SBS Survey Data Analysis: Appendix A to the 2024 Stock Assessment and Fishery Evaluation Report for the Tanner Crab Fisheries of the Bering Sea and Aleutian Islands Regions

William T. Stockhausen

2024-08-30

SBS Survey Data

BSFRF and NMFS engaged in a series of collaborative "side-by-side" selectivity studies ("SBS") for Tanner crab that coincided with the 2013-2018 NMFS surveys. During the SBS catchability studies, NMFS performed standard survey tows (e.g., 83-122 trawl gear, 30 minute tow duration) as part of its annual EBS bottom trawl survey while BSFRF performed parallel tows within 0.5 nm using a nephrops trawl and 5 minute tow duration. Because the nephrops trawl has better bottom-tending performance than the 83-112 gear, the BSFRF tows are hypothesized to catch all crab within the net path (i.e., to have selectivity equal to 1 at all crab sizes) and thus provide a measure of absolute abundance/biomass. The NMFS surveys provide relative indices of stock size across the entire stock area; the BSFRF SBS data provides (presumed) absolute indices within the smaller (annually-varying) study footprints (Figure 1). Any "trends" from these results are confounded by the varying geographic coverage of the survey stations included in the SBS studies. The NMFS SBS data (the subset of stations from the full survey each year at which SBS hauls were made) provides information on the annual "availability" of Tanner crab across the entire stock area relative to the area included in the associated SBS study. Estimates of the availability of crab in each SBS geographic area is required in order to appropriately scale population estimates of abundance, biomass, and size composition from the assessment model to the SBS geographic area for each study year.

Due to difficulties encountered by BSFRF in processing the 2018 SBS Tanner crab data, only the 2013-2017 SBS data was incorporated into previous assessments (starting in 2020: Stockhausen 2020, 2021, 2022, 2023). However, BSFRF has now provided the 2018 data and this data is incorporated for the first time into this assessment.

Prior to incorporation into the assessment, the full 2013-2018 BSFRF SBS dataset was checked against NMFS station data to match BSFRF hauls labeled "SBS" to corresponding NMFS hauls based on NMFS station location, station id, and haul time. In a few cases, the BSFRF haul location was inconsistent with the associated NMFS station id or multiple BSFRF hauls were identified as "SBS" for a given NMFS station. In the former case, the BSFRF haul was reassigned to a NMFS station based on its reported haul location. In the latter case, a single BSFRF haul was selected from the multiple hauls identified as SBS based on the haul time that most closely matched the NMFS haul time at the same station. These corrections resulted in 7 hauls/stations being dropped from the 2013-2017 dataset (Table 1; for completeness, Table 2 gives the NMFS station IDs).

In addition to dropping the inconsistent stations, small differences in area swept estimates of abundance, biomass, and size compositions between the 2013-2017 and 2013-2018 datasets were introduced by changing the strata with which the design-based calculations were made. The NMFS survey stratum areas were originally used to apply design-based estimators for abundance, biomass, size compositions to the 2013-2017 dataset. In contrast, a single "SBS" stratum was defined for each year in the 2013-2018 dataset with which to apply the design-based estimators based on areas associated with individual stations. The latter change was made to achieve better consistency in estimating the survey availability associated with the BSFRF results (see next section).

Overall, the changes (Figures 2- 5) associated with changing the strata used to calculate the design-based estimates were small (less than 1%: see the 'pct diff' column in Tables 3 and 4 for years 2013-2015) while those associated with dropping inconsistent stations were larger, but less than 13% (see the 'pct diff' column in the aforementioned tables for years 2016 and 2017).

Empirical Availability for the SBS Studies

The indices and size compositions from the BSFRF SBS studies discussed in the previous section provide information on Tanner crab stock abundance and composition in addition to that provided by the NMFS EBS bottom trawl survey but, while the NMFS surveys cover the entire EBS Tanner crab stock area, the BSFRF surveys only cover parts of the stock area. To be fit in the assessment model, the "availability" of the stock to the BSFRF survey gear needs to be determined in order to scale the predicted population size from the stock area to the area covered by the survey. The availability of the population in a given area, $A_x(z)$, is a sex-specific function of crab size because Tanner crab of different sexes and sizes typically have different spatial distributions. Because the NMFS surveys cover the entire stock area, the availability in area a in year y can be estimated from the ratio of the size compositions in area a to those from the total area derived from the NMFS survey in year y as:

$$A_x(z) = \frac{N_x^a(z)}{N_x^t(z)} \tag{1}$$

where a and t denote the SBS study area and the full survey area, respectively. As with the design-based indices discussed in the previous section, the "raw" availability curves from the 2013-2017 and 2013-2018 datasets are almost identical for 2013-2015, while differences are most evident (although still relatively minor) for 2017 (Figures 6 and 7).

In order to interpolate values for size bins with no data, as well as to reduce potential effects of sampling variability, the availability curves used in the 2023 assessment model, 22.03b (Stockhausen

2023), were “smoothed” estimates of the raw 2013-2017 empirical availability estimates, fit by sex using generalized additive models (GAMs) from the *mgcv* package from R (Wood et al. 2016; R Core Team 2022) with a lognormal error distribution (using the R function “gaussian” with a log link) using the model

$$log(A_{y,z}) = s(z, by = y) \tag{2}$$

where SBS survey year (y) was treated as a “by” variable such that a different smooth curve was estimated for each year. The 2013-2018 dataset was also fit on a sex-specific basis for the 2024 proposed model 22.03d, but the GAMs were fit assuming a binomial error distribution with a logistic link

$$\frac{log(A_{y,z})}{log(1 - A_{y,z})} = c_y + s(z, by = y) \tag{3}$$

and weighted by the size/sex-specific abundance of crab measured in the NMFS EBS survey $N_x^t(z)$. This latter approach more closely reflected the nature of the response data (i.e., the raw empirical availability estimates, which are proportions) than the the assumption of lognormal errors. To facilitate a stepwise progression from 22.03b to 22.03d, model-based estimates of empirical availability were also obtained by fitting Eq. 2 to the 2013-2018 dataset, but including the weights used to fit Eq. 3.

The inclusion of weights when fitting Eq. 2 to the 2013-2018 dataset allowed the resulting model to follow the variability in the empirical estimates somewhat more closely than the model without weights used to fit the original 2013-2017 dataset (see, e.g., the results for 2014 and 2015 in Figure 8 for males and 2016 in Figure 9 for females). Otherwise, the results of the two models were similar except at the largest crab sizes, where support from the data was scanty. In general, the binomial model 3 fit the 2013-2018 dataset in fashion similar to the weighted gaussian model except for the case of small males in 2016 (Figure 10) and at large crab sizes (2017, 2018 for males, Figure 10; 2013, 2016, and 2018 for females, Figure 11). For the cases where the binomial and gaussian models diverge at large crab sizes, the binomial models exhibit more reasonable behavior within the size ranges of the BSFRF data because the gaussian models are overly-influenced by very small proportions with small but non-zero weights.

The binomial models were chosen to represent the availability of Tanner crab to the BSFRF SBS surveys for the following reasons: 1) the binomial models better represent the nature of the data (i.e., proportions); 2) neither gaussian model follows the empirical estimates for small males in 2016, which is concerning, while the binomial model does; and 3) the binomial model predictions exhibit more reasonable behavior at large crab sizes.

References

R Core Team. 2022. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available from https://www.R-project.org/.

Stockhausen, W.T. 2020. 2020 Stock Assessment and Fishery Evaluation Report for the Tanner crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2020 final crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. Available from https://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/CrabSAFE/2020/SAFE_2020_Complete.pdf.

Stockhausen, W.T. 2021. 2021 Stock Assessment and Fishery Evaluation Report for the Tanner crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2021 final crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. p. 217. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=55d56b05-4f74-4c5d-9372-28ced4a2bfc2.pdf&fileName=C1%20Tanner%20Crab%20SAFE.pdf.

Stockhausen, W.T. 2022. 2022 Stock Assessment and Fishery Evaluation Report for the Tanner crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2022 final crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. p. 597. Available from https://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/CrabSAFE/2022/TannerCrabSAFE2022.pdf.

Stockhausen, W.T. 2023. 2023 Stock Assessment and Fishery Evaluation Report for the Tanner crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2023 final crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. p. 339. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=3e66c001-f76d-4f38-b744-f9d815d9147e.pdf&fileName=Eastern%20Bering%20Sea%20Tanner%20Crab%20SAFE.pdf.

Wood, S.N., N., Pya, and S”afken, B. 2016. Smoothing parameter and model selection for general smooth models (with discussion). Journal of the American Statistical Association **111**: 1548–1575.

Tables

List of Tables

1 Summary of stations in conversion from the 2013-2017 SBS dataset following the addition of the 2018 SBS data (referred to as the 2013-2018 SBS dataset) and additional consistency checks on station ID's and haul timing. The final column lists the number of stations dropped as a result of the consistency checks. 5
2 ID's of stations dropped in the conversion from the 2013-2017 SBS dataset to as the 2013-2018 SBS dataset due to additional consistency checks. 6
3 Comparison of abundance indices (in millions) from the BSFRF and NMFS SBS hauls by dataset. Any apparent trends are confounded by the annually-varying geographic coverage of the survey stations included in the SBS studies. 6
4 Comparison of biomass indices (in 1,000's t) from the BSFRF and NMFS SBS hauls by dataset. Any apparent trends are confounded by the annually-varying geographic coverage of the survey stations included in the SBS studies. 8

Table 1. Summary of stations in conversion from the 2013-2017 SBS dataset following the addition of the 2018 SBS data (referred to as the 2013-2018 SBS dataset) and additional consistency checks on station ID's and haul timing. The final column lists the number of stations dropped as a result of the consistency checks.

year	2013-2017	2013-2018	dropped
2013	35	35	0
2014	38	38	0
2015	47	47	0
2016	104	102	2
2017	92	87	5
2018	– –	75	––

Table 2. ID's of stations dropped in the conversion from the 2013-2017 SBS dataset to as the 2013-2018 SBS dataset due to additional consistency checks.

year	station id
2016	E-12
2016	M-08
2017	F-06
2017	GF1918
2017	HG1918
2017	IH1918
2017	JI1918

Table 3. Comparison of abundance indices (in millions) from the BSFRF and NMFS SBS hauls by dataset. Any apparent trends are confounded by the annually-varying geographic coverage of the survey stations included in the SBS studies.

					2013-2017		2013-2018	pct diff
fleet	sex	maturity	year	estimate	cv	estimate	cv	estimate
BSFRF	female	immature	2013	17.953	0.3390	17.946	0.3106	0.03857
			2014	5.743	0.3934	5.762	0.3730	− 0.31852
			2015	5.516	0.5247	5.532	0.5155	− 0.28781
			2016	51.211	0.2778	51.586	0.2678	− 0.73089
			2017	371.445	0.1734	357.912	0.1368	3.71087
			2018	− −	− −	435.834	0.1676	− −
		mature	2013	35.132	0.4876	35.118	0.4711	0.03857
			2014	14.410	0.3283	14.456	0.3022	− 0.31852
			2015	11.801	0.4657	11.835	0.4545	− 0.28781
			2016	62.793	0.3073	63.254	0.2972	− 0.73089
			2017	107.465	0.2906	101.706	0.2736	5.50605
			2018	− −	− −	90.574	0.2161	− −
	male	undetermined	2013	139.197	0.5144	139.143	0.4993	0.03857
			2014	90.888	0.2037	91.178	0.1543	− 0.31852
			2015	48.909	0.1946	49.050	0.1586	− 0.28781
			2016	170.060	0.2029	170.194	0.1930	− 0.07895
			2017	443.397	0.1413	442.105	0.1054	0.29170
			2018	− −	− −	472.029	0.1524	− −
NMFS	female	immature	2013	4.108	0.3378	4.106	0.3093	0.03857
			2014	2.202	0.5016	2.209	0.4877	− 0.31852
			2015	3.096	0.5474	3.105	0.5389	− 0.28781
			2016	5.186	0.3655	5.224	0.3576	− 0.73089
			2017	40.627	0.3531	36.239	0.3355	11.41873
			2018	− −	− −	85.823	0.1862	− −
		mature	2013	12.970	0.4598	12.965	0.4416	0.03857
			2014	5.285	0.3821	5.302	0.3608	− 0.31852
			2015	3.140	0.5183	3.149	0.5089	− 0.28781
			2016	15.343	0.3061	15.429	0.2963	− 0.55721

(continued)

				2013-2017		2013-2018		pct diff
fleet	sex	maturity	year	estimate	cv	estimate	cv	estimate
			2017	30.760	0.3425	26.951	0.3304	13.20062
			2018	— —	— —	27.421	0.2270	— —
	male	undetermined	2013	47.030	0.3561	47.012	0.3295	0.03857
			2014	60.447	0.2434	60.640	0.2046	− 0.31852
			2015	33.320	0.2472	33.416	0.2207	− 0.28781
			2016	66.644	0.1661	66.828	0.1519	− 0.27617
			2017	88.022	0.1465	86.126	0.1143	2.17748
			2018	— —	— —	128.309	0.1099	— —

Table 4. Comparison of biomass indices (in 1,000's t) from the BSFRF and NMFS SBS hauls by dataset. Any apparent trends are confounded by the annually-varying geographic coverage of the survey stations included in the SBS studies.

				2013-2017		2013-2018		pct diff
fleet	sex	maturity	year	estimate	cv	estimate	cv	estimate
BSFRF	female	immature	2013	1.5617	0.4464	1.5611	0.4273	0.03857
			2014	0.3790	0.3292	0.3802	0.3032	− 0.31852
			2015	0.1647	0.4297	0.1652	0.4169	− 0.28781
			2016	1.2753	0.3121	1.2847	0.3028	− 0.73089
			2017	5.4298	0.1692	5.4664	0.1398	− 0.67143
			2018	− −	− −	9.6492	0.1806	− −
		mature	2013	8.3690	0.4838	8.3658	0.4670	0.03857
			2014	3.4282	0.3262	3.4391	0.2999	− 0.31852
			2015	2.6332	0.4226	2.6408	0.4095	− 0.28781
			2016	11.0161	0.2865	11.0969	0.2759	− 0.73089
			2017	15.9842	0.3017	15.1868	0.2829	5.11595
			2018	− −	− −	13.5803	0.2135	− −
	male	undetermined	2013	56.5711	0.5538	56.5493	0.5406	0.03857
			2014	42.9689	0.2099	43.1060	0.1624	− 0.31852
			2015	23.2713	0.2039	23.3384	0.1701	− 0.28781
			2016	56.4141	0.1823	56.4024	0.1739	0.02080
			2017	69.4478	0.1880	70.7570	0.1748	− 1.86756
			2018	− −	− −	54.7234	0.1418	− −
NMFS	female	immature	2013	0.5216	0.3785	0.5214	0.3541	0.03857
			2014	0.1479	0.3343	0.1484	0.3088	− 0.31852
			2015	0.2545	0.6168	0.2552	0.6102	− 0.28781
			2016	0.2019	0.3313	0.2034	0.3224	− 0.73089
			2017	0.7593	0.2789	0.6953	0.2531	8.79985
			2018	− −	− −	2.4208	0.1955	− −
		mature	2013	3.0505	0.4596	3.0493	0.4413	0.03857
			2014	1.2522	0.3484	1.2562	0.3242	− 0.31852
			2015	0.7134	0.4436	0.7155	0.4315	− 0.28781
			2016	2.6542	0.2899	2.6680	0.2798	− 0.51958
			2017	4.6618	0.3343	4.0971	0.3207	12.89370
			2018	− −	− −	4.1218	0.2353	− −
	male	undetermined	2013	21.1089	0.3810	21.1008	0.3568	0.03857
			2014	30.8660	0.2420	30.9645	0.2029	− 0.31852
			2015	16.8020	0.2222	16.8504	0.1918	− 0.28781
			2016	29.1833	0.1454	29.2500	0.1316	− 0.22831
			2017	30.7193	0.1517	30.7584	0.1297	− 0.12719
			2018	− −	− −	29.6374	0.1235	− −

Figures

List of Figures

1 Annual spatial footprints of the BSFRF-NMFS collaborative side-by-side (SBS) Tanner crab catchability studies (2013-2018). BSFRF SBS tows were made in parallel to standard NMFS survey tows at a (different) subset of standard NMFS stations each year of the study. The BSFRF vessel used a modified nephrops bottom trawl assumed to capture all crab within the area swept. . . . 10
2 Conmparison of design-based estimates of abundance from SBS study stations by gear/fleet and population category. . . . 11
3 Conmparison of design-based estimates of biomass from SBS study stations by gear/fleet and population category. . . . 12
4 Conmparison of design-based BSFRF size compositions from the SBS study stations by year and population category. . . . 13
5 Conmparison of design-based NMFS size compositions from the SBS study stations by year and population category. . . . 14
6 Comparison of "raw" emprical availability estimates for male Tanner crab based on the 2013-2017 and 2013-2018 datasets. . . . 15
7 Comparison of "raw" emprical availability estimates for female Tanner crab based on the 2013-2017 and 2013-2018 datasets. . . . 16
8 Comparison of smoothed model estimates for emprical availability for male Tanner crab from the 2013-2017 and 2013-2018 datasets using Eq. 2 (the gaussian family with log link model). Lines: model estimates. Envelopes: 95% confidence intervals. Shapes: "raw" estimates; size represents the number of males measured in the full survey. The vertical lines represent the largest size (by year) caught by the BSFRF gear. See text for more details. . . . 17
9 Comparison of smoothed model estimates for emprical availability for female Tanner crab from the 2013-2017 and 2013-2018 datasets using Eq. 2 (the gaussian family with log link model). Lines: model estimates. Envelopes: 95% confidence intervals. Shapes: "raw" estimates; size represents the number of females measured in the full survey. The vertical lines represent the largest size (by year) caught by the BSFRF gear. See text for more details. . . . 18
10 Comparison of smoothed model estimates for emprical availability for male Tanner crab from the 2013-2018 dataset using Eq. 2 (labeled "gaussian") and Eq. 3 (labeled "bionomial"). Lines: model estimates. Envelopes: 95% confidence intervals. Shapes: "raw" estimates; size represents the number of males measured in the full survey. The vertical lines represent the largest size (by year) by the BSFRF gear. See text for more details. . . . 19
11 Comparison of smoothed model estimates for emprical availability for female Tanner crab from the 2013-2018 dataset using Eq. 2 (labeled "gaussian") and Eq. 3 (labeled "bionomial"). Lines: model estimates. Envelopes: 95% confidence intervals. Shapes: "raw" estimates; size represents the number of females measured in the full survey. The vertical lines represent the largest size (by year) by the BSFRF gear. See text for more details. . . . 20

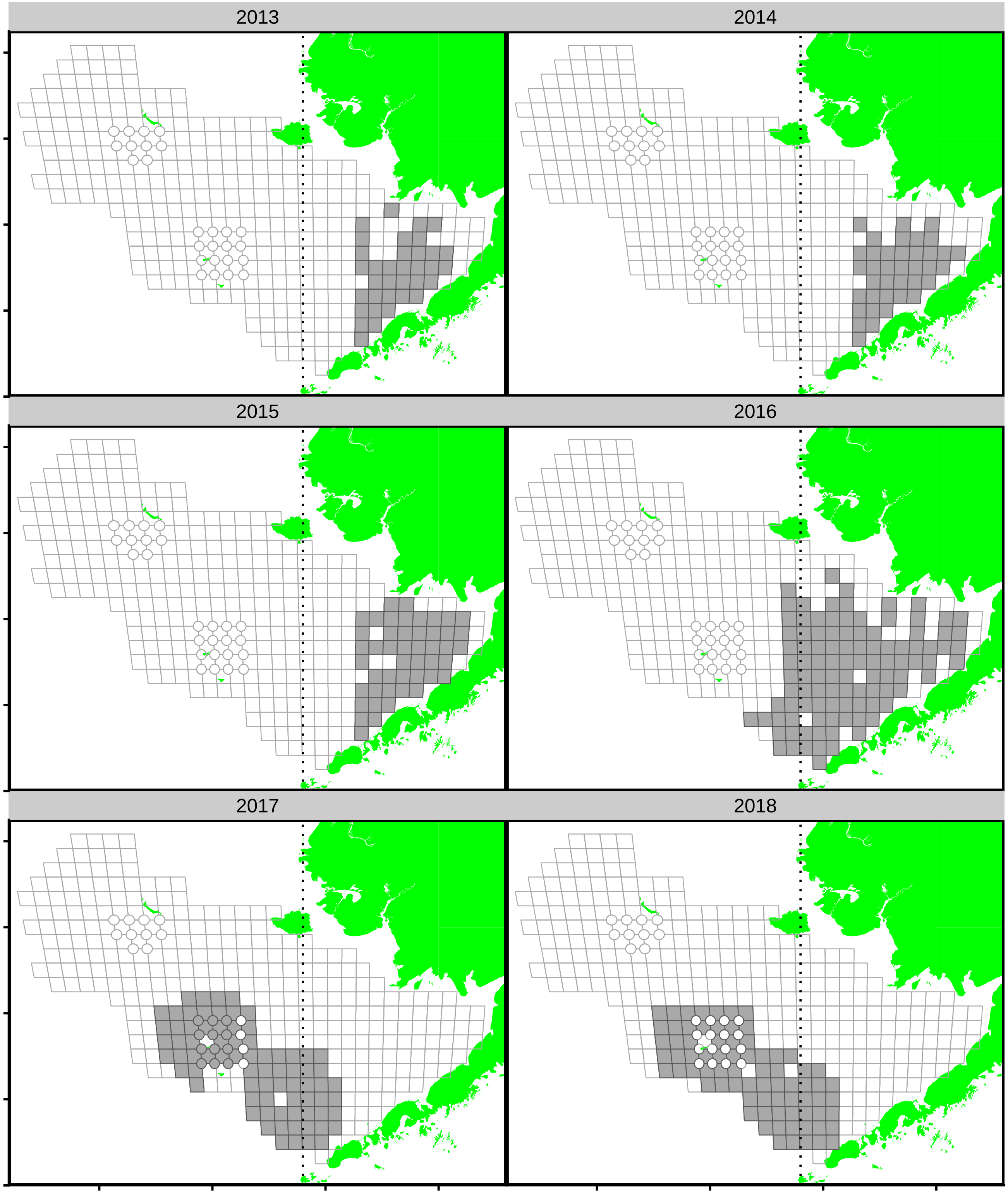

Figure 1. Annual spatial footprints of the BSFRF-NMFS collaborative side-by-side (SBS) Tanner crab catchability studies (2013-2018). BSFRF SBS tows were made in parallel to standard NMFS survey tows at a (different) subset of standard NMFS stations each year of the study. The BSFRF vessel used a modified nephrops bottom trawl assumed to capture all crab within the area swept.

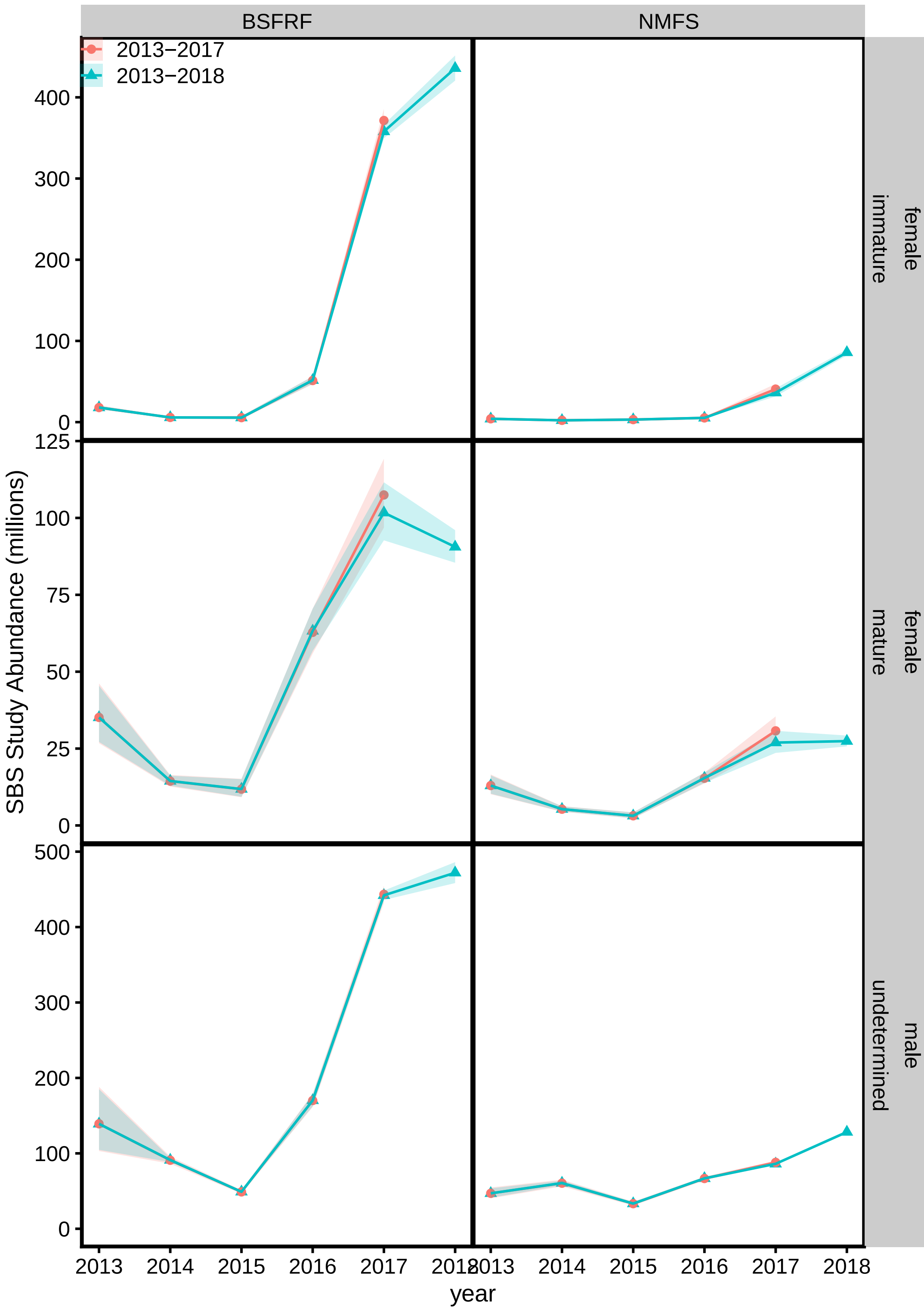

Figure 2. Conmparison of design-based estimates of abundance from SBS study stations by gear/fleet and population category.

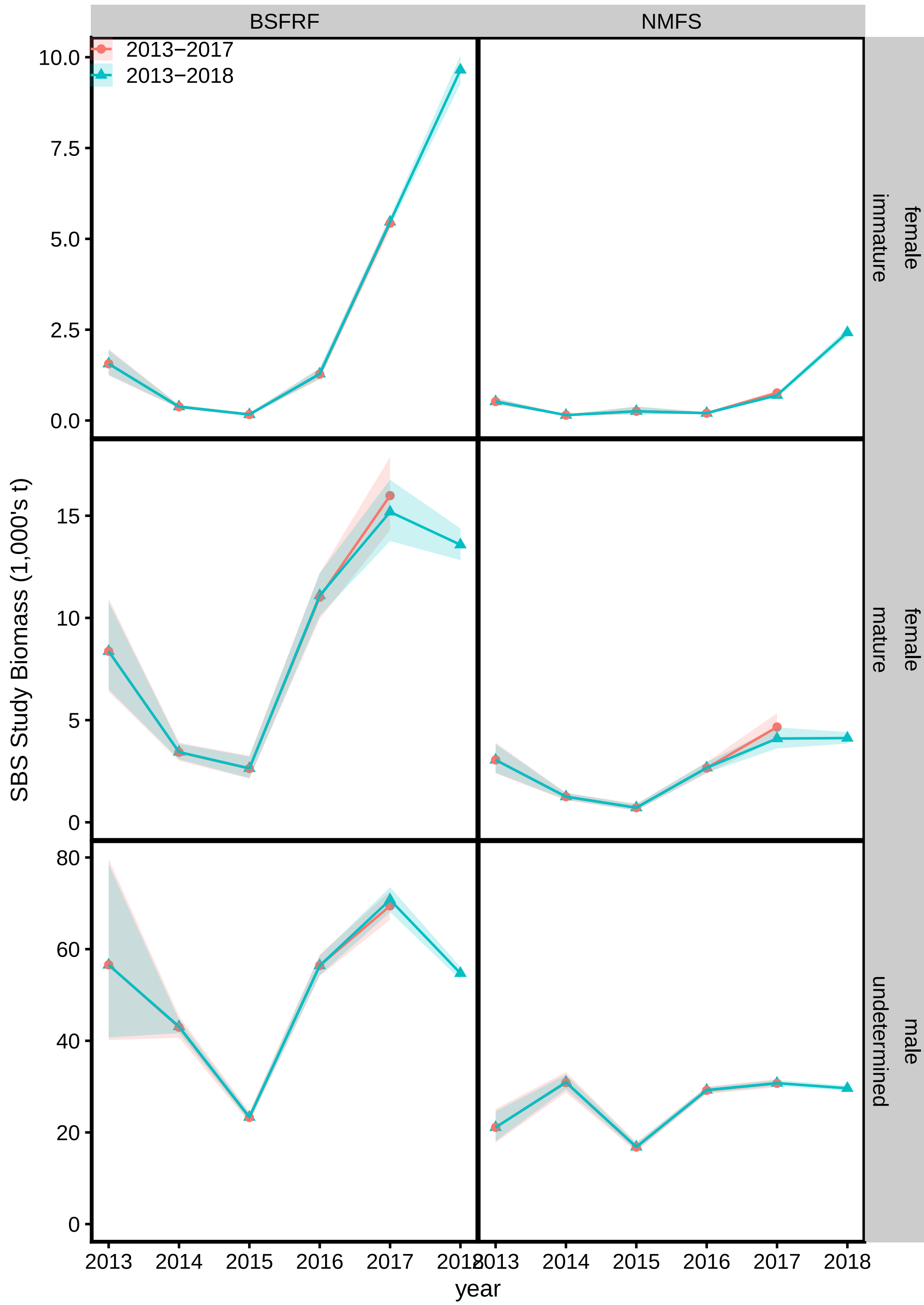

Figure 3. Conmparison of design-based estimates of biomass from SBS study stations by gear/fleet and population category.

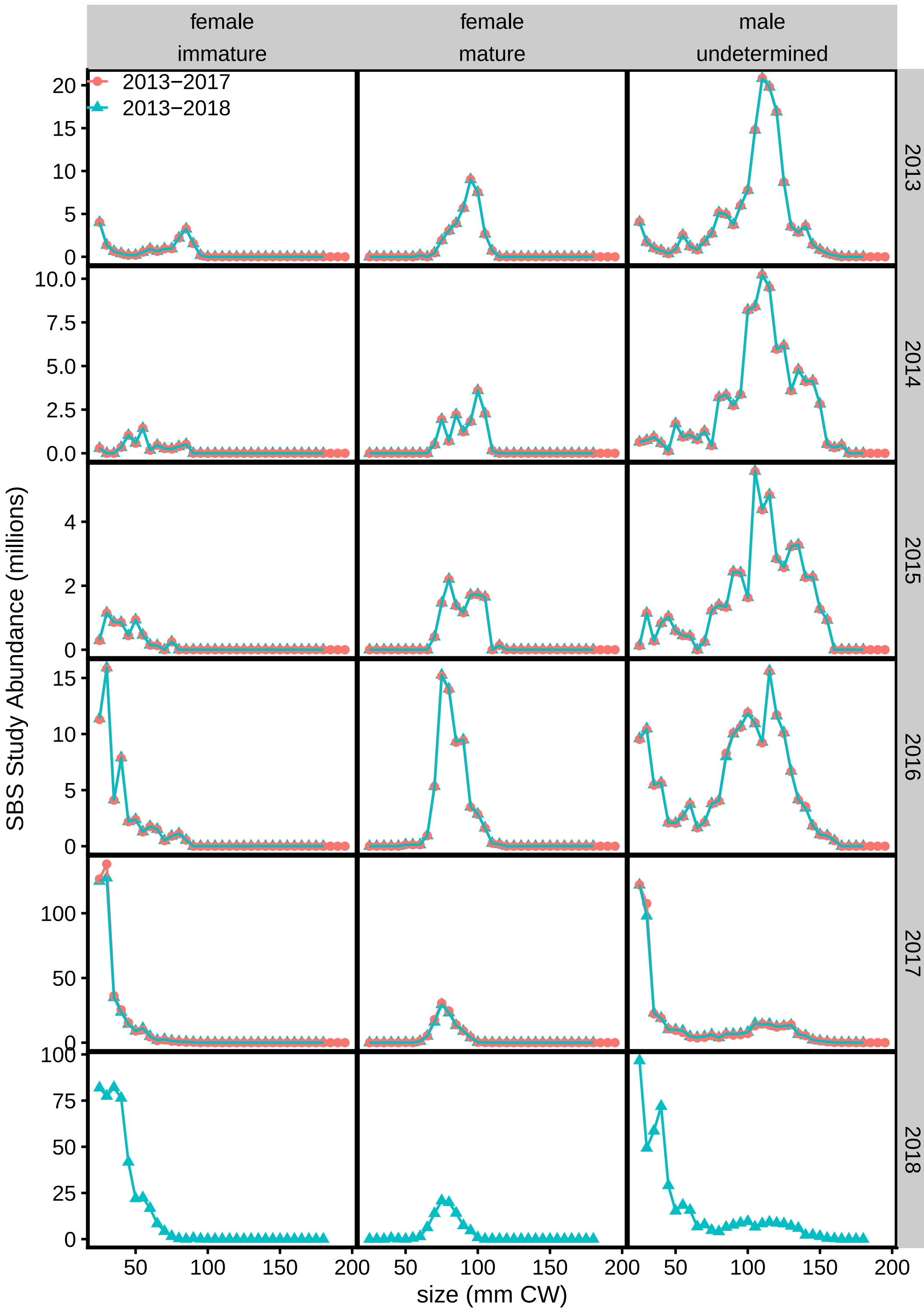

Figure 4. Conmparison of design-based BSFRF size compositions from the SBS study stations by year and population category.

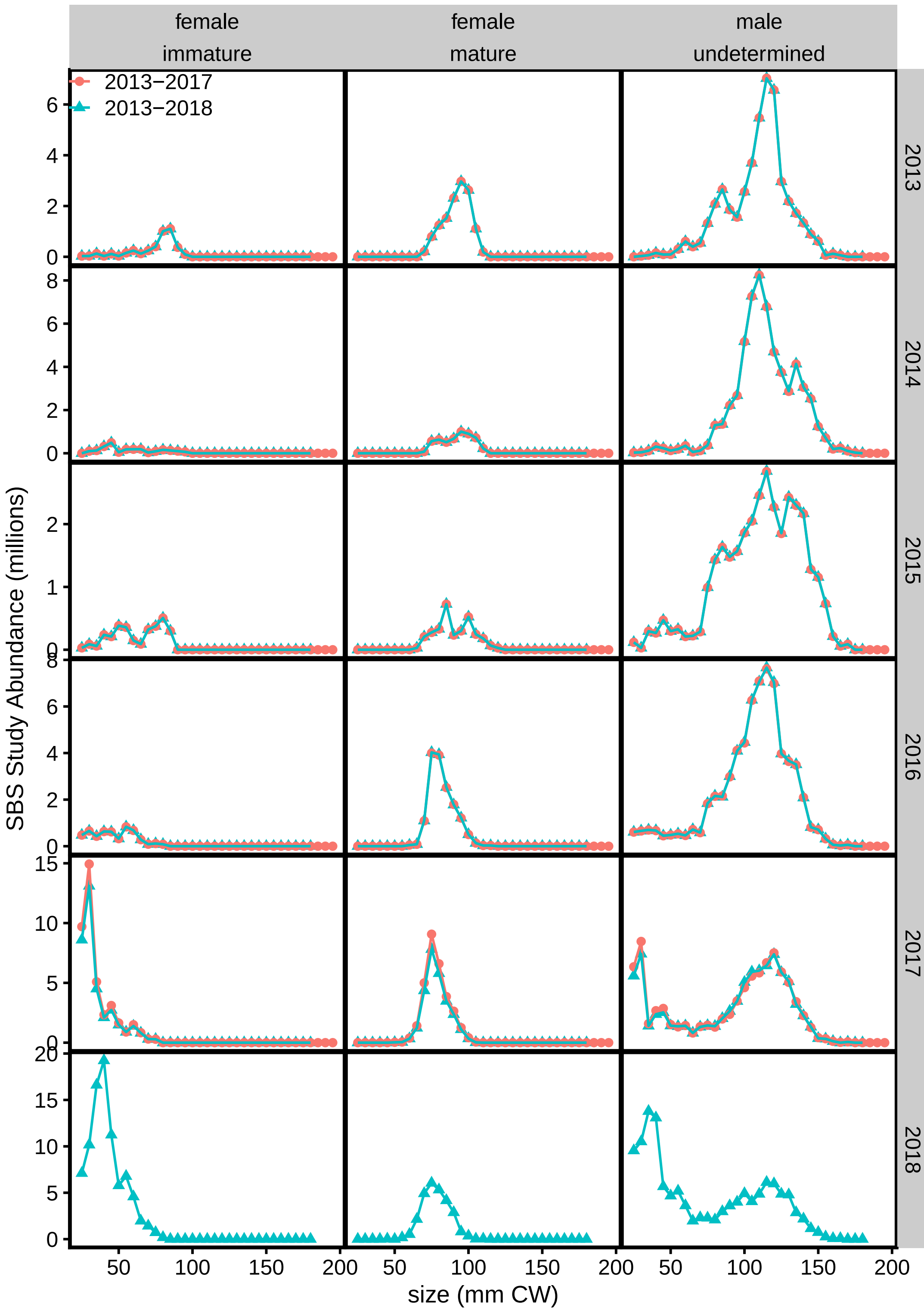

Figure 5. Conmparison of design-based NMFS size compositions from the SBS study stations by year and population category.

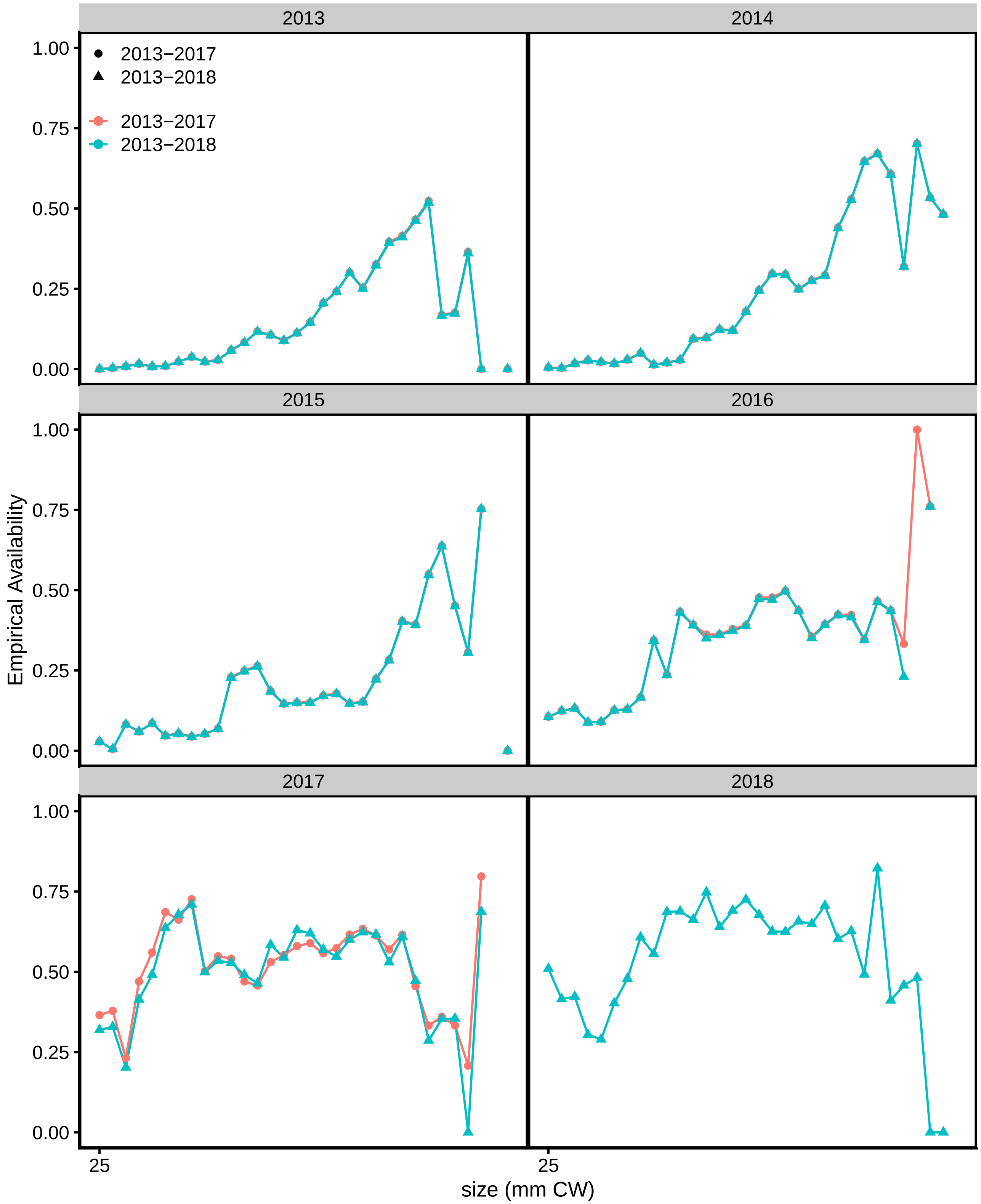

Figure 6. Comparison of "raw" emprical availability estimates for male Tanner crab based on the 2013-2017 and 2013-2018 datasets.

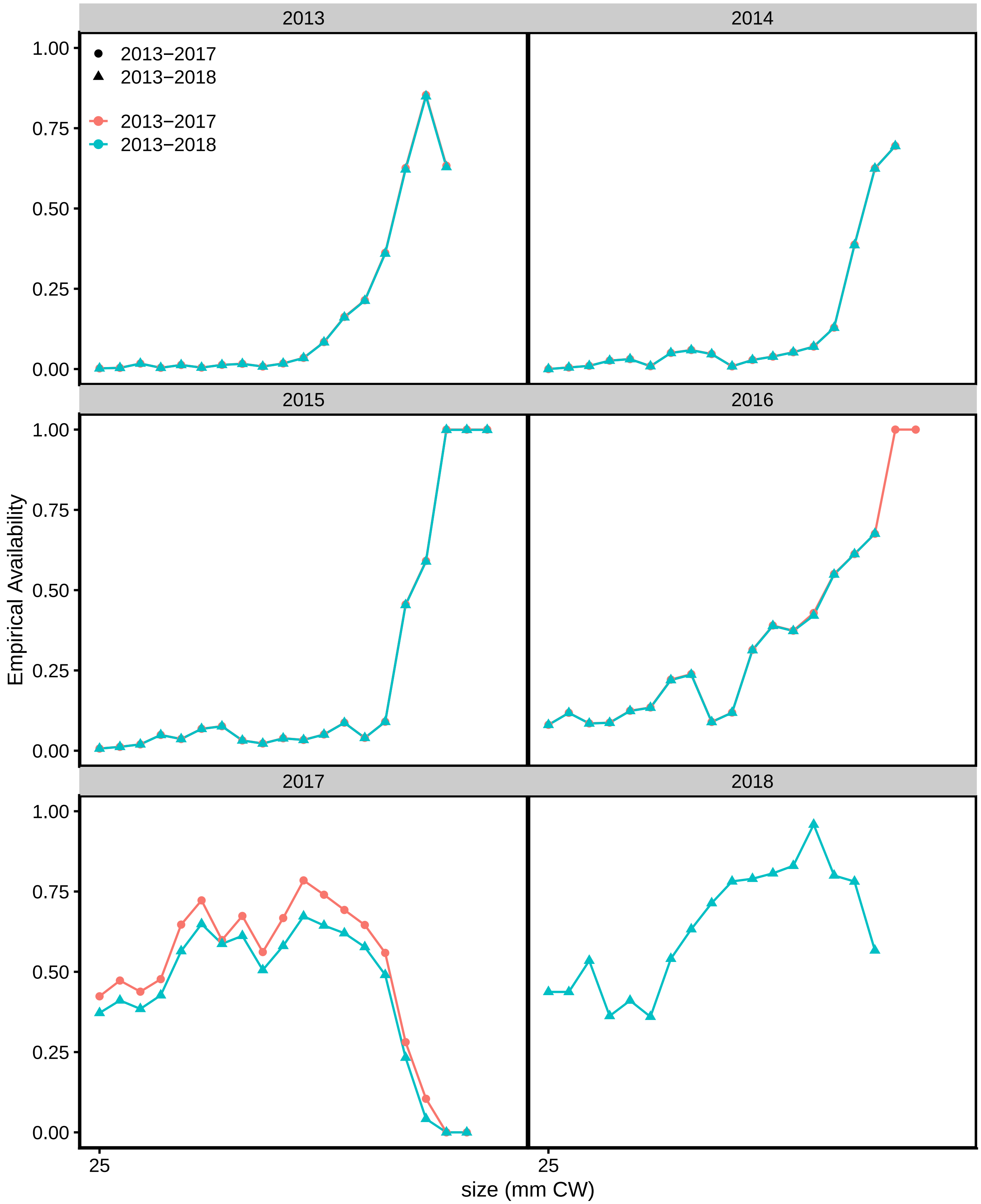

Figure 7. Comparison of "raw" emprical availability estimates for female Tanner crab based on the 2013-2017 and 2013-2018 datasets.

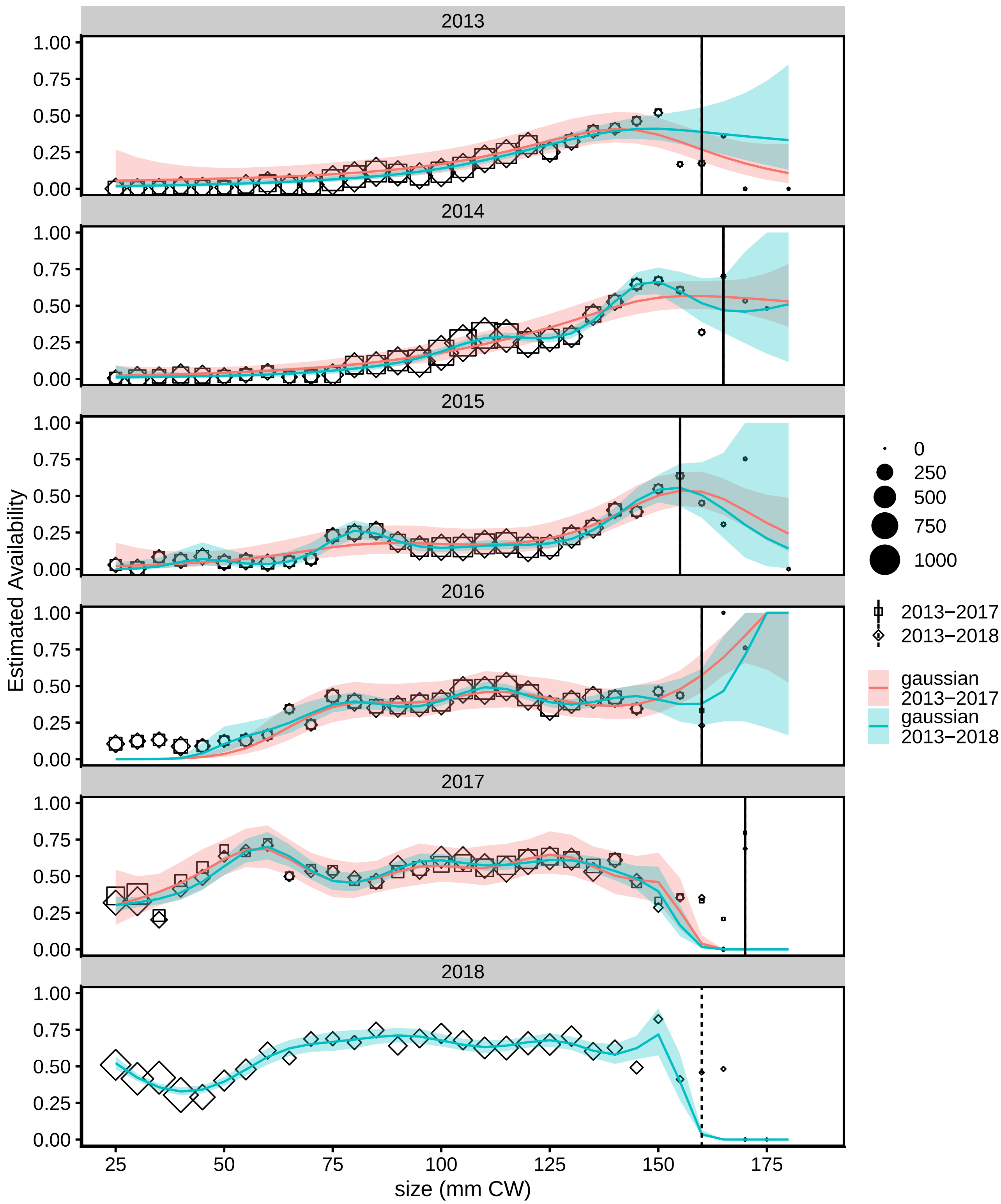

Figure 8. Comparison of smoothed model estimates for emprical availability for male Tanner crab from the 2013-2017 and 2013-2018 datasets using Eq. 2 (the gaussian family with log link model). Lines: model estimates. Envelopes: 95% confidence intervals. Shapes: “raw” estimates; size represents the number of males measured in the full survey. The vertical lines represent the largest size (by year) caught by the BSFRF gear. See text for more details.

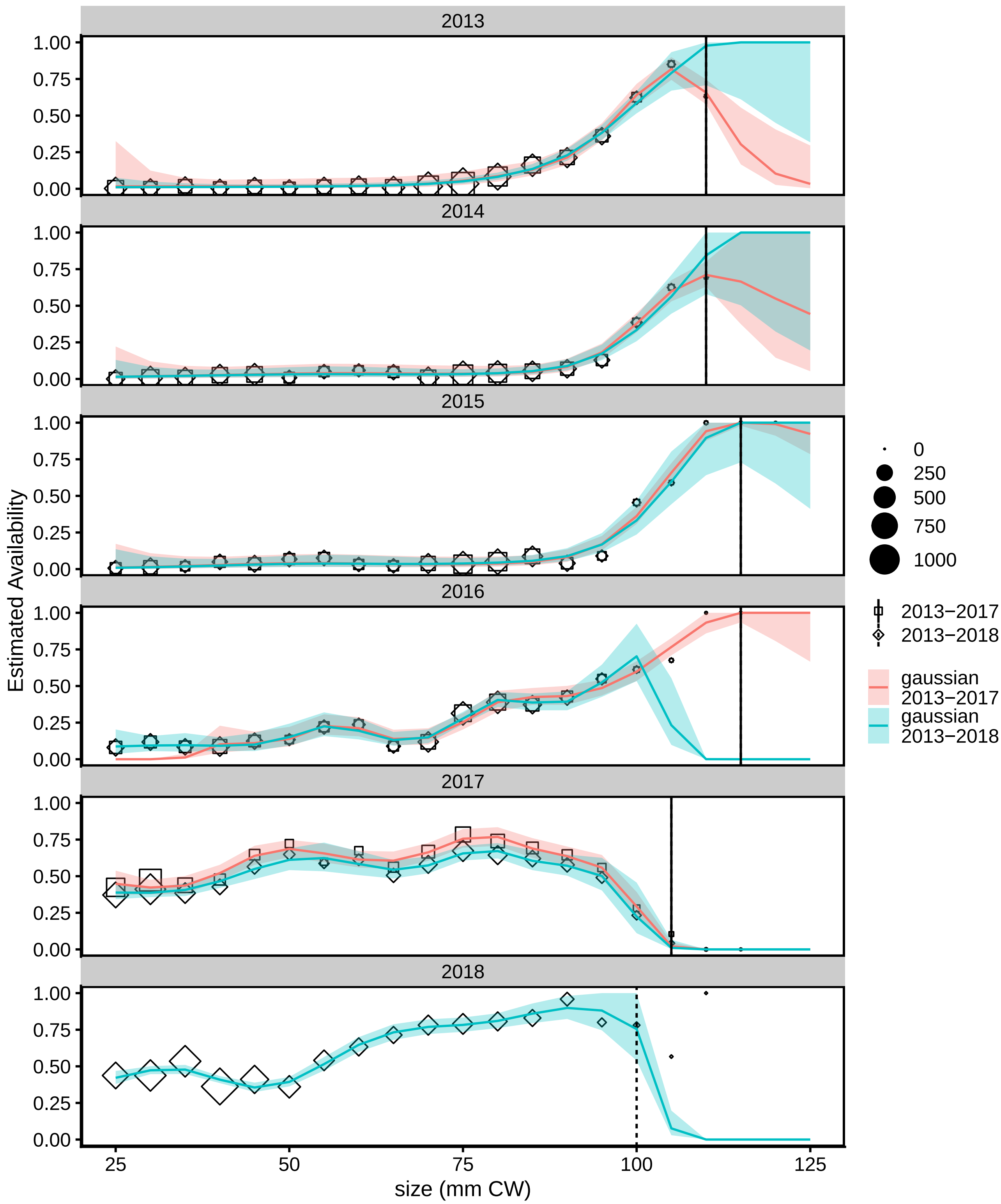

Figure 9. Comparison of smoothed model estimates for emprical availability for female Tanner crab from the 2013-2017 and 2013-2018 datasets using Eq. 2 (the gaussian family with log link model). Lines: model estimates. Envelopes: 95% confidence intervals. Shapes: "raw" estimates; size represents the number of females measured in the full survey. The vertical lines represent the largest size (by year) caught by the BSFRF gear. See text for more details.

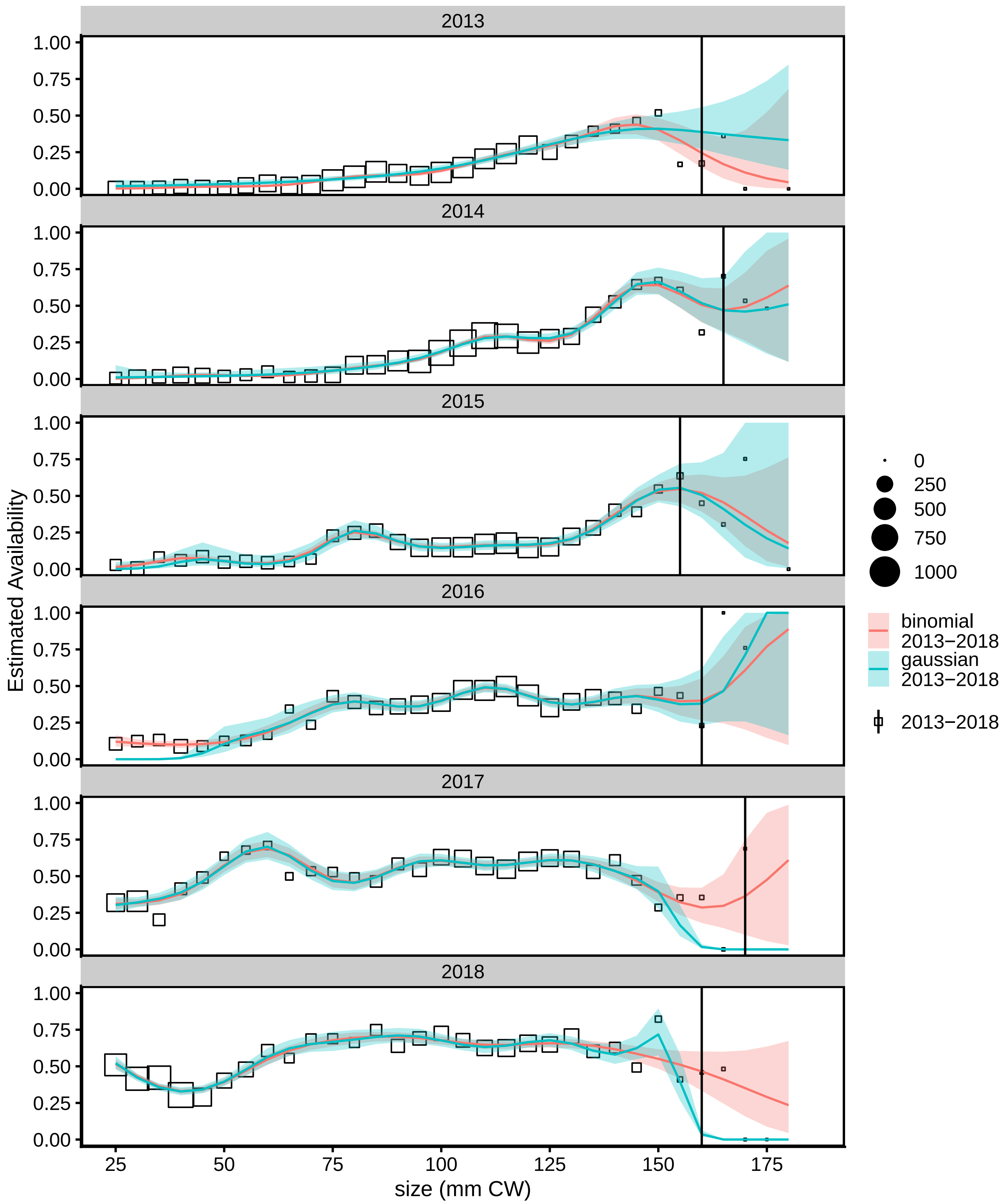

Figure 10. Comparison of smoothed model estimates for emprical availability for male Tanner crab from the 2013-2018 dataset using Eq. 2 (labeled "gaussian") and Eq. 3 (labeled "bionomial"). Lines: model estimates. Envelopes: 95% confidence intervals. Shapes: "raw" estimates; size represents the number of males measured in the full survey. The vertical lines represent the largest size (by year) by the BSFRF gear. See text for more details.

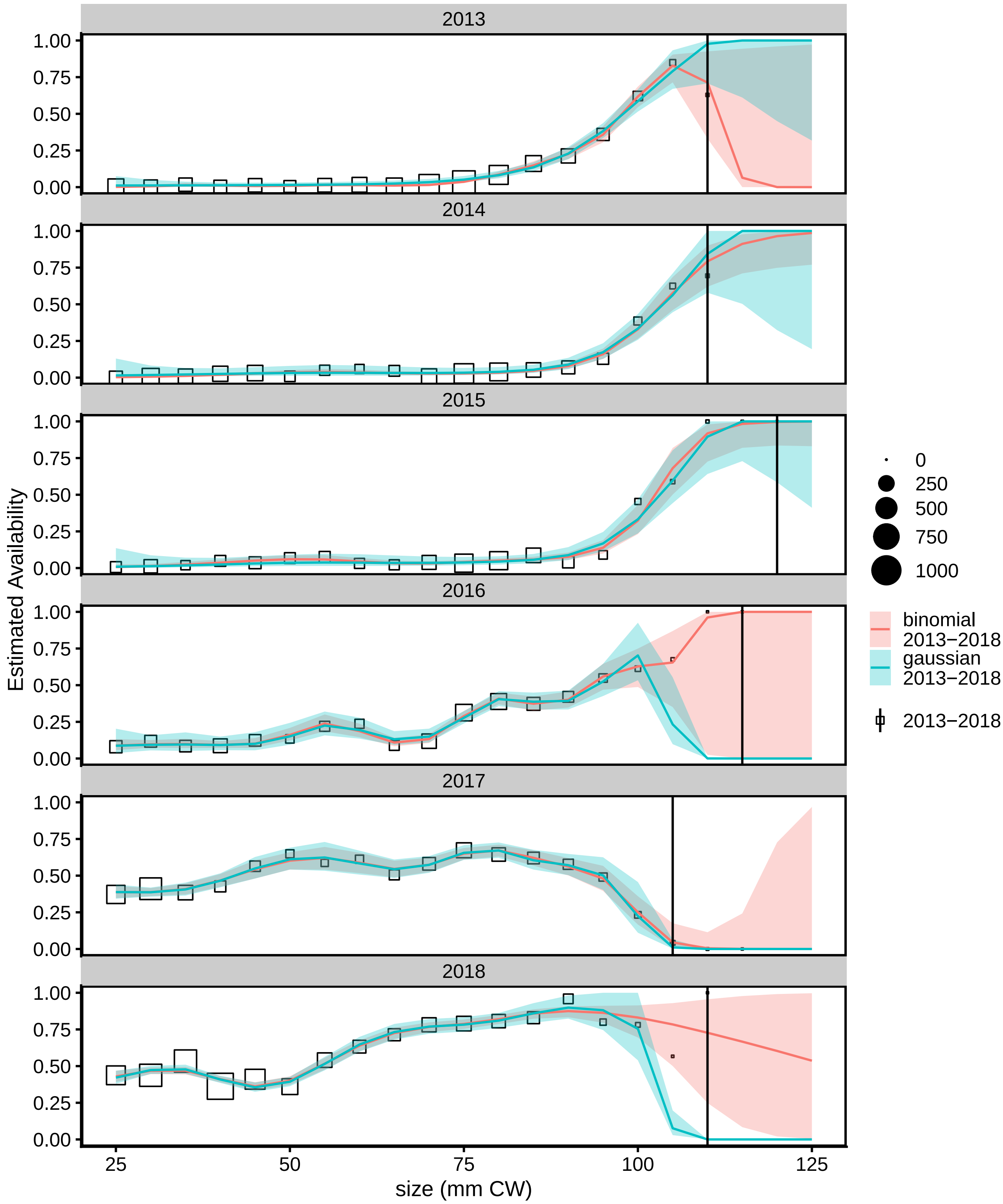

Figure 11. Comparison of smoothed model estimates for emprical availability for female Tanner crab from the 2013-2018 dataset using Eq. 2 (labeled “gaussian”) and Eq. 3 (labeled “bionomial”). Lines: model estimates. Envelopes: 95% confidence intervals. Shapes: “raw” estimates; size represents the number of females measured in the full survey. The vertical lines represent the largest size (by year) by the BSFRF gear. See text for more details.