North Pacific Fishery Management Council

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Crab Plan Team

REPORT

April 29 - May 03, 2019
Coast International Inn
Anchorage, AK

Committee Members in attendance:

Martin Dorn,	**Co-Chair** (AFSC-Seattle)	André Punt	(Univ. of Washington)
Katie Palof,	**Co-Chair** (ADF&G-Juneau)	Shareef Siddeek	(ADF&G-Juneau)
Jim Armstrong,	**Coordinator** (NPFMC)	William Stockhausen	(AFSC-Seattle)
William Bechtol	(UAF-Homer)	Diana Stram	(NPFMC)
Ben Daly	(ADF&G-Kodiak)	Cody Szuwalski	(AFSC–Seattle)
Brian Garber-Yonts	(AFSC-Seattle)	Miranda Westphal	(ADF&G-Dutch Harbor)
Krista Milani	(NMFS-AKRO-Dutch Harbor)	Jie Zheng	(ADF&G-Juneau)

Members absent:
Ginny Eckert (UAF/SFOS-Juneau)

Others in attendance:

ǂMariza Aparicio-Tovar	(ADF&G-Dutch Harbor)	*Chris Long	(NMFS-Kodiak)
ǂAsia Beder	(ADF&G-Dutch Harbor)	ǂBrie McGrath	(ADF&G-Dutch Harbor)
Karla Bush	(ADF&G-Juneau)	*Sarah Marrinan	(NPFMC)
*Erin Fedewa	(NMFS-Kodiak)	Henry Mitchell	
Josh Fortenbery	(NOAA GC)	*Ethan Nichols	(ADF&G-Dutch Harbor)
*Jason Gasper	(NMFS-AKRO)	*Jonathan Reum	(U.Wash.)
Jamie Goen	(ABSC)	*ǂJon Richar	(NMFS-Kodiak)
*Scott Goodman	(NRC/BSFRF)	Madison Shipley	(UW/BSFRF)
*Hamachan Hamazaki	(ADF&G-Anchorage)	Mark Stichert	(ADF&G-Kodiak)
Lenny Herzog	(fisherman)	*ǂJim Thorson	(NMFS-Seattle)
John Hilsinger	(Alaska Trojan)	Clem Tillion	
*ǂGenevieve Johnson	(UAF, Juneau)	*ǂCathy Tide	(NMFS AKRO)

ǂ Attended remotely via WebEx
* Presented to CPT

Contents

1. Administrative

The Crab Plan Team (CPT) meeting began at 9:07 a.m. April 29, 2019, and CPT members and others in attendance introduced themselves. WebEx / Teleconference broadcast of the meeting was made available, with login information posted to the CPT meeting agenda page on the Council website. All PowerPoint presentations were posted to the agenda, and the CPT reviewed assignments and logistics for finalizing the SAFE Introduction section and the CPT Meeting Report. The meeting agenda was altered to reflect cancellation of "Snow Crab PSC limits" on April 29, and "Crab Partial Offloads" was moved from April 30 to April 29. Additionally, PIRKC review occurred May 1 instead of April 30. Martin Dorn and Katie Palof are CPT Co-Chairs, and each took the lead on alternate days.

2. Catch Sampling and Estimation

Separate presentations were provided by Ethan Nichols (ADF&G Dutch Harbor) and Ben Daly (ADF&G Kodiak). Ethan discussed "dockside" sampling by ADF&G observers of retained catch from rationalized crab fisheries and how fish tickets are used in retained catch accounting. Ben described how ADF&G expands total catch from "at-sea" crab observer samples and issues related to changes in data collection, discard estimation, and the ability to provide complete time series of total catch for all crab fisheries.

Retained catch sampling

Crab deliveries occur in six main Alaska ports: Saint Paul, Dutch Harbor, Adak, Akutan, King Cove, and Kodiak. Approximately 80% of retained catch sampling is completed by dockside samplers and 20% is completed by onboard observers. Typically, there are 3-5 total dockside samplers distributed among ports with placement depending on season and open fisheries. Additionally, 10-15 onboard observers may be deployed in crab fisheries at any given time. Dockside staff sample up to five deliveries a day from vessels without onboard observers.

ADF&G targets sampling as many deliveries per fishery as possible, with 80% coverage being regarded as the lower acceptable bound. In the 2018/19 crab season, sampling of retained catch varied by fishery from 71% (Bering Sea Tanner crab in the western area) to 100% (Aleutian Islands golden king crab in the eastern area). The four main types of information collected when sampling retained catch are average weights, size frequencies, deadloss, and confidential skipper interviews. The resulting information is used as necessary to edit the fish tickets submitted with each delivery.

To obtain average weights a sampler counts the number of crab being thrown into a brailer compared to the brailer weight, repeated for three brailers per offload. While most processors calculate average weights independently, methods vary among processors. When the sampler's average weight is available, the number of crabs on the fish ticket is edited to reflect the sampler's estimate of the number of crab. Some crab assessment models are fit to the total catch number and some are fit to catch biomass. For example, golden king crab assessment model considers number of retained and total catch crab in each size bin for population dynamics modeling but uses catch biomass in the likelihood functions to estimate the model parameters.

Samplers take size frequency information from 100 crab at each offload. Sampling occurs while crabs are still in the tank and before sorting has occurred. Crab are chosen with an effort to take random samples from each quarter of the tank, as well as to randomly take crab from different vertical layers within the tank. Each sampled crab is identified by species and sex, measured to the nearest mm, assessed for shell condition, and assessed for legal size.

Samplers visually estimate deadloss by species and then by live/legal vs dead/illegal crab. Deadloss may be comprised of old shell crab, legal crab smaller than industry preference, contaminated crab, illegal species, dropped legs (the latter is common in the snow crab fishery when temperatures are low), females, or other reasons related to marketability. Dead crab can result from poor circulation in the recirculated seawater tanks, the introduction of fresh water into the tanks while waiting nearshore to offload, or other types of contamination. Deadloss accounts for 1-2% of crab retained in a fishery and is not used when calculating average weights. If there is a large amount of legal, but non-industry-sized crab, in an offload, these crab will be considered deadloss, and therefore not included when calculating the average weight. As a result, average weights might be slightly higher than actual retained crab. However, vessels will discard non-industry size crab at-sea if at all possible.

Confidential interviews are done by samplers at each offload and entered into an ADF&G database. The sampler reviews the captain's Federal Daily Fishing Log (DFL) with the captain for accuracy. If a string of gear crosses into multiple statistical areas, the sampler will ask the captain if he can provide information on the number of pots and CPUE for each area. If the sampler is unable to get more information on split strings, then ADF&G will calculate the percentage of the string in each statistical area and apply that percentage to the number of pots. The captain is also asked questions about rail-dumps, lost pots, gear size, trip length, and personal use. Personal use (eating while on the boat or home packs) is allowed but must be deducted from IFQ.

CPT members noted that because observers only record the number of rail-dumped pots, rail-dumped crab are not being accounted for in discard mortality. Rail-dumps most commonly occur during a vessel's last trip because the IFQ has been fully harvested but gear remains in the water. However, cooperative

vessels can share gear, so when a vessel reaches its IFQ allowance another vessel in the cooperative can pull the gear and retain the crab, thus helping to mitigate the number of rail-dumps in a fishery.

CPT members asked if information is collected about bait. Ethan stated that information is not collected but that Pacific cod and a ground up oily fish (e.g. herring, anchovies, saury, or sardines) is most commonly used. In some crab fisheries, vessels are allowed to use a limited number of groundfish pots to harvest Pacific cod for bait during the fishery. Samplers collect this information and include both Pacific cod and crab harvested in these pots.

Fish tickets are edited based on average weights, number of pots and catch by statistical area collected during the confidential interview. Deadloss, personal use, and incidental catch species on the interview are compared to the fish ticket and revised fish tickets requested from the processor when necessary.

The same effort, by statistical area, that applies to the target species is also assumed to apply to incidental retained catch on a fish ticket. CPT members noted that, as a result, total fishing effort is inflated by incidental catch effort. Assigning effort correctly to incidental catch is important when trying to estimate bycatch mortality. It was also noted that incidental deadloss is small compared to handling mortality and mortality in the target fishery.

CPT members noted that the NMFS EBS survey is done in the summer while the fisheries occur primarily in the winter. In addition, that meat fill can differ depending on the time of year. Assessments use length/weight relationships based on summer survey data, suggesting the potential for discrepancies between the survey length/weight relationships and what actually occurs during the fisheries. The CPT suggested limited studies be conducted to determine length/weight relationships during each fishery which could then be compared to survey data.

Mark Stichert (ADF&G) stated that industry has expressed interest in raising the amount of incidental crab species allowed in a fishery and that there may be a future Alaska Board of Fisheries (Board) proposal addressing this issue. Industry would like to be able to keep any crab that the vessel has IFQ for regardless of the target species. However, many processing plants do not like mixed loads as each species requires a different processing method, and meat fill for some species is low at certain times of the year. Mixed stock fisheries would present challenges. It would be difficult to determine what area the incidental catch was from, and the daily fishing logs (DFLs) do not currently show incidental catch information. Incidental catch of snow crab is not currently included in the snow crab assessment. However, Tanner crab incidental catch is currently being lumped into retained catch for the directed fishery. It was suggested that if multiple gear types were allowed simultaneously, then catch of each species in mixed loads could be associated with the pots configured for a species' directed fishery.

CPT recommendations:

- Special projects should be conducted to collect weight-length data during each fishery. It was suggested that 100-200 crab be weighed and measured from retained catch. Assessment authors should provide ADF&G with requested sampling procedures and sample sizes as soon as possible so they can start planning for staff and collection protocols.
- CPT members should begin considering ways that incidental catch data should be handled if the Board of Fisheries increases the amount of incidental crab catch allowed during a fishery. Data concerns with increased incidental crab catch should be noted and brought forward to the Board in the analysis of management alternatives.
- Assessment authors should consider desired sample sizes for retained catch size frequency data for each stock (in anticipation of possible cuts to ADF&G funding for dockside observer sampling).

The CPT would like to express its appreciation to Ethan for his willingness to present at the meeting and for the informative presentation.

Total catch estimation

Total at-sea catch of crab in the crab fisheries is estimated using a simple expansion which includes observer pot CPUE, total fishery effort, and mean crab weight. Observer pot CPUE is based on at-sea sampling for species composition. There are two types of at-seas species composition samples conducted, "count" and "measure" pots, and the daily sampling quota of each sample type varies by vessel type and fishery.

Up until 2018/19, when observers would sample, "count" pots and measure pots, they quantified the number of crab in each of the following four categories: females, sublegal males, legal/retained males, and legal/non-retained males. The retained/non-retained classification for legal males was based on the vessel's captain and/or crew said they were retaining and observing sorting on deck whether the crab would (or would not) be retained in the sorting process. Legal crab might be discarded for several reasons, including lost legs, injury, shell condition, and or being smaller than industry-preferred size. Starting in 2018/19, observers no longer assess whether legal-size male crab will be retained or not and crab in a "count" and measure pots are now classified into three categories (females, sublegal males, and legal males).

Count pots occur only in the snow and Tanner crab fisheries. In the snow crab fishery, observers' sample three "count" pots and one "measure" pot per day. In the Tanner crab fishery, they sample three count pots and three measure pots per day. Measure pots differ in that observers also record carapace length (or width, depending on species), legal size, shell condition, clutch size and condition for females, and other biological information for each crab including parasites and injuries. Observer CPUE for any category is simply the average catch per pot in that category, where all observed pots are used to determine the CPUE in the three broad categories whereas only measure pots are included when determining CPUE at finer levels of categorization (e.g., by size class or shell condition).

To expand observer CPUE to total catch, total fishery effort is determined from fish tickets and is the biggest driver for catch expansion (expansion factors of the ratio of total pots fished to the number of pots observed is typically on the order of 100s to 1000s). Mean crab weight is based on size compositions from the measure pot data, to which an appropriate length-weight regression is applied. The length-weight regressions used were developed by NMFS from the NMFS EBS trawl survey and are the same standardized formulas used to convert NMFS survey data from abundance to biomass. These regressions were last reviewed in 2015.

Because observers are no longer classifying legal crab as retained or non-retained, it is no longer possible to directly estimate discards from the observer data. Previously, discards were calculated by summing over all females, sublegal males, and legal/ non-retained males. Under the updated approach, discards are estimated by summing the total catch of females, sublegal males, and legal males and subtracting the total retained catch from fish tickets. Discard estimates are needed for estimating total fishing mortality, discard rates, and as input to some assessments. It is also useful for evaluating fishery performance and determining whether high-grading is occurring.

This "subtraction method" can be used to calculate discards of legal-sized males and can be done using numbers or weights. Ben discussed two ways the subtraction method can be done; 1) subtract retained catch from total catch of all males (sublegal and legal), or 2) subtract retained catch from total legal males and assume all sublegal crab are discarded. Ben requested feedback from the CPT on the best approach, but also noting that the subtraction method could lead to negative estimates for discards in years in which observer CPUE was lower than the fishery CPUE; method 1 might avoid this situation in most years. It may make more sense to use method 1 for the snow crab fishery because industry-preferred size and legal size of crab are very different. Most stock assessments now fit to retained catch and total catch and do not use discard estimates as data. The CPT recommends that any assessments that still include discard estimates as data now fit to total catch and retained catch instead.

The CPT discussed the usefulness of variance estimates for observer CPUE, which is currently treated as without error. It was generally thought that this would be worth looking into in more detail because it could provide an objective basis for weighting total fishery catch data in assessment model likelihoods. The CPT recommended bootstrapping the observed CPUEs to estimate variances. A better estimate on the variance of the observer CPUE might also help take care of the negative discard issue.

Ben noted that the methods used to estimate total catch (and discards) in the various crab fisheries prior to 2005/06 were not standardized or well-documented and may have varied among fisheries and between years. The CPT discussed the value of recreating the whole time series (e.g., starting in the early 1990s for snow crab, Tanner crab, and BBRKC) of total catch estimates for each fishery using a standardized (and well-documented) approach. The CPT recommended that new time series based on standardized calculations be provided before the January 2020 CPT meeting to facilitate review and incorporation into future assessments. This would give assessment authors time to compare how the new time series affects model results.

Ben asked the CPT if it was possible to standardize the types of data given to assessment authors (e.g., total catch by sex and shell condition, size compositions by sex and shell condition) or if each assessment required different types of data. Assessment authors suggested that it would be most helpful if ADF&G provided the data (i.e., "raw" observer data from count and measure pots, total sampling effort for count and measure pots, and total fishery effort) and a standard set of functions (e.g., as an R package) to calculate expanded total catch in any category required by an assessment. This would ensure standardization of expanded catch calculations, standardization of data provided by ADF&G, reproducibility of results, and flexibility for the assessment authors. The CPT concurred and recommended that ADF&G move forward along these lines.

Additional CPT recommendations:

- Stock assessment authors should let ADF&G staff know if there is information being collected that is not useful, or if they need additional data that is not being collected. For example, if count pots are not useful, ADF&G could consider sampling fewer count pots and more measure pots.
- The CPT should consider how often the length-weight regressions derived from the NMFS EBS trawl survey should be updated, and whether they are appropriate to use in fishery catch estimation.
- Re-calculated time series of total catch (and size composition data) using standardized methods should be provided by ADF&G to assessment authors before the January CPT meeting for review and potential incorporation into 2020 assessments.
- Stock assessment authors should inform ADF&G as to what categories of total catch and size composition data are needed for their assessments so that ADF&G can develop standardized "raw" datasets and a set of standardized functions that authors can apply to calculate the expanded catch estimates and size compositions that the assessments require.
- A centralized approach to distributing crab fishery data to assessment authors (such as hosting on AKFIN) should be developed.
- ADF&G staff should explore ways to calculate variance estimates for observer CPUE.

3. Snow Crab - Model discussion for September

Cody Szuwalski summarized modeling work in response to recent recommendations and proposed updates to the stock assessment for EBS snow crab. Cody summarized the September 2018 CPT and October 2018 SSC recommendations for improving the snow crab assessment model. Cody highlighted four topics where additional work is needed to improve the snow crab assessment:

Natural mortality (M)

Literature on various natural mortality estimation methods was reviewed and some of the methods were applied to estimate snow crab natural mortality. Natural mortality is affected by other modeled processes, including catchability, recruitment, growth and maturity. Models with looser priors on natural mortality fit the data better and resulted in higher estimates of natural mortality for snow crab. Incorporating chela height data and revisiting catchability may stabilize natural mortality estimates. In general, most of the evidence indicates that snow crab natural mortality is higher than the value currently used in the model.

Catchability

Survey catchability is a scaling parameter estimated in the model that relates survey abundance to true population abundance. NMFS and BSFRF side-by-side trawl survey results on catchability and selectivity were presented, and empirical and fitted availability estimates were compared. BSFRF data suggests that catchability is lower than currently estimated values. Earlier research by Dave Somerton and others showed that survey catchability was less than one and that selectivity was not logistic. The prior on natural mortality appears to influence estimates of catchability. Cody plans to do additional research on time varying catchability, explore other methods of incorporating the BSFRF data in the assessment, and develop approaches to model the movement of crabs to northern Bering Sea.

Growth

Growth is currently modeled with a piecewise linear model with estimated changepoints. In the past, instability in growth resulted in bimodal management quantities. New data suggests that female growth may be linear. The male growth data are more limited and less informative for resolving the kink in the growth curve. Kinked growth curves are a source of instability in the model but removing the kinks does not resolve the stability issues with the assessment. A single changepoint for the molt to maturity is not tenable because maturity occurs at a wider size range.

VAST

The VAST model was applied to investigate the index of abundance from the Bering Sea survey. VAST estimates were similar to area-swept estimates except that a few high outliers were lowered. VAST estimates had lower variance compared to designed-based variance estimates, and this will have greater influence on the model than the point estimates. Cody was unconvinced that these lower variances were appropriate to use in the assessment model.

Cody described the development of simplified snow crab model for males only. The motivation for developing this model is that parameter confounding and interactions in the current snow crab model structure make it difficult to understand model behavior. The simple model used simplified assumptions and removes various input data, such as removing females, condensing data over shell condition, assuming linear growth curves, and removing BSFRF data. This exercise showed that simple models could fit some of the snow crab data well. Linear growth models could be used without any model instability. However, adding BSFRF data produced mixed results. Cody concluded that the simple model is not yet ready for use in management but is useful to understand the contributions of different data sources to different population processes and model stability. The CPT suggested that the simple model might provide a more robust estimate of natural mortality.

The CPT recommends the continued evaluation of the simple model, continued research on time varying catchability, application of VAST to understand the distribution and movement of snow crab in the northern Bering Sea, and migration of the model to GMACS.

CPT recommendations on models for the September 2019 assessment include:

- The status quo model (18.1)
- Model with higher natural mortality
- Model with linear growth for females and kinked growth for the males
- Model with linear growth for both females and males

- Models that estimate a different recruitment size distribution for males and females. Investigate the interaction between this model configuration and the degree to which recruitment estimates differ between males and females
- Provide likelihood profiles for natural mortality and catchability

4. Snow Crab PSC Limits - cancelled

This agenda item was originally scheduled based on the expectation that the Council would take action on initiating analysis at the April Council meeting. When the Council recommended further information gathering be done rather than moving to analysis, the agenda item was cancelled. The CPT will review this issue as needed at an appropriate future meeting.

5. CIE Reviews of NSRKC and AIGKC

The CPT received a presentation on the CIE reviews of stock assessments for Norton Sound red king crab and Aleutian Islands golden king crab. The CIE review was held at the AFSC in Seattle on June 18-21, 2018, and was chaired by Buck Stockhausen, who introduced the presentation. The CIE reviewers were Yong Chen (University of Maine), Raouf Kilada (University of New Brunswick), and John Neilson (Independent Fisheries Scientist, BC, Canada). Buck noted that both Chen and Kilada have particular expertise in crustacean biology.

NSRKC assessment author Toshihide Hamazaki summarized recommendations from the three CIE reviewers. Common themes were:

- improving methods for treating trawl survey abundance;
- near-term improvement in the application of available biological (life-history, growth, age, maturity) and spatial distribution data in the assessment and longer-term studies to improve such data;
- improved surveys to understand the fate of larger/older crabs; and
- validation of catch and discard data self-reported on fish tickets.

Chen recommended a short-term focus on testing potential improvements in the assessment methods given currently available data. Specific recommendations included using robust model diagnostics to mitigate the effect of outliers in abundance, controlling for survey spatial variation (perhaps using the spatial delta-GLMM method), testing alternative size-intervals, employing Bayesian methods to better quantify uncertainty, and jittering to test model sensitivity to initial parameter values. The Kilada and Nielson review recommendations focused more on improving data used in the assessment, including studies to improve estimated size-at-maturity, estimation of natural mortality and life-span, and improved tagging methods. Nielson also noted the need for improved documentation of data weighting. Nome staff are currently working on collection of additional biological data. It was noted that tagging studies are difficult due to the small footprint of the fishery relative to the spatial distribution of the crab population.

AIGKC assessment author Shareef Siddeek summarized comments and recommendations from the CIE review for his assessment, noting that elements of some recommendations had already been incorporated. For example, Chen's recommendations to weight likelihood functions associated with input data sets, examine for residual patterns, conduct retrospective analyses of model scenarios, implement jittering to test sensitivity to initial parameter values, extend the survey to the WAG, application of the robust likelihood function, and maintaining model structure to understand stability over time (model has been consistent for three years) have been met or initiated. Some recommendations not implemented or initiated to date include: a full Bayesian methods to better quantify uncertainty; a VAST analysis of survey data; the use of "season" instead of "year" time steps; a computer simulation of past data to understand the effectiveness of the current survey design; evaluation of spatial and temporal variability in

weight-at-length and maturity-at-length data; and alternatives to constant discard mortality over time (an alternative to weight discard mortality by the landing weight was not accepted by the CPT in January 2019). An industry comment referred to a Kodiak Lab study showing that GKC are more durable than RKC regarding susceptibility to carapace damage.

Recommendations from the other reviewers overlapped with Chen's somewhat. One unique recommendation was to reduce the number gear codes due to an excessive number of degrees of freedom and Siddeek showed a table describing dropping 18 of 26 codes and collapsing the remainder to 5 gear codes. It was also noted that, consistent Neilson's recommendation, the current CPUE analysis uses a subset of the available vessel data, limiting to vessels that participated in the fishery continuously. The CPT discussed priorities for further assessment development responsive to review recommendations and discussed ongoing efforts to collect and improve biological data, particularly regarding growth and maturity. It was noted that chela height is now consistently collected, Ben is working on providing the assessment authors with recently received tagging data to improve growth matrix calculation, and André has a Ph.D. student also looking at new methods to improve growth matrix calculation. Next year's assessment will likely include the independent survey, and also CPT recommendations on VAST modeling approach to be addressed later during this meeting.

6. AIGKC - Final 2019 Assessment

Shareef Siddeek presented the 2019 Aleutian Islands Golden King Crab (AIGKC) assessment to the CPT. AIGKC was assessed using a male-only, length-based integrated stock assessment model fit to fishery length-composition, standardized fishery CPUE (assumed to be an index of abundance), total catch, retained catch, groundfish bycatch, and mark-recapture data. 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 was estimated in initial model runs, with likelihood profiles suggesting a value of 0.21 used for current assessment model scenarios. A knife-edge maturity is assumed at 111mm CL based on chela height data. The Francis re-weighting method for Stage-2 was used to estimated effective sample sizes for all model scenarios. The stock assessment was updated with fishery data for the 2017/18 and 2018/19 fishing years.

In last year's assessment, the 2017/18 season fishery data were not available in time for assessment, and the OFL and ABC had to be projected for the 2018/19 fishing season using the assessment with 2016/17 fishing season data and best estimated total catch in the 2017/2018 season. The 2018/19 fishery data were incorporated into this year's assessment due to early completion of the 2018/19 fishery. As such, it was not necessary to project total catch in the terminal year to project the OFL and ABC for the 2019/20 season.

Siddeek examined five model scenarios for EAG and five for WAG in this assessment cycle based on the addition of new data and alternative ways to standardize fishery CPUE. Model 18_0 was last year's base model (Model 17_0) with 2017/18 fishery data. Model 18_1 is the same as Model 18_0 except the number of gear codes was reduced for observer CPUE standardization. Model 19_0 is the same as Model 18_0 with 2018/19 fishery data. Model 19_1 is the same as Model 18.1 with 2018/19 fishery data. Model 19_2a is the same as Model 19_1 plus a year-area interaction factor during 2005/06 - 2018/19 for EAG, and Model 19_2 is the same as Model 19_1 plus a year-area interaction factor during 1995/96 - 2018/19 for WAG. Siddeek recommended either Model 19_1 or Models 19_2/19_2a for a base model for overfishing determination.

The CPT considered Models 19_0, 19_1, and 19_2/19_2a (all include the 2018/19 fishery data). Model 19_1 is preferred over Model 19_0 due to simplification of gear codes and the fact that model performance was very similar. Models 19_2 and 19_2a include a year-area interaction factors which may be important for fishery CPUE standardization. However, the CPT has concerns about the current fishing

footprint calculation, and about not using the year and area interaction factor during 1995/96-2004/05 for EAG due to high estimated log (CPUE) variances. It appears that further improvement is needed for Models 19_2 and 19_2a before adoption for a base model. As such, the CPT recommends base model 19_1 for OFL/ABC setting in 2019/20.

CPT recommendations:

- Model 19_1 should be used as the base model for OFL and ABC determination for the 2019/20 season.
- Additional development is needed for fishery CPUE standardization, including further development in year-area interactions, focusing on estimating fishing footprints for each 30X30 nm block as area weights.
- Additional work is needed to obtain an index using the cooperative pot survey data for use in the EAG assessment model. Before the survey data can be used in the model, analyze the survey length composition data to check for cohort progress over time to support recent high recruitment estimates for EAG.
- The chela measurement data should be reanalyzed using recently collected fishery and survey data to better estimate the maturity of AIGKC.
- The bias of retrospective estimates for EAG needs to be checked and investigated for any model misspecifications.
- Uncertainty of recruitment estimates in the terminal years should be accessed in each assessment to determine how many years of recruitment estimates in the terminal years should be excluded for B35% estimation. The range of years to used to estimate B35% should not be considered fixed.
- Use of GMACS for the AIGKC assessment should be explored.

Update on AIGKC state harvest policy – Ben Daly presented some of the background analyses presented at March 2019 Alaska Board of Fisheries meeting, and decisions made by the Board. The primary aspects under consideration were the sloped harvest control rules for the EAG and WAG management areas. For the EAG the board adopted a 15% ramp with a 25% cap on legal male abundance, and for the WAG a 20% ramp with a 25% cap on legal male abundance. It is anticipated that the March 2020 Board meeting will include consideration of a proposal to change the AIGKC fishing season from the existing season of August 1 to April 30 to a revised season of March 1 to October 31 to be more consistent with processor availability. If adopted, this will likely mean a shift in the AIGKC assessment cycle to have AIGKC model scenarios discussed at CPT September meeting, the final OFL/ABC recommendations developed at the CPT January meeting, the final OFL/ABC adopted by the SSC/Council in February, and the TAC setting in February.

7. Tanner Crab - Model discussion for September

William (Buck) Stockhausen summarized modeling work in response to recent recommendations and the proposed updates to the stock assessment for EBS Tanner crab. The assessment report included information on the incorporation of the side-by-side (SBS) BSFRF trawl survey data, discussed the issue of overestimation of large crab abundance in the model, and proposed model scenarios for the September 2019 CPT meeting.

Response to CPT comments

The author addressed several comments from the CPT and SSC in the new model scenarios presented. First, the author noted that the model was not as sensitive to changes in catch resulting from the reclassification of incidental catch to the appropriate fleets in the model. There were errors in the input sample sizes on size composition data that, when corrected, reduced the sensitivity of the model to catch changes. Second, issues with parameters hitting bounds were solved by reparametrizing the growth model

and eliminating parameters from the assessment related to the probability of terminal molt (parameters that could be fixed to 0 or 1). Third, the author will only fit one index (abundance or biomass) to the model from now on. The author also incorporated BSFRF data in a manner similar to snow crab by estimating an annual availability and linking estimates of NMFS data to BSFRF data via a shared availability.

Incorporation of BSFRF data

Five years of side-by-side (SBS) data exist for Tanner crab (2013–2017), varying in their spatial footprint. Data from 2018 are expected to be available and incorporated before the September CPT meeting. SBS tows were performed in Bristol Bay during 2013–2015, and expanded west in 2016. In 2017, the SBS sampling took place around the Pribilof Islands. The NMFS survey uses 83-112 trawl gear and conducts 30-minute tows while the BSFRF survey uses a modified nephrops trawl gear and conducts five-minute tows. As a result, the area swept by the two surveys is quite different. In general, the BSFRF area-swept estimates of abundance and biomass in the SBS areas were larger than NMFS estimates.

Incorporating the BSFRF data into the assessment required the estimation of a large number of additional parameters (though the effective number of parameters is somewhat tempered by the smoothing penalties applied). The author began by fixing parameter estimates in the assessment to the values estimated in last year's accepted assessment, and then estimating availability parameters sequentially by data source. The result of this was similar estimates of availability among iterations, which gave the author some confidence that the estimates of availability were reflecting the spatial footprint of the SBS data (e.g., few small crab were 'available' when the SBS tows were performed in Bristol Bay).

The BSFRF data were well fit in the assessment. Changes observed in the model output after incorporating the BSFRF data into the assessment were relatively small. Survey catchability declined slightly (~0.05 units), which resulted in a slight scaling upward of estimated recruitment. In general, the response of the CPT to incorporating the BSFRF data in this manner was positive, though a few evaluation metrics were requested before full endorsement of the process.

CPT recommendations:

- Compare the estimated selectivity to the ratio of NMFS to BSFRF numbers at length. Is estimated and empirical catchability/availability/selectivity the same? Does the 'empirical' selectivity look logistic?
- Show the fits to BSFRF length composition data by year as well as in aggregate
- Check the bounds of parameters when estimating the BSFRF data
- Indicate whether or not Hessians were produced
- Suggest rationale for chosen weighting for the second difference smoothing on the availability curve

Overestimation of large crab abundance

In recent years the model consistently estimates more large males (going back to 1996) than are observed in the total catch length composition data. One of the potential issues this causes is biased estimates of the OFL, which could be problematic for achieving management targets. The author developed a Shiny app to examine scenarios in which natural mortality on immature crab increased, natural mortality for mature crab increased, skip molting was introduced, mean growth increment was decreased, and the probability of terminal molt was shifted to the left. Scenarios in which natural mortality and skip molting were altered or introduced did not change the number of crab at large sizes. Decreases in growth and the left-shifted probability of terminal molt introduced large changes in the number of large crab and the author suggests these processes should be the entry point for exploration of improvements in model fit.

The model overestimates the mean post molt length, however, fitting the growth data more strongly resulted in non-viable models. The patterns in the residuals for fits to the total catch length composition

data and the largest observed crabs over time suggest time variation in some population processes (potentially growth or probability of maturing).

Additional CPT recommendations:

- Compare the trends in largest crab to fishing pressure and area occupied by stock
- Compare the maximum sizes seen in the fishery to the survey
- Consider blocking for the estimation of growth and probability of maturing
- Make incorporating chela height data into the assessment a priority because this might address changes in the probability of maturing over time
- Provide retrospective analysis and calculate Mohn's rho for MMB

The CPT accepted the author's recommended models for presentation in September 2019. Model 19F.2, although not considered viable, will be included in order to show all additions and subtractions of data at different steps.

8. PIRKC - Model discussion for September

Cody Szuwalski presented an evaluation of several approaches to assess the status of Pribilof Islands red king crab (PIRKC). This is the first time that PIRKC have been assessed on a biennial cycle. PIRKC are a tier 4 stock and the currently accepted assessment method is a random effects model that fits a smooth trend through male biomass greater than 120 mm CW. Previously a variance-weighted moving average had been used. BMSY is the average of biomass from 1991 to the present. Although the guidance for determining BMSY for tier 4 stocks is that it should represent years when fishing is close to MSY, the fishery for PIRKC was only open for five of the last 27 years. The CPT recommends that the assessment author re-evaluate this assumption and to propose alternatives for consideration in September 2019.

Cody indicated his view that the time was ripe to re-evaluate the assessment assumptions and methodology for PIRKC. Although an integrated assessment was tried for PIRKC previously, it was never accepted by the CPT or the SSC due to poor model fits. In addition to the random effects model, Cody proposed to bring forward a new integrated assessment for consideration in September. The CPT endorsed this recommendation and offers the following guidance:

- Attempt to leverage information from the data-rich BBRKC assessment. Information that could be borrowed include molting probabilities, growth, maturity, and selectivity.
- Fit the model to biomass rather than total abundance as has been done previously.
- Critically evaluate relative weights given to fitting the size composition data and biomass trends.

With respect to the random effects model, Cody noted that many of the CVs were exactly equal to one, which suggests potential truncation. This should be investigated further. The design-based variance estimators should be rechecked, or potentially a bootstrap variance estimator could be tried.

9. BSFRF - update on summer survey plans

Scott Goodman from the Bering Sea Research Foundation (BSFRF) presented an update on the Foundation's research activities as well as sampling plans for summer 2019. BSFRF is looking to expand their footprint with collaborative partners, including having NOAA and ADF&G aboard BSFRF research platforms, and moving into different parts of the Bering Sea and into new areas of research. For 2019, BSFRF is focusing research efforts on growth of Chionoecetes crabs, seasonal and annual movement using traditional and new tagging methods for BBRKC and Chionoecetes crabs, index area trawl sampling, and a *C. bairdi* MSE project.

Historically, the only growth studies applied to Bering Sea *Chionoecetes* species came from stocks outside of the Bering Sea. BSFRF has collected *C. opilio* (2011, 2012, 2013, and 2015, 2017, and 2019) and *C. bairdi* (2013, 2017, and 2019) from the Bering Sea for growth studies. Since pre-molt crab are thought to bury into soft sediment and be unavailable to fixed gear, specimens for growth studies are collected with the Nephrops trawl (samples were also collected in 2016 for *C. opilio* and *C. bairdi* but were omitted from presentation). In 2017 and 2019 crab were taken directly to Kodiak after collection to reduce mortality and placed in individual condos. The objective is to fill in gaps and increase sample sizes in snow and Tanner stock assessment models for growth. In 2019, BSFRF was only able to find crab in pre-molt condition north of the Pribilof Islands.

BSFRF is exploring new and innovative ways to track crab movement. The traditional approach to tagging puts a large effort into tagging crabs, but often with tag recovery focused on opportunistic recoveries in the fishes. The current focus of BSFRF tagging studies is to better understand movement of Chionoecetes crabs in and out of the Pribilof Islands closure area. For 2019, BSFRF is purchasing tags to support ADF&G projects deploying satellite pop-up tags. For a separate collaborative study on BBRKC and in an effort to overcome challenges of low recovery, BSFRF is also planning on deploying acoustic tags. Multi-year acoustic tags would be deployed on crabs caught in pots (lower impact than trawl gear) over the summer. Sail drones would be deployed first in October (pre-fishery) and, based on the success of that deployment, again in March or April, to search survey tracks in the Bering Sea and record tagged crab locations. Bristol Bay red king crab stock (males) will be the target species for this project.

BSFRF is phasing out side-by-side NMFS trawl survey efforts and focusing on indexing areas of high juvenile *C. bairdi* abundance. The main objective is to capture a third-year snapshot in high abundance areas in the NMFS standard trawl survey stations on the Bering Sea shelf. This effort is in support of finding modes of growth and monitoring mortality of smaller size classes. In 2017 and 2018 index trawl plans focused on the edge of Bristol Bay and the Bering Sea shelf, moving northwards towards the Zhemchug Canyon – but the Zhemchug area was not covered. The 2019 survey will focus more on the central area of the Bering Sea shelf.

For June 2019, BSFRF is planning to complete trawl index sampling early and then switch to pot fishing to collect, tag, and release 150 red king crab in Bristol Bay. Testing of newly released acoustic tags will occur shortly after tag release. During sampling, collections for *C. opilio* condition/lipid research and live holding experiments into gear and bycatch research will occur.

Research into a *C. bairdi* MSE is being conducted by Master's candidate Madison Shipley (University of Washington and BSFRF) will continue through summer 2019. Supercomputer time will be scheduled to run the model analyses this spring. An update will be provided to the SSC in early June with a presentation to the CPT and ADF&G in September 2019.

10. Crab Partial Offloads - discussion

Sarah Marrinan discussed a proposal the Council is considering removing a regulatory prohibition that bans vessels in the Crab Rationalization program from partially offloading crab and then returning to the fishing grounds to harvest more crab. She discussed some of the benefits to crab vessels associated with removing the prohibition including ability to retrieve pots when sea ice is advancing and being able to suspend offloading and leave the dock under high wind situations. One disadvantage is the loss of spatial data associated with the amount and size structure of the catch. Currently, statistical area is part of trip ticket reporting, but mixing catches from different areas would confound this information.

Sarah also stated that WAIGKC currently has an exemption in regulation to partake in this activity which took effect in 2016. However, the GKC fleet has only used the exemption once due to the high deadloss that occurred. Deadloss might also be an issue in other crab fisheries should the exemption expand to those fisheries.

The CPT noted that crab assessment models do not currently incorporate spatial harvest, except the East/West AIGKC split; however, the loss of statistical area information may affect the future development of spatial assessment approaches. The impacts of the regulatory change on assessment techniques would likely be determined by the extent to which partial offloads are done, and the CPT expects that the allowance will not result in widespread changes in fishery behavior based on the description of the circumstances associated with the practice.

The CPT discussed regulatory modifications such as restricting the practice to a single event rather than allowing continual rolling partial offloads for a given vessel. Additionally, restricting the partial offload to the complete emptying of a subset of a vessel's holding tanks could help retain location information for part of the catch. Because the reported situations are so variable, law enforcement is concerned about setting a unique exception for a unique situation. It was noted that fish tickets would need to be modified in order to document partial offloads.

The CPT also discussed the possibility of exploring partial offloads through a multi-year EFP that would cover several crab IFQ vessels, which could be useful for identifying and working out various practical aspects of the allowance. If an EFP were to be developed, the CPT would be interested in reviewing and providing comments on its design.

11. EBS Crab Ecosystem Status Report

Erin Fedewa gave an overview presentation on Bering Sea crab ecosystem indicators including a review of previous crab ecosystem efforts, selected indicators for stock-specific report cards, draft report cards for BBRKC, Tanner crab, and snow crab, and discussed future indicator development. Ecosystem indicators are meant to provide early warning signs and/or supplemental trend data to inform management actions. Stock-specific indicators are likely preferable to Bering Sea indicators because the limited spatial extent may be more relevant to the biology of each crab stock. Past efforts included a draft Crab Ecosystem Considerations Chapter presented to CPT in 2014 by Liz Chilton and a pilot Bristol Bay Red King Crab report card presented to CPT in 2016 by Ben Daly.

Erin discussed methods for developing stock specific report cards. The spatial extent of stock specific indicators is restricted to stock management boundaries and (for now) general indicators are applicable to all stocks but additional indicators are in development and would likely be tuned for each species/stock. Suggested general indicators included total crab biomass, pre-recruit crab biomass, CV (%) of pre-recruit biomass, total fishery removals, bottom temperature, proportion cold pool, benthic invertebrate biomass (competitors), benthic forager biomass (predators), Pacific cod predation index, and pelagic forager biomass (predators). Erin reviewed several selected indicator trends for BBRKC, Tanner crab (east and west of 166 W long.), and snow crab. Indicators show the 2018 indices compared to the 5-year mean +/- 1 s.d. of the long-term mean, and also the 5-year trend.

Recent BBRKC indicator trends include low population biomass, above average bottom temperatures, reduced cold pool extent, spikes in biomass of competitors, benthic foragers, and pelagic foragers in 2016, followed by decreases in 2017 and 2018, benthic invertebrate biomass increases in 2016, and benthic forager biomass increases in 2016 (high catches of yellowfin sole and northern rock sole). Erin suggested that increased flatfish and/or benthic invertebrate competition may be contributing to recent declines in RKC pre-recruit biomass. It was recommended that flatfish species used in this indicator be limited to those preying on that particular crab species.

Recent indicator trends for Tanner crab east of 166 W long. include reduced pre-recruit biomass and CV relative to the long-term average, while recent trends for Tanner crab west of 166 W long. include warm bottom temperatures, reduced cold pool extent, and high Pacific cod predation. Recent indicator trends for snow crab include high biomass, high bottom temperature, and low cold pool extent. Erin showed that survey stations with low Pacific cod biomass corresponded with high snow crab densities in 2017 and

2018. Stomach content analysis showed that most snow crab found in Pacific cod stomach were less than 50 mm CW.

Erin discussed potential revisions to current indicators including: 1) refining species included in foraging guilds; 2) refining the predation index by incorporating predator/prey lengths, determining a partial fullness index for crab in stomachs by weighting with the survey biomass of predators; and 3) using standard deviation of log-transformed data for pre-recruit biomass instead of CV due to highly skewed biomass data. Other recommendations by the CPT include display of indicator uncertainty when possible and scaling stomach content data at each survey station and by predator and prey sizes.

Erin discussed identification and development of additional indicators for each stock including expanding prior work by Ben Daly, refining additional indicators used in the Ecosystem Considerations report by spatially restricting to crab management boundaries, developing additional crab-relevant time series, and identifying future data collection for additional indicators. Past indicators being developed for BBRKC included a female dispersion index, which corresponds to the extent of population relative to total abundance and may have implications for larval advection, mating success, and spatial overlap with predators. Because of potential biases associated with averaging latitudes and longitudes in the dispersion calculations, it was suggested that a "home range" index may be a better indicator than dispersion, especially if directionality could be incorporated. A larval advection indicator using ROMS or OSCURS circulation models was discussed because of possible impacts on settlement strength and subsequent recruitment. The process would include selecting a predetermined location, tracking advection for a set time span, and quantifying distance traveled and direction.

Other potential indicators were discussed and include a larval abundance indicator (indication of recruitment strength; the EcoFoci spring ichthyoplankton survey likely overlaps temporally with early life history stages of EBS crab stocks), a primary/secondary production indicator (index for food availability for crab larvae: phytoplankton- Chl *a*, zooplankton), and a body condition indicator. Erin showed examples in which energetic condition of pollock prior to their first winter predicts their survival to age-1. Similarly, snow and Tanner crab showed a decrease in lipids (i.e. body condition) between 2012 (cold) and 2014 (warm), implying potential for a body condition index from crab. A preliminary study has indicated a significant positive correlation between snow crab energy density and stable $\delta^{13}C$ isotope values, implying snow crab energetic condition is improved with the use of benthic (i.e. algal and detrital based) carbon sources. Such stable isotope analyses could be used as a proxy for prey, which may be developed into a benthic prey indicator.

Erin provided an overview of next steps, including continued empirical data collection for further indicator development, developing additional indicators for each stock, producing report cards for remaining stocks, indicator selection, threshold setting, and evaluation. The long-term vision is to develop quantitative multivariate indicators for use in stock assessments and consideration during annual TAC setting. A new standardized framework termed the ecosystem and socioeconomic profile (ESP) was recently developed by groundfish scientists to test ecosystem and socioeconomic linkages within the stock assessment process. The utility of ESP approach for crab stocks should give consideration by the CPT and the SSC.

The CPT discussed the future direction of stock-specific report card for crabs. The CPT supports including the stock-specific report cards in SAFE chapters as an appendix to the main document. ADF&G biologists emphasized the value of ecosystem indicators and stock-specific report cards to qualitatively assess potential conservation concerns during TAC setting. The CPT agreed that report cards for BBRKC, Tanner, and snow crabs should be further refined before additional report cards are developed for other stocks. The CPT preferred separate report cards for Tanner east and Tanner west as finer spatial resolution would likely benefit managers. AIGKC would be a good candidate for the next stock, but the CPT suspects that the lack of a fishery-independent survey will inhibit development of some indicators.

Overall, the CPT encouraged further development of stock-specific report cards and looks forward to future iterations.

The CPT also discussed the annual timing of ecosystem report card development and review. The CPT recommends that draft report cards be prepared annually for review by the May CPT meeting, followed by final versions to be added to the SAFE chapters in September. This timing would provide the opportunity for assessment authors to consider the ecosystem indicators as they develop their stock assessments.

12. GMACS - Overview and Roadmap

André Punt provided a summary of updates made to the GMACS (generalized model for assessment of crustacean stocks) code since the January CPT meeting. The ADMB software is generalized so that it is relatively easy to add features, having input provided through three files (. DAT,. CTL and. PRJ) with few quantities "hard-wired," and allowing aspects such as phasing, priors, and parameter bounds to be easily specified. The GMACS code has been used for assessments for St Matthew Island blue king crab (single sex; three size-classes; limited fleets) and is being considered for Bristol Bay red king crab assessment (two sexes; 26 size-classes; multiple fleets; many data types) in September 2019. The code is open source, with routines to automatically produce diagnostics and summarize model results.

The DAT file contains all the data including model dimensions, season length(s), catch by fleet, stock indices, length-frequency, and tagging information. The CTL file contains model specifications including: parameters to be estimated, length and weight specifications, growth as specified through a transition matrix and molting probability, selectivity and retention probabilities, survey catchability and additional survey CV), fishing mortality priors, size-composition specifications, how natural mortality varies over time, and data weighting. The core (theta) parameters identified in the CTL file provide the overall population scaling and recruitment. It is possible to specify an initial value, lower and upper bounds, the phase for parameter estimation, the prior structure (e.g., uniform or other), and characteristics of the prior for these and other parameters. Most parameters can be set to change within time blocks over a time series. The CPT suggested having a potential input (e.g., -999) that directs the code to ignore the values for the parameters of the prior when the prior is uniform.

Growth parameters can be specified through a set of eight options for a size-transition matrix, including a pre-specified matrix with or without an estimated molt probability. Multiple options exist to set how the mean growth increments are specified. The selectivity and retention parameters section are still being revised but allows setting the type of function by fishery or survey, and whether the function differs by sex or time blocks; the user can also nest one survey inside another (e.g., the NMFS survey with the BSFRF in the BBRKC assessment). The GMACS code currently includes seven natural mortality options including fixed, random walk, cubic spline and various time blocks. Several other controls include: a verbose flag (e.g., to show or exclude output of diagnostics); stopping estimation after a specified number of function calls, or outputting diagnostics after a specified function call, etc.

The PRJ (projection) file lists the specifications for forecasts and OFL/ABC calculations. Controls include which fleets is varied when calculating F35%, OFL and ABC control rules (including buffers), harvest strategies with or without bycatch mortality, and future recruitment (e.g., S-R type). The projection module can calculate generation time, defined as the average age of spawners at unfished equilibrium. For example, generation time for St. Matthew blue king crab appears to be 11.6 years assuming model recruitment at age 5. The S-R relationship can be parameterized such that FMSY = FMSYproxy and BMSY = BMSYproxy, a methodology that has been implemented with SMBKC. Projections involve several decision points such as: time period to represent bycatch mortality, time period to represent selectivity, type of S-R model, time period to represent recruitment, F to apply, and length of projection.

Despite the multiple changes since the September 2018 and January 2019 presentations, all base models now appear to converge with low maximum gradients and no evidence of differentiability issues. In addition, fishing mortality may be implemented with an assumption of either instantaneous or continuous mortality. Steps in development since January included: adding MCMC sampler output dump, final review of the code, finalizing calculation of reference points (e.g., F35% for Tier 3 and 4 stocks), finalizing OFL calculations, and creating a forecast output file based on Tier, buffer, etc. GMACS users will continue work on graphical outputs, testing with PIRKC, and updates to SMBKC and BBRKC. A technical appendix will need to be built, likely based on the current draft available in markdown on GitHub. A major extension will be to include a terminal molt (required for snow and Tanner crabs). Much of the basic coding architecture exists, but it still needs to be tested.

The CPT discussed a process for moving forward in GMACS development. Although GMACS exists as open source in the public domain, agency crab assessment scientists will be the primary users. Additionally, the CPT recognized the importance of having agencies assume the maintenance of GMACS. Jim Ianelli has served as "gatekeeper" for adding code to the main model, but a process for model oversight and maintenance of the code needs to be developed with a lead individual identified. It was noted that SS3, the age-structured analog for GMACS used by NOAA for fish assessments, has a full-time staff member devoted to these duties. Unit testing of GMACS components is needed to ensure continuity in GMACS function. Documentation and training of end users will also need to be considered if GMACS is to be implemented widely. Cody will be developing a branch in which GMACS allows for a terminal molt using snow crab as a test case.

The following draft timeline was proposed for GMACS assessment models over the next CPT assessment year:

- GMACS assessment for BBRKC will be proposed for adoption in September 2019,
- Draft AIGKC assessment in GMACS will be presented at a January 2020 workshop for model testing and further evaluation for potential model approval in May 2020;
- Draft PIRKC assessment in GMACS will be presented in January 2020, recognizing the 2-year assessment cycle gives time for further evaluation.
- Given that terminal molt has yet to be implemented, a draft assessment in GMACS for one of the Chionoecetes stocks could potentially be reviewed in May 2020.
- A NSRKC draft assessment in GMACS will potentially be provided in September 2019.

The CPT recognized that the AIGKC assessment cycle may change based on any Alaska Board of Fisheries decision in March 2020, but the GMACS analysis could still go forward. The CPT further recommends that assessment scientists and the CPT use GitHub as a model sharing tool for GMACS moving forward.

13. BBRKC - Model discussion for September

Jie Zheng presented an update to the model-based assessment for Bristol Bay red king crab. The assessment involved three model scenarios:

- rk18A.D18. Scenario 18.0a from September 2018.
- rk18A.D18a. Scenario rk18A.D18, except groundfish fishery bycatch data are updated for 1991–2017 and separated into trawl and fixed gear for 1996–2017.
- rk18Aa.D18a. Scenario rk18A.D18a but implemented using GMACS. The assumptions for this scenario match those for rk18A.D18a, except for (a) differences in how length-composition data are normalized, (b) inclusion of constant terms in the likelihood components for catch and survey data for GMACS, unlike rk18A.D18 and rk18A.D18a, (c) estimation in GMACS of bycatch mortality in the directed Tanner crab fishery for the years where there is fishing effort

but no estimates of bycatch, and (d) differing penalties among GMACS and rk18A.D18 and rk18A.D18a.

Estimates from the GMACS scenario and the rk18A.D18a scenario (which uses the same data as the GMACS scenario), particularly the trajectory of mature male biomass, are very similar. Data fits are better for males than for females, and selectivity patterns for females differ between the two models. The fits for the GMACS scenario are such that were it a new assessment, this scenario would be accepted for use for status and OFL/ABC determination.

The CPT anticipates using the GMACS scenario for status and OFL/ABC determination in September 2019. However, the CPT wishes the authors to provide results for GMACS and rk18A.D18a so that differences in outcomes can be better understood. In particular, the CPT wishes for authors to:

- Explain why the likelihoods for size-compositions differ given the fits are very similar;
- Document how the two models penalize parameter values, in particular, differences in the sex ratio of recruits from 1:1, and explore whether the difference in results is due to difference in this penalty;
- Check whether GMACS is fitting to length-composition for males and females combined rather than by sex, and ensure that observed and predicted length-compositions are correctly plotted;
- Further examine the difference in OFL values from the two models, in particular check the inputs into the OFL calculation such as mean recruitment corresponding to MSY; and
- Explain why the number of estimated parameters in GMACS differs from rk18A.D18a (some of the additional parameters are the fully selected fishing mortalities due to bycatch in the Tanner crab fishery).

In addition, the September 2019 assessment should:

- Report fits to biomass indices (NMFS and BSFRF) and residuals by sex rather than aggregated over sex because that is how the data are included in the model likelihood;
- Include the fits by GMACS and rk18A.D18a on the same plot to ease comparisons;
- Evaluate whether the two models have converged using a jitter analysis; and
- Apply the CPT-approved naming conventions for the model scenarios.

The assessment document for Bristol Bay red king crab includes projections, though this is not now a required element in crab stock assessments. The CPT discussed whether it was necessary to conduct projections in this assessment and more generally for crab assessments. The CPT sees value in conducting projections, although these need to be interpreted with care (e.g., when catches are consistently less than TACs). In principle, GMACS can take parameter uncertainty as well as uncertainty related to future recruitment into account. However, conducting MCMC analysis to characterize parameter uncertainty for Bristol Bay red king crab would be computationally difficult. The CPT would like to see 10-year projections conducted for Bristol Bay red king crab based on the maximum likelihood estimation for the parameters.

14. Shell Condition Error - Discussion of issues

Chris Long discussed the crab shell condition aging error and its impact on crab assessment and management. Shell condition is used in determining the time since a crab's last molt and, therefore, plays an important role in determining maturity status of terminally molted *Chionoecetes*. In stock assessment, shell classification is used to separate crab into recruitment-to-maturity and post-recruitment groups. For many crab stocks, the proportion of new-shell and old-shell in the stocks are considered for determining annual total allowable catch.

Shell classification assigns crab into five shell condition categories: SC1 (soft shell), SC2 (new shell), SC3 (old shell), SC4 crab (very old shell), and SC5 (very very old shell). Classification is conducted using established criteria but is still highly subjective and many crab present attributes that are in a borderline area between classes due to either biological or environmental factors. The rate at which these errors occur is not well understood. In one limited study with 27 pre-classified crab, the error rate by shell classifiers was about 7.5%.

The impact of shell classification error depends on the prevalence of a given shell condition in the population, and the directionality of the error relative to the "correct" shell condition value. Errors occurring in "younger" crabs – those classed as being of SC2 and SC3 - will mostly affect stock assessment models, primarily because these lead to a misrepresentation of maturity status. For females, an erroneous shell condition will lead to a false determination of the female being primiparous vs multiparous. In the case of males, the SC3 classification is also a concern, as shell condition is paired with chela height data to determine the size at 50% maturity. Misclassifying SC3 as SC2 (most likely scenario) will overestimate recruitment and underestimate post-recruit. Shell classification errors on middle and older age crab (SC4 and SC5) will generally complicate tracking of pseudo-cohorts in the population. Limited radiometric-based research conducted to date (Ernst et al. 2005), suggests significant overlap in ages of crab between SC4 and SC5, due either to high classification error rates or poor environment leading to rapid deterioration in crab carapaces in certain cases.

The impact of shell classification error on stock assessment and management should not be ignored. Therefore, the CPT recommended the following:

- Encourage a special study to quantify shell classification errors on SC2/SC3, SC3/SC4, and SC4/SC5 employing different readers and taking durometer measurements (SC2/SC3 only).
- Encourage continuation of the photographic study of shell condition determination of *Chionoecetes* undertaken by ADF&G.
- Assess the impacts of SC2 /SC3 misclassification error rates on stock assessment and 50% maturity determination.

15. B_{MSY} Basis

This agenda item addressed the range of considerations involved in selecting data time series used to determine reference points for eastern Bering Sea (EBS) crab. Diana Stram presented the existing bases for B_{MSY} for EBS crab stocks which varies by assessment tier. Tier 4 stocks (n = 4) use average MMB over a period of time during which the stock was at B_{MSY}. Tier 3 stocks (n = 4) use an average recruitment over a period of time thought to represent stock productivity in the current environmental conditions. Average recruitment is then used to calculate a B_{MSY} using spawning biomass per recruit proxies.

A range of years may link to the late 1970s regime shift; others ranges relate to stock-specific dynamics. Some authors have used breakpoint analyses to identify the transitions between productivity regimes, while other time periods are based on recommendations from the CPT or SSC. Some authors include the latest year in the overall recruitment or spawning biomass time series in the calculations, while others do not. The CPT thought consistency across stocks is desirable and, when consistency is not possible, that justification for departures from standards should be provided.

There was extensive discussion on the merits of using entire time series of recruitment estimates to represent productivity of the stocks in the proxies for B_{MSY}. The argument for using a discrete time frame that is not updated with new information is that it attempts to provide a true 'reference' and avoids shifting baselines. The State of Alaska generally uses fixed time periods for determining harvest strategies such as fishery closure and exploitation rate thresholds. The assumption made for using an entire time series as the basis for B_{MSY} is that the environment is the primary driver for productivity and the continual addition of observations better characterizes average recruitment within the environmental regime.

Ultimately, the CPT agreed that there did not need to be a single prescriptive time period for all crab stocks, but there should be a well-documented justification (hopefully based on quantitative analysis) for why a reference period was chosen.

CPT recommendations:

- Exclude the terminal year of recruitment for calculating averages incorporated into reference point calculations because of high uncertainty associated with recruitment estimates at the end of the timeseries.
- If more estimates than last year are excluded, provide retrospective analysis for recruitment estimates or other analysis (for example, if estimated Rec_Dev in a year is less than R_{sigma}, include that year for mean recruitment calculation) to justify the exclusion.
- All assessments should include a section provides a justification for the years included calculating the proxies for B_{MSY} .
- Breakpoints can be identified using Rodionov's sequential t-test analysis for regime shifts (STARS) or pruned exact linear time algorithm (PELT; implemented in the R library *changepoint*)
- Dynamic B_{zero} analyses may be useful for comparison to breakpoint analyses.
- Consider other potential definitions of B_{MSY} proxies for unfished Tier 4 stocks

16. PIBKC Fieldwork and Qualitative Modeling

Chris Long summarized recent research in Pribilof Island blue king crab (PIBKC) biology/ecology, starting with a graphic showing the decline of mature female biomass in the early 1980s (attributed to a regime shift), a subsequent increase in red king crab PIRKC, and then fairly similar trends for the two stocks declining to low levels in the past decade. Previous studies had noted a lack of spatial overlap between RKC and BKC, suggesting differences in response to temperature, competition, or predation. Lab studies with temperatures of 4–20ºC for age-1 BKC and 11-20ºC for age-0 RKC showed the feeding rate peaked at about 8–11ºC for age-1 BKC and about 15ºC for age-0 RKC. A subsequent study found RKC growth declined above12ºC while BKC did not grow above 11ºC. In addition, age-0 mortality of both species increased dramatically above 15ºC. The temperature above which aerobic scope and physiological performance begins to decline (called the pejus temperature) was 8–11ºC in BKC and 12–15ºC in RKC. For comparison, recent summer bottom temperatures around the Pribilof Islands have been ~10ºC.

Additional studies looking at the potential impact of ocean acidification on young-of-year (YOY) crab mortality identified pH thresholds of ~7.5 for BKC and ~7.8 for RKC, with BKC being somewhat more tolerant. Another study evaluated 90-day survival of YOY BKC and RKC as single and mixed species on shell or cobble substrate. RKC survival was higher on shell and higher in the presence of BKC, but this was only true for shell substrate. The BKC had higher survival on cobble, but survival decreased (to the point of extirpation) in presence of RKC on either cobble or shell.

A lab study of predation mortality by halibut found higher survival for BKC than RKC in the presence of shells and simulated microalgae. The CPT discussed crab behavior such as BKC tending to be more cryptic and hide under structure, while RKC are more outgoing and climb on habitat structure, which could increase predation on RKC. A video was shown of wolf eel predation on a tethered RKC.

Recognizing that juvenile king crab survival is highly dependent on habitat, a field project is underway to evaluate recruitment limitations for PIBKC. A previous study used rock dredge and beam trawl sampling to evaluate BKC larval spatial distribution around Pribilof Island, but the current study extends to shallower water and uses settlement bags coupled with video and scuba observations to characterize larval distribution. The mesh settlement bags were placed in a variety of depths and contained either (1) shell hash and gillnet or (2) only gillnet. Preliminary results from 2017 and 2018 suggested of BKC larval

abundance is low with the spatial distribution substantially reduced from historical levels. Availability of BKC habitat is high and does not appear to have decreased relative to previous studies. However, the current study has found reasonable numbers of RKC including in the few places that BKC were found, which could result in the competition effects that were found in the lab studies. The CPT noted that YOY RKC in Southeast Alaska can be found in the upper intertidal, but BKC tend to be in deeper, cooler water, which could be a factor for Bering Sea distributions with warming ocean temperature.

Qualitative modeling approach – Jonathan Reum presented a qualitative, conceptual model on BKC responses to a range of ecosystem variables in order to explore potential management measures to promote recovery. Noting that there has been no evidence of PIBKC stock rebuilding despite fisheries closures, Jonathan explored other ecosystem interactions that may be impediments to BKC recovery. Mechanistic models combine realism and precision whereas statistical models combine generality with precision; the needed precision is these cases is difficult to provide. In contrast, qualitative models bridge generality and realism in a way that may lack precision but can be informative in terms of the direction of a change. Thus, a qualitative network might be able to characterize aspects of the positive, negative, or neutral effects of different factors under changing climate conditions. A qualitative model identifies a feedback mechanism, with interactions identified as a "community matrix". Such a model could concurrently consider ecological interactions, management levels, and climate impacts. An example of a conceptual qualitative model considered BKC life stage patterns, RKC patterns, and interactions across species and life stages. The next stage added interactions with several fish (pelagic and benthic) and invertebrate predators, and then considered the potential for increased fishing pressure (F) on specific predator species to reduce predation of BKC. The model expressed climate change impacts through warming (e.g., effect on pollock or cod distribution and effect on juvenile crab), and ocean acidification (e.g., BKC less vulnerable to OA). Finally, the model considered the potential of out stocking (i.e., release of cultured crab). Interactions were weighted based on draws from a distribution and the proportion of positive outcomes across interactions were tallied from multiple replications.

The simulation allows the impacts of one or more scenarios to be explored, e.g., out stocking plus increased fishing effort on Pacific cod. Simulations sample potential outcomes discard unrealistic results, and test for stability in results. While preliminary results suggest the primary option to increase all BKC life stages may be out stocking, even this option yields reduced benefits under climate change. The focus on qualitative modeling became an effort to identify probable linkages with the limited available information. The qualitative model also allows comparisons that consider the quality of the underlying information behind the interactions.

The CPT appreciated the value of this modeling approach to help visualize the concepts and noted that it is similar to small stock management which can be an art form and very qualitative. There is the potential to incorporate anecdotal information in cases of data-poor stocks, and perhaps to evaluate if an observation is important. The qualitative model can evaluate which of the linkages may be more important, which could guide research efforts. It was noted that the draft model appears to treat interactions linearly, although many real-world relationships are actually nonlinear. In terms of evaluating alternatives to promote BKC recovery, it is unclear if measures such as very localized fishing pressure could adequately relieve predation on BKC. The CPT would like to see more of this model as it is further developed.

17. PIBKC - Final 2019 Assessment

Buck Stockhausen presented the final assessment for PIBKC, now on a biennial schedule with the last assessment in 2017. The new assessment schedule is meant to coincide with a required rebuilding report. The status determination process for 2019 is identical to that in 2017 (approved in 2015). Fishery data include 2017/18 bycatch and 2018/19 bycatch through April 1, 2019. The directed fishery has been closed since 1999/00, and the stock was declared overfished in 2002. Buck presented spatial and temporal trends

in bycatch from crab and groundfish fisheries and temporal trends in NMFS survey data. As of April 1, 2019, one sublegal size male BKC was captured in the 2018/19 Tanner crab fishery for a total fishery expanded weight of 0.1 t. This estimate will be updated once final data from the 2018/19 crab fisheries are available. Overfishing status will be evaluated at the September CPT meeting. There were anecdotal observations of some unobserved BKC captured in the 2018/19 fishery, but that bycatch was not included in the total expanded bycatch estimate. NMFS survey data is included up to 2018. Very few BKC were captured in the NOAA trawl survey in recent years, which added to uncertainty in expanded population estimates because there were many trawl stations with zero BKC captured. Overall population estimates remained low in recent years.

A tier 5 approach for determining OFL is used, even though the stock assessment followed a tier 4 method because the stock is overfished, and no directed fishing has occurred since 1999/00. The assessment uses a random effect fit to MMB estimates from the NMFS bottom trawl survey. Process error in the random effects models approaches a CV of 1. The 2019 projection of MMB is the same as in 2018, but with larger uncertainty. Projection of 2019/20 MMB at mating includes discard mortality for both males and females and uses an average discard mortality relative to MMB applied to 2019/20. The time period of MMB for Bmsy estimation was 1980/81-1984/85; 1990/91-1997/98. Bmsy was estimated at 4,605 t.

The stock remains overfished with no signs of recovery. Overfishing will be evaluated at the September CPT meeting, but preliminary estimates suggest overfishing has not occurred. The author recommended a Tier 5 OFL of 1.16 t based on average fishing mortality during 1999/2000-2005/06, and an ABC of 0.87 t based on a 25% buffer to the OFL. The CPT concurred with OFL, ABC, and ABC buffer recommendations. There were no recommendations for reevaluating OFL calculation because the OFL is determined based on bycatch mortality in the groundfish fisheries. The CPT recommended keeping the assessment on a 2-year cycle for OFL setting.

CPT recommendations:

- Incorporate information regarding the model used for status determination criteria (now in Appendix C of the document) into the main assessment document.
- Include the parameter table in the main assessment document.
- Include an evaluation of progress towards rebuilding.

18. SMBKC Assessment and Rebuilding

Katie Palof reviewed the 2018 St. Matthew Island blue king crab stock (SMBKC) assessment, briefly discussed potential model scenarios to be run for the September 2019 assessment, summarized a breakpoint analysis she conducted to re-evaluate the time frame used to define B_{MSY} for this stock, and reported on her progress since the January 2019 CPT Meeting developing alternative rebuilding analyses to support a rebuilding plan for SMBKC. Katie is the new lead author for the SMBKC assessment, taking over that responsibility from Jim Ianelli (AFSC). She is also the lead to develop and conduct a rebuilding analysis for the SMBKC rebuilding plan. Following Katie's presentation to the CPT, Diana Stram made a separate presentation to the CPT that covered the notification to the Council that the stock is currently overfished, requirements under the MSA to prepare and implement a rebuilding plan, the requirements of a rebuilding plan, progress since the January CPT Meeting on rebuilding analyses and other work to support development of the rebuilding plan. Cathy Tide, Krista Milani, and Jason Gasper (all NMFS/AKRO) discussed different aspects of SMBKC bycatch in the groundfish fisheries in conjunction with Diana's presentation.

Using the 2018 assessment model (Model 3) for SMBKC and Tier 4 status determination criteria, the stock was found to be overfished (although overfishing was not occurring) and the Council was formally notified of this in October. Under the MSA, a rebuilding plan must be prepared and implemented by the

Council within two years of this notification. The assessment model, which uses the GMACS framework, was selected at the January 2019 CPT Meeting as the basis for the rebuilding analyses required to develop the rebuilding plan. Changes to GMACS to add the ability to run projections, a prerequisite for conducting rebuilding analyses, were implemented during the January CPT Meeting and subsequently by André Punt. There was no effect on results from re-running the assessment model with the updated code, and Katie proposed running the same suite of three alternative model scenarios (base, "fit survey", and one fitting to VAST-estimated survey data) for the Fall 2019 assessment as were used in the 2018 assessment.

At its September 2018 meeting, the CPT requested a breakpoint analysis be conducted on the recruitment time series similar to those previously conducted for Tanner crab and BBRKC, citing concerns that mean recruitment had shifted to a new, lower stable state. Katie used estimated recruitment and MMB time series from the 2018 assessment model to conduct this analysis, which tested whether two time periods with significantly different mean recruitment levels could be identified. Based on SMBKC life history, she assumed a lag time of 7 years between brood year and recruitment to the assessment in order to align the recruitment and mature biomass time series from the assessment. This also assumed that MMB was a good proxy for female spawning potential. Although stock-recruit (S/R) relationships are generally not well-defined for Alaskan crab stocks, Katie included both Beverton-Holt and Ricker S/R models in the analysis. She explained that some of the model fits appeared poor because the error bars were not included in the plots (and the uncertainty in MMB was included in the fits, as well as the uncertainty in recruitment). A common breakpoint in brood year 1989 was identified using each S/R model, while the lack of a a breakpoint was indicated to be highly unlikely.

Although the breakpoint analysis was fairly convincing, the CPT recommends the author repeat the analysis under the assumption that recruitment is independent of mature biomass. One suggested approach would be to fit a Beverton-Holt S/R curve to the time series, but with steepness set to 1. Other approaches to identify breakpoints would be to apply the STARS or PELT algorithms to the recruitment time series.

The breakpoint analysis suggested that the SMBKC stock entered a new recruitment "regime" beginning in 1996 (the year in which the 1989 brood year would recruit to the assessment model), with the consequence that the time period over which the Tier 4 $B_{MSYproxy}$ is calculated (average MMB, 1978-2017) no longer reflects the new long-term production potential. The current $B_{MSYproxy}$ for SMBKC is 3,478 t, while one based on a 1996-2017 time period would be 2,030 t, a 42% reduction.

The CPT agreed with the proposed suite of alternative model scenarios for September and recommends running a crossed design with the 2018 assessment model, the "fit survey", and the VAST-estimated survey data model scenarios crossed with the $B_{MSYproxy}$ for status determination calculated on the basis of 1) 1978-2018 and 2) 1996-2018 (i.e., using the recruitment breakpoint analysis to determine the time frame for averaging).

Based on the 2018 assessment and the breakpoint analysis, rebuilding analyses were conducted using the 2018 assessment model and the new GMACS projection capability to look at a range of combinations of recruitment, bycatch mortality, and implementation of the state harvest policy to determine the probability of recovery for each scenario. The seven scenarios for future recruitment and the $B_{MSYproxy}$ included a mix of S/R model (Ricker or Beverton-Holt) or recruitment from the assessment randomly sampled with replacement from two time periods (1978–2017 or 1996–2017), and the $B_{MSYproxy}$. These seven scenarios were repeated under two assumptions that bracket future directed fishing mortality: 1) no directed fishery in all years (TAC=0), and 2) directed fishing mortality limited by the smaller of the current State harvest strategy for SMBKC and the OFL.

Including bycatch mortality in the rebuilding projections had no impact on the results. Implementation of the State harvest strategy (HS) affected the rebuilding times under some scenarios, with most resulting in an increase in estimates of the time to rebuild. Relative to fishing at F=M (the F_{OFL}) the estimates for the

time to rebuilding were more optimistic because the harvest policy reduced F below M. When a S/R relationship was assumed to exist, estimates for T_{min} ranged from 14.5 years for the Beverton-Holt curve to 16.5 years for the Ricker curve. Results based on resampling estimated recruitment depended on the time frame used. Using 1978-2017 resulted in estimates of Tmin that were less than 10 years. These may be overly optimistic, however, given the breakpoint analysis that suggests that SMBKC shifted to a state with lower mean recruitment in 1996. Using the more recent period (1996-2017) suggested by the breakpoint analysis yielded much more pessimistic results (T_{min} > 100 years) when the rebuilding target was the current $B_{MSYproxy}$ based on average MMB over 1978-2017. Using the $B_{MSYproxy}$ calculated from the same period as the resampled recruitment, however, yielded estimates of T_{min} slightly over 10 years.

Katie noted the SSC had asked that combining the projections by weighting them based on their plausibility be considered, but that this had not yet been done because it was not apparent what weighting scheme would capture "plausibility" in a defensible manner, nor that combining the projections would result in a better representation of the current environment.

In discussion, the CPT agreed that there were several decision points associated with the rebuilding projections, the most important being assumptions on recruitment and whether or not the $B_{MSYproxy}$ should be consistent with recruitment in the analysis. The CPT favored advancing with scenarios based on resampling recruitment, rather than on assumed S/R relationships, given that this would be consistent with the assessment. Further, the CPT favored keeping both the full model time period (1978–2017) and the recent period suggested by the breakpoint analysis (1996–2017) under consideration. Martin Dorn pointed out that a recent ICES workgroup recommended using the same time frame for status proxies ($F_{MSYproxy}$, $B_{MSYproxy}$) as those used to define mean recruitment. The CPT felt this was appropriate advice and thus the CPT recommends moving forward with the two scenarios for which recruitment and the $B_{MSYproxy}$ are defined using the same time period (Scenarios 1 and 5 in the rebuilding analysis document).

The CPT noted that the scenario using the 1996–2017 time period to define average recruitment and the $B_{MSYproxy}$ for status evaluation was inconsistent with the current status determination and asked Council staff whether or not this was appropriate. Council staff responded that the CPT must define the reference points for the September assessment independent from the rebuilding plan but could consider alternative time periods to define the $B_{MSYproxy}$ at that time. The CPT thus recommends that the assessment author present alternative status determination results at the Fall 2019 assessment based on both the current time period (1978–2017) and the time period identified by the breakpoint analysis (1996–2017).

The CPT also discussed whether or not the State could change its harvest strategy during the rebuilding period. Council staff informed the CPT that the rebuilding plan could affect the State HS to make it more conservative, but that it would constrain the HS so it can't be less conservative than the current version. Because the State HS may constrain the directed F to be below the maximum allowed in federal regulations (F=M for SMBKC), the CPT recommends using the State HS as the upper bound on directed fishing mortality and dropping F=M from further consideration.

In a separate presentation, Diana outlined the requirements for the rebuilding plan and reported on progress made since January. The Council was officially notified that SMBKC was overfished on October 22, 2018. The MSA sets a 2-year period for development and implementation of the rebuilding plan from the date of notification. The plan must specify a time to rebuild, which should not exceed 10 years, unless this cannot be accomplished in the absence of all fishing mortality. Consequently, the first step in developing a rebuilding plan is to specify T_{min}, the time to rebuild, with 50% (or greater) probability, to its B_{MSY} level in the absence of any fishing mortality and Tmax, the maximum time for rebuilding. If T_{min} < 10 years, then T_{max}=10 years. Otherwise, there are three options available to specify T_{max}: 1) T_{min} plus one generation time; 2) the time required to rebuild to B_{MSY} when fished at 75% MFMT; or 3) 2 x T_{min}. In situations when T_{min} exceeds 10 years, T_{max} establishes a maximum rebuilding time based on the biology of the stock.

Diana pointed out that there were also secondary aspects that the CPT should consider in the rebuilding plan, including potential revisions to the State HS, habitat considerations, additional restrictions on groundfish fishery bycatch that would increase the likelihood of rebuilding, and whether the criteria for rebuilding should be that B_{MSY} was exceeded in one year or in two successive years. Diana also noted that the 50% probability criterion for rebuilding was a minimum standard, but that the CPT/SSC could modify this as necessary. The CPT did not see a strong justification for requiring that B_{MSY} be exceeded two successive years in order for the stock to be considered rebuilt. Although this would be a more precautionary requirement, there are more direct ways to build precaution into the rebuilding plan, such as establishing a greater than 50% probability of rebuilding. Putting in multiple decision-points muddies the analysis. Therefore, the CPT recommends that the rebuilding analysis consider the stock to be rebuilt when the stock first increases above the B_{MSY} target as determined by the stock assessment.

Martin noted that several environmental factors could affect the probability of rebuilding, including the warming of the environment is not conducive to blue king crab growth and survival, ocean acidification, and the northward expansion of Pacific cod, an important crab predator, into the SMBKC stock area. The CPT recommended that rebuilding plan include an evaluation of ecosystem factors that may affect SMBKC recovery, and suggested coordination with Erin Fedewa who developed the ecosystem report cards for other crab stock. The CPT discussed whether the State HS would change if the time periods for the $B_{MSYproxy}$ and mean recruitment changed. ADF&G staff suggested the rebuilding plan could include a provision that there be no changes to the State HS, and that the State HS could be amended to add that no directed fishing would occur while under a rebuilding plan.

Krista Milani, Cathy Tide, and Jason Gasper then characterized data on SMBKC bycatch in the groundfish fisheries and current restrictions on the groundfish fisheries in the stock area. These included size compositions of SMBKC bycatch in the groundfish fisheries, spatial patterns of observed bycatch, and area closures within the SMBKC stock area. It was noted that both males and females are taken as bycatch in the groundfish fisheries and that most bycatch occurs in ADF&G stat area 726001 (southeast of the island) by fixed gear. Area closures include the 3-mile limit state waters (open to halibut fishing but closed to crab and other fishing), the federal St. Matthew Island Habitat Conservation Area (closed to non-pelagic trawling), and the federal North Pacific Trawl Gear Modification Area (which limits the gear used for non-pelagic trawls). The ensuing discussion focused on the best options for reducing SMBKC bycatch while minimizing effects on the groundfish fleets. Potential options included a bycatch cap in the HCA, closing the HCA to fishing altogether, or to set a conservative ABC. It was suggested that additional area closures would overly impact pot cod catcher-processors that are tied to restricted areas and seasons, and that a consideration in developing the rebuilding plan was to minimize economic impact. Council and Regional Office staff suggested the most flexible option was to continue to allow in-season management to close areas to avoid overfishing based on exceeding the ABC/OFL, but with a more conservative ABC. Thus, the CPT recommends developing the rebuilding plan with the current area closures for target gear and to close areas based on avoiding exceeding ABC/OFL using in-season management.

19. Economic SAFE

Brian Garber-Yonts presented an overview of the 2018 crab SAFE economic status report. The crab economic SAFE is produced annually for the previous calendar year fishing activities. The executive summary is included in the October CPT SAFE report and the full report provided at the Council February meeting. The economic SAFE is intended as an annual summary of economic trends in the rationalized crab fisheries and includes information on fisheries operations, participants, and social indicators.

In response to SSC recommendations, several updates to the economic SAFE are being developed, including creating a report card, making the data available for the public to download, develop ownership

decomposition to determine how much of quota is harvested by owners or leaseholders, and spatial/community disaggregation of wages, and including a full time series for a limited number of indices. The SSC recommended showing net economic earnings, including net economic earning indices for the processing sector. Currently the report only includes indices from the harvesting sector. For groundfish the economic indices are being incorporated into the groundfish assessments and it was recommended that the same be done for crab assessments. The SSC would also like to see more community detail including employment, vessel ownership, and economic distribution from the crab fishery within the community. Providing more detail in the economic SAFE can be complicated due to complex ownership systems of both processors and quota, along with confidentiality associated with more specific information.

There has been interest in the development of environmental and socio-economic profiles for each crab stock. The Groundfish Plan Team (GPTs) are also working on this. The SSC has specifically requested this for the Norton Sound red king crab fishery. However, Brian recommends postponing the creation of a quantitative baseline of annual commercial engagement and dependency until the GPT explores the best way to incorporate this information into an annual report card. It may be useful to collaborate with Erin Fedewa to integrate ecological indicators.

Many of the 2017/18 commercial fisheries had their TACs cut substantially. Gross revenue for ex-vessel and wholesale value, for all crab fisheries combined, were down as much as 45%. Production volume by ex-vessel and wholesale, for all crab fisheries combined, were down 30% and 38%, respectively. Weighted average ex-vessel and wholesale prices for snow and Tanner crab were the highest seen since 1998, while prices for golden and red king crabs were both down. It is important to note that data for rationalized fisheries are reported on an annual year basis (not crab year) and may include data from the past two seasons. Therefore, closures in the Tanner crab fisheries in the 2016/17 fishery are included in this economic report.

Market prices are determined by the global market and, generally, not responsive to changes in Alaska crab TACs. Prices tend to be more responsive to changes in exchange rates. Tariffs may currently be contributing to increased inventories of frozen stock. It is recommended to include changes in tariffs and trade in future economic SAFEs. The author would also like to include revenue decompositions in a figure that would show the change in revenue and attribute the relative proportion of the change that is due to price changes versus output changes.

Residence of captains and crew have been fairly stable over recent years with approximately 33% Alaskan residents and 65% non-Alaskan residents. Crew positions and processing labor hours were down in 2017 with employment declines more pronounced in processing than crew positions. The decline in crew positions is attributed to fewer boats participating in the fisheries, presumably due to lower TACs, which also decreases the number of processing hours. The decline of processing employment was severe for residents of Pacific northwest states, decreasing by 100 people in Alaska, by 300 people in Pacific northwest states, and no decrease for other states. This may be due to improved labor markets and increased hiring in northwestern states (OR, WA, and ID). Wages declined from 2005 through 2014 for workers in the processing sector. Between 2015 and 2016 average hourly earnings for processing workers went up significantly, and in 2017 declined significantly, due to a decline in overtime hours. Processors are using labor and scheduling more efficiently and able to reduce the amount of overtime needed.

Accounting for vessel income includes labor and quota costs as well as fuel, bait, and provision costs. The report is missing data on repair and maintenance, which is difficult to obtain. Accounting for operating costs and rate of return with adjustments in TACs has been fairly consistent across the last 5 to 6 years. This is partially due to increased fleet efficiencies such as harvest coops and the inter-cooperative exchange. Over time the amount of costs attributed to leasing quota has gone up consistently although, it is impossible to determine the lease rates on a vessel's own quota. The inter-cooperative exchange has implemented a voluntary lease rate cap which has maintained a consistent lease rate at 65% in Bristol Bay

red king crab and 45% to 50% in Bering Sea snow crab. The Council has expressed interest in monitoring annual lease rates.

The number of processing facilities has declined and is the lowest in the time series; in some cases, reaching critical low thresholds.

International imports of snow and king crab went up and 2017 was the highest ever for snow crab. In 2017, international imports of red king crab were up but is still within the average range. Imports include crab that is harvested in Alaska, exported for processing, and then imported back into the United States. Net exports for both king and snow crabs were down, with 2017 net exports of snow crab the lowest in the time series.

Priorities for the 2019 crab economic SAFE are to develop report card metrics for many key economic indicators and highlight deviations from 5-yr averages. The key distinction is that the executive summary provides key economic indicators summarized over the last 5 years and uses the same types of figures as ecosystem reports. The author also plans on integrating price forecasts and estimates for current year production, including demographic detail at the community level and creating economic performance reports or socio-economic reports for selected fisheries. The CPT suggested that Norton Sound might be a good candidate for a pilot socio-economic report in order to evaluate whether such a report would be useful for other crab fisheries.

It may be useful to look at cross-sector comparisons with groundfish, although this may be difficult beyond a very high level. In the economic SAFE introduction, there is a small discussion about the ex-vessel value of crab comparing Alaska to the rest of the United States. Crab fisheries are high value and represent a high level of gross revenue compared to volume.

Additionally, the CPT recommends the author attend the ESP workshops.

20. VAST Modeling

The CPT heard two presentations relating to the VAST (vector autoregressive spatio-temporal) model, one by Jim Thorson, who presented an overview of the model and one by Jon Richar, who provided an initial look at its applicability to the NMFS bottom trawl survey data estimates of BSAI crab abundance.

Jim Thorson provided information on the parameterization of the model and its potential uses in analyzing spatial and temporal data. He also had a list of 15 decision points when using the VAST model and suggested that the CPT work to adopt some guidelines for these for the BSAI crab stocks. Some of these decisions include the spatial area to model for each crab stock, the type of smoother to use in the model, the addition of covariates into the model, choice of link functions, and overall model selection using AIC or other methods.

Jim explained some of the benefits and drawbacks for using VAST. Benefits include combining multiple data streams, a disciplined approach to spatially unbalanced data, accounting for variance associated with randomized sample location, and improved statistical efficiency. Some drawbacks are the potential to introduce bias, results that are model based, it is complicated to use and explain, and that there are many decisions to make. Jim also went over some of the basic diagnostics associated with these models including general residual checks, plots of encounter-probability vs. frequency, Q-Q plots, and advice to look at bounds and gradients for the parameter estimates. Some references were provided that compared VAST to other treatments of spatio-temporal data.

Jon Richar (NOAA Kodiak) provided initial results for applying VAST to NMFS bottom trawl survey estimates of BSAI crab abundance. Initial comparisons were to design-based estimates currently used for BBRKC, Eastern and Western Tanner crab, and snow crab. The VAST model did not contain any covariates, used the conventional delta method, applied a mesh-based spatial approximation, and had a range of 100 to 150 knots (limited due to computational speed). Initial results suggest tighter confidence

intervals around the VAST estimates and reductions in the number of large peaks in the time series using VAST compared to the design-based estimates. Model diagnostics were appeared decent but could be improved with better model set-up (i.e., the decision points that Jim presented). Additionally, there were some differences in the spatial area of the survey design-based methods vs. VAST, and refinements to match these "spatial footprints" may be necessary for future work.

CPT discussion of the use of VAST focused on how to deal with the complex geography associated with many of the crab stocks, e.g. landscape around the Aleutian Islands, and the "smoothing" of biomass estimates and associated reduction in variability. Some CPT members had concerns that VAST assumes survey values and associated variances are due mostly to survey spatio-temporal variation and therefore would be "smoothed" out before being added to the population dynamics model. This would not allow the population dynamics model to "explain" the true variation in the survey data. There was also concern that a reduction in the CV's for the survey data would need to be offset by an additional variance term, trading one type of variability in the model for another instead of reducing overall variability within the model.

CPT recommendations:

- There should be continued discussion on the use of VAST in BSAI crab models, and perhaps a joint discussion of these models in September with the groundfish plan teams.
- Guidelines should be developed for the decision points needed when using VAST for BSAI crab species.
- Provide feedback for Jon Richar on future work he will be doing with VAST, including specific requests for VAST time series for use in crab stock assessments.
- Assessment authors are encouraged to evaluate VAST estimates in assessment models in the near future.

21. Tanner Crab Genetics

Genevieve Johnson presented results from her M.S. thesis at UAF, Juneau on the population genetics of Tanner crab in the eastern Bering Sea and Gulf of Alaska. She explained that several aspects of Tanner crab life history can lead to complex spatial patterns in the species, including a relatively long pelagic larval duration coupled with potential advection by currents away from natal areas, the need to settle in suitable early benthic habitat, and the vulnerability of juveniles to predation. For example, Tanner crab larvae have been found in the Chukchi Sea, at least 500 nm from adult populations. Furthermore, although a study using a ROMS model to estimate dispersion in the early pelagic life stages (Richar et al., 2015) has shown high retention for certain spawning areas (e.g., in Bristol Bay or near the Pribilof Islands), retention rates are not high enough to prevent genetic mixing.

Genevieve noted that little genetic analysis of Tanner crab had been done previously. One previous study (Bunch et al. 1998) examined the diversity of 18 haplotypes from one mitochondrial gene in 52 crab collected from Southeast Alaska, Cook Inlet, Kodiak Island, and Bristol Bay. Results showed haplotype diversity differed among areas, but genetic diversity was significantly different only between Southeast Alaska and Cook Inlet. The spatial patterns of haplotype diversity were interpreted as evidence for larval transport by the Alaska Coastal Current (ACC), but the evidence was considered weak. Another study (Merkouris et al. 1998) found significant differentiation between samples collected in the EBS, GOA, and Southeast Alaska using 27 allozyme loci. The allele frequencies for three of the loci also differed significantly east and west of 166^{o}W longitude in the EBS, the line the State uses to demarcate management areas for Tanner crab fisheries in the EBS. However, support for genetic differences was again weak given the small sample sizes, the numbers of loci examined, and the fact that many of the loci examined were not genetically neutral.

Genetic techniques have improved since these earlier studies and it is now possible to sequence the entire genome and examine genetic variation at different levels of hierarchical organization, from within and

between individuals, to within and between subpopulations, and finally to within and between populations. The objectives of Genevieve's research were to measure the genetic diversity of Tanner crab from different areas in Alaska with genome-wide genotypes and to test for genetic differentiation among the major areas. This was done using individuals collected across 4 sites (east and west of 166ºW longitude in the EBS, Prince William Sound, and Southeast Alaska) and applying double digest restriction-associated DNA (ddRAD) sequencing to sample enough of the genome to draw inferences regarding population structure and spatial patterning. Given funding constraints, she was able to genotype 89 individuals using 2,740 neutral single nucleotide polymorphism (SNP) sites after careful screening of variable loci.

The expected heterozygosity by locus was significantly smaller than expected under Hardy-Weinberg equilibrium, which might indicate substantial inbreeding, but this was similar across the four areas and no variation was found at a regional scale. Analysis of Molecular Variance (AMOVA) found significant variation within samples (90.5%; $p<0.001$) and between samples (9.4%; $p< 0.001$), but not between regions (0.05%; $p=0.18$). Other hierarchical statistics (F_{ST}, $\boldsymbol{\varphi}_{ST}$) also indicated that almost all variation was at an individual level; little variation was found between regions. This also proved to be true when looking at variation between regions on a pairwise basis and testing for population partitioning using principal components analysis (PCA) or discriminant analysis of principal components (DAPC). Furthermore, a parametric Bayesian clustering algorithm found support for no more than one cluster.

Thus, Genevieve found she could not reject a null hypothesis of panmixia for Tanner crab across the four areas included in her study and noted the occurrence of other panmictic species in Alaska (e.g., snow crab - a congener). However, she also noted that a recent paper (Spies et al. 2015) found that managing a fished population as if it were really two genetically-distinct populations was better than managing two genetically-distinct fished populations as if they were really a single population.

The CPT raised the question whether the low value for FST for Tanner crab could indicate a previous bottleneck event for the population, perhaps associated with lower sea levels in the past. Genevieve responded that, while this was a possibility, other marine invertebrate species show similar levels of FST and thus Tanner crab are not unique in this regard. The CPT also wondered whether Genevieve had any concerns regarding the low sample sizes for this study. Genevieve replied that identifying the loci and SNPs to use in the study really constituted where most of her effort was directed and that now that they had been identified it would be much simpler (and cheaper) to expand the sample sizes in the future.

The CPT would like to express its appreciation to Genevieve for her willingness to present her work at the meeting and for her informative presentation.

22. Research Priorities

Jim Armstrong updated the CPT on the Council and SSC's recent decision to conduct comprehensive reviews of research priorities every three years instead of annually. A discussion of the best use of CPT time on this subject suggested that the identification of pressing new priorities or potential loss of critical survey funding would be highlighted at any given meeting for notification to the Council and SSC. Additionally, and noting the SSC's expectation that Plan Teams will continue to conduct annual updates, the January CPT meeting would be the most appropriate meeting to comprehensively review crab research priorities.

For this meeting, Jim had reviewed each of the SAFE chapters for identified research needs and noted additional research on acoustic tags that was presented at the meeting. Additionally, he navigated to the Council's research priority database webpage on screen, and the CPT noted that the visibility of the database on the Council's website could probably be improved. For the annual review next January, the CPT suggested that Jim present cross-tabulation of research priorities identified in the SAFE with those

listed in the database. The CPT is also planning to conduct a review of topics currently under active research for crab stocks in the North Pacific for the upcoming January 2020 meeting.

23. Model numbering

Martin Dorn reminded the CPT of the numbering convention for different model scenarios. Minutes from May 2017 CPT, June 2017 SSC, and Sept 2017 CPT meetings were reviewed to establish the CPT's preferred formatting of yy.jx where yy is year, j is a number representing a major change, and x is a letter representing a minor change (e.g., model 18.0 is last year, 19.0 is brought forward from last year, 19.1 is major revision, and 19.1a is a minor revision on 19.1). The goal of a model numbering convention to make it easier for reviewers and readers of stock assessments to understand and compare the model scenarios presented in the assessment.

24. New Business

The CPT discussed topics for the September meeting, which will be held at the AFSC in Seattle, as usual. The draft list of agenda topics is provided below. Note that the CPT is scheduled to meet during the same week as the Groundfish Plan Teams, and this is expected to provide the opportunity for joint sessions on plan team processes, and possibly ecosystem, and VAST model discussions.

Draft September 2019 CPT Meeting Agenda items:

- EBS survey results
- Fishery performance report
- Final BSAI crab stock assessments:
    - BBRKC
    - PIRKC
    - Snow crab
    - Tanner crab
    - SMBKC
- NSRKC model review for the January meeting, possibly including a GMACS implementation
- Initial review of SMBKC rebuilding analysis
- AIGKC cooperative survey operational plan
- Report on Tanner crab MSE
- Snow crab PSC limit discussion (tentative)
- Presentations on recent crab research:
    - *Chionoecetes* mating dynamics
    - Implications of skip molting
- Joint session with GFPT –
    - Review of Draft Plan Team Handbook
    - Ecosystem status report
    - VAST model discussion

Timing and locations for upcoming CPT meetings was also addressed under new business. Given the early scheduling of the Council's February meeting in 2020 (Jan 27 - Feb 3), it was tentatively decided that the CPT would meet in Kodiak during the week of Jan 13-17, 2020. Holding the meeting in Kodiak will enable participation of researchers from the Kodiak Fisheries Research Center, including the new lab director, and allow the CPT to tour facilities at the Center. The ADF&G Shellfish Observer Program is also based in Kodiak, and the CPT anticipates receiving a program overview. The CPT intends to review and discuss crab research needs at this meeting, including current research topics. A hands-on workshop on GMACS was also proposed for this meeting. The May 2020 meeting will be held in Juneau, most likely during the week of May 4-8.