

Bering Sea Snow Crab Assessment. September 2015. Results for Model 0.

Model 0 is the September 2014 model with the sd on growth = 0.5.

Table 6. Model 0 estimates of population biomass (1000t), population numbers, male, female and total mature biomass(1000t) and number of males greater than 101 mm in millions. Recruits enter the population at the beginning of the survey year after molting occurs. * Numbers by length estimated in the first year, so recruitment estimates start in second year.

Year	Biomass (1000t 25mm+)	numbers (million crabs 25mm+)	Female mature biomass (1000t)	Male mature biomass (1000t)	Total mature biomass (1000t)	Number of males >101mm (millions)	Recruitment (millions, 25 mm to 50 mm)	Male mature biomass at mating time(Feb of survey year+1) (1000t)	Full selection fishing mortality	Exp.rate of total male catch on mature male biomass
1978/79	610.9	11951.8	188.2	195.8	384.0	146.0	1686.1	140.8	0.44	0.15
1979/80	692.2	11780.8	253.0	176.1	429.0	120.7	1502.1	111.3	0.81	0.24
1980/81	774.8	11393.7	373.2	133.4	506.5	63.7	1029.3	78.7	2.20	0.31
1981/82	810.9	10328.9	398.3	126.1	524.4	35.4	343.6	92.2	1.52	0.17
1982/83	820.5	8280.3	380.8	184.4	565.2	96.4	1343.1	144.3	0.38	0.09
1983/84	843.4	8878.1	336.5	278.1	614.5	229.8	2207.3	222.8	0.15	0.06
1984/85	890.8	10969.7	315.2	323.9	639.1	300.1	2764.4	243.4	0.28	0.12
1985/86	964.1	13462.6	337.7	313.4	651.1	289.7	5018.8	219.6	0.46	0.18
1986/87	1160.1	19682.9	390.1	278.9	669.0	227.5	696.8	187.3	0.65	0.21
1987/88	1249.7	15346.9	508.1	276.3	784.4	186.5	4949.4	171.1	1.30	0.29
1988/89	1445.0	21030.0	523.6	311.1	834.7	192.7	229.9	195.0	1.47	0.30
1989/90	1476.6	15465.6	585.9	381.0	966.9	252.1	603.6	249.2	1.10	0.26
1990/91	1418.9	12514.8	564.4	468.3	1032.6	360.6	716.7	247.3	1.95	0.42
1991/92	1206.0	10557.0	487.5	423.2	910.8	301.7	6920.9	212.1	2.59	0.46
1992/93	1263.4	21507.9	420.3	352.2	772.5	237.0	1776.6	192.1	2.21	0.41
1993/94	1300.6	18660.8	542.5	311.1	853.6	209.0	1011.4	193.0	1.28	0.28
1994/95	1314.0	15462.2	607.0	274.1	881.1	130.2	293.7	194.1	0.91	0.16
1995/96	1287.6	11971.4	567.3	312.1	879.4	141.0	147.7	233.4	0.70	0.14
1996/97	1218.3	9251.5	485.3	442.8	928.1	326.5	206.6	320.5	0.54	0.16
1997/98	1060.3	7379.4	399.1	521.5	920.6	480.2	910.1	325.2	0.81	0.28
1998/99	828.7	7305.5	326.8	402.2	729.0	352.1	1159.7	249.2	0.86	0.27
1999/00	677.0	7680.3	289.4	272.0	561.4	208.6	344.3	214.0	0.20	0.07
2000/01	613.6	6356.0	279.4	222.0	501.4	163.0	329.2	175.5	0.19	0.06
2001/02	560.2	5406.5	255.7	189.7	445.4	129.2	696.5	144.7	0.34	0.10
2002/03	527.2	5446.3	222.9	179.3	402.2	124.0	1533.9	138.3	0.31	0.09
2003/04	547.4	7103.4	204.1	188.1	392.2	150.5	2280.1	147.7	0.20	0.07
2004/05	627.5	9706.3	218.8	189.1	407.8	160.5	787.8	147.8	0.19	0.07
2005/06	675.8	8520.7	267.6	181.9	449.5	142.6	979.3	136.4	0.34	0.12
2006/07	711.7	8156.6	281.2	188.2	469.4	132.9	153.7	141.9	0.37	0.11

C1 Snow Crab Model 0 Results
October 2015

Year	Biomass (1000t 25mm+)	numbers (million crabs 25mm+)	Female mature biomass(1000t)	Male mature biomass(1000t)	Total mature biomass (1000t)	Number of males >101mm (millions)	Recruit- ment (millions, 25 mm to 50 mm)	Male mature biomass at mating time(Feb of survey year+1) (1000t)	Full selection fishing mortality	Exp.rate of total male catch on mature male biomass
2007/08	703.4	6272.5	273.6	225.1	498.7	169.5	271.0	161.6	0.53	0.16
2008/09	654.1	5194.6	242.7	264.1	506.8	226.6	1418.5	196.6	0.35	0.13
2009/10	632.4	6720.8	206.9	277.6	484.5	258.9	1936.6	212.3	0.24	0.10
2010/11	657.4	8759.5	209.7	258.2	468.0	245.0	1152.5	193.2	0.28	0.12
2011/12	678.6	8582.9	247.2	224.9	472.1	201.3	1061.0	148.7	0.63	0.22
2012/13	684.7	8301.5	268.3	183.7	452.0	129.8	1485.0	124.3	0.78	0.21
2013/14	726.7	8993.1	270.9	191.7	462.5	126.8	1390.0	137.3	0.64	0.17
2014/15	777.3	9286.4	280.4	235.4	515.8	183.1	6147.0	168.0	0.54	0.17
2015/16	1023.7	19012.2	292.2	262.8	555.0	217.9	NA	NA	NA	NA

Snow Model 0 sept 2015

Table 6a. Model 0 predicted survey values for female, male and total mature biomass and numbers of males > 101mm (millions of crab).

	Predicted	Predicted	Predicted	
	Female	Male	total	model
	Survey	survey	survey	Predicted
	Mature	mature	mature	survey
	Biomass:	Biomass:	Biomass:	males>101
				(millions)
1978	146.2	195.3	341.5	146.0
1979	189.7	174.8	364.5	120.7
1980	284.8	131.2	416.0	63.7
1981	307.5	123.4	430.9	35.4
1982	169.5	113.4	282.9	61.4
1983	150.4	173.3	323.7	146.4
1984	140.5	202.7	343.2	191.3
1985	150.1	195.6	345.7	184.7
1986	173.2	172.7	345.9	145.0
1987	224.9	169.3	394.3	118.9
1988	234.2	190.7	424.9	122.8
1989	300.9	218.3	519.1	146.0
1990	290.1	268.9	559.0	208.8
1991	250.7	243.1	493.8	174.7
1992	216.1	202.3	418.4	137.2
1993	278.4	178.0	456.4	121.0
1994	311.9	156.2	468.2	75.4
1995	291.7	178.4	470.1	81.6
1996	249.6	254.4	504.1	189.1
1997	205.3	300.4	505.7	278.1
1998	168.1	231.7	399.8	203.9
1999	148.8	156.4	305.2	120.8
2000	143.6	127.5	271.1	94.4
2001	131.5	108.9	240.4	74.8
2002	114.7	103.0	217.7	71.8
2003	104.9	108.2	213.1	87.2
2004	112.4	108.7	221.1	92.9
2005	137.4	104.3	241.7	82.6
2006	144.5	107.9	252.4	76.9
2007	140.6	129.3	269.9	98.2
2008	124.8	152.0	276.8	131.2
2009	106.4	159.9	266.3	149.9

Tables 9a. Projections using a multiplier on the F35% control rule for 2015/16 to 2025/26 fishery seasons. Median total catch (ABC_{tot} 1000 t), median retained catch (C_{dir} 1000 t), Percent mature male biomass at time of mating relative to B35. Values in parentheses are 90% CI. F is full selection fishing mortality. Model 0 $B_{35\%} = 157.8$ t. $F_{35\%} = 1.42$.

a) 100%OFL Model 0, 100% $F_{35\%}$ $B_{35\%} = 157,800$ t $F_{35\%}=1.42$

Year	ABC_{tot} (1000t)	C_{dir} (1000t)	Percent MMB/ $B_{35\%}$	Full Selection Fishing Mortality
2015/16	83.1(66.2,103.7)	71.7(57.3,89.2)	93.4(83.8,108.2)	1.32
2016/17	64.3(41,86.7)	51.8(33.9,68.1)	93.7(79.5,110.8)	1.27
2017/18	67.9(45.8,86.6)	50.9(36.2,63.9)	108.4(91.2,130)	1.39
2018/19	85.6(63,111.5)	62.8(47.8,79.1)	136(113.3,167.8)	1.39
2019/20	132.7(102.6,179.8)	106.7(84.4,138.1)	167.6(131.7,226.5)	1.37
2020/21	156(117.1,242.6)	131.9(101.7,197.9)	176(123.2,280)	1.38
2021/22	127(70.5,270.8)	106.1(58,221.6)	155.8(97.3,299.4)	1.39
2022/23	102.3(38.4,252.6)	83.3(30.7,206.2)	141(80.7,298.4)	1.35
2023/24	89.4(29.2,242.5)	70.9(22.2,199.2)	129.6(72.7,306.7)	1.34
2024/25	80.8(24.5,235.2)	63.1(19,196.4)	124.3(69.6,300.1)	1.3
2025/26	83.1(23.4,232.9)	63.3(17.6,191.2)	124.3(65.8,304.1)	1.32

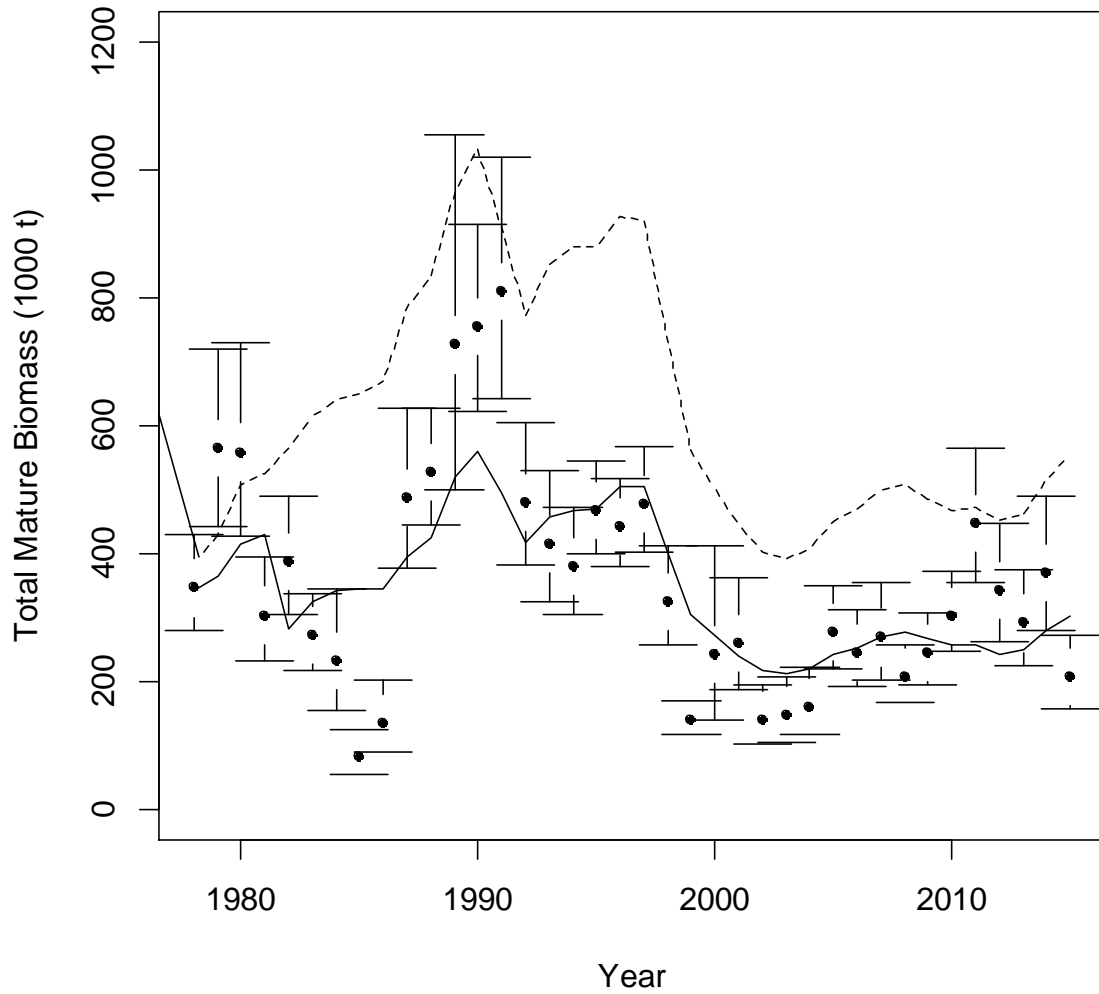


Figure 1. Model 0. Population male mature biomass (1000 t, dotted line), model estimate of survey male mature biomass (solid line) and observed survey male mature biomass with approximate lognormal 95% confidence intervals.

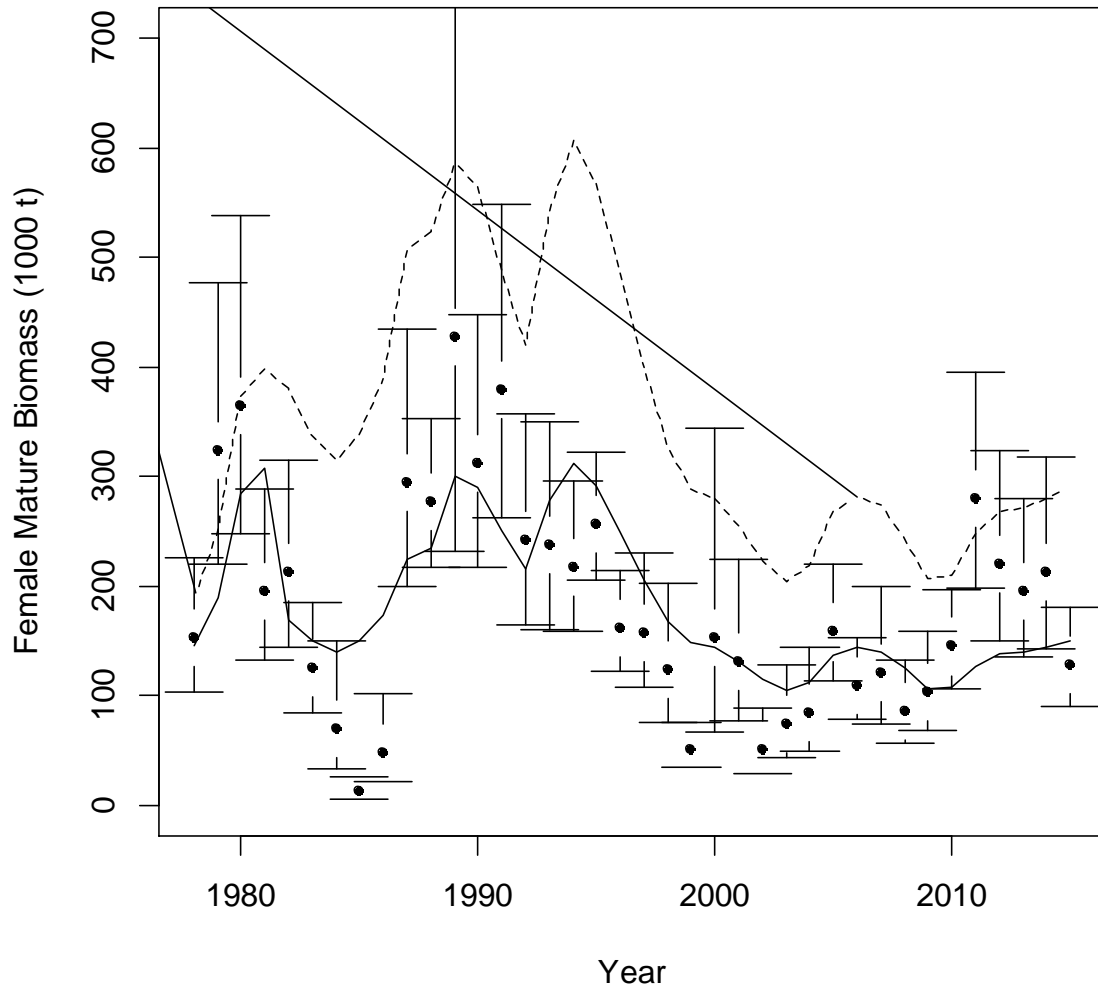


Figure 2. Model 0. Population female mature biomass (1000 t, dotted line), model estimate of survey female mature biomass (solid line) and observed survey female mature biomass with approximate lognormal 95% confidence intervals.

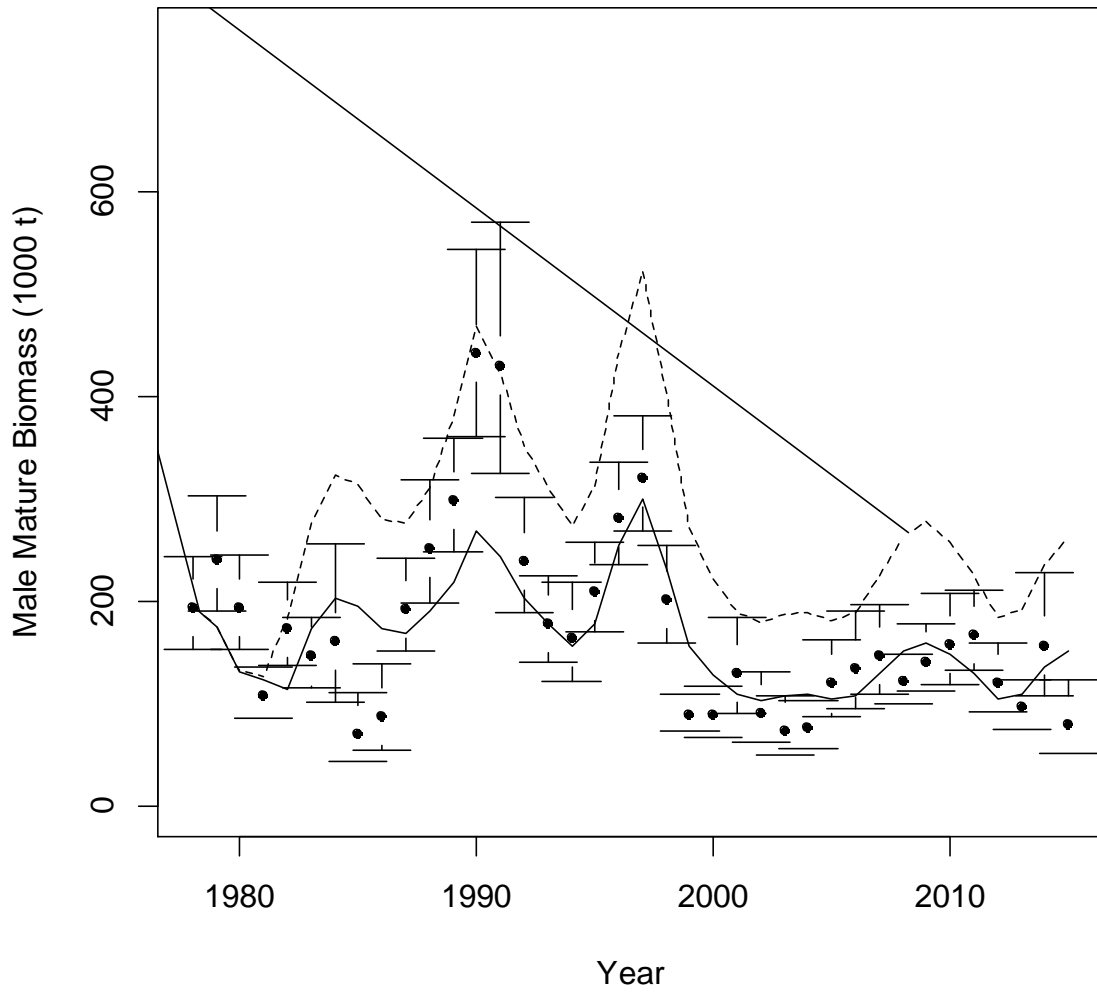


Figure 3. Model 0. Population male mature biomass (1000 t, dotted line), model estimate of survey male mature biomass (solid line) and observed survey male mature biomass with approximate lognormal 95% confidence intervals.

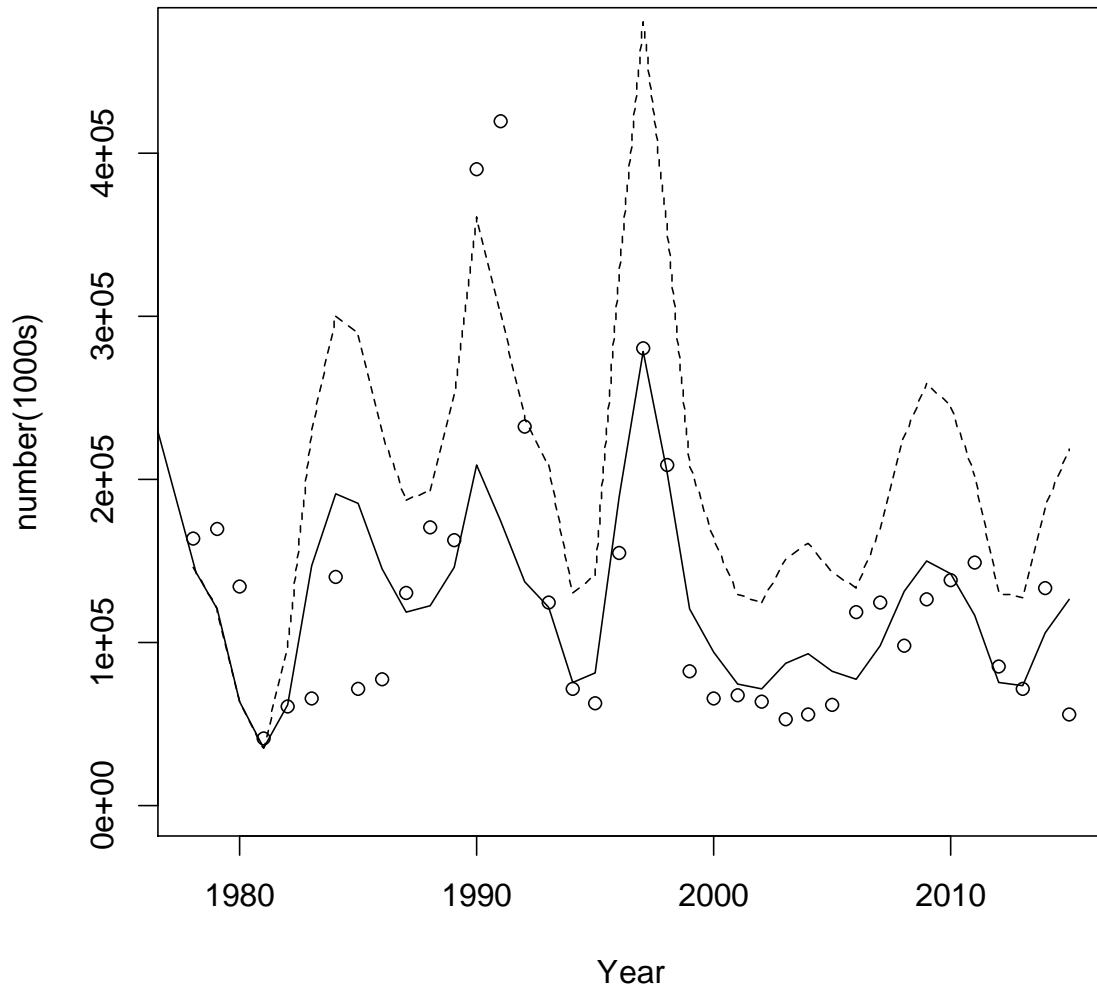


Figure 4. Model 0. Observed survey numbers of males >101mm (circles), model estimates of the population number of males >101mm (solid line) and model estimates of survey numbers of males >101 mm (dotted line).

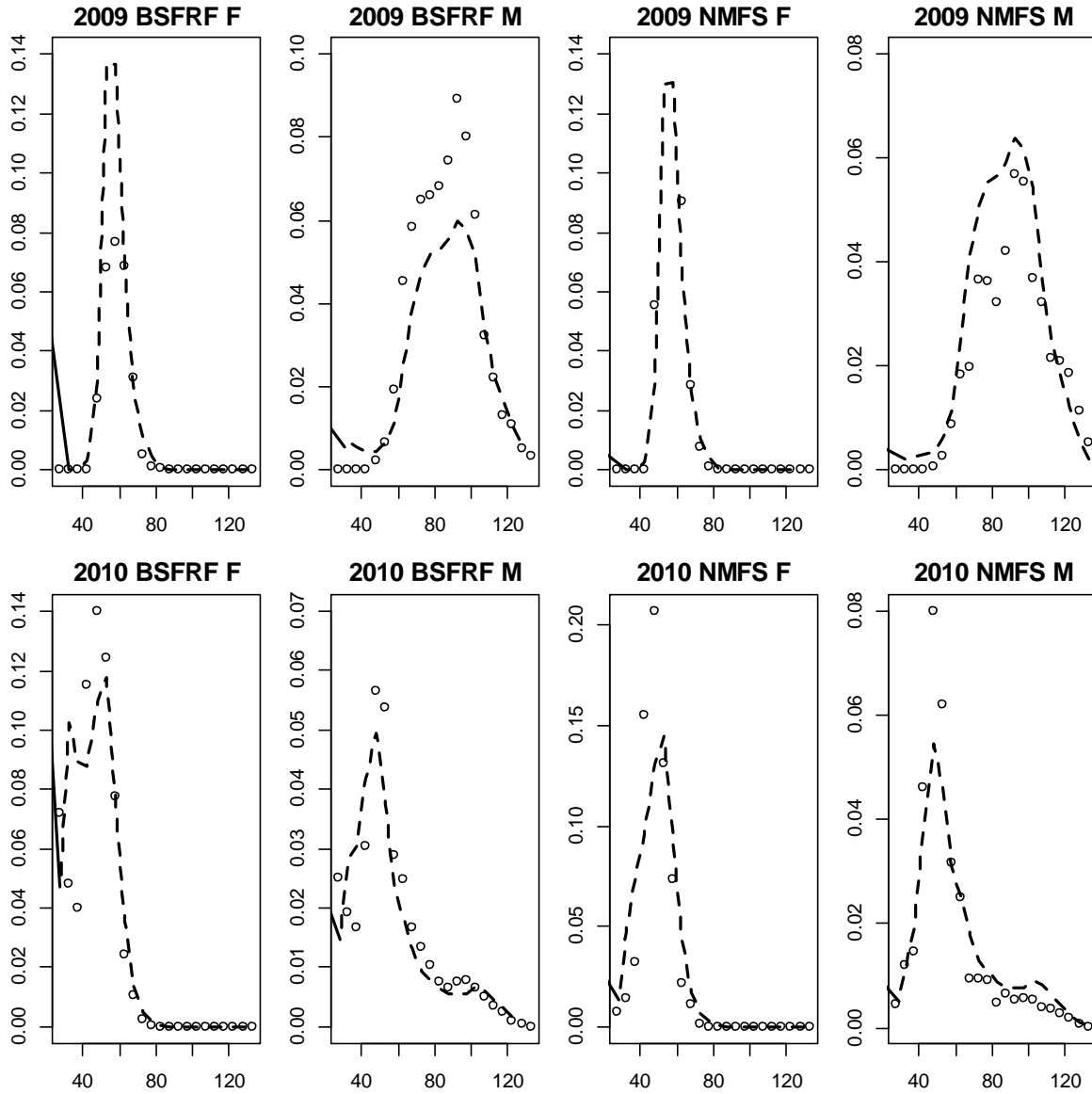


Figure 5. Model 0. Model fit to length frequency for BSFRF and NMFS females and males in the study area.

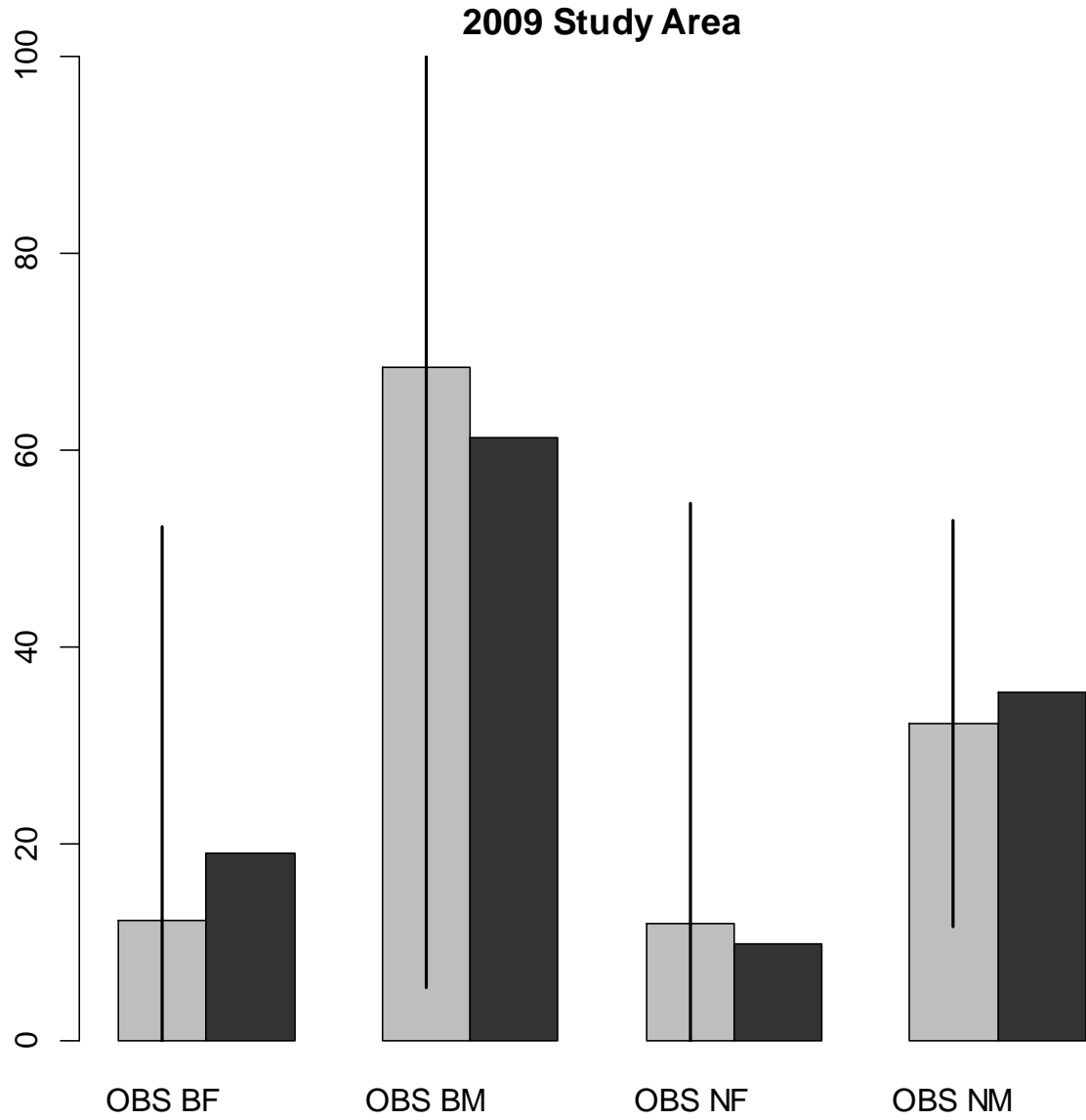


Figure 6. Model 0. Fits to 2009 study area mature biomass by sex for BSFRF and NMFS data.

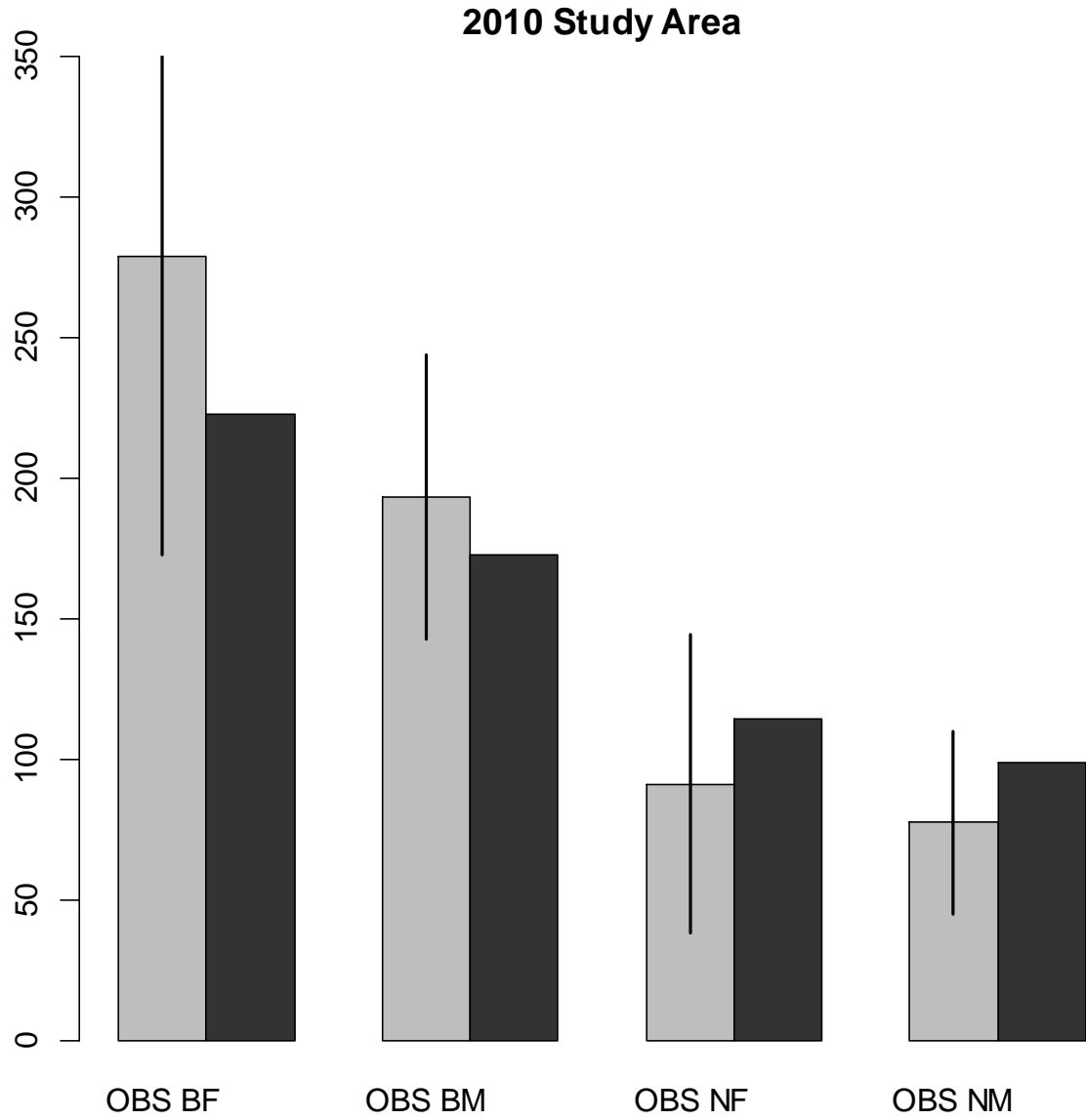


Figure 7. Model 0. Fits to 2010 study area mature biomass by sex for BSFRF and NMFS data.

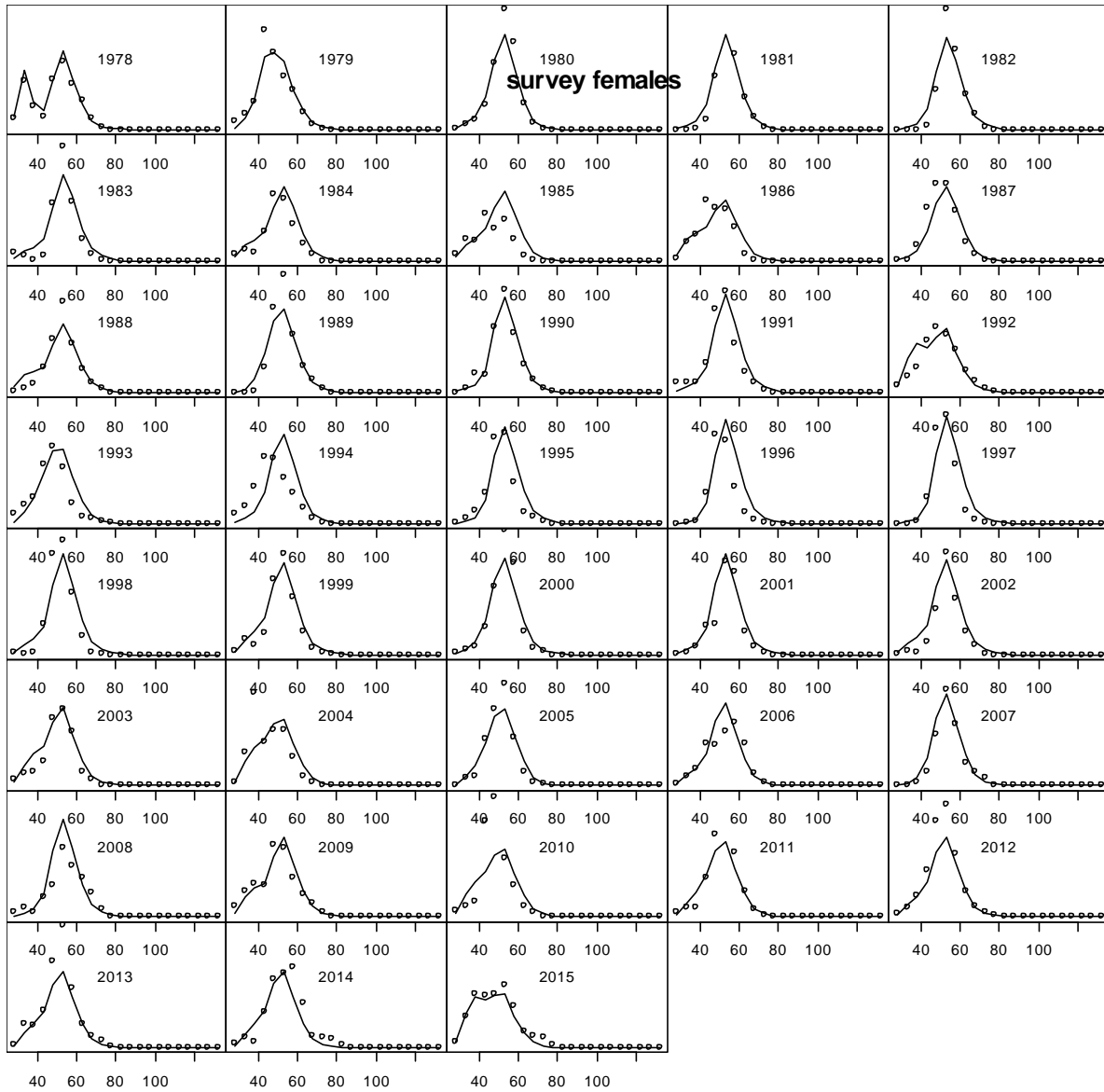


Figure 8. Model 0. Model fit to the survey female size frequency data. Circles are observed survey data. Solid line is the model fit.

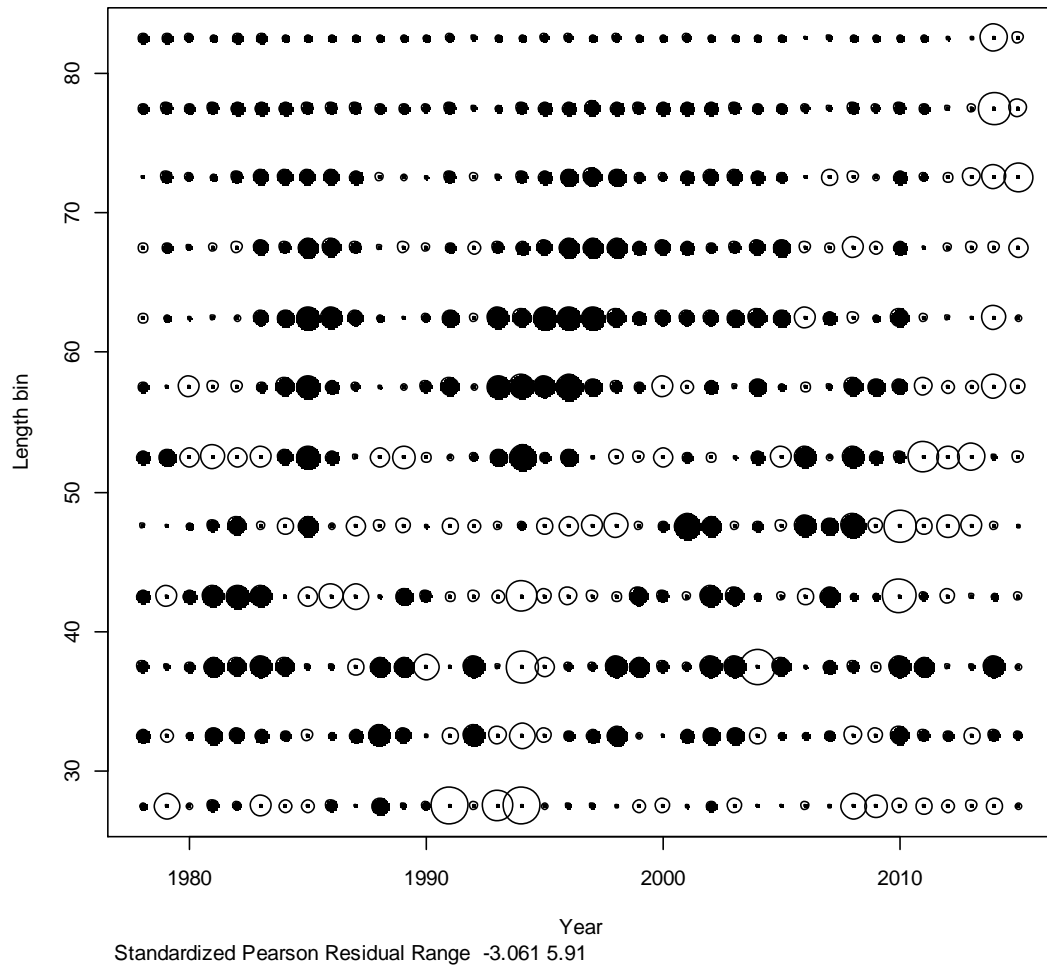


Figure 9. Model 0. Residuals of fit to survey female size frequency. Filled circles are negative residuals.

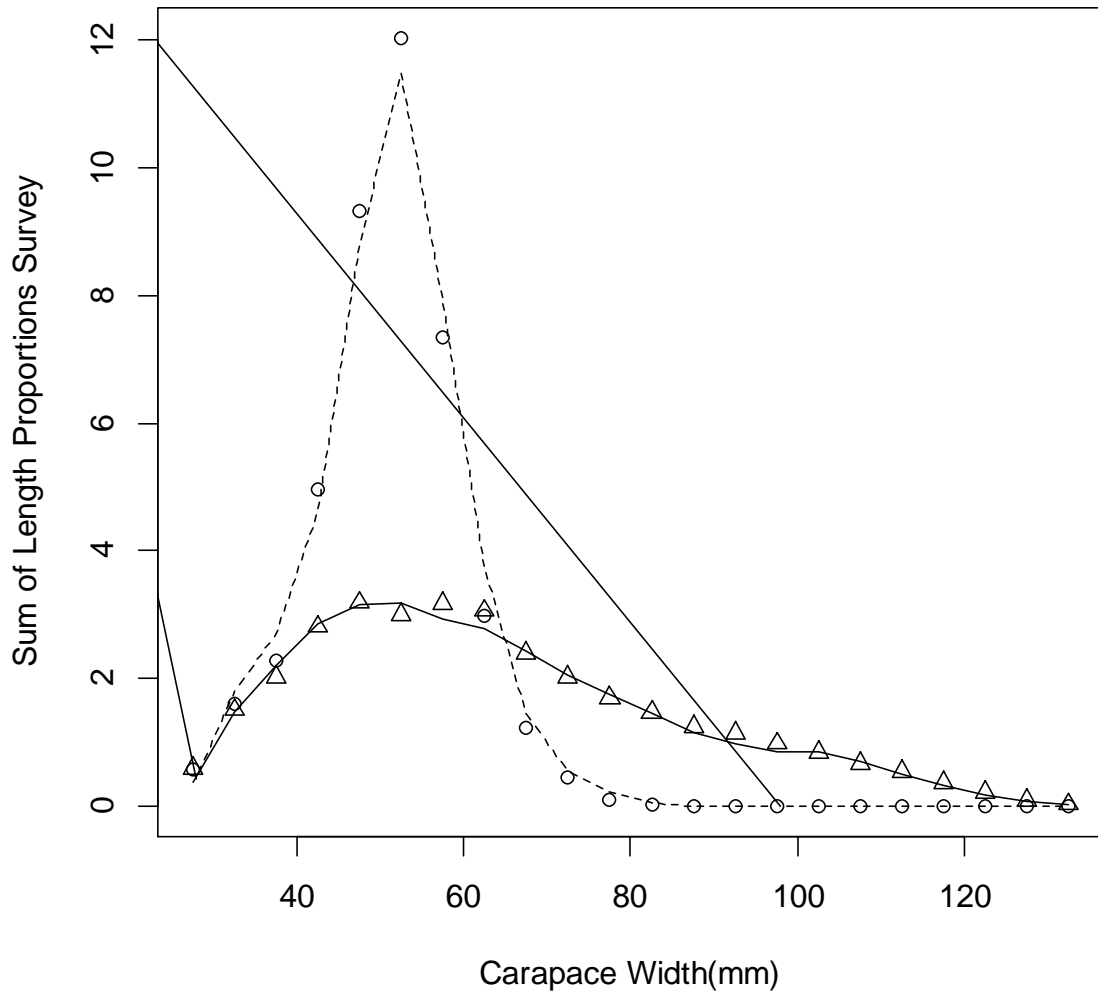


Figure 10. Model 0. Summary over years of fit to survey length frequency data by sex. Dotted line is fit for females, circles are observed. Solid line is fit for males, triangles are observed.

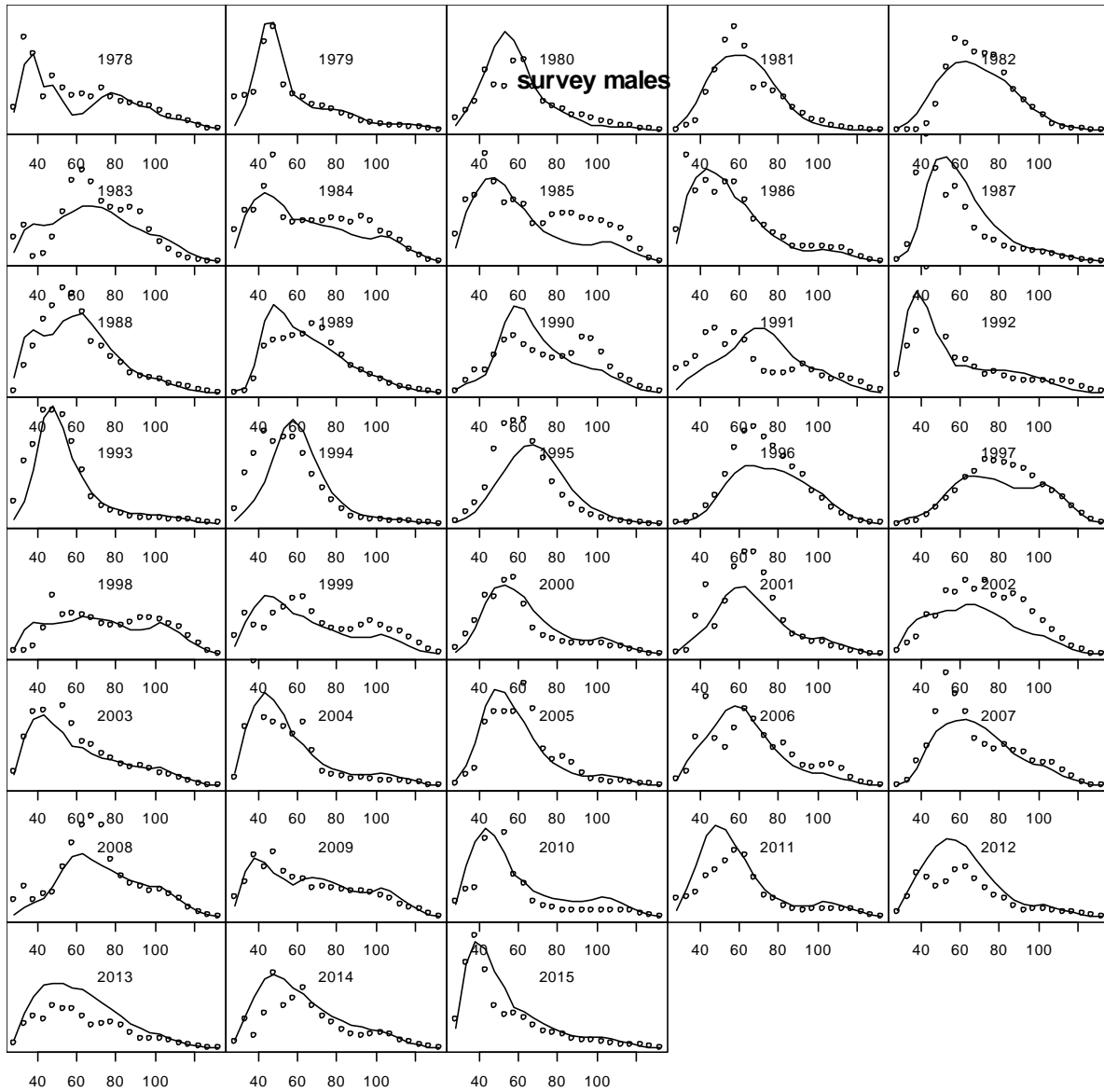


Figure 11. Model 0. Model fit to the survey male size frequency data. Circles are observed survey data. Solid line is the model fit.

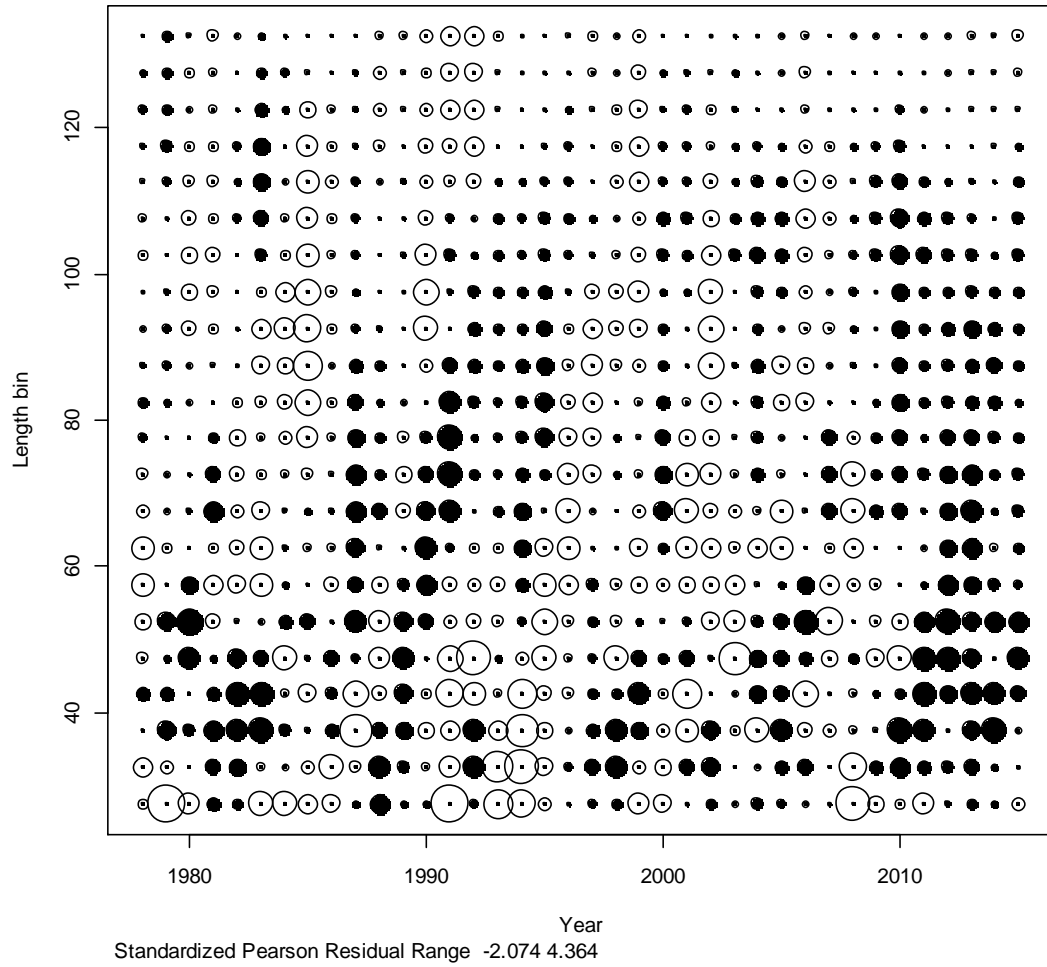


Figure 12. Model 0. Residuals for fit to survey male size frequency. Filled circles are negative residuals (predicted higher than observed).

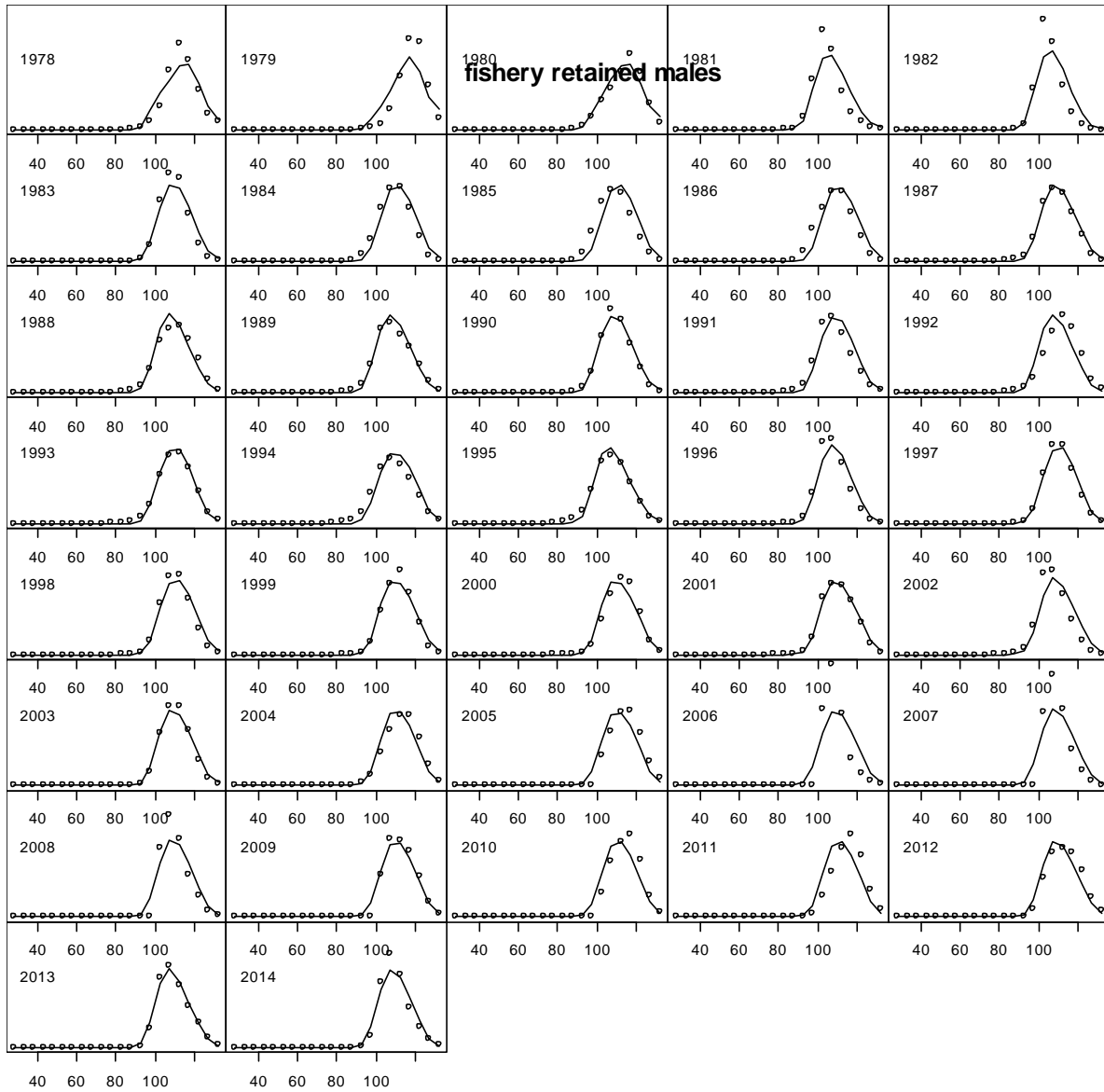


Figure 13. Model 0. Model fit to the retained male size frequency data, shell condition combined. Solid line is the model fit. Circles are observed data. Year is the survey year.

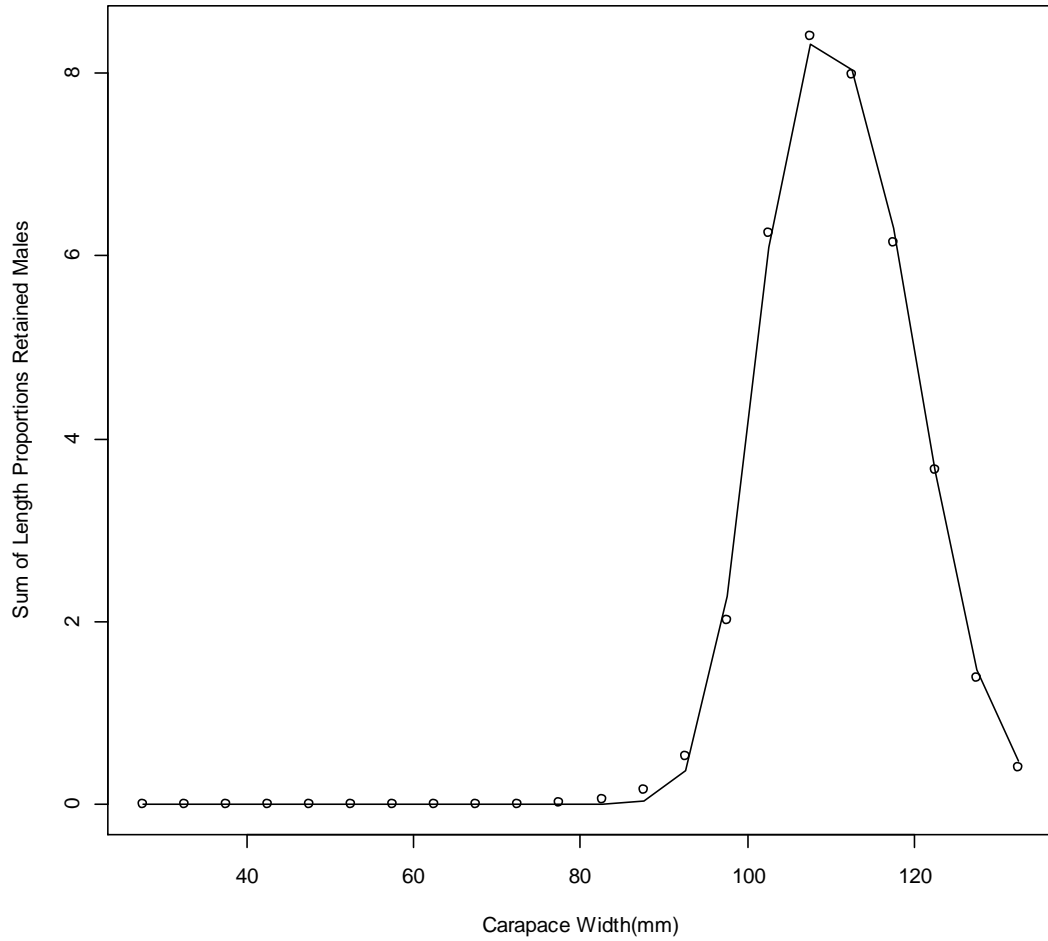


Figure 14. Model 0. Summary fit to retained male length.

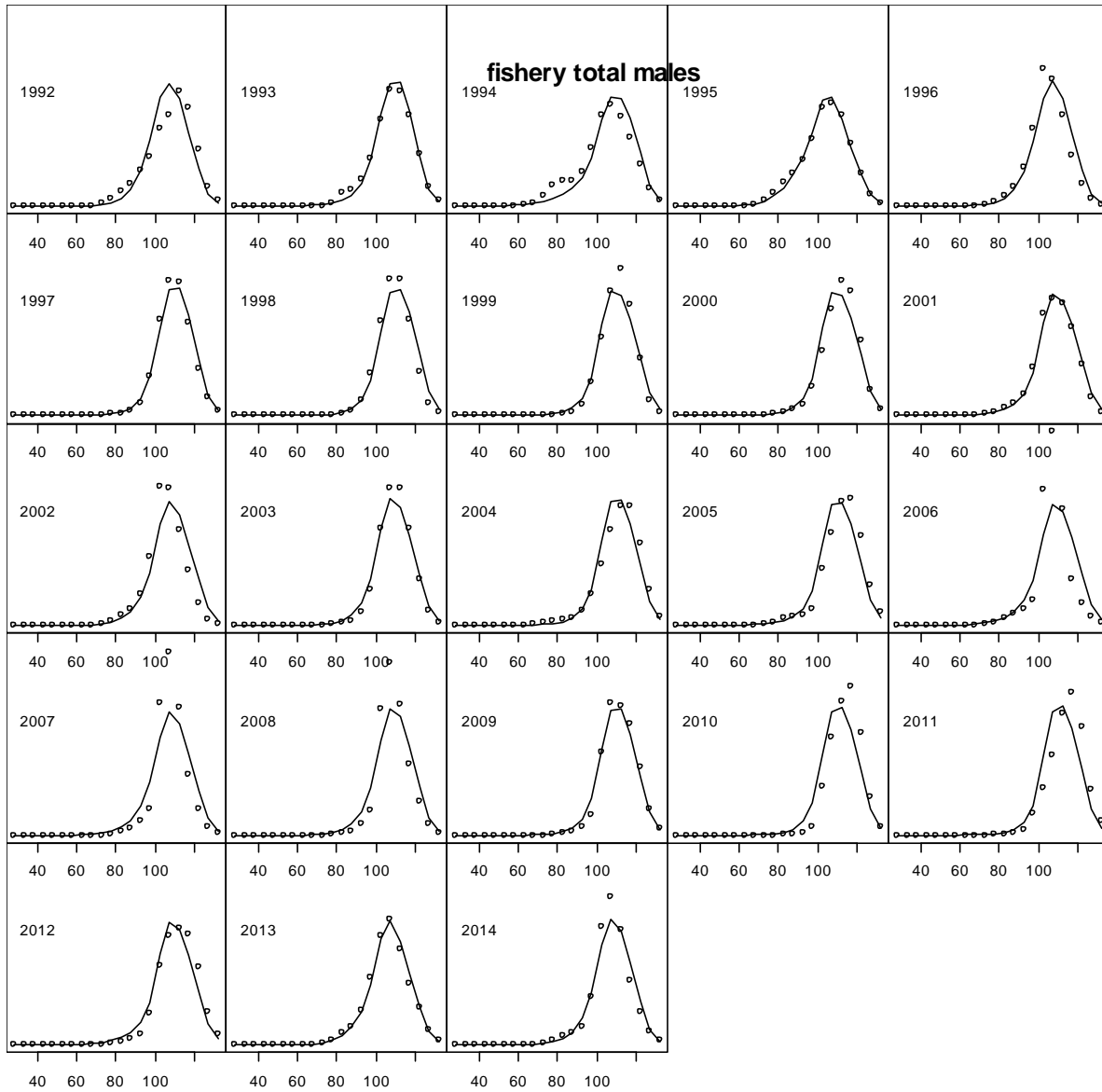


Figure 15. Model 0. Model fit to the total (discard plus retained) male size frequency data, shell condition combined. Solid line is the model fit. Circles are observed data. Year is the survey year.

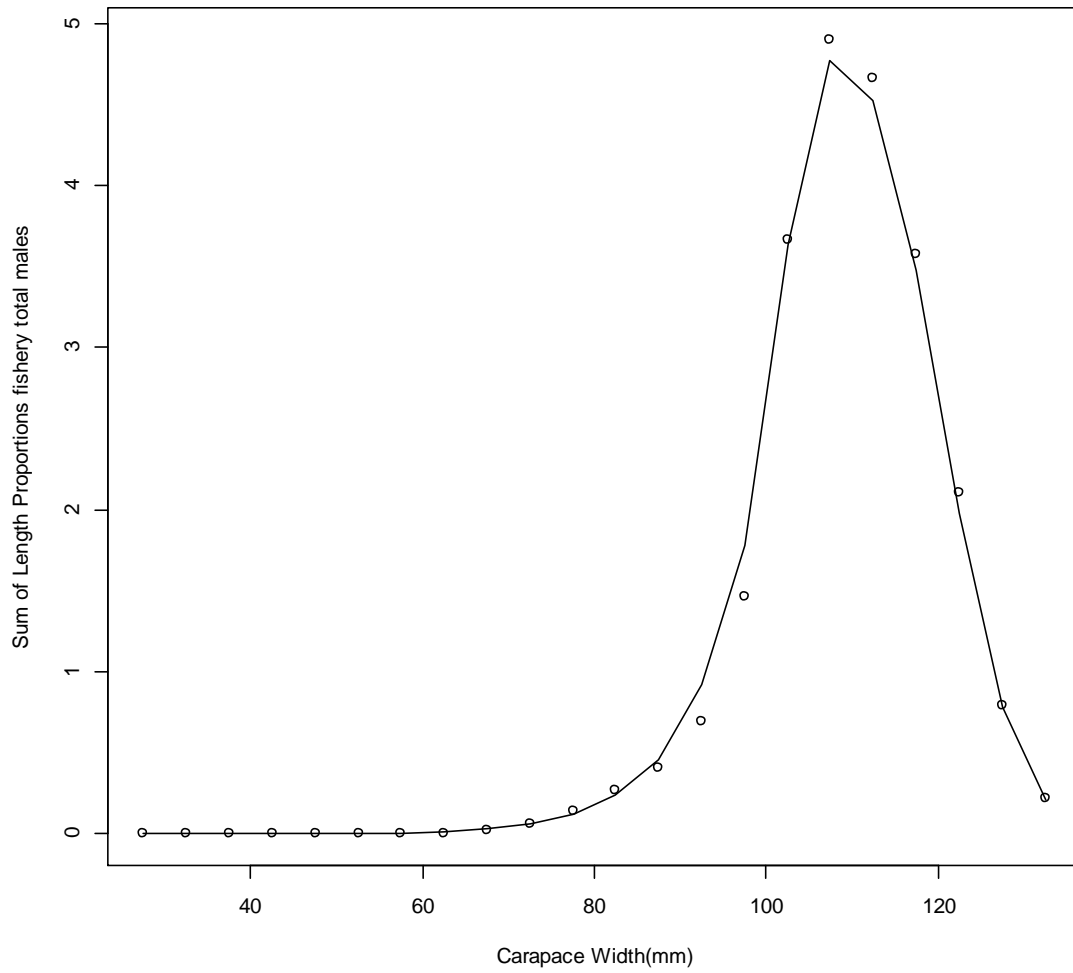


Figure 16. Model 0. Summary fit to total length frequency male catch.

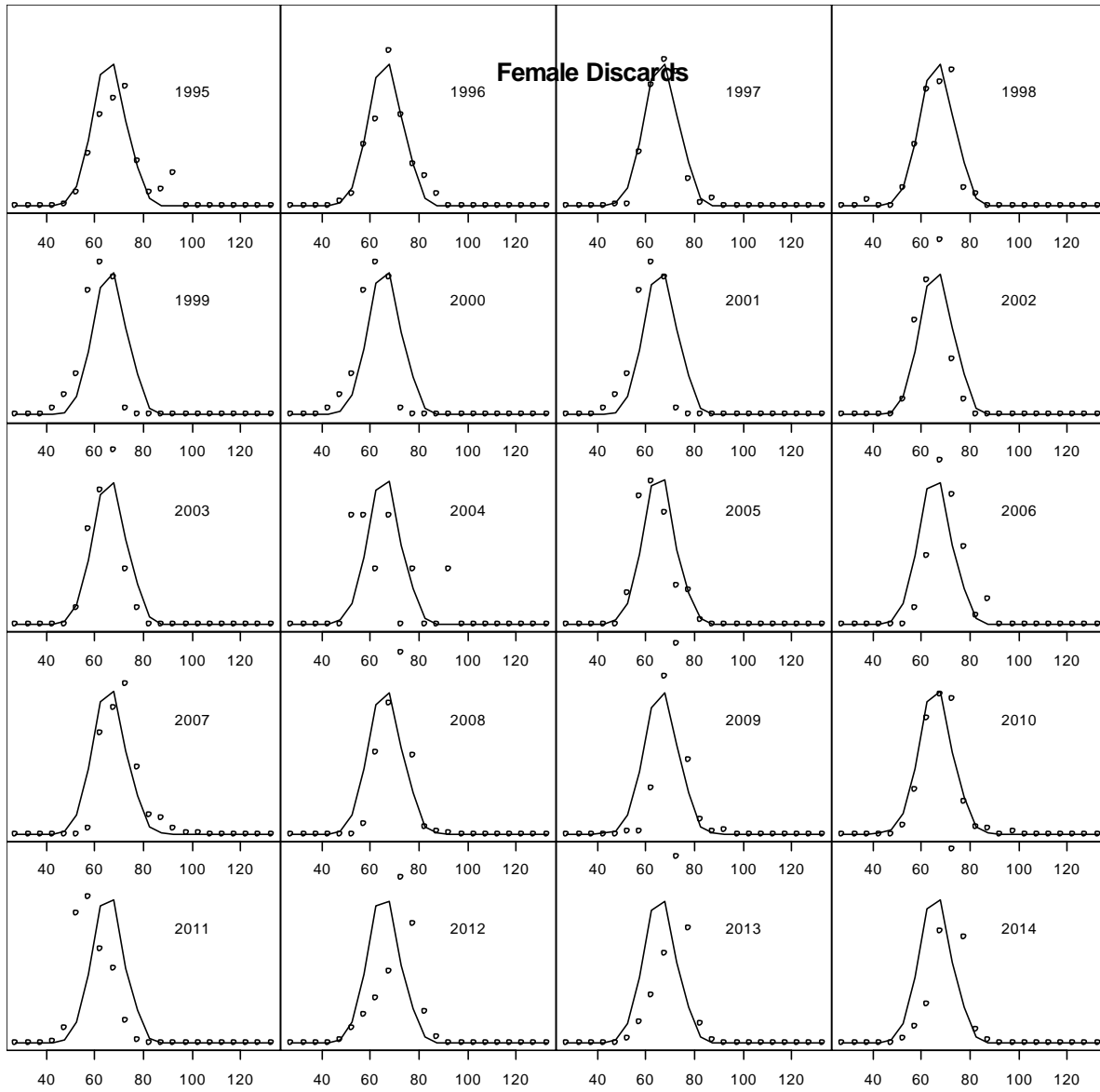


Figure 17. Model 0. Model fit to the discard female size frequency data. Solid line is the model fit. Circles are observed data. Year is the survey year.

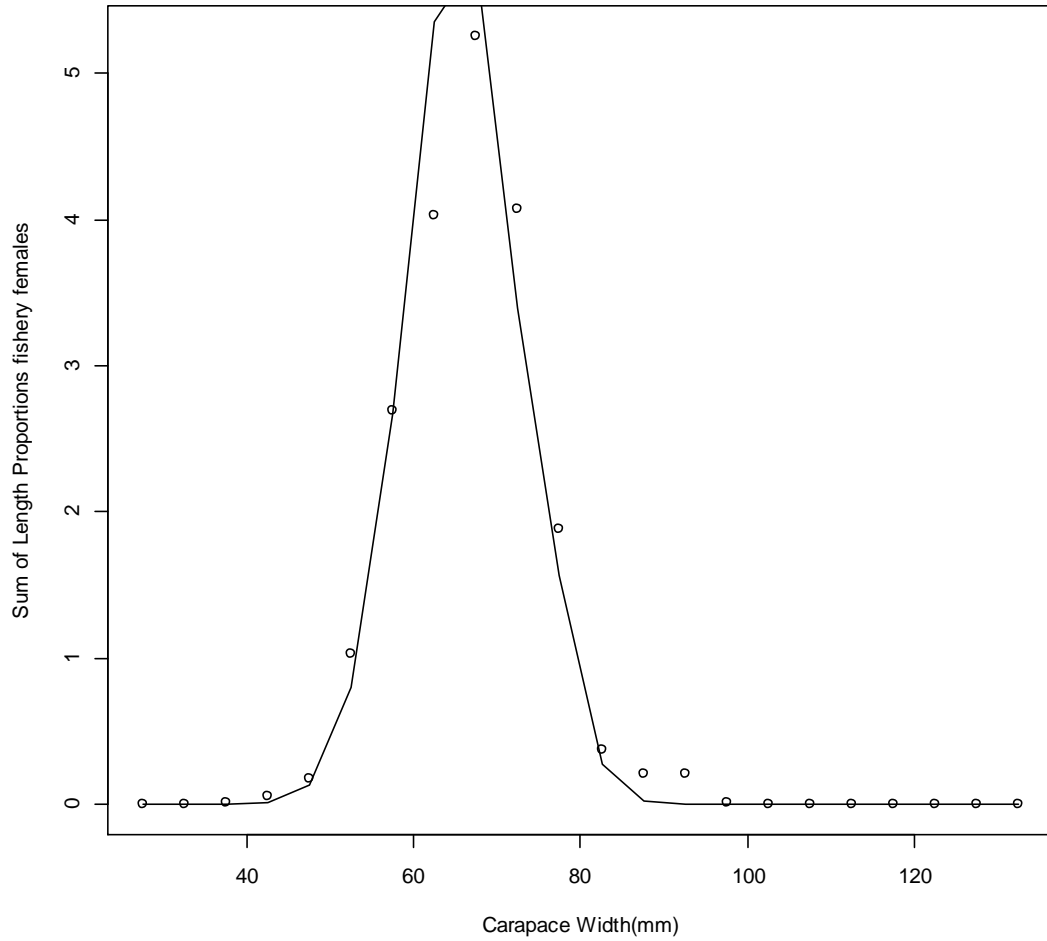


Figure 18. Model 0. Summary fit to directed fishery female discards.

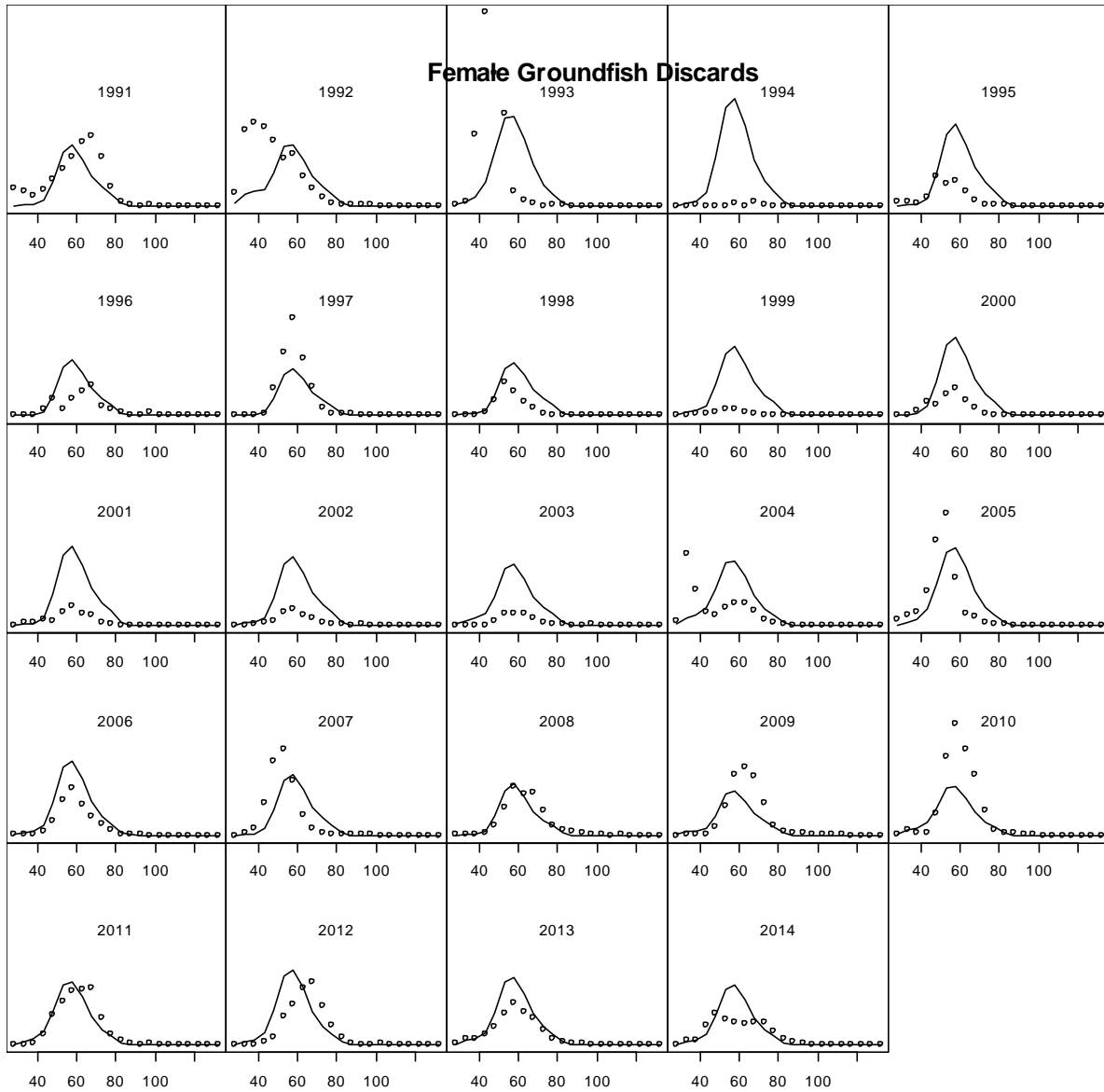


Figure 19. Model 0. Model fit to the groundfish trawl discard female size frequency data. Solid line is the model fit. Circles are observed data. Year is the survey year.

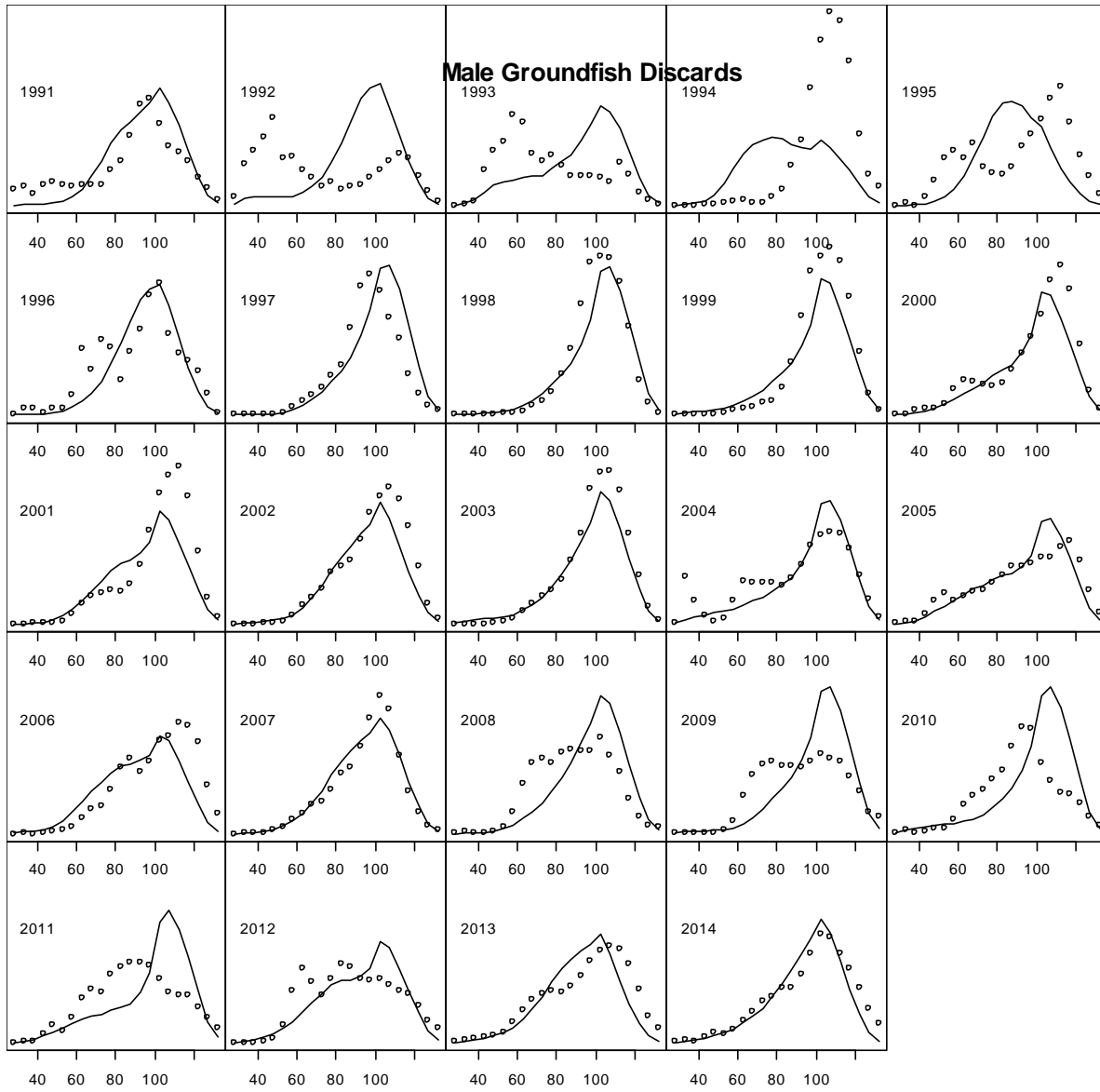


Figure 20. Model 0. Model fit to the groundfish trawl discard male size frequency data. Solid line is the model fit. Circles are observed data.

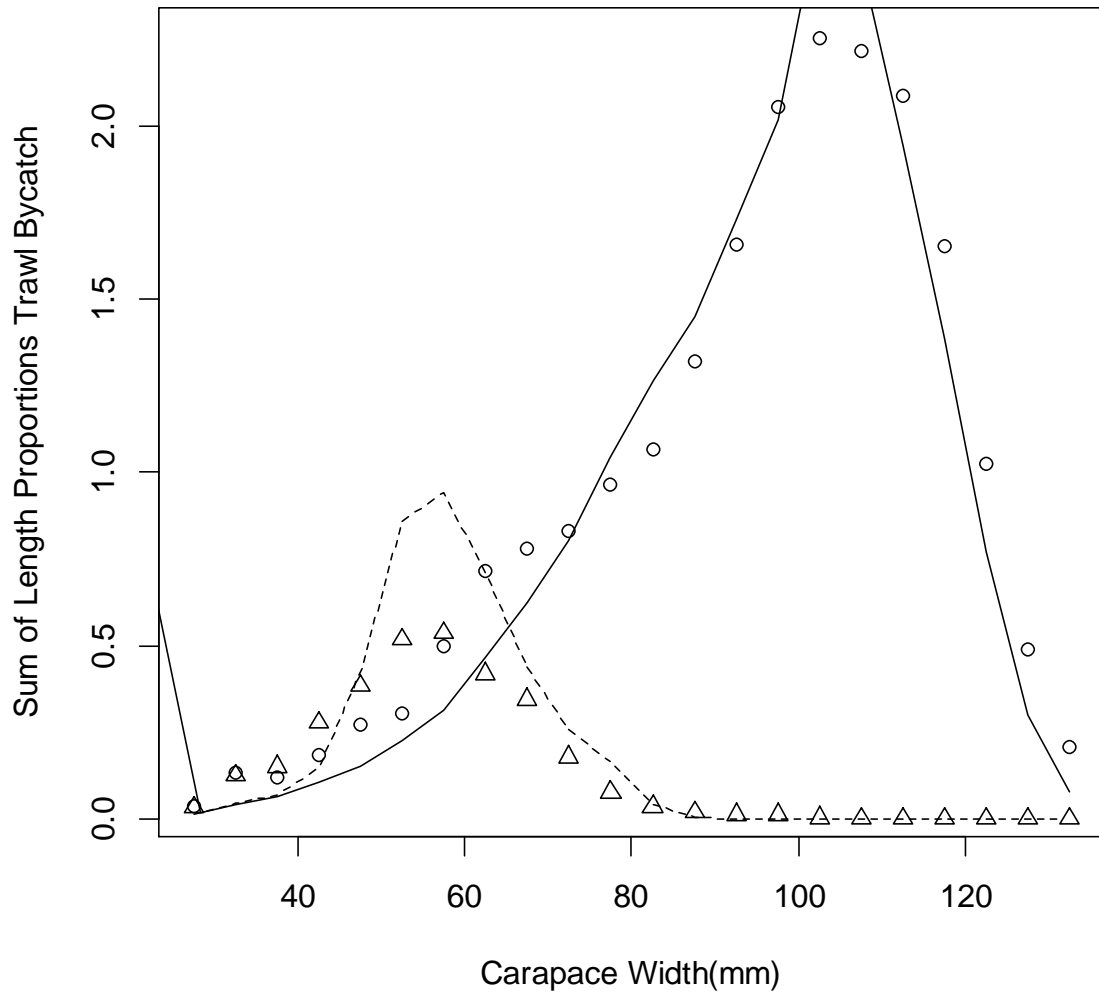


Figure 21. Model 0. Summary fit to groundfish length frequency.

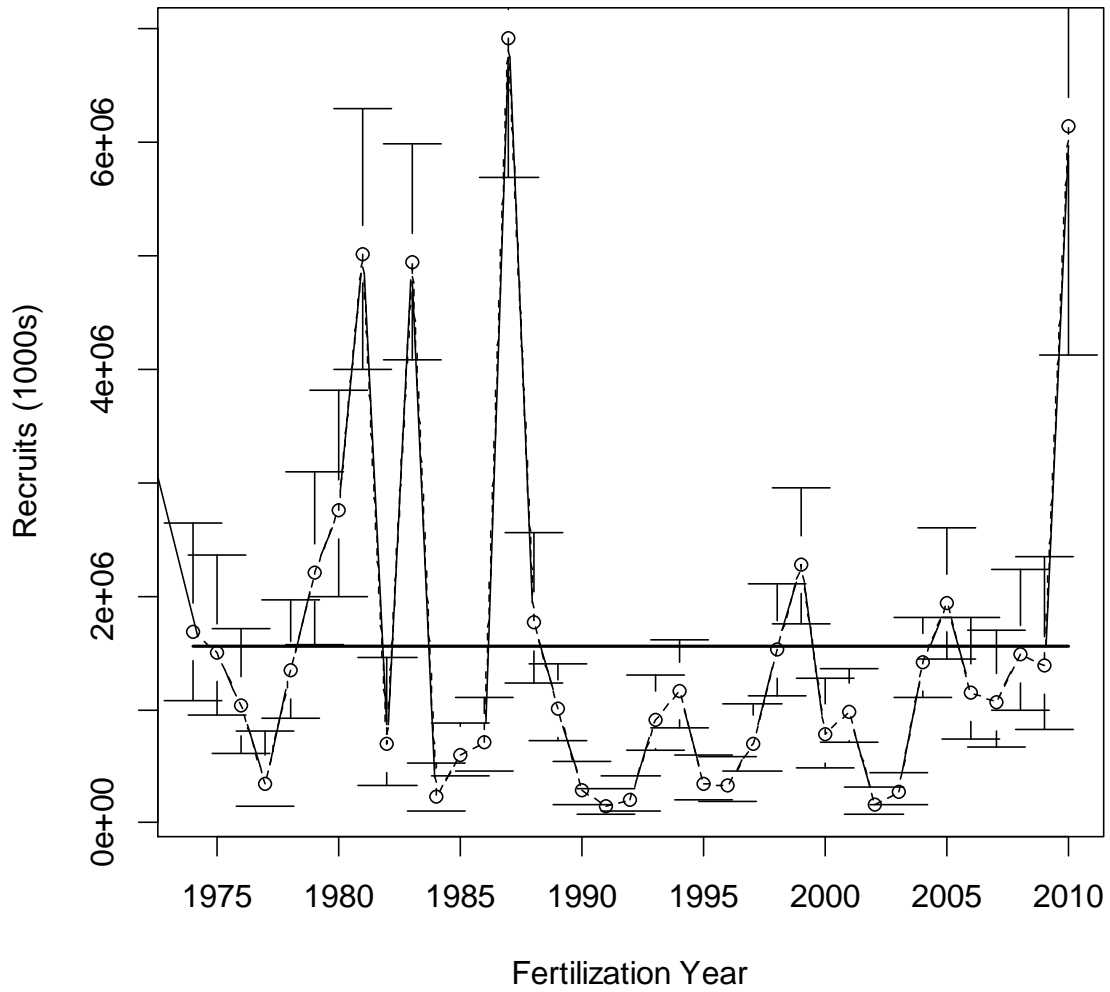


Figure 22. Model 0. Recruitment to the model for crab 25 mm to 50 mm. Total recruitment is 2 times recruitment in the plot. Male and female recruitment fixed to be equal. Solid horizontal line is average recruitment. Error bars are 95% C.I.

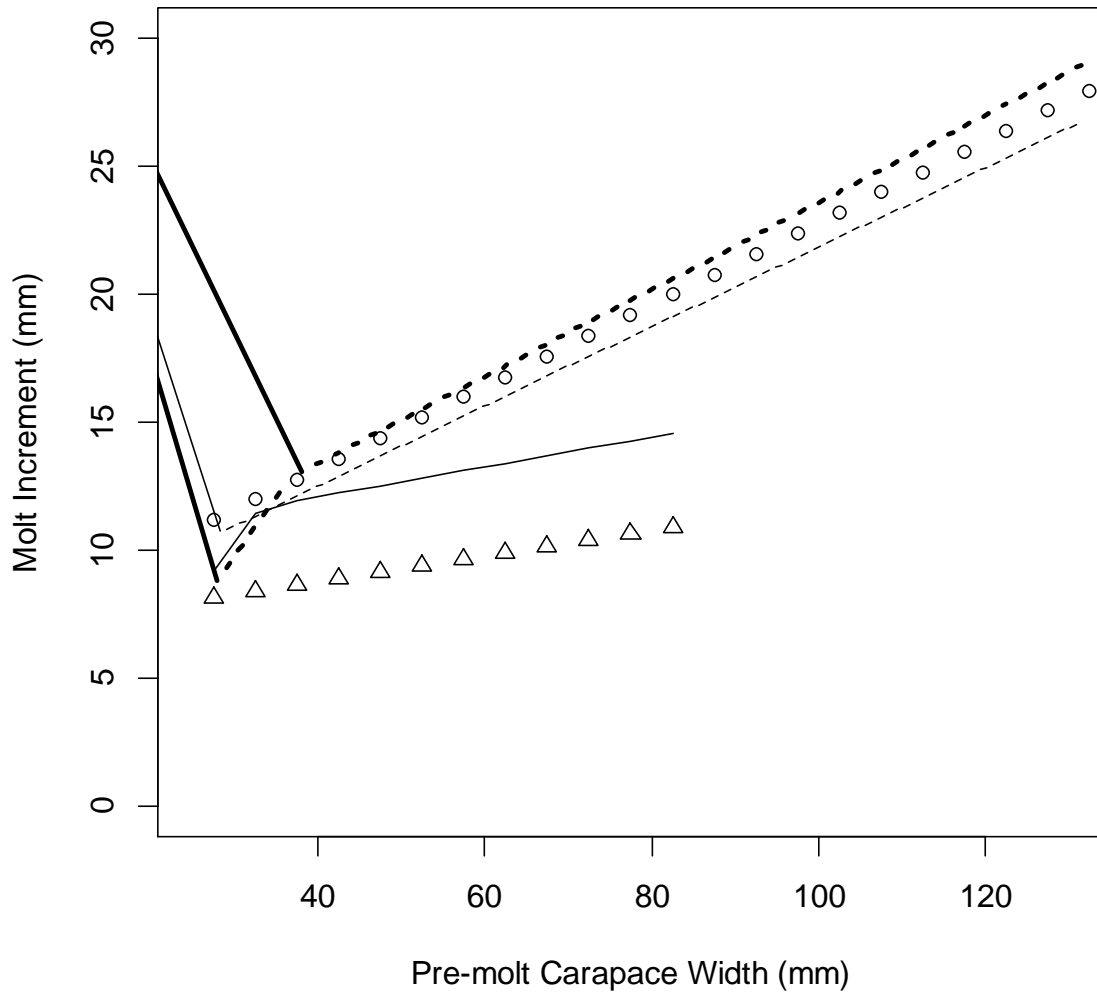


Figure 23. Growth(mm) for male(dotted line) and female snow crab (solid line) estimated from the Model 0. The priors for the growth curve used in models before September 2013 are circles (males) and triangle (females). Heavy dotted line is the growth curve estimated by Somerton for males and females from the 2011 growth study (Somerton 2012).

Female Snow Crab Growth

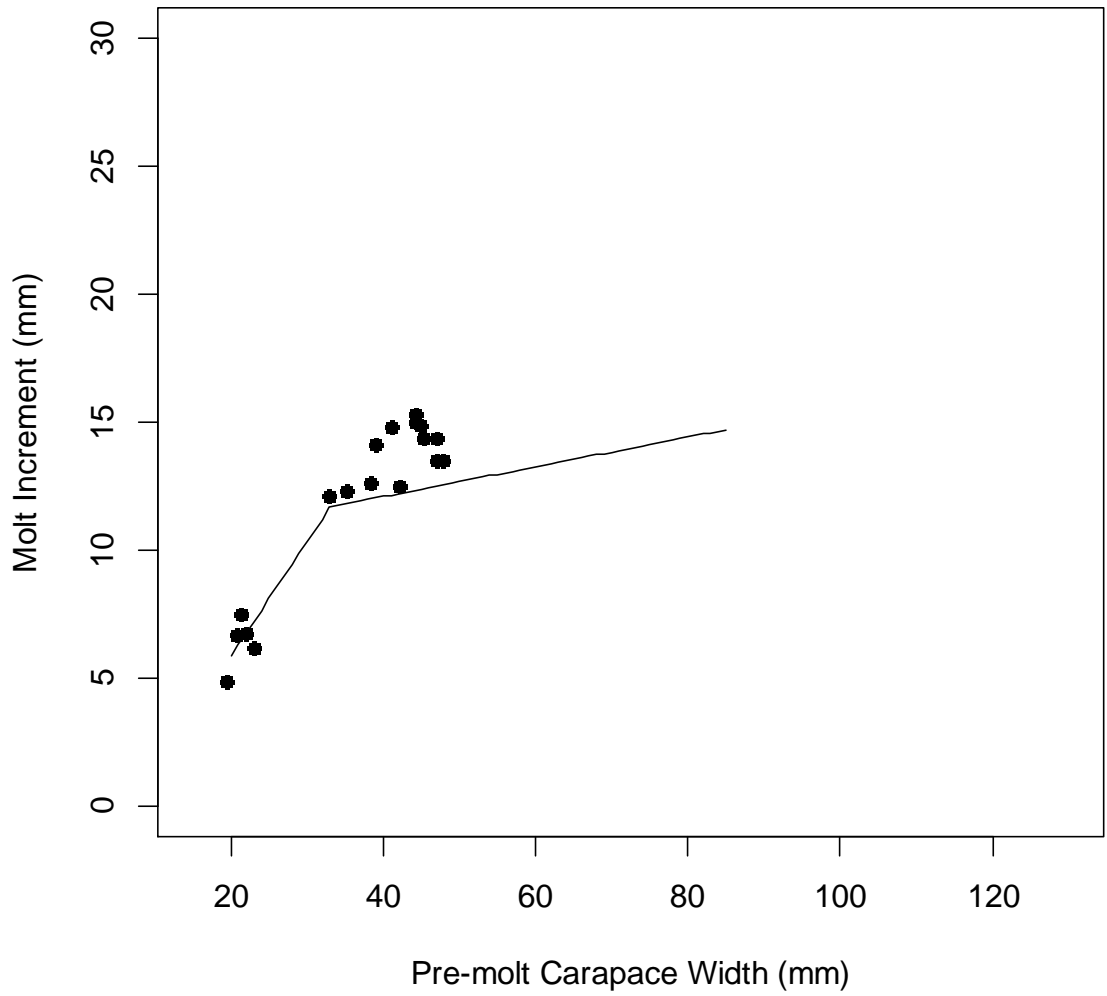


Figure 24. Female growth data from 2011 growth study and model fit.

Male Snow Crab Growth

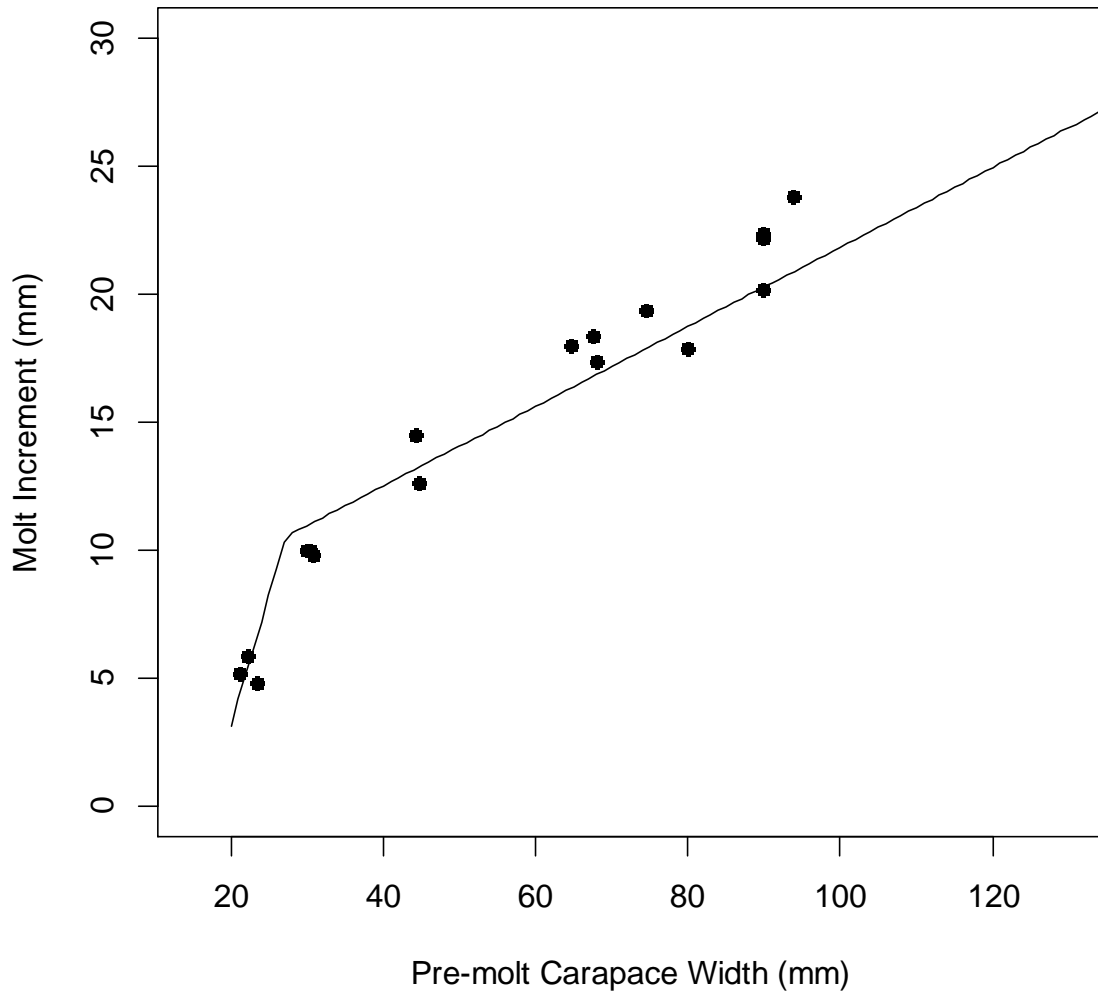


Figure 25. Male growth data from 2011 growth study and model fit.

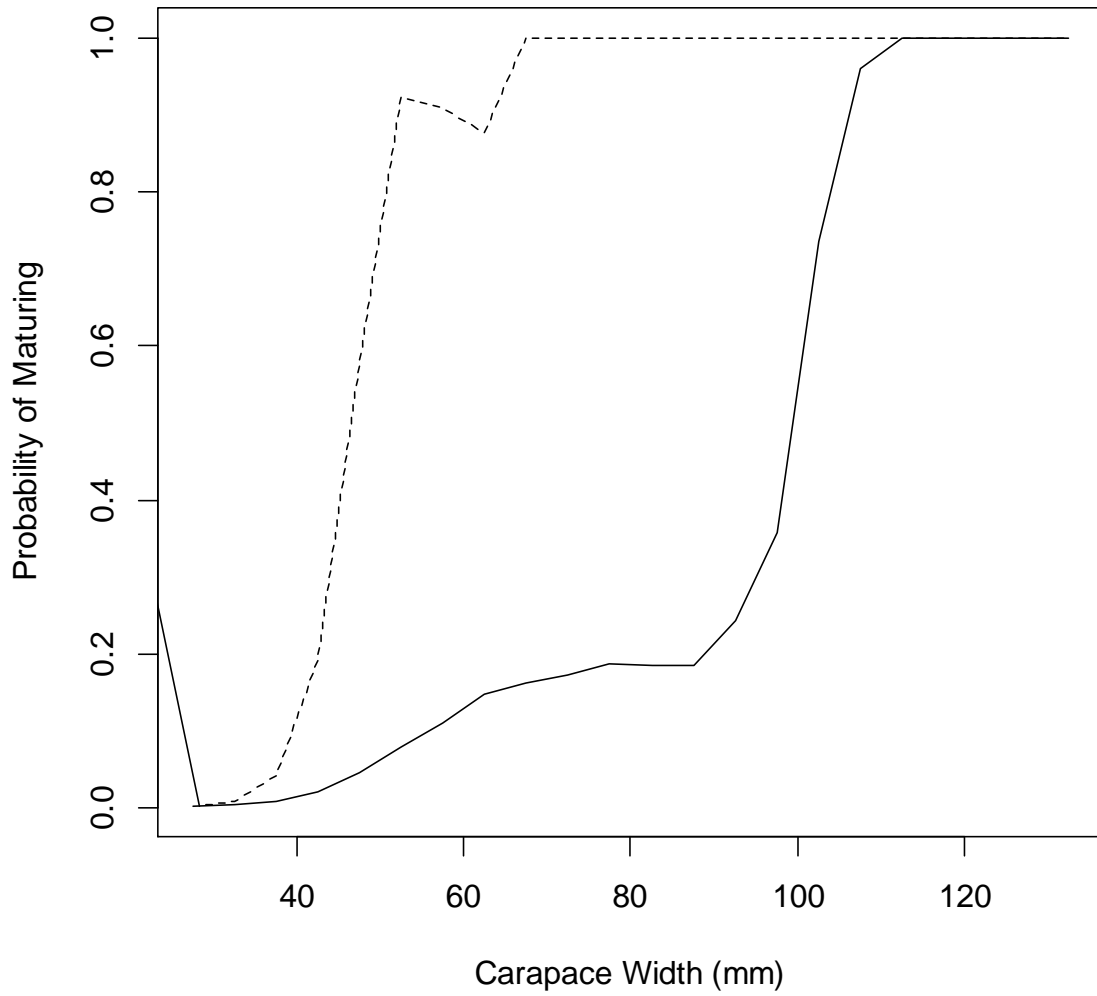


Figure 26. Probability of maturing by size estimated in the model for male(solid line) and female (dashed line) snow crab (not the average fraction mature).

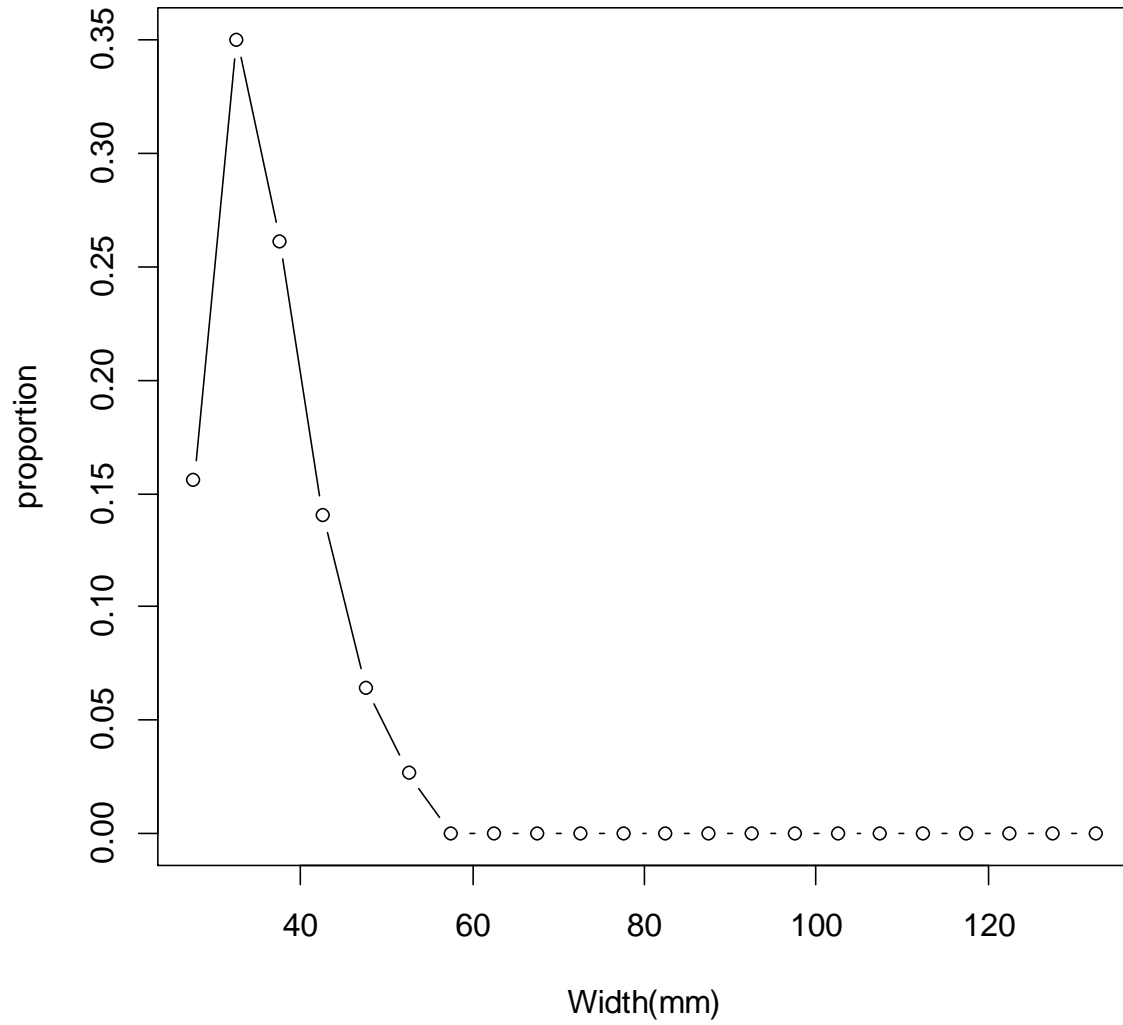


Figure 27. Model 0. Distribution of recruits to length bins estimated by the model.

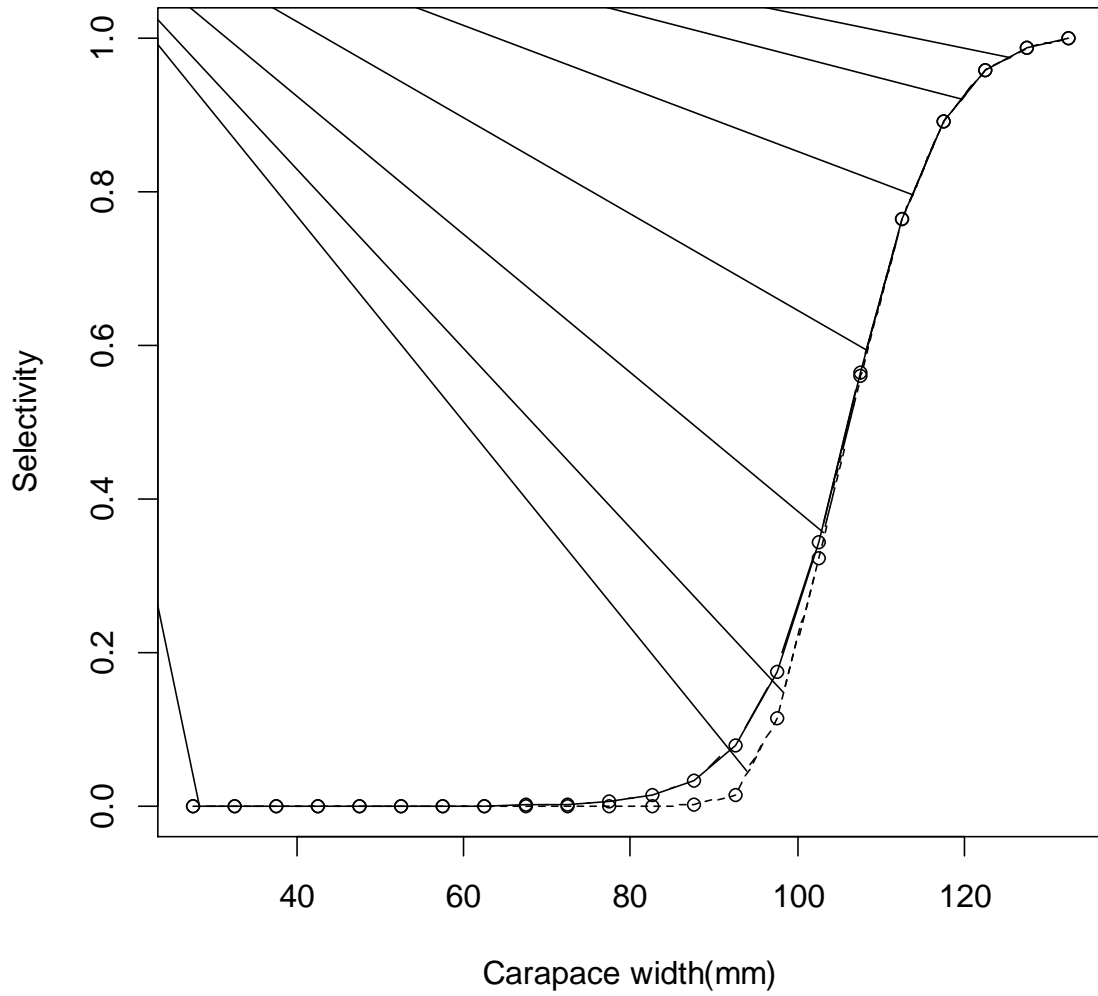


Figure 28. Model 0. Selectivity curve for total catch (discard plus retained, solid line) and retained catch (dotted line) for combined shell condition male snow crab.

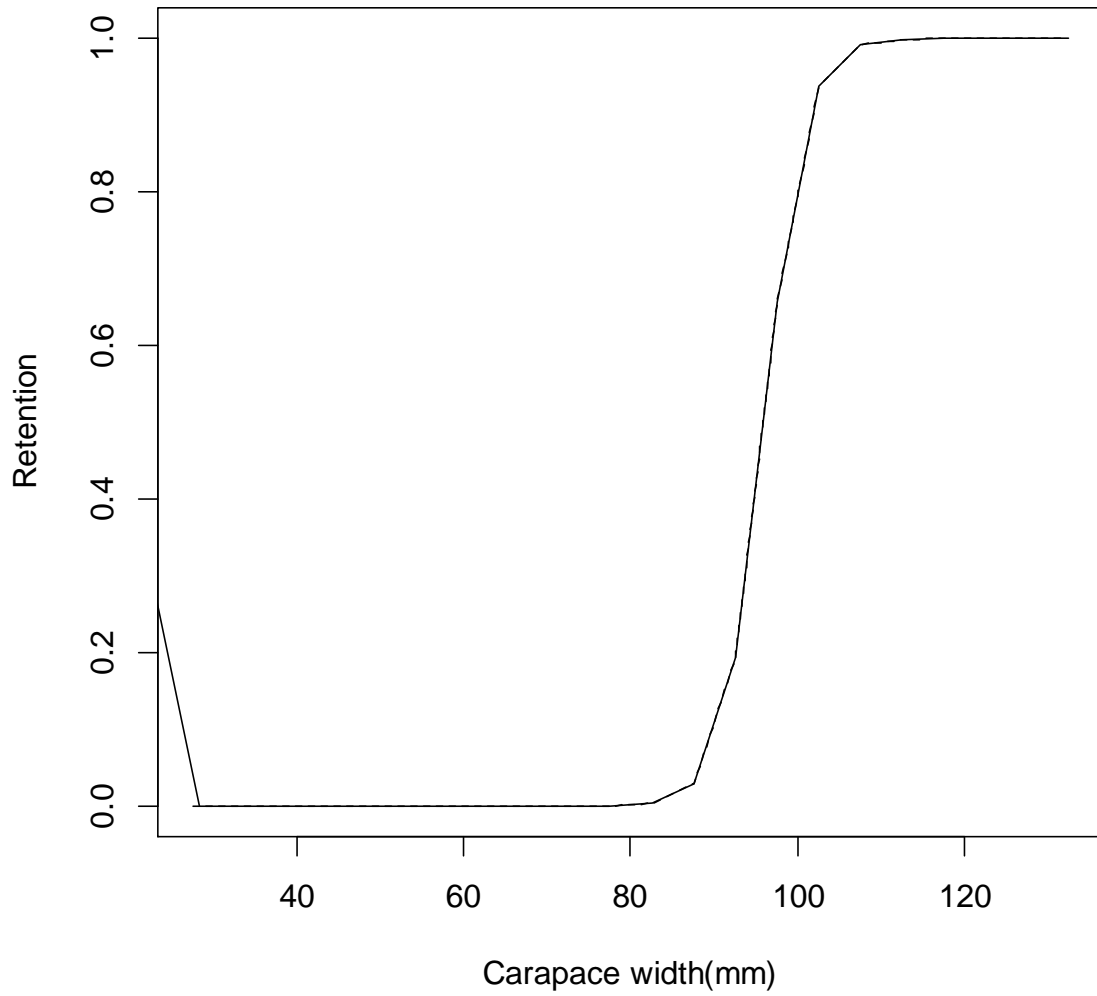


Figure 29. Model 0. Model estimated fraction of the total catch that is retained by size for male snow crab combined shell condition.

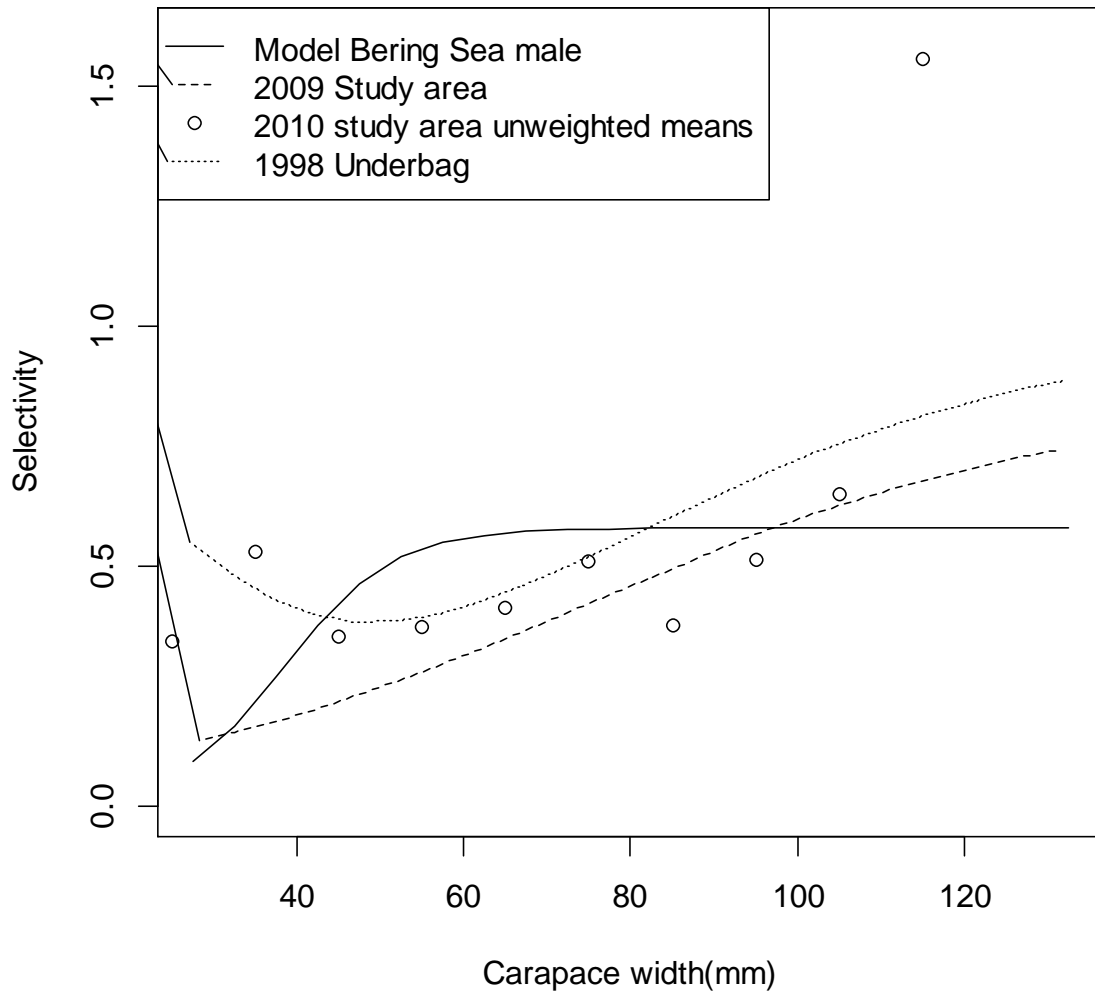


Figure 30. Model 0. Survey selectivity for male crab 1989- present (Model Bering Sea male), with selectivity curves estimated outside the model. 2009 study area is the curve estimated by Somerton from the 2009 study area data.

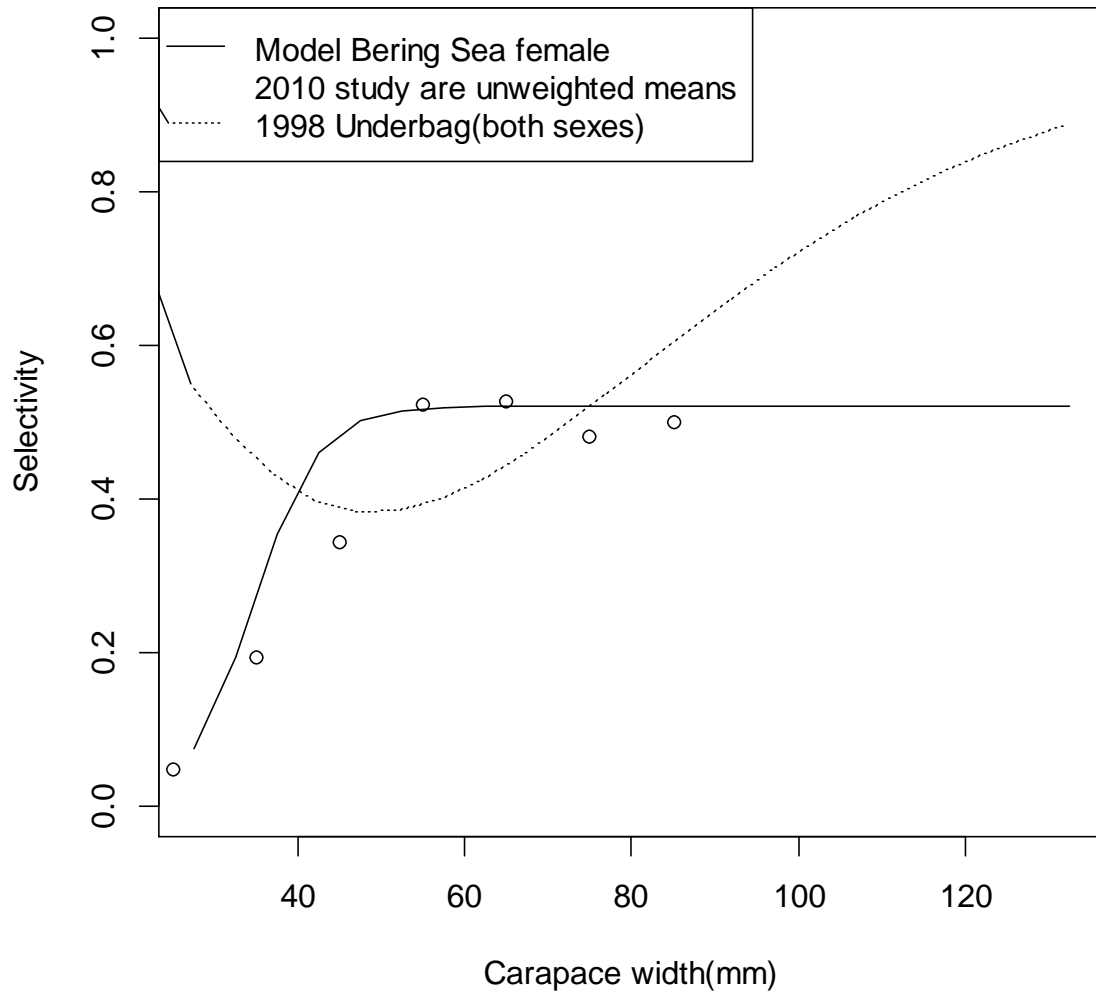


Figure 31. Model 0. Survey selectivity for female crab 1989- present (Model Bering Sea female).

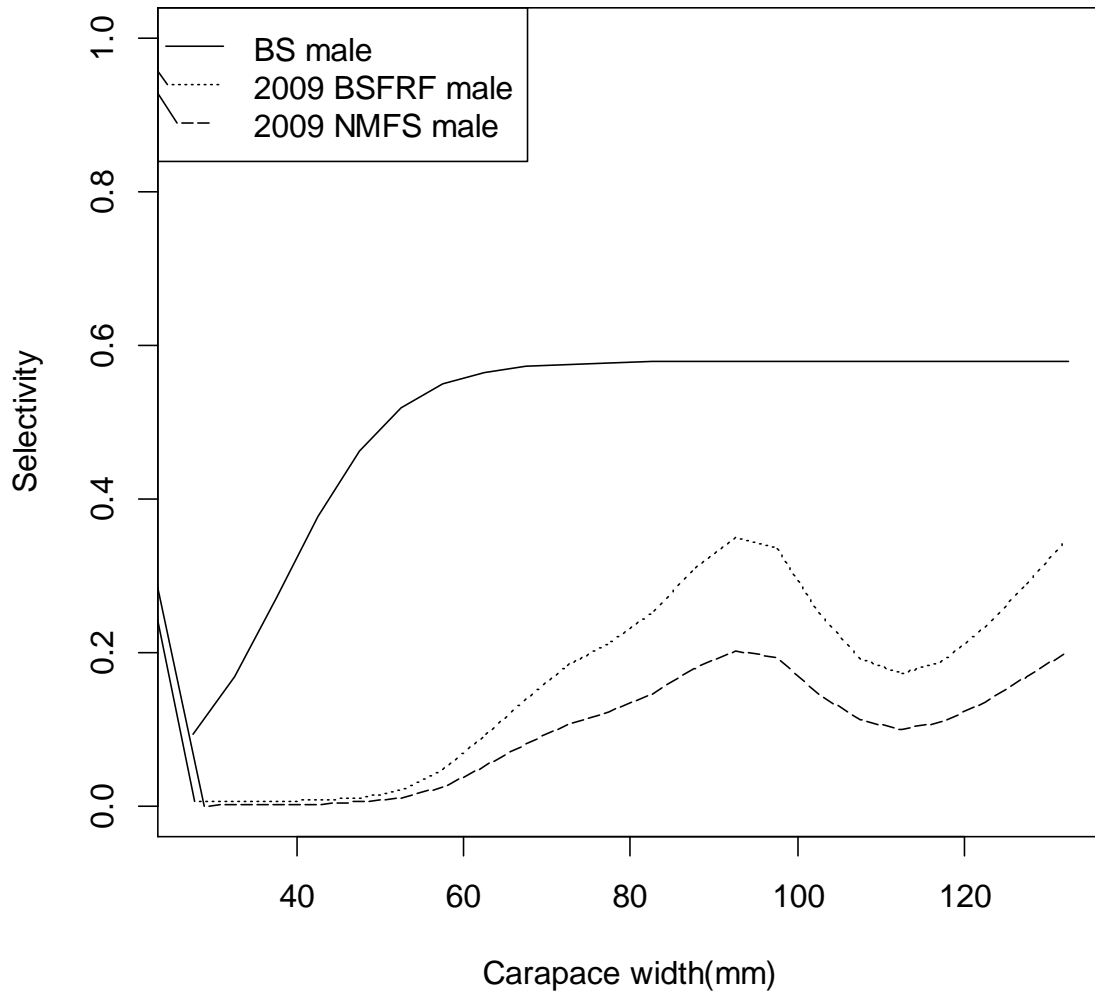


Figure 32. Model 0. Survey selectivity curves for male crab in the entire Bering sea 1989-present (BS male), 2009 study area BSFRF male and 2009 study area NMFS male.

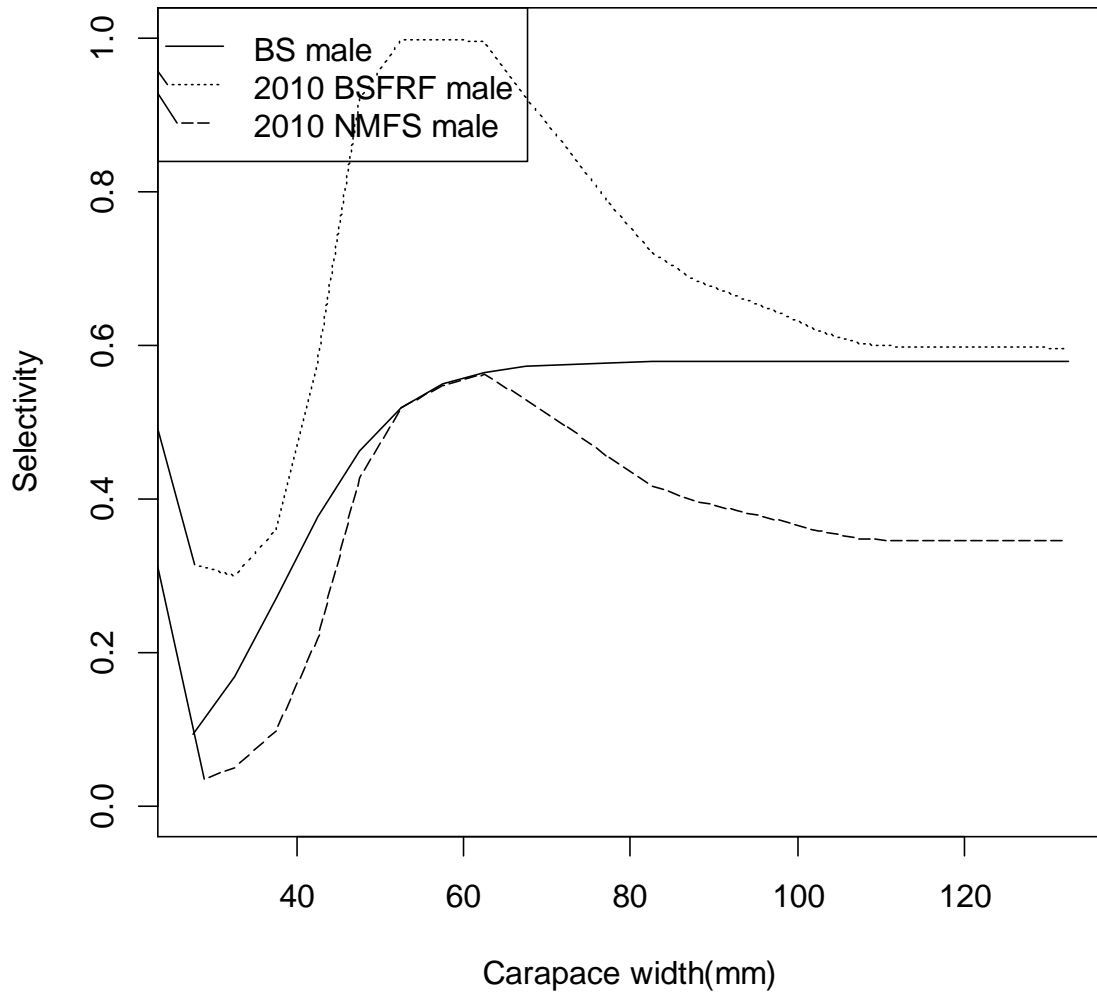


Figure 33. Model 0. Survey selectivity curves for male crab in the entire Bering sea 1989-present (BS male), 2010 study area BSFRF male and 2010 study area NMFS male.

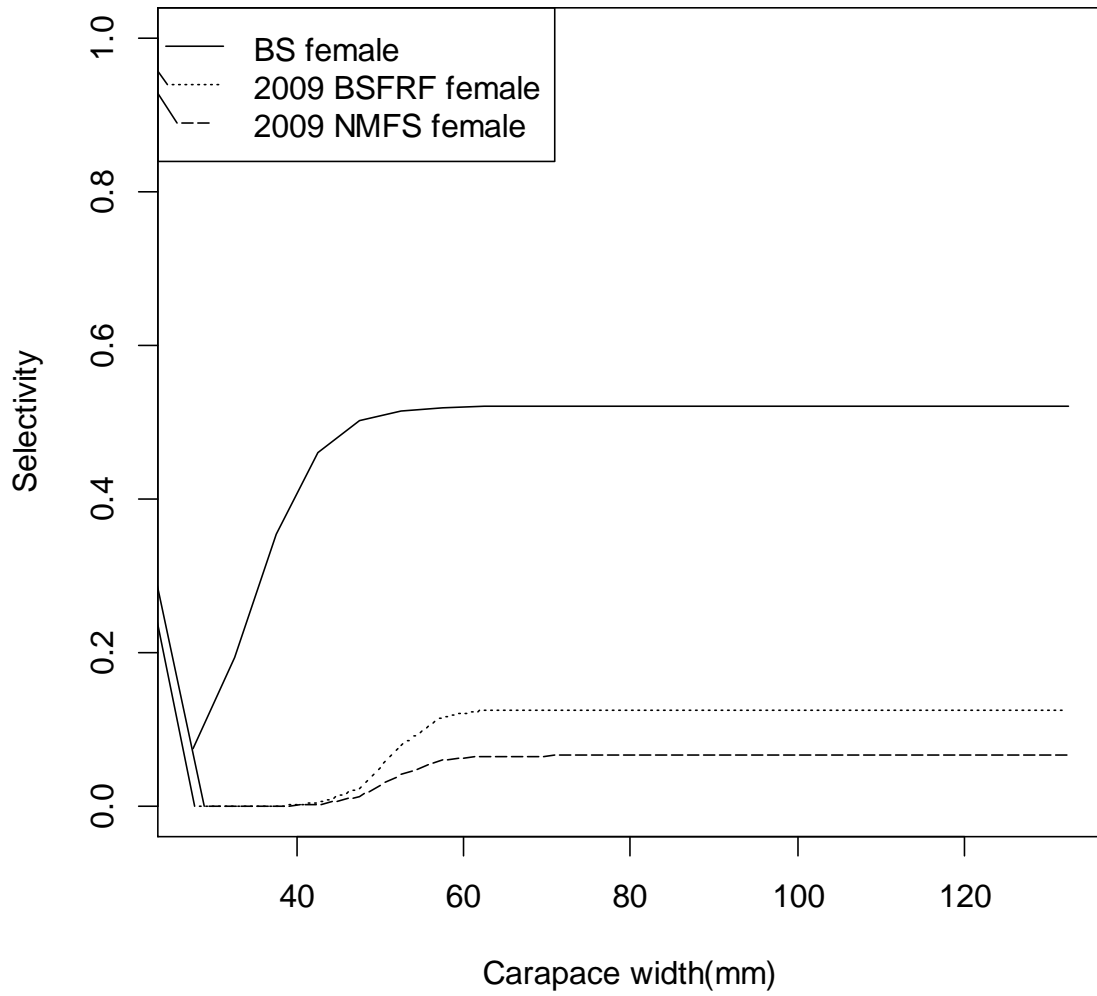


Figure 34. Model 0. Survey selectivity curves for female crab in the entire Bering sea 1989-present (BS female), 2009 study area BSFRF female and 2009 study area NMFS female.

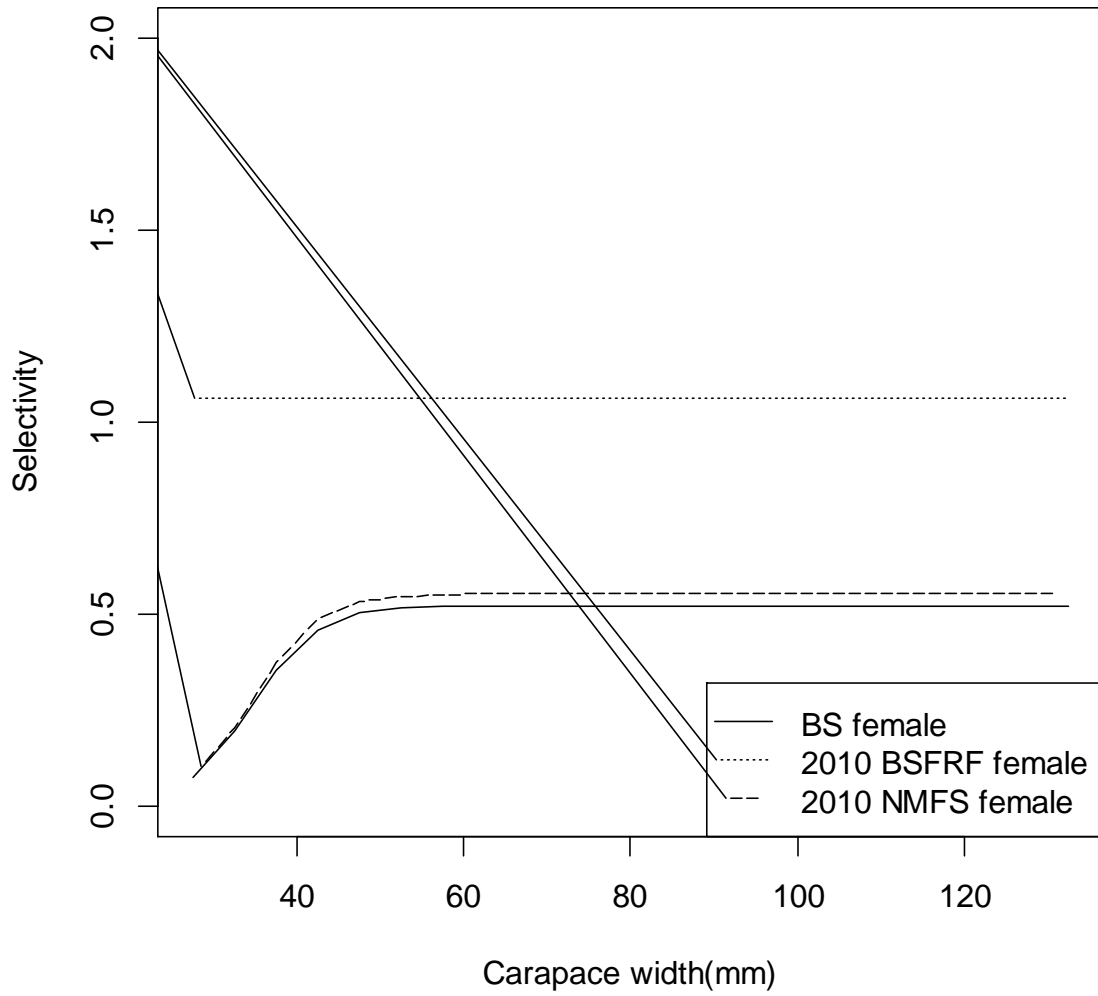


Figure 35. Model 0. Survey selectivity curves for female crab in the entire Bering sea 1989-present (BS female), 2010 study area BSFRF female and 2010 study area NMFS female.

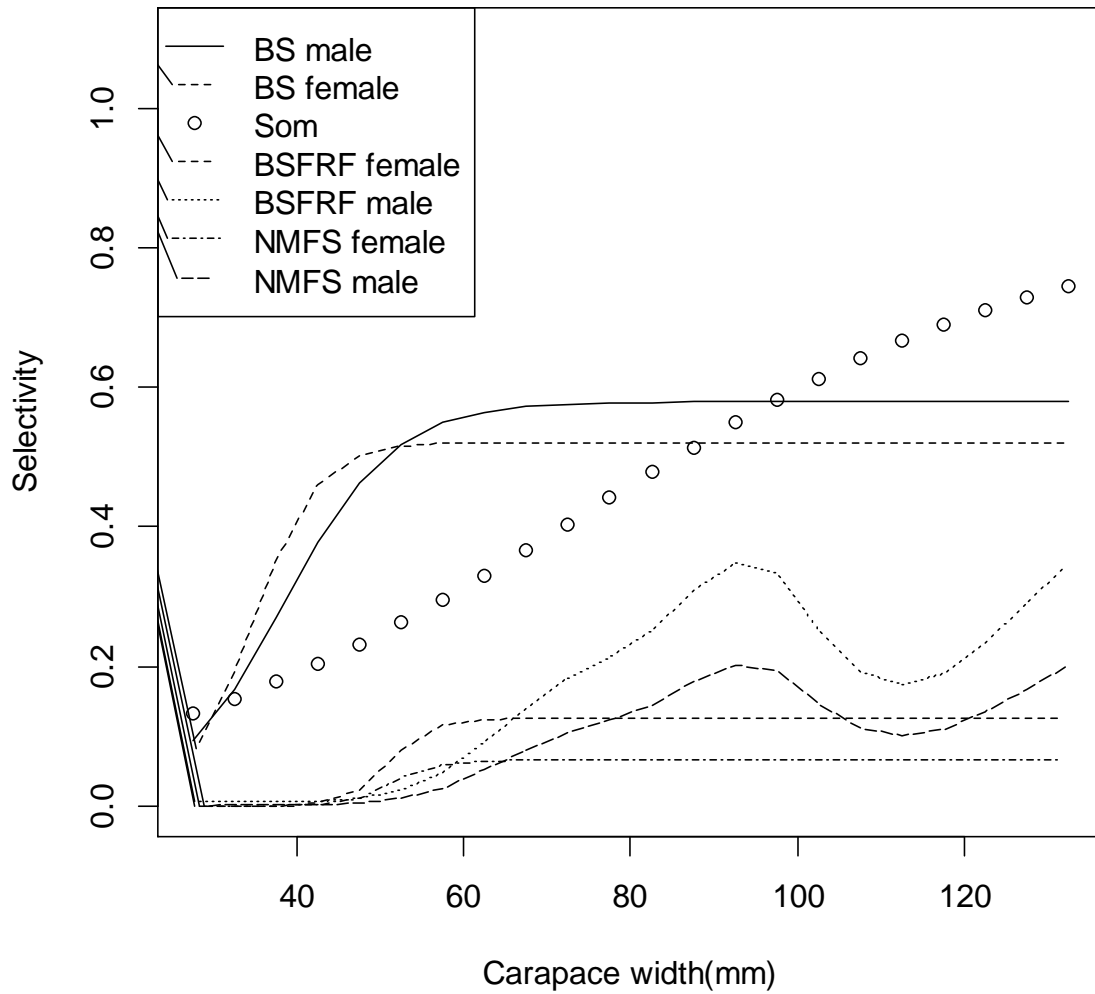


Figure 36. Model 0. Survey selectivity curves entire Bering Sea survey for female (upper dashed line) and male snow crab (solid lines) estimated by the model for 1989 to present. Survey selectivities estimated by Somerton(2010) from 2009 study area data are the circles. Lower lines are survey selectivities in the study area for 2009 BSFRF male and female crab and NMFS male and female crab.

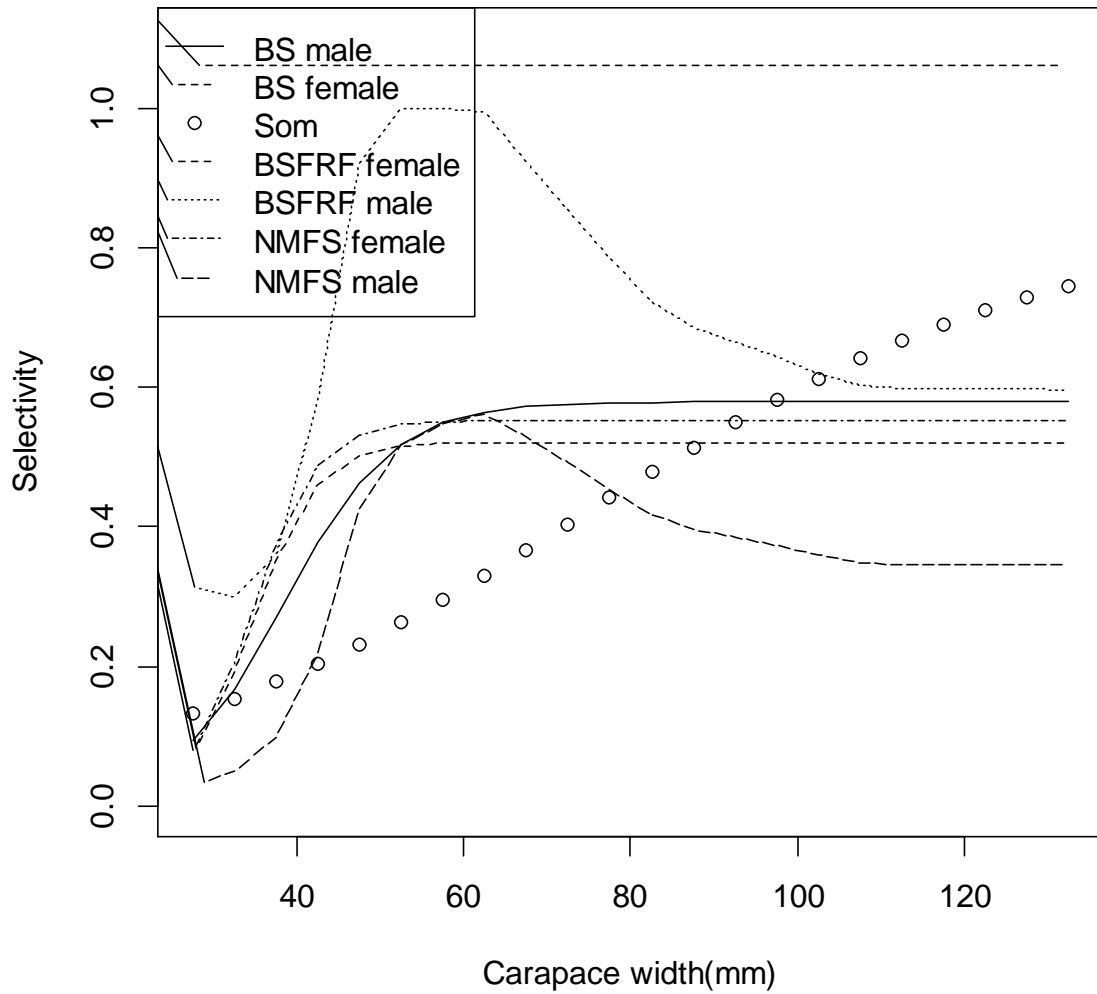


Figure 37. Model 0. Survey selectivity curves entire Bering Sea survey for female (upper dashed line) and male snow crab (solid lines) estimated by the model for 1989 to present. Survey selectivities estimated by Somerton(2010) from 2009 study area data are the circles. Lower lines are survey selectivities in the study area for 2010 BSFRF male and female crab and NMFS male and female crab.

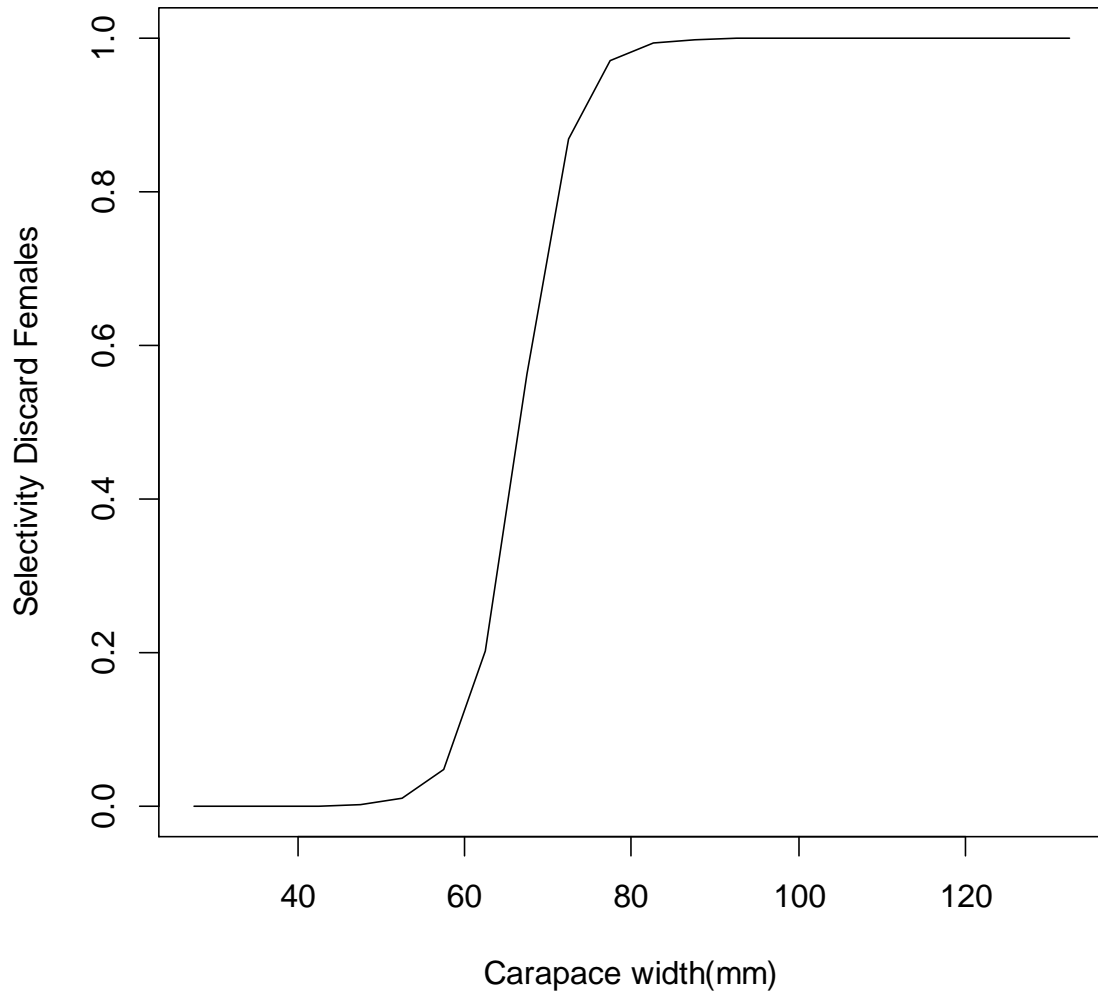


Figure 38. Model 0. Selectivity curve estimated by the model for female snow crab bycatch in the directed snow crab fishery.

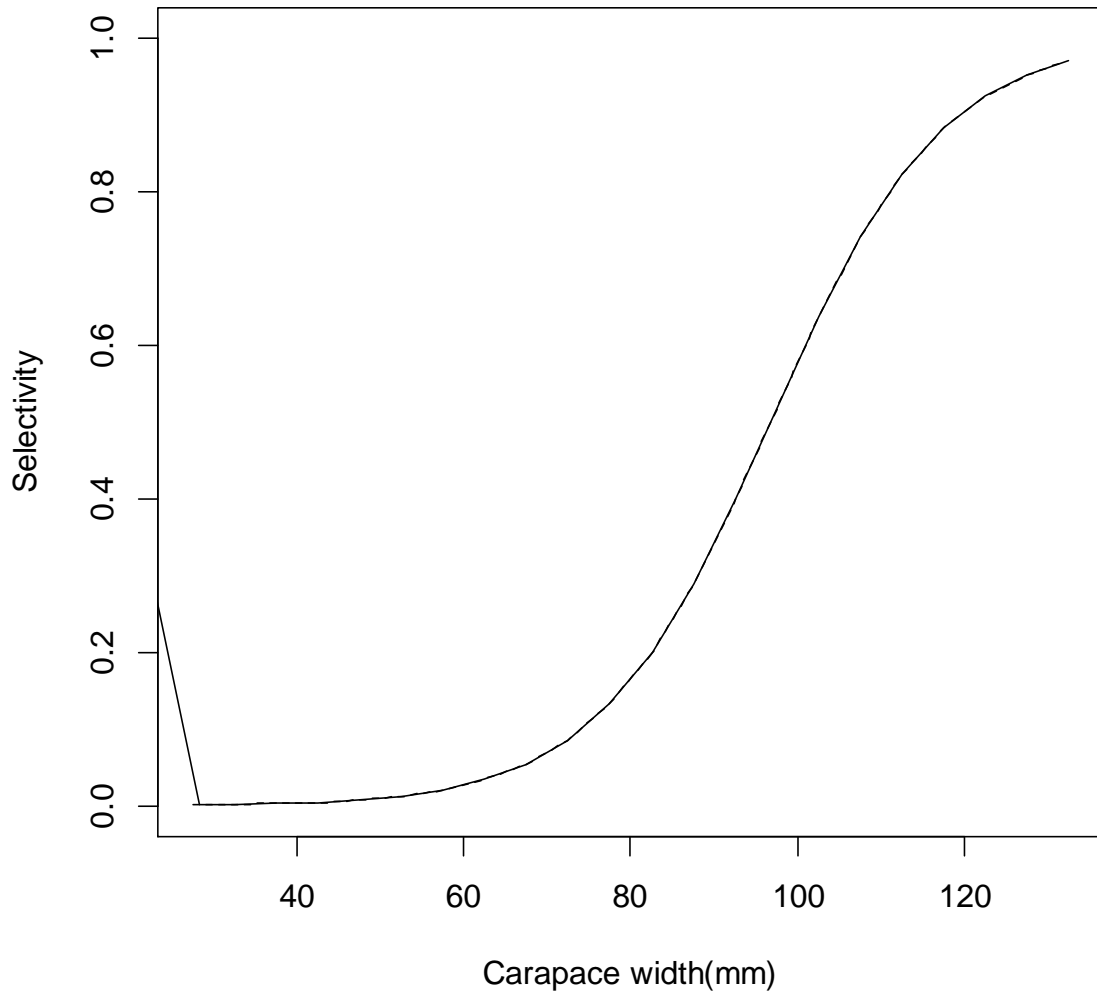


Figure 39. Model 0. Selectivity curve estimated by the model for bycatch in the groundfish trawl fishery for females and males.

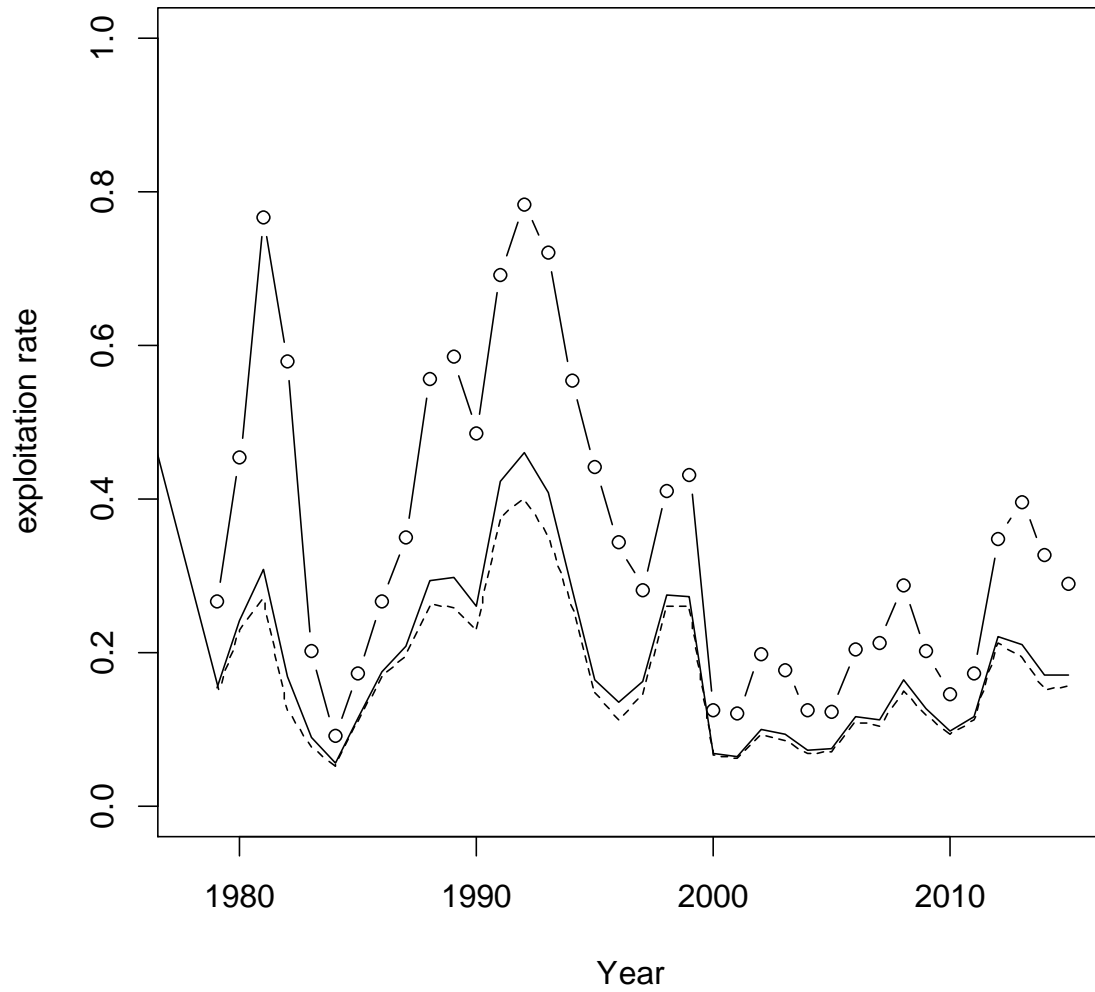


Figure 40. Model 0. Exploitation fraction estimated as the catch biomass (total or retained) divided by the mature male biomass from the model at the time of the fishery (solid line is total and dotted line is retained). The exploitation rate for total catch divided by the male biomass greater than 101 mm is the solid line with dots. Year is the year of the fishery.

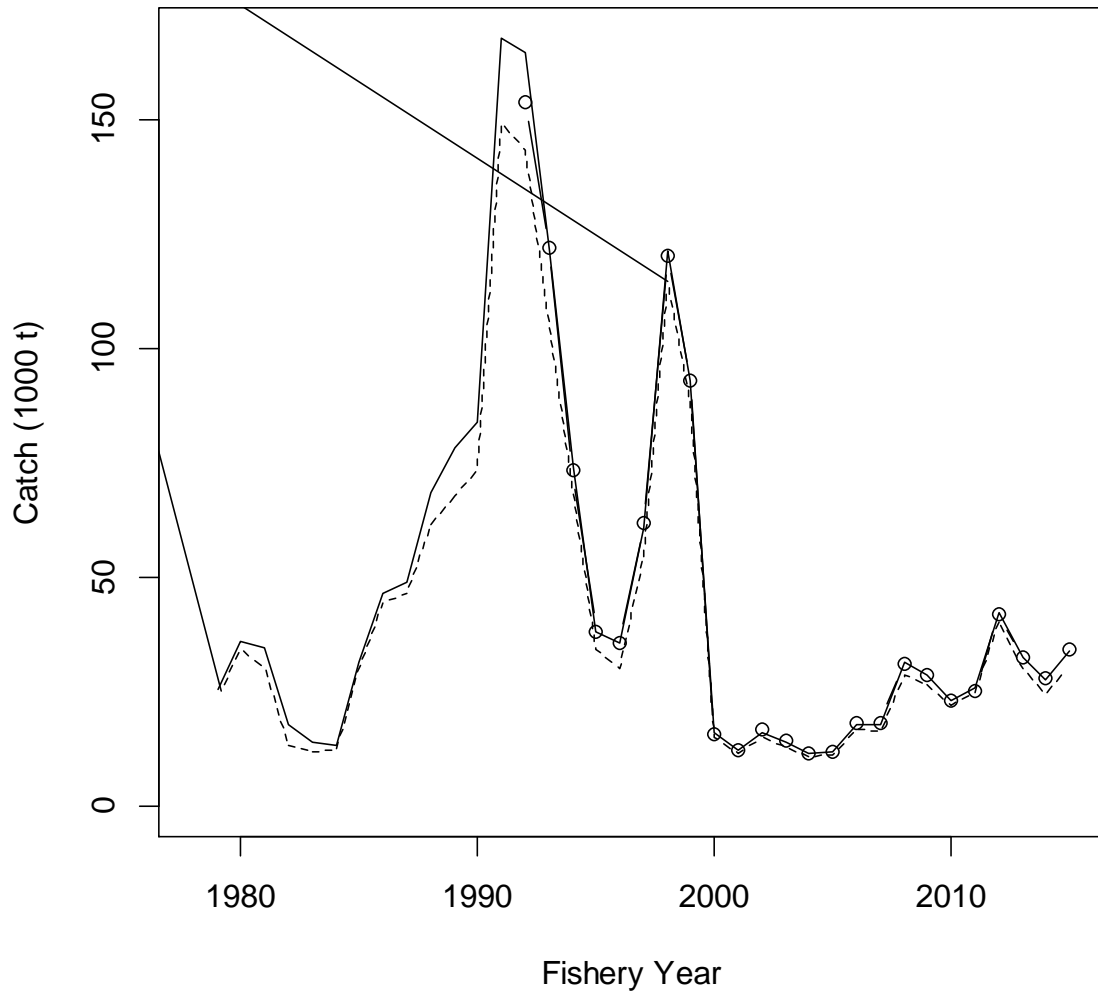


Figure 41. Model 0. Estimated total catch(discard + retained) (solid line), observed total catch (solid line with circles) (assuming 30% mortality of discarded crab) and observed retained catch (dotted line).

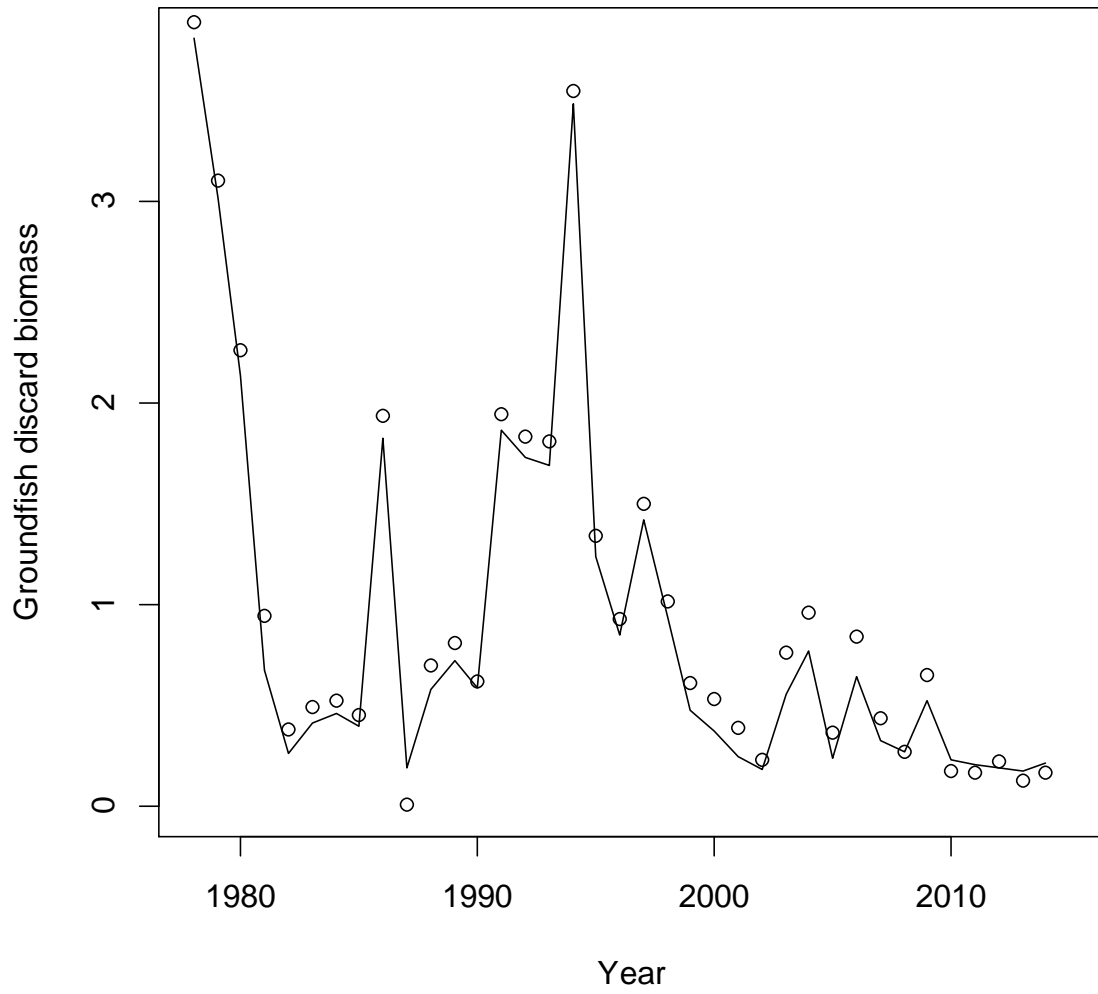


Figure 42. Model 0. Model fit to groundfish bycatch. Circles are observed catch, line is model estimate.

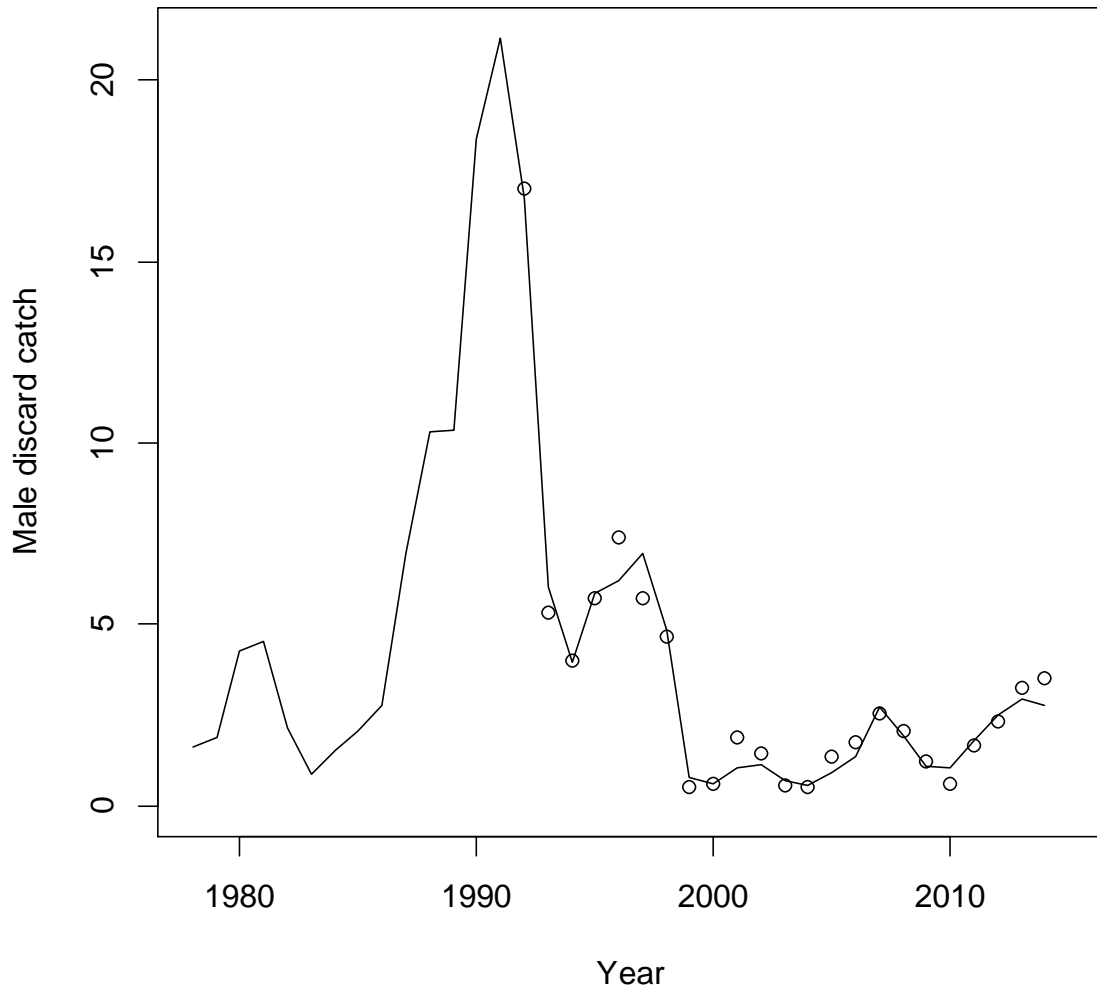


Figure 43. Model 0. Model fit to male directed discard catch for 1992/93 to present and model estimated male discard catch from 1978 to 1991.

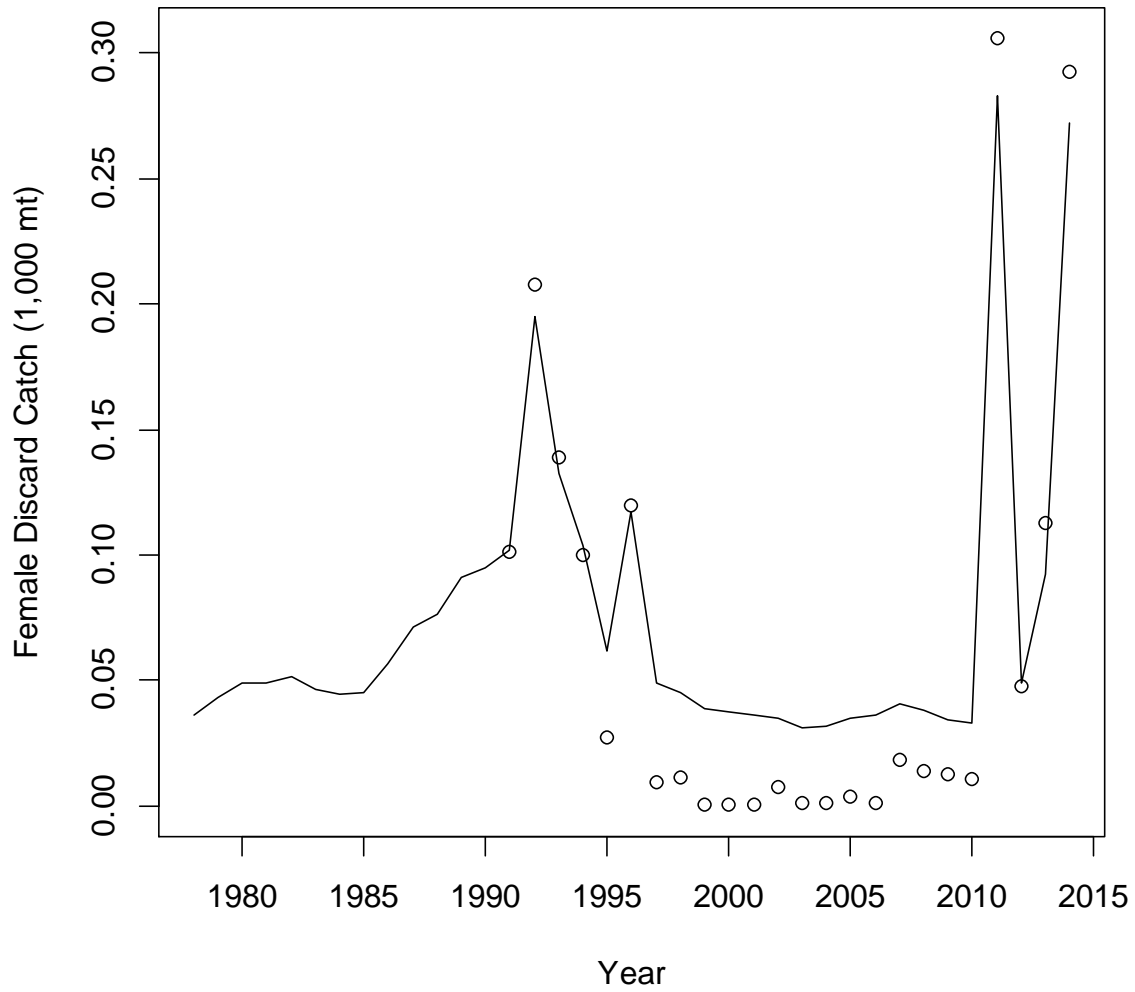


Figure 44. Model 0. Model fit to female discard bycatch in the directed fishery from 1992/93 to present and model estimates of discard from 1978 to 1991.

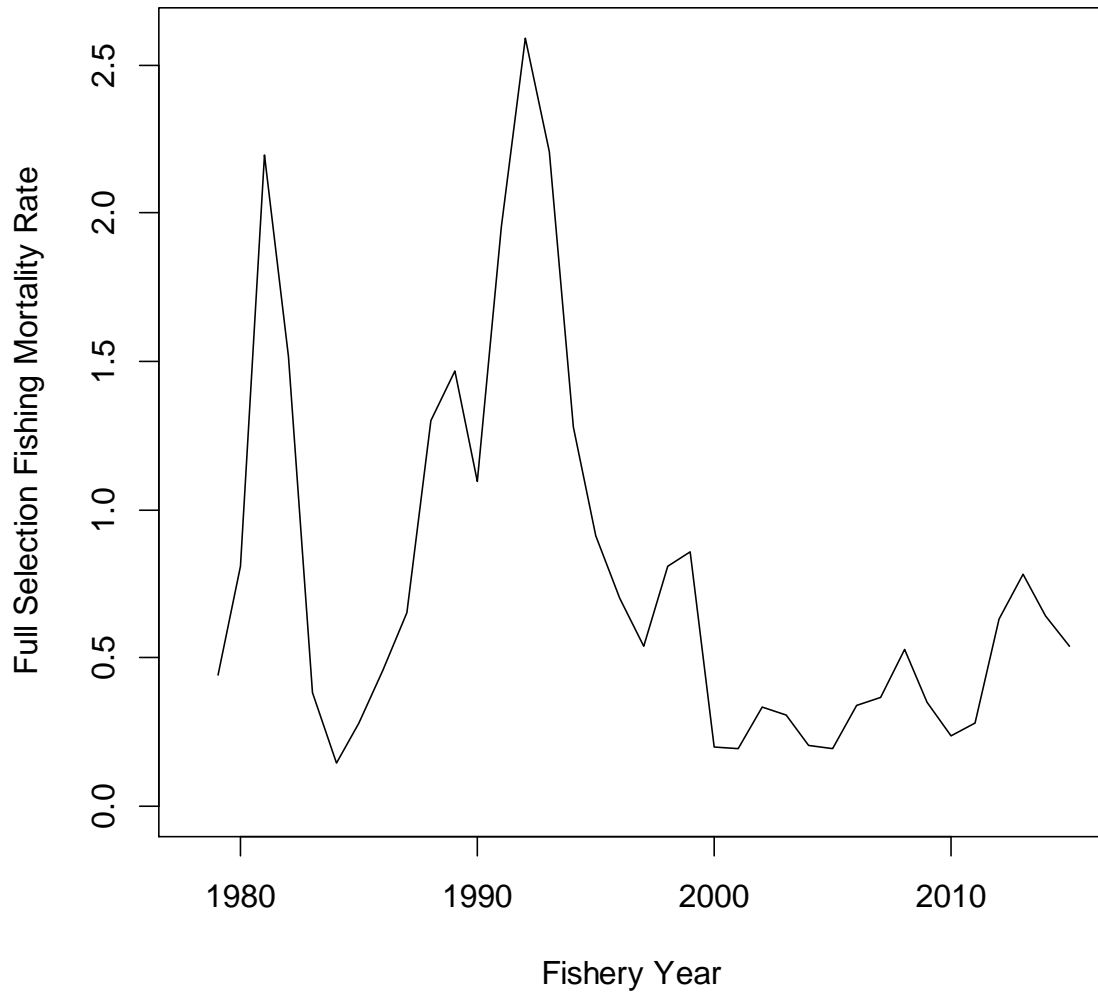


Figure 45. Model 0. Full selection fishing mortality estimated in the model from 1978/79 to present.

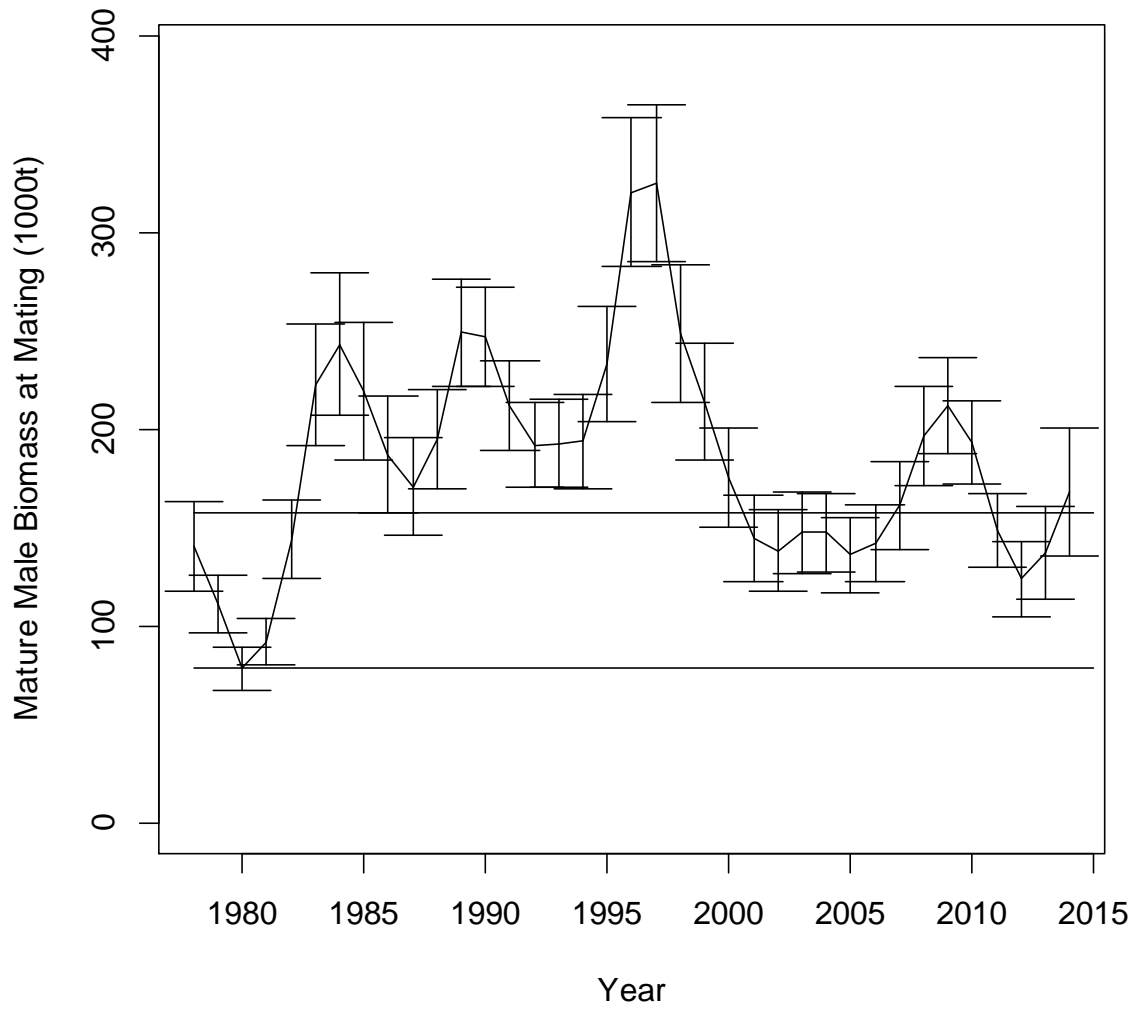


Figure 46. Model 0. Recruitment to the model for crab 25 mm to 50 mm. Total recruitment is 2 times recruitment in the plot. Male and female recruitment fixed to be equal. Solid horizontal line is average recruitment. Error bars are 95% C.I.

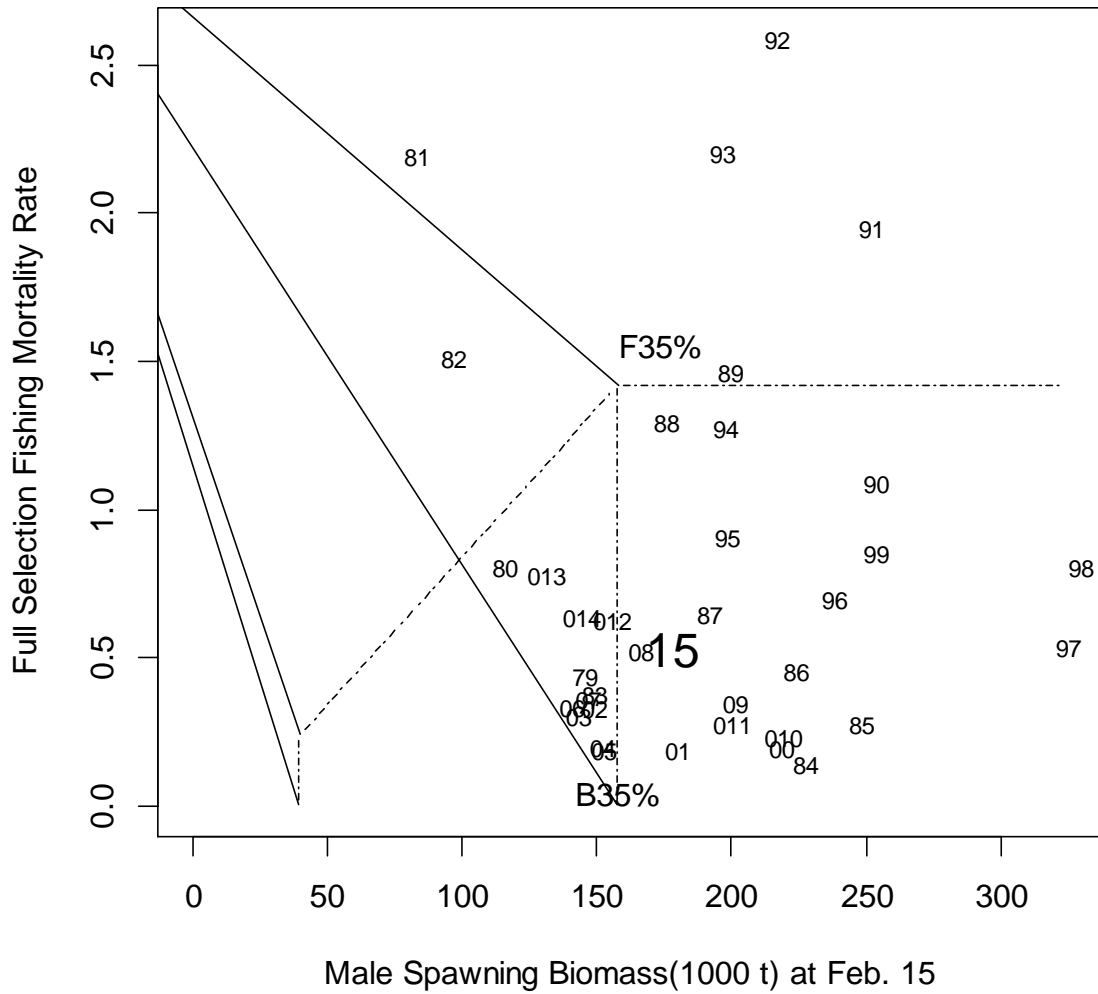


Figure 47. Model 0. Fishing mortality estimated from fishing years 1979 to 20013/14 (labeled 14 in the plot). The OFL control rule (F35%) is shown for comparison. The vertical line is B35%, estimated from the product of spawning biomass per recruit fishing at F35% and mean recruitment from the stock assessment model.

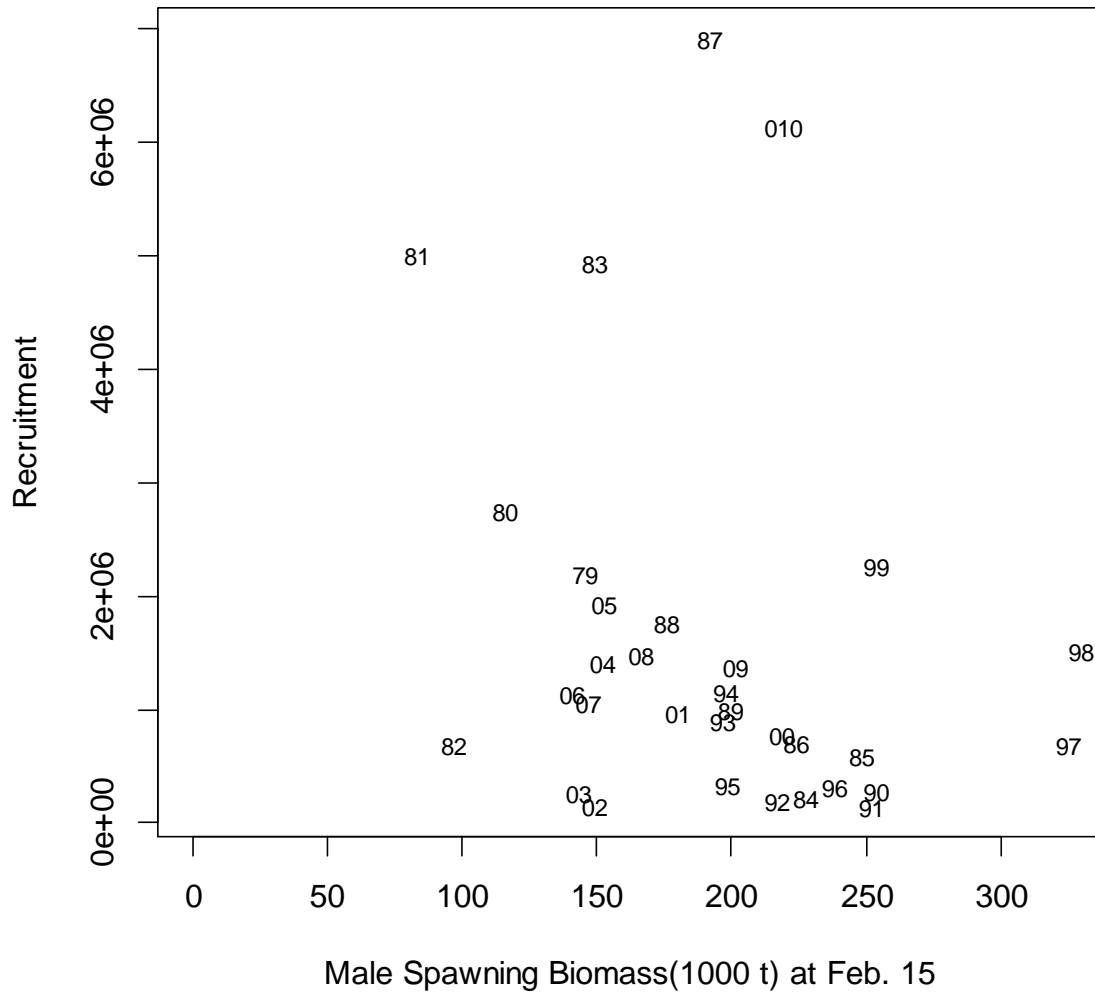


Figure 48. Model 0. Spawner recruit estimates using male mature biomass at time of mating (1000t). Numbers are fertilization year assuming a lag of 5 years. Recruitment is half total recruits in thousands of crab.