Independent Peer Review of the Aleutian Islands Golden King and Norton Sound Red King Crab Stock Assessment

Center for Independent Experts (CIE) Review prepared by:

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Executive Summary

An independent peer review of two king crab stock assessments—Aleutian Islands Golden King Crab (AIGKC, *Lithodes aequispinus*) and the Norton Sound Red King Crab (NSRKC, *Paralithodes camtschaticus*)—was conducted June 18-21, in Seattle, Washington. The document presented here was prepared under contract to the Center for Independent Experts, and responds to the Terms of Reference for the review.

Both stocks were characterized by fisheries that had undergone significant changes in fleet composition, areas fished, gear and soak time. Such changes have resulted in challenges to the catch rate standardizations. In the case of the Aleutian Islands, Golden King Crab, this issue was particularly important, as there is no fishery independent survey used in the base case model formulation. An industry survey has been started and offers good promise, but only three years of the surveys are available at this point. Both king crab stock assessments are hampered by an absence of fundamental biological information, including migrations, growth, early life history, and natural mortality. In many cases, this necessitates using proxies from other stocks that appear from a recent genetics study to be unrelated.

Notwithstanding the above limitations, it was considered that the population model and assessment results provide a sound basis for fishery management decisions at the current Tier level. Notwithstanding this, significant improvements in model robustness and accuracy can be gained by investing further resources into survey expansion and tagging studies (AIGKC) and survey re-analyses and tagging studies (NSRKC).

Background

The document presented here contains an independent peer review of two king crab stock assessments, following a Center for Independent Experts (CIE) Review conducted June 18-21, in Seattle, Washington. It is prepared under contract to the Center for Independent Experts, following the Statement of Work contained in Appendix 2.

The stocks reviewed included the Aleutian Islands Golden King Crab (*Lithodes aequispinus*) and the Norton Sound Red King Crab (*Paralithodes camtschaticus*). These stocks are referred to in the following report as AIGKC and NSRKC, respectively. The stocks are managed cooperatively between the state (Alaska Department of Fish and Wildlife) and federal authorities (US National Oceanic and Atmospheric Agency). The authors of the stock assessments reviewed were from the former agency.

Description of the Individual Reviewer's Role in the Review Activities

My role in the process was as a CIE-appointed peer reviewer only. There were three independent experts comprising the review panel (Appendix 3). My role in the process was to prepare for the meeting by reading the supplied materials, attending the four-day long Seattle meeting, and to write a report summarizing my views according to the Terms of Reference.

During the course of the review, the review panel requested some additional analyses (see Appendix 4). The authors of the stock assessment reviews provided comprehensive responses to our requests, which was greatly appreciated. The additional analyses are discussed later in this report under the appropriate Term of Reference.

Summary of Findings for each ToR

1. Strengths and weaknesses of the current Aleutian Islands golden and Norton Sound red king crab stock assessment models with regard to population dynamics, data (fishery-independent surveys, CPUE indices, etc.), likelihood components, and model evaluation.

AIGKC

The abundance indices available for AIGKC are all fishery-dependent, an unusual situation for Alaskan fishery resources. Compounding this limitation, there have been several important changes in the fishery, necessitating careful treatment of the CPUE information. Such changes included a drastic reduction in the number of vessels in the fishery that occurred in 2005, a point referred to as fishery rationalization.

A further important consequence of fishery rationalization was explored during the CIE review. The Panel requested information on the monthly distribution of the landings both pre- and post-rationalization. As shown below, there have been significant changes in the distribution of the fishery catch that have implications for the analyses. For example, the bycatch mortality rate is taken to be 18% throughout the year, and is based on observations from the Bristol Bay king crab fishery. It is reasonable to presume that the bycatch mortality rate may vary on a seasonal basis, and changes in the seasonal distribution of the fishery likely will affect the overall discard mortality rate.

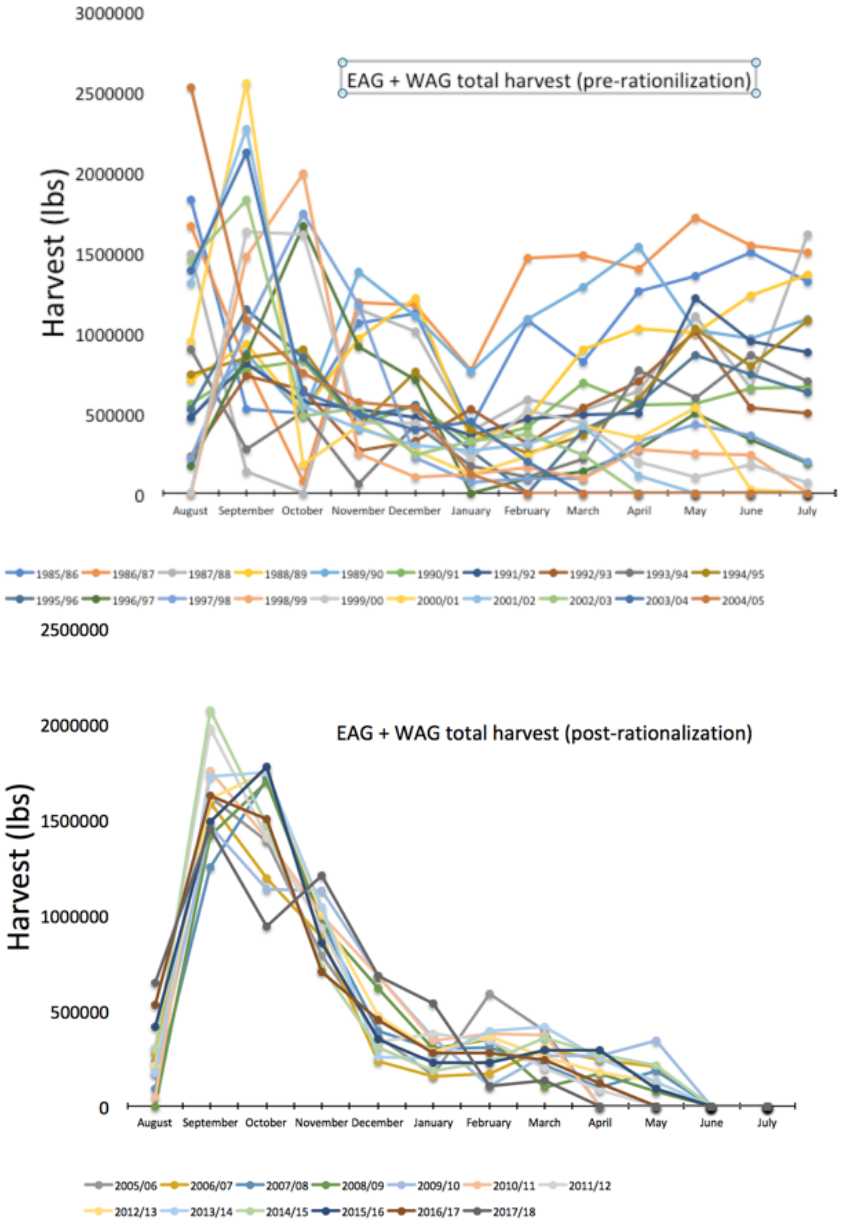

Fig. 1. Trends in monthly catch of AIGKC in the pre- and post- fishery rationalization periods. EAG means east of 174° W longitude (EAG) and west of 174° W longitude (WAG). Figures provided courtesy of B. Daly during the CIE Review, June 18-21 2018.

As the population model is length-based, there was considerable discussion of the importance of growth estimates derived from the tagging studies. From analyses produced by the author at the request of the CIE panel, it was shown that the length composition of the tagged crabs at release was broad and covered the general size range in the commercial fishery. It was also shown that the predicted sizes at age compared well with those observed from the mark-recapture studies.

The model assumptions and data weights appeared reasonable, although some appeared to be assigned by convention rather than analyses (for example, catch weight was assigned a weight of

500 based on it being known with presumed high accuracy and precision). Model equations and weights were well documented in an Appendix. The diagnostics presented appear to indicate that the model fit the observations well in most cases, and the retrospective analyses did not reveal serious issues (although an absence of retrospective analyses for recruitment is noted). A number of alternative model formulations were run as specified in earlier peer reviews to evaluate the sensitivity of the base case to certain assumptions, such as natural mortality and selectivity. Overall, the base case appears to perform well for both the EAG and WAG components of the AIGKC stock, and I concur that the model provides an adequate basis for fisheries management advice. I also note that this stock seems to be managed quite conservatively, with a TAC considerably less than the ABC. The ABC buffer is also set larger than many other Tier 3 stocks because of the reliance on commercial fishery catch rates.

The CIE Review Panel noted that while the assessment models are frequently updated, there has been no attempt to assess the historical performance of earlier models. By this, we meant those past models' projections should have been compared with the current estimates and trends of MMB from the contemporary model formulation.

NSRKC

While the AIGKC stock has significant deficiencies in biological knowledge, the shortcomings for the NSRKC resource are even more acute. Life span, habitat, distribution, maturity and size-dependent movement patterns are some of the biological components that are unknown. For modeling purposes, certain key biological assumptions are based on Bristol Bay Red King Crab (a questionable proxy, as a recent biological study shows the two stocks to be unrelated). To some extent, the paucity of biological and life history information for this stock is understandable, as Norton Sound is ice-covered for a significant part of the year. The absence of this key information impacts the credibility of the results, however. I will return to this topic later when discussing research priorities. Similar to AIGKC, the NSRKC fishery has had substantial changes that pose challenges for standardization of catch rates. Unlike the AIGKC, however, there are survey series available to assist the stock assessment.

The population dynamics model provides estimates of mature male biomass, as was the case for AIGKC. The most recent assessment contained five alternative scenarios to the base case, and focused on the M and size selectivity assumptions. Surprisingly, only one of the two surveys is freely estimated within the model. While the CIE panel enquired about the reason for this, I don't recall that a satisfactory response was received. The biggest issue with the assessment results, in my view, is the apparent large increase in M at large sizes. In reading some of the SSC reports, such a large increase has not been documented for other king crab stocks in Alaska.

Compared with the AIGKC fishery model, I have less confidence in the robustness of the results. Overall, while the model likely provides reasonable guidance for the current Tier 4 requirements, improvements in our understanding of the biology and life history of the stock are urgently required, particularly if the stock is to be considered for Tier 3.

2. Assess the strengths and weaknesses of the current Aleutian Islands golden and Norton Sound red king crab stock projection models, with regard to methodology.

AIGKC

30-year projections were completed from the 2018 model (two scenarios), and provided abundances by length class and recruitment. Annual recruitment was fixed by random draw from the period 1987-2012 (a period when recruitment was relatively precisely estimated). The terminal abundance in the population model (year 2016) was randomized by a lognormal random error. The projections provided mature male biomass, total catch, retained catch and the probability of overfishing relative to the federal overfishing control rule. These procedures for the projections seemed straightforward and reasonable.

NSRKC

The 2018 SAFE document provided for review contained estimates of MMB from 1976 to 2017 with no projections into the future.

3. Review the fishery-dependent and -independent data inputs to the stock assessment with regard to quality of information and appropriateness to the assessment for Aleutian Islands golden king crab and Norton Sound red king crab.

AIGKC

Significant changes also occurred in management measures, gear and vessels at the time of fishery rationalization (2005). The CPUE analysis is conducted over the entire time period to the present, thus including the year when fishery rationalization occurred. In my experience, important wholesale changes in the fishery with no period of overlap between "old" and "new" practices usually indicate that the data series be split into two series, and the CPUE analyses done separately.

Observer information is used to generate CPUE indices since rationalization. However, the coverage has been declining and is now quite low (2 to 4% of all pots hauled), creating uncertainty if this information reflects the whole fishery.

I did not consider it appropriate to treat "vessel" and "captain" as independent main effects in the catch rate standardization. We heard comments from the authors that while skippers may work on different vessels, they were usually associated with a particular vessel. Still on the CPUE analyses, I found it surprising to hear that there were so many degrees of freedom associated with the "gear" main effect (24 levels). This is too many, I believe, and further data filtering/combination is required to reduce the level of contrasts for this particular main effect to reflect the principal gears used in the fishery. Consulting with the fishing industry could help obtain realistic and sensible ways of combining gear types that have essentially similar selectivities.

The stock assessment authors referred to a recent paper by Bentley et al. (2012) that introduced a graphic approach for illustrating CPUE results referred to as influence plots. While I agree that this is a helpful way to illustrate the relative significance of the various factors used in the catch rate standardization, I also note that the Bentley et al. (2012) paper notes that the technique is helpful for explaining results to stakeholders, and also to seek their validation of the factors used in the catch rate standardization. I found it interesting that in the AIGKC case, no such outreach

has been made with the fishing industry to validate the catch rate models (according to the response to a question that I raised).

During the CIE Panel Review, we requested time series for standardized CPUE residual. While the EAG component showed no particular trend, the WAG showed a trend over time (successive positive and negative residuals) that requires some further thought and explanation in the next assessment:

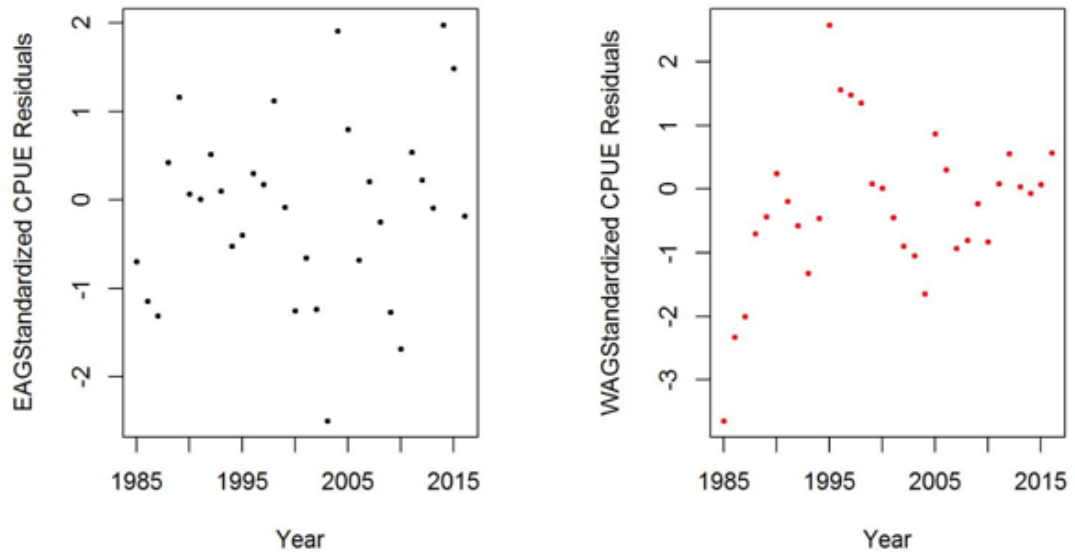

Fig. 2. Standardized CPUE residuals from the base case model, AIGKC.

Overall, however, I concluded that the catch rate standardization is reasonable, and accounts well for the observed variation in catch rates ($r^2 = 0.50$). I did notice that the QQ diagnostics for the post-rationalization period indicate some model misspecification. This may be a subject for future CPUE analyses. It is also interesting (and surprising) that the standardized indices differ only very slightly from the nominal CPUE.

It was noted that an industry survey has been commenced, with three years of data now available. The CIE panel noted that while the survey will augment the understanding of AIGKC population dynamics by fishing in non-traditional areas and using smaller mesh pots, it cannot truly be considered a fishery independent index since the survey does not standardize for soak time and depth.

NSRKC

Two fishery-independent surveys are available: a triennial NMFS trawl survey that started in 1976, and a triennial ADFG trawl survey that started in 1996. Both surveys produce estimates using the swept area method. The area covered by the surveys has varied from year to year,

creating a challenge for analysts. Importantly, for the ADFG survey in years when all stations were not sampled, it is assumed that the catches would have been zero at the unsampled stations. This would seem to introduce a bias into the analyses, and alternative methods should be examined for filling in for untrawled stations.

The commercial fishery standardization followed similar methods to the AIGKC, with the option of censoring vessels that did not have a long enough history in the fishery. Particular limitations with the CPUE analyses include different seasonality in the fishery over the series, as well as changes to the fleet and areas fished. The commercial fishery standardization does not appear to get the same weight in the assessment as in the AIGKC model.

The comparatively small vessels in this fishery make it difficult to have adequate observer coverage. In consequence, there is limited information on discarded catches. Changes in management and fishery practices (such as occurred in 2012) thus have unknown impacts on patterns of discarding. However, a small-scale observer program has been commenced in 2012. There is hope that with improved discard information, there will be an ability to estimate OFL and ACL in terms of total catch rather than retained catch, which is the current practice.

4. Recommendations for alternative approaches to evaluate model convergence and compare multiple models for Aleutian Islands golden king crab and Norton Sound red king crab.

AIGKC

The CIE Panel did not request additional model runs. However, I feel that there is scope in the future to investigate the impact of estimating the maturity at length outside of the model instead of internally, a suggestion also made by the SSC.

NSRKC

The stock assessment author explained that previous model explorations have focused on the recognized model deficiencies – namely, the assumption of high M on the oldest size classes, and the maturity assumption. Generally speaking, those investigations did not reveal large changes in the trends in MMB.

Two additional runs were made at my request during the CIE review (Appendix 4). The stock assessment author produced analyses that included the most contemporary CPUE information only (after fishery rationalization). Another run excluded the unusually high survey value in the penultimate year of the survey. Interestingly, both scenarios had no discernable effect on the trends in male mature biomass (MMB, see Figure below).

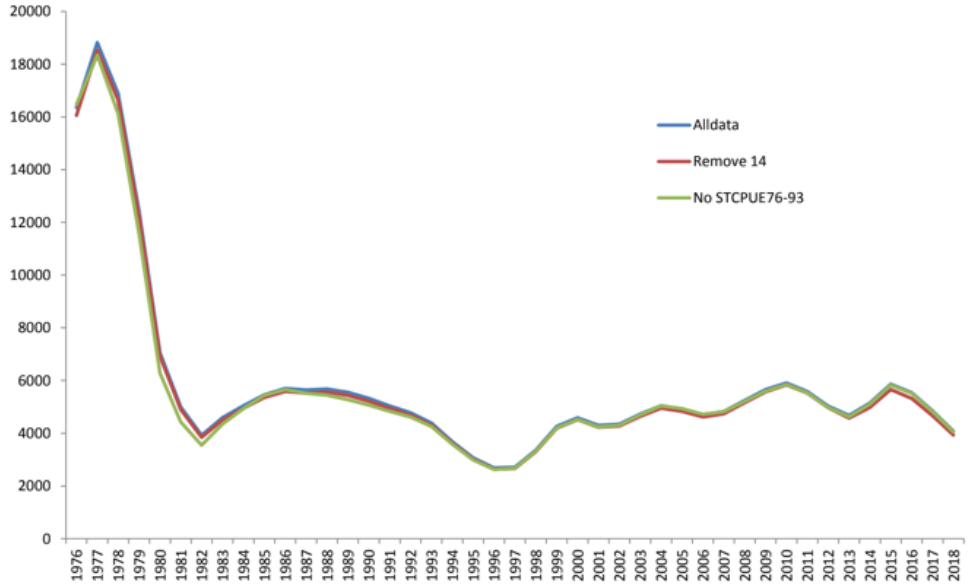

Fig. 3. Impact of CIE requested changes in inputs to the estimates of Male Mature Biomass over time.

While the model for NSRKC appears to reflect significant deficiencies in our understanding of the biology of this resource, it is worthwhile pointing out that over the assessment history, and considering the various model formulations that have been explored, the overall trends in MMB appear to be quite consistent. The figure below was provided by the stock assessment author during the review, and illustrates this point.

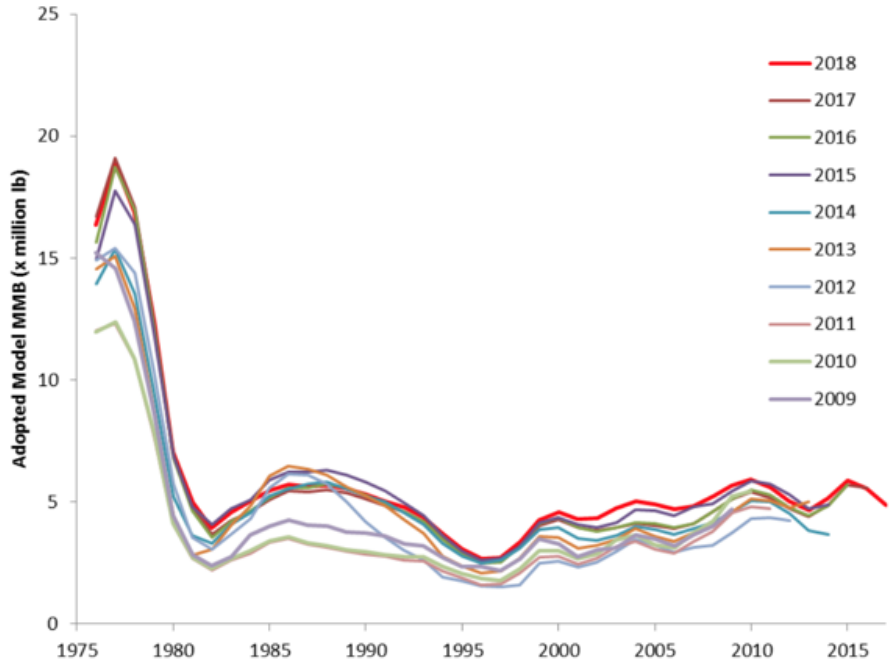

Fig. 4. Comparison of trends in mature male biomass (MMB) from the adopted base case models over time.

5. Recommendations on how various data sets should be weighted, relative to one another, in the Aleutian Islands golden king crab and Norton Sound red king crab models.

AIGKC

Weighting decisions for the model were made quite clear during the stock assessment author's presentation, and could also be found in Table A2 of the Crab SAFE report. The author indicated that retained catch is given an arbitrary and high weight of 500, because retained catch data are more reliable than other data sets. Groundfish bycatch, on the other hand, is comparatively poorly known, and were given a lower weight (0.2 per year). CPUE data were assigned a weight of 1.0. These weightings seem reasonable, and I don't have suggestions for alternatives.

NSRKC

Weighting decisions were less clear here, and I had to dig into the stock assessment document. I notice that retained catch data appear to receive lower weight than in the AIGKC, and I was unclear why this difference occurred. I also noticed that the mark-recapture data were given a weight of 0.5 in 2015, and an explanation of this weighting was not provided. It would be interesting to know why this value was assigned.

6. Recommendations on how the reduction in number of vessels and fishing area shrinkage can be addressed in the Aleutian Islands golden king crab model.

From reading the CPT minutes, I understand that there has been a decline in the area fished from 1990 to 2004, and some additional non-core areas were fished in 2013-15 due to catches during the survey. This inconsistent coverage has led to concerns that either hyper-stability or hyper-deletion (Schnute and Hilborn 1993) could occur without it being detected from the commercial fishery CPUE information.

I also saw from the CPT document that there have been attempts to define core areas for CPUE analyses, but such approaches have been criticized as still being prone to distortions in the fundamental relationship between CPUE and population abundance. I concur with the criticism raised by the CPT in this regard.

The existing CPUE analyses attempts to deal with the issue of reduction in number of vessels by filtering the data to identify vessels that have had involvement with the fishery more than a threshold number of years. This is a straightforward practical approach that has been used in other assessments.

In my view, the newly-developed industry survey offers the best hope to avoid problems with the changes in the area fished or number of vessels over time. It is also possible that the survey could be a platform for experimenting with different gear that have been used over the earlier period and comparing with contemporary gear. In that way, the relative power of the gear could be compared against the results from the standardization analysis.

7. Recommendations for integrating fishery-independent survey data into the Aleutian Islands golden king crab assessment.

Currently, there are three data points available from the survey. The survey covers the EAG only. It is interesting to note that the observer CPUE for the EAG indicates a declining trend over the three years when the industry survey data are available, whereas the survey information is generally flat (Figure B.5). Given that there are only three years available, it is probably premature to be concerned about these different trends, but should they persist they will have to be reconciled. For the survey information to be of the most use for the stock assessment, the coverage should also be expanded to include the whole stock area (i.e. the WAG).

8. Recommendations for quality control of input fishery-dependent and -independent data for Aleutian Islands golden king crab and Norton Sound red king crab.

AIGKC

The coverage of the pot fishery by observers has been declining considerably. A simulation study needs to be done to test whether recent levels of observer coverage are sufficient to characterize the catch and effort by the entire fleet.

NSRKC

There seems to be an important opportunity to improve the Norton Sound red king crab landings information. Such data are self-reported by the fishing industry. In this situation, I understand that a single processor is involved with handling the catch. It should be very straightforward to compare the annual production records to the catch data to provide a validation of the self-reported catch.

9. Recommendations for research that would reduce the uncertainty associated with key parameters assumed or estimated in the assessment models for Aleutian Islands golden king crab and Norton Sound red king crab.

AIGKC

The lead stock assessment scientist produced a list of data gaps. I include my own views in parentheses after each suggestion.

1. An independent estimate of *M* is needed - tagging experiments can help. (In the view of this reviewer, tagging using DST tags is particularly attractive to determine if larger individuals move into unfished areas. Such tags have much lower cost compared with pop-up satellite archival tags, and the observation that there are reasonably high recaptures of conventional tags in the commercial fishery makes this approach feasible. I suggest stratifying releases by size class and sex to make the most of this important opportunity. I also suggest focusing the effort on newly-molted individuals, assuming that the tags would be lost after the next molt unless recaptured in the fishery. An example of a recent study that used a similar approach may be found in Hunter et al. (2013). If conventional tagging studies are to be considered for natural mortality estimation, a fraction of the releases should be double-tagged to allow the estimation of tag loss.

2. Independent estimates of molting probability and growth are needed—lab and tagging experiments are needed to determine these parameters. (see my comments from above).

3. An arbitrary 20% handling mortality rate on discarded males was used. An experimentally based independent estimate of handling mortality is needed. (A study we did to establish a methodology to determine Atlantic halibut discard mortality can be found here. The method may have some applicability for king crab discard mortality rates. http://www.nrcresearchpress.com/doi/abs/10.1139/f89-114#.WzU_5C0ZM6g).

4. The Aleutian King Crab Research Foundation program, which is involved in the independent surveys, can help to fill the gaps in a number of assessment information and update biological information such as length-weight and maturity. (I certainly agree. Furthermore, I endorse expanding the effort to include WAG as well).

5. Chela height and carapace length data are used to get the 50% maturity size needed for MMB estimation. The maturity data available to us are not sufficient and collected in 1984 and 1991. More and recent data are needed. ADF&G is planning to collect these data from the fishery. (I agree with this).

6. Morphometric measurements provide morphometric maturity size. Ideally, an experimental study under natural environment condition is needed to collect male size at functional maturity data to determine functional maturity size. (I agree with this, but seems potentially lower priority relative to other concerns).

A further research recommendation not included in the list above is to investigate the early life history of golden king crab to determine if recruitment could originate from outside the stock area. During the CIE review, there were extensive and rather speculative discussions on this point. But without studies of the vertical distribution and behavior of early life history stages with respect to ocean current patterns, the source of AIGKC recruitment cannot be determined with certainty.

NSRKC

As a general observation, when the lead scientist was asked about data deficiencies, he tended to focus on modeling gaps. In my view, more investment in understanding the life history and biology of red king crab should be given precedence. The list below reflects my own views on the research needs for this stock.

1. One option for exploring the available NSRKC survey information would be to use some form of post-stratification (probably using depth) to allow generation of stratified estimates of abundance. A second option (also identified by the CPT and SSC) is to employ model-based approaches that could make use of all sampling conducted each year, while appropriately propagating the uncertainty associated with missing stations. This would seem to be potentially a very important suggestion, and I certainly endorse this as a research recommendation.

2. The stock assessment scientist suggested that it might be desirable to move from triennial surveys to annual surveys. My response to the review is that obtaining better information on growth might help inform this decision. If the stock assessment scientist's hunch that the lifespan of the crab is only 10 years, then having more frequent surveys might be advised. Alternatively, if

it is 20-25 years, then triennial surveys might be appropriate for monitoring changes in a relatively long-lived population.

3. With this in mind, studies of the age and growth of red king crab are an important research priority.

4. Knowing where the larger crabs go (or if they are truly subject to higher natural mortality) is a key priority and one where DST tagging could assist as described for AIGKC above.

5. Independent estimates of discard mortality.

10. Suggested priorities for future improvements to the stock assessment/projection models for Aleutian Islands golden king crab and Norton Sound red king crab.

AIGKC

I suggest focusing on the industry survey and its expansion into the WAG as the first priority (as this very useful initiative is already underway), and secondarily, as resources permit, planning a tagging study to determine the distribution of larger crabs and their natural mortality.

NSRKC

Since the data are already available, I would suggest following up on the CPT and SSC's suggestions to examine other methods to account for the missing stations in the survey data. Relative to other research recommendations, this one has comparatively little resource requirements, and it is clear to me that analytical capability exists to complete the work.

The NMFS Review Process

I found the review process to be generally very laudable. There was adequate time for questions and comprehensive responses, including model re-runs in some cases. The meeting agenda was logically organized and key people attended the meeting that could assist with CIE panel review. The lead scientists did a good job in summarizing and presenting their work. I also appreciated their willingness to conduct the additional exploration of the data that we requested. The Chair, Dr. William Stockhausen, did a good job in managing the meeting and the associated logistics. I thank him for his hospitality, and helping ensure that the meeting went well.

The use of Google drive for document sharing worked reasonably well, and it was convenient to have access to the material before, during and after the meeting. One quibble I had was that stock assessment authors provided many iterations of presentations and documents right up to the day of presenting. This was inefficient because we had limited time to prepare for the meeting. It was frustrating to carefully read the background material and electronically annotate the presumed review document, only to find that the material had been updated at the last minute (the day before the meeting, for example). Stock assessment authors should provide their documentation a week before the meeting, and asked not to update them unless absolutely essential to do so.

Conclusions

The stock assessments reviewed for Aleutian Islands golden king crab and Norton Sound red king crab interpret the available data in a reasonable manner, and provide a sound basis for management decisions at the current Tier level. Notwithstanding this, significant improvements in model robustness and accuracy can be gained by investing further resources into survey expansion and tagging studies (AIGKC) and survey re-analyses and tagging studies (NSRKC).

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Hunter E, Eaton D, Stewart C, Lawler A, Smith MT. 2013. Edible Crabs ‘‘Go West’’: Migrations and Incubation Cycle of *Cancer pagurus* Revealed by Electronic Tags. PLoS ONE 8(5): e63991. doi:10.1371/journal.pone.0063991.

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Appendix 1: Bibliography of materials provided for review

A. General

A.1 Stram, D. et al. 2017. Introduction chapter. In: 2017 Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries in the Bering Sea and Aleutian Islands. North Pacific Fisheries Management Council, Anchorage, AK. Report compiled by the CPT. https://www.npfmc.org/fishery- management-plan-team/bsai-crab-plan-team/

B. Norton Sound red king crab specific

B.1 Hamazaki and Zheng. 2017. Norton Sound red king crab assessment chapter. In: 2017 Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries in the Bering Sea and Aleutian Islands. North Pacific and Tanner Crab Fisheries in the Bering Sea and Aleutian Islands. North Pacific Fisheries Management Council, Anchorage, AK. Report compiled by the CPT https://www.npfmc.org/fishery-management-plan-team/bsai-crab-plan-team/

C. Aleutian Islands golden king crab specific

C.1 Siddeek et al. 2017. Aleutian Islands golden king crab assessment chapter. In: 2017 Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries in the Bering Sea and Aleutian Islands. North Pacific Fisheries Management Council, Anchorage, AK. Report compiled by the CPT. https://www.npfmc.org/fishery-management-plan-team/bsai-crab-plan-team/

C.2 Siddeek et al. 2017. Aleutian Islands golden king crab model discussions and scenarios for May 2018 Assessment. Draft report for the September 2017 Crab Plan Team meeting. granicus.com/npfmc/meetings/2017/9/964_A_Crab_Plan_Team_17-09-19_Meeting_Agenda.pdf

C.3 Siddeek et al. 2017. Effect of data weighting on the mature male biomass estimate for Alaskan golden king crab. CAPAM Data weighting Workshop, San Diego, California. Fisheries Research, 192: 103-113.

C.4 Siddeek et al. 2016. Standardizing CPUE from the Aleutian Islands golden king crab observer data. In: T.J. Quinn II, J.L. Armstrong, M.R. Baker, J. Heifetz, and D. Witherell (eds.), Assessing and Managing Data-Limited Fish Stocks. Alaska Sea Grant, University of Alaska Fairbanks, Alaska, USA, pp. 97-116.

C.5 Siddeek et al. 2016. Estimation of size–transition matrices with and without molt probability for Alaska golden king crab using tag–recapture data. Fisheries Research. 180:161-168.

C.6 May 2017 CPT minutes; June 2017 SSC minutes; and September 2017 CPT minutes (minutes will be submitted).

C.7 Siddeek et al. 2013. Standardization of CPUE from Aleutian Islands Golden King Crab Fishery Observer Data. Presented at the September 2013 CPT meeting King Crab Fishery Observer D (document will be submitted)

Appendix 2: CIE Statement of Work

Statement of Work
Alaska Department of Fish and Game
Center for Independent Experts (CIE)
Program External Independent Peer Review
Aleutian Islands Golden King and Norton Sound
Red King Crab Stock Assessment Review

Background

The National Marine Fisheries Service (NMFS) is mandated by the Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, and Marine Mammal Protection Act to conserve, protect, and manage our nation's marine living resources based upon the best scientific information available (BSIA). NMFS science products, including scientific advice, are often controversial and may require timely scientific peer reviews that are strictly independent of all outside influences. A formal external process for independent expert reviews of the agency's scientific products and programs ensures their credibility. Therefore, external scientific peer reviews have been and continue to be essential to strengthening scientific quality assurance for fishery conservation and management actions.

Scientific peer review is defined as the organized review process where one or more qualified experts review scientific information to ensure quality and credibility. These expert(s) must conduct their peer review impartially, objectively, and without conflicts of interest. Each reviewer must also be independent from the development of the science, without influence from any position that the agency or constituent groups may have. Furthermore, the Office of Management and Budget (OMB), authorized by the Information Quality Act, requires all federal agencies to conduct peer reviews of highly influential and controversial science before dissemination, and that peer reviewers must be deemed qualified based on the OMB Peer Review Bulletin standards[1]. Further information on the Center for Independent Experts (CIE) program may be obtained from www.ciereviews.org.

Scope

The Alaska Fisheries Science Center (AFSC) Resource Ecology and Fishery Management (REFM) Division requests an independent review of the stock assessment/projection models used to conduct the Aleutian Islands golden king crab (AIGKC) and Norton Sound red king crab (NSRKC) stock assessments. Both stocks are managed by the North Pacific Fishery Management Council (NPFMC) under the Fishery Management Plan (FMP) for the Bering Sea and Aleutian Islands King and Tanner Crabs, which was established in accordance with the Magnuson-Stevens Fishery Conservation and Management Act. This FMP establishes a cooperative State/Federal management regime that defers management of ten crab stocks to the State of Alaska with

[1] http://www.cio.noaa.gov/services_programs/pdfs/OMB_Peer_Review_Bulletin_m05-03.pdf

Federal oversight. Under this cooperative regime, researchers with the Alaska Department of Fish and Game (ADFG) are responsible for preparing draft stock assessments for the AIGKC and NSRKC stocks and presenting them to the NPFMC's Crab Plan Team (CPT) and the Science and Statistical Committee (SSC) for review. The assessments for both stocks utilize size-based, integrated assessment models that have been under continuous development both prior to, and following, approval for use by the NPFMC. The NSRKC stock assessment model was approved before the current FMP was implemented in 2008, whereas the AIGKC stock assessment model was approved in 2017.

AIGKC is the only stock in the FMP that relies exclusively on fishery-dependent data for its size-structured assessment model. In the absence of annual fishery-independent trawl or pot surveys, the model counts on fishery catch, effort, size composition, and tagging information to assess the stock in two adjacent management areas (east of 174^{o} W. longitude [the Eastern Aleutian Islands golden king crab fishery (EAG)] and west of 174^{o} W. longitude [the Western Aleutian Islands golden king crab fishery(WAG)]). Standardized observer and fishery catch-per-unit-effort (CPUE) indices and independently-estimated size-specific probabilities of maturity play an important role in the model's estimation of abundance and mature male biomass (MMB). The CPT and SSC accepted the model in 2016 and recommended using it, together with a harvest control rule based on "Tier 3" criteria, to set the overfishing level (OFL) and allowable biological catch (ABC) for the 2017/18 fishing season. Thus, the assessment level was upgraded from "Tier 5" (which uses mean catch over a specified time period to determine the OFL, rather than an assessment model) to "Tier 3" (which uses a size-structured model to determine OFL based on $F_{35\%}$ and $B_{35\%}$ proxies for F_{MSY} and B_{MSY}). The model was rather controversial throughout its initial development, and it continues to evolve. Although a new fishery-independent pot survey data set is limited to three years (2015-2017), and is only from the EAG area, it is planned to be incorporated into the model as separate abundance indices. A scientific peer review that is strictly independent of all outside influences will enhance the credibility of the model and contribute to further refinement of the model. The reviewers will be asked to address issues related to the use of fishery dependent and independent CPUE as true abundance indices and reduction in number of vessels and area since crab rationalization in 2005, and recommends way to improve the model to address those issues.

The NSRKC assessment model differs from other assessment models used for stocks under the FMP in terms of the timing of fisheries and life-history events. Fisheries occur in winter (Feb – April) near the coastal area of Norton Sound and in the summer (July – September) further offshore where about 80% of harvests occur. The fishery is currently managed using "Tier 4" considerations (the B_{MSY} proxy is based on an average mature male biomass over some time period while the proxy for F_{MSY} is based on natural mortality rates) and the OFL is calculated as retained catch for both winter and summer fisheries combined. For this stock, molting occur in late September, as opposed to other red king crab stocks where molting occurs in the spring. An important, but problematic, feature of the assessment model for NSRKC is the estimation of size dependent mortality; the model estimates that natural mortality of large (> 123mm CL) mature crab is about 3 times higher than for crabs in other length groups. This has been used primarily to improve model fit (i.e., the model would otherwise overestimate the proportion of large crab), but is not well-supported by what is known of the stock. Researchers have

examined alternative model scenarios such as: 1) large crabs moving out of the area, 2) higher natural mortality across all crabs, and 3) faster or arrested molting and growth. However, none of these alternative model scenarios have produced better or more reasonable results than the current model with size-dependent natural mortality. Reviewers will be asked to address this unique assumption and suggest further alternative scenarios.

The individual review reports are to be formatted with content requirements as specified in **Annex 1**. The Terms of Reference (ToRs) of this peer review are attached in **Annex 2**. The tentative agenda of the panel review meeting is attached in **Annex 3**.

Requirements

The selected three (3) CIE reviewers shall have the necessary qualifications to complete an impartial and independent peer review in accordance with the tasks and ToRs described in the Statement of Work (SoW) herein. The CIE reviewers shall have expertise in conducting stock assessments for fisheries management and be thoroughly familiar with various subject areas involved in stock assessment, including population dynamics, size-structured models, harvest strategies, and the Automatic Differentiation (AD) Model Builder programming language to complete the tasks of the scientific peer-review described herein. Familiarity with invertebrate stock assessment, knowledge of crab life history and biology, and harvest strategy development is desirable.

Tasks for Reviewers

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. 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 this peer review.

A. General

A.1 Stram, D. et al. 2017. Introduction chapter. In: *2017 Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries in the Bering Sea and Aleutian Islands. North Pacific Fisheries Management Council, Anchorage, AK.* Report compiled by the CPT. https://www.npfmc.org/fishery- management-plan-team/bsai-crab-plan-team/

[Review the "Stock Status Definitions" and "Status Determination Criteria" for background information on the NPFMC's status criteria and approach to OFL determination for crab stocks.]

B. Norton Sound red king crab specific

B.1 Hamazaki and Zheng. 2017. Norton Sound red king crab assessment chapter. In: 2017 Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries in the Bering Sea and Aleutian Islands. North Pacific Fisheries Management Council, Anchorage, AK. Report compiled by the CPT https://www.npfmc.org/fishery-management-plan-team/bsai-crab-plan-team/

C. Aleutian Islands golden king crab specific

C.1 Siddeek et al. 2017. Aleutian Islands golden king crab assessment chapter.
In: 2017 Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries in the Bering Sea and Aleutian Islands. North Pacific Fisheries Management Council, Anchorage, AK. Report compiled by the CPT. *https://www.npfmc.org/fishery-management-plan-team/bsai-crab-plan-team/*

C.2 Siddeek et al. 2017. Aleutian Islands golden king crab model discussions and scenarios for May 2018 Assessment. Draft report for the September 2017 Crab Plan Team meeting.
granicus.com/npfmc/meetings/2017/9/964_A_Crab_Plan_Team_17-09-19_Meeting_Agenda.pdf

C.3 Siddeek et al. 2017. Effect of data weighting on the mature male biomass estimate for Alaskan golden king crab. CAPAM Data weighting Workshop, San Diego, California. Fisheries Research, 192: 103-113.

C.4 Siddeek et al. 2016. Standardizing CPUE from the Aleutian Islands golden king crab observer data. In: T.J. Quinn II, J.L. Armstrong, M.R. Baker, J. Heifetz, and D. Witherell (eds.), Assessing and Managing Data-Limited Fish Stocks. Alaska Sea Grant, University of Alaska Fairbanks, Alaska, USA, pp. 97-116.

C.5 Siddeek et al. 2016. Estimation of size–transition matrices with and without molt probability for Alaska golden king crab using tag–recapture data. Fisheries Research. 180:161-168.

C.6 May 2017 CPT minutes; June 2017 SSC minutes; and September 2017 CPT minutes (minutes will be submitted).

C.7 Siddeek et al. 2013. Standardization of CPUE from Aleutian Islands Golden King Crab Fishery Observer Data. Presented at the September 2013 CPT meeting (document will be submitted)

Panel Review Meeting: Each CIE reviewer shall conduct the independent peer review in accordance with this SoW and ToRs, and shall not serve in any other role unless specified herein. 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 meeting will consist of presentations by ADFG stock assessment authors and other scientists to facilitate the review, to provide any additional information required by the reviewers, and to answer any questions from reviewers.

Contract Deliverables - Independent CIE Peer Review Reports: After the review meeting, reviewers shall conduct an independent peer review in accordance with the requirements specified in this SOW, OMB guidelines, and ToRs, in adherence with the

required formattin
and content guidelines. Reviewers are not required to reach a consensus.

Foreign National Security Clearance
When 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 reviewers who are non-US citizens. For this reason, the 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/ and http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreign-national-registration- system.html. The contractor is required to use all appropriate methods to safeguard Personally Identifiable Information (PII).

Place of Performance
The place of performance shall be at the contractor's facilities, and Seattle, Washington.

Period of Performance
The period of performance shall be from the time of award through July 2018. Each reviewer's duties shall not exceed 14 days to complete all required tasks.

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

Within two weeks of award	CIE selects and confirms reviewers. Reviewer contact information is sent to the NMFS Project Contact
Approximately 2 weeks prior to the review	NMFS Project Contact sends the pre-review documents to the CIE reviewers
June 2018	Each reviewer participates and conduct an independent peer review during the panel review meeting
Approximately 3 weeks later	CIE receives draft reports
Within 2 weeks of receiving draft reports	CIE submits final reports to the Government

Applicable Performance Standards
The acceptance of the contract deliverables shall be based on three performance standards: (1) The reports shall be completed in accordance with the required formatting

and content (2) The reports shall address each ToR as specified (3) The reports shall be delivered as specified in

the schedule of milestones and deliverables.

Travel
All travel expenses shall be reimbursable in accordance with Federal Travel Regulations (http://www.gsa.gov/portal/content/104790). International travel is authorized for this contract. Travel is not to exceed $13,000.

Restricted or Limited Use of Data
The contractors may be required to sign and adhere to a non-disclosure agreement.

NMFS Project Contact:
William Stockhausen
Alaska Fisheries Science Center
Email: william.stockhausen@noaa.gov
Phone: 206-526-4241

Annex 1: Peer Review Report Requirements

1. The report must be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether or not the science reviewed is the best scientific information available.

2. The report must contain a background section, description of the individual reviewers' roles 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 must describe in their own words the review activities completed during the panel review meeting, including 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, but especially where there were divergent views.

c. Reviewers should elaborate on any points raised in the summary report that they believe 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 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 report shall represent the peer review of each TOR, and shall not simply repeat the contents of the summary report.

3. The report shall include the following appendices:

Appendix 1: Bibliography of materials provided for review
Appendix 2: A copy of this Statement of Work
Appendix 3: Panel membership or other pertinent information from the panel review meeting.

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Annex 2: Terms of Reference for the Peer Review

Aleutian Islands golden king and Norton Sound red king crab Stock Assessment Review

The report generated by the consultant should include:

1. Statements assessing the strengths and weaknesses of the current Aleutian Islands golden and Norton Sound red king crab stock *assessment* models with regard to population dynamics, data (fishery-independent surveys, CPUE indices, etc.), likelihood components, and model evaluation.

2. Statements assessing the strengths and weaknesses of the current Aleutian Islands golden and Norton Sound red king crab stock *projection* models, with regard to methodology.

3. A review of the fishery-dependent and -independent data inputs to the stock assessment with regard to quality of information and appropriateness to the assessment for Aleutian Islands golden king crab and Norton Sound red king crab.

4. Recommendations for alternative approaches to evaluate model convergence and compare multiple models for Aleutian Islands golden king crab and Norton Sound red king crab.

5. Recommendations on how various data sets should be weighted, relative to one another, in the Aleutian Islands golden king crab and Norton Sound red king crab models

6. Recommendations on how the reduction in number of vessels and fishing area shrinkage can be addressed in the Aleutian Islands golden king crab model.

7. Recommendations for integrating fishery-independent survey data into the Aleutian Islands golden king crab assessment.

8. Recommendations for quality control of input fishery-dependent and -independent data for Aleutian Islands golden king crab and Norton Sound red king

crab.

9. Recommendations for research that would reduce the uncertainty associated with key parameters assumed or estimated in the assessment models for Aleutian Islands golden king crab and Norton Sound red king crab.

10. Suggested priorities for future improvements to the stock assessment/projection models for Aleutian Islands golden king crab and Norton Sound red king crab.

Annex 3: Tentative Agenda

Aleutian Islands Golden King and Norton Sound Red King Crab Stock Assessment Review

Venue:
Alaska Fisheries Science Center
7600 Sand Point Way NE
Seattle, WA USA 98115

Dates:
June 18-21, 2018

Point of Contact:
William Stockhausen
Alaska Fisheries Science Center
Email: william.stockhausen@noaa.gov
Phone: 206-526-4241

Monday: June 18 2018

8:00 -8:30am

a. Welcome and introduction (Chair)
b. Role of chair and reviewers, terms of reference (Chair)
c. Review of agenda items (Chair)

Review of Aleutian Islands golden king crab (AIGKC)

8:30–9:40 am

a. Overview of Aleutian Islands golden king crab fishery, catch, bycatch, independent surveys
b. Biology (molting, growth, natural mortality, and maturity)
c. Fishery history and current operation

9:40-9:50 am: Tea Break

9:50-11:30 pm

a. Fishery catch, effort, observer sampling procedures and data processing
b. Fishery industry collaborative survey procedure and data processing

11:30 -1:00 pm: Lunch Break

1:00-2:45 pm

a. CPUE standardization
b. Future outlook for observer and fishery CPUE standardization

2:45-3:25 pm

a. Harvest control rules and overfishing definitions

3:30 pm: Adjourned

Tuesday: June 19, 2018

8:00-10:00 am

a. Stock assessment and projection models

10:00-10:10 pm: Tea Break

10:10-12:00 pm

a. Stock assessment and projection models continued
b. Current research studies: genetics

12:00-1:30pm: Lunch break

Review of Norton Sound Red King Crab (NSRKC)

1:30-3:25 pm

a. Overview of fishery, catch, bycatch, surveys
b. Biology (molting, growth, natural mortality, and maturity)
c. Fishery history and current operation
d. Harvest control rules and overfishing definitions

3:30 pm: Adjourned

Wednesday: June 20, 2018

8:00-9:45 am

a. Fishery catch, effort, observer sampling procedures and data processing
b. NMFS and ADF&G surveys and data processing

9:45-10:00 am: Tea Break

10:00-11:30 pm

a. CPUE standardization
b. Stock assessment and projection models

11:30-1:00pm: Lunch Break

1:00-2:30 pm

a. Stock assessment and projection models continued

2:30-2:40 pm: Tea Break

2:40-3:25 pm

a. Stock assessment and projection models continued

3:30 pm: Adjourned

Thursday: June 21, 2018

8:00am–11:30pm

a. NSRKC: Reviewer discussion with stock assessment authors. Review of requested model runs, if required

b. AIGKC: Reviewer discussion with stock assessment authors. Review of requested model runs, if required

11:30 am-1:00 pm: Lunch break

1:00-3:25 pm

a. Independent discussion among reviewers on findings, recommendations, reports, etc.

3:30 pm: Adjourned

NOTE: The review will start at 8:00 am each day and will conclude at 3:30 pm on Thursday, June 21. All other specific times are tentative and may be revised.

Appendix 3: CIE Panel Membership

Dr. Yong Chen, University of Maine
Dr. John Neilson, Independent Fisheries Scientist
Dr. Raouf Kilada, University of New Brunswick

Appendix 4: Additional Work Requested by the CIE Panel During the Meeting

AIGKC

- Table/figures of trends in monthly catch by year
- Table/figures of trends in area of capture by year
- Tables comparing observed growth increments from tagging compared with those estimated in the model.

NSRKC

- Table of data CVs for survey and standardized CPUE
- Model run which excludes 2014 survey data point
- Model run without the pre-1994 standardized CPUE
- mean size at age based on projecting "cohort" forward using the growth matrix
- summary of critical deficiencies in the assessment from a global perspective
- list of steps already taken to address issues with the assessment model
- correlation between growth parameters and M estimates from ADMB .cor file