NORTH PACIFIC FISHERY MANAGEMENT COUNCIL
Angel Drobnica, Chair | David Witherell, Executive Director
1007 W. 3rd Avenue, Suite 400, Anchorage AK 99501
Phone 907-271-2809 | www.npfmc.org

Crab Plan Team

REPORT

January 8, 2024 - January 12, 2024 Anchorage, AK

Committee Members in attendance:

Katie Palof, **Co-Chair** (ADF&G-Juneau)
Mike Litzow, **Co-Chair** (AFSC-Kodiak)
Sarah Rheinsmith, **Coordinator** (NPFMC)
André Punt (Univ. of Washington)
Ben Daly (ADF&G-Kodiak)
Brian Garber-Yonts (AFSC-Seattle)
Cody Szuwalski (AFSC–Seattle)
Erin Fedewa (AFSC-Kodiak)
Ethan Nichols(ADF&G- Dutch Harbor)*
Ginny Eckert (UAF/CFOS-Juneau)
Krista Milani (NMFS- Dutch Harbor)
Tyler Jackson (ADF&G-Kodiak)
William Bechtol (UAF-Homer)
William Stockhausen (AFSC-Seattle)
Vacant, quantitative expert

*indicates members who participated remotely

Modeling Workshop

Assessment authors, some members of the CPT, and others interested in crab modeling met during a 1.5 day workshop prior to the January CPT meeting. The agenda for this meeting included a range of topics but focused on GMACS updates and implementation for new stocks, recommendations from the simpler modeling workshop in March 2023, and other ongoing research questions within the crab assessment framework.

GMACS

Andre Punt began GMACS conversations with updates on progress related to implementing GMACS for NSRKC. He presented his progress, changes to the code that were made to accommodate the unique characteristics of this stock/fishery (including the number of directed and subsistence fisheries; there is typically only one directed catch fleet for other stocks). In contrast to the figure in the NSRKC SAFE report, the updated GMACs runs for the base NSRKC model were similar to the current base model - as far as model fit and MMB estimates. During the workshop, Andre was able to make the specification changes necessary to accommodate NSRKC OFL calculations (which differ due to the increased number of directed fleets compared to other stocks) so that the resulting OFL value is now closer to the base model.

The conversations among current and future GMACs users covered questions on current GMACS procedures and items that need to be included in the base code. Andre took on code development during the meeting. This included incorporating the functional maturity changes that Cody had included for snow crab, the ability to specify weight-at-length relationships by

maturity status, updates to where authors could code TAC predictions based on State harvest strategies (now in the personal.tpl file), and many updates to the formatting of the gmacsall.out file and the projections module input and output options.

Andre asked the group for feedback on what would be useful for potential options in the projections file. He has a project starting soon to add in linkages to environmental data to allow for forecasting. The group provided him with feedback.

Simpler modeling workshop topics
The workshop group addressed topics from the simpler modeling workshop that was held during March 2023. The group discussed condensing bycatch fleets into a single fleet when conducting assessment when they were a small component of the overall catch. The contribution of each bycatch fleet compared to the directed fishery removals was highlighted as being important for assessment authors to present before considering condensing them. If bycatch fleets are condensed, the group discussed weighting handling mortality rates and size compositions as a good practice when entering data into GMACS. Stock assessment authors were encouraged to document, either in their May 2024 presentations or documents, the proportional component of bycatch fleets to the total removals.

The second topic that the group addressed was using the BSFRF survey data as a prior to estimate survey catchability (q) in the population model. Cody Szuwalski presented the method he used to do this for the 2023 snow crab assessment in GMACS. This method compared the density of all crab (both sexes) caught by size from the BSFRF survey data with the NMFS survey at the same stations in the same year using a GAM. The fit of the GAM model was used to establish a mean and variance for each size bin that was applied in GMACS using q as a non-parametric distribution, with normal priors on each size class in the model. Cody mentioned that he planned to explore potential differences between sexes and options to deal with time periods of different selectivity.

Buck Stockhausen provided some background on his work looking at paired hauls for BBRKC from the NMFS survey and BSFRF fitting with environmental and habitat variables. Buck provided the group with a summary of his work and asked for feedback on the progression.

NSRKC ADF&G survey update

Jen Bell (ADF&G - Nome) presented an overview of the Alaska Department of Fish and Game (ADF&G) trawl survey for Norton Sound red king crab (NSRKC). The overview covered a brief history of the survey from 1996-2023, survey stations and standardizations, survey coverage, and a comparison of the different indices of abundance produced by the survey. The first trawl surveys of Norton Sound were conducted by National Marine Fisheries Service (NMFS) on a triennial basis starting in 1976. NMFS discontinued the survey after 1991 due to lack of funding, but the survey was resumed in 1996 by ADF&G. The survey was conducted triennially by ADF&G from 1996 to 2014 and then annually from 2017 forward.

When ADF&G resumed the Norton Sound trawl survey in 1996, the survey grid and stations established by NMFS (10x10 nmi) were used. The historical trawl survey area was maintained, but with the addition of “tier” areas within the survey area to define survey priorities. “Core” stations were given top priority and trawled first, while stations within tiers 1, 2, and 3 were surveyed as time allowed.

The NSRKC trawl survey area was standardized in 1998 (Fair 1998) and implemented for the first time for the 1999 trawl survey. The new standardized area included the historical footprint of the survey (core, tiers 1-3), but not all survey stations were targeted to be trawled. Survey coverage was restricted by budget, time, vessel availability, weather, and station suitability (difficult to trawl given bottom structure).

From 2002 to 2017, the standardized survey area remained the same, but the locations of tiers 2 and 3 were moved outside of the standardized area. For ADF&G reporting and fishery management, abundance estimates of red king crab came only from trawled stations within the standardized area. NSRKC abundance estimates from the ADF&G trawl survey were first incorporated into an assessment model in 2004/05.

In 2018 the trawl survey area was trimmed to 60 survey stations within the core and tier survey areas, and the survey moved to being annual. During 2018 to 2023, the survey has been conducted annually, except in 2022 when a survey was not conducted. All survey stations now have the same priority, but the tier system is still used to prioritize survey areas as a backup if the survey is limited by time. All survey stations within the standardized trawl area are used for reporting abundance estimates and ADF&G fishery management. It was noted there is currently no dedicated NSRKC survey vessel and only a small amount of funding is dedicated to charter a survey vessel.

There have been 68 possible stations surveyed annually since 1996, ranging from a low of 39 stations completed during 2021 to a high of 67 completed stations during 2006. Thirty-three stations have been consistently surveyed in all survey years since 1996 and these 33 “consistent” stations all fall within the “core” survey area. Most red king crab captured in the survey came from these 33 stations and accounted for 37% to 98% of crab caught each survey year, with the highest and most consistent survey catches coming from four stations offshore of the community of Nome. High survey catches of red king crab are occasionally seen outside of the “consistent” stations but can be attributed to one-off capture events.

CPT discussion of how the survey data should be included in future assessments is summarized in the NSRKC assessment section of this report.

NSRKC- final assessment, stock status, OFL/ABC

Hamachan Hamazaki (ADF&G) presented results from three models (21.0, 23.0, and 23.1) for consideration by the CPT for status determination and OFL/ABC calculation. Model 21.0 was the accepted model from the 2023 assessment (updated with 2023 data). It assumed a constant *M* of 0.18 yr^{-1} for all length classes except the largest (i.e., >123mm CL), for which *M* was estimated at 0.61 yr^{-1}. Model 23.0 was identical in structure to 21.0 except that a single *M* was estimated and applied to all length classes. Model 23.1 addressed a request from the SSC in October 2023 and was identical to model 23.0, except that a prior was placed on the estimate of *M*. Detailed results from model 23.1 were not included in the SAFE document because they were similar to those from the other models. Overall, model 21.0 fit the data slightly better than 23.0. The estimated M (0.41 yr-1) across all size bins in model 23.0 was considered more biologically unrealistic even though the CPT found little rationale to support the estimated *M* (0.61 yr^{-1}) for the largest size class in model 21.0; herefore, and in order to maintain consistency in the absence of any evidence or rationale that model 23.0 represented an improvement on model 21.0, the CPT recommended that model 21.0 again be adopted to determine stock status and calculate the OFL and ABC.

Based on a total catch measure of removals, overfishing did not occur during 2023. Based on a length-invariant *M* calculation for the OFL as in 2023, the CPT recommends a 2024 total catch OFL of 0.332 thousand t. The SSC adopted a 30% buffer for ABC for the 2023 assessment. The CPT found that, except for a reduced retrospective pattern in the current assessment, the concerns expressed last year regarding the stock and assessment remained (see table below). The SSC requested the author provide an alternative ABC buffer based on using the long-term average fishing mortality rate as F_{OFL} in place of *M* in the OFL calculation. Using this approach, the buffer would be 41%. However, the CPT considered this approach to be more appropriate for setting the TAC than the ABC because the ABC is supposed to account for scientific uncertainty not included in the assessment model. Thus, the CPT does not recommend adopting the proposed alternative approach and instead recommends using the same ABC buffer as was endorsed by the SSC in 2023, 30%, resulting in an ABC of 0.233 thousand t.

Table 1. Recent concerns expressed about the NSRKC assessment, and their relevance for the 2024 assessment.

Concern	2024 Concern?	2023 Concern?	Reason
1. Considerations of other stocks with similar levels of uncertainty	Yes	Yes	The ABC buffer used for NSRKC is similar to those for other stocks with similar levels of uncertainty.
2. Shortage of discard data and resultant inability to manage the stock based on total catch, which is the standard for federal fisheries	Yes	Yes	The CPT recommended using model estimates of discards for status for 2022 and a retained catch OFL for 2023 (rejected by the SSC) because discard data are no longer collected. The lack of discard data with a total catch OFL increases the level of uncertainty regarding current fishing mortality rates and sustainable future rates.
3. Unresolved issues associated with the apparent high *M* for the largest size class	Yes	Yes	The default rate for *M* used for this stock is based on estimates from other stocks that experience substantially different environmental conditions and exhibit substantially different biological characteristics. Additionally, estimated *M* appears to be confounded with survey selectivity.
4. Discrepancies in stock size estimates between ADF&G and NMFS surveys as well as concerns about the spatial distribution of crab relative to the survey footprint	Yes	Yes	The NMFS and ADF&G surveys have different spatial coverage and station densities and can exhibit different short-term trends that introduce contradictory information into the assessment.

Hamachan also provided responses to several previous CPT and SSC comments on a number of topics; the CPT expressed its appreciation for the level of detail with which these issues, particularly with regard to *M*, were addressed in both the SAFE chapter and the presentation. The CPT noted that many of the CPT/SSC comments and/or requests referred to issues which had been addressed previously several times (e.g., length-specific vs. length invariant *M*) or were beyond the ability of the author to address (e.g., developing a small-scale observer program). The CPT recognized that these repeated comments/requests reflect continuing unresolved issues with the assessment, but that in many cases they are simply beyond the scope of the assessment author to address more adequately than has been done previously (e.g., addressing the issue requires a major research effort or data collection).

One request Hamachan addressed was with regard to estimating *M* outside the model using methods such those from the Barefoot Ecologist website. It was noted it was important when using methods based on estimates of maximum age to know the sampling process used to determine this value and what percentile of the population it referred to, and that most of the life history-based methods were based on fish stocks, and probably not applicable to crustaceans.

The assessment includes three surveys which use (or have used) different gear, sampling grids, and extrapolation areas. The CPT requested that Hamachan define a standard area for abundance estimation based on the surveys that were as synoptic as possible and, in a future version of the model (i.e., after transition to GMACS), revisit survey selectivity in the model (which is currently assumed to be the same for all surveys). The CPT also discussed the use of VAST to provide an "integrated" index of abundance from the three surveys. It noted that there had been considerable improvement in experience with VAST since the last time it had been considered for the assessment (2021) and recommended that the CPT receive a report from Jon Richar (AFSC) on the current "state-of-the-art" techniques and diagnostics for crab-relevant applications of VAST (and possibly other model-based approaches). The CPT also discussed a request to explore the effects of not fitting to shell condition in the assessment. Hamachan presented information that the accuracy, based on tagging study results, of shell condition determination was fairly high (80-90%). Andre Punt likened this to ageing error in age-based assessments and noted that the concern was bias, not random error, in assignment, but it looked like the assignment errors were likely unbiased. Katie Palof clarified that the original request was more informational: simply to evaluate the sensitivity of the model to the inclusion of shell condition in model fitting.

The consensus of the CPT was that any unaddressed or new recommendations should be regarded as secondary to moving the assessment model to GMACS.

A few other minor issues were identified by the CPT that should be considered or remedied in future SAFE documents:

- Determine figure format for document conversion to pdf to eliminate extraneous lines on graphs
- Tables and figures should have unique identifiers (i.e., no repeated table/figure numbers)

- Provide tables for all required results (e.g., no table for estimated recruitments was provided)
- Provide values in metric tons (or thousands of mt) in addition to millions of lbs, specifically in tables in the SAFE executive summary

Council Timing Update

Diana Evans presented information to the CPT regarding the frequency and timing of future Council meetings. The Council has been discussing ways to make the process more efficient and determined that it may be beneficial to cut back from five to four Council meetings per year. The Council could still have the option to have a shorter virtual Council meeting if necessary and/or use the funds for other stakeholder workshops or other Council priorities. Currently the Council is planning to eliminate its February meeting starting in 2025, but requested feedback from the CPT to determine whether this would lead to significant interruption to some crab items typically taken up at the February Council meeting, such as NSRKC final specifications, Economic SAFE review, and preliminary model runs for AIGKC.

The Council needs to approve the NSRKC OFL/ABC before the February 15 start of the fishery. The NSRKC assessment author stated that he receives most of the data by September except for NMFS Northern Bering Sea (NBS) survey results. Although it may be possible to obtain the NBS survey results in September, this would be a rushed timeline and may lead to issues if the CPT tries to finalize the NSRKC SAFE at the September CPT meeting for the October Council meeting. Instead, the CPT recommends reviewing and finalizing the NSRKC SAFE sometime in November, during a short virtual meeting, for review and approval at the December Council meeting. CPT members noted that if there are significant model changes (e.g.,. moving into GMACs), it would be preferable to review proposed models in person at the September CPT meeting for a more thorough review than can be done virtually. The preliminary model runs for AIGKC can be reviewed at the September CPT meeting and finalized during the May CPT meeting.

The Economic SAFE is also presented to the CPT every January, although it is not formally reviewed. The SSC currently receives a formal presentation of the Economic SAFE in February and provides feedback, but this would be moved to the April meeting. The CPT also receives some preliminary information on the Economic SAFE in September. The final Economic SAFE could be presented to the CPT at the May meeting, but it was pointed out that by that time, the information is already outdated. The CPT recommends continuing presentation of the preliminary data at the September meeting but would likely not be able to provide any comments to the SSC at that time. If there is interest, the full Economic SAFE can be presented during the May CPT meeting.

In addition to these items, the CPT also conducts a modeling workshop in January to advance model improvements for crab stocks. The CPT would like to retain an in-person modeling workshop and pointed out that discussions at these workshops are not usually part of the Council report. Although the timing can be changed if necessary, January has worked well for this workshop. This workshop has been hybrid in past years, but in-person participation is

preferred for addressing detailed aspects of model configuration and coding. For a hybrid meeting, NPFMC staff would need advanced notice as these require technical support.

The CPT noted that the workload at the September CPT meeting will increase, but it should be possible to address all crab issues without a February Council meeting. Without a February Council meeting, the CPT would not have a full CPT meeting in January, but instead can add a short virtual meeting in November to review the assessment for NSRKC. The modeling workshop could still occur in January or move to a time frame participants found more convenient.

Research Update #1: RKC genetics

Carl St. John (Cornell University) gave a research update on his genetic work on Alaskan red king crab stock structure. Carl briefly reviewed past research indicating broad-scale stock structure. St. John's project builds on this work by using low coverage whole genome sequencing (lcWGS), which provides better resolution of population structure, the potential to detect local adaptation using genome scans, and allows for comparison of whole genome sequencing data to past microsat and mtDNA data. Carl included samples from the Aleutian Islands, the eastern Bering Sea (Pribilof Islands, Bristol Bay), Gulf of Alaska (southern Alaska Peninsula, Kodiak, lower Cook Inlet), northern Bering Sea, and southeast Alaska. Carl summarized lcWGS results showing broad regional genetic differences with fine-scale population structure. Populations near the Pribilof Islands and Bristol Bay can be genetically separated enough to suggest they may be diverging evolutionarily in a relatively short time period with little mixing between populations. There was a question about whether a large recruitment event in the Pribilof Islands may have been due to larval transport from Bristol Bay. It was noted that a single event would likely not be enough to alter the genetic structure.

Genome scans and pair-wise comparisons between regions identified regions with high differentiation, including parts of the genome that differ more than others, which can suggest local adaptation (e.g., on chromosome 100 in Gulf of Alaska populations). Conclusions from this work include: 1) the Aleutian Islands, Bristol Bay, Pribilof Islands, Gulf of Alaska, North Bering, and Southeast Alaska all form separate genetic stocks; 2) the Gulf of Alaska likely harbors locally adapted alleles derived from standing genetic variation; and 3) for stock enhancement activities, genetic evidence supports sourcing broodstock from the target population. Limitations of this work include small sample sizes that limited the ability to differentiate areas within regions, trait data were not collected, which limited the ability to associate locally adapted traits to genetic differences, and the fact that red king crab data were mapped to a blue king crab genome (there is no assembled red king crab genome, but this would greatly improve future genetic studies). When asked whether we are seeing refined stock structure because a more refined tool was used, Carl replied that these analyses allow for better stock structure resolution, which could be useful for evolutionary considerations such as identifying local adaptation of various populations. When asked about looking at samples from the area just north of the Bristol Bay management boundary to see where they fall within the eastern Bering Sea stock structure, Carl noted that this is possible, and that his work would have utility in addressing this issue.

Research Priorities- Voting & Rationale

Research priorities were addressed by the CPT in two steps. The CPT first met virtually on December 1, 2023 with a focus on pre-prioritization of research priorities that were to be voted on during the January CPT meeting. The goal of the December meeting was to refine the list of existing, new, and team member submissions to approximately 10 top priorities. A presentation was provided by Nicole Watson (NPFMC staff) regarding the research priority process, a checklist of responsibilities for the Plan Teams, and background information and resources relevant to research priorities, such as the website and Research Priorities eAgenda. Prior to the meeting, CPT members were asked to provide staff and the co-chairs a list of their top five, unranked priorities as a way to focus the discussion of the pre-prioritization meeting.

A description of the prioritization process for the meeting was provided by co-chair Katie Palof. Additional clarity was provided regarding the critical ongoing monitoring topics being seen as separate from the top 5 list of research priorities that will be provided to the SSC at the February 2024 Council meeting, as well as a supplementary list of priorities deemed important but not included in the final top 5 list. The supplementary list will be an amalgamation of priorities not included in the final CPT top 5 (as determined at this meeting) but critical to ongoing monitoring.

Members were given the opportunity to discuss the top priorities that were submitted in advance of the December meeting from the existing and new submissions, providing rationale for their selections and identifying key considerations. Several members noted the need for annual surveys of Northern Bering Sea stocks, for research priorities to allow/inform management actions, and the need to consider priorities that were seen as important during the previous review. Additional comments for each of the top research priorities were compiled into the Google sheet. During this discussion, priorities were identified that warranted inclusion in the draft top 10 voting list for January.

Table 1:New submissions from CPT members were discussed, including (not listed in ranked order):

Research ID	Title
CPT001	Early life history population bottlenecks
CPT002	Better characterize "spawning stock" currency: MMB vs egg production index vs ??
CPT003	Improved maturity estimation and reproductive potential characterization for crab
CPT004	Evaluate fishing gear impacts on crab, benthic communities and essential fish habitat
CPT005	Annual monitoring survey in the NBS
CPT006	Develop and evaluate global climate models (GCMs) or other projection models to assess climate change impacts on biology (recruitment, growth, spatial distributions, and benthic productivity), and to evaluate management strategies under different climate, ecological, and economic conditions.

Public testimony by Gary Stauffer (BSFRF), Scott Goodman (BSFRF), and Cory Lescher (ABSC) highlighted the need to consider ecosystem dynamics; the connection between maturity,

reproduction and execution of the fishery; the utilization of research and findings by managers; and the need for seasonal EFH species descriptions for all life stages of crab.

After discussions and public testimony, the draft top 10 voting list was reviewed, and additional consideration was given to priorities that had not been included in this list. Priorities deemed critical ongoing monitoring were compiled into a separate list for communication to the SSC.

Table 2: Research priorities included on the top 10 list for voting in January (not listed in any ranked order):

Research ID	Title
148	Spatial distribution, habitat requirements, and movement of crabs relative to life history events and fishing
167	Alternative approaches to acquire fishery-independent abundance data for unsurveyed crab stocks.
223	Develop and evaluate global climate change models (GCM) or down-scaled climate variability scenarios to assess impacts to recruitment, growth, spatial distributions, and benthic productivity.
225	Develop projection models to evaluate management strategies under varying climate, ecological, and economic conditions and evaluate impacts to managed resources and coastal communities.
532	Natural mortality estimation for crab stocks
715	Physiological responses of crab to climate stressors
731	Norton Sound Red King Crab case study
CPT001	Early life history population bottlenecks
CPT003	Improved maturity estimation and reproductive potential characterization for crab *Combines CPT002, N008, and 592.*
CPT004	Evaluate fishing gear impacts on crab, benthic communities and essential fish habitat
CPT005	Annual monitoring survey in the NBS
CPT006	Develop and evaluate global climate models (GCMs) or other projection models to assess climate change impacts on biology (recruitment, growth, spatial distributions, and benthic productivity), and to evaluate management strategies under different climate, ecological, and economic conditions. *Combines 223 and 225*

Table 3: Critical and ongoing monitoring research priorities included for consideration and communication to the SSC (not listed in any ranked order):

Research ID	Title
145	Continuation of State and Federal annual and biennial surveys
189	Develop stock-specific ecosystem indicators and incorporate into stock assessments
226	Monitor the economic effects from fishery policy changes on coastal communities.
367	Continue to improve crab stock assessment methodology with respect to uncertainty
611	Collection of socio-economic information
612	Maintain observer program
735	Fishery monitoring and catch accounting

Descriptions of these priorities are included in the CPT Pre-prioritization supplementary document, found on the CPT eAgenda.

The CPT recognizes the need to address stocks of greatest concern and has captured these needs in these prioritization lists.

The voting results identified the top five priorities in rank order: 148, CPT004, CPT003, 715, and CPT001 (Table 4). The CPT agreed to include the bottom five that were not selected in the vote as priorities in the supplemental list to advance to the SSC (Table 5). The CPT agreed that the rationale for the top five priorities is that they will each provide information needed to address a number of pressing fishery management issues under current climate conditions, and that this rationale could be included in the list moving forward.

Following the CPT vote, Scott Goodman provided additional public comment from BSFRF, indicating that they are updating their own list of research priorities and will share those with the CPT and SSC in the future. Goodman mentioned CPT003 to highlight the need for research on all aspects of maturity, as well as the contribution of skip molt males to reproduction.

Table 4: CPT Top 5 Research Priorities in ranked order.

Research ID	Title
148	Spatial distribution, habitat requirements, and movement of crabs relative to life history events and fishing
CPT004	Evaluate fishing gear impacts on crab, benthic communities, and essential fish habitat
CPT003	Improved maturity estimation and reproductive potential characterization for crab. *Combines CPT002, N008, and 592.*
715	Physiological responses of crab to climate stressors
CPT001	Early life history population bottlenecks

Table 5: CPT research priorities that were not ranked in the Top 5, but still warrant being a priority for ongoing research.

Research ID	Title
167	Alternative approaches to acquire fishery-independent abundance data for unsurveyed crab stocks.
532	Natural mortality estimation for crab stocks
731	Norton Sound Red King Crab case study
CPT005	Annual monitoring survey in the NBS
CPT006	Develop and evaluate global climate models (GCMs) or other projection models to assess climate change impacts on biology (recruitment, growth, spatial distributions, and benthic productivity), and to evaluate management strategies under different climate, ecological, and economic conditions. *Combines 223 and 225*

Unobserved Fishing Mortality Working Group

Mike Litzow (NMFS) summarized the working group (WG) report on Unobserved Fishing Mortality (UFM); the WG included SSC and CPT members and NOAA agency personnel. Established by the Council in October 2023, the WG met virtually for four two-hour meetings in October and December 2023. Group objectives included: (1) identify data sources, major data gaps, and assumptions to estimate unobserved mortality for stock assessments and to better understand temporal/spatial extent across fisheries and gear types; and (2) provide research priority recommendations and/or identify needed research. The identified end products included: (1) a framework for estimating unobserved fishing mortality and explicitly incorporating such data into stock assessments; (2) reporting on specific research priorities and data needs; and (3) recommendations for approaches to investigate the spatial/temporal extent of unobserved

mortality by fishery and gear type to the extent practicable. Due to the complexity of estimating UFM, the report was limited to Eastern Bering Sea (EBS) snow crab, Bristol Bay red king crab (BBRKC), and EBS Tanner crab. For assessing UFM, the report considered pots, lost (ghost) pots, hook and line, non-pelagic trawl, and pelagic trawl, but did not consider gear impacts on habitats or uncertainty around observed mortalities.

The WG identified four needs for assessing UFM: (1) bottom contact by gear in time and space; (2) crab distribution in time and space; (3) the probability of crab-gear encounters; and (4) the mortality rate if interaction occurs. One tool for estimating bottom contact is the fishing effects (FE) model, which evaluates impacts to non-motile benthic fauna (e.g., sea pens) by a variety of gears, but also generates bottom contact data. Information on crab distribution is available through species distribution models (SDMs) that exist in several forms (e.g., EFH models) but often do not consider crab sex, size, and environmental factors, although these issues are being explored to some extent for EBS snow crab and BBRKC. Some projects looking at the overlap between FE and SDM are just starting and will also benefit from previous and ongoing tagging projects. One potential approach for including UFM in assessments is treating it as an additional mortality term by crab life stage and incorporating the four UFM needs identified above. While some critical data do not currently exist, this could be a useful research tool. A second approach to incorporating UFM would involve estimates generated outside of the assessment as independent or exploratory inputs, similar to efforts examining EBS snow crab sensitivity to potential UFM estimates. Independent estimates could be informed by field experiments to explore observed versus unobserved mortality rates. The WG did not discuss aspects of UFM and OFL apportionments among fleets. To incorporate UFM into assessments, most data do not exist, approaches would differ by crab stock, and any applications would go through the normal CPT, SSC, Council process before being used in management.

For developing an implementation framework, Table 1 in the report identifies the approximate spatial area of gear impacts, data availability, priority of research needed, and research priorities at the individual fishing event level and at the population level. The individual level focused on bottom contact footprint, time on bottom, and relative mortality from gear-crab interactions while the population level focused on the number of fishing events and spatial overlap with crab. Potential impacts were further specified as the magnitude of the impact, data available to assess the impact, research needed to fill data gaps, priority of the research, and time needed to implement the research. The WG discussed the temporal impacts on life stage (e.g., trawling on molting crab) but made no recommendations. Research priorities were generally low for most items, but medium for many lost pot criteria, non-pelagic trawl, and pelagic trawl, and high for pelagic trawl lethality. Table 2 summarizes data needs for modeling, available data and limitations of those data, and research needed to fill data gaps. The CPT noted that some data needs with medium priorities under Table 1 involve exploring existing data and a relatively short anticipated time period (≤ 1 year). Responding to a public question, Mike noted the WG discussed the successful use of biotwine as an existing escape mechanism; comment from ADF&G staff noted a recent study indicated that biotwine degraded as expected. Table 2 shows different information needed for estimating UFM, with each type of information evaluated for potential approaches for obtaining information, currently available data, limitations of the data or models, and research needs identified by priority. The WG report is the first step to addressing

the NPFMC request, and this effort identified large data gaps that currently prevent UFM estimation. The WG concluded that additional WG meetings are not likely useful at this time, but future meetings or public workshops should include additional experts.

Gordon Kruse (BSFRF) commended the WG efforts to address the Council's request and noted the high research priority attached to pelagic trawl impacts, that research should focus on the mating/molting period, and that the CPT should include UFM in the top 10 research priorities. Dr. Kruse also encouraged a workshop to be held to address UFM and facilitate the development of collaborative research proposals with gear experts, scientists and industry. Scott Goodman (BSFRF) reiterated Gordon's comments on including UFM as a top 10 research priority, and encouraged a UFM workshop. Scott further noted that not all efforts to implement UFM should be focused into the assessments as it will be very difficult to split out parts of mortality in meaningful ways within the models that vary greatly at times in specifying OFL. Addional collaborative research is being proposed by BSFRF and NOAA counterparts to explore the consequences of lost posts. The CPT noted that some aspects of UFM research are listed as medium priorities that have time frames of 0.5-1.0 years based on data mining; addressing these might be achievable in the near term. Data mining could include reviews of literature and previous studies (e.g., Norwegian research on UFM) and could guide future studies. In addition, stock assessments depend on catch, and underreporting is often a larger problem than unobserved mortality; and there are methods to estimate missing catch. Assessment authors could conduct qualitative exploration of model runs, similar to previous snow crab work, that could guide collection of quantitative data. The UFM report will not be presented until June when it goes before the SSC and NPFMC. The CPT also recommended that UFM research include consideration of the timing of fishing events relative to life history events such as molting and mating. Overall, the CPT endorses data mining and literature review as priority next steps, and recognizes the value of a workshop that would allow industry and the general public to weigh in.

Oct SSC general requests:

Katie Palof led a discussion of SSC comments from the October 2023 meeting that apply to all BSAI crab assessments:

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

- Aleutian Islands: 1991 - present (standard gear)
- Eastern Bering Sea: 1982 - present (standard gear, grid, and design), 1987 - present for species that inhabit the northwest corner of the survey (which was added in 1987 for snow crab and walleye pollock)

Response: The CPT noted that inclusion of the NMFS bottom trawl survey begins in the following years for different assessments: 1975 (BBRKC, Tanner, PIBKC), 1976 (PIRKC), 1978 (SMBKC), and 1982 (snow crab). The 2023 BBRKC and Tanner crab assessments also evaluated model scenarios which used survey data beginning in 1985/1982. The CPT recommended using different estimates of catchability and selectivity for different gear types and survey areas for the early years of the survey. For instance, the BBRKC and Tanner crab assessments assume different catchability and selectivity for survey data from 1975 – 1982 and 1983 – present to account for gear differences. The snow crab assessment assumes different catchability and selectivity for 1982 – 1987 and 1988 - present to account for differences in spatial coverage (which are not a concern for the Tanner and BBRKC surveys given the more restricted distributions of those stocks). The CPT also noted that authors should use as much of the available survey data as is reasonable for the stock given extensive efforts have been made in the past to clean up the pre-standardized bottom trawl survey data. The CPT also noted that changing survey years would potentially change the B_{MSY} proxy for Tier 4 stocks.

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

Response: The CPT concurred that authors should be tracking SSC and CPT comments in SAFE documents from the previous two meetings. Responses for unaddressed comments should be an estimate of the timeline for work, if applicable. In addition, assessments should include a history of the modeling approaches, and a table of historical issues addressed. At CPT meetings, members keeping minutes will review recent SSC reports to flag any comments that were not addressed.

SSC: Request risk tables for crab.

Response: The CPT heard a presentation at this meeting on the use of risk tables by the Groundfish Plan Team. The CPT will draft risk tables for AIGKC (if time allows), BBRKC, Tanner, and snow crab aligned with the 2024 assessment cycle.

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

Response: The CPT suggested that VAST may be a suitable topic for the 2025 January modeling workshop, and authors suggested that it would be useful to hear an updated review of VAST methods and use. It was noted that VAST tends to track other estimates for NSRKC, that we don’t want to “create” data for areas such as NBS where, for instance, a third of the survey stations were not sampled in 2023, and crab may have more patchy distributions than groundfish where VAST has been successfully.

SSC: [Requests that] assessment authors [be] available for questions during final specification presentations to the SSC.

Response: The CPT agreed and encourages authors to at least be available virtually during SSC presentations on their stocks.

Research update #2: Review of research on crab stock enhancement

Ben Daly (ADF&G) provided a presentation on research topics associated with stock enhancement for BSAI crab. After briefly reviewing the status of crustacean stock enhancement efforts globally, Ben highlighted recruitment limitation as a key characteristic of Alaska red king crab (RKC) population dynamics that may make these stocks candidates for enhancement. The AKCRRAB (Alaska King Crab Research Rehabilitation and Biology) program was formed in 2006 to assess the feasibility of enhancement for RKC stocks in Alaska. Research topics that have received attention from AKCRRAB include large-scale larval and juvenile hatchery rearing, juvenile cannibalism, ecological competence, and field experiments to evaluate release success. The presentation also highlighted genetic research on stock structure (indicating strong geographic differentiation) and mating systems (indicating single paternity broods in RKC).

The presentation then summarized the factors that are important for gauging the potential for success in RKC enhancement in Alaska. These include: a strong scientific basis for decision-making, including a good understanding of the basic biology, ecology, and life history of RKC; an understanding that recruitment limitation is the basis of a successful program; adoption of the Responsible Approach for enhancement; the ability to evaluate success; proper accounting for genetic considerations; an integrated management strategy; and economic feasibility for large-scale enhancement. The presentation included information about State of Alaska House Bill 41, which is legislation that creates a regulatory framework with which ADF&G can manage shellfish enhancement projects, and outlines criteria for the issuance of permits.

Finally, the presentation summarized an NPRB-funded project that will begin this year, led by Jared Weems (ADF&G), that will improve general understanding of juvenile RKC early life history ecology and population bottlenecks including habitat evaluation using a high-resolution camera sled (“CamSled”) and measuring relative larval supply throughout Bristol Bay, which will assess recruitment limitation to the C1 stage. The CPT looks forward to the results of that study and also appreciates this research update presentation.

AIGKC proposed model runs

General assessment issues

Tyler Jackson summarized the progress on developing the 2024 assessment for Aleutian Islands golden king crab (AIGKC). This assessment is based on separate models for the areas east and west of 1740°W (referred to as the EAG and the WAG, respectively). Tyler proposed model scenarios for the May 2024 assessment, which will again be based on the GMACS modeling platform. The proposed model configurations are all based on updated catch and size composition data and an updated approach to standardizing the CPUE data. The largest impacts to the catch data from these updates were related to groundfish bycatch (Fig. 8 of Appendix A) and the early (pre-2000) estimates of total catch, particularly for the EAG. The size compositions are essentially identical to those used in the May 2023 assessment, except for 1993 – 1994 for the EAG and 1992 – 1993 for the WAG. The CPUE standardization included a new variable (slope); Tyler also explored the use of a latitude-longitude interaction implemented as a two-dimensional spline.

Model scenarios and recommendations for the 2024 assessment

The assessment author proposed seven model scenarios for the EAG and WAG and an additional scenario for the EAG (23.2):

- 22.1e2. The base model used to provide management specifications in May 2023.
- 23.0. As for model 22.1e2 but using the updated catch and size composition data.
- 23.0a. As for model 23.0 but using a GAM- instead of a GLM-based standardization approach for the legal CPUE.
- 23.1. As for model 23.0a but with the size composition data truncated to 101mm CL and larger (i.e., data for animals of 100 mm CL and smaller are ignored).
- 23.1a. As for model 23.1 with the number of sampling efforts treated as stage-1 effective sample sizes for the retained size composition data.
- 23.1b. As for 23.1, but with two selectivity periods (1960-1996 and 1997-2004) for the pre-rationalized directed fishery, corresponding to regulations introducing escape mesh.
- 23.2. As for 23.1b, but with the cooperative survey as an additional fleet.

The assessment author also presented results for a preliminary model scenario in which the data for the EAG and the WAG were analyzed simultaneously, with separate directed fisheries for the EAG and the WAG and a single groundfish bycatch fleet.

The CPT agrees that the updated catch and size composition data are an improvement on the data used in the May 2023 and earlier assessments, and that use of a GAM approach implements a previous CPT recommendation. The new data extraction process will allow for more consistency in creating input data files and follows the same approach for other crab stocks. The CPT agreed that there was little benefit to applying model 22.1e2 again given that the new data on catches, size composition, and standardized CPUE improved the models. The comparisons between models 22.1e2 and 23.0a in the document presented to the CPT are sufficient to understand the effects of updating/revising the data.

The CPT recommends that the CPUE standardization be revised for the 2024 assessment by:

- exploring the use of a Tweedie instead of the negative binomial distribution;
- dropping the data for gear types 4 and 13 which have few observations;
- reporting DHARMa residuals and providing influence plots as additional diagnostics; and
- exploring the basic data used for the fish ticket CPUE index because the data on which the standardization is based for the current analyses include many zero observations – this may be because the extracted data may include trips for red king crab in the Aleutians. If the residual pattern for the fish ticket analysis (Fig. 44 of Appendix B) is not resolved, results should be presented in May 2024 for model runs that use and ignore the fish ticket CPUE index.

Other recommendations for the 2024 assessment:

- include measures of uncertainty (for at least one model configuration) in the plots for the estimates of recruitment and MMB;
- include a plot of the survey index overlaid on the observer CPUE index (EAG);
- describe why the MMB for the EAG declines substantially before 1980 while this is not the case for the WAG;
- start the y-axis for the plots of recruitment and MMB at zero;
- include the number of parameters in likelihood tables; and
- apply jittering to ensure that the reported parameters correspond to the global minimum of the objective function (model 23.1b in Table 4 converged to a local minimum).

Average recruitment for the calculation of the proxy for B_{MSY} was based on the estimates for 1987-2017. The plots of the SE of log-recruitment versus year suggest that the terminal year when computing average recruitment should be later. The CPT recommends that a consistent approach be applied to select the range of years for defining average recruitment. In the case for Aleutian Islands golden king crab, the default terminal year should be four years before the last year of the assessment, although this should be reviewed at the May 2024 meeting.

The assessment author recommended that the 2024 assessment be based on models 22.1e2, 23.1, 23.1b and 2.32 (EAG only). Models 23.1, 23.1b and 2.32 are based on updated catch and size composition data and ignore size composition data for animals smaller than 101mm CL. The CPT recommends reporting results for model 23.0a, which represents an appropriate “status quo” model.

Work for the 2025 assessment

The CPUE standardization should explore (a) the use of a geostatistical method (such as VAST) to conduct the standardization, and (b) further explore whether there is evidence for different trends in CPUE spatially and hence a basis for a year*block interaction. A key task for the 2025 assessment is to explore alternative model structures (e.g., time-varying parameters) to better fit the CPUE index for the EAG (and hence reduce the retrospective patterns). In addition, the assessment author should explore alternative treatments of additional index variance (e.g., shared among indices or set to zero for some indices). The CPT noted the progress made by

the assessment author to re-assess the size-at-maturity and looks forward to the results for additional analyses in 2025.

The combined model does not fit the CPUE for the EAG and WAG as well as the assessments by each region. This is (in part) due to differences in recruitment among areas. Future work on a combined model should consider two areas, which can be implemented by treating the two areas as different sexes within GMACS.

Economic SAFE

Brian Garber-Yonts (AFSC) presented results from the draft 2023 Crab Economic SAFE. The SSC will review the finalized SAFE document in April 2024, while the CPT was tasked with reviewing only content provided in the presentation. The document includes an executive summary, economic status and trends, and a new section that develops nowcast estimates for the harvest sector to address lags in revenue data availability. Brian mentioned that most of the data in the Economic SAFE are available via the AKFIN Human Dimensions Data Explorer portal (https://reports.psmfc.org/akfin/f?p=501:2000).

Draft report cards including 15 socioeconomic indicators were presented at the September CPT meeting, and have been updated in the current draft to include the addition of Norton Sound red king crab and Western Aleutian Islands red king crab fisheries to cover all FMP crab fisheries in the report card. The downside to these additions, however, is that data are now only presented through 2022 because rationalized fishery data are unavailable for the most recent year. In addition, less information is available for for the non-rationalized period for various fisheries, so some indices only apply to rationalized crab stocks. The number of total active vessels in all FMP crab fisheries went up due to the addition of the NSRKC fishery, which had more vessels participating in 2022 than 2021. Report card results indicate declines in numerous 2022 metrics to historical lows, including ex-vessel pounds landed, potlift effort, and ex-vessel value. Brian noted that prices have increased fairly dramatically in recent years following the COVID-19 pandemic, although crew earnings decreased during 2022. Quota lease royalty costs also decreased during 2022, which could be the result of non-labor operating cost increases. Crab earnings were also a smaller share of total fishery earnings for 2022. The slight increase in the count of active processing plants in 2022 was attributed to the inclusion of NSRKC, which operated in 2022 for the first time since 2019.

Brian also reported TACs and GHLs by fishery, emphasizing that although the BBRKC fishery opened in 2023, the volume of landings was greatly reduced compared to historic harvests. Production and revenue statistics are compiled by calendar year and indicate that golden king crab prices have since declined after a high in 2021. Overall, the COVID-19 pandemic created market prices that were very favorable for crab. However, markets declined in late 2022. Snow crab prices increased through 2022 as the fishery occurred during the first half of the calendar year when the market was stronger. In contrast, the economic value for the Eastern Bering Sea Tanner crab and Aleutian Island Golden King crab fisheries decreased during 2022 because a large portion of those fisheries occurred later in the calendar year. Employment-related metrics indicate declines in the processing sector associated with crab fisheries closures. In the

harvesting sector, vessel operating, labor and lease costs, and gross ex-vessel profit declined during 2022, most notably in the snow crab fishery. Brian mentioned that some vessels likely operated at a loss during the 2022 snow crab season. Aggregating to the fleet level, CDQ lease rates increased slightly for snow crab from 2021 to 2022, but overall lease rates have been fairly steady. Lease volume increased in the snow crab and golden king crab fisheries during 2022. With over a third of the snow crab fleet not operating during 2022, the quota share held by inactive owners increased.

Brian presented a new development in the Economic SAFE, which includes ex-vessel price and revenue nowcasts that are developed using dock price reported in fish tickets as a predictor of final selling price. Because much of the economic data is lagged due to post-season price adjustments and the limitations of staff availability for processing, nowcasts are an effort to include more current, but preliminary, data. They suggest that price increases noted in 2022 have since slightly declined for king and Tanner crabs. Overall, the increase in the U.S. dollar exchange rate since 2022 has driven a decline in export demand and wholesale crab prices because seafood products are more expensive in foreign markets. China and Japan are major export markets for snow crab and the Chinese market in particular has collapsed for multiple fisheries in recent years. King crab imports have also declined to zero following the Russian seafood import ban. To summarize, Brian reviewed priorities for completing the 2023 Economic SAFE, including continued development of price forecasts, indicators characterizing the current state of industry and stakeholders, and potentially reporting an ongoing economic impact analysis on the snow crab fishery closure. Brian also discussed ongoing efforts to better coordinate information flow and delivery of information on social, economic, and community dimensions of fishery management, but noted that staff turnover at AFSC has impeded progress for these discussions.

The CPT thanks Brian for the informative information, and interest was expressed in seeing results from the snow crab economic impact analysis, potentially at the May CPT meeting. The CPT also recommended that economic indicators, to the extent possible, include standard deviations to identify variability.

Risk Tables

Martin Dorn (former CPT member, NMFS retired) and Stephani Zador (AFSC) gave the CPT a presentation on risk table history and usage by the groundfish plan teams. The motivation behind crab risk tables was the NPFMC Oct 2023 motion for the CPT to develop risk tables “to provide a more comprehensive, transparent, and defensible justification for SSC recommendations on ABC buffers…”.

The presenters reviewed the genesis of risk tables from their initial use using version 1.0 with three categories (assessment-related, population dynamics, and ecosystem) and four rating levels (normal, substantially increased concerns, major concern, extreme concern). Risk table content is meant to be specific to the current year based on factors and issues that are not already accounted for in the assessment or modeling process and will inform the current ABC.

The presenters stressed the importance of avoiding “double-counting” information that is already part of the assessment process.

Risk tables are meant to be a place to incorporate information when recommending reductions from max ABC (groundfish) or ABC buffers (crab). Therefore they are best suited to be part of the SAFE document and prepared by the assessment authors - with consultation from the ecosystem group.

In the course of their development, some changes were made to the risk tables based on SSC/Council recommendations. First, a “fishery performance” category was added. This was meant to be reflective of the stock, and not the effects of changes in TACs, that might give some indication of stock status. Additionally, there was a recommendation to reduce the ratings to three levels of concern.

The presenters summarized lessons learned from risk tables. The benefits of risk tables included transparency, consistency, and documentation of concerns that lead to reductions in ABC, evidence that a qualitative application of data can have a quantitative impact, and documentation of novel observations and non-stationarity. Challenges of risk tables included: inconsistencies between risk levels and subsequent reductions or lack of reductions, how to complete them for bycatch stocks or low information stocks, and the difficulties in knowing which information goes into which column.

Groundfish Plan Team and SSC recommendations for updates to the risk table framework occurred during the fall of 2023 with an updated risk table framework for 2024. This is the risk table framework that crab assessment authors would use - which has four categories and three rating levels. Risk table use for crab stocks could include the same content that the CPT has used to set ABC buffer in the past but would allow assessments to track the reasoning behind the ABC buffers in a more consistent manner. The purpose is not to change the current practice in making recommendations but to organize the reasoning for transparency and consistency. The presenters suggested a proposed timeline for assessment authors to meet with the ESR/ESP group for information on the ecosystem category which aligned with the CPT meeting where proposed models for that stock were considered.

The CPT recommended the stock assessment authors that have final assessments in Sept/Oct bring forward a draft risk table for CPT review at that time. There was some discussion on whether the risk tables would be better suited in the crab SAFE intro or in individual SAFE chapters. This was left undecided.

Currency of Management

Cody Szuwalski led a discussion about different definitions of snow crab maturity that could be used to frame the currency of management for the stock (i.e., to define MMB). Cody reviewed the problem: using the observed probability of having undergone terminal molt to estimate MMB results in many mature males below legal size included in the MMB estimate. As a result, males

of legal harvest size could be subject to a higher *F* rate in order to achieve the harvest rate based on MMB (i.e., all mature males). Laboratory studies indicate that small males can fertilize females, but Canadian field observations indicate functional maturity *in situ* to be >95mm carapace width.

Cody described work he recently conducted with a general additive model (GAM) to describe variability in the probability of size at terminal molt using mature male density and ice cover. Models with density and ice in them explained the data better: higher densities of large mature males were associated with lower probabilities of terminally molting at size. Cody presented the justification for specifying a subset of morphometrically mature crab as 'functionally' mature and using this definition in the calculation of reference points and OFLs: 1) larger males are potentially more important in the reproduction dynamics, 2) larger males are more important in the fishery, and 3) larger males appear to impact maturity dynamics (higher densities of large males seem to be related to larger size at maturity).

Cody discussed how maturity is treated in the BBRKC assessment, but noted that *Chionoecetes* crab undergo a terminal molt to maturity, complicating the comparison between species. Cody noted that calculating MMB based on functional maturity is possible in GMACS and does not affect the model fit, but does impact management reference point calculations. The CPT discussed the importance of large males and the role of "sneaker" males" (i.e., small males that mate with females when larger males are preoccupied with non-mating activities) in thinking about functional maturity. It was noted that small males may be more important to the reproductive dynamics at lower densities of large males. Cody presented the time series of MMB using various functional maturity definitions including morphometric and 85, 90, 95, 100, 105 mm carapace width (CW) size cut-lines. Management measures (B35, F35, FOFL, OFL, stock status, MSST) for each maturity definition were also presented. As expected, maturity definitions greatly impact the management reference point calculations. The CPT questioned why the stock appeared to be below B_{MSY} for much of the time series in some scenarios. It was noted that under the FMP as written, the target reference levels of MMB-per-recruit can be adjusted if warranted. Cody asked whether he should fit the models to morphological (ogive-based) or functional (size-cut based) mature males, because selecting multiple ways to apportion the survey data is undesirable. The CPT discussed including density dependence related to size-at-terminal-molt in the calculation of reference points. This may be difficult because periods of strong cohorts recruiting to maturity from periods of low abundance occur when large males are in low relative abundance, thereby increasing the relative importance of smaller mature males. But temperature at the juvenile stages also influences the size at terminal molt through molting frequency (i.e., greater molting frequency in warmer conditions results in larger size at maturity). Given the uncertainty in the importance of the small mature males in the mating dynamics, the CPT supports further consideration of functional maturity as defined by a size cut-line in future assessments. The CPT felt that a 95 mm CW size cut-line was a desirable option for exploration given past Canadian studies, though future work on defining size at functional maturity is warranted.

Bering Sea Fisheries Research Foundation update

Scott Goodman from the Bering Sea Fisheries Research Foundation (BSFRF) presented to the CPT on BSFRF research priorities, on-going research projects, and future directions for the BSFRF. BSFRF research directions include distribution and movement of crab in the Bering Sea, bycatch reduction and quantifying impacts on crab populations, stock boundaries, and management options for Bering Sea crab. Scott emphasized that there were large overlaps between the CPT's identified research priorities and BSFRF's, but not exact overlap and he saw this as a useful aspect of multiple organizations pursuing Bering Sea crab research.

The Cooperative Pot Sampling 1 (CPS1) project was completed with support from NOAA and ADFG in Bristol Bay during the winter of 2023, and CPS2 planning is underway for 2024. CPS1 tagged and released red king crab, but CPS2 will not be tagging crab. CPS2 will include Nephrops trawl gear in addition to pots in light of apparently poor sampling of females by pots during CPS1. The goals of CPS2 are to characterize winter spatial distributions for BBRKC with respect to physical variables and to estimate overlaps of BBRKC with groundfish predators.

BSFRF is planning an international snow crab research and management workshop in St. John's, Newfoundland, Canada. It will be cohosted by the Canadian Department of Fisheries and Oceans (DFO) and aimed at understanding dynamics of snow crab stocks globally, comparing management approaches, and other applied research topics to help with further understanding Bering Sea crab dynamics.

BSFRF is seeking BREP funding to understand the interactions of active and derelict pot gear during and after fishing seasons. They will drop pots and monitor CPUE during the active fishery based on gear details and also leave pots in the water as simulated 'lost pots' to document the potential impacts of ghost fishing in the crab fisheries using cameras in and around pots. They also plan to census the scale and magnitude of Bering Sea pot loss to supplement existing information.

Research Update #3: Snow crab SDM

Rebecca Howard (Oregon State University) gave a research update on part of her doctoral research (with coauthors Mike Litzow, Lorenzo Cianelli, and Emily Ryznar) on sex- and maturity-specific species distribution modeling for Eastern Bering Sea snow crab, part of her doctoral research. The specific research questions being investigated are: in addition to environmental conditions, how fishing pressure, disease, and predation affect snow crab sex- and maturity-specific distributions; whether inclusion of anomalous years improves both overall predictions and spatial error; and how models trained on survey temperature data perform compared to alternatives like Regional Ocean Modeling System (ROMS) models.

Rebecca gave an overview of the spatial data incorporated into the models: crab CPUE, Pacific cod abundance, bitter crab syndrome (BCS) prevalence, and bottom temperature and depth, all from the NOAA AFSC Bottom Trawl Survey; observer data on fishing pressure in the directed fishery (aggregated and mapped as 1st principal components by population segment), and

physical features including substrate sediment grain size and sea ice concentration. The study employs Boosted regression trees (BRT), which was selected after comparison with generalized additive models (GAMs). A two-part delta method was employed, combining presence-absence and abundance model components to accommodate zero-inflated CPUE data, and (per the machine-learning approach of BRT), hyperparameters were tuned using a grid search for each of the respective model components. To introduce the following slides showing model results, Rebecca gave a brief overview of how to interpret SHAP value figures, which are commonly used in machine learning methods, but not yet been widely employed in SDM research.

A general finding is that the differences in spatial distributions of population segments (results were shown for immature females, mature females, legal males, and sublegal males) are likely explained by sex- and maturity-specific importance of habitat variables. The results for both presence/absence and abundance model stages indicated the strongest influence for longitude, depth, grain size (phi), temperature and latitude variables, and diminishing influence for day of year, ice coverage, cod CPUE, fishery loading, and BCS, respectively. Rebecca presented examples of SHAP value plots demonstrating the additive effects of paired variables. Results for sediment grain size combined with depth and temperature indicated that all population segments tend to prefer cool water and small grain size, but whereas both groups of males demonstrate a generally linear effect in both variables, both female groups indicate a threshold effect of finer grain size, with the shift from negative to positive effect occurring at a smaller grain size for mature females than for immature females. Results on additive effects more generally indicated that, for legal males and mature females, there was minimal difference in results from models of spatial-only (latitude and longitude) and spatial plus “biological” (Pacific cod, BCS, fishing pressure) covariates, whereas models with spatial plus environmental (ice, depth, temperature, and substrate grain size) variables showed a much greater spatial variation in both high and low SHAP values. For sublegal males and immature females, the spatial plus biological models provided somewhat more spatial differentiation, but the overall pattern was similar across population segments. Rebecca also reviewed results investigating whether training models with anomalous years improves predictive errors. The base analysis used 1995-2014 survey data to train the models, and 2015 to 2021 data to test, and comparing overall and spatial RMSE values from the training and test data sets. There was little difference in overall RMSE shown, but some large differences did appear in spatial RMSE in a handful of grid cells along the margins of the survey area. Finally, Rebecca briefly discussed currently ongoing work focused on training models using survey data and ROMS output for temperature to determine whether Bering10K ROMS temperature forecasts can be used to predict snow crab abundance for the next survey season. Rebecca noted that she and her coauthors have recently submitted a manuscript on some of the research completed thus far, but other than her slides, no document is being distributed at present.

The CPT discussed the treatment of temporal variation in the modeling approach. Rebecca noted that spatial observations for CPUE were paired with data from the same year for time-varying covariates (from the survey and observer program), and variation over time during a given survey year was captured by a day of year variable, which demonstrated relatively weak influence, and a variable for year of observation was tested but dropped. Rebecca also noted

that a goodness-of-fit metric was used to compare BRT and GAMs approaches and supported use of BRTs, but did not include details in the presentation. A CPT member suggested using maturity rather than size to distinguish male population segments, however, it was noted that maturity is measured for each female in the survey, but not for males. The CPT also discussed how data from the northern Bering Sea survey could be treated, given that only one year of NBS data was included in the training data set, and it was suggested that fitting the model using only observations from years when the NBS survey was conducted might better capture effects that influenced the spatial distribution of the large juvenile cohort over time. There was also a suggestion of using 2019 instead of 2018 as the anomalous year, given that the largest spatial shift in the stock occurred in 2019.

Research update #4: Fishery dependent SDMs for BBRKC

Emily Ryznar (NOAA AFSC – Kodiak Laboratory) presented current work on fisheries-dependent species distribution models for Bristol Bay red king crab (BBRKC) to the CPT. Recent declines in mature BBRKC abundance, stakeholder concern over BBRKC bycatch in groundfish fisheries, and observed shifting distributions of BBRKC from the National Marine Fisheries Service (NMFS) summer trawl were motivations to gain a better understanding of BBRKC distribution outside of the summer survey period. This work can also potentially be used for evaluating the efficacy of current and proposed closed areas such as the Red King Crab Savings Area (RKCSA) and NMFS Area 512.

The overall objective of the work was to try and gain a better understanding of BBRKC distribution in data poor periods using fishery-dependent data given that fishery-independent data is not readily available outside of the NMFS summer trawl survey. Using fishery-dependent data, Emily sought to build species distribution models to 1.) evaluate if BBRKC bycatch in non-pelagic trawl fisheries can be predicted (“Bycatch” model) and 2.) assess historic important BBRKC legal male fall habitat in relation to conservation areas (“Fall distribution” model).

Using groundfish observer data from 1998-2022, the bycatch model sought to predict bycatch occurrence and abundance by year of legal and immature males, and mature and immature females in fall/winter/spring yellowfin and rock sole trawl fisheries. Covariates used in the analysis included environmental (SST, bottom temperature, ice cover, sediment, and depth) and biological (BBRKC, yellowfin and rock sole fishery CPUE). The fall distribution model sought to predict occurrence and abundance in legal males in the fall using crab fishery observer data and directed fishery logbook data from 1998-2022. Covariates used in the analysis included environmental (SST, bottom temperature, ice cover, sediment, depth, slope, tidal maximum, current speed/direction, and wind speed/direction) and biological (BBRKC survey abundance and BBRKC bycatch in flatfish trawl fisheries). Emily is currently working on incorporating 2023 data into both models.

Emily provided an overview of the species distribution modeling approach used. Once the response and predictor data was processed and compiled, the models were fit with 80% of that data. The models were fitted in a delta model framework where occurrence and abundance are modeled separately. Within this framework, Boosted Regression Trees (BRTs) were used. Next,

to assess how well the models performed in their predictive capacity, model performance was tested using the remaining 20% of the data. Based on the predictions of models, various metrics are then calculated to assess the model predictive performance. Once satisfied with model performance, covariate importance was evaluated for both models and objectives.

Using the bycatch model, Emily explained that the first finding was that BBRKC bycatch can be reasonably predicted because all the out-of-sample performance metrics were excellent for predicting bycatch occurrence and abundance across sex, size, and maturity categories. The second finding was that BBRKC abundance from the summer survey and target groundfish fishery CPUE came out as highly important predictors for predicting bycatch across sex, size, and maturity categories. By analyzing BBRKC abundance weighted centers of distribution by latitude for NMFS survey catch, observed bycatch, and predicted bycatch, Emily showed evidence that bycatch and survey distribution has changed since the RKCSA was established in the 1990s and noted a general northerly shift.

Using the fall distribution model, Emily showed that environmental covariates were more important than biological covariates for predicting legal male fall occurrence and abundance. It was noted that three of the top five covariates for predicting fall legal male distribution are dynamic temperature covariates (summer bottom temperature, September/October SST, and July/August SST). Using fall BBRKC legal male encounter probability percentiles from the past 5 years, Emily showed that legal male encounter hot spots are generally centered around the RCKSA and NMFS Area 512, but these hot spots vary temporally. Comparing BBRKC fall male encounter hotspots in warm versus cold years (2012 vs 2015) illustrated the dynamic nature of BBRKC distribution with different environmental conditions. Emily noted that these findings have been corroborated by other studies as well and that ongoing BBRKC tagging work will further inform distribution.

Stock Prioritization

Sarah Rheinsmith reviewed the current timing of crab stock assessments and the CPT discussed changes that may be warranted. The last review was completed in January 2021, when PIRKC was moved to a triennial assessment basis and SMBKC was moved to a biennial basis. The CPT considered the timing of all stocks and considered changes for NSRKC and PIBKC. The next NSRKC assessment will be completed in December 2024 because of changes in Council meeting scheduling. The CPT discussed that the biennial timing for PIBKC is useful for providing information for biennial rebuilding status updates and for providing updates to stakeholders in fisheries that are closed as protection for this stock. The CPT proposes shifting this stock assessment to every four years. The next scheduled assessment for PIBKC is in October 2025 and the timing of this change either could be implemented after that assessment is completed or in October 2027. The CPT agreed that annual assessments should continue for the stocks currently on an annual cycle because of high variability in survey abundance over time.

Stock	Assessment Timing	Next Assessment
EBS Snow Crab	Annual	October 2024
BBRKC	Annual	October 2024
EBS Tanner Crab	Annual	October 2024
PIRKC	Triennial	October 2025
PIBKC	~~Biennial~~ Quadrennial	October 2025 (start following Oct '25 approval or extend through '27 SSC choice)
SMBKC	Biennial	October 2024
NSRKC	Annual	~~February 2025~~ December 2024
AIGKC	Annual	June 2024
PIGKC	Triennial	June 2026
WAIRKC	Triennial	June 2026

Handling mortality consistencies

Katie Palof led a discussion that revisited the handling mortality rates being applied to directed and bycatch fisheries for BSAI crab. Some inconsistencies exist among the assessments about whether the discard handling mortality rates are applied outside vs inside assessment models. The CPT recommended that total catch be fitted in the model, after which mortality rates can be applied by weighting gear-specific mortality rates (e.g., trawl vs. fixed gear) by the proportion of bycatch for each gear type. There was a question about the groundfish fisheries bycatch rates and whether the same rates should be applied for all crab stocks. The Tanner assessment assumes a 32.1% handling mortality rate for groundfish pot fisheries, while all other crab stocks use a 50% mortality rate for groundfish pot fisheries. There was some confusion about the original intent in the Tanner assessment for using 32.1% for groundfish fisheries. The CPT recommended that the Tanner assessment use 50% handling mortality rate for groundfish fixed gear (pot and long line) to be consistent with other crab assessments. There was a question about the 50% assumed handling mortality rate for groundfish pot fisheries and whether there is data to inform this rate. It was noted that very little data exists to inform this rate.

Skipper Survey Results

Cory Lescher (ABSC) provided the CPT with a summary of the recent BBRKC season skipper survey results. The skipper survey was developed by Alaska Bering Sea Crabbers in 2020 and 2021 to provide qualitative information about the fishing season. It was first implemented in the snow crab fishery during the 2021/22 season and has since been incorporated into the ESP for snow crab as a qualitative information source. The opening of the BBRKC fishery for the 2023/24 season offered an opportunity to obtain information from the fleet which catches BBRKC for the first time.

The 2023/24 fishery was opened at a low TAC of 2.15 million lbs after two seasons of fishery closures. Nearly half (13 / 31) of the vessels that participated in the fishery completed the

survey. Survey participation and results are anonymous, and were presented verbally at the meeting (not in the slides) to ensure confidentiality. A summary of the results will be incorporated into the ESP report card for this stock. ABSC was unclear if there may be systematic challenges to increasing responses (e.g., lack of connectivity, interest, etc) due to anonymity of the survey.

Overall, skipper results suggested similar conditions compared to the last open season, relayed that longer soak times resulted in a decrease of dicards (less juveniles and females in the pots), and provided additional anecdotal information about the fishery season. ABSC is hopeful to begin a skipper survey for AIGKC during the 2024/25 fishery and will explore feasibility of a questionnaire during the Tanner crab fishery, though it was noted there are some challenges with timing and communication.

Ecosystem and Socioeconomic Profile update

Erin Fedewa and Kalei Shotwell presented several discussion points regarding Ecosystem and Socioeconomic Profiles (ESPs), including timeline, prioritization for different stocks, and the internal review process. Typically, the request for indicators goes out in January/February, and the ESP information is presented to the CPT and Council in September/October. However, in September, it can be difficult to interpret report card indicators before seeing the second stage indicator analysis. It was proposed to present the modeling updates at the May CPT meeting, including second-stage indicator analyses, and any new ecosystem indicators in preparation. The condensed report cards would then be presented at the September CPT meeting and would contain current year trends and highlight indicators thought to be important. This new timeline would help with both interpretation of the indicators as well as reduce workload in September/October for the CPT and Council. The CPT agrees with this new timeline.

It was proposed that the Tanner crab ESP be postponed until May 2025 once the process and timeline of ESPs has been streamlined. It is possible that a post doc could do work on the initial Tanner crab ESP. It was also proposed to drop the Saint Matthew blue king crab (SMBKC) ESP to focus on other stocks. The SMBKC ESP contains few meaningful indicators and is of limited utility. This ESP can be revisited if/when more data become available. In May 2024 the Bering Sea snow crab and Bristol Bay red king crab ESPs will be presented with condensed report cards for each at the September meeting. There is some exploration of creating a general groundfish ESP which would contain indicators that would apply to many stocks. This same approach could be implemented for crab and may help inform risk tables for stocks that don’t yet have ESPs. Indicators could include temperature, chlorophyll production, and other automated indicators, and could be subset by crab stock area. Many of the global products for the ecosystem indicators and socio-economic indicators are automated now. It is possible to automate some information from the summer trawl survey, However, it might be difficult to have crab information in time for the September CPT meeting. A list of automated indicators could be developed for the future.

It was noted that ESPs should focus on stock health. However, often socio-economic indicators look at downstream effects, which are not drivers of stock health. These indicators are already

included in the Economic SAFE. It is also difficult to evaluate community effects by individual stocks because communities are usually impacted by an assemblage of fisheries. The scope of socio-economic information in the ESP needs to be clarified. The ESP, including socio-economic indicators, can help inform ABC (for example, risk tables) and TAC considerations.

An external review process of ESPs was suggested as a way to lessen CPT workload and engage additional subject matter experts. It was noted that ADF&G is making TAC decisions and it may be beneficial to formally engage with ADF&G about which indicators to include in the ESP that help inform that process. ADF&G staff noted that they do review the ESPs when making TAC decisions, but it is difficult to incorporate that information quantitatively.

A repository exists for standardizing templates for ESP products. Secondary stage indicator analysis is being moved to a separate repository to standardize the approach between groundfish and crab ESPs. Script development and best practices will be further developed this spring. These discussions will also be presented to the National ESP coordination team.

Research Update #5

Louise Copeman presented summaries of crab projects at the Hatfield Marine Science Center in Newport, Oregon, including: 1) laboratory experiments on temperature dependent vital rates of early juvenile crab stages, 2) fields studies focused on juvenile crab energetic condition, and 3) addressing knowledge gaps in the warming/starvation hypothesis for snow crab in the Bering Sea.

Juvenile snow crab and Tanner crab were subject to a range of temperatures to understand the impacts of different temperatures on growth and survival. The experiments lasted over two years and returned high survival for both species between 0 and 5 degrees C, but low survival below 0 and above 9 degrees C. Growth rates for Tanner crab were significantly higher at all temperatures, but absolute growth rates for both species increased with temperature until 9 degrees C and declined at 12 degrees C. An important conclusions from this study is that the realized snow crab distributions (i.e. in the cold pool) are likely due to interactive effects such as predator avoidance or food quality, but not directly a physiological thermal limitation.

Crab were collected in a cold (2012) and warm (2014) year in the Bering Sea and the fatty acids (which are a proxy for condition) were significantly poorer in the warm year. The poorer juvenile conditions appeared to be related to smaller diatom flux. Given these analyses, the authors wanted to look at the relative impacts of direct (via growth) and indirect (via foodweb effects) thermal effects. A simple condition metric was developed for juvenile snow crab based on fatty acid biomarkers derived from samples from hepatopancreas collected on the NMFS survey. Samples from 2019, 2021, 2022, and 2023 revealed anomalously low crab conditions associated with the marine heatwave in 2019 and diatom fatty acid biomarkers declined during the heatwave. Further, open water spring blooms were associated with lower diatom-sourced lipids in juvenile crabs.

In many laboratory studies, adult snow crab show strong resilience to starvation, yet the collapse in 2018 and 2019 has been suggested to be related to starvation. The authors are holding juvenile crab at 2, 5, and 8 degrees C and these crab have also shown high resilience to starvation to this point in the study. One question raised was the comparability of resilience to starvation in small boxes in the laboratory (which is how historical and the presenter's current study are designed) to the pressures experienced in the wild (e.g. need to forage, pressure from predation), but it's not clear how to make these comparisons.

New business

Upcoming meetings:
May 13th - 17th, Anchorage, AK (NPFMC offices, monday start)
September 9th - 13th, Seattle, WA (ACFC)
Nov 5th, virtual meeting to approve NSRKC final specs (morning)
Jan 13th ? (modeling workshop, no CPT meeting)

Draft May agenda topics:
AIGKC final SAFE
ESP updates
Proposed models: Snow, tanner, bbrkc, smbkc
Survey update on length-weight regressions
NSRKC GMACs update
Research updates as needed
Economic impact of snow crab closure

Others in attendance: **indicates presenter*

Andy Nault
Anna Abelman
Brent Paine
Brian Ritchie
Caitlyn Stern
Chris Siddon
Chris Woodley
Connie Meldovia
Cory Lescher
Diana Evans *
Emily Ryznar *
Gordon Kruse
Gretar Gudmundsson
Hamachan Hamazaki *
Heather McCarty
Ivonne Ortiz
Jamie Goen
Jared Weems
Jeff Steele
Jenefer Bell *
John Gauvin
John Hilsinger
Kendall Henry
Kenny Down
KJ Clark
Lance Farr
Laurie Balstad
Linda Kozak
Liza Hasan
Luke Henslee
Madison Heller-Shipley
Mark Stichert
Nicole Kimball
Nicole Watson *
Noelle Yochum
Paul Wilkins
Rachel Baker
Rebecca Howard*
Sabrina Garcia
Scott Goodman
Sherri Dressel
Stephanie Madsen
Tim Loher
Tom Suryan
Vicki Vanek
Wes Jones