# Center for Independent Experts Chesapeake Bay Menhaden Program Peer Review Report

## Beatriz A. Roel (*CEFAS*, UK)

### Executive Summary

The research areas identified by ASMFC are all important to improve understanding of the status of menhaden in Chesapeake Bay. The concept of localised depletion appears central to this review. However, the consequences of localised depletion would be different depending on whether Atlantic menhaden was a single stock or it had the structure of a meta-population consisting of sub-stocks. Removing sub-stocks of a metapopulation could result in long-term decrease in productivity. Therefore, population structure of Atlantic menhaden requires further investigation. Eleven presentations were made on April 22 as part of a Menhaden Symposium. All presentations were clear and of very good quality and appeared relevant to the objective of determining if localised depletion was occurring.

The projects related to menhaden *abundance* make essential contributions to the Research program and that includes the stock assessment training project. Projects related to *removals by predators* are essential if an ecosystem-based management of the Bay is going to be further developed in future. The projects that study the *exchange of menhaden* between Chesapeake Bay and coastal systems are of high standard. Some of them are at an advanced stage of completion. Finally, projects related to *recruitment*, which address key issues of growth and production, are important to gain understanding of the mechanisms underpinning those processes.

Main recommendations for future research are the following:

- Development of a fishery independent index of abundance of menhaden age 1 and older;
- gain understanding on the processes that influence recruitment including
    - research on reproductive biology, and
    - Investigation of the impact of both physical and biological factors that may have a direct impact on larvae and pre-recruits mortality.
- Clarifying population structure of Atlantic menhaden;
- Development of ecosystem-based reference points.

**Terms of reference**

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*

Clarifying the concept of localised depletion is key to provide the evaluation required in this ToR. 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."

A rigorous evaluation of the status of menhaden in Chesapeake Bay in the context of possible localized depletion would require estimation of the stock biomass that would be sufficient to satisfy ecological and socio-economic demands. Moreover, the menhaden biomass in Chesapeake Bay would have to be estimated precisely enough to determine if localized depletion is taking place. However, some of all the above may not be possible at this stage so indicators of localized depletion may be taken into account when making management decisions. Ecological and socio-economic requirements may well change over time therefore localized depletion may not necessarily be linked to menhaden production only. A stable menhaden population could not possibly satisfy the demands of increasing predator populations.

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. This implies that the consequences of localized depletion while no less serious locally, would not have the serious stock wide consequences that would be expected if sub-stocks of a meta-population were depleted. Removing sub-stocks of a meta-population could result in long term decrease in productivity. This is because the meta-population structure provides a broad spectrum of spawning behaviour and conditions for early survival and this is at least as important as spawning biomass to ensure long-term sustainability of the fisheries (Berkeley *et al*., 2004). Therefore, establishing the Atlantic menhaden stock structure is essential to put localised depletion in context.

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

1) Menhaden abundance in Chesapeake Bay
    a. Coastwide Atlantic menhaden stock assessment by the Population Dynamics Team;
    b. LIDAR Aerial surveys of menhaden in Chesapeake Bay by Jim Churnside, NOAA Research and Alexei Sharov, Maryland Department of Natural Resources
2) Removal of menhaden by predators in Chesapeake Bay
    a. 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
    b. Estimating removals of forage fishes by predators in Chesapeake Bay by R.J. Latour, C.F. Bonzek, and J. Gartland.
    c. 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.
3) Exchange of menhaden between Chesapeake Bay and coastal systems
    a. Probing the population structure of Atlantic menhaden (*Brevoortia tyrannus*) in the mid-Atlantic by Jason J. Schaffler, Cynthia M. Jones, Thomas J. Miller.
    b. Ingress of Larval Atlantic Menhaden to Chesapeake Bay: Supply-Side Dynamics by E. D. Houde, C. Lozano and A. Hashinaga.
    c. 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.
4) Recruitment of menhaden to Chesapeake Bay
    a. 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
    b. 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.
    c. 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 Symposium presentations were of high quality and interesting. The projects appear relevant to the objective of determining if localized depletion is occurring, the quality of the work is unquestionable and the quantity of work is impressive. Moreover, research is being conducted into the mechanisms underpinning growth and recruitment of menhaden in Chesapeake Bay. However, the status of menhaden in the Bay is likely to be linked to processes affecting the menhaden population as a whole. If recruitment to the Bay has been low in recent years is that because of a reduction in spawning, or increased mortality at the larval or pre-recruit stages? Do changes in environmental conditions point at a particular direction? These types of questions were more than likely considered when the

research program was structured however they were not clearly addressed in the presentations.

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

*Abundance*

Both assessing menhaden abundance in the Bay and at the level of the whole population are key to understanding localised depletion. The following on-going projects are relevant to estimating menhaden abundance:

- 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.)
- 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.)
- LIDAR (ASMFC grant to Maryland Department of Natural Resources.)
- Environmental Effects on Atlantic Menhaden Recruitment and Growth (FY2004 NCBO transfer to SEFSC.)

The goals, quality and quantity of work of the projects presented appeared satisfactory however, not all the projects listed above were presented.

Development of stock assessment methodology, both single and multi-species, is central to estimation of abundance. Demand on scientists with stock assessment skills is increasing as the processes leading to fisheries management become more complex and highly scrutinised. Therefore, a stock assessment training project should be supported.

The stock assessment models presented seemed appropriate given the existing data. A model designed to explore the usefulness of data that may become available such as the LIDAR estimates of abundance and the data based on otolith chemistry is potentially very useful and has not been fully explored yet.

However, the quality of the data available will determine not only the type of model that can be used but also the reliability of the results. On going projects on data collection and analysis in support of stock assessment are essential.

The project LIDAR and Video Aerial Surveys of Menhaden in the Bay was presented and discussed. LIDAR estimates of abundance appear to be a faster and cheaper alternative to acoustic survey estimates. The methods have limitations but many of those can be overcome. The team has identified best conditions to produce reliable

estimates of abundance and, funds permitting, they were confident that the methodology developed could allow estimating menhaden abundance along the entire coast. Given a survey design, uncertainty in the estimates could be provided.

*Removal of menhaden by predators in Chesapeake Bay*

Relevant on-going projects:

- 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.)
- Predator-prey interactions among fish-eating birds and selected fishery resources in the Chesapeake Bay: temporal and spatial trends and implications for fishery assessment and management.
- 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.)
- 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.)
- Modeling in support of nutrient and multispecies management (NCBO collaborative work with CBP.)

The study by the Virginia Institute of Marine Science, based on field sampling from the Chesapeake Bay Multispecies Monitoring and Assessment Program over the period 2002 - 2006, found that the proportion by weight of Atlantic menhaden in striped bass diet was less than 10%. On the other hand, a study by the Chesapeake Bay Ecological Foundation suggested that ecological depletion of Atlantic menhaden resulting from poor recruitment, high predation by striped bass and lack of ecologically sound management, was having a negative effect on striped bass condition. This study found that the menhaden was an essential food component of striped bass diet constituting more than 75% of their annual diet (by weight). The results from both studies may not be comparable because of different assumptions leading to estimators of diet composition and different sampling protocols. However, the results from the Chesapeake Bay Ecological Foundation illustrate user groups concerns related to conservation of menhaden as a major forage species for commercially important predators such as striped bass.

A study focusing on fish-eating birds completed the spectrum of menhaden predators. The study showed that fish-eating birds within Chesapeake Bay have increased exponentially in the past 40 years resulting in an important source of predation mortality. Predatory impacts on forage species are likely to vary depending on local abundance of predators and prey species. On-going data collection and multi-species monitoring programmes to provide input to multi-species models is strongly recommended.

*Exchange of menhaden between Chesapeake Bay and coastal systems*

Relevant on-going projects:

- 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.)
- Ingress of Larval Atlantic Menhaden : Supply-Side Dynamics (University of Maryland Center for Environmental Science Chesapeake Biological Laboratory)

The projects above are relevant to improve the understanding of menhaden exchange between Chesapeake Bay and the coastal systems. In particular, the project on Supply-Side dynamics attempts to quantify the ingress of larval Menhaden to the Bay and assesses its variability. Further the project analyses ingressing larvae age and growth and investigates their feeding ecology.

The project probing population using otolith chemistry has already shown the potential of the methodology developed to clarify the Menhaden population structure and to understand temporal and spatial patterns in recruitment. Determining the contribution of recruits from individual nursery areas to the adult stock could result in a better understanding of the exchange dynamics.

Indices based on RNA:DNA were developed and validated by the 2$^{nd}$ project listed above. This methodology allows the association between patterns of growth and specific habitat characteristics. The exchanges leading to individual growth and production of menhaden and striped bass have major implications for those populations' relative abundances.

*Recruitment*

Relevant on-going projects:

- 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.)
- 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.)
- Environmental Effects on Atlantic Menhaden Recruitment and Growth (FY2004 NCBO transfer to SEFSC.)

The projects above focus on modelling growth and production and gaining understanding on recruitment variability of YOY menhaden. These goals are attainable and substantial progress has been made already towards them. Getting better understanding of the mechanisms that control recruitment of menhaden is

relevant to management of the stock. However, predicting recruitment strength is likely to be more difficult (Hilborn & Walters 1992, Myers 1998, Basson 1999).

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

The pound net index of abundance of menhaden age 1 – 3 was identified as the weakest piece of information in the assessment. After recommendations from the ASMFC Menhaden Technical Committee, an effort was made to develop an improved index based on pound net landings by pound net fishing days. Although this seems a better approach than expressing the landings by licence, some of the data had to be reconstructed based on a regression. This increased the uncertainty in the index for the reconstructed years but not for the most recent years when all data were available.

Moreover, and given the contraction of the reduction fishery that took place in recent years there is little information on the Atlantic menhaden population structure.

Understanding of the mechanisms that influence recruitment is still incomplete. Although several studies are focusing on menhaden recruitment, the relative influences of predation, climate variability, larval transport and water condition in the nursery areas have not been quantified. Moreover, the possibility of changes in population fecundity as a result of a reduced age-structure in the population and / or the possibility of changes in reproductive biology as a result of changes in the environment need to be investigated.

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

Research into developing a fishery independent index of abundance of the Atlantic menhaden ages 1+ should be encouraged. In particular, the LIDAR project seems promising and with potential of providing a fast and cost-effective method of estimating population biomass.

There is currently little information on Atlantic menhaden age structure due to contraction of the reduction fishery and the lack of a fishery independent index. It would be useful to consider obtaining such information from other on-going surveys that may cover the menhaden distribution or from fishing trips that target other species.

Research to gain understanding on Atlantic menhaden population structure is recommended as having important implications both for the assessment and management of the stock. This may require analysis of a multi-disciplinary suite of characters as carried out for herring West of the British Isles (Hatfield *et al*. 2007) This project assembled evidence from body morphology, parasites as biological tags, genetic characterisation and otolith core microchemistry to describe the population structure of those herring stocks.

**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 modelling 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 forward-projecting statistical age-structured model (ASMFC). This model was used in 2006 to assess the Atlantic menhaden stock. The type of model is appropriate and is likely to make best use of the data available: catch-at-age, recruitment fishery-independent index and pound net fishery dependent time-series. Further, this model provides the facility of assigning weights to the different terms of the likelihood depending on how variable the relationship between the estimable parameters and the data is believed to be. This would influence the results and how well the model fits the different sets of data.
The model fits almost exactly the reduction fishery landings and pretty well the bait fishery. Examination of figure 6.3: residuals from catch-at-age for the reduction fishery, show clear age effects that suggest a change in selection in the fishery in the early 70s. This questions the model assumption of constant selection and should be reflected in the uncertainty in the estimated selection curves but, it is not shown. A table showing all parameter estimates and associated CVs would have been useful. The uncertainties in F, population fecundity and estimates of recruits to age-0 shown in Figures 6.10 – 12 are likely to be underestimated. It is suggested that uncertainty in parameter estimates should be estimated by bootstrapping. A contour or scatter plot showing point estimates and bootstrap estimates of F vs. SSB/ population fecundity in the final year in the assessment could better characterise the uncertainty in the parameters of interest for management advice.

Spatially Implicit Menhaden Model. This model was not presented or discussed during the Review Meeting. Comments on the document by L. B. Christensen and S. J. D. Martell: Spatially Implicit Menhaden Model, User's Guide follow.
The model is implemented as an age-structured forward projection model assuming process error in recruitment and observation error. The operating model assumes that the Atlantic menhaden constitutes a meta-population consisting of 3 sub-stocks, defined by the area to which the fish were recruited. This coupled with assumptions of homing, could allow investigation of the potential for localised depletion.
The operating model is conditioned on a disaggregated time-series of landings corresponding to Southern, Middle and Northern areas. The simulated data are the CPUE indices, the "Lidar" estimates of abundance by region and otolith microchemistry data, which would allow splitting the catch by sub-stock. The assessment model estimates a large number of parameters and is based on a number of assumptions. Sensitivities to those assumptions are not sufficiently explored.
Given the "data" and the assumptions, which include error levels in the generated data and representative sampling throughout the year for otolith chemistry, the model is able to estimate stock numbers by area. In this sense, given Lidar data the model

could estimate localised depletion in Chesapeake Bay. However, for a given area, the model is not able to estimate the proportions corresponding to each of the sub-stocks. In other words, the model would not be able to inform whether the area depletion is linked to depletion of a sub-stock or is related to local conditions that result in a reduced recruitment to the area.
The modelling exercise showed that under the hypothesis of a meta-population, the model would also require tagging data to estimate the migration matrix and the contribution of each sub-stock to regional abundance. The model has already proved useful to evaluate the usefulness of different sets of data and the data requirements to evaluate the consequences of localised depletion given a meta-population structure.

Alternative age-structured model. The model was not presented or discussed during the Review Meeting. Comments are based on the document Atlantic menhaden stock status report: New advice by L B. Christensen and S. J. D Martell.
Given lack of contrast in the data the authors proposed parameterising the model in terms of MSY and $F_{MSY}$ to avoid parameter confounding. It is claimed that this formulation would result in a more transparent process leading to management conclusions.
Examination of the Pearson residuals from model fit to the catch-at-age show some age effects. Q-Q plots for the Pearson residuals suggest that the ASMFC over weighted the catch-at-age data from the reduction fishery. The fit to the age-0 index from the alternative model is slightly poorer than that from the ASMFC model but does suggest that the index may over-estimate when recruitment is high and under-estimate when it is low, which is to be expected given the schooling nature of Atlantic menhaden. The fit to the pound net is generally better in the alternative model suggesting less inter-annual variability in the index and fluctuation about a relatively constant level in recent years.
Estimates of MSY and $F_{MSY}$ are reasonable and consistent with historic catches.

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

Traditional methods of specifying $F_{MSY}$ and $B_{MSY}$, derived by combining stock recruitment relationships (SRRs) with spawner per recruit functions, appear to perform poorly for Atlantic menhaden therefore reference points were developed from historic spawning stock per recruit relationship. $F_{MED}$ (F corresponding to a SPR equal to the inverse of the 50th percentile of observed R/SSB) and the corresponding SSB which became $SSB_{target}$ ($SSB_{threshold}$ was derived by accounting for natural morality), were adopted in 2001 (ASMFC 2001). After a review of a new benchmark stock assessment for Atlantic menhaden, population fecundity (FEC) replaced spawning stock biomass. $F_{MED}$ continued to represent $F_{threshold}$ but was estimated by using fecundity per recruit rather than SSB per recruit.

New momentum and direction to the development and application of fisheries management theory has evolved over the last two decades in response to a number of drivers. World summits (e.g. WSSD, 2002) have set targets for sustainable management of natural resources and management agencies have embraced the development of the Precautionary Approach (PA) to fisheries management (Smith 2008).

The ecosystem approach to fishery management, which plans, develops and manages fisheries to meet the multiple needs and desires of societies, would suggest targets and thresholds that take into account the impact of fishing on habitat and non-target species. The holistic approach taken by the Research Program has set the ground for developing reference points consistent with an ecosystem-based fishery management. A rigorous evaluation of the status of menhaden in Chesapeake Bay in the context of possible localized depletion would require estimation of the stock biomass that would be sufficient to satisfy ecological and socio-economic demands. Moreover, the menhaden biomass in Chesapeake Bay would have to be estimated precisely enough to determine if localized depletion is taking place in relation to thresholds.

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

This point was addressed in ToR 4 above.

**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.*

Both the ASMFC and the Christensen & Martell alternative model make use of the same data but differ in the way they weight the fishery and fishery independent data in the estimation procedure. For example, the ASMFC model places high weight on the bait fishery data despite the likelihood of undocumented catch.
Life history Generally, there are good data although some limitations appear in the reproduction data. For example there is likely to be inter-annual variation in fecundity however, this is not directly estimated based on annual samples but rather fecundity is estimated from a relationship based on fork length. Further, the possibility that older females could have enhanced reproductive capacity because of spawning during a longer period or, other possible mechanisms, does not appear to have been taken into account. This needs investigation.
Stock structure Tagging studies conducted in the 1970s indicated that although Atlantic menhaden undergoes extensive seasonal migrations it constitutes a single stock. However, morphological studies and some evidence from the tagging studies suggested potential sub-populations. This needs clarification as it could have important implications for management in the Chesapeake Bay.
Natural mortality Using an age-varying natural mortality based on results from MSVPA seems appropriate. However, natural mortality could be underestimated if other sources such as fish “kills”, diseases, red tide, etc. are not taken into account.

FISHERY INDEPENDENT DATA
Age-0 index Based on seine surveys from five states combined to obtain a coastwide index. An alternative coastwide index has recently been developed to include the New Jersey seine index to cover the Middle Atlantic region. Regarding the construction of the age-0 coastwide index the following was noted:

- The surveys were not designed to sample menhaden therefore some bias could occur as a result. However, this is not discussed in the documentation provided. CPUE indices were developed from the seine surveys using GLM.
- The model was not specified in the documentation provided and diagnostics were not presented making difficult its evaluation.
- Error and mean annual estimates from bootstrapping are shown in a series of figures where they appear almost identical. Is there a 2nd axis missing? Could those errors be used to approximate the coefficient of variation for the index in the likelihood?
- The method used to combine the regional indices is critical. The weighted average of the standardised indices takes into account area and relative menhaden production in each region. A table with the area and relative abundances used together with how they were derived would be helpful if provided in the section "Development of estimates" in the Stock Assessment Report.

FISHERY DEPENDENT DATA

Pound net CPUE index This appears to be the weakest set of data in the assessment, however it is the only index available for ages 1 – 3. The index is expected to reflect abundance in the Chesapeake Bay and Potomac River. Although a major fraction of the Atlantic menhaden appears to occupy this area, this fraction may vary from year to year. However, the pound net CPUE is used in the assessment as an index of abundance of the entire Atlantic population although it is not given much weight. There are indications that there is conflict between the pound net and the age-0 indices. Sensitivity to the likelihood weighting factor $\lambda$ for the pound net data series needs to be explored in the assessment.

Reduction fishery Landings and fishing effort are available since 1940. Landings peaked during the late 1960s. Since 2000 the reduction fishery contracted to only one fish plant and about ten vessels in Virginia. Removals from Chesapeake Bay constitute the majority of the reduction landings. Total landings appear to be unbiased. Age composition during the 1980s has been corrected for "topping off" bias. However, the contraction of the fishery in recent years is likely to result in bias in the catch-at-age towards younger ages.

Bait fishery Since the mid-1990s the AMTC recognised the increasing importance of landings of Atlantic menhaden for bait. However, accurate bait landings are only available since 1985. In recent years there has been a relative increase of bait in percent of coastal landings partly due to an improved data collection but also because of a decline in coastal reduction landings.

Sampling of the bait fishery for size and age has improved since 1988 but generally age composition data are limited. In recent years, the bait catch-at-age has contracted from both ends (fewer younger and older ages landed) due to the greater contribution of bait landings from Chesapeake Bay.

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.*

To my understanding, a Chesapeake regional assessment model was not made available to this Review. The type of data used in the Spatially Implicit menhaden model (L. B. Christensen and S. J. D. Martell: Spatially Implicit Menhaden Model, User's Guide) is the same as in the ASMFC except for the landings which are disaggregated by region. Also, this model makes assumptions regarding meta-population stock structure based on some evidence from morphological studies (Sutherland and Fish 1963; June 1965). The operating model generates LIDAR and otolith chemistry data with arbitrarily set CVs. CPUE indices are also generated and the assumed error structure appears sensible. This model, although it does perform an assessment, falls in the category of a simulation framework to explore hypotheses about stock structure and data requirements.

*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.*

Progress on the project Ingress of Larval Atlantic Menhaden to the Chesapeake Bay: supply-side dynamics developed by E. D. Houde *et al.* was presented. In the context of recent low menhaden recruitment the project looks at various aspects of menhaden larval supply from the coastal ocean to the Bay. An approach to estimate the ingress was developed and used to estimate monthly patterns and inter-annual variability in the supply. Results from November to April were presented for three years and although there is a suggestion of one or two peaks in the supply, there is high inter-annual variability. It was concluded that there is a constant but variable supply of larvae to the Chesapeake Bay from September to March.

The hatch date of the larvae was determined and monthly variability in hatch-date analysed. Estimates of growth of the ingressing larvae, diet composition and feeding success were compared by month and between years. This showed that there is substantial monthly and inter-annual variability in growth rates.

A number of questions to be addressed by the project were identified. However, questions such as "What happens to larvae once they are in the Bay?" are being addressed by some of the other research projects.

A project on probing population structure of Atlantic menhaden using otolith chemistry appeared successful in identifying area of origin in Chesapeake Bay. The various estuaries in Chesapeake Bay each have a unique chemistry and there is restrictive movement in the first year of growth. This means that the relative contribution of the sub-estuaries to overall recruitment could perhaps be estimated. It is not clear at this stage if this could be estimated precisely enough to provide guidance to management.

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.*

Several studies focusing on aspects of growth and production of young Atlantic menhaden were presented. They tried to establish the link between growth patterns and environmental conditions in the Bay. Findings could have management

implications as could lead to identification of essential habitats and to establish which nursery areas should be preferentially protected.

Good work was presented on age, growth, hatch-date distribution of menhaden based on otolith chemistry and daily increment analyses. The relationship between Sr:Ca and ambient salinity may be indicative of dispersion in the Chesapeake Bay salinity gradient. However, the relationship appears to be highly variable.

Statistical models were used to relate growth variability to environmental variables and year class strength of menhaden in Chesapeake Bay. Inter-annual and spatial variability in YOY growth was examined. High inter-annual variability in growth and production was identified together with density dependence effects. Although there appeared to be differences in productivity between regions in the Bay, no clear patterns have emerged. The project "Factors influencing growth of YOY menhaden in the Chesapeake Bay" is a classic growth modelling study and seems appropriate.

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.*

A potential relationship between larval density, growth, feeding success, temperature and a Young of the Year index was evaluated by the project "Ingress of Larval Atlantic Menhaden to the Chesapeake Bay: supply-side dynamics", developed by E. D. Houde *et al.*. At this stage, with only three years of data it is difficult to draw conclusions. However, there are very few examples in the international literature of a larval index successfully predicting recruitment. This is mainly because of high inter-annual variability in larvae mortality, which has already been suggested by the preliminary results from the project age, growth, hatch-date distribution of menhaden based on otolith chemistry and daily increment analyses.

The project aims at evaluating the potential to relate larval ingress to variability in recruitment and adult spawning stock. Although variability in the larval ingress would account for some of the variability in recruitment to the Bay, other factors related to conditions in the Bay may also influence survivorship of the pre-recruits and need to be considered.

*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.*

Chesapeake Bay and its estuaries have unique chemistries. Based on the results of the project "Probing population structure of Atlantic menhaden using otolith chemistry" presented, clarifying population structure and understanding temporal and spatial patterns in recruitment is feasible. So far, it has been determined that once the larvae have reached a nursery area there is limited movement in the 1$^{st}$ year of growth. Once a nursery area "signature" is determined, otolith chemistry would allow assigning a recruit menhaden to a nursery area. However, the nursery area signature appears to vary from year to year. The implication is that a long-term monitoring programme needs to be set up to estimate regional variability in YOY menhaden habitat utilisation.

*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 number of surveys following a stratified random design aimed a collecting stomach contents data of the main fish predators of Atlantic menhaden. The sampling methodology seemed appropriate and the assumptions underpinning the data analysis justified. A dedicated study on food habits of large Chesapeake Bay striped bass obtained extensive information on diet composition from samples collected throughout the year. Samples were collected from areas of high concentration of large striped bass which were targeted by the fishery and menhaden relative consumption was estimated based on that information. Caution should be exerted when attempting to extrapolate conclusions from this study to the entire striped bass population.

# Appendix 1

ASMFC 2001. Amendment 1 to the Interstate Fishery Management Plan for Atlantic Menhaden. Atlantic States Marine Fisheries Commission, Fishery Management Report No. 37. 127 p.

Basson, M. 1999 The importance of environmental factors in the design of management procedures. ICES Journal of Marine Science, 56: 933 – 942.

Berkeley, S. A., Hixon, M. A., Larson, R. J., and Love, M. S. 2004. Fisheries Sustainability via Protection of Age Structure and Spatial Distribution of Fish Populations. Fisheries, 29: 23–32.

Hatfield, E. M. C., Nash, R. C. M., Zimmerman, C., Shon, P-J., Kelly, C., Dickey-Collas, M., McKenzie, K., Cross, T. Geffen, A. J., Chubb, J. C. Collins, C. M. Watts, P. C. Jansen, S., O'Leary, D. B., Cross, M. A., Campbell, N. Z., Zuur, A. F., Cunningham, C. O. & J. Schlickeisen. 2007. The scientific implications of the EU Project WESTHER (Q5RS - 2002 – 01056) to the assessment and management of the herring stocks to the west of the British Isles. ICES CM 2007/L:11.

Hilborn, R and C. J. Walters 1992 Quantitative Fisheries Stock Assessment. Choice Dynamics and Uncertainty. Kluwer Academic Publishers, Boston/Dordrecht/London. 570 pp.

Myers, R. A.1998. When do environment-recruitment correlations work? REVIEWS IN FISH BIOLOGY AND FISHERIES 8: 285 – 305.

Smith, M. T. 2008. Potential reference points, precautionary management frameworks and harvest control rules for UK shellfish species. *CEFAS* Report commissioned for the Shellfish Industry Development Strategy by the Shellfish Association of Great Britain and the Marine Stewardship Council, 65 pp.

WSSD, 2002. World Summit on Sustainable Development. Johannesburg, 2002.

**Appendix 2:** Copy of the CIE Statement of Work

# Statement of Work for Dr. Beatriz Roel (CEFAS)

## 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:**

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

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.

## 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.)