Pribilof Islands Red King Crab
CPT comments May 2016

- *Continue the work on survey biomass and length frequency weighting issues to improve the model fits to abundance data;*
  - Addressed in #2 below.
- *Implement the Francis tuning method to estimate length composition effective sample sizes;*
  - The Francis effective N calculation was added to the model. In addition, other multipliers on the survey length frequencies were evaluated.
- *Provide results for a random effects model and three-year weighted average for the September meeting*
  - The random effects model was fit to the survey biomass data and MMB, OFL and ABC estimated. The estimates using the three-year weighted average are also included.

Summary of Major Changes:

- Management: None.
- Input data: Survey (2016) and bycatch (2015) data were incorporated into the assessment.
- Assessment methodology: Model output for male only fit is presented with the same model configuration as 2015.
- Assessment results: Male biomass estimates from the 3-year running average and a random effects model fit to survey male biomass >=120mm are used to estimate MMB at mating, OFL and ABC.

Crab Plan Team September 2015 comments not addressed

- *Incorporate a mean-unbiased log normal likelihood for survey numbers*
    - Next time.
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- *Discuss the poisson vs. negative binomial for survey estimates of abundance and CVs*
    - Currently all of the data in the model are those that are passed from Bob Foy and the Kodiak lab, but given the over-dispersion in the data, a negative binomial (or something similar) might be more appropriate, particularly for estimates of variance. The CVs sent by Bob are used in the assessment, but bootstrapped variances are much larger.
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- *Consider ADFG pot survey data and retained catch size frequency data*
    - These data area not yet incorporated, but may be useful in exploring the mechanics of time-varying catchability.

Pribilof red king crab (biomass in tons)

Year	MSST	Biomass (MMB at mating)	TAC	Retained Catch	Total Catch	OFL	ABC
2010/11	2,255	2,754[A]	0	0	4.2	349	
2011/12	2,571	2,775[B*]	0	0	5.4	393	307
2012/13	2,609	4,025[C**]	0	0	13.1	569	455
2013/14	2,582	4,679 [D**]	0	0	2.25	903	718
2014/15	2,871	8,894 [D**]	0	0	1.76	1,359	1,019
2015/16	2,756	9,062 [**]	0	0	0.32[1]	2,119	1,467

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,

$$BWRA_t = \frac{\sum_{t-1}^{t+1} \frac{MMB_t}{w_t}}{\sum_{t-1}^{t+1} \frac{1}{w_t}} \quad (4)$$

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:

$$w_t = \ln((CV_t^{MMB})^2 + 1) \quad (5)$$

Where,

CV_t^{MMB}	Coefficient of variation associated with the estimate of MMB at time t

Random effects model Likelihood

- $$\sum_{i=1}^{yrs}\left\{0.5\left(\log(2\pi\sigma_i^2)+\left(\frac{(\widehat{B_i}-B_i)^2}{\sigma_i^2}\right)\right)\right\}+\sum_{t=2}^{yrs}\left\{0.5\left(\log(2\pi\sigma_p^2\quad)+\left(\frac{(\widehat{B_i}-\hat{B}_{i-1})^2}{\sigma_p^2}\right)\right)\right\}$$

Where,

B_i is the log of observed biomass in year i

$\widehat{B_i}$ is the model estimated log biomass in year i

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 $e^{(2\alpha)}$, where α is a parameter estimated in the random effects model.

Yrs is the number of years of survey biomass values

Survey biomass in 2016 declined to 4,150 t from 15,173 t in 2015

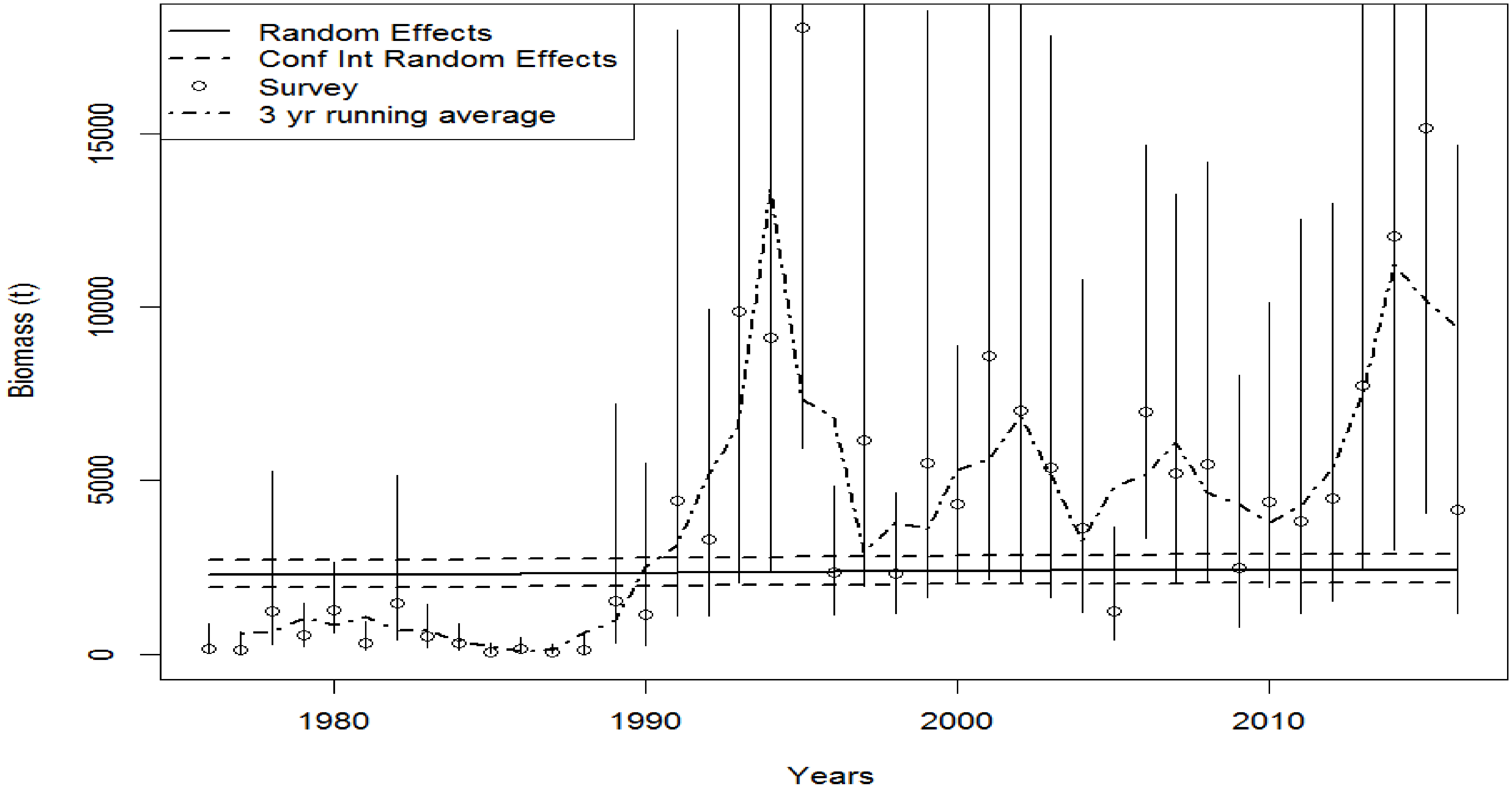


Figure 14. Three-year running average and random effects model fit to male biomass > 120mm at survey time.

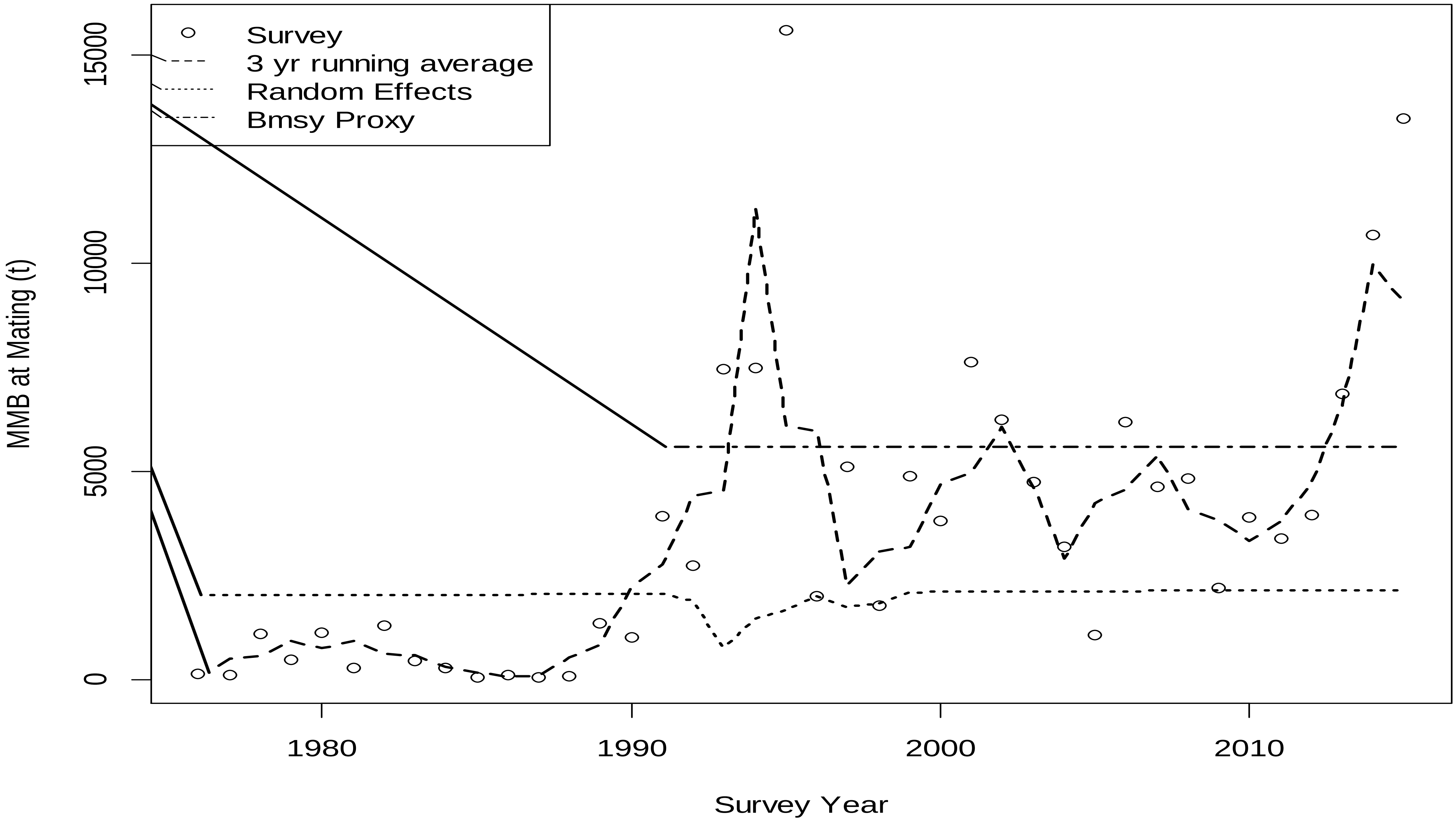


Figure 15. MMB at mating (February 15 of survey year +1) estimated from the survey data, 3 yr running average and the Random effects model. Bmsy proxy is the average of the 1991 to 2015 MMB at mating survey data (February 15 1992 to February 15 2016).

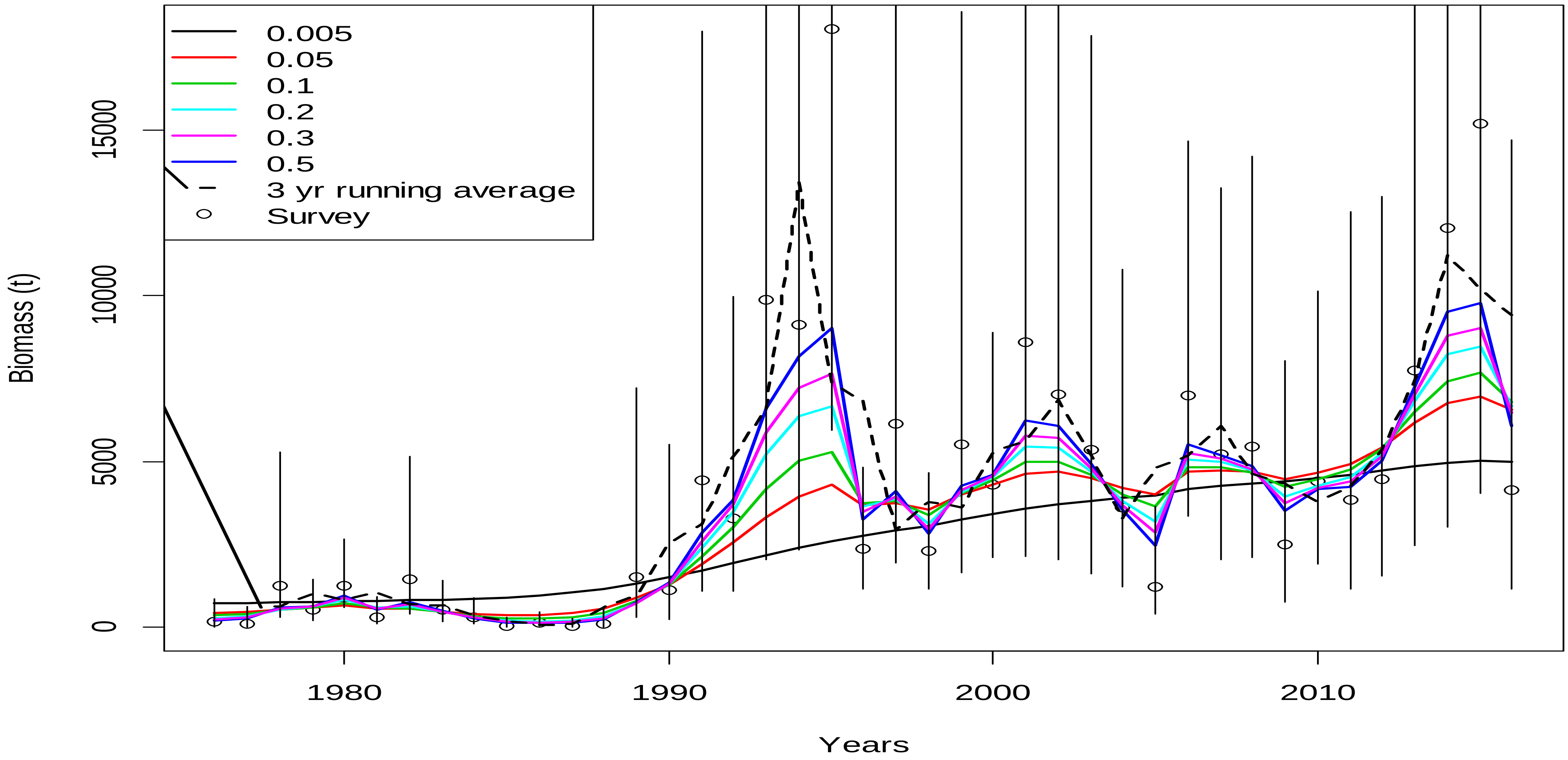
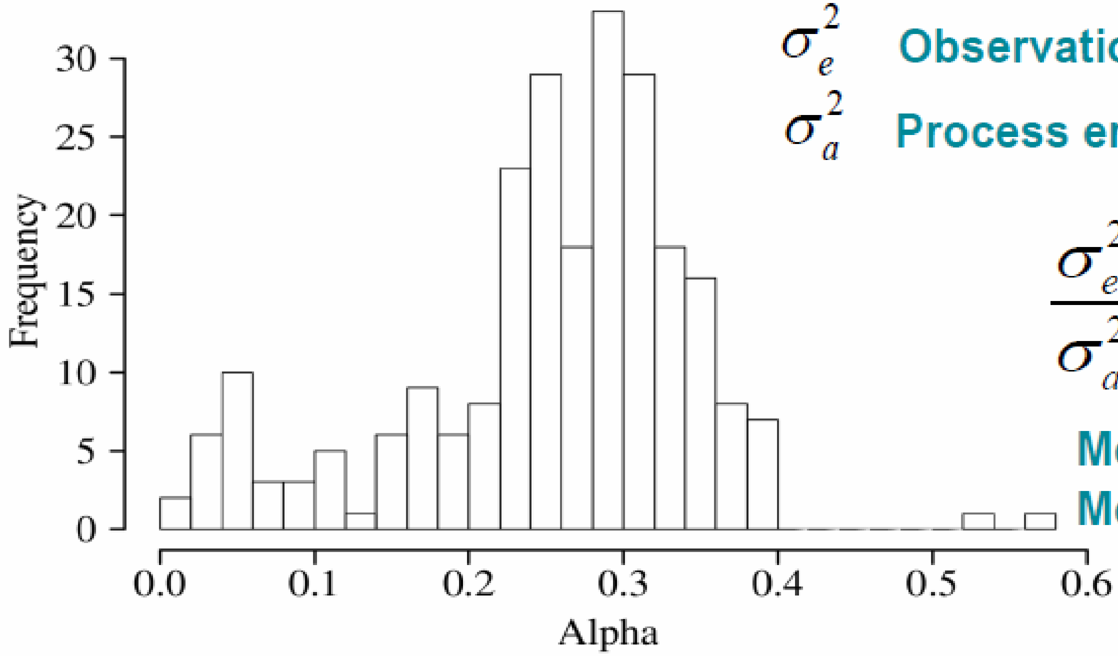


Figure 26. Random effects model estimates of biomass with process error fixed at 0.005, 0.05, 0.1,0.2,0.3 and 0.5.

From Spencer presentation at Wakefield 2015

A simple exponential smoothing model can give information on the ratio of variances

$$\hat{z}_t = (\alpha)y_t + (1-\alpha)\left[\alpha y_{t-1} + \alpha(1-\alpha)y_{t-2} + \alpha(1-\alpha)^2 y_{t-3} + \ldots\right]$$



σ_e^2 Observation error variance

σ_a^2 Process error variance

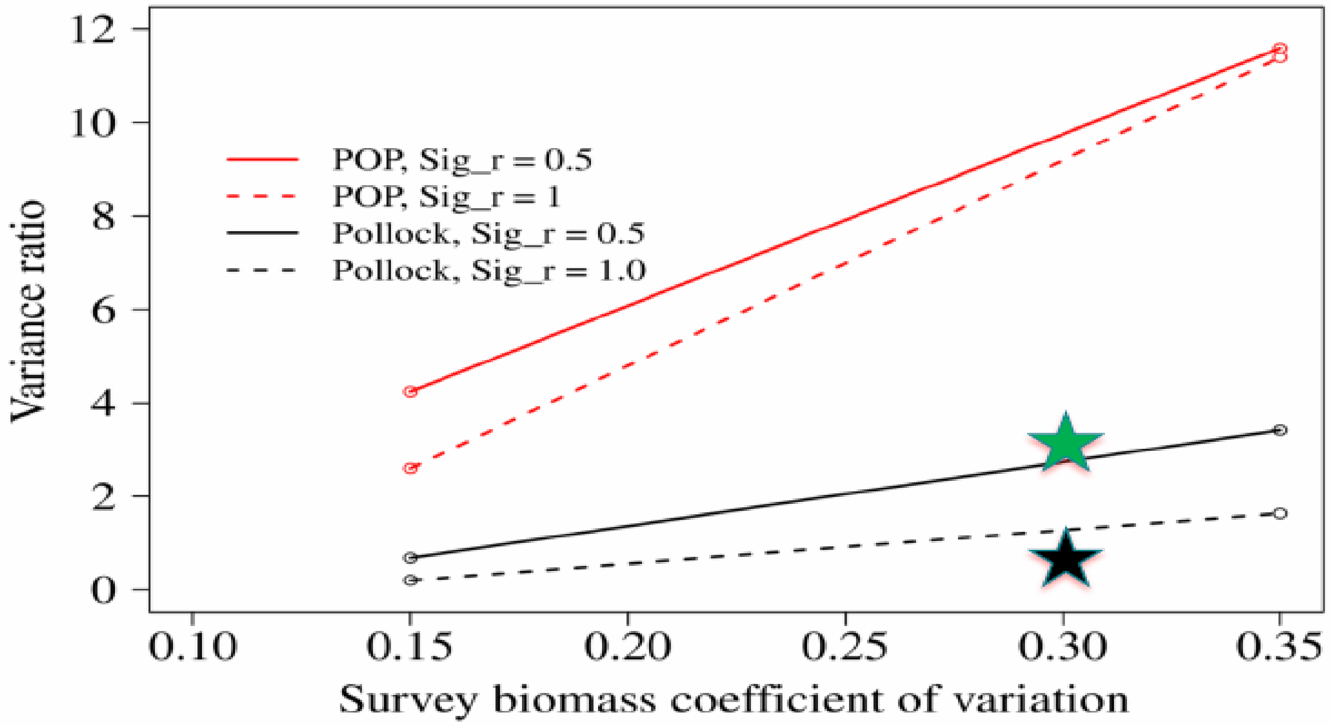
$$\frac{\sigma_e^2}{\sigma_a^2} = \frac{1-\alpha}{\alpha^2}$$

Mean α = 0.256

Mean ratio = 11.35

Spencer Wakefield 2015

The variance ratio is a function of stock longevity, recruitment variability, and survey variability



Used as a prior to constrain the estimate of process error standard deviations

Implied from fit to GOA dogfish

- Observation error variance on log scale is ln(cv^2+1)
- Mean cv of survey biomass is 0.67
- Mean Observation Error variance on log scale = 0.38
- Fitting a simple exponential model to Pribilof survey data using HoltWinters function in R gives,
- Alpha = 0.396, = variance ratio of 3.75 and process error of 0.38/3.75 = 0.102.
- Pribilof red model variance of first difference in log biomass 0.046, Bristol Bay red king crab model 0.089.

Integrated assessment model fit to male numbers (male only model)

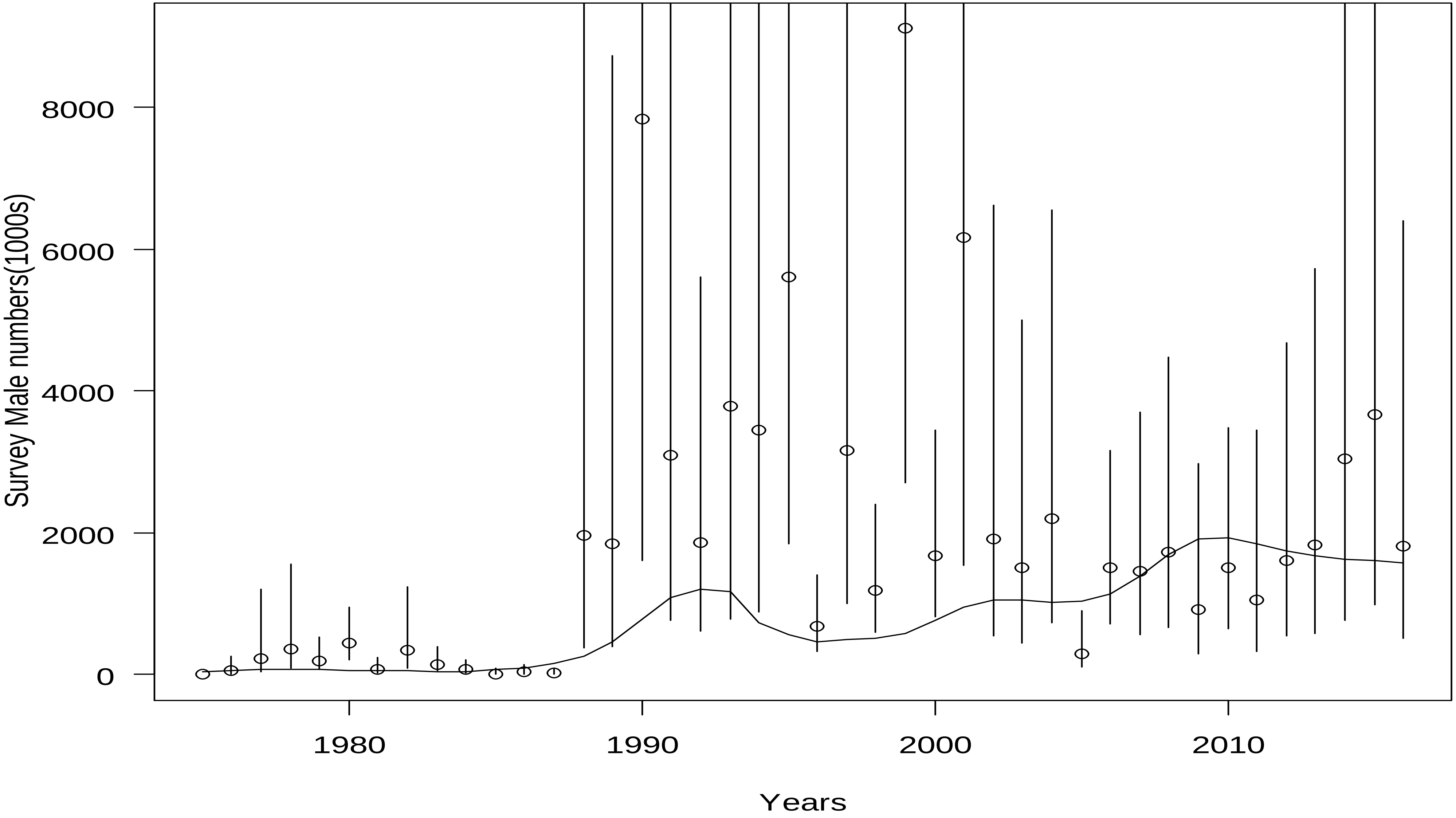
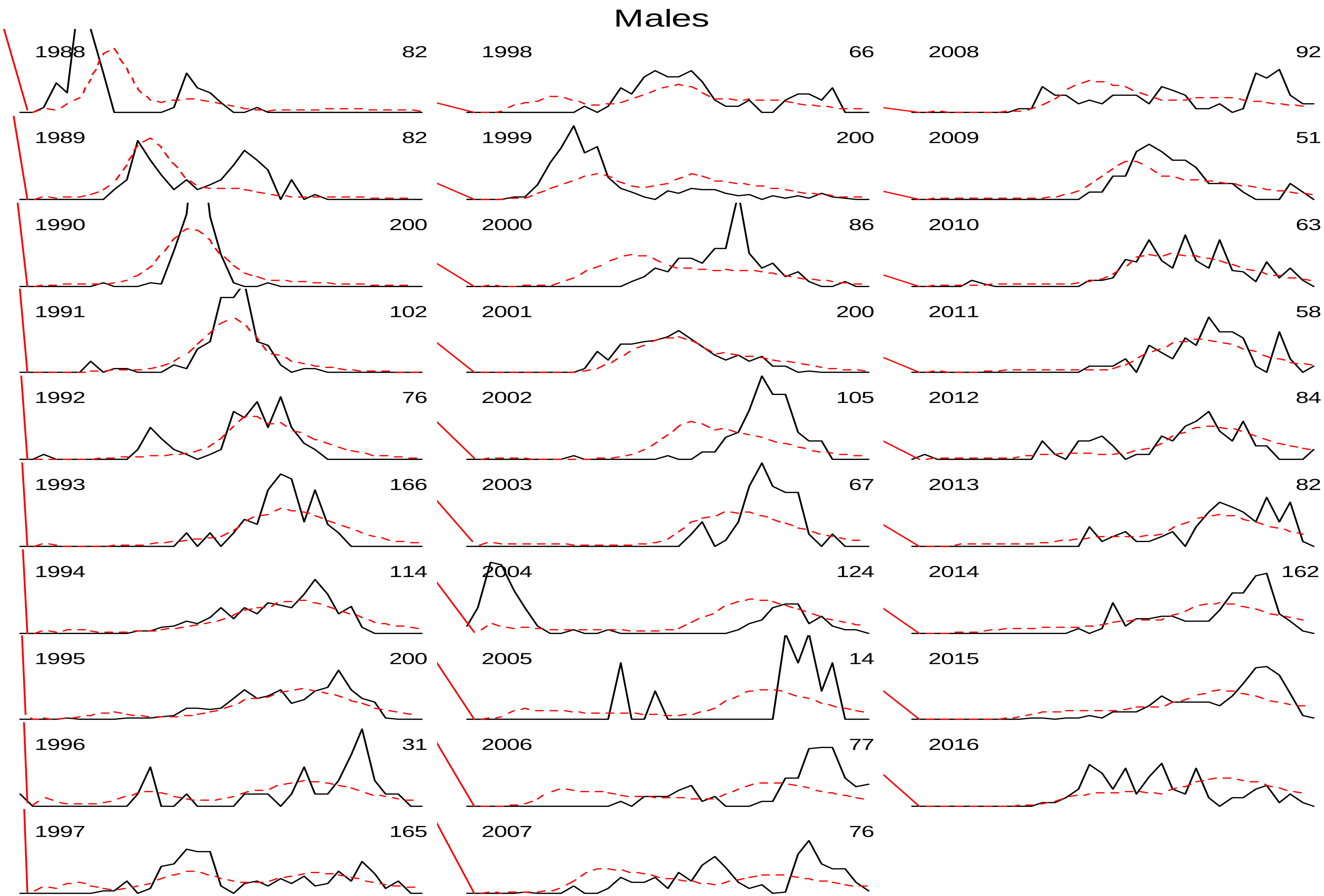


Figure 20. Model fit to survey male numbers.


Males
1988
82
1989
82
1990
200
1991
102
1992
76
1993
166
1994
114
1995
200
1996
31
1997
165
1998
66
1999
200
2000
86
2001
200
2002
105
2003
67
2004
124
2005
14
2006
77
2007
76
2008
92
2009
51
2010
63
2011
58
2012
84
2013
82
2014
162
2015
2016

Survey length sample size reduction – Francis N multiplier 0.05 (model did not converge)

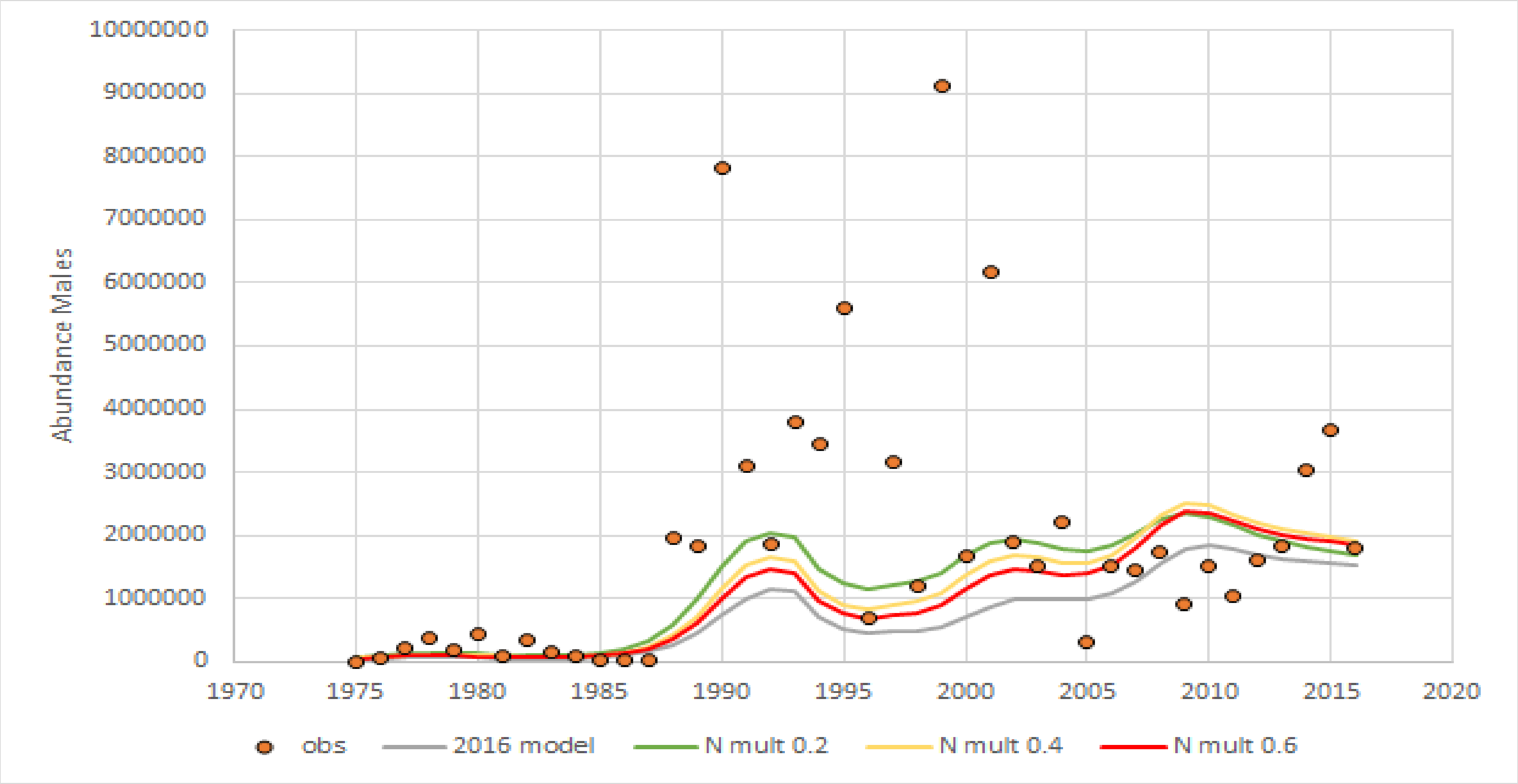


Figure 25. Fit to male abundance for the 2016 base model and model scenarios with multipliers on the survey length sample size of 0.2, 0.4 and 0.6.

Table A4. Likelihood component contribution to the likelihood and associated weights for the assessment model scenarios with multipliers on the survey length sample sizes of 0.2, 0.4, 0.6 and the base model (1.0).

Likelihood component	Base Model (1.0)	0.2	0.4	0.6	Weighting
Survey numbers (males)	45.7	29.9	32.7	36.1	.36 -1 (CVs)
Survey length frequencies (male)	10,012.3	2018.9	4024.6	6023.7	18-200 (Base model sample size)
Catch	0.003	0.001	0.001	0.001	.005(CV)
Trawl	0.019	0.019	0.019	0.019	.01 (CV)
Smoothness penalties					
Trawl fishing mortality	38.6	38.4	38.3	38.4	1 (CV)
Fishing mortality	4.3	4.3	4.3	4.3	1 (CV)
Recruitment	48.9	20.4	30.1	37.5	1 (CV)

Pribilof red king crab alternatives (biomass in tons)

Tier	Assessment Method	OFL	B_{MSY}	MMB At mating Feb 15 2017 fishing at OFL	B/B_{MSY} (MMB)	MMB at mating Feb 15 2016	γ	Years to define B_{MSY} (MMB at mating)	F_{MSY}	ABC ($p^*=0.49$)	ABC = 0.75*OFL
4	Running Average	1,462	5,512	6,980	1.25	9,062	1.0	1991/92-2015/16	0.18	1,436	1,096
4	Random Effects Model	119	5,512	2,044	0.37	2,154	1	1991/92-2015/16	0.05	114	89
4	Observed Survey	370	5,512	3,332	0.60	13,457	1	1991/92-2015/16	0.10	357	278
4	Integrated assessment (males only)	822	3,881	5,160	1.33	6127	1	1991/92-2015/16	0.18		617
3	Integrated assessment (males only)	1,931	1,598	4,066	2.5	6127	1	1983-present recruitment	0.49		1,448