North Pacific Fishery Management Council

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Crab Plan Team REPORT

January 10-13, 2022
Online Meeting

Members in attendance:

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

Others in attendance:

Andrew Munro
Andy Nault
Ashley Dunker
Bo Whiteside
Bridget Ferriss
Charlie Lean
Connie
Cory Lescher
Dana Rudy
David Witherell
Dawn W
Doug Wells
Forrest Bowers
Frank Victor Kelly
Gretchen Harrington
Jamie Goen
Jared Weems
Jen Bell
Jeremy Harris
Jim Lanelli
Jodi Pirtle *
John Gauvin
John Hilsinger
John Olson*
Jon McCracken
Jonathan Richar
Justin Leon
Kalei Shotwell
Kenny Down
Kerim Aydin *
Linda Kozak
Landry Price
Leah Zacher
Leonard Herzog
Linda Hall
Lukas DeFilippo *
Madi HS
Mark Stichert
Matthieu Veron
Maxime Olmes
Ned Laman *
Nick Sagalkin
Nicole Kimball
Paul Peyton
Paul Wilkins
Rachel Baker
Renae I
Rich Brenner
S. Ricci
Sabrina G
Sam Cunningham
Sarah Rheinsmith
Seanbob Kelly
Scott Goodman* Scott Smeltz
Steven Minor Terrance Wang Toshihide Hamazaki * Tyler Jackson
Vicki Vanek
Wes Jones
*gave a presentation to the CPT

1 Administrative

The January 2022 Crab Plan Team (CPT) meeting was held online via the Adobe Connect meeting platform, and connection information was posted to the CPT eAgenda. The meeting began at 10:00 a.m. AST on Monday, January 10, 2022, with a technical setup and overview of the meeting application. CPT Co-Chairs Martin Dorn and Katie Palof reviewed guidelines for the meeting, including how public comments would be addressed during the meeting, as well as note-taking assignments and timing for meeting deliverables, including finalizing the SAFE introduction and this CPT Meeting Report. Sarah Rheinsmith was introduced as a new NPFMC staff member working with the CPT.

2 Survey updates

BBRKC Resampling

Erin Fedewa (AFSC-Kodiak) summarized the current resampling protocol applied in years when cold water temperatures delay BBRKC female molt/mate timing, and a large proportion of mature females are thought to occur closer to the Alaska Peninsula and south of the typical survey area. Resampling occurs when ≥10% of mature females within the BBRKC management area have not completed the molt/mate cycle based on visual observation of clutch condition (i.e., eyed embryos, barren, and hatching). When implemented, retow data replace Leg 1 station data for all females, whereas Leg 1 data are alway used for males. In all resample years since 2008, >40% of mature females had not completed the molt/mate cycle, with the exception of 2021, when only 18% of females had not yet completed the molt/mate cycle. However, several concerns have emerged, including: ecosystem change in the eastern Bering Seas over time; an increasing northward shift in female distribution; and variable resampling methodology. Examples include inconsistent timing of resampling across years (adding the NBS to the survey has changed the timing of resampling), the number of resampled stations ranging from 20 to over 30, and the location of resampled stations. Erin noted the criteria for selecting resampling stations is somewhat ad hoc, but focuses on Leg 1 barren female and overall female distributions. Resampling takes 7–10 additional vessel days and represents a significant at-sea effort for the AFSC. The authors consulted Bob Foy last spring regarding the resampling protocols for a historical perspective, and the 10% threshold was found to have been implemented with little critical review.

In discussing localized movement among survey legs, Jie Zheng noted the belief that females initially occupy nearshore, rocky areas, then move into resampled stations, whereas previous studies have not seen consistent changes in male abundances. Cody Szuwalski thought it might be useful to look at the variance around the percent females, including looking at the sample size, etc., used to calculate the clutch condition threshold. In recent years, sample sizes for clutch condition have been substantially less than in 2008. Ben Daly noted that the resampling effort is trying to address changes to reproductive status and size composition (assuming growth from molting). If evaluating crab movement into the survey stations and related changes to abundance estimates is a secondary goal, we may want to focus resampling on stations closest to the nearshore area by the Alaska Peninsula. Lyle Britt (NOAA) noted that we are perhaps trying to do too many things with the resample stations; resample effort did not historically focus on trying to assess additional females for the population, and it would be difficult to add nearshore stations with standard survey tows.

The CPT questioned how the lack of a resampling program might affect stock management, noting that the ADF&G management plan has a female threshold before the fishery may be opened. Asked if the intent of a higher threshold is to reduce the frequency of retows, Erin noted that a marginal threshold increase would only have been a factor in 2021, a year during which resampling had little effect on the mature female estimate; plus, cold years are becoming less frequent, and a higher threshold might exclude resampling when only a marginal portion of the mature female molt/mate cycle is delayed.

The CPT suggested looking at: (1) impacts of past years if the threshold had been higher; (2) how the clutch condition composition changed across all survey years and all resampling years; and (3) what if resampled stations are more standardized rather than changing resampling stations based on observed female distributions during Leg 1. Erin will report back in May to address these suggestions and will propose a new threshold for the CPT to review. The CPT recommends that any changes to the resampling protocol be adopted during the May CPT meeting to ensure that the protocol is finalized prior to the start of the 2022 bottom trawl survey.

St. Matthew and Pribilof Corner Stations

Lukas DeFilippo (NOAA, AFSC) presented an analysis of the potential removal of the high density "corner stations" in the NMFS EBS shelf bottom trawl survey that was originally designed to improve sampling of blue king crab around St. Matthew and the Pribilof Islands. Fishing for blue king crab has been closed around the Pribilof Islands since 2000, with no sign of stock improvement. Fishing around St. Matthew Island has been periodically open since 1999, but most recently has been closed since 2016 and is currently under a rebuilding plan. Sampling of the corner stations requires 6–7 vessel days at a cost of ~$100k, funds that could be redirected to other priorities. The authors conducted a retrospective analysis on the effects of removing the corner stations on the precision and accuracy of design- and model-based (VAST) abundance estimates for EBS crab stocks. An empirical analysis showed that, in general, VAST estimates had similar biomass estimates, but CVs were substantially less than for the design-based estimator. The CVs were somewhat larger for Pribilof Islands blue and red and St. Matthew blue (in recent years) king crab, although these stocks might be expected to have higher CVs because of the patchy nature of their distributions. The authors then conducted a simulation analysis using an operating model to create a simulated data set and explored estimates with and without corner stations. They found little difference for Tanner and snow crab, as well as Pribilof Islands red king crab, but removing corner stations reduced median symmetric accuracy for St. Matthew blue king crab in the VAST framework. In summary, removal of corner stations had little effect on the precision and accuracy of estimates for Tanner and snow crab, but greater effects on Pribilof Islands and St. Matthew blue king crab, species for which survey precision/accuracy is low due to limited data availability, although the impact of dropping corner stations was somewhat reduced when only considering a design-based survey.

Responding to the discussion, the authors noted that they did not extend the analyses to the full stock assessments, look at the effect on composition data, or evaluate the impacts in years that had high Tanner and/or snow crab catches at the corner stations. One suggestion by the CPT was because Tanner crab <103mm CW are important in its Tier 3 assessment model, to consider the impacts that dropping corner stations have on Tanner crab binned into 25-mm size bins (currently pooled into 5-mm bins in the assessment, but 25-mm bins might be more tractable for analysis).

The CPT expressed some concerns about survey reductions, particularly since looking at changes over time is informative, and exploring changes from a design- to model-based approach led to some substantial changes in management implications. The CPT asked about considering an adaptive approach rather than simply dropping the corner stations, given that king crab are patchy and not abundant. Stan Kowticki (NMFS) noted that with so many species being assessed, how to prioritize and when to adapt may be problematic. However, a stratified random design may be more flexible to adaptation. The CPT cautioned against losing comparability when shifting to another design. The authors pointed out that this was a preliminary look at just dropping stations without actually changing the primary design; they are also exploring the utility of these data for groundfish and, potentially, ecosystem organization. Stan will plan to present an update to the CPT in May 2022, with potential changes implemented in 2023.

3 Economic SAFE

Brian Garber-Yonts presented an overview of the 2020 crab SAFE economic status report. The crab economic SAFE is produced annually by calendar year (not crab year) but is lagged one year from the stock assessments and two years from fishing activities. Since the report is by calendar year, it encompasses portions or two fishing seasons. The executive summary is included in the October CPT SAFE report and the full report is given to the Council at their 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, finished product volume, pricing, participants, quota markets and holdings, international trade, and social indicators. The full report can be accessed at https://www.afsc.noaa.gov/REFM/Socioeconomics/SAFE/defaut.php

Production across all crab fisheries was down. However, revenue for ex-vessel and wholesale value, for all crab fisheries combined, was on par with 2019. Revenue for Bristol Bay red king crab and Aleutian Islands golden king crab were at record highs while Bering Sea snow crab decreased in the share of revenue going to the ex-vessel sectors. This is likely due, in part, to fewer processing plants, which means fewer opportunities for buyers and custom processing. Overall, the processing sector continues to be more constrained by consolidation.

For the 2020 year, there was a decrease in the number of fishing vessels and the number of crab crew positions was the lowest on record, although captain and crew pay increased 7% and 11%, respectively. Processing worker wages increased and were at a historic high in 2020.

Over time, the proportion of costs attributed to the 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 cap rate, which has maintained a consistent lease rate at 65% in Bristol Bay red king crab and 45% to 50% in Bering Sea snow crab. Catcher-vessel A share quota accounts for 90% of all IFQ. Lease rates for overall quota shares are 81% to 88%.

Quota pounds leased versus pounds landed for each fishery has been increasing. Quota holders and vessel owners are largely the same groups but because the quota is generally owned by a business entity, it is difficult to determine how much intersection there is. For the harvesting sector, gross profit went down in 2020 for Bristol Bay red king crab but went up in Bering Sea snow crab despite more revenue going to lease costs.

Quota shareholdings are public information on NMFS Alaska region website. Catcher-vessel owner and catcher-processor owner shares tend to be owned by corporate entities, which muddies actual ownership. Because quota entities are corporate they tend to be located in Seattle or Anchorage. Consequently, the distribution of ownership can only be determined by decomposition and reaggregation. For Bristol Bay red king crab and Bering Sea snow crab most of the quota is held by individuals in the Seattle metropolitan area. There has been an increase over time in the amount of quota held in Kodiak and by Alaska CDQ groups (all CDQ groups are treated as a single location in the analysis). In 2018 and 2019 there was a large shift of Bering Sea snow crab quota ownership from Anchorage to CDQ. There is a certain fraction of quota ownership that cannot be broken down further than the corporate level since the quota is entrusted into estates. An increasing fraction of the quota share pool is moving into trusts and estates, which is not surprising given the original issues are aging. Additionally, an increasing fraction of the quota share pool is owned by CDQ groups.

For the 2022 economic SAFE, priorities include integrating the SAFE more with ESPs and using the same sets of indicators as in the ESP, including price estimates and current-year estimates, and analyzing the processing sector income.

4 Norton Sound Red King Crab - Final SAFE

Toshihide ("Hamachan") Hamazaki (ADF&G, Anchorage) presented the assessment for Norton Sound red king crab. The CPT expressed its appreciation to Hamachan for addressing several previous CPT and SSC concerns and requests, including providing two bridging models, and outlining assumptions regarding *M*, CPUE standardization, discard estimation, results of growth experiments, and confidence intervals on female clutch condition. The CPT also noted that Hamachan did not present results from the model used for management in 2021 with updated data (19.0b), in contrast to the standard practice to use the previous year's accepted model with updated data as the base model for evaluating alternative models.

Hamachan presented results from seven models requested by the CPT at its September 2021 meeting (models 19.0e, 21.0, 21.1, 21.2, 21.3, 21.4, and 21.1). Model 19.0e was identical to 19.0b (with updated data), with the exception that the "proportional" method was used to estimate discards and total catch rather than the "LNR2" method the CPT had recommended for the 2021 assessment. Models 21.2 and 21.3 were CPT-requested "bridging" models from 19.0e to 21.0 that evaluated the consequences of changes to the standardized fishery CPUE time series (from standardization over the time period and a single associated catchability coefficient to separate standardizations for three time periods and three catchability coefficients) and the number of time periods characterizing retention in the summer commercial fishery (from one time period to two split at 2008, reflecting a new processor requirement for "clean" crab). The changes from model 19.0e to 21.0 were based on important changes in fishing practices and thus considered important to capture. Models 21.1, 21.4, and 21.5 were based on Model 21.0 and addressed various assumptions regarding size-dependent *M*.(respectively, a fixed *M* of 0.18 yr^{-1} applied to all size classes, a single estimated *M* applied to all size classes, and two estimated *M*'s applied to size classes below and above 124 mm CL, while model 21.0 fixed *M* to 0.18 yr^{-1} for size classes < 124 mm CL and estimated a single *M* for those above).

Hamachan recommended either Model 21.0 or 21.5 for management based on model fit, noting that Model 21.5 fit the data slightly better than 21.0 but at the expense of an additional parameter. He also pointed out that none of the models solved previously-identified problems such as overestimating growth and the abundance of large crab. During the discussion, the CPT questioned whether the estimation of two size-dependent *M*'s could actually be supported by the fairly uninformative data and noted that the models were essentially indistinguishable based on a likelihood perspective.

The CPT endorsed Model 21.0 for Tier 4 status determination and OFL calculation as the more parsimonious of the two. Hamachan presented management results calculated using size-specific values for *M*, although the Tier 4 control rule refers to a single *M*. The CPT discussed the merits of Hamachan's approach, which is approved of from a technical perspective (given that *M* was size-specific in the accepted model). However, the CPT and SSC had not previously reviewed an approach for applying the Tier 4 control rule with multiple *M* values. The CPT was reluctant to unilaterally adopt this approach without prior approval from the SSC. Consequently, Tier 4 management quantities were based on the single-*M* calculations using M=0.18 yr^{-1}. Fortunately, Hamachan included results of these calculations in the SAFE draft for model 21.0 (at the end of Section G), in addition to the size-based *M* results reported in the draft document tables.

In 2021, the SSC endorsed a 40% buffer on the OFL for ABC, based on concerns regarding the stock and the assessment model enumerated in the 2021 SSC Minutes. The CPT reviewed these concerns in light of the new assessment to determine whether or not they still applied, the results of which are summarized in Tables 1 and 2 below. Despite some improvements in the stock and the assessment model, the CPT recommended continued use of the 40% buffer given the number of remaining unresolved concerns.

The CPT had several new requests for the author:

- The previous year's accepted model, updated with current data, is always the base model for the current year's assessment. Always include results from this model in the assessment. [Note: This applies to all assessments, not just NSRKC.]
- Provide values for management-related quantities for all models considered to be potentially adoptable for management advice. These should be presented in tables similar to those in the Executive Summary section of the SAFE that report the 5-year history of status determination/OFL and the basis for the OFL. . [Note: This applies to all assessments, not just NSRKC.]
- Provide a SAFE draft as free from editorial errors (e.g., sentence fragments, formatting errors, legacy text) as possible. Tables should ideally be limited to a single page (break long tables into several page-length tables with repeated table captions (use "cont." to indicate a continued table) and headers.
- Provide a brief description and discussion of the convergence criteria and other methods used to evaluate model convergence to the global minimum.
- Include a table (if necessary) identifying any parameters estimated at a bound.
- Use jittering to evaluate convergence.
- Calculate the arithmetic scale CV for lognormally-distributed data (i.e., the standardized CPUE) as $CV^2 = exp(\sigma^2) - 1$, where σ^2 is the ln-scale variance.
- Provide a table comparing discard estimates for all three current options (LNR2, subtraction, proportional), any new methods (survey-based), and estimates from the assessment model to better compare methods and identify years of concern.
- Present an evaluation of Tier 4 OFL calculations for NSRKC using the standard (single *M*) and length-dependent *M* approaches, and the associated assumptions and tradeoffs, for consideration by the CPT and SSC in the fall prior to the 2023 assessment.
- More generally, evaluate the appropriateness of the use of M=0.18 yr^{-1} for all red king crab stocks.

Older requests that have not been addressed should not be neglected; in this regard, the CPT highlighted the previous request to develop a GMACS version of the NSRKC assessment model. In addition, the CPT looks forward to updates on current research topics such as growth and maturity studies, tagging and seasonal movement, and the use of VAST for survey abundance estimation. Two suggestions for future research are to:

- Consider using a simpler model (e.g., a random-effects model similar to that used for Pribilof Islands blue king crab);
- Evaluate how the spatial distribution of catch impacts the ability to estimate discards using Option 2 (survey size compositions); and
- Re-examine the evidence for shell condition-specific discard rates and evaluate their implications for the assessment model (e.g., would this affect the overestimation of large crab).

Table 1. Concerns initially expressed by the SSC in 2020 about the NSRKC assessment, and their continued relevance for assessments in 2021 and 2022.

2020 SSC concern	**2021 CPT Still concern?**	**Reason**	**SSC 2021 Still concern?**	**CPT 2022 Still concern?**	**Reason**
1. Considerations of other stocks with similar levels of uncertainty	Yes			Yes	
2. Concerns with model specification in part indicated by a positive retrospective pattern, whereby successive assessments indicate an increasingly pessimistic estimate of stock size for the same years. The full magnitude of the retrospective bias is unknown given that peels of the data go back only a few years. The cause(s) of the pattern is unknown	No	Retrospective patterns are relatively small compared to other stocks and within commonly cited acceptable ranges. The retrospective pattern was characterized for 10 years of peels (Mohn's rho 0.180).	Yes	No	Mohn's rho 0.209. Slight increase relative to 2021.
3. Shortage of discard data and resultant inability to manage the stock based on total catch, which is the standard for federal fisheries	Less	Hamachan presented methods to account for total catch; the LNR2 method was chosen by the CPT.	Yes	Yes	Hamachan used the "proportional" method to estimate discards.
4. Unresolved issues associated with the apparent high *M* for the largest size class	Yes		Yes	Yes	

5. Discrepancies in stock size estimates between ADF&G and NMFS surveys as well as concerns about the spatial distribution of crab relative to the survey footprint	Yes		Yes	Yes	
6. Very low fishery CPUE and the inability of the fishery to attain the ABC in 2019	Yes		Yes	Yes	No summer commercial harvests in 2020, 2021
7. Unusually large numbers of old-shell males in the fishery in 2018-2019	Yes		Yes	Yes	
8. High proportions of barren females in survey and fishery observations, indicating some reproductive failures in 2019	Less	Fewer barren females in 2020 and males are reaching the appropriate size for mating.	Less	Increased	No information was presented from 2021 surveys
9. Below-average numbers of pre-recruits (<94 mm CL) in 2015-2018, suggesting that below-average recruitment to the fishery will be experienced for several more years	Yes		Yes	Less	Some evidence for recruitment to legal-sized crab in survey size compositions
10. Large uncertainty in the magnitude of the most recent year class (pre-recruits in 2019), preliminarily estimated to be large. However, these small crab are several years away from recruiting to the fishery as legal crab and they are challenged by unprecedented recent increases in Pacific cod, a crab predator, in Norton Sound.	Less	The year class is tracking and uncertainty is less now that the year class has been observed several times.	Yes	Less	The year class is tracking and uncertainty is less now that the year class has been observed several times.

Table 2. Assessment concerns identified by the SSC in 2021.

SSC 2021: Still concern? (or new)	CPT 2022: Still concern?	Explanation
1. The ADF&G survey abundance is much lower in 2020 than 2019, and the model is not fitting this new observation very well.	Less	2021 surveys are higher than 2020; model fits 2021 data well (but not 2020)
2. One of the selectivity parameters is on a bound, and it appears to be survey selectivity, which could contribute to the poor fit to the recent ADF&G survey data point. This also raises questions about whether the model has properly converged.	Yes	Parameters at bounds remain, raising concerns regarding convergence
3. The recommended ABC is increasing when the only available 2020 survey estimate is low, and fishery CPUE has steeply declined in past years. Since there was no commercial fishery in 2020, there is no fishery CPUE estimate, which increases uncertainty. The fit to recent low commercial CPUE values is poor, similar to the trawl survey. There also were no NMFS trawl survey data to evaluate.	Less	No summer commercial fishery in 2021, so no fishery CPUE estimate. However, both ADFG and NMFS NBS surveys were conducted and the model fits the estimated abundances well.
4. While an improvement, the minimal data informing the estimate of total catch OFL further emphasizes the uncertainty in the estimation of discards.	Yes	
5. The high recruitment discussed last year was supported by a high survey biomass estimate. The low biomass estimate in 2020 lowers confidence in the magnitude of this recruitment pulse. This potential large recruitment is still mostly below the preferred commercial size.	Less	Survey abundance estimates for 2021 increased 40% above the 2020 estimates and are well fit by the model. The recruitment estimate for 2018 has another year of data to support it.

5 ACLIM management scenarios for Bering Sea stocks

Kerim Aydin from the AFSC presented an overview of the Alaska Climate Integrated Modeling (ACLIM) project, with a goal of promoting discussion of scenarios generated by coupled models of the Bering Sea climatic, biological, and socio-economic systems. Kerim began by highlighting the rapid pace of Arctic warming, which has been 2-3 times the global mean rate within the observed record. This polar amplification affects the Bering Sea and is projected to continue. The Bering Sea is on a pathway for extreme warming in the coming decades, which will imply an increased frequency, duration, and intensity of marine heatwaves. The climate change pathway that the Bering Sea actually follows will depend on

global carbon emissions, which are modeled as “Shared Socioeconomic Pathways” (SSPs) in the Coupled Model Intercomparison Project Phase 6 (CMIP6). The two most extreme SSPs project a significant risk of an ice-free Arctic by mid-century.

The ACLIM project consists of a set of contingent models that provide various on-ramps for climate information into fisheries management, based on different temporal scales. In his presentation, Kerim discussed long-term temporal scales. The core model of ACLIM is a 10k ROMSNPZ (Regional Ocean Model System, Nutrients-Phytoplankton-Zooplankton). Recent work with this model projects that with little mitigation the Bering Sea stands to experience 3.5° to 4° C warming by the end of this century. This warming is projected to result in declining krill peak abundance due to the loss of sea ice algae, advanced seasonal timing of peak abundance of large zooplankton, and a decrease in fall secondary production. Specifically for crab, Szuwalski et al. (2020) project changes in abundance and centers of distribution with warming, as well as a reduction in the number of years of high recruitment towards the end of the century. Modeling results for fish to date focus on resilience, in particular from the overall cap on groundfish removals.

Kerim next focused on the limitations of ACLIM modeling to date. These include the use of population-level biological models focused on the southeast Bering Sea only, without spatial resolution, as well as a paucity of knowledge concerning benthic processes. While some processes are emergent from the models, many others need to be calibrated from observations, spatial statistical models, etc.

Kerim next highlighted the Individually-Based Model (IBM) for crab larvae being developed by Buck Stockhausen . This model is being extended from pelagic life stages to include benthic instars, will be run with downscaled CMIP6 output, and will be coupled with assessment models using connectivity between different life-history stages.

Next directions for ACLIM 2.0 will include spatially-explicit models, coverage of the northern Bering Sea, expanded work with ocean acidification impacts, as well as different management scenarios – cautious vs. maximizing yield; harvest control rules that are stable or flexible, etc. The presentation finished with a discussion of the “productivity paradox”, which describes a situation where climate-adaptive harvest control rules can result in higher exploitation rates than status quo rules.

In the discussion that followed, it was stressed that CPT is embedded in ACLIM, with three CPT members serving as ACLIM PIs, which makes communication between the two groups easy. CPT members asked if harvest caps might have been useful in forestalling the snow crab collapse. ACLIM results to date center on the multi-species groundfish cap, and may not be directly transferable to a single-species context. Further discussion centered on whether the majority of declines in populations in the multi-species models were driven by recruitment, growth, or mortality. CPT members asked if the models projected any large mortality events going forward. Those events are not well captured by the current versions of models, which, for instance, do not include starvation functions.

The discussion then centered on the information that is needed to move the ability to model crab outcomes forward. It was agreed that the answer is not straightforward. History indicates that for age-structured populations, most environmental covariates help in policy evaluations. These are useful for explaining past events but are difficult to use to improve stock assessment output. Most of the value, therefore, lies in the policy arena, in terms of providing scenarios for planning, with little or no predictive skill. Additional discussion focused on the possibility of multi-species caps for crab catches and the need for spatial management tools and spatially-resolved crab population models.

The discussion concluded with an inquiry from the CPT as to the type of input that would be most useful for building crab management into the scenario-modeling process. Kerim indicated interest from ACLIM in modeling management scenarios for crab fisheries, and the CPT invited future presentations from the ACLIM team.

6 Bering Sea Fisheries Research Foundation Update

Scott Goodman gave a brief update on Bering Sea Fishery Research Foundation (BSFRF) ongoing research projects, a summary report on BSFRF's December 16-17, 2021 Collaborative Snow Crab Workshop, and a brief discussion of pending work plans for the BSFRF steering committee.

Scott reported on progress and initial research results from a study, funded by a grant from the NOAA Bycatch Reduction and Engineering Program (BREP), to test pot gear modifications for use in the BSAI pot cod and halibut fisheries for their potential to reduce red king crab and snow crab bycatch. The BREP study is a collaborative project between BSFRF, Alaska Bering Sea Crabbers (ABSC), and Natural Resource Consultants, Inc..

Preliminary results from both lab and field experiments were shown for the control and nine experimental treatments combining different gear modifications to exclude crab entry. Preliminary results from field testing during September 2021, involving four vessels deploying different sets of gear modification showed results averaged over vessels, and separately, showing results by vessel and treatment. Aggregate results were generally consistent with the laboratory results, indicating "sock" treatments (some of which combined sock with other modifications) to be most effective in reducing crab bycatch while minimizing effects on cod CPUE. However, controlling for vessels effects indicated considerable variation in results across vessels, one of which was particularly inconsistent with results from other vessels as well as laboratory results, with Scott noting that vessel effects will be further analyzed. Going forward, BSFRF and research partners will provide a study update to the Council at the February meeting. Further experimental work will be conducted during 2022, with laboratory testing on snow crab starting in March and additional field testing for red king crab bycatch in September, with project completion expected in October.

Scott reviewed progress on the red king crab tagging study, funded by BSFRF, NOAA, and ADFG, which focuses on analyzing movement patterns of male and female Bristol Bay red king crab and assessing crabs' use of trawl closure areas. Since Scott last updated the CPT on the tagging study, researchers completed a 22-day charter onboard the *FV Provider* during October to November, 2021 to capture and tag legal male red king crab in Bristol Bay. Pop-up satellite tags deployed during the cruise were timed with varying release schedules, with the earliest release set for the week of January 2; early results as of Scott's presentation showed strong returns for released tags so far.

Scott gave a summary report on proceedings of BSFRF's December snow crab workshop, observing that most of those in attendance at the CPT meeting had participated in the workshop. He noted that the original plans for the workshop were changed following the September CPT meeting and Council and ADF&G management decisions issued for the 2021/22 season in order to refocus on questions regarding what happened to the EBS snow crab stock and what potential options are available to managers and stakeholders. Workshop objectives were to 1) be broadly informative about the scale of the changes in the stock and the current stock status; 2) to help identify what research may be needed to reveal more about the status; and 3) to conduct the workshop as a collaboration with industry stakeholders that shares information and expectations about the stock. The first day of the workshop featured presentations from Erin Fedewa, Cody Szuwalski, Ben Daly, and Mark Stichert. Scott complimented the presenters for engaging in transparent discussion with industry stakeholders and assessed the discussion as highly productive, despite the high levels of stress among industry members. Day 2 of the workshop featured discussion of research options and continuing discussion between researchers and stakeholders.

Scott concluded with an overview of upcoming work for the BSFRF steering committee. Working plans are being developed for longer-term strategic research initiatives, including work with NOAA's Crab/Climate working group being led by Mike Litzow, BSFRF's recent signing of an MOU with NPRB to provide support for strategic research on snow crab, and seeking further collaborative research opportunities. Near-term action plans being developed for ongoing research studies include: working

directly with vessels during opilio fishing; a pilot study to test new tag technology on opilio crab; facilitating researchers joining vessels at-sea during active fishing; deploying and testing research instruments (cameras, temperature, and depth gauges) on crab pots and elsewhere; and supporting additional data collection initiatives directed at the crab fishery, including ABSC's skipper survey. Final summary reports from BSFRF's 2021 workshops are being assembled and will be released soon.

Scott was asked about the scope of research covered by the MOU with NPRB and prospects for gaining NPRB approval for funding specific research. Scott responded that the MOU is a general agreement regarding long-term snow crab research and does not specify any particular research study, and indicated positive expectations for successful funding proposals, noting that Gordon Kruse has joined BSFRF in an advisory capacity. Noting the current stresses facing crab stakeholders, Scott was asked for any recent observations about crab industry members talking about climate adaptation. Scott responded that he hasn't heard specific discussion among industry members, but that it appears that more crabbers are starting to pay more attention to information about the implications of climate change.

7 Snow crab: ESP indicator update

Erin Fedewa provided an update to snow crab ESP indicators that are in development to be included in the snow crab ESP, which will be presented to CPT in May 2022. A request for indicators (RFI), which serves to initialize an ESP and formalizes data requests and submission procedures, will go out soon for the three crab stocks. The draft indicators for snow crab are grouped into physical parameters, lower trophic level parameters, and upper trophic level parameters. Preliminary data for some of the indicators, as well as a brief description of the potential mechanistic link, were presented.

The CPT provided feedback on indicators and asked, for example, why is the center of distribution limited to mature males? Erin responded that these spatial statistics can be generated for different sex/stages of crab that may be of interest. The CPT asked if these data could be used to re-test the ratchet hypothesis and other theorized drivers of snow crab, such as Pacific cod predation, and Erin responded yes, this could be done in the future. The CPT indicated that the female centers of distribution are important to evaluate the ratchet hypothesis. Benthic prey biomass data include all invertebrates because all these species are found in snow crab stomachs. However, this data set is dominated by sea stars. The CPT suggested splitting these species into a group that may be viewed as competitors, such as sea stars, and a group that represents prey, recognizing that snow crab have a very broad diet. Female snow crab size at maturity may provide insight into reproductive output. Visual indicators of bitter crab disease peaked in 2017 and have decreased since then. Additional proposed ecosystem indicators are in development. Anecdotal evidence of snow crab in cod stomachs was discussed at the December BSFRF snow crab workshop. Socioeconomic indicators are in development and fairly similar to what was presented in September.

The CPT provided feedback on this suite of indicators. The CPT noted that it is difficult to determine if these are an appropriate suite of indicators until we know more about how they relate to snow crab abundance. It was unclear to the CPT what the intended endpoint is for indicators, for example, should these data eventually be incorporated in the stock assessment model? Many of these indicators are likely not linearly or monotonically related to crab population parameters or abundance and would be difficult to include in the stock assessment model. The ESP standardized framework identifies that these indicators can inform environmental and socioeconomic variability that can inform risk tables. The CPT then asked, if the indicator doesn't influence dynamics, then why would you include it in a risk table? Others noted that there are some indicators that have a role in the life cycle, but we don't necessarily know how to model their relationship in the stock assessment – for example, phytoplankton influence on snow crab larval survival.

The CPT provided feedback that in some fished species in the North Atlantic, control of the population changes before and after collapse, so these indicators could change. Additionally, data may need to be scaled. For example, per capita consumption may increase after collapse but not show up in total consumption.

The CPT asked if these indicators could be used in a rebuilding plan. Can we forecast these parameters? If so, then these could potentially inform rebuilding. Most of these parameters are retrospective, especially those that come from the bottom trawl survey, so they are less likely forecastable. The role of the environment in stock rebuilding is important and will be discussed in a following discussion on rebuilding.

The CPT asked if the IBM model could provide additional indicators that could be useful. Erin responded that intermolt duration and settlement success are generated from the IBM model. These rely on the trajectories of dispersal from presumed hatch locations. It was noted that there is a five-year lag in snow crab between hatching and recruitment to the stock assessment model, so IBM results could lag the assessment.

The CPT provided feedback that the movement of crab into the Northern Bering Sea (NBS) and a proxy for habitat in the NBS could be included as indicators. The CPT recommended NBS habitat suitability for crab and connectivity between the two systems as potential indicators for inclusion in the snow crab RFI and ESP.

8 Snow crab: hypotheses about stock decline

Cody Szuwalski presented an analysis aimed at better understanding causes of the dramatic snow crab population decline that occurred during 2019-2021 by exploring two primary hypotheses explaining the observed survey declines: low survey catchability "q" (or movement out of the survey area), and 2) high natural mortality, "M". The context for the analysis is to assess the justification for the high natural mortality events in 2018 and 2019 that were needed to achieve model convergence in the 2021 stock assessment. Cody noted previous work that estimated time-varying natural mortality (James Murphy's recent work) and other research that implied time-varying catchability (spatial changes in sediment, depth, and snow crab distribution, Somerton et al).

Cody's analyses focused on understanding how mortality and catchability have varied over time for immature and mature male crab and what drives that variability by 1) estimating maturity, and time-varying mortality and catchability and 2) correlating changes with potentially related phenomena using GAMs. The analysis used a simplified assessment model that did not model the fishery impacts to explain the observed changes in immature and mature male abundance by estimating recruitment, total mortality, and catchability. Mortality covariates that were considered included bycatch, cannibalism, discards, disease, predation, and temperature, while catchability covariates included temperature, latitude, and longitude. Allowing for time-varying q and M allowed for greater flexibility in the model and thus better fits the population abundance survey data.

Cody described a newly developed cannibalism index, which considers the density of small and large crab in overlapping areas. A systematic refitting of the model with one year of data removed was performed to assess the robustness of modeling outcomes to data availability. Covariates explained a surprising amount of the year-to-year variability in q and M for immature and mature crabs. Effects of covariates on q were generally intuitive (i.e., higher q related to higher temperatures and abundance centroids farther west). However, the effects of some covariates on M were difficult to explain, complicating the interpretation of the analysis. For example, lower discards, bycatch, and predation were associated with higher M values. Cody noted that future work can build on the time-varying q and M analysis including 1) sensitivity analyses for assumptions, priors, and penalties, 2) considering model scenario selection, 3) refining methods for selecting smoothness penalties, 4) developing methods for incorporating variance into the

inference model, 4) testing a model scenario where the covariates are directly included in assessment model, and 5) repeating the analysis, but estimating size and year specific *M* and *q*.

The CPT was generally supportive of the analysis and noted that Cody's work helps to understand what happened and what additional analyses can be recommended to help elucidate stock dynamics. Some CPT members were skeptical about the analysis and questioned the approach of modeling total mortality vs non-fishery component of mortality. There was discussion about the ability to estimate biological processes, correlation among some covariates (such as disease and temperature), the smoothness of time-varying *M*, the general utility of the analysis. Some CPT members questioned the inter-annual "jumpiness" (dramatic fluctuations) of *M.* Smoothness penalties were implemented to smooth temporal trends in *M* and there was discussion about determining the appropriate magnitude of smoothing. There was a question about whether existing tagging data could be used to inform *M*, but Cody noted that snow crab tagging data are scarce, and would not be useful for informing time-varying *M* without a tagging data time series. Council staff noted that the analysis provides background for developing the rebuilding plan and can inform what sensitivities should be included in future projections. Future recruitment and *M* are major uncertainties for projections and will impact T_{min} and T_{max} estimation.

There was discussion about the rebuilding plan and it was noted that there are limitations with the data used in the projects: future climate conditions in the Bering Sea may be different than any experienced in the past ~40 yrs. Thus, extreme caution is needed in predictions, and using past data can help understand the past and/or "bracket the realities" of the future. A point was made that comparing forecast skill and hindcast skill by predicting the middle of the time series is useful for model testing. A suggestion was made to scale covariates in the projections if it is believed that some are more important than others.

9 Snow crab: rebuilding plan discussion

GMACS:

Cody Szuwalski presented information regarding the GMACS and its use in developing a rebuilding plan for Bering Sea snow crab due to its strength in running projections. The 2020 assessment was implemented in GMACS and endorsed by the CPT at the September 2020 CPT meeting. However, the SSC did not subsequently endorse the GMACS model due to large estimates of 2015 recruitment and recommended the "status quo model" (20.1) at the October 2020 Council meeting. The 2021 assessment was conducted using the *status quo* model (accepted by the CPT and SSC), but with high natural mortality events in 2018 and 2019, which were needed for model convergence given the dramatic decline in survey abundances.

Since September 2021, GMACS has been updated to include time-variation and a range of projections. Projected natural mortality, time-variation in the probability of having undergone terminal molt, non-parametric survey selectivity, and functional maturity have not been incorporated into GMACS yet. It was noted that while GMACS is an improvement to the assessment modeling approach, it does not solve problems related to retrospective patterns, identifying appropriate time-variation in population processes, or uncertainty around the appropriate currency of management (i.e., morphometric vs functional maturity).

Cody presented some simulation results comparing the status quo model (with time-varying *M*), the GMACS model (single *M*), and the GMACS model (with time-varying *M*). Fits to survey and catch size composition was similar among models but models with time-varying *M* capture the recent abundance/biomass decline better than the models with a single *M.* As expected, management quantities were in better agreement between the *status quo* model and the GMACS model with time-varying *M*. There was some discussion about assumptions for projected recruitment, natural mortality, and B_{MSY} calculations. Preliminary projections were conducted using 3 scenarios for projected recruitment using random draws from estimated recruitment for periods 1) 1994-2014, 2) 1994-2020, and 3) 1982-2020,

each under 3 scenarios of fishing mortality 1) 0, 2) $F_{35\%}$, 3) 2 x $F_{35\%}$. Under all recruitment assumption scenarios, time to rebuild was >18 yrs assuming F_{35}%. Assuming F=0, time to rebuild was 6-9 yrs depending on recruitment assumptions.

With the implementation of time-varying natural mortality for terminally molting animals, GMACS can now be used to project snow crab under various harvest and recruitment scenarios. Three-time series were used for projected recruitment ranging from the lowest historical recruitment to the highest. The status quo included the entire historical time series. Fishing mortalities were evaluated at F_{35}, half F_{35}, and zero. The CPT discussed whether or not productivity in the future should be based on the historical time series or if it should be adaptable. The CPT recommends examining a range of time series for projecting recruitment instead of just using the entire time series. In addition, probability plots are recommended in the future. Variable natural mortality should also be further analyzed. Natural mortality may also need to be adjusted to reflect reduced recruitment if using a model with a big jump in estimated recruitment.

The CPT recommends further discussion and approval of the GMACS implementation for snow crab at the May 2022 CPT meeting. The author should also assess the differences between the status quo model and current GMACS implementation, and re-consider the issues raised by the SSC in 2020, mainly about recruitment estimates and increased OFL projections in the GMACS implementation, and determine if they are still relevant. The CPT supports using the GMACS implementation for the rebuilding analysis, but this requires that the SSC adopt the GMACS implementation in June.

Rebuilding Plan:

Diana Stram presented information about the rebuilding timeline and considerations the CPT could recommend for the rebuilding plan. Currently, the Council is set to recommend alternatives for the rebuilding plan at their February 2022 meeting. However, due to the GMACS implementation for BSS not yet being approved by the SSC, the CPT cannot recommend a T_{min} and Tmax to the Council at this time. Consequently, this agenda item for the Council is being changed to a progress report on rebuilding. It is now expected that the Council will develop alternatives at their June 2022 meeting once the GMACS implementation for BSS has been accepted.

The CPT will need to recommend a T_{min} and T_{max} for rebuilding based on various recruitment and mortality estimates. The MSA requires Tmax to be ten years if it is projected the stock can rebuild within ten years. However, Tmin and Tmax cannot be determined until the GMACS implementation for BSS is discussed again in May.

The CPT will also need to determine if additional considerations should be analyzed for the rebuilding plan, such as changes to bycatch limits in groundfish fisheries and other habitat considerations. It may also be beneficial to look at bycatch in the fixed-gear fisheries.

There might also be other life-history stages that may be more vulnerable to bycatch and are not captured in the model. In addition, there may be non-lethal impacts on crabs as they interact with gear. It is also possible that crab mortality in groundfish fisheries is higher during certain times of the year, especially when they are molting. Most crab likely do not survive gear interactions while they are in a soft shell state. However, it is unclear how to reliably account for these issues. It was suggested to examine scenarios with varying mortalities to simulate some of these issues.

T_{target} must be set between Tmin and Tmax and the CPT will need to evaluate if a directed fishery and bycatch can occur while still rebuilding by T_{target}. The requirement is to rebuild within a 50% probability. The CPT recommends several different fishing mortality scenarios be analyzed for the May meeting, including varying bycatch mortality and varying directed fishing mortality. It was also recommended that the State's harvest strategy be considered when conducting projections. It may be possible to examine this by taking the average directed fishery TAC as a fraction of the entire OFL. However, bycatch in the directed fishery would also need to be considered.

10 Aleutian Island Golden King Crab - model explorations, scenarios for May 2022

Siddeek presented the proposed model scenarios for the May 2022 assessment of the Aleutian Islands golden king crab. All the scenarios were based on the bespoke model that has formed the basis for the assessments of the EAG and the WAG in the past. The assessment report provided the results of models implemented using GMACS for the EAG (model scenarios 21.6 and 21.7) - the next agenda item summarizes progress on moving the assessment to GMACS.

The analysts provided an estimate of the size-at-maturity based on recent chela height data and a two-regression line approach. The estimate of size-at-maturity from this analysis was 116mm CL, which is larger than the value used in previous assessments (111mm CL). The CPT requested that the document for May 2022 include details of the data on which the current size-at-maturity is based, as well as the results of fitting the two-regression line model to those data.

The assessment document provided information on the RACE slope survey. It was noted that the data from this survey are not separated to sex, and no size measurements are available. The sample sizes are also very low for some years and areas. Nevertheless, the slope survey occurs where there are fishery data and so a rough assessment of whether CPUE is an index of abundance can be conducted by comparing the time-series of CPUE (all sizes and sexes) versus that of survey biomass to assess whether CPUE is approximately linearly related to abundance.

The algorithm used to standardize the catch and effort data was updated based on recommendations from the CPT and the SSC, leading to more parsimonious models. The report included plots of the soak time smooth but it did not appear to be correctly calculated. The analysis leading to this plot should be reviewed and updated results provided for May 2022. In addition, there is a need to compare the design-based estimates of CPUE by area with those predicted by the standardization model that includes year*area interactions.

This assessment is based on a male-only model and starts the model projection in 1960 with a population at unfished equilibrium. It uses only standardized CPUE as the index of abundance due to the lack of a fishery-independent index of abundance. The data on which the analyses are based are updated, compared to those on which the May 2021 assessment was based, following the completion of the fisheries. The assessment for the WAG was modified by increasing the weight assigned to the groundfish bycatch data from 0.2 to 0.5, which led to better convergence diagnostics.

The model scenarios for the EAG and the WAG are:

- Model 21.1a: The model on which the 2021 assessment was based.
- Model 21.1a1: As for model 21.1a, except M is increased from $0.21yr^{-1}$ to $0.38yr^{-1}$ to reduce retrospective patterns (EAG assessment only)
- Model 21.1b: As for model 21.1a, except that the CPUE standardization considered year*area interactions.
- Model 21.1c: As for model 21.1a, except that separate catchability coefficients and additional CV parameters are estimated for the fish ticket, and early (1995-2004) observer and late (2005+) observer CPUE series. Model 21.1a assumed that the catchability coefficient for the fish ticket and early observer CPUE series were the same, while it also assumed that the additional CV was the same for the two observer CPUE series. The fish ticket CPUE series was restricted to 1985-1994 for this model scenario.
- Model 21.1d: As for model 21.1a, except that the data for one vessel was omitted from the CPUE standardization (WAG assessment only).
- Model 21.a2: As for model 21.1a, but with the size-at-maturity increased from 111mm to 116mm.
- Model 21.b2: As for model 21.1b, but with the size-at-maturity increased from 111mm to 116mm.

The CPT noted that all the models except model 21.1c assumed that catchability was the same for the fish ticket and early observer CPUE series, but that this was invalid. Thus, all the models for the May 2022 meeting should allow for three catchability coefficients and three additional CVs. The CPT also agreed that the CPUE data for model 21.1d were unexpected (much higher variances and changed indices for the early years when the vessel that was excluded from the analysis fished in the later years). The reasons for this should be explored, but results for model 21.1d need not be presented in May 2022. The estimate of catchability for the fish ticket CPUE series for model 21.1c had an unrealistically large standard error.

The CPT agreed that the models for which results are to be presented to the May 2022 CPT meeting are:

- Model 21.1a: The model on which the 2021 assessment was based. This model will not be considered for providing management advice but will provide a link with the previous assessment.
- Model 21.1e: As for model 21.1a, except that separate catchability coefficients and additional CV parameters are estimated for the fish ticket (1985-1998), early (1995-2004) observer, and late (2005+) observer CPUE indices.
- Model 21.1f. As for model 21.1e. except that the CPUE standardization is based on year*area interactions.
- Model 21.e2: As for model 21.1e, but with the size-at-maturity increased from 111mm to 116mm.
- Model 21.f2: As for model 21.1f, but with the size-at-maturity increased from 111mm to 116mm.

The fits to the CPUE data should be plotted separately by model given that models 21.1e and 21.1f are based on different sets of indices.

All the models proposed defined B_{35} based on average recruitment over 1987-2017. The period for defining average recruitment at B_{35} may be updated in May 2022 given the results of the 2022 assessment.

11 AIGKC GMACS

Andre Punt and Shareef Siddeek undertook a bridging analysis in December 2021 to replicate the dynamics of the status quo AIGKC model using GMACS. The analysis showed that GMACS could reliably reproduce the dynamics of the status quo model and identified that the status quo assessment shared catchability coefficients among CPUE indices. However, the presentation from Siddeek at the January CPT meeting did not clearly showcase the ability of GMACS to replicate the status quo dynamics. This was further addressed during the modeling workshop and the similarity of GMACS and the status-quo model was confirmed. Consequently, Siddeek was asked to present GMACS versions of the models for EAG and WAG to be considered in May alongside the status quo model.

12 Essential Fish Habitat Update

Jodi Pirtle (NMFS-AKRO) gave an update on Component 1 descriptions and identification for the 2022 EFH 5-Year Review, which will be reviewed by the SSC in February 2022. Jodi reviewed the iterative EFH review process and highlighted reviews by stock assessment authors and expert reviewers for Component 1. In total, 30 reviewers provided input as comments, questions, and concerns for three regional methods sections and 125 SDM ensemble EFH species. Jodi shared details of the review process and thanked reviewers for their engagement and collaboration. Examples of revisions included revising the ensemble and EFH map for one species, and including data caveat statements to results chapters where stock assessment authors had recommended using additional data sources.

Ned Laman (AFSC-RACE) highlighted crab-specific EFH component 1 results and reviews. AIGKC ensemble-predicted abundance was highest in eastern Aleutians through the passes, and the EFH area nearly doubled compared to the 2017 EFH maps. Observed differences in EFH area predictions were attributed to changes in modeling approaches (e.g. 2022 ensemble model approach vs. 2017 GAM

approach) and the addition of model covariates. Laman highlighted that SDM ensemble performance was generally an improvement compared to 2017 single SDMs.

Future directions for crab EFH maps based on reviewer comments include modeling EFH by life-history stage, exploring new environmental predictors, and using SDMs to address climate change and shifting species distributions on shorter time scales. Future EFH process recommendations include sharing modeling scripts and generating automated reports. The CPT recommended using fishery-dependent data for AIGKC EFH maps given that the NMFS trawl survey data are not currently used in the assessment and AIGKC distributions are much deeper than the standard AI bottom trawl survey grid. Ned mentioned the intent to include and combine additional data sources in future iterations, which would permit extending EFH map coverage. It was also noted that red king crab EFH maps do not capture observed abundances of NSRKC well, and Ned clarified that modeling approaches and habitat covariates are not ideal for NSRKC but future EFH work will focus on improving EFH methods for data-poor species.

John Olson (NMFS-HCD) gave an update on EFH Component 2 Effects of Fishing on EFH for the 5-year review. The fishing effects model is based on the interaction between habitat and recovery, factoring in fishing effort, gear type, and substrate type. John detailed the model inputs using VMS data, with the outcome specifying habitat disturbance on EFH. Percent habitat disturbance varies spatially in the Bering Sea, with areas such as "cod alley" indicating high percentages of habitat disturbance. John also noted a general shift north in habitat disturbance over time, likely driven by pollock fishing. John highlighted a hierarchical impact assessment method aimed at informing further action if fishing effects are evident based on correlations between habitat reduction and life history indices. The CPT recommended modifying the fishing effects model to quantify potential impacts on crab based on distributions as an extension to model-predicted habitat impacts and highlighted a potential application to indicator development for crab ESPs. John detailed BBRKC results, indicating a 2% habitat reduction area for the stock, although noting that concerns were addressed for localized impacts in spawning areas where habitat reduction exceeds 10%.

The output from the FE model is currently included as an indicator in yearly Ecosystem Status Reports and the model was recently published. John reviewed SSC responses to the FE model and highlighted overall habitat reduction for BSAI crab stocks. Habitat reductions were highest for Tanner crab, although it was noted that updates to the FE model may result in a relatively higher percentage of habitat reduction. John also showed an example overlay of updated 2022 SDMs and FE model results for AIGKC, which will be provided for all species. Olson reviewed 2017 CPT feedback on the FE model and asked for additional CPT comments on thresholds, methodology, and potential localized impacts. There was a discussion on gear impacts of pelagic trawlers given that bottom contact varies greatly between vessels and across time.

The CPT had some recommendations for the review of the fishing effects models in this meeting cycle. They include:

- Further research on contact adjustment and gear footprint relative to gear type, and suggested including potential non-fishing effects (e.g. mining impacts on NSRKC) into the model. The CPT emphasized the importance of Alaska-specific gear research for the gear parameters that are included in these models.
- Development of a flowchart for overfished crab stocks, similar to the one that exists currently to evaluate fishing effects. The importance of examining snow crab habitat affected by commercial fishing given the current overfished status and requests that the SSC discuss potentially reducing the 10% CEA threshold for overfished stocks.
- Splitting out EFH products by crab stocks within management areas versus the current species-by-species approach given the patchy distribution of king crab.
- Overall, the CPT thanks the EFH team for improvements to SDM and FE model methodology and appreciates the efforts to improve EFH information for BSAI crab stocks.

13 Alternatives to MMB for F35%

Cody Szuwalski presented alternatives related to how to define MMB based on functional maturity for *Chionoecetes* species. He reviewed the eight snow crab assessment models presented in September 2021 and indicated that the empirical survey selectivity would lead to different shapes for the probability of having undergone terminal molt, which if adopted would result in a much higher $F_{35\%}$ than in the past because a large proportion of the mature population would be 'protected' given the size preference of the fishery. Based on fits to data and population processes (survey selectivity, probability of maturing, recruitment, and natural mortality), he concluded that model 21.3 is the best model. However, this model resulted in a target fishing mortality for the directed pot fishery ($F_{35\%}$) of 4.76yr^{-1}, translating to an exploitation rate of 99.2%, which is much higher than the other models. This high rate would result in almost all males >101mm harvested in a given year. Cody highlighted that high harvest rates appear to be appropriate for Dungeness crab, but the productive snow crab fisheries in Canada have somewhat lower harvest rates.

Because some studies on Canadian snow crab indicated that functional maturity *in situ* appears to be >95mm carapace width, an approach is to change the definition of MMB from 'morphometric maturity' to 'functional maturity'. Thus, Cody suggested that a potential definition for 'functional maturity' could be >95mm carapace width for EBS snow crab.

Based on the review of snow crab models, Cody posed a question for the CPT discussion: "What do we do if we select a model that describes the population processes and dynamics of a stock in an 'ideal' manner, but produces management advice that allows 100% of exploitable biomass to be harvested?"

The CPT had a detailed discussion on this issue based on the following considerations:

- The population parameter values used to evaluate and select the $F_{35\%}$ reference point approach more than 10 years ago differ from those on which the current assessment model is based. A little over 15 years ago, natural mortality was estimated using a 1% rule to be 0.23 yr^{-1} for snow crab (Independent of sex and size given an assumed maximum age of 20 years). In contrast, model 21.3 estimated natural mortality to be 0.3 yr^{-1}. Combined trawl survey selectivity and catchability was estimated to be about 1 for almost all length groups 10 years ago, and now they are estimated to be much lower than 1. These differences would result in much higher estimated $F_{35\%}$ and OFL values than before. The CPT agreed that it is time to reevaluate the $F_{35\%}$ reference point for *Chionoecetes* stocks.
- The lifespan of Dungeness crab is about half that of snow crab, and their habitats also differ. High exploitation rates may be appropriate for Dungeness crab but may not be suitable for snow crab.
- Reproductive and mating biology is very complex for *Chionoecetes* stocks. Spatial overlap of mature males and females, abundance density, competitional behavior, size differences between males and females in mating pairs, etc., play important roles for mating success. Large males may also play a much more important role than small males for mating success. However, although male and female EBS snow crab are known to exhibit northeast-southwest ontogenetic migrations, there are insufficient data to quantify whether large males migrate back to the middle domain (50–100 m) of the intermediate shelf to mate with females there. The complex reproductive and mating biology poses a challenge for selecting a functional size for the $F_{35\%}$ reference point.

The CPT suggests that Cody proposes a study and alternatives to the CPT May 2022 meeting for review and the CPT will recommend options for Cody for the September assessment.

14 Revisions to Guidelines for Crab SAFE Report Chapters

Martin Dorn reviewed revisions and additions made to the SAFE report chapters for BSAI crab stocks, last discussed at the January 2021 CPT meeting. The SSC generally supported previous CPT-proposed changes to the Terms of Reference. Martin provided the CPT with working edits to the SAFE guidelines document and requested CPT feedback on proposed changes. CPT suggestions for further edits included:

- In Section A. Summary of Major Changes, it was suggested to eliminate 4) Changes to the assessment results, as content is redundant.
- In Section J. Ecosystem Considerations, the CPT noted that ESP products should be included as appendices to individual SAFE chapters when available. Diana will verify that ESP report cards were appended to the 2021 final SAFE chapters for snow crab and BBRKC. In the future, the CPT requests that stock assessment authors add ESP documents as appendices to their respective SAFE chapters prior to submitting a final version to Council staff.
- The CPT proposed to replicate the SSC summary table format in the BSAI SAFE introduction, as was done for the 2021 assessment cycle.
- There was a discussion regarding which model specifications should inform summary tables in individual SAFE chapters. The CPT indicated that summary tables including management performance, status, and catch specifications are helpful to see for each model run. It was therefore recommended that the executive summary table include only the author-recommended model, but that authors include summary tables for each model run as part of section "G. Calculation of the OFL subsection." Text will be added to the document to reflect this addition. Should the CPT recommend a different model than the author-preferred model, then the stock assessment author should replace summary table data in the executive summary with the CPT-recommended model.
- General comments on word choice were recommended by the CPT, with "base model" referencing the starting model from the prior year updated with new data, "proposed models" as the suite of model runs proposed by the author, and "preferred model" referencing the author-preferred model. But note that the author-preferred model may differ from the CPT-recommended model.
- There was a general discussion on developing a standardized table and figure output for all SAFE chapters, but this was beyond the scope of revisions proposed for this meeting. The CPT acknowledged that this is a larger effort that will be addressed at future modeling workshops, or in the GMACS output package. The CPT also recommended coordinating efforts with the Groundfish Plan Teams to facilitate consistency in standardized products and reproducible documentation across all NPFMC stocks.

15 Risk tables: future directions

Katie Palof presented a summary of the status of implementation of risk tables for crab stocks. She explained that the goal of these tables was to identify information related to the biological, ecological, and socio-economic conditions of the stock that are external to assessments. This process will not change the current CPT process but rather organize the existing process and potentially capture trends to better inform the SSC, Council, and public on the rationales of using factors extraneous to stock assessment that could be considered for determining ABC. Adopting risk tables for all FMP crab assessments is not an immediate priority but is the ultimate objective of the CPT.

Katie presented some takeaways from the groundfish risk assessment discussion paper presented to the SSC and Council that may be useful for crab stocks:

- Risk in the fisheries management context is defined as "risk of ABC exceeding the true (but unknown) OFL." Authors should evaluate this risk and whether a reduction of the target ABC from the max ABC is warranted or not.
- There are several biological variants that may affect the calculation of reference points and ABC. For example, the period considered for evaluation of *M* in the calculation of reference points and evaluation of stock status could be discussed in the assessment document. Including an explanation whether these are assessment anomalies or actual shifts in population dynamics is very useful. However, there should be consistency of these types of explanations across all assessments.
- ABC buffer should be based on the recent year's data and assessment, and authors are encouraged to provide recommendations for the ABC buffer. The CPT and SSC can modify these buffers if warranted.
- A risk table is not mandatory for groundfish Tiers 4-6, but authors should include rationale for why a risk table would not be informative.

Katie listed the following crab risk assessment and risk table preparation plans for the May 2022 CPT meeting:

- Snow crab (Cody, tentative since lower priority to rebuilding analysis),
- Bristol Bay red king crab (Katie), and
- Provide a useful illustration of how risk tables could be used in relation to the current use of buffers in retrospect (i.e., last year's decision).

16 BBRKC data available for Council analysis

Diana Stram discussed a Council motion to prepare a discussion paper on Bristol Bay red king crab to cover the following topics:

- Information on bottom contact by pelagic trawl gear and the impact that gear may have on BBRKC stocks.
- Boundaries used for the BBRKC survey, stock assessment, PSC limits, and the directed fishery.
- Mechanisms used in other Council-managed fisheries to create flexible, responsive spatial management measures for all gear types and how they might be applied to protect BBRKC
- Information on Bristol Bay red king crab molting/mating annual cycle and how the seasonality of this overlaps with fisheries and the effects these interactions may have.

There is increased focus on BBRKC due to a steady decline in stock abundance, and in 2021 the mature male biomass was estimated to be 58% of B_{MSY}, which is close to the overfished threshold of 50% of B_{MSY}. Application of the State of Alaska harvest control rule in 2021 led to a closure of the target fishery. Bottom trawl survey results in 2021 were also unusual in that an aggregation of red king crab was found just north of the BBRKC stock boundary, which may represent movement of BBRKC outside the current stock boundaries.

The discussion paper will be developed by Council staff, but this agenda item was an opportunity for the CPT to provide input on the availability of information for the various tasks identified in the Council motion. The CPT discussed whether it would be feasible to conduct a stock assessment for BBRKC for an area different from the current stock boundaries. Most of the survey data needed for the assessment could be compiled fairly quickly, but compiling bycatch data for new stock boundaries would require modification of the catch accounting system used by the Regional Office. While such modification is possible, it would require time and staff resources. The CPT notes that stock assessment models are unpredictable, so it is not clear how the estimates of stock abundance and status relative to reference points might change.

Since fixed gear bycatch is significant and increasing, the CPT encourages investigation of fixed gear bycatch (both longline and pot), in addition to pelagic trawl gear. Regarding the seasonality of BBRKC distribution, the CPT noted that tagging information will be available soon from cooperative research projects with BSFRF that might provide information on the movement of red king crab across stock boundaries. Finally, given the declining stock status of BBRKC, the CPT questioned whether this is the appropriate time to reconsider the current management boundaries. In addition, although some crab may be available north of the existing boundary, most harvests will likely still occur in the traditional fishing area.

17 New business/Officer elections

Officer elections were held for a new co-chair to replace outgoing co-chair Martin Dorn (NMFS). Katie Palof (ADF&G) has agreed to continue to serve as co-chair. Mike Litzow (NMFS - Kodiak) was elected as co-chair during this meeting and will begin his term effective immediately.

Proposed 2022 meeting dates:

May 16-20, 2022 Juneau (tentative).

September 12-16, 2022 (tentative).

May agenda topics:

- AIGKC final OFL/ABC
- Proposed model runs: BBKRC, Snow (adopt GMACS model), Tanner, SMBKC, PIRKC
- Snow ESP review (Erin)
- Snow crab IMB model update (Buck)
- Snow crab rebuilding plan and alternatives
- BSFRF survey catchability/selectivity updates (Buck)
- Survey updates (BBRKC resampling and corner stations updates)
- History of F_{35}% (Katie); Potential new approaches (Martin-tentative)
- Risk table: BBRKC draft
- BBRKC Council staff discussion paper (?)
- EFH component 2 (fishing effects model) update?
- Research updates:
    - Tagging (Leah or Ben?)
    - Overview of research on ocean acidification on Bering Sea crab stocks (multiple presentations, incl. Chris Long, Andre Punt, Mike Dalton)
    - Spatial assessment model for snow crab (Maxime Olmos)
    - Temperature effects on survival, intermolt duration, molt increment, and growth rates of early benthic snow crab and Tanner crab (Louise Copeman, AFSC-Newport).

18 Modeling workshop

A modeling workshop was held subsequent to the CPT meeting to support crab assessment authors with specific assessment modeling concerns, with a particular focus on the continued work and progress on GMACS. All CPT members, assessment authors, and any interested public were invited to participate.

The modeling workshop agenda focused on continued improvements to the GMACS base model in addition to updates to transition more crab assessments into GMACS. Matthieu Veron, a postdoc with Andre Punt and Cody Szuwalski, updated the group on work to merge the base GMACS code – used currently for king crab stocks – with the terminally molting version of GMACS – currently proposed for snow crab specifications. This work is ongoing, the final product will be updated base code, updated documentation for using GMACS, and updated graphical output (currently the R package 'gmr'). The modeling workshop group looks forward to more updates from this work at our next meeting.

The workshop started by testing some updates to the code made in early December to help facilitate AIGKC transition to GMACS. One of the base code updates was designating the composition data as being calculated for catch or survey data. Previous GMACS versions used survey composition calculations for all data. The updates now give authors the option of choosing either survey or catch composition data calculations in the model. These updates were tested on current models – SMBKC and BBKRC. Some corrections and adjustments to the base code were made during the workshop by Andre Punt to adjust inconsistencies in some of the old base code and changes made for AIGKC. By the end of the workshop, the results for both SMBKC and BBRKC matched the previous accepted model results (last Sept. 2021).

Additionally, the retrospective and jittering options in GMACS were tested during this workshop. Both appear to be working correctly but further sensitivity runs are needed to explore the limits of these features, particularly for snow crab given its terminal molt options.

Another goal of this workshop was to review the projection module in GMACS. This module was previously used primarily for the SMBKC rebuilding analysis, and therefore some updates were needed to ensure it was operating as intended for other stocks. Andre added features to the projection model, which included being able to adjust some of the life history and model parameter choices in the projection module separate from the estimate of the current years OFL/ABC specs. This means that the projection file now has a section for the "reference point" calculations and one for the "projection" calculations. This is helpful when modeling changes in selectivity or natural mortality that may be present in the "reference" or end year but are different in the projection output. Other updates include the addition of more documentation on the projection options in the 'gmacs_in.prj' file, an additional projection output file – DIAG file – which details the projection inputs and options chosen, edits to the OFL calculations in the terminal year to accommodate stocks with directed fishery closures, and headers in the output file for easier interpretation and plotting.

In addition to modeling improvements, this workshop focused on work towards producing a GMACS bridging model for AIGKC. Work done by Siddeek and Andre in December was presented to the CPT and modeling workshop attendees that detailed a bridging analysis to produce a GMACS EAG AIGKC model which produces results similar to the status quo EAG AIGKC model. More details of this are provided in the minutes under AIGKC GMACS model. Work was initiated during the workshop to run a WAG AIGKC model in GMACS. An initial model run was completed with the potential for a bridging analysis soon, either in May or future meetings.

Future GMACS tasks include:

- Retrospective run testing (BBRKC as an example)
- Jittering testing (SMBKC – test for higher standard errors and additional replicates)
- Projection module
    - Fix stock-recruit relationships
    - State harvest strategy section – move to personal.tpl?
- WAG AIGKC comparison of GMACS model – May?
- Progress on the unified version – May?