CHAPTER 3: MODEL PERFORMANCE AND SENSITIVITY ANALYSES

3.0 SUMMARY

The information below summarizes the base run configuration of the MSVPA-X that was used to evaluate model performance and sensitivity for the 'retrospective' MSVPA-X (See Sections 3.1 and 3.2). Section 3.3 reviews the set-up of the MSVPA-X forecast module. The results of the base run for the retrospective MSVPA-X are presented in Section 3.4. 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 of the model to changes in 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. A test of the forecast model is also presented that investigates the ability of MSVPA-X to reproduce past observations.

3.1 SINGLE-SPECIES CONFIGURATIONS

The following table details the MSVPA-X input data for each species (i.e., Atlantic menhaden, striped bass, weakfish, and bluefish) for the model's base run configuration. The input data can also be reviewed in the MSVPA-X executable by opening the project file "BaseRun_07Sept_05.prj" and then opening "Open Species" listed in the options under File. Note that the options for bluefish are limited to feeding (consumption and prey size-selectivity parameters, as well as, the proportion of biomass in each size class) and biomass (time series of biomass estimates from the single-species assessment), as it is currently modeled as a "biomass predator". The data input for explicitly modeled species includes catch-at-age, weight-at-age, size-at-age, maturity, and options regarding the single-species virtual population analysis. Feeding parameters (consumption and prey size-selectivity) for explicitly modeled species are entered under the MSVPA configuration (Section 3.2).

	Menhaden	Striped Bass	Weakfish	Bluefish
Catch-at-age	Stock Ass.	Stock Ass.	Stock Ass.	NA**
Weight-at-age	5 yr avg.	Constant	Constant	NA
Size-at-age	5 yr avg.	Constant	Constant	NA
Maturity schedule				
Age-0	0.00	0.00	0.00	
Age-1	0.00	0.00	0.90	
Age-2	0.118	0.00	1.00	
Age-3	0.864	0.00	1.00	
Age-4	1.00	0.04	1.00	
Age-5	1.00	0.13	1.00	
Age-6*	1.00	0.45	1.00	
Age-7	NA	0.89	NA	
Age-8	NA	0.94	NA	
Age-9 – 13+	NA	1.00	NA	

Single-species VPA Configuration	XSA	XSA	XSA
Apply shrinkage to the mean	Yes	Yes	Yes
CV for shrinkage mean	0.50	0.70	0.70
Number of years for shrinkage mean	4	3	3
Number of ages for shrinkage mean	3	3	2
Down weight early years	Yes	Yes	Yes
Weighting method	Tricubic	Tricubic	Tricubic
Earliest year for weighting	1982	1982	1982
M1	0.40	0.15	0.25
M2	0.00	0.00	0.00
Age-specific Natural Mortality Rates	No	No	No

* indicates the plus group for menhaden and weakfish (age-6).
** data for bluefish biomass time series is from the stock assessment (Lee, 2003); for details on bluefish feeding parameter data, see Table D.32.

3.2 MSVPA-X CONFIGURATION

This section details the steps and information used to configure the MSVPA-X for the base run. The MSVPA-X configuration process allows the model user to define the predator species ("Full MSVPA" or "Biomass Predator") and prey species ("Full MSVPA"), the time frame and seasonality, add "Other Prey" species, prey type and preference of predators, predator-prey spatial overlap, predator consumption rates, predator seasonal gut fullness, and the type of single-species VPA used for each species. The following subsections provide the examples of the information used in the base run MSVPA configuration. Full details of the input data can be reviewed in the MSVPA-X executable by opening the project file "BaseRun_07Sept_05.prj" and then opening "Open MSVPA" listed in the options under File and navigating through the set-up options.

3.2.1 New MSVPA Configuration

Full MSVPA Species	Striped bass, weakfish
Prey only MSVPA Species	Menhaden
Biomass Predator	Bluefish

3.2.2 Enter time frame for MSVPA

Years	1982-2002
Number of Seasons	4
Season 1 Length (days)	92
Season 2 Length (days)	91
Season 3 Length (days)	91

Season 4 Length (days)	91
Seasonal Spatial Overlap	Yes
Model Predator Growth	No
Annual Temperature Variation	Yes (Table D.33)

3.2.3 Enter Other Prey Data

See Chapter 2 for full descriptions on methods and data used for each "other prey" species or group (anchovy, benthic crustaceans, benthic invertebrates, clupeids, macrozooplankton, medium forage fish, and sciaenids). The minimum and maximum size and parameters for each "Other Prey" item are listed in Table D.34. Biomass estimates for each "other prey" species by year and season are entered in this field.

3.2.4 Enter Prey Preferences

Prey preferences for each predator, by age, are entered in this field using the quantitative ranking methodology covered in Section 2.6. Predators cannot eat one another nor is there cannibalism, so, for each predator, the other predators are given a preference of 0 and the preferred prey item gets a ranking of 1. Ties in preference are entered as an average of the tied rank positions (e.g., if sciaenids and menhaden were tied for third in prey type preference, they would each receive a ranking of 3.5 which is the average of the third and fourth positions occupied in the matrix). Table D.35 contains the quantitative prey preference ranks for weakfish by age.

3.2.5 Enter Spatial Overlap Data

This field allows the user to define the seasonal spatial overlap between predators and prey. Again, since predators cannot eat one another and there is no cannibalism, each predator is given a rank of 0. See Section 2.7 for further details on the methods used to develop the quantitative spatial overlap indices. Table D.36 contains the quantitative spatial overlap rankings during season 1 for weakfish by age.

3.2.6 Enter Size Preference and Consumption Parameters

The parameters for prey size preference and consumption of each predator are entered in this field (Table D.37). For striped bass, parameters are entered for three age ranges (0-4, 5-9, and 10-13+), but for weakfish and bluefish age aggregated parameters are used. If higher resolution data were available then it would be possible to have age-specific values for each predator.

3.2.7 Enter Seasonal Mean Gut Fullness

In this field, mean gut fullness is entered for each predator by age or size class.

3.2.8 Select SSVPA for each species

For this configuration, the type of VPA used for each species (menhaden, striped bass and weakfish) was the XSA.

3.3 FORECAST MODULE

This section reviews the base configuration for the forecast module of the MSVPA-X. To run the forecast module, the 'retrospective' MSVPA-X configuration on which the forecast will be based must be selected. Then the user can select the year to start the projection and number of years to run the forecast module. Additional required inputs include von Bertalanffy parameters, length and weight relationships, and stock-recruitment relationships for each of the explicitly modeled species. Options for implementing the forecast module include: selecting fishery removal methods (catch versus fishing mortality), variable fishing mortality, other predator biomass, other prey biomass, and recruitment success. Each scenario can be saved. The MSVPA-X Assessment Subcommittee cautions against projections of greater than five years, as long-term projections are constrained to the stock-recruitment relationship of short-lived prey species.

3.3.1 Configure a Forecast Model

This entry screen allows the user to enter a name for the forecast and select an MSVPA configuration, the initial year of forecast, the number of years forecasted, and whether or not to model predator growth based on prey availability.

3.3.2 Enter von Bertalanffy Parameters

Parameters for the von Bertalanffy growth curve and the length-weight relationship for each explicitly modeled species are entered in this screen.

3.3.3 Stock-Recruit Parameters

Spawning stock biomass and recruit abundance data are entered for each explicitly modeled species for each year of the 'retrospective' MSVPA-X analysis. The user can select among the Ricker, Beverton-Holt, random from quartiles, and the Shepherd flexible methods to determine the stock-recruitment relationship for each species in the forecast.

3.3.4 Configure Forecast Scenarios

This is the final input screen before executing the forecast run. The user selects the method for modeling fishery removals, either catch limits in numbers or fishing mortality rate. The user can also opt to enter variable fishing mortality rates, other predator biomass, other prey biomass, and recruitment success.

3.4 BASE RUN RESULTS

3.4.1 Population sizes

The results of the MSPA-X Base run for explicitly modeled predators are given in Figures D.37 (total biomass) and D.38 (SSB). Biomass by size class for bluefish, the biomass input predator, is given in Figure D.40. Total biomass and SSB of striped bass increases over the time series.

Weakfish experience fluctuations in total biomass, but a general increasing trend in SSB is noted. It is notable that weakfish results from this iteration of the MSVPA-X differ from the most recent single-species assessment (See Chapter 2). Bluefish population biomass exhibits high abundance early in the time series (1982 – 1988), declines throughout much of the 1990s, followed by an increase in stock size in the last 3 – 4 years.

The only explicitly modeled prey species in this iteration is menhaden. Abundance and biomass trends are shown in Figures D.40 and D.41. Total abundance and abundance at maturity (age-2+) decline, although overall SSB has remained stable yet somewhat variable (Figure D.41). This can be explained in part by an increase in weight-at-age for menhaden (ASMFC, 2004a).

Menhaden total biomass is expressed in relation to other important prey items in Figure D.42. While menhaden and anchovy biomass decline, biomass estimates of other prey species are either stable (medium forage fish and sciaenids) or dramatically increasing (clupeids). The dramatic increase in clupeid biomass is in part due to the increase of Atlantic herring. Estimated current stock size for this stock is given elsewhere; but is thought to be approximately $1.8x10^6$ mt SSB (Overholtz *et al.*, 2003). The increase in this stock has implications for both consumption by prey type and location (discussed below). It should be recognized that with the exception of menhaden, prey items in this iteration of the MSVPA are included as biomass inputs and are not explicitly modeled.

3.4.2 Diet composition

Average predicted diet compositions, across the available time series and seasons, are given for striped bass, weakfish, and bluefish (Figures D.43-D.45 respectively) by age (or size). In general, all predators are predicted to feed mainly on macrozooplankton and benthic invertebrates at younger ages or size classes. The diet composition for intermediate ages shifts to dominance by medium forage fish and anchovies. At older age classes, clupeids and menhaden dominate as many predators become more piscivorous.

One exception to the overall trend above is the prevalence of benthic crustaceans in the diet of striped bass at intermediate ages (ages 5-8). Nelson *et al.* (2003) suggest that as striped bass age, they tend to move farther north during the summer feeding period. Given this change in behavior and the lack of smaller menhaden in the prey field in this area, it is not unreasonable that striped bass in northern areas are predicted to feed more on benthic food sources than on menhaden and clupeids. At the oldest age classes (9-13+), however, type preferences apparently overcome availability, as clupeids tend to dominate the diet for the oldest striped bass. A similar result is seen in bluefish, but is lacking for weakfish; an expected result given that weakfish do not migrate as far north as the other predators.

3.4.3 Consumption and prey availabilities

Estimates of modeled consumption expressed as total biomass, for each important prey item by year are given in Figures D.46-D.48 for striped bass, weakfish, and bluefish (respectively). Striped bass increased consumption of all prey items during the time series, an expected result given their increasing abundance. Recent results suggest a decrease in benthic invertebrate consumption, which is attributed to expansion of the striped bass population to older ages (Figure D.46; comments in section 3.4.1 above). Recent increases in consumption of both clupeids and menhaden may be the result of the expanding in age structure seen in striped bass.

Weakfish consumption exhibits no overall trend. Consumption of menhaden, benthic invertebrates, and anchovies is highly variable, but may show signs of recent increases in consumption by this stock.

Estimated consumption of fish prey by bluefish increases over time, particularity for the clupeids. While menhaden consumption is well below historical levels, clupeid consumption is at a historic high. The MSVPA-X Assessment Subcommittee suggests that this consumption rate may be the product of strong overlap between bluefish and clupeids in Northern areas and the recent increase in clupeid availability, and therefore cautions that clupeid consumption may be overestimated.

For explicitly modeled species, food availability can be tied to both natural mortality and growth rates in future iterations of the MSVPA-X; however, such is not possible at this time without additional data on the relationship between food availability and survivability of the explicitly modeled predator species. Overall, the prey available to striped bass has remained fairly constant across the temporal framework for the MSVPA-X (Figure D.49). The relative food availability for weakfish declines in relation to the decline in availability of their major prey, menhaden (Figure D.50).

3.4.4 Menhaden Predation mortality (M2)

Menhaden exhibit significant changes in predation mortality by age (Figure D.51-D.54). Age-0 menhaden M2 fluctuated, but it generally increases over time as the weakfish population increases. Likewise, M2 on age-1, 2, and 3 menhaden increases as predation by both striped bass and bluefish increases, as a result of both changes in the size- and age-structure of these predators and potential overlap with menhaden in recent years.

Overall, these results suggest that predation mortality increases as predator stocks rebound. This increase is not limited to younger age classes, as it extends to older menhaden than previously assumed. However, the scale of the graphs presented cannot be ignored. It should be recognized that size-at-age drives these interactions. For example, declining predator growth and an increase in prey size-at-age will dramatically affect the outcomes of this iteration. Overall, the M2 by included predators are mostly affecting age-0 to age-2 menhaden. For menhaden above age-2, M2 appears inconsequential.