Independent Peer Review of GMACS Modeling Framework

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Representing the Center of Independent Experts

Executive Summary

The Generalized Model for Alaska of Crab Stocks (GMACS) is a generalized and flexible size-structured modeling framework that is being developed to provide a standardized size-structured assessment that is more transparent than the current approach in which assessment scientists have written species-specific software. A Center for Independent Experts (CIE) review of the GMACS modeling framework and issues related to further development and application for stock assessment was requested.

Three (CIE) reviewers conducted the peer review in accordance with the Terms of Reference (ToRs) listed below. Two weeks before the peer review, the NMFS made available a web site with all necessary background information and reports for the peer review. The CIE reviewers participated in a panel review meeting in Seattle, Washington from 29 June to 01 July 2015 to conduct a peer review of the GMACS modeling framework with the authors of the modeling. The meeting was chaired by Martin Dorn. The scientists presented the key aspects of their research and copies of the presentations were provided. Throughout the presentations, the CIE panel and others present asked questions on issues of the stock assessment modeling and related research that was presented. All presenters answered questions and expanded on some aspects of their research. There were some requests for additional information from the presenters, which was provided later.

The report generated by reviewers addressed the following TORs:

A. Evaluation of **functional forms, estimation approaches, and diagnostics** used in GMACS including uncertainty characterization and satisfying required assessment elements.
B. Evaluate application of **GMACS to the BBRKC** stock. Specifically, comment on what important features are missing relative to the current assessment approach?
C. Evaluation of **GMACS as a flexible assessment modeling too**l, in effect, its potential application to other crab stocks, e.g., Tanner crab, data poor stocks (Tier 4), and stocks with unique data sets (e.g., snow crab and Bristol Bay red king crab cooperative survey data).
D. Evaluation of utility of the **modeling framework as a community** supported modeling approach and practicality for managing into the future.
E. Recommendations for further improvements and comment on the **general applicability to the fishery management** questions (risk assessment and MSE options).

The review was undertaken of the GMACS modeling that represented work in progress with review examining the work that had been undertaken and providing suggestions of how to move forward in the finalizing the GMACS modeling and developing a Bristol Bay red king crab (BBRKC) model as a case study.

The findings of the review have been presented according to the TORs set of the panel:

> *TOR A. Evaluation of functional forms, estimation approaches, and diagnostics used in GMACS including uncertainty characterization and satisfying required assessment elements.*

A key issue in modeling fisheries was that every current stock assessment model has unique characteristics that represent the modeler's approach and method of coding. This makes it difficult for others to pick up and modify the model. In many cases it is easier for a new modeler to rewrite the model in his own format rather than interpret another modeler's approach. The general features established in the GMACS modeling approach and its documentation should make it easier to

undertake the modifications for the annual assessment and for other modelers to undertake an update of the model. While the focus of model development is for Alaskan crab stocks, the software should also be able to be applied to other crustacean stocks. The GMACS framework provides software (GMR package) for plotting the model outputs that can be used in assessment reports. There are four major components to the GMACS package:

1. Assessment model (ADMB & C++)
2. R-packages and Scripts (R & Shell Scripts)
3. Code repository (https://github.com/seacode/gmacs)
4. Documentation

Some key features of the model are the Git version control and the R package called 'gmr' which supports GMACS. It currently focuses on plotting GMACS outputs. It includes internal Roxygen format code-comments. Github's primary function is a code repository. It tracks issues, milestones, and maintains a record of historical development. The system uses a self-documentation of the code (Doxygen-API) which enables the development and update in model to be more easily performed.

GMACS can currently accommodate two sexes, new & old shell conditions, and molt increment data. Some aspects not currently incorporated in GMACS include maturity, tagging, and fishing effort. Some of the key features included:

- Natural mortality is assumed to be sex-specific, size-independent with a number of options for varying the mortality between years.
- Selectivity and retention/discards representations with selectivity able to be changed for blocks of years. Fishing mortality included discards in directed and non-directed fisheries.
- There was discussion about whether the input discard data had discard mortality already applied and this was to be checked.
- If environmental variables could be used to vary parameters such as survey selectivity then there was some consideration of explaining annual selectivity changes using environmental variables.
- Gamma distribution was used in the Growth transition matrix with an option for normal distribution. The gamma distribution could result in 'unrealistic' growth estimates and one option of dealing with this was the use of truncation to maintain growth within biological 'reasonable' levels.
- No stock-recruitment relationships were incorporated in GMACS model.
- There was an option for males and/or females mature biomasses to be estimated to represent the mature biomass. Female spawning stock was initially used in the assessments of crab stocks but more recently had moved to mature male biomass.
- There was considerable debate about whether the current set up of the GMACS model as a continuous model rather than a sequential model was appropriate. Many features of the crab biology (e.g. synchronous molting, and spawning at a specific time of year) and the fishery which is focused over a few months indicated that a sequential model may be more appropriate. If a continuous model is maintained with GMACS, then the difference between continuous and sequential approaches should be examined on its effect on the trends in the model outputs. An important consideration was the user requirements and definitions of biological reference points.

A key approach to test the integrity of the GMACS model which is modeled with ADMB was to develop a duplicate model using an R-based simulation package by independent scientist. Most of the features of this model were similar to the GMACS model; however, a key feature was that it was formulated as a pulse

fishery which provides a check to the continuous fishery simulation in GMACS. Another test of the GMACS model was also undertaken by generating simulation data to test the GMACS model.

TOR B. Evaluate application of GMACS to the BBRKC stock. Specifically, comment on what important features are missing relative to the current assessment approach?

As the current GMACS model is partially complete taking into account the two sexes, new & old shell conditions, and molt increment data but does not currently incorporate maturity, tagging, and fishing effort, it is difficult to compare the GMACS-BBRKC with the current Bristol Bay red king crab (referred to ADFG-BBRKC). Therefore comments under this TOR and others provide areas that require attention in the completion of the GMACS model and the BBRKC case study.

The ADFG-BBRKC model being used for stock assessment estimates the distribution for recruitment over size classes for each sex. There was discussion about whether the model should allow different recruitment abundance between sexes or assume 50:50 ratio. A comparison of the sex ratio in surveys for crabs in the 65-80 and 85-85 mm length class was examined. There was some variation between years and the reviewers requested to see the annual survey sample sizes in the 65-80 mm size class. The survey sample sizes of 8 to 4998 were reported for the 65-80 mm crabs with 6 samples under 30 in the 40 year survey time series. The years with large samples resulted in a recruitment sex ratio estimates close to 50:50 and there was increased departure from 50:50 for years with small samples. This indicated that a 50:50 recruitment sex ratio would be a reasonable assumption in the model.

While there may be some smoothing of the recruitment index which consists of crabs about 5-6 years old, it is still be worthwhile examining the stock-recruitment relationship (SRR), particularly as there has been some significant contrast in spawning stock over the years.

The trend in female size at maturity (SAM) was modeled as a step function for 3 blocks of years for ease of modeling growth. However, the annual SAM values indicated a smooth increasing trend between years rather than a stepwise variation. It would be useful to examine the effect of this assumption on the modeling.

A depletion analysis of blocks that are heavily fished and show a significant decline in catch rate should be undertaken as it may provide some valuable insight into fishery dynamics.

The results of the BSFRF research projects on net selectivity survey and pre-recruit surveys should be evaluated for their possible inclusion in the ADFG-BBRKC and GMACS models.

Two GMACS models of the BBRKC fishery were presented: Onesex model (male only which was more advanced in its preparation) and Twosex model which was very preliminary at the time of review. These models were compared to the ADFG-BBRKC model:

- GMACS modeled data since 1960 compared to the ADFG-BBRKC model which commences in 1975. However, it is important that discards are estimated for the early years before observed data is available.
- There was discussion about whether growth should be limited to a maximum of 30% of initial size to maintain the maximum growth at a realistic level.

TO*R C. Evaluation of **GMACS** as a flexible assessment modeling tool i.e., potential application to other crab stocks e.g., Tanner crab, data poor stocks (Tier 4), and stocks with unique data sets (e.g., snow crab and Bristol Bay red king crab cooperative survey data).*

The current development of GMACS and its proposed final development will make a very flexible assessment modeling tool. While GMACS has been established primarily for stock assessments for the Alaskan crab fisheries, it should be generally applicable to crustacean fisheries stock assessment that based on length-structured assessments

A feature of the GMACS model is that it is being developed for data-limited and data-rich fisheries and accommodates many types of data from multiple sources in an integrated analysis. It is able to deal with incomplete data sets which are likely to be common in many fisheries that are being assessed for an extended period. The observation data include abundance indices, fishing effort, survey catch rates and size composition, retained catch and discards, and tagging data. It also allows for some of the biological parameters such as growth, size at maturity, selectivity and natural mortality, to vary over time. This is an important component as there can be decadal shifts and/or long-term changes in climate that can influence these parameters in an extended assessment period.

An overview of the BSAI crab stocks, Management and Assessment which have State/Federal co-operative management approach was presented with 10 stocks under the fisheries management plan. The current Crab Management has a 5 Tier system and crab stocks are in Tiers 3 to 5. The TAC is based on abundance estimate of mature biomass not legal abundance and mature male biomass is the focus of assessment.

An audit of the key characteristics of the Alaskan crab fisheries that will need to be developed in GMACS should be undertaken to identify the basic characteristic of the species and fisheries so they could be incorporated into the GMACS stock assessment model. Particular emphasis should be on the characteristics that may be different from BBRKC which has been the main focus for GMACS development. The features of Snow and Tanner crabs that are used in the current model that need to be considered in the GMACS modeling, were summarized. They included: terminal molt, tracking of mature/immature crabs, probability of immature moving to mature stage, addition of a maturity dimension, smooth function for selectivity, morphometric identification of mature crabs, growth increment, pulse fishery, sequential model, discrete growth in all crabs, and discard numbers.

It may not be possible to incorporate all existing features of the crab stocks in the GMACS model so decisions need to be made on design changes to fit in GMACS model structure while maintaining the important features of the stocks. It will probably be due to the Crab Planning Team (CPT) to decide on the key model specifications of each stock that will be required.

An overview of API and Wiki user manual included the following points:

- The Git software provides an opportunity to keep notes for future development, list outstanding issues that need to be resolved and provide a trouble-shooting guide.
- Changes in the modeling over time are documented and the model can be recreated at any point of time. This is important as changes can result in a breakdown of the model so it is important to be able to return to a previous version of the model.
- The system is able to be cloned to a desktop to enable development outside of github and then copy back to github. However, there is a need to resolve the modeling if more than 1 person working on same issue. A GMACS project modeling team should be identified and be responsible for what changes would be accepted in the GMACS modeling framework.

TOR D. Evaluation of utility of the modeling framework as a community supported modeling approach and practicality for managing into the future.

Once the basic GMACS model structure has been completed, successfully applied to the BBRKC fishery, and project has been reviewed and published, it should gain strong community support from crustacean stock assessment scientists. While its current focus is the Alaskan crab fisheries, the final product should be generally applicable to crustacean fisheries stock assessment. GMACS has been established to provide the structure for other modelers to contribute to its development and use for their stock assessments.

The GMACS User Guide (Wiki) provides a good overview of the GMACS modeling framework. It is a software manual and developer guide so that potential contributors can contribute to the modeling. The 'developer's guide' provides some options for contributing to the source code or modifying the code. It provides the information to get started in building a model and provides an example of model inputs as well as the outputs from the running of the BBRKC.

The GMACS modeling framework has some important features that makes it a valuable as a community-supported modeling approach:

- The framework is designed with the flexibility to that of the age-structured stock assessment modeling like Stock Synthesis. Stock reduction analysis is a data-poor modeling approach that is based on using historical catch data with assumptions about natural mortality, growth and size-distribution of recruits to estimate recruitment. The method can include available information on abundance, size composition and tagging. The GMACS analysis highlights the results coming from four alternative models for the BBRKC with increasing level of input data (catch, cpue, size composition and initial states) added sequentially.
- GMACS is coded using ADMB, which is suited to efficiently estimate hundreds of parameters and is familiar to fisheries modelers which enables them to contribute to the modeling. It is formally structured which allows for easy expansion.
- The source files are publically available and open source.
- Git represented version control software that enabled documentation of changes and would enable saving of model used in each year's assessment, and models with different data sets and different models. This allows model comparisons to be easily undertaken.
- Github overview enabled modeling changes to be rejected and the model returned to previous working versions. A core modeling group should oversee the overall model development and make decisions on what developments should be incorporated into the main branch.
- The GMACS R package (GMR) facilitated the reading of model outputs for model comparison of the key results such as recruitment and size frequencies. The package enables the comparison of alternative models by plotting the results of multiple models simultaneously.
- The GMR package also facilitates the writing an update of the stock assessment report with the model outputs and diagnostics being implemented within reports.
- The modeling package enabled the documentation of functions as they are written using the Doxygen comments to facilitate the development of GMACS.

TOR E. Recommendations for further improvements and comment on the general applicability to the fishery management questions (risk assessment and MSE options).

Recommendations for completion of the project and further improvements for the general applicability to fishery management include:

- Completion of the GMACS-BBRKC model so that a proper comparison can be made with the ADFG-BBRKC model. This includes:
    - incorporating maturity, tagging, and fishing effort into the model
    - Complete the TwoSex model in BBRKC fishery
    - Undertake simulation testing
    - Selectivity specification/parameterization flexibility
    - Assess the stock-recruitment relationship using an appropriate time lag between spawning and recruitment
    - GMACS model is extended to 1960s but discards were only applied since 1975 and these would have to be estimated for the earlier years.
    - Checking whether the input discard data had discard mortality already applied
- Environmental variables could be affecting biological parameters e.g. growth, size at maturity, survey catchability. In the 2014 NMFS survey, water temperature could have affected the catchability so evaluation of environmental variables explaining catchability changes should be examined and used to adjust catchability. Water temperature may also affect the spatial distribution of the stock which could also affect the catchability if the stock is concentrated into a smaller area.
- The current GMACS model is set up as a continuous model rather than a sequential model. However, many features of the crab biology (e.g. synchronous molting, and spawning) and the fishery duration indicated that a sequential model may be more appropriate. If a continuous model is maintained with GMACS, then the difference between continuous and sequential approaches should be examined.
- The results of the BSFRF research projects on net selectivity survey and pre-recruit surveys should be evaluated for their inclusion in the ADFG-BBRKC and GMACS models. Pre-recruit abundance indices could be a valuable component of the assessment as an early warning signal for changes in abundance and facilitate an understanding of the stock-recruitment-environment relationship. This is particularly important if there are decadal shifts and long-term environmental changes. Recruitment abundance is highly variable with last 9 years averaging about 10 million crabs well below the 1984-2014 average of 20 million crabs.
- A GMACS project modeling team should be identified and be responsible for what changes would be accepted in the GMACS modeling framework. In the longer-term, there is a need to develop a strategy for long-term maintenance of the GMACS model once it has been completed and being used for stock assessments.
- Complete the GMACS model description paper.
- Complete the comparison between GMACS-BBRKC and ADFG-BBRKC.
- Future upgrades of GMACS model should consider multiple areas which could be important as some stocks may have different biological parameters in different areas such as growth and maturity and this should allow movement between stocks if necessary. There could be also be changes in the spatial distribution of the stock that may warrant changes in the spatial area being assessed.
- Commercial cpue is currently not being used in the BBRKC assessment due to gear changes making comparisons difficult. An analysis of vessels which have used consistent gear over a number of years to determine a standardized annual cpue using a GLM. The cpue before and

after the introduction of catch quotas are unlikely to be comparable due to changes in the pattern of fishing and other fishing practices. The standardized cpue would enable a cross check with survey data which is not entirely unbiased due to environmental effects on catchability.

- The standardized cpue would be valuable for the stocks at tier 5 assessments.
- Update the audit of key characteristics of the crab fisheries that will need to be developed in GMACS to identify the basic characteristic of the fisheries so they could be incorporated into the GMACS stock assessment model.
- A depletion analysis of blocks that are heavily fished during a season such that there is a significant decline in catch rate due to the effects of fishing could provide some valuable insights into fishery dynamics.
- The introduction of crab rationalization has seen the annual collection of economic data on the cost of fishing and revenues. The change in management has probably resulted in an industry focus on maximizing annual profits compared to maximizing catch share. The economic data can be combined with projected catch quotas and fishing days for a basic bio-economic assessment of where the fishery sits relative to the maximum economic yield (MEY). This may be a project that BSFRF may consider. This bio-economic assessment could become a standard option of the GMACS models that may be of interest in some fisheries.

Background

The Alaska Fisheries Science Center (AFSC) is responsible for assessments of five Bering Sea crab stocks. Collectively, these crab stocks support valuable commercial fisheries. Recently scientists at the AFSC and the University of Washington have been developing a Generalized Model for Alaska of Crab Stocks (GMACS), which is a generalized and flexible size-structured modeling framework. A goal of the project is to provide a standardized size-structured assessment that is more transparent than the current approach in which assessment scientists have written species-specific software. A CIE review of the GMACS modeling framework and issues related to further development and application for stock assessment was requested.

Three CIE reviewers (Appendix 3) conducted the peer review in accordance with the Terms of Reference (ToRs) listed below. These TORs which were agreed to at the beginning of the meeting were modified slightly from those listed in Annex 2 of Appendix 1. Two weeks before the peer review, the NMFS made available a web site with all necessary background information and reports for the peer review. The CIE reviewers participated in a panel review meeting in Seattle, Washington from 29 June to 01 July 2015 to conduct a peer review of the GMACS modeling framework with the authors of the modeling. The reviewers met with scientists involved in the modeling including those from the Alaska Fisheries Science Center and the Alaska Department of Fish and Game. The meeting was chaired by Martin Dorn. The scientists presented the key aspects of their research according to the agenda modified from that in Annex 3 of Appendix 1. Copies of the presentations were provided to the reviewers. Throughout the presentations the CIE panel and others present asked questions on issues of the stock assessment modeling and related research that was presented. All presenters answered questions and expanded on some aspects of their research. There were some requests for additional information from the presenters which was provided later. The reviewers then prepared to write their individual reports.

The report generated by reviewers addressed the following TORs:

A. Evaluation of functional forms, estimation approaches, and diagnostics used in GMACS including uncertainty characterization and satisfying required assessment elements.
B. Evaluate application of GMACS to the BBRKC stock. Specifically, comment on what important features are missing relative to the current assessment approach?
C. Evaluation of GMACS as a flexible assessment modeling tool. I.e., potential application to other crab stocks e.g., Tanner crab, data poor stocks (Tier 4), and stocks with unique data sets (e.g., snow crab and Bristol Bay red king crab cooperative survey data).
D. Evaluation of utility of the modeling framework as a community supported modeling approach and practicality for managing into the future.
E. Recommendations for further improvements and comment on the general applicability to the fishery management questions (risk assessment and MSE options).

Summary of Findings

The review was undertaken of the GMACS modeling that represented work in progress with review examining the work that had been undertaken and providing suggestions of how to move forward in the finalizing the GMACS modeling and developing a Bristol Bay red king crab (BBRKC) model as a case study.

The findings of the review have been presented according to the terms of reference set of the panel:

TOR A. Evaluation of functional forms, estimation approaches, and diagnostics used in GMACS including uncertainty characterization and satisfying required assessment elements.

A key issue in modeling fisheries was that every current stock assessment model has unique characteristics that represent the modeler's approach and method of coding. This makes it difficult for others to pick up and modify the model. In many cases, it is easier for a new modeler to rewrite the model in his own format rather than interpret other modeler's approach. It is also sometimes even difficult for modelers to update their own model if they have not updated it recently and it is not properly documented. The general features established in the GMACS modeling approach and the documentation that goes with it should make it easier to undertake the modifications for the annual assessment and for other modelers to undertake an update of the model. While the focus of model development is for the Alaskan crab stocks, the software should also be able to be applied to other crustacean stocks with similar characteristics. The GMACS framework also provides software (GMR package) for plotting the model outputs that can be used in assessment reports.

Jim Ianelli provided an overview of GMACS highlighting the four major components to the GMACS package:

- Assessment model (ADMB & C++)
- R-packages and Scripts (R & Shell Scripts)
- Code repository (https://github.com/seacode/gmacs)
- Documentation

Some key features of the model are the Git version control and the R package called 'gmr' which supports GMACS. It currently focusses on plotting GMACS outputs. It includes the internal Roxygen

format to code comments. Github's primary function is a code repository. It tracks issues, milestones, and maintains a record of historical development. The system uses a self-documentation of the code (Doxygen-API) which enables the development and update in model to be more easily performed.

GMACS can currently accommodate two sexes, new & old shell conditions, and molt increment data. Some aspects not currently incorporated in GMACS include maturity, tagging, and fishing effort.

Darcy Webber presented the GMACS model in greater detail and these are described in a draft document by the GMACS Development Team (2015a). Some of the key features included:

- Natural mortality is assumed to be sex-specific, size-independent with a number of options for varying the mortality between years if it is not assumed to be constant over time.
- Selectivity and retention/discards representations were described. Selectivity could be changed for blocks of years. Fishing mortality included discards in directed and non-directed fisheries.
- There was discussion about whether the input discard data had discard mortality already applied and this was to be checked.
- If environmental variables could be used to vary parameters such as survey selectivity then there was some consideration of explaining annual selectivity changes using environmental variables.
- A gamma distribution was used in the Growth transition matrix with an option for normal distribution. The gamma distribution could result in 'unrealistic' growth estimates and one option of dealing with this was the application of some truncation being applied to maintain growth within biological 'reasonable' levels.
- Stock-recruitment relationships were not incorporated in GMACS model.
- There was an option for males and/or females biomass to be estimated to represent the mature biomass. Female spawning stock was initially used in the assessments of crab stocks but more recently had moved to mature male biomass.
- There was considerable debate about whether the current set up of the GMACS model as a continuous model rather than a sequential model was appropriate. Many features of the crab biology (e.g. synchronous molting, and spawning at a specific time of year) and the fishery which is currently focused on a few months of the year indicated that a sequential model may be more appropriate. For example, the current assessment measures mature biomass after fishing and before molting. If a continuous model is maintained with GMACS, then the difference between continuous and sequential approaches should be examined on its effect on the trends in the model outputs. An important consideration was the user requirements and definitions of biological reference points.

A key approach to test the integrity of the GMACS model which is modeled with ADMB was to develop a duplicate model using an R-based simulation package by independent scientist Buck Stockhausen. Some of the key features included:

- Model formulated as a pulse fishery and provides a check to the continuous fishery simulation in GMACS
- Recruitment in 2 time blocks to simulate time block approach currently used
- 1 time block for survey
- Sampling error not currently incorporated, but could be included
- M estimated for different time blocks
- Females molting annually
- Allows for different sex ratios at recruitment

- Possible to make multiple runs to enable running different simulations

Jim Ianelli explained that testing of the GMACS model was also being undertaken by generating simulation data to test the GMACS model.

TOR B. Evaluate application of GMACS to the BBRKC stock. Specifically, comment on what important features are missing relative to the current assessment approach?

The current GMACS model is only partially complete as it accommodates two sexes, new & old shell conditions, and molt increment data but does not currently incorporate maturity, tagging, and fishing effort. Therefore it is difficult to compare the GMACS-BBRKC with the ADFG-BBRKC and so comments under this TOR and others provide areas that require attention in the completion of the GMACS model and the BBRKC case study.

Jie Zheng presented the current Bristol Bay red king crab (referred to ADFG-BBRKC) model (Zheng and Sideek 2015) that is being used for stock assessment. Some key features of the model and issues arising from the presentation include:

- The model covered the period since 1975 as this contained more reliable estimates of catch and bycatch from the various fisheries.
- The current BBRKC model estimates the distribution for recruitment over size classes for each sex. There was discussion about whether the model should allow different recruitment abundance between sexes or assume 50:50 ratio. A comparison of the sex ratio in surveys for crabs in the 65-80 and 85-85 mm length class was examined. There was some variation between years which was probably due to measurement error as the largest deviations from 50:50 appeared to be due to small sample size. The overall average was 53% females. The reviewers requested to see the annual survey sample sizes in the 65-80 mm size class to assess the effect of sample size. The annual sample sizes of 8 to 4998 were reported for the 65-80 mm crabs from the survey with 6 samples under 30 in the 40 year survey time series. The years with large samples resulted in a recruitment sex ratio estimates close to 50:50 and there was increased departure from 50:50 for years with small samples. This indicated that assuming a 50:50 recruitment sex ratio would be a reasonable assumption to make in the model.
- It is likely that there may be some smoothing of recruitment, which is about 5-6 year old, between years as linking the recruitment size class to a specific spawning year could not be precise. However, it is still worthwhile examining the stock-recruitment relationship (SRR), particularly as there has been some significant contrast in spawning stock over the years.
- The current BBRKC assessment highlighted the importance of having different M for different time periods e.g. 1980-84 and this flexibility would need to be adopted into GMACS for model fits.
- The 2005, 2007 and 2008 BSFRF independent surveys comparison with NMFS survey show a higher catch rates of small crabs which indicates that recruitment may be measured better by the BSFRF surveys.
- The results of the BSFRF research projects on net selectivity survey and pre-recruit surveys should be evaluated for their possible inclusion in the ADFG-BBRKC and GMACS models.
- Two different NMFS survey selectivities were estimated by sex for two periods: (1) 1975-1981, and (2) 1982-2013 due to modifications of trawl survey gear.
- Growth increments are a function of length and did not change over time for males. For females, three growth increments per molt as a function of length were estimated based on sizes at maturity changes (1975-1982, 1983-1993, and 1994-2014).

- The trend in female size at maturity (SAM) was modeled as a step function for 3 blocks of years for ease of modeling growth. However, the annual SAM values indicated a smooth increasing trend between years rather than a stepwise variation. It would be useful to examine the effect of this assumption on the modeling.
- Variations of growth increments per molt and recruitment length distribution are a gamma function.
- Recruitment abundance estimates indicate highly variable recruitment with last 9 years averaging about 10 million crabs which is well below the 1984-2014 average of 20 million crabs.

A depletion analysis of blocks that are heavily fished and show a significant decline in catch rate should be undertaken as it could provide some valuable insights into fishery dynamics.

Darcy Webber presented the current status of application of GMACS model to the BBRKC fishery (Gmacs Development Team 2015b). Two GMACS models were presented: Onesex model (male only which was more advanced in its preparation) and Twosex model which was very preliminary at the time of review. These models were compared to the ADFG-BBRKC model (Zheng and Sideek 2015):

- The main focus of the Onesex model was a fit to trawl data and high weighting was placed on this component.
- GMACS modeled data since 1960 compared to the ADFG-BBRKC model that commences in 1975. However it is important that discards are estimated for the early years before observed data is available.
- There was discussion about whether growth should be limited to a maximum of 30% of initial size to maintain the maximum growth at a realistic level.
- There are some basic differences in the two model types so it is important to compare the absolute output levels as well as output trends.

TO*R C. Evaluation of GMACS as a flexible assessment modeling tool i.e., potential application to other crab stocks e.g., Tanner crab, data poor stocks (Tier 4), and stocks with unique data sets (e.g., snow crab and Bristol Bay red king crab cooperative survey data).*

The current development of GMACS and its proposed final development will make a very flexible assessment modeling tool. While GMACS has been established primarily for stock assessments for the Alaskan crab fisheries, it should be generally applicable to crustacean fisheries stock assessment that are based on length-structured assessments.

A feature of the GMACS model is that it is being developed for data-limited and data-rich fisheries and accommodates many types of data from multiple sources in an integrated analysis. It is able to deal with incomplete data sets which are likely to be common in many fisheries that are being assessed for an extended period. The observation data include abundance indices, fishing effort, survey catch rates and size composition, retained catch and discards, and tagging data. It also allows for some of the biological parameters, such as growth, size at maturity, selectivity and natural mortality, to vary over time. This is an important component as there can be decadal shifts and/or long-term changes in climate that can influence these parameters in an extended assessment period.

Robert Foy gave an overview of the BSAI crab stocks, Management and Assessment which has State/Federal co-operative management approach. Summary of some key points:

- There are 10 stocks under the fisheries management plan.

- Current Crab Management has a 5 Tier system and 10 crab stocks are in Tiers 3 to 5.
- Bristol Bay Red King Crab State Harvest Strategy is based on Effective Spawning Biomass.
- Catch from all sources are used to assess overfishing.
- TAC is based on abundance estimate of mature biomass not legal abundance.
- BBRKC is a Tier 3 stock.
- Mature male biomass is the focus of assessment v. MSST.
- Annual Biological Catch (ABC) specification has control rules that account for uncertainty.

An audit of the key characteristics of the Alaskan crab fisheries that will need to be developed in GMACS should be undertaken to identify the basic characteristic of the species and fisheries so they could be incorporated into the GMACS stock assessment model. Particular emphasis should be on the characteristics of the fisheries that may be different from BBRKC which has been the main focus for GMACS development. Some information on this has been initiated and was provided during the meeting. The input data and model characteristics of five fisheries have been summarized. It is important that this is completed so the GMACS developing team is generally aware of key issues involved in the other crab fisheries.

Jack Turnock summarized some of the features of Snow and Tanner crabs that are used in the current model that need to be considered in the GMACS modeling, They included: terminal molt, tracking of mature/immature crabs, probability of immature moving to mature stage, addition of a maturity dimension, smooth function for selectivity (not logistic), morphometric identification of mature crabs used to estimate percent mature, growth increment collected by industry and fitted in model, pulse fishery, sequential model, discrete growth in all crabs, discard numbers.

It may not be possible to incorporate all existing features of each of the crab stocks in the GMACS model so decisions need to be made on the design changes to standardize modeling process for the GMACS model while maintaining the important features of the stock. It will probably be due to the CPT to decide on the key model specifications of each stock that will be required within GMACS.

Jim Ianelli provided an overview of API and Wiki user manual. He made the following points:

- Summarized the functions of Git software and Github as the web location
- The system provides an opportunity to keep notes for future development, list outstanding issues that need to be resolved and provide a trouble-shooting guide.
- Changes in the modeling over time are documented and the model can be recreated at any point of time. This is important as changes can result in a breakdown of the model so it is important to be able to return to a previous version of the model.
- The system is able to be cloned to a desktop to enable development outside of Github and then copy back to Github. However, there is a need to resolve the modeling if more than 1 person is working on same issue. A GMACS project modeling team should be identified and be responsible for what changes would be accepted in the GMACS modeling framework.

Other points relevant to this TOR are listed under other TORs.

TOR D. Evaluation of utility of the modeling framework as a community supported modeling approach and practicality for managing into the future.

Once the basic GMACS model structure has been completed, successfully applied to the BBRKC fishery, and the project has been reviewed and published, it should gain strong community support from crustacean stock assessment scientists. While its current focus is appropriately the Alaskan crab fisheries, the final product should be generally applicable to crustacean fisheries stock assessment that are based on length-structured assessments. The way that GMACS has been established provides the structure for other modelers to contribute to its development and use for their stock assessment purposes.

The GMACS User Guide (GMACS Wiki) provides a good overview of the GMACS modeling framework. It acts as a software manual and developer guide so that potential contributors can contribute to the modeling. The 'developer's guide' provides some options for contributing to the source code or modifying the code. It also provides the information to get started in building a model and provides an example of model inputs as well as the outputs from the running of the BBRKC.
The GMACS modeling framework has some important features that makes it a valuable as a community-supported modeling approach:

- The framework is designed with the flexibility to that of the age-structured stock assessment modeling like Stock Synthesis (Martell *et al*. poster). Stock reduction analysis is a data-poor modeling approach that is based on using historical catch data with assumptions about natural mortality, growth and size-distribution of recruits to estimate recruitment that is need to explain the historical catch trends. The method can be extended to include available information on abundance, size composition and tagging data. The poster also highlights the different results coming from 4 alternative models (M1 to M4) for the BBRKC with increasing level of input data (catch, cpue, size composition and initial states) added sequentially to the models 1 to 4.
- It is coded using ADMB which is suited to efficiently estimate hundreds of parameters. ADMB is familiar to many fisheries modelers which enables them to contribute to the modeling. It is formally structured which allows for easy expansion.
- The source files are publically available and open source.
- Git represented version control software that enabled documentation of key changes and would enable saving of model used in each year's assessment. This would allow model comparisons to be easily undertaken. The version controls for different data sets and different models can be easily achieved. This enables model comparisons between previous years' data and between model versions.
- Github overview enabled modeling changes to be rejected and return to previous working versions. A core modeling group should oversee the overall model development and make decisions on what developments should be incorporated into the main branch.
- The use of the GMACS R package (GMR) facilitated the reading of model outputs for model comparison of the key results such as recruitment biomass and annual size frequencies. The package enables the comparison of alternative models by plotting the results of multiple models simultaneously.
- The GMR package also facilitates the writing an updating of the stock assessment report with the model outputs and diagnostics being implemented within reports.
- The modeling package enabled the documentation of functions as they are written using the Doxygen comments to facilitate the development of GMACS.

TOR E. Recommendations for further improvements and comment on the general applicability to the fishery management questions (risk assessment and MSE options).

Recommendations for completion of the project and further improvements for the general applicability to fishery management include:

- Completion of the GMACS-BBRKC model so that a proper comparison can be made with the ADFG-BBRKC model. This includes:
    - Incorporating maturity, tagging, and fishing effort into the model
    - Completing the TwoSex model in BBRKC fishery
    - Undertaking simulation testing
    - Selectivity specification/parameterization flexibility
    - Assessing the stock-recruitment relationship using an appropriate time lag between spawning and recruitment
    - GMACS model has been extended to 1960s but discards were only applied since 1975 and these would have to be estimated for the earlier years
    - Checking whether the input discard data had discard mortality already applied
- Environmental variables could be affecting biological parameters (e.g. growth, size at maturity, survey catchability). In the 2014 NMFS survey, water temperature could have affected the catchability so evaluation of environmental variables explaining annual catchability changes should be examined as a means of adjusting the catchability in the BBRKC model. Water temperature may also affect the spatial distribution of the stock which also affects the catchability if the stock is concentrated into a smaller area.
- The current GMACS model is set up as a continuous model rather than a sequential model. However, many features of the crab biology (e.g. synchronous molting, and spawning at a specific time of year) and the fishery duration indicated that a sequential model may be more appropriate. If a continuous model is maintained with GMACS then the difference between continuous and sequential approaches should be examined.
- The results of the BSFRF research projects on net selectivity survey and pre-recruit surveys should be evaluated for their possible inclusion in the ADFG-BBRKC and GMACS models. Pre-recruit abundance indices could be a valuable component of the assessment as an early warning signal to managers/industry for changes in abundance and facilitate an understanding of the stock-recruitment-environment relationship. This is particularly important in areas where decadal shifts and long-term changes in the environment may be occurring. Examination of the model estimate of recruitment abundance indicates highly variable recruitment with last 9 years averaging about 10 million crabs well below the 1984-2014 average of 20 million crabs (Zheng and Siddeek 2015).
- A GMACS project modeling team should be identified and be responsible for what changes would be accepted in the GMACS modeling framework. In the longer-term there is a need to develop a strategy for long-term maintenance of the GMACS model once it has been completed and being used for stock assessments.
- Complete the GMACS model description paper.
- Complete the documentation of the comparison between GMACS-BBRKC and ADFG-BBRKC.
- Future upgrades of GMACS model could have multiple areas. This could be important as some crab stocks may have different biological parameters in different areas such as growth and maturity and this should allow movement between stocks if necessary. There could be changes

in the spatial distribution of the stock that may warrant changes in the spatial area being assessed.

- Commercial cpue is currently not being used in the BBRKC assessment due to gear changes making comparisons difficult. It may still be worthwhile examining a subset of vessels which have used consistent gear over a number of years to determine a standardized annual cpue using a generalized linear model (GLM) that takes into account factors such as vessel, gear, fishing area, soak time and month. The cpue assessment before and after the introduction of catch quotas are unlikely to be comparable due to changes in the pattern of fishing and other fishing practices such as soak time and high grading. The standardized annual cpue would enable a cross check with survey cpue data and it should be remembered that survey data is not entirely unbiased due to environmental effects on survey trawl catchability.
- Standardized commercial cpue would be particularly valuable for the stocks at tier 5 assessments.
- Update the audit of key characteristics of the crab fisheries that will need to be developed in GMACS to identify the basic characteristic of the fisheries so they could be incorporated into the GMACS stock assessment model.
- A depletion analysis of blocks that are heavily fished during a season such that there is a significant decline in catch rate due to the effects of fishing could provide some valuable insights into fishery dynamics.
- The introduction of crab rationalization has seen the annual collection of economic data on the cost of fishing and revenues. The change in management has probably resulted in an industry focus on maximizing annual profits compared to maximizing catch share. The economic data can be combined with information of projected catch quotas and fishing days for a basic bio-economic assessment of the fishery and an assessment of where the fishery sits relative to the maximum economic yield (MEY) (e.g. Caputi *et al*. 2014). The MEY assessment requires a number of years of catch and fishing days to be assessed as it examines profitability over a number of years (e.g. >5 years) rather than one year's profit. This may be a project that BSFRF may consider as it may be of particular interest to industry to assess whether the level of fishing and quota will result in maximum profitability over the long-term. This bio-economic assessment could become a standard option of the GMACS models that may be of interest in some fisheries.

Appendix 1 References and Material Provided

Anon. (2015). A Guide to the Preparation of Bering Sea and Aleutian Islands Crab SAFE Report Chapters.

Caputi, N., S. de Lestang; C. Reid; A. Hesp; J. How (2015). Maximum economic yield of the western rock lobster fishery of Western Australia after moving from effort to quota control. Marine Policy 51: 452–464. http://dx.doi.org/10.1016/j.marpol.2014.10.006.

Gmacs development team (2015a). A generalized size-structured assessment model for Crustaceans. Draft 15 June 2015, 12pp.

Gmacs development team (2015b). Gmacs Example Stock Assessment. Draft June 2015, 23pp.

Maunder, M. (2012). Generic size based stock assessment model for Alaskan crab stocks. Quantitative Resource Assessment LLC, San Diego, 34pp.

Zheng, J. and M.S.M. Siddeek (2015). Bristol Bay red king crab stock assessment in spring 2015.

Appendix 2 Consulting Agreement between the CIE and Reviewer

Review of GMACS Modeling Framework

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 Representative (COR), and reviewed by CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in **Annex 1**. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following NMFS project. Further information on the CIE process can be obtained from www.ciereviews.org.

Project Description: The Alaska Fisheries Science Center (AFSC) is responsible for assessments of 5 Bering Sea crab stocks. Collectively these crab stocks support valuable commercial fisheries. Recently, scientists at the AFSC and the University of Washington have developed a **Generalized Model for Alaska of Crab Stocks (GMACS).** GMACS is a generalized and flexible size-structured modeling framework. The first version has been designed to develop stock assessment models for the stocks of red king crab in Bristol Bay and Norton Sound, Alaska. The framework makes use of most of the available data sources for both male and female crabs, including survey and fishery indices of abundance and fishery and survey size-compositions. A workshop held in January 2015 contributed to the implementation of GMACS to data for red king crab stocks in order to test its efficacy and determine priorities for development for application to other Alaskan crab stocks. A goal of the project is to provide a standardized size structured assessment that is more transparent than the current approach in which assessment scientists have written species-specific software. A CIE review of the GMACS modeling framework and issues related to further development and application for stock assessment is requested.

The Terms of Reference (ToRs) of the peer review are attached in **Annex 2**. The tentative agenda of the panel review meeting is attached in **Annex 3**.

Requirements for CIE Reviewers: Three CIE reviewers shall conduct an impartial and independent peer review in accordance with the SoW and ToRs herein. Each CIE reviewer's duties shall not exceed a maximum of 14 days to complete all work tasks of the peer review described herein. CIE reviewers shall have the expertise, background, and experience to complete an independent peer review in accordance with the SoW and ToRs herein. CIE reviewers shall have expertise and work experience in analytical stock assessment, including population dynamics, age/length based stock assessment models, data-poor stocks, survey design, and population structure and spatial management.

Location of Peer Review: Each CIE reviewer shall conduct an independent peer review during the panel review meeting scheduled during the week of July 29th, 2015 at the Alaska Fisheries Science Center in Seattle, Washington.

Statement of Tasks: Each CIE reviewers shall complete the following tasks in accordance with the SoW and Schedule of Milestones and Deliverables herein.

Prior to the Peer Review: Upon completion of the CIE reviewer selection by the CIE Steering committee, the CIE shall provide the CIE reviewer information (name, affiliation, and contact details) to the Contract Officer Representative (COR), who forwards this information to the NMFS Project Contact no later the date specified in the Schedule of Milestones and Deliverables. The CIE is responsible for providing the SoW and ToRs to the CIE reviewers. The NMFS Project Contact is responsible for providing the CIE reviewers with the background documents, reports, foreign national security clearance, and information concerning other pertinent meeting arrangements. The NMFS Project Contact is also responsible for providing the Chair a copy of the SoW in advance of the panel review meeting. Any changes to the SoW or ToRs must be made through the COR 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/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.

AFSC will provide copies of the statement of work, stock assessment documents, prior CIE review documents, and other background materials to include both primary and grey literature.

This list of pre-review documents may be updated up to two weeks before the peer review. Any delays in submission of pre-review documents for the CIE peer review will result in delays with

the CIE peer review process, including a SoW modification to the schedule of milestones and deliverables. Furthermore, the CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein.

Panel Review Meeting: Each CIE 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 shall not be made during the peer review, and any SoW or ToRs modifications prior to the peer review shall be approved by the COR 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 the **Alaska Fisheries Science Center** in **Seattle, Washington** during **June 29th - July 1st 2015** as called for in the SoW, and conduct an independent peer review in accordance with the ToRs (Annex 2);
3) In Seattle, Washington during June 29th - July 1st 2015 as specified herein, conduct an independent peer review in accordance with the ToRs (**Annex 2**).
4) No later than **July 15, 2015**, 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 Die, CIE Regional Coordinator, via email to ddie@rsmas.miami.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.

One month prior	CIE sends reviewer contact information to the COR, who then sends this to the NMFS Project Contact
Two weeks prior	NMFS Project Contact sends the CIE Reviewers the pre-review documents
June 29th - July 1st 2015	Each reviewer participates and conducts an independent peer review during the panel review meeting
July 15, 2015	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
July 29, 2015	CIE submits CIE independent peer review reports to the COR
August 7, 2015	The COR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

Modifications to the Statement of Work: Requests to modify this SoW must be made through the COR who submits the modification for approval to the Contracting Officer at least 15 working days prior to making any permanent substitutions. The Contracting Officer will notify the CIE within 10 working days after receipt of all required information of the decision on substitutions. The COR can approve changes to the milestone dates, list of pre-review documents, and Terms of Reference (ToR) of the SoW as long as the role and ability of the CIE reviewers to complete the SoW deliverable in accordance with the ToRs and deliverable schedule are not adversely impacted. The SoW and ToRs cannot be changed once the peer review has begun.

Acceptance of Deliverables: Upon review and acceptance of the CIE independent peer review reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, these reports shall be sent to the COR for final approval as contract deliverables based on compliance with the SoW. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via e-mail the contract deliverables (the CIE independent peer review reports) to the COR (William Michaels, via William.Michaels@noaa.gov).

Applicable Performance Standards: The contract is successfully completed when the COR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards: (1) each CIE report shall have the format and content in accordance with Annex 1, (2) each CIE report shall address each ToR as specified in Annex 2, (3) the CIE reports shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Distribution of Approved Deliverables: Upon notification of acceptance by the COR, the CIE Lead Coordinator shall send via e-mail the final CIE reports in *.PDF format to the COR. The

COR will distribute the approved CIE reports to the NMFS Project Contact and regional Center Director.

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

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

2. The main body of the reviewer report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Summary of Findings for each ToR, and Conclusions and Recommendations in accordance with the ToRs.

   a. Reviewers should describe in their own words the review activities completed during the panel review meeting, including providing a detailed summary of findings, conclusions, and recommendations.

   b. Reviewers should discuss their independent views on each ToR even if these were consistent with those of other panelists, and especially where there were divergent views.

   c. Reviewers should elaborate on any points raised in the Summary Report that they feel might require further clarification.

   d. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

   e. The CIE independent report shall be a stand-alone document for others to understand the proceedings and findings of the meeting, regardless of whether or not they read the summary report. The CIE independent report shall be an independent peer review of each ToRs, and shall not simply repeat the contents of the summary report.

3. The reviewer report shall include as separate appendices as follows:

   Appendix 1: Bibliography of materials provided for review Appendix 2: A copy of the CIE Statement of Work

   Appendix 3: Panel Membership or other pertinent information from the panel review meeting.

Annex 2: Terms of Reference for the Peer Review

Review of GMACS Modeling Framework

CIE reviewers shall address the following Terms of Reference during the peer review and in the CIE reports.

CIE reviewers shall address the following Terms of Reference during the peer review and in the CIE reports.

a. Evaluation of modeling framework as a flexible assessment modeling tool.
b. Evaluation of functional forms and estimation frameworks, used in GMACS.
c. Evaluation, of the diagnostic products of GMACS. and the ability to compile assessment documents
d. Evaluation of utility of the modeling framework as a community supported modeling approach and practicality for managing into the future.
e. Evaluation, of the flexibility of the model to address the stock specific characteristics of assessed species including: spatial management (e.g., Tanner crab), data poor (Tier 4 assessments), and stocks with unique data sets (e.g., snow crab and Bristol Bay red king crab cooperative survey data).
f. Recommendations for further improvements and comment on the general applicability to the fishery management questions (risk assessment and MSE options).

Appendix 3 CIE reviewers

CIE reviewers were:

Dr Nick Caputi
Dr Mike Bell
Dr Malcolm Haddon