Review Research on Atlantic Menhaden (*Brevoortia tyrannus*).

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Executive Summary

The claim has been made that there is localized depletion of menhaden populations within the Chesapeake Bay. As the Atlantic stock is genetically a single population that undergoes annual migratory movements any localized depletion within Chesapeake Bay could only be on a relatively short time frame. The current coastwide stock assessment concludes that the stock is not overfished (the size of the standing stock is greater than a minimum reference point) and there is no overfishing (the fishing mortality is less than a defined limit reference point). However, being a coastwide assessment it cannot be used to determine whether or not there is short term depletion occurring within the Chesapeake Bay. An alternative stock assessment model now exists that uses different assumptions and that concludes that the stock is both overfished and overfishing is occurring. Presently, the standard stock assessment model provides the best fit to the available data but the alternative model is attempting to model more years and there are a number of sources of uncertainty that should be explored. The most important source of uncertainty is the validity of the index of juvenile abundance derived from a large series of fishery independent seine net survey samples. An attempt should be made to use available information in a manner optimized for the generation of a menhaden index of relative abundance. Currently there is no simple way of selecting between these two models and, ideally, this should be resolved using a management strategy evaluation framework.

The issue of potential localized depletion appears to be only an issue for populations of menhaden within the Chesapeake Bay. Research within the Atlantic menhaden research program has demonstrated that within any particular year the young of the year can exhibit a degree of site fidelity. In this migratory species such site fidelity would be a pre-requisite for localized depletion to be possible. While it is a possibility, it must be emphasized that localized depletion of juvenile menhaden populations has not been demonstrated.

The predatory requirements of both predatory birds and striped bass have been characterized. In total about 16,000 tonnes of menhaden are now consumed by predators annually (about 12,000 tonnes by striped bass, and about 4,500 tonnes by birds). This figure appears very variable from year to year but seems likely to increase if the stocks of striped bass and predatory birds continue to increase. The amount of menhaden being taken by predators has certainly increased markedly in recent years and upcoming assessments of menhaden should take these increases into explicit account. Until this is done explicitly it will be difficult to determine whether the current limit reference point on fishing mortality has been set too high.

There is evidence that striped bass condition is reduced (body fat reductions) and the incidence of disease (Myxobacteriosis) is increasing in Chesapeake Bay. However, there is no evidence that this has been brought about by a decrease in the amount of menhaden in the diet of striped bass. It has been demonstrated that striped bass are now eating more mass of menhaden than just a few years ago (in a comparison between 2004 and 2006). It would be sensible to explore alternative explanations for any changes in striped bass populations in addition to changes in the menhaden population; alternatives might relate to water quality differences around the Chesapeake Bay.

Recruitment levels of menhaden are undoubtedly relatively low. Larval supply and ingress into the Chesapeake Bay appears to be at acceptable levels but has been observed to be highly variable as to season and hydrographic conditions. No patterns were discernable between ingressing larval densities and consequent young of year densities.

The range and quality of the research projects within the Atlantic menhaden research program has been excellent. Further work could include extending the exploration of the fate of ingressing larvae once they enter the estuary. They segregate into different branch estuaries within the Bay and otolith chemistry can be used to distinguish which tributary they establish themselves within. It is thought that some areas of Chesapeake Bay contribute disproportionately to the subsequent population of juvenile menhaden. It would be worthwhile knowing if there are some areas that are more valuable to the success of a given year class than others, as this would have immediate management implications.

Background

Statement and History of the Problem

Menhaden, *Brevoortia tyrannus*, constitute an extremely important fishery for the Atlantic States with very large historical catches (100's of thousands of tonnes). The species forms the basis of a large reduction fishery that generates fish meal and related products but there is also a fishery that provides bait for a wide range of recreational and commercial fisheries.

Menhaden are a member of the herring family (Clupeidae) and form large and dense schools of fish that tend to swim near the surface. As a filter feeder (of both phyto- and zoo-plankton; the diet of the fish changes with age) and the prey of very many other species (both larger predatory fish and birds) they are important ecologically as they act to transfer nutrients from low down the food chain up to higher trophic levels. As a very common small pelagic fish they are important for both commercial as well as ecological service reasons. There is currently a perceived clash between these two uses for this species.

The commercial fishery is the basis of a significant industry that provides both important levels of employment as well as producing large amounts of feed protein and nutritionally important fatty acids. The fishery has already contracted significantly into a smallest ever fleet and there now remains only one processing reduction facility on the Atlantic coast. To maintain this industry requires the supply of large catches of menhaden. There is a perceived clash between the needs of this industry with the ecological services provided by menhaden populations to the population of one of its major predators, striped bass (*Morone saxatilis*). In addition, menhaden are an important component in the diets of many of the water bird populations in the Chesapeake Bay area. The populations of many of these bird species have expanded exponentially since surveys in 1975; these birds include iconic species such as the osprey and the bald eagle, as well as the brown pelican and double crested cormorant.

The striped bass stock along the Atlantic coast has been through a period of severe depletion, so much so that the fishery was closed for five years (only one year in Virginia). However, since the closure the striped bass population has recovered and continues to increase. A perception has arisen that this recovery is now being compromised by a lack of prey species for the striped bass. Specifically, it has been argued that there are insufficient menhaden resulting in striped bass that only achieve poor condition levels (low body fat) or are more prone to disease (mycobacteriosis is increasing in prevalence in the Chesapeake Bay). This perceived lack of menhaden has been described as a localized depletion of menhaden populations in the Chesapeake Bay. However, the current stock assessment for menhaden reports that the species is neither overfished nor is overfishing occurring. This apparent inconsistency is the source of discontent.

Menhaden undergo a migration along the Atlantic coast during development. Eggs are spawned at sea and larval forms are transported into estuaries and embayments where they develop for approximately one year. As the fish age, more and more of the older fish move northwards along the coast. This migratory behaviour implies that the menhaden along the Atlantic coast are all one stock and this has been confirmed with genetic studies. The stock assessment model for menhaden is a coast-wide assessment and it could not be used to provide a regional assessment of the population within Chesapeake Bay, as would be required if the suggested localized depletion were to be detected.

In an attempt to determine whether localized depletion of the Chesapeake Bay menhaden population was in fact occurring, the National Marine Fisheries Service sponsored and encouraged the development of an Atlantic menhaden research program. 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 Fishery Management Plan established four research areas designed to examine the possibility of localized depletion. These four areas of research were:

- 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

The purpose of this current 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).

Review Activities

Prior to attending the review meeting held at the Patuxent Wildlife Refuge in Laurel, Maryland, a wide range of materials were made available on an ftp site. These were downloaded and examined and a list of materials is presented in the Bibliography within Appendix 1. These materials included a series of webinars that had been run in 2008, a series of related powerpoint presentations, plus numerous documents describing the menhaden research and related matters.

After travelling to Laurel, Maryland on Monday 20th April, I attended two days of presentations held at the National Visitor's Center at the Patuxent Wildlife Refuge on Tuesday April 21st and Wednesday 22nd. On the first day there were two presentations of interest to the review while the second day was devoted completely to menhaden research and related questions (titles of all presentations of interest to the menhaden review are given in Appendix 2). The presentations were given in a conference format of each talk taking approximately 20 minutes in which some time was usually available for questions from the audience. Discussion of the material continued informally through the various breaks during the day.

On Thursday 23rd April a day was spent in discussion, with the principle investigators of most of the projects being present and contributing. The three reviewers were able to ask a wide array of questions about the menhaden research and the reasons behind it, with the project PIs providing clarifications and further details.

On Friday 24th April, there was a final day when the reviewers gathered with Derek Orner, project contact, to discuss the material and begin writing their individual reports.

Attendees at the Meeting on Thursday 23rd April:

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

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Terms of Reference for the CIE 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:

1. Evaluate the goals, quality and quantity of work, and relevancy of research projects conducted in four research areas identified by the Atlantic States Marine Fisheries Commission 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

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

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

4. 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.

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.

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

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

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.

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.

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.

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.

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.

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.

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 and their respective findings.

Summary of Findings

The review required a consideration of each of the 14 terms of reference. This meant assessing multiple research projects, all of which are part of the menhaden research program. However, it was noted that most of the research projects were only part way through their course. No attempt was made to predict the likely outcomes of the remaining work. Nevertheless, in all cases, sufficient material was presented and discussed to allow at least an initial impression as the scope, depth, and value of the work involved.

1. Evaluate the goals, quality and quantity of work, and relevancy of research projects conducted in four research areas identified by the Atlantic States Marine Fisheries Commission 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*

A key issue in all of this work on menhaden relates to the notion of "localized depletion". The phrase "localized depletion" can have many different meanings but all of them have negative connotations. In the discussions on Atlantic Menhaden the specific meaning ascribed to "localized depletion" did not appear to be the same for all stakeholders. Given the significance of the term, a brief description of the concept is required for clarification. 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. (Robertson, 2008). This definition captures the usual intent of the stock assessment based concept. Unfortunately, while it is possible to use such a definition it does not offer any suggestions about how to measure the basic ecological, economic, and social/cultural functions mentioned in the definition. What is left, in the absence of performance measures that relate to local depletion, is conflict. The intuition is that removing tens of thousands of tonnes of menhaden from Chesapeake Bay must be having a negative influence on the rest of the system. This belief is held even in the face of evidence that the menhaden stock is present at high levels and that catches of menhaden are at relatively low levels (very much more has been taken annually in the past without signs of negative impacts).

For local depletion to occur the stock would need to be relatively site attached. But the menhaden stock undergoes an annual migration with spawning occurring off the mid-Atlantic coast; initially there is larval ingress into the coastal embayments (Chesapeake Bay being the biggest). The larval fish use the embayment systems as nursery areas and, after about a year, the young fish join the migration to the sea and disperse along the coast before returning in an annual cyclic manner. Even though these fish are migratory there could still be local depletion within years in particular areas if the total mortality in those areas was very great. In order to determine whether local depletion really is occurring in Chesapeake Bay, the menhaden research program was initiated and constituted the four areas of endeavour listed above. These four broad areas attempt to address the key issues behind the perceived problem. By assessing the population abundance within Chesapeake Bay the issue of whether stocks of menhaden are lower in Chesapeake Bay than in earlier years can be determined. In addition, any site attachment during the year and potential for local short term depletion can be determined. The removals by predators (both fish and birds) is important work as it defines the scale of ecological services provided by menhaden and attempts to answer whether there is sufficient menhaden remaining in the Bay to provide for all the predators feeding on menhaden. As the menhaden in Chesapeake Bay are not resident for long periods, the exchange of fish with the Atlantic Ocean was also studied to ensure that the supply of larval and other fish into the Chesapeake Bay had not declined in recent years. Finally, because the underlying problem is stated to be a shortage of 0+ aged fish in the right place at the right time (the young of the year), studies of the recruitment dynamics have been made. The widespread seine surveys that are used to characterize the abundance of juvenile menhaden have shown relatively low numbers of young fish in recent years; in other words, recruitment levels appear relatively low. One of the primary issues is the claim that migratory striped bass have access to insufficient juvenile menhaden to stay in peak condition. Instead of stating that there are insufficient menhaden, the issue should really be stated that there are relatively low numbers of juvenile menhaden in the areas inhabited by the migratory striped bass. Such a re-statement of the perceived issue clarifies what to look for and where to look for it. In fact, all four research areas can profitably be explored as each enlightens about important components of the dynamics of the menhaden stock, especially within Chesapeake Bay. The level of depredations by fish and birds is essential knowledge if there is to be a greater attempt at ecosystem based fisheries management. All four of these areas have value in characterizing the scale and reality of the perceived problems relating to harvesting menhaden in Chesapeake Bay.

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

The range of projects addressing the four research areas appears very broad and relatively thorough. Identifying whether localized depletion occurs within Chesapeake Bay forms the underlying objective behind all the research projects. The four research areas defined cover the requirements reasonably well. The examination of methods, such as using LIDAR, to estimate local abundance within the Chesapeake Bay and along the coast is a creative approach at trying to gain estimates of the abundance of a mobile species spread over a very extensive area. Because menhaden are a migratory species, the time scale over which local depletion might be detected had to be determined. The various studies of fine scale geographical distribution (for example, using otolith chemistry and more classical ageing methods) demonstrated that within a year there is a degree of site attachment in the juvenile fish, at least at the scale of a tributary. This means that localized depletion at such a scale is at least a possibility. The supply of larval fish from the ocean to the Chesapeake Bay is fundamental to the availability of young of the year fish in the Bay and the survey of larval ingress provided a classical demonstration of the variability that exists in larval supply. Overall, the scale of research conducted into the problem of localized depletion of menhaden in Chesapeake Bay was appropriate and thorough. The quality of the research was excellent and broad ranging, and appeared to have provided good value for the money expended.

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

While the scope and relevancy of the work conducted has been broad and valuable, there will always be room for additional work of value. Focusing on menhaden in the Chesapeake Bay, it could be suggested that further studies aimed at understanding how and where ingressing larval fish distribute themselves around the estuary would have value. Currently their fate is only known in general terms. The issue that appears to cause the most strife is an apparent lack of juvenile menhaden in the main stream of the estuary (where the large migratory striped bass are concentrated). It would be valuable to know whether the distribution of juvenile menhaden was variable and dependent upon the relative abundance of juvenile fish. At the same time, the seining surveys used to estimate the relative abundance of juvenile menhaden are in fact designed and targeted at other species (especially striped bass). It would be a worthwhile exercise to examine the extensive available data and determine whether there was some analytical design that would be better adapted at estimating menhaden abundance. Essentially, are there stations currently included in the analysis which never capture menhaden, or are there others which are extremely variable? Is there a post-hoc stratification of the available data that would provide a better (more precise and less variable) time series of juvenile menhaden abundance through time? Very different time series of relative abundance could be derived by treating the data differently (for example, a summation across stations rather than taking a mean abundance generated a completely different time series). This is a source of uncertainty in the assessment that could benefit greatly from further examination and this would only need to be a desk top study.

The depredations of fish and birds on menhaden form an important source of information, a source that should explicitly be included into the assessment of menhaden in the future. To do this, the estimation of removals of menhaden by predators should continue.

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

a) Examine the fate of larval/juvenile forms of menhaden within the Chesapeake Bay either with chemical tagging or the use of natural tags (for example otolith chemical signatures).
b) Examine the stratification and analytical strategy of the seine survey data in an attempt at post-hoc optimization for juvenile menhaden abundance estimates.
c) Estimate the size distribution of menhaden taken by bird and fish predators. This would inform any selectivity of predators used in the assessment of menhaden.

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 scientist's 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.

Unfortunately the presentations concerning the menhaden stock assessment and an alternative stock assessment model were relatively limited during the review, and the modelling was mainly examined through reading the relevant documents (AMTC, 2009; Christensen & Martell, 2009). The stock assessment model used (AMTC, 2006) is a statistical catch at age forward projection model that uses abundance indices (juvenile seine index, pound capture index), recorded landings, and annual samples of size and age compositions from the landings. The stock is assessed relative to two biological based reference points: a limit fishing mortality rate (F = 0.75) and a limit reference point on fecundity. With respect to the standard assessment neither limit reference point is breached so, by definition the stock is not being overfished and overfishing is not occurring. These phrases have caused some concern by some commenters but they are confusing a colloquial usage of these terms with the formal terms. A policy decision has been made that fishing mortality should be less than 0.75 /yr (equivalent to taking at most 52.76% of exploitable biomass each year). For overfishing to be occurring the instantaneous fishing mortality rate would need to be greater than 0.75. On the basis of the standard assessment, those people who claim that overfishing is indeed occurring are, by definition, making a mistake. From their point of view, instead of claiming that the assessment scientists are incorrect, they should be arguing that the limit reference point for fishing mortality is set at too high a level to permit adequate ecosystem services. Whether it is possible to argue such a case validly would depend on the required levels of such services.

There are a number of sources of uncertainty in the current standard assessment. There are no estimates of total abundance and the main indices of relative abundance relate to estimates of juvenile abundance and these are obtained from fishery independent surveys targeted mainly at other species (the seine surveys for striped bass, etc). Of serious concern is the development of an alternative assessment model (Christensen & Martell, 2009). While the details of this new model are only described in a manuscript not seen by the reviewers, there is sufficient in the draft manuscript that was made available to highlight that there is considerable model uncertainty in this assessment. This alternative model has some advantages (it is based on direct estimates of MSY and F_{MSY}) and disadvantages (it is new and relatively untested and its limitations are currently less clear). Nevertheless, the fact that it concludes with exactly the opposite outcome (that the menhaden stock is both overfished and overfishing is occurring) is enough to raise serious concerns. One very strong difference between the two models is the relative emphasis or weights placed on the different data sources. In the standard assessment model, most weight is placed upon the catch-at-age data while in the alternative model a more balanced distribution of weights is placed on the catch-at-age data and the relative abundance indices. It is surprising that in the list of model runs (Appendix D in AMTC, 2009) there was no exploration of runs where the different data series were given alternative weighting schemes. It is standard practice to examine the degree of information in each time series of data by varying the relative weight ascribed to each time series as a source of likelihood in the model fit. This may have been done in the past with the standard model but it needs to be updated with the most recent data sets.

An important change that will be needed in the next update of the assessment, irrespective of which assessment model is used, will be to explicitly include the depredations by predatory water birds and fish. The estimates of predation currently suggest a catch by predatory birds of approximately 16,000 tonnes of all fish species, with menhaden making up a significant proportion of the diet of some species. With a population doubling time for some of the birds as short as four years and an average of nine years, this quantity is likely to increase substantially over relatively short time periods. It may be necessary to include such a large take of menhaden explicitly in any future assessment model, treating the birds as another fleet with an appropriate selectivity curve to more accurately account for the impact on the dynamics of the stock. This is not just a component of natural mortality. With the exponential increase in these predatory water fowl this is an unaccounted source of mortality which is becoming significant even to such a large stock as menhaden.

In summary, the current stock assessment appears adequate and appropriate, however, the availability of an alternative assessment model demonstrates that somewhat different assumptions lead to very different conclusions. This is sufficient to stimulate the need for further work that attempts to reduce the uncertainty in the assessment, especially with respect to the availability of a worthwhile index of relative abundance through time. The time series of relative juvenile abundance derived from the seine net surveys should be reviewed to determine whether an index customized more to menhaden can be derived from the available data. Sensitivity tests for the standard assessment model should be run that vary the relative weights ascribed to the various data sources to determine the sensitivity of the model outputs to the various input data streams. The impact of predatory water fowl should be explicitly included as a distinct new fleet in future stock assessment models.

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

The recruitment dynamics of many fish species have been studied intensively and few are amenable to predictive relationships. The present limit reference point relating to egg production needs to be recognized more as a guideline. Just because egg production is predicted to be high does not imply that larval production will similarly be high. There is an asymmetry to such things whereby a high egg production is necessary for high larval production but it does not guarantee high larval success. The closer to the final harvested stage the better predictions can be made about changing productivity. Thus, an accurate or more representative estimate of the young of the year should provide a better index of relative abundance than a count of egg production. What the studies of recruitment and larval ingress have demonstrated is that recruitment in menhaden is highly variable and poorly predictable. The larvae that enter the Chesapeake Bay range in age from 20 – 90 days old and so presumably derive from a wide range of water bodies along the Atlantic coast.

An important question is whether the fishing mortality limit reference point is set appropriately. While this is formally a policy decision and amounts to an allocation decision, at least there can be scientific estimates of the ecosystem requirements typical in the Chesapeake Bay. The recent exponential increase in predatory bird populations has been well documented and the study of the diet of these birds has been executed in detail. It is now known that their impact on the stock amounts to about 16,000 tonnes extracted each year. For at least one species the proportion of this made up by menhaden was about 28%, implying a total predatory take by birds of about 4,500 tonnes. Once this is included explicitly in the stock assessment it should be possible to determine whether or not the limit reference point for fishing mortality will need to be changed to make allowance for the bird derived mortality. This issue will become even more important if the populations of these birds continue to increase. While there is a scientific aspect to this issue (i.e. exactly how much is eaten by the birds and from where), this will become more of a policy issue rather than a scientific question and it would be forward looking and reasonable to begin to consider possible solutions now before the issue becomes very much more influential. It does mean that studies of the scale of bird depredation will need to continue, or perhaps it would be sufficient to simply monitor the size of the bird populations.

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

A significant source of uncertainty in the stock assessment is the index of relative abundance of juvenile menhaden deriving from the seine net surveys. This time series is long and informative but does not appear to have been optimized for the estimation of menhaden juvenile abundance. A study of post-hoc stratification should be conducted to determine whether an alternative analytical design would provide a more precise and unbiased estimate of juvenile abundance. The sensitivity of the assessment models to this time series needs to be explored.

The current assessment is coastwide but the reduction fishery has now contracted to the more southerly States. An attempt has been made to account for the effect of this contraction by blocking years into groups and altering the selectivity applied to the fishery through time. Alternatively, attempts could be made to obtain age structured data from the bait fisheries in those States where the reduction fishery is now banned. If the fishing mortality imposed by the fishery really has declined in recent years then the age structure of the fish should change towards increases in the older fish. However, as these fish are more concentrated in the northern States, which have banned reduction fishing, a different sampling regime will need to be developed.

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 of the alternative coastwide stock assessment model was relatively restricted and Martell *et al* (*in press*) was needed to fully understand the methodology applied. Nevertheless, the data used and the schedule of natural mortality against age was the same as used in the standard stock assessment model. Both models constitute statistical catch-at-age models but there are significant differences in the primary parameters estimated when fitting each model. The alternative model is based around direct estimates of parameters that have immediate management implications. Thus, it estimates the maximum sustainable yield and the fishing mortality which imposed should give rise to the MSY. In addition, there are significant differences in the manner in which the models are initiated. In the coming re-assessment and consideration of the available data due to occur later in 2009, attention should be paid to the differences between this model and the standard model. There are significant differences between them (not least is that they come to diametrically opposed conclusions) including the standard model having fewer parameters than the alternative (though it also models fewer years of the fishery). At this preliminary stage and before the formal reassessment and review, it is too early to select between these two models, nevertheless, the fact that alternatives exist and that their results are in contrast to each other means that a serious review of the alternatives has become necessary. With the available information there is no simple diagnostic that enables one to separate the two models. Currently the standard model provides an overall better fit to the available data but the alternative model is attempting to model more years. The best way in which the two models may be separated is if a Management Strategy Evaluation were conducted contrasting the two model structures and how they behave under different known conditions.

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 only documents relating to a regional stock assessment were Christensen & Martell (2009b), which was more of a user guide to using some software that allowed the exploration of scenarios where the menhaden stock was sub-divided into a meta-population of sub-stocks. This work was still at a provisional stage and no conclusions had yet been reached. The use of LIDAR to provide local estimates of abundance (at least of the number of schools) would appear to be a very promising technique but is highly dependent upon the aircraft observers operating the equipment. A combination of LIDAR and high definition video appeared to provide the best results. The key element in this exploratory model was that the stock structure was not fixed and alternative arrangements could be considered. The idea behind this modelling was to determine how sensitive the modelling was to alternative potential stock structures. While some of the otolith chemistry research (Miller & Jones 2006, 2007, 2008, etc) demonstrated that there was a degree of site attachment once the larval fish are dispersed within the Chesapeake Bay, the genetics studies previously conducted all point to the stock being a panmictic (interbreeding) population with only minor internal structure. There would appear to be short term structuring of the population but these do not continue into the breeding populations, and so any local adaptations or changes wrought by developing in different tributaries are absorbed into the whole when the population gathers at sea to breed. The attempt at a regional assessment was interesting but has not succeeded in demonstrating that localized depletion can occur.

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.

There has been a clear reduction in the recruitment levels of menhaden into the Chesapeake Bay (as determined by the regularly conducted seine surveys) and the underlying causes of this reduction have been explored in a number of ways. Menhaden exhibit highly variable recruitment patterns and the survey work examining the relative ingress of larval Menhaden (Houde, et al, 2009 a, b, c) attempts to answer a number of questions. The most important objective of this work with respect to developing a functional assessment was the last objective listed: “Evaluate Potential to Relate Larval Ingress to Variability in Recruitment and Adult Spawning Stock.” While the intent might have been to generate an index of relative abundance for young of the year (YOY) menhaden, the stated objective very sensibly restricted itself to that which might be achieved in three or four years. The variability in the density, location, and timing of larval ingress was such that no consistent pattern was discovered. Nevertheless, all the listed objectives of this work were achieved. It is possible that more intensive sampling, perhaps weekly instead of monthly, or more stations sampled in any single survey, may have provided more detail and possibly elucidated patterns unobservable at the scales of sampling adopted. However, given the amount of vessel time required by the survey the sampling regime adopted was a good compromise between total cost and coverage.

The ability to age the incoming larval fish demonstrated that the oceanic origin of the larval forms was spread over an extensive area.

The major conclusions of this study were that larval ingress is highly variable and that to generate some index of relative abundance based upon larval ingress would be time consuming, expensive, and most likely have a very poor relationship with consequent year class strength. This classical fisheries science nevertheless clarifies much that was unknown about the early larval ecology of menhaden. There may well be a relationship between larval ingress and hydrographic/oceanographic factors, but three years were insufficient to elucidate such a relationship.

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.

There were a number of studies that attempted to relate otolith chemistry and growth modelling (either of modal progressions of length data or of age structure data) to both YOY relative population size and localization of sub-populations within the Chesapeake Bay. Localized depletion could only occur if the juvenile fish remain relatively site attached for long enough for depletion to be imposed (either by fishing of by natural processes). There were some clear demonstrations that such micro-structuring of the juvenile population occurred. It was clearly possible to distinguish the otolith chemistry of fish from different tributaries, indicating that they had stayed long enough in those estuaries for the slightly different water chemistries to influence the chemical composition of the larval otoliths. This provides a clear demonstration that environmental factors can influence YOY menhaden. It should therefore be possible to trace the origins of adult menhaden and hence determine whether some nursery areas are more significant to the success of a particular year class. In this way it might be possible to identify those areas in Chesapeake Bay that would benefit the menhaden stock the most through protection or improvement in water quality.

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 variability exhibited by the estimates of larval ingress was wide ranging. There were no obvious seasonal patterns (each of the three years sampled so far have been different). The depth, salinity, and temperature of the water containing the most larval forms varied markedly between months and years. Finally, the hatch dates were sufficiently widely spread that the larvae must have derived from a wide range of oceanic features. In brief, the variability observed in larval ingress was such that no relationship with the abundance of young of the year could be determined. It is possible that many of the young of the year derive from a limited range of larval ages, implying that the successful young of the year may be derived from only a sub-set of the larvae entering the Chesapeake Bay. But further work would be required to determine if this were a real phenomenon rather than simply an artifact of sampling.

The surveying of larval ingress was informative but demonstrated high levels of variation and was relatively expensive. As a means of predicting potential year class strength this would require a great deal more sampling and even then appears unlikely to produce a worthwhile predictor of juvenile abundance.

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.

There were clear demonstrations that otolith chemistry could be used to identify regional variation in young of the year juvenile menhaden. The water chemistry in different tributaries was sufficiently different that the otolith chemistry could be consistently identified to tributary (although calibration of each tributary was required each year). This demonstrated a degree of within year site fidelity, which would be a pre-requisite to any demonstration of the possibility of localized depletion. In addition, it should be possible to determine the origin of juvenile menhaden by examination of the larval core of the otolith, permitting examination of the fine scale sources of successful juvenile populations. The larval cores of the otolith provide a natural tag that should allow fine scale movements to be tracked within the Chesapeake Bay.

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 and their respective findings.

There were two sides to the depredations on menhaden that have been examined. The predatory birds of the Chesapeake Bay include the osprey, the bald eagle, the brown pelican, the double-crested cormorant, and others. The total quantity of fish consumed is approximately 16,000 tonnes, of which menhaden are making up a declining proportion (e.g. declining from 75% to 28% by mass during the period 1985-2007). Although the proportion in the diet has declined, the absolute mass of menhaden consumed appears to have increased. Thus, in 1985 about 3,000 tonnes of fish were consumed; if 75% were menhaden, this would be equivalent to 2,250 tonnes. In 2007, about 16,000 tonnes of fish were consumed and if 28% were menhaden this suggests a total take of 4,480 tonnes (a doubling of the menhaden catch). It is suggested that there has also been a decline in osprey condition and reproductive success, but this may be related to an increased consumption of blue catfish, which are reported to accumulate relatively high levels of PCB and other potentially toxic chemicals.

The methods used to determine the diet are a mix of traditional (an examination of regurgitations and scats) and novel (an examination of stable isotope ratios, especially carbon and sulphur, to identify whether particular species have been eaten). The predatory bird population continues to increase, however, it is possible that their populations will eventually become food limited. It would be valuable to know the size of fish gathered by these birds to determine whether they target the fish before or after they have reached a size vulnerable to commercial harvest.

While the predatory birds are an important issue, the value of menhaden to the diet of striped bass appears to be of greater concern to more people. Unfortunately, the available data fail to present a consistent picture. Some work suggests that menhaden constitute a very significant component in the diet of migratory striped bass, while other work suggests menhaden are only of moderate importance. It is undoubtedly the case that the population of striped bass has exhibited an increase in recent years. Just as with the predatory birds, it appears likely that the absolute amounts of menhaden consumed by striped bass has also increased in recent years. The stock of menhaden appears to be relatively healthy although there are only relatively low levels of recruitment. The issue with striped bass is that there is a reported increase in the number of fish in poor condition (relatively low levels of body fat) and an increase in the incidence of Mycobacteriosis within the Chesapeake Bay. However, estimates of menhaden consumed by striped bass show a marked increase since 2004. In 2004, there were about 1,000 tonnes of menhaden eaten by striped bass, but by 2006 this had increased to about 12,000 tonnes (Latour et al, 2007, 2009). The diets of striped bass are clearly relatively variable from year to year but in the face of declining recruitment the amount of menhaden consumed appears to have increased. This does not suggest there are insufficient menhaden for the striped bass to eat. The populations of striped bass have increased markedly recently, so much so that their behaviour appears to have altered and some of the larger migratory fish are over-wintering inside the Chesapeake Bay. If there were a shortage of food, whatever species are eaten as prey, then it would be expected that the number of fish with empty stomachs would have increased. This does not appear to be the case. There needs to be more investigation as to the effect of poor water quality on the distribution and condition of striped bass. The presentation on the evaluation of the thermal niche-oxygen squeeze hypothesis suggests that striped bass are sensitive to their physical environment. It is possible that striped bass will become food limited but it is not valid to conclude that they are food limited because some are in poor condition and others are diseased.

Conclusions/Recommendations

The goals, quality and quantity of work, and the relevancy of the projects conducted under the Atlantic menhaden research program were all valuable and well executed. They tackled difficult problems (for example, using LIDAR to estimate abundance) but did so well and with surprising success. The idea of localized depletion is extremely difficult to demonstrate in such a mobile species; if it does occur then it could only occur at a relatively small scale for a relatively short time. The single species assessment of menhaden has uncertainties that should be addressed in the future. There are currently two assessment models and these generate different management advice. It will be important to distinguish between these alternatives and it is suggested that a management strategy evaluation framework be developed to assist with making management decisions in the future. The time series index of relative abundance of juvenile menhaden should be re-examined to determine whether the analytical design of the available data can be optimized for menhaden abundance estimates. The removals of menhaden by predatory birds and fish within the Chesapeake Bay should be explicitly included in future versions of the assessment model, which implies that estimates of predatory removals need to continue into the future. Food limitation of predators may occur in the future in Chesapeake Bay but there is only weak evidence for this at present. Ecosystem modelling of the main species within Chesapeake Bay may have value in determining whether any single species is limiting the dynamics of stocks within the Bay. However, it must be noted that the system is showing no signs of being in equilibrium; the stocks of many of the species present appear to be undergoing significant changes over relatively short time periods.

The study of recruitment and its variability has confirmed that this is extremely variable within menhaden. No simple relationship has been found between larval ingress into Chesapeake Bay and subsequent year class strength in the young of the year. It has been demonstrated that some site fidelity to different nursery grounds exists for at least part of the year, so much so that the nursery origin of different fish can be distinguished by examination of otolith chemistry. Thus, short term localized depletion is a possibility but it was not demonstrated to occur within Chesapeake Bay.

The review process was conducted in a professional but friendly fashion. This particular review was complex with 14 terms of reference, with multiple projects and multiple Principle Investigators. Some of the terms of reference had a degree of overlap but were generally understandable without clarification. The conference format for the presentations was sensible given the range of subjects and number of people involved. However, many of the major issues were more issues of policy rather than of science. The primary issue was more one of allocation rather than of localized depletion, and allocation issues cannot be solved scientifically. Nevertheless, the discussions were conducted in a reasonable manner and despite obvious passionate differences of opinion all parties were trying to find solutions. The high level of collaboration between institutions, states, and individuals was also good to see.

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Appendix 2. List of Seminars

Tuesday April 21, 2009

Evaluation of the thermal niche-Oxygen squeeze hypothesis for Patuxent Estuary striped bass based upon acoustic telemetry; D.Secor, R. Kraus, and R. Wingate. 1:10-1:30

The role of Mycobacteriosis in elevated natural mortality of Chesapeake Bay striped bass: developing better models for stock assessment and management; D. Gauthier, J. Hoenig, W. Vogelbein, M. Smith, R. Latour, P. Sadler and M. Matsche. 1:30-1:50.

Wednesday April 22, 2009

Atlantic Menhaden Coastwide Assessment; R. Latour. 9:50-10:00

LIDAR and Video aerial surveys of menhaden in the Chesapeake Bay; J. Churnside and A. Sharov. 10:00-10:20

Probing the population structure of Atlantic menhaden (*Brevoortia tyrannus*) in the Mid-Atlantic; C. Jones, T. Miller, and J. Schaffler. 11:10-11:30

Ingress of larval Atlantic menhaden: Supply-side dynamics; A. Hashinaga, E. Houde, and C. Lozano. 11:30-11:50

Do environmental conditions in nursery habitat contribute to a mismatch in growth and production of young Atlantic menhaden and striped bass; B. Ciotti, J. Edwards, T. Miller, and T. Targett. 11:50-12:10

Ecological depletion of Atlantic menhaden/ Effects on Atlantic coast striped bass: A yer-round food habit study of large Chesapeake Bay striped bass; J. Boone, A. Overton, and J. Price. 1:30-1:50

Estimating removals of key-forage species by predators in the Chesapeake Bay. C. Bonzek, j. Gartland, and R. Latour. 1:50-2:10

Predator-prey interactions among fish-eating birds and selected fishery resources in the Chesapeake Bay; A. Duerr, G. Garman, S. Macko, S. McInish and C. Viverette. 2:10-2:30

Menhaden abundance and productivity: linking recruitment variability to environment and primary productivity in the Chesapeake Bay; E. Annis, L. Harding, E. Houde, and M. Wilberg. 3:00-3:20

Age, growth, hatch-date distributions and otolith chemistry of young-of-year Atlantic menhaden in the Chesapeake Bay; E. Houde, D. Secor, and M. Wilberg. 3:20-3:40

Factors influencing growth of Young-of-year Atlantic menhaden in the Chesapeake Bay; E. Houde, D. Secor, and M. Wilberg. 3:40-4:00.

Appendix 3:

Attachment A: Statement of Work for Dr. Malcolm Haddon (CSIRO)

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.

<u>Contract Deliverables - Independent CIE Peer Review Reports</u>: 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.

<u>Other Tasks – Contribution to Summary Report</u>: 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:

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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 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.)