May 2019 Report for Developments in the Tanner Crab Stock Assessment

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Responses to SSC and CPT Comments

1. Responses to the most recent two sets of SSC and CPT comments on assessments in general.

October 2018 SSC Meeting
No new general comments.

September 2018 Crab Plan Team Meeting
No new general comments.

June 2018 SSC Meeting
No new general comments.

May 2018 Crab Plan Team Meeting
No new general comments.

2. Responses to the most recent two sets of SSC and CPT comments specific to the assessment. [Note: for continuity with the previous assessment, the following includes comments prior to the most recent two sets of comments.]

October 2018 SSC Meeting
Comment: The SSC supports "the author's plans to investigate the sensitivity of the model to just a few early years of catch data".
Response: As described in Section 3.2, the apparent sensitivity of the model to changes in the early 1990s crab observer data was instead due to using erroneous input sample sizes for several years of fishery size composition data. After correcting these errors, the results using the revised crab fishery data are much more reasonable. The author recommends adopting the revised crab fishery data, which is based on a painstaking reclassification of directed vs. incidental effort in the early Tanner and snow crab fisheries that more closely reflects current ADFG practices.

Comment: "The SSC continues to recommend that the authors try to resolve the parameters on the bounds issue by either simplifying the model or experimenting with removing the bounds".
Response: Available time limited efforts to address this continuing issue. A number of formerly-estimated parameters related to the sex- and size-specific probability of undergoing the terminal molt to maturity have been eliminated because they were, unsurprisingly, estimated at their bounds (implying a probability of 0 for a terminal molt of very small immature crab or 1 for very large immature crab). This had no discernable effect on the MLE solution.

Comment: "The author should justify fitting both abundance and biomass indices in the model or fit only one index".
Response: The author sees no justification for fitting both abundance and biomass indices in the current model configuration and so will only include fits to one index in the model optimization. Fits to the other index may provide a diagnostic capability.

Comment: “The team looks forward to seeing the BSFRF work included in the future If the catchability study is to be used to inform selectivity and catchability estimates in the model, it could be as a prior instead of as fixed inputs”.
Response: A preliminary model scenario incorporating the BSFRF side-by-side tow studies is presented here using an approach similar to that used in the snow crab model. Its use as a prior is an intriguing possibility but would require substantial additional model development and remains to be explored.

September 2018 CPT Meeting
Comment: ???
Response: ????

June 2018 SSC Meeting
The SSC endorsed the CPT suggestions from its May meeting.
Response: none.

The SSC requested an evaluation of all parameters estimated to be at or very near bounds, or substantially limited by priors (unless those priors can be logically defended).
Response: Mean growth on a log-log (post-molt, pre-molt) scale was re-parameterized from a linear equation based on slope and intercept parameters to one based on estimated postmolt sizes at specified premolt sizes, which eliminated the slope/intercept parameters being estimated on their bounds.

May2018 Crab Plan Team Meeting
The CPT outlined a number of alternative models built on the 2017 assessment model (2017AM) as the base model to be evaluated.
Response: The CPT referred to these models as 2018B0, 2018B1, 2018B2, 2018B3, 2018B4 and 2018B5. These models were all run for this assessment, but renamed as 18A, 18B, 18C0, 18C1, 18D0, and 18D1, where “18” refers to the assessment year, A/B/C/D refers to different datasets included in the likelihood, and 0/1 refers to whether (1) or not (0) survey abundance time series were included in the fitting process in addition to survey biomass time series. 2017AM is subsequently referred to herein as 17AM. In addition to the alternative model scenarios requested by the CPT, several additional scenarios were also run: 17AMu, 18C0a, 18C1a, 18C2a, and 18C3a. Scenario 17AMu represents the 2017 assessment model re-run with revised (i.e., “u”pdated) data for the crab fisheries. The “a” in the remaining scenarios refers to ones in which the likelihood component for male maturity ogive data was down-weighted, whereas “2” and “3” refer to fixing the survey catchability and selectivity parameters to match ones from Somerton and Otto (1999)’s underbag experiment.

1. Introduction

The purpose of this chapter is to report on recent work on issues related to the Tanner crab assessment. These include assessment model development (Section 2), issues with crab fishery data (Section 3), issues with overestimation of abundance of large crab (Section 4), and incorporation of side-by-side tow data from BSFRF and NMFS EBS Shelf Surveys into the assessment model (Section 5). Each of these topics is discussed in the relevant section below, with more detail included in accompanying appendices. In the final section (Section 6), a suite of model scenarios is proposed to be evaluated for the Fall 2019 CPT Meeting.

2. Assessment Model Development

The TCSAM02 assessment model code used in the 2018 assessment (Stockhausen, 2018) is described in Appendix A2.1. Recent developments with the model that are not described in the appendix include: 1) adding the ability to specify or estimate "nonparametric" selectivity/availability functions; 2) calculation of cohort progressions reflecting model processes (e.g., natural mortality, growth, etc.) for a specified year; 3) implementation of a simple harvest control rule to calculate TAC based on model inputs, estimated quantities, and the calculated OFL; and 4) implementation of "operating model" and "estimation model" modes that facilitate running a Management Strategy Evaluation (MSE). The latter two efforts are to facilitate a MSE project by Madison Shipley (NRC, UW) to evaluate potential Tanner crab harvest control rules proposed by ADFG. The cohort progression calculation provides a way to investigate tradeoffs among model processes in determining population structure. To facilitate more efficient investigation into tradeoffs among model processes in determining population structure, the cohort progression calculations have also been implemented as an R Shiny application (Chang et al., 2018) available as an R package on GitHub (shinyTC.CohortProgression).

The ability to specify or estimate "nonparametric" selectivity/availability functions allows the incorporation of BSFRF side-by-side trawl survey data into the assessment model in a manner similar to that used in the snow crab model (Szuwalski, 2018). Since 2013, the BSFRF has conducted a series of "side-by-side" (SBS) trawl gear studies in conjunction with the NMFS EBS Shelf Bottom Trawl Survey. At an SBS station, a BSFRF-chartered fishing vessel tows a modified nephrops trawl on a parallel course to a NMFS-chartered vessel towing its standard 83-112 trawl gear. The two vessels maintain approximately the same speed and direction, with a separation of ~0.5 nm, while the tows last; the BSFRF tow lasts 5 minutes while the NMFS tow lasts 30 minutes. While the SBS stations are a subset of the standard NMFS survey grid, somewhat different areas have been included in the SBS comparisons in different years.

The expected size-specific abundance of crab by the two surveys from the area covered by an SBS study is modeled as

$$\tilde{n}_{x,z}^{s} = q_x^s \cdot S_{x,z}^{s} \cdot A_{x,z} \cdot n_{x,z} \qquad (2.1)$$

where $\tilde{n}_{x,z}^{s}$ is the expected abundance of crab classified as *x* in size bin *z* for survey gear *s*, q_x^s denotes *x*-specific survey catchability, $S_{x,z}^{s}$ denotes survey selectivity, $n_{x,z}$ denotes overall population abundance, and $A_{x,z}$ denotes the sex- and size-specific *availability*, i.e. the fraction of type *x* crab in size bin *z* within the SBS study area relative to the overall population (an additional subscript for year is implied on the *n*'s and *A*, because the SBS studies were conducted in multiple years using different areas). Here, "*x*" denotes some life-stage based classification of crab (e.g., sex or sex/shell condition, etc.).

The BSFRF survey gear is assumed to be fully-selective for all crab within an SBS study area and thus provide an absolute, rather than relative, estimate of abundance within the SBS area. This implies $q_x^{BSFRF} \equiv 1$ and $S_{x,z}^{BSFRF} \equiv 1$ and thus, for a BSFRF survey, Eq. 2.1 reduces to

$$\tilde{n}_{x,z}^{BSFRF} = A_{x,z} \cdot n_{x,z} \tag{2.2}$$

In contrast, the full NMFS survey is assumed to encompass the entire Tanner crab population, so availability $A_{x,z} \equiv 1$ and the expected survey abundance for the entire survey, $\hat{n}_{x,z}^{NMFS}$, is given by

$$\hat{n}_{x,z}^{NMFS} = q_x^{NMFS} \cdot S_{x,z}^{NMFS} \cdot n_{x,z} \tag{2.3}$$

and thus provides a measure of relative abundance because q_x^{NMFS} is confounded with $n_{x,z}$. However, at just the SBS stations, the expected NMFS survey catch can be modeled as

$$\tilde{n}_{x,z}^{NMFS} = q_x^{NMFS} \cdot S_{x,z}^{NMFS} \cdot A_{x,z} \cdot n_{x,z} = q_x^{NMFS} \cdot S_{x,z}^{NMFS} \cdot \tilde{n}_{x,z}^{BSFRF} \tag{2.4}$$

where the second relationship follows from Eq. 2. Because $\tilde{n}_{x,z}^{BSFRF}$ is assumed known (although with sampling error), q_x^{NMFS} is no longer confounded and can be uniquely determined.

Following the snow crab assessment model, availability $A_{x,z}$ is modeled as a smooth "nonparametric" function of size, with a logit-scale parameter $p_{x,z}$ estimated for each size bin across a specified range of sizes such that

$$A_{x,z} = \frac{1}{1+\exp\left(-p_{x,z}\right)} \tag{2.5}$$

and a 2nd difference penalty on the parameters

$$\mathcal{L}_S = \lambda \cdot \left[\nabla(\nabla p_{x,z})\right]^2 \tag{2.6}$$

(λ is a likelihood weighting factor and ∇ is the first difference operator, i.e. $\nabla p_{x,z} = p_{x,z+1} - p_{x,z}$) is added to the overall model likelihood to ensure $A_{x,z}$ is a smooth function of size.

3. Fishery Data Issues

3.1. Incidentally-retained Tanner crab
Prior to the 2018 stock assessment, ADFG provided values for retained catch abundance and biomass by shell condition from fish ticket data for 2005/06-2016/17, with new values for 2017/18, which included a breakout of incidental retained Tanner crab catch in the snow crab and BBRKC fisheries (Table 3.1). Previously, only total retained catch had been provided and all retained catch was attributed to the directed fisheries. In general, incidental retained catch of Tanner crab in the snow crab and BBRKC fisheries has been very small (typically < 1-2%) compared with retention in the directed fishery and, thus, attributing this mortality to the directed fisheries has been a negligible approximation. However, the maximum retention rate was increased west of 166ºW in 2017 from 5% to 35% and industry has expressed a desire to allow full retention in the snow crab fishery. Although actual retention rates have not yet increased, it will become more important when it does occur to attribute this mortality to the correct source, which will necessitate estimating a size-specific retention function for (at least)the snow crab fishery in addition to that for the (combined) directed fisheries.

3.2. Revised total catch estimates
ADFG also provided revised estimates of total catch (retained + discards) abundance, biomass, and size compositions in all three crab fisheries by sex and shell condition for 1990/91-2016/17, with new estimates provided for 2017/18, based on "at-sea" crab observer sampling (Tables 3.2-3, Figures 3.1-5). Fishery effort, sampling effort, and the expansion factors used to scale observed catch to total catch are listed in Table 3.4. Values for total male catch in the (combined) directed fisheries and the snow crab fishery in the early 1990's (1992 in particular) differed substantially between the revised values and those previously used in the stock assessment (Figures 3.1-2). Total catch size compositions estimated from at-sea "measure pot" sampling were also fairly different for sampling in the snow crab fishery but nearly identical in the combined directed fisheries and the BBRKC fishery (Figures 3.3-5). While model scenarios with the revised data were run for the 2018 assessment, the overall results were substantially different from those using the previous data (updated to include 2017/18; Stockhausen, 2018)). Because the CPT had not had the chance to review the revised estimates prior to the assessment, it chose to recommend a model based on the previous data for status determination and setting the OFL for 2018/19 (CPT, 2018).

Following the 2018 assessment, ADFG was requested to review the revised estimates of total catch it had provided to verify the calculations behind the estimates and provide more confidence in their veracity, particularly given the substantial differences with previous values for males in the directed fisher and snow crab fisheries in 1992, as well as the apparent impact the revised values had on the assessment model results. ADFG has done so (B. Daly, pers. comm., April, 2019) and verified the calculations. The changes in the estimates are mainly due to an effort by D. Pengilly (ADFG) to reclassify early 1990's fishery effort in the snow crab and Tanner crab fisheries to more closely reflect "true" directed effort using the proportion of those species in the landed catch by delivery. At the time, directed and incidental effort was not apportioned between the Tanner and snow crab fisheries whereas it is now apportioned on a vessel trip basis.

In addition, a rather painstaking effort was undertaken to identify the causes of the substantial differences in assessment model results using the previous and revised data. In the course of substituting the revised data for the previous values one year at a time for each fishery in the model data files and re-running the assessment model, several errors were discovered in the input sample sizes assigned to the revised retained catch and total catch size compositions. Once these sample sizes were corrected, the model results with the revised data were much closer to those using the previous data (Table 3.5, Figures 3.1-6).

Table 3.5 and Figures 3.1-6 provide a comparison of selected results from running the assessment model using the previous data (model scenario 19.0) and running the model using the revised crab fishery data with the corrected sample sizes for the size compositions (model scenario 19.1b). Table 3.5 also includes OFL-related quantities from the 2018 assessment's model scenario 18A, which was run with the revised fishery data but erroneous sample sizes. Using the erroneous sample sizes with the revised data (18.A) lead to average recruitment being estimated 44% larger than the scenario with the correct sample sizes (19.1b) and 75% larger than the scenario with the previous values (19.0). As discussed in the 2018 SAFE chapter (Stockhausen, 2018), this effect was tied primarily to lower estimates for survey catchability in scenario 18.A. Average recruitment from model scenario 19.1b was only 21% larger than that from 19.0, again reflecting lower estimated size-specific survey catchability (Figure 3.8). Estimated fully-selected fishery capture rates and selectivity curves in the directed fishery are similar for the two models (Figure 3.9-10), with the early 1990s being an exception, as one would expect given changes in the fishery data being fit. The fully-selected capture rates are also fairly different in 1978/79-1979/80, which is somewhat unexpected and bears further investigation. On the other hand, the estimated capture rates in the snow crab fishery are substantially different in terms of scale for females across the entire model time period and for males for 1978/79-2003/04 (Figure 3.11). However, the differences for females are extremely small on an absolute scale (<0.06) for females and can be attributed for males to the differences in data (aggregated catch biomass and size compositions, Figures 3.2 and 3.4), subsequent estimated selectivity curves (Figure 3.12 for 1996), and average recruitment (Table 3.5). Estimated capture rates for bycatch in the BBRKC fishery and groundfish fisheries (not shown) differ only in relative scale reflecting the difference in average recruitment between the model results; the estimated selectivity curves (not shown) are almost identical.

Thus, in this author's opinion, the issues that led the CPT to be reject model scenarios based on the revised fishery data in the 2018 assessment have been resolved. Ben Daly (ADFG; pers. comm., April 2019) has also stated that the revised data represents the best available estimates of total fishery catch based on a careful revision of directed effort in the crab fisheries, and that it may not be possible to identify the exact series of calculations used to obtain the older estimates.

3.3. Fishery catch expansion

In the interest of streamlining the process for obtaining crab fishery data, the author attempted to replicate the manner in which ADFG expands at-sea observer sampling to estimate total catch and bycatch in the directed Tanner crab and incidental bycatch of Tanner crab in the snow crab and BBRKC fisheries. This has been described anecdotally as a simple expansion of observed catch in sampled pots from the number of pots sampled to the total effort (potlifts) in the fishery in question. Thus, if a crab in some category (e.g., male, female) are caught in n_s sampled pots, then the estimated total catch abundance of crab in that category, A, would be

$$A = \frac{n_T}{n_s} \cdot a \qquad (3.1)$$

where n_T is the total number of pots fished in the fishery.

Ben Daly (ADFG) provided the author with expanded estimates of total catch abundance and biomass, total effort, "measure pot" sampling effort, and "measure pot" sampling data for 1990/91-2017/18 in the directed Tanner crab fisheries, the snow crab fishery, and the BBRKC fishery. "Measure pots" are observer-sampled pots in which the observer records sex, size, shell condition, and other biological characteristics for each crab caught ("summary pots" are the other type of observer-sampled pot; male crab are enumerated within "legal retained", "legal not-retained", and "sublegal" classifications while females are simply enumerated). As described in Appendix 3.1 in more detail, the author calculated expanded estimates of catch abundance and biomass in each crab fishery using Eq. 3.1 and observed abundance by sex extracted from the measure pot data provided, as well as the total effort and sampling effort data, and compared these estimates with those from ADFG. There seems to be pretty good agreement between the author's estimates and those provided by ADFG after 2005/06 for all four crab fisheries—but there are substantial differences prior to 2005/06 for bycatch in the snow crab fishery, with smaller relative discrepancies evident in the directed Tanner fisheries and the BBRKC fishery (Appendix Figures 3.1-4). While it is certainly possible that this author's calculations are incorrect, one would expect to see disagreement in the estimates across the entire time series for each fishery. Instead, it seems more likely that the ADFG estimates are based on something other than the simple expansion in Eq. 3.1 from the measure pot data. This could involve, for example, first extrapolating measure pot abundances to summary pot abundances (measure pots are a subset of the summary pots) or extrapolating to fill in missing data. Whatever the case, this author believes it is worthwhile identifying the actual procedures used to estimate total at-sea catch abundance and biomass.

3.4 Tables

Table 3.1. Retained catch of Tanner crab by fishery. TCF: Tanner crab fisheries; SCF: snow crab fishery; RKF: BBRKC fishery.

	TCF						SCF		RKF	
	West 166W		East 166W		all EBS		all EBS		all EBS	
year	Abundance	Biomass (kg)	Abundance	Biomass (kg)	Abundance	Biomass (kg)	Abundance	Biomass (kg)	Abundance	Biomass (kg)
2005	376, 080	365, 110	0	0	376, 080	365, 110	67, 897	67, 112	0	0
2006	333, 508	320, 187	583, 650	633, 937	917, 158	954, 124	7, 115	6, 784	1, 830	1, 883
2007	232, 345	228, 829	679, 137	711, 640	911, 482	940, 469	9, 328	8, 761	6, 354	6, 334
2008	48, 171	47, 157	760, 166	809, 022	808, 337	856, 179	3, 300	2, 535	18, 732	21, 068
2009	0	0	476, 668	592, 417	476, 668	592, 417	2, 544	1, 714	6, 751	8, 402
2010	0	0	0	0	0	0	1, 689	1, 154	6	3
2011	0	0	0	0	0	0	3, 095	2, 092	0	0
2012	0	0	0	0	0	0	1, 643	1, 111	4	3
2013	722, 469	593, 617	704, 201	654, 271	1, 426, 670	1, 247, 888	13, 256	9, 882	5, 842	6, 322
2014	3, 121, 442	2, 368, 693	4, 378, 199	3, 829, 288	7, 499, 641	6, 197, 981	19, 512	14, 458	3, 691	3, 792
2015	4, 817, 145	3, 770, 319	5, 998, 876	5, 107, 722	10, 816, 021	8, 878, 041	39, 011	30, 252	1, 386	1, 350
2016	0	0	0	0	0	0	1, 733	1, 177	33	21
2017	1, 322, 542	1, 117, 483	139	119	1, 322, 681	1, 117, 602	17, 688	15, 018	25	17

Table 3.2. Comparison of the total catch estimates (1000's t) for male crab in the (combined) directed Tanner crab fisheries ('TCF') used in the accepted 2018 stock assessment model (18AM17; 2018 SAFE) and the revised estimates provided by ADFG.

year	TCF	
	2018 SAFE	ADFG
1991	--	25.82
1992	22.10	37.01
1993	11.54	11.85
1994	6.67	7.32
1995	4.68	5.07
1996	0.94	0.30
2005	0.89	0.68
2006	2.33	1.71
2007	3.00	2.46
2008	1.31	1.30
2009	0.67	0.66
2013	1.63	1.68
2014	8.67	8.36
2015	11.95	12.23
2017	2.11	1.36

Table 3.3. Comparison of total bycatch estimates (1000's t) for male Tanner crab in the snow crab ('SCF') and BBRKC ('RKF') fisheries used in the accepted 2018 stock assessment model (18AM17; '2018 SAFE') and the revised estimates provided by ADFG.

year	SCF		RKF	
	2018 SAFE	ADFG	2018 SAFE	ADFG
1990	--	7.08	--	3.72
1991	--	8.36	--	1.97
1992	25.76	2.49	1.19	1.32
1993	14.53	2.87	2.97	3.13
1994	7.12	1.35	--	--
1995	4.80	1.02	--	--
1996	0.83	1.96	0.03	0.27
1997	1.75	1.96	0.16	0.16
1998	1.99	0.66	0.12	0.12
1999	0.70	0.13	0.08	0.08
2000	0.15	0.31	0.07	0.07
2001	0.32	0.55	0.04	0.04
2002	0.56	0.17	0.06	0.06
2003	0.19	0.06	0.06	0.05
2004	0.08	0.13	0.05	0.05
2005	0.97	1.16	0.04	0.04
2006	1.46	1.53	0.03	0.03
2007	1.87	1.86	0.06	0.06
2008	1.12	1.10	0.27	0.28
2009	1.32	1.56	0.15	0.19
2010	1.34	1.45	0.03	0.03
2011	2.12	2.14	0.02	0.02
2012	1.19	1.56	0.04	0.04
2013	1.83	1.84	0.11	0.13
2014	5.38	5.33	0.30	0.31
2015	3.92	3.92	0.20	0.20
2016	2.58	2.58	0.18	0.18
2017	1.11	1.08	0.18	0.18

Table 3.4. Total fishery effort , at-sea observer sampling effort ("measure pots"), and expansion factors in the (combined) Tanner crab fisheries ('TCF'), the snow crab ('SCF'), and the BBRKC ('RKF') fishery used for the revised estimates provided by ADFG.

year	RKF			SCF			TCF		
	potlifts	measure pots	expansion	potlifts	measure pots	expansion	potlifts	measure pots	expansion
1990/91	262,761	138	1,904	1,382,908	--	--	494,299	--	--
1991/92	227,555	267	852	1,278,502	2,127	601	500,914	531	943
1992/93	206,815	281	736	969,209	1,188	816	675,592	774	873
1993/94	254,389	556	458	716,524	1,119	640	326,720	999	327
1994/95	697	--	--	507,603	711	714	249,536	207	1,205
1995/96	547	--	--	520,685	418	1,246	248,442	231	1,076
1996/97	77,081	33	2,336	754,140	406	1,857	73,522	51	1,442
1997/98	91,085	586	155	930,794	547	1,702	0	--	--
1998/99	145,689	387	376	945,533	613	1,542	0	--	--
1999/00	151,212	171	884	182,634	400	457	0	--	--
2000/01	104,056	671	155	191,200	56	3,414	0	--	--
2001/02	66,947	466	144	326,977	239	1,368	0	--	--
2002/03	72,514	485	150	153,862	457	337	0	--	--
2003/04	134,515	725	186	123,709	176	703	0	--	--
2004/05	97,621	534	183	75,095	172	437	0	--	--
2005/06	116,320	1,841	63	117,375	672	175	6,346	139	46
2006/07	72,404	1,202	60	86,328	350	247	19,790	230	86
2007/08	113,948	1,911	60	140,857	506	278	33,709	554	61
2008/09	139,937	1,831	76	163,537	552	296	21,737	424	51
2009/10	119,261	1,939	62	137,292	477	288	6,635	188	35
2010/11	132,183	1,864	71	147,478	617	239	0	--	--
2011/12	45,784	692	66	270,602	654	414	0	--	--
2012/13	38,842	433	90	225,627	834	271	0	--	--
2013/14	46,589	657	71	225,245	751	300	39,675	309	128
2014/15	57,725	520	111	279,183	663	421	141,463	962	147
2015/16	48,763	413	118	202,526	530	382	215,235	1,308	165
2016/17	33,608	413	81	118,548	396	299	0	--	--
2017/18	49,169	803	61	114,673	322	356	19,295	183	105

Table 3.5. Comparison of OFL-related quantities from three assessment model scenarios. 19.0: 2018 assessment model with previous fishery data; 19.1b: 2018 assessment model with revised data and corrected sample sizes; 18A: 2018 assessment model with revised data but erroneous sample sizes.

case	OFL	Fofl	prjB	curB	Fmsy	Bmsy	MSY	B100	avgRec
19.0	20.87	0.74	35.95	66.64	0.74	30.29	12.75	86.55	223.63
19.1b	26.09	0.89	38.82	76.90	0.89	31.56	14.08	90.17	271.81
18A	42.01	1.22	53.87	114.10	1.22	42.00	19.24	120.00	391.22

3.5 Figures

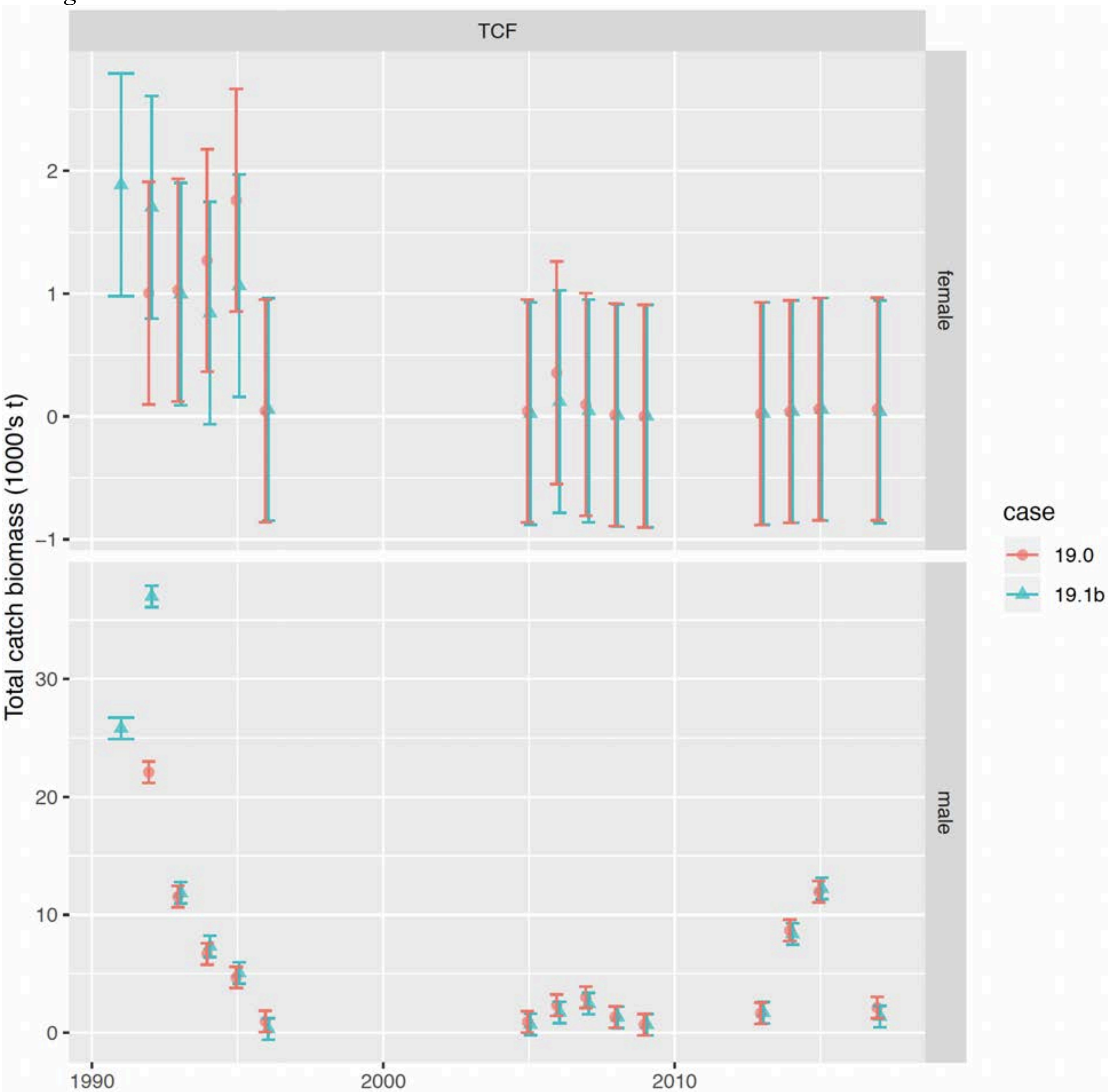


Figure 3.1. Comparison of the time series for "previous" and "revised" estimates of total catch biomass for the (combined) directed fisheries: 19.0: previous total catch biomass estimates; 19.1b: revised estimates (including 1991). Error bars represent 95% confidence intervals for an assumed standard deviation of 500 t.

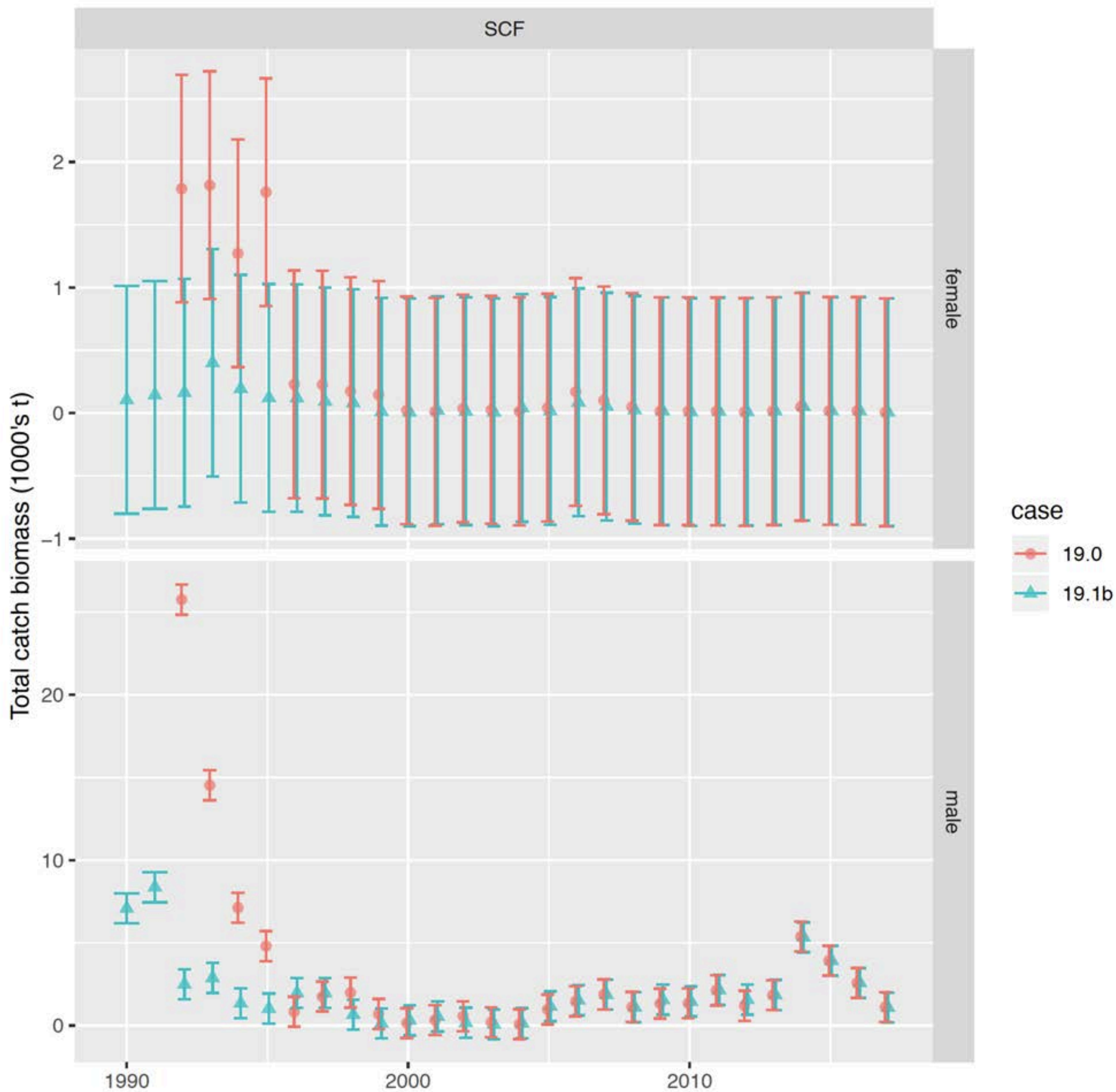


Figure 3.2. Comparison of the time series for “previous” and “revised” estimates of total bycatch biomass for the snow crab fishery (SCF): 19.0: previous total catch biomass estimates; 19.1b: revised estimates (including 1990 and 1991). Error bars represent 95% confidence intervals for an assumed standard deviation of 500 t.

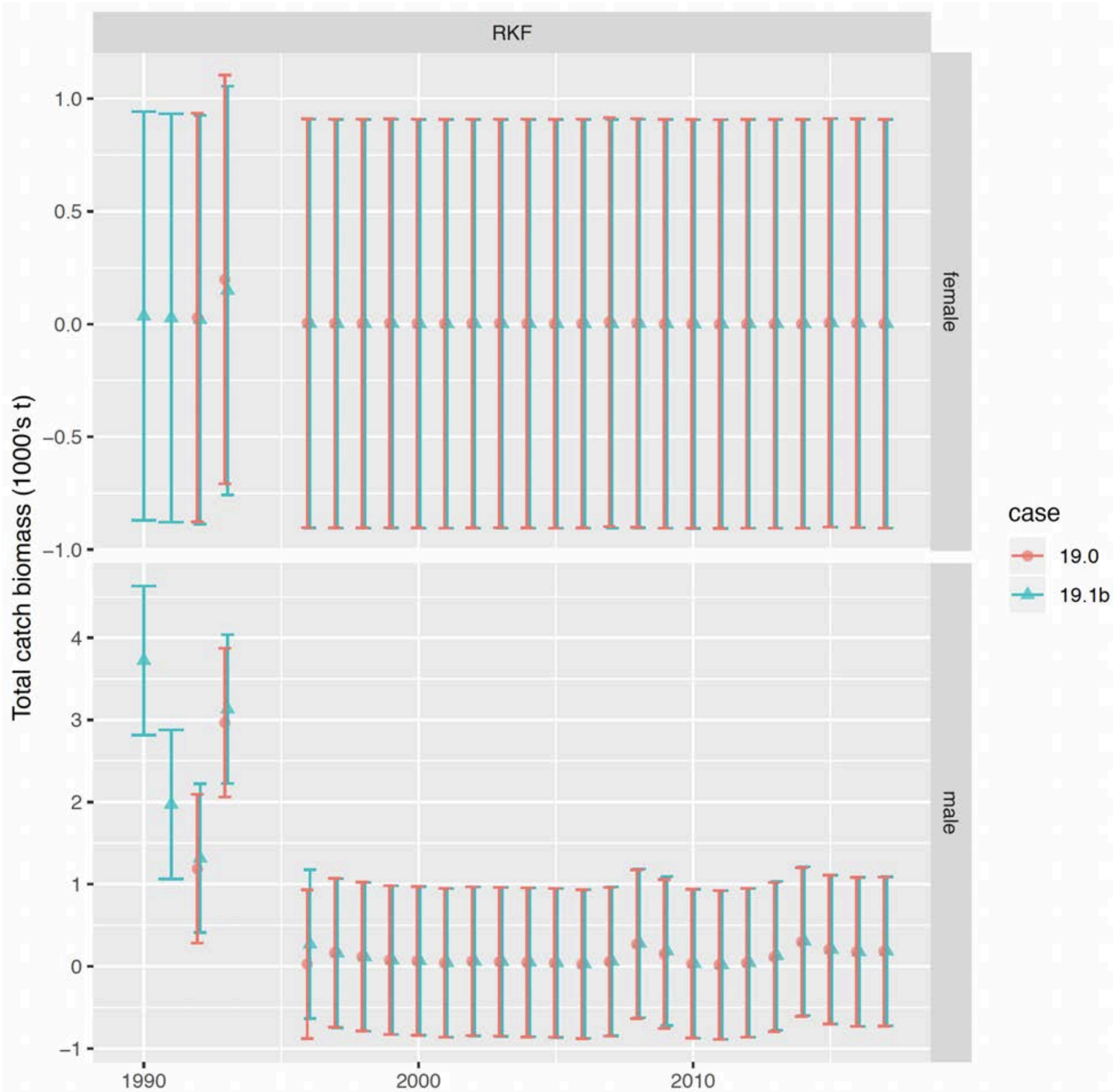


Figure 3.3. Comparison of the time series for “previous” and “revised” estimates of total bycatch biomass for the BBRKC fishery (RKF): 19.0: previous total catch biomass estimates; 19.1b: revised estimates (including 1990 and 1991). Error bars represent 95% confidence intervals for an assumed standard deviation of 500 t.

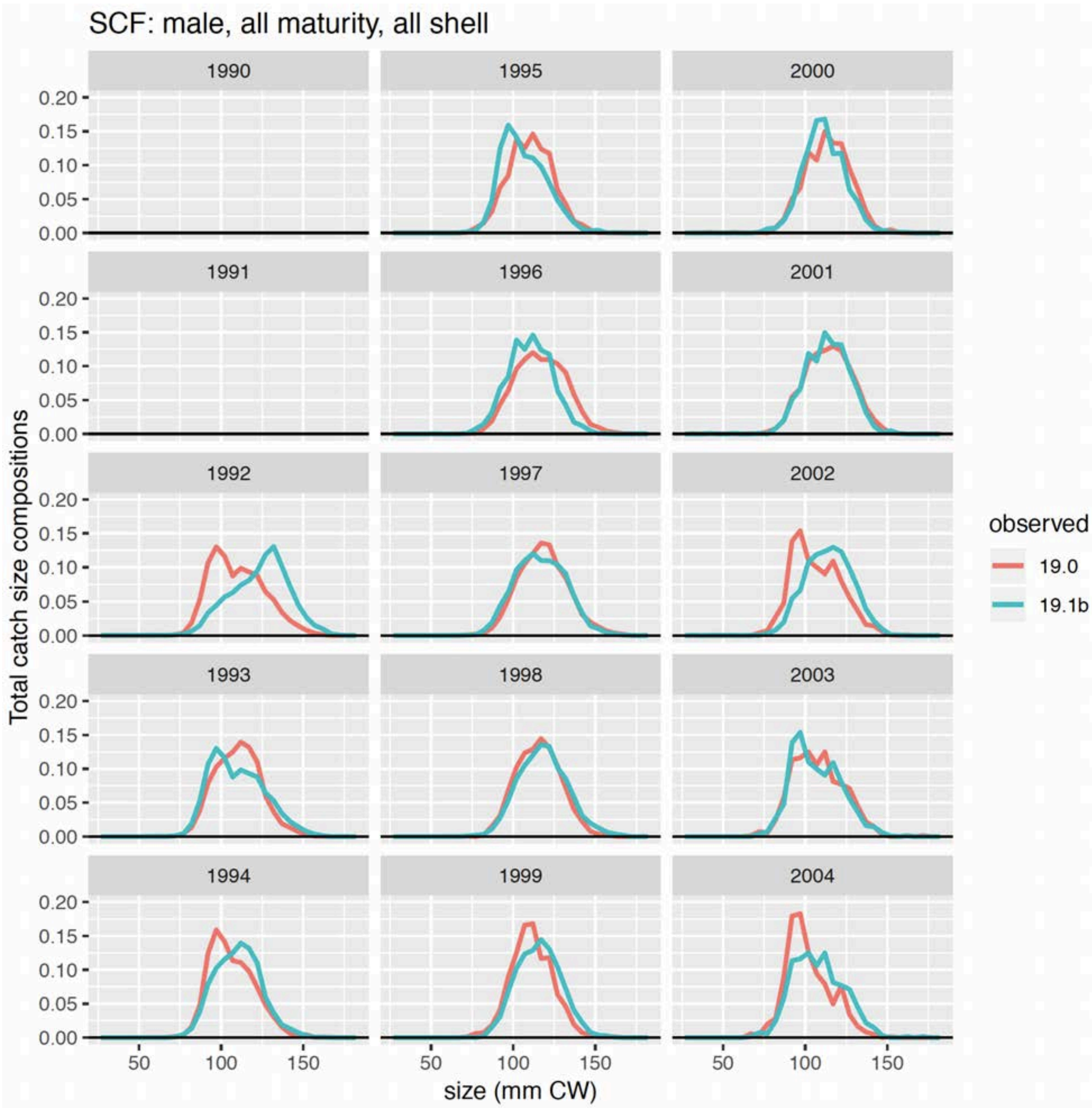


Figure 3.4. Comparison of the time series for “previous” and “revised” estimates of male bycatch size compositions for the snow crab fishery (SCF): 19.0: previous estimates; 19.1b: revised estimates.

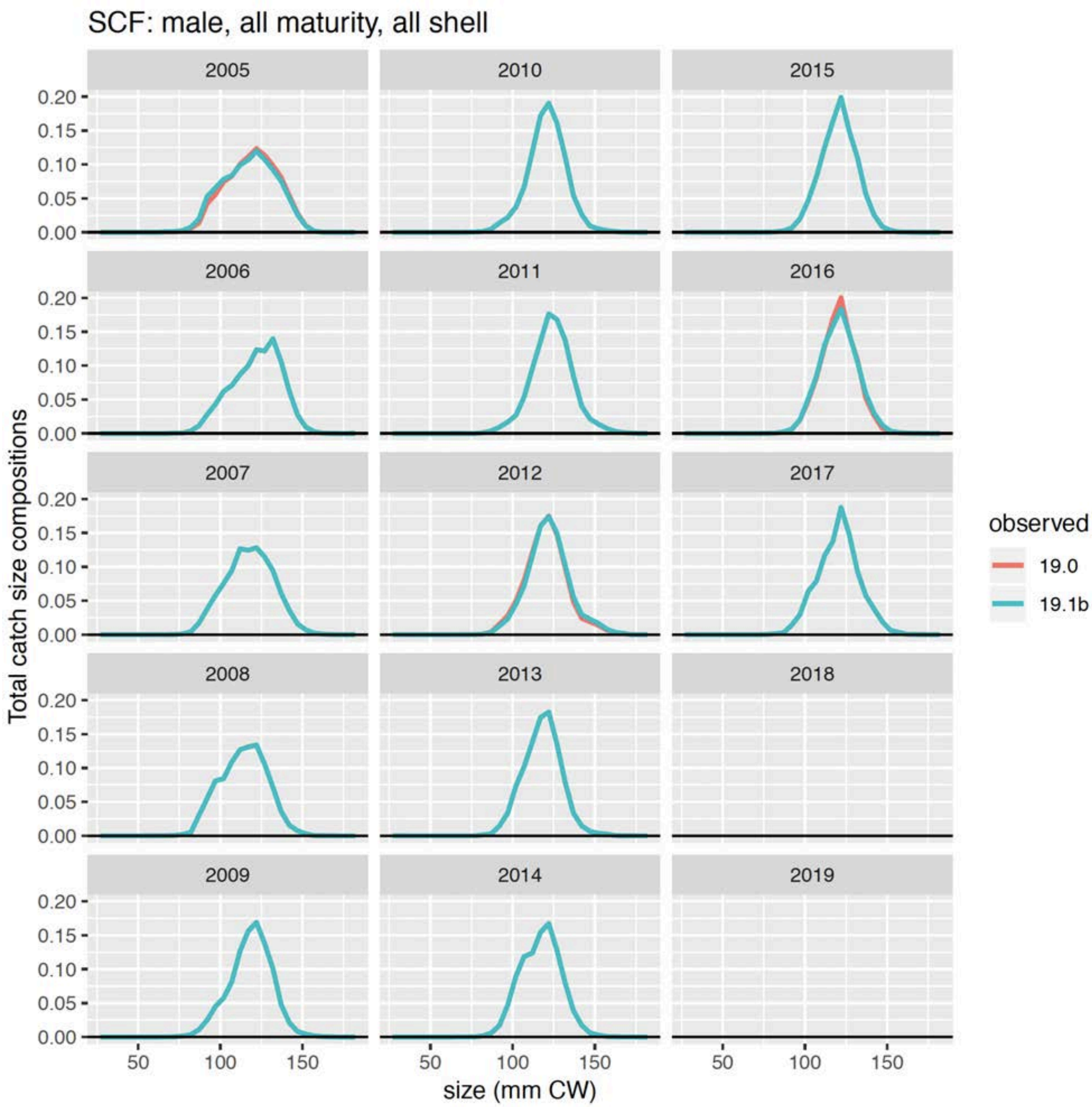


Figure 3.4 (cont.). Comparison of the time series for “previous” and “revised” estimates of male bycatch size compositions for the snow crab fishery (SCF): 19.0: previous estimates; 19.1b: revised estimates.

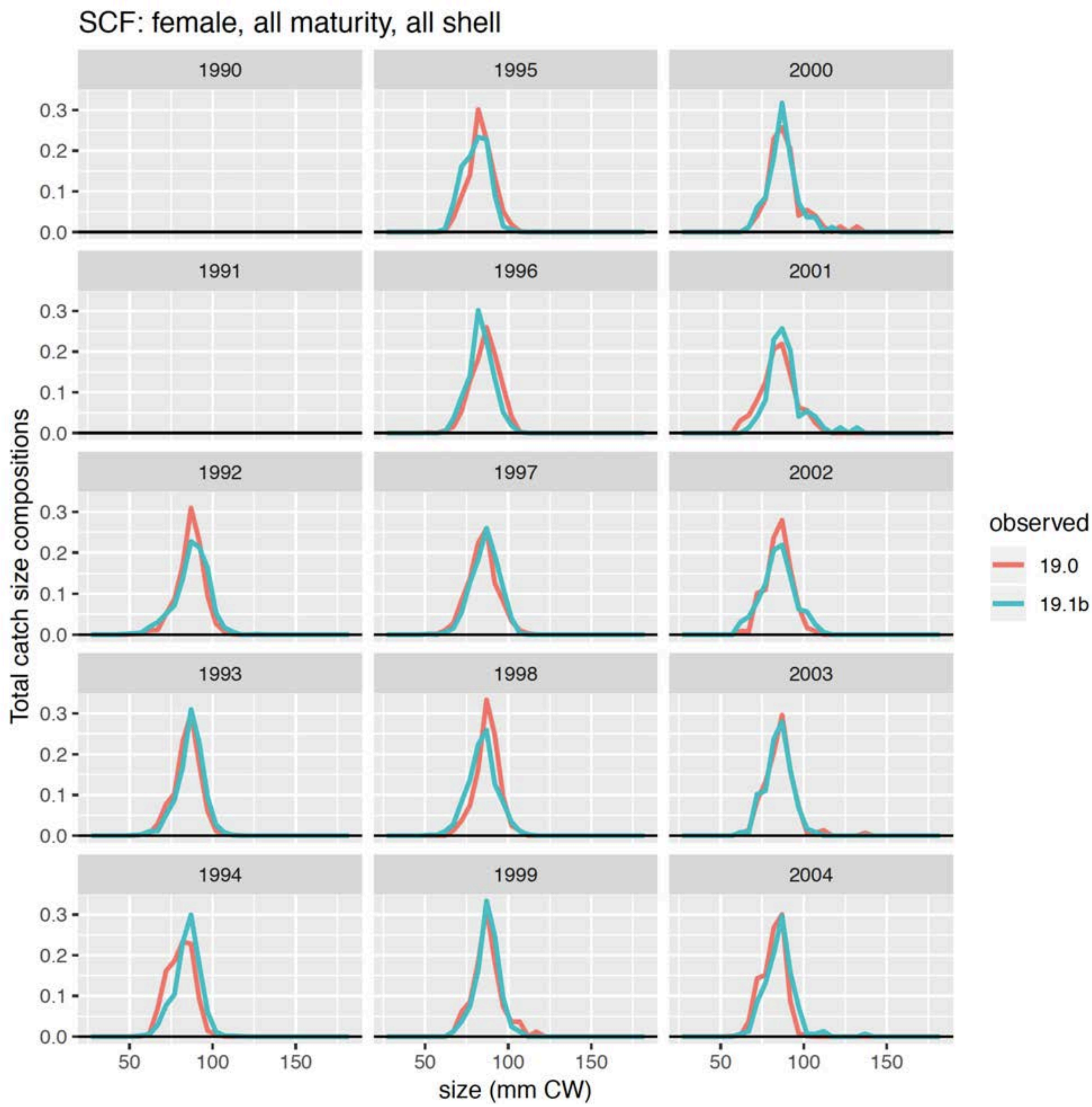


Figure 3.5. Comparison of the time series for "previous" and "revised" estimates of female bycatch size compositions for the snow crab fishery (SCF): 19.0: previous estimates; 19.1b: revised estimates.

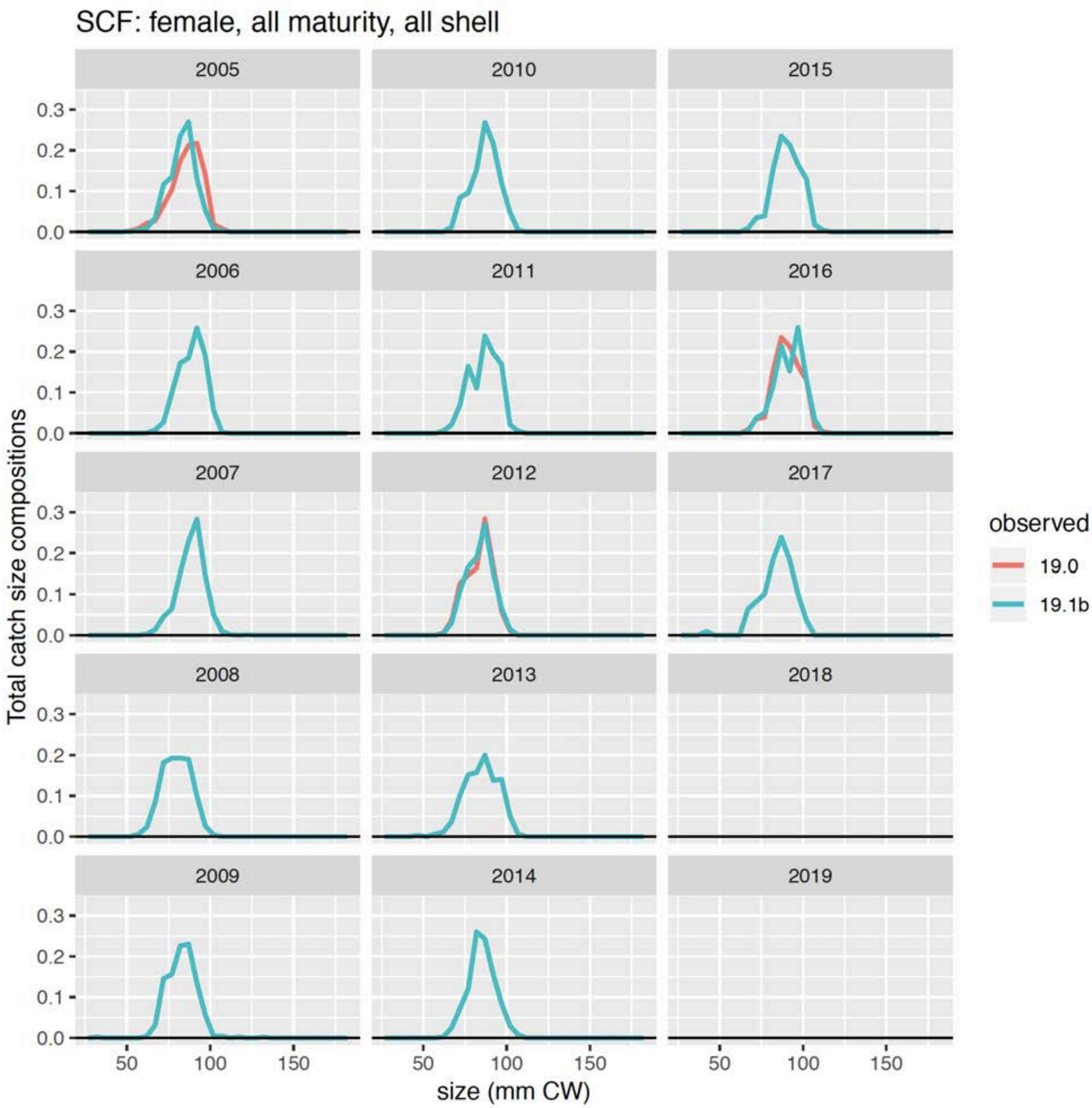


Figure 3.5 (cont.). Comparison of the time series for "previous" and "revised" estimates of female bycatch size compositions for the snow crab fishery (SCF): 19.0: previous estimates; 19.1b: revised estimates.

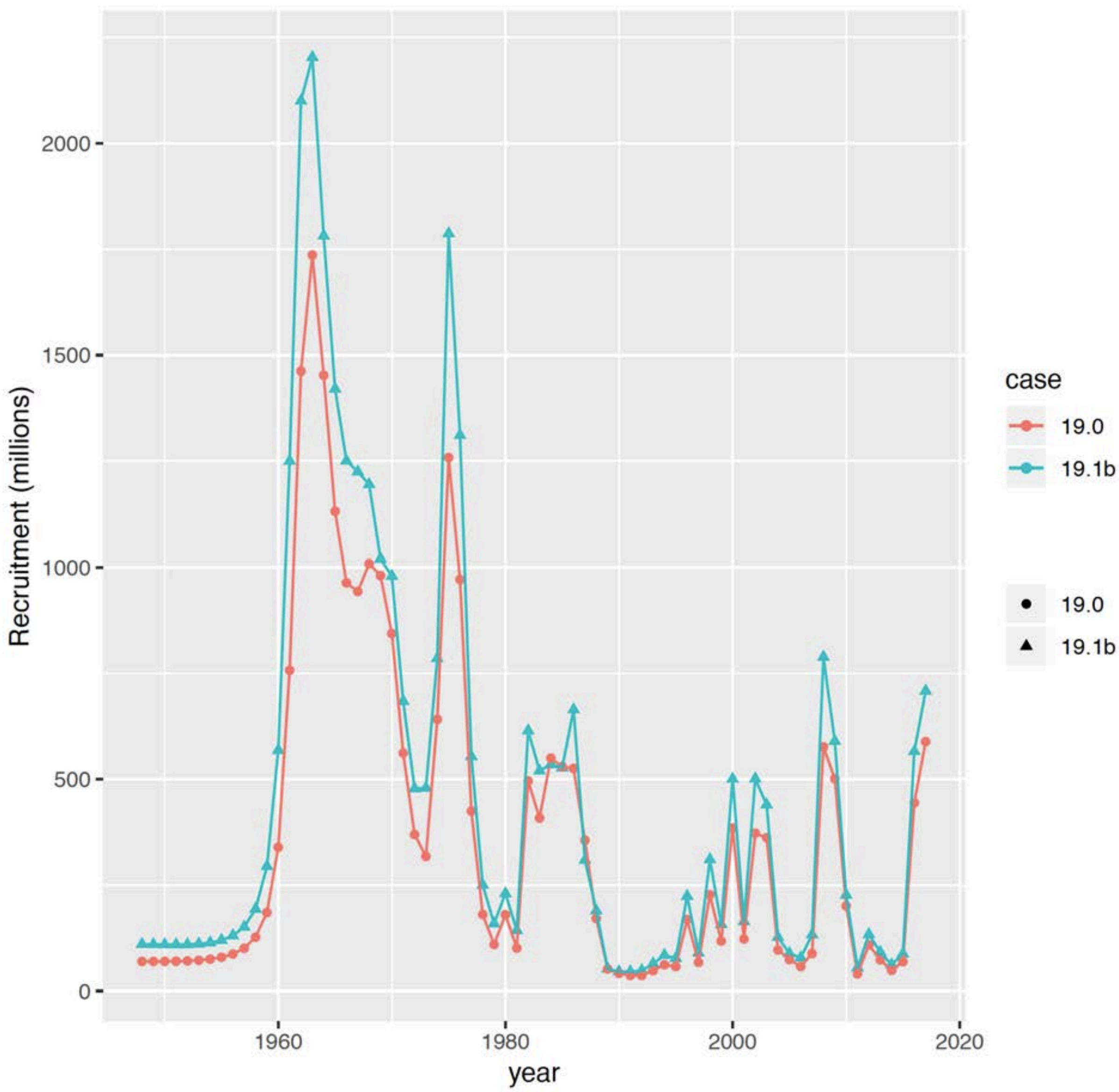


Figure 3.6. Comparison of estimated recruitment for models using the previous crab fishery data (19.0) and the revised crab fishery data with corrected sample sizes (19.1b).

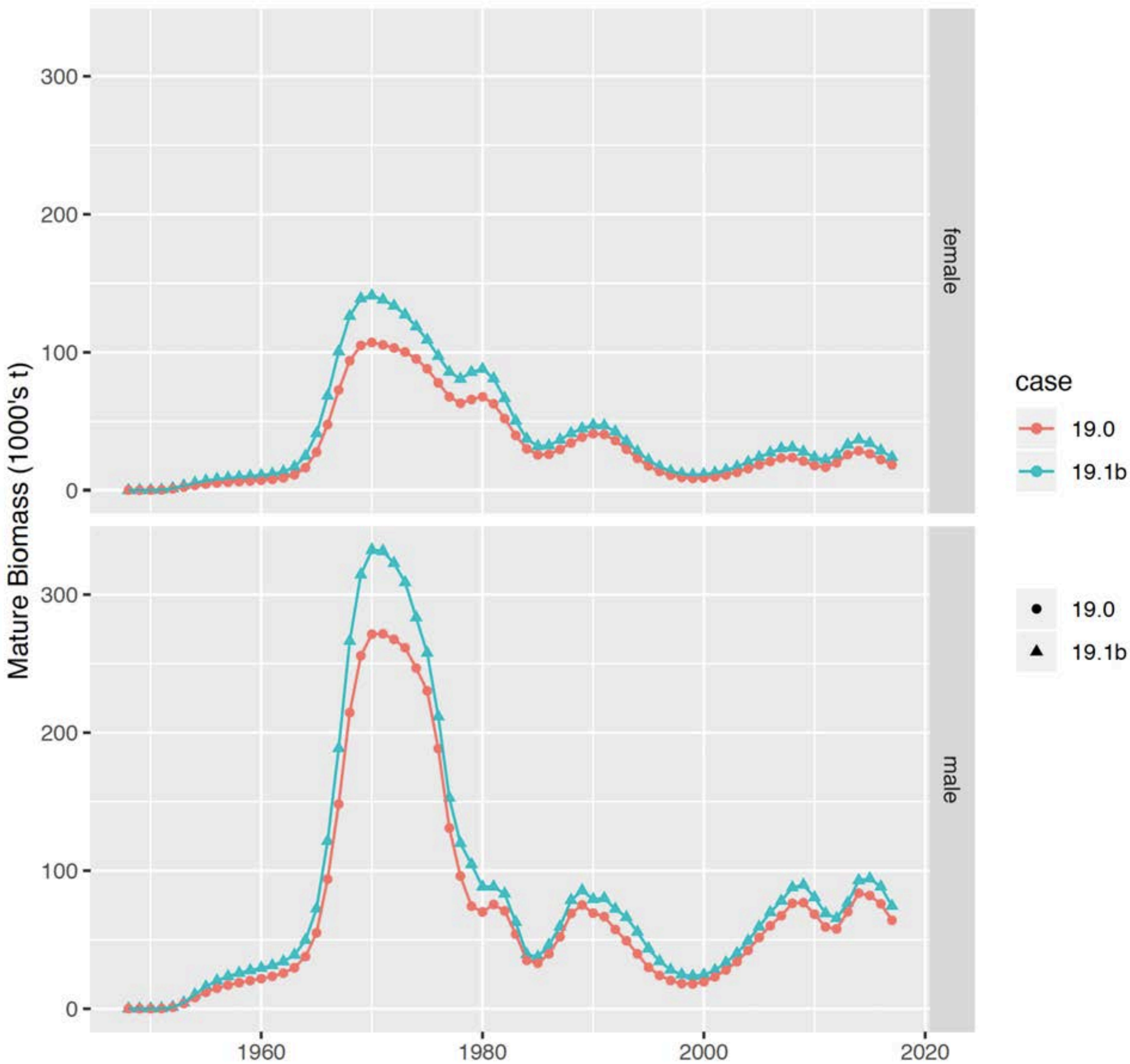


Figure 3.7. Comparison of estimated mature biomass for models using the previous crab fishery data (19.0) and the revised crab fishery data with corrected sample sizes (19.1b).

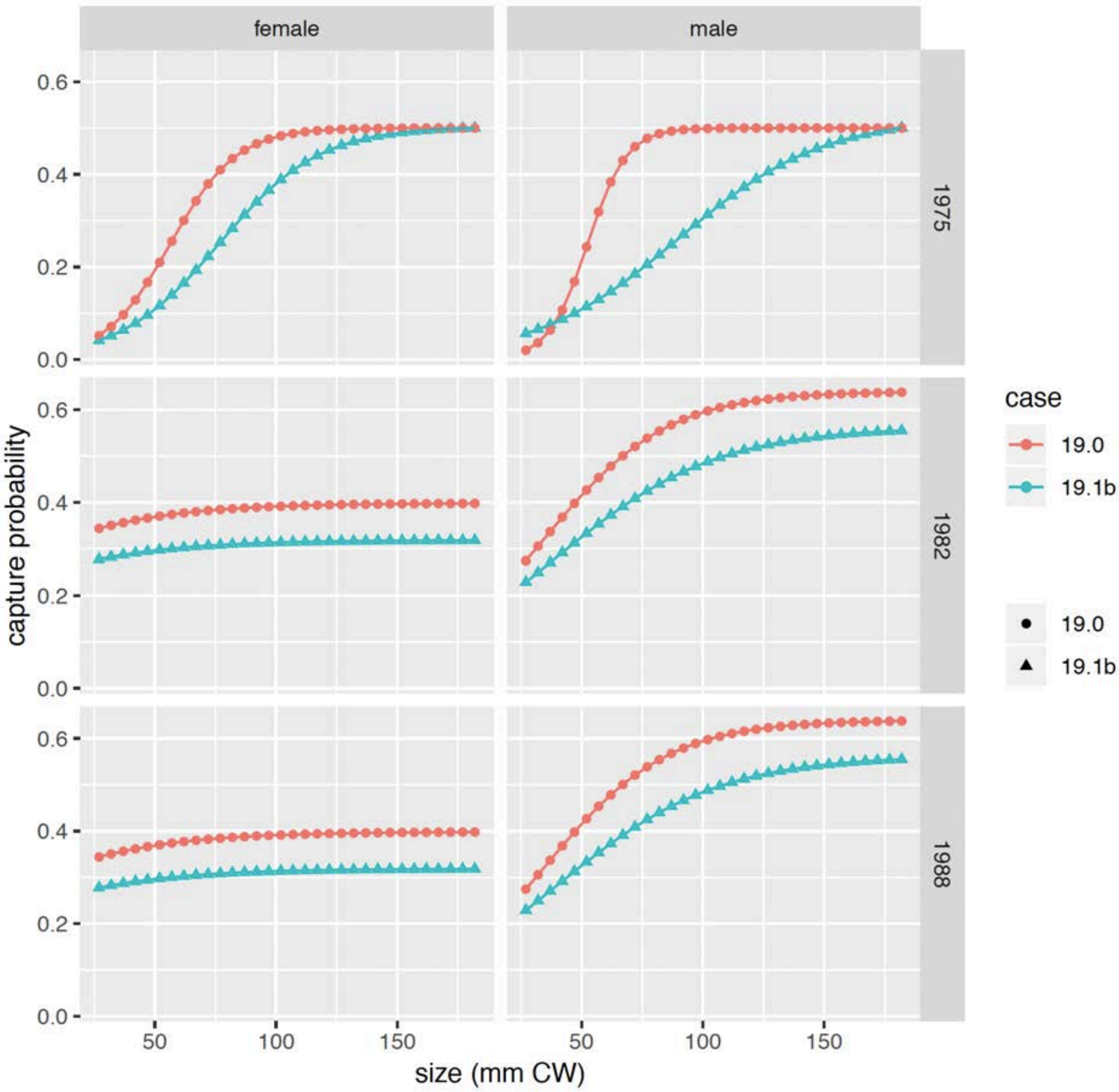


Figure 3.8. Comparison of estimated size-specific survey catchability curves for models using the previous crab fishery data (19.0) and the revised crab fishery data with corrected sample sizes (19.1b).

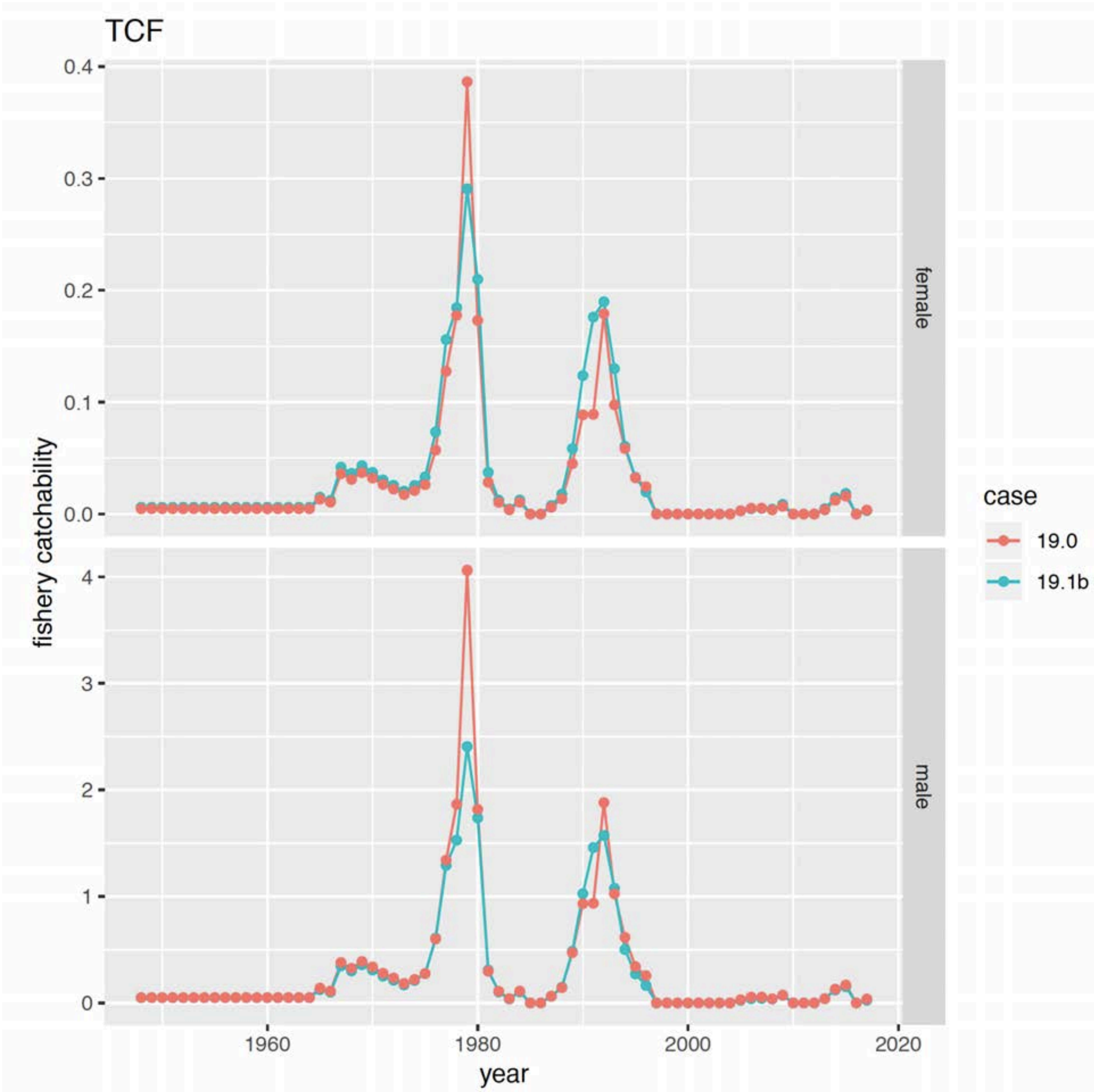


Figure 3.9. Comparison of estimated fully-selected fishery capture rates for the (combined) directed fisheries for models using the previous crab fishery data (19.0) and the revised crab fishery data with corrected sample sizes (19.1b).

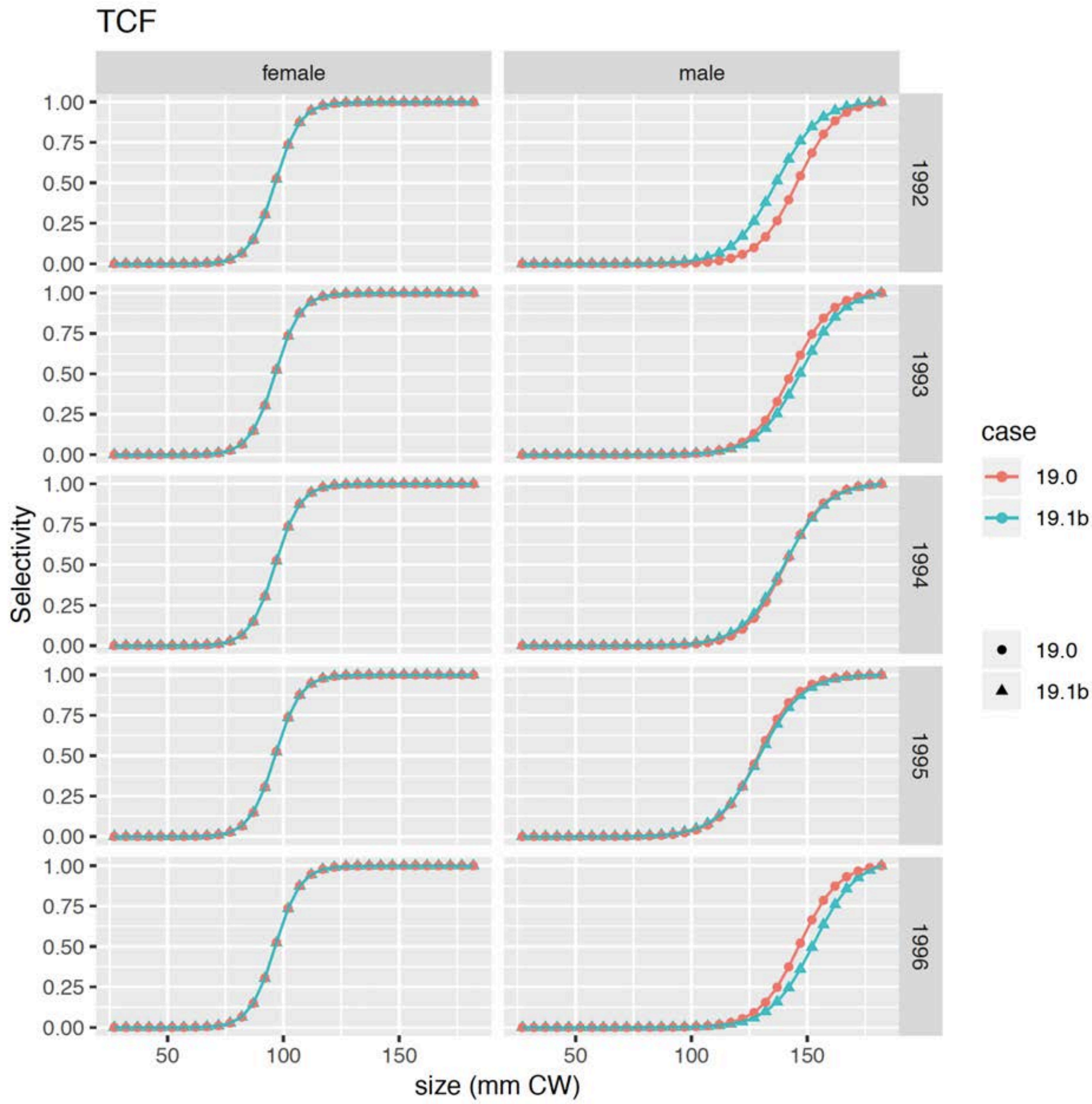


Figure 3.10. Comparison of estimated selectivity curves for 1992-1996 for the (combined) directed fisheries for models using the previous crab fishery data (19.0) and the revised crab fishery data with corrected sample sizes (19.1b).

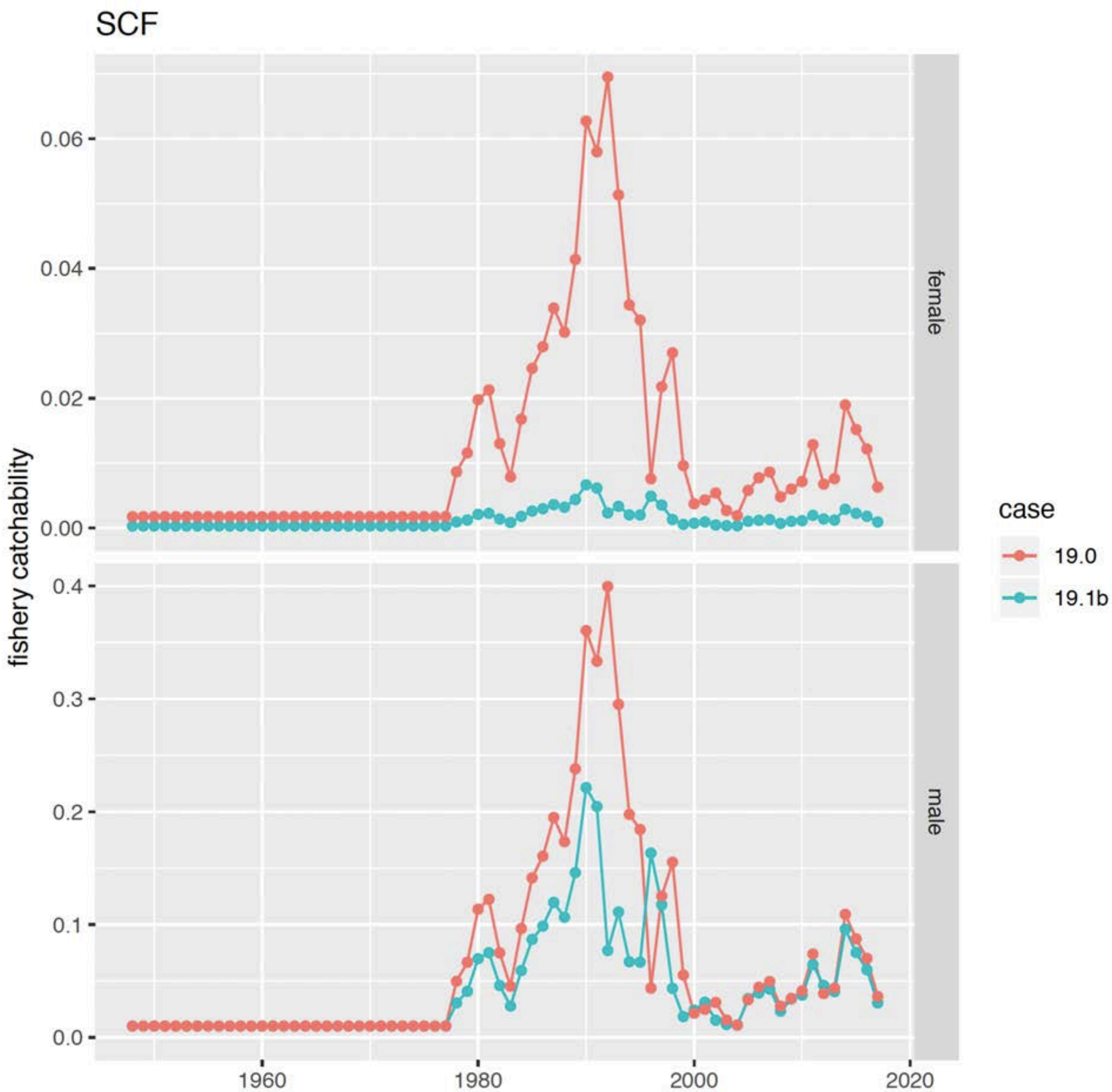


Figure 3.11. Comparison of estimated fully-selected fishery capture rates for the snow crab fishery (SCF) for models using the previous crab fishery data (19.0) and the revised crab fishery data with corrected sample sizes (19.1b).

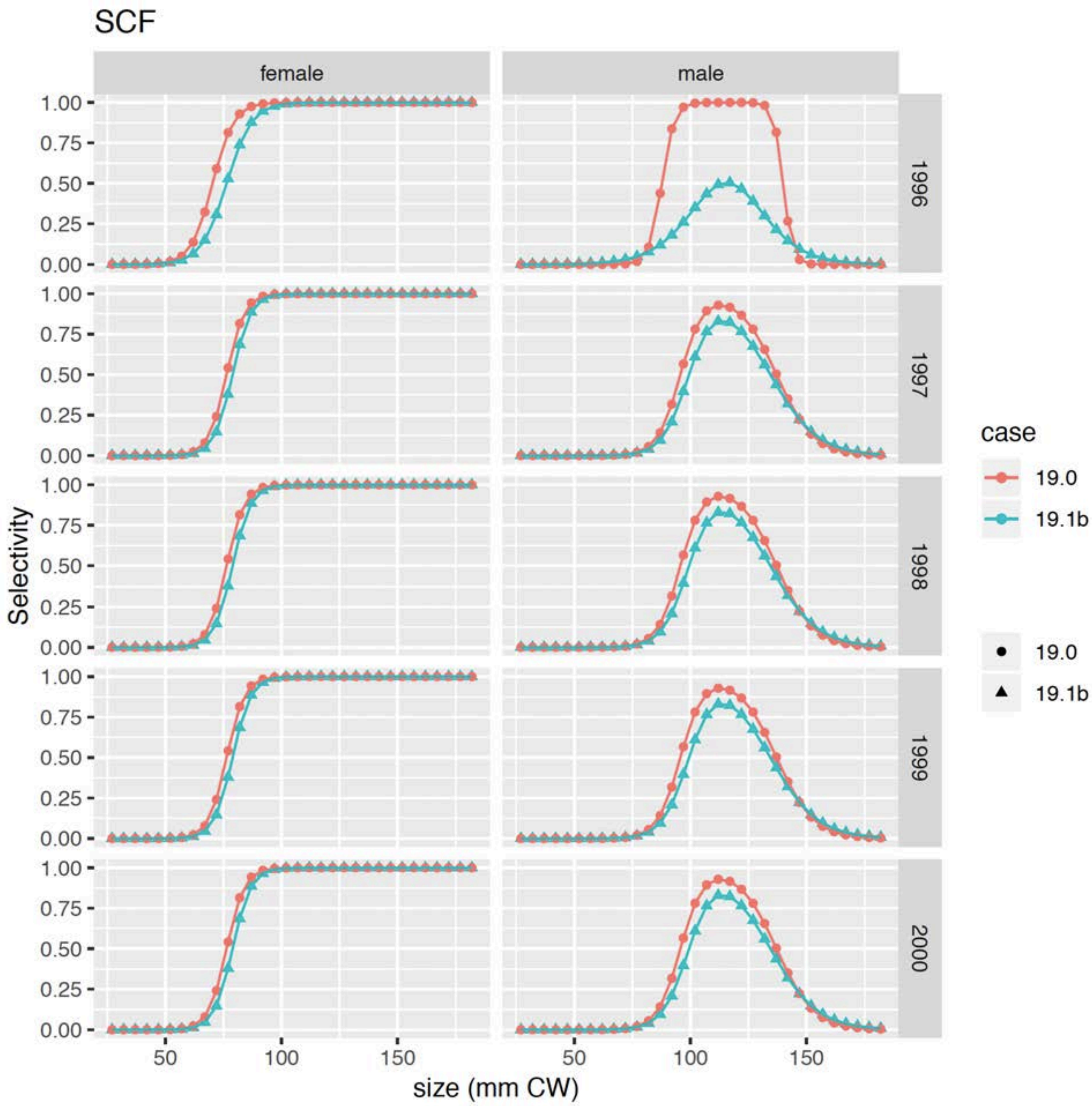


Figure 3.12. Comparison of estimated selectivity curves for 1996-2000 for the snow crab fishery (SCF) for models using the previous crab fishery data (19.0) and the revised crab fishery data with corrected sample sizes (19.1b).

4. Issues Related to the Overestimation of Abundance of Large Crab

4.1. Introduction

As illustrated by the residual plots from the 2018 Tanner crab assessment (Figure 4.1), the assessment model typically overestimates abundance of mature crab at larger sizes in survey size compositions starting in 1996. A similar pattern occurs in total catch size compositions from the directed fishery (Figure 4.2). Overestimating the of abundance of large crab is a matter of concern for several reasons: 1) it inflates the OFL, leading to the possibility for overfishing the stock; 2) it may inflate the TAC, if ADFG decides to use model-estimated survey or population abundance in its harvest control rules, and 3) it indicates either a deficiency in modeling (or estimating) the population dynamic processes for the Tanner crab stock or an unresolved conflict in the data used to inform the model.

The purpose of this section is to present results from recent work to address this issue.

4.2 Growth data

One factor that may contribute to this is that the assessment model consistently overestimates the mean growth of immature crab (Figure 4.3). The figure shows estimates of mean growth from: 1) a TMB model ("TMB" in the figure) that fit growth data outside the assessment model; 2) the 2018 assessment model ("2018AM") which fit growth data in addition to catch biomass and size compositions from surveys and fisheries; and 3) the 2016 assessment model ("2016AM") which did not include growth data. Details of the TMB model are available in Appendix 4.1. Not including the growth data in the assessment model resulted in higher growth estimates for both males and females (2016AM) relative to the TMB estimates, whereas including it in the assessment model (2018AM) resulted in growth estimates for females that were similar to the TMB estimates but did not change the estimates for males.

The possible effect of the lower growth rates estimated using the TMB model on the bias in predicted abundance for large crab was assessed by fixing the growth parameters in the 2018 assessment model to those from the TMB model. However, fixing the growth parameters (model scenario 19.2b) did little to change the resultant fits to the mean survey size compositions relative to the 2018 assessment model (19.0; Figure 4.4).

4.3 Other considerations

There are several other factors in addition to growth that have an influence on the abundance of large crab in the assessment model. The first is natural mortality, *M*. Natural mortality rates are estimated separately for immature crab (males and females together), mature females and mature males so higher rates of M for mature crab, relative to immature crab, would reduce the relative abundance of large crab which have undergone terminal molt. The estimated rate for mature males was 0.265 yr^{-1} in the 2018 assessment, which was only slightly higher than that for immature crab (0.231 yr^{-1}). The estimated rate for females was somewhat higher at 0.319 yr^{-1}. The estimates for mature males and females were constrained by the prior placed on it (the relevant parameter estimates exceeded the prior mean by ~3 and ~8 standard deviations, respectively). Another factor is the probability of terminal molt. Since crab no longer grow once they have undergone terminal molt, the size dependence of the probability of terminal molt will affect the abundance of large crab independent of mean growth. A third additional factor might be skip-molting. In the assessment model, molting and subsequent growth of immature crab is assumed to occur annually. Skip molting would add additional time to the immature stage, with a concomitant decrease in the eventual number of mature crab due to additional natural mortality.

In order to facilitate exploring potential tradeoffs among natural mortality, molt frequency, growth and terminal molt processes, the author (as already noted in Section 2) developed a Shiny application in R (Chang et al., 2018) to quickly visualize the effects of changing the values of model parameters that affect these processes on the progression of a cohort of crab through time (see Tanner crab Shiny app and Appendix 4.2). Natural mortality, growth and terminal molt processes are functionally identical to those in TCSAM02. The size-specific probability of annual molt (the converse to the probability of skip molting) is not currently a modeled population process in TCSAM02—immature crab undergo an annual molt at all sizes. It was included in the Shiny app to evaluate its potential importance to the problem of overestimating abundance for large crab. Fishing mortality was not included, so the results reflect those for an unfished stock. The default configuration for the app duplicates the 2018 assessment model (scenario 19.0 here); more details are provided in Appendix 4.2.

Model processes in the app are illustrated in Figure 4.5 for the 2018 assessment model (scenario 19.0 here). The resulting projection is shown for 12 years in Figure 4.6, using the assumed size distribution of recruits entering the assessment model in a year. The abundance of immature old shell crab is 0 at all sizes in all years because all immature crab molt annually in this scenario.

Five exploratory scenarios were considered to evaluate the importance of perturbations to the model processes in Scenario 19.0 on the resulting cohort progression (Figure 4.7). Natural mortality rates on immature and mature crab were doubled from the baseline 0.23 yr^{-1}in Scenarios 19.4a and 19.4b, respectively. Skip molting was allowed in Scenario 19.4c, with immature crab > 70 mm CW having a 50% chance of skipping. Lower growth (smaller post-molt size) was considered in Scenario 19.4d, and the size-specific probability of immature crab undergoing the terminal molt to maturity was increased by shifting the curve 20 mm CW toward smaller sizes in Scenario 19.4e. The resulting cohort progressions are illustrated in Figure 4.8.

It is admittedly a bit difficult to draw any firm conclusions from the cohort progression plots. Comparing the equilibrium size distributions (essentially the size-specific sum of the progressions) rather than the annual cohort progressions would be more informative and will be implemented in the future. However, it is still clear from the results that changes in either growth (19.4d) or the terminal molt probability curve have the most impact on the qualitative shape of the cohort's size distribution for mature crab. Changes in M for immature crab (19.4a) affect the overall scale of the progression more so than equivalent changes in M for mature crab (19.4b), and so would affect the equilibrium size distribution, but neither substantially affects the qualitative shape of the progression for mature crab. Similar conclusions hold for skip molting (19.4c).

Consequently, enabling the assessment model to estimate growth that is more consistent with the available growth data (given that the model overestimates male growth in particular relative to the growth data, although the results from Section 4.2 suggest this is not enough by itself) in conjunction with estimating higher probabilities of terminal molt for somewhat smaller immature males may improve the current bias in abundance for large crab. This might be achieved by increasing the weight on fitting the available growth data in the model and by re-introducing fits to the available data on male maturity (possibly with a revised approach to incorporating the fits into the likelihood).

A final consideration is that growth has changed over time, although the 2018 assessment model used a single time block for growth such that the same relationships held across the entire model period. The pattern of residuals in the fits to survey size composition for mature males (Figure 4.1) suggests the possibility that growth (or terminal molt processes) changed on a multidecadal scale somewhere around 1996 (when overestimation of large male abundance became a consistent feature). Time series plots of the size of the largest crab (Figure 4.9) also suggest longterm changes in growth may have occurred. Based on the time series for the size of the largest 1% of crabs, it is possible a break occurred in the mid 1990s for females. Otherwise, changes in growth appear to have been gradual over time. The assessment model can currently accommodate multiple time periods during which growth processes are constant, but it does not accommodate gradual changes—although this may be an area for future development.

4.4 Figures

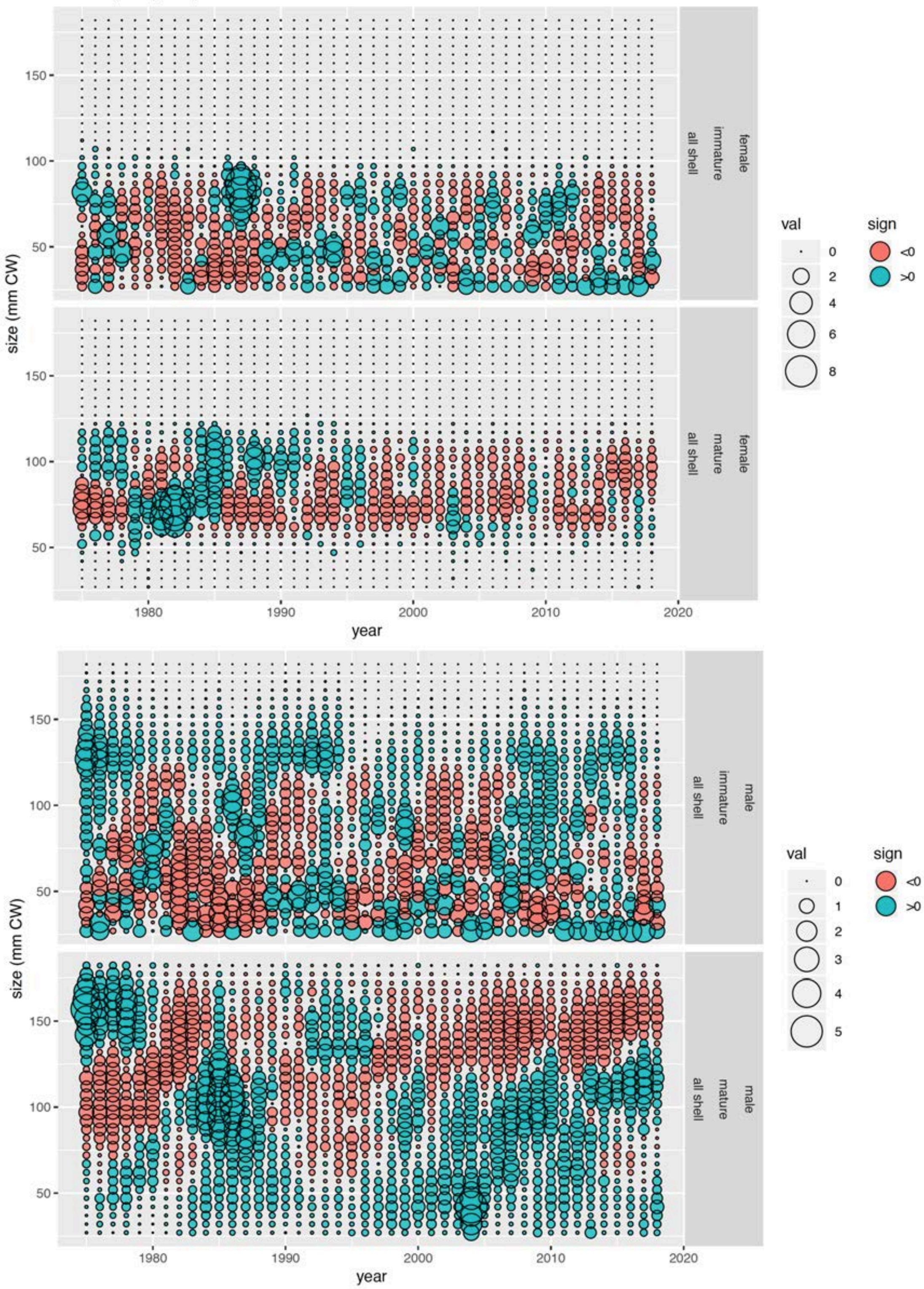


Figure 4.1. Residuals from fits to survey size composition data from the 2018 assessment model (model 18AM17 in Stockhausen, 2018 and model 19.0 here). Negative residuals indicate model over-estimates of abundance.

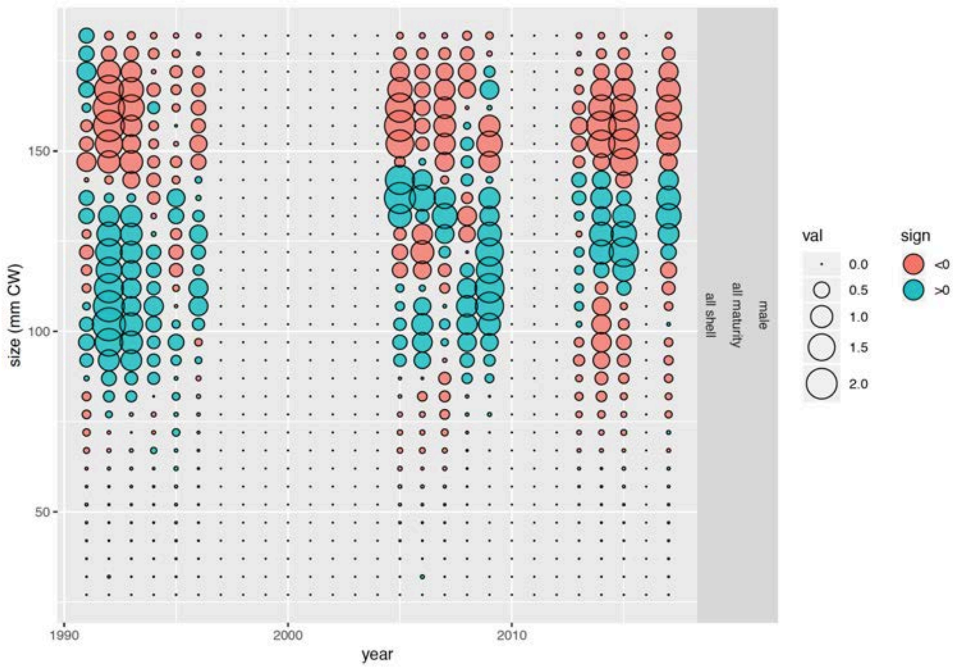


Figure 4.2. Residuals from fits to total catch size compositions in the directed fishery from the 2018 assessment model (model 18AM17 in Stockhausen, 2018 and model 19.0 here). Negative residuals indicate model over-estimates of abundance.

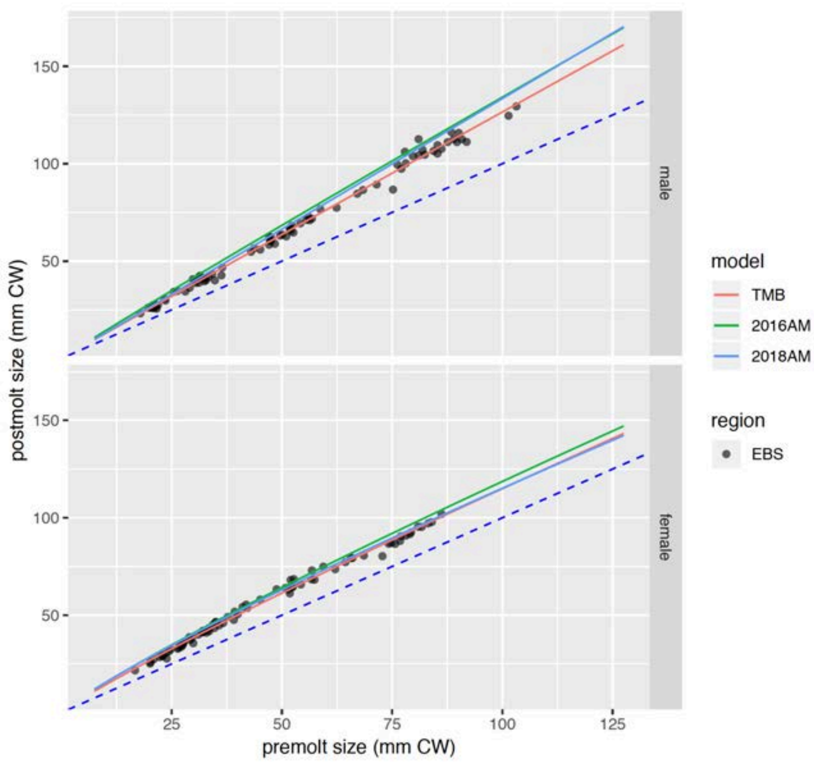


Figure 4.3. Model fits to Tanner crab growth data from the 2018 assessment model (model 18AM17 in Stockhausen, 2018 and model 19.0 here).

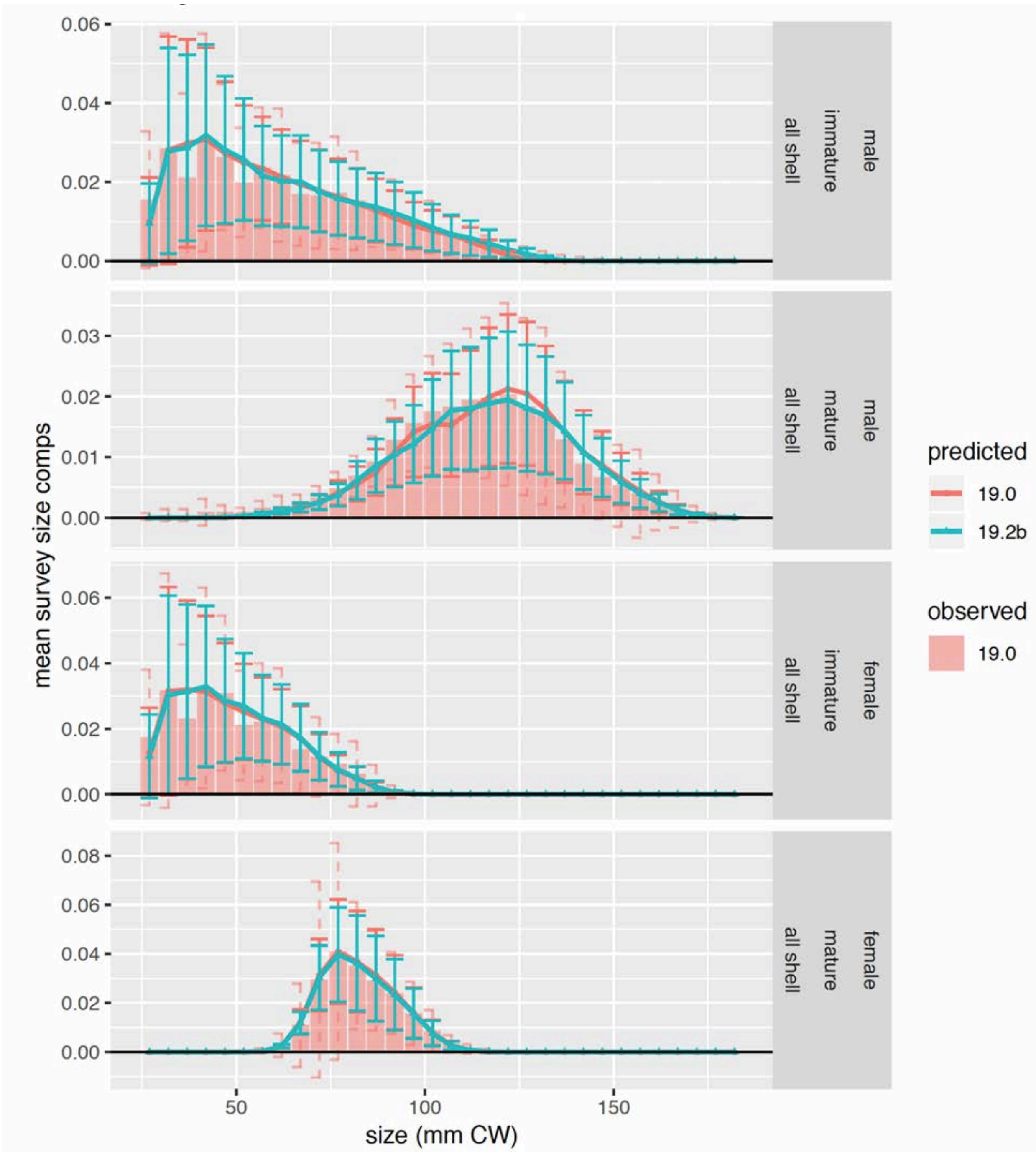


Figure 4.4. Model fits to mean survey size compositions for scenarios 19.0 (the 2018 assessment model) and 19.2b (the model with growth parameters fixed to the TMB model estimates).

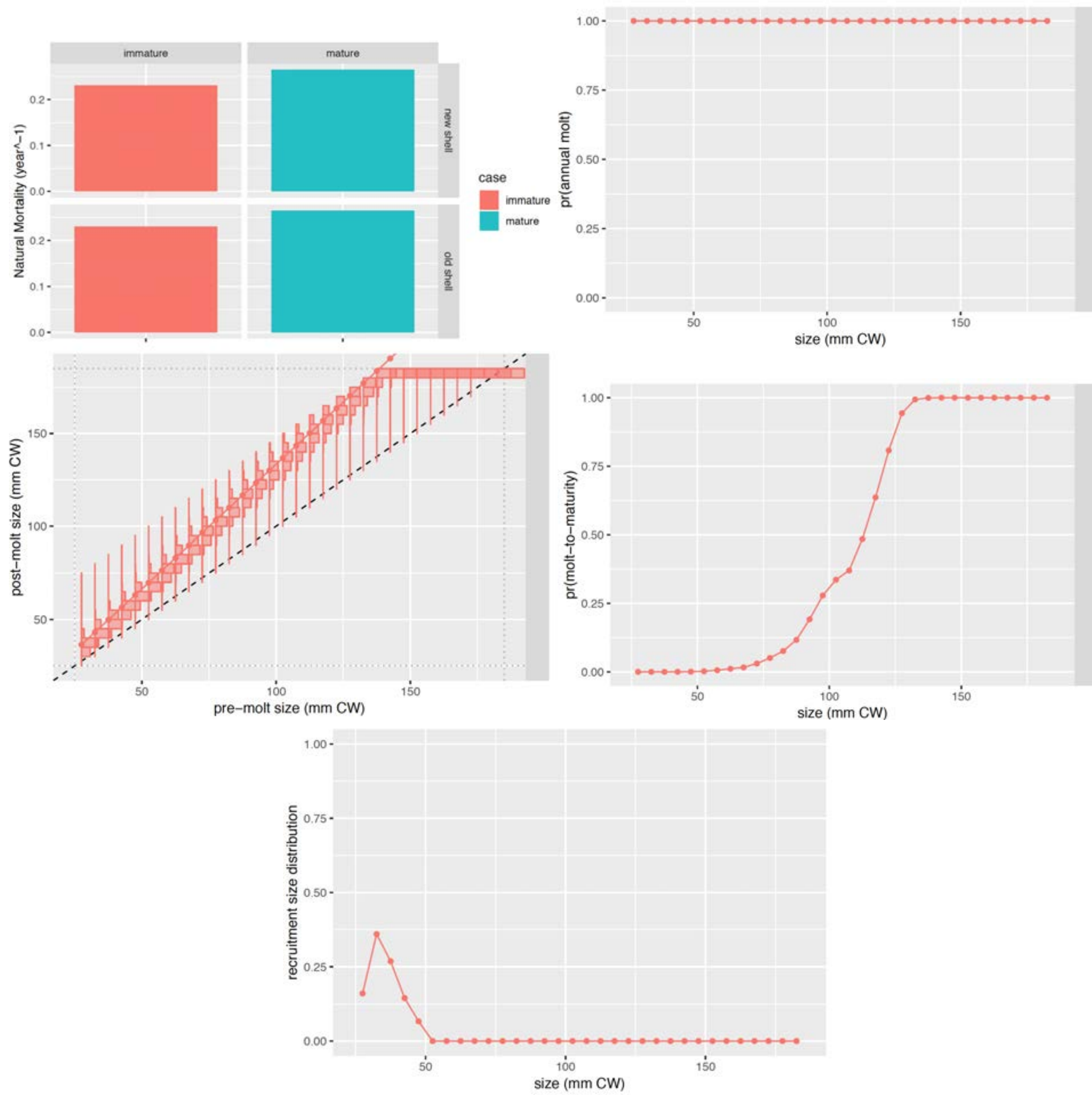


Figure 4.5. Model processes from the Shiny app using the 2018 assessment model (scenario 19.0 here) model parameters for males. Upper left: natural mortality rates. Upper right: Probability of annual molt. Center left: growth as probability of post-molt size given pre-molt size (max growth limited to 11 size bins > pre-molt size). Center right: probability of terminal molt, given pre-molt size. Bottom: size distribution of “cohort” at recruitment to the assessment model.

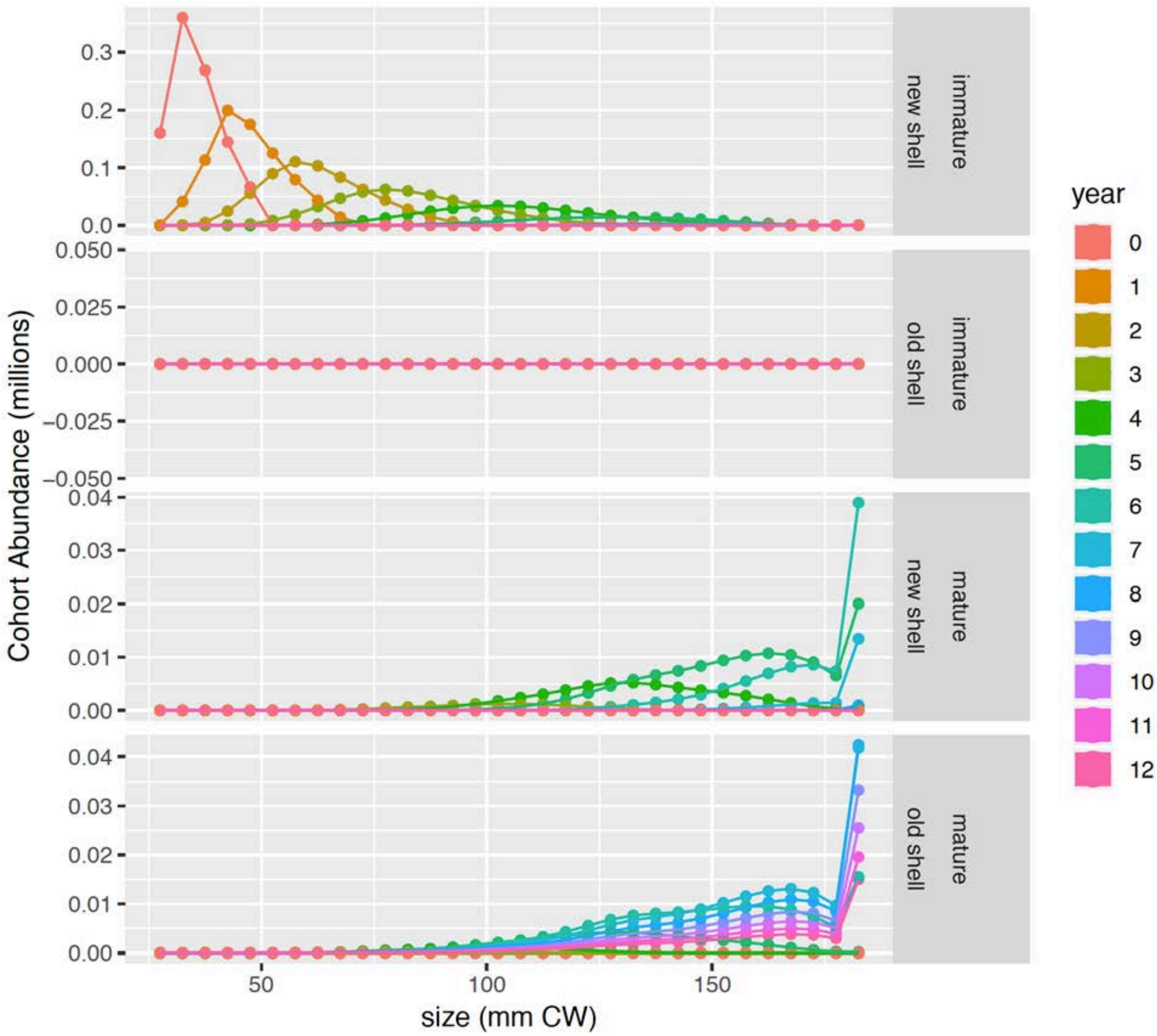


Figure 4.6. The cohort progression over 12 years after entering the model, based on scenario 19.0.

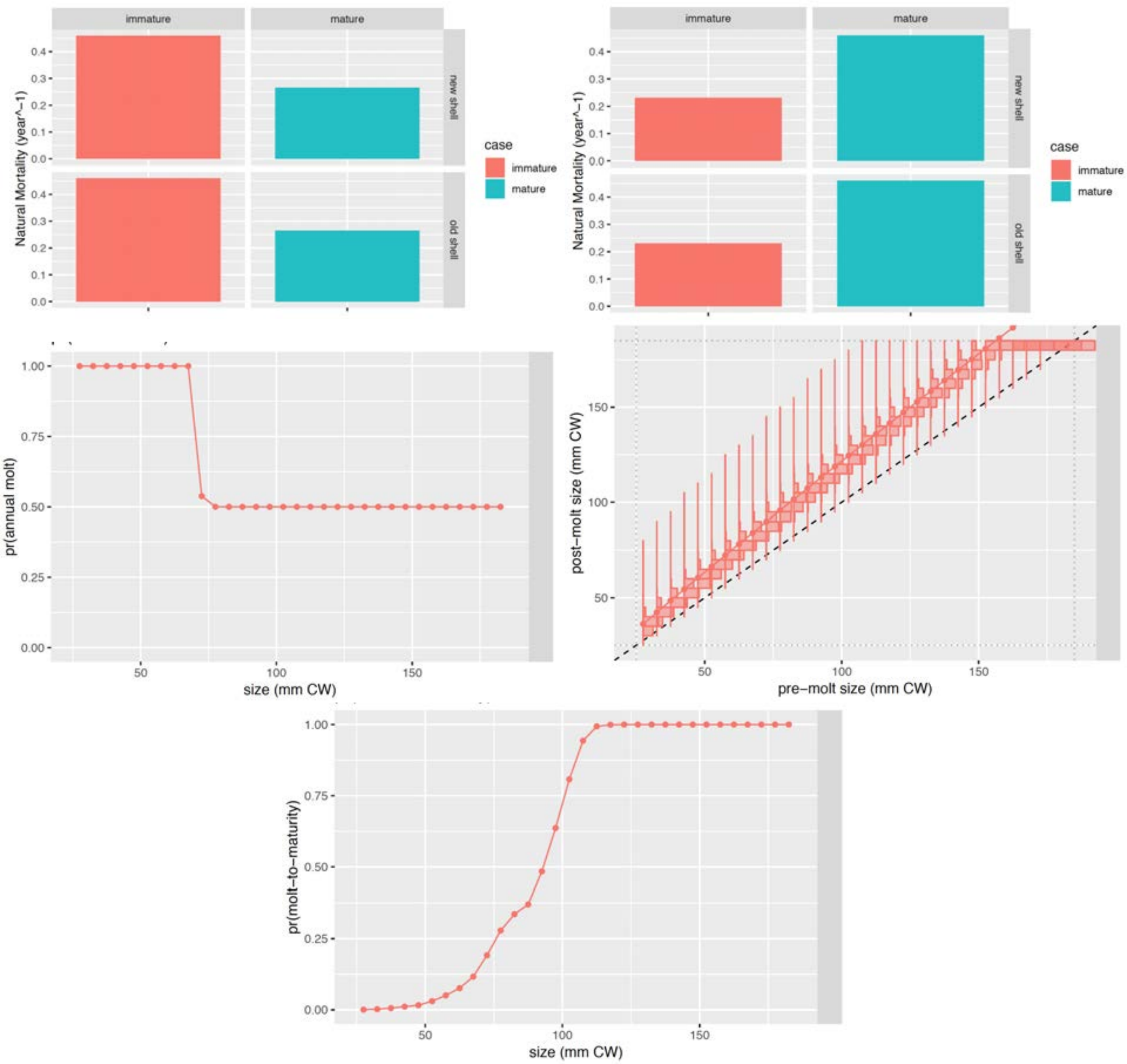


Figure 4.7. Perturbed model processes for exploratory scenarios. Upper left: increased M for immature crab (scenario 19.4a). Upper right: increased M for mature crab (scenario 19.4b). Center left: reduced probability of annual molt (scenario 19.4c). Center right: reduced growth (scenario 19.4d). Bottom: left-shifted probability of terminal molt (scenario 19.4e).

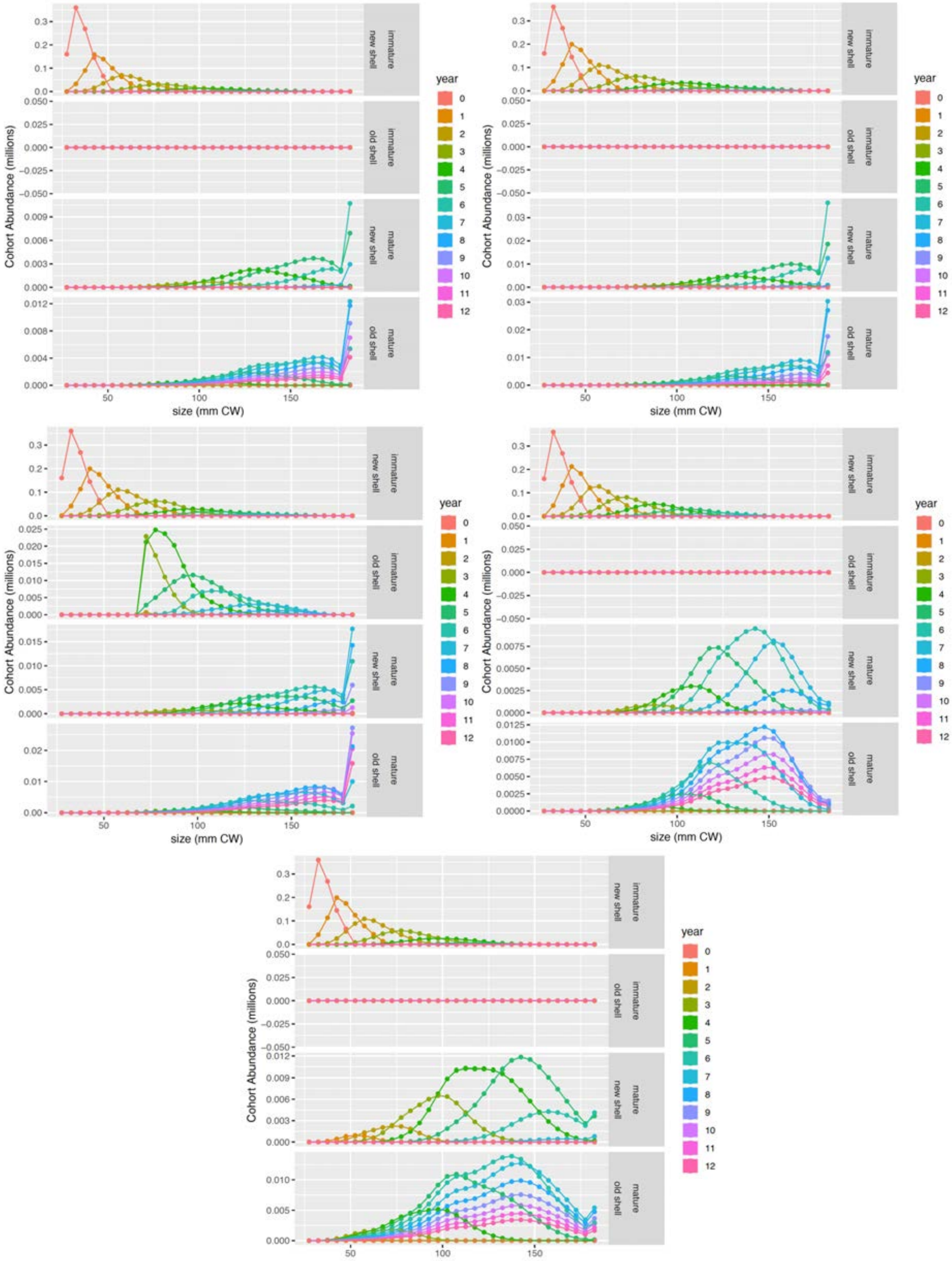
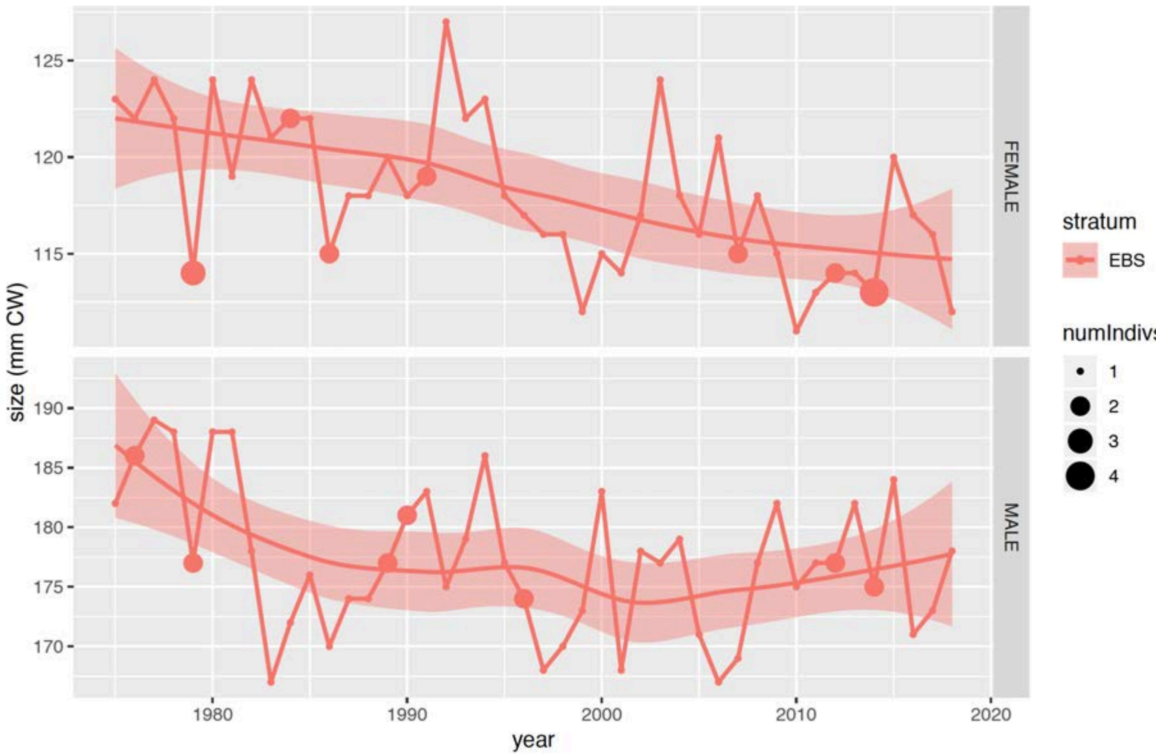


Figure 4.8. Cohort progressions for exploratory scenarios. Upper left: Scenario 19.4a. Upper right: Scenario 19.4b. Center left: Scenario 19.4c. Center right: Scenario 19.4d. Bottom: Scenario 19.4e.



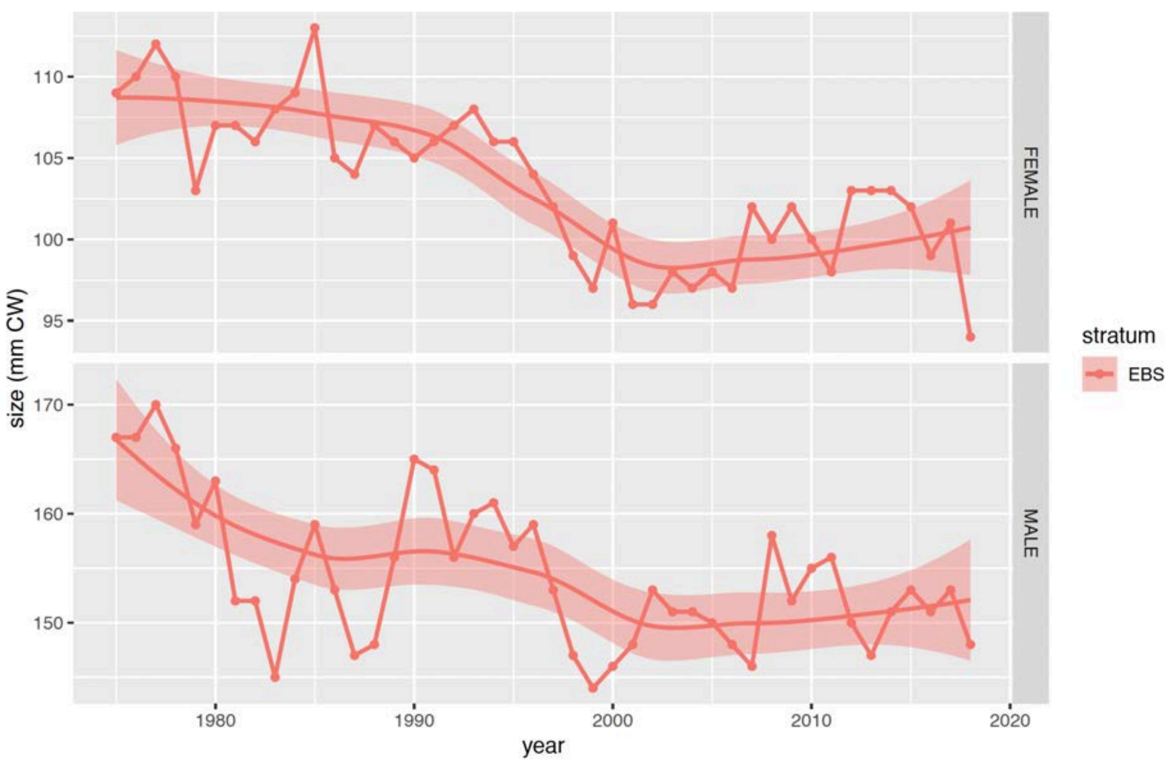


Figure 4.9. Tine series plots of max size (upper plot) and upper 1% size of crabs in the NMFS EBS bottom trawl survey.

5. Incorporating BSFRF Side-by-Side Tow Information

5.1. BSFRF Side-by-Side Survey Integration

As noted in the previous section on Model Development, the BSFRF has conducted a series of "side-by-side" (SBS) trawl gear studies in conjunction with the NMFS EBS Shelf Bottom Trawl Survey. Since 2013, these studies have focused on better characterizing the NMFS survey gear selectivity for Tanner crab and have been conducted annually since then. At an SBS station, a BSFRF-chartered fishing vessel tows a modified nephrops trawl on a parallel course to a NMFS-chartered vessel towing its standard 83-112 trawl gear. The two vessels maintain approximately the same speed and direction with a separation of ~0.5 nm while the tows last; the BSFRF tow lasts 5 minutes while the NMFS tow lasts 30 minutes. While the SBS stations are always a subset of the standard NMFS survey grid, somewhat different areas have been included in the SBS comparisons in different years (Figures 5.1-5), with most studies (2013-2016) occupying stations in western Bristol Bay. Studies in 2017 and 2018 (data from the latter not available at this time) occupied stations near the Pribilof Islands, as well.

Male crab were caught at most SBS stations with both gears while the catches of females were much sparser and, if females were caught at station, frequently only by one gear type (Figures 5.1-5). In each of the five years considered here, higher abundance and biomass of immature females, mature females, and males across the SBS study areas was estimated using area-swept calculations from the BSFRF survey data compared with the NMFS survey data (Figures 5.6-7). The NMFS survey tended to catch more crab above ~50 mm CW in the SBS tows, while the BSFRF survey caught more small crab (< 50 mm CW; upper plots in Figures 5.8-12). However, the area-swept estimates of size-specific abundance across the SBS study areas were almost always larger for the BSFRF gear compared with the NMFS gear (lower plots in Figures 5.8-12) due to the former's smaller trawl footprint.

The sex- and size-specific ratios of CPUE from the NMFS SBS stations to the sum of CPUE from the NMFS and BSFRF SBS stations provides an indication of the relative sex/size-specific catchability of crab between the two survey gears. On a station-by-station basis, the BSFRF gear generally has higher catchability for females < 80 mm CW than the NMFS gear (ratios < 0.5), whereas aggregated across all SBS stations for a given year it has higher catchability up to 110 mm CW (upper two plots, Figure 5.13). For males, the BSFRF gear has higher catchability at sizes smaller than 60 mm CW on a station-by-station basis, while this size range extends to ~160 mm CW when aggregated across the study areas (lower two plots, Figure 5.13).

The SBS data was incorporated into the assessment model as annual estimates of abundance and biomass, as well as size compositions, for three life stage categories (immature females, mature females, and males) aggregated across the associated SBS study area using standard NMFS survey area-swept calculations for both the BSFRF and NMFS surveys. Because of the special bottom-tending characteristics of the gear used, the BSFRF survey was regarded as providing estimates of absolute, rather than relative, abundance and biomass for each life stage within the SBS study areas (Eq. 2.2; as per the snow crab assessment).

Standard model likelihood components (see Appendix A2.1, Section J) were added for each data type (abundance, biomass and size composition) and life stage based on the relationships outlined in Section 2 for each survey. Thus, likelihood components for aggregated abundance were of the form (Eq. J.4 in Appendix A)

$$\ln(\mathcal{L}^{LN})_c \;=-\frac{1}{2}\sum_y \left\{\frac{\left[ln\left(a_{y,c}^{obs}+\delta\right)-ln\left(a_{y,c}^{mod}+\delta\right)\right]^2}{\sigma_{y,c}^2}\right\} \qquad (5.1)$$

where $a_{y,c}^{obs}$ is the observed abundance/biomass value in year y for life stage c, $a_{y,c}^{mod}$ is the associated model estimate, and $\sigma_{y,c}^2$ is the ln-scale variance associated with the observation. The model estimate of abundance for the BSFRF SBS survey, using Eq. 2.2, is

$$a_{y,c}^{mod} = \sum_z A_{y,c,z} \cdot n_{y,c,z} \tag{5.2}$$

where $A_{y,c,z}$ is the estimated availability for life stage c in size bin z in year y and $n_{y,c,z}$ is the estimated population abundance whereas the model estimate for the NMFS SBS survey, using Eq. 2.4, is

$$a_{y,c}^{mod} = \sum_z q_{c,z} \cdot S_{c,z} \cdot A_{y,c,z} \cdot n_{y,c,z} \tag{5.3}$$

Catchability, selectivity and availability were modeled as sex-specific, but not maturity-state specific.

5.2. Model scenarios

Several model scenarios incorporating survey data from the SBS studies were run to explore different aspects of using the SBS data to inform the assessment model. The base model was taken to be 19.0, the 2018 assessment model. Other model scenarios are outlined in Table 5.1. All included abundance and biomass estimates, as well as size compositions, aggregated over the appropriate SBS study area from the BSFRF and NMFS SBS surveys. Separate sex-specific availability curves were estimated for each SBS study year using smooth "nonparametric" selectivity functions (see Section 2) Model scenario 19.3a fixed all model parameters from 19.0, but fit the NMFS SBS biomass and size composition data to estimate the annual availability functions associated with the SBS study area. Similarly, model scenario 19.3b fixed all model parameters from 19.0, but fit the BSFRF SBS biomass and size composition data to estimate the annual availability functions associated with the SBS study area. Model 19.3c also fixed all model parameters from 19.0 but fit both the BSFRF and NMFS SBS biomass and size composition data to estimate the annual availability functions. These three scenarios were used to obtain initial estimates of the availability functions under the assumptions that the estimated model population abundance from 19.0 was correct. These were also used to assess the extent to which the BSFRF and NMFS SBS data reflected the same availability patterns.

Model scenarios 19.3c1 and 19.3c2, as well as scenario 19.3c, were run to assess the impact of different levels of smoothing on the estimated availability functions. Scenario 19.3c (as well as scenarios 19.3a and 19.3b) were run with a smoothness penalty multiplier (SMP) of 100, whereas scenarios 19.3c1 and 19.3c2 were run with SMPs of 10 and 1, respectively. Smaller values for the SMP impose smaller penalties on curvature in the estimated availability functions.

Finally, scenarios 19.3d and 19.3e were run estimating all parameters from 19.0, the 2018 assessment model, as well as the availability parameters. The two scenarios differed by the level of smoothing imposed (larger for 19.3d, smaller for 19.3e).

5.3. Model results

Estimated sex-specific availability curves from scenarios 19.3a, 19.3b and 19.3c are shown for in Figure 5.14. The estimated curves from the three scenarios were quite similar to one another for both sexes over 2013-2015 (years in which the SBS studies occurred in Bristol Bay and along the Alaskan Peninsula), indicating consistency between the BSFRF and NMFS SBS survey data for those years. The curves for the three scenarios were much less similar for 2016 and 2017 (in which the SBS study stations were further to the west), as well as qualitatively different from those in 2013-2015. The curves for 2013-2015 indicate that small crab were essentially unavailable in the SBS study areas during these years, while those for 2016 and 2017 indicate that small crab were much more available in the more western study areas in these years.

The effect on the estimated availability functions of reducing the penalties on smoothness is illustrated in Figure 5.15. The overall patterns are (unsurprisingly) similar, but the scenarios with lower smoothing penalties (19.3c1 and 19.3c2) a few more "wiggles" than scenario 19.3c with the highest penalty. Reducing the smoothing penalty from 100 to 10 has a larger effect than reducing it from 10 to 1.

There is surprisingly little change in the fully-selected survey catchabilities, selectivity curves, and availability curves when all parameters estimated (scenarios 19.3d, 19.3e; Figure 5.17). However, it should be noted that these scenarios were run starting with the estimated parameters from scenario 19.0, which might overly constrain the search for an optimal solution to the vicinity of that found for scenario 19.0—time did not allow a full set of jittered initial parameter runs. The main effect of including the SBS study data on the model was to decrease fully-selected catchabilities for the NMFS survey (Figure 5.16, upper left plots) and further slightly reduce the NMFS survey selectivity for small females (Figure 5.16, upper right plots). The estimated availability curves are quite similar to those estimated in scenarios 19.3c and 19.3c2, but not identical.

Differences among fits to mature survey biomass from the full NMFS survey were negligible for the scenarios, as were differences among fits to male biomass and immature/mature female biomass in the SBS surveys (Figure 5.17). Similarly, comparisons to mean size compositions from the full NMFS survey (Figure 5.18) were nearly identical. Comparisons to mean size compositions from the BSFRF SBS survey (Figure 5.19), and the NMFS SBS surveys (Figure 5.20) indicate that 19.3e (with smaller smoothing penalty) fits these data slightly better than 19.3d. Including the SBS studies data in the model optimization did not affect fits to the fishery or growth data.

The main effect adding the SBS studies data to the assessment model was to increase mean recruitment somewhat, with consequent increases for mature biomass (Figure 5.21) and overall population abundance. These changes were also reflected in a small overall increase in fully-selected fishery catchability across all fisheries. Very small changes also occurred in estimated natural mortality rates ($<|0.02|$). Overall, these changes led to small increases in OFL-related quantities such as B_{100}, B_{MSY}, projected B, F_{MSY}, MSY, and OFL (Table 5.2).

5.4 Tables

Table 5.1. Model scenarios exploring SBS data integration.

Scenario	Description
19.3a	only fit to BSFRF SBS data included in likelihood SMP = 100 (smoothness penalty multiplier) other model parameters fixed at 19.0 values
19.3b	only fit to NMFS SBS data included in the likelihood SMP = 100
	other model parameters fixed at 19.0 values
19.3c	fit to both NMFS and BSFRF SBS data SMP = 100 other model parameters fixed at 19.0 values
19.3c1	19.3c + SMP = 10
19.3c2	19.3c + SMP = 1
19.3d	19.3c + all 19.0 parameters estimated (SMP=100)
19.3e	19.3c2 + all 19.0 parameters estimated (SMP=1)

Table 5.2. OFL-related quantities for model scenarios 19.0, 19.3d, and 19.3e.

case	OFL	Fofl	prjB	curB	Fmsy	Bmsy	MSY	B100	avgRec
19.0	20.87	0.74	35.95	66.64	0.74	30.29	12.75	86.55	223.63
19.3d	25.86	0.82	41.02	78.97	0.82	33.48	14.63	95.66	287.96
19.3e	25.50	0.81	40.78	78.22	0.81	33.53	14.61	95.80	291.55

5.5 Figures

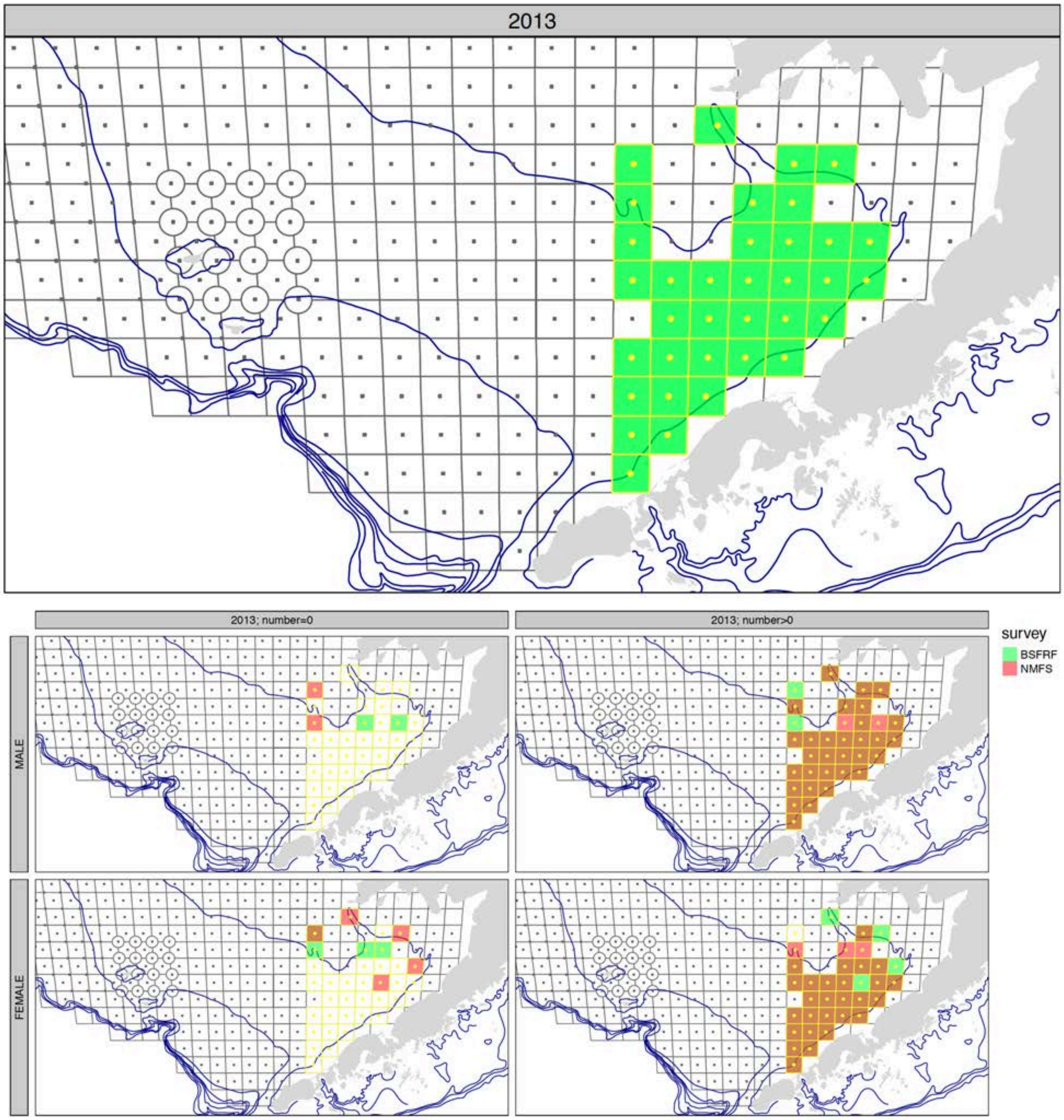


Figure 5.1. Upper map: 2013 SBS study locations. Lower maps: Stations with 0 and non-0 catches.

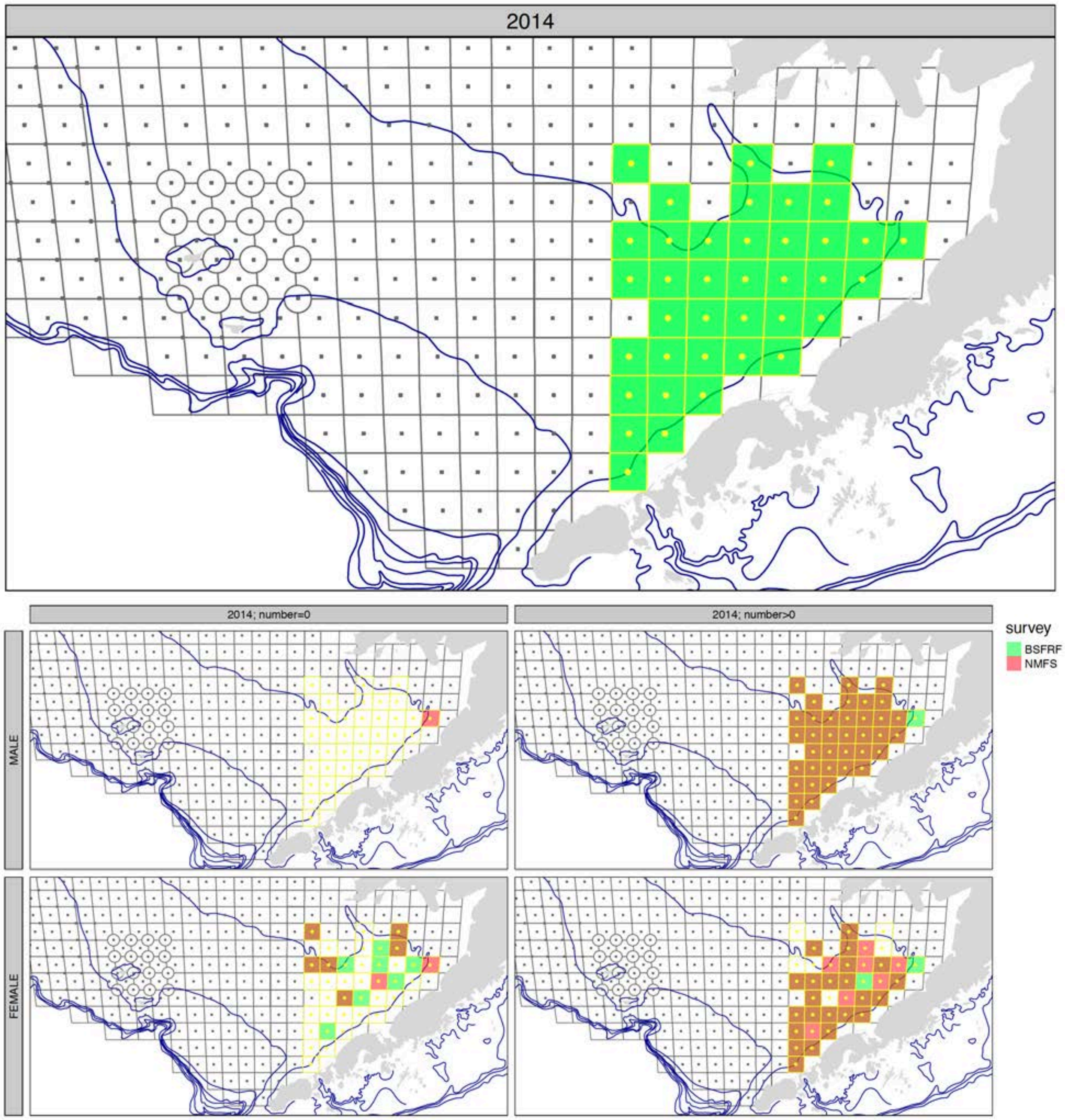


Figure 5.2. Upper map: 2014 SBS study locations. Lower maps: Stations with 0 and non-0 catches.

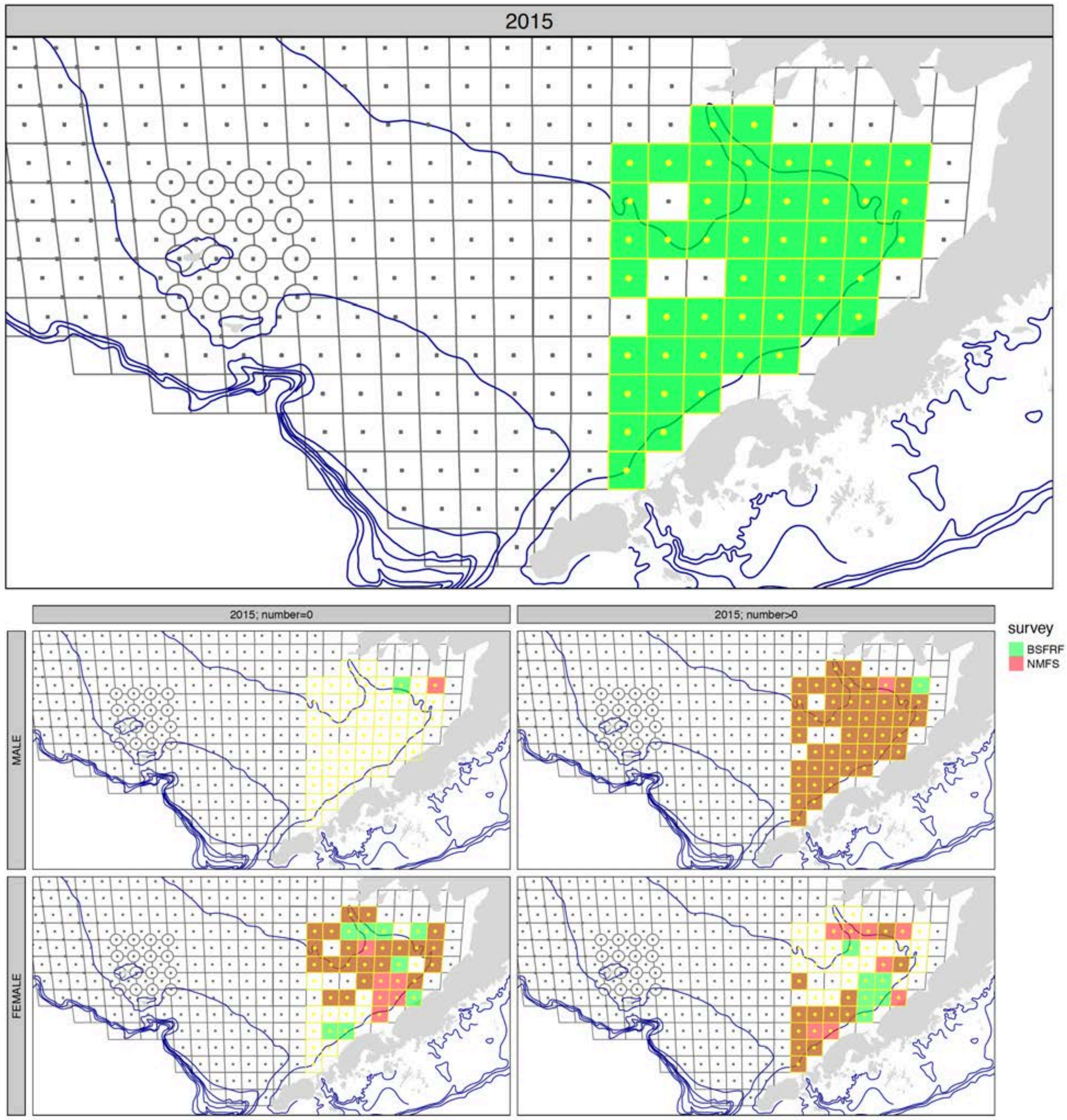


Figure 5.3. Upper map: 2015 SBS study locations. Lower maps: Stations with 0 and non-0 catches.

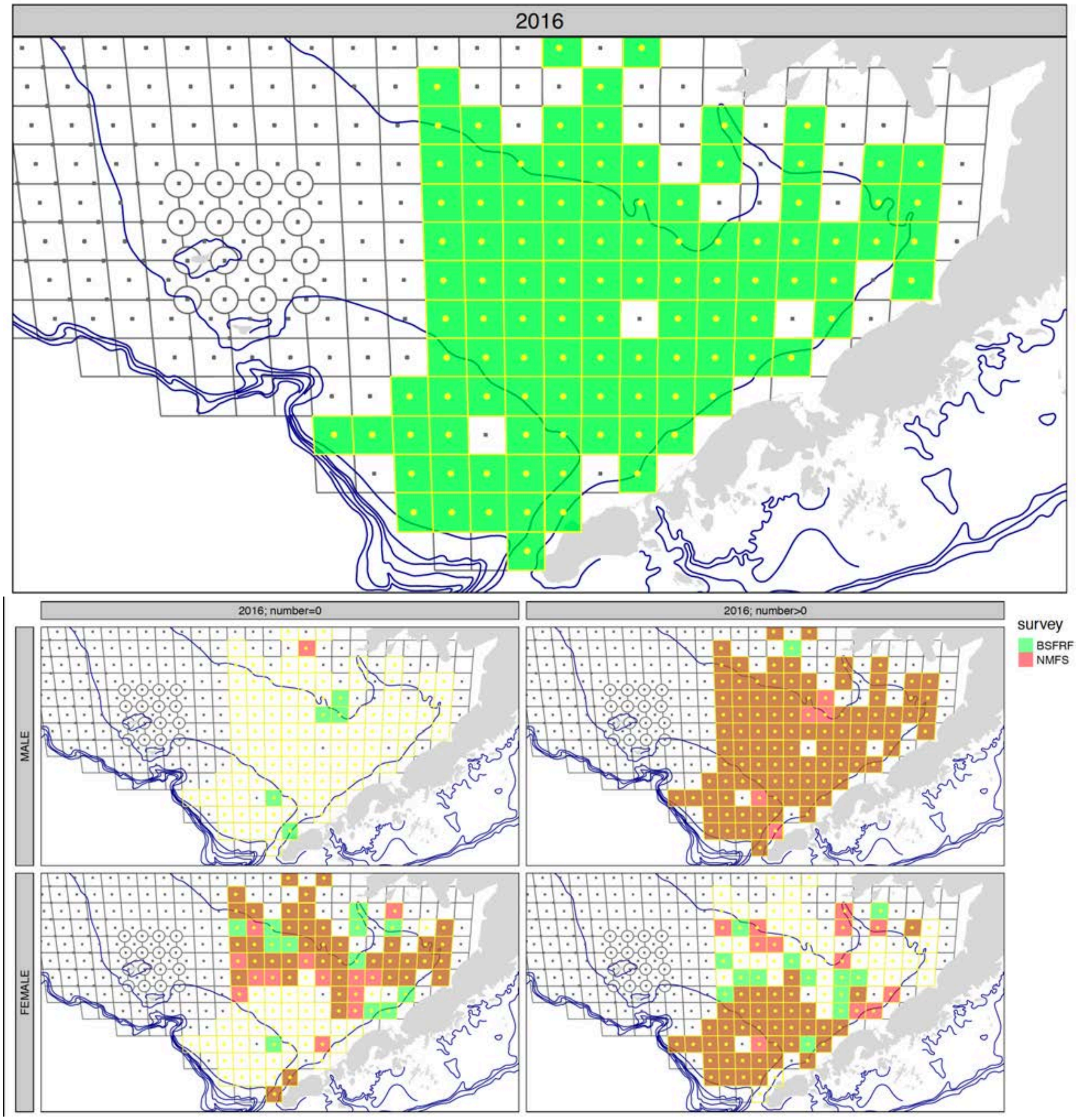


Figure 5.4. Upper map: 2016 SBS study locations. Lower maps: Stations with 0 and non-0 catches.

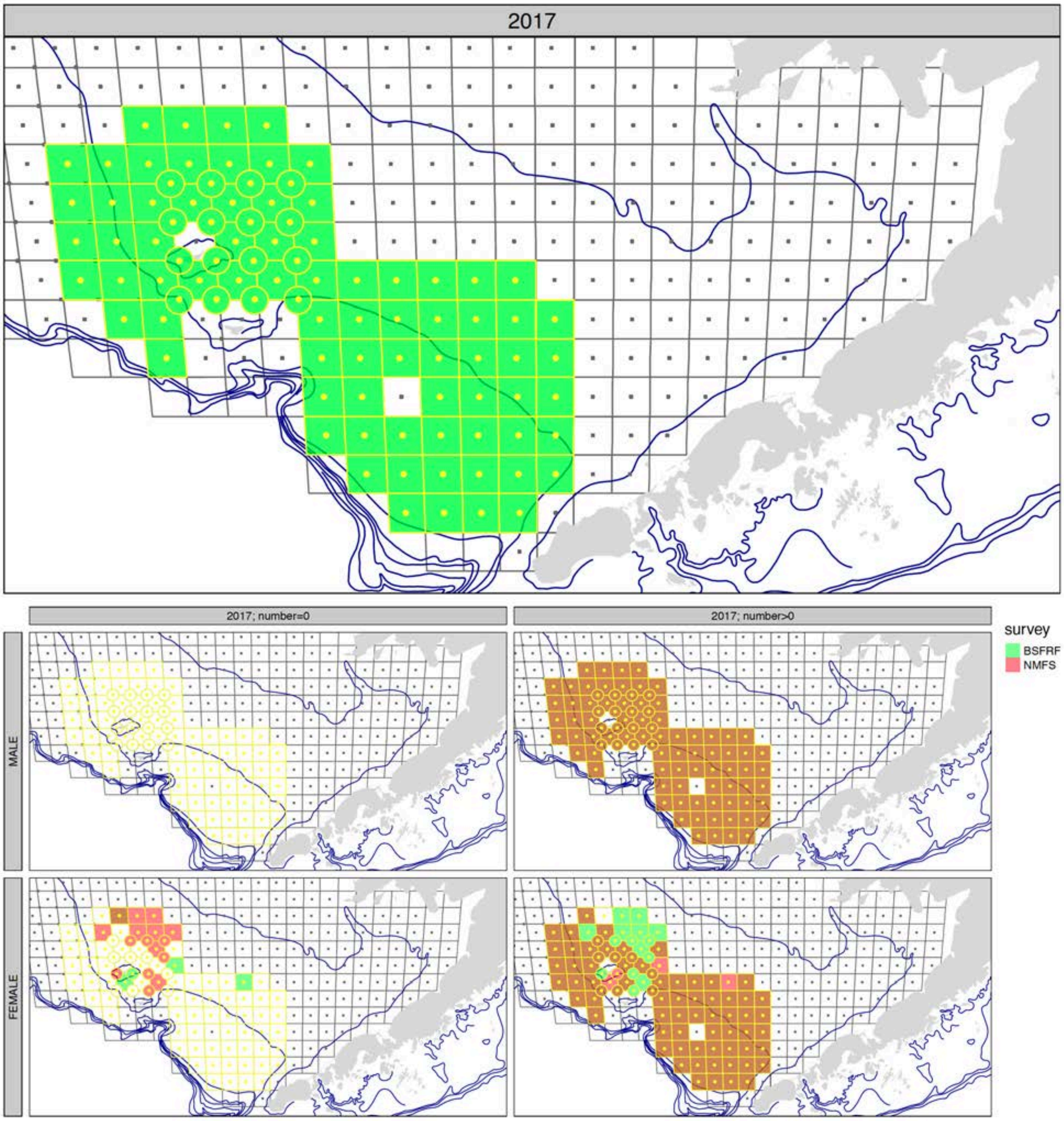


Figure 5.5. Upper map: 2017 SBS study locations. Lower maps: Stations with 0 and non-0 catches.

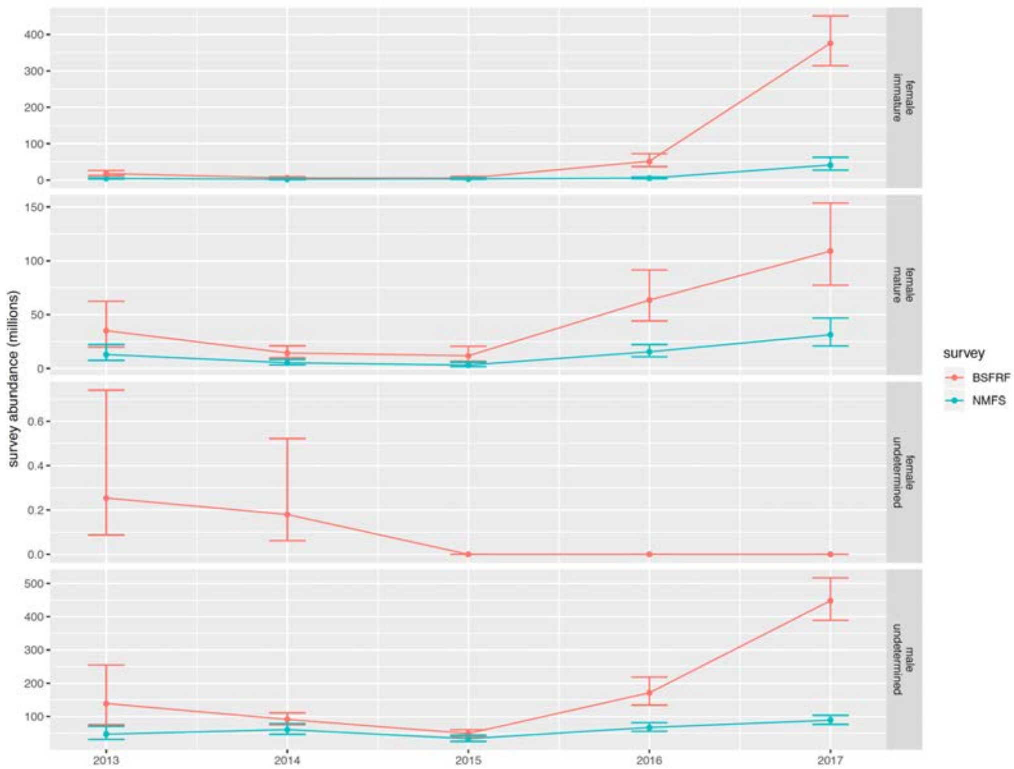


Figure 5.6. Estimated survey abundance for the SBS study area each year.

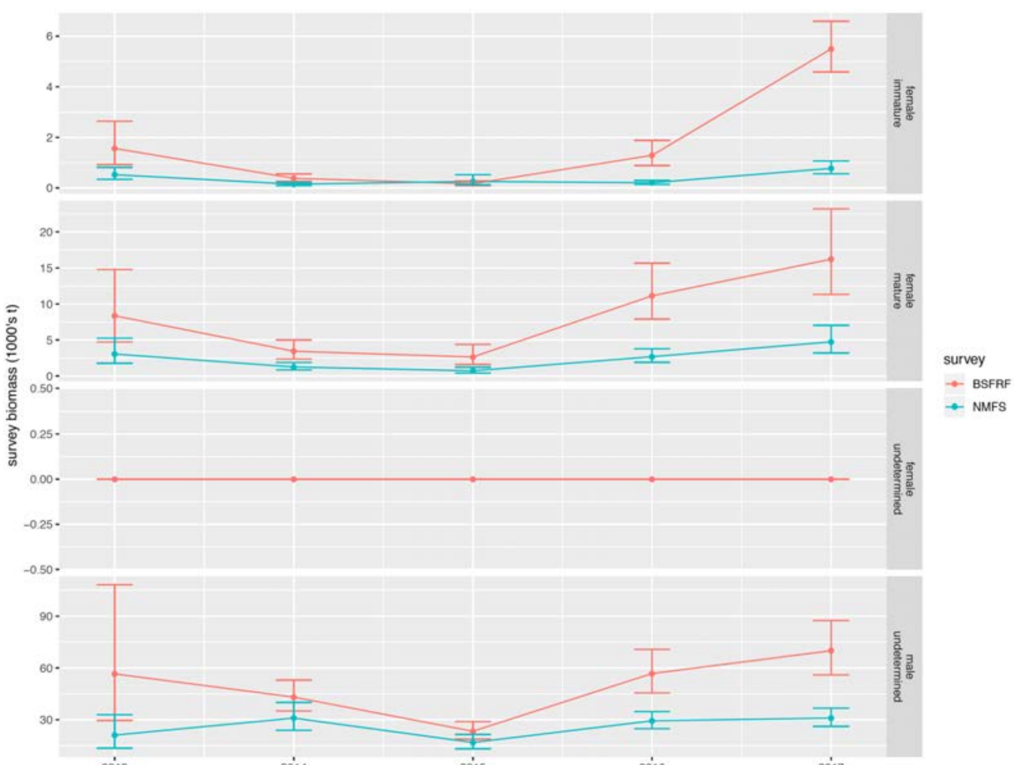


Figure 5.7. Estimated survey biomass for the SBS study area each year.

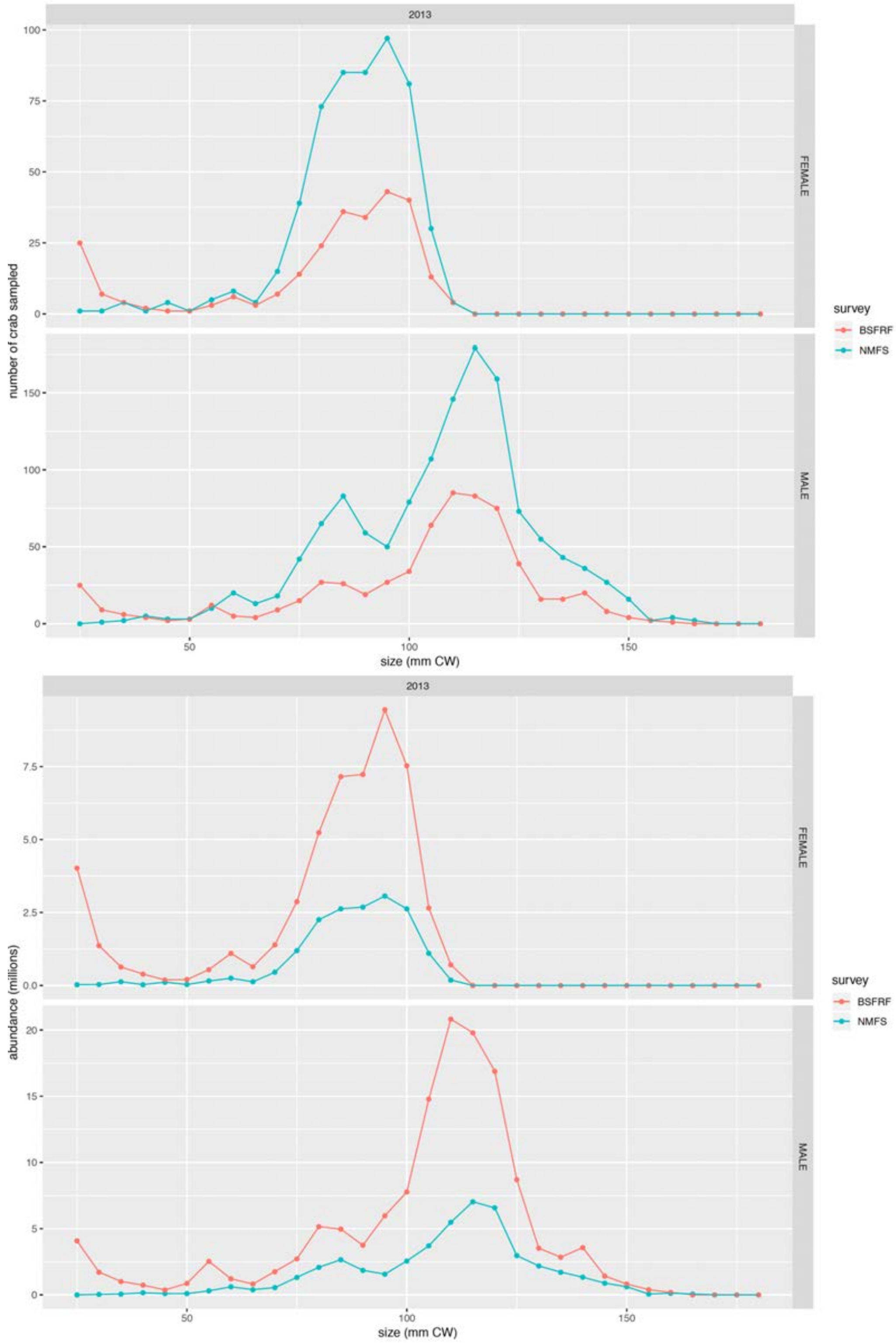


Figure 5.8. Upper two plots: observed numbers of crab in 2013 by 5 mm CW size bin. Lower two plots: estimated abundance in the SBS study area by 5 mm CW size bin.

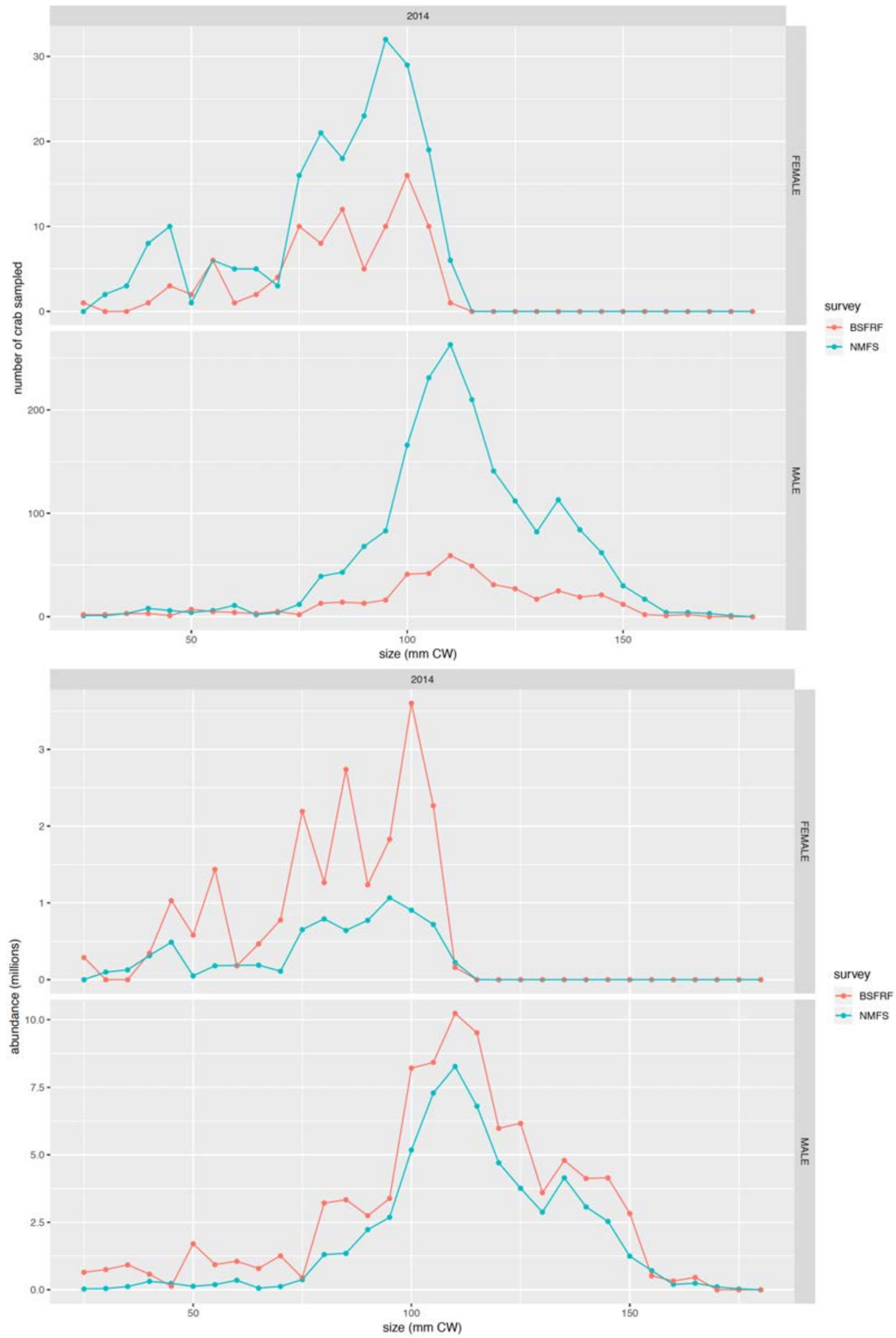


Figure 5.9. Upper two plots: observed numbers of crab in 2014 by 5 mm CW size bin. Lower two plots: estimated abundance in the SBS study area by 5 mm CW size bin.

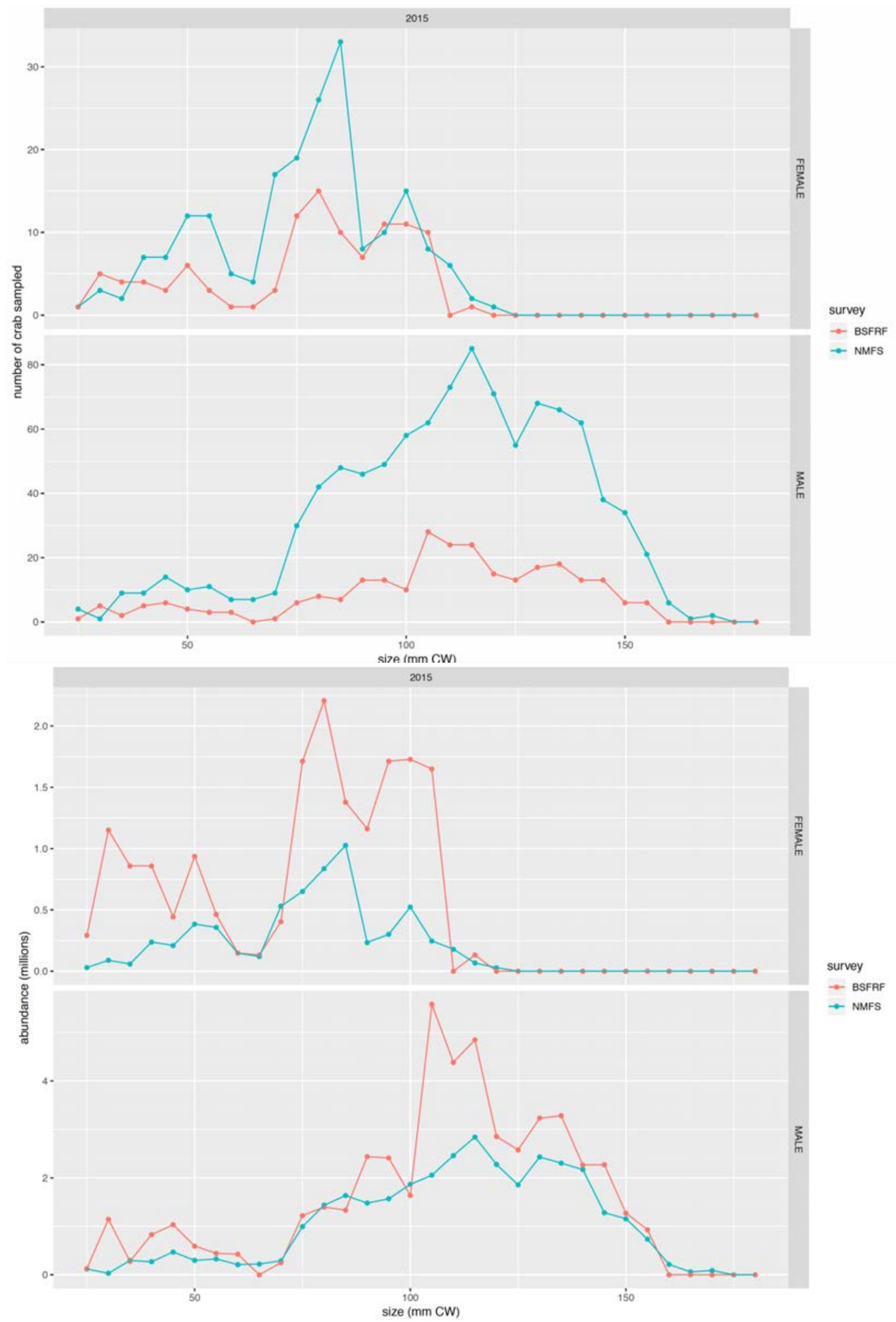


Figure 5.10. Upper two plots: observed numbers of crab in 2015 by 5 mm CW size bin. Lower two plots: estimated abundance in the SBS study area by 5 mm CW size bin.

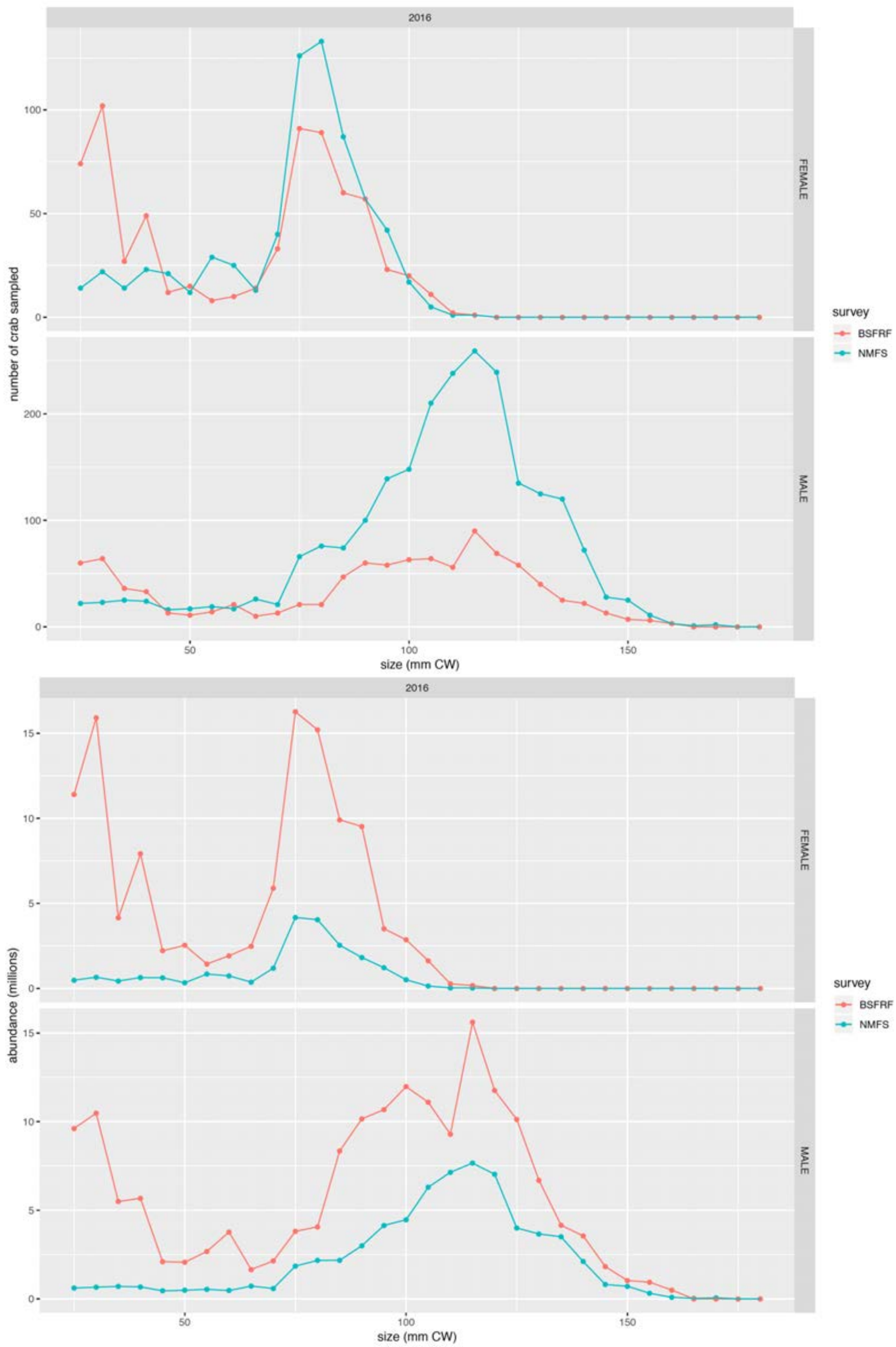


Figure 5.11. Upper two plots: observed numbers of crab in 2016 by 5 mm CW size bin. Lower two plots: estimated abundance in the SBS study area by 5 mm CW size bin.

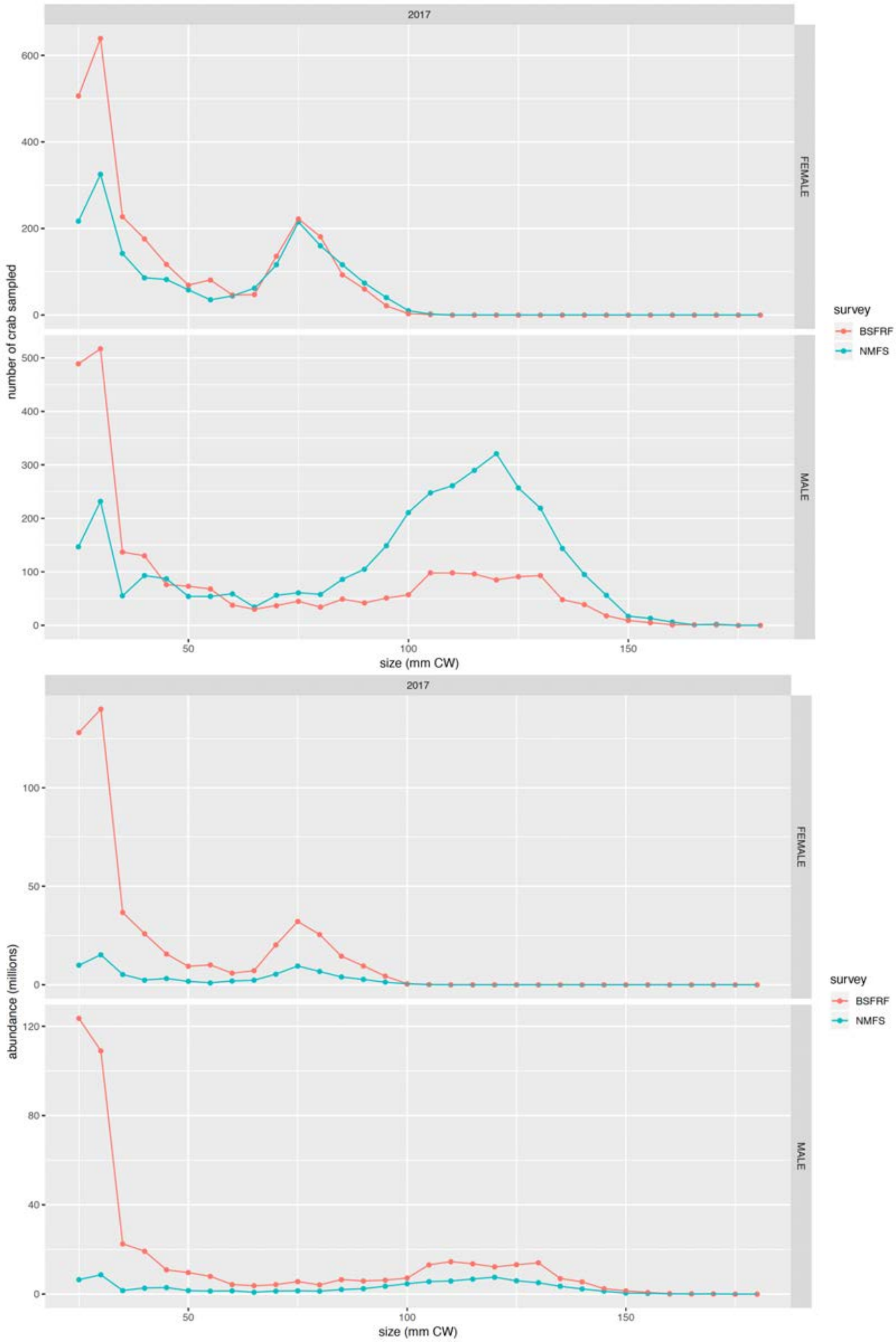


Figure 5.12. Upper two plots: observed numbers of crab in 2017 by 5 mm CW size bin. Lower two plots: estimated abundance in the SBS study area by 5 mm CW size bin.

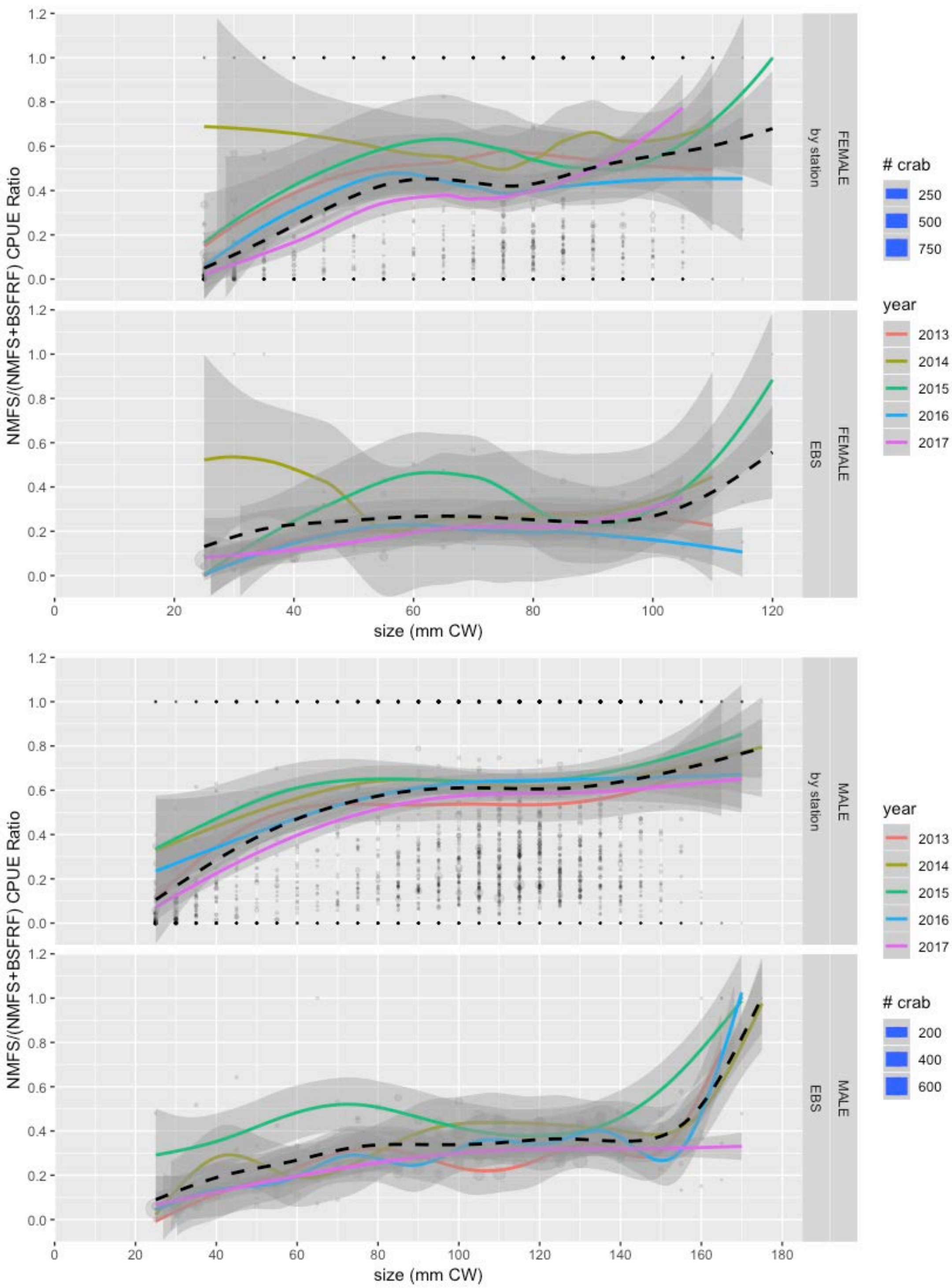
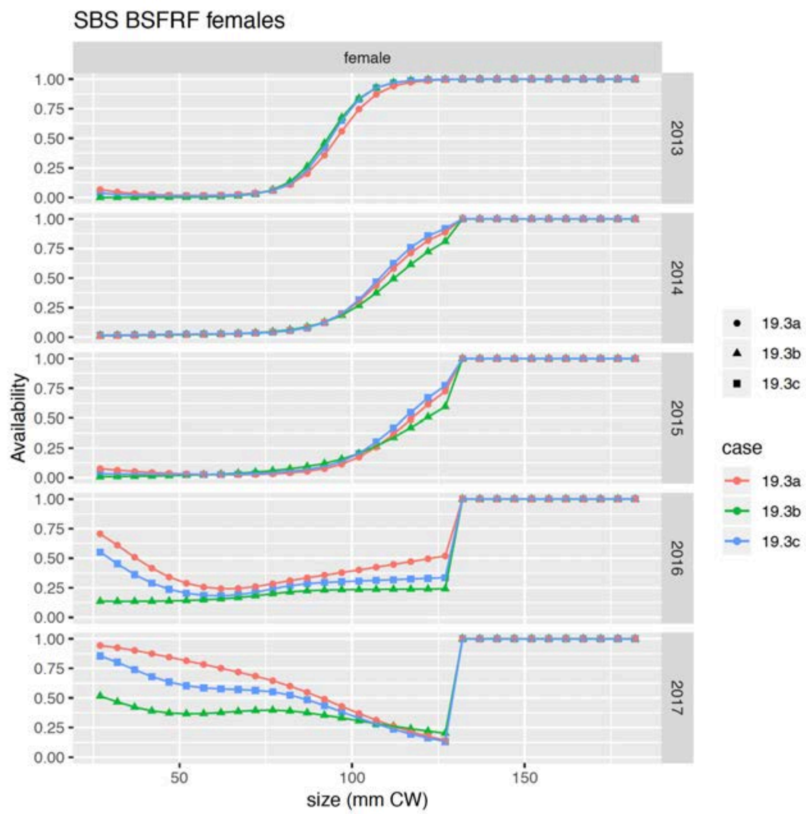


Figure 5.13. Ratios of NMFS CPUE to the sum of NMFS and BSFRF CPUE by size bin by station (upper plot of each pair) and averaged over the SBS study area (lower plot of each pair). Dark dashed line: LOESS smoothed curve fit to all years, colored solid lines: gam-smoothed curves fit by year.



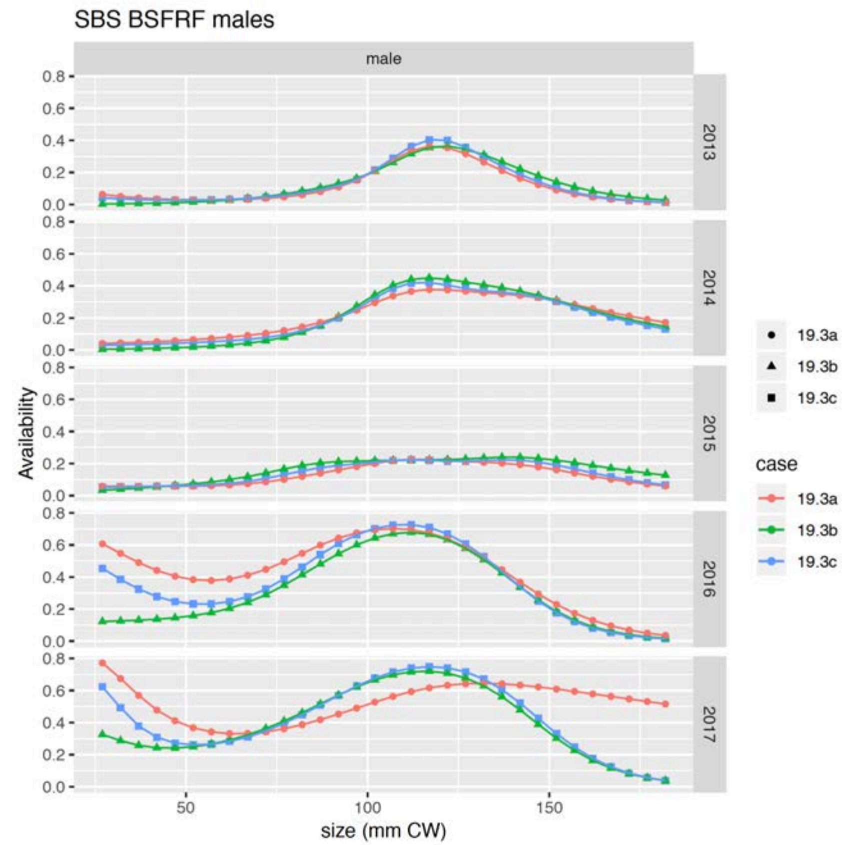


Figure 5.14. Estimated availability curves from scenarios 19.3a, 19.3b, and 19.3c.

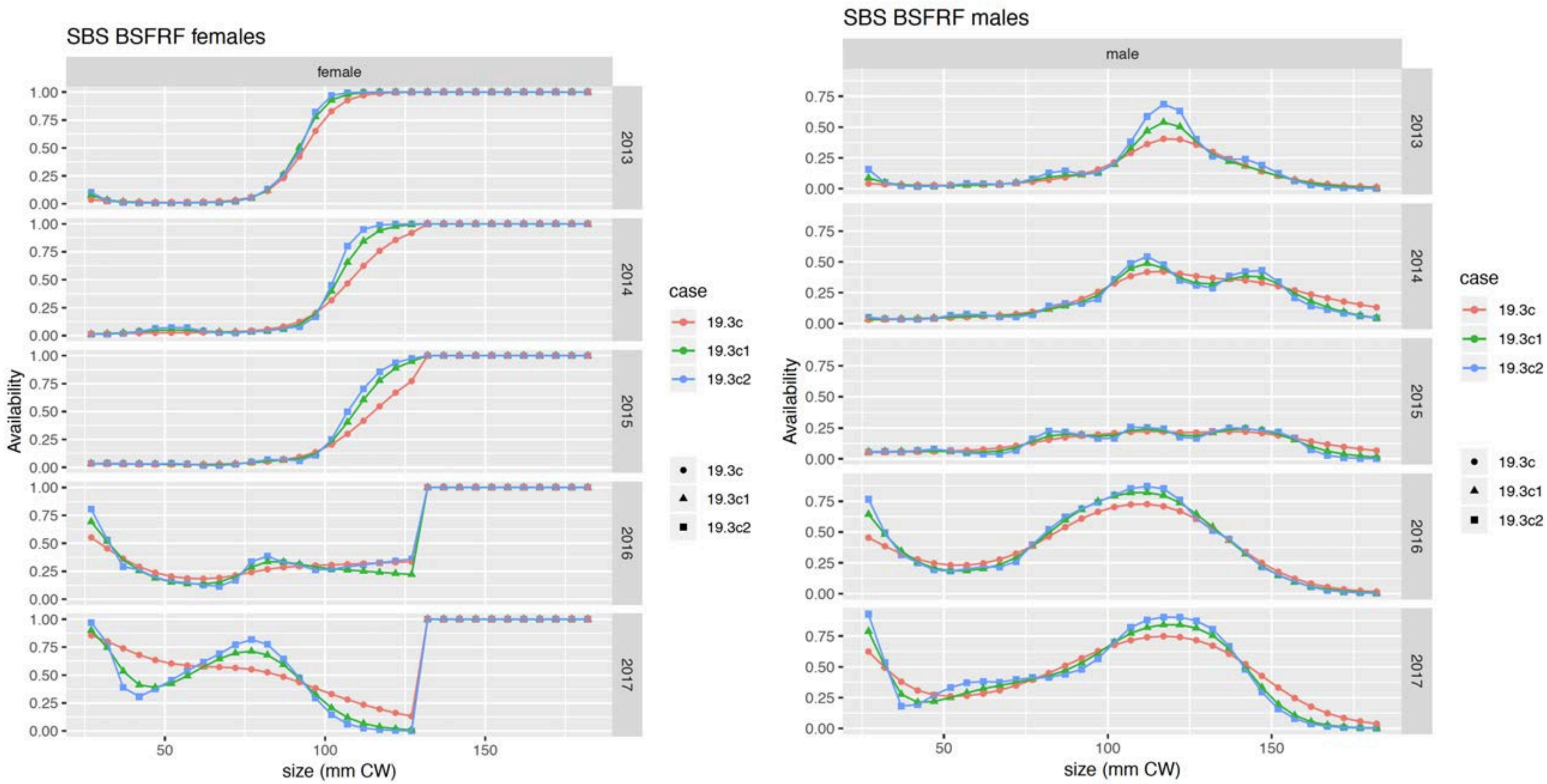


Figure 5.15. Estimated availability curves from scenarios 19.3c (SMP=100), 19.3c1 (SMP=10) and 19.3c2 (SMP=1) indicating the effects of reduced smoothing penalties on the estimated curves.

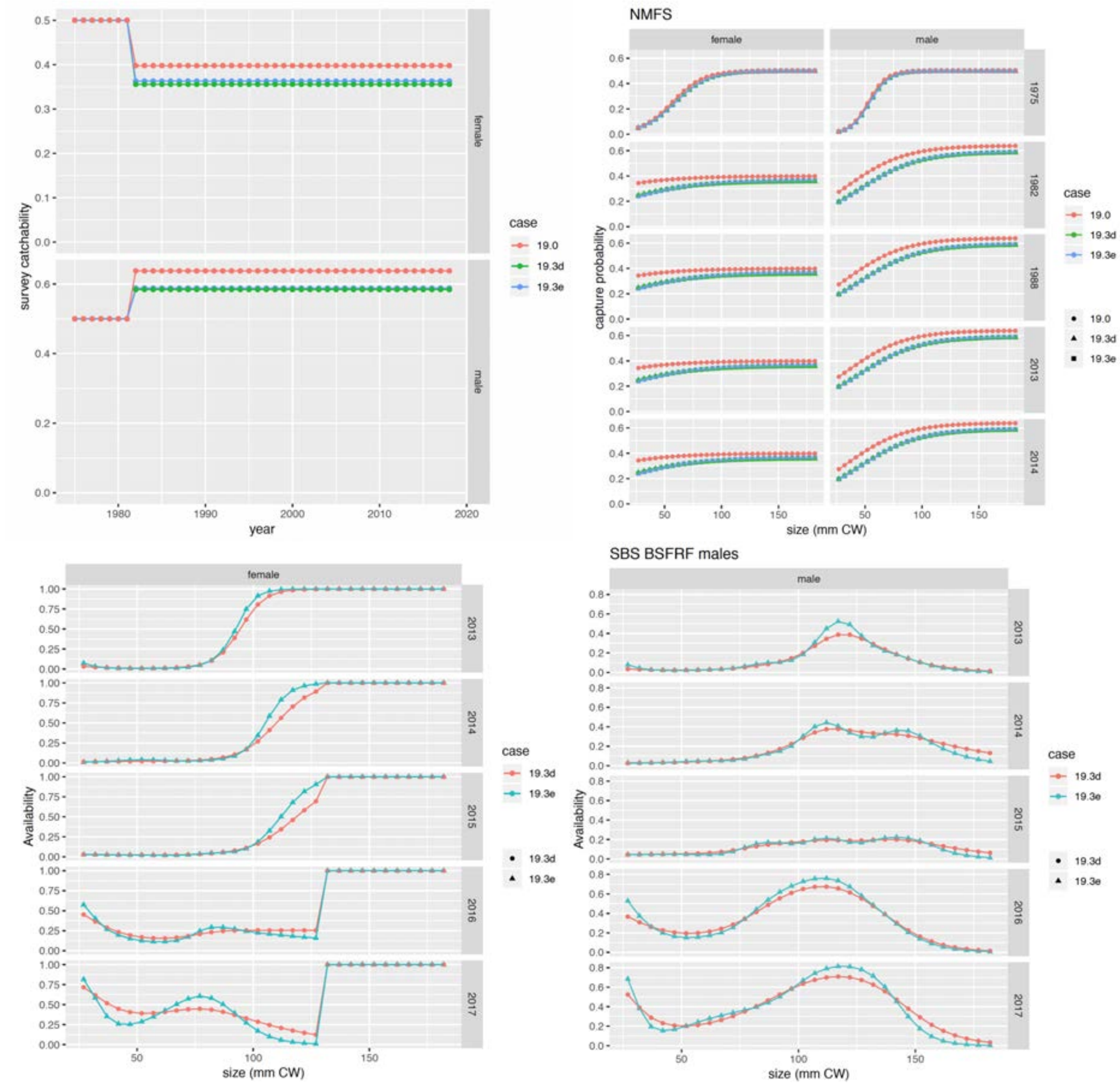


Figure 5.16. Estimated NMFS full-selected catchability (upper left plot) , NMFS full-survey catchability curves (upper right plot), and availability curves for the SBS study areas (lower rows) from scenarios 19.0, 19.3d and 19.3e.

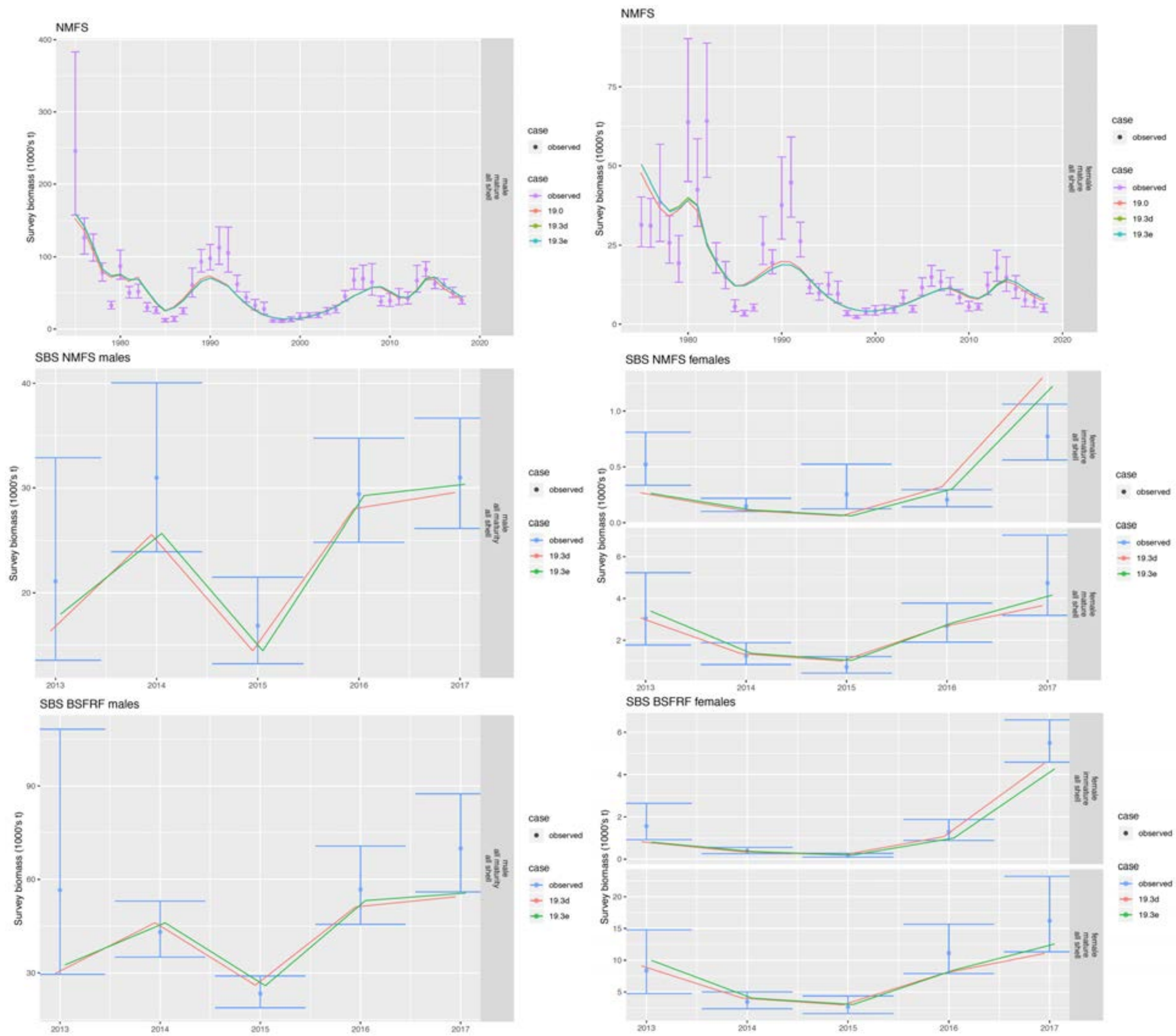


Figure 5.17. Fits to survey biomass components for model scenarios 19.0, 19.3d and 19.3e.

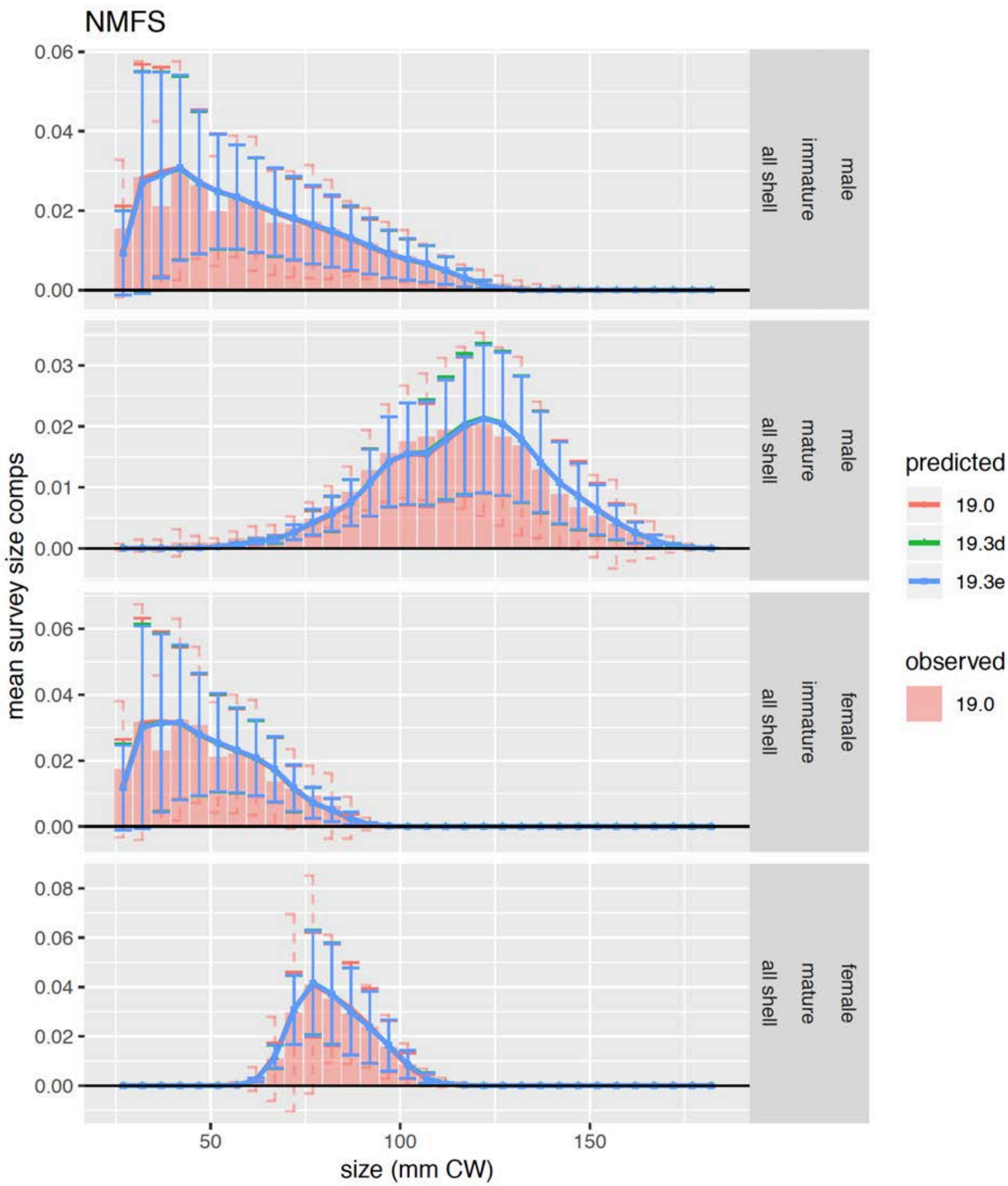


Figure 5.18. Fits to mean survey size composition components from the full NMFS survey for model scenarios 19.0, 19.3d and 19.3e.

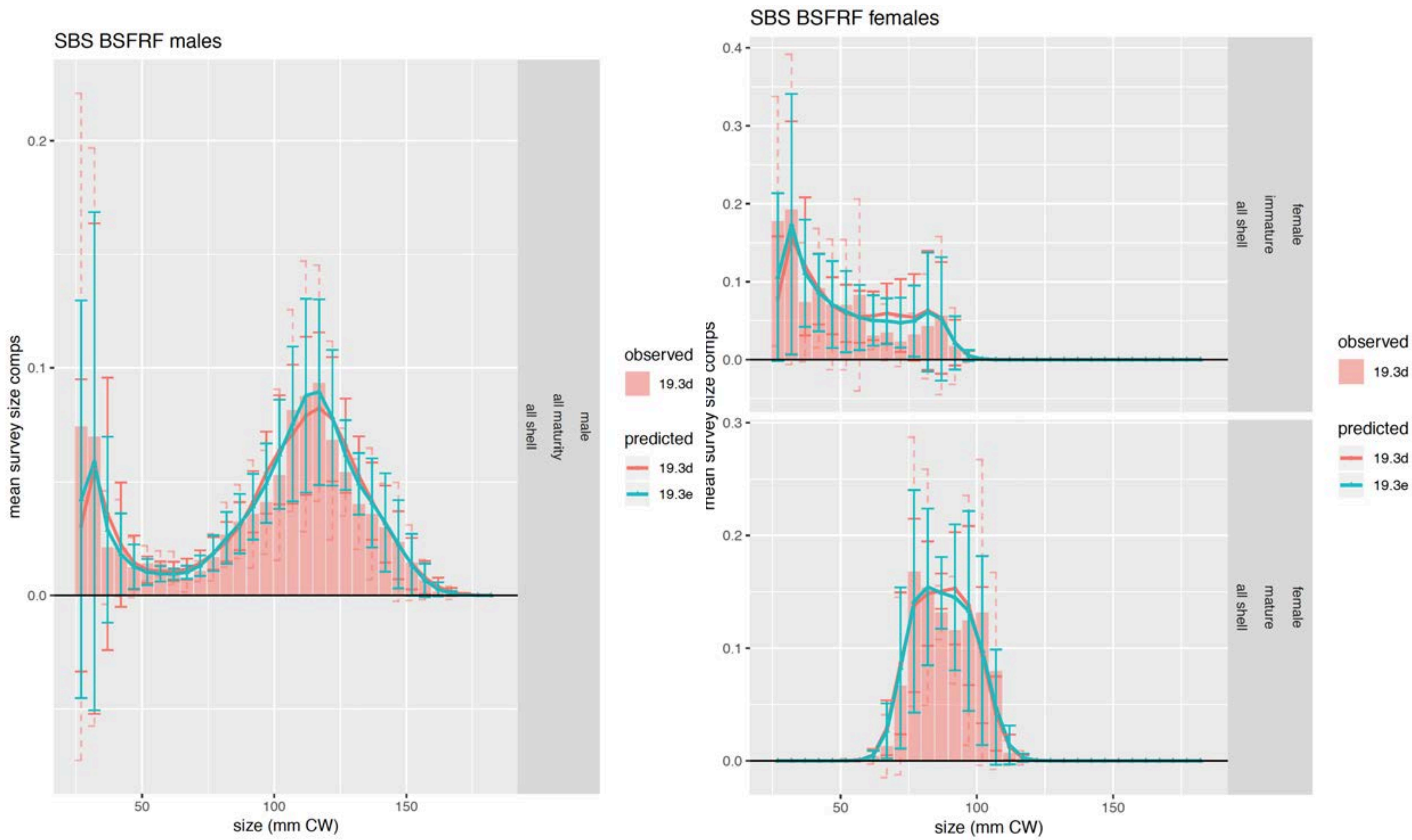


Figure 5.19. Fits to mean survey size composition components from the BSFRF SBS surveys for model scenarios 19.0, 19.3d and 19.3e.

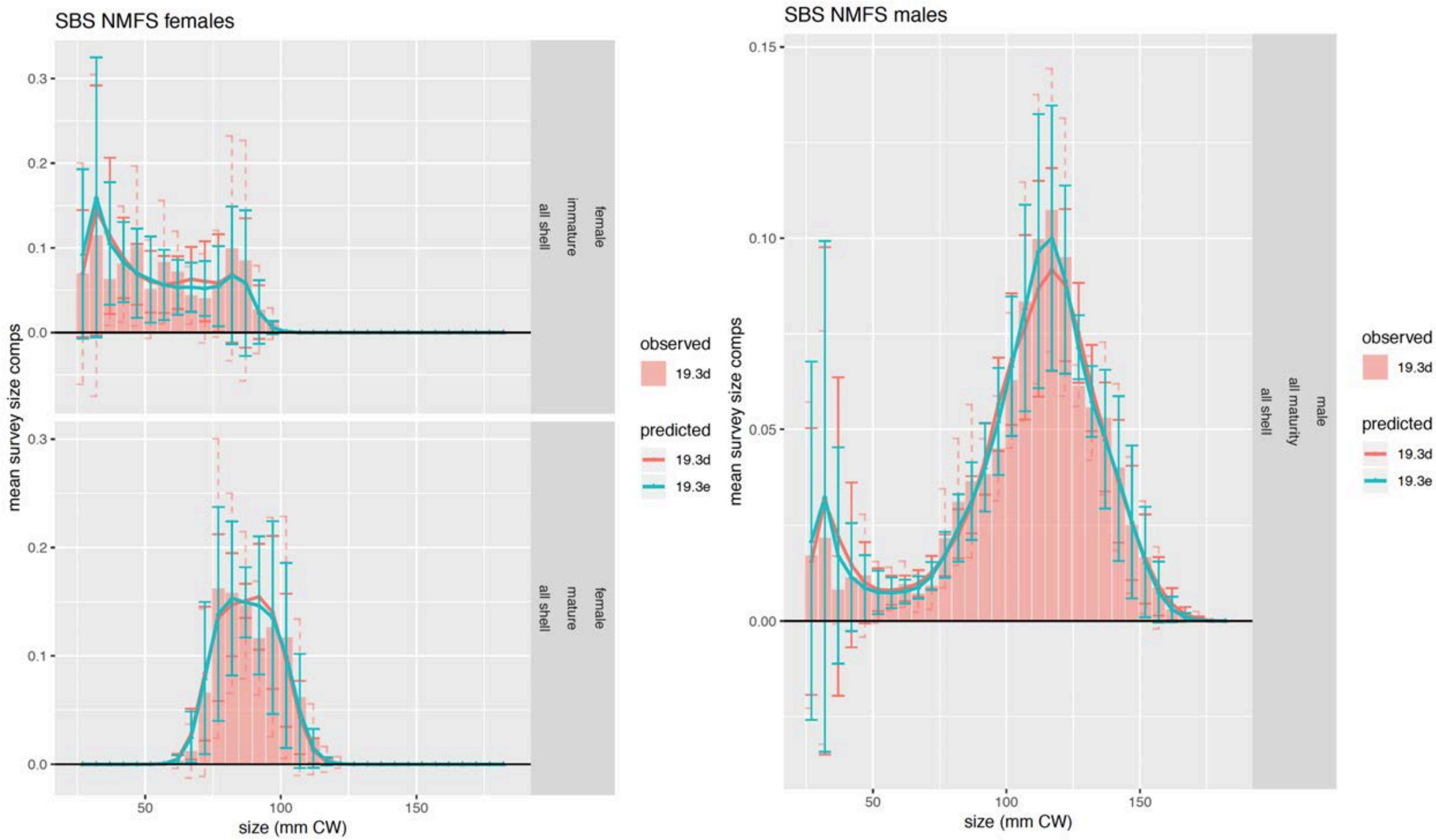


Figure 5.20. Fits to mean survey size composition components from the NMFS SBS surveys for model scenarios 19.0, 19.3d and 19.3e.

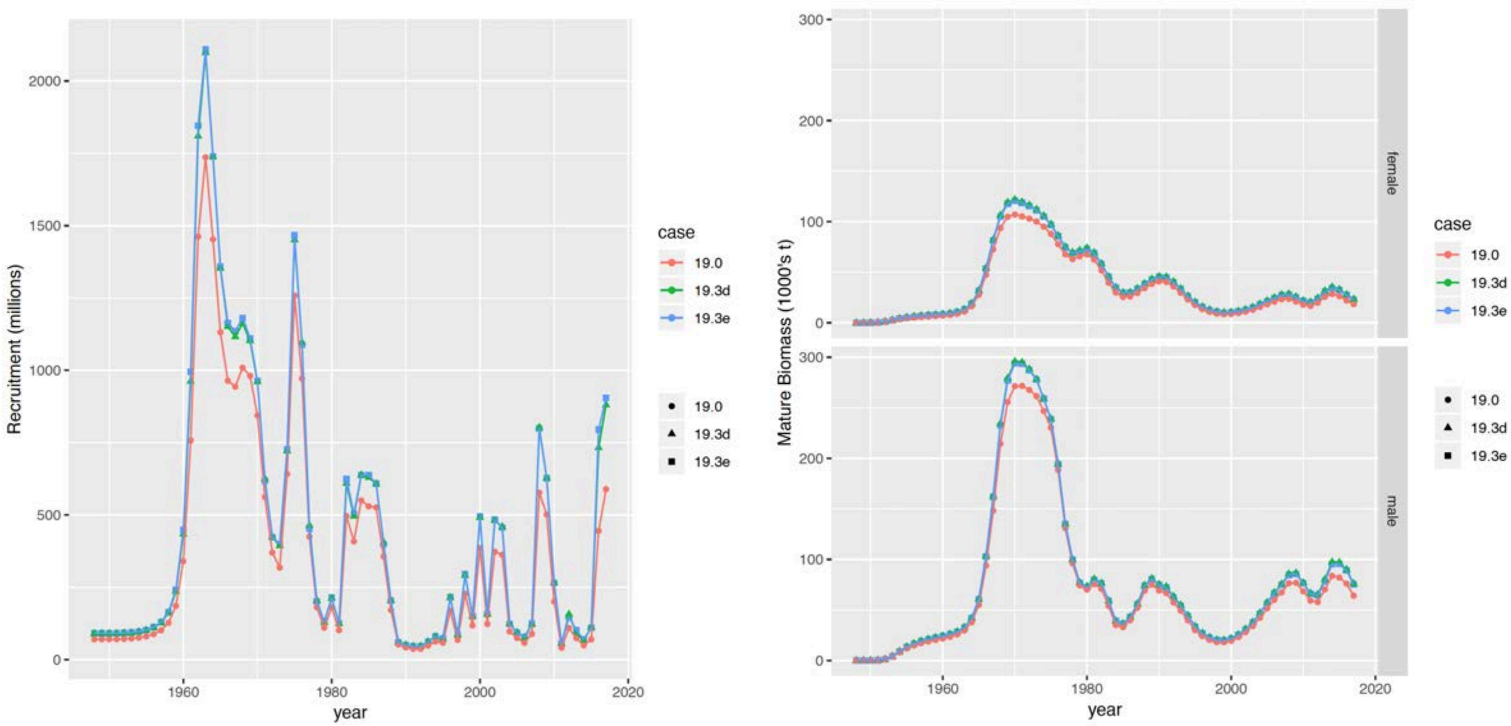


Figure 5.21. Estimated recruitment and mature biomass time series from scenarios 19.0, 19.3d and 19.3e.

6. Proposed Model Scenarios for Fall, 2019 Assessment

The following suite of models is proposed to be evaluated at the 2019 Fall CPT Meeting as part of the 2019 stock assessment for Tanner crab in the Bering Sea and Aleutian Islands:

Final Scenario	Current Scenario	Description
19F.0	19.0	2018 assessment model as base (18AM17)
19F.0a	19.1b	19F.0 with revised fishery data through 2017/18
19F.1	19.1b+	19F.0a + 2019 NMFS Trawl Survey data, 2018/19 fishery data, 2018 growth data
19F.2		19F.1 + fits to male chela height (maturity ogive) data
19F.3		19F.2 - male maturity classification based on Rugolo and Turnock ogive
19F.4		19.F1 + SBS data incorporation
19F.5		19F.3 + SBS data incorporation

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References

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