Crab Plan Team Report
January 12-13, 2016

The North Pacific Fishery Management Council's Crab Plan Team (CPT) met January 12-13, 2016 at the Hilton Hotel in Anchorage, AK.

Crab Plan Team members present:
Bob Foy, Chair (NOAA Fisheries /AFSC – Kodiak)
Karla Bush, Vice-Chair (ADF&G – Juneau)* teleconference
Diana Stram (NPFMC)
Doug *Pengilly (ADF&G – Kodiak)*
Laura Stichert (ADF&G – Kodiak)
Jack Turnock (NOAA Fisheries/AFSC – Seattle)
Shareef Siddeek (ADF&G – Juneau)
Martin Dorn (NOAA Fisheries /AFSC)
William Stockhausen (NOAA Fisheries /AFSC)
Ginny Eckert (Univ. of Alaska – Fairbanks)* teleconference
Andre Punt (Univ of Washington)
Jason Gasper (NOAA Fisheries-Juneau)

Crab Plan Team members not present: Bill Bechtol, Brian Garber Yonts

Members of the public and State of Alaska (ADF&G), Federal Agency (AFSC, NMFS), and Council (NPFMC) staff that were present for all or part of the meeting included: Ruth Christiansen, Jie Zheng, Hamachan Hamazaki, Ben Daly, Wes Jones, Scott Goodman, Anne Vanderhoeven, Darcy Webber.

Administration

The team approved the attached agenda. Dates for upcoming meetings and locations are as follows:

May CPT meeting (Anchorage) May 9-13, 2016

September CPT meeting (Seattle) September 19-23, 2016

The team noted that future modeling workshops are most likely to always be held in Seattle due to travel restrictions and the intent to broaden participation at these workshops.

Diana Stram provided the team a brief overview of discussion with the SSC and Council in December with regards to evaluating the current membership and expertise of all Council Plan Teams in order to ensure that Teams have the expertise needed to meet their role in assessment review. The CPT Chair (Foy), Vice Chair (Bush) and Coordinator(Stram) will work to evaluate needs for additional expertise as needed for the CPT and report back to the Team in May for suggestions on membership.

Norton Sound red king crab assessment

Toshihide "Hamachan" Hamazaki (ADF&G) presented the 2016 stock assessment for Norton Sound red king crab. He discussed results for the (January) 2015 assessment model, updated with new data from 2015, as the base model, as well as 15 alternative model scenarios.

There were no changes to the management of the fishery in 2015. New data for the assessment included the 2015 summer commercial fishery (total catch, catch length composition, and discard length composition), the 2014/15 winter commercial catch, and the 2014/15 subsistence catch. The commercial catch CPUE time series and associated CVs were also updated, using the same standardization methodology as in previous recent assessments (SAFE 2013). In his presentation, Hamachan presented a figure showing the temporal extent of all available data sources (whether included in the model or not). The CPT commended the author for providing this information in his presentation and requested it be included in the Executive Summary as well as the body of the SAFE chapter.

There were no changes to the assessment methodology. The author's preferred model and the CPT's recommended model (Model 5) differed from the 2014 model structure by extending the size range for size classes defined in the model and by estimating (rather than fixing) the multiplier on natural mortality (M) for size classes > 123 mm.

Alternative models considered in the assessment explored several options (in an orthogonal design): 1) fix or estimate natural mortality (four variations), 2) expand the size range included in the model (from 74-124 to 64-134 mm CL), and 3) decrease the width of the size bins (from 10 mm to 5 mm CL). The four approaches considered to handle natural mortality (M) were: 1) fix M for all bins to 0.18 yr^{-1}, with a fixed multiplier on M of 3.6 applied to bins > 123 mm CL; 2) fix M in all bins to 0.18 yr^{-1}, but estimate the multiplier on M for bins > 123 mm CL; 3) estimate a single M for all bins (fixing the multiplier for bins > 123 mm CL to 1.0); and 4) estimate both the baseline M (applied to bins < 123 mm CL) and the multiplier on M applied to bins > 123 mm CL.

The CPT noted that likelihoods could only be compared directly between model scenarios that are based on the same data (i.e., data that used the same size bins and bin intervals). With that caveat, models that estimated M but fixed the multiplier to 1 (models 2, 6, 10, 14) fit much more poorly than models that estimated the multiplier and were subsequently eliminated from consideration. The CPT noted that the values chosen for fixing M (0.18 yr^{-1}) and the multiplier (3.6) were the result of previous model fitting, so it was not surprising (but reassuring) that the other models achieved similar results (what are results). The other models had very similar fits to the data, so Hamachan selected the base model 0 and models 1, 5, and 13 (M fixed, multiplier estimated) as the most reasonable for further consideration. These models all apply substantially higher natural mortality rates to size classes > 123 mm CL to achieve reasonable fits to the length- composition data. The CPT discussed possible reasons the model is forced to do this, and suggested that in the current model, growth into the largest size bins is occurring at too fast a rate thereby forcing the model to "kill off" crab in the largest size bins to better fit the size composition data.

Among the four models still under consideration, Hamachan selected Model 5 as his preferred model based on its having the smallest value of Mohn's rho when retrospective model results were considered. The CPT noted that there is no real way yet to distinguish "good" versus "bad" retrospective patterns using the value of Mohn's rho, and that it is more important to look at the actual retrospective patterns themselves rather than choose a model based on the statistic. That said, the CPT and the author agreed that Model 5 exhibited the best retrospective patterns of the remaining models. Thus the CPT agreed with the author's selection for his preferred model, but based on the plot of the retrospective pattern, not on the relative value of Mohn's rho.

The CPT noted that the OFL calculation used by the author in the draft chapter presented at the CPT meeting did not account for natural mortality between Feb. 1 (when MMB is calculated) and July 1 (when the summer commercial fishery catch is calculated) or explicitly account for the catch in the winter commercial fishery (as separate from the summer commercial fishery). During the meeting, Hamachan provided a revised OFL calculation for 2016 that corrected the first omission (a simple change). The CPT noted that the current harvest strategy caps the winter fishery at 8% of the OFL, but that this fishery might not take that much. Thus the OFL would weakly depend on how much the winter fishery was assumed to take. The CPT discussed several ways to include the winter fishery catch in the OFL calculation and requested the author provide values based on two assumptions: 1) the winter fishery takes the 8% allocated to it, and 2) the winter fishery takes a fraction of the allocation equal to an average harvest over recent years.

The CPT has the following recommendations for the next assessment:

- Calculate OFL by including M from Feb. 1 to July 1.
- Provide OFL values calculated assuming:
    - The winter fishery will take 8% of the OFL
    - The winter fishery will take X% of the OFL, where X = the average fraction taken by the winter fishery over the last few (e.g., 5) years.
- Evaluate whether using a growth function that "slows" growth prior to the largest size bins can improve the model's estimation of abundance of large crab relative to size composition data without having to invoke a higher natural mortality for the large crab.
    - Consider a piecewise linear growth model (like that used for snow crab)
    - Consider modeling molting probability using a nonparametric curve with a random walk penalty
- Evaluate applying the natural mortality multiplier 'ms' to only the largest size bin, not all bins > 123 mm.
- Evaluate estimating selectivity in the summer pot fishery in two time periods: before and after the change in buyers' preferred size (2005)
- For time series plots that include $B_{MSY\ proxy}$, do not extend the line indicating $B_{MSY\ proxy}$ beyond the temporal extent used to calculate it

Snow Crab

Jack Turnock discussed his plans for addressing CPT and SSC comments on the snow crab assessment that arose during the last assessment cycle. In 2015, a snow crab model similar to the previous year's model was used to set the OFL and ABC, rather than a model in which a number of changes had been implemented. This was regarded as a fallback alternative that was adopted because of the difficulty the CPT and SSC had in understanding how each model change was affecting model results.

Jack presented a list of 18 models that would be needed to step through each incremental change from model 0 in last year's assessment to model 4, where all the proposed changes for last year were implemented. This sequence of models did not include the CPT's request to split the fishing mortality time series, which would result in additional runs. The CPT does not think it will be necessary to provide results for each of the 18 models to get a good understanding of how model changes affect results. Below we provide suggestions for ways to consolidate model runs. As a general principle, it is acceptable to consolidate changes when model results are only slightly affected by model changes. If differences in results are large or unexpected, then further investigation is needed and results should be compared. The CPT cannot anticipate everything that might occur while preparing the next snow crab assessment, and assessment authors should be prepared to use their best judgement in developing a set of model runs for review in May.

Models 1-7 in the list are models in which the leading parameters have been changed (re-parameterized) to improve their statistical properties, a change that should not affect model results. If, as expected, there are no changes due to re-parameterization, then these runs can be consolidated. If there are changes to model results, further investigation is warranted.

The CPT recommends that jittering be done for snow crab model as a way to address the concerns about model convergence. Jittering involves randomly perturbing the initial values for the estimated parameters, and keeping track of whether the model converges to the same solution. Buck Stockhausen has model code to implement jittering for ADMB models and has provided the code to Jack. Several other approaches are possible, such as inserting code in the ADMB preliminary calculations section to add random variation to initial values, or to read the PIN file (initial parameter values) using R, add the random variation, and then export the modified PIN file for use by ADMB.

The effect of new data, particularly new survey data, on model results has been an important issue for the last two assessments for snow crab. To address this concern, the CPT recommends the sequential impact of adding new data to the assessment be evaluated in the next assessment. This evaluation should be done before considering any changes in model configuration, so the effect of new data can be evaluated in isolation from proposed model changes. The following sequence should be followed when adding new data to any existing model.

1. Directed catch
2. Bycatch fisheries
3. Survey indices
4. Survey size composition
5. Directed fishery size composition
6. Bycatch size composition

Showing model results at this level of detail is only needed when the effect of new data is considerable or unexpected; otherwise some level of consolidation is appropriate.

An incorrect (too high) discard biomass for 2013/14 was used in the September 2014 snow crab assessment. The correct estimate was used in the September 2015 assessment. However, this value was still higher than the long term average relative to the retained catch. The discard biomass in the 2014/15 fishery was also higher than average. The model uses discard data as well as survey length and biomass to inform recruitment estimates. The model interprets the increase in discard biomass in recent years as an increase in recruitment. The higher recruitment estimates are shifted to earlier years, resulting in a larger increase in biomass in the last years of the time series as the projected recruits grow into the mature biomass. The model estimates increased biomass from 2013 through 2015 due to the information from higher discards and the survey length frequency. The model estimates a very high 2015 recruitment based on the 2015 survey length data. However, this recruitment will not affect estimates of mature male biomass for several years. The CPT did not have specific recommendations regarding this issue, but encourages the assessment authors to continue their research into the reliability of discard estimates to inform recruitment. A retrospective analysis (dropping data from the end of the assessment sequentially) might address whether recruitment estimates are consistently biased. Allowing for inter-annual variability in selectivity, such as the approach used in the Tanner crab assessment, may provide a way to reduce the influence of the recent discard data if they are found to be misleading.

Jack provided results for a model run in which the weight for trawl bycatch likelihood was multiplied by four to address a concern about the poor fit to trawl bycatch data. Increasing the likelihood weight was found to change the biomass estimate (~10% decrease), which is a surprising result given bycatch in the trawl fishery is very low compared to other sources of mortality. Further exploration of this model variant is needed to better understand its behavior. The CPT recommends that a log-normal likelihood be evaluated rather than the normal likelihood presently being used. The CPT also reiterates its request that likelihood weights be expressed as CVs rather than as arbitrary weights so reasonable assumptions can be made about the uncertainty of different data inputs.

The CPT notes that there appeared to be slight divergence between some population estimates used in the snow crab assessment and the estimates provided directly by the survey group at the NMFS Kodiak laboratory. This concern only applies to some of the more complicated survey estimates, such as mature female biomass (which depends on clutch condition). Historically, these quantities were estimated by assessment authors for use as assessment inputs. The CPT recommends that assessment authors work with the survey group to ensure that data used in the assessment matches the estimates developed by the survey group, so there is only one set of "official" estimates.

Ecosystem Report card

Ben Daly presented an overview of the Bering Sea Ecosystem Report Cards used in the Groundfish SAFE Ecosystem Considerations Chapter. Ten indicators are used for the Eastern Bering Sea and there are 26 indicators for the Aleutian Islands. The team discussed 1) the value of a single crab chapter, 2) using report cards for individual crab stocks, 3) determining which indicators may be most useful for crab stocks, and 4) the process for providing data to support report cards. The team discussed the benefit to having a unique chapter specific to crab although there would be some overlap with the Ecosystems Considerations chapter in the GF SAFE. The authors will discuss creation of a single Ecosystems Considerations document that address both GF and crab concerns. If the CPT were to have a separate ecosystems report, it would only be updated every 3-5 years. The team agreed that a report card focused on an individual stock would be a good method to use. The North Pacific climate indicator was noted as the primary driving force behind sea ice duration and coverage and that sea ice strongly impacts benthic productivity.

The team agreed that report cards will be would be helpful in team discussions, both for large-scale environmental forcing that affects all crab stocks, and at the individual stock level . The CPT suggested that an initial effort should focus on developing a report card for single stock. Bristol Bay red king crab seemed to be the most logical choice for preliminary single stock report card development.

Red King Crab Selectivity

Scott Goodman (Bering Sea Fisheries Research Foundation, BSFRF) provided a review and update on the BSFRF-NMFS cooperative research project to provide data for estimating NMFS trawl survey selectivity of red king crab in Bristol Bay. Goodman has presented much of this material at previous CPT meetings, most recently at the September 2015 meeting. Studies were performed in 2013, 2014, and 2015 concurrent with the NMFS EBS trawl survey. The study area is defined by 59 NMFS survey stations in inner Bristol Bay (the entire Bristol Bay area comprises 136 NMFS survey stations). Side-by-side tows were performed in each of the 59 stations in each study year. One tow in a side-by-side pair of tows was performed by a NMFS survey vessel towing the standard 83-112 trawl net used in the survey according to standard survey protocols and the other by a vessel chartered by BSFRF towing a Nephrops trawl net. The tows performed by the BSFRF vessel with the Nephrops net swept approximately 1/6 the area of the tows performed by the NMFS vessel with the 83-112 net. The Nephrops net is assumed to catch all crabs in the area it sweeps.

Goodman reviewed results from the three study years. Rough estimates of selectivity for sex-size classes by the NMFS trawl were presented as the ratio of CPUE by the NMFS 83-112 net to CPUE by the BSFRF Nephrops net, where CPUE is number of crab per nmi^2 swept for all 59 stations. In the 2013 study, the ratios were 0.48 for males <110 mm CL, 0.48 for males 110–134 mm CL, 0.66 for males >134 mm CL, 0.28 for females <90 mm CL, and 0.86 for females ≥90 mm CL. In the 2014 study, the ratios all increased relative to 2013 and were close to 1.0 for larger size classes: 0.74 for males <110 mm CL, 1.01 for males 110–134 mm CL, 0.98 for males >134 mm CL, 0.48 for females <90 mm CL, and 1.04 for females ≥90 mm CL. Bristol Bay bottom temperatures in 2013 were colder than average, with the cold pool extending well into Bristol Bay, whereas bottom temperatures in 2014 were warmer than average. Goodman had initially hypothesized that the higher CPUE ratios in the 2014 study were due to the warmer temperatures causing an increase in selectivity by the NMFS 83-112 net (e.g., crab may be more active at warmer temperatures, making them more available to the 83-112 net). That hypothesis was seriously challenged by the results of the 2015 study, however. Bottom temperatures in 2015 were warm and comparable to 2014, but the 2015 CPUE ratios were lower than the 2014 CPUE ratios and generally lower than the 2013 CPUE ratios: 0.33 for males <110 mm CL, 0.51 for males 110–134 mm CL, 0.56 for males >134 mm CL, 0.35 for females <90 mm CL, and 0.77 for females ≥90 mm CL. Goodman also presented two plots with regression lines of the CPUE ratio within stations against station bottom temperature; although showing a trend consistent with the hypothesized dependence of CPUE ratio on temperature, the relationship was weak ($R^2 = 0.07$ in one plot, $R^2 = 0.14$ in the other).

The CPT discussed and sought a better understanding of two results from the side-by-side tow study: the results from 2014 relative to those from 2013 and 2015 (see above) and the results for females relative to males (i.e., why was the CPUE ratio for females ≥90 mm CL in each study year greater than the ratios for males 110–134 mm CL and for males >134 mm CL?). The team discussed the possibility that selectivity by the NMFS 83-112 net may be affected by bottom characteristics and gradients in substrate type across the study area and that bottom temperature could affect selectivity indirectly through the effects of temperature on the distribution of red king crab by sex and size in Bristol Bay (e.g., more constricted to nearshore areas in cold summers and more widely distributed in warm summers). Goodman noted, however, that there is little variation in substrate type within the study area; sandy bottom prevails throughout. It was discussed without resolution whether a spatial analysis of the side-by-side data could provide a better understanding of the results and if such analyses would be needed to estimate selectivity by the NMFS 83-112 net. Discussion on the surprising results from 2014 turned to the vessel pairs that were used in the side-by-side studies: was there anything unusual in the performance by any of the four vessels used in the 2014 study? Bob Foy and Goodman noted that a review of the data recorded on performance of tows (e.g., net mensuration data, bottom contact data, speed of vessel while towing, etc) by both NMFS and BSFRF vessels in 2014 revealed that nothing was unusual and that all vessels performed their tows according to established protocols. Goodman did, however, note that the surprising results from 2014 were due to the data collected from one pair of side-by-side vessels; the other pair of side-by-side vessels in 2014 produced results consistent with the results from the pairs of vessels in the 2013 and 2015 studies.

The CPT discussed approaches for incorporating the 2013–2015 side-by-side data into the Bristol Bay red king crab assessment model for estimation of trawl survey selectivity (the 2015 assessment model used data from the from the 2007 and 2008 BSFRF Bristol Bay surveys using a Nephrops net to estimate trawl survey selectivity with the estimate of trawl survey Q from the Otto-Somerton double-bag study as a prior for Q). After discussion of approaches to model the linkage of pairs in the side-by-side study design, the team decided that using the "separate survey" approach that has been used in the snow crab assessment model since 2011 (see pages 64–65 of the snow crab assessment chapter in the 2015 SAFE) is a good first step for incorporating the 2013–2015 side-by-side data into the assessment model. It was initially suggested by the team that the 2013–2015 side-by-side study area was large enough relative to the stock distribution that there would be no need to estimate availability in the study area; however, Jie Zheng (the lead assessment author) argued successfully that availability would need to be estimated for the BSFRF survey time series.

CPT requests to the Bristol Bay red king crab assessment authors for May 2016 meeting: The CPT requested two assessments in which data from the 2007 and 2008 BSFRF surveys and the 2013–2015 BSFRF side-by-side are used to estimate trawl survey selectivity using the aforementioned snow crab model "separate survey" approach: one assessment without a prior for survey Q from the Otto-Somerton double-bag study; one assessment with a prior for survey Q from the double-bag study. The CPT also recommended that an approach be developed where the paired design of 2013-2015 BSFRF surveys is used to directly estimate selectivity. This would involve adding size-structured tow-by-tow data in new likelihood component in the assessment model, and was considered as a project for model development. There was no expectation by the CPT that such a model would be a candidate base model for review at the May CPT meeting.

Goodman also presented data on Tanner crab that had been collected during the 2013–2015 side-by-side studies in Bristol Bay and from the BSFRF nearshore red king crab pre-recruit surveys in Bristol Bay. The CPT discussed whether those data were sufficient for estimating Tanner crab selectivity by the trawl survey. The CPT noted that answering that question requires consideration of: 1) how much of the stock biomass is in the study area as opposed to outside of the study area; and 2) what the possible effects of temperature are relative to the cold pool distribution inside and outside of the study area.

Snow crab bycatch

This topic evolves from the ACL analysis of 2009 and 2010 and resulting discussion papers. The State of Alaska takes bycatch of crab in groundfish fisheries into account when setting TACs, but there were not methods in the groundfish FMP to restrict fisheries based on crab bycatch. It was noted that, to assure avoidance of exceeding the ACL for the St. Matthew blue king crab stock in some seasons, the State has included potential bycatch mortality due to groundfish fisheries in the computation of the directed fishery's TAC. Resultantly, PSC limits were applied to groundfish fisheries based on bycatch by crab stock and accounting was revised to smaller spatial areas than the large NMFS reporting areas. Currently, we are discussing the Council's request to evaluate whether the area used for bycatch accounting of an example stock, snow crab, is effective at protecting crab. The *Chionoecetes opilio* bycatch limitation zone (COBLZ) was put in place in 1997 (through Amendment 40 to the BSAI GF FMP) as an area over which a trigger limit set to 0.1133% of snow crab survey abundance was applied to groundfish trawl fisheries.

Diana Stram and Bob Foy presented information related to this topic, including proportions of snow crab bycatch caught inside and outside of COBLZ by year, snow crab survey abundance, and data collected by observers during groundfish fisheries, including size frequencies of snow crab bycatch by sex and groundfish gear type and distributions relative to COBLZ boundaries of groundfish effort and crab bycatch by gear type. The PSC limit for snow crab was exceeded only once since it has been applied, by yellowfin sole in 2010.

Discussion of this issue focused on the fact that snow crab mortality from trawl fishery bycatch is very low relative to ABCs set for this stock. On the other hand, a CPT member noted that, with the poor understanding of habitat requirements for snow crab, the trawl bycatch limits in the COBLZ had been seen as a measure that promotes protection of snow crab habitat from potentially destructive fishing gear: the bycatch limits encourage avoidance of trawling in areas where bycatch rates are high and such areas presumably support important habitat for snow crab. It was unclear to the CPT what problem was being addressed by the discussion paper, and the CPT discussed whether there would be benefit for the Council to clarify its objectives given the low impact on the assessment due to groundfish removals.

- If the Council does decide to move forward with evaluation of crab PSC limits in the groundfish fishery, the CPT recommends the following: Since COBLZ boundaries appear arbitrary relative to the recent distribution of the stock, if an area is needed as an accounting measure, it should be expanded to the entire eastern Bering Sea (rather than revising the area over time as the stock distribution shifts).
- Apply the trigger limit percentage to the model estimate of the snow crab population as a more refined estimate of the stock than provided by the survey abundance estimate.
- Revise the trigger limit percentage based on maximum bycatch levels observed over the prior 20 years (or some other period).

The CPT also discussed PSC being managed in numbers versus the weight used in the assessments. This was an issue in the past when PSC accounting relied on estimates of numbers that were converted to weights for the crab stock assessments. The NMFS Regional Office worked with AKFIN to provide assessment authors with PSC removal in weight using the North Pacific Observer Program's sampling protocol. These improvements provided assessment authors with data by weight and crab stock area rather than needing to rely on fishery-level average crab weights to convert PSC from numbers. From an assessment perspective, the numbers to weight issue has been resolved.

Data Weighting

Some of the outcomes of the Data Weighting Workshop held in October 2015 in San Diego were briefly discussed in the light of what can be included in the terms of reference (TOR) for crab stock assessments. The Workshop report is yet to be published. However, workshop discussion focused on setting the initial (or input) sample sizes and using the McAllister and Ianelli (1997) and Francis (2011) methods for iterating the effective sample sizes for length composition data. It was noted that the McAllister and Ianelli method implicitly assumes independence among size proportions whereas the Francis method accounts for correlation in the residuals between size classes. The workshop concluded the following:

[a] The adjusted input sample sizes should be based on the harmonic mean of the ratios of the effective to input sample sizes if the McAllister and Ianelli method is used. The adjusted effective sample sizes may be compared with the output effective sample size for equivalency??

[b] Assessments should report the Francis weights and contrast them with the weights determined using the McAllister and Ianelli method.

SAFE guidelines

The CPT revised the current guidelines for BSAI Crab stock assessments. These revised guidelines are attached. The Team requests all authors to review the guidelines and strive to adhere to those sections that are applicable to their Tier level. The Team also added some guidelines for presentation of final assessments to facilitate comprehension and review on an annual basis.

The meeting adjourned at 1:30pm on Wednesday January 13th.