C1 BSAI Crab

The SSC received a detailed report on the September 2022 Crab Plan Team (CPT) meeting from Sarah Rheinsmith (NPFMC) and the CPT co-chairs, Mike Litzow (NOAA-AFSC) and Katie Palof (ADF&G). Cody Szuwalski (NOAA-AFSC) presented the Eastern Bering Sea (EBS) snow crab assessment and rebuilding plan projections. 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 received considerable oral public testimony on BSAI crab harvest specifications under multiple stocks. These include: Frank Kelty (City of Unalaska), Edward Poulsen, Craig Rose (FishNext Research), Heather McCarty (Central Bering Sea Fishermen's Association; CPSFA), Mateo Paz-Soldan (City of Saint Paul Island), Craig Lowenberg, Joshua Songstad (F/V Handler), Cory Lescher and Jamie Goen (ABSC), Scott Goodman (Bering Sea Fisheries Research Foundation; BSFRF), Gretar Gudmundsson, Lenny Herzog (Homer Crab Cooperative), Keith Colburn, and Siri Dammarell. Additional written testimony was provided by Scott Goodman (BSFRF), Cooper Curtis (Highmark Marine LLC), Scott Campbell (F/V Seabrooke, F/V Lady Alaska), Clint Moudy (Kodiak Hydraulics Inc), Calista Songstad (Compass Rose Fisheries LLC), Heather McCarty (CBSFA), Gabriel Prout (F/V Silver Spray), Mikal Mathisen (F/V Karin Lynn), Jamie Goen (Alaska Bering Sea Crabbers; ABSC), Gary Painter (F/V Trailblazer), David Wilson (F/V Keta), Mike Shelford (Shelford's Boat Ltd.), Ty Warnock, Joshua Songstad (F/V Handler), Dennis Scates, Craig Rose (FishNext Research), Oystein Lone (Lone Larsen LLC, Lone Shelton LLC, F/V Pacific Sounder, F/V Confidence), Neal Hillstrand (F/V Time Bandit), Jonathan Hillstrand (F/V Time Bandit), and Andrew Hillstrand (F/V Time Bandit).

The SSC appreciates the extensive public testimony on BSAI crab agenda items that reiterated the unprecedented and difficult situation before the NPFMC. Public testimony is characterized under the specific BSAI crab sections below. The SSC recognizes that the severe economic consequences of the potential closures of Bristol Bay red king crab (BBRKC) and EBS snow crab stocks and reduced catch limits in other stocks would be devastating to fishermen, small businesses and communities that strongly rely on crab fisheries. While the SSC is charged with setting harvest specifications based on the best available science, it also acknowledged the impacts that these specifications will have. Although the EBS appears to be returning to cooler environmental conditions in 2021/22, the SSC noted that crab stocks face increased uncertainty in a changing climate.

The SSC noted that federal OFL and ABC determinations for crab are generally based on mature male biomass, but in cases like BBRKC, state management also accounts for the need to maintain female biomass (threshold for female biomass). This creates a disconnect between the population assumptions and biological considerations in the model and in the State harvest control rule (HCR; see also BBRKC section below). **The SSC recognizes the need to protect female crab and their habitat and supports collaborative approaches between federal and State agencies to fully account for the reproductive potential of crab stocks in stock assessment models**, while recognizing that management is primarily for mature male crab. The SSC also supports collaboration to make crab assessment models as informative as possible for State management.

The SSC supports the CPT plans to discuss appropriate model start dates as well as reference periods for B_{MSY} (e.g., SMBKC and PIRKC) at their January 2023 meeting to provide guidance to stock assessment authors. The SSC recommends that the CPT explore a consistent approach across all EBS stocks to use trawl survey data after 1982 when gear and sampling designs were more standardized.

With regards to the timing of crab assessments, the SSC appreciates the discussion at the CPT to explore shifting harvest specifications for EBS snow crab to December and supports this exploration. In addition to the possibility of shifting harvest specifications to December, **the SSC encourages crab authors to continue to move as much of the research and model development as possible to earlier in the year**, as this would streamline reviews in the fall and facilitate the use of VAST models and inclusion of Northern Bering Sea (NBS) survey data into crab assessments.

The SSC encourages further considerations or ideas on potential cooperative pot surveys for different crab stocks, as suggested in public testimony.

Crab models have become increasingly complex over time, and model parsimony is a key goal for assessments. It is difficult to balance this with the need to account for the complex dynamics of crab populations. For multiple crab stocks, the SSC suggests that fitting a range of simpler models and data limited approaches, such as the Tier 4 calculation, can also provide insight into the differences between raw survey observations and integrated assessment model output. This would highlight the information available on natural mortality, which demographic components of the biomass are most important, which years are representative of MSY, and how catchability affects the scaling of the model estimates. **The SSC recommends a working group to address the use of simpler models for at least snow crab, Tanner crab and BBRKC.** This effort is intended to fundamentally support the use of Tier 3 size structured models such as GMACS, not replace them, and may help inform pathways toward greater model parsimony and stability. The move to GMACS that has been implemented or recommended for many crab stocks should give authors an opportunity to start from a simpler base model and add features, rather than continuing to replicate legacy model complexities in GMACS. The SSC further recommends that the working group include State scientists, in an effort to explore whether any inconsistent approaches between Federal assessments and State harvest control rules or TAC-setting considerations are based on scientific considerations that could be reconciled.

The SSC recommends the formation of a working group to develop a framework for how to estimate the magnitude of unobserved mortality for crab stocks and how these estimations may be utilized in BSAI crab stock assessments. The SSC acknowledges that there are studies informing some of the inputs needed for this analysis, but that a framework for the calculations should be very explicit about each of the data sources and assumptions needed. There may be multiple approaches, perhaps including the spatial overlap of stock and various fisheries, the mortality rate of interactions and/or the ratio of unobserved to observed encounters.

The SSC recommends that all crab authors plot length compositions over years with the most recent year at the bottom of the plot.

Ecosystem Status Report Preview

The SSC received remote presentations from Elizabeth Siddon (NOAA-AFSC), Ivonne Ortiz (NOAA-AFSC), and Bridget Ferriss (NOAA-AFSC). There was no public testimony. The SSC thanks the presenters for their efforts in providing excellent, targeted information related to crab stock assessments. In particular, the SSC greatly appreciates the presentation of slides with the "big picture" summary at the top, and then supporting information provided below in highly condensed form. The new format resulted in a smooth, clear, efficient presentation.

In general, there were no new major environmental concerns reported to date in 2022. The major climate indices were in the normal range, with indications that the marine heatwaves were of less concern in the GOA and EBS but continued in the Aleutian Islands (AI).

Eastern Bering Sea

The authors provided a highly condensed discussion of ecosystem aspects that have the potential to influence crab stocks in the EBS marine ecosystem. Although the Arctic Oscillation has been positive since spring 2021, 2021-2022 exhibited near-normal sea surface temperatures (SST). Marine heatwaves were infrequent and brief. Winds in winter 2022 were more northerly than the long-term average, with rapid sea ice growth in November 2012 and rapid loss in April 2022. Sea ice was thinner than in 2021. The cold pool was average in extent when compared to other cool years.

For 2022, pH was relatively low over the outer and middle shelf of the EBS, and near the Bering Strait, decreasing at a rate comparable to the global oceans due to ocean acidification. **These conditions have been shown experimentally to negatively impact the growth and survival of red king crab and Tanner crab.**

Prey resources for crab in the EBS marine ecosystem appear to have been near the long-term mean. Chlorophyll-a biomass was near the long-term mean, as was bloom timing. A coccolithophore bloom was recorded, the implications of which may include longer trophic chains and reduced foraging success for visual predators. In spring 2022, copepods were more abundant than in 2021, especially small copepods. Visual inspection of collection vials suggested that *Calanus* spp. were low in lipids.

Competitors for benthic crab remained high or increased in 2022 (brittle/sea stars and other echinoderms, epibenthic fish), as did competitors for pelagic crab. Both pelagic (pollock and herring) and benthic predators of crab (Pacific cod and arrowtooth flounder) increased in 2022, and 2022 was the largest Bristol Bay sockeye run on record (>78 million). Pacific cod condition was average for the EBS survey area and was improved from the below-average condition in 2021.

Finally, the authors noted two issues of general concern in the EBS: 1) the continued failures of some salmon runs in western Alaska that impact a number of fisheries and communities, and 2) impacts from Typhoon Merbok. Typhoon Merbok circulated in western Alaska in September 2022 and caused considerable damage to coastal communities, especially hunting and fishing camps and subsistence harvests. The impacts on benthic and pelagic communities have not been investigated.

The SSC concluded that none of these physical or biological elements presented unusually problematic conditions for EBS crab stocks.

Gulf of Alaska

Based on the data available to date, there were no emerging concerns related to groundfish that need to be considered at this point in the GOA. The multi-year recovery from the marine heatwave of 2016-2018 continues, as seen with a shift to a negative Pacific Decadal Oscillation (PDO) and average summer SST warming. Lower trophic-level productivity may have been above average, while there were mixed signals concerning upper trophic-level productivity. One area of concern was the first identified presence of invasive green crab in SE Alaska, though the implications for species of concern to the NPFMC remain unclear.

Aleutian Islands

Sea surface temperatures remained high in 2022 throughout the AI, with temperatures above the 1985-2014 mean. This has resulted in an almost continuous moderate marine heatwave throughout the AIs with periodic brief periods of strong or severe heatwaves. It should be noted that the SSTs in the eastern Aleutians are well above a level that would be considered a severe marine heatwave elsewhere in the Aleutians. The ecosystem implications of these sustained high temperatures are not known.

Trawl Survey Updates

The SSC received an excellent presentation on the 2022 EBS and Northern Bering Sea (NBS) bottom trawl surveys from Mike Litzow (NOAA-AFSC). There was no oral public testimony on the trawl survey specifically; however, testimony on other crab agenda items were related to the survey. In general, public testifiers questioned the ability of the bottom trawl survey to survey crab stocks adequately and noted the disconnect between the timing of the survey and the execution of some crab fisheries. Public testimony also mentioned the need for data from the NBS, which is very challenging to incorporate in the October specifications process. **The SSC commends AFSC survey staff for completing the bottom trawl surveys in 2022 under what continue to be challenging logistical conditions.** The SSC continues to be impressed with the rapid turnaround of the survey data and is pleased to hear that efforts are underway to modernize survey data processing, including efforts to develop Vector Autoregressive Spatio-Temporal (VAST) survey estimates for crab species. The SSC also commends the crab assessment authors for updating model runs and assessments in a very short time.

In general, the combined mature male biomass (MMB) increased relative to last year but remains very low overall. **The SSC continues to register substantial concern for the BSAI crab stocks as a result of these survey trends**. However, there were a few positive signs to note. MMB for most stocks increased relative to last year, though the clear exception was EBS snow crab. There may be some incoming recruitment for several stocks, including EBS snow, Tanner, and St. Matthew blue king crab (SMBKC). However, crab stocks in general continued to be in a depressed state.

The survey found that a proportion of female BBRKC had not completed their molt-mate cycle, triggering discussions of whether re-towing should take place. After taking into consideration multiple factors, including the threshold analysis presented in May 2022, the low female biomass, and the broad distribution of females in Bristol Bay, AFSC staff made the decision not to undertake a survey re-tow. This decision was supported by the CPT. The SSC requests a re-evaluation of the consequences of re-towing for data quality, including the potential value in assessments (see request in BBRKC section below). Public testimony noted there may be benefits to re-towing when the fishery is closed. As recommended in October 2021, the SSC continues to encourage investigations into the drivers of temporal variability in the molt-mate cycle, as re-towing protocols are typically triggered in cold years.

The SSC appreciated the presentation of more detailed survey results provided for EBS snow crab. The survey trends for EBS snow crab continue to be worrisome. Legal male snow crab biomass was down 44% from 2021, which had already declined by 69% from 2019. However, there were some positive signs of incoming recruitment, including an increased proportion of new shell crabs of both sexes and a large increase in immature female biomass. Immature male biomass continued to decline, however. Another stock of concern is Pribilof Island blue king crab, another overfished crab stock, for which mature male and female biomass decreased 44% and 72%, respectively, from last year. Mature Tanner crab male biomass west of 166° also declined but increased in the eastern area. Survey biomass of mature females had mixed results.

BSAI Crab Harvest Specifications and SAFEs

Table 1 includes the stock status determination criteria, Table 2 includes the October 2022 SSC recommendations, and Table 3 details the maximum permissible ABCs and SSC-recommended ABCs. The SSC endorsed all of the OFL and ABC recommendations of the CPT (Table 2). St. Matthew blue king crab and Pribilof Islands blue king crab are overfished and under rebuilding plans. EBS snow crab are overfished and a rebuilding plan is being developed. None of the other crab stocks were overfished or approaching overfished status. None of the crab stocks were subject to overfishing.

Table 1. Stock status in relation to status determination criteria for 2021/22 as estimated in October 2022[2,3]. 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	91.6	183.1	41.2	0.23	7.5	3.6	**Overfished**
2	BB red king crab	3	12.01	24.0	16.6	0.69	2.2	0.10	
3	EBS Tanner crab	3	17.37	34.7	62.1	1.79	27.2	0.78	
4	Pribilof Islands red king crab	4	0.86	1.71	3.88	2.22	0.86	0.001	
5	Pribilof Islands blue king crab	4	2.05	4.10	0.18	0.04	0.00116	0.00	**Overfished**
6	St. Matthew Island blue king crab	4	1.63	3.26	1.2	0.37	0.05	0.001	**Overfished**
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	
9	Pribilof Islands golden king crab[3]	5					0.093	0.021	
10	Western AI red king crab	5					0.056	< 0.001	

[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. Stock status for NSRKC is determined in February.
[3] PIGKC specifications are set on a calendar year basis.

Table 2. SSC recommendations for Eastern Bering Sea crab stocks. Stocks for which specifications are rolled over between assessments (Pribilof Islands blue king crab, Pribilof Islands golden king crab and Western Aleutian Islands red king crab) or were set in February (Norton Sound red king crab) or June 2022 (Aleutian Islands golden king crab) are also included. 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 is set in February.

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	3b	0.32	183.1	1982 – 2021	55.0	0.30		0.28, 0.29	10.32	7.7	25%
2	Bristol Bay red king crab	3b	0.20	24.0	1984- 2021	17.0	0.71		0.18	3.04	2.43	20%
3	E. Bering Sea Tanner crab	3a	1.17	34.7	1982 - 2021	47.58	1.37		0.23	32.81	26.25	20%
4	Pribilof Is. red king crab	4a	0.21	1.71	2000- 2021	3.88	2.27	1	0.21	0.685	0.51	25%
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	4b	0.06	3.26	1978 - 2021	1.31	0.40	1	0.18	0.07	0.05	25%
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 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 3. Maximum permissible ABCs (maxABC) 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. For those stocks where maxABC was not calculated, OFL was used as a proxy (maxABC=OFL). Stocks for which specifications are rolled over between assessments or were set in February or June 2022 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 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	10.3	7.7
2	Bristol Bay RKC [1]	3	3.04	2.43
3	Tanner Crab[2]	3	32.76	26.25
4	Pribilof Islands RKC [1]	4	0.69	0.51
5	Pribilof Islands BKC [3]	4	0.00104	0.00087
6	Saint Matthew BKC [1]	4	0.07	0.05
7	Norton Sound RKC [4]	4	0.30	0.18
8	Aleutian Islands GKC [4]	3	3.74	2.82
9	Pribilof Islands GKC [3]	5	0.092	0.07
10	Western Aleutian Islands RKC[3]	5	0.056	0.014

Basis for P* calculation of maxABC:
[1] maxABC was not calculated for this stock therefore Max ABC = OFL as a proxy
[2] ADMB sd_report
[3] Tier 5 (90% OFL)
[4] CV on OFL

EBS Snow Crab

The SSC received extensive written and oral comments relevant to snow crab from the individuals and organizations listed in the General Crab Comments section.

Public testimony clearly expressed the interdependence of the industry across crab stocks, specifically including snow crab, BBRKC and Tanner crab. The SSC recognized public testimony made under each of these species in the context of the review for the snow crab assessment and rebuilding analysis. As highlighted by the extensive testimony, the SSC recognizes the socio-economic importance of the snow crab fishery to small businesses and communities with a strong reliance on crab fishing, processing or support services. The abrupt change in stock dynamics for snow crab – from an increasing biomass to overfished status - occurred in the absence of the bottom trawl survey in 2020. Public testimony reflected the importance of even a small fishery during rebuilding in order to maintain vessels and crews, and the need for flexible management options during the rebuilding process. **The SSC recognizes both the consequence of these large impacts and that these impacts will continue due to low abundance and fishery yield during rebuilding.**

The SSC thanks the stock assessment author and supporting analysts for their hard work and innovation in advancing both stock assessment methods and the understanding of the relationship between the EBS ecosystem and stock dynamics over the last two years. The detailed research to identify likely causes of mortality and to investigate other potential sources of change (distributional shifts or changes in survey catchability) have been crucial to support the estimation of elevated mortality in 2018-2019. The SSC notes that the timing of data availability for this assessment, in tandem with the need for a rebuilding analysis under the tight federal timeline, has precluded completing many of the previous recommendations from the SSC, and that a more thorough exploration of continued poor assessment model behavior may have been possible if more time were available between when survey data became available and assessment results were needed for review by the CPT in September.

The SSC appreciates the snow crab ESP, which has helped to provide additional context for the public testimony and the biological conditions facing the stock. The SSC offers no additional recommendations for the snow crab ESP at this time.

The SSC emphasizes that, despite missing survey data in 2020 and complex population response to warming waters, a critical conclusion from this assessment is the continued low abundance of larger snow crab in the EBS based on both the available data and modeled dynamics. This supports the explanation of a large mortality event rather than a distributional shift or change in catchability.

The author and CPT presented a lengthy discussion regarding the evaluation of models that have reached a local minimum but not the maximum likelihood estimate (MLE). The SSC emphasizes that local likelihood minima are artifacts of fallible computational tools (there are no perfect tools). With perfect likelihood minimizing tools or search algorithms, results from any solution other than the MLE would never be considered. The SSC highlights that results from local minima should not be accepted as the basis for management; only model results from the best likelihood identified through minimization, jittering or any other convergence tests should be considered. If results corresponding to the MLE for a specific model are deemed implausible (e.g., due to extremely high estimated fishing mortalities; F), then alternative model structures should be explored. The SSC notes that this type of model instability often signals key issues with respect to model complexity or conflicting and/or uninformative data. In the context of snow crab, **the results presented as Model 22.1ab did not represent the MLE and should not be considered**, other than to indicate that the likelihood surface for that model structure was challenging and that some simplification of the model might be needed to ensure reliable convergence across a range of starting conditions.

The SSC considered three options for the 2022 assessment: 1) Model 22.1 - a slightly updated version of last year's GMACS model with this year's data, 2) Model 22.1a - a solution that was considered 'close' to

the MLE based on the jittering analysis, and 3) rejecting this year's models and "rolling over" last year's OFL/ABC/stock status. Model 22.1 had poor fit due to overly restrictive initial conditions and implausibly high estimated historical fishing mortality, both of which were addressed with changes added for Model 22.1a. However, Model 22.1a, as noted by the author and CPT showed implausibly high Fs in 2020-2021, at least for the fully selected segment of the population. Further, it was not clear whether Model 22.1a was similar to the actual MLE with regard to all management quantities as was assumed by the CPT and author. The SSC would have strongly favored a model corresponding to the MLE generated during the jitter analysis. The SSC noted that these challenges did not appear to be a function of moving the assessment to GMACS, but rather related to the large number of estimated parameters and the challenge of modeling the complicated population dynamics for this species. However, the SSC highlights that the model instability observed in 2022 when the model was presented with new data is of great concern and underscores the need for continued model refinement.

After considerable discussion of the options for setting specifications, the SSC recognized the value of moving this assessment to GMACS, and of using one model for both the assessment and rebuilding analyses. **The SSC recommends basing the OFL, ABC and stock status on Model 22.1a as the best alternative available.** Based on concerns over convergence for Model 22.1a, the SSC discussed increasing the buffer recommended by the CPT (25%) by an additional 5%. After further consideration, the SSC noted that the buffer for snow crab was elevated from 20% to 25% for 2020 and 2021 due to the increased uncertainty in the population dynamics surrounding the mortality event resulting in part from the absence of a 2020 survey, which has been reduced due to an additional year of survey data in 2022. **Therefore, the SSC recommends a buffer of 25% (from the Tier 3b OFL to the ABC) reflecting the 20% value used prior to 2020 and an additional 5% accounting for the lack of results representing the MLE in 22.1a.** The SSC sees this as an interim choice and expects model results based on convergence to the MLE in the next assessment; finding ways to simplify this assessment may aid in this task.

The SSC renewed its request from 2021 for a Tier 4 calculation, intended to provide a "fall back" in case a clearly acceptable Tier 3 model is not available (as has been the case in 2021 and 2022). More broadly, **the SSC recommends a working group to explore the use of simpler models across crab stocks as noted in General Crab Comments**. For snow crab, a male-only model may also be worth exploring as part of this effort.

The SSC strongly supports consideration of moving the snow crab assessment to December, noting that the October timing remains problematic for crab assessments due to insufficient time to address unexpected problems and a lack of availability of NBS data for inclusion in the assessments. The SAFE report and author's presentation to the SSC repeatedly highlighted how the limited timeframe precluded a more thorough analysis of model instability issues in 2022. The SSC encourages consideration of ways to move more of the research and model development to the spring, so that fewer model changes are needed in the fall when the new year of data is added.

The SSC highlighted several recommendations from previous reviews and a few minor suggestions to the document:

- 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.

- Explore ways to simplify the number of selectivity parameters, particularly the selectivities used for the BSFRF data, especially in reducing the number of estimated parameters while still informing the relative selectivity and catchability of the NMFS trawl survey.

- Continue to investigate an appropriate definition of maturity to describe the reproductive output of the stock. This issue highlights the unknown importance of the NBS, where a large proportion of the biomass (relative to the EBS) is composed of morphometrically mature males that are smaller than commercially preferred crab. Direct biological research is needed on this topic.

- 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 42-43).

Bristol Bay Red King Crab

The SSC warmly welcomes Katie Palof (ADF&G) as the new lead author of BBRKC assessment and extends its appreciation for the concise and informative presentation. The responses in the document to the SSC and CPT were thorough and detailed.

Public testimony was received from Joshua Songstad, Jamie Goen (ABSC), Cory Lescher (ABSC), Oystein Lone, Lenny Herzog (Homer Crab Cooperative), Keith Colburn, Scott Goodman (BSFRF), and Siri Dammarell. Most significantly, the testimony highlighted the devastating social and economic impacts of the low crab stocks and closures and the need for flexibility to have small open fisheries if possible. The needs for continued improvements in data in response to climate change and transboundary movements were also highlighted.

The SSC notes that, when there is a new assessment author, it is generally prudent to introduce minimal changes to the inherited model, as done here. The SSC supports the exploration of starting the model in 1985 (models 22.0 and 22.0a) instead of 1975 (Model 21.1b). This change eliminates the high M and high recruitment period that have high uncertainty and have been frequently questioned by the CPT and SSC. The later starting point resulted in negligible changes in the reference points or shared recruitment estimates, so this change seems pragmatic and parsimonious. In addition, 22.0a reduces the retrospective trend slightly and fits the data better than the other two model alternatives.

However, the SSC supports the author and CPT recommendation to evaluate the most appropriate starting date for survey data and time periods used for recruitment when calculating reference points at their January CPT workshop as noted in the SSC's General Crab Comments before accepting a new starting point for this assessment. **Therefore, SSC agrees with the CPT recommendation to use Model 21.1b for specifications with a 20% buffer between the OFL and ABC.** The SSC recommends that the series of low recruitments and low survey biomasses should not be used in the rationale for this buffer since their associated uncertainty is already included in the model. However, due to an increasing and substantial retrospective bias, the continued use of the 20% buffer is appropriate.

Given the current status of the fishery and the transition to a new lead author, the SSC encourages the authors to bring forward new explorations as they become more familiar with the data and model. Specifically, **the SSC recommends that a high priority be placed on trying to isolate factors that reduce the retrospective bias in mature male biomass.** The authors provided a likelihood profile for M showing that the maximum likelihood value for M appears substantially higher than the value used in the assessment, and similar for both males and females. Fixing male and female M at this value and running a retrospective analysis would help determine if this is contributing to the bias. In addition, we encourage the authors to consider other possibilities such as the very tight prior on trawl survey catchability derived from Weinberg et al. (2004), and the value of estimating the sex ratio.

In addition, the SSC provides these comments and longer-term recommendations for BBRKC.

- The SSC looks forward to the stock structure template being applied to all EBS red king crabs.

- 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 supports cooperative research between the BSFRF, NMFS and ADF&G on tagging to examine hypotheses regarding spatial shifts in distribution.

- The SSC appreciates the BBRKC ESP and encourages further exploration of predation and community indicators for this stock.

- The SSC recommends that the authors consider the contributions of crab found to the north of the management area to this stock and consider the implications of including crab from this area for the assessment and sustainability of the stock.

- The accumulation of large males and particularly large females in the plus group indicates length bin groups may need to be re-evaluated.

- The SSC noted that the State and NMFS determined that the survey re-tows would not be conducted in 2022, despite meeting the threshold to do so. The SSC requests an examination from the assessment author of the potential value of these re-tows, and whether re-tows provide a more or less accurate index of abundance.

Pribilof Island Red King Crab

The SSC received a presentation of the 2022 Pribilof Island red king crab (PIRKC) stock assessment. There was no public testimony. This is a Tier 4 stock, and the assessment was moved to a triennial cycle in 2019. The assessment is implemented using GMACS and uses a B_{MSY} proxy defined as 35% of the average model estimated mature male biomass (MMB) from 2000 to present. The directed fishery was closed in 1999.

Three assessment models were presented. The base model 22.1, which is the approved 2019 model (19.1) updated with new data; Model 22.1a, which adds bycatch size composition and estimated bycatch selectivity to Model 22.1; and Model 22.1b, which adds a constant estimated growth increment, consistent with other king crab stocks, to Model 22.1a.

The author's preferred model was 22.1b based on inclusion of bycatch size composition data, fits to the data sources and a more biologically realistic parameterization of the molt increment. The CPT endorsed the author's preferred model for specifications and recommended retaining the 25% ABC buffer used in the previous assessment (2019). This level of buffer is used with other low information king crab stocks (SMBKC, PIBKC). **The SSC concurs with the author- and CPT- recommended model and buffer to specify the OFL and ABC for PIRKC.**

The SSC notes the author's plan to work with other red king crab authors to complete a stock structure template for red king crab and looks forward to the outcomes. It is notable that, despite little change in apparent PIRKC abundance, there has been an increase in the number of survey stations where PIRKC were present in recent years. This increasing trend in the area occupied is encouraging but should be interpreted with caution.

The SSC endorses the CPT recommendations that 1) the assessment author and other red king crab assessment authors (e.g. BBRKC) review the existing growth data and review potential additional sources of growth information, and 2) that the author examine whether the standard deviation around the growth increment is consistent with results from the tagging data for BBRKC.

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

- Explore covariates (e.g., temperature) associated with historical BBRKC tagging growth increment data towards selecting records that best align with Pribilof Island regional conditions.

- Explore the use of a molt increment growth transition matrix.

- Explore analyses of molting at length for males towards specifying PIRKC molting probability in the assessment.

- Examine catchability and availability of PIRKC in the NMFS survey to shed some light on divergent changes in abundance in recent years. Data collected during the Bering Sea Fisheries Research Foundation (BSFRF) selectivity studies around the Pribilof Islands in 2017 and 2018 may support this effort.

- Examine retrospective patterns in future assessments.

- Consider the use of Bayesian methods with relatively uninformative priors for population processes to better account for uncertainties.

Tanner Crab

The 2022 NMFS summer EBS trawl survey revealed an overall stable abundance of both mature male and legal male Tanner crab but showed an increase east of 166º and a decrease in the western area when compared with 2021 survey estimates.

No public testimony specific to Tanner crab was provided. However, there were multiple comments within other crab presentations on the importance and desire to execute a Tanner crab fishery as one of the major Bering Sea crab fisheries.

The Tanner crab stock has been assessed with a size-structured model since 2012, which is currently informed by abundance and size compositions from the NMFS EBS trawl survey, landings and discards from the directed fishery, and bycatch in the BBRKC, EBS snow crab, and groundfish fisheries. In recent years, this assessment has struggled with striking an optimal balance in model complexity, resulting in persistent issues with parameters estimated at or near bounds and retrospective patterns in recruitment. The stock assessment author has made marked improvements over the past years and the SSC commends their efforts and responsiveness to previous CPT and SSC comments.

Three models were presented by the assessment authors, including:

- **Model 22.01** – The model used in 2021 for assessing stock status with updated data from 2021/22.

- **Model 22.03** – An updated version of 22.01 that combined male and female bycatch fishery biomass data.

- **Model 22.07** – An updated version of 22.01 that started the model in 1982 (rather than 1948).

The SSC notes that all models successfully converged with few parameters hitting bounds, which has been a significant issue in the past. Model 22.07 was not endorsed by the CPT or SSC, despite the anticipated reduction in model complexity, as it included 50 additional parameters. The SSC supports reconsideration of the model start date and notes that a standardized approach for changing start dates would be applicable

to this stock (See General Crab Comments). Model 22.03 produced similar results to the base model, but also provided a better representation of the total catch mortality. However, the SSC notes that fits to MMB diverged markedly from the survey trends in the terminal years. **Nevertheless, the SSC supports the use of Model 22.03 for 2022/2023 harvest specification, in agreement with the CPT and assessment author.**

Based on Model 22.03, the 2022/23 mature male biomass is estimated at 137% of B_{MSY}, thus qualifying this stock under Tier 3a. Though the assessment author recommended an increase to the ABC buffer, the CPT recommended continuation of the 20% buffer between OFL and ABC for 2022/23 that was first adopted in 2020. **The SSC supports the CPT recommendation of a 20% buffer between OFL and ABC** as a reflection of continued uncertainty due to the lack of survey data for 2020, a severe decline in recruitment for 2019, the observation that recruitment pulses observed at small sizes in surveys have not subsequently resulted in large year classes in the modeled population, and the poor fits to the survey data for large crab.

A wide range of recommendations for future model development have been identified by the assessment author, the CPT, and the SSC since October 2020. While many of these are in the process of being addressed, the SSC highlights the following areas as highest priority for the Tanner crab assessment:

- Transition the Tanner assessment model to GMACS

- The investigation of model outputs that better inform State management, especially males of industry-preferred size to ensure proper scaling.

  - The SSC suggests fitting a range of simpler models or data limited approaches. This effort is fundamentally intended to support the use of Tier 3 size structured models, not replace them, but may help inform pathways toward greater model parsimony and stability.

  - The move to GMACS should give the authors an opportunity to start from a simpler base model and add features, rather than continuing to replicate legacy model complexities in GMACS and provide for a more collaborative approach to assessing this stock.

Additionally, the SSC supports the development of methods and rationales for changing the start date of all crab models (including Tanner), as well as a working group to consider simpler models, as noted in the SSC General Crab Comments.The SSC also discussed the potential for the Tanner crab assessment to be considered for stock prioritization at a biennial or triennial assessment interval. This was suggested during the CPT meeting given that Tanner crab catches are consistently and markedly below ABC/OFL, which is one of the groundfish stock prioritization criteria for reducing assessment frequency. This would provide additional time for the author to implement recommended changes and pursue related research. **Finally, the SSC recommends that the CPT review the assessment frequency (see also Stock Prioritization section) for Tanner crab and provide the SSC their recommendation.**

St. Matthew Blue King Crab

The SSC received a presentation from the CPT on the 2022 SMBKC stock assessment and an update on rebuilding progress. SMBKC is currently managed as a Tier 4 stock. The last full assessment was in 2020 as this stock was moved to a biennial cycle. A GMACS model (16.0-2022) was used, based on the last accepted model in 2020 with updated fishery data from 2020/21 and 2021/22 and the 2021 and 2022 surveys. The SMBKC fishery has remained closed to targeted fishing since 2015, and bycatch has been limited so no overfishing is occurring, but the stock remains overfished and under a rebuilding plan.

For catch specifications, the SSC endorses the author's and CPT's recommended model and a 25% ABC buffer due to continued uncertainty in the assessment as evidenced by a retrospective pattern in MMB, two diverging survey trends, and limited stock specific life history information.

The SSC appreciates the author's work and encourages continued development of the assessment by following up on previous SSC recommendations as time allows, which include exploring:

- Data weighting (Francis and other approaches) and evaluation of models with and without the 1998 natural mortality spike;

- Causes of observed retrospective analyses;

- Potential explanations for the discrepancy in the time trends of the two types of survey data;

- Estimates of survey biomass based on VAST compared to design based estimates, and estimates that combine the two surveys;

- Random walk on catchability;

- Assumed and estimated life history parameters (e.g., natural mortality, growth, and maturity) to ensure the best available science is being used to assess this stock.

Overfishing Status Updates

PIBKC was last assessed in June 2021 as a Tier 4 stock and harvest specifications for 2021/2022 were set at that time. The CPT provided an update on the total catch, which was below the OFL, so overfishing did not occur. PIBKC continues to be overfished. This stock is assessed on a biennial schedule. The next full assessment will occur in 2023.

The SSC also received overfishing status updates for Aleutian Islands golden king crab (AIGKC), Pribilof Island golden king crab (PIGKC) and Western Aleutian Islands red king crab (WAIRKC). Catch for each of these three stocks was below the OFL, so overfishing did not occur in 2021 for PIGKC or in 2021/2022 for AIGKC and WAIRKC. AIGKC is assessed annually in June, but the harvest was not complete at the time specifications were adopted. PIGKC and WAIRKC are assessed on a triennial schedule, where the OFL and ABCs from their respective 2020 assessments will remain in effect until updated assessments are presented in 2023.

Norton Sound Red King Crab Model Runs

The SSC received the CPT report on proposed Norton Sound red king crab (NSRKC) model runs for February 2023. The SSC thanks the authors for their responses to the SSC comments and suggestions. In addition to the base model (21.0), three new models were presented. Model 22.0 includes retention probabilities specific to shell condition, Model 22.1 includes model 21.0 with individual M estimates for each of 8 length bins, and Model 22.2 includes model 22.0 with individual M estimates for each of 8 length bins. The additional parameters resulted in negligible improvements in model fits and similar results to those from the more parsimonious base model. **Therefore, the SSC supports the CPT recommendations to bring forward Model 21.0 with updated data.**

The SSC requests that the methodology for calculating F_{OFL} based on a length-based M as requested by the CPT be clearly documented with supporting rationale.

The SSC further agrees with the CPT request for consideration of different methods for estimating discards to be brought forward in January 2023. It is acknowledged that data for a historical discard rate are limited to 2012–2019, so any bias should be clearly identified. Information from regional processors on increased cod fishery effort in recent years should also be considered. The SSC noted that the potential catches are close to ABC depending on how total catches (with discards) are calculated and could have implications for Annual Catch Limit overages.

For October 2023, the SSC requests that the author provide an update on GMACS development for this stock, an update on potential movement of adult RKC to help explain perceived mortality in the model, and the details behind laboratory maturity studies that the author noted may result in a substantial decrease in size of functional maturity.

The survey selectivity parameter that is stuck on the bound forces survey selectivity to be 1 at all length bins. The SSC requests that the authors explore an inverse logistic (or other descending right limb pattern) selectivity to assess whether we may be missing larger crabs, due to either movement or gear selectivity. If this pattern were the case, it could have important implications for estimating higher natural mortality at the larger sizes. If this is not estimable, then it would make sense to fix selectivity at one for all size classes. Finally, the SSC requests a better explanation of the parameter r1 ('proportion of length composition 1') and what the implications are of r1 being on the boundary.

Snow Crab Rebuilding

The SSC acknowledged the extensive work completed in preparation for the June meeting and in response to SSC comments. Specifically, the SSC noted that new methods to sample historical recruitment and natural mortality were developed and successfully applied to improve this rebuilding analysis.

Of the four time-periods for resampling recruitment and mortality requested by the SSC in June, two prioritized time series were included in the document: 1982-2017 and 2005-2019. Results were presented from models 22.1a and 22.1ab; **the SSC did not consider results from 22.1ab for the rebuilding timeline due to the concerns raised during review of the assessment noted above.** The CPT recommended using the period 1982-2017 and Model 22.1a.

The SSC recognizes that the recent history of the stock includes both the largest recruitment and the mortality events estimated in the time-series, but that these events are not included in the author and CPT recommended resampling time-period. Further, temperature appears to be critically important to snow crab bioenergetics and mortality, and temperature is projected to be increasing over the species' distributional range. The 2005-2019 time-period approximately corresponds to the frequency of temperature anomalies projected during the next decade.

The SSC appreciated the detailed investigation by the author identifying that the mortality event in 2018 appeared to result from the combination of temperature and extreme density-dependent mortality of large crab. Such high densities, and therefore another high mortality event, are unlikely to be observed over the duration of the rebuilding plan.

The SSC supports the CPT recommendation to move forward with the rebuilding analysis using Model 22.1a with the recruitment and mortality resampling period set to 1982-2017. This would establish T_{MAX} at 10 years (2033), and therefore a rebuilding plan that provides for consideration of management alternatives that achieve rebuilding targets between T_{MIN} (2029) and T_{MAX} (2033).

The SSC highlights that continued effects of climate change, including increased frequency of reduced ice cover and reduced cold pool extent, as well as potential distributional shifts suggest a challenging future for the EBS snow crab stock. Although not recommended as the basis for rebuilding reference points, the SSC suggests that retaining a figure illustrating the population projection relative to current reference points using the shorter time series (2005-2019) is appropriate to highlight the possibility that the rebuilding plan may need to be revised depending on observed climate and population dynamics in the near- to medium-term.

The SSC noted that reported median times to rebuilding were sensitive to rounding to integer values. In particular, the preliminary result that the rebuilding time in the absence of bycatch was longer than that for the state harvest control rule plus bycatch in Table 2 was indicated, by the author, to be a rounding error.

Similarly, the reported median rebuilding times using model 22.1a were identical for no fishing, bycatch only, and state + bycatch, despite clear differences in the graphical results. **To reduce confusion, the SSC recommended that the rebuilding analysis identify differences in rebuilding times for management alternatives (potential T_{target} values) even when these values may round to the same year**.

To meet requirements of National Standard 2, the SSC highlights previous requests to SAFE authors, ESP analysts, and Plan Teams to consider carefully the addition of social and community indicators in appropriate SAFE-related documents. 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 allocate both overfishing restrictions and recovery benefits fairly and equitably as required under the Magnuson-Stevens Act (MSA).

The SSC recommends, as noted in SSC General Crab Comments, that the assessment authors and CPT develop approaches for the estimation of unobserved crab mortality associated with interactions between crab and trawl gear (non-pelagic and pelagic). This will be particularly important for informing rebuilding analyses for snow crab as the status quo assumption that unobserved mortality is zero is clearly biased and the magnitude of the true mortality is unknown. Noting that changes to the historical mortality estimates affect model scale and parameter estimates, this effort should begin with the stock assessments, rather than rebuilding analyses.