North Pacific Fishery Management Council

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Crab Plan Team

REPORT

January 17-20, 2023 Anchorage, AK.
Hybrid Meeting: Anchorage, AK. NPFMC Building

CPT Members in attendance:

Mike Litzow, **Co-Chair** (AFSC-Kodiak)
Katie Palof, **Co-Chair** (ADF&G-Juneau)
Sarah Rheinsmith, **Coordinator** (NPFMC)
William Bechtol (UAF-Homer)
Ben Daly (ADF&G-Kodiak)-Zoom
Erin Fedewa (AFSC-Kodiak)-Zoom
Brian Garber-Yonts (AFSC-Seattle)-Zoom
Shareef Siddeek (ADF&G-Juneau)
William Stockhausen (AFSC-Seattle)
Cody Szuwalski (AFSC–Seattle)
Krista Milani (NMFS- Dutch Harbor)
Ginny Eckert (UAF/CFOS-Juneau)
Andre Punt (Univ. of Washington)
Miranda Westphal (ADF&G-Dutch Harbor)-Zoom

Members absent: No members were absent.

Others in attendance:

Aja Szumylo
Alix Laferriere
Andy Nault
Andy Nault
Angel Drobnica
Anna Henry
Anne Vanderhoeven
Beth Concepcion
Brent Paine
Chris Long**
Chris Woodley
Christine Forcucci
Cory Lescher
Darren Pilcher **
David Bryan
David Witherell
Dawn
Diana Stram
Doug Duncan
Emily Ryznar
Frank Kelty
Hamachan Hamazaki**
Henry Tashjian
Ian Stewart
Jamie Goen
Jared Weems
Jared Weems**
Jean Lee
Jen Gardner
Jennifer Bell
John Gauvin
John Hilsinger
Jon McCracken
Jon Richar
Jonathan Richar
Kendall Henry
Kenny Down
Leah Zacher**
Lenny Herzog
Mark Stichert
Linda Kozak
Madi Heller-Shipley
Martin Dorn
Mason Smith
Matthieu Veron
Michelle Stratton
Nicole Kimball
Noelle Yochum
Rachel Spain
Renae Ivanoff
Sam Cunningham
Sarah Marrinan
Scott Goodman **
Sherri Dressel
Tyler Jackson
Vicki Vanek
Wes Jones

**indicates presenter

Modeling Workshop

CPT members, assessment authors, and others involved in crab assessment modeling met to discuss topics of interest and concern for crab population modeling. The workshop started out with some recent topics that have been discussed at fall Council meetings on modeling natural mortality and unobserved fishing mortality. Participants noted that proposals are in the works to pursue these topics and the potential for a SSC endorsed workshop/working group on unobserved fishing mortality.

The modeling workshop mainly focused on GMACS (Generalized Model for All Crustacean Stocks). Matthieu Veron, a post-doc with Andre and Cody, summarized recent updates to GMACS, which included the task of merging the king crab and snow crab coding branches. He also presented updates to the 'gmr' R package, which includes R scripts and routines to compare model output among versions to ensure version quality and control as the base code gets updated. During the GMACS work, participants were also introduced to a base level of GitHub interactions to help with version control and having multiple code contributors.

Code updates currently in place or underway:

- Simulation code – mostly coded into the latest version
- Environmental variable linkages - underway

Additional GMACS topics (either underway or future):

- Documentation for GMACS and the gmr R package to use this, including vignettes for new users (Matthieu is working on this)
- AIGKC is ready to move to GMACS, bridging analysis was completed and shows comparable results
- NSRKC GMACS model development sometime this year. Discussions are underway to determine the best steps forward for this stock
- Future of GMACS – where it will be held (stay on GitHub?) and who would be the "gatekeeper"
- Modifying the code to include entering data on the molting probability (Cody)
- Potential changes to the format of the .dat and .ctl files. (Buck)

Administrative

The January 2023 Crab Plan Team (CPT) meeting was at the NPFMC building in Anchorage, AK, with a virtual component held on Zoom, and connection information posted to the CPT eAgenda. The modeling workshop portion of the meeting began at 8:30 a.m. AKT on Tuesday, January 17, 2023. The CPT meeting began at 1:00 pm AKT on Wednesday, January 18, 2023, with technical setup and overview of the meeting application. CPT Co-Chairs Mike Litzow and Katie Palof reviewed guidelines for the meeting, including how public comments would be addressed during the meeting, as well as note-taking assignments and timing for meeting deliverables, including finalizing the SAFE introduction and this CPT Meeting Report.

Economic SAFE

Brian Garber-Yonts provided an overview of the Economic Status Report, which covers data through the 2021 calendar year, with some limited data through 2022. Jean Lee and Anna Abelman (AKFIN) contributed to the report. The document was not available to the CPT in advance of this meeting or at the time of the presentation. The complete economic SAFE will be reviewed by the SSC during their April 2023 meeting.

Much of the data in the Economic SAFE are available online on the AKFIN human dimensions data explorer website, where data tables may be queried. (https://reports.psmfc.org/akfin/f?p=501:2000). The data are reported by calendar year unless otherwise indicated; for fishery seasons that substantially span calendar years (AI golden king crab and BS Tanner crab), calendar year values reported include early and late portions of successive crab years.

A set of report card indices is included in the Executive Summary, and are presented as time series figures as developed for use in Ecosystem and Socioeconomic Profiles, though not the same set of indicators as reported in ESPs. The indices report the mean and standard deviation (SD), with data represented as black dots (within one SD of the mean), red dots (above one SD of the mean) and blue dots (below one SD of the mean). The CPT commented that these plots are difficult to interpret for low levels in recent years and requested that the plots be revised to include an additional y-axis so that low values are easier to discern. Many of these quantities had much higher values before rationalization. Several indices are at historical lows, including the number of participating vessels, pounds landed, and the number of active processors.

Record high prices were recorded in 2021 for AI golden king crab, BS Tanner crab, and BS snow crab. These prices were likely driven by the shift from food service markets to retail markets during COVID-19 lockdowns. Prices started to decline at the end of 2021, likely as retail demand declined with relaxing lockdown measures, while food service markets could not sustain the higher prices. As a result, there remains considerable unsold inventory, which effectively drove prices down. As an aside, the largest snow crab producer globally is the Canadian Atlantic, and their harvest increased by about one-third last year. Russian red king crab and snow crab flowed into US markets well into 2022, as previously contracted imports were exempted from embargos on imports from Russia put into place early in the year.

Crew positions and crew days at sea decreased in 2021, but crew pay per day increased. On average across all crab stocks, crew pay was over $1,100 per day in 2021. Total processing labor hours and wage earnings increased by approximately 20% in 2021, while hourly processor wages increased slightly.

A new set of figures that describe crew and processing employment and income by community was presented. Note that the y-axis varies among these plots, so they cannot be directly compared within and outside of Alaska. Total crew employment numbers for Alaska and Washington are approximately equal, however, aggregate Washington crew earnings are substantially higher than for Alaska. Residents from Alaska and Washington each made up 33% of the 2021 crew labor pool. The largest component of processing employees is seasonal workers from outside of Alaska. The CPT requested that one plot incorporate Alaska and non-Alaska communities simultaneously to make these comparisons easier to visualize. The non-Alaska communities could be added on top of the Alaska ones so that both are visualized. Including Alaska-specific graphs is helpful for seeing differences among Alaskan communities.

Regarding vessel income and costs, gross profit in 2021 was $1.3 million, up 14% from 2020. Lease costs represented 39% of gross revenue for the average vessel. However, vessel owners can report lease costs in different ways, making it difficult to determine actual lease costs. At the fleet level, the quota share sector had 56% of aggregate gross profit, and the vessel sector had 44%, although all operating costs are not included. Generally, there is an increasing trend in distribution of operating profits towards the quota share sector.

Quota share pool holdings have increased over time in trust/estate and CDQ/nonprofit ownerships and away from corporate ownership, although some of the latter shift may be a result of data coding changes over time. The quota share pool held by active owners (defined as a person holding ownership in a QS entity and in a crab vessel active in one or more crab fisheries during the same crab year) varied among QS pools. For example, AI golden king crab fisheries quota is predominantly held by active owners, while snow crab, king crab, and Tanner crab have lower active ownership. Active quota share participants across Bristol Bay red king crab, snow crab, and Tanner crab held 62% of the quota shares in the 2020/21 crab year, but this percentage dropped to 55% during 2021/22. In contrast, active quota share participants

in the AI golden king crab fishery remained over 85% in the eastern area and 95% in the western area. There is also a trend in increased shares owned by CDQ groups.

Priorities for the 2023 Economic SAFE will be to: track economic conditions during the period of closures and develop additional indices; better integrate the crab and groundfish economic SAFEs; improve accessibility of data through AKFIN; and prepare for the 2023 NPFMC review of the crab rationalization plan.

Alaska Bering Sea Crabbers commented that they are reaching out to NOAA Fisheries to inquire about how independent crab fishermen may be supported as they are more vulnerable to crab closures than other entities engaged in fishing.

NSRKC- final assessment, stock status, OFL/ABC

Leah Zacher presented laboratory studies performed at the NMFS lab in Kodiak aimed at understanding the functional size at maturity for Norton Sound red king crab (NSRKC). The current definition for NSRKC size at maturity (≥ 94 mm carapace length [CL]) was based on observations of BBRKC size at maturity, with and adjustment for the smaller body size of NSRKC. Leah described experiments conducted with male crab NSRKC that were transported to Kodiak and held with mature female crab to observe the probability of fertilization success by size of male crab. There was near 100% fertilization success for males larger than 79 mm CL. The CPT was supportive of studies used to inform assumptions about maturity in assessment and management, while encouraging caution and consideration of the potential for lab effects. Consideration of mate competition and potential size interactions among sexes (e.g., is it difficult for a very large male to fertilize a very small female) could be useful. Similar studies for other stocks of red king crab would be beneficial more generally. The CPT recommended more discussion about when and how to change maturity definitions to establish guidelines for the future given the potential impact on reference points used in management.

Hamachan Hamazaki presented one model scenario (model 21.0) with updated fishery and survey data for consideration by the CPT for status determination and OFL/ABC calculation in the NSRKC fishery. The model is a length-based integrated population model that tracks male crab abundances and incorporates size-dependent natural mortality. Animals >123 mm CL have an estimated M of 0.62 yr^{-1}; smaller animals have a specified M of 0.18 yr^{-1}. Two large decision points were considered by the CPT with respect to the assessment: 1) whether to use a length-dependent OFL calculation that incorporates the size dependent natural mortality in model 21.0, and 2) how to calculate discards to determine what the total catch is for comparison against the OFL.

The CPT recommended that we continue to use a length-independent OFL calculation (i.e., one that does not increase the F_{MSY} proxy for the larger size bins in which additional M is estimated beyond that implied by the selectivity pattern) because the original intention of the harvest control rule was a single M. Incorporating size-variation in M was not discussed when evaluating candidate Tier 4 rules. The CPT recommended using the model-predicted discards from this year to calculate the total catch because of a lack of observer data. There is no current plan to collect future data on discards and the CPT noted that using the model to predict discards is somewhat circular. Consequently, the CPT recommended returning to retained catch OFL beginning in 2023.

The CPT recommended decreasing the buffer between the OFL and ABC to 30% from the 40% used in 2022. Several of the concerns that motivated the choice of a 40% buffer in 2022 are no longer present (Table 1). Based on a total catch measure of removals, overfishing did not occur in 2022. Based on a length-invariant OFL, the CPT recommended a 2023 retained catch OFL of 0.292 thousand t. The recommended ABC after applying a 30% buffer was 0.204 thousand t.

The CPT appreciated the quick fix to the jittering analysis the analyst provided during the meeting, which indicated the model converges to the same answer given different starting points. A few other minor issues were identified by the CPT that should be considered or remedied in future SAFE documents, including providing unique identifiers for figures and tables (there were duplicate figure and table numbers in the document) and not including the projected year when setting the proxy for B_{MSY} (the 2023 estimated biomass was included in the calculation of the B_{MSY} proxy).

Table 1. Concerns initially expressed by the SSC in 2020 about the NSRKC assessment, and their continued relevance for assessments in 2021 and 2022.

2020 SSC concern	2021 CPT Still concern?	Reason	CPT 2022 Still concern?	CPT 2023 Still concern?	Reason
1. Considerations of other stocks with similar levels of uncertainty	Yes		Yes	Yes	
2. Concerns with model specification in part indicated by a positive retrospective pattern, whereby successive assessments indicate an increasingly pessimistic estimate of stock size for the same years. The full magnitude of the retrospective bias is unknown given that peels of the data go back only a few years. The cause(s) of the pattern is unknown	No	Retrospective patterns are relatively small compared to other stocks and within commonly cited acceptable ranges. The retrospective pattern was characterized for 10 years of peels (Mohn's rho 0.180).	No	No	Mohn's rho 0.226. Slight increase relative to 2021.

2020 SSC concern	2021 CPT Still concern?	Reason	CPT 2022 Still concern?	CPT 2023 Still concern?	Reason
3. Shortage of discard data and resultant inability to manage the stock based on total catch, which is the standard for federal fisheries	Less	Hamachan presented methods to account for total catch; the LNR2 method was chosen by the CPT.	Yes	Yes	CPT recommended using model estimates of discards for status for 2022 and a retained catch OFL for 2023.
4. Unresolved issues associated with the apparent high *M* for the largest size class	Yes		Yes	Yes	
5. 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	Yes	
6. Very low fishery CPUE and the inability of the fishery to attain the ABC in 2019	Yes		Yes	No	The 2022 CPUE was one of the highest in the last two decades.

2020 SSC concern	2021 CPT Still concern?	Reason	CPT 2022 Still concern?	CPT 2023 Still concern?	Reason
7. Unusually large numbers of old-shell males in the fishery in 2018-2019	Yes		Yes	No	
8. High proportions of barren females in survey and fishery observations, indicating some reproductive failures in 2019	Less	Fewer barren females in 2020 and males are reaching the appropriate size for mating.	Increased	No	Many fewer barren females in recent surveys.
9. Below-average numbers of pre-recruits (<94 mm CL) in 2015-2018, suggesting that below-average recruitment to the fishery will be experienced for several more years	Yes		Less	No	The recruitment that was observed in 2019 has persisted.

2020 SSC concern	2021 CPT Still concern?	Reason	CPT 2022 Still concern?	CPT 2023 Still concern?	Reason
10. Large uncertainty in the magnitude of the most recent year class (pre-recruits in 2019), preliminarily estimated to be large. However, these small crab are several years away from recruiting to the fishery as legal crab and they are challenged by unprecedented recent increases in Pacific cod, a crab predator, in Norton Sound.	Less	The year class is tracking, and uncertainty is less now that the year class has been observed several times.	Less	No	The year class is tracking, and uncertainty is less now that the year class has been observed several times.

BSFRF Update

Scott Goodman gave a brief update on Bering Sea Fishery Research Foundation (BSFRF) ongoing research projects and recent efforts to secure funding. Scott identified three major parts of BSFRF's strategy to address problems faced by the crab industry due to fishery closures: 1) financial relief to the industry and affected communities, 2) identifying and promoting flexible management options that may be considered or implemented in the near term, and 3) focused research that is part of BSFRFs research portfolio. BSFRF's larger work plan includes preparing existing data for publication and distribution to interested parties, and an overall update of the strategic plan in light of the status of Bering Sea crab stocks and economic crisis facing the industry. Scott noted the priority of work focused on snow crab, specifically, conservation measures for the depressed crab population and spatial studies to identify important snow crab areas (females, juveniles, nursery grounds, etc.), and raised for discussion the potential role of the Northern Bering Sea survey and the snow crab management area boundary, in the context of management flexibility and potential to allow a small fishery during rebuilding. Scott and CPT members agreed that the NBS population does not currently or historically appear to contribute to recruitment of large males to the commercial fishery, but it was noted that longer-term changes in environmental conditions and stock distribution could change this, and that it may be an area for research. Scott further noted that crab bycatch research is an ongoing priority for BSFRF, with a focus on gear work (through current BREP projects) in directed and non-directed fisheries. Unobserved fishing mortality (UFM) is also a focus area, to help further understanding of the scale and magnitude of the issues for crab.

An immediate BSFRF project is a research charter of two commercial crab vessels to conduct field work in Bristol Bay, to collect data to help improve understanding of the winter-spring spatial distribution of the stock. This includes a methods-based pot survey of the core BBRKC habitat area to measure CPUE, and satellite tagging study of red king crab in high density areas; in addition, an experiment will be conducted to test three pot gear design modifications to reduce bycatch. The CPUE study will use standard commercial RKC pots, with prescribed soak times and gear modifications to improve retention of juveniles, and a planned 1,000 to 1,200 potlifts. Rather than being a direct analog to the NMFS trawl survey and abundance estimates, the pot survey and CPUE results are intended to allow comparison of the spatial distribution of the stock during winter, relative to the summer distribution captured by the trawl survey. Scott noted that the charter is expected to span 20-25 days, most of which will be spent on the pot survey, and for the last 4-6 days one vessel will perform collection and tagging of male RKC in the four highest density stations identified during the pot survey (with a planned 175 tags, programmed to release just prior to the start of the NMFS trawl survey), and the other vessel conducting tests for the pot gear modification experiment. Scott noted that both NOAA and ADFG are supporting this work directly with about $850k in immediate funding, with a number of CPT members involved in study design, and that the science party on each boat will include personnel from NMFS, ADFG, and BSFRF. The charter and fieldwork are expected to begin in mid-March, and data and results are expected to be made available for the fall assessment cycle.

Scott gave an overview of project synopses of five BSFRF research areas for which funding support continues to be sought: crab movement; crab surveys; habitat and recruitment; bycatch; and crab predation. With assistance of Alaska Bering Sea Crabbers (Executive Director Jamie Goen), BSFRF was recently successful in gaining $2.75 million research funding in Congressionally Directed Spending through Sen. Murkowski's office (with support from Sens. Sullivan, Murray, and Cantwell) to partially fund some of the outlined work and stabilize operations for BSFRF; indications are that funds will be released to support BSFRF and its research later this year.

Scott concluded his presentation by posing several questions of immediate interest to the BSFRF Board and crab industry, touching on issues discussed by the CPT earlier in the presentation, including: CPT expectations for snow crab conservation measures and spatial protections, and the plan for including northern Bering Sea area in assessment and management. CPT members cautioned against expectations of a substantial reversal of population trends coming from the 2023 trawl survey, and challenged the premise that spatial protections have strong potential to aid snow crab recovery, given the strong juvenile cohort preceding the warming events of 2018-2019, and lack of apparent corresponding change in trawl effort and spatial distribution. Scott acknowledged the points, but noted growing industry concern about the snow crab assessment and the survey, and clarified that hopes are for signs of continued juvenile population development rather than near-term appearance of abundant mature males, and emphasized that finer temporal and spatial scale analysis of potential spatial protections may identify critical habitat or other factors that may be key to maximizing the potential for snow crab recovery. Scott also noted BSFRF interest in the new SSC UFM working group, and in being involved as its work develops; Sarah Rheinsmith noted that, at its December 2022 meeting, the Council endorsed the SSC's recommendation for forming the working group, and that organization of the working group is pending.

Snow Crab Rebuilding- final action update

Sarah Rheinsmith and Jon McCracken provided the CPT with an update on the status and timeline for final action by the Council on the Bering Sea snow crab rebuilding plan. Sarah summarized the Council's December meeting selection of Alternative 2 (adopt a rebuilding plan and identify a target rebuilding timeline), and Option 2 (allow bycatch and a directed snow crab fishery under State harvest guidelines) as the Preliminary Preferred Alternative for the rebuilding plan. The projected minimum rebuilding time (T_{min}) is 6 years and the projected maximum time (T_{max}) is 10 years. The Council will take final action in February 2023.

Jon presented an analysis responding to a request for projected catch and removals during rebuilding. Removals are projected to be low over the next four years given the current stock status. However, there is considerable uncertainty around these projections, and the projections should be used for reference and context only. The CPT discussed the changing ratio between bycatch and directed fishery removals over time in these projections, and it was noted that examining projection model output might resolve these concerns.

The analysis of economic impacts and CDQ ownership trends noted that economic data for 2021/22 were based on projected prices because actual price data were not available in time for the analysis. One result of the social and economic analysis was that non-diversified entities are expected to experience the strongest impacts early during the rebuilding process, which implies the potential for vessels to leave the fishery. Ex-vessel revenue during the final two years of rebuilding was projected between $76 million and $109 million. The CPT also discussed the fact that these were median estimates and thus underestimated the variability that should be expected. The 5th and 95th percentiles for population projections might be a better basis for characterizing the full range of expected variability.

Finally, the expected effects of Alternative 1 were discussed. Alternative 1 and Alternative 2 have similar expected effects, with the exception that marine mammals may be impacted by not conducting a rebuilding plan under Alternative 1.

Crab Updates and Crab Conservation Prioritization

Sarah Rheinsmith led a discussion regarding a request from the Council December 2022 meeting for the CPT to prioritize five among management issues and provide feedback on their ability to improve crab stock conditions:

- Consider the efficacy and ability to identify areas (static and/or dynamic) for groundfish fishery closures to protect snow crab, and suggested areas that could bring meaningful savings.
- Align crab PSC limit boundaries with the crab stock management area for snow crab.
- Remove or revise trawl crab PSC limit floors for Bristol Bay red king crab and Eastern Bering Sea snow crab.
- Update trawl crab PSC limits based on status of crab stocks.
- Establish non-trawl crab PSC limits.

The CPT was also asked to assess work that has been completed that could inform management decisions on these issues, and provide insights into additional research that might be needed for meaningful review of management measures. Sarah noted that the CPT's role is to evaluate which measures may provide conservation to a stock based on available or achievable science, and not comment on which management measures the Council should implement.

Prior to the meeting, Sarah polled CPT members for their initial thoughts on each of the five issues. Although poll results varied, many members were uncertain of the benefit provided to the stock in many cases, and noted that more research is generally needed to assess which would provide the most benefit to crab stocks.

The CPT discussed the idea of directional measures, meaning some measures could be implemented that may provide positive benefits to the stock, but the magnitude of the effect is unknown. However, in some cases it is not always clear if the direction is positive or negative for the stock under given proposed management measures (e.g., groundfish fishery closures may result in negative effects on the stock due to increased abundance of predators). The CPT noted that, in many cases, it is not possible to design experiments at a population level to gain knowledge on the benefit of these measures to the overall stock condition.

There was also discussion on whether additional tools can be used for bycatch management other than PSC accounting, specifically to address unobserved mortality in gear that may interact with crabs but not bring them on deck to be observed. The fishing effects model and EFH maps are tools that may be used to help inform bycatch. However, more research is needed to utilize these tools and should be made a priority. Currently the fishing effects model output is available by month. The usefulness of this tool for in-season management depends on the timeliness of the data. It was suggested that it might be useful to look at the seasonal forecast instead of using data for in-season management.

The CPT noted that the idea behind having PSC limits is to modify fishing behavior. Theoretically, if PSC limits are set at lower levels, fishing fleets would make more effort to move out of areas with high crab bycatch. Following are the key takeaways from CPT discussion by management issue:

- ***Consider the efficacy and ability to identify areas (static and/or dynamic) for groundfish fishery closures to protect snow crab, and suggested areas that could bring meaningful savings.***

There have been no spatial closure analyses related to the snow crab stock, but there have been several for BBRKC closures, which may provide information that is also applicable to snow crab. Several types of closures were identified during the April 2022 BBRKC discussion paper. In-season management closures (season closures, partial area closures, modification of gear in the management areas, etc.) are possible, but closure times can be delayed if catch data are not timely and it can take time to publish a closure in the federal registrar. Other possible closure types include incentive closures such as rolling hot spots, or time and area closures (permanent closed areas or seasonal closures). However, permanent year-round or seasonal closures would require more information on the distribution of snow crab during different life stages, and highly vulnerable periods (i.e., molting and mating) that may require extra protections. The EFH five year review provides some information on snow crab distribution and overlap of groundfish fishing.

The CPT agreed that additional research is needed to fully understand crab distribution by life history stages in order to effectively implement this measure. A retrospective analysis to assess skill in predicting fisheries interactions using survey and fishery data may be useful in identifying candidate areas for protection. However, it is likely that more data would be needed to get an accurate prediction. Collecting data on trophic interactions and crab distribution across ontogeny will require longer-term research. However, some immediate research could utilize outputs from EFH and ecosystem models, which may be completed in 3-5 years. Some limited work has occurred on spatial distribution of snow crab as bycatch in the groundfish fisheries. Looking at these data more closely may improve understanding of seasonal crab distributions.

It is difficult to predict how beneficial this measure would be to the overall stock condition. Closing areas may reduce PSC and protect crab during sensitive life stages, which would likely be directionally positive for the stock. However, closing areas may increase groundfish populations and predation, which may have negative consequences for the stock. There is an interest to have more groundfish stomachs analyzed to learn more about groundfish predation on snow crab to further explore the extent that a groundfish fishery closure may have on snow crab.

In summary, the CPT concluded that the directional impacts and magnitude of the impacts that this action may have are largely unknown, given the current data available.

Align crab PSC limit boundaries with the crab stock management area for snow crab.

There are several analyses and discussion papers that suggest there is limited direct impact of groundfish bycatch levels on crab stocks. Currently, trawl snow crab PSC is only accounted for in the COBLZ area,

but COBLZ does not cover the entire stock area. Historically, more snow crab PSC has been taken within the COBLZ area.

It is uncertain what the exact effects of this measure would be on snow crab stocks, but it is likely directionally positive. Aligning boundaries would provide transparency in PSC management and simplify spatial boundary designations. There is research and information available from previous analyses and discussion papers to inform this topic, and the CPT indicated that best science practices would encourage aligning the PSC boundaries with stock boundaries.

Remove or revise trawl crab PSC limit floors for Bristol Bay red king crab and Eastern Bering Sea snow crab.

Several discussion papers and analyses have examined this issue but no action has been taken. It was noted that the PSC limits would likely not be exceeded under any of the past proposed alternatives. Under the current snow crab rebuilding analysis, abundance levels in 2007-2010, 2022, and 2023 would have been lower than the current PSC limit floor. However, it does not appear that the removal of the PSC limit floor would have not been a constraining factor for groundfish fisheries in those years.

The CPT recommended that the best scientific advice for management of crab populations at low levels of abundance would be a trigger on PSC limits that would result in a reduction of bycatch levels, rather than a static PSC floor that would result in increasing bycatch rates as the population falls. Consistent with control rules, exploitation rates should at least decrease proportionally as stock abundance decreases. Although it is uncertain how much benefit this measure would have on stocks, it is likely directionally positive and given that crab stocks are currently at historic lows, it could be enacted as a precautionary approach. No research is necessary for this measure, as required data already exist in past analyses and papers.

Update trawl crab PSC limits based on status of crab stocks.

The February 2021 analysis looked at this issue and no action was taken.

The CPT noted that this issue was similar to the previous issue and that exploitation rates should not increase as stock abundance decreases to very low levels. Although it is uncertain how much benefit this measure would have on stocks, it is likely directionally positive. No research is necessary for this measure. The data already exist in past analyses, and the CPT noted that population-level experiments to quantify the direction and magnitude of the proposed effect are not plausible.

Establish non-trawl crab PSC limits.

Several analyses provide information on this issue. The majority of historic crab bycatch occurs in pot gear while fishing for Pacific cod, and non-pelagic trawl gear while fishing for yellowfin sole. The October 2022 BBRKC discussion paper looked specifically at PSC in pot gear and found that PSC is extremely variable from year to year, which would make it difficult to determine an appropriate limit. Snow crab bycatch in fixed gear is also variable in COBLZ. The CPT noted that considerations for establishing a non-trawl PSC limit include: determining appropriate boundaries, determining appropriate observer coverage levels needed for sufficient data, standardizing the approach across all stocks, deciding if a hard cap is necessary, and determining if the COBLZ area is an appropriate boundary for snow crab non-trawl fishing.

The PSC variability in the Pacific cod pot fishery is likely due to the limited number of observers deployed on the fleet. Observer coverage is limited to a single (or few) vessel(s) may cause the PSC extrapolations to unobserved vessels to be higher or lower than reality. Adequately monitoring PSC in the pot Pacific cod fishery would likely require higher observer coverage, which may come at a cost of lower

observer coverage in other fisheries. Data exist to evaluate PSC in non-trawl fisheries. It is uncertain how much benefit this measure would have on stocks, but it is likely directionally positive.

PIGKC proposed models

The Pribilof Islands golden king crab stock is currently a Tier 5 stock, with the OFL determined by average catch over a specified time frame. The assessment is conducted every three years and the last assessment was conducted in 2020. Because no new data will be available in May 2023 to update the model, model selection by the SSC in February will effectively determine management reference points for the next three years.

Tyler Jackson (ADF&G) presented an evaluation of several candidate models previously requested by the SSC to conduct the PIGKC assessment. These fell into 3 broad categories: 1) the previously-accepted Tier 5 model with updated catch estimates; 2) Tier 4 models that use a random effects approach to fit NOAA EBS slope survey data for PIGKC mature male biomass (MMB), determine a proxy for B_{MSY} from average model-estimated MMB and estimate a projected MMB, and use M as a proxy for F_{MSY}; and 3) a mixed (groundfish) Tier 4/5 approach that uses the "raw" estimates of survey biomass to determine the current biomass based on a straightforward average of survey MMB.

Tyler noted that the assessment authors attempted to address a number of CPT and SSC comments from the previous assessment. The NOAA EBS slope survey provides the only basis for fishery-independent data to assess the PIGKC stock, but the data are limited in temporal extent to (2002, 2004, 2008, 2010, 2012, 2016) and size composition data appeared to be lacking for the first two survey years. The authors were unable to recover any size composition data from the 2002 and 2004 surveys. The authors considered rescaling the fishery catch data (much of which is confidential given the limited number of vessels participating in the fishery in any given year) to be able to show temporal trends in catch, but were advised by ADF&G staff that this was unlikely to sufficiently anonymize the data to prevent the breach of confidentiality. The authors lacked time to develop a GMACS model for the stock or explore the use of VAST to provide model-based estimates of survey biomass. However, they were able to improve the calculation of CVs (from that used in the 2020 assessment) for the 2002 and 2004 MMB estimates using the variance for the multiplication of random variables and to use the "rema" R package developed by groundfish assessment authors to fit random effects models to the slope survey data as part of the Tier 4 approaches evaluated.

For this stock, the previously-accepted Tier 5 approach calculates OFL from a combination of: 1) the average retained catch during 1993–1998; 2) the average ratio of bycatch mortality to retained catch during 2001–2011 (when observer data were available to compute the ratio); 3) average bycatch mortality in the snow and grooved Tanner crab fisheries during 1994–1998; and 4) the average bycatch mortality in the groundfish fisheries during 1992/93–1998/99. One change to the Tier 5 approach from the previous assessment was to estimate bycatch by weight using CPUE (crab/pot), effort (potlifts), and average weight by crab group of sublegal, female, and legal crab when observers did not perform size-composition sampling. This aligns the method for estimating PIGKC bycatch in the directed fishery with those used for other managed crab stocks, resulting in a small change to the Tier 5 OFL (94.7 t, compared to the previous OFL of 93.0 t).

The Tier 4 approach that Tyler presented uses *M* as a proxy for F_{MSY} and average MMB (over some time period) as a proxy for B_{MSY} to determine the OFL based on the ratio of model-projected MMB to B_{MSY} and a sloping F_{OFL} harvest control rule. Given the limited temporal extent of the survey data, the time frame for averaging MMB was taken to be the entire set of years with survey data period included in each model scenario. Average MMB was calculated by fitting a random effects model using the "rema" R package to the observed MMB and CV time series from the slope survey, modeling changes in MMB as a log-scale random walk. For the 2008-2016 surveys, a knife-edge size-at-maturity was used in conjunction with size-composition data to estimate MMB for each survey year. For the 2002 and 2004 surveys (where

size composition data was unavailable), the mean ratio of MMB to total biomass determined from the 2008-2016 surveys was used to convert total biomass to MMB. The authors evaluated using the random effects model to fit the data in several scenarios (23.0, 23.0a, 23.1, 23.1a, and 23.1b), which differed in terms of the years selected to fit (2002-2016 or 2008-2016), the CV assumed for 2002, and/or the prior assumed for the ln-scale process error variance. The CPT noted that the "penalty" used in Model 23.1a was simply another prior, similar to those used in 23.1b. Model results were fairly sensitive to the choice of which survey years were included in the analysis, and the prior on process error variance, with estimates of B_{MSY} and the ratio of MMB to B_{MSY} ranging from 507 to 576 t and 0.89 to 1.03, respectively.

The Tier 4/5 approach followed the approach used in the 2010 GOA spiny dogfish assessment, as requested by the SSC: the OFL was calculated as the assumed value for *M* multiplied by average MMB, where average MMB was the average observed MMB from the survey. The CPT noted that terminology used in Appendix B should be revised to reflect that this approach treats *M* as an exploitation rate, not as a fishing mortality rate.

Tyler presented Tier 4 and 4/5 OFLs using values for *M* from the previous assessment (0.18 yr^{-1}, as specified in the FMP for king crab) and an SSC-requested value of 0.21 yr^{-1} from the AIGKC assessment. The CPT noted that M=0.22 yr^{-1} is now used in the AIGKC assessment.

In further discussion, Tyler observed that analysis of recent chela height (CH) data from the fishery suggests that size-at-maturity (based on a break in the CH to CL relationship) may be much larger than that found by Somerton and Otto (133 to 107 mm CL, respectively). He also noted that the "rema" package can include an additional CPUE index in the model fitting process by estimating a scaling parameter, *q*. However, he felt that standardization of a fishery CPUE index would be problematic because participation of individual vessels in the fishery is inconsistent, providing little basis for comparison. The CPT concurred with this conclusion and did not recommend further work to develop a CPUE index. Mike Litzow (NMFS) stated that AFSC had plans to conduct a comparison study between the gear used for the EBS slope and shelf surveys this summer which would possibly be focused on the area of the slope relevant to PIGKC. He also stated that the "vision" going forward was to unify the slope, shelf, and NBS surveys so there was some hope that the survey time series would be extended in the future. The CPT was encouraged that this might eventually lead to moving the assessment to Tier 4.

For the May assessment, Tyler recommended continued use of the Tier 5 approach, given the lack of new, and sparsity of old, survey data available to inform a Tier 4 assessment. The CPT noted that the purpose of the Tier 4 approach was to reflect the dynamic nature of the stock, which could not be captured until more survey data become available.

In summary, the CPT:

- commends the authors for their work addressing previous CPT and SSC comments;
- recommends using the Tier 5 model to determine OFL in May 2023;
- recommends using M=0.22 yr^{-1}, or another value consistent with the AIGKC assessment, in future Tier 4 models to be considered when more data becomes available; and
- recommends revising the terminology used for *M* in Appendix B to an exploitation rate

AIGKC proposed models

General assessment issues and exploratory model scenarios

Siddeek Shareef presented the proposed assessment of Aleutian Islands golden king (AIGKC) crab, which is based on separate models for areas east and west of 174^0W (referred to as EAG and WAG, respectively), as well as the proposed model scenarios for the May 2023 assessment. Discussion noted that Tyler Jackson (ADF&G, Kodiak) will assume the lead on the AIGKC assessment per Siddeek's upcoming retirement.

Model 21.1e2Q aimed to account for time-varying fishery catchability. However, the sigma parameter was estimated, which is invalid when estimation is based on a penalized likelihood. Future work with this type of model formulation should either be based on treating the deviations in catchability (the Q-deviations) as random effects, or the model objective function should include a penalty on the parameter that determines the inter-annual variation in the Q-deviations.

The assessment report compared the CPUE data and the Aleutian Islands slope survey indices. The correlation between these variables is low, but the CPT notes that the sample sizes for the slope survey can be very low in some years, making this comparison difficult to interpret.

Model scenarios and recommendations for the 2023 and 2024 assessments

The assessment authors proposed eight model scenarios, of which the first two are "core" models (note that models 21.1e2Q and 21.1g were only applied to the EAG):

- 21.1e2: The base model from the May 2022 assessment, except that the pre-specified value of *M* was changed from $0.21yr^{-1}$ to $0.22yr^{-1}$ based on a re-analysis of historical tagging data (Siddeek et al., 2022: *Fish. Res*. 251, 106304).
- 21.1f: As for model 21.1e2, except that the CPUE index is based on a standardization that includes a Year:Area interaction.
- 21.1e2 LF14: As for model 21.1e2, except that size-composition data for 2015-2021 are ignored when fitting the model.
- 21.1f LF14: As for model 21.1f, except that the size-composition data for 2015-2021 are ignored when fitting the model.
- 21.1e2CPUE5Wt: As for model 21.1e2, except that the CPUE data are upweighted by a factor of 5.
- 21.1fCPUE5Wt: As for model 21.1f, except that the CPUE data are upweighted by a factor of 5.
- Model 21.1e2Q: As for model 21.1e2, except that allowance is made for time-varying catchability.
- Model 21.1g: As for model 21.1e2 with observer CPUE indices for 1995/96-2014/15 and co-operative survey data for 2015/16 to 2021/22 (less 2020/21 as no survey occurred during that year).

Results were also provided for variants of model 21.1e2 in which the period used to define average recruitment was changed from 1987-2017 to 1987-2019, 1987-2020, and 1987-2021.

All models estimate separate catchability coefficients and additional variance parameters for three time-blocks of CPUE (1985-1998, 1995-2004, and 2005-2021), as requested by the CPT and SSC, and assume a size-at-maturity of 116 mm CL. Models 21.1e2 LF14, 21.1f LF14, 21.1e2CPUE5Wt, 21.1fCPUE5Wt, and 21.1e2Q were developed in response to requests from the CPT and SSC to examine reasons for conflicts between the CPUE and size-composition data and are not candidates to form the basis for the 2023 assessment. These models (expectedly) reduced the retrospective pattern evident for model 21.1e2,

particularly for the EAG. However, the results were markedly different and need more exploration for the 2024 assessment.

The CPT endorsed the change to the value for *M* (from 0.21 to 0.22yr^{-1}) and recommends that the 2023 assessment be based on models 21.1e2 and 21.1f for the EAG and the WAG, along with model 21.1g and a variant of model 21.1f that includes the co-operative survey data for the EAG.

Recommendations for the 2023 assessment.

- Confidence interval plots for total catch need to be corrected as they appear to be incorrectly plotted in the assessment document and do not match the assumed CV of 0.2.
- The retrospective analysis exploring how CPUE and effort are predicted for the WAG. This analysis should involve developing a model to predict CPUE and effort based on seasonally-truncated data sets, and an evaluation of the skill of the resulting predictions based on the truncated CPUE and effort data. The 2023 assessment document should report the sensitivity of the results to different assumptions regarding the effort and CPUE for the entire 2022-23 season if the WAG fishery is still ongoing when the 2023 assessment is conducted.
- The time-period for setting the years that define average recruitment should be justified; for example, using a plot of years versus the variances of the recruitment deviations. This type of analysis should be included in all future assessments.
- The fits to the three CPUE series should be reported on separate plots.
- The smoothers estimated in the analyses of fishery and CPUE data should be plotted to assess whether they are overfit (i.e., do not have undue "wiggliness").
- The combined model (i.e., fitting the data for the EAG and WAG as a single-area model) led to an OFL that is similar to the sum of those for the assessments of the EAG and WAG separately for the model 21.1e2 specifications. However, no fit diagnostics were provided for the combined model so the 2023 assessment should include an appendix with the fit diagnostics for an updated (with new data since this meeting) combined model.
- The rationale for considering model 21.1f should be included in the assessment document, along with plots that show the extent to which the trend in CPUE varies among locations.
- The assessment document should include information on the likely connectivity between the EAG and WAG as this appears to be very limited, justifying separate EAG and WAG assessments.

Recommendations for the 2024 assessment.

- Models 21.1e2CPUE5Wt and 21.1fCPUE5Wt fit the CPUE data for the EAG much better than the base model (as expected) but without an obvious visual change in the fit to the size-composition data. Models that are forced to achieve better fits to the CPUE indices should be explored; in particular, it is necessary to conduct analyses to identify the data sources that preclude the model fitting the CPUE index data well.

Transition to GMACS

The assessment authors provided bridging models to assess the extent to which the assessment of AIGKC can be moved to being conducted using GMACS. The current (bespoke) model and the GMACS implementations provide very similar estimates of the time-series of numbers-at-size and MMB, except during the early (pre-data) period and the first few years with data. The difference in results for the early years occurs because the mean recruitment used to compute the initial (unfished) biomass for the current

model is based on the average recruitment during 1987-2017 whereas GMACS estimates the initial recruitment and defines annual recruitments as deviations about initial recruitment, which does not guarantee that the initial recruitment is equal to the arithmetic average over 1987-2017. The difference in unfished recruitment leads to differences in reference point estimates and hence values for the OFL. Another reason for the differences in reference point estimates and OFL values between the current model and GMACS is because the current assessment calculates $F_{35\%}$ based on a grid search method whereas GMACS uses a (more accurate) Newton-Raphson algorithm.

The CPT agreed that the GMACS approach for setting unfished recruitment is appropriate and that the model fits are sufficiently similar between the current model and GMACS. It is therefore recommended that the May 2023 assessment be conducted using GMACS only, and that the legacy model not be brought forward for the May assessment

Guidelines for moving the start date of models

Katie Palof, Mike Litzow, and Buck Stockhausen provided information on documenting general guidelines for the time frame of data utilized in the stock assessment models.

To provide context for the conversation, Mike detailed some information on the survey history that may be important to consider for model start dates. In the early years of the time series, fewer stations were sampled. The strata areas for generating area-swept abundance and biomass estimates are based on the product of mean catch per unit effort and strata area. However, stratum areas are based on the total area of the stations sampled in each year, and so change over time, which confounds comparison of area-swept estimates across the time series. These changes to estimated abundance are external to the population dynamics of crab stocks, and may create difficulties in fitting models to the data. This may be a consideration for Tanner crab, snow crab and BBRKC survey time series.

Buck Stockhausen summarized start date considerations for the Tanner crab model, including the effect of variable survey coverage early in the time series. This model has a 1948 start date, with the start date for different data sources ranging from the 1950s (for BBRKC fishery data) to the 1990s (for directed fishery observer data). Buck presented a sensitivity analysis that compared the 1948-2022 base model with a truncated 1982-2022 version of the model. This analysis showed that time series of estimated R and MMB were highly similar between the two models, as were estimates of different management reference points. Katie provided the information available to consider moving the start date for BBRKC. Moving the start date for BBRKC would remove the large mortality event that occurred at the beginning of the time series, and also eliminate the large recruitment estimates needed to accommodate this large mortality. Similar to tanner crab the reference point calculations only use data from 1984 onward, so no large changes to the current outlook or reference points would occur with early data removal.

The CPT discussed the general rationale for moving the start date of the time series, as requested by the SSC in June 2022, when models with later start dates were first brought forward for consideration. The CPT concluded that in most cases more data is better and recommended that the default approach should be to use data. However, the CPT would consider removing early data if: 1) data quality is suspect or determined to not be appropriate use; 2) inconsistencies between current data and historic data exists that lead to convergence issues or divergent trajectories for the stock; or 3) ecosystem driver or regime shifts have occurred that present difficulties in modeling periods of very different population dynamics for the stock in question. When authors propose removing early data for one of these reasons the CPT would like to see diagnostics, similar to those presented here by authors, to show that removal would not affect the current reference point calculations or stock status determinations.

Simpler modeling workshop scoping

The SSC recently noted in its Oct 2022 meeting that *"Crab models have become increasingly complex over time, and model parsimony is a key goal for assessments. It is difficult to balance this with the need to account for the complex dynamics of crab populations. For multiple crab stocks, the SSC suggests that fitting a range of simpler models and data-limited approaches, such as the Tier 4 calculation, can also provide insight into the differences between raw survey observations and integrated assessment model output."* Katie Palof started discussion about a working group that would address the idea of simpler modeling approaches for snow crab, Tanner crab and BBRKC. The rationale for the formation of such a working group includes the instability of models observed in recent years (such as snow crab), the potential for over-parameterization, the desire to better coordinate the information sources used among Federal and State management processes, and to generally reconsider whether current levels of model complexity are consistent with the goal of stock assessment parsimony. The objectives would be to better align and simplify the crab models, to establish a simpler "base" model for stocks and then add features from there (for each stock), and to bridge the differences between the State and Federal processes – both in the models used and in the currency of management. The CPT noted that a simplified model tuned to the state abundance estimates could be developed for TAC setting, but there are negative consequences of parameterizing multiple models to estimate the same quantities. The point was made that the fundamental difficulty in size-structured models versus age-structured models is a core challenge in crab assessments. Better linkages between the Federal and State processes would be useful. The CPT generally agreed that forming a working group to evaluate this issue could be useful, followed by discussion about working group membership; various Federal and State CPT members agreed to participate.

Research update #1: BBRKC bycatch distribution models

Emily Ryznar presented her recent work on BBRKC bycatch distribution models. Her motivation for this work is to better understand BBRKC spatial distribution in non-summer months and identify the biological/environmental drivers of distributional shifts. The idea is to create models that predict the distribution of BBRKC bycatch in fall/spring bottom trawl fisheries and identify covariates that drive inter-annual changes in distribution. Emily looked at legal male BBRKC bycatch in yellowfin sole fisheries (Apr/May and Sept/Oct) and northern rock sole (Apr/May) for years 1997-present. The covariates examined include surface temperature, ice area fraction, bottom temperature, depth, BBRKC survey abundance, target fish survey abundance, sediment grain size, and target fishery quota. Emily discussed the species distribution models (SDMs) she used including algorithm-based (boosted regression trees) and framework-based (Delta models) approaches. The overall approach was to evaluate covariate collinearity, randomly split data into training (80%) and testing (20%) modules, fit models with training data, and evaluate model performance with testing data (by looking at predictive ability of bycatch occurrence and magnitude).

Predicted centers of distribution were generally consistent with observed centers of distribution, except for specific years with low bycatch. This is encouraging because predictive ability in years with high bycatch is more critical. The BBRKC survey abundance, target fish survey abundance, and sediment were influential covariate in the models. The models showed good predictive ability with regards to occurrence with yellowfin sole models slightly better than rock sole models. Models performed relatively well at predicting bycatch abundance. It was concluded that the SDMs may be useful tools for predicting BBRKC bycatch, survey data are important, and differences in covariate importance for bycatch in different seasons/fisheries should be explored. The next steps include developing bycatch prediction models for mature female BBRKC and including the pot cod fishery as well as SDMs for predicting fall/winter BBRKC spatial distributions. Emily hopes to incorporate tagging data in future work. An industry representative noted that the A80 fleet is interested in this work, but questioned why April/May was used as a time period for the rock sole fishery since the rock sole fishery mostly occurs in Jan-Mar. Emily noted that April/May was used because most RKC catch in the observer data occurs in these

months. Others noted that this issue could be related to targeted species in trips vs hauls, and how targeted species get recorded in the observer database. For example, a vessel may be "targeting" a particular species, but the catch may be recorded as a different target based on the catch composition.. It was also mentioned that the TACs for groundfish such as northern rock sole are rarely met, so TACs may not be the best explanatory variable for these analyses. There was a comment that despite not being fully captured, TACs could still be a useful predictor, even if the mechanistic process is not fully understood. The CPT thanked Emily for presenting her work and encouraged her to continue this line of research.

Research update: tagging updates

Leah Zacher (NMFS), and Jared Weems (NMFS) provided an informational update on the ongoing crab tagging studies in the Alaska region. Leah began by detailing the acoustic tagging work for red king crab (RKC) in the Bristol Bay region. Research using acoustic tags was initiated in 2019. The tags are attached to the crab's carapace via a harness and are buoyant to allow them to float above the crab as it moves along the seafloor.

Early tagging data investigated male crab movement from summer into fall when the BBRKC fishery is operating. In 2019 148 tags were deployed, 84 tags were deployed in 2020 and during 2021, 15 and 16 tags were deployed, respectively. The fishery did not operate during 2021/22 so the tags were deployed during the NMFS summer bottom trawl survey. In 2019 and 2020, the data showed similar movement from summer to fall as crab appeared to move into the RKCSA. Some of the crab that were tagged in the north district appeared to move south, but did not join the core Bristol Bay stock.

A hotspot map for fishing activity and RKC movement showed that the areas that were hotspots for fishing and RKC movement were fairly identical. In 2020, the tags popped off prior to the start of the fishery, but data showed general movement toward the center of the RKCSA. Discussion surrounding why RKC are moving into the RKCSA was had, and Leah noted that late October and early November tend to show the warmest temperatures along the seafloor and that the movement may be temperature-driven, but is uncertain. In all years, male crabs moved at about 0.5mi/day.

In recent years, tagging studies throughout the year have been utilized. In 2021/22, 90 crab were tagged from the fall into winter to understand individual movements. Results showed less movement from the fall to winter months. An additional winter survey in 2022/23 showed that crab within the RKCSA were relatively stationary.

Recently, spring surveys have been utilized to observe female movement. It is more challenging to tag males during the spring as they are molting; whereas, females do not molt until later in the season. 225 tags were deployed on female RKC over six months. Results show that females were heading east to nearshore areas throughout the eastern side of Bristol Bay. Spring is an especially important time of year for females, as they are mating and are likely moving to areas to reproduce and release larvae. Tagging studies on females during this period of time can be especially beneficial in determining larval release sites, and suitable larval settlement habitats. At one time, Unimak island was thought to be a larval release site for female RKC. However, recent tagging data has shown no movement toward this area, but rather an area further north. Female crab moved 0.25mi/day during the spring. Leah noted that she did not conclude that male crabs are faster than females, but rather the females may be taking longer as they are undergoing mating during that period.

In summary, male movement in the fall exhibited consistent directional movement into the RKCSA, Male movement in the winter showed movement west of the RKCSA and a "turn around" period back east. Lastly, female movement during spring showed evidence of mating/molting grounds in the eastern Bristol Bay, both nearshore and offshore. However, there was no evidence of females moving into historical mating grounds near Unimak island.

Jared provided an update on the use of autonomous underwater vehicles (gliders) to track crab movements. His presentation detailed a pilot project to explore the use of gliders in tracking crab movement throughout the Alaska region. His work specifically investigated the use of gliders in combination with acoustic tags to track the movement of Tanner crab in Marmot Bay- Kodiak, AK. His research had three main objectives: 1) conduct signal range tests using fixed benthic moorings to determine how far away the receiver can be from the glider; 2) assess potential signal interference using two acoustic tabs (V13s, V9s); and 3) determine Tanner crab position and movement.

Jared conducted his work using a solcum G3 glider, which has the capability to track oceanographic conditions such as temperature, pH, etc. He deployed 40 tags on to crab using a traditional harness method. The glider ran 20+ transects across the study site to gather information on crab movements.

Weems et al., determined that the approximate range for the glider was 1,000m. The V9 acoustic tags performed significantly better than the V13 acoustic tags. The interference was unknown but appeared to have a limited impact on the glider's ability to receive a signal. Lastly, all 40 tags were recovered from the crab, and showed that crab move less than 3,000m, but the majority were moving less than 1000m. Only the crab that were tagged centrally and north moved northeast along the basin area, but southern crab did not appear to descend into the basin. A full suite of oceanographic conditions were collected, but the data has yet to be analyzed.

Future work includes utilizing gliders in the Bering sea to gather data on oceanographic conditions in the Bering Sea. The use of gliders is fairly new, but they may be useful in fisheries management, particularly to gain insight into stock decline and monitoring crab movement.

Research update: Ocean Acidification

Darren Pilcher (NOAA-PMEL) gave an update on ocean acidification modeling efforts to support BSAI crab management. Darren first gave an overview of strategic planning efforts, including accurate model projections, socioeconomic models, and vulnerability assessments. Tactical planning efforts have included an OA indicator developed for Ecosystem Status Reports and Ecosystem and Socioeconomic Profiles. Overall, long-term projections from the Bering 10K ROMS model demonstrate a decrease in pH, and bottom water values are projected to pass critical pH thresholds for commercial crab species sooner than surface waters. Darren also demonstrated an application of biological sensitivity experiments that can be used to project habitat suitability, and noted an overall decline in favorable Bristol Bay habitat over the 21st century. These outputs have also been integrated into ACLIM and ACLIM 2.0.

On a shorter-term time frame, the ROMS model has been used to simulate past and present spatiotemporal patterns in pH and aragonite saturation states. Hindcasts suggest that inner shelf waters are much higher in pH than outer shelf waters, and there has been a steady, long-term decline in pH since the 1970's. Validation of model output with in situ water samples was conducted on the fall 2022 BASIS survey. Results indicate that the model has high skill and low overall bias but the model tends to overestimate variability in pH and underestimate variability in alkalinity. Darren noted that the largest recorded coccolithophore bloom in 2022 likely explains skill assessment results and highlights a key mechanism missing from the seasonal forecast model. The CPT discussed the utility of using pH data collected on ADF&G St. Matthew BKC pot surveys to continue model validation efforts. Overall, the CPT thanks Darren for his presentation and the continued efforts to integrate long-term forecasts and hindcasts into crab management.

Chris Long (NOAA-Kodiak) followed up with a summary of laboratory studies conducted in Kodiak to examine the effects of OA on BSAI crab stocks. Chris first highlighted a recent study aimed at examining pH effects on development time, survival, morphology, dry mass, and elemental composition of RKC larvae. Results indicated that there was no difference in survival or development time, suggesting RKC larvae are well adapted to a broad range of pH conditions. A second study to look at exoskeleton properties concluded that acidified conditions resulted in a 30-40% decrease in claw hardness, thinning of

the cuticle, and less calcium in the carapace. While Chris noted that these are sublethal effects, study results could suggest strong indirect effects though foraging and predator evasion. Initial results from a snow crab juvenile experiment examining pH effects on survival, growth and morphology show an increase in the rate of mortality at pH 7.5 later in the experiment, likely due to an overlap with molt timing. Overall, lab studies highlight that snow crab and BKC appear to be better adapted to OA, while RKC and Tanner crab are more sensitive. Across life stages, juveniles appear to be the most sensitive to the effects of OA, while larvae are fairly resilient. The CPT commends Chris for the comprehensive summary and his efforts to better understand the impacts of ocean acidification on BSAI crab stocks.

New Business

CPT Topics/ Ongoing research spreadsheet- **For internal CPT use only!**

May 15th- 19th, 2023 (Location TBD- Juneau or Anchorage)
Topics:

- AIGKC final SAFE
- PIGKC final SAFE
- WAIRKC final SAFE
- Proposed models:
    - BBRKC (discussion of growth/molting data)
    - Snow crab
    - Tanner crab
    - PIBKC

- Stock prioritization
- BBRKC discussion paper update (tentative)
- "simpler" modeling workshop update
- GMACS updates (NSRKC progress?)
- BSFRF update
- Bering sea red king crab stock structure template (see SSC minutes June 2022)
- catch accounting updates on treatment of crab data in EM (see minutes from Sept 2022)

Sept 2023 (9/11-9/15 (T) - AFSC Seattle, WA)
Jan 2024 (1/08-1/12)
Note:
Potential for a Jan 2024 interagency meeting
UAA first day of classes 1/16