Report on the evaluation of the Chesapeake Bay Fisheries Science Program: Atlantic Menhaden Research Program
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Executive Summary

It is understood that the overarching objective of projects undertaken under the four research areas identified by the Technical Committee of the Atlantic States Marine Fisheries Commission (ASMFC) is ascertain whether localized depletion is occurring in Chesapeake Bay, and if it is, to identify the causes, understand the mechanisms, and evaluate the consequences. Considerable progress has been achieved in gathering information that would help achieving this objective, but much remains to be done.

Each individual research project seemed relevant and well designed, but it is not clear how the overall package had been structured to determine if localized depletion was occurring. In addition, in the absence of an operational definition of localized depletion, it is not possible to fully evaluate the goals, quality and quantity of work, nor the relevance of research projects conducted in the four research areas identified by ASMFC as key to understanding the status of menhaden in Chesapeake Bay and to determine if localized depletion is occurring.

While an operational definition of localized depletion has not been agreed, it can be predicted with relative confidence that as the abundance of predators continues to increase, their food requirements will also continue to increase, to the point where they may become food limited. In a fisheries management context, it would therefore be useful to assess the extent of present or future conflicts between the commercial fishery, the recreational fishery and the predators in terms of times, areas, and sizes of fish consumed. The increased consumption of menhaden by striped bass between 2004 and 2006 appears to be due both to higher striped bass stock size, but also longer residency in Chesapeake Bay of migratory striped bass. That it was possible for striped bass to increase its consumption of menhaden substantially in such a short period of time suggests that menhaden biomass in Chesapeake Bay is substantial. Whether there is enough for the increasing demands of striped bass and other predators, including the commercial and the recreational fisheries, will be a difficult and possibly very expensive question to resolve. Time and area restrictions as well as zoning of the fisheries that are competing for menhaden might provide a more rapid mechanism to mitigate the possible negative consequences of competing fisheries and predators. In the medium term, an operational definition of localized depletion will have to be agreed in terms of the quantities of menhaden allocated to the competing fisheries and to the predators.

The projects reviewed have been focused in Chesapeake Bay. The available information suggests that Atlantic menhaden is a single stock for the Atlantic coast, including Chesapeake Bay. Understanding the recruitment dynamics in Chesapeake Bay will require that the spawning times and location be further studied and that the fate of eggs and larvae be also investigated.

Background

The NOAA Chesapeake Bay Office (NCBO) has been coordinating a competitive-based research program to increase the knowledge on Atlantic menhaden populations along the Atlantic Coast – specifically to address the concerns of the potential for 'localized depletion' in Chesapeake Bay. Addendum II to Amendment 1 to the Interstate Fishery Management Plan (ISFMP) for Atlantic menhaden established a research program for the Chesapeake Bay focused on four research priorities:

1) determine menhaden abundance in Chesapeake Bay;
2) determine estimates of menhaden removals by predators;
3) evaluate the rate of exchange of menhaden between Bay and coastal systems; and
4) conduct larval studies to determine recruitment to the Bay.

This research program is moving forward under the direction of NCBO.

In 2009, the Atlantic States Marine Fisheries Commission (ASMFC) Atlantic menhaden Technical Committee will hold data and assessment workshops to complete a full stock assessment scheduled for a South East Data and Assessment Review (SEDAR) in 2010.

Prior to the development of a full stock assessment, it was considered useful to review on-going activities and how that information (preliminary and/or final) should be included in the assessment.

The NCBO funds partially or entirely research projects on several Chesapeake Bay species. Progress and results on these research projects have been reviewed through symposia. Exceptionally, in 2008, webinars were organized instead of a symposium. In 2009, a two day symposium was organized. Day 1 was devoted to species other than menhaden and Day 2 was devoted to Atlantic menhaden in Chesapeake Bay.

Prior to the 2009 symposium, I downloaded and read the main assessment papers as well as the menhaden power point presentations prepared for the 2008 symposium. I attended Day 2 of the 2009 NCBO as an observer and, along with the other two CIE reviewers, participated in discussions with the principal investigators who had kindly agreed to meet with us on Thursday April 23. The three CIE reviewers, with the help of Derek Orner met on Friday April 24 to discuss their preliminary findings and share their views on the symposium, on the discussions with the principal investigators, and on the relative merits of the research projects. Following the meetings in Maryland, I consulted documentation supplied by Derek Orner on the discussions at the ASMFC Technical Committee leading to the development of the research program and I prepared this report.

Summary of Findings for each ToR

It is understood that the overarching objective of projects undertaken under the four research areas is ascertain whether localized depletion is occurring in Chesapeake Bay, and if it is, to identify the causes, understand the mechanisms, and evaluate the consequences.

The Technical Committee of the Atlantic States Marine Fisheries Commission defined localized depletion as: "*Localized depletion in the Chesapeake Bay is defined as a reduction in menhaden population size or density below the level of abundance that is sufficient to maintain its basic ecological (e.g. forage base, grazer of plankton), economic and social/cultural functions. It can occur as a result of fishing pressure, environmental conditions, and predation pressures on a limited spatial and temporal scale*."

This definition would not consistently lead to the same conclusion following an evaluation of the available information: based on the same information, one observer could conclude that localized depletion is occurring while a different one might conclude the opposite. This is possible because the quantity of menhaden needed for each of the basic ecological, economic and social/cultural function is not quantified. Therefore, depending on their own, generally unstated objectives, different observers could legitimately reach different conclusions from the same information.

It is noteworthy that as populations of predators/prey and economic/social/cultural functions change over time the quantities of menhaden required for the various expected functions would also be expected to change. For example, other things being equal, increases in the population sizes of predators, either fish, avian or mammals, feeding on menhaden would be expected to result in less menhaden being available for the other functions. In the extreme, unchecked growth of predators could lead to no or very few menhaden being available for the other functions AND insufficient menhaden for the predators themselves with consequent slower growth/poorer condition[1]. The concept of localized depletion does not explicitly capture the possibility that menhaden population size or density could be too low because of increased requirements, not only because of reductions in population size or density. This would broaden the scope for management action.

The ASMFC Technical Committee definition provides a good basis for a more operational definition where the threshold "*of abundance that is sufficient to maintain its basic ecological (e.g. forage base, grazer of plankton), economic and social/cultural functions*" would be identified. It would be particularly timely to agree on such threshold as, given current conditions, if predators continue to increase, it is

[1] There are indications of a possible negative relationship between striped bass biomass and menhaden recruitment (http://ian.umces.edu/pdfs/menhaden_recruit_news.pdf)

likely that menhaden has a relatively high probability of falling below reasonable thresholds in the foreseeable future.

Based on tagging and genetic studies, the Atlantic menhaden stock on the Atlantic coast of North America, including Chesapeake Bay, is considered to be a single stock. If Atlantic menhaden is indeed a single stock, the negative consequences of localized depletions, by definition, would be expected to be limited in space and time. While available evidence points to a single stock, if Atlantic menhaden were in fact a meta-population with several sub-stocks, the stock wide consequences of localized depletion could be more extensive geographically and temporally. If sub-stocks of a meta-population are depleted, long term decreases in the productivity of the meta-population could occur.

Program Management:

1. *Evaluate the goals, quality and quantity of work, and relevancy of research projects conducted in four research areas identified by ASMFC as key to understanding the status of menhaden in Chesapeake Bay and to determine if localized depletion is occurring:*

    - *Menhaden abundance in Chesapeake Bay*
    - *Removal of menhaden by predators in Chesapeake Bay*
    - *Exchange of menhaden between Chesapeake Bay and coastal systems*
    - *Recruitment of menhaden to Chesapeake Bay*

    On April 22, 2009, eleven presentations were made under the four research areas by principal investigators. The presentations were:

    Menhaden abundance in Chesapeake Bay

    1. Coastwide Atlantic menhaden stock assessment by the Population Dynamics Team
    2. LIDAR Aerial surveys of menhaden in Chesapeake Bay by Jim Churnside, NOAA Research and Alexei Sharov, Maryland Department of Natural Resources

    Removal of menhaden by predators in Chesapeake Bay

    1. Ecological depletion of Atlantic menhaden - effects on Atlantic coast striped bass: first year-round food habit study of large Chesapeake bay striped bass by Jim Price
    2. Estimating removals of forage fishes by predators in Chesapeake Bay by R.J. Latour, C.F. Bonzek, and J. Gartland.
    3. Finfish-Waterbird Trophic Interactions in Chesapeake Bay and its Tributaries by Greg Garman, Cathy Viverette, Steve McIninch, Bryan Watts, Adam Duerr, Stephen Macko and Jim Uphoff.

Exchange of menhaden between Chesapeake Bay and coastal systems

1. Probing the population structure of Atlantic menhaden (*Brevoortia tyrannus*) in the mid-Atlantic by Jason J. Schaffler, Cynthia M. Jones, Thomas J. Miller.
2. Ingress of Larval Atlantic Menhaden to Chesapeake Bay: Supply-Side Dynamics by E. D. Houde, C. Lozano and A. Hashinaga.
3. Do Environmental Conditions in Nursery Habitat Contribute to a Mismatch in Growth and Production of Young Atlantic Menhaden (*Brevoortia tyrannus*) and Striped Bass (*Morone saxatilis*)? by Jason L. Edwards, Benjamin J. Ciotti, Timothy E. Targett, and Thomas J. Miller.

Recruitment of menhaden to Chesapeake Bay

1. Menhaden Abundance and Productivity: Linking Recruitment Variability to Environment and Primary Production in Chesapeake Bay by Edward D. Houde, Eric R. Annis, Lawrence W. Harding, Jr. and Michael J. Wilberg
2. Age, growth, and otolith chemistry of YOY Atlantic menhaden in the Chesapeake Bay by Rebecca L. Wingate, David H. Secor, Carlos Lozano, Edward D. Houde, Philip M. Piccoli.
3. Factors Affecting Growth of YOY Atlantic Menhaden in Chesapeake Bay by Michael Wilberg, David Secor, and Edward Houde.

Principal investigators kindly stayed for further discussion of the projects objectives, methods and results with the CIE Review Panel on April 23, 2009.

The following participants attended the Meeting on Thursday 23rd April:

Churnside, Jim	Price, Jim
Haddon, Malcolm	Roel, Beatriz
Houde, Ed	Schaffler, Jason
Jones, Cynthia	Secor, David
Maguire, Jean Jacques	Sharov, Alexei
Miller, Tom	Speir, Brad.
Orner, Derek	Wilberg, Mike

The presentations were very interesting, all the projects appear relevant to the objective of determining if localized depletion is occurring and / or what are the mechanisms, the quality of the work is unquestionable and the quantity of work is impressive. It is somewhat surprising, however, that no investigation has been undertaken outside of Chesapeake Bay on spawning aggregations. What is happening in the Bay is expected to be linked in some way to what is happening on the spawning grounds and it would seem that to understand the mechanisms that influence the abundance, distribution, and movements of menhaden eggs, larvae and adults after spawning it would be necessary to sample outside the Bay. Given variable environmental conditions and ocean currents, it would seem unlikely that a constant quantity or a constant fraction of the larvae produced at the two spawning locations and times would enter Chesapeake Bay.

While each individual research project seemed relevant and well designed, it is not clear how the overall package had been structured to determine if localized depletion was occurring.

In the absence of an operational definition of localized depletion, it is not possible to fully evaluate the goals, quality and quantity of work, nor the relevance of research projects conducted in the four research areas identified by ASMFC as key to understanding the status of menhaden in Chesapeake Bay and to determine if localized depletion is occurring.

2. *Evaluate the goals, quality and quantity of work, relevancy and feasibility of on-going research projects to better understand the four research areas.*

While all projects are relevant, interesting and would be expected to bring useful additional information, this term of reference is used to comment more specifically on some projects.

It is necessary to understand what is happening to Atlantic menhaden over the whole coast to be able to place events occurring in Chesapeake Bay in their proper perspective. Therefore, continuing to do and improve the accepted coast wide assessment is a high priority. While the spatially implicit menhaden model by Christensen and Martell (2009b) was incomplete, it would provide an alternate perspective on the data and information available and it seems highly desirable to develop this model further.

The assessment uses six young-of-the-year (YOY) indices (NC, VA, MD, NJ, CT, RI) and one pound net (Potomac River) index for all ages (0+). Other indices of stock size, both in the Bay and coast wide would be helpful to increase the reliability of the stock assessment. Two approaches appear promising: the cooperative work with the spotter plane pilots and aerial surveys using LIDAR and video. While considerable work remains to be done to develop an index of stock size from the combined LIDAR-video survey, once fully developed, this approach is expected to be considerably less expensive than conventional ship-based acoustic or trawl surveys. Both approaches (spotter plane pilots and LIDAR) should be pursued.

Understanding the trophic relationships between menhaden and its fish and avian predators within Chesapeake Bay will require continuous systematic monitoring because relationships would be expected to change as the abundance and distribution of preys and predators change.

The project assessing the ingress of larval Atlantic menhaden into Chesapeake Bay has been highly successful and met most of its objectives. There is no doubt that continuation of the project would bring useful information, but results to date for this project and from larval studies on other species in other areas suggest that it will not be possible to predict recruitment from ingress of larvae. Coast wide estimates of the abundance of larvae (or eggs) could provide an index of the spawning stock size but,

as indicated above, it is unlikely that Chesapeake Bay receives a fixed proportion of the spawning products every year.

As indicated under ToR 1, while each individual research project seemed relevant and well designed, it is not clear how the overall package had been structured to determine if localized depletion was occurring.

3. *Identify scientific and data gaps that will contribute to understanding in the four research areas.*

Menhaden abundance in Chesapeake Bay

If the Atlantic menhaden stock is indeed a single homogenous stock then the abundance of menhaden in Chesapeake Bay would be expected to be somewhat loosely related to the total abundance of menhaden coast wide. The actual abundance in the Bay could be related to some unknown factor that influences how many larvae do enter the Bay and presumably return there for a few years following their annual migration out of the Bay. It would therefore be useful to investigate spawning time and locations and follow the eggs and larvae to try to understand what influences their final destination. Preliminary information can probably be gathered from past sampling programs and this could be used to design a targeted program for menhaden.

Removal of menhaden by predators in Chesapeake Bay

Full understanding of the influence of predators on menhaden will require systematic and targeted sampling of all predators over several years. If the objective is to understand the requirements of predators, other important prey would need to be considered and it would be necessary to understand the dynamics of the prey as well as those of the predators. This is not a simple question to resolve: predator – prey relationships are likely to change as the abundance and distribution of predators, prey and competitors are changing. Global (climate) change would add another layer of complexity. Opportunistic sampling is unlikely to provide the data necessary to reduce the uncertainties in the interactions – only consistent, continuous extensive and systematic sampling has a chance to explain changes in diet composition. Still, years of extensive sampling are unlikely to lead to precise and reliable predictive capabilities – predictions will remain highly uncertain. While gathering diet composition data will certainly lead to increased knowledge of the interactions between species, it is far from certain that predictions would be seen as sufficiently reliable to provide the scientific basis for decision making. Instead, it might be preferable to adopt a risk based approach, based on an agreed operational definition of localized depletion and to implement management measures that have a reasonable likelihood of avoiding localized depletion.

Exchange of menhaden between Chesapeake Bay and coastal systems

The research projects presented during the symposium and discussed during this review have identified that the ingress of larvae is variable from year to year and that once in Chesapeake Bay larval / juvenile menhaden have a tendency to remain in the areas where they have first settled. This therefore suggests that, at this stage, localized depletion is possible, and that it would be mostly due to predators because those sizes are not caught in the fishery. If the larvae and juveniles do remain in the areas where they have settled, it is possible, but remains to be demonstrated, that ages 1 and older do the same. Because the mobility of menhaden increases substantially at age 1 and older, it would be expected that they would be less attached to specific sites and have a greater ability to explore new environment / habitats within and outside Chesapeake Bay. This could mean that the possibility / likelihood of localized depletion decreases as the menhaden are getting older.

There are two components to the exchange of menhaden between Chesapeake Bay and coastal systems: 1/ how many / what proportions of menhaden enter Chesapeake Bay, and 2/ in what precise location do they go once they get back in the Bay. In other words, is there homing to the Bay and if so, does it also occur within the Bay?

Recruitment of menhaden to Chesapeake Bay

The standard assessment suggests that menhaden recruitment was low in the 1960s, that it increased during the 1970s peaking in the late 1970s – early 1980s and that it has generally trended downwards since. It should be noted, however, that while recruitment has generally been trending downwards since the early 1980s it remains generally higher than in the 1960s. The juvenile indices used in the assessment suggest that recruitment in the southern part of the menhaden range, including Chesapeake Bay, has decreased more than in the northern part of the range. This however does not necessarily mean that localized depletion is occurring; it could be due to less menhaden getting into the Bay for biological or oceanographic reasons.

Under the current understanding that Atlantic menhaden is a single stock, recruitment of menhaden to Chesapeake Bay is expected to be a function of overall recruitment to the entire stock, which is likely to be a function of spawning stock biomass and some yet to be identified environmental factors (both biological and physical), and oceanographic conditions that will influence the proportion of the overall larval production that does enter Chesapeake Bay. Local condition in Chesapeake Bay will determine the fate of those larvae that do enter the Bay.

4. *Provide recommendations for future research projects to address information and data gaps identified in ToR #3.*

The main thrust of the comments under ToR #3 is that it is difficult to fully understand recruitment to Chesapeake Bay by conducting investigation only in Chesapeake Bay. Clearly, recruitment to Chesapeake Bay is linked to how much

spawning takes place outside of the Bay, where and when this spawning occurs, and where the spawning products go. If a constant number of larvae or a constant proportion of the total number of larvae produced entered Chesapeake Bay, it would be less important to conduct investigations outside of the Bay, but results to date show that the number of larvae entering the Bay varies from year to year without a clear pattern.

The other main thrust, is that the investigation of predator – prey relationships is a demanding process that should be conducted under strict sampling protocols over extensive period of times. Even under the best of conditions, pre-season predictions are likely to remain highly uncertain. Mechanisms to provide in-season predictions could reduce the uncertainty.

General

The 2003 Atlantic menhaden stock assessment peer review panel concluded that the current assessment model and methodology cannot address localized depletion questions. Terms of reference 5 through 7 are focused on modeling and data collection changes or improvements to advance managers and scientists' ability to answer localized depletion questions.

5. *Evaluate the adequacy, appropriateness, and utility of models used to assess Atlantic menhaden stock, including the model focusing on the Chesapeake Bay sub-stock, and characterize the uncertainty in those models.*

   The models used to assess Atlantic menhaden appear to be adequate, appropriate and useful to estimate the dynamics of the stock as a whole. The standard stock assessment is a statistical catch at age forward projection model that uses abundance indices (several juvenile seine index and one pound net 1+ index), recorded landings, and annual samples of size and age compositions from the landings. It has little or no spatial structure, and as such, as recognized by the ASMFC, does not have the ability to identify or assess localized depletion. An alternate assessment model, with more spatial structure has started to be developed and its development should continue. However, it is not clear that the biological understanding of menhaden abundance, distribution and movement will be sufficient to discriminate between various hypotheses in terms of localized depletions. Additional tagging studies may be needed (given the limited geographic scope of the fishery, intelligent tags may be a more effective way to gather additional information than conventional tags) to determine if the juveniles that have spent their first year in the Bay return to the Bay in their second year of life and subsequently. If there is complete panmixing, localized depletion, while still important locally, would be expected to be less of a problem for overall stock productivity.

There are no estimates of total abundance in the standard assessment and the main indices of relative abundance relate to estimates of juvenile abundance from fishery independent seine surveys designed mainly for other species (e.g. striped bass) or species groups (e.g. Alosids). It might be possible to increase the usefulness of those data by either post-stratifying or using only a subset of the data that is considered more representative of juvenile menhaden abundance.

Given the increased abundance of menhaden predators (fish, avian and possibly marine mammal), it would be important to continue the development of multispecies assessment techniques to formally take into account the increased predation mortality. As the abundance of avian predators can be expected to continue to increase, it will become more and more important to include their removals in the menhaden assessment and consider them explicitly in fisheries management decisions.

While the current stock assessment appears adequate and appropriate, preliminary results of an alternative assessment model (Christensen and Martell 2009a) suggest different conclusions with respect to reference points. It would therefore seem appropriate to develop further the alternative model to allow fuller and more meaningful comparisons.

6. *Evaluate the scientific findings of the Research Program and their potential to provide knowledge for development and implementation of biological reference points.*

Based on the 2006 standard assessment, it appears that existing reference points are based on proxies and may be adjusted in each assessment to take account of changes in growth, mortality and selectivity parameters. The data and assessment results are sufficient to calculate MSY reference points and this should be done. It should be noted, however, that stock wide reference points, either MSY based or proxies, may not be useful in determining if local depletion is occurring in Chesapeake Bay. An operational definition of localized depletion, however, could serve as an additional reference point in making fisheries management decisions.

For the largest majority of marine species, and more particularly for pelagic species, recruitment appears to be only loosely related to spawning stock biomass or to egg production. The survival rate from eggs to larvae and from larvae to juveniles is notoriously variable and it is possible to obtain large recruitment from small egg production and vice versa. The 2006 assessment results for menhaden support this general observation with a below average year class produced at the highest estimated population fecundity and the largest year class produced at average or slightly above average population fecundity (Atlantic Menhaden Committee 2006,Fig. 7.2). The fecundity based reference points appear well supported by the assessment results (Atlantic Menhaden Committee 2006, Fig. 7.6 and 7.7).

As indicated above, predation mortality is estimated to have increased, and it would be reasonable to expect that it will continue to increase. A policy decision will be

required at some point in the future, possibly in the context of the ecosystem approach to fisheries, to decide how to take such increased predation into account. If predation is allowed to continue to increase, fishing mortality reference points would have to be decreased to allow for the increased mortality due to predation.

7. *Develop recommendations to improve data collection based on evaluation of the reviewed research projects and identified data gaps.*

   As indicated above, it might be possible to improve the indices of relative abundance for juvenile menhaden by post-stratification or by selecting subsets of the stations of the surveys. It would also be useful to find a meaningful way of combining them into a single index. At present, each index is given a weighting derived from "estuarine and fluvial drainage areas along the Atlantic coast, combined with menhaden productivity of streams along the Atlantic coast…". It might be possible to improve on this approach by trying to expand the survey results in each system to potential menhaden habitat and then to add-up the estimates in a process similar to estimating the biomass from random-stratified bottom trawl surveys.

   The current standard assessment covers the whole Atlantic coast, which seems appropriate given available information on stock structure. However, the geographical coverage of the fishery has been considerably reduced compared with the area covered at the beginning of the assessment period. As a result, there is greater uncertainty on the abundance of the older and larger menhaden which are believed to occur mostly outside of the areas where the majority of the fishery now takes place. Therefore, in addition to the index of abundance for adults in the area of the fishery, it would also be useful to have information on menhaden abundance for the whole area.

   If menhaden abundance is high outside of the area where the fishery occurs, it would further decrease the stock wide concerns about menhaden productivity, but it would not alleviate the concerns about localized depletion in Chesapeake Bay.

   If an area specific assessment model is developed and used, it would be expected to require additional sampling in terms of size composition and changes in abundance.

Project Specific:

Abundance Estimates

8. *Alternative coastwide stock assessment model – Evaluate the adequacy and appropriateness of all the data used in the assessment including life history, natural mortality, stock structure, recruitment dynamics, and patterns in F-I and F-D surveys.*

   The documentation available did not allow a full evaluation of the alternative coast-wide assessment model (Christensen and Martell 2009s) and the model appears to be still under development. The data used and natural mortality at age appears to be the

same as in the standard stock assessment model and both use statistical catch-at-age models. The main differences appear to be in the primary parameters estimated when fitting each model. The alternative model estimates directly MSY and F_{MSY} and there are also differences in the manner in which the models are initiated.

It is expected that a fuller evaluation of the alternative model and detailed comparison with the standard assessment will take place during the 2009-2010 assessment cycle. Preliminary estimates suggest that stock trends are similar in both assessments, but reference points are different leading to different conclusions about whether the stock is overfished or if overfishing is occurring. It is also expected that comparing the two models will lead to a better understanding of uncertainties and of the possible states of nature. In this sense, it should help decision making to consider the results from both models.

The sensitivity of both models should be investigated more by omitting data series one at a time, or by combining them in a different manner (different weightings), and by doing retrospective analyses (i.e. removing one year of data at a time to see how the assessment results would change under the accepted model configuration).

During the presentations, it was stated that the catch at age for menhaden is considered to be very reliable. If this is really the case, VPA methods (using similar natural mortality at age estimates) could also be used to compare estimates of recruitment for the converged part of the population number matrix. As indicated above, it would also be important to take increase predation into account, either in the modeling approaches or using MSVPA.

9. *Chesapeake Bay regional stock assessment model – Evaluate the adequacy and appropriateness of all the data used in the assessment including life history, natural mortality, stock structure, recruitment dynamics, and patterns in F-I and F-D surveys.*

   The documentation of the regional stock assessment (Christensen and Martell 2009b) was mostly a user guide for the software developed to explore scenarios of what would happen if the menhaden stock was sub-divided into sub-stocks. Results are preliminary and no conclusions were reached. Great care should be taken in taking the results of this scenario modeling too far until there is evidence that menhaden do form sub-stocks. While there is information that larvae and juvenile have some site attachment, indications are that mixing occurs at older ages.

   An assessment based on assuming sub-stocks, whether these exist or not, would require data on abundance (juveniles and adults) in each area and information on age-structure. As these data are currently limited or only available for one of the areas, the results of a regional assessment based on assuming sub-stocks would be expected to be more uncertain, particularly for each assumed sub-stock.

Larval / Recruitment Processes

10. *Evaluate the potential of the pilot-scale larval ingress surveys to provide measure of relative abundance of ingressing larvae, variability in seasonality of ingress, hatch date determination, trophodynamics, and relationship to hydrographic/oceanographic factors.*

    The pilot-scale project has clearly demonstrated its ability to provide measures of relative abundance of ingressing larvae, variability in seasonality of ingress, hatch date determination, and relationship to hydrographic/oceanographic factors within the Bay.

    Larvae did get inside Chesapeake Bay in each of the four years (three seasons) that sampling was conducted. The quantity of larvae varied from one year to the other, and also during each season, without clear pattern. The supply of larvae to Chesapeake Bay is believed to come from at least two spawning areas in different seasons. The ingress of larvae did not follow a regular increasing then decreasing pattern, suggesting that biological and oceanographic factors outside the Bay are important in determining when and how many larvae enter the Bay.

    It was possible to identify the specific estuaries where the larvae grew by analyzing otolith chemistry. This showed that larval menhaden, once they had reached an estuary, generally stayed in that one area. There are insufficient data to determine the relative contribution of each estuary and to evaluate if the contributions are variable over time.

    While studies elsewhere suggest that the relationship between larval abundance and subsequent recruitment is generally weak, particularly for pelagic fish species, in some cases, larval abundance could be related to the size of the spawning stock that produced the larvae. It is unlikely, however, that the sampling of larvae in Chesapeake Bay would provide a reliable indication of the size of the spawning stock that produced the larvae. Such an index of stock size could possibly be obtained if extensive surveys were conducted closer temporally and spatially to the spawning areas and time.

11. *Evaluate feasibility of the age and growth analysis and relationships to environmental factors of YOY juvenile menhaden based on otolith microstructure, modal length-frequency analyses, and on growth modeling.*

    The results of projects under this ToR showed that growth of juveniles is variable by area, month and year. Results are insufficient to evaluate if consistent patterns over space and area exist. The projects show that it is feasible to study growth in relationship to environmental factors. Continuing these studies could lead to findings with potential management implications if it were possible to identify essential habitats and to establish which nursery areas should be preferentially protected. It is not clear, however, that low recruitment to Chesapeake Bay is related more to the

overall production of larvae / juveniles, to what happens to the larvae that do get into the Bay, to what happens to larvae / juveniles in the Bay or to what happens to menhaden outside the Bay?

12. *Evaluate the potential to relate YOY juvenile menhaden recruitment (i.e., abundance, hatch dates, growth, and regional habitat utilization) to larval ingress abundances, seasonality and dynamics.*

The slide below, from the presentation *Ingress of Larval Atlantic Menhaden to the Chesapeake Bay: supply-side dynamics* by E. D. Houde et al., is inconclusive. More data would be required to confirm the existence or lack of relationship. As indicated earlier, studies on other species in other areas have suggested that the relationship between larval abundance and subsequent recruitment is at best weak. This project considers more than larval abundance alone, but even with only three years of data, the results do not look promising.

Menhaden Larvae: Chesapeake Bay Mouth

Concordance Evaluation

Year	Larval Abundance	Growth Rate	Prey Incidence	Feeding Success	Temperature	MD DNR YOY Index[1]
2005-06	2	2	2	2	2	0.62
2006-07	1	1	3	3	3	0.86
2007-08	3	3	1	1	1	0.93

1= lowest
2= intermediate
3= highest

[1]Geometric mean catch per seine haul

Zooplankton ?
Hydrographic Indices ?

Exchange Rates

13. *Evaluate the feasibility of utilizing otolith chemistry to determine regional variability in YOY juvenile menhaden habitat utilization and migrations within Chesapeake Bay.*

The results presented suggest that it is possible to use otolith chemistry to determine regional variability in YOY juvenile menhaden habitat utilization and migrations within Chesapeake Bay. However, a longer term monitoring project would be necessary to assess variability and changes in habitat utilization.

Removals by Predators

14. Evaluate and comment on the methodologies utilized to sample major predators of Atlantic menhaden and to analyze stomach content of those predators.

A combination of traditional (stomach, regurgitation and scat analyses) and novel (stable isotope ratios) methods are used to identify the diet composition of major avian (osprey, bald eagle, brown pelican, the double-crested cormorant, and others) and fish (striped bass, weakfish and summer flounder) predators. Some of the results came from programs designed specifically to study the diet of major predators in Chesapeake Bay with sampling distributed over time and space while other results came from more opportunistic sampling. It is therefore not surprising that the results of such studies may be conflicting. Generally speaking, the results from programs where there is good spatial and temporal coverage would be expected to be more reliable than those where sampling is more opportunistic. It should be noted, however, that even when the spatial and temporal coverage of the diet is good, the predictive value of the results may be low. That is, the results could provide a general estimate of what may be consumed by predators, but the actual diet composition could vary substantially depending on the distribution and abundance of the prey and predators.

It can be predicted with relative confidence, however, that as the abundance of predators continues to increase, their food requirements will also continue to increase, to the point where they may become food limited. In a fisheries management context, it would therefore be useful to assess the extent of present or future conflicts between the commercial fishery, the recreational fishery and the predators in terms of times, areas, and sizes of fish consumed.

The results of diet studies do show variable results, but the more comprehensive sampling program suggests that striped bass consumed approximately 1 000t of menhaden in 2004 and 12 000t in 2006. The increased consumption appears to be due both to higher striped bass stock size, but also longer residency in Chesapeake Bay of migratory striped bass. That it was possible for striped bass to increase its consumption of menhaden so substantially in such a short period of time suggests that menhaden biomass in Chesapeake Bay is substantial. Whether there is enough for the increasing demands of striped bass and other predators, including the commercial and the recreational fisheries, will be a difficult and possibly very expensive question to resolve. Time and area restrictions as well as zoning of the fisheries that are competing for menhaden might provide a more rapid mechanism to mitigate the possible negative consequences of competing fisheries and predators. In the medium term, an operational definition of localized depletion will have to be agreed in terms of the quantities of menhaden allocated to the competing fisheries and to the predators.

Conclusions and Recommendations

It is understood that the overarching objective of projects undertaken under the four research areas is ascertain whether localized depletion is occurring in Chesapeake Bay, and if it is, to identify the causes, understand the mechanisms, and evaluate the consequences. The ASMFC Technical Committee definition provides a theoretical definition that should be operationalised by identifying the threshold "*of abundance that is sufficient to maintain its basic ecological (e.g. forage base, grazer of plankton), economic and social/cultural functions*". It would be particularly timely to agree on such a threshold as, given current conditions, if predators continue to increase, it is likely that menhaden has a relatively high probability of falling below reasonable thresholds in the foreseeable future.

While each individual research project seemed relevant and well designed, it is not clear how the overall package had been structured to determine if localized depletion is occurring. In the absence of an operationalised definition of localized depletion, it is not possible to fully evaluate the goals, quality and quantity of work, but particularly the relevancy of research projects conducted in four research areas identified by ASMFC as key to understanding the status of menhaden in Chesapeake Bay and to determine if localized depletion is occurring.

It is difficult to fully understand the factors influencing recruitment to Chesapeake Bay by conducting investigation only in Chesapeake Bay. Recruitment to Chesapeake Bay is expected to be linked to how much spawning takes place outside of the Bay, where and when this spawning occurs, and where the spawning products go. If a constant number of larvae or a constant proportion of the total number of larvae produced entered Chesapeake Bay, it would be less important to conduct investigations outside of the Bay, but results to date show that the number of larvae entering the Bay varies from year to year without a clear pattern. It would therefore be important to investigate spawning times, location and success, which mostly occur outside Chesapeake Bay.

The investigation of predator – prey relationships is a demanding process that should be conducted under strict sampling protocols over extensive period of times. Even under the best of the conditions, pre-season predictions are likely to remain highly uncertain. Mechanisms to provide in-season predictions could reduce the uncertainty.

Given the increased abundance of menhaden predators (fish, avian and possibly marine mammal), it would be important to continue the development of multispecies assessment techniques to formally take into account the increased predation mortality. As the abundance of avian predators can be expected to continue to increase, it will become more and more important to include their removals in the menhaden assessment and consider them explicitly in fisheries management decisions. A policy decision will be required at some point in the future, possibly in the context of the ecosystem approach to fisheries, to decide how to take such increased predation into

account. If predation is allowed to continue to increase, fishing mortality reference points would have to be decreased to allow for the increased mortality due to predation.

The ASMFC Technical Committee stock assessment appears adequate and appropriate. However, preliminary results of an alternative assessment model suggest different conclusions with respect to reference points. It would therefore seem appropriate to develop further the alternative model to allow fuller and more meaningful comparisons. An assessment based on assuming sub-stocks, whether these exist or not, would require data on abundance (juveniles and adults) in each area and information on age-structure. As these data are currently limited or only available for one of the areas, the results of a regional assessment based on assuming sub-stocks would be expected to be more uncertain, particularly for each assumed sub-stock. If the menhaden catch at age is considered reliable, VPA methods (using similar natural mortality at age estimates) could also be used to compare estimates of recruitment for the converged part of the population number matrix. The sensitivity of all models should be investigated more extensively by omitting data series one at a time, or by combining them in a different manner (different weightings), and by doing retrospective analyses (i.e. removing one year of data at a time to see how the assessment results would change under the accepted model configuration).

Results to date from the project reported in *Ingress of Larval Atlantic Menhaden to the Chesapeake Bay: supply-side dynamics* by E. D. Houde et al., are inconclusive. More data would be required to confirm the existence or lack of relationship between the abundance, growth, feeding success and temperature in Chesapeake Bay and subsequent recruitment in the Bay. Studies on other species in other areas have suggested that the relationship between larval abundance and subsequent recruitment is at best weak. This project, however, considers more than larval abundance alone, but even considering that only three years of data are available, the results do not look promising.

The results of diet studies do show variable results, but the more comprehensive sampling program suggests that striped bass consumed approximately 1 000t of menhaden in 2004 and 12 000t in 2006. The increased consumption appears to be due both to higher striped bass stock size, but also longer residency in Chesapeake Bay of migratory striped bass. That it was possible for striped bass to increase its consumption of menhaden so substantially in such a short period of time suggests that menhaden biomass in Chesapeake Bay is substantial. Whether there is enough for the increasing demands of striped bass and other predators, including the commercial and the recreational fisheries, will be a difficult and possibly very expensive question to resolve. Time and area restrictions as well as zoning of the fisheries that are competing for menhaden might provide a more rapid mechanism to mitigate the possible negative consequences of competing fisheries. In the medium term, an operational definition of localized depletion will have to be agreed in terms of the quantities of menhaden allocated to the competing fisheries and to the predators.

Appendix 1: Bibliography of materials provided for review

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Price, J. 2009. Ecological depletion of Atlantic menhaden effects on Atlantic coast striped bass. First Year-round food habit study of large Chesapeake Bay Striped Bass. Powerpoint presentation.

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Appendix 2: A copy of the CIE Statement of Work

Statement of Work for Jean-Jacques Maguire

External Independent Peer Review by the Center for Independent Experts

Chesapeake Bay Fisheries Science Program: Atlantic Menhaden Research Program

Scope of Work and CIE Process: The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract to provide external expertise through the Center for Independent Experts (CIE) to conduct impartial and independent peer reviews of NMFS scientific projects. This Statement of Work (SoW) described herein was established by the NMFS Contracting Officer's Technical Representative (COTR) and CIE based on the peer review requirements submitted by NMFS Project Contact. CIE reviewers are selected by the CIE Coordination Team and Steering Committee to conduct the peer review of NMFS science with project specific Terms of Reference (ToRs). Each CIE reviewer shall produce a CIE independent peer review report with specific format and content requirements (**Annex 1**). This SoW describes the work tasks and deliverables of the CIE reviewers for conducting an independent peer review of the following NMFS project.

Project Description: The NOAA Chesapeake Bay Office (NCBO) has been coordinating a competitive-based research program to address the needs of Atlantic menhaden populations along the Atlantic Coast – specifically to address the concerns of the potential for 'localized depletion' in Chesapeake Bay. Addendum II to the Amendment 1 to the ISFMP for Atlantic menhaden established a research program for the Chesapeake Bay focused on four research priorities: 1) determine menhaden abundance in Chesapeake Bay; 2) determine estimates of menhaden removals by predators; 3) evaluate the rate of exchange of menhaden between Bay and coastal systems; and 4) conduct larval studies to determine recruitment to the Bay. This research program is moving forward under the direction of NCBO.
In 2009, the ASMFC Atlantic menhaden Technical Committee will hold data and assessment workshops to complete a full stock assessment scheduled for SEDAR review in 2010.
Prior to development of a full stock assessment, it would prove beneficial to hold a research program review of on-going activities and how that information (preliminary and/or final) should be included in the assessment. This would entail 'interviews' with current PIs of funded work as some of the work isn't complete.

The Terms of Reference (ToRs) of the peer review are attached in **Annex 2**. The tentative agenda of the panel review meeting is attached in **Annex 3**. List of projects related to Atlantic Menhaden that are underway and should be reviewed are attached in **Annex 4**.

Requirements for CIE Reviewers: Three CIE reviewers shall conduct an impartial and independent peer review in accordance with the SoW and ToRs herein. Each CIE

reviewer's duties shall not exceed a maximum of 14 days to complete all work tasks of the peer review described herein. CIE reviewers shall have the expertise, background, and experience to complete an independent peer review in accordance with the SoW and ToRs herein. CIE reviewer shall have expertise and work experience in fisheries stock assessment, fisheries data analysis, multi-species interactions, and ecosystem-based fisheries management.

Location of Peer Review: Each CIE reviewer shall conduct an independent peer review during the panel review meeting scheduled in Annapolis (Laurel), Maryland during April 21-24, 2009

Statement of Tasks: Each CIE reviewers shall complete the following tasks in accordance with the SoW and Schedule of Milestones and Deliverables herein.

Prior to the Peer Review: Upon completion of the CIE reviewer selection by the CIE Steering committee, the CIE shall provide the CIE reviewer information (name, affiliation, and contact details) to the COTR, who forwards this information to the NMFS Project Contact no later the date specified in the Schedule of Milestones and Deliverables. The CIE is responsible for providing the SoW and ToRs to the CIE reviewers. The NMFS Project Contact is responsible for providing the CIE reviewers with the background documents, reports, foreign national security clearance, and information concerning other pertinent meeting arrangements. The NMFS Project Contact is also responsible for providing the Chair a copy of the SoW in advance of the panel review meeting. Any changes to the SoW or ToRs must be made through the COTR prior to the commencement of the peer review.

Foreign National Security Clearance: When CIE reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for CIE reviewers who are non-US citizens. For this reason, the CIE reviewers shall provide requested information (e.g., name, contact information, birth date, passport number, travel dates, and country of origin) to the NMFS Project Clearance for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations, available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/sponsor.html).

Pre-review Background Documents: Two weeks before the peer review, the NMFS Project Contact will send by electronic mail or make available at an FTP site the CIE reviewers all necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE on where to send documents. The CIE reviewers shall read all documents in preparation for the peer review. The NCBO Fisheries Program Manager is currently pulling together a pdf document that will include a selection of pre-review documents. This will include background materials, i.e. minutes of management board meetings, call

for proposals) as well as performance reports and in some cases, final reports for projects that have been funded.

This list of pre-review documents may be updated up to two weeks before the peer review. Any delays in submission of pre-review documents for the CIE peer review will result in delays with the CIE peer review process, including a SoW modification to the schedule of milestones and deliverables. Furthermore, the CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein.

Panel Review Meeting: Each CIE reviewers shall conduct the independent peer review in accordance with the SoW and ToRs. **Modifications to the SoW and ToRs can not be made during the peer review, and any SoW or ToRs modifications prior to the peer review shall be approved by the COTR and CIE Lead Coordinator.** Each CIE reviewer shall actively participate in a professional and respectful manner as a member of the meeting review panel, and their peer review tasks shall be focused on the ToRs as specified in the contract SoW. The NMFS Project Contact is responsible for any facility arrangements, (e.g., conference room for panel review meetings or teleconference arrangements). The CIE Lead Coordinator can contact the Project Contact to confirm any peer review arrangements, including the meeting facility arrangements.

- Prior to the meeting, all reviewers shall review summary document to be provided, including background material and performance reports) in support of this review.
- The panel chair shall serve during the meeting as chairperson where duties include control of the meeting, coordination of presentations, control of document flow and facilitation and discussion.
- After the meeting, a summary report, which summarizes the findings of individual panelist's review reports, shall be completed.

Contract Deliverables - Independent CIE Peer Review Reports: Each CIE reviewer shall complete an independent peer review report in accordance with the SoW. Each CIE reviewer shall complete the independent peer review according to required format and content as described in Annex 1. Each CIE reviewer shall complete the independent peer review addressing each ToR as described in Annex 2.

Other Tasks – Contribution to Summary Report: Each CIE reviewer will assist the Chair of the panel review meeting with contributions to the Summary Report. CIE reviewers are not required to reach a consensus, and should instead provide a brief summary of their views on the summary of findings and conclusions reached by the review panel in accordance with the ToRs.

Specific Tasks for CIE Reviewers: The following chronological list of tasks shall be completed by each CIE reviewer in a timely manner as specified in the **Schedule of Milestones and Deliverables**.

1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review;
2) Participate during the panel review meeting in Annapolis, Maryland, from April 22-24, 2009, as called for in the SoW, and conduct an independent peer review (in accordance with the ToRs Annex 2);
3) No later than REPORT SUBMISSION DATE, each CIE reviewer shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Manoj Shivlani, CIE Lead Coordinator, via email to shivlanim@bellsouth.net, and CIE Regional Coordinator, David Sampson, via email to david.sampson@oregonstate.edu. Each CIE report shall be written using the format and content requirements specified in Annex 1, and address each ToR in Annex 2;
4) CIE reviewers shall address changes as required by the CIE review in accordance with the schedule of milestones and deliverables.

Schedule of Milestones and Deliverables: CIE shall complete the tasks and deliverables described in this SoW in accordance with the following schedule.

18 March 2009	CIE sends reviewer contact information to the COTR, who then sends this to the NMFS Project Contact
8 April 2009	NMFS Project Contact sends the CIE Reviewers the pre-review documents
22 April 2009	CIE reviewers attend symposium in Annapolis (Laurel), Maryland
23-24 April 2009	CIE reviewers participates and conducts an independent peer review during the panel review meeting in Annapolis (Laurel), Maryland
8 May 2009	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
22 May 2009	CIE submits CIE independent peer review reports to the COTR
29 May 2009	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

Modifications to the Statement of Work: Requests to modify this SoW must be made through the Contracting Officer's Technical Representative (COTR) who submits the modification for approval to the Contracting Officer at least 15 working days prior to making any permanent substitutions. The Contracting Officer will notify the CIE within 10 working days after receipt of all required information of the decision on substitutions. The COTR can approve changes to the milestone dates, list of pre-review documents, and Terms of Reference (ToR) of the SoW as long as the role and ability of the CIE reviewers to complete the SoW deliverable in accordance with the ToRs and deliverable schedule are not adversely impacted. The SoW and ToRs cannot be changed once the peer review has begun.

Acceptance of Deliverables: Upon review and acceptance of the CIE independent peer review reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, these reports shall be sent to the COTR for final approval as contract deliverables based on compliance with the SoW. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via e-mail the contract deliverables (the CIE independent peer review reports) to the COTR (William Michaels, via William.Michaels@noaa.gov).

Applicable Performance Standards: The contract is successfully completed when the COTR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards: (1) each CIE report shall have the format and content in accordance with Annex 1, (2) each CIE report shall address each ToR as specified in Annex 2, (3) the CIE reports shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Distribution of Approved Deliverables: Upon notification of acceptance by the COTR, the CIE Lead Coordinator shall send via e-mail the final CIE reports in *.PDF format to the COTR. The COTR will distribute the approved CIE reports to the NMFS Project Contact and regional Center Director.

Key Personnel:

William Michaels, Contracting Officer's Technical Representative (COTR)
NMFS Office of Science and Technology
1315 East West Hwy, SSMC3, F/ST4, Silver Spring, MD 20910
William.Michaels@noaa.gov Phone: 301-713-2363 ext 136

Manoj Shivlani, CIE Lead Coordinator
Northern Taiga Ventures, Inc.
10600 SW 131st Court, Miami, FL 33186
shivlanim@bellsouth.net Phone: 305-383-4229

NMFS Project Contact:

Derek Orner

NOAA Chesapeake Bay Office
410 Severn Avenue, Suite 107A, Annapolis, MD 21043
Derek.Orner@noaa.gov Phone: 410-267-5676

Annex 1: Format and Contents of CIE Independent Peer Review Report

1. The CIE independent report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations.

2. The main body of the reviewer report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Summary of Findings for each ToR, and Conclusions and Recommendations in accordance with the ToRs.

   a. Reviewers should describe in their own words the review activities completed during the panel review meeting, including providing a detailed summary of findings, conclusions, and recommendations.

   b. Reviewers should discuss their independent views on each ToR even if these were consistent with those of other panelists, and especially where there were divergent views.

   c. Reviewers should elaborate on any points raised in the Summary Report that they feel might require further clarification.

   d. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

   e. The CIE independent report shall be a stand-alone document for others to understand the proceedings and findings of the meeting, regardless of whether or not they read the summary report. The CIE independent report shall be an independent peer review of each ToRs, and shall not simply repeat the contents of the summary report.

3. The reviewer report shall include as separate appendices as follows:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: A copy of the CIE Statement of Work
   Appendix 3: Panel Membership or other pertinent information from the panel review meeting.

Annex 2: Terms of Reference for the CIE Peer Review

Chesapeake Bay Fisheries Science Program: Atlantic Menhaden Research Program

Statement of Purpose

The intent of the Atlantic Menhaden Research Program is to define and evaluate the biology and status of menhaden along the Atlantic Coast – and to the extent practical, the potential for localized depletion in Chesapeake Bay. Addendum II to the Atlantic Menhaden FMP establishes the four research areas (see TOR 1 below) to examine the possibility of localized depletion. The purpose of this review is to evaluate progress made on both a project-by-project basis and programmatic level towards the overall goal. The results of this review will: 1) inform managers' decision making processes; 2) help funding agencies focus existing research efforts; and 3) provide guidance for future research to aid management that could extend beyond the Program's initial phase (2006-2010).

Program Management:

15. Evaluate the goals, quality and quantity of work, and relevancy of research projects conducted in four research areas identified by ASMFC as key to understanding the status of menhaden in Chesapeake Bay and to determine if localized depletion is occurring:
    - Menhaden abundance in Chesapeake Bay
    - Removal of menhaden by predators in Chesapeake Bay
    - Exchange of menhaden between Chesapeake Bay and coastal systems
    - Recruitment of menhaden to Chesapeake Bay

16. Evaluate the goals, quality and quantity of work, relevancy and feasibility of *on-going* research projects to better understand the four research areas.

17. Identify scientific and data gaps that will contribute to understanding in the four research areas.

18. Provide recommendations for future research projects to address information and data gaps identified in ToR #3.

General:

The 2003 Atlantic menhaden stock assessment peer review panel concluded that the current assessment model and methodology cannot address localized depletion questions. Terms of reference 5 through 7 are focused on modeling and data collection changes or improvements to advance managers and scientists' ability to answer localized depletion questions.

19. Evaluate the adequacy, appropriateness, and utility of models used to assess Atlantic menhaden stock, including the model focusing on the Chesapeake Bay sub-stock, and characterize the uncertainty in those models.

20. Evaluate the scientific findings of the Research Program and their potential to provide knowledge for development and implementation of biological reference points.

21. Develop recommendations to improve data collection based on evaluation of the reviewed research projects and identified data gaps.

Project Specific:

Abundance Estimates

22. Alternative coastwide stock assessment model – Evaluate the adequacy and appropriateness of all the data used in the assessment including life history, natural mortality, stock structure, recruitment dynamics, and patterns in F-I and F-D surveys.

23. Chesapeake Bay regional stock assessment model – Evaluate the adequacy and appropriateness of all the data used in the assessment including life history, natural mortality, stock structure, recruitment dynamics, and patterns in F-I and F-D surveys.

Larval / Recruitment Processes

24. Evaluate the potential of the pilot-scale larval ingress surveys to provide measure of relative abundance of ingressing larvae, variability in seasonality of ingress, hatch date determination, trophodynamics, and relationship to hydrographic/oceanographic factors.

25. Evaluate feasibility of the age and growth analysis and relationships to environmental factors of YOY juvenile menhaden based on otolith microstructure, modal length-frequency analyses, and on growth modeling.

26. Evaluate the potential to relate YOY juvenile menhaden recruitment (i.e., abundance, hatch dates, growth, and regional habitat utilization) to larval ingress abundances, seasonality and dynamics.

Exchange Rates

27. Evaluate the feasibility of utilizing otolith chemistry to determine regional variability in YOY juvenile menhaden habitat utilization and migrations within Chesapeake Bay.

Removals by Predators

28. Evaluate and comment on the methodologies utilized to sample major predators of Atlantic menhaden and to analyze stomach content of those predators.

Annex 3: Tentative Agenda

Chesapeake Bay Fisheries Science Program: Atlantic Menhaden Research Program

The Project Contact will submit an agenda to the COTR William.Michaels@noaa.gov no later than 15 February 2009. The agenda will include the symposium agenda, including the agenda during the 22 April 2009 when CIE reviewer shall attend the symposium. The agenda will also include the panel review meeting during 23-24 April 2009.

Annex 4: List of Projects (not all inclusive)

- Ecopath with Ecosim – Ecosystem model focusing on menhaden and predator interactions (NCBO grant to University of British Columbia.)
- Probing the population structure of Atlantic menhaden in the Mid-Atlantic (NCBO grants to Old Dominion University and University of Maryland – Chesapeake Biological Laboratory.)
- Do Environmental Conditions in Nursery Habitat Contribute to a Mismatch in Growth and Production of Young Atlantic Menhaden and Striped Bass? (NCBO/ASMFC grants to University of Maryland – Chesapeake Biological Laboratory and University of Delaware.)
- Stock Assessment Training Program – initial focus on menhaden (NCBO grants to University of British Columbia and Virginia Institute of Marine Science.)
- Menhaden Abundance and Productivity in Chesapeake Bay: Linking the Environment and Primary Production to Variability in Fish Recruitment (NCBO grant to University of Maryland – Chesapeake Biological Laboratory.)
- Temporal and Spatial Variability in Growth and Production of Atlantic Menhaden and Bay Anchovy in Chesapeake Bay (MDNR/NCBO grant to University of Maryland – Chesapeake Biological Laboratory.)
- Data collection and analysis in support of single and multispecies stock assessments in Chesapeake Bay: the Chesapeake Bay multispecies monitoring and assessment program (VMRC/NCBO grant to Virginia Institute of Marine Science.)
- Specimen analysis in support of single species and multispecies stock assessments in Chesapeake Bay (NCBO grant to Virginia Institute of Marine Science.)
- Striped Bass stock health assessment: mycobacteriosis prevalence and distribution (NCBO grant to University of Maryland.)
- Estimating total removals of key forage species by predators in Chesapeake Bay (NCBO grant to Virginia Institute of Marine Science.)
- LIDAR (ASMFC grant to Maryland Department of Natural Resources.)
- Estimating Relative Abundance of Ecologically Important Juvenile Finfish and Invertebrates in the Virginia Portion of Chesapeake Bay (VMRC/NCBO grant to Virginia Institute of Marine Science.)
- Modeling in support of nutrient and multispecies management (NCBO collaborative work with CBP.)
- Functional morphology of the gill raker feeding apparatus in Atlantic Menhaden (FY2004 NCBO transfer to NEFSC.)
- Environmental Effects on Atlantic Menhaden Recruitment and Growth (FY2004 NCBO transfer to SEFSC.)

Appendix 3: Panel Membership or other pertinent information from the panel review meeting.

The review activities consisted in attending the second day (April 22) of the 2009 NOAA Chesapeake Bay Office (NCBO) sponsored symposium on research projects in Chesapeake Bay, participating in a meeting with principal investigators on April 23, and discussions with other panel members on April 24. Derek Orner from the NCBO chaired the symposium and the April 23 discussions with principal investigators. The panel meeting on April 23 was a free exchange of views on the Terms of References.

Panel members were Malcolm Haddon from the Commonwealth Scientific Research Organization (CSIRO), Australia, Jean-Jacques Maguire from Halieutikos in Québec, Canada and Beatriz Roel from Center for Environmental Fisheries and Aquaculture Science (CEFAS), UK.

Principal investigators who attended the April 23, 2009 discussion were:

Churnside, Jim – NOAA Research
Houde, Ed – University of Maryland
Jones, Cynthia – Old Dominion University
Miller, Tom – University of Maryland
Price, Jim – Chesapeake Bay Ecological Foundation
Schaffler, Jason – Old Dominion University
Secor, David – University of Maryland
Sharov, Alexei – Maryland Department of Natural REsources
Speir, Brad - ASMFC
Wilberg, Mike – University of Maryland