SCIENTIFIC AND STATISTICAL COMMITTEE
REPORT TO THE
NORTH PACIFIC FISHERY MANAGEMENT COUNCIL
February 4th – 6th, 2019

The SSC met from February 4th through 6th at the Benson Hotel, Portland, OR.

Members present were:

Gordon Kruse, Co-Chair	Anne Hollowed, Co-Chair	Sherri Dressel, Vice Chair
University of Alaska Fairbanks	*NOAA Fisheries—AFSC*	*Alaska Dept. of Fish and Game*
Chris Anderson	Amy Bishop	Mike Downs
University of Washington	*Alaska Sea Life Center*	*Northern Economics*
Dana Hanselman	Brad Harris	George Hunt
NOAA Fisheries—AFSC	*Alaska Pacific University*	*University of Washington*
Dayv Lowry	Andrew Munro	Franz Mueter
Washington Dept. of Fish and Wildlife	*Alaska Dept. of Fish and Game*	*University of Alaska Fairbanks*
Terry Quinn	Kate Reedy	Ian Stewart
University of Alaska Fairbanks	*Idaho State University Pocatello*	*Intl. Pacific Halibut Commission*
Alison Whitman		
Oregon Dept. of Fish and Wildlife		

Members absent were:

Ron Felthoven	Jason Gasper	Heather Renner
NOAA Fisheries—AFSC	*NOAA Fisheries – Alaska Region*	*U.S. Fish and Wildlife Service*

SSC Election of Officers

The SSC reappointed Anne Hollowed (NOAA-AFSC) and Gordon Kruse (UAF) as co-chairs. Dr. Hollowed will act as chair for the April, June and October meetings, and Dr. Kruse will chair the February and December meetings. Sherri Dressel (ADF&G) was re-appointed as vice chair.

SSC Administrative Discussion: SSC Handbook

Diana Evans (NPFMC) presented a draft SSC Handbook for review. The handbook is intended to compile existing information on SSC terms of reference, membership, meeting procedures, and other administrative practices from the Council's Standard Operating Procedures and Policies (SOPPs) with additional interpretation and guidance prepared by previous SSC chairs and other reference material on the Council and SSC process. In addition to serving as a handy reference guide to the Council family, the handbook will improve the resources that are provided to new SSC members to advance their understanding of the Council process. The Council requested SSC feedback on the content, including the need for clarifications and identification of gaps to be addressed. Diana indicated that a revised draft will be shared with the SSC by email or at the April meeting prior to seeking Council approval of the handbook. She pointed out that the process to change language borrowed from the Council's SOPPs is more complicated than changing other language in the handbook, as those changes require approval by the Secretary of Commerce, but still welcomed any suggestions. Requested changes to the SOPPs will be noted, but will not be implemented until approved.

The SSC greatly appreciates staff efforts to assemble this SSC Handbook. Not only will this be very useful to new SSC members, but it will also serve as a valuable reference for all SSC members, as well as the broader Council family. The SSC looks forward to working with Council staff to prepare a revised version for Council approval. Towards this, the SSC offers the following comments.

- Under section 2, Terms of Reference, it states that "Independent experts on the SSC cannot be employed by an interest group or advocacy group." This statement may require some additional explanation. Certainly, SSC members should not be on the payrolls of interest or advocacy groups. However, on occasion, SSC members have conducted research with funds that were provided by various industry groups, such as the At-Sea Processors or Bering Sea crab fleet; in many cases this is handled by a separate board (e.g., PCCRC, BSFRF) that makes funding decisions, etc. Presumably, this does not constitute "employment."

- Under Objectives and Duties #1, consider replacing "preventing overfishing" with "overfishing levels."

- Under Objectives and Duties #3, it says: "Assist in the identification, development, collection, and evaluation of statistical, biological, economics, social and other scientific information deemed relevant to the Council's fishery management planning, particularly with regard to determining the best scientific data available as required by National Standard 2." This bullet could use some revision. Perhaps a simplified replacement statement could be: "Assist the Council's planning and execution of fishery management by determining the best scientific information available as required by National Standard 2." A follow-up sentence could go on to characterize what constitutes best scientific information and create a hotlink to National Standard 2.

- On the top of p. 4, replace "on preparing" with "by providing."

- Regarding Table 1, SSC members were asked to provide their own description of their areas of expertise. This revised list will be provided separately. In the revised table, consider providing hot links to the curricula vitae of SSC members. Finally, it was noted that Gordon Kruse was first appointed to the SSC in 1990, when he was a member for three years. He later rejoined in fall 2002. Please check the dates of "initial appointment."

- In Section 3.1, the SSC was asked to consider the merits of the current one-year terms. The SSC felt that one-year terms are fine and noted that the email method to indicate interest for reappointment works well.

- In Section 3.5, consider clarifying the bullet on influential scientific information (ISI) to indicate that the SSC chair will work with the Deputy Director of the Council to identify which items are considered ISI in advance of each meeting. Also, consider adding a follow-up sentence stating that, for such information, the SSC shall indicate who testified, characterize their testimony and indicate how the SSC addressed their comments.

- Also in Section 3.5, in the last bullet under Chair, indicate that the "Chair will work with the Vice-Chair to accept/reject proposed edits to the SSC report and will approve the SSC report to the Council."

- In Section 3.5 under duties of the Chair, add a new bullet indicating that, "At the beginning of each SSC meeting, the Chair shall ask all SSC members to divulge any conflicts of interest that may influence their ability to conduct an impartial review of the science of each issue on the agenda."

- In Section 3.5 under Vice Chair, after "Keep records of SSC deliberations and recommendations to help with editing SSC report" add ", when requested by the Chair."

- Also in section 3.5 under Vice Chair, add a new bullet after bullet 2 for "During review of SAFE documents, verify that the correct tables of OFLs/ABCs are used in the SSC's report."

- Finally, in Section 3.5 under Vice Chair, modify the last bullet to read "After the meeting, work with the SSC chair to ensure…" To the end of this sentence, add "Substantial changes shall be approved by the Chair."

- In Section 3.6, revise the second bullet to read "Be familiar with the documents in advance…" After that sentence, add a second sentence to the effect that "For issues for which you are assigned as a lead, become intimately familiar with the topic, be prepared to ask insightful questions and be able to provide expert guidance to the analysts to assure that the documents represent the best available science to the extent practicable for the situation."

- Modify the last bullet of section 3.6 to read something like "Disclose potential conflicts to the Chair regarding a particular topic at the time that SSC assignments are made before each meeting and publicly at the beginning of the meeting."

- Under Staff Report on p. 8, add a statement that SSC members shall "Raise all major points to appear in the SSC report during staff questioning so that any misunderstandings or misinterpretations can be clarified prior to preparation of the SSC report."

- At the bottom of p. 8 and top of p. 9, add a phrase to indicate that the SSC review is different than a peer-review of a journal manuscript to the extent that SSC members have a collegial relationship with staff allowing interactions before, during and after review to improve the analyses and their documentation.

- Section 4.4 – change "SSC Minutes" to "SSC Report."

- In bullet 15 on p. 10, indicate that documents may be posted on Google Docs.

- Reconcile bullet 16 on p. 10 to reflect duties of the Chair and Vice Chair as previously amended in the document.

- In the fourth paragraph under "Travel Expenses and Reimbursement" at the bottom of p. 12, does "scheduled to end" at 5 pm include preparation of the SSC report on Wednesday afternoon? If so, please clarify.

- At the top of p. 16, clarify the wording regarding scallops to reflect that the SSC sets an overall ABC for scallops.

- In the middle of p. 16, replace "peer review panel" with "the operation of the SSC as a peer-review panel." Also, would it be helpful to refer to influential scientific information in this context?

- At the bottom of p. 17, add a paragraph concerning the nomination of plan team members, including a summary of the balance of plan team membership by area of expertise, and consider some statement about the desirable characteristics of members of the Social Science Plan Team as per previous SSC discussion.

- The SSC recommends that language is added to acknowledge our added responsibility to review reports, recommendations, and analytical methods proposed by the FEP.

- The SSC also reviews updated status reports on marine mammals and seabirds as well as methods used to implement actions relevant to fisheries management that pertain to these species under the Endangered Species Act.

- Consider adding an appendix with hot links to frequently referenced documents, such as tier specifications, fishery management plans, and so on.

- Also, consider adding a chart of the typical annual cycle that includes workshops, research priorities, and crab and groundfish specifications.

Planning for the Seventh National SCS Meeting

Anne Hollowed, Gordon Kruse, and Diana Stram serve as NPFMC contacts for the Scientific Coordination Subcommittee (SCS) of the Council Coordination Committee (CCC). This committee is responsible for planning the Seventh National Meeting of the SCS (SCS7), formerly known as the "National SSC Meeting." Anne Hollowed provided an update on the planning for this meeting. She reported that the SCS identified the NPFMC as a potential host for the SCS7, as the NPFMC has not yet hosted one of these meetings. Upon discussion with NPFMC staff, the NPFMC agreed to host the meeting in 2020. Preferred dates for this meeting are mid- to late-July, with potential venues yet to be determined.

The SCS identified three proposed focal topics for SCS7:

1) How to incorporate various ecosystem indicators in the stock assessment process,

2) Approaches for conducting multispecies assessments and setting reference points for species significantly affected by trophic interactions, and

3) How to assess and manage species exhibiting distributional changes.

The SCS will prepare a report of its recommendations for the May 13-16 CCC meeting.

B-1 Research Priorities Process

The SSC acknowledges the considerable progress that has been made on the review process for NPFMC research priorities and the dissemination of those priorities to the general public and appropriate funding agencies. The changes to the online database, the revised categorization methods, and the additional coordination with NPRB have improved the process greatly. However, in recent years the task of developing an annual list of research priorities has become onerous and time-consuming for the Plan Teams, SSC, and Council. A working group composed of select Council members, Council staff, and the SSC co-chairs developed a proposal in April 2018 with several suggested changes to the annual review process. These changes focused on the development of a "top ten" list and categorically excluded the Critical Ongoing Monitoring and Strategic priorities from the 2018 review. The SSC implemented these suggested changes on a trial basis in June 2018.

In their June 2018 minutes, the SSC expressed continued frustration with the review process, even with the implemented changes, and questioned the value added to the process through an annual review with limited time to address the suggested research priorities during the meeting. Due to the growing list of research priorities, the considerable time required for a comprehensive review by the whole SSC, and the limited time generally available, the annual review has become limited, primarily focusing on reviewing new priorities and suggested changes from the Plan Teams, and has not been as comprehensive as originally planned. In June 2018, the SSC discussed options for addressing this issue, many of which had been presented in the working group report in April 2018. These options included increasing the interval between reviews or reviewing only subsets of the list based on the category or research topic, and the SSC requested additional input from the working group moving forward. Unfortunately, the working group was not able

to provide input by the February 2019 meeting and, absent this, the SSC discussed several options for changes to the review process.

After some discussion, **the SSC proposed completing a thorough review of the research priorities and "top ten" list once every three years at its June meeting. The SSC could start the review cycle in June 2019, but recognizes that this might need to change depending on the time available on the SSC's June 2019 agenda because of items affected by the government shutdown.** For the year of review, the SSC recommends that the review be highly prioritized with a significant portion of SSC agenda time devoted to it. The process for the Plan Teams and the FEP teams would be aligned with this timeframe, and the SSC acknowledges that in on-cycle years, more time would likely also be required for the teams' review of research priorities. The SSC felt uncomfortable with a longer interval between reviews, despite the fact that the federal mandate only requires submission of research priorities every five years, given the relative urgency of some of the research priorities and the quickly changing environmental conditions and species' abundances and distributions. In the year of review, it would be helpful to receive summary statistics, such as how many research priorities have been added, how many completed, and how many funded. It would also be valuable for the SSC, and likely the Council, to receive a report annually on what research priority topics have been funded.

Two other options were considered in SSC discussions. The first alternative proposal suggested reviewing subsets of research priorities on a rotating basis, with Urgent and Important research priorities reviewed every two years and Critical Ongoing Monitoring and Strategic research priorities reviewed every five years. Newly proposed priorities from the Plan Teams and FEP teams would be added on an annual basis. The second alternative proposal recommended an annual review of the "top ten" list or reviewing only new proposed priorities in each year with a review of Urgent, Important, Critical Ongoing Monitoring, and Strategic research priorities every three years. Ultimately, these options were rejected in favor of simplifying the review process and concerns that the workload would still be considerable in off-cycle years, particularly for the Plan Teams that contribute to the "top ten" list.

B-3 Alaska Fisheries Science Center Report (including update on surveys)

The SSC received a brief update on research and administrative activities at the AFSC from Science Director Bob Foy. In past years a full accounting of recent and planned research activities has been presented at the February meeting, but the federal furlough precluded that this year. A comprehensive briefing will occur when details of the FY19 budget are finalized in April. The briefing delivered at this meeting focused on two major areas: 1) effects of the recent furlough; and 2) plans for the 2019 bottom trawl surveys. No public testimony was received in person or via the online comment portal.

Most AFSC staff were furloughed from December 22nd through January 25th, representing the longest partial government shutdown in U.S. history. This created a substantial backlog of work and efforts are currently underway to identify tasks that must be eliminated, and prioritize remaining tasks. Several contracting, budgeting, and other crucial administrative processes have been delayed and efforts to complete these by prescribed deadlines are taxing staff. As a result of reduced preparation time, the GOA acoustic pollock survey will be abbreviated in 2019 by dropping the Shumagin and Kenai regions from the cruise schedule. Additionally, innovative research planning and preparation that typically occurs during the "slow period" from December through January was reduced or eliminated for many work units this year. Fortunately, most survey and research efforts planned to occur after April of 2019 will occur as scheduled despite the furlough, provided another shutdown does not occur. The full budgetary impact of the furlough will take months to assess, and an updated presentation to the SSC is anticipated when this evaluation is complete.

Select staff members were allowed to continue working through the furlough in order to maintain facility infrastructure, live research specimens, laboratory equipment, and to perform other critical functions. Fundamental to fishery monitoring, the observer program continued to be supported during the shutdown

(e.g. IT infrastructure for the observer program, observer training and support), but post-deployment debriefings did not occur and are being conducted now. This means that typical quality assessment and control activities did not occur, and any impacts of this delay have yet to be evaluated. **The SSC looks forward to information on the effects of the furlough on debriefings during the annual observer report.**

Historically, a complement of five vessels has been used to conduct bottom trawl surveys of the eastern Bering Sea (EBS) shelf, Gulf of Alaska (GOA), Aleutian Islands, northern Bering Sea (NBS), and Bering Sea slope – with alternating coverage between even and odd years. In recent years, deviations from this level of effort have occurred because of various funding and contracting issues (as detailed in SSC minutes from October and December 2018). For 2019, four vessels will be chartered to conduct these surveys: two in the EBS and two in the GOA. The lack of a fifth vessel means that the GOA survey will be limited in scope by eliminating stations in the deepest strata, eliminating far-east stations, reducing station density, or some combination of these. If funding is sufficient, one of the EBS vessels will also survey the NBS with the standard station spacing used in 2010 and 2017. The decision to deploy vessels in this manner was informed by a cooperative effort between an SSC subcommittee and AFSC staff to prioritize regional survey effort under various budget reduction scenarios. Additional analyses by AFSC staff to evaluate statistical impacts of reductions in station density and sample frequency are ongoing but have been delayed as a result of the furlough. **The SSC looks forward to receiving a full briefing on the results of these analyses such that impacts to long-term data series integrity can be evaluated. The SSC cautions that sparser survey coverage may make it more challenging to assess the impact of climate change on the distribution of stocks.**

Bottom trawl surveys in the EBS shelf, GOA, Aleutian Islands, NBS, and Bering Sea slope are fundamental to federal fisheries management and have been identified as Critical Ongoing Monitoring. Securing annual funding for a full complement of at least five vessels is paramount to successful management, especially considering shifting fish distributions and a quickly changing environment. At a time when historical norms are being upended by unprecedented ecosystem change, the Council will need *more* data, rather than less, to be adaptive to these changes in coming years. Models based on data collected under past oceanic regimes (e.g., VAST) cannot substitute for the collection of new data. Dr. Foy reported that current base funding for surveys is insufficient to sustain the full five boats needed in 2019 and further survey reductions may occur in the future under current base funding**. The SSC strongly recommends that the Council clarify and reinforce the importance of surveys as a critical on-going data need.**

C-1 BSAI Crab

The SSC received a detailed report on the January 2019 Crab Plan Team (CPT) meeting from Jim Armstrong (NPFMC), Katie Palof (ADF&G), and Ben Daly (ADF&G). The presenters noted that many key agenda items were postponed until May due to the government shutdown and the lack of federal participation in the meeting.

Norton Sound Red King Crab

Ben Daly and Katie Palof presented the Norton Sound red king crab assessment. No public testimony was provided. This stock supports a summer commercial fishery, which catches about 85% of the total harvest, as well as winter commercial and subsistence fisheries. Four types of surveys have been used to assess the stock, which have been conducted at variable frequencies and include a summer trawl, summer pot, winter pot, and pre-season summer pot survey.

Survey results showed decreased relative abundance in 2018 and the models suggested a decrease in biomass, but a slight increase in abundance due to large numbers of small pre-recruit individuals. The increase was due to two stations at which very large numbers of pre-recruits were caught and may indicate a stronger incoming year class after the recent period of low recruitment. Alternatively, the apparent increase could be due to measurement error associated with high counts from these two stations, but these competing views cannot be distinguished without further data collection.

The assessment uses a male-only, size-structured model to estimate the biomass and abundance of male crab > 94 mm CL on February 1 (the start of the model year) from 1976-2018 (Table 15) as an estimate of mature male biomass (MMB). Maturity data are not available, and knife-edge maturity at 94 mm is assumed. The average MMB for 1980-2019 was used as a proxy for B_{MSY}. The model assumes a constant M=0.18 for all length classes except for crab >123 mm CL. A higher mortality for larger crab has been estimated in recent years to account for the low numbers of observed red king crab in the larger size classes. Logistic functions are used for the fishery and for survey selectivities, except a dome-shaped function is used for the winter pot fishery because larger crab are presumably unavailable to the nearshore, under-ice fishery.

This year's assessment was updated to include retained catch and catch length composition data (retained and discards) for the 2018 summer commercial fishery, 2017/18 winter commercial retained catches and their length composition; 2017/18 winter subsistence catches (total and retained), and 2018 ADF&G survey abundances and length compositions. In addition, the standardized commercial CPUE index was updated to include data for 1977-2018.

Eight alternative models were presented in this year's assessment: The base model 18.0 is the same model that was used in 2017 and 2018, and was updated with new data. Additional model runs this year included a series of models (18.1) that include summer commercial length composition data for 2012-18 and a second series of models (18.2) that additionally include winter commercial length composition data, which were available for 2015-18 only. Model variants 18.1a and 18.2a drop a discontinued time series of discard length-compositions (1987-1994) from the model, but no clear rationale was provided for excluding these data. Two additional models in the 18.1 series (18.1c, 18.1d) examined the use of separate retained catch (18.1c) or total catch (18.1d) selectivity for the periods prior to and after a major management change (super-exclusive designation in 1994). Splitting selectivity into two blocks had very little impact on the likelihood or on the results, hence there seems to be no need to estimate separate selectivity curves.

The author and the CPT recommend model 18.2b because it uses all of the available data, including four years of winter fishery length composition, and resulted in acceptable fits to the available data. The length composition data will likely be collected in the future and the SSC agrees with the CPT that the data should be used in the model. **The SSC therefore concurs with the use of model 18.2b for this year's specifications.** The stock has been managed under Tier 4, primarily because of the lack of maturity data. **The model-estimated biomass is below the B_{MSY} proxy, but above MSST, hence the stock is on the sloping part of the control rule in Tier 4b. The SSC agrees to continue the use of the 20% buffer for this stock with reference to the rationale provided last year. This results in a retained catch OFL of 110 t (0.24 million lb) and a retained catch ABC of 90 t (0.19 million lb) for 2019.**

The SSC provides these additional comments and recommendations

- The SSC noted that, in general, the model choice does not have much impact on the results or on the Tier 4 reference points, hence the focus for this stock assessment should be on the input data.

- **OFL and ABC**: The new model provides estimates of both retained catch and total catch OFLs and ABCs. The preferred method for all stocks is to use total catches when possible. Therefore, the

authors and CPT should bring forward total catch OFLs and ABCs for specifications next year or provide a rationale why the retained catch OFL and ABC are still more appropriate at this time.

- **Tier designation:** In response to requests from the CPT and SSC, the author provided Tier 3 calculations, which resulted in substantially higher estimates of biomass and OFL. However, the CPT had little time to discuss the suitability of the Tier 3 approach and the continued lack of maturity data and uncertainty in mortality do not justify moving the stock to Tier 3 at this time. The SSC notes that maturity data for crab was highlighted as one of the top 10 research priorities in 2018.

- **Tier 4 calculations:** The SSC continues to be concerned about the inconsistency between the mortality estimation, which estimates a higher M in the largest size classes, and the use of a fixed M=0.18 in the Tier 4 calculation. This use of M = 0.18 was endorsed last year because of the uncertainty about a large step-increase in mortality at 124 mm, which has not been demonstrated in any other king crab stock in Alaska. This uncertainty has not yet been resolved and the SSC recommends that the authors bring forward alternatives to the current parameterization for next year's assessment that include options with an estimated constant M across size classes (including the largest class) and a dome-shaped selectivity for the summer commercial fishery and for the summer survey.

- **Natural mortality:** Uncertainty in estimates of natural mortality is unlikely to be reduced through modeling alone and the SSC suggests an examination of available natural mortality estimates across other stocks in Alaska and Russia that span a range of habitats and temperature conditions, including, if possible, Kotzebue Sound red king crab.

- **Spatial distribution:** One possible explanation for the unexplained lack of large crab in the survey and fishery is that these crab migrate beyond the survey area into deeper waters. Also, the prospect that they could move into the nearshore areas closed to commercial fishing and unavailable to bottom survey trawls was also raised. If it has not been conducted yet, a thorough examination of the spatial distribution of red king crab, in particular spatial differences in size composition, across the northern Bering Sea beyond Norton Sound would be helpful. Available data include the 2010 and 2017-2018 NMFS bottom trawl surveys. The SSC noted the new ability to tag and follow crab migrations - a pilot study is currently underway to tag king crab in Bristol Bay and locate them using a saildrone. The SSC recommends that a tagging study of this type be conducted for Norton Sound red king crab.

- **Spatial modeling:** The SSC appreciates the table summarizing results from paired NMFS and ADF&G survey stations. The table illustrates the small sample sizes, especially for the ADF&G survey. Although actual numbers were not included, the number of crab caught per trawl appears to be very small in most cases with many zeros. The SSC therefore encourages the authors to compare the ADF&G and NMFS surveys using appropriate methods for zero-inflated distributions, such as those offered in various R packages (e.g., pscl, gamlss, INLA, VAST, glmmfields).

- **Survey time series:** The authors should explore using two catchability parameters for the differing time blocks of the survey time series shown in Figure 7 which uses a different length range after 1995 to compute the abundance index.

- **Local and traditional knowledge:** Both summer and winter fisheries for red king crab have been taking place in Norton Sound as well as in Kotzebue Sound for a long time and the SSC suggests that local commercial fishermen may have considerable knowledge about spatial patterns in size distributions, changes in spatial distribution, migratory behavior, and other aspects of red king crab dynamics in the region, as may local subsistence users of the resource, including elders. For instance, local users may possess valuable insights into the disposition of the "missing" large male

crab. We strongly encourage the authors, through collaborations at the local level, to consider these sources of knowledge.

● **Male maturity**: The author provided some sensitivity analyses to different assumptions about maturity by using different length cutoffs for determining MMB and found that there was little effect on F_{OFL}. The SSC received some clarification about the origin of the current maturity estimates, which was based on applying the ratio of male to female size at maturity from the Bristol Bay red king crab stock to female size at maturity for Norton Sound. While this may be a useful approach in the absence of local data, new maturity studies are clearly needed to improve the assessment and to consider this stock for an increase in tier status in the future. In addition, the author should explore Russian data on maturity if available. Also, the relationship between maturity and temperature across stocks should be explored for potential predictive capability for Norton Sound.

● **Length-composition data**: In response to a CPT request, the author showed that current observer sampling is not representative of where the fishery occurs, which could lead to biases in the size composition of the catch. The authors noted that further analyses are needed to examine spatial differences in length compositions. The SSC suggests that they consider weighting the existing samples by the catch in each spatial area to correct for the disparate sampling.

● **Data weighting:** The author included an examination of implied effective sample sizes vs. input sample sizes, which are currently set at a fixed portion of the actual sample size or a minimum value. Sample sizes vary greatly and the SSC encourages the author to consider other, less arbitrary weighting approaches based on iterative tuning, using the number of hauls sampled, or other approaches that have been recommended by the Plan Teams for other stocks.

● **CPUE standardization**: In response to a request for examining the possible effect of buyers changing the acceptable size for purchase in 2005, the author states that the "year effect" accounts for any changes in regulations. However, the goal of the standardization is to adjust for the influence of external factors on CPUE and the change in legal size may bias the CPUE index as it is currently computed. A possible effect of the change in the effective size limit on the apparent CPUE should be accounted for by including a categorical variable (before/after) in the model used for standardization.

● **Retrospective analysis:** The SSC was pleased to see an evaluation of retrospective model performance. The analysis suggests a possible retrospective bias, but was too short for a full evaluation of this bias. The SSC recommends that the analysis be extended to peel more than three years of recent data to better evaluate the potential bias. Retrospective analyses typically evaluate retrospective performance over about 10 years. The authors should ensure they are using the "revised Mohn's rho" like the groundfish assessments, where the value is the sum of the deviations divided by the number of peels. It appears the current reported values are the sum of the deviations.

● **Length compositions:** The SSC appreciates the addition of fits to the length-composition data in Figures 9-14 and requests that, in addition to the residual plots by year, the author include the fit to the overall length compositions (across years) for each of the datasets.

● **Table 16:** The calculations for total catch and Catch / MMB in 2018 are incorrect.

● **Table 12:** It appears at least two parameters are at their bounds, r_1 and log-phi$_{st1}$. The CIE recommended conducting some jittering exercises; these should include checking parameter bounds.

● **Figure 7:** Please clarify if the time series of CPUE is showing different measures of CPUE for the time periods prior to and after 1995. If the estimates are not a consistent measure of the same portion of the stock, they should be adjusted or the "break" in the time series should be indicated in the

figure. The SSC also requests clarification about the rationale of different length compositions before 1995 (>74 mm CL) and after (>64 mm CL) in the same plot, as length composition data seem to be available for all size classes and for all years (Figure 11).

Aleutian Islands Golden King Crab

The author conducted a preliminary stock assessment in response to previous SSC and CPT requests and in preparation for the May CPT meeting to review this year's assessment. The author updated the projection of the terminal year's catch, chela data, the industry survey, year-area interactions in CPUE standardization, retrospective analysis, jittering and application of time-varying discard mortality.

The author identified three alternative models to bring forward: 18.0 Base model, 18.1 Revised CPUE standardization using fewer gear codes, and 18.1a scaling the pot bycatch rate by the amount of bycatch. The CPT did not feel the pot bycatch rate was justified at the population level and recommended dropping that alternative, and adding a new alternative model 18.2 with new area definitions for the CPUE standardization, which may allow an area-year interaction to be identified in the CPUE standardization. **The SSC concurred with the CPT**, which results in three models for review in May/June: 18.0, 18.1, and 18.2.

The SSC suggested:

- exploration of geostatistical models (e.g., VAST) for spatial analysis of the NMFS and ADF&G survey information,

- removing one dataset at a time from the model to identify the source of the large estimated recruitment three years ago; the CPUE time series does not show this increase and the source of information for this large recruitment estimate should be identified,

- exploring the use of the industry survey for purposes other than stock assessment modeling, such as length compositions, and

- pursuing other CPT recommendations, including a comparison with the May 2017, September 2017, and May 2018 assessments to assess the impact of incremental model and data changes. This type of retrospective comparison among assessment results has been reported in some groundfish assessments and, if routinely reported, would provide useful information on the development of the assessment model.

GMACS Applications

The SSC continues to strongly support the development of a generalized framework for conducting crab stock assessments. Further bridging and conversion of existing crab stock assessments will serve to both test the framework and expand its options to meet the full suite of needs. Several extensions to accommodate features of existing analyses, including the addition of a terminal molt are still under development. The SSC recognized the work of the development team in expanding and improving the GMACS framework and recent efforts to train analysts in its capabilities (January workshop held in Juneau). The SSC encourages continued planning for transitions for crab assessment authors, potentially including workshops on standard practices and approaches, as well as for long-term maintenance and improvement of the code. The CPT and SSC will continue to participate in this process through review of the framework after significant development milestones and review of specific applications as they are used for management.

Tanner Crab Management Strategy Evaluation

The SSC was briefed on the status and timeline for a Management Strategy Evaluation (MSE) of state harvest policy options for Tanner crab conducted by Madison Shipley (University of Washington). There was a discussion of the role of the SSC in reviewing the stock assessment for Tanner crab and setting OFLs/ABCs under which the state of Alaska applies its own harvest policy. The SSC noted that there are potential areas for improvement with regard to the data supporting the application of harvest policies relative to the model results that form the basis for federal specifications. The SSC welcomes the opportunity to review the technical details of the MSE and subsequent results. Noting the timeline for this research and other SSC review obligations, the SSC suggests that a presentation in April 2019 may represent the best opportunity to provide feedback prior to the BOF reviewing the results in March 2020, if a large portion of the SSC's June agenda is allocated to research priorities. However, if the SSC does not address research priorities in June, then June would be an ideal meeting to schedule this MSE as the CPT will take up the issue in May.

Outreach Activities

The SSC highlighted the outreach efforts made by the CPT during the January meeting in Nome. These included a meeting with the Norton Sound Economic Development Corporation (NSEDC), an update on the Norton Sound red king crab fishery and research, a Norton Sound Seafood Products (NSSP) plant tour, and a trip to the field to view winter crab pot ice fishing. These types of interactions are made possible through holding meetings and workshops in different locations, which can be expensive and logistically challenging but are very important. Such exchange of ideas is valuable for both scientists and stakeholders and may provide specific opportunities for the sharing of local and traditional knowledge on a range of issues of direct relevance to the CPT. The SSC strongly supports similar efforts in the future for crab and other species. The SSC further notes that the aggregate cost of the reciprocal of such outreach, collecting information and/or bringing stakeholders to the analysts, can also be very large.

Saint Matthew Blue King Crab Rebuilding Plan

Diana Stram (NPFMC) and Katie Palof (ADF&G) presented a summary of: the ongoing process for developing a Saint Matthew blue king crab (SMBKC) rebuilding plan, the CPT comments, and other related issues. Public testimony was provided by Gerry Merrigan (Freezer Longline Coalition).

The timeline for developing a rebuilding plan for SMBKC officially began with the NMFS overfished declaration in October 2018. This declaration gave the NMFS two years to develop and implement a formal rebuilding plan for the stock. The CPT's anticipated schedule for plan development represents a challenging timeline. In general terms, the process will include: defining rebuilding parameters (T_{min}, T_{max}, mean generation time, etc.), identifying management options that achieve at least a 50% probability of rebuilding in the required time period, and revising state and federal crab and groundfish measures. The Team noted that, due to the small number of participants in some relevant fisheries, there are challenging confidentiality issues with mapping the data on SMBKC bycatch.

Noting that the CPT was not able to fully evaluate this topic during its January meeting due to the government shutdown and lack of participation by federal scientists, the SSC provides a limited set of comments and recommendations, and looks forward to additional discussion in June 2019 after the CPT holds another more fully attended meeting in May.

The SSC recognized that the calculation of B_{MSY}, defining the stock status, and rebuilding target are closely linked to the projection of future recruitments, and therefore the rebuilding trajectory. The SSC suggests that an overarching goal should be to establish consistency between the assessment/status determination

and rebuilding plan regarding how recruitment, stock-recruitment, and B_{MSY} calculations are performed. Following on its previous comments (e.g., October 2018 SSC Minutes) regarding the relative importance of fishing vs. environmental conditions to SMBKC and other crab stocks, the SSC recommends continued exploration of the dynamic B_0 approach as one option and investigation of how this may be included in both status and rebuilding analyses.

The CPT report clearly identified the importance of the choice of method used to project future recruitment for the calculation of rebuilding reference points and probabilities of recovery. Possible methods include resampling from a stock-recruitment relationship, the full time series of recruitment, and subsets of the time series corresponding to the previous rebuilding period and/or the most recent low-productivity portion of the time-series. The SSC encourages the CPT to consider the biology of the species and the life history basis for each of these methods as alternative hypotheses. Noting the need for consistency with the calculation of B_{MSY}, the SSC identified the following potential alternatives and associated rationales:

1. Use of a stock-recruitment relationship: future recruitments will be primarily driven by the spawning biomass, subject to considerable interannual variability. It was noted that the fitted S-R relationship was not considered to be strong.

2. Use of the full time series of recruitment: future recruitments will be primarily driven by environmental conditions, which are assumed to be relatively constant over time.

3. Use of shorter periods (stanzas) of recruitment (the previous rebuilding period, or a recent period): future recruitments will be primarily driven by environmental conditions, which are assumed to be variable and resemble those in the period selected.

4. Sampling weighted toward recent recruitment (consistent with a dynamic B_0 calculation): future recruitments will be driven by variable (and perhaps trending) environmental conditions (and spawning biomass if an S-R relationship had been used in the assessment).

Alternatives 1 & 2 both appear to be relatively implausible given the estimated historical time-series of recruitment, the previous rebuilding trajectory, and the dynamics observed for PIRKC, which all suggest that environmental conditions are likely to be variable and important for recruitment dynamics. The SSC noted that a combination of these hypotheses (weighted according to their plausibility) can be explicitly included in the rebuilding analysis as it is a stochastic simulation. Experts on the CPT might develop weightings based on the life history and biology of the species. Preliminary results indicated that even a small amount of weight on options 3-4 will likely lead to a $T_{min} > 10$ years and associated alternative considerations for the calculation of $T_{max,}$ if the same set of recruitments are not used in the calculation of B_{msy}.

The CPT raised the question of whether a rebuilt determination should be based on a single year of estimated $B>0.5B_{MSY}$ or two. The SSC identifies this consideration as a Type I error rate question: how often is a false positive acceptable? Although this could be addressed via a closed-loop simulation (including estimation error), the results of which will depend on the degree of estimation error and the slope at which the rebuilt threshold is approached, this may not be necessary as it largely represents a policy decision.

The CPT report and subsequent SSC discussion highlighted several differences between the distribution of SMBKC survey sampling and fishery encounters. This raises the concern of shifting stock distribution and its potential effect on observed abundance indices and the efficacy of fishery restrictions. Of particular concern is the north side of St. Matthew Island. The SSC encourages evaluation of other sources of information that could inform understanding of potential distributional shifts, potentially including consideration of the role of climate variability and marine mammal activity. Noting the incomplete overlap

of data sources and the critical sensitivity of a single survey station (R24), the SSC continues to encourage the development of a geostatistical model which could provide the capability to better integrate dynamic spatial processes associated with crab distribution.

The SSC requests that the CPT carefully consider the role of bycatch in the rebuilding analysis, and provide the technical details of how bycatch is included. This may require disaggregating the available data in order to identify specific effects from each gear type, and the sensitivity of rebuilding trajectories to these effects. Further, clarification of how discard mortality rates are used in both the assessment and rebuilding plan may be necessary to ensure consistency in both analyses. This information may have implications for both fishery and spatial restrictions.

The SSC also encourages the Team to consider the conditions under which a rebuilding 'reset' (when progress toward rebuilding is determined to be clearly deviating from that expected when the plan was developed) may be triggered. Although this is not a desirable outcome, given the great uncertainty in both the stock and rebuilding reference points, as well as the uncertainty in the processes likely to be driving future recruitment, SMBKC could experience such a revision.

C-4 BSAI Pacific Cod Trawl CV Analysis Initial Review

The SSC received a presentation on an initial review draft of a Regulatory Impact Review (RIR) and Social Impact Assessment (SIA) by Darrell Brannan (Brannan & Associates) and Mike Downs (Wislow Research Associates). Public testimony was provided by Jeff Lackey (FV Seeker), Brent Paine (United Catcher Boats), Nicole Kimball (Pacific Seafood Processors Association), Todd Loomis (Ocean Peace), and Dennis Robinson (City of Unalaska). Additional public testimony from three constituents was submitted via the online portal.

The SSC commends the analysts for compiling and organizing a tremendous amount of information about the harvesting and processing businesses that would be affected by the proposed actions. The analysts did a thorough job of characterizing the harvesters and processors who would qualify to harvest, deliver, and/or receive Pacific cod in the Bering Sea under the numerous combinations of year stanza options associated with the specified alternatives. It is particularly impressive that a clear characterization emerged despite the persistent and widespread challenges with data confidentiality when numbers of vessels or processing plants are small. After some discussion, and in consideration of the importance and urgency of addressing the influx of effort in the BSAI Pacific cod trawl CV fishery, **the SSC recommends that the analysis of Alternatives 1, 2, 3, 4 and 6 be released for public review, after some critical additional analysis**. Alternative 5 was presented for discussion, and there is no analysis of its effects in this document, thus it cannot be advanced for further consideration at this time.

The RIR thoroughly describes the alternatives, and the SIA presents community-level dependence on the fishery and time series showing how participation has changed. An active reader can find information in the tables that depict the accelerating race to fish: CV participation has increased from the 40s in 2009-2012 to 61 in 2018 (Table A.2); the season has shortened from closing in mid-March prior to 2015 to early February in 2018 (Table 2-5); and, concurrently, vessels delivering to motherships have increased from 2-3 catcher processors in 2008-2015 to 7-8 in 2016 – 2018 (Table A.16). Mothership deliveries accounted for 17.7% of landings in 2018, twice the previous average (Table 2-48). A description of the already-closed 2019 A-season indicated further season-shortening, increased halibut bycatch, and about 31% of Pacific cod delivered to eight motherships, suggesting an accelerating trend. The community profiles illustrate that the cod fishery has historically contributed high levels of wholesale and tax revenue especially to Dutch Harbor/Unalaska, Akutan, and King Cove through shoreside landings, whereas A80 and AFA motherships are owned in the Pacific Northwest (predominantly the Seattle metropolitan statistical area). Catcher vessels

are predominantly from the Pacific Northwest and Kodiak; Pacific Northwest vessels hire Pacific Northwest crew, and Alaskan vessels draw crew half from Alaska and half from the Pacific Northwest.

To allow the public and the Council to understand the impacts of the alternatives, the RIR compares the first wholesale value of a ton of Pacific cod delivered offshore and shoreside, using gross revenue as a proxy for profit in the absence of cost information. Since the values are negligibly different (less than 10% of the interannual standard deviation), the analysis concludes that the allocation between offshore and shoreside delivery does not affect the profits earned from the fishery, which comprise the net benefits to the nation. However, at that rate, the RIR also calculates that the value of 1% of the 2018 fishery was worth approximately $400,000, which can be used to estimate the scale of the wholesale revenue associated with re-allocating 0-10% of landings between sectors through this action.

However, the analysis presented in the RIR and SIA does not use this value to characterize the effects of the alternatives on different stakeholders. Public testimony illuminated the measures of interest to the public, but they were not developed in the analysis. Public testimony further raised the extent of the escalating race to fish, and the role that the growth in mothership participation played in accelerating the fishing season. **The SSC recommends the analysis incorporate predictions of how effectively the alternatives will attenuate entry and the race to fish, and develop a synthesis that considers consequences for crew safety, bycatch, ecological impacts of shortened seasons, etc**.

Testimony also discussed how local tax revenues would fall in proportion to the level of offshore delivery, the role of support services, and local infrastructure impacts**. The SSC recommends the analysts use history to predict which communities will gain or lose landings under the various alternatives, and apply the differential tax rates to describe the *changes in* the total tax revenue levels that are currently a focus of the community dependence analysis in the SIA.** Public testimony was also concerned with how reduced fish deliveries would affect shoreside plants. **The SSC recommends that the analysis predict port-specific reductions in landings under the alternatives to gauge employment impacts, perhaps using a social accounting matrix appropriate for economic impact analysis in isolated fishing communities.**

In developing these predictions, **the SSC recommends that the analysts thoroughly consider possible differences in costs between shoreside and offshore delivery of Pacific cod.** The RIR discusses categories of cost, but does not reflect on their relative scale. In this analysis, **the absence of cost data is particularly problematic because it not only prevents the calculation of net benefits to the nation, but also the prediction of the entry of new CVs and motherships, which is the fundamental economic driver of the problem to be addressed by this action. Particularly as Alternative 5 evolves, the SSC strongly encourages development of a system for collecting cost data that would permit evaluation of action objectives.**

In presenting results, expected decreases in the Pacific cod ABC reduce the probative value of impact estimates scaled to historical stock and landings levels. Therefore, **the SSC recommends that the analysts complement calculations of the effects of alternatives at historical ABC levels with predictions of effects at the projected lower ABC levels for 2020.**

The SSC struggled with whether these predictions that illuminate the effects of the alternatives on different user groups—involving scientific and modeling judgement that would ideally be reviewed by the SSC—justified delaying release of this analysis. In the end, the SSC determined the rapid change within this fishery presented an urgency for the Council to consider this action, but the SSC is willing to review additional analyses as this action moves forward if so desired by the Council.

In addition to these analytical treatments of the data presented, the SSC recommends the following minor additions:

- The SSC appreciates the discussion of the state GHL fishery. It would be useful to consider the extent to which the State of Alaska may elect to continue expanding its inshore GHL fishery to ensure a continued supply for shore-based processors, if the federal fishery continues to move activity offshore.

- Consistently calculate eligibility criteria using either trip-specific fish tickets or weekly aggregated landings from the catch accounting system, reflecting the Council's intent. Currently, Alternative 4 is evaluated with fish tickets, as requested by the Council, but the others with the CAS. The preferred alternative is to use fish ticket data in all cases because aggregating data to week tends to underestimate the number of trips targeting cod when they coincide with numerous trips targeting other species.

- The literature review presented as a discussion of the effects of limited rights programs in the analysis of Alternative 5 focuses primarily on constructive criticism of older programs. More recent catch share programs have had features designed to mitigate these adverse effects, and a more developed synthesis of this literature would also provide case-based guidance on lessons learned from these efforts.

- Incorporate season length in days in Table 2-5 to highlight the race to fish, with simple symbol annotations for different reasons for closure; retitle Table 2-42 to reflect that it is the value of the reallocation, not the change in value through reallocation; redesign Table X (in errata) to show the changes in taxation rates or revenue, rather than status quo revenue composition.

- Be explicit about the baseline for impact comparison, because the status quo is rapidly changing.

- Description of trends in the fishery may be better represented with figures than tables. For example, Table 2.1 presents time series, and the box on page 11 might be more clearly communicated with a pie chart.

- In section 2.6.5 on Amendment 113, clarify what is already implemented and what is in the proposed revisions.

- Remove speculations about subsistence impacts in Section 9 that are based upon data from other regions/cultures of Alaska. Reach out to the Office of Subsistence Management for more current Aleutian subsistence data.

- Explore ways to potentially repackage data in contexts with small numbers of participants that still preserves confidentiality.

While probably too dramatic a redesign for this document, the SSC discussed ways to make analyses like this one more effective in the future. Specifically, the SSC believes analyses would be more useful to the public, and to the Council, in a format that focused on an analytical synthesis that provides insight about the likely effects of the proposed alternatives. Ideally, results would illuminate the tradeoffs presented by the alternatives. In this format, data describing the status quo is important in empirically characterizing the problem described in the purpose and need statement, and providing context for predicted changes as a result of the proposed alternatives. Then, the presented analysis should focus on predicting likely changes using the best available science, and comparing consistent outcome measures among alternatives. **The SSC recommends greater integration between RIRs and SIAs to characterize how economic changes described in the RIR will lead to changes in social indicators in the SIAs.** While such analysis may often be scenario- or range-based, rather than through mechanistic models generating precise predictions,

these exercises can still provide essential insight about the effects of action alternatives, and represent best available science.

D-7 Marine Mammal Conservation Status

The SSC received an update on northern fur seal status and trends from Dr. Jeremy Sterling (AFSC-MML). This presentation was in response to a request from the SSC to receive annual updates on the status of marine mammals of conservation or fishery interaction interest.

Public testimony was provided by Lauren Divine (Aleut Community of St. Paul Island), who encouraged the SSC to consider requesting additional research conducted by co-management groups in addition to that conducted by NMFS staff. **The SSC looks forward to working with co-management groups to explore what additional information can be shared, and how changes to marine mammal populations impact communities on St. Paul.**

The presentation covered two major topics, population status and ongoing research projects. Dr. Sterling reported that in 2018 pup production was 6% lower on St. Paul than in 2017, a reduction similar to the long-term decline of 4.1% per year since 1998. At St. George, the pup production numbers were small but there was no trend in the population since 1998. The population at Bogoslof Island has been increasing (10.1% increase per year since 1997). The last survey at Bogoslof was in 2015 (there have been no recent surveys due to volcanic activity on the island in 2016-17); the next pup production survey is planned for summer 2019. Dr. Sterling indicated that they are uncertain what is driving the different population trajectories among the colonies, but noted that emigration and movement between colonies have been observed. There was no funding for flipper tagging activities in 2018 and likely no funding for 2019, which limits the ability to track entire cohorts, which is particularly important in increasingly atypical years like 2018. **The SSC recognizes and supports efforts to continue monitoring important population demographics of northern fur seals.**

The SSC received an update on two ongoing research projects. The first began in 2016 and uses unmanned surface vehicles (saildrones) to map prey landscapes and elucidate northern fur seal behavioral responses to prey availability. This study tracked 50 adult female fur seals between 2016-2018, a subset of which also carried accelerometers and crittercams. Saildrones collected concurrent spatial data on age-0 and adult pollock backscatter. Trawling was used to validate the identity of acoustic targets. Preliminary results indicated associations between fur seal distributions and diving behaviors, and pollock vertical distributions and abundance. The addition of the crittercams provided novel insights into capture efficiency and foraging effort associated with different prey species, albeit on a limited basis due to the number of cameras deployed. **The SSC appreciates the value gained from the addition of the crittercams, and supports this method as a fascinating and effective way to look at interactions between fur seals and prey resources.** Dr. Sterling noted that there are funds for saildrone deployment in summer 2019, but no funds at this time to deploy tags on fur seals. **With increasing variability in ocean conditions and fish distributions in the Bering Sea, the SSC encourages this type of research and other studies that can help understand the impacts of changing ocean conditions on northern fur seal foraging. Knowledge gained from these studies can assist the NPFMC in evaluating and/or improving ecosystem-based approaches to fur seal conservation and management of fisheries for relevant prey species**. The SSC looks forward to further results of this project and efforts to use these data to address how foraging patterns link to reproductive success.

The second project presented was a large collaborative effort that combines a spatially explicit northern fur seal bioenergetic model with outputs from end-to-end ecosystem (FEAST) and multispecies stock assessment (CEATTLE) models. The project will initially focus on target years between 1991-2018 with

high-resolution data spanning variable environmental conditions and pollock age-structure in order to develop models of the energetic requirements of fur seals in the Bering Sea by sex and age-class. Analysts utilized several past and current datasets to derive parameters for pup growth rates, lactation, metabolism, and at-sea behavior. Preliminary results indicated annual and colony-specific diet variation in prey size and bioenergetics (gross energy intake by age-class). The SSC noted an interesting element of the research was that Atka mackerel was a prevalent diet item for some fur seal diet groups and years, yet Atka mackerel has low abundance in Bering Sea surveys. This suggests prey biomass as determined in the trawl surveys may not be an effective predictor of northern fur seal diets or foraging behavior, due to survey selectivity, dietary preference, or a combination of the two.

The next steps for this project include linking the bioenergetic and spatial fur seal models to FEAST and CEATTLE to evaluate mechanisms underlying observed declines and changes in fur seal populations. **The SSC notes this project is a particularly good example of how coupled biophysical models that link physics to fish and fisheries can be utilized in retrospective studies to understand interactions between species groups, and can be useful for important Council issues.** The application to fur seals particularly stands out for highlighting the importance of seasonality in models. The SSC looks forward to continued updates on this and other marine mammal (e.g., North Pacific right whale) research in 2020.

SSC Ecosystem Modeling Workshop

The SSC held a workshop focused on the current status of coupled biophysical models and their utility in informing fishery management in the EBS and GOA. Ivonne Ortiz (JISAO, UW), Al Hermann (JISAO, UW), Wei Cheng (JISAO, UW), Kelly Kearney (JISAO, UW), and Georgina Gibson (UAF) updated the SSC on progress towards the development and application of coupled biophysical models for use in informing fisheries management in the EBS and GOA. Due to the federal government shutdown, the workshop primarily focused on physics, nutrient, and plankton models although the presenters noted instances when high resolution dynamic ocean models were utilized to inform fishery management.

The SSC considered ecosystem indicators and early versions of high resolution dynamic ocean models in previous workshops. In 2010 the SSC held a workshop focused on Ecological and Economic Indicators and in 2014 the SSC reviewed the Bering Sea Project Models. Since that time, the Gulf of Alaska Integrated Ecosystem Research Program completed its projects. The 2019 SSC workshop provided an opportunity for the SSC to learn about and comment on existing and planned modeling activities. In particular, the SSC hoped to use the outcome of the workshop to formulate core questions to, or recommendations for, teams organizing the Ecosystem Socio-economic Profile and Fishery Ecosystem Plan workshops in the spring of 2019.

The SSC recognized that substantial improvements to the models have been implemented since our last review in 2014 and was impressed by the progress to date. This work represents a fundamental pathway to incorporate ecosystem considerations into stock assessments. The models, coupled with observations on limited temporal and spatial scales, have contributed to a much improved understanding of ecosystem dynamics in the eastern Bering Sea and Gulf of Alaska over the last decade. Advances in computing power have also greatly reduced the run-time for simulations, but the time to prepare the forcing files that provide boundary conditions limits the number of runs that can be conducted. This, in turn, limits the ability to assess variability in model results.

Bering Sea Project Modeling

The SSC received three presentations on modeling efforts in the Bering Sea. Dr. Ortiz provided an overview of current efforts and examples of current and planned applications. She highlighted that models are used to provide hindcasts for retrospective analyses, seasonal forecasts for tactical use, and multidecadal

projections for strategic advice. She also noted that inherent process variability makes short-term projection (i.e., 1-5 years) exceedingly difficult. Drs. Hermann, Cheng, and Kearney reviewed the most recent versions of the Regional Ocean Modeling System (ROMS), which is a high resolution dynamic ocean model that incorporates two way coupling to a nutrient phytoplankton zooplankton (NPZ) model. The Bering Sea ROMS is implemented using 10 km grid spacing (Bering-10K). The Bering-10K model is based on an earlier coastwide version of ROMS that was developed for the GLOBEC North Pacific Ecosystem Project (NEP 5 model). Early versions of the Bering-10K model tracked 10 depth layers while the most recent version of the model tracks 30 depth layers. The presentations described the major assumptions of the coupled biogeophysical models and presented an assessment of model skill based on hindcasts of physical properties and phytoplankton dynamics. The Bering-10K model was skillful in reproducing most physical properties, but phytoplankton dynamics are currently not well reproduced in the high-resolution model, as noted below. Importantly, the spatial pattern of bottom temperature anomalies and cold pool extent, important indicators for groundfish habitat on the shelf, compare very favorably with observations from the bottom trawl survey.

Clearly, the high resolution dynamic ocean model has evolved considerably since 2014. This coupled ocean model holds considerable potential to inform the long-range strategic planning of the NPFMC (e.g. impacts of climate change). Outputs are already being used to improve stock assessments. The SSC looks forward to future presentations by the GOA and EBS modeling teams.

Gulf of Alaska Integrated Ecosystem Research Program

Georgina Gibson described the high resolution dynamic ocean model (also based on ROMS NEP 5) developed for the Gulf of Alaska. In this application this ROMS also includes two-way coupling to a nutrient-phytoplankton-zooplankton (NPZ) model and operates on a 3 km grid (GOA-3K). Higher spatial resolution was needed to resolve the more complex topography and oceanography of the region. The GOA IERP investigators used output from the GOA-3K model to drive individual-based models (IBMs) for several groundfish species. She presented results of the application for sablefish.

The GOA IERP team seeded the GOA-3K along the slope based on what is known about their depth preferences and spawning times to quantify the connectivity between potential spawning locations and viable nursery grounds. Currently, feeding is not included in the model but zooplankton densities from the model are used for several applications. Estimates of temperature-dependent growth for sablefish larvae are currently not available but can be incorporated when they become available. Other inputs to the model can be updated as understanding of active versus passive swimming behavior, depth preferences, stage duration, spawning behavior, and other early life history characteristics improves. Current efforts focus on incorporating information on suitable juvenile habitat, which can be used to better quantify settlement success (beyond a preferred depth range). The SSC looks forward to monitoring how these mechanisms could be more fully utilized in the stock assessment.

Dr. Gibson noted that selected biophysical indices were extracted from GOA-3K output to assess their explanatory value in predicting observed recruitment. Predictive skill was moderate with up to 40-60% of the variance in recruitment explained over the short period covered by the analysis (1996-2011) when several explanatory variables were included in a regression model. Measures of connectivity alone accounted for about 20% of the variability in recruitment. The SSC noted that the analysis did not include connectivity to or from the Bering Sea and Aleutian Islands or the waters of B.C. and the continental U.S.

The presenters identified some of the current limitations and remaining sources of uncertainty in the models:

1. The Bering-10K does a good job of replicating the major temporal and spatial physical features (bottom and surface temperature and sea ice) over the eastern Bering Sea shelf. However, some evidence of sub-region temperature biases were detected and seasonal evolution of stratification in some regions was not fully replicated.

2. Mesoscale eddies and other fine-scale phenomena are not well resolved in the Bering-10K model. Georgina Gibson noted that a 4-km version of this model exists that might help resolve some small-scale features.

3. The biogeochemistry and its effects on phytoplankton is an area of active research. In particular, iron cycling is a difficult process to capture in the model and few observations of iron are available in the Bering Sea.

4. Phytoplankton and zooplankton dynamics are also an active area of research. The analysts noted that an early 10-layer version of the model replicated high phytoplankton biomass in some of the right places but for the wrong reasons. The newer 30-layer model missed key features, such as the green belt and other features that are apparent in measurements and satellite derived observations. Similarly, the timing of the bloom was poorly replicated in the model. The reasons are likely related to the difficulties regarding iron noted above, as growth in the model is primarily limited by light rather than nutrients or micronutrients.

5. Three to nine month forecasts offer a measurable improvement in model skill for predicting temperatures beyond the simple persistence of present-day anomalies. Forecasts are currently limited by the nine month forecasts of forcing variables that are available from the NOAA Climate Forecast Center (CFS). Medium-term forecasts out to five or 10 years have very high uncertainty, while multi-decadal forecasts presumably capture the main features of future seasonal and interannual variability in the ocean. Dr. Beth Fulton (CSIRO) noted that in Australia, researchers are finding that reasonable projections can be obtained even in the medium term, if they are based on known mechanisms underlying large-scale ocean climate coupling.

The presenters identified several instances where output from the Bering-10K or the GOA-3K coupled model was being used for retrospective analyses, to inform stock assessments, and to evaluate essential fish habitat. Most of these applications utilize seasonal maps of physical properties (primarily surface or bottom temperature) for use in predicting spatial shifts in distribution or metabolic demands. Only a few models utilize dynamic model outputs for estimating larval drift and connectivity. The fully coupled end-to-end model (FEAST), which includes fish and fisheries, has not been updated since the completion of the Bering Sea Project. The FEAST model will be updated pending improvements to the phytoplankton and zooplankton dynamics in the model. Analysts anticipate that they will have preliminary short-term forecasts in the fall of 2019.

SSC comments and recommendations

The SSC recognizes that maintaining the high resolution dynamic ocean models for the GOA and EBS requires a commitment of staff and computing resources. To date these models have been used to identify core mechanisms or demonstration projects for proof of concept. Periodic updates of hindcasts and long-term (multi-decadal) projections will be adequate for researchers evaluating potential mechanisms underlying fish production (hindcasts) or assessing the performance of alternative harvest strategies (long-term projections). However, if these models are transitioned to operational use in short-term forecasts, some guarantee that outputs will be available on a timely basis will be necessary.

It would be useful for analysts to identify suites of indicators needed to improve their assessments. This would help to distinguish what modeled products could be derived from the CFS and/or HYCOM (HYbrid Coordinate Ocean Model) projections and which products require dynamic downscaled output. Once these

core indicators are identified it would be useful to develop an interactive portal to provide easy access to the data.

The SSC offers a few examples of potential applications that arose in our discussion:

- Model predictions of seasonal bottom temperatures could potentially improve catchability estimates for some flatfish assessments, which are currently based on NMFS bottom trawl survey temperatures.

- Outputs of water temperature, salinity, and other characteristics from the 3-dimensional model could be used to estimate habitat volume for zooplankton prey or for pelagic life stages of fish, which may inform assessment models.

- The SSC encourages authors to explore the predictive skill of different geo-spatial models (e.g., VAST or spatial GAMs) that incorporate outputs from the Bering-10K or GOA-3K models with, and without, density dependent processes.

- Predictions of fish distributions in the northern Bering Sea in years when no survey is conducted could be very valuable.

- Current-year conditions and nine-month projections could inform recruitment dynamics where suitable mechanisms linking environmental variability to early life stages can be identified. Recruitment or other dynamics are often poorly estimated at the end of existing time series and up-to-date models can help inform these more recent estimates.

- Nine-month projections of ocean temperatures could inform the growth of zooplankton prey or fish during the critical overwintering period.

- Individual-based models focusing on the early life history are already improving our understanding of processes underlying recruitment success of snow crab and GOA groundfish. Additional collaborations between IBM modelers and stock assessment authors have the potential to inform variability in larval survival, settlement and overwinter success of these and other species.

Some important challenges for tactical applications of these models remain. These include the considerable work that is required to provide updated model outputs, as noted above, and the lack of appropriate measures of uncertainty. The use of some established approaches, such as ensemble modeling or bootstrapping, is limited in the near term due to the prohibitively long run times for simulations. Efforts to estimate process errors and model misspecification errors through other approaches will be useful for assessment authors. Ecosystem indicators can be incorporated into assessments through known functional relationships or as additional 'data' that are used to estimate parameters governing functional relationships. The latter approach is typically preferred because process error can be propagated in the model, but the approach requires variance estimates. Comparing hindcasts of predicted properties from the model with available observations that is used to assess lack of fit and bias may provide an avenue for obtaining variance estimates. While these are unlikely to provide reliable estimates of the overall scaling of the variance, they could provide estimates of the interannual variability in variance.

Similarly, once estimates of seasonal phytoplankton and zooplankton indices are available, some guidance on how model uncertainty would be propagated into the assessment will be needed. Dr. Kearney noted that the Bering 10K NPZ models were sensitive to changes in structural assumptions and input parameters. Efforts to quantify these sensitivities could be useful to assessment authors.

The SSC notes that the medium (1-10 year) time frame for forecasts is a particularly important time frame for consideration of biological reference points. The SSC encourages the team to continue to investigate mechanisms underlying interannual to decadal variability to explore whether medium term forecasts are possible.