Bristol Bay Red King Crab stock assessment review

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Executive summary, findings and recommendations

Summary

The Alaska Fisheries Science Center (AFSC – Seattle) through the Center for Independent Experts (CIE) requested an independent review for the 2009 Bristol Bay red king crab (BBRKC) stock assessment. This review includes a NMFS trawl survey, a stock assessment model and a harvest strategy for the red king crab (*Paralithodes camtschaticus*) of the southeastern Bering Sea. This review was carried out at NOAA-Sand Point in Seattle (Washington) from June 29 to July 3 of 2009. The other CIE member for the review panel was Dr. Nick Caputi.

During the review process, several people from AFSC, NMFS, ADF&G, BSFRF and NPFRC gave presentations on biology, management, stock assessment, IFQs, survey methodology and observer programs. The meeting was well-organized. Participants engaged in fruitful discussions and were responsive to most of our queries.

The stock assessment is based on a complex sex, stage (old-new shell) and size structured model. It was written in ADMB (Otter Research 2001) and allows for simultaneous estimation of over 200 parameters. Parameter uncertainty is readily available from the ADMB statistical environment. The first version of this model was designed in 1995 and has been used ever since for BBRKC assessment. The stock assessment documentation is large and comprehensive, but requires some improvements to accurately describe the model equations implemented in ADMB. A general overview of the entire code does not indicate any major coding problems, but it is strongly recommended that the code also be implemented in a user friendly platform (i.e., EXCEL) to check for bugs and to facilitate the technical interaction between ADF&G and NMFS scientists.

The reviewers asked Dr. Jie Zheng to re-run the BBRKC stock assessment model under different natural mortality and catchability scenarios. These scenarios produced suboptimal fits to the data, indicating that the current model configuration (Scenario 3 from BBRKC stock assessment report) is better supported by the data. From these additional run results it seems that the model is performing numerically well.

We made several recommendations throughout the text, some strictly related to assessment issues and others to future research work to improve the assessment.

Findings and recommendations

ToR 1: A statement of the strengths and weaknesses of the Bristol Bay red king crab stock assessment and stock projection models.

Strengths

- Since 1991, the EBS NMFS survey gear, vessel and instrumentation have remained fairly constant and provide a consistent methodological approach.
- EBS NMFS survey re-tows (about 30 core stations) seem to be a good empirical approach for dealing with environmental uncertainty in the estimation of fertilized females.
- The new industry survey (Bering Sea Fisheries Research Foundation, BSFRF) represents a good cross-check for NMFS survey abundance estimates.
- The sex and length structured stock assessment model was developed in an appropriate statistical environment (ADMB) which allows for point and standard error estimation.
- Retrospective analysis shows temporal consistency in the relevant population statistics.
- Survey data is generally consistent with fishery data (CPUE).
- Despite the need for further sensitivity analysis, the fixed model parameter values in this case (natural mortality and survey catchability) were more likely than those obtained in alternative case studies requested by the reviewers.
- Stock assessment report includes comments on ecological considerations to try to explain temporal changes in parameter values.

Weaknesses

- Some relevant fisheries data were omitted from the stock assessment. The time series of catch-per-unit effort (catch-per-pot) was not used in the stock assessment, and it would have been useful to have a second index of relative abundance.
- There is a potential bias with inter-annual variability in the EBS NMFS trawl survey abundance estimates due to timing of the survey, spatial dynamics and environmental variability.
- Parameter uncertainty in fixed model quantities was not appropriately addressed in the stock assessment document.
- There is a lack of a general conceptual model that integrates life history and spatial dynamics. This would help to interpret the survey data, model configuration and relevant statistics for management.
- There is a lack of theoretical support for variable natural mortality scenarios. These might be replaced by more mechanistic bycatch mortality scenarios.
- The stock assessment document is extensive but incomplete in describing all model equations and formulations.
- The selection of recruitment time series interval for reference points calculations is debatable.

ToRs 2 and 3: Recommendations of alternative model assumptions and estimators.

- Re-analyze EBS NMFS trawl survey data using an alternative likelihood based geostatistical approach (Roa and Niklitschek 2007). If the same approach is used, the criteria for estimating abundance and its variance across the entire time series should be unified.
- Include new mechanistic scenarios that address more clearly the decline in female and male abundance during the early 1980s (use Griffin et al. 1983 bycatch rates to complete the time series).
- Explore alternative configurations for initial conditions and evaluate their effects on the assessment parameters.
- Improve diagnostics and comparative analyses of different model configuration results (scenarios), including fixed parameter values, effect of likelihood weights, initial conditions.
- More precisely assess the effect of including and excluding the BSFRF survey, with an emphasis on current biomass estimates (males and females) and likelihood value of different pieces of information.
- Use observed proportions as opposed to predicted ones in the variance term of the normal likelihood function.
- Compute implicit sample sizes and variances for each piece of information and compare it to the ones used in the assessment.
- Consider a formal statistical approach to estimate the male size transition matrix externally, using historical tagging data (Punt et al 2009).
- If male molting probabilities are estimated outside of the model (from tagging data), then there should be no need to use old shell and new shell categories in the dynamics of the model. This would simplify model assumptions and the number of parameters to be estimated.
- Assess mature male molting time. If a fraction of mature males are not capable of mating during the survey time (Dew 2009), then the current calculation of mature males available for mating (>120 mm) would be overestimated.
- Because an unknown fraction of the population remains unsampled in the survey and this proportion varies from year to year, it would appropriate to implement a scenario that allows for inter-annual variation in survey availability. Ideally this variation could be modeled based on oceanographic data during the survey, or available year around from ROMs outputs.
- Implement a management strategy evaluation to assess harvest rates under different productivity scenarios.

ToR 4: A review of the results of the BSFRF Bristol Bay red king crab supplemental survey and its potential contribution to the stock assessment.

No technical reports on the BSFRF Bristol Bay red king crab supplemental survey were provided before or during the CIE review. Mr. Steve Hughes, from BSFRF, gave a detailed presentation ("Bering Sea Crab Trawl Surveys 2005-2008") on the motivation, key methodological differences and results differences with EBS NMFS trawl survey. Two surveys were carried out for red king crab in Bristol Bay area in 2007 and 2008. Both had similar configurations and matched in general the NMFS survey grid.

Main differences between surveys are:

- BSFRF includes some stations that are further inshore, especially the geographical area between the historical sampling grid and the Aleutian Islands.
- Sampling nets are different and the BSFRF net allows for a higher proportion of small crab to be captured.
- BSFRF survey tows are shorter and more frequently spaced (4 times).
- NMFS survey uses traditional systematic sampling estimators for mean, variances and BSFRF geostatistical estimators.

The comparison of both approaches indicates that the BSFRF survey yields larger abundance estimates, this being even greater for smaller crab. Confidence bounds are, in general, narrower for the BSFRF survey (using geostatistical analysis). Differences in abundance for larger males are smaller and they can potentially be reduced if geostatistical estimators are used for the NMFS survey data.

I believe that, despite the great methodological differences, the abundance estimates come close together, especially for stock assessment relevant abundance data (larger males). These results validate the NMFS trawl survey, at least from a methodological approach.

The male and female abundance density plots provided by Mr. Steve Hughes do a good job of highlighting a very important point depicted by Dew and McConnaughey (2005), namely, that an unknown fraction of adult males and/or females probably remain outside of the survey area during May and June of each year. This unsampled area encompasses the zone between the southeastern border of the survey polygon and the Aleutian Islands.

The BSFRF survey is a very flexible research platform (i.e. shorter tows, smaller net, crab oriented sampling) for carrying out an exploratory survey in the uninvestigated zone. The spatial dynamics between the researched and unresearched areas are not clear. Swept area sampling and potentially mark recapture studies (using the fishery to recapture the samples) should provide a great opportunity to learn about connectivity between these two areas and the spatial dynamics of this stock in general. Dew (2008) proposed that a fraction of the mature biomass migrate to shallow waters, out of the survey area. This process is also variable in the inter-annual basis, probably regulated by near bottom temperature (NBT).

ToR 5: A review of the cost and benefit of diverting research from studies that would reduce uncertainty in key parameters used in the assessment to conduct a dedicated crab survey.

The BSFRF survey provides a good methodological contrast to assess the performance of the standard multispecies EBS NMFS trawl survey in evaluating red king crab abundance. Despite several technical differences in the sampling procedure, results were similar for relevant stock statistics. From that point of view a dedicated crab survey in the same time period would not be advantageous. Replacing the BBRKC traditional survey by a dedicated crab survey (with BSFRF characteristics) has the disadvantage of breaking the survey time series.

I foresee three main advantages of a dedicated crab survey:

- The possibility of using a different survey gear and sample a larger amount of smaller crab. This might be advantageous for the stock assessment, but it should be evaluated in a MSE framework.
- Delaying survey time to evaluate potential biases in crab abundance because of late migration of a fraction of the population into the survey area. This could also have an inter-annual component.
- Extending the survey area to the zone between the standard NMFS sampling grid and the Aleutian Islands.

The dedicated crab survey can also provide with a good research platform to develop mark recapture programs, aimed at the study of migration, mortality, growth increments and molting probabilities.

ToR 6: Suggested research priorities to improve the stock assessment

- Re-analyze survey data to obtain a consistent time series of mean and variance abundance estimates, considering tow length corrections in early years, re-tows, hotspots and variable swept area.
- Design a survey to estimate the abundance between the survey grid and the Aleutian Islands (potentially based on BSFRF survey).
- Re-analyze the male growth tagging data using a formal statistical approach (Punt et al. 2009) and parameterize the size transition matrix outside the model.
- Standardize CPUE data to generate a fisheries derived index of relative abundance, using soaking time and fishing power.
- Make better use of spatial information of the NMFS survey data to understand the spatial patterns and dynamics of males and females throughout their life history.
- Analyze the historical data on fishing effort, catch by statistical area and perform local depletion estimates using catch and effort data. This, in combination with catch-effort data, should help to understand the localized effect of the fishery.
- Implement a tagging program to better understand the potential ontegenetic migrations (endless belt model, Dew and McConnaughey 2005) and the seasonal

reproductive movement during survey time (male and female inshore-offshore movement).

- Initiate a tagging program to study male molting probabilities and female growth (size transition matrix).
- Extend the time series analysis of recruitment and environmental factors to explore statistically potential regime shifts assumed throughout the assessment document.

Background

The Alaska Fisheries Science Center (AFSC – Seattle) through the Center for Independent Experts (CIE) requested an independent review for the 2009 Bristol Bay red king crab (BBRKC) stock assessment. This review included the NMFS trawl survey, the stock assessment model and the harvest strategy of red king crab (*Paralithodes camtschaticus*) of southeastern Bering Sea.

The Bristol Bay red king crab stock assessment model was developed in 1995 for use in TAC setting. The model incorporates a sex, stage and size-structured statistical stock assessment approach and uses various sources of information. The model has recently been updated for use in setting over fishing levels and determining reference points. This is the first CIE review for this stock.

Description of review activities

Documentation

Before the staff meeting at the AFSC/NOAA in Sand Point (Seattle), several papers from the official BBRKC CIE review webpage were uploaded:

ftp://ftp.afsc.noaa.gov/afsc/public/crab/CrabWS.htm

Before and during the meeting

1. Dew, B. 2008. Red King Crab Mating Success, Sex Ratio, Spatial Distribution, and Abundance Estimates as Artifacts of Survey Timing in Bristol Bay, Alaska. North American Journal of Fisheries Management 28:1618–1637.
2. Dew, B. and McConnaughey, R. 2005. Did trawling on the brood stock contribute to the collapse of Alaska's king crab? Ecological Applications, 15(3): 919–941.
3. Loher, T. and Armstrong, D. 2005. Historical changes in the abundance and distribution of ovigerous red king crabs (*Paralithodes camtschaticus*) in Bristol Bay (Alaska), and potential relationship with bottom temperature. Fish. Oceanogr. 14:4, 292–306.
4. North Pacific Fishery Management Council (NPFMC). 2007. Environmental assessment for proposed amendment 24 to the fishery management plan for Bering Sea and Aleutian Islands king and Tanner crabs to revise overfishing definitions.
5. Otto, R. S. 1986. Management and assessment of eastern Bering Sea king crab stocks. Canadian Special Publication of Fisheries and Aquatic Sciences 92:83–106.
6. The BSAI king and Tanner crab FMP Amendment 24.
7. Weinberg, K., Otto, R. and Somerton, D. 2004. Capture probability of a survey trawl for red king crab (*Paralithodes camtschaticus*). Fish. Bull. 102:740–749.
8. Zheng, J. 2005. A review of natural mortality estimation for crab stocks: data-limited for every stock? Pages 595-612. IN G. H. Kruse, V. F. Gallucci, E.E. Hay, R. I. Perry, R. M. Peterman, T. C. Shirley, P. D. Spencer, B. Wilson, and D.

Woodby (eds.). Fisheries Assessment and Management in Data Limited Situations. Alaska Sea Grant College Program, AK-SG-05-02, Fairbanks, AK.

9. Zheng, J. and G. H. Kruse. 2000. Recruitment patterns of Alaskan crabs and relationships to decadal shifts in climate and physical oceanography. ICES J. Mar. Sci. 57:438-451.
10. Zheng, J. and G. H. Kruse. 2002b. Assessment and management of crab stocks under uncertainty of massive die-offs and rapid changes in survey catchability. Pages 367-384. IN A. J. Paul, E. G. Dawe, R. Elner, G. S. Jamieson, G. H. Kruse, R. S. Otto, B. Sainte-Marie, T. C. Shirley, and D. Woodby (eds.). Crabs in Cold Water Regions: Biology, Management, and Economics. University of Alaska Sea Grant, AK-SG-02-01, Fairbanks.
11. Zheng, J. and G. H. Kruse. 2002a. Retrospective length-based analysis of Bristol Bay red king crabs: model evaluation and management implications. Pages 475-494. IN A. J. Paul, E. G. Dawe, R. Elner, G. S. Jamieson, G. H. Kruse, R. S. Otto, B. Sainte-Marie, T. C. Shirley, and D. Woodby (eds.). Crabs in Cold Water Regions: Biology, Management, and Economics. University of Alaska Sea Grant, AK-SG-02-01, Fairbanks.
12. Zheng, J. and G. H. Kruse. 2006. Recruitment variation of eastern Bering Sea crabs: climate forcing or top-down effects? Prog. Oceanography 68: 184-204.
13. Zheng, J., M.S.M Siddeek. 2008. Bristol Bay Red King Crab Stock Assessment in Fall 2008. **In** the Stock Assessment Fishery Evaluation Report for the King and Tanner Crab Fisheries of the Bering Sea and Aleutian Islands Regions. North Pacific Fishery Management Council, 605 W. 4th Ave. #306, Anchorage, AK.

Review in Seattle

The CIE review was held at NOAA Sand Point in Seattle between June 29 and July 3 of 2009 to consider the 2009 Bristol Bay red king crab stock assessment. The meeting was chaired by Dr. Bob Foy (NMFS, Kodiak) and Dr. Anne Hallowed (AFSC, Seattle).

During the first two days, we had several presentations by people from NMFS, ADF&G, Bering Sea Fisheries Research Foundation and North Pacific Fisheries Management Council, which included topics such as stock assessment, harvest strategies, crab biology, economics and the rationalization of the fishery, observers program, survey methodology, ecosystem considerations, among others. Debate and discussions developed throughout the presentations and the working environment was appropriate.

During Days 3 and 4 we continued with discussions on particular assessment issues, and we asked Dr. Zheng to re-run the model for particular model configurations. These were presented on day four. On the last day both reviewers discussed and shared points of view about the review.

Dr. Nick Caputi from the Department of Fisheries (Western Australia) was the other CIE member on the review panel.

Summary of findings

Conceptual model

The modeling of population dynamics and fishery management of invertebrate stocks can be a difficult task to accomplish, mainly because of a complex life history, spatial dynamics and a lack of age information. The complexity of stock assessment models used for stock status evaluation balances out between a good description of key biological and fishery processes affecting the population dynamics and the amount of available data to estimate key model parameters.

From the stock assessment report and other available documents and papers, it can be inferred that the Bristol Bay red king crab has a complex life history, spatial dynamics and exploitation history. The stock assessment process would greatly benefit from the development of a clear conceptual model that summarizes key life history traits, spatial patterns of abundance and spatial dynamics. This would help to interpret survey and model results, judge several model assumptions and develop auxiliary research work to increase knowledge beyond the scope and structure of the stock assessment model.

Some key components that require special attention are:

- Key life history characteristics (male molting period, female size-at-maturity, etc.)
- Sex specific spatial patterns in the Bristol Bay area and its changes throughout the ontogeny.
- Female lifetime movement from northeast to southwest of Bristol Bay (endless belt hypothesis Dew and McConnaghey 2005).
- Seasonal movement between the survey area and the zone adjacent to the Aleutian Islands and the effect of environmental covariates.
- Timing of multiparous spawning and the effect of environmental factors.

Mark recapture studies and early life history IBMs can help to understand the spatial dynamics of this stock and test hypotheses like the disruption of the pot Sanctuary area by trawlers (Dew and McConnaghey 2005).

EBS NMFS trawl survey

The annual Eastern Bering Sea NMFS trawl survey follows a systematic sampling design, with one station sampled at the center of each 20x20 nm grid. Since 1973, the survey has covered the entire BBRKC stock distribution. The database is being compiled and maintained by NMFS personnel in Alaska; it is currently under review and several improvements have been introduced to account for temporal biases and variance calculations.

In the last forty years, several changes/improvements have been introduced in the sampling procedure. This information will soon be documented in a comprehensive technical survey report. Figure 1 summarizes these changes.

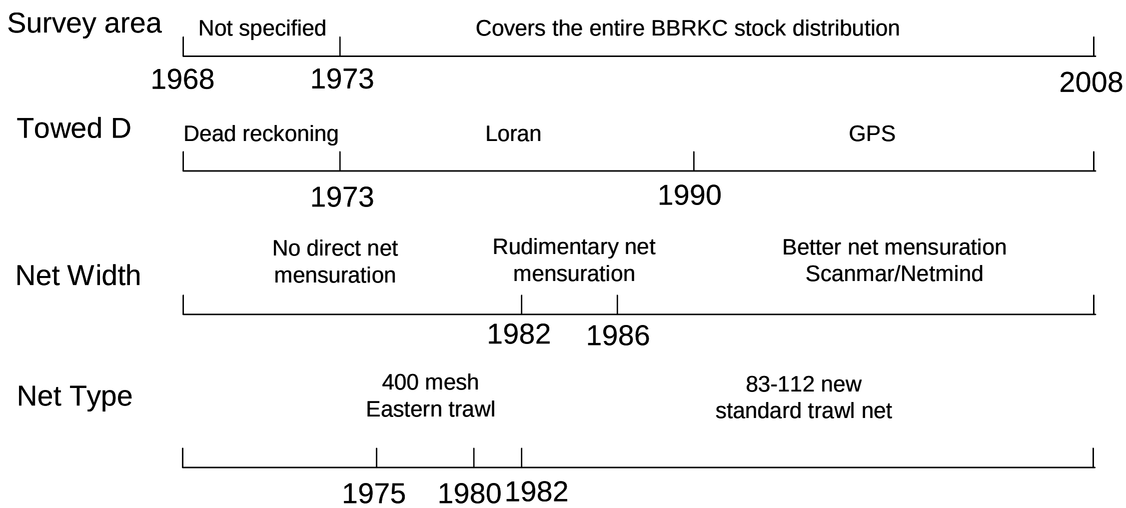

Figure 1: Relevant changes in EBS NMFS trawl survey.

The estimation of density for one particular tow (not accounting for selectivity) would be a function of the following five quantities.

$$\hat{D} = \frac{\alpha\, q\, N}{w\, L}$$

$\hat{D}$: estimated density
α : availability coefficient
q : catchability coefficient
N : number of crab in the gear
w : width of net
L : total distance traveled by the gear

Generally w and L are known quantities (with no measurement error). These quantities have been assessed with accurate instruments since 1986. Net width mensuration was only rudimentary between 1982 and 1986. The early part of the time series did not have a direct net width measurement, towing distance was estimated by dead reckoning and probably the survey did not covered the entire stock distribution. These factors might have induced some biases or at least generate greater uncertainty in abundance estimates. From the information provided in the stock assessment report, the point estimates and their associated uncertainty of survey abundance between 1968 and 1972 were taken at face values from assessment reports. Figure 12a from Zheng and Siddeek (2009) shows very precise abundance estimates, which could be affecting the stock assessment in early years. I recommend to carefully address this issue and consider the possibility of running some scenarios with more uncertainty associated to those abundance estimates.

Different initial conditions and very uncertain abundance estimates for the first five years of the series might create a different recruitment pattern, which might have consequences for reference point calculations.

Several other issues were discussed during the meetings, some of them being re-tows, hot-spot and the possibility of using geostatistics for abundance estimation. I recommended the use of likelihood based geostatistics (Roa and Niklitscheck 2007).

Initial conditions

The initial conditions of statistical stock assessment models can strongly affect the dynamics of early years of the population. These model equations were not found in the stock assessment document and need to be incorporated. Drs. Zheng and Siddeek indicated during the meeting that they based the initial population size structure on a 1968 survey size frequency and an estimated parameter that scaled the proportions to abundance at size.

The size structure from the survey in those early years was probably very unreliable, so we recommend assessing the sensitivity of the model to this assumption using other initial conditions. Of special interest is the effect on the time series of estimated recruitments for early years of the time series.

Growth

Somatic growth is an important component of size-structured models and is represented in Bristol Bay red king crab by a size transition matrix and a molting probability function (males).

Size transition matrix

Sex specific size transition matrices are used in the red king crab stock assessment model. The probability of growing from one size bin to another is modeled by gamma density with a variable mean growth increment at size and an estimated beta parameter for each sex. For males, mean size increments were estimated outside the stock assessment model based on historical tagging data (Figure 2). It is recommended to re-analyze the male tagging data and estimate the full size transition matrix outside of the model using formal statistical procedures (Punt et al 2009). This would reduce the number of estimated parameters within the stock assessment model, probably reducing potential parameter confounding effects.

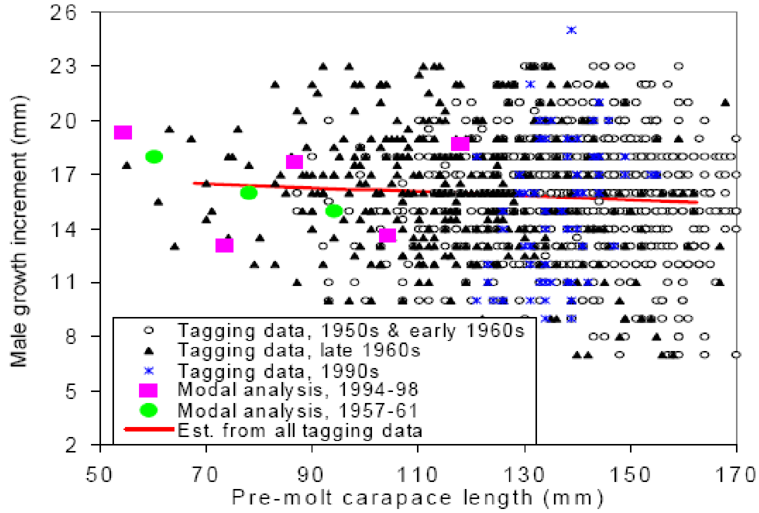

Figure 2: Size increments at size for the male red king crab (from Zheng and Siddeek 2009)

Tagging data is not available for Bristol Bay red king crab female size transition matrix parameterization. The mean size increment was estimated based on modal decomposition analysis. The general pattern is a sharp decline in molt increments at the onset of maturity and a less conspicuous linear decline at sizes greater than 90 mm (Figure 3). The size increment data shows a clear linear trend and not much variability, probably because the data was derived from a von Bertalanffy growth model.

I suggest developing a tagging program, to better characterize red king crab female growth in the Bristol Bay area, and to fully estimate the size transition matrix parameters outside the stock assessment model.

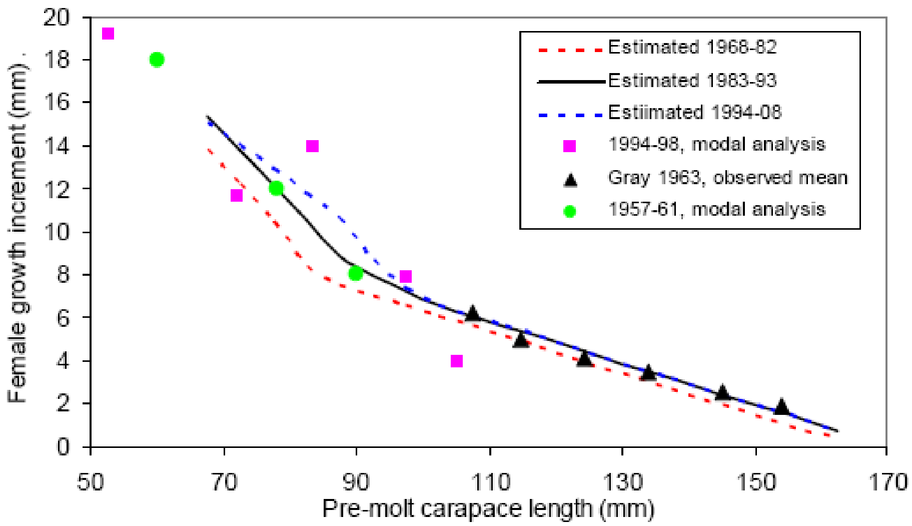

Figure 3: Female growth increments at size for BBRKC females (from Zheng and Siddeek 2009)

Molting probabilities

A molting probability function is only used to model male growth. Females show an annual molting schedule. The molting probability function is probably confounded with mean size increment, because morphometric changes can be explained by molting frequency and size increments at molt.

Male molting probabilities that were estimated internally within the stock assessment model coincide with molting probabilities that were estimated from tagging data. I recommend using tagging data to estimate male molting probabilities outside the stock assessment model.

Natural mortality

Natural mortality was computed based on an estimated maximum age of 25 years and the 1% rule (Zheng 2005). The estimated M=0.18 value should be handled with care, because no good estimate of maximum age is available for red king crab. Zheng (2005) compiled red king crab natural mortality estimates from the scientific literature and values ranged from 0.1 to 1.75, clearly indicating that the natural mortality value for BBRKC is an open question.

In the stock assessment model, natural mortality is allowed to change in some particular years (males and females independently) to deal with some major unexplained mortalities. Some of these mortalities are associated with the high bycatch of trawl and pot fisheries in the early 1980s. More plausible alternative mechanistic bycatch mortality scenarios should be explored before letting difficult to defend abrupt natural mortality changes account for unaccounted mortalities.

Based on additional model runs and under scenario 3 model configuration (Zheng and Siddeek 2009), values of M=0.13 and M=0.26 are less likely (based on the assessment data) than an M value of 0.18 (see additional model runs). Nevertheless these results apply under the model configuration of scenario 3.

It is recommended that a more comprehensive sensitivity analysis be performed considering other model configurations (scenarios) to evaluate M.

Females are only affected by natural and bycatch mortalities (less confounding effect with F); therefore a good tagging project might help to obtain more appropriate natural mortality estimates for females.

Fisheries data

The commercial pot fishery catch rates are included in the stock assessment report, but not in the assessment. Despite the fact of being non-standardized data, it tracks, in general, the abundance survey very well (Figure 4). Major differences arise at the beginning and at the end of the time series. Good observer data should be available from the middle of the time series, so that it might be possible to standardize the catch rates from 1988 through 2008. Prior archival data might be available to standardize the first half of the time series. After the rationalization of the fishery (2005), soaking time seems to be an important factor to have in mind. It is good to have a second source of relative abundance to calibrate the stock assessment model, especially one closely associated to fishery. This statistic would be necessary for implementing a bioeconomical modeling approach and estimating bioeconomical reference points.

A spatial analysis of catch and effort information should provide helpful insights on spatial and temporal patterns of target crab catch and bycatch. This, in conjunction with spatial information provided by the survey, can reveal some unexplained spatial dynamics.

Additionally, analyzing catch and effort data by statistical areas throughout the season (one or 2 weeks) might provide estimates of local harvest rates through Leslie-Delury estimators (Hilborn and Walters 1992).

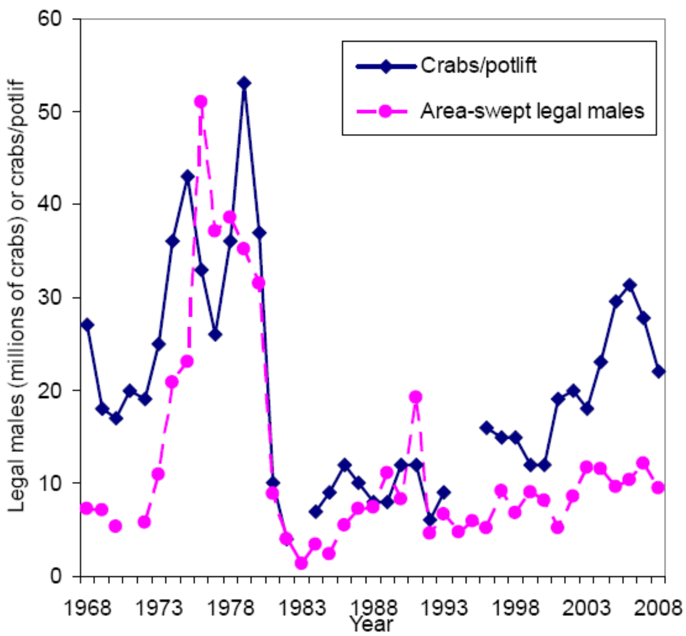

Figure 4: NMFS survey abundance estimates and commercial pot catch rates for BBRKC (source: Zheng and Siddeek 2009)

Historical by-catch data

Dew and McConnaghey (2005) and Dew (2008) indicated that much of the rapid historical BBRKC decline could be explained by massive bycatch mortalities induced by trawl and red king and tanner crab pot fisheries between the mid-1970's and 1980's. Regular bycatch sampling in the BBRKC and tanner crab fishery started only in the 1988/1989 season, so direct estimates are not available for those years.

During the meetings in Seattle, Dr. Lou Rugolo and Jack Turnock pointed out that the Griffin et al, 1983 report provides good bycatch rate estimates of sublegal males and females from the red king crab fishery. Using those discard rates before and after 1983, they were able to reconstruct the female and undersized male crab bycatch time series for those years (Figure 5). Dr Zheng indicated that this calculation would hold only if the population size structure was at equilibrium. His point was well taken, but additional information was provided by Mr. Turnock, indicating that the ratio of males in the 110-134 mm to greater than 110 mm categories had not changed dramatically (Figure 5b).

I recommend that a stock assessment scenario on Tanner and RKC crab bycatch be evaluated on the basis of these numbers or something along these lines. This could potentially explain the great decay in females and smaller males throughout this period and avoid the need to incorporate sudden changes in natural mortality.

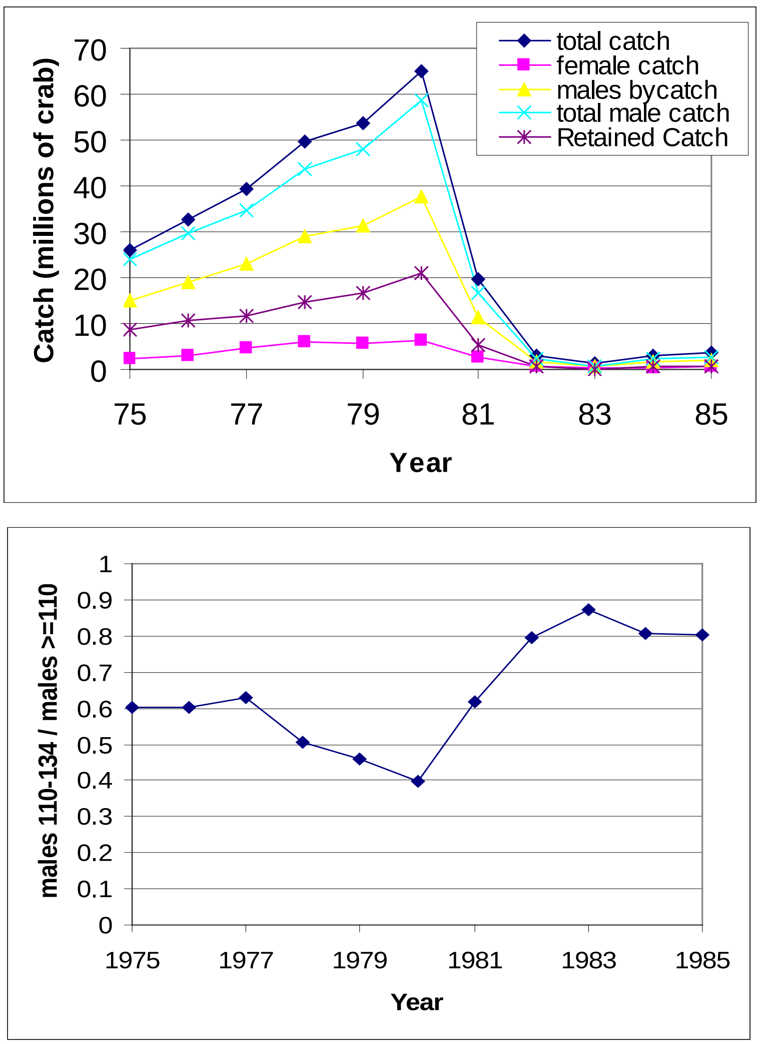

Figure 5: Upper panel: Estimated bycatch of small males and females from the red king crab fisheries. Lower panel: Ratio of males between 110 and 134 mm to males greater than 110 mm.

Stock assessment report

The stock assessment report is comprehensive. Some model equations in the report need improvement to facilitate the reader an accurate interpretation of the stock assessment model. A glossary with all parameters of the model, including weights/variances and sample sizes would definitely facilitate the understanding and interpretation of the model. Of special interest is a clear specification of which parameters are being estimated. The description of the initial conditions was missing in the report.

The current multinormal likelihood function for proportions might be producing biased results. Maunder and Watters (2003) switched predicted for observed proportions in the variance component of the length frequency likelihood. I recommend to check this option or to try a multinomial likelihood.

All the candidate scenarios should be clearly organized in a table, including model configurations. The results of model sensitivity to different assumptions should be better organized, presenting in a table the values for each likelihood component, gradient and number of parameters (see additional model runs).

Implicit variance and effective sample size calculation were missing in the report, these are helpful diagnostics.

Scenarios

The variances and sample sizes can, in some cases, have a large influence on the stock assessment results, therefore a sensitivity analysis should be carried out to determine the influence of the sample sizes and variance components. I recommend including an additional variance component to the initial part of the survey time series, because it should be more uncertain. This might be playing an important role in the early years of the assessment.

Other scenarios should consider alternative initial conditions, M and q values. Based on the BSFRF survey it can be inferred that a fraction of the crab population is not available to the survey between May and June (Figure 6). Dew (2008) proposed some relationship with temperature. I recommend an exploratory scenario, where additional near bottom temperature related availability parameters be incorporated into de model.

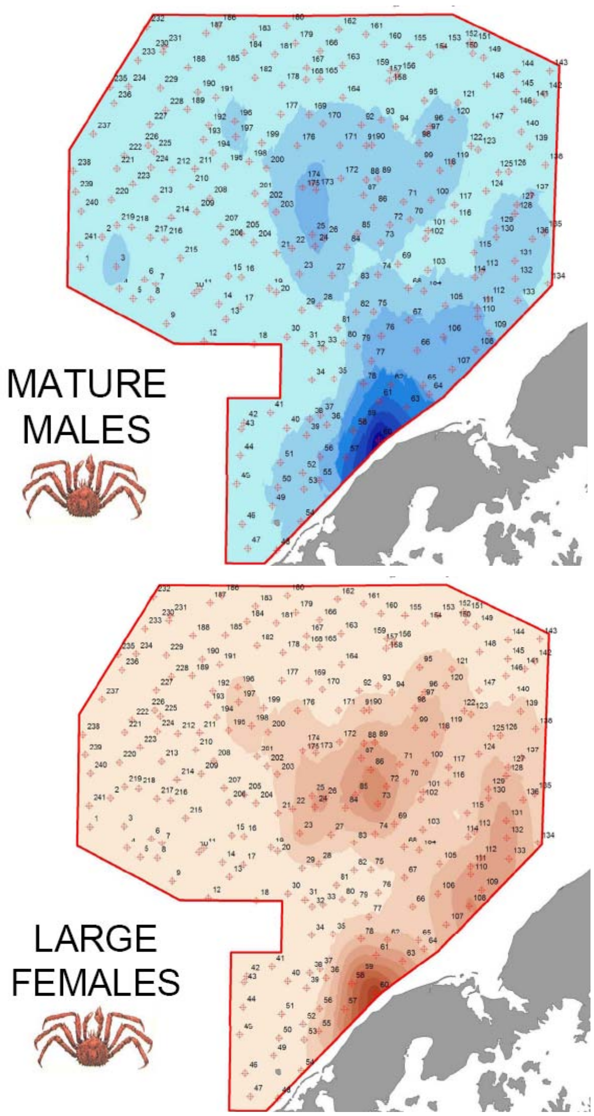

Figure 6: Mature males and large female density plots during 2008 survey (source: Presentation by Mr. Steve Hughes from BSFRF).

Additional model runs

The CIE reviewers asked Dr. Jie Zheng to do some additional model runs to evaluate the sensitivity of the stock assessment model to alternative survey catchability and natural mortality values. In order to keep this exercise simple, we chose scenario 3 (from the stock assessment report) as the base case scenario. This scenario was also chosen by the Crab Plan Team for the 2009 assessment.

The following table summarizes different model run characteristics:

Scenarios	Parameters M	Parameters q	N estimated parameters	Description
3(base)	0.18	Est.	223	Three additional natural mortality parameters are estimated
SC3a	0.18	0.5	222	
SC3b	0.26	0.5	222	
SC3c	0.13	0.5	222	
SC3	0.18	Est.	223	No additional M estimated. Additional bycatch is estimated for Tanner RKC fisheries 1980-1984.
3d	0.26	Est.	223	Same as 3(base) but M=0.26

The results include likelihood values for each piece of information, implied reference points based on mean male recruitment for 1995-2008 and recruitment per mature male biomass.

Table 1: Likelihood components of each piece of information for six different model runs requested by the CIE reviewers (Data provided by Dr. Jie Zheng after the CIE review in Seattle).

	Negative Log Likelihood Components					
	3(base)	**SC3a**	**SC3b**	**SC3c**	**SC3**	**3D**
M	**0.18**	**0.18**	**0.26**	**0.13**	**0.18**	**0.26**
q	**Est.**	**0.5**	**0.5**	**0.5**	**Est.**	**Est.**
Recruitment Variation	148	139	136	148	134	150
Sex Ratio of Recruitment	0.007	0.021	0.006	0.030	0.001	0.017
Length Comp - Retained Catch	-992	-986	-996	-981	-1089	-917
Length Comp -Pot Male Discard	-712	-714	-708	-715	-711	-704
Length Comp - Pot Female Discard	-1865	-1871	-1841	-1875	-1870	-1858
Length Comp Survey	-48885	-48813	-48789	-48830	-48741	-48880
Length Comp Trawl Discard	-1674	-1665	-1670	-1663	-1670	-1682
Pot Discd Male Biomass	132	131	133	130	113	134
Retained Catch Biomass	30	30	29	31	35	29
Survey Biomass	75	86	95	120	106	78
Others	-111	-111	-113	-106	-53	-107
Total Negative Log Likelihood	-53854	-53773	-53724	-53741	-53745	-53757
Maximum Gradient Component	0.960	0.675	0.660	0.992	0.596	0.971

Results indicate that base case scenario 3 is the one mostly supported by the data, with a difference of about 80 and 100 units of likelihood with respect to scenarios 3a and 3D. This implies that under base case Scenario 3, lower catchability values or higher/lower natural mortality rates are less supported by the data. Results of Scenario SC3 indicate that even under a constant mortality rate of M=0.18, including additional sources of bycatch mortality greatly improve the fit to length frequency data of the catch (Table 1).

Only scenarios with different natural mortality values yielded different reference points, as expected smaller with lower M and larger with higher natural mortality.

The model behaved well (converged) under different parameter configurations and the original parameters that are being used are more consistent with the available data.

Table 2: Estimated reference points for six different model runs requested by the CIE reviewers (Data provided by Dr. Jie Zheng after the CIE review in Seattle).

	F_{ref} and B_{ref} (mill lbs)					
	Bref based on mean male R for 1995-2008					
	3(Base)	SC3a	SC3b	SC3c	SC3	3d
M	0.18	0.18	0.26	0.13	0.18	0.26
q	Est.	0.5	0.5	0.5	est.	Est.
F_{35}	0.33	0.32	0.51	0.22	0.32	0.53
B_{35}	77.5	48.6	39.1	66.5	73.0	61.2
F_{40}	0.26	0.26	0.41	0.18	0.26	0.42
B_{40}	89.8	55.2	44.5	75.6	83.2	70.0

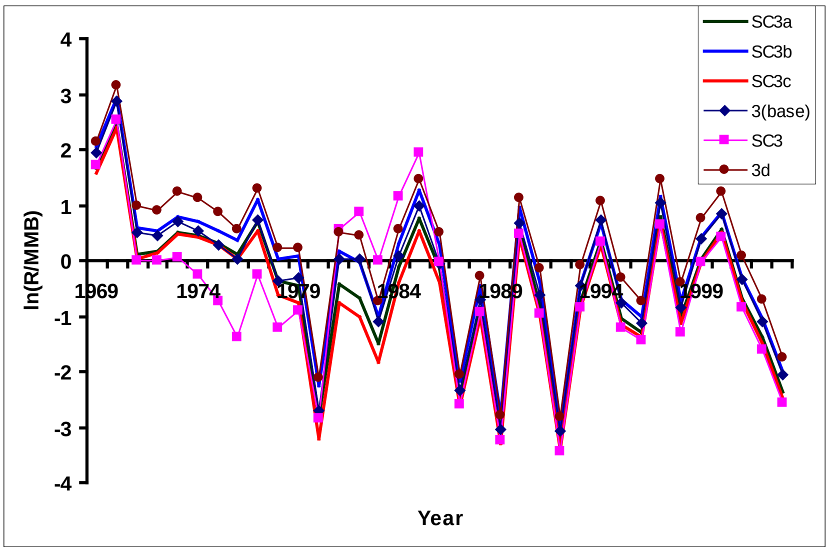

Figure 7: Recruit per spawner (mature male biomass) for six different model runs requested by the CIE reviewers (Figure provided by Dr. Jie Zheng after the CIE review in Seattle).

Recruitment

The estimated recruitment time series for scenario 3 in the stock assessment report (Figure 33b) shows some degree of autocorrelation, some inter-annual variability and three periods of different average recruitment (1969-1984, 1984-1994 and 1995-2008). During the meeting there was substantial debate on possible causes of recruitment changes being finally summarized by the following five points:

1. Environmental conditions (decadal signal) have directly affected red king crab recruitment.

2. Environment has favored the increase in ground fish populations, which have negatively impacted red king crab survival of early life stages.

3. Ground fishery:

a) Induced high RKC female mortality through bycatch during early years
b) Induced a change in habitat

4. The cold pool retracted the spatial distribution of the reproductive potential to the NE.

5. The spatial distribution of the reproductive potential has affected the larval distribution.

Some of these mechanisms imply a change in the underlying stock recruitment relationship (1, 3b and 5). This is relevant at the moment of defining the mean recruitment level used for reference point calculation.

Figure 7 shows a drop in the recruit-per-spawner relationship between 1968-1979. The early part of the time series is affected by different scenarios, so more analysis could show a less abrupt change in productivity. Nevertheless, the very early years of the time series are always going to be the most productive ones, in order to account for a phenomenal increase in biomass from1968 to 1977.

Management Strategies evaluation

As in many other crustacean stocks Bristol Bay red king crab does not have a well defined stock-recruitment relationship. There is a lot of uncertainty in the current productivity level of this stock. Is the stock in a low, medium or high productivity level? To deal with this kind of structural and parameter uncertainty, it is recommended to implement a formal management strategy evaluation to assess harvest strategies under current control rules. They derive from Federal and State regulations.

Different scenarios of recruitment trends and variability can be explored, addressing some of the 5 hypothesis mentioned above.

Bibliography

Dew, B. 2008. Red King Crab Mating Success, Sex Ratio, Spatial Distribution, and Abundance Estimates as Artifacts of Survey Timing in Bristol Bay, Alaska. North American Journal of Fisheries Management 28:1618–1637.

Dew, B. and McConnaughey, R. 2005. Did trawling on the brood stock contribute to the collapse of Alaska's king crab? Ecological Applications, 15(3): 919–941.

Hilborn, R. y C. Walters. 1992. Quantitative fisheries stock assessment: Choice, dynamics and uncertainty. Routledge, Chapman y Hall, New York, 570 pp.

Maunder M. and Watters, G. (2003). A-SCALA: An age-structured statistical catch-at-length analysis for assessing tuna stocks in the eastern Pacific Ocean. INTER-AMERICAN TROPICAL TUNA COMMISSION Vol. 22, No. 5.

Punt, A, Buckworth, C., Dichmont, C. and Yimin, Y. 2009 Performance of methods for estimating size–transition matrices using tag–recapture data. Marine and Freshwater Research 60, 168–182.

Roa-Ureta, R., and Niklitschek, E. 2007. Biomass estimation from surveys with likelihood-based geostatistics. – ICES Journal of Marine Science, 64: 1723–1734.

Zheng, J. 2005. A review of natural mortality estimation for crab stocks: data-limited for every stock? Pages 595-612. IN G. H. Kruse, V. F. Gallucci, E.E. Hay, R. I. Perry, R. M. Peterman, T. C. Shirley, P. D. Spencer, B. Wilson, and D. Woodby (eds.). Fisheries Assessment and Management in Data Limited Situations. Alaska Sea Grant College Program, AK-SG-05-02, Fairbanks, AK.

Zheng, J., M.S.M Siddeek. 2009. Bristol Bay Red King Crab Stock Assessment in Spring 2009. 135 p.

Appendix 1: Statement of Work for Dr. Billy Ernst

External Independent Peer Review by the Center for Independent Experts

Bristol Bay Red King Crab Stock Assessment

Scope of Work and CIE Process: The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract to provide external expertise through the Center for Independent Experts (CIE) to conduct impartial and independent peer reviews of NMFS scientific projects. This Statement of Work (SoW) described herein was established by the NMFS Contracting Officer's Technical Representative (COTR) and CIE based on the peer review requirements submitted by NMFS Project Contact. CIE reviewers are selected by the CIE Coordination Team and Steering Committee to conduct the peer review of NMFS science with project specific Terms of Reference (ToRs). Each CIE reviewer shall produce a CIE independent peer review report with specific format and content requirements (**Annex 1**). This SoW describes the work tasks and deliverables of the CIE reviewers for conducting an independent peer review of the following NMFS project.

Project Description: The CIE requests a review of the population dynamics and harvest strategy models for the Bristol Bay red king crab (*Paralithodes camtschaticus*) assessment. While a red king crab stock assessment model was developed in 1995 for use in TAC setting, the model has recently been revised for use in setting overfishing levels and determining reference points. An independent review of this revised model is needed to evaluate it's suitability in defining overfishing definitions and reference points.

The red king crab assessment is a high profile assessment and with the adoption of revisions to the overfishing definitions it is critical that it provides the best available science on the status of this resource. The CIE requests a review of the use of Bering Sea trawl survey data in the assessment, the stock assessment model structure, assumptions, life history data, and harvest control rule. New overfishing definitions for Bering Sea crab stocks require the use of the red king crab stock assessment model to estimate reference points and the status of the stock relative to those reference points. Uncertainty exists in several key parameters including the survey selectivity and catchability, molting probabilities, natural mortality, discard mortality and age. This review will help in the decision process as to which alternative model is most appropriate, given the current state of knowledge of Bristol Bay red king crab.

The CIE also requests a review of the potential utility of conducting a dedicated crab survey for eastern Bering Sea stocks including Bristol Bay red king crab (BBRKC). The current survey is a multispecies survey that has issues with respect to survey timing relative to mating, molting and egg extrusion, survey boundaries and movement, and catchability. The CIE should comment on the costs and benefits of a crab specific survey relative to other research needed to improve the red king crab stock assessment.

The Terms of Reference (ToRs) of the peer review are attached in **Annex 2**.

The tentative agenda of the panel review meeting is attached in **Annex 3**.

Requirements for CIE Reviewers: Two CIE reviewers shall conduct an impartial and independent peer review in accordance with the SoW and ToRs herein. Each CIE reviewer's duties shall not exceed a maximum of 14 days to complete all work tasks of the peer review described herein. CIE reviewers shall have the expertise, background, and experience to complete an independent peer review in accordance with the SoW and ToRs herein. CIE reviewer expertise shall include working experience with stock assessment, estimates of survey catchability and selectivity, population dynamics, length based models, knowledge of crab life history and biology, harvest strategy models for invertebrates, and the AD Model Builder programming language.

Location of Peer Review: The CIE reviewers shall participant during a panel review meeting in Seattle, Washington to conduct a peer review of the stock assessment with the authors of the red king crab assessment in accordance to the Schedule of Milestones and Deliverables herein.

Statement of Tasks: Each CIE reviewers shall complete the following tasks in accordance with the SoW and Schedule of Milestones and Deliverables herein.

Prior to the Peer Review: Upon completion of the CIE reviewer selection by the CIE Steering committee, the CIE shall provide the CIE reviewer information (name, affiliation, and contact details) to the COTR, who forwards this information to the NMFS Project Contact no later the date specified in the Schedule of Milestones and Deliverables. The CIE is responsible for providing the SoW and ToRs to the CIE reviewers. The NMFS Project Contact is responsible for providing the CIE reviewers with the background documents, reports, foreign national security clearance, and information concerning other pertinent meeting arrangements. The NMFS Project Contact is also responsible for providing the Chair a copy of the SoW in advance of the panel review meeting. Any changes to the SoW or ToRs must be made through the COTR prior to the commencement of the peer review.

Foreign National Security Clearance: When CIE reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for CIE reviewers who are non-US citizens. For this reason, the CIE reviewers shall provide requested information (e.g., name, contact information, birth date, passport number, travel dates, and country of origin) to the NMFS Project Clearance for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations (available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/sponsor.html).

Pre-review Background Documents: Two weeks before the peer review, the NMFS Project Contact will send by electronic mail or make available at an FTP site the CIE reviewers all necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE on where to send documents. The CIE reviewers shall read all documents in preparation for the peer review including the following:

1. Zheng, J., M.S.M Siddeek. 2008. Bristol Bay Red King Crab Stock Assessment in Fall 2008. **In** the Stock Assessment Fishery Evaluation Report for the King and Tanner Crab Fisheries of the Bering Sea and Aleutian Islands Regions. North Pacific Fishery Management Council, 605 W. 4th Ave. #306, Anchorage, AK.
2. North Pacific Fishery Management Council (NPFMC). 2007. Environmental assessment for proposed amendment 24 to the fishery management plan for Bering Sea and Aleutian Islands king and Tanner crabs to revise overfishing definitions.
3. The BSAI king and Tanner crab FMP Amendment 24.
4. Zheng, J. 2005. A review of natural mortality estimation for crab stocks: data-limited for every stock? Pages 595-612. IN G. H. Kruse, V. F. Gallucci, E.E. Hay, R. I. Perry, R. M. Peterman, T. C. Shirley, P. D. Spencer, B. Wilson, and D. Woodby (eds.). Fisheries Assessment and Management in Data Limited Situations. Alaska Sea Grant College Program, AK-SG-05-02, Fairbanks, AK.
5. Zheng, J. and G. H. Kruse. 2000. Recruitment patterns of Alaskan crabs and relationships to decadal shifts in climate and physical oceanography. ICES J. Mar. Sci. 57:438-451.
6. Zheng, J. and G. H. Kruse. 2002a. Retrospective length-based analysis of Bristol Bay red king crabs: model evaluation and management implications. Pages 475-494. IN A. J. Paul, E. G. Dawe, R. Elner, G. S. Jamieson, G. H. Kruse, R. S. Otto, B. Sainte-Marie, T. C. Shirley, and D. Woodby (eds.). Crabs in Cold Water Regions: Biology, Management, and Economics. University of Alaska Sea Grant, AK-SG-02-01, Fairbanks.
7. Zheng, J. and G. H. Kruse. 2002b. Assessment and management of crab stocks under uncertainty of massive die-offs and rapid changes in survey catchability. Pages 367-384. IN A. J. Paul, E. G. Dawe, R. Elner, G. S. Jamieson, G. H. Kruse, R. S. Otto, B. Sainte-Marie, T. C. Shirley, and D. Woodby (eds.). Crabs in Cold Water Regions: Biology, Management, and Economics. University of Alaska Sea Grant, AK-SG-02-01, Fairbanks.
8. Zheng, J. and G. H. Kruse. 2006. Recruitment variation of eastern Bering Sea crabs: climate forcing or top-down effects? Prog. Oceanography 68: 184-204.

This list of pre-review documents may be updated up to two weeks before the peer review. Any delays in submission of pre-review documents for the CIE peer review will result in delays with the CIE peer review process, including a SoW modification to the schedule of milestones and deliverables. Furthermore, the CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein.

Panel Review Meeting: Each CIE reviewers shall conduct the independent peer review in accordance with the SoW and ToRs. **Modifications to the SoW and ToRs can not be made during the peer review, and any SoW or ToRs modifications prior to the peer review shall be approved by the COTR and CIE Lead Coordinator.** Each CIE reviewer shall actively participate in a professional and respectful manner as a member of the meeting review panel, and their peer review tasks shall be focused on the ToRs as specified in the contract SoW. The NMFS Project Contact is responsible for any facility arrangements (e.g., conference room for panel review meetings or teleconference arrangements). The CIE Lead Coordinator can contact the Project Contact to confirm any peer review arrangements, including the meeting facility arrangements.

Contract Deliverables - Independent CIE Peer Review Reports: Each CIE reviewer shall complete an independent peer review report in accordance with the SoW. Each CIE reviewer shall complete the independent peer review according to required format and content as described in Annex 1. Each CIE reviewer shall complete the independent peer review addressing each ToR as described in Annex 2.

Other Tasks – Contribution to Summary Report: Each CIE reviewer will assist the Chair of the panel review meeting with contributions to the Summary Report. CIE reviewers are not required to reach a consensus, and should instead provide a brief summary of their views on the summary of findings and conclusions reached by the review panel in accordance with the ToRs.

Specific Tasks for CIE Reviewers: The following chronological list of tasks shall be completed by each CIE reviewer in a timely manner as specified in the **Schedule of Milestones and Deliverables**.

1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review;
2) Participate during the panel review meeting at the NMFS Alaska Fisheries Science Center from June 29 – July 3, 2009, as called for in the SoW, and conduct an independent peer review in accordance with the ToRs (Annex 2);
3) No later than July 17, 2009, each CIE reviewer shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Mr. Manoj Shivlani, CIE Lead Coordinator, via email to shivlanim@bellsouth.net, and CIE Regional Coordinator, via email to David Die at ddie@rsmas.miami.edu.
4) Each CIE report shall be written using the format and content requirements specified in Annex 1, and address each ToR in Annex 2;
5) CIE reviewers shall address changes as required by the CIE review in accordance with the schedule of milestones and deliverables.

Schedule of Milestones and Deliverables: CIE shall complete the tasks and deliverables described in this SoW in accordance with the following schedule.

25 May 2009	CIE sends reviewer contact information to the COTR, who then sends this to the NMFS Project Contact
15 June 2009	NMFS Project Contact sends the CIE Reviewers the pre-review documents
29 June - 3 July 2009	Each reviewer participates and conducts an independent peer review during the panel review meeting (June 29-July 3, 2009)
17 July 2009	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
31 July 2009	CIE submits CIE independent peer review reports to the COTR
7 August 2009	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

Modifications to the Statement of Work: Requests to modify this SoW must be made through the Contracting Officer's Technical Representative (COTR) who submits the modification for approval to the Contracting Officer at least 15 working days prior to making any permanent substitutions. The Contracting Officer will notify the CIE within 10 working days after receipt of all required information of the decision on substitutions. The COTR can approve changes to the milestone dates, list of pre-review documents, and Terms of Reference (ToR) of the SoW as long as the role and ability of the CIE reviewers to complete the SoW deliverable in accordance with the ToRs and deliverable schedule are not adversely impacted. The SoW and ToRs cannot be changed once the peer review has begun.

Acceptance of Deliverables: Upon review and acceptance of the CIE independent peer review reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, these reports shall be sent to the COTR for final approval as contract deliverables based on compliance with the SoW. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via e-mail the contract deliverables (the CIE independent peer review reports) to the COTR (William Michaels, via William.Michaels@noaa.gov).

Applicable Performance Standards: The contract is successfully completed when the COTR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards: (1) each CIE report shall have the format and content in accordance with Annex 1, (2) each CIE report shall address each ToR as specified in Annex 2, (3) the CIE reports shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Distribution of Approved Deliverables: Upon notification of acceptance by the COTR, the CIE Lead Coordinator shall send via e-mail the final CIE reports in *.PDF format to the COTR. The COTR will distribute the approved CIE reports to the NMFS Project Contact and regional Center Director.

Key Personnel:

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Annex 1: Format and Contents of CIE Independent Peer Review Report

1. The CIE independent report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations.

2. The main body of the reviewer report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Summary of Findings for each ToR, and Conclusions and Recommendations in accordance with the ToRs.

   a. Reviewers should describe in their own words the review activities completed during the panel review meeting, including providing a detailed summary of findings, conclusions, and recommendations.

   b. Reviewers should discuss their independent views on each ToR even if these were consistent with those of other panelists, and especially where there were divergent views.

   c. Reviewers should elaborate on any points raised in the Summary Report that they feel might require further clarification.

   d. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

   e. The CIE independent report shall be a stand-alone document for others to understand the proceedings and findings of the meeting, regardless of whether or not they read the summary report. The CIE independent report shall be an independent peer review of each ToRs, and shall not simply repeat the contents of the summary report.

3. The reviewer report shall include as separate appendices as follows:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: A copy of the CIE Statement of Work
   Appendix 3: Panel Membership or other pertinent information from the panel review meeting.

Annex 2: Terms of Reference for the Peer Review

Review of the Bristol Bay Red King Crab Assessment

. The report generated by the consultant should include:

1. A statement of the strengths and weaknesses of the Bristol Bay red king crab stock assessment and stock projection models;
2. Recommend for alternative model configurations or formulations;
3. Recommendations of alternative model assumptions and estimators.
4. A review of the results of the BSFRF Bristol Bay red king crab supplemental survey and its potential contribution to the stock assessment.
5. A review of the cost and benefit of diverting research from studies that would reduce uncertainty in key parameters used in the assessment to conduct a dedicated crab survey.
6. Suggested research priorities to improve the stock assessment.

APPENDIX 2: Meeting Agenda
Schedule for CIE review of the Bristol Bay Red King Crab stock assessment

June 29-July 3, 2009
Alaska Fisheries Science Center, Seattle, WA

Purpose: To solicit expert advice on the stock assessment for Bristol Bay Red King Crab. We are requesting a review of issues critical to formulating overfishing definitions, biological reference points, input parameters, modeling approaches and methods to deal with uncertainty.

Day 1

9:00 Welcome and Introductions (Foy or Hollowed)
9:15 History of crab management (Stram)
9: 45 Fishery dependent data sources (historical fishery, catch levels, bycatch) (Zheng)
ADF&G Observer program (Doug Pengilly)
10:30 ***Break***
10:50 Biology (growth, natural mortality, diets, spawning areas, nursery areas, maturity curves) (Zheng)
11:30 Field experiments on survey selectivity (Weinberg)
12:00 ***Lunch***
1:00 Biology continued, mating, Age Determination, shell condition (Rugolo or Foy)
2:00 On-going research—reproductive potential of RKC (Kathy Swiney)
3:00 Harvest Control Rules and Overfishing Definitions (Siddeek)
3:30 Survey methodology and analysis (Foy or Rugolo)
4:30 Bering Sea Fisheries Research Foundation survey (Steve Hughes)

Day 2

9:00 Ecosystem considerations - Predation, prey (Aydin)
9:30 Crab rationalization (IFQ) (Garber-Yonts)
10:00 Report on crab data weighting workshop (Kinzey)
11:00 Description of Bristol Bay red king crab assessment model (Zheng)
12:00 ***Lunch***
1:00 Continued description of assessment model and discussions

Day 3

9:00 Examination of the harvest control rules and Continued discussion of assessment model
12:00 ***Lunch***

Day 4

Reviewer discussions with assessment authors

Day 5

Reviewer discussions and preparation of report