C3 Bering Sea Aleutian Islands Crab

The SSC received a detailed report on the May 2022 Crab Plan Team (CPT) meeting from Sarah Rheinsmith (NPFMC) and the CPT co-chairs, Mike Litzow (NOAA-AFSC) and Katie Palof (ADF&G). The SSC appreciates the CPT's efforts to streamline their presentation to the SSC. Not all CPT agenda items were presented to the SSC, though they are detailed in the CPT report. Items on which the SSC provided comments are below. Table 1 includes the stock status determination criteria, Table 2 includes the June 2022 SSC recommendations, and Table 3 details the maximum permissible ABCs and SSC-recommended ABCs.

Table 1. Stock status in relation to status determination criteria for 2021/22 as estimated in June 2022. Specifications for Pribilof Island Blue King Crab are rolled over from June 2021. Hatched areas indicate parameters not applicable for that tier. Values are in thousands of metric tons (kt).

Chapter	Stock	Tier	MSST[1]	B_{MSY} or $B_{MSYproxy}$	2021/22[2] MMB	2021/22 MMB/ MMB_{MSY}	2021/22 OFL	2021/22 Total Catch	Rebuilding Status
1	EBS snow crab	3							
2	BB red king crab	3							
3	EBS Tanner crab	3							
4	Pribilof Islands red king crab	4							
5	Pribilof Islands blue king crab	4	2.05	4.10	0.18	0.04	0.00116	0[4]	**Overfished**
6	St. Matthew Island blue king crab	4							
7	Norton Sound red king crab	4	1.03	2.05	2.27	1.10	0.29	0.003	
8	AI golden king crab	3	5.85	11.72	12.59	1.07	4.81	2.72[3]	
9	Pribilof Islands golden king crab[4]	5							
10	Western AI red king crab	5							

[1] As estimated in the 2022 assessment.
[2] For Norton Sound red king crab, MMB on 2/1/2022 is estimated using the current assessment in January 2022.
[3] Catch and overfishing determination will be finalized in October after fishery is completed.
[4] PIGKC specifications are set on a calendar year basis

Table 2. SSC recommendations from the final 2022 Aleutian Islands Golden King Crab SAFE in June 2022. Specifications for Pribilof Island Blue King Crab are rolled over from June 2021. Biomass values are in thousand metric tons (kt). Tier designations in this table are based on the projected stock status in 2022/2023. Stocks for which the SSC recommended different harvest specifications from the CPT are bolded. Harvest specifications for SAFE Chapters 1 – 4 and 6 are set in October and Chapters 5 and 8 – 10 are set in June, in the year according to the assessment frequency cycle (see current SAFE Introduction for assessment cycle). Chapter 7 (Norton Sound Red King Crab) is set in February. OFLs and ABCs for 2021/2022 are available in the October 2021 SSC report.

SAFE Ch.	Stock	Tier	F_{OFL}	B_{MSY} or $B_{MSYproxy}$	B_{MSY} basis years[1]	2022/23[2] MMB	2022/23 MMB / MMB_{MSY}	γ	Natural Mortality (M)	2022/23 OFL	2022/23 ABC	ABC Buffer
1	E. Bering Sea snow crab	3										
2	Bristol Bay red king crab	3										
3	E. Bering Sea Tanner crab	3										
4	Pribilof Is. red king crab	4										
5	Pribilof Is. blue king crab	4c	0	4.10	1980/81-1984/85 & 1990/91-1997/98 [MMB]	0.18	0.04	1	0.18	0.00116	0.00087	25%
6	St. Matthew blue king crab	4										
7	Norton Sound red king crab	4a	0.18	1.90	1980 – 2022 [MMB]	2.42	1.27	1	0.18 (0.58 >124mm)	0.30	0.18	40%
8	Aleutian Is. golden king crab[3]	3a	0.52 (EAG) 0.43 (WAG)	11.72	1987 - 2017	11.94	1.02		0.21	3.76	2.82	25%
9	Pribilof Is. golden king crab[4]	5	-	-	See intro chapter	-	-		-	0.093	0.070	25%
10	W. Aleutian Is. red king crab	5	-	-	1995/96-2007/08	-	-		-	0.056	0.014	75%

[1] For Tiers 3, 4 where B_{MSY} proxy is estimable, the years refer to the time period over which the estimate is made. For Tier 5 stocks it is the years from which the catch average for OFL is estimated. MMB on 2/1/22 is estimated using the current assessment for Norton Sound red king crab.
[2] MMB is estimated on 2/1/2022 for Norton Sound red king crab and on 2/15/2022 for all other stocks, using the current assessments.
[3] AIGKC OFL and ABC are calculated by combining two separate assessment models for the EAG and WAG, as presented in the current assessment

[4] PIGKC specifications are set on a calendar year basis

Table 3. Maximum permissible ABCs for 2022/23 and SSC-recommended ABCs for stocks where the SSC recommendation is below the maximum permissible ABC, as defined by Amendment 38 to the Crab FMP. Stocks for which specifications are rolled over between assessments or were set in February or June 2021 are included. Values are in thousand metric tons (kt). Harvest specifications for SAFE Chapters 1 – 4 and 6 are set in October, and Chapters 5 and 8 – 10 are set in June, in the year according to the assessment frequency cycle (see current SAFE Introduction for assessment cycle). Chapter 7 (Norton Sound Red King Crab) is set in February. PIGKC specifications are set on a calendar year basis.

SAFE Ch.	Stock	Tier	2022/23 Max. ABC	2022/23 ABC
1	EBS Snow Crab[1]	3		
2	Bristol Bay RKC[2]	3		
3	Tanner Crab[3]	3		
4	Pribilof Islands RKC[4]	4		
5	Pribilof Islands BKC[5]	4	0.00104	0.00087
6	Saint Matthew BKC[2]	4		
7	Norton Sound RKC[2]	4	0.30	0.18
8	Aleutian Islands GKC[2]	3	3.74	2.82
9	Pribilof Islands GKC[5]	5	0.092	0.07
10	Western Aleutian Islands RKC[5]	5	0.056	0.014

Basis for P* calculation of Max ABC,
[1] P* was not used to calculate the Max ABC for this stock therefore Max ABC = OFL
[2] CV on OFL
[3] MCMC
[4] CV on terminal year biomass
[5] Tier 5 (90% OFL)

General Comments to Crab Assessment Authors

The SSC had a number of comments applicable to multiple crab assessments.

The SSC noted that a stock structure template exists as part of the NPFMC spatial management policy, but has not been completed for any crab stocks. The entire red king crab (RKC) population in the EBS would benefit from a thorough examination of stock structure via this stock structure template. Given the very specific spatial assessment of RKC stocks and the potential for climate-induced spatial distribution shifts, a better understanding of their stock structure would be useful. **The SSC recommends that the RKC authors work together to complete a stock structure template for June 2023.**

The SSC also noted that there are two 250+ page documents produced for BBRKC per year. Particularly during preliminary model runs for May, a full document need not be produced and a focused summary of model features and runs would be sufficient.

The SSC also suggests that the CPT develop guidelines for when to change model start dates. Both BBRKC and Tanner crab assessments proposed changes to their starting dates with similar, but not identical rationales. While changing start dates may lead to improved model fits to available data and allow for reduced model complexity in terms of removing time blocks for natural mortality or other parameters, there is a potential to lose historical context or the ability to better understand what might have caused model difficulties or demographic changes (e.g., increased mortality events). Thus, the overall goal of these guidelines would be to ensure a full discussion and consistent criteria be applied to proposed changes across stocks into the future. The SSC recommends that these guidelines for start date changes should consider data availability, model complexity, impacts to estimates of the average level and variation in recruitment, loss of historical context and perspective on natural mortality changes and how this would impact short and long-term projections for stock dynamics.

Aleutian Islands Golden King Crab

The SSC received the summary of the AIGKC stock assessment from the CPT Co-Chairs. Public testimony provided by John Hilsiger (F/V Alaska Trojan) focused on concern over using chela - carapace width relationships without biological confirmation of functional mating and concern about potential increasing trawl effort. Public testimony provided by Scott Goodman (Aleutian King Crab Research Foundation) reiterated the need to understand spatial variability in maturity, support for the 25% ABC buffer, and the need for a GMACS model to be able to better incorporate CPUE and maturity data.

The SSC thanks the stock assessment authors for the consideration of and responses to previous CPT and SSC comments. In particular, the SSC appreciates the substantial improvement in the GMACS AIGKC stock assessment model, considerations for minimum maturity, and updating the time series used for average recruitment. The AIGKC stock is managed by ADF&G on a two-area basis (east and west of 174°W longitude; EAG and WAG, respectively) with a harvest strategy based on model estimated mature male abundance specifying a 15% maximum harvest rate for EAG and 20% maximum harvest rate for WAG. The AIGKC stock assessment is based on two separate models (the EAG and WAG) that are configured similarly and model results summed to provide stock-wide management advice.

The SSC appreciates the authors addressing catchability and retrospective concerns by exploring time-varying catchability for the post-rationalization period in EAG. The SSC noted that there was an increasing trend in catchability with fairly clear steps in 2011 and 2014. By the end of the time series of estimates, the catchability is closer to that of WAG. **The SSC requests a future iteration of time-varying catchability constrained with appropriate penalties and/or exploring the use of time blocks within the post-rationalization period.**

While the fishery in the EAG was complete in time to inform this stock assessment, only 73% of the TAC for the WAG had been harvested at the time of the assessment so the author assumed that the final catch would equal the TAC and this year's CPUE would be based on the data available. While this assumption is consistent with recent practices, the **SSC agrees with the CPT recommendation that the authors provide a retrospective analysis to compare the actual CPUE at the end of the season to that projected and used in the model.** The retained catch and bycatch mortality was similar to or lower than in other recent years. Fishery CPUE decreased in 2021-22 in the EAG and the WAG for the third year in a row (close to the average CPUE since 2003 and the lowest point since 2004, respectively).

The authors reconsidered the maturity estimates by comparing older and newer data sets using a broken stick model, resulting in a range of minimum size at maturity depending on which data set is used. **The SSC agrees with the CPT recommendation that the results of the new data (116 mm CL) be used this year because of the higher sample size and consistency in the data collection.** The SSC noted that the total mean maturity value for all samples combined in Appendix C presented by the authors did not appear to be accurate and asked that the table be checked. It was also noted during SSC discussion and public testimony that the minimum size at maturity was different in each region. **The SSC requests that a future analysis consider the spatial footprint of the historical and new data sets to determine if the data exists to show a temporal trend in the spatial variability in size at maturity.** This analysis should also consider temperature data that may be informative as to the cause of temporal or spatial variability.

The authors provided the 2022 assessment with five models that included Model 21.1e with three catchability parameters and associated additional CVs, Model 21.1f that substituted observer CPUE data standardized using year-area interactions, and similar models with a new minimum size at maturity of 116 mm CL. The authors also provided GMACS versions of each of the five models, for a total of ten models. **The SSC supports the CPT's recommendation to use model Model 21.1e2 for both the EAG and the WAG as the basis for status determination and the OFL.** The SSC continues to be concerned about the strong positive EAG retrospective bias and fit to CPUE index trends. In addition, the retrospective bias for the WAG, while still small, has increased since 2021 and should be monitored for any potential serial over- or underfitting of the abundance index.

A 25% buffer to the maximum permissible ABC for AIGKC was applied from 2017 to 2020 but increased to 30% in 2021 due to model convergence concerns. The authors conducted jitter analyses and concluded that there are no convergence concerns in the current model. Therefore, **the SSC agrees with the CPT recommendation to return to the 25% buffer,** noting the following remaining uncertainties: no fishery-independent index of abundance, uncertainty in natural mortality, limited spatial distribution of catch data relative to stock distribution, small number of data points to derive CPUE estimates, retrospective patterns in the EAG, and recent changes in length frequencies in catch data. The SSC thanks the CPT for continuing to provide a clear table identifying additional uncertainties that should be considered in an ABC buffer.

The SSC supports the specific CPT recommendations for additional research and development of upcoming assessments. In addition, **the SSC has the following requests:**

- In the next assessment cycle, provide a model that includes year:area interaction in the CPUE index that includes all diagnostic tools, in particular, a retrospective analysis.
- Investigate the potential source of conflict between the CPUE indices and size composition data that may be causing the retrospective trend in EAG as suggested by the model with time-varying catchability.
- As the GMACS analysts develop and combine code, consider the ability of the model to accommodate 1) a unified (east and west) single-area AIGKC stock assessment model; 2) a two-

area spatial model with some shared parameters and connectivity; and 3) the time series of cooperative survey data now available in both regions.

- Consider a focused AIGKC GMACS item on the January modeling workshop for comparison with the non-GMACS model.

- Based on public testimony regarding increasing trawl overlap with the AIGKC distribution, provide a map of historical trawl fishery distribution relative to the AIGKC fishery.

Bristol Bay Red King Crab Model Runs

The SSC received a report on model alternatives for Bristol Bay Red King Crab (BBRKC) as part of the CPT report. The SSC congratulates CPT co-chair Katie Palof (ADF&G) on assuming the lead author role for this assessment and thanks Jie Zheng for his many prior years of assessments and responsiveness to requests from the SSC. Eleven models were considered related to how catchability and natural mortality were modeled, the inclusion of BSFRF data, and the start year of the model. The rationale for removing the BSFRF data were unrealistically high catchability coefficients when estimated, improved retrospective patterns without the time series, 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.

The author recommended Model 22.0d in which M was fixed to 0.18 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. The CPT and SSC disagreed with removing the BSFRF data at this time. Significant time and thought have gone into the BSFRF survey, and it would be unfortunate to remove it rather than continue to determine how to best use it. Given the very high confidence intervals around the BSFRF estimates, they are unlikely to exert a strong influence on the model. Model 22.0b estimates a catchability over 1 which was used as a rationale to not use the BSSRF data. The SSC notes that there are several factors that could result in a catchability over unity: 1) confounding with misspecified selectivities and M, 2) demographic leakage from other red king crab stocks outside of the BBRKC stock boundaries, and 3) as mentioned in the assessment, the BSFRF nets may be herding crab. **The SSC recommends exploring how to estimate both catchabilities but with a linked prior to influence them to scale together (i.e., assume some approximate value of how much higher q is for that survey).**

The CPT did not recommend Model 22.0d, but recommended Model 21.1b (base GMACS model with updated bycatch data) and 22.0a which estimates M, retains the BSFRF data and starts in 1985. The SSC concurs with the CPT that starting in 1985 is an improvement. The catch history of BBRKC can still be documented, but the elevated M period has been a distraction from other model improvements and has little effect on harvest recommendations. The SSC suggested that it would be helpful if the CPT developed a set of criteria for choosing the start year of models (see General Comments for Crab Assessment Authors section). The model (through likelihood profiles) and data (better fits) point toward a higher estimate of M. The SSC continues to encourage aging studies on this stock, but current understanding of maximum age supports a higher M. **The SSC concurs with the CPT recommended models.**

The SSC recommended in the General Comments to Crab Assessment authors that the RKC authors work together to complete a stock structure template for June 2023. Further, the SSC also commented that a full document may not need to be produced for documentation of preliminary model runs, noting the BBRKC document at this June 2022 meeting was greater than 250 pages (see General Comments to Crab Assessment Authors section above).

Tanner Crab Model Runs

The SSC received a presentation describing analyses related to the Tanner crab stock assessment and proposed models for setting harvest specifications in October 2022. There was no public testimony. 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) revising survey input sample sizes using bootstrap variance estimates, 4) modeling discrete fisheries in the ADF&G management areas for Tanner crab, and 5) starting the model in 1982. Model results clearly showed concerns with the revision to survey input sample sizes and modeling discrete fisheries, and they were appropriately dropped from the final proposed models. The SSC supports incorporation of updated groundfish fishery bycatch information in all proposed models for review at the September CPT meeting, acknowledging that impacts to estimated demographic and management quantities of interest were minimal.

The SSC supports the CPT recommended models to bring forward for harvest specifications:

- Model 22.01: Base model from last year updated with new data (which includes the updated groundfish bycatch estimates)
- Model 22.03: 22.01 plus fitting to fishery aggregate biomass (instead of sex-specific catches and size composition data).
- Modified model 22.06a: 22.03 plus initial size composition starting in 1982 with a relatively small smoothing penalty (eg., 0.1) applied. The SSC supports author discretion in selecting the most appropriate smoothing penalty.
- Modified model 22.06a as described above plus bootstrap estimates of annual input sample sizes.

Even though the estimation of input samples sizes did not perform as expected (it produced even higher sample sizes than default values in the base model), the SSC supports the CPT recommendation to revisit this approach with the revised start date (1982). In addition, the SSC commends the authors for proposing two models (22.01 and 22.03) with no parameters hitting bounds and the remaining models having only two or three parameters at bounds (depending on smoothing). The SSC recommends continued efforts to examine and address the remaining parameters that are still estimated at their bounds.

The SSC supports CPT recommendations 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. However, the SSC recognizes that there may be benefits of waiting until additional improvements in GMACS occur, specifically the adoption of a GMACS model for snow crab.

The SSC also suggests that the CPT develop guidelines for changing model start dates. Both BBRKC and Tanner crab assessments proposed changes to their starting dates with similar rationales. Please refer to the General Comments for Crab Assessment Authors section above for a more detailed SSC recommendation.

St. Matthew Blue King Crab Model Runs

The SSC appreciates the CPT's presentation of the highlights from their May meeting on SMBKC. The SSC is tasked with recommending model runs for SMBKC and general options for assessments given the available data. There was no public testimony.

The last full assessment, which was in September 2020 (upon the move to a biennial cycle), concluded that the population was still below MSST and remains under a rebuilding plan to be updated this fall (2022). No changes to fishing regulations or further bycatch restrictions are expected. The CPT focused on recruitment expectations, core model issues, discrepancies in trends between pot survey and trawl survey,

spatial hot spots in surveys and poor fit of models to survey data after 2010. SMBKC is considered a Tier 4 stock. The next full assessment for SMBKC will be completed in October 2022.

The assessment author responded to three specific concerns raised by the CPT and SSC in earlier meetings; namely, ideas as to why a discrepancy exists between the pot and trawl surveys, the usefulness of time varying catchability relative to model performance, and a validation of the parameters in the model relative to biological characteristics of the stock.

The difference between the pot and trawl survey's spatial footprint could result in the differences seen in the trends. The CPT presented analyses from the author that support this idea and point the way to further approaches for resolving the observed differences in time trends between surveys. To help with the diagnostics, a comparison of trends between surveys in the areas where they overlap would be informative.

Allowing for time varying Q did not seem to resolve any of the issues raised in earlier assessment reviews and certainly would not be relevant to resolving issues potentially related to differences in survey coverage.

Regarding relevant biological characteristics gathered from the population that would be useful to compare and validate model parameters, the SSC recognizes that blue king crab life history parameters are not available as no focused studies on those characteristics exist on that stock and therefore these are borrowed from other species. At this time, only sensitivities of the model to increased natural mortality (M) were evaluated (Models 22.0a and 22.0b). Sensitivities to the model assumptions on growth and maturity will be explored at a later date.

The model was found to not be very sensitive to increases in natural mortality. The removal of the 1998 spike in M led to changes in MMB and recruitment, but doesn't improve the fit to size composition data and these models were not recommended for consideration in October by the CPT. **The CPT recommended bringing forward Model 16.0 – 2020 version and Model 16.0 – updated with data for 2022. The SSC agrees with these proposed models.**

An update will be provided in October on rebuilding status.

Size bins in the model are being considered for modification. It is unclear as to how these modifications compare to biological expectations relative to absorbing other correlated processes in the model. Further exploration of this issue would be helpful. As increases in size bins are considered to improve model fit, authors should consider the empirical measures of molting probability that inform the model fit (growth matrix).

Pribilof Island Red King Crab Model Runs

The SSC received a presentation on the PIRKC proposed model runs. There was no public testimony.

PIRKC is assessed on a triennial cycle. The last full assessment was in 2019 and employed a GMACS assessment model. There has been no directed fishery for this stock since the 1998/99 season. Stock status is assessed using a B_{msy} proxy of 35% of the unfished (2000-present) biomass and catch is bycatch only.

The assessment author proposed:

- Model 22.1, which is the base 2019 GMACS model with updated survey and bycatch data,
- Model 22.1a which is Model 22.1 with size composition weights set to 50 and

- Model 22.1b, which is also Model 22.1 but with size composition weights divided by two.

The CPT supported bringing Model 22.1 forward for SSC review in October but did not support models 22.1a or 22.1b. Instead, the CPT recommended three new models for consideration:

- Model 22.1c which is Model 22.1 with ADF&G pot data,
- Model 22.1d – Model 21.1 with trawl survey size composition, and
- Model 22.1e – Model 21.1 with both ADF&G pot data and trawl survey size composition.

Models 22.1c, 22.1d and 22.1e were not reviewed by the CPT in May.

It is unusual to have CPT-recommended models presented to the SSC in June that were not reviewed by the CPT in May. **In general, the SSC prefers to avoid this situation and requests that authors address SSC requests for model runs in time for review.** In this case, **the SSC notes that the recommended models are responsive to previous SSC requests and supports the CPT's recommended models moving forward.** The SSC notes that any model brought forward in October, but not reviewed in June, will be held to a greater level of scrutiny.

The SSC also appreciates the exploration of BS-wide PIRKC stock connectivity and concurs with the CPT recommendation to continue this investigation. Further, the SSC encourages the continued development of PIRKC-specific life history characteristics (currently borrowed from BBRKC).

Snow Crab Proposed Model Runs (GMACS)

The SSC received presentations on transitioning the EBS snow crab model to GMACS, recommendations on proposed October assessment model alternatives, and an overview of factors that may have contributed to the apparent collapse of the snow crab stock.

The SSC received written comments from Scott Goodman (Bering Sea Fisheries Research Foundation) and Jamie Goen (Alaska Bering Sea Crabbers), as well as testimony and discussion from Scott Goodman, Cory Lescher (ABSC), Edward Poulsen (F/V Patricia Lee), John Gauvin (Alaska Seafood Cooperative), and Mateo Paz-Soldan (City of St. Paul).

The SSC appreciates the comprehensive comparison of the current ('status quo') model and the proposed GMACS model that clarified differences between the two models for the CPT and SSC. The SSC rejected the GMACS model in October 2020 and further explorations of GMACS were paused in 2021 as the platform at the time was not able to incorporate variations in non-fishing mortality that proved essential to capture recent snow crab dynamics. The document clearly lays out the advantages of GMACS over the status quo model and **the SSC agrees with the author and CPT recommendation to use the GMACS modeling platform for the 2022 assessment and for the snow crab rebuilding analyses.** The main reasons for moving to GMACS are summarized in the CPT report and include:

- Better convergence characteristics than the status quo model, which result in more robust parameter estimates
- Improved transparency and reproducibility, which will facilitate future review and benefit crab modeling efforts across stocks
- The ability to do projections, which are essential for the rebuilding analyses

- Improved fits to survey biomass data

- Improved fits to the BSFRF size compositions and recent size compositions for the NMFS surveys (in particular for immature crab)

In addition to the previously accepted base model ('status quo' model 21.sq) and the similar but not identical GMACS model (21.g), the author presented two versions of 21.g that fix either natural mortality (21.g.m) or both natural mortality and growth parameters (21.g.mg) at the values estimated in the status quo model. While model fits were similar overall, the GMACS configuration resulted in better fits to most data components but estimated substantially higher natural mortalities than the status quo model (0.36, 0.34, 0.35, and 0.38 in GMACS (21.g) versus 0.27, 0.28, 0.27, and 0.27 in the status quo model (21.sq) for mature males, mature females, immature males, and immature females, respectively), which resulted in a lower estimate of $B_{35\%}$.

The SSC shares CPT concerns over the high natural mortality estimates, which are a substantial departure from earlier assumptions about the likely range of M values. These high estimates resulted from a much broader prior on natural mortality assumed in the GMACS model. An additional, minor concern was the overestimation of catches and abundances of large crab in 1982-1984 that apparently arose from the fixed numbers-at-age vector assumed in the status quo model. **Therefore, the SSC agrees with the CPT proposal to bring forward the following models for the September CPT meeting**:

1. Model 21.g (GMACS version that matches the previous base model as closely as possible)

2. Model 21.g with priors on M that match those used in 21.sq

3. Model 21.g with an alternative specification of the initial numbers-at-age vector

4. Model 21.g with both of the above changes

5. In addition, the SSC requests to see Tier 4 calculations with the value for M (not including the elevated values in 2018-2019) from the last accepted model as a fall back for specifications

The SSC notes that models 2-4 are considered bridging analyses for evaluating the separate and combined impacts of changes in the initial numbers-at-age vector and in the prior on M on model results.

As noted by the authors, there are still many structural issues with these GMACS models, but the SSC agrees that the move to GMACS should facilitate resolution of these issues and provide a much improved basis for future model development. Considering the required rebuilding analyses, the SSC agrees that moving to a stable GMACS version is the highest priority at this point, and recognizes that other issues such as those noted in the October 2021 SSC report may not be resolved in the near term. However, the SSC highlights in particular the following priorities:

- **The SSC strongly recommends that the urgency of accounting for snow crab in the northern Bering Sea requires that analysts prioritize working towards a model-based survey index that incorporates the NBS data**, as well as considering the possibility that smaller, mature males are present in this area. The SSC recognizes that current year data are not available in time to be included in the assessment under the current schedule for assessment and review but suggests that even an index without the most recent year of NBS data (as well as sparse NBS data in other years) is likely to be superior to only including survey biomass in the standard EBS survey area. In this context, the SSC also highlighted the need to improve understanding of changes in distribution, abundance and catches of snow crab in Russian waters.

- The SSC highlights the importance of assessing the current definition of male snow crab maturity given the possibility of snow crab maturing at smaller sizes and the sensitivity of reference points to assumptions about growth and maturity, as previously illustrated by the author. However, while we welcome further explorations on this issue, the SSC supports the current maturity assumptions for this year's model and rebuilding analyses considering other priorities.

- **The SSC strongly recommends including uncertainty intervals on estimates of biomass and abundances** when presenting assessment results.

- **The SSC continues to request an explanation for why the GMACS model estimates such a skewed sex-ratio for recruitment** (much higher females than males or the status quo) and whether it is reasonable or necessary to estimate sex-specific recruitment.

- **The SSC recommends that the author work with BSFRF to summarize observations from harvesters,** including fishery CPUE across space and depth among years, that may help inform stock dynamics.

- Finally, to more fully account for the effects of changing temperatures in the Bering Sea, the SSC encourages future explorations of temperature-dependent variations in growth and maturity.

With regards to the Ecological and Socio-economic Profile (ESP) for snow crab, the SSC highlights previous requests to ESP analysts and Plan Teams to consider carefully the addition of social and community indicators in appropriate documents to meet requirements of National Standard 2. This is especially important for this stock in the context of upcoming rebuilding analyses and will be critical to track changes during rebuilding to account for the needs of affected communities and to ensure a fair and equitable distribution of rebuilding benefits and costs. The SSC highlights in particular the cascading effects of the snow crab collapse on communities that strongly depend on the resource, such as St. Paul.

With respect to causes for the apparent collapse of the snow crab stock in the EBS, the SSC appreciates the author's expanded exploration of the potential mechanisms that may have led to the observed decline. These included potential effects of discarding, bycatch, cannibalism, disease, predation and temperature on non-fishing mortality and effects of temperature and spatial distribution on catchability. Key results from these analyses suggest that neither increasing predation from Pacific cod nor the increased frequency of bitter crab disease were plausible mechanisms for the decline. The author and CPT also considered bycatch and unobserved mortality to be unlikely culprits for the declines. However, the SSC notes that declines in observed bycatch associated with trawl gear modifications does not account for unobserved mortality, and while these sources of mortality are an unlikely cause of the decline, their effects on the stock's ability to rebuild should be considered. The SSC suggests the authors continue to include the possibility of movement out of the area in addition to mortality hypotheses in future explorations.

The author's analyses suggest that bottom temperatures were a good predictor of mortality for immature snow crab. Potentially detrimental effects of high temperatures on immature survival and recruitment are consistent with previous research. The SSC suggests that the potential impacts of increased temperatures on immature snow crab could be explored through a bioenergetics model. **Critically, this observed link between temperature and mortality provides support for the use of high mortality scenarios or events for projections in rebuilding analyses that better represent recent conditions.**

Updates to Snow Crab Rebuilding Plan

The SSC received a presentation on the snow crab rebuilding analysis and CPT recommendations. The SSC recognizes the efforts that the author, the authors of the many supporting analyses, and the CPT have made on this stock's rebuilding analysis and in providing essential biological and fishery context.

The SSC received written comments and public testimony on snow crab as described above under the Snow Crab Proposed Model Runs section.

The SSC recognizes the additional challenge for the snow crab rebuilding analysis due to it coinciding with the technical transition from the status quo model to GMACS. It is generally not ideal to have three different models used for rebuilding, for last year's assessment and for the fall 2022 assessment. Some of the SSC's recommendations are intended to create as much consistency between these models as is possible. The SSC also recognizes the compressed timing of the analysis, acknowledging the need to press forward on the regulatory timeline, specifically noting that the CPT attempted to select the best alternative from only the information that was available in May.

The SSC highlights that snow crab are literally on the leading edge of climate change in the Bering Sea: the new and changing dynamics observed in the last few years appear to have rapidly transformed a healthy stock into one in need of rebuilding. Current climate projections suggest that the frequency of 'borealization', intermittent extreme temperature events, is already elevated relative to the historical period and is likely to continue to increase in the future. In light of these projections, the SSC recognizes that the range of rebuilding options should be structured accordingly, not simply assuming that the historical period is a good predictor of the future. **The SSC supports the CPT recommendation to use GMACS as the basis for rebuilding analyses but was not able to select appropriate rebuilding parameters given the information currently available. Therefore, the SSC provided guidance on rebuilding projections and fishing mortality alternatives that should be included in the next iteration of the analysis.**

The top priority for the rebuilding analysis is to use the tighter prior on M that is consistent with both last year's model and the preferred model recommended for the 2022 harvest specifications cycle by the CPT. This change will affect both the rebuilding trajectories as well as the B_{MSY} on which the rebuilding parameters will be determined.

The SSC supports the basic approach of selecting time-periods from which to resample recruitment strengths for structuring alternative rebuilding trajectories and notes that this is consistent with methods used for other crab rebuilding analyses. The SSC had considerable discussion regarding the treatment of M, noting that although a simple approach of creating rebuilding trajectories that use an average from a year (or years) as was done in the analysis thus far is technically appealing. However, this method is unlikely to adequately represent the effects of episodic mortality events on rebuilding. The SSC notes that these episodic elevated crab mortality events are not isolated to snow crab but have been identified in several other BSAI crab stock assessments. **The SSC recommends a stochastic treatment of M, resampling of annual M values from the same period of years used for recruitment resampling.** To bracket a range of plausible trajectories, four time periods were recommended:

- 1982-2017: This period was recommended by the CPT, and will be similar to the results already provided, except for the use of the tighter prior on M during estimation. The SSC notes that this will likely be the most optimistic case, as it does not include the high estimated M associated with the apparent mortality event in 2018-2019.
- 1982-2019: This period matches the fully observed time series, including the elevated mortality in 2018-2019, but does not reflect the anticipated increased frequency of mortality events due to climate change.
- 1994-2019: This period follows the author's rationale for a break in the recruitment time series, reflecting more recent conditions while still allowing for the possibility of some high recruitment events.

- 2005-2019: This period corresponds to the most recent period of alternating warm and cool conditions in the Bering Sea and approximates a one in seven chance of an elevated mortality event, consistent with estimates of near-term future temperature variability in the Bering Sea.

Consistent with the treatment of mortality events for other crab stocks and for GOA Pacific cod, the SSC recommends using only the 'base' mortality rate (not including the 2018-2019 event), for each projection period, along with the resampled recruitments to calculate the B_{MSY} for determining rebuilding parameters. The SSC notes that longer term climate projections suggest even shorter periods for elevated temperature events that could generate a one in three chance of elevated mortality. The SSC highlights that, under this scenario, it is unlikely that the snow crab stock could rebuild to current reference points. The SSC discussed when and how B_{MSY} might be adjusted to reflect a higher mortality rate, i.e., specifically making the decision to adjust to the new 'prevailing conditions' and a different and lower level of productivity, allowing fishing at stock levels that would previously have been considered to be too low to provide for a fishery.

The SSC recognizes that these recommendations require technical changes to the analysis, possibly requiring modification to the GMACS projection methods. If it is not possible to add a stochastic resampling of annual M values to the rebuilding projections, the SSC notes that an average M over the range of years might still provide a reasonable basis for the rebuilding analysis. **Noting the compressed timeline for this rebuilding analysis, the SSC suggests if all of the four projection time-periods cannot be evaluated that the first and fourth would be the highest priority.**

The SSC notes that the range of recommended projections may result in a T_{min} that exceeds 10 years. Therefore, the SSC supports the CPT recommendation to also calculate an updated mean generation time for snow crab, and if necessary, the three methods for determining T_{max} when $T_{max} > 10$ years.

The SSC supports the CPT recommendations of fishing mortality alternatives to include in each projection, with two additions for a total of five alternatives: No fishing mortality ($F = 0$), the average bycatch over a recent period (including both groundfish and other crab fisheries), an approximation of the State of Alaska's Harvest Control Rule (HCR) with recent bycatch, an approximation of the State of Alaska's HCR without recent bycatch, and $F = F_{ABC}$ as the upper bound.

The SSC noted that the results presented at this meeting showed no rebuilding sensitivity (within one projection) to recent bycatch levels. However, the SSC recommends including one sensitivity projection using the State HCR and a larger value for bycatch that might represent an upper bound reflecting the inclusion of unobserved mortality. The SSC understands that the author may need to qualitatively consider research on unobserved mortality to develop this scenario, and only intends this sensitivity for comparative purposes. The SSC notes that unobserved mortality represents an unmodelled source of mortality that is already embedded in the observed time-series and that an appropriate treatment would need to first re-estimate population parameters while explicitly including this mortality. If the $F = 0$ or approximated State HCR alternatives result in population trajectories that are approaching T_{max}, it may be helpful to determine how large bycatch would have to be for the median trajectory to reach T_{max}.

The SSC requests that future rebuilding analyses provide a summary of the technical specifications of how the projections are being run (e.g., how many forward simulations, which sources of uncertainty are included, whether Monte-Carlo error has been evaluated and is negligible for the quantities of interest). To aid in specific evaluation and comparison of rebuilding parameters, the SSC also requests that they be provided in tabular format including: T_{min}, T_{max}, mean generation time, and specific rebuilding times for fishing alternatives (potential T_{target} values).

The CPT identified several management actions that could be taken as part of a snow crab rebuilding plan.

These included expanding the COBLZ area, revising the approach to the PSC limit via either changing the 'floor' at 4.5 billion crabs or specifying PSC for specific size-classes. The SSC also received public testimony identifying other potential tools including spatial and/or habitat specific management. The SSC notes that consideration of the efficacy of such actions will be possible when T_{max} has been selected and potential T_{target} values can be compared.

Finally, the SSC wishes to emphasize that the missing EBS/NBS survey in 2020 created a lag in the ability to recognize the declining stock trend and resulted in current analyses relying heavily on the 2021 survey data point; both the rebuilding analysis and the assessment may be strongly informed by the information gathered in 2022. The SSC also notes that the NBS may be increasingly important to the stock dynamics and fishery. To the extent possible, the SSC recommends including 2022 information in both the rebuilding and assessment analyses.

Survey Updates – Bristol Bay Red King Crab Resampling

The SSC received a presentation on changes proposed for the EBS trawl survey BBRKC resampling protocol. Public testimony was provided by Cory Lescher and Jamie Goen (Alaska Bering Sea Crabbers), Edward Poulson (F/V Patricia Lee), and Lenny Herzog (Bering sea crab fishermen). Written comments were provided by Jamie Goen (Alaska Bering Sea Crabbers) and Scott Goodman (Bering Sea Fisheries Research Foundation). 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. Resampling occurs in 20–30 stations and involves 7–10 days at sea. The proposed change is to increase the resampling threshold to ≥25% and limit the number of resampled stations to 20.

In response to CPT and SSC requests, the analysts clarified that the primary goal of the BBRKC resampling program is to improve the accuracy of size composition data for post-molt females. Improving abundance estimates for mature females and estimates of reproductive status were secondary and tertiary goals, respectively. They reported a strong bottom water temperature effect on the proportion of pre- mate-molt females but noted that the availability of spring bottom temperature information limits its use as a pre-survey resampling predictor. Further, efforts to investigate other predictors of molt-mate phenology (e.g., prey availability) were limited because of a lack of data. Finally, the analysts reported that due to the unpredictable movement of crab from nearshore areas into the survey domain, it is not practicable to standardize the resampled stations.

Looking back to 1999, the analysts noted that resampling would have been triggered at 10% but not at 25% in one year (2021) only. Comparisons of the size composition and estimates of abundance with and without resampling in 2021 were provided to support their conclusion that the proposed change would have minimal impact on BBRKC stock assessment. The CPT supported the proposed change and noted that resampling is likely to become less common as the Bering continues to warm.

The SSC appreciated the thoughtful examination of the proposed change to BBRKC resampling. The SSC noted that there were no analyses indicating that the proposed change would improve the accuracy of size composition data for post-molt females, mature female abundance estimates, or estimates of reproductive status. In response to SSC inquiries, the analysts indicated that the primary purpose of the proposed change was to create flexibility in survey sampling station allocation in the future. Further, while the SSC appreciated the examination of 2021 data with and without resampling, the results did not elucidate the broader impacts of the proposed change on the BBRKC stock assessment going forward. The SSC also noted that public testimony provided by the representatives and members of the Bering Sea crab industry was not supportive of the proposed change.

The SSC does not support the CPT recommendation to implement the proposed BBRKC resampling

threshold and recommends that BBRKC resampling be included in future survey strategic planning analyses.

Survey Updates – Corner Station Analysis

The CPT co-chairs presented an analysis of the impacts of dropping corner stations around the Pribilof and St. Matthew islands from the EBS survey. Public testimony was provided by Cory Lescher and Jamie Goen (Alaska Bering Sea Crabbers) and Edward Poulson (Bering Sea crab fisher). Written comments were provided by Jamie Goen (Alaska Bering Sea Crabbers) and Scott Goodman (Bering Sea Fisheries Research Foundation). The 26 corner stations require six to seven survey vessel days at a cost of about $100k and serve to increase sampling in areas that historically supported blue king crab and red king crab fisheries. The consideration of dropping these stations is part of an effort to free up staff resources to allow NMFS survey sampling in other areas including the potential for 10 deep stations along the northwest edge of the EBS survey grid near the international border. The analysts highlighted the need to balance the benefits of a standardized sampling design vs. the costs of permanent commitments to low-information sampling, flexibility needed to support allocation of sampling effort to other areas (e.g., deeper stations) and increased workload due to NBS sampling leading to increased injury rates of survey staff.

The analysis explored the impacts to abundance, length composition, and general crab stock assessment results. Results suggest minimal effects on Tanner and snow crab. However, removal of corner stations would likely increase uncertainty within the PIRKC and SMBKC assessments and produce reduced biomass estimates for SMBKC The survey group concluded that the additional flexibility gained by dropping the corner stations would offset the impacts to abundance, length composition, and general crab stock assessment results.

The CPT expressed concern about how changing the design would impact the long-term sampling of ecological information, discussed the possibility of dropping a subset of corner stations or other stations chosen at random and noted their support for sampling of deeper stations. Ultimately, the CPT did not recommend dropping corner stations this year but encouraged further exploration. Testimony from representatives and members of the fishing industry also opposed dropping the corner stations.

The SSC appreciated the thorough work of the analysts and acknowledged that the current sampling demands are challenging for survey funding and staffing. **The SSC concurred with the CPT and does not recommend dropping corner stations.** The SSC expressed concern over the increased pressure on survey staff and reports of rising injury rates and noted that these issues should be addressed separately from the sampling needs to first ensure safe working conditions for survey staff and support high quality data collection for stock assessments. The SSC recommends that corner station sampling be included in future survey strategic planning analyses.

Draft Risk Table for Bristol Bay Red King Crab

The SSC received a brief presentation of a draft risk table for BBRKC. The author and CPT requested SSC input on developing the table and whether to bring a draft table forward for review in October. The CPT was generally supportive of the risk table approach and noted the importance of flagging new concerns and those that are no longer applicable for crab stocks, given the CPT is tasked with recommending whether to maintain an existing ABC buffer, or to change it each year.

The SSC confirmed that the if risk tables are implemented for crab, risk tables should be developed by the stock authors with input from the CPT and that the tables should be included in the crab SAFE documents. In agreement with the CPT, the SSC noted that crab risk tables are likely to be different from those developed for groundfish owing to the crab ABC buffer selection process. The SSC noted that the items

listed, and levels of concern reported, are not relative to an "ideal" assessment. The SSC reiterated that the tables are intended to capture items that are not addressed in the assessment, by the harvest control rule and that the level of concern for each should be based on the degree to which that item contributes to the risk of the true ABC exceeding the OFL. For example, the current draft cites recent decreased recruitment as a population dynamics concern, but this is a concern that should be contained in the OFL determination from the model and control rule. Further details are provided in the SSC's Risk Table Workshop Report.

The SSC commends the author for both taking on the BBRKC assessment and developing the draft risk table. The SSC requests that an updated draft version be brought forward in October.