AGENDA C-3(b)
FEBRUARY 2012

MEMORANDUM

TO: Council and AP Members

FROM: Chris Oliver
Executive Director

DATE: January 26, 2012

SUBJECT: BSAI crab issues

ESTIMATED TIME
8 HOURS
ALL C-3 ITEMS

ACTION REQUIRED

(b) Crab Modeling workshop report and pdf of OFL report (SSC only)

BACKGROUND

A technical crab modeling workshop took place from January 9-13, 2012, at the Alaska Fisheries Science Center in Seattle WA. The over-arching objectives of the workshop were to review assessment models for Aleutian Islands golden king crab and Bering Sea Tanner crab which are currently under development and to provide the assessment authors with feedback and recommendations on model development, with the aim that these models could be used in the future for estimating stock status and biological reference points. The workshop followed a split-model format to facilitate real-time model development. Discussions about the data, assumptions, assessment models, and interpretation of the results took place during workshop. A series of consensus recommendations were identified for both the AIGKC model and the data used by that model, and for the Tanner crab model. Workshop participants agreed that a meeting dedicated solely to model development for two stocks provided the ability to delve into aspects of models including model fitting, coding and data which would not be possible during a routine meeting of the CPT. It recommended that consideration be given to holding targeted workshops for crab assessment models in the future. The workshop report is attached as **Item C-3(b)(1)**. Presentations will be given by stock assessment authors on the developing models as well as by Dr. Jim Ianelli (AFSC, workshop chair) and Dr. Steve Martell (UBC) on the workshop recommendations and developments on model progress following that meeting. Additional documentation on both models has been mailed to you prior to the workshop convening.

In conjunction with the workshop meeting week, one half day of the workshop was devoted to discussions regarding methods for estimating probability distributions for the overfishing limit (OFL). This was a separate meeting convened during the week to facilitate participation of crab modelers, but also included biologists working on groundfish stock assessments in addition to the key members of the CPT and SSC. This meeting formed a follow-up to the workgroup that has met informally since summer 2011 to discuss these issues and to provide guidance to the crab stock assessment authors on appropriate ways to estimate probability density functions (pdfs) for the OFL given that the Crab FMP now contains maxABC control rules by tier. These rules are explicitly linked to the estimated extent of uncertainty in the OFL. Consistency in how the pdf for the OFL is determined is necessary so that there is consistency in maxABC specifications for crab stocks. However, there are also implications for how this pdf is determined for groundfish stocks because uncertainty in ABC control rules is presently being analyzed. The report from this meeting will be presented separately to the SSC by Dr. Jim Ianelli (chair of the workgroup) and is attached as **Item C-3(b)(2).**

North Pacific Fishery Management Council Crab Modeling Workshop

January 9-13, 2012
Alaska Fisheries Science Center, Seattle WA

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1 Summary

A technical crab modeling workshop took place from January 9-13, 2012, at the Alaska Fisheries Science Center in Seattle WA. The workshop was chaired by Jim Ianelli (AFSC), and was attended by members of the Crab Plan Team (CPT), the authors of crab and groundfish stock assessment models, outside technical stock assessment expertise, and the general public (see section 4 for list of participants).

The over-arching objectives of the workshop were to review models which are currently under development and provide the assessment authors with feedback and recommendations on model development, with the aim that these models could be used in the future for estimating stock status and biological reference points. One half day of the workshop was devoted to discussions regarding methods for estimating probability distributions for the overfishing limit (OFL). This discussion included biologists working on groundfish stock assessments in addition to the key members of the CPT and SSC (a summary is reported separately for Council presentation).

Assessment models for Aleutian Islands golden king crab and Bering Sea Tanner crab were presented to the workshop. The workshop followed a split-model format to facilitate real-time model development. Model code and documentation were provided to two members of the crab plan team for review two weeks prior to the workshop. Discussions about the data, assumptions, assessment models, and interpretation of the results took place during workshop.

A series of consensus recommendations were identified for both the AIGKC model and the data used by that model, and for the Tanner crab model. The workshop agreed that a meeting dedicated solely to model development for two stocks provided the ability to delve into aspects of models, model fitting, coding and data which would not be possible during a routine meeting of the CPT. It recommended that consideration be given to holding targeted workshops for crab assessment models in the future

AIGKC model

Although much progress has been made in developing the model for this stock, issues mainly related to data processing (prior to inclusion in the model), along with some aspects of the specifications of the model required resolution before this model can be accepted for use in management. The workshop noted that the model equations predict the abundance of new and old shell individuals via a molting probability coupled with a growth transition matrix, but there are no direct observations on new and old shell abundance/composition to reliably estimate parameters that predict molting probabilities. A prior using externally estimated L50 from tagging data was used for molting probability estimation. Moreover, model outcomes are sensitive to assumed values (in the form of a prior) for the relationship between molting probability and size. A workplan to conduct detailed evaluations using general linear models (GLMs) for standardizing the CPUE data was identified as a high priority research topic, and this work will be reviewed at the May 2012 CPT for eventual inclusion in the assessment.

Tanner crab model

The Tanner crab model was essentially unchanged from that present to the September 2011 meeting of the CPT. Consequently, a relatively large number of model changes and requests for evaluations were done on a compressed schedule during the week. It became apparent that many aspects of the model code are hard-wired often requiring new variable declarations and complex coding. One approach to helping with this would be to write more general code and control model configurations more easily through the use of switches in control files. Also diagnostic display tools could be simplified to aid in evaluating model alternatives. Nonetheless, the authors worked to provide the group with results that could be used for revised rebuilding analyses.

The discussions on this model focused mainly on factors in the survey methods that might be causing poor fits to the survey data if no allowance is made for selectivity and catchability for males to differ markedly between 1982-87 and 1988+. Discussion also focused on whether the Somerton & Otto underbag experiment provided a reliable estimate of survey q for males for the years 1988+. The workshop generally considered the large change in survey q implied by the base model (0) was unrealistic. The analysts presented a long list of aspects of the survey that changed over time and could have impacted catchability and selectivity. However, these factors, taken individually and in combination, failed to explain the estimated change in apparent catchability. An alternative explanation, which would also be consistent with observed CPUE from the fishery, was that there was a movement or mortality event during the early 1980s that caused the observed decline in the survey biomass estimates. This possibility led to two sets of model runs: (a) the "Hide'em" scenarios in which the low survey estimates between 1982-87 were due to animals being unavailable to the gear for some reason, and (b) the "Kill'em" scenarios in which these low estimates were due to animals having died. Both scenarios are able to mimic the data better than assuming that catchability was constant from 1982 onwards, but at the same time both rest on assumptions which cannot be validated independently. The workshop noted that the same weight was assigned to each annual length-composition. However, the sample sizes vary markedly among years, sexes, and fisheries. The workshop identified an approach to weight these data based on the number of crabs sized, subject to a maximum weight.

Several modelling issues were identified which require further work. In addition, a number of inconsistencies between how data are treated in the Tanner crab and golden king crab models (e.g., lognormal vs normal errors for the reported catch, multinomial vs. robust normal for size compositions) were noted. Nevertheless, scenarios to employ for projections were identified for moving forward with a Tanner crab rebuilding plan while the model is still under development.

2 Aleutian Islands golden king crab model

The following document was sent for review prior to and during workshop: (www.tinyurl.com/AIGKC-2011). During the week a number of updates were distributed.

2.1 Summary of discussions

Siddeek provided an overview of the current status of the AIGKC model and the progress made since it was last reviewed by the CPT (September 2011).

Currently, the stock is split into eastern Aleutian (EAG) and western Aleutian (WAG) components for assessment and management purposes. A number of data-analysis-related issues were noted by the workshop and this was formed the main focus for discussion. Model runs were nonetheless requested to illustrate sensitivity to the different data and assumptions. In particular, the use of the results of analyses of the tagging data results as prior information for the molting probability (with high precision) effectively anchored the magnitude of the population. The discussions on the use of tagging data (for population and growth estimates), length compositions as derived by dockside and observers (and weighted by catch), and derivation of CPUE indices (from observers and dockside landings) are presented in the subsequent sections.

2.1.1 Tagging data

The workshop noted that the tagging for the eastern area is used to estimate growth for both areas and to provide independent estimates of exploited legal male biomass for the eastern area. The workshop had concerns about both of these uses of the tagging data. The recovery rate for the tagging data was estimated at approximately 5-8%. The group requested additional information on the tagging data, further documentation on the actual recovery rates, further analysis of the tagging data itself, as well as a sensitivity analysis of model performance with and without the tagging data. Currently, there are no data by shell condition (new-and old-shell) which provide information to estimate the parameters for the molting probability function. Rather, an informative prior for the length-at-50% molting is included in the assessment, and this prior is based on the results of the tagging study. A starting point would be to model the tagged population explicitly. The author should incorporate the tagging data directly into the model and determine its influence on the estimates of molting probability. Alternatively, the author could recode the population dynamics model so that it does not explicitly account for new shell/old shell individuals as it currently does, because the size-composition data used when fitting the model are aggregated over new and old shell crab. Owing to a lack of information on reporting rates and other uncertainties related to the tagging data, the workshop agreed that the tagging data should not be used as the basis for priors on exploited legal male biomass .

2.1.2 Length-composition data

The workshop discussed the length-composition data used in the model and how these data were weighted. It was suggested that the length-composition data may be over-weighted. The justification of the relative weights used was lacking and should be evaluated through clearer diagnostic tools. The workshop recommended using the length-frequencies collected by the observers while disregarding the dockside [length-frequency]. It was also suggested that the model be fitted to the length-composition for the total (landed and discarded animals) catch and the length-composition from dockside monitoring (as is the case for Tanner crab), and hence use the model to differentiate between landings and discards.

2.1.3 CPUE

The workshop discussed the treatment of CPUE data in the model and the possible confounding of use of both discard and retained CPUE. The dockside (retained) CPUE provides a longer data series (back to 1985) and would be preferable for use in the model. More details regarding the raw catch and effort data were requested such as the number of vessels, number of samples etc. This was central to the runs requested and presented in the next section. There was also some concern in the lack of independence between the retained and discarded catch CPUE, because both of these measures are based on the same effort measure; use of the dockside CPUE would resolve this issue.

2.1.4 Model run requests

The workshop requested several overnight runs during the course of the workshop. These runs were based on a variant of the original model which (a) did not include the estimates of legal male biomass calculated from the tagging data in the assessment, (b) reparameterized how the initial conditions were specified, and (c) omitted the penalty on the change in q due to rationalization. The runs (which were sequential) were:

Run 1: Downweight discard CPUE (longer term remove or have ability to remove)
Run 2: Dockside retained CPUE from 1998, then
Run 3: Dockside retained CPUE back to 1985.

Results from these runs indicated (in the first iterations) some counter intuitive changes in the magnitude of the population biomass. These runs were corrected in subsequent evaluations and the results were more consistent (See Tables 1 - 2 and Figures 1-5). But complete runs from both areas required more time than was available during the workshop due to convergence issues.

2.2 AIGKC recommendations

2.2.1 Near term (prior to May CPT meeting)

The following data tasks were identified to be completed prior to the May 2012 CPT:

1. Length data compilations
    a. Observer versus dockside/landed separately as is the case for Tanner crab (i.e., split the data by dockside landings from those taken at sea by observers).
    b. Examine issue that the dockside length-frequencies may be difficult to break out by areas for 1996-97 (there was some indication from D. Penguilly that area-specificity might be a problem in those years—need to be checked)
2. Comparative analysis of length frequency data between dockside and observers for consistency (recognizing dockside is legal males only)
3. CPUE modeling (GAM/GLMs) to look at effects of soak time, and other explanatory variables (start with the observer data, which includes more covariates and is shorter)
4. Develop a way to include the tagging data in the assessment as a basis for estimating growth.

2.2.2 Longer term work

1. Provide better documentation, especially on data compilation steps (e.g., the tagging study results)
2. Include clear rationales for selection of data weights
3. Follow SAFE report guidelines
4. Modeling:
    a. Adopt a more generalized modeling framework (avoid dealing with compile-time changes to model; Siddeek to work with Steve Martell to help on this; a prototype for this has already been started and is hosted on an SVN repository at: https://code.google.com/p/generic-crab-model/)
    b. Compute output diagnostics that provide an easy measure to judge goodness of fit (e.g., standard deviations of normalized residuals (SDNRs) or mean absolute deviations (MADs))
    c. Consider developing scripts to more easily create model fit figures and diagnostics (R might be preferred over Excel for this task)
    d. Use a non-robust multinomial likelihood during the early phases of the estimation since robust likelihoods may avoid fitting real signal in the data if used during the early phases of the estimation
5. Examine the feasibility of a single model for both areas as this may help with parameter estimation and better accounting of parameter "sharing" between regions

3 Bering Sea Tanner crab model

3.1 Summary of discussions

The following document was sent for review prior to and during workshop: (www.tinyurl.com/BSAITC-2011). The model was reviewed by the CPT in September 2011 and the SSC in October. This workshop focused on survey data aspects, and subsequently how other data interacted in the model.

3.1.1 Survey data

The presentation covered the main sources of information for the assessment, with particular focus on the bottom trawl survey and the time series of biomass estimates. In Fig. 3 of the assessment document there appears to be a high abundance of ~61mm crab in 1980 (for males) which fails to show up in subsequent years (females persist over more years). It was noted that the information in this figure is not used directly when fitting the model; rather the values shown are converted to biomass and proportions at length and these are used for fitting. Nonetheless, the anomaly is striking, and alternative causes were discussed. Predation was considered since in some years over 200 thousand t of tanner crab are estimated to have been consumed by Pacific cod. However, the size of crab found in stomachs would be smaller than the crab that were seen in the survey. It was also considered that the high mode in Fig. 3 arose from a random anomaly (or "luck") of a few high densities in survey trawl stations.

The authors presented information (Table 3) to illustrate all the factors and changes in the survey gear in an effort to find a critical disconnect in survey methods. The effects on catchability suggest that directionality (bias) may be possible, but not in the magnitude or in aggregate that would appear to explain the underestimated biomass I.e., that the catch in some years exceeded the survey biomass. Experimental data indicate that the survey catchability should be on the order of 0.88. However, the base model (Model 0) from the assessment assumes that that catchability for males was about 0.88 only during 1988-2011, and that the effective catchability was much lower (and freely estimated) during 1982-87. The CPT and workshop participants agreed that evidence for such a large change in catchability was difficult to defend given the state of knowledge about Tanner crabs. One suggestion was to analyze the survey data further, but taking into account information that was previously unavailable (e.g., substrate, current direction at time and locale of tow, etc) and see if that provides any further insight. Model alternatives to dealing with this are presented below.

Growth was also considered as a potential source of difference in biomass trends. The growth rate data are from the Gulf of Alaska. Rugolo and Turnock (2010) derived the growth relationships for male and female Tanner crab using data collected in the Gulf of Alaska near Kodiak (Munk pers. comm., Donaldson et al. 1981), and examined growth relationships developed by Zheng and Kruse (1999). The participants indicated that there were likely more important issues behind the discrepancies in estimated catchability.

3.1.2 Modeling

The workshop was presented with an overview of the Tanner crab model and had a number of questions for clarification including some related to inconsistencies in the pre-1991 selectivity parameters (appeared to be missing for the 1989-90 period in Table 8 of SAFE report).

Prior to the workshop participants had requested:

1. Profiles in M (mature male) and Q (male)
2. A display of the information from Somerton (1981a) east-west of 177 to better judge differences
3. Historical F for king and snow crab predicted from effort not catch

4. Male lengths (survey) fitted for combined shell condition prior to the availability of chela data.
5. An evaluation and discussion of the rationale for q estimated during the middle period
6. Consider estimating the beta parameters.
7. Replace the weights by CVs

During the week, the most recent time series of Fs from the RKC fishery was provided to address item 3. Most of the other analyses were focused on item 5 and in developing alternative models which fit the 1980s survey data but do not imply a very large change in survey catchability.

The workshop directed that focus should be on the primary effects (such as q or external mortality sources) first and that secondary factors such as input sample sizes second. As such, several model issues were identified. One was to assume that catchability was constant after 1982 but there was an "extra mortality" event in the early 1980s. Others included changing the year that the survey catchabilities were assumed to be the same (in the three-period model) and examining different prior distributions on catchability and evaluate which likelihood components were most affected. The following runs were thus requested:

1. For model 1 (and 0) remove penalty on survey q
2. Increment year of change in middle selectivity period (change to 1988, 89, 90, 91,92, 93; but start with 93 and perhaps 1990)
3. Kill-em-off scenario (add in mortality event...) from Model 1
4. Try profile on q for period 3—conduct runs with different prior means on survey q for period 3 (means less than 0.88).
5. Total catch length frequencies—examine right hand side of length compositions from observer and dockside data.
6. Look at dropping the 1980 survey length frequency (Model 0 or "best")
7. Evaluate sensitivity to the early groundfish discard catch data—maybe by setting 1st two years of data to the 3rd year of data...

Related to these model changes were the following requested outputs for evaluation purposes:

1. Report q for a standard length by sex (for comparison purposes only)—include in table for comparisons
2. Overlay different model q's over time, separate panels for males and females
3. Show diagnostics on residuals of observed vs predicted catches
4. Check assumption for directed fishery prior to 1991 for selectivity parameters (perhaps mislabeled)
5. Check on bycatch estimates prior to real data and how bycatches are extrapolated to earlier years (pre 1991).

After the first 6 model alternatives were examined, the group focused on factors that appeared to be driving some of the results. For example, the length frequency of the Tanner crab bycatch in the red king crab fishery had the largest likelihood component and appeared to have a large influence on the results (Table 4). The fit to survey data was better when the bycatch length-frequency information was downweighted, suggesting a conflict between these data sources (Table 5).

It was apparent after the first iteration of model evaluations that input sample size specifications (where all gears had an input multinomial sample size of 200 in each year) played a role. This was clearly a strong assumption for Tanner crab catch in other fisheries where there were many years of data but relatively few animals were measured for size. During the meeting, runs were made in which the assumed multinomial sample sizes were markedly downweighted (a value of 1), which led to better fits to the survey data.

Consequently, the participants discussed the desire to have sample sizes specified by year. As a first pass the authors normalized all sample sizes to have a mean value of 200. However, the differences in sampling intensity were high between the different gear types so the workshop requested that they be normalized and scaled relative to each other with the most intensively sampled gear (the directed fishery) set to have a mean value of 200 (although any resulting annual sample sizes were constrained not to exceed 400). The results of this work are presented in Tables 6 and 7.

For better evaluation of input sample sizes, the spatial coverage of length measures should be examined and the number of units (tow or pot) sampled should be evaluated relative to the number of animals measured.

3.1.3 Coding issues

The following summarizes discussion from the workshop and also findings during and after the workshop (in preparing the report) from examining the Tanner crab model code in more detail. The chair of the workshop chose to include these issues here since they need further clarification/investigations going forward in an effort to improve model stability.

It was noted that the selectivity in the snow crab fishery was specified as a double-logistic, dome-shaped and that pre -and post-rationalization discard selectivity estimates were separate. The model also uses the "max()" function which may create differentiability issues. One resolution would be to examine normalizing selectivity to a specific length bin. Another area where non-differentiability may arise was in the following statement: `if(fmortd_rk(i)< 0.01) fmortd_rk(i)= 0.01;` which could cause estimation issues. Using the derivative checker in ADMB (the –dd option) and examining the corresponding "ders.dat" should be used as a diagnostic tool to ensure the objective function is continuous and differentiable.

On examination there were 22 components to the objective function that is being minimized. Each of these also contain one or more components, for example, penalrec is the penalty on the recruitment that contains two components, a quadratic penalty on the annual recruitment deviations with a user specified weight like wghtrecf, and a quadratic penalty on the first differences of the early recruitment anomalies that are used to initialize the model with a weight of 1. A table that summarizes these weights in terms of the corresponding variance components is needed to clearly understand aspects of model tuning (i.e., variances should be specified as the appropriate combination of weights and input variances). Some of these weights are for likelihood components and others are prior distributions, whereas other components of the objective function are applied to input variances corresponding to specific data components.

3.1.4 Catch and fishing mortality penalties

The Tanner crab model is specified to fit catches from all fisheries (directed and bycatch) under the assumption that the catches are normally distributed (i.e. a penalty is included in the objective function based on the sums of squared differences between observed and model catches). The weight assigned to this penalty (10.0) implies a constant standard deviation of 223 t which causes the model to fit low catch years with less precision than large catches (i.e., the CV varies as a function of catch). Previous versions of the model used to assume lognormal errors in the measured catch; this is probably a more sensible and would increase the precision in fitting small catches relative to large catches.

Fishing mortality rates were fixed for the RKC fishery (not estimated), and the impact of this was unclear. The document (Fig. 12) shows that the peak predicted catches (all fisheries combined) was almost double the landed catch (35.52 thousand t; Table 1 of SAFE report).

The impact of appropriately scaling the sampling effort (instead of assuming 200 for all fleets and all years of data) may apparently have allowed the 3-period selectivity for RKC behave poorly by fitting the absolute catches only by changing selectivity (as opposed to changing the fishing mortality). On examining the code and results in more detail after the workshop, it appears that the last fishing mortality is ignored and hence the estimate is only based on the fmort-dev calculations - the reason for this is unclear.

3.2 Recommendations

3.2.1 General

The following summarizes the key recommendations arising from the workshop:

- Better documentation (with subscripts for year etc) of the model code and data inputs,
- Clearer accounting of relative variances among gear types (i.e., likelihood weights and variance combinations make tracking the assumed standard error or standard deviations unclear). For example the fit to the "observed" catches had a sums-of-squares penalty of 10.0 which implies a standard deviation of 223 t regardless of fishery.
- Diagnostic tools need to be improved. They are incomplete and comparisons between different model configurations were difficult to interpret and see.
- Develop the model to be more generally applicable. Presently, most model specifications are implemented by recoding and recompiling the model. Input control switches should help clean the presentation and improve the ability to evaluate alternatives in a timely and efficient manner.
- Consider alternative logistic selectivity parameterizations based on the difference between the lengths at 50% and 95% selectivity since the scale of these parameters are in millimeters and can provide more intuitive prior distribution specifications (if needed).
- The spatial coverage of length measures should be examined to better evaluate assumptions related to input sample sizes. The number of units (tow or pot) sampled should be evaluated relative to the number of animals measured. This might be preferred given the contagious nature of sampling process.
- Conduct a GLM for survey biomass estimates to evaluate factors that are presently ignored (e.g., currents speed relative to tow direction, substrate type (given that tanner crab appear to "hunker down" in mud), gear temperature etc.
- Others?

3.2.2 Rebuilding requirements

The workshop noted that there is an urgent need for some models to carry forward for projections and rebuilding analyses. Specifically, a bookend of two model configurations was recommended to go forward for projection purposes for the rebuilding analysis: these model configurations were those based on the early 1980s additional mortality scenario with and without priors on survey catchability for the 2nd period (1982-2011). Both of these model configurations should use the sample sizes recommended by the workshop. A second set of bookends to be used in conjunction with these model configurations involves two sets of implied recruitment scenarios for estimation of the B_{MSY} proxy (and hence rebuilding target): one using the recruits which gave rise to the biomass estimated during 1974-80 and a second using recruits from 1982-2011. The full set of rebuilding scenarios (RBS) are as follows:

Rebuilding scenario	Survey catchability prior 1982-2011	Recruitment/biomass period
RBS 1	LN(0.88, 0.05^2)	1974-1980
RBS 2	LN(0.88, 0.05^2)	1982-2011
RBS 3	Freely estimated	1974-1980
RBS 4	Freely estimated	1982-2011

Each of these scenarios should be reported for projections under the following fishing mortalities:

Projection case	Description
PC 0	F=0 all fisheries
PC 1	F=recent 3-year average F from groundfish fishery, F=0 for all other fisheries
PC 2	As in PC 1, but also with 3-year average F from RKC fishery
PC 3	As in PC 2, but also F= projected snow crab catches
PC 4	As in PC 3, but with reduced snow crab catch
PC 5	As in PC 4, but with combinations of directed Tanner fishing and snow crab to contrast rebuilding times

The workshop noted that the Council be clear that selection of these model runs does not preclude nor presuppose the direction of the final Tanner model specification accepted by the CPT and SSC. These options are selected in hopes that they bracket the likely range of results to facilitate Council analysts in drafting the appropriate NEPA document for Council consideration.

4 Workshop participants and attendees

Jim Ianelli	AFSC Seattle (Chair)
Diana Stram	NPFMC
Robert Foy	AFSC Kodiak
Ginny Eckert	UAF Juneau
Siddeek Shareef	ADFG Juneau
Paul Starr	New Zealand
André Punt	UW
Jason Gasper	NMFS RO Juneau
Lou Rugolo	AFSC Seattle
Jack Turnock	AFSC Seattle
Doug Pengilly	ADFG Kodiak
Jack Tagart	BSFRF
Doug Woodby	ADFG Juneau (SSC member)
Anne Hollowed	AFSC Seattle (SSC member)
Pat Livingston	AFSC Seattle (SSC chair)
Jie Zheng	ADFG Juneau
Steve Martell	UBC

Scott Goodman
Steve Hughes
Dick Powell
Denby Lloyd
Dave Somerton
Linda Kozak
Tom Casey
Hamachan Hamazaki
Edward Poulson
Dick Tremaine
Rip Carlton
Buck Stockhausen
Bing Hinckle

5 Tables

Table 1. Likelihood values for base scenario (Scenario 1) and three runs with different sets of conditions (see figure captions for detail) for EAG.

EAG	Scenario 1	Run 1 Ignore Penalty	Run 2 DocksideRetCPUE 1998-2010	Run 3 DocksideRetCPUE 1985-2010
like_retlencomp	-1560.530	-1570.830	-1574.650	-1541.370
like_discdlencomp	-1020.510	-1021.670	-1025.710	-1021.420
like_gdiscdlencomp	-450.298	-481.088	-485.574	-475.814
like_survcpuelen	-184.681	-204.428	-209.295	-206.630
like_retcpue	-91.785	-176.098	-213.320	-317.770
like_discdcpue	-302.501	-1.161	-0.436	-0.198
like_survcpue	-39.026	67.311	51.343	56.138
like_retdcatchB	12.658	9.551	7.675	8.077
like_discdcatchB	20.838	3.803	4.231	5.092
like_gdiscdcatchB	7.622	7.180	6.821	6.757
like_rec_dev	22.156	8.683	5.279	6.063
like_Pot_F	0.0011	0.0006	0.0009	0.0009
like_GroundFish_F	93.581	87.445	83.649	83.131
like_Legal_Discd_QQ	1.326	0.486	0.671	0.749
like_ExpolitedLegal97	13.921	0	0	0
like_ExploitedLegal00	29.921	0	0	0
like_ExploitedLegal03	1.924	0	0	0
like_ExploitedLegal06	7.469	0	0	0
like_moltL50	47.078	0.711	3.878	4.071
like_Growth_beta	6.640	3.203	2.210	3.153
like_q_ratio	0.003	0	0	0
Total negative log likelihood	-3384.190	-3266.900	-3343.230	-3389.98

Table 2. Likelihood values for base scenario (Scenario 1) and three runs with different set s of conditions (see figure captions for detail) for WAG.

WAG	Scenario 1	Run 1 Ignore Penalty	Run 2 DocksideRetCPUE 1998-2010	Run 3 DocksideRetCPUE 1985-2010
like_retlencomp	-1577.530	-1577.260	-1577.790	-1562.580
like_discdlencomp	-739.823	-739.611	-739.788	-738.876
like_gdiscdlencomp	-409.590	-410.075	-409.913	-410.918
like_retcpue	-3.139	-2.324	-11.873	-15.183
like_discdcpue	-1.998	0.089	-0.109	0.137
like_retdcatchB	3.711	3.634	4.379	4.998
like_discdcatchB	7.121	7.579	8.419	8.400
like_gdiscdcatchB	1.952	1.818	1.915	1.898
like_rec_dev	6.857	6.857	6.606	12.886
like_Pot_F	0.0691	0.0821	0.0728	0.0945
like_GroundFish_F	24.234	22.594	23.776	23.599
like_Legal_Discd_QQ	0.002	0.002	0.002	0.005
like_moltL50	1.452	1.087	1.300	0.533
like_Growth_beta	0.057	0.061	0.059	0.666
like_q_ratio	0.082	0	0	0
Total negative log likelihood	-2686.550	-2685.470	-2692.950	-2674.34

Table 3. Description of NMFS summer EBS bottom trawl survey changes over time.

Year	Description of change
1982	1st year of new net (83-112)
1982-	Focused examination on net configurations, protocols (e.g., warp lengths, tow speeds)
1988	Combinations of 6 vessels; one of principals underpowered / single screw / 3.0 kts
1982	distance traveled est. via Loran C and chart dividers
1982	time fished from brake-set to haul-back; data show 30.0 min & 2.778 km > implies input
1986	vessel non-standard trawl doors > net spread
1980s	evolving net mensuration & methods to est. spread (no electronics)
1986	SCANMAR 1st tested 1986 & implemented in 1988
1988	began use Loran C Buroughs program to calculate distance fished
1989	began use of standard scope table
1989	Rose and Walters (1990) mean net width-inverse scope to calculate net spread all tows pre-1988
1990	P: increase quantification net performance and data quality – scope table used to today when net width values not recorded
1992	Branker depth/temperature logger for 'on-bottom' evidence
1993	West coast 'trawlgate' marked start critical examination & standardizing survey protocols
1993	Trident 'A-boats' > well powered and standard design
1994	standard setting & retrieval protocol
1995	distance fished via GPS stream data
1995	begin on-bottom / off-bottom w/ bottom contact sensor

Table 4. Likelihood values for some Tanner crab initial model runs.

	Model 0			Model 1			
	priors	no priors	no 1980lf	priors 2 sel	no priors	Kill em off 83	Kill em off 83
	V25	25a	25b	V26	26a	26b	no priors
recruitment deviations	1.6	1.8	1.8	1.3	1.2	1.3	1.4
Maturity smoothness constraint	2.0	2.0	1.9	1.9	2.0	1.9	2.0
Survey q penalty	12.0	0.0	22.9	32.9	0.0	30.9	0.0
F penalty	30.6	29.8	30.8	29.2	30.1	29.1	28.5
retained length	106.6	96.3	97.8	126.7	119.5	125.7	112.9
total directed length	67.6	60.1	61.1	69.4	61.1	68.0	58.4
female directed length	63.6	61.4	62.6	61.6	58.6	61.7	58.9
survey length	320.2	310.4	298.0	378.5	361.4	388.3	373.6
groundfish fishery length	271.8	276.7	274.1	287.0	275.7	287.2	279.0
snow fishery length	572.5	575.4	571.6	597.2	596.9	596.4	589.7
red king fishery length	1268	1255	1257	1314	1312	1315	1287
survey biomass	201.1	208.8	199.8	245.6	262.8	227.7	277.9
fishery cpue	-	-	-	-	-	-	-
directed fishery male discard catch	4.7	5.4	5.0	4.3	5.3	4.4	5.8
directed fishery male retained catch	11.6	11.7	12.6	13.1	12.2	12.8	13.1
directed fishery female discard catch	11.6	12.2	11.7	11.7	11.2	11.8	11.8
grndfish fishery male + female catch	3.1	2.3	2.9	1.8	1.4	1.8	1.4
snow fishery male + female catch	16.7	13.8	16.4	16.5	13.2	16.3	12.7
red king fishery male + female catch	19.3	16.7	18.4	18.7	14.8	18.8	14.0
natural mortality penalty	37.1	30.6	39.1	34.7	24.8	34.2	24.4

Table 5. Likelihood values for Tanner crab model runs with red-king crab sample size set to 1 (middle column) and all bycatch fisheries set to 1 (last column).

	Model 1 No priors Kill em off 83		
	N=200	RKC N=1	AllByc N=1
Recruitment deviations	1.4	1.3	1.4
Maturity smoothness constraint	2.0	2.0	1.7
Survey q penalty	0.0	0.0	0.0
F penalty	28.5	29.8	19.8
Retained length	112.9	118.5	114.2
Total directed length	58.4	57.9	58.0
Female directed length	58.9	57.5	61.5
Survey length	373.6	345.9	263.0
Groundfish fishery length	279.0	268.9	5.4
Snow fishery length	589.7	601.7	8.9
Red king fishery length	1286.9	8.6	8.8
Survey biomass	277.9	251.7	215.3
Fishery cpue	-	-	-
Directed fishery male discard catch	5.8	5.6	6.2
Directed fishery male retained catch	13.1	11.6	13.5
Directed fishery female discard catch	11.8	11.2	10.7
Groundfish fishery male + female catch	1.4	1.4	1.5
Snow fishery male + female catch	12.7	13.4	8.8
Red king fishery male + female catch	14.0	11.4	12.9
Natural mortality penalty	24.4	17.7	16.8

Table 6. Actual number of Tanner crab measured.

Directed retained		Directed total			SnowCrab		
New+Old Shell			Male	Female	Year	Females	Males
1980	13,310	1991	13,386	2,984	1991	14,031	478
1981	11,311	1992	15,007	1,374	1992	11,708	686
1982	13,519	1993	13,511	2,871	1993	6,280	859
1983	1,675	1994	5,792	2,132	1994	6,969	1,542
1984	2,542	1995	5,589	3,119	1995	2,982	1,523
1988	12,380	1996	352	168	1996	1,898	428
1989	4,123	2005	15,459	879	1997	3,265	662
1990	120,676	2006	24,226	4,432	1998	2,747	515
1991	126,299	2007	26,091	1,577	1999	870	271
1992	125,193	2008	19,797	294	2000	103	22
1993	71,622	2009	16,229	147	2001	892	38
1994	27,658				2002	2,086	140
1995	1,525				2003	565	49
1996	4,430				2004	162	21
2005	705				2005	686	692
2006	2,940				2006	9,212	368
2007	5,827				2007	9,468	1,256
2008	3,490				2008	13,113	728
2009	14,315				2009	8,435	722
					2010	11,014	474
					2011	12,073	250

	Bristol Bay RKC Fishery - Discard Catch			Groundfish			Surveys
Year	Females	Males	Year	Females	Males	Year	Both sexes
1989	642	193	1973	1,604	1,212	1974	200
1990	1,580	43	1974	4,155	2,789	1975	200
1991	2,273	89	1975	16	24	1976	200
1992	2,056	105	1976	2,928	2,526	1977	200
1993	2,647	1,196	1977	10,873	9,803	1978	200
1996	15	5	1978	11,724	8,105	1979	200
1997	1,030	41	1979	24,924	16,953	1980	200
1998	335	18	1980	10,424	5,598	1981	200
1999	130	10	1981	12,956	6,817	1982	200
2000	605	36	1982	7,690	5,694	1983	200
2001	372	26	1983	14,112	7,983	1984	200
2002	555	43	1984	24,303	10,589	1985	200
2003	440	40	1985	26,334	12,765	1986	200
2004	412	41	1986	3,224	1,776	1987	200
2005	980	70	1987	3,310	1,690	1988	200
2006	691	68	1988	3,082	1,918	1989	200
2007	1,123	89	1989	2,812	2,188	1990	200
2008	2,574	98	1990	3,015	1,985	1991	200
2009	2,611	70	1991	14,432	6,155	1992	200
2010	581	28	1992	4,903	1,749	1993	200
			1993	1,148	279	1994	200
			1994	854	328	1995	200
			1995	4,404	2,248	1996	200
			1996	3,458	2,364	1997	200
			1997	12,176	5,314	1998	200
			1998	10,139	4,282	1999	200
			1999	12,037	4,399	2000	200
			2000	12,391	3,701	2001	200
			2001	12,910	2,485	2002	200
			2002	15,498	3,232	2003	200
			2003	13,542	3,292	2004	200
			2004	11,110	2,788	2005	200
			2005	13,424	4,097	2006	200
			2006	17,129	3,498	2007	200
			2007	17,513	3,150	2008	200
			2008	10,658	2,832	2009	200
			2009	6,435	1,973	2010	200
			2010	5,952	2,096	2011	200
			2011	2,055	697		

Table 7. Revised input sample sizes for Tanner crab model (see text for details).

Directed retained		Directed total			SnowCrab		
New+Old Shell			Male	Female	Year	Females	Males
1980	89.75	1991	20.12	90.26	1992	4.63	78.95
1981	76.27	1992	9.27	101.19	1993	5.79	42.35
1982	91.16	1993	19.36	91.11	1994	10.4	46.99
1983	11.29	1994	14.38	39.06	1995	10.27	20.11
1984	17.14	1995	21.03	37.69	1996	2.89	12.8
1988	83.48	1996	1.13	2.37	1997	4.46	22.02
1989	27.8	2005	5.93	104.24	1998	3.47	18.52
1990	400	2006	29.89	163.36	1999	1.83	5.87
1991	400	2007	10.63	175.93	2000	0.15	0.69
1992	400	2008	1.98	133.49	2001	0.26	6.01
1993	400	2009	0.99	109.43	2002	0.94	14.07
1994	186.5				2003	0.33	3.81
1995	10.28				2004	0.14	1.09
1996	29.87				2005	4.67	4.63
2005	4.75				2006	2.48	62.12
2006	19.82				2007	8.47	63.84
2007	39.29				2008	4.91	88.42
2008	23.53				2009	4.87	56.88
2009	96.53				2010	3.2	74.27

	Bristol Bay RKC Fishery - Discard Catch			Groundfish			Surveys
Year	Females	Males	Year	Females	Males	Year	Both sexes
1992	1.30	13.86	1973	10.82	8.17	1974	200
1993	0.29	17.85	1974	28.02	18.81	1975	200
1996	0.60	0.1	1975	0.11	0.16	1976	200
1997	0.71	6.95	1976	19.74	17.03	1977	200
1998	8.06	2.26	1977	73.32	66.1	1978	200
1999	0.03	0.88	1978	79.06	54.65	1979	200
2000	0.28	4.08	1979	168.06	114.32	1980	200
2001	0.12	2.51	1980	70.29	37.75	1981	200
2002	0.07	3.74	1981	87.36	45.97	1982	200
2003	0.24	2.97	1982	51.85	38.4	1983	200
2004	0.18	2.78	1983	95.16	53.83	1984	200
2005	0.29	6.61	1984	163.88	71.4	1985	200
2006	0.27	4.66	1985	177.57	86.08	1986	200
2007	0.28	7.57	1986	21.74	11.98	1987	200
2008	0.47	17.36	1987	22.32	11.4	1988	200
2009	0.46	17.61	1988	20.78	12.94	1989	200
2010	0.60	3.92	1989	18.96	14.75	1990	200
			1990	20.33	13.38	1991	200
			1991	97.32	41.5	1992	200
			1992	33.06	11.79	1993	200
			1993	7.74	1.88	1994	200
			1994	5.76	2.21	1995	200
			1995	29.7	15.16	1996	200
			1996	23.32	15.94	1997	200
			1997	82.1	35.83	1998	200
			1998	68.37	28.87	1999	200
			1999	81.17	29.66	2000	200
			2000	83.55	24.96	2001	200
			2001	87.05	16.76	2002	200
			2002	104.5	21.79	2003	200
			2003	91.31	22.2	2004	200
			2004	74.92	18.8	2005	200
			2005	90.52	27.63	2006	200
			2006	115.5	23.59	2007	200
			2007	118.09	21.24	2008	200
			2008	71.87	19.1	2009	200
			2009	43.39	13.3	2010	200
			2010	40.13	14.13	2011	200
			2011	13.86	4.7		

6 Figures

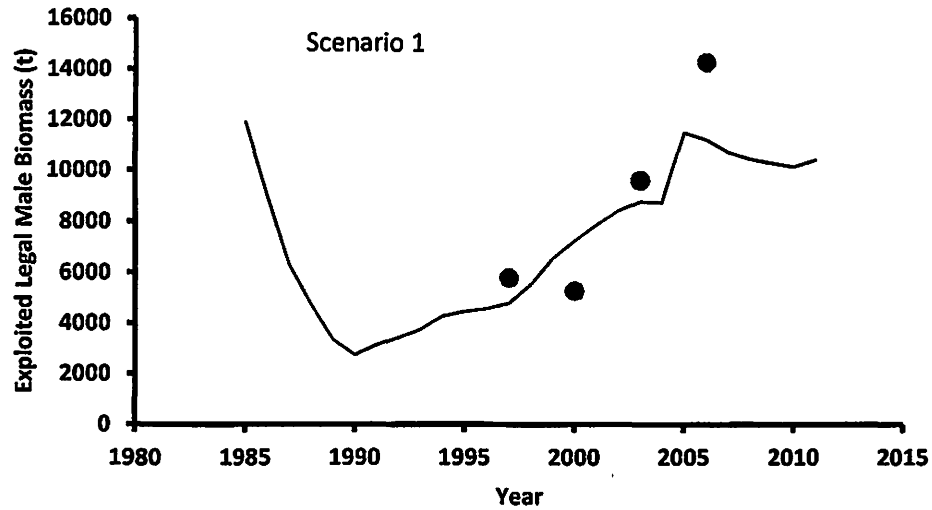

Figure 1. Tagging data estimated exploited legal male biomass (filled circle) superimposed on predicted exploited legal male biomass (solid line). Tagging data estimated biomass values were used as penalty in the model fit under Scenario 1 for EAG.

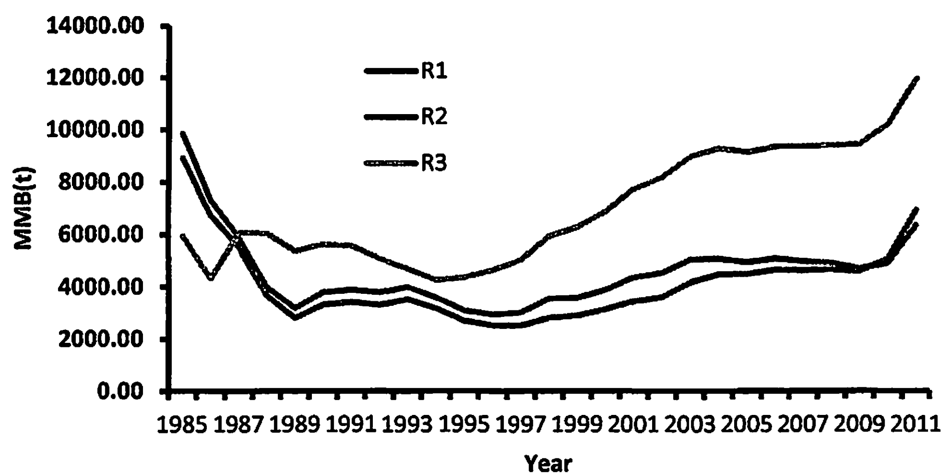

Figure 2. EAG mature male biomass (MMB) time series for R1: Run 1 – set first five initial population generation parameters (alphaN) to 0; omit all LMB priors (tagging related biomass estimates), omit q_ratio penalty, include molt probability and growth function beta penalty, down weight (0.25) discard CPUE; and consider the 1998-2010 CPUE time series as used in the report; R2: Run 2 – Same condition as R1, but observer retained CPUE is replaced by dockside CPUE; and R3: Run 3 – Same conditions as in R2, but dockside retained CPUE is extended back to 1985.

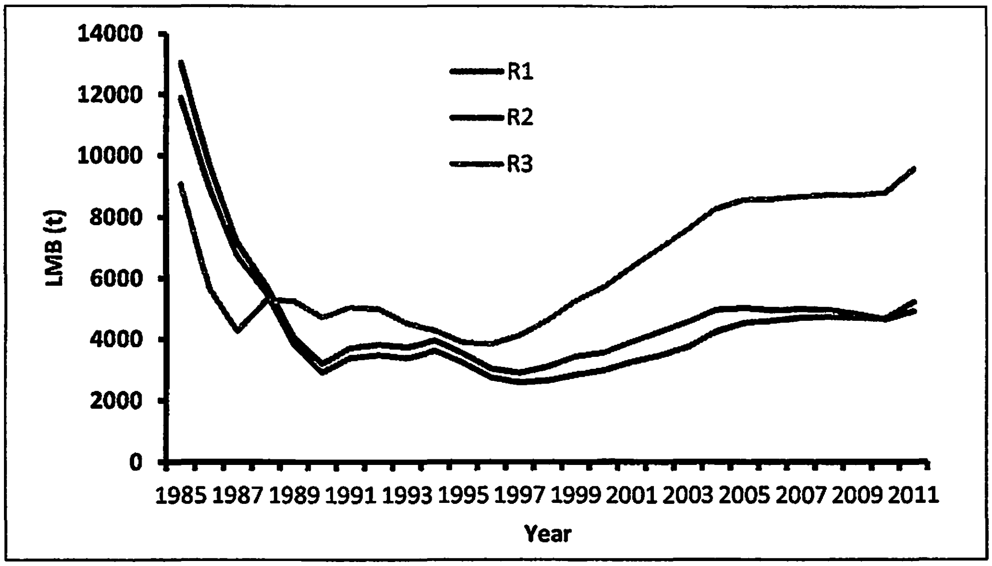

Figure 3. EAG legal male biomass (LMB) time series for R1: Run 1 – set first five initial population generation parameters (alphaN) to 0; omit all LMB priors (tagging related exploited biomass estimates), omit q_ratio penalty, include molt probability and growth function beta penalty, down weight (0.25) discard CPUE; and consider the 1998-2010 CPUE time series as used in the report; R2: Run2 – Same condition as R1, but observer retained CPUE is replaced by dockside CPUE; and R3: Run 3 – Same conditions as in R2, but dockside retained CPUE is extended back to 1985.

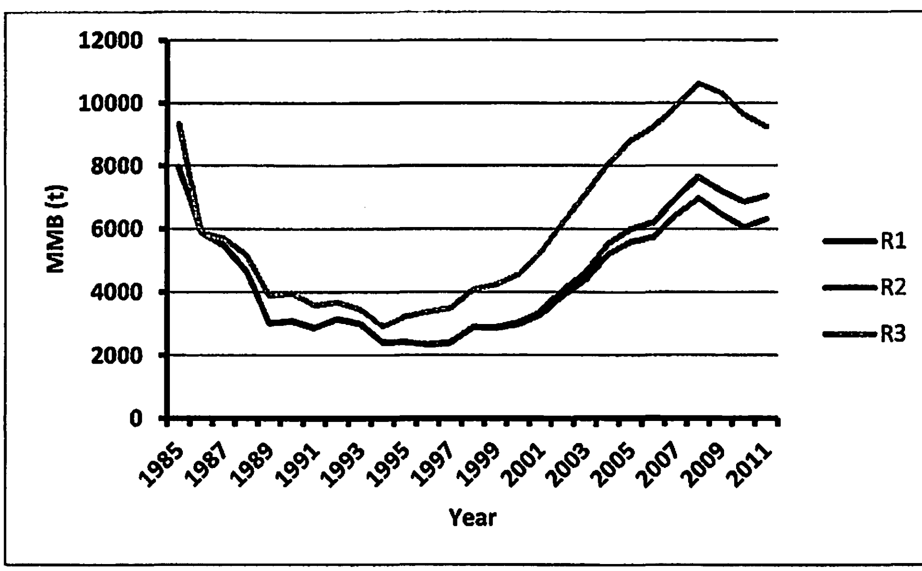

Figure 4. WAG mature male biomass (MMB) time series for R1: Run 1 – set first five initial population generation parameters (alphaN) to 0; omit q_ratio penalty, include molt probability and growth function beta penalty, down weight (0.25) discard CPUE; and consider the 1998-2010 CPUE time series as used in the report; R2: Run 2 – Same condition as R1, but observer retained CPUE is replaced by dockside CPUE; and R3: Run 3 – Same conditions as in R2, but dockside retained CPUE is extended back to 1985.

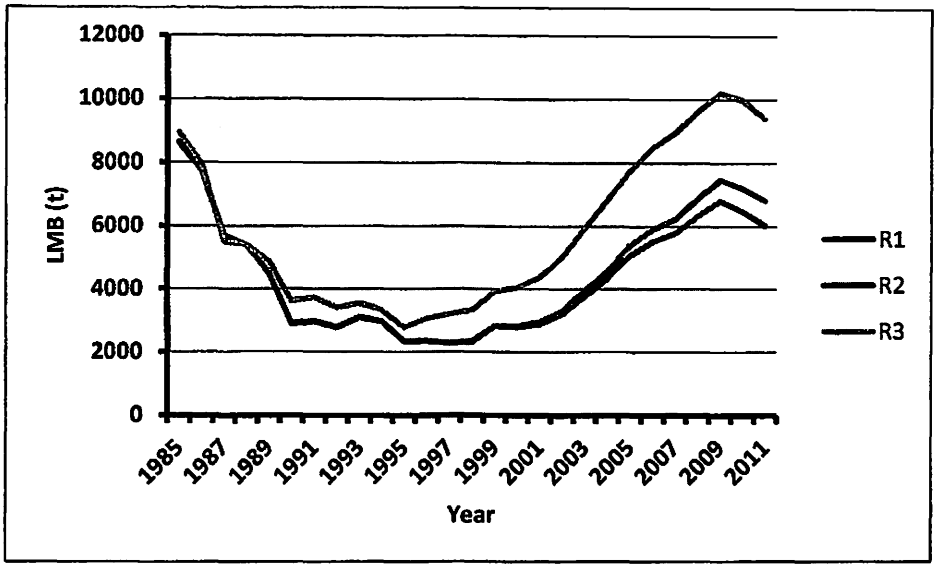

Figure 5. WAG legal male biomass (LMB) time series for R1: Run 1 – set first five initial population generation parameters (alphaN) to 0; omit q_ratio penalty, include molt probability and growth function beta penalty, down weight (0.25) discard CPUE; and consider the 1998-2010 CPUE time series as used in the report; R2: Run2 – Same condition as R1, but observer retained CPUE is replaced by dockside CPUE; and R3: Run 3 – Same conditions as in R2, but dockside retained CPUE is extended back to 1985.

Estimating the probability density function of the Overfishing Limit for crab stocks

1-5pm, January 10th, 2012
Alaska Fisheries Science Center, Seattle WA

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1 Introduction

A workgroup was convened in summer 2011 (informally by email) to provide guidance to the crab stock assessment authors on appropriate ways to estimate probability density functions (pdfs[1]) for the OFL given that the Crab FMP now contains maxABC control rules by tier. These rules are explicitly linked to the estimated extent of uncertainty in the OFL. Consistency in how the pdf for the OFL is determined is necessary so that there is consistency in maxABC specifications for crab stocks. However, there are also implications for how this pdf is determined for groundfish stocks because uncertainty in ABC control rules is presently being analyzed. A public meeting was held to facilitate further discussion and recommendations in conjunction with the Crab Modeling Workshop at the Alaska Fisheries Science Center (and by Webex) on January 10th. This meeting included biologists working on groundfish stock assessments in addition to the key members of the CPT and SSC (a summary is reported separately for Council presentation). Participants in the meeting (as well as the members of the workgroup) are listed in Appendix 1.

The meeting reviewed the methods employed in the past by the Crab Plan Team to calculate the pdf for the OFL, compared these methods with how ABCs are determined for groundfish stocks, and focused on the practicalities of alternative estimators (from assessments) for this pdf. Presently, only for Tier 1 groundfish stocks does the relationship between the OFL and the ABC relate to a pdf, whereas for crab stocks, Tiers 1-4 (as described in Box 1) account for uncertainties. The Tier 1 stocks for groundfish rely on estimates of pdfs for F_{msy}. For crab stocks, a "P*" approach was developed, which gives an ABC that has a specified level of probability of exceeding the "true" OFL.

Discussion at this meeting focused upon three main topics:

a) distinctions between the estimated OFL used in management which may be adjusted by control rules, the estimate of OFL without the control rule and the true, but unknown OFL.
b) calculation of the variance of the OFL and the probability of exceeding *OFL*, including risk-neutral assumptions (i.e., avoid specifying precautionary assessment model assumptions) inherent in the OFL; and
c) how to handle sources of uncertainty not captured in the stock assessment, including the implied assumption that OFL estimates are derived from "risk neutral" methods (e.g., the uncertainty for proxies of F_{msy}).

[1] Note that the strict definition of the function describing the probability density (PDF) may not necessarily apply and that what was discussed and meant were probability density estimates (which may involve simulation algorithms rather than analytical functions)

2 Summary

The meeting reviewed the methods employed by the crab Plan Team and that for groundfish, with focus on the practicalities of alternative estimators (from assessments) for OFL. At the outset, participants wished to clarify some of the goals and terminologies that are used when referring to an "OFL pdf". It was noted that the term "OFL" is sometimes used to represent the actual value that is specified for management (typically by applying a control rule and typically published in the Federal Register). The *specified* OFL is a fixed value, in contrast to the *true-but-unknown* OFL, which is a random variable. Since the true-but-unknown OFL is a random variable, it has a probability density function that can be computed from the stock assessment. The pdf for the true-but-unknown OFL allows probability statements to be made about the relationship between candidate ABC values and the true OFL (e.g., a value of x will have y probability of being larger than the true-but-unknown OFL). Since the pdf cannot be observed, estimators—either parametric or non-parametric-- are required. For example, if the pdf is approximately normal, the mean can be approximated by the mode of the posterior density and the variance can be approximated by inverting the Hessian matrix (or some proxy such as squaring the product of the posterior mode and the survey biomass CV).

The meeting clarified that inferences from these estimators are implicitly treated as Bayesian due to the probability statements that are required[2].

For the Tier 1 groundfish stocks, since the pdf of F_{msy} is required to be reliable, the computations can be done straightforwardly from the Hessian approximation to the posterior density (Box 2). The meeting noted that, in practice, Tier 1 assessments sometimes result in a relatively small buffer between OFL and ABC and that this is counter-intuitive given the difficulty of accurately measuring abundances and the typical variability observed between the outcomes of alternative (but equally plausible) model specifications. Presently, management strategy evaluations are underway with various post-docs and research projects which aim to quantify the size of this effect, and identify alternative risk-averse approaches that are suitable for groundfish stocks in other Tiers (in addition to Tier 1).

The meeting suggested that one approach to evaluate whether existing proxies are appropriate and existing control rules are consistent would be to apply lower tier control rules to higher tier (and perhaps simulated) stocks. This might prove useful for both crab and groundfish OFL/ABC specification systems.

For crab, the focus was on methods for computing pdfs for stocks in Tiers 3 and 4. A procedure was outlined which (for both tiers) involves extensive, but straightforward simulations. These are (revised slightly from previous methods) shown in Box 3. As outlined, computing OFL pdfs for Tier 3 crab stocks involves summarizing output from MCMC (as a representation of the posterior probability density). Provided these have "converged" (i.e., form a reliable estimate of the posterior density function), then the MCMC method has several advantages including 1) distributional assumptions for computing the pdf for the OFL are unnecessary; 2) marginal distributions will account appropriately for "curvature" in the posterior surface; and 3) application of control rules for each individual "draw" from the posterior distribution can be done straightforwardly. A drawback of using MCMC is that obtaining the maxABC for a single model run can be time consuming and can detract from explorations of alternative model specifications/options (which may play a larger role in illustrating model sensitivity/uncertainty). Another is that both achieving and demonstrating convergence are difficult problems. The use of the Hessian approximation to the joint posterior density was considered potentially satisfactory since the

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[2] A frequentist approach would address a statement such as "there is a 95% probability that the μ_{OFL} is contained within $\hat{X}_{OFL} \pm 1.96\hat{S}_{OFL}$ (for a normally distributed random variable)"

calculations involved are much faster. However, the meeting noted that comparisons between Hessian-based estimates of the distribution for the OFL and those from MCMC analyses should be undertaken.

For Tier 4 crab stocks, using a truncated normal (as opposed to a log-normal) distribution for Tier 4 stocks (see Box 3) was noted as a potential concern. There was some indication that this formulation avoided some pathologies in which previous approaches led to distributions of the OFL with medians that were substantially different from the 'best' estimates.

Regarding the issue of what to use when uncertainty in some quantities is unavailable, the meeting discussed alternative estimates of variability. For example, scientists working with west coast groundfish proposed an inverse method to specify probabilities of different stock sizes based on sensitivity tests. Specifically, the steps for that method are:

1. identify a low ending biomass (or OFL) considered half as likely as the base ending biomass (expert judgment on the part of the CPT);
2. assume these represent the 0.5 and 0.125 points along a log-normal distribution (given that they are supposed to represent 50% and 25% of the probability distribution); and
3. take the natural log of the ratio of ending biomass in base state to that in the low state. Divide by 1.15 to get an estimate of standard error of the logarithm of the OFL.

An advantage of this method is that it is transparent and can be used to account for extra-model uncertainty in obtaining the low biomass scenario. The meeting noted that there would be difficulty in subjectively identifying a low ending biomass (or OFL) that is considered "*half as likely*" as the base ending biomass and that it may be easier and just as intuitive to specify the variance of the OFL directly.

For crab stocks, a distinguishing characteristic relative to groundfish is that the OFL is computed using control rules instead of being based on direct consideration of F_{msy}. For example, it can be argued that μ_{OFL} (or $\hat{X}_{OFL}$ as the estimator) should be based directly on F_{msy} (i.e., $\hat{X}_{OFL} = f\left(\hat{F}_{msy}\right)$ and that then catch limits based on a control rule (call it OFL') be used for evaluation purposes. Quantities such as the probability of OFL' and any relevant ABCs exceeding $\hat{X}_{OFL}$ would then be relative to actual overfishing (which could be interpreted as exceeding F_{msy}[3]) rather than the probability of exceeding a specific FMP definition of the OFL control rule. This was an aside from the task of following the present definitions of OFL control rules. However, it reflects the discussion the meeting had on the added complexity of the calculations for crab, especially for Tier 3 and 4 stocks for which the OFL follows a sloping control rule.

3 Recommendations:

Shorter term considerations

1. Make clear distinctions between regulatory values (OFL and ABC), true but unknown values (μ_{OFL}), and estimators (e.g., $\hat{X}_{OFL}$)
2. Calculate the pdf of the OFL using pragmatic approaches such as using point estimates of OFL and variances from the uncertainty estimates either from the Hessian or MCMC.
3. Simulation approaches as outlined above for crab Tier 3 and 4 should be implemented in a standard software package with clear documentation Note that there is potential for lack of

[3] The actual MSFCMA's definition reads, "The terms 'overfishing' and 'overfished' mean a rate or level of fishing mortality that jeopardizes the capacity of a fishery to produce the maximum sustainable yield on a continuing basis."

transparency because since the simulation procedure is complex it may detract from other fundamental issues related to the probability that F_{msy} will be exceeded.

Longer-term broader considerations for both groundfish and crab control rules:

4. Alternative candidate pdf estimators for OFL-ABC determinations might best be evaluated relative to F_{msy} instead of relative to legally-defined OFL control rules (which have explicitly been designed to avoid exceeding F_{msy}, when biomass is estimated to be below B_{msy})
5. Evaluate/reconsider the utility of computing probabilities of proxies:
    a. Do they accurately reflect the uncertainty in actual F_{msy} estimates?
    b. Should post-control rule computation of uncertainties (i.e., computing probabilities of exceeding control rule outputs rather than of F_{msy}) be avoided?
    c. What is the latitude for legal definitions of OFL (via a pre-specified control rule) versus $\text{OFL}=f\left(F_{msy}\right)$?
6. Evaluate the consequences of applying control rules from lower tiers to higher-tier stocks to understand general consistency (in terms of risk aversion) and conditions where they vary
7. For crab examine method applied in 2010 to compute OFL pdfs for Tier 4 to a range of stocks including uncertainty in B_{msy} (proxy) and consider bootstrapping to generate uncertainty similar to Tier 3 estimates (using MCMC). It may be difficult to predict how distributional assumptions will compare (e.g., log-normal vs normal since with larger variances more "samples" will be truncated/omitted).
8. Quantify the impact of each source of uncertainty for pdf estimates based on multiple sources of uncertainty (e.g. the Tier 4 OFL control rule). For example, for Tier 4 stocks, what is the contribution to the variance for the OFL from the assumed level of uncertainty associated with natural mortality compared to that related to stock size and the B_{msy} (proxy)? This could be done by successively turning off each source of uncertainty to evaluate the relative impact on results. This has been done in the Crab ACL analysis in conjunction with σ_B values.
9. Examine model-based uncertainty compared to survey-based values. Uncertainty may be underestimated for data-poor stocks for which the assessment pre-specifies many parameters. For Alaska crab and groundfish, survey CVs may provide a consistent treatment across tier levels commensurate with the reliability of stock size estimates as observed in surveys. In general, the stock size and associated reference points of a stock with a high survey CV is considered more uncertain and in need of a larger buffer, then a stock with a low survey CV. However, assuming the uncertainty of the estimate of OFL is primarily due to survey CVs assumes uncertainty in biological rates plays a minor role, and that both survey catchability and selectivity is reasonably high.
10. The size of the buffer between the OFL and the ABC for crab stock is small because of the specification P* = 0.49. Perhaps a comprehensive reconsideration of the Crab Tier system including both the OFL and ABC control rules should be pursued.

    There should be a "risk neutral" treatment of uncertainty and other measures inherent in current specifications process. For example, MMB as a measure of spawning biomass and treatment of 'total catch' when control rules currently applied to MMB (only) and females added in afterwards and B_{msy} includes only males and yet the MSST should conceptually include females. CPT to discuss progress towards using an alternative (and more appropriate) measure of effective spawning biomass/reproductive potential for crab stocks in May.

11. Identifying additional uncertainty in OFL distribution
    a. σ_B,
    b. asymmetry of the uncertainty (if assessment and OFL estimates are not "risk neutral")

c. The impact of pre-specifying rather than estimating parameters. For example, in stocks where fishery availability may change significantly from year to year due to spatial targeting of strong recruitments, more data would be needed to account for this process and model appropriately. In low data situations, the assessment would (typically) assume constant selectivity and hence likely overestimate the precision of abundance and mortalities.

Tiers 1 through 3

For Tiers 1 through 3, reliable estimates of B, B_{MSY}, and F_{MSY}, or their respective proxy values, are available. Tiers 1 and 2 are for stocks with a reliable estimate of the spawner/recruit relationship, thereby enabling the estimation of the limit reference points B_{MSY} and F_{MSY}.

- Tier 1 is for stocks with assessment models in which the probability density function (pdf) of F_{MSY} is estimated.
- Tier 2 is for stocks with assessment models in which a reliable point estimate, but not the pdf, of F_{MSY} is made.
- Tier 3 is for stocks where reliable estimates of the spawner/recruit relationship are not available, but proxies for F_{MSY} and B_{MSY} can be estimated.

For Tier 3 stocks, maturity and other essential life-history information are available to estimate proxy limit reference points. For Tier 3, a designation of the form "F_X" refers to the fishing mortality rate associated with an equilibrium level of fertilized egg production (or its proxy such as mature male biomass at mating) per recruit equal to X% of the equilibrium level in the absence of any fishing.

The OFL and ABC calculation accounts for all losses to the stock not attributable to natural mortality. The OFL and ACL are total catch limits comprised of three catch components: (1) non-directed fishery discard losses; (2) directed fishery discard losses; and (3) directed fishery retained catch. To determine the discard losses, the handling mortality rate is multiplied by bycatch discards in each fishery. Overfishing would occur if, in any year, the sum of all three catch components exceeds the OFL.

Tier 4

Tier 4 is for stocks where essential life-history, recruitment information, and understanding are insufficient to achieve Tier 3. Therefore, it is not possible to estimate the spawner-recruit relationship. However, there is sufficient information for simulation modeling that captures the essential population dynamics of the stock as well as the performance of the fisheries. The simulation modeling approach employed in the derivation of the annual OFLs captures the historical performance of the fisheries as seen in observer data from the early 1990s to present and thus borrows information from other stocks as necessary to estimate biological parameters such as γ.

In Tier 4, a default value of natural mortality rate (M) or an M proxy, and a scalar, γ, are used in the calculation of the F_{OFL}. Explicit to Tier 4 are reliable estimates of current survey biomass and the instantaneous M. The proxy B_{MSY} is the average biomass over a specified time period, with the understanding that the Council's Scientific and Statistical Committee may recommend a different value for a specific stock or stock complex as merited by the best available scientific information. A scalar, γ, is multiplied by M to estimate the F_{OFL} for stocks at status levels "a" and "b," and γ is allowed to be less than or greater than unity. Use of the scalar γ is intended to allow adjustments in the overfishing definitions to account for differences in biomass measures. A default value of γ is set at 1.0, with the understanding that the Council's Scientific and Statistical Committee may recommend a different value for a specific stock or stock complex as merited by the best available scientific information.

If the information necessary to determine total catch OFLs and ACLs is available for a Tier 4 stock, then the OFL and ACL will be total catch limits comprised of three catch components: (1) non-directed fishery discard losses; (2) directed fishery discard losses; and (3) directed fishery retained catch. If the information necessary to determine total catch OFLs and ACLs is not available for a Tier 4 stock, then the OFL and ACL are determined for retained catch. In the future, as information improves, data would be available for some stocks to allow the formulation and use of selectivity curves for the discard fisheries (directed and non-directed losses) as well as the directed fishery (retained catch) in the models. The resulting OFL and ACL from this approach, therefore, would be the total catch OFL and ACL.

Tier 5

Tier 5 stocks have no reliable estimates of biomass and only historical catch data is available. For Tier 5 stocks, the OFL is set equal to the average catch from a time period determined to be representative of the production potential of the stock, unless the Scientific and Statistical Committee recommends an alternative value based on the best available scientific information. The ABC control rule sets the maximum ABC at less than or equal to 90 percent of the OFL and the ACL equals the ABC.

For Tier 5 stocks where only retained catch information is available, the OFL and ACL will be set for the retained catch portion only, with the corresponding limits applying to the retained catch only. For Tier 5 stocks where information on bycatch mortality is available, the OFL and ACL calculations could include discard losses, at which point the OFL and ACL would be applied to the retained catch plus the discard losses from directed and non-directed fisheries.

Box 1. Description of the Tier system in place for crab stocks.

Under Amendment 56, the SSC determines if a stock qualifies under Tier 1. This determination is based on if "reliable" estimates of F_{msy} and its pdf are available. A short background comes from Thompson (1996) where risk averse and risk neutral approximations can be provided given these estimates.

The Tier 1 harvest level is calculated as the product of the harmonic mean of F_{msy} and the geometric mean of the projected biomass estimate: $B_{GM} = \exp\left(\ln \hat{B} - 0.5CV^2\right)$ where $\hat{B}$ is the point estimate (highest posterior density; HPD) of the projected biomass and CV^2 is the coefficient of variation of the point estimate.

For ABC determinations the harmonic mean of F_{msy} is computed as $F_{HM} = \exp\left(\ln \hat{F}_{msy} - 0.5\sigma^2_{\ln F_{msy}}\right)$, where $\ln \hat{F}_{msy}$ is the HPD of log-F_{msy} and $\sigma^2_{\ln F_{msy}}$ is the estimated variance. For both B_{GM} and F_{HM} the CV^2 and $\sigma^2_{\ln F_{msy}}$ are approximated by the Hessian matrix which is the critical part of deriving estimates of the PDF of F_{msy}. Thus simply $ABC = F_{HM}B_{GM}$.

OFL for Tier 1 groundfish is similarly computed as: $OFL = F_{AM}B_{GM}$ where $F_{AM} = \exp\left(\ln \hat{F}_{msy} + 0.5\sigma^2_{\ln F_{msy}}\right)$.

For EBS pollock, the exploitation-rate type value that corresponds to the F_{msy} level was applied to the "fishable" biomass for computing ABC levels. For a future year, the fishable biomass is defined as the sum over ages of predicted begin-year numbers multiplied by age specific fishery selectivity (normalized to the value at age 6) and mean body mass (10-year average). For northern rock sole and yellowfin sole, the biomass is defined as being greater than age 5.

Box 2. Specification of OFL (and ABC) for groundfish

Tier 3 crab stocks
Form a cumulative distribution for the OFL from the MCMC sample. Find the median of the distribution. Using normal quantiles to rescale the distribution so that the median is equal to the OFL (similar to a bias-corrected bootstrap). Alternatively use the variance from the MCMC sample (or Hessian approximation) to form the cumulative distribution.

Tier 4 crab stocks
Calculation of a distribution for the OFL for Tier 4 stocks involves repeating four steps (detailed below). The aim is to have the median of the distribution for the OFL equal the point estimate (so that P*=0.5 implies that the ABC equals to the point estimate of the OFL). The proposed steps are:

(a) Sample current MMB from a normal distribution with mean given by the point estimate of current MMB and CV equal to the sampling CV.
(b) The B_{MSY} proxy is the average MMB over a pre-specified set of years. Uncertainty in the B_{MSY} proxy only accounts for uncertainty in MMB for the years for which it is assumed the stock was "at B_{MSY}" and not uncertainty in the years concerned. For each of the years used when defining the B_{MSY} proxy, sample MMB from a distribution with mean given by its point estimate and CV equal to the sampling CV. The pseudo B_{MSY} proxy is then the average of the samples values.
(c) Sample M from a normal distribution with mean equal to the assumed M and CV equal to an assumed CV (e.g. 0.2).
(d) Compute the OFL.

Form a cumulative distribution for the OFL from the sampled values. Find the median of this distribution. Using normal quantiles to rescale the distribution so that the median equals the OFL (similar to a bias-corrected bootstrap).

Box 3. Proposed OFL PDF methods for Tier 3 and Tier 4 crab stocks.

Appendix 1: List of OFL workshop participants

Jim Ianelli	AFSC Seattle (Chair)
Diana Stram	NPFMC
Robert Foy	AFSC Kodiak
Ginny Eckert	UAF Juneau
Siddeek Shareef	ADFG Juneau
Paul Starr	New Zealand
André Punt	UW (PFMC SSC member)
Jason Gasper	NMFS RO Juneau
Lou Rugolo	AFSC Seattle
Jack Turnock	AFSC Seattle
Doug Pengilly	ADFG Kodiak
Jack Tagart	BSFRF
Doug Woodby	ADFG Juneau (NPFMC SSC member)
Martin Dorn	AFSC Seattle (PFMC SSC member)
Pat Livingston	AFSC Seattle (NPFMC SSC chair)
Jie Zheng	ADFG Juneau
Steve Martell	UBC
Grant Thompson	AFSC Seat`tle
Dana Hanselman	AFSC Juneau
Buck Stockhausen	AFSC Seattle
Bill Gaeman	ADFG Juneau
Denby Lloyd	
Dave Somerton	AFSC Seattle
Edward Poulson	
Hamachan Hamazaki	ADFG Anchorage