Pribilof Islands Red King Crab
CPT comments May 2017

The CPT recommended that the author continue to develop the random effects model and consider the following for models at the September CPT:

1. Better describe the exponential smoother methods and bring forward one model with the exponential model result as a prior and one model with the process error based on the exponential model fixed.

Included are 3 runs of the random effects model: 1) fixed process error at simple exponential model value, 2) with cv of 2.2 in the prior and 3) cv of 4.0 in the prior.

2. Status quo 3-year running average.

Included.

3. Consider fitting to the female biomass to determine if assessing the effects of single sex high biomass tows are informative for determining the observed error relative to process error.

The random effects model did not converge using female biomass. The simple exponential model was fit to female biomass to compare the estimate of process error to fitting male biomass.

4. Consider fitting spatial models (e.g., Thorson et al. 2015) to the survey data that may better account for zero tows and high biomass tows.

Not done.

SSC comments June 2017

There were no comments specific to the Pribilof red king crab assessment by the SSC in June 2017.

Summary of Major Changes:

- Management: None.
- Input data: Survey (2017) and bycatch (2016/17) data were incorporated into the assessment.
- Assessment methodology: The 3-year running average and random effects models only are presented in this assessment.
- Assessment results: Male biomass estimates from the 3-year running average and a random effects model were fit to survey male biomass >=120mm with process error fixed at the value estimated from a simple exponential model and with a prior with mean equal to the process error estimated from the simple exponential model and with cv=2.24 and cv=4.0. Tier 4 control rules are used to estimate MMB at mating, OFL and ABC for the four models.

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch	OFL	ABC
2011/12	2,571	2,775	0	0	5.4	393	307
2012/13	2,609	4,025	0	0	13.1	569	455
2013/14	2,582	4,679	0	0	2.25	903	718
2014/15	2,871	8,894	0	0	1.76	1,359	1,019
2015/16	2,756	9,062	0	0	0.32	2,119	1,467
2016/17	2,751		0	0	0.49	1,492	1,096

A 3 year running average of male biomass (>=120mm) at survey time was calculated using the weighted average with weights being the inverse of the variance,

$$BWRA_t = \frac{\sum_{t-1}^{t+1} \frac{MMB_t}{w_t}}{\sum_{t-1}^{t+1} \frac{1}{w_t}}$$

- **Where,**
-
- MMB_t Estimated male biomass (>=120mm) from the survey data
- w_t The weight associated with the estimate of MMB in year t
-
- w_t is calculated as the variance of the log(biomass) using the CVs of the estimates of MMB from the survey provided by the Kodiak lab:
-
- $w_t = \ln((CV_t^{MMB})^2 + 1)$
-
- CV_t^{MMB} Coefficient of variation associated with the estimate of MMB at time t

Likelihood equation for Random Effects Model

- $\sum_{i=1}^{yrs}\left\{0.5\left(\log\left(2\pi\sigma_i^2\right)+\left(\frac{(\hat{B}_i-B_i)^2}{\sigma_i^2}\right)\right)\right\}+\sum_{t=2}^{yrs}\left\{0.5\left(\log\left(2\pi\sigma_p^2\right)+\left(\frac{(\hat{B}_t-\hat{B}_{t-1})^2}{\sigma_p^2}\right)\right)\right\}$
- Where,
- B_i is the log of observed biomass in year i,
- $\widehat{B_i}$ is the model estimated log biomass in year t,
- σ_i^2 is the variance of observed log biomass in year i,
- σ_p^2 is the variance of the deviations in log survey biomass between years (i.e. process error variance), σ_p^2 was estimated as $e^{(2\lambda)}$, where λ is a parameter estimated in the random effects model and,
- Yrs is the number of years of survey biomass values.

A simple exponential model can be used to estimate the ratio of observation error to process error in a time series,

- $\hat{z}_t = \alpha y_t + \alpha(1-\alpha)y_{t-1} + \alpha(1-\alpha)^2 y_{t-2} + \alpha(1-\alpha)^3 y_{t-3} + \cdots$,
- Where,
- $\hat{z}_0$ is set equal to y_0, the log of observed biomass in the first year,
- y_t is the log of observed biomass in year t and,
- α is the parameter estimated in the model which ranges from 0 to 1.

An estimate of the ratio of observation error (σ_o^2) to process error (σ_p^2) (log scale) is,

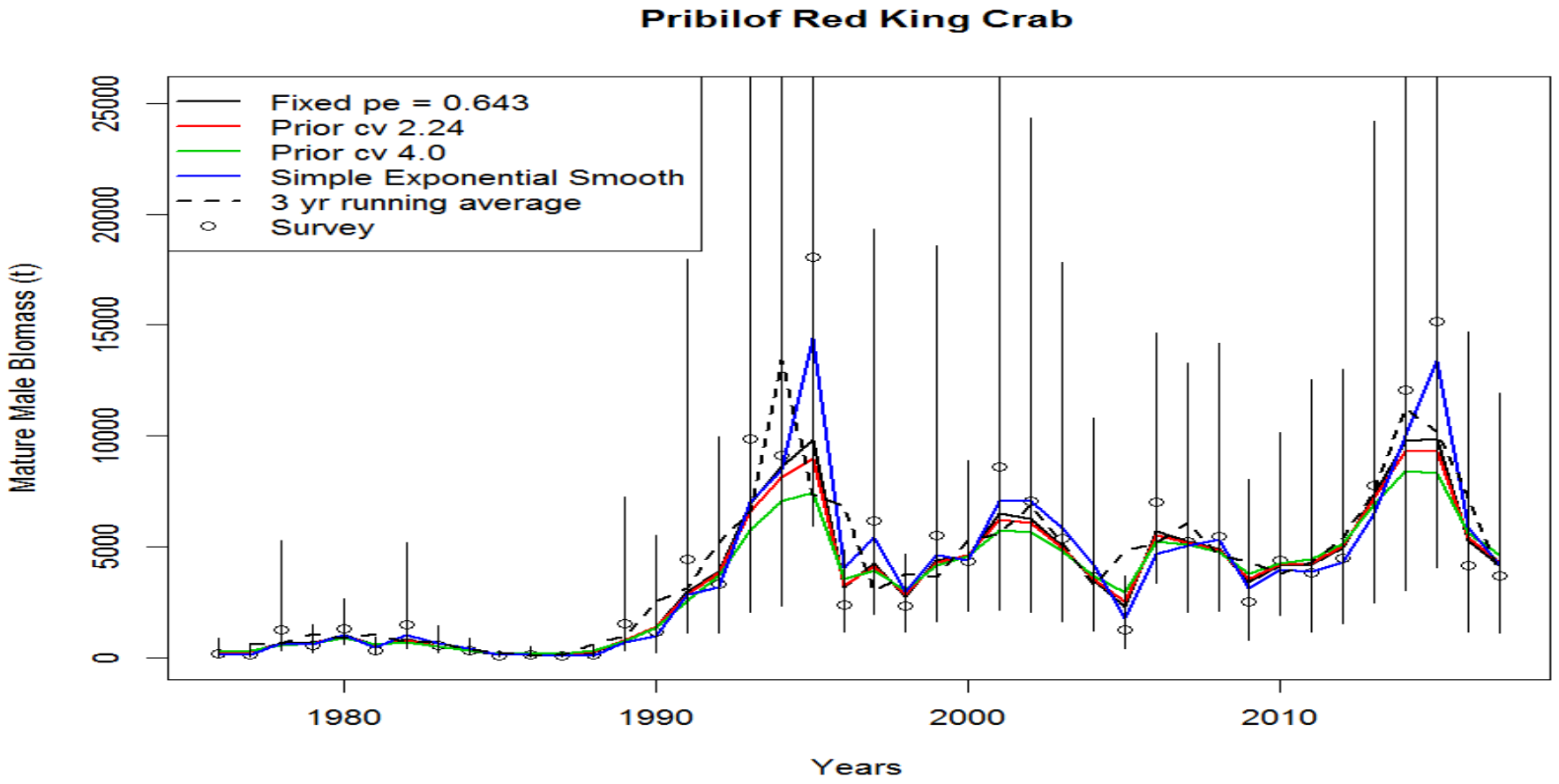
- $\frac{\sigma_o^2}{\sigma_p^2} = \frac{(1-\alpha)}{\alpha^2}$
- .
- Observation error was estimated as the mean over all years of the variances on the log scale of observed biomass. An estimate of λ to use as a prior in the random effects model is,
- $\lambda = 0.5 \log(\sigma_p^2)$
- The variance of α is an output of the arima function in R which was used to fit the simple exponential model. A bootstrap using the logit distribution on α was used to approximate the variance of λ for use in the prior that is added to the likelihood in the random effects model,
- $0.5 \frac{(\lambda-\lambda_p)^2}{\sigma_\lambda^2}$
-
- Where,
- λ_p is the prior estimate of λ from the simple exponential model
- σ_λ^2 is the variance of λ_p estimated from the parametric bootstrap.

Random Effects Model estimated process error

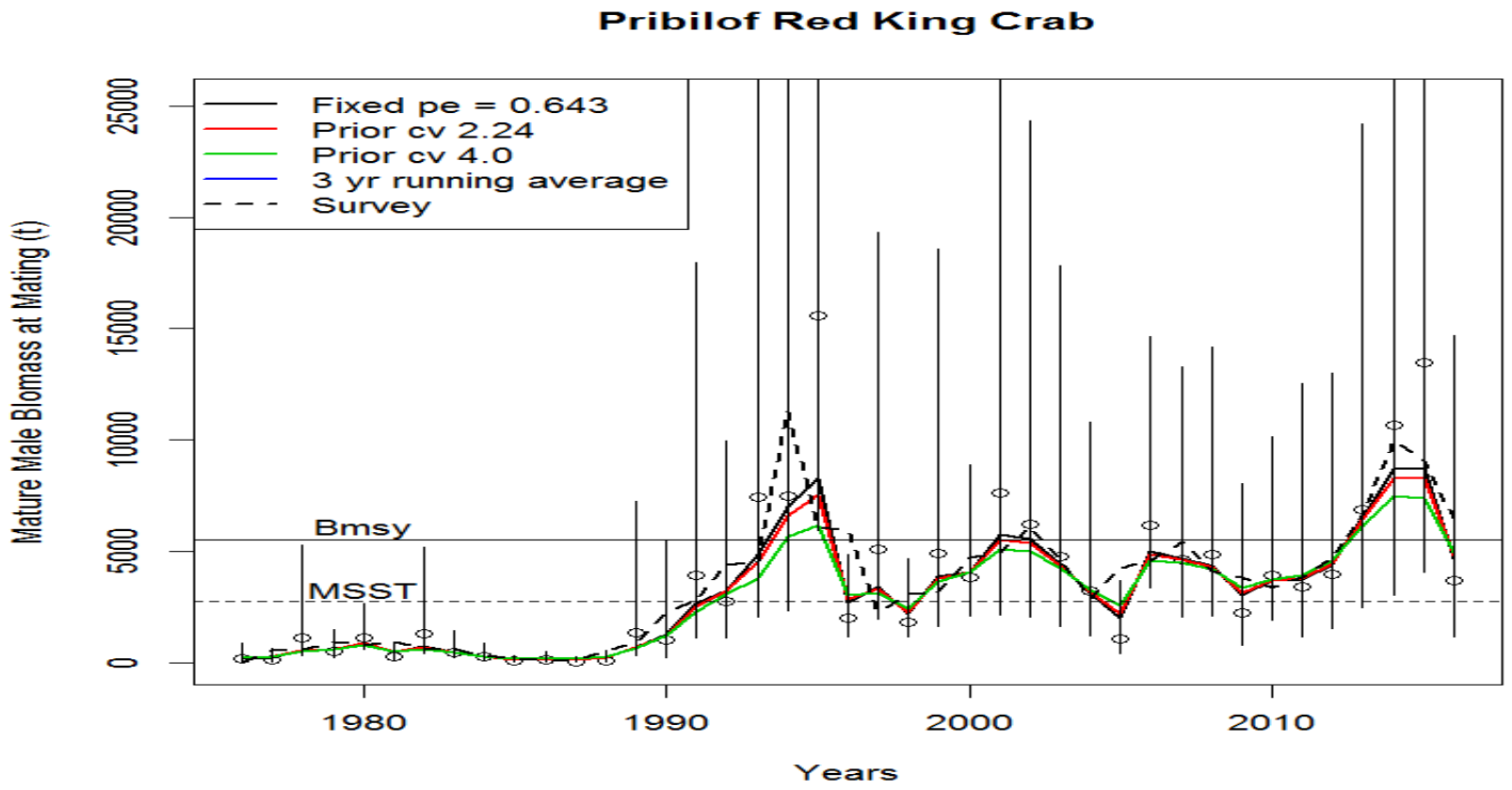
Random effects Model	λ	σ_p^2	CV
λ fixed	-0.221	0.643	NA
with prior on λ	-0.364	0.483	2.24
with prior on λ	-0.640	0.278	4

Random effects model fit to female biomass did not converge.
A fit using the simple exponential model estimated process error at 0.28.

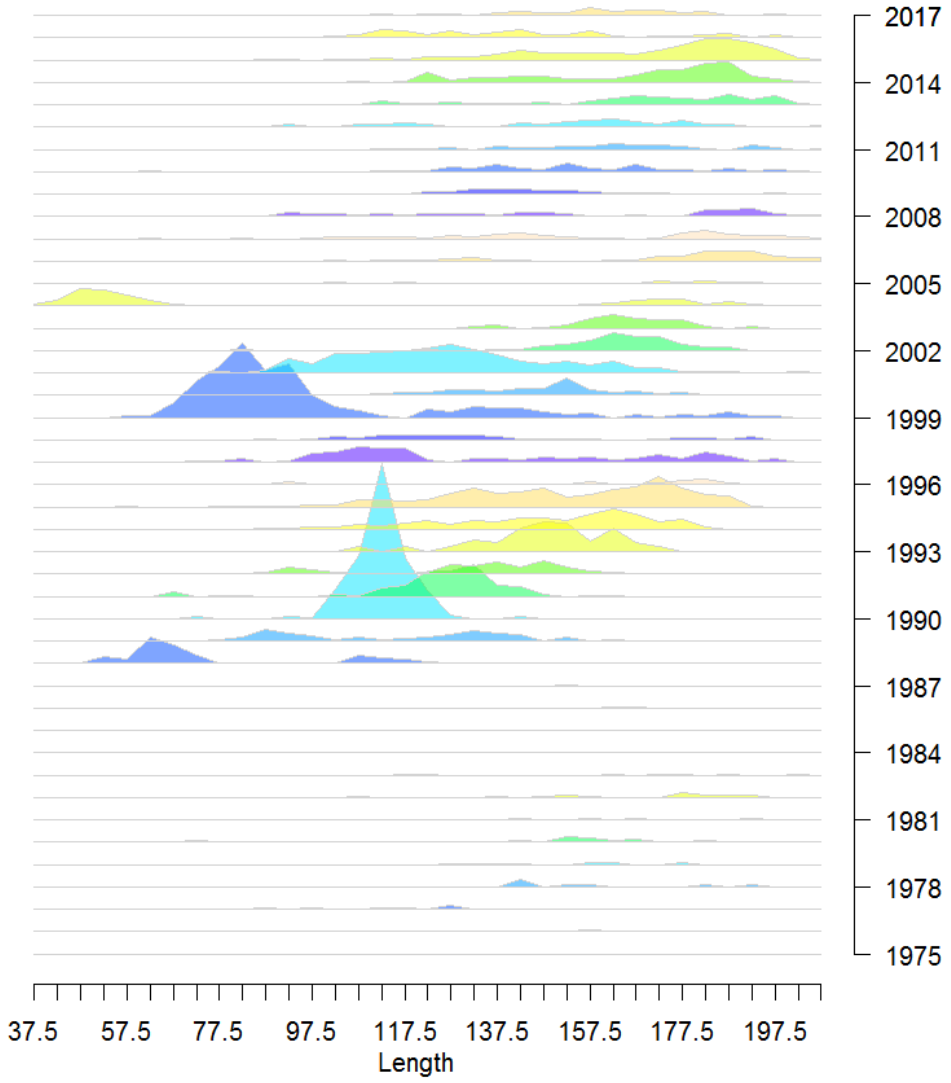
Pribilof Islands Red King Crab



MMB at Mating



- Figure 10. Observed numbers at length by 5 mm length classes of Pribilof Islands male red king crab (Paralithodes camtschaticus) from 1975 to 2017.



Alternative Models –Bmsy estimated from observed survey data

Tier	Assessment Method	OFL	B_{MSY}	MMB At mating[A]	B/B_{MSY} (MMB)	MMB at mating Feb 15 2017	γ	Years to define B_{MSY}	F_{MSY}	ABC (p*=0.49)	ABC = 0.75* OFL
4b	3-yr weighted Running Average	330	5,502	3,139	0.57	6,445	1	1991/1992-2016/2017 (MMB)	0.06	319	248
4b	Random Effects Model fixed	380	5,502	3,336	0.61	4,683	1	1991/1992-2016/2017 (MMB)	0.10	367	285
4b	Random Effects Model prior cv 2.24	404	5,502	3,439	0.63	4,788	1	1991/1992-2016/2017 (MMB)	0.11	390	303
4b	Random Effects Model prior cv 4.0	468	5,502	3,669	0.67	4,961	1	1991/1992-2016/2017 (MMB)	0.11	453	351
4b	Observed Survey	291	5,502	2,971	0.54	3,681	1	1991/1992-2016/2017 (MMB)	0.09	280	218

A: Feb 15 2018 fishing at OFL

Alternative Models – Bmsy estimated using Random effects model biomass

Tier	Assessment Method	OFL	B_{MSY}	MMB At mating[A]	B/B_{MSY} (MMB)	MMB at mating Feb 15 2017	γ	Years to define B_{MSY}	F_{MSY}	ABC (p*=0.49)	ABC = 0.75* OFL
4b	3-yr weighted Running Average	330	5,502	3,139	0.57	6,445	1	1991/1992-2016/2017 (MMB)	0.06	319	248
4b	Random Effects Model fixed	442	4,711	3,274	0.69	4,683	1	1991/1992-2016/2017 (MMB)	0.12	428	332
4b	Random Effects Model prior cv 2.24	482	4,604	3,364	0.73	4,788	1	1991/1992-2016/2017 (MMB)	0.13	467	362
4b	Random Effects Model prior cv 4.0	573	4,397	3,563	0.81	4,961	1	1991/1992-2016/2017 (MMB)	0.14	554	429
4b	Observed Survey	291	5,502	2,971	0.54	3,681	1	1991/1992-2016/2017 (MMB)	0.09	280	218

A: Feb 15 2018 fishing at OFL