APPENDIX D1: SENSITIVITY ANALYSES

D1 1.0 SENSITIVITY ANALYSIS SUMMARY

The sensitivity of the MSVPA-X to changes in input is presented in this Appendix (D1). Several analyses were conducted to evaluate the sensitivity of the MSVPA-X to changes in input parameters. Specifically, sensitivity analyses of model to changes in "other natural mortality" (M1), prey type selectivity, prey size selectivity, predator weight-at-age, gastric evacuation rate parameters, predator and prey spatial overlap, and the addition and deletion of 'other prey' items are presented. An examination into the retrospective bias of the model in terminal year estimates is presented. In addition, a test of the forecast model is also presented that investigates the ability of MSVPA-X to reproduce past observations.

D1 1.1 RETROSPECTIVE BIAS

A series of retrospective runs were conducted to investigate bias in terminal year estimates for explicitly modeled species. Retrospective analyses were run by adjusting the terminal year in the configuration screen and comparing results for several years. Presented are the retrospective results of these runs for weakfish, striped bass, and menhaden fishing mortality (F) and spawning stock biomass (SSB). An examination of potential bias in predation mortality (M2) for menhaden is also presented.

Results suggest little retrospective bias in menhaden fishing mortality and spawning stock biomass (Figures D1.1 and D1.2 respectively). While a persistent bias is not evident in striped bass fishing mortality or spawning stock biomass (SSB) (Figures D1.3 and D1.4), large changes in terminal year estimates are observed. Similarly, weakfish fishing mortality (F) and SSB do not show a consistent bias in the terminal year (Figures D1.5 and D1.6), but large differences in both SSB and F are noted in the terminal years. M2 for menhaden is also variable in the terminal year; however, a persistent bias in the estimation of predation mortality is not apparent (Figure D1.7). Overall the results for both striped bass and weakfish are not surprising given the retrospective output in the single-species models for each (ASMFC, 2003; ASMFC, 2004; and Kahn, 2002).

D1 1.2 DROPPING "OTHER PREY" ITEMS

A sensitivity analysis to examine the effects of removing important "other prey" items from the model was conducted. To remove the selected prey item, the type preference for a given item was set to zero. Relative ranks of the remaining items were kept constant by adjustment within the type preference input. Items removed included bay anchovy, clupeids (herrings and others), and medium forage fish. Shown are the effects of these removals on menhaden M2, SSB and the average diet composition for striped bass across the time series.

Removal of prey items causes some departure from the base run with respect to menhaden predation mortality (Figure D1.8). The exclusion of anchovy produces the most substantial relative effect. In general, removal of prey items increases predation mortality on menhaden, particularly early in the time series. However, no effect is noted on modeled SSB for menhaden (Figure D1.9) despite an increase in predation mortality.

Diet composition is also affected by removal of prey items for striped bass. As expected, striped bass diet composition changes as prey items are removed (Figures D1.10-D1.13). Removing clupeids appears to create the greatest effect on diet composition for striped bass, especially within the older age classes.

Predation mortality by predator across the time series was also examined (Figures D1.14-D1.17). The results suggest that the importance of striped bass consumption on M2 for menhaden diminishes when other prey items are removed. Weakfish consumption increases with removal of some items. Bluefish consumption of menhaden changes little until clupeids are removed.

D1 1.3 CHANGE IN M1

"Other natural mortality" or M1 is a component of natural mortality related to all natural mortality causes other than predation. M1 usually constitutes a smaller component of total M for prey species and is a larger fraction or a full value of total natural mortality for a predator. Misspecification of M1 will generate some bias in total natural mortality estimates and consequently, bias in population abundance estimates. The sensitivity of a number of MSVPA outputs was investigated by varying M1 systematically on the range of 0.1-0.5 year^{-1} with a step of 0.1 and M1=0.3 as a base or reference value. Corresponding changes in total menhaden abundance, biomass, spawning biomass, abundance of ages-0 and -1, predation M and average F for fully recruited ages are reported below.

D1 1.3.1 Age-0, age-1 and total menhaden abundance

Menhaden total abundance is lowest when M1=0.1. Increasing M1 leads to increased absolute abundance of menhaden (Figure D1.18) as expected. Changing M1 from 0.1 to 0.5 increased abundance approximately twofold. The relationship between changes in M1 and total abundance is slightly nonlinear, exhibiting larger relative changes in abundance as M1 increases (Figure D1.19). Consequently, population size estimates will be biased more by a positive bias in M1 than by a negative bias in M1 (e.g., the absolute change in population estimate will be larger when M1 increases by 50% than when it declines by 50%). Changes in absolute abundance of age-0 and age-1 groups are similar in direction and scale, with age-0 abundance responding at a slightly higher rate to the change in M1 (Figures D1.20 and D1.21).

D1 1.3.2 Menhaden total biomass and spawning stock biomass

Since total biomass is a product of abundance and weight-at-age, biomass responses to changes in M1 are similar to total abundance responses. Minimum values of biomass are estimated at M1=0.1 and biomass increases as M1 increases (Figure D1.22). Spawning stock biomass responses are similar to those for total biomass (Figure D1.23). Both total biomass and spawning stock biomass exhibit a slightly lower response rate to changes in M1 than does total abundance.

D1 1.3.3 Average fishing mortality for fully recruited age groups

Changing M1 values lead to changes in fishing mortality that are opposite the changes in biomass and abundance. The lowest levels of M1 produce the highest estimates of fishing mortality and vice versa (Figure D1.24). Changes in fishing mortality are strictly proportional to changes in M1, which was predicted. The relative magnitude of change in F is substantially lower than that of the biomass and abundance (i.e., the F estimate is less sensitive to changes in M1 compared to biomass and abundance).

D1 1.3.4 Predation mortality (M2) of ages 0 and 1 menhaden

Predation mortality has responded to changes in M1 similarly to the average fishing mortality – an increase in M1 causes a decline in estimated predation mortality and vice versa (Figures D1.25 and D1.26). Predation mortality changes proportionally to changes in M1. The relative magnitude of change in M2 is similar to changes in fishing mortality and is substantially lower than that of biomass and abundance. Consequently, M2 estimates are less sensitive to changes in M1 compared to biomass and abundance.

D1 1.3.5 Conclusions

In general, the effect of ‘other mortality’ on estimated parameters of the menhaden population, such as abundance, biomass and spawning biomass, and fishing and predation mortality, is predictable and modest to low in magnitude. An increase in M1 leads to higher values of population size (numbers at age, biomass, spawning biomass) and lower values of predation and fishing mortalities. While changes in fishing and predation mortalities are symmetrical and proportional to changes in M1, population size parameters respond to changes in M1 nonlinearly, with greater changes following larger values of “other mortality”. Consequently, population size parameters seem to be more sensitive to changes or misspecifications of M1 than predation and fishing mortality estimates. A larger bias would be expected in population size estimates when M1 is overestimated.

D1 1.4 EVACUATION RATES

Consumption rates of fishes can be estimated given information on gastric evacuation rates and stomach contents (Elliott and Persson, 1978). Gastric evacuation rates are influenced by a variety of factors including temperature, size of predator, prey type, size of prey, time since previous meal, size of meal, and number of meals. For striped bass, weakfish, and bluefish, very limited, experimentally derived data on gastric evacuation rates exist (see Hartman, 2000b and Buckel *et al.,* 1999 data on age-0 striped bass and bluefish, respectively). Because basic data to parameterize the simple evacuation rate model across all predator species, size, prey, and temperature combinations are not available, base values for the parameters associated with the exponential decay evacuation rate model (i.e., $\alpha = 0.004$ and $\beta = 0.115$) are obtained from the literature (Durbin *et al.,* 1983). These standard parameters are applied to all species and age classes in the current application

To conduct this sensitivity analysis, changes in the evacuation rate parameter values (α and β) were chosen that allowed for a coarse examination of the effect those changes had on the MSVPA-X. Changes in each of the gut evacuation rate parameters for each predator were conducted to evaluate the importance of impacts on menhaden abundance, biomass, predation mortality, fishing mortality, and consumption outputs in the MSVPA-X. For each predator, four alternate model simulations were performed. Relative to the base value of $\alpha = 0.004$, this parameter was set equal to 0.002 and 0.006, while the parameter β was changed from a base value of $\beta = 0.115$ to 0.05 and 0.20.

D1 1.4.1 Abundance

Changes in the gastric evacuation rate parameter α for each predator has a slight impact on the abundance of age-0 menhaden (Figure D1.27 a.-c.). Decreases in β for each predator causes moderate decreases in age-0 menhaden abundance, while increasing β has little effect on age-0 menhaden abundance (Figure D1.28 a. – c.). The impact of changes to α and β on age-1 menhaden is negligible.

D1 1.4.2 Spawning Stock Biomass

Spawning stock biomass of menhaden is insensitive to selected changes to both α and β.

D1 1.4.3 Predation Mortality (M2)

Changes in predator gut evacuation rate parameters results in changes in both the magnitude and pattern of the M2 estimates from the MSVPA-X. Changes in α for weakfish systematically impact the M2 rates on age-0 and, to a lesser extent, age-1 menhaden, while the M2 rates on older fish are not affected (Figure D1.29a. – b.). Predation mortality of all ages of menhaden is affected by altering the values for α of bluefish, but interestingly the magnitude of the change to M2 on age-0 menhaden is less than on each older age-class (Figure D1.30a. – b.). Changing the α value for striped bass impacts all age-classes, with age-1 menhaden experiencing the greatest divergence in M2 values from the base run (Figure D1.31a. – b.).

Decreasing β for weakfish causes a decrease in M2 for age-0 menhaden, while increasing β results in M2 values similar to the base run for age-0 menhaden (Figure D1.32a.). For age-1 and greater menhaden, M2 is consistently lower than the base run when β is both increased and decreased for weakfish (Figure D1.32b.). Changing β values, either up or down, for bluefish causes M2 of age-0 menhaden to decrease from base run levels (Figure D1.33a.). Decreasing β for bluefish results in lower M2 values on older menhaden, while increasing β generally leads to higher M2 values through the early 1990s and then to M2 rates similar to the base run (Figure D1.33b.). Decreasing β values for striped bass yields lower M2 rates on all ages of menhaden, while increasing β leads to lower M2 rates than the base run until the late 1980s when M2 rates increase to higher levels for all age classes (Figure D1.34a. – b.).

D1 1.4.4 Fishing Mortality

Average recruited fishing mortality on age-2+ menhaden is largely insensitive to changes in the values of α and β.

D1 1.4.5 Consumption

Changing the α parameter for striped bass causes systematic changes in consumption, as both increasing and decreasing α led to an increase and decrease in consumption of the same magnitude (Figure D1.35a. – c.). Consumption of weakfish and bluefish is not affected by changes in α for striped bass (Figures D1.36a. – c and D1.37a. – c.). Changing α for bluefish and weakfish also cause systematic changes in consumption. Notably, striped bass consumption is slightly affected late in the time series (2000-2002), by changes in the α values for weakfish.

Changing β for a single predator species impacts consumption rates for the other two predator species. Reducing β for striped bass results in decreased consumption by both striped bass and bluefish, but weakfish consumption is similar to that of the base run. For weakfish, increasing β does not result in large departures in consumption from the base run, but both striped bass and bluefish consumption are reduced (Figure D1.38 a. – c.) Decreasing β for weakfish leads to lower consumption for all predators. Increasing β for bluefish increases bluefish consumption, but lowers striped bass and weakfish consumption; decreasing β for bluefish reduces consumption for all predators (Figure D1.39a. – c). Increasing β for striped bass leads to increased striped bass consumption, reduced bluefish consumption, and increased consumption by weakfish late in the time series (Figure D1.40a. – c).

D1 1.5 PREY TYPE PREFERENCES

D1 1.5.1 Introduction and Outline of Sensitivity Runs

This section describes a sensitivity analysis examining the ranks for prey preferences used in the base MSVPA-X run. To represent inherent uncertainties in developing ranks for prey preferences, two approaches were developed to explore the sensitivity of MSVPA-X to the base input ranks for prey preferences of the three predator species explicitly modeled (Tables D1.1A-D1.3A). This sensitivity is explored through two alternate simplifications of the base model rank preferences.

The first approach assumes that the ranks for all prey groupings not equal to zero were equally preferred for each predator and age modeled (Tables D1.1B-D1.3B). Four sensitivity MSVPA-X runs were made for this approach: three runs, each modifying just one predator species at a time (e.g., bluefish, weakfish, and striped bass); and one run modifying all three predator species at once. This approach is referred to as all ranks equal, and the short hand reference in the figures in the results section is 'Equal'.

The second approach distinguishes two major prey groupings: fish and invertebrates. All prey categories within each of these two groups were given equal rank for prey preference (Tables D1.1C-D1.3C). In many instances, rankings of fish and invertebrate prey categories were intermixed. To address that situation for the sensitivity runs, all prey categories of the group (fish or invertebrate) with the top ranking received the highest ranking regardless of initial position. For example, if, for a given predator species and age, benthic crustaceans were initially ranked as 1, clupeids ranked 2, and macroinvertebrates ranked 3, then the final sensitivity rankings would be benthic crustaceans 1.5, macroinvertebrates 1.5 (i.e., all 'invertebrates', reflecting the ranking for two groups tied), and clupeids 3. As with the first approach, four sensitivity MSVPA-X runs were made, first modifying one predator at a time (3 runs) and then modifying all three predators (1 run). This approach is referred to as equal ranks of fish and invertebrates, and the short hand reference in the figures in the results is 'Fish/Invert'.

The remainder of this section describes the results of these sensitivity MSVPA-X runs relative to the results from the base run (described elsewhere, but here implying the initial base rank prey preference matrices for the three predator species). In particular, aspects of menhaden population dynamics (natural and fishing mortality, abundance for ages 0-1, and spawning stock biomass) and predator diet of menhaden (percent diet composition and consumption of menhaden) are explored.

D1 1.5.2 Results of Sensitivity Runs

Annual menhaden M2 at age-0,-1, and -2

M2 is that portion of menhaden natural mortality associated with predation by three predators (bluefish, weakfish and striped bass) explicitly modeled in MSVPA-X. Table D1.4 summarizes annual estimates of M2 on ages 0-2 menhaden for the first approach with all ranks equal, while Table D1.5 summarizes annual estimates of M2 on ages 0-2 menhaden for the second approach with equal ranks for fish and invertebrate.

Although the general pattern of predator mortality on age-0 menhaden (M2 on age-0 menhaden) are similar, estimates of M2 from the base run are highest compared to all ranks equal for one or all of the three predator species (Figure D41). Lowest estimates of M2 on age-0 menhaden are obtained when all ranks equal for all three predators. For a single predator, the lowest estimates are associated with all equal ranks for weakfish. Little difference is noted with all ranks equal for bluefish. Similar patterns are found when equal ranks of fish and invertebrates are assumed (Figure D1.42). The primary difference is a narrowing in differences with the various sensitivity runs for this alternate assumption in rank preferences.

The general pattern and magnitude of predator mortality on age-1 menhaden (M2 on age-1 menhaden) are similar, with estimates of the base run generally intermediate to most of the sensitivity runs for all equal ranks assumed in one or all of the three predator species (Figure D1.43). Highest estimates of M2 on age-1 menhaden are associated with bluefish, and lowest estimates with weakfish when assuming equal rank preference. Similar patterns are also found when equal ranks of fish and invertebrates are assumed (Figure D1.44). Highest estimates of M2 on age-1 menhaden are associated with simplifying rank assumption for bluefish and weakfish, and the lowest values for base, striped bass and all three predators.

Although the general pattern and magnitude of predator mortality on age-2 menhaden (M2 on age-2 menhaden) are similar, the lowest estimates of M2 on age-2 menhaden are associated with the base run, striped bass and weakfish compared to the assumption of all equal ranks for bluefish and all predators (Figure D1.45). Similar results are found when equal ranks of fish and invertebrates are assumed (Figure D1.46).

Annual menhaden average recruited F

Annual estimates of average F (for age-2+ menhaden) are summarized for both alternate approaches to sensitivity in ranking (Table D1.6). Only very minor differences are noted among various runs with the base run for average recruited F (Figures D1.47 and D1.48). Hence, annual estimates of average recruited F appear to be insensitive to errors in rank preferences.

Annual menhaden abundance at age-0 and 1

Annual estimates of abundance of age-0 and age-1 menhaden (in millions of fish) are summarized for all ranks equal (Table D1.7) and for equal ranks of fish and invertebrates (Table D1.8).

Although the general temporal pattern and magnitude of age-0 abundance of menhaden is maintained, there are moderate deviations from the base run when all equal ranks are assumed in one or all of the three predator species (Figure D1.49). Generally the highest estimates are associated with the base run, and lowest estimates associated with equal rank preferences for weakfish all three predators. Similar patterns are also found when equal ranks of fish and invertebrates are assumed, but with intermediate levels for the base run (Figure D1.50).

Only very minor differences are noted among various sensitivity runs for abundance of age-1 menhaden compared to the base run (Figures D1.51 and D1.52). Hence, annual estimates of age-1 menhaden appear to be fairly insensitive to alternative simplification in rank preferences.

Annual menhaden SSB

Annual estimates of menhaden spawning stock biomass (in 1000 mt) are summarized for all ranks equal (Table D1.9) and for equal ranks of fish and invertebrates (Table D1.10). Only very minor differences are noted among the various sensitivity runs compared to the base run for spawning stock biomass (SSB; Figures D1.53 and D1.54). Hence, annual estimates of menhaden SSB appear to be insensitive to alternative simplification of rank preferences.

Percent menhaden in diet composition

Age-specific diet composition of menhaden (percent composition) for the three predator species are summarized by predator age for sensitivity to both alternate ranking approaches (Table D1.11).

Age-specific patterns in diet composition of menhaden in striped bass are presented in Figures D1.55 and D1.56. For the assumption of all equal ranks, all sensitivity runs show a pattern of low percent of menhaden in diet of young striped bass, and higher percent of menhaden in diet of older striped bass. Diet compositions, when all equal ranks are assumed for striped bass and all three predators, are lower for younger ages of striped bass (age 1-6) and higher for older ages of striped bass (age 9-13), as compared to the base run and assumption of all equal ranks for bluefish and weakfish. This same pattern with age is found also for the assumption of equal ranks for fish and invertebrates.

Regardless of sensitivity run, the pattern is somewhat different for diet composition of menhaden with the shorter-lived (as modeled) weakfish (Figures D1.57 and D1.58). For these sensitivity runs, the base run and both alternate rank preferences for striped bass and bluefish give the highest percent of menhaden in the diet of weakfish. Low percentages are associated with both alternate rank preferences for weakfish and all three predators.

Discerning changes in bluefish diet composition by size class is difficult because only three size classes of bluefish are modeled. Nonetheless, menhaden increase in abundance in bluefish diets as bluefish size increases (Figures D1.59 and D1.60). Similar to the diet compositions of menhaden for striped bass and weakfish, two groupings of similar estimates are found. One group consists of the base run and diet composition estimates with both alternate rank preferences for striped bass and weakfish, and the other group consists of both alternate rank preferences for bluefish and all three predators.

Consumption of menhaden by predators

Consumption of menhaden by predators (biomass, 1000 mt) is summarized for all ranks equal (Table D1.12) and for equal ranks of fish and invertebrates (Table D1.13).

The general pattern and magnitude of menhaden consumption by striped bass are similar among sensitivity runs, with generally increasing consumption of menhaden over time for the base run and sensitivity runs for the assumption of all ranks equal in one or all predator species (Figure D1.61). Low values of menhaden consumption are found with striped bass and all three predators, while higher values are associated with the base run and all ranks equal for weakfish and bluefish. A similar pattern is found when equal ranks for fish and invertebrates are assumed (Figure D1.62).

High menhaden consumption by weakfish is found for the base run and for all equal ranks for striped bass and bluefish (Figure D1.63). Lower values of menhaden consumption are found for all ranks equal for weakfish and for all three predators. A similar pattern is found when equal ranks for fish and invertebrates are assumed (Figure D1.64).

Low values of menhaden consumption by bluefish are found for the base run and for assumed equal rank preferences for striped bass and weakfish (Figure D1.65). Higher values of menhaden consumption are found for all ranks equal for bluefish and for all three predators. A similar pattern is found when equal ranks for fish and invertebrates are assumed (Figure D1.66).

D1 1.5.3 Discussion

The first alternate approach, assuming equal ranks for all positive species groupings, assumes that little is known about prey preference beyond which species groups are preyed upon by a particular age or size group of predator (Table D1.1B-D1.3B). The second alternate approach, separating prey preference into equal ranks for fish and invertebrates, allows for some separation of ranks between these larger groupings (Table D1.1C-D1.1C).

When considering the results of these sensitivity runs, first we investigated different aspects of menhaden population dynamics: annual estimates of natural mortality by predation (ages 0-2), fully recruited fishing mortality (age-2+), and abundance (age-0 and 1, and spawning stock biomass). Natural mortality is split into fixed base natural mortality due to a variety of sources (M1), and that portion of natural mortality that is explicitly considered in this model due to predation by striped bass, weakfish, and bluefish (M2). Specifically, we consider the sensitivity of M2 for ages 0-2 menhaden (Table D1.4-D1.5 and Figures D1.41-D1.46). When comparing M2 among the base run and each of the two alternate simplifying assumptions for rank preference for all three predators, M2 from the base run was highest for age-0, generally intermediate for age-1, and lowest for age-2. On the other hand, average recruited F (ages 2+) for menhaden show very little, if any, sensitivity to the ranks for prey preference (Table D1.6 and Figures D1.47-D1.48).

Menhaden abundance is considered in two ways. First, we estimate abundance in numbers of age-0 and age-1 menhaden, and next we estimate spawning stock biomass (weight of mature female menhaden, SSB). We note some sensitivity in estimating abundance of age-0 menhaden, with the base run providing generally higher estimates than from the two alternate simplifying assumptions for rank preferences for all three predators. However, little sensitivity in abundance is observed for age-1 menhaden (Table D1.7-D1.8 and Figures D1.49-D1.52). Furthermore, there is negligible sensitivity observed in SSB (Table D1.9-D1.10 and Figures D1.53-D1.54). This suggests that we should not expect sensitivity in abundance of menhaden age-3 or older.

Next, we considered the sensitivity in measures of menhaden in the diet of the modeled predators. This aspect was considered in two ways: percent menhaden in the diet composition of the three predators by predator age, and annual estimates of consumption of menhaden biomass in the predator diets (Tables D1.11-D1.13 and Figures D1.55-D1.66). For diet composition and consumption of menhaden, most deviation from the base run is associated with the simplifying rank preference assumption applied to the species considered and all three predators.

D1 1.6 WEIGHT-AT-AGE

This sensitivity analysis examined the effects of changes of constant weight-at-age (based on time series average) and variable weight-at-age (observed data from stock assessment reports) for striped bass and weakfish.

D1 1.6.1 Methods

The weight-at-age matrix for striped bass and weakfish in the base run is based on average values calculated from observed data (1982-2002 for striped bass and 1991-2002 for weakfish) from research studies. In the alternative run, constant weight-at-age tables for striped bass and weakfish were replaced with observed (variable) weight-at-age values (obtained from assessment documents) and its impact on predator total consumption rate, predator consumption of menhaden, and menhaden predation mortality (M2) was evaluated.

D1 1.6.2 Results

Total Consumption Rate:

Total consumption rate for striped bass change little under variable (observed) weight-at-age scenario (Figure D1.67). For weakfish, the variable weight-at-age generates higher total consumption rates during early 1980s, but differences in recent years are not significant (Figure D1.68).

Predator Consumption of Menhaden

Predator consumption of menhaden by striped bass changes little under variable weight-at-age scenario (Figure D1.69). For weakfish, the variable weight-at-age generates higher consumption of menhaden during early 1980s, but differences in recent years are not significant (Figure D1.70).

Predation mortality (M2)

Predation mortality (M2) of menhaden by striped bass calculated based on variable (observed) weight-at-age are similar to those calculated based on constant weight-at-age (Figure D1.71). For weakfish, predation mortality (M2) calculated based on variable weight-at-age is significantly higher during early to mid 1980s and differences are less significant in recent years (Figure D1.72).

D1 1.7 SPATIAL OVERLAP

D1 1.7.1 Introduction and Outline of Spatial Overlap Sensitivity

This series of model runs examined the sensitivity of the MSVPA-X model to changes in the 'Base' spatial overlap values of each predator by age, and their associated prey for all seasons. Spatial overlap values range from 0 (no overlap) to 1 (complete overlap) and therefore, there are thousands of possible spatial overlap combinations for a given predator, prey and seasonal combination. To help simplify the analysis, runs were conducted using spatial overlap values equal to 1 for all species combinations (i.e., all prey for all seasons set equal to 1 for a given predator) and the results were evaluated relative to the 'Base' run (See Table D1.14, S.B. – All, termed Predator Runs). A feature of the MSVPA-X allows the modeler to remove the seasonal aspect of the spatial overlap index if seasonal data is not available or, potentially, if seasonal aspects or movements are not important. Therefore, sensitivity runs comparing spatial overlap values with seasonality and without seasonality were also investigated (Table D1.14, N.S. 1 and N.S. Ave, termed Seasonal Runs).

D1 1.7.2 Annual Menhaden M2 Results

Menhaden M2 is slightly sensitive to changes in spatial overlap values for the Predator runs and sensitivity tend to decrease with age: age-0 being most sensitive and age-2 being least sensitive (Figures D1.73a – c). Setting the weakfish spatial overlap equal to 1, Weak run, lowers age-0 M2 compared to the Base in almost all years but has little effect on age-1 and age-2 M2. When the bluefish spatial overlap is set equal to 1, Blue run, menhaden M2 increases for all ages in the early part of the time series (1982 – 1987) when bluefish abundance was at its peak; while menhaden M2 increases for all ages in the later part of the time series (1997 – 2002) for the striped bass run, S.B., as the striped bass population recovered.

The Seasonal runs show similar sensitivity trends in that M2 was slightly sensitive to the seasonal aspect of the spatial overlap values, however sensitivity tend to increase with age (Figures D1.74a – c). Seasonal runs tend to be more variable than Predator runs for all age groups and menhaden M2 increased for all age groups compared to the Base. As expected, the All and N.S. 1 runs – all predators' spatial overlap values equal to 1 – produce similar results. The N.S. Ave run, averaging the seasonal spatial overlap values, tend to produce the highest M2 estimates for all ages and is the greatest departure from the Base run estimates. These results emphasize the overall importance and sensitivity of the seasonality aspect incorporated in the model, and the need to accurately describe the movements of the predators in relationship to their prey.

D1 1.7.3 Annual Menhaden Abundance for Ages 0 and 1Results

Age-0 menhaden total abundance is less sensitive to spatial overlap changes than the age-0 M2 estimates (Figure D1.75a). Also, age-0 abundance trends for a particular model run are what one would expect based on the M2 results – i.e., higher M2 estimates for a particular model run, compared to the Base, produces higher abundance estimates. Age-1 menhaden abundance is not sensitive to changes in spatial overlap values with all Predator runs producing similar results (Figure D1.75b).

Seasonal runs produce similar results as the Predator runs – a slight sensitivity for age-0 abundance, no real sensitivity for age-1 and logical abundance estimates are produced based on the M2 results (Figures D1.76a - b).

D1 1.7.4 Annual Menhaden SSB Results

Menhaden spawning stock biomass estimates are not sensitive to changes in spatial overlap values for either the Predator runs or the Seasonal runs with all runs producing nearly identical results (Figures D1.77a - b). These results are expected since most of the menhaden spawning stock is comprised of 3+ individuals and menhaden predation mortality is predominantly on age

0 – 2. Also, as discussed above, model sensitivity to menhaden predation mortality decreases with age and therefore, has a decreased effect on spawning tock biomass.

D1 1.7.5 Annual Menhaden Average Recruited (2+) F Results

Similar to menhaden spawning stock biomass, annual fully recruited F estimates are not very sensitive to changes in the spatial overlap values for both the Predator and Seasonal runs (Figures D1.78a - b).

D1 1.7.6 Predator Diet Composition Results

Increasing a particular predator's spatial overlap to 1 for all prey and all seasons has a mixed effect on menhaden in the diet when compared to the Base run. For example, menhaden predation (i.e., more menhaden in diet) increases for ages 4 – 8 striped bass and decreases for the other ages, weakfish predation on menhaden is significantly lower for all ages, while bluefish predation increases for middle aged bluefish and decreases for young and old bluefish (Figures D1.80a – c). When all three predators's spatial overlap values are set equal to 1 (All), menhaden predation remains relatively the same in striped bass and bluefish when compared to their specific predator run; while weakfish predation increases slightly compared to the weakfish specific run for all ages but remains below Base run levels (Figure D1.80b).

Changes in diet composition for the other prey types are also highly variable as well as species and age dependent. Clupeids are more abundant in the diet for all ages of striped bass, while medium forage fish and anchovies are much less common (Figures D1.79d and D1.80a). The same pattern is true for bluefish as well (Figures D1.79f and D1.80c). Due to the increase in spatial overlap, clupeids are significantly more common in the diets of weakfish. This result is logical because the clupeid group, largely consisting of Atlantic herring, is found predominantly in New England and the Gulf of Maine where weakfish are not commonly found. Medium forage fish and bay anchovy are more common in the diet of older weakfish and macrozooplankton and benthic invertebrates are much more abundant among all ages (Figures D1.79b and D1.80b). As with menhaden, the diet composition of the other prey types for all three predators remains relatively similar between their predator specific model run and the All predator run, with weakfish the most variable between the runs (Figures D1.79d – f and D1.80a – c).

In predator specific runs (striped bass, weakfish, or bluefish), diet composition only changes in the predator whose spatial overlap is set to 1, the other predators' diets are relatively unaffected (Figures D1.79a – c).

D1 1.7.7 Total Predator Consumption by Prey Type Results

Due to the high sensitivity in the predator diet composition, predator consumption as also highly sensitive to changes in spatial overlap values. Menhaden consumption by striped bass increases from the Base run, as does the associated variability in all years when the striped bass spatial overlap was equal to 1, particularly in the later part of the time series with the increasing and expanding striped bass population (Figure D1.81a). Weakfish consumption of menhaden is the lowest for the weakfish specific run which corresponds to the decrease of menhaden in the diet for that particular run (Figure D1.81b). Bluefish consumption of menhaden is the greatest for the Blue and All predator runs and the most variable early in the time series when bluefish abundance is high (Figure D1.81c).

Other prey consumption was also highly variable depending upon the prey type and model run but reflected the results observed in the diet composition. For example, there is a substantial increase in clupeid consumption by weakfish in the Weakfish and All predator model runs due to the large increase of clupeids in their diet (Figure D1.81b).

D1 1.8 PREY SIZE PREFERENCE

D1 1.8.1 Background

Prey size-selectivity comprises one component of feeding selectivity in the MSVPA-X and a critical consideration in determining the suitability of prey item are predator-prey length ratios. For a predator of a given length, prey size-selectivity will be dome shaped. For example, prey selected by a predator must fall within a suitable size range that the predator can catch and consume. If a predator can consume a wide variety of prey sizes relative to its own size, the selectivity curve will be 'flattened' or 'squashed'. Predators that have a limited range of suitable prey sizes have a more 'peaked' or 'narrow' selectivity curve. There is limited data on prey size-selectivity available for the predator species, in particular for weakfish and bluefish. To account for the uncertainty inherent in these data sensitivity analyses were performed to determine the impact of slight changes in the prey size-selectivity curve parameters, directional shifts in median size of prey, and changes in the prey size range consumed by predators.

D1 1.8.2 Methods

The following scenarios were tested to test the sensitivity of the MSVPA-X to various size selectivities. Each scenario was compared to the output from the base run output, and the outputs evaluated were predation mortality (M2) on age-0, 1, and 2 menhaden, the total abundance of age-0 and 1 menhaden, spawning stock biomass of menhaden, and average recruited F on age-2+ menhaden, and predator diet composition and consumption rates. In general, results are reported as percent change from the base run result relative to the change in the input value. Prey size-selectivity parameters can be changed in the MSVPA-X configuration for striped bass and weakfish, but bluefish must be changed in the single-species configuration for each sensitivity run. The values of the size selectivity parameters, α and β, used in the analyses are provided in Tables D1.15 and D1.16.

1) Size selectivity parameters (α and β) were adjusted by ± 1% for all predators in the model (striped bass, bluefish, and weakfish). The goal of this scenario was to determine if the model is highly sensitive to small changes in α and β values.

2) Scenarios were conducted to investigate how shifts in the median prey size-selectivity impact each of the specified outputs above. For all predators combined, shifts in median prey size-selectivity of ± 10% and ± 20% were investigated. The α and β values were

adjusted using the 'sizesel' macro in Excel that calculates the size selectivity parameters the same way as in the MSVPA-X model.

3) To evaluate the impacts of changes in the range of prey sizes selected by predators, the size ranges or predator-prey size ratios were expanded or contracted by ± 10% employing a similar method as in 2. Values for α and β were selected that achieved a 10% expansion and a 10% contraction in the size range of prey selected, while keeping the median size consistent with the base run median size. Striped bass data were available in prey size ranges, but bluefish and weakfish data were presented in terms of predator to prey length ratios; however, the adjustments to the size selectivity curves were performed the same.

D1 1.8.3 Results

1) The MSVPA is robust to 1% changes in the prey size-selectivity curve parameters α and β as these changes slightly altered the output parameters investigated: total, age-0 and age-1 abundance (Table D1.17); spawning stock biomass (Table D1.18), predation mortality (M2) on age-0 and age-1 menhaden (Table D1.19), fishing mortality (Tables D1.20 and D1.21), predator diet composition (Figure D1.82a.- c.), predator consumption rates (Figure D1.83a.-c.).

2) Changes in the median size prey selected by the predators results in expected changes in the output variables observed.

Total, age-0 and age-1 abundance (Figure D1.84 a.-c., Table D1.22)

Decreases in median size of 10% and 20% changes the abundance of age-0, age-1 and total abundance from less than 1% to approximately 10%. Increases in median sizes to 10% and 20% greater than the base run, results in changes in abundance of the same order and in a few cases exceed the change in the input values for α and β. Age-0 abundance is more sensitive than both age-1 and total abundance for each scenario, except the decrease in median prey size by 20%.

Spawning stock biomass (Table D1.23)

Spawning stock abundance is insensitive to changes in median prey size of ± 10% and ± 20%.

Predation mortality (M2) on age-0 and age-1 menhaden (Figure D1.85a.-b., Table D1.24)

Predation mortality estimates behaves expectedly for the given changes in α and β. Note that in the scenarios for age-1 menhaden in which median prey size-selectivity is increased, M2 is substantially higher than the base run and the scenarios where median prey size is decreased.

Fishing mortality (Figure D1.86a.-c., Table D1.25)

Fishing mortality by age and average recruited F are not sensitive to shifts in median prey size.

Predator diet composition & predator consumption rates (Figures D1.82a.-c. and D1.83a.-c.; Table D1.26)

The proportion of menhaden in the diet of the predator species and the consumption of menhaden are the MSVPA-X outputs most affected by changing the median size range of prey selectivity. The changes in proportion of menhaden in each predator diet and the amount of menhaden consumed typically changes relative to the change in median prey size and trends are generally consistent across the scenarios investigated; however, two scenarios affect the proportion of menhaden in the diet of striped bass (Figure D1.826a, the 10% decrease in median prey size and the 20% increase in median prey size).

3) Changes in the range of prey sizes selected by predators, the size ranges

Total, age-0 and age-1 abundance (Figure D1.87)

Abundance of menhaden (age-0, age-1, and total) is insensitive to contractions and expansions in the range of prey size-selectivity for all predators.

Spawning stock biomass (Figure D1.88)

Spawning stock biomass of menhaden was insensitive to contractions and expansions in the range of prey size-selectivity for all predators.

Predation mortality (M2) on age-0 and age-1 menhaden (Table D1.26)

Decreasing the size range of prey selected increases M2 on the smaller and younger menhaden and reduces M2 on older and larger menhaden compared to the base run. Increasing the size range of prey selectivity has the inverse effect.

Fishing mortality (Figure D1.89; Table D1.25)

Neither fishing mortality by age nor average recruited F is sensitive to increases or decreases in prey size-selectivity.

Predator diet composition and predator consumption rates (Figures D1.90a.-c. and D1.91a.-c.)

Estimates and trends in the proportion of menhaden in the diet of the predator species and the consumption of menhaden are predictable and consistent for most of the scenarios tested. For the scenario in which the prey size-selectivity decreased, the largest impact on a predator is for bluefish. In that scenario, consumption of menhaden by bluefish declines substantially; however, total consumption for bluefish of all prey types increases early in the time series, 1982-1990 (Table D1.27). Beginning in 1991, total consumption of bluefish with a decreased size selectivity range is lower than the base run and remains so for the duration of the time series. The total consumption of bluefish in the base run and in the scenario with an increased size range is similar throughout the time series. In addition, the proportion of menhaden consumed declines in the largest size group of bluefish.

D1 2.0 FORECAST PROJECTION RESULTS AND ACCURACY

The MSVPA-X application includes a forecast module that allows exploration of the potential effects of various exploitation patterns, recruitment successes and other "Full MSVPA prey" biomass dynamics. When simulating fishing pressure, the user can enter expected levels of removals in total weight for both prey (menhaden) and predators (striped bass, blue fish, weakfish) or fishing mortality rates for the designated forecast period. Forecasting options for recruitment include several stock-recruitment functions, probability matrices, as well as, the ability to prescribe specific values for each year of the forecast. While these options provide flexibility for future exploration of stock dynamics, it is desirable to test the reliability of model predictions prior to the practical use of the forecasting module.

D1 2.1 FORECAST MODULE ACCURACY

One possible approach to testing the model is to investigate if the forecasting module can reproduce historical observations. To test the ability of the model to reproduce past observations, we used the results of the base run for the 1982 –2002 period. MSVPA-X estimates of population sizes for 1996 were used as a starting point and projections were made for the 1997-2002 period. Estimates of striped bass, weakfish and menhaden recruitment for 1997-2002 from the base run were used as recruitment input for the projection module. Base run estimates of predators fishing mortality rates for the same period served as an input for the forecast module. Fishing pressure on menhaden was simulated in two ways: by entering observed catches for each year of the forecast and by entering "observed" values of fishing mortality (from the "base" run). Projected dynamics of predators and prey were compared with "observed" values from the base run.

Forecasted trends in menhaden total abundance, biomass, spawning stock biomass, predation mortality are similar to those in the base run (Figure 1.92). The forecasted results are not sensitive to the method of fishing removal. Whether the removals are imitated via the total number of fish removed or the fishing mortality applied to the stock, the outputs are very similar, except for the estimate of average recruited F for menhaden. Due to the calculation method used in the forecast module, it is advised to use fishing mortality for the projection rather than absolute catch values. Forecasted and base run values of total absolute abundance and biomass are very close as well. However, there are some differences in the forecasted and "observed" values of menhaden spawning stock biomass (lower values are predicted), predation and fishing mortality (higher predicted values compared to observed for both predation and fishing mortality of menhaden). While the predicted predation mortality on age-0 menhaden does not differ much from the observed, the differences in predicted and observed values of predation on age-1 are more substantial. We were not able to pinpoint the exact reason of such divergence, and further careful analysis is warranted.

D1 2.2 FORECAST MODEL RESULTS

The forecast model is implemented using the base run configuration for the MSVPA-X model with a 5-year projection from 2003-2007. This time frame is chosen based to the potential limitations of the stock-recruitment relationship for menhaden (Section 2.1). The input for the von Bertalanffy and length-weight relationships for each explicitly modeled species are:

	L_{inf}	K	T_{zero}	L-W α	L-W β
Menhaden	33	0.3737	-0.5642	-10.787	2.9565
Striped Bass	158	0.075	-0.9855	-8.753	2.41222
Weakfish	73.44	0.1745	-0.4719	-6.822	1.7642

The stock-recruitment relationships used in this example projection for each species are: menhaden – random from quartiles, striped bass – Ricker, and weakfish – random from quartiles. Bluefish, and other prey biomasses were assumed to be stable across the projected time frame. Likewise, fishing removals (as F) for all explicitly modeled predators and prey were also assumed constant.

Figure 1.93 (a-c) display the results of the forecast projection for: spawning stock biomass of menhaden, striped bass and weakfish; predation mortality on age-0 through age-4 menhaden; and the amount of menhaden consumed by striped bass, weakfish and bluefish. Overall weakfish and striped bass SSB are expected to decrease over the projected time frame, while menhaden SSB is expected to increase. Predation mortality on ages 1-3 menhaden is simulated to remains fairly constant while predation mortality for age-0 menhaden is projected to decrease slightly. However, the weakfish consumption on menhaden is projected to grow, peaking around 2004.

APPENDIX D1 REFERENCES

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APPENDIX D1 TABLES

Table D1.1. Base and alternate prey-preference rankings for striped bass in sensitivity MSVPA-X runs.

A. Base	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13
Striper_2002_13+	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Weakfish_2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Menhaden_2002	0	3	3	2	2	2	2	4	4	5	5	5	5	5
Bay Anchovy	0	7	7	6	7	6	5	6	6	6	6	6	6	6
Benthic Crustaceans	0	1	1	4	3	3	3	2	2	2	2	2	2	2
Benthic Invertebrates	1	5	5	3	5	5	8	7	7	7	7	7	7	7
Clupeids	0	0	0	0	6	8	7	5	5	4	4	3	3	3
Macrozooplankton	2	6	6	7	8	7	6	0	0	0	0	0	0	0
Medium Forage Fish	0	4	4	1	1	1	1	1	1	1	1	1	1	1
Sciaenids	0	2	2	5	4	4	4	3	3	3	3	4	4	4

B. Equal	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13
Striper_2002_13+	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Weakfish_2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Menhaden_2002	0	4	4	4	4.5	4.5	4.5	4	4	4	4	4	4	4
Bay Anchovy	0	4	4	4	4.5	4.5	4.5	4	4	4	4	4	4	4
Benthic Crustaceans	0	4	4	4	4.5	4.5	4.5	4	4	4	4	4	4	4
Benthic Invertebrates	1.5	4	4	4	4.5	4.5	4.5	4	4	4	4	4	4	4
Clupeids	0	0	0	0	4.5	4.5	4.5	4	4	4	4	4	4	4
Macrozooplankton	1.5	4	4	4	4.5	4.5	4.5	0	0	0	0	0	0	0
Medium Forage Fish	0	4	4	4	4.5	4.5	4.5	4	4	4	4	4	4	4
Sciaenids	0	4	4	4	4.5	4.5	4.5	4	4	4	4	4	4	4

Table D1.1 (Cont'd). Base and alternate prey-preference rankings for striped bass in sensitivity MSVPA-X runs.

C. Fish/Invert	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13
Striper_2002_13+	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Weakfish_2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Menhaden_2002	0	5.5	5.5	2.5	3	3	3	3	3	3	3	3	3	3
Bay Anchovy	0	5.5	5.5	2.5	3	3	3	3	3	3	3	3	3	3
Benthic Crustaceans	0	2	2	6	7	7	7	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Benthic Invertebrates	1.5	2	2	6	7	7	7	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Clupeids	0	0	0	0	3	3	3	3	3	3	3	3	3	3
Macrozooplankton	1.5	2	2	6	7	7	7	0	0	0	0	0	0	0
Medium Forage Fish	0	5.5	5.5	2.5	3	3	3	3	3	3	3	3	3	3
Sciaenids	0	5.5	5.5	2.5	3	3	3	3	3	3	3	3	3	3

Table D1.2. Base and alternate prey-preference rankings for weakfish in sensitivity MSVPA-X runs.

A. Base	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
Striper_2002_13+	0	0	0	0	0	0	0
Weakfish_2002	0	0	0	0	0	0	0
Menhaden_2002	4	1	1	3	3	1	3
Bay Anchovy	3	2	4	6	6	6	5
Benthic Crustaceans	0	6	5	5	4	4	4
Benthic Invertebrates	2	7	6	8	8	8	8
Clupeids	0	0	0	2	2	2	2
Macrozooplankton	1	5	7	7	7	7	7
Medium Forage Fish	0	4	3	4	5	5	6
Sciaenids	0	3	2	1	1	3	1

B. Equal	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
Striper_2002_13+	0	0	0	0	0	0	0
Weakfish_2002	0	0	0	0	0	0	0
Menhaden_2002	2.5	4	4	4.5	4.5	4.5	4.5
Bay Anchovy	2.5	4	4	4.5	4.5	4.5	4.5
Benthic Crustaceans	0	4	4	4.5	4.5	4.5	4.5
Benthic Invertebrates	2.5	4	4	4.5	4.5	4.5	4.5
Clupeids	0	0	0	4.5	4.5	4.5	4.5
Macrozooplankton	2.5	4	4	4.5	4.5	4.5	4.5
Medium Forage Fish	0	4	4	4.5	4.5	4.5	4.5
Sciaenids	0	4	4	4.5	4.5	4.5	4.5

C. Fish/Invert	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
Striper_2002_13+	0	0	0	0	0	0	0
Weakfish_2002	0	0	0	0	0	0	0
Menhaden_2002	3.5	2.5	2.5	3	3	3	3
Bay Anchovy	3.5	2.5	2.5	3	3	3	3
Benthic Crustaceans	0	6	6	7	7	7	7
Benthic Invertebrates	1.5	6	6	7	7	7	7
Clupeids	0	0	0	3	3	3	3
Macrozooplankton	1.5	6	6	7	7	7	7
Medium Forage Fish	0	2.5	2.5	3	3	3	3
Sciaenids	0	2.5	2.5	3	3	3	3

Table D1.3. Base and alternate prey-preference rankings for bluefish in sensitivity MSVPA-X runs.

A. Base	**Size 1**	**Size 2**	**Size 3**
Striper_2002_13+	0	0	0
Weakfish_2002	0	0	0
Menhaden_2002	4	4	5
Bay Anchovy	2	7	6
Benthic Crustaceans	5	6	4
Benthic Invertebrates	6	8	7
Clupeids	7	2	3
Macrozooplankton	8	5	8
Medium Forage Fish	1	1	1
Sciaenids	3	3	2

B. Equal	**Size 1**	**Size 2**	**Size 3**
Striper_2002_13+	0	0	0
Weakfish_2002	0	0	0
Menhaden_2002	4.5	4.5	4.5
Bay Anchovy	4.5	4.5	4.5
Benthic Crustaceans	4.5	4.5	4.5
Benthic Invertebrates	4.5	4.5	4.5
Clupeids	4.5	4.5	4.5
Macrozooplankton	4.5	4.5	4.5
Medium Forage Fish	4.5	4.5	4.5
Sciaenids	4.5	4.5	4.5

C. Fish/Invert	**Size 1**	**Size 2**	**Size 3**
Striper_2002_13+	0	0	0
Weakfish_2002	0	0	0
Menhaden_2002	3	3	3
Bay Anchovy	3	3	3
Benthic Crustaceans	7	7	7
Benthic Invertebrates	7	7	7
Clupeids	3	3	3
Macrozooplankton	7	7	7
Medium Forage Fish	3	3	3
Sciaenids	3	3	3

Table D1.4. Estimates of M2 (age 0-2) for menhaden with equal prey-preference ranking.

	Base			Bluefish			Weakfish			Striped Bass			All Predators		
Year	**Age 0**	**Age 1**	**Age 2**	**Age 0**	**Age 1**	**Age 2**	**Age 0**	**Age 1**	**Age 2**	**Age 0**	**Age 1**	**Age 2**	**Age 0**	**Age 1**	*Age 2*
1982	0.672	0.328	0.207	0.637	0.355	0.256	0.508	0.314	0.206	0.672	0.327	0.207	0.471	0.340	0.256
1983	0.607	0.276	0.171	0.576	0.296	0.211	0.459	0.265	0.170	0.605	0.274	0.171	0.424	0.284	0.211
1984	0.508	0.252	0.168	0.479	0.272	0.206	0.392	0.246	0.168	0.503	0.250	0.168	0.357	0.264	0.206
1985	0.542	0.241	0.164	0.511	0.262	0.203	0.406	0.237	0.164	0.536	0.239	0.163	0.367	0.255	0.204
1986	0.620	0.235	0.158	0.598	0.264	0.200	0.461	0.230	0.158	0.612	0.231	0.158	0.429	0.255	0.199
1987	0.637	0.193	0.119	0.621	0.217	0.149	0.488	0.188	0.119	0.626	0.188	0.118	0.459	0.207	0.148
1988	0.538	0.180	0.099	0.525	0.198	0.123	0.436	0.175	0.099	0.521	0.173	0.098	0.405	0.186	0.121
1989	0.396	0.167	0.093	0.384	0.183	0.114	0.335	0.164	0.093	0.370	0.158	0.091	0.297	0.171	0.112
1990	0.377	0.166	0.093	0.367	0.182	0.113	0.322	0.164	0.094	0.344	0.155	0.091	0.277	0.168	0.111
1991	0.404	0.162	0.087	0.394	0.178	0.105	0.346	0.160	0.087	0.365	0.152	0.086	0.297	0.166	0.104
1992	0.394	0.130	0.062	0.384	0.140	0.073	0.292	0.129	0.062	0.353	0.121	0.061	0.240	0.130	0.073
1993	0.534	0.148	0.068	0.524	0.159	0.080	0.391	0.148	0.068	0.478	0.136	0.068	0.323	0.147	0.080
1994	0.678	0.158	0.068	0.667	0.167	0.078	0.477	0.157	0.068	0.616	0.144	0.068	0.403	0.152	0.078
1995	0.854	0.188	0.072	0.840	0.196	0.083	0.635	0.185	0.072	0.784	0.172	0.072	0.551	0.179	0.083
1996	0.765	0.185	0.063	0.753	0.193	0.072	0.592	0.180	0.063	0.703	0.174	0.064	0.519	0.178	0.073
1997	0.752	0.191	0.060	0.741	0.200	0.068	0.608	0.183	0.059	0.691	0.182	0.061	0.534	0.183	0.069
1998	0.794	0.217	0.070	0.783	0.228	0.080	0.647	0.209	0.070	0.714	0.207	0.072	0.555	0.209	0.082
1999	0.745	0.214	0.073	0.733	0.226	0.085	0.621	0.209	0.073	0.665	0.200	0.074	0.528	0.208	0.086
2000	0.697	0.206	0.077	0.685	0.221	0.091	0.583	0.204	0.078	0.630	0.195	0.079	0.503	0.207	0.092
2001	0.835	0.228	0.090	0.821	0.247	0.107	0.664	0.224	0.090	0.771	0.218	0.092	0.583	0.233	0.109
2002	1.050	0.261	0.109	1.032	0.286	0.130	0.812	0.256	0.109	0.996	0.254	0.112	0.736	0.273	0.133

Table D1.5. Estimates of M2 (age 0-2) for menhaden with fish/invert prey-preference ranking.

	Base			Bluefish			Weakfish			Striped Bass			All Predators		
Year	Age 0	**Age 1**	**Age 2**	**Age 0**	**Age 1**	**Age 2**	**Age 0**	**Age 1**	**Age 2**	**Age 0**	**Age 1**	**Age 2**	**Age 0**	**Age 1**	**Age 2**
1982	0.672	0.328	0.207	0.664	0.375	0.267	0.590	0.322	0.207	0.671	0.327	0.208	0.581	0.369	0.268
1983	0.607	0.276	0.171	0.599	0.313	0.218	0.534	0.272	0.171	0.603	0.275	0.171	0.522	0.308	0.218
1984	0.508	0.252	0.168	0.501	0.289	0.214	0.452	0.250	0.168	0.501	0.250	0.168	0.439	0.285	0.215
1985	0.542	0.241	0.164	0.534	0.279	0.211	0.474	0.239	0.164	0.533	0.239	0.164	0.457	0.275	0.211
1986	0.620	0.235	0.158	0.619	0.280	0.208	0.545	0.233	0.158	0.610	0.232	0.158	0.535	0.276	0.208
1987	0.637	0.193	0.119	0.636	0.228	0.154	0.566	0.191	0.119	0.625	0.189	0.118	0.554	0.223	0.155
1988	0.538	0.180	0.099	0.536	0.207	0.128	0.492	0.178	0.099	0.522	0.175	0.099	0.475	0.201	0.127
1989	0.396	0.167	0.093	0.396	0.191	0.118	0.368	0.166	0.093	0.372	0.161	0.092	0.345	0.184	0.118
1990	0.377	0.166	0.093	0.378	0.189	0.117	0.351	0.165	0.093	0.345	0.159	0.093	0.320	0.181	0.116
1991	0.404	0.162	0.087	0.404	0.184	0.108	0.377	0.161	0.087	0.367	0.157	0.088	0.341	0.179	0.109
1992	0.394	0.130	0.062	0.390	0.144	0.075	0.343	0.130	0.062	0.352	0.125	0.063	0.296	0.140	0.077
1993	0.534	0.148	0.068	0.529	0.163	0.082	0.461	0.148	0.068	0.478	0.144	0.070	0.399	0.159	0.084
1994	0.678	0.158	0.068	0.670	0.170	0.080	0.573	0.158	0.068	0.617	0.153	0.070	0.505	0.165	0.082
1995	0.854	0.188	0.072	0.840	0.200	0.084	0.733	0.186	0.072	0.781	0.181	0.076	0.650	0.192	0.088
1996	0.765	0.185	0.063	0.754	0.196	0.073	0.661	0.181	0.063	0.702	0.182	0.066	0.589	0.189	0.077
1997	0.752	0.191	0.060	0.742	0.202	0.070	0.678	0.187	0.060	0.699	0.191	0.063	0.616	0.199	0.073
1998	0.794	0.217	0.070	0.785	0.231	0.081	0.717	0.213	0.070	0.725	0.217	0.075	0.641	0.226	0.086
1999	0.745	0.214	0.073	0.738	0.230	0.086	0.684	0.213	0.073	0.677	0.210	0.077	0.611	0.225	0.090
2000	0.697	0.206	0.077	0.691	0.225	0.093	0.642	0.205	0.078	0.646	0.206	0.082	0.586	0.225	0.097
2001	0.835	0.228	0.090	0.828	0.253	0.110	0.750	0.226	0.090	0.784	0.228	0.095	0.693	0.251	0.114
2002	1.050	0.261	0.109	1.041	0.293	0.134	0.935	0.259	0.109	1.004	0.264	0.115	0.881	0.294	0.140

Table D1.6. Menhaden annual average F (age 2+) with both prey-preference ranking.

	Base	Bluefish		Weakfish		Striped Bass		All Predators	
Year	**-**	**Equal**	**F&I**	**Equal**	**F&I**	**Equal**	**F&I**	**Equal**	**F&I**
1982	1.594	1.546	1.539	1.596	1.594	1.593	1.593	1.547	1.538
1983	1.442	1.407	1.401	1.443	1.442	1.442	1.442	1.407	1.4
1984	1.486	1.448	1.442	1.484	1.486	1.486	1.486	1.448	1.442
1985	1.534	1.492	1.485	1.529	1.534	1.534	1.534	1.491	1.485
1986	1.180	1.148	1.142	1.171	1.180	1.180	1.180	1.147	1.142
1987	1.053	1.032	1.030	1.042	1.053	1.053	1.053	1.032	1.03
1988	1.268	1.249	1.245	1.248	1.268	1.269	1.268	1.245	1.245
1989	1.219	1.201	1.198	1.192	1.219	1.220	1.218	1.195	1.197
1990	1.156	1.141	1.139	1.130	1.156	1.157	1.156	1.135	1.139
1991	1.363	1.351	1.348	1.334	1.363	1.364	1.362	1.337	1.347
1992	1.014	1.006	1.004	0.988	1.014	1.014	1.013	0.992	1.003
1993	1.036	1.027	1.026	1.002	1.036	1.035	1.033	1.011	1.024
1994	0.969	0.963	0.962	0.938	0.969	0.968	0.966	0.948	0.96
1995	1.237	1.231	1.229	1.199	1.237	1.237	1.235	1.207	1.227
1996	0.750	0.746	0.745	0.726	0.750	0.749	0.749	0.730	0.744
1997	0.915	0.911	0.910	0.891	0.915	0.914	0.913	0.892	0.908
1998	1.339	1.332	1.331	1.303	1.339	1.338	1.336	1.308	1.328
1999	1.182	1.174	1.173	1.145	1.182	1.181	1.179	1.153	1.175
2000	0.883	0.876	0.876	0.857	0.883	0.883	0.882	0.860	0.874
2001	1.243	1.235	1.233	1.212	1.243	1.242	1.241	1.212	1.231
2002	1.175	1.168	1.167	1.145	1.175	1.174	1.173	1.148	1.166

Table D1.7. Menhaden abundance at age 0-1 (millions) with equal prey-preference ranking.

	Base		Bluefish		Weakfish		Striped Bass		All Predators	
Year	**Age 0**	**Age 1**	**Age 0**	**Age 1**	**Age 0**	**Age 1**	**Age 0**	**Age 1**	**Age 0**	**Age 1**
1982	10187.5	8817.3	10190.0	9234.6	8565.8	8696.5	10187.5	8808.0	8309.5	9143.5
1983	15412.0	3413.4	15423.0	3546.7	13331.2	3380.2	15377.7	3411.2	13301.2	3509.8
1984	18489.6	5068.0	18623.2	5253.0	16493.2	5038.0	18352.7	5058.9	16504.3	5217.8
1985	16256.0	6647.8	16484.1	6931.6	14166.3	6621.7	16112.4	6629.3	14243.7	6887.1
1986	12039.3	5937.9	12156.2	6235.7	10188.9	5913.9	11889.3	5924.5	10172.6	6192.0
1987	11209.1	4263.8	11346.1	4420.3	9577.9	4244.0	10956.9	4242.4	9539.6	4379.1
1988	16877.3	3938.7	16985.8	4063.8	15167.0	3920.2	16447.0	3908.1	14941.0	4015.2
1989	6690.1	6374.5	6763.3	6532.8	6267.3	6358.1	6439.5	6317.7	6110.3	6459.2
1990	9613.7	2917.2	9679.1	2988.6	9087.7	2906.5	9228.7	2879.2	8790.2	2946.1
1991	10432.6	4208.9	10478.5	4292.2	9871.6	4202.0	9997.4	4173.1	9505.8	4251.2
1992	9118.2	4094.4	9173.9	4163.9	8266.5	4089.0	8683.5	4065.9	7903.7	4128.6
1993	7338.8	3857.4	7395.8	3925.9	6362.5	3857.4	6894.7	3818.8	5970.5	3884.8
1994	11130.9	2843.4	11163.8	2889.7	9113.9	2841.5	10355.6	2810.1	8453.5	2850.3
1995	7299.2	3728.8	7261.8	3781.1	5793.6	3718.2	6745.1	3682.4	5491.5	3727.6
1996	6800.5	2045.6	6801.4	2073.5	5655.5	2035.1	6358.7	2026.1	5303.4	2046.7
1997	6357.5	2096.7	6375.8	2126.8	5435.6	2081.6	6051.0	2082.0	5100.8	2096.8
1998	8061.8	1990.2	8103.7	2025.0	6921.7	1971.7	7375.7	1971.8	6385.2	1991.1
1999	6265.4	2395.8	6343.4	2447.2	5531.2	2383.2	5750.0	2369.9	5135.1	2410.6
2000	3806.0	1884.5	3865.4	1938.7	3387.3	1880.1	3535.8	1868.2	3198.8	1915.9
2001	7725.9	1224.4	7805.6	1263.6	6552.3	1220.7	7230.7	1214.0	6127.2	1247.7
2002	9427.0	2228.8	9657.2	2289.2	8045.1	2242.1	8939.1	2222.0	7566.3	2277.3

Table D1.8. Menhaden abundance at age 0-1 (millions) with fish/invert prey-preference ranking.

	Base		Bluefish		Weakfish		Striped Bass		All Predators	
Year	**Age 0**	**Age 1**	**Age 0**	**Age 1**	**Age 0**	**Age 1**	**Age 0**	**Age 1**	**Age 0**	**Age 1**
1982	10187.5	8817.3	10672.2	9452.3	9354.3	8768.9	10173.9	8808.0	9793.4	9402.4
1983	15412.0	3413.4	16066.5	3614.7	14359.3	3400.7	15368.1	3411.2	14874.9	3600.2
1984	18489.6	5068.0	19386.0	5348.6	17483.4	5054.7	18309.0	5059.7	18235.4	5330.4
1985	16256.0	6647.8	17194.8	7068.8	15182.9	6630.7	16075.5	6630.7	15921.0	7047.7
1986	12039.3	5937.9	12587.3	6359.8	11061.9	5932.8	11862.5	5926.7	11531.2	6348.7
1987	11209.1	4263.8	11607.4	4481.7	10418.7	4255.3	11043.6	4251.7	10719.7	4457.9
1988	16877.3	3938.7	17360.2	4108.1	16232.9	3929.9	16526.7	3919.2	16249.7	4084.0
1989	6690.1	6374.5	6905.5	6591.9	6498.5	6369.0	6488.1	6339.9	6518.7	6550.3
1990	9613.7	2917.2	9848.0	3013.3	9366.6	2912.2	9290.0	2894.4	9277.7	2991.4
1991	10432.6	4208.9	10638.7	4318.8	10171.7	4208.9	10077.9	4195.8	10005.8	4305.7
1992	9118.2	4094.4	9317.8	4186.8	8671.7	4094.4	8745.4	4090.0	8465.0	4174.8
1993	7338.8	3857.4	7467.5	3963.6	6837.6	3857.4	6945.2	3852.1	6298.5	3939.7
1994	11130.9	2843.4	11244.2	2901.7	10007.8	2843.4	10457.2	2837.5	9508.7	2894.8
1995	7299.2	3728.8	7302.8	3797.7	6433.9	3725.3	6786.3	3719.3	6032.6	3783.8
1996	6800.5	2045.6	6875.1	2084.0	6113.2	2037.0	6390.6	2043.9	5795.2	2073.5
1997	6357.5	2096.7	6420.3	2133.5	5880.3	2090.5	6056.6	2104.5	5643.7	2132.5
1998	8061.8	1990.2	8165.2	2032.5	7455.1	1980.9	7535.2	1993.3	7121.6	2023.8
1999	6265.4	2395.8	6410.4	2460.2	5898.4	2393.6	5891.4	2396.1	5694.8	2458.8
2000	3806.0	1884.5	3920.4	1949.9	3591.8	1884.5	3637.2	1891.3	3546.5	1956.2
2001	7725.9	1224.4	7870.2	1274.0	7073.8	1221.6	7381.4	1228.2	6971.4	1274.6
2002	9427.0	2228.8	9708.9	2297.1	8720.7	2226.8	9115.8	2230.7	8538.6	2316.2

Table D1.9. Menhaden spawning stock biomass (1000 mt) with equal prey-preference ranking.

Year	**Base**	**Bluefish**	**Weakfish**	**Striped Bass**	**All Predators**
1982	86.3	88.6	86.3	86.4	88.6
1983	68.7	70.5	68.7	68.7	70.5
1984	92.9	94.3	92.9	93.0	94.3
1985	52.3	53.3	52.3	52.3	53.4
1986	55.6	57.0	55.6	55.6	57.0
1987	107.6	109.8	107.6	107.6	109.8
1988	142.1	143.8	142.1	142.1	143.8
1989	111.2	112.6	111.2	111.2	112.6
1990	117.5	118.9	117.5	117.5	118.9
1991	127.7	128.8	127.7	127.7	128.8
1992	81.0	81.5	81.0	81.0	81.5
1993	80.8	81.3	80.8	80.8	81.4
1994	102.2	102.9	102.2	102.4	102.9
1995	101.4	101.8	101.4	101.4	101.9
1996	70.8	71.2	70.8	70.8	71.2
1997	181.7	182.4	181.8	181.8	182.5
1998	161.1	161.6	161.1	161.2	161.7
1999	89.0	89.4	89.0	89.0	89.4
2000	77.8	78.2	77.8	77.8	78.3
2001	101.4	102.0	101.4	101.5	102.1
2002	79.6	80.1	79.6	79.7	80.2

Table D1.10. Menhaden spawning stock biomass (1000 mt) with fish/invert prey-preference ranking.

Year	**Base**	**Bluefish**	**Weakfish**	**Striped Bass**	**All Predators**
1982	86.3	88.9	86.3	86.4	89.0
1983	68.7	70.7	68.7	68.7	70.8
1984	92.9	94.5	92.9	93.0	94.5
1985	52.3	53.5	52.3	52.3	53.5
1986	55.6	57.2	55.6	55.6	57.3
1987	107.6	110.2	107.6	107.6	110.2
1988	142.1	144.1	142.1	142.1	144.1
1989	111.2	112.8	111.2	111.3	112.8
1990	117.5	119.1	117.5	117.6	119.2
1991	127.7	128.9	127.7	127.8	129.0
1992	81.0	81.6	81.0	81.1	81.6
1993	80.8	81.4	80.8	80.9	81.5
1994	102.2	103.0	102.2	102.5	103.1
1995	101.4	101.9	101.4	101.5	102.1
1996	70.8	71.3	70.8	70.9	71.4
1997	181.7	182.6	181.8	181.9	182.7
1998	161.1	161.6	161.1	161.3	161.8
1999	89.0	89.4	89.0	89.1	89.5
2000	77.8	78.3	77.8	77.9	78.4
2001	101.4	102.1	101.4	101.5	102.3
2002	79.6	80.2	79.6	79.7	80.4

Table D1.11. Diet composition of menhaden (%) for each predator age.

Striped Bass									
When modifying:		**Bluefish**		**Weakfish**		**Striped Bass**		**All Predators**	
Age Class	**Base**	**Equal**	**F/I**	**Equal**	**F/I**	**Equal**	**F/I**	**Equal**	**F/I**
Age 0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Age 1	2.4%	2.4%	2.5%	2.2%	2.3%	1.1%	0.6%	1.1%	0.6%
Age 2	8.4%	8.5%	8.6%	8.0%	8.2%	4.1%	2.2%	4.0%	2.2%
Age 3	8.7%	8.8%	8.9%	8.4%	8.5%	5.1%	2.7%	5.0%	2.8%
Age 4	11.2%	11.4%	11.5%	10.9%	11.1%	5.2%	9.4%	5.1%	9.5%
Age 5	28.1%	28.5%	28.6%	27.5%	27.8%	18.4%	21.4%	18.2%	21.6%
Age 6	29.7%	30.1%	30.3%	29.3%	29.5%	19.8%	22.1%	19.7%	22.4%
Age 7	28.2%	28.6%	28.8%	27.9%	28.1%	25.7%	28.6%	25.8%	29.0%
Age 8	28.9%	29.3%	29.5%	28.7%	28.8%	27.0%	29.7%	27.2%	30.1%
Age 9	31.1%	31.5%	31.6%	30.9%	31.0%	38.2%	41.3%	38.4%	41.8%
Age 10	35.8%	36.2%	36.3%	35.8%	35.8%	44.7%	47.2%	45.0%	47.7%
Age 11	31.3%	31.6%	31.7%	31.2%	31.2%	41.0%	43.0%	41.3%	43.4%
Age 12	29.3%	29.6%	29.7%	29.2%	29.3%	38.8%	40.5%	39.1%	40.9%
Age 13	29.1%	29.4%	29.5%	29.1%	29.1%	38.4%	39.9%	38.7%	40.2%

Weakfish									
When modifying:		**Bluefish**		**Weakfish**		**Striped Bass**		**All Predators**	
Age Class	**Base**	**Equal**	**F/I**	**Equal**	**F/I**	**Equal**	**F/I**	**Equal**	**F/I**
Age 0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Age 1	4.0%	4.0%	4.1%	1.0%	2.4%	3.9%	3.9%	1.0%	2.3%
Age 2	26.9%	27.1%	27.4%	13.8%	20.7%	26.5%	26.6%	13.5%	20.7%
Age 3	41.5%	41.8%	42.1%	27.2%	33.8%	41.0%	41.2%	27.0%	33.9%
Age 4	48.9%	49.4%	49.6%	37.5%	43.3%	48.5%	48.7%	37.5%	43.7%
Age 5	53.9%	54.3%	54.5%	38.8%	43.9%	53.5%	53.7%	38.9%	44.3%
Age 6	47.7%	48.2%	48.3%	42.1%	46.6%	47.5%	47.6%	42.2%	47.1%

Bluefish									
When modifying:		**Bluefish**		**Weakfish**		**Striped Bass**		**All Predators**	
Age Class	**Base**	**Equal**	**F/I**	**Equal**	**F/I**	**Equal**	**F/I**	**Equal**	**F/I**
Size 1	3.1%	1.7%	4.4%	2.8%	2.9%	3.0%	3.0%	1.5%	4.1%
Size 2	29.7%	24.7%	29.8%	29.1%	29.4%	29.4%	29.5%	23.9%	29.3%
Size 3	29.0%	36.7%	38.0%	29.0%	29.0%	29.0%	29.0%	36.5%	37.9%

Table D1.12. Consumption of menhaden (1000 mt) by predators for equal prey-preference ranking.

	When modifying:														
	Base			**Bluefish**			**Weakfish**			**Striped Bass**			**All Predators**		
Year	**SB**	**WF**	**BF**	**SB**	**WF**	**BF**	**SB**	**WF**	**BF**	**SB**	**WF**	**BF**	**SB**	**WF**	**BF**
1982	6.9	80.0	160.7	7.1	81.2	183.3	6.8	52.4	158.8	5.3	80.8	161.1	5.3	53.1	181.6
1983	6.2	74.6	107.5	6.3	75.3	118.2	6.0	44.7	105.6	4.3	75.3	107.7	4.3	45.5	116.7
1984	8.4	68.7	107.0	8.6	69.6	112.9	8.2	41.2	105.4	5.6	69.1	107.1	5.6	41.9	111.5
1985	10.6	65.8	120.2	10.9	67.2	129.9	10.4	36.9	118.5	7.2	66.1	120.3	7.3	37.8	128.3
1986	16.7	85.3	160.1	17.1	86.4	183.6	16.2	48.2	157.5	11.2	85.4	160.0	11.2	49.0	181.1
1987	20.6	98.9	123.8	21.0	100.1	143.4	20.0	60.0	121.7	14.3	98.4	123.3	14.2	60.7	141.2
1988	34.2	122.9	102.5	34.6	123.5	113.7	33.4	82.2	100.9	22.6	122.2	101.9	22.4	82.3	111.6
1989	34.6	38.5	85.4	35.0	38.8	98.9	34.5	27.2	85.2	24.7	38.1	84.9	24.9	27.2	98.2
1990	42.4	37.3	70.6	42.8	37.4	80.0	42.1	24.7	70.3	29.9	36.7	70.0	30.0	24.4	79.2
1991	45.0	35.9	56.9	45.2	36.0	64.6	44.7	24.2	56.7	33.3	35.4	56.5	33.3	23.8	64.0
1992	39.7	26.9	34.8	40.0	27.0	39.5	39.3	14.8	34.6	29.6	26.4	34.6	29.4	14.6	39.2
1993	47.2	30.8	33.8	47.5	31.0	39.3	46.4	16.5	33.6	36.1	30.0	33.6	35.7	16.0	38.9
1994	58.0	60.1	29.4	58.3	60.2	33.3	56.1	30.4	28.9	43.0	57.9	29.1	41.8	29.3	32.6
1995	54.1	57.3	26.5	54.2	57.0	30.8	52.4	33.3	26.2	41.9	55.4	26.3	41.3	32.9	30.4
1996	65.0	85.6	29.7	65.1	85.3	34.4	62.6	52.5	29.2	50.1	83.2	29.5	48.7	51.1	33.7
1997	64.8	83.5	29.9	65.0	83.3	34.6	62.7	55.6	29.4	50.7	82.7	29.8	49.0	54.1	33.9
1998	86.7	97.0	33.4	87.3	97.1	37.9	83.7	62.7	32.7	64.9	93.1	32.9	63.4	60.6	36.8
1999	80.2	68.5	36.8	81.2	69.1	42.6	78.6	46.4	36.3	61.1	66.0	36.4	60.6	45.2	41.7
2000	56.6	38.7	37.1	57.4	39.2	44.4	55.8	26.2	36.8	46.0	37.6	36.8	46.1	25.8	43.9
2001	70.7	84.8	46.7	71.6	85.6	52.9	68.4	51.0	45.7	54.3	82.4	46.2	53.1	49.4	51.3
2002	79.2	134.2	69.2	81.0	137.6	78.5	79.3	83.6	69.3	63.1	131.7	68.8	63.2	81.4	77.0

Table D1.13. Consumption of menhaden (1000 mt) by predators for fish/invert prey-preference ranking.

	When modifying:														
	Base			**Bluefish**			**Weakfish**			**Striped Bass**			**All Predators**		
Year	**SB**	**WF**	**BF**	**SB**	**WF**	**BF**	**SB**	**WF**	**BF**	**SB**	**WF**	**BF**	**SB**	**WF**	**BF**
1982	6.9	80.0	160.7	7.2	82.8	200.7	6.8	65.5	159.9	5.7	80.6	160.9	5.9	68.3	200.0
1983	6.2	74.6	107.5	6.4	76.9	129.4	6.1	58.6	106.6	4.4	75.1	107.6	4.5	60.7	128.5
1984	8.4	68.7	107.0	8.8	71.1	125.7	8.3	54.3	106.2	5.4	68.8	106.9	5.6	56.5	124.9
1985	10.6	65.8	120.2	11.1	68.8	143.8	10.5	50.1	119.4	7.0	65.9	120.1	7.2	52.4	142.9
1986	16.7	85.3	160.1	17.3	87.9	200.8	16.4	65.3	158.6	11.7	85.1	159.7	12.1	67.9	199.6
1987	20.6	98.9	123.8	21.2	100.9	155.2	20.4	78.4	122.9	15.4	98.8	123.6	15.6	80.5	154.1
1988	34.2	122.9	102.5	34.9	124.4	124.1	34.1	103.4	102.2	24.8	122.3	102.1	25.1	103.7	123.0
1989	34.6	38.5	85.4	35.2	39.0	106.6	34.6	33.0	85.3	27.1	38.2	85.0	27.6	33.2	106.2
1990	42.4	37.3	70.6	43.0	37.6	86.3	42.3	30.7	70.5	31.9	36.9	70.2	32.3	30.6	85.9
1991	45.0	35.9	56.9	45.4	36.0	69.9	44.9	30.1	56.9	35.9	35.6	56.7	36.2	29.9	69.5
1992	39.7	26.9	34.8	40.2	27.2	42.5	39.5	20.1	34.7	31.3	26.5	34.7	31.4	20.0	42.3
1993	47.2	30.8	33.8	47.7	31.0	42.2	46.8	22.7	33.7	39.0	30.1	33.7	38.5	21.4	41.6
1994	58.0	60.1	29.4	58.3	60.1	35.8	56.9	42.6	29.1	46.0	58.3	29.2	45.5	41.5	35.3
1995	54.1	57.3	26.5	54.2	56.7	33.0	53.2	42.7	26.3	44.9	55.6	26.4	44.5	41.3	32.7
1996	65.0	85.6	29.7	65.3	85.2	36.8	63.6	64.3	29.4	52.8	83.5	29.6	52.1	62.4	36.3
1997	64.8	83.5	29.9	65.1	83.0	37.0	63.7	67.7	29.6	55.3	82.3	29.8	54.7	66.1	36.6
1998	86.7	97.0	33.4	87.4	96.9	40.8	85.2	77.2	33.0	70.9	94.4	33.1	70.5	75.6	40.2
1999	80.2	68.5	36.8	81.4	69.1	45.7	79.5	56.8	36.6	67.3	67.1	36.6	67.7	56.2	45.3
2000	56.6	38.7	37.1	57.6	39.3	47.3	56.2	32.0	36.9	51.5	38.3	37.0	52.0	32.1	47.2
2001	70.7	84.8	46.7	71.6	85.3	57.0	69.2	65.5	46.0	59.7	83.4	46.5	59.8	65.6	56.3
2002	79.2	134.2	69.2	80.6	136.5	84.4	79.1	106.8	69.1	68.7	133.3	69.1	69.4	106.2	84.0

Table D1.14. Summary of the Spatial Overlap sensitivity runs – model run name and a brief description. Refer to table when looking at figures below. Areas highlighted in grey are referred to as 'Predator Runs' and those in yellow are 'Seasonal Runs'. * Description of how original 'Base' run spatial overlap values were developed is described in document.

Model Run Name	Spatial Overlap Description/Combination
Base	Original spatial overlap values *
Ex 1	**Striped Bass** values = 1 for all prey and seasons Other predators same as Base
Ex 2	**Weakfish** values = 1 for all prey and seasons Other predators same as Base
Ex 3	**Bluefish** values = 1 for all prey and seasons Other predators same as Base
Ex 4	**All Predators** = 1 for all prey and seasons
Ex 5	**All Predators** = 1 for all prey and **NO seasons** Compared to Ex 4
Ex 6	Average seasonal values for **All predators** and **NO seasons.** Compared to Base

Table D1.15. Values of the prey size selectivity curve parameters, α and β, for the base run and sensitivity analyses scenarios 1) Is the MSVPA highly sensitive to the values selected for α and β (± 1% change in the parameters), and 2) How sensitive is the MSVPA to shifts in median size of animals consumed.

	Base Run		**-1% Change in α and β**		**+1% Change in α and β**		**-10% Shift in median size**		**+10% Shift in median size**		**-20% Shift in median size**		**+20% Shift in median size**	
Size Selectivity Parameters	α	β	α	β	α	β	α	β	α	β	α	β	α	β
Age 0-4 Striped Bass	2.98	11.244	2.9502	11.13156	3.0098	11.35644	2.7	10.8	3.3	11.6	2.37	11.6	3.7	12.15
Age 5-9 Striped Bass	9.1	35.2	9.009	34.848	9.191	35.552	8.05	30	10.72	32	6.75	28.4	12.3	33
Age 10+ Striped Bass	13.9	51.2	13.761	50.688	14.039	51.712	8.65	50	16	53	10.6	48	19.5	25
Weakfish	10.1	25.5	9.999	25.245	9.191	35.552	8.65	25	11.1	25	7.5	24.5	12.5	25
Bluefish	10.1	25.5	9.999	25.245	9.191	35.552	8.65	25	11.1	25	7.5	24.5	12.5	25

Table D1.16. Values of the prey size selectivity curve parameters, α and β, for the scenarios with a change in prey size range compared to the base run to test the sensitivity of the model to dramatically different prey size selectivity curves.

	Base Run		**Decrease in prey size range (10%)**		**Increase in prey size range (10%)**	
Size Selectivity Parameters	α	β	α	β	α	β
Age 0-4 Striped Bass	2.98	11.244	6.85	31	2.55	9
Age 5-9 Striped Bass	9.1	35.2	20.2	82	6.7	25
Age 10+ Striped Bass	13.9	51.2	33	130	12.1	44
Weakfish	10.1	25.5	27.2	72	8	20
Bluefish	10.1	25.5	27.2	72	8	20

Table D1.17. Percent change in abundance (numbers) of age-0, age-1 and total abundance of menhaden given a ± 1% change in the prey size selectivity curve parameters α & β from the base run condition for all predators combined (striped bass, weakfish and bluefish) in the MSVPA-X.

	-1% change in α & β			**+1% change in α & β**		
Year	**Age 0**	**Age 1**	**Total**	**Age 0**	**Age 1**	**Total**
1982	0.287	0.105	0.172	0.287	0.105	0.173
1983	0.041	0.000	0.028	0.041	0.000	0.029
1984	0.270	0.079	0.209	0.262	0.079	0.205
1985	0.292	0.086	0.211	0.233	0.056	0.165
1986	0.365	0.093	0.235	0.365	0.025	0.210
1987	-0.224	0.000	-0.123	0.160	0.000	0.096
1988	0.248	0.000	0.177	0.350	0.109	0.269
1989	0.312	0.041	0.151	0.043	0.044	0.036
1990	0.062	0.171	0.080	0.000	0.000	0.010
1991	0.101	-0.005	0.061	-0.090	0.000	-0.056
1992	-0.027	0.000	-0.017	-0.013	-0.110	-0.038
1993	-0.354	0.000	-0.192	-0.132	-0.029	-0.097
1994	0.119	-0.127	0.058	0.113	0.035	0.072
1995	0.256	0.000	0.136	0.864	0.094	0.509
1996	0.290	-0.044	0.171	0.209	0.112	0.151
1997	-4.400	-0.105	-2.783	0.171	0.000	0.116
1998	0.394	-0.075	0.261	0.175	0.085	0.137
1999	0.313	0.008	0.193	0.000	0.054	0.013
2000	0.247	-0.005	0.129	0.097	0.000	0.063
2001	0.841	-0.016	0.629	-0.326	0.000	-0.244
2002	0.152	0.000	0.111	0.075	0.045	0.065

Table D1.18. Spawning stock biomass (SSB) in thousands of metric tons of menhaden from the base run MSVPA configuration and the SSB of menhaden a ± 1 percent change in the prey size selectivity curves α & β.

Base Run SSB	**SSB with a -1% change in α & β**	**SSB with a +1% change in α & β**
86.31	86.31	86.3
68.73	68.73	68.72
92.93	92.98	92.93
52.3	52.3	52.27
55.58	55.58	55.58
107.6	107.58	107.58
142.1	142.09	142.07
111.24	111.24	111.23
117.54	117.53	117.53
127.72	127.72	127.72
81.02	81.02	81.02
80.75	80.76	80.77
102.24	102.25	102.38
101.38	101.39	101.38
70.78	70.78	70.77
181.74	181.75	181.67
161.14	161.15	161.14
89	89.01	89
77.76	77.79	77.74
101.38	101.38	101.38
79.57	79.59	79.57

Table D1.19. Change in predation mortality (M2) for age-0 and age-1 menhaden from the base run when the size selectivity curve parameters (α & β) in the MSVPA-X are changed by ± 1 percent.

Year	Age 0			Age 1		
	Base Run M2 Rates by Year	Change in M2 from Base Run		Base Run M2 Rates by Year	Change in M2 from Base Run	
		-1% Change in α & β	+1% Change in α & β		-1% Change in α & β	+1% Change in α & β
1982	0.672	-0.002	0.003	0.328	-0.001	0
1983	0.607	-0.002	0.002	0.276	0	0
1984	0.508	-0.001	0.002	0.252	0	0
1985	0.542	-0.001	0.002	0.241	0	0
1986	0.62	-0.002	0.002	0.235	0	0
1987	0.637	-0.002	0.002	0.193	0	0
1988	0.538	-0.002	0.002	0.18	0	0
1989	0.396	-0.002	0.001	0.167	0	0
1990	0.377	-0.001	0.002	0.166	0	-0.001
1991	0.404	-0.002	0.001	0.162	0	0
1992	0.394	-0.001	0.002	0.13	-0.001	0
1993	0.534	-0.002	0.002	0.148	0	0
1994	0.678	-0.003	0.003	0.158	0	0
1995	0.854	-0.003	0.003	0.188	0	0.001
1996	0.765	-0.003	0.002	0.185	0	0
1997	0.752	-0.001	0.003	0.191	0.001	0
1998	0.794	-0.004	0.004	0.217	0	0
1999	0.745	-0.004	0.004	0.214	0	0
2000	0.697	-0.003	0.003	0.206	0	0
2001	0.835	-0.004	0.004	0.228	0	0
2002	1.05	-0.004	0.005	0.261	0	-0.001

Table D1.20. Change in fishing mortality (F) for age-0 and age-1 menhaden from the base run when the size selectivity curve parameters (α & β) in the MSVPA-X are changed by ± 1 percent.

Year	Age 0			Age 1		
	Base Run F Rates by Year	Change in F from Base Run		Base Run F Rates by Year	Change in F from Base Run	
		-1% Change in α & β	+1% Change in α & β		-1% Change in α & β	+1% Change in α & β
1982	0.018	0	0	0.157	0	0
1983	0.104	0	0	0.23	0	0
1984	0.112	0	0	0.316	0	0
1985	0.062	0	0	0.247	0	0
1986	0.013	0	0	0.055	0	0
1987	0.006	0	0	0.174	0	0
1988	0.031	0	0.001	0.104	0	0
1989	0.033	0	0	0.272	0	0
1990	0.047	0	0	0.071	0	0
1991	0.13	0	0	0.387	0	0
1992	0.065	0	0	0.263	0	0
1993	0.014	0	0	0.14	0	0
1994	0.013	0	0	0.141	0	0
1995	0.014	0	0	0.218	0	0.001
1996	0.008	0	0	0.146	0	0
1997	0.007	-0.001	0	0.172	-0.001	0
1998	0.016	0	0	0.135	0	0
1999	0.053	0	0	0.185	0	0
2000	0.034	0	0	0.094	0	0
2001	0.005	0	0	0.052	0	0
2002	0.036	0	0	0.141	0	0

Table D1.21. Average recruited fishing mortality on age-2 and older menhaden for the base run and for ±1% changes in the size selectivity curve parameters α and β.

	Average Recruited F		
Year	**Base Run**	**-1% change in α and β**	**+1% change in α and β**
1982	1.594	1.594	1.594
1983	1.442	1.442	1.442
1984	1.486	1.486	1.486
1985	1.534	1.534	1.534
1986	1.18	1.18	1.18
1987	1.053	1.053	1.053
1988	1.268	1.268	1.269
1989	1.219	1.219	1.219
1990	1.156	1.156	1.156
1991	1.363	1.363	1.363
1992	1.014	1.014	1.014
1993	1.036	1.036	1.035
1994	0.969	0.969	0.968
1995	1.237	1.237	1.237
1996	0.75	0.75	0.75
1997	0.915	0.915	0.915
1998	1.339	1.338	1.339
1999	1.182	1.181	1.182
2000	0.883	0.883	0.883
2001	1.243	1.243	1.243
2002	1.175	1.174	1.175

Table D1.22. Percent change from base run MSVPA-X abundance results for age-0, age-1 and total abundance of menhaden for sensitivity analysis scenarios in which the median size of prey selected for each predator was shifted by ± 10% and ± 20%.

	Percent Change from Base Run Results for age-0, age-1, and Total Menhaden Abundance											
	10% Decrease in Median Prey Size			10% Increase in Median Prey Size			20% Decrease in Median Prey Size			20% Increase in Median Prey Size		
Year	**Age 0**	**Age 1**	**Total**	**Age 0**	**Age 1**	**Total**	**Age 0**	**Age 1**	**Total**	**Age 0**	**Age 1**	**Total**
1982	3.989	1.955	2.934	-13.352	-7.949	-9.226	-4.663	0.915	-1.539	-21.181	-13.486	-15.136
1983	3.504	1.178	2.831	-10.646	-7.093	-8.320	-3.576	0.756	-2.082	-16.957	-11.880	-13.469
1984	2.895	0.985	2.436	-10.696	-5.649	-8.825	-1.997	1.569	-1.024	-17.756	-9.382	-14.717
1985	6.188	0.719	4.340	-14.567	-5.939	-11.012	-4.879	2.162	-2.464	-27.462	-9.814	-20.458
1986	9.196	2.046	6.179	-15.529	-5.824	-10.520	-6.550	2.253	-2.854	-30.617	-10.253	-20.543
1987	11.338	2.451	7.622	-16.989	-5.134	-11.149	-6.693	1.485	-3.320	-31.819	-10.033	-21.149
1988	6.758	2.628	5.457	-9.507	-5.728	-7.771	-0.410	1.262	0.053	-15.002	-10.816	-12.655
1989	4.517	1.773	2.902	-7.991	-5.244	-5.664	2.984	1.997	2.286	-12.740	-8.889	-9.375
1990	4.551	2.002	3.414	-7.171	-5.570	-5.577	2.326	3.003	2.225	-13.382	-9.454	-10.325
1991	4.496	1.587	3.318	-6.943	-4.778	-5.581	2.567	2.336	2.295	-11.743	-7.921	-9.482
1992	5.349	1.497	3.753	-9.036	-5.065	-6.903	2.365	2.489	2.223	-15.165	-8.028	-11.554
1993	6.174	1.807	4.040	-11.610	-6.828	-8.520	1.649	3.417	2.048	-20.563	-10.357	-14.657
1994	10.796	2.149	7.825	-13.192	-8.279	-10.630	-0.985	3.285	0.086	-26.139	-13.368	-20.552
1995	9.855	2.481	6.362	-6.628	-8.949	-6.561	3.296	2.419	2.697	-13.027	-15.477	-12.369
1996	7.394	3.143	5.421	-7.689	-8.951	-6.855	3.845	1.755	2.938	-14.039	-16.108	-12.709
1997	8.186	3.730	6.089	-10.284	-9.205	-8.621	5.850	1.111	4.058	-17.499	-16.125	-15.101
1998	8.627	3.889	6.821	-10.230	-11.366	-9.291	7.327	2.040	5.568	-16.334	-19.099	-15.264
1999	8.426	3.740	6.394	-9.471	-11.178	-8.952	7.138	3.114	5.404	-15.646	-18.804	-15.067
2000	8.290	3.757	5.814	-10.533	-10.597	-8.960	5.483	3.805	4.275	-18.290	-17.808	-15.681
2001	10.419	3.953	8.511	-13.154	-11.173	-11.446	4.204	3.839	3.801	-23.222	-18.564	-20.254
2002	8.806	2.786	7.204	-12.641	-9.947	-11.339	1.650	3.343	1.926	-20.814	-16.013	-18.731

Table D1.23. Percent change in menhaden spawning stock biomass from MSVPA-X base run configuration and for four scenarios in which the median size of prey selected for each predator was shifted by ± 10% and ± 20%.

	Percent Change in Spawning Stock Biomass from MSVPA-X Base Run Configuration			
Year	**10% Decrease in Median Prey Size**	**10% Increase in Median Prey Size**	**20% Median Decrease in Median Prey Size**	**20% Median Increase in Median Prey Size**
1982	2.61	0.94	1.56	0.32
1983	2.27	0.58	1.43	-0.06
1984	1.83	0.96	1.07	0.62
1985	1.89	0.75	1.20	0.31
1986	2.54	0.95	1.66	0.31
1987	2.27	0.70	1.55	0.05
1988	1.44	0.40	0.96	-0.18
1989	1.50	0.22	1.02	-0.58
1990	1.39	-0.13	1.00	-1.24
1991	1.06	-0.13	0.77	-1.14
1992	0.90	-0.41	0.68	-2.00
1993	0.97	-0.92	0.83	-2.72
1994	0.70	-1.03	0.63	-3.31
1995	0.71	-0.94	0.64	-3.00
1996	1.03	-1.23	0.88	-4.99
1997	0.73	-0.69	0.57	-4.74
1998	0.56	-0.41	0.43	-5.00
1999	0.66	-0.66	0.53	-4.60
2000	0.94	-0.86	0.77	-4.50
2001	0.96	-0.70	0.75	-3.45
2002	1.12	-0.60	0.84	-3.63

Table D1.24. Predation mortality (M2) values for age-0 and age-1 menhaden for the base run MSVPA-X configuration and for four scenarios in which the median size of prey selected for each predator was shifted by ± 10% and ± 20%.

	Age-0					Age-1				
Year	Base Run	10% Decrease in Median Prey Size	10% Increase in Median Prey Size	20% Median Decrease in Median Prey Size	20% Median Increase in Median Prey Size	Base Run	10% Decrease in Median Prey Size	10% Increase in Median Prey Size	20% Median Decrease in Median Prey Size	20% Median Increase in Median Prey Size
1982	0.672	0.644	0.735	0.731	0.764	0.328	0.322	0.406	0.33	0.451
1983	0.607	0.578	0.664	0.662	0.691	0.276	0.279	0.35	0.28	0.392
1984	0.508	0.486	0.564	0.554	0.598	0.252	0.254	0.314	0.246	0.347
1985	0.542	0.498	0.632	0.618	0.705	0.241	0.253	0.307	0.233	0.34
1986	0.62	0.55	0.723	0.706	0.806	0.235	0.234	0.292	0.227	0.326
1987	0.637	0.541	0.742	0.725	0.819	0.193	0.181	0.245	0.188	0.285
1988	0.538	0.487	0.584	0.567	0.603	0.18	0.165	0.231	0.178	0.27
1989	0.396	0.369	0.423	0.397	0.433	0.167	0.158	0.216	0.155	0.244
1990	0.377	0.346	0.411	0.378	0.434	0.166	0.158	0.214	0.148	0.239
1991	0.404	0.369	0.432	0.401	0.453	0.162	0.153	0.208	0.143	0.232
1992	0.394	0.355	0.419	0.404	0.447	0.13	0.122	0.17	0.111	0.188
1993	0.534	0.47	0.564	0.55	0.601	0.148	0.141	0.197	0.124	0.218
1994	0.678	0.591	0.721	0.714	0.775	0.158	0.147	0.219	0.135	0.245
1995	0.854	0.783	0.839	0.843	0.837	0.188	0.172	0.262	0.172	0.304
1996	0.765	0.73	0.754	0.743	0.756	0.185	0.163	0.257	0.178	0.302
1997	0.752	0.709	0.746	0.721	0.742	0.191	0.161	0.267	0.189	0.314
1998	0.794	0.744	0.79	0.752	0.783	0.217	0.188	0.311	0.207	0.36
1999	0.745	0.692	0.743	0.71	0.741	0.214	0.19	0.307	0.195	0.354
2000	0.697	0.649	0.698	0.682	0.707	0.206	0.185	0.288	0.183	0.326
2001	0.835	0.754	0.87	0.856	0.907	0.228	0.205	0.316	0.204	0.356
2002	1.05	0.939	1.096	1.101	1.135	0.261	0.233	0.346	0.239	0.39

Table D1.25. Average recruited fishing mortality estimates for age-2+ menhaden from the base run configuration of the MSVPA-X and four scenarios in which the median size of prey selected for each predator was shifted by ± 10% and ± 20%.

	Average Recruited F for Age 2+ Menhaden				
Year	**BASE**	**(-)10% Median**	**(+)10% Median**	**(-)20% Median**	**(+)20% Median**
1982	1.594	1.634	1.597	1.619	1.582
1983	1.442	1.47	1.441	1.461	1.429
1984	1.486	1.519	1.49	1.508	1.479
1985	1.534	1.568	1.538	1.559	1.524
1986	1.18	1.209	1.184	1.201	1.173
1987	1.053	1.073	1.055	1.068	1.046
1988	1.268	1.29	1.268	1.284	1.256
1989	1.219	1.238	1.213	1.234	1.198
1990	1.156	1.17	1.147	1.168	1.133
1991	1.363	1.379	1.353	1.377	1.335
1992	1.014	1.024	1.004	1.023	0.988
1993	1.036	1.046	1.021	1.046	1.004
1994	0.969	0.978	0.955	0.978	0.937
1995	1.237	1.249	1.221	1.248	1.187
1996	0.75	0.758	0.739	0.758	0.717
1997	0.915	0.923	0.905	0.922	0.878
1998	1.339	1.351	1.323	1.348	1.288
1999	1.182	1.193	1.166	1.191	1.135
2000	0.883	0.893	0.874	0.891	0.85
2001	1.243	1.257	1.233	1.254	1.202
2002	1.175	1.186	1.164	1.184	1.134

Table D1.26. Predation mortality (M2) estimates for age-0 through age-6 menhaden for the base run configuration for the MSVPA-X for two scenarios in which the range of prey size selectivity for each predator was increased or decrease by ± 10%.

M2	Age-0			Age-1			Age-2			Age-3			Age-4		
Year	**Base**	**-10%**	**+10%**	**Base**	**-10%**	**+10%**	**Base**	**- 10%**	**+10%**	**Base**	**- 10%**	**+10%**	**Base**	**- 10%**	**+10%**
1982	0.672	0.994	0.628	0.328	0.204	0.319	0.207	0.018	0.202	0.137	0.002	0.137	0.091	0	0.095
1983	0.607	0.895	0.567	0.276	0.175	0.271	0.171	0.016	0.168	0.113	0.002	0.114	0.075	0	0.079
1984	0.508	0.734	0.481	0.252	0.148	0.246	0.168	0.015	0.164	0.113	0.002	0.114	0.075	0	0.079
1985	0.542	0.763	0.518	0.241	0.143	0.236	0.164	0.015	0.16	0.11	0.002	0.111	0.073	0	0.077
1986	0.62	0.803	0.589	0.235	0.113	0.232	0.158	0.012	0.154	0.108	0.001	0.108	0.073	0	0.077
1987	0.637	0.748	0.598	0.193	0.069	0.195	0.119	0.007	0.117	0.079	0.001	0.08	0.054	0	0.057
1988	0.538	0.68	0.499	0.18	0.068	0.183	0.099	0.006	0.1	0.064	0.001	0.066	0.043	0	0.047
1989	0.396	0.543	0.362	0.167	0.073	0.166	0.093	0.007	0.095	0.059	0.001	0.062	0.04	0	0.043
1990	0.377	0.488	0.351	0.166	0.082	0.164	0.093	0.01	0.096	0.058	0.002	0.062	0.038	0	0.043
1991	0.404	0.527	0.373	0.162	0.076	0.161	0.087	0.01	0.091	0.054	0.002	0.059	0.037	0.001	0.042
1992	0.394	0.517	0.369	0.13	0.067	0.13	0.062	0.008	0.066	0.036	0.001	0.041	0.025	0	0.029
1993	0.534	0.681	0.503	0.148	0.081	0.149	0.068	0.011	0.074	0.039	0.002	0.045	0.027	0.001	0.032
1994	0.678	0.852	0.631	0.158	0.091	0.162	0.068	0.013	0.075	0.038	0.002	0.044	0.025	0.001	0.031
1995	0.854	1.098	0.799	0.188	0.104	0.198	0.072	0.014	0.082	0.039	0.002	0.047	0.026	0.001	0.033
1996	0.765	0.99	0.711	0.185	0.094	0.2	0.063	0.012	0.073	0.032	0.002	0.039	0.02	0	0.026
1997	0.752	1.016	0.684	0.191	0.087	0.205	0.06	0.009	0.071	0.028	0.001	0.035	0.017	0	0.022
1998	0.794	1.07	0.715	0.217	0.103	0.229	0.07	0.012	0.083	0.033	0.002	0.041	0.02	0	0.026
1999	0.745	1.015	0.67	0.214	0.103	0.224	0.073	0.011	0.086	0.035	0.001	0.044	0.021	0	0.027
2000	0.697	0.924	0.636	0.206	0.098	0.214	0.077	0.01	0.089	0.038	0.001	0.047	0.023	0	0.03
2001	0.835	1.098	0.761	0.228	0.105	0.234	0.09	0.011	0.101	0.046	0.001	0.055	0.028	0	0.035
2002	1.05	1.334	0.961	0.261	0.115	0.267	0.109	0.013	0.119	0.057	0.002	0.067	0.035	0	0.044

Table D1.26 (Cont'd). Predation mortality (M2) estimates for age-0 through age-6 menhaden for the base run configuration for the MSVPA-X for two scenarios in which the range of prey size selectivity for each predator was increased or decrease by ± 10%.

M2	**Age-5**			**Age-6**		
Year	**Base**	**-10%**	**+10%**	**Base**	**-10%**	**+10%**
1982	0.062	0	0.068	0.043	0	0.05
1983	0.051	0	0.057	0.035	0	0.041
1984	0.051	0	0.057	0.035	0	0.041
1985	0.05	0	0.055	0.034	0	0.04
1986	0.051	0	0.057	0.035	0	0.041
1987	0.039	0	0.043	0.029	0	0.033
1988	0.031	0	0.035	0.023	0	0.027
1989	0.028	0	0.032	0.021	0	0.025
1990	0.027	0	0.031	0.02	0	0.024
1991	0.028	0	0.033	0.02	0	0.025
1992	0.02	0	0.024	0.016	0	0.02
1993	0.021	0	0.026	0.017	0	0.022
1994	0.02	0	0.025	0.016	0	0.021
1995	0.02	0	0.026	0.016	0	0.021
1996	0.015	0	0.019	0.012	0	0.016
1997	0.012	0	0.016	0.009	0	0.012
1998	0.014	0	0.019	0.01	0	0.014
1999	0.015	0	0.02	0.011	0	0.015
2000	0.016	0	0.022	0.012	0	0.017
2001	0.02	0	0.026	0.015	0	0.02
2002	0.025	0	0.033	0.019	0	0.026

Table D1.27. Total biomass (000 MT) consumed by bluefish for the base run configuration for the MSVPA-X for two scenarios in which the range of prey size selectivity for each predator was increased or decrease by ± 10%.

Year	Base Run	Decreased Range	Increased Range
1982	558.72	724.41	560.67
1983	428.04	673.61	434.35
1984	487.23	671.36	491.3
1985	452.55	691.32	457.97
1986	469.84	603.41	469.9
1987	359.98	407.24	360.39
1988	315.98	367.03	315.59
1989	283.69	305.33	282.91
1990	263.72	295.18	264.08
1991	261.59	253.08	261.45
1992	197.03	187.96	197.13
1993	177.53	177.99	178.47
1994	154.36	162.96	154.6
1995	184.95	157.04	185.39
1996	182.73	141.69	182.92
1997	178.99	138.39	179.08
1998	186.09	148.96	185.78
1999	244.06	203.46	243.54
2000	272.14	227.37	272.01
2001	353.88	262.26	352.76
2002	409.46	359.72	409.18

APPENDIX D1 FIGURES

Figure D1.1. Plot of menhaden fishing mortality over time to investigate retrospective bias in terminal year F estimation in MSVPA-X.

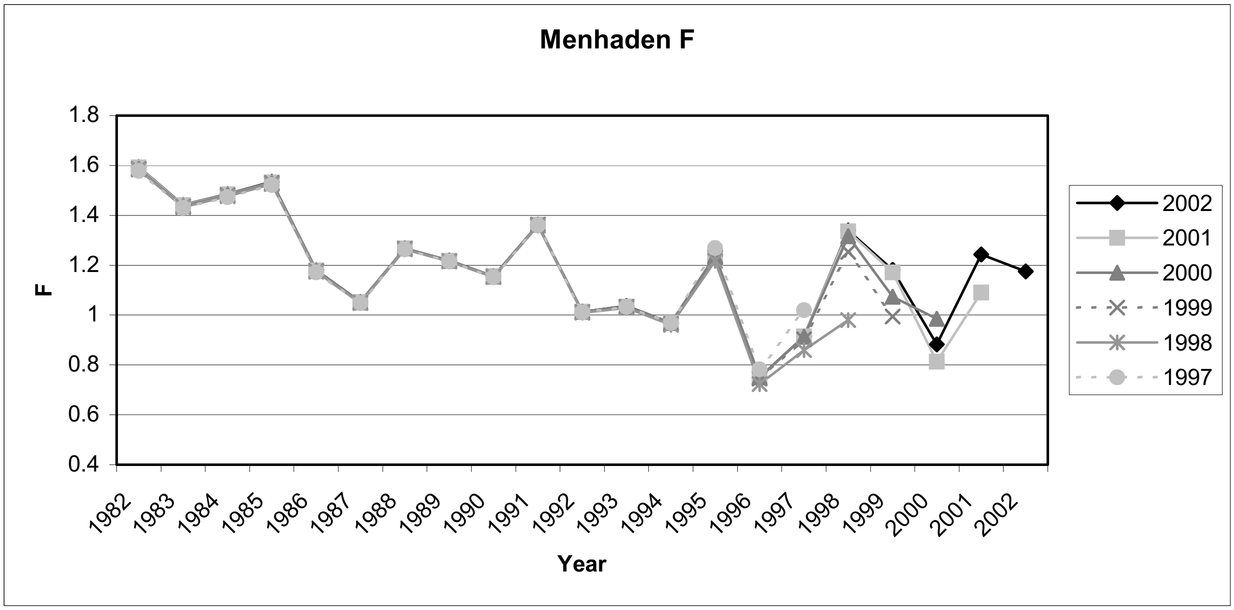


Figure D1.2. Plot of menhaden spawning stock biomass (SSB in 000 mt) over time to investigate retrospective bias in terminal year SSB estimation in MSVPA-X.

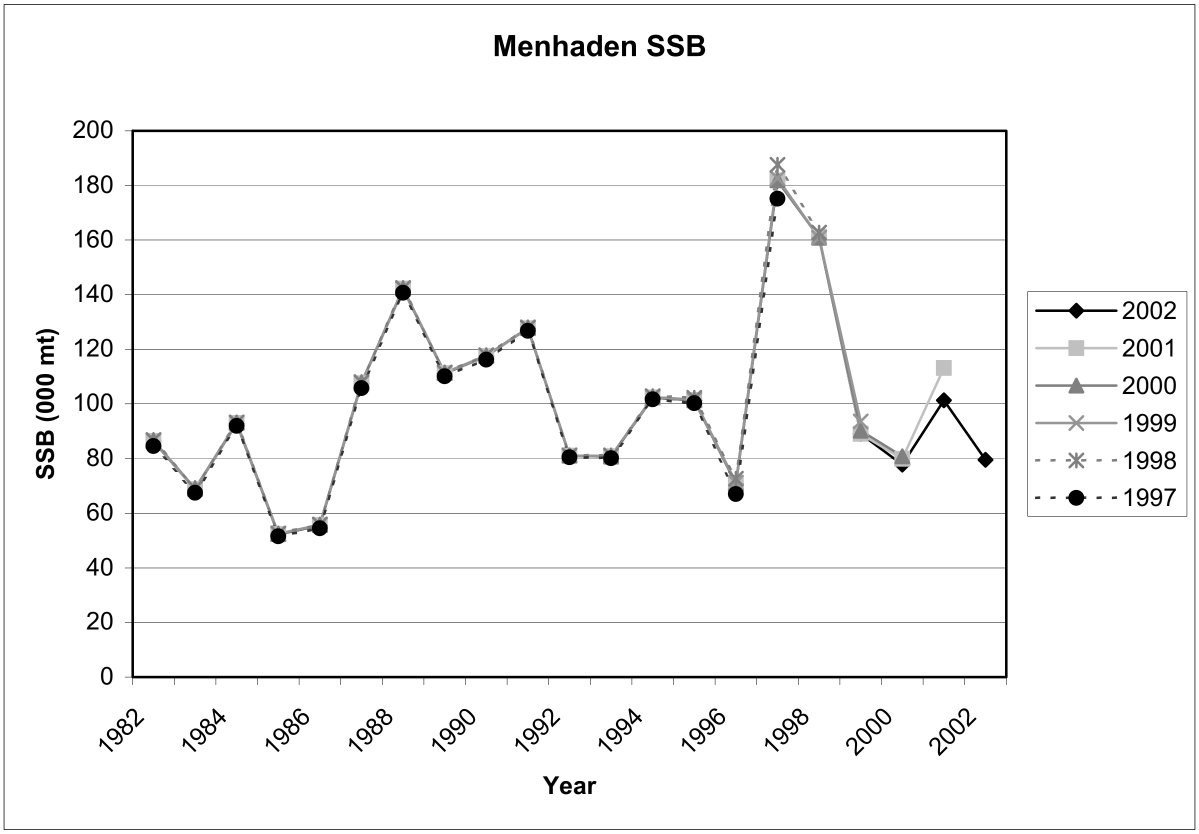


Figure D1.3. Plot of striped bass fishing mortality (F) over time to investigate retrospective bias in terminal year F estimation in MSVPA-X.

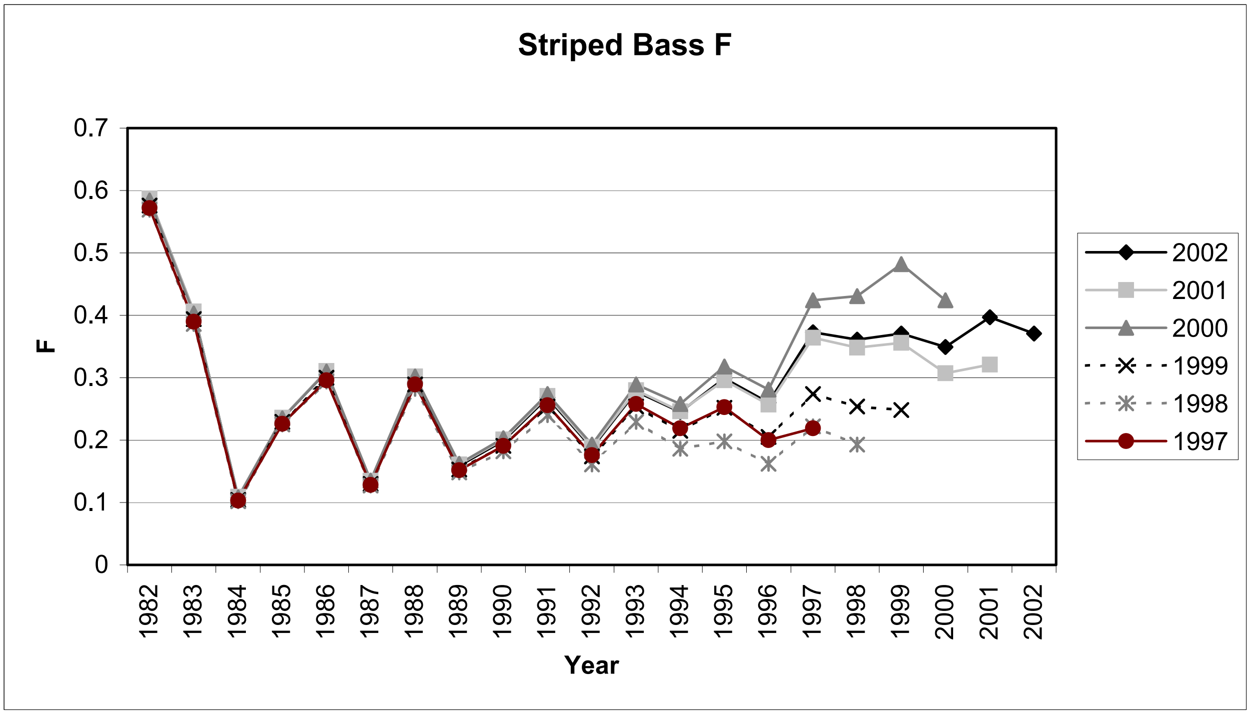


Figure D1.4. Plot of striped bass spawning stock biomass (SSB in 000 mt) over time to investigate retrospective bias in terminal year SSB estimation in MSVPA-X.

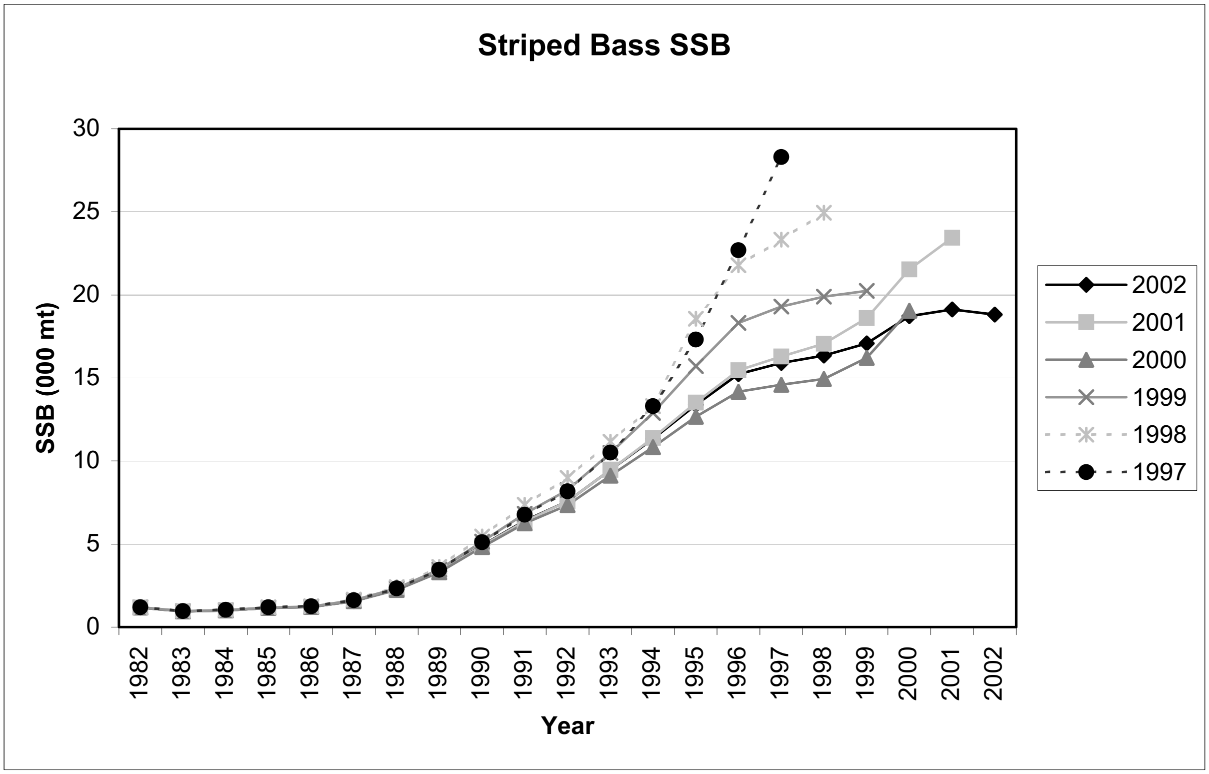


Figure D1.5. Plot of weakfish fishing mortality (F) over time to investigate retrospective bias in terminal year F estimation in MSVPA-X.

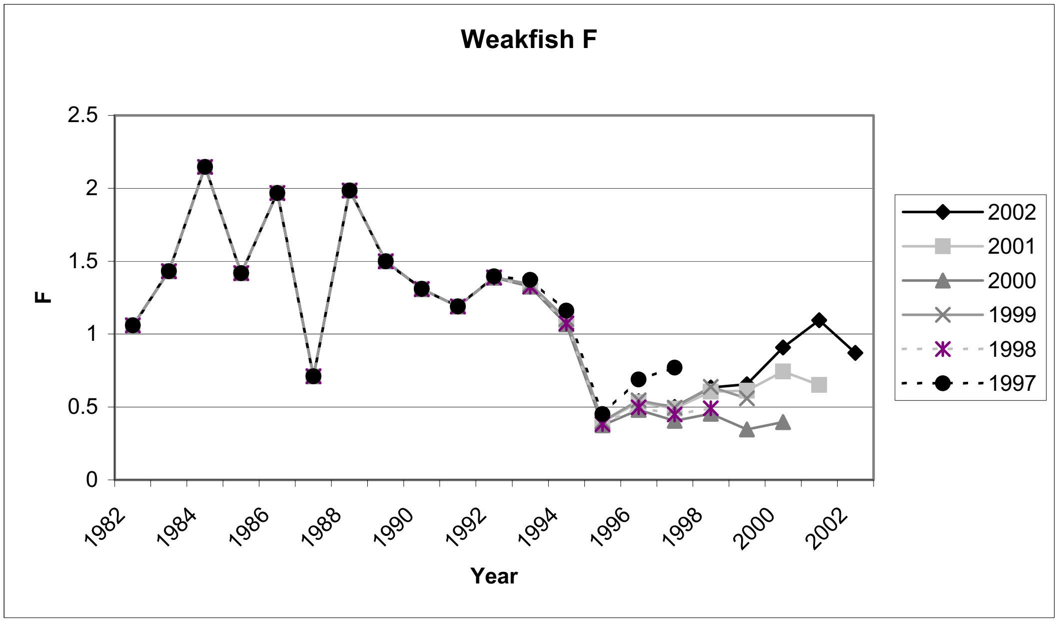


Figure 1.6. Plot of weakfish spawning stock biomass (SSB in 000 mt) over time to investigate retrospective bias in terminal year SSB estimation in MSVPA-X.

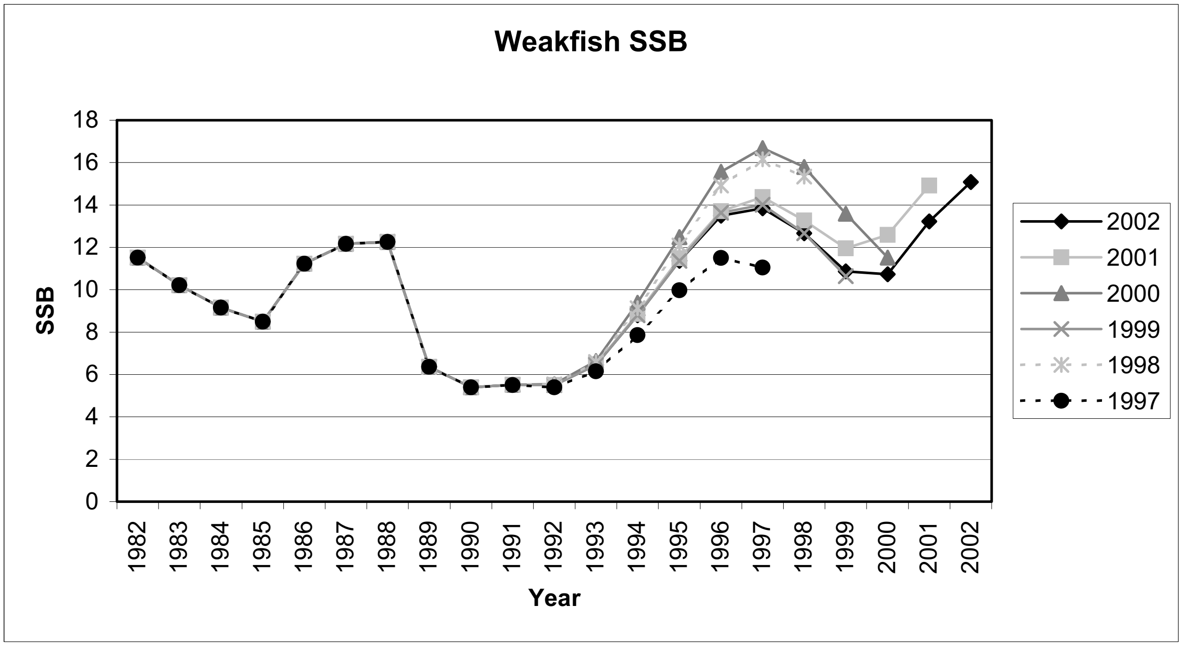


Figure D1.7. Terminal year predation mortality (M2) estimates for age-0 menhaden over time to investigate terminal year bias in M2 estimation in the MSVPA-X model.

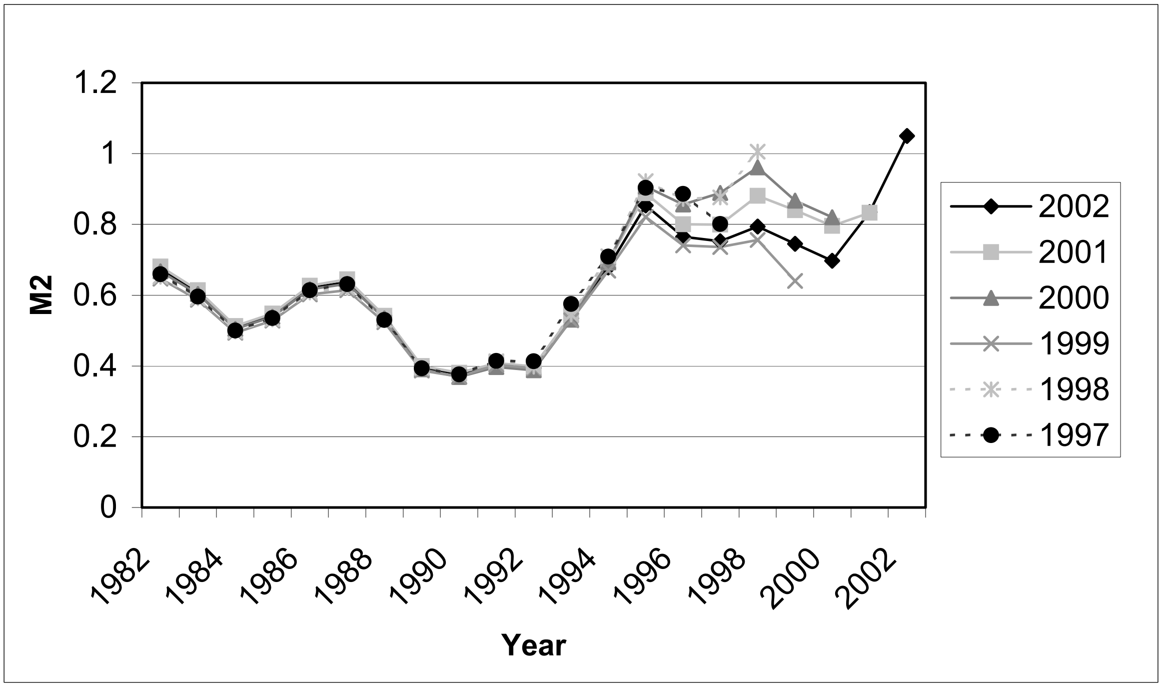


Figure D1.8. Predation mortality estimates for age-0 menhaden for the base run and 3 scenarios where one "other prey" group was removed. Runs were made with the removal of each of the following groups: bay anchovy, clupeids, and medium forage fish.

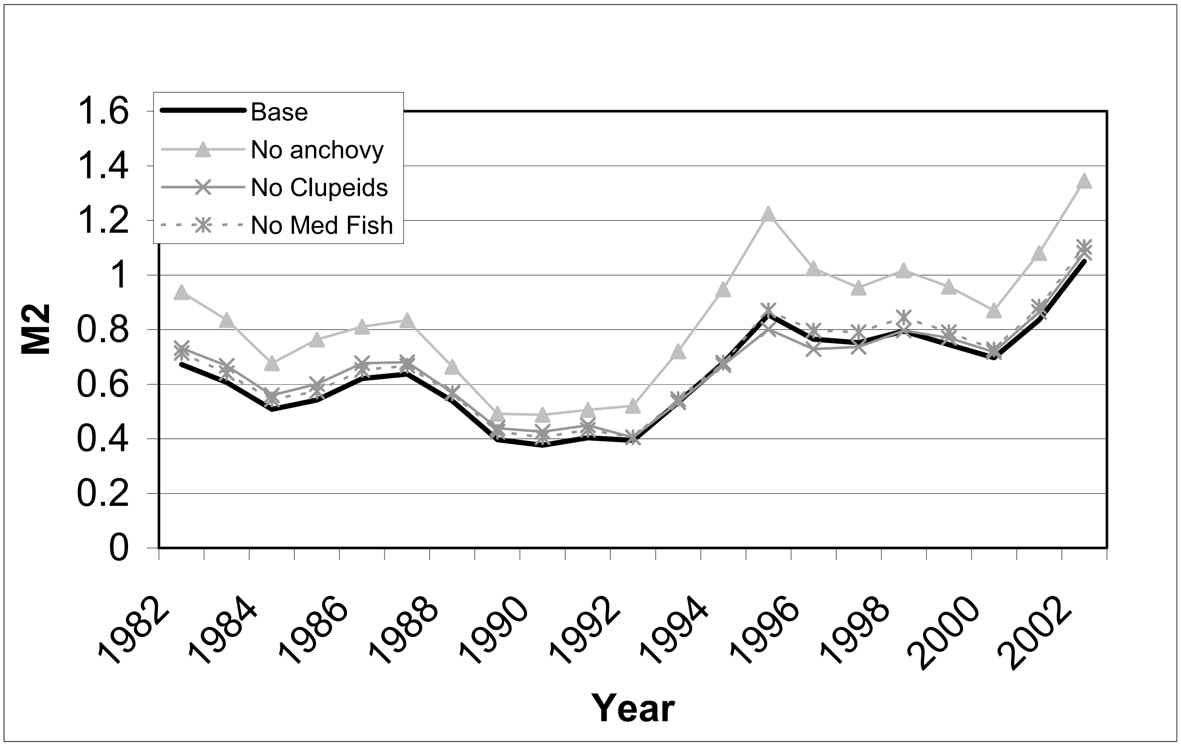


Figure D1.9. Spawning stock biomass (SSB in 000 mt) estimates for menhaden for the base run and 3 scenarios where one “other prey” group was removed. Runs were made with the removal of each of the following groups: bay anchovy, clupeids, and medium forage fish.

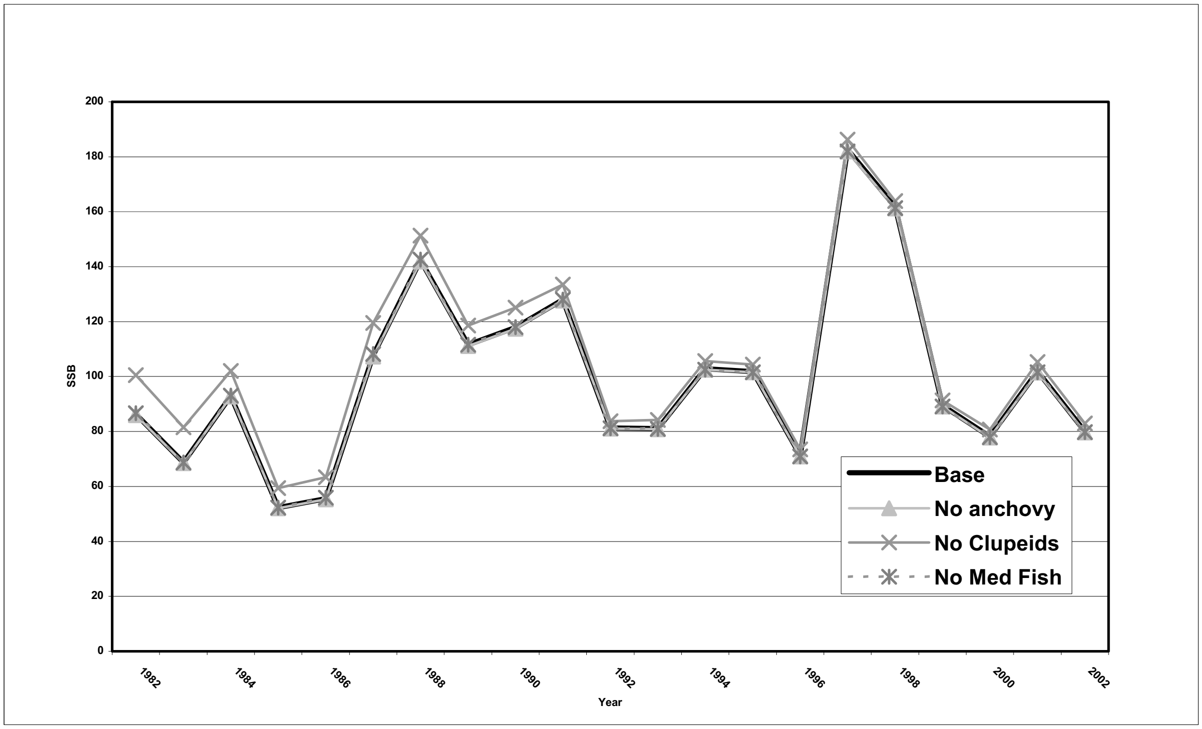


Figure D1.10. The average diet composition across years modeled (1982-2002) for striped bass by age in the base run MSVPA-X model.

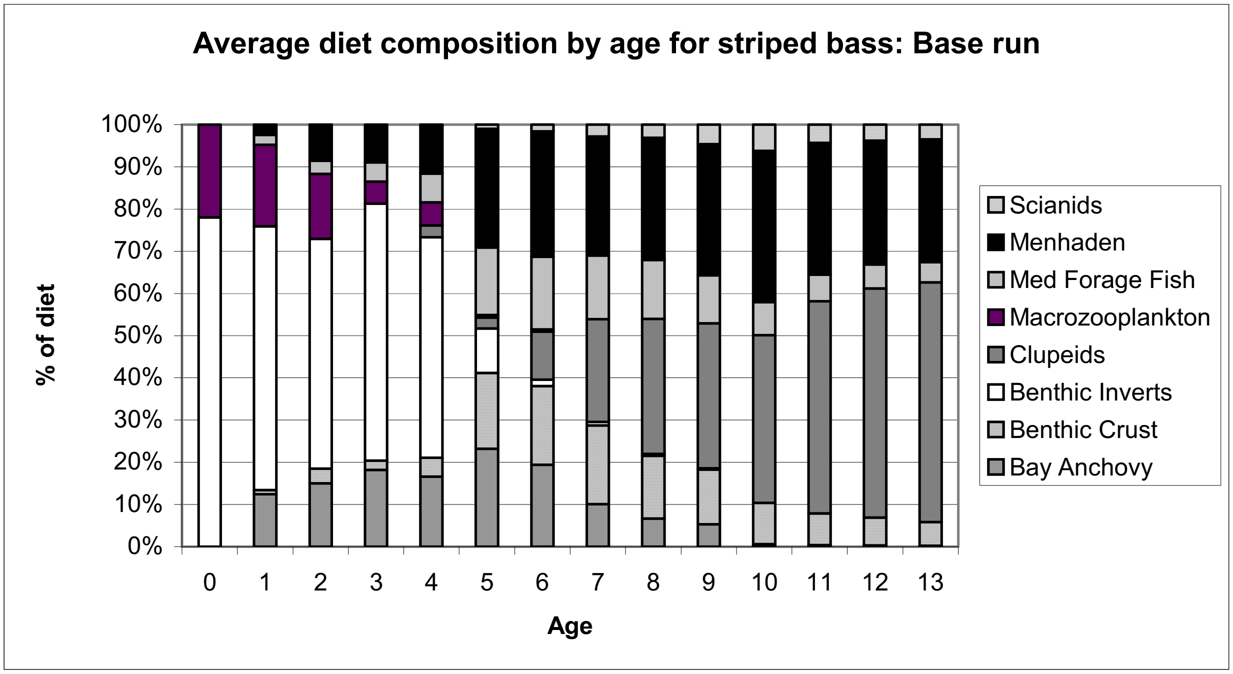


Figure 1.11. The average diet composition across years modeled (1982-2002) for striped bass by age in the 'no anchovy run' in the MSVPA-X model.

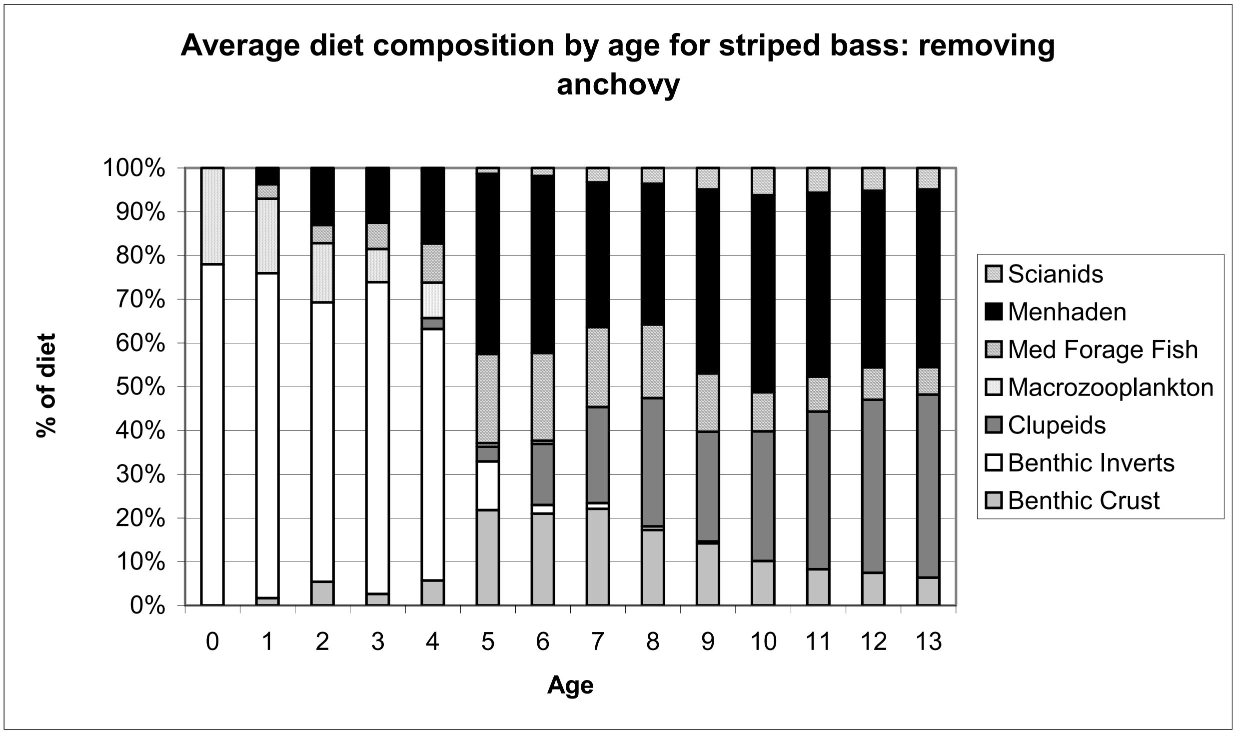


Figure D1.12. The average diet composition across years modeled (1982-2002) for striped bass by age in the 'no clupeids run' in the MSVPA-X model.

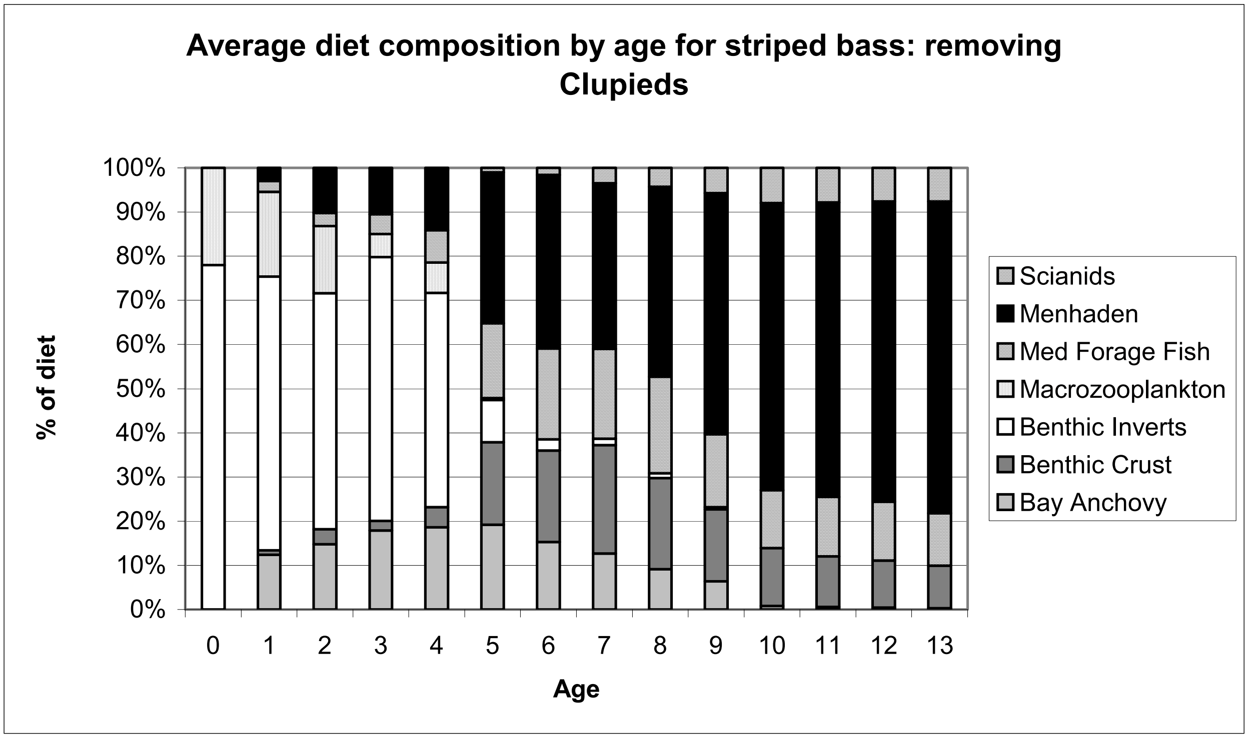


Figure D1.13. The average diet composition across years modeled (1982-2002) for striped bass by age in the 'no medium forage fish run' in the MSVPA-X model.

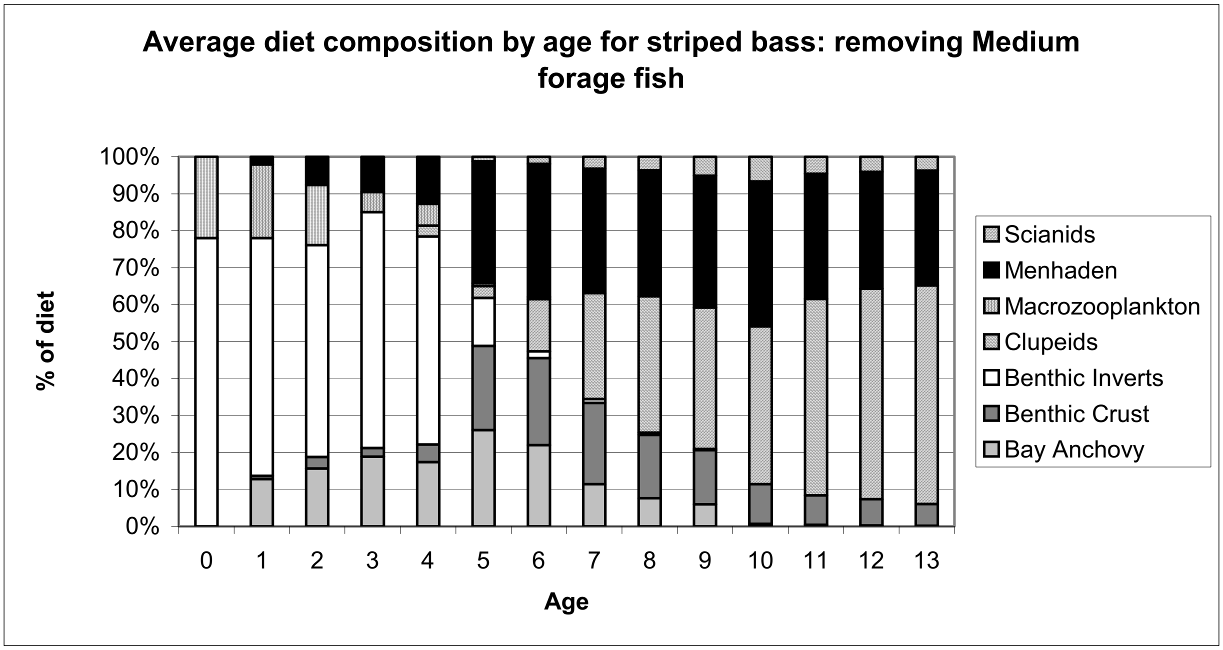


Figure D1.14. Predation mortality (M2) by predator and year for age-0 menhaden in the base run of the MSVPA-X model.

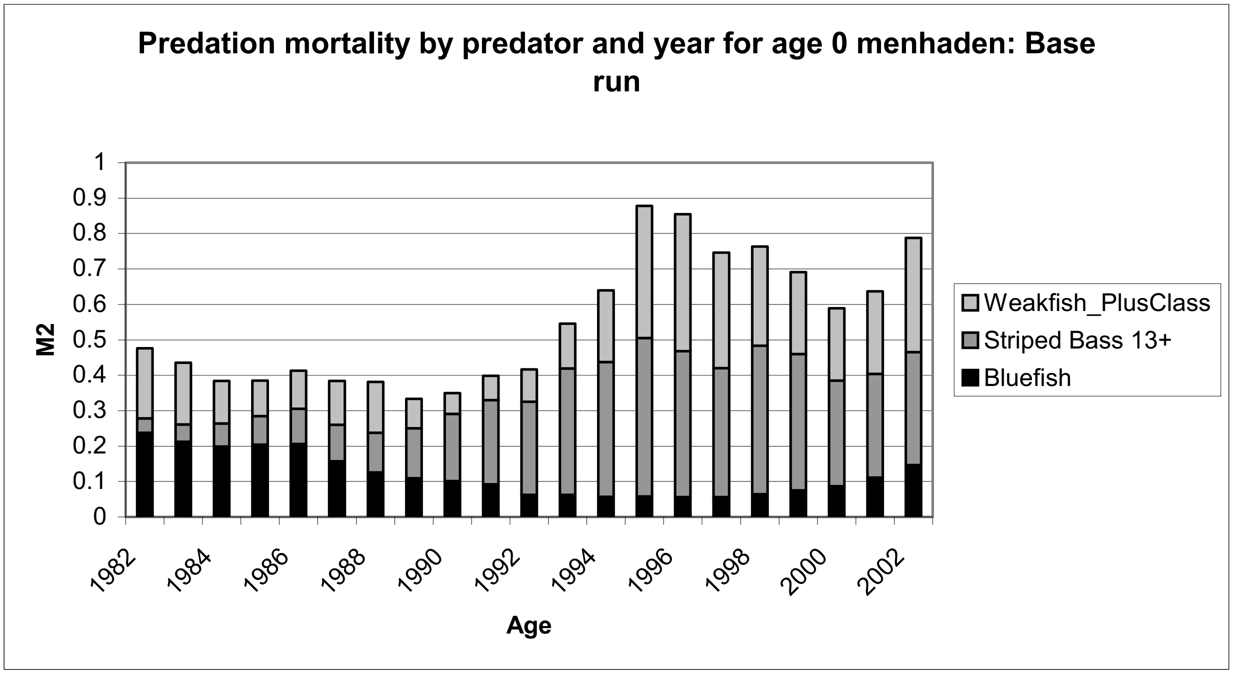


Figure D1.15. Predation mortality (M2) by predator and year for age-0 menhaden in the 'no clupeid run' of the MSVPA-X model.

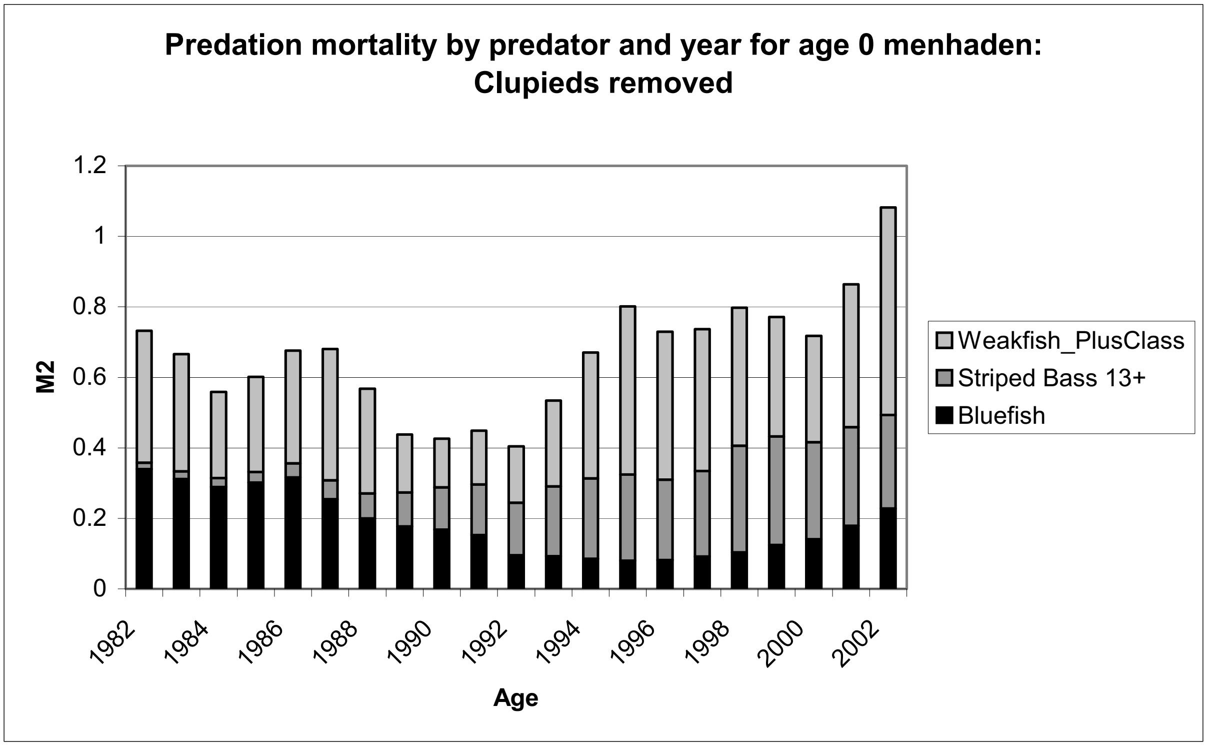


Figure D1.16. Predation mortality (M2) by predator and year for age-0 menhaden in the ‘no anchovy run’ of the MSVPA-X model.

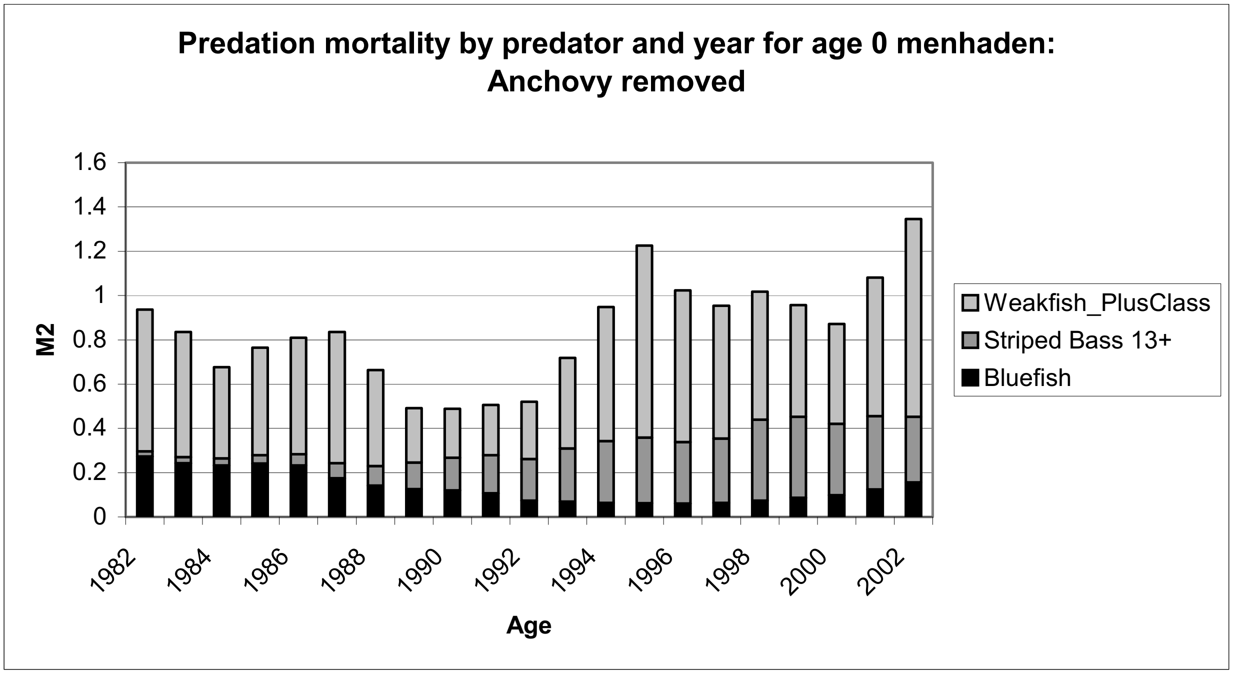


Figure D1.17. Predation mortality (M2) by predator and year for age-0 menhaden in the ‘no medium forage fish run’ of the MSVPA-X model.

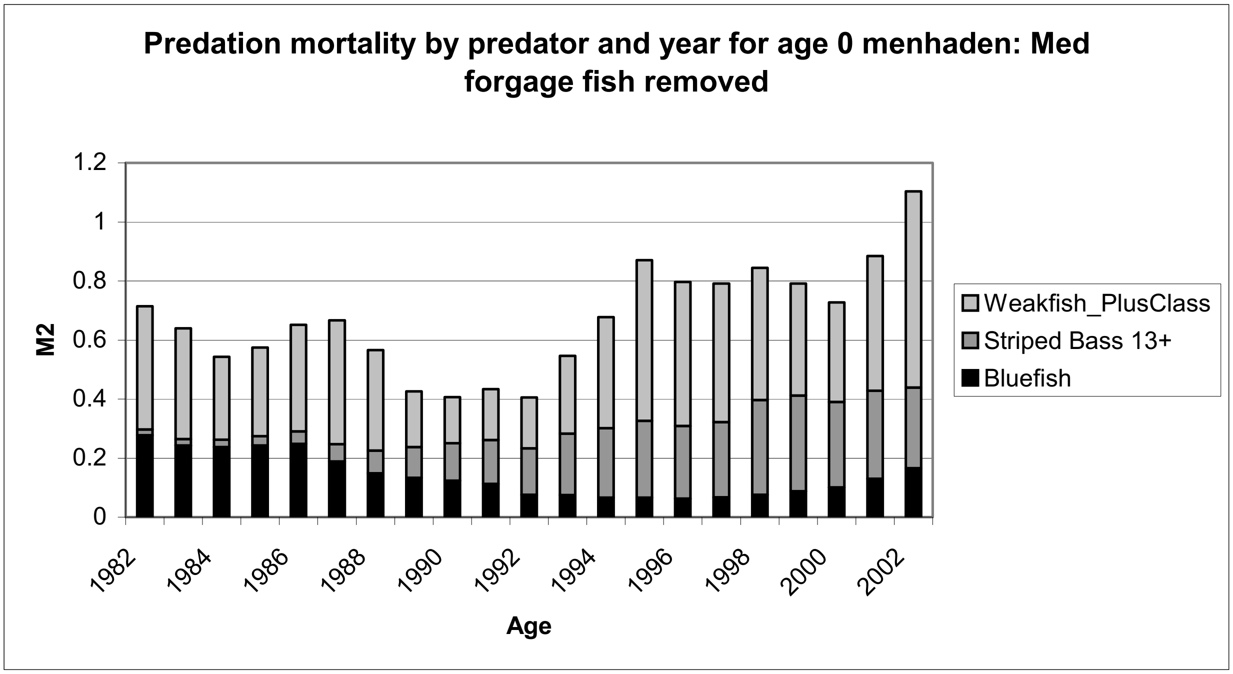


Figure D1.18. Total abundance of menhaden population at different values of M1.

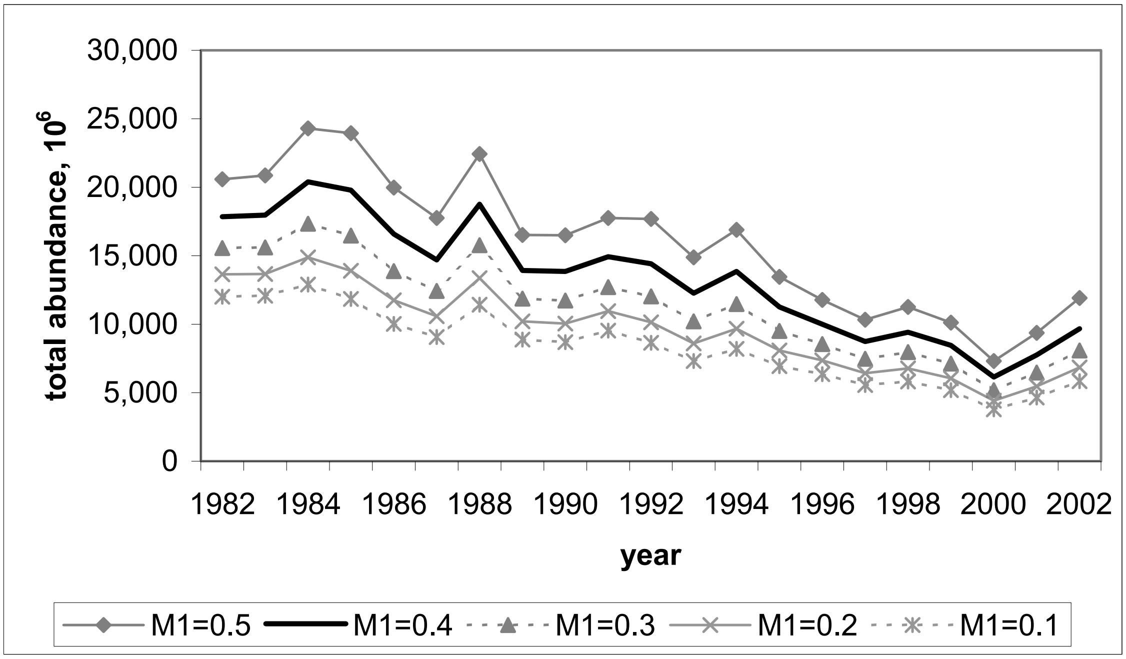


Figure D1.19. Relative changes in menhaden abundance in response to changes in M1.

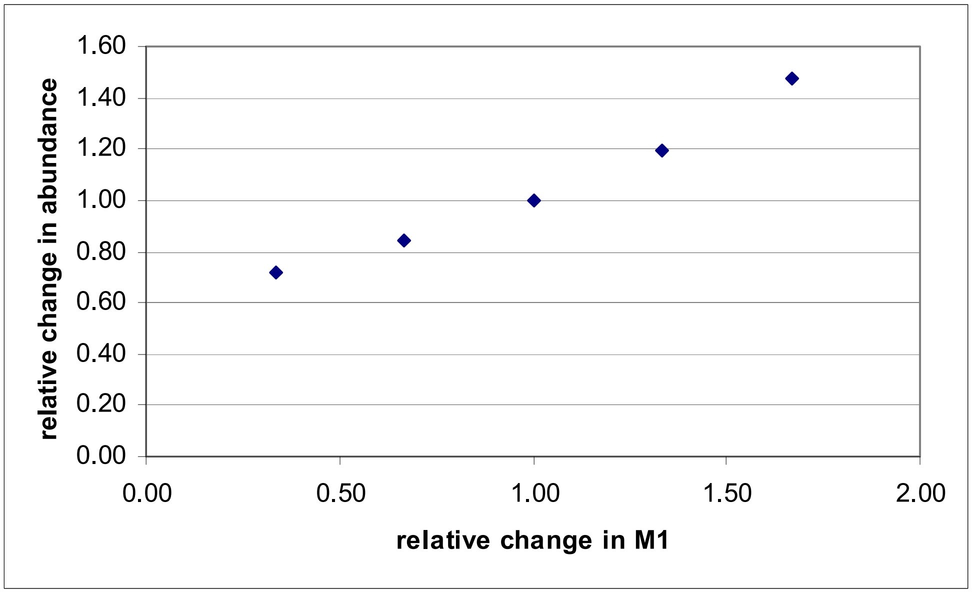


Figure D1.20. Total abundance of age-0 menhaden at different values of M1.

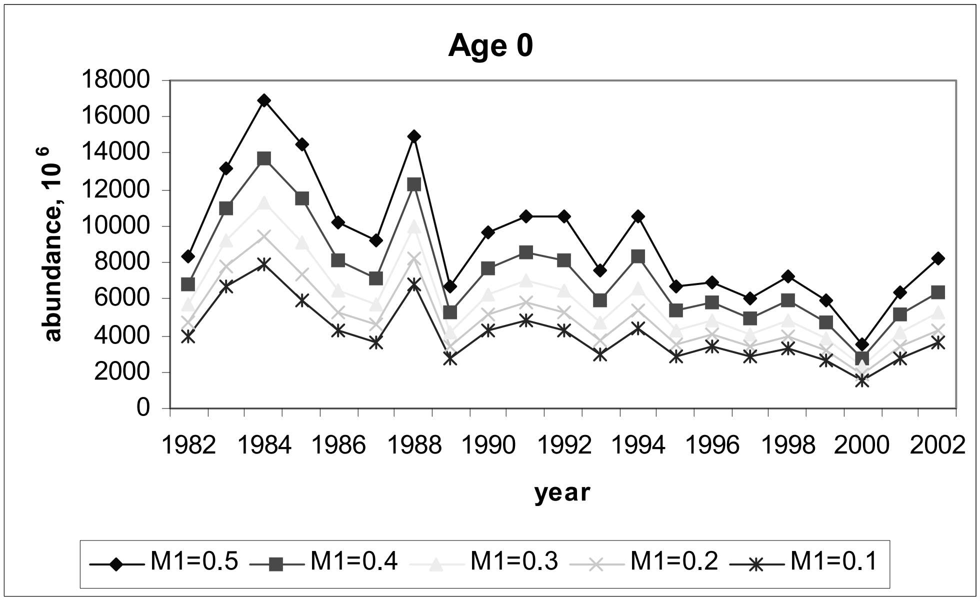


Figure D1.21. Total abundance of age-1 menhaden at different values of M1.

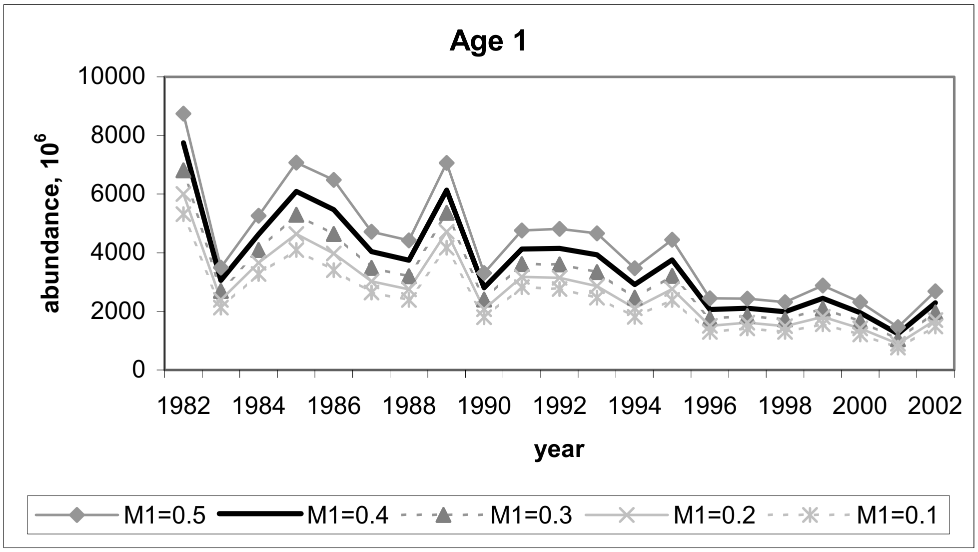


Figure D1.22. Total biomass of menhaden population at different values of M1.

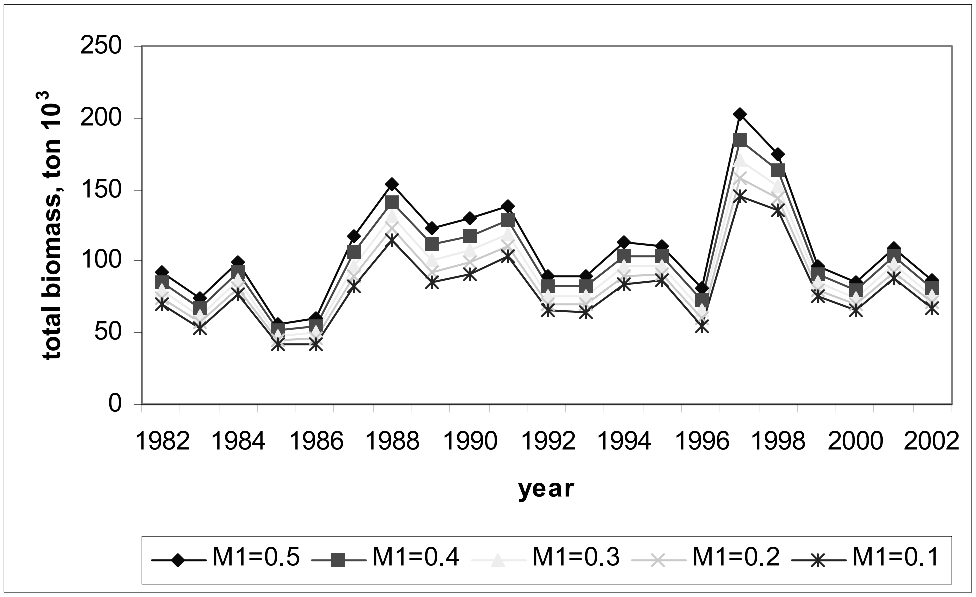


Figure D1.23. Spawning stock biomass of menhaden population at different values of M1.

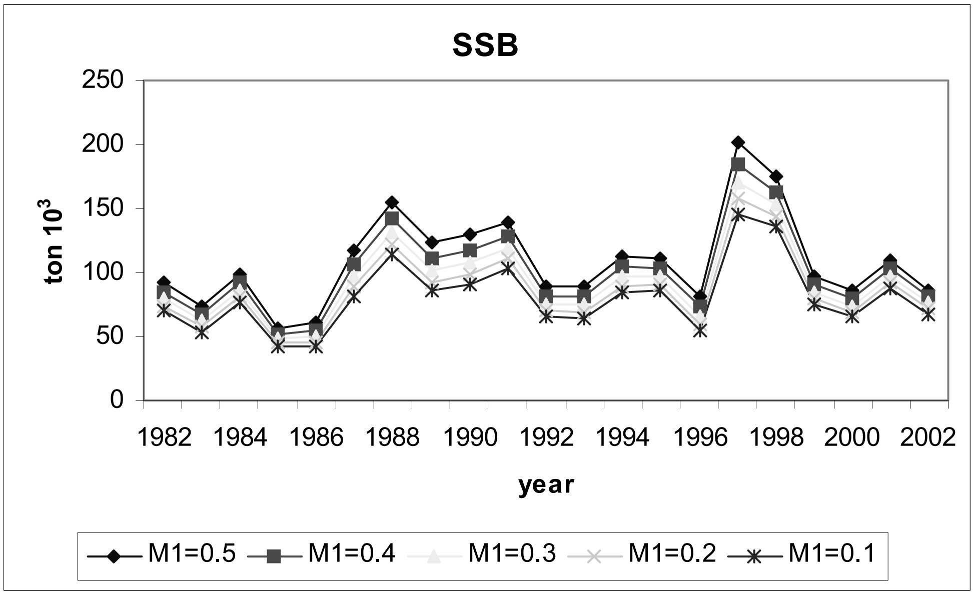


Figure D1.24. Average fishing mortality for fully recruited age groups and different M1 values.

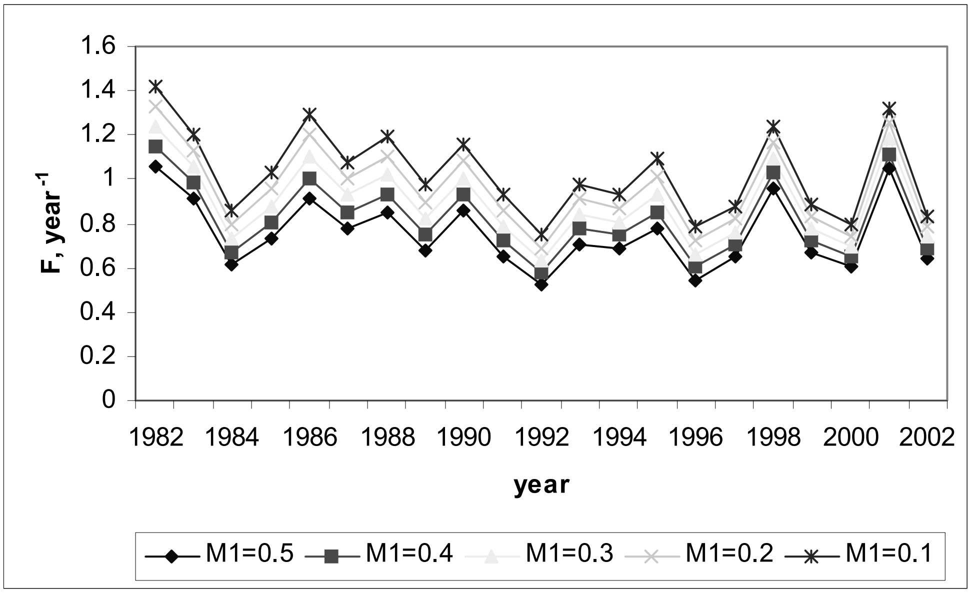


Figure D1.25. Predation mortality (M2) for fully age-0 menhaden and different M1 values.

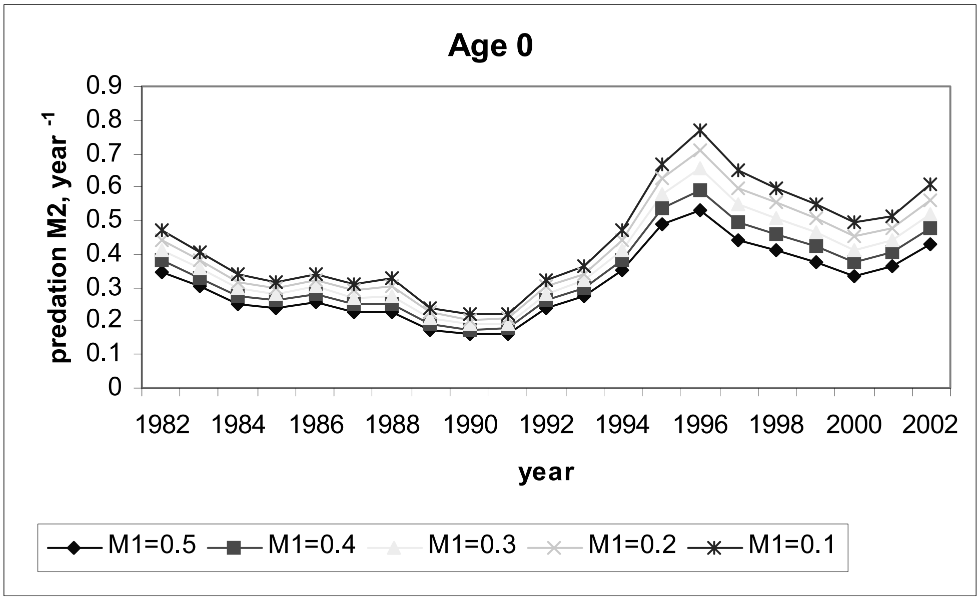


Figure D1.26. Predation mortality (M2) for fully age-1 menhaden and different M1 values.

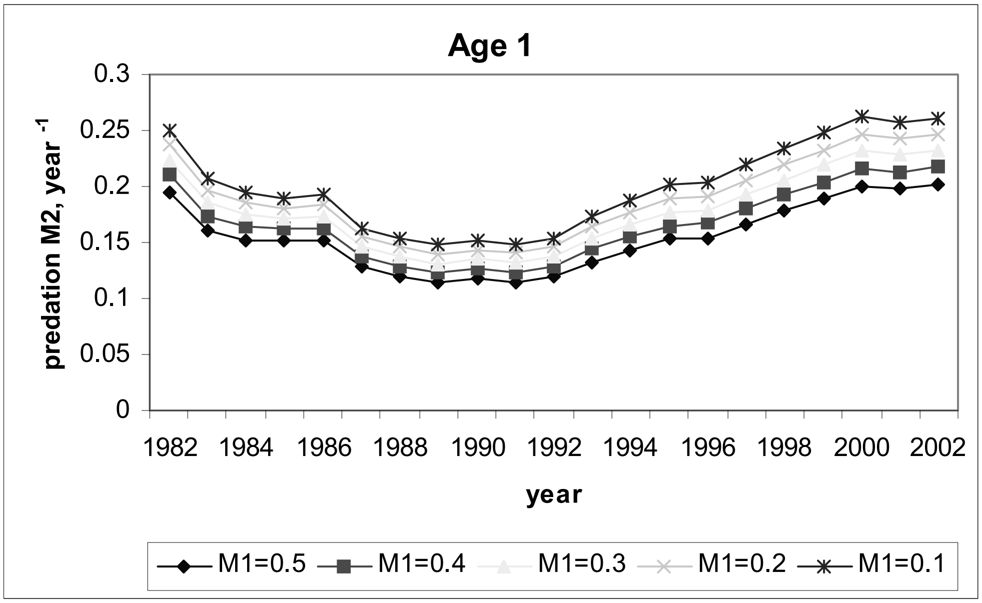
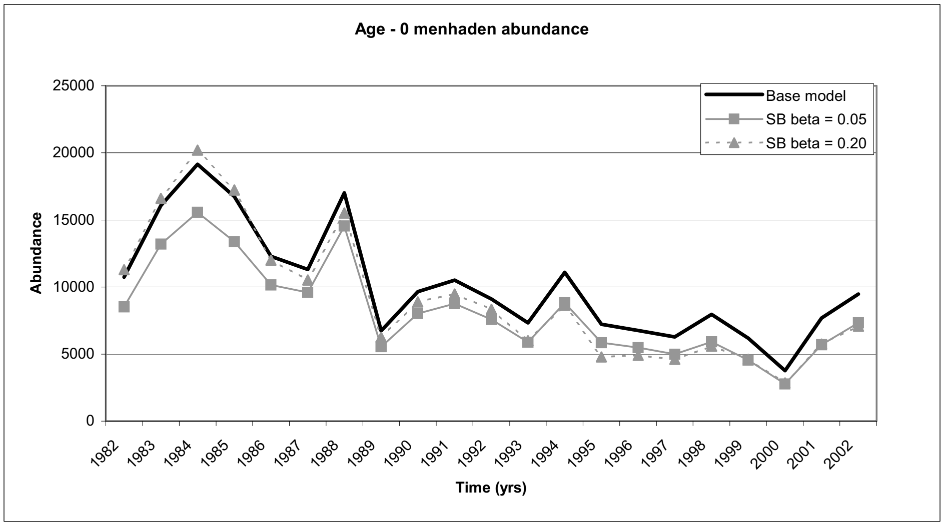
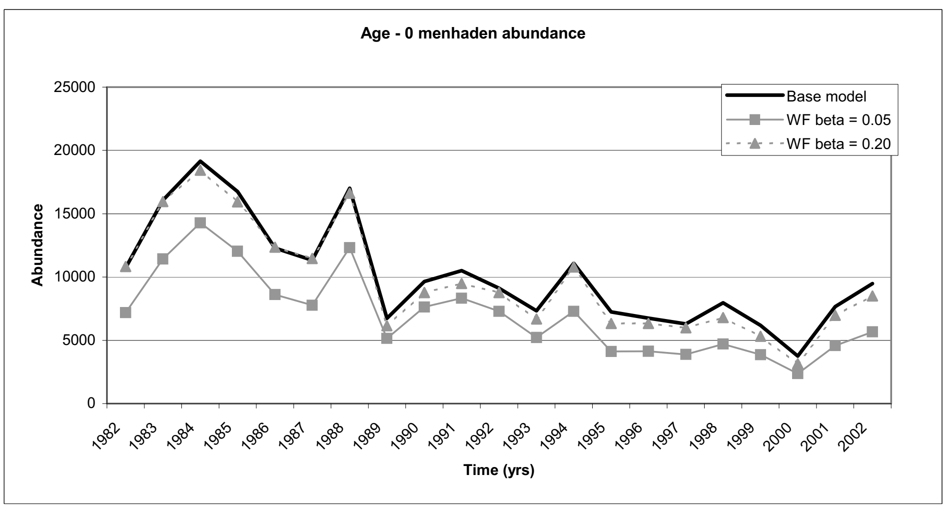


Figure D1.27. Impact of alternative values for the gastric evacuation rate parameter α on the abundance (millions of fish) of age-0 abundance of menhaden in the MSVPA-X model.

a)



b)



c)

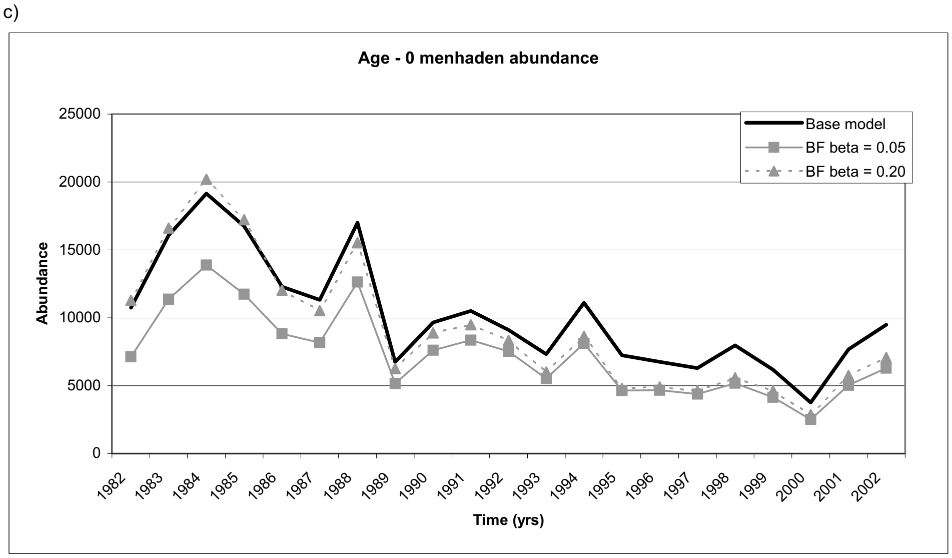
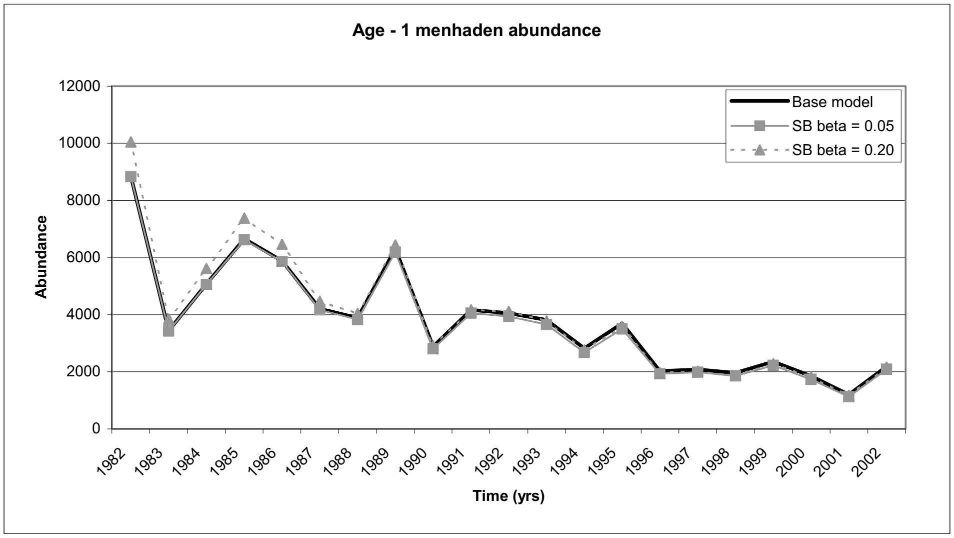
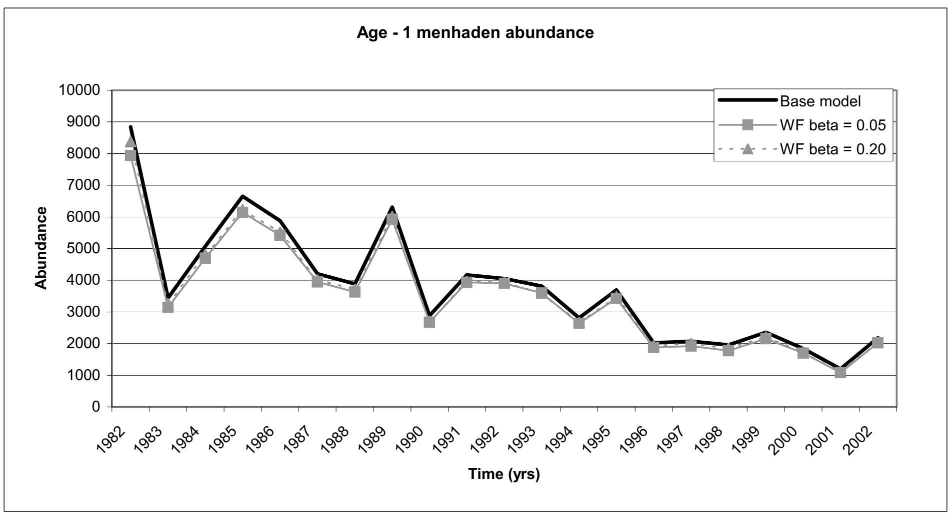


Figure D1.28. Impact of alternative values for the gastric evacuation rate parameter β on the abundance (millions of fish) of age-0 abundance of menhaden in the MSVPA-X model.

a)



b)



c)

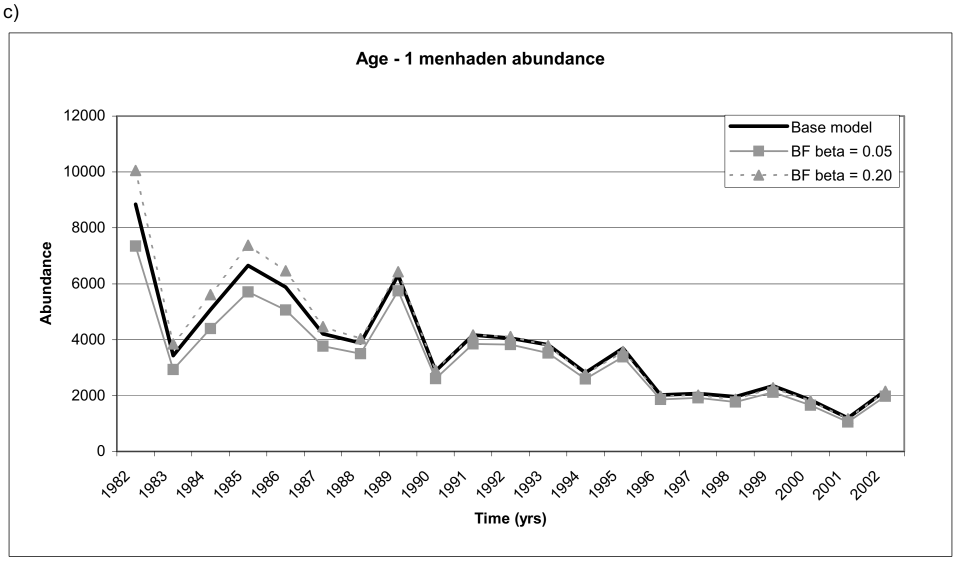
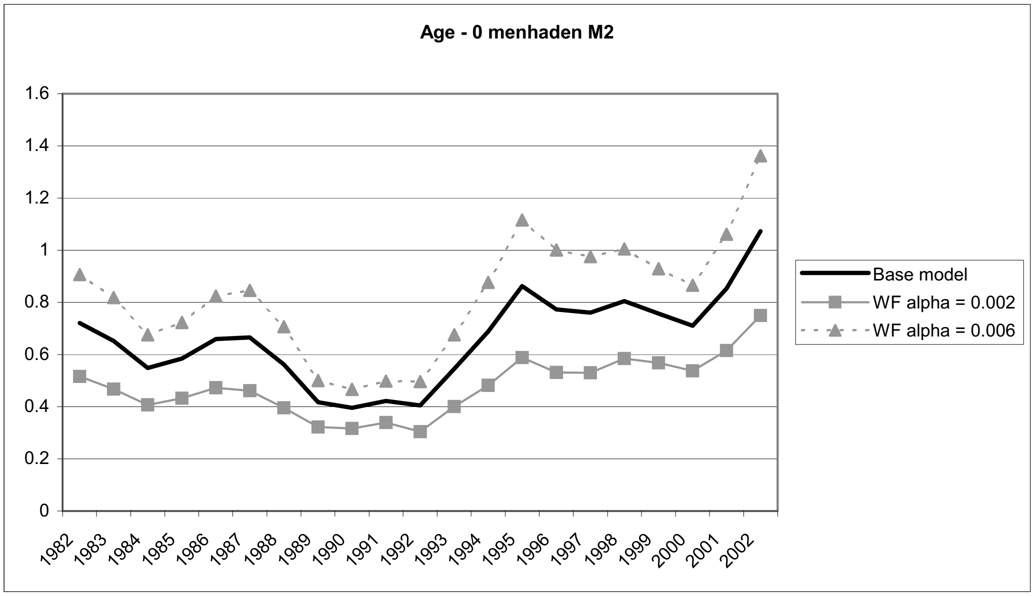


Figure D1.29. The affect of changing the gastric evacuation parameter α for weakfish on the predation mortality (M2) on a) age-0 and b) age-1 menhaden.

a)



b)

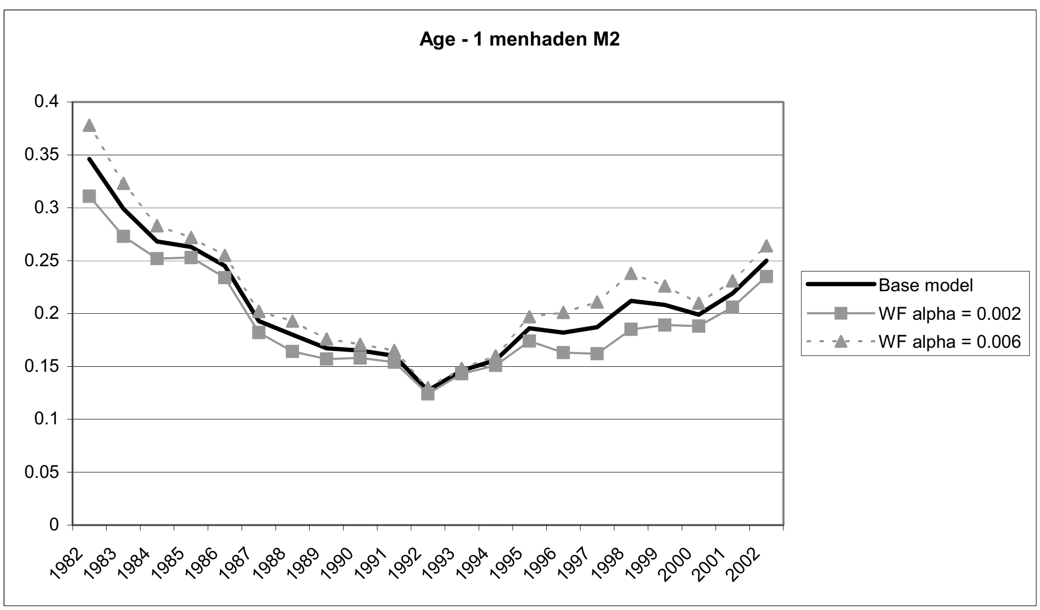
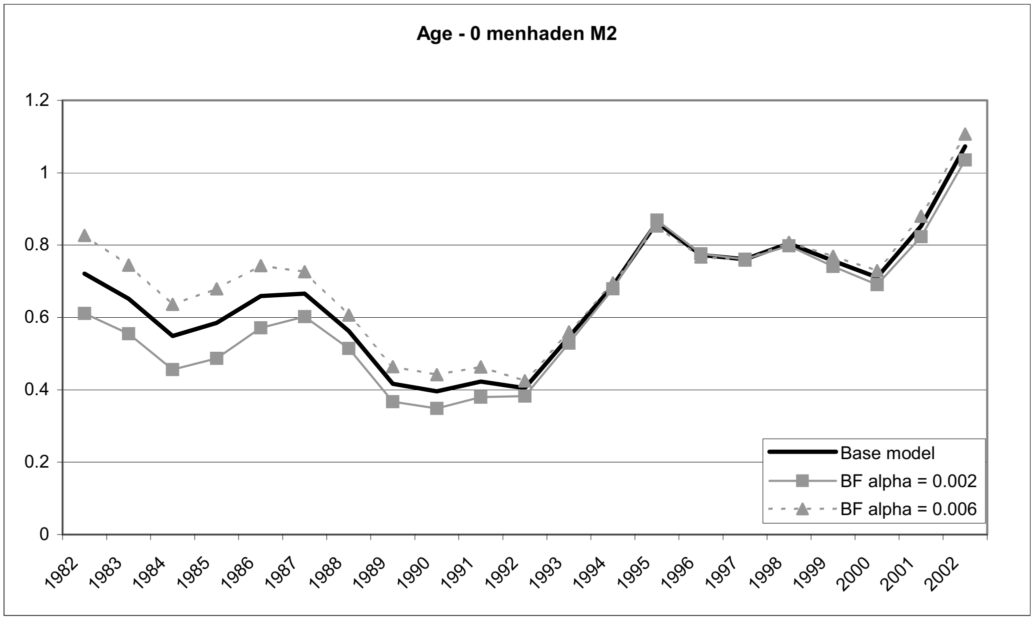


Figure D1.30. The affect of changing the gastric evacuation parameter α for bluefish on the predation mortality (M2) on a) age-0 and b) age-1 menhaden.

a)



b)

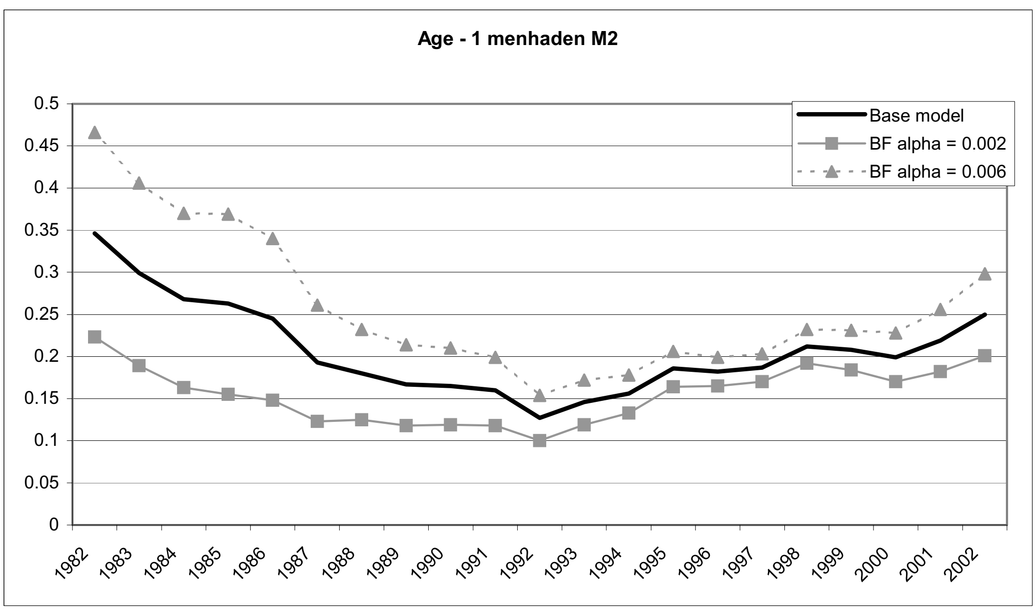
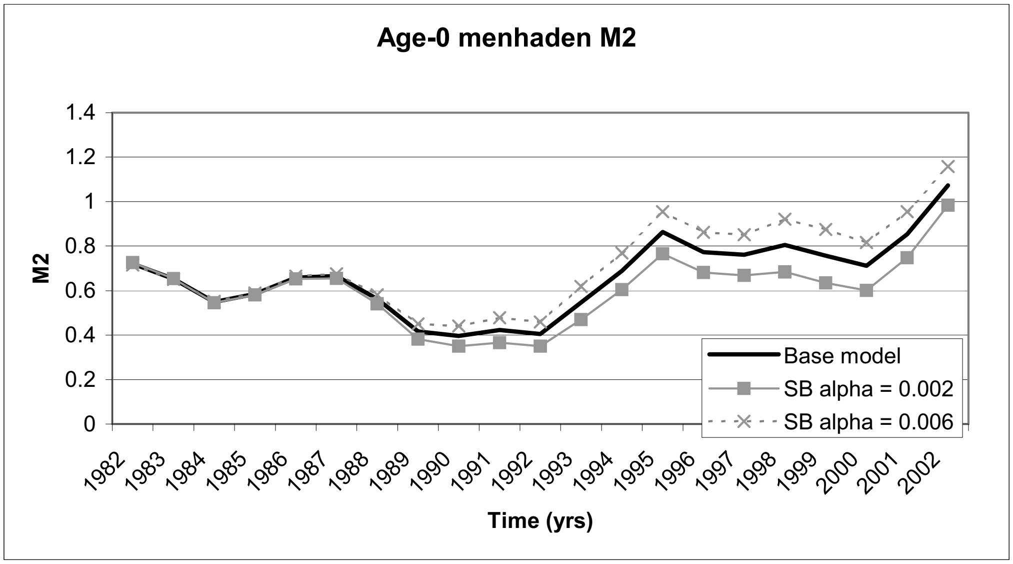


Figure D1.31. The affect of changing the gastric evacuation parameter α for striped bass on the predation mortality (M2) on a) age-0 and b) age-1 menhaden.

a)



b)

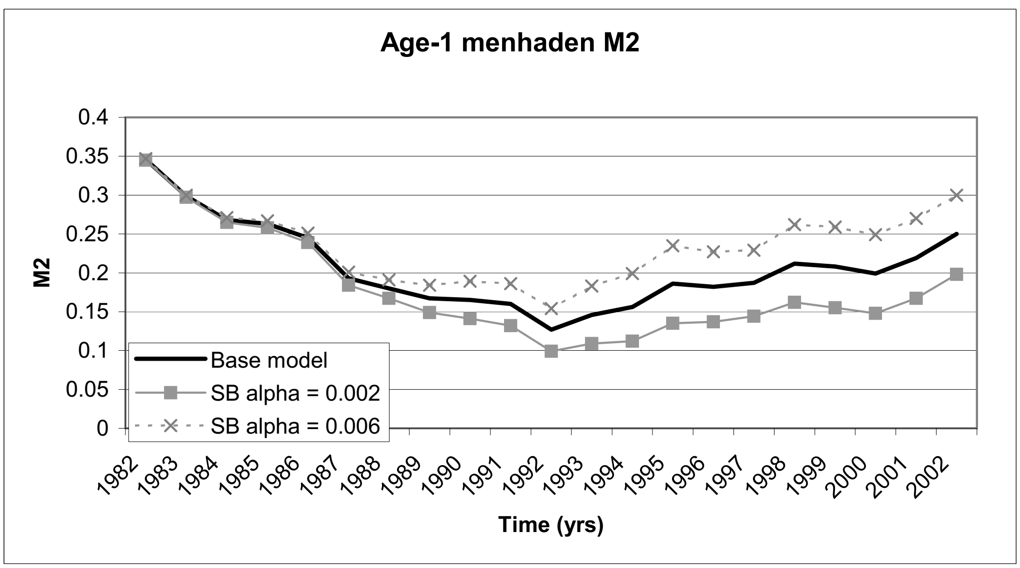
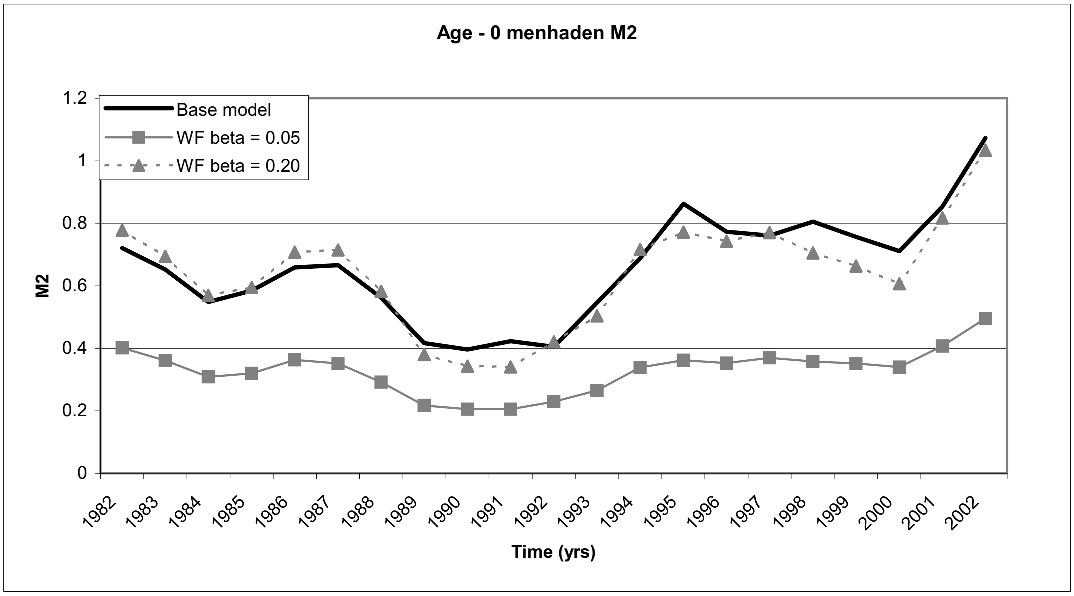


Figure D1.32. The affect of changing the gastric evacuation parameter β for weakfish on the predation mortality (M2) on a) age-0 and b) age-1 menhaden

a)



b)

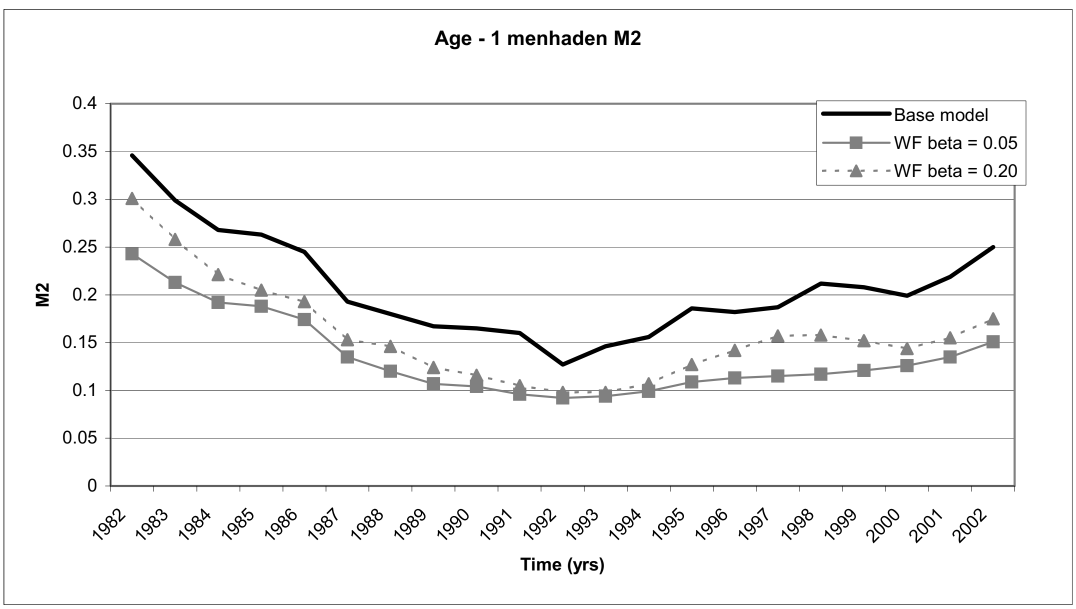
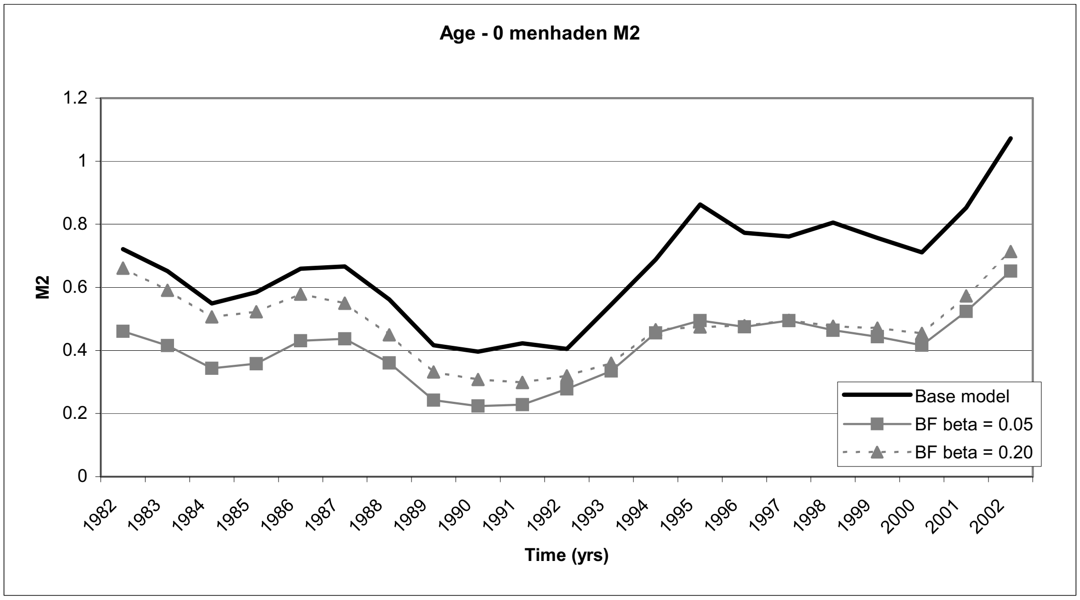


Figure D1.33. The affect of changing the gastric evacuation parameter β for bluefish on the predation mortality (M2) on a) age-0 and b) age-1 menhaden

a)



b)

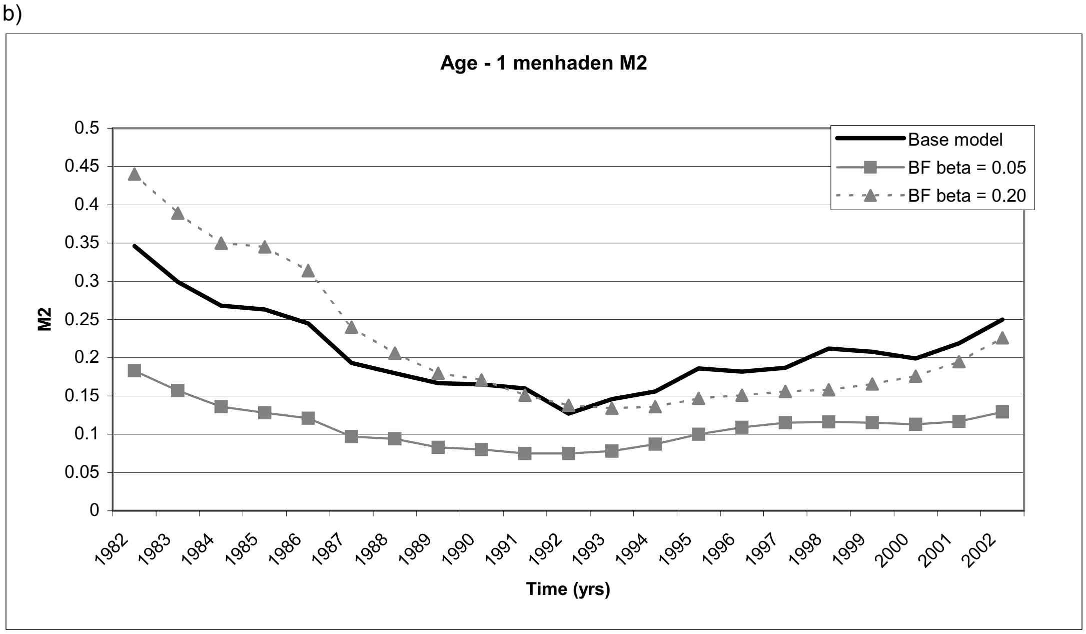
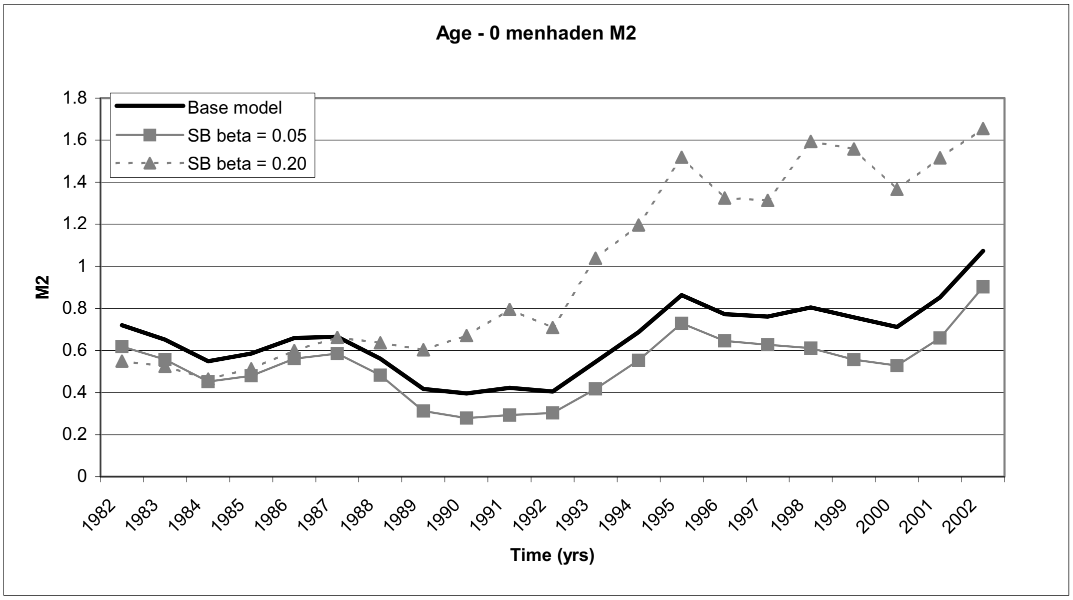


Figure D1.34. The affect of changing the gastric evacuation parameter β for striped bass on the predation mortality (M2) on a) age-0 and b) age-1 menhaden.

a)



b)

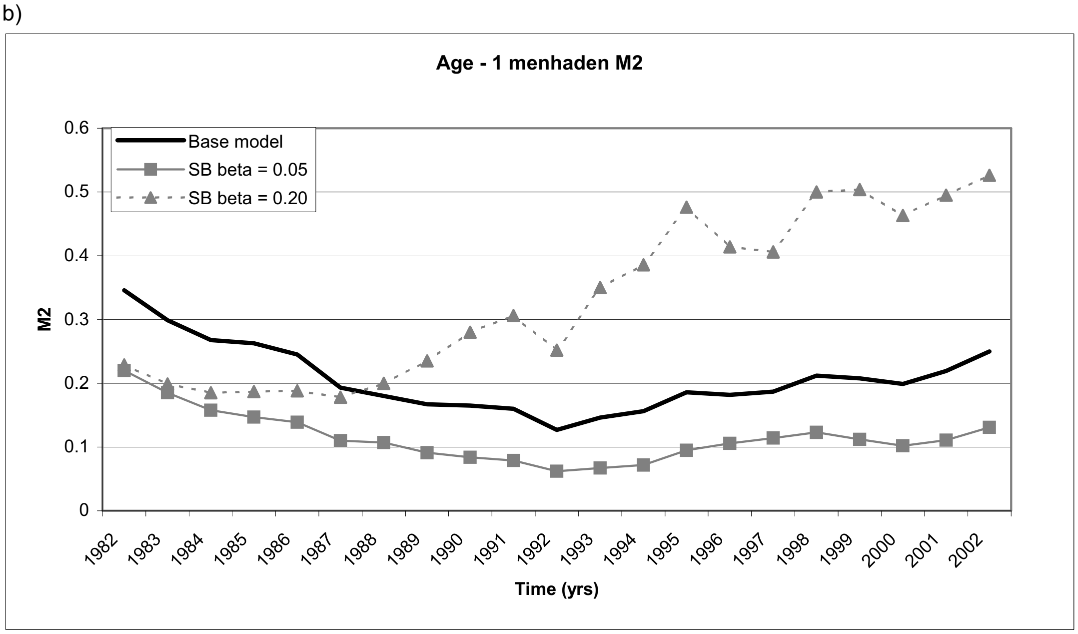
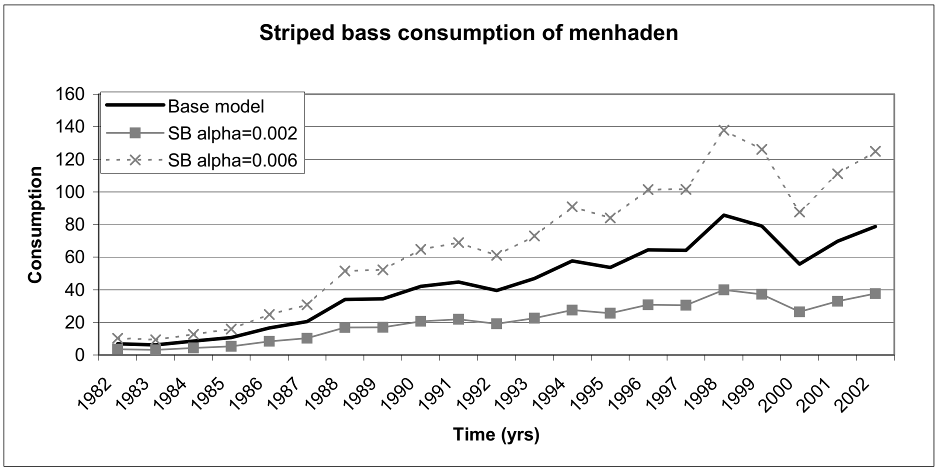


Figure D1.35. The affect of changing the gastric evacuation parameter α for striped bass on the consumption (000 mt) of a) striped bass, b) weakfish, and c) bluefish.

a)



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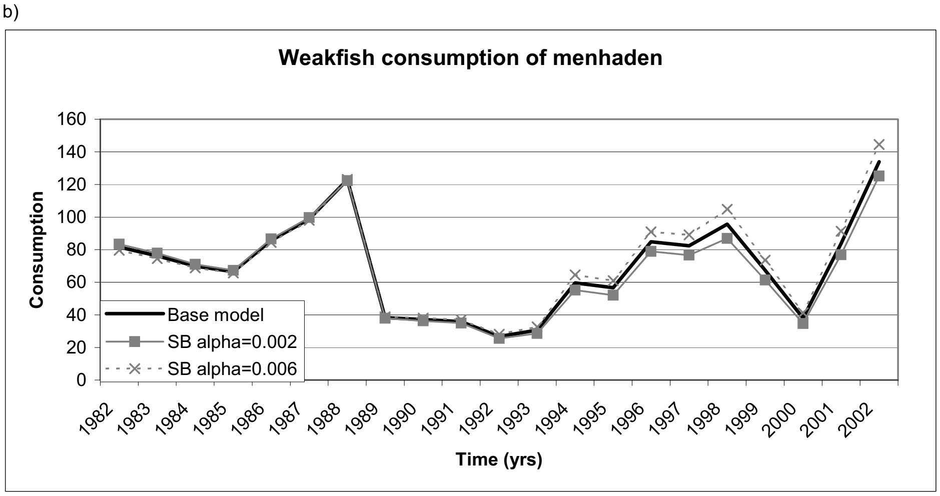


c)

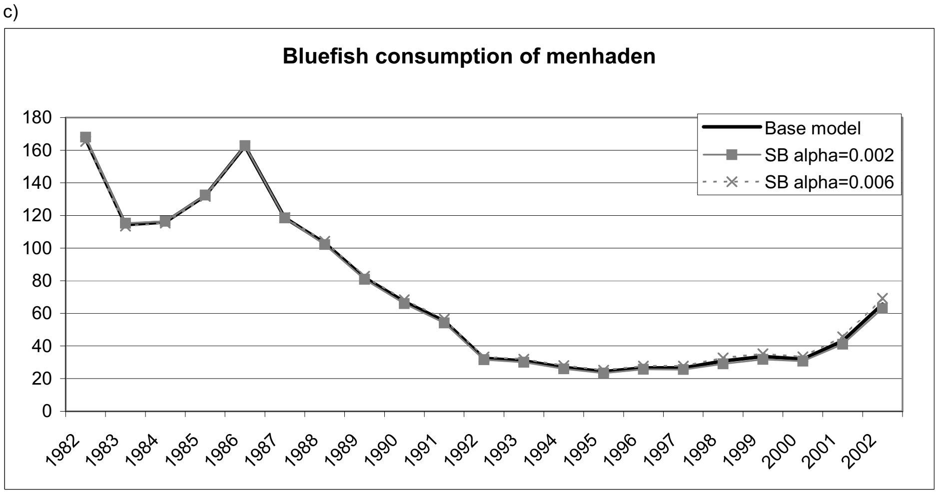
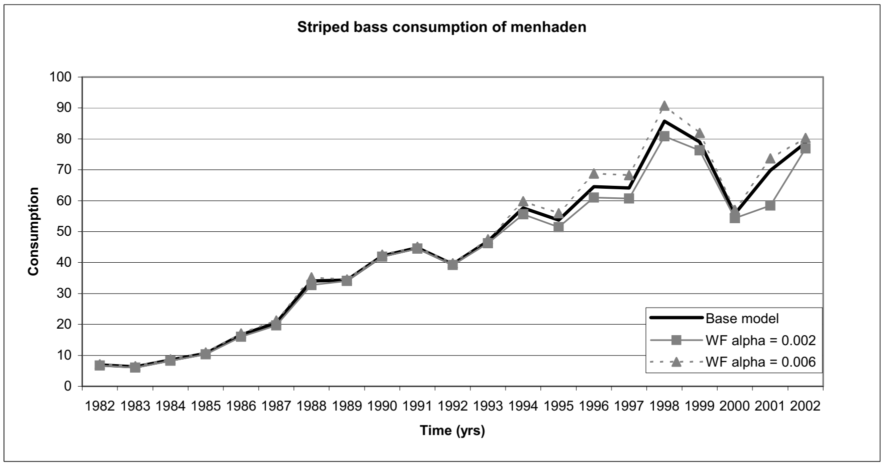
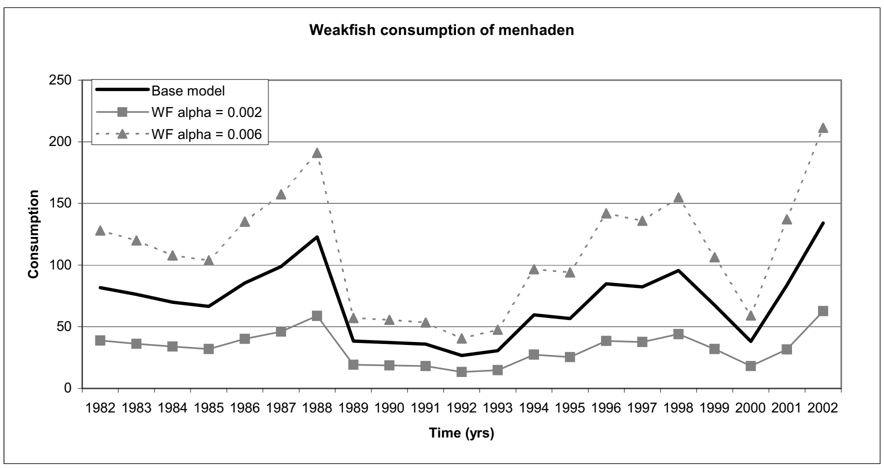


Figure D1.36. The affect of changing the gastric evacuation parameter α for weakfish on the consumption (000 mt) of a) striped bass, b) weakfish, and c) bluefish.

a)



b)



c)

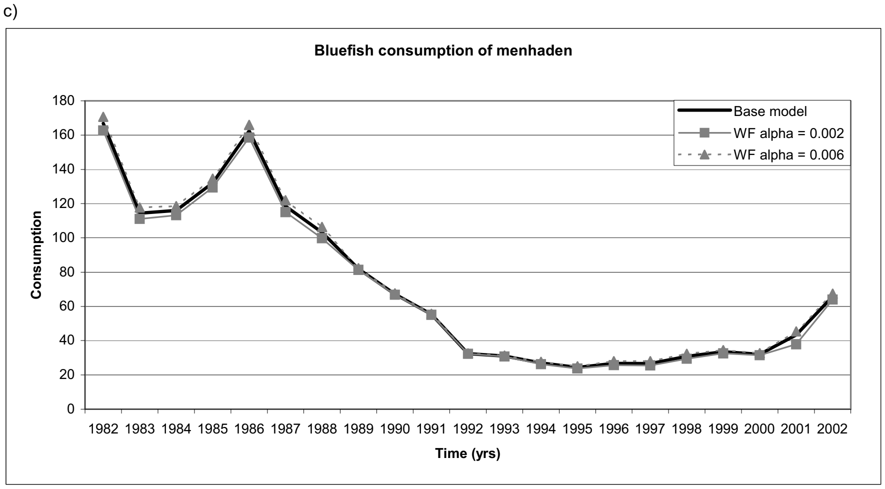


Figure D1.37. The affect of changing the gastric evacuation parameter α for bluefish on the consumption (000 mt) of a) striped bass, b) weakfish, and c) bluefish.

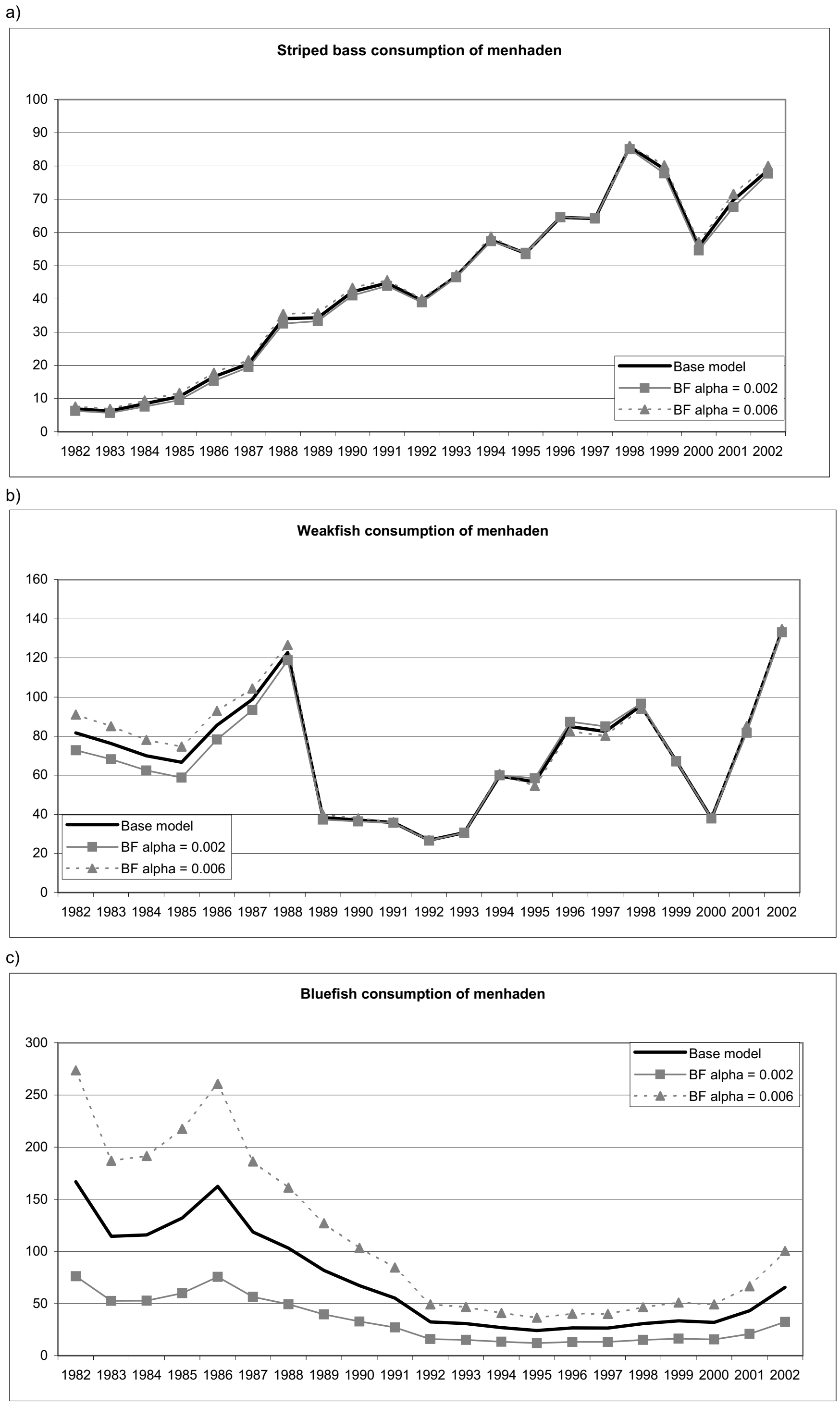
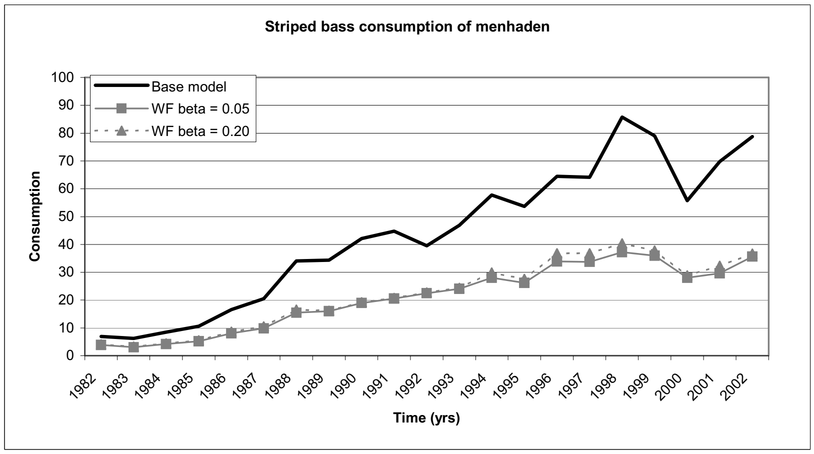
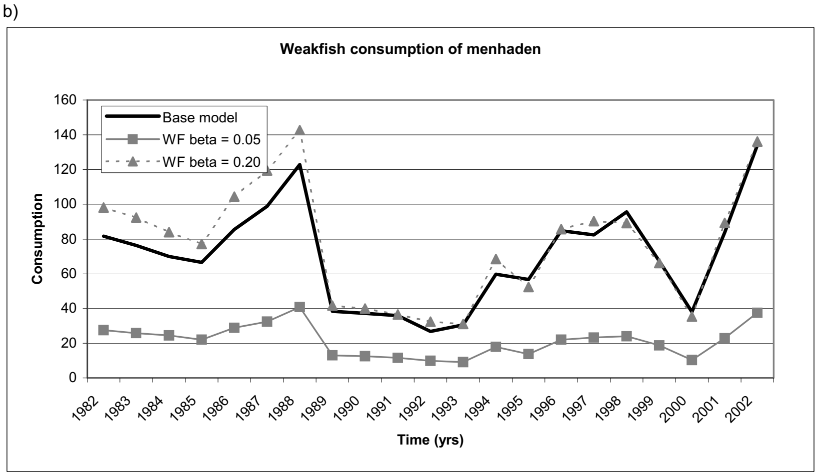


Figure D1.38. The affect of changing the gastric evacuation parameter β for weakfish on the consumption (000 mt) of a) striped bass, b) weakfish, and c) bluefish.

a)



b)



c)

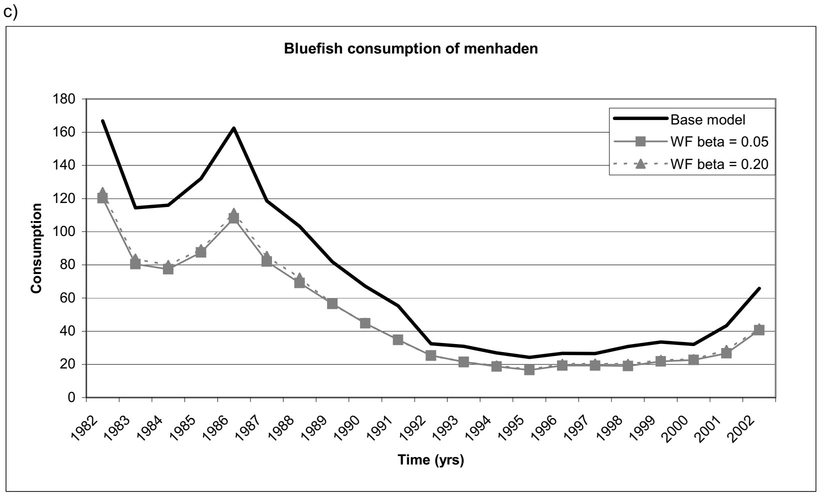
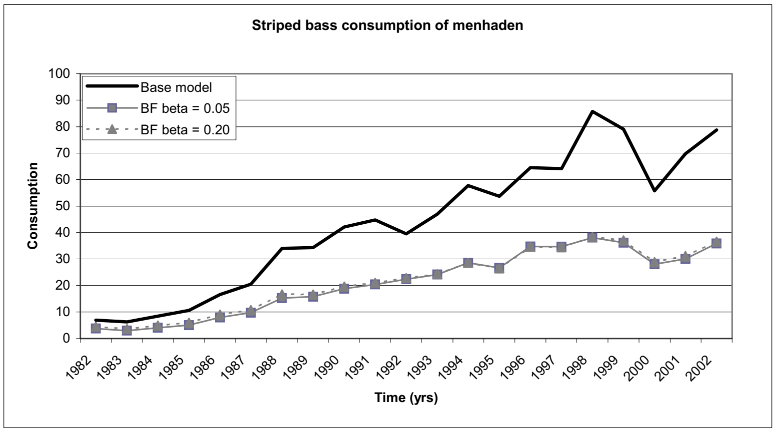
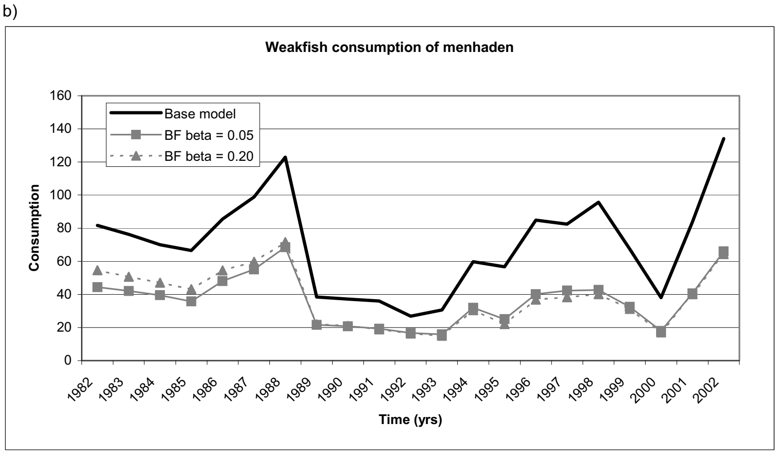


Figure D1.39. The affect of changing the gastric evacuation parameter β for bluefish on the consumption (000 mt) of a) striped bass, b) weakfish, and c) bluefish.

a)



b)



c)

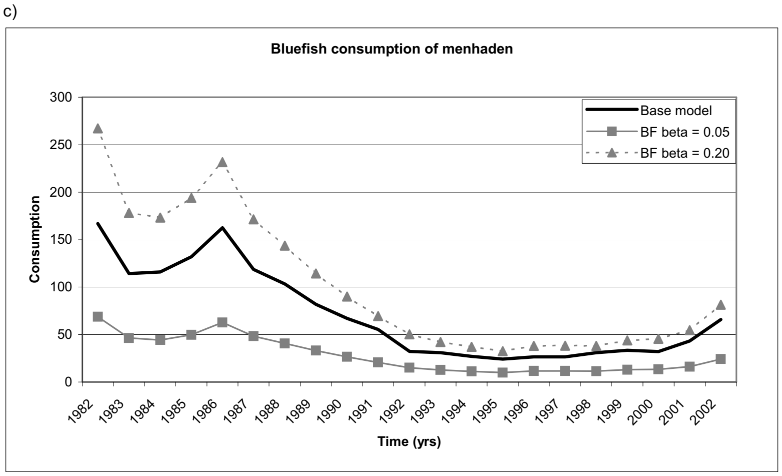
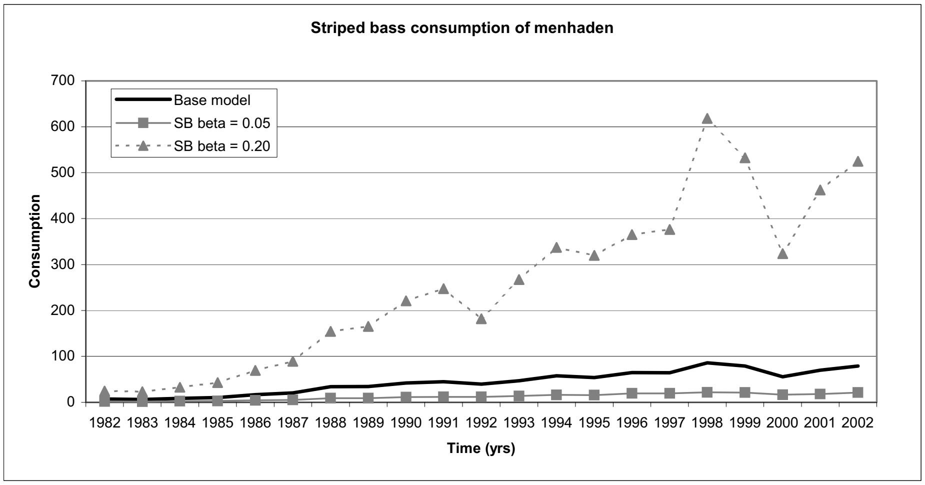
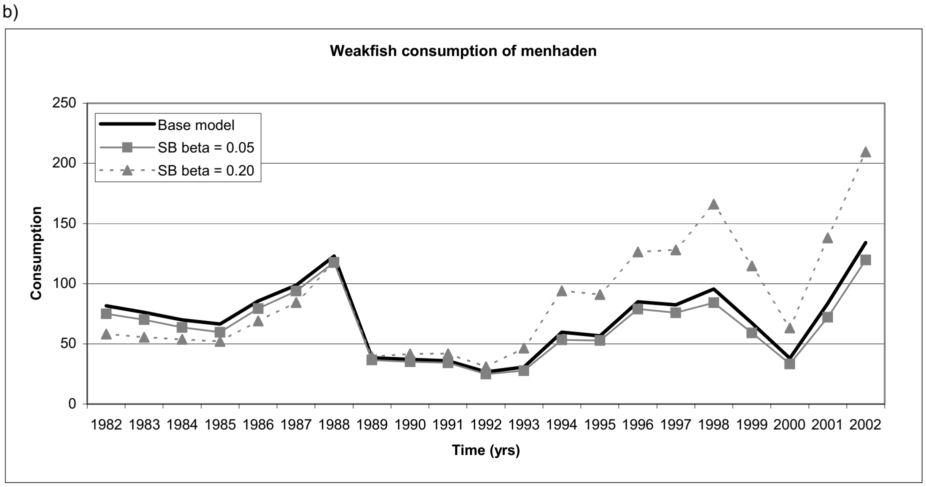


Figure D1.40. The affect of changing the gastric evacuation parameter β for striped bass on the consumption (000 mt) of a) striped bass, b) weakfish, and c) bluefish.

a)



b)



c)

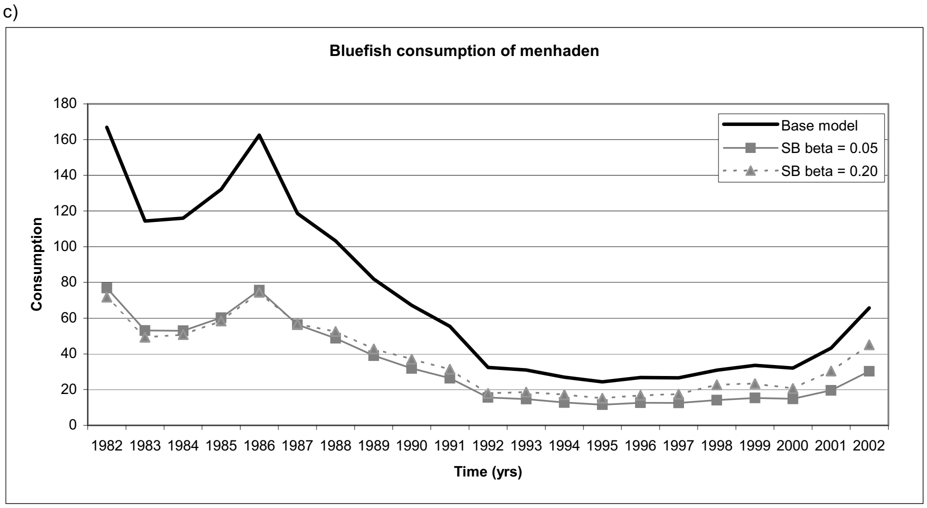


Figure D1.41. Comparison of predation mortality (M2) for age-0 menhaden with preference typed ranking all equal.

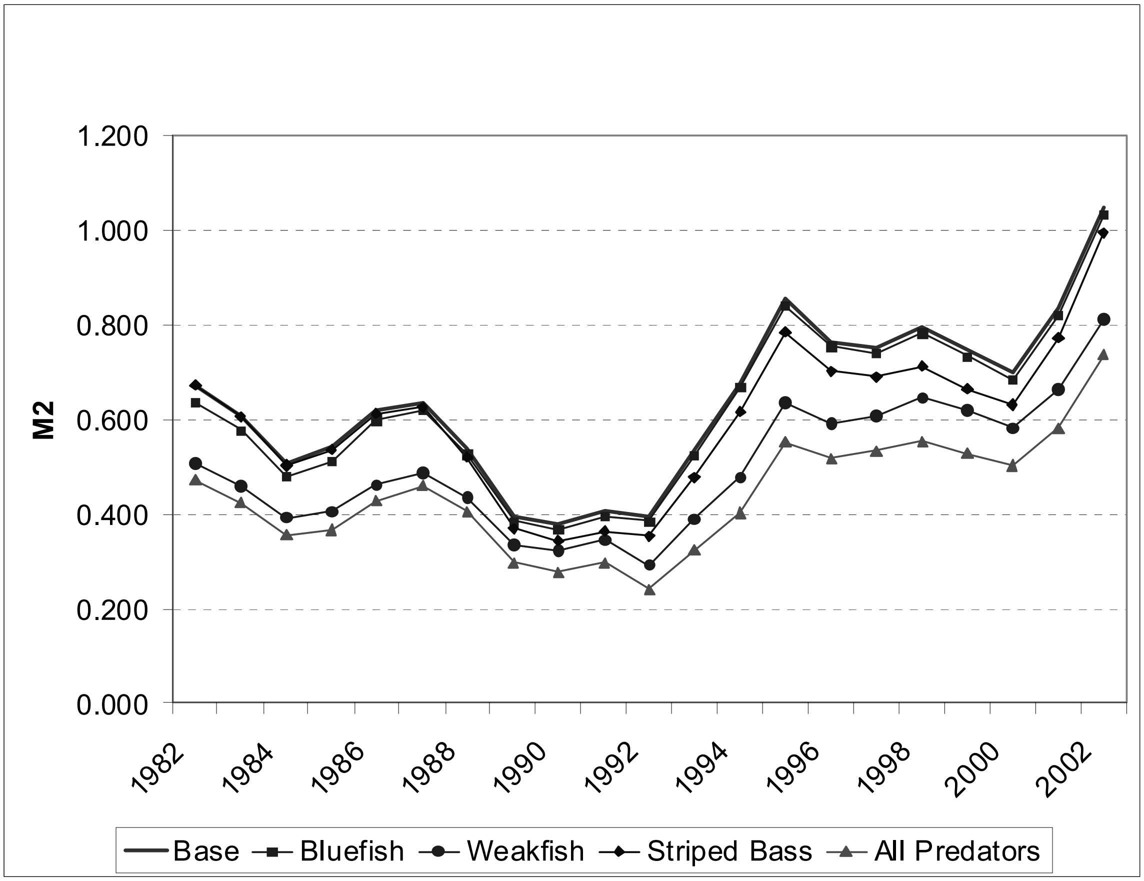


Figure D1.42. Comparison of predation mortality for age-0 menhaden with preference type ranking equal for fish and invertebrates.

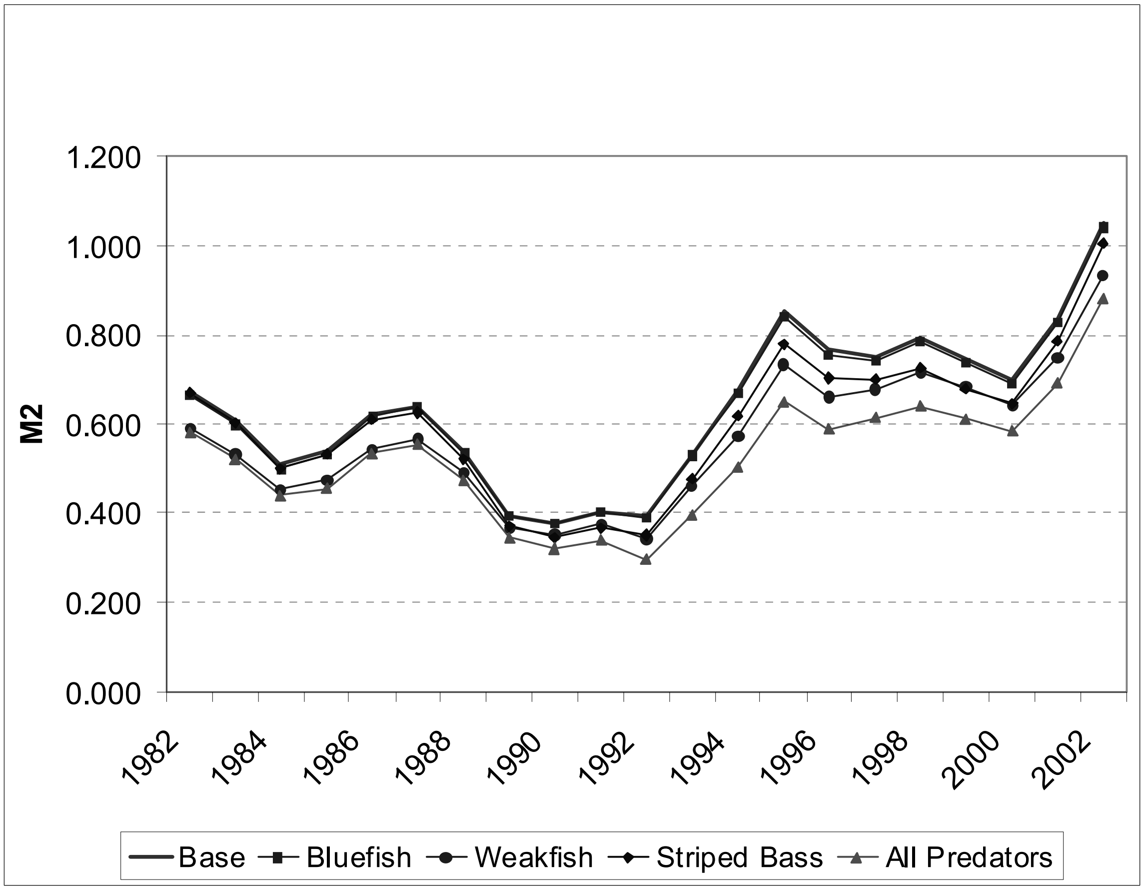


Figure D1.43. Comparison of predation mortality (M2) for age-1 menhaden with preference type ranking all equal.

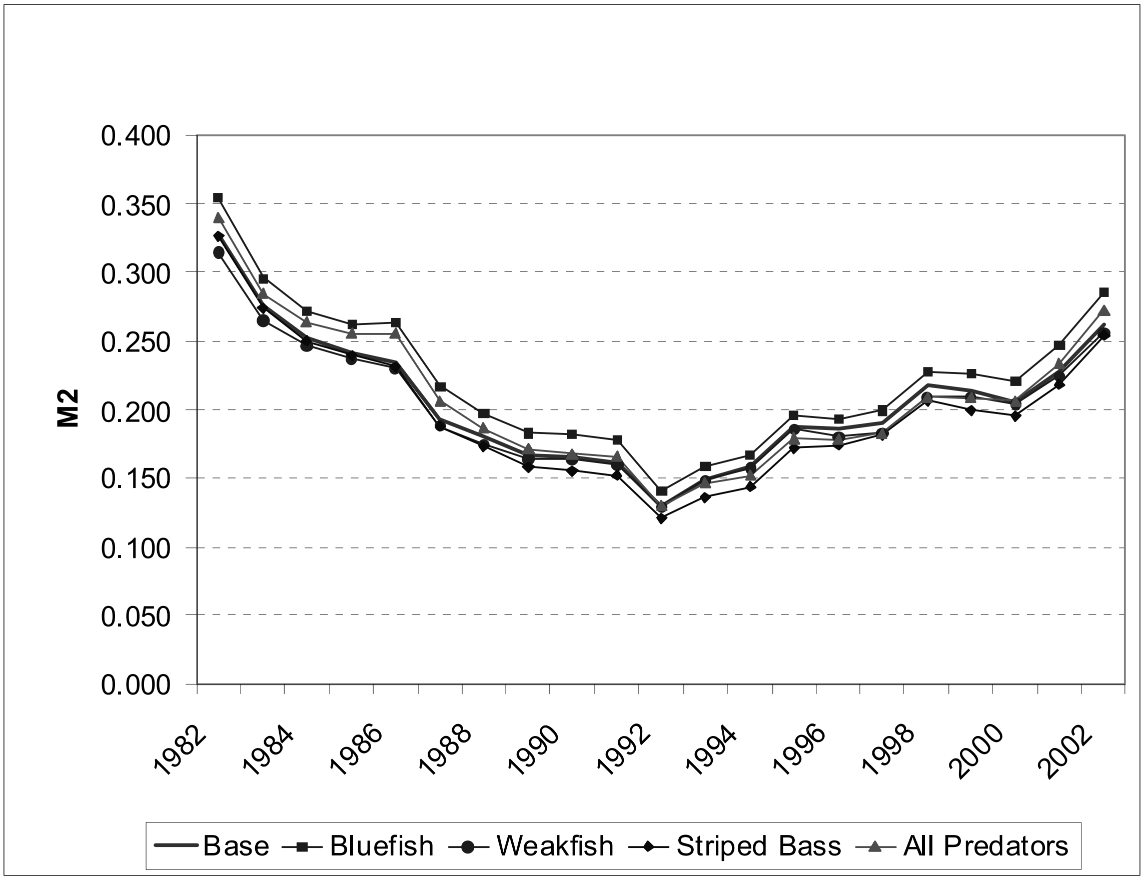


Figure D1.44. Comparison of predation mortality for age-1 menhaden with preference type ranking equal for fish and invertebrates.

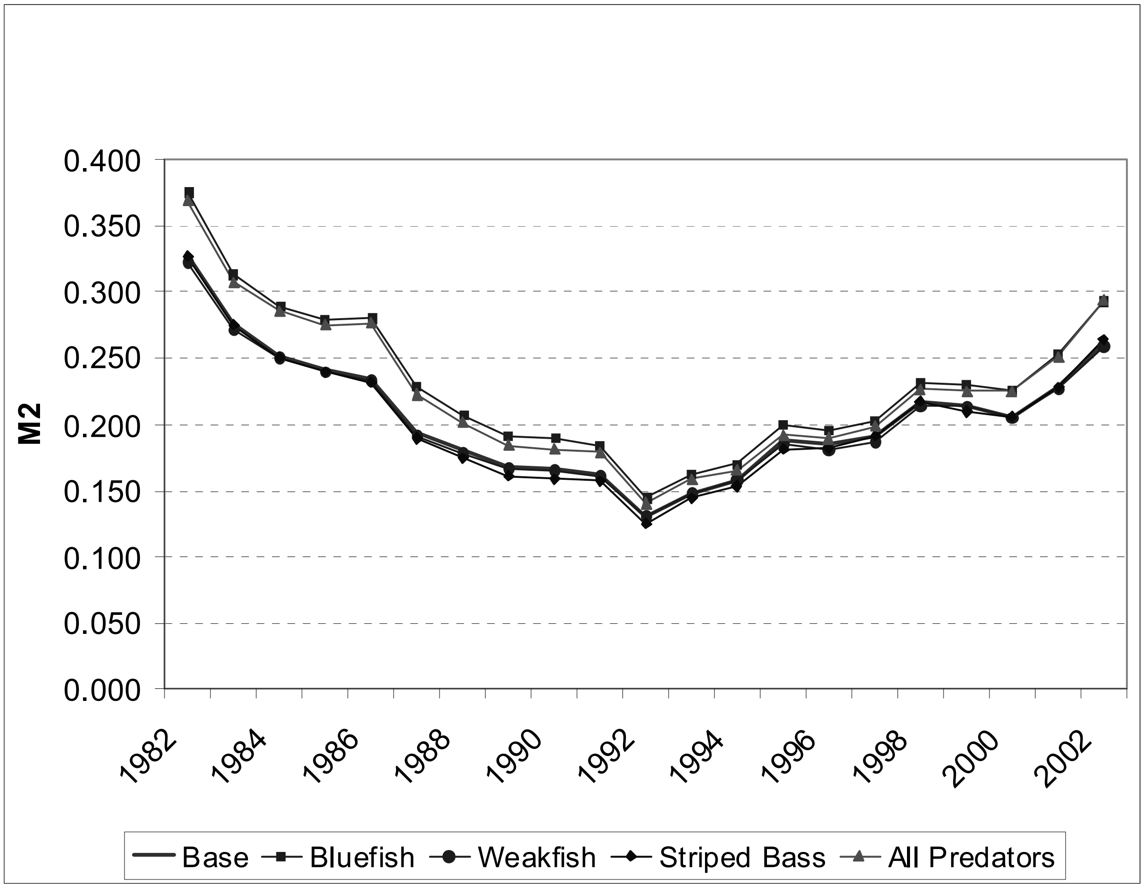


Figure D1.45. Comparison of predation mortality (M2) for age-2 menhaden with preference type ranking all equal.

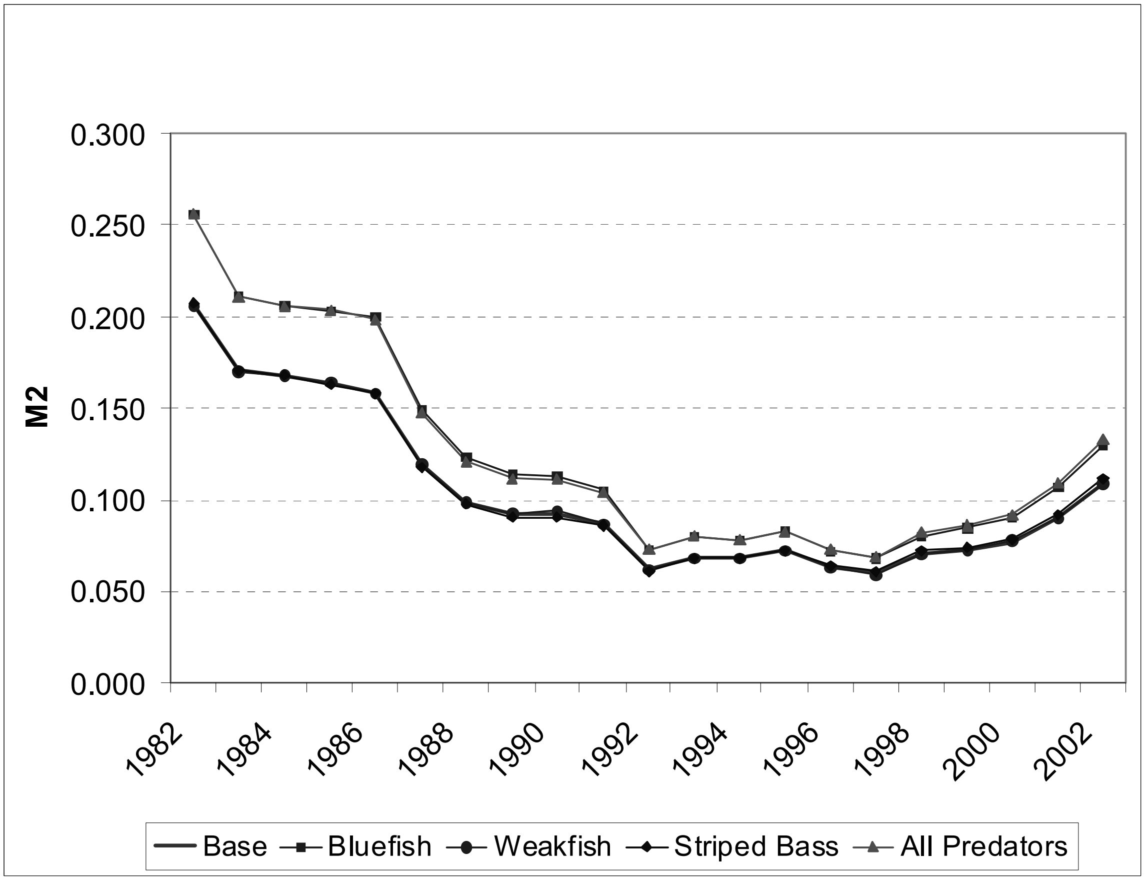


Figure D1.46. Comparison of predation mortality (M2) for age-2 menhaden with preference type ranking equal for fish and invertebrates.

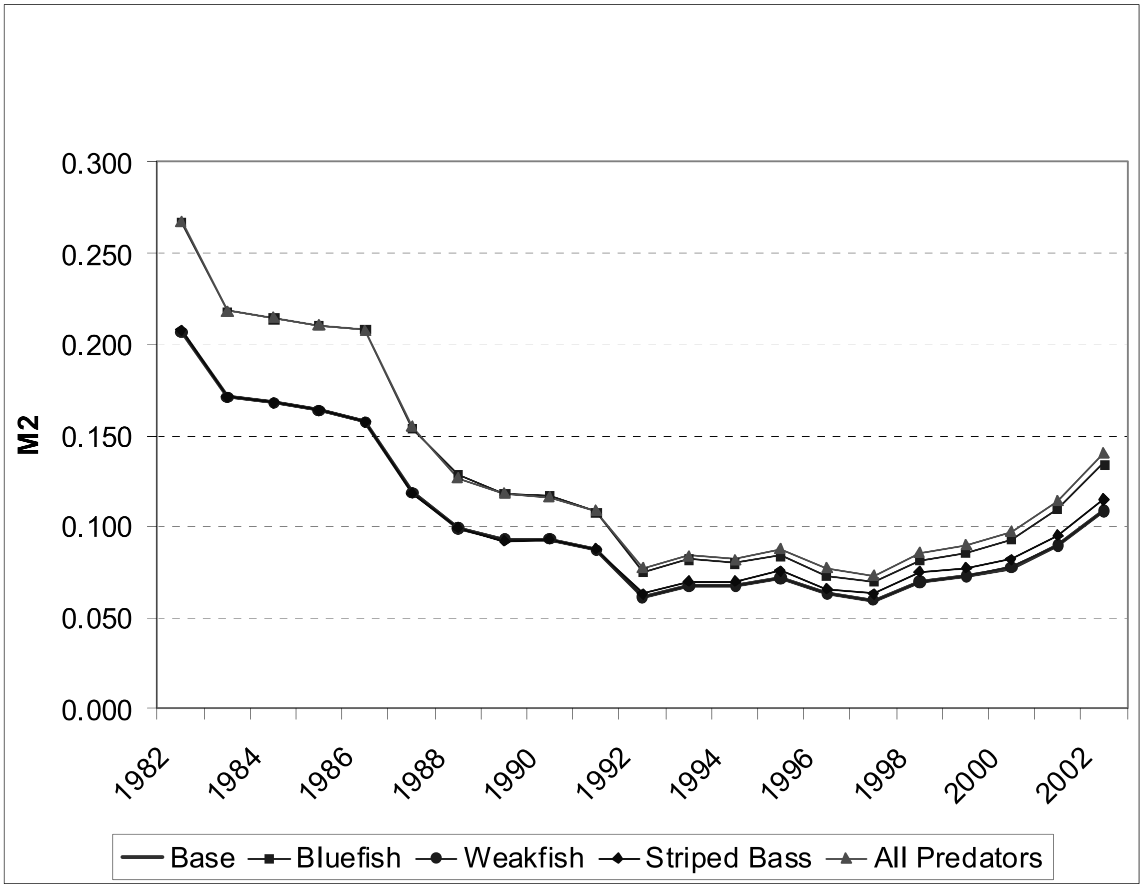


Figure D1.47. Comparison of average fishing mortality (F) for menhaden with preference type ranking all equal.

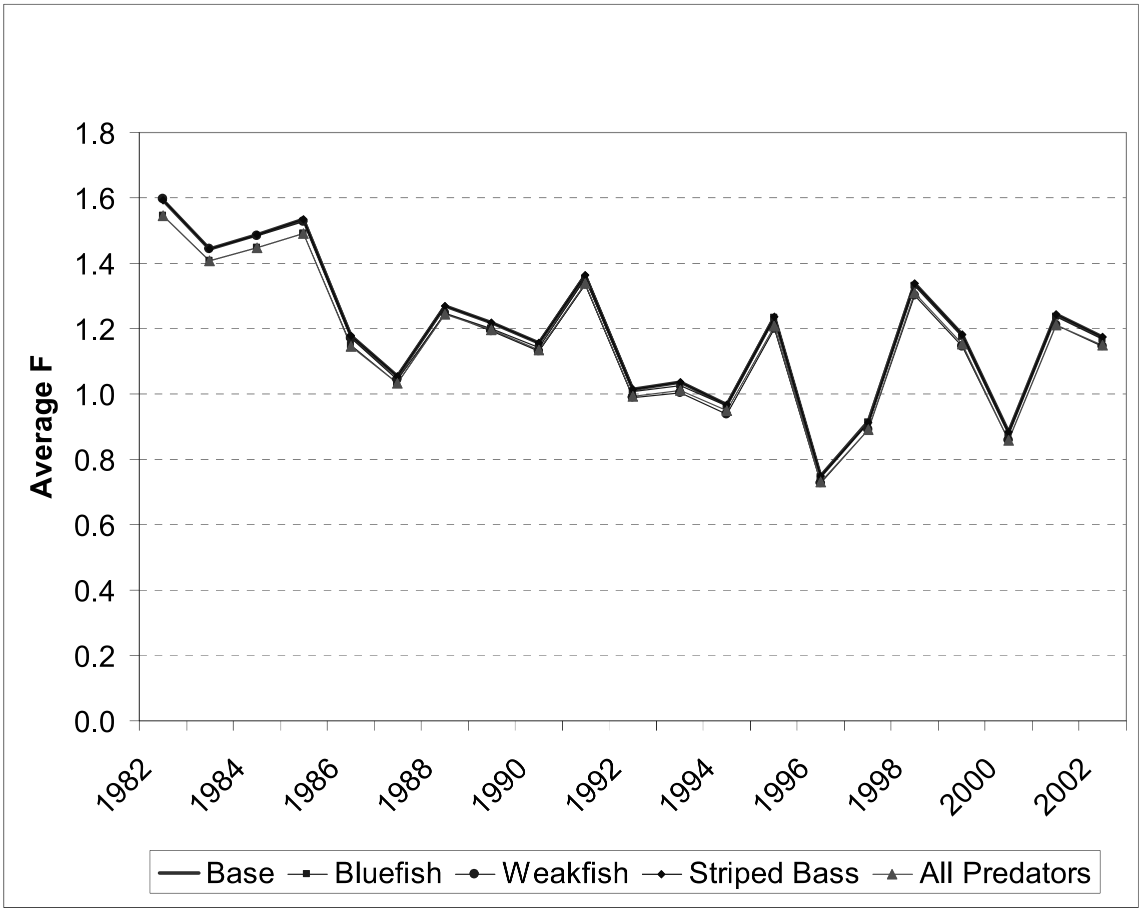


Figure D1.48. Comparison of average fishing mortality (F) for menhaden with preference type ranking equal for fish and invertebrates.

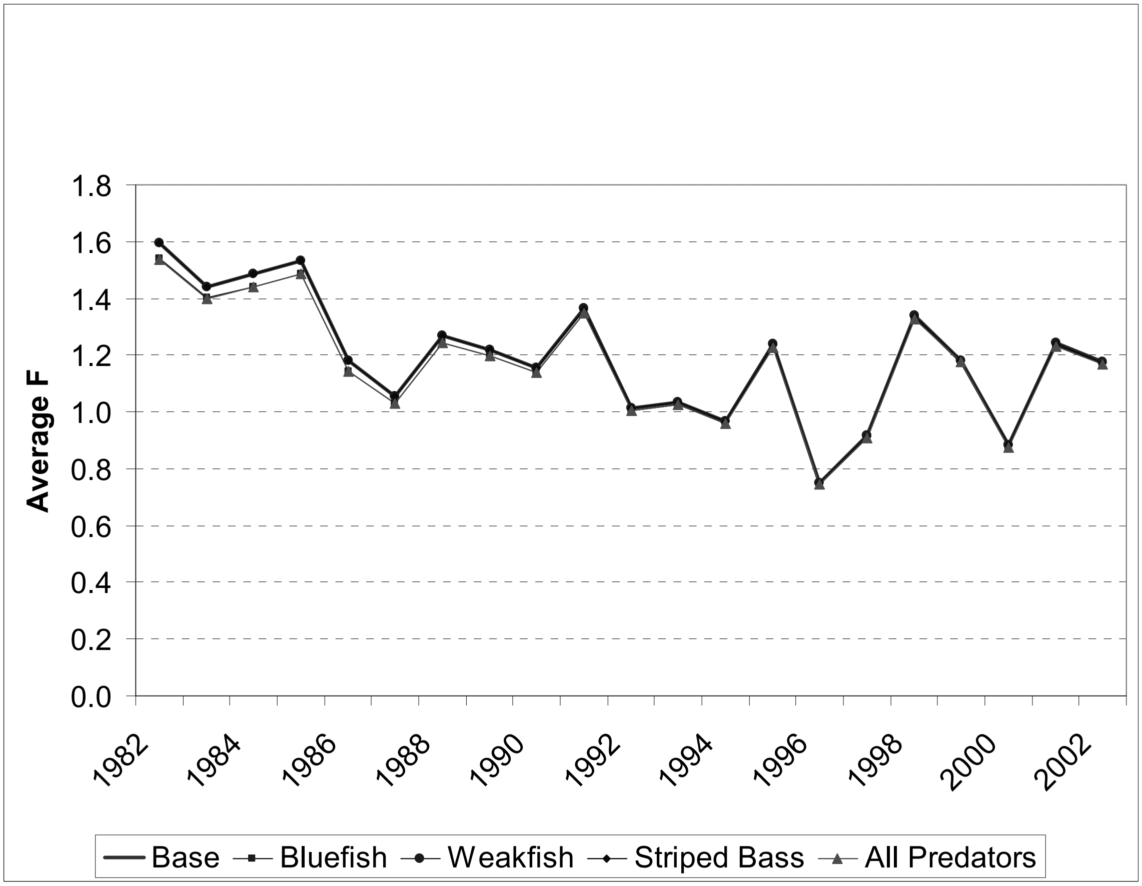


Figure D1.49. Comparison of abundance of age-0 menhaden with preference type ranking all equal.

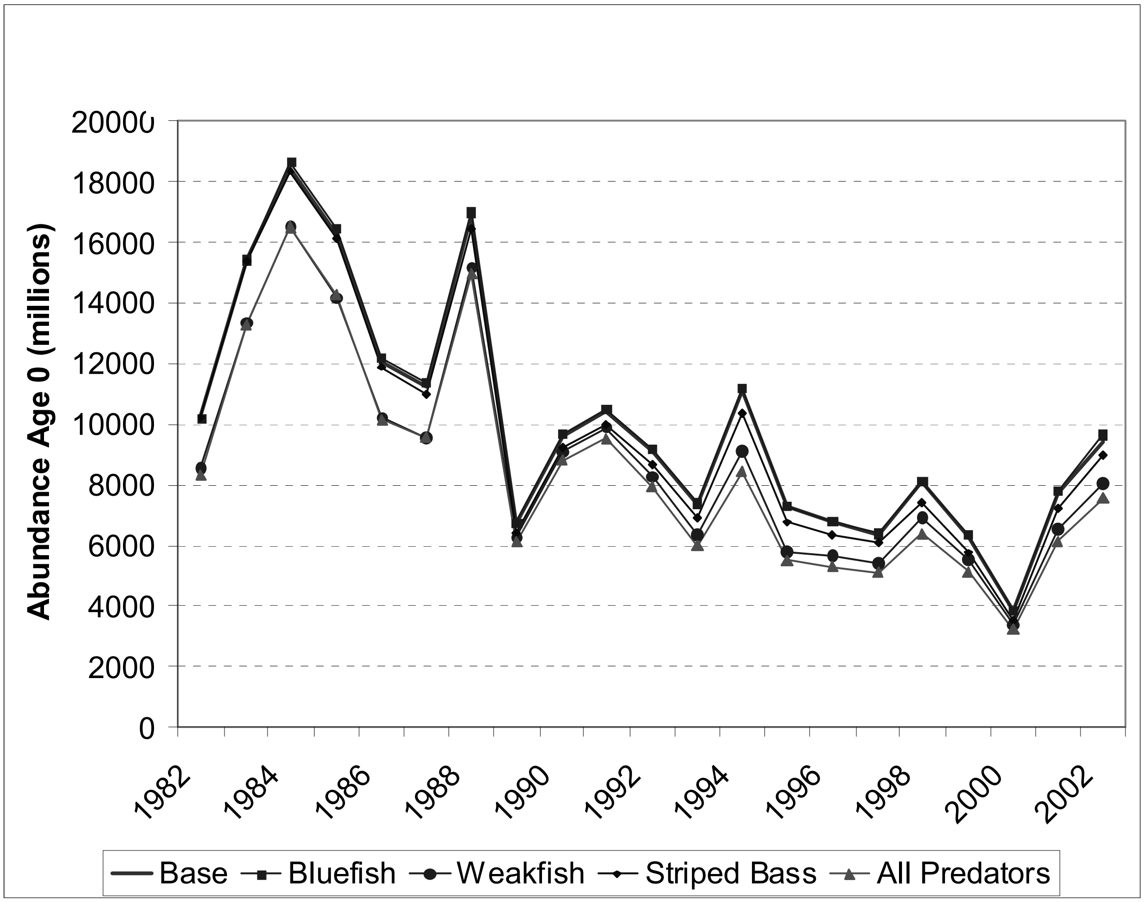


Figure D1.50. Comparison of abundance of age-0 menhaden with preference type ranking equal for fish and invertebrates.

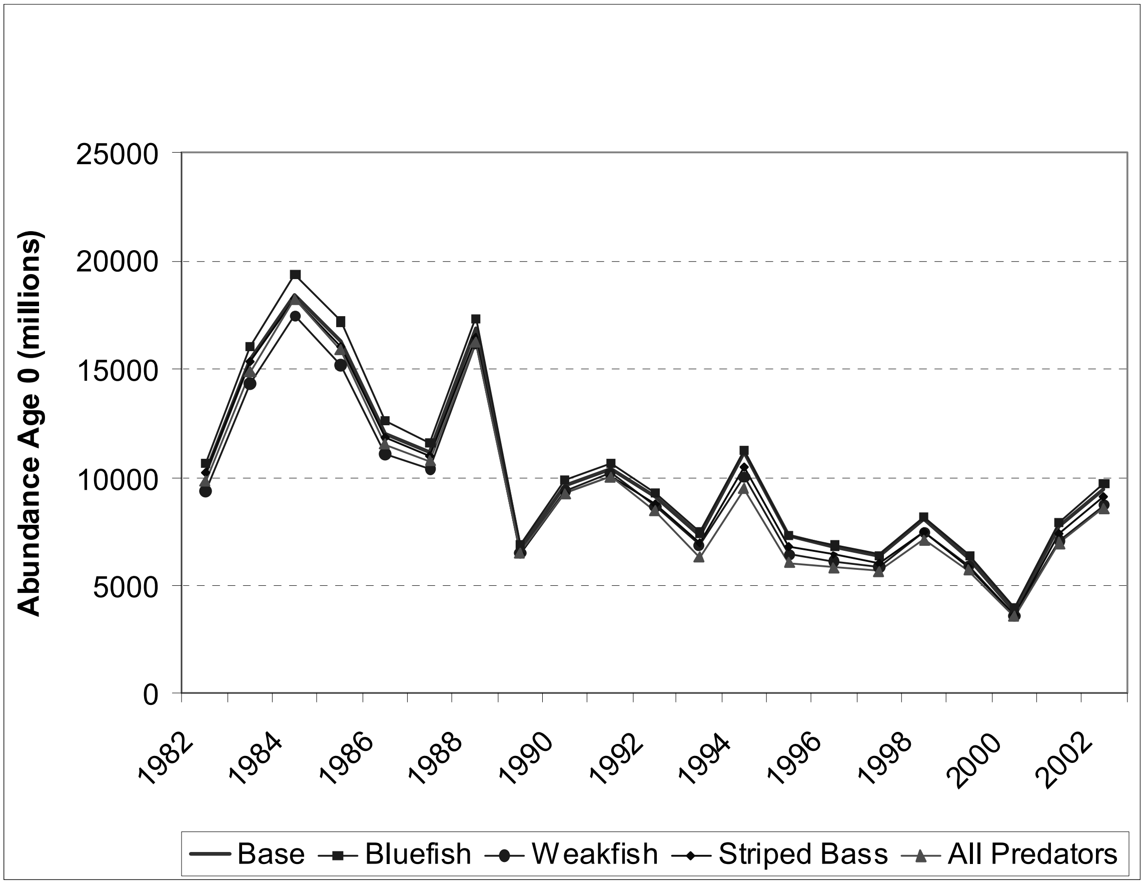


Figure D1.51. Comparison of abundance of age-1 menhaden with preference type ranking all equal.

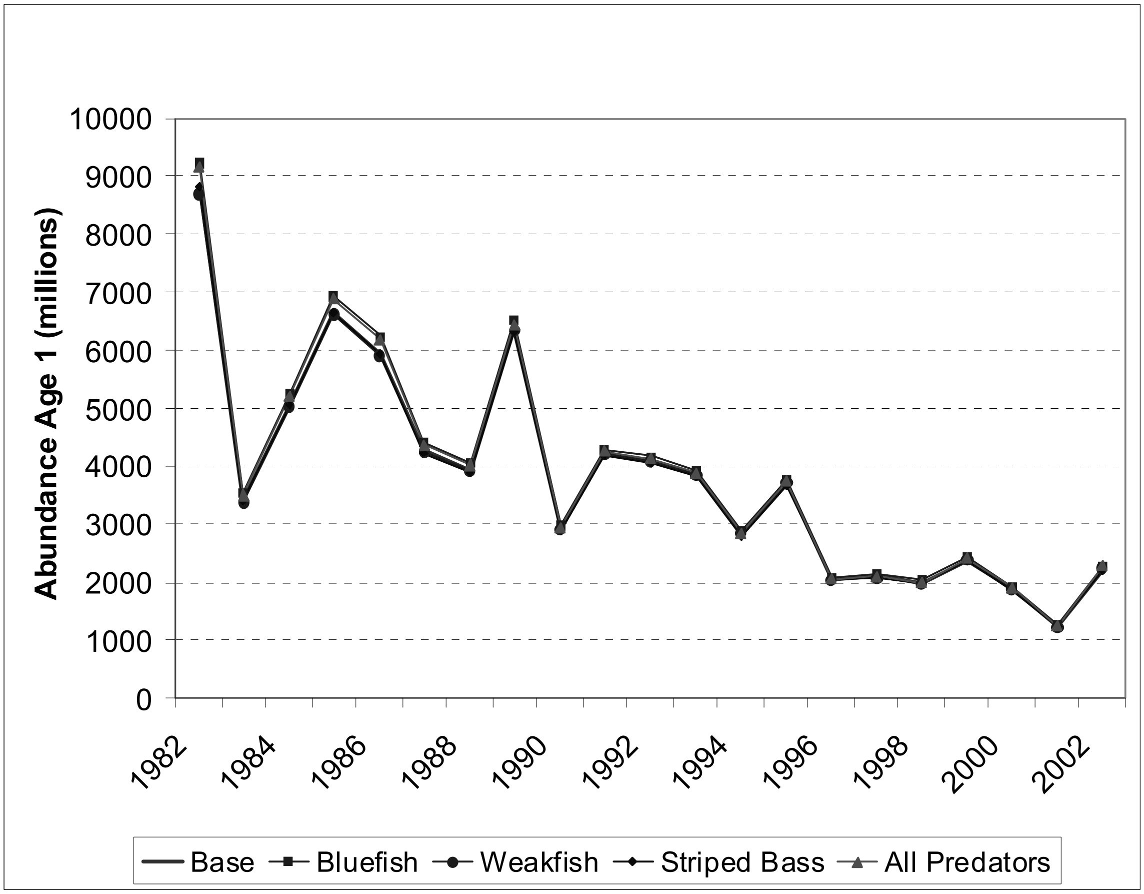


Figure D1.52. Comparison of abundance of age-1 menhaden with preference type ranking equal for fish and invertebrates.

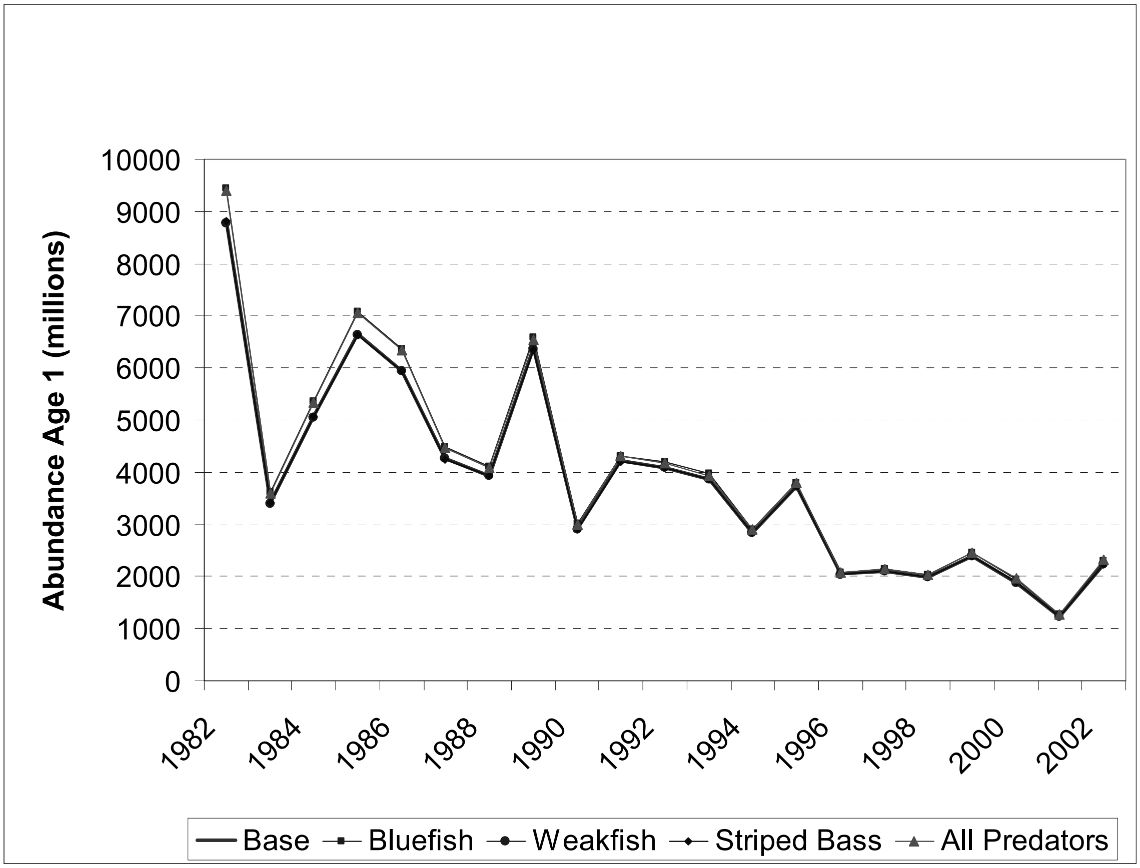


Figure D1.53. Comparison of menhaden spawning stock biomass (SSB) with preference type ranking all equal.

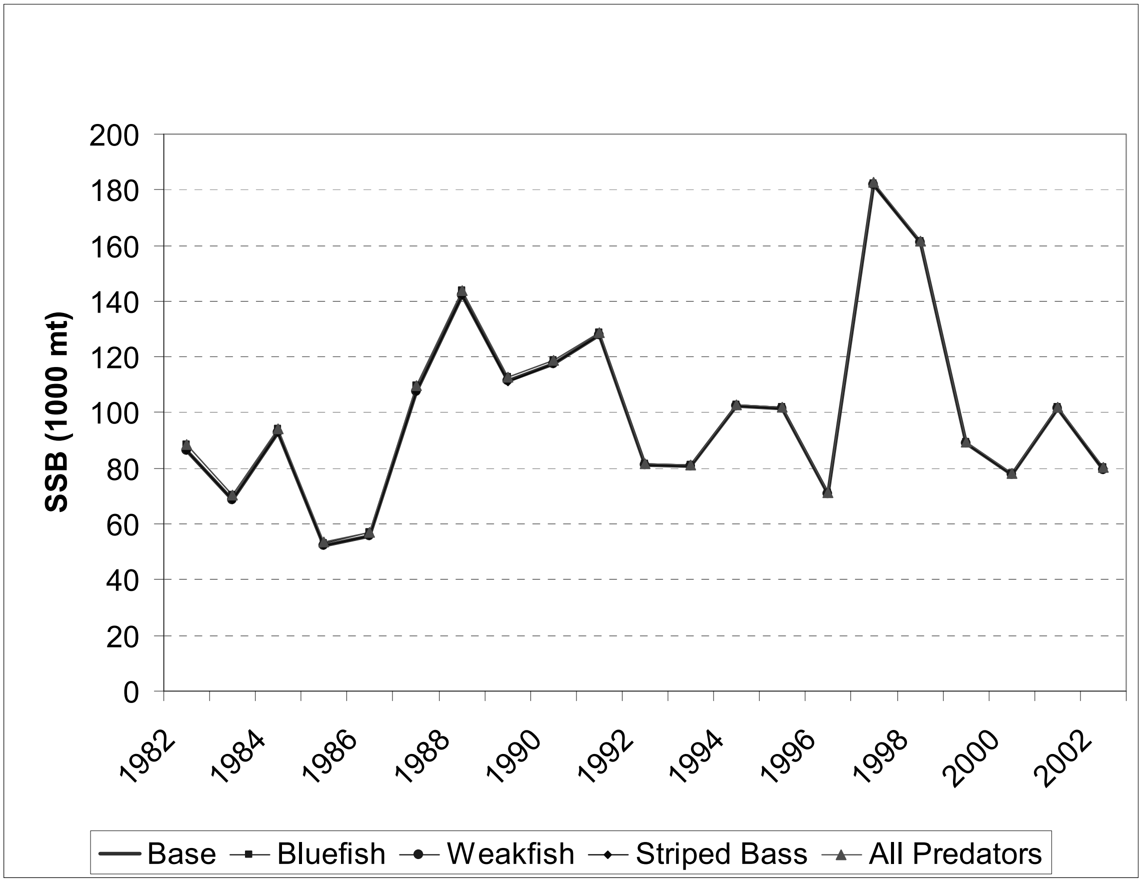


Figure D1.54. Comparison of menhaden spawning stock biomass (SSB) with preference type ranking equal for fish and invertebrates.

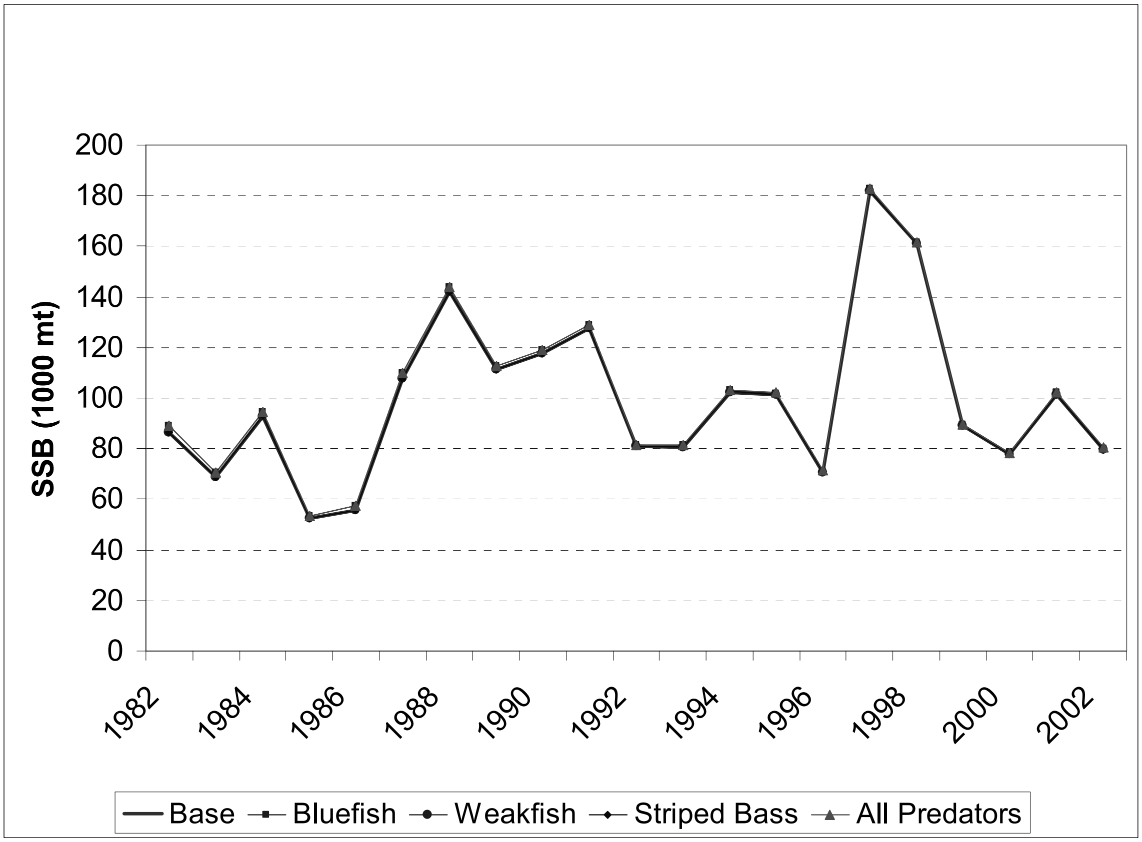


Figure D1.55. Menhaden in diet of striped bass (equal weighting).

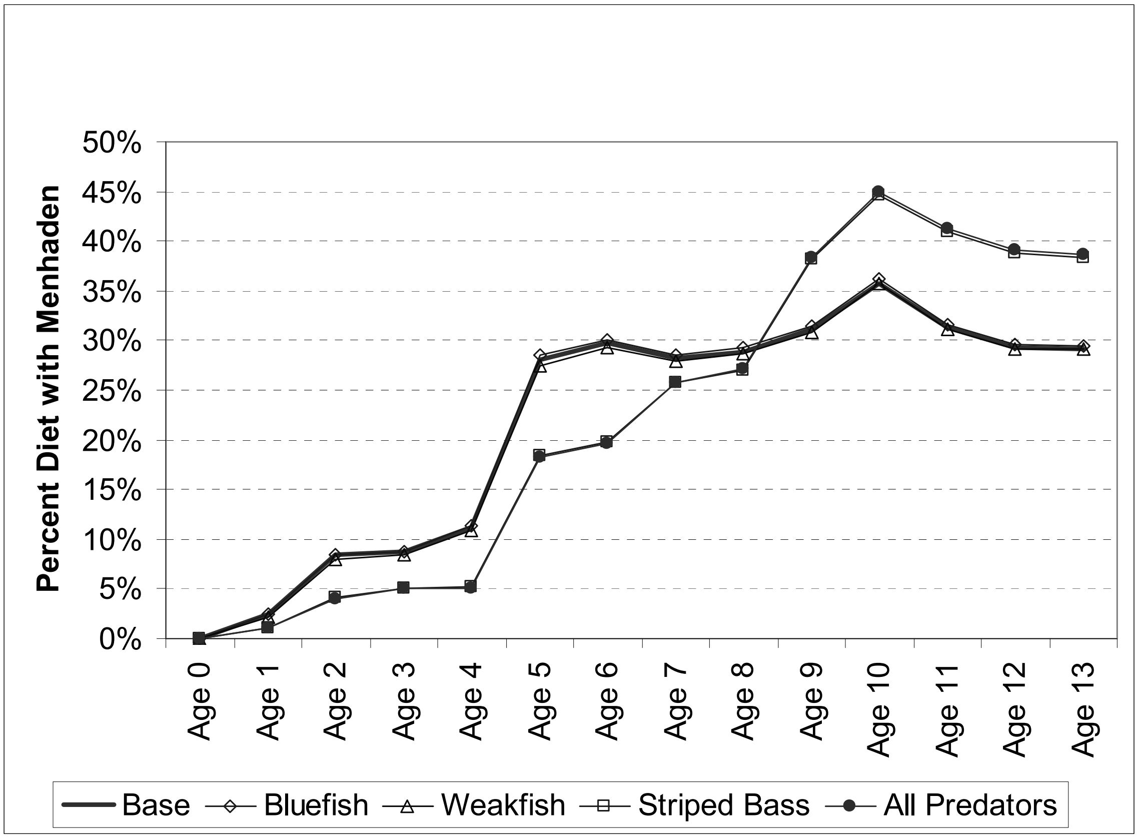


Figure D1.56. Menhaden in diet of striped bass (fish and invertebrate equal weighting).

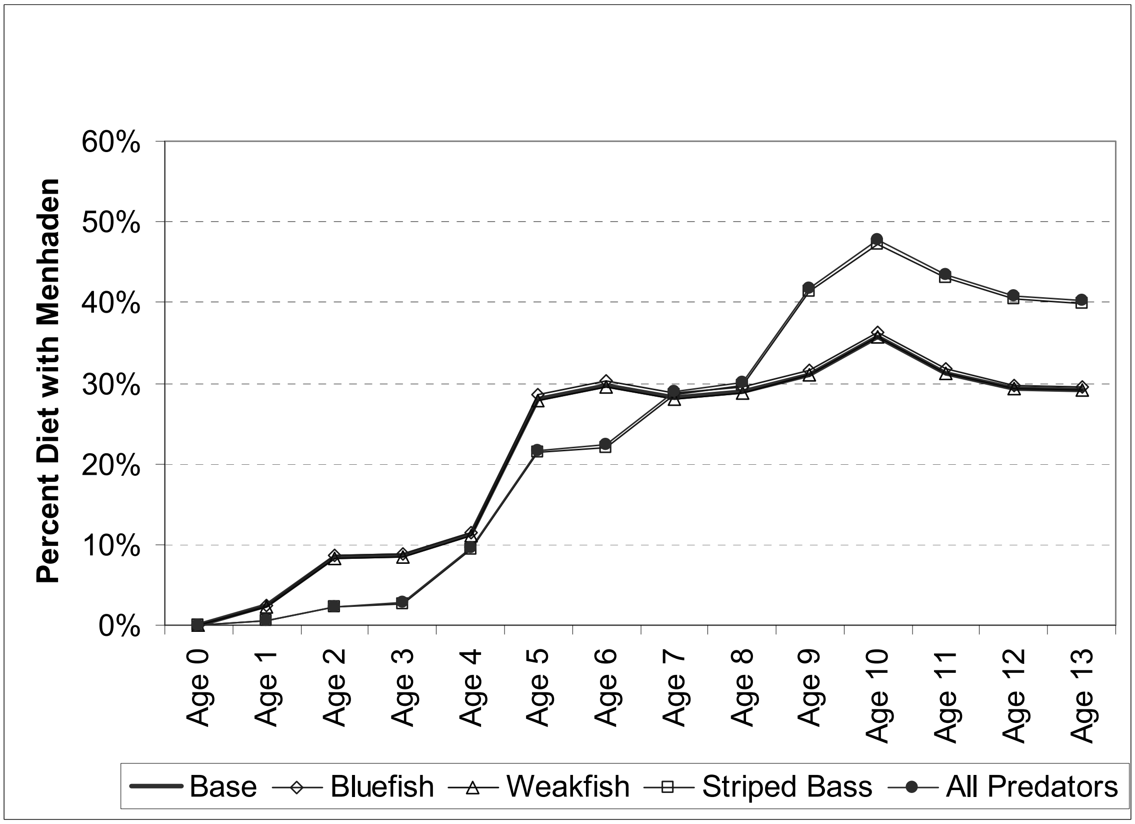


Figure D1.57. Menhaden in diet of weakfish (equal weighting).

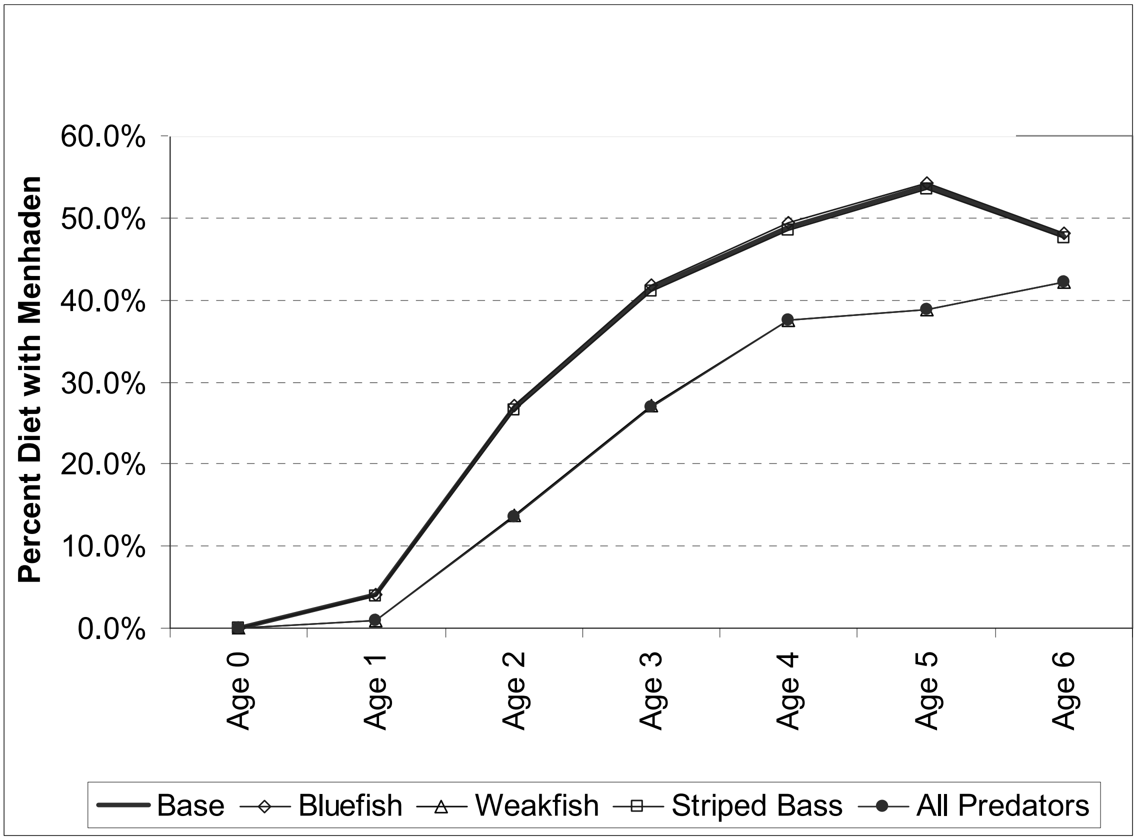


Figure D1.58. Menhaden in diet of weakfish (fish and invertebrate equal weighting).

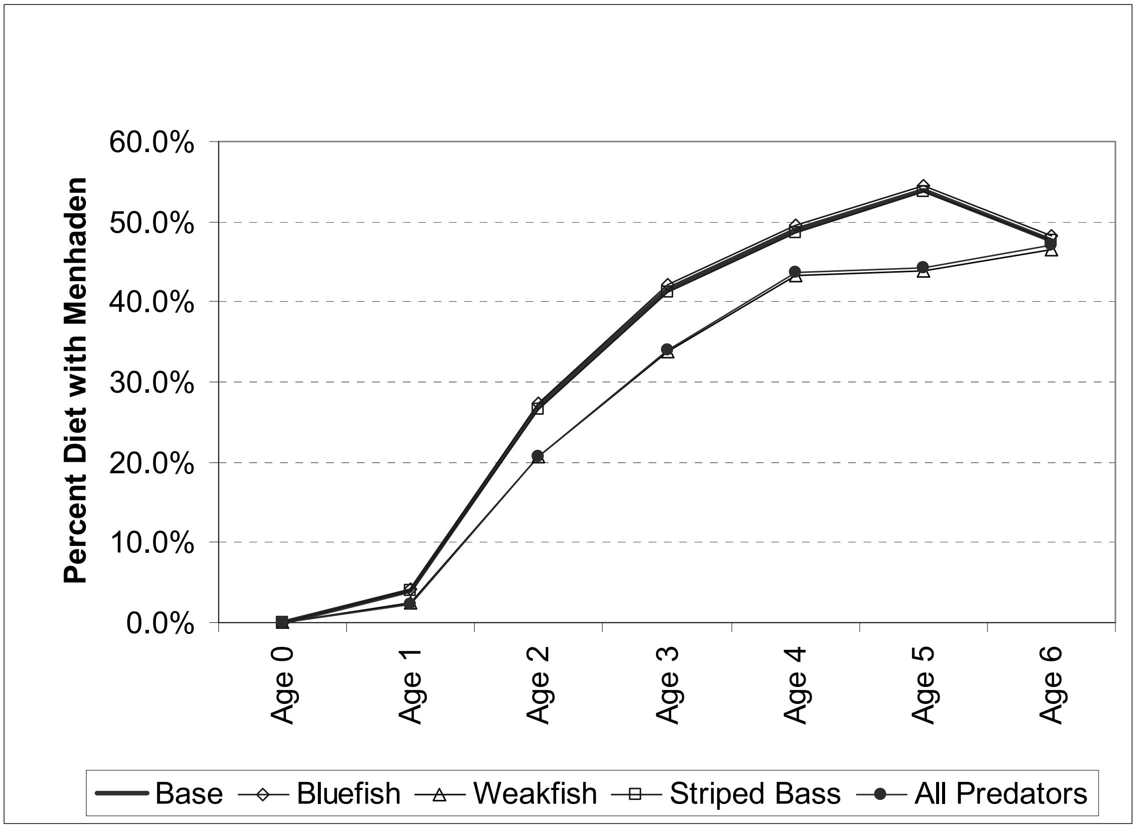


Figure D1.59. Menhaden in diet of bluefish (equal weighting).

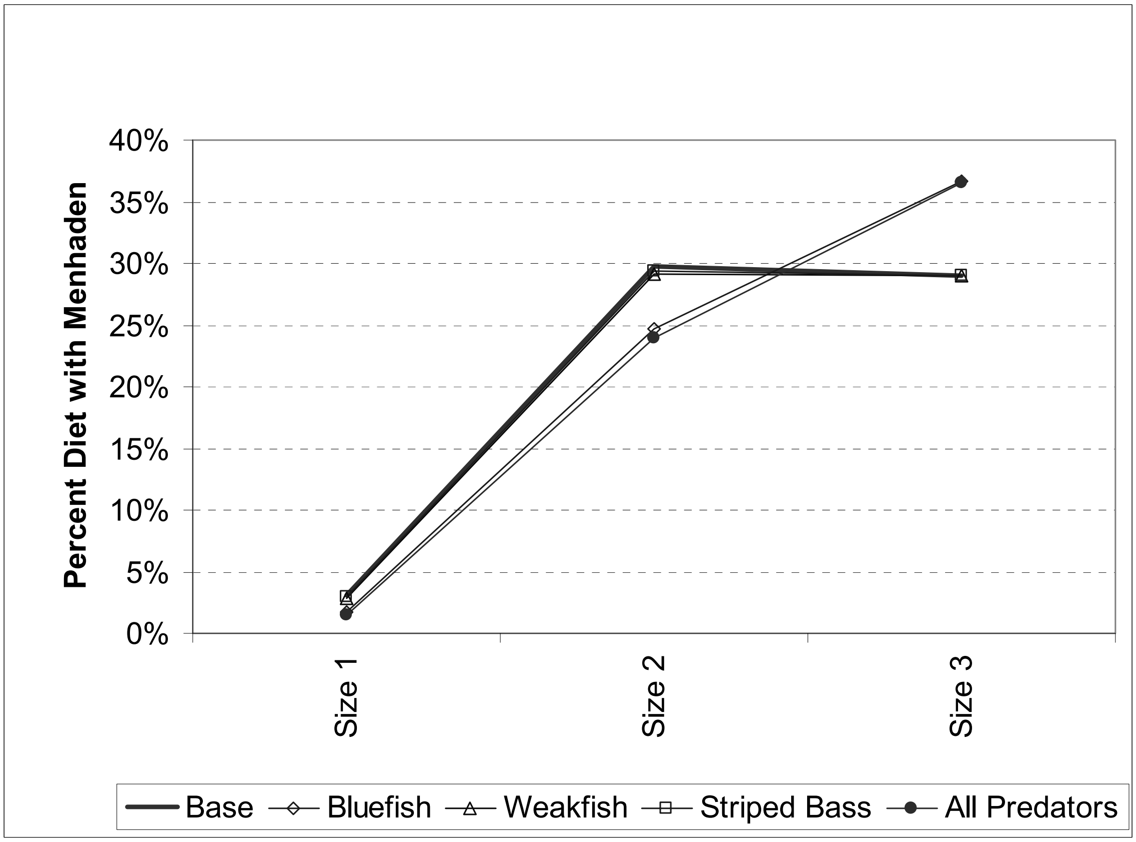


Figure D1.60. Menhaden in diet of bluefish (fish and invertebrate equal weighting).

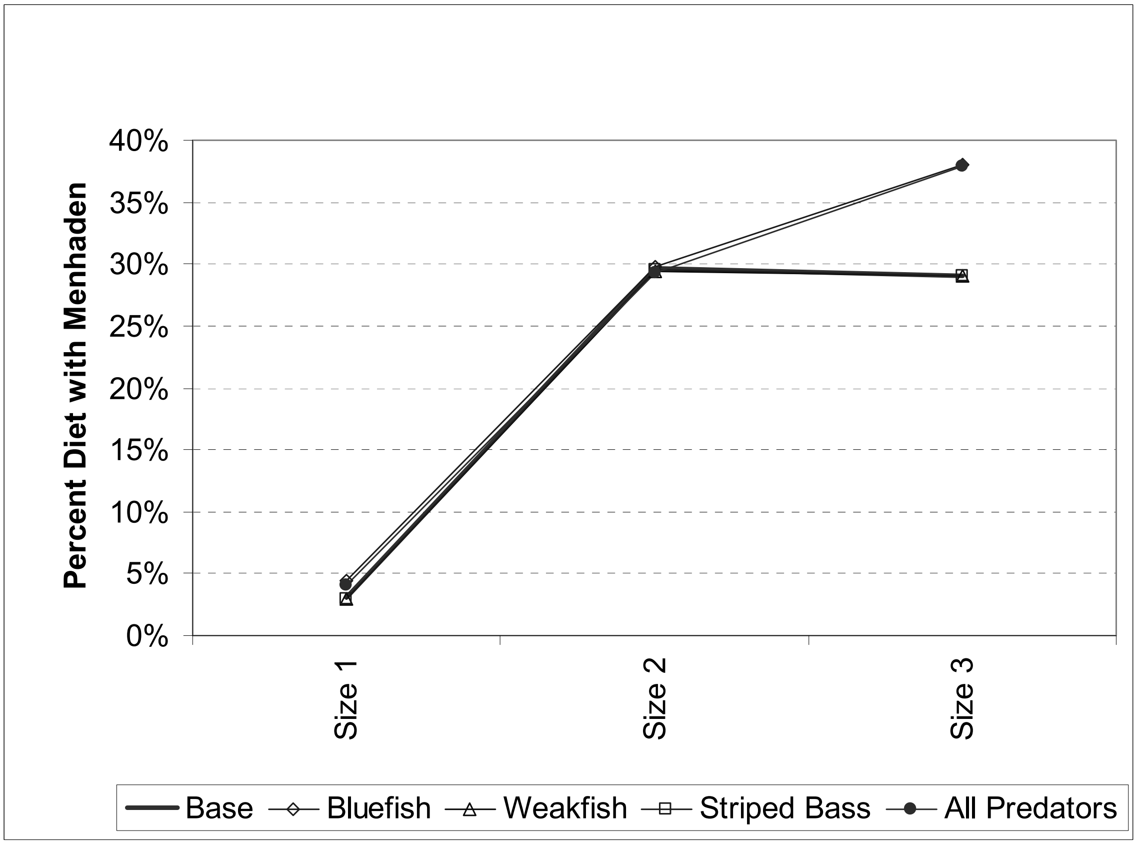


Figure D1.61. Consumption of menhaden by striped bass (equal preferences).

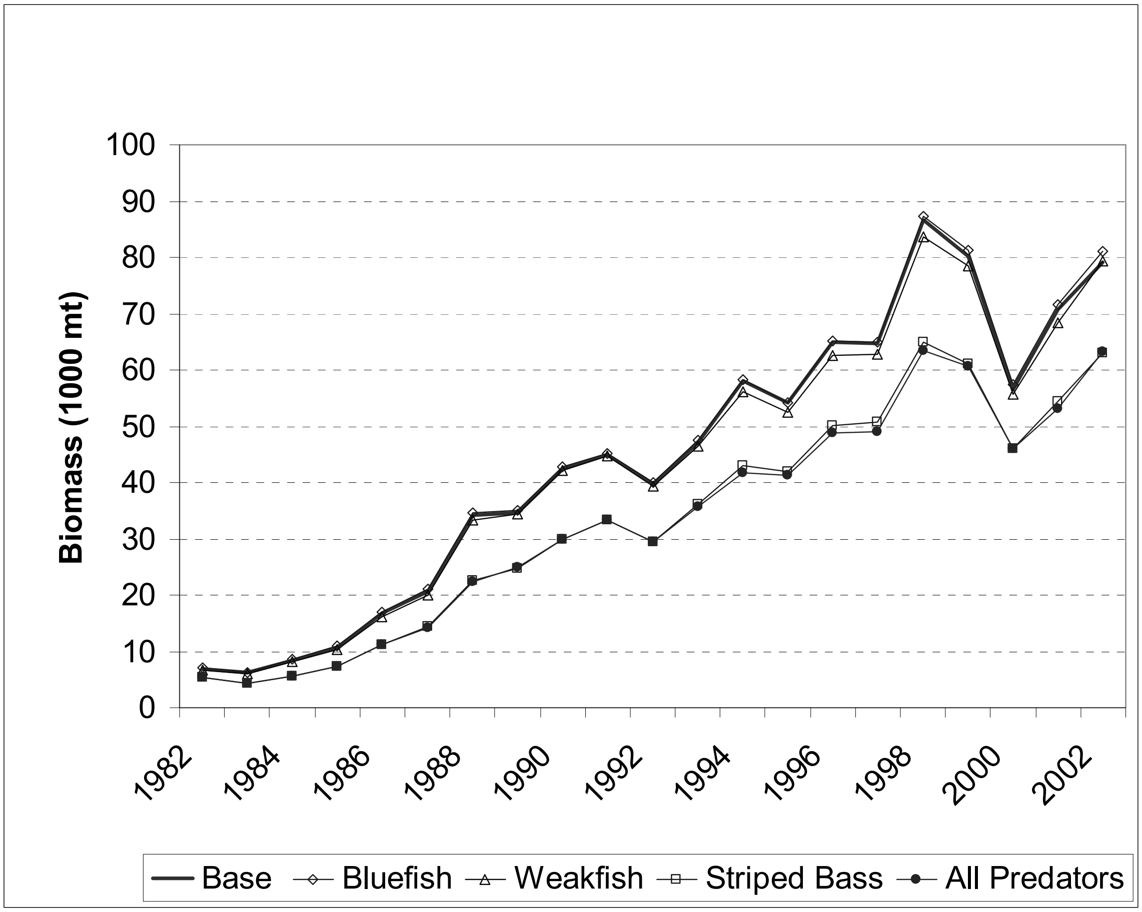


Figure D1.62. Consumption of menhaden by striped bass (fish and invertebrates equal preferences).

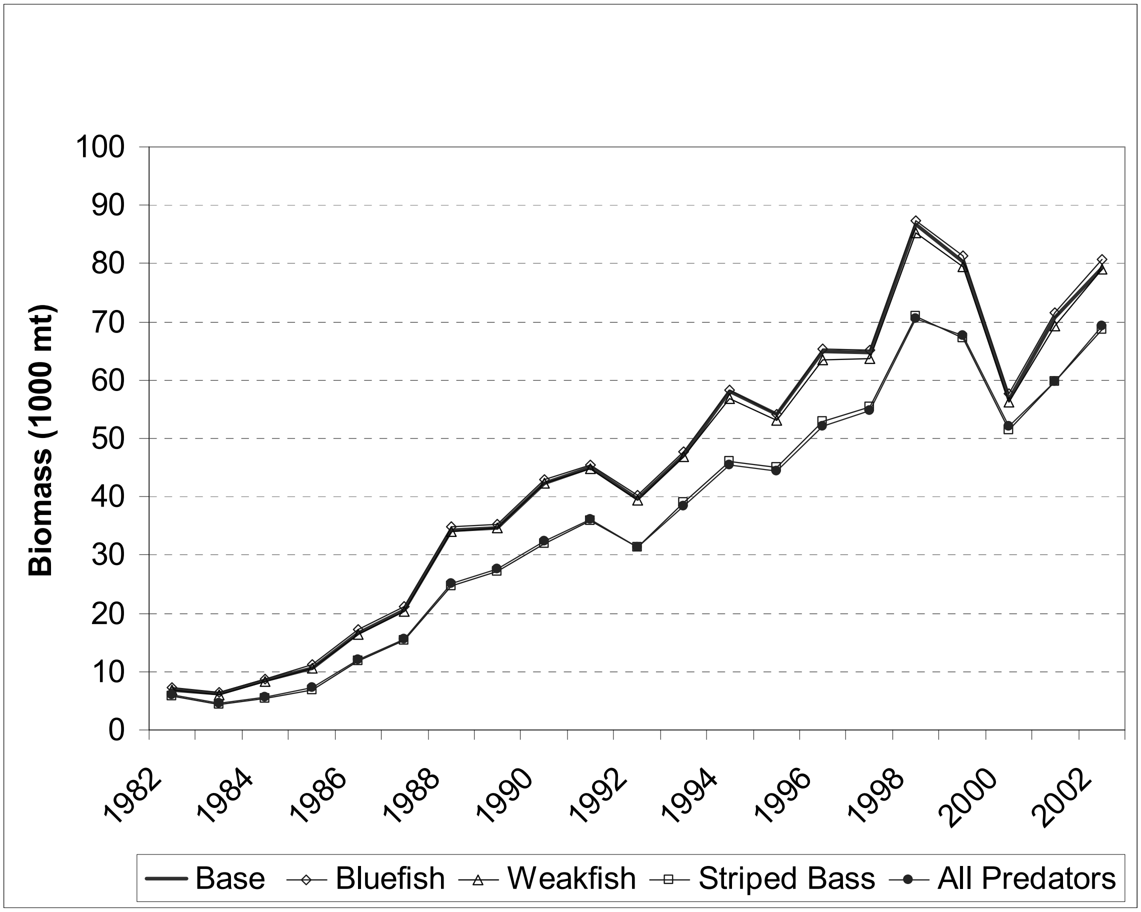


Figure D1.63. Consumption of menhaden by weakfish (equal preferences).

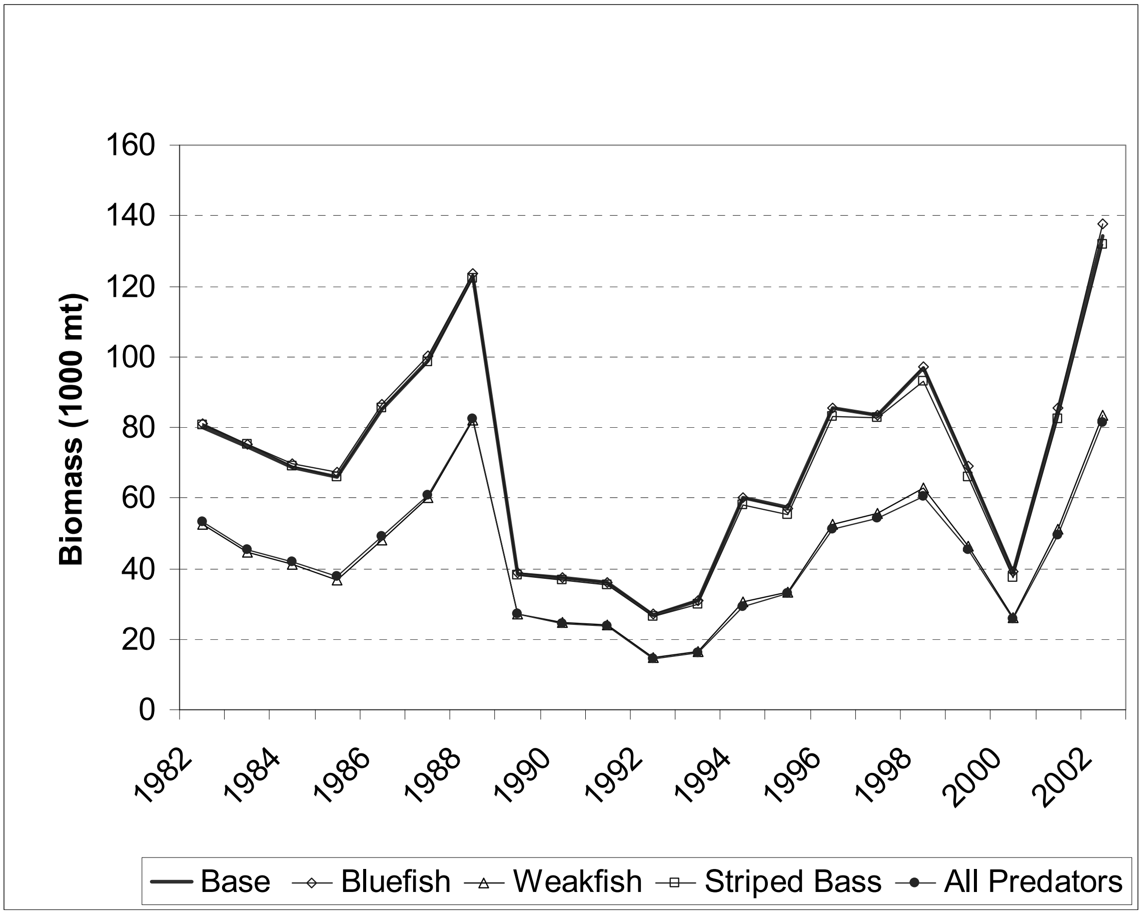


Figure D1.64. Consumption of menhaden by weakfish (fish and invertebrates equal preferences).

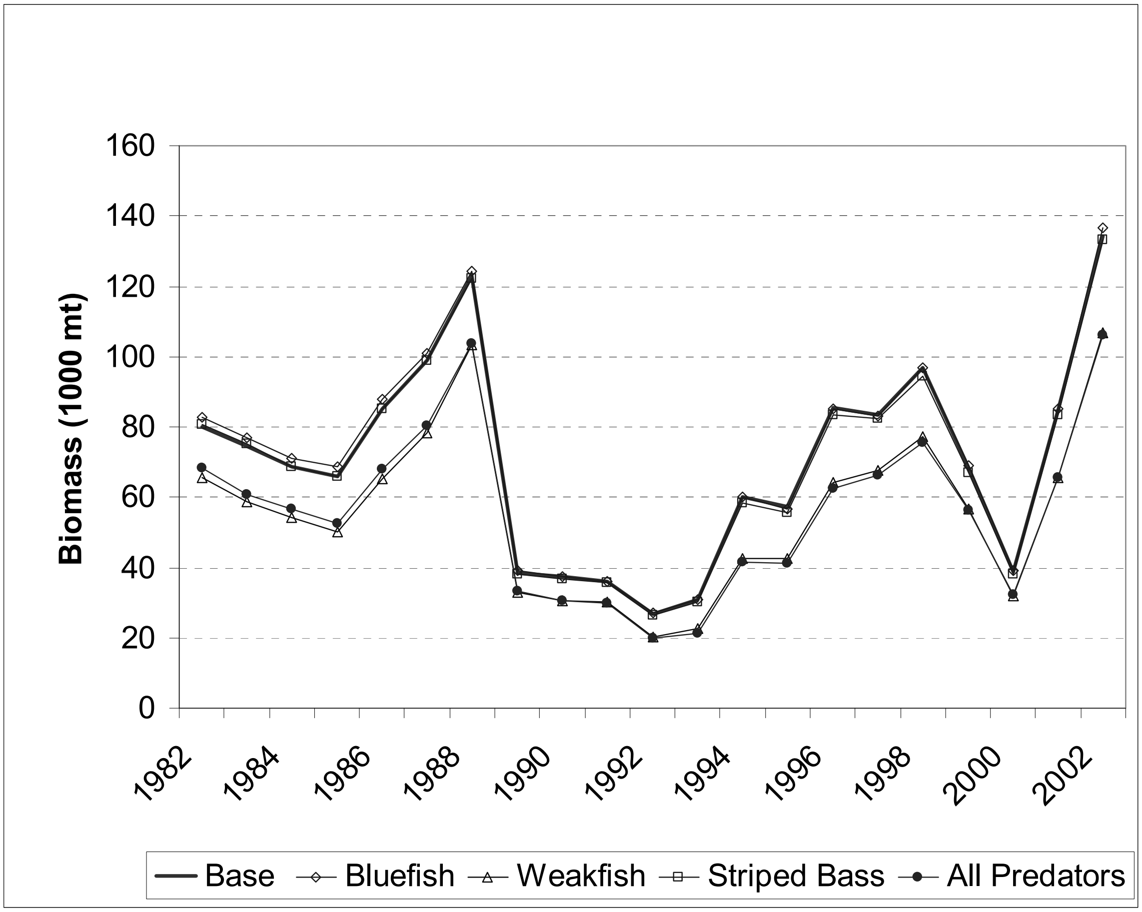


Figure D1.65. Consumption of menhaden by bluefish (equal preferences).

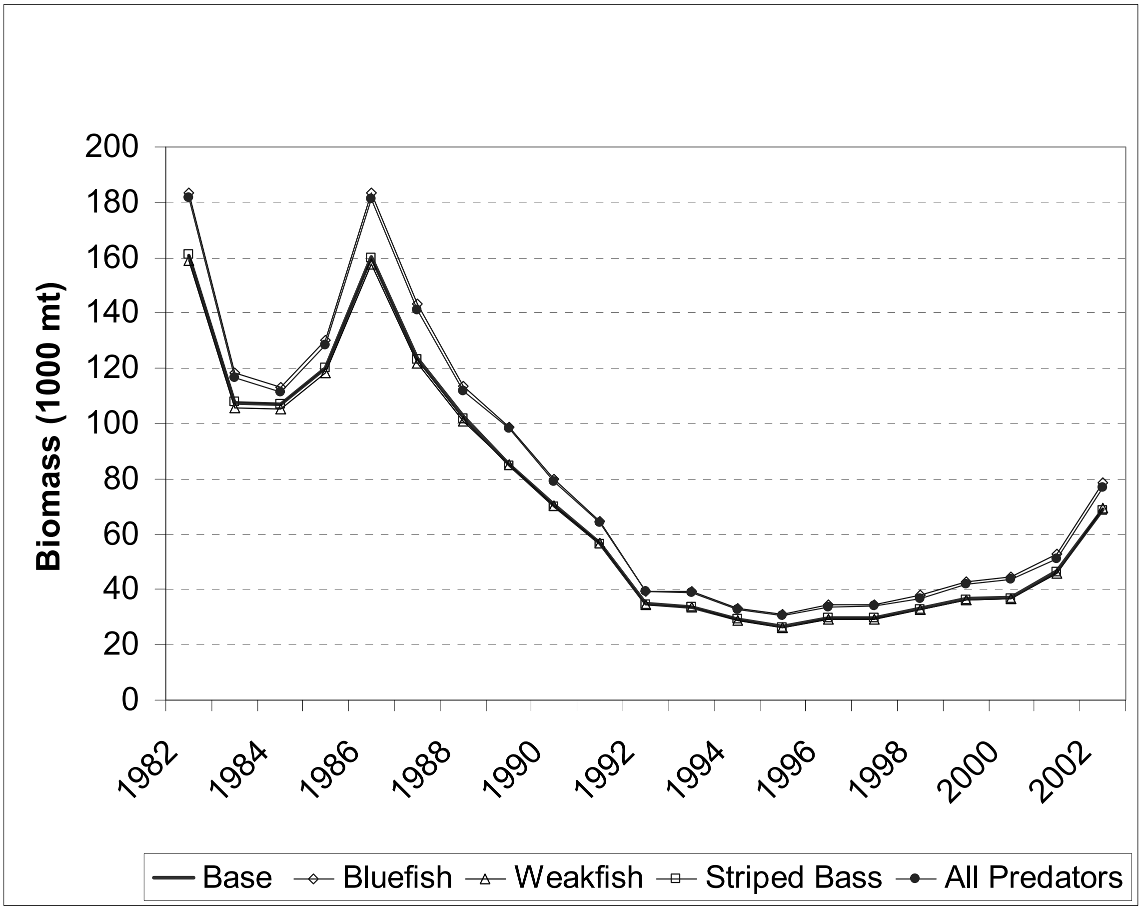


Figure D1.66. Consumption of menhaden by bluefish (fish and invertebrates equal preferences).

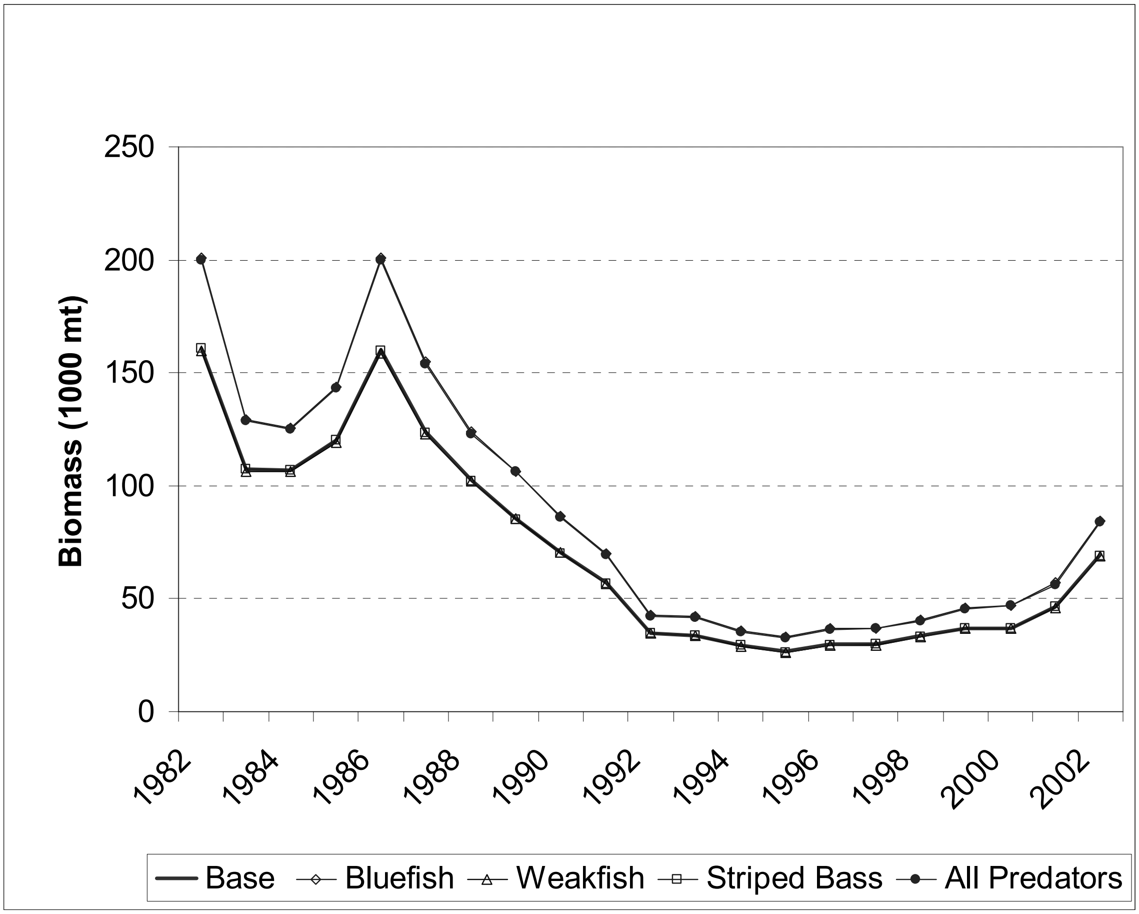


Figure D1.67. Total consumption (000 mt) of prey by striped bass for the base run configuration, which employed average weight-at-age over time and the alternate run employing the observed or variable weight-at-age over time.

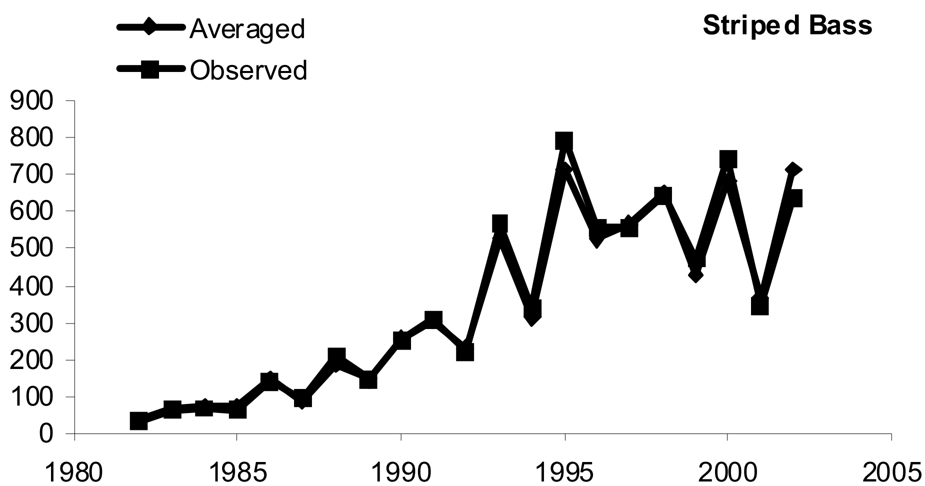


Figure D1.68. Total consumption (000 mt) of prey by weakfish for the base run configuration, which employed average weight-at-age over time and the alternate run employing the observed or variable weight-at-age over time.

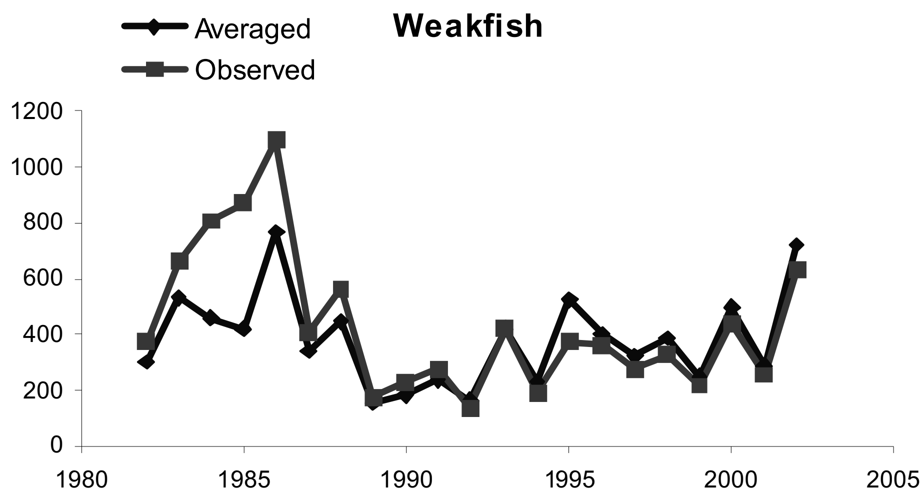


Figure D1.69. Total consumption (000 mt) of menhaden by striped bass for the base run configuration, which employed average weight-at-age over time and the alternate run employing the observed or variable weight-at-age over time.

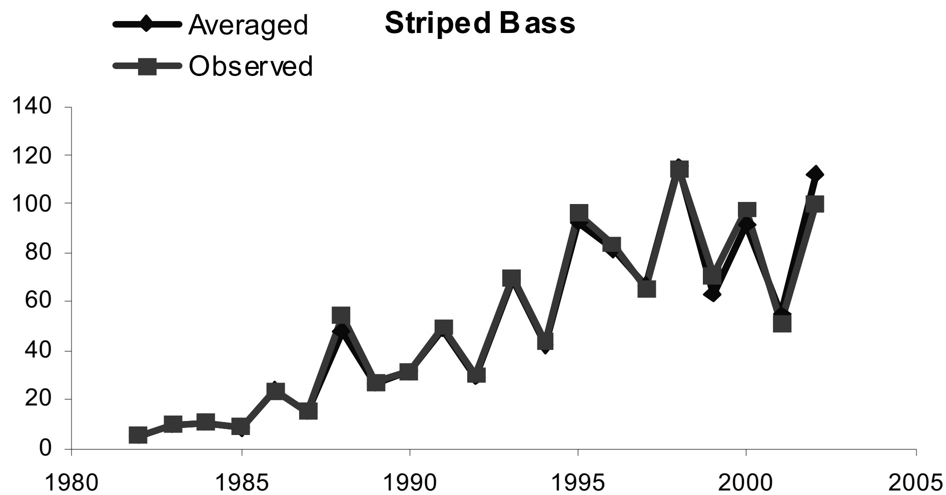


Figure D1.70. Total consumption (000 mt) of menhaden by weakfish for the base run configuration, which employed average weight-at-age over time and the alternate run employing the observed or variable weight-at-age over time.

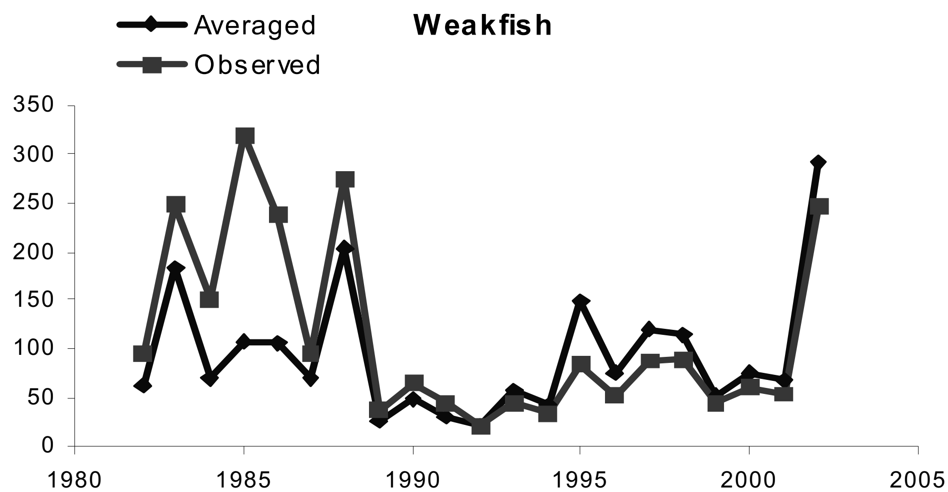


Figure D1.71. Predation mortality (M2) of menhaden by striped bass calculated based on variable (observed) weight-at-age and based on constant weight-at-age.

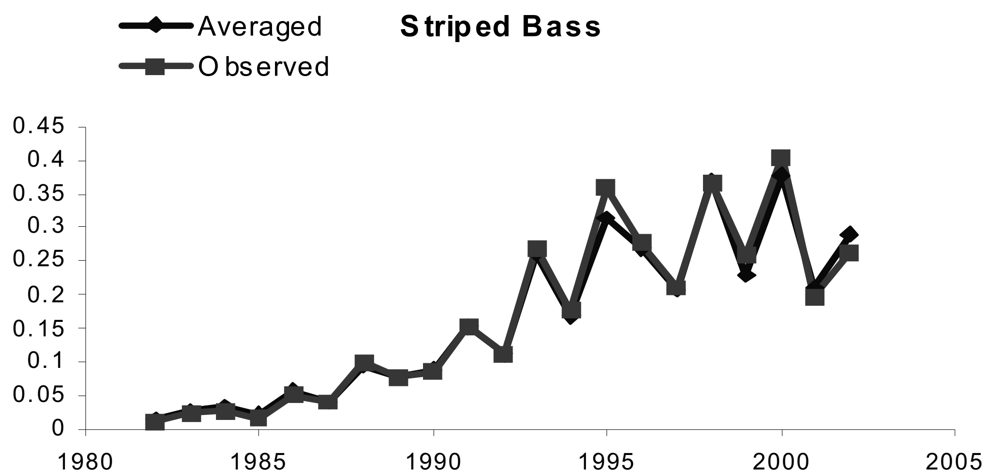


Figure D1.72. Predation mortality (M2) of menhaden by weakfish calculated based on variable (observed) weight-at-age and based on constant weight-at-age

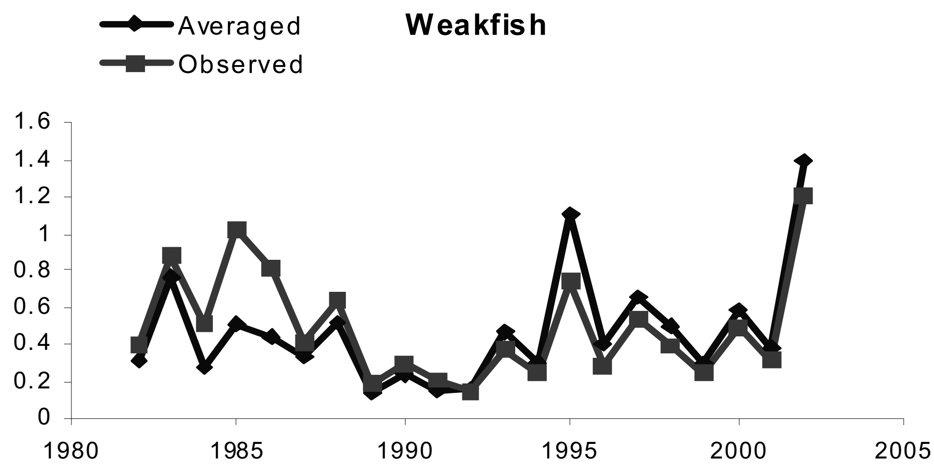
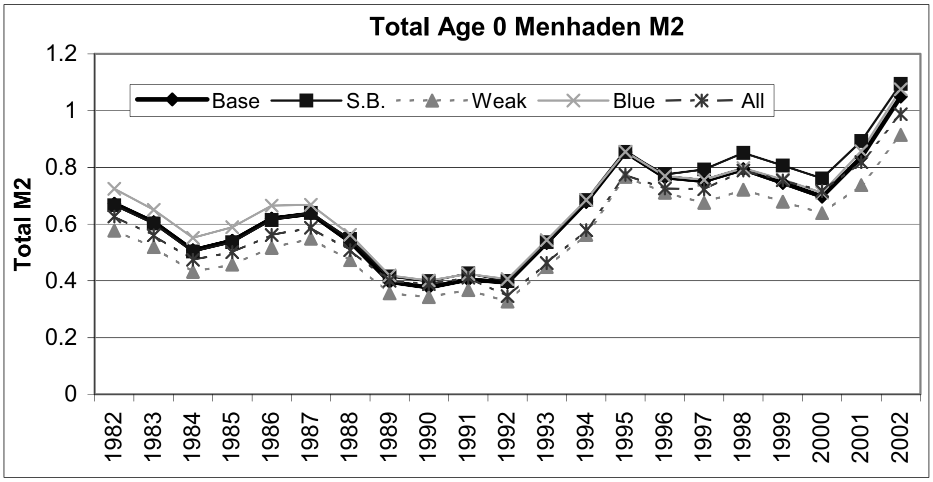
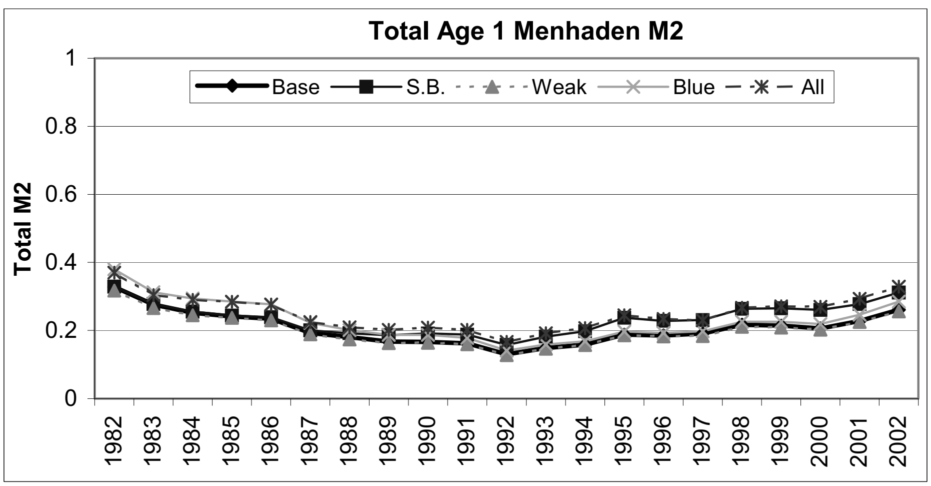


Figure D1.73a - c. Annual total menhaden predation mortality for the different predator runs. See Table D1.14 for explanation of model runs.

a.)



b.)



c.)

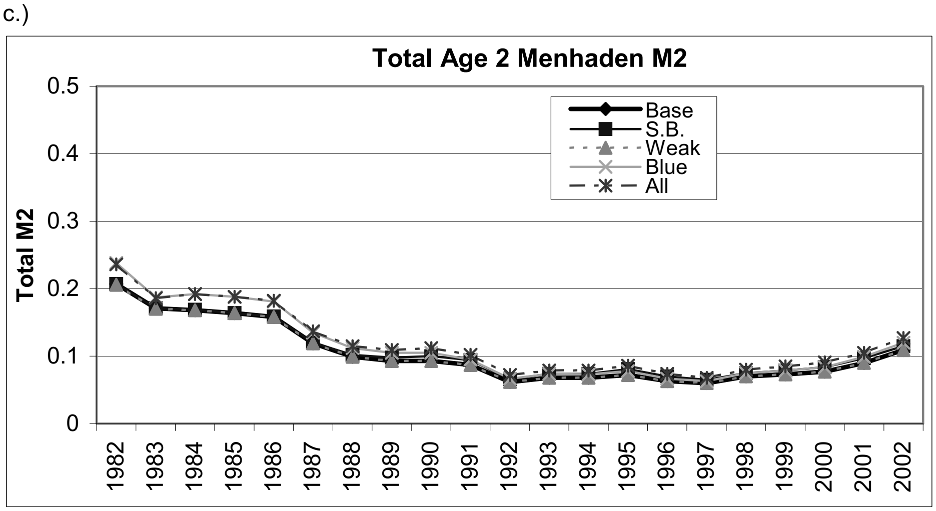
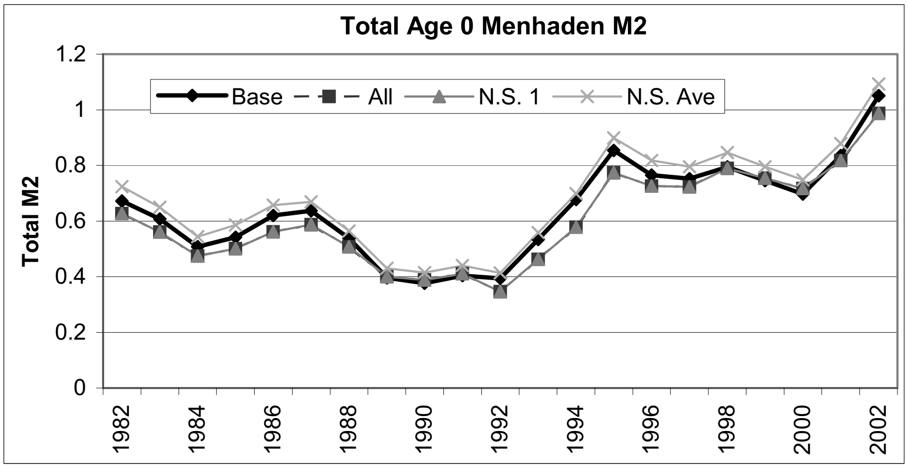
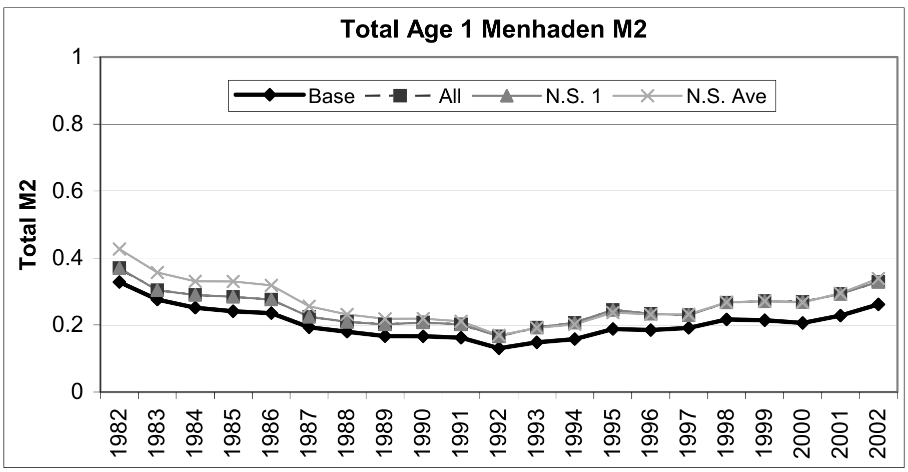


Figure D1.74a - c. Annual total Menhaden predation mortality for the different seasonal runs. See Table D1.14 for explanation of model runs.

a.)



b.)



c.)

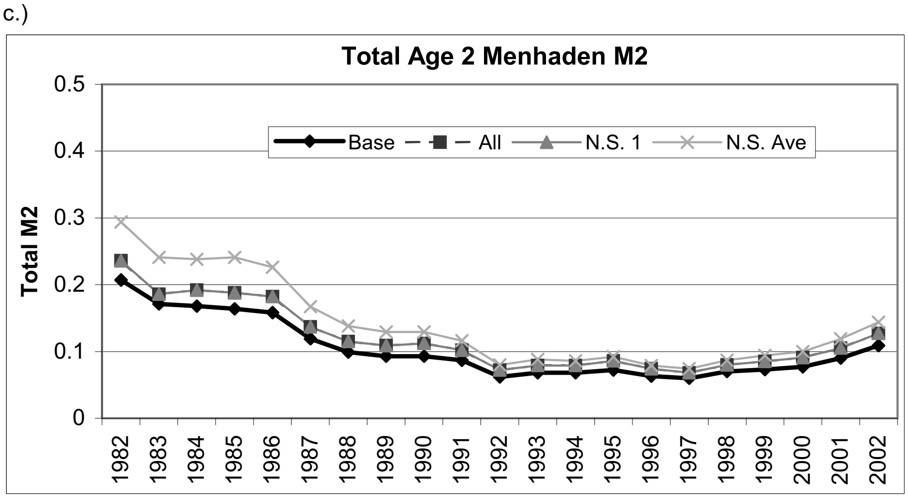
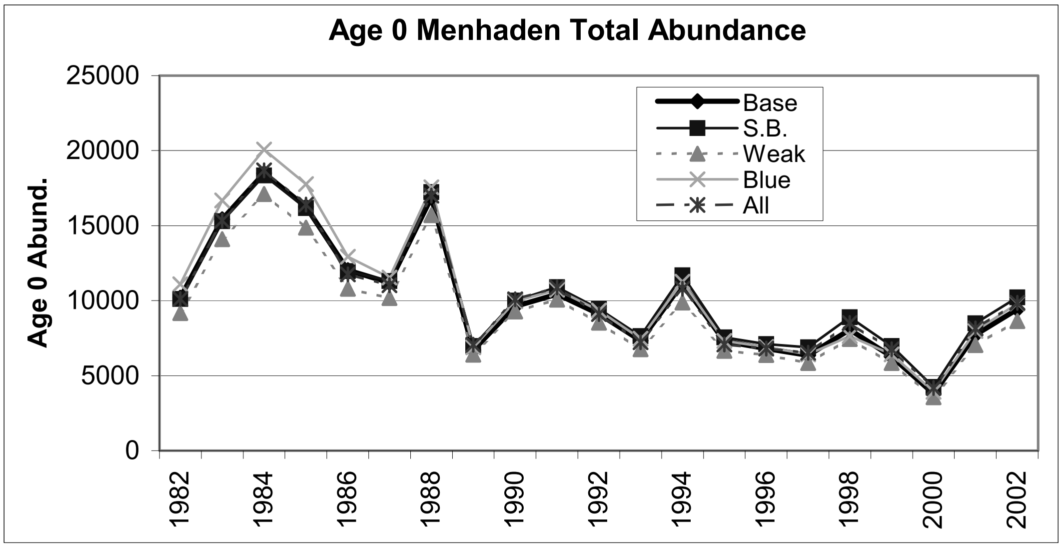


Figure D1.75a - b. Total menhaden abundance (millions of fish) by age for the different Predator runs.

a.)



b.)

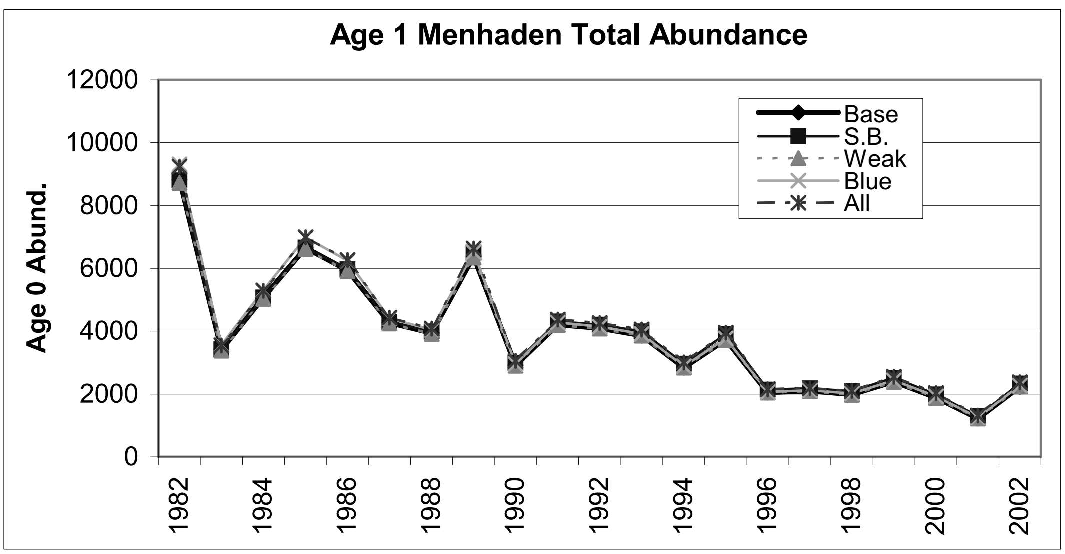
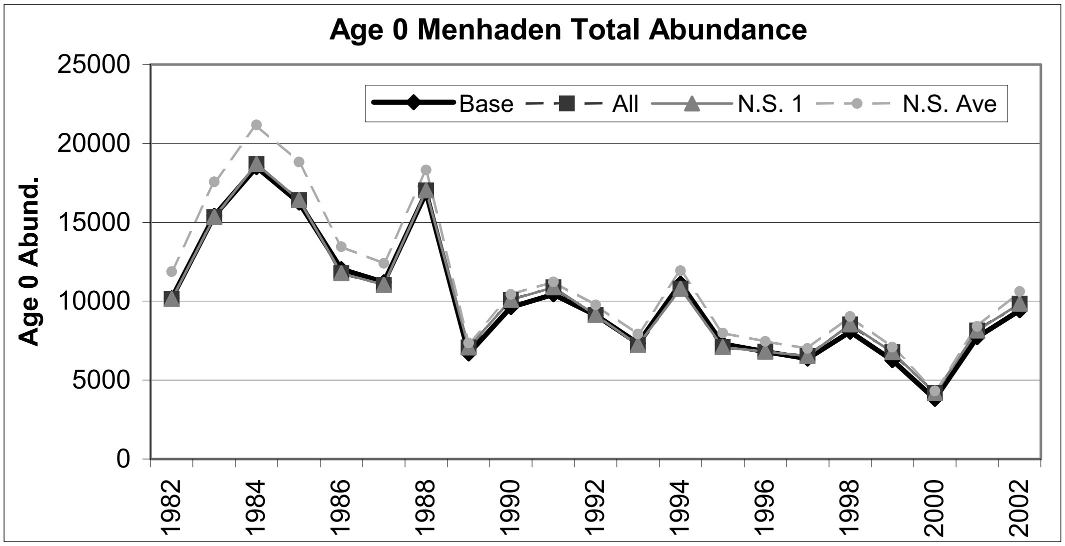


Figure D1.76. Total menhaden abundance (millions of fish) by age for the different Seasonal runs

a.)



b.)

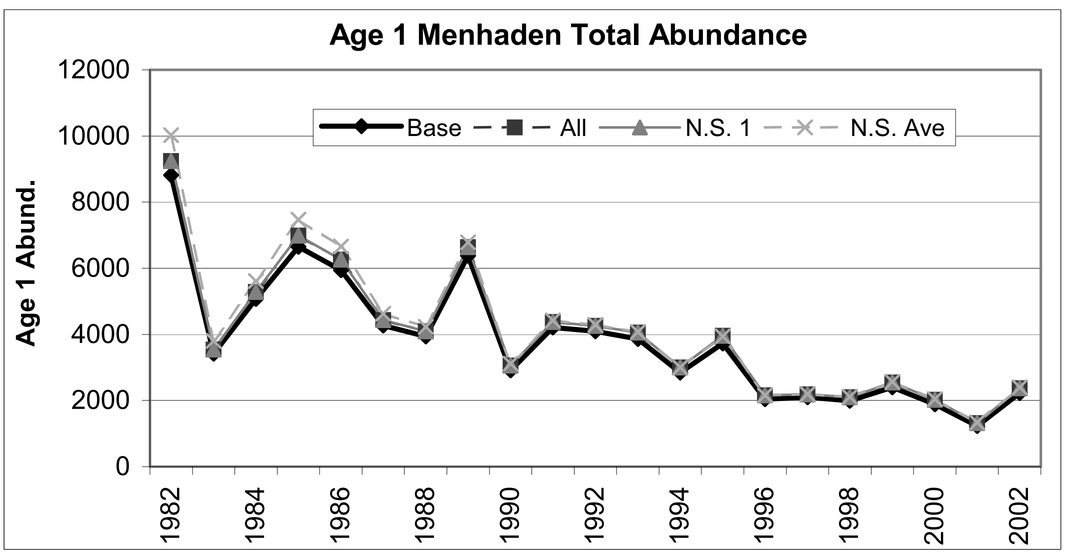
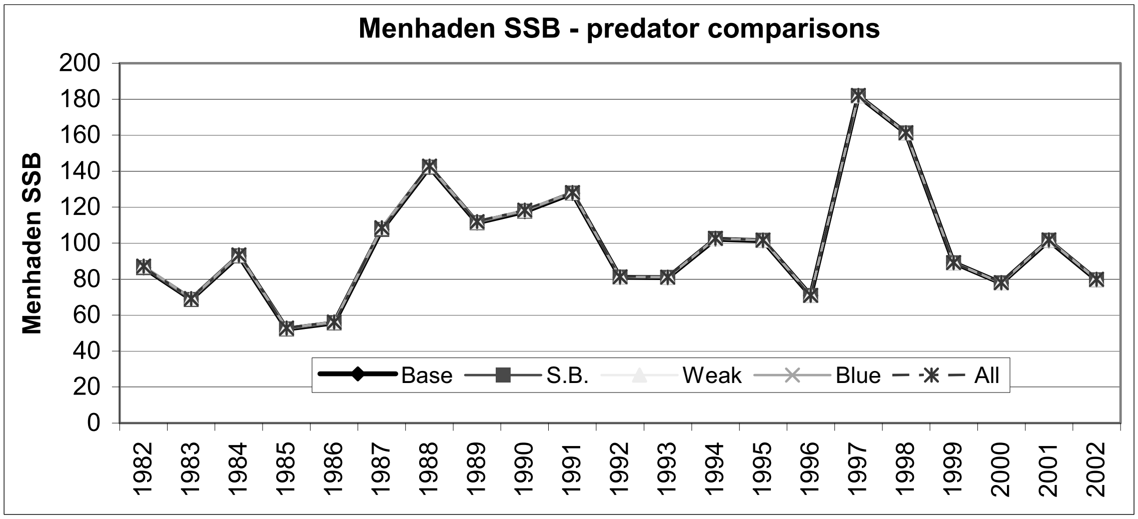


Figure D1.77. Annual menhaden spawning stock biomass (SSB in 000 mt) a.) Predator runs b.) Seasonal runs.

a.)



b.)

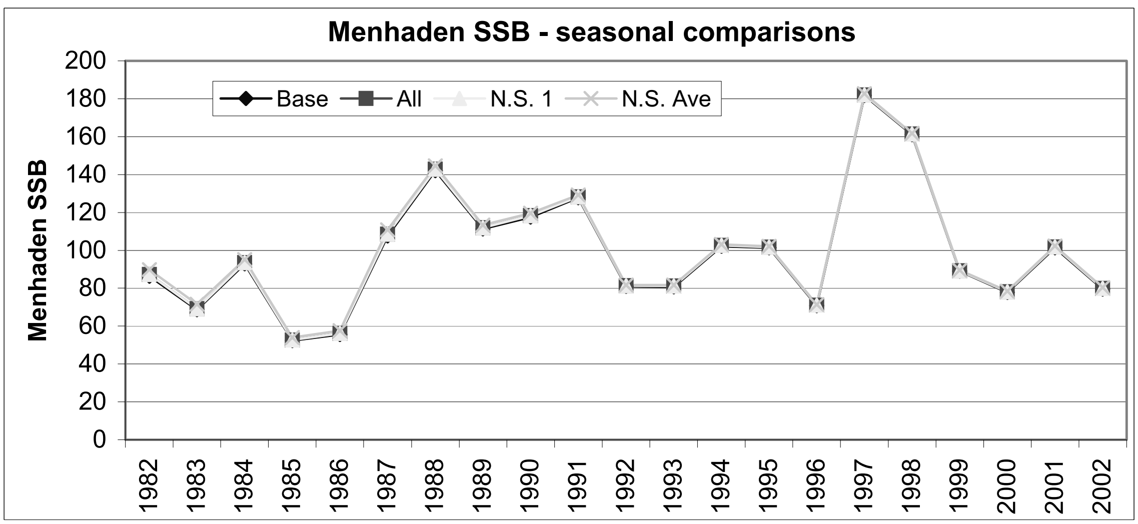
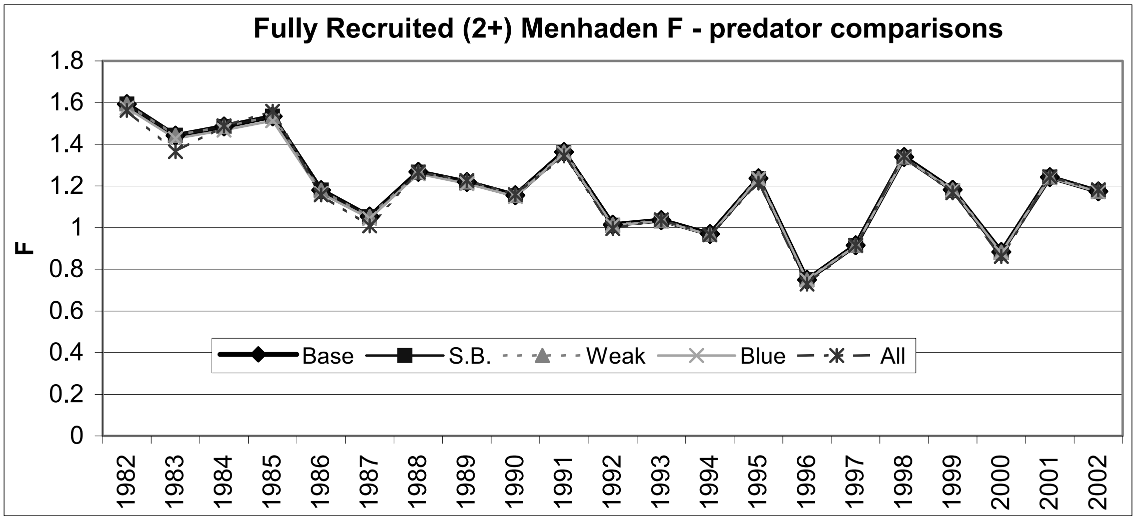


Figure D1.78a - b. Annual menhaden fully recruited (2+) fishing mortality (F) a.) Predator runs b.) Seasonal.

a.)



b.)

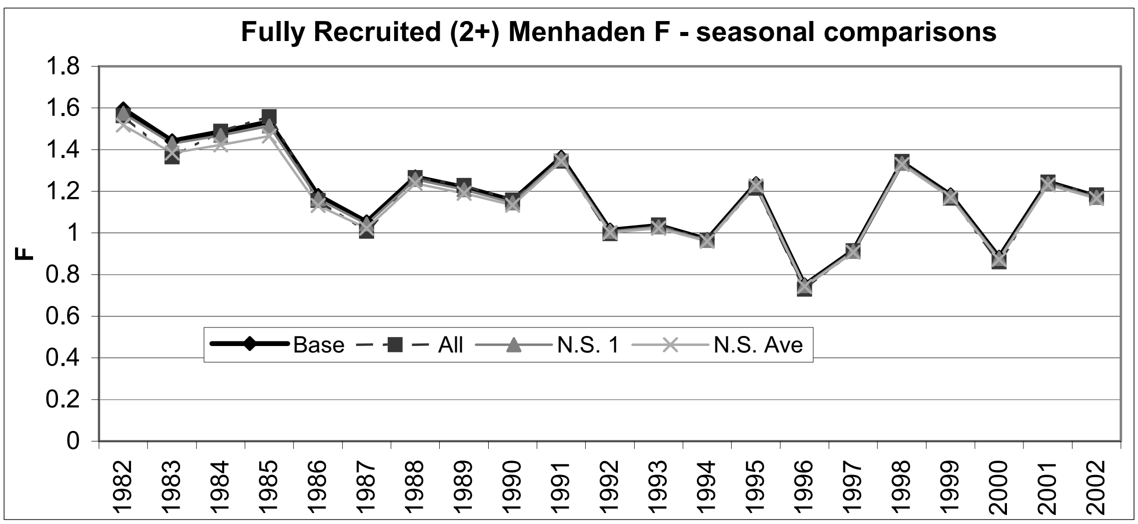


Figure D1.79a - f. The relative change in the proportion of a particular prey item in the diet of each predator by age ((sensitivity run prop./base run prop.) -1)). Figures a – c compare the Weak run to the Base and figures d - f compare the All predator run to the Base.

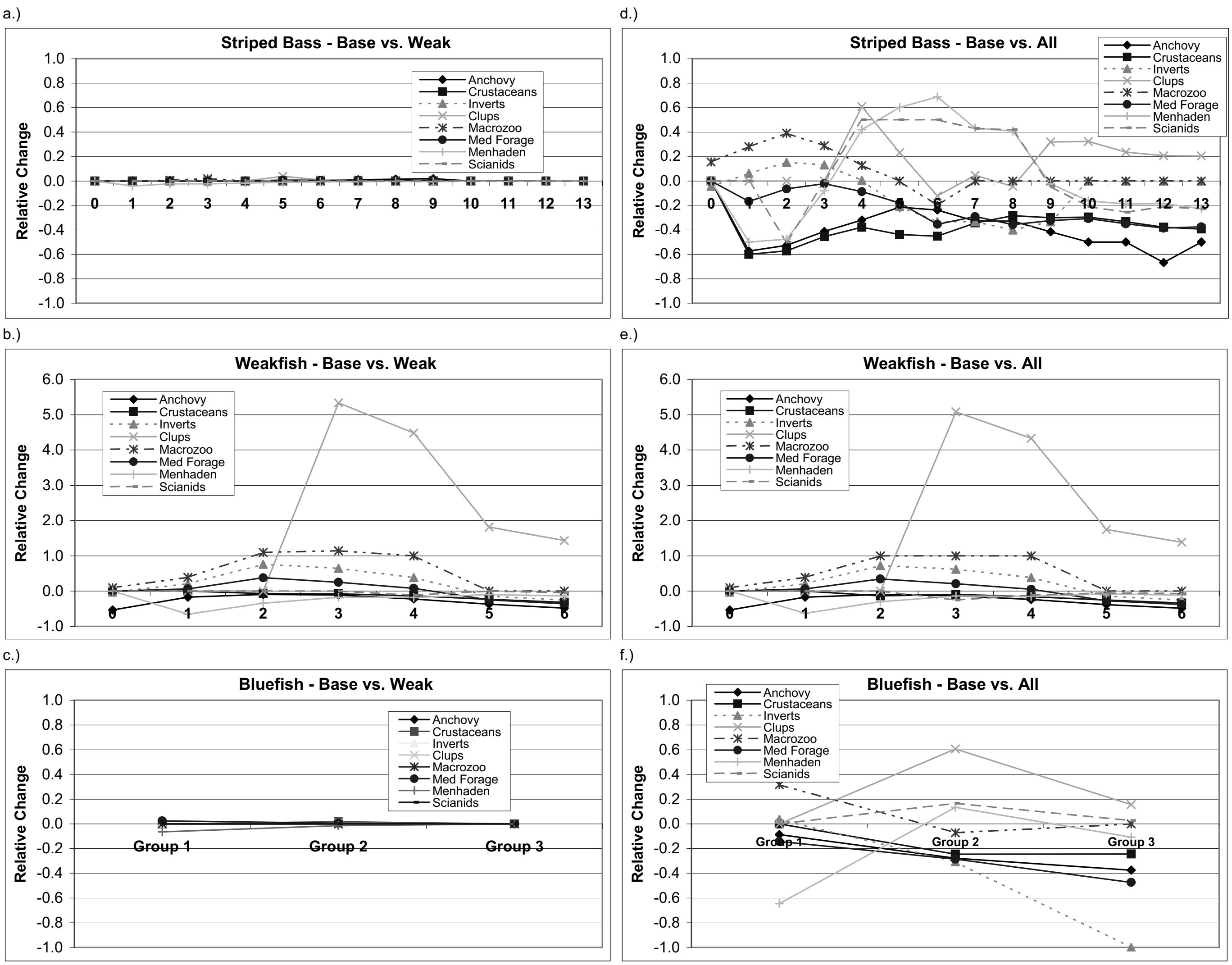


Figure D1.80a - c. Average proportion of prey, for a few key species, in diet by predator and age. Figures compare Predator runs for the Base, the model run where that specific predator spatial overlap was = to 1, and where all predators overlap was equal to 1 - a.) striped bass b.) weakfish c.) bluefish.

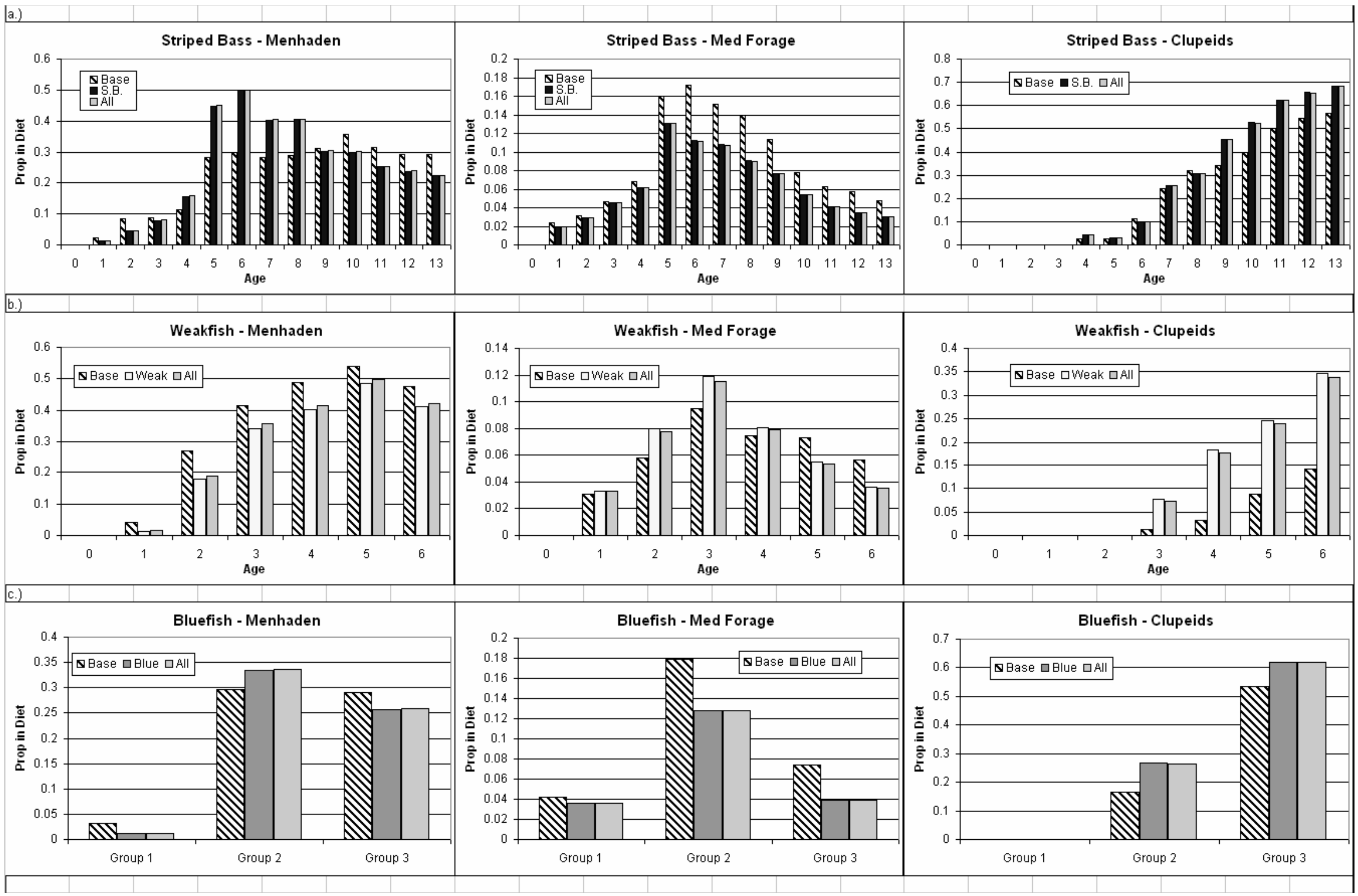


Figure D1.81a - c. Total consumption (biomass, 1000 mt) by year and by each predator for a few key prey species for each Predator run - a.) striped bass b.) weakfish c.) bluefish.

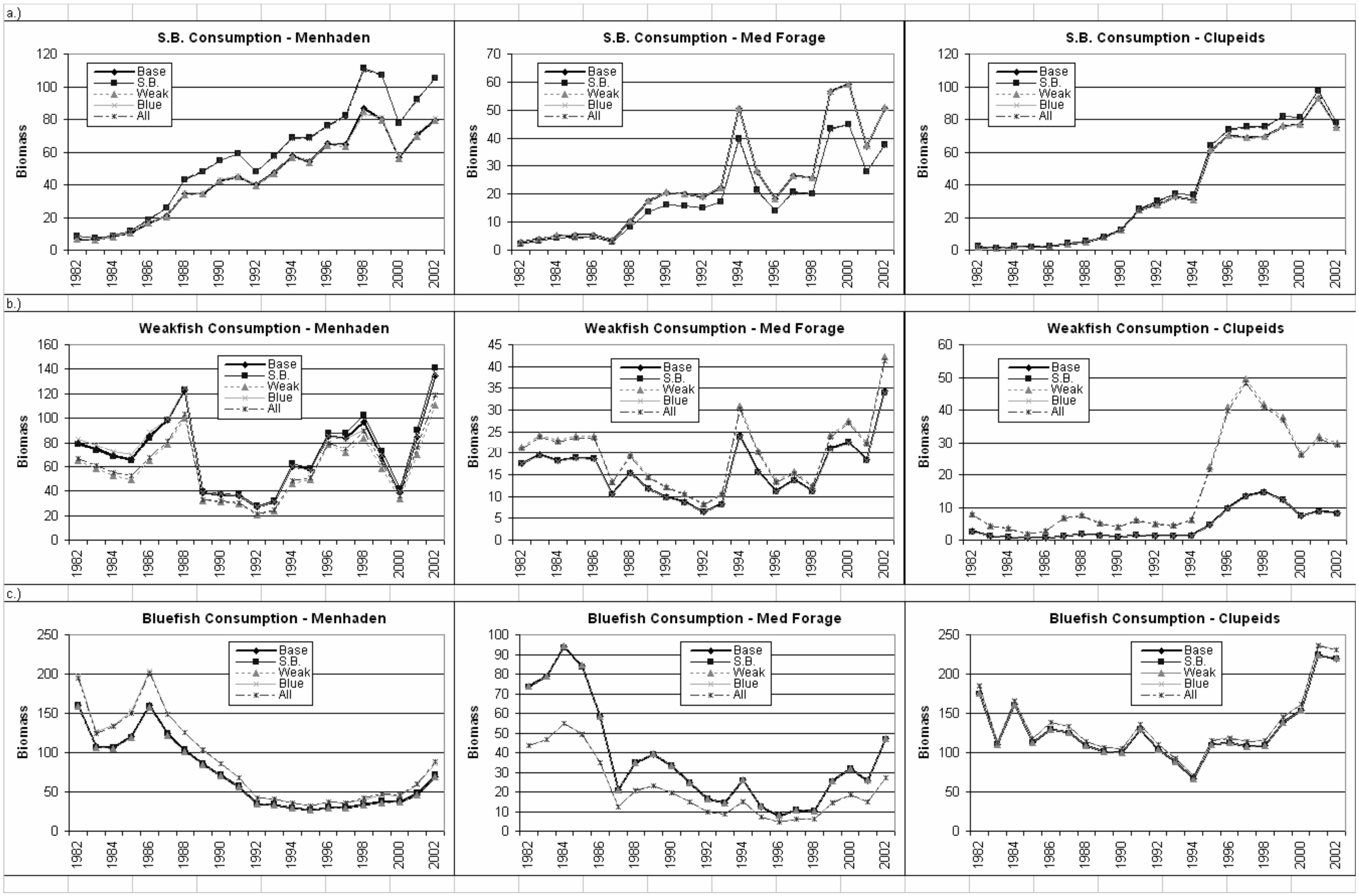
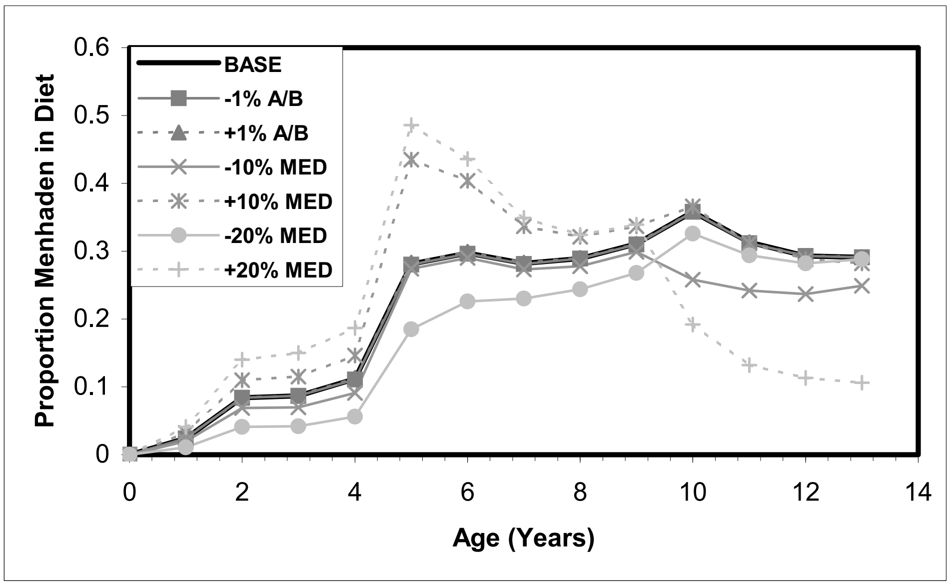


Figure D1.82. Average proportion of menhaden in striped bass (a), weakfish (b) and bluefish (c) diets by year. Results are shown for the base run, two scenarios in which the size selectivity curve parameters α and βwere changed by ± 1%, and four scenarios in which the median size of prey selected for each predator was shifted by ± 10% and ± 20%.

a)



b)

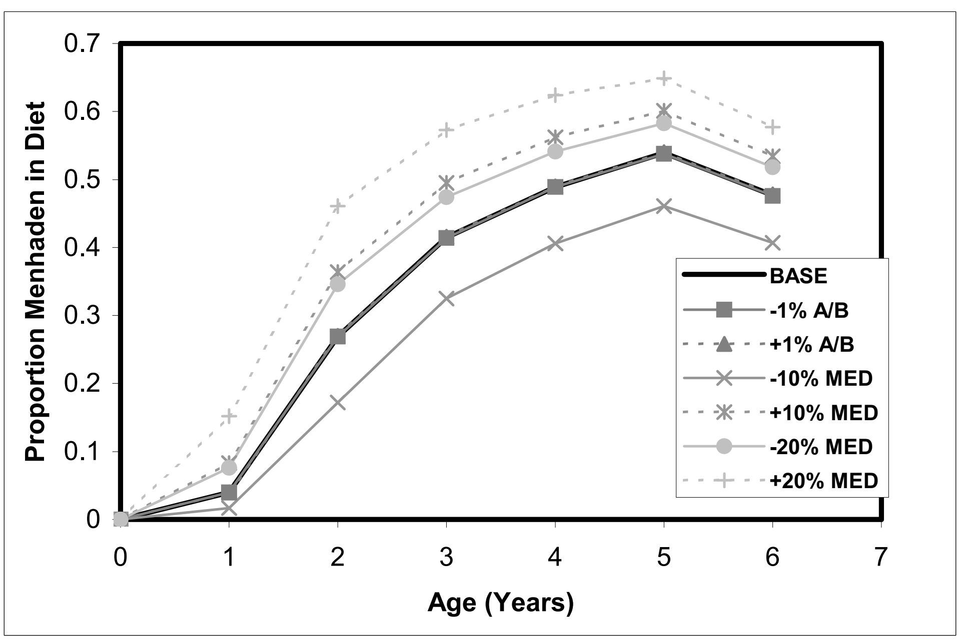


Figure D1.82 (Cont'd). Average proportion of menhaden in striped bass (a), weakfish (b) and bluefish (c) diets by year. Results are shown for the base run, two scenarios in which the size selectivity curve parameters α and βwere changed by ± 1%, and four scenarios in which the median size of prey selected for each predator was shifted by ± 10% and ± 20%.

c)

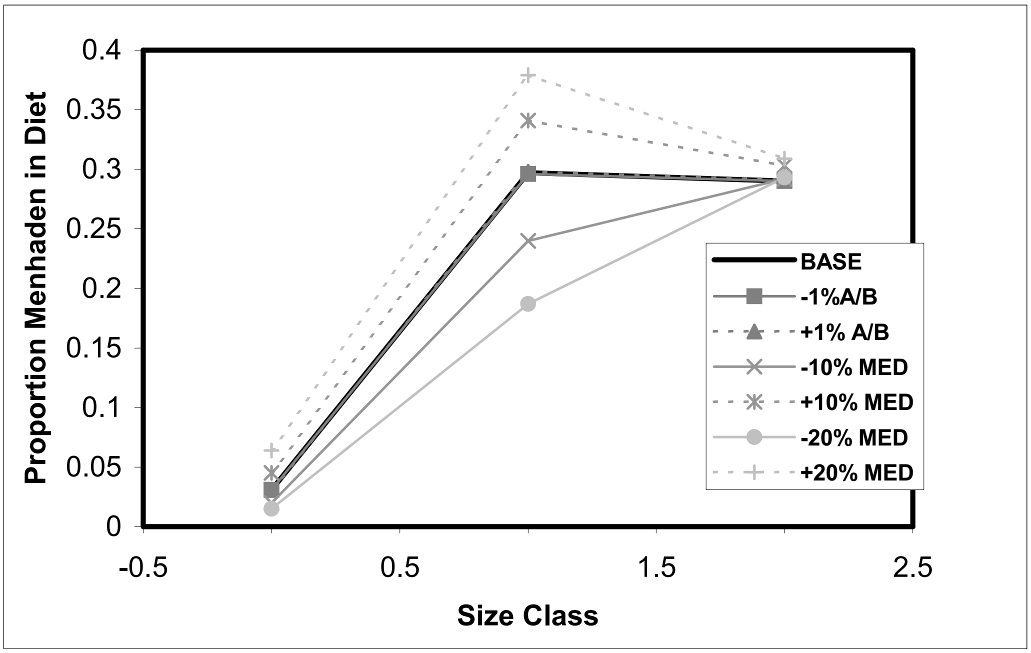
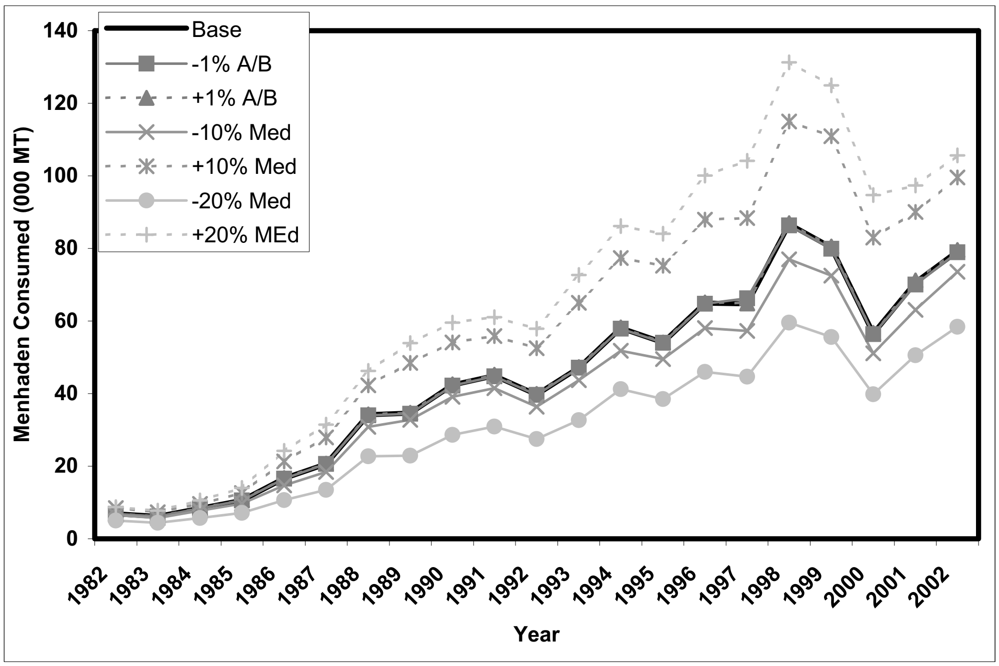


Figure D1.83. Total menhaden consumed in thousands of metric tons by striped bass (a), weakfish (b), and bluefish (c) by year. Results are shown for the base run, two scenarios in which the size selectivity curve parameters α and βwere changed by ± 1%, and four scenarios in which the median size of prey selected for each predator was shifted by ± 10% and ± 20%.

a)



b)

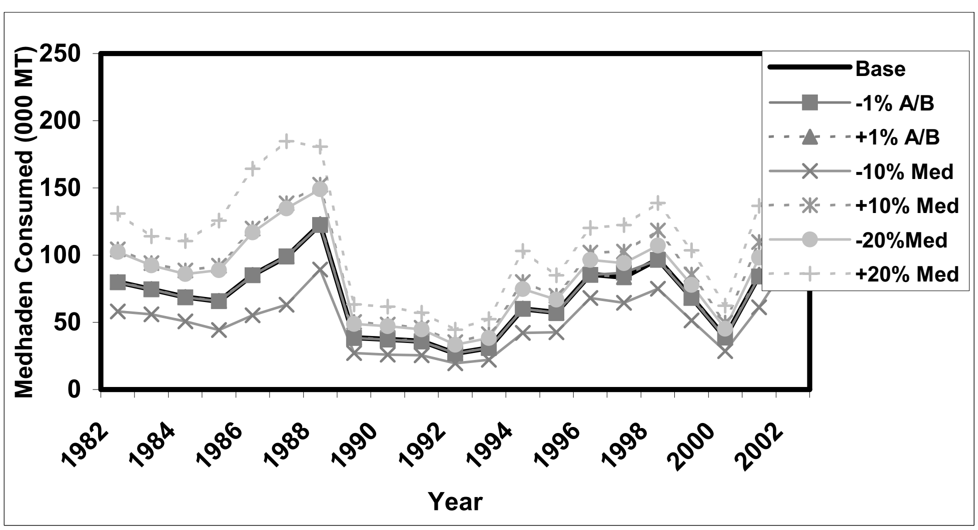


Figure D1.83 (Cont'd). Total menhaden consumed in thousands of metric tons by striped bass (a), weakfish (b), and bluefish (c) by year. Results are shown for the base run, two scenarios in which the size selectivity curve parameters α and βwere changed by ± 1%, and four scenarios in which the median size of prey selected for each predator was shifted by ± 10% and ± 20%.

c)

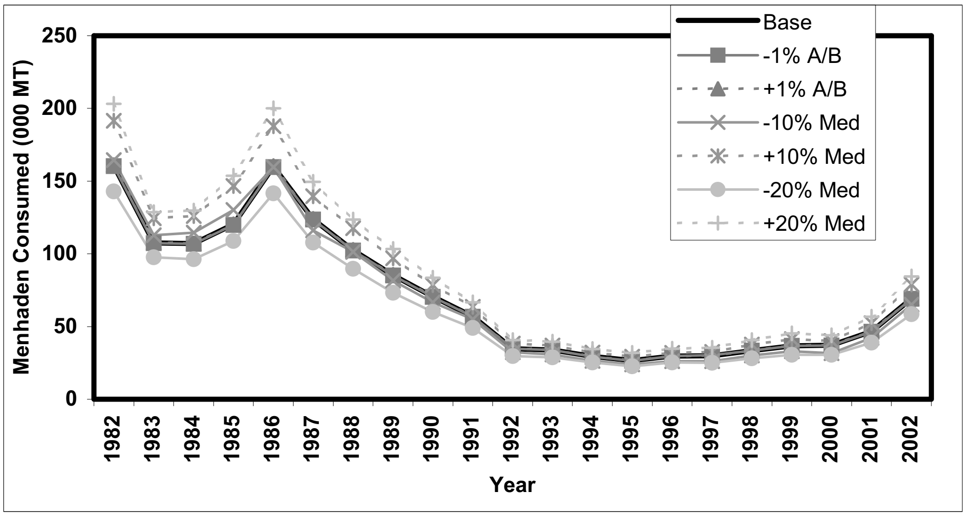
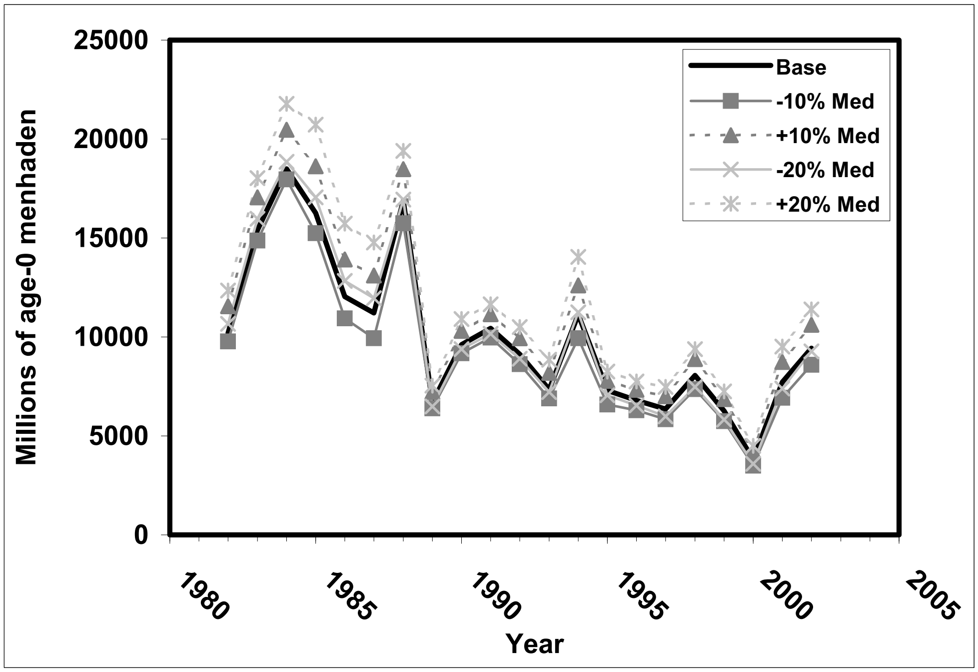


Figure D1.84 Age-0 (a), age-1 (b), and total abundance (c) of menhaden from the base run MSVPA and for four scenarios in which the median size of prey selected for each predator was shifted by ± 10% and ± 20%.

a)



b)

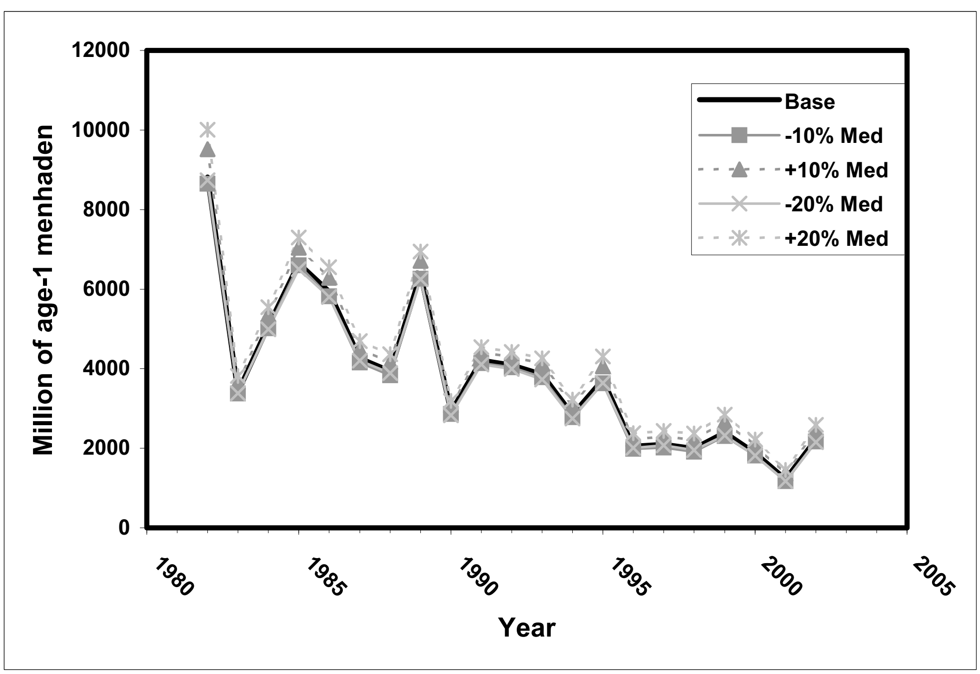


Figure D1.84 (Cont'd). Age-0 (a), age-1 (b), and total abundance (c) of menhaden from the base run MSVPA and for four scenarios in which the median size of prey selected for each predator was shifted by ± 10% and ± 20%.

c)

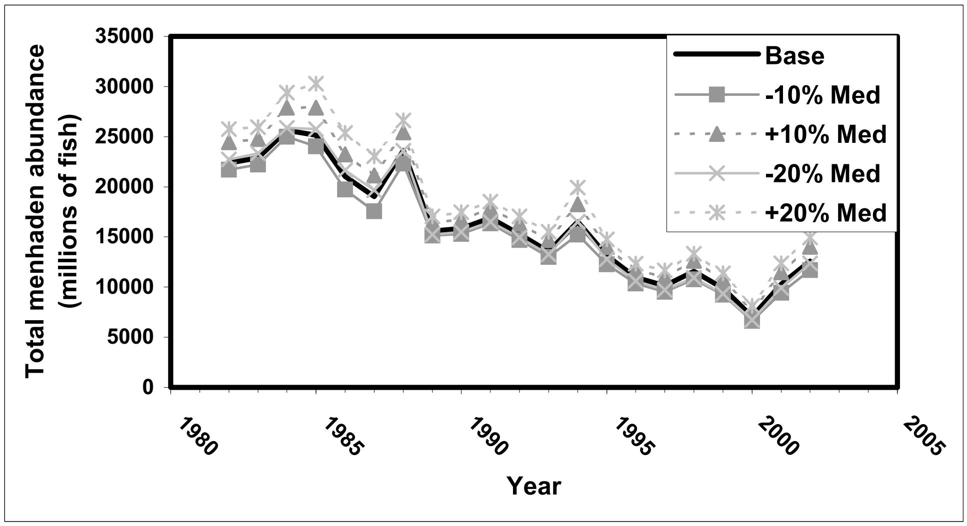
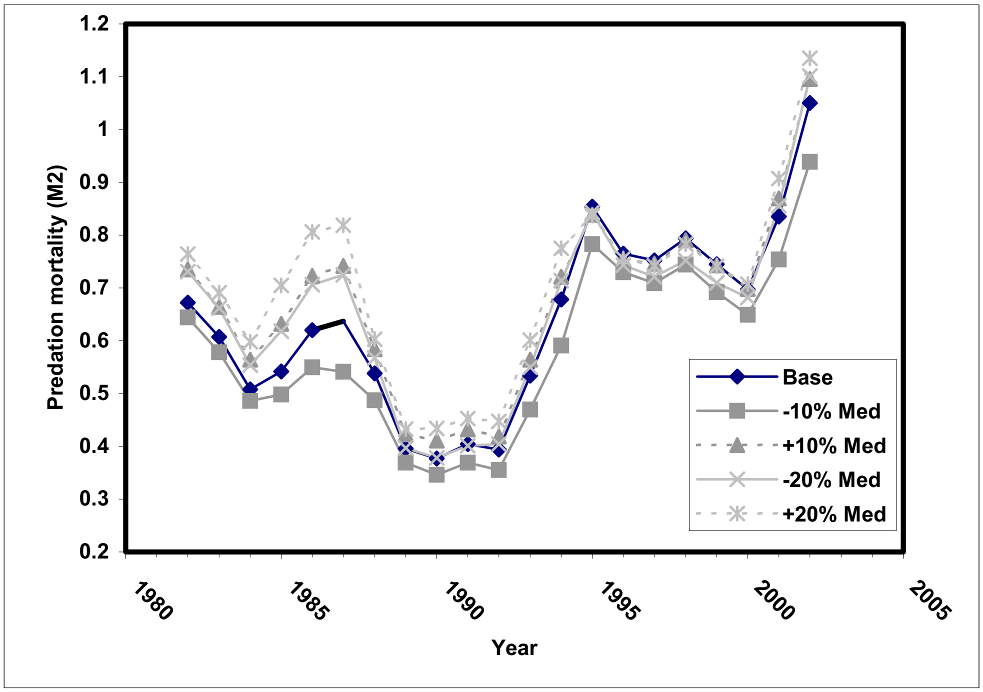


Figure D1.85. Predation mortality rates (M2) on age-0 (a) and age-1 (b) menhaden for each year. M2 values for the base run configuration are plotted against M2 values from scenarios in which the median size of prey selected for each predator was shifted by ± 10% and ± 20%.

a)



b)

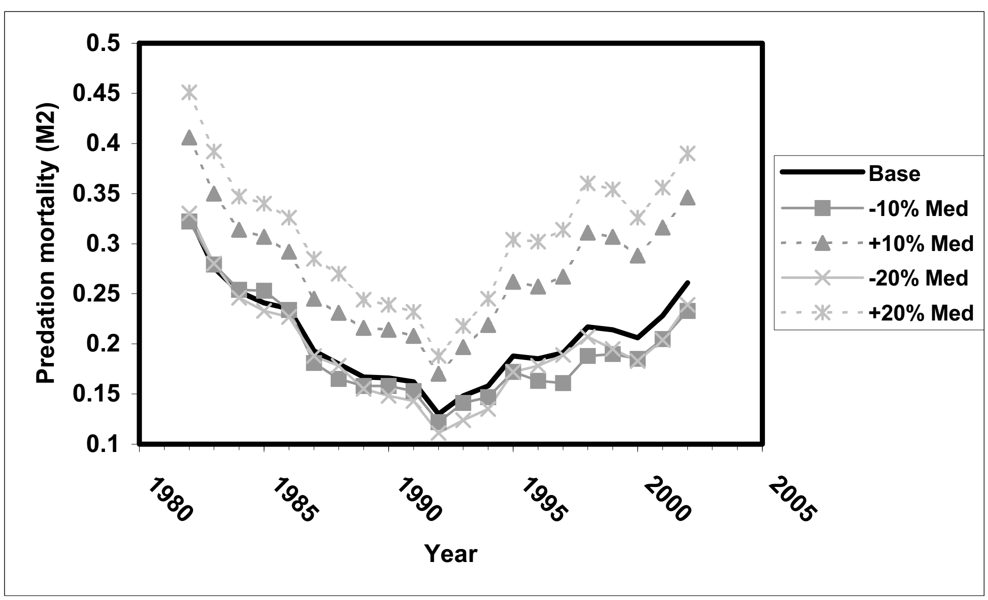
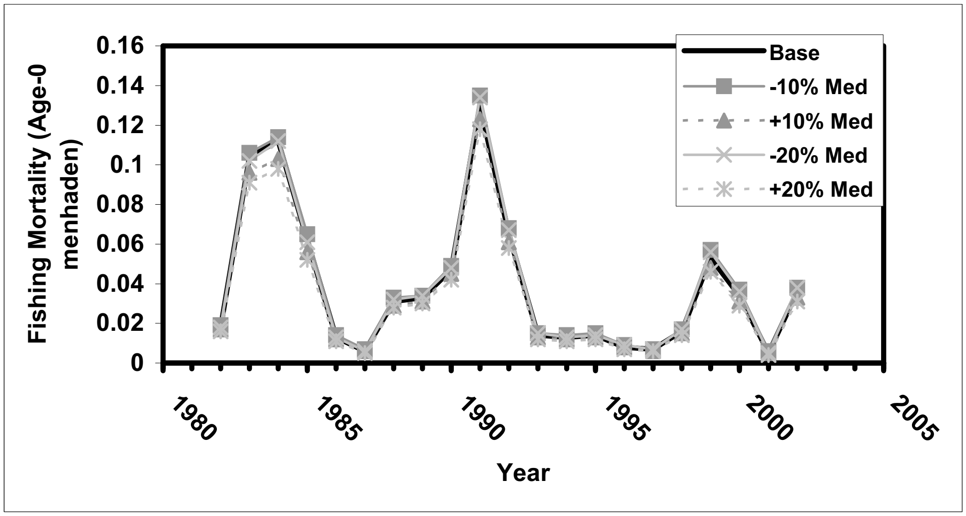


Figure D1.86. Fishing mortality estimates on age-0 (a), age-3 (b) and age-6+ (c) menhaden in the MSVPA-X. Results are shown for the base run configuration and for scenarios in which the median size of prey selected for each predator was shifted by ± 10% and ± 20%.

a)



b)

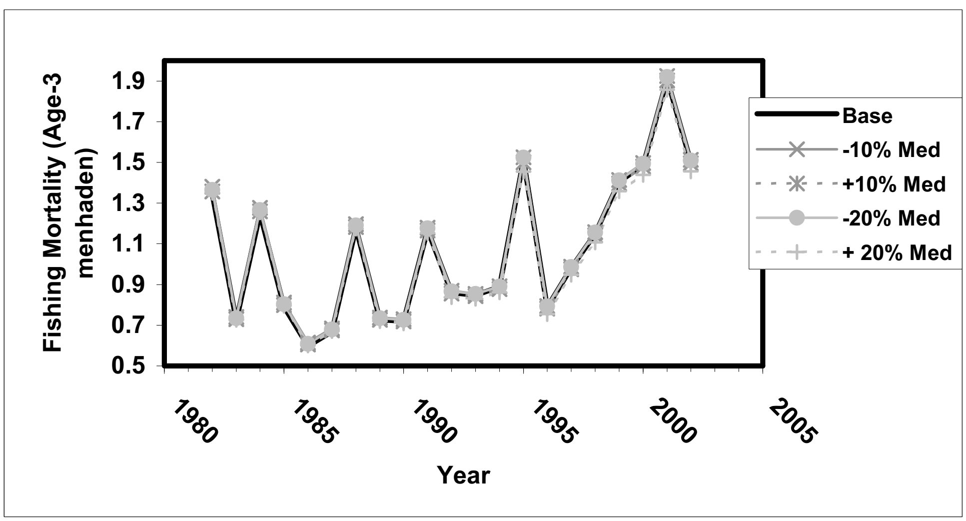


Figure D1.86 (Cont'd). Fishing mortality estimates on age-0 (a), age-3 (b) and age-6+ (c) menhaden in the MSVPA-X. Results are shown for the base run configuration and for scenarios in which the median size of prey selected for each predator was shifted by ± 10% and ± 20%.

c)

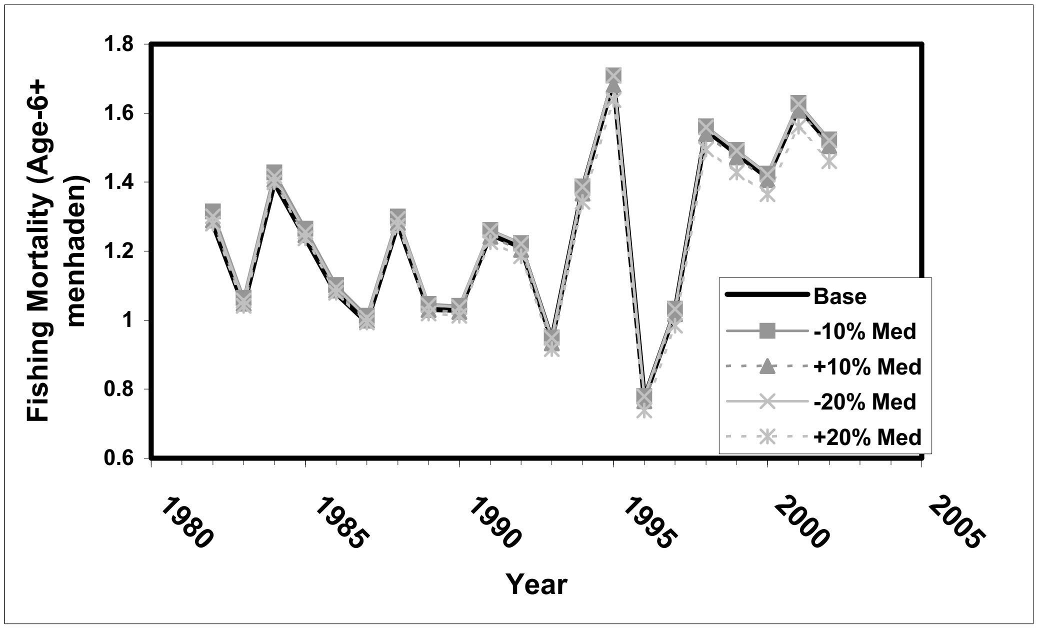
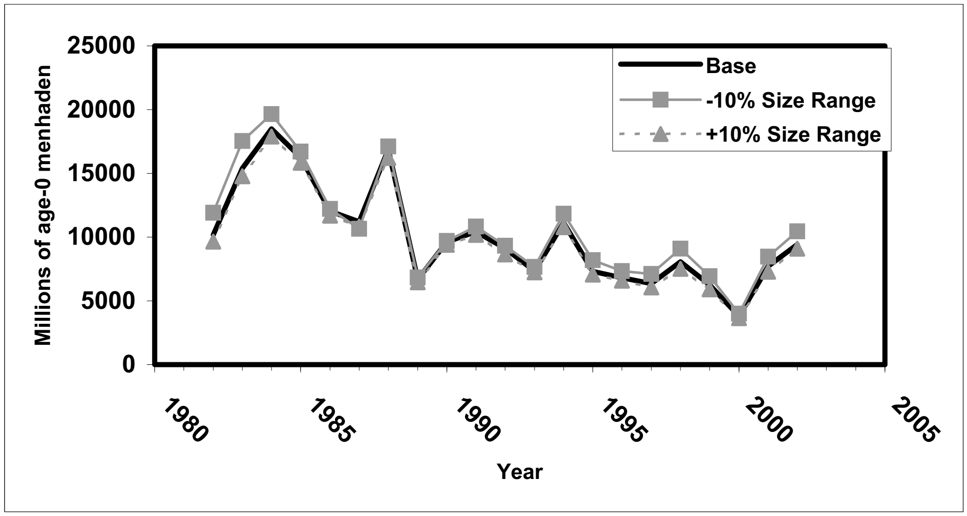


Figure D1.87. Age-0 (a), age-1 (b) and total abundance (c) of menhaden from the base run MSVPA for two scenarios in which the range of prey size selectivity for each predator was increased or decrease by ± 10%.

a)



b)

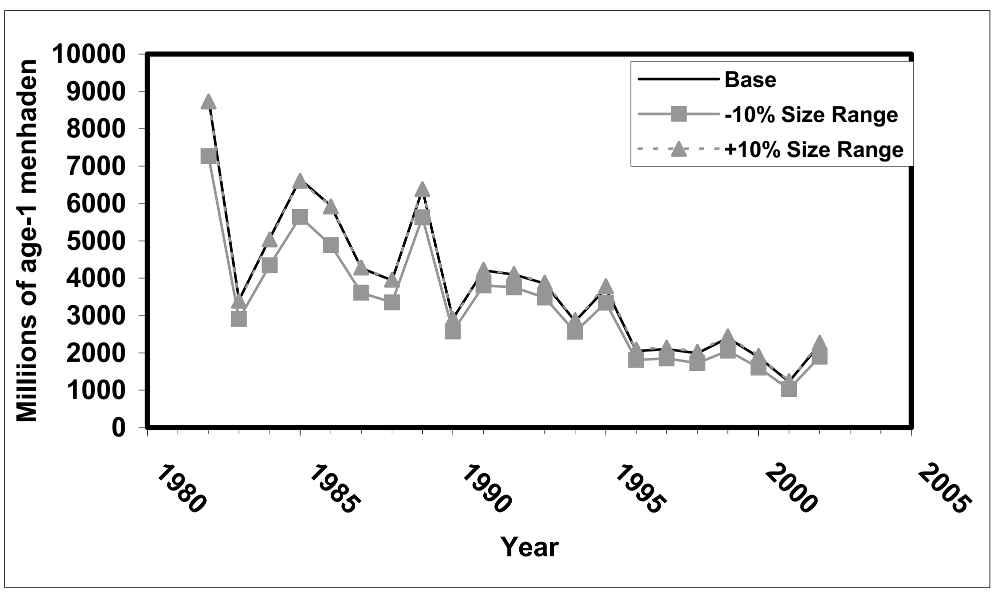


Figure D1.87 (cont'd). Age-0 (a), age-1 (b) and total abundance (c) of menhaden from the base run MSVPA for two scenarios in which the range of prey size selectivity for each predator was increased or decrease by ± 10%.

c)

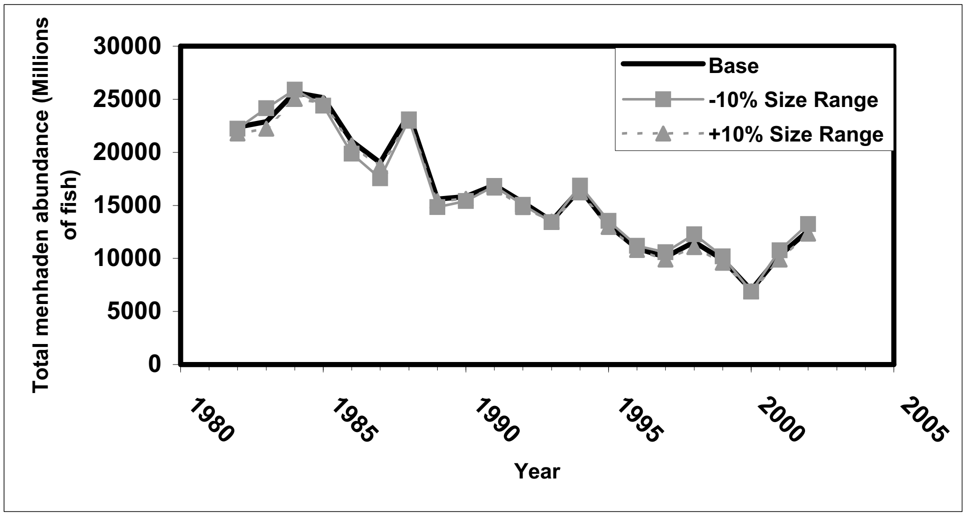


Figure D1.88. Spawning stock biomass (SSB in 000 mt) of menhaden from the base run MSVPA and for two scenarios in which the range of prey size selectivity for each predator was increased or decrease by ± 10%.

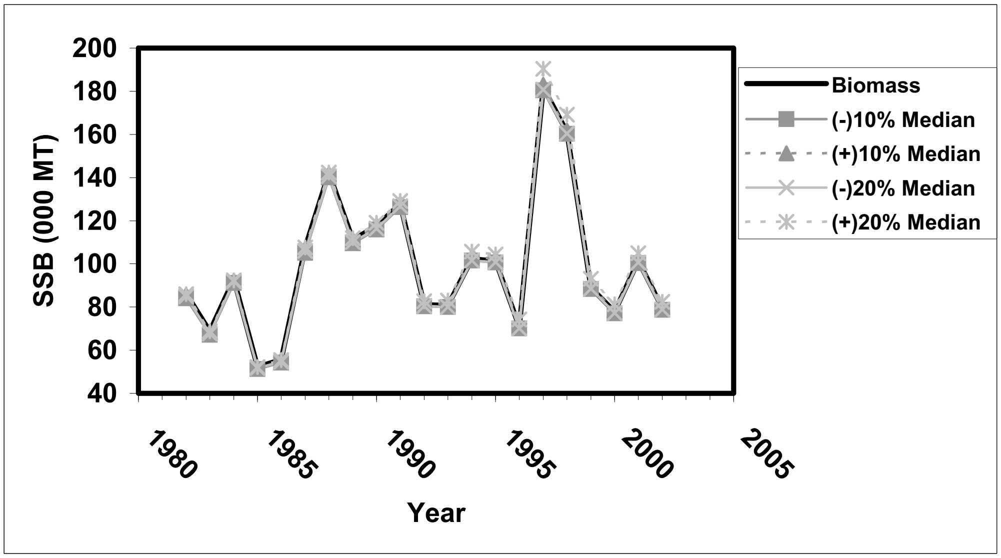
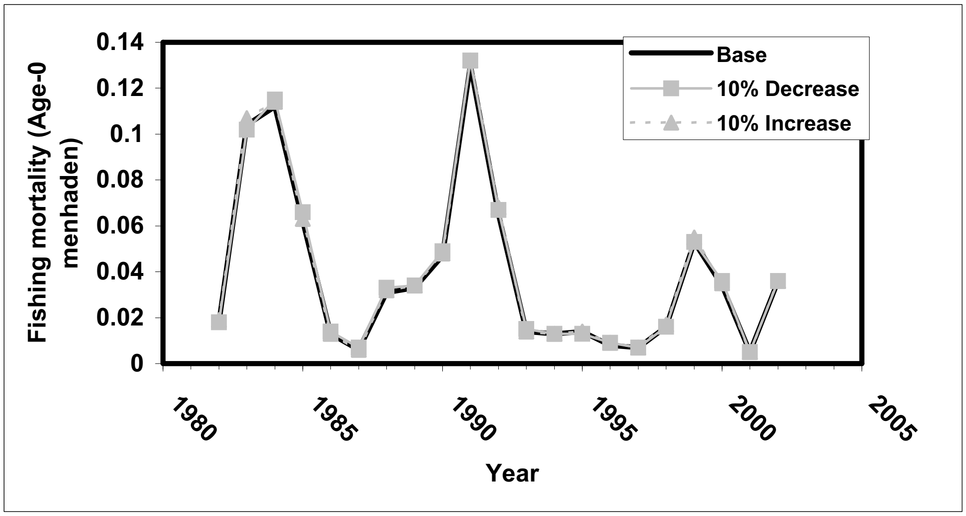


Figure D1.89. Fishing mortality (F) estimates for age-0 (a), age-3 (b), age-6+ (c) and average recruited F (age-2+) menhaden from the base run MSVPA and for two scenarios in which the range of prey size selectivity for each predator was increased or decrease by ± 10%.

a)



b)

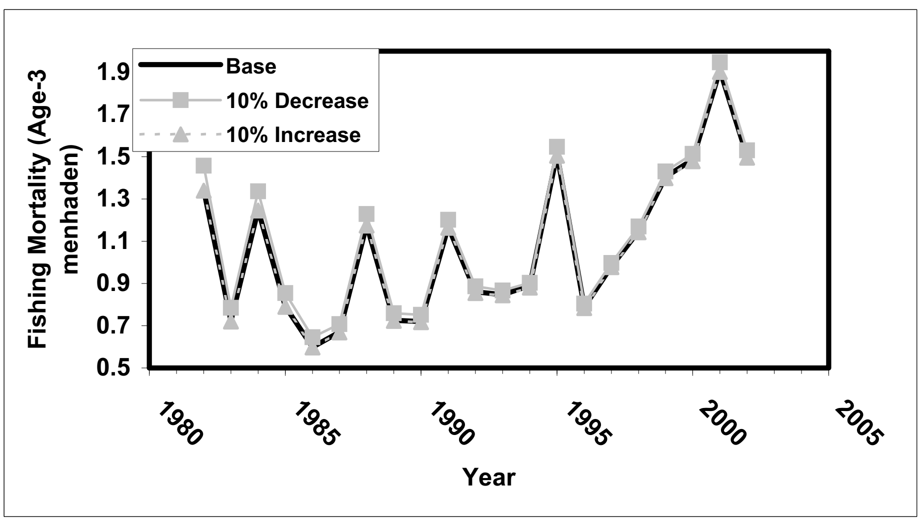
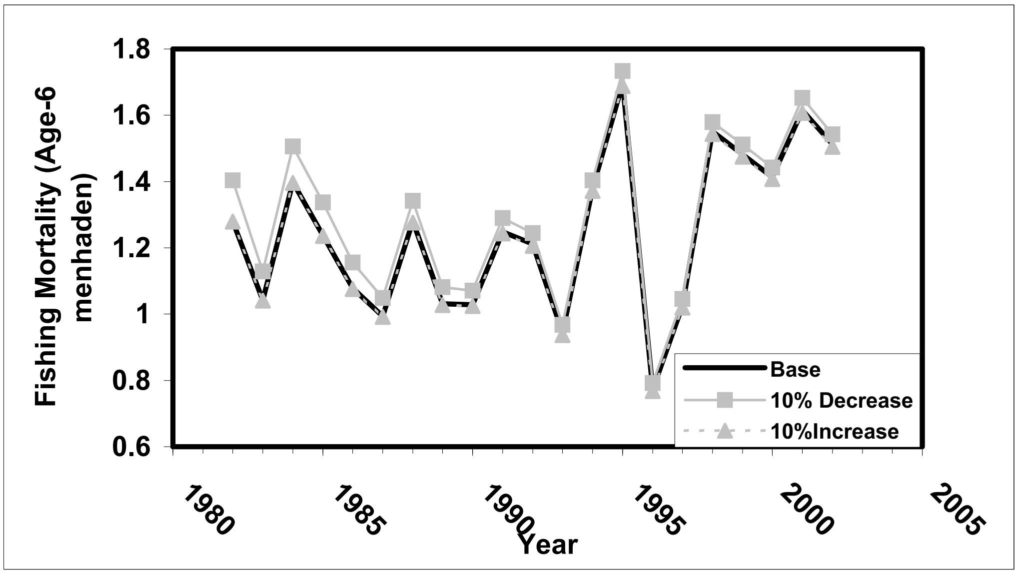


Figure D1.89 (cont'd). Fishing mortality (F) estimates for age-0 (a), age-3 (b), age-6+ (c) and average recruited F (age-2+) menhaden from the base run MSVPA and for two scenarios in which the range of prey size selectivity for each predator was increased or decrease by ± 10%.

c)



d)

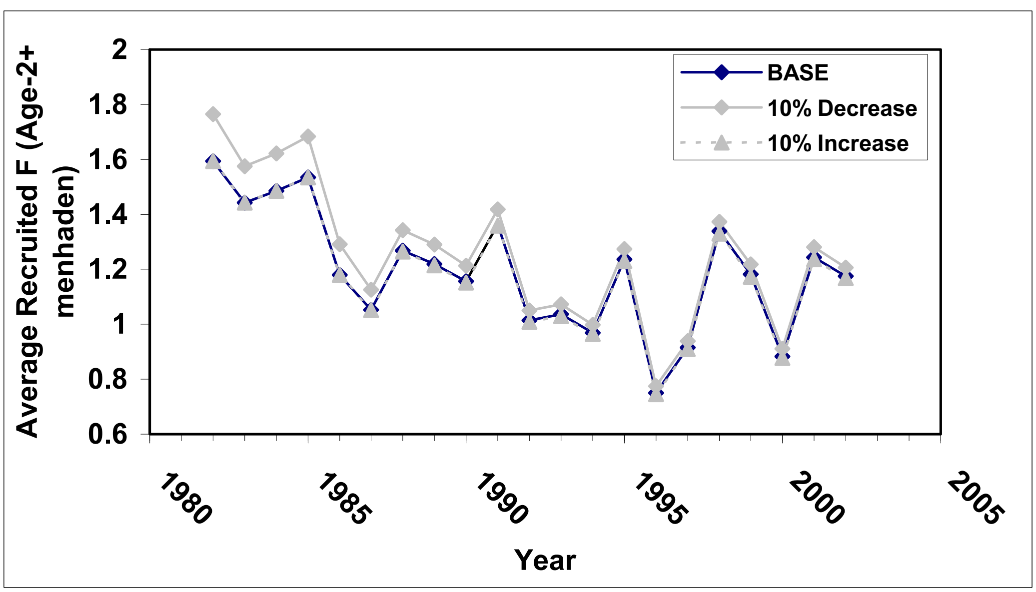
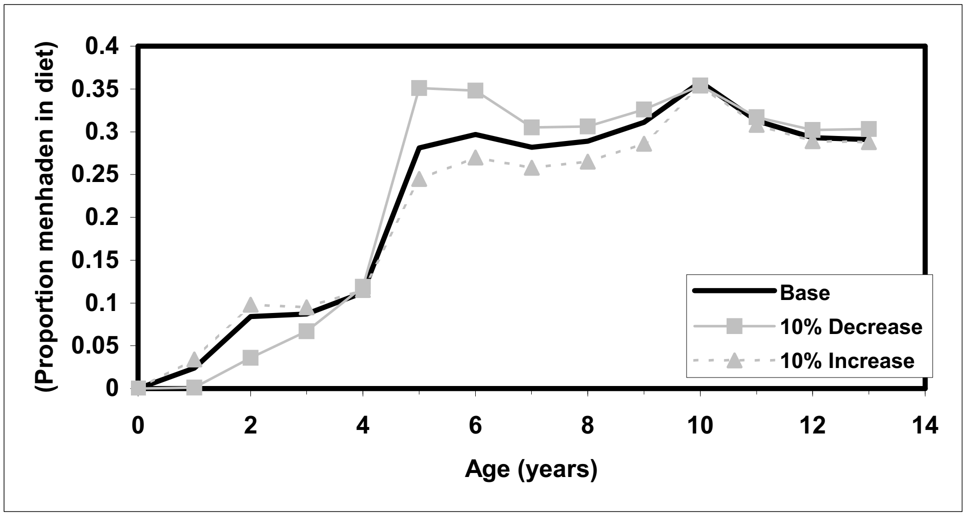


Figure D1.90. Proportion of menhaden in the dirt of the diet of striped bass (a), weakfish (b), and bluefish (c) by age for the base run MSVPA-X configuration and for two scenarios in which the range of prey size selectivity for each predator was increased or decrease by ± 10%.

a)



b)

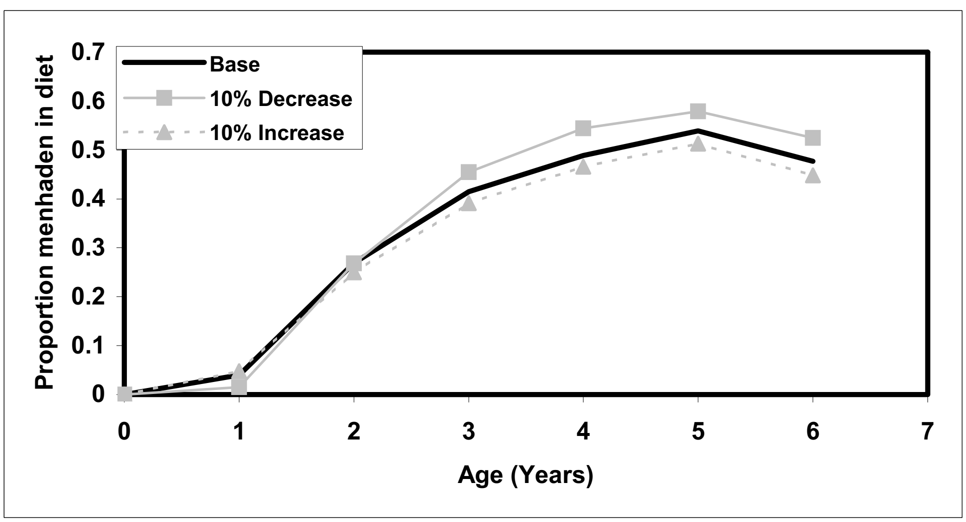


Figure D1.90 (cont'd). Proportion of menhaden in the dirt of the diet of striped bass (a), weakfish (b), and bluefish (c) by age for the base run MSVPA-X configuration and for two scenarios in which the range of prey size selectivity for each predator was increased or decrease by ± 10%.

c)

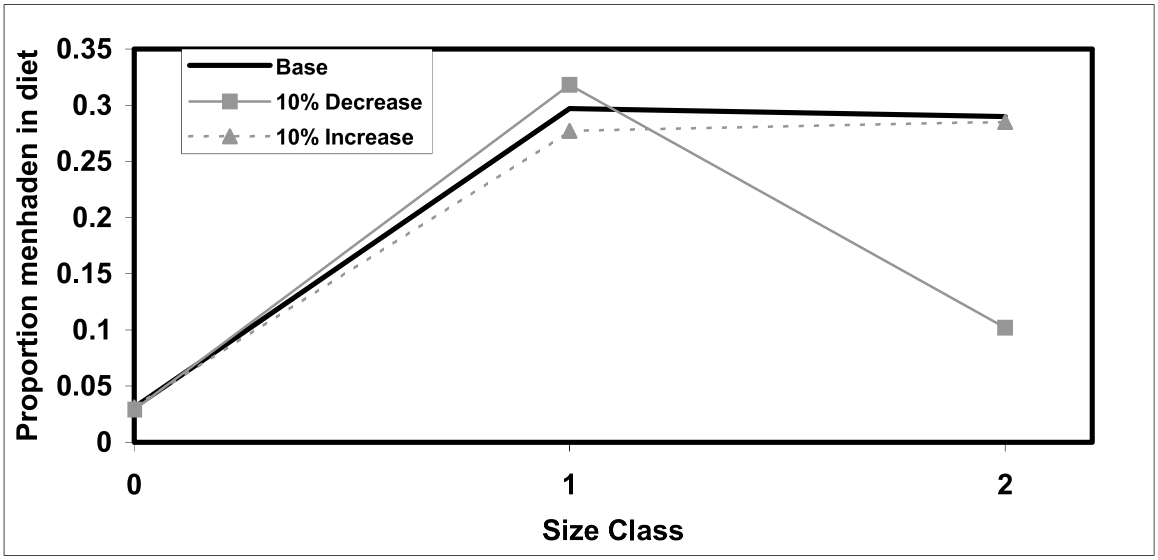
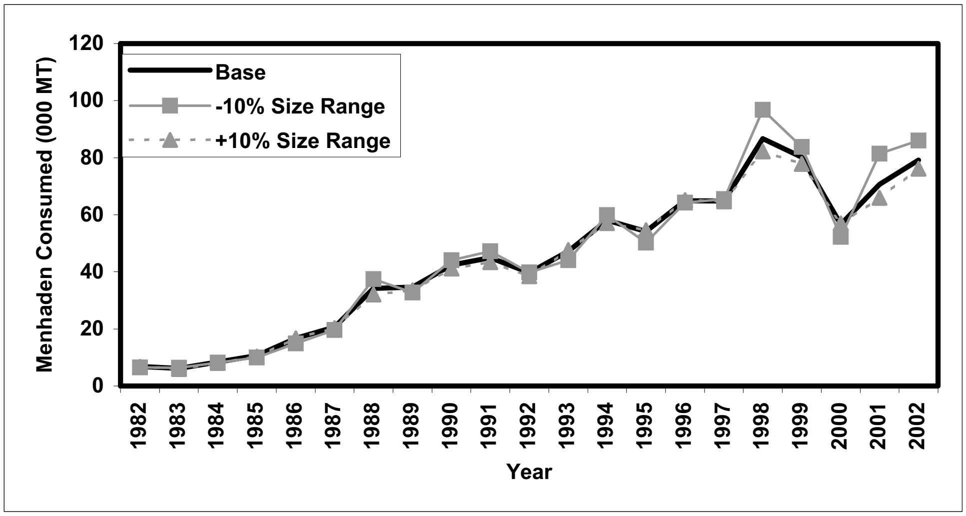


Figure D1.91. Total menhaden consumed by striped bass (a), weakfish (b), and bluefish (c) by year for the base run MSVPA-X configuration and for two scenarios in which the range of prey size selectivity for each predator was increased or decrease by ± 10%.

a)



b)

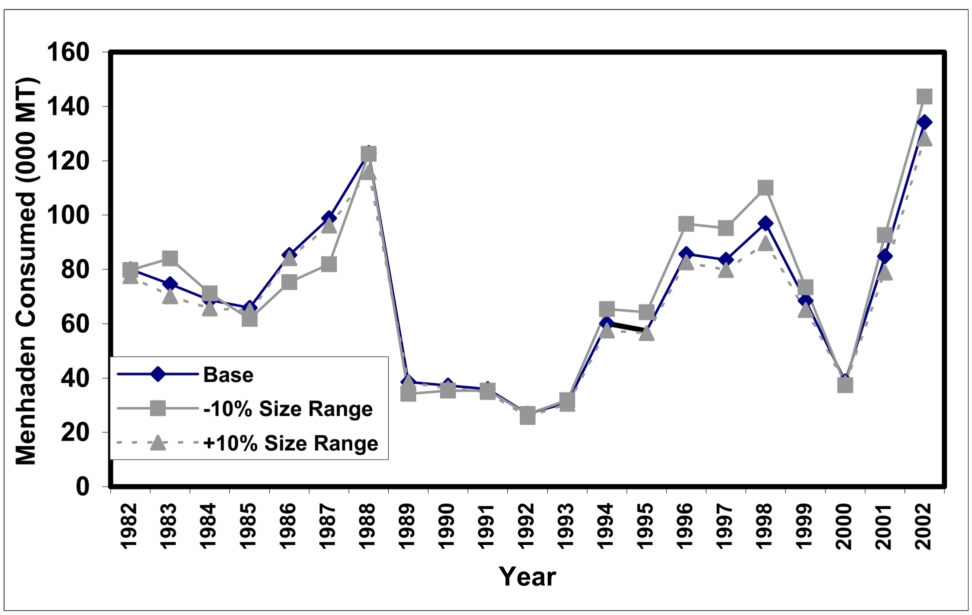


Figure D1.91 (cont'd). Total menhaden consumed by striped bass (a), weakfish (b), and bluefish (c) by year for the base run MSVPA-X configuration and for two scenarios in which the range of prey size selectivity for each predator was increased or decrease by ± 10%.

c)

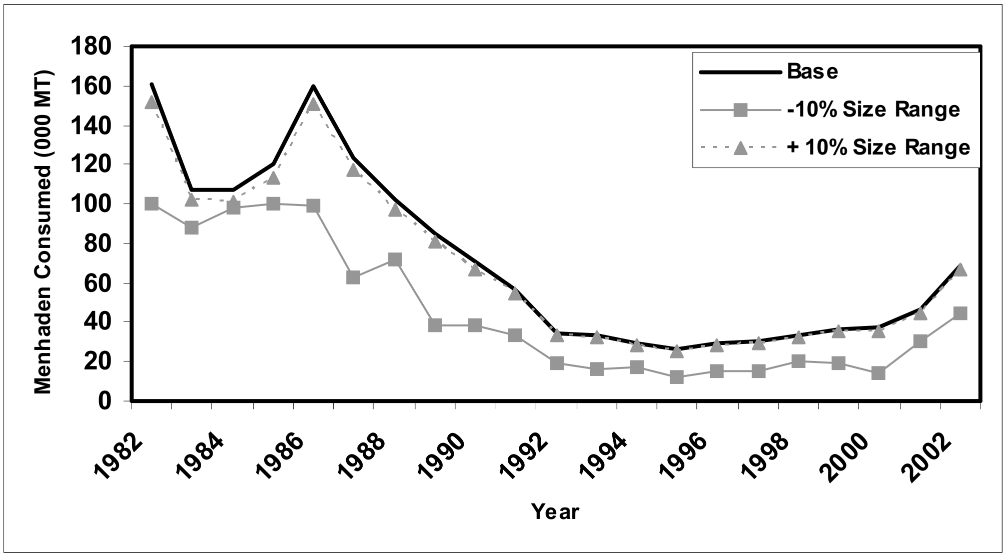


Figure D1.92. Comparison of observed (base run) and forecasted (using observed catch or observed F) menhaden population parameters dynamics for 1996-2002. The units for total biomass and spawning stock biomass are in 000 mt and total abundance is in millions of fish.

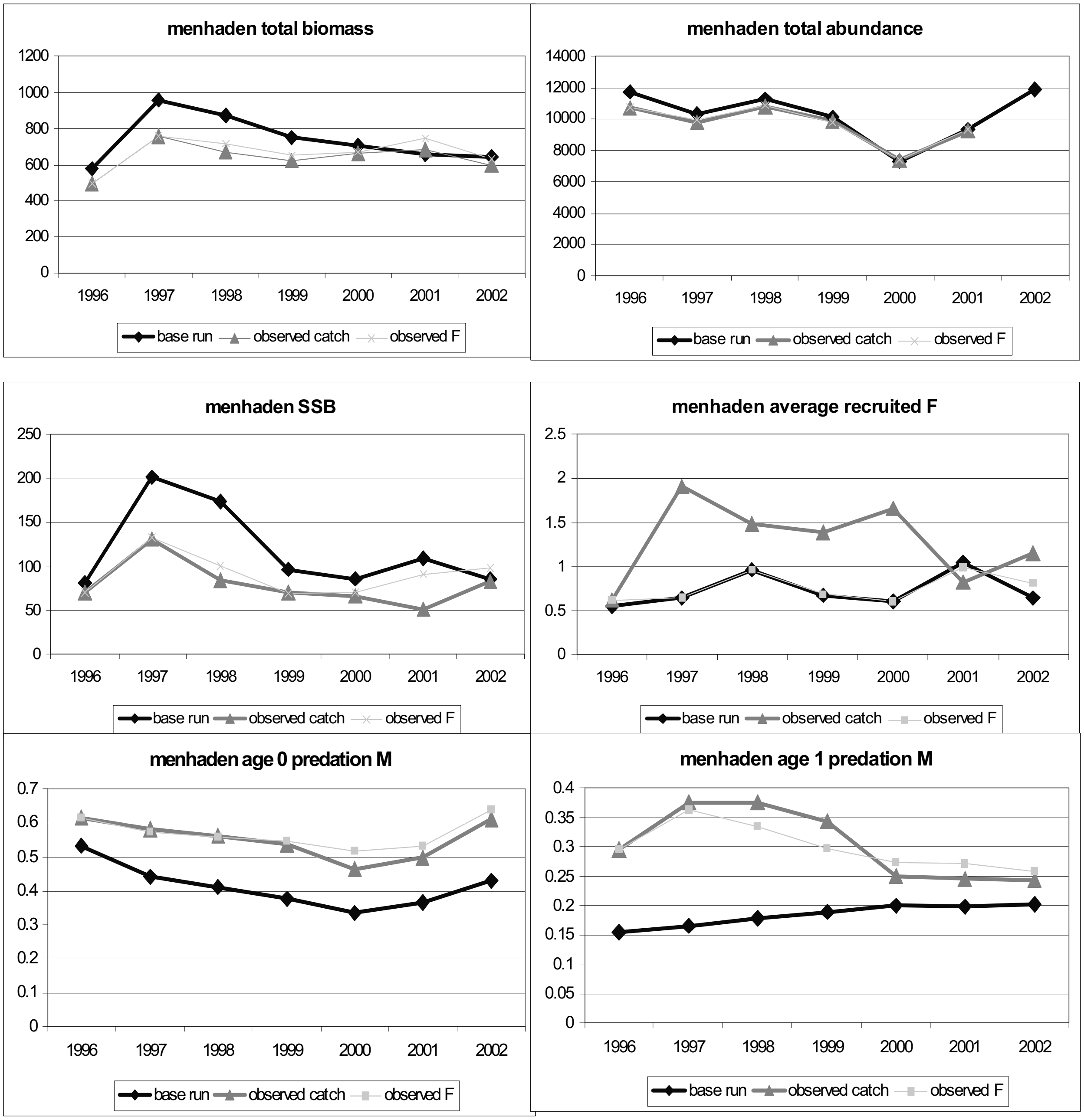
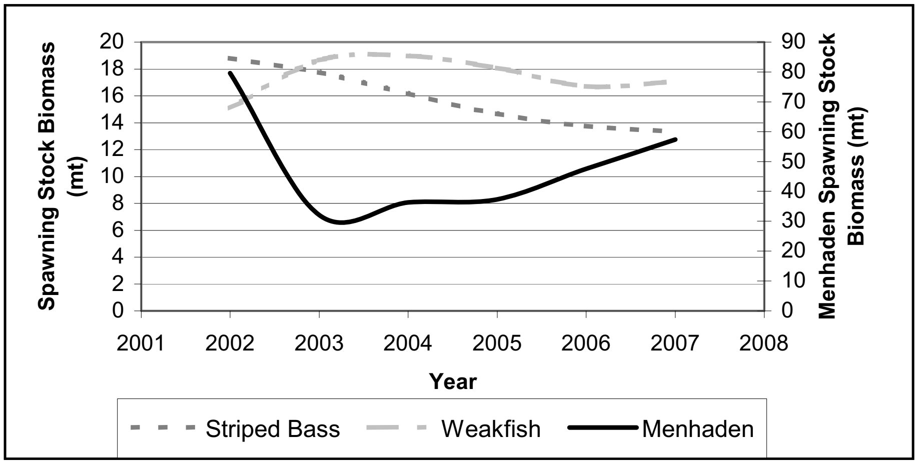
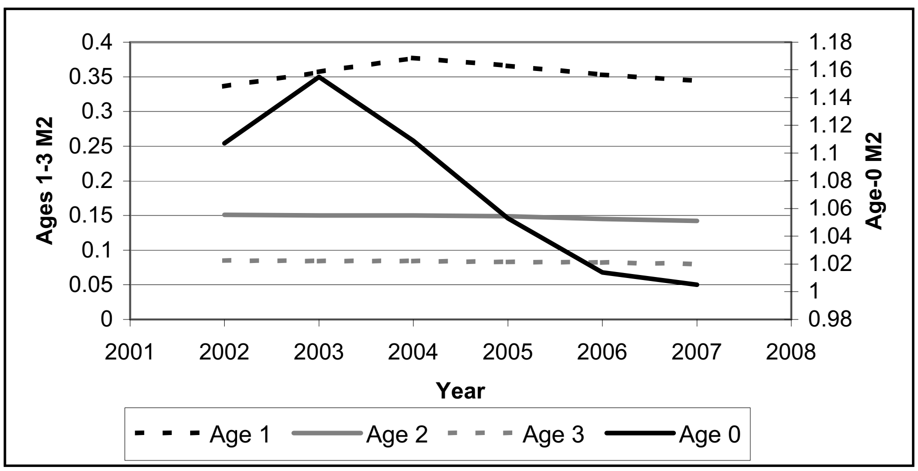


Figure D1.93(a-c). Results of the forward projection for: a) spawning stock biomass of menhaden, striped bass and weakfish; b) predation mortality on age-0 through age-3 menhaden; and c) the amount of menhaden consumed by striped bass, weakfish and bluefish.

a)



b)



c)