Atlantic States Marine Fisheries Commission

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MEMORANDUM

TO: Atlantic Menhaden Management Board

FROM: Ecological Reference Point Work Group and Atlantic Menhaden Technical Committee

DATE: April 26, 2021

SUBJECT: Atlantic Menhaden Spatial Model Needs

At the 2021 Winter Meeting, the Atlantic Menhaden Management Board tasked the Ecological Reference Point Work Group (ERP WG) and Atlantic Menhaden Technical Committee (TC) to provide additional detail regarding the research recommendation in the 2019 benchmark stock assessment to "develop a spatially-explicit model." Specifically, the Board requested information on what data would be needed, a timeline for development and implementation, and if it would resolve questions regarding management of menhaden in the Chesapeake Bay.

The ERP WG and TC discussed potential approaches for developing a spatially-explicit model for Atlantic menhaden. These approaches cover a range of spatial complexity, data needs, and timelines, and provide different levels of information to support management. In this memo, the ERP WG and TC provide an initial outline of potential approaches, including the data and modeling development needs, timelines, and expected management information produced, and highlight areas where Board input is needed. The ERP WG and TC stress that the needs and timelines listed here are based on the group's current understanding of what is feasible and may change once model development and data analysis are underway. The approach the group chooses will depend on management goals, as well as data and funding availability.

Attributes	Approach
Coarse spatial scale, minimal additional data requirements	Coastwide Beaufort Assessment Model (BAM) + coastwide Northwest Atlantic Coastal Shelf Model of Intermediate Complexity for Ecosystems (NWACS-MICE) + supplemental Bay information
	Coarse spatial BAM + coastwide NWACS-MICE ERPs
Fine spatial scale, significant additional data requirements	Coarse spatial BAM + coarse spatial NWACS-MICE ERPs
	Detailed spatial BAM + detailed spatial ERPs (NWACS-MICE or alternative detailed spatial multispecies model)

1. Coastwide BAM and NWACS-MICE with supplemental Bay information

These approaches would use the existing BAM plus NWACS-MICE approach to develop coastwide ERPs for Atlantic menhaden to produce a Total Allowable Catch (TAC) that takes into account Atlantic menhaden's role as a forage fish on a coastwide basis, as is done now, but would also provide supplemental information on the Chesapeake Bay.

a. Supplemental Bay Atlantic menhaden abundance information

Approach*:* Supplemental information on absolute Atlantic menhaden abundance in the Chesapeake Bay, such as from an aerial survey, could be used to determine what proportion of the TAC could be taken from the Chesapeake Bay in order to keep exploitation in the Bay at an acceptable level. This simpler, escapement-based approach could be an efficient way to develop information to inform the Chesapeake Bay Cap; however, it would not provide broader spatial information and therefore would not provide advice for regional allocation discussions. In addition, the ERPs developed would be on the coastwide scale, and thus would not include consideration of predator-prey interactions or needs on a finer spatial scale. The ERP WG and TC also noted the uncertainty introduced by combining two different methods of abundance estimation (the BAM and the fishery-independent Bay method), and the lack of information on seasonal migration rates into and out of the Bay.

Data & development needs: This approach would not require additional model development, but would require a significant investment in a robust source of information on absolute abundance in the Chesapeake Bay, which is currently does not exist. It may be possible to use a shorter time series of abundance in this framework than the 10 years that the TC requires for indices of relative abundance within the BAM; however, this will depend on review of the data after collection. An absolute abundance survey would likely require 1-2 years of gear calibration and pilot studies, plus a minimum of 3 years data, in order to evaluate interannual variability and uncertainty in the abundance estimates from the survey, meaning this approach could potentially be taken to peer review within 5-7 years of initiating the survey. However, if interannual variability is high, more years of data would be needed before the approach is ready for management use. Although shorter time series might be sufficient for the initial analysis, the survey would need to be conducted on a regular basis in order to provide management advice in subsequent years.

b. Supplemental Bay multispecies indicators

Approach: Supplemental information such as the state of major predators (striped bass, blue fish, birds) abundance and body fat condition for the Bay could be used as ecosystem indicators to inform management control rules in parallel with the single species BAM and MICE models. Indicators would likely provide qualitative rather than quantitative advice on the Bay cap.

Data & development needs: Ecosystem indicators could be developed from existing datasets, but would require some work to synthesize different data sources and develop a meaningful control rule or traffic light approach to inform management.

2. Coarse spatial model approaches

These approaches would provide information on a coarse spatial scale, e.g., North, Mid, and South Atlantic plus a Chesapeake Bay region. However, it is important to note that, due to data limitations, the Chesapeake Bay region would include the coastal waters of Maryland and Virginia. Additional analysis of the tagging data would be required to determine the significance of including ocean waters and whether or not this information could be used to inform the Bay Cap. Both of these approaches would take approximately 5-7 year to complete, though this could change depending on funding and data availability.

a. Coarse spatial BAM with coastwide NWACS-MICE ERPs

Approach: This approach would refine the BAM to include spatial dynamics at a coarse scale and produce regional estimates of biomass, while the NWACS-MICE model would provide coastwide ERPs. The BAM plus NWACS-MICE would be used to develop a coastwide TAC, as is done now. An escapement-based approach could be used to determine what proportion of the TAC could be taken from each region. Regions would be defined to match management needs and the existing information on migration rates. Again, in the coarse approaches the Chesapeake Bay region would include Maryland and Virginia coastal waters due to its inclusion in the Bay region in the historical tagging study. The coastwide ERPs would not include the ecosystem considerations on a finer spatial scale. Currently, genetic and tagging data indicate Atlantic menhaden comprise a single stock on the Atlantic coast, and the BAM includes some consideration of spatial dynamics with the fleets-as-areas approach. Incorporating spatial structure could provide some improvements to our understanding of the stock, including differences in recruitment and life history characteristics.

Data & development needs: Catch-at-age data are already available on a coarse regional basis. Existing fishery-independent indices could be assigned to or developed at the regional level. The existing information on migration rates between large scale regions is not differentiated by age, and so the model would assume that all ages share the same migration patterns. This would introduce additional uncertainty in the spatial model. Information on the proportion of total recruitment that comes from each region could also be a limitation for this model. This approach could be attempted with the existing datasets, but would require investment of personnel time and effort. This approach would likely be ready for peer review in 5-7 years, but that frame could be longer if existing data are not adequate.

b. Coarse spatial BAM with coarse spatial NWACS-MICE ERPs

Approach: This approach would build on the coarse spatial BAM approach described above, but combine it with a coarse spatial NWACS-MICE. To develop ERPs that take into account spatial dynamics in predator-prey interactions, a spatially-explicit multispecies model is necessary. The most straightforward approach would be to combine a spatially-explicit version of the NWACS-MICE model with a spatially-explicit version of the BAM. Both models would have a similar coarse spatial scale determined by management needs and data availability. Again, note that the Chesapeake Bay region would include Maryland and Virginia coastal waters. This approach could be used to provide advice on both the Chesapeake Bay Cap and broader regional allocation discussions. For example, it would be possible to run scenarios with differing levels of

fishing in the Chesapeake Bay region to estimate specific impacts on predators that use the region.

Data & development needs: A spatially-explicit multispecies model is more data intensive than the spatially-explicit BAM. To develop a coarse NWACS-MICE spatial model, we would need estimates of dispersal rates for all modeled species, information on seasonal spawning, recruitment, and migration patterns, and also information on spatial fishing effort for all fishing fleets in the model. In absence of actual data, expert opinion and rules-of-thumb can be used to parameterize the spatial model. For calibration and validation of the spatial model, we would need reliable species distribution maps that are seasonally resolved, region-specific trends in abundance and catch, fishing effort maps, and region-specific food habit data. The scale of the existing diet data is a weakness in current data availability in developing ERPs that account for finer scale ecosystem dynamics, especially for non-finfish predators. Investment in enhanced diet data collection from new or existing fishery-independent sampling programs at the state or federal level for the species in the NWACS-MICE model would benefit these models. This approach could be attempted with the existing datasets, but would require investment of personnel time and effort. This approach would likely be ready for peer review in 5-7 years; however, that frame could be longer if existing data are not adequate or shorter if resources are made available and more time can be allocated to model development.

3. Complex Spatial Modeling Approaches

These approaches would further refine the spatial scale. If the data were available, these approaches could provide information on the Chesapeake Bay specifically (i.e., not including ocean waters) and other regions beyond the coarse spatial scale. Both of these approaches would likely take at least 10 years, though this could change depending on funding and data availability.

a. Refined spatial BAM with NWACS-MICE ERPs

Approach: This approach would develop a more refined spatial BAM, which would be able to provide information on the Chesapeake Bay specifically (separate from MD and VA ocean waters) and other regions beyond the coarse spatial scale described above. It could be used with a coastwide NWACS-MICE or a refined spatial NWACS-MICE, depending on data availability. Depending on which NWACS-MICE approach was used, this approach would provide information similar to the escapement-based approaches or the coarse NWACS-MICE approach, respectively, but on a more refined spatial scale.

Data & development needs: In order to provide information on a true Chesapeake Bay region, or other regions beyond the coarse spatial scale described above, the BAM would require more fine-scale information on migration rates at age between the regions of interest. This would require a new comprehensive tagging study to provide that information. If complementary data on seasonal spatial distribution maps and trends in abundance and catch were available for the NWACS-MICE model, ERPs could be developed on a similar scale to the BAM's regional structure. If not, coastwide ERPs could be used in conjunction with the more refined BAM model. The refined spatial ERPs require significant investment in movement studies as well as in

diet data and model development. This approach would not be feasible until the necessary movement data are available.

b. Detailed spatial BAM and detailed spatial ERPs

Detailed spatial BAM and detailed spatial ERPs

Approach: The most complex approach would be to develop a fully-realized fine-scale spatial multispecies or ecosystem model for Atlantic menhaden. This could be achieved with NWACS-MICE, or another model such as the multi-species statistical catch-at-age model developed for the 2019 ERP Benchmark Assessment. A fully realized NWACS-MICE or other spatial model would use a much finer spatial resolution (on the order of 10-minute squares) that represented habitat gradients and jurisdictional boundaries. The model could be driven by static and/or spatial-temporal habitat maps, for example from satellite data or oceanographic model. This approach could simulate a broader range of environmental and policy options, such as warming sea temperatures and species range expansion into the northern region. Higher spatial resolution in the model would allow for better representation of spatial fishing effort in and out of the Bay.

Data & development needs: The disadvantage of this approach is that it is far more computationally demanding and requires information on species-habitat interactions that may not be available for some species. Typically, the habitat preference functions are derived from survey data. Assembling habitat maps, combining survey datasets, and estimating species preference functions for the different habitat types adds considerable time to model development. For species/life stages that are not captured in any surveys, expert opinion and online data repositories such as AquaMaps can be used instead. Validating the high-resolution spatial MICE model could be done by comparing region-specific time series (similar to the coarse scale model), comparing predicted and observed species distribution maps, or on a point-by-point basis. Higher resolution movement and diet data would significantly enhance model development and result in more reliable ERP estimates. Spatially-explicit statistical catch-at-age models do exist (i.e., Stock Synthesis and others); however, they do not exist in a multispecies model construct at this point, so would require software development. This approach would not be feasible until the necessary spatial data are available.

Immediate Funding Needs

The ERP WG and the TC indicated that some form of a coarsely structured spatial model was possible to develop for the next benchmark assessment if the Board was willing to accept a longer time frame for the next benchmark (2027-2028 instead of 2025). The approach that the groups pursue will depend on management goals (see 'Management input needs' below), data availability, and development resources. Table 1 provides a comparison of the approaches based on advice provided, data needs, and timeline.

The major areas that would require or benefit from funding to address data or model limitations are summarized below. In addition, the ERP WG and TC noted that timeline for model development could be shortened somewhat with funding for dedicated modelers.

Approach	Major Funding Need
Coastwide model with supplemental Bay information	3-5+ years of reliable absolute abundance estimates for the Chesapeake Bay
Coarse spatial ERPs	Spatially and seasonally explicit diet data and spatial distributions for key predator and prey species; additional model development
Refined spatial ERPs	Spatially- and seasonally-explicit diet data for key predator and prey species; fine-scale information on migration rates between regions by age; additional model development

Management input needs

The TC and ERP WG need guidance from the Board on specific goals and priorities to determine a path forward. The ERP WG and TC pose the following questions to the Board:

- What is the primary goal for spatially-explicit modeling? (e.g., advice on Chesapeake Bay Cap, regional allocation advice, enhance accuracy of coastwide ERPs, something else)
- Are there secondary goals?
- Are the ecosystem management objectives for the Chesapeake Bay the same as those used to develop the coastwide ERPs?
- What tradeoffs is the Board willing to make between the spatial scale/detail of the modeling and the timeline for the next benchmark?
- Would the Board be satisfied with a regional approach that separates MD and VA from the rest of the coast if modeling the Chesapeake Bay separately is not feasible for the next benchmark?

For example, the primary goal could be to provide advice on the Chesapeake Bay Cap by the next benchmark assessment, and the secondary goal could be to provide information to inform regional allocations. In this case, if there were challenges with developing a model to provide regional allocation information in the next benchmark timeframe, the group could switch to an approach that would only provide advice on the Chesapeake Bay Cap. Alternatively, if the Board prioritized regional allocation in addition to the Bay Cap and indicated that they were willing to wait longer for results, the group could delay completion of the benchmark assessment in order to complete that approach.

The TC and ERP WG will need direction from the Board as soon as possible (no later than Annual Meeting) in order to pursue a spatially-explicit modeling as part of the next benchmark stock assessment and follow the current assessment schedule.

Table 1. Comparison of potential approaches for developing a spatially-explicit model for Atlantic menhaden.

Approach	Advice				Data Needs		Timeline***
	Single-spp. CB	Multi-spp. CB	Multi-spp. Regional Allocations	Fine-scale Spatial Dynamics	Possible w/ Existing Data	Addt'l data needs	
Coastwide BAM + NWACS-MICE + supplemental Bay abundance	✓					Absolute abundance estimates in C. Bay	5-7 years
Coastwide BAM + NWACS-MICE + Bay indicators	✓*	✓*			✓		5-7 years
Coarse spatial BAM + coastwide NWACS-MICE ERPs	✓**				✓		5-7 years
Coarse spatial BAM + coarse spatial NWACS-MICE ERPs	✓**	✓**	✓		✓	Better diet data for ERP species	5-7 years.
Refined spatial BAM + NWACS-MICE ERPs	✓	✓	✓			Migration at age data for desired regions, better diet data for ERP species	10+ years
Detailed spatial BAM + detailed spatial ERPs	✓	✓	✓	✓		Finer scale data (all types) for ERP species	10+ years

*: This approach would likely provide qualitative, not quantitative, information on Chesapeake Bay Cap

**: Existing data could provide information on MD and VA separately from the rest of the coast, but not Chesapeake Bay itself.

***: These timelines are preliminary estimates and could be revised once model development is underway.