North Pacific Fishery Management Council

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Crab Plan Team
REPORT

May 16-19, 2022, 8am-4pm AKDT
Hybrid Meeting: Anchorage, AK

Members in attendance:

Mike Litzow, **Co-Chair** (AFSC-Kodiak)
Katie Palof, **Co-Chair** (ADF&G-Juneau)
Sarah Rheinsmith, **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)
Martin Dorn (AFSC-Seattle)
André Punt (Univ. of Washington)
Shareef Siddeek (ADF&G-Juneau)
William Stockhausen (AFSC-Seattle)
Cody Szuwalski (AFSC–Seattle)
Miranda Westphal (ADF&G-Dutch Harbor)

Others in attendance:

Ali Whitman
Alyssa Hopkins
Andrew Olson
Angel Drobnica
Anne Vanderhoeven
Austin Estabrooks
Bo Whiteside
Calista
Carlos Paz-Soldan
Chris Siddon
Cory Lescher
Dana Hanselman
David Harris
Diana Evans
Diana Stram
Doug Duncan
Doug Wells
Edward Paulsen
Emily R.
Ernie Weiss
Ethan Nichols
Frank Kelty
Franz Mueter
George Hunt
Hamachan Hamazaki
Jamie Goen
Jason Gasper
Jeff Steele
Jim Armstrong
John Gauvin
John Hilsinger
John Olson
Jon McCracken
Julie Bonney
Kalei Shotwell
Kelly Cates
Kendall Henry
Kenny Down
Lance Farr
Landry Price
Laurie Balstad
Lenny Herzog
Lewis Barnett
Linda Kozak
Lukas DeFilippo*
Madison Heller-Shipley
Maria Anne
Mark Henkel
Mark Stichert
MatthieuVeron
Maxime Olmos *
Paul Wilkins
Rachel Alinsunurin
Ruth C
S. Ricci
Sarah Marrinan
Scott Goodman
Sherri Dressel
Terence Wang
Tyler Jackson
Wes Jone

1. Administrative

The May 2022 Crab Plan Team (CPT) meeting was held hybridly at the Hilton in Anchorage, AK and simultaneously on zoom, and connection information was posted to the CPT eAgenda. The meeting began at 8:00 a.m. AST on Monday, May 16, 2022, with a technical setup and overview of the meeting application. CPT Co-Chairs Mike Litzow 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.

2. Survey Updates - Corner Stations

Lukas DeFilippo and Mike Litzow provided an update on an analysis of the impacts of dropping corner stations from the EBS survey around the Pribilof and St. Matthew islands. These 26 stations require 6–7 vessel days at a cost of ~$100k in areas that historically supported blue king crab and red king crab fisheries. Dropping the 26 corner stations would free up staff resources that could perhaps allow sampling of 10 deep (200 m) stations along the northwest edge of the FBS survey grid near the international border. The analysis focused on impacts to abundance, length composition, and general stock assessment results.

Exclusion of corner stations generally had limited effects on abundance estimates and CVs for Tanner and snow crabs, whereas effects were somewhat larger for Pribilof and St. Matthew red and blue king crabs, especially for design-based estimates. However, it was noted that estimates for Pribilof and St. Matthew red and blue king crabs are highly uncertain to begin with, although some of this uncertainty might be reduced by using model-based estimators.

Again, there was little effect on design-based length composition estimates for Tanner and snow crabs, with a somewhat greater effect on composition estimates for Pribilof red and blue and St. Matthews blue king crabs, again with high uncertainty on the Pribilof and St. Matthew stocks. The analysts commented that length composition data are pooled across years, but those data are available by year for Tanner crab in Appendix A of the Tanner crab document. The CPT noted that size composition data are very informative for Pribilof red king crab.

The analysts also worked with Buck Stockhausen on Tanner crab and Katie Palof on St. Matthew blue king crab to examine the effects of corner station exclusion on management quantities from the stock assessments. For Tanner crab, management reference points were very similar with or without corner stations. For St. Matthew blue king crab, estimates of MMB, B_{MSY}, and OFL were somewhat lower without corner stations, although population trends over time were similar. The CPT noted that dropping corner stations affects the CVs, which changes the weighting in the assessment models.

The CPT discussed aspects of dropping the corner stations, which notably represent a long-term component of the EBS survey. A pot survey has periodically been conducted for St. Matthew blue king crab by ADF&G, and is a better indicator of status for that stock. However, trawl data from these stations are a better ecological indicator. In terms of dropping stations, the analysts did not explore dropping only a portion of the corner stations, such as randomly selecting stations to drop. The CPT also discussed the possibility of dropping corner stations around only one island (most likely St. Matthew) and adding the ten deep stations as possibly a better approach for collecting new information while minimizing changes to the long-term design.

However, the analysis did not explore the effects of dropping corner stations around only one island. If the ten deep-water stations are added to the northwest border of the survey area, it would require a long-term commitment of more than a few years to build a reliable time series of data at those stations. It is not clear what conditions would result in adding the corner stations back into the survey at a later time. The CPT also noted that many of the northwest deep-water border stations are also partial survey grid cells.

While the CPT supports collecting data on the deep-water border stations, other options should be explored, such as a collaborative industry survey. There is currently a pilot satellite tagging project with snow crab near the northwest border deep-water stations and a review of the results in the future may be useful in determining the value of sampling the additional border stations. The CPT further suggested that if stations need to be dropped in order to add the deep-water stations, we could perhaps randomly select stations from the entire survey grid, with randomly dropping stations from the Northern Bering Sea survey area preferred by the CPT, although it would be important to maintain a balanced survey design. There is a plan to revisit the EBS survey design, but a redesign is not a near-term goal. The analysts noted a desire to compare shelf and slope gear with the potential of combining historical data, but this would take several years of data. Scott Goodman (BSFRF) noted the strong industry interest in the border stations, but it is also important to think about how the data would be used.

The CPT greatly appreciates the effort put into the analysis, and is also aware of not wanting to make major changes this close to the 2022 survey. We recommend further explorations on this topic for next spring if changes are desired to the 2023 survey.

3. AIGKC Final 2022 SAFE

Shareef Siddeek (ADF&G Juneau) presented the final assessment for Aleutian Islands golden king crab (AIGKC), including the responses to past requests from the CPT and the SSC, alternative models, results of model runs and diagnostics, and values for the OFL under the Tier 3 control rule. Although the assessment regards AIGKC as a single stock, ADF&G manages the stock on a two-area basis (east and west of 174°W longitude; EAG and WAG, respectively) and separate models are fit to data from the two areas in this assessment. The fishery in EAG was complete at the time of the assessment (March 13, 2022), but only 73% of the TAC for the WAG had been harvested at the time of the assessment. The WAG fishery closes April 30 and final retained catch and bycatch data will be available soon thereafter. The overfishing determination for this stock will be finalized in September.

Previous CPT and SSC comments

Siddeek addressed several previous CPT and SSC comments and requests. He provided an updated analysis of male size-at-maturity based on chela height versus carapace length that addressed questions and concerns raised by the CPT and SSC when the original analysis was presented last year. The new analyses followed methods recently applied to southeast Alaska golden king crab stocks in a peer-reviewed study. Specifically, results from broken stick model fits were presented using older data collected in the 1980s and 1990s, newer data collected since 2018, and the combined dataset. The estimates of size-at-maturity differed depending on which dataset was used (~108 mm CL using the older data, 118 mm CL using the newer data, and 123 mm CL using the combined dataset), as well as by area using the newer data (110 mm CL for the EAG and 120 mm CL for the WAG).

The CPT selected the size-at-maturity estimate based on the newer data alone as the best estimate for the following reasons: the sample sizes are much higher in the newer data, the sampling protocols for the newer data are documented and well-understood, and information on how the earlier data were collected is lacking. The CPT suggested that it may be worthwhile to use area-specific values for size-at-maturity in the future, but that this decision should be addressed within a broader consideration of stock structure.

As requested by the CPT, Siddeek presented an example plot of the “smooth” for soak time used in the CPUE standardization, and noted that the previous standardization had been double-checked and had been conducted correctly. He also stated that all of the alternative models considered for the assessment included a third time period for catchability, correcting an error in the previous assessment model noted by the CPT. He also noted that GMACS versions of all models were included in the assessment report, as requested by the CPT and SSC, addressing requests that GMACS models be included in the assessment for consideration. Siddeek also responded to an SSC request to provide a rationale for using the 1982-2017 time period to compute average recruitment, rather than ending with a more recent year. He noted that using the 1982-2018 time period to calculate average recruitment led to a nearly identical result, and thus saw no convincing reason to change to the more recent time period. The CPT rejected this logic and pointed out that the choice of averaging period was not a static decision but needed to be re-evaluated every year, basing the result on the most recent “well estimated” recruitment.

Finally, Siddeek addressed continued CPT and SSC concerns regarding the retrospective patterns evident in EAG models and presented results from a diagnostic model that incorporated time-varying catchability to explore the influence of estimated catchability on these patterns. Including time-varying catchability substantially reduced the retrospective patterns, and subsequent discussion suggested this probably reflected a conflict between the CPUE indices and size compositions. It was noted that the model was run with no penalties on the catchability “devs”, and that it might have been more informative to have run the model with a penalized likelihood for the variability in the devs.

The CPT was very appreciative of Siddeek’s (and the other authors’) responsiveness to addressing CPT and SSC requests, but did note that several of previous requests remain to be addressed (e.g., a comparison of biomass trends from the RACE AI survey and the standardized assessment CPUE, a single-area model).

Assessment and alternative models

The assessment authors examined ten model scenarios applied to each area in this assessment cycle. Model 21.1a was last year’s assessment model. Model 21.1e included three catchability parameters and associated additional CVs, which corrected the error in Model 21.1a identified by the CPT in which the same catchability was applied to both the fish ticket and observer CPUE time series. Otherwise, 21.1e was identical to 21.1a (the latter used two time blocks for catchability and associated CV’s). Model 21.1f was similar to 21.1e, but substituted observer CPUE data standardized using year-area interactions for the previous standardization that did not include the interaction terms. Because the fishery in the WAG was still open at the time the assessment was conducted, the final catch taken in the WAG for 2021/22 was uncertain, as was the total effort; the authors made the assumption (strongly supported by fishery performance in recent years) that the entire TAC would be taken by the time the fishery was closed, while the CPUE would be similar to that when the assessment was conducted, in order to estimate final effort.

The CPT supported the authors' approach, but recommends that they conduct a retrospective analysis to better evaluate how well the projected CPUE at the time of the assessment captures that at the end of the season.

For the WAG, all three models fit the respective standardized CPUE indices and catch data equally well and produced similar estimates for recruitment and MMB time series. Retrospective patterns for Models 21.1a and 21.1e were small (the authors did not conduct retrospective analyses for Model 21.1f), while estimated selectivity and retention curves, recruitment estimates, and estimated trends in MMB were very similar across the models. For the EAG, all three models exhibited very poor fits to the respective standardized CPUE indices in the post-rationalization period. It was suggested that this reflected an inability of the models to simultaneously fit the index data and the size composition data, and was the reason for poor retrospective patterns exhibited by Models 21.1a and 21.1e (the authors did not conduct a retrospective analysis for 21.1f). This was shown to be the case when a diagnostic model with annual catchability coefficients was able to reduce the retrospective patterns.

Two additional models for each area, 21.1e2 and 21.1f2, were identical to the respective 21.1e and 21.1f models, but used the new estimate of size-at-maturity to calculate reference points. Other than the values for the reference points, the results from 21.1e2 and 21.1f2 were identical to those from 21.1e and 21.1f. Finally, GMACS versions of each of the five models (21.1a, 21.1e, 21.1f, 21.1e2, and 21.1f2) for each area were also examined. Fits to the data were very similar between the corresponding models, while trends in MMB differed only as expected in the model "spin-up" period prior to the index data due to known differences in R_0 between the two types of models.

The authors' preferred models for both the EAG and WAG were the respective GMACS versions of Model 21.1e2, given the similarity of results compared with the non-GMACS versions and the advantages to moving to GMACS. The CPT also preferred the GMACS versions, but it was discovered during the meeting that the OFL calculation in GMACS for the AIGKC models was incorrect (OFL calculations for other stocks were correct). Consequently, the GMACS versions of Model 21.1e2 were not selected by the CPT as bases for reference point calculations. Models 21.1f were also not selected by the CPT because the authors did not provide retrospective analyses for them. The CPT therefore endorsed Model 21.1e2, using 116 mm CL as the new knife-edge size-at-maturity, for both the EAG and the WAG as the basis for status determination and the OFL.

Stock status for AIGKC is currently based on the ratio of area-combined current MMB to area-combined B_{MSY}. Once determined, the area-wide status is used to determine an area-wide multiplier for the area-specific values of F_{MSY} using the Tier 3 control rule. This approach was developed by the CPT in 2017 because, as in this year, the EAG sub-stock was found to be in Tier 3a while the WAG sub-stock was in Tier 3b. Since a single stock is recognized in the Federal FMP, this approach results in a unique tier level for the stock. This has not been an issue in assessments subsequent to 2017 because area-specific stock status was the same for the EAG and WAG (both in Tier 3a). Although the CPT applied the current logic to determine the OFL, concerns were expressed that it would lead to higher fishing mortality rates in the lower tier area than would be allowed under a calculation of the area-wide OFL as a sum of the area-specific OFLs. This issue may be more appropriate to deal with at the state level when area allocations are determined.

Selection of an ABC Buffer

This is the only crab assessment that relies solely on fishery CPUE as an index of abundance, with the CPUE index standardization process subject to past CPT and SSC review, and this is a key reason for the 25% buffer between the OFL and the ABC in past years. Concerns raised in recent assessments are summarized in the following table:

Concern	year expressed	CPT 2022 concern?	Reason
Only crab assessment that relies entirely on fishery CPUE as an index of abundance	2020	Yes	No change
Uncertainties in size at maturity, including the untested regression approach involving chela height against carapace length	2020	Less	Uncertainties in size-at-maturity remain, but regression approach has been tested and revised in line with other studies. Results warrant an increase in size-at-maturity used for MMB calculations.
Uncertainty in natural mortality	2020	Yes	No change
The limited spatial coverage of the fishery with respect to the total stock distribution	2020	Yes	No change
The small number of vessels on which CPUE is based	2020	Yes	No change
Retrospective pattern for the EAG	2020	Yes	Retrospective patterns continue to be an issue
CPUE standardization is still subject to some methodological concerns	2020	Less	Principal methodological concerns have been met
Fewer large animals in the total catch length-frequency for the EAG between 2016 and 2020	2021	Yes	No change

Catches from the WAG that were not included in the assessment	2021	Less	WAG fishery not concluded at time of assessment, as a stopgap measure authors assumed TAC removal for the final year estimation
CPUE index for the WAG declined more when account was taken of year*area interactions	2021	Yes	No change
The size at maturation may be larger than currently assumed	2021	No	Larger size at maturity now used
Model convergence concerns reflecting potential parameter confounding (jitter analysis resulted in multiple solutions for MMB and B35% at same likelihood values)	2021	No	Jitter analysis resulted in no apparent convergence issues

The SSC adopted a 30% buffer for the ABC in 2021/22 based primarily on concerns raised by a jitter analysis that suggested the model was converging to local minima, exhibiting multiple values for reference points associated with a single value for the likelihood. No problems of this sort occurred for this year's recommended models, while the CPT found reasons to reduce or eliminate several other concerns. However, several previously expressed concerns continue to exist, the principal one being the retrospective patterns that continue to be exhibited by the recommended EAG model. Thus, the CPT recommends reducing the 2022/23 buffer for the ABC back to 25%, its value before last year.

CPT Recommendations
The CPT made the following recommendations to the assessment authors:

- Transition to GMACS for the AIGKC assessment should continue to be a priority.
- Continue work to obtain an index using the cooperative pot survey data for use in the EAG assessment model.
- Identify and eliminate the conflict between the model and the data giving rise to the retrospective patterns for EAG models.
- Revisit the analysis considering a model with time-varying catchability, but impose a penalty on the devs to allow the index data to inform the model.
- Plot observed vs. predicted values for fitted data to help diagnose misfits.
- Add confidence intervals to plots of fits to catch data (i.e., retained catch, total catch) reflecting assumed data uncertainty.

- Perform retrospective analyses for all models that have the potential to serve as the basis for calculating reference points.
- Calculate reference points using both combined-area and area-specific size-at-maturity values.
- Perform a retrospective analysis on the ability to predict year-end CPUE prior to the end of the season.
- Re-evaluate the time frame over which to calculate mean recruitment every year.
- Address issues raised in previous CPT/SSC comments, including:
    - A comparison of biomass trends from the RACE AI survey and the standardized assessment CPUE
    - A single-area model

4. Spatial Assessment Model for Snow Crab

Maxime Olmos presented his work on spatiotemporal considerations to better understand, predict and manage natural resources using EBS snow crab as a case study, and summarized his recent work on two post-doc projects: integrated population models (IPM) and management strategy evaluations (MSEs). Maxime first discussed his work with IPMs and noted that spatiotemporal IPMs can be implemented at a fine spatial scale to allow population processes to vary continuously across space by utilizing spatial correlation to account for a continuous approximation of spatial dynamics; can directly fit to fishery and survey data at the scale they are collected; and are able to attribute variation in survey data among sampling locations to both sampling error and spatial process heterogeneity. Maxime noted that spatial considerations are important for EBS snow crab because the fishery is spatially concentrated, ontogenetic migrations occur, the cold pool imposes spatial structure on snow crab vital rates and distribution, and the potential for future warming to influence spatial dynamics.

Maxime's work extends recent work by Jie Cao and his collaborators, by fitting to actual data, improving the representation of biological and sampling processes such as selectivity and maturity, and by accounting for seasonal movement. Maxime described the calculations for densities at a given size class, location, and time using annual survey data, and noted the temporal mismatch between the survey and fishery data (i.e., summer vs winter timing). To account for this, Maxime simulated fishery removals in the summer by comparing survey and fishery centroids and modified fishery data spatially to simulate the fishery removals occurring in summer (i.e., survey timing). Maxime described some explorations including the effect of the cold pool on spatiotemporal variation in juvenile distribution, with the idea that the cold pool acts as a thermal barrier to Pacific cod (i.e., broad juvenile distribution in cold years vs a more contracted juvenile distribution in warm years). Maxime noted some results from the analysis: 1) the center of gravity of the exploitable portion of the population occurred at high latitudes in years with low abundance and low latitudes at high abundance; 2) abundances of recruits had a sporadic pattern but with high abundance levels generally associated with high latitudes; 3) years with low fishing mortality had a more constrained distribution with a center of gravity more north and west; 4) the western part of the EBS was strongly exploited during the 1990s and in some areas catches represented 80% of the abundance; 5) exploitation of the stock was greatly reduced after 1999 when the stock was declared overfished; 6) some areas have high abundance but very low harvest; 7) a positive correlation exists for size-class 1 juveniles (0-40 mm CW) and the cold pool extent; and, 8) spatiotemporal dynamics of juveniles seem to be driven by the cold pool (broad spatial distribution of both juveniles and the cold pool in cold years vs more restricted abundance of juvenile and cold pool extent in warm years).

In summary, Maxime highlighted the development of the size-structured spatiotemporal model which is being applied to to EBS snow crab and accounts for the temporal mismatch of the survey and fishery and estimates fine-scale spatial dynamics and fishery impacts, the distribution of exploitable biomass and fishing mortality, sporadic and spatially concentrated recruitment, and a relationship between juvenile spatial distribution and the cold pool. Maxime was asked about temperature-dependent growth and what happens when temperatures become too warm. Maxime was interested in getting feedback about what is realistic regarding growth.

Maxime went on to describe his MSE research, which aims to understand how fisheries management should respond to climate change by investigating the ability of management strategies to achieve fisheries management objectives considering current and future impacts of climate change. The analysis uses a spatially explicit framework to better represent mechanisms driving the system and to test various management strategies under a set of climate change scenarios. The operating model accounts for population dynamics (sex, shell condition, maturity, size, in space) and life history processes (probability of maturing, natural mortality, probability of molting, growth, recruitment, movement). The analysis consists of four scenarios, with one scenario allowing life history processes to be driven by environmental variations and preferred habitat (based on temperature). Maxime presented example maps showing spatially variable growth for projections out to years 2030, 2050, and 2070 under various climate scenarios with linear, quadratic, and logistic preferential habitat functions. The maps illustrated the sensitivity of growth probabilities to various preferential habitat functions. Maxime solicited feedback about crab biology for inclusion in the analysis. There was a question about growth probability around St. Matthew Island (there were some high growth probabilities close to the island on the northern shore). Maxime noted that the probabilities are driven by temperature and the habitat preference function (warmer temperatures nearshore cause greater growth, this result depending on the preference habitat function used). There was a question about whether growth potential would decrease at some hypothetical warm temperature value and how that would be handled in the model. Maxime responded that growth frequency would increase with temperature but noted that the time step and the number of molt events should be considered. There was a question about focusing on specific portions of the population spatially (for example east vs west of 170° W long). Maxime has not looked at subsets of the population in space. Cody Szuwalski noted that looking at "clustering" of biomass and effort might be a good approach to this issue (for example, looking at 2 centers of gravity).

The CPT was grateful for the research update and looks forward to hearing about further developments.

5. Climate Change and Snow Crab

Mike Litzow provided an overview of research investigating the role of climate change in the decline of snow crab during the past several years. This research project first generated a borealization index, in which a variety of time series were summarized using Dynamic Factor Analysis to describe the change from an Arctic to a subarctic ecosystem. CPT members questioned how much of the variance in this index is explained by the data. Mike responded that the index includes an estimate of error in the index itself, but there are no metrics of fit. Mike also noted that some of these variables are correlated with each other.

The next step evaluated the relationship between the borealization index and immature snow crab abundance using a Bayesian autoregressive regression model. A challenge is that there are few observations for snow crab – there was a decline in 2019, no survey in 2020 and a crash in 2021 – so Mike generated a model-imputed value for 2020. Immature survey abundance declined with increasing values of the borealization index. The CPT commented that this statistical model includes process and observation error in combination and that a better approach would be to use a state-space model to separate process and observation error. Further, the CPT noted that SST may be adequate for explaining snow crab abundance because variables considered in the borealization index are largely correlated with temperature. The CPT asked if lags in variables were incorporated and Mike indicated that they were not. The third step was to attribute the borealization index to the SST anomaly, and these fit quite well. A climate attribution analysis indicated that recent extreme warm temperatures in the Bering Sea and resulting borealization are the result of human activities. Projections from climate models suggest future borealization and negative impacts to the southeast Bering Sea snow crab population. Mike suggested that such climate-induced mortality might be rephrased as 'non-fishing mortality' rather than 'natural mortality'. The CPT commented that these analyses are timely, given the current efforts in snow crab rebuilding.

6. BBRKC Proposed Model Runs

Katie Palof presented models run prepared by Jie Zheng before his retirement. Katie Palof will be taking over the BBRKC assessment, effective immediately. The models presented to the CPT are responsive to requests made in September 2021, including exploring the impacts of differences in ways of specifying or estimating *M* on model output, identifying the cause for increases in retrospective patterns recently, starting the model in 1985, and reviewing the definitions and implications of stock boundaries.

Eleven models aimed at answering these questions were presented and the substantive considerations were around how catchability and natural mortality were modeled, whether or not the BSFRF data were included in the model, and when the model started. Author justification for allowing for time-variation in *M* in 2015-2018 included an increased proportion of older crab in the population (though the CPT had difficulty reconciling this point) and decreases in retrospective patterns. The justifications for removing the BSFRF data were unrealistic catchability coefficients when estimated, improved retrospective patterns, and general lack of influence in the model given the existing prior on survey catchability. The justification for starting the model in 1985 rather than 1975 is that the time-block of elevated *M* in the early 1980s would no longer be required.

Although the models with an extra time-block of *M* from 2015-2018 appeared to fit the data better in recent years, the CPT expressed concern with using *M* blocks because there are often knock-on effect in estimated processes elsewhere in the model. This is one of the reasons that the CPT suggested exploring starting the model in 1985. The CPT were somewhat uncomfortable removing the BSFRF data and suggested that finding a more appropriate way to use the data in the model would be preferable to removing them entirely. Further, when exploring the impact of the BSFRF data, the very informative prior on survey catchability needs to be simultaneously considered because the utility of the BSFRF data comes in informing survey catchability, which can put it in direct conflict with this prior. The CPT generally were supportive of starting the model in 1985, while recognizing that excluding some of the history of the stock also removes some context for management.

The author recommended model 22.0d in which *M* was fixed to 0.18 yr^{-1} for males, the model started in 1985 to avoid modeling the dramatic decline in abundance in the early 1980s, and the BSFRF data were dropped. Modeling only from 1985 would require revision of the time period used to calculate reference points and also would exclude some of the large recruitments associated with the high *M* being estimated (though only a year of recruitment would be 'lost' given current definitions). Katie indicated that she would focus on appropriate estimation of survey *q*, evaluating retrospective patterns, and what years to use for recruitment in September.

In addition to the author-recommended model 22.0d, the CPT recommended bringing forward models 21.1b and 22.0a in September. Model 21.1b is the status quo model with updates to GMACS and updates to the bycatch data, but all other inputs and assumptions remain the same. Model 22.0a started in 1985, estimated natural mortality, did not have a time-block of M in 2015, included the BSFRF data, and fixed the BSFRF catchability coefficient to 1.

The CPT also recommended examining how the initial conditions of abundance are treated in a future analysis, but not necessarily in September.

7. Draft BBRKC Risk Tables

Katie Palof presented a draft risk table for Bristol Bay red king crab, and discussed some of the issues associated with preparing the table. Risk tables for crab stocks were temporarily put on hold last year while the SSC developed its report on risk tables. The SSC report finalized in January 2021 concluded that risk tables are working well in developing ABC recommendations for groundfish, so moving forward this year with evaluating their utility for crab stocks seemed warranted.

Katie identified several issues that created difficulties in preparing the BBRKC risk table. It was not difficult to identify various concerns associated with the stock, since this is a normal part of the CPT evaluation of assessments. However, Katie found it difficult to identify the appropriate risk level, especially since this choice is somewhat subjective. In addition, it was unclear whether the concerns in the table should represent new concerns or ongoing concerns, or both.

The CPT was generally supportive of the risk table approach since it systematizes what the CPT is already doing in providing a rationale for its ABC buffer recommendation. Parsing concerns among categories of assessment-related issues, population dynamics, environmental/ecosystem issues, and fishery performance is a useful way to organize the considerations, though there is some interaction between the various categories. Risk tables should include both on-going and new considerations, though some way of flagging new concerns and those that are no longer applicable is important for crab stocks. This is because the task for the CPT each year is to recommend whether to maintain an existing buffer, or to increase or reduce it.

There was discussion about who should be responsible for developing the risk table, assessment authors or the CPT. Crab assessments involve more extensive engagement of the CPT than is the case for groundfish assessments and the GPTs. The CPT generally makes the initial recommendation on an ABC buffer, and provides its rationale for that recommendation. For now, the CPT proposes that assessment authors provide a draft risk table in the assessment that can be reviewed and modified as needed by the CPT.

The CPT would like to carry forward the draft risk table into the BBRKC assessment in September and is looking for SSC approval for this approach. The CPT is interested in any additional advice that the SSC would like to provide on developing risk table crabs for crab, and in particular whether there are any recommendations on the timeline for developing risk tables for other crab stocks.

8. Snow Crab Individual-Based Models

Buck Stockhausen presented work on snow crab individual-based models (IBMs) and benthic cohort models (BCMs) which could form the basis for potential ecosystem and socioeconomic profile (ESP) indicators. The IBM tracks individual simulated larvae through larval and post-larval life stages from hatch location to settlement. The IBM included movement patterns, growth, mortality (assumed), and settlement habitat (based on depth and temperature). The IBM analysis included annual model runs for 1971-2019, each with five hatch dates (April 1, 15, May 1, 15, and June 1), with 32,651 individual simulated larvae per hatch. The IBM considered spatiotemporal variation in mature female biomass by weighting spawning areas by mature female biomass. Buck presented annual hatching and settlement patterns for two assumptions related to mortality: 0% mortality per day and 8% mortality per day. Buck also summarized results by moderate, warm, and cold temperature regimes. Moderate years yielded the highest rates of successful settlement. In general, settlement patterns were affected by temperature regime: colder years have larger settlement areas but were subject to higher mortality overall due to the longer pelagic duration, and thus had lower settlement success, whereas warm years induced faster larval development (thus shorter pelagic duration, reduced pelagic mortality), but the smaller cold pools corresponded to reduced settlement areas. These results are somewhat counter to what one might expect: higher settlement in cold years with larger settlement areas. The CPT asked about whether the assumed mortality rates were independent of spatial location, as spatially-varying mortality could affect results greatly. Buck noted that assumed mortality did not vary in space and reiterated that we need to know more about how to inform spatially explicit mortality. The CPT made the general point that predator/prey abundance is likely more important than temperature effects on development rate and settlement habitat extent. Buck acknowledged IBM uncertainty including within-season hatch variation, benthic settlement habitat characteristics, and assumed mortality related to starvation and predation. Buck compared predicted settlement from the IBM and recruitment from the assessment model, but there was a general lack of correlation between the two. Buck concluded that 1) the IBM results integrate best science with respect to snow crab early life history (acknowledging that there is much that we don't know), 2) EBS females likely contribute to Chukchi stocks, 3) moderate temperature years may be most productive, and 4) settlement and recruitment are decoupled (predicted settlement abundance has little relationship to estimated recruitment five years in the future). The lack of correlation between IBM-predicted settlement and assessment predicted recruitment may be due missing factors in the IBM such as starvation or spatiotemporal patterns in predation or misspecification of benthic settlement habitat. Buck noted that better information on snow crab early life history is needed for predicting recruitment.

The CPT asked if there were any consideration about possible differences between spatial location during hatch areas vs survey distributions. Buck noted the short timespan between hatching and survey, so survey data are a reasonable indication about where females with ripe eggs are at hatch time. Further, primiparous females likely exhibit the most movement, but Buck only considered multiparous females, thus IBM assumptions are likely reasonable.

There was a question about cold pool timing and whether the cold pool likely gets mixed by late-summer/fall winds. Buck acknowledged that this is a possibility but would be incorporated in the simulations if reflected in the ROMS model output. Buck was asked if he thought the IBM results were robust to differences in the temporal resolution of the ROMS output, given his study used weekly averages. Buck noted the computational and computing storage constraints with fine temporal resolution of ROMS outputs and acknowledged this potential impact on results and suggested sensitivity study could get at this by comparing results for a single year using different ROMS model time steps (e.g., hourly vs weekly).

Buck went on to discuss the benthic cohort progression model (BCM), which incorporates IBM settlement results, instar growth, and instar-specific temperature-dependent mortality. The BCM tracks benthic instar abundance in the ROMS grid by settlement cohort and incorporates ROMS-based bottom temperatures, which in turn affects molt duration and mortality rates (related to cod spatial overlap: cod presence excluded from the cold pool). Buck showed cohort progression results for warm vs cold years, and with and without the incorporation of cod predation. Relative abundance of the BCM results, immature survey abundance, and assessment-predicted recruitment were compared over time. However, there was a lack of correlation between the BCM and estimates of recruitment. Possible explanations of this lack of correlation could include mistreatment of P.cod predation, density dependence, or other missing mortality factors. Juvenile movement was not considered in the BCM because the modeled crab are very small so movement is assumed to be minimal. Spatial distribution of recruitment is assumed to be the same as that of settlement (i.e., settlement patterns drives spatial distribution of recruitment); however, Buck noted that mortality could impact spatial distribution (spatial structure of small snow crab based on predation by cod was due to cod thermal preference). Buck showed plots of the cold pool extent for a 5-year period between settlement and recruitment and noted that predation (mortality) changes with cold pool extent. The output of the BCM was negatively correlated with the assessment model estimates of recruitment, implying other factors are at play not captured in the BCM (e.g., the BCM did not estimate the large recent recruitment event in 2017 + 2018). Buck was asked if he compared spatial variation patterns between mature female and immature crab in survey data. Buck noted he has not done this yet, but plans to. There was a question about whether the model can be run backwards (i.e., start with settlement). Buck noted that yes, the model could be run backwards to see where settlers came from. There was a question about what should be done to improve the IBM. Buck noted measurements of larval distribution in the field for comparison to the IBM and data to inform spatial patterns of predators and food of pelagic larvae would help.

9. Crab Handling Mortality

The CPT received an informational presentation from Council staff, Sarah Rheinsmith, and ADF&G staff, Ben Daly, on the history of current crab handling mortality rates being used both in the bycatch fisheries and directed fisheries. Handling mortality is the mortality rate applied to crab that are caught but not retained as catch, i.e. a handling mortality rate of 80% implies that only 20% of the crab caught survive the experience of capture and return to their habitat. This topic has come up during Council discussion on bycatch of crab in other fisheries, specifically during the April Council discussion of the BBRKC discussion paper. When accounting for total mortality on a crab stock it is important to, as accurately as possible, account for those crab that are caught and returned to the ocean but do not survive.

The handling mortality rate of 80% for the trawl groundfish fisheries is based primarily on Stevens (1990), who reported on trawl research conducted on the BSAI joint ventures fisheries in the late 1980s. Other studies around the same time contributed to our understanding of crab survival after being caught in trawl gear, highlighting the influence of crab shell condition and time out of the water as two important variables. There are no direct research studies to inform our understanding of crab mortality in either the longline or pot groundfish fisheries. Over time 30 to 45% has been used in various council analyses based on Stevens (1990) results. As of 2008 a rate of 50% has been applied to the fixed gear bycatch.

Ben Daly (ADF&G) presented on handling mortality rates that are applied to crab caught in other directed crab fisheries. Ben provided an overview of handling mortality, specifically highlighting that there are short- and long-term contributions to this mortality. The short-term contributors are more easily measured in field studies, such as physical trauma to crab and on-deck exposure to air and cold temperatures. However, longer-term effects are difficult to track and are related to the crab's ability to feed, reproduce, molt, or evade predation over time. Current handling mortality rates vary between 20% and 32.1% within each of the crab fisheries, depending on whether they are applied to crab caught in the targeted crab fishery or another crab fishery (See Table below).

Ben provided his summary of the origin of these rates. Personal communication with Jie Zheng, the BBRKC assessment author, provided insight into past and current rates. In these communications Jie stated that the rates for BBRKC were based on historical studies – which estimated rates of 10% or less – but the uncertainties associated with these studies and unknown rates of delayed mortality called for higher rates to be considered – hence the 20% rate is applied. Additionally, BBRKC caught during either the snow or Tanner crab fishery would be susceptible to lower temperatures and therefore would have increased mortality (25% is applied in the Tanner fishery).

Most of the rates for crab fisheries were based on research conducted during the 1990s and 2000s, with some more recent research on the RAMP procedure for snow and Tanner crab. Ben provided a summary of this research that estimated short-term mortality based on injury, crab response or reflexes (basis of the RAMP protocol), and exposure to cold air. He also summarized how handling mortality rates have varied over time in parallel with research studies. The current approach for assumed handling mortality rates in crab fisheries is to buffer the estimated short-term mortality estimates to account for unknown long-term effects.

Ben also pointed out that low (<2%) deadloss estimates in the directed fishery (i.e., mortality between capture and delivery to the processor) likely underestimates true handling mortality since the fishery retains large crab in good condition and deadloss does not reflect the long-term effects crab would experience upon their return to the ocean.

The CPT discussed whether current assumed rates should be re-visited. For example, it was noted that Lesher et al (2021) provides information on the application of a RAMP-based approach for estimating RKC post-discard mortality rates. Handling mortality rates will remain unchanged and the CPT recognizes that with the exception of RAMP on RKC, no new studies have been conducted to inform new estimates. As such, the CPT continues to encourage future RAMP and handling mortality studies to improve handling mortality estimates. The CPT also suggested the crab assessment authors provide documentation on the rates used in their assessment, potentially as an appendix to the SAFE report.

The following table summarizes current handling mortality rates:

Targeted stock	Directed HM	Indirect HM	GF – trawl	GF – fixed
BBRKC	20%	Tanner 25%	80%	50%
Snow	30%		80%	50%
Tanner	32.1%	Snow 32.1% BBRKC 32.1%	80%	50%
AIGKC	20%	None	80%	50%

10. Survey Updates - BBRKC Resampling Protocol

Erin Fedewa updated the CPT on changes proposed by NOAA Fisheries for the BBRKC resampling protocol during the EBS trawl survey. Under existing protocols, resampling occurs if ≥10% of the mature BBRKC females sampled during Leg 1 of the EBS survey have not completed their mate-molt cycle, as determined by the lack of uneyed eggs. Resampling occurs in 20–30 stations representing 80% of the Leg 1 distribution; stations are typically contiguous. Resampling involves another 7–10 days at sea. The proposed change is to resample when ≥25% of BBRKC mature females have not completed the mate-molt cycle, and resampling would be conducted on the 20 stations that represent 80% of mature females with incomplete mate-molt cycles. During January 2022 discussion of the proposed change, the CPT posed four requests: (1) clarify the goals of resampling; (2) compare reproductive condition across all years compared to resampled years; (3) assess the impacts in past years if the threshold had been higher than 10%; and (4) consider standardizing the stations selected for resampling.

Regarding resampling goals, Erin clarified that the primary goals are to improve the accuracy of size-composition data for post-molt females, improve abundance estimates during cold years when post-molt mature females may be in nearshore areas unavailable to Leg 1 survey gear, and improve the accuracy of mature female reproductive status by including post-molt females. In the 11 years where resampling occurred since 1998, there was a dramatic increase in the proportion of mature females with uneyed eggs in the resample. Comparing the effects of a 10% vs. 25% threshold, the resampling protocol would have still been triggered in 10 of the 11 years where resampling occurred during 1998–2021 (2021 would not have been resampled under a 25% protocol). Resampled stations in previous years have typically been nearshore, contiguous stations.

The analysts proposed setting the resampling effort at 20 contiguous stations if the resampling threshold is exceeded, with resampling encompassing stations that represent 80% of the females with incomplete molt-mate cycles within the BBRKC management district.

The SSC in February 2022 further suggested examining: (1) the relationship between bottom temperature and resampling due to the mate-molt cycle, and (2) ROMS bottom temperature as a predictor of the percent of survey Leg 1 mature post-molt female condition. The analysis found eight years that had bottom temperatures below 2.5ºC that would have still been resampled under a 25% limit. For the 14 years with temperatures above 2.5ºC, three years were resampled under the 10% protocol, but only the 2021 survey year would not have been resampled under the proposed 25% protocol. Erin also pointed out that the ROMS bottom temperature projections are not available until just before the survey, and, when available, the projections are not a great predictor of female reproductive status in Leg 1.

The CPT supports the proposed change, albeit recognizing that EBS environmental conditions are changing. With the expectation of increasing water temperatures in the future, we might anticipate fewer years in which resampling is needed. Industry representatives stressed the importance of the resampling protocols, particularly given the current stock status of BBRKC. Forwarding CPT recommendations to the SSC will provide additional opportunity for public input on the resampling protocols.

11. Snow Crab ESP Updates

Erin Fedewa and Brian Garber-Yonts presented an update on the draft Ecosystem and Socioeconomic Profile (ESP) for Eastern Bering Sea Snow Crab (EBSSC). The full ESP will be presented at the September 2022 CPT meeting and will include updates and current year indicators, with the goal to include it as an Appendix to the EBSSC SAFE.

The ecosystem component includes a conceptual model of life history and tables for key processes. The socioeconomic section lacks a well-defined conceptual model about how fishery and economic performance indicators interact with the stock assessment. Preliminary ideas suggest the fishery affects the status of the stock and the economic drivers affect fishery behavior.

The 11 ecosystem indicators representing physical, lower trophic, and upper trophic aspects were presented in January and were not covered in detail in the presentation at this meeting of the CPT. The document includes a trend analysis and a traffic light table for each of these indicators, with negative impacts coded red. The lack of a bottom trawl survey in 2020 resulted in some gaps in ecosystem indicators. Data on summer consumption of snow crab by groundfish that are sampled by the bottom trawl survey are potentially useful but are not available as a current year indicator due to the time needed for stomach sample processing.

The CPT discussed the male snow crab size at maturity indicator, which is based on survey data and influenced by recruitment and cohort effects. The CPT discussed the potential difficulty in interpreting this metric as it could be difficult to know if seeing many small males is "good" or "bad". However, using the ratio of mature crab that are newshell provides an indicator of which animals have undergone the terminal molt and would be a useful indicator.

The probability of having undergone terminal molt also varies over time. As a long-term trend, annual size at maturity may be informative and the CPT recommended keeping this indicator for now, while recognizing potential confounding factors.

Eight socioeconomic indicators were presented. Fishery performance indicators include: 1) center of gravity of the snow crab fishery; 2) CPUE; 3) total potlifts; 4) number of active vessels; and 5) incidental catch. Economic indicators include 1) ex-vessel value, 2) ex-vessel price, and 3) ex-vessel revenue share. No community indicators are included at present because linkages to the fishery and economic performance are not well understood. Data for economic indicators are not yet available. The CPT suggested the analysts describe the center of distribution using terms other than high/low/neutral to indicate north/south/average distributions.

Stage 1 indicator scores ranged from -1 to +1. Physical and upper trophic scores have been generally negative in recent years, while lower trophic level scores have been neutral or positive. Fishery performance scores have been negative, and economic performance scores have been positive (only available to 2020). The stage 2 indicator analysis uses a Bayesian approach and scales effect and inclusion probability for indicators where there are longer time series. Effect sizes all overlap 0, and inclusion probabilities are quite small (less than 0.5). Predicted recruitment based on this Bayesian approach does not fit observed recruitment. Some indicators have different lags, and the CPT asked that these be explained in the future document.

The CPT questioned if these parameters should be called “indicators” if they have little predictive capacity. Future ESP efforts will identify criteria for inclusion as “indicators”.

Ecosystem summary: The 2020 Arctic Oscillation Index was the highest on record, and the cold pool extent was well below average; bitter crab syndrome has continued to decline from a high in 2016; temperatures occupied by juvenile snow crab remained above average in 2021; the male population center of abundance shifted northwest in 2021; and size at 50% maturity declined dramatically.

Socioeconomic summary: The 2022 fleet consolidated to 37 vessels (60% of recent average fleet size), while strong market demand maintained high ex-vessel price and revenue (to 2020).

The CPT noted that the IBM and benthic cohort model results are not yet ready for inclusion as ESP indicators.

12. Snow Crab Decline - Explorations of Possible Mechanisms

Cody Szuwalski presented an update on his research seeking to identify the causes of the apparent collapse of the Eastern Bering Sea snow crab stock between 2018 and 2021. This research seeks to first determine how non-fishing mortality (M) and catchability (q) have changed over time, and then attempts to identify covariates to explain these changes. The analysis uses a size-structured population dynamics model for male snow crab. The model is based on 5mm size bins for carapace sizes 30–95 mm, for data from years 1989–2021, and is fit to crab abundance (not biomass) and size-composition data.

Estimated parameters include initial numbers for immature and mature males, mean mortality for immature and mature males, annual deviations for mortality and survey catchability by maturity state, annual recruitment, and the proportion of recruitment falling into the first two size bins. Input processes included, growth, survey selectivity derived from BSFRF data, and the probability of having undergone terminal molt. Cody also noted that the upper size cutoff for crab included in the model removed the need to account for directed fishing mortality.

The CPT had some questions about model fits, particularly to the first two size bins, and Cody explained that sometimes a peak in abundance is needed in the first two size bins to explain the abundance of larger crab in subsequent years. Cody then highlighted the potential difficulty of estimating annual M and q simultaneously. He explained that this problem is potentially tractable because changes in M affect crab permanently (they are removed from the population), while changes in q can allow crab to be available to be observed in the survey over time. However, q is also confounded with observation error, which makes estimation of time-variation in q difficult. Nonetheless, the possibility for estimating historical M and q may be well served by this approach.

Cody then covered a list of items that had been identified as "to-do" at his last presentation on the topic. He began with a sensitivity analysis. This consisted of fitting the model 108 times with different values for poorly constrained input parameters. This analysis revealed little sensitivity in model fits to the values selected for these parameters. However, the estimated processes (M and q) were more sensitive to the selected values for these parameters. The CPT speculated as to whether the propensity of q to reach bounds set from the BSFRF data might have suggested that those bounds were inconsistent with the data. Cody also noted that smoothness in the time-variation of M was one of the largest drivers of differences in results among models (specifically in the smoothness of estimated M over time).

Simulations were run with two estimation models fit to 100 populations for six scenarios of data quality from an operating model with time-varying M and q. One of these estimation models included time-varying M and q, while the other only included time-varying M. The latter model estimated the underlying M better, though both models fit the simulated data fairly well and estimated M well. Estimating q was less successful, and the estimation models did a poor job with the scale of estimated values of recruitment (all models overestimated). However, the models did a better job in estimating temporal patterns in recruitment, suggesting that estimates of recruitment, as well as M, may be suitable for correlation tests with covariates.

The list of candidate covariates for mortality includes discarding, bycatch, cannibalism, disease, predation, and temperature. Covariates for catchability included temperature, latitude, and longitude. Considerations for different covariates in the mortality model were then presented. The majority of missing crab were above the size range thought to be vulnerable to Pacific cod predation, arguing against increasing cod predation as plausible main driver of the apparent collapse. Similarly, the peak in observed bitter crab disease on survey does not match the timing of the decline, arguing against disease as a major explanation. Considerations around bycatch were also considered, including the difficulty of modeling unobserved mortality, and the declining trend in observed bycatch that seems to match poorly with the snow crab decline.

GAMs were fit to evaluate the relationship between covariates and time series of estimated *M* and *q*, and were evaluated in terms of leave-one-out cross validation, three-year forward prediction, and randomization. The results suggest that the decline in mature *M* in 2018 and 2021 could not have been predicted with the data available at the time. On the other hand, the increase in immature *M* could have been predicted by the GAM given accurate projections of the covariates (which were unfortunately not available at the time), and the results suggested that temperature was a good predictor for immature *M*. Cody then concluded the presentation with a list of next steps. These included further consideration of whether to use *M*-varying or *M*- and *q*-varying models, and the values to use for the sensitivity parameters. These results also provided background for the selection of an appropriate value of *M* for the rebuilding plan.

The CPT then took public comment noting that the recent population decline may have been the result of a confluence of negative conditions, and that recent conditions may not be an appropriate guide for future projections. It was noted by the CPT that the models in this presentation are not meant to be stock assessment or projection models, and are meant for strategic thinking and the evaluation of different hypotheses for the decline. Public comment was also taken concerning the availability of cod diet data from the freezer-longliner fleet that might help broaden the seasonal coverage of available diet data. The presentation concluded with CPT discussion of the possible metabolic impacts of high temperature for immature snow crab.

13. Snow Crab Proposed Model Runs

Cody Szuwalski presented the argument that the assessment of snow crab for September 2022 should be based on GMACS (Generalized Model for Assessing Crustacean Stocks). The advantages of GMACS are that its use will increase transparency and reproducibility of assessments, in particular that model specifications are more clearly understood, and conducting sensitivity analyses is easier. Cody also highlighted that GMACS is more “stable” (in the sense of providing parameter estimates more robustly) and that it can conduct projections.

Cody noted that GMACS had been adopted for some EBS crab stocks in 2018 but the limitation of a GMACS implementation for EBS snow crab has been the lack of code to implement terminal molt, and hence an inability to directly compare the N-matrix between the current (status-quo) assessment framework and one based on GMACS. This limitation was addressed in a branch of the GMACS code and in September 2020 the CPT recommended that the EBS snow crab assessment be conducted using GMACS in September 2020 based on better model fits, improved structure and assumptions, improved model stability and having a common code base. The SSC, however, did not support the CPT recommendation, citing concerns about changes in estimates of stock size, recruitment and fishing mortality and retrospective patterns. Cody noted that the recruitment from GMACS was as expected given the survey results and that the concern related to retrospective patterns was true of the status-quo model and GMACS because both models do not capture all key biological processes. Concern was also raised by the SSC about high fishing mortality during the early period, but this was an issue for the status-quo model and not GMACS. Cody highlighted that the population dynamics model underlying GMACS and the status-quo model are the same except for how fishing mortality is modeled.

The differences between the status-quo model and GMACS also include that the status-quo model is based on several additional likelihood components and that where "similar" penalties are imposed (e.g., on natural mortality, *M*), they are implemented differently and their weighting may be different.

Cody provided four models for consideration by the CPT: (a) the status-quo model (21.sq), (b) a similar – but not identical – GMACS model (21.g), (c) a version of 21.g in which natural mortality is fixed at the value estimated in 21.sq (21.sq.m), and (d) a version of 21.g.m. in which the growth parameters are fixed at the values estimated in 21.sq (21.g.mg). He summarized the key structural differences between 21.sq and 21.g as: (a) growth is estimated in GMACS (the status-quo model cannot estimate growth within the model-fitting process), (b) GMACS estimates freely estimated availability parameters for the BSFRF survey while the status-quo model assumes a logistic function for females, (c) GMACS estimates natural mortality for male and female immature crab as separate parameters while the status-quo model assumes them to be the same, and (d) the parameterization of recruitment differs between GMACS and the status-quo model.

The status-quo model exhibited convergence issues (a maximum gradient of 0.18), whereas the maximum gradients for the GMACS models were all 0.002 or less. Although the models are based on different assumptions and weights, GMACS fits to the survey data were better than those of the status-quo model for some years, but GMACS did not always fit the retained catch data as well as the status-quo model (this issue is likely related to data weighting). GMACS estimated more large males than observed in the catch in the first three years of the modeled period (1982-1984) in contrast to the status-quo model while GMACS fits the BSFRF data better than the status-quo model. GMACS mimics the survey length-composition data notably better than the status-quo model for 2019 and 2021. GMACS estimates one very large 2015 recruitment while the status-quo model estimates large recruitments for 2015 and 2016 such that the total recruitment from the two models over 2015 and 2016 is about the same. The reason for the difference between GMACS and the status-quo model estimating the recruitments for 2015 and 2016 differently is likely related to the way recruitment is parameterized in the two models (separate time-series for males and females for the status-quo model and a time-series of total recruitment and a time-series of male:female recruitment proportions for GMACS).

Estimates of model parameters differed between the GMACS and the status-quo models (e.g., *M* was higher in GMACS). The estimate of $B_{35\%}$ from GMACS was lower than for the status-quo model, but Cody showed that this was due to the differences in the estimates of *M*.

The CPT supported the use of GMACS for the September 2022 assessment of snow crab given that the fits are better, the model specification process is more transparent and hence easier to review, and GMACS is set up for projections unlike the status-quo model. The improvements of GMACS over the status-quo model substantially outweigh the minor concerns with the GMACS model. The CPT agreed that the models for the September meeting should:

1. Implement alternative specifications for the initial numbers-at-age vector to eliminate the overestimation of catch and abundance of large animals in 1982-1984 – this change will improve the fits visually but will have little impact on final model outcomes.
2. Use a prior on *M* that matches that used in the status-quo model.
3. Both #1 and #2.

The CPT also recommended that a jitter analysis be conducted on the GMACS models to further examine the convergence properties of GMACS for EBS snow crab. The reason that GMACS suggests that F_{OFL} is zero but the status-quo model suggests that it is non-zero was requested to be explored further. It was found during the CPT meeting that the differences in incoming recruitment between the status-quo model and GMACS was part of the reason, but the primary reason was an error in the calculation of F_{OFL} within GMACS. GMACS was updated during the meeting and the assessment document for the SSC should be updated with this correction.

14. Snow Crab Rebuilding Plan - Council Staff Update

Jon McCracken presented a review of considerations for the development of a rebuilding plan for snow crab to the CPT. He noted that the timing for the rebuilding plan was becoming more compressed and the plan must be implemented by October 2023. MSA section 304 requires a rebuilding plan be developed and implemented within two years of a stock being declared overfished.

Jon summarized the possible alternatives for a rebuilding plan as coming down to two approaches. A more optimistic scenario would see the minimum time to rebuild at 50% probability (T_{MIN}) ~ 7 years and the maximum time to rebuild (T_{MAX}) = 10 years. This scenario would allow options for directed fishing, depending on levels of non-fishing mortality (M) and recruitment (R). Jon also reviewed three approaches for estimating T_{MIN} under a less optimistic scenario.

Since the Council lacked the necessary information to select alternatives at the February meeting, that decision has been pushed back to the upcoming June meeting. That timing requires the CPT to discuss alternatives and make a recommendation at the current CPT meeting.

The CPT asked Jon if a T_{MIN} value greater than 10 years would require that T_{MAX} also be selected at this meeting using one of the methods that Jon had presented. Jon answered that from the analysts' perspective, the more clarity from the CPT and SSC the better. The CPT then discussed the implications of a pessimistic outlook that shows no recovery (e.g., with M set to the level estimated for 2018). In this case T_{MIN} is infinite, which would appear to give no guidance for setting T_{MAX}. The CPT also discussed approaches for estimating snow crab generation time.

The CPT then discussed how to structure the meeting to ensure that all scenarios necessary to making the required decision were adequately reviewed. This began with a discussion of possible approaches for selecting T_{MIN} and T_{MAX} and then focused on different scenarios of fishing mortality (F) to consider. The importance of identifying a scenario for F that mimicked the State's TAC-setting process was emphasized. Different approaches for accomplishing this were discussed.

The CPT then discussed stakeholder comments about the importance of considering other parts of the rebuilding plan besides the projected time to recovery, including the harvest strategy, bycatch control, and habitat protection. The CPT asked Council staff for clarity on whether CPT was expected to make other recommendations beyond T_{MIN} and T_{MAX}, such as recommendations concerning bycatch mitigation or habitat protection. Staff answered that recommendations for these other considerations were possible but not required of the CPT.

The CPT then discussed the potential for looking at previous rebuilding plans for guidance, and the idea that while different scenarios for F were able to address bycatch, habitat considerations were not part of any recent analyses and were therefore difficult to evaluate analytically.

The CPT then took public comment from Alaska Bering Sea Crabbers about the importance of considering other MSA requirements for the rebuilding plan, in particular bycatch and habitat considerations.

It was stressed that the Council is looking for guidance from CPT and the SSC on these issues. The very dire economic consequences of the apparent snow crab collapse were also noted, and it was stressed to CPT that the stakes involved in decisions around the rebuilding plan were very high for people relying on the fishery. Following this public comment, CPT continued discussing these issues, and it was agreed that alternatives to evaluate bycatch and habitat considerations could be made by CPT, even if concrete ideas were not proposed.

15. Snow Crab Rebuilding Plan - CPT Discussion

The CPT then discussed recommendations for the snow crab rebuilding plan. This discussion was based on the range of relevant information that had been presented at the meeting, including proposed model runs for the snow crab stock assessment, explorations of potential mechanistic explanations for the population decline, the overview of climate change issues potentially related to the decline, and staff updates on the requirements for the rebuilding plan.

The CPT began this discussion by again reviewing the steps involved in the rebuilding analyses and rebuilding plan, along with the issues for which the CPT would need to make recommendations at this meeting. A rebuilding analysis is one component of the technical basis for a rebuilding plan. A rebuilding analysis is used to set the values for T_{MIN} (the minimum time to rebuild to the proxy for B_{MSY} in the absence of human-caused removals), and T_{MAX} (the maximum permissible time for rebuilding). *The CPT recommends that the rebuilding analysis be based on GMACS as it can conduct projections.* The remaining specifications for the rebuilding analysis that CPT discussed were: (a) how to set the period for generating future recruitment (R), (b) how to set the period for setting mean R when calculating the proxy for B_{MSY} (here $B_{35\%}$), (c) what value (or values) to use for future M and whether the B_{MSY} proxy should depend on past or future non-fishing mortality (M) or a time-series reflecting changes in environmental conditions), (d) how to calculate generation time, and (e) what harvest strategies to consider in the analyses. Cody Szuwalski then presented biomass projections from his earlier presentation on proposed stock assessment model runs to aid the discussion. These projections were based on future recruitments drawn from three time periods of historic recruitment from the observed record, and two choices for projected M based on estimates from two subsets of the observed record, and defined the B_{MSY} proxy based on the period 1982-2019 and the past M.

The CPT based its considerations on model 21.g given it is the model that is closest to the model which CPT recommended for the September 2022 assessment, and the model the projections were based on. It was noted that decisions on T_{MIN} and T_{MAX} will need to be made at the SSC and Council meetings in June 2022. It was also noted that the OFL and ABC for the 2022/23 fishing year will be based on an assessment that uses the 2022 survey data, and that the rebuilding plan will be first implemented in September or October 2023.

The recruitment scenarios included in the assessment document were: (a) 1982-2019 (the currently used time period for calculating reference points), (b) 1994-2019 (starting the period roughly since the collapse of recruitment that precipitated the overfished declaration in 1999), and (c) 1994-2014 (as for option b but excluding the recent period [2015-present] that includes the largest recruitment ever observed).

The two natural mortality scenarios were: (a) the rate that applied to 1982-2017, and (b) the rate for 2018 (indicative of the recent mortality event).

The projections on which T_{MIN} are based involved zero fishing mortality from all sources (directed fishery and bycatch in the groundfish fishery). The two scenarios regarding future M cover the range from likely overly optimistic to likely overly pessimistic for the next 20 years. However, the CPT agreed that based on information from Mike Litzow (see discussion on Climate Change and Snow Crab), the rate for 2018 was unlikely to be representative for the next twenty years, as temperatures as extreme as observed in that year are not projected to become the mean state for the Bering Sea at that time scale. *The CPT therefore recommended that a value of* M *estimated for 1982-2017 be used in projections for estimating* T_{MIN} *and* T_{MAX}. Given the focus on the scenarios for 1982-2017 M, T_{MIN} is less than 10 years, irrespective of the period used as the basis for generating future recruitment. Thus, T_{MAX} is 10 years for EBS snow crab. T_{MIN} is less than 10 years when B_{MSY} is based on recruitment for 1982-2017 (Cody's Fig. 26), so it will be 10 years or less if an alternative period is used to define mean recruitment when computing B_{MSY}.

The CPT recognized that there was considerable uncertainty regarding the appropriate choices for recruitment and mortality projections. The rebuilding analysis for St. Matthew blue king crab considered multiple scenarios so that Council decision making was based on an appropriate characterization of the possible future of the stock and the CPT agreed that the rebuilding analysis for EBS snow crab should also reflect the key uncertainties.

The CPT recommended that Cody compute the generation time for EBS snow crab given that the value used in the last rebuilding plan (5.5 years) seemed unrealistically low. The CPT recommended that the range of harvest strategies include: (a) no future removals, (b) bycatch only, (c) an approximation to the State of Alaska harvest strategy (e.g., the ABC control rule multiplied by the average of the TAC to ABC ratios), and (d) the ABC control rule, so that a wide range of alternatives is available for analysis.

The CPT noted that the effect of bycatch in the groundfish fisheries will be proportionally larger during rebuilding than when the stock is larger than B_{MSY}, and that the projections of the groundfish fishery impacts are parameterized based on observer bycatch estimates, hence ignoring other unobserved causes of mortality due to the groundfish fishery. The CPT also clarified that the rebuilding analysis would be based on the 2017 EFH review because the current review will not be completed when the rebuilding plan is considered for adoption.

The CPT noted that the Council could consider expanding the boundary of the COBLZ and revising the PSC limit formulas. Consideration could also be given to revising the measure of population abundance used to define the PSC limit from total abundance from the assessment to a metric that better reflects the size-classes impacted by the groundfish fishery. Additionally, while the PSC limit is based on a constant proportion of total abundance when abundance exceeds 4.5 billion crab, the limit is independent of total abundance below the threshold of 4.5 billion crab, and the stock is currently below this threshold for the first time in over a decade. The Council may wish to examine an alternative in which the PSC limit declines with abundance below this threshold as an element of the rebuilding plan, mimicking the way the OFL and ABC change with changing abundance for the directed fishery for EBS snow crab.

16. EFH Component Two

Molly Zaleski (NMFS-AKRO) gave an update on plans for the Council's 2022 Essential Fish Habitat (EFH) 5-Year Review, and the process and timeline for crab assessment authors' and experts' review of Fishing Effects (FE) model results for FMP crab stocks. Requirements under MSA for FMCs to develop plans for EFH began in 2005, with a 5-year update and review cycle. The EFH team is following the process for EFH analysis initially recommended by the SSC in 2017 and modified at their February, 2022 meeting. Molly reviewed the timeline for the ongoing analysis, noting that the review of Species Distribution Model (SDM) results was completed during September, 2021 and review of FE model results began this April (reviewers received an email from Molly on April 5), and the deadline for CPT members to complete their reviews is June 30. The email to reviewers contained links to the Google Drive folder for the respective species containing reviewer instructions and a decision tree guide, review materials including FE model output and EFH summary table, and the Google form being used to collect FE review responses.

Molly gave an overview of the three-step process of FE analysis (noting that John Olsen [NMFS AKRO]) gave a full presentation to the CPT at the January, 2022 meeting), with the expert review comprising the final step, assessing the potential FE impacts to crab species' life history parameters, especially in cases where the stock is below MSST, greater than 10% of the core EFH area is disturbed, or if the reviewer has concerns about the representativeness of FE model results for their stock. The presentation went through an example for Tanner crab of the mapped SDM and FE model results as of December 2020 and time series of FE results, showing percentage of habitat disturbed based on VMS data from observed fishing trips only and from combined observed and unobserved fishing trips.

Martin Dorn inquired about the difference in approach to controlling for non-fishing (e.g., transiting) vessel behavior in VMS data from observed versus unobserved trips. Scott Smeltz (Alaska Pacific University, APU) replied, recommending that the respective time series be interpreted as lower- and upper-bounds on percent of area disturbed. VMS data as provided to APU by NMFS were already filtered to eliminate the transiting portion of VMS tracks, but analysts found that data from observed trips were also missing some fishing activity, whereas data from unobserved trips still included non-fishing tracks. Scott indicated that APU analysts attempted to develop an algorithm that would more thoroughly filter non-fishing VMS tracks from the unobserved vessel data, but were not satisfied with results and elected to use the data for this analysis as provided by NMFS, but will continue efforts to improve data filtering. Scott also noted that observed trips represent approximately 90% of total gear footprint (not 90% of total vessels), given that unobserved trips primarily represent non-trawl gear with comparatively small footprint. Martin pointed out that the lower/upper bounds shown in the time-series plot for Tanner crab span the 10% threshold, and Scott recommended that reviewers consider the uncertainty within the bounds as a qualitative factor in their review.

Molly stepped through the Google form (crediting Sarah Rheinsmith for creating the form), emphasizing that reviewers should examine each step in the decision tree before entering their responses to review questions. Two questions in the form elicit qualitative scoring (none/low/medium/high) and written explanation of reviewers' concerns, one regarding the reviewers' confidence that the SDM results adequately addresses review comments raised in the previous review of the SDM analysis, and a separate question addressing confidence in the FE model results due to data limitations. Molly noted that the EFH summary table already indicates whether the 10% threshold is exceeded, which, for crabs, only occurs for EBS Tanner crab, but emphasized that reviewers for other species should complete the relevant portions of the form, particularly regarding recommendations for further research. Question 4 in the form prompts evaluation of the 50% CEA threshold, with the option of either recommending a 75% threshold or performing a qualitative assessment based on other information, with additional review questions and follow-up communications conditional on either response.

Cory Lescher (ABSC) inquired about the application of the 10% area disturbed threshold to the entire species range for the EFH analysis rather than the management area of specific stocks, noting that red king crab habitat area disturbed within the Bristol Bay management area likely exceeds 10%. Molly indicated that FE model results and maps are provided to reviewers at the stock-level for smaller spatial areas, and Gretchen Harrington (AKRO) clarified that under MSA and the EFH final rule, determinations regarding EFH are made at the species level, although FE results are provided at the stock level, and reviewers have the latitude to raise concerns related to the applicability of thresholds based on stock-specific habitat area and other issues. Scott also noted that FE model results for individual stocks were distributed to reviewers and can be provided on request for use in additional research and analysis outside of the FE review.

Scott Goodman (BSFRF) inquired whether any of the reviewers had completed their reviews and could comment on their analysis, and whether review findings would be available in a public report. Molly indicated that no Google forms have been completed to date, and that there will be two separate reports prepared for September/October plan team and SSC meetings, documenting the review process and FE analysis, respectively. Jamie Goen (ABSC) inquired about the status of the HAPC recommendation for Bristol Bay made by the CPT in 2012. Question 9 of the Google form addresses HAPC issues for consideration by the Council, and the reviewer for Bristol Bay red king crab will follow up with Jamie.

17. Tanner Crab Proposed Model Runs

William (Buck) Stockhausen presented a summary of work on the EBS Tanner crab assessment since September 2021 and proposed model scenarios for the September 2021 assessment. The work conducted since September 2021 addressed 1) revisions to the historical bycatch estimates in groundfish fisheries, 2) fitting to aggregate fishery biomass rather than sex-specific biomass, 3) evaluating the effect of removing the survey corner stations, 4) revising survey input sample sizes using bootstrap variance estimates, 5) modeling discrete fisheries in the ADF&G management areas for Tanner crab, 6) starting the model in 1982 with non-equilibrium size structure and various levels of smoothing the initial size structure, 7) adding the capacity to do multi-year projections.

The following viable models were presented in the Tanner crab report:

- Model 21.22a: Base model from last year
- Model 22.01: Updated bycatch estimates for the historical groundfish fisheries
- Model 22.02: Input sample sizes for survey size compositions based on effective sample sizes from bootstrapping in place of default value of 200
- Model 22.03: Fitting to aggregated fishery catch biomass instead of sex-specific biomass, and fitting to male and female size composition data jointly
- Model 22.05a: Starting model in 1982, estimating initial population size using individual parameters on log scale, no smoothing on parameters, all data prior to 1982 dropped
- Model 22.05b: Same as previous scenario except for a smoothing weight = 0.1
- Model 22.05c: Same as previous except for a smoothing weight = 1.0
- Model 22.05d: Same as previous except for a smoothing weight = 10.0
- Model 22.06a-d: Same as the previous series of models, except that initial population size is estimated on a logistic scale.

The revision of the historical bycatch estimates and fitting to aggregate biomass both had trivial impacts on model results, and were viewed by the CPT as clear improvements to the base model. Removal of corner stations also had negligible impacts on assessment results. This result, as well as similar analyses for other stocks, will help to inform the decision whether to drop the corner stocks in this year's survey and in future surveys.

Using a two-stage bootstrap sampling procedure resulted in higher input sample sizes than the current default of 200. This result is consistent with previous work using Dirichlet-multinomial likelihoods that indicated the estimate of "effective" sample size was the upper bound of the input sample size of 200. Use of these input sample sizes in the assessment model gave more weight to the composition data and degraded the fit to the survey biomass estimates. This model scenario estimated higher stock sizes than the base model and all other model alternatives.

It was noted that several models had a number of parameters hitting their bounds. These appeared to be mostly selectivity parameters that specify the fully selected sizes in the selectivity curve, and are unlikely to have major consequences on model convergence and results. Nevertheless, the CPT considers parameters that go to bounds as problematic, and requests that Buck explore whether reparameterization or wider parameter bounds would address this issue.

Models that started in 1982 reduced model complexity by allowing removal of the 1980-84 period of increased natural mortality, and estimating a single set of selectivity and catchability parameters for the EBS bottom trawl survey, which was standardized in 1982. Results were very similar to models with an extended spin-up period. Since the models without smoothing of the initial size composition had trouble converging, it appeared that some smoothing was necessary (though of course there are other ways to parameterize the model initialization that also could be tried). Estimating initialization parameters in log or logit space did not matter. The CPT agreed that the least amount of smoothing necessary to obtain converged models was probably the best approach, and preferred the logit parameterization because it was more consistent with GMACS.

Based on these the following four models are requested by the CPT for the September CPT meeting:

- Model 22.01: Base model from last year updated with new data
- Model 22.03: Updated bycatch estimates for the groundfish fisheries, and fitting to fishery aggregate biomass.
- Modified model 22.06a: Initial size composition in 1982 with a smoothing weight of 0.1, and initial composition parameters estimated on a logit scale, but also including the features of model 22.03.
- Modified model 22.06a as described above plus bootstrap estimates of input sample sizes.

The CPT also encourages Buck to continue exploring alternative approaches to incorporating the BSFRF survey data in the assessment, attempting to model the ADF&G management areas as separate fisheries, and to continue making progress on a GMACS implementation for Tanner crab.

18. History of F35%

Martin Dorn presented a review of the history of $F_{35\%}$ and considerations for *Chionoecetes* reference points as a request from the snow crab stock assessment author to assess the appropriateness of using $F_{35\%}$ for crab stocks. In 2007 the NPFMC adopted reference points and proxies in Amendment 24 for the tier system within the FMP for F_{OFL}, F_{MSY}, B, and B_{MSY}. Fishing mortality $F_{35\%}$ and the biomass reference point $B_{35\%}$ are significant elements in assessing Tier 3 crab stocks.

Chionoecetes spp. crab are unique amongst other crab genera and, of course, very different from groundfish species. *Chionoecetes* crab are characterized by a terminal molt to maturity, effective mating is associated with terminal molt, female crab are able to store sperm which implies crab may not need to mate annually, males and females exhibit strong sexual dimorphism, and larger males may have a competitive advantage in mating.

The $F_{35\%}$ proxy for F_{MSY} was based on applying the Clark method for estimating a min-max approach for selecting a harvest rate that should achieve high yield uncertainty about the stock-recruitment relationship. "Spawning biomass" was taken to be mature male biomass unlike groundfish applications that were based on female spawning biomass. Alaska commercial crab fisheries are male only retention, so the groundfish definition was revised when adopted for use in crab stocks using assumed stock-recruit relationships for Bristol Bay red king crab. At the time, $F_{35\%}$ seemed to be somewhat applicable for crab, since Lithodid life history is more similar to groundfish than *Chionoecetes* crab. $F_{35\%}$ can result in a very high mortality rate in crab fisheries and doesn't account for the greater reproductive contribution from larger males beyond that assumed with larger mass. Additionally, crab fisheries target the largest mature males while smaller mature males are not selected or retained, which may exert a strong selective pressure for maturity (terminal molt) at a smaller size. It was noted that fishing mortality (F) has been increasing in the assessments over the last decade or so possibly due to a shift in selectivity and a shift to smaller size at maturity. Due to a terminal molt where *Chionoecetes* crab do not grow past maturity, there is a very high mortality on large males. Assessment authors and the CPT have become increasingly uncomfortable in recommending such high fishing mortality rates as the F_{MSY} proxy (and the OFL) as there is little evidence that these stocks could withstand such high fishing mortality rates.

Possible methods to address issues with using $F_{35\%}$ are to switch all *Chionoecetes* assessments to Tier 4 and set $F_{35\%}$ equal to natural mortality (M) and define B_{MSY} as the mean biomass over a specified time period, change from morphometric maturity to functional maturity definitions in assessments, employ a stepped maturity function in the assessment to give greater weight to the reproductive contribution of larger males, partition unfished mature biomass into discrete categories (e.g. lower, middle, and upper third of the unfished distribution for MMB) so that $F_{35\%}$ reduces mature male biomass to no less than 35% of unfished biomass in all categories, and to quantify selective pressure on large males using reaction norms to compare fished and unfished populations.

There was discussion around the idea of partitioning the stock into categories. Partitioning the stock into categories gives the opportunity to look at the stock as a distribution of different sizes of crab, instead of saying there is one number we are aiming for with fishing mortality, you are aiming to spread out mortality to each category, effectively managing portions of MMB instead of the whole quantity. However, given that selectivity tends to be asymptotic, the value of $F_{35\%}$ will be determined by the impact of fishing on the "largest" partition. It was noted that when calculating effective spawning biomass (ESB) for red king crab, consideration is given to the size of males and females and this may work for this partitioning scenario because it would give greater weight to the spawners. It was also noted that ADF&G already employs this approach in the state harvest strategies for *Chionoecetes* stocks. Additionally, it was agreed that functional maturity seems to be the clearest change that can be made since this metric is based on crab biology, although legal sizes may also need to be reevaluated because that research is outdated.

It was noted that senescence be taken into account when looking at this issue because older crab (older shell condition) die out of the fishery and the fishery may high-grade for larger newer shell crab. This is complicated because mature *Chionoecetes* crab do not continue to grow after maturing and if they are maturing at a smaller size they will not ever be available to the fishery. This may lead to MMB not being representative of the functionally mature population of male crab.

The CPT noted that no changes are being recommended at this time, although stock assessment authors are requested to examine trends in F_{OFL} for evidence of increases over time. The CPT also recommends that assessment authors look at F for other crabs stocks inside and outside Alaska to see how they compare. It was suggested that an evaluation of stock responses to historical fishing mortality would be helpful, as well as a counterfactual analysis of impacts on the stock of the OFL harvest rates that are currently being recommended. This exploration may have been done in the past but there is no evidence of definitive results and it may be worth exploring now. The CPT would like to hear any guidance that the SSC may have on this topic and then revisit this again at the January 2023 CPT meeting.

19. PIRKC Proposed Model Runs

Proposed model runs for the Pribilof Island red king crab (PIRKC) stock were presented by Cody Szuwalski. This assessment was moved to a triennial cycle in 2021, with the last full assessment taking place during 2019. In 2019, the CPT and SSC accepted a GMACS version of the assessment model that was able to incorporate both survey trends and size-compositions for this stock. There has been no directed fishery since the 1998/99 season, and with the adoption of the GMACS model B_{MSY} was defined as 35% of average biomass from 2000 to present, which was a period of no fishing on this stock.

Since the total catch (as bycatch) was less than OFL, overfishing did not occur; and since the biomass was above B_{MSY} the stock was not overfished in 2021/22.

Previous comments from CPT and SSC included weighting of size composition data, investigating dynamic B_0, incorporating the ADF&G pot survey data, and incorporating PIRKC into larger red king crab dynamics. Many of these tasks are still in process but the author provided an introduction of analyses underway on the metapopulation dynamics of red king crab in the Bering Sea and provided model runs for size-composition weighting. Distribution maps of red king crab in the Bering Sea – showing PIRKC, BBRKC, and northern area RKC – indicate there may be linkages between these stocks in some years but more investigation is needed to determine if these potential linkages are related to recruitment or movement, and if changes in climate were related. The CPT encouraged this direction of work to better understand red king crab metapopulation dynamics throughout the Bering Sea, especially considering increases in the Northern area in the 2021 survey data.

Four models were proposed for model runs in September 2022:

- Model 19.1 – 2019 accepted model
- Model 22.1 – 2019 accepted model with new data
- Model 22.1a – 22.1 + all size composition weight set to 50
- Model 22.1b – 22.1 + all size composition weights divided by 2

The CPT recommended that the author use the accepted model numbering for future documentation; this would change model 22.1 above to model 19.1 (2022 updated data).

All model fits with updated data (22.1, 22.1a, 22.1b models) lowered the biomass estimates to better fit the last two years of survey data, but the length composition fits were similar except for the initial years, which fluctuated due to GMACS estimation process of initial years data. Trends in SSB and overall model fit were similar for all models, showing a slight decline in biomass from the last assessment but the stock is still healthily above the B_{MSY} proxy. The author noted that many of the life history characteristics for this model were borrowed from BBRKC and future work should include sensitivity analyses for these in the model.

Models recommended for September included:

- Model 19.1
- Model 19.1 (2022 updated data)
- (a) Model 19.1 (2022 updated data) + ADF&G pot survey data
- (b) Model 19.1 (2022 updated data) + trawl survey size composition (estimate bycatch selectivity)
- Model combining (a) and (b)

20. St Matthew Is. Blue King Crab Proposed Model Runs

Katie Palof (ADF&G) presented the CPT with potential model scenarios for the St. Matthew blue king crab (SMBKC) assessment in September 2022. This stock was first declared overfished in 1999 and the fishery closed for 10 years. The directed fishery resumed in 2009/2010 for four years of modest harvests, and closed again in 2013/14.

The fishery resumed again in 2014/15 with a TAC of 300 t, but fishery performance was relatively poor with a retained catch of 140 t. The retained catch in 2015/16 was even lower at 48 t, and the fishery has remained closed since 2016/17. The NMFS trawl survey biomass and recruits in 2021 were low, if not the lowest, in the 1978-2021 biomass time series. This fishery is currently managed under a rebuilding plan.

Katie also presented preliminary results from a detailed comparison of the ADF&G pot survey and NMFS trawl surveys, focusing on evaluating trends in areas common to both surveys, as well as examining the influence of a single NMFS survey station (R-24) on the abundance indices.

The SMBKC assessment is on a biennial cycle, with the last full assessment conducted in September 2020. A 3-size bin length-based, male-only model has been used to assess this stock since 2012, with the model implemented in GMACS since 2016. The model estimates population abundance and biomass from 1978 to the current year by fitting to data on commercial catch and bycatch, groundfish trawl and fixed-gear bycatch, NMFS trawl survey estimates of biomass and size compositions, and ADF&G pot surveys. The 2020 assessment model (Model 16.0 2020) used a fixed value for M for all years except 1998, for which year M was estimated. The base model used to develop and evaluate potential model scenarios for September (Model 16.0 2022) was updated from the 2020 assessment (Model 16.0 2020) to include abundance data and size compositions from the 2021 NMFS trawl-survey, 2021/22 fishery total catch, and updated groundfish bycatch data for 2010-2020. The most recent ADF&G pot survey data included in the model was conducted in 2018.

The authors examined a suite of models comprising the base model and three other models which explored model sensitivity to the assumed rate of natural mortality:

- Model 16.0 – 2022 base model: updated with 2021/22 fishery total catch, 2021/22 groundfish bycatch, and 2021 NMFS trawl survey data
- Model 22.0a – the 2022 base model, but with fixed M = 0.21 yr^{-1}
- Model 22.0b – the 2022 base model, but with fixed M = 0.26 yr^{-1}:
- Model 22.0c – the 2022 base model, but with natural mortality fixed for all years at 0.18 yr^{-1} a separate M in 1998 was not estimated).

Removing the 1998 time block used for estimating higher M in model 22.0c led to substantial changes in the model output. Not estimating M for 1998 led to large changes in MMB during the 1990s compared to estimates from models that include a 1998 time block for M (models 16.0, 22.0a, and 22.0b). Model 22.0c did not fit the size compositions from the NMFS survey, the ADF&G pot survey, and the pot fishery very well; and there was an unusual recruitment peak in the late 1990s. Comparison of ADF&G pot survey and NMFS survey indices in comparable stations around St. Matthew Island indicated different trends since 2010. Models without the pot survey indices had different MMB trends in recent years. The iInfluence of station R24 samples on abundance estimation was minor in recent years.The authors concluded that the base model with updated data (16.0 – 2022 base model) was the best option to move forward with this stock.

The CPT discussed the model scenarios and results and decided to keep the number of scenarios addressed in September 2022 to a minimum considering the limitations on data, the lack of population dynamic information available for this stock, and the current rebuilding status of this stock.

The CPT agreed with the author's recommendation to bring a single model forward for the September 2022 assessment: the accepted 2020 assessment model (16.0 2020) updated with 2021/22 data (Model 16.0 2022). The CPT has no additional recommendations.

21. BBRKC Council Staff Discussion Paper

Sam Cunningham with contribution from Kelly Cates presented highlights from an expanded discussion paper on Bristol Bay red king crab requested by the Council. The CPT will not formally review this discussion paper so CPT input is being sought during the preparation of the paper. In addition to the expanded discussion paper, the Council also requested voluntary fishery sector reports to the Council on how individual sectors can reduce red king crab bycatch in Bristol Bay.

Ahead of the October 2022 meeting, the Council has asked the directed crab fishing fleets to report on measures to reduce Bristol Bay red king crab discards thereby reducing discard mortality and reducing handling mortality. Non-directed fishing sectors that operate in Bristol Bay are asked to report on voluntary measures that can be put in place prior to 2023 to reduce crab mortality. All sectors (directed and non-directed) are requested to identify research that informs development of flexible and effective spatial management measures, gear modifications that would reduce crab mortality, and identify ways to evaluate unobserved mortality in the trawl sectors.

The expanded discussion paper will include tables of known data, impacts of annual and seasonal groundfish closures (i.e., the Red King Crab Savings Area), and fishery timing in relation to crab molting and mating. Council staff will be seeking input on scientific information needed to establish dynamic closed areas to protect molting and mating crab, information needed for the Amendment 80 fleet to implement hotspot reporting to reduce red king crab bycatch, and information on the impact of groundfish predation on red king crab. Additionally, the paper will include the impacts of prohibiting Pacific cod pot fishing in area 512 and implementing a hard cap on red king crab protected species cap (PSC) for the Pacific cod pot sector.

The CPT was asked to provide feedback on the following topics:

- Dynamic closed areas to protect mature females and to give input into medium- and long-term research into establishing these closed areas and the effect they have on the red king crab stock;
- Identify areas important for juvenile settlement;
- Characterize and refine timing of molting and mating for the Bristol Bay stock and whether it is useful to distinguish between primiparous and multiparous females;
- Identify if red king crab are susceptible to hook and line (longline) gear;
- Information on the energetics and feeding behaviors of molting red king crab;
- Sources of predation on red king crab in all life stages;
- Input on questions to ask the sectors regarding factors that contribute to red king crab mortality.

There was some discussion on these topics by CPT members and Council staff informed the CPT that there may be another opportunity for contributions on the requested topics.

The CPT provided feedback to Council staff on crab molting and feeding. It was noted that crab do not feed prior to molting or during the time post-molt when they are in a soft-shell condition. It was also noted that there is a temporal mismatch between summer groundfish stomach collections and the time period when most predation on RKC occurs (i.e. spring molting period), and there is a backlog of groundfish stomachs that need to be processed. Larval crab predation by salmon is a long-standing hypothesis but sockeye salmon stomach collections on NOAA BASIS surveys occur in the fall when RKC larvae have already settled to the benthos so any crab eaten would not be present in salmon stomach samples collected by that survey.

The CPT also discussed the role that thermal habitat niche may play for all life-stages of crab, as well as movement in response to temperature that will hopefully be addressed through on-going tagging projects. It was also noted that it is important to protect all crab in the springtime while they are molting and mating. Female red king crab molt and mate during different times in the spring depending on their age (e.g., primiparous in winter/early spring and multiparous in late spring into June). It was noted by Council staff and the CPT that there is an insignificant amount of red king crab bycatch seen in trawl fisheries but that may be because crab are not susceptible to large mesh size on some trawl gear while the trawl gear may be causing unobserved mortality of red king crab due to gear interactions.

CPT also recommended that Council staff consider including information on in-person observer coverage and EM monitoring in addition to extrapolations on bycatch.

22. Modifying Timing of Crab Assessments

Sarah Rheinsmith (NPFMC) summarized the Council's evaluation of proposed changes to the crab harvest specifications timing cycle and directed questions to the CPT for general discussion. The Council acknowledges that there is an extremely compressed schedule for survey data, assessments, review and the October 15th crab fishery opening. Sarah reviewed some proposed changes including: 1) delaying the October 15th fishery start date, 2) delaying review of all crab stocks except BBRKC to December, and 3) standardizing crab specifications cycles to align with groundfish.

During discussions, the CPT emphasized that the January workshop is of great importance to stock assessment authors because many assessment models are still moving to GMACS and a winter workshop allows authors time to incorporate changes before the May meeting. The CPT recommends that dedicated time be provided for an in-person workshop each January, and noted that while the workshop doesn't need to be in conjunction with a CPT meeting, travel logistics are simplified when the two coincide. The CPT also noted that the availability of data from the NMFS northern Bering Sea bottom trawl survey determines the timing for the stock assessment of NSRKC, although it is possible that the assessment author may have time to incorporate new data by a December deadline.

The crab industry expressed concern with changes to the crab harvest specifications timeline because a delay in fishery opening dates provides little time to make decisions regarding quota allocation, as well as the transport of vessels from Seattle and personnel to staff processing plants. The CPT agreed that shifting to ABC/OFL/TAC setting in December is too late for industry to consider fishing a January opening.

The CPT emphasized that industry should have ample time to weigh in before any decisions on changes to the harvest specifications timeline are made

The CPT also noted a suite of other concerns related to changes to harvest specifications including the potential ramifications for rebuilding plans and bycatch accrual with a gap-year in the ABC and OFL as the timeline initially shifts to a calendar year. CPT members involved in the ADF&G TAC setting process also noted that these meetings are very labor intensive and it will be difficult to conduct TAC setting for most BSAI crab stocks at the same time. From an administrative side, any changes to crab fishery seasons may require other federal fisheries seasons to be adjusted accordingly.

Finally, the CPT expressed concern with including crab assessments for SSC review in December alongside groundfish assessments, worrying that time for critical review and public testimony may be compromised.

The CPT concluded the discussion by acknowledging that the number of proposed model runs recommended at the May CPT meeting is often burdensome for assessment authors given the timeframe of the September meeting. It was suggested to streamline the May CPT meeting by recommending two models to move forward in September: the base model with new data and the new preferred model, and then assessment authors can prioritize other models as time allows. The CPT looks forward to continued discussions regarding changes to the crab harvest specifications timing cycle and encourages the Council to solicit input from individual assessment authors.

23. BSFRF Updates

Scott Goodman gave a brief update on Bering Sea Fishery Research Foundation (BSFRF) ongoing research projects and efforts to secure funding. Scott is currently prioritizing completion and distribution of nephrops trawl survey data sets to crab assessment authors. He reviewed the BSFRF portfolio of research projects under topic areas: crab movement research, crab survey research (not including the nephrops trawl survey), habitat and recruitment, bycatch, and crab predation. Current collaborations include potential work with the Amendment 80 sector on a winter survey and tagging study in habitat oriented around habitat protection areas in Bristol Bay, BREP research on pot cod gear modifications, NPRB project development to fund increased tag sampling, and additional work on bycatch and fishing impacts on crab. Scott also noted that BSFRF researcher Madison Heller-Shipley will be entering the PhD program at UW/SAFS in the Punt Lab, focusing on *Chionoecetes* research. Regarding the BSFRF movement and tagging research, Scott noted the engineering challenge of fitting satellite tags to snow crab, given the large size of the tags. Katie asked whether the size of tags could influence the movement of snow crabs, and Scott indicated that there are efforts underway to study those effects and identify improved methods of attaching tags to snow crab and potentially develop a customized tag design for snow crab with grant funding.

Scott discussed efforts and objectives related to the BSFRF bycatch research, particularly with regard to unobserved fishing mortality (UFM), noting that "unobserved" in this context is in regard to mortality associated with unobserved contact with fishing gear, distinct from observer coverage and unobserved fishing trips. The object of this analysis is to better quantify the magnitude of UFM effects with available data, considering scaling factors including time, space, bottom contact, density estimates, mortality estimates, and other factors, to characterize the footprint of different fishing gear and produce estimates of UFM.

Scott showed estimates of the footprint of crab pots in the directed crab fisheries based on 2019/20 and peak-year (post-2005) numbers of pots lifted in the respective fisheries. Efforts are ongoing to acquire datasets and maps to facilitate similar estimates of the comparable footprint of the pollock trawl fishery. Scott emphasized that he does not consider UFM effects to be a principal cause of the recent decline of crab stocks, but that it should be considered as a potential limiting factor on recovery. Katie inquired whether Scott is aware of whether the researchers at Alaska Pacific University that performed the fishing effects analysis under the EFH review have examined data and methods to estimate the footprint or scale of disturbance of pot gear in the directed crab fisheries. Scott agreed that interaction and collaboration with APU researchers would be beneficial, but in particular hopes to develop BSFRF efforts in collaboration with the CPT.

24. Research Estimating Unobserved Mortality

Craig Rose gave an informational presentation to the CPT on his work estimating rates of crab injury and mortality from trawl encounters. Craig's first research question addressed methods to measure unobserved crab mortality rates. Results indicate that survival is much greater if crab encounter but aren't caught by the net. In follow-up studies, Craig and colleagues recaptured crab after encountering different parts of bottom trawl gear (footrope and sweep) and alternative footrope and sweep designs to quantify injury rates and estimate delayed mortality using reflex action mortality predictors (RAMP). Most deaths were in the first few days and the number of reflexes missing was a good indicator of survival probability. Craig noted that RKC are much more vulnerable when losing just one reflex and study results indicated that RKC had the highest mortality rates, with snow and tanner crab rates very similar. Craig emphasized that crab were more likely to die after encountering the footrope, but that mortality rates were fairly high (32%) for RKC that passed under the trawl wings. Another study that tested alternative footrope designs for unobserved morality and catch rates concluded that modified sweeps significantly reduced mortality rates for Tanner, snow and RKC, although Craig noted that the proportion of crab caught can change substantially with minor footrope differences. The CPT discussed using the percent of crab caught in combination with a multiplier to estimate the number of unobserved encounters, and then apply mortality rates from Rose et al. studies to estimate unobserved mortality. Craig noted that encounter and mortality estimates would be largely driven by the precision of the multiplier, and this would be further confounded by the lack of standardization in gear and rigging across the trawl fleet.

Craig also reviewed other studies that have explored crab-trawl interactions, noting that while results from other systems are consistent with Alaska results, these studies often employed different footrope designs, used longer tows and did not control for handling damage. Craig concluded the presentation with an Alaskan study aimed at assessing discard versus unobserved mortality rates in Tanner crab. The study found that air exposure is a major factor for discard mortalities, and that reflexes predicted less mortality from discards than unobserved mortalities. Craig emphasized the importance of distinguishing between a RAMP calibrated using crab discard handling studies versus unobserved-bycatch studies, noting that mortality rates differ significantly between the two predictors. There was further discussion on the applicability of deploying cameras and secondary nets to quantify crab trawl encounters, but John Gauvin (Amendment 80 sector) noted that camera work is difficult because bottom trawls often tow in soft sediment and visibility is very poor. It was also noted that auxiliary nets designed to catch crab missed by the net can change how the main net fishes.

The CPT discussed the implications of Craig's work on estimating crab injury and mortality during molting. Craig noted that while very few soft-shell crab were captured in his studies, mortality was 100%, suggesting that crab are extremely vulnerable to gear interactions during the molt.

Overall, the CPT appreciates Craig's willingness to share his research and thanks him for his efforts to improve mortality estimates from trawl encounters. The CPT recognizes that this is a difficult area of research, and continues to encourage studies designed to improve mortality estimates and quantify long-term, delayed mortality following interactions with trawl gear. The CPT also emphasized that the timing of crab-gear encounters is of great importance and recommends that further efforts be made to protect crab during this vulnerable stage.

25. New Business

Upcoming meeting dates:

September 12-16, 2022 (Seattle / hybrid)
Jan 17- 20, 2023 (Location TBD)
May 15 - 19, 2023 (Location TBD)

Sept agenda topics:

- Summer trawl survey results
- 2021/22 fishery summary
- Ecosystem status report
- ESP snow crab
- Report cards for BBRKC / SMBKC
- Snow crab rebuilding initial review
- Snow crab final SAFE
- Tanner crab final SAFE
- BBRKC final SAFE
- SMBKC final SAFE / rebuilding update
- PIRKC final SAFE
- Overfishing status updates: WAIRKC, PIGKC, PIBKC, AIGKC
- NSRKC proposed model runs/ research updates
- EFH stock author report (~1 hr)
- Modifying timing of crab assessment update
- GMACS updates/ Jan model workshop planning