North Pacific Fishery Management Council

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Crab Plan Team

REPORT

September 12-15, 2022, 9am-5pm PDT
Hybrid Meeting: Seattle, Washington, AFSC Traynor Room

Crab Plan Team 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)
Krista Milani (NMFS- Dutch Harbor)
Erin Fedewa (AFSC-Kodiak)
Brian Garber-Yonts (AFSC-Seattle)
Martin Dorn (AFSC-Seattle)
Shareef Siddeek (ADF&G-Juneau)
William Stockhausen (AFSC-Seattle)
Cody Szuwalski (AFSC–Seattle)
Miranda Westphal (ADF&G-Dutch Harbor)

Members Absent

André Punt (Univ. of Washington)
Ginny Eckert (UAF/CFOS-Juneau)

Others in attendance:

Alex Dowlin
Alyssa Hopkins
Andrew Olson
Anne Hollowed
Anne Vanderhoven
Austin Eastbrooks
Beth Concepcion
Bo Whiteside
Bridgett Ferriss
Cassie Whiteside
Chad See
Charlie Hensel
Chris Lunsford
Chris Siddon
Chris Woodley
Christine Baier
Colin Wallace
Connie Melovidov
Cory Lescher
Craig Lowenberg
Craig Rose
Dana Rudy
Dawn Wehde
Diana Evans
Diana Stram
Edward Ricketts
Elizabeth Siddon **
Ernie Weiss
Ethan Nichols
Forrest Bowers
Frank Kelty
Gary Stauffer
George Steers
Gordon Kruse
Gretar Gudmundsson
Gretchen Harrington
Toshihide Hamazaki**
Heather McCarty
Henry Tashihan
Ian Stewart
Jamie Goen
Jason Anderson
Jason Gasper
Jim Armstrong
Jim Ianelli
Jodi Pirtle
John Gauvin
John Hansen
John Olsen
Jon McCracken
Jon Warrenchuck
Jonathan Richar
Joshua Songstad
Karl Haflinger
Kat Meyer
Kendall Henry
Kenny Down
Kerim Aydin
Krista Oke
Lance Farr
Laundry Price
Lauren Decker
Laurie Balstad
Leah Zacher
Lenny Herzog
Linda Kozak

Madison Heller-Shipley
Maria Anne
Megan Mackey
Megan O'Neil
Mike Shelford
Molly Zaleski**
Nat Nichols
Nick Sagalkin
Nicole Kimball
Noelle Yochum
Paul Wilkins
Peg Parker
Rachel Alinsunurin
Rachel Baker
Ryan Burt
Sarah LaBelle
Scott Callahan
Scott Goodman
Scott Smeltz**
Sean Rohan
Shannon Caroll
Sherri Dressel
Stephanie Madsen
Steve Martell
Steve Minor
Steve Ricci
Tyler Jackson
Wes Jone
** presenter

1. Administrative

The May 2022 Crab Plan Team (CPT) meeting was at the AFSC in Seattle, Washington with a virtual component held on Zoom, and connection information was posted to the CPT eAgenda. The meeting began at 9:00 a.m. PST on Monday, September 12, 2022, with a 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.

2. Summer Trawl Survey Updates

Mike Litzow from the Alaska Fisheries Science Center (AFSC) Shellfish Assessment Program presented the 2022 Eastern Bering Sea (EBS) summer survey results (see The 2022 Eastern Bering Sea Continental Shelf Trawl Survey:Results for Commercial Crab Species). The survey chartered two fishing vessels and sampled in tandem within the most recent standardized grid in the EBS and NBS starting May 30, 2022. It was noted that the workload for onboard survey staff was decreased from previous years to 4 tows per day to decrease injury for staff and vessel crew.

In 2022, the cold pool (< 2°C) was of intermediate extent, comparable to the long-term mean, for the EBS shelf area extending midway down the shelf, eastward of the Pribilof Islands. AFSC has begun work to create a timeseries of comparable bottom temperatures, standardizing for changes in area and locations of temporary stations, using GAM-modeled estimates. CPT noted that similar efforts are underway with the groundfish group and an effort to have consistency between the two analyses is recommended.

June sampling indicated a proportion of Bristol Bay red king crab females (14% of mature female crab) had not completed the molt-mate cycle, initiating internal discussions of retowing in Bristol Bay. The objectives for retowing are primarily to quantify changes in mature female size distribution with a secondary objective to estimate post-mating/molting abundance. Taking into consideration the discussion and recommendations regarding retows at the May 2022 CPT meeting, low mature female biomass, and broad, unconcentrated distribution of mature females within Bristol Bay, AFSC staff decided to not go forward with retowing this year. CPT supports the decision to not retow this year based on the threshold analysis presented at the May 2022 CPT meeting. It was also noted that a similar situation occurred with the 2013 survey and resulted in

a decision to not retow. The CPT recommends ongoing evaluation of the consequences of retowing for data quality in situations where a relatively small proportion of the population has not undergone molt-mate by the time of leg 1.

Survey results indicated a southerly shift of the center of distributions of mature male and female red king crab abundances in Bristol Bay. Size frequency distributions for male and female red king crab continue to indicate limited recruitment. Mature females were mostly located within the center of Bristol Bay and biomass increased slightly (3%) from the 2021 survey low. Legal male abundance was concentrated in the mid- to lower-bay and mature male biomass increased 38% from the 2021 survey.

It was noted that all biomass data presented at the September 2022 CPT meeting were plotted on a log-scale y-axis due to values being too low to differentiate on an arithmetic scale. Red king crab biomass north of Bristol Bay decreased 24% from a time series high in 2021 for mature females and increased 96% for mature males compared to the 2021 survey. Biomass of mature red king crab in the Pribilof Islands decreased 30% for females and increased 36% for males. Biomass of St. Matthew Island blue king crab increased 59% for mature females and increased 17% for mature males from the 2021 survey, but remains low compared to the survey time series. For Pribilof Islands blue king crab, biomass of mature females and mature males are both down from 2021, 44% and 72% respectively. Biomass of mature crab in the Pribilof Island blue king crab stock remains depressed.

Estimated biomass decreased from 2021 for all size-sex categories of Tanner crab west of 166º W , while Tanner crab results were more variable east of 166º W. Mature female biomass decreased 36% in the east and 15% in the west. There was a prevalence of old shell females in the west at the larger sizes with evidence of some recruitment of smaller females in the east. It was noted that many Tanner recruit pulses don't appear to move into the mature population. Mature males decreased 9% in the west and increased 74% in the east. Tanner crab size frequencies show the stock remains depressed.

Distribution maps of Bering Sea snow crab show low densities of crab throughout their range. The stock overall remains depressed. The 2022 biomass of snow crab legal males declined 44% from 2021 (the 2021 survey declined 69% from 2019), while industry-preferred size males (≥102 mm CW) increased 9% from 2021 (the 2021 survey declined 56% from 2019), and immature male biomass declined 23% from 2021 (the 2021 survey declined 96% from 2019). Mature female biomass declined 16% from 2021 (2021 was a 70% decline from 2019), and immature female biomass increased 8,700% (after a 99% decrease in 2021). Increased proportions of new-shell males and females were observed. The mature female center of distribution shifted north of St. Matthew Island, while the mature male center of distribution shifted southeast. The high incidence of old shell mature female crab seen in 2021 was not apparent in 2022, with mature females being mostly new shell. New shell mature females (primiparous) are brooding their first clutch which tend to be less full, therefore less productive than older shell females. Mature female hybrid *Chionoecetes* biomass decreased 49% while mature hybrid male biomass increased 21%.

Work is ongoing to monitor the prevalence of bitter crab syndrome through PCR testing and to validate spatiotemporal trends in visual diagnosis of the disease in the field. Ongoing studies suggest that visual detection methods may greatly underestimate true prevalence rates. Data from the Northern Bering Sea are currently being processed and should be distributed soon. It was also noted that data processing for this

survey is undergoing modernization (moving from SQL to R) with an effort to streamline the survey technical memo publication efficiency.

The CPT requests that graph axes be standardized, and for any axes presented in log scale, a companion graph in arithmetic scale may also be presented to allow technical memos to be compared among years and to increase understanding of the information presented for all audiences. It is requested that more morphological maturity data be presented for *Chionoecetes* crab stocks. Understanding that the timing between the end of the survey and the September CPT meeting is tight, any effort to publish NBS survey data is useful. The CPT discussed changing the timing for this survey to allow more time for stock assessment authors to analyze the data but noted that any changes would disrupt the continuity of all data sets collected.

The CPT appreciated the survey team's enormous effort to successfully complete the 2022 survey and for making the raw data and VAST abundance estimates available to stock assessment authors in time for analyses before the September CPT meeting.

3. Fishery Summary 2021- directed and bycatch

Ben Daly (ADF&G) and Krista Milani (NOAA) gave an overview of crab catch and fishery performance by BSAI commercial crab stock. Minimum fishery observer coverage goals in directed crab fisheries were met for the season and coverage levels were near-average. Krista reviewed full and partial coverage for groundfish vessels, noting that selection rates are generally met every year. In recent years, electronic monitoring (EM) has been utilized for catch estimation in hook-and-line and pot fisheries and compliance monitoring in pelagic trawl pollock fisheries. Krista noted that EM reviewers are having difficulties distinguishing crab from video footage and the CPT raised concern with unidentified crab not being applied to bycatch. The CPT requests a follow-up presentation on EM, including 1) estimates of the proportion of crab remaining unidentified, 2) the percentage of the fleet moving to EM, and 3) a summary of bycatch data collection and processing (e.g. weight extrapolation, mortality rates applied). The CPT also recommends reviewing the potential impacts to data quality and the ability to spatially map bycatch assuming an increase in the use of EM in the near future. Jamie Goen (ABSC) raised concern that observer coverage in the directed crab fisheries observer coverage is inadequate and Dr. Daly emphasized that CV's of average pot CPUE are fairly small in observer-covered vessels, implying that observer coverage is adequate.

Ben reviewed maps of retained catch in the directed BBRKC crab fishery, noting that while the BBRKC fishery was closed in 2021/2022 due to low mature female abundance, there was still a cost-recovery fishery. CPUE was one of the lowest in the rationalized time series during the cost recovery fishery and slightly smaller males were caught compared to previous seasons. Krista covered incidental catch of BBRKC split out by gear type and noted that most bycatch is generated by the Pacific cod pot fishery in the fall. The 2021-2022 low incidental catch may be attributed to lower observer coverage, or an increased use of crab excluders in pot fisheries. Observers reported more females in pot gear (72-91%) than in trawl gear (20-46%). Industry expressed interest in Krista presenting fleet movement month to month to potentially explain higher BBRKC discard rates in late summer/fall when yellowfin sole harvest is low.

Moving on to snow crab, Ben highlighted that the 2021/2022 retained catch CPUE was the lowest in the rationalized time series. Most of the fishing was NW of St. Matthew Island, and the catch centroid for

2021/2022 was second furthest north in the timeseries next to 2020/2021. Anecdotal observations from the fleet included heavy freezing spray conditions and "pothole" fishing with only small pockets of high CPUE fishing. Discard mortality rates in 2021/2022 were up from last year to ~24% and for every legal crab retained, ~1 crab was tossed. Industry recommended more discussion on the applied 30% handling mortality rates because boats record very little dead loss and have seen dramatic improvements in catch sorting (i.e. shelter decks, conveyor belts as mechanisms to protect from elements) in recent years. The CPT recommends a discussion on handling mortality rates at the January meeting. Mean weights of retained catch declined in 2021/2022 and an increasing proportion of sub-4 inch crab were retained which is likely a function of the size composition of the population, although industry acknowledged that they are working with processors to retain smaller crab. Krista noted that the majority of snow crab bycatch is attributed to non-pelagic trawl gear and rates were highest in February/March during the yellowfin sole fishery.

Tanner crab retained catch was reported as East/West subareas combined (Tanner E closed in 2021/2022), and Ben noted that 97% of the harvest took place up against the 166W boundary line. Tanner W retained catch CPUE was average, and most of the fishing occurred in January-February. Anecdotal observations included very good fishing along the 166W long boundary, and concern about bottom trawl flatfish fisheries. Bycatch mortality rates were consistent over the past four seasons. Ben highlighted a large decline in retention size this past season due to a market for small tanner crab with the greatly reduced snow crab TAC. Bycatch of Tanner crab in groundfish fisheries was primarily from pot and non-pelagic trawl gear, and fairly low reported pot-gear bycatch could be due to lower Pacific cod TAC's and an increased use of excluders.

Aleutian Island golden king crab retained catch over time was slightly lower in the WAG than past years and CPUE was the lowest in the post-rationalized time series. Due to limited federal observer coverage, Krista noted that years with high incidental catch are biased due to the extrapolation of State pot vessels targeting sablefish. Four vessels participated in the PIGKC fishery and fished south of St. George Island in Pribilof Canyon. Only 34,216 lbs of the 130,000 lb GHL were harvested. The majority of bycatch occurred from June to August in the rockfish and arrowtooth flounder fisheries. There was no fishery bycatch for SMBKC in directed crab fisheries and the majority of groundfish bycatch occurred in pot gear because trawl closures and rocky habitat limit trawl activity. Krista also noted that there is historically very little bycatch for NSRKC because there are few groundfish fisheries in Norton Sound and most boats that fish are too small to qualify for observer coverage. The CPT thanks Ben and Krista for the summary and looks forward to an update in January on EM methods and discussions on handling and discard mortality rates.

4. Ecosystem Status Report

Elizabeth Siddon presented the ecosystem status report for the Bering Sea. Crab-relevant information that was available from 2021 was presented along with 2022 data and preliminary forecasts for 2023.

The ecosystem status report (ESR) is divided into larval pelagic indicators and benthic adult indicators.

Environmental Processes

There are five climate indices that describe the North Pacific, but two seem to describe the Bering Sea (BS) directly; the North Pacific Index (NPI)and the Arctic Oscillation (AO). The NPI reflects the Aleutian low pressure system (ALPS) and positive values mean a weak ALPS and calmer conditions along the BS shelf. The NPI has been positive for five of the last six winters. The AO is a measure of the polar vortex and has been mostly positive which usually means colder temperatures, except that in 2021/22 winter temperatures were near normal.

La Nina conditions are predicted for winter of 2022/23, making it the third year in a row. This is unusual and this will be the third time it has happened in the last 50 years. The Bering Sea shelf had cool to average conditions last fall and winter sea surface temperatures had an inner shelf of more than 2.0 degrees lower than normal. Summer temperatures were slightly above average. The sea surface temperatures have been close to or below the long-term mean with some warming in the summer of 2022. Marine heatwaves have been infrequent in 2022 compared to recent years.

Wind affects sea ice. In years where there is little sea ice there are also usually strong winds from the south. In 2022 winds prevailed from the north. In November of 2021 there was rapid sea ice growth due to record cold temperatures in Western Alaska and less open water in the Chukchi Sea. The sea ice extent was the highest recorded since 2012. In April 2022 there was dramatic sea ice loss. The maximum sea ice extent occurred February 17 and about a month earlier than the historic median. Sea ice thickness can impact the cold pool and algae growth. The ice thickness was lower in 2022 than in 2021 and Norton Sound was the second lowest on record. The cold pool was near the historical average and was similar to 2017.

Low pH conditions persist on the outer continental shelf and pH was at the lowest in the time series in April 2022. More information is needed as to whether these low pH areas overlap with crab stocks, although crab-specific pH indices are included in the SMBKC and BBRKC ESP's, and were presented at this meeting. Snow crab appear to be more resistant to low pH conditions than king crab, although Ebett acknowledged that ocean acidification may be an added stressor for crab species in years where the level is not highly corrosive. There are ongoing efforts to collect in situ pH measurements to validate the ROMS model hindcasts, which should be available in the full ESR.

Prey

There are no direct measurements for benthic infauna. Continuous plankton recorders have been collecting data on diatoms, copepod community size, and mesozooplankton biomass for the past four years. In 2021 mean diatoms and mesozooplankton biomass declined and the copepod community size increased. The 2022 spring bloom chlorophyll biomass trends for 2022 are close to their long-term averages. The bloom timing was also average. It was also noted that there is an ongoing coccolithophores bloom in the Bering

Sea similar to what was seen in 2020 and 2021. Coccolithophores tend to result in longer trophic chains, are a less desirable food source for predators, and also reduce visibility for visual predators. Copepods were more abundant than in 2021, especially small copepods. Larval crab are included in the copepod index.

Competitors

Bottom trawl survey data for 2022 were not available in time for this report. The 2021 data indicate that motile epifauna biomass (sea stars, crab, etc) is above the long-term mean. However, sea stars and brittle stars were above average and driving the overall biomass rather than crab. Benthic foragers (yellowfin sole, rock sole, etc) are seen as indirect indicators of benthic infauna and were at the lowest level of their time series in 2021.

Predators

Pelagic forager biomass (pollock, jellyfish, etc) dropped to the second lowest of the time series in 2021. Apex predators (Pacific cod, arrowtooth flounder, etc) were within one standard deviation of their long-term mean in 2021. In 2019 there was a shift of groundfish northward, but in 2021 there was a reversal of this trend.

Adult Pacific cod body condition was below average in 2021. Some bioenergetics work indicates that Pacific cod have been located in warmer waters, which increased metabolic demand and decreased foraging rate and prey energy.

In 2022 Bristol Bay sockeye salmon had the largest run on record. Juvenile sockeye feed on zooplankton and age-0 pollock in warm years and adults feed on zooplankton and krill. Larval crab is likely included in these zooplankton.

Forecast for 2022/23

There is a weak to moderate el Nina projected into April of 2023. Sea ice condition forecasts are a range, but most models predict near to normal conditions that would result in ice extending south of 60 degrees north and as far south as Bristol Bay.

5. Discussion on timing of MMB estimates for status determinations and fisheries specifications

Sarah Rheinsmith presented the CPT with a summary of the timing for Mature Male Biomass (MMB) estimates that are used for stock determination (i.e., overfished status) and for setting fisheries specifications (e.g., the Overfishing Limit [OFL] and Acceptable Biological Catch [ABC]). Overfished status is determined using the MMB estimate at the time of the previous completed fishery, and the overfishing determination is made using the Minimum Stock Size Threshold (MSST) from the most recent stock assessment model. Fisheries specifications, on the other hand, are set using the fishing mortality rate associated with the OFL (F_{OFL}) as estimated from the most recent assessment, compared with MMB projected forward to the time of the next fishery. This approach was established in 2007 and was modeled after the groundfish assessment process.

In subsequent discussion, it was clarified that projected MMB for setting fisheries specifications assumes that the full fishing mortality occurs (either F_{OFL} or F_{MSY}, depending on where the stock falls on the overfishing control rule plotted in Fig. 1 of the SAFE Introduction). It was further clarified that projections of MMB assume that natural mortality (M) occurs continuously from the time that MMB was estimated for the completed fishery, and then assumes that F occurs as an instantaneous pulse during the next fishery. This treatment of F as an instantaneous source of mortality reflects the historical nature of derby-style fisheries prior to the current quota system. Diana Stram also stated that when this approach was designed in 2007, the authors avoided overly prescriptive language in order to give future stock assessment authors and the CPT the flexibility to follow the approach for projecting MMB that was judged to be the most scientifically robust at the time. The CPT agreed that the approach for determining overfished status and setting fishery specifications should be laid out in a table in the SAFE Introduction.

6. SMBKC Report Card

Erin Fedewa presented the most recent SMBKC Ecosystem and Socioeconomic Profile (ESP) report card, and noted that this information in its current form is meant to provide context for management until indicators demonstrate predictive skill for inclusion as direct inputs in the assessment model. The SMBKC ESP was the first ESP completed for BSAI crab and the 2022 report card included recent year updates to existing indicators, rather than adding new indicators. Indicators are spatially subset for the SMBKC stock by the management region. Erin noted several general ESP activities/updates including participation in a National ESP Workshop in July 2022, submission of all ESP indicators through AKFIN, and the development of a Request for Indicators that will be completed each January-February for each given stock. Erin reviewed several ecosystem indicator time series: physical (cold pool extent, summer bottom temperature, pH index, wind stress), lower trophic (Chl-*a* production), and upper trophic (Pacific cod density, benthic invertebrate density, male recruit abundance). Erin presented the indicator traffic light table, which is meant to summarize indicator current year status (when possible) and proposed directional impacts on SMBKC. There was some discussion about why the cold pool and bottom temperature indicators have differing effects on SMBKC. The thought was that the cold pool extent and bottom temperature might affect SMBKC differently depending on life history stage, and the CPT recommended that these linkages be clarified within indicator descriptions in future ESP documents.

Erin then summarized indicator status and potential impacts on SMBKC. Current year physical indicators suggest that the return of cold-water conditions following a 2018-2019 heat wave is indicative of optimal conditions for the highly specific thermal and habitat requirements of SMBKC. However, despite fisheries closures, SMBKC recruitment still remains below-average and ROMS model carbonate chemistry hindcasts indicate persistent, corrosive bottom waters surrounding St. Matthew Island. Increasingly acidified bottom waters suggest potential impacts on shell formation, growth, and survival of BKC, although laboratory studies suggest that negative impacts are not likely until pH reaches 7.5.

Brian Garber-Yonts described the socioeconomic indicators reported in the ESP, which were grouped into two categories: fishery performance (catch-per-unit-effort, total potlifts, number of active vessels, incidental catch) and economic performance (TAC utilization, ex-vessel value, ex-vessel price/lb, ex-vessel revenue share). Brian noted that conversations about criteria for including socioeconomic indicators in ESPs are ongoing, but a general convention has been adopted limiting socioeconomic indicators to those that reflect the performance of the fishery or factors that could be drivers of fishing behaviors. As such, the

larger ESP group decided to retain fishery and economic indicators but drop community indicators. Most SMBKC socioeconomic indicators stopped in 2014 due to fishery closures and data confidentiality and, as such, the socioeconomic traffic light table is fairly limited in utility for assessing trends of current year socioeconomic indicators. The SMBKC indicators were further distilled into two broad categories (ecosystem and socioeconomic) for high-level interpretation, and analyses indicated below-average physical conditions and above-average lower trophic level conditions for SMBKC. With the exception of incidental catch, there is no new information for socioeconomic indicators associated with the target SMBKC fishery, which has remained closed since the 2015-2016 season.

Future ESP development plans include updating the intermediate stage indicator analysis (Bayesian Adaptive Sampling), additional indicator development (e.g., fecundity, habitat quality, larval processes), producing a Request for Indicators (RFI) in February 2024 to propose new indicator contributions, and updating ecosystem and socioeconomic indicators for the 2024 September CPT meeting. There was discussion about the visualization of the indicator terminal year estimate and symbology in time series figures. The CPT expressed confusion in the position, directionality, and color coding of the terminal year symbol relative to proposed directional effects on the stock and recommended that additional efforts be made to more effectively convey effects on SMBKC visually. There was also a recommendation to think more about presentation of indicator trends, such as grouping indicators by current-year stock impacts. There was some mention about re-structuring indicators such that negative trends indicate "bad" for stock and vice versa. The CPT continues to support ESP development and their inclusion in the SAFE chapters.

7. SMBKC Final SAFE and Rebuilding Plan Update

Katie Palof (ADF&G) presented the 2022 assessment for the Saint Matthew Island blue king crab stock (SMBKC) to the CPT. The SMBKC stock is currently overfished and under a rebuilding plan. The rebuilding progress is monitored with no anticipated changes to existing fishing regulations or further bycatch restrictions, and a focus on recruitment expectations. Overfishing did not occur in the crab years 2020/21 and 2021/22. The assessment is on a biennial cycle with the last full assessment in 2020. A three-size bin length-based (≥90 mm CL), male-only model has been used to assess this stock since 2012. This assessment is conducted in GMACS, which was first accepted for use by the SSC in June 2016. Two variants of the base model 16.0, accepted in 2020, were presented:

- 16.0 -2021: 2020 accepted model, fixed M = 0.18 all years except 1998 - time block where M is estimated, updated with 2020/21 groundfish bycatch and 2021 NMFS trawl survey data.
- 16.0 – 2022: model 16.0 - 2021 updated with 2021/22 groundfish and crab bycatch and 2022 NMFS trawl survey data.

Katie presented the historical NMFS survey male biomass fit, ADF&G pot survey CPUE fit, MMB and recruitment trends, and size compositions fits for the NMFS trawl and ADF&G pot surveys. It was noted that a 2022 ADF&G pot survey is ongoing and data will be available for the next full assessment. The author presented 10-year MMB projections with short (1978-2021) and long (1966-2021) time series of estimated recruitment to assess the rebuilding progress. The author also presented retrospective analyses on MMB to assess the adequacy of model fits. The NMFS survey biomass trend showed a small increase from 2017 to 2022; whereas ADF&G pot survey CPUE has declined since 2010 although the pot surveys were focused on shallow areas near the island. The 2022 data did not change the fitted parameter estimates

appreciably from the previous assessment. The influence of station R24 samples on abundance estimation was minor in recent years as this has not been a "hot spot" since 2015. There were no discernible differences in the estimated MMB trends between the two model scenarios, and a slight increase was indicated in 2022 MMB. The two model scenarios also showed increased recruitment in 2020 and 2021 with a tendency to rise in recent years. The size composition fits were satisfactory considering a coarse, three bin, model. As expected, zero fishing mortality in the projections leads to MMB reaching the target MMB much quicker and less than 10 years compared to two higher fishing mortalities (0.09 and 0.18). Rebuilding is highly dependent on increased recruitment and the recent increase in recruitment is an encouraging sign. The CPT noted that we don't have a standardized approach to determine progress toward rebuilding, although that determination is made by the NMFS Regional office.

Based on model fits and estimated population processes, the author recommended the OFL estimate from model 16.0-2022 be used for the 2022/23 and 2023/24 fisheries, with a 25% buffer to set the ABC. The CPT discussed the model configurations and outputs and agreed with the author's recommended OFL and ABC. The 25% buffer is justified for the following reasons:

- This stock is in a fixed rebuilding time frame.
- There is a significant retrospective pattern on MMB estimates.
- Limited life history information is available for correctly specifying the population processes.
- ADF&G pot survey data, last available in 2018, have shown a declining trend.
- ADF&G pot and NMFS trawl survey data give contradictory trends.

The author identified several avenues for future work, such as (a) comparing and reconciling index trends between the surveys, (b) filling the gaps in life history parameters, and (c) investigating catchability processes in the NMFS and ADF&G pot surveys. **The CPT concurred with these suggestions.**

The CPT made the following additional recommendations:

Short-term:

- Clarify the projection steps taken to assess the progress of rebuilding.
- Reconcile with differing NMFS and ADF&G abundance index trends; perhaps, through appropriate modeling of catchabilities.
- Address the persistence presence of retrospective patterns in biomass trends.
- Compare model runs using indices of abundance calculated using VAST to the current design-based estimates.

Long-term:

- Consider increasing the number of size bins so that cohorts might be more easily tracked and growth better estimated.
- Explore the assumed and estimated life history parameters (e.g., natural mortality, growth, and maturity) to ensure the best available science is being used to assess this stock. Implement methods for more appropriately weighting the data sources in the model.

8. Climate Model Updates

Mike Litzow (NOAA-Kodiak) provided an update to climate research presented at the May 2022 Crab Plan Team meeting. Overall, the premise of this work is to build predictive capacity for proposed environmental-snow crab linkages to potentially inform rebuilding analyses. Mike reviewed the borealization approach presented in May that is aimed primarily at understanding how borealization affects snow crab. Dynamic factor analysis was used to reduce a suite of individual time series and produce a borealization index. Using the borealization index as an explanatory variable in a Bayesian autoregressive regression model, Mike noted that the May model was used to produce an immature abundance forecast prior to the completion of the 2022 survey, and then updated with 2022 data this fall. The CPT suggested exploring the use of recruitment output from the assessment model in lieu of the multiple imputation approach to estimate 2020 abundance due to the missing bottom trawl survey, although the CPT recognizes that there are uncertainties associated with this approach as well. The CPT also recommends assessing post-hoc how much variability in the time series trends are incorporated into the DFA shared trend.

Mike then presented 23 CMIP6 ocean models projecting changes in SST in the North Pacific using a shared emission scenario. Because the borealization time series is highly correlated with SST and we can't yet project borealization, SST was used as a proxy for the borealization index. Mike presented attribution statistics, which explain how much of the risk for an event can be attributed to human activity, and how much more likely an event is to happen due to human activity. Attribution statistics suggest that recent SST anomalies in the Bering Sea are human-caused and rapid borealization events would not have occurred in a pre-industrial climate.

Mike discussed evaluating candidate time blocks as the most plausible representation of the current climate for the development of the snow crab rebuilding plan. Annual SST anomaly distributions for four SSC proposed time blocks were presented and evaluated against the estimated current climate using the proportion of SST anomalies greater than 4 standard deviations of the pre-1950 climatology. Mike noted that there have been 3 of these events since 2016, and as such, 20% of the years included in the 2005-2019 time block were above 4 standard deviations (compared with only 3% in the 1982-2017 time block). Given the distribution of SST anomalies projected by the CMIP6 climate models for the current climate state (17% > 4SD), the 2005-2019 time block is the most plausible representation of the current climate, although Mike acknowledged that sensitivity to model-weighting and model forecasting abilities represent potentially significant sources of uncertainty. Overall, the CPT appreciates the update to the ongoing work to provide context for the snow crab rebuilding plan and present a rationale for climate-informed assessments of time blocks for selecting population parameters for rebuilding projections.

9. ESP Snow Crab

Erin Fedewa (AFSC-Kodiak) and Brian Garber-Yonts (AFSC-Seattle) presented the ecosystem and socioeconomic profile (ESP) for Eastern Bering Sea snow crab. In response to the SSC, the authors have concentrated efforts on developing socioeconomic indicators associated with health of the stock and conduct of the fishery for snow crab. Fishery-derived community indicators developed from the Alaska Bering Sea Crabbers (ABSC) skipper survey were incorporated into the 2022 ESP. It was noted that ecosystem processes are evaluated across life history stages to identify critical indicators for

monitoring, and linkages between socioeconomic processes and stock health are hypothesized in the absence of a working conceptual model.

Ecosystem indicators are assembled into physical, lower trophic and upper trophic groups. Cold pool extent and sea ice returned to near normal conditions in the Bering Sea. Temperature ranges for areas occupied by juvenile snow crab decreased nearly 3° from 2021 suggesting colder waters are available for refuge from predators. Chlorophyll-*a* biomass was at a time series high which is considered favorable prey for larval and benthic snow crab. For juvenile snow crab, bottom temperature and prevalence of disease were neutral. Male snow crab center of distribution to the north is considered favorable as they move into colder waters. Crab consumption of snow crab by Pacific cod in 2021 was below the mean.

Socioeconomic indicators are grouped into fishery performance, economic, and community metrics. Most indicators for snow crab such as fishery CPUE, fisher effort, and TAC utilization were neutral, while the number of vessels fishing decreased to 42 (68% of the average fleet size) and is the lowest since 1977, which was not favorable for fishermen and communities relying on snow crab. Recent market trends combined with adverse fishery performance indicators reported for 2022 are evidence of severe economic stresses in the fishery and dependent stakeholders.

The ABSC skipper survey is given to vessel captains at the end of their fishing season and has been distributed the past 2 seasons. The 2021/22 survey showed that more skippers reported that commercial sized males and sub-commercial sized males decreased compared to the previous season. Skippers (28%) reported discarding more than 25% from last season and 70% of skippers reported seeing more Pacific cod in their pots. For fishing behavior, 23% of the skippers noted they finished deeper than in the previous season and 23% reported no changes in their behavior due to smaller fishery harvest.

Going forward in the ecosystem component, EFH maps are being developed by snow crab life history stage in order to subset the data for physical and lower trophic level data groups. Indicators are also being developed that quantify snow crab physiological responses to rapid changes in the Bering Sea. For the socioeconomic indicators, research into the spatial aspects of the fishery in relation to the stock assessment is needed to further develop informative indicators. Additionally, efforts should focus on improving the timeliness of indicators to include models for nowcast/forecasts.

10. Snow Crab Final SAFE

Cody Szuwalski (AFSC Seattle) presented the 2022 assessment of Eastern Bering Sea snow crab to the CPT. The assessment was based on a new GMACS model that was approved for use by the SSC in June 2022. The GMACS implementation for snow crab is a size- and sex-structured model in which crabs are categorized as immature or mature, and account is taken of a terminal molt. The model is fitted to biomass and size frequency data from the NMFS trawl survey, total catch data from the directed fishery, bycatch data from the trawl fishery, size frequency data for male retained catch in the directed fishery, and male and female bycatch in the directed and trawl fisheries. The model is also fitted to biomass estimates and size frequency data from the 2009 and 2010 BSFRF surveys. Updated data in the 2022 assessment include retained and total catch and length frequencies from the 2021/22 directed fishery, discard catch and length frequencies from the 2021/22 groundfish fisheries, and biomass and length frequencies from the 2022

NMFS bottom trawl survey. Results from the 2022 NMFS bottom trawl survey indicated similar abundance to the 2021 survey, but represented a severe decline in snow crab abundance relative to previous surveys.

The assessment author presented several models for evaluation:

- 21.1 – Last year's accepted model (status quo) fit to last year's data.
- 22.1 – The GMACS model approved by the SSC and fit to this year's data, with a tighter prior on M.
- 22.1a – 22.1 with an alternate configuration to estimate initial size composition in which all parameters are freely estimated rather than estimating an ogive and a scaling parameter.
- 22.1ab – 22.1a from an alternate mode detected by the jittering analysis.
- A set of tier 4 assessments with alternative definitions for reproductive output in response to an SSC request from last year.

The CPT considered model 22.1a a straightforward improvement from 22.1 that allows the model additional flexibility in initializing the model. Discussion primarily focused on whether 22.1a or 22.1ab should be recommended by the CPT. These two "models" were actually not different models, but rather different solutions of the same model identified by jittering the model parameters. Model 22.1a was the maximum likelihood estimate (MLE), while Model 22.1ab represented a local minimum (about 5.3 log likelihood units higher than the MLE). The assessment author recommended Model 22.1ab because model fits were reasonable and the estimated fishing mortality in 2020/21 was considered plausible.

CPT discussed how to interpret the results of the jittering analysis, in which random error was added to estimated parameters and the model rerun. The CPT looked at results from West Coast assessments (Pacific ocean perch and sablefish) where many of the jittered runs either failed to converge or converged to local minima. It was also noted that the jitter runs for the most recent AIGKC assessment often converged to local minima. Therefore, it must be concluded that it is not standard practice to reject a model simply because multiple minima were found in a jittering analysis. Jittering runs are typically used only to confirm that the model solution is in fact the global minimum (i.e., the MLE). Based on the jitter analysis that was presented for the model, it appears that 22.1a is indeed the MLE.

The CPT also considered the fact that the jitter runs converged to a range of values for the MLE and with different final gradients. These uneven convergence properties suggest the likelihood surface in the region of the MLE may be poorly defined, but again this would not normally be a rationale for rejecting the model. It does, however, suggest that additional work is needed to ensure that parameters are well specified and, perhaps, that a more parsimonious model for snow crab be considered.

The CPT considered whether it would be appropriate to average the results for models 22.1a and 22.1ab. If likelihood-based weights were to be used for averaging, a difference of 5.3 log likelihood units for model 22.1ab would imply that its weight would be less than 1% of 22.1a, indicating any averaging procedure would be completely dominated by model 22.1a results. Cody noted that all of these conclusions are conditional on the data weights used in the assessment, and that alternative weights could easily shift the MLE from one minimum to the other.

In the end, CPT could not find a scientific basis for choosing a model solution that differed from maximum likelihood estimate and therefore recommended model 22.1a to determine stock status and set the OFL and ABC for 2022/23. The CPT acknowledges that the high fishing mortality estimate in 2020/21 is a concern for this model (the estimated F in 2020/21 was approximately 5). However, the model is configured to estimate higher natural mortality only in 2018/19 and 2019/20, and the high fishing mortality estimate occurs in the following year, after stock abundance has been reduced by extremely high natural mortality. Due largely to the lack of an EBS survey in 2020, there are major uncertainties associated with timing and the dynamics of the snow crab collapse. These uncertainties would argue against overinterpretation of the high 2020/21 mortality estimate. Public comment also noted that the concentration of harvest along the US/Russia boundary in 2020/21 may indicate harvesting of crab that are not a part of the assessed EBS population in that year.

In response to a SSC request, Cody presented Tier 4 assessments using four possible metrics calculated from the summer survey data for reproductive output: 1) morphometrically mature male biomass; 2) legal males (>78 mm carapace width); 3) males >95 mm carapace width; and 4) preferred males (>101 mm carapace width). All of these options would lead to closure of the fishery in 2022/23. The first of these, morphometrically mature male biomass, is the only metric currently used for BSAI crab management. Changing to a different metric would require a careful evaluation. Cody noted that the OFL calculated using a Tier 4 approach exceeded the estimated biomass of commercially targeted males in some years when using either morphometrically mature male or legal males as the basis for the calculation. For these reasons, the CPT did not consider a Tier 4 assessment to be a viable approach for assessing the stock. The CPT concluded that life history information for snow crab (e.g., for maturity and recruitment) remains adequate for estimating reference points, and that the stock should remain in Tier 3 for assessment. The CPT also concurred that moving between Tiers is not a "back up" solution to when more complex models are not fitting well. Demoting a stock to a different Tier has implications on our confidence in the data and modeled population processes and should not be a fall back option.

The CPT recommends that the EBS snow crab be classified as a Tier 3 stock, so the OFL is determined by the F_{OFL} control rule using $F_{35\%}$ as the proxy for F_{MSY}. The proxy for B_{MSY} ($B_{35\%}$) is the mature male biomass at mating based on average recruitment over 1982 to 2021 (183.1 kt). Snow crab was declared overfished in 2021 on the basis of the 2021 assessment that indicated that the MMB was below the MSST. A rebuilding plan is under development for the stock. The current assessment estimates that MMB for February 15, 2022 (41.2 kt) was 23% of B_{MSY} (183.1 kt), consequently the stock remains in an overfished status. The projected MMB at the time of mating when fishing at the OFL for 2022/23 (55.0 kt, 30% of B_{MSY}) is above the criteria for a directed fishery closure based upon the Tier 3 control rule in the FMP (0.25 B_{MSY}).

The CPT recommends that the ABC be set less than the maximum permissible ABC. The buffer between the ABC and OFL used by the CPT and the SSC in 2021 was 25%. The CPT recommends continuation of a 25% buffer, and notes reduced concern about the lack of model vetting (an issue last year), but identifies a new concern about the presence of multiple minima in the likelihood surface and irregular model convergence. It now appears more likely that snow crab experienced a high mortality event in the last few years given the low biomass estimates in two successive surveys, but the timing of that event and the relative attribution to ecological/environmental processes (i.e., natural mortality) or fishing mortality remain highly uncertain.

11. BBRKC Report card

Erin Fedewa presented the BBRKC Ecosystem Socioeconomic Profile (ESP) report card, which includes 12 indicators grouped into three categories: physical (Arctic Oscillation, cold pool extent, summer bottom temperature, pH index, wind stress), lower trophic (Chl-*a* biomass), and upper trophic (benthic invertebrate density, juvenile sockeye salmon abundance, Pacific cod density, male recruit abundance, area occupied, catch distance from shore). Erin described the indicator trends, the associated traffic light table, and ecosystems considerations. Overall, in 2022, bottom temperatures returned to near-average and the cold pool extended into the Bristol Bay management area. The spatial extent of mature male red king crab in Bristol Bay was above average in 2022, coinciding with increases in abundance. In addition, red king crab have experienced a steady decline in bottom water pH in the past two decades and continued declines to threshold pH levels of 7.8 could negatively affect juvenile red king crab growth, shell hardening and survival. There was some discussion about the sockeye salmon abundance indicator and it was suggested to consider ADFG escapements as a possible refinement to the sockeye salmon indicator. There was discussion about the Pacific cod density indicator, which is meant to be a proxy for predation as the survey timing may not adequately sample RKC predation, likely due to the timing to the survey occurring after molting events (when crab are most vulnerable to predation).

Brian Garber-Yonts described BBRKC socioeconomic indicators grouped into two categories: fishery performance (catch-per-unit-effort, total potlifts, number active vessels, incidental catch) and economic (TAC utilization, ex-vessel value, ex-vessel price/lb, ex-vessel revenue share). As with the SMBKC, the larger ESP group did not include community indicators as part of the BBRKC socioeconomic ESP. Erin also presented the stage 1 score as a way to summarize the ecosystem and socioeconomic profiles for broad interpretation. Erin proposed a sockeye salmon predation indicator based on stomach content data collected via the NOAA BASIS survey and a gear interaction indicator using the Fishing Effects Model as potential indicators for development. There was a question about how the 2021/22 fishery closure was reflected in the socioeconomic indicators. It was noted that the closure was reflected in several indicators such as annual ex-vessel value, pot lifts, etc. A point was made that community-based indicators may better highlight impacts of fishery closures.

12. BBRKC final SAFE

Katie Palof (ADF&G-Juneau) presented the draft 2022 stock assessment for Bristol Bay red king crab (BBRKC) to the CPT. Katie noted that she took over the BBRKC assessment earlier this year after longtime author Jie Zheng retired. The 2021/22 OFL was 2,230 t while the ABC was 1,780 t. ADF&G set the TAC at 0 t and 20 t was retained in a cost-recovery fishery. Total catch mortality was 100 t, which was less than the OFL, so overfishing did not occur. Based on the CPT's recommended model (Model 21.1b), MMB on Feb. 15, 2022 (16,640 t) was above MSST (12,010 t), so the stock was not overfished in 2021/22.

Mature male (>119 mm CL) area-swept abundance in the 2022 NMFS EBS trawl survey for BBRKC was estimated at 8.2 million crab, a 30% increase from the previous (2021) survey. Immature male abundance was 4.3 million, up 26% from 2021 (3.5 million), while immature female abundance increased somewhat from 1.4 million in 2021 to 2.5 million in 2022. The estimated mature female (> 89 mm CL) abundance for red king crab in Bristol Bay was 7.5 million crab, an increase of 19% over that for 2021 (6.4 million crab). However, this remained below the threshold (8.4 million mature females) in the State's harvest

strategy for opening the BBRKC fishery. While an official closure had not been announced by ADF&G at the time of the CPT meeting, it appears likely that the directed fishery will be closed for 2022/23, as it was for 2021/22. Females, originally sampled in June, were not resampled in August per standardized survey protocols based on the fraction of mature females in June without newly-extruded egg clutches. The "re-tow" protocol is generally triggered in years with cold bottom conditions (delaying egg hatching and subsequent extrusion of a new clutch), and a fairly extensive cold pool was evident during the survey. Overall, 14% of females had not completed the annual molt-mate cycle at the time of sampling in June, which was slightly above the 10% threshold to consider resampling. State and Federal managers examined preliminary results and models to determine the efficacy of resampling a subset of the Bristol Bay stations. It was determined that resampling would not appreciably change the assessment, so resampling of Bristol Bay stations was not conducted at the end of the survey.

In 2021, immature male and mature female red king crab were found by the survey in the Northern District (north of Bristol Bay and south of Nunivak Island) in high abundance compared with previous years, but these crab were outside the BBRKC stock boundary and were not included in the assessment. Several members of the public expressed concern that these crab were not included and the CPT noted the potential need to expand the stock boundaries in the future to accommodate a northward expansion of the stock under warming environmental conditions. In 2022, the biomass of mature females in the Northern District declined 24% from that in 2021 such that the fraction of mature females in the Northern District was ~10% of all mature females. Although the biomass of mature males in the Northern District in 2022 almost doubled (+96%) relative to 2021, this represented less than 10% of all mature males. Thus, the absolute scale of red king crab biomass in the Northern District remains small relative to that in Bristol Bay.

Katie presented results from three models requested by the CPT and SSC in the spring: 21.1b, 22.0, and 22.0a. The base model, 21.1b, was the 2021 assessment model (21.1) but based on an updated version of GMACS (2.01.E) and including bycatch data from the groundfish fisheries using AKRO's new algorithm for estimating total bycatch from observer data. Model 22.0 represented a simpler version of 21.1b that started in 1985 rather than in 1975; otherwise, it was identical to 21.1b. Model 22.0a was similar to 22.0, except that it estimated a constant value of M for males (instead of using a fixed value). Starting the model in 1985 removes the need for the model to deal with the gear change between 1981 and 1982 in the NMFS survey by estimating potential differences in survey catchability and selectivity between the two time periods. It also eliminates the need to estimate a separate value for M during the 1980-1984 natural mortality "event".

The estimated natural mortality rate on females was higher in 22.0a than in Models 21.1b and 22.0 (0.261 vs. 0.238 and 0.232, respectively), as was the rate for males estimated in 22.0a (0.228) compared with the fixed rate assumed the other two models (0.18). The elevated natural mortality rates in 22.0a were accompanied by slight rightward shifts in the estimated NMFS and BSFRF survey selectivity patterns toward larger sizes, resulting in slightly lower survey catchability at any size in 22.0a compared with 21.1b and 22.0. Estimated MMB-at-mating was slightly higher in 22.0a compared with the other two models across most of the 1985-2021 time period, but with the difference decreasing with time such that terminal year MMB (Feb. 15, 2022) was nearly identical for all three models. The projected MMB for 2022/23 was slightly lower for 22.0a than for the other two models. All three models fit the fishery catch and bycatch biomass, NMFS survey biomass, and BSFRF survey biomass time series data similarly well. They also fit the associated size composition data well. Model 22.0a, as with models in previous assessments that

estimated higher *M* for males, exhibited slightly better fits to the plus group in size compositions relative to the other models. All three models exhibited fairly substantial retrospective patterns in MMB, with estimates of year-specific MMB increasing (displaying positive bias) as peels were removed. Mohn's rho for these patterns was smallest for Model 22.0a (0.33) and largest for 22.0 (0.45), with that for 21.1b closer to 22.0a (0.37).

The CPT raised questions regarding the differences in the molting probabilities derived from two tagging studies and the values estimated by the models. Katie noted that she needed to review the studies to determine the source of the differences between the two studies and reconcile them with the model results. She also noted that the SAFE draft incorrectly referred to Model 22.0a as having a worse fit than 22.0. Although 22.0a, estimating *M* for males, had an improved fit over 22.0, Katie wanted to investigate the apparent model tradeoffs between *M* and survey catchability/selectivity further before recommending this model. The CPT also raised a question concerning the larger value for Mohn's rho (indicating a poorer retrospective pattern) from Model 22.0 relative to 21.1b given the similarity of results from the two models in other respects. Katie indicated that she had noted this as well and it was something she meant to look into in the future. CPT discussion also included the shift in model start time from 1975 in 21.1b and 1985 in 22.0 and regarded it as a positive development toward simplifying the model both in terms of dynamics (eliminating the necessity of estimating a separate time block for M in 1980-1984) and removing potentially conflicting data (the 1975-1981 NMFS survey data collected using different gear). Mike Lizow (AFSC-Kodiak) noted that the Shellfish Assessment group has been engaged in reviewing the early survey data as part of an effort to modernize the code used to process the data and that there are some discontinuities in the early data in the size of the strata used to expand area swept abundance to the population level that might potentially create challenges for modelers when fitting to those early data. He indicated that a report on this aspect of the survey data would be presented to the CPT at its January workshop. The CPT looks forward to this presentation and noted that it would fit in well as it addresses the SSC's request from its June 2022 meeting for the CPT to develop guidelines and criteria for adopting changes to the time frame used in an assessment model.

In selecting a model on which to base management decisions, the CPT noted it has not had the opportunity yet to respond to the SSC's request to develop guidelines and criteria for adopting changes to the time frame used in an assessment model, but that these will be addressed at its January 2023 meeting. Given this and the overall similarity among the three models' fits and results, the CPT agreed with the assessment author that there was not a strong enough reason to recommend either of the 22.0 models (both of which adopted a new time frame for the assessment) for status determination and OFL setting. Thus, the CPT recommends that the author's preferred model, 21.1b, be used to determine stock status and calculate the OFL for 2022/23.

The OFL for 2022/23 from the recommended model (21.1b) is 3,040 t, with a projected MMB on Feb. 15, 2023 of 16,950 t. B_{MSY} for this model was 24,030 t, so the stock was in Tier 3b (MMB/ B_{MSY}=0.71). Last year, the CPT recommended setting the buffer used to set ABC to 20%. The CPT has previously identified a base buffer of 20% as consistent with recurring concerns for this stock (cold pool distributional shifts, declining trends in mature biomass, lack of recruitment, retrospective patterns) and the base buffer used for other Tier 3 stocks. For 2022, the CPT recommends continuing to use a 20% buffer; it found that the level of perceived additional uncertainty in the assessment associated with the concerns expressed in 2021 remained, although the basis for those concerns has changed slightly. This basis includes:

- Continued lack of recent recruitment
- Poor and variable environmental conditions
- NMFS female survey biomass in 2022 remains at historically low levels
- The lack of model fit to the 2018-2022 NMFS female survey biomass
- The retrospective patterns exhibited by the recommended model

The CPT received a number of questions and comments from the public regarding clarification of the buffer setting process and subsequent differences between the ABC and the TAC. The CPT explained that its buffer-setting deliberations start with the previous year's buffer and it determines whether the reasons articulated for last year's buffer have been reduced, allowing a reduction in the buffer. It then considers whether there are new, additional concerns that warrant an increased buffer. It was also noted that the TAC-setting process is a State process in which the TAC is constrained by the ABC and subject to harvest strategies outlined in State regulation. Broadly speaking, the State harvest strategies have been designed to maintain a minimum sustainable population size and set allowable catch in the directed fishery such that total fishing-related mortality (retained catch, discards, and bycatch mortality) remains below the federal ABC.

Katie also presented MCMC results for the "probability of approaching" an overfished status. This consisted of using MCMC realizations to estimate whether or not the probability that the stock would fall below its MSST in the next two years would be greater than 50%. For each MCMC realization, the ratios of MMB projected to 2022/23 to B_{MSY} were evaluated and the proportion of realizations in which the ratio was less than 0.5 was determined. Based on this approach, the probability of approaching an overfished status was 0. She also provided 10-year projections for a range of fully-selected F values in the directed fishery (from 0 to 1.5 x F_{OFL}). Results showed that if the stock were not fished at a directed fishing mortality of more than 0.167 yr^{-1} in the 2022/2023 and 2023/2024 seasons, the projection using the lowest recruitment periods during 2013-2021 would not likely result in "approaching an overfished condition" within the next four years.

The CPT had the following suggestions:

- Include the terminal model year in plots of values from projections
- Identify the source of the difference in retrospective patterns between Models 21.1b and 22.0 (given their otherwise similar results)
- Given the recent closures, consider investigating a scenario where the fishery actually was conducted and determine its influence on stock dynamics (the CPT recognizes the difficulties associated with doing this, given that the survey data the model fits to will not reflect the hypothetical removals by the fishery)
- In coordination with other red king crab assessment authors, apply the groundfish stock structure template across all red king crab stocks in the EBS (as requested by the SSC)
- Resolve differences between molting probabilities estimated in historical tagging studies, which suggest substantially different probabilities of molting at a given size for males
- Continue to investigate the causes of the substantial retrospective patterns exhibited by these models

13. Snow Crab Rebuilding

Sarah Rheinsmith began the snow crab rebuilding discussion with a brief presentation on the timeline for developing a snow crab rebuilding plan and the role of CPT during this meeting cycle. Snow crab were declared overfished on October 19, 2021, which began the two-year period for developing a rebuilding plan. In October 2022 the SSC will review CPT-recommended model projections to select T_{min} and T_{max} for the rebuilding plan. In December of 2022 the Council will conduct an initial review of the snow crab rebuilding plan and potentially select a preliminary preferred alternative. In February 2023 the Council will take final action and select a preferred alternative to recommend to the Secretary of Commerce. The role of CPT at the current meeting is to select from candidate population projections presented by Cody Szuwalski as the basis for establishing T_{min} and T_{max}. The goal when selecting from candidate projections is to establish the most realistic framework as the basis for a successful rebuilding plan.

Cody Szuwalksi then presented four candidate sets of snow crab population projections that served as the basis for CPT's recommended T_{Min} and T_{Max} for the rebuilding plan. Cody began his presentation by walking CPT through the methods used for the model projections that were being considered as the basis for the recommended rebuilding timeline.

Of the four time blocks for deriving estimates of *R* and *M* that the SSC recommended for consideration during the June 2022 meeting, adequate time was available for projecting with values from the two priority time blocks: 1982-2017 and 2005-2019. These projections incorporated 2022 survey data, and CPT recognizes and appreciates the effort that this involved, given the very short time between data availability and the September CPT meeting. Following a recommendation from the SSC, rebuilding timelines for each projection scenario were generated using two possible values of B_{35} (the B_{MSY} proxy) as the target biomass reference point: 1) B_{35} calculated with *R* estimated from the full time series (1982-2021), which is the same method used from the recommended assessment model; and 2) B_{35} calculated with *R* estimates drawn only from the period from which *R* was drawn for the particular projection under consideration (i.e., either 1982-2017 or 2005-2019). As requested by the SSC at the June 2022 meeting, *R* and *M* were both modeled as draws from the values estimated for the time block distribution under consideration.

In addition, each combination of possible *R* and *M* was projected under values of fishing mortality (*F*) corresponding to five fishing scenarios: no fishing, bycatch only, the State of Alaska harvest control rule (HCR) with no bycatch, the State of Alaska HCR with bycatch, and the ABC, calculated with a 25% buffer on the OFL, with the OFL based on known population parameter values. The HCR for these scenarios was simulated at 40% of the ABC, a value that is consistent with recent management of the fishery. In addition to these fishing scenarios, *F* was simulated with unobserved mortality set at levels five times and 100 times as great as currently estimated observed mortality from non-directed fisheries. Each scenario was run through 2000 iterations, without stochastic variability in either the initial status or the parameter values. The projections were plotted as median estimated MMB at each time step from the 2000 iterations, and uncertainty was illustrated with error ribbons corresponding to the 95% inter-simulation range of the scenarios. Each scenario was projected forward to 2040.

The projections that CPT considered were generated with model 22.1a, except for the unobserved mortality scenarios, which were generated with model 22.1ab. While these "models" were given unique names in the draft SAFE report for snow crab, they are actually two possible solutions for the same model, based on two

modes of parameter values that were identified during a jittering analysis that was conducted as a part of model evaluation (see discussion under snow crab SAFE). The CPT recommended the MLE solution, 22.1a, as the assessment model. Cody stressed that while some projections were based on the alternate model solution (22.1ab), these projections were still useful in the strategic evaluation that CPT was now considering. While there are slight differences between the two model solutions in terms of projected population trajectories, the most important considerations for rebuilding timeline are the values of R and M that are selected, in addition to the size of the population at the beginning of the rebuilding period. The projected status of the stock at the time of mating during the 2022/23 fishing season (MMB / B_{35}) is similar between the two solutions (0.30 for 22.1a and 0.36 for 22.1ab), which facilitates comparisons among projections generated with the two solutions.

After this explanation of his methods, Cody summarized the most important results from the projections:

- Population trajectories under the no fishing and bycatch only scenarios were very similar, and trajectories for the State HCR with and without bycatch were very similar. These two results indicate that observed bycatch mortality is expected to play little role in rebuilding progress.
- The lowest value of B_{35} is from the status quo approach, and the highest value is generated from R drawn from the 2005-2019 time block. However, the three values of B_{35} were quite similar, and did not generally result in large differences in estimates of T_{Min} and T_{Max}.
- R drawn from the two time blocks resulted in similar timeline projections. The 1982-2017 time block has a lower mean R with a lower standard deviation, while R drawn from the 2005-2019 time block has a higher mean and standard deviation, driven by a single large recruitment event. The two distributions of R produce similar scales of population size and resulting rebuilding timelines, though the 2015-2019 time block produces a shallower slope in trajectories, since population growth is largely driven by the infrequent sampling of the large event.
- Estimates of M are the dominant consideration for rebuilding scenarios. The 1982-2017 time period excludes the large 2018-2019 mortality event, and rebuilding timelines were quite similar when M was drawn from this time block, regardless of R. On the other hand, 2005-2019 includes the 2018-2019 mortality event, and drawing M from this time block simulates a situation when large mortality events occur on average once every seven years. In this situation projections often failed to reach B_{35}, resulting in an undefined, or infinite, estimated time to rebuild.
- Small differences were observed in T_{Min} when unobserved bycatch mortality was estimated as five times observed mortality.
- Estimating unobserved bycatch mortality at 100 times observed mortality resulted in very different projections for the no fishing and bycatch only scenarios. In addition, the State HCR without bycatch was very similar to the bycatch only scenario. Estimating unobserved mortality at this high level had considerable effects on a range of model parameter estimates. In particular, the scale of the population increased due to changes in selectivity estimates. Estimating unobserved mortality at this level also had important management implications, as all of the OFL was shunted away from the directed fishery and into bycatch. In addition, a reduction in F_{35} was observed due to the allocation of F. Full understanding of the implications of 100 times scenario would require a retrospective analysis.

Cody then presented his approach for selecting among the different rebuilding scenarios, based on an evaluation of the most likely values of *R*, *M*, and unobserved mortality. His approach for selecting *R* and *M* was based on an update of the analysis into the causes of the snow crab collapse that he presented to CPT in May 2022. This analysis is based on a male-only population dynamics model fit to a restricted size range (30 - 95 mm carapace width). Time-varying estimates of *M* are then fit to a range of different covariates to evaluate the plausibility of different hypothesized causes of the collapse. This result identifies bottom temperature and population density as the two most plausible causes of elevated *M* during the population collapse. Cody presented an analysis of combined laboratory-derived temperature-dependent metabolic requirements, observed bottom temperatures, and modeled population density to evaluate the possible combined effects of temperature and density on population-level metabolic demands. This analysis suggested a quadrupling of population-wide metabolic demands during the extreme warming event observed in 2018. Cody further noted the area-occupied indicator presented by Erin Fedewa as a part of the ESP for the 2022 snow crab SAFE. This time series shows that the high abundance of snow crab in 2018-2019 co-occurred with the lowest area occupied in the 1988-2022 survey time series. The combination of high abundance and restricted range suggests increased difficulty in satisfying population-level metabolic demands during the 2018 warming event that apparently precipitated the collapse.

The CPT then discussed the implications of these results for selecting an appropriate time block for estimating *M* during rebuilding. The 2005-2019 time block simulates a situation where extreme warming events occur on average once every seven years, and this rate of perturbations is consistent with the climate change analysis presented by Mike Litzow at this meeting. However, Cody's analysis of the causes of observed mortality events provides a strong scientific argument that the collapse was the combined result of warm temperatures and high population density. Since high density is not a likely outcome in the projections that were presented for the rebuilding analysis, this creates a strong scientific argument for decoupling the expected distribution of *M* from the expected distribution of temperatures during the rebuilding period. The CPT therefore recommends values of *M* drawn from the 1982-2017 time block as the most realistic choice for modeling *M* during the low-density, high-temperature conditions that are expected during rebuilding.

The CPT then discussed the most realistic time block for representing *R* during rebuilding. Cody noted previously-published work by himself and colleagues indicating a positive relationship between sea ice concentration and Bering Sea snow crab recruitment (Szuwalski et al., 2021; Climate change and the future productivity and distribution of Bering Sea crab). This work indicates that the lower range of possible *R* values is the most realistic, though Cody noted that even this lower range is likely optimistic. Given the expectation for reduced sea ice coverage during the rebuilding period, CPT recommends the time block with lower average *R* (1982-2017) as the most realistic choice for modeling *R* during rebuilding.

Finally, Cody reviewed the available evidence for projecting the effects of unobserved mortality. The five times scenario produces no appreciable difference in population trajectories compared with the status quo approach to estimating unobserved mortality, indicating that rebuilding scenarios are insensitive to the effects of unobserved mortality at this magnitude. The 100 times scenario created complexities in population modeling and catch allocation that would require more study before being incorporated into rebuilding analyses**.** Given these results, CPT recommends that unobserved mortality be modeled using the status quo approach for rebuilding projections.

The projected time to reach $B_{35\%}$ with no fishing under a scenario generated with these recommendations (*R* and *M* modeled from the 1982-2017 time block, status quo treatment of unobserved mortality) is 2029. Since the resulting T_{Min} is less than 10 years, T_{Max} would be set at 10 years. The CPT therefore recommends values of T_{Min} = 2029, and T_{Max} = 2033 for the snow crab rebuilding plan.

The CPT recognizes the considerable uncertainty in model projections for a stock that has recently experienced the largest climate perturbation in the observed time series, resulting in rapid demographic and distribution changes, along with the heightened uncertainty that arises from the need to project population trajectories forward into climate conditions that are likely to differ substantially from conditions that have been observed to date. However, the CPT considers the recommended timeline to be the most realistic scenario given the data that are available to model the stock post-collapse (i.e., only with survey data from 2021 and 2022).

14. PIRKC Final SAFE

Cody Szuwalski presented the 2022 Pribilof Island red king crab stock assessment. This is the first assessment since 2019 when this stock was moved to a triennial cycle. This stock is in Tier 4 and assessed with a GMACS model which was approved in 2019. In 2019 the B_{MSY} proxy for this stock was defined as 35% of the average model estimated mature male biomass (MMB) from a period of no fishing (2000 to present). The directed fishery for this stock is closed due to bycatch restrictions in the PI blue king crab fishery, therefore no overfishing is occurring, and the stock is not overfished.

Cody presented three model scenarios for consideration by the CPT. Model 22.1, which is the approved 2019 model (19.1) updated with new data and small fixes to bugs in the code; Model 22.1a which includes bycatch size composition into the base model, adding an additional data set and ability to estimated bycatch selectivity in the model; and Model 22.1b which builds on 22.1a and adds a constant estimated growth increment which is more consistent with other king crab stocks.

Cody acknowledged the SSC request to work with other red king crab authors to complete a stock structure template for Bering Sea red king crab. Size composition comparisons were presented for the three red king crab stocks. There has been an increase in the number of stations reporting RKC over time, even though the number of crab caught hasn't changed much over time. These trends suggest increasing spatial area for red king crab in the Bering Sea.

The model fits were different with model 22.1b having the lowest estimates of MMB, model 22.1a having the highest, and model 22.1 falling between these two. Selectivity estimates changed among models, as would be expected when the additional size composition data from the bycatch fleets were added to the model (22.1a and 22.1b). Estimated fishing mortality (*F*) was consistent among models, mostly low due to the lack of a directed fishery. As expected due to the difference in the MMB estimates, recruitment estimates also differed among the three models.

Model 22.1b included a change to the molt increment relationship; the previous models used a linear relationship between molt increment and size, while this model has a constant molt increment over all sizes, which is consistent with the BBRKC assessment parameterization.

The author's preferred model was 22.1b, with the rationale that it fits all the data sources well and has more realistic, based on the biology of red king crab, parameterization of molt increments. Additionally, this model includes another data source (bycatch size composition data). This model is viewed as an improvement over the base model (22.1). The CPT endorsed the author's preferred model for specifications, and kept the ABC buffer at 25%. The rationale for the buffer level is consistent with the previous assessment (2019). The rationale includes that this model borrows life history information from other stocks, and that this level of buffer is consistent with other low information king crab stocks (SMBKC, PIBKC).

The CPT discussed the likelihood of having a directed PIRKC fishery, but this seems unlikely due to the expected level of bycatch of PIBKC during any directed fishery.

The CPT recommends:

- That the assessment author and other red king crab assessment authors (BBRKC) review the existing growth data and review potential additional sources of growth information. Work that is underway in the NMFS Kodiak lab was mentioned.
- The CPT also recommended that the author examine whether the standard deviation around the growth increment matches the spread around the tagging data for BBRKC.

15. Tanner Crab Final SAFE

William ("Buck") Stockhausen (AFSC-Seattle) presented four models to the CPT: model 22.01 (the accepted model from 2021 with updated data), model 22.03 (22.01, but fitted to combined male + female bycatch fishery biomass data), model 22.07 (started the model in 1982), and 22.08 (used bootstrapped effected sample sizes for NMFS survey data input sample sizes). Variants of the first three of these models (22.01, 22.03, and 22.07) in which a separate retention function for 2021/22 was estimated were also presented.

Estimating separate retention functions did not impact the results appreciably and were an ad hoc adjustment not reviewed by the CPT or SSC, so they were not endorsed by the author. Models 22.07 and 22.08 started the model in 1982 by estimating initial numbers-at-size/sex/maturity state/shell condition (rather than starting the model in 1948 and building up the population structure through recruitment) required 50 more estimated parameters than Models 22.01 and 22.03 and the SSC has identified standardizing criteria for changing model start time as an action point for the CPT, so the author did not endorse these models. The author-preferred model was model 22.03 because fitting to male and female total catch separately can place an undue weight on female catches. Combining the total catch data by sex before calculating the associated likelihood components provides a better representation of the total catch mortality on stock dynamics. The CPT concurred with the author's preferred model.

Based on the author-preferred model, the stock is not overfished and did not experience overfishing in 2021. The OFL calculated using model 22.03 was 32.81 kt. The author suggested increasing the buffer used in calculating the ABC to 25% based on concerns around estimated recruitments that have not been propagating to larger size classes. Furthermore, the fits of the model to the terminal years of survey MMB were diverging from the survey trend and missed the confidence intervals of the data. The CPT recommended using the same buffer as last year (20%) because these were not new problems and were listed as justification for the buffer last year.

The author identified several avenues of research to be pursued in the coming year, including: transitioning to GMACS, completing the BSFRF/NMFS survey selectivity analysis, exploring time-varying natural mortality, investigating non-parametric approaches to selectivity, and a more thorough evaluation of a model that starts in 1982. The CPT was supportive of these pursuits. **Additionally, the CPT asked that the author:**

- Show plots for jitter analyses that could demonstrate (or rule out) bimodality in management quantities (the author noted that the models presented converged to the MLE over 50% of the time in 800 jitter runs, but diagnostic plots were not presented).
- Provide a plot of the fits to male and female components separately when they are fit in an aggregated fashion (as in 22.03). Are the fits to either sex substantially degraded?
- Provide some discussion as to why there was an exceptionally small retrospective pattern in spite of the issues with recruitments that appear and then do not propagate through the population.
- Continue to explore ways to eliminate the overestimates of large crab (the interplay between growth estimates and non-parametric selectivity might be a useful avenue to explore)

16. Overfishing status updates: WAIRKC, PIGKC, AIGKC, PIBKC

Western Aleutian Islands Red King Crab (WAIRK), Pribilof Islands Golden King Crab (PIGKC), Aleutian Islands Golden King Crab (AIGKC)

Ben Daly (ADF&G-Kodiak)provided an overview of the catch in relation to overfishing limits (OFL) for WAIRKC (2021/22), PIGKC (2021), and AIGKC (2021/22). Total catch was below the OFL for each of the three stocks therefore overfishing did not occur. WAIRKC and PIGKC are on triennial assessment cycles and stock assessments were last completed by the CPT in May 2020. The OFL and ABC for WAIRKC and PIGKC stocks will remain in effect until the next assessment in May 2023. AIGKC is on an annual cycle and was last assessed in May 2022, but the 2021/22 fishery was not completed at the time of the assessment. As such, overfishing status was determined at the September CPT meeting using completed fishery data.

Pribilof Islands Blue King Crab (PIBKC)

William Stockhausen (AFSC-Seattle) provided an overview of the catch in relation to the overfishing limit for the 2021/22 PIBKC fishery. Total catch was below the OFL, therefore overfishing did not occur. The PIBKC stock is overfished and the status has not changed since 2002. This stock is on a biennial cycle and was last assessed at the May 2021 CPT meeting. The OFL and ABC for this stock will remain in effect until the next assessment for this stock in September 2023.

17. EFH Stock Author Report

Molly Zaleski (NMFS-AKRO) and Scott Smeltz (Alaska Pacific Univ.), with Jodie Pirtle (NMFS-AKRO) assisting, gave an update on the Council's 2022 Essential Fish Habitat (EFH) 5-Year Review, and presented the EFH Fishing Effects Evaluation Discussion Paper. Molly referred the CPT to recent presentations the EFH team gave to the CPT at the January and May meetings. The FE Evaluation process begins with FE model output, which is then analyzed for species-specific core EFH areas, stock author review of the model

output and analysis, and finally plan team, SSC and Council review. In addition to the discussion paper being reviewed at this meeting, the EFH team provided supporting material, including folders containing the species-specific FE model maps, FE model output time series figures, EFH maps, and comparative maps of 50% core EFH areas (CEA) from 2017 and 2022, and two supporting discussion papers: Supplemental Analysis for the Species Distribution Model (SDM) Ensemble EFH Maps for the 2022 5-year Review (September, 2022) and Discussion Paper on Advancing EFH Descriptions and Maps for the 2022 5-year Review (reviewed by SSC January 2022, revised March 2022). Chapter 4 of the main discussion paper reports the FE analysis results by species, including estimated percent of habitat disturbed and summarized stock author (SA) responses regarding FE model concerns (Section 4.2), detailed SA responses regarding species with data limitations (including four BSAI crab species), and detailed FE assessments for species with ≥ 10% CEA disturbed, which included EBS Tanner crab. Full results of the SA assessments for all species are in an appendix.

Scott provided an overview of the FE model process and results. He noted that the model was developed for the 2017 review, and is intended to assess FE over time at large spatial scales. Changes to the FE model since 2017 included a correction to an error in model code, identified after the 2017 review was completed, that transposed inputs for trawl and longline gear, additional fishing data time series through 2020, and new information on some minor categories of fishing gear, which was limited to the Gulf of Alaska and did not affect results for BSAI crab stocks. Scott briefly described the process of overlaying SDM maps (EFH Component 1) with FE maps. EFH Component 1 is required under regulation to identify EFH by species at the scale of the FMP management unit, defined as the upper 95% of predicted area occupied. As directed by the SSC, the FE assessment is limited to the Core EFH, representing the upper 50% likelihood predicted EFH, and includes both observed and unobserved fishing effects. Sixteen individual species (including EBS Tanner crab) were identified in the FE analysis as being above the threshold of 10% of CEA disturbed, compared to no species identified above the threshold in the 2017 analysis. Scott attributed the difference between the 4.7% CEA disturbance model result used in the 2017 assessment and the current results for Tanner crab mainly to the code error in the 2017 model runs, noting that the SDM model that was used in 2017 was rerun with corrected code, with results indicating that EFH disturbance was 11.1% as of November 2016 and 11.4% as of December, 2020, compared to the current ensemble SDM results of 10.6% and 10.9%, respectively.

Molly reviewed the stock author review process, which began in April, noting that authors and species experts were asked to provide an assessment under three conditions: if the stock was below the MSST, if the species was above the 10% CEA disturbance threshold, or if the author felt a qualitative assessment was warranted in addition to the model-based assessment, and complimented the crab SAs and experts for their contributions. SA assessments were provided for EBS BKC and EBS snow crab, which are both currently below MSST (with FE results of 2.3% and 3.8% CEA disturbance), and for EBS Tanner crab (10.9% CEA disturbance). SAs for BKC did not recommend elevating for mitigation of habitat impacts, however SAs for snow crab, Tanner crab, AI GKC, EBS RKC, and AI RKC all indicated that there was insufficient information available on which to make a recommendation. Molly summarized crab FE evaluation concerns from SA reviewers, which spanned reviews submitted for most crab species. These included seasonal differences - FE model results based on summer distributions may be missing important impacts during winter distributions and/or during important life stages (e.g. molting or mating); spatial scale - EFH is based on FMP management units rather than stock sub-regions; life history – juveniles may be more susceptible to disturbance than adults, but FE model is limited to older life stages; and insufficient information – all

species except BKC were identified as being too information-limited to determine if elevation for mitigation measures was warranted.

A more detailed summary of the snow crab SA assessment was presented and discussed (slides for other SA assessments for individual crab stocks were included but not presented). The snow crab SA indicated that there was insufficient information to elevate snow crab habitat mitigation, but raised concern that inclusion of Northern Bering Sea in the EFH map for snow crab may dilute meaningful fishing effects in more important snow crab areas. While no significant correlations between life history indices and CEA disturbance trends were reported in FE model results, the SA noted that a longer times series (including 1990s) would provide a better basis for correlation tests, and "where" and "when" disturbance occurs is important for the stock but was not considered. Molly noted that HAPC recommendations were included in two of the SA assessments: for Aleutian Islands RKC, Petrel Bank was recommended for consideration, and for BKC, HAPC consideration was recommended for nursery habitats around the Pribilof Islands, St. Matthew Island, and St. Lawrence Island.

Molly elicited comments from the CPT regarding guidance on evaluating FE beyond what is provided in the discussion paper and supporting documents. The CPT recognized that the EFH process as currently established does not allow FE determinations to be made on the basis of stock boundaries or smaller sub-regions, but reiterated the points made by the SAs in their assessments regarding the need to focus more specifically on fishing effects in critical habitat areas for individual crab stocks and biologically meaningful spatial and temporal scales to capture impacts on specific life-history stages. There was a discussion of how the more detailed analysis would be accomplished, whether as part of the next EFH 5-year review, or given the depressed condition of most crab stocks, in the more near-term, outside of the formal EFH process. CPT members noted that the EFH team has produced a rich base of information on which to expand the analysis in this direction (and that detailed spatio-temporal model results were provided to some crab SA's for this assessment and could potentially be provided as a consistent part of the process in the future), but that it was unclear that individual SAs or the CPT as a whole would have adequate resources to perform this level of analysis within the EFH process as it is currently structured. It was also noted that the CPT could develop the issue as a research priority at a future meeting.

The CPT concluded with a discussion of recommendations for HAPC consideration of specific areas, in addition to those identified in the SA review (the Petrel Bank area identified for Aleutian Islands RKC, and BKC nursery habitats around the Pribilof Islands, St. Matthew Island, and St. Lawrence Island). Additional areas were identified for further evaluation by the CPT for potential formal HAPC recommendations separate from the EFH process. However, the CPT recognized the need for review of existing habitat protections and more thorough analysis, and elected not to make formal recommendations at this time. It was noted that further consideration of habitat protections is a matter of urgency given the depressed condition of most crab stocks, and the CPT identified the following as an initial list of candidate areas to revisit for the January CPT meeting:

- BBRKC habitat in southern portions of statistical areas 509 and 516. It was also noted that the CPT identified RKC habitat concerns during the 2010 EFH review, and the Council last reviewed a discussion paper on the issue in February, 2013, but ultimately took no action, and that process may warrant reconsideration.
- Near-shore areas in Norton Sound affected by mining activity with the potential to affect NSRKC.

- Critical rearing habitat for Aleutian Islands RKC on the northern side of the Alaska Peninsula, shoreward of the 50 meter isobath
- Areas of high survey abundance of female snow crab northeast of the Pribilof Islands that are also subject to high trawl activity

18. NSRKC proposed model runs

Toshihide "Hamachan" Hamazaki summarized the most recent fishery results for Norton Sound red king crab followed by some of the issues involved to consider for the final assessment in January 2023. The summer 2022 fishery had the highest CPUE over the past decade with the summer commercial fishery quota taken in about a month. The 2022 fishery retained a total of 0.14 kt (338,343 lb). Discard mortality varied with the estimation approach and was discussed by the CPT. The 2022 NMFS trawl survey produced an estimate of 2.3 million crab, but was just recently completed and data are not yet included in model runs.

The author asked for input on three issues in advance of the January SAFE presentation: (1) selection of model(s) to bring forward; (2) how to estimate discards in the absence of observer data; and (3) whether the OFL-ABC should be calculated with length-dependent or length-independent M. The CPT has previously discussed that a major assessment issue is that catch and survey observations of large, especially old shell, crab decline rapidly in a way that is difficult to model. Some of the options to address this are either changing mortality (e.g., applying a higher *M* for the largest size classes) or selectivity for these crab.

Hamachan presented four potential models to bring forward in January 2023:
21.0 – previous model with updated data
22.0 – model 21.0 with shell-specific retention probabilities
22.1 – model 21.0 with individual *M* estimates for each of 8 length bins
22.2 – model 22.0 with individual *M* estimates for each of 8 length bins

Preliminary exploratory runs indicated few differences between models 21.0 and 22.0 (the presented model runs still lack 2022 trawl survey data). There was little improvement to model fits, and little change to MMB and B_{MSY}. Model results differed primarily in length and shell composition data for the trawl survey. The old shell retention probability decreased under 22.0, and size-dependent *M* increased under 22.1. The AIC values suggest model 21.0 is more parsimonious since results really didn't change much relative to adding four additional parameters. For this reason, the CPT requests model 21.0 be brought forward in January. The CPT noted in its discussion that while model 21.0 had been at times described as using "length-independent" approach for modeling *M*, this model actually uses an *a priori* value of $M = 0.18$ for $\leq$ 123 mm CL, and estimates *M* for > 123 mm CL within the model.

The author noted that the size of functional maturity may be 75 mm CL based on preliminary results from a Kodiak lab study; the size at maturity currently used is 94 mm CL based on information borrowed from Bristol Bay. Because this stock is currently in Tier 4, mature male biomass is used for B_{MSY} calculation. The CPT requests an update on maturity studies from the Kodiak lab in January.

This fishery was historically managed with a retained catch OFL, but the author has been asked to develop a total catch OFL. There is virtually no bycatch occurring for NSRKC other than in the directed fishery, and the assessment author expressed concerns over estimating discards for this stock. Opportunistic

observer coverage occurred during 2012–2019, providing some data on bycatch in those years, but no bycatch data have been available since 2020. The author remains concerned that opportunistic observer coverage during 2012–2019 may produce biased bycatch estimates. The CPT suggested that selectivity is estimated in the model and could perhaps be used to help estimate discards. The CPT further discussed the reality that adequate data are lacking for estimating important parameters for a number of stocks, but assessment authors have to make the best use of the data that are available. The NSRKC OFL is set assuming a discard rate and total catch could be developed using the historical discard rate. The CPT requests that the author provide information in January 2023 on different methods for estimating discards, providing both the discard rate (i.e., as a proportion of the retained catch) and associated total catch with each method.

Hamachan then discussed options of length-dependent versus length-independent F_{OFL} for calculating OFL. If M is constant, this would not be an issue. The author recommends length-dependent OFL consistent with the length-dependent M model structure. Alternatively, if a length-dependent model structure for M is chosen along with a length-independent F_{OFL}, then an appropriate ABC buffer level could be chosen as an option for addressing resulting uncertainty about the OFL. The CPT requested that the author bring forward two calculations for OFL from the preferred model (21.0) in January: the traditional calculations with a constant F_{OFL}, and also results from another approach, based on separate F_{OFL} values corresponding to the two length-dependent values of M in the model.
Additional CPT suggestions are to include jittering to evaluate model convergence, and placing a prior on M in the smaller size bin in future explorations of models 22.1 and 22.2 to keep the M estimate above 0.

19. BSFRF Update

Scott Goodman gave a brief update on Bering Sea Fishery Research Foundation (BSFRF) ongoing research projects and efforts to acquire funding. He reviewed the BSFRF portfolio of research projects under topic areas: crab movement research, crab survey research, habitat and recruitment, bycatch, and crab predation. Scott highlighted that the tagging and movement research is a high-profile multi-year effort project focusing mainly on red king crab, but highlighting intentions to include snow crab in future tagging efforts. The BSFRF is preparing to deploy crab tags in October/ November of 2022. Tag retrieval will begin in Jan-March of 2023. Current tagging efforts will hopefully help fill data gaps surrounding crab movement and distribution. The BSFRF is also working to include additional crab survey research that will hopefully incorporate winter surveys, pot surveys, and trawl surveys to act as an option to the availability of crab-specific abundance data in the Bering Sea.

Scott presented BSFRF's current efforts to better characterize unobserved fishing mortality (UFM). Estimates of UFM use a variety of scaling factors and are distinctly different than observer coverage and unobserved fishing trips data. The object of this analysis is to better quantify the magnitude of UFM effects with available data, considering scaling factors including time, space, bottom contact, density estimates, mortality estimates, and other factors, to characterize the footprint of different fishing gear and produce estimates of UFM.

Scott also noted that BSFRF researcher Madison Heller-Shipley will be entering the PhD program at UW/SAFS in the Punt Lab, focusing on habitat and recruitment research in *Chionoecetes* spp. Scott announced the joint effort between BSFRF and Alaska Bering Sea Crabbers to facilitate a Crab Science

Symposium to discuss the ongoing status of crab stocks. The Crab Science symposium was held at Leif Erickson Hall at 9:00am-1:00pm on Friday 9/16/2022. To conclude the presentation, Scott was able to share videos BSFRF had taken from within crab pots.

20. GMACS Updates and Priorities for January Modeling Workshop

The following agenda items were identified as topics at the January modeling workshop:

- R markdown tips and tricks – code sharing.
- Incorporating time varying mortality – logistics of how to model and overall applicability.
- GMACS progress:
    - Update from postdoc work and plans for future development and contributions.
    - Merged version of king crab/snow crab GMACS models.
    - Review updated model and demo GitHub.
    - Updates on: AIGKC, NSRKC, Tanner crab (if any).
        - What needs to be added for NSRKC and Tanner implementations.
    - What do we still need to code/work on?
        - Katie will circulate a draft list prior to the meeting that can be updated during the meeting.
    - Jittering – document methods used in GMACS
        - Guidelines for use, interpretation of results
    - 'Gmr' package for plotting/diagnostics

21. New Business

Proposed meeting dates:

Jan 17- 20, 2023 (Kodiak - tentative)
May 15 - 19, 2023 (Juneau - tentative)
Sept 11 - 15, 2023 (Seattle)

January agenda items:

- NSRKC final SAFE
- PIGKC proposed models
- AIGKC proposed models
- Economic SAFE
- Snow crab rebuilding plan update
- Guidelines for moving data start date (year); caveats concerning early survey data
- Handling mortality discussion - next steps, objectives/goals
- (May?) Update on catch accounting /groundfish bycatch
    - Specifically how data is collected and reported
    - EM changes to data collections
- Observer data CV crab
- HAPC areas and considerations - continuation of Sept discussion from EFH
- Research updates. The January meeting is traditionally an opportunity to present research updates to CPT. The following possible presentations were identified, along with the recognition that time

for these items may ultimately be limited by the need to preserve time on the agenda for the modeling workshop:

- Tagging work
- Overview of research on ocean acidification on Bering Sea crab stocks (multiple presentations, incl. Chris Long, Andre Punt, Mike Dalton, Darren Pilcher)
- Discard mortality - Noelle Yochum
- Temperature effects on survival, intermolt duration, molt increment, and growth rates of early benthic snow crab and Tanner crab (Louise Copeman, AFSC-Newport)
- Bitter crab disease spatiotemporal dynamics (Laurinne Balstad)
- BBRKC SDM development (Emily Ryznar).

In addition, the CPT has recently lost two long-serving members. The CPT recommends that replacements for these seats should have the following skills and abilities to fill current gaps:

- Quantitative skill set / stock assessment skill set
- Experience with other NPFMC plan teams or regions