BSAI Crab Plan Team Report

May 8-10, 2018
Anchorage Hilton Hotel

The North Pacific Fishery Management Council's Bering Sea Aleutian Islands (BSAI) Crab Plan Team (CPT) met May 8-10, 2018 at the Hilton Hotel, Anchorage, AK

Crab Plan Team members present:
Bob Foy, Chair (NOAA Fisheries /AFSC – Kodiak)
Ben Daly, Vice-Chair (ADF&G – Kodiak)
Diana Stram (NPFMC)
Miranda Westphal (ADF&G – Dutch Harbor)
Shareef Siddeek (ADF&G – Juneau)
Martin Dorn (NOAA Fisheries /AFSC - Seattle)
William Stockhausen (NOAA Fisheries /AFSC - Seattle)
Bill Bechtol (Univ. of Alaska Fairbanks/CFOS)
Brian Garber-Yonts (NOAA Fisheries – AFSC - Seattle)
Ginny Eckert (Univ. of Alaska Fairbanks/CFOS – Juneau)
André Punt (Univ. of Washington)
Katie Palof (ADF&G - Juneau)
Krista Milani (NMFS AKRO - Dutch Harbor)

Members of the public and Agency personnel in attendance for all or part of the meeting (also via teleconference): Jamie Goen (ABSC), Paul Wilkins (CVRF), Keri Medjo (F/V Early Dawn), Mark Medjo (F/V Early Dawn), Bo Whiteside (ADFG Kodiak), Jocelyn Runnebaum (ADFG Juneau), Josh Fortensbery (NOAA GC Juneau), Steve Martell (SeaState), Madison Shipley (BSFRF/UW), Scott Goodman (BSFRF), Scott Kent (NSEDC), David Capri (Alaskan Trojan), Jill Capri (Alaskan Tojan), Rip Carlton (A-1 Patricia Lee), Linda Kozak, Edward Poulson (A-1 Patricia Lee), Jie Zheng (ADFG Juneau), Mark Stichert (ADFG Kodiak), Justin Leon (ADFG Nome), Hamazaki Hamachan (ADFG Anchorage)

Administration

The CPT approved the agenda with the following changes: remove agenda items on stock prioritization and St Matthew blue king crab assessment and add presentations on crab aging and a proposed management strategy evaluation (MSE) for Tanner crab. The CPT gratefully acknowledges the participation of Jack Turnock for many years, acknowledges his many contributions to North Pacific crab stock assessment and management. We wish him well in his retirement. The CPT notes several vacancies based on members who have moved to other jobs or retired and will seek nominations from ADF&G and NMFS to fill these.

Research Priorities

The CPT reviewed all current research priorities and recommended several status changes to CPT priorities, and revisions to existing project titles (note these are contained in a spreadsheet in a separate agenda item for the Council). One new research priority was also added to the list regarding benthic

production expectations with future climate change. There are several research priorities related to social and economic research that, while important, do not directly relate to the CPT stock assessment discussions. The CPT recommends that the newly formed Social Science Planning Team be tasked with research recommendations and prioritization of these research topics. To assist with the Council's goal to highlight top priorities, the CPT identified five research topics as having the highest priority for 2018. The top five topics were identified during the research priority review and subsequently prioritized in a discussion by the CPT.

Research ID	Title	CPT Priority	Priority Rank
148	Spatial distribution and movement of crabs relative to environmental variability, life history events, and fishing	Urgent	1
232	Develop management strategy evaluations that incorporate changing climate and economic conditions and impacts to coastal communities	Urgent	2
196	Genetics, population dynamics, and management implications of hybridization between Tanner and snow crab in the Bering Sea	Important	3
592	Maturity estimates for Bering Sea and Aleutian Island crab stocks	Urgent	3
174	Develop spatially-explicit stock assessment models	Important	4

148: Spatial distribution and movement of crabs relative to environmental variability, life history events, and fishing

Environmental conditions are changing rapidly in the eastern Bering Sea, driving related changes in the distribution of commercial crab stocks. Fishing behavior and life history timing (e.g., reproduction, growth) may subsequently be influenced by changes in crab distribution. The CPT discussed collection of data on distribution and movement relative to oceanographic conditions as critical for the development of the complex models needed to predict future stock abundance, stock boundaries, stock production, and management strategies.

232: Develop management strategy evaluations that incorporate changing climate and economic conditions and impacts to coastal communities

Developing Management Strategy Evaluations that incorporate climate projections is critical as crab management becomes more uncertain with environmental change. The subsequent effects of fishery

management changes on the economics and social functioning of resource-dependent communities also need to be considered. Predicting the sustainability of crab resources under changing environmental and management scenarios will lead to better-informed harvest strategies.

196: Genetics, population dynamics, and management implications of hybridization between Tanner and snow crab in the Bering Sea

Chionoecetes bairdi and *C. opilio* hybrids represent an unknown portion of Chionoecetes spp. biomass in the eastern Bering Sea. Current identification procedures are not consistent among fisheries and surveys, and available genetic data suggest a high probability of back crosses being identified as *C. opilio* or *C. bairdi* (as opposed to hybrids). Fishery landings are further complicated by hybrid designations and may incorrectly inform the OFL and TAC setting processes.

592: Maturity estimates for Bering Sea and Aleutian Island crab stocks

The availability of maturity data from male and female crab are incomplete for use in stock assessment models. Key parameters defining size at maturity, proportion mature at size, and the potential for biennial reproductive cycles are currently uncertain for many stocks. Methods for determining spatial and temporal variability of these quantities are needed to adequately characterize mature biomass.

174: Develop spatially explicit stock assessment models

Spatially-explicit stock assessment models are currently not used for management of commercial crab fisheries in the eastern Bering Sea. However, there is likely spatial variability in life history parameters, often correlated with environmental (i.e. temperature) conditions, for *Chionoecetes* spp. Spatially explicit models would also account for spatial trends in catch data and in stock boundaries.

BSFRF Update

Scott Goodman (Bering Sea Fisheries Research Foundation, BSFRF) provided an update on BSFRF research projects and priorities. BSFRF plans to continue survey work in the Bering Sea to study trawl selectivity for Bering Sea Tanner crab through side-by-side surveys with NOAA, as well as to investigate recruitment patterns using high-density "index" stations. This survey is patterned after the snow crab trawl selectivity surveys that took place in 2009 and 2010.

Goodman shared results from the bairdi trawl selectivity survey in 2017. BSFRF was unable to complete all planned tows around the Pribilof Islands, but made several index area tows in other areas of high crab abundance. The side-by-side survey was conducted at 95 of the 209 NMFS survey stations that caught bairdi, accounting for 53% of the bairdi catch. In these stations the NMFS survey caught 12,600 bairdi for a 921k CPUE and the BSFRF caught 22,400 for a 6,149k CPUE. BSFRF completed another 156 index area tows in 101 stations; 20 stations were surveyed in the eastern district, and the remaining stations were in the western district.

Graphs from 2017 showed the abundance of males and females by carapace width and the CPUE ratio (NMFS survey:BSFRF survey). The BSFRF and NMFS surveys showed similar abundance trends by size, except that the BSFRF survey data showed a higher abundance of smaller crab due to the use of a smaller mesh size. NMFS trawl survey gear does not typically catch crab below 35 mm CW. Side-by-side graphs of female versus male abundance by 1 mm carapace width increments for all crab collected in the BSFRF survey (from the side-by-side survey and index stations) were also shown. The data suggest that small Tanner crab females may grow slightly faster than the males; however, more data are needed to confirm this observation.

In 2018, a side-by-side survey is planned alongside the NMFS survey, and BSFRF plans to tow at the same stations as the NMFS survey. Conducting a complete side-by-side survey is a high priority. BSFRF plans to survey the same 95 substations as in previous years; maybe adding more index stations in the west and are hoping to make tows around St. George which was missed in 2017. The survey is slated to begin around June 15.

Sampling for bairdi trawl selectivity should be completed by 2018. The next steps are to decide how to incorporate the Tanner crab selectivity data into the assessment model and to choose appropriate modeling methods. This process will begin using an approach similar to that used for snow crab, with the recognition that index sites are treated differently from side-by-side station comparisons. The Tanner crab stock assessment author will work with BSFRF to obtain these data and to develop possible ways to incorporate it into future assessments.

Goodman shared information about the ongoing crab growth research being conducted on Tanner and snow crab from the Bering Sea. Small pre-molt Tanner and snow crab are collected and held in tanks or in containment nets, and data are collected on the size of each crab before and after molt. This research is ongoing with about 150 cumulative growth points recorded to date and will continue into 2018. These could be used to fill data gaps for smaller crabs and were recently used for snow crab (see January CPT meeting notes for Bimodality in 2017 snow crab reference point estimates).

Goodman discussed the Collaborative Bairdi Workshop held Dec 17-18, 2017 and hosted by BSFRF. This workshop was a collaborative review on bairdi biology, the stock assessment, and the harvest strategy. The workshop focused on issues regarding the female biomass control rule in the harvest strategy. Workshop participants recommended options for moving forward with the harvest strategy, with less of an emphasis on female biomass. These recommendations focused on a longer term review, revision to the current strategy that is part of the current BOF/ADF&G timeline, and using an MSE approach. The CPT requested that a report from the workshop be made available, which would minimally include the agenda and a summary of discussions from the workshop. Goodman stated that results of this workshop would be available soon.

Goodman mentioned BSFRF is supporting Madison Shipley, a graduate student at the University of Washington, who is working on a Management Strategy Evaluation for Tanner crab. BSFRF seeks feedback from the CPT and other scientists on her work, plans on sharing any information that comes out of the study, and wants to explore ways to use the results to inform the stock assessment and the State's harvest strategy. BSFRF is also supporting several upcoming tagging projects, including a NMFS project to conduct an R&D tagging study on red king crab, and an ADF&G satellite tagging project on Tanner crab movement in and out of the Pribilof Island Conservation Area closure.

Snow Crab model scenarios

Cody Szuwalski, the current snow crab assessment author who has worked as a consultant the past two years, will start a full-time position in August 2018 at AFSC. He will continue as the principal author for this assessment.

Szuwalski's presentation reviewed the bimodality in the likelihood profile in the 2016 assessment and the interim solution to use a Bayesian analysis to address this issue when providing management advice. The issue was traced to a gap in growth data at the kink in the growth curve. The addition of growth data in the subsequent year and fitting female natural mortality (compared to fixing this parameter) removed the

bimodality in the likelihood surface. Addition of the new growth data led to removal the kink in the female growth curve in the best fitting model. The male growth data were more limited and less informative for resolving the kink in the growth curve. The Bayesian approach was compared to the Maximum Likelihood Estimation (MLE) approach (with the changes described above) and the two now provide similar results.

One of the advantages of the Bayesian approach is that it provides distributions for the OFL, which could be useful to inform scientific uncertainty for management advice. The disadvantage of the Bayesian approach is that justifiable priors are difficult to obtain and computation of the posterior distribution can take a very long time (days). The plan going forward is to not use the Bayesian approach because of these challenges, particularly given that the MLE results are similar. The CPT supports the use of the MLE approach with jittering from here forward. The CPT questioned whether the female growth curve may project unrealistic post-molt sizes for crab above ~50-mm CW, but is it also unclear whether we have any observed female sizes in this larger range

There were two other issues that would be desirable to address in September. There are poor fits to females survey biomass data and the assumption of catchability of 1.0 for females. One option is to explore setting female catchability as an offset from male selectivity with a penalty. Another approach is to use the BSFRF side-by-side data. The hope in the future is to incorporate female reproductive potential into reference points, and it may make sense to use different recruitment deviations for males and females because of differences in growth. The raw data for the side-by-side experiments would be useful for informing survey catchability. Bob will work with BSFRF to facilitate transfer of these data.

The CPT would like future model runs that include male growth with and without the kink to understand the sensitivity of model results. There are additional recommendations from previous CPT discussions that would be worthwhile to consider in the next assessment. However, the recommendations that related to the lack of growth data might not be necessary.

Runs for September 2018:

1) September 2017 version M17A-D17A
2) September 2017 version M17C
3) Model should be fitted to the total and retained size comps rather than the total and discarded size comps (previous suggestion).
4) Consider including likelihood profiles for natural mortality

AIGKC final assessment

Shareef Siddeek gave a presentation to the CPT on the 2018 Aleutian Islands Golden King Crab (AIGKC) stock assessment. AIGKC was assessed using a length-based integrated stock assessment model that was fit to fishery length-composition data and standardized fishery CPUE, assumed to be an index of abundance. Separate assessment models were developed for AIGKC west and east of 174° W long. The model was initialized in 1960 under equilibrium assumptions and allowed to estimate recruitments to 1985 when stock assessment data first become available. Natural mortality is estimated in initial model runs, then fixed. The stock assessment was updated with fishery data for the 2016-17 fishing year.

Siddeek explained that the model is actually being used to estimate OFLs and ABCs for the 2017-2018 fishing year, even though the OFL and ABC will be used for the 2018-19 fishing year. The 2017-18 fishing season is completed, but data are not available in time to be used in the stock assessment used for setting OFLs and ABCs. Data for the 2017-18 fishing season are used later in the year in the State of Alaska process for setting the TAC. The CPT had not fully understood this procedure previously and discussed ways to improve the timeliness of scientific advice. The CPT recommends that the best estimate of 2017-18 total catch be used in the assessment, and that a projection using the Tier 3 harvest control rule be used to estimate the OFL and ABC for the 2018-19 fishing year. This is similar to the process that is used to set ABCs and OFLs for groundfish.

The breakpoint analysis of chela measurement data to estimate the length at maturity was revised, as requested by the CPT, using a plot of log (chela height/carapace length) vs. carapace length. Although this approach gave a clearer result, the estimate of the breakpoint did not change, and 111 mm CL was again used as a knife edge breakpoint for maturity in the model. Breakpoint analyses have been widely used to estimate crab maturity, but the CPT is concerned about the potential that male mature biomass will be overestimated with this approach. New chela measurement data will be collected by observers and dockside samplers in the AIGKC fishery, which will provide an opportunity for further analysis. In addition, new analytical techniques have been developed at the AFSC Kodiak lab for analyzing snow and Tanner crab chela measurement data, and these should be tried for AIGKC.

Seven scenarios were presented for consideration for estimation of management quantities for the eastern stock (EAG), and six were presented for the western stock (WAG), including the base model from last year's assessment. The scenarios were as follows:

Model 17_0. Base model for last year updated with new data. A different area definition was used for the fishery CPUE analysis, such that ADF&G statistical areas (40-50 areas total) were defined as areas, rather than groups of ADF&G statistical areas (10 areas total) as had been done previously. The effect on the estimated CPUE trend was negligible.

Model 17_0a. A model that used an abundance index from a VAST analysis of CPUE data rather than the standard GLM approach. The CPT considered the VAST analysis as exploratory in nature, and additional research is needed before VAST can be confidently applied to fishery CPUE data. In addition, as has been also found for groundfish, application of VAST spatial model to the Aleutians Islands is challenging due to the elongated shape of the area, complex bathymetry, and the presence of numerous islands.

Model 17_0b. A model that used an abundance index from a GLM analysis that uses AIC rather than r^2 for model selection. In general, the CPT does not recommend using AIC for CPUE standardization. CPUE standardizations typically use very large data sets in which the individual data points are not independent. Using AIC for model selection in this situation usually results in overly complex models being selected.

Model 17_0c. A model that used an abundance index from a GLM analysis that includes year-area interaction terms in the CPUE analysis. When year-area interactions are included in a GLM model, it is no longer appropriate to use the year effect as an index of abundance, as was done for this analysis. A betterapproach would be obtain separate indices for each area and use area weights to obtain an overall index. Area weights should be based on a measure of the fishing footprint within an area and not the total area.

Model 17_0d. This model adds a third catchability and selectivity period for 2013-2016. This scenario had the largest impact on estimated abundance trends and harvest projections. The CPT regarded four years as being too short to estimate catchability and was concerned that this model was simply fitting noise in the CPUE index. The CPT also notes this model estimated a large change in catchability for the EAG model, but almost no change for the WAG model, indicating strongly contrasting results for the two areas. Because of these concerns the CPT does not recommend that this model be used for harvest recommendations.

Model 17_0e. The McAllister and Ianelli method was used for tuning the length composition data rather than the Francis method. The Francis method has been successfully used for tuning the length composition data in the AIGKC assessment, and the purpose of this run was to evaluate the sensitivity of model results to using a different tuning method. Since there was little impact on abundance trends and harvest estimates, the CPT concluded that it was appropriate to continue using the Francis method for tuning the length composition data.

Model 17_0f. This model includes an abundance index from a GLM analysis of the three years of collaborative pot survey data in the EAG model. The GLM analysis for the cooperative pot survey apparently used fixed effects for year, unique strings, and unique pots. It was unclear how such a model, which would estimate more parameters than data points, could even be feasible. The CPT regarded the GLM analysis of the cooperative pot survey data as a work in progress and does not recommend use of this model scenario.

None of the new scenarios were considered by the CPT as improvements over last year's base model for the reasons discussed above, and therefore the CPT recommends adopting the base model 17_0 for harvest projections.

CPT recommendations

1. Base OFL and ABC recommendations on a model projection for the coming fishing year that includes total catch for the concluded fishing year.
2. Reanalyze chela measurement data for AIGKC using new analytical techniques developed for snow crab and Tanner crab.
3. Work on appropriate statistical models for analysis of ADF&G cooperative pot survey that reflect the nested sampling design of vessels, strings within vessel, and pots within strings and consider the use of random effects as appropriate.
4. Continue work on the VAST spatial modeling approach. This work can be given lower priority until approaches using VAST for CPUE data are better established and suitable model diagnostics become available.
5. Continue exploration of year-area interactions using appropriate analytical methods, and develop area weights using fishing footprint calculations.
6. A standard set of plots should be prepared to summarize the B0 calculations for each model-based crab assessment, including AIGKC. Plot 1 should compare dynamic B0 and the estimated time series of mature male biomass. Plot 2 should plot the B0 depletion ratio, MMB/B0. Plot 3 should plot the estimated recruitment time series. These plots should be collated, and used to develop recommendations on the use of B0 in Bering Sea crab assessments at the September 2018 CPT meeting for subsequent SSC review. This should be flagged as a general recommendation applicable to all assessed stocks.

Crab aging study update

April Rebert, biologist at the ADF&G's Mark, Tag, and Age Lab and M.S. student at UAF, presented the results of her NPRB project evaluating potential age structures for red king and snow crabs in Alaska. The main objective of this project was to develop consistent reliable aging methods for these two Alaskan species. Based on published research, three structures were evaluated for aging, including the eye stalks and paired stomach parts: the zygocardiac and the mesocardiac. These hard structures have been proposed as being retained through the molting cycle. Using five small and five large crab for both red king and snow crabs, these hard parts were evaluated for aging. The structures were prepared using resin and thin sectioned throughout the structure to look for banding patterns. There were three parts to explore aging possibilities: thickness of thin sections; orientation of sections, and site of optimum readability within the structure. The zygocardiac was chosen as the most readable part and consistent methods were chosen (120-200 µm sections, previously published orientation, and a preferable section of the structure). The preferred methods had a readability of only about 25% in red king crab and 35% in snow crab.

Next, experts were consulted to help determine how to interpret the banding patterns. Once criteria were established, sections were given to several test readers for band counts. Counts were compared among readers and had an average percent error (APE) of 18.57%. For reference, otolith reading for species with well-established protocols, yelloweye rockfish, has an APE of 3%. Exploration found a linear relationship between band counts and size lengths. These methods were next applied to crabs of different shell conditions. New, old, and very old shell male snow crab were examined for band counts (~20 in each group). There was no significant mean difference in band counts across shell condition. This may support the hypothesis that band counts are associated with molting, since old shell crab have reached terminal molt, but more research is needed to verify this hypothesis. These crabs were also examined for the size of the endocuticle, and there was no significant difference between shell conditions. Current work is underway using histology to determine if the endocuticle is retained during the molting cycle to verify that these bands are related to growth. The bands are related to size and seem to be independent of shell condition, but more work is needed to validate that bands are connected to molting or growth.

The CPT discussed how age data might be included in length-based models. Potential uses are informing the growth matrix and natural mortality estimation. However, aging methods are likely at least several years away.

EBS Tanner Crab

William (Buck) Stockhausen summarized modelling work in response to recent recommendations and the proposed updates to the stock assessment for EBS Tanner crab. The assessment report included analyses of some of the data used in the assessment (sex ratio data and NMFS survey capture probability), described new model components, and provided results for a wide variety of model scenarios.

Data explorations

The model assumes a 50:50 male:female sex ratio in the first size-class. Plots of male: female abundance in the NMFS survey for small (<45mm CL) animals suggest the sex ratio is slightly female-biased. There is variation among crab assessments in terms of including year-specific recruitment differences between sexes; this could be discussed during a modelling workshop.

Buck explored bootstrapping to estimate effective sample sizes for the composition data. Effective sample sizes were generally larger than the 200 assumed as stage-1 weights for the assessment. Bootstrapping involved sampling N hauls within each stratum. For each randomly-selected haul, M individuals were randomly-selected with replacement. The size composition was calculated with the area-stratified approach used to calculate the original size composition.

Chela height data were used to estimate the proportion mature (by size-class) as recommended in the January 2018 modeling workshop. The CPT noted that some small (<60mm CL) animals are designated as mature, which is unrealistic, and the data need to be corrected; 60mm CL is considered to be the minimum size-at-maturity for males, and further analyses need to impose this minimum.

Model explorations

Buck has made several modifications to the modeling framework since the January 2018 modeling workshop. Specifically, an alternative way to keep parameters within bounds (and to avoid parameter estimates on bounds) has been developed (but did not appear to eliminate the number of parameters on bounds), and a new way to ensure that "devs" vectors sum to zero was implemented.

An alternative formulation of the penalty on the recruitment deviations was outlined, which could allow estimation of the extent of variation in recruitment and not impose a penalty on the change in recruitment deviations among years (the "smoothing penalty"). However, the CPT noted that the approach for estimating the extent of variation in recruitment would be biased (or lead to zero estimates), while dropping the smoothing penalty can result in unrealistically large estimates of recruitment for some years.

A major change to the modeling framework is the ability to estimate the probability of male maturation by fitting to the data on the male proportion mature by year and size-class from the chela height data. These data are included in the model under the assumption the data are binomially distributed, which suggests that the analyst should check for overdispersion. The CPT suggests adding the sampling-based confidence intervals to graphs of the fits to the proportion data.

Buck outlined several alternative ways to parameterize growth that are now options in the model. He showed results for several analyses including an analysis implementing "dynamic B_0", and an evaluation of how the choice of terminal year impacts the average recruitment on which the B_{MSY} proxy is based. The initial results for dynamic B_0 provide no evidence for a regime shift after 1977 (corresponding to the 1982 recruitment in the model). There was little difference in average recruitment among choices for the options regarding the terminal year, suggesting that any standardization of how average recruitment is calculated among crab assessments is unlikely to be consequential for EBS Tanner crab.

Assessment options

Buck outlined the factors considered in the model scenarios (Table 4.1.2) and the data set choices (Table 4.1.1). The CPT and analyst agreed that not imposing the smoothness penalty on the early recruitments could lead to occasional outlying estimates. In addition, the CPT did not support indicator "a" in Table 4.1.2 as it is not possible to estimate the extent of recruitment variation. The CPT noted there were advantages to assuming a log-normal rather than a normal likelihood for the catches. However, the results were not sensitive to this choice (e.g., runs F0 vs. G0), and agreed not to recommend model scenarios with the log-normal likelihood at present.

Data set "C" includes the male maturity data, and hence estimates the maturation ogive accounting for these data. However, data set "C" also includes size-composition data based on the earlier Turnock-Rugulo approach – as such it uses the same data in two ways. Model scenarios based on data set C are informative about the impact of changes in methodology but are not viable as candidate model scenarios. In addition, the CPT has previously expressed concern about the reliability of the old shell designation (which was further emphasized by the unusual old shell abundances in the NMFS surveys in the 1970s), so the final model considerations include two scenarios in which the model is fitted to size-composition data aggregated over shell condition.

Model scenarios for September 2018

Buck proposed six model scenarios:

- 2017AM: the 2017 assessment model configuration
- 2018B0: the 2017 assessment model configuration with updated data for 2018
- 2018B1: 2018B0 + include the male maturity ogive data in the model optimization, with the probability of the male molt-to-maturity fixed at 0 in size bins < 60 mm CW.
- 2018B2: 2018B1 + exclude NMFS survey data in the 2017AM configuration that included estimates of immature and mature male biomass determined outside the model using Rugolo' and Turnock's empirical maturity ogive include NMFS survey biomass and size composition data for males by shell condition and for females by maturity status and shell condition in the model optimization
- 2018B3: 2018B2 + include aggregated NMFS survey abundance estimates in the model optimization
- 2018B4: 2018B3 + use lognormal fits to fishery catch biomass in the objective function

The CPT agreed that scenario 2018B1 would provide a bridging model but could not be considered as the basis for management advice in September 2018. In addition, the CPT did not see value in carrying forward model scenarios in which the catch data are assumed to be log-normal. The CPT requests that the following model scenarios be presented at the September 2018 meeting:

- 2017AM: the 2017 assessment model configuration
- 2018B0: the 2017 assessment model configuration with updated data for 2018.
- 2018B1: 2018B0 + include the male maturity ogive data in the model optimization, with the probability of the male molt-to-maturity fixed at 0 in size bins < 60 mm CW (bridging model only).
- 2018B2: 2018B1 + include the NMFS survey data as the total biomass by sex, and the size-composition for males by shell condition and for females by maturity status and shell condition
- 2018B3: 2018B1 + include the NMFS survey data as the total biomass by sex, and the size-composition for males aggregated over shell condition and for females by maturity status (aggregated over shell condition).
- 2018B4: 2018B2 + include aggregated NMFS survey abundance estimates in the model optimization
- 2018B5: 2018B3 + include aggregated NMFS survey abundance estimates in the model optimization

Issues for possible consideration in future modelling workshops:

- How to decide whether it is necessary to estimate sex-specific recruitment.
- Develop a way to apply the Francis method for stocks (such as Tanner and snow crab) for which the composition data are potentially by sex, maturity state, and shell condition.

MSE Study on Tanner crab

Madison Shipley, University of Washington M.S. student, outlined her study on a management strategy evaluation (MSE) for Bering Sea Tanner crab. She plans to formulate a "full" MSE using the current stock assessment model and a "simple" MSE based on estimates sampled from a biomass distribution. Goal 1 is to implement the "full" MSE with the specified ADF&G harvest control rule (HCR) and estimate a set of performance statistics based on simulations (e.g., mean catch, catch variability, and number of closures). The goal 1 product is deliverable to ADF&G by 2019 and to the Alaska Board of FIsheries by 2020. Goal 2 is to implement the "simple" MSE, with the same ADF&G HCR, estimate the same set of statistics, and compare the performance statistics between the "full" and the "simple" MSE. This comparison will either support or reject the use of "simple" MSEs in this assessment. It was noted that the comparison between a "full" MSE and "simple" MSE would not necessarily be clear-cut for Tanner crab, since the ADF&G harvest control rule uses both survey estimates and quantities estimated by the stock assessment.

GMACs update and BBRKC model scenarios

Dr. Andre Punt updated the group on progress implementing the BBRKC assessment in GMACS. Previously, there were major discrepancies between the results from Dr. Jie Zheng's model and GMACS. In a recent effort, Dr. Punt plugged in same initial value as the BBRKC model (rk75172b) with three objectives in mind. Objective 1 was to match values for growth, natural mortality, and selectivity, and modify the code of one or both packages to ensure this is the case (completed), to check the N-matrix given assumptions: about fishing mortality by fleet (directed fishery, bycatch in the trawl fishery, bycatch in the fixed gear fishery, bycatch in the Tanner crab fishery) (completed), to check the model predictions that are included in the likelihood (still underway); and check the likelihood value (not started yet). Objective 2 was to estimate parameters once the likelihood can be replicated (not started yet). Objective 3 was to compare predicted values of management-related quantities (not started yet).

Dr. Punt focused on attempting to match Dr. Zheng's model results in GMACs by: adding a new option to specify the numbers-at-length that the start of the first year, adding a new "blockdev" option for M, adding that discard exists before data on discard are collected as long as there is an F for the directed fishery, and correcting a bug in how molt probability was set.

Issues relative to the current BBRKC model were identified/modified and included that normalization of the initial conditions may create oldshell males in the last class, initial values of many of the parameters being set to the average of the bounds, the fact that some variables (e.g., sel_ret0) are used but not initialized, one variable is defined but never used, the linear model for selectivity has several "if" statements, and sel_fit vector needs to be validated. Dr. Punt included the GMACS catch equations in the BBRKC model to increase comparability.

Issues relative to GMACS that have yet to be addressed include (a) whether M-devs should be devs or parameters; (b) GMACS cannot have different numbers of size-classes for males and females; (c) fishing mortality for EBS Tanner crab is related **directly** to effort in RK75172b, but this option does not exist in

GMACS; (d) discard mortality is independent of sex but read in by sex; (e) there is no ability to have sex-specific recruitment distributions; (f) there is no ability to impose a maximum on the number of classes to which recruitment occurs; (g) there is no ability to have time-varying size-transition matrices (which is needed for BBRKC), (h) GMACS does not compute landed+discarded (i.e. total) catch, (i) the method to include effort-predicted F needs to be checked, and (j) how to handle instantaneous fisheries using the GMACS catch equation needs to be addressed.

Dr. Punt made the point that these issues with GMACS need to be worked out, and that the goal is to have results from the two models be closer, realizing exact matches are not necessary to be confident in the performance of GMACs. Dr. Punt hopes to come to the September CPT meeting being able to reproduce Dr. Zheng's model results when using the same data inputs. Where GMACs goes from there should be discussed at the September CPT meeting, but will likely fall to NOAA and ADF&G to determine the future direction of the BBRKC assessment in GMACS.

BBRKC assessment

Dr. Jie Zheng presented the draft Bristol Bay Red King Crab (BBRKC) SAFE document, including updated BBRKC assessment including estimating male discard biomass without legal retained status information (as described in Appendix C of SAFE document), retrospective analysis of terminal years of recruitment, dynamic B_0 computation (as depicted in Appendix D of SAFE document), and high estimated trawl survey q values. Dr. Zheng described issues with past at-sea observer legal retention status information and proposed using the "subtraction" method (i.e., total male catch from observer data – retained catch) which has been adopted for the AIGKC model. Dr. Zheng presented annual legal discard rates for 2005-2017 using both the previous method (LegalNR/(Legalret+LegalNR)) and the "subtraction" method and highlighted that the two methods produce different discard rates for legal sized crabs. However, when comparing the two methods for total male discard rates (i.e., sublegal males included in the calculation), they were more comparable, and it was generally thought that subtraction method is a reasonable way to estimate total male discard biomass in the directed pot fishery. There was some discussion about fitting discards, and the inability to get at size composition data with the subtraction method. The recommendation is to fit total catch and total retained catch, and not try to fit male discard biomass. As such, this recommendation makes the "subtraction" method for estimating legal discards moot.

Dr. Zheng compared model results from five scenarios (2b, 2bn1, 2bn2, 2b85, 2c85). Scenario 2b is the scenario 2b in the SAFE draft report in September 2017, scenario 2bn1 is the same as scenario 2b except that the approach in Appendix C ("subtraction" method) is used to estimate for male annual bycatch biomass since rationalization (2005-present) and total observer male length composition data are used to compute log negative likelihoods in the directed pot fishery, scenario 2bn2 is the same as scenario 2bn1 except that only one logistic curve is estimated for all years for retained proportions and annual retention adjusted factors are estimated to modify retained proportions for years after 2004, scenario 2b85 is the same as Scenario 2b except for starting the model in 1985, and scenario 2c85 is the same as Scenario 2c in the draft SAFE report in May 2017 except for starting the model in 1985 and constant natural mortality of 0.18 for all years.

Model fit was similar among scenarios for total biomass, mature male abundance, mature female abundance. Model fit to mature male biomass on Feb 15 (projection) showed some differences among scenarios, which appeared to be related to values of Q. Notably, estimates in recent years was lower for

scenario 2bn1, likely related to the high value for Q (1.0). Observed and predicted catch mortality biomass under the five scenarios were similar for total catch, male discards, and female discards in the directed fishery. Some minor differences were noted among scenarios for estimated selectivities for the NMFS and BSFRF surveys. Dr. Zheng showed directed pot fishery selectivities for scenarios 2bn1 and 2bn2. Scenario 2bn1 had three logistic curves: total selectivity, retained proportion for 1975-2004, and retained proportion for 2005-present. Scenario 2bn2 had two logistic curves: total selectivity and retained proportion with annual adjusted factors for 2005-present. There was a fair amount of discussion about fisheries selectivities among years and whether the annual estimated selectivity rates were realistic. There was a recommendation to look at time varying fishery selectivity and retained proportions for the September CPT meeting. Fits to the NMFS survey, BSFRF, and retained catch size composition data was generally satisfactory among model scenarios. The residual bubble plots looked generally satisfactory for the two recommended model scenarios (2bn1 and 2bn2).

Dr. Zheng showed the retrospective pattern of hindcast estimates of total recruitment for scenario 2b from 1976 to 2017 made with terminal years 2011-2017. Recruitment estimates in terminal years were highly uncertain, and uncertainties of recruitment estimates decreased sharply from one year estimated in the model to two or more years in the model. It was recommended that the terminal year should not be used for estimating B35%. Dr. Zheng also showed estimated B0, MMB with fishing, and ratios of MMB/B0 from 1975 to 2017 for scenario 2bn2 and pointed out that estimated B_0 values change greatly over time. However, without an S-R model and quantified environmental effects, estimated B_0 values do not provide much valuable information.

Recommendations for model simulations for the September 2018 CPT meeting include: 1) fitting the total catch estimated from at-sea observer data and total retained catch without incorporating the "subtraction" method for estimating legal discards, 2) incorporating time varying fishery selectivity and annual retained proportions, and 3) the recruitment in terminal year should not be used for estimating B35% (i.e., mean recruitment is estimated from recruitments from 1984 to endyear – 1).

NSRKC

Commercial and Subsistence Fisheries – Justin Leon (ADF&G, Nome) summarized Norton Sound Red King Crab (NSRKC) fisheries. Subsistence fisheries shifted primarily from handline to pot gear in the late 1970s. Subsistence fishing is open year-round, but summer subsistence data are not included in the assessment model. Harvest and effort are monitored through a calendar-based household permit. The recent 10-year average has been 99 winter permits and 17 summer permits annually. The subsistence fishery has no crab sex or size restrictions.

The winter commercial fishery occurs through the ice, is opened by ADF&G Emergency Order, and typically lasts from January 15 to April 30, but opened March 3 this year. A major factor is coordinating with processors. The winter fishery involves both CDQ and open access (OA) harvesters with a 20 pot limit, enforced through pot tags, with a 10-yr average of 21 permits/year; OA permits increased in recent years. The recent fishery mainly supported a market for live crab ≥5-inch CW with no limbs missing. There is high pot loss from moving ice, and pot loss is likely underestimated. Most harvests (93% in past 5 years) are from the Nome area. Biological data for the winter commercial fishery are based on weekly processor sampling for a total of 500 crab/season. The voluntary observer program, started in 2012, collects discard and handling time data. Increased OA fishery participation is likely related to good prices, relatively low fishery entry costs, and support by Norton Sound Economic Development Corporation.

The summer commercial fishery began in 1977, shifted to smaller vessels in 1994, and runs from June 15 to September 3 with a 40-pot limit. Most current vessels are in the 20–40 foot range. The 10-year average is 31 permit holders/year. The summer fishery serves both a live and a frozen market from OA harvesters and has been fairly stable for vessel number. Most harvests occur off Nome to White Mountain, with a spatial bound restricting vessel access toward shore. Summer processor monitoring involves sampling 20 crab/tote from each delivery for an annual total of 5,000–7,000 crab. Onboard observer sampling started in 2012 aboard voluntary vessels to collect catch, discard, sex, size, and shell condition from 5 crab/pot. In total, observers sampled 1–2% of crab harvested since 2012, focused on areas of major harvests. Summer processor protocols relaxed restrictions against crab with missing limbs. The CPT suggested that several graphics, such as the proportion of harvest by reporting area relative to total harvest, be included in the assessment.

Biology of Norton Sound RKC – Jennifer Bell (ADF&G, Nome) described some of the available information and uncertainties on biology of RKC in Norton Sound. This is currently a male-only model, with M a function of size (higher for larger crab), discard mortality of 0.2, and a September molt. A triennial bottom trawl survey samples 10x10 nm grids across core and Tier 1 stations with Tier 2 and Tier 3 grids sampled as time allows; 60 stations were trawled in 2017. Trawl surveys by NMFS occurred in 2010 and 2017 across 20x20 nm grids. Catches may be patchy in the trawl survey, as shown by a single station in 2014 producing most of the survey catch. The current protocol is to base the crab population estimate on surveyed grids, and pooling area-swept estimates across surveyed grids without expansion to unsampled grids. As a result, population estimates vary based on survey effort. Stations immediately south of Nome have the highest survey catches. Tagging studies (~30,000 tagged) from 2012–2015 recovered only 279 with clear recovery location (2,703 tags total recoveries), but indicated a general southwest movement of northern crab. In contrast, NSEDC crab tagged off Unalakleet moved northwest toward the larger population, suggesting a single mixed population. There remains few data on winter movement. Ecdysteroid sampling was conducted during January to October in 2014 and 2015 to examine molt timing. Hormone increases were anticipated 2–4 weeks prior to molting, and observed hormone concentrations peaked in July, but samples were mainly from offshore trawl survey areas. Sublegal males appear to molt earlier, and molt increment appears to decrease with pre-molt size. The CPT discussed determination of size at maturity, which seems arbitrary without supporting data, but is core to both the assessment and a Tier 3 designation.

Summer handling mortality is assumed to be low (assessment model assumes 0.2) due to warm temperatures, small pots, and the use of escape mechanisms. Although the legal crab size is 4 ¾ inch CW, the market preference is ≥5 inch CW. High abundance of sublegal crab noted in Norton Sound spring surveys in 2013-2015. Although greater observation of summer fishery discards would be good, there are a limited number of vessels suitable for carrying observers. Winter fishery discards are broken into retained vs. non-retained when observed, but not measured due to effort to encourage rapid release to water. Most crab are released in ≤2 minutes. High-grading occurred in 2018 due to focus on live market with all legs attached, although the issue was raised about potentially higher discard mortality for crab missing limbs. Crab are typically held in live tanks. Personal use retention by commercial harvesters is not well documented but was thought to be a minimum of 5% (1,100 lb) from the recent CDQ fishery and is not limited but unknown for the OA fishery.

The CPT discussed aspects of moving from the current Tier 4 assessment to a Tier 3 assessment. Life history information is generally similar for Tier 3 and Tier 4 assessments. Going to Tier 3 would allow use of different Ms for different size classes when computing the harvest rate used in the calculation of

the OFL. A major concern is that the assessment is largely tied to the triennial trawl survey. There is a recognized need to develop a stratification method to provide a consistent survey area. Not all crab move offshore and it is believed that some crab stay inshore and skip molt. Little is known regarding skip molting, and information on sublegals, functional maturity of males, discard estimates and long-term effects of cold temperatures on discards, and recruitment is lacking, as well as information related to growth and yield-per-recruit. However, these concerns are relevant to both the current Tier 4 and any proposed Tier 3 assessment. For observer information, such as discards, it is not clear that the available data are representative given the small number of observed harvesters. The ADF&G GHL is set in regulation as a percent of legal male biomass, tied on a sliding scale to tiers of biomass. The GHL is currently capped at a maximum of 13%. Because the legal biomass is smaller than the ABC and OFL (which are tied to MMB), going to Tier 3 and looking at harvest allocation closer to Tier 3 might allow a larger harvest, but would still be affected by a buffer. The CPT noted that decreasing the tier status might not necessarily reduce the buffer, which is an expression of uncertainty in the assessment model. However, Tier 3 would give a consistent way to calculate OFL, and it would be important to continue to collect data for incorporation into the assessment process.

NPRB Growth Project

André Punt provided an overview of progress on a North Pacific Research Board-funded project that is aiming to improve methods for specifying the mathematical form of the size-transition matrices used in size-structured assessment models and those used to estimate the parameters of size-transition matrices. The work entails objectives related to testing alternative modelling approaches using simulation and implementing the best-performing approaches in GMACS. André reported that he and graduate student Lee Cronin-Fine had found that the approaches for parameterizing growth in size-structured models provided unbiased estimates of the model parameters when growth was discrete, and all animals had initial size equal to the mid-point of the modelled size-classes. However, there was bias when these assumptions were violated. The project is continuing to explore the consequences of this bias in terms of the entries of the size-transition matrix and inferred equilibrium size-distributions.

Crab observer data

Ben Daly (ADF&G) gave an update on sublegal, legal retained, and legal not retained designations by on-board crab observers in the Bering Sea and Aleutian Islands crab fisheries. Fishermen discard legal crab in the fishery for several reasons: industry preferred size, which is larger than legal size for Tanner and snow crab; injured, diseased, or unmarketable crab; conservative sorting ‘by eye’ on deck by fishing crew; and/or crab damaged by the observer. Currently, male crab are designated as either sublegal (code 0), legal retained (code 1), or legal not retained (code 2), with the retained designation based on the observer’s belief, through conversations with the skipper, as to whether or not the vessel would discard or retain a legal sized male. There are many questions about the reliability of these data and a consensus that they should not be considered valid.

In January, stock assessment modelers were asked to evaluate whether legal retained/not retained designations could be eliminated and to report back to the CPT during the May meeting. After the January meeting, ADF&G determined that in order to implement any changes in the 2018/19 crab season, the shellfish observer program would need to begin work before May. Daly contacted stock assessment authors in February to get feedback on how removing the legal retained/not retained designation would affect the models. The Bristol Bay Red King crab model would need to find a new way to determine

discards (see BBRKC assessment notes from this meeting), but the assessment author thought this was possible. The Snow crab model would also require a minor change. All other models that take discards into account already use the "subtraction method" (or something similar) to determine discards.

Given this feedback, ADF&G plans to eliminate legal retained/not retained designations in the 2018/19 crab fisheries. The legal status of crab will still be collected by observers; sublegal crab (code 0) and legal but retention status unknown (code 6). Daly noted that there are multiple ways this raw data could be applied and that stock assessment authors should be able to estimate discards from raw observer data if needed. He also stated that ADF&G will most likely use the "subtraction method" to determine discards during TAC setting.

Crab Economic SAFE

Brian Garber-Yonts presented a brief summary of the economic report that will be published later on key economic status indicators and performance of BSAI FMP crab fisheries including a new analysis of operating costs for vessels. The upcoming crab SAFE will include a decomposition analysis of vessel ownership entities and Individual Fishing Quota ownership entities working back through corporate ownership of quota to the individual owners to ensure that quota and vessel owners do not exceed federal use caps. Additionally, this analysis is working to resolve the unknown extent of quota leasing and determine the degree to which quota is being fished by leaseholders rather than quota owners and how ownership patterns have changed over time. At the suggestion of the SSC, the upcoming crab SAFE will include an economic report card that will include asocial and economic component for each crab stock.

Garber-Yonts gave a brief review of the 2016 economic data with some updates including the 2017/18 Bristol Bay red king crab fishery. The author noted that all information is in a calendar year, not a crab fishing year therefore the 2017 report will include fishery data from the end of the 2015/16 crab season and also fishery data from the beginning of the 2016/17 crab season, which concluded in the 2017 calendar year.

The total volume of ex-vessel landings sold to processors during 2016 was down 30% across all stocks due to decreases in TACs, although the decline was mitigated by an increase in ex-vessel and wholesale prices. Ex-vessel and wholesale prices were up across all stocks. The ratio between ex-vessel and wholesale remained fairly constant for red king and snow crab fisheries due to the arbitration process in the rationalized fishery which acts to maintain the historical distribution of prices. For golden king crab, a decreasing share of the wholesale price is going to ex-vessel although it is uncertain why this is occurring. Revenue dropped off in snow and Tanner crab due to reductions in fishing but remained relatively unchanged for the other fisheries. The reduction in harvest is a result of fishery closures combined with offsetting price increases.

There have been a number of reductions in the amount of employment throughout the fisheries. The number of crew positions decreased 10%. There was also a decrease of 33% in processing hours in 2016 compared to the previous year as a result of the decrease in TACs across all stocks. Median processing wages decreased, most likely due to increased efficiencies in processing procedures and a resultant decrease in overtime pay. For Bristol Bay red king crab, crew daily wages have increased due to a decrease in the TACs meaning that crews are spending less time fishing and have less expenditure. Vessel income for Bristol Bay red king crab, has been increasing slightly for mean vessels from 2012 through 2016, averaging $500,000 per vessel in 2016. At the aggregated fleet level, total gross earnings for Bristol Bay red king crab were just under $90 million. At the fleet level this distributes gross profits

between the vessel owner sector and the quota owner sector. At the fishery level, this is a transfer of profit between vessel and quota owners.

At the fishery level, profit includes what is retained by vessel owners as well as payment for quota leases. The quota share sector is collecting approximately 40- 50% of the gross revenue. The gross profit combined with the vessel owner's earnings is close to 75% of the gross revenue. The fishery is quite profitable at the gross profit level with most of the profit going to the quota share sector, although there is overlap in this sector with the vessel owner sector.

For the AFA groundfish fisheries, one of the surveys that are conducted on an annual basis, the vessel master is required to fill out a short survey regarding the effectiveness of incentives under amendment 91, fishing conditions on the ground, the effect of management changes, etc. This survey is currently under revision but has provided a systematic way for skippers to communicate effectively with stock assessment authors about how changes in management or conditions on the ground affect fishing. Garber-Yonts suggests that a similar survey be utilized in the crab fisheries so that fishermen can communicate systematically with the stock assessment authors pending successful testing in the groundfish trawl fisheries. There was some discussion amongst CPT members and Council staff regarding the utility and efficacy of such a survey. NOAA general counsel pointed out that if the survey were to be distributed to more than ten people, it would need to be approved through a federal process first.

Future economic SAFEs will work to incorporate report card metrics and graphics in addition to utilizing price forecasts to represent estimates of revenue and price for the most recent year, adding demographic and ownership details, and more detail for the processing sector income. A discussion paper will be published that will review all of the economic data reports and data collected that could potentially initiate a process of research priorities to collect and analyze economic data more efficiently and consistently. Economic analysts are working to format economic reports for all SAFEs that are currently under development in a handful of the groundfish fisheries. Once testing is complete, the results will be presented to the CPT for consideration in incorporation into the crab SAFEs.

The economic SAFE is located at https://www.afsc.noaa.gov/REFM/Socioeconomics/SAFE/default.php

New Business/meeting planning

CIE review for the AIGKC and NSRKC stock assessments: June 18-21, 2018 at AFSC, Seattle.

September CPT: September 10-13, 2018 at AFSC, Seattle
Items: Final assessments and OFL/ABC for BBRKC, Snow Crab, Tanner crab, SMBKC. Modeling scenarios for NSRKC; overview of CIE comments; Review progress on GMACs for BBRKC; other items to be added as needed

January CPT: Dates TBD; Exploring options for January meeting an Alaska coastal community. Nome and Dutch Harbor were suggested as options
Items: GMACs (longer-term planning); Snow and Tanner crab tuning in assessments; B0 discussion across all stocks, Effective spawning biomass update and progress review; Modeling scenarios for AIGKC; final OFL/ABC for NSRKC