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