Season 3	Season 4
1982	110,416	110,416	110,416	110,416
1983	109,847	109,847	109,847	109,847
1984	111,803	111,803	111,803	111,803
1985	134,136	134,136	134,136	134,136
1986	169,316	169,316	169,316	169,316
1987	194,636	194,636	194,636	194,636
1988	194,190	194,190	194,190	194,190
1989	238,739	238,739	238,739	238,739
1990	333,739	333,739	333,739	333,739
1991	430,538	430,538	430,538	430,538
1992	512,740	512,740	512,740	512,740
1993	582,657	582,657	582,657	582,657
1994	567,693	567,693	567,693	567,693
1995	621,144	621,144	621,144	621,144
1996	773,173	773,173	773,173	773,173
1997	758,926	758,926	758,926	758,926
1998	759,705	759,705	759,705	759,705
1999	713,108	713,108	713,108	713,108
2000	853,894	853,894	853,894	853,894
2001	786,066	786,066	786,066	786,066
2002	665,084	665,084	665,084	665,084
2003	655,634	655,634	655,634	655,634
2004	669,065	669,065	669,065	669,065
2005	628,571	628,571	628,571	628,571
2006	676,261	676,261	676,261	676,261
2007	667,825	667,825	667,825	667,825
2008	594,332	594,332	594,332	594,332
2009	590,650	590,650	590,650	590,650
2010	585,890	585,890	585,890	585,890

Figures

Figure 1. Coastwide juvenile abundance index (black line) based on the delta-lognormal GLM with fixed factors year, month, and state fitted to seine catch-per-haul data for 1959-2011 from all states combined. Coefficients of variations (CV; grey line) were calculated from jackknifed derived SEs.

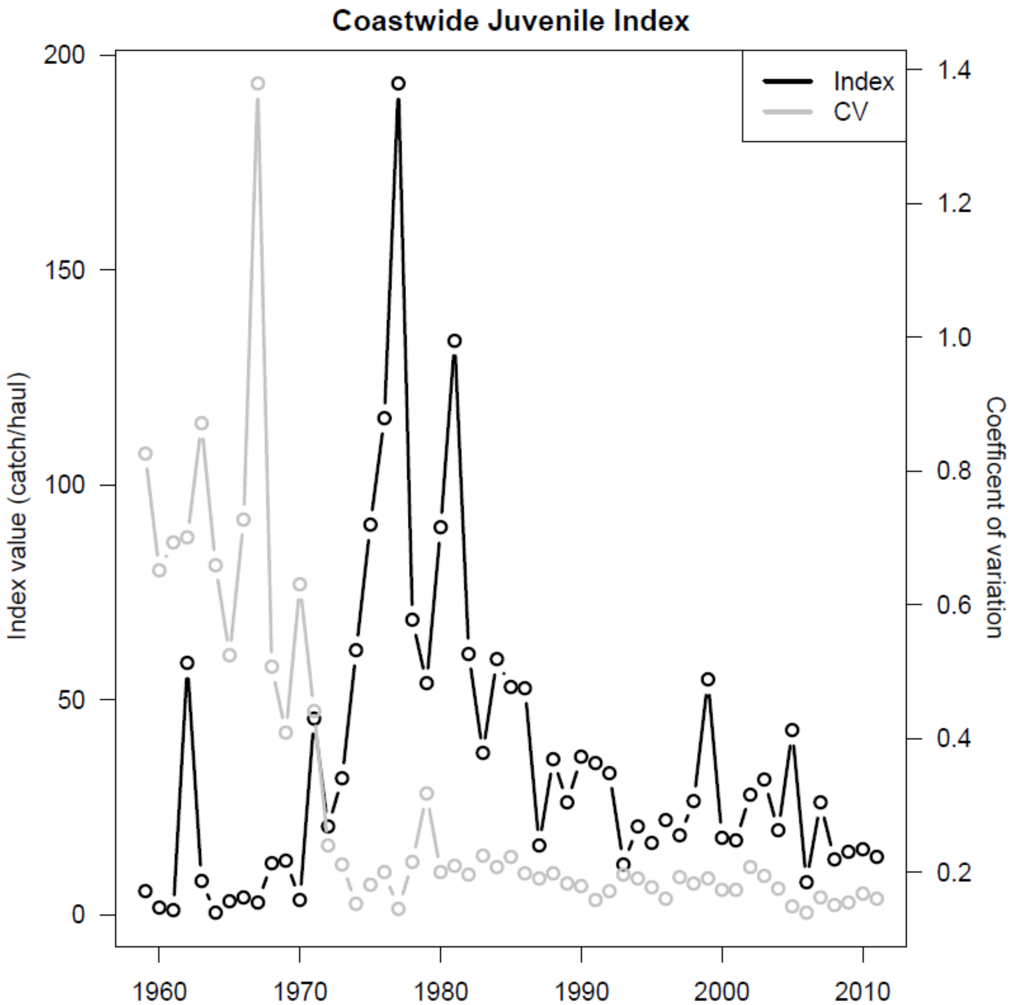


Figure 2. PRFC adult Atlantic menhaden (primarily ages-1 through 3) index of relative abundance derived from annual ratios of pounds landed and pound net days fished. CPUE for the years 1964-1975 and 1981-1987 were estimated from regressions of published landings (to obtain annual landings) and licenses (to obtain total annual days fished).

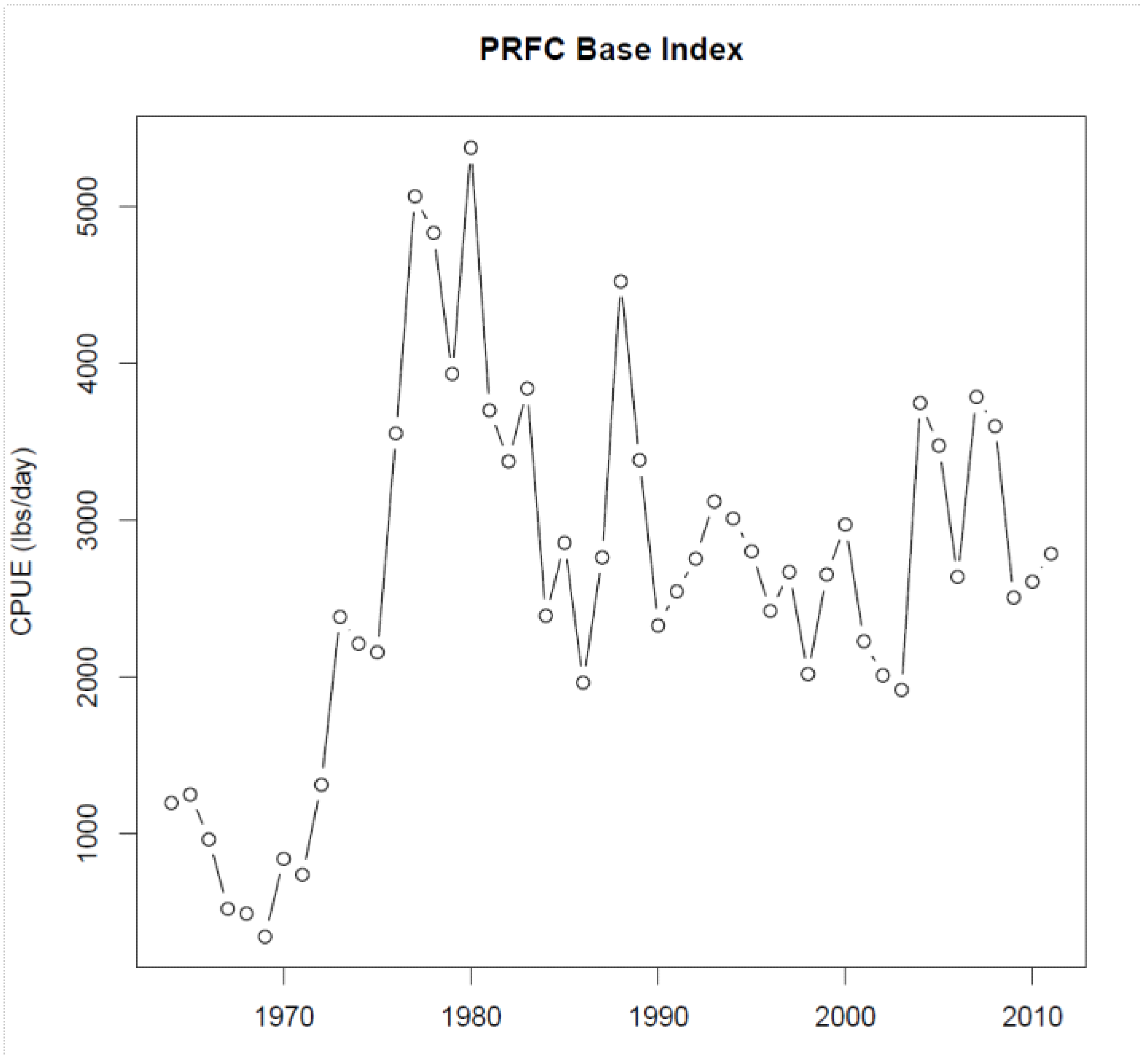


Figure 3. Bluefish biomass trends – a comparison between the 2009 and 2012 base runs.

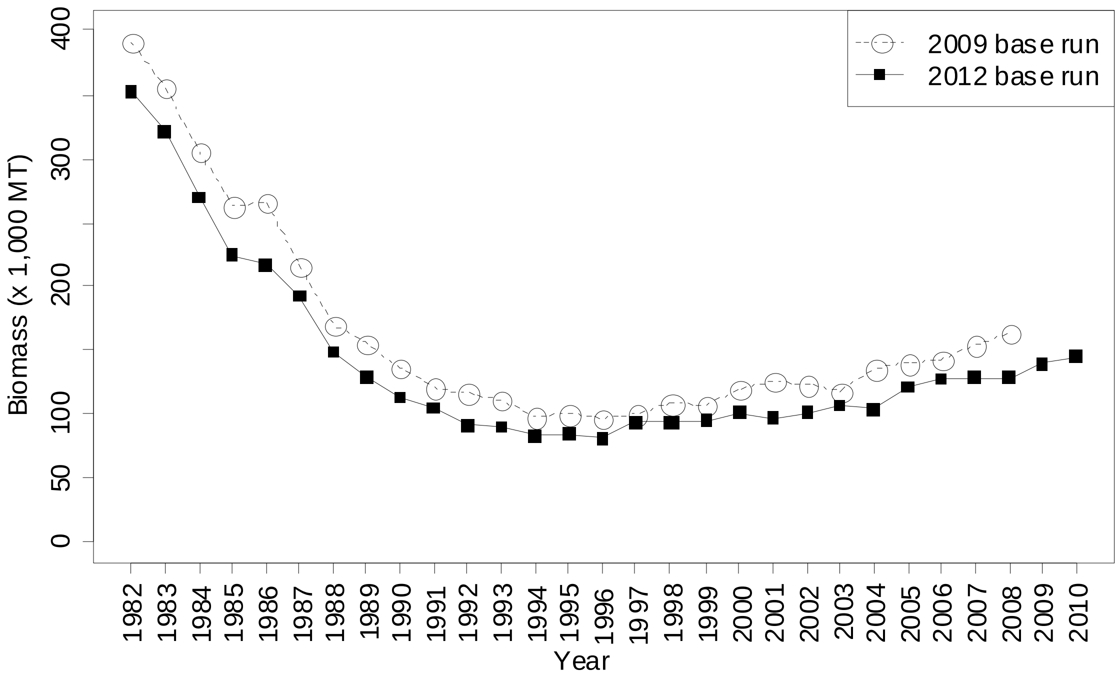
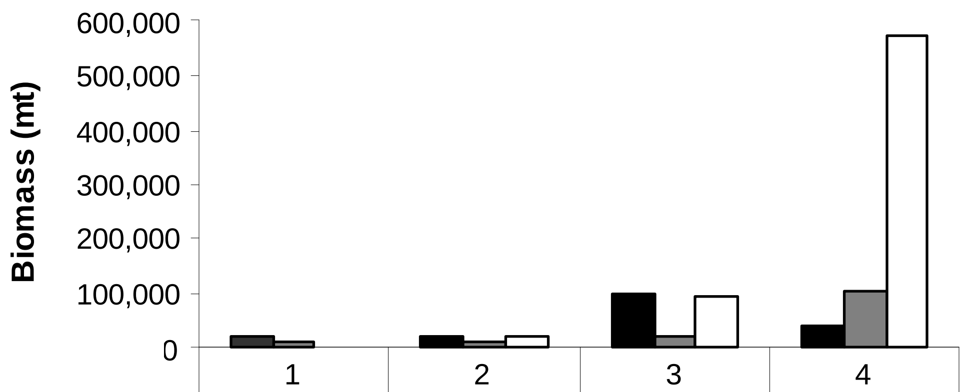


Figure 4. Seasonal bay anchovy biomass (mt) estimates for the Chesapeake Bay developed for the 2005 and 2007 assessment (Rilling and Houde, 1999; Jung and Houde 2004) and the New Jersey coast.



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

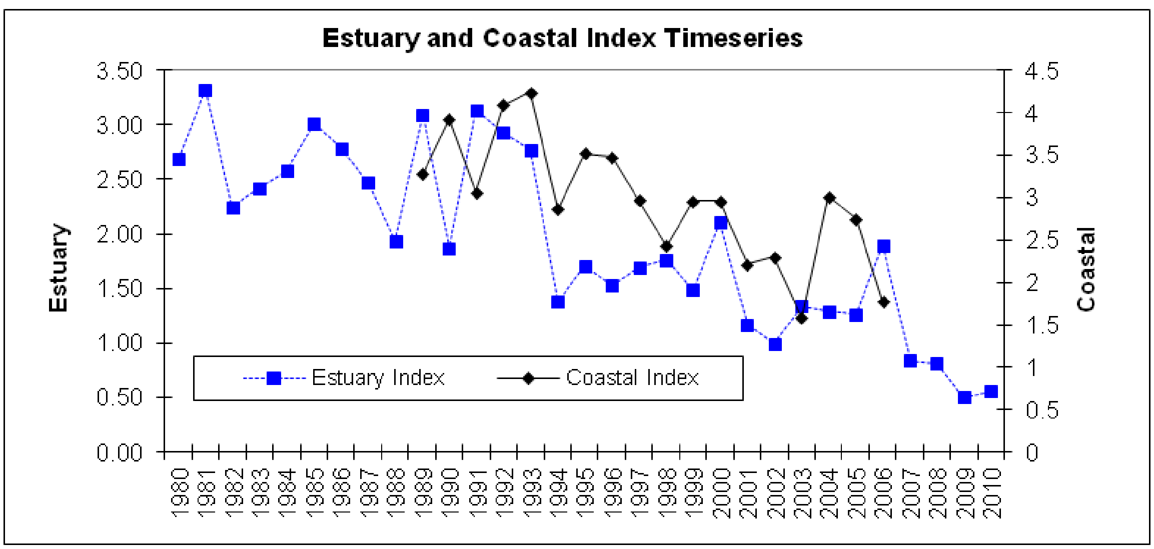


Figure 6. Age 1+ abundance (x 1 million fish) of Atlantic menhaden estimated by the 2009 and 2012 base runs.

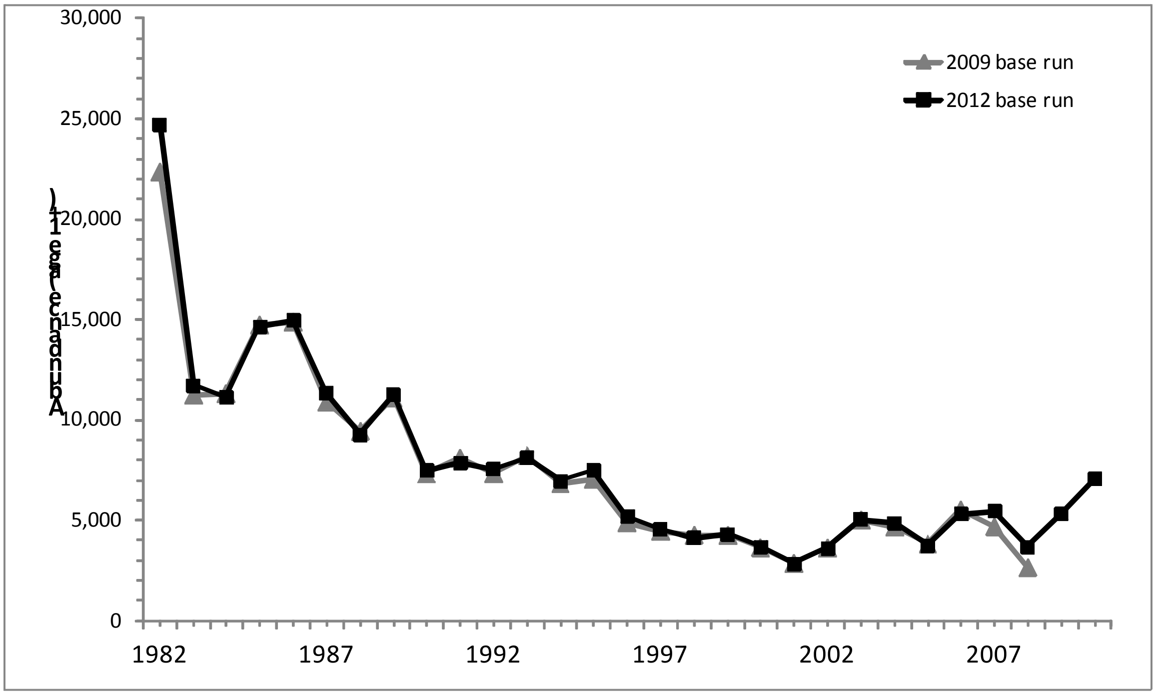


Figure 7. A comparison between assessment update estimates of the bluefish predation component of natural mortality (M2) on Atlantic menhaden averaged across ages 0 to 2.

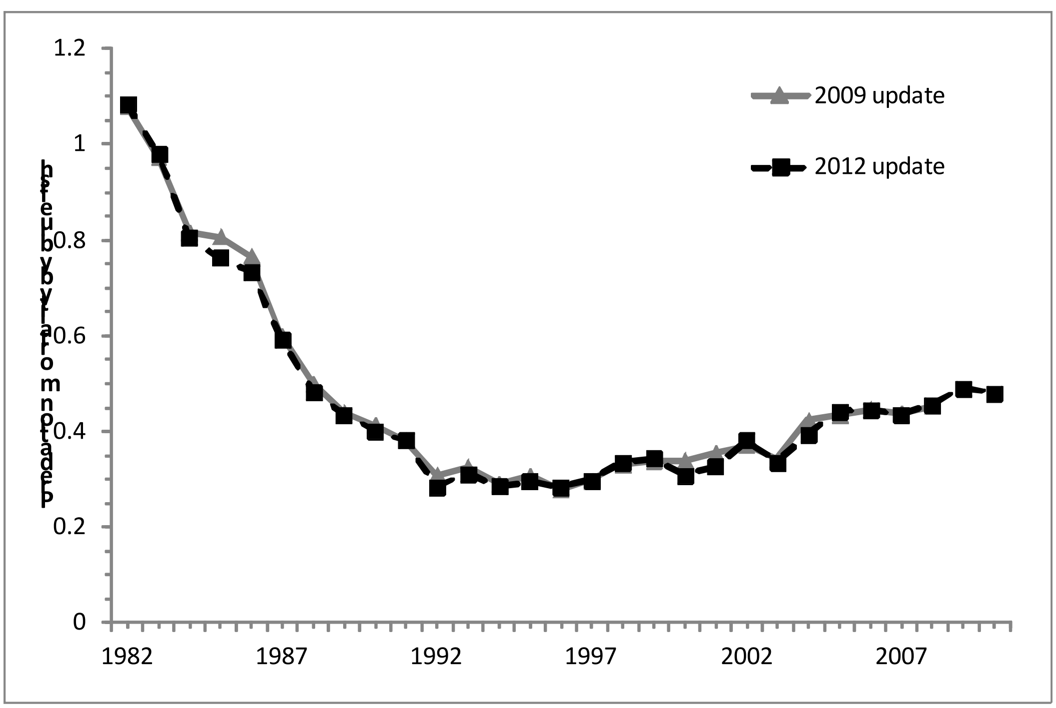


Figure 8. A comparison between assessment updates of the striped bass predation component of natural mortality (M2) on Atlantic menhaden averaged across ages 0 to 2.

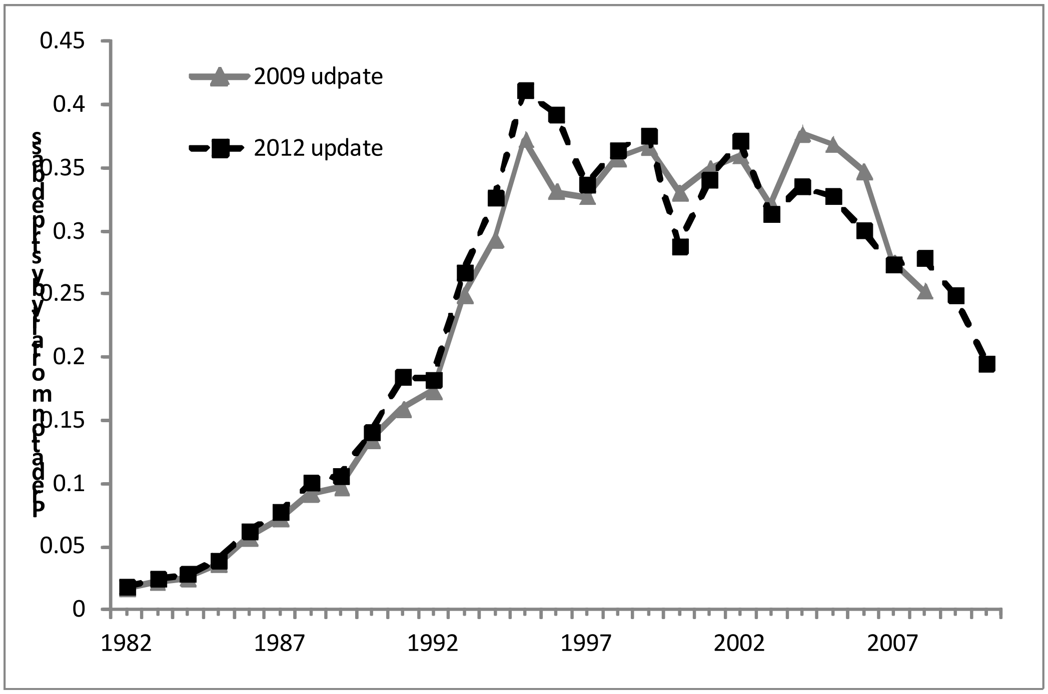


Figure 9. A comparison between assessment updates of the weakfish predation component of natural mortality (M2) on Atlantic menhaden averaged across ages 0 to 2.

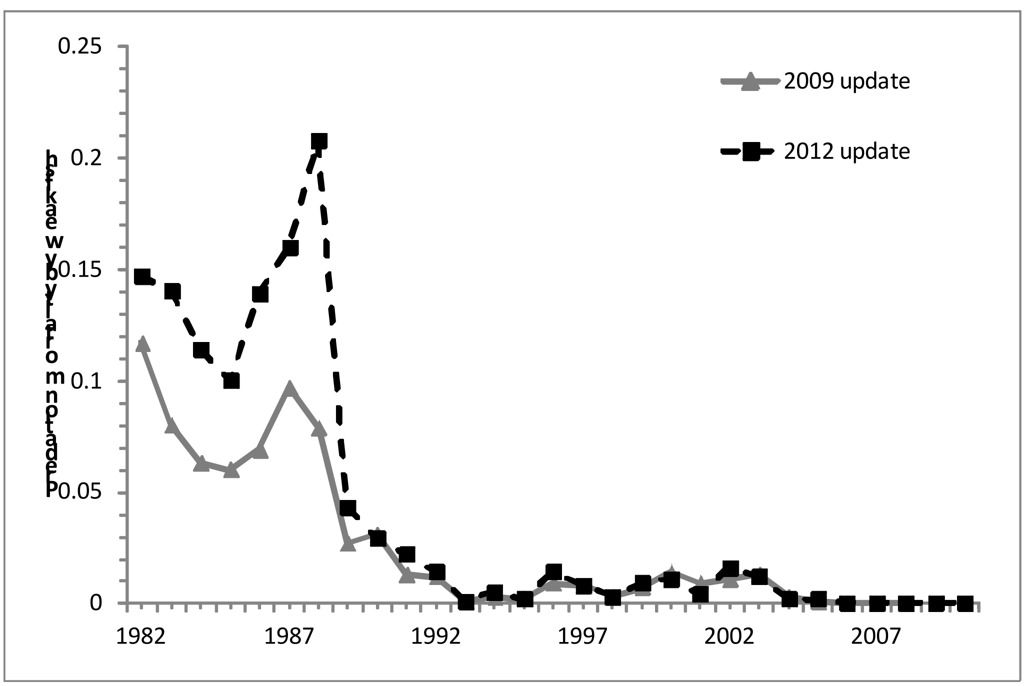


Figure 10. A comparison between assessment updates of estimates of the predation component of natural mortality (M2) on Atlantic menhaden for all predators averaged across ages 0 to 6+.

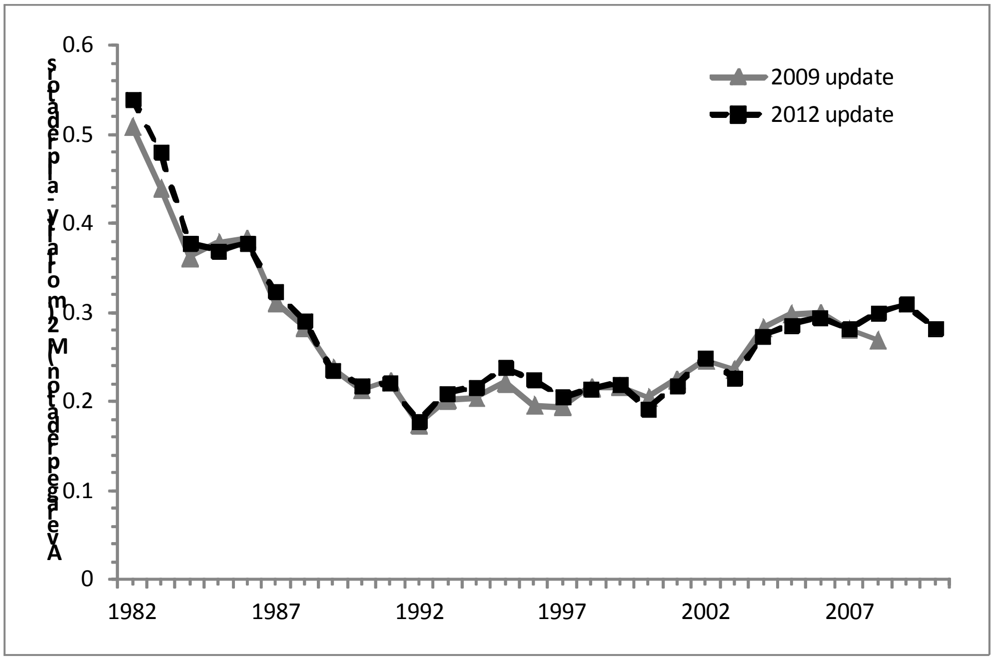


Figure 11. A comparison between assessment updates of estimates of the predation component of natural mortality (M2) by all predators on 6+ Atlantic menhaden.

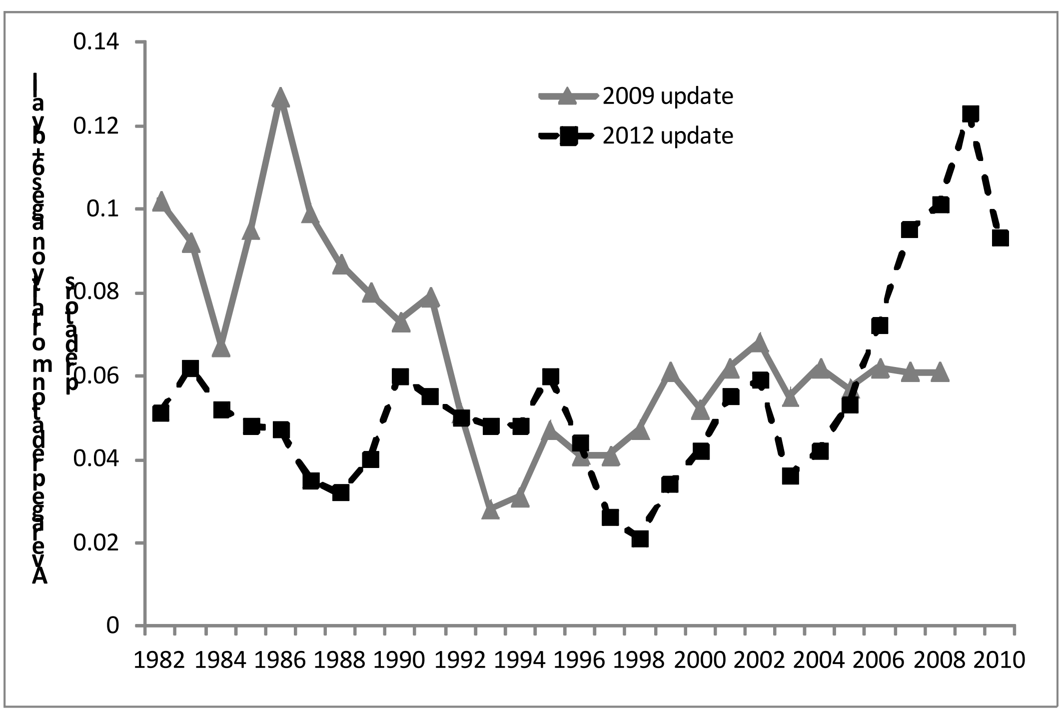


Figure 12. Abundance estimates (ages 0+) of striped bass from two configurations of the MSVPA-X.

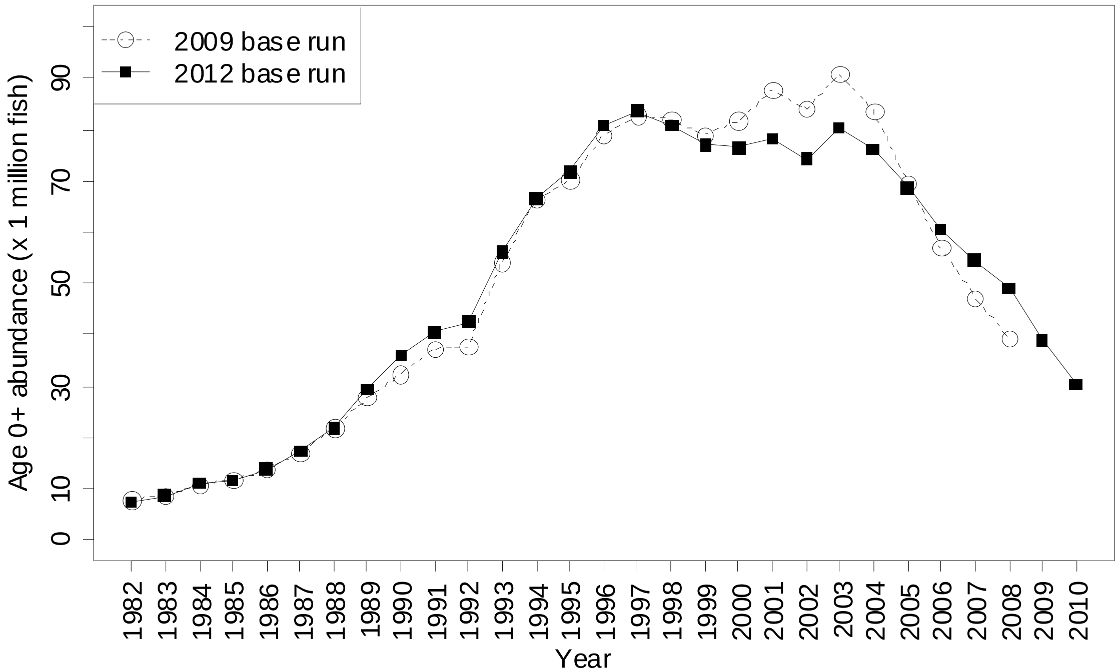


Figure 13. Recruitment estimates (abundance of age 0 fish) of striped bass from two configurations of the MSVPA-X.

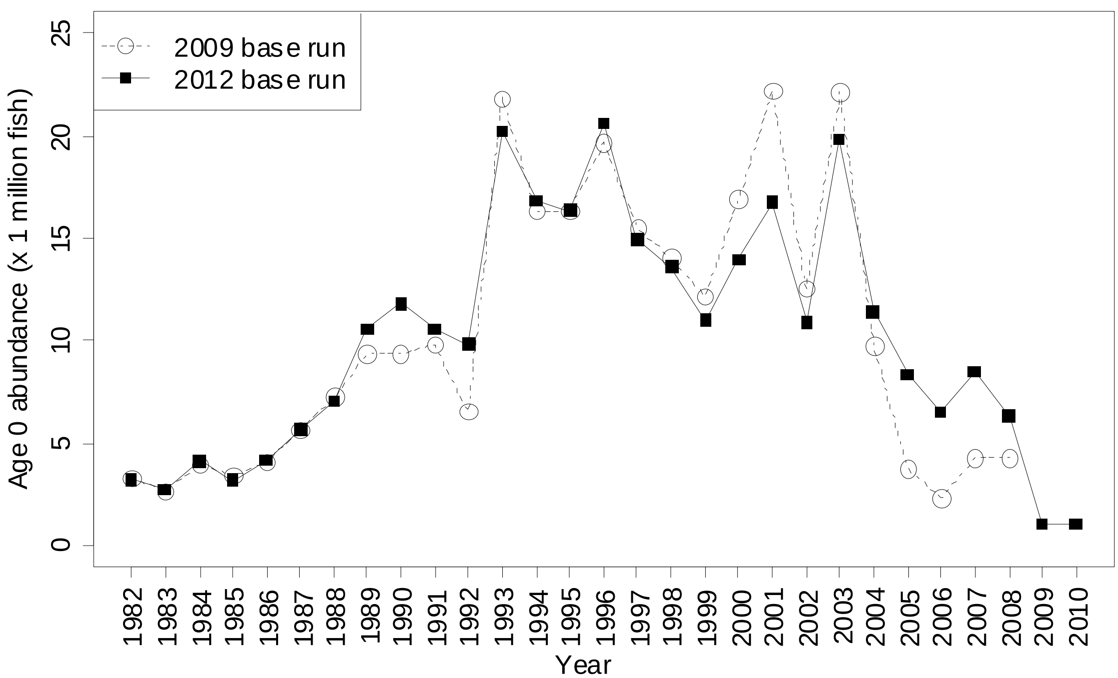


Figure 14. Spawning stock biomass (SSB) of striped bass from two configurations of the MSVPA-X.

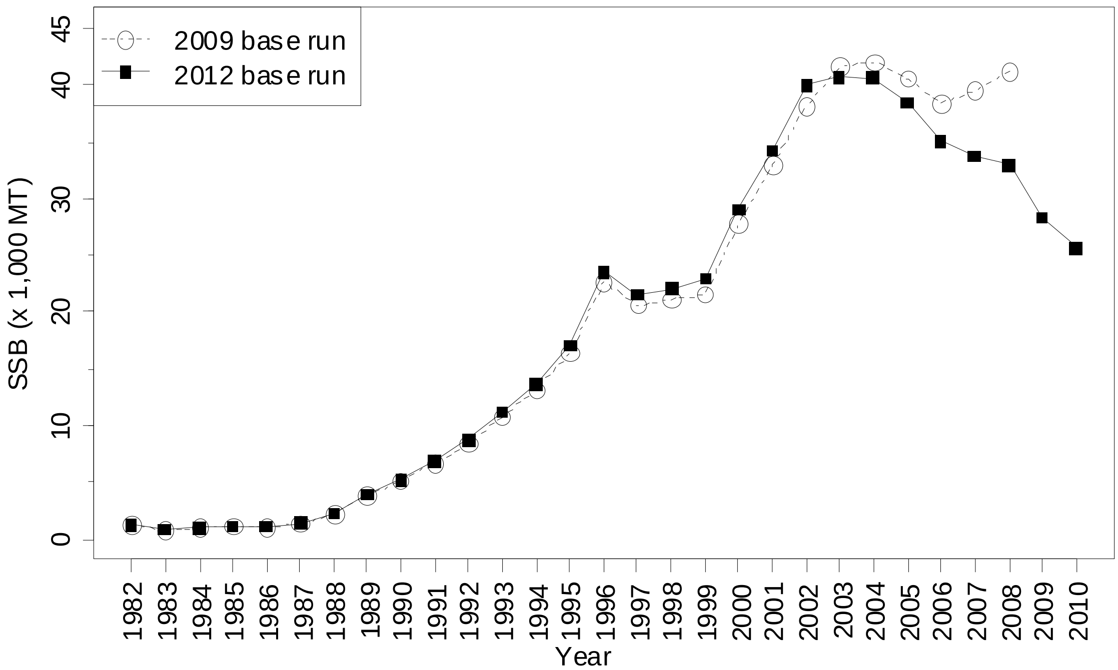


Figure 15. Average fishing mortality (F) of striped bass from two configurations of the MSVPA-X.

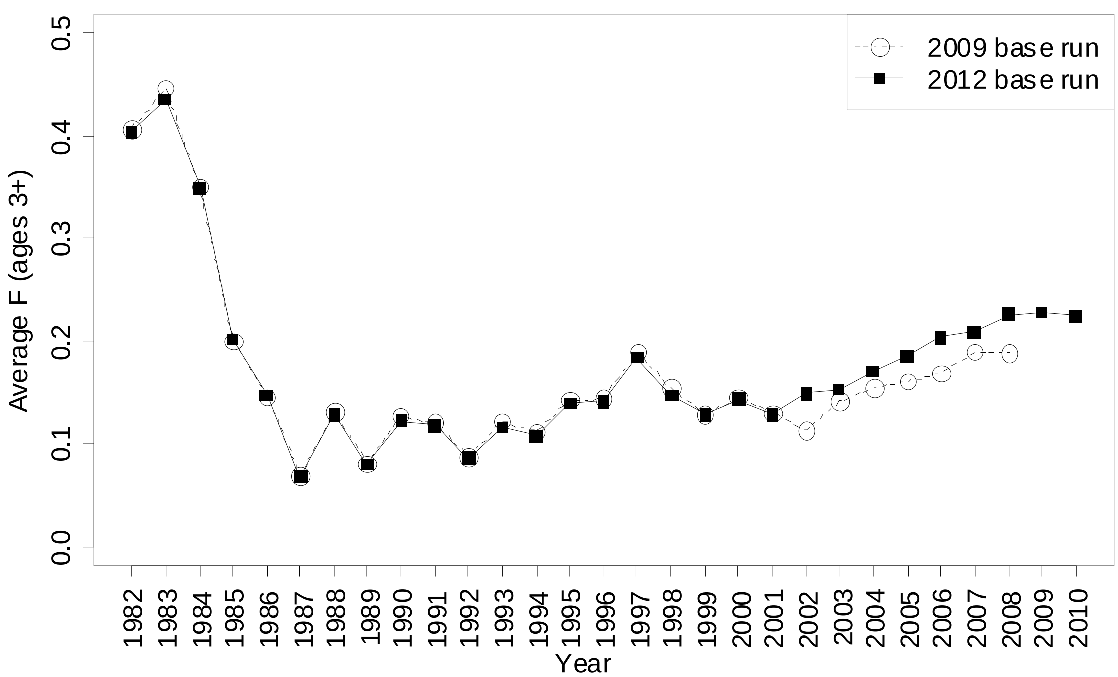


Figure 16. Abundance estimates (ages 1+) of striped bass from two configurations of the MSVPA-X as well as from the most recent single species striped bass stock assessment.

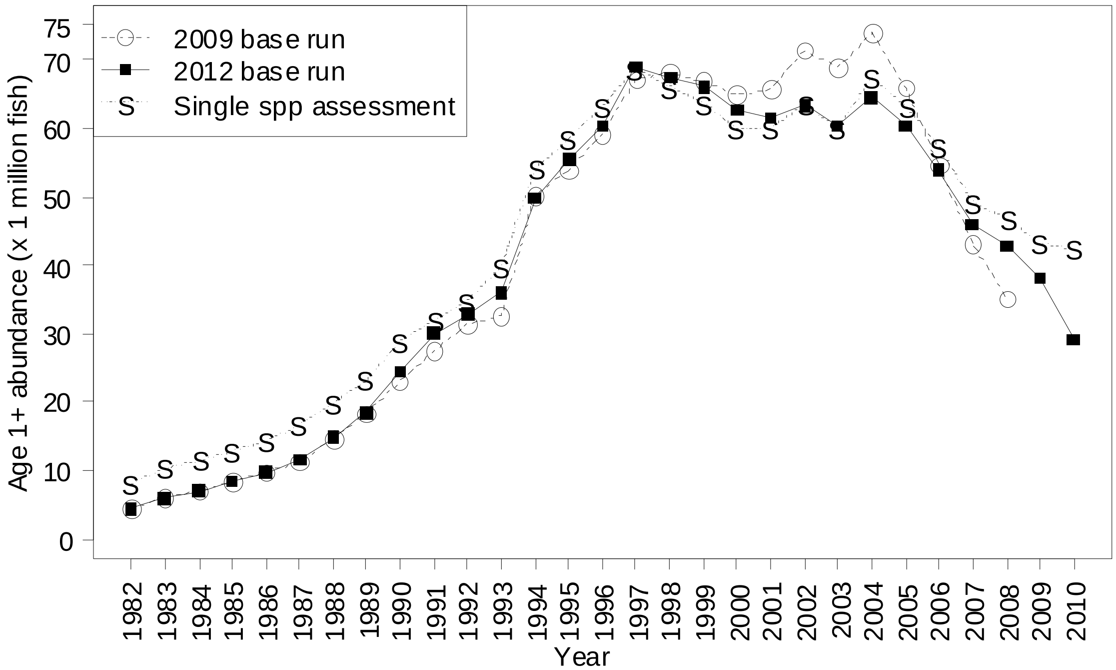
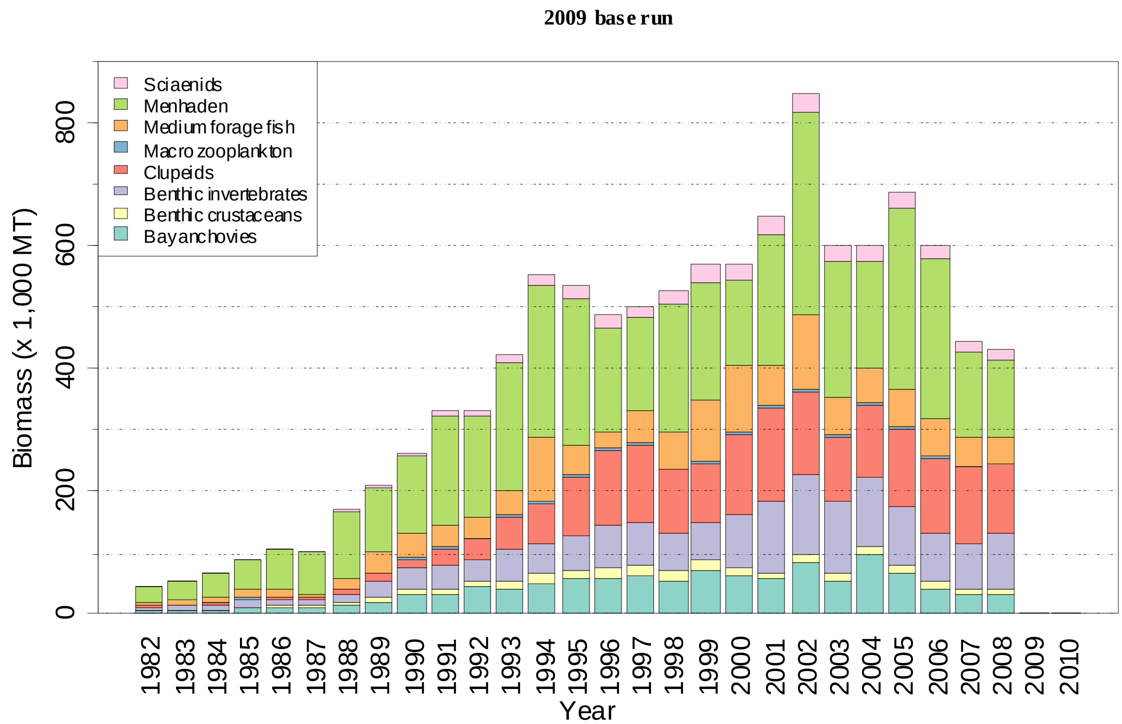


Figure 17. Comparison of prey consumption by striped bass between two configurations of the MSVPA-X.



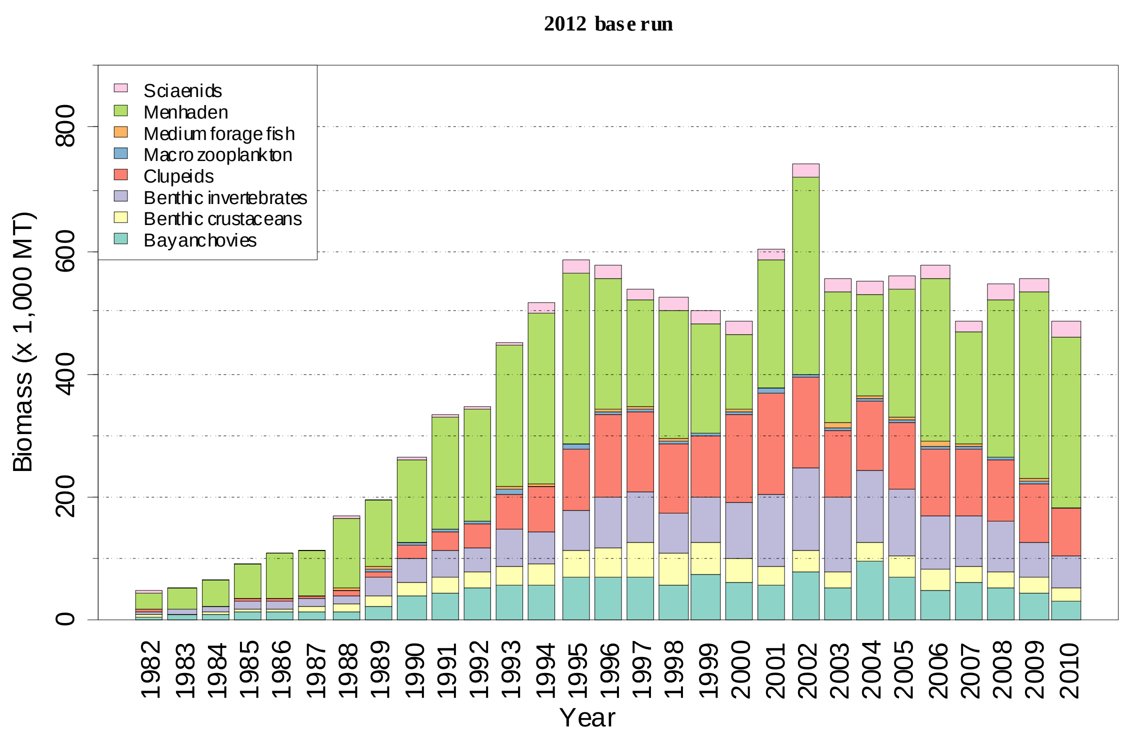


Figure 18. Total consumption of menhaden by striped bass for two configurations of the MSVPA-X.

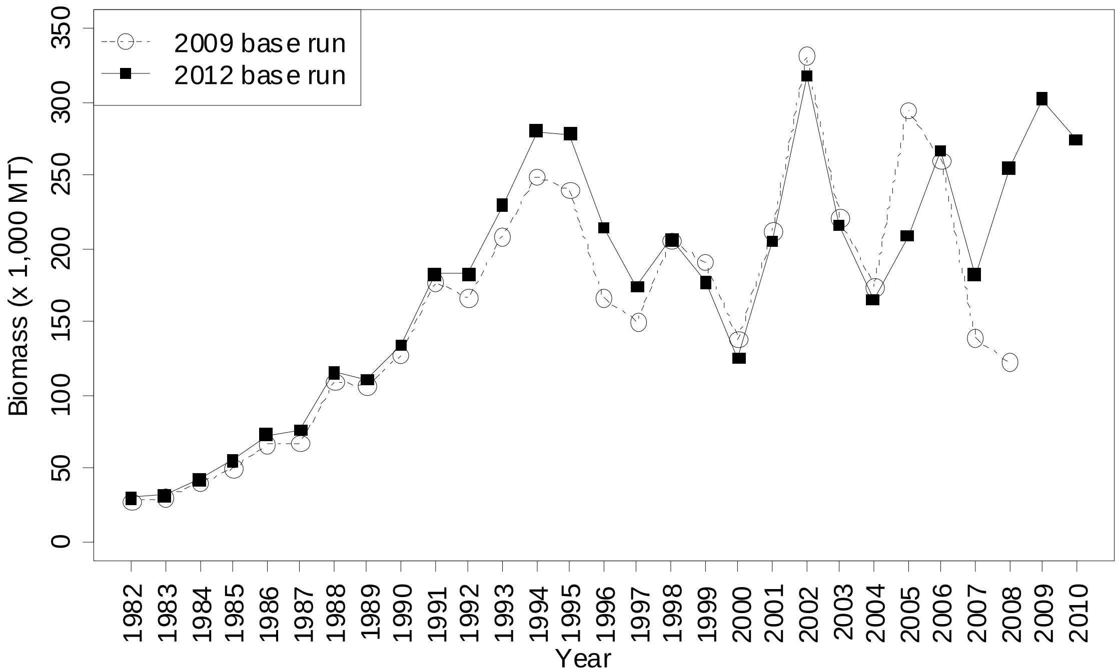


Figure 19. Estimated weakfish abundance 1982-2010 for two configurations of the MSVPA-X.

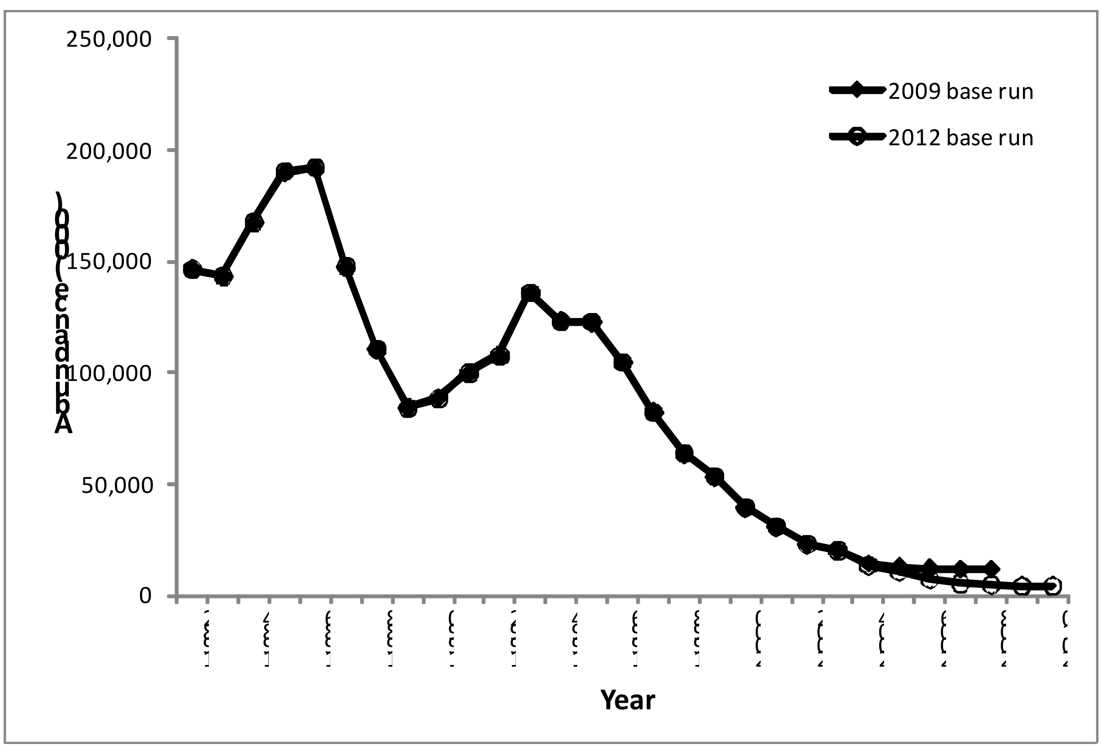


Figure 20. Estimated fishing mortality rates for weakfish 1982-2010 for two configurations of MSVPA-X.

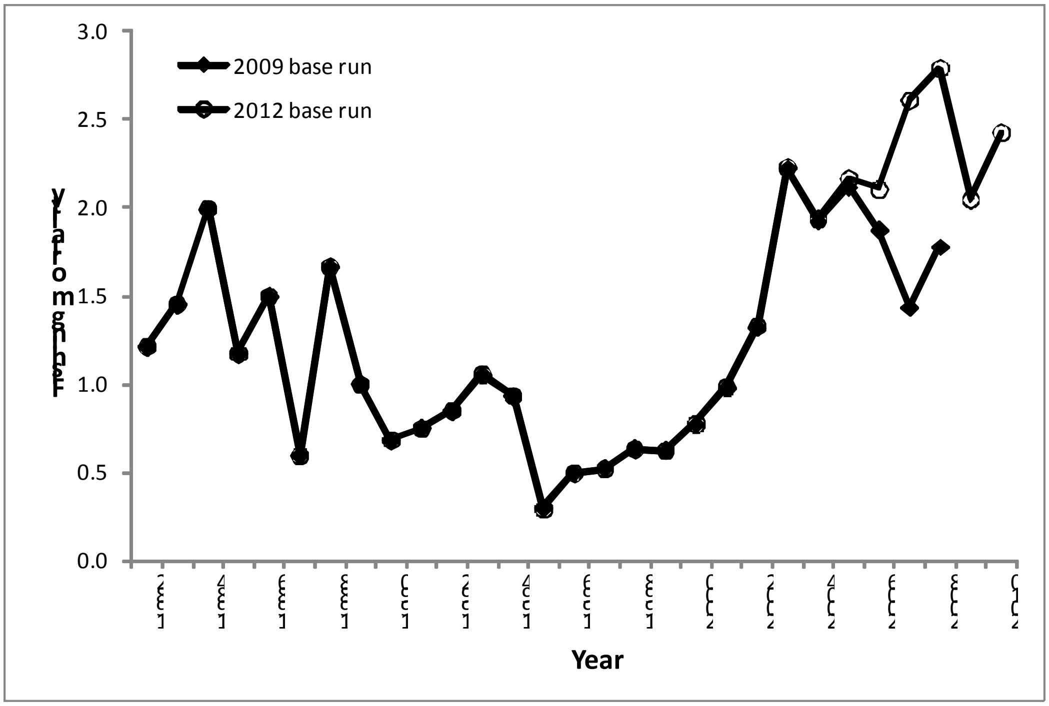


Figure 21. Estimated weakfish spawning stock biomass (SSB) 1982-2010 for two configurations of MSVPA-X.

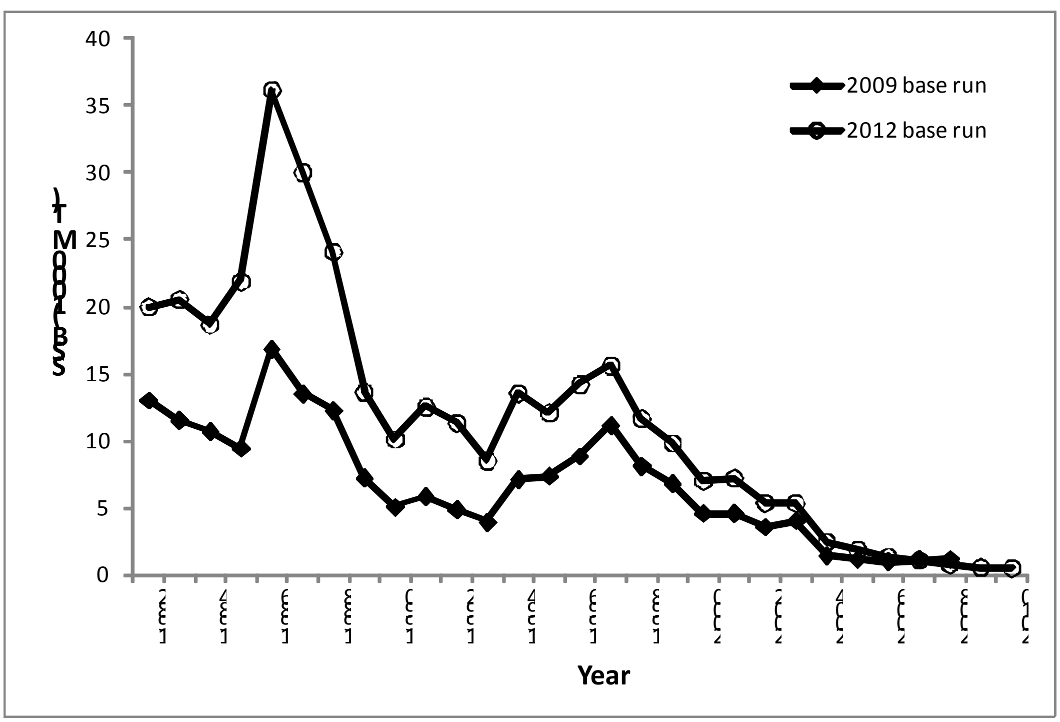


Figure 22. Estimated weakfish recruitment (age-0) 1982-2010 for two configurations of the MSVPA-X.

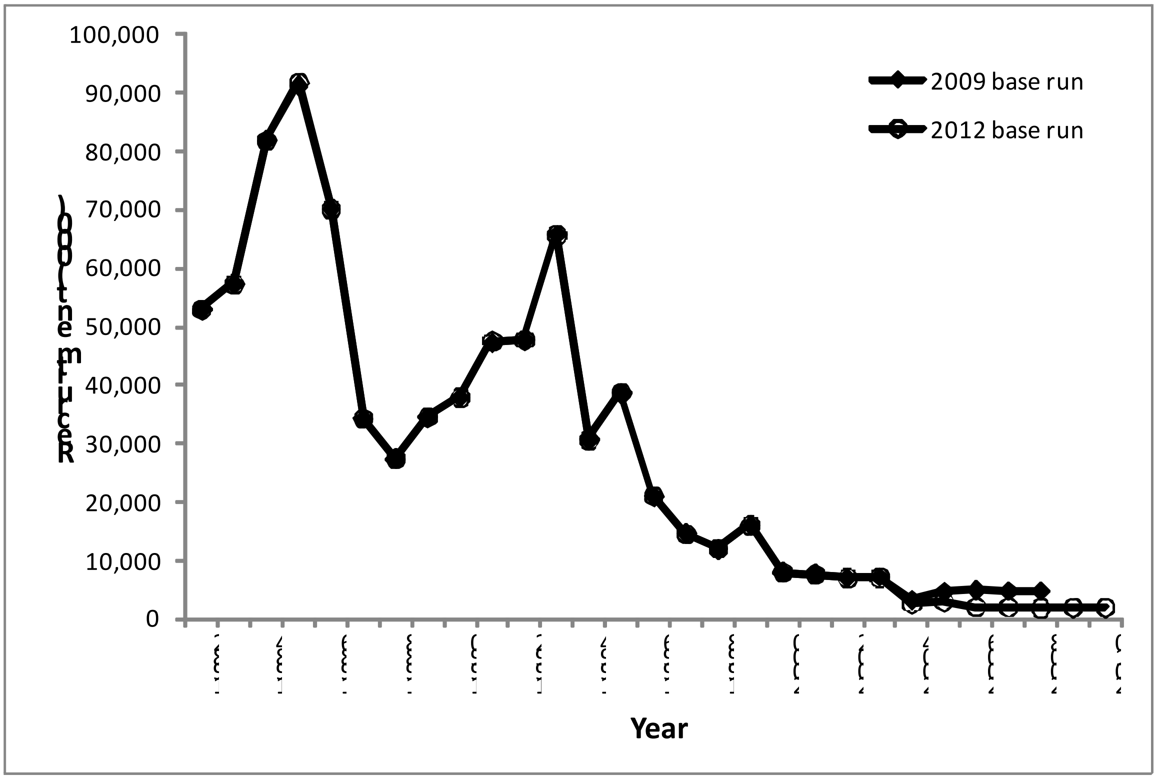
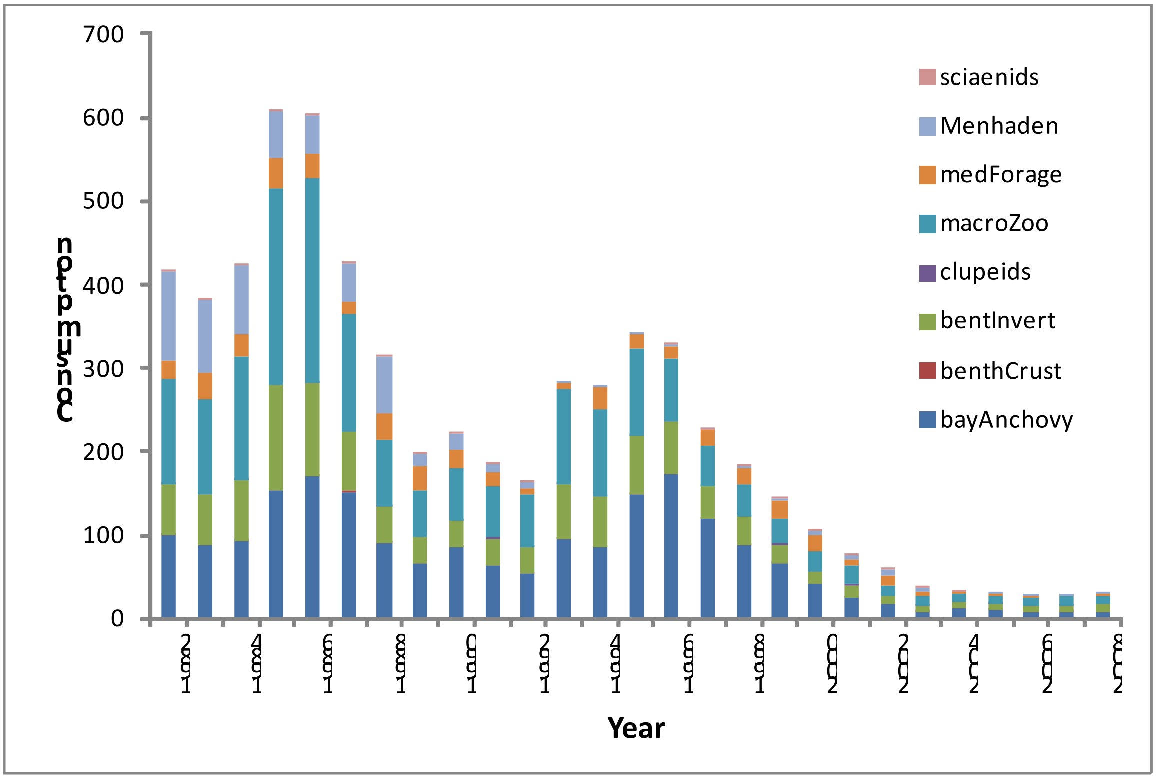


Figure 23. Consumption of various prey species by weakfish 1982-2010 for the 2009 (top) and 2012 (bottom) updates.



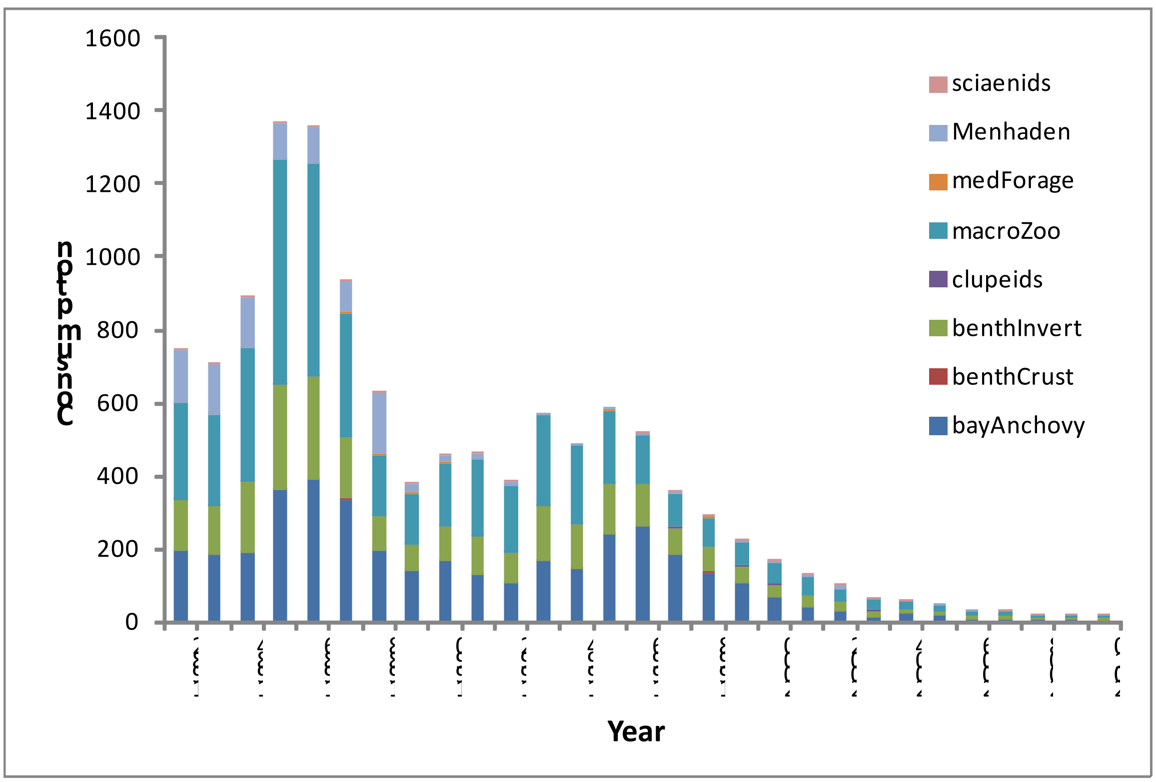


Figure 24. Comparison of estimated biomass trends among three modeled predators in the MSVPA-X (2012 base run), 1982-2010.

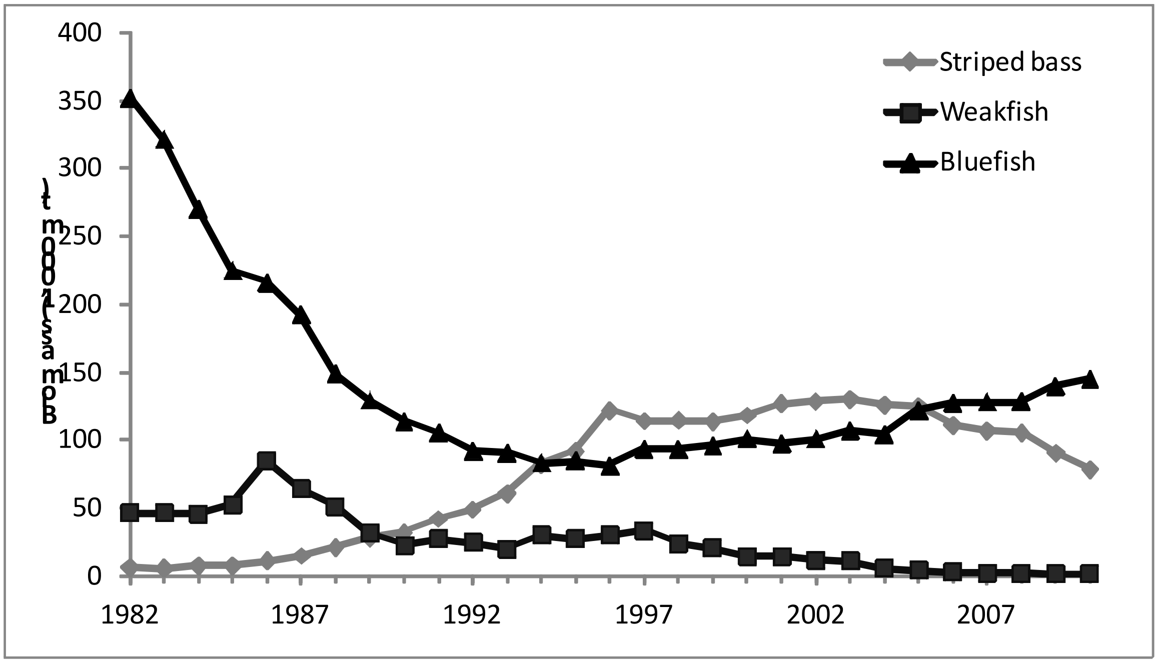


Figure 25. Bluefish diet composition from two configurations of the MSVPA-X.

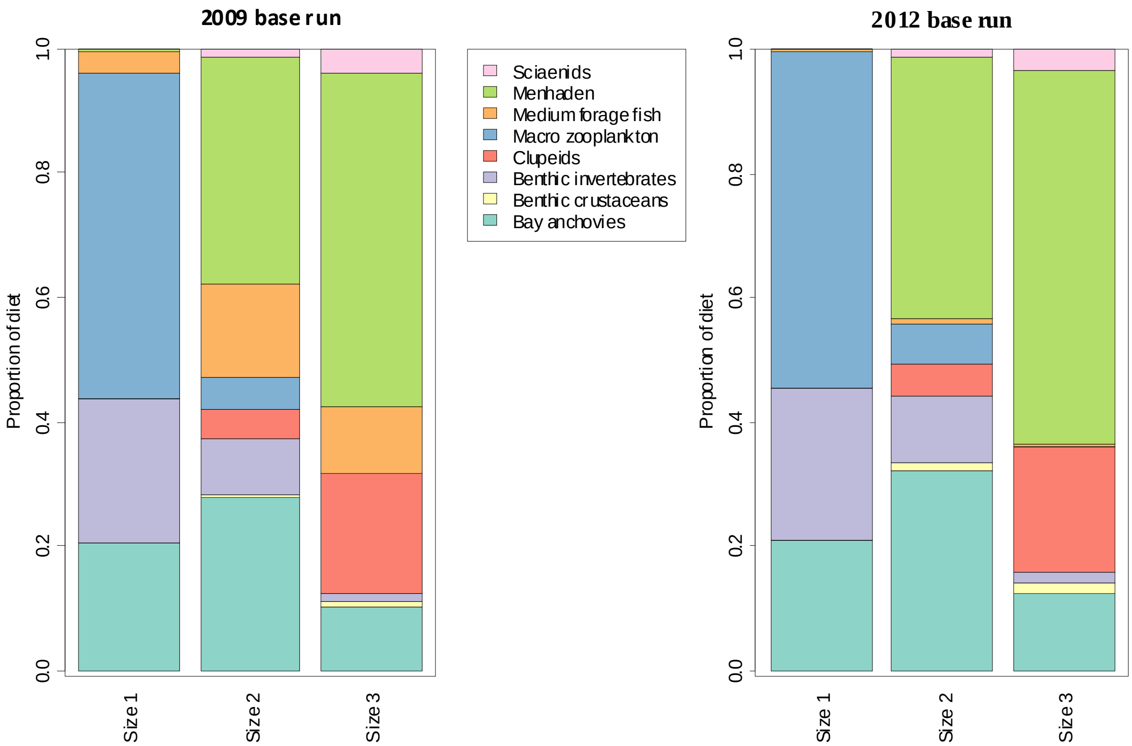


Figure 26. Comparison of prey consumption by bluefish between two configurations of the MSVPA-X.

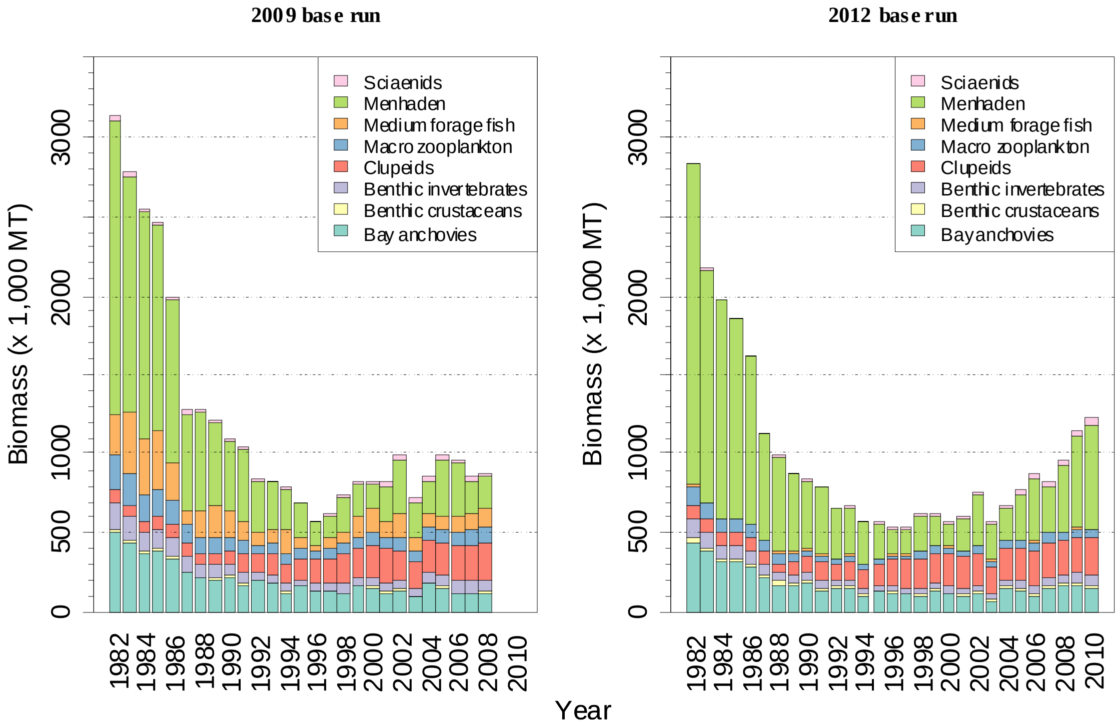


Figure 27. Comparison of menhaden consumed by the three predators in the MSVPA-X (2012 base run). Weakfish consumption is plotted on the left-hand axis; striped bass, bluefish, and total consumption (striped bass + weakfish + bluefish) are plotted on the right--hand axis.