C1 BSAI Crab

The SSC received a detailed report on the September 2023 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 were detailed in the CPT report. Items on which the SSC provided comments are below.

General Crab Comments

The SSC recognizes the valuable contributions of Miranda Westphal (ADF&G) on the CPT and wishes her well in her future endeavors.

Risk tables have proven to be a valuable component of groundfish stock assessments in providing a rationale for making ABC recommendations that reflect concerns about the stock assessment, population dynamics, the fishery, and the ecosystem. In their June 2021 motion, the Council supported delay of application of the risk table to the crab specifications process until further progress is made on groundfish. Based on the SSC preliminary guidance and recommendations in the Risk Table Workshop Report (p. 33 of June 2021 SSC Report, Appendix A) and further positive experience with risk tables for groundfish, the SSC recommends that risk tables be developed for crab assessments. Risk tables would be used to provide a more comprehensive, transparent, and defensible justification for CPT and SSC recommendations on ABC buffers. The SSC emphasizes that the use of risk tables does not change its overall approach to setting ABC buffers for crab and recognizes that it may take more than one assessment cycle to develop.

The SSC requests that the CPT develop a process for ensuring that authors have provided a response to all previous (including at least the last assessment) SSC recommendations, even those for which no work has been completed, so these requests can be more easily tracked over time.

The SSC requests that future BBRKC, Tanner and snow crab assessments routinely include a simple Tier 4 analysis that includes a smoothed time series of survey vulnerable biomass (legal size or smaller to accommodate discard mortality) using the REMA package and not adjusted for natural mortality. This model will provide a consistent alternative should the preferred Tier 3 approach fail in some way and also a point of comparison with Tier 3 and State methods used as a basis for TAC setting. The simple Tier 4 approach may also provide some value in identifying survey observations that are outside the level of process error observed in the rest of the time series. The SSC recommends that the CPT consider whether the method used for setting the buffer for the Tanner crab analysis, based on the terminal year's CV rounded to the nearest 5%, would be an appropriate method for all simple Tier 4 analyses.

The SSC also requests that all crab authors include uncertainty intervals when showing time series of biomass/abundance estimated by the stock assessment models so that alternative models and retrospective patterns can be evaluated in the context of the modeled uncertainty.

The SSC reiterates its February 2023 guidance:

- o For the inclusion of trawl survey data, the SSC suggests crab assessment authors and the CPT be more explicit about best practices for which standard years are included for bottom trawl survey data. The SSC suggests that the years recommended by the Groundfish Plan Teams would be a good starting point, which specify using the following bottom trawl survey data years:

  - Aleutian Islands: 1991 - present (standard gear)

  - Eastern Bering Sea: 1982 - present (standard gear, grid, and design), 1987 - present for

species that inhabit the northwest corner of the survey (which was added in 1987 for snow crab and walleye pollock)

The SSC suggests that the CPT and crab authors continue to evaluate whether VAST or similar approaches, when specified carefully for individual crab stocks (i.e., the choice of error distributions and number of knots) might provide more robust survey time-series.

Ecosystem Status Report Preview

The SSC received presentations by Elizabeth Siddon (NOAA-AFSC), Bridget Ferriss (NOAA-AFSC), and Ivonne Ortiz (U. Washington) previewing the Ecosystem Status Reports (ESR) for the Eastern Bering Sea (EBS), the Gulf of Alaska (GOA) and the Aleutian Islands (AI), with specific attention to indicators that may be influential to consider for crab stock assessments. The SSC appreciates the effort to provide this information at the October meeting as data are still incoming and being incorporated. The SSC looks forward to the full ESR in December.

Generalized summaries were provided for the GOA and AI ESRs. No ecosystem concerns were identified for the GOA, and the author noted ocean temperatures remain near the long-term average with mixed pelagic feeding conditions for adult groundfish. For the AI, warming conditions persisted, characterized by high sea surface temperatures, with the winter of 2022/23 representing one of the warmest on record since 2013. The strongest effects of this warming were present in the western and central AI. The SSC suggested information on which species are most vulnerable to these persistent conditions would be helpful for understanding ecosystem impacts.

For the EBS, specific to crab stocks, it was noted that oceanographic conditions in 2022/23, including regional sea surface temperature trends and cold pool extent, were near the long-term averages with no red flags, suggesting good conditions for both pelagic and benthic crab. In 2023, there was a shift in timing of sea ice, with delayed sea ice growth due to slow freeze-up in Chukchi and impact of ex-typhoon Merbok. Modeled output from ROMs suggest expansion of bottom water ocean acidification (OA) conditions in 2023 (aragonite and pH). The author noted while these OA values are concerning, they were not expected to be driving crab declines as snow crab are not sensitive to declining aragonite concentrations and the nearshore habitat in Bristol Bay appears to be buffered. The SSC looks forward to seeing future work ground-truthing the modeled OA indicators.

Biological indicators showed mixed conditions for pelagic and benthic crabs. For pelagic crab, prey conditions (e.g., chlorophyll-a biomass estimates, copepod abundance, and copepod lipid content) were low in summer and fall 2023 Pelagic foragers, which are predators on pelagic crab stages, were high in 2022. For benthic crabs, indirect measurements of infaunal prey based on the 2022 benthic forager guild indicated adequate availability, but competitors and predators of benthic crabs remained high in 2022. The SSC noted that the continued high abundance of motile epifauna biomass, driven by brittle stars and other sea stars, represents a trophic 'dead-end' for energy in the benthic community and these organisms also may have direct interactions with benthic crab. It is unclear if this may represent a new community state.

Broad-scale climate patterns reflect a transition from La Niña to El Niño conditions with anticipated warmer ocean temperatures arriving in early spring 2024. Ecological impacts of this transition remain unclear and will depend on the duration, depths, and timing of the warmer conditions. The ESR team expects to have updated forecasts of El Niño conditions for their December presentation.

Other notable observations included high bycatch of herring in the flatfish and pollock fisheries. A flatfish fishery exceeded herring PSC in 2023, the first time since 1992, and the pollock fishery was near the PSC cap. There were indications that herring were deeper and in more variable areas than in the past. This, along with predicted shifts in ice extent and phenology, highlight that the changing spatial and temporal dynamics of physical conditions may result in not only increasing or decreasing trends in biological components, but

also in shifting distributions and changing biophysical interactions. The SSC discussed that even when physical conditions return to baseline, there may still be variability in the biological components, and supports the ESR authors' current efforts to develop spatio-temporal indicators of stratification and composite indices to better understand horizontal and vertical shifts in distribution that affect prey availability, species interactions, and interactions with fisheries.

Trawl Survey Updates

The SSC received an excellent presentation on the 2023 EBS and NBS bottom trawl survey results relevant to BSAI crab from Mike Litzow (NOAA-AFSC, CPT co-chair). There was no public testimony on the survey results specifically. **The SSC commends AFSC survey staff for completing the bottom trawl surveys in 2023 under what continue to be challenging logistical conditions.** Further, the SSC continues to be impressed with the rapid turnaround of the survey data and commends the crab assessment authors for updating model runs and assessment documents on the short timeframe necessitated by the survey timing.

Overall, many population components of BSAI crab on the surveys continue to decline or to remain close to all-time low levels. There were few exceptions to this. **The SSC continues to register substantial concern for the BSAI crab stocks as a result of these survey trends**.

All major components of the EBS snow crab male population continue to be at or near all-time survey lows. However, there appears to be some incoming recruitment of small snow crab (30-40 carapace width (CW)). Mature females are also at an all-time low. The survey size composition data show a decline in the larger size classes, which is expected as the population has seen little to no recruitment in recent years. Clutch fullness was higher in 2023 than in 2022. Results from the NBS survey continue to indicate that snow crab are not migrating north, with primarily small animals encountered in the NBS.

BBRKC male abundance declined compared to 2022 but mature female abundance increased substantially (46%). While this last note is encouraging, given the recent fishery closures, a large portion of this increase was from a single station (roughly 37% of the overall catch; 141 crab). Some caution interpreting these results is warranted, though it was noted that this patchiness is not atypical and the spatial distribution of mature females in 2023 was similar to previous years. Long-term, mature females continue to be at a relatively low point in the available time series. No re-tows were conducted in 2023, with a relatively low proportion of females having an incomplete molt-mate cycle.

Tanner crab abundance in the eastern area declined but increased in the western management area. The largest recruitment event on record was noted. There is some evidence for a shift to the northwest of Tanner crab. For example, more old shell crab were seen in the eastern management area and more new shell crab in the western area. The SSC encourages additional investigation into this apparent shift, noting that ADF&G has a couple of pilot projects to investigate Tanner crab movement, as this could impact management of this stock in the future.

No PIBKC mature males were encountered on the survey. The SSC encourages investigation of previous survey data, particularly the ADF&G pot surveys mentioned at the CPT meeting, to provide context for current survey results for this species. PIRKC male abundance was down from 2022 (49%) and mature females increased slightly (9%). SMBKC mature male abundance was similar to 2022 but mature females declined by 71% in 2023.

BSAI Crab Harvest Specifications and SAFEs

Table 1 includes the stock status determination criteria and Table 2 includes the October 2023 SSC recommendations. The SSC endorsed all of the OFL and ABC recommendations of the CPT, with the exception of EBS snow crab and Tanner crab (Table 2).

Table 1. Stock status in relation to status determination criteria for 2022/23. 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_{MSY} proxy[1]	2022/23 MMB	2022/23 MMB/ B_{MSY}	2022/23 OFL	2022/23 Total Catch	Rebuilding Status
1	EBS snow crab	3	136.9	155.91	92.4	0.59	10.32	0.05	**Overfished**
2	BB red king crab	3	9.68	19.36	18.34	0.95	3.04	0.07	
3	EBS Tanner crab	3	18.19	36.39	74.17	2.04	32.81	2.62	
4	Pribilof Islands red king crab	4	0.85	1.71	3.88	2.27	0.685	0.004	
5	Pribilof Islands blue king crab	4	2.10	4.20	0.18	0.043	0.00116	0.00	**Overfished**
6	St. Matthew Island blue king crab	4	1.63	3.26	1.31	0.40	0.07	0.002	**Overfished**
7	Norton Sound red king crab [2]	4	0.95	1.90	2.42	1.27	0.30	0.16	
8	AI golden king crab	3	5.83	11.66	13.60	1.17	3.76	2.61	
9	Pribilof Islands golden king crab [3]	5					0.093	Conf.	
10	Western AI red king crab	5					0.056	<0.001	

[1] As estimated in the 2023 assessment

[2] For Norton Sound red king crab, all values in the table except 2022/23 total catch were projected using the January 2022 assessment. Stock status for NSRKC is determined in February (2022/23 MMB was projected for 2/1/23 and compared with the projection of B_{MSY} proxy for the 2022/23 year).

[3] PIGKC specifications are set on a calendar year basis.

Table 2. SSC recommendations for EBS crab stocks. Stocks for which specifications are rolled over between assessments (PIRKC and SMBKC) or were set in February (NSRKC) are included. Biomass values are in thousand metric tons (kt). Tier designations in this table are based on the projected stock status in 2023/2024. 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 is set in February.

Ch	Stock	Tier	F_{OFL}	B_{MSY} or B_{MSY} proxy	B_{MSY} basis years[1]	2023/24[2] MMB	2023/24 MMB/ B_{MSY}	Natural Mortality (M)	2023/24 OFL	2023/24 ABC	ABC Buffer
1	E. Bering Sea snow crab	**3b**	14.96	155.91	1982-2022	65.77	0.42	0.29	**15.44**	**7.72**	**50%**
2	Bristol Bay red king crab	3b	0.30	19.36	1984-2022	14.98	0.77	0.23	4.42	3.54	20%
3	E. Bering Sea Tanner crab	3a	1.16	36.39	1982-2022	48.77	1.34	0.23	36.20	**28.96**	**20%**
4	Pribilof Is. red king crab	4a	0.21	1.71	2000-2021	3.88	2.27	0.21	0.685	0.51	25%
5	Pribilof Is. blue king crab	4c	0	4.20	1980/81-1984/85; 1990/91-1997/98	0.18	0.04	0.18	0.00116	0.00087	25%

[1] For Tiers 3 and 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 average catch for OFL is estimated.

[2] MMB is estimated on 2/1/2024 for NSRKC and on 2/15/2023 for all other Tier 1-4 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 2 cont. SSC recommendations for EBS crab stocks. Stocks for which specifications are rolled over between assessments (PIRKC and SMBKC) or were set in February (NSRKC) are included. Biomass values are in thousand metric tons (kt). Tier designations in this table are based on the projected stock status in 2023/2024. 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 is set in February.

Ch	Stock	Tier	F_{OFL}	B_{MSY} or B_{MSY} proxy	B_{MSY} basis years[1]	2023/24[2] MMB	2023/24 MMB/ B_{MSY}	Natural Mortality (M)	2023/24 OFL	2023/24 ABC	ABC Buffer
6	St. Matthew blue king crab	4b	0.06	3.26	1978-2021	1.31	0.40	0.18	0.07	0.05	25%
7	Norton Sound red king crab	4a	0.18	1.98	1980-2023	2.40	1.21	0.18	**0.31**	**0.22**	30%
8	Aleutian Is. golden king crab[3]	3	0.59 (EAG) 0.50 (WAG)	11.66	1987-2017	12.07	1.04	0.22	4.18	3.14	25%
9	Pribilof Is. golden king crab[4]	5	-	-	-	-	-	-	**0.114**	**0.085**	25%
10	W. Aleutian Is. red king crab	5	-	-	-	-	-	-	0.056	0.014	75%

[1] For Tiers 3 and 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 average catch for OFL is estimated.

[2] MMB is estimated on 2/1/2024 for NSRKC and on 2/15/2023 for all other Tier 1-4 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

EBS Snow Crab

The SSC received written and oral comments relevant to EBS snow crab from Jamie Goen (Alaska Bering Sea Crabbers; ABSC), Scott Goodman (Bering Sea Fisheries Research Foundation; BSFRF), and Gretar Gudmundsson (self). Ms. Goen raised the issue that the PSC cap could be larger than next year's OFL, and suggested that a lower PSC cap be considered to distribute the costs of rebuilding snow crab more equitably. She also noted that PSC cap is a tool to restrict both bycatch and unobserved fishing mortality. The SSC certainly supports snow crab rebuilding, but did not make a specific recommendation since the PSC cap is a Council decision. Both Mr. Goodman and Mr. Gudmundsson expressed a lack of understanding as well as lack of confidence in the stock assessment modeling. It was suggested that preparing a simple stock assessment narrative that documents recent history on model development for stakeholders could improve comprehension and buy-in. The SSC understands that assessment methods are technical and complex, and agrees that more effort is needed to communicate assessment methods and outcomes in a more accessible way.

Since the directed snow crab fishery was closed last year, the primary source of new information for the assessment was the 2023 EBS bottom trawl survey. Survey results indicated continuing low abundance of snow crab, with little evidence of stock rebuilding. There are some indications of recruitment to the population, but it will be several years before these crab are available to the fishery. A concerning feature of the 2023 survey results was the very low abundance of the mature biomass of both sexes, as well as the exploitable portion of the stock. All these estimates were the lowest in the survey time series.

The SSC acknowledges the stock assessment author's efforts and innovation in advancing stock assessment methods for snow crab. Several important changes were evaluated in stepwise fashion in this year's assessment. The first model change (Model 23.2) was to use the survey estimates of the probability of molt to maturity directly in the model, rather than to estimate the maturation curve in the model. Next, several models explored how the BSFRF survey data were used in the assessment to inform the selectivity and catchability of the summer EBS bottom trawl survey. One model (Model 23.3) included the derived selectivity/catchability estimates directly in the model, while another model (Model 23.3a) used these selectivity estimates as priors in the model. Both the change in modeling maturity and modeling survey selectivity brought information into the assessment in a more direct way. The use of a selectivity prior also allows the model to deal appropriately with the uncertainty in the BSFRF survey data. A final model (23.3b) looked at loosening the prior for natural mortality, but the resulting estimate was not consistent with snow crab longevity and this model was not considered further.

Model 23.3a did not show problems with model stability, model convergence (multiple minima), or strong retrospective patterns that have been a problem in previous snow crab assessments. The assessment author and CPT agreed that Model 23.3a should be the basis for providing management advice. Nevertheless, there are several aspects of the model fit that suggest additional refinements are needed. In some years, Model 23.3a overpredicts the larger males in the total and retained size compositions. In addition, results for Model 23.3a show a substantial revision upwards in the estimates of fishing mortality throughout the time series, in some years to very high levels. This suggests that historical exploitation rates for this stock have been much higher than intended. However, the catch over exploitable biomass ratio (called realized exploitation rate in the SAFE chapter) is not as extreme, though still relatively high. **The SSC acknowledges the substantial improvements to the assessment and agrees with the assessment author and the CPT that Model 23.3a should be used for management advice.**

Snow crab is classified as a Tier 3 stock because the assessment is a size-structured model that allows estimation of proxies for F_{MSY} and B_{MSY}. The OFL for a Tier 3 stock uses these proxies in a harvest control rule that specifies the fishing mortality as a function of mature male biomass. The F_{MSY} value sets the fishing mortality rate, while B_{MSY} is the inflection point where the fishing mortality is ramped down in response to low stock size. B_{MSY} is also important for determining stock status: $\frac{1}{2}B_{MSY}$ is the minimum stock size

threshold below which the stock is overfished. B_{MSY} is also the target stock size for rebuilding plans if the stock is overfished, as is currently the case for snow crab. The default proxy for F_{MSY} is $F_{35\%}$ and the default proxy for B_{MSY} is $B_{35\%}$, considered as 35% of unfished mature male biomass.

A major issue with Model 23.3a is that the value of $F_{35\%}$ is extremely high, and would effectively remove all the industry preferred crab from the population. This occurs because snow crab mature at a smaller size than the size at which snow crab are retained by the fishery, so there is a component of mature males that are protected from fishing mortality. This was already an issue in the base model (23.1), but was further exacerbated in 23.3a as the effective maturity was moved to younger males and the length of full selection increased with the addition of the empirical terminal molt probabilities. The analysis that provided the basis for the $F_{35\%}$ harvest rate (Clark 1991[1]) assumed that maturity and fishery selection curves were the same, but also considered scenarios where maturation occurred earlier than fishery selection. The extreme mismatch between maturation and selectivity seen for snow crab was not considered in Clark (1991). Furthermore, this mismatch was not found to be an issue when the analyses were done to support adoption of the tier system in the crab FMP. Therefore, potential alternatives to $F_{35\%}$ should be considered for snow crab in the future. It is important to note that this flexibility is built into the crab FMP, which indicates that alternative values to the default reference points $F_{35\%}$ and $B_{35\%}$ can be recommended by the SSC based on best available information.

The assessment authors and the CPT evaluated several options for setting the OFL and determining status, including using natural mortality (M) instead of $F_{35\%}$ and replacing $B_{35\%}$ with average MMB for 1982-2022. The terminology adopted by the assessment author and the CPT (and discussed at the Simpler Modeling Workshop) in referring to these alternatives is potentially misleading, in that the options represent modifications to the Tier 3 harvest control rule, rather than different versions of the Tier 4 control rule. A Tier 4 calculation was also provided using survey estimates of industry preferred biomass (>101 carapace width). Since the model was considered suitable for providing management advice, the CPT focused on options that used model estimated reference points, rather than the Tier 4 survey calculation. The SSC had previously requested the Tier 4 approach using survey biomass as a "fallback option" when the model has insurmountable problems and cannot be used for management, as well as a way to provide context for Tier 3 estimates. The authors used the terminal year survey MMB decremented for natural mortality instead of using the REMA model on male survey biomass. The SSC noted that this number was on a different scale than was requested and noted that the MMB used was much smaller than the model estimated MMB. The SSC requests for future years that the authors bring forward the Tier 4 estimate using vulnerable male survey biomass and the REMA model, and do not correct for natural mortality, as, for example, in the 2023 Tanner crab assessment (see also general crab comments).

The CPT and the assessment author recommended the option that used both M for $F_{35\%}$ and the average MMB (1982 - 2022) for $B_{35\%}$. The CPT put forward several arguments for their recommendation. They noted that both F=M and B_{MSY} = Average MMB are reference points for Tier 4 and are included in the FMP. They mentioned that the use of average MMB for B_{MSY} resulted in snow crab being below the minimum stock size threshold in the final year, which was better in alignment with their prior expectations of what stock status should be. They also noted that if the stock were fished at $F_{35\%}$ to equilibrium at $B_{35\%}$ there would be virtually no larger male crab that may have higher reproductive value.

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[1] W. G. Clark, 1991 Groundfish exploitation rates based on life history parameters, *Canadian Journal of Fisheries and Aquatic Sciences*, 48, Pages 734–750.

The SSC did not support replacement of M for $F_{35\%}$ in the Tier 3 OFL control rule. Due to the delayed fishery selectivity pattern relative to size composition of the exploitable males, natural mortality may be an extremely conservative harvest policy, and it would not be advisable to adopt without further evaluation.

The SSC also finds weak support for moving to average MMB for the B_{MSY} proxy as $B_{35\%}$ provides a reasonable reference point. The stock has varied above and below $B_{35\%}$ primarily due to recruitment variability that does not appear directly associated with harvesting. Indices of female reproduction have remained high, and the proportion of large males in the population has remained stable even while overall abundance has declined.

The SSC recommends that the OFL be based on a Tier 3 calculation using Model 23.3a. Due to concerns about the very high fishing mortality rate for $F_{35\%}$, and uncertainty about the reproductive capacity of small males, the SSC recommends an ABC buffer of 50%. This buffer results in an ABC that is lower than last year's ABC. Addressing the concern about the high $F_{35\%}$ fishing mortality rate is the highest priority for the snow crab assessment.

Overfishing is not occurring for snow crab, and the stock is above the minimum stock size threshold, but will remain under a rebuilding plan until it has rebuilt to the B_{MSY} level.

In addition, the SSC encourages the author to consider the following avenues for further improvements to the model:

- **The SSC strongly supports the plans of the CPT to evaluate other metrics for reproductive output.** The CPT may want to consider a multi-attribute measure of reproductive output. For example, both percent reduction in mature male biomass and percent reduction in large males could be evaluated as a function of fishing mortality.

- The SSC requests a yield analysis be done for snow crab, including the relationship between fishing mortality and catch, MMB, functional maturity, and the proportion of large males in the population. The stock production curve, i.e., yield as a function of MMB, should also be developed.

- The modeling approaches presented for snow crab were sophisticated and insightful. The SSC suggests that the authors consider greater use of the modeling structure to diagnose problems in how the data are being interpreted as opposed to more generally viewing resulting models as potential options for management. Sensitivity and other exploratory approaches using the model should be conducted and presented diagnostically to inform a smaller set of self-consistent models for management considerations.

- One idea for statistical exploration regarding the shape of the within-model empirical smoothed estimate of selectivity would be to examine to what extent the spatial distribution of differences in availability of small and large crab (or males and females) would be sufficient to explain the anomalous shape of the survey selectivity curve.

- The SSC still requests an analysis of the probability of maturing/terminal molt which treats years as random effects. A hierarchical fit to molt data might be better than annual independent GAMs.

- The SSC would like to better understand the sampling design for molt data and is concerned about the weighting of the spatial samples in the analyzing; weighting should be based on abundance if the sampling rate differs by area (which it would, unless abundance were uniform and/or the targets were in direct proportion to abundance). Hierarchical fit to molt data might be better than annual independent GAMsS.

- Figure 23 on page 73 of the SAFE report shows the decline in CPUE over a season by statistical area and year. This represents a kind of depletion experiment, suggesting that total mortality (Z) could be estimated from the linear parameters representing each line. This might help determine spatial patterns in F, indicate the natural bounds for F and M, and assist in determining stock status.

- Providing a clear crab specification narrative would help the SSC and the public navigate the tiers, models, and justifications for both. In addition, it would be helpful to clearly identify models that are being explored for diagnostic purposes as opposed to models that are directly relevant for use in decision making. Public testimony indicated that help and financial support for developing such a narrative might be available.

- Regarding the missing socioeconomic indicators coded as NAs in Table 1b (page 123 of the SAFE report), while having all general socioeconomic indicators in one table would seem useful, the labels "low", "neutral" and "high" are not ordered consistently enough across categories to provide a quick good/bad assessment as the stoplight approach does in Table1a. So, in addition to considering remedies for that (is high good or bad?), consider separating quantitative metrics from qualitative metrics. Putting these two types of metrics in separate tables might help in interpreting the information, and if the stoplight coloring is used, putting the quantitative value within the colored box may also help succinctly present the information.

Recognizing the extensive work on major issues completed in this assessment this year, the SSC looks forward to a more complete document next year, including figures of composition residuals. The SSC also reiterates several recommendations from 2022 that were not addressed this year (these bullets are directly quoted from the October 2022 SSC report):

- VAST modeling of trawl survey data including both the NBS and EBS should be prioritized. This could help understand some of the inconsistent recruitment/growth trends observed in recent years as well as prepare for potential changes in stock distribution or productivity under future warming of the Bering Sea. VAST modeling should evaluate alternative error distributions and other model configurations as appropriate.

- Investigate whether there is information outside the assessment model (e.g., larval or post-settlement data) or in the model supporting estimated skewed sex-ratios at recruitment.

- Avoid connecting 2019 and 2021 when plotting survey time-series (e.g., Figure 14) as there were no data in 2020.

- Report the scale of standardized residuals where plotted (e.g., Figures 42 and 43).

Bristol Bay Red King Crab

The SSC received a summary of the CPT report as well as an overview of the BBRKC stock assessment . The SSC received written testimony from Jamie Goen (ABSC), Scott Goodman (BSFRF), Kristin Stahl-Johnson (OceanPeople Resources) and Braxton Dew. There was no oral testimony.

Trawl survey results from 2023 indicated continued low biomass and abundance of the BBRKC stock relative to historical levels. Surveys observed a 22% decrease in mature male abundance from 2022, a 35% increase in immature males, and a 16% decrease in immature females. A 46% increase in mature female abundance was seen in the 2023 survey; however, 37% of the survey catch was attributed to a single survey station. Re-tows, intended to provide additional samples of mature females were not conducted, as only 6% of females sampled in June had not yet molted and mated. The directed fishery for BBRKC was closed by the State of Alaska during the 2021/22 and 2022/23 seasons based on mature female abundance below the State management threshold of 8.4 million.

Results and evaluation of three models were provided: the accepted model in 2022 using a newer version of GMACS (21.1b) and a fixed value of male natural mortality (0.18), an alternative model developed last year using 1985 as the start year (22.0), and a model estimating a base level of male natural mortality (0.23, with a very tight prior distribution, SD=0.04, centered at 0.18) for the entire time-series (23.0a).

In discussions of the pros and cons of truncating the time series, the SSC recognized the uncertainty in early survey methods, and the additional complexity needed to model the transition from high to lower biomass levels attributed to an elevated period of natural mortality in the early 1980s. The SSC noted that despite uncertainty in the actual dynamics during this period, the current status and reference point calculations did not depend heavily on the modeling choices (the recruitment period for calculating B_{MSY} is 1985-2022), as shown by the very similar results from Model 22.0.

The SSC supports the CPT and author's choice of Model 23.0a for specifications. The results of this model place the stock in Tier 3b. This stock is not estimated to have been experiencing overfishing, and the stock is not overfished. Based on the projections of recent low recruitment (2013-2022), the BBRKC stock is not approaching an overfished condition. The SSC recognizes that this stock has had sustained low recruitment over the last decade. The SSC acknowledges that there is a growing disconnect between the slowly shifting reference points estimated in the stock assessment, as each assessment adds one additional year of recruitment to the estimated B_{MSY} calculation, compared to the approach used by the State that does not annually update the recruitment series and includes a fixed mature female abundance threshold in place since 2003. Even with no change in biomass or recruitment, eventually the stock in this assessment will approach the decreasing estimate of B_{MSY} due to including additional (and recently very low) recruitments as they occur. This may lead to a potential continued divergence between federal stock status and State management thresholds.

The SSC supports the CPT recommended buffer of 20%, based on the large retrospective pattern, the very tight constraint on both M and Q and the poor fit to the BSFRF data as the major concerns in this model. The SSC recognized the importance of low biomass/abundance and recent recruitment, but noted that it is already included in the assessment model results and control rule application and so should not be 'double counted' in the consideration of the ABC buffer. **The SSC requests that the author provide the basis for the extremely tight priors on M and catchability, and in the next assessment present models with more flexibility in both of these parameters.** Ideally these alternatives would be constructed after addressing the truncated size bin structure of the models which currently accumulates a much larger fraction of the large crab in the last bin than is preferable for these types of models and may be affecting the ability to estimate M and/or other dynamics. During the evaluation of catchability, the SSC encourages consideration of availability as it relates to the unknown stock structure (e.g., potential connection to the northern district) in addition to gear catchability, which appears to be the primary information currently informing the very tight prior.

The SSC thanks the author for providing the Tier 4 calculation using the REMA model, and defining the vulnerable biomass as legal male biomass plus the crab within approximately one molt of legal size, exactly as requested, for comparison with the Tier 3 results.

The SSC had a considerable discussion regarding the potential value of geostatistical models for crab stocks, noting that initial work was problematic, but that unbalanced survey designs and highly skewed catch rates (such as the single large tow of mature females observed in 2023) might benefit from model-based estimators. As noted in the General Comments for Crab stocks, the SSC suggests that the CPT and crab authors continue to evaluate whether VAST or similar approaches, when specified carefully for individual crab stocks (i.e., the choice of error distributions and number of knots) might provide more robust survey time-series.

The SSC noted that some indicators showed predictive power in the Bayesian adaptive sampling results included in the ESP and suggested further consideration of when such promising indicators should be quantitatively investigated in the assessment model or used to inform assessment model inputs.

The SSC offers the following additional recommendations, including those from 2022 that were not addressed in this assessment:

- The SSC suggested tracking increases in Dungeness crab abundance in the EBS and discussion of whether/how this might affect BBRKC dynamics.

- Consider using the BSFRF data as a prior on selectivity/catchability as was done in the snow crab assessment

- Continue work on stock structure, possibly including a combined model of Bristol Bay and the northern district

- Explain why equal sample sizes are used for male and female composition data

- The SSC appreciates the MCMC outputs for examining the probability of going below reference points, but requests that some basic MCMC diagnostics such as autocorrelation plots and parameter chains be included.

- The SSC recommends investigation of the highly biased fits to the BSFRF index and suggests that the current approach of inflating the variance to account for lack of fit is inappropriate when obvious bias is present.

- The SSC suggests further exploration of the effects of the apparent recruitment observed in the 2011 survey that was not subsequently observed in later years, with particular attention to whether this could be contributing to the retrospective pattern and/or bias in the fit to other data.

Pribilof Island Blue King Crab

The SSC received a presentation on the stock assessment for Pribilof Island Blue King crab (PIBKC) and recommendations for harvest specifications. There was no public testimony.

The PIBKC stock is assessed biennially. The last full assessment was in 2021 and therefore, a full assessment was conducted in 2023. The assessment for this stock uses the R package *rema* to implement a survey averaging random effects model to smooth NMFS bottom trawl survey estimates in mature male biomass (MMB). The underlying model structure was the same as used in 2021 (approved in 2015) even though the implementation of the model switched from ADMB to TMB. The directed fishery has been closed since 1999/2000, and the stock was declared overfished in 2002. The survey MMB time series and related data for PIBKC were updated with results from the 2022-2023 NMFS EBS shelf bottom trawl surveys and the 2020/21-2022/23 crab and groundfish fisheries for retained and discarded catch. Status determination is based on the Tier 4 approach, while a Tier 5 approach is used for determining an OFL.

The B_{MSY} proxy for this stock is based on MMB at mating from 1980/81-1984/85 and 1990/91-1997/98. The projected MMB at mating for 2023/24 (0.18 kt) remains well below the MSST (2.1 kt), placing the stock in Tier 4c. There is no directed fishing. The stock remains overfished with no signs of recovery. Overfishing is not occurring.

Given continuing concerns for the stock with regards to lack of recruitment, the CPT recommended continuing with the 25% ABC buffer as used in previous years. The 25% buffer acknowledges the low

status of the stock, the accommodations made in the rebuilding plan to set the OFL, and the current status of low bycatch in non-directed fisheries. **The SSC agrees with this recommendation.**

These recommendations represent no change from the last specification and **the SSC agreed with the CPT-recommended OFL and ABC for 2023/24 and 2024/25**.

The population is at very low levels. Given the low survey catch levels, the SSC suggests that the frequency of full assessments might be reduced, with continued monitoring of survey catches. This could be discussed during the January CPT meeting, as part of a stock prioritization process across stocks.

The SSC had the following additional comments:

The SSC continues to look forward to the report on the blue king crab stock structure template in the near future.

The SSC recommends exploring the strengths and weaknesses of the current methods (bottom trawl surveys) for surveying PIBKC – acknowledging the capacity and budgetary constraints of implementing other survey methods.

There were no mature males caught in the 2023 NMFS bottom trawl survey and only seven mature females. The assessment is conducted using the *rema* model with an NA for mature males substituted for the zero that was observed in the survey. The author tried two alternative approaches. A simple work-around, replacing the zero with a small constant, such as the smallest non-zero value in the time series, was sensitive to the exact value used. The author also explored the use of the Tweedie distribution, as opposed to the lognormal, for the random effects model, and while it seemed to work for the single assessment, the model had trouble converging. The SSC noted that the Tweedie can easily be over-parameterized and that James Thorson (NOAA-AFSC) uses a reduced version known as a Compound Poisson Gamma (CPG). The SSC recommends continued exploration of the Tweedie or other alternative distributions for use in the *rema* smoother.

Tanner Crab

The SSC received a presentation on the 2023 stock assessment for the Tanner crab stock in the Bering Sea. Public testimony from Jamie Goen (Alaska Bering Sea Crabbers) suggested that the CPT-proposed 5% increase in the ABC buffer for 2023/24 was not justified, given that the concerns articulated by the CPT in support for the buffer increase are not new or elevated for 2022/2023 and therefore do not warrant increased precaution.

The SSC appreciates efforts by the author to address past SSC comments. The Tanner crab stock has been considered under Tier 3 since the 2012/13 assessment cycle given the informative nature of fishery, survey, and life history information for this stock. The SSC highlights that the 2022/23 TAC set for Tanner crab by the State of Alaska, when combined across east and west areas, remains significantly below the OFL.

The 2023 EBS shelf bottom trawl survey yielded promising signs for new recruitment, in terms of increased abundance of small male crabs in the area west of 166 longitude and female crab across the EBS shelf. However, the author and CPT discussion clearly highlight that caution is warranted given that several recent cohorts first observed as 25-50 mm carapace width crab in the 2017-2019 surveys, initially appeared strong but failed to materialize as older mature or industry-preferred crab.

The author proposed and the CPT endorsed Model 22.03b, which is the accepted model from 2022 with a small update to address a parameter describing the slope of the fishery retention probability curve (2005/06-

2009/10) that was formally estimated at a bound. The author has convincingly demonstrated that this small change has at most negligible impacts on model fits to data.

Overall, Model 22.03b exhibits reasonable fits to most indices of abundance and to removals in the directed and bycatch fisheries. Fits to length composition data in the recent period remain a concern, exemplified by large negative residuals in length composition fits for the largest observed length bin in recent years and as a strong positive retrospective pattern in recruitment. **The SSC supports usingModel 22.03b for 2023/24 harvest specifications. Based on this model B/B$_{MSY}$ is 1.34, placing this stock in Tier 3a.** The BSAI Tanner crab stock is not overfished, nor is it subject to overfishing.

The CPT recommended a buffer between maxABC and ABC for this stock of 25%, a 5% increase from the 2022/23 buffer, based on the uncertainty in recent recruitment events and overestimation of large crab, uncertainty in the population trajectory and a lack of recent cohorts reaching large size. However, the SSC recommends a buffer of 20% given that, despite uncertainty in recent recruitment events, the current influx of small crab is both high in magnitude and extensive across space beyond the southern extent of the cold pool. Moreover, the current assessment model structure seems to provide a reasonable fit to index, composition, and harvest data with limited bias.

With respect to the spatial distribution of Tanner crab captured in the NMFS bottom trawl survey, the SSC appreciates the inclusion of Figures 38-42 which highlight both the large number of small male crab encountered in 2023 and the spatially expansive nature of that increase in CPUE. The SSC encourages exploration of differences in the spatial distribution of small male crab in the NMFS survey, to identify if the distribution of small crab encountered in 2003-2005 and 2008-2010, which successfully propagated to larger sizes, showed differences in habitat use compared with the cohort first observed in 2017-2019, which did not propagate to larger sizes. Likewise, the SSC recommends that a comparison of environmental conditions experienced by small crabs during these periods may help to elucidate why some cohorts appear to propagate and others do not.

The SSC recommends the author consider the following avenues for further improvements to the assessment:

- Explore what might be driving the residual pattern in the fit to the NMFS survey data.

- Consider using the Bering Sea Fisheries Research Foundation (BSFRF) survey data to inform selectivity and catchability, as implemented in the EBS snow crab assessment, as an alternative to fitting these data as a separate index

- Consider directly incorporating annual molt to maturity data, as implemented in the EBS snow crab assessment, if sufficient data are available.

- Briefly summarize the history of the GOA Tanner crab fishery and stock dynamics, given the possible value of this information for the interpretation of BSAI Tanner crab stock dynamics.

The SSC appreciates the author's development of a simplified Tier 4 model for use as a backup in the event that extreme and insurmountable issues are encountered by the Tier 3 assessment model in the future. The SSC supports the structure of the Tier 4 model as presented, based on the estimate of vulnerable male crab biomass from the NMFS EBS bottom trawl survey and including the use of the coefficient of variation in projected biomass as a reasonable basis for defining the ABC buffer. **With respect to the reference time period for calculating B$_{MSY}$, the SSC concurs with the CPT recommendation to use the entire time series since 1982.**

The SSC continues to support development of a parallel or simplified version of the Tanner crab assessment model in the GMACS platform, and the author's proposed development timeline in fall 2023.

Overfishing Status Updates

The SSC received overfishing status updates for Aleutian Islands golden king crab (AIGKC), Pribilof Island golden king crab (PIGKC), Pribilof Island red king crab (PIRKC), Western Aleutian Islands red king crab (WAIRKC), and St. Matthew blue king crab (SMBKC). Total catch mortality for each of these stocks was below the OFL, so overfishing did not occur in 2022/2023 (2022 for PIGKC because specifications are on a calendar year basis). Estimated MMB for SMBKC is below MSST; therefore, this stock remains in an overfished status and under a rebuilding plan. The next full assessment of SMBKC will be in 2024. PIRKC and AIGKC estimated MMB are above MSST and are not overfished. Both WAIRKC and PIGKC are Tier 5 stocks, and an overfished status determination cannot be made.

Norton Sound Red King Crab Model Runs

The SSC received a presentation on the Norton Sound red king crab (NSRKC) model runs proposed for consideration in January 2024. The NSRKC assessment employs a length-based model with 8 male length classes. Abundance estimates are made for males with CL ≥64 mm to CL ≥134 mm portioned by 10-mm length intervals (8 length classes). The model treats new shell and old shell male crab separately but assumes they have the same molting probability and natural mortality.

The author proposed to bring forward two models for review. Model 21.0, the status quo model, uses a length dependent M, fixed at 0.18 for crab with CL <124 mm and estimated for crab >124 mm CL. Model 23.0 is identical except that M is fixed at 0.41. **The SSC endorses the CPT's recommendation that both of these models be brought forward for review. The SSC concurs with the CPT recommendation to remove shell condition from the models owing to challenges with accurately identifying new and old shell animals.**

The SSC supports the CPT's recommendations regarding the sampling approach used in the ADF&G survey. These include providing maps of all of the survey years in all future assessments, adding a figure that shows how many stations were used for each year to develop the index of abundance, comparing the index of abundance currently used to an index of abundance based only on stations that were consistently sampled over the length of the time series, and a comparison of the current index of abundance to one developed using the VAST model.

The CPT and the SSC questioned the use of 0.18 as a fixed natural mortality for crab with CL <124mm. This value is no longer used for other RKC stocks. The SSC supports the CPT recommendation to explore using existing tagging data to estimate maximum age and use it in the Barefoot Ecologist's natural mortality calculator. This may provide a prior with which to estimate natural mortality within the assessment.

The SSC discussed the limited resources available to support the development of a small-scale observer program aimed at improving catch accounting and discard mortality estimates. The SSC continues to have concerns about this but understands the choice to prioritize the Norton Sound ADF&G trawl survey at this time given its importance in the assessment.

The SSC appreciates the efforts of the author to address our previous recommendations and continues to encourage the implementation of GMACS in the near future for NSRKC.

BSFRF Research Update

The SSC appreciates the updates provided on research conducted by the Bering Sea Fisheries Research Foundation (BSFRF) and their written comments submitted under C1 BSAI crab. The research conducted by this group provides critical information needed to improve management of BSAI crab stocks and is currently incorporated into several assessments in a variety of ways. Current BSFRF work is focused on a cooperative winter pot survey for BBRKC. The SSC looks forward to seeing additional results from this survey, as scheduling dictates. Planning for a second pot survey in 2024 is underway. The SSC appreciates the direct connections between the NPFMC research priorities and this group's research focus. This is a great example of these connections. With regards to the questions addressed specifically to the SSC on the BSFRF's priorities provided in the written comments, the SSC notes that their questions align with recent SSC requests and discussions, and that the Council as a whole is making some progress on these questions.

Crab Plan Team Vacancies

The SSC notes that the CPT has some key team vacancies in management expertise and stock assessment, as well as a social scientist. The SSC supports the CPT filling these gaps in the team as soon as possible. The SSC also noted that a stock assessment scientist that is familiar or involved with groundfish assessments would be valuable for sharing expertise across Plan Teams.