D: EXPANDED MULTISPECIES VIRTUAL POPULATION ANALYSIS (MSVPA-X) STOCK ASSESSMENT MODEL

EXECUTIVE SUMMARY

In recent years stakeholder groups, government officials, and scientists have called for an ecosystem approach to fisheries management on both local and federal levels. While mangers have traditionally relied on analytical methods to help them make informed choices on a single-species basis, few analytical tools are available to evaluate decisions at the ecosystem level. The Expanded Multispecies Virtual Population Analysis (MSVPA-X) was conceived to support to fisheries management decisions made in a multispecies context.

TERMS OF REFERENCE

1. Evaluate adequacy and appropriateness of model input data, including fishery-dependent data, fishery-independent data, selectivities, etc. as configured. Chapter 2

This configuration of the MSVPA-X utilized the best available single-species assessment and diet data, attempted to fill the data gaps, and tested the model formulation and structure through sensitivity analyses. The results are presented to assess the feasibility of the MSVPA-X model. Utilization for management purposes will require updated single-species assessments, diet matrices, and other relevant information.

Atlantic menhaden: Atlantic menhaden are the only explicitly modeled prey species in this configuration of the MSVPA-X. The XSA is used as the single-species assessment model because it incorporates fishery independent survey data as tuning indices and is consistent with the approach used in the forward-projection single-species assessment model.

Striped bass: XSA is used as the single-species VPA model for striped bass, which is a predator species in this application. The XSA approach is similar to the ADAPT VPA methodology utilized in the single species striped bass stock assessment in that it utilizes tuning indices in the estimation procedures for fishery mortality rates.

Weakfish: The XSA model is used as the single-species VPA approach for weakfish, which is a predator species in this configuration of the MSVPA-X. A series of XSA evaluation runs were developed for the period from 1982-2000 for comparison to the ADAPT VPA and integrated catch-at-age (ICA) analysis used in the 2002 assessment document.

Bluefish: Due to the unavailability of catch-at-age information from a peer reviewed stock assessment during the model reference period (1982 – 2002), bluefish is included in the MSPVA-X application as a "biomass predator". In this formulation, the predator population dynamics are not modeled. Model input requirements include a time series of total predator biomass, limited information on predator size structure, and feeding selectivity parameters. The biomass dynamics model (ASPIC) previously used to assess the bluefish stock utilized commercial and recreational landings data. The recreational CPUE and NEFSC inshore fall survey are used as tuning indices for this approach.

Other Prey: To account for available non-menhaden prey, biomass estimates were developed for several "other prey" species groups that comprise important components of the predator species' diets throughout their life history and range. "Other prey" items included in this configuration include: clupeids (Atlantic herring and threadfin herring); medium forage fish (squids and butterfish); anchovies; sciaenids (spot and croaker); macrozooplankton; benthic invertebrates; and benthic crustaceans. When available, the data and estimates from current stock assessments are utilized; however, for some "other prey" items, biomass estimates are derived using available fishery-independent, fishery-dependent and life-history data. As with the single-species assessments, the MSVPA-X will benefit from improved population estimates for all "other prey" items.

2. Evaluate assumptions for data gap filling when reliable data are not available (diet, biomass of prey species, feeding selectivity). Chapter 2

An extensive review of available diet data for striped bass, weakfish, and bluefish was conducted. There is a general lack of coast wide diet data for all ages of the predator species modeled. The most spatially and temporally comprehensive data set for all three species is the Northeast Fisheries Science Center Food Habits database. However, this survey is limited to the coastal (i.e., non-estuarine) waters, is only available during spring and fall, and generally does not have large sample sizes for older fish. For each species, there are additional regional studies that provide diet information for estuarine waters and other times of the year. The MSVPA-X utilizes a thorough compilation of the available diet data.

Predation mortalities in the standard International Council for the Exploration of the Seas (ICES) MSVPA approach are calculated based upon a simplified feeding model, based on a constant ration for a predator of a given age-class and year. This constant ration does not reflect effects of food availability on feeding rates or temperature effects on predator metabolism. Food consumption rates in fish can vary strongly, particularly between seasons as a function of food availability, changing temperatures, and metabolic demands. To account for these processes, a more detailed consumption model is implemented in the MSVPA-X using the Elliot and Persson (1978) evacuation rate approach, including a modified functional relationship between food availability and predator consumption rates.

The standard MSVPA formulation assumes that predator feeding rates are independent of prey availability, resulting in a Holling type II predator-prey feeding response (Magnusson, 1995). Type II feeding responses result in depensatory dynamics in predation mortality rates, which creates a "predation pit" at low prey biomass that can result in unrealistic model dynamics such as prey extinction due to predation. In contrast, the MSVPA-X employs type III functional responses that are compensatory in nature in that the feeding rate on a particular prey item will decline at low prey abundances, and hence predation mortality pressure is released.

The feeding model also includes a "suitability index", which is comprised of seasonal spatial overlap of predators and prey, prey type preference and prey size preference. The MSVPA-X model employs a flexible unimodal function to describe the relationship between prey length and the proportion of the prey in the diet. The size selection index for a prey of a particular size thus corresponds to the predicted proportion of prey of that size in the predator's diet.

The selectivity model used in the MSVPA-X relies upon a rank index for prey type preference. These indices are derived from summaries of available diet composition data when they are available. For the predators considered here, there are multiple diet studies published in the literature; however, these are generally smaller scale studies focusing on particular places, seasons, and time periods.

While the MSVPA-X model is not fully spatially explicit, it is necessary to define a spatial domain and strata at regional scales to evaluate seasonal spatial overlap between predators and prey. The spatial resolution of these strata is primarily limited by available data on the spatial distribution of the species included in the model. The spatial distribution of each taxon is evaluated on a seasonal basis using landings, survey, or regional density data as appropriate. These relative spatial distributions are then used to calculate the seasonal spatial overlap (using Schoener's index) between each predator age class and each prey species.

3. Review model formulation (overall setup, data handling, VPA calculations, assessment options, sensitivity analyses, recruitment model options, and forecast projection options) of model as configured. Chapters 1, 3 and Appendix D1.

The Multispecies Virtual Population Analysis (MSVPA) approach was developed within International Council for the Exploration of the Seas (ICES) as a multispecies extension of cohort analysis or virtual population analysis (VPA). The approach can be viewed essentially as a series of single-species virtual population analysis models that are linked by a simple feeding model to calculate natural mortality rates. The system of linked single-species models is run iteratively until the predation mortality (M2) rates converge. Predation mortality is the portion of natural mortality of a species that is the result of predation by another species. The basic model is performed in two primary iteration loops. First, all single-species VPAs are run to calculate population size at all ages for predators and prey, then predation mortality rates are calculated for all age classes of each species based upon the simple feeding model. The single-species VPAs are run again using the calculated M2 rates, and this iteration is repeated until convergence (reviewed in Magnusson, 1995).

The MSVPA-X approach described here builds upon the framework of the standard MSVPA by incorporating a variety of single-species VPA approaches (including a "tuned" VPA), modification of the consumption model, introducing a weak Type III functional feeding response, formalizing the derivation of selectivity parameters from diet data, altering the size-selectivity model, and including predators without age-structured assessment data. These additions allow for a clearer definition of the input parameters used to model predator diets and consumption rates, and improve the MSVPA equations to reflect processes controlling feeding and predation rates.

Total biomass and spawning stock of striped bass increases over the time series. Weakfish experience fluctuations in total biomass, but a general increasing trend in spawning stock biomass (SSB) is noted. 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. Total abundance and abundance at maturity (age-2+) decline, although overall SSB has remained stable yet somewhat variable. This is in part due to an increase in weight-at-age for menhaden (ASMFC, 2004a).

4. Develop research recommendations for data collection, model formulation, and model results presentation. Chapter 5

Recommendations for data collection improvements:

- Add a bluefish age-structure/catch-at-age matrix.
- Adult index for menhaden (e.g., an aerial line transect survey) and other species.
- Obtain population weight-at-age estimates.
- Conduct a coast wide diet and abundance study (i.e., an Atlantic coast "year of the stomach").
- Collect more diet data for all four MSVPA-X species along the entire Atlantic coast.
- Conduct stomach selectivity research for predator species to improve prey ranking matrix.
- Encourage existing fishery-independent surveys to take regular gut contents.
- Evaluate if striped bass disease (mycobacteria) is correlated with natural mortality (M1) and food availability or if disease is disrupting striped bass feeding and causing starvation.
- Estimate carrying capacity for the system to evaluate what model estimates/suggests for carrying capacity.
- Improve estimates of biomass for prey species on coast wide basis.
- Conduct a parallel comparison with ICES MSVPA model on a system that has the necessary data collected (Georges Bank or the North Sea) to identify the differences in results.
- Explore the ability to add other predators to model (birds, mammals, other fish, other systems)
- Explore the utility of implementing the Williamson spatial overlap index in the model
- Investigate type II and type III feeding responses of the MSPVPA-X species in field studies

Recommendations for the improvement of model formulation:

- Add uncertainty to model forecast and incorporate elements of Monte Carlo simulations on recruitment curves.
- Alter biomass predator bin sizes for more flexible way to vary for projection model, if necessary after conducting sensitivity analyses or until an age-structured stock assessment is developed for bluefish.
- Add ICA and production model options to retrospective.
- Develop a similar application to the "amoeba" program that allows the user to easily vary changes to model parameters.

Recommendation for the forecast component of the MSVPA-X:

- Determine the affect sensitivity of the model to the removal of all fishing pressure from system
- Insert recovery benchmarks
- Explore options for adaptive management framework with stock-recruitment options

5. Evaluate whether or not the model and associated data are of sufficient quality to develop recommendations to management. Chapter 4

The model has the potential to improve assessments in single-species assessments by suggesting the predation mortality rate at age (or by year, as appropriate) for explicitly modeled prey species. This has already been accomplished for menhaden in the 2003 assessment (ASMFC, 2004a). An earlier iteration of MSVPA-X produced estimates of menhaden natural mortality at age; however, menhaden population size was estimated using a separate single-species assessment model and overall natural mortality was specified within that single-species assessment.

Additionally, decision makers can be shown potential impacts of fishing and predation mortality by age class for explicitly modeled prey. Such an analysis may suggest optimum harvest strategies for both predators and prey when fisheries for both exist and are managed under the same body. Further analyses may allow for the management of prey using total mortality, rather than fishing mortality. The model may also provide insight on multiple species target biomass based on trade offs among predators and prey. The model may provide guidance for rebuilding predator stocks and the interactions between a specific predator biomass targets and the availability of prey species for other stocks of concern should that target be realized.

Based on thorough review and testing of the MSVPA –X model, the committee suggests that this formulation is capable of answering management questions about predator-prey interactions among explicitly modeled species. With clear understanding the MSVPA-X's abilities and limitations described fully within the following assessment report, the MSVPA-X approach has the potential to provide much accessory information for fisheries managers.

PREFACE

The MSVPA-X is a new model developed to aid the ASMFC in better quantifying predator and prey interactions and accounting for these effects on both predator and prey populations. In developing the model, the ASMFC conducted an Internal Review of the MSVPA-X to evaluate model formulation, input data, gap filling procedures, and develop recommendations on incorporating the model and its results in Commission stock assessments for individual species. The Internal Review Panel was formed primarily of scientists involved with ASMFC multispecies projects, but also included an expert on the "standard" ICES MSVPA and two stakeholders involved with the ASMFC.

To provide SARC reviewers a framework to evaluate the model using the Terms of Reference listed below, recommendations of the ASMFC Internal Review Panel are included to preface the Terms of Reference. Although the model will be able to estimate multispecies benchmarks and explore trophic relationships between species, the MSVPA-X is not designed to address all ecosystem level questions or local depletion issues. The ASMFC Panel was comfortable using the model for the following purposes:

- Improve single-species models for single-species population adjustments (i.e., age and year specific inclusion of M)
- Insight on multiple species benchmarks based on species trade offs
- Investigate predation mortality versus catch for important prey species by age class
- Determine the trade offs among harvesting strategies when fisheries exist for both predator and prey
- Develop short-term projections for explicitly modeled species
- Provide guidance for rebuilding predator stocks
- Evaluate change in predator management and it's effects on prey and competing predators
- Explore potential feedbacks between lack of prey, abundance of alternative prey, fishing mortality on the predator populations
- Longer projections can be performed as exploratory tool to investigate linkages among species but should not be used as a management tool
- Examine the role of predator consumption in reduced prey recruitment to the fishery

However, the Panel noted this model should not address the following issues:

- Setting reference points or harvest limits for single-species from MSVPA-X
- Estimations of absolute abundance for explicitly modeled species
- Examining local abundance or depletion
- Long-term projections are subject to the limitations of recruitment variability for the prey population and predator populations

Atlantic States Marine Fisheries Commission MSVPA-X Multispecies Assessment Subcommittee/Stock Assessment Committee

The MSVPA-X Multispecies Assessment Subcommittee presented its work to the Stock Assessment Committee on September 28, 2005:

MSVPA-X Multispecies Assessment Subcommittee Members
Matt Cieri – Subcommittee Chair, Maine Department of Marine Resources
Lance Garrison – Garrison Environmental Analysis and Research
Robert Latour – Virginia Institute of Marine Science
Behzad Mahmoudi – Florida Fish and Wildlife Conservation Commission
Brandon Muffley – New Jersey Department of Environmental Protection
Alexei Sharov – Maryland Department of Natural Resources
Doug Vaughan – National Marine Fisheries Service, Center for Coastal Fisheries and Habitat Research

ASMFC Stock Assessment Committee members present:
John Carmichael – Committee Chair, South Atlantic Fisheries Management Council
Matt Cieri – Subcommittee Chair, Maine Department of Marine Resources
Doug Grout – New Hampshire Department of Fish and Game
Kim McKown – New York Department of Environmental Conservation
Brandon Muffley – New Jersey Department of Environmental Protection
Mike Murphy – Florida Fish and Wildlife Conservation Commission
Des Kahn – Delaware Department of Natural Resources
Alexei Sharov – Maryland Department of Natural Resources
Doug Vaughan - National Marine Fisheries Service, Center for Coastal Fisheries and Habitat Research

Dr. Lance Garrison is acknowledged for his continued work with the MSVPA-X Assessment Subcommittee to fine tune the MSVPA-X model formulation, which he developed with Dr. Jason Link (National Marine Fisheries Service).

Appreciation is also extended to the ASMFC striped bass, Atlantic menhaden, weakfish, and bluefish Technical Committees that reviewed the input data that has been utilized in the model and the model formulation.
Special appreciation is given to the ASMFC staff dedicated to the coordinating and assisting the efforts of the ASMFC Multispecies Assessment Subcommittee in the preparation of this document to send to peer review – Patrick Kilduff, Joe Grist and Peter Mooreside. The ASMFC also appreciates the efforts of former staff Dr. Lisa Kline, Geoff White and Jeff Brust on multispecies projects.

TABLE OF ACRONYMS

ADAPT	A VPA that incorporates one or more abundance indices
ASAP	Age Structured Assessment model
ASMFC	Atlantic States Marine Fisheries Commission
ASPIC	A Surplus Production Model Including Covariates
CFDB	Commercial fishery database
CPUE	Catch per unit effort
GIS	Geographic Information Systems
ICA	Integrated Catch-at-Age
ICES	International Council for the Exploration of the Seas
MD DNR	Maryland Department of Natural Resources
MRFSS	Marine Recreational Fisheries Statistics Survey
MSVPA	Multispecies Virtual Population Analysis
MSVPA-X	Expanded Multispecies Virtual Population Analysis
NEFSC	Northeast Fisheries Science Center
NJ DEP	New Jersey Department of Environmental Protection
NJ OTS	New Jersey Ocean Trawl Survey
SEAMAP	Southeast Area Monitoring and Assessment Program
SEFSC	Southeast Fisheries Science Center
SSB	Spawning stock biomass
SSVPA	Single species virtual population analysis
VIMS	Virginia Institute of Marine Science
VPA	Virtual population analysis
XSA	Extended Survivors Analysis
YOY	Young of year

CONVERSION TABLE

Imperial	**Metric**
1 million pounds	454 metric tons (mt)
1 pound (lb.)	0.454 kilograms (kg)
1 pound (lb.)	454 grams (g)
1 ounce (oz.)	28.35 grams (g)
1 inch (in.)	2.54 centimeters (cm)
1 inch (in.)	25.4 millimeters (mm)
1 foot (ft.)	30.48 centimeters (m)
1 yard (yd.)	.914 meters (m)
1 mile	1.609 kilometers (km)
1 yard^2 (yd^2)	0.836 meters^2 (m^2)
1 mile^2	2.59 kilometers^2 (km^2)
1 yards^{3-} (yd^3)	meter^3 (m^3)

LIST OF VARIABLES

Definitions of variables described in Chapter I of MSVPA-X Assessment Report.

$R_{i,a}$ - total food consumption rate in biomass for a predator *i* and age class *a*

$v_{i,a}$ is a constant ration (biomass prey / biomass body weight)

$w_{i,a}$ is body weight of predator *i* of age *a*.

C_{ia}^{ys} - total consumption in year, *y,* for a predator during a given season, *s* for predator *i*, age class *a*.

SC_s is the mean stomach contents weight relative to predator *i* age *a* body weight in a season *s*,

D_s is the number of days in the season *s*

w_{ys} is the average weight-at-age for the predator *i* age *a*

N_{ys} is the abundance of the predator *i* age *a* during season *s* in year *y*.

E_s^{ia} is the evacuation rate for a predator *i* and age class *a* in season s - the rate at which food leaves the stomach

$\overline{SC_s^{ia}}$ - an average stomach contents across years for predator *i,* age class *a*, in season *s*

S_{jb}^{ia} - suitability index" for a given prey species, *j*, and age class, *b*, for predator species, *i*, and age class, *a* is calculated as a product of spatial overlap index, general vulnerability and size selection.

O_{ij} - spatial overlap index, defines similarity of spatial distribution of predator I and prey j based upon the relative abundance of predators and prey in defined areas within the model spatial domain. The index ranges between zero and 1.

A_i - type selection, reflects preference for a particular species relative to all others. Type selection is entered as a proportionalized rank index, equivalent to the expected diet composition for the predator given equal prey abundances and equal prey sizes.

$S(\alpha,\beta)$ - Size selection reflects primarily capture and ingestion probabilities and is a function of relative prey to predator length.

SB_{jb}^{ia} - Suitable biomass, total food available for predator i and age class a

$\overline{N_{jb}}$ - the average number of prey available during the time interval, where α and β are the beginning and end of the time period being considered expressed as a proportion of a year.

P_{jb}^{ia} - The biomass of a particular prey consumed by a predator is the product of total consumption by the predator and the proportion of total suitable biomass represented by that prey type

$M2_{jb}^{ia}$ - the predation mortality rate due to the predator is the ratio of these removals to the average abundance of the prey during the time interval

$M2_{jb}$ - total predation mortality rate for a given prey species and age class is finally the sum across all predators.