Blue Crab Stock Assessment Review
2010

March 2011
Baltimore, Maryland

Billy Ernst

Department of Oceanography

University of Concepción

Chile

Executive summary

This report is a review of the 2010 blue crab benchmark assessment in Chesapeake Bay. This assessment is based on a new sex and two-stage structured model. The demographic model follows the dynamics of abundance of year 0 and year 1+ crabs and has a modified Ricker stock recruitment model as a renewal function. It allows for adult males and females to contribute to compensatory mechanisms affecting recruitment at larger population sizes and primarily adult females to affect recruitment at low population levels. The model is fitted to four main sources of information, including overall catch of Chesapeake Bay blue crab, Baywide winter dredge survey, Maryland DNR trawl survey and Virginia juvenile finfish and blue crab trawl survey. A sensitivity analysis to model assumptions is presented in the assessment document. Biological reference points are defined for stock abundance and exploitation rates.

The 2010 assessment model is a major improvement to its predecessors (2005 and 1997) and is a valid approach. Biological reference points are calculated internally and correctly implemented in the model and are consistent with underlying model assumptions. This is a major advance with respect to previous models. Keeping track of males and females separately is appropriate considering that current management has affected the sex ratio.

The main points of concern with respect to this assessment are:

- The assessment model results are not robust to treating the winter dredge survey as a relative index of abundance. If q is different from one the overall model fit improves substantially and is a much easier assumption to support.
- Model structure configuration implicitly assumes that female fecundity does not change with age. The impact of this on the reference point calculation is unknown.
- Stock recruitment function is not plausible with respect to mature male abundance.

An extended list of short term and future recommendations are presented in this document. It is recommended that the short-term list be considered before drafting the final report.

Recommendations

Short term

The document

1. There is an appropriate description and mathematical representation of the stock assessment model in the main document; nevertheless it is necessary that the authors include some modifications in the final document:

    a. A conceptual model should be included, which would provide a better description of the components, biological timeline and how this connects to the assessment, especially with regard to survey data. Main model assumptions should also be addressed.

    b. The stock recruitment function should include the bias correction factor to avoid misinterpretation of recruitment parameters estimates.

    c. Initial conditions of the population dynamic model should be clearly specified in the document.

    d. Appropriate documentation should be provided of the non-precautionary nature of the stock-recruitment function, particularly at low population stock size.

    e. A better description is needed of the sensitivity tests presented in the document, including estimated parameter values and standard errors, likelihood values associated to each data component, and uncertainty around the main model outputs.

    f. Sensitivity tests undertaken during the review should be described.

    g. Data points on the reference point figures (6.1 and 6.14) should be annotated with the years, as this would link better with the text.

    h. A composite reference point figure should be provided, including: a) the 2005 method for standardizing the survey data and the 2005 reference points, b) the 2010 standardized data with the 2005 reference points and c) the 2010 standardized data with the 2010 reference points. This figure should be accompanied with an interpretation of the changes when moving from the 2005 to the 2010 assessment.

2. In many ways this fishery can be considered data rich and from all available data the winter dredge survey is the most important piece of information. It is used in the assessment and the evaluation of stock status relative to the reference points. It is important that this survey is continued.

3. The structure of model (Age-0/Age-1+ and sex) seems appropriate considering the nature of the historical data. It also allows one to keep track of meaningful population statistics (spawning abundance by sex), which is of special relevance under recent changes to the management regime in the fishery.

4. The calculation of reference points is incorporated within the assessment model. This is a major advantage over previous models, because it assures consistency between statistics.

5. One inconvenience of collapsing the entire adult age structure into one age group is losing track of female fecundity at age. The implicit assumption is that female fecundity remains constant, which is probably rather unlikely to happen. Additionally it is unclear how this would influence the spawning stock size at MSY calculations.

6. In the assessment report there was an important effort to assess model structure uncertainty (results of two additional models were presented). Despite the intrinsic value of this exercise, a direct comparison of reference points between the models is not possible, because female spawning stock is not available for the other models. Nevertheless of the three assessment models provided, the best model is the SSCMSA.

7. On the other hand the parameter uncertainty of the proposed model was not fully characterized through the documented sensitivity tests, nor was the robustness of reference points estimates adequately presented. For example, test runs during the review highlight that the assessment model output is extremely sensitive to treating the winter dredge survey as a relative index of abundance. The fit was much better than the base case presented in the report. This is of great concern, as traditionally the default assumption is to treat surveys as a relative index of abundance. It is recommended that:

a) A sensitivity test is run using the raw winter dredge survey indices.

b) The entire calculation of survey catchability should be checked in detail and possible sources of difference should be investigated.

8. The reference point calculations seem appropriate based on the structure of the new model. The authors followed the Federal reference points system to define the limit reference points and the New England and Mid-Atlantic Fishery Management Councils' system to define target reference points. This seems appropriate, but is in the end a policy decision. With respect to stock based reference points there is a value judgment about how precautionary the overfished limit and target reference point needs to be. Different values arise using different male to female F ratios, and coincidentally the one chosen in the report is not the most precautionary one.

Future work

9. This assessment lacks a catch per unit effort index of abundance, an index that captures the condition of the stock from the fisheries perspective. Future assessments should investigate the feasibility of generating a standardized catch rate index. This would ultimately be of importance in future economic analyses.

10. The substantial difference between the model and estimated catchability coefficient of the winter dredge survey requires immediate attention. This is a high priority task.

11. The spatial component seems to play an important role in the population dynamics of different ontogenetic stages of Chesapeake Bay blue crab. A detailed data-driven analysis (combining all of the pieces of information) of spatial and temporal dynamics of different stock components should be undertaken. Environmental covariates should also be factored in.

12. More work on the natural mortality parameter estimation should be undertaken using the available mark recapture data. Alternative Brownie model parameterization should be considered in the analysis, to explicitly model natural and instantaneous fishing mortality rates. Ultimately, the tagging data could be directly incorporated into a more integrated stock assessment estimation model.

13. Only a nominal index of abundance was constructed from the Virginia trawl survey data during this assessment. Index standardization should be undertaken. A second index of abundance can be potentially developed based on the winter portion of the Virginia trawl survey, which could provide information on the female spawning stock.

14. Interaction terms were omitted in the standardization of survey indices. It is recommended to develop additional models with interaction terms in the second stage of the delta GLM analysis.

15. In recent years some areas in the Chesapeake Bay seem to be experiencing higher recreational fishing mortality than reported in this analysis. It is recommended that a new baywide recreational survey be undertaken.

16. Despite the data-rich nature of this assessment, there is a major need for accurate and complete catch and effort information. Some of these factors are presented in the following list: (a) the conversion of the catch in weight to numbers should be based on measured average weight in the catch, rather than using a constant factor. This means that mean size in the catch by year is required; (b) a better and more direct estimate of soft and peeler crab mortality should be developed for the assessment; (c) the adjustment of past changes in catch reporting requires some independent verification. The catch data is influential to the assessment results; (d) Anecdotal information suggests that incidental winter dredge and summer pot fishery mortality might be important. It is important to quantify these additional sources of mortality.

17. Additional model runs should be undertaken to assess the robustness of the results to: (a) using the modified/original time series of catch; (b) estimating the catchability coefficient of winter dredge survey for adult crab; (c) using different pieces of information; (d) not estimating observation and process error simultaneously; (e) to free up the assessment model to allow for a better fit of extreme values. A sensitivity test might be organized in a systematic and comprehensive way, using appropriate techniques (i.e. FAST, designed experiments).

18. Include additional sources of information into the assessment such as Baywide Multispecies Monitoring and Assessment Program and Potomac daily catch data.

19. Adjust the reporting changes in the catch internal to the assessment model and input the intervention parameter so that this acknowledges some of the uncertainty.

20. Incorporate formally the different fisheries into the assessment. In addition reparameterize the partial recruitment parameter into formal selectivity and growth components.

21. The initial conditions of the model should have 4 as opposed to 2 parameters. If initial conditions stay in a 2-parameter configuration, the implicit assumption for the other 2 parameters should be consistent with the rest of the model configuration.

22. In equation 7 and 11, kappa should be multiplied by only F and M should be scaled by time.

23. Incorporate some kind of compensatory component into the stock recruitment relationship to avoid non-precautionary behavior of the model (i.e., depleting male population, while maintaining high recruitment rate).

24. A more complex version of the model might include: (a) size structure; (b) monthly time step to allow for the evaluation of in-season regulations; and (c) spatial structure. The model development could be frameworked into a MSE type of configuration.

Conclusions

The 2010 assessment model is a major improvement to its predecessors (2005 and 1997) and is a valid approach.

This fishery is data-rich based on fisheries independent information, but data-poor from fisheries dependent perspective. More effort needs to be devoted to improving catch and effort data.

The modified Ricker stock recruitment function is non-precautionary and that needs to be addressed in the document.

The assessment models results are not robust to departures in the assumption of winter dredge survey being an absolute index of abundance.

Background

NOAA Chesapeake Bay Office through the Center for Independent Experts (CIE) requested an independent review for the 2010 Chesapeake Bay blue crab stock assessment. This review included three fisheries independent surveys, fisheries dependent information, the 2010 stock assessment model and the reference point calculation of blue crab (*Callinectes sapidus*) in Chesapeake Bay.

Blue crab is the most important commercial fishery and an icon in the Chesapeake Bay region. The blue crab stock has been subject to Baywide stock assessment on two previous occasions. The first Baywide stock assessment was developed by Rugolo et al. (1997). It concluded that the stock was moderately to fully exploited and at average levels of abundance. The second blue crab stock assessment was reported by Miller et al. (2005) and consisted of a Catch-Survey-Analysis (Collie and Sissenwine, 1983) that used fisheries dependent and independent data. Reference points were calculated using individual based yield per recruit analysis (Bunnell and Miller 2005) and stock status estimates were compared to these values. Based on these reference points, the assessment concluded that exploitation rates in the fishery were too high. Since 2005, the status of the blue crab stock has been updated annually and its status determined relative to the reference points. In 2010 a third Baywide assessment was conducted through a highly collaborative and integrated program to address specific concerns raised by the international CIE review panel from 2005. The 2010 assessment activities are divided into eight specific Terms of Reference (TOR), and are the base for the current CIE Peer Review.

Description of review activities

Before and during the meeting

Documentation

Two weeks before the staff meeting at the Sheraton Baltimore City Center Hotel in Baltimore, several papers and software from the official "*Assessment of blue crab in Chesapeake Bay*" review webpage were uploaded:

http://hjort.cbl.umces.edu/crabs/Assessment.html

This website link was timely provided by Mr. Derek Orner.

The list of documents was the following:

- Executive Summary.
- Full Assessment.
- Working paper 1 - Survival analysis.

- Working paper 2 - Depensation analysis.
- Working paper 3 - Production modeling.
- Working paper 4 - CMSA model.
- Research Recommendations.

Previous Assessments

- 2005 Assessment.
- Limits and Targets (2001).
- Miller and Houde (1999).
- Rugolo et al. (1997).

The list of software was the following:

- Catch Data (EXCEL document).
- Control Rule Calculations (EXCEL document).
- ADMB code and input file.
- R scripts.

During the meeting and upon request, the team provided the following additional documentation, information and tests:

1. Correction of the lagged plots
2. Extra residual and predicted versus observed plots
3. An additional model run assuming that the winter dredge survey is a relative index of abundance.

Before the meeting

Panel members were invited by Mr. Derek Orner to attend on Monday the 28th the Blue Crab Advanced Research Consortium (BCARC) presentations at the National Shellfish Association's Annual Meeting in Baltimore. Interesting and updated information on blue crab ecology was presented all day long, providing some background information on this species.

Review Activities

The review workshop was conducted at the Sheraton Baltimore City Center Hotel in Baltimore, Maryland over three days: Tuesday the 29th to Thursday the 31st of March 2011. An extra morning of work (Friday April 2011) was necessary to wait for extra runs results and complete the Summary Report from CIE Review Panel Members.

The assessment team was composed of the following four groups and most of them participated in the review:

- Thomas Miller, Michael Wilberg and A.R. Colton from Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, Solomons, MD.
- G. R. Davis, A. F. Sharov. Fisheries Service, Maryland Department of Natural Resources, Annapolis, MD
- R. N. Lipcius, G. Ralph. Virginia Institute of Marine Science, Gloucester Point, VA
- E. G. Johnson, A. G. Kaufman, Smithsonian Environmental Research Center, Edgewater, MD

Other people present throughout the review

- Robert O'Reilly. Virginia Marine Resource Commission.
- Derek Orner. National Oceanic and Atmospheric Administration Chesapeake Bay Office.

The review panel was constituted by:

- Dr. Catherine Dichmont (CSIRO, Marine and Atmospheric Research, Queensland, Australia).
- Dr. Billy Ernst (UDEC, Concepción, Chile).
- Dr. Julian Addison (independent fisheries consultant, France).

The meeting was coordinated by Mr. Derek Orner of NOAA on behalf of the CIE review team, but the summary review was the view solely of the CIE panel members.

Dr Tom Miller gave a presentation on the first day of the review covering all aspects of the above Terms of Reference (ToR). On the second day, the review panel and assessment team discussed the research with the assessment team against each ToR. The assessment team was extremely helpful in this review.

Thursday and Friday morning were devoted by the review panel members for discussion and preparation of the CIE review panel member summary report. The timetable of presentations and discussions is presented in Annex 3.

Findings and recommendations

ToR A: Critically assess and where necessary revise the life history and vital rates of blue crab in the Chesapeake Bay that are relevant to an assessment of the stock.

Stock structure

The Chesapeake Bay blue crab is assessed as an independent stock, separated from Delaware and southern populations. A definitive statement about spatial population structure from a genetic standpoint is still lacking, but larval distribution studies provide evidence of a quasi-discrete stock and movement of benthic stages is restricted to the Chesapeake Bay or adjacent areas in the estuary. Based on available information it seems appropriate to treat the Chesapeake Bay blue crab benthic population as a separate stock. Random stock exchange with adjacent areas during early life stages is possible in the assessment model through the recruitment residuals parameters of the stock-recruitment function.

Conceptual model

This species, as many other crustaceans, has a complex life history with extended and massive female reproductive migrations, rapid growth and maturation, female terminal molt, crab over wintering and high natural mortality. Probably some of these processes are affected by gradients and fluctuations in environmental conditions.

There is a need for better documentation of a comprehensive and formal conceptual model that encompass the life history, spatial dynamics and timing of different benthic ontogenetic stages of blue crab in Chesapeake Bay. This conceptual framework might help during the development of scientific surveys, interpretation of the data and the development of stock assessment models of different levels of complexity. The conceptual model will become very important for defining parsimonious operating and estimation models in a future management strategy evaluation (MSE) framework (Smith et al. 1999).

The different trawl and dredge surveys constitute a valuable source of information that provides both spatial and temporal contrast to the data. This spatially explicit database should be analyzed thoroughly to reveal spatial pattern and spatial dynamics of this species and its relationship with the environment. This can be entirely a data driven approach such as the one reported by Ernst et al. (2005) for snow crab in the Eastern Bering Sea.

Fecundity

The relationship between fecundity and size is important, as indicated in the document Prager et al. (1990), but the key issue is how female fecundity changes with age.

The 2010 stock assessment model keeps track of Age-0 and Age-1+ males and females. Assuming Age-1+ is a good proxy of mature females, the model lumps all adult females in one category, regardless of their age. This could be appropriate if fecundity does not vary with age, but is probably not the case for this species. As with other terminal molt crustaceans (e.g. snow crab), fecundity probably drops as female senesce (Orensanz et al 2005). Female blue crabs mate only once, right after the last molting event. Anecdotal information generated during the review discussions indicates that most of the sperm load is used during the first spawning season, through multiple spawning batches, which probably makes this iteroparous species to effectively reproduce as a quasi-semelparous one. This factor can be of major importance in spawning size calculations and its impact on reference point calculation is probably relevant.

It would be valuable to construct an empirically based clutch fullness index of egg-berried females to assess time dependent changes in female fecundity. This is an extra covariate that needs to be measured during the surveys (Orensanz et al 2005) and is a valuable tool to identify sperm limitation.

Mating

Under the current model configuration the effective sex ratio at mating becomes an important variable to assess, because it affects reference point determination. Experimental laboratory work might be valuable for defining biologically precautionary sex ratios at mating. It is important to mention that sex ratios should be computed at scales that are meaningful to the mating process, especially for this species that has extensive ontogenetic sex/age dependent latitudinal migrations.

Growth

A growth function is not explicitly part of this assessment model, because length or biomass information is not used as hard data in the assessment. The only link between age and size is at the moment or parsing the survey data into the two-stage categories. These assignations are based on size cut-points that were derived from historical modal decomposition analysis applied upon survey based size frequency data (this was explained to us during the presentations). Some figures that were shown to us showed very distinct modes, which probably justify the chosen cut-points. From the provided data it is hard to judge how much uncertainty is involved in the age assignation (especially for different times of the year and sexes) and it would be valuable to put forward a quantitative analysis that characterizes some of this uncertainty.

Age information derived from Ju et al. (1999) and Puckett et al. 2008 is also used to condition the partial recruitment parameter.

Natural mortality

It is important to acknowledge that since the first assessment a substantial amount of effort has been allocated to assess natural mortality. This effort is greater than expected for a regular stock assessment. Estimates of natural mortality were thoroughly reviewed in a previous assessment (Miller et al 2005). Indirect methods for estimating M were developed using growth parameters, age at maturity, longevity and temperature. Natural mortality values from these methods ranged from 0.3 to 2.35. The distribution is centered at 1.1, a value that is substantially higher than the natural mortality estimate used in the 1997 assessment. Despite potential problems associated with indirect approaches described by Pascual and Iribarne (1993), these methods provide parameter estimates that integrate various life-stages throughout the ontogeny of blue crab.

Several medium to long-term initiatives are providing valuable mark-recapture information on terminal molted female blue crab in Chesapeake Bay. This is a major breakthrough because it allows for direct estimates of natural mortality from this stock.

The survival analysis paper by Lipcius and Smith (2011) used a Brownie model to estimate yearly survival and recovery rates. Model selection was used to define the optimal saturation level of the model, being the one with time dependent survival and recovery rates. Unfortunately M was not estimated directly from the Brownie model, but using again longevity information from the mark-recapture data. Two venues of model development aimed at improving the estimation of natural mortality are proposed:

- Use an alternative parameterization of the Brownie model, one which includes explicitly the catch equation for harvest rate calculation (Frusher and Hoenig 2001), with or without fishing effort information.

- Integrate the mark recapture data directly into the assessment model (Maunder 2001).

Despite the method used for estimating M with current mark-recapture data, it is important to remember that it reflects survival rates associated with terminal molted females. It is recommended that in a medium time framework an additional mark-recapture experiment be implemented for males and Age-0 individuals. Males do not have terminal molt and natural mortality rates might be different than females. This would require a different kind of tag (i.e. T-bars).

ToR B: Evaluate and recommend biological reference points for the Chesapeake Bay blue crab population. The potential for implementing sex-specific reference points should be evaluated.

One important advantage and improvement of the current assessment model over its predecessors is the possibility of calculating directly biologically meaningful and consistent reference points. The derivation of reference point calculations is adequately implemented in the model and considers a sex-specific formulation of the stock-recruitment relationship. Once the biological reference points are estimated, limit reference points are calculated using the Federal reference point system. This seems to be totally adequate. Because of the nature of the stock recruitment model and the possibility to harvest males and females differently, several yield curves are produced, depending on F_{males}: $F_{females}$ ratios. Implicit biological reference points are various, and there is a value judgment about how precautionary the overfished limit and target reference point needs to be. It would be more convenient to provide the stakeholders with a matrix that would lay out possible combinations of fishing effort ratios and implicit reference points. The limit reference points that were chosen by the assessment team do not represent the more precautionary ones.

Target reference points, on the other side are also based on biological reference points from the model, but use the Mid-Atlantic and New England Fishery Management Councils' system to define them. This is appropriate, but is again a value judgment and there are several others that could be considered. The choice is a policy decision.

Potential relevant factors that might affect biological reference points that deserve further attention are:

- Dredge survey index being treated as a relative index of abundance for Age-1+ crabs. This is of major concern.
- Factoring in fecundity into the spawning stock calculation and having fecundity vary by age (as is probably the case).

ToR C: Describe and quantify patterns in fishery-independent surveys. Analyses should include evaluation of the impacts of environmental and abiotic factors on survey catches, to maximize the information content of resultant survey time-series.

The strongest component of the 2010 Chesapeake Bay blue crab assessment is the fisheries independent data. Three different surveys were considered for this stock assessment; (a) The Virginia Institute of Marine Sciences (VIMS) trawl survey (1968 – 2009), (b) Maryland trawl survey (1977-2009) and (c) The Winter Dredge Survey (WDS) (1989-2009).

VIMS juvenile finfish and blue crab trawl survey

This annual survey consists typically of 60 stations, organized in 7 strata. Historically random and fixed assignments of stations have been employed. In this assessment only the spring portion of this trawl survey was used, because migration is less important in that part of the year. To eliminate biases of different coverage areas over time, only three main tributaries were considered in the assessment (James, Cork, Rappahannock rivers). The VIMS trawl survey time series was not standardized and only nominal catch per tows values are available. Correction of gear catchability was introduced directly to the data to compensate for two conspicuous changes in the gear. Age-1+ female and male abundance show very similar patterns, a highly variable period up to 1990 and low levels of variability and abundance after that. Correlation analysis between Age-0(t) and Age-1+(t+1) crab were presented. There is not a high correlation between these two metrics. Given the spatial dynamics of these species there should not necessarily be such a correlation for females, because an important fraction of Age-1+ females have migrated from the upper Bay. Until the migration patterns and rates by sex are better understood, such correlations are probably not very meaningful.

MD DNR trawl survey

This trawl survey started in 1977 and expanded first in 1984 and later in 2003. Coverage has been inconsistent temporally and spatially from year to year. The gear has been consistent throughout the years (16 foot semi-balloon otter trawl). This data set was standardized using a delta GLM method, which is a two-stage approach that models presence and absence in the first stage and the abundance in the second. Several covariates were used in the analysis, including year, month, strata, salinity, temperature and depth. This approach seems appropriate, but no interaction terms were used in the standardization. They should be included.

Winter Dredge Survey

This is by far the best available set of information from the assessment. It covers the entire bay, at a moment the crabs become quiescent and are closely related or buried in the sediments. The survey has been running since 1991 and, on average, 1200 stations are visited each year. Each year trials are conducted to estimate vessel and year-specific catchability coefficients. These coefficients with area swept are used to come up with absolute abundance.

During the meetings the review panel members were suspicious about using this time series as an absolute index of abundance in the assessment. When this assumption was relaxed and q was estimated for this survey, the fit to different pieces of information improved substantially.

ToR D: Describe and quantify patterns in catch and effort by sector and region, including analyses that examine the impacts of reporting changes and trends in CPUE.

The assessment report considers the description/analysis of catch data of three different jurisdictions. Collecting information from different jurisdictional agencies, processing the data and interpreting the results was probably a major task in itself. In the assessment report only catch information was available for this analysis. Effort and CPUE data were excluded from the report. This is unfortunate, because it is always valuable to have fisheries indicators that directly relate to the fishery. It is important that the collection and analysis of such data be prioritized. The availability of such data becomes even more important if economic assessments are needed in the near future.

Fisheries in the Chesapeake Bay encompass a diversity of sectors, including recreational and commercial fisheries. Catch statistics come from 3 different jurisdictions (Virginia, Maryland and Potomac River fisheries commission), Virginia and Maryland being the most prominent ones. The most important concerns with respect to Chesapeake Bay blue crab catch data is misreporting of landings or missing entire sections of landings.

Changes in the reporting system and how this has been taken into account has been a point of controversy in previous assessments. The current assessment model does not keep track of gear, fleet or jurisdiction. Therefore it requires only one overall catch time series. The problem of adjusting the reporting systems in the Virginia and Maryland jurisdictions remains and the current time series approach to deal with the 1993 discontinuity seems appropriate. Nevertheless the adjustments levels in the past catch records are substantial, so three additional procedures are recommended:

a) Do additional model runs with unadjusted catch levels to assess the sensitivity to this scenario.

b) Use unadjusted catch records, but use an additional intervention parameter in the model to deal with this discontinuity. This approach should pass some of the uncertainty around changes in reporting system into the assessment.

c) Look for independent data to verify the year and level of the scaling factor needed to correct the time series of catch.

The assessment model estimates observation and process error simultaneously. As part of model development it would be convenient to fix the catch related observation error by assigning specific coefficient of variation values to different parts of the catch time series, reflecting the relative uncertainty (confidence) around those estimates.

The lack of biological data (i.e. size and size-weight) in the historical catch records is also a weak point of fisheries related information of this stock. Catch in weight is converted to numbers, before being used in the assessment model, by using a constant scaling factor throughout the years, as opposed to each year's average weight. This point deserves some attention.

Other relevant current and historical factors affecting overall catch levels are:

a) Soft Peeler fishery data was not incorporated in the analysis.

b) Recreational catch underreporting, especially in some areas.

    o New sensitivity runs for different levels of recreational catch seem appropriate.

    o Develop a second phone survey.

c) Incidental mortality not being adequately addressed:

    o Mortality from the dredge winter fishery. Testimonial of some watermen before the fishery closure indicated a high Age-0 female incidental mortality. Some sensitivity accounting for some levels of additional mortality are recommended.

    o Summer pot fishery had up to 50-70% of incidental mortality.

    o In the trotline fishery.

ToR E: Develop and implement assessment models for the Chesapeake blue crab fisheries. In particular, models that permit estimates of the trends and status of the crab population and fisheries on a sex-specific basis should be evaluated.

The new assessment is an improvement with respect to its predecessors. This two-stage model keeps track of sex-specific abundance in the population and the catch, and the "age-structure" matches up with the available structured information from the surveys. This is a good example of a parsimonious model, which balances out complexity and simplicity. The renewal function is a modified Ricker model with both sexes affecting recruitment at larger population sizes and only females at low population levels. The rationale for the development of this recruitment function was discussed during the meeting and it seems to be valid, but in practical terms the recruitment function does not pass through the origin under some modeling conditions. In fact, as reported in the document yield is maximized when males are fished out of the populations. This is not a very precautionary model configuration. Some modifications in the model need to be introduced to avoid such non-precautionary behavior.

Under the current management scheme for the Chesapeake Bay blue crab fishery, the assessment model is only used for reference point calculation and not for stock status estimation. Models are run every five to eight years, and abundance is derived from an empirically based winter dredge survey (WDS) on a yearly basis. This procedure heavily relies on the assumption of WDS to be an absolute index of abundance. This issue deserves some additional investigation and to evaluate the option of running yearly assessments to yield model based stock status estimates.

The initial conditions of the assessment model were not documented in the assessment model. This needs to be corrected in the document. A direct inspection of the model equations in the ADMB code revealed that the initial condition assumptions are not fully consistent with the rest of the model's configuration. This issue will probably not be very influential in stock assessment results, given the short lifespan of this species, but it should be corrected for model consistency.

As pointed out previously, fecundity needs to be considered in the model for spawning stock calculation. Under the current model configuration fecundity is assumed to be constant across ages of terminal molted females. This will probably lead to an overestimation of spawning stock size, as fecundity should drop in female blue crab after the first reproductive season. The effect of this on reference point calculation is yet to be evaluated.

In the future, improvements to the stock assessment model should consider:

a) The use of size structure in the assessment. This can be done either by keeping the age structure of the model and using size data as an additional source of information (Fournier et al. 1998) or migrating into a fully size-structured model (Sullivan et al. 1990).

b) Include gear type through gear specific selectivity parameters. Under the current model configuration this could be done by re-parameterizing the partial recruitment parameter in the demographic equations by growth related and selectivity components. Under this new configuration the evaluation of management tactics and strategies on different gears types and its effect on the blue crab population dynamics will be readily available.

c) Some degree of spatial component to address different jurisdictions and something that takes into account key elements of the complex spatial dynamics of this species (i.e. upper portion of the Bay as mating grounds and lower portion of the Bay as a natural repository of mature females). The appropriate number of spatial components will emerge from a balance between important spatial dependent processes that need to be modeled and the amount of available data to parameterize these models.

Two other assessment models were presented in the stock assessment report, an update of the 2005 assessment and a biomass dynamic model. The different metrics of these models make them hard to compare with the new model.

ToR F: Examine density-dependent exploitation patterns derives from survey-based and model-based approaches.

The paper by Lipcius (Assessment working paper 2) presents convincing evidence of density-dependent exploitation operating on the Chesapeake Bay blue crab stock. The author used a set of linear and non-linear models to test for density-dependent harvest by using the winter dredge survey data. Therefore his analysis was entirely driven by survey-based data. No analysis based on the assessment's model-based abundance and exploitation rate estimates were presented.

The author should include a table with parameter estimates and standard error, as well as likelihood and AIC values. This will allow the reader to quantitatively judge the amount of evidence in favor of each model.

ToR G: Characterize scientific uncertainty with respect to assessment inputs and stock status.

The current assessment model is used for reference point calculation, as stock status is based on the winter dredge survey abundance estimates.

Uncertainty in a stock assessment model can be of various types, including for example model and parameter uncertainty, observation and process error (Francis and Shotton 1997). Model uncertainty was somehow covered in the current assessment, by using 3 different stock assessment models. The results were not fully compared, because they have different metrics.

Parameter uncertainty was addressed by a sensitivity analysis considering the following varying factors:

- Levels of natural mortality (M).
- Estimation of male natural mortality (M_{male}).
- Levels of recruitment parameter (r).
- Estimation of sex ratio.
- Estimation of recruitment parameter.

The results show low levels of variation in the point estimates of biological reference points (u_{MSY} varying from 0.3-0.36).

As part of model development, it seems appropriate to extend this effort by increasing the number of scenarios to include:

- Sensitivity to different model parameters.
- Assess the consistency of the results (stock status and reference points) by fitting the model to different pieces of information separately.
- Using different catch histories (or estimating intervention parameter).
- Estimation of either process or observation error in the model, at various levels. With the current configuration it is hard to infer the implications of different assumptions (observation/process error levels) in that regard.

During the assessment review, the review panel asked the stock assessment modelers to re-run the model under the assumption that the winter dredge survey was not an absolute index of abundance for Age-1+ crabs. The results are summarized in the following table:

Name	Mf	Mm	rf	sex_r	neg_LL	Nf2010	Frat 68-06	Frat2009	Nf(MSY)	Nf2009/Nf_targ2009	uMSY 2009	utarg2009
Base	0.9	0.90	0.6	0.52	248.4	181	0.97	1.39	158	0.84	0.34	0.25
low M	0.6	0.60	0.6	0.52	232.9	179	1.21	1.70	183	0.73	0.38	0.28
High M	1.2	1.20	0.6	0.52	246.2	182	0.84	1.25	145	0.92	0.30	0.22
low r	0.9	0.90	0.3	0.52	252.7	181	0.99	1.42	174	0.80	0.33	0.24
high r	0.9	0.90	0.9	0.52	247.1	180	0.97	1.37	153	0.86	0.34	0.26
est male M	0.9	1.39	0.6	0.52	86.7	197	0.73	1.72	211	0.68	0.35	0.26
est sex ratio	0.9	0.90	0.6	0.64	78.3	199	0.90	2.19	245	0.60	0.36	0.27
est rf	0.9	0.90	1.0	0.52	246.9	180	0.97	1.37	150	0.86	0.34	0.26
est WDS q	0.9	0.9	0.6	0.52	41.9	15.8	0.4	0.5	45.7	0.3	0.65	0.45
comb SR	0.9	0.9	0.6	0.52	248.5	180.3	0.9	1.4	129.3		0.34	0.25

These results are very different than any of the previous sensitivity tests. This is a main point of concern, because assuming that an index of abundance is absolute as opposed to relative is the exemption rather than the norm. The fit to the different pieces of information is much better under this scenario than the base case. It is highly recommended that the dredge survey assessment team discuss this issue with the stock assessment team to find plausible explanations. Under the *q different from 1* scenario the stock status time series index derived from the survey needs to be properly adjusted by the new catchability coefficient.

Uncertainty around model parameter estimates, model-based stock status and reference points were not provided in the document. Reporting partial likelihoods associated with each piece of information is also valuable.

Reporting the partial likelihoods is highly recommended in order to capture the uncertainty under different scenarios.

ToR H: Evaluate stock status with respect to reference points.

The assessment team presented a consistent way of calculating model-based biological reference points, and then a reasonable procedure for calculating target and limit reference points. This information was appropriately summarized in figure 1.

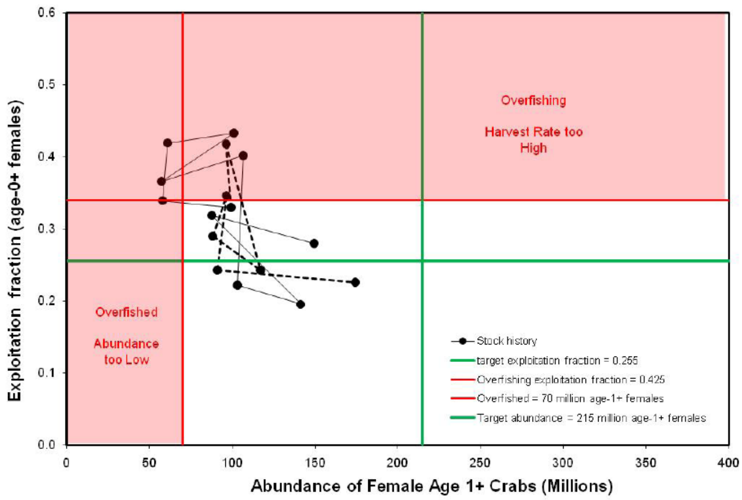

Figure 1: Control rule extracted from the 2010 Chesapeake Bay blue crab assessment (Figure 6.14 from the main assessment report).

Under the base case scenario, the stock in recent years is neither experiencing overfishing nor is it overfished.

The following recommendations emerged during the review to improve the representation and interpretation of the results:

- Include a year-caption associated to each stock status data point.
- A composite reference point figure, including: a) the 2005 method for standardizing the survey data and 2005 reference points, b) the 2010 standardized data with 2005 reference points and c) the 2010 standardized data with the 2010 reference points. This figure should be accompanied by an interpretation of the changes when moving from the 2005 to the 2010 assessment.

Preliminary extra model runs with estimated winter dredge survey catchability show different reference points and much higher exploitation rates throughout the years. This is presented in Figure 2. Under this scenario the stock has been experiencing overfishing and has been overfished for a great portion of the time series. This point requires further discussion, as the model results are extremely sensitive to this scenario.

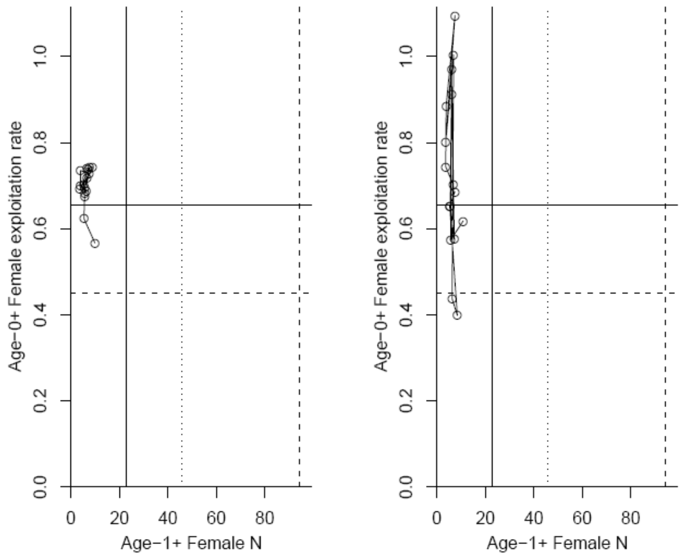

Figure 2: Recommended revised control rule under the estimated q for the winter dredge survey scenario. Figures were provided during the meeting from additional model runs. Vertical and horizontal lines represent limit an target reference points.

Acknowledgements

I would like to thank Derek Orner from the NOAA Chesapeake Bay Office for the coordination of the review process in Baltimore and for inviting us to the National Shellfisheries Association Symposium. He was very helpful and supportive. Tom Miller (University of Maryland) did a great job summarizing the assessment, Michael Wilberg was very responsive in rerunning the model and Romuald Lipcius gave great feedback on the winter dredge survey program. The entire assessment team was very open to questions raised by the review panel during the meeting. I would like to thank Manoj Shivlani (CIE), for contacting me and taking care of contractual and practical arrangements in an efficient manner.

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Attachment A: Statement of Work for Dr. Billy Ernst

External Independent Peer Review by the Center for Independent Experts

Blue Crab Benchmark Stock Assessment - 2010

Scope of Work and CIE Process: The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. The Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Technical Representative (COTR), and reviewed by CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in **Annex 1**. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following NMFS project. Further information on the CIE process can be obtained from www.ciereviews.org.

Project Description: The blue crab stock has been subject to Baywide stock assessments on two previous occasions. In the years between benchmark assessments, updates on the stock status are provided by the NOAA Chesapeake Bay Office's Chesapeake Bay Stock Assessment Committee. The most recent update concluded that the stock was not overfished and was not then experiencing overfishing. Since the 2005 assessment, the three management jurisdictions have implemented a range of regulatory changes aimed at attaining the target exploitation rate of 46% of the available stock. Thus, it is appropriate that another, Baywide benchmark assessment be conducted. The blue crab resource, specifically for soft and peeler crabs, in Chesapeake Bay has recently been declared a fisheries resource disaster by the Secretary Commerce. In 2009 and 2010, annual updates (not peer-reviewed) have shown slight improvements in the resource. Blue crab is the most important commercial fishery in Chesapeake Bay with annual Baywide landings recently as low as 50 million pounds – roughly 25 million pounds below the long-term average. 2010 predicted landings (if fished at the target exploitation level) could top 100 million pounds. This is obviously a large fluctuation in landings and thus value of the resource to the Bay community.

The first Baywide stock assessment was conducted using a length-based approach to estimate exploitation, and an unweighted average of the four principal fishery-independent surveys to determine abundance. Consequently biological reference points were crude.

In 2001, the technical subcommittee of the Bi-State Blue Crab Advisory Committee (BBCAC) developed a new management framework that relied on exploitation and biomass threshold and target reference points. Threshold reference points were proposed based on a maintaining 10% of the virgin spawning potential and on the lowest observed abundance in the surveys. A target exploitation rate that would lead to an effective doubling of the spawning stock present in 2001 was also selected. The most recent Baywide benchmark assessment for blue crab in the Chesapeake Bay was conducted in 2005. This assessment critically evaluated and revised estimates of the natural mortality rate, the impact of reporting changes on landings estimates, and spawning potential ratio reference points. The 2005 assessment, using data through 2003, recommended adopting the exploitation fraction, defined as the proportion of crabs available at the beginning of the season that are subsequently harvested, in place of less intuitive measures (F) used in previous assessments. Estimates of exploitation fractions were calculated based on the Baywide winter dredge survey (WDS) and within a modified catch-survey analysis that permitted the use of multiple surveys. The approach used in the 2005 assessment was reviewed by a panel of international scientists with expertise in crustacean fisheries who found that it was a substantial improvement over previous assessments. However, the panel also identified issues to be addressed in future assessments. In particular, the panel recommended exploration of the impact of density-dependent processes in life history traits, improvements to the fishery-independent surveys, particularly with regard to catchability, the possibility of developing a sex-specific assessment model and reference points, and a fuller analysis of the impacts of uncertainty on all aspects of the assessment.

The 2010 assessment and targeted research program is a highly collaborative and integrated program to address specific concerns raised by the international review panel from 2005.
The assessment activities are divided into eight specific Terms of Reference (TOR) that were developed based on the review comments received from panel of experts convened to review the 2005 assessment, and from extensive discussion with managers from MDNR, the Potomac River Fisheries Commission and the Virginia Marine Resources Commission, the three relevant management jurisdictions.

NOAA Fisheries is playing a significant role in coordinating disaster assistance to Maryland and Virginia to ensure a sustainable blue crab fishery in Chesapeake Bay. This 2010 Benchmark assessment and research program represents a large investment by NOAA and the state management agencies and should be reviewed internationally.

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**.

Requirements for CIE Reviewers: Three CIE reviewers shall conduct an impartial and independent peer review in accordance with the SoW and ToRs herein. CIE reviewers shall have working knowledge and recent experience in the application of stock assessment and crustacean fisheries. Each CIE reviewer’s duties shall not exceed a maximum of 14 days to complete all work tasks of the peer review described herein.

Location of Peer Review: Each CIE reviewer shall conduct an independent peer review during the panel review meeting scheduled in Baltimore, Maryland during the tentative dates of 29-31 March 2011.

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 (full name, title, affiliation, country, address, email) 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 other information concerning 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., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact 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) to the CIE reviewers the 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 Lead Coordinator on where to send documents. 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. The CIE reviewers shall read all documents in preparation for the peer review.

Panel Review Meeting: Each CIE reviewer shall conduct the independent peer review in accordance with the SoW and ToRs, and shall not serve in any other role unless specified herein. **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 herein. The NMFS Project Contact is responsible for any facility arrangements (e.g., conference room for panel review meetings or teleconference arrangements). The NMFS Project Contact is responsible for ensuring that the Chair understands the contractual role of the CIE reviewers as specified herein. The CIE Lead Coordinator can contact the Project Contact to confirm any peer review arrangements, including the meeting facility arrangements.

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 may assist the Chair of the panel review meeting with contributions to the Summary Report, based on the terms of reference of the review. Each CIE reviewer is not required to reach a consensus, and should provide a brief summary of the reviewer's 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 the Baltimore, Maryland during the tentative dates of 29-31 March 2011, and conduct an independent peer review in accordance with the ToRs (**Annex 2**).
3) No later than 14 April 2011, submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Mr. Manoj Shivlani, CIE Lead Coordinator, via email to shivlanim@bellsouth.net, and Dr. David Sampson, CIE Regional Coordinator, 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**.

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

22 February 2011	CIE sends reviewer contact information to the COTR, who then sends this to the NMFS Project Contact
15 March 2011	NMFS Project Contact sends the CIE Reviewers the pre-review documents
29-31 March 2011	Each reviewer participates and conducts an independent peer review during the panel review meeting
14 April 2011	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
28 April 2011	CIE submits CIE independent peer review reports to the COTR
5 May 2011	The COTR distributes the final CIE reports to the NMFS project contact

Modifications to the Statement of Work: Requests to modify this SoW must be approved by the Contracting Officer at least 15 working days prior to making any permanent substitutions. The Contracting Officer will notify the COTR 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 ToRs within the SoW as long as the role and ability of the CIE reviewers to complete the deliverable in accordance with the SoW is not adversely impacted. The SoW and ToRs shall not 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 and ToRs. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via e-mail the contract deliverables (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 completed with 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 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 CIE reports to the NMFS Project Contact and Center Director.

Support Personnel:

William Michaels, Program Manager, 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

Roger W. Peretti, Executive Vice President
Northern Taiga Ventures, Inc. (NTVI)
22375 Broderick Drive, Suite 215, Sterling, VA 20166
RPerretti@ntvifederal.com Phone: 571-223-7717

Key Personnel:

NMFS Project Contact:
Derek M. Orner
NOAA Chesapeake Bay Office, 410 Severn Avenue, Suite 107A, Annapolis, MD 21403
Derek.orner@noaa.gov Office: (410) 267-5676 Cell: (410) 570-2268

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, and specify whether the science reviewed is the best scientific information available.
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 in which the weaknesses and strengths are described, 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 brief summary of findings, of the science, 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 weaknesses and strengths of the science reviewed, 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 the following appendices:
   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 Peer Review

Blue Crab Benchmark Stock Assessment - 2010

The stock assessment review has the following eight specific terms of reference:

a) Critically assess and where necessary revise the life history and vital rates of blue crab in the Chesapeake Bay that are relevant to an assessment of the stock.

b) Evaluate and recommend biological reference points for the Chesapeake Bay blue crab population. The potential for implementing sex-specific reference points should be evaluated.

c) Describe and quantify patterns in fishery-independent surveys. Analyses should include an evaluation of the impacts of environmental and abiotic factors on survey catches, to maximize the information content of resultant survey time series.

d) Describe and quantify patterns in catch, effort and survey-based estimates of exploitation by sector and region, including analyses that examine the impacts of reporting changes and trends in CPUE.

e) Develop and implement assessment models for the Chesapeake blue crab fisheries. In particular, models that permit estimates of the trends and status of the crab population and fisheries on a sex-specific basis should be evaluated.

f) Examine density-dependent exploitation patterns derived from survey-based and model-based approaches.

g) Characterize scientific uncertainty with respect to assessment inputs and stock status.

h) Evaluate stock status with respect to reference points.

Annex 3: Tentative Agenda
2010
Blue Crab Stock Assessment Review
Sheraton Baltimore City Center Hotel
101 West Fayette St., Baltimore, MD
March 29-31, 2011

March 29, 2011

12:30 Welcome & Introductions
Orner
- Stock Assessment Committee
- Review Panel

12:45 Presentation of the 2010 Blue Crab Stock Assessment
Miller

4:00 General / Open Question Period
Orner
- Public Comment
- Review Panel

5:30 Adjourn

March 30, 2011

8:30 Term of Reference Review and Discussion

I. Critically assess and where necessary revise the life history and vital rates of blue crab in the Chesapeake Bay that are relevant to an assessment of the stock.

II. Evaluate and recommend biological reference points for the Chesapeake Bay blue crab population. The potential for implementing sex-specific reference points should be evaluated.

III. Describe and quantify patterns in fishery-independent surveys. Analyses should include evaluation of the impacts of environmental and abiotic factors on survey catches, to maximize the information content of resultant survey time-series.

IV. Describe and quantify patterns in catch and effort by sector and region, including analyses that examine the impacts of reporting changes and trends in CPUE.

12:30 Lunch

1:30 Term of Reference Review and Discussion (continued)

V. Develop and implement assessment models for the Chesapeake blue crab fisheries. In particular, models that permit estimates of the trends and status of the crab population and fisheries on a sex-specific basis should be evaluated.

VI. Examine density-dependent exploitation patterns derives from survey-based and model-based approaches.

VII. Characterize scientific uncertainty with respect to assessment inputs and stock status.

VIII. Evaluate stock status with respect to reference points.

5:15 Adjourn

March 31, 2011

9:00 Review Session *[closed-door]*

- Review Panel to discuss assessment methodologies and develop individual opinions.
- Initiate development of summary documents

12:00 Lunch

1:15 Review Session (continued)

4:30 Adjourn