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Fisheries Climate Vulnerability Assessment Review

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Representing the Center for Independent Experts

Executive Summary

The Center for Independent Experts (CIE) requested a review by three reviewers of the NMFS Fisheries Climate Vulnerability Assessment using the Northeast region case study. The CIE reviewers participated in a panel review meeting chaired by Dr Anne Hollowed at the University of Rhode Island, Narragansett, during 28-30 October 2014. The response to the nine the terms of reference (TOR) set for the panel is as follows:

TOR 1: Evaluate and provide recommendations on the conceptual basis (vulnerability assessments) and design-process (workshops, pilots, NE implementation) for the NMFS Fisheries Climate Vulnerability Assessment

The methodology for the Vulnerability Assessment is suitable for evaluating climate vulnerability for fish and invertebrate species. The assessment considered exposure attributes and combined adaptive capacity with the sensitivity component which was deemed to be appropriate. The design process was very thorough and appropriate for the development of the methodology. The methodology enables the assessment of marine and diadromous species which may be data-rich or data-poor.

TOR 2: Evaluate and provide recommendations on the assessment structure, assumptions, and scoring procedures for the NMFS Fisheries Climate Vulnerability Assessment including:

a. *Does the methodology contain a valid list of attributes? Could any be added or removed?*
b. *Does the methodology appropriately account for expert bias?*
c. *Is the logic method appropriate?*
d. *Is the methodology consistent with existing tools and approaches being used by other organizations to assess natural resource climate vulnerability?*

The methodology contained a valid list of attributes. Some additional exposure attributes that could be considered for future assessments of this and other regions were ocean productivity and occurrence and intensity of hurricanes. There was also considerable discussion about whether the use of both air temperature (proxy for shallow water temperature) and sea surface temperature (SST) resulted in double counting of exposure variables.

The methodology appropriately accounted for expert bias and a sensitivity assessment found that the assessment was not sensitive to the removal of individual experts. The experts in this development phase of the project were NMFS scientists to help facilitate the process. For the implementation phase it is important to include scientists from other institutions to ensure a broad array of expertise.

The use of the logic method to develop a component score is an appropriate approach to assess the sensitivity and exposure components. The method has attempted to develop appropriate standardized algorithms for measuring the vulnerability that can be used across the regions and

enables an appropriate assessment of the relative vulnerabilities. The method is based on a small number of attributes with the highest scores, which can be viewed as a strength in the assessment as it focuses on the attributes that are assessed as most likely to affect the species vulnerability. However the method can be sensitive to 1 or 2 attributes. The logic model focuses on the 'number' of exposures' above a certain level but it is the implication of how the 'total level of change of exposure variables that may affect the species' that is the critical issue and change in one exposure category for a species can be more devastating than three exposure changes that are more moderate. The project team could consider whether the exposure component scores could be adjusted to take into account this qualitative assessment. However if these differences are difficult to capture by the logic model, they could be discussed in the species narrative.

The methodology is broadly consistent with existing tools and approaches being used by other organizations to assess natural resource climate vulnerability. The focus on the climate change effects on the vulnerability of species highlighted that this approach would not formally identify two aspects of climate change effect on fisheries, viz. species that may increase in productivity and/or change in their distribution, that would be of strong interest to managers and stakeholders. The species narrative can be used to highlight these changes as both would be of interest to managers and stakeholders.

TOR 3: Evaluate the strengths and weaknesses of the methodology

The key strengths of the methodology of the assessment are:

- The algorithm for combining the scores of the experts provides appropriate summary statistics of each attribute.
- Expert scoring is undertaken objectively giving all the experts clear guidelines. While the experts are not required to reach consensus, there is a process for the experts to revise their scores after consideration of other expert comment.
- Undertaking the assessment at the species level is important to gain an overall assessment of the vulnerability of the species in the region. However, if the information at a stock level is available it is also valuable to indicate what the climate change response is likely to be at the stock level as this is important to managers and fishers.
- Taking account past variability when evaluating the projected changes in exposure factors.
- The vulnerability narratives are a valuable component of the outputs.
- The inclusion of stock status is an important sensitivity attribute that reflects a stock's resilience and adaptive capacity.

Some weaknesses of the methodology of the assessment are:

- As there is not an exposure attribute associated with each sensitivity attribute, except for temperature and ocean acidity (OA), exposure and sensitivity attributes are evaluated separately and then combined to obtain a vulnerability score. The exposure assessment takes into account (a) its overlap between species distribution, and (b) the magnitude of the expected environmental change. This treats all exposure factors equally and does not consider whether the exposure factor is likely to influence the species. OA is an example where it is typically ranked as very high in exposure, because there is overlap with species and the magnitude of change is likely to be high, irrespective of whether OA is

likely to affect the species. It may be useful to add a third aspect to the evaluation of exposure attributes such as 'the likelihood of the change in the exposure variable affecting the species being evaluated'. This would enable OA to be rated higher for species such as molluscs and lower for other species unlikely to be affected by OA.

- The study specifies a 'logic approach' with a vulnerability matrix used to obtain the vulnerability ranking. An alternative description resulting in the same outcome, which is used in most risk assessments, consists of numbering the sensitivity and exposure rankings 1 to 4 and multiplying them and then classifying the combined score, e.g. 1-3 (as low vulnerability), 4-6 (moderate) , 8-9 (high) and 12-16 (very high).
- Sensitivity bins: Other stressor attribute focuses on the number of stressors affecting the species in its scoring information but the focus should be on the overall level of stress whether from one or more stressors. Similarly for complexity in reproduction strategy, the level of complexity is more relevant than the number of characteristics. For stock status the low category of 1.5 for B/Bmsy may be too precautionary and a level of about 1.2 may be more appropriate.

TOR 4 Evaluate and provide recommendations on the application of the NMFS Fisheries Climate Vulnerability Assessment using the Northeast region case study as an example.

The key strengths of the application of the NMFS Fisheries Climate Vulnerability Assessment using the Northeast region case study as an example are:

- A comprehensive number of species were examined covering 5 functional groups which should provide a robust test of the methodology.
- The time period to 2055 is appropriate as it is focused on the coming decades and would be of more interest to managers and fishers than a 100 year future time period.
- A large number of models were examined for the various exposure attributes.
- Good array of expertise in fisheries science, stock assessment, ecology and oceanography, used in the assessment with managers and stakeholders attending as observers.
- A summary of the species profile was compiled by contractors. These were then reviewed by the species experts and used as a tool for the vulnerability assessment scoring.
- A number of analyses were conducted, such as the non-metric multidimensional scaling of the sensitivity scores for the 79 species, to examine similarity between functional groups; and sensitivity analyses assessing the importance of some factors (experts, attributes) on the vulnerability rankings.
- The assessment of the risk of distribution change is an important component of the study.
- Management implications highlight how the vulnerability assessment could be used.

The key weaknesses of the application of the NMFS Fisheries Climate Vulnerability Assessment using the Northeast region case study as an example are:

- Need to explain the basis of using RCP 8.5 (business as usual model) and comment on the sensitivity of the assessment to this choice.
- Every species has high or very high exposure to climate change, which is mainly related to the exposure of most species to water temperature and ocean acidity changes (as well as air temperature which is a proxy for shallow water temperature). From a risk ranking perspective it is not useful to have all species classified into only 2 categories.

- An important validation of the vulnerability assessment is to see how species that have undergone detailed studies on the effect of climate change rate on the sensitivity, exposure and overall vulnerability.
- Consider whether OA may be overrated in the assessment as sensitivity may be based on some laboratory experiments using 2100 and 2200 levels of change with expected changes to 2055 being relatively smaller with a relatively high level of uncertainty.

TOR 5 Provide a recommendation as to whether the methodology provides results and information that can assist U.S. federal, state, and local fishery managers in understanding and considering possible climate impacts on fish stocks (fishery includes exploited shellfish and finfish species).

The methodology provides results that can be used to raise awareness of the implication of climate change on fisheries in the region. The results highlight to managers and stakeholders, the species that may be vulnerable to climate changes and so should be monitored more closely with possible climate change effects taken into account in the stock assessment and management settings. It also highlights areas of uncertainty that require additional research to understand the effect on stocks and ocean acidity as a key area of uncertainty that has been identified.

The vulnerability assessment provides an opportunity to highlight to managers and stakeholders that one of the best mechanisms to deal with climate change effects on fisheries is the early detection of the change in abundance and having a harvest strategy that is sensitive to climate change. The use of pre-recruit abundance (if available) probably provides the most valuable measure to respond rapidly to changes in abundance.

TOR 6: Provide a recommendation as to whether the methodology is appropriate for use in other regions. Has it provided useful information in the Northeast and could it provide useful information in other regions?

The methodology is considered appropriate for use in other regions. It was developed with input from scientists in other regions, which should aid its implementation in these regions. It has provided useful information in the Northeast and so should be useful in other regions. It has been recognized that some exposure variables will be specific to each region but it would be useful that variables that are common between regions to be treated similarly. However there was some debate about whether all the bin scores should be standardized relative to the historic variability in all the regions as the variability could be very low in some regions.

The availability of regionally downscaled models to assess the climate impacts would be considered in some regions and this should improve the spatial resolution of projections that should be more appropriate for coastal species.

The comparability of the results between regions needs to be assessed as the methodology is sensitive to the number of exposures that are rated high and the way the exposures are treated between regions can affect the regional comparisons of the vulnerability assessment.

TOR 7: Provide recommendations for possible ways to improve the methodology or its application/use.

- The assessment of climate change effects on the vulnerability of species means that this approach would not formally identify two aspects of climate change effect on fisheries, viz. species that may increase in productivity and/or change in their distribution, that would be of strong interest to managers and stakeholders. The species narrative should be used to highlight these changes.
- The vulnerability assessment is undertaken by species to gain an overall assessment of the species in the region. However, if the information at a stock level is available for one or two species, e.g. Atlantic cod, it may valuable to indicate what the climate change response is likely to be at the stock level as this is important to managers and fishers.
- Some additional exposure attributes that could be considered for future assessments of the Northeast and other regions were ocean productivity and occurrence/intensity of hurricanes. A re-evaluation needs to be undertaken about whether the exposure attributes, air temperature (proxy for shallow water temperature) and SST, resulted in double counting.
- Exposure assessment takes into account (a) overlap between species distribution, and (b) the magnitude of the expected environmental change. This approach does not consider whether the exposure factors are likely to influence the species being considered, e.g. OA. It may be useful to add a third aspect to the evaluation of exposure attributes such as 'the likelihood of the change in the exposure variable affecting the species being evaluated'.
- The experts in this development phase of the project were NMFS scientists to help facilitate the process. For the implementation phase it is important to include scientists from universities and other institutions to ensure a broad array of expertise.
- The logic model focuses on the 'number' of exposures' above a certain level but it is the implication of how the 'total level of change of exposure variables that may affects the species' that is the critical issue and change in one exposure category for a species can be more devastating than three exposure changes that are more moderate. The project team could consider whether the exposure component scores could be adjusted to take into account this qualitative assessment of the exposure attributes or they could be discussed in the species narrative.
- The availability of regionally downscaled models to assess the climate impacts should be considered in regions.
- A validation check of the vulnerability assessment could be undertaken by examining species that have undergone detailed studies on the effect of climate change.
- The vulnerability assessment identifies the key species with the highest vulnerability to climate change and a priority for monitoring and further investigation for climate change adaptation. However other socio-economic factors are also relevant to the priority setting process for assessing climate change effects.
- A socio-economic assessment could be undertaken on the impact of climate change on coastal communities considering a process developed for Australian coastal communities using a self-assessment web site: http://coastalclimateblueprint.org.au/

- OA was identified as an important exposure factor that may affect some species, particularly molluscs, but it does represent an area of considerable uncertainty that requires further research.

TOR 8: Brief description on panel review proceedings highlighting pertinent discussions, issues, effectiveness, and recommendations.

The NMFS made available background information and reports for the peer review with some additional case studies of species profile and species specific results of the assessment as well as some reference papers also provided. The meeting was run well by the panel chair allowing all issues that were raised during the presentations by the project team to be thoroughly discussed and these are discussed under the various TORs.

TOR 9: Panel Chair prepares a short summary to be presented to NMFS Fisheries Climate Vulnerability Assessment leads and NMFS Leadership at the end of the Panel Review.

The Panel Chair in consultation with the review panel prepared a short summary that was presented to NMFS Fisheries Climate Vulnerability Assessment leads and NMFS Leadership (via a phone hookup) at the end of the Panel Review. The panel chair and panel members answered questions about the findings presented.

Background

The Center of Independent Experts (CIE) requested a review of the NMFS Fisheries Climate Vulnerability Assessment using the Northeast region case study.

Three CIE reviewers (Appendix 4) conducted the peer review. About two weeks before the peer review, the NMFS made available background information and reports for the peer review (Appendix 1). Some additional case studies of species profile and species-specific results of the assessment, which form part of the narratives, were provided just before the meeting at a reviewer's request. The CIE reviewers participated in a panel review meeting in University of Rhode Island, Narragansett, Rhode Island, during 28-30 October 2014 to conduct a peer review with the authors of the assessment. The presenters are listed in the agenda (Appendix 2).

The meeting was chaired by Dr Anne Hollowed. The scientists presented the key aspects of their research on the first two days according to the agenda in Appendix 2. Printed copies of the presentations were provided at the meeting and electronic copies were provided after the meeting. Additional reference papers discussed during the meeting were provided to the reviewers. Throughout the presentations the CIE panel present asked questions on issues of the assessment and related research that was presented. All presenters answered questions and expanded on some aspects of the assessment and research. Late on the second day and early on the third day the CIE panel met with Dr Hollowed to determine the preliminary summary findings of the review. These findings were summarised as a PowerPoint presentation by Dr Hollowed, which she presented to NMFS staff that participated in the review as well as NMFS leadership that were part of a phone hookup. Dr Hollowed and panel members answered questions about the findings presented. The reviewers then prepared to write their individual reports.

The report generated by reviewers addressed the following Terms of References (TORs):

1. Evaluate and provide recommendations on the conceptual basis (vulnerability assessments) and design-process (workshops, pilots, NE implementation) for the NMFS Fisheries Climate Vulnerability Assessment.
2. Evaluate and provide recommendations on the assessment structure, assumptions, and scoring procedures for the NMFS Fisheries Climate Vulnerability Assessment including:
    a. Does the methodology contain a valid list of attributes? Could any be added or removed?
    b. Does the methodology appropriately account for expert bias?
    c. Is the logic method appropriate?
    d. Is the methodology consistent with existing tools and approaches being used by other organizations to assess natural resource climate vulnerability?
3. Evaluate the strengths and weaknesses of the methodology
4. Evaluate and provide recommendations on the application of the NMFS Fisheries Climate Vulnerability Assessment using the Northeast region case study as an example.

5. Provide a recommendation as to whether the methodology provides results and information that can assist U.S. federal, state, and local fishery managers in understanding and considering possible climate impacts on fish stocks (fishery includes exploited shellfish and finfish species)
6. Provide a recommendation as to whether the methodology is appropriate for use in other regions. Has it provided useful information in the Northeast and could it provide useful information in other regions?
7. Provide recommendations for possible ways to improve the methodology or its application / use.
8. Brief description on panel review proceedings highlighting pertinent discussions, issues, effectiveness, and recommendations
9. Panel Chair prepare a short summary to be presented to NMFS Fisheries Climate Vulnerability Assessment leads and NMFS Leadership at the end of the Panel Review

The objective of the CIE review was to assess the scientific credibility of the NMFS Fisheries Climate Vulnerability Assessment methodology including its structure and process, utilizing the results of the Northeast Assessment as a worked example. Key questions for the CIE review were:

- Does the methodology adequately meet its design goals and objectives?
- Is it consistent with existing tools and approaches being used by other organizations to assess natural resource climate vulnerability?
- Do the results assist federal, state or tribal fisheries managers in understanding and considering possible impacts of climate change on fish stocks?
- Are there changes or modifications that should be made before implementing in different regions?
- Are there improvements that can be made in the implementation of the methodology based on the worked exampled in the Northeast?
- Does the methodology provide a useful framework or model for possible application to other NMFS trust resources (e.g., protected species, endangered species, and critical habitats)?

Summary of Findings

The findings of the review have been presented according to the terms of reference (TOR) set for the panel:

TOR 1: Evaluate and provide recommendations on the conceptual basis (vulnerability assessments) and design-process (workshops, pilots, NE implementation) for the NMFS Fisheries Climate Vulnerability Assessment

The conceptual basis (vulnerability assessments) was appropriate for the NMFS Fisheries Climate Vulnerability Assessment for evaluating climate vulnerability for fish and invertebrate species. The assessment considered sensitivity and exposure attributes and combined adaptive

capacity with the sensitivity component rather than assessing adaptive capacity as a separate component. The panel members generally agreed to this formulation of the assessment.

The design-process (workshops, pilots, Northeast implementation) was very thorough and appropriate for the development of the methodology. The methodology enables the assessment to be undertaken on marine and diadromous species that may be data-rich or data-poor. The methodology can be applied to other regions after consideration of the key exposure attributes that are important in the region. It would be useful to maintain a core set of exposure attributes that were relevant across all regions.

Dr Hollowed also noted that the assessment contributed to two objectives of draft NMFS climate strategy.

TOR 2: Evaluate and provide recommendations on the assessment structure, assumptions, and scoring procedures for the NMFS Fisheries Climate Vulnerability Assessment including:

a. *Does the methodology contain a valid list of attributes? Could any be added or removed?*
b. *Does the methodology appropriately account for expert bias?*
c. *Is the logic method appropriate?*
d. *Is the methodology consistent with existing tools and approaches being used by other organizations to assess natural resource climate vulnerability?*

The methodology contained a valid list of attributes. Some additional exposure attributes that could be considered for future assessments of this region and for other regions were ocean productivity and occurrence and intensity of hurricanes. There was also considerable discussion about whether the use of both air temperature (proxy for shallow water temperature) and sea surface temperature (SST) resulted in double counting of exposure variables for species that were influenced by both variables. One way to evaluate this issue is to consider the following question: 'if SST information was available for shallow water would it be treated as a separate variable from SST information offshore'.

The project team conducted a thorough review of the literature on expert bias. The methodology appropriately accounted for expert bias and undertook a sensitivity assessment to assess the effect of bias for individual experts and found that the assessment was not sensitive to the removal of individual experts. The approach adopted provided some training in the scoring method before allowing the experts to score the attributes independently. Then a workshop was conducted that identified possible outliers, which were discussed between experts and provided them an opportunity to correct any errors and adjust their scores if they wished. The experts in this development phase of the project were NMFS scientists to help facilitate the process. For the implementation phase it is important to include scientists from universities and other institutions to ensure a broad array of expertise from different institutions. Some assessment of the expert bias of using only NMFS staff in the NE implementation should also be undertaken.

The use of the logic method to develop a component score is an appropriate approach to assess the sensitivity and exposure components. The method has attempted to develop appropriate standardized algorithms for measuring the vulnerability that can be used across the regions and enables an appropriate assessment of the relative vulnerabilities. Using this method, the focus is on a small number of attributes with the highest scores, which can be viewed as a strength in the

assessment as it focuses on the attributes that are assessed as most likely to affect the species vulnerability assessment (i.e. it does not 'minimize the importance of individual high means'). However the method can be sensitive to one or two attributes. For example, there was a significant discussion during the review about whether having air temperature and SST as two separate variables meant that this issue was double counted. Depending on how it was treated it resulted in many species shifting between high and very high exposure.

The logic model focuses on the 'number' of exposures' above a certain level but it is the implication of how the 'total level of change of exposure variables that may affects the species' that is the critical issue and change in one exposure category for a species can be more devastating than three exposure changes that are more moderate. The project team could consider whether the exposure component scores could be adjusted to take into account this qualitative assessment. However if these differences are difficult to capture by the logic model, they could be discussed in the species narrative.

The methodology is broadly consistent with existing tools and approaches being used by other organizations to assess natural resource climate vulnerability. The focus on the climate change effects on the vulnerability of species highlighted that this approach would not formally identify two aspects of climate change effect on fisheries, viz. species that may increase in productivity and/or change in their distribution, that would be of strong interest to managers and stakeholders. Morrison et al. (L481-490) correctly emphasize that even species with 'low vulnerability' because they are able to adapt to climate change by undertaking distributional shifts should be drawn to the attention of managers and stakeholders as they will require adjustment to their management. The species narrative can be used to highlight these changes that may not formally be highlighted in the vulnerability assessment. This issue needs to be treated sensitively as it may cause some communication difficulty with stakeholders for not highlighting the positive changes and ignoring the productivity downturn in areas where fishers are fishing the part of the stock that has been negatively affected by climate change.

TOR 3: Evaluate the strengths and weaknesses of the methodology

The key strengths of the methodology of the assessment are:

- The design-process (workshops, pilots, Northeast implementation) was very thorough and appropriate for the development of the methodology. The methodology enables the assessment to be undertaken on marine and diadromous species that may be data-rich or data-poor.
- Combining the adaptive capacity with the sensitivity component simplifies the assessment without any loss in the quality of the assessment.
- The algorithm for combining the scores of the experts (Morrison et al. L245) provides an appropriate summary statistics of each attribute.
- Expert scoring is undertaken objectively giving all the experts clear guidelines. It would be useful to add to Morrison et al. (near L191) that while the experts are not required to reach consensus that there is a process for the experts to revise their scores after consideration of other experts' comments (discussed later near L430).

- Undertaking the assessment at the species level is important to gain an overall assessment of the vulnerability of the species in the region. However, if the information at a stock level is available, it is also valuable to indicate what the climate change response is likely to be at stock level as this is important to managers and fishers operating on those stocks. This could be attempted for one or two species, e.g. Atlantic cod, which may have enough information at a stock level to undertake this assessment, to assess whether there is a different level of vulnerability identified for any particular stock compared to the overall species assessment.
- Morrison et al. (L392-399) emphasize the importance of taking into account past variability when evaluating the projected changes in exposure factors.
- The vulnerability narratives are a valuable component of the outputs (Morrison et al. L456-462). As well as emphasizing the 'species' expected response to climate change' it is useful to emphasize if there is a 'current response to climate change' that is occurring as this strengthens the case for the projected changes.
- The inclusion of stock status is an important sensitivity attribute that reflects a stock's resilience and adaptive capacity.

Some weaknesses of the methodology of the assessment are:

- As there is not a particular exposure attribute associated with each sensitivity attribute, except for temperature and ocean acidity (OA), the exposure and sensitivity attributes are evaluated separately and then combined to obtain an overall vulnerability score. The Exposure assessment takes into account (a) the overlap between species distribution, and (b) the magnitude of the expected environmental change (Morrison et al. L133) where the magnitude of change is a function of past variability (Hare et al. L393). This treats all exposure factors equally and does not consider whether the exposure factor being considered is likely to influence the species being considered. OA is an example where it is typically ranked as very high in exposure, because there is overlap with species and the magnitude of change is likely to be high, irrespective of whether OA is likely to affect the species being assessed. It may be useful to add a third aspect to the evaluation of exposure attributes such as 'the likelihood of the change in the exposure variable affecting the species being evaluated'. This would enable OA to be rated higher for species such as molluscs and lower for other species unlikely to be affected by OA.
- It appears that the experts have to vote for every attribute and their uncertainty is reflected by spreading their tallies across a number of bins. The project team should consider whether experts should only vote in areas they are familiar with rather than creating unnecessary uncertainty in the assessment by having non-experts in a field generating uncertainty in an attribute by spreading their tallies across bins.
- The study specifies a 'logic approach' with a vulnerability matrix used to obtain an overall vulnerability ranking. An alternative description resulting in the same outcome that is used in most risk assessments consists of numbering the sensitivity and exposure rankings 1 to 4 and multiplying them and then classifying the combined scores, e.g. 1-3 (as low vulnerability), 4-6 (moderate) , 8-9 (high) and 12-16 (very high). The example provided by Morrison et al. (L280-281) is correct when the basis of the sensitivity and exposure assessment are the same. However it also illustrates the problem outlined above when there is a mismatch between the basis of the sensitivity assessment and the basis of

the exposure assessment. For example, it is possible that the sensitivity to a category such as OA may be low and therefore not an important part of the sensitivity assessment but the exposure assessment is being highly influenced by OA because of its high ranking.

- Sensitivity bins:
    - 'Other stressor attribute' is also an important component of the assessment but rather than only focusing on the number of stressors affecting the species in its scoring (Morrison et al. supplementary information) the focus should be on the overall level of stress whether from one or more stressors.
    - Similarly for complexity in reproduction strategy, the level of complexity is more relevant than the number of characteristics
    - For stock status the low category of 1.5 for B/Bmsy may be viewed as too precautionary and a level of about 1.2 may be more appropriate. This allows the moderate bin to be within of 20% of Bmsy.

TOR 4 Evaluate and provide recommendations on the application of the NMFS Fisheries Climate Vulnerability Assessment using the Northeast region case study as an example.

The key strengths of the application of the NMFS Fisheries Climate Vulnerability Assessment using the Northeast region case study as an example are:

- A comprehensive number of species were examined covering five functional groups, which should provide a robust test of the methodology.
- The time period to 2055 is appropriate as it is focused on the coming decades and would be more of interest to managers and fishers than a 100-year future time period.
- A large number of models were examined for the various exposure attributes e.g. air temperature (35 models), sea surface temperatures and salinity (25 models) and pH (11 models), which should provide an indication of the level of uncertainty.
- Good array of expertise in fisheries scientists, stock assessment, ecologist and oceanographers, was used in the assessment with managers and stakeholders attending as observers. The experts participated in a 3-day workshop to discuss and review results.
- A summary of the species profile was compiled by contractors. These were then reviewed by the species experts and used as a tool for the vulnerability assessment scoring.
- A number of analyses were conducted, such as the non-metric multidimensional scaling of the sensitivity scores for the 79 species, to examine similarity between functional groups; and sensitivity analyses were conducted for assessing the importance of some factors (experts, attributes) on the vulnerability rankings. Given the importance of the three exposure attributes, SST, air temperature and ocean acidity, it would be interesting to undertake sensitivity analysis with the combined removal of a number of the other variables.
- The assessment of the risk of distribution change is an important component of the study.
- Management implications section 5.4 in Hare et al. (L517) highlights how the vulnerability assessment could be used and suggests additional precaution in quota setting for species with high vulnerability. It may be useful to specify the importance of having a harvest strategy for species deemed vulnerable and the need to review existing

harvest strategies to ensure that they consider the outcomes of the vulnerability assessment by taking into account climate variability.

- There is a focus on current changes in species/stocks due to climate change in the species narratives as a way of verifying the vulnerability assessment to other scientists, managers and stakeholders. Consider using demonstrated sensitivity to climate variability as an attribute (Hare et al. L419-428, 573-574).

The key weaknesses of the application of the NMFS Fisheries Climate Vulnerability Assessment using the Northeast region case study as an example are:

- Need to explain the basis of using RCP 8.5 (business as usual model) (Hare et al. in prep. L190-192) and comment on the sensitivity of the assessment to this choice, e.g., which exposure categories are most sensitive to this choice.
- It is interesting that every species has high or very high exposure to climate change, which is mainly related to the exposure of most species to water temperature and ocean acidity changes. The dominance of these two factors (as well as air temperature, which is a proxy for shallow water temperature) is confirmed by the sensitivity analysis (Hare et al. Table 5B). As discussed above, the dominance of OA in the exposure category is of concern given that many species may not be sensitive to it. Also, from a risk ranking perspective it is not useful to have all species classified into only two categories and a review of the exposure classification would be valuable.
- It would be useful to provide a brief overview of current and projected climate changes in the region before discussing the exposure of species (Hare et al. L320+).
- The issue of whether climate vulnerability is assessing the risk of a 'change in abundance' as specified by Hare et al. (L418) or whether the focus of the risk is the decline in abundance due to climate change was clarified during the meeting.
- An important validation of the vulnerability assessment is to see how species that have undergone detailed studies on the effect of climate change rate on the sensitivity, exposure and overall vulnerability. It may be useful to summarise how many species have undergone these more detailed studies and how they compare with the vulnerability assessment approach. If there are a large number of 'disagreements' between the two assessment methods, stakeholders may lose confidence in the vulnerability assessment. Hare et al. (L 429-453) specify a number of examples where 'more detailed studies seemingly contradict the results' of the vulnerability assessment. While it is true that the vulnerability assessment is 'never going to completely agree' with the results of the more detailed studies, it is important that that the level of agreements and disagreements are summarized and any major disagreements are discussed as they provide a basis for assessing whether the vulnerability assessment needs to change. The Yellowtail Flounder is presented as an example where there is disagreement with the assessment indicating that the decline was attributed to changes in environmental conditions but it was ranked low in the vulnerability assessment. This is explained by the vulnerability assessment being undertaken at a species level but the detailed assessments undertaken at stock level. The species profile specifies overfishing as factor in the decline, which may be another reason for the disagreement. The species profile presents stock status for three stocks showing one having good abundance but two having poor abundance. Could these be combined to give an overall abundance?

- Consider whether OA may be overrated in the assessment as sensitivity may be based on some laboratory experiments using 2100 and 2200 levels of change with expected changes to 2055 being relatively small with a relatively higher level of uncertainty. Its high ranking may be viewed as a precautionary approach and highlights OA as major gap requiring further research.
- Species narratives; Alewife. Discussion of OA may be contradictory as species profile indicates that OA is not important but the species narrative states that 'exposure to OA is also important;

TOR 5 Provide a recommendation as to whether the methodology provides results and information that can assist U.S. federal, state, and local fishery managers in understanding and considering possible climate impacts on fish stocks (fishery includes exploited shellfish and finfish species).

The methodology provides results that can be used to raise awareness of the implication of climate change on fisheries in the region. The results highlight to managers and stakeholders, the species that may be vulnerable to climate changes and so should be monitored more closely with possible climate change effects taken into account in the stock assessment and management settings. It also highlights areas of uncertainty that require additional research to understand the effect on stocks and ocean acidity was a key area of uncertainty that has been identified.

The vulnerability study emphasizes the need for 'increasing the adaptability of the fishery' in order to 'quickly respond to recruitment failure' (Morrison et al. L508 and 540) and Hare et al. (L517) suggests additional precaution in quota setting for species with high vulnerability. Therefore the vulnerability assessment provides an opportunity to highlight to managers and stakeholders that one of the best mechanisms to deal with climate change effects on fisheries is the early detection of the change in abundance and having a harvest strategy that is sensitive to climate change. If the monitoring of the stocks enables an assessment of the pre-recruit abundance, then the use of the measures of pre-recruit abundance of stocks in the harvest strategy probably provides the most valuable measure for scientists, managers and fishers to respond rapidly to changes in abundance due to climate change before fishing even takes place on the poor abundance year classes. These pre-recruit measures are particularly valuable for species that are highly variable with a relatively short life span (Brown et al. 2012). These measures have proved very useful for the stock assessment and pro-active management of all key invertebrate species in Western Australia (Caputi *et al*. 2014a) and many of the harvest strategies of these fisheries take into account pre-recruit measures in their management settings.

It is also important to highlight to managers and other users of the outputs, what are the limitations of the methodology so that there is no misinterpretation of the results.

One of the Research Questions asked of the CIE reviewers was 'does the methodology provide a useful framework or model for possible application to other NMFS trust resources (e.g., protected species, endangered species, and critical habitats)'. Morrison et al. (Line 113) provide an adequate response to this question as they indicate that with the current set of attributes, the methodology is not applicable to marine mammals, sea-birds, or sea turtles. However, the general framework of the methodology could be adapted for these groups.

TOR 6: Provide a recommendation as to whether the methodology is appropriate for use in other regions. Has it provided useful information in the Northeast and could it provide useful information in other regions?

The methodology is considered appropriate for use in other regions. It was developed with input from scientists in other regions, which should aid its implementation in these regions. It has provided useful information in the Northeast and should provide useful information in other regions. It has been recognized that some of the exposure variables will be specific to each region but it would be useful that variables that are common between regions be treated similarly. However there was some debate about whether standardizing all the bin scores relative to the historic variability was the correct procedure in all the regions. The variability in some regions was relatively low so any small increase would result in a high exposure. This issue would have to be considered in each region.

The availability of regionally downscaled models to assess the climate impacts would be considered in some regions and this should improve the spatial resolution of projections that should be more appropriate for coastal species.

Once there is some experience in the applications of the methodology in other regions the comparability of the results needs to be assessed. As the methodology is sensitive to the number of exposures that are rated high, then the way the exposures are treated between regions can affect the regional comparisons of the vulnerability assessment.

TOR 7: Provide recommendations for possible ways to improve the methodology or its application/use.

See Recommendation section below.

TOR 8: Brief description on panel review proceedings highlighting pertinent discussions, issues, effectiveness, and recommendations.

The panel review proceedings were well organized by Jon Hare and the review panel received all the necessary documentation in adequate time. The meeting was run well by the panel chair, allowing all issues that were raised during the presentations by the project team to be thoroughly discussed. All panel members questioned the project team members, which resulted in valuable discussions on some of the following key issues:

- the focus of the vulnerability assessment on the decrease in productivity of species;
- the use of both air temperature and SST as exposure attributes;
- the treatment of exposure attributes independently of sensitivity attributes;
- application of the logic model;
- how data quality should be measured and presented;
- incorporation of adaptive capacity within the sensitivity component;
- the bins for some exposure attributes, other stressors, complexity of reproduction and stock status;
- exposure assessment for all species classified as high and very high; and
- RCP level chosen for assessment.

TOR 9: Panel Chair prepares a short summary to be presented to NMFS Fisheries Climate Vulnerability Assessment leads and NMFS Leadership at the end of the Panel Review.

The Panel Chair in consultation with the review panel prepared a short summary that was presented to NMFS Fisheries Climate Vulnerability Assessment leads and NMFS Leadership (via a phone hookup) at the end of the Panel Review. The panel chair and panel members answered questions about the findings presented.

Conclusions

The methodology developed for the NMFS Fisheries Climate Vulnerability Assessment was appropriate for evaluating climate vulnerability for fish and invertebrate species. The assessment considered sensitivity and exposure attributes and combined adaptive capacity with the sensitivity component rather than assessing adaptive capacity as a separate component. The panel members generally agreed to this formulation of the assessment.

The project team undertook a thorough design-process consisting of review of relevant studies, workshops, pilot studies, and the Northeast implementation, for the development of the methodology. The methodology enables the assessment to be undertaken on marine and diadromous species that may be data-rich or data-poor. The methodology can be applied to other regions after consideration of the key exposure attributes that are important in the region.

The methodology is broadly consistent with existing tools and approaches being used by other organizations to assess natural resource climate vulnerability. The focus on the climate change effects on the vulnerability of species highlighted that this approach would not formally identify two aspects of climate change effect on fisheries, viz. species that may increase in productivity and/or change in their distribution, which would be of strong interest to managers and stakeholders. The species narratives can be used to highlight these changes that may not formally be highlighted in the vulnerability assessment. This issue may cause some communication difficulty with stakeholders for not highlighting the positive changes and ignoring the productivity downturn in areas where fishers are fishing the part of the species distribution that has been negatively affected by climate change.

The CIE review panel raised a number of issues that require further consideration in the methodology and application to the Northeast and other regions (summarized under Recommendations). Once there is some experience in the applications of the methodology in other regions the comparability of the results between regions needs to be assessed. As the methodology is sensitive to the number of exposures that are rated high, then the way the exposures are treated between regions can affect the regional comparisons of the vulnerability assessment.

Vulnerability assessments and detailed modeling studies of climate change effects on species, either implicitly or explicitly, require some assumptions about how projections for climate change exposure attributes outside the historic range of the environmental variable may affect the species. Therefore it is important to be aware that extrapolation of any relationship between historic environmental variability and biological variables (e.g., recruitment) may not be reliable.

Scientists should be prepared for 'surprises' in a species response to environmental changes outside historic levels (Fulton (2011).

The vulnerability assessment provides an opportunity to raise awareness amongst managers and stakeholders about the species that may be vulnerable to climate change and so should be monitored closely with possible climate change effects taken into account in the stock assessment and management settings. Probably the best mechanisms to deal with climate change effects on fisheries is the early detection of the change in abundance (preferably using a pre-recruit measure) and having a harvest strategy that is sensitive to climate change. The assessment also highlights areas of uncertainty that require additional research to understand the effect on stocks, e.g., ocean acidity.

Recommendations

- The assessment of climate change effects on the vulnerability of species means that this approach would not formally identify two aspects of climate change effect on fisheries, viz. species that may increase in productivity and/or change in their distribution, which would be of strong interest to managers and stakeholders. The species narratives should be used to highlight these changes that may not formally be highlighted in the vulnerability assessment. This issue needs to be treated sensitively as it may cause some communication difficulty with stakeholders for not highlighting the positive changes and ignoring the productivity downturn in areas where fishers are fishing the part of the stock that has been negatively affected by climate change.
- The vulnerability assessment is undertaken at the species level to gain an overall assessment of the species in the region. However, if the information at a stock level is available for one or two species (e.g., Atlantic cod) it may valuable to indicate what the climate change response is likely to be at stock level as this is important to managers and fishers operating on those stocks.
- Exposure attributes: It would be useful to maintain a core set of exposure attributes that were relevant across all regions. Some additional exposure attributes that could be considered for future assessments of the NE region and for other regions were ocean productivity and occurrence and intensity of hurricanes. A re-evaluation needs to be undertaken about whether the exposure attributes, air temperature (proxy for shallow water temperature) and SST, resulted in double counting of exposure variables for species that were influenced by both variables.
- The Exposure assessment takes into account (a) the overlap between species distribution, and (b) the magnitude of the expected environmental change where the magnitude of change is a function of past variability. This approach does not consider whether the exposure factors are likely to influence the species being considered. OA is an example where it is typically ranked as very high in exposure, because there is overlap with species and the magnitude of change is likely to be high, irrespective of whether OA is likely to affect the species being assessed. It may be useful to add a third aspect to the evaluation of exposure attributes such as 'the likelihood of the change in the exposure variable affecting the species being evaluated'. This would enable OA to be rated higher for species such as molluscs and lower for other species unlikely to be affected by OA.

- Some suggested changes to the sensitivity bins:
    - 'Other stressor' attribute is also an important component of the assessment but rather than only focusing on the number of stressors affecting the species in its scoring, the focus should be on the overall level of stress whether from one or more stressors.
    - Similarly for 'complexity in reproduction strategy', the level of complexity is more relevant that the number of characteristics.
    - For stock status the low category of 1.5 for B/Bmsy may be viewed as too precautionary and a level of about 1.2 may be more appropriate. This allows the moderate bin to be within of 20% of Bmsy.
- The experts in this development phase of the project were NMFS scientists to help facilitate the process. For the implementation phase it is important to include scientists from universities and other institutions to ensure a broad array of expertise from different institutions. Some assessment of the expert bias of using only NMFS staff in the NE implementation should also be undertaken.
- The logic model focuses on the 'number' of exposures' above a certain level but it is the implication of how the 'total level of change of exposure variables that may affects the species' that is the critical issue and change in one exposure category for a species can be more devastating than three exposure changes that are more moderate. The project team could consider whether the exposure component scores could be adjusted to take into account this qualitative assessment of the exposure attributes or they could be discussed in the species narrative.
- The reason for using RCP 8.5 (business as usual model) needs to be discussed and there should be comment on the sensitivity of the vulnerability assessment to this choice, e.g., which exposure categories are most sensitive to this choice.
- The availability of regionally downscaled models to assess the climate impacts should be considered in regions where it is available and this should improve the spatial resolution of projections and make them more appropriate for coastal species.
- A validation check of the vulnerability assessment could be undertaken by examining species that have undergone detailed studies on the effect of climate change rate and comparing their assessment with the sensitivity, exposure and overall vulnerability.
- The vulnerability assessment identifies the key species with the highest vulnerability to climate change and a priority for monitoring and further investigation for climate change adaptation. However other socio-economic factors are also relevant to the priority setting process for assessing climate change effects. Therefore it is important to see how the vulnerability assessment for climate change fits in with the risk assessment for the ecosystem-based fisheries management (EBFM) (Fletcher *et al*. 2010; 2012), which has been used as a basis for priority setting for research and management by the Department of Fisheries in Western Australia. There are three components of the risk assessment approach, which evaluates the ecological risk of species but also takes into account the economic value of the species as well the social amenity (i.e. no-economic benefits) derived by the community (Fletcher *et al*. 2010; 2012). Caputi et al. (2014b) has applied this process for priority setting in the risk assessment of climate change for fisheries in Western Australia.

- A socio-economic assessment could be undertaken on the impact of climate change on coastal communities, considering a process developed for Australian coastal communities (Frusher et al. 2013) using a self-assessment web site: http://coastalclimateblueprint.org.au/
- OA was identified as an important exposure factor that may affect some species, particularly molluscs, but it does represent an area of considerable uncertainty that requires further research.

Acknowledgements

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Fletcher, W. J., D. J. Gaughan, S. J. Metcalf, and J. Shaw (2012). Using a regional level, risk-based framework to cost effectively implement ecosystem-based fisheries management. *In*: Global Progress in Ecosystem-Based Fisheries Management. G. H. Kruse, H. I. Bowman, K. L. Cochrane, D. Evans, G. S. Jamieson, P. A. Livingston, D. Woodby, and C. I. Zhang (eds). Alaska Sea Grant, University of Alaska Fairbanks. Doi:10.4027/gpebm.2012.07.

Frusher et al. (2013) A marine climate change adaptation blueprint for coastal regional communities. FRDC Final report 2010-542, http://frdc.com.au/research/final-reports/Pages/2010-542-DLD.aspx#sthash.FCm4foHh.dpuf

Fulton, E. A. (2011). Interesting times: winners, losers, and system shifts under climate change around Australia. ICES J. Mar. Sci. doi:10.1093/icesjms/fsr032

Appendix 1: Bibliography of materials provided for review

Background References – describing the approach of climate vulnerability assessments and the several applications to marine system

04 Chin et al. 2010 GCB - Chin, A., Kyne, P. M., Walker, T. I., & McAuley, R. (2010). An integrated risk assessment for climate change: analysing the vulnerability of sharks and rays on Australia's Great Barrier Reef. Global Change Biology, 16(7), 1936-1953.

05 Foden et al 2013 - Foden, W. B., Butchart, S. H., Stuart, S. N., Vié, J. C., Akçakaya, H. R., Angulo, A., ... & Mace, G. M. (2013). Identifying the world's most climate change vulnerable species: a systematic trait-based assessment of all birds, amphibians and corals. PLoS One, 8(6), e65427.

06 Johnson and Welch 2009 Rev Fish Sci - Johnson, J. E., & Welch, D. J. (2009). Marine fisheries management in a changing climate: a review of vulnerability and future options. *Reviews in Fisheries Science*, *18*(1), 106-124.

07 Moyle et al 2013 PLOS - Moyle, P. B., Kiernan, J. D., Crain, P. K., & Quinones, R. M. (2013). Climate change vulnerability of native and alien freshwater fishes of California: a systematic assessment approach. *PloS one*, *8*(5), e63883.

08 NWF Scanning the Conservation Horizon - P. Glick and B.A. Stein, editors. 2010. Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment. Draft. National Wildlife Federation, Washington, D.C.

09 Pecl et al 2011 Fisheries Aquaculture Risk Assessment - Pecl GT, Ward T, Doubleday Z, Clarke S, Day J, Dixon C, Frusher S, Gibbs P, Hobday A, Hutchinson N, Jennings S, Jones K, Li X, Spooner D, and Stoklosa R (2011). Risk Assessment of Impacts of Climate Change for Key Marine Species in South Eastern Australia. Part 1: Fisheries and Aquaculture Risk Assessment. Fisheries Research and Development Corporation, Project 2009/070.

NMFS Fisheries Climate Vulnerability Assessment Methodology (FCVA) – This set of documents describes the methodology and contains some of the documents developed to facilitate a regional implementation

10 FCVA Methodology Manuscript – Describes the methodology; submitted to ICES Journal of Marine Science

11 Species Profiles Template– A excel file formatted documented to be used to summarize information on each species or stock to be assessed. These species profiles are provided to the experts to facilitate their scoring during the assessment.

12 Sensitivity Attribute Definitions – A clear definition of each attribute and guidance for scoring. This document is reviewed with the expert panel prior to scoring through a webinar or in-person meeting.

Northeast Fisheries Climate Vulnerability Assessment (NEVA) – This set of documents describes the implementation of the FCVA Methodology for 79 fish and shellfish species in the Northeast U.S. Continental Shelf Ecosystem

13 NEVA Manuscript – A DRAFT manuscript (not yet submitted to a journal) that describes the implementation of the FCVA methodology in the Northeast U.S. Continental Shelf Ecosystem

14 Species Profiles – 6 example species profiles; one from each of the six groups defined in the assessment: Coastal, Pelagic, Groundfish, Shellfish, Elasmobranch, and Diadromous. Species profiles were prepared as a first step in the assessment and then provided to the experts to support their scoring. There are 79 species profiles, one for each species in the assessment. An additional 11 profiles provided just before the meeting at a reviewer's request.
15 Species Narratives – 6 example species narratives; one from each of the six groups defined in the assessment: Coastal, Pelagic, Groundfish, Shellfish, Elasmobranch, and Diadromous. Species narratives present the species specific results of the assessment. The species narratives are still being completed, there will be one for each of the 79 species in the assessment. An additional 11 species specific results of the assessment which form part of the narratives were provided just before the meeting at a reviewer's request.

Copies of all presentations listed in the Agenda (Appendix 2) were provided to the review team as well as the following additional references:

Bell, R J. Jonathan A. Hare, John P. Manderson, and David E. Richardson (2014). Externally driven changes in the abundance of summer and winter flounder. ICES Journal of Marine Science; doi:10.1093/icesjms/fsu069

Hare, J A, J P. Manderson, J A. Nye, M A. Alexander, P J. Auster, et al. (2012). Cusk (*Brosme brosme*) and climate change: assessing the threat to a candidate marine fish species under the US Endangered Species Act. ICES Journal of Marine Science, 69(10), 1753–1768. doi:10.1093/icesjms/fss160

McClure, M M, M Alexander, D Borggaard, D Boughton, L Crozier, R Griffis, *et al*. (2013). Incorporating Climate Science in Applications of the U.S. Endangered Species Act for Aquatic Species. Conservation Biology, Volume 27, No. 6, 1222–1233

Nye, J. A., Jason S. Link, Jonathan A. Hare, William J. Overholtz (2009). Changing spatial distribution of fish stocks in relation to climate and population size on the Northeast United States continental shelf. Marine Ecology Progress Series Vol. 393: 111–129 doi: 10.3354/meps08220

Richardson, David E. Michael C. Palmer, and Brian E. Smith (2014). The influence of forage fish abundance on the aggregation of Gulf of Maine Atlantic cod (*Gadus morhua*) and their catchability in the fishery Can. J. Fish. Aquat. Sci. 71: 1349–1362 dx.doi.org/10.1139/cjfas-2013-0489

Seney, E. E., Melanie J. Rowland, Ruth Ann Lowery, Roger B. Griffis, and Michelle M. Mcclure (2013). Climate Change, Marine Environments, and the U.S. Endangered Species Act. Conservation Biology, Volume 27, No. 6, 1138–1146.

Appendix 2: CIE Review Agenda

NMFS Fisheries Climate Vulnerability Assessment Review

Day 1 - Tuesday 28 October 2014

09:00-09:15	**Introductions / Logistics** lead: Jon Hare
09:15-09:30	**Charge to the Review Panel** lead: Roger Griffis & Anne Hollowed
09:30-10:30	**Review of Process for Establishing Methodology** lead: Wendy Morrison
10:30-12:00	**Open Discussion** lead: Anne Hollowed
12:00-13:00	**Lunch**
13:00-15:00	**Review of Methodology** lead: Mark Nelson
15:00-17:00	**Open Discussion** lead: Anne Hollowed

Day 2 - Wednesday 29 October 2014

09:00-09:15	**Logistics** lead: Jon Hare
09:15-10:45	**Northeast Implementation** lead: Jon Hare
10:45-12:00	**Open Discussion** lead: Anne Hollowed
12:00-13:00	**Lunch**
13:00-14:00	**Broader Application (Stakeholder POVs)** lead: Roger Griffis
14:00-15:00	**Open Discussion** lead: Anne Hollowed
15:00-17:00	**Closed Panel Discussion** lead: Anne Hollowed

Day 3 - Thursday 30 October 2014

09:00-11:00	**Closed Panel Writing**
11:00-12:00	**Panel Summary with POCs and NMFS Leadership** lead: Anne Hollowed
12:00	**End of Review**

Appendix 3: Statement of Work for Dr. Nick Caputi

External Independent Peer Review by the Center for Independent Experts

NMFS Fisheries Climate Vulnerability Assessment Review

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: Through in-depth investigations of specific fish stocks, NMFS has a strong understanding of how climate change may impact some high profile fish species (e.g. Hare et al. 2010, Hollowed et al. 2009, Hazen et al. 2012). However, repetition of these detailed analyses for all managed stocks (~450) is not feasible as these studies are resource intensive and require data sets that are not available for many fish stocks. Given the pace at which climate change is expected to occur and the need for NMFS to develop science priorities and management considerations now, there has been a demand to develop a practical and efficient tool to assess the vulnerability of a wide range of fish stocks in a changing climate. This tool would not replace detailed studies. Rather, it is designed to provide information until detailed studies can be completed and to help guide more detailed studies by identifying high risk species and important climate factors. To develop this tool - a climate vulnerability assessment for marine fish and invertebrate species - NMFS convened a working group composed of fishery scientists and managers from across the country. The methodology was built off a standard vulnerability assessment framework and specifically incorporated elements of two prior marine species climate vulnerability assessments. The methodology was recently implemented in the Northeast region for 79 fish and invertebrate species. This methodology was designed to identify the relative vulnerability of exploited species based on a series of life history attributes and projections of the expected changes in key physical or chemical characteristics of the species' environment with changes in the planet's climate system. The vulnerability information is intended to be used to help inform considerations of how best to focus limited research and assessment resources (e.g., focus on stocks of highest concern). Additionally, the results are intended to promote conversation among scientists, managers, fishermen and other stakeholders about what climate-related changes are expected in marine ecosystems, how climate change may impact living marine resources, and what actions could be considered to reduce impacts and increase resilience of these important marine resources in a changing climate.

NMFS plans to use this methodology to assess climate vulnerability of managed species in other regions as part of the scientific advice provided to support fisheries management under the Magnuson-Stevens Act. Vulnerability assessments are now being used extensively by federal, state and tribal natural resource agencies and partners to identify key resources at risk and inform planning for how to reduce risks and increase resilience in a changing climate. In addition, the methodology is responsive to several mandates for federal agencies to assess climate vulnerability and advance adaptation planning to promote resilience of natural resources (e.g., Executive Order 13653 "Preparing the United States for the Impacts of Climate Change"; National Fish Wildlife and Plants Climate Adaptation Strategy, and the National Ocean Policy).

The objective of the CIE review is to assess the scientific credibility of the methodology including its structure and process, utilizing the results of the Northeast Assessment as a worked example. Key questions for the CIE review are:

- Does the methodology adequately meet its design goals and objectives?
- Is it consistent with existing tools and approaches being used by other organizations to assess natural resource climate vulnerability?
- Do the results assist federal, state or tribal fisheries managers in understanding and considering possible impacts of climate change on fish stocks?
- Are there changes or modifications that should be made before implementing in different regions?
- Are there improvements that can be made in the implementation of the methodology based on the worked exampled in the Northeast?
- Does the methodology provide a useful framework or model for possible application to other NMFS trust resources (e.g., protected species, endangered species, and critical habitats)?

We envision a three-day review. Day one will focus on the methodology. Day two will focus on the implementation in the Northeast. Day three will provide the review panel time for discussion and preparation of their review and also a summary meeting with the methodology designers and members of NMFS leadership. 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: CIE reviewers shall conduct an impartial and independent peer review in accordance with the SoW and ToRs herein. CIE reviewers shall have a combination of the following expertise: the application of natural resource climate vulnerability assessments, ecosystem-based approaches to natural resource management, and climate change effects on marine species and ecosystems. We do not expect all of these skills to be represented by each reviewer, but request that review panel as a whole have the expertise to cover the topics listed above. Vulnerability assessments have been widely used in terrestrial systems and terrestrial scientists with experience in vulnerability assessments would be appropriate. Each CIE reviewer's duties shall not exceed a maximum of 14 days to complete all work tasks of the peer review described herein.

The chair or the panel will be chosen by NMFS and will be a fisheries scientist with an understanding of current marine fisheries issues in the Northeast Region.

Location of Peer Review: Each CIE reviewer shall conduct an independent peer review during the panel review meeting scheduled in Narragansett, Rhode Island from 28-30 October 2014.

Statement of Tasks: Each CIE reviewer 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/
http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreign-national-registration-system.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.

1. Methodology Manuscript
    a. Database Description
    b. Sensitivity Attribute Definition Document
2. Northeast Application Manuscript
    a. Exposure Factor Definition Document

b. Species Profiles Example
c. Species Narrative Examples

3. Chin et al. (2009) Paper
4. Johnson and Welch (2009) Paper
5. Moyle et al.(2013) Paper
6. Pecl et al. (2011) Report
7. Foden et al. (2013)
8. National Wildlife Foundation - A Guide to Climate Change Vulnerability Assessment

For more examples see: http://www.natureserve.org/conservation-tools/standards-methods/climate-change-vulnerability-index.

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 at Narragansett, Rhode Island from 28-30 October 2014 as specified herein, and conduct an independent peer review in accordance with the ToRs (**Annex 2**).

3) No later than 14 November 2014, each CIE reviewer shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Dr. Manoj Shivlani, CIE Lead Coordinator, via email to mshivlani@ntvifederal.com, 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.

Please provide the actual dates in the following table. Please use this table format.

22 September 2014	CIE sends reviewer contact information to the COTR, who then sends this to the NMFS Project Contact
14 October 2014	NMFS Project Contact sends the CIE Reviewers the pre-review documents
28-30 October 2014	Each reviewer participates and conducts an independent peer review during the panel review meeting
14 November 2014	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
28 November 2014	CIE submits CIE independent peer review reports to the COTR
5 December 2014	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

Modifications to the Statement of Work: This 'Time and Materials' task order may require an update or modification due to possible changes to the terms of reference or schedule of milestones resulting from the fishery management decision process of the NOAA Leadership, Fishery Management Council, and Council's SSC advisory committee. A request to modify this SoW must be approved by the Contracting Officer at least 15 working days prior to making any permanent changes. The Contracting Officer will notify the COTR within 10 working days after receipt of all required information of the decision on changes. 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) The CIE report shall completed with the format and content in accordance with **Annex 1**,
(2) The 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:

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Key Personnel:

NMFS Project Contact:

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

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

NMFS Fisheries Climate Vulnerability Assessment Review

1. Evaluate and provide recommendations on the conceptual basis (vulnerability assessments) and design-process (workshops, pilots, NE implementation) for the NMFS Fisheries Climate Vulnerability Assessment
2. Evaluate and provide recommendations on the assessment structure, assumptions, and scoring procedures for the NMFS Fisheries Climate Vulnerability Assessment including:
    a. Does the methodology contain a valid list of attributes? Could any be added or removed?
    b. Does the methodology appropriately account for expert bias?
    c. Is the logic method appropriate?
    d. Is the methodology consistent with existing tools and approaches being used by other organizations to assess natural resource climate vulnerability?
3. Evaluate the strengths and weaknesses of the methodology
4. Evaluate and provide recommendations on the application of the NMFS Fisheries Climate Vulnerability Assessment using the Northeast region case study as an example.
5. Provide a recommendation as to whether the methodology provides results and information that can assist U.S. federal, state, and local fishery managers in understanding and considering possible climate impacts on fish stocks (fishery includes exploited shellfish and finfish species)
6. Provide a recommendation as to whether the methodology is appropriate for use in other regions. Has it provided useful information in the Northeast and could it provide useful information in other regions?
7. Provide recommendations for possible ways to improve the methodology or its application / use.
8. Brief description on panel review proceedings highlighting pertinent discussions, issues, effectiveness, and recommendations
9. Panel Chair prepare a short summary to be presented to NMFS Fisheries Climate Vulnerability Assessment leads and NMFS Leadership at the end of the Panel Review

Annex 3: Tentative Agenda

NMFS Fisheries Climate Vulnerability Assessment Review

Narragansett, Rhode Island
Security POC: Jon Hare

Day 1 – 28 October 2014

9:00-9:15	Introductions / Logistics
9:15-9:30	Charge to the Review Panel (Chair)
9:30-10:30	Review of Process for establishing methodology
10:30-12:00	Open Discussion
1:00-3:00	Review of methodology
3:00-5:00	Open Discussion

Day 2 – 29 October 2014

9:00-9:15	Logistics
9:15-10:45	Northeast Implementation
10:45-12:00	Open Discussion
1:00-2:00	Broader Application (Stakeholder POVs)
2:00-3:00	Open Discussion
3:00-5:00	Closed Panel Discussion

Day 3 – 30 October 2014

9:00-11:00	Closed Panel Writing
11:00-12:00	Panel Summary with POCs and NMFS Leadership
	Adjourn

Appendix 4: Panel Membership

The panel membership for the CIE consisted of Dr Ken Drinkwater, Dr Jeff Hutchings and Dr Nick Caputi. The meeting was chaired by Dr Anne Hollowed.