Center for Independent Experts (CIE) Independent Peer Review of 2018 Benchmark Stock Assessment for the Main Hawaiian Islands Kona Crab

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Executive Summary

A benchmark stock assessment for Main Hawaiian Islands Kona crab (*Ranina ranina*) was conducted by scientists at the Pacific Islands Fisheries Science Center (PIFSC) and will provide the basis for management of this culturally important species.

A Center for Independent Experts (CIE) review of the stock assessment was requested with two CIE reviewers, with the panel chair being Dr Steve Martell who provided a chairman's summary report that included input from the CIE reviewers. The reviewers were provided access to eight documents as background information and stock assessment report and participated in a panel review meeting in Honolulu, HI, from 10-14 September 2018. The reviewers met with managers and scientists involved in the fishery and the stock assessment modeling. There were some formal requests for additional information from the presenters which was provided later. There was a verbal and two written presentations from experienced fishers during the public comment period. The panel chair presented the panel views to the meeting attendees on Friday 14 September. The panel received excellent support from the scientists and managers involved in the review. This included timely provision of documents, the organization and conduct of the meeting, the arrangements at the venue, the presentations during the meeting and the responding to questions and formal requests for additional analyses. The report generated by reviewers addressed the eleven TORs that are listed below (italics) with the review response:

1. *Is the uncertainty with respect to input data quality and filtering methods well documented, including its potential effect on results?*

Kona crabs caught with hoop nets were identified as the key records to be used in the assessment and these were regularly reported as fishing gear for Kona crab catch from 1958, so the stock assessment used records 1958 to 2016. A strength of the assessment was the use of a single-reporting day for fishers using hoop nets as the unit of effort, the identification of the unique commercial marine license (CML) over the year, and adjustment of female discard mortality. However, there was uncertainty associated with a large unreported catch and the quality of the reported catch and effort data, and the effect of management changes on the CPUE. Reviewers requested that the time series of the number of single-reporting days be added to the report as it gives an indication of nominal effort trends. Based on the information provided on uncertainty with respect to input data quality and filtering methods, the answer to TOR 1 is yes.

2. *Is the CPUE standardization properly applied and appropriate for this species, fishery, and available data?*

CPUE was standardized using generalized linear mixed models (GLMMs) with a Gaussian error structure. It was completed with the general categories of factors: temporal, spatial, individual fisher effects, habitat, and oceanographic. Kona crab CPUE series are standardized separately for 'Period 1 (1958 to 2006) and 'Period 2 (2007-2016) due to the prohibition of female catch beginning on September 1, 2006. All variables were modeled as fixed effects with the exception of CML number, which was modeled as a random effect. Reviewers requested an alternative assessment be undertaken using CML as a fixed variable to assess its effect on the standardized CPUE (SCPUE). This approach would also provide an assessment of the relative fishing power of fishers. The model which fitted the criteria for selection for both periods included CML (random effect), year and fishing area. The criteria adopted were based on adding each predictor if in the resulting model there was 2% reduction of Akaike's information criterion from the preceding model. Reviewers queried whether the criteria was too restrictive and requested that the effect of adding other variables be assessed. It would be useful to explore the differences in the trends in SCPUE between some key areas of the fishery such as Penguin Bank that contributes 53% of the catch with a catch per trip of about 4 times that of other islands. Based on the information provided on CPUE standardization, the answer to TOR 2 is yes with some recommendations to assess and compare some alternative analyses.

3. *Are the assessment models used reliable, properly applied, adequate, and appropriate for the species, fishery, and available data?*

The assessment implemented a modeling framework entitled Just Another Bayesian Biomass Assessment (JABBA), which is a tool for conducting state-space Bayesian surplus production models. It estimates both process and observation error variance. JABBA estimates Bayesian posterior distributions of model outputs by means of a Markov Chain Monte Carlo (MCMC) simulation. The surplus production model estimates maximum sustainable yield (MSY) and the biomass to produce MSY, B_{MSY}. JABBA provides diagnostic plots to illustrate several components of model performance and produces the Root-Mean-Squared-Error (RMSE) to quantitatively evaluate the relative accuracy of model predictions. A number of suggestions were made by reviewers on alternative formulations of the model to assess the effect on model outputs. There was a lot of discussion on the statistical properties of the estimator, where three variance terms were included in the model. It was suggested that the fixed observation error term be removed from the model. The assessment model developed was suitable for the data available therefore, the answer to TOR 3 is yes with some recommendations to assess and compare some alternative analyses.

4. *Are decision points and input parameters reasonably chosen?*

Reference points for this assessment come from the Western Pacific Regional Fishery Management Council's (WPRFMC) Fishery Ecosystem Plan (FEP) for the Hawaiian Archipelago for Northwest Hawaiian Islands lobster stocks. The threshold for defining the Kona crab stock as overfished is $B/B_{MSY} < 0.7$. The value of 0.7 comes from the minimum stock size threshold defined as $(1\text{-}natM)*B_{MSY}$, since *natM* is assumed to be 0.3 yr^{-1} in this assessment. The overfishing definition is often referred to as $H/H_{MSY} > 1$. Based on the information provided on the decision points, the answer to TOR 4 is yes.

5. *Are primary sources of uncertainty documented and presented?*

Sensitivity analyses were undertaken to examine the effect on model-estimated results of varying prior values relative to the base case values. They were conducted by altering input parameter values for priors in isolation and comparing results to base case model results. Sensitivity analyses were conducted on the input parameters: carrying capacity (K), intrinsic population growth rate (r), shape parameter (m), initial year proportion of biomass to carrying capacity, process error, fixed observation error, and unreported catch ratios. A key uncertainty was unreported catch which was estimated to be about 50% higher than the reported catch. The authors have done all they can to take into account this issue, but it remains a considerable source of uncertainty in the assessment. Based on the information provided on the primary sources of uncertainty, the answer to TOR 5 is a conditional yes as some assessment of effort efficiency creep (e.g. 1% per year) should be made as part of the sensitivity assessment.

6. *Are model assumptions reasonably satisfied?*

Assumptions of this model included that production follows a specified functional form, the assessment is applicable to exploitable individuals, all exploitable individuals were mature and equally vulnerable to fishing, and that biomass was proportional to SCPUE. The base case assumes that the adjustment for unreported catch (1.54 ratio) was consistent over the years. This can have important implications regarding the stock status. Some variability in the unreported catch ratio was explored in one of the sensitivity assessments, but this did not result in a marked variation in catch from the base case. Reviewers were concerned about whether the SCPUE was reflecting the abundance trends in the fishery. For example, marked reduction in catch and effort since the early 2000s did not appear to be reflected in an increase of the standardized CPUE. However, based on the information provided on model assumptions, the answer to TOR 6 is yes.

7. *Are the final results scientifically sound, including estimated stock status in relation to the estimated biological reference points, and can the results be used to address management goals stated in the relevant FEP or other documents provided to the review panel?*

The standardized residuals of SCPUE minus production model estimated SCPUE showed some systematic trends for both periods. There appeared to be some underestimation in the early part of the time series and overestimation towards the end of the time series. The biomass estimates from JABBA over the whole time period showed a consistent increase in biomass after the 2000s. However, there appeared to be little evidence of an increase in SCPUE in period 2, 2007-2016. The increase in the estimated model biomass would be dependent on the estimated relative catchabilities for the two time periods before and after 2006. Model results showed that Hawaii Kona crabs have never been overfished. Biomass relative to B_{MSY} (B/B_{MSY}) has increased steadily since 2004 as catch has decreased and estimated abundance gradually increased. The stock experienced overfishing for two years in the early 1970s, but has not been experiencing overfishing since. There have been some considerable improvements in catch and effort data handling in the current assessment, however it was difficult to reconcile the marked change in the current stock status assessment compared to the 2015 assessment. The model was sensitive to alternative catch scenarios which include annual catch values that are both much greater and lower than the base case. Based on the information provided on stock status, the answer to TOR 7 is yes.

8. *Are the methods used to project future population status adequate and appropriately applied for meeting management goals as stated in the relevant FEP?*

Projection analyses were executed using posterior distributions from the base case model for Hawaii Kona crab. The projection results accounted for uncertainty in the distribution of estimates of model parameters from the posterior of the base case model. Under the projection scenario using the lowest future catches which are also most similar to current reported catches (~3,496 lbs), B/B_{MSY} continues to increase to slightly greater than 2.0. The reported catch amount corresponding to a 50% risk of overfishing in 2025 is 44,488 lbs; this corresponds to a 0.008% chance of being overfished in 2025. Based on the information provided on the projection model, the answer to TOR 8 is a conditional yes for the relatively low projected reported catches (e.g. <20,000 lbs) that could be appropriately applied for meeting management goals. There is likely to be larger uncertainty associated with the larger reported catch projections as these would represent marked increases from the catches in recent years.

9. *If any results of these models should not be applied for management purposes with or without minor short-term further analyses (in other words, if any responses to any parts of questions 1-8 are "no"), indicate:*

   Which results should not be applied and describe why, and

   Which alternative set of existing stock assessment results should be used to inform setting fishery catch limits instead and describe why.

There are no responses with no in questions 1-8 but there are some with 'conditional yes' and the caveats that should be considered to inform management settings.

10. *As needed, suggest recommendations for future improvements and research priorities. Indicate whether each recommendation should be addressed in the short/immediate term (2 months), mid-term (3-5 years) and long-term (5-10 years). Also indicate whether each recommendation is high priority (likely most affecting results and/or interpretation), mid priority, or low priority.*

Recommendations short/intermediate term (2 months):

- Average weight can be estimated for 45% of Kona crab single reporting days that report total numbers and total weight. The long-term trend of mean weight of legal-crabs could be assessed using a GLM assessment. This would be a mid-priority issue as it may provide some insights on the effect of fishing and/or recruitment pulses.
- Some of the single-reporting days for Kona crabs also catch other species. If there is some targeting of other species on these days, then it could have a negative effect on the CPUE of Kona crabs. This could be particularly an issue since the fishery became male only. This could be tested in the standardization of the CPUE. This would be a mid-priority issue.
- The assessment of the CML as a fixed variable in the standardization process could also provide an assessment of the relative fishing power of fishers which may highlight those consistently targeting Kona crabs and others who are not focused on the crabs. This would be a mid-priority issue.
- It would be useful to add the time series of nominal effort and a standardized effort estimate (based on Catch/SCPUE) to the report. This is high priority issue.

Recommendations mid-term (3-5 years):

- There are interesting patterns in the time series of SCPUE with peaks occurring in the early 1960s, early 1970s and late 1990s. It would be useful to identify if there are any environmental factors that can explain the variation in the SCPUE. This would require an assessment of environmental variables lagged 5-6 years as environmental effects commonly impact the spawning, larval and early juvenile phase of the life cycle. This would be a mid-priority issue as it may provide insight into factors affecting recruitment and whether there are long-term trends.

- The stock assessment has some uncertainty associated with a large unreported catch and the quality of the reported catch and effort data, and the effect of management changes on the CPUE. One way to address this would be by establishing a cost-effective fishery-independent survey of key fishing areas (e.g. Penguin Bank and Niihau). This survey could be done with the collaboration of the 3-4 key fishers that fish in the areas designated for surveys. The survey would provide abundance indices for a number of size classes such as undersize, legal-size and mature female. The survey could be combined with a tagging study that would provide additional information on biological parameters, harvest rates and the relative catch contribution from commercial and recreational fishers. This survey recommendation should be a high priority as it will have a marked effect on the results and interpretation of stock status and provide valuable ancillary data in the stock assessment.
- Another approach that could be adopted to estimate catchability and biomass estimates would be a depletion study. This species appears to be well suited to a novel depletion approach based on a star pattern of fishing that has been developed by Liese Carleton (lcarleton@vims.edu) and John Hoenig (hoenig@vims.edu) (Virginia Institute of Marine Science).
- While reviewers understand the motivation of moving to a male-only fishery to protect the mature female biomass, it is important to understand the implications of a male-only fishery. For example, some other male-only fisheries have found that there may be insufficient males of an appropriate size to mate females, so there may be an increasing percentage of unmated mature females. Therefore, some monitoring of the status of mature females may be informative of the effect and value of this regulation. This change has also resulted in increased handling of female crabs resulting in some mortality. In a fishery with appropriate controls on catch, consideration should be given to removing other regulations such as a ban on female retention. This recommendation would be a medium priority as it may be may provide information on the unintended effect of this regulation on the stock status and improve the economic viability of the fishery.

11. *Draft a report (individual reports from each of the panel members and a Summary Report from Chair) addressing the above ToR questions.*

The reviewers drafted their individual reports and provided input into the Chair's Summary Report as well as the Chair's presentation to the meeting of the preliminary conclusions of the review.

Background

A benchmark stock assessment for Main Hawaiian Islands Kona crab (*Ranina ranina*) was conducted by scientists at the Pacific Islands Fisheries Science Center (PIFSC) and will provide the basis for management of this culturally important species. Previous stock assessments for Kona crab were conducted by non-NOAA scientists in 1978 and in collaboration with PIFSC scientists in 2010-2011. The benchmark assessment incorporates data from 1948 through 2016 and uses a production model, incorporating improvements to data standardization and model assumptions. Specifically, catch per unit effort (CPUE) in the model includes new standardization coefficients and was split into two time series (fishing year 1958-2005 and 2006-2016) due to passage of Hawaii state law prohibiting the taking of female Kona crab in 2006. The assessment model accounts for unreported catch by evaluating the use of published estimates of non-reporting ratios estimated for other fisheries in the Main Hawaiian Islands as well as by incorporating estimates of fishing effort specific to crustaceans from ancillary surveys. Stock status is evaluated against MSY-based reference points set in the Fishery Ecosystem Plan. Projections are provided to inform management setting of annual catch limits.

A CIE review of the stock assessment was requested. The specified format and contents of the individual peer review reports are found in Annex 1 of Appendix 1. The Terms of Reference (TORs) of the peer review are listed in Annex 2. The agenda of the panel review meeting is attached in Annex 3.

Two CIE reviewers (Appendix 3) conducted the peer review in accordance with the ToRs listed below. The meeting was chaired by Dr Steve Martell who provided a chairman's summary report that included input from the CIE reviewers. Two weeks before the peer review, Dr John Syslo, NOAA Fisheries, PIFSC, Honolulu, provided access to eight documents as background information and stock assessment report for the peer review. The reviewers participated in a panel review meeting in Honolulu, Hawaii from 10-14 September 2018 to conduct a peer review of the Kona Crab stock assessment. The reviewers met with managers and scientists involved in the fishery and the stock assessment modeling. The scientists presented the key aspects of their research according to the agenda. Copies of the presentations were provided to the reviewers. Throughout the presentations, the CIE panel and others present asked questions on issues of management, data collection, 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 formal requests for additional information from the presenters which were provided later.

There was a verbal and two written presentations from experienced fishers during the public comment period of the agenda. All three highlighted the negative effect the introduction of the male-only rule had on the profitability of the Kona crab fishery.

The reviewers undertook some discussions regarding their review of the stock assessment and discussed their preliminary views of the assessment with the panel chair. The panel chair presented the panel views on each of the TOR to the meeting on the Friday 14

September. The panel then prepared to write their individual reports which were provided to the panel chair, so he could write the final summary report.

The panel received excellent support from the scientists and managers involved in the NMFS review. This included timely provision of documents, the organization and conduct of the meeting, the arrangements at the venue, the presentations during the meeting and the responding to questions and formal requests for additional analyses.

The report generated by reviewers addressed the following TORs:

1. Is the uncertainty with respect to input data quality and filtering methods well documented, including its potential effect on results?
2. Is the CPUE standardization properly applied and appropriate for this species, fishery, and available data?
3. Are the assessment models used reliable, properly applied, adequate, and appropriate for the species, fishery, and available data?
4. Are decision points and input parameters reasonably chosen?
5. Are primary sources of uncertainty documented and presented?
6. Are model assumptions reasonably satisfied?
7. Are the final results scientifically sound, including estimated stock status in relation to the estimated biological reference points, and can the results be used to address management goals stated in the relevant FEP or other documents provided to the review panel?
8. Are the methods used to project future population status adequate and appropriately applied for meeting management goals as stated in the relevant FEP?
9. If any results of these models should not be applied for management purposes with or without minor short-term further analyses (in other words, if any responses to any parts of questions 1-8 are "no"), indicate:

    Which results should not be applied and describe why, and

    Which alternative set of existing stock assessment results should be used to inform setting fishery catch limits instead and describe why.

10. As needed, suggest recommendations for future improvements and research priorities. Indicate whether each recommendation should be addressed in the short/immediate term (2 months), mid-term (3-5 years) and long-term (5-10 years). Also indicate whether each recommendation is high priority (likely most affecting results and/or interpretation), mid priority, or low priority.
11. Draft a report (individual reports from each of the panel members and a Summary Report from Chair) addressing the above TOR questions.

Summary of Findings

The review was undertaken of the stock assessment for Main Hawaiian Islands Kona crab. For questions 1-8 off the TOR and their subcomponents, reviewers were asked to provide a "yes" or "no" answer. Only if necessary, caveats may be provided to these yes or no answers, but when provided they must be as specific as possible to provide direction and clarification. Therefore, the findings of the review have been presented according to the TOR set of the panel (*in italics*) and highlight the key points associated with each of the TOR followed by the answer to the question:

1. *Is the uncertainty with respect to input data quality and filtering methods well documented, including its potential effect on results?*

- Kona crabs caught with hoop nets were identified as the key records to be used in the assessment and these were regularly reported fishing gear for Kona crab catch from 1958, so the stock assessment uses records beginning in this fishing year 1958 to 2016. Therefore a 'single-reporting day' for fishers using hoop nets was used as the effort unit.
- Issues associated with the uncertainty of key input data, catch, effort and catch per unit (CPUE) data were well documented. These issues were also examined as part of sensitivity assessment.
- Data filtering included adjusting the reported catch by adding discarded female mortality following the 2006 prohibition of possessing female Kona crabs. This adjustment was based on a study that showed that post-release mortality of female crabs was 10.77% (Wiley and Pardee, 2018).
- Unreported catch was one of the key sources of uncertainty in the stock assessment. A ratio of unreported catch to reported catches (UCR of 1.54) was estimated with available finfish information and applied to Kona crabs as there was little crab specific data available. Sensitivity assessment was used to explore alternative assessments of unreported catch.
- PIFSC scientists linked fishers back through time using names and as a result, individual fishers are tracked by CML number.
- Some of the single-reporting days contained other species and the reviewers discussed the effect of catching these other species on the CPUE of Kona crabs (Fig. 8).
- Reviewers requested that the time series of the number of single-reporting days be added to the report as it gives an indication of nominal effort trends (Fig. 7). These can be compared to the total number of trips catching Kona crabs (Fig. 1). The trend in the number of participants of the Kona crab catches (Fig. 4) is also useful background information for the fishery section of the report. It highlights an increasing trend from the 1950s to about 2000, reaching about 90 participants, with a decline to about 25 participants in recent years with most of the catch coming from three vessels in these years.

- There is also value in including the Kona crab nominal CPUE of catch per day in the report as it gives an indication of what the fishers are achieving per day, particularly as this is much higher than the standardized CPUE (Fig. 6).

A strength of the assessment was the use of a single-reporting day as the unit of effort, the identification of the unique CML over the years, and adjustment for female discard mortality. However, there was uncertainty associated with a large unreported catch and the quality of the reported catch and effort data, and the effect of management changes on the CPUE. Based on the information provided on uncertainty with respect to input data quality and filtering methods, the answer to TOR 1 is yes.

2. Is *the CPUE standardization properly applied and appropriate for this species, fishery, and available data?*

CPUE was standardized using generalized linear mixed models (GLMMs) with a Gaussian error structure. This represents a standard approach for assessing CPUE. It was completed with the following general categories of factors: temporal, spatial, individual fisher effects, habitat, and oceanographic. Temporal factors explored for CPUE standardization include fishing year, month, and season with seasons based on the female reproductive cycle. Spatial factors explored include DAR grid area and island.

- Individual fisher effects were explored using two different metrics: cumulative fisher experience and commercial marine license (CML) number. CML numbers that report 5 or fewer total Kona crab single-reporting days in the entire time series were pooled under one of four dummy CML numbers unique to the four island areas (affecting 1,250 of 11,015 single reporting days). The reviewers requested an assessment without the CMLs that reported 5 or fewer single reporting days to assess what effect this was having on the standardized CPUEs (SCPUE). A comparison of the two SCPUEs with and without these CMLs showed little difference.
- Habitat factors explored included depth, slope, and bottom hardness of substrate in each fishing area. Oceanographic factors explored include the Pacific Decadal Oscillation (PDO) index, and El Niño Southern Oscillation (ENSO) index 3.4 on monthly time scales. These effect of oceanographic factors on the CPUE at the time of fishing examined their effect on catchability. However, it would also be useful to assess the effect of environmental variability on the abundance of the stock by examining environmental variables lagged 5-6 years.
- Kona crab CPUE series are standardized separately for 'Period 1' (1958 to 2006) and 'Period 2' (2007-2016) due to the prohibition of female catch that begun on September 1, 2006.
- All variables were modeled as fixed effects with the exception of CML number, which was modeled as a random effect. This approach was recommended by the Hall (2015) review of the Thomas et al. (2015) stock assessment. Reviewers requested an alternative assessment be undertaken using CML as a fixed variable to assess its effect on the SCPUE. This was undertaken and did not show much difference in the SCPUE time series. This approach would also provide an

assessment of the relative fishing power of fishers which may highlight those consistently targeting Kona crabs.

- The model which fitted the criteria for selection for both periods included CML (random effect), year and fishing area. The criteria used was based on adding each predictor if the resulting model met the minimum criteria of 2% reduction of Akaike's information criterion (AIC) from the preceding model. Reviewers queried whether the criteria was too restrictive and requested that the effect of adding other variables on the SCPUE be assessed. For example, month and year*area interaction should be examined even though they did not pass the minimum AIC criteria as these could be affecting the time series trend of the SCPUE. Thomas et al. (2013) noted greater declines in catch rate in areas with higher population such as Oahu. It would be useful to explore the differences in the trends in SCPUE between some key areas of the fishery such as Penguin Bank that contributes 53% of the catch (Fig. 2) with a catch per trip of about four times that of other islands (Fig. 3). Thomas et al. (2013) examined these trends by the four islands.
- The assessment of adding month or fishing season showed that this produced some changes in the time series of SCPUE. This time series was then requested to be assessed in the surplus production assessment.

Based on the information provided on CPUE standardization, the answer to TOR 2 is yes with some recommendations to assess and compare some alternative analyses.

3. *Are the assessment models used reliable, properly applied, adequate, and appropriate for the species, fishery, and available data?*

- The assessment implemented a modeling framework entitled Just Another Bayesian Biomass Assessment (JABBA), which is a tool for conducting state-space Bayesian surplus production models (Winker et al. 2018). It estimates both process error variance and observation error variance. JABBA estimates Bayesian posterior distributions of model outputs by means of a Markov Chain Monte Carlo (MCMC) simulation. The paper describing the methods has recently been peer reviewed and published and used in a number of stock assessments.
- Surplus production models (SPMs) are frequently implemented to estimate sustainable levels of harvest (biomass removals) at corresponding levels of stock biomass. Maximum sustainable yield (MSY) is the maximum level of catch that can be removed from a stock over time while maintaining biomass at B_{MSY}, the biomass to produce MSY. JABBA formulates the surplus production function of the generalized three-parameter Pella and Tomlinson SPM.
- The SPM for Hawaii Kona crab using JABBA included explicit observation and process error terms that have been commonly used for fitting production models with relative abundance indices. The exploitable biomass time series was estimated by fitting model predictions to the observed relative abundance indices (SCPUE). In particular, total observation error likelihood measured the discrepancy between observed and predicted CPUE. Prior distributions for input parameters are used to

represent the relative degree of knowledge about the probable values of model parameters.

- A Bayesian estimation approach was used to estimate production model parameters. Prior distributions were employed to represent existing knowledge about the likely values of model parameters. The carrying capacity parameter K, the intrinsic growth rate parameter r, the production shape parameter m, the initial proportion of biomass to carrying capacity parameter, two catchability parameters q, the process error, and the estimable component of observation error, each had prior distributions.
- Convergence of the MCMC samples to the posterior distribution was monitored via visual inspection of the trace, and other diagnostics implemented in the coda R package. JABBA provides additional diagnostic plots to illustrate several components of model performance. JABBA produces the Root-Mean-Squared-Error (RMSE) to quantitatively evaluate the relative accuracy of model predictions of the entire time series with respect to observed values, scaled as a percentage of deviation.
- Reviewers asked whether goodness of fit parameters such as RMSE could be shown for the sensitivity analyses.
- A retrospective analysis was conducted to assess whether there were consistent patterns in model estimated outputs based on increasing periods of data.
- A number of suggestions were made by reviewers on alternative formulations of the model to assess the effect on model outputs. In particular, there was a lot of discussion on the statistical properties of the estimator, where three variance terms were included in the model. It was suggested that the fixed observation error term be removed from the model.

The assessment model developed was suitable for the data available, therefore, the answer to TOR 3 is yes with some recommendations to assess and compare some alternative analyses.

4. *Are decision points and input parameters reasonably chosen?*

- Reference points for this assessment come from the Western Pacific Regional Fishery Management Council's (WPRFMC) Fishery Ecosystem Plan (FEP) for the Hawaii Archipelago for Northwest Hawaiian Islands lobster stocks. These reference points were borrowed based on discussions with staff from the Pacific Islands Regional Office and WPRFMC, since no reference points are specified for Hawaii Kona crab. The threshold for defining the Kona crab stock as overfished is $B/B_{MSY} < 0.7$. The value of 0.7 comes from the minimum stock size threshold defined as $(1\text{-}natM)*B_{MSY}$, since *natM* is assumed to be 0.3 yr^{-1} in this assessment. The overfishing definition depends on biomass: overfishing occurs when $H/H_{MSY} > 1$ if $B > B_{MSY}$. Alternatively, overfishing occurs when $H/H_{MSY} > B/B_{MSY}$ when $B \leq B_{MSY}$. The risk of overfishing is calculated according to these conditions, but since B very rarely falls below B_{MSY} in model runs, the overfishing definition is often referred to as simply $H/H_{MSY} > 1$ throughout the rest of this document.

Based on the information provided on the decision points, the answer to TOR 4 is yes.

5. *Are primary sources of uncertainty documented and presented?*

- Sensitivity analyses were undertaken to examine the effect on model-estimated results of varying prior values relative to the base case values. They were conducted by altering input parameter values for priors in isolation and comparing results to base case model results. Sensitivity analyses were conducted on the following input parameters: carrying capacity (K), intrinsic population growth rate (r), shape parameter (m), initial year proportion of biomass to carrying capacity, process error, fixed observation error, and unreported catch ratios.
- A key uncertainty that was documented and assessed in the base case and through sensitivity analyses was unreported catch which was estimated to be about 50% higher than the reported catch. The authors have done all they can to take this issue into account, but it remains a considerable source of uncertainty in the assessment.
- The reviewers queried whether some efficiency creep (e.g. 1% per year) should be taken into account, particularly for the period before 2006. This can occur due to technological improvements such as GPS or the contraction of effort to the high abundance areas due to the overall reduction in effort. The level of targeting Kona crabs since 2006 could have changed compared to that which occurred before 2006 because of the changes in the profitability of fishing crabs since the fishery became male only. The effect of these changes could be examined as part of the sensitivity assessment.

Based on the information provided on the primary sources of uncertainty, the answer to TOR 5 is a conditional yes as some assessment of effort efficiency creep should be made as part of the sensitivity assessment.

6. *Are model assumptions reasonably satisfied?*

- Assumptions of this model included that production follows a specified functional form, the assessment is applicable to exploitable individuals, all exploitable individuals were mature and equally vulnerable to fishing, and that biomass was proportional to SCPUE.
- The base case assumes that the adjustment for unreported catch (1.54 ratio) was consistent over the years. This can have important implications regarding the stock status. Some variability in the unreported catch ratio was explored in one of the sensitivity assessments, but this did not result in a marked variation in catch from the base case and therefore little change in the stock assessment parameters.
- Reviewers were concerned about whether the SCPUE was reflecting the abundance trends in the fishery. For example, marked reduction in catch and effort since the early 2000s did not appear to be reflected in an increase of the SCPUE. This could be partly due to the change to a male-only fishery in 2006 which could have resulted in reduced targeting of Kona crabs since then and hence reduced CPUE.

Based on the information provided on the model assumptions, the answer to TOR 6 is yes.

7. Are the final results scientifically sound, including estimated stock status in relation to the estimated biological reference points, and can the results be used to address management goals stated in the relevant FEP or other documents provided to the review panel?

- The standardized residuals of SCPUE minus production model estimated SCPUE showed some systematic trends for both periods. There appeared to be some underestimation in the early part of the time series and overestimation of the SCPUE towards the end of the time series.
- The biomass estimates from JABBA over the whole time period from the two time series showed a consistent increase in biomass after the 2000s. However, there appeared to be little evidence of an increase in SCPUE in period 2, 2007-2016, which may be due to a change of targeting practices because of the change to a male-only fishery. The increase in the estimated model biomass would be dependent on the estimated relative catchabilities for the two time periods before and after 2006.
- Model results showed that Hawaii Kona crabs have never been overfished. Biomass relative to B_{MSY} (B/B_{MSY}) has increased steadily since 2004 as catch has decreased and estimated abundance gradually increased. The stock experienced overfishing for two years in the early 1970s, but has not been experiencing overfishing since. Harvest rates relative to H_{MSY} (H/H_{MSY}) are below 1.0 since 1973 and down to less than 0.1 since 2013. Posterior median 2016 estimates for B/B_{MSY} are 1.79 and for H/H_{MSY} are 0.053. There was a 0% chance of experiencing overfishing and a 0% chance of being overfished in 2016. Authors acknowledge there is uncertainty associated with model estimates.
- The assessment of stock status in this study is in direct contrast to that of Thomas et al. (2015) that was based on catch and effort data to 2006 and showed stock had consistent periods of overfishing/overfished. There have been some considerable improvements in catch and effort data handling in the current assessment; however, it was difficult to reconcile the marked change in stock status assessment between the two stock assessments.
- The model was sensitive to alternative catch scenarios which include annual catch values that are both much greater and lower than the base case. *UCR* (unreported catch ratio) scenarios of adjusted reported catch (*UCR*=0) and high unreported catch (*UCR*=5) are the scenarios with very different total catch values from the base case (UCR=1.54), and showed the greatest departure from base case results. Using adjusted reported catch only (*UCR*=0) assumes that total catch is ~60% lower than in the base case model, and this decreased total catch *MSY*, B_{MSY}, and *B2016* all by ~60%. However, the *MSY* from the *UCR*=0 scenario is 32,617 lbs, which is similar to the reported catch *MSY* from the base case model of 30,346 lbs. The *H2016* was reduced by 15% in the adjusted reported catch scenario. Using the annual *UCR*s increased B_{MSY} by 11% and increased *K* by 9%. Assuming a high unreported catch ratio of 5 had the greatest impact: B_{MSY} increased by 135%, *MSY* increased by 142%, and *B2016* increased by 139%.

Based on the information provided on stock status, the answer to TOR 7 is yes.

8. *Are the methods used to project future population status adequate and appropriately applied for meeting management goals as stated in the relevant FEP?*

- Projection analyses were executed using posterior distributions from the base case model for Hawaii Kona crab. The projection results accounted for uncertainty in the distribution of estimates of model parameters from the posterior of the base case model. In the results for projections, total catches were converted back to reported catches for management purposes. It was noted that the female mortality needed to be removed from the reported catches presented. Projections performed for this assessment produced overfishing risks associated with a range of catch values (Fig. 5), risks of overfishing or being overfished, biomass, and harvest rates, among other estimates. Stock biomass does not drop below the B/B_{MSY} = 0.7 overfished threshold in any year for any projected catch scenario from 2020 to 2025, though scenarios with high reported catches above ~10,000 pounds trend downwards through the projection period. Under the projection scenario using the lowest future catches, which are also most similar to current reported catches (~3,496 lbs, red increasing lines), B/B_{MSY} continues to increase to slightly greater than 2.0. The reported catch amount corresponding to a 50% risk of overfishing in 2025 is 44,488 lbs; this corresponds to a 0.008% chance of being overfished in 2025.

Based on the information provided on the projection model, the answer to TOR 8 is a conditional yes for the relatively low projected reported catches (e.g. <20,000 lbs) that could be appropriately applied for meeting management goals. There is likely to be larger uncertainty associated with the larger reported catch projections as these would represent marked increases from the catches in recent years.

9. *If any results of these models should not be applied for management purposes with or without minor short-term further analyses (in other words, if any responses to any parts of questions 1-8 are "no"), indicate:*

    Which results should not be applied and describe why, and

    Which alternative set of existing stock assessment results should be used to inform setting fishery catch limits instead and describe why.

There are no responses with no in questions 1-8 but there are some with 'conditional yes' and the caveats that should be considered to inform management settings.

10. *As needed, suggest recommendations for future improvements and research priorities. Indicate whether each recommendation should be addressed in the short/immediate term (2 months), mid-term (3-5 years) and long-term (5-10 years). Also indicate whether each recommendation is high priority (likely most affecting results and/or interpretation), mid priority, or low priority.*

Suggestions for future improvements and research priorities, by time frame and priority, include:

- Short/intermediate term (2 months)
    - The authors identify size or weight categories of individual crabs as an important data category to improve future assessments. While these data are not available, average weight can be estimated for 45% of Kona crab single reporting days that report total numbers as well as total weight. The long-term trend of mean weight of legal-crabs could be assessed using a GLM assessment similar to that used on CPUE and would have to be undertaken for the same two time periods as the second period is male only. This may provide some information on whether there has been any effect of fishing on the size structure (e.g. reduced mean size) over the last 50-60 years. It may also identify if there have been periods of high recruitment that may result in a short-term reduction in mean size. This would be a mid-priority issue as it may provide some insights on the effect of fishing and/or recruitment pulses.
    - Some of the single-reporting days for Kona crabs also catch other species. If there is some targeting of other species on these days, then it could have a negative effect on the CPUE of Kona crabs. This could be tested in the standardization of the CPUE. This would be a mid-priority issue.
    - The assessment of the CML as a fixed variable in the standardization process could also provide an assessment of the relative fishing power of fishers which may highlight those consistently targeting Kona crabs and others who are not focused on crab fishing. This may help the data filtering process. There could be some confounding between the fisher and the location factors given the relatively higher abundance in some areas such as Penguin Bank. This would be a mid-priority issue.
    - It would be useful to add the time series of nominal effort and a standardized effort estimate (based on Catch/SCPUE) to the report. This is a high priority issue.
- mid-term (3-5 years)
    - Environmental factors affecting the CPUE at the time of fishing (e.g. catchability effects) were examined as part of the GLMM analysis. However, there are interesting patterns in the time series of standardized CPUE with some peaks occurring in the early 1960s, early 1970s and late 1990s, and possibly 2013. It would be useful to identify if there are any environmental factors that can explain the variation in the SCPUE. This would require an assessment of environmental variables such as ENSO, PDO and sea surface temperature lagged 5-6 years as environmental effects commonly affect the spawning, larval and early juvenile phase of the life cycle. This assessment becomes more valuable if any of the environmental drivers affecting recruitment are affected by climate change trends as this would have implications on the stock assessment and management of the fishery. This would be a mid-priority issue as it may provide some insights into the factors affecting recruitment to the fishery and whether there are long-term trends occurring.

- The stock assessment under review provided a thorough analysis of the available catch and effort data. However, because of the uncertainty associated with a large (~60%) unreported catch and the quality of the reported catch and effort data, and the effect of management changes on the CPUE, there remains uncertainty associated with the assessment. One way to address this would be to explore the possibility of establishing a cost-effective fishery-independent survey of key fishing areas (e.g. Penguin Bank and Niihau) for this culturally-important fishery. This survey could be done with the collaboration of the 3-4 key fishers that take the majority of the catch and fish in the areas designated for surveys. The survey would need to be planned in collaboration with the PIFSC scientists and would require observers. It could be undertaken annually, if possible, at an appropriate time of year that would also suit fishers. It could even be considered for the closed season with the appropriate management exemptions as this would provide valuable information on spawning females. It would be in the interests of fishers to improve the stock abundance estimates of Kona crab as this would give greater confidence in the management settings. The fishers could offset their costs by keeping the legal catch if this could be approved under the management regime. The survey would provide abundance indices for a number of size classes such as undersize, legal-size and mature female.
- The undersize male abundance may prove valuable for predicting legal-size abundance in future years (Caputi et al. 2014). The undersize abundance of a certain size range may also provide an index of year-class strength which could be used to understand the factors affecting the recruitment to the fishery as discussed above. The abundance of mature females could be used to develop a spawning index and examine the proportion of mature females berried.
- The survey would provide valuable size composition data and life history data that Kapur et al. (2018) and Hall et al. (2015) indicated would be valuable for any future size-structured model. The survey could be combined with a tagging study that would provide additional information on biological parameters, harvest rates and the relative catch contribution from commercial and recreational fishers. This survey recommendation should be a high priority as it will have a marked effect on the results and interpretation of stock status, and provide valuable ancillary data in the stock assessment.
- Another approach that could be adopted to estimate catchability and biomass estimates would be a depletion study. This species appears to be well suited to a novel depletion approach based on a star pattern of fishing that has been developed by Liese Carleton (lcarleton@vims.edu) and John Hoenig (hoenig@vims.edu) (see abstract in Appendix 4). This could be undertaken in a cost-effective way by fishers retaining the catch from the study.

    - While reviewers understand the motivation of moving to a male-only fishery to protect the mature female biomass, it is important to understand the implications of a male-only fishery. For example, some other male-only fisheries have found that there may be insufficient males of an appropriate size to mate females, so there may be an increasing percentage of unmated mature females. Therefore, some monitoring of the status of mature females may be informative of the effect and value of this regulation. This change has also resulted in increased handling of female crabs resulting in some mortality. In a fishery with appropriate controls on catch, consideration should be given to removing other regulations such as a ban on female retention. This recommendation would be a medium priority as it may provide information on the unintended effect of this regulation on the stock status and improve the economic viability of the fishery.
- long-term (5-10 years)
    - Developing a size and sex structured model would be a medium priority if the appropriate data was collected such as fishery-independent survey data.

11. *Draft a report (individual reports from each of the panel members and a Summary Report from Chair) addressing the above ToR questions.*

The reviewers drafted their individual reports and provided input into the Chair's Summary Report as well as the Chair's presentation to the meeting of the preliminary conclusions of the review.

References

Caputi, N. S. de Lestang, A. Hart, M. Kangas, D. Johnston, J. Penn (2014). Catch Predictions in stock assessment and management of invertebrate fisheries using pre-recruit abundance; case studies from Western Australia. Reviews in Fisheries Science 22:1, 36-54.

Brown, I.W., 1985. The Hawaiian Kona Crab Fishery. Queensland Department of Primary Industries, Brisbane.

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Hall, N.G., 2015. Center for Independent Experts (CIE) Independent Peer Review Report of the Kona Crab Benchmark Assessment 1–33.

Maia R. Kapur, Mark D. Fitchett, Annie J. Yau, Felipe Carvalho, 2018. 2018 Benchmark Stock Assessment of Main Hawaiian Islands Kona Crab.

Onizuka, E.W., 1972. Management and Development Investigations of the Kona Crab, Ranina ranina (Linnaeus). Honolulu, HI.

Thomas, L.R., DiNardo, G.T., Lee, H.-H., Piner, K.R., Samuel E. Kahng, 2013. Factors influencing the distribution of Kona crabs Ranina ranina (Brachyura: Raninidae) catch rates in the Main Hawaiian Islands. J. Crustac. Biol. 33, 1–8. doi:10.1163/1937240X-00002171

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Winker, H., Carvalho, F., Kapur, M., 2018. JABBA: Just Another Bayesian Biomass Assessment. Fish. Res. 204, 275–288. doi:10.1016/j.fishres.2018.03.010

Appendix 1: **Consulting Agreement between the CIE and Reviewer**

Statement of Work

External Independent Peer Review by the Center for Independent Experts
Performance Work Statement (PWS)
National Oceanic and Atmospheric Administration (NOAA)
National Marine Fisheries Service (NMFS)
Center for Independent Experts (CIE) Program
External Independent Peer Review

2018 Benchmark Stock Assessment for the Main Hawaiian Islands Kona Crab

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.
(http://www.cio.noaa.gov/services_programs/pdfs/OMB_Peer_Review_Bulletin_m05-03.pdf).
Further information on the CIE program may be obtained from www.ciereviews.org.

Scope:

A benchmark stock assessment for Main Hawaiian Islands Kona crab (*Ranina ranina*) was conducted by scientists at the Pacific Islands Fisheries Science Center and will provide the basis for management of this culturally important species. Previous stock assessments for Kona crab were conducted by non-NOAA scientists in 1978 and in collaboration with PIFSC scientists in 2010-2011. The benchmark assessment incorporates data from 1948 through 2016 and uses a production model, incorporating improvements to data standardization and model assumptions. Specifically, catch per unit effort (CPUE) in the model includes new standardization coefficients and was split into two time series (fishing year 1948-2005 and 2006-2016) due to passage of Hawaii state law prohibiting the taking of female Kona crab in 2006. The assessment model accounts for unreported catch by evaluating the use of published estimates of non-reporting ratios estimated for other fisheries in the Main Hawaiian Islands as well as by incorporating estimates of fishing effort specific to crustaceans from ancillary surveys. Stock status is evaluated against MSY-based reference points set in the Fishery Ecosystem Plan. Projections are provided to inform management setting of annual catch limits. The specified format and contents of the individual peer review reports are found in **Annex 1**. The Terms of Reference (TORs) of the peer review are listed in **Annex 2**. Lastly, the tentative agenda of the panel review meeting is attached in **Annex 3**.

Requirements:
NMFS requires two reviewers who are external to PIFSC, Pacific Islands Regional Office (PIRO), and the Western Pacific Regional Fishery Management Council and its affiliated bodies to conduct an impartial and independent peer review in accordance with this PWS, OMB Guidelines, and the TORs in Annex 2.
CIE reviewers shall have:

- Working knowledge and recent experience in the application of stock assessment models, including production models, sufficient to complete a thorough review;
- Knowledge of data limited assessment methods;
- Expertise with measures of model fit, identification, uncertainty, forecasting, and biological reference points;
- Familiarity with federal fisheries science requirements under the Magnuson-Stevens Fishery Conservation and Management Act;
- Familiarity with local Pacific Islands fisheries as well as artisanal fisheries and fishing practices;
- Familiarity with crustacean fisheries and assessment models;
- Excellent oral and written communication skills to facilitate the discussion and communication of results.

Tasks for Reviewers:
Each of the CIE reviewers shall complete the following tasks in accordance with the PWS and Schedule of Milestones and Deliverables.
Pre-review Background Documents: No later than two weeks before the peer review, the NMFS Project Contact will provide reviewers the necessary background information and reports for the peer review. The reviewers shall read all documents prior to the peer review in accordance with the PWS scheduled deadlines.

Required pre-review documents: see Appendix 2

Panel Review Meeting: Each CIE reviewer shall conduct the independent peer review in accordance with the PWS and TORs, and shall not serve in any other role. 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. The NMFS Project Contact is responsible for any facility arrangements (e.g., conference room for panel review meetings or teleconference arrangements). NMFS will provide a Chair for this in-person panel review. The NMFS Project Contact is responsible for ensuring that the Chair understands the contractual role of the CIE reviewers.

Contract Deliverables - Independent Peer Review Reports: Each reviewer shall complete an independent peer review report in accordance with the PWS. Each reviewer shall complete the independent peer review according to required format and content as described in Annex 1. Each reviewer shall complete the independent peer review addressing each TOR as described in Annex 2. Reviewers are not required to reach a consensus.

Other Tasks – Contribution to Summary Report: This Benchmark Review consists of two CIE reviewers and one review Chair–not provided by the CIE. Each CIE reviewer will assist the Chair with contributions to the Summary Report, based on the TORs of the review. Each CIE reviewer is not required to report a consensus finding. Reviewers should provide a brief synopsis of their own views on the summary findings and conclusions reached by the review panel in accordance with the TORs.

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 50 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-nationalregistration-system.html. The contractor is required to use all appropriate methods to safeguard Personally Identifiable Information (PII).

Place of Performance:
Each reviewer shall conduct an independent peer review during the panel review meeting scheduled in Honolulu, Hawaii at the Finance Factors Building, 164 Bishop St #140, Honolulu, HI 96813, during **September 10– 14, 2018**.

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

Schedule of Milestones and Deliverables:
The contractor shall complete the tasks and deliverables in accordance with the following schedule.

Within two weeks of award: Contractor selects and confirms reviewers

No later than two weeks prior to the review: Contractor provides the pre-review documents to the reviewers

September 10 - 14, 2018 Panel review meeting

Within three weeks of the panel review meeting: Contractor receives draft reports
Within 2 weeks of receiving draft reports: Contractor 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; and
(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 $7,500.

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

NMFS Project Contact:
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Beth.Lumsden@noaa.gov
FRMD/PIFSC/NMFS/NOAA
1845 Wasp Boulevard, Bldg. #176
Honolulu, Hawaii 96818
808.725.5330

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.
3. 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.
4. 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.
5. Reviewers should elaborate on any points raised in the summary report that they believe might require further clarification.
6. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.
7. 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.
8. 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.

Annex 2: Terms of Reference for the Peer Review

External Independent Peer Review under the Western Pacific Stock Assessment Review framework: 2018 Benchmark Stock Assessment for the Main Hawaiian Islands Kona Crab

For questions 1-8 and their subcomponents, reviewers shall provide a "yes" or "no" answer and will not provide an answer of "maybe". Only if necessary, caveats may be provided to these yes or no answers, but when provided they must be as specific as possible to provide direction and clarification.

1. Is the uncertainty with respect to input data quality and filtering methods well documented, including its potential effect on results?
2. Is the CPUE standardization properly applied and appropriate for this species, fishery, and available data?
3. Are the assessment models used reliable, properly applied, adequate, and appropriate for the species, fishery, and available data?
4. Are decision points and input parameters reasonably chosen?
5. Are primary sources of uncertainty documented and presented?
6. Are model assumptions reasonably satisfied?
7. Are the final results scientifically sound, including estimated stock status in relation to the estimated biological reference points, and can the results be used to address management goals stated in the relevant FEP or other documents provided to the review panel?
8. Are the methods used to project future population status adequate and appropriately applied for meeting management goals as stated in the relevant FEP?
9. If any results of these models should not be applied for management purposes with or without minor short-term further analyses (in other words, if any responses to any parts of questions 1-8 are "no"), indicate:

    Which results should not be applied and describe why, and

    Which alternative set of existing stock assessment results should be used to inform setting fishery catch limits instead and describe why.

10. As needed, suggest recommendations for future improvements and research priorities. Indicate whether each recommendation should be addressed in the short/immediate term (2 months), mid-term (3-5 years) and long-term (5-10 years). Also indicate whether each recommendation is high priority (likely most affecting results and/or interpretation), mid priority, or low priority.
11. Draft a report (individual reports from each of the panel members and a Summary Report from Chair) addressing the above ToR questions.

Annex 3: Tentative Agenda

2018 Benchmark Stock Assessment for the Main Hawaiian Islands Kona Crab

Western Pacific Regional Fishery Management Council Office

1164 Bishop St., Suite 1400; Honolulu, HI 96813

September 10-14, 2018, 9am - 5pm*

*The agenda order may change and the meeting will run as late as necessary to complete scheduled business.

Day 1, Monday, September 10

1. Welcome and introductions
2. Background information – Objectives and Terms of Reference
3. Fishery operation and management
4. History of stock assessments and reviews
5. Data
    - a. State of Hawaii fisher reporting system data
    - b. Post-release mortality and sex ratio
6. Presentation and review of stock assessment
    - a. Life history
    - b. Catch (reported and unreported)
    - c. CPUE
    - d. Assessment model
        - i. Base case model and priors
        - ii. Base case results
    - e. Retrospective analysis
    - f. Sensitivities
    - g. Projections

Day 2, Tuesday, September 11

7. Continue presentation and review of stock assessment

Day 3, Wednesday, September 12

8. Continue review of stock assessment

Day 4, Thursday, September 13

9. Continue review of stock assessment
10. Public comment period
11. Panel discussions (closed)

Day 5, Friday, September 14

12. Continue panel discussions (closed)
13. Panel presents results
14. Adjourn

Appendix 2: Required reading

Brown, I.W., 1985. The Hawaiian Kona Crab Fishery. Queensland Department of Primary Industries, Brisbane.

Fishery Ecosystem Plan for the Hawaii Archipelago, 2009.

Hall, N.G., 2015. Center for Independent Experts (CIE) Independent Peer Review Report of the Kona Crab Benchmark Assessment 1–33.

Maia R. Kapur, Mark D. Fitchett, Annie J. Yau, Felipe Carvalho, 2018. 2018 Benchmark Stock Assessment of Main Hawaiian Islands Kona Crab.

Onizuka, E.W., 1972. Management and Development Investigations of the Kona Crab, Ranina ranina (Linnaeus). Honolulu, HI.

Thomas, L.R., Lee, H.-H., Piner, K.R., 2015. Kona Crab Benchmark Assessment 4–5.

Wiley, J., Pardee, C., 2018. Post Release Mortality In The Hawaiian Kona Crab Fishery. Western Pacific Regional Fishery Management Council.

Winker, H., Carvalho, F., Kapur, M., 2018. JABBA: Just Another Bayesian Biomass Assessment. Fish. Res. 204, 275–288. doi:10.1016/j.fishres.2018.03.010

Appendix 3: CIE reviewers

CIE reviewers were Dr Nick Caputi and Prof. Malcolm Haddon. Dr Steve Martell was the chair of the panel.

Appendix 4: Depletion analysis abstract: Fishing gear calibration using a depletion estimator for open populations – catches from concentric circles

Liese M. Carleton and John M. Hoenig, Virginia Institute of Marine Science

Depletion studies are often used in closed systems to estimate population size and catchability coefficient. Application of depletion methods to open water systems is hindered by the uncertain size of the defined domain due to the attraction of fish from the outside into the study area. In a novel design approach, the study area is comprised of two concentric circles. The diameter of the outer circle is specified by the length of a bottom longline, which is set repeatedly in a star pattern to serially deplete the circle. Catches are recorded as either within the smaller inner circle or in the outer ring. This design allows us to include an immigration component into the depletion model so that initial abundance, catchability, and net movement can be estimated. Gear efficiency can be derived from the estimated catchability, and could then be used to convert a survey index of abundance (e.g., catch per hundred hooks) into an estimate of absolute population size (animals per km^2). The method is illustrated with bottom longline sets for Atlantic sharpnose shark (*Rhizoprionodon terraenovae*) in the Gulf of Mexico.

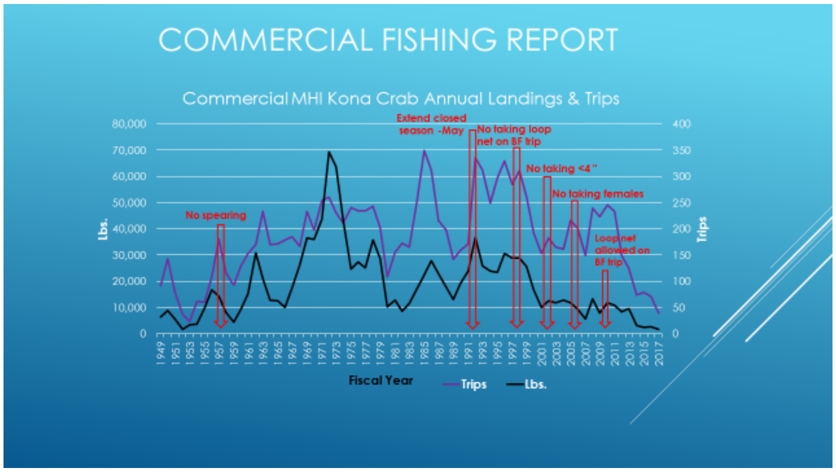

Fig. 1. Kona crab landings and trips (presented by Reginald Kokubun (DLNR-DAR, State of Hawaii).

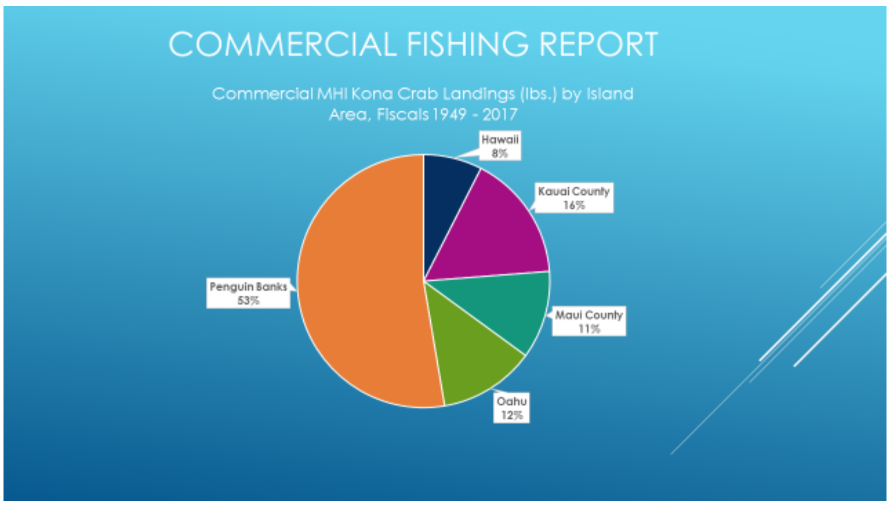

Fig. 2. Kona crab landings by Islands (presented by Reginald Kokubun (DLNR-DAR, State of Hawaii).

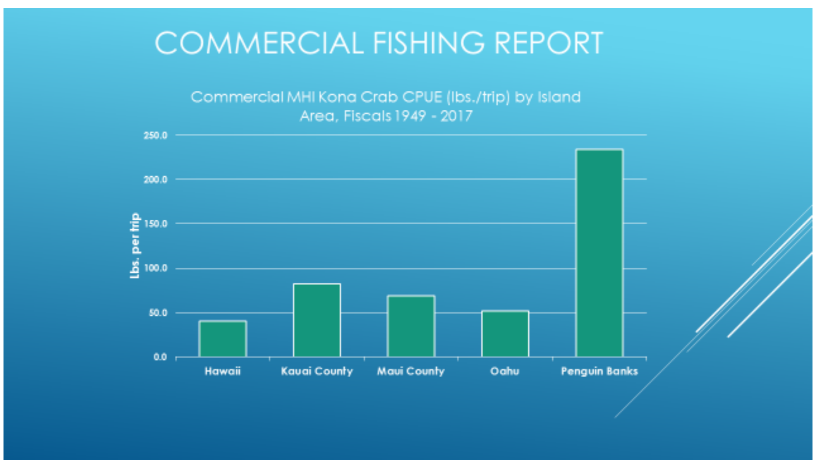

Fig. 3. Kona crab landings (lbs) per trip by Islands (presented by Reginald Kokubun (DLNR-DAR, State of Hawaii).

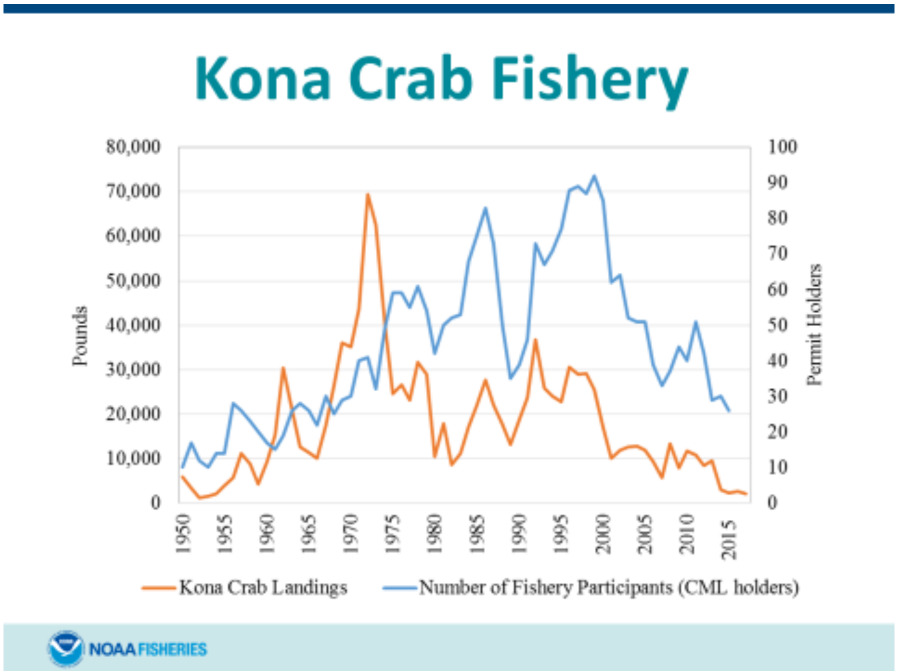

Fig. 4. Kona crab landings (lbs) and number of participants (presented by Kate Taylor, Sustainable Fisheries Division (Pacific Islands Regional Office, NOAA Fisheries)

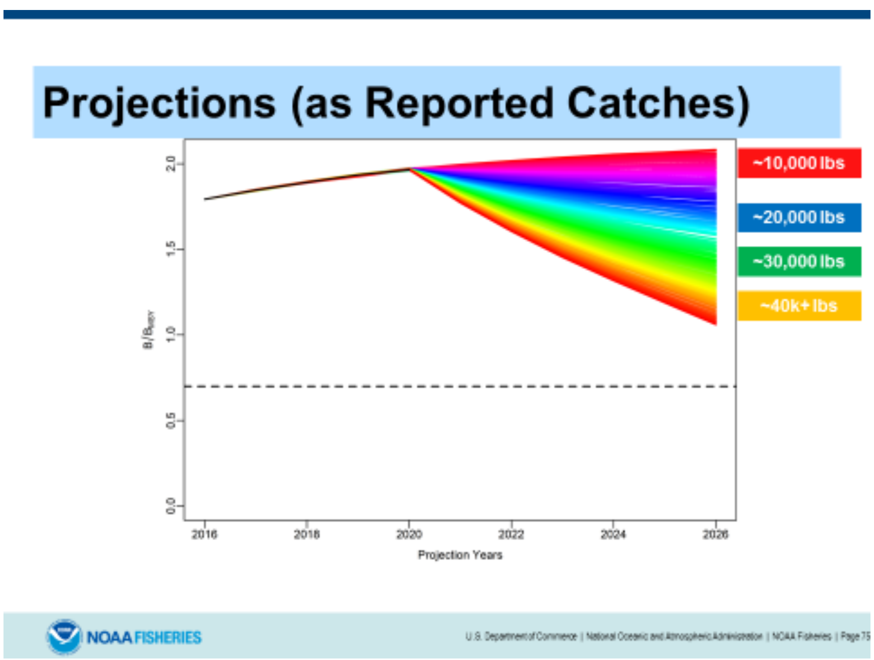

Fig. 5. Kona crab projections (lbs) of reported catches on B/B_{MSY} (presented by Maia Kapur, PIFSC)

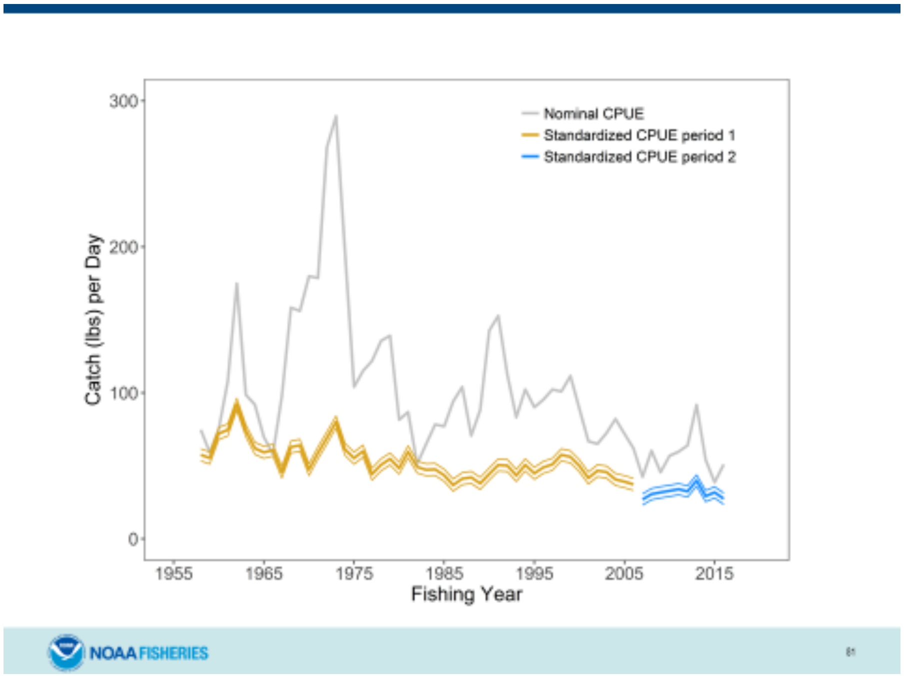

Fig. 6. Kona crab catch (lbs) per day for nominal and standardized CPUE (presented by Maia Kapur, PIFSC)

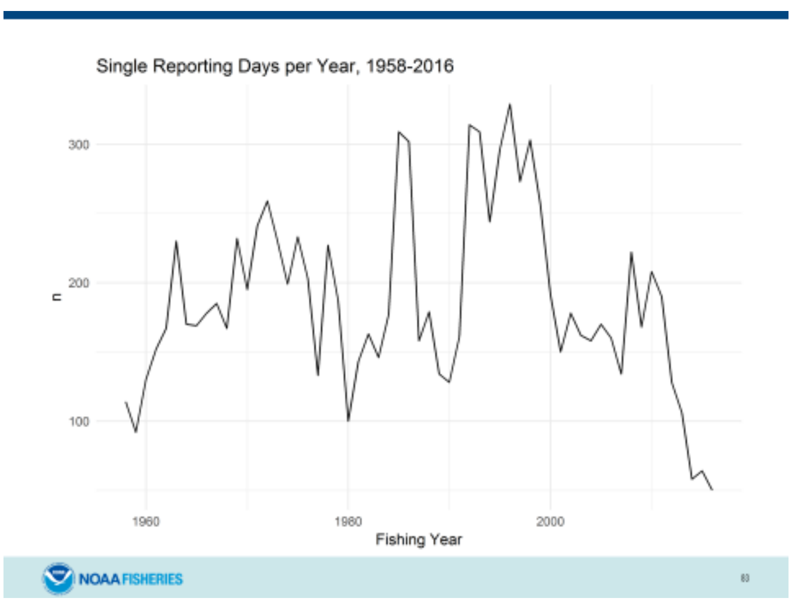

Fig. 7. Kona crab single-reporting days (presented by Maia Kapur, PIFSC)

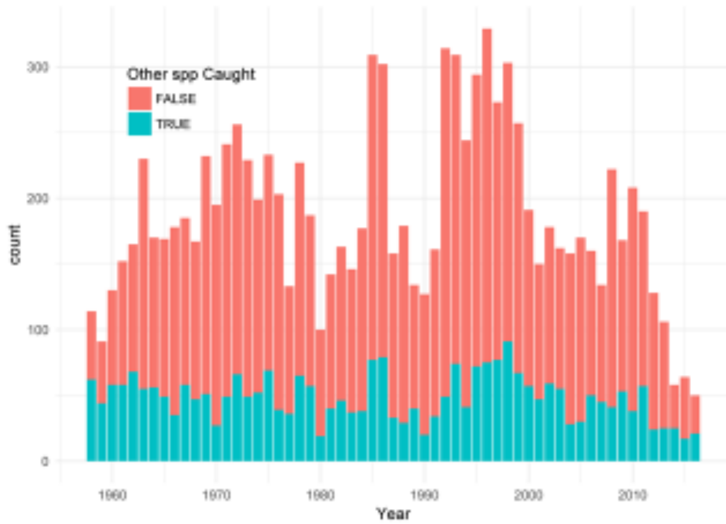

Fig. 8. Kona crab trips with and without other species caught (presented by Maia Kapur, PIFSC)