Bering Sea Snow Crab Growth and Alternative Model Scenarios

Benjamin J. Turnock

Alaska Fisheries Science Center

April 16, 2013

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Mean growth per molt by premolt width was estimated in the September 2012 snow crab assessment model as a linear function with likelihood penalties on the intercept and slope. The intercept was estimated as one parameter for male and female crab (as recommended by the SSC) , while the slope was estimated as two sex specific parameters. There is a likelihood penalty for each growth parameter in the September 2012 Base model. The parameters in the likelihood penalty for the intercept and the male slope were based on the growth data collected by Rugolo (cooperative seasonality study, 14 crab). The parameter for the female slope was based on growth data from Canadian snow crab. The parameters for the slopes for males and females were adjusted so that the growth curve with equal intercept was similar to estimates from the Rugolo data for males and the Canadian curve for females (Table 1).

The September 2012 model estimates of mean growth for males was lower than the growth based on priors and the female growth was estimated higher (Table 2 and Figure 1).

Somerton’s (2013) estimates on growth for Bering sea snow crab combined several data sets as well as female and male data. The best model determined by Somerton(2013) included the following data :

1. Transit study; 14 crab
2. Cooperative seasonality study (Rugolo); 6 crab
3. Dutch harbor holding study; 9 crab
4. NMFS Kodiak holding study held less than 30 days; 6 crab

Total sample size was 35 crab. Somerton(2013) excluded data from the NMFS Kodiak holding study with crab held more than 30 days and also for the ADF&G Kodiak holding study where crab were collected during the summer survey and held until molting in the next spring because growth was lower significantly lower than the above four data sets.

Some data points were excluded from 1, 2 and 3 above (above has final sample size). Females molting to maturity (molt increment is smaller) were excluded from all data sets. Crab missing more than two limbs were excluded due to other studies showing lower growth. Crab from Rugolo’s seasonal study were excluded that were measured less than 3 days after molting due to difficulty in measuring soft crab accurately.

Somerton fit each data set starting with (1) above and testing the next data set for significant difference. Two linear models were fit that joined at 36.1 mm (Figure 2),

For < =36.1mm

Postmolt = -4.0 + 1.46 \* Premolt

>= 36.1 mm

Postmolt = 6.59 + 1.17 \* Premolt

The fitted parameters with standard errors are shown in Table 3. The uncertainty for intercept values is higher and for slope parameters lower than the growth priors used in the September 2012 Base model.

The assessment model was revised to include the joined linear growth with parameters equal for males and females (Scenario 1) and also with separate parameters for males and females (except a1 which was the same for males and females)(Scenario 2).

For < =35 mm (first two length bins 25-30, 30-35mm)

Postmolt = a1 + b1 \* Premolt

>= 35 mm (all length bins >=35mm)

Postmolt = a2 + b2 \* Premolt

A Likelihood penalty was added for each parameter:



Where pest is the estimated parameter in the model, psom and sdp are the values from Somerton in Table 3.

A likelihood component was added to constrain the two linear segments of the mean growth to be similar at 36.1 mm,



sd = 0.2 (assumed)

P1 is postmolt size at 36.1mm premolt size with a1 and b1 parameters. P2 is postmolt size at 36.1mm premolt size with a2 and b2 parameters.

Mean growth for scenario 1 for male crab was less at small sizes and higher at larger sizes than the Base model. Estimated growth for female crab is higher than base model.

Scenario 1 has one more parameter and a higher total likelihood (104 higher) than the Base model (Table 4). Survey length likelihood is 40 points more, discard catch 20 and growth penalty, 18. Scenario 2 has 49 higher likelihood points than the Base model. 29 more growth prenalty, 8 survey length and 10 discard catch. Scenario 2 growth for males was very similar to the base model above the first two size bins. Estimated female growth was lower in the first 2 sizes bins and higher at larger size bins than the base model.

Fits for the September 2012 Base model are in Figures 4-11.

Fits for the Scenario 1 model are in Figures 12-19.

Fits for the Scenario 2 model are in Figures 20-27.

Figures 28 and 29 compare population mature biomass for males and females for each Scenario. Scenario 1 female mature biomass is higher than the Base 2012 and Scenario 2 biomass due to lower survey Q (Table 6) and higher growth for females. Male mature biomass is very similar between the alternative scenarios.

**Literature Cited**

Somerton, D., S. Goodman, R. Foy, L. Rugolo and L. Slater. 2013. Growth per Molt of Snow Crab in the Eastern Bering Sea, North American Journal of Fisheries Management, 33:1, 140-147.

Table 1. Empirical growth parameters.

|  |  |  |
| --- | --- | --- |
|  | parameter | Se |
| intercept male and female | 6.773 | 0.3 |
| male slope | 1.16 | 0.1 |
| female slope | 1.05 | 0.1 |

Table 2. Growth parameters estimated in Base model, september 2012.

|  |  |
| --- | --- |
| intercept male and female | 7.45743 |
| female slope | 1.06336 |
| male slope | 1.13306 |

Table 3. Parameters for best model estimated by Somerton (2013).

|  |  |  |
| --- | --- | --- |
|  | param | Se |
| <36.1mm |  |  |
| Intercept | -4.0 | 1.36498 |
| slope | 1.46 | 0.05234 |
| >36.1mm |  |
| Intercept | 6.59 | 0.73012 |
| slope | 1.17 | 0.01186 |

Table 4. Likelihood values.

|  |  |  |  |
| --- | --- | --- | --- |
| Likelihood Component | Base Model 2012 sept | Scenario 1New growth MF same | Scenario 2New growth MF sep |
| no. parameters | 329 | 330 | 333 |
| Recruitment | 33.19 | 34.78 | 33.84 |
| Initial numbers old shell males small length bins | 2.38 | 2.40 | 2.39 |
| ret fishery length | -1954.44 | -1946.99 | -1953.56 |
| total fish length | 788.61 | 794.32 | 790.52 |
| female fish length | 175.98 | 176.42 | 173.41 |
| survey length | 3493.46 | 3530.80 | 3501.52 |
| trawl length | 256.76 | 259.43 | 255.39 |
| 2009 BSFRF length | -79.33 | -78.99 | -79.43 |
| 2009 NMFS study area length | -70.34 | -68.61 | -70.43 |
| M prior | 6.13 | 4.80 | 5.92 |
| maturity smooth | 50.61 | 52.02 | 48.85 |
| growth intercept | 2.60 | 5.40 | 6.56 |
| growth slope and join constraint | 0.05 | 15.42 | 25.11 |
| 2009 BSFRF biomass | 0.14 | 0.16 | 0.13 |
| 2009 NMFS study area biomass | 0.06 | 0.06 | 0.06 |
| retained catch | 3.03 | 3.46 | 3.32 |
| discard catch | 119.83 | 138.31 | 129.86 |
| trawl catch | 9.78 | 10.28 | 9.65 |
| female discard catch | 65.10 | 62.20 | 64.87 |
| survey biomass | 165.24 | 168.43 | 167.09 |
| F penalty | 80.25 | 82.58 | 80.30 |
| 2010 BSFRF Biomass | 0.54 | 0.51 | 0.51 |
| 2010 NMFS Biomass | 2.30 | 1.97 | 2.20 |
| initial numbers fit | 515.55 | 519.49 | 515.69 |
| 2010 BSFRF length | -60.96 | -61.01 | -59.44 |
| 2010 NMFS length | -76.88 | -74.08 | -75.72 |
| male survey selectivity smooth constraint | 3.83 | 3.81 | 3.86 |
| init nos smooth constraint | 54.77 | 54.65 | 54.89 |
|   |   |  |  |
| Total | 3588.26 | 3692.03 | 3637.33 |
|  |  |  |  |

Table 5. Growth parameters.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | Base model Sept 2012 | Scenario 1M = F | Scenario 2M, F separate |  |
| females | a1 |  | equal male | equal male |   |
|  | b1 |  | equal male | 1.30 |   |
|  | a2 |  | equal male | 4.64 |   |
|  | b2 |  | equal male | 1.13 |   |
|  |   |  |   |  |  |
| males | a1 |  | 0.08 | -0.86 |  |
|  | b1 |  | 1.34 | 1.38 |  |
|  | a2 |  | 5.61 | 7.18 |  |
|  | b2 |  | 1.16 | 1.14 |  |
| September 2012 Base model |  |  |  |  |  |
| Female | a | equal male |  |  |  |
|  | b | 1.063 |  |  |  |
| Males | a | 7.457 |  |  |  |
|  | b | 1.133 |  |  |  |

Table 6. Survey Q and natural mortality parameters.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | Base 2012 | Scenario 1 | Scenario 2 |
| Survey Q 1989-Present | male |  | 0.59 | 0.59 | 0.59 |
| Survey Q 1989-Present | female |  | 0.58 | 0.52 | 0.57 |
| M | Immature male and female | 0.329 | 0.330 | 0.334 |
| M | mature female (fixed) | 0.230 | 0.230 | 0.230 |
| M | mature male | 0.273 | 0.268 | 0.272 |



Figure 1. Somerton (2013) estimated growth with Base model priors and estimated growth.



Figure 2. Somerton (2013) estimated growth with Base model and Scenario 1 estimated growth.



Figure 3. Estimated growth for males and females (dashed lines) separate parameters (except a1), same parameters, estimated in Base model September 2012, and estimated by Somerton(2013) for male and females together.

Base Model Figures



Figure 4. Base Model. Model fit to the survey female size frequency data. Circles are observed survey data. Solid line is the model fit.



Figure 5. Base Model. Residuals of fit to survey female size frequency. Filled circles are negative residuals.



Figure 6. Base Model. Model fit to the survey male size frequency data. Circles are observed survey data. Solid line is the model fit.



Figure 7. Base Model. Residuals for fit to survey male size frequency. . Filled circles are negative residuals (predicted higher than observed).



Figure 8. Base Model. Summary over years of fit to survey length frequency data by sex. Dotted line is fit for females, circles are observed. Solid line is fit for males, triangles are observed.



Figure 9. Base Model. Population female mature biomass (1000 t, dotted line), model estimate of survey female mature biomass (solid line) and observed survey female mature biomass with approximate lognormal 95% confidence intervals.



Figure 10. Base Model. Population male mature biomass (1000 t, dotted line), model estimate of survey male mature biomass (solid line) and observed survey male mature biomass with approximate lognormal 95% confidence intervals.



Figure 11. Base Model. Model fit to male directed discard catch for 1992/93 to 2010/11 and estimated male discard catch from 1978 to 1991.

Scenario 1 Figures



Figure 12. Scenario 1. Model fit to the survey female size frequency data. Circles are observed survey data. Solid line is the model fit.



Figure 13. Scenario 1.Residuals of fit to survey female size frequency. Filled circles are negative residuals.



Figure 14. . Scenario 1. Model fit to the survey male size frequency data. Circles are observed survey data. Solid line is the model fit.



Figure 15. Scenario 1. Residuals for fit to survey male size frequency. . Filled circles are negative residuals (predicted higher than observed).



Figure 16. Scenario 1.Summary over years of fit to survey length frequency data by sex. Dotted line is fit for females, circles are observed. Solid line is fit for males, triangles are observed.

Figure 17. Scenario 1. Population female mature biomass (1000 t, dotted line), model estimate of survey female mature biomass (solid line) and observed survey female mature biomass with approximate lognormal 95% confidence intervals.



Figure 18. Scenario 1.Population male mature biomass (1000 t, dotted line), model estimate of survey male mature biomass (solid line) and observed survey male mature biomass with approximate lognormal 95% confidence intervals.



Figure 19. Scenario 1.Model fit to male directed discard catch for 1992/93 to 2010/11 and estimated male discard catch from 1978 to 1991.

Scenario 2 Figures.



Figure 20. Scenario 2. Model fit to the survey female size frequency data. Circles are observed survey data. Solid line is the model fit.



Figure 21. . Scenario 2. Residuals of fit to survey female size frequency. Filled circles are negative residuals.



Figure 22. . Scenario 2. Model fit to the survey male size frequency data. Circles are observed survey data. Solid line is the model fit.



Figure 23. . Scenario 2. Residuals for fit to survey male size frequency. . Filled circles are negative residuals (predicted higher than observed).

Figure 24. . Scenario 2. Summary over years of fit to survey length frequency data by sex. Dotted line is fit for females, circles are observed. Solid line is fit for males, triangles are observed.Figure 25. Scenario 2. Population female mature biomass (1000 t, dotted line), model estimate of survey female mature biomass (solid line) and observed survey female mature biomass with approximate lognormal 95% confidence intervals.



Figure 26. . Scenario 2. Population male mature biomass (1000 t, dotted line), model estimate of survey male mature biomass (solid line) and observed survey male mature biomass with approximate lognormal 95% confidence intervals.



Figure 27. . Scenario 2. Model fit to male directed discard catch for 1992/93 to 2010/11 and estimated male discard catch from 1978 to 1991.



Figure 28. Population female mature biomass (1000t) for Base 2012, Scenario 1 and Scenario 2.



Figure 29. Population male mature biomass (1000t) for Base 2012, Scenario 1 and Scenario 2.