

## **C1 Bering Sea Aleutian Islands Crab**

The SSC received a detailed report on the May 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 are detailed in the CPT report. Items on which the SSC provided comments are below. Table 1 includes the stock status determination criteria and Table 2 includes the June 2023 SSC recommendations.

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 <sup>1</sup>	B <sub>MSY</sub> or B <sub>MSY</sub> proxy	2022/23 MMB	2022/23 MMB/ B <sub>MSY</sub>	2022/23 OFL	2022/23 Total Catch	Rebuilding Status
1	EBS snow crab	3			55.0		10.32		
2	BB red king crab	3			17.0		3.04		
3	EBS Tanner crab	3			47.58		32.81		
4	Pribilof Islands red king crab	4			3.88		0.685		
5	Pribilof Islands blue king crab	4			0.18		0.00116		
6	St. Matthew Island blue king crab	4			1.31		0.07		
7	Norton Sound red king crab <sup>2</sup>	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 <sup>3</sup>	5					0.093	Conf.	
10	Western AI red king crab	5					0.056	<0.001	

<sup>1</sup> As estimated in the 2023 assessment

<sup>2</sup> 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<sub>MSY</sub> proxy for the 2022/23 year).

<sup>3</sup> 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 <sub>OFL</sub>	B <sub>MSY</sub> or B <sub>MSY</sub> proxy	B <sub>MSY</sub> basis years <sup>1</sup>	2023/24 <sup>2</sup> MMB	2023/24 MMB/ B <sub>MSY</sub>	Natural Mortality (M)	2023/24 OFL	2023/24 ABC	ABC Buffer
1	E. Bering Sea snow crab										
2	Bristol Bay red king crab										
3	E. Bering Sea Tanner crab										
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										
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	<b>0.31</b>	<b>0.22</b>	30%

<sup>1</sup> For Tiers 3 and 4, where B<sub>MSY</sub> 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.

<sup>2</sup> 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.

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.

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8	Aleutian Is. golden king crab <sup>3</sup>	3	<b>0.59 (EAG)</b> <b>0.50 (WAG)</b>	11.66	1987-2017	12.07	1.04	0.22	4.18	3.14	25%
9	Pribilof Is. golden king crab <sup>4</sup>	5	-	-	-	-	-	-	<b>0.114</b>	<b>0.085</b>	25%
10	W. Aleutian Is. red king crab	5	-	-	-	-	-	-	0.056	0.014	75%

<sup>1</sup> For Tiers 3 and 4, where B<sub>MSY</sub> 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.

<sup>2</sup> 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.

<sup>3</sup> AIGKC OFL and ABC are calculated by combining two separate assessment models for the EAG and WAG, as presented in the current assessment

<sup>4</sup> PIGKC specifications are set on a calendar year basis

## **General BSAI Crab Comments**

The SSC highlights that the estimation of unrealistically high instantaneous fishing mortality rates appears to be an emergent property of several crab assessments (e.g., Tanner crab, snow crab), likely related to the complexity of variation in growth and its interaction with selectivity and retention. These estimates result in ABC recommendations that would remove virtually all legal sized crab from the population. The SSC encourages collaboration among assessment authors to identify the root causes of this common issue and potential solutions and suggests potentially using a hypothesis driven approach. The SSC recommends that this is a high priority topic for the crab modeling workshop planned for January 2024.

The SSC recommends that, as some crab assessment models are re-evaluated starting from simpler base models, any changes to model structure are made incrementally to evaluate the effect of each change individually.

The SSC recommends that when “fallback” Tier 4 alternatives are provided, as recommended by the crab Simpler Modelling Workshop, plots that compare the OFLs predicted by the existing status quo Tier 3 model against the OFLs recommended by Tier 4 models for previous years be included. In addition, when estimating biomass for Tier 4 models, the SSC recommends that the authors base these on the whole time series or develop justification for a better time block that represents current fishing potential for the stock. The SSC also recommends that, for “fallback” Tier 4 models, the authors and CPT recommend an appropriate ABC buffer, so the SSC has CPT advice should the SSC decide a “fallback” Tier 4 assessment needs to be used. The SSC notes that buffers will likely differ between Tier 3 and Tier 4 models depending on whether concerns relate primarily to the Tier 3 model structure or to other factors.

## **Aleutian Islands Golden King Crab**

The SSC received a summary of the Aleutian Islands golden king crab (AIGKC) stock assessment. The SSC thanks the stock assessment authors for their responses to previous CPT and SSC comments. For previous comments that have not yet been addressed, the SSC notes that they may be best addressed through future modifications and sensitivity analyses applied to the recently implemented GMACS model (e.g. fit diagnostics, fit to CPUE indices, and combined area model). The SSC is also pleased to see the new estimate of natural mortality and the new size-at-maturity information.

AIGKC is managed as a Tier 3 stock with a single OFL and ABC. However, ADF&G manages the fishery on a two-area basis (east and west of 174°W longitude; EAG and WAG, respectively) with a harvest strategy based on model-estimated mature male abundance that splits the TAC and specifies a 15% maximum harvest rate for EAG and 20% maximum harvest rate for WAG. The AIGKC assessment is based on two separate models (the EAG and WAG) that are configured similarly and model results are summed to provide stock-wide management advice.

Harvest in the EAG and WAG had not been completed by the time the assessment was conducted. The authors estimated the final catch based on expected effort. The retained catch and bycatch mortality were similar to, or lower than, other recent years. Fishery CPUE increased in 2022-23 in the EAG and the WAG (but remains close to the average CPUE since 2003).

The authors presented three models for the WAG and five models for the EAG. Models common to both areas included:

- For reference, Model 22.9c (2022 accepted Model 22.1e2 with modifications for GMACS transition)
- GMACS Model 22.1e2 (base model)

- GMACS Model 22.1f that included a Year:Block interaction for the CPUE index

The following additional models for the EAG were presented but not considered for harvest specifications:

- GMACS Model 22.1g (Model 22.1e2 with the cooperative survey from 2015-2022)
- GMACS Model 22.1h (Model 22.1f with the cooperative survey from 2015-2022).

**The SSC supports the CPT’s recommendation to use Model 22.1e2 for both the EAG and the WAG as the basis for harvest specifications and status determination. Results from these models indicate that AIGKC is not overfished.** Overfishing will be evaluated at the October 2023 SSC meeting, after the fishery is complete. The SSC recommends that for the future all models under consideration for setting harvest specifications, the authors should include the appropriate diagnostics and figures showing model fits to all data sources to evaluate model performance and convergence which will allow the CPT and SSC to better understand differences among proposed models.

Specifications for the Tier 3 AIGKC assessment are based on the combined areas of EAG and WAG; however, because the EAG and WAG areas are modeled separately, area-specific status is available. The EAG stock was above  $MMB_{35\%}$  (Tier 3a), while the WAG stock was below  $MMB_{35\%}$  (Tier 3b) in 2022/23. The SSC notes that the OFL calculation method in the current assessment does not exactly follow the method approved by the SSC and CPT in 2017. However, current OFL calculations are likely conservative compared to the result of the OFL calculation method approved by the SSC and CPT in 2017. **Therefore the SSC supports the CPT-recommended OFL specified in the current assessment**, but, recommends returning to calculation of a single OFL and ABC for the combined model results (as in 2017) in the future (not summing model-specific OFLs for Models 22.1e2 applied to the separate areas (EAG and WAG)). The SSC recommends continued exploration into single-area or a two-area spatially explicit model, noting that a two-area spatially explicit model may be a “bridge” between previous separate model approaches and a combined model approach. The SSC notes that, if the model changes to a single area or a two-area spatially explicit model, the specific method for calculating the OFL may change.

A 25% buffer to the maximum permissible ABC for AIGKC was applied from 2017 to 2020 but was increased to 30% in 2021 due to model convergence concerns. The buffer was subsequently reduced to 25% in 2022 due to a reduction in these concerns. **The SSC agrees with the CPT recommendation for a 25% buffer for this assessment, and supports the resulting ABC. For the future, the SSC specifically requests that jitter and retrospective analyses be conducted for all final models that have the potential to be used for setting harvest specifications.** The SSC thanks the CPT for continuing to provide a clear table identifying factors that are considered in a buffer for this stock.

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

- The SSC places a high priority on incorporating information from the cooperative survey into the assessment and supports the CPT recommendation that this be incorporated as a separate fleet.
- Further examination of the retrospective pattern in terms of magnitude, direction and cause continues to be important.
- Revisit the choice to maintain the recruitment years at 1987 – 2017 rather than successively adding recent years to the time series, as is done for other crab stocks.

- The CPT recommended removing the data on the smallest size bin for the total catch prior to 2005/2006. The SSC requests first plotting these data and the model fit and providing further consideration of why these data may or may not be representative of the fishery at that time.
- The current method of projecting the remaining landings for the current incomplete season seems overly complicated and the SSC recommends that a more straightforward method for determining total catch be considered, such as basing it on the average fraction harvested to date.
- Further analysis and discussion of the retrospective pattern is needed to justify the size of the buffer used.

### **Pribilof Islands Golden King Crab**

The SSC received a presentation on the full Pribilof Islands golden king crab (PIGKC) SAFE report. This is a Tier 5 stock that is managed on a calendar-year basis (January 1 - December 31), with assessments occurring triennially. The last assessment was conducted in 2020. The OFL and ABC for calendar years 2024 - 2026 are set using this year's assessment.

The fishery has been managed with an ADF&G guideline harvest level (GHL) of 59 t since 2015 and participation in this fishery is sporadic. Total catch was well below the OFL of 93 t, so **overfishing did not occur in 2020, 2021 or 2022.**

In response to previous SSC requests, the author presented a Tier 4 approach and a Tier 4/5 approach, in addition to the status quo Tier 5 approach, which has been used since 2012. Both the Tier 4 and Tier 4/5 analyses were conducted with M values of 0.18 and 0.22 yr<sup>-1</sup> and used fisheries-independent data from the NMFS slope survey. The Tier 4 approach examined 5 models that explored differences in survey years included in MMB calculation, the CV for MMB, penalties to the likelihood and priors on process error as implemented in the R package *rema*. The Tier 4/5 approach was based on the method used in the 2010 GOA spiny dogfish assessment. This method computed OFL using natural mortality as a proxy exploitation rate (E) so that  $E = M = F_{OFL}$  and  $OFL = E \times B$  where B is the average MMB (517 t) for 2002-2016 EBS slope surveys to capture the range of potential productivity of the stock.

The CPT report summarized the potential benefits and drawbacks of moving the stock to Tier 4, noting that while it more accurately reflects the uncertainty associated with old survey data, the uncertainty for MMB estimates increases monotonically with the length of time since the last available data point. The last slope survey was conducted in 2016 and given that there are currently no plans to reinstate the slope survey, the CPT recommended that Tier 5 remains the best approach for managing this stock.. However, the CPT noted that if new survey data become available the Tier 4 approach has the advantage of allowing for dynamic population estimates and should be reconsidered.

**The SSC discussed the CPT's and author's rationale for using the Tier 5 approach but instead recommends using the Tier 4/5 method for specifications.** This approach uses survey estimates of MMB from a more recent time period (2002 - 2016) than the fishery total catch data used in Tier 5 (1993-1998). The SSC discussed the potential concern that survey biomass may change over time due to climate change and would be unknown without future surveys, but still recommended that Tier 4/5 be used, because this is a deep water species that is less affected than shallow water crab species. The Tier 4/5 approach uses a natural mortality multiplier of 0.22 on MMB that is a reasonable approximation of the productive capacity of the stock and based on recent work on Aleutian Island golden king crab (Siddeek et al., 2022). The ABC was computed using a 25% buffer on OFL, consistent with Tier 4 calculations for EBS crab stocks.

Finally, the SSC notes an experimental survey expanding the shelf trawl sampling to depths up to 400 meters is forthcoming and looks forward to updates regarding the potential of this work to inform future assessments.

### **Western Aleutian Islands Red King Crab**

The SSC received a presentation on the Western Aleutian Islands red king crab (WAIRKC) SAFE Report. This is a Tier 5 stock that is assessed triennially. The fishery has been closed since the 2003/04 season and the OFL is calculated using annual retained catch, non-directed crab discard mortality, and groundfish discard mortality averaged over the reference period 1995/96 - 2007/08. Bycatch mortality of WAIRKC has been very low in recent years and the relative increase in the proportion of WAIRKC bycatch during 2017/18 - 2019/20 was attributed to the Pacific ocean perch bottom trawl fishery. Since the last assessment in 2020, **overfishing did not occur during the 2020/21-2022/23 seasons** because the estimated total catch did not exceed the Tier 5 OFL established for those years (56 t).

**The SSC supports CPT and author-recommended Tier 5 OFL and ABC, using the status quo buffer of 75%. As noted by the CPT, the 75% buffer reflects the depressed status of the stock and the lack of new data sources. In future assessments, the SSC requests further clarification regarding why the 75% buffer was originally selected.**

The CPT report emphasized that although stock status cannot be determined for Tier 5 stocks, extremely low survey CPUE levels since 2002 suggest that the WAIRKC stock is “overfished”. **The SSC understands the CPT’s concern but corrected the record to indicate that there are insufficient data to support an overfished designation at this time. However, based on the very limited amount of historical information available, the stock is likely at a low level..** Additionally, the CPT noted that the EFH Fishing Effects analyses show areas of high cumulative habitat disturbance in some areas of Petrel Bank and suggest this region be considered for habitat protection. The SSC recommends the author consult with the APU FAST Lab Fishing Effects analysts to ascertain the gear-specific and seasonal disturbance trends that could support further consideration of possible habitat protection measures.

### **Bristol Bay Red King Crab Model Runs**

The SSC received a report on model alternatives for setting harvest specifications for Bristol Bay red king crab (BBRKC) for October. The SSC thanks the author Katie Palof (ADF&G) for addressing CPT and SSC comments as she takes over this stock assessment. The assessment has been run in GMACS since 2018. There has been no directed fishery in the last two years due to State of Alaska harvest control rules for female biomass.

Nine models were considered (including the base model) that included updated GMACS code (21.1b), changes to the start date of the model (22.0), multiple methods for fixing or estimating M (23.0, 23.0a, 23.0b), considerations for NMFS survey catchability (Q) (23.1a), and an assessment of how influential the NMFS survey re-tow data are (23.2).

Updating to the new GMACS code led to some minor differences in reference points, the causes of which were not clear. The SSC requests that the cause of these changes be identified.

The justification for starting the model in 1985 rather than 1975 is that the time-block of elevated M in the early 1980s would no longer be required. However, this change resulted in increased retrospective patterns. The SSC requests further development of this model in the future.



Survey Q prior CVs were reconsidered to try to address the unrealistically high catchability coefficients when the BSFRF data are included.

M was fixed in two model runs based on recent publications and previous likelihood profile work and a constant M was estimated within the model. The results from different M estimation led to variable effects on recruitment, selectivity, and reference points. The CPT discussed the similarities with snow crab and called into question the value of F35% for this as well as other crab stocks. However, among all the model runs, the estimation of M in the model led to reduced retrospective patterns. The SSC discussed the potential for future model runs to incorporate both the M estimate and later model start date but the author noted that this had been done and did not fix the retrospective patterns associated with the later start date. The SSC also discussed the merits of updating previous work on the relationship between environmental variables and M, but no recommendation was made by the SSC..

The model runs that removed NMFS survey retow data showed a large effect on estimated female biomass in years when a high proportion of females had not completed the molt mate cycle. In 2021, when only about 10% of the females had not gone through the molt mate cycle, the effects on estimated female biomass and modeled size compositions were much lower, suggesting that a retow is only necessary above 10%. Additional data would be valuable to support a higher threshold.

The author and CPT recommended bringing forward Models 21.1b, 22.0, 23.0a, and a fallback Tier 4 calculation based on survey biomass (as recommended in the Simpler Model Workgroup Report) for the October meeting. **The SSC concurs with this recommendation.**

The SSC supports additional research on the following issues:

- Further consider how to estimate survey catchability relative to including the BSFRF survey data in the model. The SSC supports focus on this at the January CPT modeling meeting.
- Revisit blocking on molting probability from tagging data.
- Continue to look at initial conditions, sensitivity on growth, and retrospective patterns.

### **Tanner Crab Model Runs**

The SSC received a presentation on the proposed EBS Tanner crab stock assessment model runs for September 2023. The SSC appreciates the efforts by the author to explore a range of Tier 3 model alternatives, including: (1) use of a finer one millimeter size bin structure, (2) fitting to a model-based (VAST) trawl survey abundance index and incorporation of time-varying natural mortality, (3) estimating growth outside the assessment model and basing survey selectivity on BSFRF survey data, and (4) a modified version of the simple Tier 4 fallback model defined during the March Simple Modelling Workshop.

**The SSC supports the CPT recommended models for the September 2023 assessment cycle.** These include:

- Model 22.03b – base model with minor changes, change in ADMB version and fixing a single parameter that was previously estimated at the bounds
- A Tier 4 “fallback” model consistent with the guidelines identified during the March Simpler Models Workshop

While the SSC agrees with the CPT that the Model 23.02 including the model-based (VAST) survey abundance index may provide a valuable future direction for model development, it does not recommend

this model be brought forward for September 2023. **The SSC reiterates its support for transitioning this model, or a simplified version thereof, into the standardized GMACS platform. The SSC feels that transitioning this assessment into GMACS is a higher priority at this point than continued exploration of model alternatives (e.g. 23.02, 23.05) within the existing framework.** The SSC further reiterates its recommendation from October 2022 that the GMACS implementation of the Tanner crab model could represent a simplified version of the current model structure, as a foundation upon which additional features may be explored and incorporated sequentially.

It was clarified during discussion that one of the minor changes to Model 22.03b was fixing the slope for a logistic retention function which had been at an upper bound, indicating a knife-edged functional form. With respect to the reference time period (years) for status determination under the Tier 4 calculations, the CPT recommended that the rationale for the time period be based on the justification provided during the last time this stock was assessed using Tier 4 methods. The SSC requests that a clear justification for the choice of reference time period be provided in the September SAFE document, beyond simple precedent, and that several alternative time periods be considered (each with its own justification).

The SSC concurs with the CPT that continued exploration of constrained time-varying natural mortality may be appropriate, when paired with external estimation of growth and use of BSFRF data to inform priors on selectivity. This may represent a suitable balance in terms of the added complexity of time-varying natural mortality, against reductions in the complexity of growth and selectivity estimation. **However, the SSC recommends that these explorations be conducted using a GMACS version of the assessment model, when successfully implemented.**

### **Pribilof Island Blue King Crab Model Runs**

The SSC received a presentation on model alternatives to be brought forward for setting harvest specifications for Pribilof Islands Blue King Crab (PIBKC) in October 2023. PIBKC is assessed under Tier 4 biennially using a state-space random walk model fit to survey design-based estimates of mature male biomass. The model is currently implemented in ADMB. The stock author presented an alternative implementation of this model fit in TMB using the *rema* package in R, which is also used for Tier 5 groundfish assessments. No changes to the underlying model structure were made. The author presented results from both model implementations and differences in the results were negligible, as anticipated. The author and CPT recommended using the results from the *rema* R package at the October meeting to set specifications for this stock, which would better align methods with lower-tier groundfish assessments and make use of model code with a broader user and development community. **The SSC concurs with the author and CPT recommended application of the *rema* R package for this Tier 4 assessment.** The SSC also looks forward to the SAFE section on rebuilding in September as the rebuilding plan nears its second decade.

### **Snow Crab Proposed Model Runs**

The SSC received a presentation on proposed model runs for the September 2023 snow crab assessment. In 2022, the snow crab assessment transitioned to the GMACS modeling platform, but considerable modeling issues arose during the September assessment cycle, including convergence problems, bimodality in management quantities, unrealistically high target fishing mortality rates and large retrospective patterns. This year, exploratory modeling work was motivated by recommendations from the simpler modeling working group for more robust assessment modeling approaches. The SSC acknowledges the effort of the assessment author in conducting these investigations in the relatively short time since the March workshop.

In addition to the status quo GMACS model from last year, four models were evaluated in the draft assessment, a research model with simplified stock dynamics but with addition of time-varying natural mortality, two “bridging models” that brought some of the features of the research model into the GMACS

status quo model, and a Tier 4 assessment. The SSC found this terminology to be confusing, as previously the term “bridging model” has been used to refer to models used to support a transition from one modeling platform to another. Both the bridging models and the research models featured improved model fits and reduced retrospective patterns, but the CPT considered the research model to be too preliminary for use in October.

**The CPT recommended four models for consideration in October: 1) the status quo model; 2) a simpler model in which the probability of terminal molt is pre-specified based on survey data and survey selectivity is informed by priors derived from the BSFRF catchability studies; 3) and a Tier 4 (fallback) random effect model based on survey biomass.** The CPT noted that the simpler model continued to exhibit convergence problems, and should only be brought forward if those issues are addressed. **The SSC agrees with the CPT to bring forward the status quo model and a Tier 4 random effects model. The SSC recommends that some variant of the simpler model be brought forward at the assessment author’s discretion, but does not want to be prescriptive about the configuration of the model.** Any model that is brought forward should show adequate convergence properties, and the incremental effect of each change from the status quo model should be evaluated.

The stock assessment author has initiated a process of rethinking the fundamental assumptions that led to the current status quo model. The SSC fully supports this process, but recognizes this is likely to be a multi-year effort. The SSC offers the following comments to facilitate future model development.

Assessment models with time-varying M often show desirable properties but it is important to recognize time-varying M can absorb variation in other parameters that are time-varying. Ideally it would be preferable to directly incorporate an environmental covariate in the assessment to inform temporal changes in natural mortality, but it must be acknowledged that such covariates are seldom available. The SSC recommends that a conservative approach be used for incorporating time-varying M. For example, it may be reasonable to fit an initial model with time-varying M in all years, and use that model to identify a smaller set of years where there is a strong signal to model with time-varying M.

Pre-specifying model parameters is a good approach to reduce model complexity, but much can be learned by comparing the performance of models where the only difference is external versus internal estimation of important parameters. Ideally parameters such as growth should be estimated within the model to include all the information that informs these parameters and accurately propagate uncertainty, but the SSC recognizes that this may not always be possible. When the external estimation approach is taken, estimates of uncertainty should be included in the assessment in addition to the point estimates, so that the uncertainty in external estimation is propagated through to assessment results. The SSC supports exploration of models with pre-specified growth parameters, as well as using BSFRF survey data as a prior for survey selectivity/catchability.

The SSC considers treating the probability of maturing/terminal molt as an annually-varying parameter estimated externally from the model as a very promising approach. Data to inform these estimates are observations of the ratio of large-claw new shell crab (recently molted and mature) to small-claw new shell crab (recently molted but immature). Field biologists and crab life history experts should be consulted to understand the reliability of these data for stock assessment. Rather than adding the raw survey estimates to the model, an initial analysis in a GLM modeling framework, which treats years as random effects, should be considered. This approach could provide smoother estimates, accommodate differing sample sizes by year and length, and deal appropriately with years in which data are missing.

While a male-only assessment for snow crab is worth exploring as a simplification, the SSC recommends other approaches be considered to reduce the tension in the model between fitting male and female data. For example, it may be worthwhile to uncouple female and male population dynamics as much as possible

in the current two-sex model. The SSC supports the CPT recommendation for a model that includes males and females, does not model groundfish bycatch, but estimates selectivity and recruitment by sex, and includes a penalty of how much recruitment can vary between the sexes. A more strategic approach to data weighting could also be considered, such that female data would receive less weight than male data in model fitting. The primary consideration should be that estimation of female parameters should not have a large effect on male parameter estimation.

Similar considerations also apply to how to reduce the tension between modeling bycatch fisheries and modeling the snow crab in the target fishery. Again, the primary consideration should be that estimation of bycatch parameters should not have a large effect on estimation of parameters for the target fishery.

Contrary to the original intent of the tier system, due to changes in the estimates of terminal molt probability, the  $F_{35\%}$  fishing mortality rate no longer results in a meaningful conservation constraint on the fishery for snow crab. **To evaluate a potential alternative to the status quo, the SSC recommends that OFL and ABC estimates be provided for a modified Tier 3 approach for each model carried forward.** This approach has the following characteristics: the OFL is calculated by replacing  $F_{35\%}$  in the Tier 3 harvest control rule by the model estimate of natural mortality. Biomass reference levels and status determination would be calculated using MMB as usual for Tier 3. **The SSC requests evaluation of this approach by the assessment author and the CPT.**

### **Simpler Modeling Workgroup Report**

The SSC received an overview of the CPT discussion on outcomes from a joint inter-agency and SSC workgroup that met on March 27-28 in Seattle, WA. The working group was formed in response to a recommendation made by the SSC during its October 2022 meeting that SSC members and stock assessments authors jointly explore model parsimony and legacy assumptions for three crab stocks: BBRKC, Tanner and snow. This request originated from concerns about ongoing convergence issues, poor fits, and unrealistic management outputs (e.g., fishing mortality rates). In addition, modeling efforts being migrated to GMACS was seen by the SSC as an opportunity to evaluate fundamental model assumptions and complexity. **The SSC appreciated the opportunity to collaborate with the stock assessment authors and CPT members on these issues and found the exercise informative and useful.**

The working group discussed a set of [objectives](#) to guide discussion. The first two objectives focused on assumptions associated with Tier 3 base models and creating opportunities for authors to explore new models without being tied to legacy models. As noted in the CPT minutes and workgroup report, the workgroup identified several pathways to help assessment authors focus development efforts to evaluate basic legacy assumptions on crab biology and model formulations, and to potentially simplify base model approaches. The workgroup identified several items for future work, including:

1. Pre-specifying growth and maturity from analyses outside of the model. In addition, the SSC requests the authors explore methods to propagate uncertainty from the growth and maturity analysis through to assessment results;
2. consider using Bering Sea Fisheries Research Foundation (BSFRF) data to inform a prior on  $Q$  and/or survey selectivity rather than treating the BSFRF data as separate survey to be fit by the model; and
3. combining all mortality sources other than the directed fishery into a single “fleet” to avoid estimating multiple time series of fishing mortality rates for bycatch fisheries.

**The SSC supports the workgroup and CPT recommendations described above and also recommends the following issues be considered during evaluation of simpler model structures:**

- Information on the trade-offs related to model parsimony (i.e., empirically examine the performance of simple versus complex formulations). Some examples include retrospective analysis, comparison of fit statistics, and information about the ability of the model to accurately characterize biological processes and output realistic management quantities.
- Retrospective plots that compare the OFLs predicted by the existing status quo Tier 3 model plotted against the Tier 4 models.
- Identify specific simulations and/or analyses to help identify trade-offs between model performance vs shifting to a lower tier.
- Highlight data/information issues. For example, this may include considering the relative confidence in available data and how these data may relate to data weighting schemes and the estimation of parameters inside or outside of the models.
- Investigate alternative methods that improve modeling of both female and male processes. Specific recommendations are described under each stock's agenda item.
- A detailed evaluation of State versus federal harvest control rules for setting the OFL/ABC and the TAC was beyond the scope of the workgroup, although an overview of differences was discussed. Differences between the State and federal harvest specification processes should continue to be considered when model changes are evaluated. Specifically, considerations for exploitation rates that differ between the processes should be a future discussion point.

**The SSC supports the CPT recommendations that further work on evaluating the simplified model processes be incorporated into the CPT modeling workshop schedule, as appropriate.** The SSC looks forward to future updates on progress.

Finally, the workgroup recommended a Tier 4 survey biomass approach to address potential model specification and fit issues that may arise when setting limits. This recommendation builds from the SSC October 2022 recommendation. The approach sets  $F=M$  and an estimate of biomass estimated from the trawl survey to specify the ABC/OFL, as well as specifying a reference period for status determination (i.e.,  $B_{MSY}$  proxy). The intent is to use the Tier 4 survey biomass approach only if serious issues prevent selection of alternative approaches for specification. Some examples of possible serious model deficiencies (“failed model”) include convergence issues as opposed to unrealistic  $F$  rates or biomass values or poor retrospective patterns.

**The SSC supports the Tier 4 survey biomass approach, recognizing that feasible Tier 3 approaches are preferred. The SSC also supports the workgroup recommendation that the survey biomass use vulnerable male biomass estimated from the survey using the *rema* R package (male crabs likely to be susceptible to both directed and incidental catch fisheries).**

### **Catch accounting update on EM and Crab**

The SSC received an informational summary of the federal electronic monitoring program (EM), the proportion of different fleets moving to EM and catch estimations for crab resulting from this alternate observer program. The CPT requested the presentation primarily to understand how retained crab were accounted for in the Bering Sea pelagic trawl fishery where discarding of crab is prohibited and EM is used to monitor compliance. Few crab are seen in pelagic trawl EM offloads, but once the EM program for the Bering Sea pelagic trawl fleet is fully implemented in 2025, the data should be available for integration into stock assessments.

There is partial coverage for fixed-gear (i.e., hook-and-line and pot) fisheries for vessels greater than or equal to 40 feet in overall length that opt into EM rather than having an observer onboard. EM is used on a trip-by-trip basis in place of observers and crab are required to be discarded. As it is difficult to identify crab to species using EM, discards from trips with EM are treated as unidentified and not counted towards any stock removals. Unaccounted crab bycatch is largely from vessels fishing pots and relatively rare in hook-and-line fisheries. Work is underway to incorporate a stock-area component into prohibited species estimates and developing methodology for identifying crab species on EM video. The SSC looks forward to any updates on this issue as progress is made.

### **Bering Sea Fisheries Research Foundation update (including spring BBRKC survey preliminary results)**

The SSC received an informational summary on current and planned research being conducted by the Bering Sea Fisheries Research Foundation, including preliminary results of a collaborative pot survey project conducted this past winter with ADF&G and AFSC. The SSC appreciates this update and supports the research but suggests that as these efforts move forward, consideration be made as to whether the survey methods and timing of surveys may be modified to better understand the effectiveness of crab protections that are currently in place.

### **Unobserved mortality working group (next steps)**

In October 2022, the SSC recommended the formation of a working group to develop a framework for how to estimate the magnitude of unobserved fishing mortality for crab stocks and how these estimates may be incorporated into BSAI crab stock assessments. The Council approved this recommendation in December 2022. The issue of unobserved fishing mortality of crab has been discussed recently by the Council, Council committees and advisory bodies. A summary of when unobserved mortality has been discussed in the Council process, as well as outcomes of the discussions, was provided by Council staff. Given the paucity of research on unobserved mortality, Council staff are seeking additional direction to clarify the objectives of the working group as well as instruction on the expected timeline for meeting these objectives.

The CPT discussed the next steps for addressing unobserved fishing mortality during their May 2023 meeting and received a presentation on work currently being done to estimate crab injury and mortality from trawl encounters. The CPT proposed that an inter-agency working group would be appropriate for making long-term progress on this topic, but that holding one or more workshops would be useful for gaining a broad range of perspectives that could provide additional information to help develop estimates for unobserved crab mortality. The CPT also noted that even if estimates of unobserved mortality were not included in stock assessments, gaining a better understanding of this source of mortality would still be useful for informing conservation or management measures. The SSC supports the CPT's suggestion of holding a workshop in addition to an inter-agency working group.

The SSC recommends that the goal, or purpose, of the working group be clarified and suggests slightly modified wording from the October 2022 SSC report and the December 2022 Council motion:

To develop a framework for how to estimate the magnitude and extent of unobserved fishing mortality for crab stocks along with guidance for explicitly incorporating these estimates in BSAI crab stock assessments and informing other council actions related to the conservation and management of crab stocks.

The SSC highlighted that the goal of the working group and workshop would be to develop a framework, guidance, and research priorities, but not to do the actual research and calculations. As such, the SSC recommends the working group could be established for a finite time frame. The SSC acknowledged in the October 2022 SSC report that there are studies informing some of the inputs needed to achieve this goal, but that a framework for the calculations should be very explicit about each of the data sources and required assumptions. The SSC noted that multiple approaches may be needed.

**To accomplish this goal, the SSC suggests the following objectives** for the working group:

- Identify data sources, major data gaps, and assumptions needed to estimate unobserved mortality for stock assessments.
- Provide recommendations for research priorities and/or needed research projects to be able to estimate unobserved mortality and to better understand the temporal and spatial patterns of unobserved mortality across fisheries and gear types. For example:
  - Field studies designed to improve mortality estimates and quantify long-term, delayed mortality following interactions with trawl gear (e.g., CPT - May 2022; Crab Workplan – December 2022).
  - Spatial analyses for estimating unobserved mortality that may involve the spatial overlap of stocks and various fisheries, the mortality rate of interactions and/or the ratio of unobserved to observed encounters (SSC – October 2022).
  - Technical approaches for including unobserved mortality in crab stock assessments.
- Organize a workshop with stakeholder participation to gain a broader perspective and refine research needs (see Council’s October 2022 [request for information](#) for input from industry on research that would, among other things, evaluate unobserved mortality).
  - The SSC suggests that the initial public workshop should include representatives of communities and user groups, stock assessment authors (if not already part of the working group), and external experts.
  - The SSC also recommends having a facilitator lead the workshop so that working group members can fully participate.

The SSC discussed that depending on the outcomes of the workshop, the membership of the working group may change to reflect the expertise needed moving forward. The SSC also recommends that the working group consider all relevant gear types unless otherwise specified or prioritized by the Council.

The SSC envisions that the final products of the working group include:

- A framework for estimating unobserved fishing mortality for crab stocks and explicitly incorporating these estimates into stock assessments.
- A report on specific research/data needs related to unobserved fishing mortality of crab.
- Recommendations for approaches to investigate spatial/temporal extent of unobserved mortality over fisheries and gear types, to the extent practicable (the scope may be narrowed to what may be reasonably achieved).

The increased interest in accounting for unobserved fishing mortality, given the recent collapse of the BBRKC and EBS snow crab stocks and the rebuilding plan for snow crab, suggests that it is important to make immediate progress on this issue while realizing that achievement of the goal of the working group may take time. Therefore, the SSC recommends establishing the working group and convening their first meeting no later than early 2024. Ideally, developing research priorities, holding at least one workshop and finalizing recommendations from the workshop would be accomplished by the end of 2024. Development of the framework for estimating unobserved mortality and guidelines for incorporating unobserved mortality into stock assessments and understanding its temporal/spatial extent across fisheries and gear types may take longer.

## **Stock structure template for Red King Crab**

The SSC received a report on a draft stock structure template for red king crab, focusing on stocks in the eastern Bering Sea (EBS). In June 2022, the SSC requested that a stock structure template be completed for red king crab to evaluate support for the existing stock units, particularly whether red king crab in the Northern District are part of the Bristol Bay stock. The stock structure template was developed for groundfish stocks and provides a framework for evaluating the appropriateness of current management boundaries (stock definitions). The template synthesizes available information concerning stock structure, including genetic studies, biological characteristics, distribution, retention areas and any other relevant information. The available document is a draft with several incomplete sections. The SSC recommends that the draft be completed and included as an appendix to the BBRKC SAFE document, as has been the practice for groundfish stock structure templates. Links to the document should be included in other red king crab SAFE documents.

Information provided in the draft template suggests that there is continuity between the Bristol Bay stock and red king crab in the Northern District. This grouping was distinct from the Pribilof Island and Norton Sound red king crab stocks. The biomass in the Northern District is small relative to the Bristol Bay stock. There is some evidence of a slight increasing trend of abundance in the Northern District. It is unclear whether red king crab in the Northern District interact biologically with main Bristol Bay crab stock, for example, whether they would migrate south to participate in spawning along the Alaska Peninsula.

SSC recommendations for completing the document are as follows:

- Provide a more thorough summary of recent tagging data. Maps of tagging data showed eastward movement on average but no interpretation was provided.
- Include distribution maps for the EBS using the bottom trawl survey data.
- Provide biomass trends by stock to compare the relative magnitude of the different stocks.
- Include EFH species distribution maps for red king crab.
- If time allows, include maps of bycatch in the groundfish fishery using observer data.
- Summarize research on larval drift patterns for BBRKC in Daly et al. (2020<sup>1</sup>) and other relevant information on oceanographic retention mechanisms for crab in the EBS.

The SSC identified a research need for a genetic study focusing on EBS red king crab stocks. In addition, the SSC recommends that any future tagging work consider deploying tags in the Northern District to evaluate whether there is exchange between the Northern District and Bristol Bay.

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<sup>1</sup> Daly, B., C Parada, T. Loher, S. Hinckley, A.J. Hermann and D. Armstrong. Red king crab larval advection in Bristol Bay: Implications for recruitment variability. 2020. Fisheries Oceanography, Vol. 29:505-525.