

# **Updates on Bristol Bay Red King Crab Stock Assessments, Spring 2018**

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# Purposes

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## Address the CPT and SSC requests

- 1. Estimating male discard biomass without legal retained status information (Appendix C).*
- 2. Retrospective analysis of terminal years of recruitment.*
- 3. Dynamic  $B_0$  computation (Appendix D).*
- 4. High estimated trawl survey  $Q$  values.*
- 5. Other comments.*

# Subtraction Method

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1. Issue: Past legal male discard status information is not good, and no more such information is available next season.
2. Propose approach: Subtraction Method, the same approach CPT and SSC have adopted for AI golden king crab:

Observed discard male abundance and biomass =  
total male abundance and biomass estimated from observer data -  
total commercial catch abundance and biomass for a given year

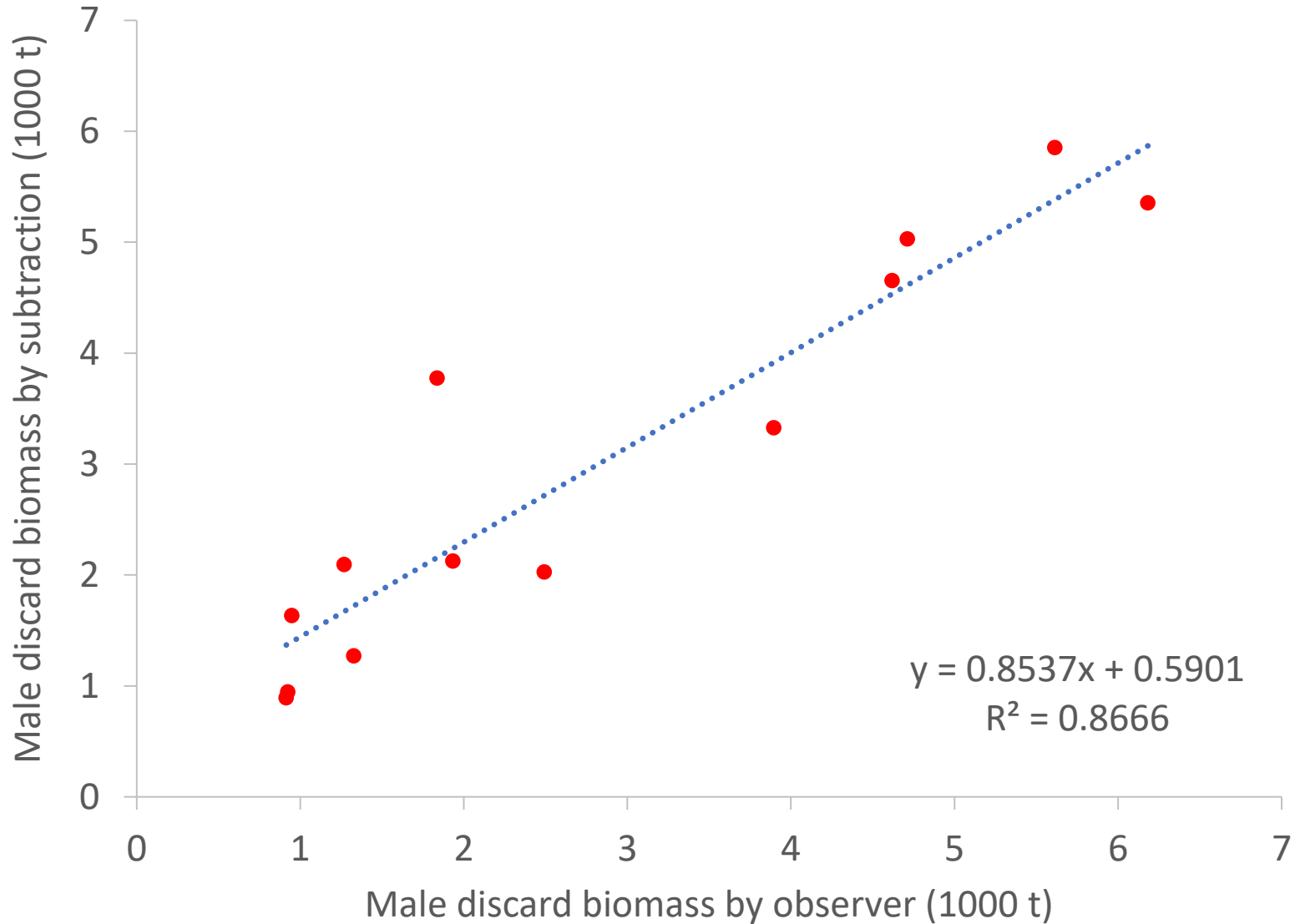
Table C1. Numbers of sampled crab and potlifts, total number of potlifts and observer legal discard rates by the Bristol Bay red king crab directed pot fishery and cost-recovery fishery based on observer data for crab  $\geq 65$  mm carapace length since rationalization for the Bristol Bay. Notations: NR = none retained, UR = unknown retained status.

Year	Fishery	Female	Sublegal	Legal_NR	Legal_UR	Legal_Ret	Samp.pots	Tot.pots	Leg-disc-rate
2005	Directed	26824	44103	11052	0	39639	1855	114944	21.80%
2006	Directed	3646	28504	1602	0	36423	1214	71735	4.21%
2007	Directed	12457	57295	1049	0	53231	1918	113214	1.93%
2008	Directed	8737	48903	808	0	40620	1849	139937	1.95%
2009	Directed	6050	49023	1420	0	42173	1950	118521	3.26%
2010	Directed	6862	34935	471	0	31253	1891	131627	1.48%
2011	Directed	1752	19277	240	0	20709	696	45166	1.15%
2012	Directed	562	6894	320	0	12947	437	38159	2.41%
2013	Directed	6070	12723	1111	0	16427	657	45927	6.33%
2014	Directed	1953	10082	2964	0	15494	520	58702	16.06%
2015	Directed	5927	6975	1061	0	13986	413	48008	7.05%
2016	Directed	4315	8087	1413	1298	15712	413	33126	8.25%
2017	Directed	3834	11416	1178	0	14625	803	48222	7.45%
2005	Cost-rec								
2006	Cost-rec	386	2787	82	0	4738	110	1067	1.70%
2007	Cost-rec	250	1638	32	0	2436	61	734	1.30%
2008	Cost-rec	0	0	0	0	0	0	0	
2009	Cost-rec	17	2337	6	0	3233	114	740	0.19%
2010	Cost-rec	29	1283	4	0	1364	46	556	0.29%
2011	Cost-rec	179	1141	5	0	1680	51	618	0.30%
2012	Cost-rec	2	133	18	0	1203	35	683	1.47%
2013	Cost-rec	7	466	68	0	1720	35	662	3.80%
2014	Cost-rec	714	1006	11	0	1666	38	665	0.66%
2015	Cost-rec	1533	660	0	0	1932	42	755	0.00%
2016	Cost-rec	1519	1038	11	0	2473	40	482	0.44%
2017	Cost-rec	214	738	38	0	2018	51	927	1.85%

Table C2. Estimated abundances of sublegal, legal and total males, commercial catch abundance and biomass, and estimated discard male biomass and discard rates of legal males for the Bristol Bay red king crab fishery, for crab  $\geq 65$  mm carapace length. Abundance is in millions of crab and biomass is 1000 tons.

Year	Abundance			Biomass	Abundance	Biomass	Biomass	Disc-rate
	Sublegal	Legal	Total male	Total male	Com.catch	Com.catch	Disc.male	Legal
2005	2.7652	3.1716	5.9368	13.7533	2.7627	8.3997	5.3536	12.89%
2006	1.7111	2.2936	4.0047	9.1704	2.4769	7.1432	2.0272	-7.99%
2007	3.4005	3.2337	6.6342	13.9566	3.1543	9.3039	4.6526	2.46%
2008	3.7009	3.1354	6.8363	15.0687	3.0640	9.2161	5.8526	2.28%
2009	2.9944	2.6706	5.6650	12.3003	2.5529	7.2725	5.0278	4.41%
2010	2.4464	2.2248	4.6711	10.0874	2.4099	6.7615	3.3258	-8.32%
2011	1.2632	1.3799	2.6431	5.7326	1.2978	3.6071	2.1255	5.95%
2012	0.6041	1.1823	1.7864	4.5681	1.1756	3.6217	0.9464	0.57%
2013	0.8980	1.2598	2.1578	5.2607	1.2720	3.9910	1.2697	-0.97%
2014	1.1553	2.1130	3.2683	8.3127	1.5012	4.5386	3.7741	28.96%
2015	0.8225	1.7838	2.6064	6.7064	1.5270	4.6137	2.0928	14.40%
2016	0.6612	1.5076	2.1688	5.5572	1.2812	3.9239	1.6333	15.02%
2017	0.6986	0.9864	1.6850	3.9865	0.9972	3.0937	0.8928	-1.10%

# Comparison of total estimated male discard biomasses using observer legal retained status and Subtraction method



Total selectivity for males is assumed to be a logistic curve:

$$S_l^{dirt,mal} = \frac{1}{1+e^{-\beta^{dir,mal} (l-L_{50}^{dir,mal})}} \quad (C1)$$

and the retained proportions of legal males also follow a logistic function:

$$S_l^{dirt,ret} = \frac{1}{1+e^{-\beta^{dir,ret} (l-L_{50}^{dir,ret})}} \quad (C2)$$

Two approaches to adjust annual retained proportions:

1. **Scenario 2bn1 (or 17.0a)**: two logistic curves for retained proportions: the first one for 1975-2004, before rationalization, and the second one for 2005-present.
2. **Scenario 2bn2 (or 17.0b)**: only one logistic curve for retained proportions for all years; annual adjusted factor parameter,  $x_t$ , is estimated for each year after 2004 and a logit transformation is used to make sure the adjusted factor,  $u_t$ , be  $<1.0$ :

$$u_t = \frac{e^{x_t}}{1+e^{x_t}} \quad (C3)$$

Annual retained proportions after 2004 are estimated as:

$$S_{l,t}^{dirt,ret} = u_t S_l^{dirt,ret} \quad (C4)$$

To avoid overfitting the data, a negative likelihood value is computed as:

$$\sum_t (u_t - 1.0)^2 / (2\sigma^2) \quad (C5)$$

where  $\sigma$  is the standard deviation of  $u_t$  and is assumed to be 0.1. The model results hardly change with either 0.1 or 0.2.

# Model Scenarios

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**2b (or 17.0):** the scenario 2b in the SAFE draft report in September 2017.

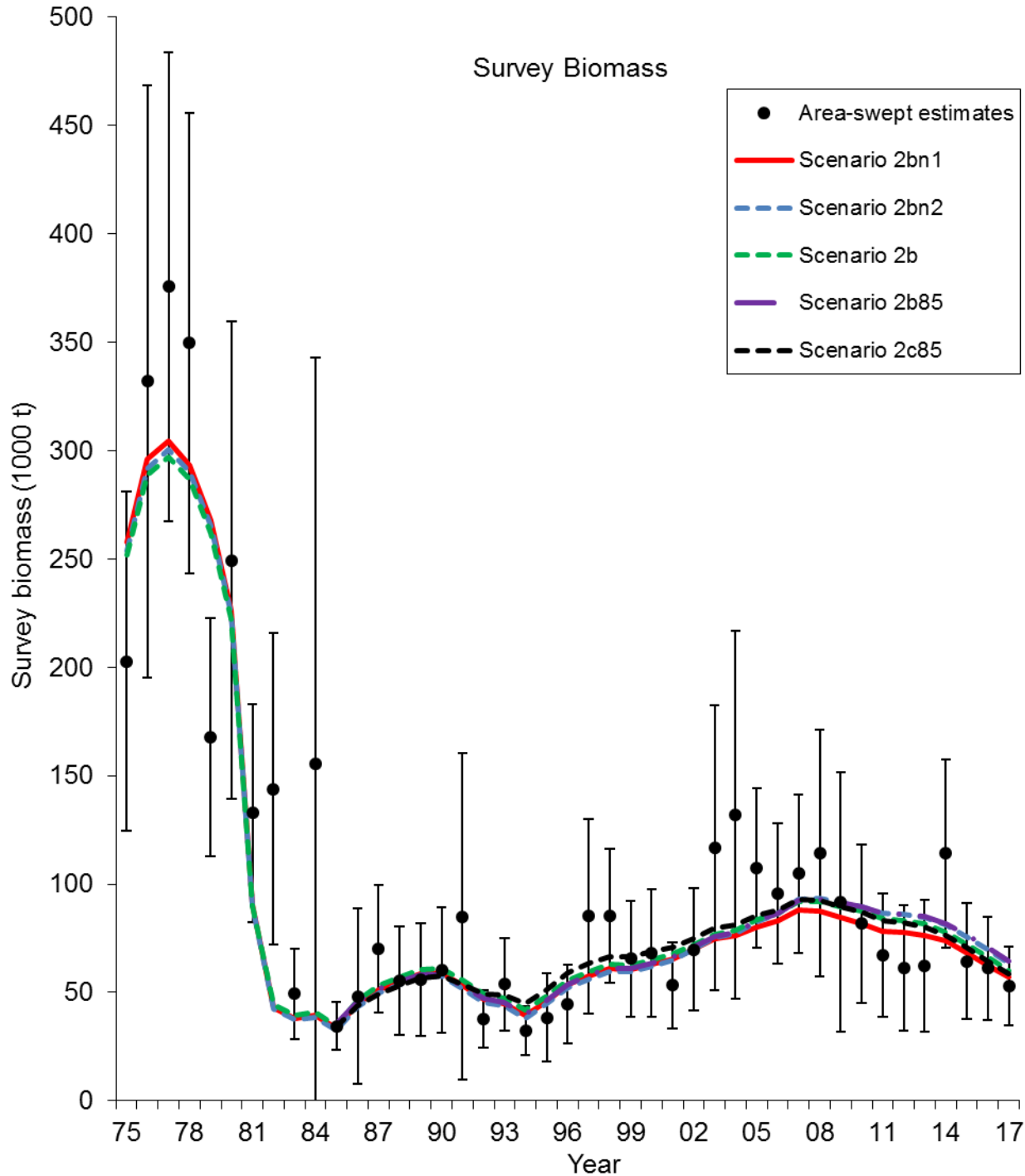
**2bn1 (or 17.0a):** Subtraction Method approach 1.

**2bn2 (or 17.0b):** Subtraction Method approach 1.

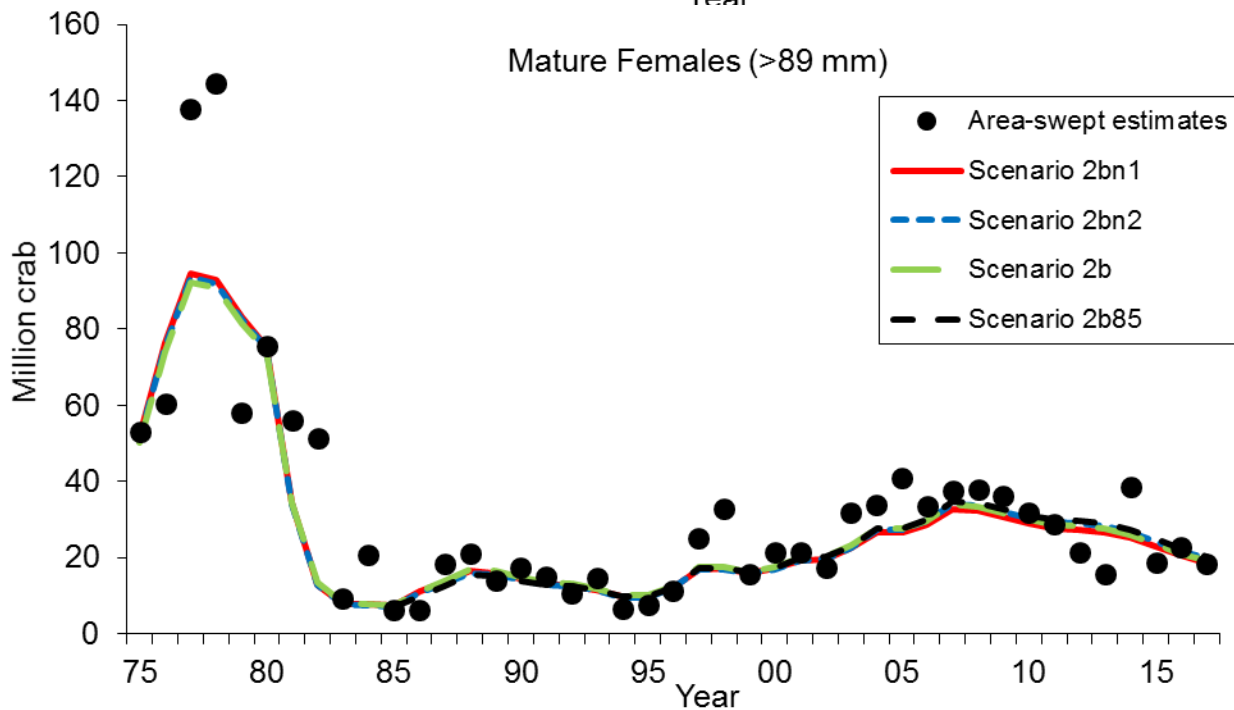
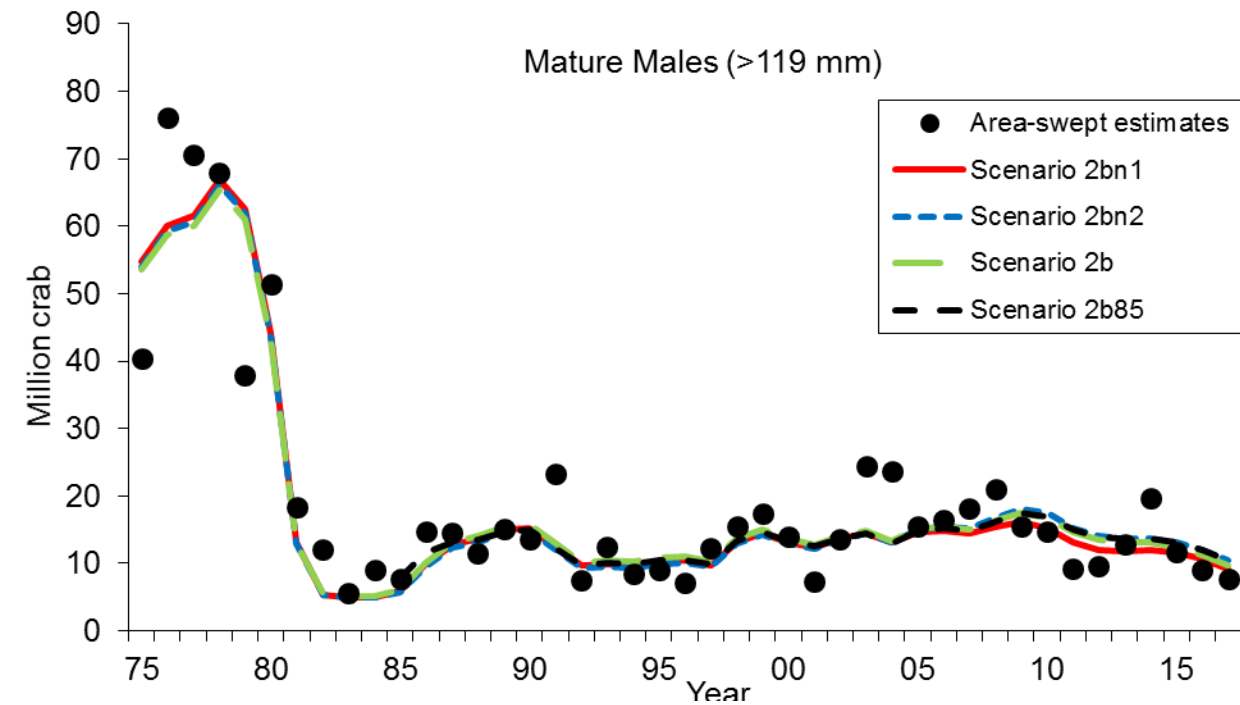
**2b85 (or 17.0c):** the same as Scenario 2b except for starting the model in 1985.

**2c85 (or 17.0d):** the same as Scenario 2c in the draft SAFEE report in May 2017 except for starting the model in 1985 and constant natural mortality of 0.18 for all years.



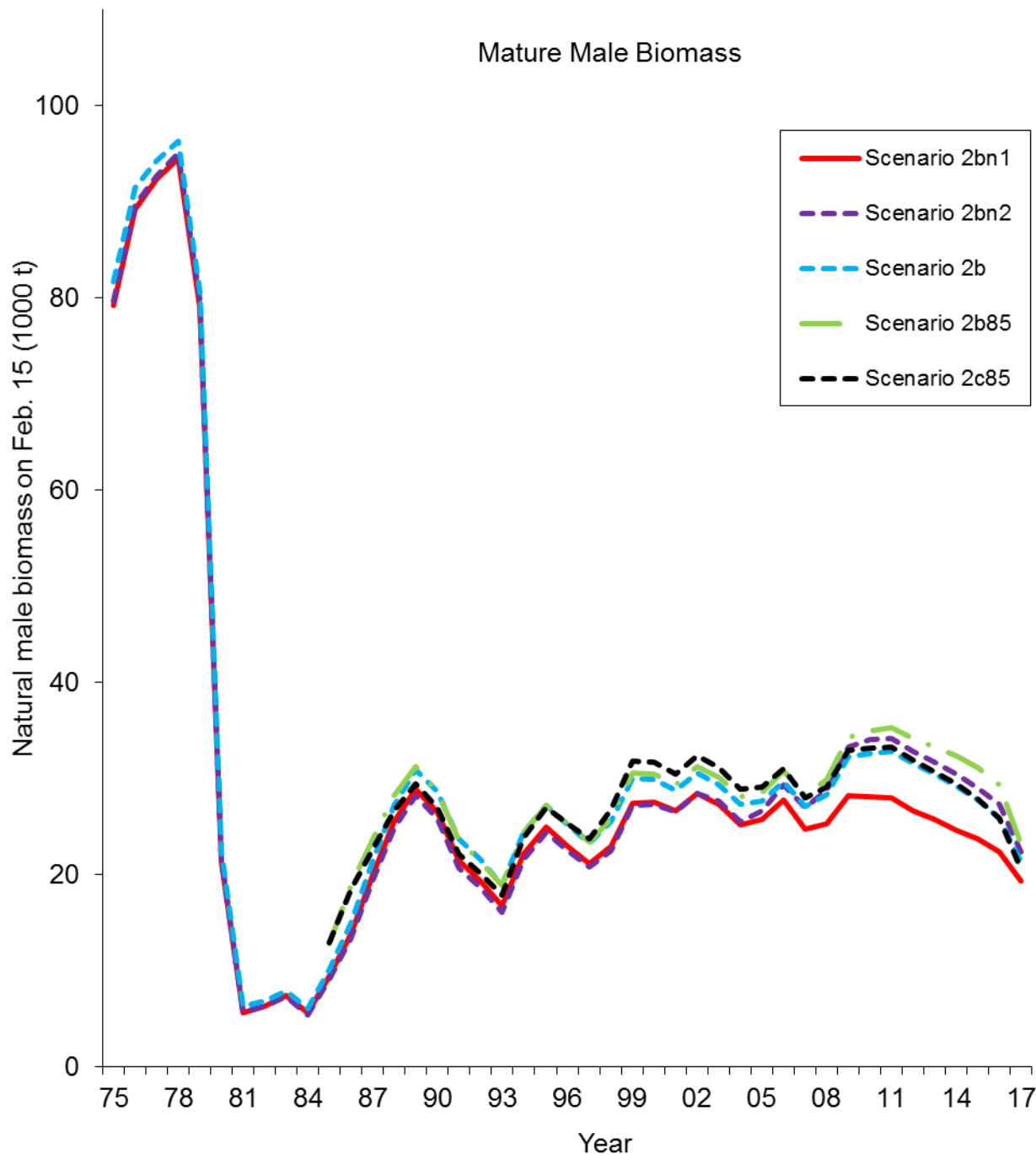


Comparisons of area-swept estimates of total NMFS survey biomass and model prediction for model estimates in 2017 under scenarios 2b, 2bn1, 2bn2, 2b85 and 2c85. The error bars are plus and minus 2 standard deviations.



Comparisons of NMFS survey area-swept estimates of male (>119 mm) and female (>89 mm) abundance and model prediction for model estimates in 2017 under scenarios 2b, 2bn1, 2bn2 and 2b85

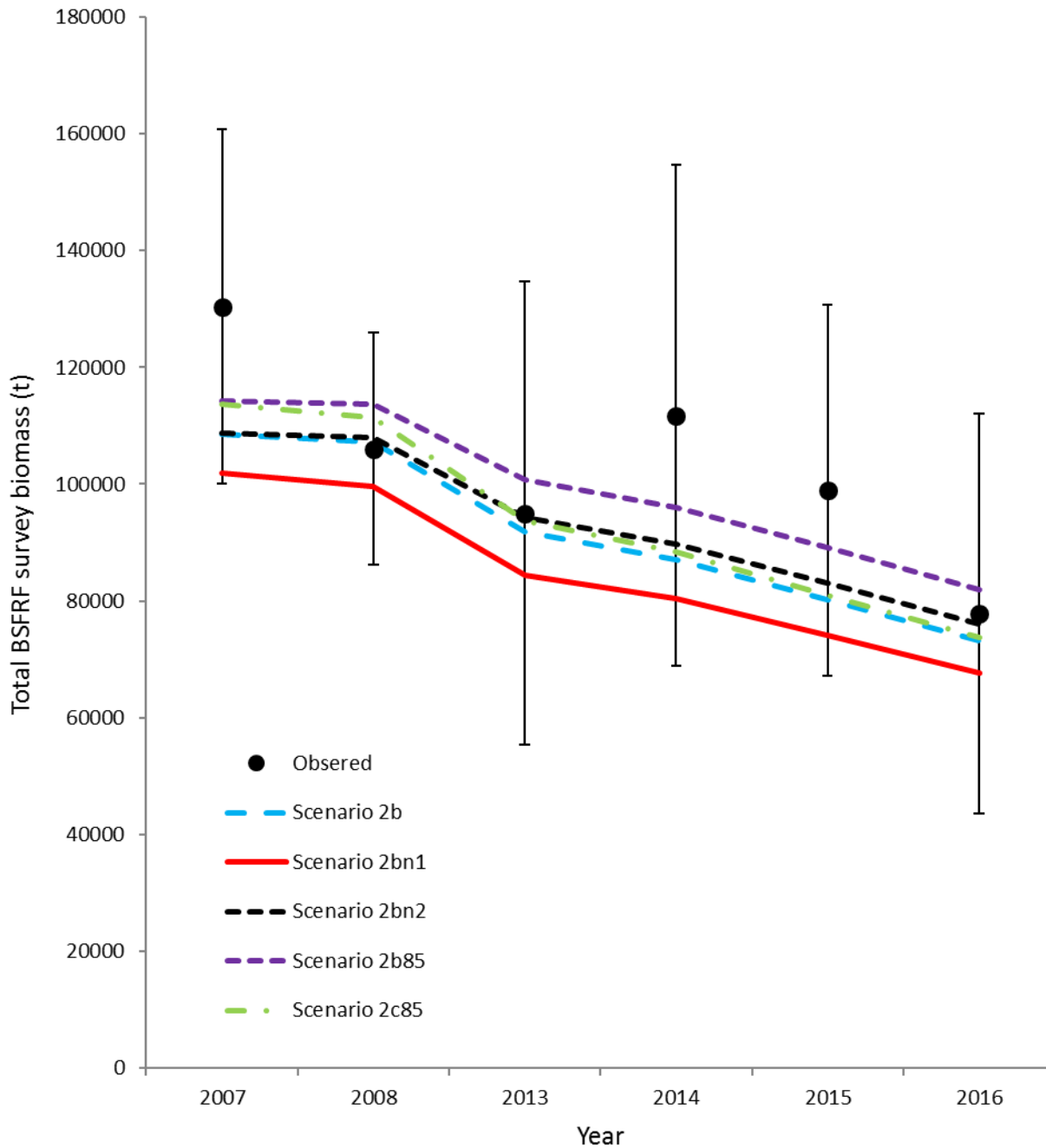
### Mature Male Biomass



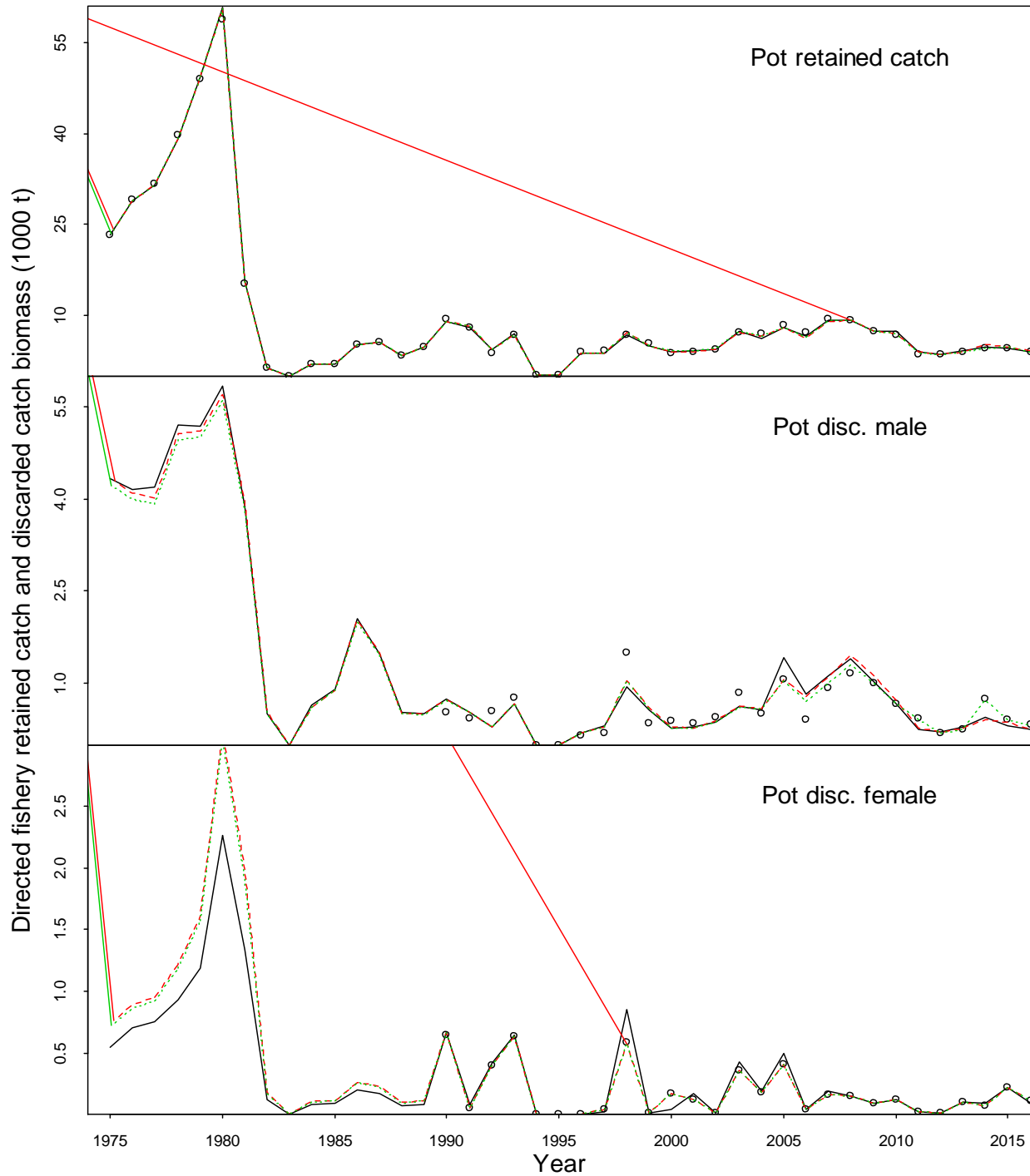
Comparisons of mature male biomass on Feb. 15 under scenarios 2b, 2bn1, 2bn2, 2b85 and 2c85

Estimated trawl survey catchabilities:

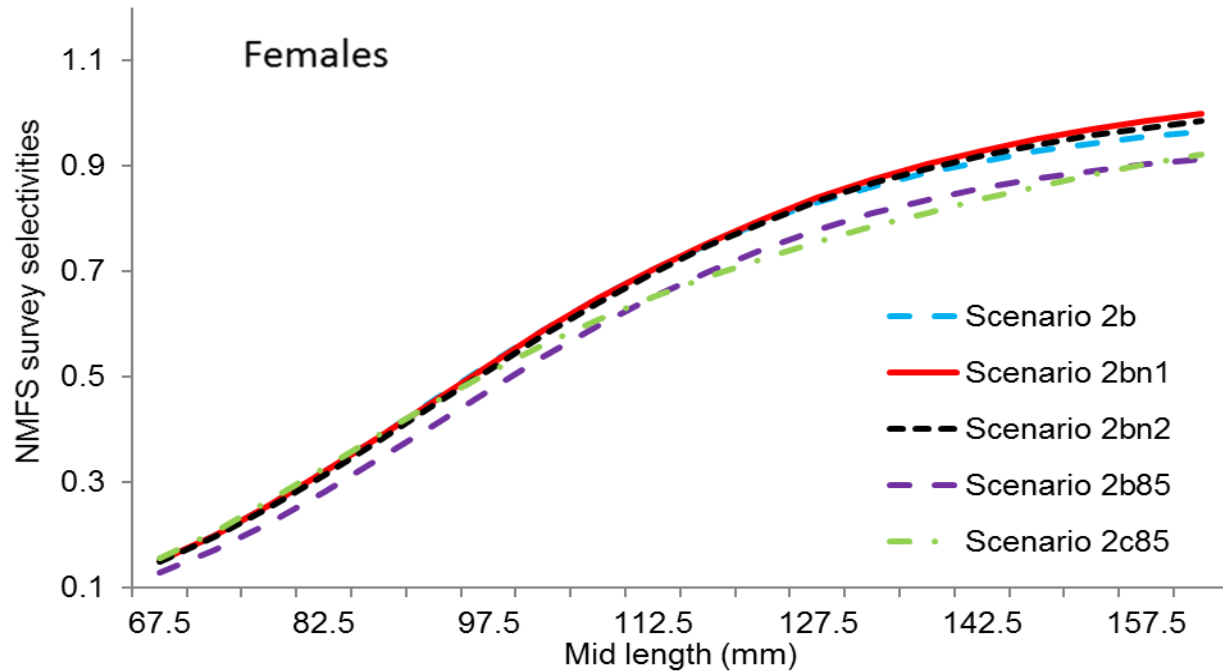
Scenario	Q
2b	0.96
2bn1	1.00
2bn2	0.98
2b85	0.91
2c85	0.92



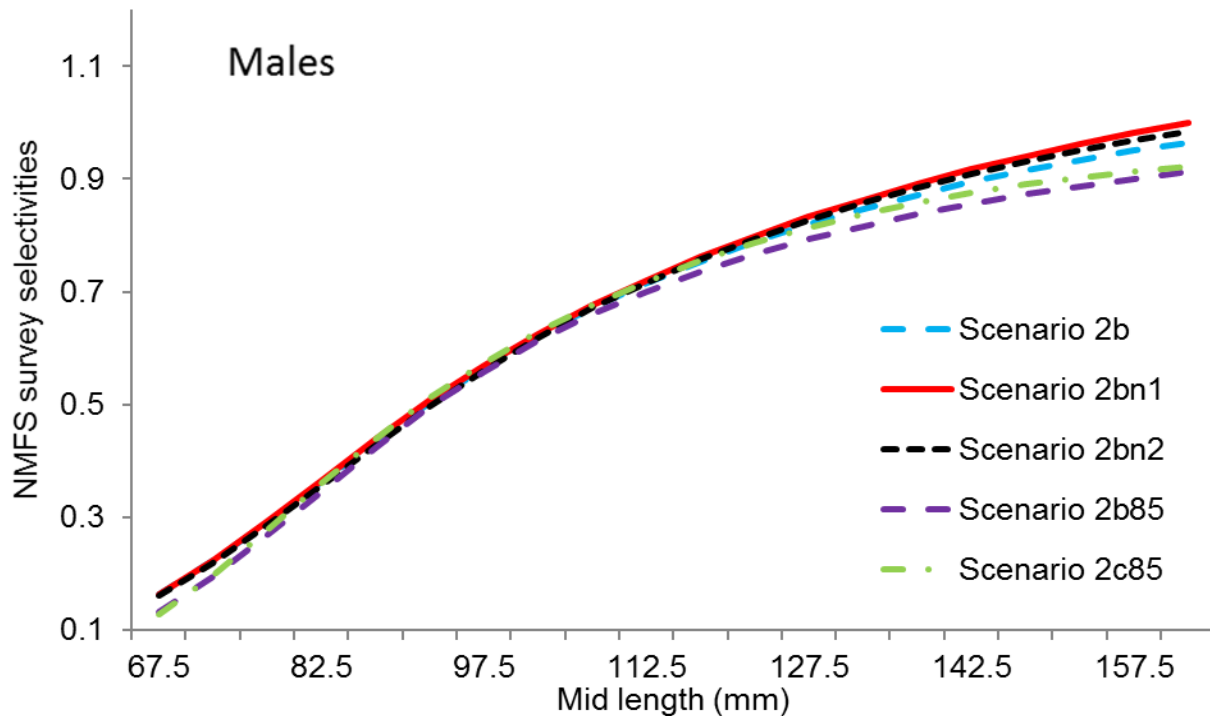
Comparisons of total survey biomass estimates by the BSFRF survey and the model for model estimates in 2017 (scenarios 2b, 2bn1, 2bn2, 2b85 & 2c85). The error bars are plus and minus 2 standard deviations of scenario 2b.

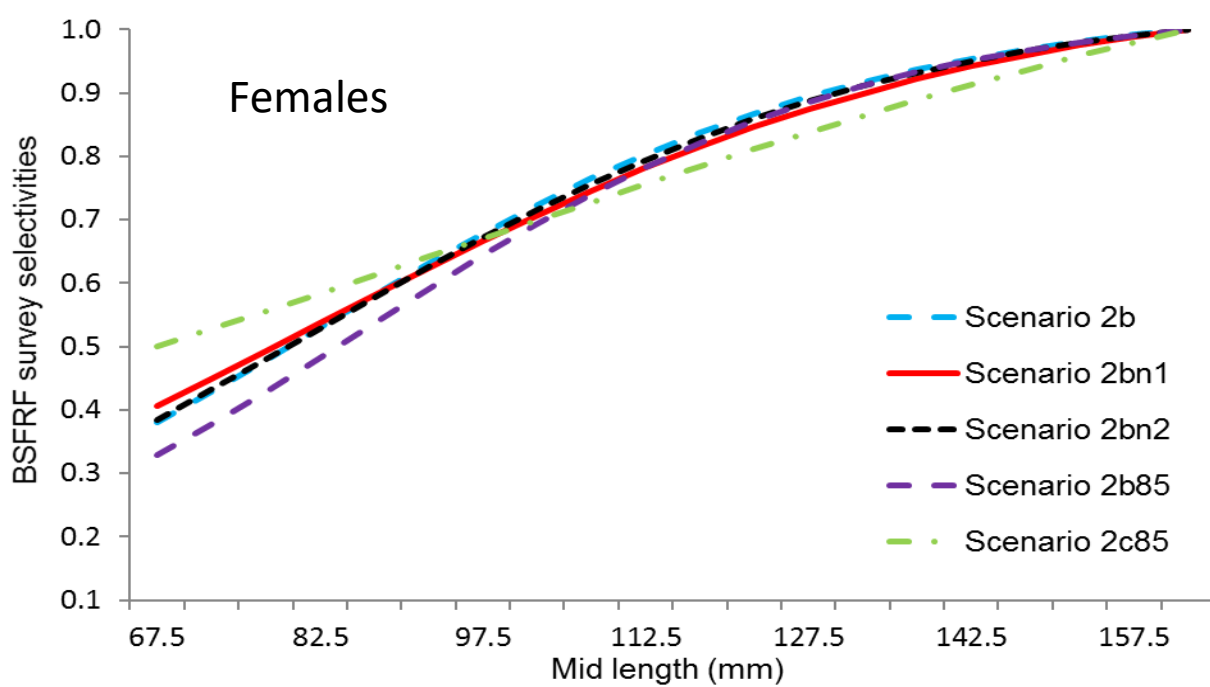


Comparisons of observed and predicted catch mortality biomass under scenarios 2b(solid black), 2bn1(dashed red), and 2bn2(green lines). Mortality biomass is equal to caught biomass times a handling mortality rate.

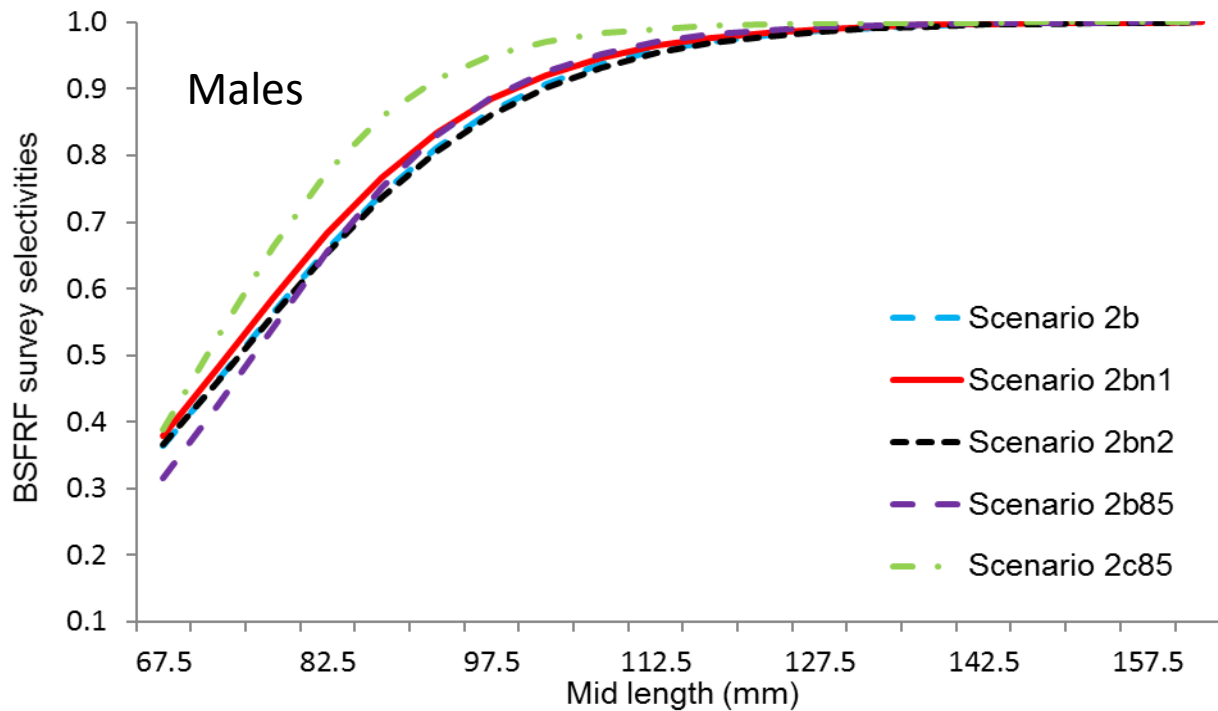


Estimated selectivities of NMFS trawl survey during 1982-2016 with different dataset of BSFRF survey data and five scenarios

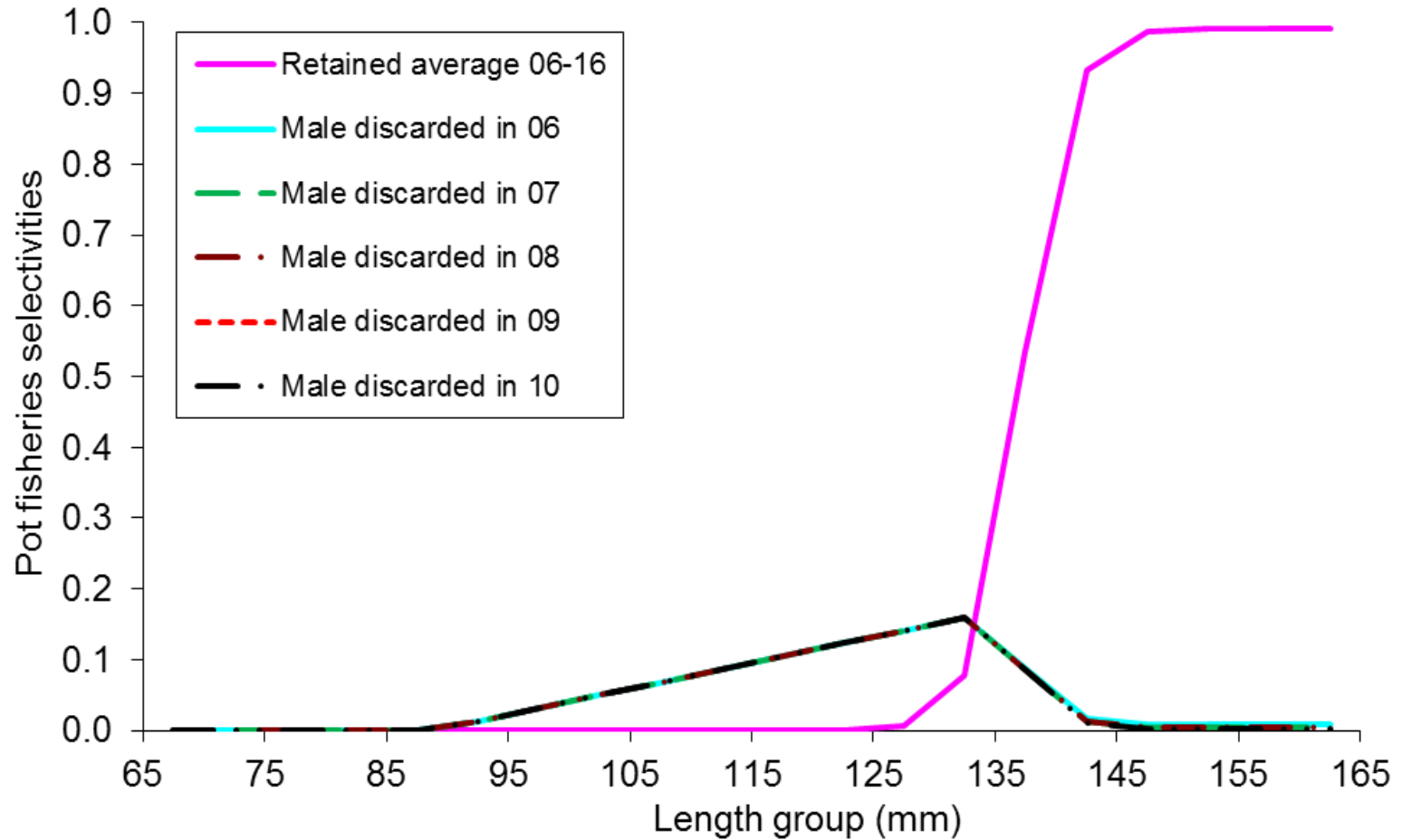




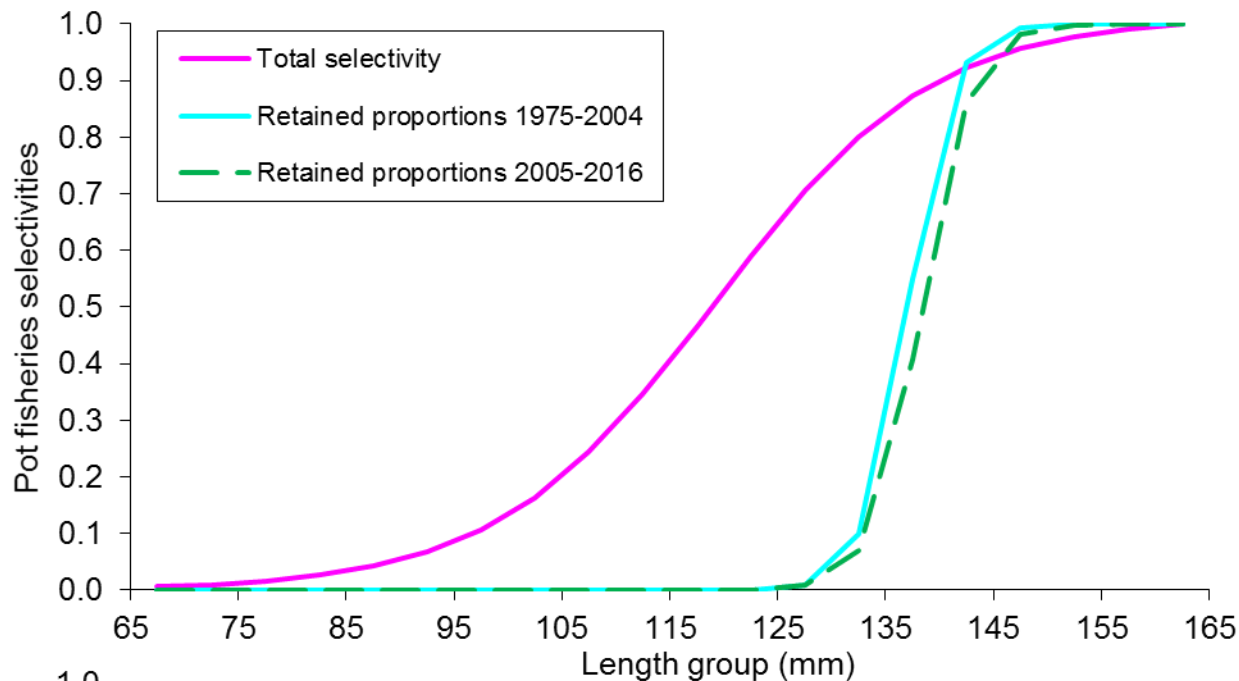
Estimated selectivities of BSFRF trawl survey during 2007-08 and 2013-2016 with five scenarios



## Estimated directed pot fishery selectivities for scenario 2b





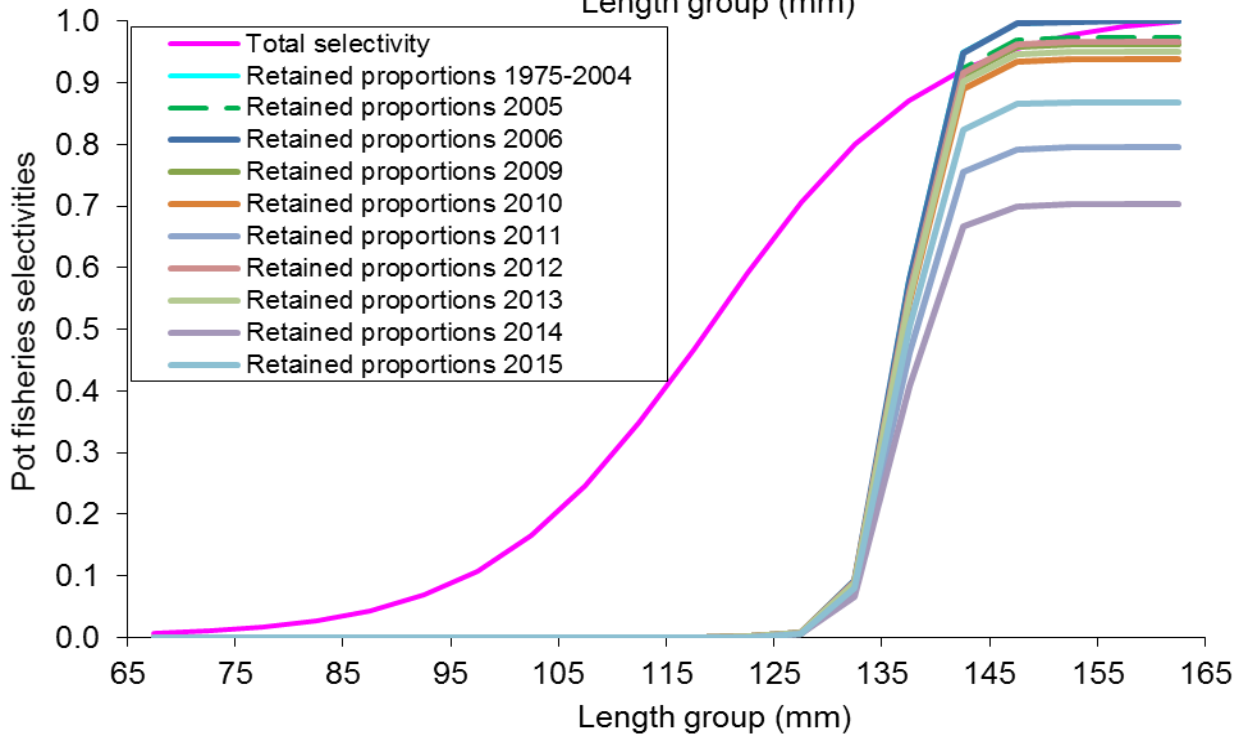


## Directed pot fishery Selectivity

Scenario 2bn1:

Three logistic curves:

1. Total selectivity,
2. Retained proportion (1975-2004),
3. Retained proportion (2005-present)

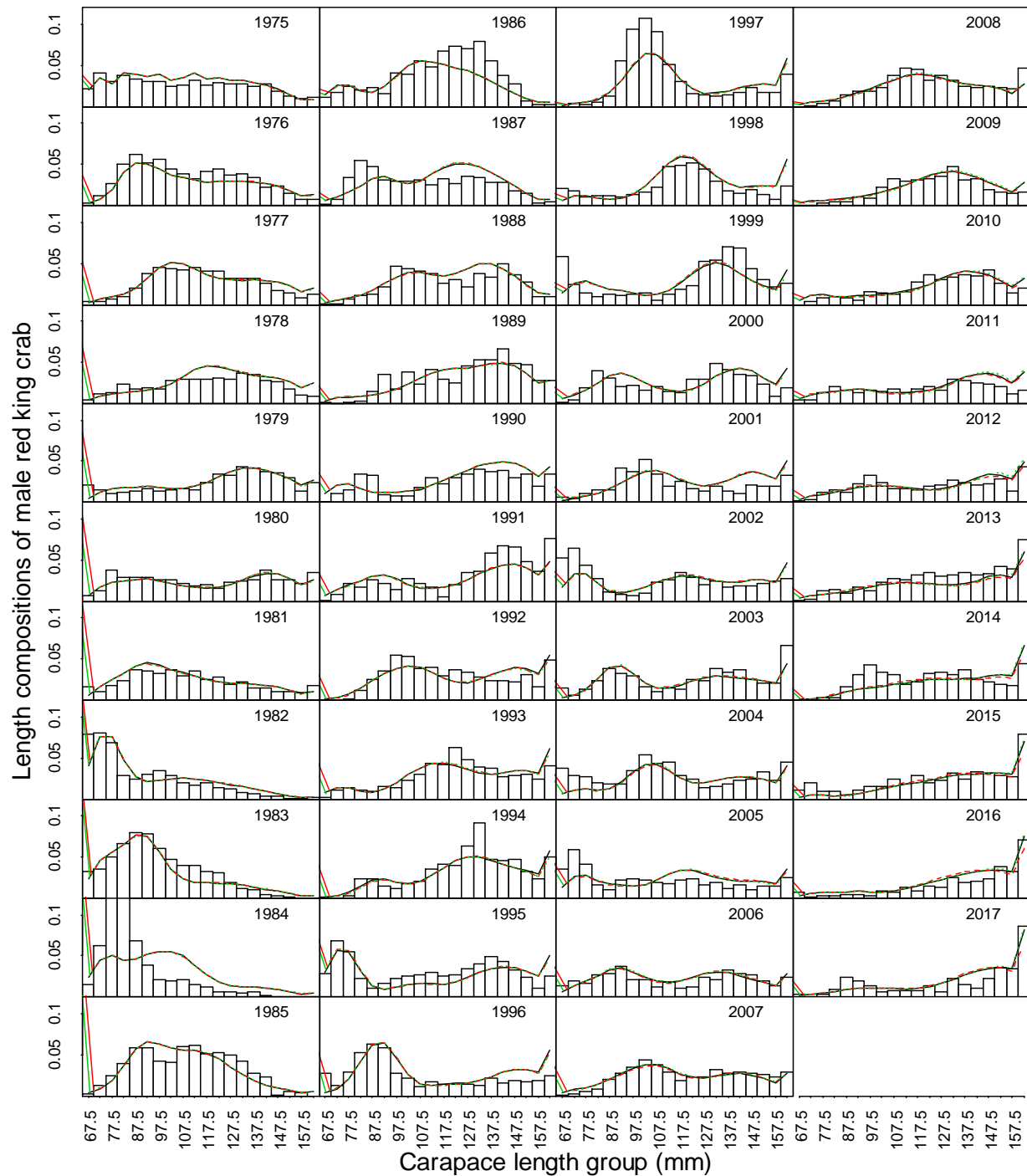


Scenario 2bn2:

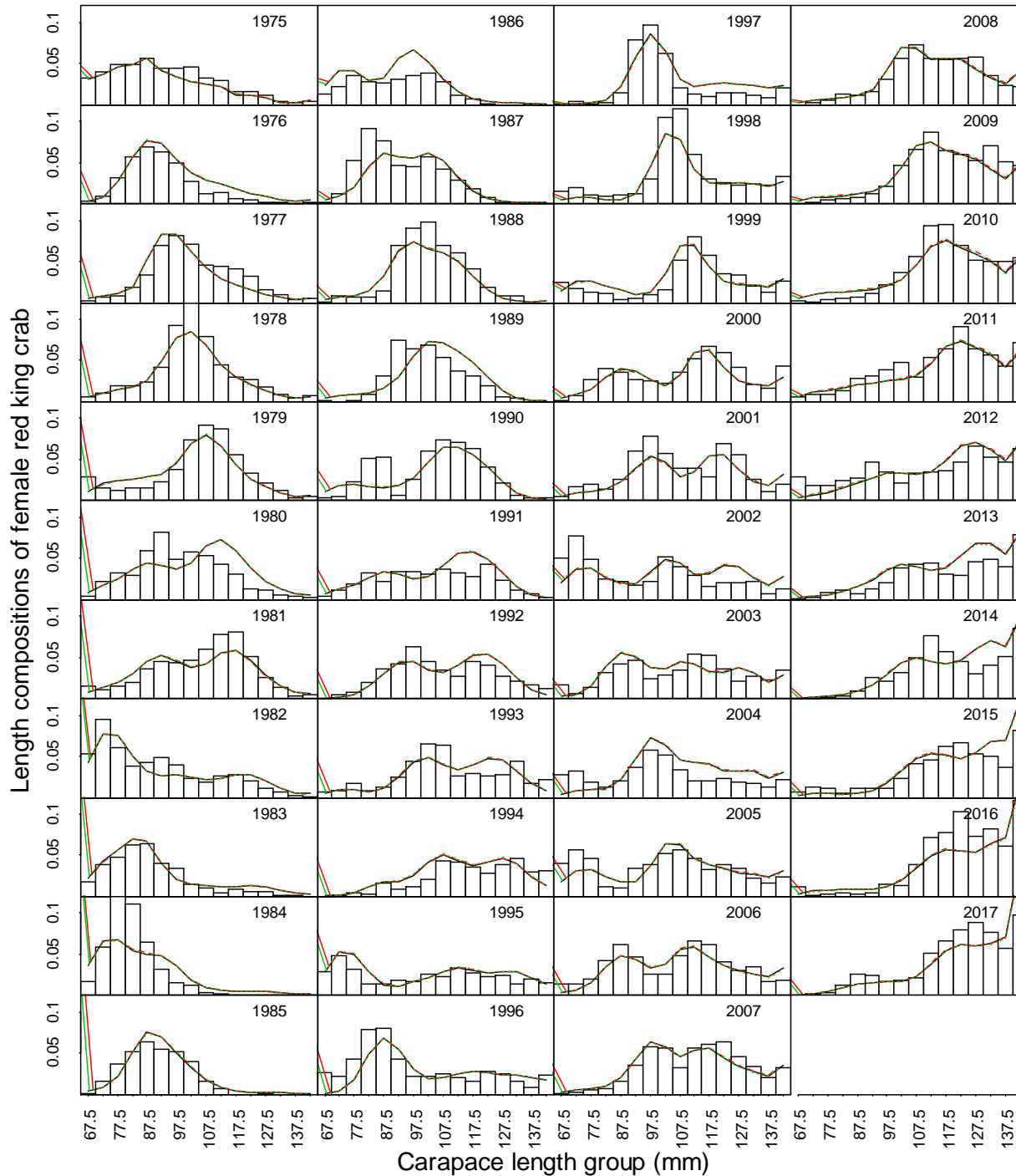
Two logistic curves:

1. Total selectivity,
2. Retained proportion, and annual adjusted factors, 2005-present.

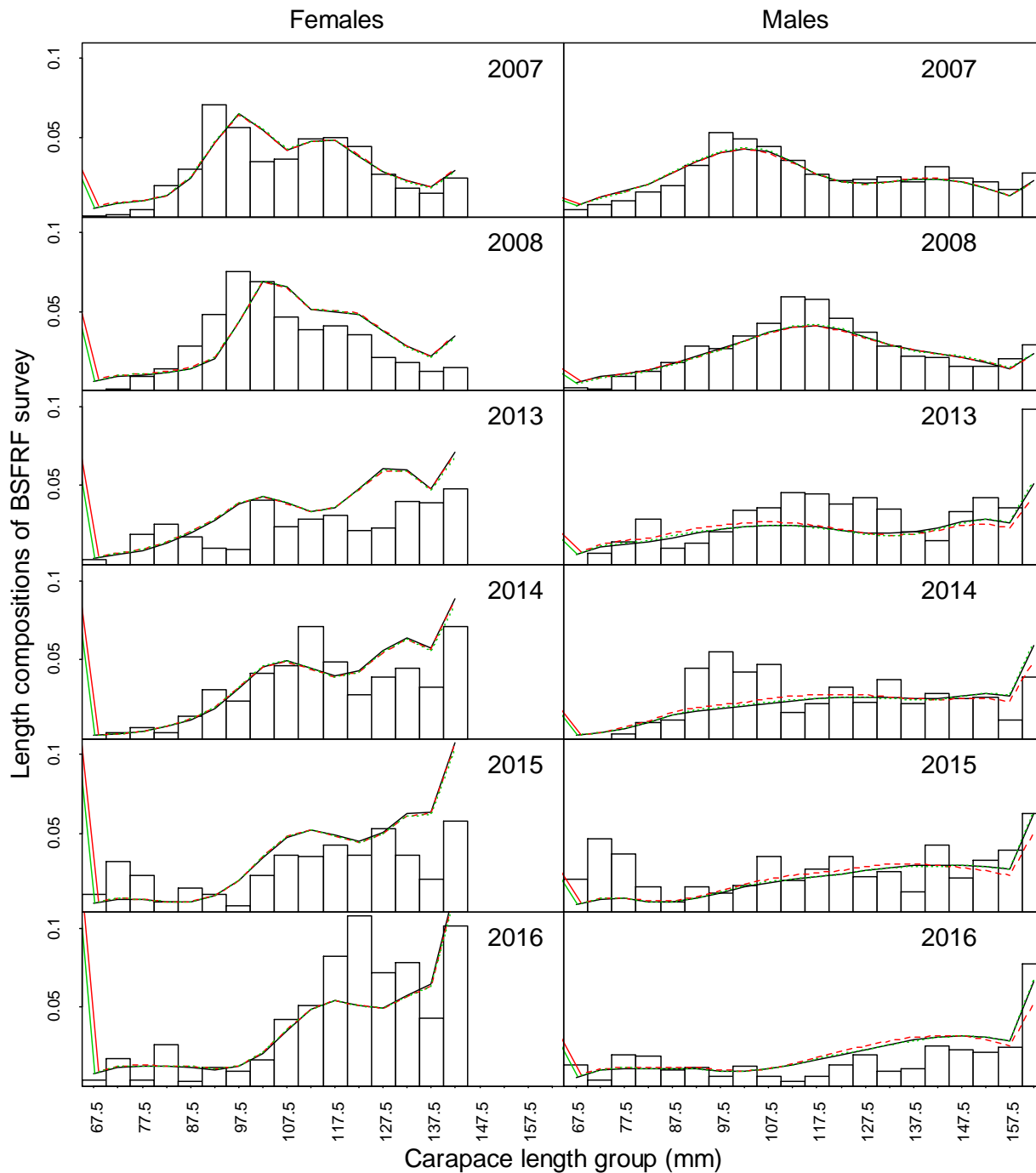
All other no-plotting retained proportions are within the ranges of max and min proportions here.



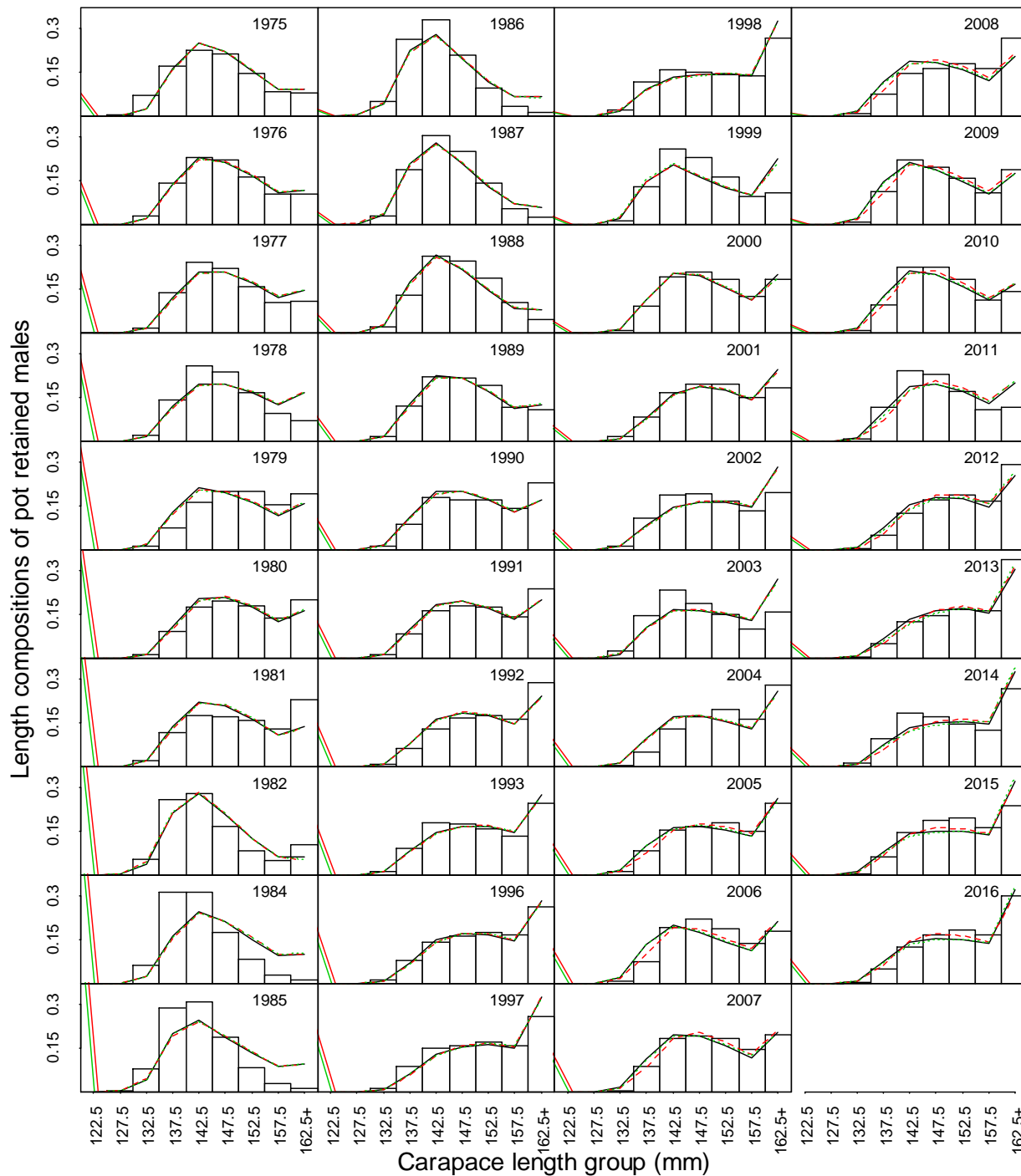
Comparison of area-swept and model estimated NMFS survey length frequencies of Bristol Bay male red king crab by year under scenarios 2b(solid black), 2bn1(dashed red), and 2bn2 (green lines)



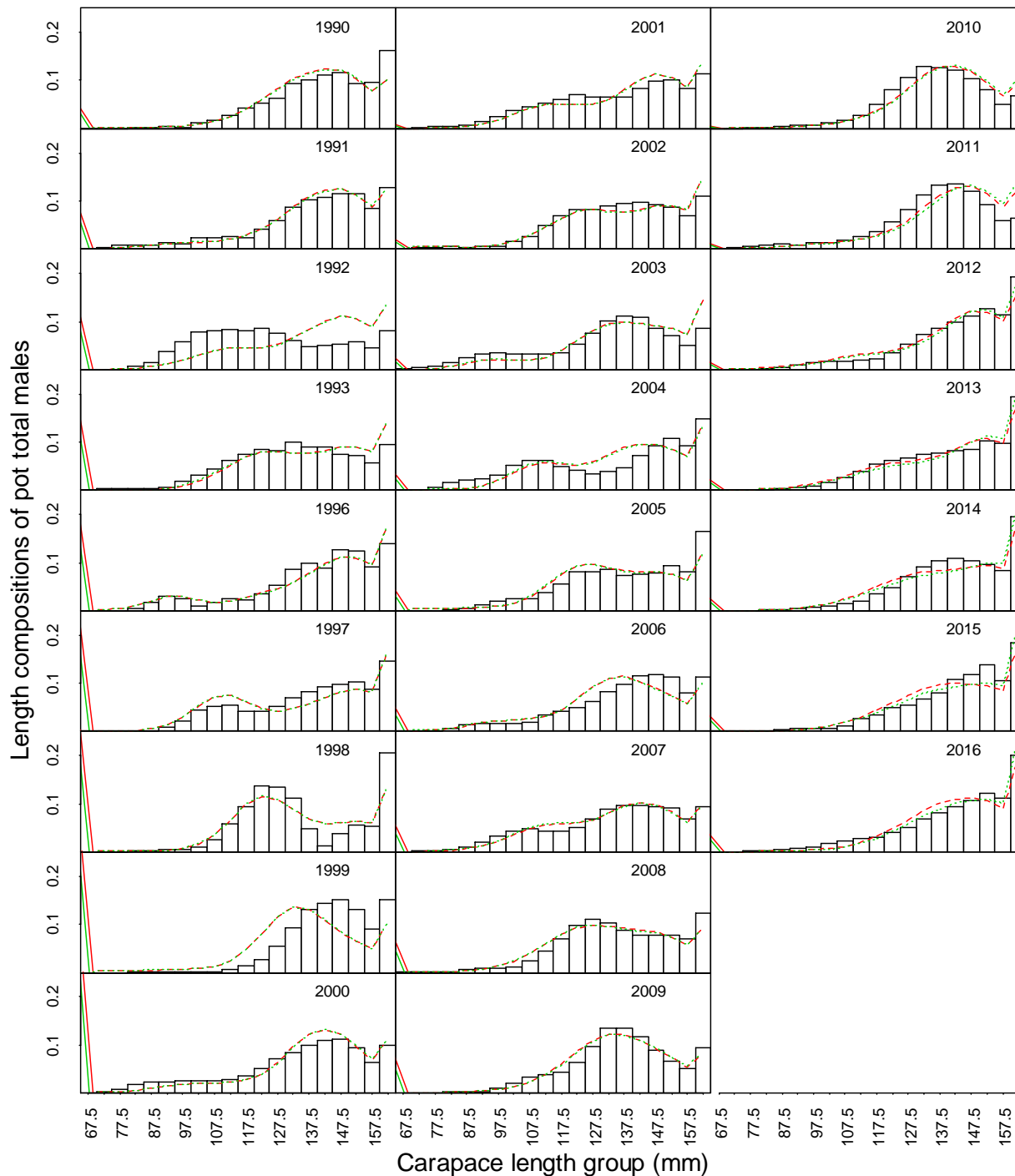
Comparison of area-swept and model estimated NMFS survey length frequencies of Bristol Bay female red king crab by year under scenarios 2b(solid black), 2bn1(dashed red), and 2bn2 (green lines)



Comparison of area-swept and model fits of BSFRF survey length compositions with scenarios 2b (black lines), 2bn1 (red lines), and 2bn2 (green lines)



Comparison of observer and model estimated retained length frequencies of Bristol Bay male red king crab by year in the directed pot fishery under scenarios 2b(solid black), 2bn1 (dashed red), and 2bn2 (green lines).

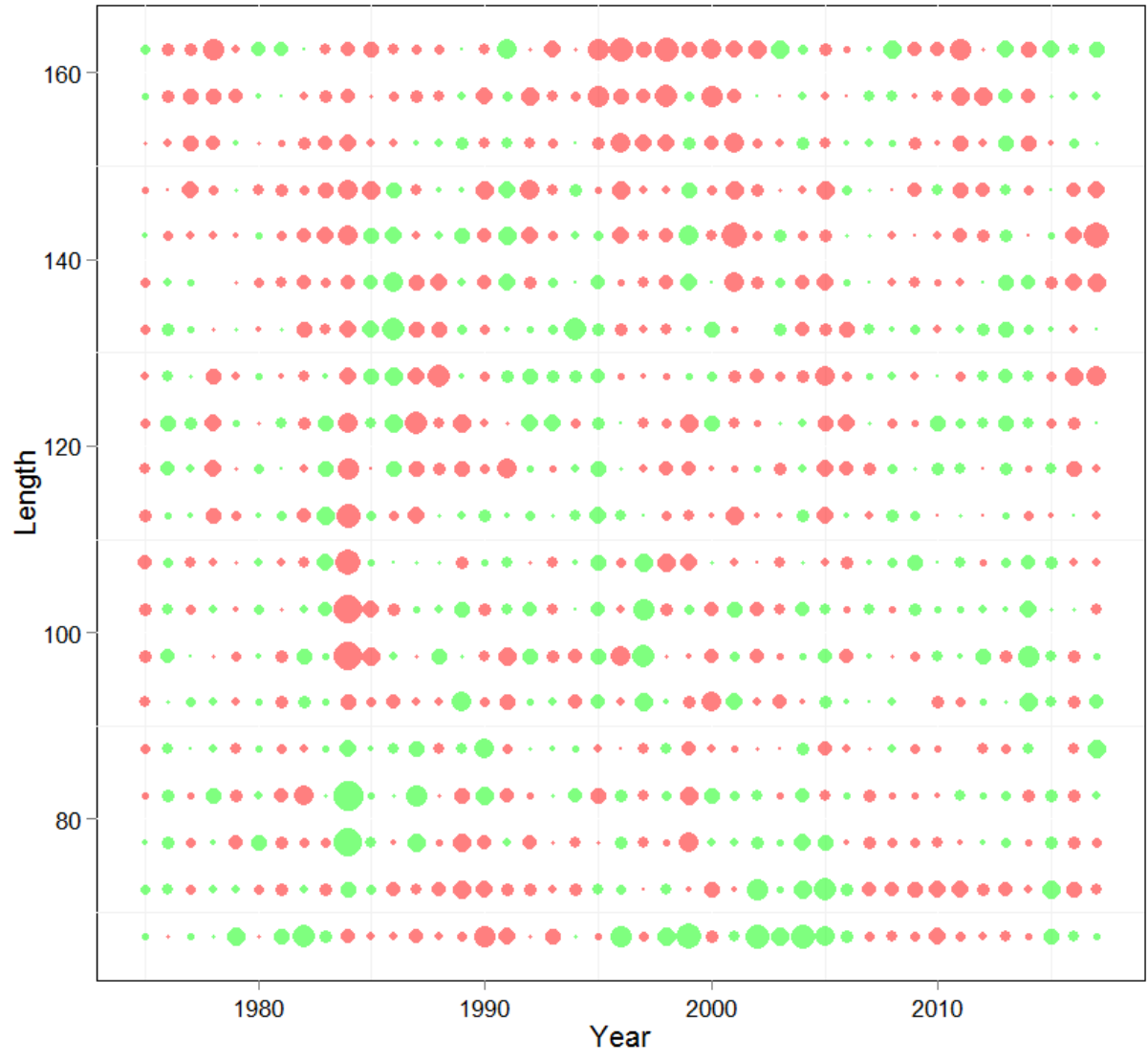


Comparison of observer and model estimated total length frequencies of Bristol Bay male red king crab by year in the directed pot fishery under scenarios 2bn1(dashed red), and 2bn2 (green lines).

# Scenario 2bn1, Trawl Survey Males

clr • <0 • >0

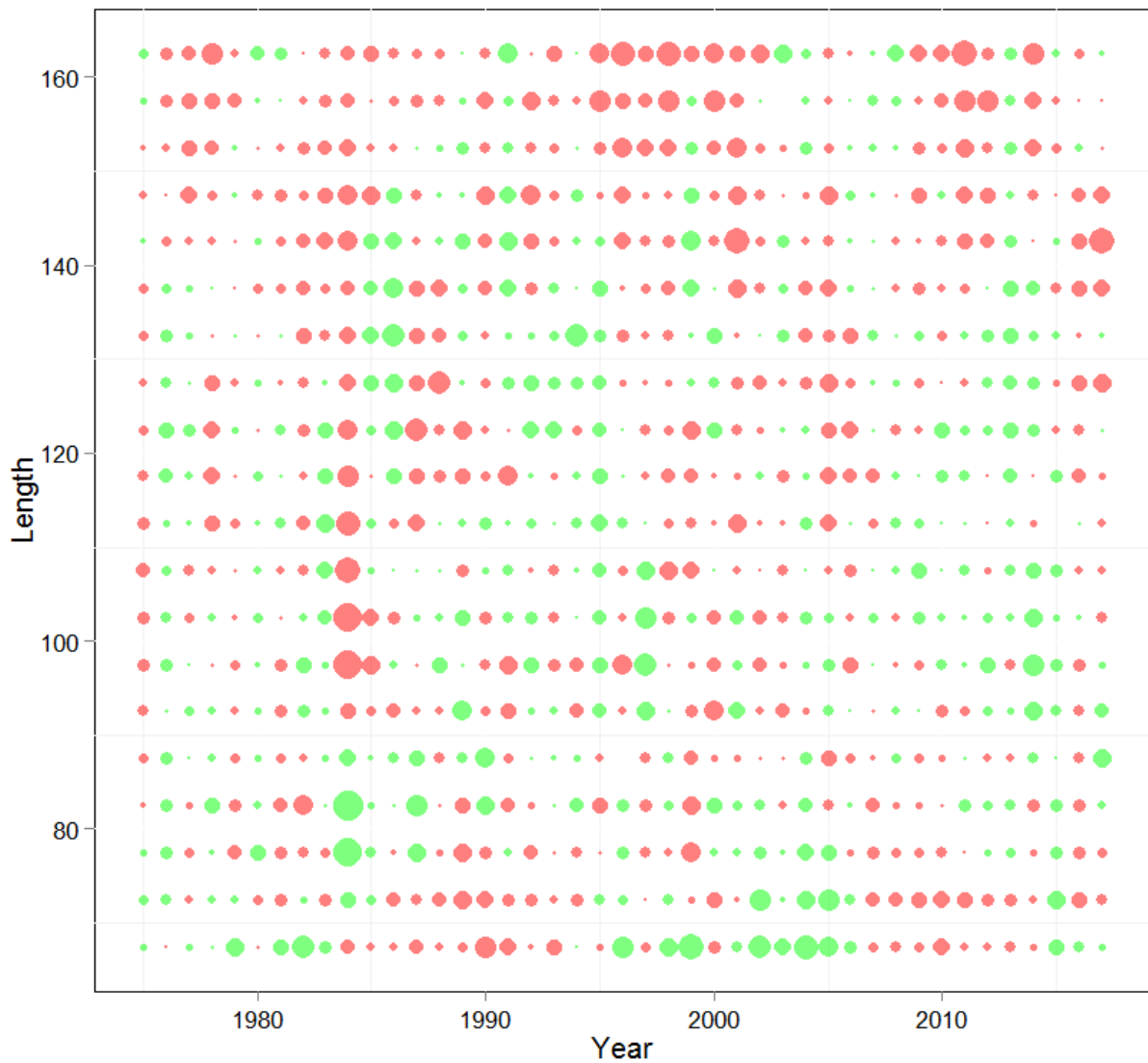
Residual  0.5  1.0  1.5  2.0  2.5



# Scenario 2bn2, Trawl Survey Males

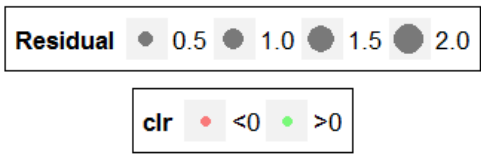
clr • <0 • >0

Residual • 0.5 • 1.0 • 1.5 • 2.0 • 2.5





# Scenario 2bn1, Trawl Survey Females



# Scenario 2bn2, Trawl Survey Females

clr • <0 • >0

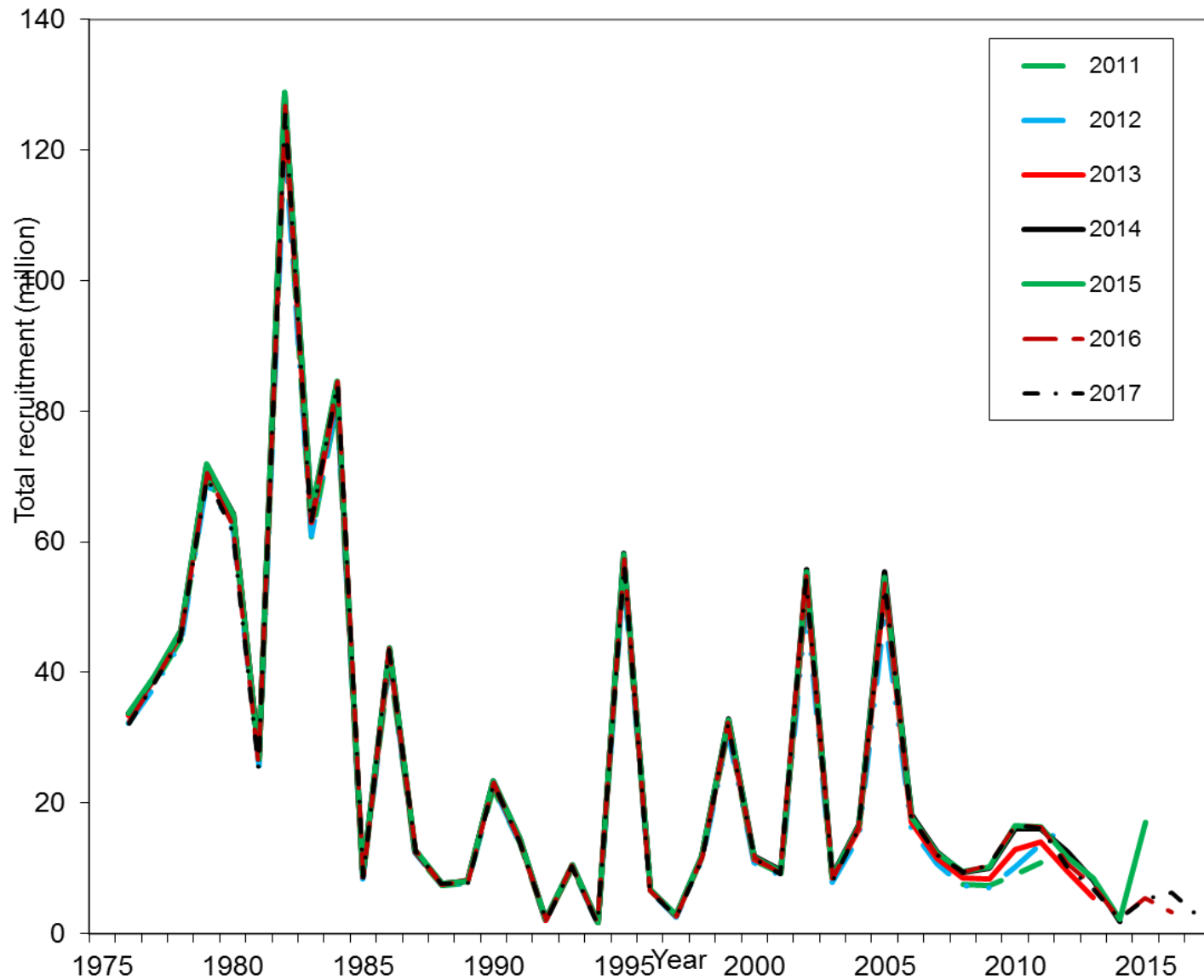
Residual ● 0.5 ● 1.0 ● 1.5



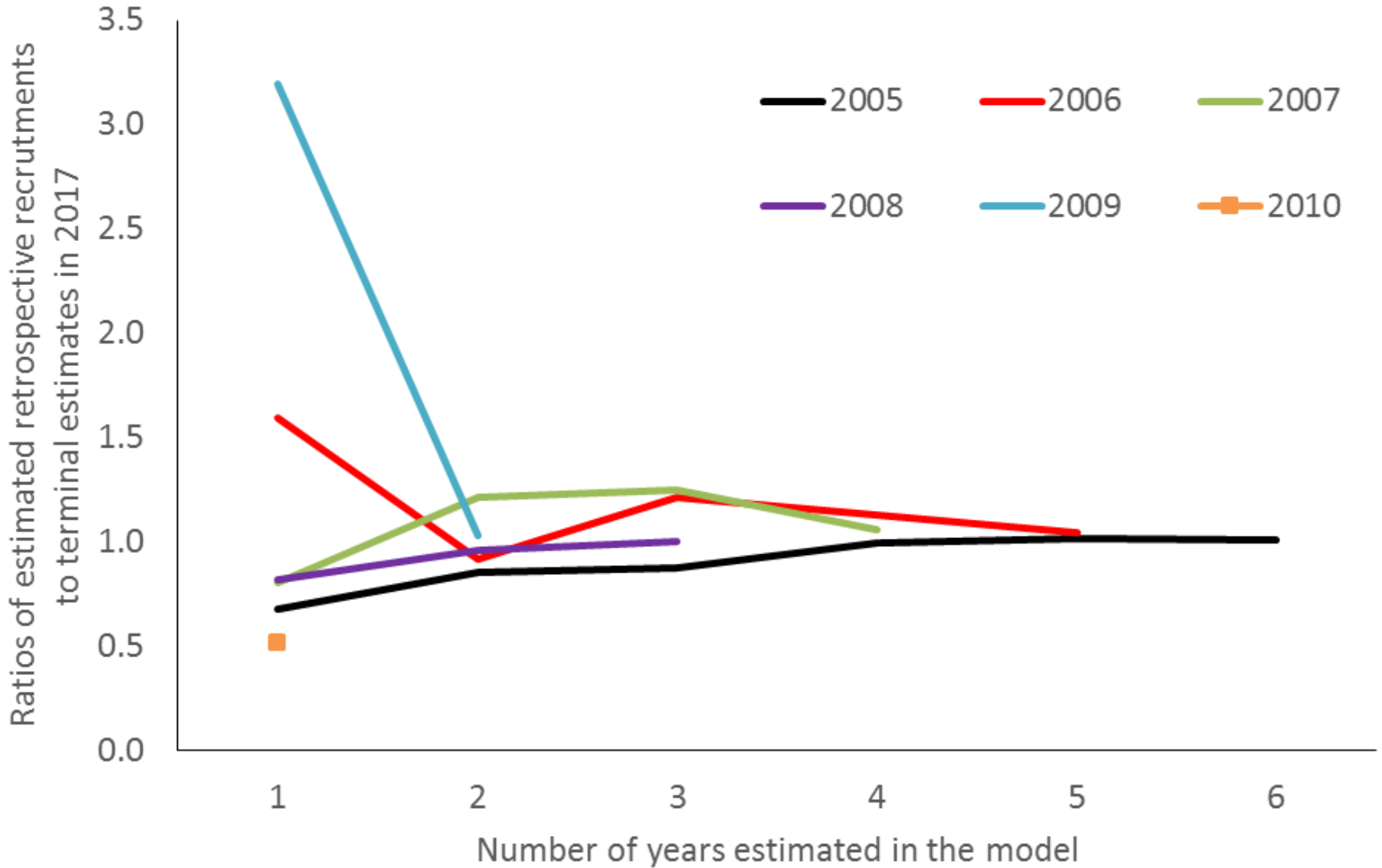
# Negative loglikelihood components for scenarios 2b, 2bn1, 2bn2, 2b85 & 2c85 and differences in negative loglikelihood components among model scenarios

	Scenario									
	2b	2bn1	2bn2	2b85	2c85	2b- 2bn1	2b- 2bn2	2bn1- 2bn2	2b85- 2c85	
Negative log likelihood	2b	2bn1	2bn2	2b85	2c85	2b- 2bn1	2b- 2bn2	2bn1- 2bn2	2b85- 2c85	
R-variation	87.22	87.80	86.27	48.06	54.29	-0.58	0.95	1.53	-6.23	
Length-like-retained	-1038.9	-1047.0	-1039.5	-834.8	-834.4	8.09	0.62	-7.47	-0.40	
Length-like-male	-1092.4	-1224.4	-1226.3	-1092.6	-1094.2	132.00	133.89	1.89	1.59	
Length-like-discfemale	-812.44	-812.44	-811.84	-795.32	-796.43	0.00	-0.60	-0.60	1.11	
Length-like-survey	-48629	-48610	-48632	-37848	-37759	-18.60	3.00	21.60	-88.50	
Length-like-disctrawl	-3767.1	-3784.5	-3785.1	-2957.1	-2962.0	17.38	17.97	0.59	4.92	
Length-like-discfix	-773.41	-773.29	-774.05	-773.38	-773.13	-0.12	0.64	0.76	-0.25	
Length-like-discTanner	-467.04	-468.17	-468.51	-468.44	-465.25	1.13	1.47	0.34	-3.20	
Length-like-bsfrfsurvey	-645.73	-645.18	-647.28	-644.35	-641.97	-0.55	1.55	2.10	-2.38	
Catchbio_retained	51.14	68.04	47.04	49.39	48.37	-16.90	4.10	21.00	1.02	
Catchbio_discmale	229.04	275.48	191.62	224.63	220.82	-46.44	37.42	83.86	3.80	
Catchbio-discfemale	0.11	0.09	0.10	0.08	0.45	0.02	0.01	-0.01	-0.37	
Catchbio-disctrawl	0.22	0.24	0.25	0.05	0.07	-0.03	-0.03	0.00	-0.01	
Catchbio-discfix	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Catchbio-discTanner	0.13	0.15	0.15	0.10	1.72	-0.02	-0.02	-0.01	-1.62	
Biomass-trawl survey	103.70	105.66	108.41	51.06	53.65	-1.95	-4.71	-2.75	-2.59	
Biomass-bsfrfsurvey	-8.30	-7.41	-8.52	-8.47	-8.40	-0.89	0.22	1.11	-0.07	
Q-trawl survey	3.84	8.60	6.22	0.22	0.00	-4.76	-2.38	2.38	0.22	
Others	18.10	17.89	26.90	14.99	14.33	0.21	-8.80	-9.02	0.66	
Total	-56741	-56809	-56926	-45034	-44942	68	185	117	-92	
Free parameters	292	293	304	246	245	-1	-12	-11	1	
B35%(t)	25050	24283	25119	23512	21985	767	-69	-836	1527	
F35%	0.29	0.31	0.33	0.30	0.30	-0.02	-0.04	-0.02	0.00	
MMB2017(t)	21312	19269	22347	23089	20570	2043	-1035	-3078	2519	
OFL2017	5599.7	4659.0	6186.5	7448.9	6269.2	940.7	-586.8	-1527.5	1179.7	
ABC2017(t)	5039.7	4193.1	5567.9	6704.0	5642.3	846.6	-528.1	-1374.8	1061.7	
Fofl2017	0.24	0.24	0.29	0.29	0.28	0.00	-0.05	-0.05	0.01	
Q82-17	0.97	1.00	0.98	0.91	0.92	-0.03	-0.01	0.02	-0.01	

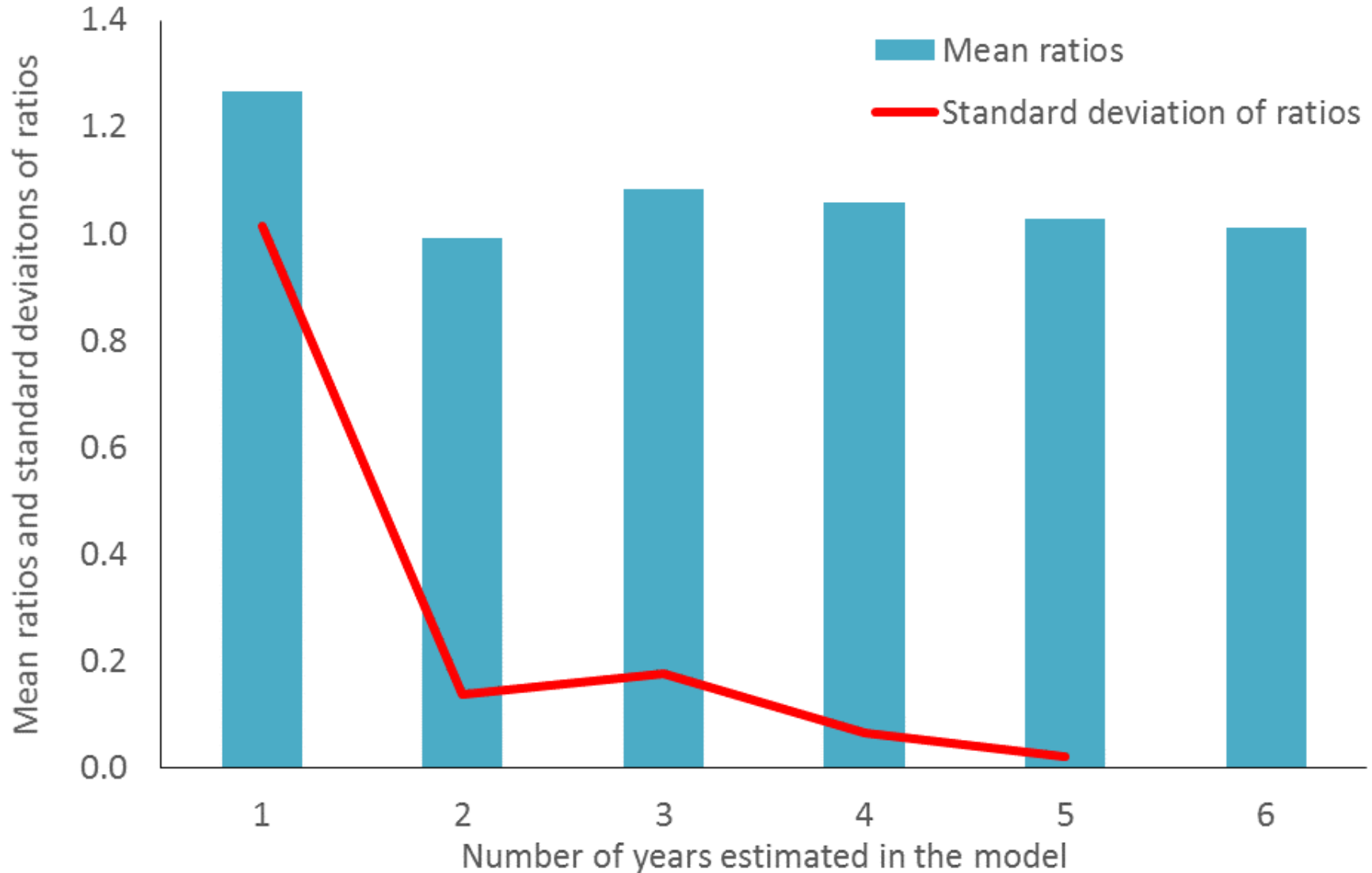
# Comparison of hindcast estimates of total recruitment for scenario 2b from 1976 to 2017 made with terminal years 2011-2017.



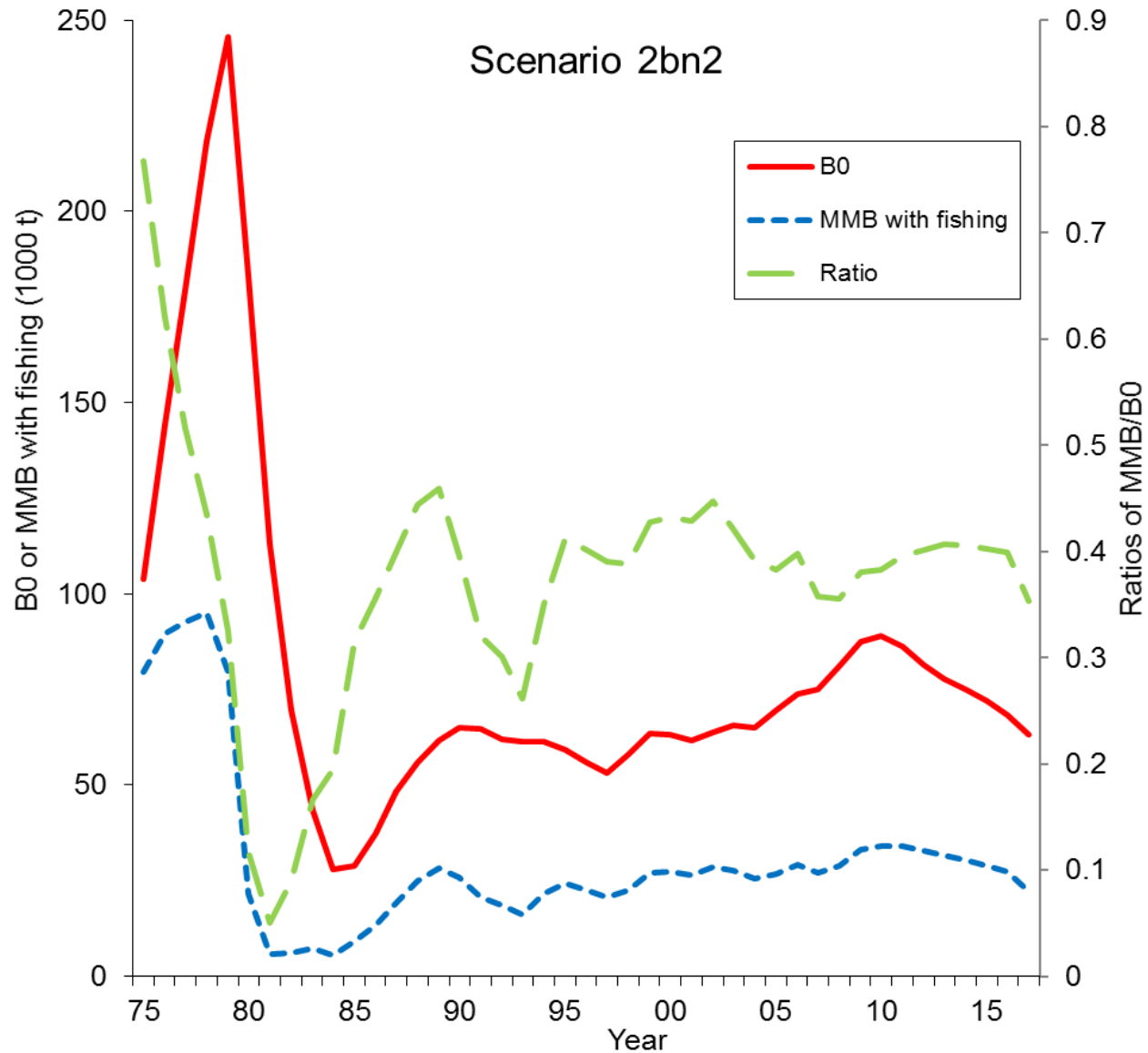
# Evaluation of retrospective errors on recruitment estimates as a function of the number of years in the model for scenario 2b



Mean ratios of retrospective estimates of recruitments to those estimated in the most recent year (2017) and Sdev. of the ratios as a function of the number of years in the model for scenario 2b.



Estimated B0, MMB with fishing, and ratios of MMB/B0 from 1975 to 2017 for scenario 2bn2 for Bristol Bay red king crab.



# Summary

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- 1) Subtraction method is a reasonable way to estimate total male discard biomass in the directed pot fishery.
- 2) Scenario 2bn2 fits the data very well and results in similar absolute mature male biomass estimates to those by scenario 2b.
- 3) Starting the model in 1985 generally results in lower trawl survey catchability estimates.
- 4) Recruitment estimates in terminal years are highly uncertain, and uncertainties of recruitment estimates decrease sharply from one year estimated in the model to two or more years in the model.
- 5) Estimated  $B_0$  values change greatly over time; however, without an S-R model and quantified environmental effects, estimated  $B_0$  values do not provide much valuable information.



# Recommendations

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- 1) Scenario 2bn2 for September 2018 assessments because of better fit to the data and better estimating male discard biomass in the directed pot fishery.
- 2) Recruitment in terminal year should not be used for estimating  $B_{35\%}$ . That is, mean recruitment is estimated from recruitments from 1984 to endyear – 1.

*Thanks*