AGENDA D-1
APRIL 2010

MEMORANDUM

TO: Council, SSC and AP Members

FROM: Chris Oliver
Executive Director

ESTIMATED TIME
6 HOURS

DATE: March 28, 2010

SUBJECT: Crab Management

ACTION REQUIRED

(a) Preliminary review of BSAI Crab Annual Catch Limit analysis and BSAI Snow/Tanner rebuilding plans.
(b) Preliminary review of Pribilof Island blue king crab rebuilding plan.
(c) Design of 2010 NOAA/BSFRF field research (SSC only).

BACKGROUND

(a) Preliminary review of BSAI Crab Annual Catch Limit analysis and BSAI Snow/Tanner rebuilding plans.

At this meeting, the Council will review a preliminary review analysis of amendments to address BSAI Crab ACLs and two of three rebuilding plans under consideration at this time (for Snow and Tanner crab, the third for Pribilof Islands blue king crab is addressed in a separate document under D-1(b) of this agenda item). The executive summary of the ACL and snow and Tanner crab rebuilding analysis is attached as Item D-1(a)(1). Section 3.4.2 is excerpted here as Item D-1(a)(2) for clarity (the equations did not reproduce sufficiently in the copy mailed to you). Additional information regarding the snow crab model scenarios employed in this analysis and the Tanner crab model (and draft stock assessment) used in the analysis are attached as Items D-1(a)(3) and Item D-1(a)(4) respectively. An external review of snow crab commissioned by BSFRF intended to evaluate the 2009 EBS trawl survey snow crab net efficiency data and its relation to the assessment is attached as Item D-1(a)(5). Implementation of both ACLs and rebuilding plans must occur for the 2011/12 crab fishing year.

This preliminary environmental assessment evaluates three actions to amend the BSAI Crab FMP.

- Action 1: to amend the FMP to specify the method by which the Council will establish annual catch limits (ACLs) to meet the requirements of the revised Magnuson-Stevens Act. These ACLs are to be established based upon an acceptable biological catch (ABC) control rule which will be set forth in the FMP and will account for the uncertainty in the overfishing limit (OFL) point estimate. Two alternative means of establishing the ABC control rule are considered: 1) a constant buffer approach where the ABC for each stock would be set by application of a constant pre-specified buffer value below the OFL; and 2) a variable buffer approach where the ABC would be established based upon a pre-specified percentile of the distribution for the OFL which accounts for scientific uncertainty regarding the OFL. A range of constant buffers and probabilities are considered under each alternative approach.

- Action 2: to prepare and implement an amended plan to rebuild the snow crab stock in compliance with section 304(e)(3) of the Magnuson-Stevens Act. A range of alternative time frames are considered for rebuilding the stock.

- Action 3: to prepare and implement a plan to prevent overfishing of Tanner crab in compliance with section 304(e)(3) of the Magnuson-Stevens Act. A range of alternative time frames are considered for rebuilding the stock. Initial review for this analysis is scheduled for June 2010 with final action for October 2010.

The Board of Fisheries (BOF) received a report from Council staff on March 16th regarding the ACL analysis for BSAI Crab stocks and rebuilding plans. A letter from the BOF to the Council is attached as Item D-1(a)(6). The Crab Plan Team met from March 29-April1in Seattle, Washington to review the ACL and rebuilding analysis and to provide recommendations on these documents. The CPT report will be available at the meeting.

(b) Preliminary review of Pribilof Island blue king crab rebuilding plan.

This preliminary draft environmental assessment evaluates five proposed alternative rebuilding measures for the Pribilof Islands blue king crab stock. The Pribilof Islands blue king crab stock remains overfished and the current rebuilding plan has not achieved adequate progress to rebuild the stock by 2014. This revised rebuilding plan considers five alternatives. Four of the alternatives are different closure configurations to restrict groundfish fisheries in the areas of the stock distribution. The fifth alternative considers a prohibited species bycatch cap on the groundfish fisheries. The preliminary impacts of these alternatives on rebuilding the blue king crab stock as well as the environmental and social/economic impacts of these measures are considered in this analysis. The executive summary of the analysis is attached as Item D-1(b)(1). Crab Plan Team comments on this analysis are contained in the CPT report which will be distributed at the meeting. Initial review for this analysis is scheduled for June 2010 with final action in October 2010.

(c) Design of 2010 NOAA/Bering Sea Fisheries Research Foundation (BSFRF) field research (SSC only)

The SSC requested in February that it be given the opportunity to review and comment on the survey design for the 2010 cooperative NOAA/BSFRF research survey. Representative from both organizations will provide a presentation of their plans to the SSC at this meeting.

Executive Summary

The king and Tanner crab fisheries in the Exclusive Economic Zone (EEZ) (3 to 200 miles offshore) of the Bering Sea and Aleutian Islands off Alaska are managed under the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs (FMP). The FMP establishes a State/Federal cooperative management regime that defers crab fisheries management to the State of Alaska (State) with Federal oversight. State regulations are subject to the provisions of the FMP, including its goals and objectives, the Magnuson-Stevens Act, and other applicable Federal laws.

There are three proposed actions contained in this analysis:

Action 1-Annual Catch Levels for BSAI Crab Stocks: The first proposed action is to establish annual catch levels (ACLs) to meet the requirements of the revised Magnuson Stevens Act. The Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 (MSRA, Public Law 109-479) includes provisions intended to prevent overfishing by requiring that FMPs establish a mechanism for specifying annual catch levels (ACLs) in the plan (including a multiyear plan), implementing regulations, or annual specifications, at a level such that overfishing does not occur in the fishery, including measures to ensure accountability (accountability measures or AMs). All crab fisheries must have ACL and AM mechanisms by the 2011/2012 crab fishing year. The MSRA includes a requirement for the SSC to recommend acceptable biological catch (ABC) levels to the Council, and provides that ACLs may not exceed the fishing levels recommended by the Science and Statistical Committee (SSC).

These ACLs are to be established based upon ABC control rules which account for the uncertainty in the overfishing limit (OFL) point estimate. To meet the ACL requirements, the ABCs for each stock will be established under the FMP such that ACL = ABC and the total allowable catches (TAC) and guideline harvest levels (GHLs) must be established sufficiently below the ABC so as not to exceed the ACL. Determinations of TACs and GHLs are Category 2 management measures and are deferred to the State following the criteria in the FMP. ABCs must be annually recommended by the NPFMC SSC.

Actions 2 and 3- Rebuilding Plans for Snow and Tanner Crab Stocks: The second proposed action is a revised rebuilding plan for the eastern Bering Sea (EBS) snow crab stock. The third proposed action is a new rebuilding plan for the EBS Tanner crab stock. The EBS snow crab stock will not rebuild by the end of the rebuilding time frame of 2009/2010, thus a revised rebuilding plan must be developed for this stock. The EBS Tanner crab is approaching an overfished condition and a rebuilding plan must be prepared.

All three of these proposed actions must be implemented prior to the start of the 2011/12 crab fishing year. These actions are considered together in this analysis as the implementation timing is identical and the actions themselves are related in the interplay between rebuilding plan catch constraints and ACL catch constraints for the EBS snow and Tanner crab stocks. For the remaining eight BSAI crab stocks for which rebuilding provisions are not considered in this analysis, only Action 1 (establishment of ACLs) applies. Additionally, Pribilof Islands blue king crab remains overfished. The current rebuilding plan has not achieved adequate progress to rebuild the stock by 2014. The Council is preparing an amended Pribilof Islands blue king crab rebuilding plan. This rebuilding plan will be analysed in a separate document because the primary rebuilding alternatives address bycatch in groundfish fisheries.

3.4.2 Tier 5

Three BSAI FMP crab stocks are currently classified as Tier 5 stocks (NPFMC 2009):

- Western Aleutian ("Adak") red king crab (WAIRKC)
- Aleutian Islands golden king crab (AIGKC)
- Pribilof Islands golden king crab (PIGKC).

Note that the AI GKC stock is anticipated to be re-classified as a Tier 4 stock, pending adoption of a stock-assessment model that has been developed for the stock (NPFMC 2009, p. 23), and ACLs are also examined for AI GKC stock in the analyses for Tier 4 stocks using the stock-assessment model in its current state of development.

The overfishing limit (OFL) for each of the Tier 5 stocks "is specified in terms of an average catch value over an historical time period, unless the Scientific and Statistical Committee recommends an alternative value based on the best available scientific information" (NPFMC 2009, p. 3):

> The OFL represents the average retained catch from a time period determined to be representative of the production potential of the stock. The time period selected for computing the average catch, hence the OFL would be based on the best scientific information available and provide the appropriate risk aversion for stock conservation and utilization goals. In Tier 5, the OFL is specified in terms of an average catch value over 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.
>
> For most Tier 5 stocks, only retained catch information is available so the OFL will be estimated for the retained catch portion only, with the corresponding overfishing comparison on the retained catch only. In the future, as information improves, the OFL calculation could include discard losses, at which point the OFL would be applied to the retained catch plus the discard losses from directed and non-directed fisheries" (NPFMC 2009, p. 5).

Due to insufficient history and confidentiality of data on discards and bycatch, the OFL for the BSAI crab Tier 5 stocks has been defined in terms of the retained catch only. The provision that the time period chosen to compute the average catch be chosen to "provide the appropriate risk aversion for stock conservation" (in addition to it being "from a time period determined to be representative of the production potential of the stock") is presumably superseded by the implementation of ACLs. In practice, the Tier 5 OFLs have been set according the SSC's advise that the OFL serve as "appropriate proxy for the long-term average production potential" and that "risk aversion is more appropriately applied when setting harvest level" (June 2008 SSC minutes, p. 15).

3.4.2.1 Short-term implications

The short-term implications of the alternatives are evaluated by calculating the buffer applied to the OFL and the resulting ABC for the most recent year (2010 or 2009/10, depending on the stock) using Equations 3.1 and 3.2. The buffer corresponding to each choice of P* (and choice for the extent of additional uncertainty) and the value of P* (for each alternative considered to account for the extent of additional uncertainty) for each buffer value is reported here.

The ABC values for each stock are assumed to be retained-catch ABCs so that implications can be judged by direct comparison with the TAC or guideline harvest level (GHL) as currently determined by the SOA. Although the harvest control rule for determining the TAC for the AIGKC stock exists in SOA regulations, there is no harvest control rule in SOA regulations for either the WAIRKC or PIGKC stocks.

Due to the lack of assessment models for these stocks and lack of reliable biomass estimates, implications of a buffer (either the fixed buffer, B, or the P*-based buffer, B_y) cannot be estimated in terms of the biological effects to stock biomass and productivity beyond computing the removals from the unknown stock biomass due to the retained catch. Likewise, due to lack of an assessment model in the Tier 5 scenario, the long-term implications are not analysed.

Values of P* were computed under the Tier 5 assumption that the average retained catch is an "appropriate proxy for the long-term average production potential" (June 2008 SSC minutes, p. 15) and that the years chosen to compute the long-term average are from a time period that is, in fact, "representative of the production potential of the stock." Under that assumption one can conceptualize the catch in each year during the chosen time period as a random observation from an imaginary infinite sequence of annual catches during which the "long-term average production potential" was maintained. In that case, buffer, B_y, based on the P* approach can be determined from the distribution of the sample mean by using a t-distribution to compute the lower bound of the approximate (1-2P*) confidence interval for the mean (i.e., of the "long-term average production potential"). That is, the B_y can be computed as,

$$B_y = \frac{\bar{x} - t_{(P*,df=n-1)} s_{\bar{x}}}{\bar{x}} \quad (3.3)$$

where,

$\bar{x} = \textit{sample mean of } n \textit{ annual catches in time period.}$

$t_{(P*,df=n-1)} = \textit{the } P* \textit{ percentile of a } t \textit{ distribution with } n-1 \textit{ degrees of freedom, and}$

$s_{\bar{x}} = \textit{the standard error of the mean computed from the sample of } n \textit{ annual catches}$

.

This approach has appeal in that buffers so computed will decrease the ABC relative to the OFL not only with increasing estimated variability of the OFL (as measured by the CV = ratio of standard error of the mean to the mean), but also with decreasing sample size (i.e., the time period over which the mean catch was used to estimate the OFL). Although the sample distributions of annual retained catch for each of the stocks show some strong departures from a normal distribution and sample sizes are small (as few as 6 years for the PIGKC sample and up to 24 years for the WAIRKC sample), an analysis (not reproduced in this report) of 1,000 bootstrapped sample means generated from the annual retained catches from each of the Tier 5 stocks for the time periods from which the OFLs were computed show that a t-distribution with the appropriate degrees of freedom provides a useful approximation to the sampling distribution of the mean retained catch.

The standard error of the mean does not capture all uncertainty on the OFL for the Tier 5 stocks, however. There is, for example, qualitatively large uncertainty on whether the time period chosen actually is a time period that is "representative of the production potential of the stock." Uncertainty on the time period for computing OFLs can also exist due to the length of the time period relative to the life span of the species. Additionally, the time since the last year of the time period used to compute the OFL increases uncertainty on the OFL because of uncertainty that that time period is applicable to present conditions of the stock and environment.

Three additional options were explored for incorporating additional uncertainty in the computation of buffers and ACLs: scaling the buffer to the ratio of the length of the time period used to compute the OFL to the life span of the species; use of an extra variance term in the measure of uncertainty (i.e., the standard error of the mean); and increasing the measure of uncertainty (i.e., the standard error of the mean) in proportion to the time since the last year of the time period used to compute the OFL.

To examine the effects of scaling the buffer to the ratio of the length of the time period used to compute the OFL to the life span of the species, we followed Zheng and Siddeek (2009) in assuming that the lifespan of BSAI king crabs is 25 years.

To examine use of an extra variance term to account for additional uncertainty, Equation 3.3 was modified by adding an extra variance term, σ^2, to the measure of uncertainty, $s_{\bar{x}}$, to obtain a buffer, $B_{y,\sigma}$, computed as,

$$B_{y,\sigma} = \frac{\bar{x} - t(P^*, df = n-1)\left(s_{\bar{x}}^2 + \sigma^2\right)^{1/2}}{\bar{x}}. \tag{3.4}$$

Buffers, $B_{y,\sigma}$, were computed according to Equation 3.4 for each of four values of σ^2, determined by $\sigma = CV \cdot \bar{x}$, for values of CV = 0.2, 0.3, 0.4, and 0.5 and for values of P* from 0.1 to 0.5 in increments of 0.1.

Lastly, use of increasing the measure of uncertainty in proportion to the time lag since the last year of the time period used to compute the OFL was examined as a means to account for additional uncertainty. To do so the measure of uncertainty, $s_{\bar{x}}$, was scaled by $(1+l/n)$, where l is the time lag (in years) since the last year of the time period used to compute the OFL and n is the number of years in the time period, and Equation 3.4 was modified to obtain a buffer, $B_{y,l}$, computed as,

$$B_{y,l} = \frac{\bar{x} - t(P^*, df = n-1)\left(1 + \frac{l}{n}\right)s_{\bar{x}}}{\bar{x}}. \tag{3.5}$$

3.4.2.2 Medium-term implications

Assuming that the OFL and time periods for computing the OFLs remain constant, buffers will be unchanged for all P*-based approaches except for the approach of adding uncertainty to account for time lag since the last year of the time period used to compute the OFL. Buffers determined under the approach of adding uncertainty to account for time lag since the last year of the time period used to compute the OFL will decrease linearly (until reaching 0) with time for fixed values of P^*_l and the implications are examined through fishing years 2018/19.

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LLC

Quantitative Resource Assessment LLC
San Diego, CA
USA.

Evaluation of snow crab catchability and selectivity estimated by trawl survey experiments.

Nontechnical summary
The BSFRF survey data from both the side by side and the pilot study experiments was examined to determine how the implied biases in survey catchability and selectivity (catchability by size) assumed in the stock assessment model would influence the stock assessment results. First the data was analyzed to determine the survey catchability and selectivity. Then the selectivity was included in the stock assessment model and results compared to the results using the current assessment assumptions.

The BSFRF survey data from both the side by side and the pilot study experiments shows that the catchability of the NMFS survey is lower than assumed in the stock assessment and that the selectivity increases with crab size. There appears to be spatial differences in both the absolute level of catchability and how it changes with size. This spatial variation complicates the calculation of catchability from the BSFRF survey data and may explain why there are differences in catchability between males and females.

The implications of the new selectivity curve and catchability estimated by the experiments is not straightforward and the implications are dependent on the other assumptions used in the stock assessment model. The model fit to the data is substantially degraded when the new selectivity curve is used in the assessment model. Therefore, the model assumptions need to be modified to improve the fit to the data. Despite the experiments indicating that the abundance of crabs is larger than previously thought, model adjustments that allow the model to fit the data reduce the productivity of the stock (e.g. reduced male growth rates or modified natural mortality) and produce harvest levels that are similar to those based on the original catchability and selectivity. However, the implications are still uncertain due to uncertainty in the model assumptions.

The BSFRF survey is much better at catching small crab and is therefore a much better indicator of cohorts that will enter the fishery in the future. If the growth assumptions are accurate, there have been several years of poor recruitment recently, but a moderate or good recruitment class can be seen for crab about 40mm.

In conclusion, the new catchability and the selectivity curve estimated from the BSFRF survey are substantially different from that assumed in the current assessment model and they are not consistent with some of the current model assumptions. Therefore, considerably more research and modeling work is needed to ensure that appropriate choices are being made about important model assumptions such as growth, natural mortality, and recruitment.

Data

Data was received from Jack Taggart in the file "BSFRF 09 Densities - to Taggart.xls". The file included data from both the side by side trawls and the pilot study. The average across all (or tows within a strata) tows (or station averages in the case of the BSFRF tows for the pilot study) of the density in each 5mm carapace width bin were used.

In general, the two survey trawls show a similar length frequency distribution for large crab, but the BSFRF survey trawl catches more individuals (Figures 1 and 2). The NMFS survey trawl catches few small crabs. A large single mode of small crab is seen in the BSFRF data.

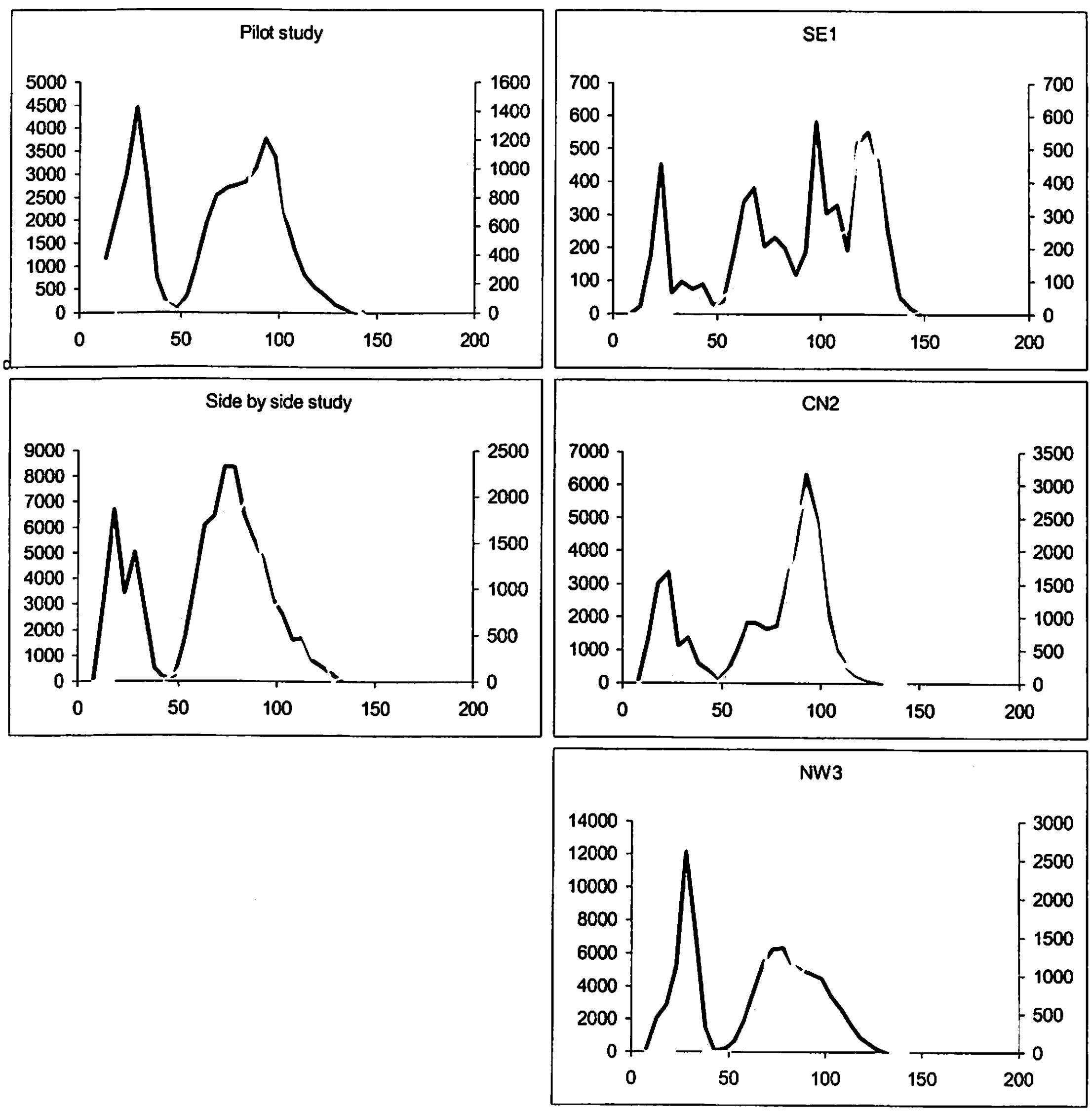

Figure 1. Comparison of average densities between the NMFS (grey – right hand axis) and BSFRF (black – left hand axis) surveys for males.

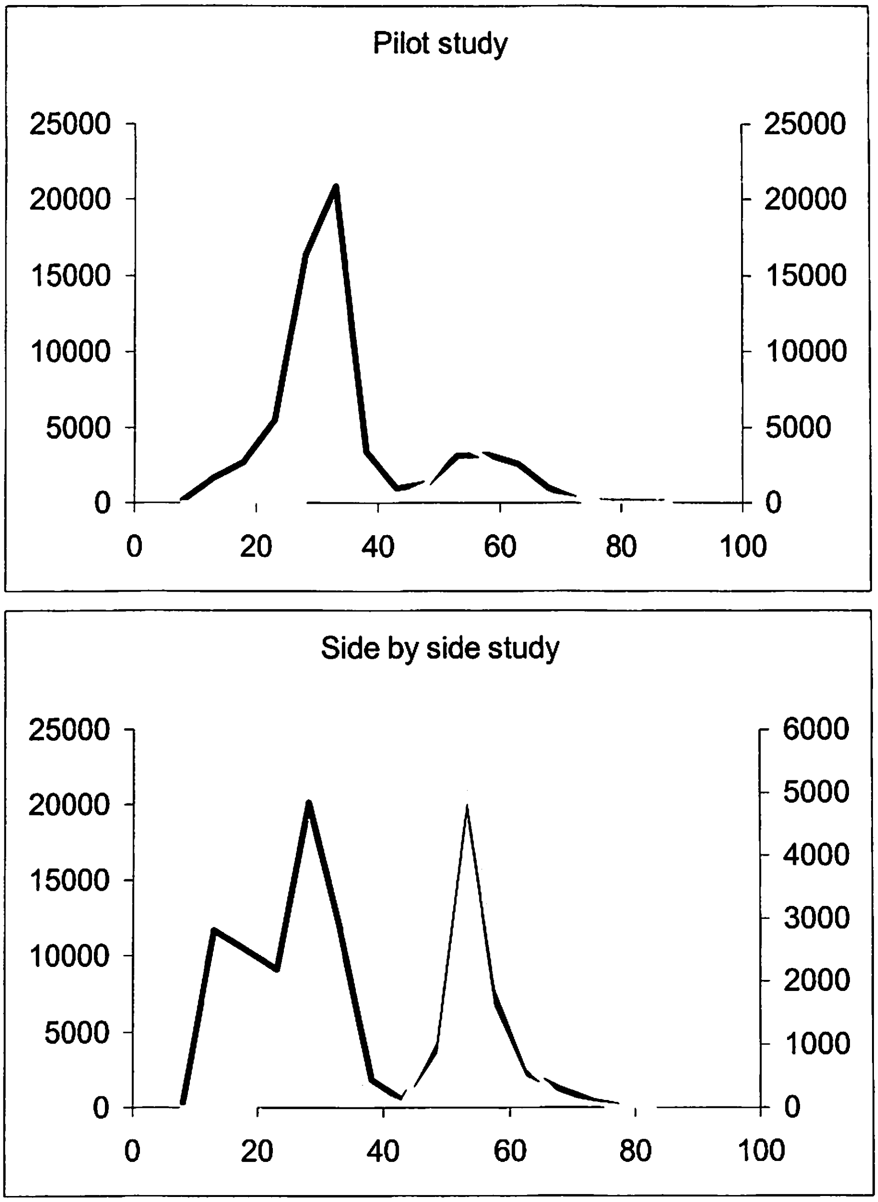

Figure 2. Comparison of average densities between the NMFS (grey – right hand axis) and BSFRF (black – left hand axis) surveys for females.

Selectivity Model

A logistic curve scaled by a catchability parameter was used to model the selectivity.

$$s_{CW} = \frac{q}{1+\exp(-slope(CW - CW_{50\%}))}$$

The selectivity was used to predict the catch-at-carapace width from the NMFS trawl given the BSFRF catch. This assumes that the BSFRF survey catches all the snow crab within its path. A negative log-likelihood based on the normal approximation to the binomial distribution was used to fit the predicted catch-at-carapace to the observed data. A scaling parameter was added for the standard deviation to account for additional variance. The scaling parameter is particularly important to appropriately weight the data sets when the two surveys are combined.

$$-\ln[L] = \sum_i \ln[\sigma] + \frac{(\text{NMFS}_i - s_i\text{BSFRF}_i)^2}{2\sigma^2}$$

$$\sigma = \delta\sqrt{np(1-p)}$$

Due to the large difference in the catchability of crabs less than 50 mm carapace width, the selectivity model is only fit to data from crabs above 50 mm carapace width. A few carapace width bins have no individuals in the BSFRF survey and these data are not included in the analysis.

Results

Visual examination of the number of crab caught in the NMFS and BSFRF surveys suggest that the catchability of the NMFS survey for the most abundant (in the NMFS survey) sized males is approximately 0.25 (2000/8000) from the side by side and 0.4 (1500/4000) for the pilot study (Figure 1). The catchability differs between the three regions in the pilot study SE1 = 1.0 (600/600); CN2 = 0.5 (3000/6000); and NW3 = 0.3 (1800/6000). The catchability may differ between males and females. The catchability of the NMFS survey for the most abundant sized females (in the NMFS survey) is approximately 0.25 (5000/20000) from the side by side and (above one) 1.3 (4000/3000) for the pilot study (Figure 2). It should be noted that the most abundant size occurs at a different size in each area. For example, the maximum abundance occurs at about 130mm for SE1, but at about 75mm for NE3. Catchability also appears to change with size, for example, although catchability is about one at 140mm for SE1, it is approximately 0.5 and 0.25 at 100mm and 60mm, respectively.

The NMFS survey was much less efficient at catching small crab with carapace widths less that about 50mm (Figures 1 and 2). Cab less than this size form a single mode which may represent a single cohort recruiting to the survey. Future BSFRF surveys would be useful to see how this cohort changes over time and how the NMFS selectivity for small crab changes over time.

The selectivity increases approximately linearly with carapace width for carapace widths above about 50mm and this relationship is generally consistent across the two surveys (Figure 3). However, female selectivity appears to be higher in the pilot study. This may be due to differences in selectivity among areas and different spatial distribution of females compared to males.

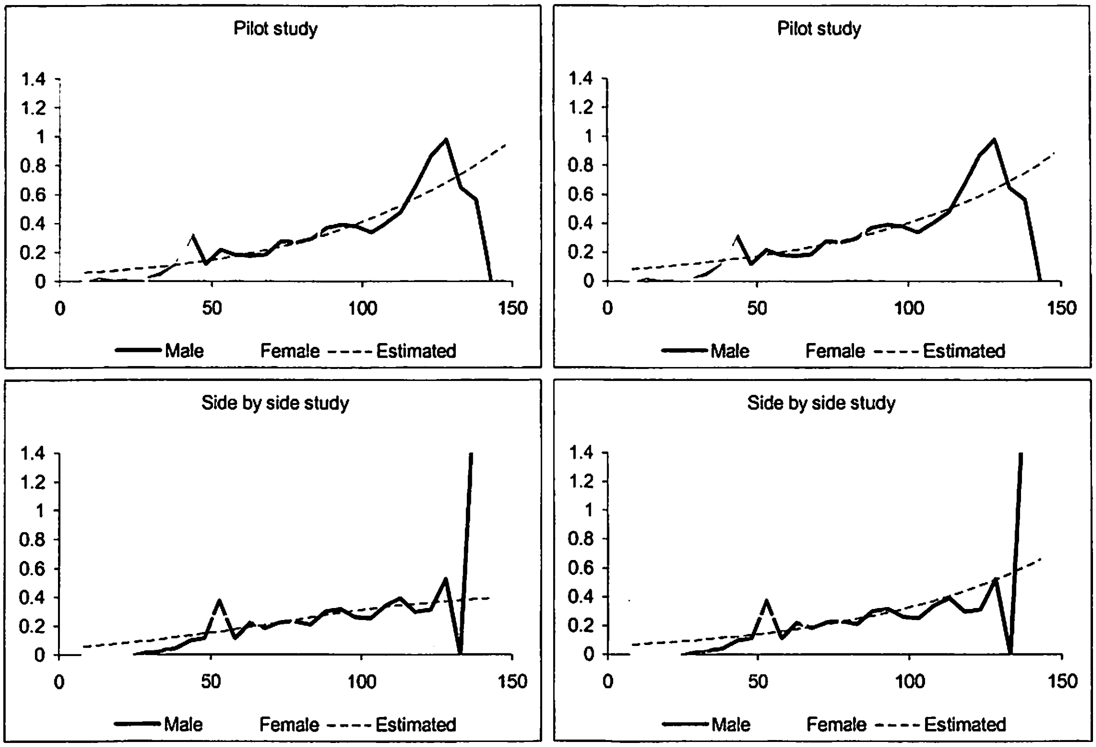

Figure 3. Comparison of empirical (solid lines) and estimated (dashed line) selectivity for the two studies. (note that these estimates are done outside the assessment model) The estimates on the left hand side are estimated independently for each study. The estimates on the right hand side share the slope and CW50% parameters between the two studies.

Implications of the selectivity and catchability on the stock assessment model

The stock assessment model code and data files were received from Jack Turnock (via Jack Tagart). The files included both the model code (AD Model Builder tpl file) and the executable. However, recompiling the code produced different answers than the supplied executable. The "original" results presented below were based on recompiling the model code and not on the supplied executable so as to standardize the comparisons with the results from models for which I modified the code.

The stock assessment model was run with the selectivity and catchability fixed at the values estimated from the combined 2009 experimental survey data. The input data file utilized the "recalculated" annual trawl survey abundance time series. The selectivity model was refit for the combined data using the selectivity formulation used in the stock assessment model to enable the transfer of parameters to the stock assessment model.

$$s_{CW} = \frac{q}{1+\exp(-\ln[19](CW - CW_{50\%})/(CW_{95\%} - CW_{50\%}))}$$

The estimated selectivity is substantially different than that assumed in the current assessment model in both shape and the catchability (Figure 4). The selectivity curve used in the current assessment model assumes that crab are fully selected at about a carapace width of 40 mm. The model was also run with the new selectivity and estimating mean growth (priors removed), estimating both mean growth and the standard deviation of the growth, estimating natural mortality, and estimating both growth and natural mortality. I had insufficient time to conduct forward projections to determine the sensitivity of annual catch calculations to the survey catchability and other assumptions. However, the Guideline Harvest Level calculations are provided as part of the stock assessment author's generated model outcomes (see: "Harvest Strategy and Projected Catch" [p 55] in Turnock and Rugolo 2009) and these should provide a general indication of the sensitivity of annual catch calculations.

Definitions

Original: Model run from tpl file

New select: Model run with selectivity and catchability fixed at the values estimated from experiment

Growth: "New select" with the parameters of the mean growth increment estimated.

Growth sd: "Growth" with the parameter representing the variation in growth estimated.

EstM: "New select" with the immature and mature female natural mortality estimated (mature males equals immature)

EstM2: "New select" with the immature, mature female and mature male natural mortality estimated.

M2G: "EstM2" with the parameters of the mean growth increment estimated.

Results

The estimated biomass is much higher using the new selectivity curve (Figure 5; Table 1). This is still true when the growth and natural mortality are estimated (Figure 5).

The fit to the survey biomass data is substantially degraded when the new selectivity curve is used (Figure 6; Table 2). The fit is improved if growth or natural mortality is estimated (Figure 6; table 2).

The GHL (Guideline Harvest Level) is larger when the new selectivity is used, but reduces when growth and/or natural mortality are estimated (Table 1).

Growth is estimated to be higher for females and lower for males compared to that assumed in the original analysis. Although, when both growth and natural mortality are estimated, the female growth rate is similar to that assumed in the original model.

The estimates of natural mortality vary depending on what components of natural mortality are estimated and whether growth is also estimated (Table 3). In general, mature male natural mortality is estimated to be higher than female and higher than immature individuals. Mature female natural mortality is estimated to be the same or lower than for immature individuals. These results are opposite to that assumed in the original model. However, some of the estimates of natural mortality are unrealistic indicating that the model is mispecified.

Estimating growth improves the overall fit to the data compared to either estimating the survey selectivity or natural mortality (Total in Table 2). However, estimating the survey selectivity provides the best fit to the survey length frequency data (Table 2). In general, the improvement in fit to the data is substantial if measured using typical statistical standards. However, the statistical properties of the model may be poor and statistical hypothesis tests unreliable.

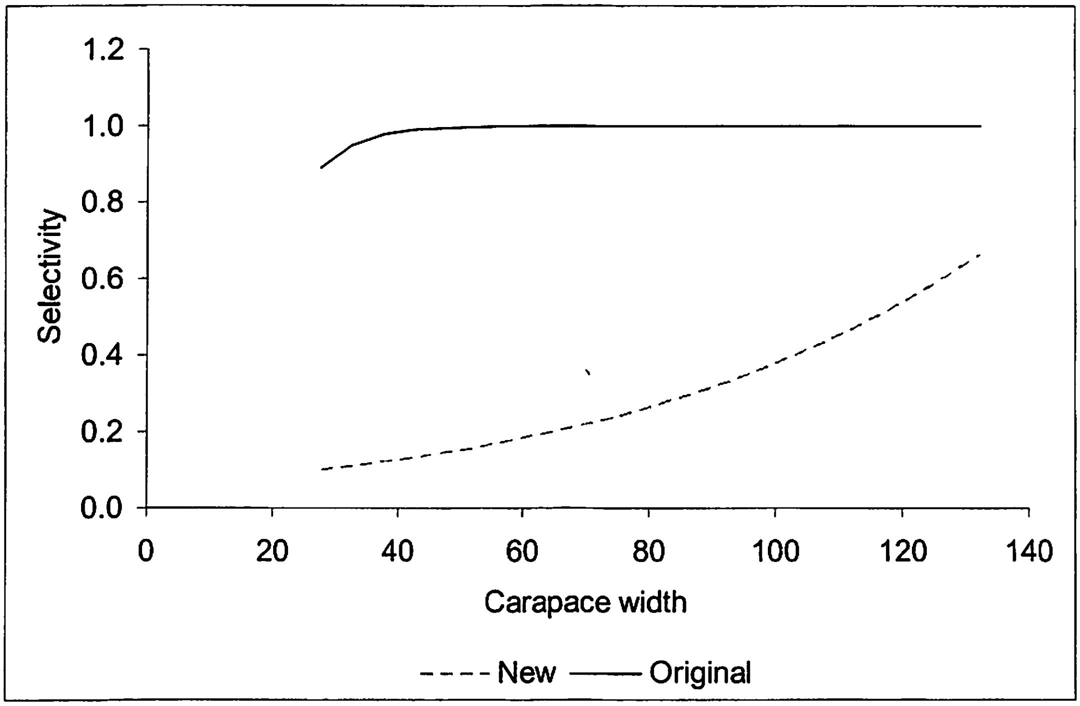

Figure 4. Comparison of the selectivity curve used in the current assessment (Original) to that estimated here (New).

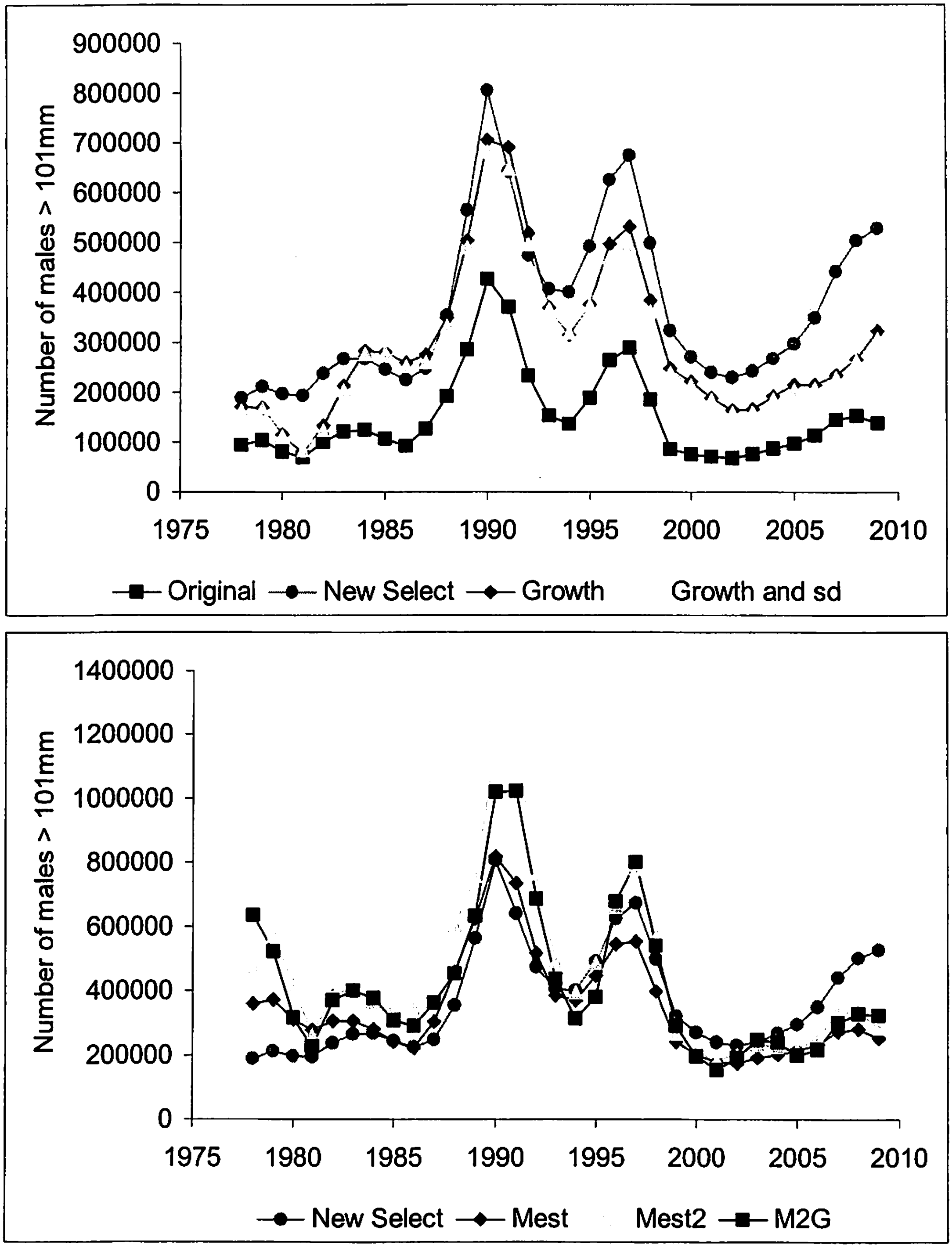

Figure 5. Comparison of the estimates of the number of males greater than 101 mm carapace width.

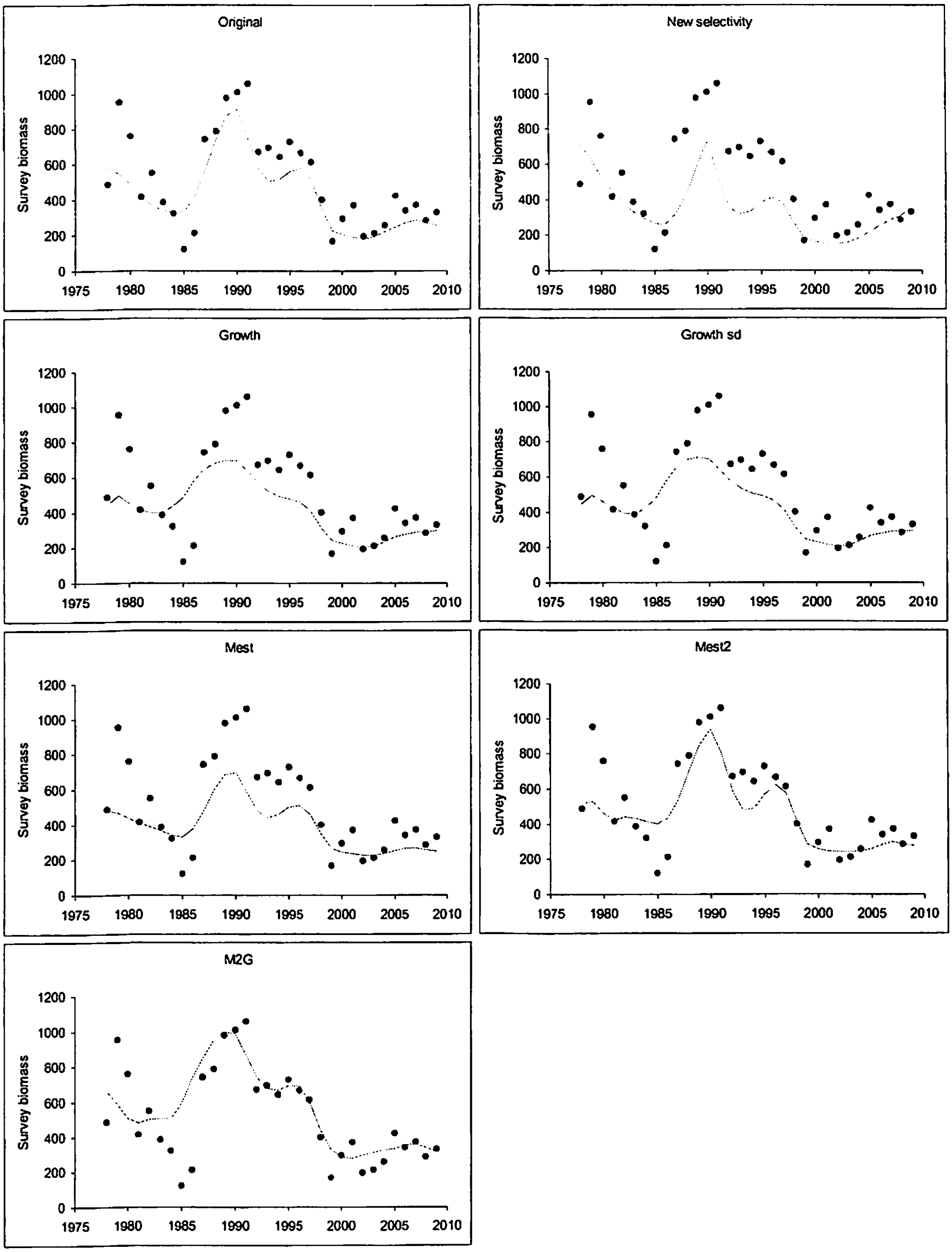

Figure 6. Comparison of the fits to the survey estimates of biomass.

Table 1. Results from the stock assessment model.

	2009 harvest rate	GHL ton	GHL num	2009 Males>101 Number	Biomass
Original	0.14	43	34	138	97
new select	0.17	97	76	528	388
Growth	0.15	49	39	322	180
growth sd	0.15	49	38	309	173
EstM	0.14	38	30	252	183
EstM2	0.14	38	30	285	200
M2G	0.14	40	31	324	184

Table 2. Negative log likelihood values (lower is better) for the different data components.

	rec	length total	length survey	fpen	Catch	survey	Init	Total	Dif
Original	24.9	5806.5	4125.0	1172.1	671.7	2381.0	87.8	9710.4	0.0
New select	33.4	7742.3	5434.0	1887.9	2109.8	12271.2	114.5	23155.0	13444.6
Growth	24.8	4782.7	5143.0	1096.8	662.8	2320.5	93.8	8510.5	-1199.9
Growth sd	27.0	4696.6	4975.2	1095.1	653.8	2309.8	90.7	8408.0	-1302.4
EstM	22.0	7353.4	5045.2	1855.1	574.4	2273.9	88.7	11748.4	2038.0
EstM2	15.3	6302.5	5342.6	1016.4	596.1	2141.2	45.8	9750.3	39.9
M2G	22.9	5947.9	6730.8	1046.4	545.7	2006.0	65.4	7011.9	-2698.5

Table 3. Estimates of natural mortality.

	Immature Female	Male	Mature Female	Male	Old shell Female	Male
Original	0.23	0.23	0.29	0.23	0.29	0.23
EstM	0.41	0.41	0.10	0.41	0.10	0.41
EstM2	0.13	0.13	0.14	2.58	0.14	2.58
M2G	0.35	0.35	0.24	1.02	0.24	1.02

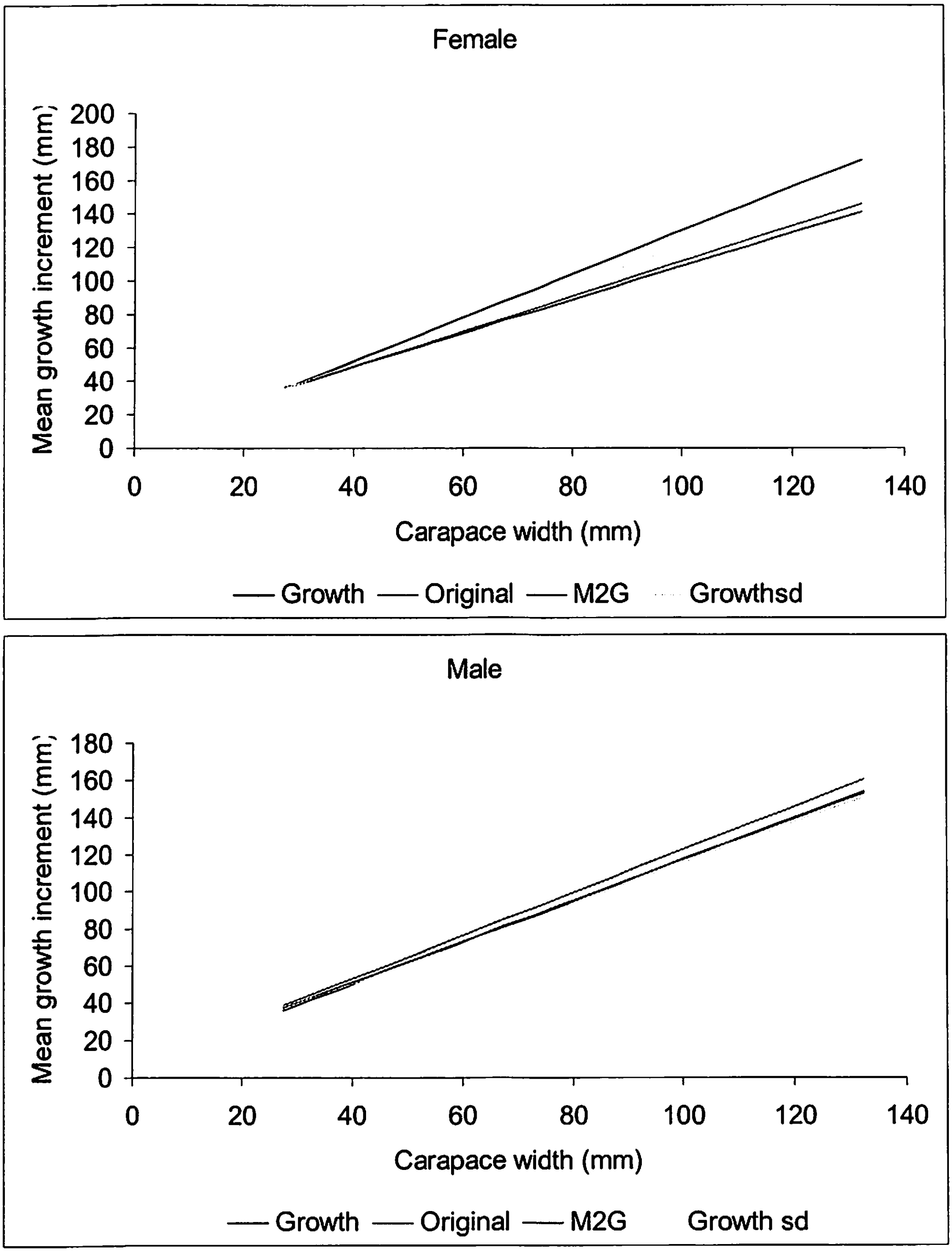

Figure 7. Estimates of mean growth increment from the models that estimate growth with that assumed in the original model.

Spatial variation in selectivity
The pilot study indicates that there is spatial variability in the selectivity (Figure 7). There is also spatial variability in the densities of crab (Figure 8). Females tend to be found mainly in the northwest and they have a higher selectivity than males in that region. Therefore, females are estimated to have a higher selectivity than males.

Conclusions
The selectivity estimated from the two studies is generally similar in shape and catchability, but there appears to be spatial differences in both the shape and catchability. The spatial variation in selectivity and the spatial difference in the male and female distribution may produce different selectivities for males and females. The new selectivity estimates are very different to those used in the current assessment. Using the new selectivity curve in the stock assessment produces larger estimates of abundance, but harvest levels are also dependent on the other parameters used in the model (e.g. growth and probably natural mortality).

The BSFRF survey catches substantially more small crab. Due to the low catchability of the NMFS survey it is not a good indicator of recruitment and the catchability/selectivity of these individuals may be highly variable from year to year. Therefore, it may be prudent to only include individual of 50 mm and greater carapace width in the assessment model. The BSFRF survey should be a better indicator of the incoming recruitment. If the growth assumptions are accurate, there have been several years of poor recruitment recently, but a moderate or good recruitment class can be seen with a model of about 40mm.

Literature Cited:

Turnock, B.J. and L.J. Rugulo. 2009. Stock Assessment of eastern Bering Sea snow crab. P 29-130, *in* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands Regions 2009 Crab SAFE. North Pacific Fishery Management Council, 605 W. 4th Avenue, #306 Anchorage, AK 99501.

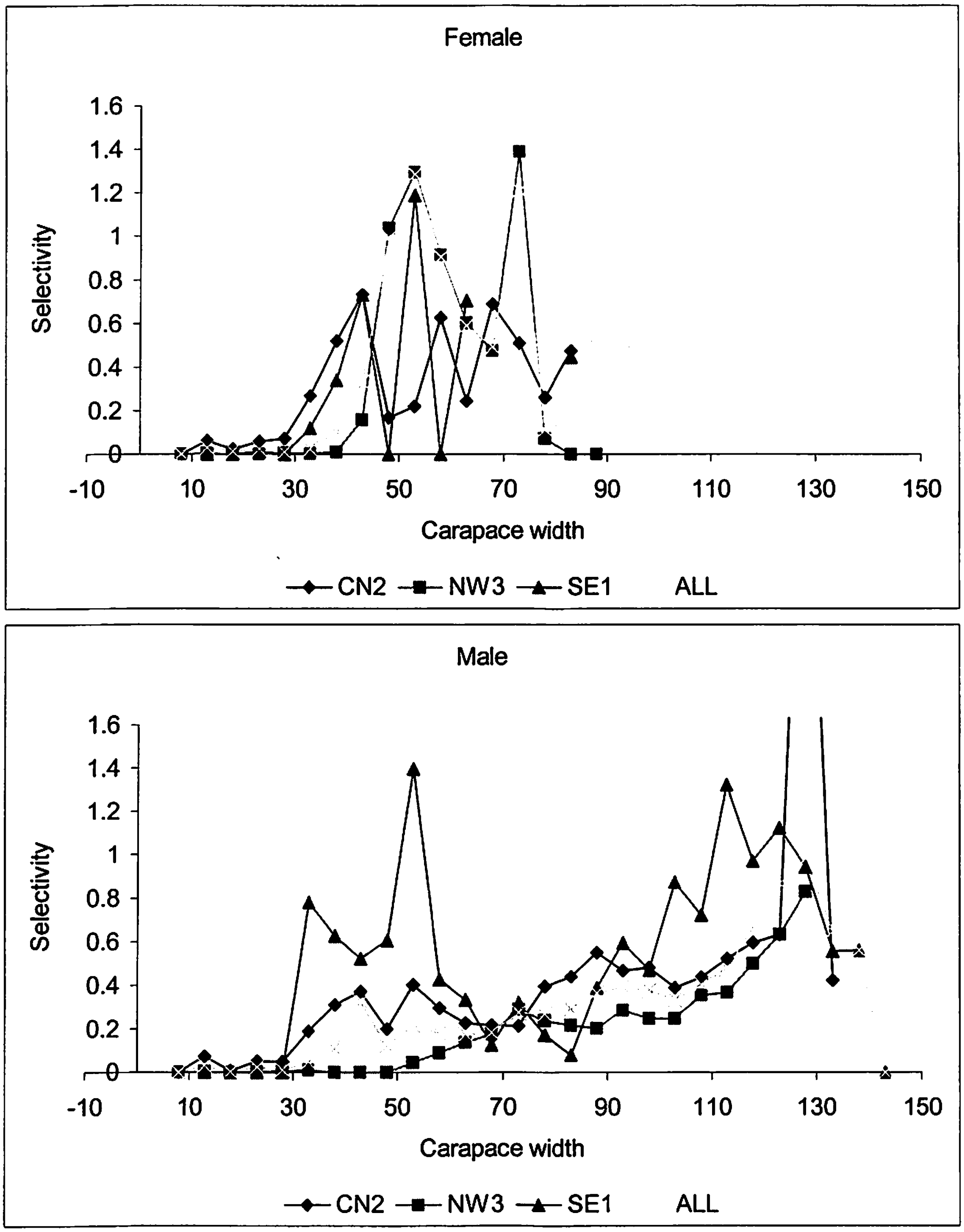

Figure 7. Selectivity by area from the pilot study.

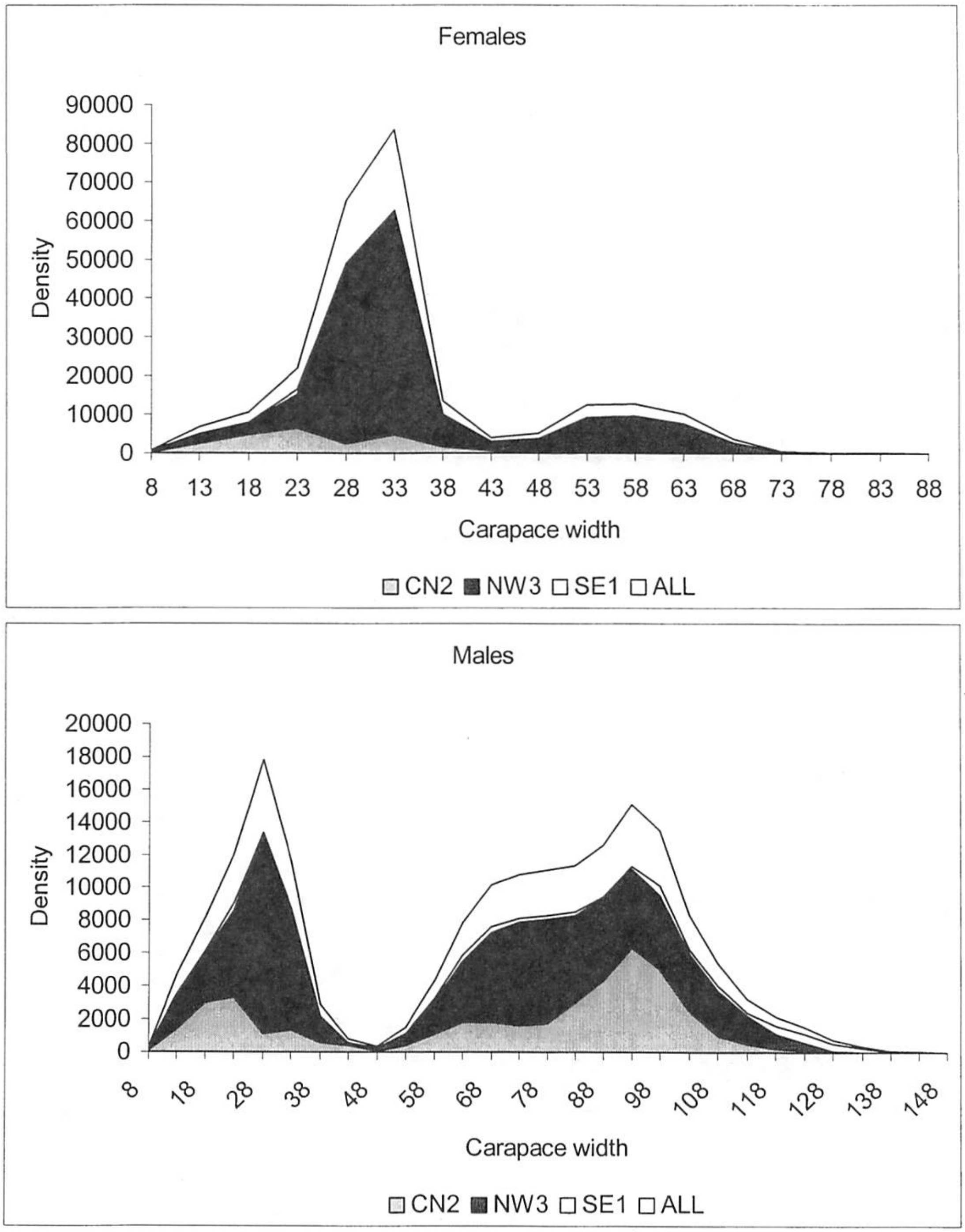

Figure 8. Average density by area from the BSFRF survey pilot study.

Appendix A: Modifications made to the assessment model to allow the fixing of survey selectivity and estimation of growth and natural mortality.

```
DATA_SECTION
 init_int Mbase_phase
 init_int matnM_phase
 init_int matnF_phase
 init_int matoM_phase
 init_int matoF_phase

 //init_vector M(1,2)    //natural mortality females then males
 //init_vector M_matn(1,2) //natural mortality mature new shell female/male
 //init_vector M_mato(1,2) //natural mortality mature old shell female/male


INITIALIZATION_SECTION
 srv1_q 7.235827369
 srv2_q 7.235827369
 srv3_q 7.235827369
 srv1_sel95 411.1253983
 srv1_sel50 254.3996434
 srv2_sel95 411.1253983
 srv2_sel50  254.3996434
 srv3_sel95 411.1253983
 srv3_sel50  254.3996434

 lnMbase -1.46967597
 lnmatnM 0
 lnmatnF 0.231801614
 lnmatoM 0
 lnmatoF 0

PARAMETER_SECTION
 init_number lnMbase(Mbase_phase)
 init_number lnmatnM(matnM_phase)
 init_number lnmatnF(matnF_phase)
 init_number lnmatoM(matoM_phase)
 init_number lnmatoF(matoF_phase)

 vector M(1,2)    //natural mortality females then males
 vector M_matn(1,2) //natural mortality mature new shell female/male
 vector M_mato(1,2) //natural mortality mature old shell female/male

 init_bounded_number af(0,20,4)
 init_bounded_number am(0,20,4)
```

```
 init_bounded_number bf(1,2,4)
 init_bounded_number bm(1,2,4)

 init_bounded_vector growth_beta(1,2,0.2,2,4)

 init_bounded_number srv1_q(0.2,1000,survsel1_phase)
 init_bounded_number srv1_sel95(30.0,15000,survsel1_phase)
 init_bounded_number srv1_sel50(0.0,15000,survsel1_phase)
 init_bounded_number srv2_q(0.7,1000,survsel1_phase+1)
 init_bounded_number srv2_sel95(30.0,16000,survsel1_phase)
 init_bounded_number srv2_sel50(0.0,9000,survsel1_phase)
 init_bounded_number srv3_q(0.7,1000,survsel1_phase+1)
 init_bounded_number srv3_sel95(40.0,15000,survsel_phase)
 init_bounded_number srv3_sel50(0.0,9000,survsel_phase)


PROCEDURE_SECTION
 M(1)=mfexp(lnMbase);
 M(2)=mfexp(lnMbase);

 M_matn(1)=M(1)*mfexp(lnmatnF);
 M_matn(2)=M(2)*mfexp(lnmatnM);

 M_mato(1)=M_matn(1)*mfexp(lnmatoF);
 M_mato(2)=M_matn(2)*mfexp(lnmatoM);


FUNCTION get_selectivity
    //if(survsel_phase<0)
       {
         //sel_srv3(1,j)=sel_som(1)/(1.+sel_som(2)*mfexp(-
1.*sel_som(3)*length_bins(j)));

       }
       //else
         {
          sel_srv3(1,j)=srv3_q*1./(1.+mfexp(-1.*log(19.)*(length_bins(j)-
srv3_sel50)/(srv3_sel95-srv3_sel50)));
        }
// this sets time periods 1 and 2 survey selectivities to somerton otto as well
         //if(survsel1_phase<0){
          //sel_srv1(1,j)=sel_srv3(1,j);
          //sel_srv2(1,j)=sel_srv3(1,j);
         //}
       //else
         {
```

```
//logistic curve if estimating selectivity parameters
          sel_srv1(1,j)=srv1_q*1./(1.+mfexp(-1.*log(19.)*(length_bins(j)-
srv1_sel50)/(srv1_sel95-srv1_sel50)));
          sel_srv2(1,j)=srv2_q*1./(1.+mfexp(-1.*log(19.)*(length_bins(j)-
srv2_sel50)/(srv2_sel95-srv2_sel50)));
        }


FUNCTION evaluate_the_objective_function

//bayesian part - likelihood on growth parameters af,am,bf,bm
 if(active(af))
 {
  //like_af  = .5 * square((af  - af_obs)  / sd_af);
  //like_bf = .5 * square((bf - bf_obs) / sd_bf);
  //f += like_bf;
  //cout<<"f8 = "<<f<<endl;
  //f += like_af;
  //cout<<"f9 = "<<f<<endl;
//  cout<<" af = " <<af<<endl;
//  cout<<" bf = " <<bf<<endl;

 }
 if(active(am))
  {
   //like_am  = .5 * square((am-am_obs)/sd_am);
   //f += like_am;
  //cout<<"f10 = "<<f<<endl;
//  cout<<" am = " <<am<<endl;
  }
 if(active(bm))
  {
   //like_bm = .5 * square((bm-bm_obs) /sd_bm);
   //f += like_bm;
  //cout<<"f11 = "<<f<<endl;
//  cout<<" bm = " <<bm<<endl;
  }
```

Appendix B: Data use in the analysis

Table B1. Average densities in the Pilot study.

	Male		Female	
Mid	NMFS	BSFRF	NMFS	BSFRF
8	0	85.39246	0	213.1679
13	34.46916	1161.109	53.25318	1670.626
18	8.107168	2040.538	39.6497	2672.668
23	67.46291	3005.442	133.7272	5452.824
28	40.49666	4447.991	154.2895	16304.81
33	136.4814	2904.128	522.3855	20882.96
38	77.9971	733.8245	337.8954	3385.399
43	64.54525	200.4797	333.5783	1013.202
48	10.60329	88.9746	1281.975	1289.896
53	81.93582	378.9262	4012.022	3121.494
58	191.5722	1079.102	2902.408	3211.96
63	345.3966	1957.249	1502.351	2550.799
68	461.0787	2537.441	477.0992	972.4466
73	744.6441	2702.339	166.1203	137.0303
78	742.4754	2762.742	4.740669	41.19289
83	829.0446	2833.772	4.920931	30.84465
88	1149.478	3146.768	2.494087	5.081887
93	1480.748	3769.883		
98	1269.807	3367.003		
103	698.1526	2085.83		
108	545.7079	1349.701		
113	385.7673	809.2092		
118	364.3706	551.3759		
123	335.7719	386.7841		
128	185.4787	189.2667		
133	56.82636	87.9036		
138	9.900891	17.63309		
143	0	7.16527		
148	2.865184	0		

Table B2. Average densities in the side by side study.

	Male		Female	
Mid	NMFS	BSFRF	NMFS	BSFRF
8	0	0	0	288.3127
13	0	61.71356	12.40568	11687.95
18	0	3289.271	27.97698	10460.36
23	12.71591	6693.813	51.78511	9092.591
28	51.41471	3418.099	679.7046	20135.77
33	119.2187	5011.237	471.3678	11876.16
38	119.3241	2862.175	254.7341	1851.787
43	48.0061	497.6494	62.62637	487.0589
48	13.44713	120.5089	1048.814	3640.33
53	77.7459	206.4607	5154.052	20890.6
58	191.5574	1712.457	1899.992	6841.381
63	840.2757	3807.414	634.519	2238.404
68	1086.423	6102.907	146.9129	1199.055
73	1438.764	6476.023	53.19557	439.2814
78	1893.742	8381.856	12.40568	49.00244
83	1736.907	8328.462	0	0
88	1941.378	6474.802		
93	1730.577	5505.125		
98	1215.324	4714.182		
103	796.0568	3177.64		
108	878.8614	2591.658		
113	631.5737	1617.381		
118	491.0256	1671.607		
123	251.8889	814.0721		
128	288.6207	550.2574		
133	0	258.331		
138	43.32561	21.6357		
143	0	0		
148	0	0		

Table B3. Average male densities in the Pilot study by area.

	SE1		CN2		NW3	
Mid	NMFS	BSFRF	NMFS	BSFRF	NMFS	BSFRF
8	0	0	0	80.35558	0	175.8218
13	0	24.07302	97.28601	1366.629	6.121482	2092.624
18	0	173.2468	24.3215	3013.974	0	2934.393
23	0	453.1488	177.9968	3346.098	24.3919	5217.078
28	0	63.22172	54.31991	1130.828	67.17007	12149.92
33	75.65173	96.74267	259.3848	1371.912	74.40773	7243.728
38	46.55353	74.4607	187.4378	604.5526	0	1522.46
43	46.91175	89.86471	146.724	395.8192	0	115.7552
48	15.92385	26.30757	15.88603	80.08917	0	160.5271
53	52.7332	37.75953	162.5207	405.2378	30.55359	693.7812
58	78.20128	183.5185	319.5704	1073.894	176.945	1979.895
63	114.1663	340.8948	417.9189	1837.018	504.1048	3693.835
68	46.7824	382.5411	393.7257	1805.12	942.728	5424.662
73	65.35746	205.1363	346.457	1629.99	1822.118	6271.89
78	40.15454	231.5307	683.3843	1731.83	1503.887	6324.864
83	15.57209	198.7375	1330.99	3015.078	1140.572	5287.501
88	45.84016	118.404	2385.69	4341.265	1016.903	4980.634
93	112.1623	188.9373	2961.326	6327.597	1368.757	4793.114
98	275.2351	583.8318	2418.283	5018.278	1115.904	4498.899
103	268.2294	306.7921	970.3887	2501.799	855.8397	3448.9
108	238.7118	330.8717	448.0089	1024.861	950.4031	2693.371
113	254.9011	192.3027	261.0147	498.2694	641.386	1737.056
118	504.694	519.8754	143.335	241.0256	445.0827	893.2266
123	621.7368	551.978	74.94104	118.4054	310.6377	489.9689
128	429.3881	454.7582	44.21667	13.27882	82.83134	99.76305
133	137.4546	246.1729	7.400519	17.53789	25.62393	0
138	29.70267	52.89926	0	0	0	0
143	0	21.49581	0	0	0	0
148	8.595551	0	0	0	0	0

AGENDA D-1(a)(4)
APRIL 2010

Stock Assessment of eastern Bering Sea Tanner crab

Louis J. Rugolo and Benjamin J. Turnock
National Marine Fisheries Service
27 March 2010

EXECUTIVE SUMMARY

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INTRODUCTION

Tanner crab *Chionoecetes bairdi* is one of five species in the genus *Chionoecetes*. The common name for *C. bairdi* of "Tanner crab" (Williams et al. 1989), was recently modified to "southern Tanner crab" (McLaughlin et al. 2005). Prior to this change, the term "Tanner crab" has also been used to refer to other members of the genus, or the genus as a whole. Hereafter, the common name "Tanner crab" will be used in reference to "southern Tanner crab".

Tanner crabs are found in continental shelf waters of the north Pacific. In the east, their range extends as far south as Oregon (Hosie and Gaumer 1974) and in the west as far south as Hokkaido, Japan (Kon 1996). The northern extent of their range is in the Bering Sea (Somerton 1981a) where they are found along the Kamchatka peninsula (Slizkin 1990) to the west and in Bristol Bay to the east.

In the eastern Bering Sea (EBS), the Tanner crab distribution may be limited by water temperature (Somerton 1981a). *C. bairdi* is common in the southern half of Bristol Bay, around the Pribilof Islands, and along the shelf break where water temperatures are generally warmer. The southern range of the cold water congener the snow crab, *C. opilio*, in the EBS is near the Pribilof Islands (Turnock and Rugolo 2009). The distributions of snow and Tanner crab overlap on the shelf from approximately 56° to 58°N, and in this area, the two species hybridize (Karinen and Hoopes 1971).

Stock structure

Tanner crabs in the EBS are considered to be a separate stock distinct from Tanner crabs in the eastern and western Aleutian Islands (NPFMC 1998). The unit stock is that defined across the geographic range of the EBS continental shelf, and managed as a single unit. Clinal differences in some biological characteristics may exist across the range of the unit stock (Somerton 1981a).

FISHERY HISTORY

Management Unit

Fisheries have historically taken place for Tanner crab throughout their range in Alaska, but currently only the fishery in the EBS is managed under a federal fisheries management plan (NPFMC 1998). The plan defers certain management controls for Tanner crab to the State of Alaska (SOA) with federal oversight (Bowers et al. 2008). The SOA manages Tanner crab based on registration areas, divided into districts. Under the plan, the SOA can adjust or further subdivide these districts to avoid overharvest in a particular area, change size limits from other stocks in the registration area, change fishing seasons, or encourage exploration (NPFMC 1998).

The Bering Sea District of Tanner crab Registration Area J (Figure 1) includes all waters of the Bering Sea north of Cape Sarichef at 54° 36' N lat. and east of the U.S.-Russia Maritime Boundary Line of 1991. This district is divided into the Eastern and Western Subdistricts at 173° W long. The Eastern Subdistrict is further divided at the Norton Sound Section north of the latitude of Cape Romanzof and east of 168° W long. and the General Section to the south and west of the Norton Sound Section (Bowers et al. 2008).

The domestic Tanner crab pot fishery rapidly developed in the mid-1970s (Figure 2, Tables 1a and 1b). For stock biomass and fishery data tabled in this document, we adopted the convention that 'year' refers to the survey year, and fishery data are those subsequent to the survey, through prior to the survey in the following year. Other notation is explicit – e.g., 2008/09 is the 2008 summer survey and the winter 2009 fishery. United States landings were first reported for Tanner crab in 1968 at 1.01 million pounds taken incidentally to the EBS red king crab fishery (Table

1a). Tanner crab was targeted by the domestic fleet thereafter and landings rose sharply in the early-1970s, reaching a high of 66.6 million pounds in 1977 (Table 1a, Figure 2). Landings fell precipitously after the peak in 1977 through the early 1980s, and domestic fishing was closed in 1985 and 1986 as a result of depressed stock status. In 1987, the fishery reopened and landings rose again in the late-1980s to a second peak in 1990 at 40.1 million pounds, and then fell sharply through the mid-1990s (Figure 3). The domestic Tanner crab fishery closed between 1997 and 2004 as a result of severely depressed stock condition. The domestic Tanner crab fishery re-opened in 2005 and has averaged 1.7 million pounds retained catch between 2005-2007 (Table 1a). Landings of Tanner crab in the foreign Japanese pot and tangle net fisheries were reported between 1965-1978, peaking at 44.0 million pounds in 1969 (Table 1a). The Russian tangle net fishery was prosecuted between 1965-1971 with peak landings in 1969 at 15.6 million pounds. Both the Japanese and Russian Tanner crab fisheries were displaced by the domestic fishery by the late-1970s.

Discard losses of Tanner crab originate from the directed pot fishery, and bycatch losses from the non-directed pot fisheries (notably, snow crab and red king crab) and the groundfish trawl fisheries (Table 1b). Discard and bycatch mortalities were estimated using post-release handling mortality rates of 50% for the pot fishery and 80% for trawl fisheries bycatch (NPFMC 2008).

Since re-opening of the domestic fishery in 2005, the relationship of total male discard and bycatch losses by all pot and trawl fisheries combined to retained catch shifted significantly relative to that observed between 1980 and 1996. For the years 2005, 2006, 2007, and 2008, the ratio of total male discard losses to retained catch was 4.3, 3.8, 4.6, and 2.4, respectively, and averaged 3.8 (se=0.5). The majority of these male losses are sub-legal sized crab, and a principal contributor to these non-retained losses is the directed Tanner crab fishery. This contrasts the pre-closure performance of the domestic fishery between 1980 and 1996 which averaged 1.1 (se=0.1) pounds of non-retained male losses to each pound of retained catch. These ratios in terms of numbers of non-retained male losses to retained legal crab are more striking due to the contribution of sub-legal sized crab to total male discards. Discard and bycatch losses of male and female Tanner crab (Table 1b) during the closures of the directed domestic fishery (1997-2004) reflect losses due to non-directed EBS pot fisheries and the domestic groundfish trawl fishery.

Exploitation Rates

The historical patterns of fishery exploitation on legal male biomass (LMB) and male mature biomass (MMB) were calculated in the following manner. The exploitation rate on LMB was estimated as the predicted retained catch biomass divided by the estimated legal male biomass at he time of the fishery, while that on MMB as the predicted total catch biomass (retained plus discard) divided by the estimated male mature biomass at the time of the fishery. The patterns of exploitation rates on LMB and MMB are similar over the period of record, 1969-2009. Exploitation rates were high in 1980 and fell with stock condition through the mid-1980s, followed by a second period of prominent rates during 1989-1993 (Figure 5). The pattern of fishery exploitation of this stock coincides with the modes of high catches in the late-1970s and the early-1990s. Exploitation rates on MMB peaked at 0.42 in 1990 and closely followed the build up of the secondary mode of stock biomass during the late-1980s to early-1990s period. These high rates of exploitation on MMB and LMB exceed the equivalent value of mortality at M=0.23 for this stock; the EBS Tanner crab stock did not persist at sustainable or healthy stock levels under these rates. Rugolo and Turnock (2009) discuss the history of exploitation rates on the male Tanner crab stock based on observed survey data and postulate that these rates were excessive and led to the erosion of stock biomass. Exploitation rates on mature and legal male biomass since 1998 (rebuilding period) have approximated 5-10% (Figure 5).

DATA

The Survey

The NMFS conducts an annual trawl survey in the EBS to determine the distribution and abundance of commercially-important crab and groundfish fishery resources. The survey has been conducted since 1968 by the Resource Conservation and Engineering (RACE) Division of the Alaska Fisheries Science Center. It's occurred annually since 1975 when it was also expanded into Bristol Bay and the majority of the Bering Sea continental shelf. Since 1988, 376 standard stations have been included in the survey covering a 150,776 nm^2 area of the EBS with station depths ranging from 20 to 150 meters depth. The annual collection of data on the distribution and abundance of crab and groundfish resources provides fishery-independent estimates of population metrics and biological data used for the management of target fishery resources. Crustacean resources targeted by this survey and enumerated annually by NMFS are red king crab (*Paralithodes camtschaticus*), blue king crab (*P. platypus*), hair crab (*Erimacrus isenbeckii*), Tanner crab (*C. bairdi*) and snow crab *(C. opilio*). The sampling methodology specifies the majority of tows made at the centers of squares defined by a 20 x 20 nmi (37 x 37 km) grid (Figures 6 and 7). Near St. Matthew Island and the Pribilof Islands, additional tows were made at the corners of squares that define high density sampling strata for blue king crab and red king crab.

The eastern otter trawl with an 83 ft (25.3 m) headrope and a 112 ft (34.1 m) footrope has been the standard gear since 1982. Each tow was approximately 0.5 h in duration towed at 3 knots, and conducted in strict compliance with established NMFS groundfish bottom trawl protocols (Stauffer 2004). Crabs are sorted by species and sex, and then a sample of the catch measured to the nearest millimeter to provide a size-frequency distribution. Derived population metrics are indices of relative abundance and biomass and do not necessarily represent absolute abundance or biomass. They are most precise for large crabs, and are least precise for small crabs due to gear selectivity, and for females of some stocks due to differential crab behavior.

Data Sources

Estimates of Tanner crab stock biomass, population metrics and length frequencies from the trawl survey used in this assessment were those based on the true area-swept calculations using actual net widths spreads for 1976-2009. Survey data in 1969, 1970 and 1972-1975 for males and 1974-1975 for females were extracted form historical International Pacific Fisheries Commission (INPFC) documents. Figures 6 and 7 present the distribution catch-per-unit effort by tow for legal males, sublegal males, ovigerous females, barren mature females and immature females from the 2009 survey. The highest abundance of males and females occurs from 163 to 167 degrees West longitude with the distinction that males also reveal moderate levels of abundance in the area of the Pribilof Islands. Figures 8 and 9 show the observed abundance by carapace width (millions of crab) estimated from the survey for male and female Tanner crab.

Size frequency data on retained Tanner crab from the directed fishery from 1981-1996 and from the 2005/06 to 2008/09 fishing seasons were used in the analysis. Figure 2 shows the retained male Tanner crab for the domestic and foreign fisheries from 1965 to 2008/09. Observers were placed on directed crab fishery vessels starting in 1990. Size frequency data on the discard catch in the directed fishery were available from 1992-1996 and from 2005/06-2008/09. Retained catch data were available for the entire time period of this model from 1969-2008/09. Total discard catch was estimated from observer data from 1992 to 2008/09. The discard male catch was estimated from 1978-1991 in the model using the estimated fishery selectivities based on observer data from 1992 to 2008/09 and an applied post-release mortality rate of 50% for pot released crab. Male and female Tanner crab length frequency and catch data from the snow crab fishery were available from 1989-2008/09. Male and female Tanner crab length frequency and catch data from the Bristol Bay red king crab fishery were available from 1989-1993 and 1996-2008/09. Trawl bycatch estimates included in the model were from 1973 to 2008/09.

The following table contains the various data components used in the model,

Data Component	Years
Retained male crab directed fishery size frequency by shell condition	1981-1996, 2005-2008/09
Discarded male and female directed fishery size frequency and catch	1992/93-1996/97, 2005/06-2008/09
Male and female Tanner length freq and catch in snow crab fishery	1989/90-2008/9
Male and female Tanner length freq and catch in red king crab fishery	1989-1993, 1996-2008
Retained catch estimates	1969-2008/09
Trawl bycatch estimates	1973-2008/09
Survey size frequencies by sex and shell condition	1969,1970,1972-2009 (males) 1974-2009 (females)
Total survey biomass estimates and coefficients of variation	1969,1970,1972-2009 (males) 1974-2009 (females)

LIFE-HISTORY

Reproduction

In most majid crabs, the molt to maturity is the final or terminal molt. For *C. bairdi,* it's now accepted that both males (Tamone et al. 2007) and females (Donaldson and Adams 1989) undergo terminal molt at maturity. Females terminally molt from their last juvenile, or pubescent, instar usually while being grasped by a male (Donaldson and Adams 1989). Subsequent mating takes place annually in a hard shell state (Hilsinger 1976) and after extruding their clutch of eggs. While mating involving old-shell adult females has been documented (Donaldson and Hicks 1977), fertile egg clutches can be produced in the absence of males by using stored sperm from the spermathacae (Adams and Paul 1983, Paul and Paul 1992). Multiple consecutive egg fertilization events can follow a single copulation using stored sperm to self-fertilize the new clutch (Paul 1982, Adams and Paul 1983), however, egg viability may decreases with time and age of the stored sperm (Paul 1984).

Maturity in males can be classified either physiologically or morphometrically. Physiological maturity refers to the presence or absence of spermataphores in the male gonads whereas morphometric maturity refers to the presence or absence of a large claw (Brown and Powell 1972). During the molt to morphometric maturity, there is a disproportionate increase in the size of the chelae in relation to the carapace. While many earlier studies on Tanner crab assumed that morphometrically mature male crabs continued to molt and grow, there is now substantial evidence supporting a terminal molt for males (Otto 1998, Tamone et al. 2007). A consequence of the terminal molt in male Tanner crab is that a substantial portion of the population may never reach the legal harvest size (NPFMC 2007).

Although observations are lacking for the eastern Bering Sea, seasonal differences have been observed between mating periods for pubescent and multiparous Tanner crab females in the Gulf of Alaska (GOA) and Prince William Sound. There, pubescent molting and mating takes place over a protracted period from winter through early summer, whereas multiparous mating occurs over a relatively short period during mid April to early June (Hilsinger 1976, Munk et al. 1996, and Stevens 2000). In the EBS, egg condition for multiparous Tanner crab assessed between April and July 1976 also suggest that hatching and extrusion of new clutches for this maturity status began in April and ended sometime in mid-June (Somerton 1981a).

Fecundity

A variety of factors affect female Tanner crab fecundity including female size, maturity status (primiparous vs. multiparous), age post terminal molt, and egg loss (NMFS 2004a). Of these factors, female size is the most important, with estimates of 89 to 424 thousand eggs for EBS females 75 to 124 mm carapace width (cw) respectively (Haynes et al. 1976). Maturity status is another significant factor affecting fecundity with primiparous females being only ~70% as fecund as equal size multiparous females (Somerton and Meyers 1983). The number of years post maturity molt, and whether or not, a female has had to use stored sperm from that first mating can also affect egg counts (Paul 1984, Paul and Paul 1992). Additionally, older senescent females often carry small clutches or no eggs (i.e., barren) suggesting that female Tanner crab reproductive output is a declining function of age (NMFS 2004a).

The fraction of barren mature females by shell condition (Figure 10) and the fraction of mature females with clutches one-half full or less by shell condition (Figure 11) are shown. After 1991, 20-40% of new shell females brooded clutches less than or equal to 50% full, and in 2009 this number was approximately 23%. In this analysis, we developed a Tanner crab Egg Production Index (EPI) by female shell condition that incorporates observed clutch size measurements taken on the survey and fecundity by carapace width for 1976-2009 (Figure 12). Figure 12 also presents estimates of male and female mature biomass relative to the shell condition class EPIs in these years. Although male and female mature biomass increased after 2005, egg production does not increase proportionally to mature biomass (Figure 12).

Size at Maturity

We estimated the maturity at length (cw) schedules for male and female Tanner crab from extant NMFS trawl survey data. For females, we used egg and maturity code information collected on the survey from 1976-2009 to estimate the maturity curves for new shell females, and for the aggregate class of females all shell conditions combined. SM50%, for females all shell classes combined was estimated to be 68.8 mm cw, and that for new shell females was 74.6 mm cw. For males, we used data from the special collection of morphometric measurements taken to the 0.1 mm in 2008 on the NMFS survey to derive the classification rules between immature and mature crab based on chela allometry using the mixture-of-two-regressions analysis. We estimated classification lines between chela height and carapace width defining morphometric maturity for the unit Tanner crab stock, and for the sub-stock components east and west of 166° West longitude. We then applied these rules to historical survey data from 1990-2007 to apportion male crab to the immature and mature populations. We examined and found no significant differences between the classification lines of the sub-stock components (E and W of 166° W longitude), or between the sub-stock components and that of the unit stock classification line. SM50%, for males all shell condition classes combined was estimated to be 91.9 mm cw, and that for new shell males was 104.4 mm cw. By comparison, Zheng (1999) in development of the current SOA harvest strategy used knife-edge maturity of >79 mm cw for females and >112 mm cw for males. The maturity curve for new shell females was used in the model to represent the conditional probability of new shell immature females maturing where SM50% was estimated to be 74.6 mm cw (Table 4 and Figure 13). The conditional probability of new shell immature males maturing in the model was assumed to be the same as that used in the OFL analysis (NPFMC 2007) (Table 4 and Figure 13).

Mortality

Due to a lack of reliable age information, Somerton (1981a) estimated mortality separately for individual EBS cohorts of juvenile (pre-recruits) and adult Tanner crab. Somerton postulated that because of net selectivity of the survey sampling gear, age five Tanner crab (mean cw=95 mm) were the first cohort to be fully recruited to the gear; he estimated an instantaneous natural mortality rate of 0.35 for this size class using catch curve analysis. Using catch curve analysis with two different data sets, Somerton estimated natural mortality rates of adult male crab from the fished EBS stock to range from 0.20 to 0.28. When using CPUE data from the Japanese fishery the estimated rate of M ranged from 0.13 to 0.18. Somerton concluded that M estimates of 0.22 to 0.28 estimated from models that used both the survey and fishery data were the most representative. We examined empirical evidence for reliable estimates of oldest observed age for male Tanner crab. Unlike its congener the snow crab, estimates of longevity of Tanner crab are lacking. We reasoned that longevity in a virgin population of Tanner crab would be analogous to that of the snow crab (Turnock and Rugolo 2009) given the close analogues in population dynamic and life-history characteristics, where longevity would be at least 20 years. Using 20 years as a proxy for longevity and assuming that this age represents the upper 98.5th percentile of the distribution of ages in an unexploited population (if observable), M is estimated to be 0.23 (Hoenig 1983). If 20 years is assumed to represent the 95% percentile of the distribution of ages in an unexploited stock, M is estimated to be 0.15. We used M=0.23 for both male and female Tanner crab in this analysis.

Growth

We 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). We also examined growth relationships developed by Zheng and Kruse (1999) (Figure 14). Somerton (1981a) estimated growth for EBS Tanner crab based on modal size frequency analysis of Tanner crab in survey data assuming no terminal molt at maturity. Consequently, Somerton's approach did not directly measure molt increments and his findings were confounded by the failure to recognize that the progression of modal lengths between years was biased as a result that male and female crab ceased growing after their maturity molt. We compared our growth per molt (gpm) relationships with those of Stone et al. (2003) for Tanner crab in southeast Alaska in terms of the overall pattern of gpm over the size range of crab. We found that gpm is expressed by two distinct rates of growth for both males and females – a higher rate of growth to an intermediate size in the area 90-100 mm cw, coupled with a decrease in growth rate from that intermediate size thereafter (Figure 14). Such "dog-leg" shaped growth curves are corroborated in work of Stone et al. (2003), Somerton (1981), Donaldson et al. (1981) and in the data of Munk. Our gpm relationships were based on observed growth increment data for males to approximately 140 mm cw and for females to approximately 115 mm cw. For the 'dog-leg- portion of the gpm curves, we extrapolated the rate of increase (slope) for males from Zheng and Kruse (1999), and approximated that slope for females after their respective inflection points.

Weight at Length

We derived weight at length relationships for male, immature female and mature female Tanner crab based on special collections of length and weight data on the NMFS trawl survey in 2006, 2007 and 2009 (Figure 15). The fitted weight (kg)-length (mm cw) relationship for males of shell condition classes 2 (SC2) through class 5 (SC5) inclusive is: $W=0.00016(cw)^{3.136}$. Those for immature (SC2) and mature (SC2-SC4) females are, respectively, $W=0.00064(cw)^{2.794}$ and $W=0.00034(cw)^{2.956}$.

MODEL APPROACH

The model structure was developed following Fournier and Archibald's (1982) methods, with many similarities to Methot (1990). The model was implemented using automatic differentiation software developed as a set of libraries under C++ (ADModel Builder). ADModel Builder can estimate a large number of parameters in a non-linear model using automatic differentiation software extended from Greiwank and Corliss (1991) and developed into C++ class libraries. This software provides the derivative calculations needed for finding the objective function via a quasi-Newton function minimization routine (e.g., Press et al. 1992). The model implementation language (ADModel Builder) gives simple and rapid access to these routines and provides the ability to estimate the variance-covariance matrix for all parameters of interest.

The model estimates the abundance by length bin and sex in the first year (1969) as parameters rather than estimating the recruitments previous to 1969. There are 32, 5mm length bins in the model starting from 25-29 mm up to a cumulative bin at 180-184 mm. This results in 64 estimated parameters for the initial numbers by length.

Recruitment is determined from the estimated mean recruitment, the yearly recruitment deviations and a gamma function that describes the proportion of recruits by length bin,

$$N_{t,1} = pr_l R_0 e^{\tau_t}$$

where,

R_0 Mean recruitment

pr_l Proportion of recruits for each length bin

τ_t Recruitment deviations by year.

Recruitment is estimated equal for males and females in the model.

Crabs are distributed to length bins based on a premolt to postmolt length transition matrix. For immature crab in year t-1 that remain immature in year t,

$$N^s_{t,l} = (1 - PM^s_l)\sum_{L=l_1}^{l'} G^s_{l',l} e^{-Z^s_{l'}} N^s_{t-1,l'}$$

$G^s_{l',l}$ Growth transition matrix by sex, premolt and postmolt length bins. Defines the fraction of crab of sex s and premolt length bin l', that move to length bin l after molting.

$N^s_{t,l}$ Abundance of immature crab in year t, sex s and length bin l

$N^s_{t-1,l'}$ Abundance of immature crab in year t-1, sex s and length bin l'

$Z^{s}_{l'}$	Natural and fishing mortality by sex s and length bin l'
PM^{s}_{l}	Fraction of immature crab that become mature for sex s and length bin l
l'	Premolt length bin
l	Postmolt length bin

Growth

Growth was modeled using a fixed linear function to estimate the mean carapace width after molting given the mean carapace width before molting (Figure 14),

$Width_{t+1} = a + b^{*} width_{t}$

Parameters values used in the model and whether parameters were estimated in the model, excluding recruitments and fishing mortality parameters are listed in Table 4.

Crab were assigned to 5mm width bins using a two-parameter gamma distribution with mean equal to the growth increment by sex and length bin and a beta parameter (which determines the variance),

$$G^{s}_{l',l} = \int_{l-2.5}^{l+2.5} gamma(x / \alpha_{s,l'}, \beta_{s})$$

$\alpha_{s,l'}$ is the expected growth interval for sex s and size l' divided by the shape parameter β.

$G^{s}_{l',l}$ is the growth transition matrix for sex, s and length bin l' (premolt size), and postmolt size l.

The Gamma distribution is,

$$gamma(x / \alpha_{s,l}, \beta_{s}) = \frac{x^{\alpha_{s.l}-1} e^{-\frac{x}{\beta_{s}}}}{\beta^{\alpha_{s,l}} \Gamma(\alpha_{s,l})}.$$

Where x is length, β for both males and females was set equal to 0.75.

The probability of an immature crab becoming mature by size is applied to the post-molt size. Crab that mature and reach their terminal molt in year t then are mature new shell during their first year of maturity ($NMN^{s}_{t,l}$),

$$NMN^{s}_{t,l} = PM^{s}_{l} \sum_{L=l_1}^{l'} G^{s}_{l',l} \, e^{-Z^{s}_{l'}} N^{s}_{t-1,l'}$$

Crab that are new shell mature in year t-1, no longer molt, and move to old shell mature crab in year t ($NMO^{s}_{t,l}$). Crab that are old shell mature in year t-1 remain old shell mature for the rest of their lifespan.

$$NMO^{s}_{t,l} = e^{-Z^{s,old}_{l}} NMO^{s}_{t-1,l} + e^{-Z^{s,new}_{l}} NMN^{s}_{t-1,l}$$

Fishing occurs before growth (molting) takes place. Crab that molted in year t-1 are defined as new shell until after the spring molting season, which occurs after the fishery. Crab that molted to maturity (the terminal molt) in year t-1 are new shell mature until the next molting season when they become old shell mature.

Mature male biomass is the sum of all mature males at the time of mating multiplied by the weight at length for male crab.

$$B_t = \sum_{L=1}^{lbins} (NMO^{males}_{tm,l} + NMN^{males}_{tm,l}) \, W^{males}_{l}$$

where,

tm	is time of mating, which is after the fishery occurs, and before molting
l	Length bin
Lbins	number of length bins in the model
$NMO^{males}_{tm,l}$	abundance of mature old shell males at time of mating in length bin l
$NMN^{males}_{tm,l}$	abundance of mature new shell males at the time of mating in length bin l
W_l	weight of a male crab for length bin l

Catch of Tanner crab by fishing fleet or fishery was estimated as a pulse fishery 0.62 yr after the beginning of the assessment year (July 1),

$$catch_f = \sum_s \sum_l \frac{F_{f,s,l}}{F_{tot,s,l}} (1 - e^{-(F_{tot,s,l})}) w_{s,l} N_{s,l} e^{-M*.62}$$

The sum over all fisheries is the total catch. Fishing mortalities by fishery, sex and length are the full selection F by fishery and sex multiplied by the appropriate selectivity curve.

$F_{tot,s,l}$	Sum over fisheries of full selection fishing mortality multiplied by the appropriate fishery selectivity curve
$F_{f,s,l}$	Full selection fishing mortality by fishery multiplied by the appropriate fishery selectivity curve
$w_{s,l}$	weight by length bin l
$N_{s,l}$	Numbers by length for length bin l
M	Natural Mortality

Selectivity

The selectivity curves for total catch (Figure 16), catch in the red king crab fishery (Figure 17), snow crab fishery (Figure 18), and catch in the groundfish fisheries (Figure 19), were estimated as two-parameter ascending logistic curves,

$$\text{Selectivity}_l = \frac{1}{1 + e^{(-a(l-b))}}$$

Where a is slope and b is length at 50% selectivity. Separate selectivity curves for males and females were estimated for the directed, snow and red king crab fisheries.

The probability of retaining crabs by size in the directed fishery with combined shell condition was estimated as an ascending logistic function. The selectivities for the retained catch were estimated by multiplying a two parameter logistic retention curve (same logistic equation as the total selectivity) by the selectivities for the total catch,

$$S_{ret,l} = (\textit{selectivity total})(\textit{retention})$$

The selectivities for the survey were estimated with three-parameter, ascending logistic functions (Survey selectivities in Figure 20).

$$\text{Selectivity}_l = \frac{Q}{1 + e^{\left\{\frac{-\ln(19)(l - l_{50\%})}{(l_{95\%} - l_{50\%})}\right\}}}$$

Survey selectivities were set equal for males and females. Separate survey selectivities were estimated for the period 1969 to 1975, 1976 to 1981, and 1982 to the present that address evolving survey design and gear changes. The maximum selectivity was fixed at 1.0 in the model. The separate selectivities were used due to the change in catchability in 1982 from the trawl net change. Survey selectivities have been estimated for Bering Sea Tanner crab from underbag trawl experiments (Somerton and Otto 1999) (Figure 20). A bag underneath the regular trawl was used to catch animals that escaped under the footrope of the regular trawl, and was assumed to have selectivity equal to 1.0 for all sizes.

Likelihood Equations
Weighting values (λ) for each likelihood equation are shown in Table 6.

Catch biomass for the directed fishery, snow crab fishery, red king crab fishery and groundfish fishery is assumed to have a normal distribution,

$$\lambda \sum_{t=1}^{T} \left[(C_{t,fishery,obs}) - (C_{t,fishery.pred}) \right]^2$$

There are separate likelihood components for the retained catch, discard in the directed fishery, discard in the snow crab fishery, discard in the red king crab fishery and groundfish bycatch.

The robust multinomial likelihood is used for length frequencies from the survey and the catch (retained and total) for the fraction of animals by sex in each 5mm length interval. The number of samples measured in each year is used to weight the likelihood. However, since thousands of crab are measured each year, the sample size was set at 200.

$$Length\ Likelihood = -\sum_{t=1}^{T} \sum_{l=1}^{L} nsamp_t * p_{obs,t,l} \log(p_{pred,t,l}) - Offset$$

$$Offset = \sum_{t=1}^{T} \sum_{l=1}^{L} nsamp_t * p_{obs,t,l} \log(p_{obs,t,l})$$

Where, T is year, L is length bin and p is the proportion by length bin.

An additional length likelihood weight (2) is added to the first year survey length composition fit to facilitate the estimation of the initial abundance parameters. A smoothness constraint is also added to the numbers at length by sex in the first year,

$$\sum_{s=1}^{2} \sum_{l=1}^{L} (first\ differences(N_{1969,s,l}))^2$$

The survey biomass assumes a lognormal distribution with the inverse of the standard deviation of the log(biomass) in each year used as a weight,

$$\lambda \sum_{t=1}^{ts} \left[\frac{\log\left[\frac{SB_{obs,t}}{SB_{pred,t}}\right]}{sqrt(2) * s.d.(\log(SB_{obs,t}))} \right]^2$$

$$s.d.(\log(SB_{obs,t})) = sqrt(\log((cv(SB_{obs,t}))^2 + 1))$$

Recruitment deviations likelihood equation is,

$$\lambda \sum_{s=1}^{2} \sum_{t=1}^{T} (e^{\tau_{s,t}})^2$$

Fishery cpue in average number of crab per pot lift.

$$\sum_{t=1}^{tf} \left[\frac{\log\left[\frac{CPUE_{obs,t}}{CPUE_{pred,t}}\right]}{sqrt(2) * s.d.(\log(CPUE_{obs,t}))} \right]^2$$

Penalties on Fishing mortality deviations.

$$\lambda \sum_{t=1}^{T} (e^{\varepsilon_t})^2$$

A total of 284 parameters for the 41 years of data (1969-2009) were estimated in the model (Table 4). The 116 fishing mortality parameters (one set for the directed fishery, 1970-2009, deviations and one mean value), one set for the snow crab fishery, 1992-2009, one set for the red king crab fishery, 1992-2009, and one set for the trawl fishery bycatch, 1973-2009) estimated in the model were constrained so that the estimated catch fit the observed catch closely. There were 40 recruitment deviation parameters estimated in the model, one for the mean recruitment (male and female recruitment were fixed to be equal). There were16 fishery selectivity parameters that did not change over time as in previous assessments. Survey selectivity was estimated for three different periods resulting in 6 parameters estimated. One parameter was estimated to fit the pot fishery CPUE time series.

Molting probabilities for mature males and females were fixed at 0, i.e., growth ceases at maturity which is consistent with the terminal molt paradigm (Rugolo et al. 2005 and Tamone et al. 2005). Molting probabilities were fixed at 1.0 for immature females and males. The intercept and slope of the linear growth function of postmolt relative to premolt size were fixed in the model using parameters estimated from growth measurements for Bering Sea snow crab (4 parameters, Table 4). A gamma distribution was used in the growth transition matrix with the beta parameters fixed at 0.75 for male and females.

The model separates crabs into mature, immature, new shell and old shell, and male and female for the population dynamics. The model estimate of survey mature biomass is fit to the observed survey mature biomass time series by sex. The model fits the size frequencies of the survey by immature and mature separately for each sex. The model fits the size frequencies for the pot fishery catch by new and old shell and by sex.

Crabs 25 mm cw and larger were included in the model, divided into 32 size bins of 5 mm each, from 25-29 mm to a plus group at 180-185 mm. In this report the term size as well as length will be considered synonymous with cw. Recruits were distributed in the first few size bins using a two parameter gamma distribution with the parameters estimated in the model. The alpha parameter of the distribution was fixed at 11.5 and the beta parameter was fixed at 4.0. 104 parameters were estimated for the initial population size composition of new and old shell males and females in 1969. No spawner-recruit relationship was used in the population dynamics part of the model. Recruitments for each year were estimated in the model to fit the data.

The NMFS trawl survey occurs in summer each year, generally in June-July. In the model, the time of the survey is considered to be the start of the year, July, rather than January. The modern directed Tanner crab pot fishery has occurred generally in the winter months (January to February) over a short period of time. In contrast, in the early years the fishery occurred over a more protracted time period. Natural mortality is applied to the population from the time the survey occurs until the fishery occurs, then catch is removed. The fishing mortality was applied as a pulse fishery at the mean time for that year. After the fishery, growth and recruitment take place in spring, with the remainder of the M taken through the end of the year as defined above.

Discard mortality

Discard mortality was assumed to be 50% for this assessment. The fishery for snow crabs occurs in winter when low temperatures and wind may result in freezing of crabs on deck before they are returned to the sea. Short term mortality may occur due to exposure, which has been demonstrated in laboratory experiments by Zhou and Kruse (1998) and Shirley (1998), where 100% mortality occurred under temperature and wind conditions that may occur in the fishery. Even if damage did not result in short term mortality, immature crabs that are discarded may experience mortality during molting some time later in their life.

Projection Model Structure

Variability in recruitment, as well as implementation error, was simulated with temporal autocorrelation. Recruitment was generated from a Beverton-Holt stock-recruitment model,

$$R_t = \frac{0.8\, h\, R_0\, B_t}{0.2\, spr_{F=0}\, R_0(1-h) + (h-0.2)B_t}\, e^{\varepsilon_t - \sigma_R^2/2}$$

$spr_{F=0}$ mature male biomass per recruit fishing at F=0. $B_0 = spr_{F=0}\, R_0$

B_t mature male biomass at time t

h	steepness of the stock-recruitment curve defined as the fraction of R_0 at 20% of B_0
R_0	recruitment when fishing at F=0
σ_R^2	variance for recruitment deviations, estimated at 0.74 from the assessment model

The temporal autocorrelation error (ε_t) was estimated as,

$$\varepsilon_t = \rho_R \varepsilon_{t-1} + \sqrt{1+\rho_R^2}\ \eta_t \qquad where\ \eta_t \sim N(0;\sigma_R^2) \qquad (2)$$

ρ_R	temporal autocorrelation coefficient for recruitment, set at 0.6

Recruitment variability and autocorrelation were estimated using recruitment estimates from the stock assessment model. R_0 and steepness were estimated such that $F_{35\%} = F_{MSY}$ and $B_{35\%} = B_{MSY}$ using a Beverton-Holt stock recruitment relationship.

Implementation error was modeled as a lognormal autocorrelated error on the mature male biomass used to determine the fishing mortality rate in the harvest control rule,

$$B_t^{'} = B_t e^{\phi_t - \sigma_I^2/2}; \quad \phi_t = \rho_I \phi_{t-1} + \sqrt{1+\rho_I^2}\ \varphi_t \qquad where\ \varphi_t \sim N(0;\sigma_I^2)$$

$B_t^{'}$	mature male biomass in year t with implementation error input to the harvest control rule,
B_t	mature male biomass in year t,
ρ_I	temporal autocorrelation for implementation error, set at 0.6 (estimated from the recruitment time series),
σ_I	standard deviation of φ which determines the magnitude of the implementation error, set at the estimate of variance of ending biomass from the assessment model plus additional uncertainty (cv) of 0.0, 0.2 and 0.4.

Implementation error in mature male biomass resulted in fishing mortality values applied to the population that were either higher or lower than the values without implementation error. The autocorrelation was assumed to be the same value as that estimated for recruitment. Implementation autocorrelation was used to more closely approximate the process of estimating a biomass time series from within a stock assessment model. The variability in biomass of the simulated population resulted from the variability in recruitment and variability in full selection F arising from implementation error on biomass. Uncertainty in initial numbers by length was added using a lognormal distribution with cv of ending biomass from the assessment model. The population dynamics equations were identical to those presented for the assessment model in the model structure section of this assessment.

RESULTS

Table 5 provides the likelihood values by component for the Tanner crab assessment model.

Figure 3 presents observed retained male catch and predicted retained plus discarded catches of male Tanner crab in the directed fishery, and total male catch in all fisheries combined.

Mature male biomass declined sharply from its high in 1969 to the mid-1980s, increased modestly to a secondary mode in 1990, then declined thereafter through the early-2000s (Figure 4). The model does not fit the increasing biomass trend in survey biomass observed in 2005-2008 but does fit the estimated 2009 survey biomass. The increasing biomass trend in 2005-2008 was driven principally by the occurrence of hot-spot tows in those years of the survey which inflated total EBS biomass estimates. Exploitation rates on legal and mature male biomass demonstrated two peaks: the first in the late-1970s through early-1980s and the second in the early-1990s (Figure 5).

Fisheries selectivities for the total and retained directed male catch were estimated in the model (Figure 21). Survey selectivities were estimated for three different time periods: 1969-1975, 1976-1981 and 1981 to the present (Figure 20). For the model presented here, catchability was fixed at 1.0 for all three time periods while the other two parameters of the selectivity model were estimated. Somerton and Otto (1999) estimated maximum selectivity for male Tanner crab to be 0.87 (Figure 20).

Model fits to mature female biomass and mature male biomass are shown in Figure 22 and Figure 4 respectively. Figure 16 shows the retention curve for male Tanner crab in the directed fishery. Figures 17 through 19 show estimated selectivity curves for the Bristol Bay red king crab fishery, the snow crab fishery and the groundfish trawl fishery, respectively.

Model fits to the survey length frequencies for female and males including observed survey biomass and lognormal 95% confidence intervals are presented in Figures 23 and 24. A summary plot of the model fit to the survey length frequencies for males and females over all years is shown in Figure 25. Observed survey numbers of legal males and model estimates of the population of legal males and of the survey number of legal males are shown in Figure 26.

Figure 27 illustrates estimates of recruitment to the model of crab 25-50 mm cw and average recruitment from 1969-2004 lagged 5 years. The distribution of recruits by carapace width to the model is shown in Figure 28. Figures 29 through 33 present summary plots of model fit to length frequencies for retained males, total males, females in the directed fishery, discards in the snow crab fishery and discards in the Bristol Bay red king crab fishery. Full-selection fishing mortality rates varied from near zero to approximately 1.5 (Figure 34). The pattern of recruitment to the model vs. male mature biomass is illustrated in Figure 35. Figure 36 shows realized instantaneous fishing morality rate vs. male mature biomass at mating and the F35% control rule for the period 1969-2008/09. Figure 37 presents the trajectory of estimated male mature biomass at the time of mating from 1969-2009. From the high biomass in 1970, MMB at mating has demonstrated a one-way trip of precipitously declining biomass through the mid-2000s. A modest mode of MMB was observed in the late-1980s to early-1990s, peaking in 1990, but this peak represented only approximately 16% of the 1970 estimate. The male size frequencies from 1969-2009 (Figure 24) reveals a contraction of the length frequency and shift to smaller sizes coincident with the decline; the modest increase in biomass associated with the 1990 mode is seen in the progression of a lengths from 1987 through 1992. Inspection of the metrics of stock and fishery performance of the EBS Tanner crab over the history from 1969-2009 are indicative of stock collapse.

Current State of Alaska Harvest Strategy

The current SOA harvest strategy (Zheng and Kruse 2000) is as follows: Let MFB_t be the estimate of mature female biomass in the Eastern Subdistrict (i.e., the waters of the Bering Sea District east of 173° W longitude) at the time of the survey in year t defined as the estimated biomass of females > 79 mm carapace width (cw), MFB_{t-1} be the estimate of mature female biomass in the Eastern Subdistrict at the time of the survey in the previous year ($t-1$), $MMMA_t$ be the molting mature male abundance in each area east and west of 166° W longitude within the Eastern Subdistrict at the time of the survey in year t defined as the estimated abundance of all new-shell males > 112-mm cw plus 15% of the estimated abundance of old-shell males > 112-mm cw, $ELMA_t$ be the exploitable legal male abundance in each area east and west of 166° W longitude within the Eastern Subdistrict at the time of the survey in year t defined as the estimated abundance of all new-shell legal males ≥138 mm cw plus 32% of the estimated abundance of old-shell legal males ≥138 mm cw, W_t be the average weight of legal males in the Eastern Subdistrict east or west of 166° W longitude in year t estimated by applying a weight-length relationship to the survey size-frequency data for legal (≥138 mm cw) males, HG_{COMP} be the total allowable catch computed for each area east and west of 166° W longitude in the Eastern Subdistrict, HG_{CAP} be the capped total allowable catch derived for each area east and west of 166° W longitude in the Eastern Subdistrict. In applying the control rule, [i] a separate HG is determined as the minimum of the HG_{COMP} and the HG_{CAP} for each area east and west of 166° W longitude, and [ii] the HG of legal males in each area east or west of 166° W longitude in the Eastern Subdistrict is capped at 50% of the exploitable legal male abundance.

The control rule for the HG during year t in each area east and west of 166° W longitude in the Eastern Subdistrict is as follows: (mp=million pounds).

1. If $MFB_{t-1} < 21.0$ mp and $MFB_t < 21.0$ mp, then $HG_{COMP}=0$ and $HG_{CAP}=0$.
2. If $MFB_{t-1} < 21.0$ mp and 21.0 mp $\leq MFB_t < 45.0$ mp, then $HG_{COMP}=0.05 MMMA_t W_t$ and $HG_{CAP}=0.25 ELMA_t W_t$.
3. If $MFB_{t-1} < 21.0$ mp and $MFB_t \geq 45.0$ mp, then $HG_{COMP}=0.1 MMMA_t W_t$ and $HG_{CAP}=0.25 ELMA_t W_t$.
4. If $MFB_{t-1} \geq 21.0$ mp and $MFB_t < 21.0$ mp, then $HG_{COMP}=0$ and $HG_{CAP}=0$.
5. If $MFB_{t-1} \geq 21.0$ mp and 21.0 mp $\leq MFB_t < 45.0$ mp, then $HG_{COMP}=0.1 MMMA_t W_t$ and $HG_{CAP}=0.5 ELMA_t W_t$.
6. If $MFB_{t-1} < 21.0$ mp and $MFB_t \geq 45.0$ mp, then $HG_{COMP}=0.2 MMMA_t W_t$ and $HG_{CAP}=0.5 ELMA_t W_t$.

Overfishing Control Rule

Amendment 24 to the NPFMC fishery management plan (NPFMC 2007) introduced revised the definitions for overfishing for EBS crab stocks. The information provided in this assessment is sufficient to estimate overfishing limits for Tanner crab under Tier 3b. The OFL control rule for Tier 3b is based on spawning biomass-per-recruit reference points (NPFMC 2007) (Figure 54).

$$F = \begin{cases} Bycatch\ only,\ Directed\ F = 0, & if\ \frac{B_t}{B_{REF}} \le \beta \\ \frac{F_{REF}\left[\frac{B_t}{B_{REF}} - \alpha\right]}{(1-\alpha)} & if\ \beta < \frac{B_t}{B_{REF}} < 1 \\ F_{REF} & if\ B_t \ge B_{REF} \end{cases} \qquad (12)$$

where,

B_t	mature male biomass at time of mating in year t
B_{REF}	proxy for B_{MSY} defined as mature male biomass at time of mating resulting from fishing at F_{REF} (proxy F_{MSY})
F_{REF}	F_{MSY} proxy defined as the fishing mortality that reduces mature male biomass at the time of mating-per-recruit to specified percent of its unfished level
α	fraction of B_{REF} where the harvest control rule intersects the x-axis if extended below β
β	fraction of B_{REF} below which directed fishing mortality is 0

The total catch, including all bycatch of both sexes from all fisheries, is estimated by the following equation,

$$catch = \sum_f \sum_s \sum_l \frac{F_{f,s,l}}{F_{tot,s,l}} (1 - e^{-(F_{tot,s,l})}) w_{s,l} N_{s,l}\, e^{-M*.62}$$

Where $N_{S,l}$ is the 2009 numbers at length(l) and sex at the time of the survey estimated from the population dynamics model, M_s is natural mortality by sex, 0.62 is the time elapsed (in years) from when the survey occurs to the fishery, F is the value estimated from the harvest control rule using the 2009 mature male biomass projected forward to the time of mating time (Feb. 2010), and $w_{s,l}$ is weight at length by sex. $Sel_{s,l}$ are the fishery selectivities by length and sex for the total catch (retained plus discard) estimated from the population dynamics model (Figure 23).

Estimation of $B_{35\%}$

The biomass reference point B_{REF} used in the 2009 stock assessment for OFL setting under Tier 4 status was estimated using the fixed net width survey MMB at mating data from the period 1969-1980 as recommended by the CPT and the SSC. Using the revised NMFS survey data that considers measured net widths, this definition of MMB at mating was 83,850 t. The average model estimate of MMB at mating from 1969 to 1980 was 118,600 t. For comparison, the average model estimate of MMB at mating over the entire time period (1969-2008) was 48,800 t.

Prior to the adoption of Amendment 24 to the NPFMC fishery management plan (NPFMC 2007) that established new overfishing definitions, the B_{MSY} proxy was 86,000 t, computed as the 15 year average (1983-1997) of observed survey total mature biomass (TMB) of males and females combined. The male mature biomass component of this average TMB was 52,800 t. This 15 year period comprises years in which the stock had dramatically declined from its peak abundance in the late-1960s and early-1970s to exceedingly low levels, punctuated by a modest mode of male survey mature biomass peaking in 1990 at 72,800 at 23.6% of the 1970 value (Figure 4 and Table 3).

The Tanner crab stock has experienced essentially a one-way trip from relatively high biomass levels in the late-1960s and early-1970s to exceedingly low biomass levels throughout the 1980's which have essentially persisted to the present. By all metrics indicative of stock and or fishery health, the EBS Tanner crab stock has collapsed over the observed period of record. The historical bimodal distribution in male biomass (Figure 4) reflects that of the attendant directed fisheries with peak modes in the mid-1960s and mid-1970s and early-1990s and collapsed stock status following these modes (Figures 2 and 3). Full-selection fishing mortality rates estimated in the model concur with excessive exploitation (Figure 34), averaging 0.9 (1974-81) or 1.2 (1977-81) and 1.4 (1989-95) coincident with peak extraction of catch (Figure 3) and decline in stock biomass. If the $F_{35\%}$ OFL control rule established by Amendment 24 had been in effect from 1969-2009, in 27 of the 41 years the realized F would have exceeded the limit and overfishing determined to have occurred (Figure 36). Fishing mortality rates on males associated with the catches of Tanner crab have often exceeded the OFL, however, this did not constitute overfishing in the past because Amendment 24 was only implemented in 2008.

Recruitment to the model of crab 25 mm to 50 mm cw fluctuated widely from 1965-2004 displaying a prominent mode of high recruitment in the late-1970s to early-1980s, 3.5 times the average for the entire time period (Figure 27). This dominant recruitment mode was the antecedent of the only modest mode in male mature biomass seen in late-1980s to early-1990s which, as noted, represented approximately 27% of the peak MMB in 1970. We have not observed the recruitments which gave rise to the peak male mature biomass levels in the late-1960s to early-1970s, nor the high biomass levels in 1969-1980. For Figure 27, the issue is one of the lack of scale given the observation history which over-emphasizes the magnitude of the dominant recruitment mode in the late-1970s to early-1980s. This over-emphasis applies equally to the observed history of recruitment vs. MMB at the time of mating (Figure 35) which shows highest observed recruitment in 1978, 1979 and 1980 at moderate MMB levels. Regardless of limitations in observed history to suitably characterize recruitment history, resultant male mature biomass and the recruit-per-spawner relationship, recruitment to the stock from the declining and low biomass period have been low and insufficient to prevent the decline or maintain the stock at levels observed pre-1980.

The EBS Tanner crab stock was under a rebuilding plan for part of the time period, and the directed fishery closed from 1997 to 2004 as a result of severely depressed stock status. Under the former BSAI King and Tanner Crab fishery management plan (NPFMC 1998) and overfishing definitions, the Tanner crab stock was above the B_{MSY} level indicative of a restored stock for the second consecutive year in 2007 and declared rebuilt.

$B_{35\%}$ under Tier 3 is defined as the product of average recruitment over a specified time period and the spawning biomass per recruit fishing at $F_{35\%}$. Using average recruitment for the period 1969-1985, $B_{35\%}$ was estimated by this approach to be 36,885 t. This estimate represents approximately 76% of the average MMB over the entire time series (1969-2009) which included the rebuilding period and severely depressed stock biomass periods.

For projections presented here, the biomass reference period agreed upon by the CPT and SSC for the September 2009 assessment was applied. We estimated B_{REF} using the average 1969-1980 observed survey data to be 83,850 t.

We intend to examine alternative approaches to estimate the $B_{35\%}$ proxy for B_{MSY} including initiating the model before 1969 to estimate recruitments that resulted in the stock biomass levels in 1969-1980, and simulating the stock to estimate B_0 from which $B_{35\%}$ can be derived. The goal of this work is to result in a more realistic and meaningful estimate of $B_{35\%}$ for use in the Tier 3 specification for this stock.

Rebuilding Analyses

Stock projections were run using the OFL control rule for buffers of 1.0, 0.8 and 0.6, with additional level of uncertainty=0.20 using the Beverton-Holt stock-recruitment relationship and without the SOA harvest strategy constraining the TAC (Tables 7, 8 and 9). The Beverton-Holt stock-recruitment relationship was estimated such that $F_{MSY}=F_{35\%}$ =0.687 and $B_{MSY}= B_{REF}$=83,850 t. In the first year, 2009/10, retained catch was set at the TAC established by the SOA. Rebuilding under F=0 occurs in 2021/22 (Draft EA for ACL and Rebuilding Analysis). Rebuilding with buffer=1.0 occurred with a 51.5% probability in 2031/32, with buffer=0.8 with a probability of 52.3% in 2028/29, and with buffer=0.6 with a probability of 52.6% in 2026/27.

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Table 1a. Eastern Bering Sea *Chionoecetes bairdi* retained catch in the United States pot, the Japanese tangle net and pot, and the Russian tangle net fisheries, 1965-2009.

Eastern Bering Sea Chionoecetes bairdi Retained Catch (10^6 lb)

Year	US Pot Fishery	[Crabs/Pot]	Japan	Russia	Total
1965			2.58	1.66	4.24
1966			3.73	1.66	5.39
1967			21.50	8.48	29.98
1968	1.01	12.0	29.95	8.73	39.69
1969	1.02	29.0	43.98	15.61	60.60
1970	0.17	8.0	41.73	14.31	56.20
1971	0.11	10.0	35.04	10.51	45.66
1972	0.23	6.0	37.04		37.27
1973	5.04	115.0	23.67		28.72
1974	7.03	72.0	26.58		33.60
1975	22.30	63.0	16.62		38.92
1976	51.50	68.0	14.67		66.17
1977	66.60	51.0	11.72		78.32
1978	42.50	42.0	4.00		46.50
1979	36.60	30.0	5.30		41.90
1980	29.60	21.0			29.60
1981	11.00	10.0			11.00
1982	5.27	8.0			5.27
1983	1.21	8.0			1.21
1984	3.15	12.0			3.15
1985	0	0			0
1986	0	0			0
1987	2.20	8.0			2.20
1988	7.01	16.0			7.01
1989	24.50	15.0			24.50
1990	40.10	19.0			40.10
1991	31.80	10.0			31.80
1992	35.10	13.0			35.10
1993	16.90	13.0			16.90
1994	7.80	13.0			7.80
1995	4.23	8.0			4.23
1996	1.81	5.0			1.81
1997	0	0			0
1998	0	0			0
1999	0	0			0
2000	0	0			0
2001	0	0			0
2002	0	0			0
2003	0	0			0
2004	0	0			0
2005	0.95	0			0.95
2006	2.12	13.8			2.12
2007	2.11	17.0			2.11
2008	1.94	12.6			1.94

Table 1b. Eastern Bering Sea *Chionoecetes bairdi* discard losses (1000 t) in the domestic eastern Bering Sea crab pot and groundfish trawl fisheries, 1969-2009. Discard mortality rates applied to the discarded crab (pot fisheries=50%; groundfish trawl fisheries=80%).

	Discard Losses (1000 t) of Tanner Crab by Fishery						
	Directed Fishery		Snow Crab		Red King Crab		Groundfish
Year	Male	Female	Male	Female	Male	Female	M+F
1969							
1970							
1971							
1972							
1973							14.3013
1974							19.7931
1975							7.6624
1976							3.3212
1977							2.2468
1978							2.5808
1979							2.0617
1980							1.6915
1981							1.1797
1982							0.3593
1983							0.5372
1984							0.5154
1985							0.3194
1986							0.5191
1987							0.5118
1988							0.3702
1989							0.5372
1990							0.7550
1991							2.0363
1992	5.4933	0.8936	12.8800	0.8938	0.5940	0.0144	2.2069
1993	3.4157	0.9072	7.2653	0.9069	1.4837	0.0989	1.4084
1994	1.5650	0.6351	3.5624	0.6357			1.6770
1995	1.3813	0.8800	2.3989	0.8795			1.2196
1996	0.1179	0.0454	0.4165	0.1146	0.0135	0.0021	1.2777
1997			0.8748	0.1131	0.0824	0.0015	0.9437
1998			0.9945	0.0876	0.0593	0.0015	0.7477
1999			0.3476	0.0726	0.0382	0.0019	0.5045
2000			0.0728	0.0108	0.0333	0.0012	0.5917
2001			0.1616	0.0056	0.0215	0.0009	0.9474
2002			0.2785	0.0184	0.0309	0.0014	0.5771
2003			0.0965	0.0132	0.0278	0.0016	0.3376
2004			0.0391	0.0069	0.0240	0.0014	0.5408
2005	0.1429	0.0136	0.4838	0.0215	0.0210	0.0009	0.4973
2006	0.6215	0.1610	0.7310	0.0846	0.0132	0.0013	0.5735
2007	1.0501	0.0499	0.9362	0.0509	0.0282	0.0046	0.5554
2008	0.2155	0.0068	0.5594	0.0248	0.1348	0.0022	0.4247
2009							

Table 2. Observed survey female, male and total spawning biomass (1000 t) and numbers of males ≥138mm (millions of crab).

Year	Observed survey female mature biomass	Observed survey male mature biomass	Observed survey total mature biomass	Observed number of males ≥138 mm (millions)
1969		286.76	286.76	192.55
1970		65.21	65.21	42.45
1971		-	-	
1972		18.08	18.08	7.80
1973		155.62	155.62	64.55
1974	53.90	211.81	265.71	80.88
1975	34.55	288.29	322.85	157.51
1976	45.99	152.09	198.08	89.16
1977	47.59	130.41	177.99	69.32
1978	26.43	80.62	107.06	40.09
1979	20.43	47.82	68.25	22.39
1980	70.42	86.33	156.76	29.96
1981	45.24	50.67	95.91	10.83
1982	64.76	49.67	114.43	7.75
1983	20.72	29.04	49.76	5.01
1984	14.72	26.15	40.87	6.60
1985	5.68	11.71	17.39	3.71
1986	3.49	13.18	16.67	2.44
1987	5.27	24.18	29.46	6.47
1988	25.57	59.51	85.08	16.37
1989	25.47	101.48	126.96	34.04
1990	36.36	103.17	139.52	44.52
1991	45.56	110.82	156.37	36.30
1992	27.76	108.12	135.88	42.44
1993	11.91	62.12	74.03	20.28
1994	10.37	44.55	54.92	15.91
1995	13.44	33.86	47.30	10.17
1996	9.80	27.32	37.12	9.27
1997	3.53	11.07	14.60	3.45
1998	2.31	10.56	12.87	2.16
1999	3.81	12.40	16.21	2.08
2000	4.17	16.45	20.63	4.71
2001	4.61	18.20	22.81	5.98
2002	4.48	18.23	22.71	6.07
2003	8.35	23.71	32.06	6.61
2004	4.70	25.56	30.26	4.77
2005	11.62	43.99	55.61	11.21
2006	15.79	66.89	82.68	14.42
2007	13.33	72.63	85.97	11.97
2008	11.33	59.70	71.03	13.14
2009	8.22	37.60	45.82	7.97

Table 3. Model estimates of population biomass (1000 t), population numbers, male, female and total mature biomass (1000 t) and number of legal sized males (≥138mm cw) in millions. Recruits enter the population at the beginning of the survey year after molting occurs.

Year	Biomass (million lbs 25mm+)	numbers (million crabs 25mm+)	female mature biomass	Male mature biomass	Total mature biomass	Number of males ≥138mm (millions)	Recruitment (millions, 25 mm to 50 mm)	MMB at mating (survey year t+1)	Full selection fishing mortality
1969	454.87	1667.21	39.80	289.72	329.51	249.91	*	222.90	0.149
1970	407.24	1448.87	38.15	308.23	346.38	224.93	156.45	238.50	0.141
1971	342.62	1524.96	29.84	251.30	281.14	174.74	401.41	193.99	0.146
1972	301.40	1551.86	23.85	193.05	216.90	130.18	362.35	147.45	0.164
1973	289.11	1494.95	22.43	151.90	174.33	95.42	280.52	103.07	0.341
1974	288.54	1268.01	26.15	134.32	160.47	71.45	106.15	81.12	0.675
1975	281.24	1067.25	31.29	144.21	175.50	81.49	98.95	104.18	0.383
1976	272.36	1119.50	34.01	161.58	195.59	93.63	301.80	107.70	0.530
1977	233.20	1000.90	32.32	140.98	173.31	74.92	153.14	82.00	0.874
1978	182.81	865.69	28.10	105.05	133.15	50.35	123.05	64.18	0.866
1979	149.14	683.11	26.49	81.91	108.40	36.81	33.18	46.94	1.127
1980	118.53	524.72	25.25	58.72	83.97	22.85	20.21	31.04	1.650
1981	93.67	418.77	21.98	41.48	63.46	12.91	39.66	26.17	1.225
1982	81.57	342.33	18.60	39.06	57.66	13.95	31.57	28.11	0.608
1983	81.16	837.67	15.70	40.83	56.52	17.39	576.33	31.51	0.277
1984	86.23	1213.70	14.14	40.31	54.46	18.48	553.50	30.51	0.291
1985	96.45	1453.53	15.67	34.80	50.47	15.75	494.84	29.17	0.037
1986	118.16	1482.56	23.54	31.74	55.28	14.24	330.08	26.23	0.051
1987	146.78	1450.85	35.75	31.64	67.39	13.30	277.38	25.19	0.138
1988	176.72	1327.94	45.56	40.72	86.28	16.55	184.62	29.85	0.356
1989	197.88	1191.54	48.68	59.97	108.65	28.14	159.74	36.62	0.887
1990	192.62	958.56	44.57	72.76	117.33	36.54	60.82	38.81	1.254
1991	165.41	735.24	37.95	70.12	108.07	34.39	35.37	37.11	1.105
1992	132.32	563.48	31.57	60.20	91.78	28.86	39.45	25.59	1.699
1993	91.19	410.14	23.98	39.97	63.95	17.07	28.32	17.95	1.760
1994	64.72	310.06	18.24	28.04	46.28	11.15	26.41	14.36	1.605
1995	49.15	262.49	14.44	21.92	36.36	8.71	39.19	12.21	1.277
1996	38.23	224.63	11.78	17.16	28.93	6.78	30.84	11.33	0.808
1997	33.44	237.78	10.25	14.62	24.87	5.53	64.61	9.46	0.780
1998	29.51	221.00	9.18	11.88	21.06	4.30	36.92	7.50	0.877
1999	28.34	312.92	8.48	9.58	18.05	3.32	141.99	6.52	0.789
2000	29.12	294.50	8.39	8.74	17.14	3.01	48.30	6.00	0.785
2001	33.08	414.17	8.79	8.67	17.46	3.14	182.54	5.73	0.918
2002	38.12	459.17	9.83	9.00	18.83	3.35	133.01	5.77	1.043
2003	45.03	535.14	11.26	9.97	21.24	3.83	173.98	6.39	1.034
2004	54.68	677.07	13.11	11.99	25.10	4.77	256.11	7.18	1.283
2005	63.00	624.39	15.56	14.35	29.91	6.02	92.18	8.96	1.031
2006	70.69	556.80	17.96	17.65	35.62	7.60	68.29	10.03	1.327
2007	74.95	498.46	19.96	20.24	40.20	8.63	67.81	13.57	0.736
2008	79.31	460.61	20.70	26.09	46.79	12.06	74.53	21.36	0.131
2009	88.44	665.07	19.88	36.29	56.17	18.51	302.70	30.74	

* Numbers by length estimated in the first year, so recruitment estimates start in second year.

Table 4. Parameters values and whether parameters were estimated in the model, excluding recruitments and fishing mortality parameters.

		Estimated? (N=No, Y=Yes)
Natural Mortality all crab	0.23	N
Female intercept (a) growth <=95mm	2.683	N
Female slope(b) growth<=95mm	1.221	N
Male intercept(a) growth<=105mm	3.87	N
Male slope (b) growth<=105mm	1.186	N
Female intercept (a) growth >95mm	17.75	N
Female slope(b) growth >95mm	1.07	N
Male intercept(a) growth >105mm	15.75	N
Male slope (b) growth >105mm	1.07	N
Alpha for gamma distribution of recruits	11.5	N
Beta for gamma distribution of recruits	4.0	N
Beta for gamma distribution female growth	0.75	N
Beta for gamma distribution male growth	0.75	N
Fishery selectivity total males slope	0.1438	Y
Fishery selectivity total males length at 50%	139.57	Y
Fishery selectivity retention curve males slope	0.684	Y
Fishery selectivity retention curve males length at 50%	137.39	Y
Directed Fishery discard selectivity female slope	0.1875	Y
Directed Fishery discard selectivity female length at 50%	99.90	Y
Snow crab fishery male selectivity slope	0.230	Y
Snow crab fishery male selectivity length at 50%	93.31	Y
Snow crab fishery female selectivity slope	0.143	Y
Snow crab fishery female selectivity length at 50%	87.91	Y
Red king crab fishery male selectivity slope	0.124	Y
Red king crab fishery male selectivity length at 50%	122.729	Y
Red king crab fishery female selectivity slope	0.178	Y
Red king crab fishery female selectivity length at 50%	104.70	Y
Groundfish Fishery selectivity slope	0.177	Y
Groundfish Fishery selectivity length at 50%	136.5	Y
Survey Q 1969-1977	1.0	N
Survey 1969-1977 length at 95% of Q	66.71	Y
Survey 1969-1977 length at 50% of Q	53.249	Y
Survey Q 1978-1981	1.0	N
Survey 1978-1981 length at 95% of Q	65.394	Y
Survey 1978-1981 length at 50% of Q	41.200	Y
Survey Q 1982-present	1.0	N
Survey 1982-present, length at 95% of Q	149.99	Y
Survey 1982-present length at 50% of Q	53.249	Y
Fishery cpue q	0.0001	Y
Probability of maturing males logistic curve slope	0.0775	N
Probability of maturing males logistic curve length at 50%	130.85	N
Probability of maturing females logistic curve slope	0.1439	N
Probability of maturing females logistic curve length at 50%	74.60	N

Table 5. Likelihood values by component for the Tanner crab assessment model.

Likelihood Component	Likelihood
Recruitment deviations	36.6
initial numbers smooth	13.2
F penalty	146.1
retained length	289.1
total directed length	168.9
female directed length	40.3
survey length	10139.5
trawl length	43.3
snow fishery length	1319.8
red king fishery length	19.1
survey biomass	1060.2
fishery cpue	40.6
directed fishery discard catch	19.6
retained catch	48.0
directed fishery female catch	10.7
groundfish catch	168.6
snow fishery catch	60.2
red king fishery catch	1.1
Total Likelihood	13624.8

Table 6. Weighting factors for likelihood equations. Sample size for all length components was set at 200.

Likelihood component	Weighting factor
Retained, directed discard male, snow fishery and red king fishery	25
Directed female catch, groundfish catch	1
Total catch length comp	1
Retained catch length comp	1
Female directed fishery length comp	0.2
Survey length comp	1
Groundfish fishery length comp	0.25
snow fishery and red king fishery length comp	1.0
Survey biomass	1.0 (survey cv by y)
Recruitment deviations	1
Fishing mortality deviations	5
Initial length comp smoothness	1
Fishery cpue	0.14 (cv = 5.0)

Table 7. Projections of median total catch (1000t), retained catch (1000t) and MMB at mating (1000t) for buffer=1.0 and the F35% (0.687) CR with B35%=83.85 (1000t). The SOA harvest strategy is not applied. In the first year (2009/10), retained catch is set at the TAC. Additional uncertainty=0.20. Values in parentheses are 90% confidence intervals. Probability of rebuilding in a year is estimated based on MMB above B35% for two years in a row.

Year	Total Catch	Retained catch	MMB at mating	Prob Rebduild.	Prob. Overfishing	Prob. MMB<0.5Bmsy
2009	2.169(1.992,2.349)	0.6017(0.6016,0.6017)	30.09(25.84,34.39)	0	-	1
2010	5.877(4.110,8.112)	3.273(2.106,4.818)	34.36(30.03,38.74)	0	0.440	1
2011	5.81(4.198,7.877)	3.408(2.260,4.898)	34.23(30.20,38.3)	0	0.464	0.999
2012	4.782(3.381,6.428)	2.686(1.713,3.816)	31.6(28.05,35.32)	0	0.435	1
2013	4.131(3.046,5.669)	2.072(1.381,3.061)	29.62(26.4,32.93)	0	0.421	1
2014	4.453(3.253,5.978)	2.124(1.389,3.097)	30.61(27.28,34.15)	0	0.431	1
2015	5.543(3.869,7.86)	2.878(1.844,4.242)	33.89(29.9,38.56)	0	0.441	0.994
2016	6.301(4.149,10.90)	3.474(2.132,5.925)	35.45(30.38,44.33)	0	0.453	0.900
2017	6.298(3.604,13.71)	3.36(1.831,7.563)	35.74(28.26,49.95)	0	0.444	0.809
2018	7.087(3.185,18.82)	3.574(1.488,9.928)	37.57(26.48,57.06)	0.001	0.429	0.663
2019	9.8(3.426,27.11)	4.855(1.530,13.44)	43.05(26.82,70.42)	0.001	0.444	0.469
2020	13.64(3.874,37.89)	7.157(1.792,20.82)	50.77(28.67,87.33)	0.018	0.420	0.301
2021	17.85(4.505,49.38)	9.894(2.160,27.1)	57.33(31.94,104.2)	0.060	0.477	0.199
2022	19.41(5.543,54.49)	11.16(2.529,31.92)	60.62(34.69,120.4)	0.119	0.440	0.146
2023	20(6.461,56.9)	11.70(3.267,34.23)	62.69(36.4,125.3)	0.184	0.434	0.109
2024	20.32(7.35,56.85)	11.75(3.817,34.62)	63.64(38.64,130.5)	0.220	0.419	0.081
2025	21.18(7.5,55.67)	11.97(3.988,33.19)	64.76(39.37,133.5)	0.253	0.439	0.077
2026	22.53(7.739,59.96)	12.77(4.069,34.72)	66.25(40.18,134.6)	0.292	0.452	0.070
2027	23.79(7.878,60.78)	13.27(4.124,35.74)	68.26(40.4,140.3)	0.332	0.452	0.064
2028	24.37(8.12,62.62)	13.79(4.179,35.62)	69.01(40.81,143.9)	0.382	0.443	0.060
2029	24.8(8.333,64.81)	13.98(4.105,37.69)	70.72(42.78,149.4)	0.432	0.433	0.040
2030	26.95(9.082,66.6)	14.98(4.605,39.3)	72.69(43.39,157.6)	0.473	0.439	0.039
2031	27.79(8.883,72.67)	15.37(4.761,41.17)	74.7(44.42,161.1)	0.515	0.414	0.036
2032	30.13(9.174,77.54)	16.83(4.993,44.38)	77.47(44.89,172.7)	0.559	0.438	0.034
2033	31.18(10.03,78.9)	17.42(5.281,46.61)	79.58(46.26,178.7)	0.609	0.417	0.033
2034	31.42(10.60,79.61)	17.65(5.568,47.52)	80.51(47.14,185.6)	0.654	0.412	0.023
2035	31.88(10.73,83.93)	17.92(5.837,49.83)	82(46.83,188.8)	0.683	0.445	0.021
2036	32.00(10.72,88.18)	17.99(5.717,52.7)	82.05(47.56,186.0)	0.714	0.447	0.018
2037	32.82(10.62,82.37)	18.46(5.708,48.18)	83.8(48.19,193.1)	0.735	0.449	0.016
2038	34.47(10.92,84.75)	19.3(5.69,49.31)	85.91(49.11,198.3)	0.766	0.447	0.016

Table 8. Projections of median total catch (1000t), retained catch (1000t) and MMB at mating (1000t) for buffer=0.8 and the F35% (0.687) CR with B35%=83.85 (1000t). The SOA harvest strategy is not applied. In the first year (2009/10), retained catch is set at the TAC. Additional uncertainty=0.20. Values in parentheses are 90% confidence intervals. Probability of rebuilding in a year is estimated based on MMB above B35% for two years in a row.

Year	Total Catch	Retained catch	MMB at mating	Prob Rebduild.	Prob. Overfishing	Prob. MMB<0.5Bmsy
2009	2.169(1.992,2.349)	0.6017(0.6016,0.6017)	30.09(25.84,34.39)	0	-	1
2010	4.782(2.617,9.297)	2.467(0.9381,5.702)	34.98(29.86,40.12)	0	0.263	0.991
2011	4.926(2.477,9.63)	2.733(0.8329,6.239)	35.33(29.61,40.95)	0	0.31	0.975
2012	4.063(2.088,7.905)	2.106(0.6162,5.027)	32.87(26.57,38.54)	0	0.288	0.994
2013	3.532(1.877,7.238)	1.631(0.4596,4.176)	30.96(25.07,36.3)	0	0.307	0.999
2014	3.804(2.022,7.572)	1.675(0.4628,4.234)	31.92(26.03,37.37)	0	0.308	0.999
2015	4.78(2.345,10.12)	2.345(0.6505,5.853)	35.34(28.56,41.99)	0	0.296	0.947
2016	5.549(2.551,12.96)	2.852(0.8478,7.445)	37.26(28.87,47.38)	0	0.303	0.807
2017	5.583(2.446,14.48)	2.785(0.7859,8.242)	37.48(27.48,53.73)	0	0.296	0.718
2018	6.218(2.282,19.24)	2.988(0.6519,10.41)	39.45(26.6,61.52)	0.001	0.303	0.591
2019	8.574(2.567,26.6)	3.981(0.822,14.01)	44.45(26.85,77.03)	0.004	0.307	0.427
2020	11.69(2.987,35.48)	5.906(1.067,19.08)	52.74(29.3,96.33)	0.036	0.292	0.288
2021	16.25(3.396,44.47)	8.75(1.323,25.17)	60.99(32.71,116.2)	0.093	0.292	0.200
2022	17.53(4.118,50.28)	10.04(1.551,29.3)	65.04(35.26,131.8)	0.189	0.266	0.137
2023	18.85(4.985,52.44)	10.98(2.043,31.76)	67.19(37.51,140.2)	0.258	0.243	0.100
2024	18.8(5.897,53.46)	10.70(2.527,33.20)	69.96(39.29,149.1)	0.312	0.250	0.074
2025	20.55(5.809,52.71)	11.51(2.641,32.05)	70.97(40.62,150.9)	0.366	0.254	0.065
2026	21.70(5.969,56.1)	12.09(2.721,32.73)	73.25(41.48,150.9)	0.423	0.250	0.057
2027	22.92(6.477,58.42)	12.82(3.068,34.59)	74.93(41,161.0)	0.464	0.263	0.056
2028	23.75(6.741,59.89)	13.20(3.191,33.89)	78.03(42.78,163.0)	0.523	0.250	0.046
2029	24.89(6.499,61.61)	13.83(3.077,35.95)	79.12(43.98,168.7)	0.579	0.238	0.033
2030	26.52(7.343,61.54)	14.83(3.426,37.21)	81.29(45.75,178.1)	0.619	0.234	0.033
2031	27.48(7.42,67.36)	15.16(3.294,39.47)	84.87(46.09,182.5)	0.656	0.230	0.027
2032	30.16(7.309,71.56)	17.21(3.358,41.82)	87.07(47.17,197.4)	0.704	0.225	0.024
2033	30.62(7.61,74.79)	17.39(3.59,43.67)	91(48.17,204.3)	0.750	0.192	0.023
2034	31.09(8.726,75.38)	17.73(4.017,45.83)	93.94(49.02,213.3)	0.787	0.211	0.021
2035	31.59(9.593,79.49)	17.75(4.948,47.2)	96.03(49.91,211.3)	0.802	0.217	0.015
2036	31.92(9.638,83.6)	18.15(4.631,49.48)	96.29(49.47,215.4)	0.830	0.217	0.015
2037	33.26(8.913,77.61)	18.74(4.299,46.98)	99.05(49.39,221.3)	0.849	0.212	0.011
2038	33.91(9.299,80.95)	19.35(4.682,47.11)	100.9(50.72,227.2)	0.871	0.219	0.016

Table 9. Projections of median total catch (1000t), retained catch (1000t) and MMB at mating (1000t) for buffer=0.6 and the F35% (0.687) CR with B35%=83.85 (1000t). The SOA harvest strategy is not applied. In the first year (2009/10), retained catch is set at the TAC. Additional uncertainty=0.20. Values in parentheses are 90% confidence intervals. Probability of rebuilding in a year is estimated based on MMB above B35% for two years in a row.

Year	Total Catch	Retained catch	MMB at mating	Prob Rebduild.	Prob. Overfishing	Prob. MMB<0.5Bmsy
2009	2.169(1.992,2.349)	0.6017(0.6016,0.6017)	30.09(25.84,34.39)	0	-	1
2010	3.872(2.163,7.489)	1.789(0.619,4.402)	35.66(30.65,40.73)	0	0.112	0.983
2011	4.146(2.163,8.136)	2.118(0.5664,5.119)	36.67(31.07,42.18)	0	0.145	0.942
2012	3.532(1.868,6.946)	1.671(0.4204,4.362)	34.46(28.66,40.04)	0	0.144	0.987
2013	3.111(1.742,6.391)	1.305(0.3221,3.611)	32.62(27.02,37.77)	0	0.157	0.998
2014	3.367(1.856,6.658)	1.346(0.33,3.588)	33.63(27.87,39.05)	0	0.160	0.993
2015	4.164(2.139,8.944)	1.896(0.4637,5.168)	37.22(30.71,43.63)	0	0.153	0.892
2016	4.842(2.303,11.43)	2.364(0.6286,6.541)	39.29(31.38,49.81)	0	0.164	0.695
2017	4.979(2.227,12.83)	2.327(0.5812,7.218)	39.64(29.67,56.88)	0	0.144	0.609
2018	5.54(2.081,17.36)	2.501(0.4744,9.248)	41.75(28.66,65.65)	0.001	0.157	0.505
2019	7.572(2.351,23.41)	3.39(0.6197,12.39)	47.09(28.80,82.1)	0.011	0.162	0.354
2020	10.36(2.706,29.88)	5.04(0.8311,16.25)	56.49(31.18,104.0)	0.045	0.137	0.227
2021	14.66(3.046,37.58)	7.751(1.063,21.27)	65.48(34.77,129.5)	0.124	0.120	0.148
2022	16.21(3.803,44.18)	9.066(1.288,25.6)	71.23(37.58,147.5)	0.248	0.097	0.090
2023	17.89(4.496,46.59)	10.34(1.773,28.42)	74.27(40.96,159.6)	0.344	0.086	0.059
2024	18.30(5.391,49.35)	10.22(2.161,29.82)	77.38(43.06,168.3)	0.402	0.077	0.040
2025	19.84(5.682,48.24)	10.99(2.375,28.75)	79.57(44.66,176.6)	0.468	0.086	0.027
2026	20.98(5.765,50.69)	11.74(2.479,29.6)	82.45(46.04,175.0)	0.526	0.066	0.027
2027	22.30(6.326,52.58)	12.54(2.697,31.62)	85.25(46.14,184.6)	0.575	0.074	0.024
2028	23.00(6.453,53.79)	12.87(3.008,30.57)	87.62(47.39,188.5)	0.629	0.074	0.019
2029	23.93(6.38,54.94)	13.50(2.890,31.94)	90.26(49.24,197.0)	0.683	0.072	0.018
2030	25.19(7.229,56.1)	14.02(3.255,34.6)	92.83(51.29,206)	0.726	0.058	0.015
2031	25.82(7.133,62.12)	14.32(3.072,35.88)	96.53(51.42,206.9)	0.763	0.046	0.012
2032	27.79(7.178,65.91)	15.66(3.147,38.18)	100.7(52.93,231.5)	0.808	0.042	0.010
2033	28.18(7.606,67.04)	16.05(3.41,40.32)	104.3(54.13,234.5)	0.848	0.051	0.010
2034	28.81(8.506,68.99)	16.2(3.937,41.74)	108.1(55.24,248.3)	0.867	0.045	0.007
2035	28.74(9.154,73.39)	16.32(4.715,43.49)	110.7(56.21,249.1)	0.882	0.035	0.005
2036	29.21(9.265,77.72)	16.71(4.671,45.88)	112.3(55.98,255.3)	0.902	0.043	0.002
2037	30.65(9.061,73.23)	17.23(4.231,43.67)	115.3(55.92,259.9)	0.919	0.048	0.006
2038	31.18(9.439,74.16)	17.85(4.621,43.16)	117.8(57.32,267.1)	0.932	0.049	0.009

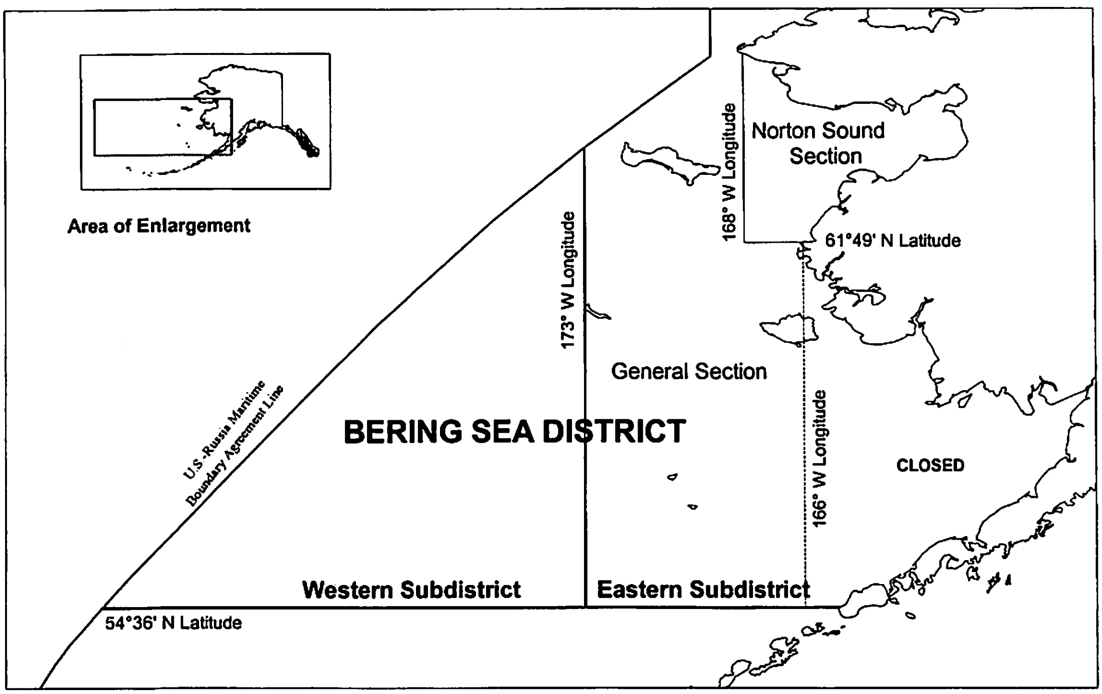


Figure 1. Eastern Bering Sea District of Tanner crab Registration Area J including subdistricts and sections (From Bowers et al. 2008).

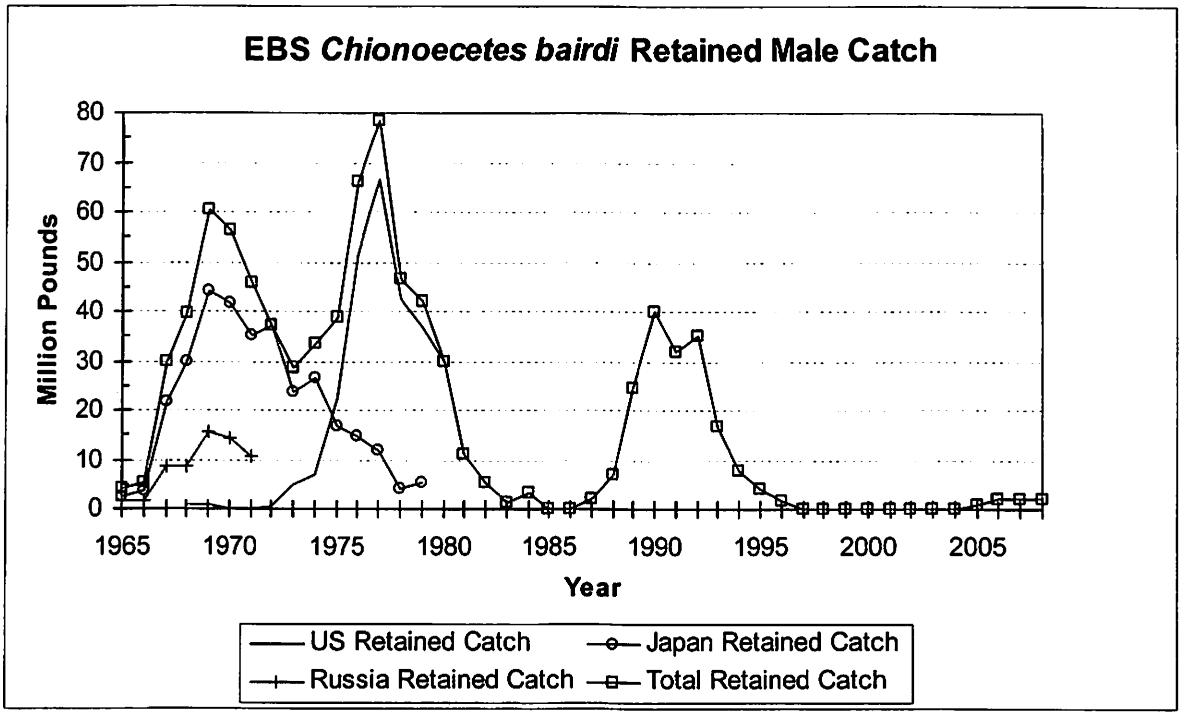


Figure 2. Eastern Bering Sea *Chionoecetes bairdi* retained male catch in the directed United States, Russian and Japanese fisheries, 1965-2009.

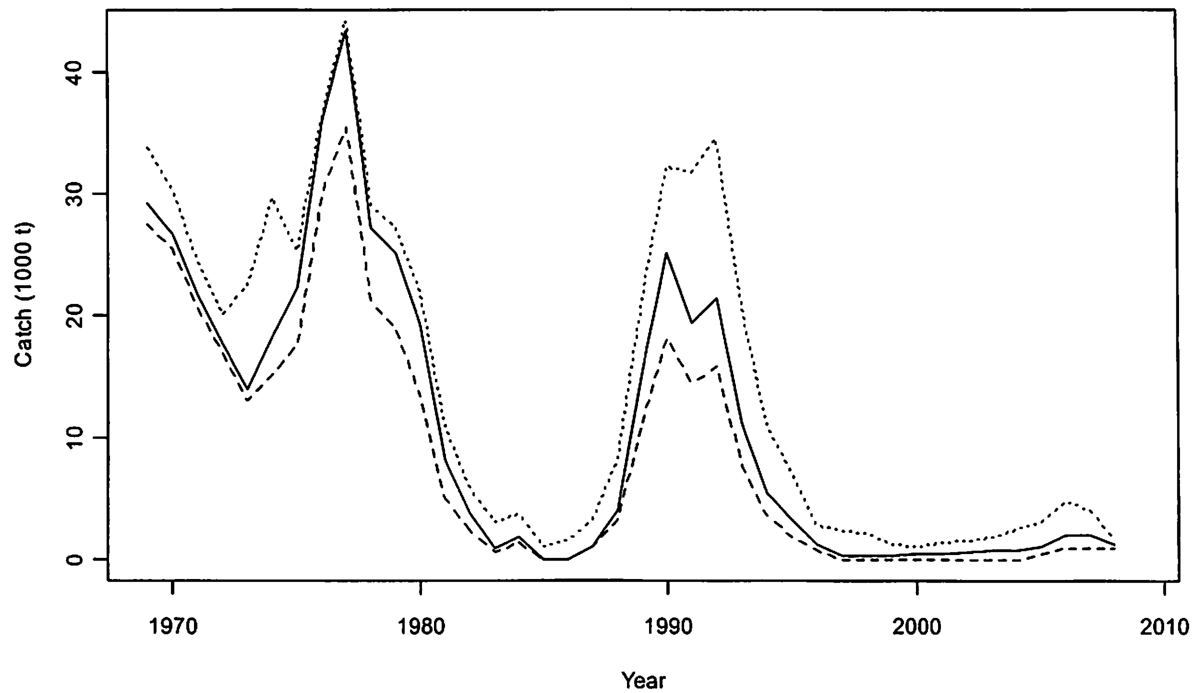


Figure 3. Male Tanner crab catch biomass by survey year (e.g., 2008 is the 2008/09 fishing year). [solid line=predicted retained plus discarded male catch in the directed fishery; dashed line=predicted retained male catch in the directed fishery; dotted line=predicted total male catch from all sources]

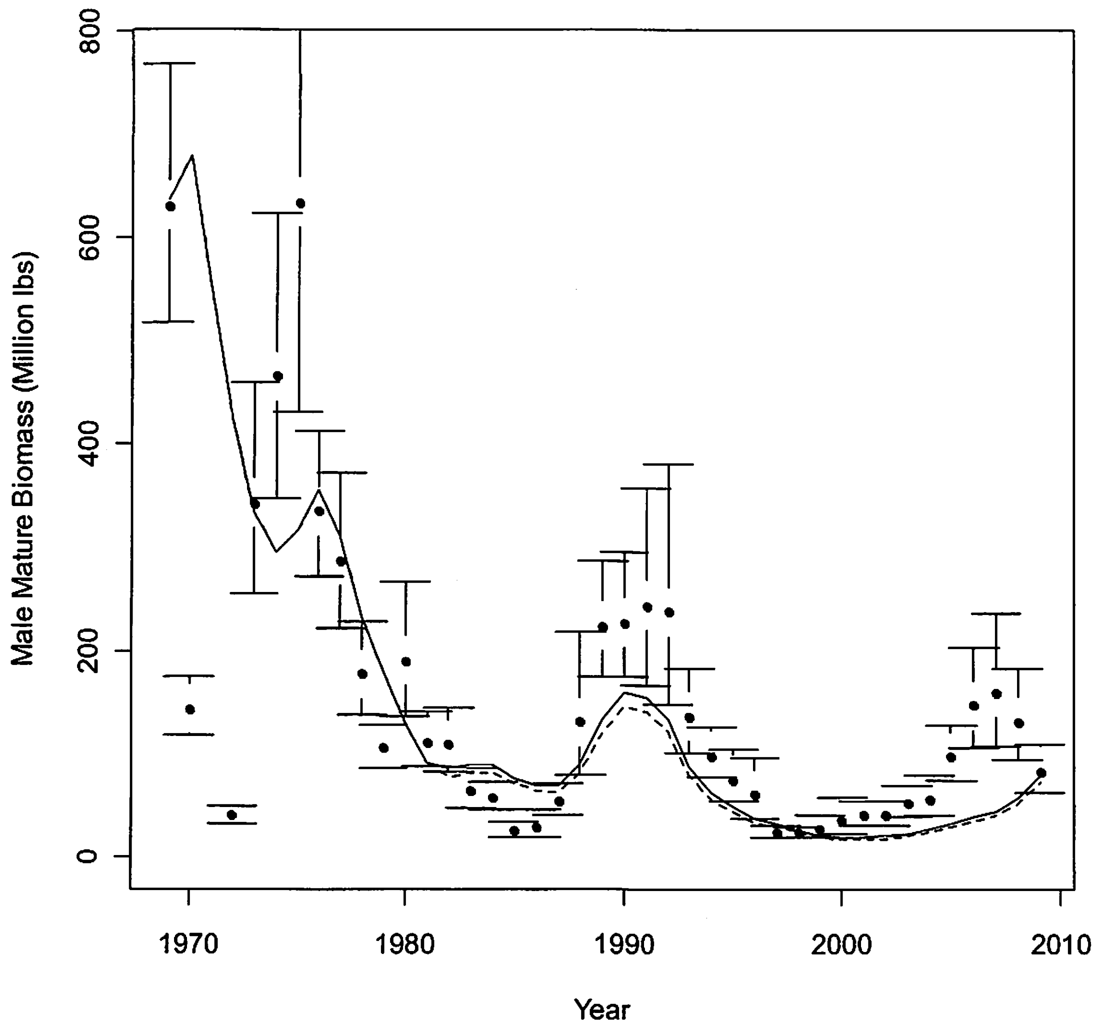


Figure 4. Population mature male biomass (millions of pounds, solid line) at the time of the survey, model estimate of survey mature biomass (dotted line) and observed survey mature male biomass with approximate lognormal 95% confidence intervals.

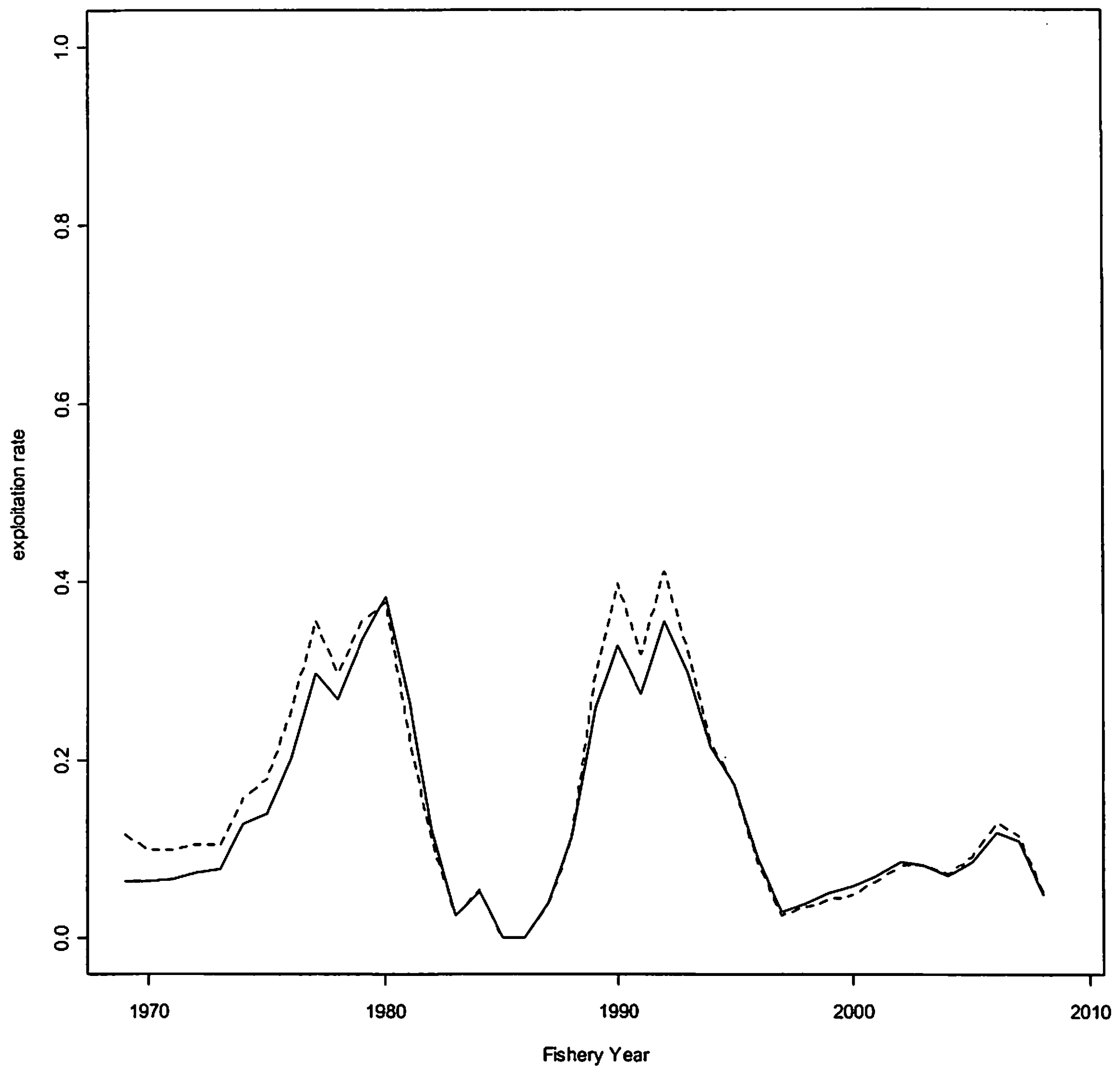
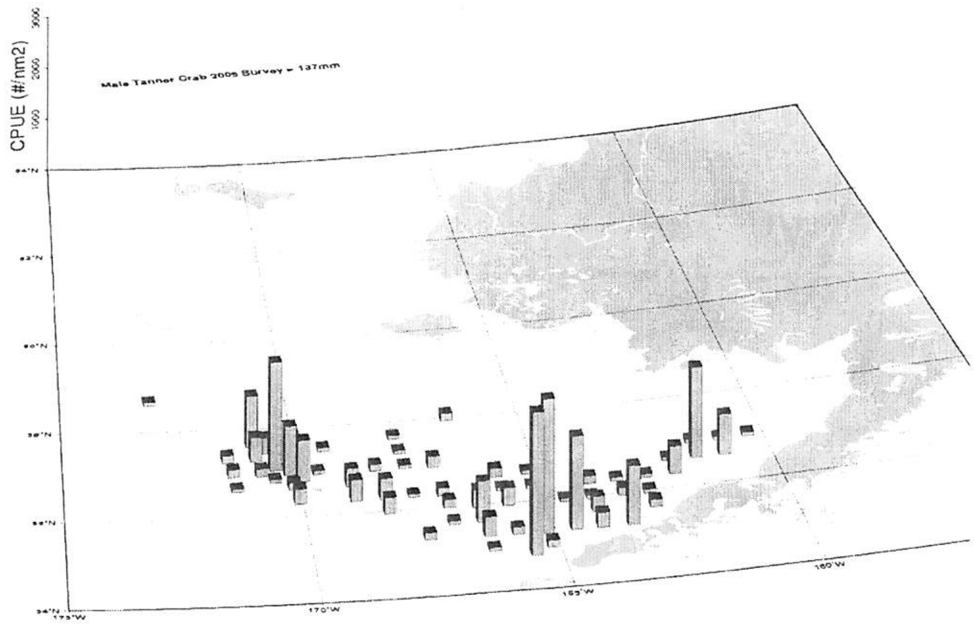


Figure 5. Exploitation fraction estimated as the predicted catch biomass of legal males in all fisheries divided by the estimated legal male biomass at the time of the fishery (solid), and the predicted total catch (retained plus discard) divided by the estimated male mature biomass at the time of the fishery (dotted). Year is the year of the fishery.



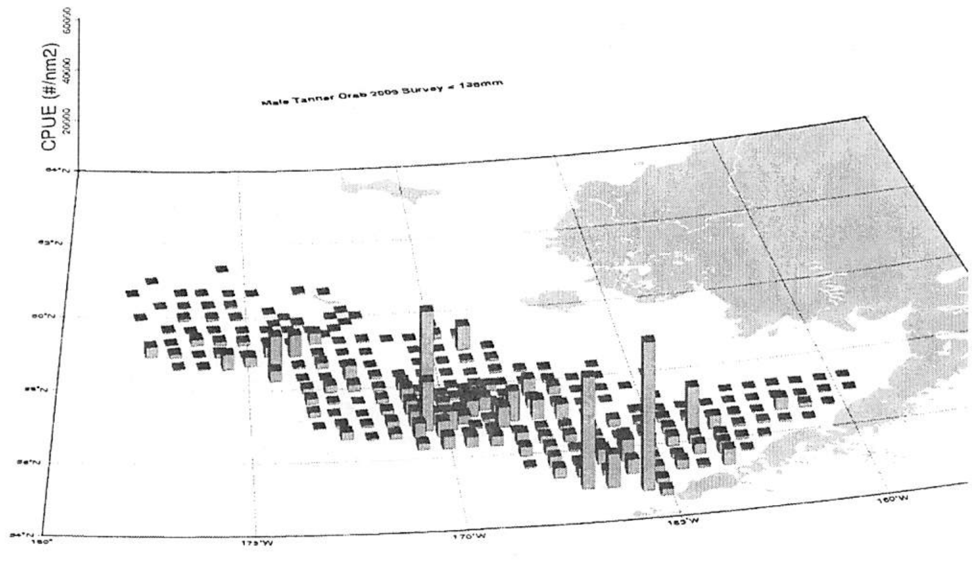


Figure 6. Distribution and abundance of legal (>= 138 mm cw) and sublegal (< 138 mm cw) male Tanner crab in the summer 2009 NMFS EBS trawl survey.

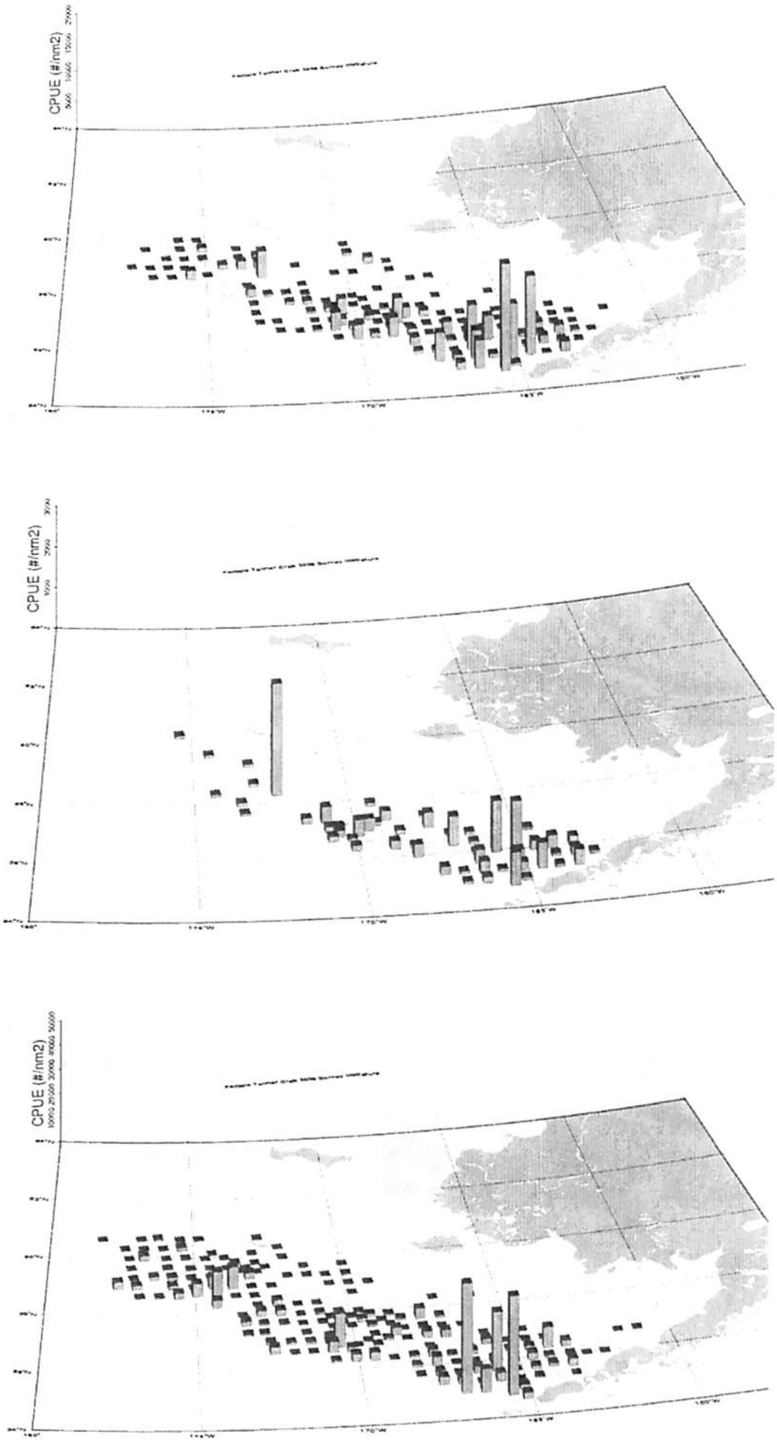


Figure 7. Distribution and abundance of ovigerous, barren mature, and immature female Tanner crab in the summer 2009 NMFS EBS trawl survey.

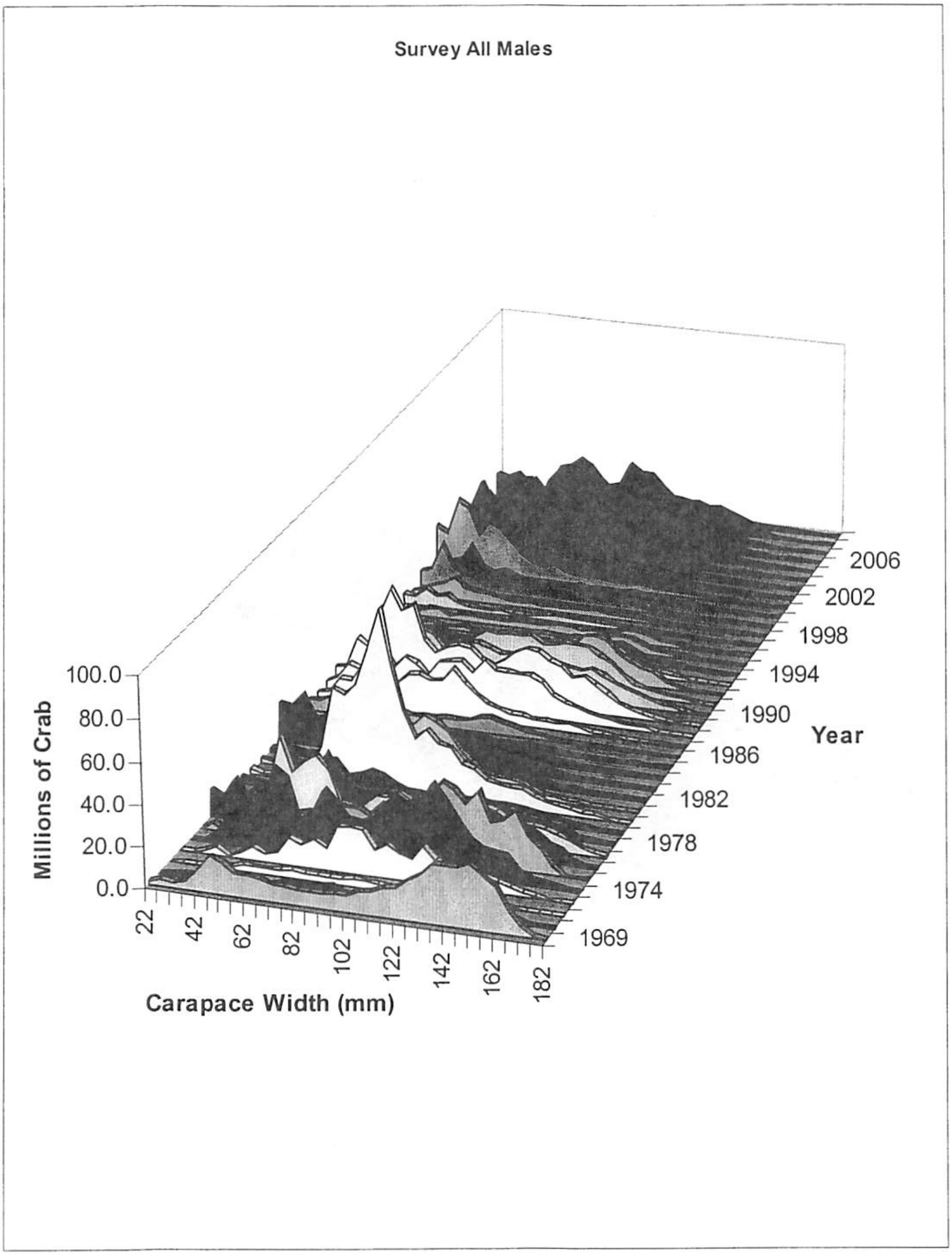


Figure 8. Observed survey numbers (millions of crab) by carapace width and year for male Tanner crab.

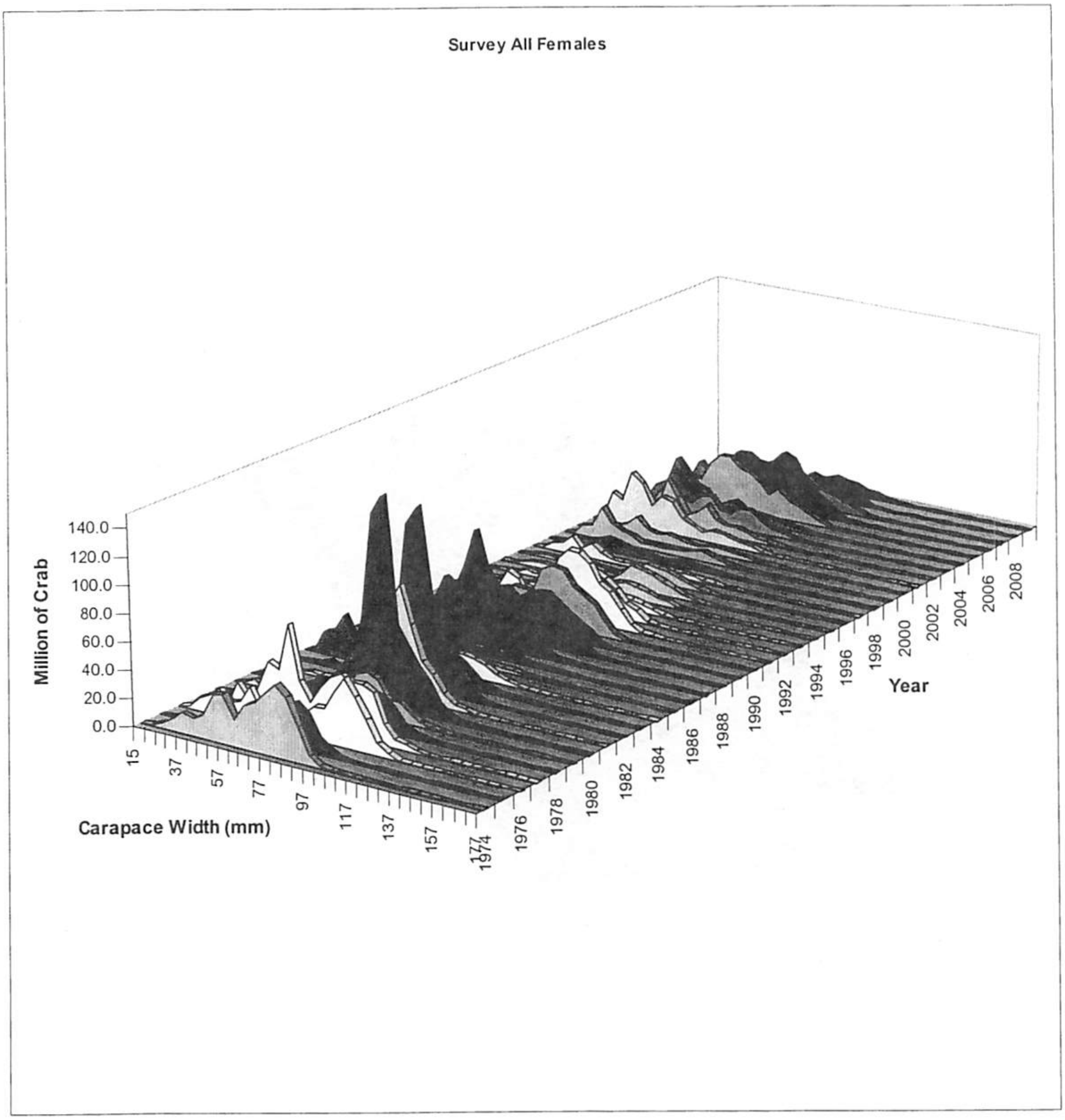


Figure 9. Observed survey numbers (millions of crab) by carapace width and year for female Tanner crab.

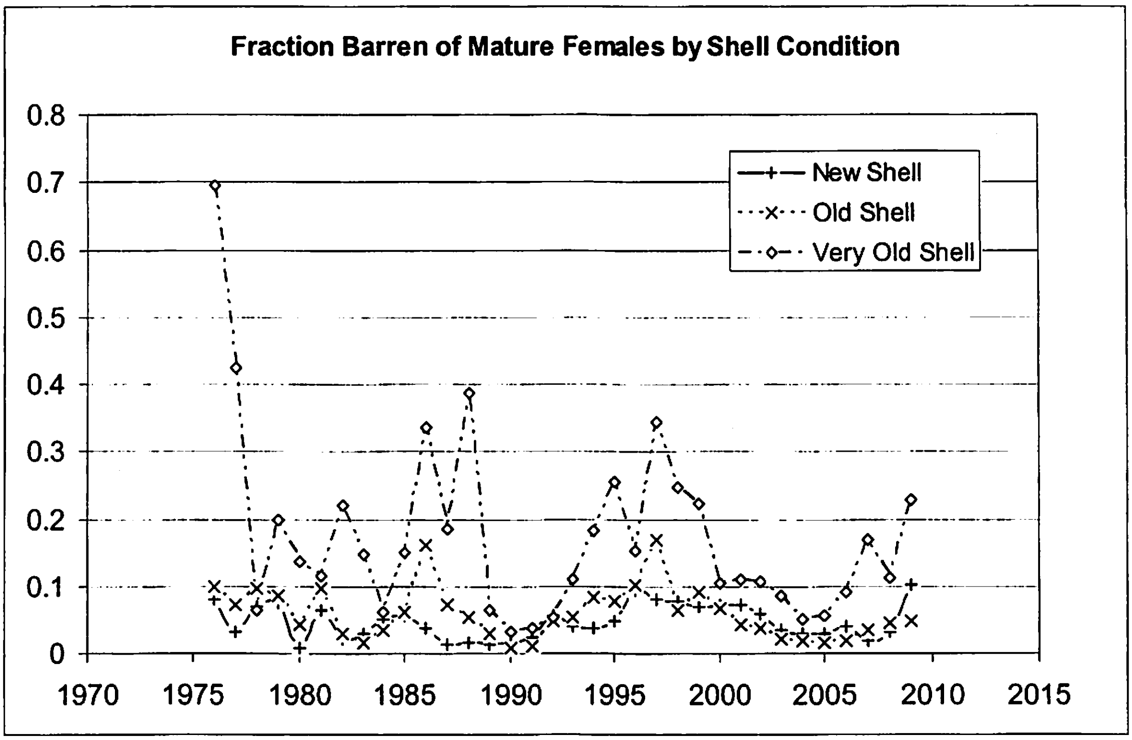


Figure 10. Proportion of female Tanner crab with barren clutches by shell condition from survey data for 1976 to 2009.

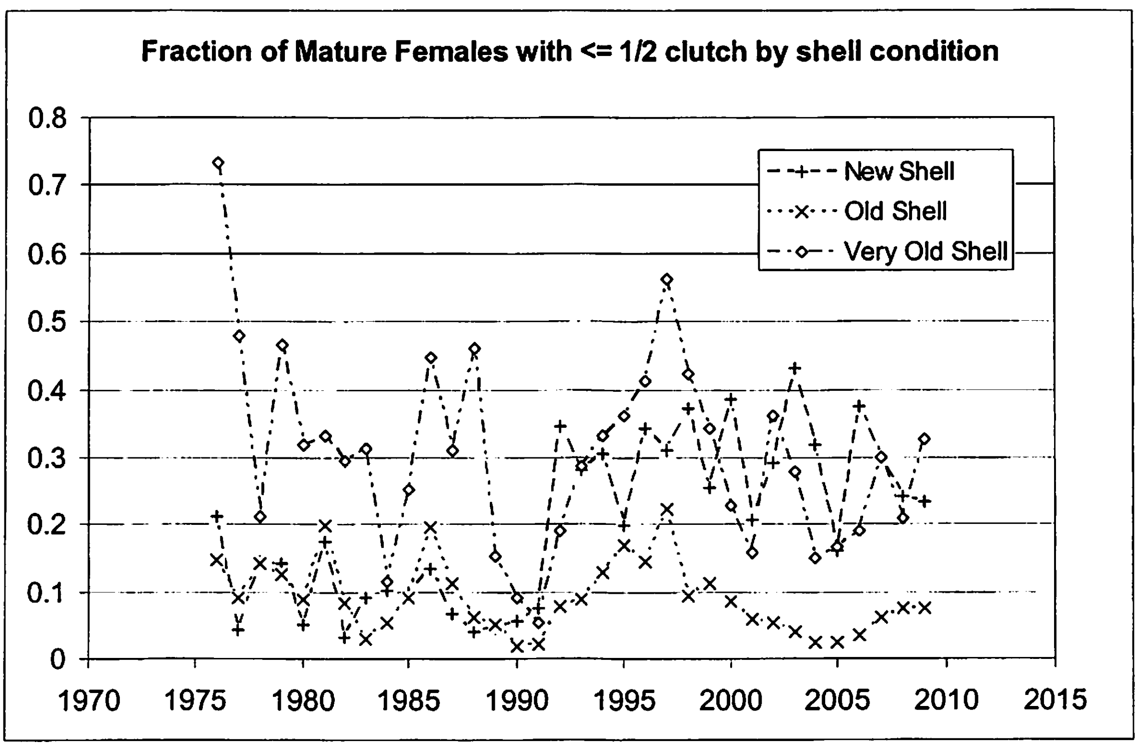


Figure 11. Proportion of female Tanner crab with less than or equal to one-half full clutch by shell condition from survey data 1976 to 2009.

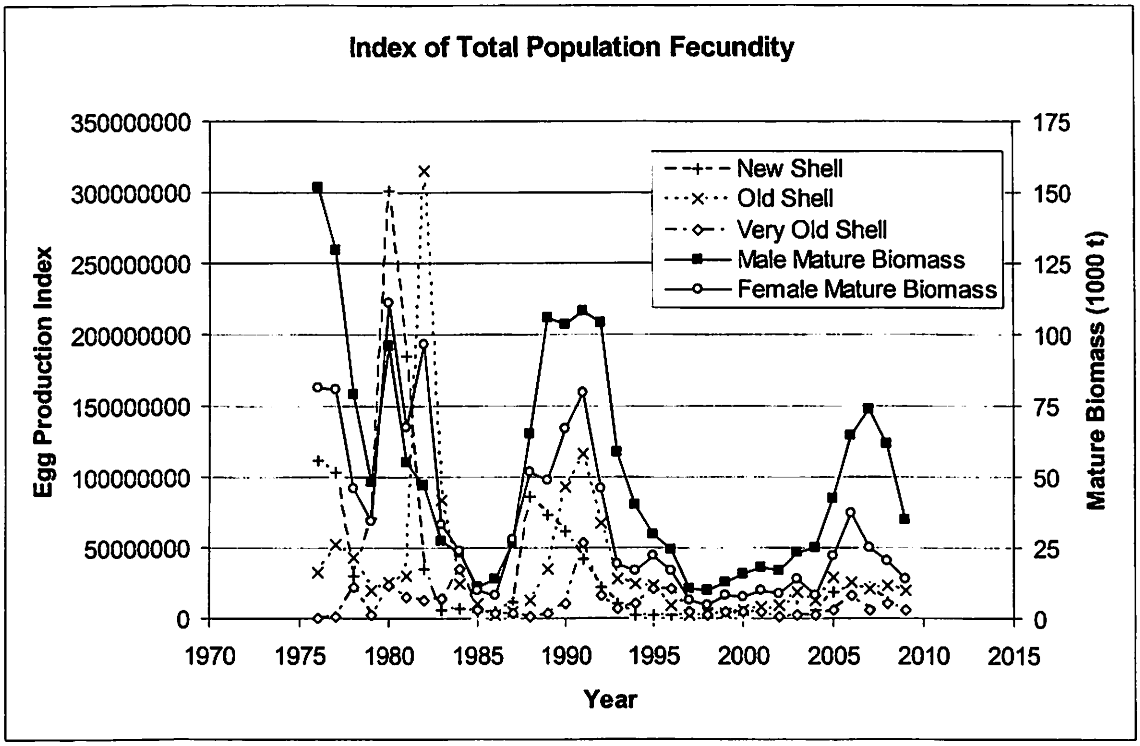


Figure 12. Tanner crab female egg production index (EPI) by shell condition, survey estimate of male mature biomass (1000 t), and survey estimate of female mature biomass (1000 t) from survey dåta for 1976 to 2009.

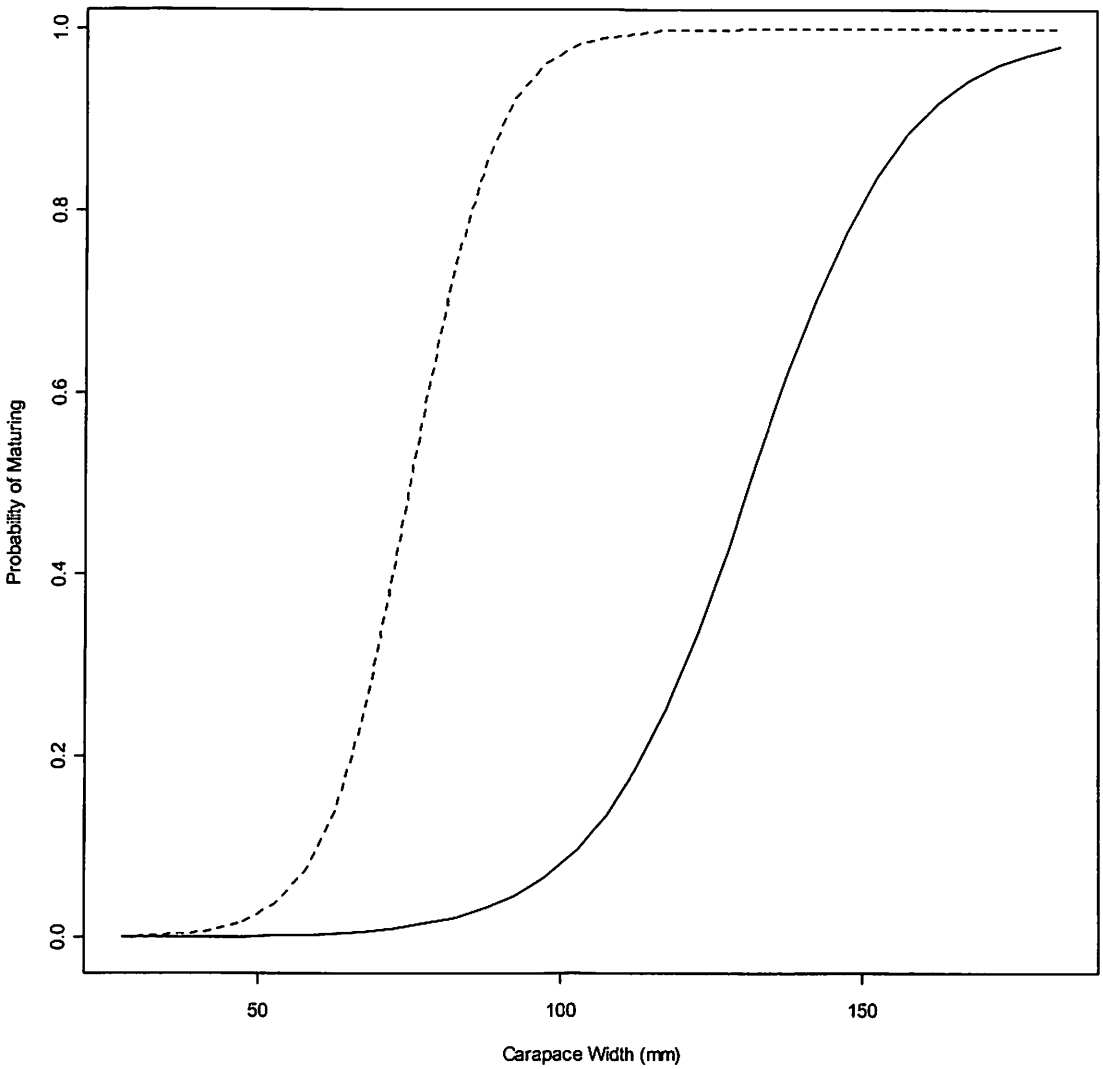


Figure 13. Probability of maturing by size for male and female tanner crab (not the average fraction mature). Dotted line = females, solid line = males.

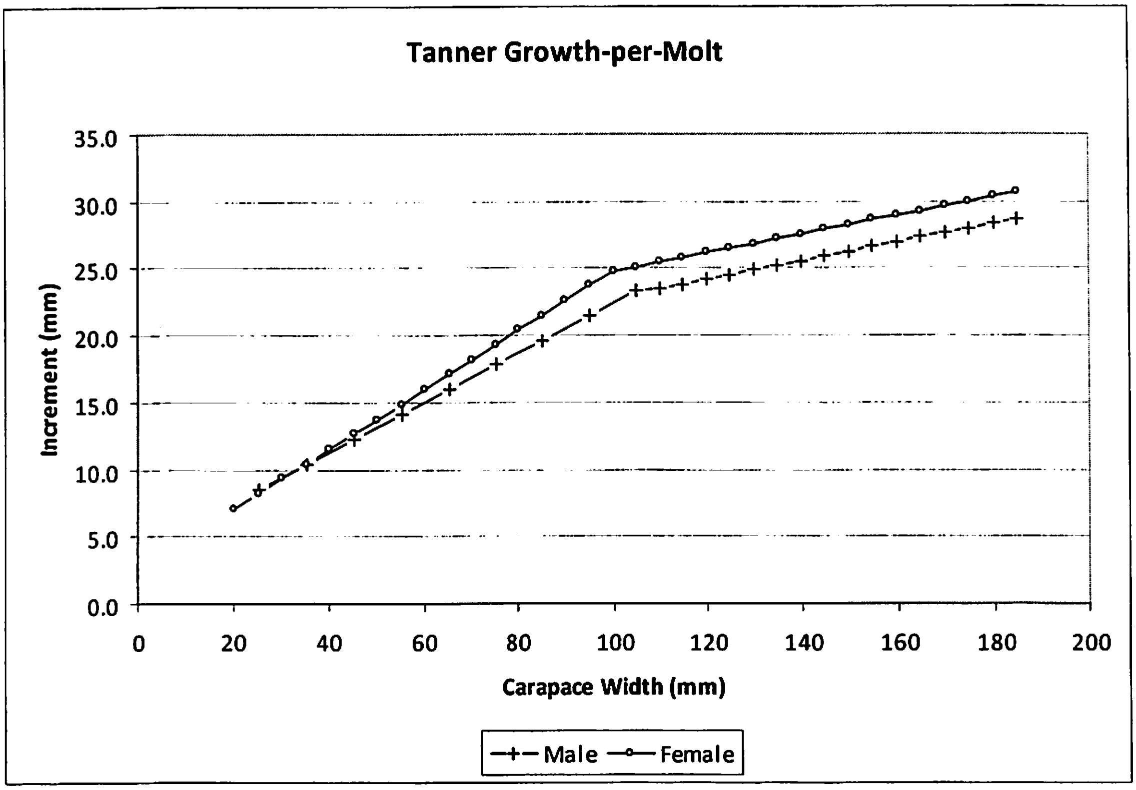


Figure 14. Growth increment as a function of premolt size for male and female Tanner crab. Estimated by Rugolo and Turnock 2010 based on data from GOA Tanner crab (Munk, unpublished data).

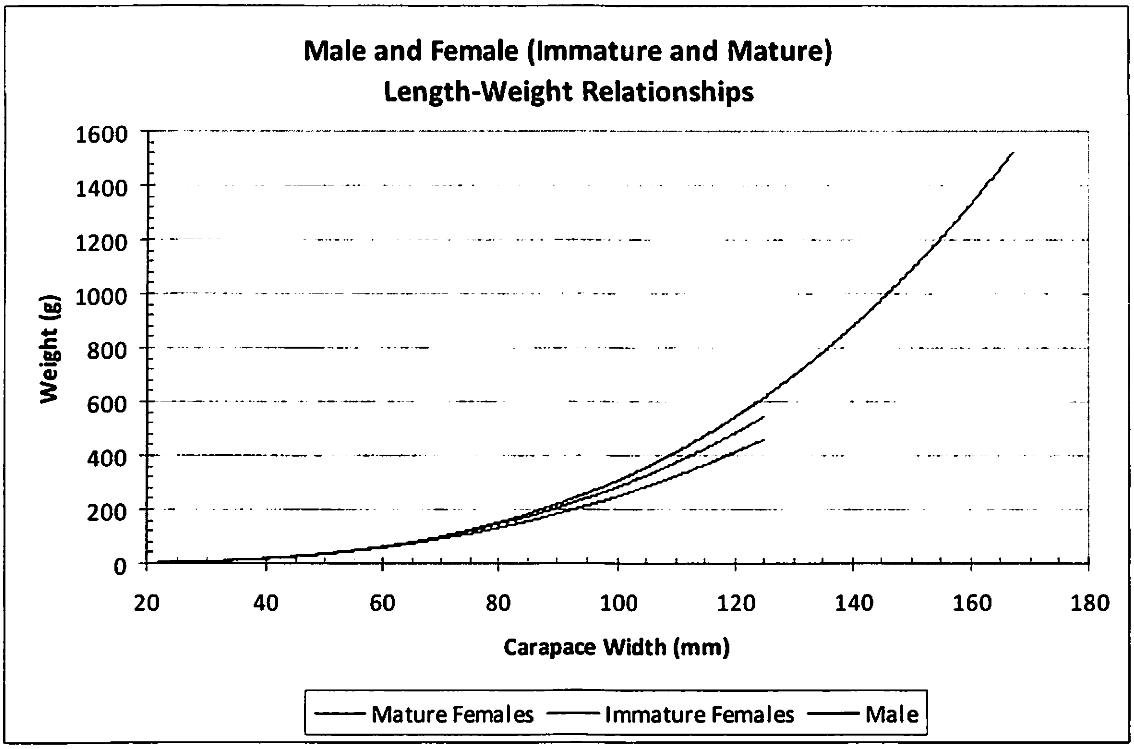


Figure 15. Weight (kg) – size (mm) relationship for male (top), mature female (middle) and immature female (bottom) Tanner crab.

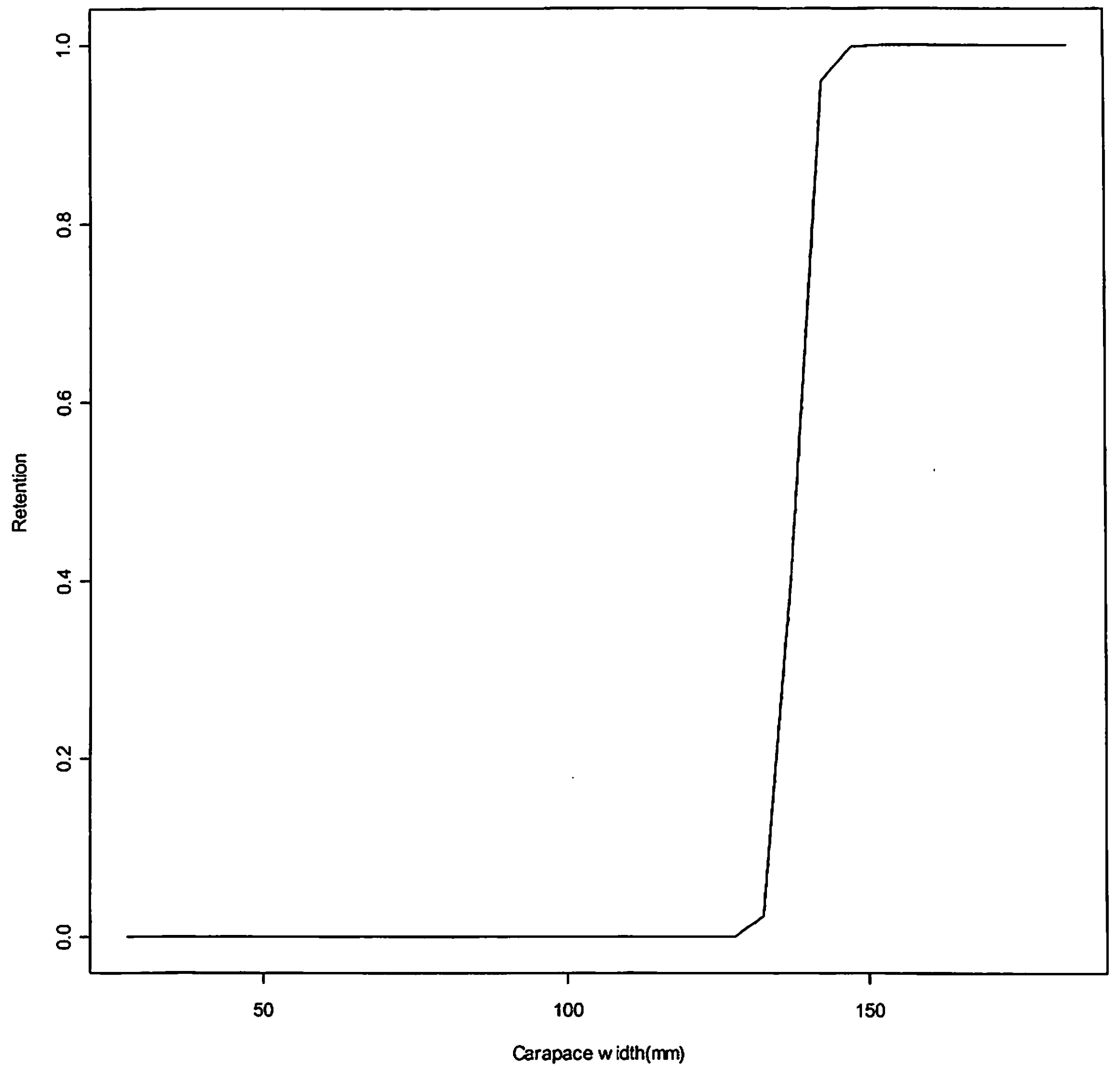


Figure 16. Model estimated fraction of the total catch that is retained (retention function) by size for male Tanner crab in the directed fishery all shell conditions combined. This retention function is multiplied by the total directed male selectivity curve to estimate the directed fishery retained selectivity.

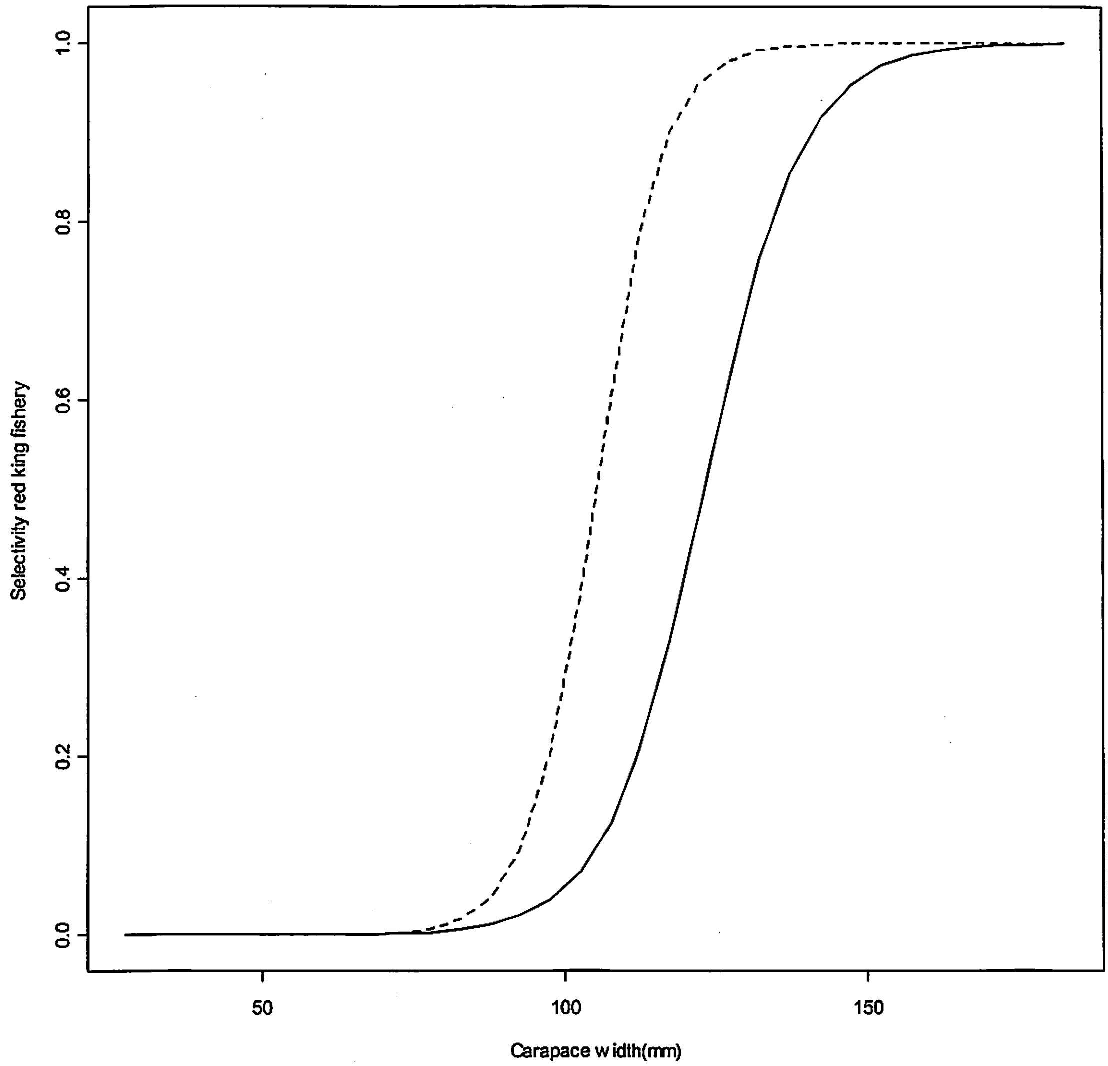


Figure 17. Selectivity curve estimated by the model for bycatch in the Bristol Bay red king crab fishery for females (dotted) and males (solid).

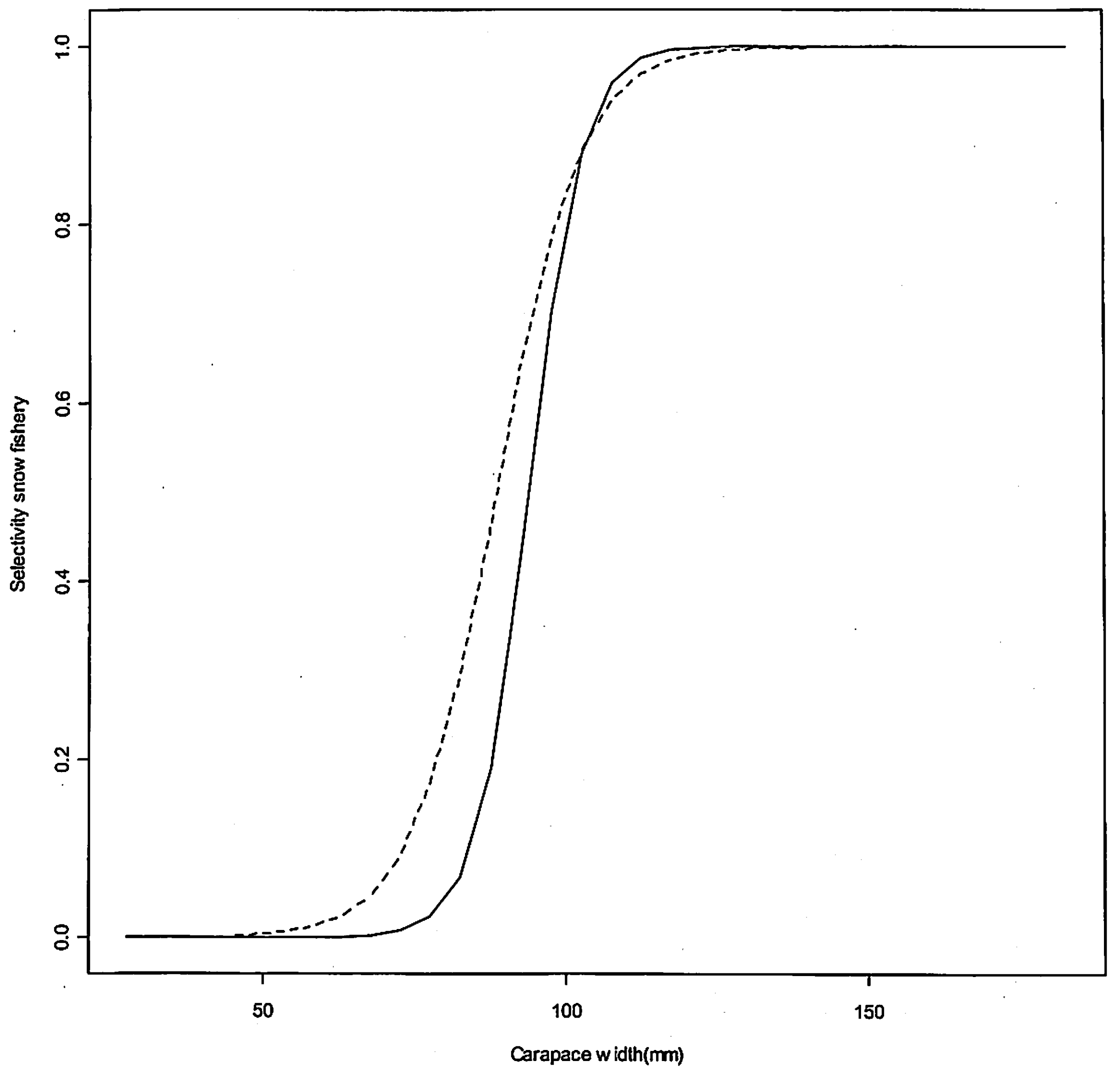


Figure 18. Selectivity curve estimated by the model for bycatch in the snow crab fishery for females (dotted) and males (solid).

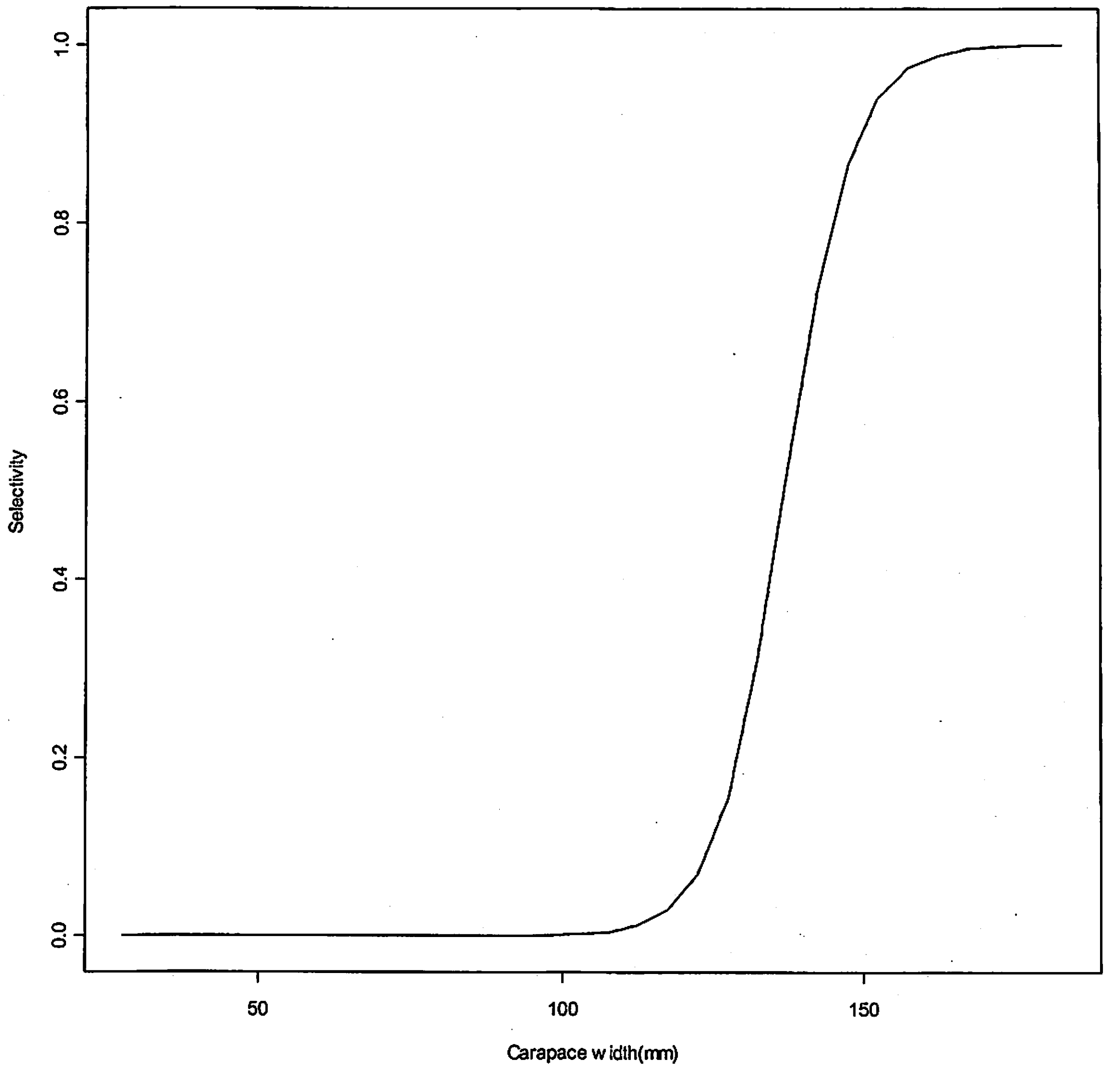


Figure 19. Selectivity curve estimated by the model for bycatch of males and females combined in the groundfish fishery.

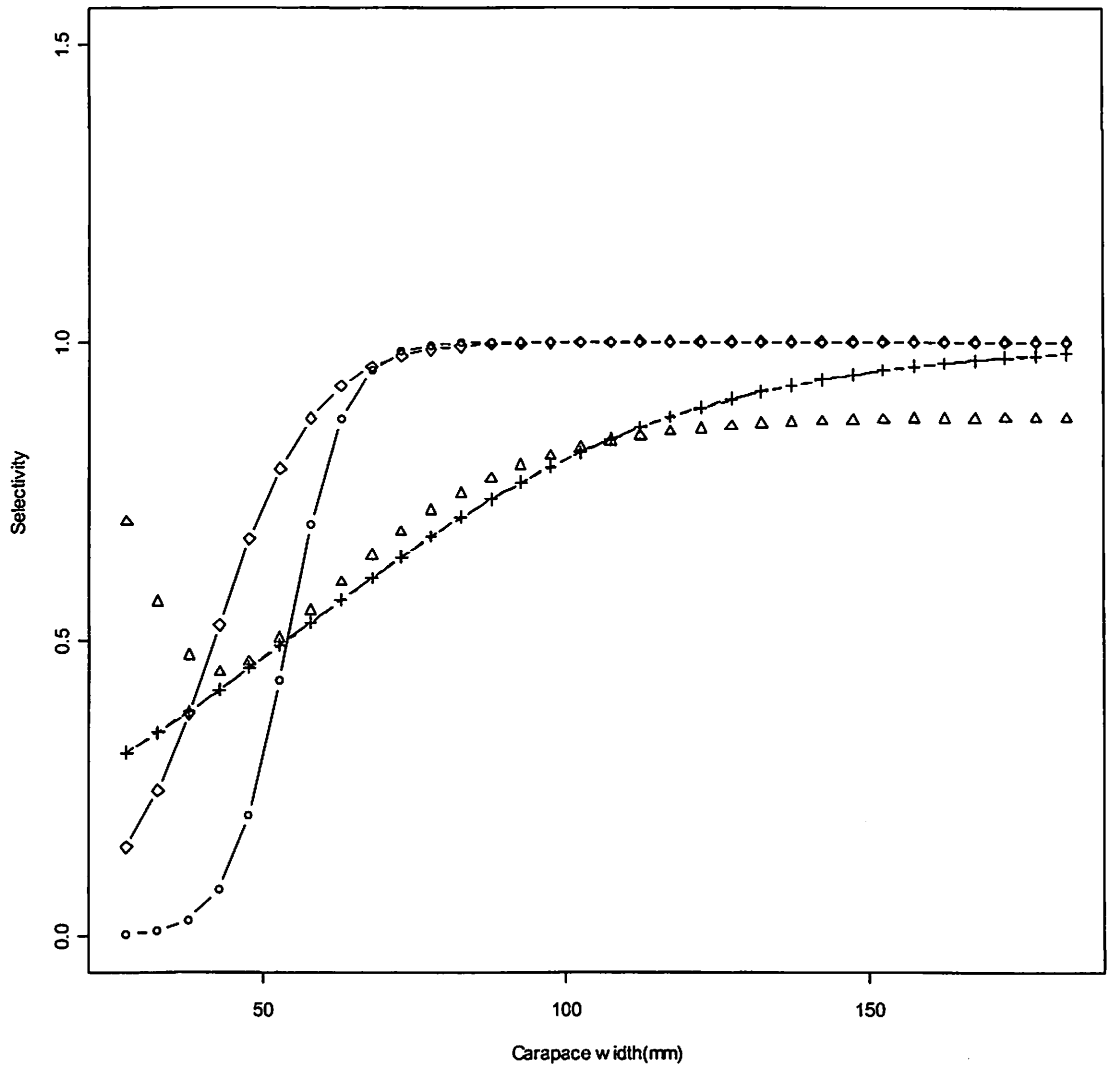


Figure 20. Survey selectivity curves for female and male Tanner crab estimated by the model for 1969-1975 (solid line with circles), for 1976 to 1981 (solid line with diamonds), and 1982 to present (solid line with pluses). Survey selectivities estimated by Somerton and Otto (1998) are triangle symbols.

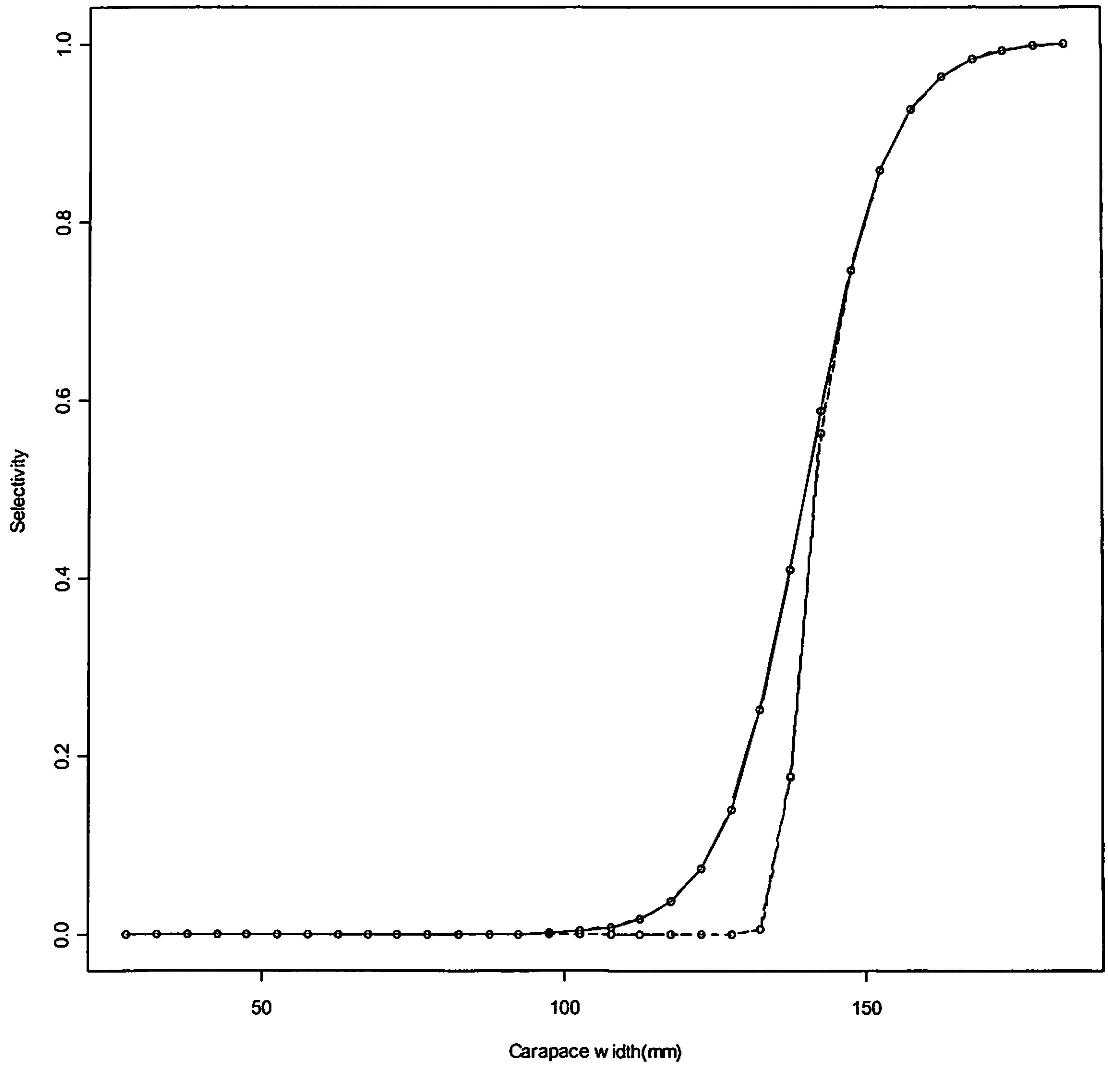


Figure 21. Selectivity curve for total catch (discard plus retained, solid line) and retained catch (dotted line) for combined shell condition male Tanner crab.

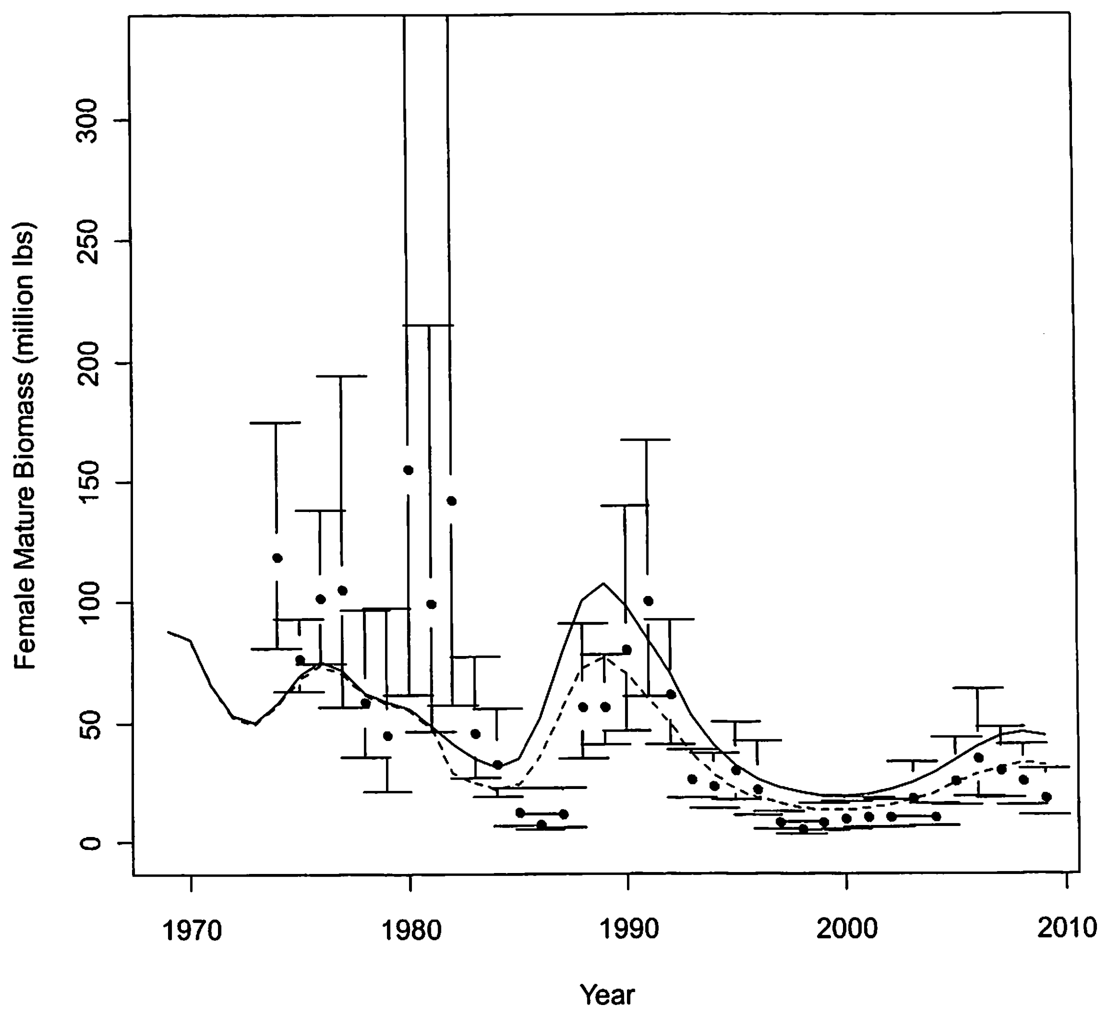


Figure 22. Population female mature biomass (millions of pounds, solid line), model estimate of survey female mature biomass (dotted line) and observed survey female mature biomass with approximate lognormal 95% confidence intervals.

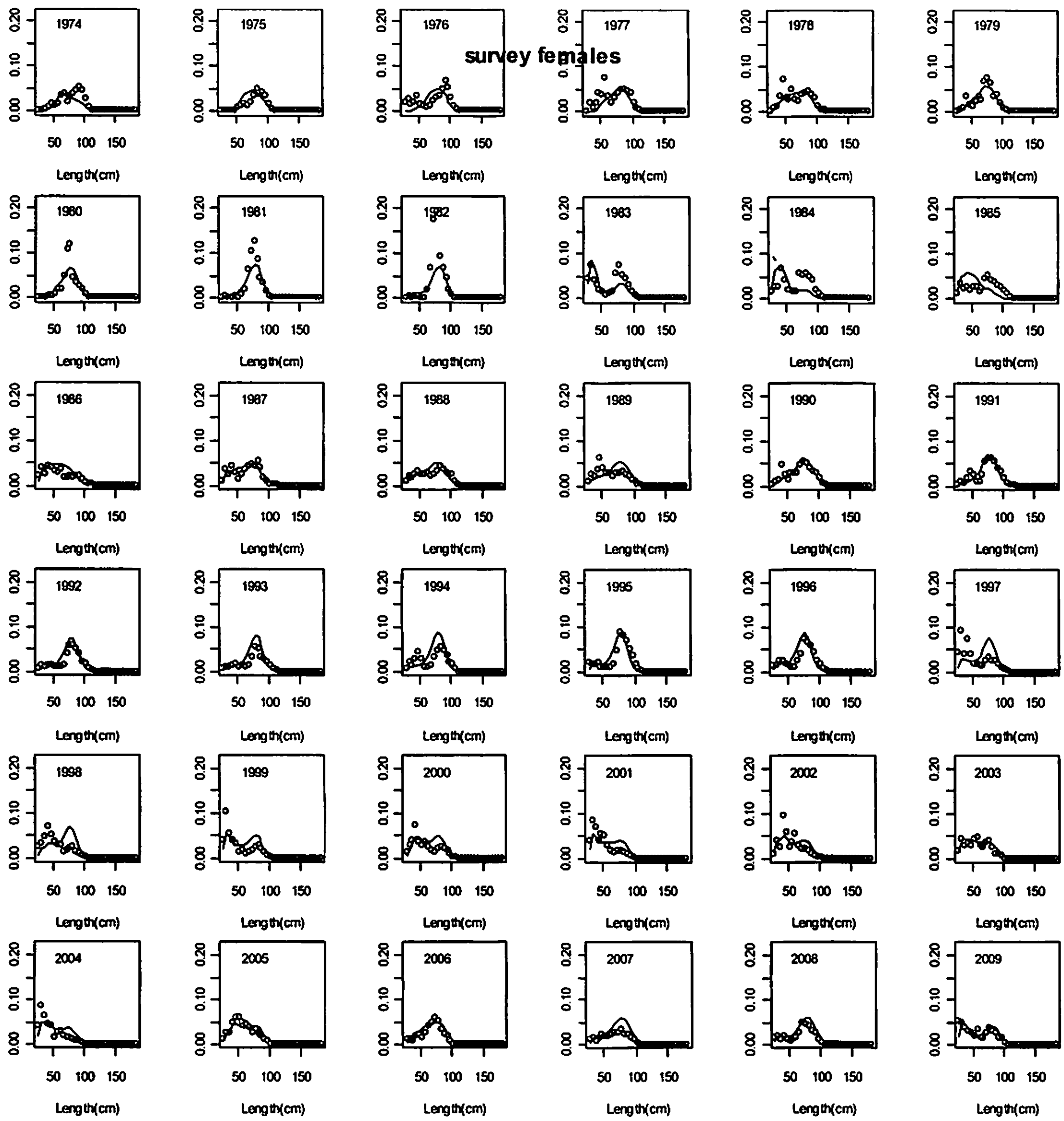


Figure 23. Model fit to the survey female size frequency data. Circles are observed survey data. Solid line is the model fit.

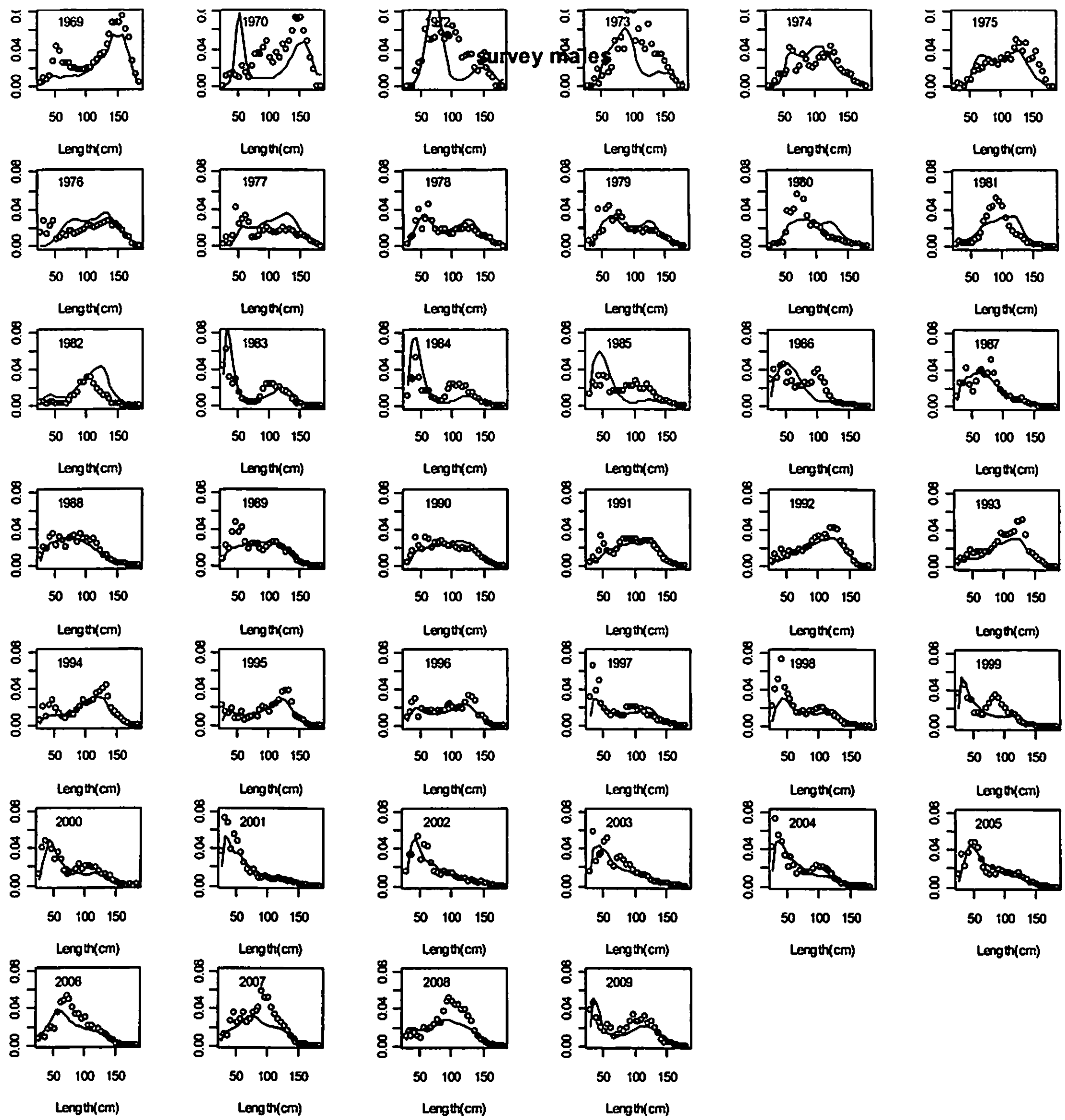


Figure 24. Model fit to the survey male size frequency data. Circles are observed survey data. Solid line is the model fit.

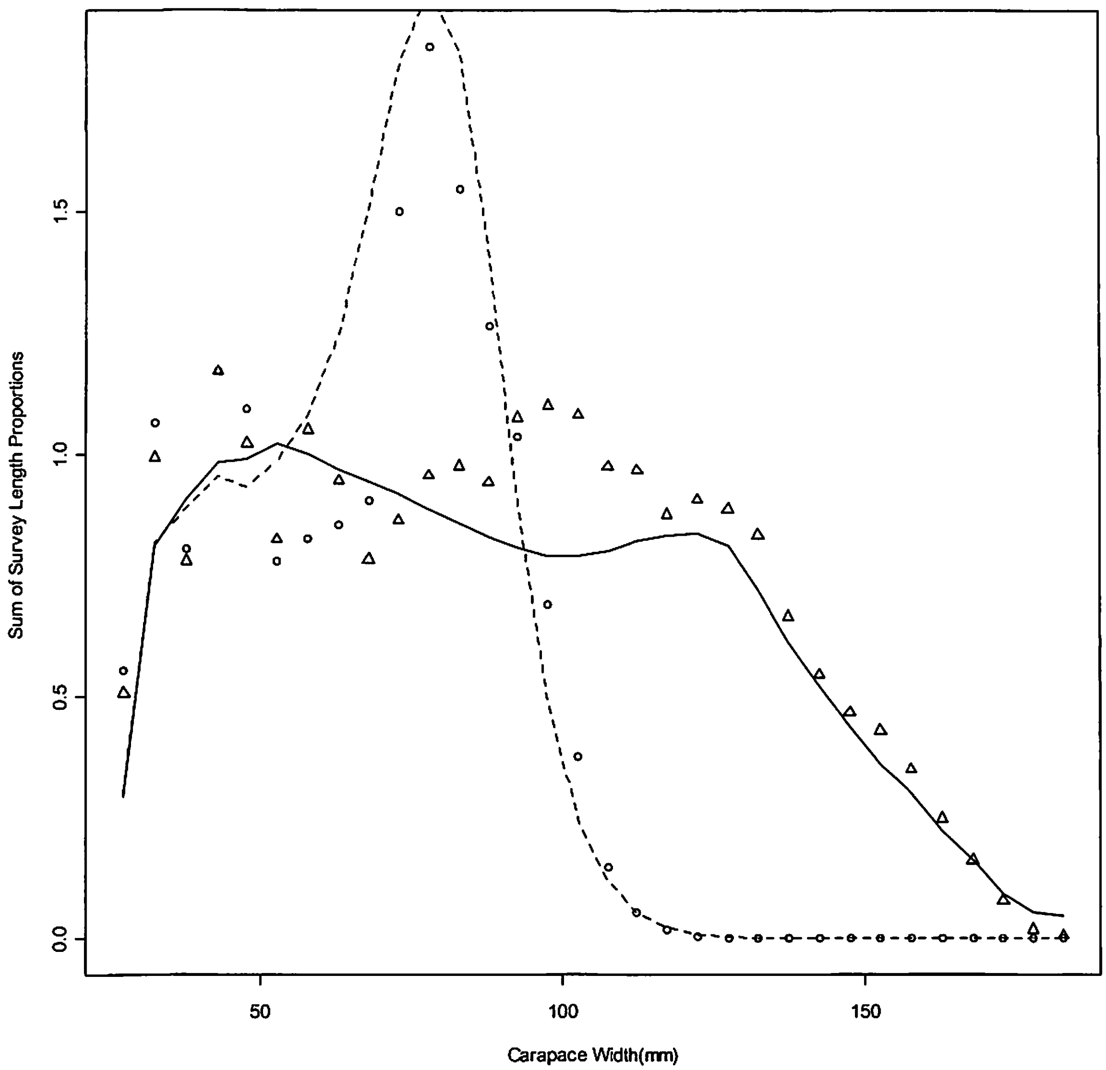


Figure 25. Summary model fit to the survey male (solid line) and female (dotted line) size frequency data, all shell conditions combined. Symbols are observed data.

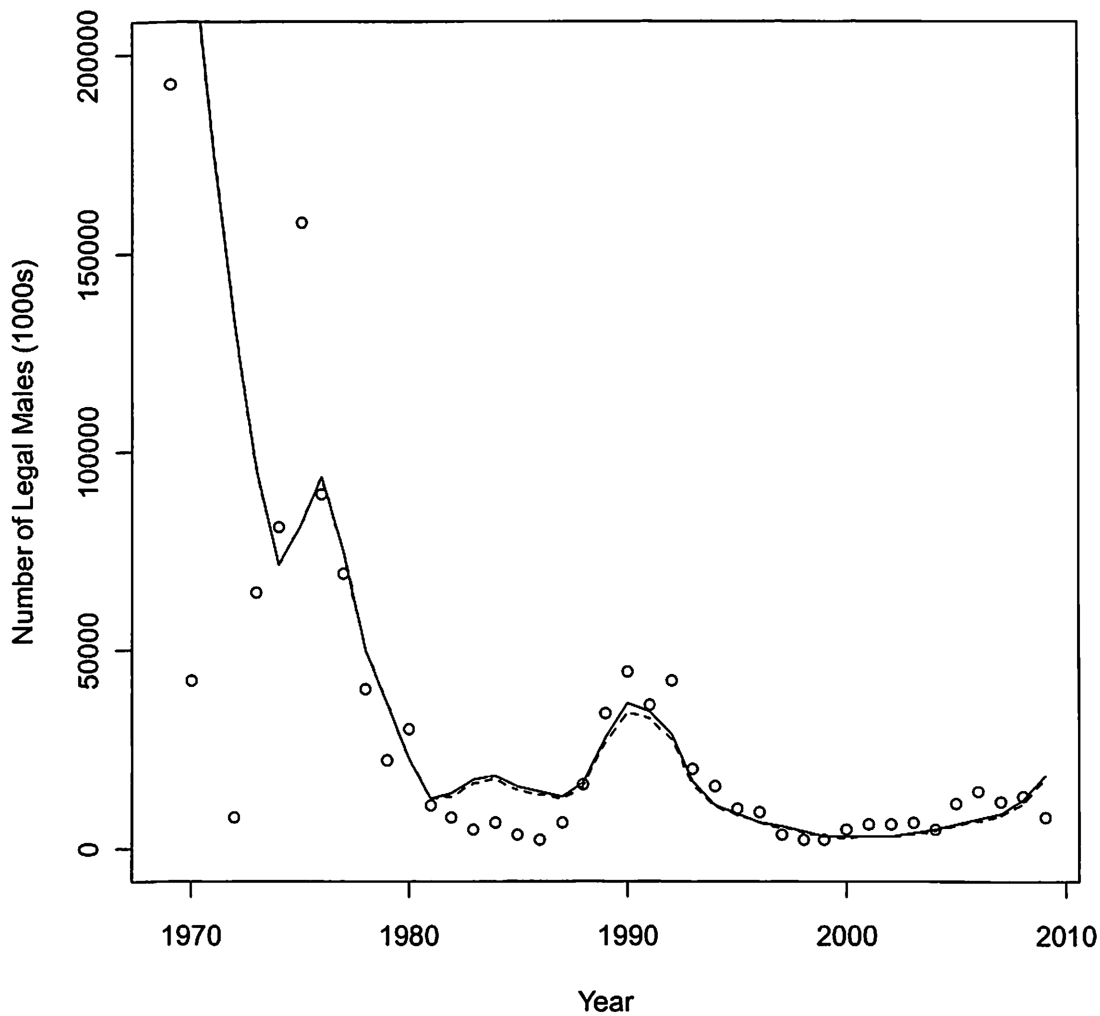


Figure 26. Observed survey numbers of males ≥138mm (circles), model estimates of the population number of males ≥138mm (solid line) and model estimates of survey numbers of males ≥138mm (dotted line).

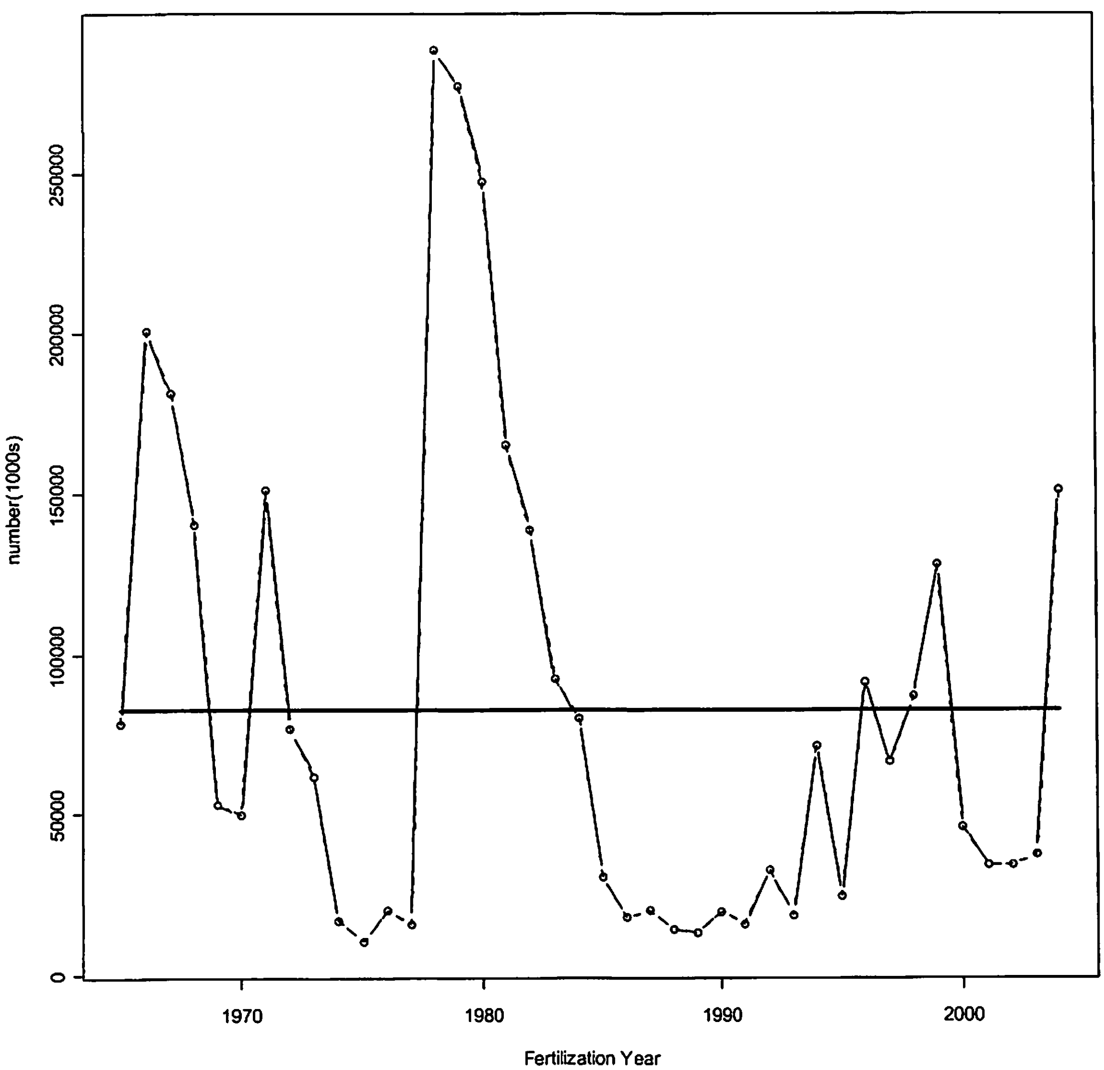


Figure 27. Recruitment to the model for crab 25 mm to 50 mm. Total recruitment is 2 times recruitment in the plot given that male and female recruitment is set to be equal. Solid horizontal line is average recruitment.

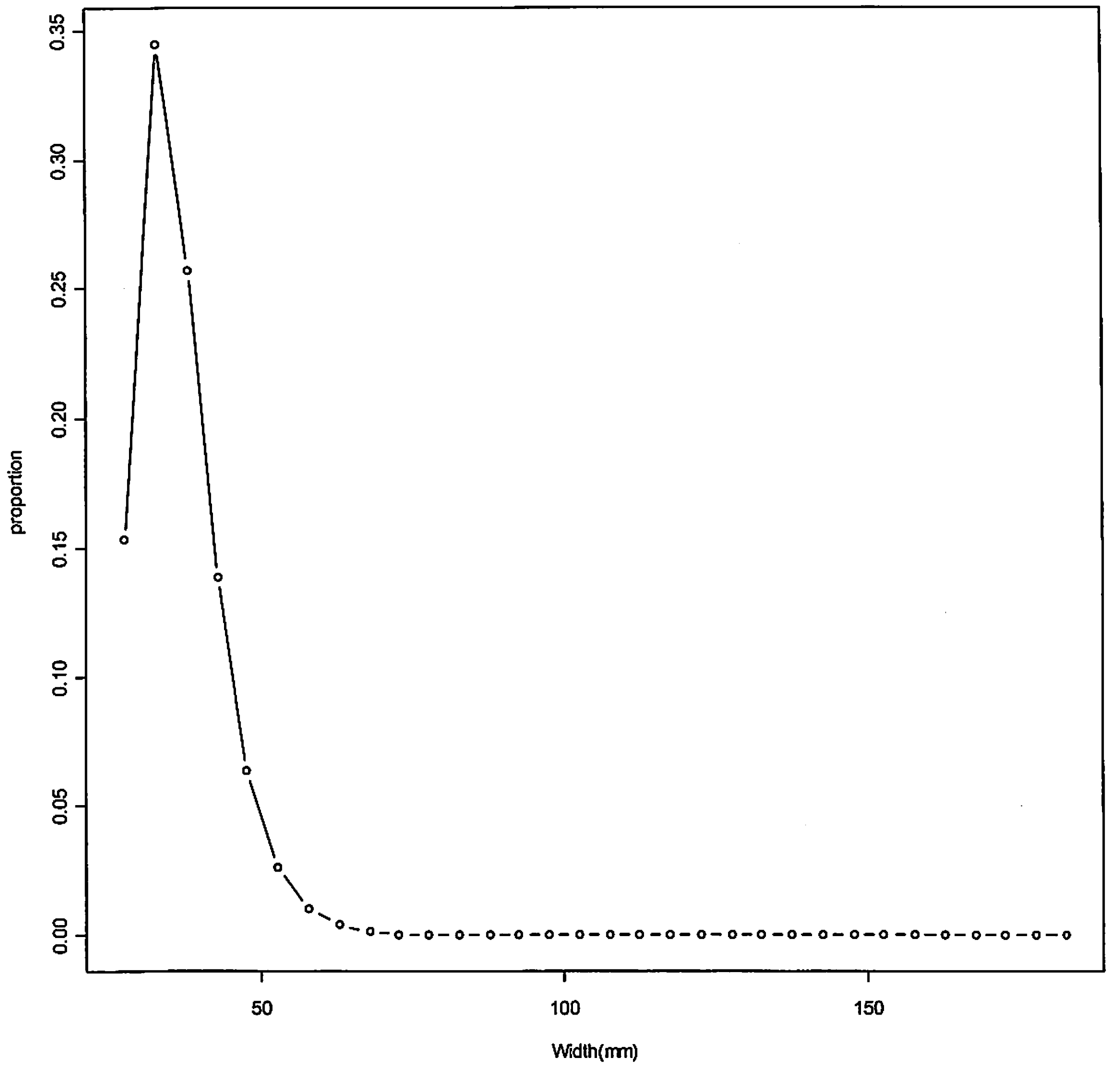


Figure 28. Distribution of recruits to length bins estimated by the model.

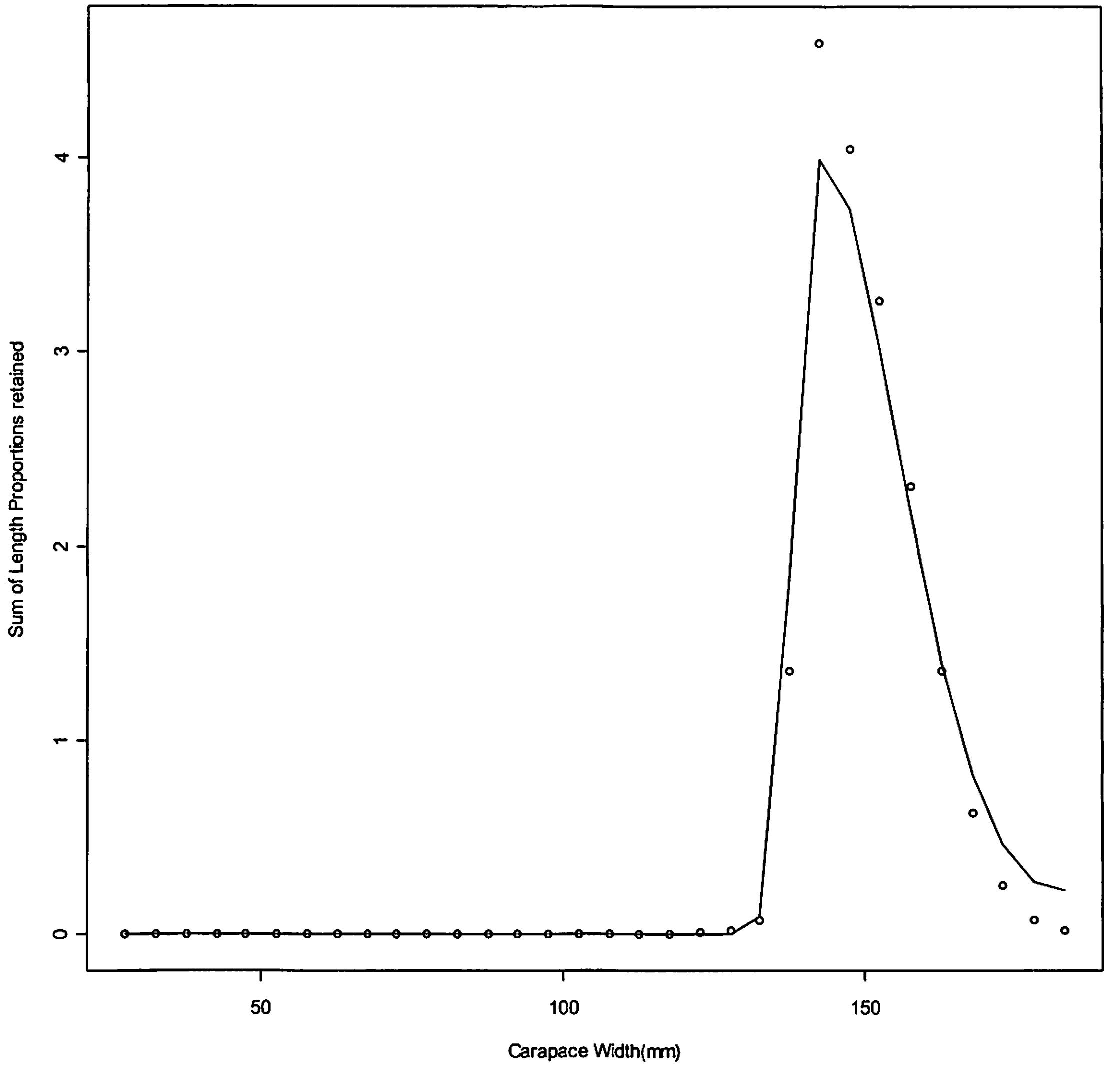


Figure 29. Summary model fit to the retained male size frequency data, shell condition combined. Solid line is the model fit. Circles are observed data.

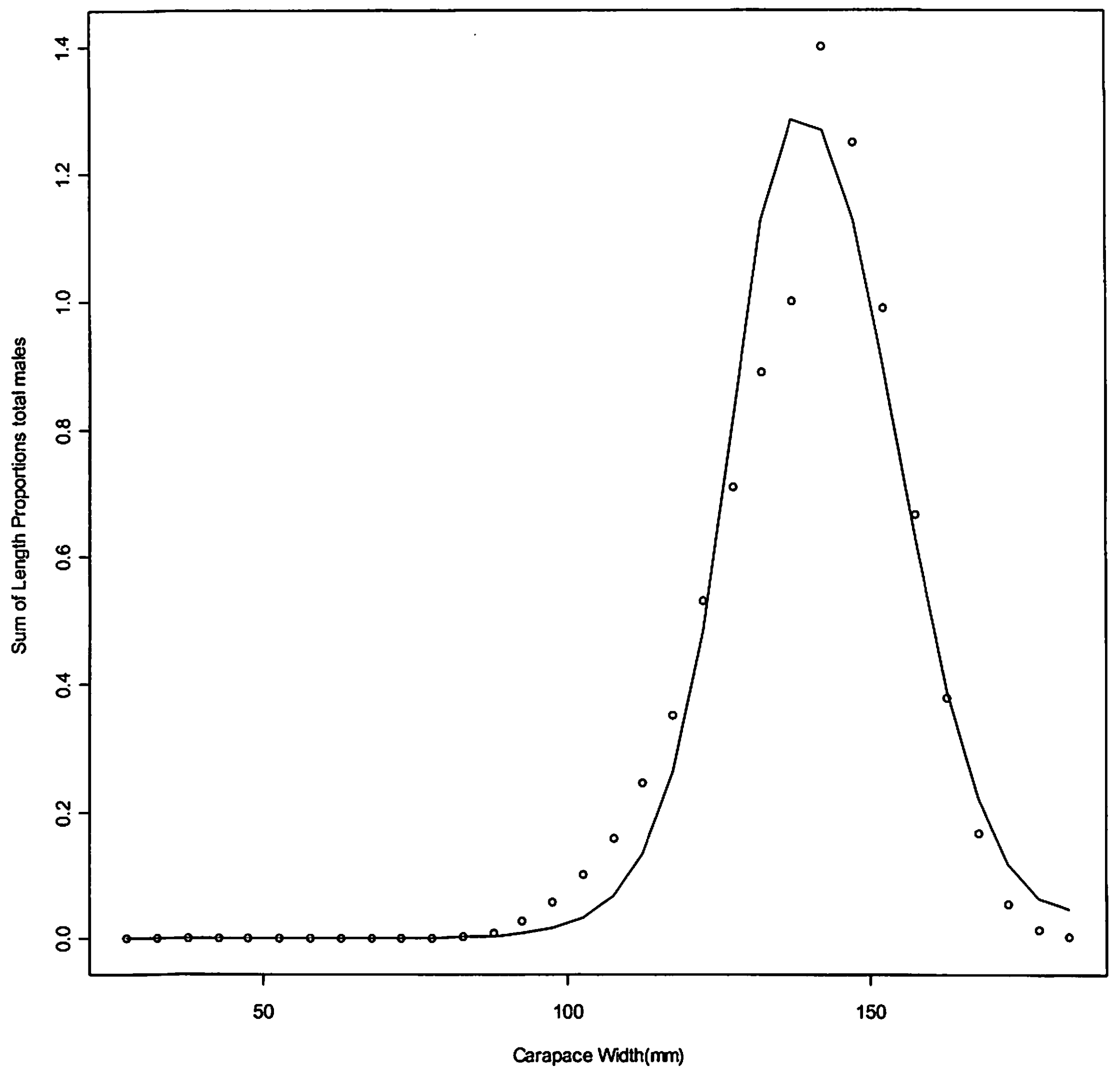


Figure 30. Summary model fit to the total (discard plus retained) male size frequency data, shell condition combined. Solid line is the model fit. Circles are observed data.

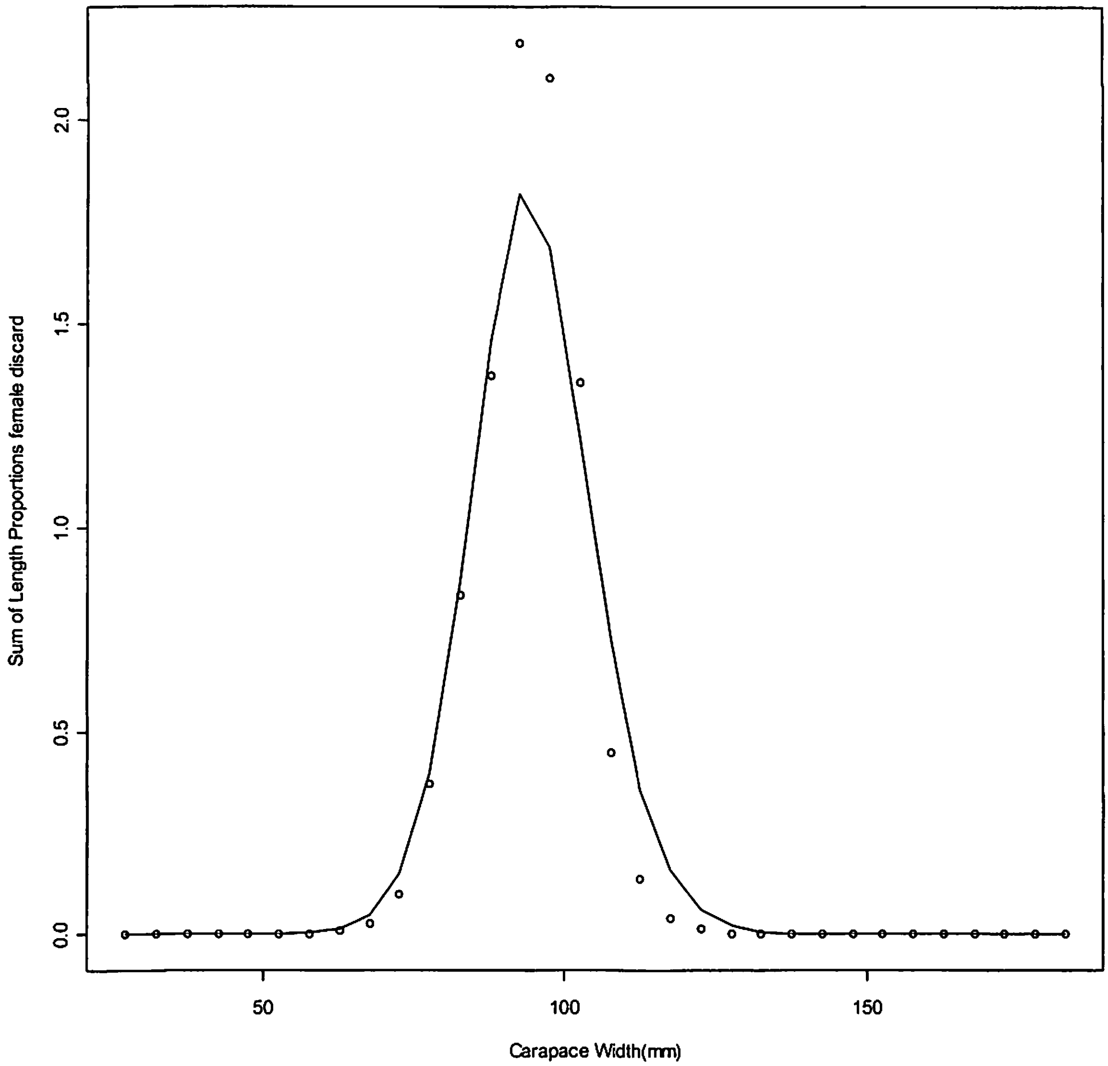


Figure 31. Summary model fit to the discard female size frequency data in the directed fishery. Solid line is the model fit. Circles are observed data.

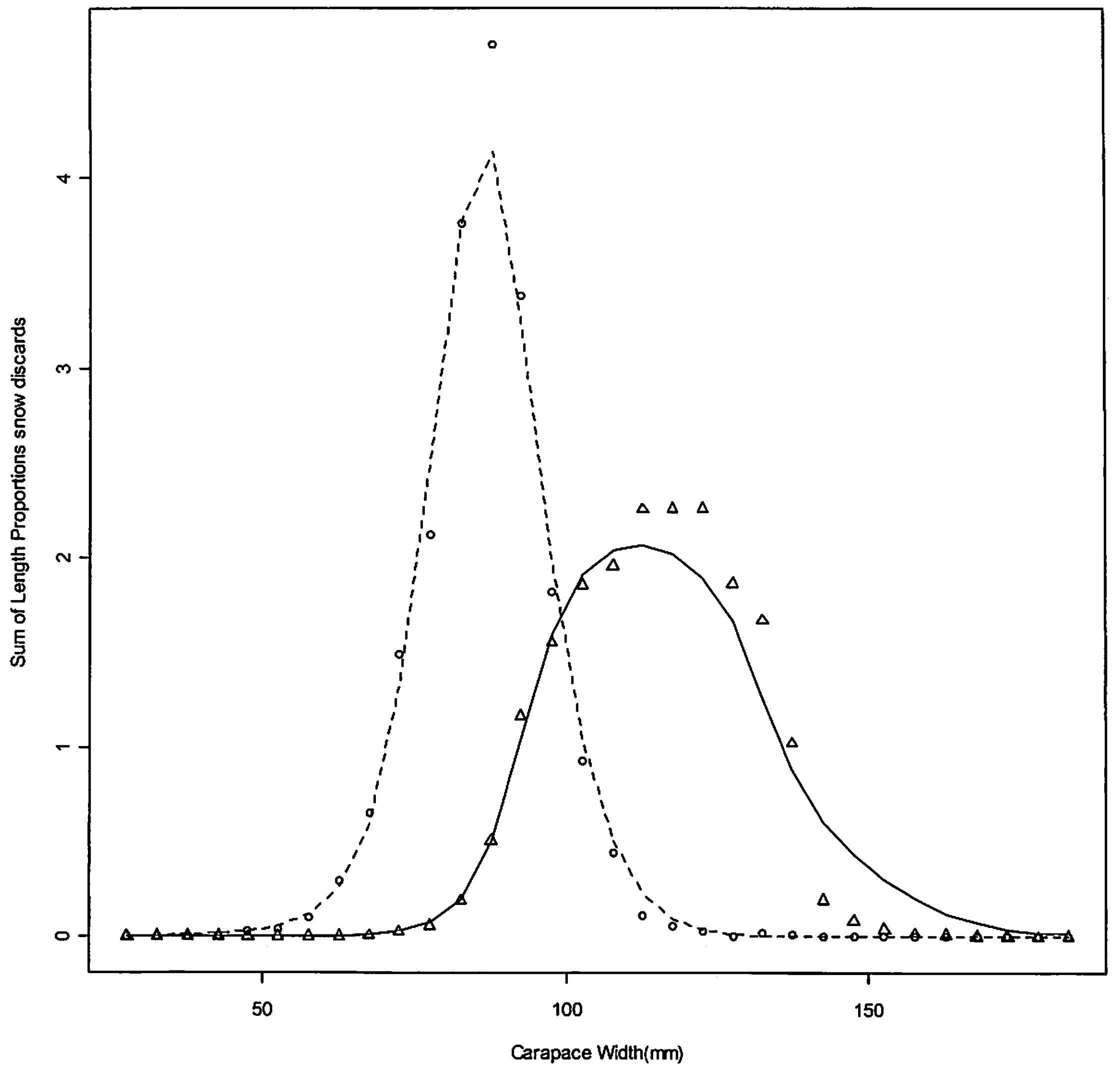


Figure 32. Summary model fit to the discards in the snow crab fishery for males (solid line) and females (dotted line) size frequency data. Symbols are observed data.

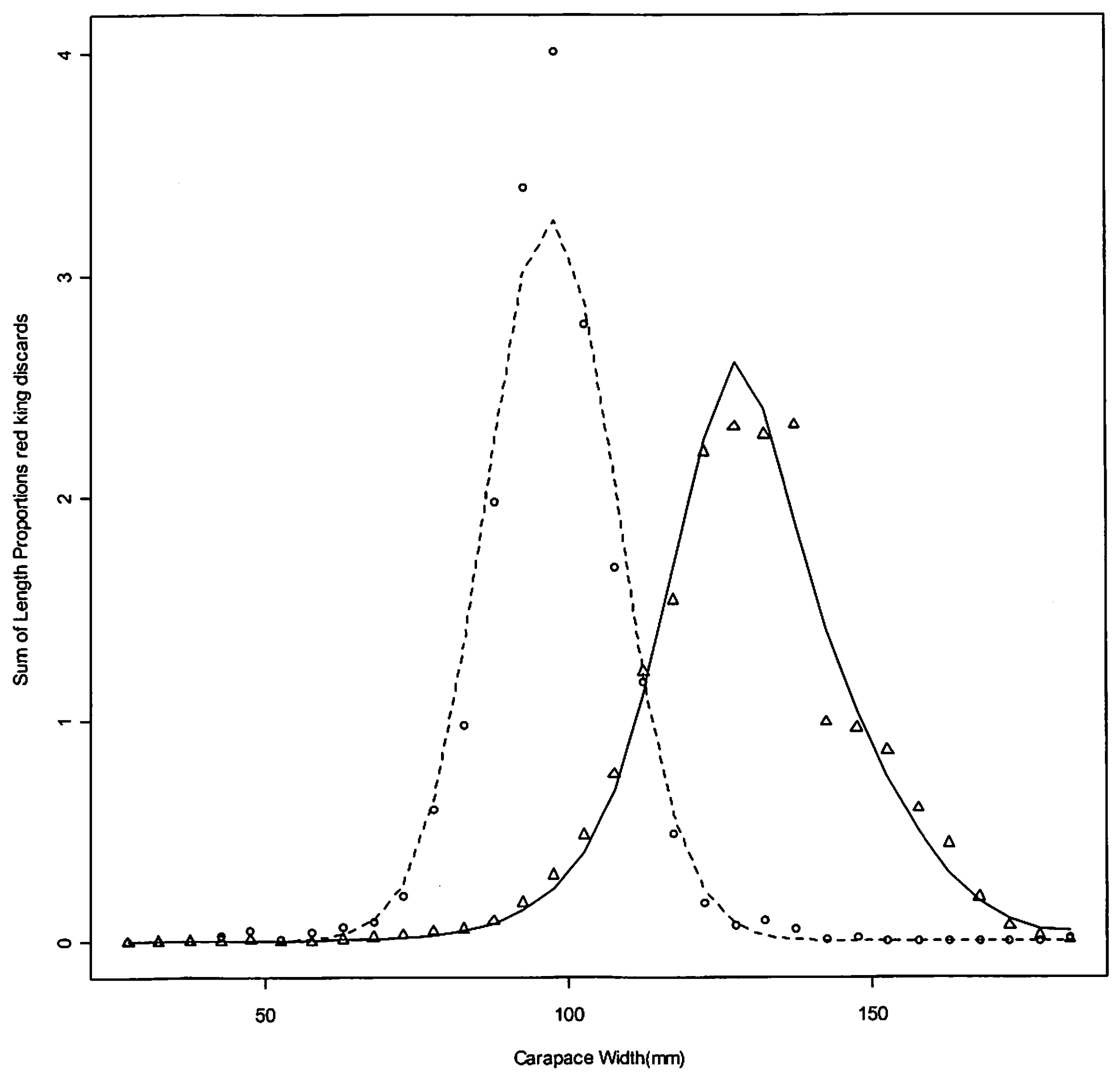


Figure 33. Summary model fit to the discards in the Bristol Bay red king crab fishery for males (solid line) and females (dotted line) size frequency data. Symbols are observed data.

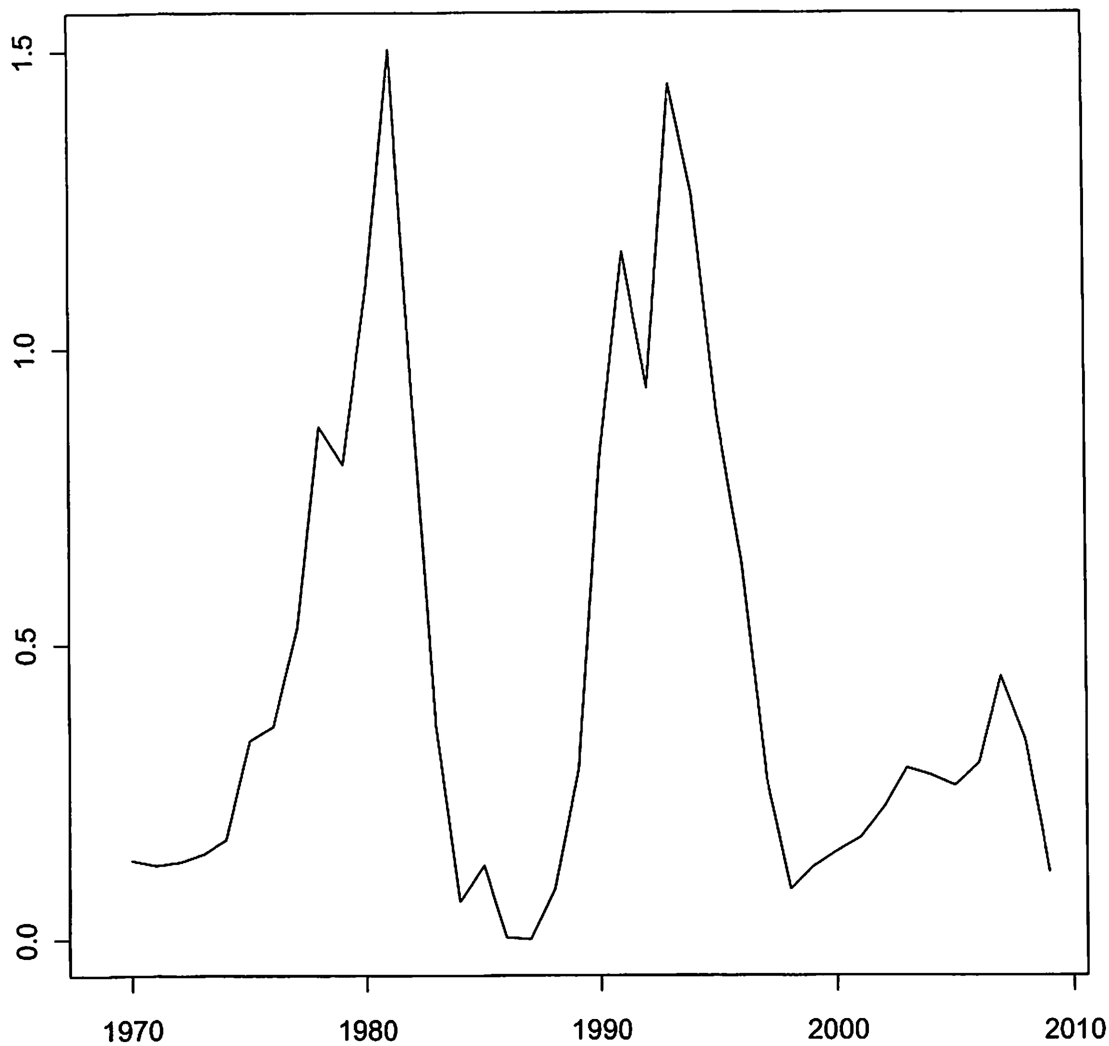


Figure 34. Full selection fishing mortality rates estimated in the model from 1970 to 2009 fishery seasons (1969 to 2008 survey years).

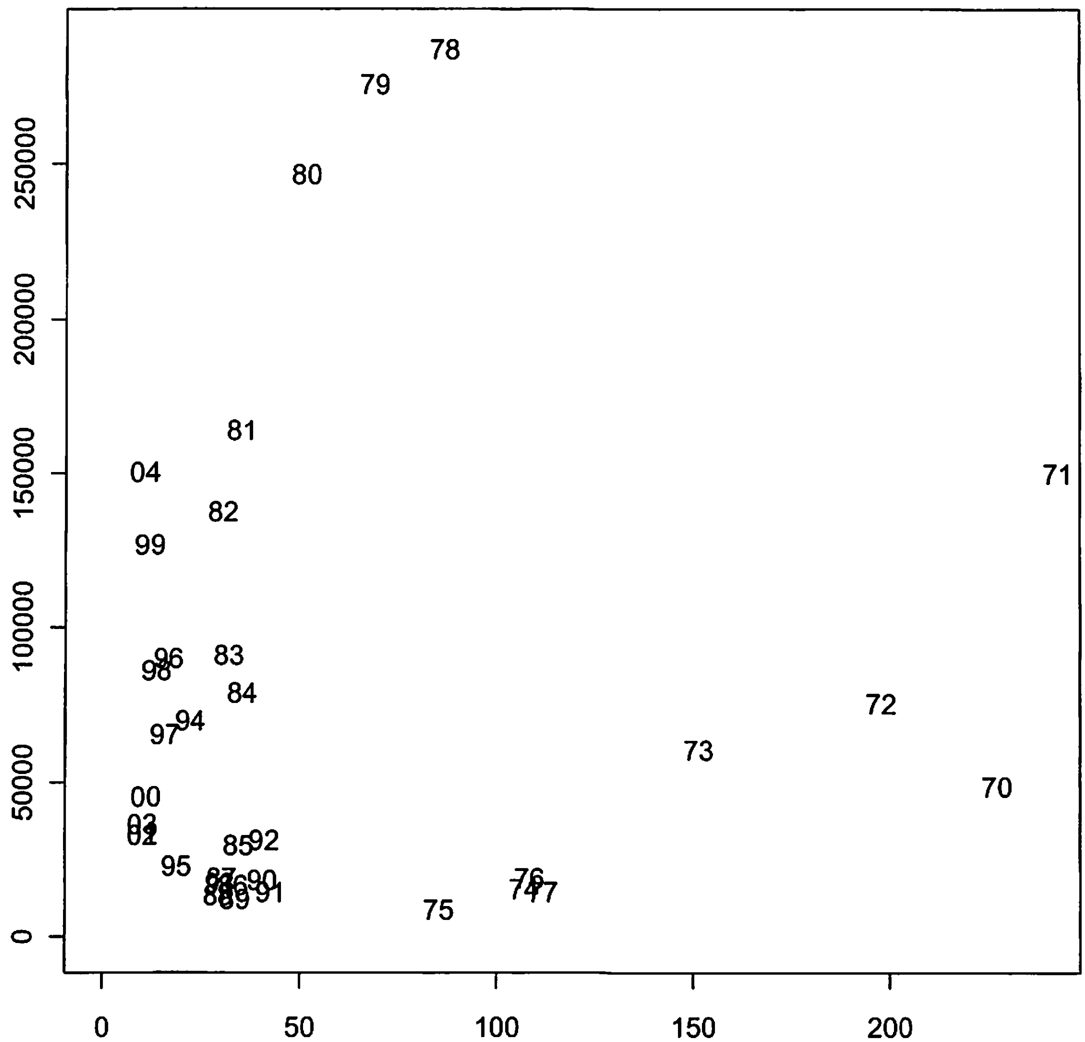


Figure 35. Recruitment (1000 of crab) vs. male mature biomass at the time of mating (1000 t). Two digit year numbers are fertilization year assuming a lag of 5 years. Recruitment is one-half of total recruits.

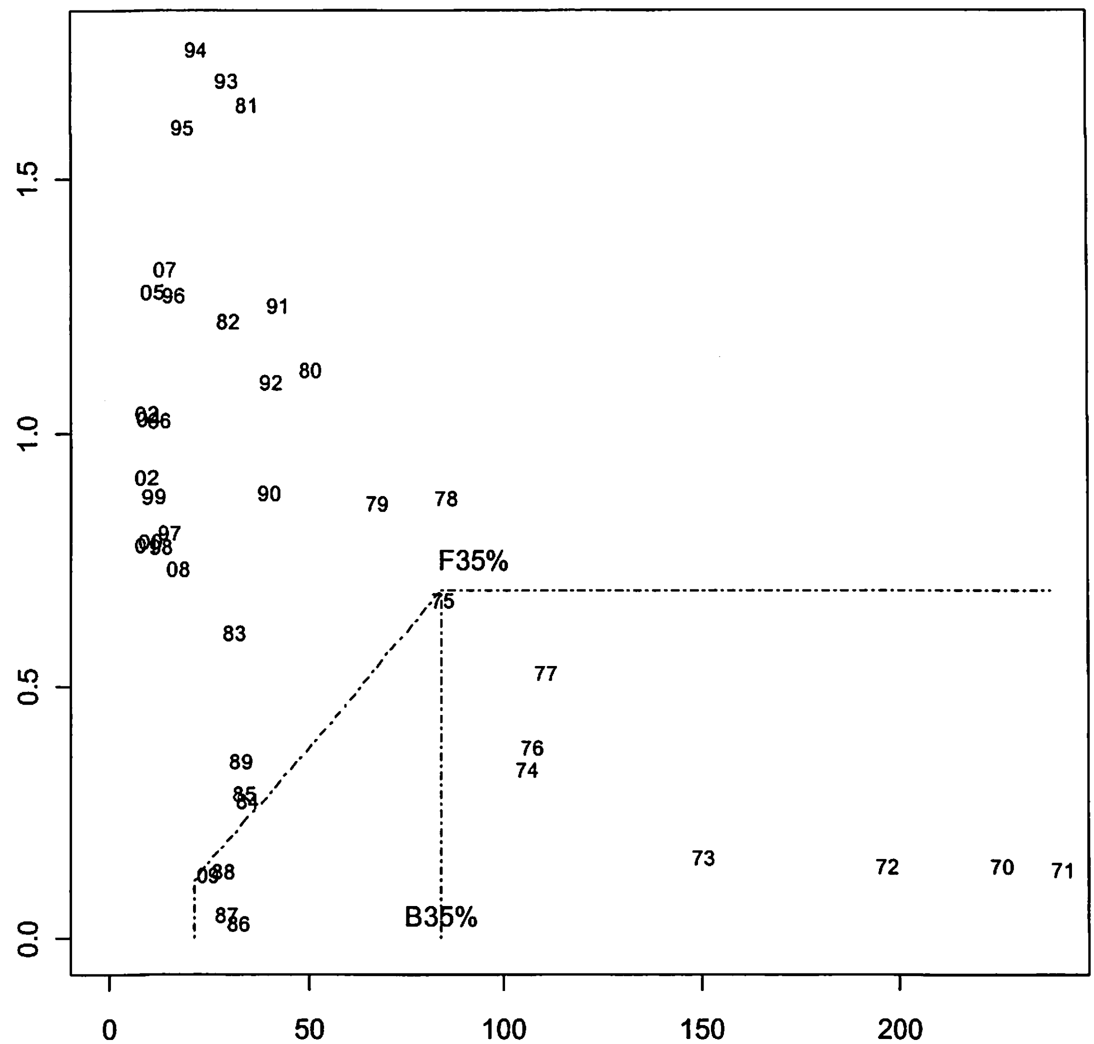


Figure 36. Fishing mortality estimated from fishing years 1970 to 2008/09 (labeled 09 in the plot). The OFL control rule (F35%) is shown for comparison. The vertical line the location of the B_{MSY} proxy B35%.

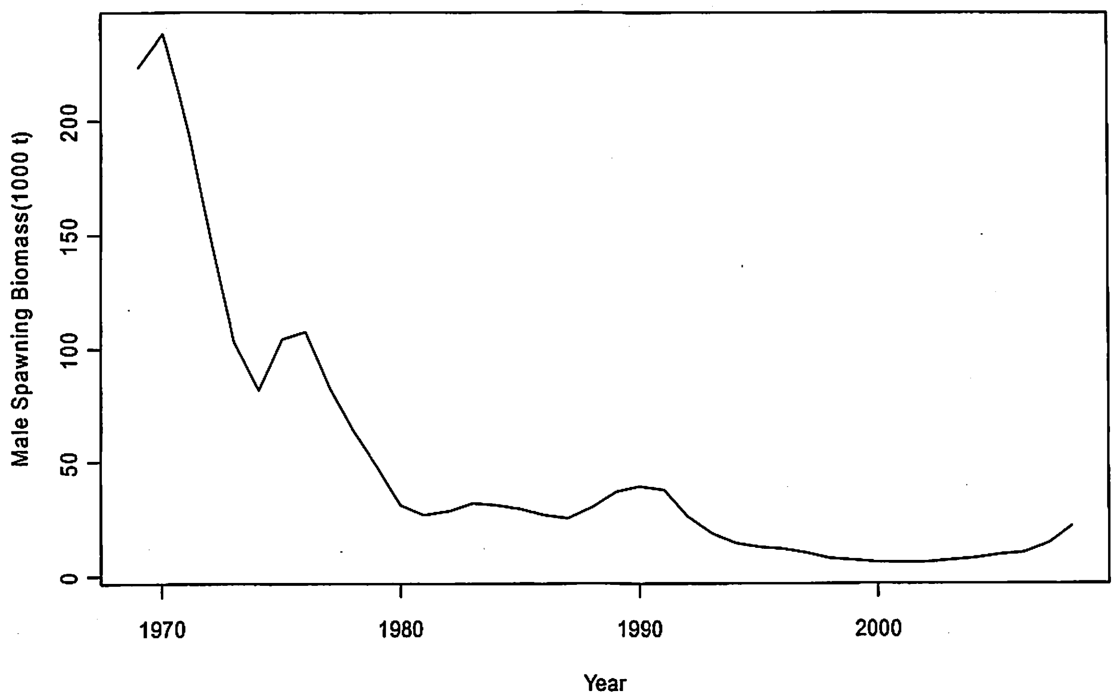


Figure 37. Time-trajectory of mature male biomass at the time of mating for EBS Tanner crab (1000 t).

Bering Sea snow crab model scenario descriptions and likelihood values

Benjamin J. Turnock
Alaska Fisheries Science Center
March 25, 2010

Background

This report describes eight model scenarios for the Bering Sea snow crab stock assessment, that represent sequential changes from the September 2009 assessment model (Turnock and Rugolo 2009). These models represent changes from the September 2009 assessment, as well as model scenarios for sensitivity analyses recommended by the Crab Plan Team as well as the SSC. Models 1-4 were used for draft ACL/Rebuilding analyses (with the same model numbers, Table 1). Models 5-8 are presented here to quantify the impact of each of the Model changes from the September 2009 assessment to the Models 1-4 (Table 1).

The CPT, SSC and NPFMC all requested a review of the implications of incorporating the results of the 2009 Bering Sea Fisheries Research Foundation (BSFRF) trawl survey into the snow crab assessment. In addition, the SSC requested that the author explore the implications of separate selectivity curves for males and females and the implications of different assumptions regarding natural mortality. A sensitivity analysis was presented to the SSC at the February 2010 Council meeting (Turnock 2010). In this analysis likelihood profiles were examined for different assumptions regarding survey catchability and natural mortality.

The analysis presented here builds on that earlier analysis by addressing key recommendations from the CPT. The CPT recommended in September 2009 that the best way to use the BSFRF survey data from summer 2009 was to add it to the assessment model as a separate survey to inform survey selectivity in the model. To address these requests, a sensitivity analysis was performed to evaluate the implications of different assumptions regarding survey selectivity, survey catchability, and natural mortality rate.

Description of Data

All model scenarios utilized the revised NMFS bottom trawl survey data (Foy personal communication).

BSFRF conducted a survey of 108 tows in 27 survey stations (10,827 sq nm, hereafter referred to as the "study area") in the Bering Sea in summer 2009(see Somerton et al 2010 for more details). The abundance estimated by the BSFRF survey in the study area was 66.9 million male crab >=100 mm compared to 36.7 million for the NMFS net (Table 1). The NMFS abundance of females >=50mm (121.5 million) was greater than the BSFRF abundance estimate in the study area (113.6 million) (Table 2).

The abundance of male crab in the entire Bering sea survey for 2009 was greatest in the 30 – 60mm size range (Figure 1). The abundance of crab in the 35 to 60mm size range for the BSFRF net in the study area was very low compared to the abundance of the same size range for the NMFS entire Bering Sea survey. The differences in abundance by size for the NMFS entire Bering Sea survey and the BSFRF study area are due to availability of crab in the study area as well as capture probability. While the abundance of larger male crab for the NMFS net in the study area is less than for the BSFRF, the abundance of females >45 mm is greater for the NMFS net than the BSFRF. This difference may be due to different towing locations for the two nets within the study area, or to higher catchability of females possibly due to aggregation behavior. The ratio of abundance of the NMFS net and BSFRF net in the study area are quite different for males and females (Figure 3). The ratio of abundance indicates a catchability for mature females (mainly 45 – 65 mm) that is greater than 1.0 for the NMFS net.

The largest tows for small crab in the entire Bering Sea area were north of the study area near St. Matthew Island (Figures 4, 5 and 6). Some higher tows for large males (>=100mm) and for mature females occurred in the study area as well as outside the study areas. These distributions indicate the availability of crab throughout the Bering Sea.

Description of the Models

Following the recommendation of the CPT, abundance estimates by length as well as survey biomass for the study area for the BSFRF tows as well as the NMFS tows were added to the stock assessment model as an additional survey. Survey selectivities were estimated using logistic curves for males and females for the NMFS standard survey in the entire Bering Sea area, the BSFRF tows in the study area and the NMFS tows in the study area. Likelihood equations were added to the model for fits to the length frequency by sex for the BSFRF tows in the study area and the NMFS tows in the study area. A likelihood equation was also added for fit to the mature biomass by sex in the study area for the BSFRF tows and NMFS tows separately.

The maximum selectivity for the NMFS study area was estimated by the product of the Q for the NMFS Bering Sea area and the Q for the BSFRF survey in the study area. The Q for the BSFRF survey in the study area was assumed to represent the fraction of crab available in the study area relative to the entire Bering Sea. The maximum catchability of the BSFRF net in the study area was assumed to be 1.0. A separate parameter for females was estimated and multiplied by the male Q to estimate female Q for the NMFS survey in the entire Bering Sea and for the NMFS survey in the study area. The maximum survey selectivity (Q) estimated for the entire Bering Sea area in Somerton et al. 2010 was estimated at 0.76 at 140 mm. The maximum size bin in the model is 130-135, which for the Somerton curve has a maximum selectivity of 0.75.

The similarities and differences between models is provided in Table 3. Male survey selectivity curves were estimated as follows:

a) 2009 BSFRF survey selectivity = Q (availability) * logistic selectivity

b) 2009 NMFS survey selectivity in study area = Q(availability)* Q (entire Bering Sea) * logistic selectivity

c) NMFS survey entire Bering sea 1989 to 2009 period =
Q (entire Bering Sea) * logistic selectivity

2) For models 5, 6 and 7 and the September 2009 assessment model, female survey selectivity is equal to male selectivity (Table 3). For Models 1-4 and 8, separate female survey selectivity was estimated as follows:

(a) For the 1978 – 1981, and the 1982 to 1988 periods,
Female survey selectivity = female mult. * Q male * male logistic selectivity
(b) For 1989 to 2009,

i)Female selectivity = female mult.* Q(male) * female logistic selectivity curve

ii)Female logistic selectivity curve has two estimated parameters separate from male selectivity.

iii)2009 NMFS female survey sel in study area =
female mult. * Q(availability) * Q (entire Bering Sea) * logistic selectivity

iv) Q for females = female mult. * Q (males)

Sensitivity Results

The results are summarized in Table 4. Model fits are not directly comparable because the number of parameters differs between models. Likelihood values for the eight model scenarios are in Table 4. The models with the highest number of parameters (Models 1 and 4) had the best likelihood. Survey length data fit best with Model 1, while survey biomass fit is better for Model 4. As expected, the fits to BSFRF biomass data are best for Model 3 with selectivity fixed at the Somerton selectivity curve followed by Model 2 with male Q fixed at 0.75. Model 3 has the worst fit to the survey biomass, the second worst fit to the survey length data, and the worst fit to the trawl catch, the discard catch and the female discard length. Comparison of Models 7 and 8 shows estimation of separate selectivities for male and female snow crab results in an improvement to the fit of the model. Models 1 and 4 differ only in the female mature M, where M=0.23 for all crab in model 1 and model 4 has mature female M higher at 0.29, the same as the September 2009 assessment. The male Q for model 1 was estimated at 0.95, while the male Q for model 4 was estimated in the model, however, went to the maximum value of 1.0 (Q was bounded at 1.0). Previous runs have shown the September 2009 model to have the best likelihood at Q=1.2 (Turnock 2010).

References

Somerton, D. , K.Weinberg and S. Goodman. 2010. Review of the research to estimate snow crab selectivity by the NMFS trawl survey. Report to the North Pacific Fishery Management Council, 605 West 4th Ave, Anchorage, AK. 99501, February, 2010.

Turnock, B.J. 2010. Bering Sea Snow Crab Assessment Model Sensitivity to Survey Selectivity. Report to the North Pacific Fishery Management Council, 605 West 4th Ave, Anchorage, AK. 99501, February 2010.

Turnock, B. and L. Rugolo. 2009. Stock assessment of eastern Bering Sea snow crab (*Chionoecetes opilio*). Report to the North Pacific Fishery Management Council, 605 West 4th Ave, Anchorage, AK. 99501. 102 p.

Table 1. Model scenario changes from the September 2009 assessment model. All models contain new survey data. Models 1-3 have M=0.23 for all crab, models 4 -8 have M=0.29 for mature females (same as September 2009 assessment model).

Model Scenario	Description
1	New survey data, no extra weight on survey biomass, BSFRF 2009 survey data added, separate survey selectivities males and females, probability of maturing estimated, all M=0.23
2	New survey data, no extra weight on survey biomass, BSFRF 2009 survey data added, separate survey selectivities males and females, probability of maturing estimated, all M=0.23, male survey Q for 1989-2009 fixed at 0.75.
3	New survey data, no extra weight on survey biomass, BSFRF 2009 survey data added, separate survey selectivities males and females, probability of maturing estimated, all M=0.23, male survey selectivity for 1989-2009 fixed at the Somerton curve.
4	New survey data, no extra weight on survey biomass, BSFRF 2009 survey data added, separate survey selectivities males and females, probability of maturing estimated
5	new survey data
6	New survey data, no extra weight on survey biomass
7	New survey data, no extra weight on survey biomass, BSFRF 2009 survey data added
8	New survey data, no extra weight on survey biomass, BSFRF 2009 survey data added, separate survey selectivities males and females

Table 2. Abundance estimates of females and males by size groups for the BSFRF net in the study area, the NMFS net in the study area, and the NMFS survey of the entire Bering Sea. Mature abundance uses a maturity curve.

		Females			Males	
	>25mm	>50mm	mature	>25mm	mature	>100
BSFRFStudy	585.3	113.6	129.4	422.9	200.9	66.9
NMFS Study	150.2	121.5	120.5	119.2	76.9	36.7
NMFS Bering Sea	1773.5	828.7	1,143.9	1,225.0	463.8	147.2

Table 3. Model scenarios showing changes from September 2009 assessment model.

Model	new survey data	no extra weight survey biomass	BSFRF survey	Separate survey select. female	Prob. Mature estimated	M=0.23 all crab	Q fixed 0.75	male sel. Fixed Somerton
1	X	X	X	X	X	X		
2	X	X	X	X	X	X	X	
3	X	X	X	X	X	X		X
4	X	X	X	X	X			
5	X							
6	X	X						
7	X	X	X					
8	X	X	X	X				

Table 4. Likelihood values for 8 model scenarios.

Model	1	2	3	4	5	6	7	8
No. params	266	265	263	266	219	219	219	222
male Q	0.95	0.75	0.75	1	1	1	1	1
female Q	0.951	0.805	1	1.26	1	1	1	1.13
Recruitment	33.1	31.9	30.0	33.3	26.9	31.5	33.6	33.6
retained length	-1903.4	-1897.1	-1910.4	-1901.3	[redacted]	-1809.7	-1809.7	-1809.1
total male fishery length	688.1	689.5	692.5	688.3	775.4	746.1	746.0	745.7
female discard length	159.3	162.7	174.5	154.6	170.7	166.8	166.7	165.6
survey length	3919.3	3939.4	4092.8	3935.2	4135.3	3991.5	3993.5	3999.2
trawl length	225.5	216.1	207.4	212.9	232.9	224.8	225.0	225.1
BSFRFstudy area length	36.8	36.5	38.7	36.5	-	-	33.1	32.9
nmfs study area length	-58.3	-58.8	-47.8	-57.6	-	-	-59.4	-63.4
fpen	50.4	50.9	56.2	50.8	56.9	62.4	62.3	62.4
discard catch	121.9	131.1	147.0	119.9	167.5	143.5	143.4	144.0
retained catch	3.5	3.6	4.0	3.5	8.9	4.4	4.4	4.4
female discard	5.7	5.5	6.8	6.7	10.5	10.9	10.8	10.8
trawl catch	8.1	9.1	15.4	7.7	11.4	7.5	7.3	7.3
survey biomass	155.6	176.3	215.7	151.8	96.0[1]	160.4	161.8	152.2
BSFRFstudy area biomass	0.7	0.4	0.3	0.7	-	-	0.7	0.7
nmfs study area biomass	0.3	0.2	0.2	0.4	-	-	0.4	0.4
initial numbers	3.1	3.1	2.8	3.1	4.2	3.4	3.4	3.4
intial numbers smooth	55.8	57.9	51.8	55.5	68.4	58.2	58.2	57.9
maturity smooth	23.4	21.9	30.6	23.7	-	-	-	0-
fishery cpue	0.2	0.1	0.1	0.2	0.2	0.2	0.2	0.2
total	3529.1	3580.4	3808.8	3525.8	4076.4	3801.9	3781.8	3773.3

[1] unweighted value of survey biomass likelihood for comparison to fits of other models.

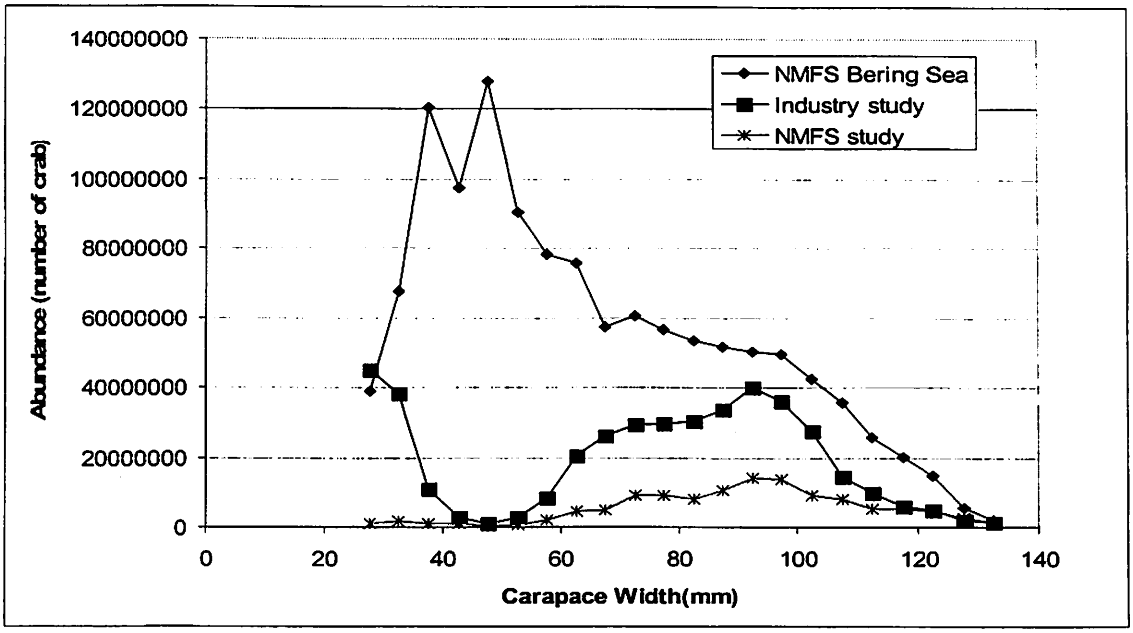


Figure 1. Abundance estimates of male snow crab by 5 mm carapace width(>=25mm) for the NMFS survey of the entire Bering Sea survey area (NMFS Bering Sea), the BSFRF net in the study area (108 tows) and the NMFS survey in the study area.

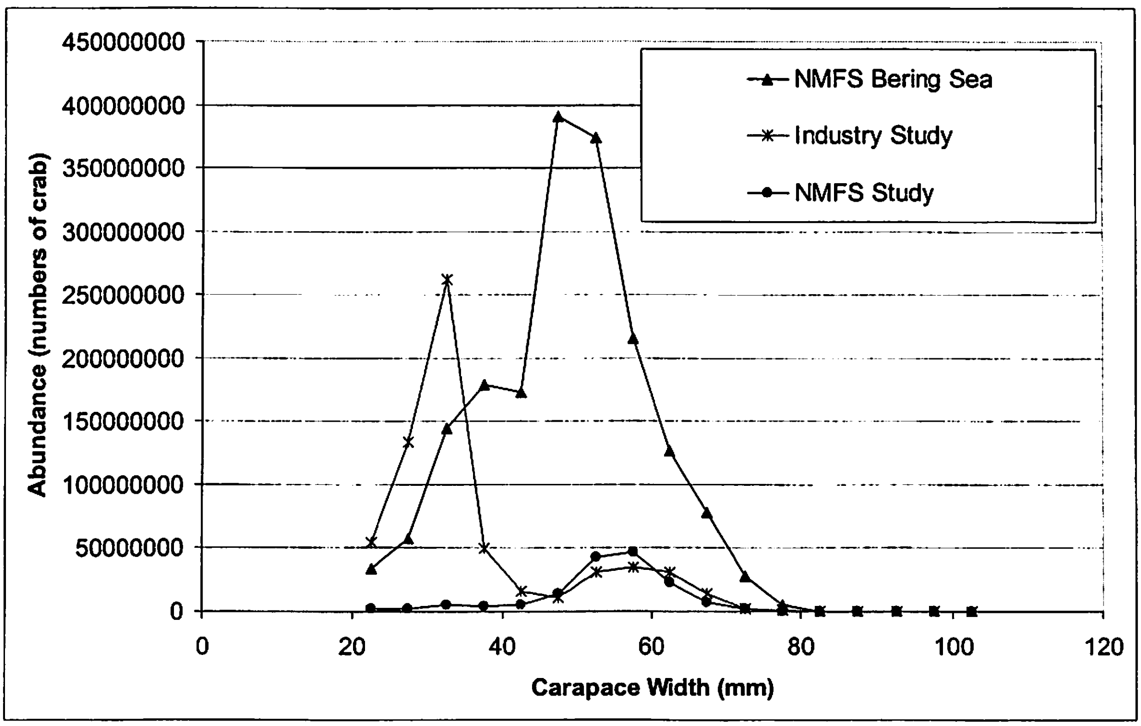


Figure 2. Abundance estimates of female snow crab by 5 mm carapace width for the NMFS survey of the entire Bering Sea survey area (NMFS Bering Sea), the BSFRF net in the study area (108 tows) and the NMFS survey in the study area.

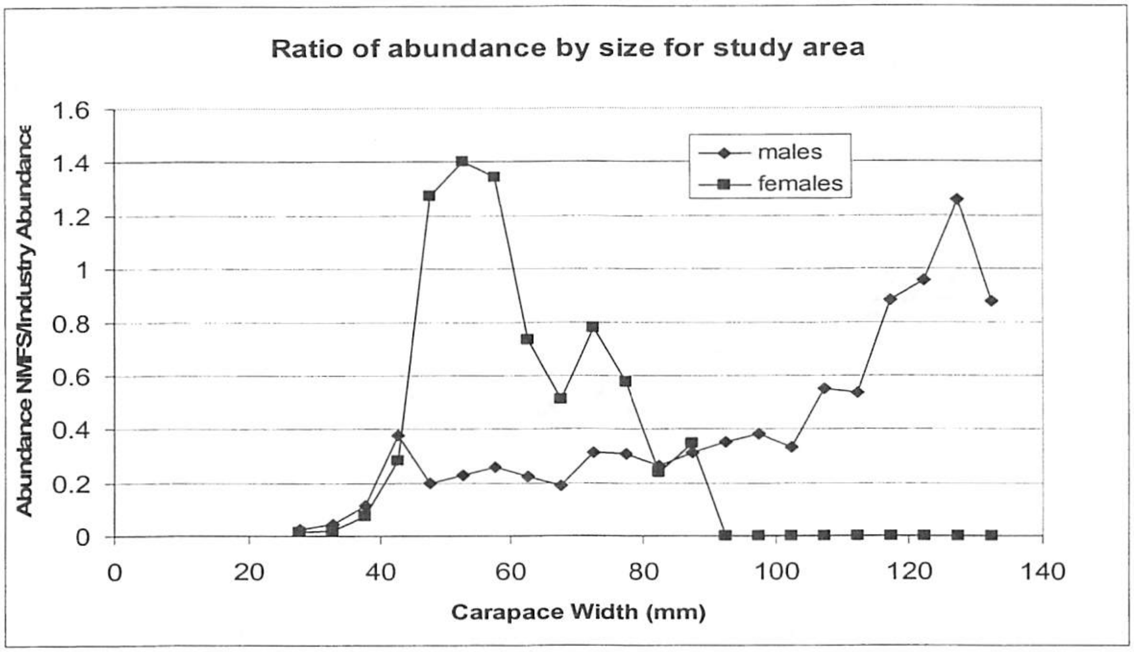


Figure 3. Ratio of abundance in the study area from the NMFS net to the BSFRF net for male and female crab.

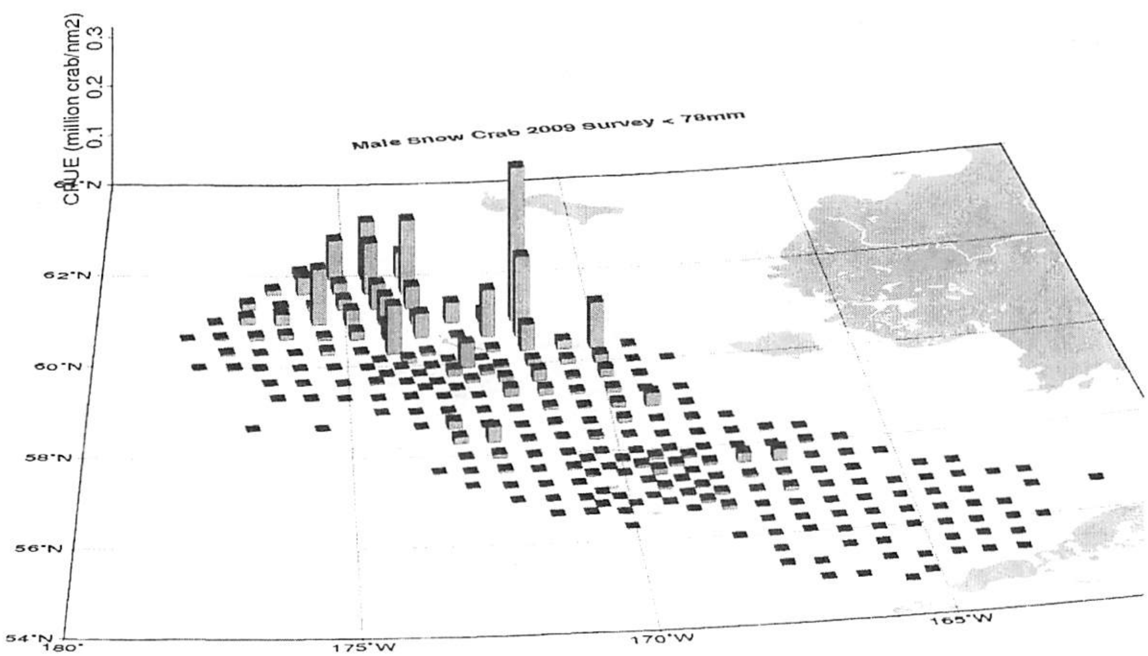


Figure 4. 2009 Survey CPUE (million crab per nm2) of males < 78 mm by tow.

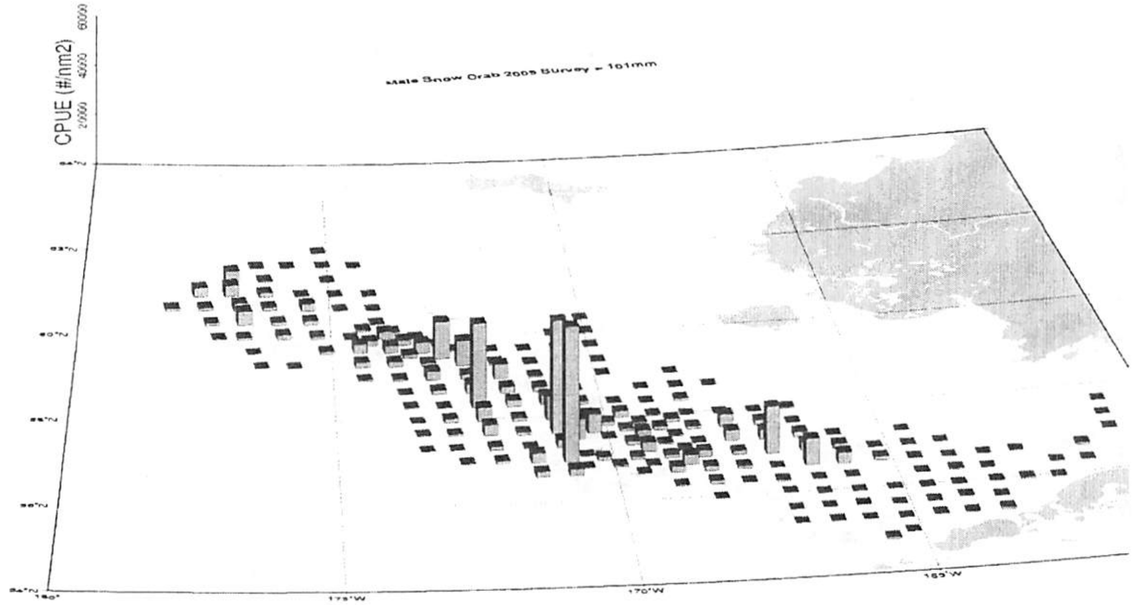


Figure 5. 2009 Survey CPUE (number per nm2) of males > 101 mm by tow.

-

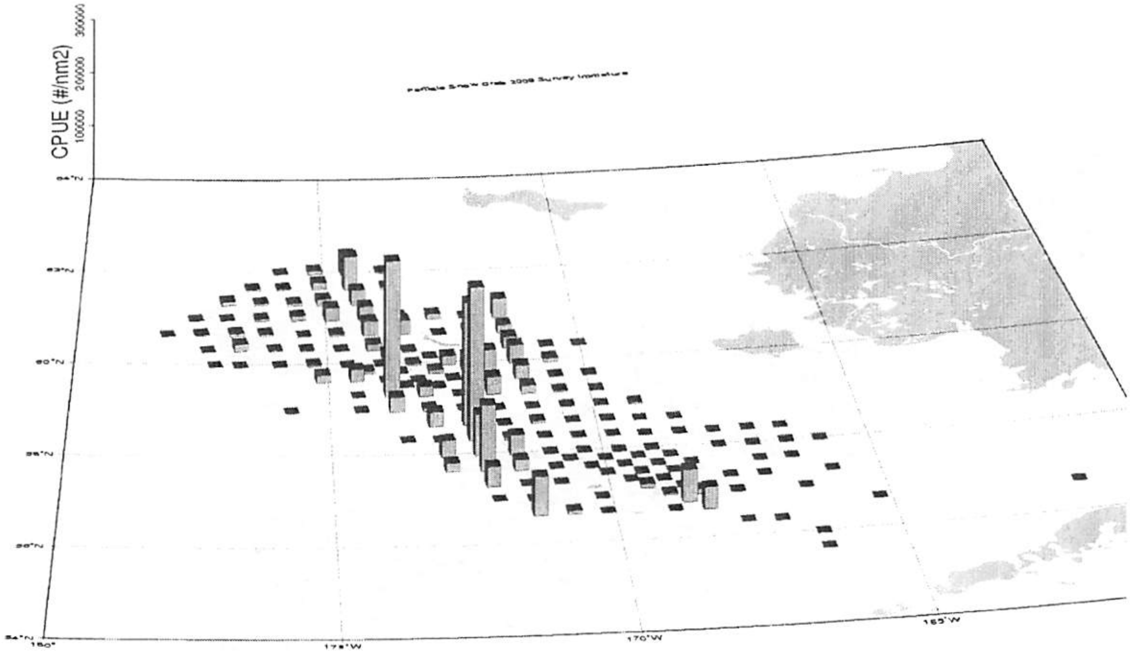


Figure 6. Female survey cpue by haul for mature females with eggs. Scale not same as other plots.

STATE OF ALASKA

SEAN PARNELL, GOVERNOR

DEPARTMENT OF FISH AND GAME

ALASKA BOARD OF FISHERIES

ADF&G
P.O. BOX 115526
JUNEAU, AK 99811-5526
PHONE: (907) 465-4110
FAX: (907) 465-6094

March 23, 2010

Mr. Eric Olson, Chairman
North Pacific Fishery Management Council
605 West 4th, Suite 306
Anchorage, AK 99501-2252

Re: BSAI crab and statewide scallop federal fishery management plan amendments

Dear Chairman Olson:

At our December 2009 joint North Pacific Fishery Management Council (council)/Alaska Board of Fisheries (board) meeting, we received briefings on several Bering Sea/Aleutian Islands (BSAI) crab and statewide scallop fishery management actions scheduled for final action by the council in October 2010. That briefing provided an introduction to more detailed presentations delivered during our March 2010 meeting where we reviewed the preliminary range of alternatives for three crab rebuilding plans and received an overview of alternatives to meet crab and scallop Annual Catch Limit (ACL) requirements. In addition, we were provided a summary of federal fishery management plan (FMP) framework and the state's authority under our joint state-federal management structure for BSAI crab and statewide scallops. This letter provides input from the board meant to assist and inform the council as analyses move forward and preferred alternatives are selected. A detailed briefing document we utilized in shaping the recommendations contained herein is enclosed for your reference.

In establishing ACLs, the board requests that the council give serious consideration to approaches that reasonably meet MSA requirements – without being so precautionary as to encroach upon the state's authority to set TACs. ACL buffers more conservative than required to comply with federal law would diminish the state's ability to exercise policy discretion provided under the BSAI crab FMP. ACL requirements were developed as a means to achieve National Standard 1 under the revised MSA and do not change FMP goals and objectives. The state's conservative approach to harvest strategy implementation and proven ability to account for and respond to the best available stock status information provide added protections from overharvest and should be considered additional protections as the council recommends regulatory buffers to prevent overfishing.

Alternatives for rebuilding overfished crab stocks include a range of rebuilding time periods; options that could be coupled with those alternatives increase the probability of rebuilding in a given time period. The full range of alternatives and options is achieved through harvest rate adjustments, some of which restrict the state's authority and flexibility in setting annual TACs. We are concerned that an overly prescriptive approach to crab rebuilding plans would be inconsistent with the spirit of state-federal joint management established under the BSAI crab

FMP, and could represent a degradation of state's role in meeting rebuilding requirements and management objectives specified in the FMP and as National Standards.

The board is also concerned about crab bycatch in groundfish fisheries and associated impact on stock rebuilding and directed fishery harvest potential. We understand that the council received a crab bycatch discussion paper in October 2009 and subsequently requested that an expanded discussion paper be brought forward in 2010. The board encourages the council to continue review of this issue by initiating analysis of crab bycatch in BSAI groundfish fisheries and to evaluate the impact of bycatch and current bycatch limits on the directed crab fisheries under the council's preferred alternatives for rebuilding plans and ACL management measures.

The intent of the BSAI crab FMP is to preserve the state's management flexibility within the bounds of federal law and the board has consistently met that intent by exercising its FMP deferred authority to adopt harvest strategies satisfying both MSA requirements and FMP management objectives. These harvest strategies, crafted through a transparent regulatory process, demonstrate sound management policy, and provide fishery managers the necessary flexibility to establish TACs within federal rebuilding plan and ACL requirements. In acknowledgment of the state's consistent compliance with federal law and expertise in managing BSAI crab and statewide scallop stocks, we ask that when considering alternatives for rebuilding plans and ACLs, the state's traditional FMP deferred role in establishing TAC levels be recognized and retained. We request the council adopt preferred alternatives that provide the greatest flexibility to the state in setting TACs.

We believe that these requests will inform the process used to establish crab rebuilding plans and ACLs for crab and statewide scallops, leading to better managed fisheries. In furthering the shared interest of continued dialogue on rebuilding plans and ACLs we suggest that the Joint Protocol Committee of the Board of Fisheries and North Pacific Fishery Management Council meet in September, before final action by the council, and after a preliminary preferred alternative has been selected. We also, as always, invite council and NMFS representatives to participate in the board process and to collaborate with us on topics of mutual interest.

The Board of Fisheries looks forward to the continued coordination on these important fishery topics. Thank you.

Sincerely,

Vince Webster
Chairman, Alaska Board of Fisheries

Enclosure

cc: Jim Balsiger, Regional Administrator, National Marine Fisheries Service
Denby Lloyd, Commissioner, Alaska Department of Fish and Game

Briefing to the Alaska Board of Fisheries on BSAI crab FMP amendments

Alaska Department of Fish and Game Division of Commercial Fisheries

March 16, 2010

The following briefing identifies issues the Board of Fisheries (board) may wish to consider in response to pending North Pacific Fishery Management Council (council) actions related to Bering Sea and Aleutian Islands (BSAI) crab. This briefing is intended to supplement the presentation you will receive as staff report RC5.

Analyses have been initiated for implementation of Annual Catch Limits (ACL), and development of Pribilof Islands blue king, Bering Sea snow, and Bering Sea Tanner crab stock rebuilding plans. Some alternatives in the analyses have considerable potential to negatively impact management authority deferred to the State of Alaska (state) in the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs (FMP).

ACLs

National Standard 1 guidelines developed in response to 2007 amendments to the Magnuson-Stevens Fishery Conservation and Management Act (MSA) require that ACLs be adopted for each crab stock listed in the FMP and that ACLs must be implemented beginning with the 2010/2011 fishing season. ACLs will establish a buffer between the federal overfishing level (OFL; the estimate of the total annual catch that would jeopardize the capacity of a stock to produce maximum sustained yield on a continuing basis) adopted by the council and the maximum Total Allowable Catch (TAC) set by the state. ACL buffers must be crafted to account for biological and management uncertainty for each stock. Examples of biological uncertainty include imprecision in the estimate of abundance and imprecision in the estimates of parameters, such as the natural mortality rate, used in the population model. Examples of management uncertainty include imprecision in estimating the expected number of crab discards, such as sub-legal Tanner crabs in the directed Tanner crab fishery.

An ACL buffer is a precautionary measure implemented to explicitly address overall uncertainty in stock assessment and OFL determinations. This scientific uncertainty must be incorporated when an ACL is specified, and not during the stock assessment process or when adopting an OFL for a specific crab stock. Precautionary measures mitigating for scientific uncertainty (e.g., assuming that the National Marine Fisheries Service bottom trawl survey net captures nearly 100% of the legal crabs in its path) have previously been implicitly integrated into some assessment models, rebuilding plans, and OFLs.

It is notable that state harvest strategies provide for incorporation of additional precautionary considerations during TAC setting beyond those specifically prescribed in regulation. The state has employed this flexibility in prior assessment cycles by implementing time and area fishery closures, lowering harvest rates, and accounting for bycatch mortality to prevent overfishing. In exercising FMP deferred management authority, the state often approaches TAC setting more conservatively than required by federal law, taking into account management concerns not specifically incorporated into stock assessments. This flexibility in TAC setting is among the state's strongest contributions to BSAI crab management under the FMP.

Rebuilding Plans

Bering Sea snow crab and Pribilof Islands blue king crab stocks have failed to make adequate progress towards rebuilding and new rebuilding plans for these stocks must be implemented beginning with the 2011/2012 fishing season. In addition, the board and council have been advised that the Bering Sea Tanner crab stock is approaching an overfished condition, thereby requiring implementation of a rebuilding plan for that stock by the 2011/2012 fishing season.

The council will adopt preferred alternatives for crab rebuilding plans to meet specific goals; rebuilding plans must be crafted within both National Standard guidelines and the framework-nature of the FMP. Previous council actions have been sensitive to the state's FMP Category 2 responsibility and authority to set TACs. This authority was initially deferred in recognition of the state's responsive fishery management practices and use of the best available scientific information in managing BSAI crab stocks. The FMP makes the state and federal government partners in achieving the goals of rebuilding plans. The state's expertise in managing BSAI crab stocks and flexibility in incorporating new information provide assurance that the state is committed to rebuilding BSAI crab stocks.

Options proposed for consideration include annual adjustments to the rebuilding harvest rate for both snow and Tanner crab. Such a prescriptive approach to crab rebuilding plans would be inconsistent with the spirit of the FMP and represents a degradation of the state's deferred management responsibilities. Considerations for annual changes in stock reproductive potential and the highly cyclic nature of BSAI stocks are specific reasons why TAC setting authority is deferred to the state and provide strong justification for options that do not include annual adjustment to the rebuilding goals.

Rebuilding alternatives also consider the time frame for rebuilding. To take maximum advantage of the state's flexibility and knowledge in managing BSAI crab stocks, the time frame specified for stock rebuilding must be responsive to the status and biology of each stock, environmental conditions, and the needs of fishing communities.

Bycatch considerations

Bycatch control measures, along with habitat protection and harvest strategies, represent key components of crab rebuilding plans. In the directed crab fisheries, the state has implemented bycatch control measures including accounting for bycatch in each crab fishery as well as specific area closures; however, under the current management structure, commensurate measures do not exist to control crab bycatch in the groundfish fisheries. Several crab stocks lack any bycatch limits in groundfish fisheries and crab bycatch limits that are in place have little relationship to the OFL for the crab stock.

Bycatch mitigation in crab fisheries is incorporated into the state TAC setting process, thereby reducing directed crab fishery harvests; however, the impact of crab bycatch during groundfish fisheries and current crab bycatch limits on directed crab fisheries under the alternatives for ACL management measures and each of the three rebuilding plans is not well understood and is of concern. Crab ACLs and rebuilding plans must account for crab bycatch in BSAI groundfish fisheries.

Summary

The state has consistently exercised a high degree of cooperation with the federal government in managing BSAI crab stocks and frequently seeks guidance to ensure that state management actions are in compliance with MSA and the FMP. Given the long history of cooperative BSAI crab management, the board may wish to provide input to the council at this time for their consideration as alternatives are refined in April and June and preferred alternatives are selected in October. Board recommendations or concerns could provide a record demonstrating need and interest to retain the state's management authority and flexibility provided under the BSAI crab FMP.

Executive Summary

The King and Tanner crab fisheries in the Exclusive Economic Zone (EEZ) (3 to 200 miles offshore) of the Bering Sea and Aleutian Islands (BSAI) off Alaska are managed under the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs (FMP). The FMP establishes a State/Federal cooperative management regime that defers crab fisheries management to the State of Alaska (State) with Federal oversight. State regulations are subject to the provisions of the FMP, including its goals and objectives, the Magnuson-Stevens Act, and other applicable Federal laws.

This proposed action is a revised rebuilding plan for the Pribilof Island blue king crab (PIBKC) stock. The Pribilof Islands blue king crab remains overfished. The purpose of this proposed action is to reduce the risk of overfishing the PIBKC stock by developing an amended rebuilding plan for this stock in compliance with the Magnuson-Stevens Act and the national standard guidelines.

Five alternatives are considered in this analysis. Four of the alternatives consider time and area closures to better protect the PIBKC stock while the 5th alternative considered a prohibited species cap (PSC) on bycatch in groundfish fisheries. Alternatives 2-5 retain all of the current protection measures in place for the PIBKC stock and apply additional measures as described in the specific alternatives and options.

Alternative 1 retains the current Pribilof Island Habitat Conservation Zone (PIHCZ) trawl closure around the Pribilof Islands. Alternative 2 applies the PIHCZ closure additionally to all groundfish fishing (Alternative 2a) or to fishing for Pacific cod with pot gear (Alternative 2b). Alternative 3 proposes to apply the existing State of Alaska crab closure areas to all groundfish fishing (Alternative 3a) or to fishing for Pacific cod with pot gear (Alternative 3b). Alternative 4 proposes two closure configurations to cover the distribution of the PIBKC stock. These closures are then proposed to apply to either all groundfish fishing (Alternative 4a) or to fishing for Pacific cod with pot gear (Alternative 4b). Alternative 5 proposes a cap on groundfish removals of PIBKC at the level of the annually specified overfishing limits (OFL).

Analysis of the impacts of these closure configurations on the rebuilding potential for the Pribilof Island blue king crab stock shows limited effect on rebuilding between the ranges of alternative closures. Alternative 5 is discussed qualitatively and further consideration of this alternative will be given in the initial review draft. This analysis is preliminary and will be revised following input from the Crab Plan Team (CPT) at the March CPT meeting as well as preliminary review at the April Council meeting. Initial review is scheduled for June 2010, with final action by the North Pacific Fishery Management Council (NPFMC, or Council) in October 2010.

AGENDA D-1
Supplemental
APRIL 2010

Agenda

PACIFIC NORTHWEST CRAB INDUSTRY ADVISORY COMMITTEE (PNCIAC)
120 Second Avenue South
Edmonds, WA 98020
360 440 4737
steve@wafro.com

March 12, 2010

Mr. Vince Webster, Chairman
Alaska Board of Fisheries
PO Box 11526
Juneau, Alaska 99501

RE: Comment on Crab Rebuilding Plans and Implementation of Annual Catch Limits (ACLs)

Dear Mr. Webster:

The Pacific Northwest Crab Industry Advisory Committee (PNCIAC) is the Alaska Board of Fisheries (ABOF) and North Pacific Fishery Management Council (NPFMC) designated non-resident industry advisory committee, representing industry participants from Washington and Oregon. The PNCIAC was established in 1990, at the time that the Bering Sea and Aleutian Islands (BSAI) King and Tanner Crab Fishery Management Plan (FMP) was implemented. Since that time the State of Alaska, the NMFS, the NPFMC and the PNCIAC have worked together to improve resource management while maintaining the balance of power and delegation of authority carefully defined in the FMP.

This collective effort has resulted in a highly successful fishery management model, including an innovative catch shares program that has just completed its fifth year; and success in rebuilding fisheries under the guidelines of the Magnuson-Stevens Act. These plans have been developed jointly under the shared leadership of the Alaska Department of Fish and Game, the National Marine Fisheries Service, the NPFMC and the PNCIAC.

The MSA now requires that Annual Catch Limits (ACLs) be developed and implemented by the 2010/2011 season. The PNCIAC is concerned because the imposition of poorly designed ACLs may actually reduce management flexibility, rather than improve our current stock management processes.

The State of Alaska has unique authority under the joint state-federal management structure, and the Alaska Department of Fish & Game already employs a wide range of precautionary management measures. Specifically, we are concerned that a too rigid approach to ACLs will undermine the State's management authority and resource management flexibility.

We recognize that ACLs are required under the MSA. The ADF&G already uses time and area closures, conservative harvest rates and by-catch and handling mortality buffers to achieve resource rebuilding and sustainability goals. This management flexibility may be undermined by inappropriately over-reaching ACLs.

The BSAI King and Tanner Crab FMP remains a twenty-year successful model of shared state and federal management based on a balance of power embedded in the FMP. It is a system that should be enhanced, not degraded.

Sincerely,

QuickTime™ and a
decompressor
are needed to see this picture.

Steve Minor, Chairman
PNCIAC

Cc: Denby Lloyd, Commissioner, ADFG
Eric Olson, Chair, NPFMC
Jim Balsiger, AA/NMFS/AKR
Forrest Bowers, Chair, BSAI Crab Plan Team

Mar 30 10 10:52a Phil Whitley 2067849377 p.3

Inter-Cooperative Exchange Policy Advocacy Committee (ICEPAC)
17249 15th Ave NW
Shoreline, WA 98177
206-992-3260
edpoulsen@comcast.net

AGENDA ITEM D-1

March 12, 2010

Vince Webster, Chairman
Alaska Board of Fisheries (BOF)
PO Box 25526
Juneau, AK 99802-5526

Re: Annual Catch Limits (ACL) for Bering Sea/Aleutian Islands Crab

Dear Chairman Vince Webster,

The Inter-Cooperative Exchange Policy Advocacy Committee (ICEPAC) represents approximately 70% of the Bering Sea crab harvesters.

The North Pacific Fishery Management Council (NPFMC) is currently looking at options that would implement Annual Catch Limits (ACLs) for Bering Sea/Aleutian Island crab stocks. ACLs are intended to provide a further buffer during TAC setting to address uncertainties in regards to science, biomass, and management. The crab stocks are federal fisheries but are managed by the State of Alaska, including TAC setting authority, with federal oversight through a Fishery Management Plan.

The Alaska Department of Fish and Game has done an excellent job in providing a long term sustainable yield for our crab stocks in the Bering Sea and Aleutian Islands through the TAC setting process. The Bering Sea snow crab, Bristol Bay red king crab, St. Matthews blue king crab, and Bering Sea bairdi stocks are all at higher resource levels than 10 years ago. Stocks that are showing little sign of rebuilding are closed with industry support such as the Pribilof blue king crab fishery. We are confident in ADF&G's ability to manage these crab stocks for the future and are supportive of their leadership in this role.

ICEPAC is concerned that the ACL process could result in de facto federal management of our crab stocks in regards to TAC setting. Depending on the ACL alternative chosen by the NPFMC, ADF&G may have little to no flexibility in TAC setting with an overly conservative ACL buffer. ICEPAC believes ADF&G currently has enough conservative buffers in place to ensure a long term sustainable yield of the fisheries our members are dependent upon.

In summary, ICEPAC is confident in ADF&G's ability to manage the TAC setting process for Bering Sea/Aleutian Islands crab and is concerned that the ACL process could limit or remove ADF&G authority in this process.

Sincerely,

Edward Poulsen
ICEPAC, Executive Director

Crab Plan Team Report

The Crab Plan Team (CPT) met March 29-April 1, 2010 at the Alaska Fisheries Science Center in Seattle, WA.

Crab Plan Team members present:

Forrest Bowers, Chair	*(ADF&G)*
Ginny Eckert, Vice-Chair	*(Univ. of Alaska – Fairbanks and Sitka)*
Diana Stram	*(NPFMC)*
Doug Pengilly	*(ADF&G – Kodiak)*
Gretchen Harrington	*(NOAA Fisheries – Juneau)*
Wayne Donaldson	*(ADF&G – Kodiak)*
Jack Turnock	*(NOAA Fisheries/AFSC – Seattle)*
Shareef Siddeek	*(ADF&G – Juneau)*
Herman Savikko	*(ADF&G – Juneau)*
Lou Rugolo	*(NOAA Fisheries /AFSC – Kodiak)*
André Punt	*(Univ. of Washington)*
Bill Bechtol	*(Univ. of Alaska – Fairbanks)*
Bob Foy	*(NOAA Fisheries /AFSC – Kodiak)*
Brian Garber-Yonts	*(NOAA Fisheries – AFSC Seattle)*
*Josh Greenberg was absent.	(Univ. of Alaska – Fairbanks)

Members of the public and State of Alaska (State), Federal Agency, and Council staff present for all or part of the meeting included: Pat Livingston, Clayton Jernigan, Jack Tagart, Lenny Herzog, John Gauvin, Tom Casey, Arni Thomson, John Olson, Matt Eagleton, Diana Evans, Sarah Melton, Ed Poulson, Stefanie Moreland, Scott Miller, Russ Nelson, Scott Goodman, Steve Hughes, Grettar Gudmanson, Anne Hollowed, Doug Woodby, Bob Lauth, Craig Rose, Buck Stockhausen, Tom Wilderbuer, Martin Dorn, Paul Spencer, Sandra Lowe, Rob Rogers, Jay Bowlden, Lance Farr, Tom Suryan, Kevin Kaldestad, Jim Stone, Neil Rodriguez, Jie Zheng, Linda Kozak, and Dick Powell.

The attached agenda was approved for the meeting.

Essential Fish Habitat (EFH) 5-year review

Diana Evans and Matt Eagleton provided an overview of the EFH 5-year review requirements and progress-to-date. Bob Foy coordinated the review of EFH Fishery Management Plan (FMP) text by the individual crab assessment authors, and presented the findings to the CPT. During the course of the discussion, Craig Rose and John Olson provided further clarification about the methodology used for the evaluation of fishing impacts on crab EFH. It is important to recognize that for crab species, the Level 1 EFH description is defined by general distribution only. The CPT noted there was some inconsistency among the criteria used by the authors in their reviews, and tried to address that in their recommendations, as follows.

General CPT Recommendations:

- **The CPT recommends that further analysis be undertaken to evaluate fishing effects on crab stocks, and to decide whether the conclusions in the FMP are valid.** CPT notes that the methodology used in the 2005 effects of fishing analysis may not adequately capture actual impacts of fishing on crab populations. Other parameters may need to be considered for crab stocks, such as the importance of spawning and larval distribution relative to oceanographic currents (pelagic habitat) for crab settlement. This is applicable to the assessment of all crab stocks. Additionally, the conclusions imply that more is known about the effects of fishing on the habitat needs and life history stages of crab (especially growth to maturity) than can be substantiated, based on research-to-date.

- **Additionally, research over the next five years should be directed to allow a better definition of "essential" habitat for crab species.**
- The CPT recommends that the clarification that Level 1 EFH definition has been accepted by the Council as the general distribution of the species should be explicitly added to the FMP text and maps for all species. Given the clarification (by the presenters), the CPT recommends no changes be made to the map descriptions for crab species because no additional information on crab distribution was provided.
- In conjunction with the revisions to general EFH information noted by the authors in Appendix 3, new studies may be available on trophic information. The description of the fishery may need to be revised for some species for consistency.
- Changes to the crab review summary table (Table 8 in the EFH summary report) are noted below in shading.
- Recommendations on the crab FMP EFH text should be considered a high priority for Council action.

Red King Crab Recommendations:

- **CPT agrees with the assessment author that there is evidence that the effect of fishing on spawning/ breeding populations could be substantial.** As per the CPT's general recommendation above, further evaluation is required to determine whether a change to the FMP's conclusions is warranted.
- **The Council should consider identifying red king crab spawning habitat as a HAPC priority type.** A specific area in southwest Bristol Bay has been identified that may provide important habitat for red king crab spawning, with direct oceanographic transport to juvenile rearing areas. **Should the Council choose to move forward with this as a HAPC priority, the CPT will be prepared to put forward a proposal to the Council to nominate this area as a HAPC in the time frame the Council allows for these proposals, as it appears to meet the criteria identified by the Council for HAPCs (e.g., ecological function and rarity).**
- **The CPT is generally concerned about fishery interactions with red king crab in this area, for both bycatch and habitat impacts. If this concern cannot be addressed through the HAPC process, the CPT would like the Council to consider alternative mechanisms for protecting crabs in this area.**

Blue King Crab Recommendations:

- As noted above, the CPT disagrees with assessment author's recommendation to change EFH information from 'Level 1' (where information is available to describe EFH) to 'Unknown,' based on the presenter's clarification.
- The CPT agrees with assessment author's modification of the effects of fishing on growth to maturity from minimal and temporary (MT) to unknown. No studies are available on growth to maturity, such that a conclusion of MT could be supported.

Golden King Crab Recommendations:

- As with blue king crab, the CPT recommends retaining current description of EFH (based on general distribution) for late juvenile, adult, and egg life history stages, with appropriate clarifications added.
- The CPT recommends modifying the water column association for larvae (table on page 31 of Appendix 3) from 'P' (pelagic) to 'U' (unknown).
- For the evaluation of fishing effects, the CPT recommends that the MT conclusion be provisionally retained for spawning and breeding (consistent with the rationale for blue king crab,

where some information is available on the number of breeding crabs caught as bycatch in fishing operations). The CPT supports 'unknown' for the other conclusions.

Tanner Crab Recommendations:

- The CPT disagrees with the assessment author's proposed change to the EFH description for eggs, based on the presenter's clarification that the rationale for this determination is that egg distribution can be reasonably inferred from adult distribution.
- The CPT recommends that the fishing effects evaluation conclusions be modified to 'unknown' for consistency with the approach discussed under the CPT's general recommendations above.

Snow Crab Recommendations:

- As with snow crab, the CPT recommends modifying the fishing effects conclusions to be consistent with previously articulated recommendations. The summary text should be edited to include this rationale.

Species	Recommended changes to the FMP text: EFH description			Recommended changes to the FMP text: General information						Recommended changes to the FMP text	Worksheet recommendations		Plan Team: priority recommendation
	text	map	available level of information	tables of associations	life history, gen. distribution	Trophic information	biological/ habitat associations	literature	description of fishery	2005 evaluation of fishing effects on EFH	HAPC	EFH conservation and enhancement	
Red king crab	-	-	-	yes	yes	- yes	-	-	yes	yes	yes	-	high
Blue king crab	-	-	~~yes~~ no	yes	e/c	- yes	e/c	-	e/c	yes	-	-	high
Golden king crab	~~yes~~ no	-	~~yes~~ no	yes	yes	- yes	yes	yes	yes	yes	-	-	high
Tanner crab	e/c	-	~~e/c~~ no	yes	yes	yes	yes	yes	yes	~~e/c~~ yes	-	-	high
Snow crab	-	-	-	yes	yes	yes	yes	yes	yes	~~e/c~~ yes	-	-	high

e/c = editorial changes only

EFH Research Priorities:

- **The CPT recommends a research priority to determine critical spawning and nursery grounds for all crab species.** Information from this research could be used in future HAPC considerations. Research should look at substrate needs as well as pelagic habitat (e.g., the importance of oceanographic transport mechanisms) in determining critical spawning areas.
- **Analyze temporal trends in spatial distribution of crab stocks to assess the current EFH descriptions.** Include historical data and analyze shifts in distribution over time.
- **Evaluate relationships between, and functional importance of, habitat-forming living substrates to juvenile and adult crab.**
- **Quantify crab habitat characteristics utilizing appropriate technology to allow increased precision of survey catch rate estimates.**

Survey Time Series Revisions

Bob Foy summarized work done since the September 2009 CPT meeting to standardize the trawl time series. Recall that changes implemented to the time series data released to the assessment authors last September included error fixes, substitution of measured survey net width for the previous assumed net width and incorporation of unmeasured crab, and a time series based only on standard tows. Additional work has been ongoing over the winter, but remains incomplete. Specific aspects currently under review include: (1) which data sets to include in survey estimates; (2) how to treat areas that were not sampled during portions of the time series; and (3) how to treat special tows, hot spots, re-tows (currently apply only the 2nd tow), and high density tows. A more focused effort is needed for analysis of the survey spatial and temporal data; specifically, how changes to survey estimates may be driven more by shifts in the actual survey area rather than from changes in stock abundance; and how pre-1975 assessment data might be incorporated. Based on sequential periods of approximately similar spatial distribution in the trawl survey, eight different sequences of survey years have been identified.

CPT Recommendations:

- The upcoming assessments should use the existing time series structure as made available in September 2009, but updated for an additional year of survey data because:
    - Work is still ongoing on those revisions; and
    - The assessment authors and the CPT are currently involved with a variety of changes due to the stock assessments related to development of ACLs, the development of several rebuilding plans, etc. Thus, it would be less complex to not revise the survey time series in the assessment at this time, but instead to apply the same basic time series that was applied in September 2009.
- Any future updates to the survey structure should be presented in September and not in May because the assessments are due in May.

Eastern Bering Sea (EBS) Snow Crab: Review net selectivity and model sensitivity, recommend direction for May assessment, and plans for 2010 cooperative survey.

Updated EBS Snow Crab Assessment:
The CPT was briefed by Jack Turnock on the sensitivity of the results of the snow crab assessment and on how survey selectivity and catchability are treated, taking account of the survey data collected by the Bering Sea Fishery Research Foundation (BSFRF) and the NMFS in 2009. The estimates of survey selectivity were based on data from 108 tows in three subsets of the survey region. Unlike the September 2009 assessment, all of the model runs presented were based on survey indices computed using measured net widths and the survey data were weighted using the survey coefficients of variation (rather than being overweighted). The survey indices of abundance and the associated length composition data from the 2009 BSFRF survey and the associated NMFS tows were included as separate data components in the assessment. Turnock presented the results of eight sets of model specifications (based on different assumptions regarding parameters that are fixed or estimated).

The CPT **agrees** with the general approach used to include the BSFRF survey data in the assessment but notes that the fit of the model to the length-frequency data for BSFRF survey is very poor. **The CPT recommends that a model configuration that is able to fit all of the data sources be created and identify five possible ways to improve the fit of the model to the BSFRF length-frequency data: (1) disaggregate the data spatially and perhaps fit the model to each of the three subsets of the survey region separately; (2) replace the logistic selectivity function with a selectivity pattern that is smooth but more flexible than the logistic curve (the selectivity pattern needs to account for both gear selectivity and availability); (3) drop the data for size-classes smaller than 40mm (or 50mm); (4) estimate natural mortality with a prior based on the results of the Canadian tagging data**

(consider re-analyzing the Canadian data using mark-recapture methods); and (5) estimate growth within the model. It may be necessary to combine some of items (1)-(5) to create a model which fits all of the data adequately.

The CPT recommends that the assessment for May 2010 include at least: (a) the current base model; (b) a model that sets Q to 0.75; and (c) a model which assumes the Somerton selectivity and sets Q to 0.75. A likelihood profile for survey Q should also be reported in the assessment.

The CPT notes that considerable work remains to complete the stock assessment for EBS snow crab. Moreover, the assessment is needed for both the Rebuilding Plan and ACL environmental assessment (EA) and for status determination and Over Fishing Limit (OFL) calculation. **The CPT suggests the following work plan: (a) the period between now and the May 2010 CPT meeting should be used primarily to explore model formulations as outlined above; (b) the final ACL/rebuilding calculations should be based on the model selected during the May 2010 CPT meeting using the data currently available; and (c) status determination and OFL calculation should be based on the model selected during the May 2010 CPT meeting and should also take account of the data from the 2009/10 fishing season and the 2010 survey.** The CPT notes that this may mean that, for example, the estimate of the time to recover to B_{MSY} may differ between the analyses in the final EA and those presented to the CPT in September 2009.

Plans for the 2010 BSFRF Survey:
Robert Foy summarized the proposed survey plan for 2010. The design for the BSFRF survey attempts to overcome the difficulties caused by the spatial and temporal differences between the NMFS and BSFRF tows during 2009. These difficulties are partially a cause of the current problems associated with including the BSFRF survey data in the stock assessment. Side-by-side surveys will be conducted north-east of the Pribilof Islands including the high density area around St. Matthew Island. The area chosen for the side-by-side sampling includes a number of covariates likely to impact survey selectivity, based on past research.

The CPT **supports** the proposed design, noting that it overcomes several of the problems with the 2009 design. The CPT notes, however, that the proposed design does not encompass the same area as the NMFS survey because the design reflects a balance between being representative and logistically feasible. The CPT **encourages** continued efforts to ensure that the sampling will be representative of the entire population because this will ease later data analysis. The CPT also **emphasizes** the importance of the survey researchers continuing to work closely with the assessment author to ensure that the data collected during the survey can be easily included in the May 2011 stock assessment.

Crab Annual Catch limits and Rebuilding

General:
The CPT **emphasizes** the importance of assessment authors following the guidelines for stock assessments adopted last year and the need for assessments to fully document the stock assessment method if this has not been published.

The team **clarified** that the analysis defines buffer as a multiplier, not the difference between ABC and OFL. This should be modified in the next draft for consistency (so that the buffer is between OFL and ABC and the value in calculations is defined as a multiplier).

If a single P* is chosen, the buffer depends on the perception of uncertainty, but future uncertainty is unknown. There should be a discussion in the next draft of the implications of changes in the estimate of how much uncertainty there is on the size of the buffer if the P* method is applied and the risk of overfishing if the fixed buffer method is applied.

The results in which the State strategy constrains the outcome of the ABC control rule provide the best appraisal of the economic impacts of the alternatives, while the results in which the State strategy is ignored provide the best appraisal of the biological (stock risk) impacts of the alternatives. The CPT **recommends** that results be presented for both of these cases for all stocks.

The CPT **recommends** that the fit of the assumed stock-recruitment relationship to the stock and recruitment data be reported for all stocks, and that the definition of the probability of overfishing be included in the headers for the tables which report this probability. The team recommends that the authors individually determine which S-R curve is to be carried forward in the analysis, the use of B-H or Ricker S-R relationship.

The team agreed that for the initial draft review there must be a focus on how to effectively communicate results to the public so that the public may provide informed comments to the Council.
For all tables, the analysis should use 2 decimal places, and units presented in metric tonnes (t). The remainder of comments on the analysis are provided by Chapter below. The team **notes** that the presumption of the entire analysis is that, on average, the estimate of the OFL is correct given the level of information available by stock (i.e., that precautionary assumptions are not included in the estimation of the OFL). A graph should be added showing OFL, TAC and buffers for all stocks to show relative impacts of alternatives.

Chapters 1 and 2

Diana Stram provided a review of the timing and objectives for the CPT's review and presented an overview of Chapters 1 and 2 of the analysis. She provided the following (attached) overview of the objectives for the CPT to review and comment on at this time, noting that the opportunity to comment on a preferred alternative will be provided at either the May or September 2010 CPT meetings.

- The team clarified that the analysis defines buffer as a multiplier, not the difference between ABC and OFL. This should be modified in the next draft for consistency (so that the buffer is between OFL and ABC and the value in calculations is defined as a multiplier).
- If a single P* is chosen, the buffer depends on the perception of uncertainty, but future uncertainty is unknown. There should be a discussion in the next draft of the implications of changes in the estimate of how much uncertainty there is on the size of the buffer if the P* method is applied and the risk of

Accountability Measures:
This draft EA does not include alternatives for AMs, but they must be included in the next draft.

The CPT is **concerned** that implementing AMs with this action could result in only the directed crab fishery being subjected to any AM constraints, regardless of what source of fishing mortality caused the ACL to be exceeded. The CPT believes that all sources of fishing mortality should be held accountable for their contribution to removals under AMs.

The CPT notes that limits on the groundfish fishery are included in the "Alternatives considered and not carried forward" section of the EA. It **recommends** that a discussion paper should be drafted that considers the issues related to groundfish bycatch of crab identified previously by the Council's Advisory Panel (AP). The CPT also notes, however, that crab bycatch in the groundfish fisheries has both allocative and conservation impacts. The fraction of the ACL/Annual Biological Catch (ABC) that consists of bycatch in groundfish fishery will be substantial for some stocks. The State has no control of this component of mortality. The CPT therefore **requests** that Council staff assemble data for some crab stocks (e.g., Tanner) to assess the temporal and spatial overlap between groundfish fisheries and crab abundance, and to assess the fraction of the ACL (for various buffer levels) that would consist of bycatch in the groundfish fishery and report these assessments to the CPT in May 2010.

The CPT feel that an appropriate way to move forward with AMs, and to begin feedback with the groundfish FMP, is to use the Pribilof Island blue king crab rebuilding plan crab bycatch limits in groundfish fisheries as a starting point. This approach could provide an example of how future crab bycatch limits in groundfish fisheries may be applied for all crab stocks. The Tanner crab rebuilding plan may also consider measures to limit Tanner crab bycatch in the groundfish fishery.

Options for modifying the NPFMC review process:
The CPT reviewed three options for modifying the Council review process of crab OFLs/ACLs. The CPT discussed the three Options related to timing and felt that Option 1 (delay TAC-setting to provide for SSC recommendation on the ABC in conjunction with the October Council meeting) was the most viable. The CPT recommended that the discussion of these options should be expanded to include issues such as: (1) the process for issuance of Individual Fishing Quotas / Individual Processor Quotas has been streamlined and can occur within one week; and (2) the public may be disadvantaged by a truncated process. The CPT is interested in public comment on whether fishery participants would benefit from greater lead time between TAC announcement and the start of the fishery.

Chapter 3: Methodology

André Punt, Doug Pengilly, and Brian Garber-Yonts summarized the methodology for the ACL analysis, including: (1) options of buffers and the P* method; and (2) the process to examine short-term (2009/2010 fishing year), medium-term (2009-2015), and long-term (30-year) effects on total catch, directed catch, Mature Male Biomass (MMB), probability of overfishing, probability of being overfished, and gross revenue (under different discount rates). Aspects of harvest control by either ABC or State control rules were discussed. Additional clarity is needed on assigning uncertainty, perhaps to include uncertainty associated at stock assessment tiers.

CPT Recommendations:

- The assessment should conduct the medium- and long-term projections of both with and without removals imposing the State control rule.
- Care should be taken to make sure that the buffer is the difference between the OFL and the ABC, and not the multiplier on the OFL.
- The analysis needs to clarify the criteria by which additional uncertainty (σ_b) is set for each stock, including the potential specification of default values. **The CPT recommends that the final values recommended in the EA be the default for σ_b, noting that characterizing this as a default allows future modifications by the SSC contingent on stock assessment information or stock status changes.**
- Add a table or graph to exhibit the relationship between variance and the resultant error bounds; i.e., what is the relative increase in the bounds from a unit increase in sigma?
- For the analysis process, an equation should be inserted showing how the numbers-at-length are used when computing the estimated OFL/ABC.
- The text needs to clarify that P* = 0.5 is provided only for comparative purposes (i.e., a representative bound), because National Standards require that P*<0.5.
- Authors need to verify that the definition of probability of being overfished is consistent among different assessments; e.g., does the probability overfished for the long-term simulations indicate being overfished at least once during the 30-year period or an annual probability of being overfished?

- A figure should be added showing the stock-recruit relationship.
- Because individual simulations are highly variable, the CPT suggested that a figure could be provided in the Methods section that shows how the individual simulations vary over time. The legend could be clarified within chapters that the dark line is a median.
- To reduce redundancy, the table showing the relationships among P*, the additional uncertainty, and the buffer, should be moved from the species-specific chapters to Chapter 3.
- Uncertainty is likely underestimated in the economics analysis. Aspects to consider include:
  - Uncertainty in (PRR) (Table 3-6) might also be incorporated into overall economic model;
  - Ratios of prices by species (Table 3-5) are treated as without variability, but variability does exist in the prices (send variability estimates to Andre).
- Section X.1.1 in each assessment should list the coefficient of variation (CV) for *MMB*.
- Andre to check on use of 3-y versus best-estimate lag in model for Recruit year
- Additional economic issues to be resolved for the next iteration of the ACL analysis are:
  - More fully addressed P* alternatives and compare to fixed buffers;
  - Characterize tradeoff of risk reduction/costs and time-varying uncertainty;
  - Utilize species cost information, where available, rather than proxies.
- Economic analysis issues related to rebuilding:
  - Clarification on which snow crab and Tanner crab rebuilding alternatives should be reflected in the economic analysis is needed.
  - Clarification on the confounding of discounting rates and the time series of the buffer effects is needed.
  - Qualitatively discuss further economic impacts (processors, change in fishing behavior, etc.).
- General comment for all chapters: be consistent in presentation of data in tables in regards to number of decimal places.

Chapter 6: Bristol Bay Red King Crab (BBRKC)

Andre Punt provided an overview of the BBRKC chapter.

Additional Uncertainty:
Uncertainty in the 2009 MMB estimate is low (CV = 5%), but unknown levels of uncertainty in some assessment and control rule parameters (e.g., fixed M or $F_{35\%}$) exist. **Therefore, the CPT recommends that an additional CV value of 0.2 is appropriate for this stock.**

Chapter 4: Snow Crab

Jack Turnock introduced the results of the rebuilding analysis and ACL calculations for EBS snow crab.

Uncertainty Characterization:
In relation of uncertainty characterization, the estimate of uncertainty from the assessment for snow crab (CV = 0.086) is higher than for BBRKC (CV = 0.05). Reasons for this include higher survey CVs and that more parameters are estimated. **The CPT recommends that the EA should note that survey catchability is estimated and not pre-specified, and that some aspects of growth (e.g., terminal molt) are estimated. The CPT recommends that a CV of 0.2 best characterizes uncertainty for EBS snow crab.**

ACL Analysis:
In relation to the ACL analysis, the CPT **recommends** that:

- In order to ease the comparison of impacts among buffers, results should be provided for a base model for all buffers from 0.1 to 1 in steps of 0.1, in addition to a buffer of 0.75, and results should be provided for a subset of the buffers for all of the models.
- Add the breakdown of the ABC among fleets to the header for Table 4.1.
- The results in Table 4.1 should be checked because there appears to be an error in how P* and/or the buffer are calculated for some options.

General Rebuilding:
The CPT **emphasizes** that the EA needs to be clear that the number of years a stock needs to be assessed to be above B_{MSY} before it is considered to be recovered is a decision point for the analysis. The results in the EA for EBS snow and Tanner crab are based on a definition for "rebuilt" that involves the mature male biomass (MMB) being above B_{MSY} (or its proxy) for two years in a row. The reason behind this definition is that status determination has, in the past, been based on survey estimates of abundance (rather than model outputs). These estimates can fluctuate substantially from one year to the next. Using a two-year rule for defining recovery leads to more confidence that recovery has indeed occurred. In contrast, while model-based estimates of biomass do vary from one year to the next, this variability is likely to be much less than for individual survey estimates of MMB. The CPT therefore **requests** additional direction from the Council on whether to continue basing the analysis on this definition of recovery or to include an option in the EA to modify this definition for EBS snow and Tanner crab. The consequences of being rebuilt are not currently accounted for in the analysis; e.g., what F is applied after the stock is defined as rebuilt?

The CPT **recommends** that the option to annually increase the probability of rebuilding should be moved to the "Alternatives considered and not carried forward" section because it is problematic to analyze the impacts of this option. The intent of this option can be captured by the selection of an alternative in which the probability of rebuilding by T_{target} is greater than 0.5. The CPT also **recommends** that staff reorganize the alternatives so it is more clear that Alternatives 6-8 have more opportunity for course correction to account for inevitable uncertainty in the assessment outcomes and recruitment success, yet still achieve rebuilding. There is also a need to add text to Section 3 that illustrates the operational aspects of rebuilding and revising rebuilding owing to course correction. This could involve plots that show how the rate of fishing mortality could be adjusted on an annual basis using examples of how the results of assessment change.

In relation to the rebuilding analysis, the CPT **recommends** that:

- Results should be provided for all model configurations and for a subset of assumptions regarding fishing mortality once the stock is assessed to be rebuilt.
- Add a column that reports the probability of being rebuilt, defined as above Bmsy once before and including the current year, and the probability of being rebuilt for two years in a row.
- Compute and report the probability that the stock would be assessed to be rebuilt, given that it is and is not actually rebuilt using the projection model.

Chapter 5: Tanner Crab

Lou Rugolo and Jack Turnock presented an overview of the Tanner crab chapter and the draft Tanner crab assessment model.

Tanner Crab Model:
The *C. opilio* length based stock assessment model was adapted to *C. bairdi* population and fishery dynamics. Model B_{ref} was 118,600 t, compared to the 83,850 t estimate based on survey estimates of MMB. The major issue with the model was the lack of fit to the MMB from ~2000 to 2009, where the model predicted estimates of female mature biomass are above, and MMB are below, the corresponding survey estimates. **The authors were asked to run different scenarios based on these comments to assess the model performance at the May 2010 CPT meeting.**

The CPT recommended that the model may be used for ACL analysis as the basis for long-term projections. The current model (presented at this meeting) will be used for development of initial review EA in June 2010. For this analysis, the current model should be used to estimate the long term impact. The Tier 4 control rule (using survey estimates as well as model output) should be used to evaluate short-term impacts. Results should not be presented for medium-term predictions to avoid giving the impression that such results are reliable.

The CPT noted that rebuilding plan development will be delayed until it is possible to find a model that better fits the data. The CPT will review a revised model in May 2010 and reassess the timeline and alternatives for rebuilding based on that review. The understanding is that the rebuilding plan analysis must be completed within two years of when the actual determination of overfished is made.

CPT Requests:
The CPT makes the following specific **requests** to the assessment authors for the May 2010 assessment review:

- Units that were used to fit the data need to be clarified. The units should be based on collected measurement (i.e., catch in number instead of catch in weight).
- Authors should consider the results of the Bechtol et al. 2010 study on minimum size limit. There is genetic research that addresses geographic stock separation and warrants review by the CPT. The SSC convened a workshop on genetic stock separation in 2009. The report from this workshop should be considered by the CPT, discussed at the May CPT meeting, and potentially presented at that time.
- Consider size distribution of Tanner crab east and west of 166 longitude.
- Add the profile for 'M.'
- Fit a gamma distribution to the growth data.
- Address lack of model fit to MMB and females:
  - Show residual patterns for the model fit to MMB.
  - Change m/f ratios at birth to potentially help fit the sexes similarly to the survey.
  - Research the probability of maturity at size over time.
  - Consider a spatially segregated approach.
- Address the survey length versus carapace width fits.
- Assess the growth or maturity functions to fix the model specification.

Tanner Crab ACL Analysis:

- Uncertainty in the model
  - The CPT **recommends** that additional uncertainty be 0.4, similar to other Tier 4 stocks.
  - Add the uncertainty associated with fixed q, tier 4 control rule, and the survey data in this section.
- Model description
  - Specify in the text to distinguish between the short-term tier 4 control rule and the model used for long-term projection.

- Projections
  - In the short term ACL calculations, ADFG TAC needs to be added to the headers and units need to be standardized.
  - This table will be replaced with a Tier 4 analysis.

Chapter 10: Norton Sound Red King Crab

Diana Stram provided an overview of the results of the Norton Sound red king crab analysis (Chapter 10 of the preliminary review draft EA).

Needed Edits to the Text:

- Section 10.1.1 (Uncertainty in stock assessment) needs to provide the estimated coefficient of variation for the estimate of mature male biomass.
- Text in Section 10.1.1 (Uncertainty in stock assessment) stating, "Given the relative amount of information available for NSRKC, an additional variance level of 0.2 or 0.4 seems warranted" needs to be changed to, "Given the relative amount of information available for NSRKC, an additional variance level of 0.4 seems warranted." (but see below)

The CPT Recommends:

- There is additional uncertainty relative to other Tier 4 stocks due to lack of bycatch data and estimates. During discussion on the lack of bycatch estimates, the Norton Sound red king crab stock assessment author expressed plans to estimate the bycatch using BBRKC selectivity. It was also noted that there has apparently been some limited observer coverage recently (an ADF&G biologist served as on-board observer one season and there has been some voluntary reporting of bycatch and discards by harvesters) and that that data may be available by the May 2010 meeting.
- Should consider employing higher additional uncertainty with CV > 0.4 (e.g., consider CV = 0.6) until directed fishery bycatch estimates are available.
- Although the stock is surveyed, the periodic / triennial nature of the survey (as opposed to an annual survey) is an additional source of uncertainty that should be noted in the text of the draft EA.
- There were questions on the summer commercial fishery versus the winter commercial and the subsistence fishery. The analysis only considers the economic outputs for the summer fishery that is fished according to the State harvest strategy and will need to be clarified in the text. (The State harvest strategy applies only to the summer commercial fishery and the catch in the winter commercial fishery. The subsistence fishery is apparently small relative to the summer commercial fishery.)
- The economic analysis will need to adjust prices from Bristol Bay (larger retained size and fall / winter fishery) to Norton Sound (summer fishery and smaller retained size).

Chapter 7: Pribilof Island Red King Crab (PIRKC)

Bob Foy presented the overview of the results for the PIRKC analysis.

Characterization of Uncertainty:

- The CPT noted that there was no discussion of the model. The CPT recommends that further discussion of the proposed assessment model occur at the May 2010 CPT meeting.
- Add to the text on uncertainty that analysis employs model under development and not reviewed by the CPT.
- The CPT **recommends** that the value considered for additional uncertainty of 0.4 may be insufficient and recommends the use of a higher value (e.g., 0.6).

- Need to correct survey CV in model; used 0.145, but should be 0.637.

Impacts of Alternatives:

Medium-Term Impacts:

- Recommend deleting sentence on p.227 referring to 20% exploitation rate and 60% cap on harvest of legal males.

Long-Term Impacts:

- Table 7.7, column "P[overfished]" – clarify why for this assessment the stock is shown as currently overfished; need to note that this is not the model used for the status of stock determination

General Comments:

- The CPT **recommends** for Table 7.1 (Short-Term); Andre used CSA model to calculate the OFL for 2009 and hence ABCs for different buffer levels; need to add an equivalent table needs to be added which is based on survey data, buffers and Tier-4.

Chapter 8: Pribilof Island Blue King Crab

Bob Foy presented the analysis for PIBKC. There has been similar model development to PIRKC. The model has been modified from the State catch survey analysis model used for TAC setting. The model incorporates bycatch of fixed gear and groundfish. The model has not been reviewed by the CPT and has not been used previously for assessments.

The "Characterization of uncertainty" section needs to include that the model is under development. The CPT **recommends** that the additional uncertainty of 0.4 may be insufficient and a higher value (e.g., 0.6) should be considered.

Chapter 9: St Matthew Blue King Crab

Diana Stram presented the analysis for this stock. The team noted that many of the suggestions for improvement for the previous chapters apply to this chapter.

Uncertainty in Stock Assessment:

The CPT noted that this stock is also a candidate for using a higher additional CV than 0.4. Uncertainty in the survey estimates should be added due to the availability of the stock to the survey; i.e., the catchability of mature crab to the survey.

Andre will redo calculations using the same method to characterize parameter uncertainty as was used for snow crab in Tables 9-1 and 9-2. The CPT discussed why the long term trajectories show biomass dipping below B_{MSY} in Figure 9-3. Andre Punt said that he will look into this.

Chapter 11: Aleutian Island Golden King Crab (AIGKC)

Siddeek Shareef and Doug Pengilly provided an overview of the AIGKC analysis. This analysis includes both a Tier 4 and Tier 5 formulation for presentation of impacts.

Tier 4 AIGKC Model:

The CPT received a presentation on the male-only length-based assessment model. Separate models have been developed for each stock (Dutch Harbor and Adak). This model is under development and has not yet been accepted for assessment purposes. Results of the model indicate that the ABC is high relative to the current harvest. This model will be presented to the CPT in May 2010 for possible use in the

2010/2011 assessment cycle. The CPT recommends using the model to evaluate ACL alternatives and options under a Tier 4 control rule.

Tier 4 Review:
The CPT recommends an additional CV level of ~0.4 (medium level). The CPT notes that relative to other stocks with no consistent survey (i.e. , PIRKC), there is more information on this stock.

Tier 5 Review:
The CPT recommends an additional CV level of ~0.5, given current information availability on this stock in relation to other Tier 5 stocks.

Chapter 12: Pribilof Islands Golden King Crab (PIGKC)

Doug Pengilly provided an overview of results from the analysis for the PIGKC stock.

The CPT Recommends:

- The PIGKC GHL is not established by State regulation. A brief discussion of accountability measures centered around ADF&G's ability to control harvest should be included since the fishery is not rationalized. This discussion should characterize, however, that typically the fleet is small, there are low pot limits, 100% observer coverage, and the fishery has successfully been contained to the GHL in prior years.
- A high level of additional CV (e.g., 0.6) is recommended due to high uncertainty in total-catch OFL. There is more uncertainty than for AIGKC (when treated as a Tier 5 stock) due to the number of years with no catch or effort data and to 1998 being the last year of catch data used to compute the OFL.

Chapter 13: Adak Red King Crab

Doug Pengilly provided an overview of results from the analysis for the PIGKC stock.

The CPT notes that additional uncertainty is high and recommends a high additional CV (e.g. 0.6).

Comparison of Alternatives

Diana Stram provided an overview of the section comparing results across alternatives (Chapter 2 section 2.4) and sought feedback from the CPT on additional comparisons to include for the initial review draft. The team made the following **suggestions**:

- Include a characterization of which stocks have assessment models to highlight the relative levels of information available by stock;
- Provide a 'look up' table of buffers and P*s across all stock pulling the results for the recommended additional uncertainty
- Compile a table which characterizes the relative uncertainty by stock;
- Include figures which indicate the relative harvest constraint at different buffer levels by stock (i.e., similar to those included in the PIGKC chapter).
- Discussion of relative risk for Tier 5 stocks given implications in the AIGKC analysis of Tier 4 versus 5 in comparison to the other Tier 5 stocks.

Pribilof Island Blue King Crab Rebuilding Plan

Bob Foy and Scott Miller provided an overview of the preliminary review draft of the PIBKC rebuilding plan. **In discussing alternative 5, the CPT recommends considering analysis of different levels of PSC besides default OFL in current analysis; e.g. ABCs considered in the ACL analysis. The CPT also recommends considering modifying the alternatives to include the alternative area closures which are triggered by a range of PSC cap levels. In conjunction with ACL discussions of accountability measures, the team notes that any PSC cap would require revision of the BSAI groundfish FMP.**

Rebuilding Projections

- S-R: noted that comparison b/w random recruitment and S-R curves should include earlier years to provide better comparison; as performed, comparison confounded with difference in S-R over time; could improve potential for random recruitment specification to produce rebuilding
- if random recruitment is representative of current environmental conditions, and current B_{MSY} is unattainable, suggestion that lower B_{MSY} should be identified under this scenario

Impacts of Alternatives on Rebuilding:

- **The projected rebuilding response to changes in bycatch reductions is minimal, and projections indicate no significant difference between any of the alternatives in potential for rebuilding. Therefore the CPT notes that the only benefit of alternatives is the prevention of overfishing. The alternatives should be analyzed relative to the probability of preventing overfishing.**

Additional Recommendations:

- Request for map with stock boundaries for St. Matthew BKC in relation to those for PIBKC.
- Add B_{MSY} to population projection plots.
- Noted that negative MMB is incorrect (check model constraints);
- Show projection with recruitment/year.
- Evaluate probability of overfishing due to bycatch only over the rebuilding timeframe.
- More simulations could be run if there is a desire to reduce the jaggedness of the median projections.
- Stellar Sea Lions (SSL) closures within alternative closure areas should be noted.
- Include extent of halibut fishing activity within alternative closure areas and associated bycatch (to the extent the data is available).
- Add a comparison between PIRKC and hair crab population trends.
- Incorporate figures that break down historical distribution of population segments (size/sex).
- Summarize historical bottom temperatures.
- **Discuss the allocative implications of including bycatch in catch limitations under both ACL and rebuilding analyses; in context of PIBKC, discuss relative merits of spatial closure versus PSC, where PSC limit has potential to force broad fishery suspensions**
- Given objective of eliminating any take of blue king crab, CPT highlights importance of distributing burden of conservation on all fishery participants.
- **Consider including a trigger cap alternative (e.g., combining PSC/ACL levels with spatial closures) in the range of alternatives for analysis**
- Analysis of status quo should evaluate the impacts on relative bycatch of PIBKC of the Pribilof Islands Habitat Closure Zones (PIHCZ) closure following implementation.

Economic Impacts:

- Noted that confidential nondisclosure limitations constrain resolution and detail of reporting economic effects; e.g., aggregation of CP and CV revenues and use of 1st wholesale value

Recommendations:

- Add six year average and std dev of revenue and catch under EA alternative as summary.
- Add relative value or revenue at risk as % of total revenue of affected sectors.

New Business

The CPT approved the September 2009 minutes and discussed agenda items for the May 2010 meeting noting this meeting is in Girdwood. The Team intends to review the ACL and rebuilding analyses again at the May meeting and potentially comment on preferred alternative approaches at that time.

Objectives for CPT Review and Recommendation to the analyses by section:

This outline was provided to the team by Diana Stram prior to their review of the analyses in order to highlight potential areas for additional clarification and recommendations on the preliminary analysis of ACLs and rebuilding.

- Assessment overview
    - Is information sufficient to provide understanding of stock status and assessment?
- Uncertainty in stock assessment
    - Is uncertainty inherent in the assessment characterized correctly?
    - Is the recommendation of additional uncertainty appropriate?
    - Does the recommendation follow naturally from the listed uncertainty in the section?
- Impacts of alternatives
    - Are the direct effect impacts reasonable?
    - What should be done differently for initial draft?
    - What additional sections will be considered for initial draft?
- Additional aspects
    - Are there additional items we would like to see in initial review draft?
    - Should sub sections be unified and moved elsewhere?
    - Additional figures/tables?
    - How best to characterize results for communicating to public?

Rebuilding Plans:

- All ACL considerations, in addition
    - Are alternatives sufficient?
        - Implications
    - Are rebuilding scenarios reasonable?
        - Additional scenarios
    - Additional economic evaluations
- Rebuilding plans
    - Alternatives 2 and 3
        - Framed as target years for rebuilding to B_{MSY} with pre specified probability.
    - Options for probabilities to T_{TARGET} (fixed probabilities increasing)
    - Max rebuilding T_{END} (snow) T_{MAX} (Tanner)
- Comparison of alternatives
    - How uncertainty is considered?
    - Within assessment uncertainty
    - How is additional uncertainty characterized?

NPFMC CRAB PLAN TEAM

DRAFT AGENDA (FEBRUARY 20, 2010 VERSION) March 29-April 1st 2010

A. Crab Plan Team

	Monday March 29	**Traynor Room (all week)**
9:00	Introductions	Introductions, Additions to agenda and approval of agenda, Review and approval of September 2009 minutes, discussion of report finalization, May meeting agenda topics
9:15	Essential Fish Habitat	Review EFH designations by species and recommend changes as necessary
10:45	*Break*	
11:00	EFH Cont'	
12:00	*Lunch*	
13:00	Survey time series revisions	Review time series revisions and strata; recommend whether to use revised dataset in 2010 assessments
14:00	EBS snow crab	Review net selectivity results and model sensitivity, recommend direction for May assessment, recommend direction for 2010 survey
15:00	*Break*	
15:15	EBS snow crab	Cont'
	Tuesday March 30	
9:00	Crab ACLs and rebuilding	Review preliminary draft and recommend changes
		Review Alternatives: Chapter 2
10:00		Review methodology for ACL projections; organization of results presentation: short-term, medium-term, long-term (biological and economic)
10:45	*Break*	—
11:00		Results for BBRKC
12:00	*Lunch*	
13:00	Crab ACLs and rebuilding (cont')	Snow crab ACL and rebuilding results
15:00	*Break*	—
15:15		Tanner crab ACL and rebuilding results
	Wednesday March 31st	
9:00	Crab ACLs and rebuilding (cont')	NSRKC, PIRKC, PIBKC (ACL only),
10:45	*Break*	—
11:00		St Matthew BKC, AIGKC (Tier 4 and Tier 5 comparison)
12:00	*Lunch*	
13:00	Crab ACLs and rebuilding (cont')	Tier 5 stocks: PIGKC, Adak RKC
14:00		Comparison of results across all alternatives for ACLs
15:00	*Break*	—
15:15	PIBKC rebuilding plan	Review alternatives, impacts on rebuilding PIBKC stocks, impacts on groundfish fisheries and economic analysis
	Thursday April 1	
9:00	PIBKC rebuilding plan (cont')	Continue with review of impacts, recommendations on analysis and alternatives
10:45	*Break*	

11:00	Crab Plan Team report	Report finalization: all sections and recommendations on screen
12:00	*Lunch*	—
13:00	Crab Plan Team report (cont')	Report finalization: all sections and recommendations on screen
15:00	*Break*	—
15:15	New business	Additional topics or discussion for May or September meetings, planning for May meeting, discuss additional new business as necessary
17:00	*Adjourn*	—

Executive Summary

The king and Tanner crab fisheries in the Exclusive Economic Zone (EEZ) (3 to 200 miles offshore) of the Bering Sea and Aleutian Islands off Alaska are managed under the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs (FMP). The FMP establishes a State/Federal cooperative management regime that defers crab fisheries management to the State of Alaska (State) with Federal oversight. State regulations are subject to the provisions of the FMP, including its goals and objectives, the Magnuson-Stevens Act, and other applicable Federal laws.

There are three proposed actions contained in this analysis:

Action 1-Annual Catch Levels for BSAI Crab Stocks: The first proposed action is to establish annual catch levels (ACLs) to meet the requirements of the revised Magnuson Stevens Act. The Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 (MSRA, Public Law 109-479) includes provisions intended to prevent overfishing by requiring that FMPs establish a mechanism for specifying annual catch levels (ACLs) in the plan (including a multiyear plan), implementing regulations, or annual specifications, at a level such that overfishing does not occur in the fishery, including measures to ensure accountability (accountability measures or AMs). All crab fisheries must have ACL and AM mechanisms by the 2011/2012 crab fishing year. The MSRA includes a requirement for the SSC to recommend acceptable biological catch (ABC) levels to the Council, and provides that ACLs may not exceed the fishing levels recommended by the Science and Statistical Committee (SSC).

These ACLs are to be established based upon ABC control rules which account for the uncertainty in the overfishing limit (OFL) point estimate. To meet the ACL requirements, the ABCs for each stock will be established under the FMP such that ACL = ABC and the total allowable catches (TAC) and guideline harvest levels (GHLs) must be established sufficiently below the ABC so as not to exceed the ACL. Determinations of TACs and GHLs are Category 2 management measures and are deferred to the State following the criteria in the FMP. ABCs must be annually recommended by the NPFMC SSC.

Actions 2 and 3- Rebuilding Plans for Snow and Tanner Crab Stocks: The second proposed action is a revised rebuilding plan for the eastern Bering Sea (EBS) snow crab stock. The third proposed action is a new rebuilding plan for the EBS Tanner crab stock. The EBS snow crab stock will not rebuild by the end of the rebuilding time frame of 2009/2010, thus a revised rebuilding plan must be developed for this stock. The EBS Tanner crab is approaching an overfished condition and a rebuilding plan must be prepared.

All three of these proposed actions must be implemented prior to the start of the 2011/12 crab fishing year. These actions are considered together in this analysis as the implementation timing is identical and the actions themselves are related in the interplay between rebuilding plan catch constraints and ACL catch constraints for the EBS snow and Tanner crab stocks. For the remaining eight BSAI crab stocks for which rebuilding provisions are not considered in this analysis, only Action 1 (establishment of ACLs) applies. Additionally, Pribilof Islands blue king crab remains overfished. The current rebuilding plan has not achieved adequate progress to rebuild the stock by 2014. The Council is preparing an amended Pribilof Islands blue king crab rebuilding plan. This rebuilding plan will be analysed in a separate document because the primary rebuilding alternatives address bycatch in groundfish fisheries.

These three proposed actions are scheduled for preliminary review at the April 2010 Council meeting. As such, this analysis is preliminary in nature and will be updated to reflect considerations raised in conjunction with both the Crab Plan Team (CPT) March review and the April Council meeting. Not all sections are included in this draft and are noted with [PLACEHOLDER], as necessary. All sections will be updated for the initial review draft scheduled for review in June 2010. Final action by the Council is scheduled for October 2010.

Review of actions under consideration and overview of preliminary impacts

Action 1: Annual Catch Levels for BSAI Crab Stocks

The proposed action is to amend the FMP to specify the method by which the Council will establish annual catch limits (ACLs) to meet the requirements of the revised Magnuson-Stevens Act. These ACLs are to be established based upon an acceptable biological catch (ABC) control rule which will be set forth in the FMP and will account for the uncertainty in the overfishing limit (OFL) point estimate. To meet the ACL requirements, ABCs will be annually established under the ABC control rule and ACLs will be set such that ACL is set equal to the ABC.

Three alternatives are considered under Action 1, with multiple options under Alternative 2 and Alternative 3:

Alternative 1-Status Quo: Alternative 1 would continue the current practice of annually established OFLs for the 10 BSAI crab stocks and would not establish annual catch limits below these values. All catch levels (TACs and GHLs) for these stocks are established by the State of Alaska using the management categories outlined in the FMP. Note this alternative is considered for comparative purposes against other alternatives in this analysis but per revised federal guidelines would not meet all applicable legal requirements.

Alternative 2 and Alternative 3-Establish ACLequal to ABC: Alternative 2 and Alternative 3 address how the ABC control rule will be specified, the process by which the SSC will recommend the ABC to the Council annually, and the accountability measures that are enacted if the ACLs are annually exceeded. Two approaches are considered for the specification of the ABC control rule, a constant buffer approach and a variable buffer approach.

Alternative 2- Constant Buffer: The ACL would be set equal to the total-catch acceptable biological catch (ABC). The ABC for each stock would be set to the product of a constant pre-specified buffer less than 1 and the established OFL. Once the buffer value is selected, the ABC would be annually set below the annual OFL based on the most recent stock assessment using the fixed buffer.

Buffer values under consideration in this alternative include the following[1]:

Option 1: ABC = OFL (no buffer)
Option 2: ABC = 90% of OFL
Option 3: ABC = 80% of OFL
Option 4: ABC = 70% of OFL
Option 5: ABC = 60% of OFL
Option 6: ABC = 50% of OFL
Option 7: ABC = 40% of OFL
Option 8: ABC = 30% of OFL
Option 9: ABC = 20% of OFL
Option 10: ABC = 10% of OFL

Alternative 3- Variable Buffer: The ACL would be set equal to the total-catch acceptable biological catch (ABC). The ABC would be established based upon a pre-specified percentile of the distribution for the OFL which accounts for scientific uncertainty regarding the OFL. Here, the probability of the ABC exceeding the OFL (P(ABC>OFL)) is equal to a specified value, P*[2] ('P star').

[1] Note that other buffer values may be selected within these ranges.
[2] Further information on the background rationale and utility of P* as a reference value for risk is contained in Chapter 3 of this analysis.

A range of P* values are considered and result in stock-specific percentage buffer values that vary over time depending on the assessed extent of scientific uncertainty. Once the P* value is selected, the ABC would be annually established below the annual OFL using the buffer which corresponds to the selected P* and taking account of the annual assessed extent of scientific uncertainty. The OFL is based upon the most recent stock assessment.

P* values under consideration in this alternative include the following[3]:

Option 1:	P* = 0.5
Option 2:	P* = 0.4
Option 3:	P* = 0.3
Option 4:	P* = 0.2
Option 5:	P* = 0.1

Process for ABC recommendation: In order to modify this process to allow for the SSC to recommend the ABC on an annual basis, three options are considered:

Option 1:	SSC recommends ABC levels annually at October Council meeting (delayed TAC-setting)
Option 2:	SSC recommends ABC levels annually prior to October Council meeting (shift timing of October Council meeting)
Option 3:	SSC recommends ABC levels annually prior to October Council meeting (convene special SSC meeting prior to TAC-setting)

Accountability Measures: Accountability measures (AMs) must also be specified in the case that ACLs are annually exceeded. Additional information on AMs and proposed approachies will be contained in a subsequent draft of this analysis.

Summary of impacts of Action 1

The treatment of uncertainty is a critical aspect in this analysis. Two aspects to uncertainty are considered: assessment uncertainty and additional uncertainty. Stock-specific OFL distributions are contained in each chapter and indicate the relative uncertainty characterized within the assessment itself due, for example, to the ability of the population dynamics model to mimic the observed length-frequency and survey biomass data. As noted in each stock-specific chapter however, this characterization of uncertainty may not be sufficient to adequately capture the true uncertainty of the stock's OFL. For this reason, a qualitative section is included for each stock that outlines the additional sources of uncertainty not captured in the assessment itself, but which should still be considered when assessing the true uncertainty associated with the estimate of the OFL. The sources listed for each stock are restricted to calculation of OFL in the short-term and do not consider issues such as changes over time in productivity and habitat loss. Whether and how much additional uncertainty is included by stock has a substantial impact on the size of the resulting buffer value.

Based on results of the preliminary analysis, the stocks with the most precise estimates of within-assessment uncertainty are the following: Bristol Bay red king crab, EBS snow crab, St. Matthew blue king crab, AI golden king crab, and Tanner crab. Of these however, the OFL for St Matthew blue king crab in particular should be based on higher (assumed) levels of additional uncertainty, despite the low uncertainty associated with the estimate of the OFL from the assessment itself. It is not possible to estimate the extent of uncertainty associated the OFL for Tier 5 stocks in a manner similar to stocks in Tiers 1-4 due to lack of reliable biomass estimates. Thus a different characterization of uncertainty was employed for Tier 5 stocks.

[3] Note that other P* values may be selected within these ranges.

Additional uncertainty (i.e., in addition to the estimated 'within assessment' uncertainty described above) is included by conducting analyses for range of constants that represent different levels of additional uncertainty, from 0.0 (no additional uncertainty), to 0.2 and 0.4. For all stocks, it is recommended that some additional uncertainty should be allowed for computing ABCs. A value must thus be recommended for each stock. It is recommended that unless a different value is recommended by the CPT and endorsed by the SSC, the additional uncertainty should be set to 0.2 for Bristol Bay red king crab and EBS snow crab and to 0.4 for EBS Tanner crab, St. Matthew blue king crab, Pribilof Islands blue king crab, Pribilof Islands red king crab, and Norton Sound red king crab. Note that the impacts of accounting for these levels of additional uncertainty compared with only employing the buffer resulting from the within-assessment variability can be substantial.

Directed Harvest Constraint (Short-term)

Results in each chapter of this analysis (Chapters 4-12) summarize the impact of a range of ACL buffer values on the short-term harvest, i.e. whether the ABC control rule at different buffer values would constrain the State harvest strategy for that stock. Here the State harvest strategy is used to approximate the TAC level in future years.

For Bristol Bay red king crab, the retained component of the catch based on the state harvest strategy would be constrained at buffer levels below 0.9 (i.e., a 10% buffer, or ABC established at 90% of the OFL). For Pribilof red king crab, any buffer (i.e., even at a 0% buffer or ABC established at the OFL) would constrain the State harvest strategy (note that the State harvest strategy has not been employed for this stock since 1993 due to concerns with the potential for bycatch of the Pribilof blue king crab stock in a directed Pribilof Island red king crab fishery and stock fluctuations within the Pribilof Island red king crab stock). All directed catch remains at zero for Pribilof blue king crab stock so there is no short-term impact of any buffer size on the directed catch component of the ABC for this stock. For St. Matthew blue king crab, the retained catch component would be constrained at all buffer levels for the ABC. For Norton Sound red king crab, only buffer levels below 0.5 would constrain the current harvest strategy estimate. For AI golden king crab, only buffers below 0.1 would constrain the retained catch component of an ABC for this stock. For Pribilof Island golden king crab, buffer values below 0.8 would constrain the estimated GHL (based on the 2010 GHL amount). The western Aleutian Islands (WAI) red king crab stock is currently closed at this time thus buffer values considered do not impact the directed catch for this stock at this time.

Probability of Overfishing

More constraining buffers (or lower values for P*) decrease the probability that stocks will become overfished in the future. This is shown quantitatively for those stocks for which biomass estimates and projections of stock status are possible. This is highly dependant however upon individual stock status and recruitment assumptions inherent to these models. Additional information by stock should be considered in evaluating long-term implications of these ACL alternatives.

Actions 2 and 3: Rebuilding Plans for Snow Crab and Tanner Crab Stocks

Action 2: Revised Rebuilding Plan For Snow Crab Stock

The purpose of this proposed action is to prepare and implement an amended plan to rebuild the snow crab stock. Several alternatives are considered under Action 2, which are framed in terms of the time frames necessary to rebuild the stock.

Alternative 1: No Action

This is the no action alternative. This alternative would be future management under which ever alternative is selected under Action 1.

Alternative 2: Set target rebuilding time frame (T_{target}) based on the minimum number of years necessary to rebuild the stock.

This alternative would set T_{target} based on minimum number of years necessary to rebuild the stock, under the current assessment of the snow crab stock, if all sources of fishing-related mortality are set to zero.

Alternative 3 to Alternative 8: Set T_{target} above the minimum number of years (between 1 above the minimum and T_{end}).

Alternative 3:	3 years to rebuild
Alternative 4:	4 years to rebuild
Alternative 5:	5 years to rebuild
Alternative 6:	6 years to rebuild
Alternative 7:	7 years to rebuild
Alternative 8:	8 years to rebuild (T_{end})

In addition to these alternatives, options are considered that would increase the probability of rebuilding by the agreed T_{target}. Increasing probability of rebuilding for a given T_{target} is achieved through directed fishery harvest constraints.

Action 3: Rebuilding Plan for EBS Tanner Crab Stock

The purpose of this proposed action is to prepare and implement a plan to prevent overfishing of Tanner crab. Tanner crab is approaching a condition of being overfished and this action is necessary to meet the requirements under section 304(e) of the Magnuson-Stevens Act: to prevent overfishing in the fishery, if possible, and, if necessary, to rebuild the stock in as short a time as possible while accounting for the needs of fishing communities and the status and biology of the Tanner crab and snow crab stocks.

Alternative 1: No Action

This is the no action alternative. This alternative would be future management under which ever alternative is selected under Action 1.

Alternative 2: Set target rebuilding time frame (T_{target}) based on the minimum number of years necessary to rebuild the stock.

This alternative would set T_{target} based on minimum number of years necessary to rebuild the stock, under the current assessment of the Tanner crab stock, if all sources of fishing-related mortality are set to zero.

Alternative 3 to Alternative [#TBD]: Set T_{target} above the minimum number of years (between 1 above the minimum and T_{max}).

Here the alternatives are framed similarly to the snow crab alternatives under Action 2 where alternatives increase the rebuilding times in one-year increments from the T_{min} estimate to the T_{max} estimate.

In addition to these alternatives, options are considered that would increase the probability of rebuilding by the agreed T_{target}.

Summary of impacts of Actions 2 and 3

ACLs and rebuilding strategies are considered simultaneously for EBS snow and Tanner crab stocks. For these stocks, the probability of rebuilding under different buffer values was estimated.

For EBS snow crab, consideration is also given to different ways to estimate the survey selectivity curve and maximum selectivity, Q. The upper limit of the buffer examined for rebuilding was 0.75 as prescribed by the National Standard Guidelines 1 for stocks that have failed to rebuild at the end of a rebuilding plan. Note this is an interim measure until a revised harvest strategy under the rebuilding plan is adopted or when the stock is rebuilt. For snow crab, the earliest year the stock would achieve a 50% probability of rebuilding under F=0.0 is estimated to be 2014/15, while the latest year the stock would be considered rebuilt is 2019/20 fishing at the maximum permissible $F=0.75F_{OFL}$.

For EBS Tanner crab, the earliest year the stock would achieve a 50% probability of rebuilding under F=0.0 is estimated to be 2021/2022. This is equivalent to ten years from the start of the rebuilding plan in 2011/12 if fishing mortality is set to zero in the directed and non-directed fisheries. Longer-term scenarios indicate that rebuilding would occur with varying probabilities with ranges of catch levels included. Further model scenarios will be provided for initial review that may modify this estimate for the minimum rebuilding time frame.

The selection of rebuilding strategies for snow crab and Tanner crab must be done in concert. Decisions regarding the harvest of snow crab invariably affect the Tanner crab rebuilding probability due to the bycatch of Tanner crab in the directed snow crab fishery. A comparison of the rebuilding probabilities for Tanner crab based upon the range of alternatives considered for the snow crab rebuilding plan will be provided for the initial review draft.

Additional information on direct and indirect economic impacts of all three actions as well as consideration of impacts on other resource categories and cumulative effects will be contained in the initial review draft.

PRIBILOF ISLANDS STEWARDSHIP PROGRAM
P.O. BOX 938
ST. GEORGE ISLAND, AK 99591
907-859-2257

Date: **29 March 2010**

To: **North Pacific Fishery Management Council**
605 West 4th, Suite 306,
Anchorage, Alaska 99501-2252

Re: **NPFMC April 2010**
Agenda Item D-4 (b) HAPC Criteria and Priorities; D-4 (a) EFH 5-year Review; D-1 (b) Preliminary Review of Pribilof BKC rebuilding plan

Dear Council Members:

I would first like to reiterate what I stated in my last letter (12 February 2010) regarding the HAPC Criteria and EFH. Comments on Pribilof King Crab Rebuilding are also included from a habitat protection perspective.

Agenda Item D-4 (b) HAPC Criteria and Priorities
Distracting potentially meaningful discussions on canyons over semantics and questions such as "are they rare"? or, "are they unique" has stymied action for over a decade. **One glance at a chart of Alaska or of the entire planet will affirm that canyons are RARE. And, if industrial fishing, marine mammal foraging and seabird foraging are independently or jointly considered a proxy for "uniquely productive", the Bering Sea shelf edge canyons certainly stand out: they are UNIQUE. Canyons and the gyres they generate are targeted by all of these predators every year.**

Shelf edge submarine canyons are well-documented sites of enhanced biomass due to their unique shape and connections from deep to shallow environments, with unique ocean current mechanisms that lead to the concentration of prey items like krill. Canyons on the Bering Sea shelf edge seem to serve as conduits for funneling deep oceanic forage species like myctophids and large copepods onto the shelf environment. Recognizing the uniquely productive properties of canyons, many countries globally and many states nationally have protected undersea canyons from fishing and non-fishing threats. Despite over ten years of testimony, proposals and recommendations by the Plan Teams, SSC, and the public; you - the Council have avoided taking action to fully analyze canyons under the directives of EFH or HAPC (see Council EFH committee and other records 1999 – present).

Delays in identifying acceptable "criteria" for meeting the EFH mandates in the MSFCA has likely had irreversible repercussions to canyon habitats. How many more trawls have eviscerated canyon water column and seabed depths in the decade over which the NPFMC has contemplated alternate management measures for canyons? Meanwhile, by-catch has skyrocketed, Pollock has plummeted and declines in seabirds, fur seals and sea lions at the Pribilof Islands continue at an alarming rate. Both the physical modeling of ocean currents, information on movement of plankton, foraging routes of mammals and birds and other data document that connections to the canyon are essential for the well-being of the Pribilof shallow water complexes. Severing this linkage through allowing continued high-intensity trawling and other industrial fishing on the shelf edge between the canyon and adjacent shallows is not unlike severing the umbilical connection from fertile canyon depths to shallow nourishing waters surrounding the Pribilof Island nesting, pupping habitats, and juvenile crab nurseries.

Rather than leave canyons strictly to a HAPC long term discussion, it may be more prudent to consider an FMP level EFH amendment to analyze whether ALL canyons, like ALL seamounts in the past, merit special consideration for protection from fishing and other threats. I propose that the NPFMC undertake analysis of an FMP-level amendment addressing all canyons in the Alaskan EEZ immediately.

The well documented skate nurseries identified by NOAA and other researchers harbor many species of these long-lived elasmobranchs, including adults, baby skates and extensive egg case deposition areas. Work at the Alaska Sea Life Center has documented that some species require at least three years just for embryonic development! How many egg cases have been disturbed or redistributed to less favorable habitats during these years of posturing at the Council?

I agree with the SSC requests that "the footnoted definition of habitat that accompanies the revised criteria be extended to include the water column as well as the seafloor substrate." I also agree with the SSC's comment, from the February meeting, about the importance of "research to improve our understanding of EFH for squid and for forage fish." Forage fish and squid, a major forage species, play a major ecological role in the Bering Sea ecosystem as primary "currency" for the transfer of energy from secondary producers to marine mammals and seabirds. Although EFH was identified for these species groups, no explicit management or mitigation measure has been undertaken to minimize effects of fishing or other activity on this critical suite of organisms.

RECOMMENDATIONS

1. Include data on species assemblages in forage fish category and squid category – it may be more appropriate to include EFH information on the emerging "Ecosystem Category" species being contemplated. Indicate what FMP and non-FMP species in the GOA-BSAI consume those forage species. Characterize trophic position as best possible to clarify role in foodweb. Provide species-specific distributional maps – whether complete or incomplete.
2. Provide full profile by species by fine scale area by fishery showing what forage and squid species are harvested incidentally as by-catch.

3. Identify multi-species forage fish and squid "hotspots" based on distribution and by-catch data.
4. Craft an FMP amendment package advancing measures which protect forage species in hotspots from seabed to sea surface from effects of fishing and non-fishing activities.
5. Immediately craft an FMP-level amendment addressing ALL canyons in the Alaskan EEZ as HAPC and consider appropriate measures to mitigate the impacts of fishing on canyon habitats.

D-4 (a) EFH 5-year Review
Human Humility and Responsibility

Despite some efforts to map EFH and protect some features in the EEZ, it is imperative that we recognize that Alaska is but one region within the global ocean – with an ecosystem in a fluid, multidimensional realm flowing over a tapestry of physical seabed features. It is even more complex than the terrestrial environment – where many early efforts to "protect" large predators and other creatures from extinction involved establishing small parks and refuges that comprised only a tiny fraction of the animals' home ranges. Isolating sections of habitat from the connectivity among species and adjacent habitats led rapidly to the demise of most of the very species (Tigers, gorillas, pandas, etc) people sought to protect. The degree of habitat fragmentation and ecosystem unraveling that has occurred in terrestrial environment is now taking place in aquatic systems globally. I would therefore urge the Council to consider that:

- EFH includes physical locations important to FMP species and their prey – even if the organisms do not occupy the benthos for their entire life history.
- Both motile species and their prey depend upon more than the physical seabed under laying their distribution – they are connected to the system in which they live through benthic-pelagic coupling processes, vertical movement of species within the water column, and species interrelationships we may not yet fully understand.
- Marine spatial management measures considered under EFH and HAPC should acknowledge the full definitions with the MSFCMA and provide adequate spatial buffers around physical habitats and the associated water column to better provide for comprehensive protection of the ecological functions those habitats provide for FMP species and their prey.

RECOMMENDATIONS

1. Dedicate staff time and request research assistance from NOAA to address items #1 and #2 on the "Immediate Concerns" Habitat list beginning on page 69 of the EFH 5-year review as soon as possible:
    a. Evaluate habitats of particular concern:
        i. Assess whether Bering Sea canyons are habitats of particular concern, by assessing the distribution and prevalence of coral and sponge habitat, and comparing marine communities within and above the canyon areas, including mid-level and apex predators

(such as, short-tailed albatrosses) to neighboring shelf/slope ecosystems.

ii. Assess the extent, distribution, and abundance of important skate nursery areas in the EBS, to evaluate the need for designation of new HAPCs.

2. Dedicate staff time to address items listed in section II: Habitat Mapping and (research on) ecological function.
3. Initiate an FMP level amendment addressing ALL canyons in the Alaskan EEZ as multispecies EFH and consider appropriate measures to mitigate the impacts of fishing on canyon habitats.

D-1 (b) Preliminary Review of Pribilof BKC rebuilding plan: habitat considerations
The Pribilof Island Habitat Conservation Area (PIHCA) is considered by many a *de facto* EFH protection measure, and is often referred to as such by NOAA and NPFMC staff. Effectiveness of this measure in meeting the goals for which it was established should be analyzed. If the area and the fishing restrictions within the PIHCA were designed using the best available science to protect king crab and other species, **it appears as the "best" science isn't good enough**. Could it be that protecting only the shelf without protecting the corridor connecting it to the deep sea that feeds it is in fact contributing to habitat fragmentation without achieving alleged goals of the action? In the case of king crab, for example, there has been no detectable recovery of Pribilof blue king crab and no significant increase in red king crab in the PIHCA since established in 1995. And now, we realize that this region is important for struggling opilio species as well.

The 2007 submarine documentation showing juvenile king crab in Pribilof Canyon, plus bycatch information, pot surveys and trawl surveys provide ample evidence that adult and juvenile crab are distributed on the shelf and in deep canyon waters, and likely migrate to and from the Canyon depths to the shelf shallows. If the PIHCA included the shelf break and Canyon as was originally proposed, we may have seen a rebuilding of the BKC stock by now. **Bounds of the PIHCA should be reconsidered for both crab and other species habitat protection. In the mean time, we request that NOAA-NMFS and ADFG crab co-managers immediately consider reducing the footprint of government TRAWL SURVEYS in the PIHCA, at least in the nearshore regions important for juvenile crab.**

Since 2004 the St. George Traditional Council has been requesting for the Council and NMFS, with whom they co-manage northern fur seals and Steller sea lions, "that the 20 nautical protected zone around St. George Island haul-outs be reinstated so that it is comparable to other Alaskan haul-out sites used by similar numbers of Steller sea lions." In the January 2010 draft minutes from the Steller Sea Lion Mitigation Committee Meeting on page 3 it is reported: "At Dalnoi Point on St. George (EBS), scat samples collected in June 2009 found 80% frequency of occurrence of Pollock, all >40 cm in length (commercial size). This is just further evidence of the importance of extending the PIHCA to include the self-break south of St. George and to include the Pribilof Canyon to protect the forage base for Steller sea lions, as well as fur seals, birds and other species.

Pribilof Islands Habitat Conservation Zone

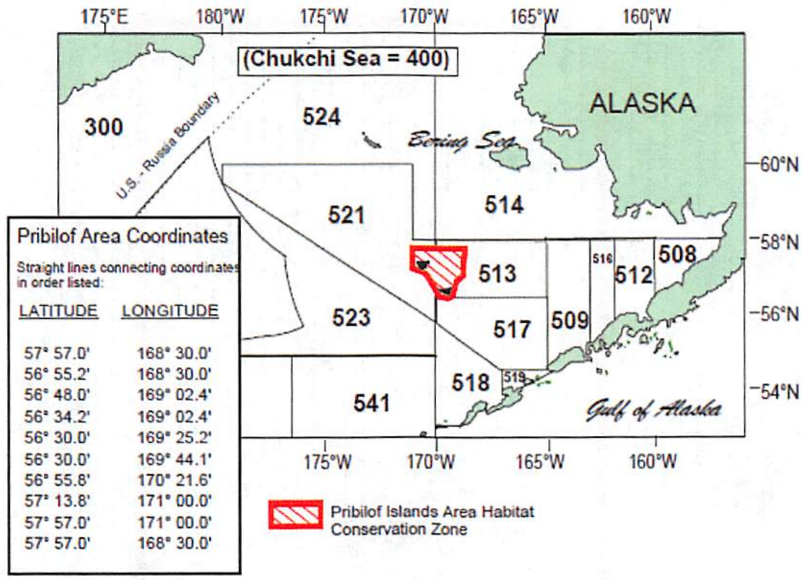
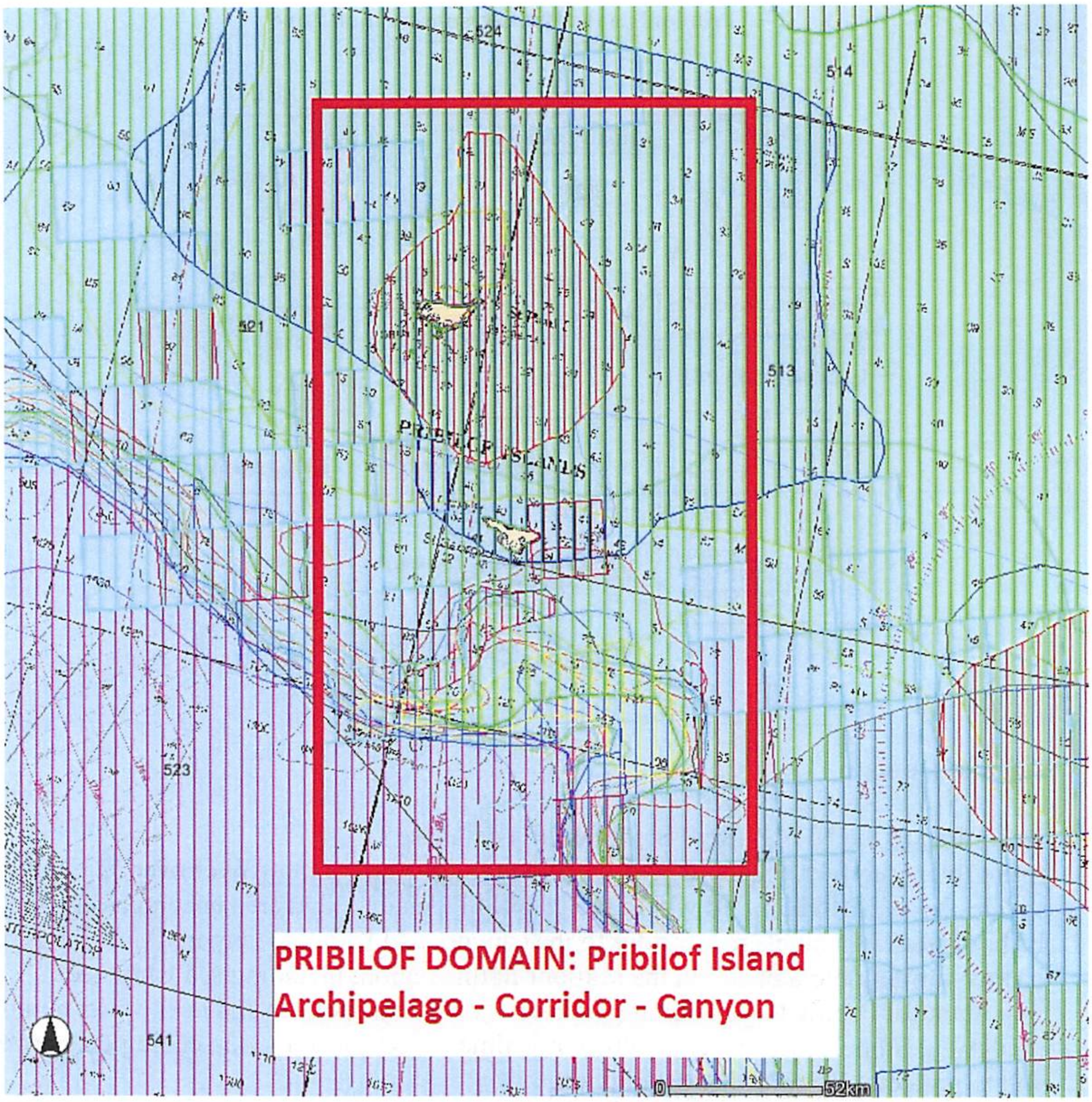


Figure 10 to Part 679. Pribilof Islands Area Habitat Conservation Zone in the Bering Sea

Pribilof Domain

According to the NOAA-NMFS online EFH database (http://mapping.fakr.noaa.gov/Website/EFH/viewer.htm?simple) over over 32 FMP species have EFH identified within the Pribilof Domain ... that area encompassing the Pribilof Island archipelago, corridor to the canyon, and Pribilof Canyon. Many important habitat-forming biota occur on the seafloor in this region, including sea whip beds important for Pacific Ocean Perch (Brodeur et al 1997), sponges and deep water corals (Ridgway, Stone, Hocevar, et al 2007). It is time to recognize it as an ecological corridor and to protect it from further destruction.



This map shows EH layers for over 32 FMP species as designated by NMFS.

RECOMMENDATION

1. Provide analysis of PIHCA efficacy in meeting its purpose for establishment – using EFH criteria for mitigation measures may be appropriate since it is in EFH and considered an EFH protection measure. Is it working? If not meeting objectives, consider requesting staff to develop an EFH amendment which addresses forage fish and extending the PIHCA to encompass the shelf edge off St. George island and Pribilof Canyon – thereby reconnecting an ecological corridor which will likely provide more comprehensive protection from the habitats and species associated with the Pribilof Island region.

Thank you for your consideration of my comments. Best wishes in your endeavor to mitigate human impacts to our marine habitat.

Sincerely,

Karin Holser
Pribilof Islands Stewardship Program

cc. Dr. Anne Hollowed, NOAA-NMFS, NPFMC SSC
Dr. Douglas Demaster, Director, Alaska Fisheries Science Center
Dr. James Balsiger, Alaska Regional Administrator, NOAA-NMFS
Dr. Jane Lubchenco, Under Secretary of Commerce for Oceans and Atmosphere
Pat Montanio, Director, NOAA Habitat Division
Dr. Eric Schwaab, Assistant Administrator for Fisheries, NOAA
Matthew Eagleton, NOAA-NMFS Habitat Division, Alaska Region
Dr. Joe Uravitch, Executive Director, Marine Protected Areas FAC
Dr. Thomas Hourigan, Deep Sea Corals Program, NMFS
Kaya Brix, NOAA-NMFS, Director, Protected Resources Division
Phil Zavadil, St. Paul Eco-System Conservation Office
Chris Merculief, President, St. George Traditional Council

4/10

PUBLIC TESTIMONY SIGN-UP SHEET

Agenda Item: D-1(a) BSAI Crab ACL/Snow-Tanner Rebldg. Plans

	NAME *(PLEASE PRINT)*	TESTIFYING ON BEHALF OF:
~~1~~	Edward Poulsen	ICEPAC
~~2~~	Leonard Herzog	Bering Sea Research Foundation
~~3~~	Arni Thomson	A. C. C.
~~4~~	Frank Kelty	City of UnAlaska
5	Linda Kozak	Crab Group
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NOTE to persons providing oral or written testimony to the Council: Section 307(1)(I) of the Magnuson-Stevens Fishery Conservation and Management Act prohibits any person " to knowingly and willfully submit to a Council, the Secretary, or the Governor of a State false information (including, but not limited to, false information regarding the capacity and extent to which a United State fish processor, on an annual basis, will process a portion of the optimum yield of a fishery that will be harvested by fishing vessels of the United States) regarding any matter that the Council, Secretary, or Governor is considering in the course of carrying out this Act.

Jenny Hertzog

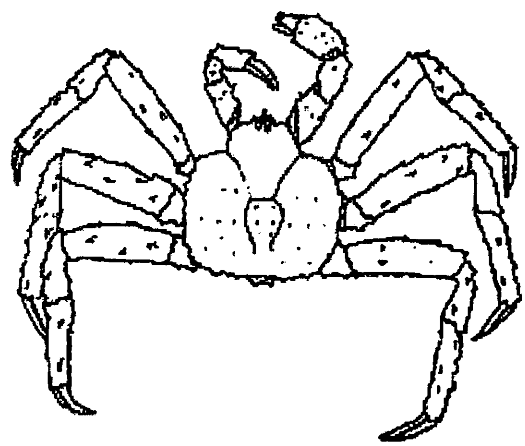
AGENDA Item D-1(a)
APRIL 2010

Preliminary Review Draft

ENVIRONMENTAL ASSESSMENT
for three proposed amendments

TO THE FISHERY MANAGEMENT PLAN FOR THE BERING SEA AND ALEUTIAN ISLANDS KING AND TANNER CRABS

to comply with Annual Catch Limit requirements; to revise the rebuilding plan for EBS snow crab; and to prepare a rebuilding plan for Tanner crab.



Abstract: This environmental assessment analyses three actions to amend the BSAI Crab FMP. Action 1: to amend the FMP to specify the method by which the Council will establish annual catch limits (ACLs) to meet the requirements of the revised Magnuson-Stevens Act. These ACLs are to be established based upon an acceptable biological catch (ABC) control rule which will be set forth in the FMP and will account for the uncertainty in the overfishing limit (OFL) point estimate. Two alternative means of establishing the ABC control rule are considered: 1) a constant buffer approach where the ABC for each stock would be set by application of a constant pre-specified buffer value below the OFL; and 2) a variable buffer approach where the ABC would be established based upon a pre-specified percentile of the distribution for the OFL which accounts for scientific uncertainty regarding the OFL. A range of constant buffers and probabilities are considered under each alternative approach. Action 2: to prepare and implement an amended plan to rebuild the snow crab stock in compliance with section 304(e)(3) of the Magnuson-Stevens Act. A range of alternative time frames are considered for rebuilding the stock. Action 3: to prepare and implement a plan to prevent overfishing of Tanner crab in compliance with section 304(e)(3) of the Magnuson-Stevens Act. A range of alternative time frames are considered for rebuilding the stock. The impacts of the alternatives considered under all three actions upon crab resources, fishery participants, habitat, marine mammals, and other groundfish resources are discussed in the analysis.

For further information contact:
Diana Stram
North Pacific Fishery Management Council
605 West 4th Ave, Anchorage, AK 99501
(907) 271-2809

March 2010

Table 4-11 Survey selectivity fixed at Somerton curve model rebuilding with adfg strategy and buffer. $B_{35\%}$ = 160 (1000t).

(a) Additional uncertainty = 0.2(buffer = 0.75)

Year	ABC_{tot} ('000t)	C_{dir} ('000t)	MMB (1000t)	Prob Rebuilding(2 yrs)	Prob (overfishing)	Prob Overfished	Catch Revenue ($ million)		
2009	24.27(24.22,24.33)	21.79(21.79,21.79)	238.0(201.9,274.5)	1	0	0	125.54 (78.18-169.03)	125.54 (78.18-169.03)	125.54 (78.18-169.03)
2010	27.88(14.32,57.93)	25.26(12.82,52.75)	240(199.8,279.1)	1	0.001	0	192.21 (84.87-429.42)	187.16 (82.64-418.13)	179.64 (79.32-401.33)
2011	27.32(13.14,54.79)	24.81(11.77,50.24)	237.7(198.5,276.9)	1	0.002	0	207.55 (86.55-466.22)	196.78 (82.06-442.03)	181.28 (75.59-407.21)
2012	27.45(13.49,59.26)	23.80(11.62,51.32)	245.5(206,288.6)	1	0.001	0	187.61 (73.98-445.41)	173.2 (68.3-411.19)	153.15 (60.39-363.59)
2013	38.96(18.22,89.7)	33.82(15.68,78.2)	293.5(237.2.364.9)	1	0.012	0	228.97 (73.67-557.7)	205.82 (66.22-501.33)	174.68 (56.2-425.47)
2014	51.03(22.19,124.9)	45.71(19.47,110.4)	336.3(261.8,465.5)	1	0.018	0	240.13 (56.77-721.69)	210.18 (49.69-631.69)	171.21 (40.47-514.56)
2015	54.22(20.58,154)	49.43(18.52,136.8)	341.3(243,541.1)	1	0.019	0	213.55 (24.92-742.51)	182 (21.23-632.82)	142.29 (16.6-494.77)
2016	52.1(18.21,167.3)	47.04(16.38,147.7)	339.8(225.2,566.1)	1	0.02	0	236.47 (27.72-933.53)	196.24 (23.01-774.7)	147.26 (17.26-581.35)
2017	49.75(16.93,161.9)	44.71(15.05,146.1)	341.2(207.9,567.3)	1	0.015	0	287.52 (57.31-1012.43)	232.33 (46.31-818.09)	167.34 (33.36-589.24)
2018	49.91(16.11,167.9)	44.99(14.34,149.1)	341.1(196.8,593.6)	1	0.027	0	328.82 (78.37-1252.72)	258.72 (61.66-985.64)	178.86 (42.63-681.39)
2019	52.04(16.38,160.1)	46.56(14.45,141.2)	342.1(194.7,611)	1	0.018	0	355.31 (75.06-1212.24)	272.21 (57.5-928.72)	180.62 (38.16-616.24)
2020	48.35(14.88,174)	42.94(13.32,154.6)	338.8(192.0,609.2)	1	0.019	0	314.44 (66.68-1275.25)	234.57 (49.74-951.31)	149.39 (31.68-605.86)
2021	52.21(15.09,169.0)	46.93(13.24,148.2)	334.9(190.3,620.4)	1	0.013	0	271.84 (36.31-1080.08)	197.45 (26.37-784.53)	120.7 (16.12-479.57)
2022	50.13(15.36,169.1)	44.25(13.56,150.3)	335.0(193.1,634.7)	1	0.01	0	214.99 (13.31-953.89)	152.06 (9.41-674.66)	89.21 (5.52-395.83)
2023	51.48(15.61,183.7)	45.48(13.71,160.3)	340.9(196.7,630.9)	1	0.02	0	220.79 (7.47-1073.42)	152.06 (5.14-739.24)	85.63 (2.9-416.29)

April 11, 2010

D-1(a) Crab ACL Analysis and BSAI snow and Tanner crab rebuilding

The Council directs staff to incorporate SSC and Plan Team recommendations as well as the following comments in preparing the analysis for initial review.

The Council supports the SSC and AP recommendations on the draft snow crab rebuilding plan and proposed ABC control rules that would be used to annually establish crab ACLs.

Despite this support, the Council has the following concerns: should avoid inc. of multiple cons. buffers

- ~~Precautionary assumptions may already be incorporated into~~ the annual stock assessment and OFL specification process. ~~To prevent excessive layering of precautionary buffers~~ the Council believes ~~that conservative assumptions in stock assessment models must be reevaluated and~~ that the appropriate venue for consideration of precautionary measures is in recommendation of ABC by the Crab Plan Team and SSC and in TAC setting conducted by the State of Alaska.

- The Council would like to have a clearer understanding of the National Standard 1 guideline requirements to inform selection of a preliminary preferred alternative. For example, would a range for additional uncertainty of 0.1-0.3 rather than 0.2-0.6 satisfy requirements?

- Moving the timing of ABC recommendation to June as described in the SSC and AP minutes under a new Option 4 would not allow for use of survey data from the most recent year. This may be an unnecessary risk given the sometimes dramatic inter-annual fluctuations in abundance experienced by some crab stocks.

- Accountability Measures are a means of addressing crab bycatch in fisheries contributing to crab mortality. The Council should begin to develop crab bycatch management measures including PSC limits for each crab species. It is the Council's intent that PSC limits be analyzed to identify the groundfish fishery sectors contributing to crab bycatch and quantify their relative contribution to total crab bycatch mortality. The Council believes that Accountability Measures should establish a linkage between the crab and groundfish FMPs to equitably spread the burden of crab bycatch mortality amongst all fishery participants.

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PUBLIC TESTIMONY SIGN-UP SHEET

Agenda Item: D-1(b) Pribilof BKC Rebldg. Plan

	NAME *(PLEASE PRINT)*	TESTIFYING ON BEHALF OF:
1	Arni Thomson	A.C.C
2	Smadsen	APA
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