[Draft] Guidance for BSAI Crab SAFE Chapters

Introduction

The Bering Sea and Aleutian Islands Crab Plan Team (BSAI CPT) is providing this document as a guide for stock assessment authors and others engaged in the preparation and review of the Council's annual BSAI Crab SAFE.

Assessment authors serve as the primary point of contact for a given Crab SAFE chapter and, in developing the assessment, have to evaluate and prepare data inputs, explore candidate assessment models, code models into computer applications, review model diagnostics, and interpret assessment outputs. This can be a very complicated process and assessment authors encounter numerous analytical decision points at each stage of their work. Additionally, stock assessments change over time, both necessarily through annual updates, and also as knowledge increases about species' life history, movement and distribution, ecosystem interactions, and changes in fishery operations and market patterns.

The CPT and SSC review numerous BSAI crab stock assessments in a two step process at their respective meetings. At the second set of meetings, the CPT and SSC review the final stock assessment, which, if accepted by the SSC is used for determining stock status and OFL/ABC for the upcoming fishing year.

All this complexity creates the potential for confusion for CPT and SSC reviewers about which decision points and assumptions they should focus on in order to determine the adequacy of an assessment as a basis for management decisions. This confusion is minimized when the content of stock assessments is organized according to a logical and predictable framework. When the characteristics of candidate population models, for example, are arranged nicely in tables or depicted clearly in figures, discussion can focus on the comparison rather than on trying to find the information itself. Stability in the organization of SAFE chapters should save time for stock assessment authors because assessment programs can be configured to provide output in an agreed upon format. Therefore, assessment authors should provide final stock assessments to CPT and SSC reviewers in the form of properly formatted SAFE chapters consistent with the standards contained in this guide.

Notes:

- Provide SAFE chapters in MSWord.
    - Use the provided NPFMC template for appropriately formatting headings, text, lists, etc.
- The standard units of mass for SAFE chapters is metric tons (t), however, in the SAFE Executive Summary and where the document discusses State harvest strategies, units of pounds (lb) are *also* included.
- When moving between units, use these conversion factors, as limited by the precision of the data or model quantities:

  t = 2,204.622622 lb
  lb = 0.00045359237 t

- Significant digits in OFL/ABC should allow for meaningful values after converting to pounds for State management
- Fishing mortality rates are reported as fully-selected (F at selectivity = 1.0).

Contents of SAFE Report Chapters

Title

Please use the following convention:

"Crabstock "

YYYY

author[1], author[2]

[1]affiliation, [2]affiliation

Example:

Saint Matthew Island Blue King Crab

2020

Katie Palof[1], Jie Zheng[1], Jim Ianelli[2]

[1]Alaska Department of Fish and Game, [2]National Marine Fisheries Service

Executive Summary

1. **Stock**: species/area.
2. **Catches**: Description of trends and current levels, table reference
3. **Stock biomass:** Description of trends and current levels relative to virgin or historic levels, description of uncertainty, table reference.
4. **Recruitment**: Description of trends and current levels relative to virgin or historic levels, table reference.
5. **Management performance**: Table showing estimates of mature male biomass (at the time of mating), overfishing levels (OFL and MSST), allowable biological catch (ABC), TACs, retained catch and discards in all fisheries; show results for five years prior to and including the current year (Table 2 of this Appendix lists examples of how these tables should be constructed for stocks in each Tier) in 1000 t (first) then million lb (second).

Year	MSST	MMB	TAC	Retained Catch	Total Catch	OFL	ABC
2016/17	1.97	2.23	0.00	0.00	0.001	0.14	0.11
2017/18	1.85	2.05	0.00	0.00	0.003	0.12	0.10
2018/19	1.74	1.15	0.00	0.00	0.001	0.04	0.03
2019/20	1.67	1.06	0.00	0.00	0.001	0.04	0.03
2020/21		1.12				0.05	0.04

6. **Basis for the OFL:** Table listing estimates of M (default value 0.18 for king crabs and 0.3?? for Tanner and snow crabs), Tier level, current mature male biomass (MMB, at the time of mating), B_{MSY} (or the proxy thereof) and the basis for the calculation of B_{MSY}, current mature male biomass relative to B_{MSY} (or its proxy), γ, and the basis for calculating average catch; show for five years prior to and including the current year (Table 3 of this document lists examples of how these tables should be constructed for stocks in each Tier).

Year	Tier	B_{MSY}	Current MMB	B/B_{MSY} (MMB)	F_{OFL}	Years to define B_{MSY}	Natural Mortality
2016/17	3b	25.8	24.0	0.93	0.27	1984-2016	0.18
2017/18	3b	25.1	21.3	0.85	0.24	1984-2017	0.18
2018/19	3b	25.5	20.8	0.82	0.25	1984-2017	0.18
2019/20	3b	21.2	16.0	0.75	0.22	1984-2018	0.18
2020/21	3b	25.4	14.9	0.59	0.16	1984-2019	0.18

7. **Probability Density Function of the OFL** (if applicable) and what additional uncertainty is included in this estimate.
8. **Basis for ABC recommendation** (if the recommendation is below maxABC, report both the recommended and maxABC).
9. **Summary of Rebuilding Analyses** (if applicable): table showing the year by which rebuilding is expected to occur, the rebuilding time period, the catch for the next fishing year and probability of recovery to the proxy for B_{MSY} for a range of harvest strategies (including one for which the probability of recovery within the rebuilding period is 0.5).

A. Summary of Major Changes

1. **Changes (if any) to the management of the fishery.**
2. **Changes to the input data** (e.g. specify any new data sources and which data sources have been updated).
3. **Changes (if any) to the assessment methodology**.
4. **Changes to the assessment results,** including projected biomass, TAC/GHL, total catch (including discard mortality in all fisheries and retained catch), and OFL.

B. Responses to SSC and CPT Comments

Responses to SSC and CPT comments in SAFE chapters provide a history of the development of the various stock assessments, and authors are encouraged to provide meaningful responses to all applicable comments.

The SSC and CPT provide two types of comments: *general* comments to assessment authors, and comments that are *specific* to a particular assessment. Additionally, assessment authors provide two versions of their assessments (draft and final) for SSC and CPT review. Responses to SSC and CPT comments, therefore, should indicate whether they are *general* or *specific* and whether they came from SSC review of the *draft* or *final* assessment. If a comment has not been addressed in the assessment, the comment should be listed and the reasons for not addressing it must be provided.

C. Introduction

1. **Species**
   Common name, *Scientific name*, Area.

2. **General Distribution**
   Description of general distribution (including a map, showing the stock boundary and, if possible, the actual distribution).

3. **Stock Structure**
   Evidence of stock structure, if any.

4. **Life History Characteristics**
   Description of life history characteristics relevant to stock assessments (e.g., special features of reproductive biology).

5. **Management History**
   Brief summary of management history. A complete summary of the management history will be provided in the ADF&G Area Management Report appended to the annual SAFE.

6. **ADF&G harvest strategy**
   Brief description of the annual ADF&G harvest strategy. All parameters for stocks with an approved harvest strategy should be provided in tables in both t and million lb.

7. **History of B_{MSY}**
   Summary of the history of the basis and estimates B_{MSY} or $B_{MSYPROXY}$

D. Data

1. **Summary of New Information**
   Similar to Section A.2).

2. **Fishery Catch Data**
   Should be presented as time series, separately by sex and, depending on the assessment, also by maturity state and shell condition (table headers should indicate when the data were extracted, and the source for the data; years should be reported as fishing year 2xxx/yy or calendar year, depending on the fishery concerned):

   a. **Total catch**,
      partitioned by strata used in the assessment model, if any.

   b. **Discards**
      Information on bycatch and discards. Non-retained catches and discards should ideally be reported using the categories in Table 4 to this document (the table header should specify the mortality rates applied to discards and bycatch, and whether the values in the table have had these mortality rates applied or not).

   c. **Fishery size comps**
      Catch-at-length (with sample sizes) for fisheries, bycatch, discards.

   d. **Fishery CPUE**
      Catch-per-unit effort time-series (if used in the assessment) and how the data were standardized with diagnostics tables/plots.

3. **Survey Catch Data**

   a. Survey biomass estimates (with measures of uncertainty).
   b. Survey catch-at-length (with sample sizes), as appropriate.
   c. Survey CPUE

d. Growth-per-molt; frequency of molting, etc. (by sex and perhaps maturity state).
e. Weight-at length or weight-at-age (by sex).

4. **Omitted Information**
Info from any data sources that were available, but were excluded from the assessment.

Note: Information on length-composition may be more appropriately presented in the form of plots, especially for assessments for which there are a substantial amount of such data.

The reported samples sizes should reflect the actual number of samples; information on the sample sizes assumed when fitting any population models should also be reported.

E. Analytic Approach

1. History of modeling approaches for this stock

a. Summarize CIE review comments from past reviews and sequentially address how those comments have been taken into account.
b. Provide a brief summary (table or bulleted list) describing model changes over time since the model was first accepted for use in the assessment.

2. Model Description

a. Description of overall modeling approach (e.g., age-/size-structured versus biomass dynamic, maximum likelihood versus Bayesian). If the model has not been published in its current form, its equations should be listed in full in an appendix. If there is a technical appendix, items b-f below should be included in the appendix, and only a short description of the model and its estimation scheme needs to be included in this section. Specify when the fishery is assumed to occur and, if necessary, provide a table which lists the assumed time of the fishery for each year of the assessment periods.
b. Reference software used (e.g., Synthesis, AD Model Builder).
c. Description of all likelihood components.
d. Description of how the state of the population at the start of the first year of the assessment period is determined and the size-range that the model covers.
e. Parameter estimation framework:
    i. List all of the parameters which are estimated outside of the assessment (e.g., the natural mortality rate, parameters governing the maturity schedule), along with how the values for these parameters were estimated (methods do not necessarily have to be statistical, e.g., *M* could be estimated by referencing a previously published value).
    ii. List all of the parameters that are estimated conditionally on those described above (e.g., full-selection fishing mortality rates, parameters governing the survey and fishery selectivity schedules, recruitments) and indicate any bounds and/or priors placed on these parameters and whether the parameter estimate is within x% of the bound.
    iii. List any constraints imposed on the estimated parameters (including penalties on recruitment and selectivity).
    iv. The default for average recruitment should include the entire time series. Justifications for including fewer years should be provided along with model runs of both the full and truncated time series.

f. Definition of model outputs

   i. Biomass measures (e.g., biomass of animals 50 mm and larger). Indicate the assumed time of mating and that of the fishery.

   ii. Recruitment (e.g., number of males and females in the 50-55 mm size-class).

   iii. Fishing mortality (e.g., full-selection F multiplied by selectivity for lengths 80 mm and above). Whether fishing mortality is an exploitation rate or an instantaneous rate should be reported in table headers and the text. The ideal is to report “fishing mortality” as the fully-selected instantaneous fishing mortality rate at the time of the fishery to enhance comparability amongst stock assessments.

g. Critical assumptions and consequences of assumption failures (for example, highlight assumptions regarding *M*, *q*, and selectivity, to which assessments are often very sensitive).

h. Changes to any of the above since the previous assessment.

i. Outline of methods used to validate the code to implement the model and whether the code is available.

3. Model Selection and Evaluation

a. Describe alternative model configurations[1], if any (e.g., alternative *M* values or likelihood weights; use a hierarchical approach where possible (e.g., asymptotic vs. domed selectivities, constant vs. time-varying selectivities)). The model configuration on which the previous assessment was based must be included in the set of models considered in order to retain comparability with previous assessments[2].

b. Show a progression of results from the previous assessment to the preferred base model by adding each new data source and each model modification in turn to enable the impacts of these changes to be assessed. Clearly identify the model used as the basis for each model run. If changes in model results occur, sufficient information should be provided for the CPT / SSC to understand the cause for the changes.

c. Label the approved model from the previous year as model 0.

d. Provide evidence of search for balance between realistic (but possibly over-parameterized) and simpler (but not realistic) models.

e. Provide convergence status and convergence criteria for the base-case model (or proposed base-case model) such as randomization run results or other evidence of a search for the global best estimates.

f. Provide a table (or plot) of the sample sizes assumed for the compositional data. There are several ways for specify input sample size, including:

   i. the number of animals actually measured;

   ii. a fixed constant (e.g., 500);

[1] For Tier 5 assessments “model configuration” refers to the time period over which the mean catch is computed while for Tier 3 and 4 assessments it includes the time period used to define B_{MSY}/B_{REF}.

[2] This information should be included in the May and September versions of the assessment report. However, for ease of reading, information on model configurations and results of model runs considered, but not adopted, should be included in an appendix to the assessment report or in an online location readily accessible during the CPT meetings.

iii. the application of bootstrapping approaches (e.g., Folmer and Pennington, 2000); and

iv. as for i and iii, with a maximum imposed on the input sample size.

The first, third, and last of these approaches allows the input sample sizes (and hence the weight assigned to the compositional data) to reflect uneven sampling over time. The basis for specifying the input sample sizes should be justified, and analyses should be conducted (see Section 4.4 below) to justify the final effective sample sizes.

g. Provide the basis for data weighting, including whether the input effective sample sizes are tuned and the survey CV adjusted.

h. Do parameter estimates for all models make sense and are they credible?

i. Describe criteria used to evaluate the model or to choose among alternative models, including the role (if any) of uncertainty.

j. Show residual analysis (e.g., residual plots, time series plots of observed and predicted values, or other approaches). Note that residual analysis is expected for the base-case model below.

k. Show evaluation of the model, if only one model is presented, or evaluation of alternative models and selection of a final model, if more than one model is presented.

4. Results (best model(s))[3]

Although the author may focus on the author's recommended model run, results should be provided for all model runs that the assessment author considers or the CPT may consider sufficiently plausible that they could form the basis for management advice. Assessment authors should come to the plan team meeting prior to the final reference point setting meeting prepared to present detailed results for all analyses conducted, even if detailed results are not included in the assessment.

1. All tables and figures should be labeled in numerical order (i.e., 1, 2, 3, etc.) and included in the document in sequentially numbered pages.
2. List effective sample sizes, the weighting factors applied when fitting the indices, and the weighting factors applied to any penalties.
3. Include a table showing differences in likelihood.
4. Include tables of estimates (all quantities should be accompanied by confidence intervals or other statistical measures of uncertainty, unless infeasible; include estimates from previous SAFEs for retrospective comparisons), including:
    a. All parameters (include recruitments, selectivity parameters, any estimated growth parameters, catchability, etc.).
    b. Abundance and biomass time series, including spawning biomass and MMB.
    c. Recruitment time series (including average recruitment).
    d. Time series of catch divided by spawning biomass (e.g., MMB).

[3] There may be several "best" models in the Initial assessment draft, but there should be one "best" model in the Final assessment draft as identified by the CPT at the previous meeting.

5. Include graphs of estimates (all quantities should be accompanied by confidence intervals or other statistical measures of uncertainty, unless infeasible), including:
    a. Fishery and survey selectivities, molting probabilities, and other schedules depending on parameter estimates.
    b. Estimated male, female, mature male, total and effective mature biomass time series (indicate the proxy for B_{MSY} on the relevant plots).
    c. Estimated full-selection F over time.
    d. Estimated fishing mortality versus estimated spawning stock biomass, including applicable OFL and maximum F_{target} definitions for the stock (see, for example, Fig. 54 of Turnock and Rugolo, 2008). Graphs of this type are useful to evaluate management performance.
    e. Fit of a stock-recruitment relationship, if feasible.
6. Show evaluation of the fit to the data. Model fits should be represented by a solid line while population estimates should be represented by a dotted line. Estimated confidence intervals should be provided on the fit (results for the models [1-3] included in the document should be plotted together to assist with comparisons between estimates).
    a. Graphs of the fits to observed and model-predicted catches (retained catch and discards), including model-predicted catches and discards for all years to allow discards to be inferred for years for which data are not available.
    b. Graphs of model fits to survey numbers (include confidence intervals for the data and model predictions).
    c. Graphs of model fits to catch proportions by length (e.g., using bubble and/or line plots).
    d. Graphs of model fits to survey proportions by length (e.g., using bubble and/or line plots).
    e. Marginal distributions for the fits to the compositional and tagging data.
    f. Plots of implied versus input effective sample sizes and time-series of implied effective sample sizes.
    g. Tables of the root-mean-square errors (RMSEs) for the indices and a comparison with the assumed values for the coefficients of variation assumed for the indices.
    h. Quantile-quantile (q-q) plots and histograms of residuals (to the indices and compositional data) to justify the choices of sampling distributions for the data.
7. Include retrospective and historical analyses (provide BOTH).
    a. Retrospective analysis of the key management parameter (e.g., MMB; retrospective bias in base model or models by taking the “best” model and truncating the time-series of data on which the assessment is based).
    b. Historical analysis (plot of actual estimates from current and previous assessments).
8. Include uncertainty and sensitivity analyses. Highlight unresolved problems and major uncertainties, along with any special issues that complicate scientific assessment, including questions about the best model, etc.
    a. The best approach for describing uncertainty depends on the situation. Possible approaches (not mutually exclusive) include:

i. Sensitivity analyses (tables or figures) that show ending biomass levels, OFLs, and/or likelihood component values obtained while systematically varying (e.g., halving and doubling) the emphasis factors for each type of data (and penalty) in the model.

ii. Likelihood profiles for parameters or biomass levels.

iii. CVs for biomass or OFL estimated by bootstrap, the delta method, or Bayesian methods.

iv. Subjective appraisal of the magnitude and sources of uncertainty.

v. Retrospective and historical analyses (see above).

vi. Comparison of alternate models and or assumptions (i.e., model structure uncertainty, as evaluated in Section E.3 of this document).

b. It is important that some qualitative or quantitative information about relative probability be stated if a range of model runs (e.g., based on CV's or alternative assumptions about model structure or recruitment) is used to depict uncertainty. It is important to state that all scenarios (or all scenarios between the bounds depicted by the runs) are equally likely if no statements about relative probability can be made.

c. Simulation results.

9. Examine retrospective patterns in estimation of recruitment deviations using squid plots. Do not include the last year in average recruitment calculations.
10. Conduct 'jitter analysis' that involves randomly adjusting all of the initial values (by ~10%), re-running the model fitting process, and recording the resulting likelihood and OFLs or terminal MMB.

F. Calculation of the OFL

1. Include specification of the Tier level and stock status level for computing the OFL, along with the basis for the selection. For Tier 4 and 5 stocks, the rationale for the time period used to define proxy B_{MSY}, B_{REF} (Tier 4) and the average retained catch used to compute the OFL (Tier 5) needs to be specified. Note that the default time period to define B_{REF} is the entire time series (including the current year). Justification and comparative results should be provided for both alternatives.

2. List parameter and stock size estimates (or best available proxies thereof) required by limit and target control rules specified in the fishery management plan.

3. Include specification of the total catch OFL:

   a. Provide the equations (from Amendment 24) on which the OFL is to be based, including the equations used to project discard and bycatch by sex (the mathematical specifications for this need to be documented in a peer-reviewed publication or in a technical appendix).

   b. Provide the basis for projecting MMB to the time of mating (the mathematical specifications for this need to be documented in a peer-reviewed publication or in a technical appendix).

   c. Include specification of F_{OFL}, OFL, and other applicable measures (if any) relevant to determining whether the stock is overfished or if overfishing is occurring (e.g., B_{REF}, $B_{35\%}$). Include estimates from the present assessment and the assessments since 2006/07. Table 2 of this Appendix lists examples of tables for Tiers 3, 4 and 5.

4. Include specification of the retained catch portion of the total catch OFL:

   a. Provide the equations on which the recommendation for the retained portion of the total catch OFL is to be based.

5. Include recommendations for F_{OFL}, OFL total catch, and the retained catch portion of the OFL for the coming year. List the OFLs by sector (retained catch, discard in the directed fishery, bycatch in other crab fisheries, the groundfish fishery, etc.), where appropriate.

G. Calculation of the ABC

1. Include specification of the probability distribution of the OFL used in the ABC control rule, including clear explanation and justification for use of the median or mean.
2. List variables related to scientific uncertainty considered in the OFL probability distribution.
3. List additional uncertainties relative to setting the ABC and include calculation methods for an alternative ABC.
4. Include an author recommended ABC and, if less than maxABC, provide rationale for establishing less than maximum permissible.
5. Always include the maxABC value regardless of author's recommendation.

H. Rebuilding Analyses

Rebuilding analyses should be provided for stocks which are currently under a rebuilding plan.

1. Include the definition of recovery (including the definition of the proxy for B_{MSY} and the number of years that the biomass needs to exceed the proxy for B_{MSY} for the stock to be recovered).
2. State the year in which the rebuilding plan started and the year by which the stock should be recovered to the proxy for B_{MSY}.
3. Include specification of the approach used to project the model forward (e.g., assumptions about parameter uncertainty, future recruitment and selectivity, and how discards and bycatch are computed given fishing mortality on mature males).
4. Include projections under different levels of fishing mortality on mature males to evaluate the probability of recovery to the proxy for B_{MSY} over time. Results should be produced for (a) no targeted fishing, (b) bycatch only, (c) probabilities of recovery of 0.5, 0.6, 0.7 and 0.8, and (d) a harvest strategy corresponding to 75% of the F_{OFL}.
5. Include tables of total catch, retained catch, and probability of recovery against time for the rebuilding strategies listed under (4).
6. Include a graph of the annual status of the stock relative to the B_{MSY} and MSST from the start of the rebuilding period to the present.

I. Data Gaps and Research Priorities

Identify information which could feasibly be collected and analyses which should be undertaken to improve the assessment. Ideally, data collection and analysis needs should be listed in priority order.

J. Literature Cited

Include citations that are relevant to understanding the stock and its status, but are not cited in the report in a special "extra references" section.

K. Presentations

1. Provide single plot of all model data sources and years applicable for each.(add this to Exec summary section too)
2. Provide code for figures to be shared in a repository.

L. Data weighting

1. Provide the weights assigned to the data in the form of CVs (for indices and catches) and effective sample sizes for compositional data.
2. Assessment authors should explore whether the assumed CV for the indices (or catches) match the variation of the residuals. Weighting of indices would involve adding an estimated "extra CV" parameter, which would be estimated.
3. The weighting of the compositional data should be based on computing effective sample sizes for each year using the McAllister-Ianelli (1997) method. If the effective sample sizes are to be tuned, the tuning process should involve multiplying the input sampling sizes by the harmonic mean of the ratio of the McAllister-Ianelli method to the input effective sample size.
4. The McAllister-Ianelli method can lead to biased estimates of effective sample sizes if the residuals are not independent. An alternative approach is that Francis (2011), which involves calculating an effective sample size based on the difference between expected and observed mean lengths by year. Authors should compute the weighting factor developed by Francis (2011), equation TA1,8, and ideally show sensitivity to using Francis weight.

Table 1. Requirements for assessments by Tier level.

Report Section	Tiers 1-3; Tier 4 (with assessment)	Tier 4 (no assessment)	Tier 5
Executive Summary	Yes	Yes	Yes
A. Summary of Major Changes	Yes	Yes	Yes
B. Responses to SSC and CPT comments	Yes	Yes	Yes
C. Introduction	Yes	Yes	Yes
D. Data	Yes	Yes[1]	Yes[2]
E. Analytical Approach	Yes	Yes[3]	Yes[3]
F. Calculation of the OFL	Yes	Yes	Yes
G. Calculation of the ABC	Yes	Yes	Yes
H. Rebuilding Analyses	Yes[4]	Yes[4]	Yes[4]
I. Data Gaps and Research Priorities	Yes	Yes	Yes
J. Ecosystem Considerations	Yes	Yes	Yes
K. Literature Cited	Yes	Yes	Yes

1 – Items 2c, 2e need not be reported in full
2 – Items 2c -2e need not be reported in full
3 – Limited to plots of survey data and catches
4 – Only for stocks under rebuilding

Table 4. Categories for which information on catches and discards should ideally be provided.

Directed pot fishery (males)
Directed pot fishery (females)
Bycatch in other crab fisheries (by sex)
Bycatch in groundfish pot (by sex)
Bycatch in groundfish trawl (by sex)
Bycatch in the scallop fishery