Peer review of

Stock Assessment of the Blue Crab in Chesapeake Bay 2005

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Report to

University of Miami, Center for Independent Experts

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Executive summary

- This report is a review of the 2005 assessment of blue crab in Chesapeake Bay. The assessment re-evaluated and updated life-history parameters and vital rates of blue crab in the Bay, described patterns in fishery-independent surveys and catch data, developed a new analytical assessment model and re-evaluated and updated control rules for the fishery.
- The 2005 assessment is a major advance on the first Bay-wide blue crab assessment, which took place in 1997.
- The assessment provided convincing evidence that natural mortality is considerably higher than had been previously assumed. A most likely value of M=0.9 was adopted, with upper and lower boundaries of 0.6 and 1.2. This update is extremely important, since analytical assessment outputs and biological reference points for exploitation rate are very sensitive to assumptions about M.
- Four fishery-independent survey indices were considered, varying in length of time-series and spatial coverage. Taken together, they provide a robust description of trends in blue crab abundance. Spatial, temporal and size criteria used for defining abundance indices could be refined, however, and there is scope for further analysis to examine spatial and temporal coherence between the different indices. The data also provide the opportunity to test whether variations in recruitment or mortality are the driving force behind interannual fluctuations in abundance, and to determine whether a stock-recruitment relationship exists.
- Data on the commercial catch were corrected for changes in reporting system, using a statistically rigorous method of time-series analysis. This represents a major improvement on the data considered by the 1997 assessment.
- A new analytical assessment model was developed, allowing use of multiple series of fishery-independent abundance indices. The assessment outcomes provide a longer temporal perspective on blue crab populations than is possible using the 16 year time-series of the Winter Dredge Survey, otherwise the best source of information for inferences about stock trends. The review makes some suggestions for changes to the model and its inputs.
- Biological reference points are defined for stock abundance and exploitation fraction. The stock appears not to be overfished, but perceived status in relation to limits and targets for exploitation fraction depends strongly on assumptions about M. The review questions the value of reference points based on exploitation rate, given that mortality is not necessarily the controlling factor behind stock fluctuations.
- The review suggests that further consideration of uncertainty is needed for stock and exploitation metrics. Confidence intervals for stock abundance and exploitation fraction would allow fishery management decisions to be placed in the context of risk assessment. There is a need for explicitly defined management targets.

Background

Blue crabs (*Callinectes sapidus*) are an important component of the estuarine ecosystem of Chesapeake Bay and constitute a major commercial and recreational fishery resource for the region. The first Bay-wide assessment of the resource was undertaken in 1997 (Doc2). This report reviews a major re-assessment of blue crab stocks in Chesapeake Bay undertaken in 2005 (Doc1). Life-history parameters, fishery-independent survey data and commercial landings data were re-examined and updated, a new assessment model was developed and control rules for the fishery were re-evaluated. The assessment was reviewed by four independent scientists, acting under the aegis of the University of Miami's Center for Independent Experts. The review panel was chaired by Dr Malcolm Haddon (University of Tasmania), Dr Nick Caputi (Australian Department of Fisheries), Dr Paul Medley (independent consultant) and the present author (Dr Michael Bell, independent consultant). The remit for the review was to evaluate the Chesapeake Bay blue crab stock assessment, including input data, assessment methods, and model results (see Statement of Work at Appendix 3).

Description of review activities

Assessment documents (see Bibliography at Appendix 1) were provided to reviewers in advance of the review meeting. A review meeting took place at the Radisson Hotel, Annapolis, Maryland, from 9-11 August 2005 (see Agenda at Appendix 2). The host for the meeting was Derek Orner of the National Oceanic and Atmospheric Administration Chesapeake Bay Office. The 2005 blue crab assessment for Chesapeake Bay was presented by its lead author, Professor Thomas Miller of the University of Maryland Center for Environmental Science. A number of other researchers and representatives of various agencies were also present, and they were able to provide supporting information on biological studies and fishery-independent surveys. The first day of the review was a formal presentation of the assessment, with opportunity for the reviewers and others to ask questions and seek clarification. The second day's meeting was led by the chair of the review panel, and was an opportunity for the reviewers to ask detailed questions relating to each Term of Reference for the assessment. The final day was a closed-door session for the review panel, for panel discussions and individual exploration of the assessment data provided. Also on the final day, Derek Orner and his colleagues from NOAA kindly arranged for the review panel to see Chesapeake Bay at first hand, onboard a NOAA research boat. Blue crab fishing was much in evidence during this short tour.

No new sensitivity runs for the assessment were requested by the review panel during the meeting, but each panel member was able to explore the assessment data using the files provided on CD. The assessment team were extremely open in providing access to the data and the results of analyses. This review is based on the overview of the assessment provided by the assessment documents and presentations and discussions between the review panel and blue crab assessment scientists.

Summary of findings

General

It should be stated at the outset that the team involved in the 2005 assessment of the blue crab stocks in Chesapeake Bay have performed an excellent job, and the assessment report provides a sound scientific basis for future fishery management. It represents a major advance on the 1997 assessment (Doc2). The team have questioned and tested the assumptions, parameters and data sources underlying the assessment. Where no single best scientific judgement could be made about particular assessment inputs, the sensitivity of assessment outcomes to the range of likely range of inputs was examined. Full use was made of advances in assessment methodology and of the findings of recent research on blue crab biology. The assessment benefited from an outstanding set of fishery-independent survey data, and full use was made of this resource.

Inevitably, there are aspects of the assessment that could be improved or developed in future. These aspects were generally recognised and acknowledged in the assessment report. The review below identifies some of these aspects and makes suggestions for future research and development of methodologies. The review is structured according to the Terms of Reference (ToR) given in the Statement of Work at Appendix 3.

ToR 1: Adequacy and appropriateness of data used in the assessment

Life history and vital rates of blue crab in Chesapeake Bay

The 2005 blue crab assessment report provides a comprehensive and up-to-date overview of blue crab life history patterns in Chesapeake Bay. Full use was made of recent (post-1997) studies:

- to demonstrate that the stock of blue crab in Chesapeake Bay is functionally discrete from neighbouring stocks;
- to describe blue crab growth patterns in Chesapeake Bay and neighbouring areas, based on laboratory and mesocosm studies, and mark-recapture and size-frequency analysis in the field;
- to develop size-dependent maturity ogives for female blue crab;
- to describe spawning behaviour and movements within the Bay;
- to determine the longevity of blue crab under natural conditions; and
- to determine the likely range of values for natural mortality (M).

Recent information was not available on fecundity patterns. The results of an earlier study showed only a weak linear relationship between egg numbers and female size (Prager, 1990), probably because of within-season variability. Concern was expressed that density-dependent changes in fecundity may make the 1990 results of doubtful relevance to the current Bay population which is at a much lower level of abundance. It will be important to develop an improved understanding of the biological and environmental factors influencing egg production in Chesapeake Bay blue crabs, particularly if reference points based on spawning potential are to be applied in stock management. Up to a point, these reference points should not be too sensitive to absolute fecundity estimates, since they are calculated on a relative scale. However, departure from a linear relationship with size (e.g. a cubic or other power of carapace width) may have consequences for the individual-based per-recruit model that may be worth further investigation.

Inferences about stock status depended critically on assumptions about rates of growth and natural mortality. These two biological processes were given due emphasis in the assessment report. Growth patterns were described in two different ways, reflecting their uses in the assessment. Firstly, von Bertalanffy growth parameters were drawn from a variety of recent field, laboratory and mesocosm studies, finding a range of plausible values to apply in empirical and theoretical relationships used in the indirect estimation of M. Emphasis was rightly given to studies where growth parameters were estimated directly (length-frequency analysis, lipofuscin calibration of age) rather than those depending on external assumptions. The assessment report appears to provide an effective and comprehensive summary of growth patterns in blue crab in Chesapeake Bay and neighbouring areas. The growth parameter values taken forward for use in the estimation of M cover the range of likely values.

Continuous growth functions provide a poor approximation to discontinuous crustacean growth patterns over short time scales. For this reason a moult process model was developed for use in calculation of biological reference points. The moult process model did not depend on the results of recent growth studies, but was partially validated by comparison of observed and predicted size distributions. An important component of the model is the accumulation of degree-days required for moulting. A fuller description of the moult process model is given in Doc3, but the temperature-dependent function is not explicitly given. It would be useful to see a clearer development of this model component, together with the supporting data.

One aspect not covered in the description of growth was the distinction between males and females. Female blue crabs have a functional terminal moult, and growth up to this point is similar to males. High mortality rates, causing very few crabs to survive beyond the point when size-at-age differs between males and females, mean that sex-related growth differences for older crabs can probably be ignored. This is certainly the case for the estimation of M. However, it may be useful in future to explore the possible consequences of se-related growth differences for the per-recruit model. The issue of distinguishing between male and female dynamics is discussed further below in relation to the assessment model and control rules (ToRs 2 and 3).

It is a very strong point in the 2005 blue crab assessment that there is full consideration of the most appropriate value for natural mortality. Perceptions about stock status in relation to thresholds for overfishing depend heavily on the value of M. In previous assessments (Doc2), a value of M=0.375 was assumed, based on a lifespan of 8 years (M=3/lifespan). The assessment report demonstrates convincingly that this is a substantial underestimate for M, on the grounds that lifespan is probably much less than 8 years and that 4.33/lifespan gives a better approximation for M than 3/lifespan (Doc4). The report gives a range of empirical and theoretical relationships for the derivation of M from life-history and environmental variables. The report recognises the limitations of these methods, and the fact that relationships derived for finfish do not necessarily apply to crustaceans. Nevertheless, the results are broadly indicative of the range of plausible values for M. Direct estimates for mature females in the Bay, based on mark-recapture data and exploitation fractions, lie well within the range. The adopted 'best' value of M=0.9, and the boundaries for likely values of 0.6 and 1.2 are defensible and rigorously derived, and represent a major advance on previous assessments. It is nevertheless recommended that research effort continues to be directed at finding improved values for M, and particularly at how M varies between different segments of the population. Predation pressure and other sources of natural mortality are likely to be very different for juvenile blue crabs in sea grass and other complex habitat types than for adults in more open environments. Similarly, spawning females undertaking large-scale movements are likely to experience a different mortality regime to adult males. If cannibalism is a major mortality source, then M would be expected to be density-dependent and to decline with age as crabs grow into the less vulnerable size-classes. It is notoriously difficult to estimate M directly, but short- and medium-term tagging experiments are possibly the most effective way of examining how natural mortality might vary between different segments of the population.

Patterns in fishery-independent surveys

The Chesapeake Bay blue crab assessment benefited from access to four major fishery-independent survey data sets. These vary in spatial scale from a restricted area around Calvert Cliffs, Maryland (Calvert Cliffs Pot Survey) to the whole of Chesapeake Bay (Winter Dredge Survey), and in length of time-series from 16 years (Winter Dredge Survey) to 49 years (VIMS Trawl Survey). Each survey provides a different spatial and seasonal perspective on the population dynamics of blue crab in the Bay, which is reflected in different aggregations of months and areas and different size criteria for distinguishing age-classes (Table 4 of Doc1) in providing abundance indices. As a general point, it is worth noting that the 2005 assessment did not seek to update previously established spatial, temporal and size criteria in the definition of survey indices. It will be an important task for the future to re-examine these criteria in the light of new perspectives on growth and spatial population dynamics.

The report provides an extensive account of trends in survey indices, in terms of both survey catch rates and standardized Z-scores. Each survey was examined for coherence of the population signals, i.e. whether variation in the pre-recruit age-class was reflected in older age-classes in subsequent years. The correlations between age-classes were generally low, but there was at least some evidence that the surveys were able to track year-class strength. Coherence between surveys was also examined briefly, although details of the analysis were not given in the assessment report. Spatial patterns in the distribution of crabs from the Winter Dredge Survey were outlined in the assessment report and fully described in supporting documents (Docs 5-7).

The surveys were taken forward in the assessment in three different ways:

(i) the trawl and dredge surveys were used to provide indices of pre-recruit and age 1+ stock sizes in a catch-survey stock assessment model;

(ii) the four surveys were combined to give overall Z-scores for pre-recruit and age 1+ abundance for the period 1955-2004, and used to evaluate stock status in relation to control rules for the fishery; and

(iii) the Winter Dredge Survey was used to quantify total abundance of blue crab in Chesapeake Bay, used in the calculation of exploitation fractions.

The use of the survey indices in the assessment model is discussed under ToR 2, below.

The main issues relating to combining the survey indices into overall Z-scores are that each survey is treated as if it is measuring the same stock trend, and that each survey is considered to have equal validity as a measurement of that trend without taking into account spatio-temporal factors or survey precision. The spatially restricted Calvert Cliffs survey is treated with equal weight to the Bay-wide Winter Dredge Survey, and surveys covering different months and areas are combined into overall averages. Geostatistical analyses of the Winter Dredge Survey data show that trends in blue crab abundance are not spatially homogeneous across Chesapeake Bay, and it may be important to understand the role of spatial variation in defining the long-term dynamics of the stock. A generalized linear modelling (GLM) or similar approach would be useful in determining the patterns within the fishery-independent surveys. This could be used to address: the extent to which spatial factors need to be taken into account as a component of overall abundance variation (could the VIMS and Maryland DNR Trawl Surveys be combined additively, as they cover different areas?); coherence of the overall abundance signal between the different surveys, and perhaps extraction of that signal as a modelled year effect; precision and uncertainty in the overall abundance trends. There is also scope to explore the population dynamic patterns apparent in the data, such as the relative roles of recruitment and mortality in explaining the annual variations in abundance. This topic is discussed further in relation to control rules for the fishery (ToR 3). In summary, the individual and combined fishery-independent survey indices are considered to provide an adequate description of stock trends in Chesapeake blue crab, but there is scope for further development of the use of these indices in describing stock dynamics.

The Winter Dredge Survey is undoubtedly the best source of fishery-independent information on blue crab trends in Chesapeake Bay, being well designed (random stations within strata), having a large number of stations (>1,200) and, importantly, covering the entire Bay. Its only shortcoming is that the time-series is short (16 years) in comparison with the trawl and pot surveys (up to 49 years). As part of the GLM analyses suggested above, it would be worth considering whether the Winter Dredge Survey time-series could be cast backwards in time through calibration with the VIMS and Maryland DNR

Trawl surveys. This would require appropriate account to be taken of spatial correspondence between the surveys. The principal value of lengthening the dredge time-series is that it would also allow calculation of a longer series of exploitation fractions for comparison with harvest control rules.

The value of the Winter Dredge Survey for estimating exploitation fractions rests partly on the validity of the dredge efficiency estimates used to convert CPUE to absolute density and abundance. Catchability coefficients (q) are rigorously defined at a year- and boat-specific level, based on the results of depletion experiments and the application of Leslie and log-linear models, as described by Vølstad *et al.* (2000). If precise GPS positions are available for the dredge hauls, it may be worth considering the use of the Rago patch model for depletion, which explicitly accounts for differences in track between hauls (NEFSC, 2003, 2004). Another possibility for future investigation is the derivation of parsimonious maximum-likelihood estimates of q (i.e. model selection within a GLM-like framework) rather than averaging of estimates for individual experiments. Whichever estimation method is used, it is recommended that variance in q be accounted for in confidence intervals presented for the absolute abundance estimates, and that the full uncertainty in abundance estimates be carried forward into other computations such as the calculation of exploitation fractions.

Patterns in catch and effort by sector and region

Methods of reporting for the commercial landings were changed several times in both Maryland and Virginia. The 2005 assessment used methods of time-series analysis to assess the impacts of reporting changes and to calculate adjusted landings figures for years prior to the reporting changes. The resulting estimates of Bay-wide landings are both statistically rigorous and parsimonious in the application of adjustment factors. There is an assumption that current landings data represent a base-line of correctness to which earlier estimates should be adjusted, and this assumption appears to be justified given the current mandatory reporting system in each state. Discard mortality appears not to be an issue, so the adjusted landings data are considered a satisfactory representation of total removals by the commercial fisheries.

The adjusted time-series for commercial landings represent a significant advance on the 1997 assessment (Doc2), when apparent increases in landings after the 1981 reporting change in Maryland were accepted as representing increased abundance. A longer perspective in time and the application of statistically rigorous analysis has established that this was not the case.

Estimation of the Bay-wide catch in numbers involves a series of data aggregations and conversions between weights and numbers. Each stage of the process involves its own uncertainties, and it would be useful to see how these translate into overall uncertainties for the Bay-wide catch numbers and uncertainties in the exploitation fractions. An important assumption underlying the conversion of hard crab weights to numbers is that annual, sex-specific mean carapace widths from the fishery-independent trawl surveys are representative of the sizes of crabs in the landings. It is not expected that this might be an important source of bias in the calculation of catch numbers, but it would be worth validating this assumption using measurements of crabs sampled from the commercial landings.

The recreational harvest is potentially an important omission from the overall removals data. Data do not exist to allow Bay-wide harvest estimates to be adjusted for recreational landings before 2001. The 2005 assessment examined the potential for this to cause biases in the estimation of fishing mortality rates and exploitation fractions, and considered that estimated trends were likely to be reliable, even if there was some uncertainty about absolute levels. Nevertheless, it is recommended that the sensitivity of assessment outcomes (e.g. stock status in relation to overfishing thresholds) to omission of the recreational harvest be examined, possibly through Monte Carlo simulations.

Reliable commercial effort and CPUE data were not available, largely because of the difficulties of both monitoring and meaningful measurement of effort in complex and diverse fishery sectors. The absence of effort data does not detract from the value and validity of the 2005 assessment, but it will be important to address this issue in future. The principal value of effort data would be that it might allow effective management tools to be designed.

ToR 2: Adequacy, appropriateness and application of the assessment models

Two aspects of the overall stock assessment for blue crabs in Chesapeake Bay are relevant here:

(i) the use of the Winter Dredge Survey to estimate overall stock abundance in the Bay, and the calculation of exploitation fractions using the estimated catch numbers; and

(ii) the analytical assessment model whereby stock abundance and fishing mortality are estimated using catch data and fishery independent indices with an underlying model of population dynamics.

The calculation of exploitation fractions using data from the Winter Dredge Survey and estimated catch numbers has already been discussed above in relation to fishery-independent and catch data. It is worth re-iterating here that both the fishery and fishery-independent data sets contain their own uncertainties, and for the purposes of (a) robust inference of stock and fishery trends, and (b) risk assessment in fishery management, it would be useful to include that uncertainty (e.g. as confidence intervals) in presentations of abundance and exploitation estimates. The Winter Dredge Survey represents the single most useful source of information on the status of blue crab stocks in Chesapeake Bay. As mentioned above, there is some scope for improving or validating the definitions of age-class segments of the population, but this survey, and quantities such as exploitation fraction calculated on the basis of the survey, should be regarded as the benchmark for all other assessment procedures applied to the blue crab stock. The geostatistical approach to estimating and mapping abundance is commendably rigorous.

The main value of the analytical assessment is that it extends the time frame for measured stock trends beyond the 16 years possible with the Winter Dredge Survey. The 2005 assessment using a development of the Collie-Sissenwine catch-survey (CS) model represents a major advance on the length-based approach used in the 1997 assessment (Doc2). The original CS model formulation uses a single series of pre-recruit and fully recruited stock indices and incorporates a process error which has the effect of smoothing the annual stock estimates towards the underlying model for population dynamics. Applications of this model include assessment of American lobsters (Conser & Idoine, 1992) and northern shrimp (Cadrin *et al.*, 1999). Recently the method has been advocated as an alternative to fully age-based methods for species in which age-determination is difficult or age composition data are missing (Mesnil, 2002, 2003a). The 2005 blue crab assessment model is a development of the CS model, allowing it to be applied to multiple series of pre-recruit and/or fully recruited stock indices, hence it is termed the Catch-Multiple-Survey (CMS) model. Comments on this model and its application will be divided into three issues: (a) the model formulation and estimation; (b) the treatment of data inputs for the assessment; and (c) interpretation of model outcomes, and their sensitivity to input values.

The CMS model includes two major developments on the original CS model. Firstly, instead of estimating stock size separately for each year, the CMS model estimates stock size only for the first year, with stock sizes in subsequent years being derived from the population dynamic model (i.e. the survivors from the previous year's stock and recruitment). This allows use of multiple series of pre-recruit and fully recruited stock indices, each of which may be of different length and have missing values for some years. The second development is the efficient maximum-likelihood estimation of q_n, the catchability index for fully recruited crabs in each survey series, essentially as a geometric mean over years of the ratio between the fully recruited survey index and the estimated stock size in each year. The assessment model formulation given in the assessment report cannot be faulted, and undoubtedly this model will be used in the future for assessment of blue crabs and other species. Essentially the same model formulation has been derived independently by Benoit Mesnil (Ifremer, Nantes, France), described in an unpublished program documentation presented at an ICES Working Group meeting (Mesnil, 2003b), but was not fully developed for application to multiple survey indices. The Mesnil model application also differs from the CMS application to blue crabs in that it does not use a mixed error approach, minimizing measurement error only. Mesnil (2003b) cites several reasons for excluding process error, including difficulties in defining appropriate error terms and weighting factors. Earlier applications of similar models have also excluded process errors (Collie & Kruse, 1998). It is not clear what role the process error is playing in the fitting of the CMS model to the blue crab data, and the authors of the assessment are encouraged to explore the possibilities of a measurement error only approach.

The reason for including multiple survey indices in the assessment model is that "taken together, these surveys may integrate a sufficient spatial or temporal domain to adequately index the entire population". The Winter Dredge Survey could be considered an adequate index in its own right, but only over a relatively short time-series. The authors of the assessment chose not to combine the separate indices into a single long-term series, instead treating each survey as a separate stock index, each with an appropriate statistical weighting. The question arises: does the use of the three surveys (Winter Dredge Survey, VIMS Trawl Survey, Maryland DNR Trawl Survey) achieve the desired integration of spatial and temporal domain? In terms of the temporal domain, the answer is certainly "yes". The two trawl surveys allow the start of the assessment to be cast back as far as 1968, although with the slight drawback that the assessment relies solely on the VIMS survey prior to 1977. The spatial integration is less certain. The two trawl surveys cover different areas of Chesapeake Bay, and it could be argued that each measures a different aspect of the overall population dynamic trend. This runs counter to the implicit assumption in the CMS model that each survey is essentially a different measurement of the same underlying abundance signal, the difference lying in the relative scaling of the survey index values and in the error associated with each survey. This is partly dealt with by using different seasonal 'windows' to calculate the survey indices, the selection of window reflecting spatial population dynamic patterns. However, this can be only a partial solution, since male and female blue crabs appear to have different seasonal patterns of movement within the Bay, meaning that no spatio-temporal subset of a survey data set could be an entirely satisfactory integration of the stock as a whole. Geostatistical analysis of the Winter Dredge Survey results demonstrates that trends over years differ between areas of the Bay. One possibility would be to consider the two trawl surveys as additive rather than independent, since each covers a large but different fraction of the Bay. Conceivably, the additive survey effects could be considered within the structure of an extended CMS model, but in practice it might be simpler to use the results of a statistical model fitted to the two data sets, such as the year effects from a GLM. A second possibility would be to combine all three survey series into a single index, probably scaled to the Winter Dredge Survey. The assessment report raises concerns that coefficients of variation differ between surveys, possibly leading to additional bias or uncertainty if the surveys were combined. The way in which the errors from each survey propagate into a combined index and into the outcomes of the assessment model could be explored by Monte Carlo simulations. The GLM analyses suggested for the fishery-independent data (see above, ToR 1) could be informative about whether an overall abundance signal could be identified. Whichever method is selected to represent survey abundance estimates into the overall assessment model, <u>it is recommended that the spatial coherence of the survey index values in the assessment be further examined</u>.

A striking (and unsurprising) feature of the assessment outputs is that they were very sensitive to the value of M. The assessment using the 'most likely' value of M=0.9 provided estimates of exploitation fractions that were closest to the direct estimates based on Winter Dredge Survey abundances. The match was particularly close for the final five years, when both direct and CMS estimates showed the same order of decline in exploitation fraction (Fig. 39 of Doc1). However, CMS estimates of exploitation fraction for the mid-1990s were much higher than the corresponding direct estimates. As noted above, the Winter Dredge Survey should probably be regarded as the baseline, from which it follows that these CMS estimates were probably too high. This is further indicated by the fact that exploitation fractions estimated from the CMS model results exceeded 1 in several years. If the upper boundary of M=1.2 is selected, then all exploitation fractions were less than 1. This should not be taken to mean that the higher estimate of M is 'better', since the match with directly estimated exploitation fractions was worse than for M=0.9. More likely, the 'bad behaviour' of the CMS estimates, even for the best possible value of M, reflects a failure of the model to account for interannual variability in population dynamic processes (e.g. in M). Alternatively, the survey indices themselves may fail to reflect interannual variability in, for example, the size criteria for distinguishing pre-recruits from the fully recruited stock. The issue of sensitivity of assessment outcomes to assumptions about M is discussed further below in relation to harvest control rules (ToR 3).

The assessment report draws attention to a feature of the assessment outcomes which was apparent at all values of M: there appears to be a strong negative relationship between estimates of exploitation fraction and the abundance of the fully recruited stock. The inference is drawn that there is a depensatory mechanism in the fishery, whereby exploitation pressure increases as the stock declines. This pattern might arise if fishermen are able to direct their activities towards the remaining stock concentrations as the stock declines. If true, this pattern could have important consequences for fishery management – as the report points out, such depensation is not conducive to sustainability. It will be important to determine whether the apparent depensation is a real feature of the data, or is in fact an artefact of the method of calculation. There will inevitably be a negative relationship between exploitation fraction and stock size, since the first variable is calculated using the second variable as a denominator. This may or may not be enough to account for the relationships shown in the control plots of Figs 39-42 of Doc1. A simple randomization test may be enough to determine whether the observed negative correlations are greater than would be expected by chance given the nature of the calculation.

Differences between male and female stock dynamics are not included in the assessment model. Male and female blue crabs show different patterns of movement within Chesapeake Bay, have different patterns of moulting and growth after maturity, and presumably experience different regimes of both fishing and natural mortality. Exploitation fractions are substantially higher for females than males (Fig. 37 of Doc1). The aggregation of data across males and females may or may not cause problems for the assessment, and there may well not be sufficient data for adequate parameterisation of assessment models for the sexes separately. Nevertheless, it is recommended that the potential impacts of male-female differences on the assessment outcomes be examined further. Differences between males and females may also have implications for the calculation and use of biological reference points, discussed below under ToR 3.

Finally under this ToR, it would be useful to see some estimates of uncertainty around assessment outcomes, e.g. confidence intervals around the stock abundance estimates. Bootstrapping would be a suitable method to estimate both confidence intervals and bias in the estimates. Ideally, this uncertainty would be carried forward into comparison of assessment outcomes with biological reference points – i.e. the context of risk assessment for fishery management. If prior distributions could be determined for M or other assessment parameters, then this component of uncertainty could also be incorporated.

ToR 3: Scientific basis for the control rule for the Chesapeake Bay blue crab fishery

Three biological reference points (BRPs) are defined for the Chesapeake Bay blue crab fishery:

(i) The exploitation rate at which spawning potential is reduced to 10% of that expected for an unexploited stock is set as the threshold for overfishing. The 10% criterion follows precedents set by other crustacean fisheries, e.g. American lobsters.

(ii) The exploitation rate at which spawning potential is reduced to 20% of that expected for an unexploited stock is set as the target for fishery management. The 20% criterion is used in the absence of explicit management targets as a measurably higher value than the overfishing threshold.

(iii) The 1968 stock abundance is set as the minimum stock size, i.e. the overfished threshold. The 1968 value was the lowest of all annual values in the combined fishery-independent survey index. The basis for this reference point is that it was the lowest estimate of the stock which subsequently supported a fishery.

The first two BRPs were defined in terms of exploitation fraction rather than instantaneous fishing mortality and are referred to as $\mu_{10\%}$ and $\mu_{20\%}$. This is a matter of scaling rather than substance, but the assessment authors preferred the use of exploitation fractions since their calculation from the Winter Dredge Survey would not need to be updated if new values were adopted for M (although the BRPs themselves *would* be changed by a new value of M, irrespective of their scaling).

<u>The use and definition of a minimum stock abundance threshold for the overfished state is entirely reasonable and scientifically defensible under a precautionary fishery management regime</u>. The use of CMS assessment results suggested that 1975 rather than 1968 provided the minimum abundance from which the stock subsequently recovered. However, the most recent stock estimate or stock index values were above the threshold whichever combination of year and abundance metric was used. <u>The use of the threshold could be further enhanced by providing confidence intervals for the stock abundance metric</u> (CMS estimate or combined survey Z-score). This would provide a context for fishery managers to assess the risk that the true value of stock abundance is in fact above the threshold.

The use of $\mu_{10\%}$ and $\mu_{20\%}$ as BRPs is more contentious. Firstly, <u>there is a philosophical difficulty with defining $\mu_{20\%}$ as a target</u>. The reason for adopting this as a BRP is that it is far enough away from $\mu_{10\%}$ as to be measurably different. This is very close to the definition of 'pa' reference points under the ICES framework for the precautionary approach to fishery management (ICES, 2001). Under this framework, a 'pa' value of fishing mortality (or stock biomass) is adopted as being far enough away from a 'lim' value for exploitation estimated at this level to be at very low risk of actually being beyond the limit. The greater precision with which fishing mortality is known, the closer is the 'pa' point to the 'lim' point. According to this philosophy, the 'pa' point, or $\mu_{20\%}$ in the case of the blue crab fishery, is effectively an operational limit rather than a target. This highlights two issues in relation to BRPs for Chesapeake Bay blue crabs: (a) there is a need for managers to define explicit targets for the fishery – do managers want maximum yield, employment, profit or something else from the fishery?; and (b) as with the minimum abundance threshold, measurement of uncertainty around exploitation fractions would set a context for risk assessment by fishery managers.

A second difficulty with the spawning potential BRPs is that they are highly sensitive to assumptions about M. If the lower boundary of M=0.6 was adopted, then all the CMS estimates of exploitation fractions were above $\mu_{10\%}$ after 1991. Conversely, if the upper boundary of M=1.2 was adopted, then the CMS estimates of exploitation fraction were below $\mu_{20\%}$ for 1999 onwards. This situation is almost inverted if the direct estimates of exploitation were used instead. Again, the issue highlighted here is one of uncertainty and risk assessment. As noted under ToR2, there may be a case for defining a prior distribution for M, reflecting the relative likelihood of different values.

Thirdly, there is a question of whether spawning potential BRPs are suitable for a stock of this kind. The dynamics of short-lived species experiencing naturally high levels of mortality are often defined more by variations in annual recruitment than by variations in mortality (e.g. estuarine bivalves, Van der Meer *et al.*, 2001). Particularly when recruitment is linked more to environmental factors (e.g. hydrographic conditions favouring retention or return of larvae) than to the size of the parental stock (egg production), fishing mortality has very little bearing on stock trajectories. In some cases there may even be compensatory mechanisms whereby fishing mortality has the potential to replace rather than add to some components of natural mortality (Bell *et al.*, 2001). It is recommended that two types of exploratory analysis be undertaken for Chesapeake Bay blue crabs. Firstly, the fishery-independent abundance indices should be examined to determine the extent to which the fluctuations in annual stock abundance can be explained by recruitment or mortality variations. This could be undertaken as part of the GLM analyses suggested above under ToR1. Secondly, the relationship between stock and recruitment should be examined. Fishery-independent survey indices and the CMS model outcomes all offer the possibility to explore this relationship. Information the abundance of blue crab zoeae outside the Bay, and of megalopae within the Bay could also be used to explore the relationship between stock abundance and larval production, and between larval abundance and the magnitude of recruitment. The use of spawning potential BRPs could be re-evaluated in the light of the findings of these analyses. For example, Monte Carlo simulation could be used to measure the performance of fishery management using these BRPs, with a variety of scenarios involving variations in recruitment and mortality and different relationships between stock and recruitment. The individual-based per-recruit model is scientifically excellent, but it will be important to establish that it produces reference points with the desired property of protecting future recruitment.

In summary, the abundance threshold appears to be the most defensible and workable reference point for fishery management. Given the availability of stock and recruitment estimates, e.g. from the CMS model, it would be possible to formulate stock projections to evaluate the likelihood of future abundance remaining above this threshold in the short- to medium-term at a given level of fishing mortality. Recruitment values could be sampled from the observed data, or if a particular stock-recruitment relationship was adopted then residuals from this relationship could be sampled to provide future recruitment values. Simulations under this approach would allow a probability profile to be constructed for future abundance levels given a particular management regime.

ToR 4: Recommendations for future research for improving data collection and assessment

The assessment report lists 14 conclusions and 11 recommendations arising from the assessment (Chapter 8 of Doc1). The conclusions and recommendations are comprehensive and show that the assessment team are entirely aware of the limitations of the available data and the issues surrounding inferences drawn from these data. The conclusions are justified and based on strong scientific evidence. Conclusions 1 and 2, about the current and past status of blue crabs in Chesapeake Bay, could perhaps be qualified as depending on assumptions, particularly about the value of M. However, it is worth stating that the assumptions are based on the best scientific judgement, and the conclusions are thus relate to the most likely assessment outcomes. Conclusion 12 relates to the apparent negative relationship between exploitation fraction and stock abundance. It will be important to confirm that this is a real feature of the data rather than a statistical artefact arising from the method of calculation.

I agree with the recommendations for future research. Most of the recommendations anticipate points raised during the review, and several are re-iterated in the recommendations given below. Recommendation 9 is for management based on reference points for exploitation rates. I agree that the 10% and 20% spawning potential criteria should be re-examined, but would widen the exercise to include the question of whether the reference points based on exploitation rates are appropriate at all (see discussion above, under ToR 3). Conclusion 10 relates to the negative relationship between exploitation fraction and abundance. As noted above, this pattern will need to be confirmed. The recommendation of a higher abundance threshold as a trigger for action may nevertheless be justified on precautionary grounds (risk assessment), irrespective of whether the negative relationship is confirmed.

Conclusions and recommendations

This section collates the conclusions and recommendations that have been made above under Summary of findings. Underlined text in the Summary of findings already indicates the main points arising from the review, re-iterated below.

(1) The 2005 assessment report provides a sound scientific basis for management of the Chesapeake Bay blue crab fishery.

(2) Analysis of fishery and fishery-independent data, understanding of life-history parameters and vital rates, and assessment methodology have all been advanced significantly compared with the previous Bay-wide blue crab assessment.

(3) The most important single improvement in the assessment has been the re-evaluation of natural mortality. The most likely value of M=0.9, and the upper and lower boundaries of 0.6 and 1.2, represent the best scientific judgement.

(4) Further research is needed to improve the understanding of some biological processes. Most importantly, an improved understanding is required of how M varies between different ages and segments of the population. There is also scope to develop an improved understanding of how population density and environmental factors affect blue crab egg production and recruitment success in Chesapeake Bay.

(5) Fishery-independent survey data provide an excellent resource for assessment of blue crab stocks. It is recommended that the spatial, temporal and size criteria used to define abundance indices be re-examined in the future. In particular, there may be scope to improve the separation of pre-recruits from the fully recruited stock.

(6) The individual and combined survey indices appear collectively to provide a reliable picture of variations in blue crab abundance in Chesapeake Bay. The Winter Dredge Survey undoubtedly gives the best abundance index, by virtue of its complete spatial coverage. It is recommended that GLM or other statistical approaches be used to address the following issues with the fishery-independent survey data:

    (a) coherence of trends in annual abundance inferred from the different surveys;

    (b) spatial coherence between the Winter Dredge Survey results and the two trawl surveys, including consideration of whether the two trawl surveys could be combined in a single index coving a greater overall area than either of the surveys individually;

    (c) evidence for a stock-recruitment relationship; and

    (d) determining whether recruitment variation may be the principal driver for variations in abundance rather than mortality.

(7) Exploitation fractions estimated directly from Winter Dredge Survey data provide the best measurement of fishing pressure on the blue crab stock. It is recommended that confidence intervals be estimated for the exploitation fractions, incorporating uncertainty in the estimation of abundance (includes uncertainty around mean CPUE and uncertainty in the catchability values applied to convert CPUE to density) and uncertainty in the estimates of numbers in the catch.

(8) The time-series methodology used to correct commercial landings for reporting changes are statistically rigorous, and provide the most scientifically defensible estimates of trends in fishery removals. It is recommended that statistical uncertainty involved in this correction be incorporated into measurements of uncertainty for derived values such as catch numbers and exploitation fractions.

(9) Catch numbers are estimated from catch weights assuming that mean sizes in fishery-independent surveys are representative of commercial removals. This assumption should be validated by sampling of commercial landings.

(10) Catch numbers and exploitation fractions do not account for recreational removals of blue crabs from Chesapeake Bay. It is recommended that the implications of this omission for assessment outcomes be explored by Monte Carlo simulation, and that monitoring of the recreational harvest be continued into the future.

(11) Reliable commercial effort and CPUE data were not available. It is recommended that there be increased research activities directed towards methods for the measurement of effective fishing effort, and increased monitoring activities directed towards collection of basic effort data.

(12) A new Catch Multiple Survey (CMS) model was constructed for the blue crab assessment, being a development of the Collie-Sissenwine catch-survey model. The principal advance is that it allows use of multiple survey indices of abundance, hence extending the temporal perspective on population dynamics beyond the 16 years provided by the Winter Dredge Survey. The model is a great step forward from the previously used length-based assessment. It is recommended that the role of process error in the model estimation is re-examined, and that a measurement error only approach be considered for the future.

(13) It is recommended that the spatial and temporal coherence of the fishery-independent survey indices be further examined in relation to their inclusion in the CMS model. There is the possibility of combining the two trawl surveys to provide a more complete spatial integration of the measured stock trend.

(14) A negative relationship between exploitation fraction and stock abundance was inferred from the assessment results, taken to indicate a depensatory pattern of greater exploitation at lower stock abundance – a pattern adverse to sustainable exploitation. The correlation could be a statistical artefact, arising from the use of stock abundance to calculate exploitation fraction. It is recommended that randomization tests or other appropriate methods are used to exclude this possibility.

(15) The stock assessment does not take into account the possible differences in biology and exposure to mortality between male and female blue crabs. This potentially an important omission, and it is recommended that:

(a) the sensitivity of the assessment outcomes to sex-related differences be examined; and

(b) the possibility to include distinctions between males and females in future assessment models be explored.

(16) Measurements of uncertainty are not included alongside the assessment outcomes. It is recommended that bootstrapping or other methods are used to provide confidence intervals around the assessment estimates. This would allow risk assessment when comparing assessment outcomes with biological reference points.

(17) A threshold minimum stock abundance is defined as a biological reference point (BRP) for Chesapeake Bay blue crabs, below which the stock would be defined as overfished. The value chosen is the lowest abundance observed to have subsequently supported a fishery. The basis for this BRP is both robust and precautionary, although there is scope for change in the reference year, depending on revision of survey indices and assessment models.

(18) BRPs are also defined for exploitation fraction, aimed at preserving 10% (limit) or 20% (target) of the maximum spawning potential. An individual-based per-recruit model was used to calculate these BRPs. Both the assessment estimates of exploitation fractions and the BRP estimates against which they are compared are very sensitive to assumptions about M. It is recommended that all sources of uncertainty around the comparison with BRPs are considered in the context of risk assessment.

(19) It is very important that managers should set targets for the fishery, defining the desired outcome of fishery management. The current 'target' is more akin to a precautionarily higher operational limit, reflecting uncertainty about real values and acceptable risk. Comparison of stock and exploitation indices with BRPs should be placed firmly in the context of uncertainty and risk assessment. A definition of acceptable risk is needed from managers for this to be applied in practice.

(20) There is a strong possibility that recruitment rather than mortality is the driving force behind blue crab population dynamics in Chesapeake Bay. If true, this would have strong implications for fishery management in that control of fishing mortality would not be an effective management tool. It is recommended that:

(a) fishery-independent survey indices be examined (e.g. by GLM) to identify the extent to which recruitment or mortality are the driving forces behind interannual fluctuations;

(b) fishery-independent survey indices and assessment outputs are examined to determine whether a stock-recruitment relationship can be described; and

(c) Monte Carlo simulations be used to examine the performance of the BRPs in preventing adverse stock trends.

(21) It is recommended that the use of short- and medium-term stock projections be investigated with a view to determining likely stock trajectories in relation to minimum abundance thresholds.

Acknowledgements

I would like to thank Derek Orner and his colleagues at the NOAA Chesapeake Bay Office for hospitality during the review meeting and for arranging for the review panel to see something of Chesapeake Bay and its blue crab fishery. Tom Miller, University of Maryland, supported by colleagues from various Maryland agencies, provided a clear and cogent presentation of the 2005 blue crab assessment and its supporting data, and were very open in answering review questions and providing access to the data. I am grateful to Manoj Shivlani and Tom Barry, University of Miami's CIE, for the smooth running of the contractual and practical arrangements for attending the review. Thanks also to my colleagues on the review panel, Malcolm Haddon, Nick Caputi and Paul Medley, for stimulating discussions and good humour during the meeting.

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APPENDIX 1: Bibliography of materials provided during the review meeting

Doc1: Miller, T.J., Martell, S.J.D., Bunnell, D.B., Davis, G., Fegley, L., Sharov, A., Bonzek, C., Hewitt, D., Hoenig, J. & Lipcius, R., 2005. *Stock Assessment of Blue Crab in Chesapeake Bay 2005.* Final Report (in draft). Technical Report Series No. TS-487-05, University of Maryland Center for Environmental Science. 163 pp.

Doc2: Rugolo, L., Knotts, K., Lange, A., Crecco, V., Terceiro, M., Bonzek, C., Stagg, C., O'Reilly, R. & Vaughan, D., 1997. *Stock Assessment of Chesapeake Bay Blue Crab (Callinectes sapidus).* National Oceanic and Atmospheric Administration. 267 pp.

Doc3: Bunnell, D.B. & Miller, T.J., in press. An individual-based modelling approach to per-recruit models: blue crabs *Callinectes sapidus* in the Chesapeake Bay. *Canadian Journal of Fisheries and Aquatic Science*.

Doc4: Hewitt, D.A. & Hoenig, J.M., in press. Comparison of two approaches for estimating natural mortality based on longevity. *Fishery Bulletin*.

Doc5: Jensen, O.P., Seppelt, R., Miller, T.J. & Bauer, L.J., in press. Winter distribution of blue crab (*Callinectes sapidus*) in Chesapeake Bay: application of a two-stage generalized additive model (GAM). *Marine Ecology Progress Series*.

Doc6: Jensen, O.P. & Miller, T.J., in press. Geostatistical analysis of blue crab (*Callinectes sapidus*) abundance and winter distribution patterns in Chesapeake Bay. *Transactions of the American Fisheries Society*.

Doc7: Jensen, O.P., Christman, M.C. & Miller, T.J., in press. Landscape-based geostatistics: a case study of the distribution of blue crab in Chesapeake Bay. *Environmetrics*.

Doc8: Fogarty, M.J. & Miller, T.J., 2004. Impact of a change in reporting systems in the Maryland blue crab fishery. *Fishery Research*, **68**, 37-43.

In support of Doc1 a data CD was provided, containing the assessment report (Doc1) and other documents (Docs3-7) in electronic form, spreadsheets containing most of the data and calculations contained in the report, output from statistical analyses, and AD Model Builder code and output for the assessment model.

APPENDIX 2: Agenda for the review meeting

Blue Crab Stock Assessment Review

Radisson Hotel Annapolis

210 Holiday Court
Annapolis MD

August 9-11, 2005

August 9, 2005

12:30	Welcome & Introductions - Stock Assessment Committee - Review Panel	Orner
12:45	Presentation of the 2005 Blue Crab Stock Assessment	Miller
3:00	General / Open Question Period - Public Comment - Review Panel	Haddon
5:00	Adjourn	

August 10, 2005

8:30 Term of Reference Review and Discussion

I Assess and quantify the life history and vital rates of blue crab in the Chesapeake Bay that are relevant to an assessment of the stock.

II Describe and quantify patterns in fishery-independent surveys.

III Describe and quantify patterns in catch and effort by sector and Region

12:30 Lunch

1:45 Term of Reference Review and Discussion (continued)

IV Develop and implement assessment models for the Chesapeake blue crab fisheries

V Re-evaluate, and where necessary, update control rules for Chesapeake Bay blue crab fishery

5:15 Adjourn

Blue Crab Stock Assessment Review

Radisson Hotel Annapolis

210 Holiday Court
Annapolis MD

August 9-11, 2005

August 11, 2005

9:00	Review Session *[closed-door]*	Haddon
	Review Panel to discuss assessment methodologies and develop individual opinions.	
	Initiate development of summary documents	
12:00	Lunch	
1:15	Review Session (continued)	Haddon

APPENDIX 3: Statement of Work

Consulting Agreement between the University of Miami and Dr. Michael Bell

July 21, 2005

Background

The blue crab supports the most important commercial fishery in the Chesapeake Bay. Commercial landings have exceeded 100 million pounds historically (1993) with more recent average landings reaching approximately 72 million pounds. The total impact of the blue crab fishery to the Chesapeake region exceeds $200 million annually.

Sound management of this resource requires accurate information on the status and trends of the blue crab population and on the dynamics of the fisheries that exploit the stock. There have been two recent stock assessments completed for the blue crab (1997, 1998) and the NOAA Chesapeake Bay Office (NCBO) has produced annual 'Advisory Reports' for blue crab to assist resource managers in the decision making process. Seeing the need for an updated assessment, the NCBO supported the development of a full blue crab stock assessment utilizing FY2003 funds.

This assessment was initiated in October 2003. Due to the political nature of any decision regarding fisheries in Chesapeake Bay, especially blue crab, an independent and expert review of the science is necessary for management of this important fisheries resource. The Habitat Conservation Office is requesting that the Center for Independent Experts (CIE) conduct a review for the NOAA Chesapeake Bay Office's Blue Crab Stock Assessment.

The review workshop for the Chesapeake Bay blue crab assessment will take place in Annapolis, Maryland on August 9-11, 2005. The NOAA Chesapeake Bay Office will provide the following documents prior to the Chesapeake Bay blue crab stock assessment review meeting:

- 2005 Chesapeake Bay blue crab assessment report;
- 1997 and 1998 blue crab stock assessments;
- Annual blue crab advisory reports;
- Adopted management strategies establishing targets and thresholds;
- Chesapeake Bay Fishery Management Plan (1997); and
- Other key publications as necessary.

Objectives of the CIE Review

The Blue Crab Assessment Review Panel will evaluate the Chesapeake Bay blue crab stock assessment, including input data, assessment methods, and model results. The following are the main terms of reference for the review:

1) Evaluate the adequacy and appropriateness of all data used in the assessment, including the following:
   - Life history and vital rates of blue crab in Chesapeake Bay.
   - Patterns in fishery-independent surveys.
   - Patterns in catch and effort by sector and region.
2) Evaluate the adequacy, appropriateness, and application of the assessment models used for the Chesapeake Bay blue crab fisheries and characterize the uncertainty in the assessment.
3) Evaluate the scientific basis for the control rule for the Chesapeake Bay blue crab fishery.
4) Develop recommendations for future research for improving data collection and the Chesapeake Bay blue crab assessment.

The Assessment Review Panel's primary duty is to review the assessment presented. In the course of this review, the Chair may request a reasonable number of sensitivity runs, additional details of the existing assessments, or similar items from technical staff. However, the Review Panel is not authorized to conduct an alternative assessment or to request an alternative assessment from the technical staff present. The Review Panel should outline in its report any remedial measures that the Panel proposes to rectify shortcomings in the assessment.

Specific Activities and Responsibilities

The CIE shall provide a Chair and three Review Panelists to conduct the review of the Chesapeake Bay blue crab stock assessment.

<u>Tasks</u>

Each panelist's duties shall occupy a maximum of 14 workdays (i.e., a few days prior to the meeting for document review; the review meeting; and a few days following the meeting to prepare a Review Report). The Panelist Review Reports will be provided to the Review Panel Chair, who will produce the Summary Report based on the individual Review Reports.

Roles and responsibilities:

(1) Prior to the meeting: review the Chesapeake Bay blue crab assessment report and other relevant documentation in support of this review.

(2) During the meeting: participate, as a peer, in panel discussions on assessment validity, results, recommendations, and conclusions especially with respect to the adequacy of the assessment in serving as a basis for providing scientific advice to management.

(3) After the meeting: prepare individual Review Reports, each of which provides an executive summary, a review of activities and a summary of findings and recommendations, all in the context of responsiveness to the terms of reference. Advice on additional questions that are directly related to the assessment and are raised during the meeting should be included in the report text. See Annex 1 for further details on report contents and milestone table below for details on schedule. No later than August 25, 2005, these reports shall be submitted to the CIE for review[1] and to the Chair for summarization. The CIE reports shall be addressed to "University of Miami Independent System for Peer Review," and sent to Dr. David Sampson, via e-mail to David.Sampson@oregonstate.edu and to Mr. Manoj Shivlani via e-mail to mshivlani@rsmas.miami.edu.

Milestones or Report Delivery Dates

The following table provides the milestones and delivery dates for conducting the panel review of the Chesapeake Bay blue crab stock assessment.

Milestone	**Date**
Panel review meeting in Annapolis, MD	August 9-11, 2005
Individual panelists provide their draft reports to CIE for review and to Chair for initiating development of the Summary Report	August 25, 2005
CIE provides reviewed individual panelist reports to NMFS COTR for approval	September 1, 2005
COTR notifies CIE of approval of individual panelist reports	September 8, 2005
CIE provides final individual panelist reports to COTR (with signed cover letter) and to Chair to complete Summary Report	September 13, 2005
Chair provides CIE with draft Summary Report for review	September 20, 2005
CIE provides reviewed Summary Report to COTR for approval	September 27, 2005
COTR notifies CIE of approval of Summary Report	September 30, 2005
CIE provides final Summary Report with signed cover letter to COTR	October 5, 2005
COTR provides final Summary Report to NEFSC contact	October 7, 2005

No consensus opinion among the CIE reviewers is sought, and all reports will be the product of the individual CIE reviewer or chairperson.

NOAA Contact person:
Derek Orner, NOAA Chesapeake Bay Office, 410 Severn Avenue, Annapolis, MD 21403; Derek.orner@noaa.gov

[1] All reports will undergo an internal CIE review before they are considered final.

ANNEX 1: Contents of Panelist Report

1. The report shall be prefaced with an executive summary of findings and/or recommendations.

2. The main body of the report shall consist of a background, description of review activities, summary of findings, conclusions/recommendations, and references.

3. The report shall also include as separate appendices the bibliography of all materials provided during the review meeting and any papers cited in the Panelist's Report, along with a copy of the statement of work.