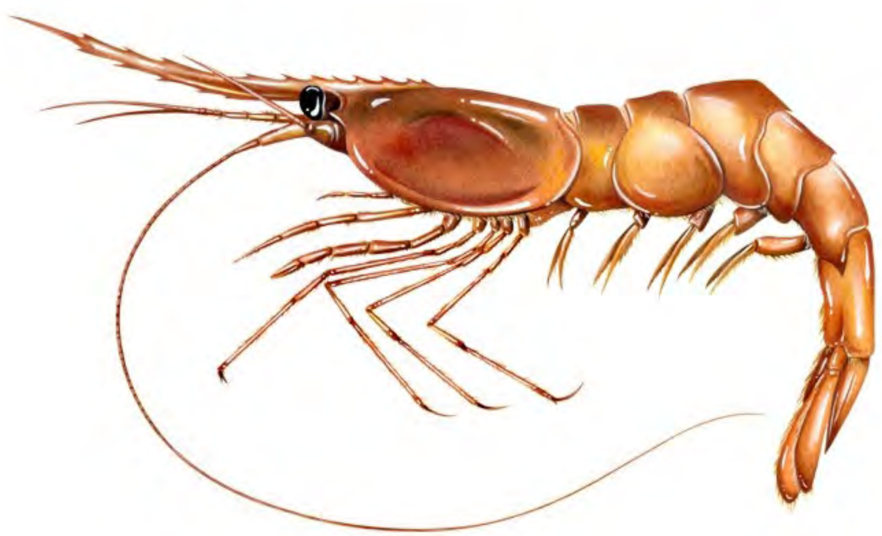
Atlantic States Marine Fisheries Commission

Northern Shrimp Stock Assessment Update 2024



Vision: Sustainably Managing Atlantic Coastal Fisheries

Atlantic States Marine Fisheries Commission

Northern Shrimp Stock Assessment Update

Prepared by the
ASMFC Northern Shrimp Technical Committee

Lulu Bates, Maine Department of Marine Resources
Matthew Lee, New Hampshire Fish and Game Department
Tracy Pugh, Massachusetts Division of Marine Fisheries
and
Katie Drew, Atlantic States Marine Fisheries Commission
Chesley Tuohy, Atlantic States Marine Fisheries Commission

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Executive Summary
The most recent benchmark assessment for Gulf of Maine northern shrimp (*Pandalus borealis)* was conducted in 2018 (ASMFC 2018a). An assessment update was completed later in 2018 (ASMFC 2018b) and 2021 (ASMFC 2021), with regular data updates since then. This stock assessment update presents new data compiled since 2021 and the results from the accepted statistical catch-at-length model and traffic light analyses. Data sources include indices of abundance and biomass from fishery-independent data sources and environmental data through 2023, with the exception of the fall survey data for 2023, which were not available at the time of this assessment. With the suspension of the summer survey after the 2023 sampling season, the only data source for 2024 was the ME-NH inshore trawl survey and the temperature time-series.

Stock status for northern shrimp continues to be poor, as illustrated by both the traffic light analyses and the catch-at-length model. The 2023 summer survey indices of abundance, biomass, and recruitment were at time-series lows, and spawning stock biomass was the lowest in the 1984-2023 time-series. Environmental conditions continue to be unfavorable for northern shrimp. The predation pressure index spiked again in 2021 compared to 2017-2019, and declined to just above the 80th percentile of the reference time period in 2023. Spring bottom temperatures and winter sea surface temperatures declined somewhat in 2023, but were still above the 80th percentile threshold.

A commercial fishing moratorium has been in place since 2014, and fishing mortality since then, attributed to several small industry sampling and research projects, has been extremely low. Spawning stock biomass in 2024 was estimated to be at 279 mt, the lowest in the time-series and well below the time-series median of 4,732 mt. Recruitment also remained low for 2022-2023, a continuation of the series of below-average year classes for the last ten years.

Model bias, illustrated by retrospective patterns, was small. After 2015, SSB was overestimated in some years and the exploitation rate was underestimated. Recruitment was consistently overestimated in the terminal year.

Long- and short-term stock projection results varied depending on assumptions about future natural mortality and recruitment levels, as well as fishing mortality. Under the recent unfavorable levels of natural mortality and recruitment, spawning stock biomass was projected to decline from 2023 levels and stabilize at an SSB level of 263 mt in the long-term. If both recruitment and natural mortality returned to their long-term values, the population would recover to 2,897 mt, still below the long-term median population size. Under the current conditions, research catches of 0.5-3.2 mt had a minimal effect on SSB, resulting in a median SSB that was less than 1% lower than SSB under the no fishing scenario, while catching 53 mt, the maximum research set aside from previous years, resulted in a median SSB that was 13% lower in 2025 than under the no fishing scenario.

Given the continued poor condition of the resource, the extremely low likelihood of being able to fish sustainably, and the value of maximizing spawning potential to rebuild the stock if environmental conditions improve, the Northern Shrimp Technical Committee (NSTC) does not

see any biological justification for harvest and recommends that the Section extend the moratorium on fishing. The NSTC based its recommendation on its assessment of current stock status, the biology of the species, and the stated management objectives to protect and maintain the northern shrimp stock at sustainable levels that will support a viable fishery and minimize the adverse impacts the shrimp fishery may have on other natural resources (Amendment 3 to the FMP, ASMFC 2017).

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TOR 1. Update fishery-dependent data (landings, discards, catch-at-age, etc.) that were used in the previous peer-reviewed and accepted benchmark stock assessment.
Historically, fisheries for northern shrimp occurred in Maine, New Hampshire and Massachusetts, with landings from Maine dominating the modern era (1960-present, Table 1 and Table 4, Figure 1). Fishery-dependent data were derived from a combination of dealer reports, harvester reports, port sampling, sea sampling, and licensing data. Landings were equated with removals because discarding is uncommon in this fishery.

A commercial fishery moratorium has been in place since 2014. Landings since then have been limited to industry research trips for sample collection. Removals since 2014 have included discards. No industry research trips were made in 2022-2024.

TOR 2. Update fishery-independent data (abundance indices, age-length data, etc.) that were used in the previous peer-reviewed and accepted benchmark stock assessment.
The time series for fishery-independent data were extended from the previous assessment update (ASMFC 2021) through 2023, with some exceptions noted below.

Fishery-independent data include abundance and biomass indices from the ASMFC summer shrimp offshore trawl survey (1984–2023), the Northeast Fisheries Science Center (NEFSC) fall bottom trawl survey (1986–2008 and 2009–2022), and the Maine-New Hampshire spring inshore trawl survey (2003–2024) (Table 2, Figure 2 and Figure 3). Length and sex-stage compositions were also developed from the summer and fall surveys. All surveys used a random stratified design. Model-based indices of abundance were developed using a spatio-temporal standardization approach and calculated using the VAST package in R. None of these surveys were conducted during 2020 due to COVID-19 restrictions, and shrimp data from the NEFSC fall 2023 and 2024 surveys had not been processed as of this report due to NEFSC staffing limitations.

A recruitment index was calculated from the summer survey standardized catch of assumed 1.5-year-old shrimp which are typically 11–18 mm dorsal carapace length (Figure 4). An index of spawning stock biomass (SSB) was estimated by applying a length-weight relationship for non-ovigerous shrimp to the abundance of females at each length, and summing over lengths. The observed proportion female-at-length from the summer survey is used to calculate SSB in the UME model.

The NEFSC fall survey vessel and gear were replaced in 2009, and this is considered the beginning of a new survey time series for shrimp; the NEFSC trawl survey is split into an Albatross index (1986-2008) and a Bigelow index (2009-2022).

In 2017 the ASMFC summer shrimp survey adopted new trawl gear, switching from Portuguese doors to lighter-weight Bison doors. Using data from alternating gear research tows, Miller and Chase (2021) found little evidence for unequal efficiencies of the two gears for shrimp. Therefore, no calibration of the summer survey data to account for the gear change was performed.

Other fishery-independent data include time series of February–March sea surface temperatures (SST) at Boothbay Harbor, Maine, spring bottom temperature anomalies from NEFSC spring bottom trawl survey strata in offshore shrimp habitat areas (also without 2020), and summer bottom temperature measured by the ASMFC summer shrimp survey.

An index of predation pressure (PPI) was developed from NEFSC survey data by weighting predator biomass indices by the long-term average percent frequency of shrimp in each predator's diet estimated from food habits sampling (Appendix 2). The average of the 2019 and 2021 PPIs was used for the missing 2020 value in the UME model.

TOR 3. Tabulate or list the life history information used in the assessment and/or model parameterization (M, age plus group, start year, maturity, sex ratio, etc.) and note any differences (e.g., new selectivity block, revised M value) from benchmark.

The University of Maine statistical catch-at-length model (UME model) used the same parameterization as the 2018 benchmark assessment (ASMFC 2018a), including time-varying M and maturity at length. Model structure is summarized in Table 3; see Appendix 2 for annual M-at-length and proportion female-at-length plots.

The 2018 benchmark assessment did not use the ME-NH spring inshore survey in the base run, but with the termination of the ASMFC summer survey after the 2023 sampling season, the NSTC chose to include the ME-NH spring inshore survey as part of the base run as it will need to be used going forward. The NSTC also chose to use 2023 as the terminal year of the assessment, as the only data available for 2024 was the ME-NH spring inshore survey. Sensitivity runs were conducted around model choice and terminal year.

TOR 4. Update accepted model(s) or trend analyses and estimate uncertainty. Include sensitivity runs and retrospective analysis if possible and compare with the benchmark assessment results.

For this assessment, the Northern Shrimp Technical Committee (NSTC) updated the Traffic Light Analysis (TLA) and the UME model for northern shrimp.

Traffic Light Approach

The TLA is an index-based approach to evaluate stock status and resource conditions and was applied to indices of abundance, fishery performance, and environmental trends from 1984 to present. Two qualitative stock status reference levels were developed for the traffic light approach. For the abundance and biomass indices, being below the 20th percentile of the time series from 1984-2017 indicated an adverse state, and being above the 80th percentile indicated a favorable state. For the environmental indicators, the opposite was true: being below the 20th percentile indicated a favorable state while being above the 80th percentile indicated an adverse state, as higher temperature and predation pressure have negative consequences for northern shrimp.

The traffic light analysis was updated with the 2022 and 2023 ASMFC summer survey data, the 2021 and 2022 NEFSC fall survey data, and the 2022-2024 ME-NH spring inshore data, as well as with 2022–2023 data for temperature indicators and the 2021-2023 data for the predation index.

The traffic light analysis of 2023 data indicated continued decline in stock status with all indices at new time-series lows (Table 5, Figure 5 - Figure 7). Environmental conditions continued to be unfavorable for northern shrimp. The predation pressure index spiked again in 2021 compared to 2017-2019, and declined to just above the 80th percentile of the reference time period in 2023. Spring bottom temperatures and winter sea surface temperatures declined somewhat in 2023, but were still above the 80th percentile threshold (Table 6, Figure 8).

UME Statistical Catch-at-Length Model

The UME model indicated total abundance and spawning stock biomass for northern shrimp continued to decline in 2022-2023 (Table 7 and Figure 9). Spawning stock biomass in 2024 was estimated to be at 279 mt, the lowest in the time-series and well below the time-series median of 4,732 mt and the 20th percentile of the reference period of 2,721 mt.

An average fishing mortality (*F*) for the time series (i.e., abundance-weighted average F on shrimp ≥22 mm carapace length) was calculated to account for differences in selectivity patterns across years and between fleets. Average fishing mortality has been extremely low since the implementation of the moratorium in 2014 (Table 7 and Figure 10). The average *F* peaked shortly before that in 2011 and 2012. Fishing mortality was extremely low in 2020 (*F*=0.002), the last year of the winter sampling program, and zero for 2022-2023.

Recruitment also remained low from 2022-2023 (Table 7, Figure 11), a continuation of the series of below average year classes in recent years. Ten of the last twelve years of recruitment have been less than the 20th percentile of the 1984-2017 estimates (equal to 1.9 billion shrimp). Recruitment in 2022 and 2023 were the lowest in the time-series, estimated to be 0.26 and 0.13 billion shrimp respectively. Variability in recruitment has increased since 2000, with higher highs and lower lows in recruitment deviations than 1984-1999 (Figure 11).

The retrospective pattern in the assessment was small, with SSB being slightly overestimated and exploitation rate being slightly underestimated in recent years; however, the pattern changed around 2015, with SSB being underestimated in some years and exploitation rate being overestimated in earlier years (Figure 12). The retrospective pattern in recruitment was more variable over the time series, but was consistently overestimated in the terminal year (Figure 12). Overall, the magnitude of the bias remained small.

Estimates of average *F* from the 2024 assessment were slightly lower than estimates from the 2021 assessment for the earliest part of the time series, and estimates of SSB from the 2024 assessment were slightly higher (Figure 13). This is due to a combination of the retrospective pattern that affected the estimates of *F* and SSB in earlier years, as well as the inclusion of the ME-NH inshore trawl survey (Figure 14).

The base run of the model included the ME-NH spring inshore survey and had a terminal year of 2023; sensitivity runs were conducted without the ME-NH survey and with a terminal year of 2024 for comparison. Model runs that included the ME-NH spring inshore survey, with a terminal year of either 2023 or 2024, resulted in slightly higher estimates of SSB and lower estimates of *F* over most of the time-series, but estimates from 2020 onward were very similar and showed the same declining trend in SSB (Figure 14). Estimates of recruitment were generally similar across all runs and showed the same strong and weak year-classes, but the model run with a terminal year of 2024 estimated a higher recruitment for 2024 when the ME-NH spring inshore survey was not included (Figure 14). This is because the model had no information on recruitment or abundance (i.e., no ASMFC summer survey or catch data) for 2024 if the ME-NH survey was not used, making the 2024 estimate of recruitment highly uncertain in that model run.

Long-term projections were carried out under different assumptions about M and recruitment. The population was projected forward for 50 years with no fishing mortality under different combinations of recent recruitment (the median of recruitment estimates from 2013-2023), long term median recruitment, recent natural mortality (the mean of natural mortality from 2019-2023), and long-term mean natural mortality (Figure 15). Under recent M and recent recruitment, the population continued to decline from 2023 levels and stabilized at an SSB level of 263 mt (Figure 16) in the long-term. If both recruitment and natural mortality returned to their long-term values, the population would increase to 2,897 mt, barely above the 20^{th} percentile of the stable period (1984-2017) (Figure 16), due to the long series of low recruitment events in recent years which has brought long-term median recruitment down compared to the median recruitment of the stable period.

TOR 5. Update the biological reference points or trend-based indicators/metrics for the stock. Determine stock status.

There are currently no biological reference points for northern shrimp. Based on the results of the 2024 Stock Assessment Update, the northern shrimp stock in the Gulf of Maine remains depleted, with spawning stock biomass (SSB) at extremely low levels since 2013. Spawning stock biomass in 2024 was estimated to be at 279 mt, the lowest in the time-series and well below the time-series median of 4,732 mt and the 20^{th} percentile of the reference period of 2,721 mt. In addition, recruitment continues to be low, with the 2022 and 2023 year-classes being the lowest in the time series (Table 7). Fishing mortality has been very low in recent years due to the moratorium, but high levels of natural mortality and low recruitment have hindered rebuilding.

Given the continued poor condition of the resource, the extremely low likelihood of being able to fish sustainably, and the value of maximizing spawning potential to rebuild the stock if environmental conditions improve, the NSTC does not see any biological justification for harvest and recommends that the Section extend the moratorium on fishing. The NSTC bases its recommendation on its assessment of current stock status, the biology of the species, and the stated management objectives to protect and maintain the northern shrimp stock at sustainable levels that will support a viable fishery, and minimize the adverse impacts the shrimp fishery may have on other natural resources (Amendment 3 to the FMP, ASMFC 2017).

TOR 6. Conduct short term projections when appropriate. Discuss assumptions if different from the benchmark and describe alternate runs.

Short-term projections were conducted using the same set of assumptions about M and recruitment that were used in the long-term projections (see TOR 4 above, and Figure 15), and six levels of *F*: *F*=0, *F*=the mean of the research period (2014-2020), *F*=the maximum of the research period, and values of *F* that produced catches similar to previous research catches.

Under recent levels of M and recruitment, median SSB was projected to decline 54% from 2023, even under the *F*=0 scenario (Table 8). Research catches of 0.5-3.2 mt had a minimal effect on SSB, resulting in a median SSB that was less than 1% lower than SSB under the no fishing scenario, while catching 53 mt, the maximum research set aside from previous years, resulted in a median SSB that was 13% lower in 2025 than under the no fishing scenario (Table 8).

TOR 7. Comment on research recommendations from the benchmark stock assessment and note which have been addressed or initiated. Indicate which improvements should be made before the stock undergoes a benchmark assessment.

A number of research recommendations were identified from the benchmark stock assessment in 2018. Some of the highest priority focused on efforts to improve the sampling, modeling, and biological understanding of the northern shrimp species. Due to the continued moratorium of the fishery and the COVID-19 pandemic, many of these recommendations, particularly the fishery-dependent priorities, were not addressed.

Fishery-dependent priorities included an evaluation of shrimp selectivity from the two gear types (traps and trawls), continued port, sea, and RSA sampling to confirm and potentially update length-frequency of the species, and identify by-catch in the fishery. In order to continue sample collection during the fishing moratorium, winter sampling efforts were conducted through an RSA program, however this ended in 2018. Should a fishery reopen, these recommendations could be considered.

Progress on fishery independent and life-history priorities were summarized in ASMFC (2021).

The TC supports the modeling research recommendations from the benchmark assessment, and has adopted the recommendation to include model diagnostics for the index standardization as an appendix to this report. No progress has been made on other model recommendations to date.

References

Atlantic States Marine Fisheries Commission. 2017. Amendment 3 to the interstate fishery management plan for northern shrimp. 102pp. https://www.asmfc.org/uploads/file/59f0f084NShrimpAmendment3_Oct2017.pdf

Atlantic States Marine Fisheries Commission. 2018a. Northern Shrimp Benchmark Stock Assessment and Peer Review Report. 356pp. https://www.asmfc.org/uploads/file/5bc798aaNShrimpBenchmarkAssessment_PeerReviewReport_2018_web.pdf

Atlantic States Marine Fisheries Commission. 2018b. Assessment report for Gulf of Maine northern shrimp – 2018. 78 pp. https://www.asmfc.org/uploads/file/5c000eb2NShrimpAssessmentUpdateReport_2018.pdf

Atlantic States Marine Fisheries Commission. 2021. Northern Shrimp Stock Assessment Update 2021. 38 pp. https://asmfc.org/uploads/file/63ee4ae1NShrimpAssessmentUpdateReport_2021.pdf

Miller, T.J. and Chase, P. 2021. An evaluation of efficiency differences between alternative trawl door configurations of the Gulf of Maine shrimp survey gear. Appendix 2 to ASMFC Northern Shrimp Stock Assessment Update 2021.

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Tables

Table 1. Total removals in metric tons by season, state, and gear type. Seasons include the previous December. The Maine fishery was "Mixed" until Trawl and Trap landings could be distinguished beginning in 2000. Removals in 2014–2020 are from RSA and winter sampling programs, and include discards. 2009 data for Massachusetts and New Hampshire are combined here to preserve reporting confidentiality.

Season		Maine		Massachusetts	New Hampshire	Total	Total	Total	Total
	Trawl	Mixed	Trap	Trawl	Trawl	Trawl	Mixed	Trap	
1985		2,946.4		968.8	216.7	1,185.5	2,946.4	0.0	**4,131.9**
1986		3,268.2		1,136.3	230.5	1,366.8	3,268.2	0.0	**4,635.0**
1987		3,680.2		1,427.9	157.9	1,585.8	3,680.2	0.0	**5,266.0**
1988		2,258.4		619.6	157.6	777.2	2,258.4	0.0	**3,035.6**
1989		2,384.0		699.9	231.5	931.4	2,384.0	0.0	**3,315.4**
1990		3,236.3		974.9	451.3	1,426.2	3,236.3	0.0	**4,662.5**
1991		2,488.6		814.6	282.1	1,096.7	2,488.6	0.0	**3,585.3**
1992		3,070.6		289.3	100.1	389.4	3,070.6	0.0	**3,460.0**
1993		1,492.5		292.8	357.6	650.4	1,492.5	0.0	**2,142.9**
1994		2,239.7		247.5	428.0	675.5	2,239.7	0.0	**2,915.2**
1995		5,013.7		670.1	772.8	1,442.9	5,013.7	0.0	**6,456.6**
1996		8,107.1		660.6	771.7	1,432.3	8,107.1	0.0	**9,539.4**
1997		6,086.9		366.4	666.2	1,032.6	6,086.9	0.0	**7,119.5**
1998		3,481.3		240.3	445.2	685.5	3,481.3	0.0	**4,166.8**
1999		1,573.2		75.7	217.0	292.7	1,573.2	0.0	**1,865.9**
2000	2,249.5		266.7	124.1	214.7	2,588.3	0.0	266.7	**2,855.0**
2001	954.0		121.2	49.4	206.4	1,209.8	0.0	121.2	**1,331.0**
2002	340.8		50.8	8.1	53.0	401.8	0.0	50.8	**452.7**
2003	987.0		216.7	27.7	113.0	1,127.7	0.0	216.7	**1,344.4**
2004	1,858.7		68.1	21.3	183.2	2,063.2	0.0	68.1	**2,131.4**
2005	1,887.1		383.1	49.6	290.3	2,227.1	0.0	383.1	**2,610.1**
2006	1,928.0		273.6	30.0	91.1	2,049.1	0.0	273.6	**2,322.7**
2007	3,986.9		482.4	27.5	382.9	4,397.3	0.0	482.4	**4,879.7**
2008	3,725.0		790.7	29.9	416.8	4,171.7	0.0	790.7	**4,962.4**
2009	1,936.3		379.4	MA & NH:	185.6	2,121.8	0.0	379.4	**2,501.2**
2010	4,517.9		1,203.5	35.1	506.8	5,059.9	0.0	1,203.5	**6,263.3**
2011	4,644.4		925.3	196.4	631.5	5,472.2	0.0	925.3	**6,397.5**
2012	2,026.8		193.1	77.8	187.8	2,292.4	0.0	193.1	**2,485.4**
2013	269.5		20.2	18.9	36.9	325.3	0.0	20.2	**345.5**
2014	0.3		0.0	0.0	0.0	0.3	0.0	0.0	**0.3**
2015	5.6		0.5	0.6	0.0	6.2	0.0	0.5	**6.7**
2016	7.4		4.1	0.0	1.8	9.2	0.0	4.1	**13.3**
2017	24.1		7.1	0.9	0.5	25.5	0.0	7.1	**32.6**
2018	0.1		0.0	1.9	1.1	3.1	0.0	0.0	**3.1**
2019	0.0		0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
2020	0.0		3.1	0.0	0.0	0.0	0.0	3.1	**3.1**
2021	0.0		0.0	0.0	0.0	0.0	0.0	0.0	**0.0**

Table 2. Summary of indices used in the northern shrimp assessment update.

	ASMFC Summer Survey	NEFSC Fall Survey (Albatross)	NEFSC Fall Survey (Bigelow)	ME-NH Inshore Trawl Survey
Index Metric	Number per tow	Number per tow	Number per tow	Number per tow
Design	Stratified Random	Stratified Random	Stratified Random	Stratified Random
Standardization	VAST	VAST	VAST	VAST
Time of Year	Jul-Aug	Sep-Nov	Sep-Nov	Apr-Jun
Years	1984-2023	1986-2008	2009-2022	2003-2024
Size caught	10+mm	10+mm	10+mm	10+mm
Missing data	2020	--	2020	2020
Included in	UME, TLA	UME, TLA	UME, TLA	TLA

Table 3. Model structure and life history information used in the UME model.

Years in Model	1984-2023
Time step	Seasonal (Jan-Jun, Aug-Dec)
Size Classes	10-34mm (carapace length)
Fleets	3 (Mixed trap & trawl, trawl only, trap only)
Selectivity blocks	Mixed fleet: 1984-1999 Trawl fleet: 2000-2013, 2014-2023 Trap fleet: 2000-2013, 2014-2023
Natural mortality	Time- and length-varying
Proportion mature at length	Time-varying

Table 4. Fishery performance indicators for GOM northern shrimp traffic light analysis. Colors indicate status relative to reference levels, where: RED = at or below the 20th percentile; YELLOW = between the 20th and the 80th percentiles; and GREEN = at or above the 80th percentile of the commercial fishery time series from 1984-2013. Values from 2014-2021 represent RSA/winter sampling. Dashes (-) indicate no data.

Fishing Season	Number of trips	Commercial CPUE (mt/trip)	Price per lb landed (2018 dollars)	Total landings value (2018 dollars)
1984	6,912	0.43	-	-
1985	6,857	0.60	$1.05	$9,564,744
1986	7,902	0.59	$1.45	$14,816,717
1987	12,497	0.42	$2.50	$29,023,857
1988	9,240	0.33	$2.40	$16,061,646
1989	9,561	0.35	$2.04	$14,910,780
1990	9,758	0.48	$1.43	$14,699,046
1991	7,968	0.45	$1.71	$13,516,239
1992	7,798	0.44	$1.81	$13,806,670
1993	6,158	0.35	$1.89	$8,928,900
1994	5,990	0.49	$1.30	$8,354,991
1995	10,465	0.62	$1.51	$21,493,893
1996	11,791	0.81	$1.19	$25,026,625
1997	10,734	0.66	$1.25	$19,619,763
1998	6,606	0.63	$1.50	$13,779,332
1999	3,811	0.49	$1.40	$5,759,047
2000	4,554	0.63	$1.18	$7,427,163
2001	4,133	0.32	$1.24	$3,638,596
2002	1,304	0.35	$1.54	$1,536,852
2003	3,022	0.44	$1.21	$3,586,328
2004	2,681	0.79	$0.60	$2,819,337
2005	3,866	0.68	$0.75	$4,315,765
2006	2,478	0.94	$0.47	$2,406,687
2007	4,163	1.17	$0.47	$5,056,211
2008	5,587	0.89	$0.59	$6,454,695
2009	3,002	0.83	$0.48	$2,646,864
2010	5,979	1.03	$0.61	$8,423,072
2011	7,095	0.90	$0.86	$12,129,566
2012	3,648	0.68	$1.06	$5,808,201
2013	1,322	0.23	$1.98	$1,508,183
2014	5	-	No landings	No landings
2015	50	-	$3.77	$55,446
2016	68	-	$7.11	$208,767
2017	153	-	$6.55	$470,579
2018	18	-	Confidential	Confidential
2019	0	-	-	-
2020	160	-	No landings	No landings
2021	0	-	-	-
1984-2013 mean	**6,229**	**0.60**	**$1.29**	**$10,245,509**
2014-2021 mean	**76**	**NA**	**$5.81**	**$244,931**
80th percentile (1984-2013)	**9,304**	**0.81**	**$1.75**	**$14,854,342**
20th percentile (1984-2013)	**3,523**	**0.41**	**$0.69**	**$3,617,689**

Table 5. Fishery independent indicators (model-based survey indices) for GOM northern shrimp traffic light analysis. Colors indicate status relative to reference levels, where: RED = at or below the 20th percentile; YELLOW = between the 20th and 80th percentiles; and GREEN = at or above the 80th percentile of the time series from 1984-2017. Dashes (-) indicate no data.

Survey	ASMFC Summer	NEFSC Fall Albatross	NEFSC Fall Bigelow	ME-NH Spring	ASMFC Summer			
Indicator	**Total Abundance**	**Total Abundance**	**Total Abundance**	**Total Abundance**	**Total Biomass**	**Harvestable Biomass**	**Spawner Biomass**	**Recruitment (age ~1.5)**
1984	1.286				1.43	0.73	0.72	0.143
1985	1.398				1.63	1.40	0.71	0.240
1986	1.247	0.68			1.64	1.28	0.96	0.238
1987	0.882	0.40			1.09	0.87	0.58	0.199
1988	1.584	0.34			1.41	0.83	0.62	1.018
1989	1.423	0.78			1.61	0.93	0.73	0.270
1990	1.237	0.59			1.67	1.44	0.81	0.104
1991	0.826	0.32			0.98	0.80	0.68	0.338
1992	0.536	0.19			0.63	0.46	0.40	0.149
1993	1.267	1.04			0.92	0.50	0.39	0.827
1994	1.117	1.09			0.97	0.48	0.40	0.375
1995	1.141	0.59			1.19	0.83	0.77	0.254
1996	1.007	0.40			1.12	0.82	0.66	0.316
1997	1.075	0.53			0.97	0.63	0.55	0.544
1998	0.752	0.97			0.73	0.39	0.38	0.206
1999	0.671	1.21			0.73	0.51	0.43	0.197
2000	0.891	0.96			0.82	0.56	0.52	0.491
2001	0.309	0.50			0.35	0.19	0.21	0.037
2002	1.220	0.69			0.87	0.39	0.41	0.937
2003	0.861	0.40		0.55	0.91	0.47	0.54	0.130
2004	1.119	0.88		0.62	1.09	0.90	0.60	0.382
2005	2.702	2.85		1.88	2.10	1.11	1.02	1.315
2006	4.872	3.69		2.21	4.20	1.98	2.02	1.054
2007	1.867	2.41		1.93	1.91	1.25	1.09	0.235
2008	1.794	1.51		2.21	1.82	1.48	0.86	0.529
2009	1.907		4.62	2.40	2.01	1.47	1.16	0.699
2010	1.689		3.20	3.48	1.63	0.94	0.78	0.643
2011	1.010		2.45	3.30	1.08	0.64	0.65	0.281
2012	0.323		0.88	0.92	0.39	0.30	0.27	0.035
2013	0.089		0.25	0.14	0.14	0.13	0.11	0.005
2014	0.282		0.52	0.37	0.21	0.07	0.09	0.202
2015	0.080		0.21	0.15	0.11	0.09	0.09	0.005
2016	0.314		0.16	0.34	0.32	0.19	0.19	0.175
2017	0.054		0.17	0.18	0.07	0.05	0.05	0.001
2018	0.078		0.31	0.10	0.09	0.06	0.05	0.045
2019	0.054		0.19	0.08	0.08	0.06	0.06	0.002
2020								
2021	0.034		0.03	0.124	0.053	0.045	0.045	0.00151
2022	0.005		0.01	0.019	0.008	0.008	0.007	0.00005
2023	0.001			0.007	0.002	0.002	0.002	0.00000
2024				0.001				
1984-2013 mean	**1.27**	**1.00**	**2.28**	**1.78**	**1.27**	**0.82**	**0.67**	**0.41**
2014-2023 mean	**0.10**	**NA**	**0.20**	**0.15**	**0.10**	**0.06**	**0.06**	**0.05**
80th percentile	**1.49**	**1.16**	**2.75**	**2.25**	**1.64**	**1.16**	**0.79**	**0.58**
20th percentile	**0.45**	**0.40**	**0.20**	**0.31**	**0.54**	**0.35**	**0.34**	**0.14**

Table 6. Environmental condition indicators for GOM northern shrimp traffic light analysis. Colors indicate status relative to reference levels, where: RED = at or above the 80th percentile; YELLOW = between the 80th and 20th percentiles; and GREEN = at or below the 20th percentile of the time series from 1984-2017. Dashes (-) indicate no data.

Survey	NEFSC	ASMFC	NEFSC	Boothbay Harbor, ME
Indicator	Predation Pressure Index	Summer Bottom Temperature	Spring Bottom Temperature	Feb-Mar Surface Temperature
1984	433.9	4.1	5.7	2.9
1985	597.5	4.0	5.2	2.8
1986	611.9	6.3	6.1	2.6
1987	390.5	6.0	5.1	1.8
1988	505.8	6.5	5.7	2.7
1989	521.1	5.6	4.9	1.9
1990	632.3	3.6	4.1	2.6
1991	509.2	6.1	5.6	3.4
1992	489.6	6.3	5.7	3.2
1993	473.9	5.8	4.4	1.2
1994	353.2	6.8	5.4	1.8
1995	637.7	6.6	5.9	3.3
1996	560.1	7.1	6.2	3.3
1997	382.0	6.8	6.1	3.7
1998	470.8	6.3	6.1	2.9
1999	745.9	6.1	5.7	2.9
2000	823.5	6.7	6.2	3.1
2001	730.5	6.5	5.8	2.9
2002	1,305.5	7.1	6.4	4.1
2003	1,054.5	5.6	4.9	2.4
2004	493.6	4.7	4.3	3.0
2005	472.4	4.9	5.1	3.0
2006	670.4	7.1	6.4	5.5
2007	712.7	5.9	5.4	2.0
2008	860.7	5.9	6.0	2.3
2009	737.7	6.0	5.5	2.6
2010	1,124.4	7.4	6.0	4.1
2011	1,117.6	7.7	7.4	2.9
2012	1,155.3	7.9	7.2	5.5
2013	742.6	7.1	6.4	3.9
2014	955.1	6.2	5.8	2.2
2015	829.4	5.8	5.2	1.4
2016	1,525.8	7.2	6.6	4.2
2017	951.7	6.9	6.1	3.8
2018	924.9	6.7	6.1	4.5
2019	674.2	7.1	6.6	3.5
2020	-	-	-	4.6
2021	1286.2	7.6	7.2	4.0
2022	1354.3	7.6	7.1	3.7
2023	956.1	7.6	-	4.6
2024	-	-	-	4.4
1984-2013 mean	**677.2**	**6.1**	**5.7**	**3.0**
2014-2023 mean	**1,062.7**	**6.9**	**6.3**	**3.6**
20th percentile (1984-2017)	**483.3**	**5.7**	**5.2**	**2.3**
80th percentile (1984-2017)	**953.0**	**7.1**	**6.2**	**3.8**

Table 7. Summary of results from the UME model.

Year	Average F	Recruitment (billions of shrimp)	Total Abundance (billions of shrimp)	Spawning Stock Biomass (mt)	Total Biomass (mt)
1984	0.208	2.03	7.67	7,065.7	24,978.2
1985	0.171	3.41	7.63	6,049.6	28,225.2
1986	0.234	2.64	5.98	7,036.3	24,255.1
1987	0.413	2.57	5.09	6,838.1	19,280.7
1988	0.209	7.04	9.73	5,970.0	21,619.4
1989	0.250	2.01	6.46	7,237.3	23,177.5
1990	0.292	1.81	4.97	4,541.7	21,568.8
1991	0.340	3.12	5.16	4,860.3	16,840.3
1992	0.365	2.12	4.44	5,805.1	14,964.4
1993	0.216	7.57	9.69	4,807.2	18,365.0
1994	0.223	3.10	7.67	6,069.8	22,774.4
1995	0.284	2.83	7.44	8,894.9	28,362.1
1996	0.497	2.02	5.05	6,972.3	21,673.5
1997	0.737	3.51	5.59	5,545.7	16,482.2
1998	0.533	2.25	5.06	4,751.7	15,486.8
1999	0.241	2.21	4.63	4,318.6	15,178.5
2000	0.654	9.13	10.75	4,082.2	17,183.2
2001	0.549	1.58	4.40	2,772.3	12,705.8
2002	0.071	42.78	44.37	4,527.5	42,035.0
2003	0.359	1.61	6.83	2,731.7	19,986.3
2004	0.225	3.98	5.76	1,727.6	13,951.2
2005	0.268	15.92	18.60	5,241.1	25,916.3
2006	0.174	17.76	26.44	6,777.7	47,167.8
2007	0.248	3.96	13.68	11,118.6	47,996.3
2008	0.178	9.93	15.27	6,360.7	42,423.5
2009	0.123	12.20	16.60	9,238.6	35,490.9
2010	0.451	21.77	27.25	7,687.6	44,686.4
2011	1.033	4.26	9.01	4,712.9	24,783.1
2012	0.555	1.00	2.80	2,706.0	10,868.0
2013	0.113	1.01	1.58	1,613.5	4,703.4
2014	0.000	4.32	4.87	1,964.2	6,669.2
2015	0.003	0.85	1.93	1,378.7	5,287.8
2016	0.004	4.82	5.46	1,797.7	7,589.9
2017	0.020	0.45	0.97	973.5	2,842.5
2018	0.002	0.94	1.21	790.4	2,486.9
2019	0.000	0.33	0.64	821.3	1,915.2
2020	0.002	1.45	1.71	736.1	2,724.3
2021	0.000	0.59	0.96	681.4	2,228.4
2022	0.000	0.26	0.42	483.4	1,177.1
2023	0.000	0.13	0.20	279.1	576.4

Table 8. Projected catch and SSB in 2025 from the UME model under different *F* scenarios using recent M and recent recruitment.

Year	F Rate	Catch	Probability that SSB_{2025} > SSB_{2023}	SSB (mt)	Change in SSB from 2023	Change in SSB_{2025} Compared to F=0
2025	F = 0	0 mt (0 lbs)	0%	127.4	-54%	--
2025	F = 0.01	0.5 mt (1,120 lbs)	0%	127.2	-54%	-0.2%
2025	F = 0.03	3.2 mt (7,092 lbs)	0%	126.5	-55%	-0.7%
2025	F = 0.07	6.7 mt (14,755 lbs)	0%	125.4	-55%	-1.6%
2025	F = 0.14	13.8 mt (30,408 lbs)	0%	123.4	-56%	-3.1%
2025	F = 0.36	32.5 mt (71,699 lbs)	0%	117.6	-58%	-7.6%
2025	F = 0.63	53 mt (116,881 lbs)	0%	110.6	-60%	-13.1%

Figures

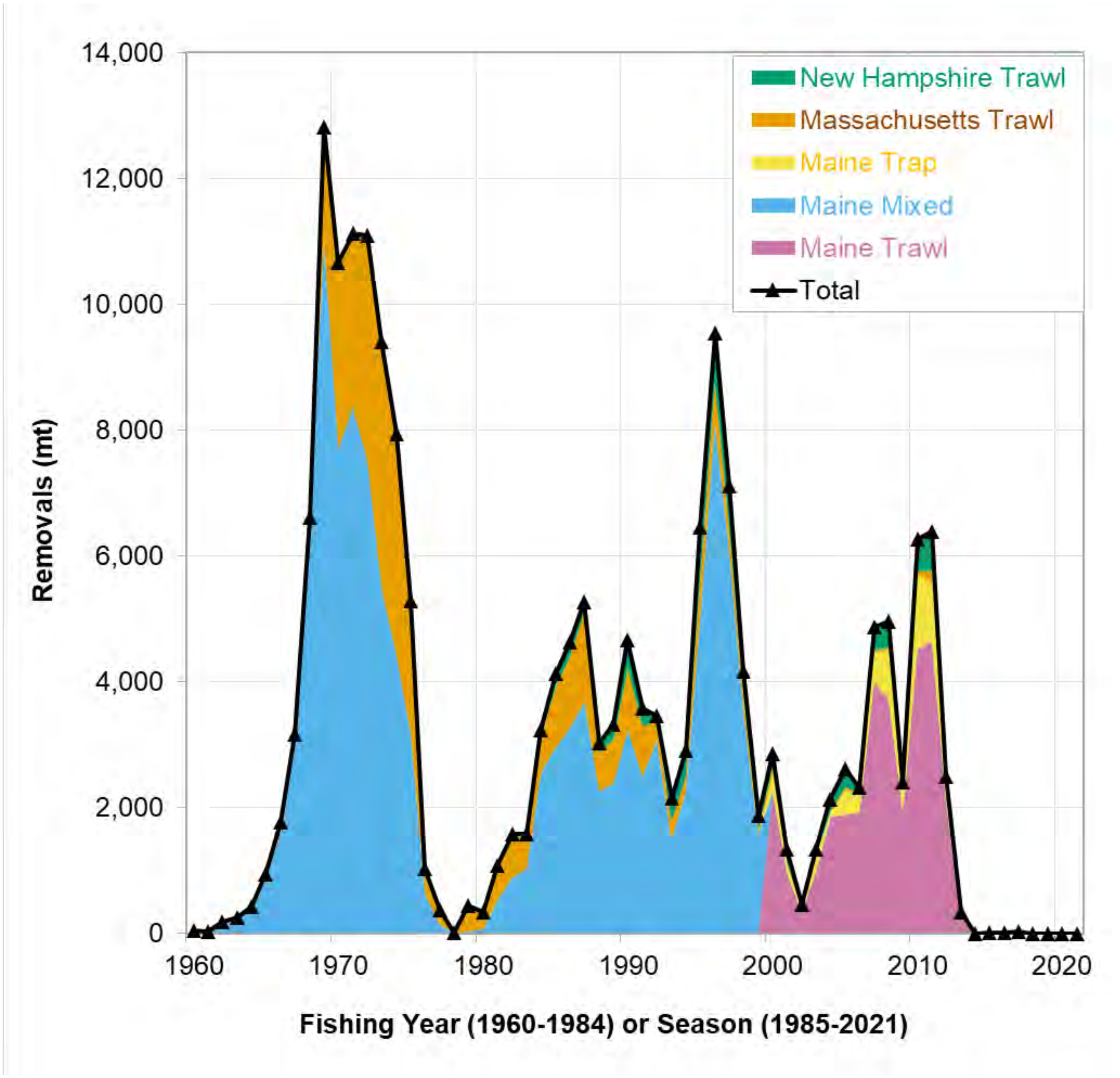


Figure 1. Northern shrimp landings from the Gulf of Maine by state and gear.

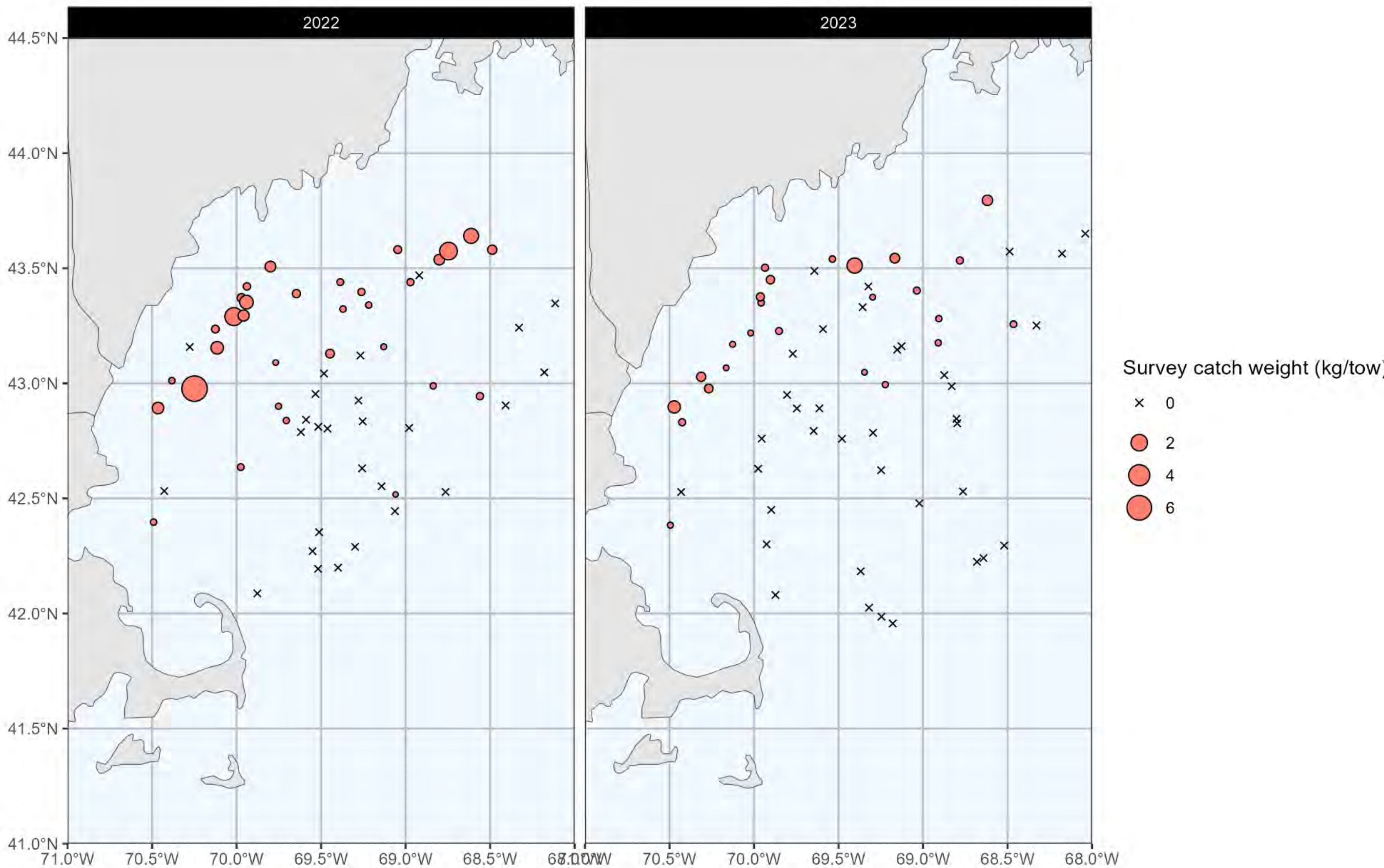


Figure 2. 2022-2023 ASMFC summer survey catches (kg per tow) by tow location.

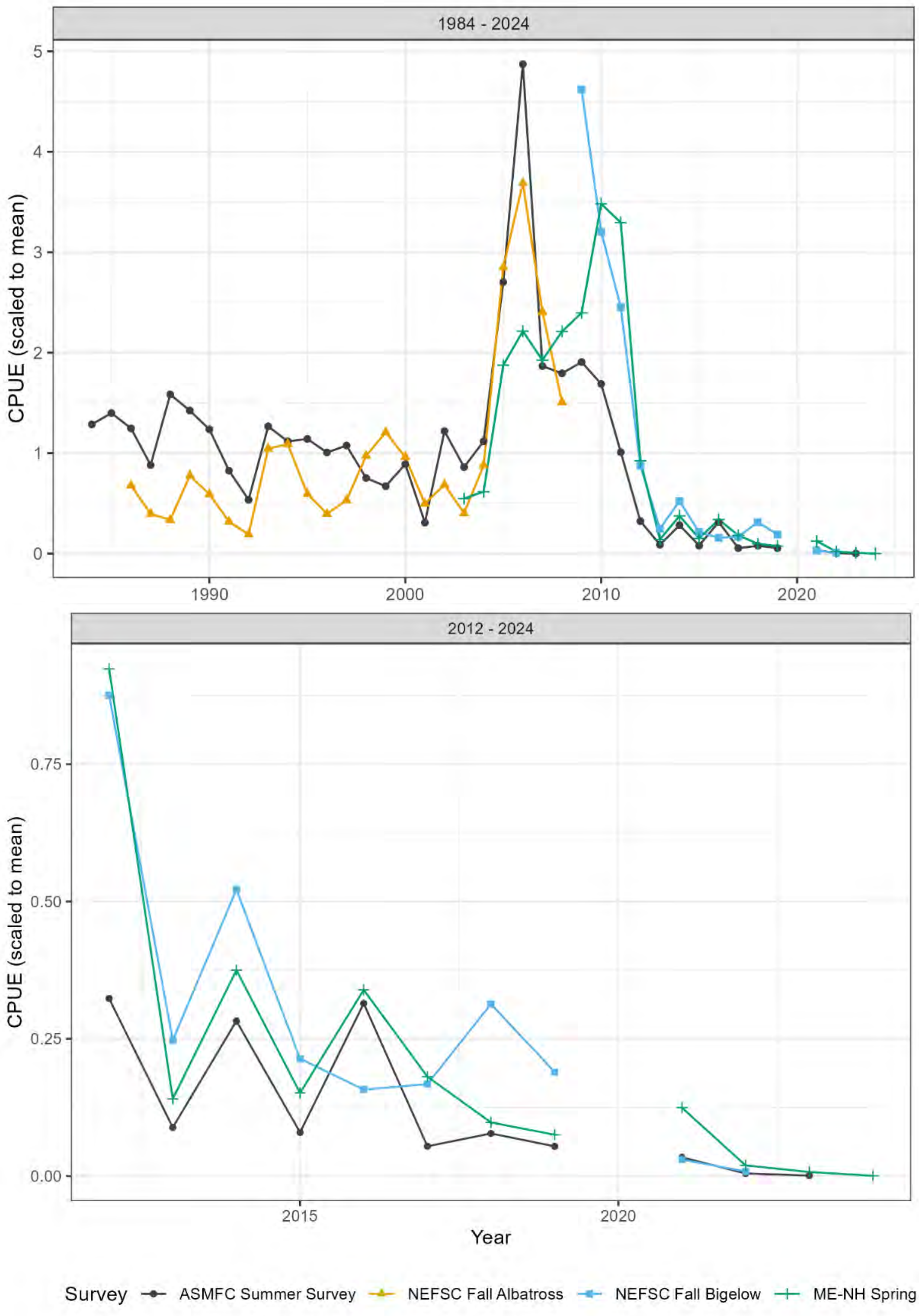


Figure 3. Standardized indices of abundance for Gulf of Maine northern shrimp for 1984-2024 (top) and truncated to 2012-2024 to show detail in recent years (bottom).

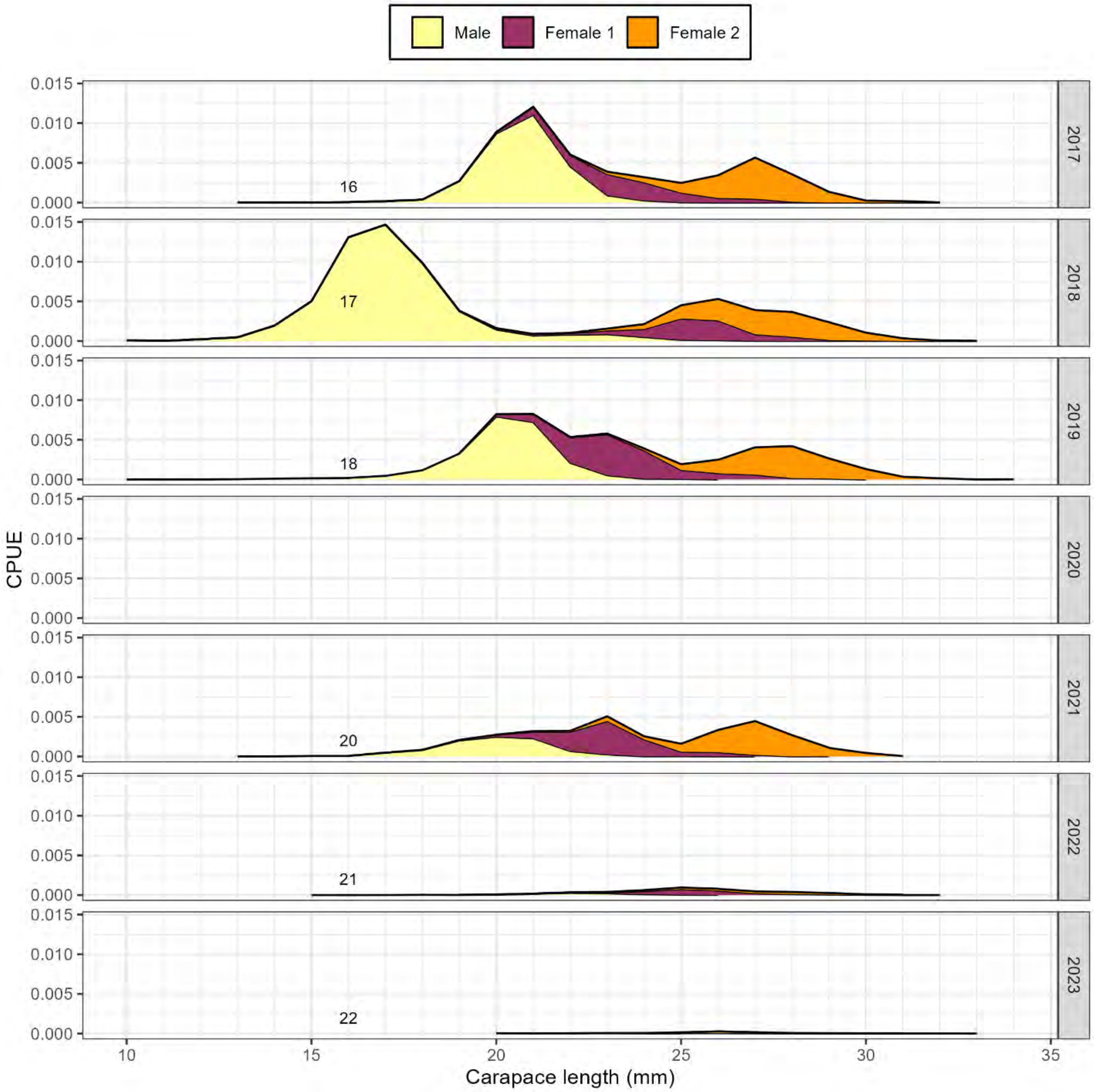


Figure 4. **Gulf of Maine northern shrimp Summer Survey abundance by year, length, and development stage for 2017 – 2023. Two-digit numbers indicate the year class of the recruits. See Appendix 2 for the version of this plot with all years of data.**

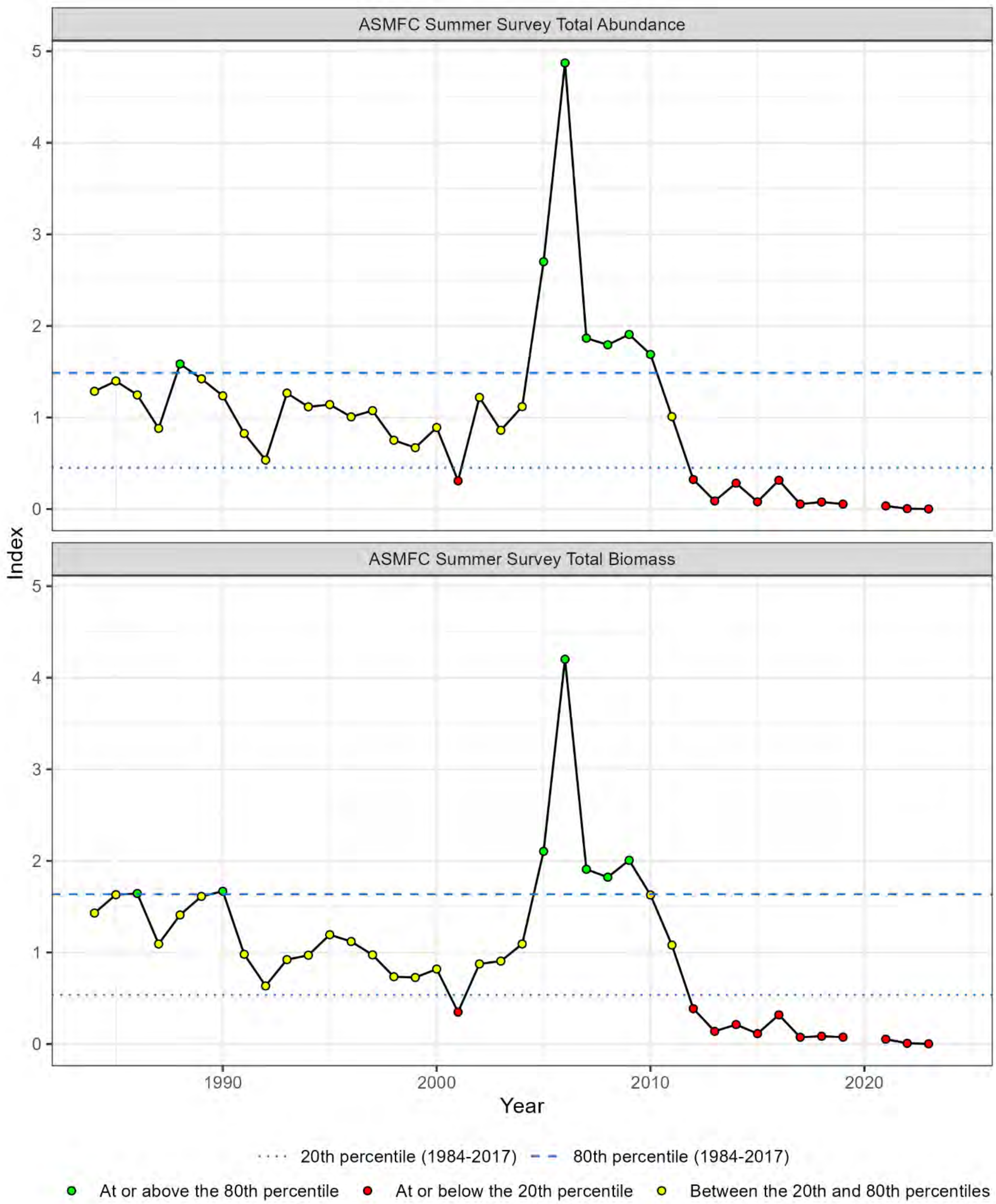


Figure 5. Traffic light analysis for the model-based index of abundance (top) and biomass (bottom) of Gulf of Maine northern shrimp from the Summer Shrimp Survey, 1984-2023. The 20th percentile of the time series from 1984-2017 delineated an adverse state, and the 80th percentile of the time series from 1984-2017 delineated a favorable state.

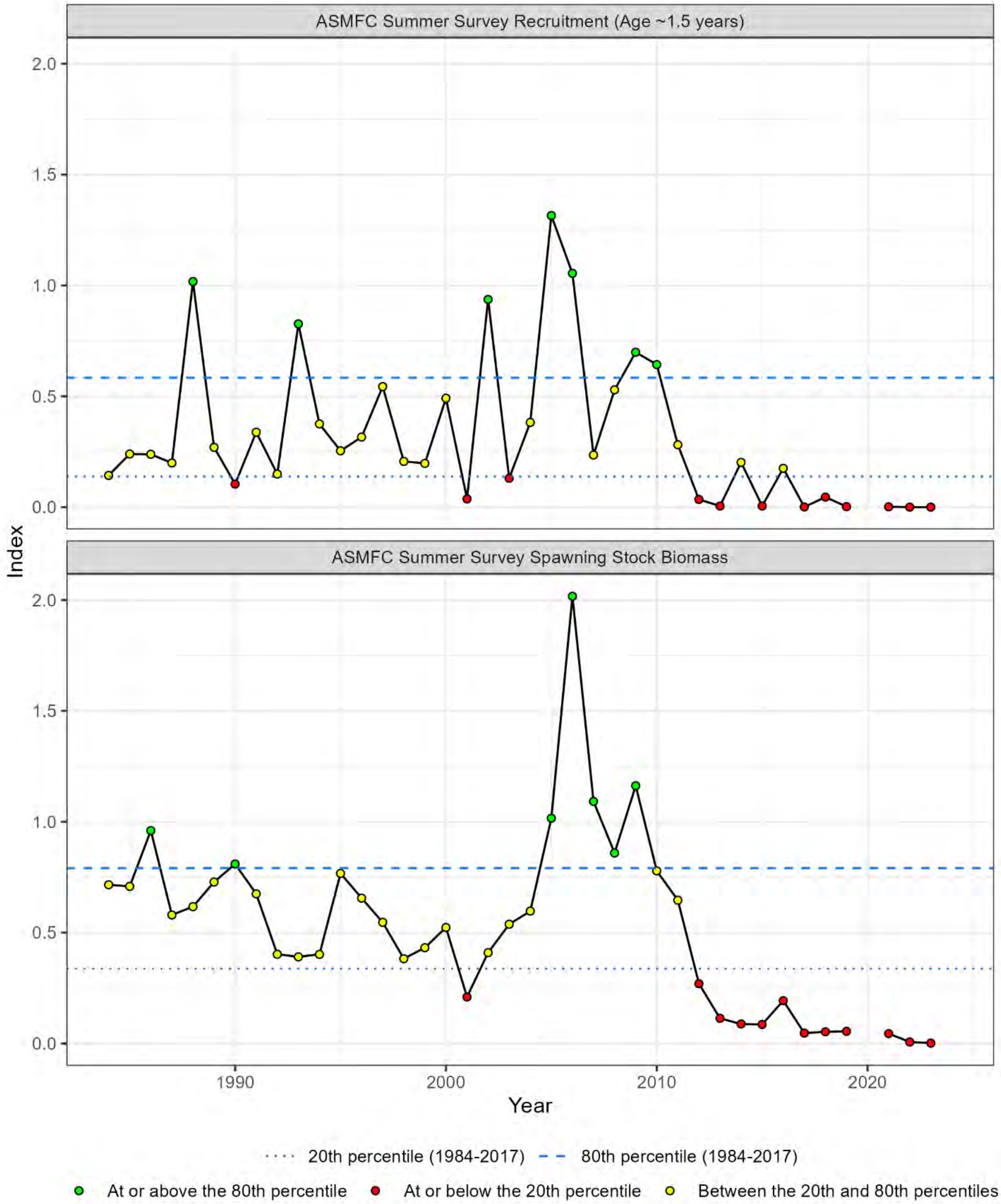


Figure 6. Traffic light analysis of recruitment (top) and spawning biomass (bottom) of Gulf of Maine northern shrimp from the Summer Shrimp survey, 1984-2023. The 20th percentile of the time series from 1984-2017 delineated an adverse state, and the 80th percentile of the time series from 1984-2017 delineated a favorable state.

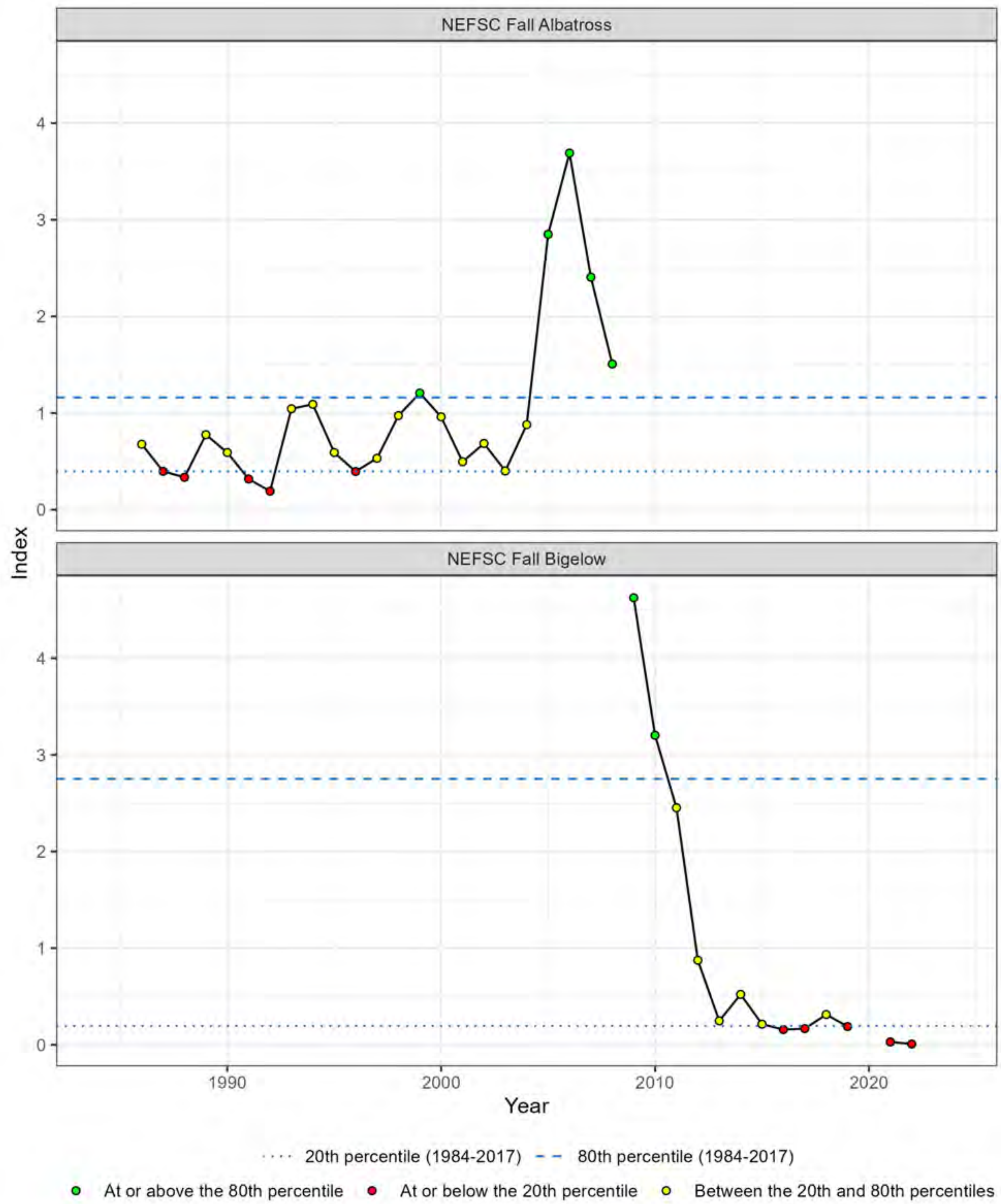


Figure 7. Traffic light analysis for the model-based index of abundance of Gulf of Maine northern shrimp from the NEFSC Fall Survey, 1984-2022 (Albatross years top, Bigelow years bottom). The 20th percentile of the time series through 2017 delineated an adverse state, and the 80th percentile of the time series through 2017 delineated a favorable state.

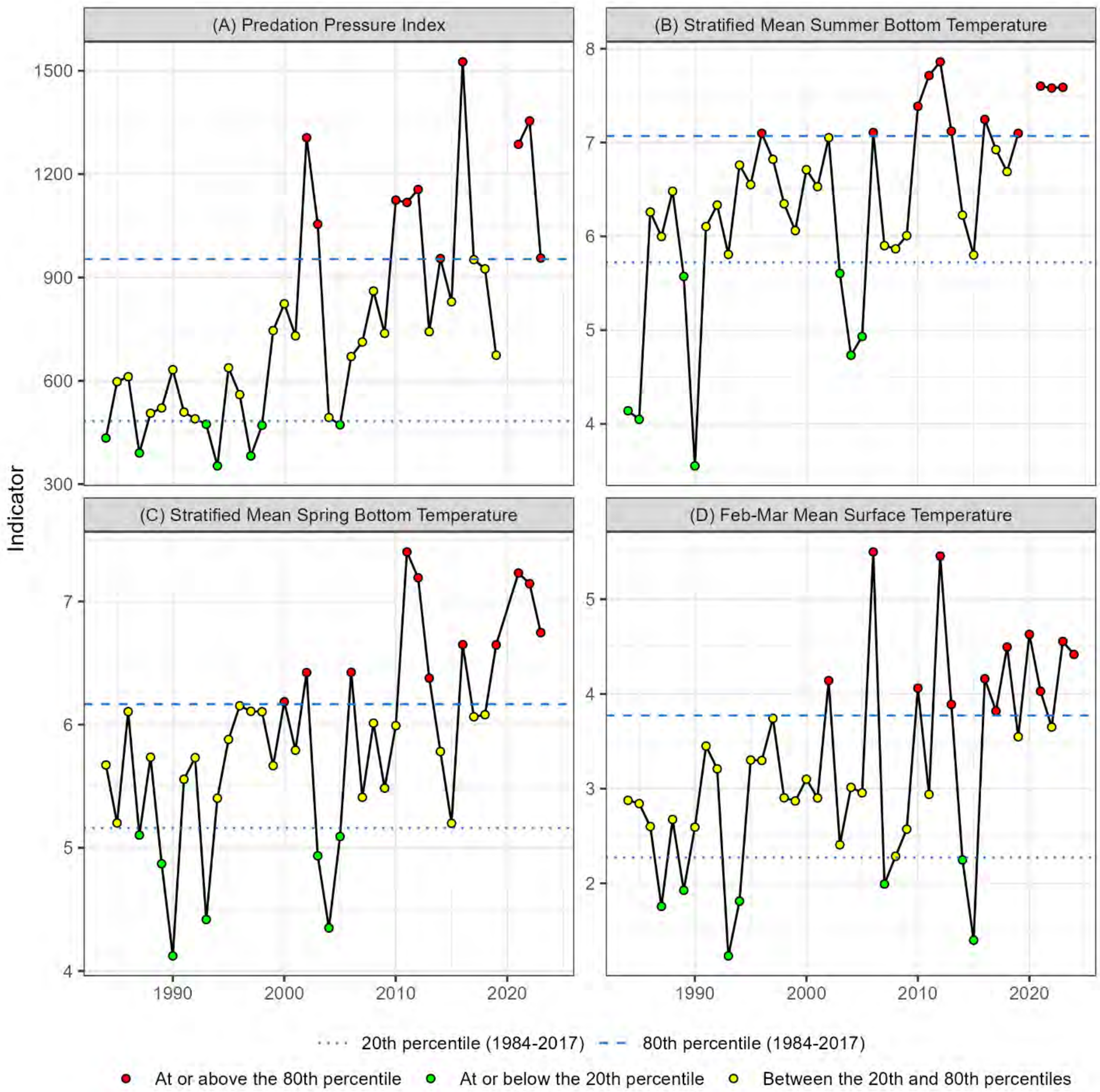


Figure 8. Traffic light analysis of environmental conditions in the Gulf of Maine 1984-2023, including predation pressure (A), summer bottom temperature (B), spring bottom temperature (C), and winter sea surface temperature (D). The 20th percentile of the time series from 1984-2017 delineated a favorable state, and the 80th percentile of the time series from 1984-2017 delineated an adverse state.

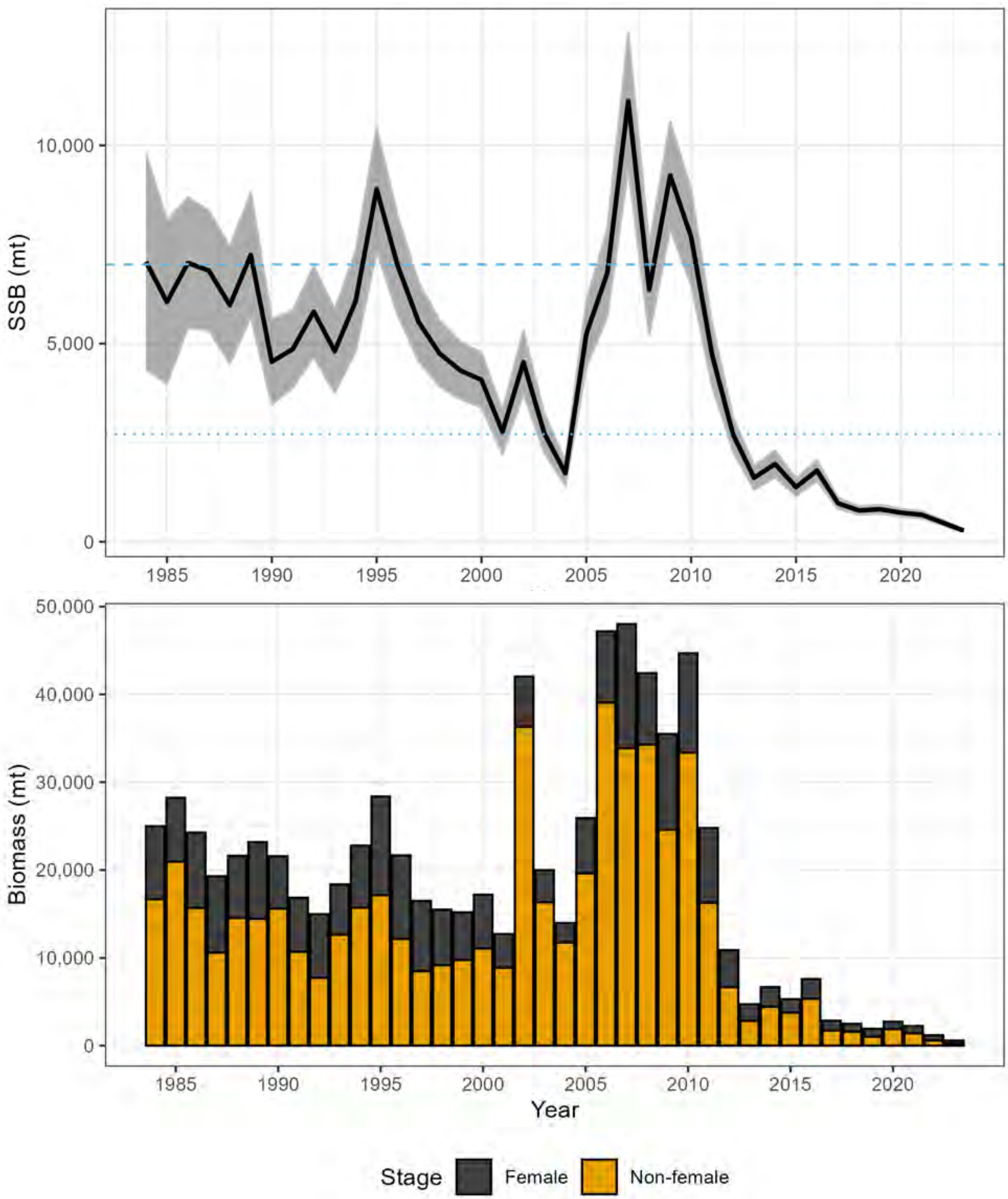


Figure 9. **Estimates of Gulf of Maine northern shrimp spawning stock biomass with 95% confidence intervals (top) and total biomass by stage (bottom) from the UME model. Dashed lines in the top figure indicated the 80th and 20th percentiles of the 1984-2017 SSB estimates.**

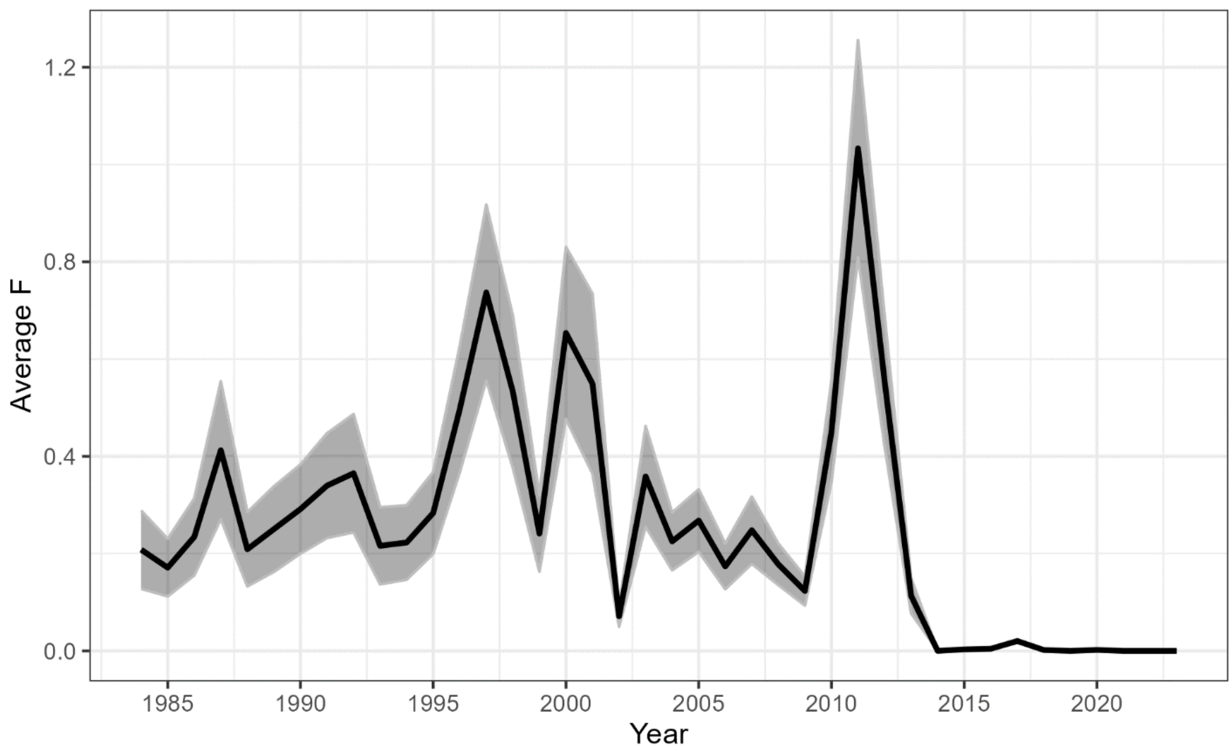


Figure 10. Average fishing mortality on Gulf of Maine northern shrimp estimated by the UME model with 95% confidence intervals.

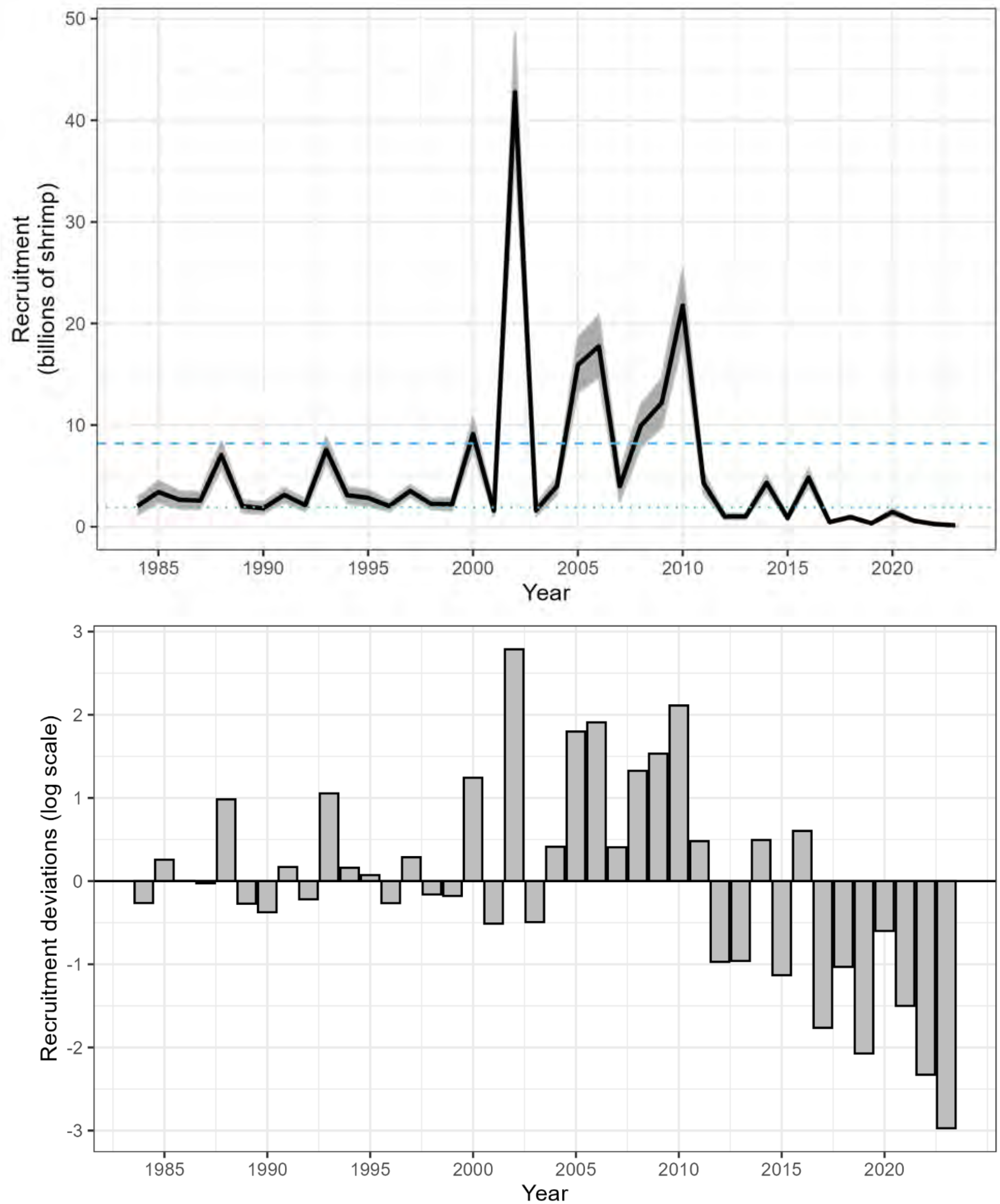


Figure 11. Estimates of total recruitment with 95% confidence intervals (top) and annual deviations from mean recruitment (bottom) for Gulf of Maine northern shrimp from the UME model. Dashed lines in the top plot indicate the 80th and 20th percentiles of the 1984-2017 estimates.

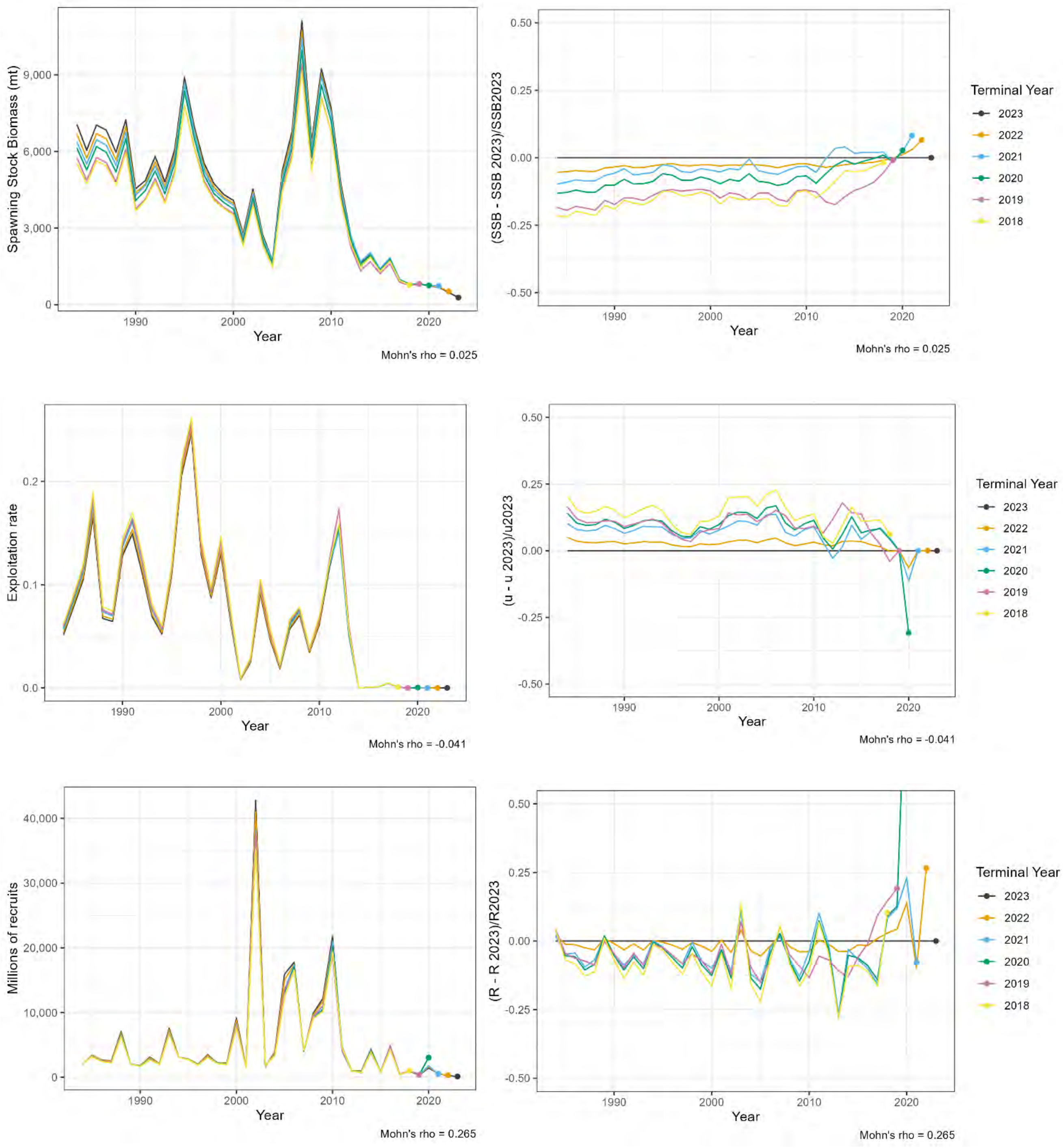


Figure 12. Retrospective analysis of UME model results for spawning stock biomass (top), exploitation rate (middle), and recruitment (bottom).

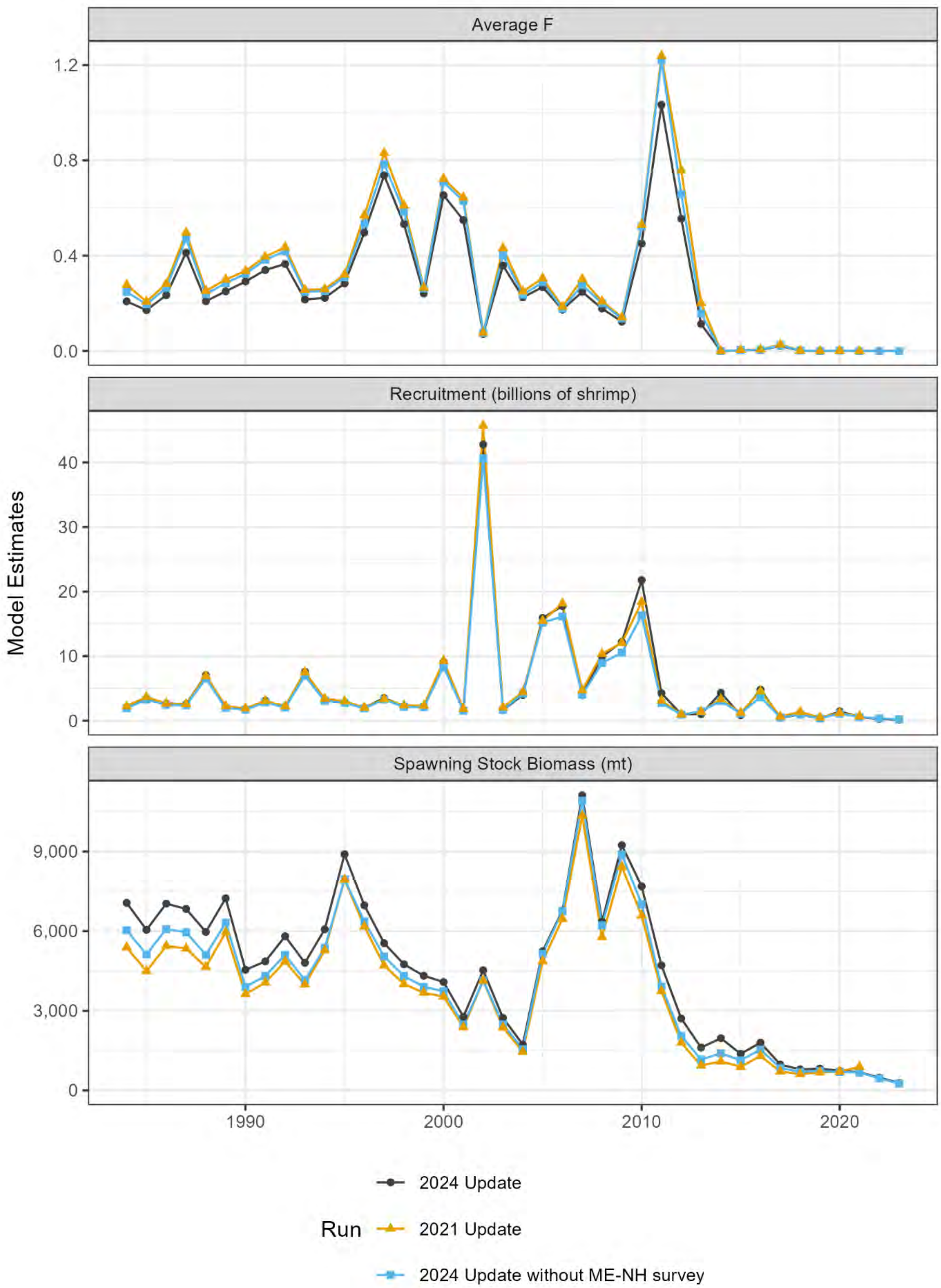


Figure 13. Comparison of results from the 2024 assessment update with and without the ME-NH survey and the 2021 assessment update.

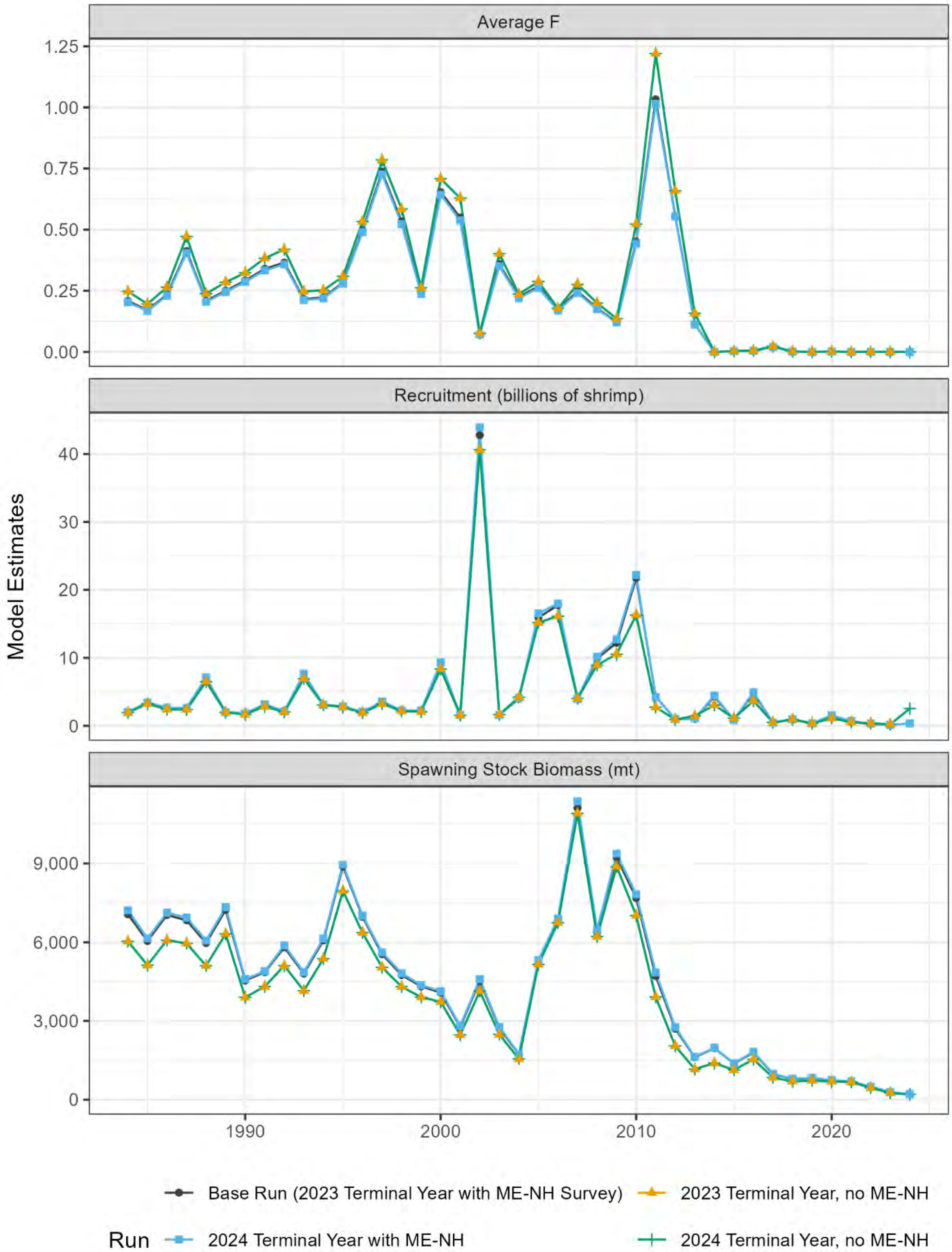


Figure 14. Comparison of results for the base model and sensitivity runs with a terminal year of 2024 and with and without the ME-NH survey.

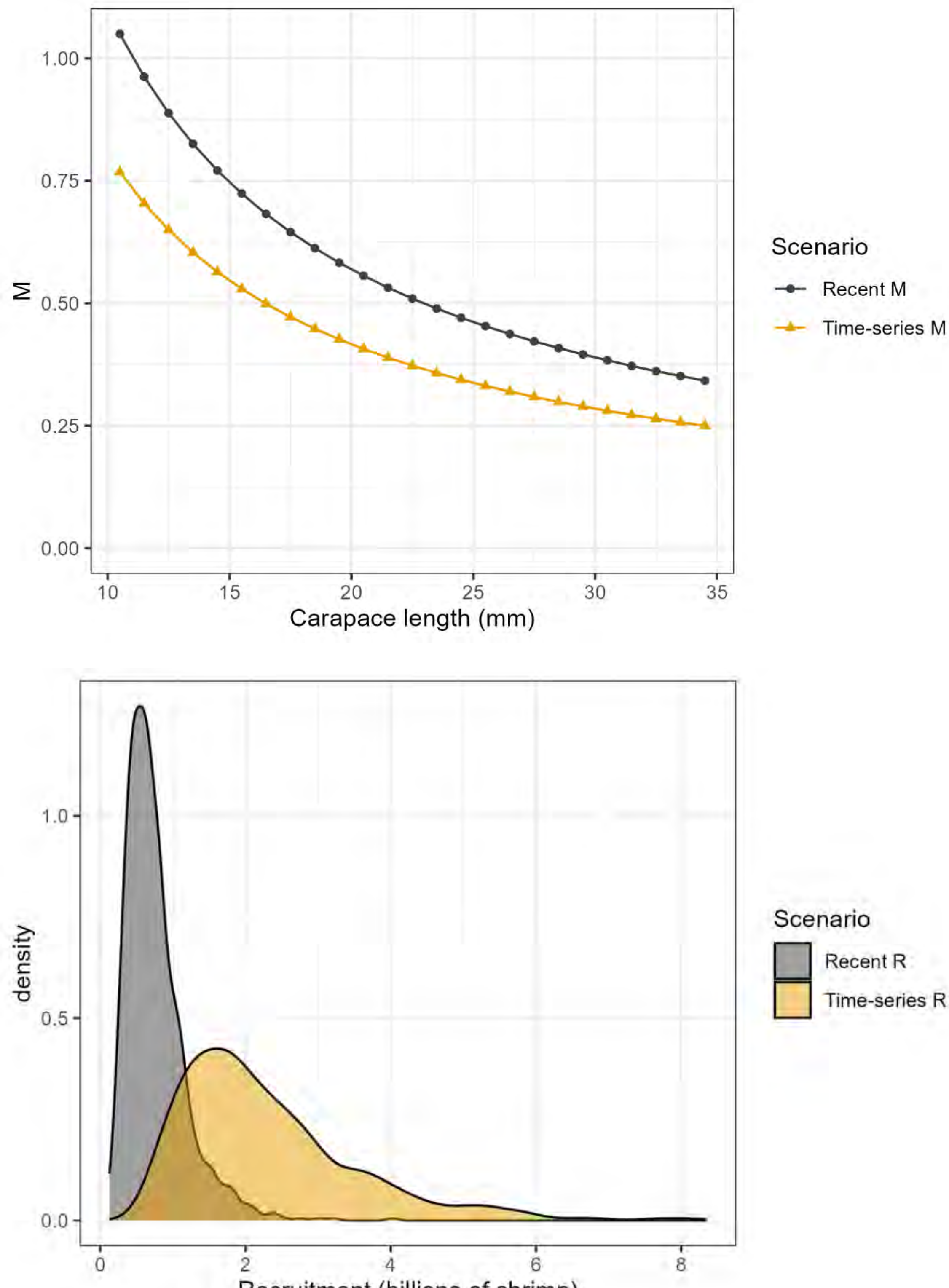


Figure 15. Estimates of M (top) and recruitment (bottom) used in the short- and long-term projections.

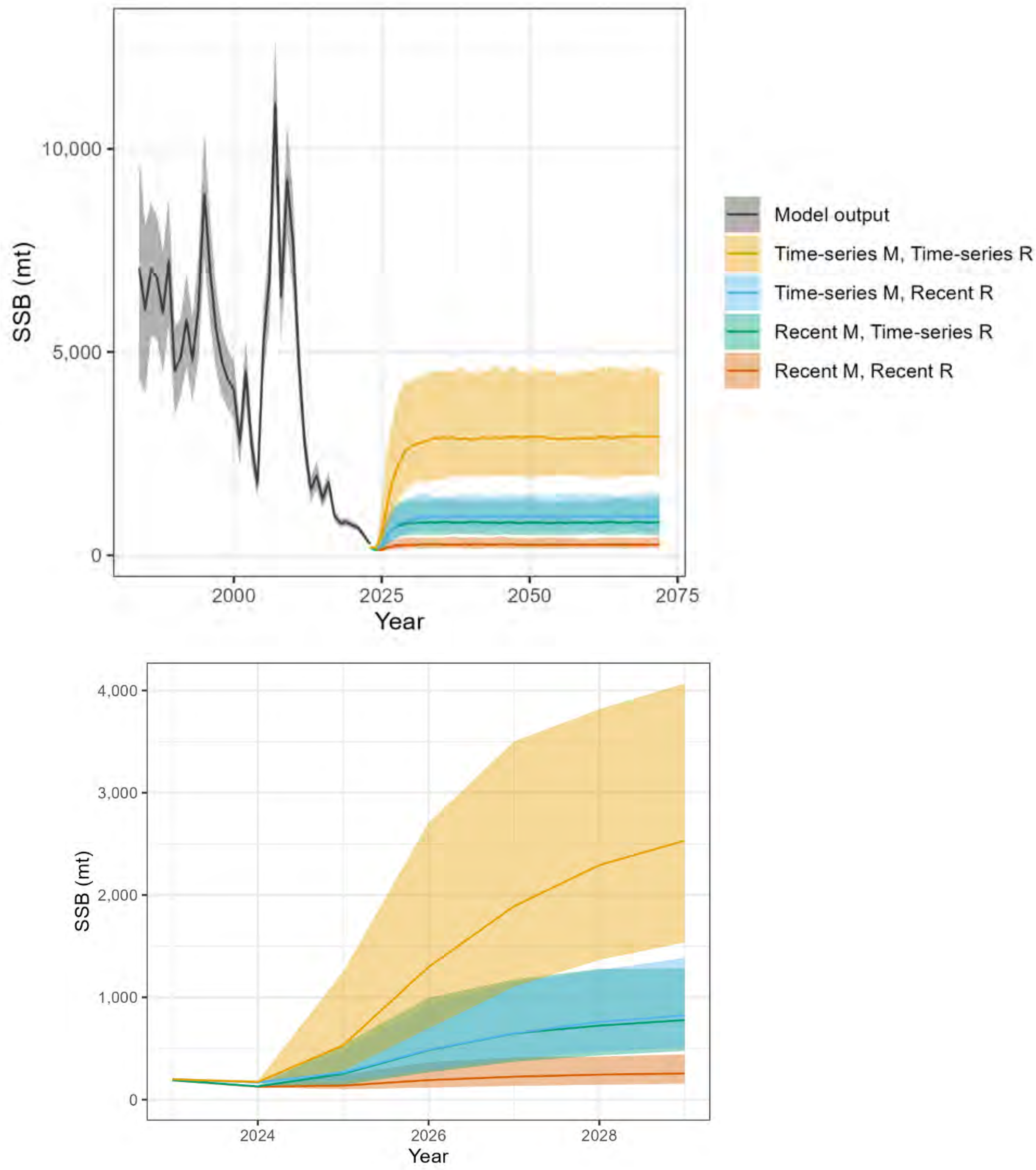


Figure 16. Trajectory of long term (top) and short term (bottom) median spawning stock biomass estimates for Gulf of Maine northern shrimp under different natural mortality and recruitment scenarios in the absence of fishing. Shaded areas indicate 95% confidence intervals.

Appendix 1: Diagnostic Plots for the VAST Index Standardization Models

N. Shrimp 2024 Assessment Update

Table 1. VAST model configuration for the ASMFC Summer Survey index standardization.

```
$Version
[1] "VAST_v13_1_0"

$n_x
[1] 100

$Region
[1] "other"

$strata.limits
     STRATA
1 All_areas

$zone
[1] NA

$FieldConfig
  Omega1 Epsilon1   Omega2 Epsilon2
       1        1        1        1

$RhoConfig
   Beta1    Beta2 Epsilon1 Epsilon2
       0        0        0        0

$VamConfig
Method   Rank Timing
     0      0      0

$OverdispersionConfig
    Vessel VesselYear
         0          0

$ObsModel
[1] 2 3

$vars_to_correct
[1] "Index_cyl" "Index_ctl"

$Options
         SD_site_density       SD_site_logdensity          Calculate_Range
Calculate_evenness
                       0                        0                        1
0
Calculate_effective_area         Calculate_Cov_SE      Calculate_Synchrony
Calculate_Coherence
                       1                        0                        0
0

$grid_size_km
[1] 25

$max_cells
[1] 2000
```

```
$knot_method
[1] "grid"

$Method
[1] "Mesh"

$use_anisotropy
[1] TRUE

$fine_scale
[1] TRUE

$bias.correct
[1] FALSE
```

Table 2. VAST model configuration for the NEFSC Fall Survey index standardization.

```
$Version
[1] "VAST_v14_0_1"

$n_x
[1] 100

$Region
[1] "other"

$strata.limits
     STRATA
1 All_areas

$zone
[1] NA

$FieldConfig
  Omega1 Epsilon1   Omega2 Epsilon2 
       1        1        1        1 

$RhoConfig
   Beta1    Beta2 Epsilon1 Epsilon2 
       0        0        0        0 

$VamConfig
Method   Rank Timing 
     0      0      0 

$OverdispersionConfig
    Vessel VesselYear 
         0          0 

$ObsModel
[1] 2 0

$vars_to_correct
[1] "Index_cyl" "Index_ctl"

$Options
         SD_site_density       SD_site_logdensity          Calculate_Range 
                       0                        0                        1 
      Calculate_evenness Calculate_effective_area         Calculate_Cov_SE 
                       0                        1                        0 
     Calculate_Synchrony      Calculate_Coherence 
                       0                        0 

$grid_size_km
[1] 25

$max_cells
[1] 2000
```

```
$knot_method
[1] "grid"

$Method
[1] "Mesh"

$use_anisotropy
[1] TRUE

$fine_scale
[1] TRUE

$bias.correct
[1] FALSE
```

Table 3. VAST model configuration for the ME-NH Spring Survey index standardization.

```
$Version
[1] "VAST_v13_1_0"

$n_x
[1] 100

$Region
[1] "other"

$strata.limits
     STRATA
1 All_areas

$zone
[1] NA

$FieldConfig
  Omega1 Epsilon1   Omega2 Epsilon2
       1        1        1        1

$RhoConfig
   Beta1    Beta2 Epsilon1 Epsilon2
       0        0        0        0

$VamConfig
Method   Rank Timing
     0      0      0

$OverdispersionConfig
    Vessel VesselYear
         0          0

$ObsModel
[1] 2 3

$vars_to_correct
[1] "Index_cyl" "Index_ctl"

$Options
         SD_site_density       SD_site_logdensity           Calculate_Range
                       0                        0                         1
      Calculate_evenness Calculate_effective_area          Calculate_Cov_SE
                       0                        1                         0
     Calculate_Synchrony      Calculate_Coherence
                       0                        0

$grid_size_km
[1] 25

$max_cells
[1] 2000

$knot_method
```

```
[1] "grid"

$Method
[1] "Mesh"

$use_anisotropy
[1] TRUE

$fine_scale
[1] TRUE

$bias.correct
[1] FALSE
```

Table 4. VAST parameter estimates for the ASMFC Summer Survey

Parameter	Initial Value	Lower Bound	Estimate	Upper Bound	Standard Deviation	Final Gradient
ln_H_input	-0.149	-5	-0.149	5	0.137	-2.916E-11
ln_H_input	0.297	-5	0.297	5	0.159	4.078E-09
beta1_ft	6.087	-Inf	6.087	Inf	1.890	-4.005E-09
beta1_ft	4.814	-Inf	4.814	Inf	1.661	-7.801E-09
beta1_ft	3.762	-Inf	3.762	Inf	1.387	2.585E-09
beta1_ft	4.689	-Inf	4.689	Inf	1.538	-6.990E-11
beta1_ft	5.384	-Inf	5.384	Inf	1.670	1.265E-09
beta1_ft	5.699	-Inf	5.699	Inf	2.114	-6.291E-09
beta1_ft	5.112	-Inf	5.112	Inf	1.883	-1.163E-09
beta1_ft	6.281	-Inf	6.281	Inf	1.964	-2.070E-09
beta1_ft	3.279	-Inf	3.279	Inf	1.369	2.128E-09
beta1_ft	6.328	-Inf	6.328	Inf	2.059	9.405E-10
beta1_ft	3.956	-Inf	3.956	Inf	1.607	3.808E-10
beta1_ft	5.678	-Inf	5.679	Inf	1.739	-4.982E-09
beta1_ft	3.313	-Inf	3.313	Inf	1.338	2.191E-09
beta1_ft	8.288	-Inf	8.288	Inf	3.048	-2.009E-10
beta1_ft	3.882	-Inf	3.881	Inf	1.649	-1.719E-09
beta1_ft	2.670	-Inf	2.670	Inf	1.230	3.472E-09
beta1_ft	5.507	-Inf	5.507	Inf	1.835	-8.076E-09
beta1_ft	5.093	-Inf	5.093	Inf	1.503	1.434E-09
beta1_ft	5.847	-Inf	5.847	Inf	1.788	-3.204E-09
beta1_ft	4.879	-Inf	4.879	Inf	1.489	2.077E-09
beta1_ft	4.257	-Inf	4.257	Inf	1.391	3.147E-09
beta1_ft	2.050	-Inf	2.051	Inf	1.221	-1.608E-08
beta1_ft	4.150	-Inf	4.150	Inf	1.549	1.442E-10
beta1_ft	3.949	-Inf	3.949	Inf	1.471	2.205E-09
beta1_ft	1.160	-Inf	1.160	Inf	1.222	1.515E-08
beta1_ft	1.928	-Inf	1.928	Inf	1.484	2.415E-09
beta1_ft	0.760	-Inf	0.760	Inf	1.145	-3.651E-09
beta1_ft	0.782	-Inf	0.782	Inf	1.176	3.962E-09
beta1_ft	-1.364	-Inf	-1.364	Inf	1.167	4.235E-09
beta1_ft	-2.850	-Inf	-2.850	Inf	1.199	1.016E-08
L_omega1_z	3.356	-Inf	3.356	Inf	0.628	-1.077E-08
L_epsilon1_z	1.082	-Inf	1.082	Inf	0.466	-5.604E-08
logkappa1	-2.928	-4.567	-2.928	-1.274	0.239	4.000E-08
beta2_ft	10.096	-Inf	10.096	Inf	0.810	1.941E-10
beta2_ft	10.631	-Inf	10.631	Inf	0.786	-3.895E-09
beta2_ft	10.279	-Inf	10.279	Inf	0.786	2.590E-09
beta2_ft	9.872	-Inf	9.872	Inf	0.785	3.390E-10
beta2_ft	10.040	-Inf	10.040	Inf	0.808	-7.383E-10
beta2_ft	10.365	-Inf	10.365	Inf	0.792	-7.186E-10

Parameter	Initial Value	Lower Bound	Estimate	Upper Bound	Standard Deviation	Final Gradient
beta2_ft	10.231	-Inf	10.231	Inf	0.796	7.383E-12
beta2_ft	9.897	-Inf	9.897	Inf	0.792	2.770E-10
beta2_ft	9.380	-Inf	9.380	Inf	0.791	6.821E-10
beta2_ft	10.012	-Inf	10.012	Inf	0.793	-6.528E-10
beta2_ft	9.935	-Inf	9.935	Inf	0.799	1.338E-10
beta2_ft	10.055	-Inf	10.055	Inf	0.799	1.404E-10
beta2_ft	9.477	-Inf	9.477	Inf	0.804	6.267E-10
beta2_ft	9.689	-Inf	9.688	Inf	0.803	-5.957E-10
beta2_ft	9.238	-Inf	9.238	Inf	0.794	7.796E-11
beta2_ft	9.453	-Inf	9.453	Inf	0.795	6.388E-10
beta2_ft	9.764	-Inf	9.764	Inf	0.797	-5.370E-10
beta2_ft	8.820	-Inf	8.820	Inf	0.795	-4.757E-10
beta2_ft	9.951	-Inf	9.951	Inf	0.797	1.266E-10
beta2_ft	9.682	-Inf	9.682	Inf	0.786	-2.175E-09
beta2_ft	10.129	-Inf	10.129	Inf	0.788	2.081E-09
beta2_ft	10.954	-Inf	10.954	Inf	0.782	7.522E-10
beta2_ft	11.554	-Inf	11.554	Inf	0.805	-2.011E-10
beta2_ft	10.282	-Inf	10.282	Inf	0.782	1.421E-10
beta2_ft	10.395	-Inf	10.395	Inf	0.786	-1.613E-09
beta2_ft	10.305	-Inf	10.305	Inf	0.783	-4.738E-10
beta2_ft	9.851	-Inf	9.851	Inf	0.788	-7.053E-10
beta2_ft	9.367	-Inf	9.367	Inf	0.781	-4.773E-10
beta2_ft	8.047	-Inf	8.047	Inf	0.786	-1.230E-09
beta2_ft	6.562	-Inf	6.562	Inf	0.792	1.165E-09
beta2_ft	7.810	-Inf	7.810	Inf	0.789	-3.882E-10
beta2_ft	6.800	-Inf	6.800	Inf	0.805	1.247E-10
beta2_ft	8.109	-Inf	8.109	Inf	0.788	9.616E-10
beta2_ft	6.242	-Inf	6.242	Inf	0.805	5.529E-10
beta2_ft	6.554	-Inf	6.554	Inf	0.827	2.478E-10
beta2_ft	6.092	-Inf	6.092	Inf	0.800	1.165E-09
beta2_ft	5.871	-Inf	5.871	Inf	0.804	8.794E-10
beta2_ft	4.506	-Inf	4.506	Inf	0.819	6.789E-10
beta2_ft	3.277	-Inf	3.277	Inf	0.841	1.149E-10
L_omega2_z	-1.611	-Inf	-1.611	Inf	0.188	2.427E-10
L_epsilon2_z	0.634	-Inf	0.634	Inf	0.037	-1.604E-07
logkappa2	-3.339	-4.567	-3.339	-1.274	0.106	9.099E-08
logSigmaM	-0.158	-Inf	-0.158	10	0.018	-3.581E-08

Table 5. VAST parameter estimates for the NEFSC Fall Survey

Parameter	Initial Value	Lower Bound	Estimate	Upper Bound	Standard Deviation	Final Gradient
ln_H_input	-0.395	-5	-0.395	5	0.259	5.235E-09
ln_H_input	0.312	-5	0.312	5	0.312	-6.694E-09
beta1_ft	1.961	-Inf	1.961	Inf	1.129	-1.136E-09
beta1_ft	1.016	-Inf	1.016	Inf	1.114	-2.239E-09
beta1_ft	1.043	-Inf	1.043	Inf	1.113	1.275E-09
beta1_ft	1.284	-Inf	1.284	Inf	1.112	6.741E-10
beta1_ft	0.870	-Inf	0.870	Inf	1.109	-8.746E-11
beta1_ft	1.646	-Inf	1.646	Inf	1.109	-1.868E-09
beta1_ft	1.577	-Inf	1.577	Inf	1.107	-1.174E-10
beta1_ft	1.733	-Inf	1.733	Inf	1.108	-8.925E-10
beta1_ft	0.152	-Inf	0.152	Inf	1.114	5.002E-10
beta1_ft	-0.145	-Inf	-0.145	Inf	1.114	4.466E-10
beta1_ft	-0.238	-Inf	-0.238	Inf	1.110	-3.751E-10
beta1_ft	-0.621	-Inf	-0.621	Inf	1.102	-6.009E-10
beta1_ft	-2.018	-Inf	-2.018	Inf	1.169	-4.433E-10
L_omega1_z	-2.037	-Inf	-2.037	Inf	0.412	1.034E-08
L_epsilon1_z	0.347	-Inf	0.347	Inf	0.391	-4.740E-10
logkappa1	-3.473	-4.826	-3.473	-1.155	0.284	2.545E-09
beta2_ft	9.780	-Inf	9.780	Inf	0.562	8.520E-11
beta2_ft	9.350	-Inf	9.350	Inf	0.567	1.590E-11
beta2_ft	9.040	-Inf	9.040	Inf	0.563	-8.797E-11
beta2_ft	7.980	-Inf	7.980	Inf	0.564	1.386E-11
beta2_ft	6.567	-Inf	6.567	Inf	0.576	4.965E-11
beta2_ft	7.358	-Inf	7.358	Inf	0.554	2.776E-11
beta2_ft	6.488	-Inf	6.488	Inf	0.556	-2.328E-11
beta2_ft	6.285	-Inf	6.285	Inf	0.549	-1.854E-10
beta2_ft	6.259	-Inf	6.259	Inf	0.603	3.096E-11
beta2_ft	7.013	-Inf	7.013	Inf	0.611	-7.583E-11
beta2_ft	6.564	-Inf	6.563	Inf	0.597	7.021E-12
beta2_ft	4.901	-Inf	4.901	Inf	0.608	-1.030E-11
beta2_ft	4.164	-Inf	4.164	Inf	0.733	-1.042E-10
L_omega2_z	1.604	-Inf	1.604	Inf	0.196	-2.038E-08
L_epsilon2_z	0.579	-Inf	0.579	Inf	0.181	3.319E-08
logkappa2	-2.951	-4.826	-2.951	-1.155	0.231	-2.764E-08
logSigmaM	-0.033	-Inf	-0.033	10	0.058	3.767E-08

Table 6. VAST parameter estimates for the ME-NH Spring Survey

Parameter	Initial Value	Lower Bound	Estimate	Upper Bound	Standard Deviation	Final Gradient
ln_H_input	0.535	-5	0.535	5	0.329	6.901E-11
ln_H_input	1.617	-5	1.617	5	0.731	3.598E-09
beta1_ft	1.201	-Inf	1.200	Inf	1.609	6.064E-10
beta1_ft	-0.495	-Inf	-0.496	Inf	1.609	-6.525E-10
beta1_ft	1.788	-Inf	1.787	Inf	1.610	-1.690E-09
beta1_ft	0.869	-Inf	0.868	Inf	1.607	-3.874E-09
beta1_ft	1.113	-Inf	1.112	Inf	1.609	1.413E-09
beta1_ft	1.076	-Inf	1.076	Inf	1.610	1.471E-09
beta1_ft	1.350	-Inf	1.349	Inf	1.607	1.439E-09
beta1_ft	1.097	-Inf	1.096	Inf	1.609	2.806E-10
beta1_ft	1.396	-Inf	1.395	Inf	1.611	2.324E-09
beta1_ft	0.696	-Inf	0.695	Inf	1.605	2.965E-10
beta1_ft	-0.160	-Inf	-0.161	Inf	1.611	-1.173E-09
beta1_ft	0.551	-Inf	0.550	Inf	1.606	-1.604E-09
beta1_ft	-1.383	-Inf	-1.384	Inf	1.609	-2.107E-09
beta1_ft	0.074	-Inf	0.073	Inf	1.606	4.621E-10
beta1_ft	-0.641	-Inf	-0.641	Inf	1.605	-1.679E-10
beta1_ft	-1.593	-Inf	-1.594	Inf	1.605	5.291E-09
beta1_ft	-1.937	-Inf	-1.938	Inf	1.609	3.655E-09
beta1_ft	-2.111	-Inf	-2.112	Inf	1.614	1.617E-09
beta1_ft	-2.398	-Inf	-2.399	Inf	1.623	1.165E-09
beta1_ft	-3.650	-Inf	-3.650	Inf	1.631	-9.598E-12
beta1_ft	-6.246	-Inf	-6.247	Inf	1.691	8.828E-10
L_omega1_z	5.152	-Inf	5.152	Inf	0.888	-5.679E-08
L_epsilon1_z	-0.739	-Inf	-0.739	Inf	0.209	3.328E-08
logkappa1	-2.647	-4.855	-2.647	-0.952	0.309	2.988E-07
beta2_ft	7.563	-Inf	7.563	Inf	0.832	-8.399E-10
beta2_ft	7.666	-Inf	7.666	Inf	0.841	4.506E-10
beta2_ft	9.122	-Inf	9.122	Inf	0.831	9.377E-10
beta2_ft	9.011	-Inf	9.011	Inf	0.831	4.055E-10
beta2_ft	9.134	-Inf	9.134	Inf	0.832	-2.261E-09
beta2_ft	9.131	-Inf	9.131	Inf	0.832	-8.985E-10
beta2_ft	9.400	-Inf	9.400	Inf	0.826	-7.394E-10
beta2_ft	9.984	-Inf	9.984	Inf	0.831	-1.482E-09
beta2_ft	9.659	-Inf	9.659	Inf	0.828	-5.263E-10
beta2_ft	8.340	-Inf	8.340	Inf	0.831	3.874E-10
beta2_ft	6.513	-Inf	6.513	Inf	0.840	6.786E-10
beta2_ft	7.425	-Inf	7.425	Inf	0.837	2.013E-10
beta2_ft	6.115	-Inf	6.115	Inf	0.850	3.319E-10
beta2_ft	7.367	-Inf	7.367	Inf	0.837	2.222E-10
beta2_ft	6.352	-Inf	6.352	Inf	0.840	-6.101E-11

Parameter	Initial Value	Lower Bound	Estimate	Upper Bound	Standard Deviation	Final Gradient
beta2_ft	5.617	-Inf	5.617	Inf	0.849	1.878E-10
beta2_ft	5.004	-Inf	5.004	Inf	0.853	5.513E-10
beta2_ft	6.319	-Inf	6.319	Inf	0.855	-2.159E-10
beta2_ft	4.388	-Inf	4.387	Inf	0.871	-1.167E-10
beta2_ft	4.096	-Inf	4.096	Inf	0.872	-5.384E-10
beta2_ft	1.849	-Inf	1.849	Inf	0.931	3.555E-10
L_omega2_z	3.087	-Inf	3.087	Inf	0.558	-8.998E-09
L_epsilon2_z	-0.917	-Inf	-0.917	Inf	0.146	2.334E-08
logkappa2	-2.447	-4.855	-2.447	-0.952	0.211	2.277E-08
logSigmaM	0.006	-Inf	0.006	10	0.024	-1.685E-08

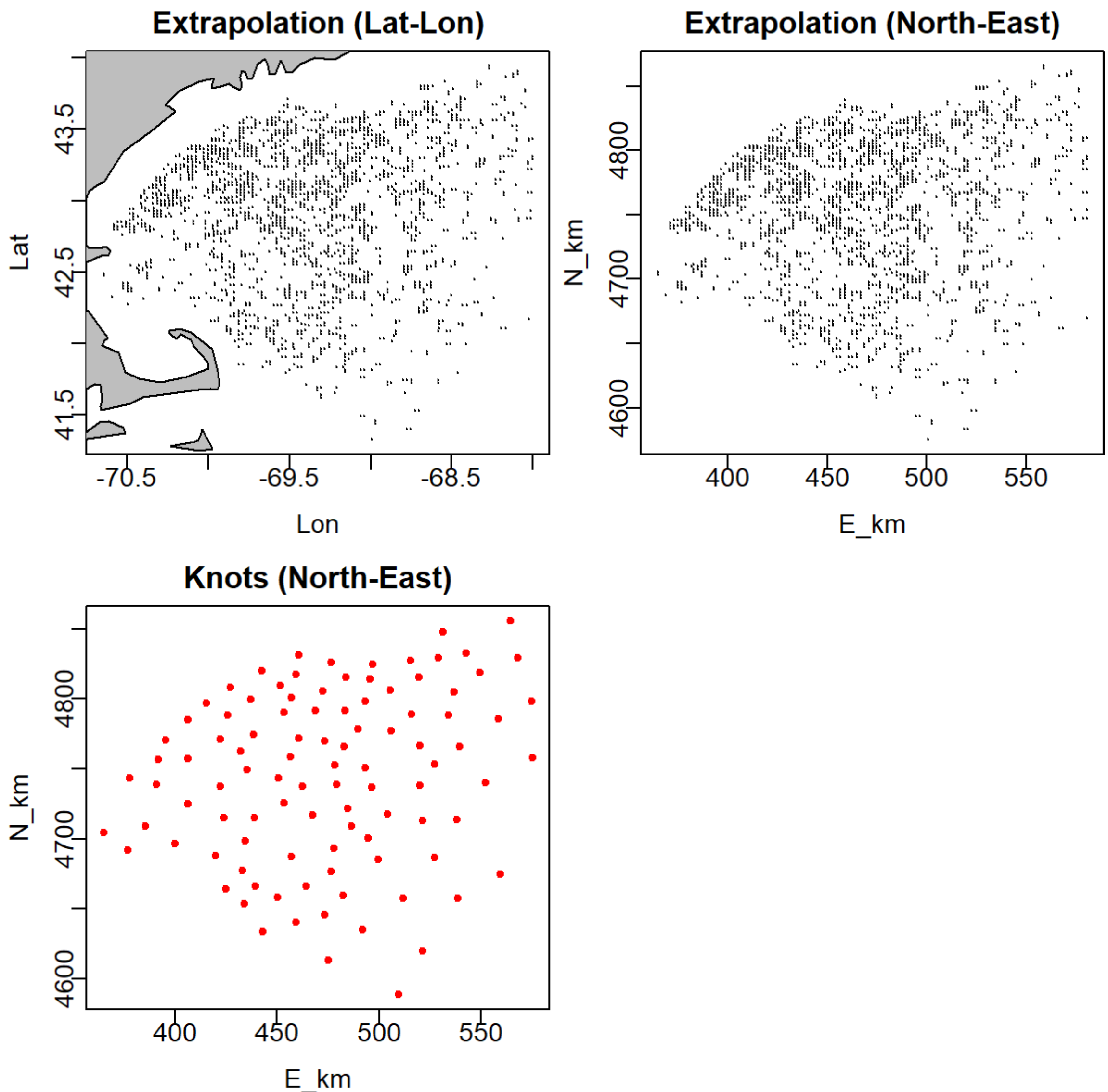


Figure 1. Extrapolation grid and knots for ASMFC Summer Survey.

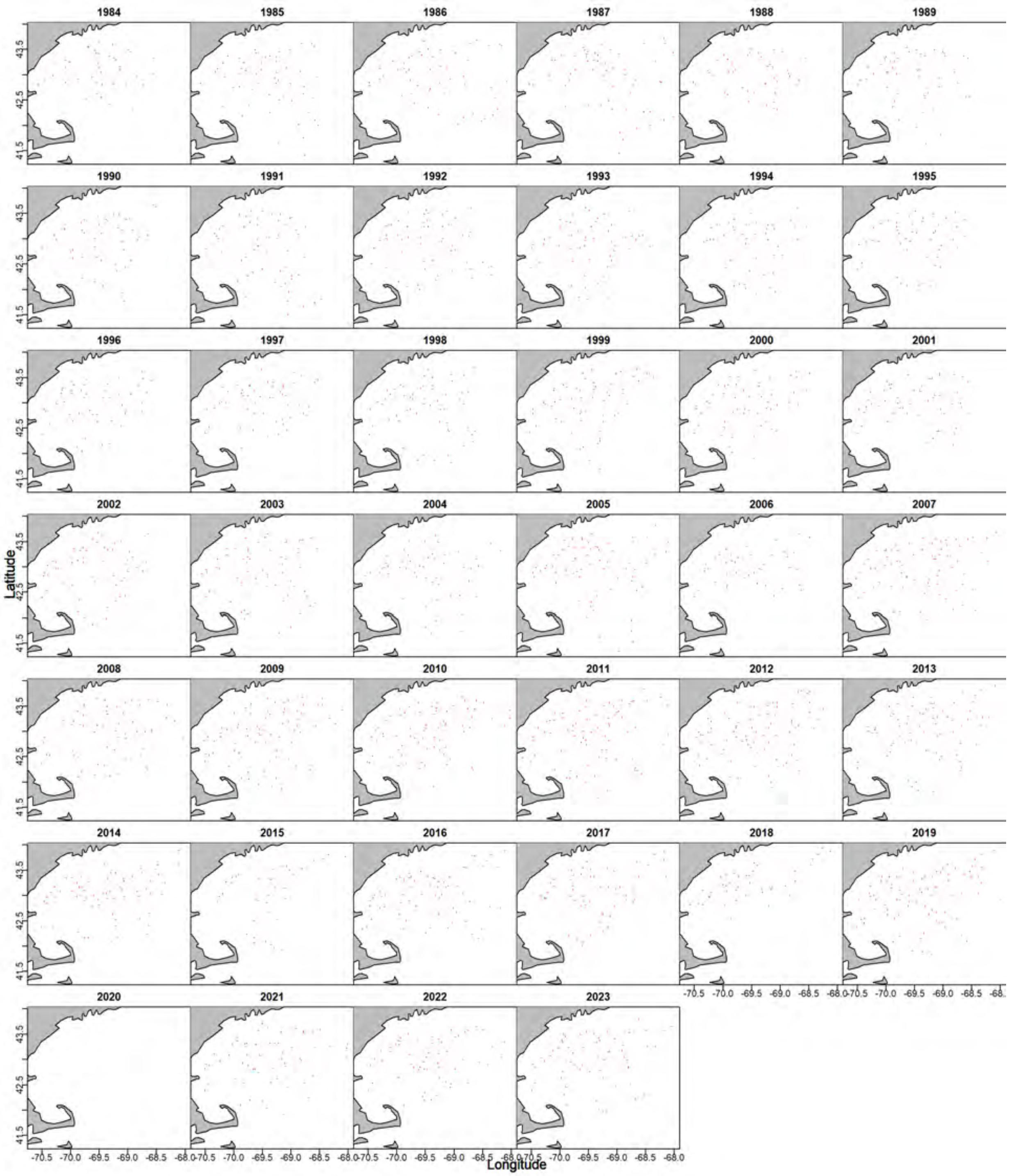


Figure 2. ASMFC Summer Survey catch locations by year.

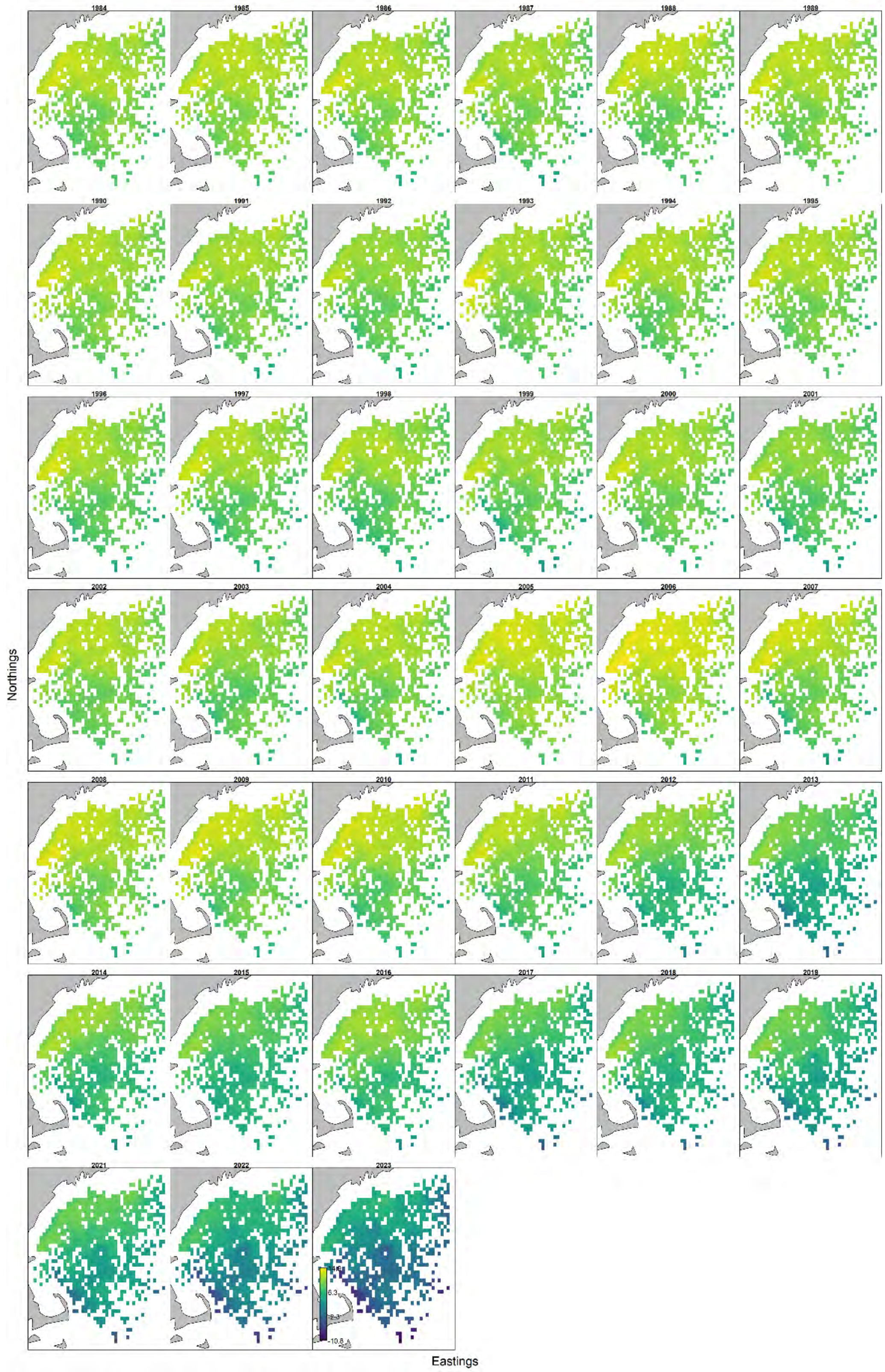


Figure 3. Annual predicted population density (log-scale) by area for the ASMFC Summer Survey.

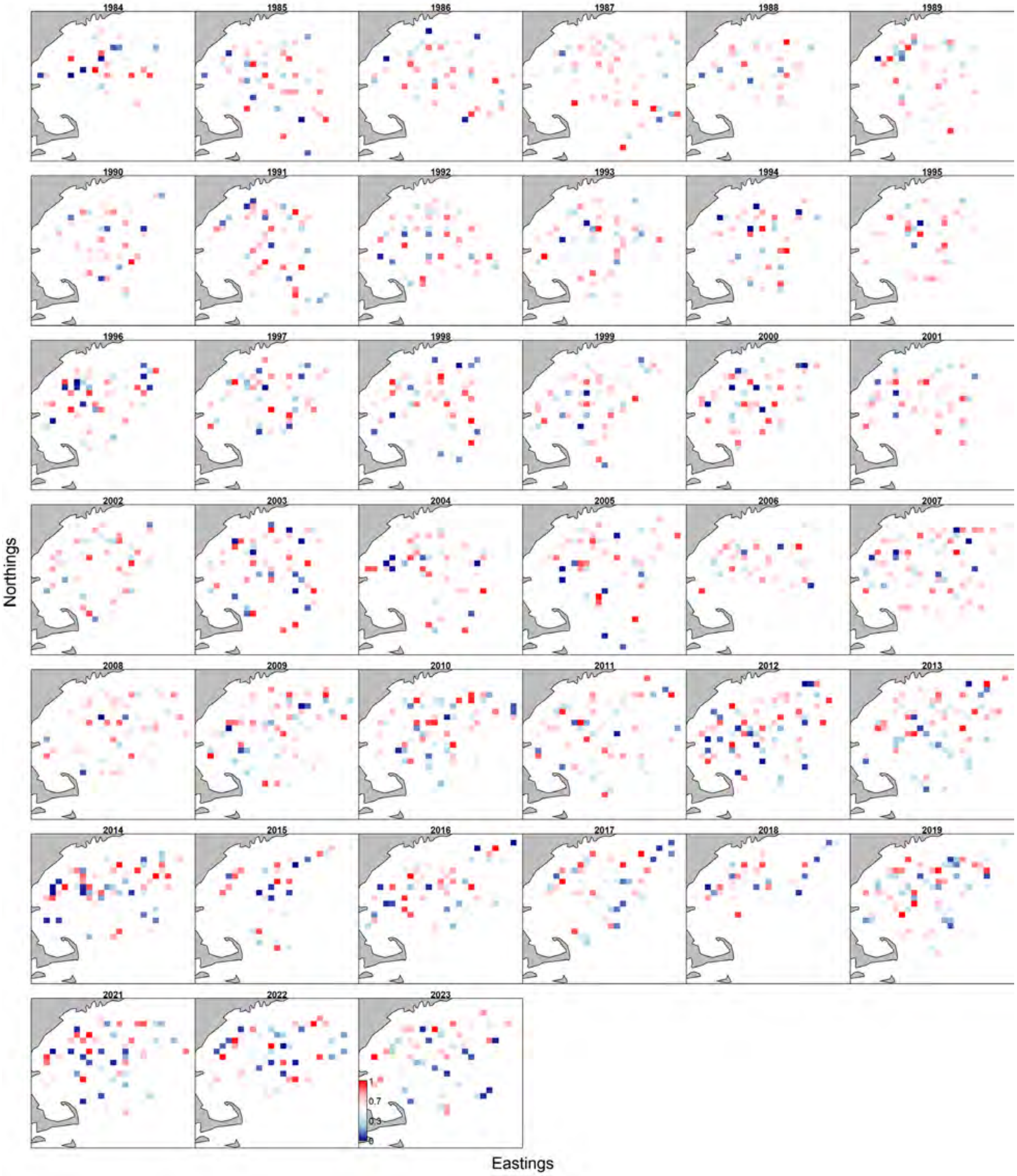


Figure 4. Annual quantile residuals by area for the ASMFC Summer Survey.

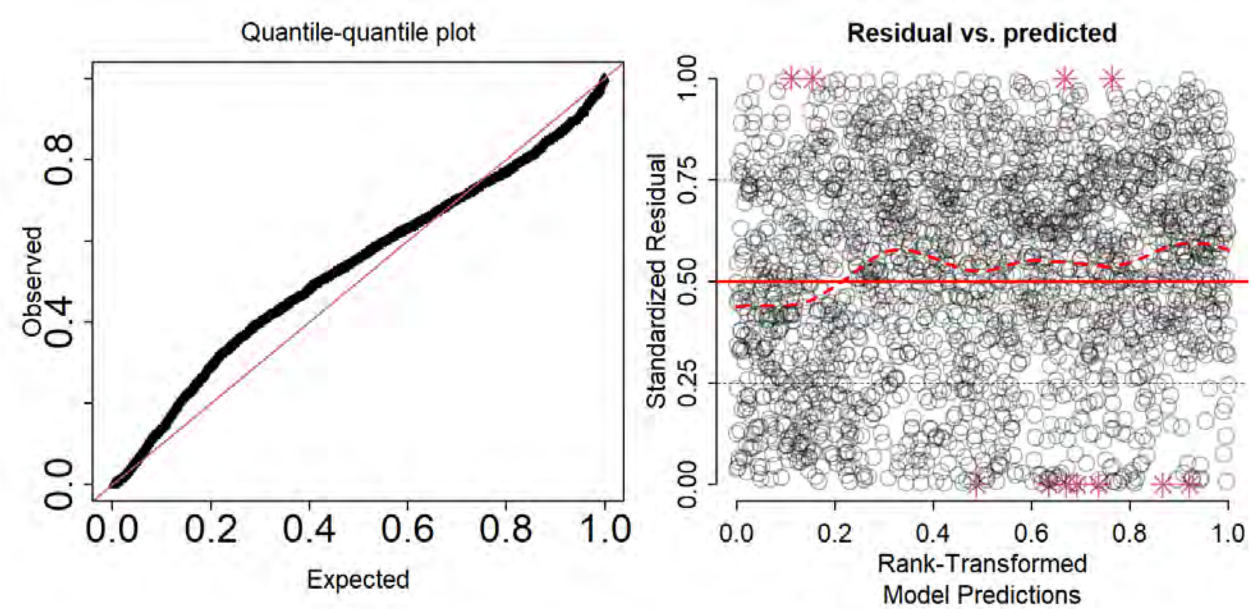


Figure 5. Quantile results for the ASMFC Summer Survey.

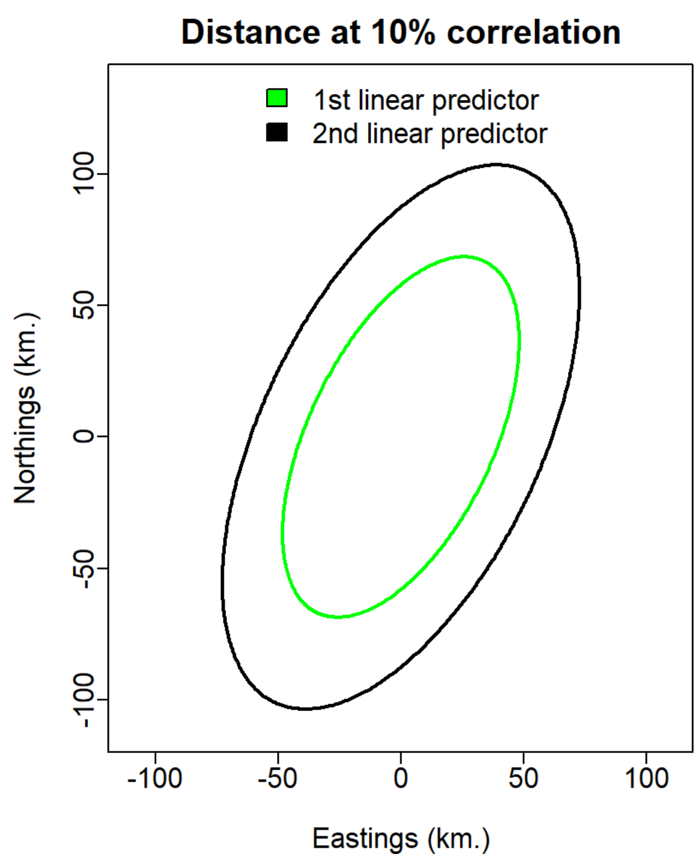


Figure 6. Direction of geometric anisotropy for the ASMFC Summer Survey.

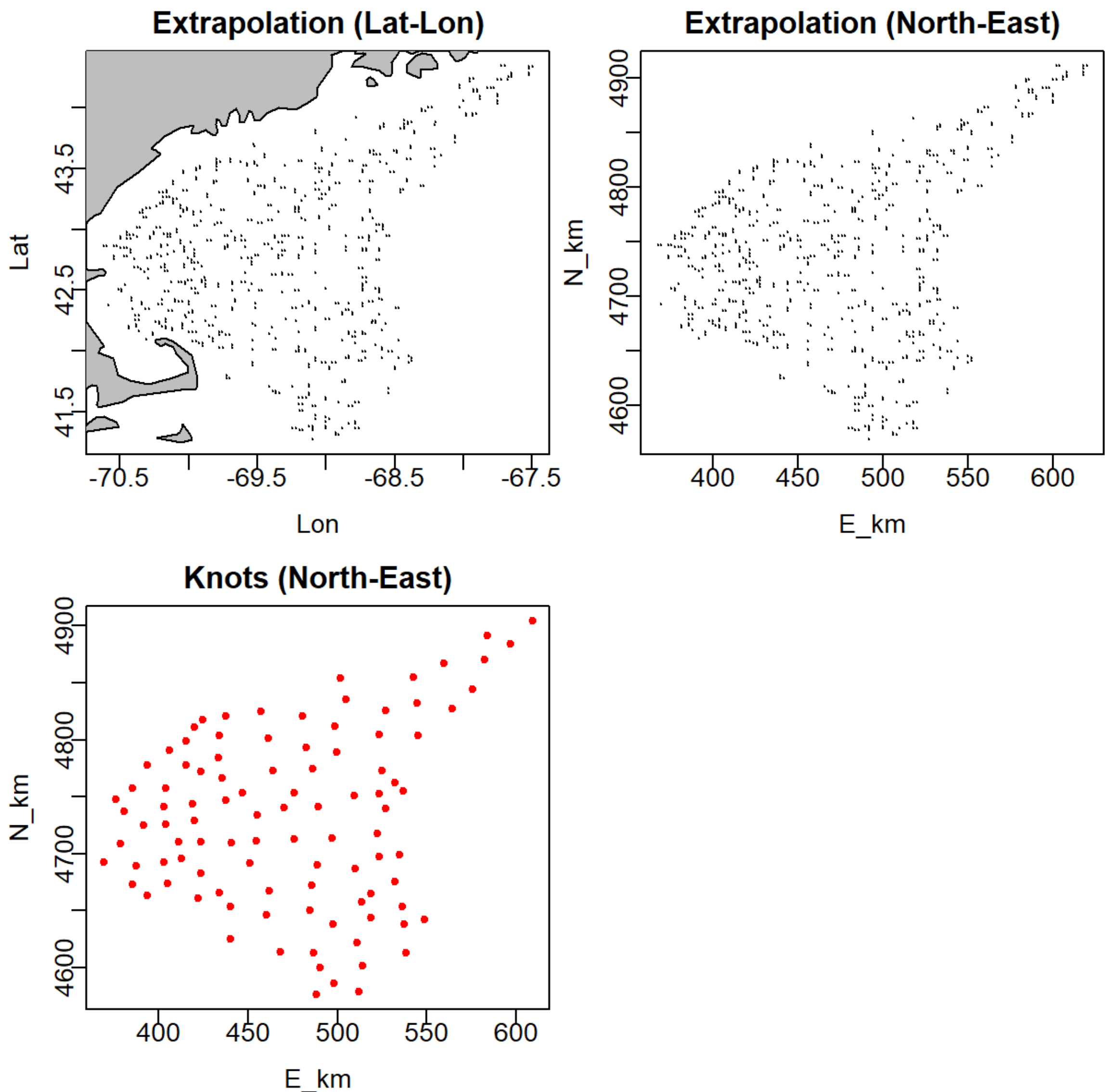


Figure 7. Extrapolation grid and knots for NEFSC Fall Survey.

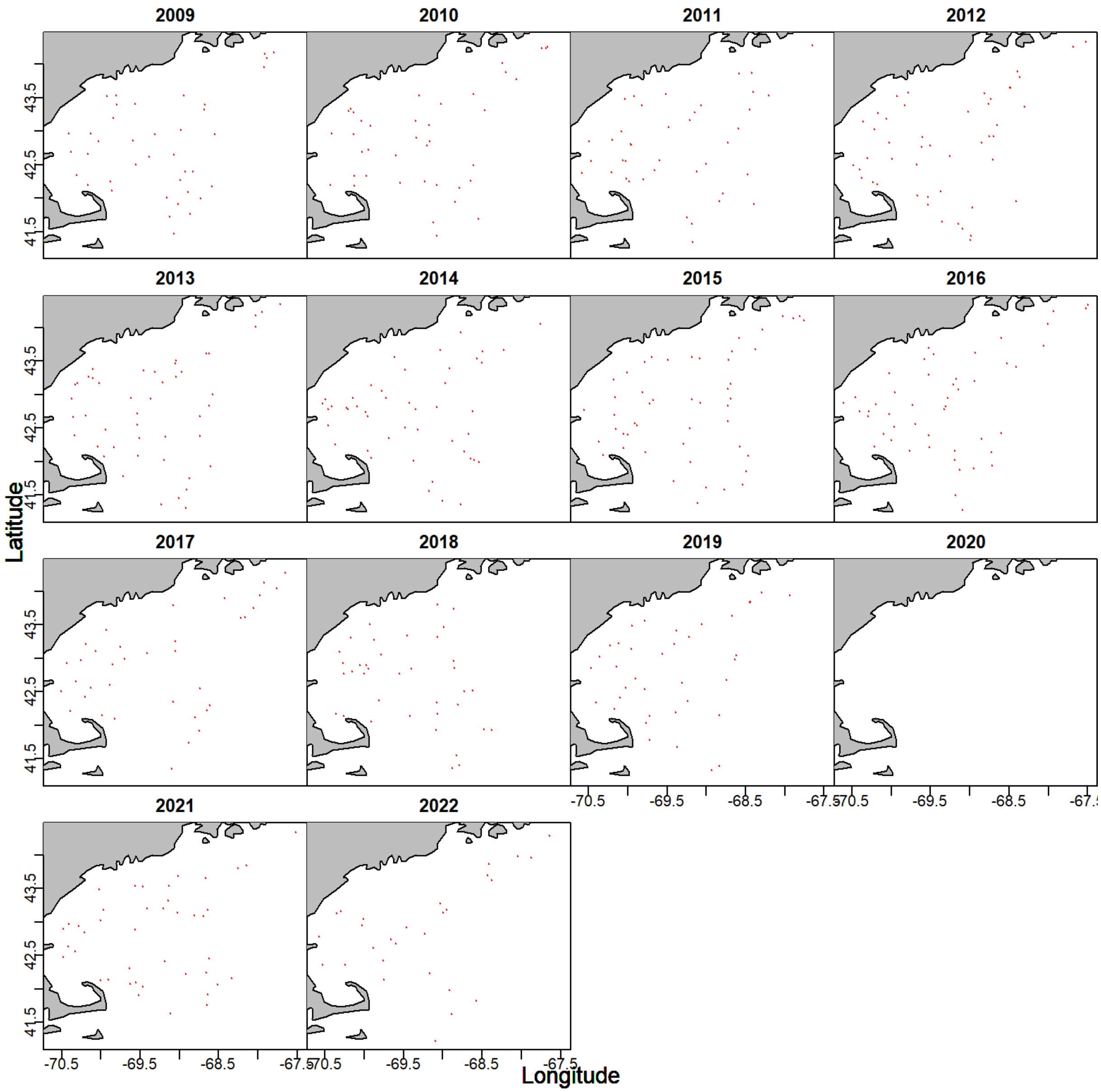


Figure 8. NEFSC Fall Survey catch locations by year.

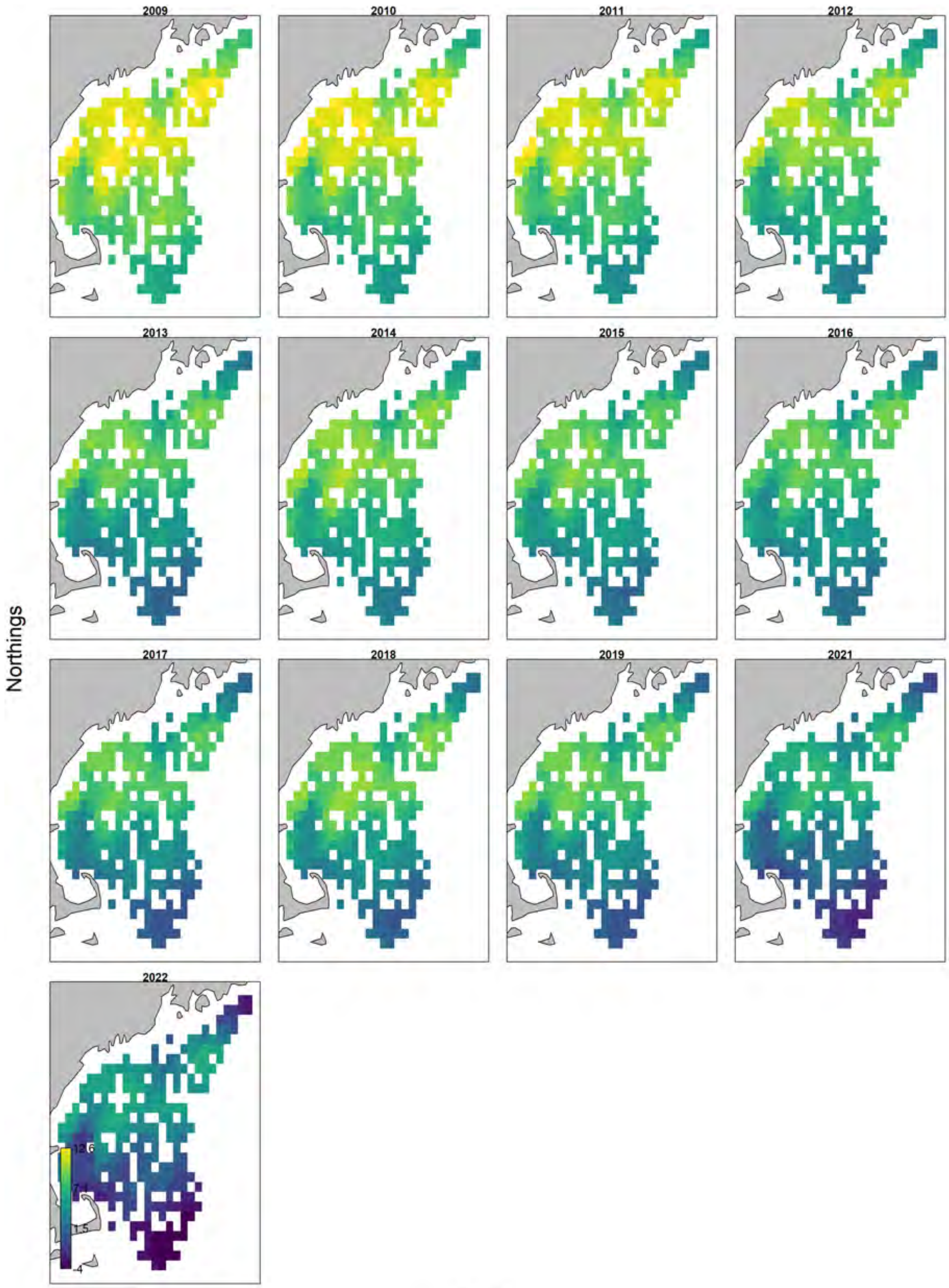


Figure 9. Annual predicted population density (log-scale) by area for the NEFSC Fall Survey.

Figure 10. Annual quantile residuals by area for the NEFSC Fall Survey.

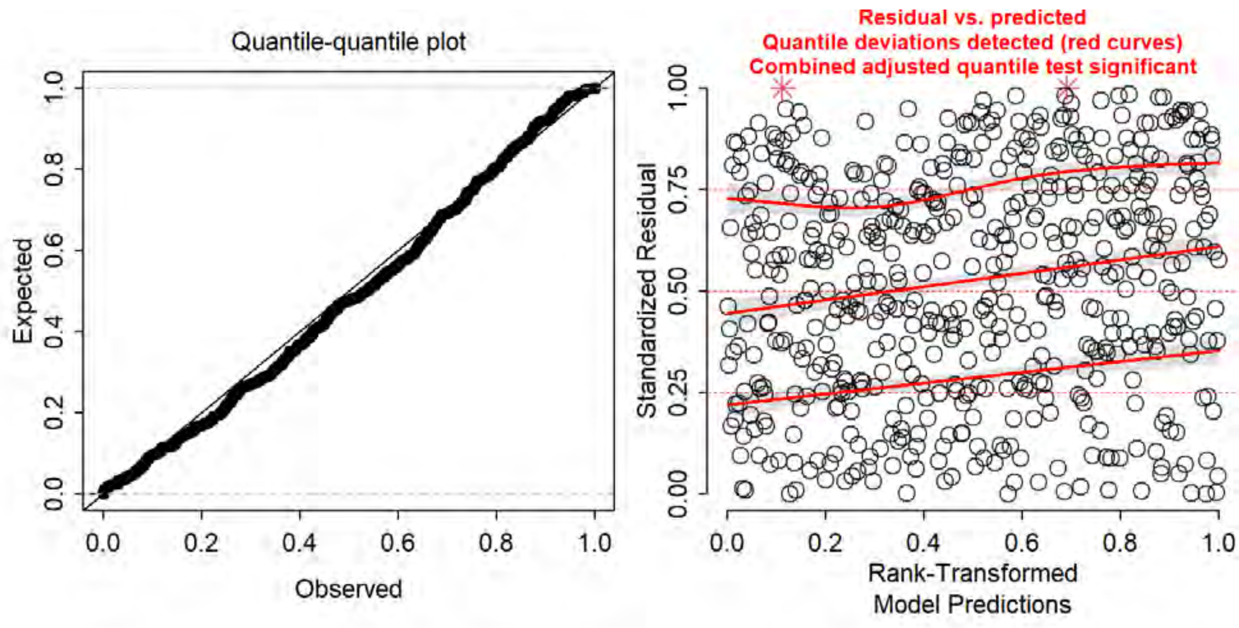


Figure 11. Quantile plots for NEFSC Fall Survey residuals.

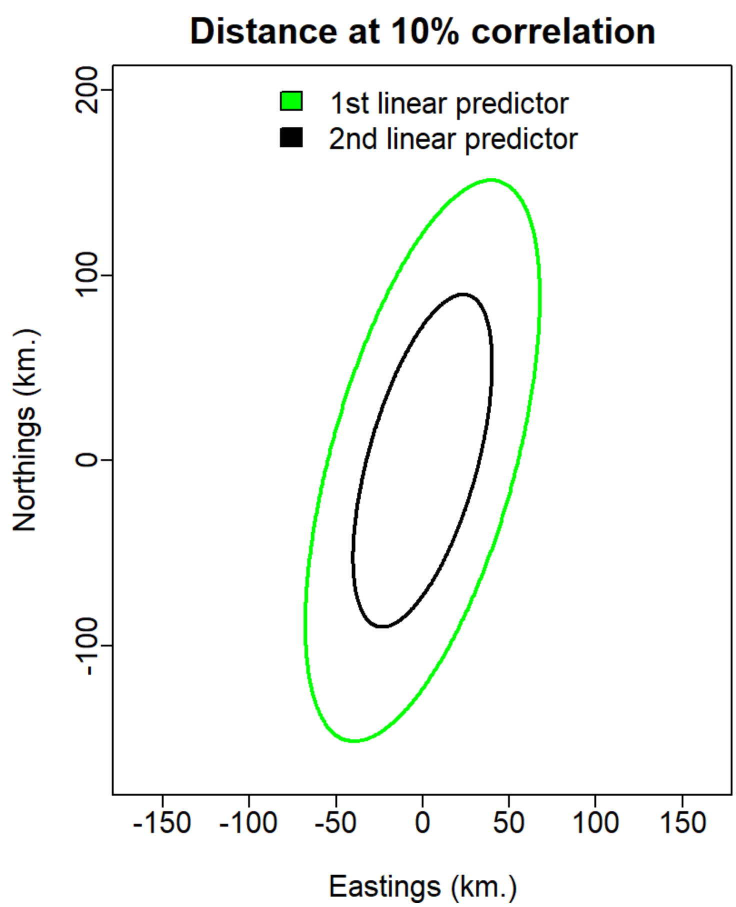


Figure 12. Direction of geometric anisotropy for the NEFSC Fall Survey.

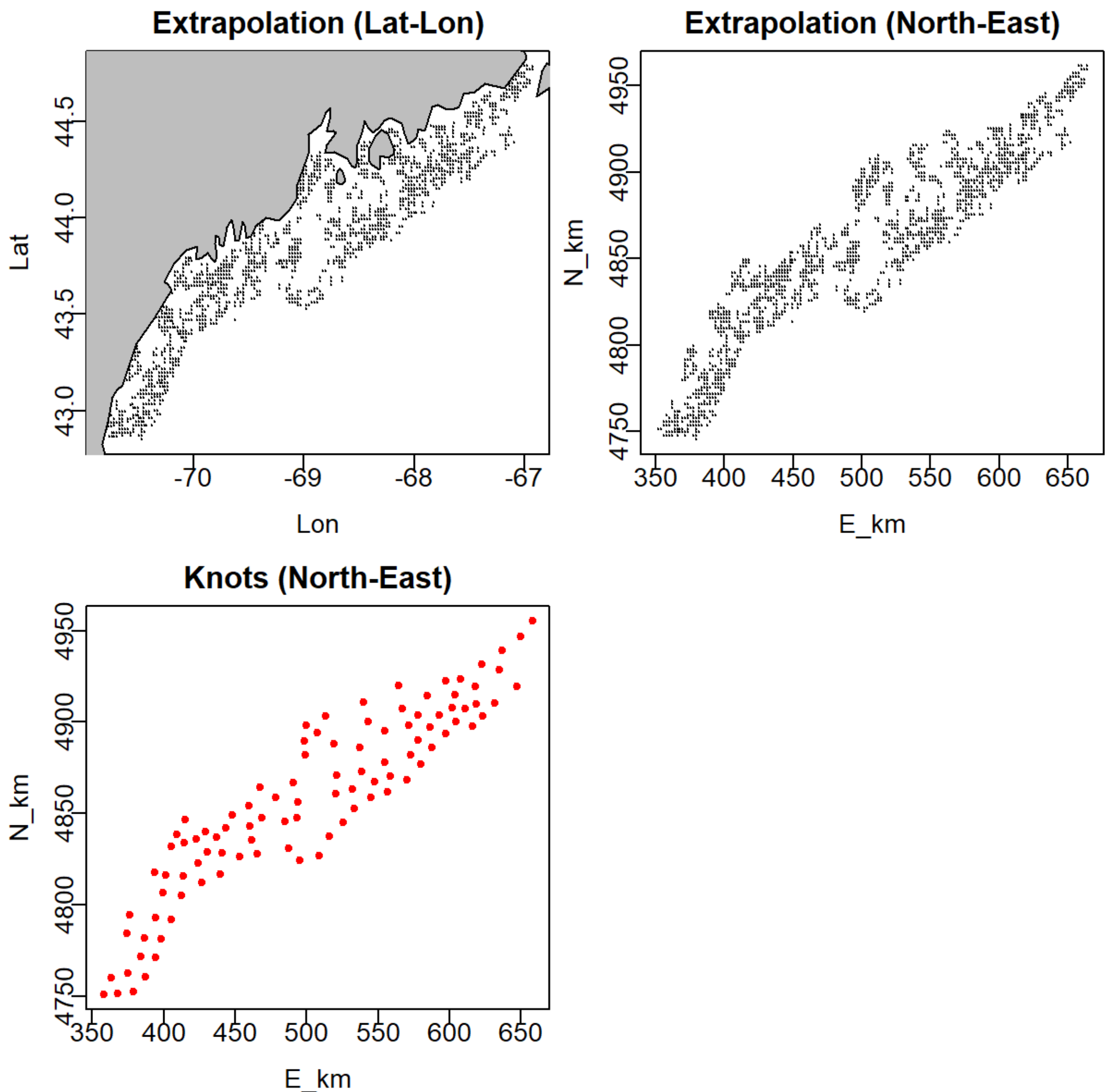


Figure 13. Extrapolation grid and knots for ME-NH Spring Survey.

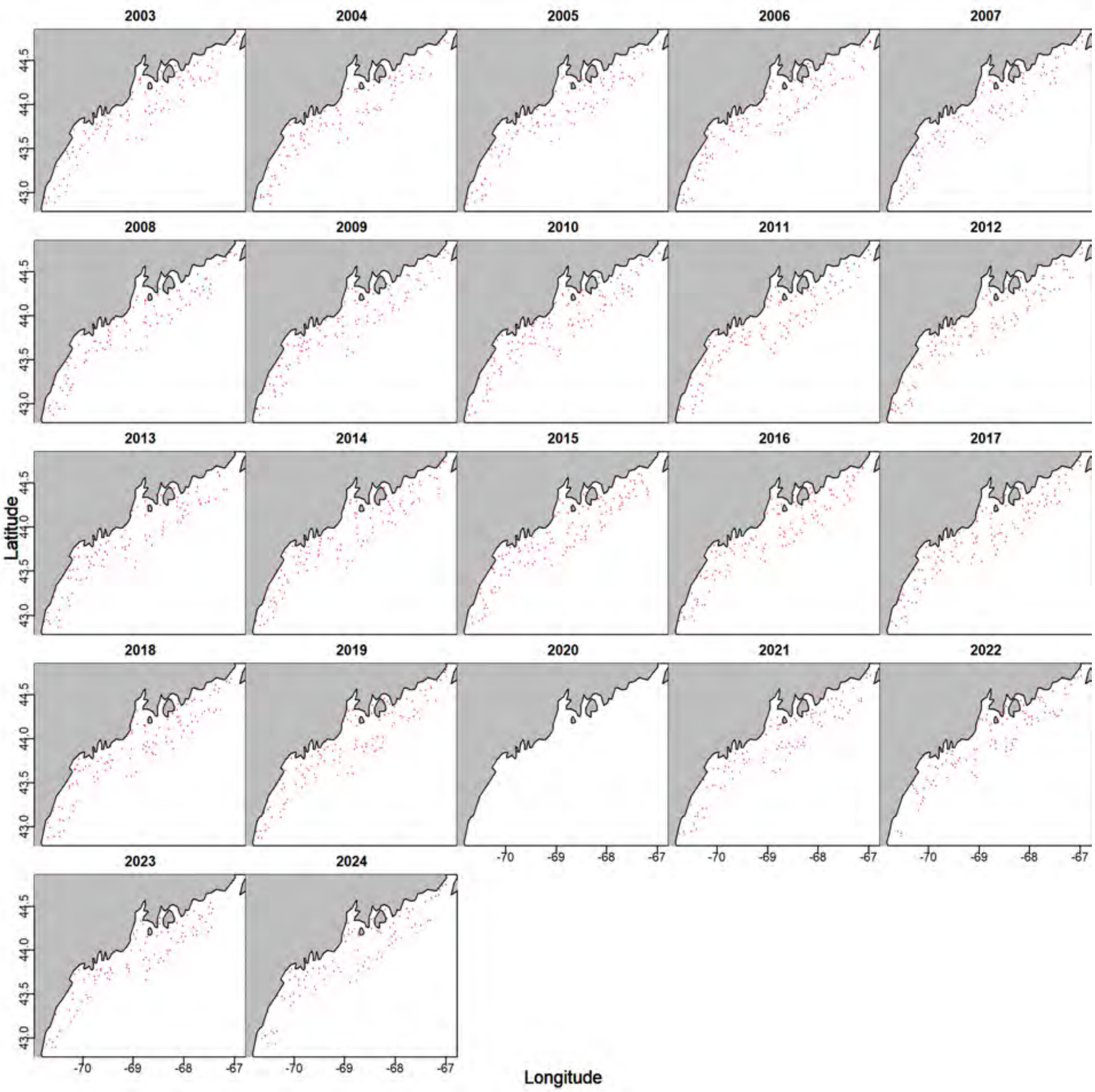


Figure 14. ME-NH Survey catch locations by year.

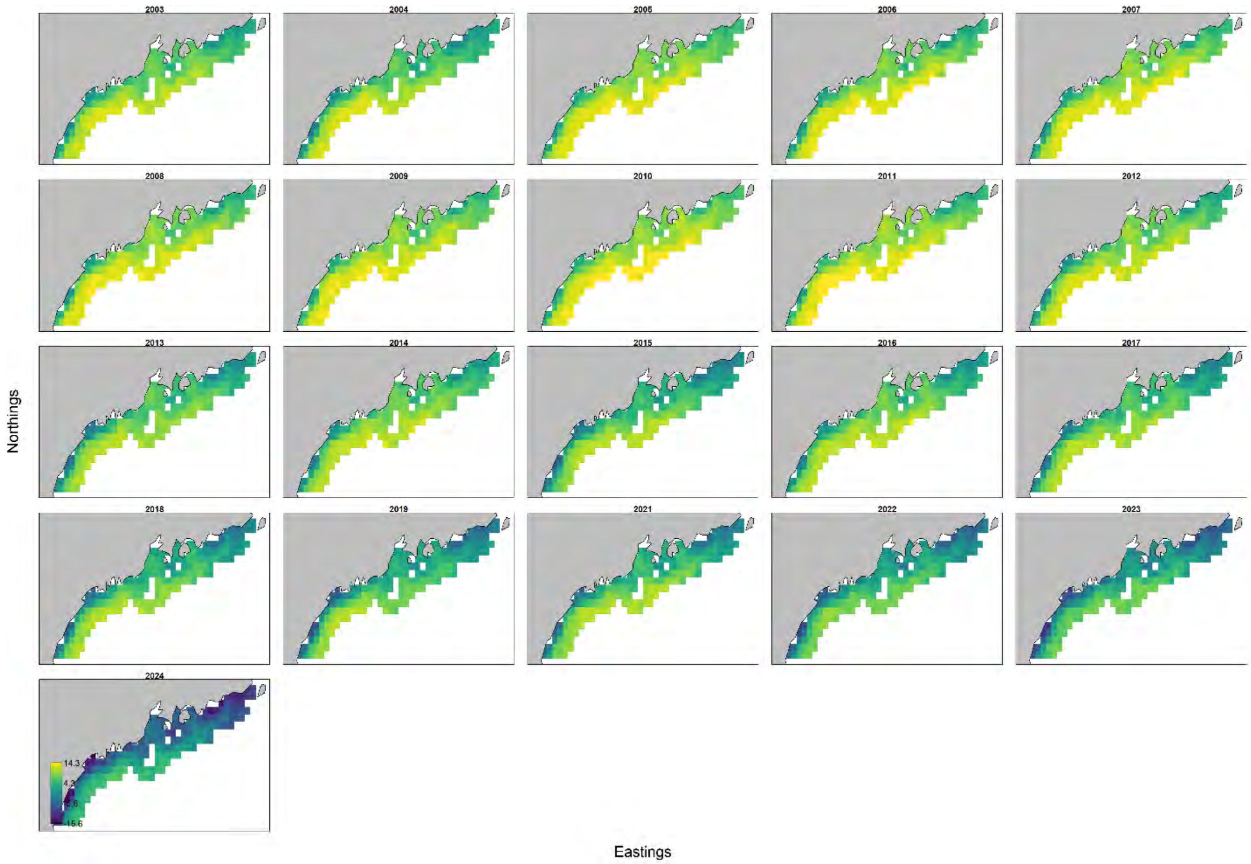


Figure 15. Annual predicted population density (log-scale) by area for the ME-NH Spring Survey.

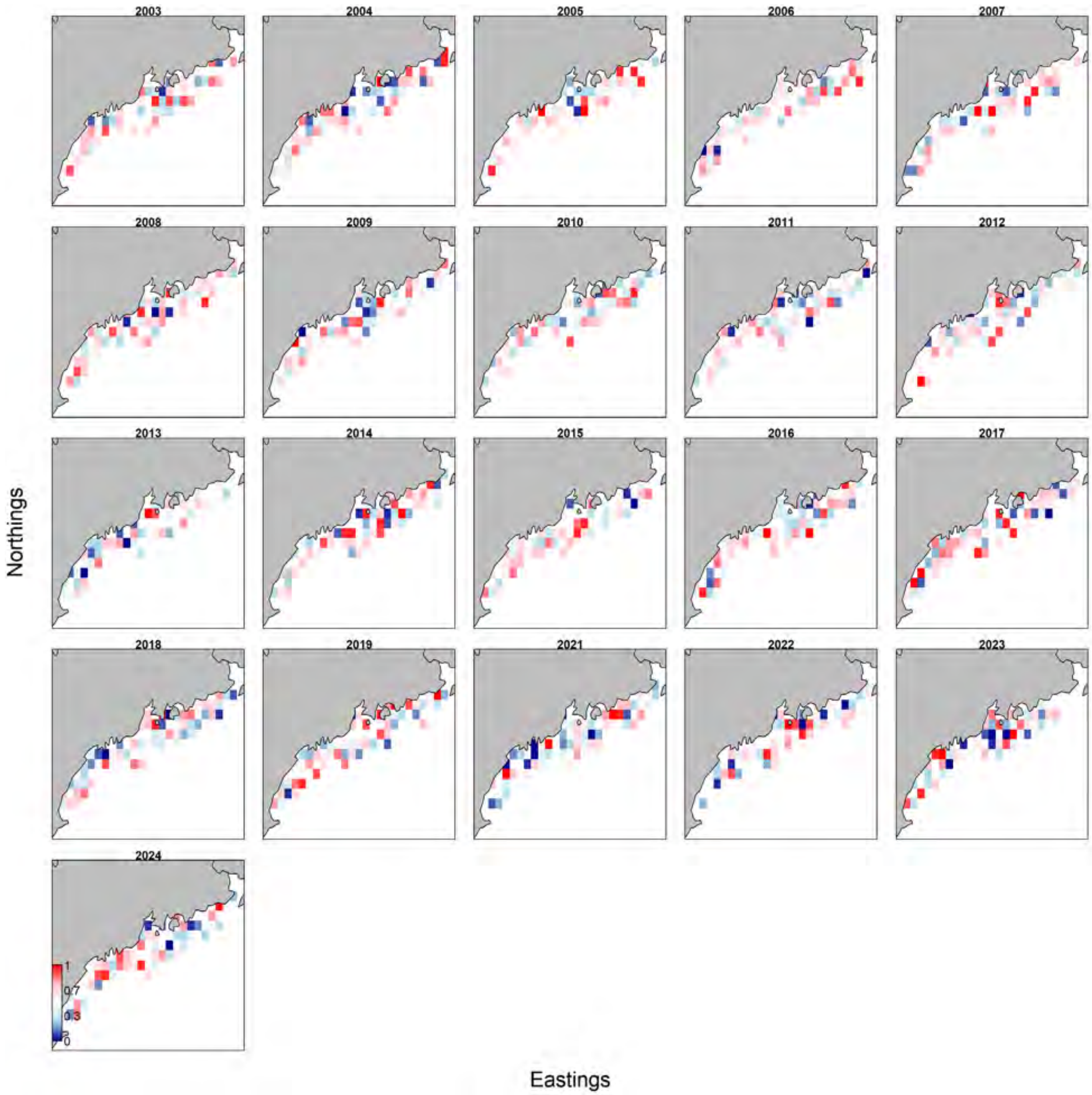


Figure 16. Quantile residuals by area for the ME-NH Spring Survey.

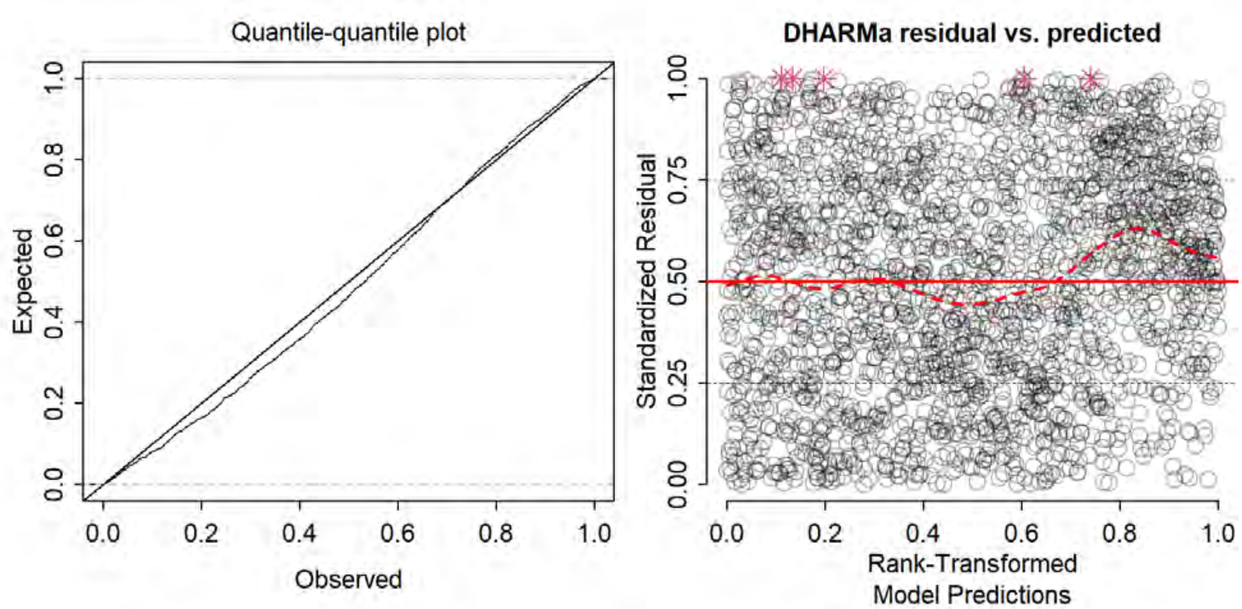


Figure 17. Quantile-plot for ME-NH Spring Survey residuals.

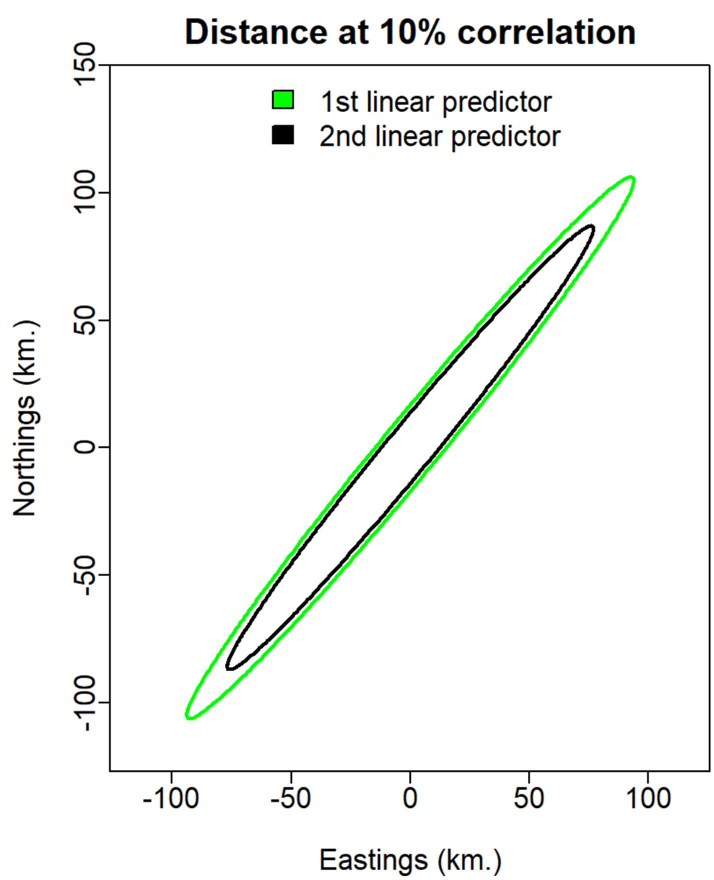


Figure 18. Direction of geometric anisotropy for the ME-NH Spring Survey.

Appendix 2: Model Input and Diagnostic Plots for the UME Statistical Catch-at-Length Model

N. Shrimp 2024 Assessment Update

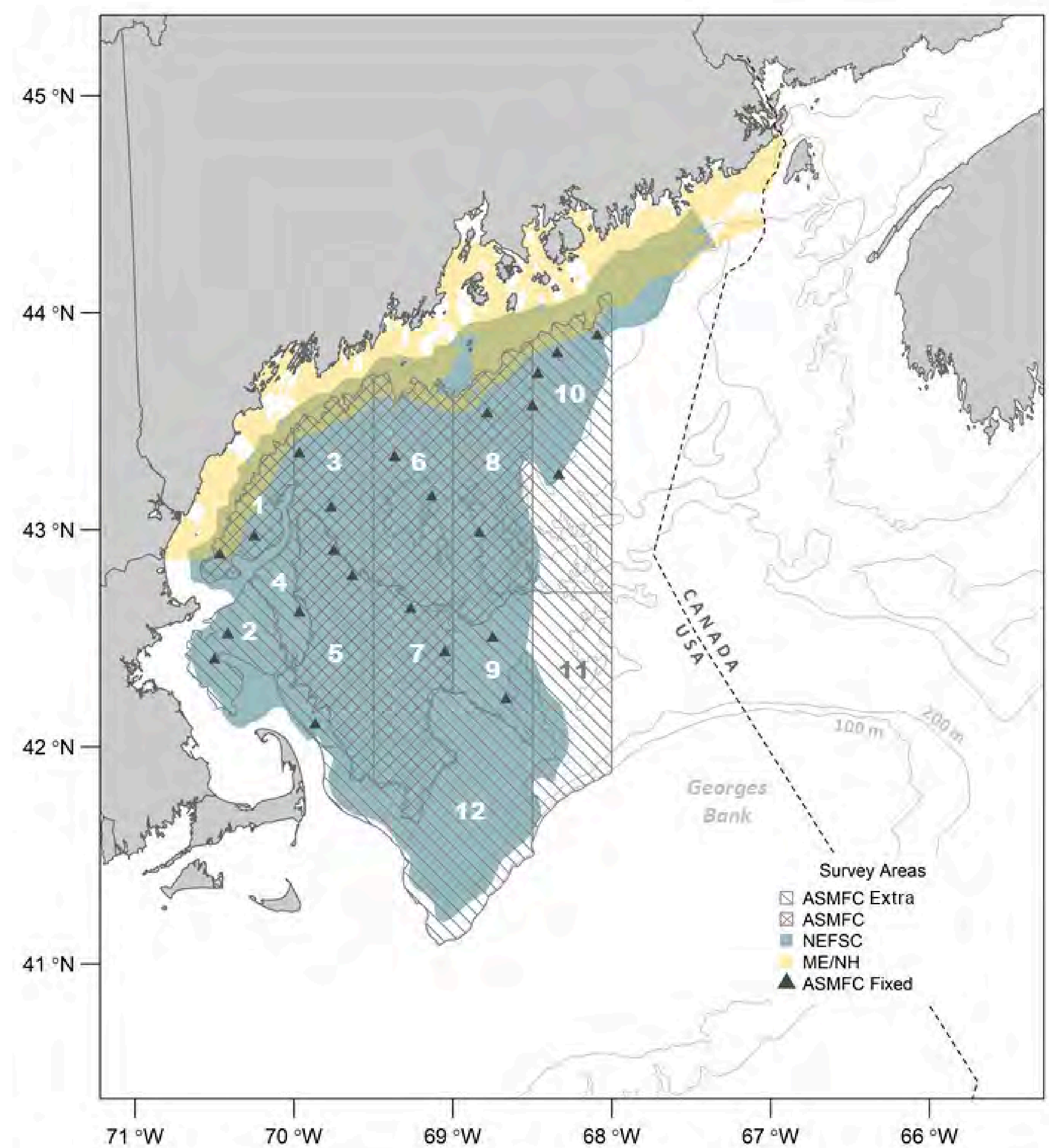


Figure 1. Area covered by the surveys used in the Gulf of Maine northern shrimp assessment. ASMFC extra strata were historically not used to develop the index of abundance, but the current assessment uses all strata.

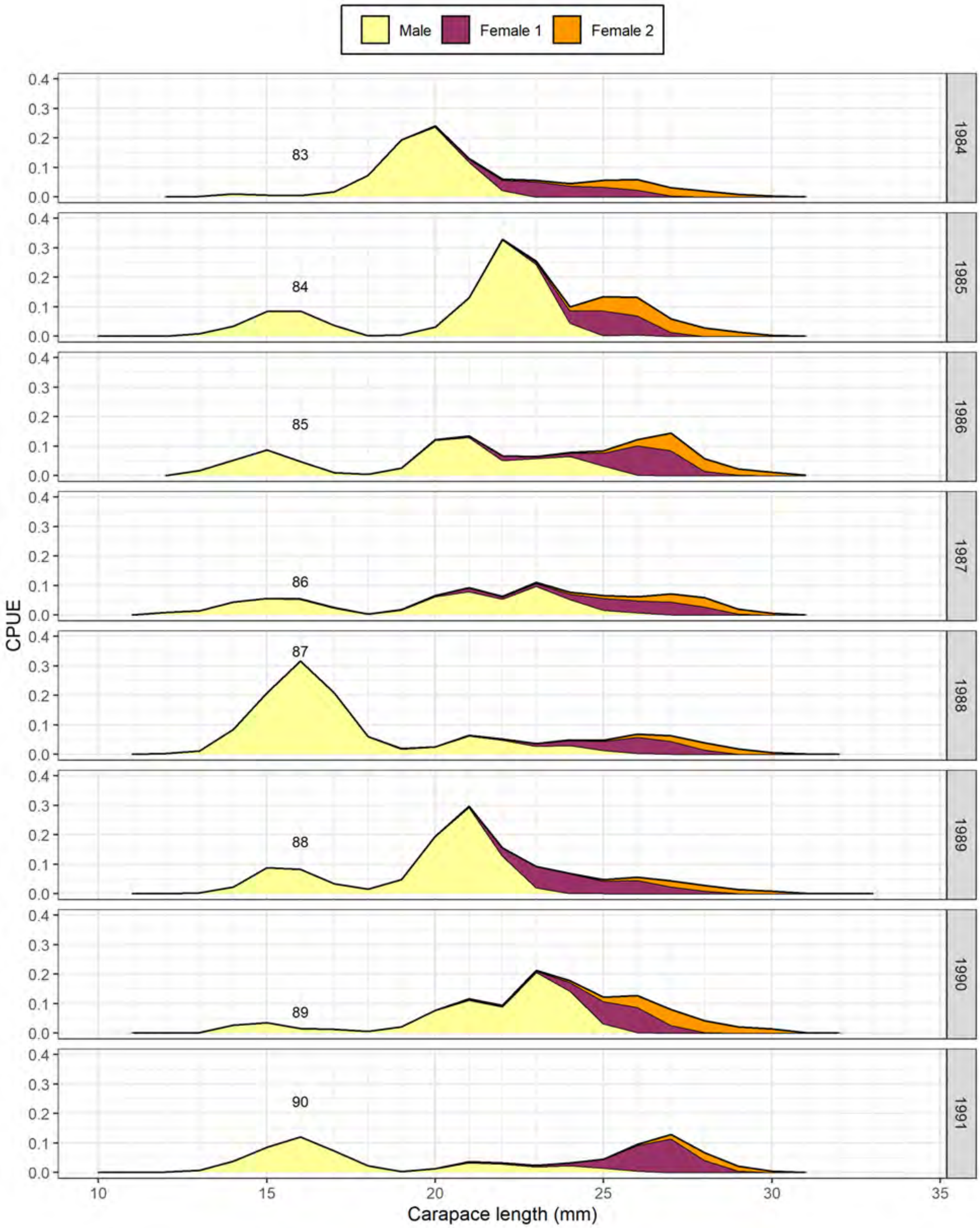


Figure 2. Gulf of Maine northern shrimp Summer Survey index by year, length, and development stage for 1984-2021. Two-digit years on plot indicates year class at assumed age 1.5.

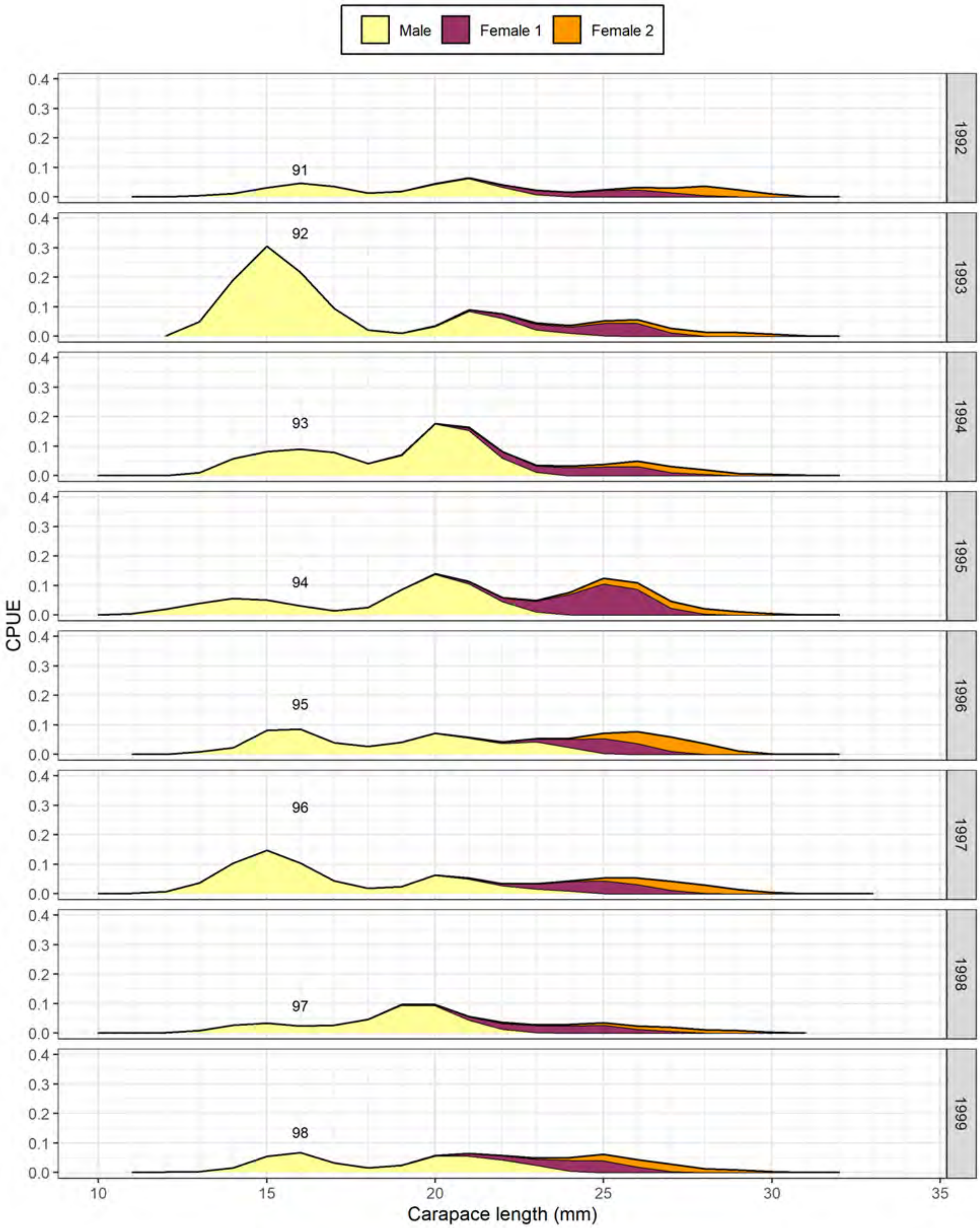


Figure 2 (cont)

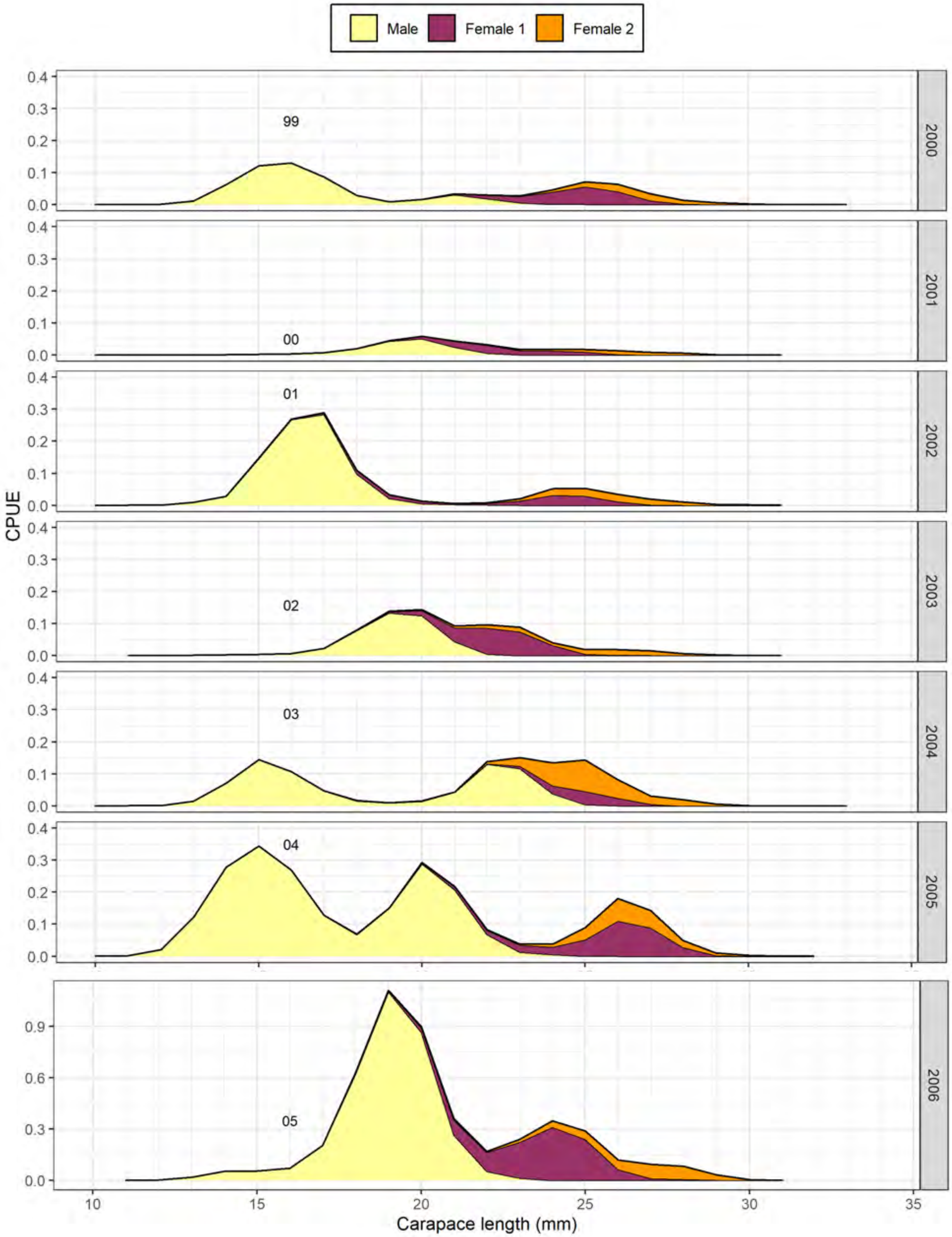


Figure 2 (cont.)

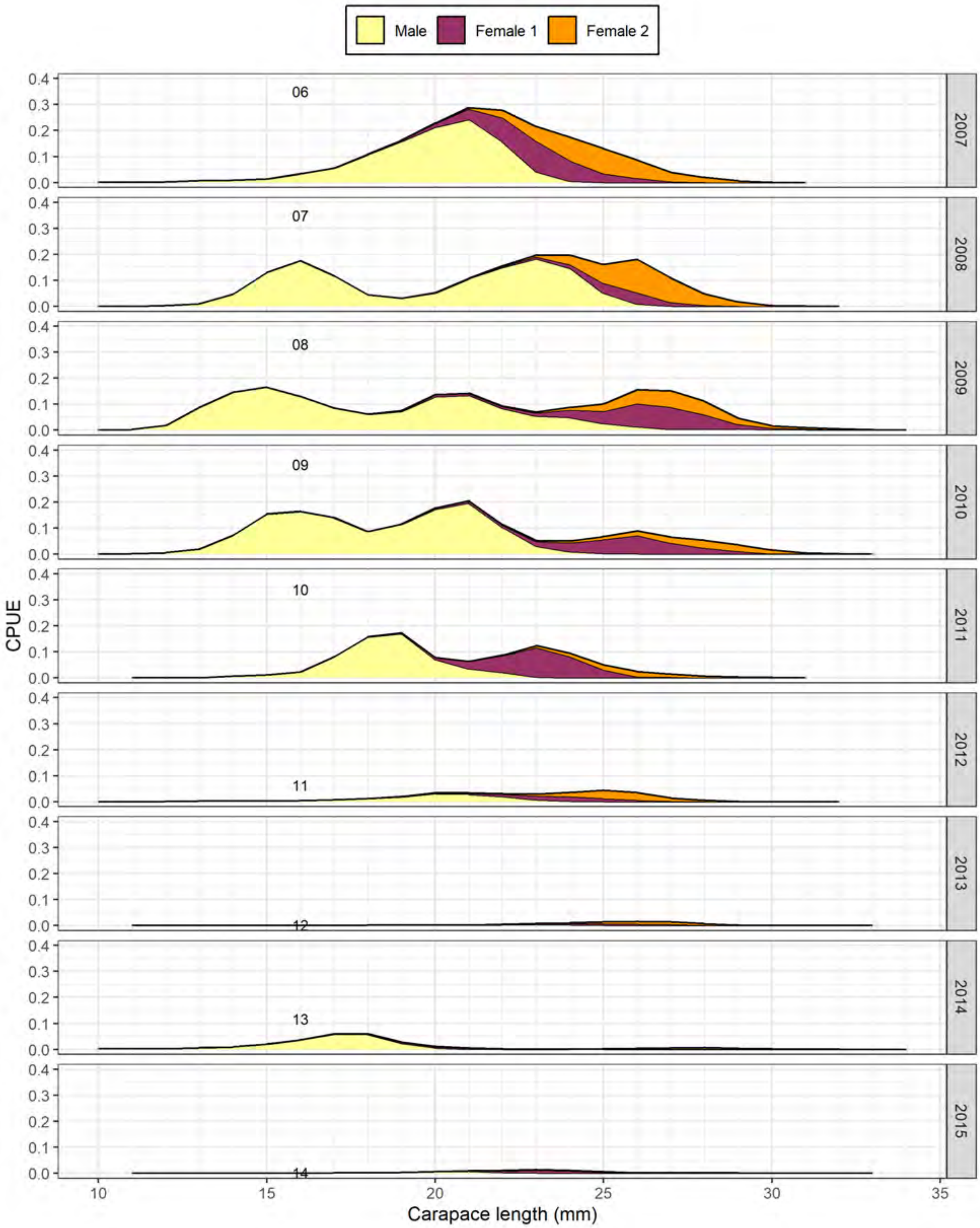


Figure 2 (cont)

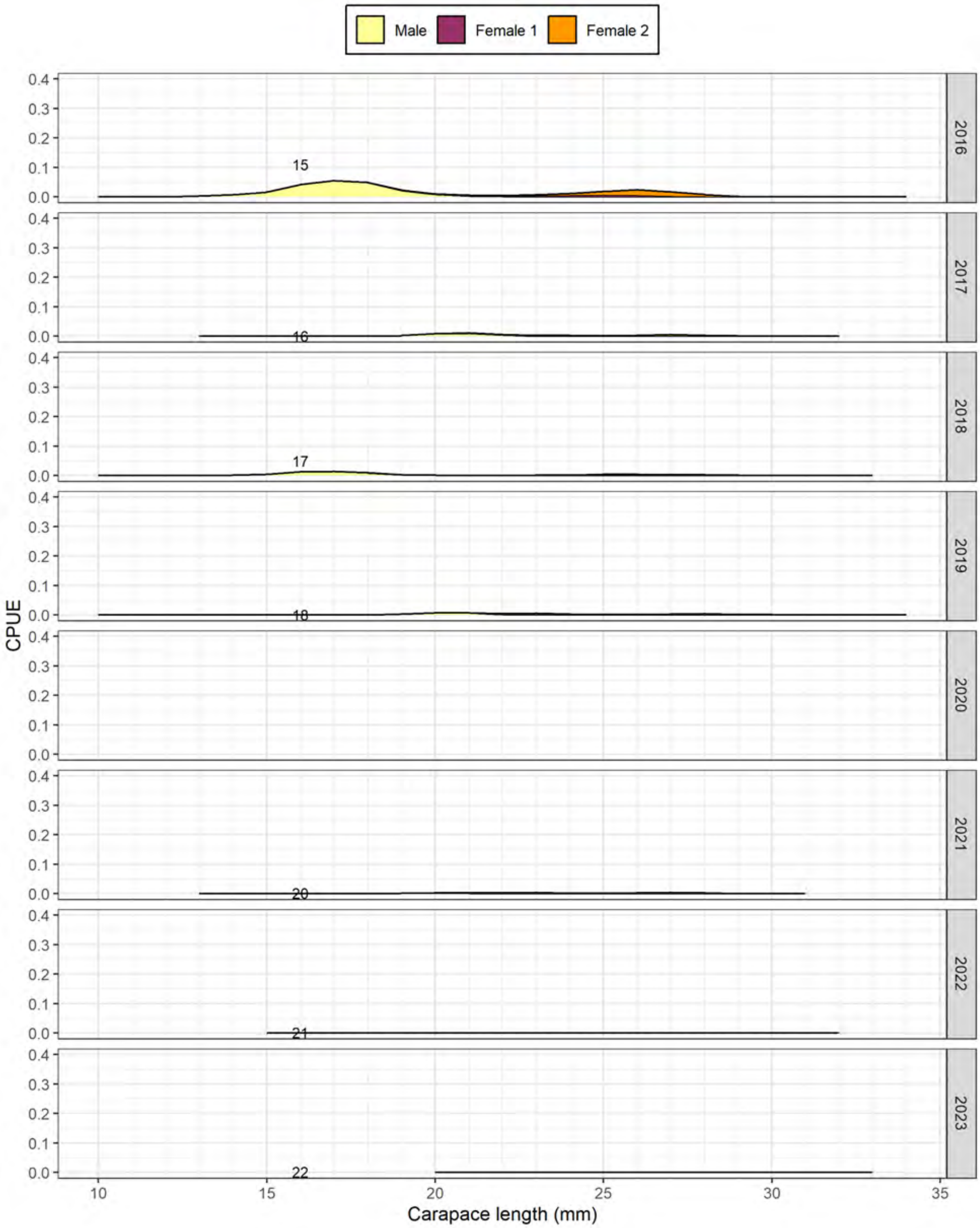


Figure 2 (cont.)

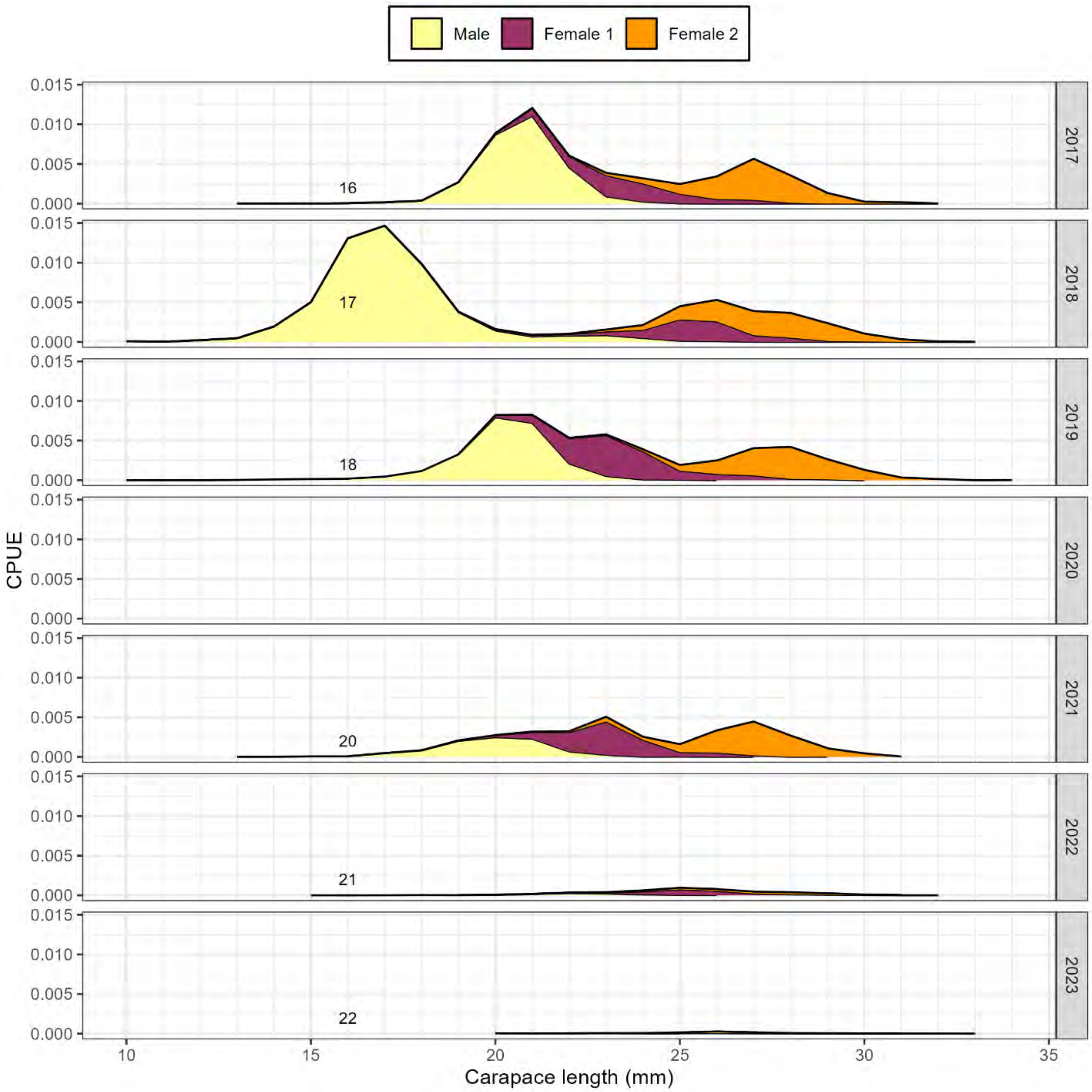


Figure 3. Gulf of Maine northern shrimp Summer Survey abundance by year, length, and development stage for 2017 – 2023 with an expanded axis to show detail. Two-digit years are year class at assumed age 1.5.

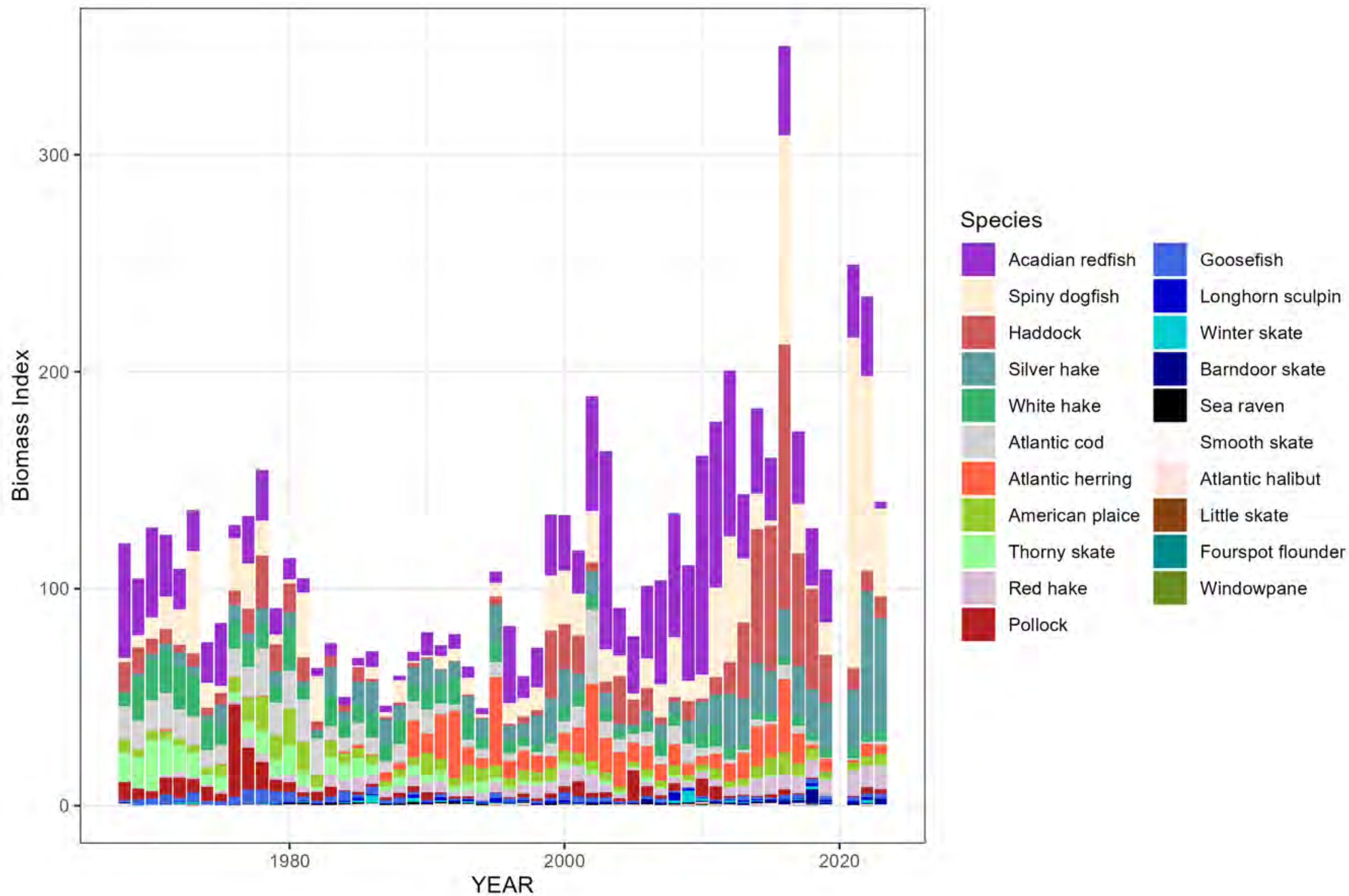
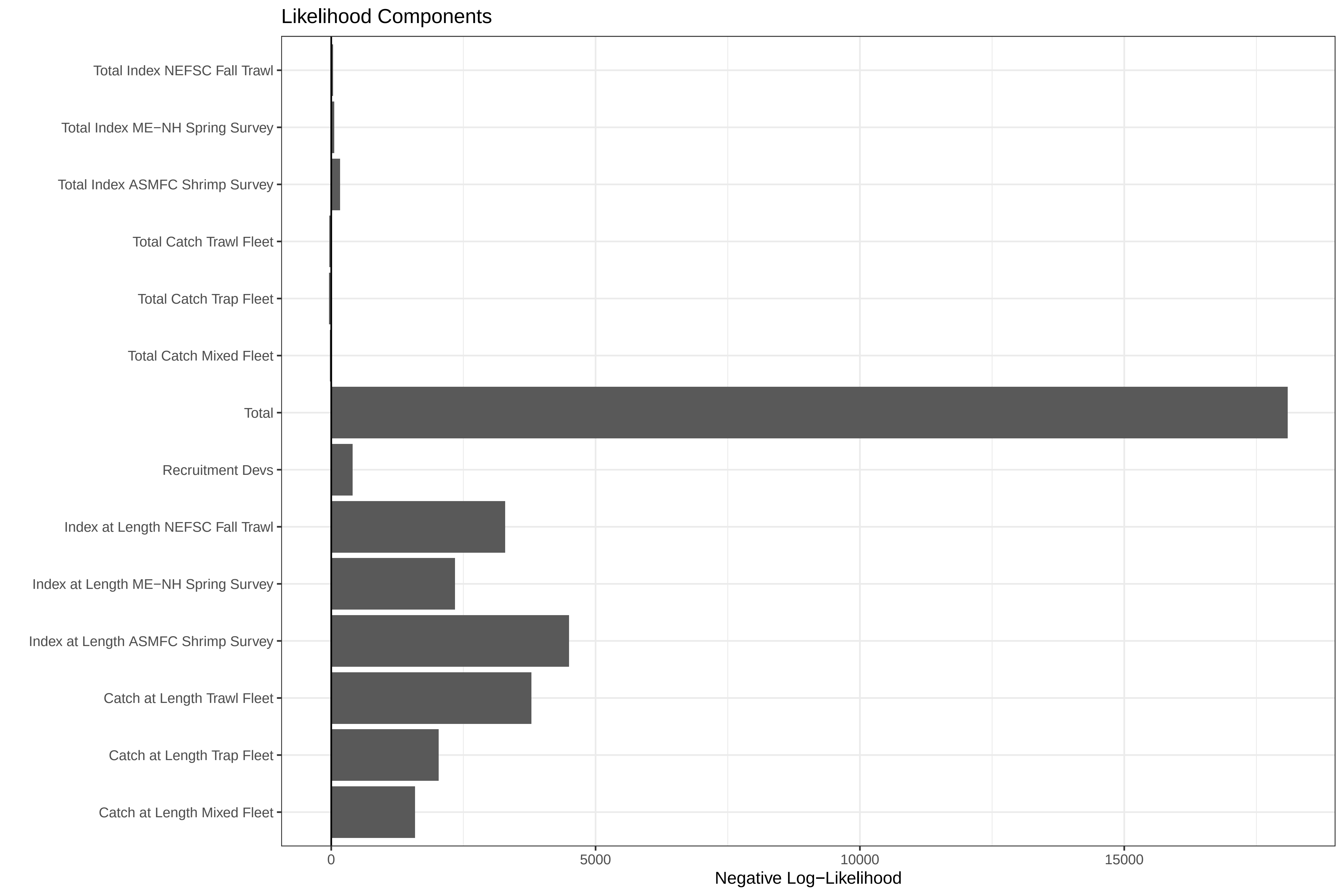
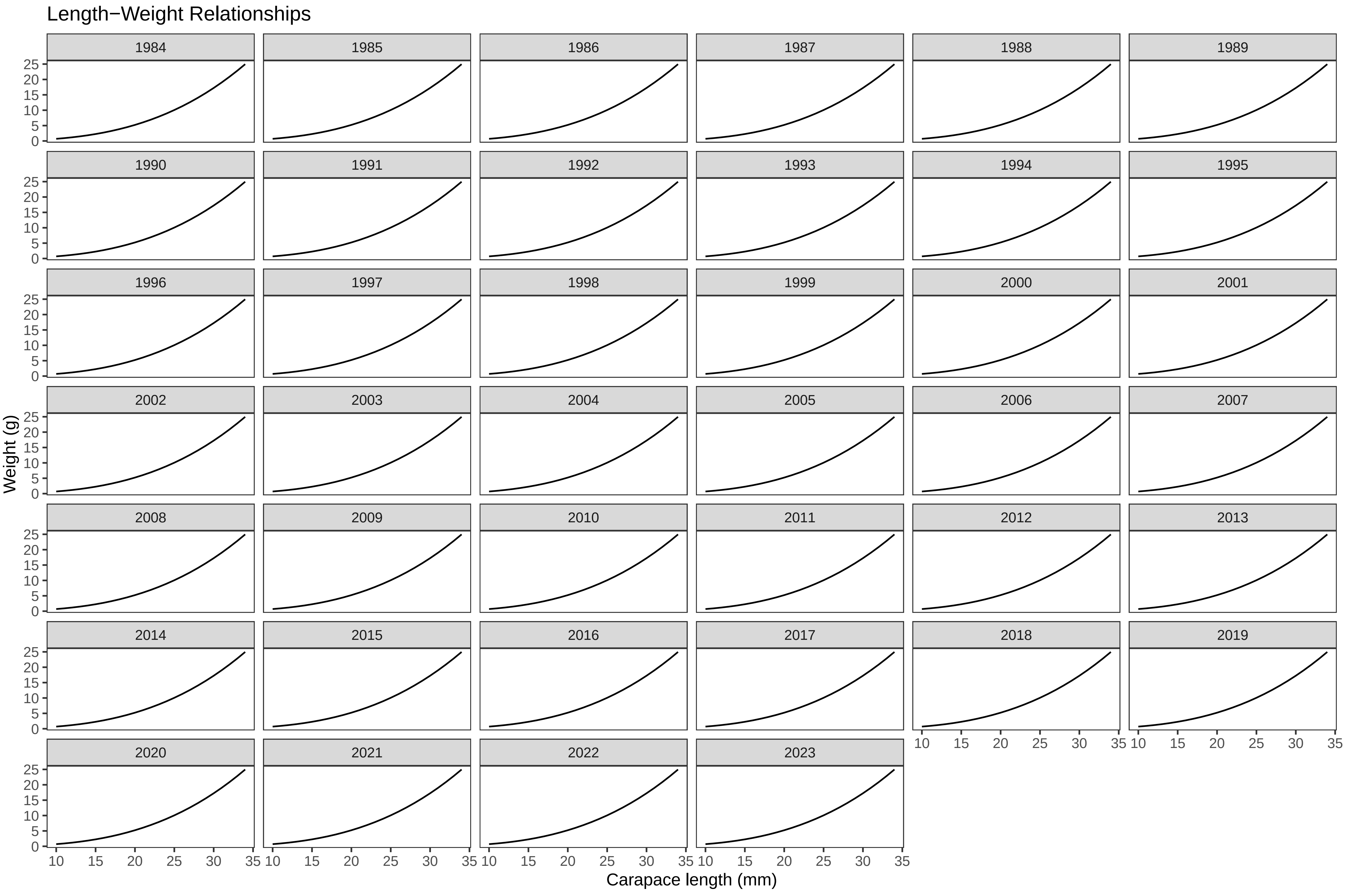


Figure 4. Biomass indices of the key northern shrimp predators used to develop the predation pressure index (PPI) used in the assessment.


Likelihood Components
Total Index NEFSC Fall Trawl
Total Index ME−NH Spring Survey
Total Index ASMFC Shrimp Survey
Total Catch Trawl Fleet
Total Catch Trap Fleet
Total Catch Mixed Fleet
Total
Recruitment Devs
Index at Length NEFSC Fall Trawl
Index at Length ME−NH Spring Survey
Index at Length ASMFC Shrimp Survey
Catch at Length Trawl Fleet
Catch at Length Trap Fleet
Catch at Length Mixed Fleet
0
5000
10000
15000
Negative Log−Likelihood



Length−Weight Relationships
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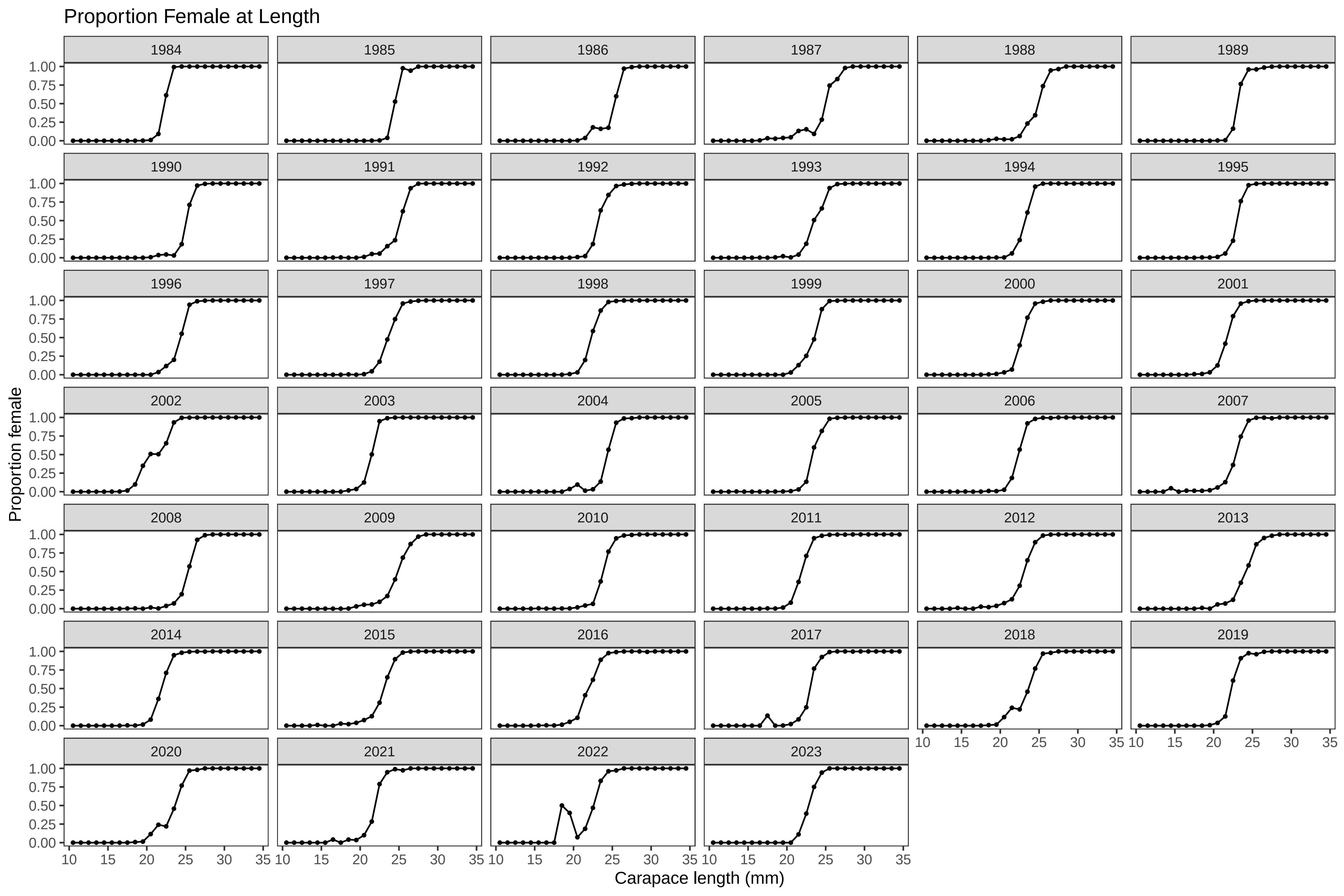
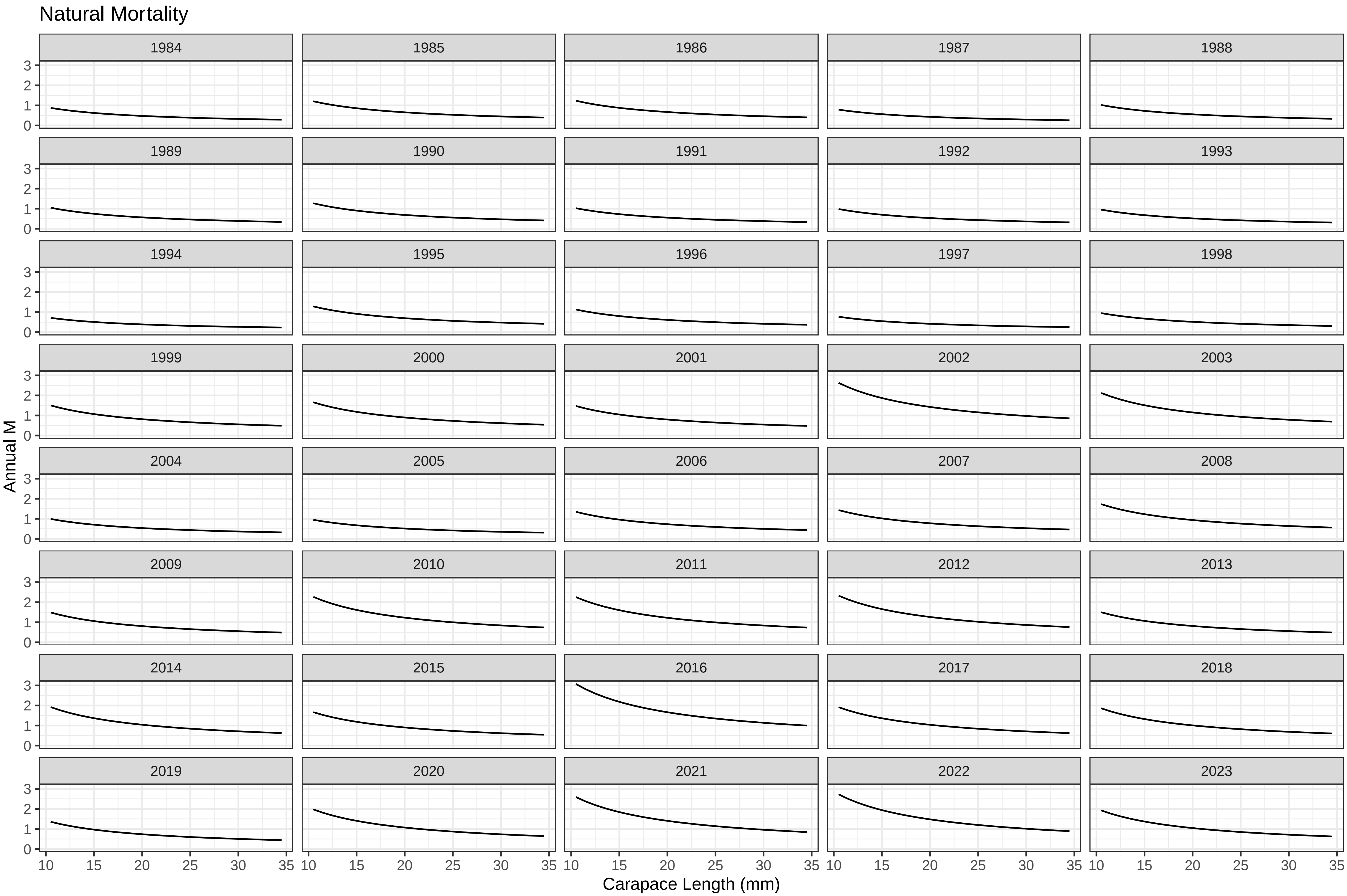
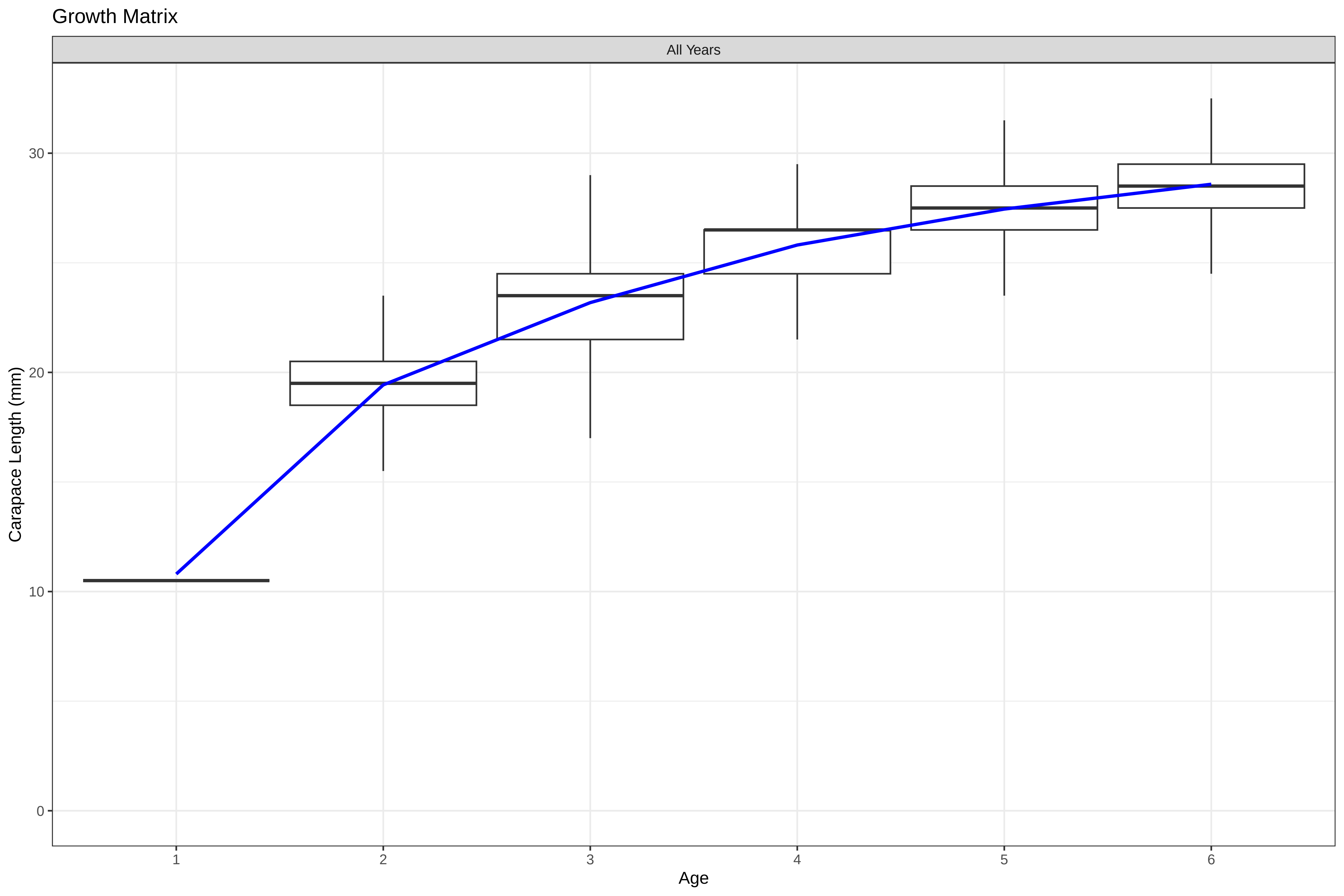
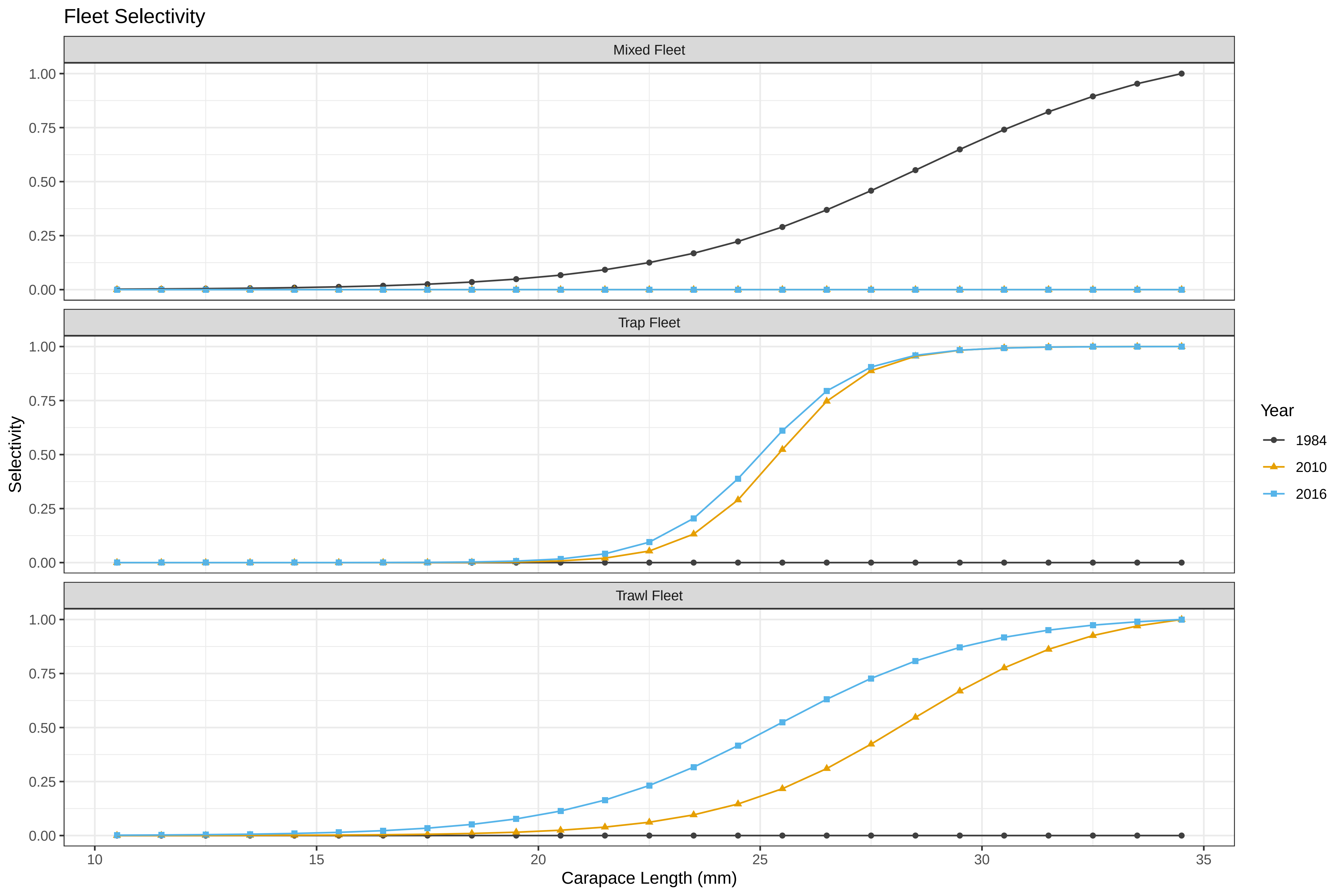
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
Weight (g)
0
5
10
15
20
25
10
15
20
25
30
35
Carapace length (mm)


Proportion Female at Length
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
Proportion female
0.00
0.25
0.50
0.75
1.00
Carapace length (mm)
10
15
20
25
30
35

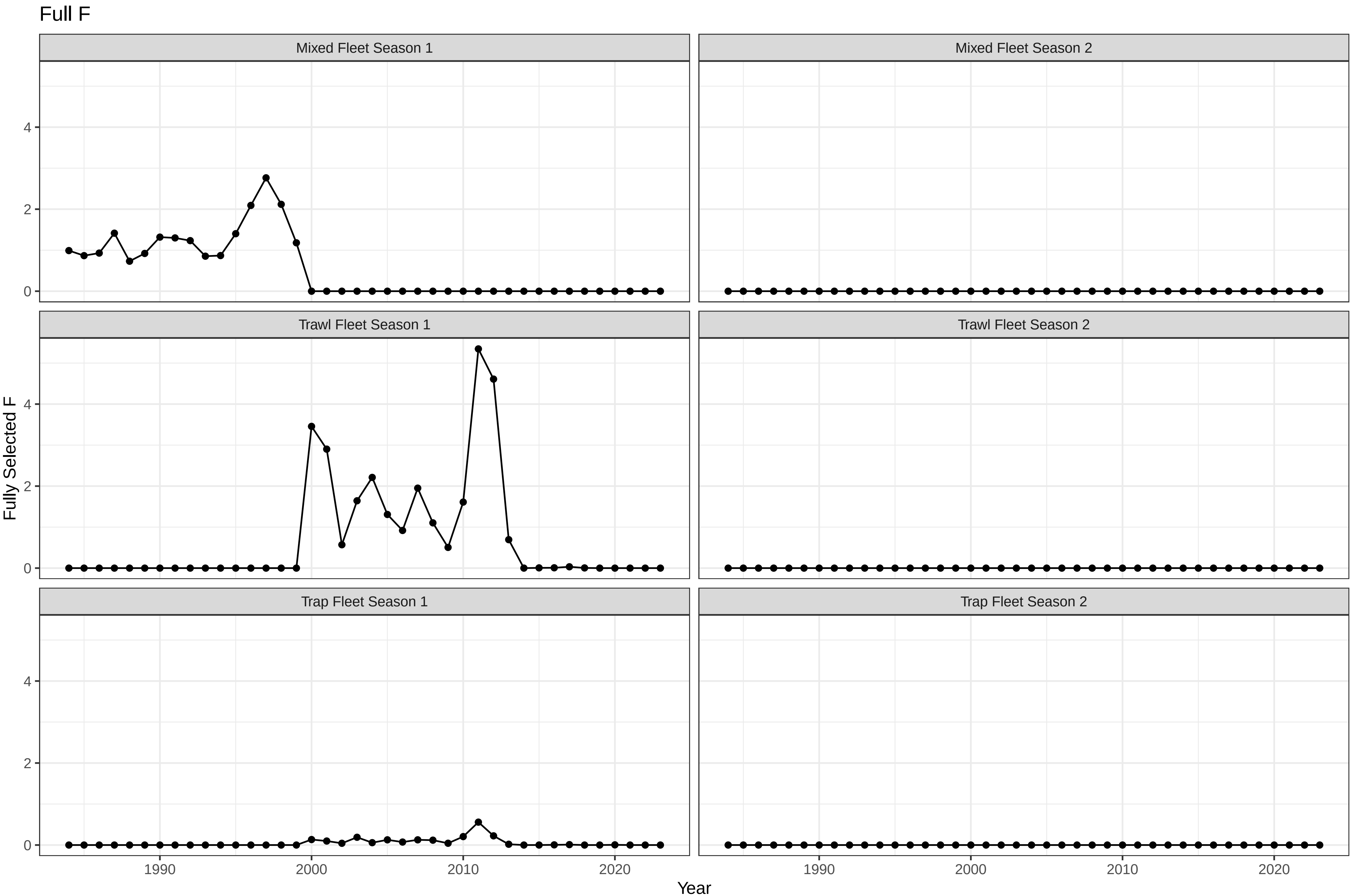

Natural Mortality
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
Annual M
0
1
2
3
10
15
20
25
30
35
Carapace Length (mm)



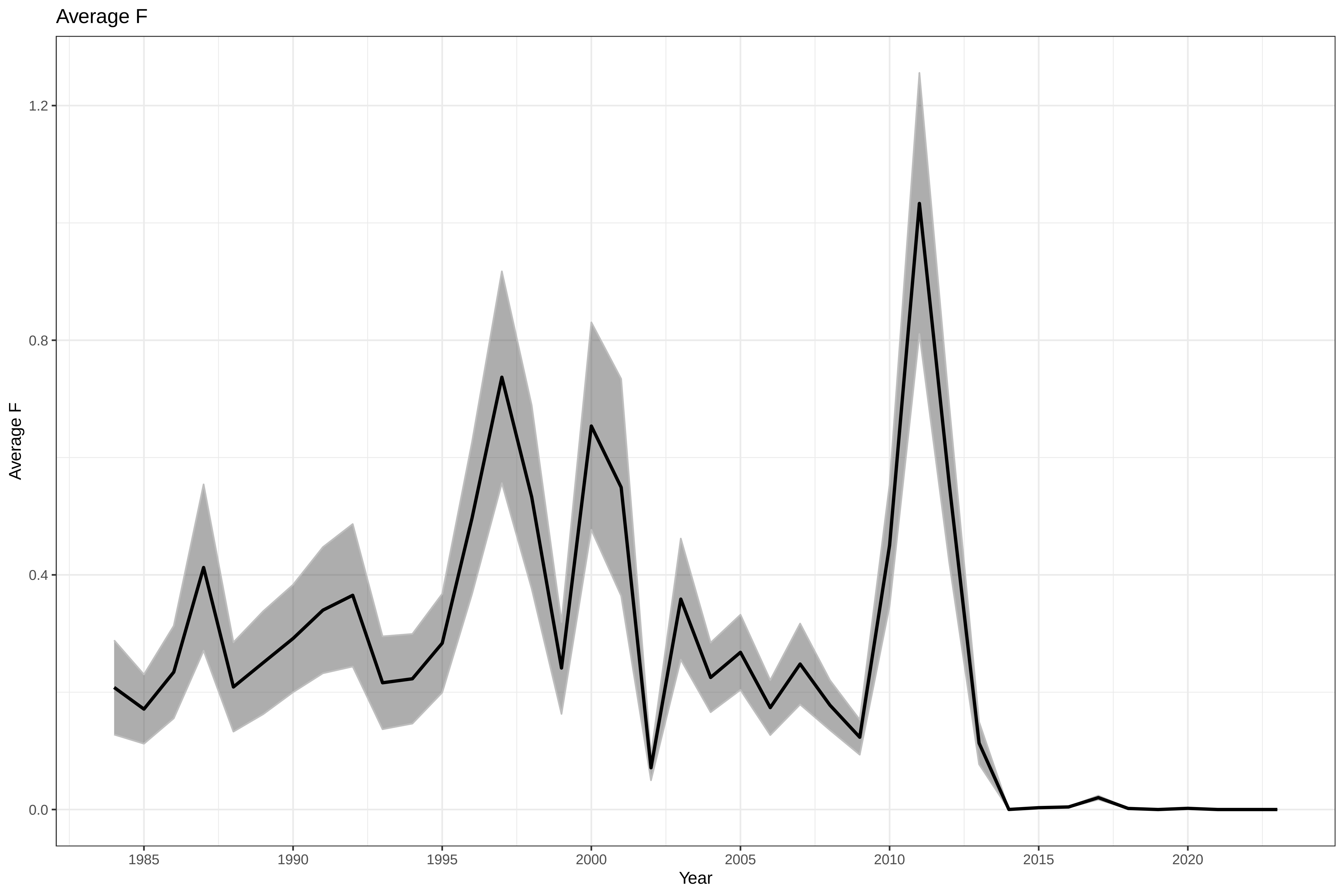
Growth Matrix
All Years
Carapace Length (mm)
30
20
10
0
1
2
3
4
5
6
Age



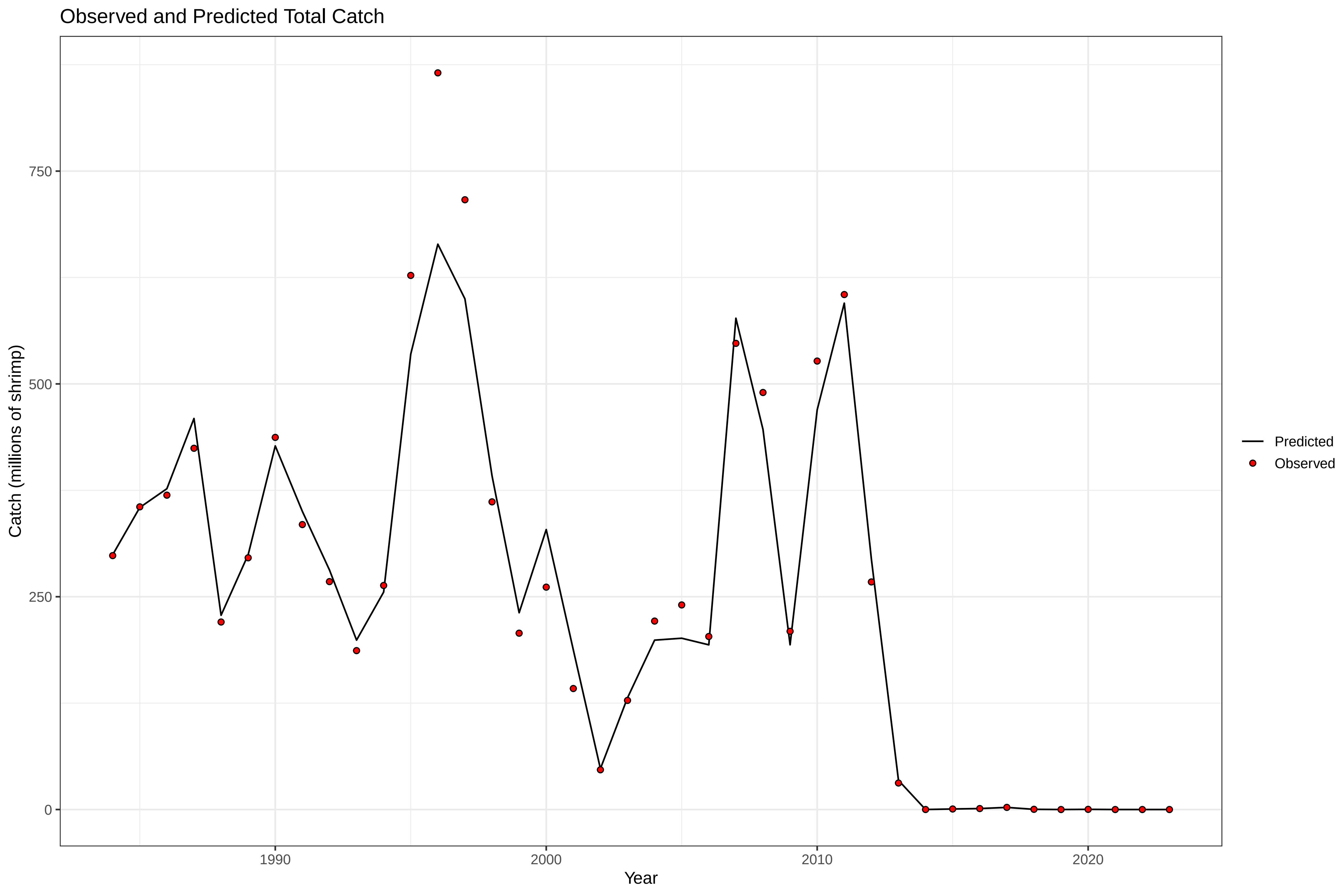
Fleet Selectivity
Mixed Fleet
Trap Fleet
Trawl Fleet
1.00
0.75
0.50
0.25
0.00
Selectivity
10
15
20
25
30
35
Carapace Length (mm)
Year
1984
2010
2016

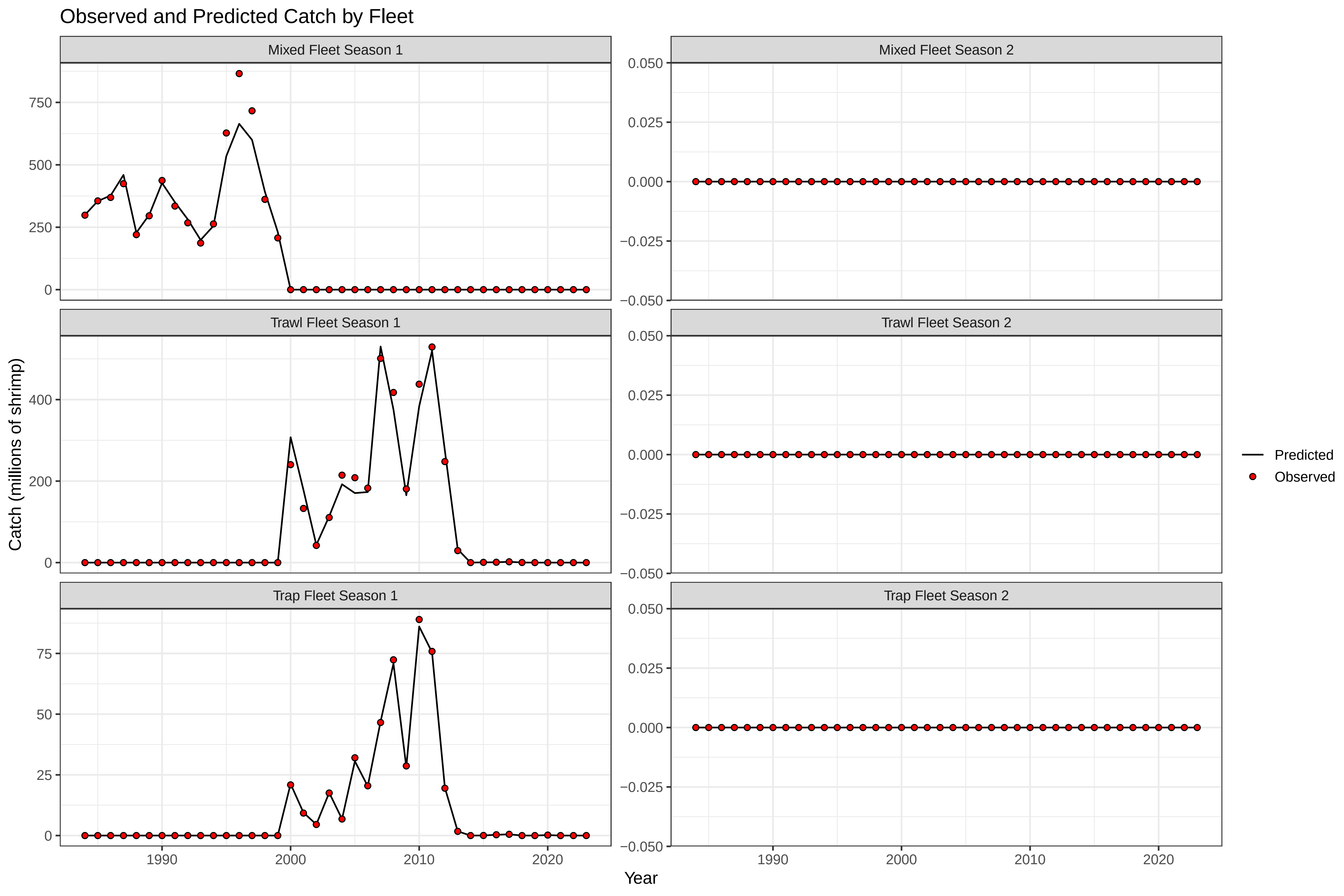


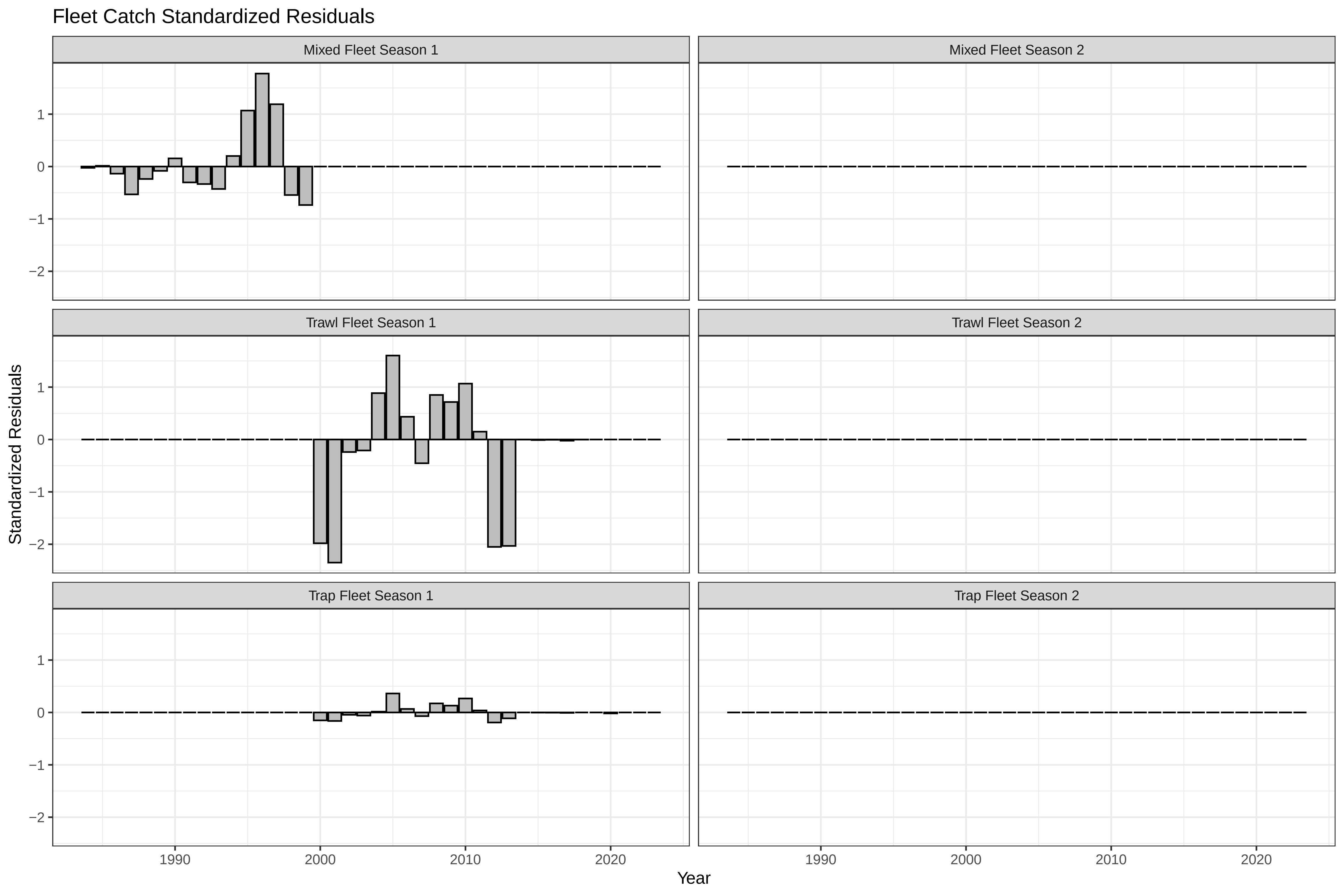
Full F
Mixed Fleet Season 1
Mixed Fleet Season 2
Trawl Fleet Season 1
Trawl Fleet Season 2
Trap Fleet Season 1
Trap Fleet Season 2
Fully Selected F
0
2
4
1990
2000
2010
2020
Year



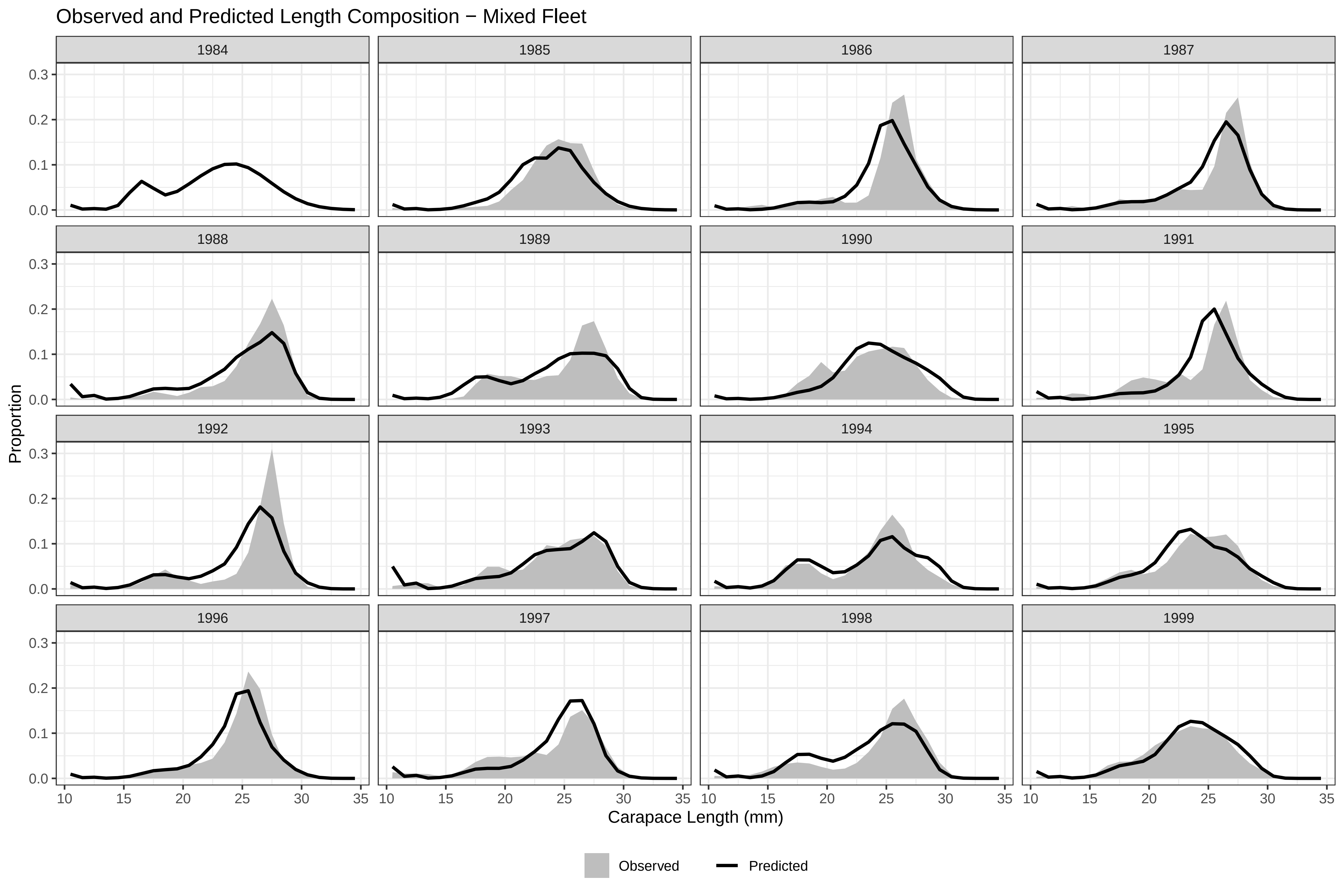
Average F
1.2
0.8
0.4
0.0
Average F
1985
1990
1995
2000
2005
2010
2015
2020
Year

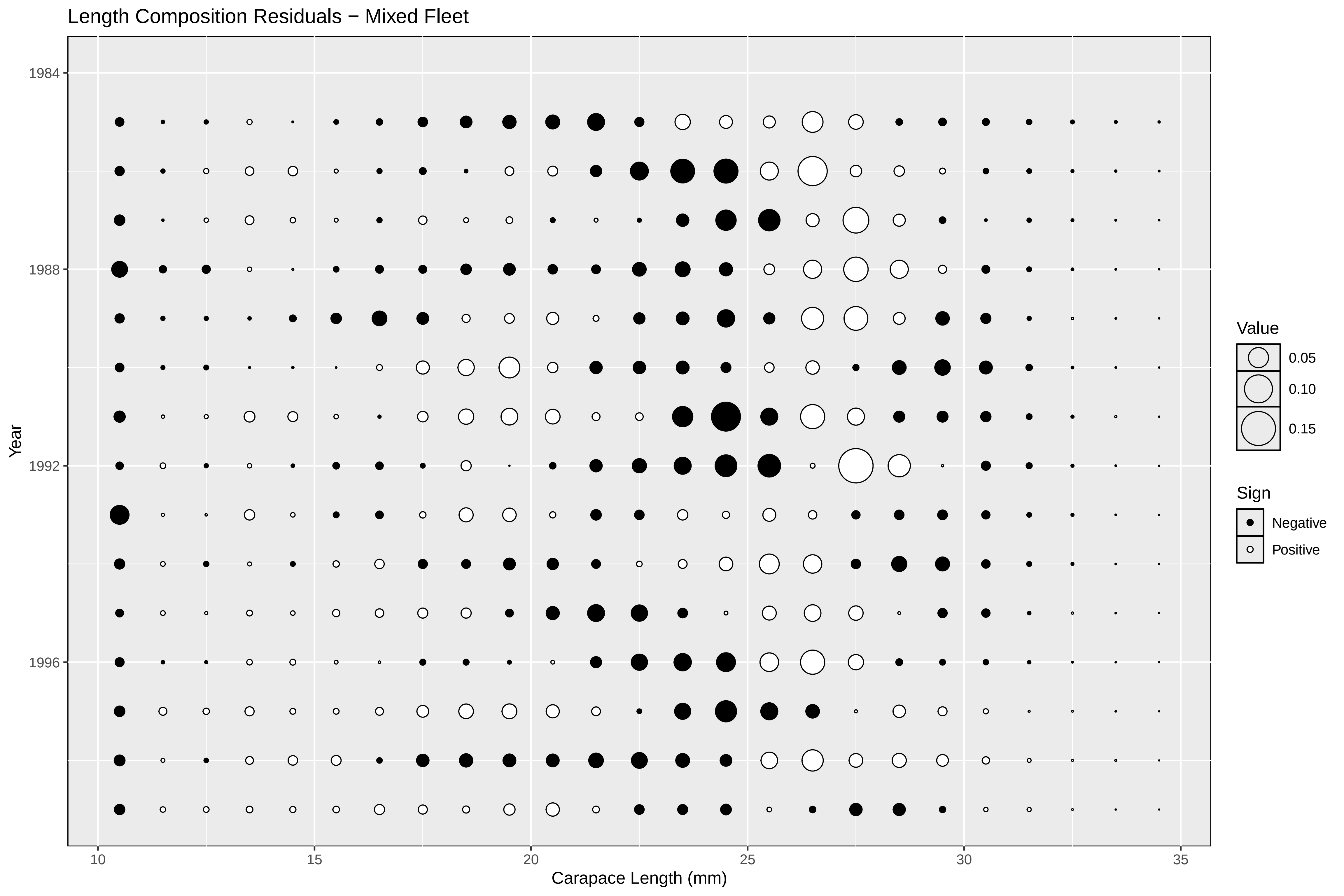

Observed and Predicted Total Catch
750
500
250
0
Catch (millions of shrimp)
1990
2000
2010
2020
Year
Predicted
Observed

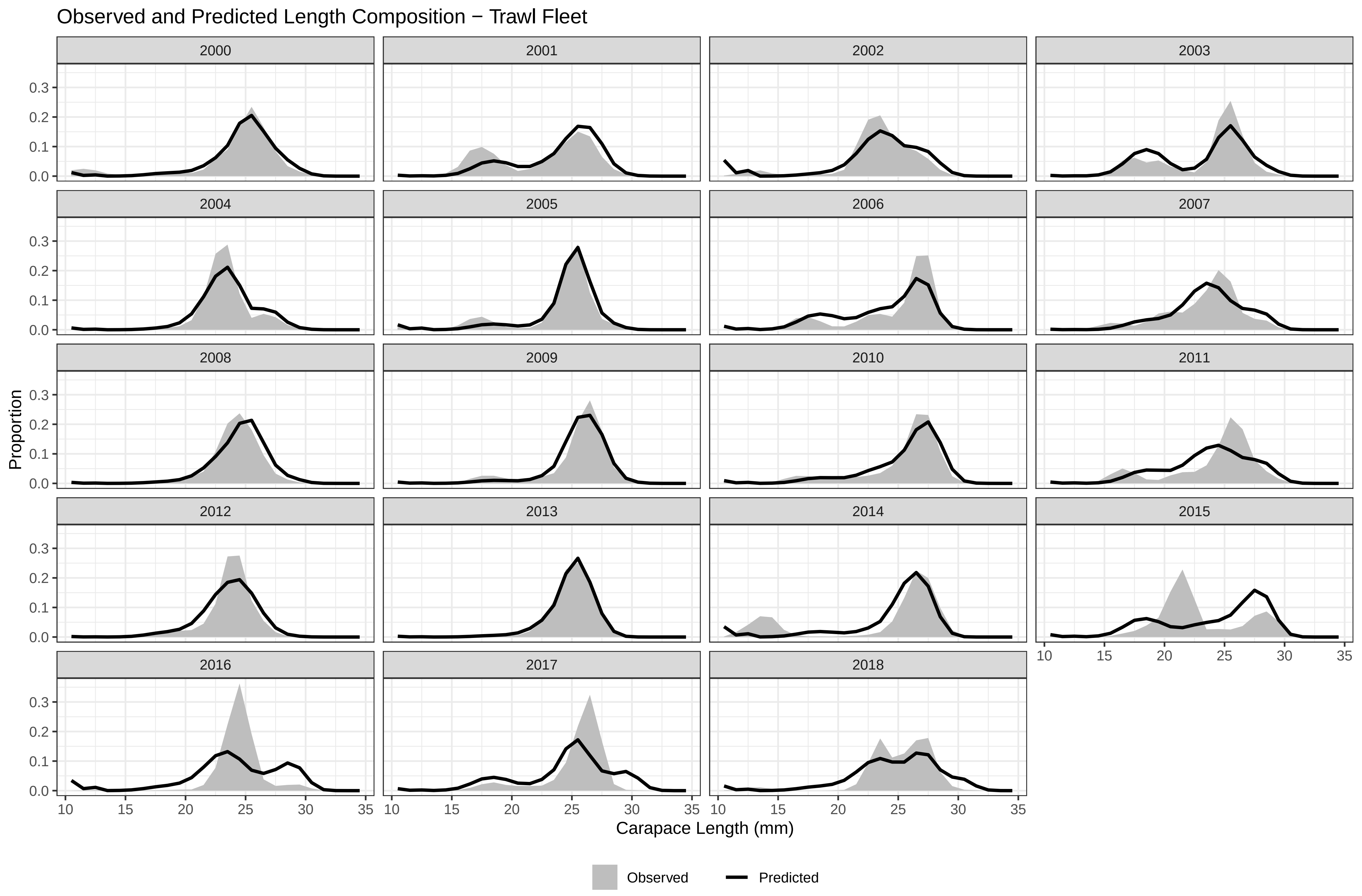

Observed and Predicted Catch by Fleet
Mixed Fleet Season 1
Mixed Fleet Season 2
Trawl Fleet Season 1
Trawl Fleet Season 2
Trap Fleet Season 1
Trap Fleet Season 2
Catch (millions of shrimp)
Year
Predicted
Observed
0
250
500
750
200
400
25
50
75
0.050
0.025
0.000
−0.025
−0.050
1990
2000
2010
2020



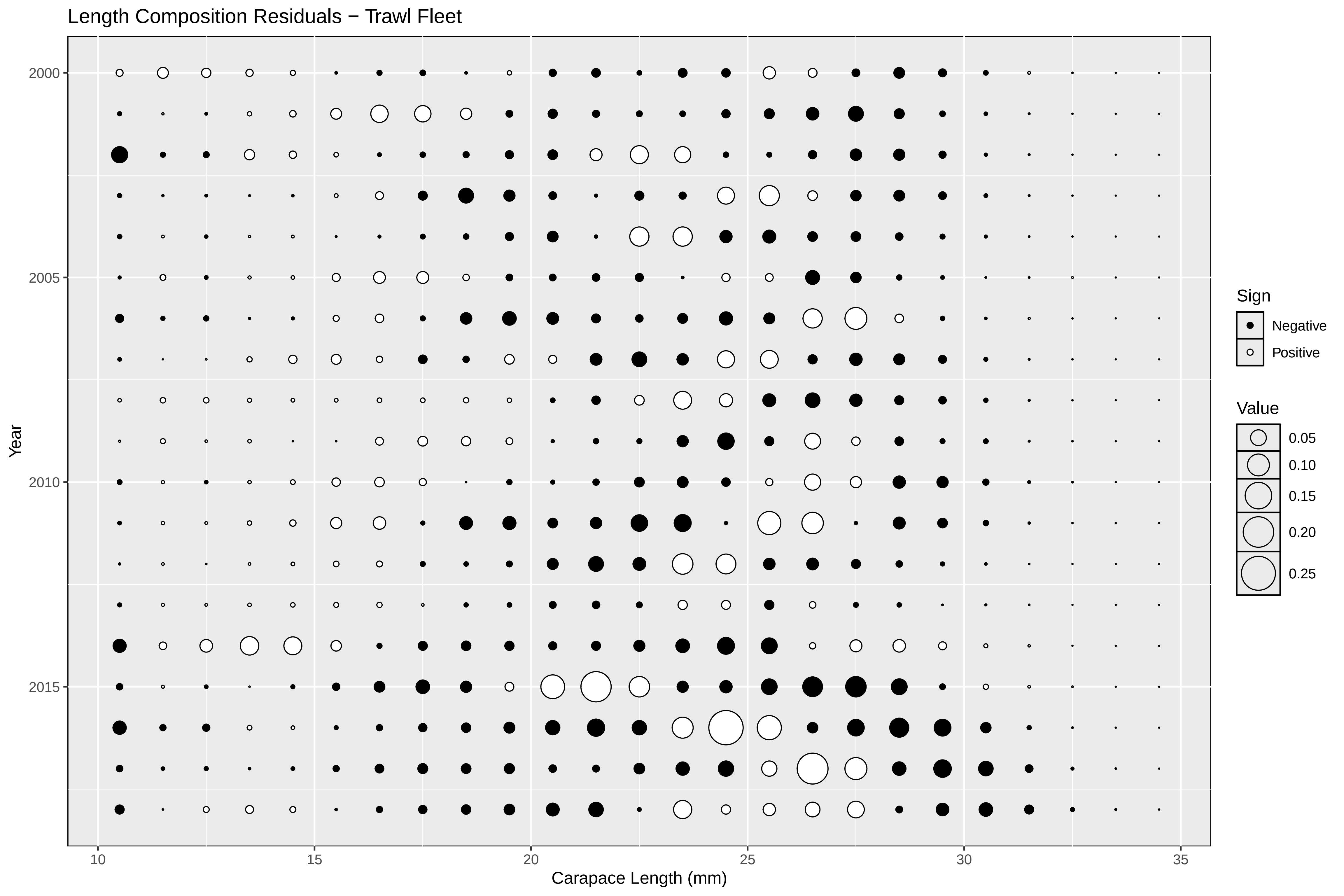
Fleet Catch Standardized Residuals
Mixed Fleet Season 1
Mixed Fleet Season 2
Trawl Fleet Season 1
Trawl Fleet Season 2
Trap Fleet Season 1
Trap Fleet Season 2
Standardized Residuals
1
0
−1
−2
1990
2000
2010
2020
Year


Observed and Predicted Length Composition − Mixed Fleet
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
Proportion
0.0
0.1
0.2
0.3
10
15
20
25
30
35
Carapace Length (mm)
Observed
Predicted

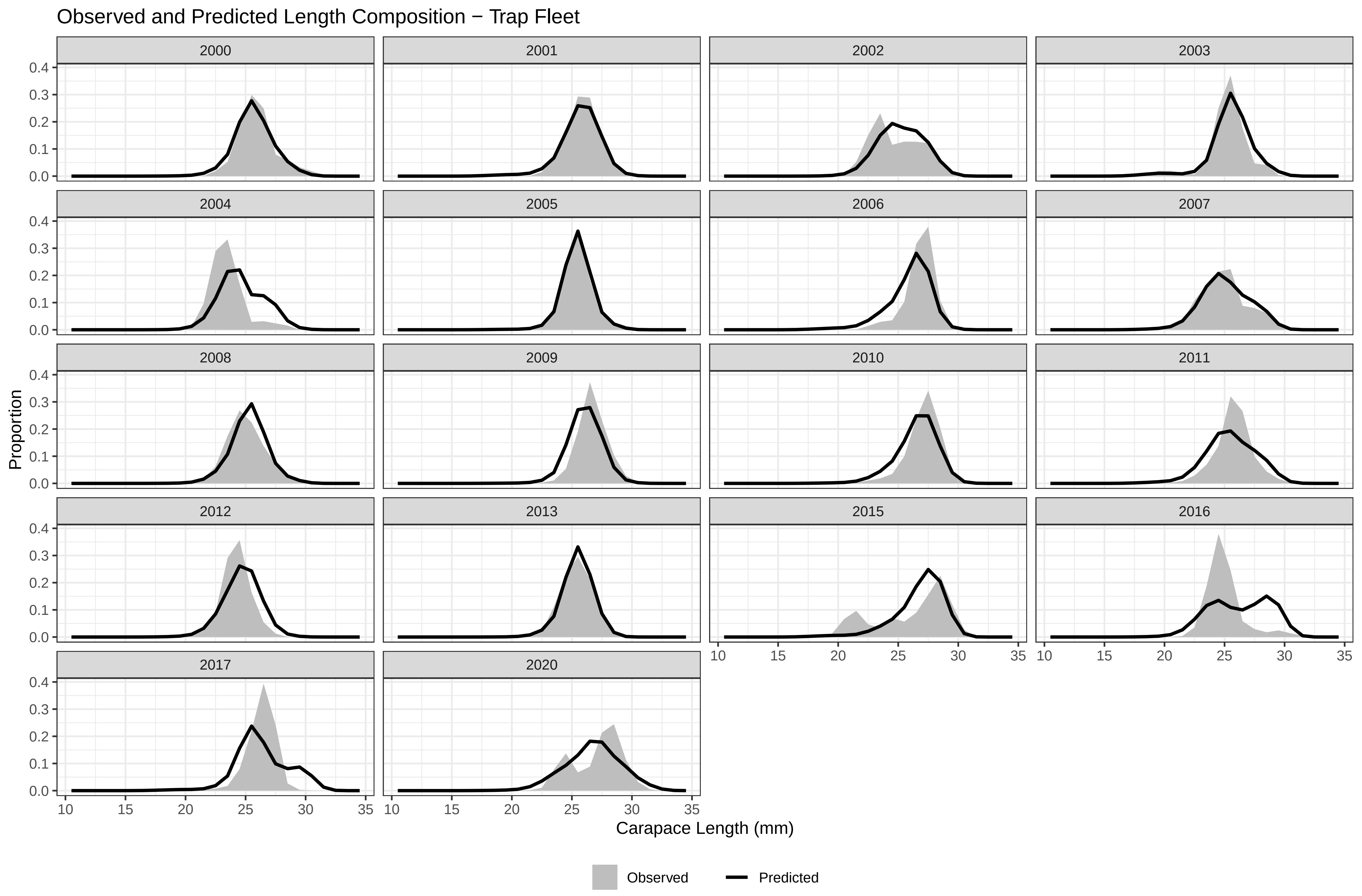

Length Composition Residuals − Mixed Fleet
1984
1988
1992
1996
Year
10
15
20
25
30
35
Carapace Length (mm)
Value
0.05
0.10
0.15
Sign
Negative
Positive



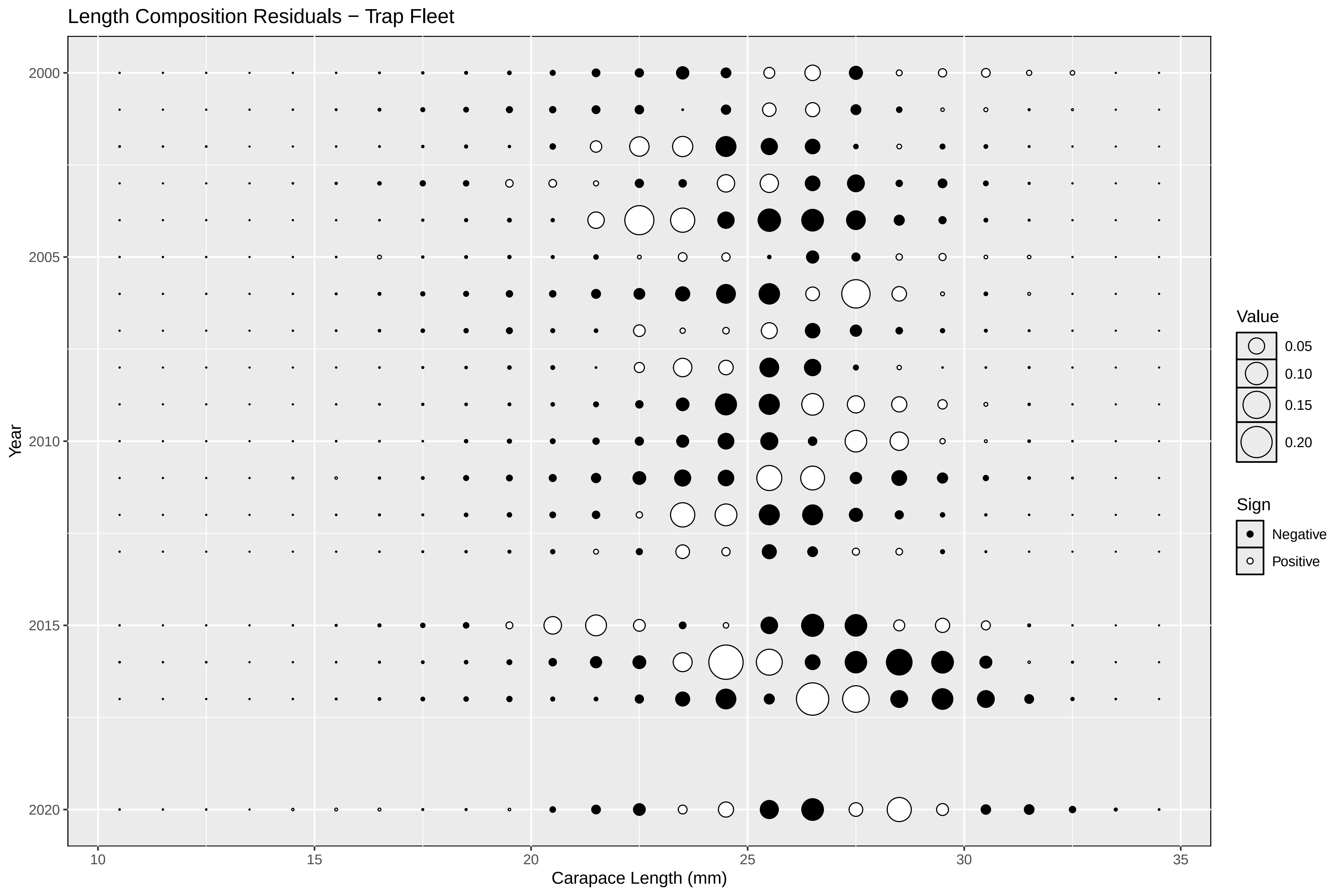
Observed and Predicted Length Composition − Trawl Fleet
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
Proportion
0.0
0.1
0.2
0.3
10
15
20
25
30
35
Carapace Length (mm)
Observed
Predicted



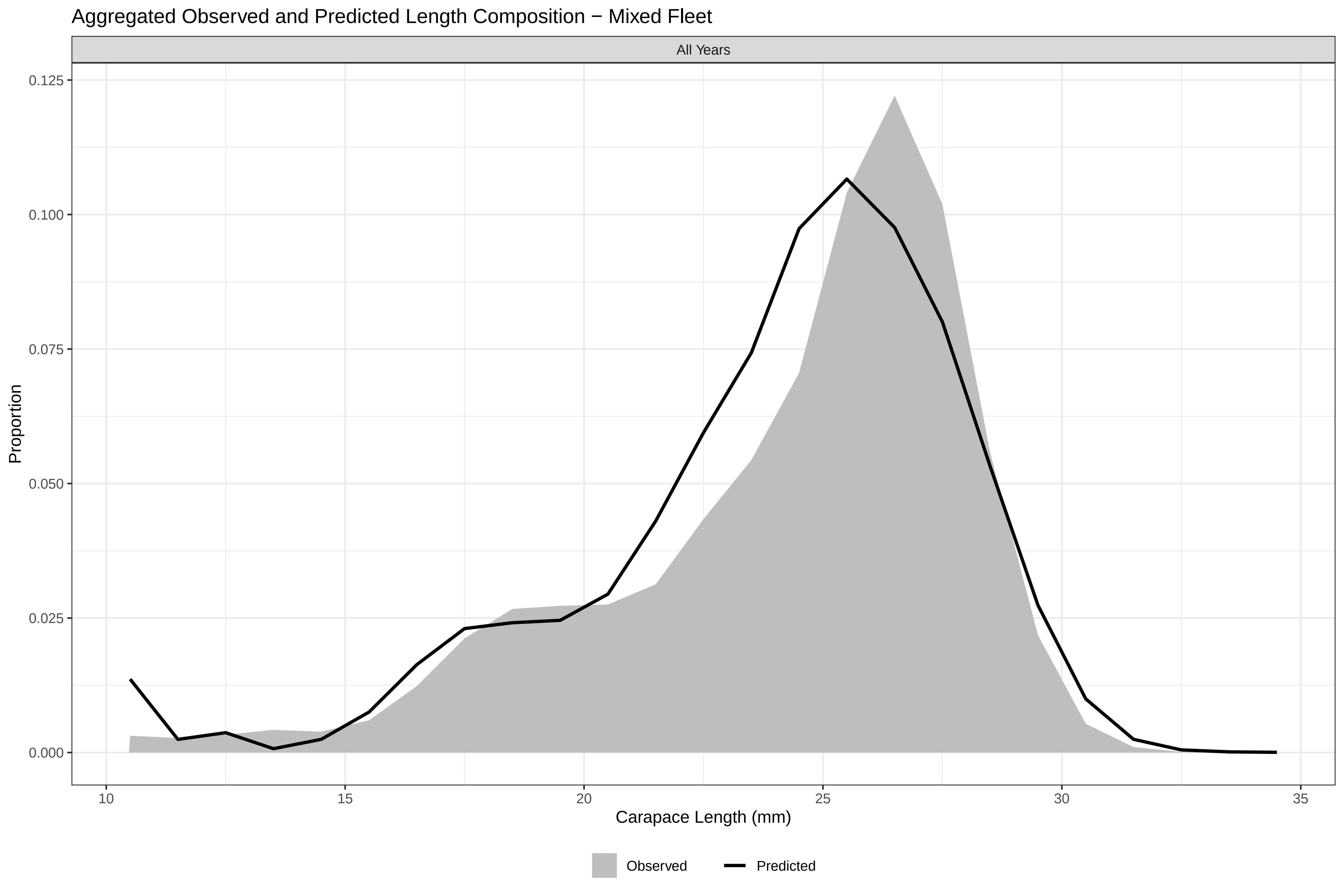
Length Composition Residuals − Trawl Fleet
Year
2000
2005
2010
2015
Carapace Length (mm)
10
15
20
25
30
35
Sign
Negative
Positive
Value
0.05
0.10
0.15
0.20
0.25



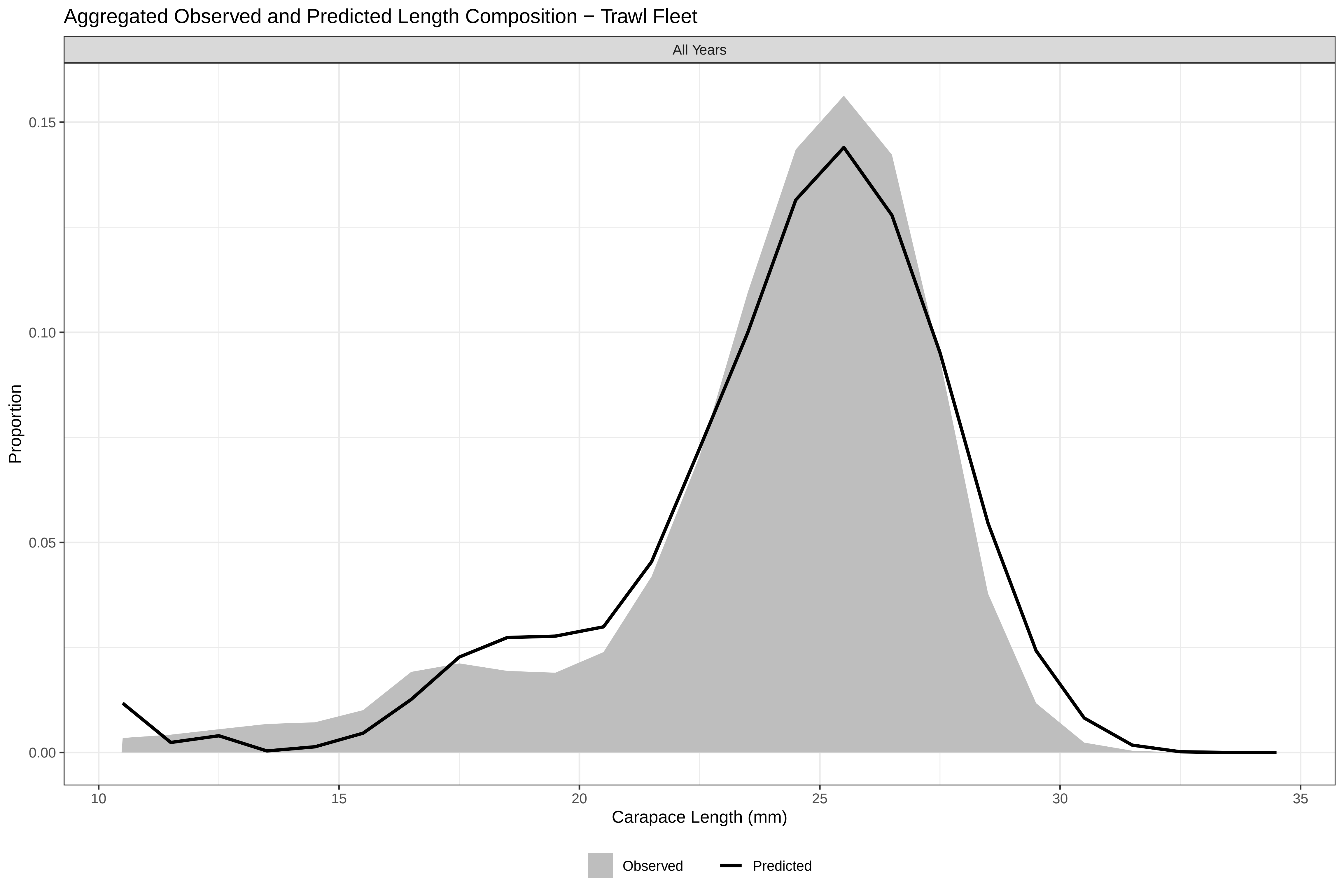
Observed and Predicted Length Composition − Trap Fleet
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2020
Proportion
0.0
0.1
0.2
0.3
0.4
10
15
20
25
30
35
Carapace Length (mm)
Observed
Predicted

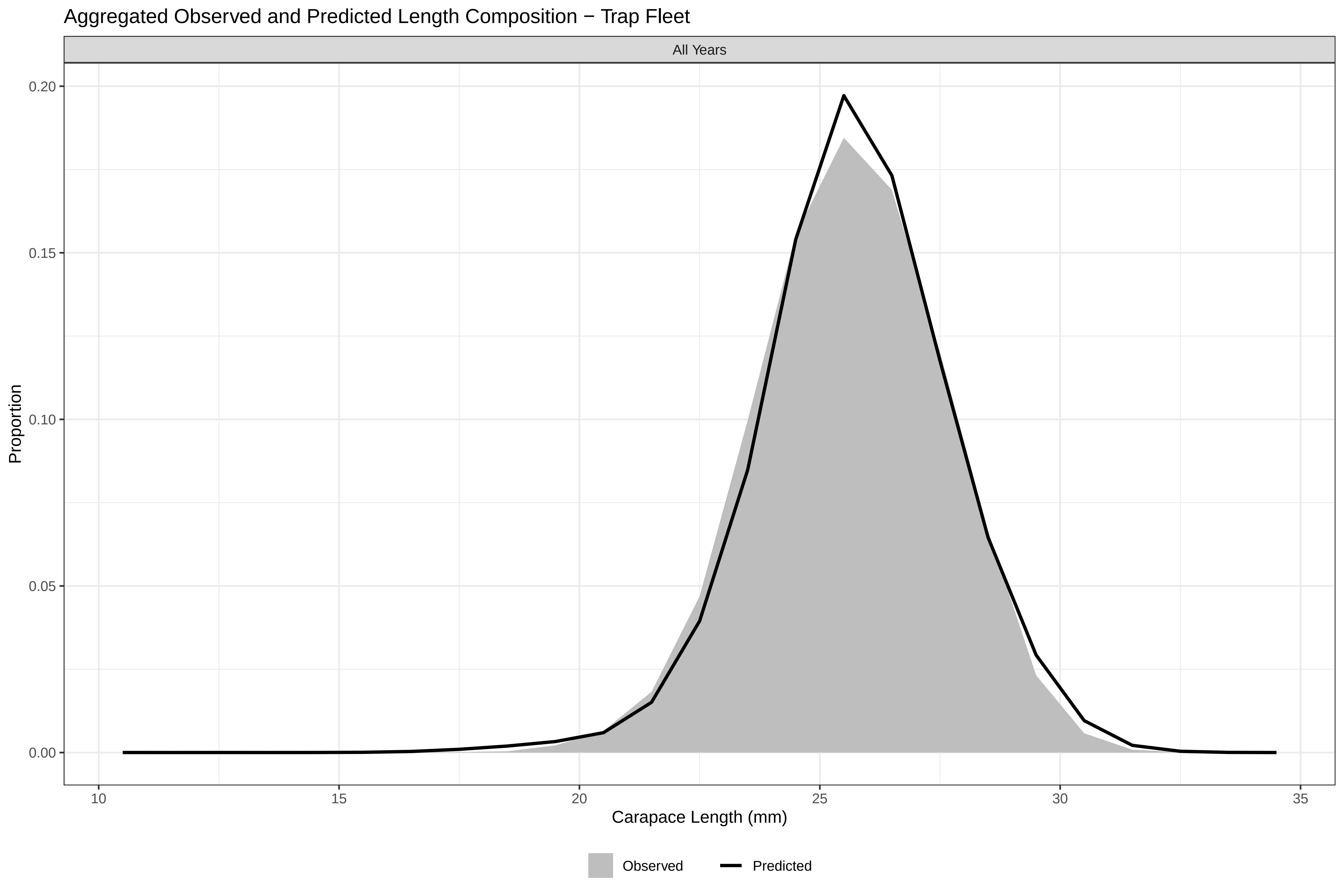


Length Composition Residuals − Trap Fleet
Year
2000
2005
2010
2015
2020
Carapace Length (mm)
10
15
20
25
30
35
Value
0.05
0.10
0.15
0.20
Sign
Negative
Positive

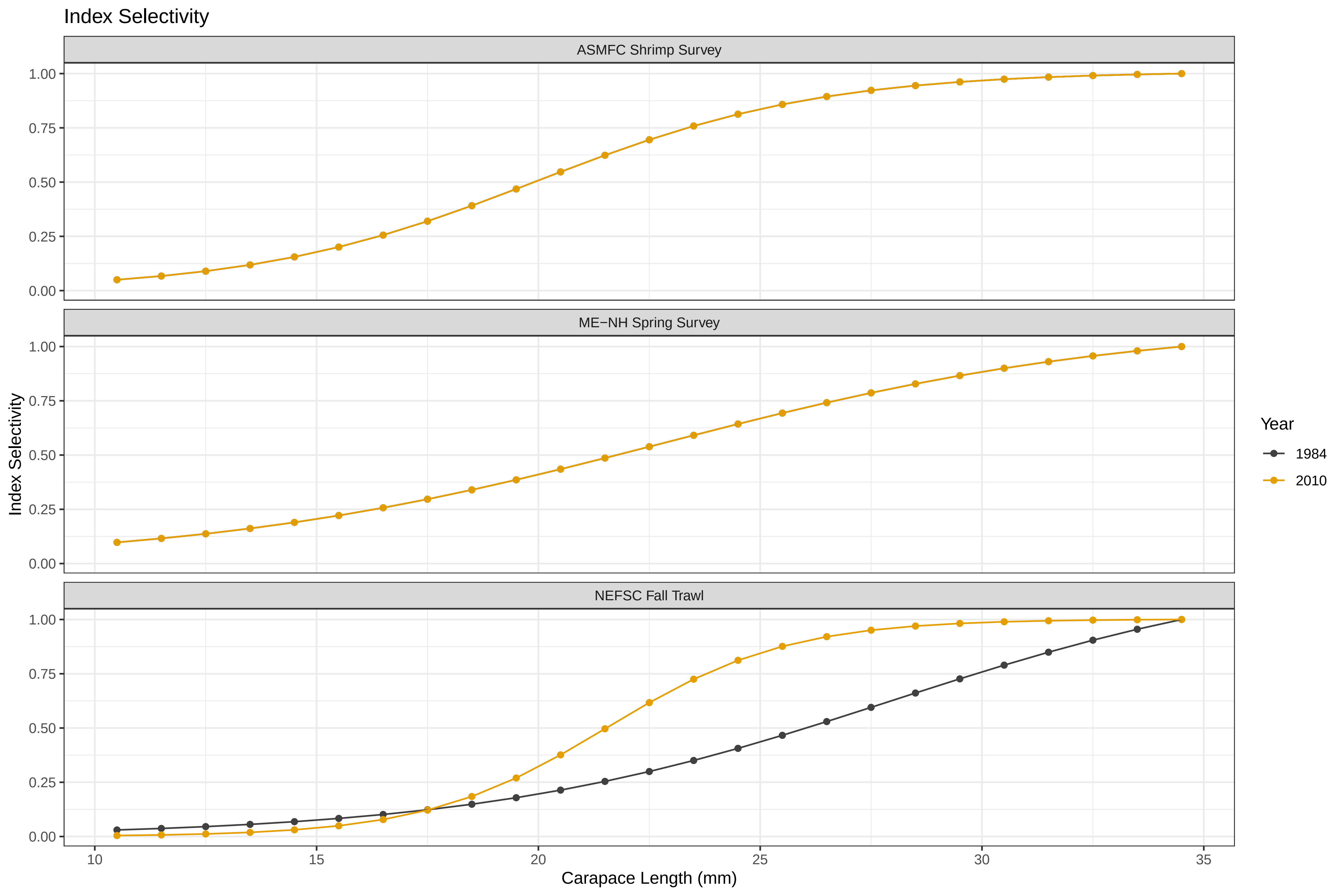


Aggregated Observed and Predicted Length Composition − Mixed Fleet
All Years
Proportion
0.125
0.100
0.075
0.050
0.025
0.000
10
15
20
25
30
35
Carapace Length (mm)
Observed
Predicted

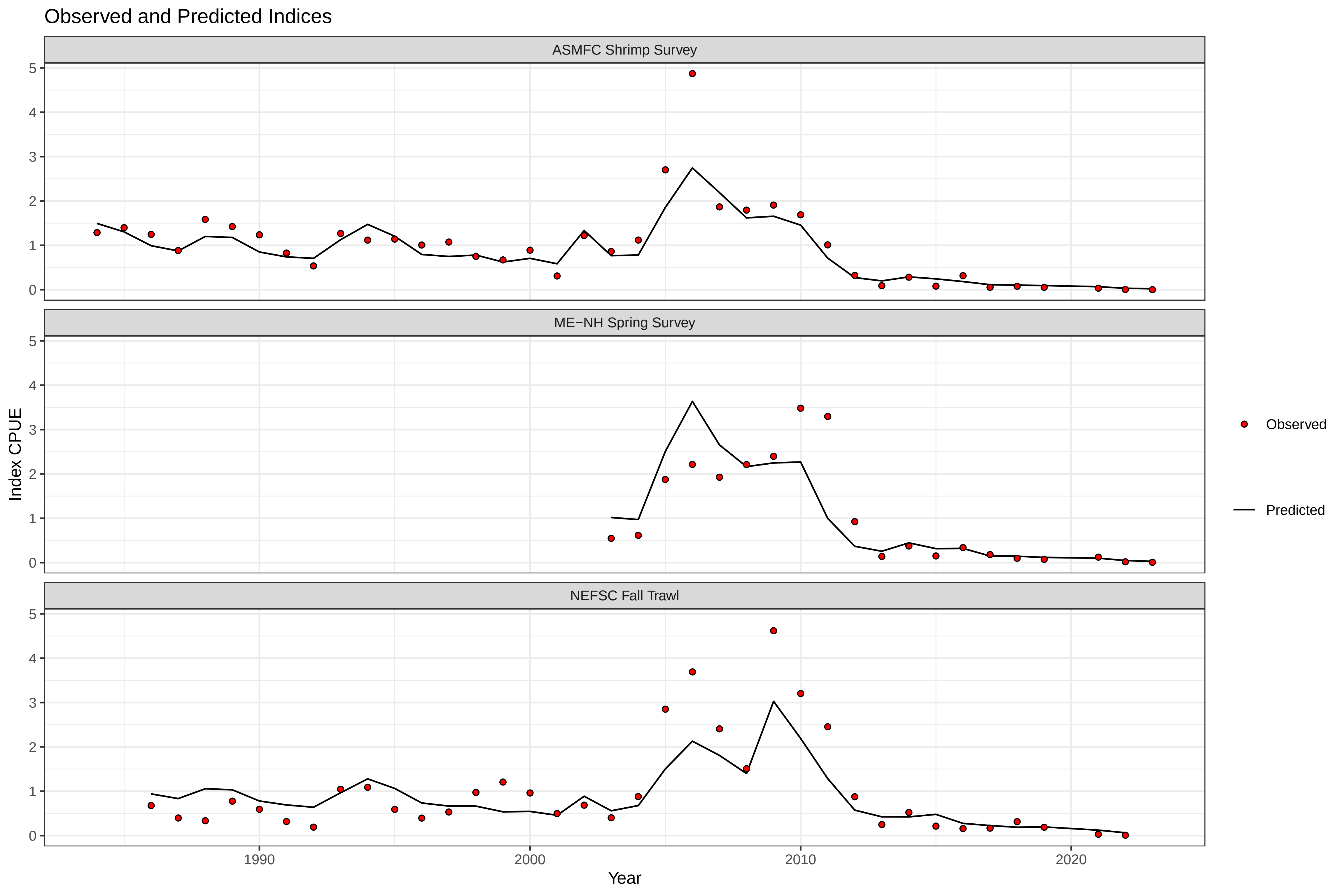

Aggregated Observed and Predicted Length Composition − Trawl Fleet
All Years
Proportion
0.15
0.10
0.05
0.00
10
15
20
25
30
35
Carapace Length (mm)
Observed
Predicted

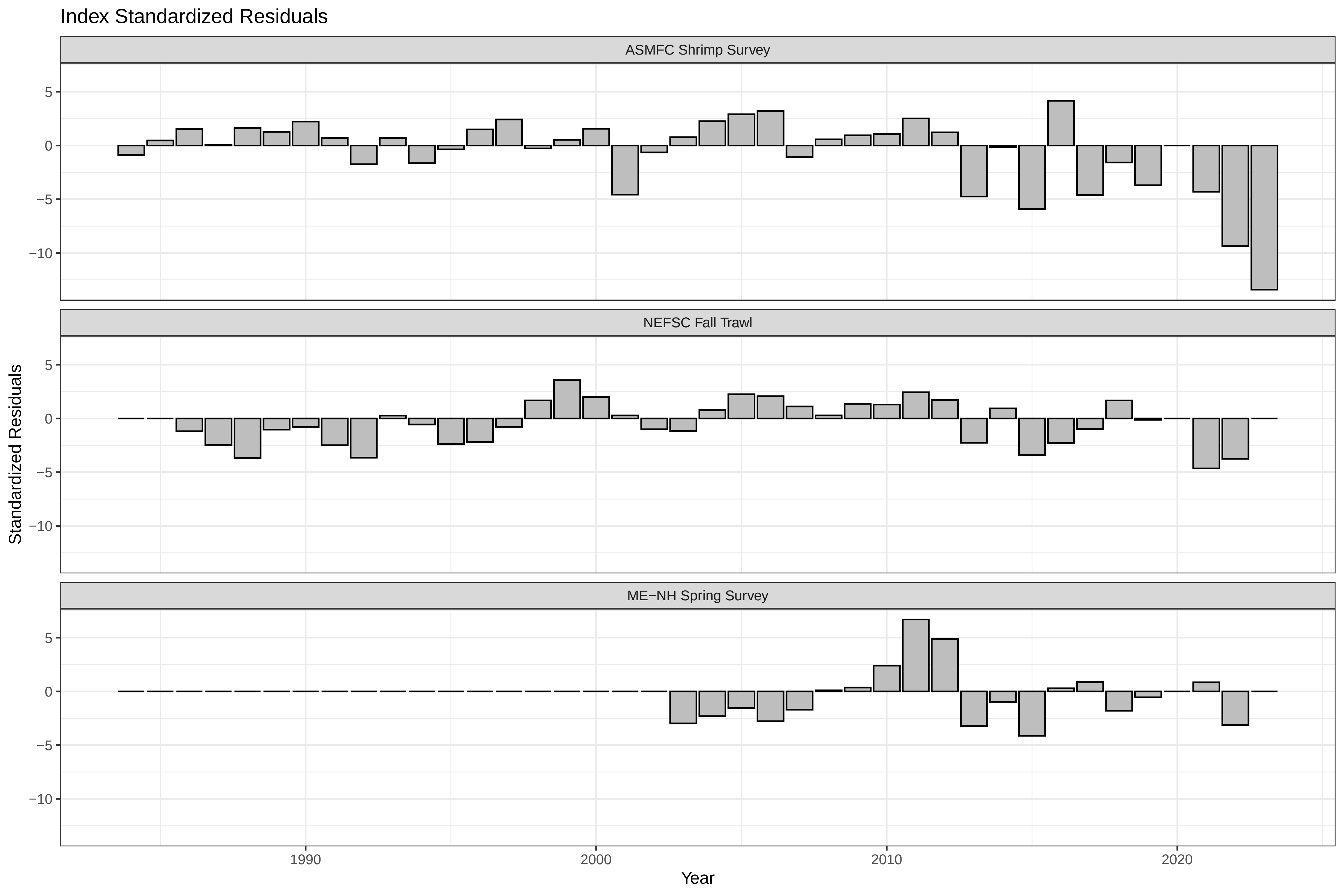


Aggregated Observed and Predicted Length Composition − Trap Fleet
All Years
Proportion
0.20
0.15
0.10
0.05
0.00
10
15
20
25
30
35
Carapace Length (mm)
Observed
Predicted

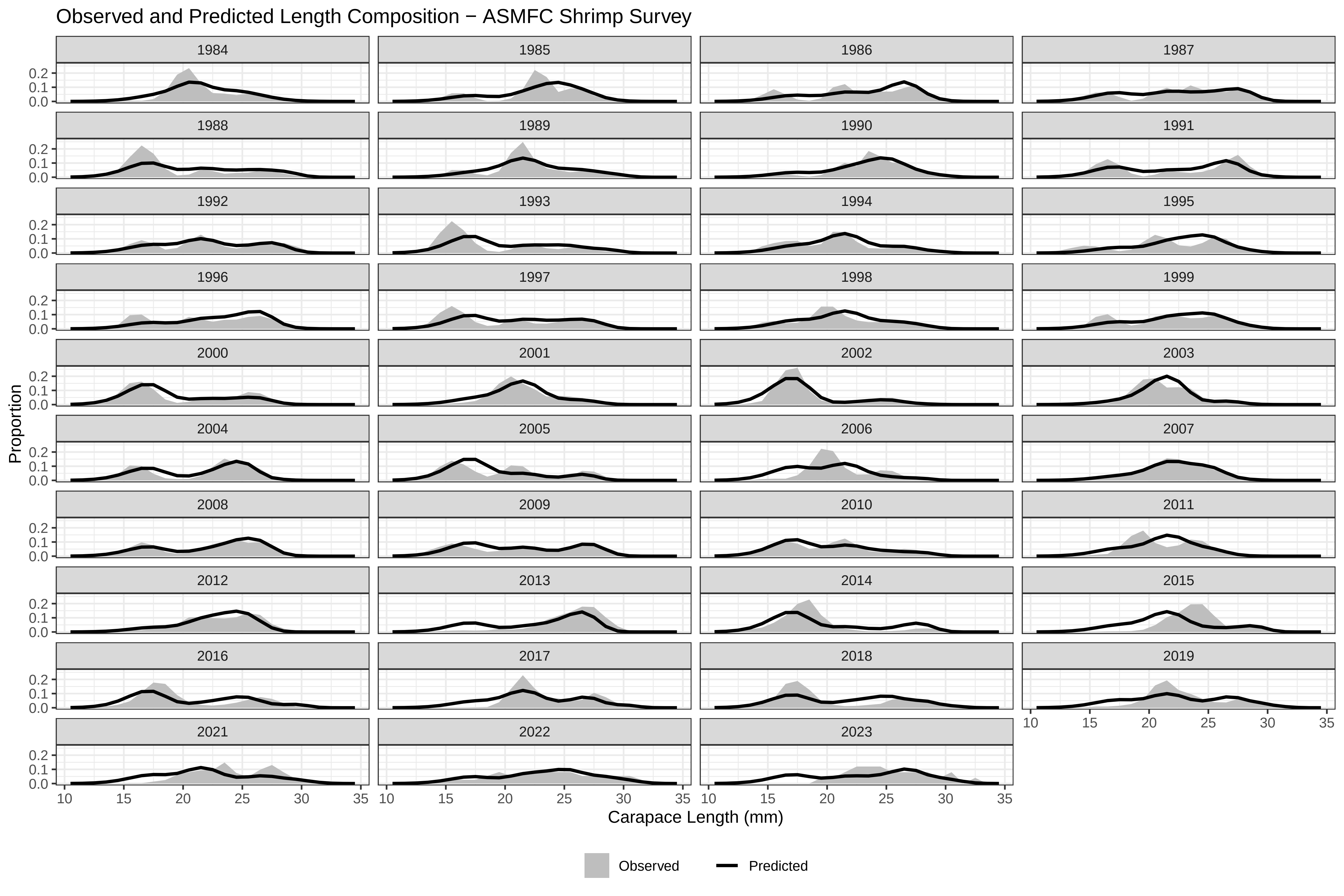


Index Selectivity
ASMFC Shrimp Survey
ME−NH Spring Survey
NEFSC Fall Trawl
Index Selectivity
1.00
0.75
0.50
0.25
0.00
10
15
20
25
30
35
Carapace Length (mm)
Year
1984
2010

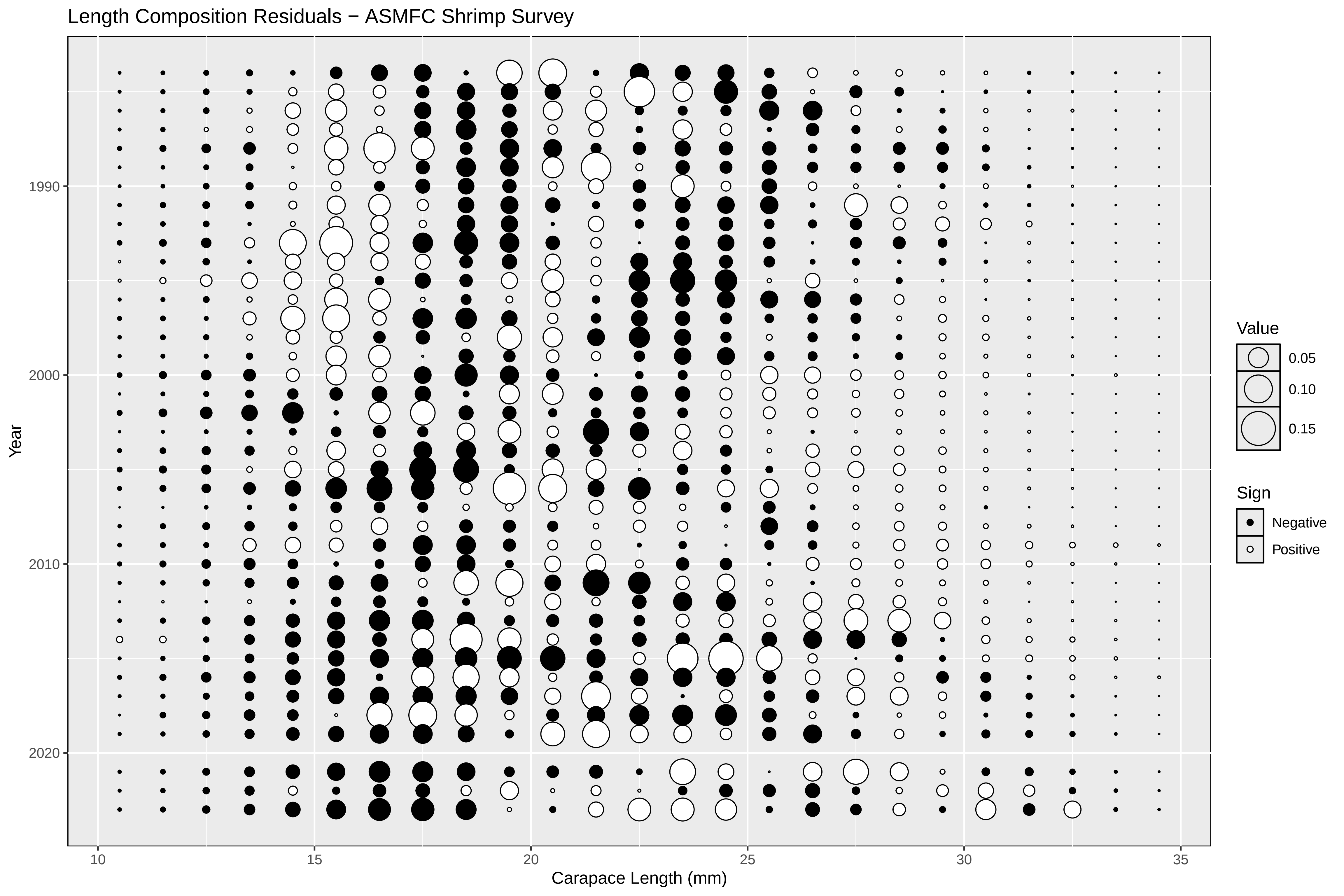

Observed and Predicted Indices
ASMFC Shrimp Survey
ME−NH Spring Survey
NEFSC Fall Trawl
Index CPUE
Year
0
1
2
3
4
5
1990
2000
2010
2020
Observed
Predicted

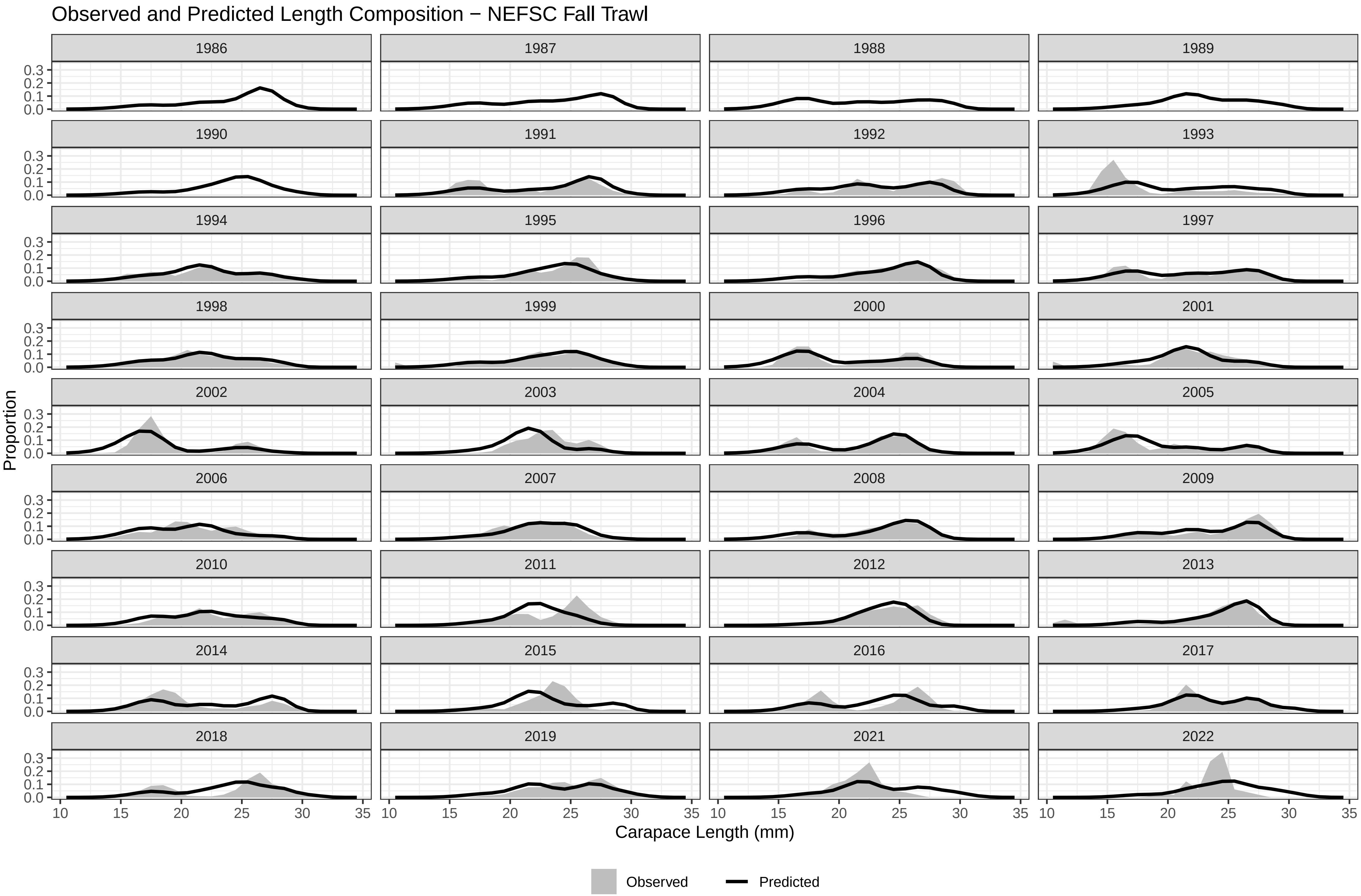


Index Standardized Residuals
ASMFC Shrimp Survey
NEFSC Fall Trawl
ME−NH Spring Survey
Standardized Residuals
5
0
−5
−10
1990
2000
2010
2020
Year

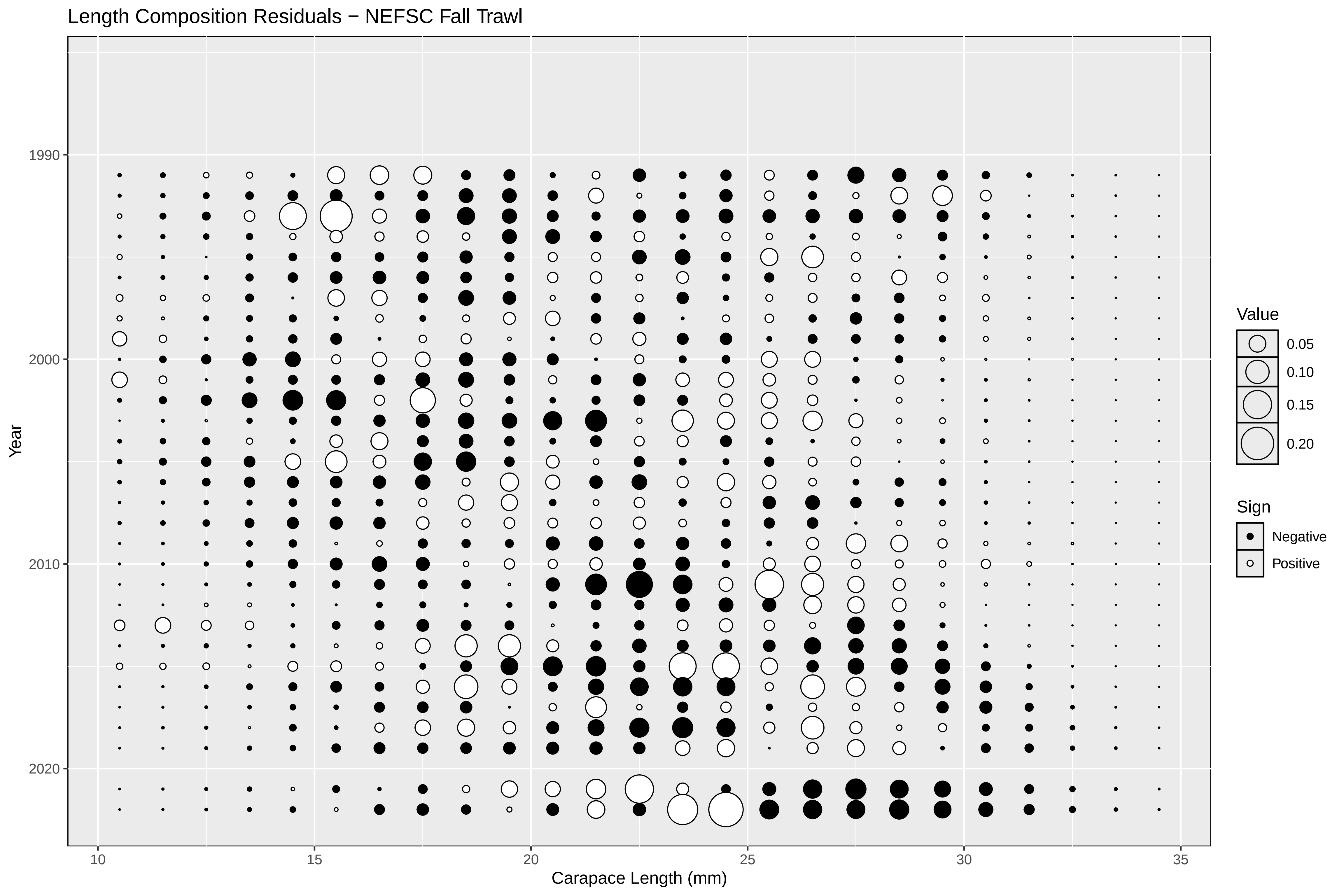


Observed and Predicted Length Composition − ASMFC Shrimp Survey
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2021
2022
2023
Proportion
0.0
0.1
0.2
Carapace Length (mm)
10
15
20
25
30
35
Observed
Predicted

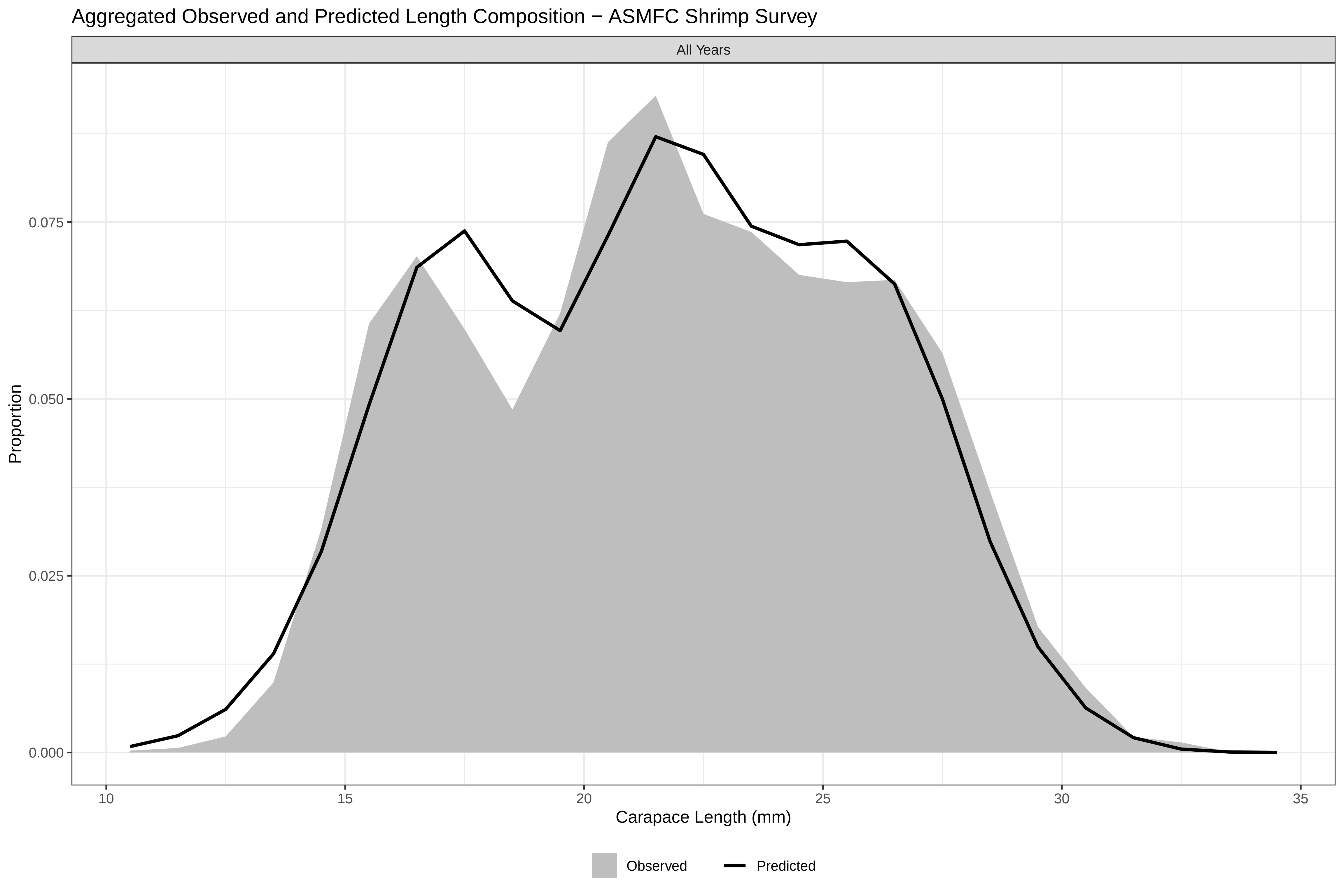

Length Composition Residuals − ASMFC Shrimp Survey
Year
1990
2000
2010
2020
10
15
20
25
30
35
Carapace Length (mm)
Value
0.05
0.10
0.15
Sign
Negative
Positive

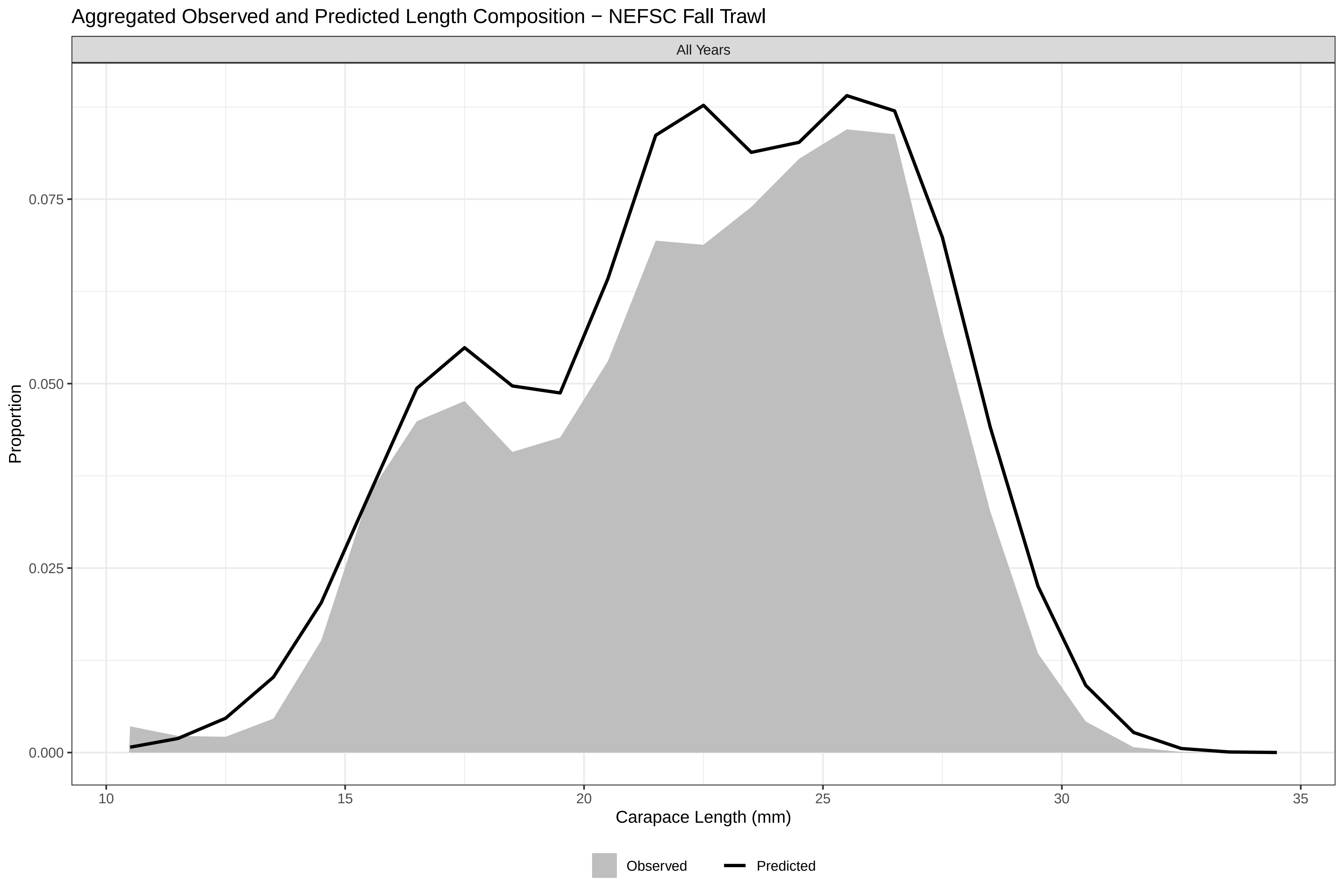


Observed and Predicted Length Composition − NEFSC Fall Trawl
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2021
2022
Proportion
0.0
0.1
0.2
0.3
Carapace Length (mm)
10
15
20
25
30
35
Observed
Predicted

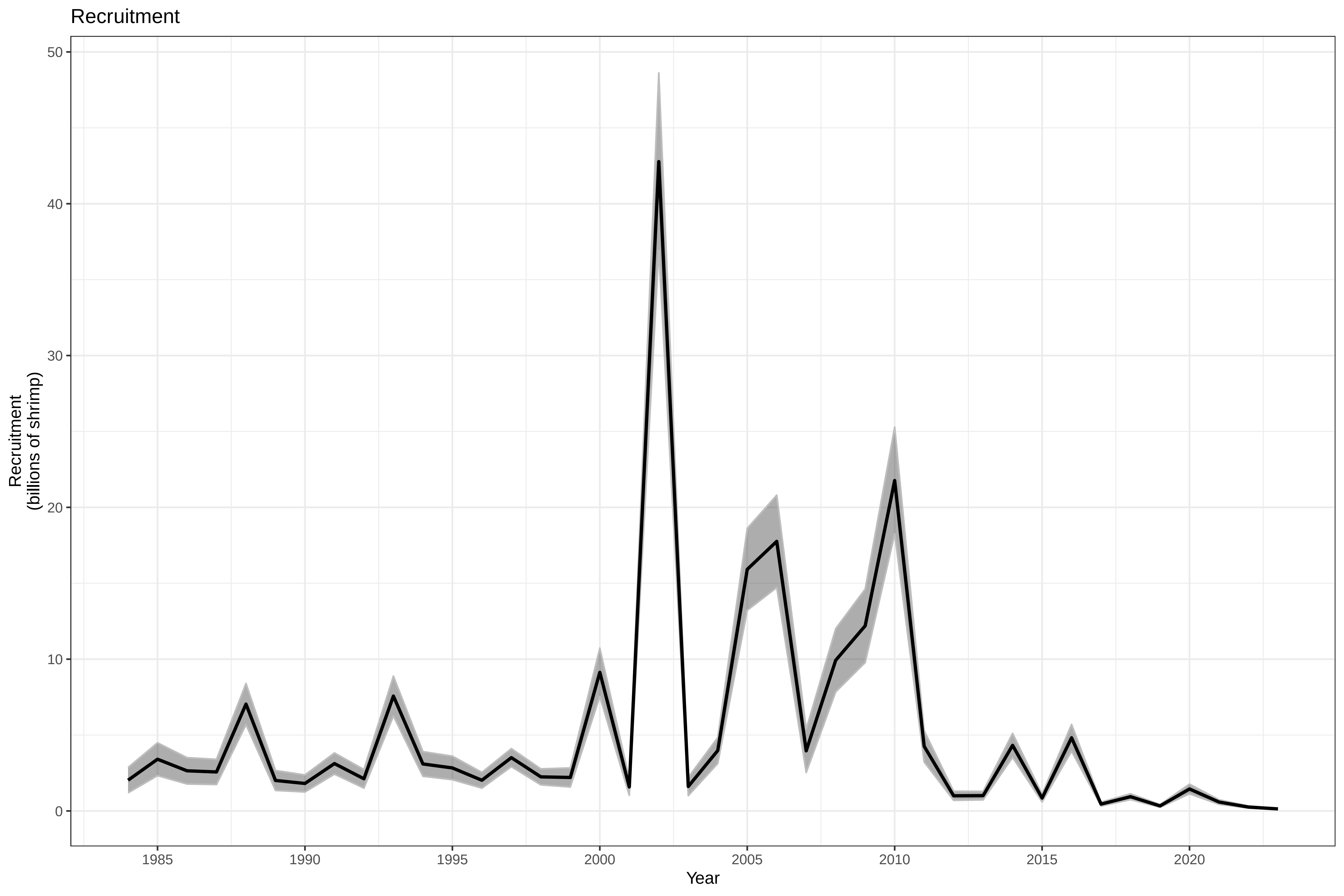


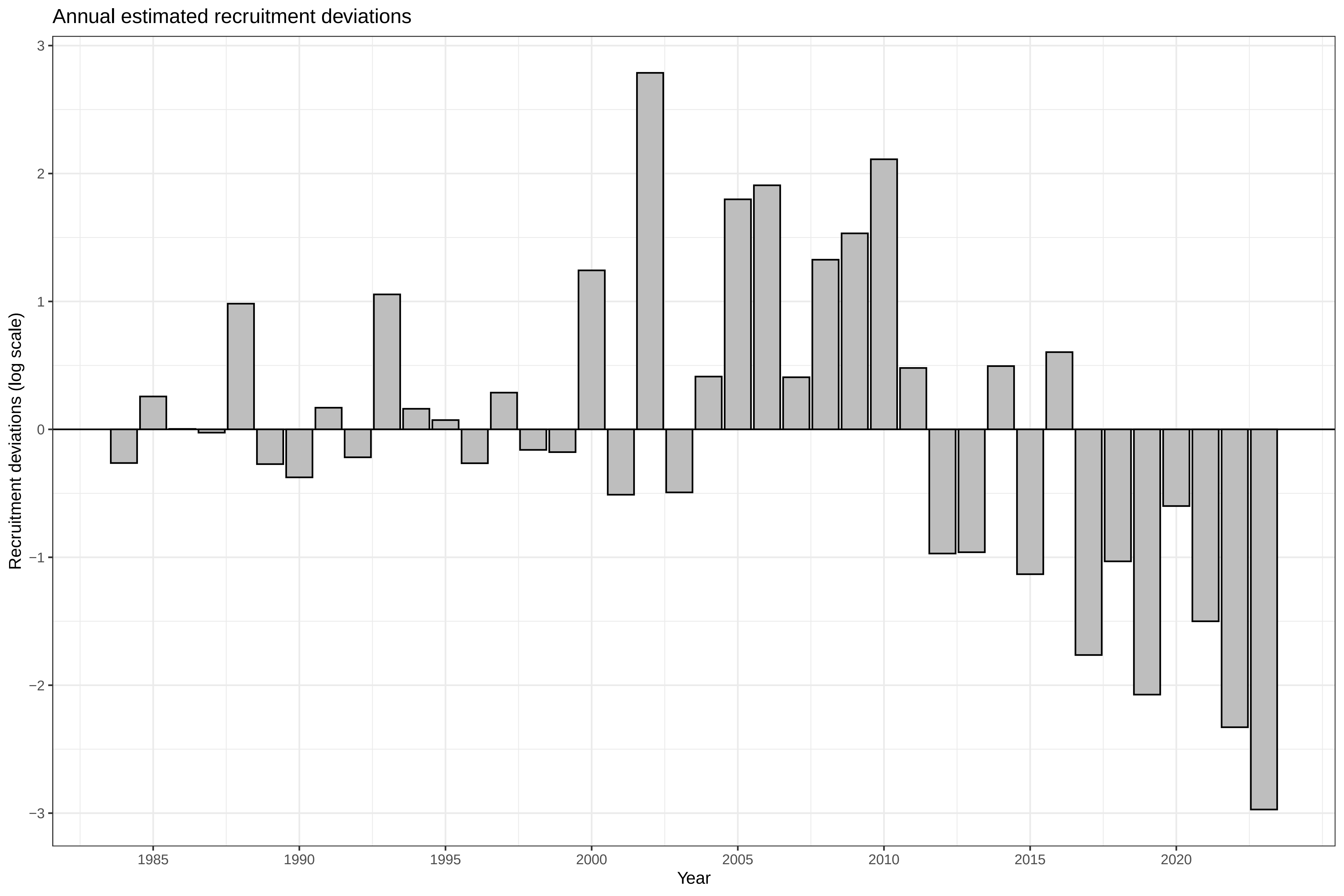
Length Composition Residuals − NEFSC Fall Trawl
Year
1990
2000
2010
2020
Carapace Length (mm)
10
15
20
25
30
35
Value
0.05
0.10
0.15
0.20
Sign
Negative
Positive


Aggregated Observed and Predicted Length Composition − ASMFC Shrimp Survey
All Years
Proportion
0.075
0.050
0.025
0.000
10
15
20
25
30
35
Carapace Length (mm)
Observed
Predicted



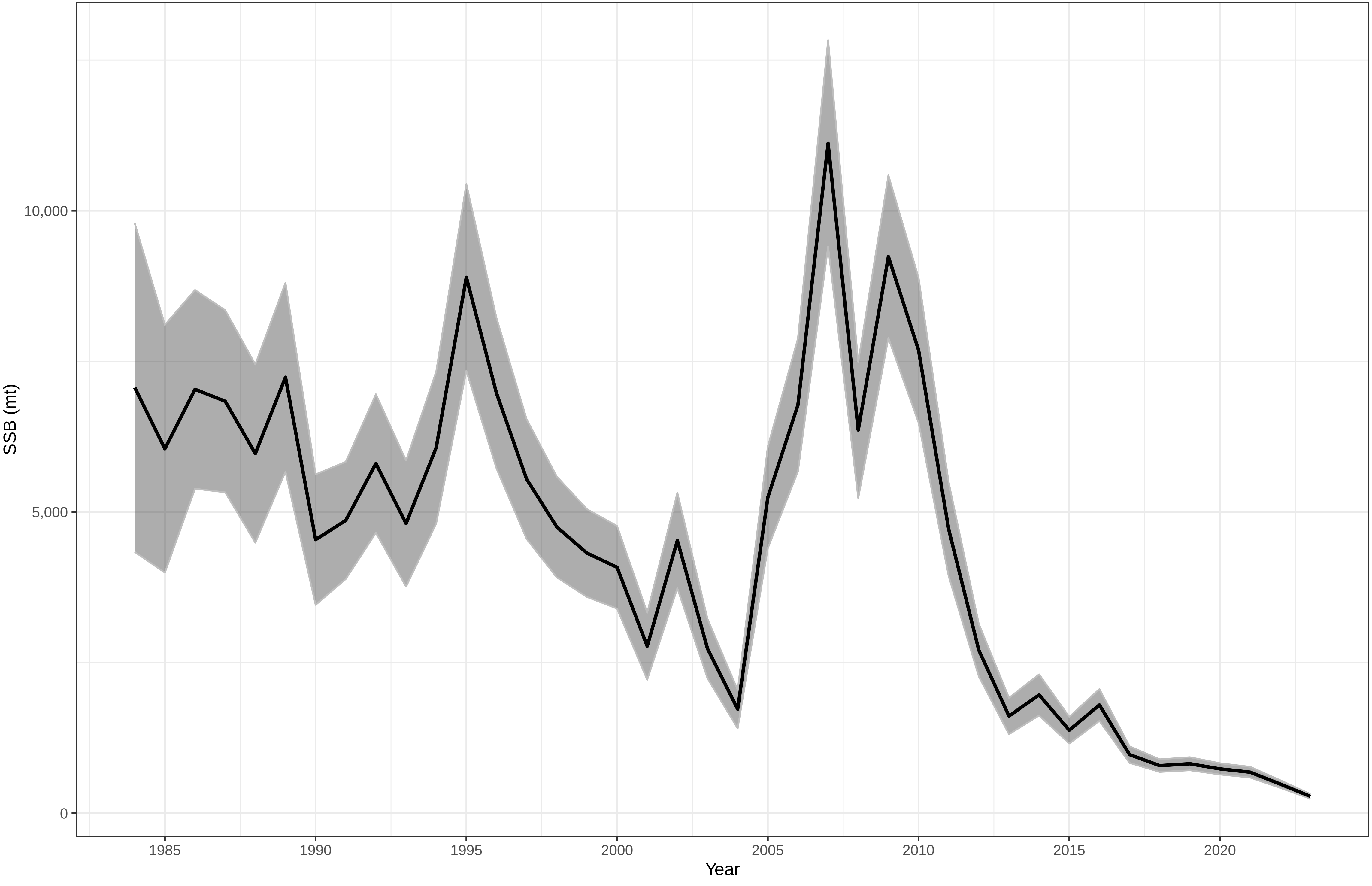
Aggregated Observed and Predicted Length Composition − NEFSC Fall Trawl
All Years
Proportion
0.000
0.025
0.050
0.075
10
15
20
25
30
35
Carapace Length (mm)
Observed
Predicted


Recruitment
Recruitment
(billions of shrimp)
Year
0
10
20
30
40
50
1985
1990
1995
2000
2005
2010
2015
2020

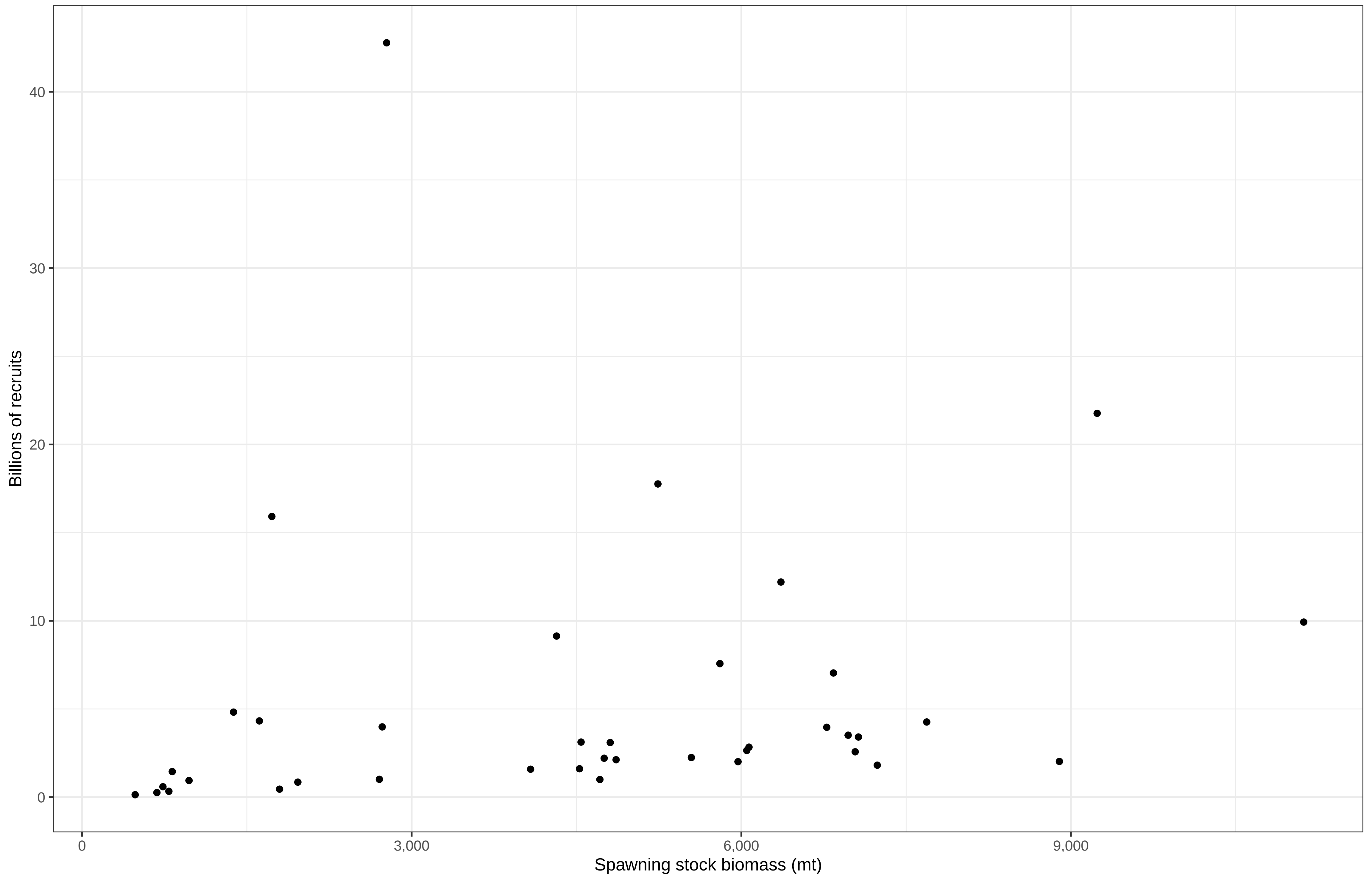


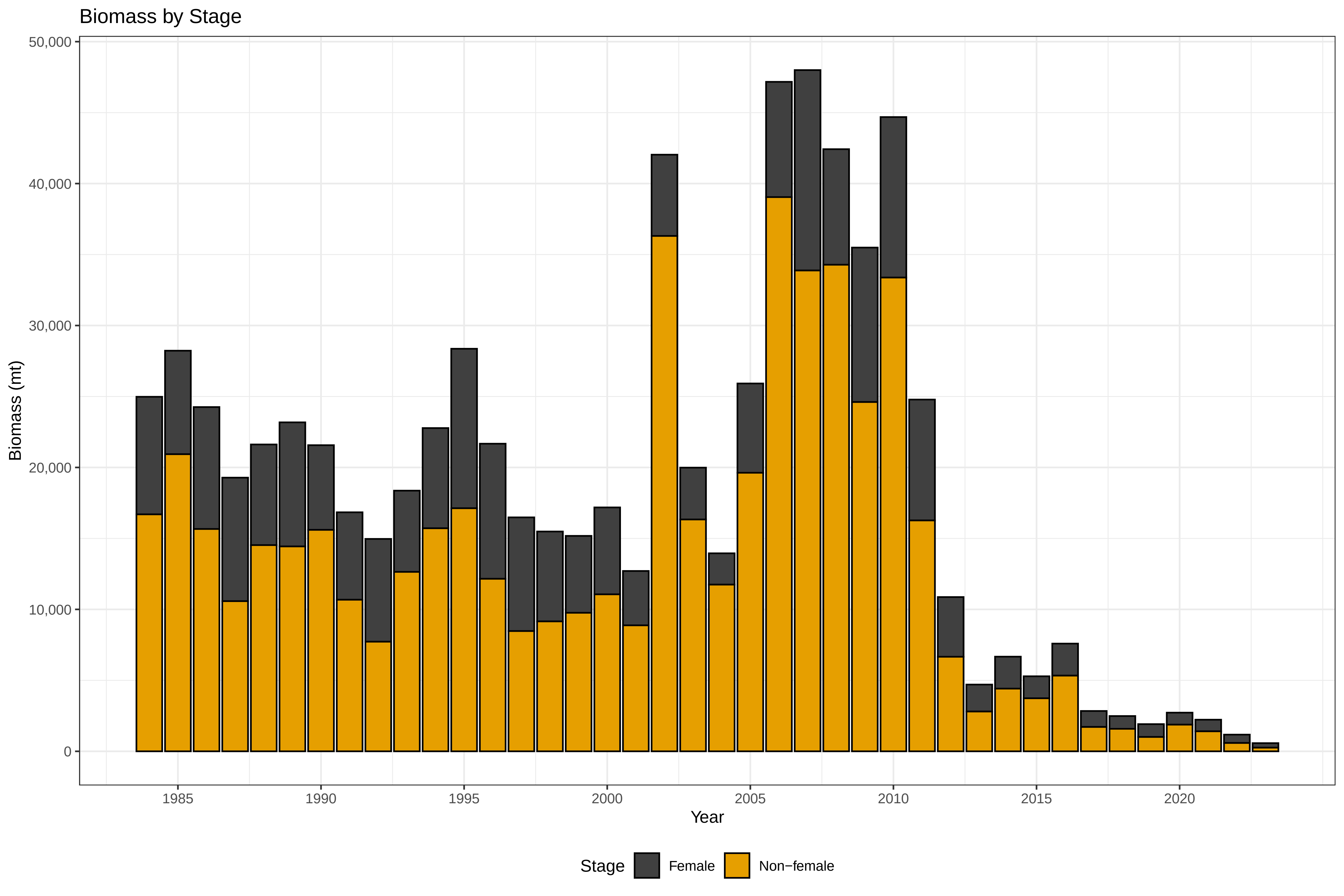
Annual estimated recruitment deviations
Recruitment deviations (log scale)
3
2
1
0
−1
−2
−3
1985
1990
1995
2000
2005
2010
2015
2020
Year

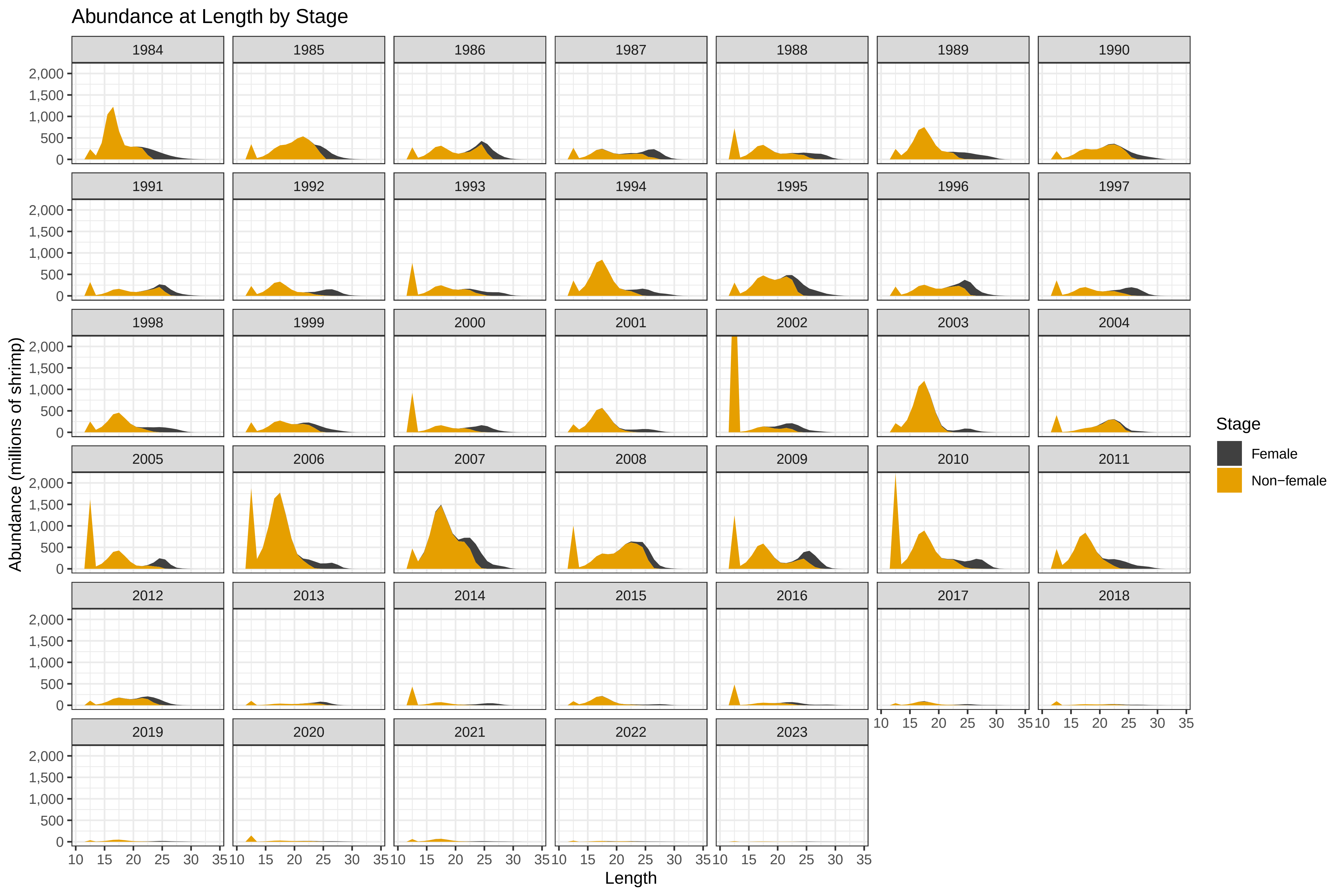
Spawning Stock Biomass



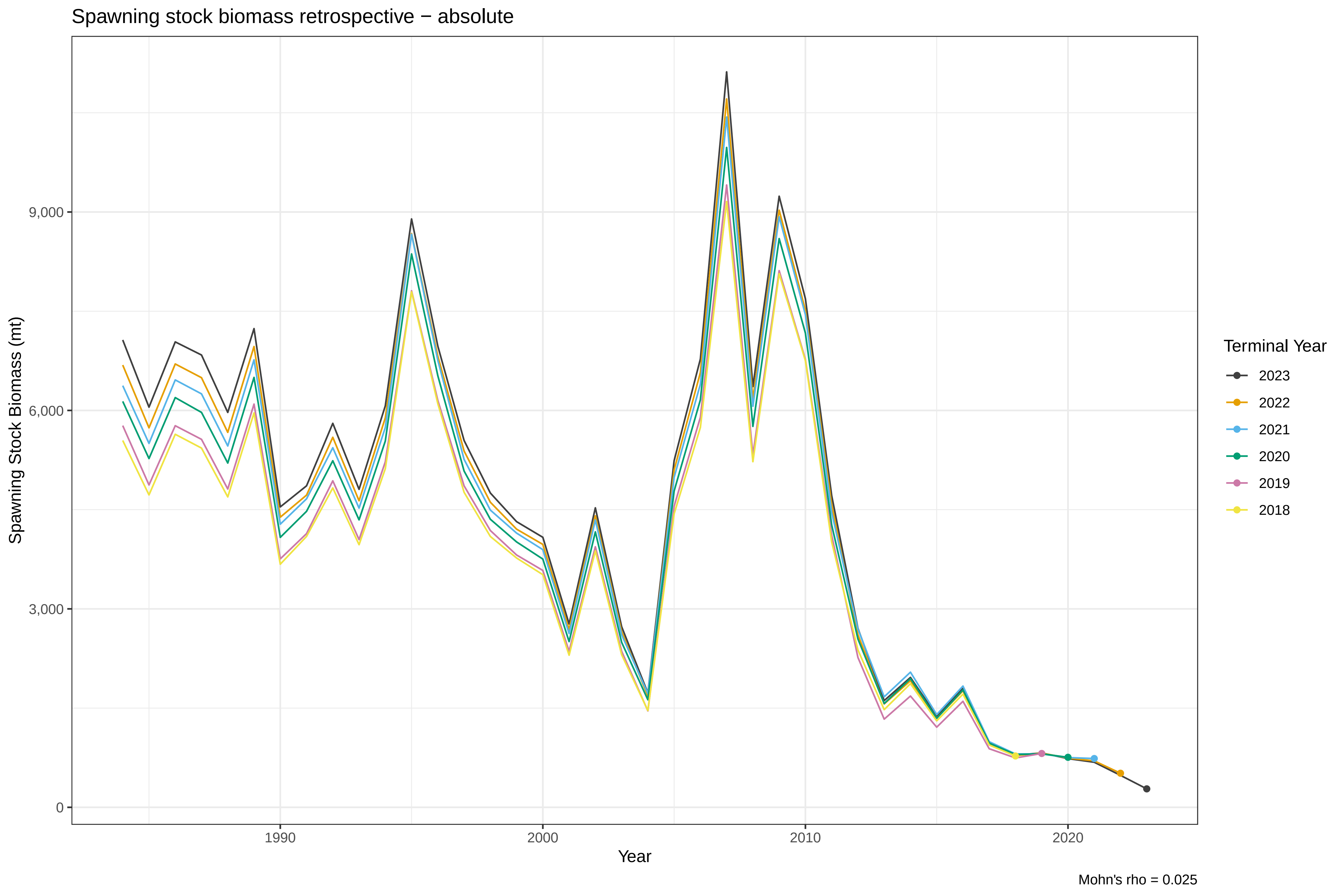
Stock−Recruitment Relationship



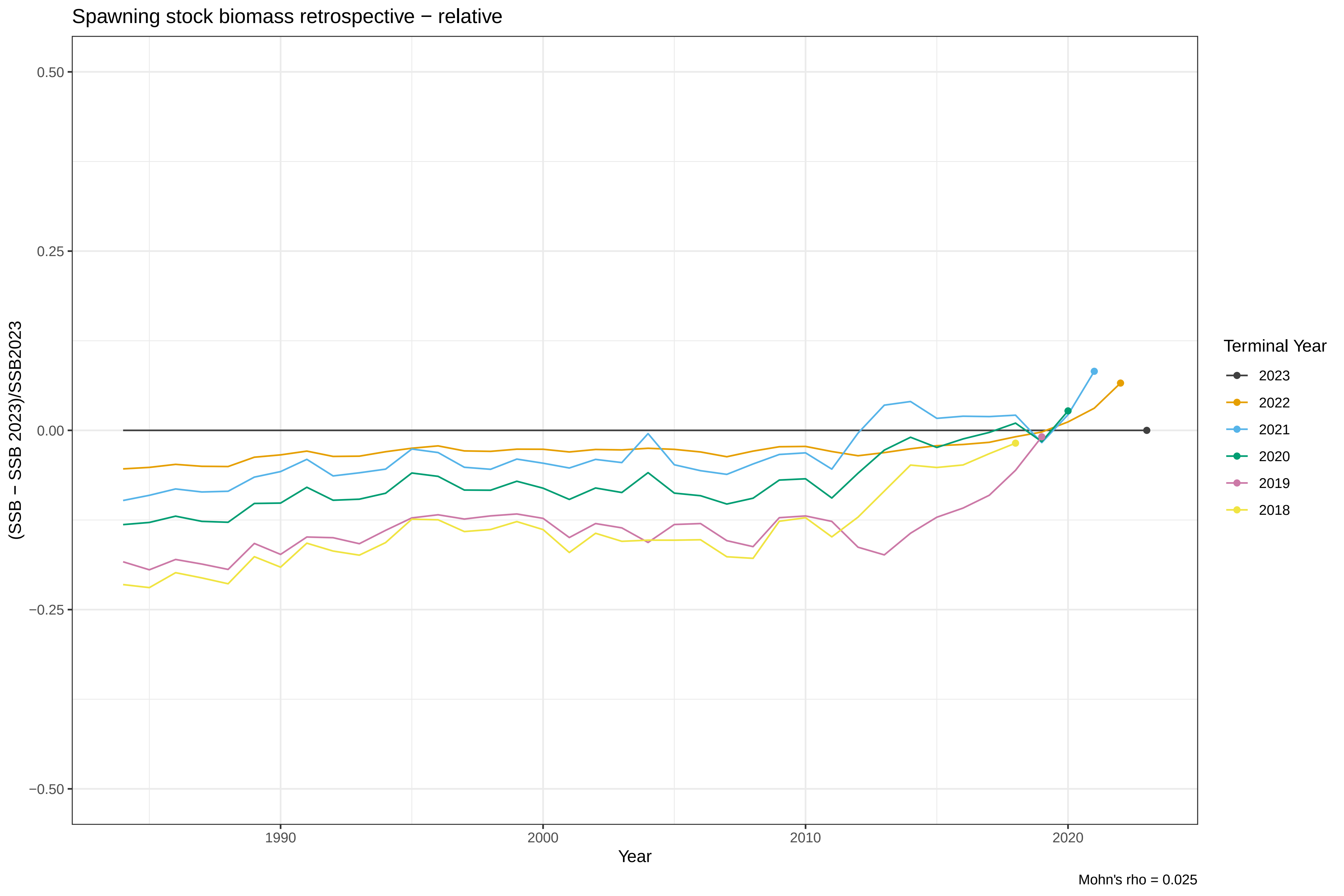

Biomass by Stage
Biomass (mt)
50,000
40,000
30,000
20,000
10,000
0
1985
1990
1995
2000
2005
2010
2015
2020
Year
Stage
Female
Non−female



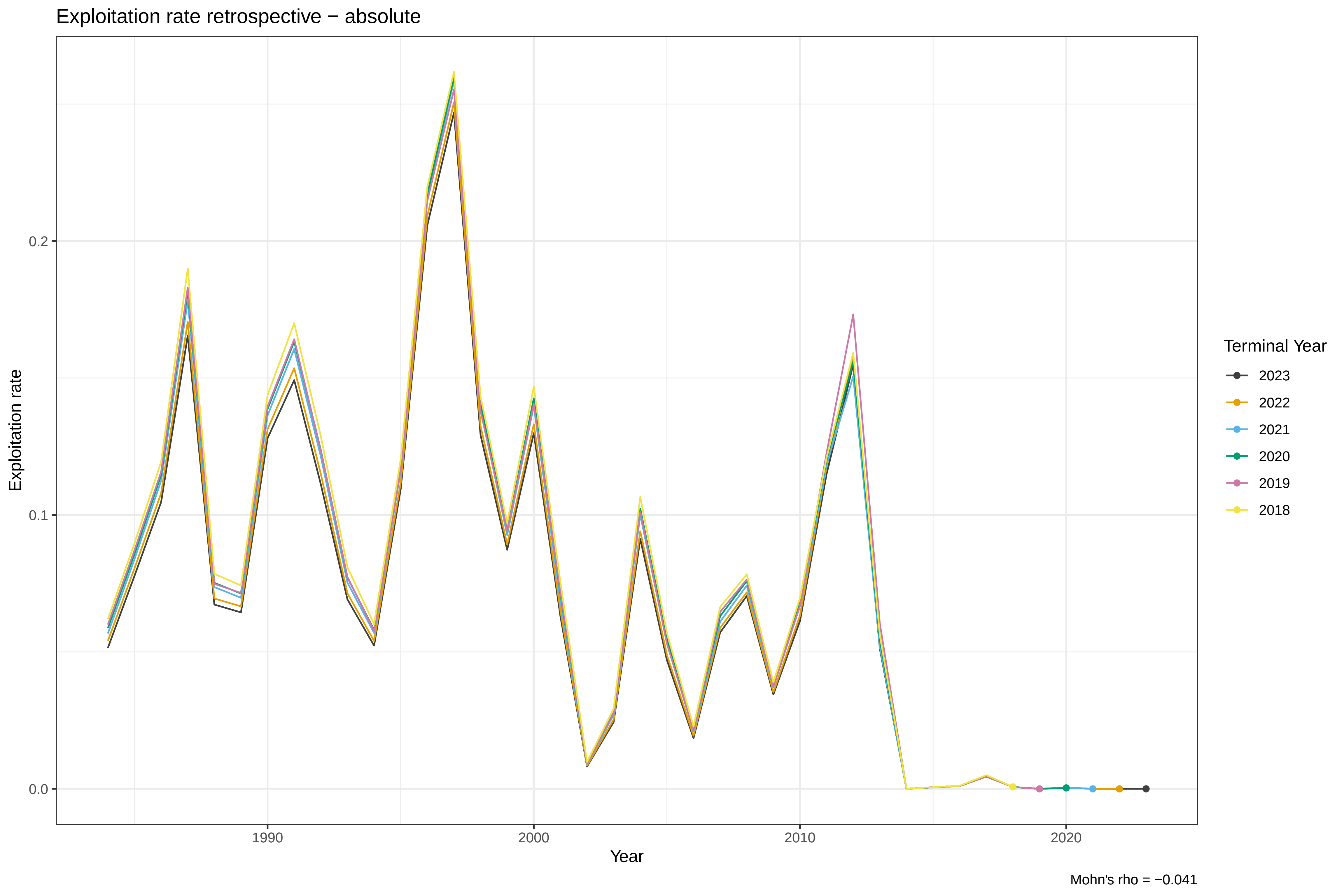
Abundance at Length by Stage
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2,000
1,500
1,000
500
0
10 15 20 25 30 35
Abundance (millions of shrimp)
Length
Stage
Female
Non−female



Spawning stock biomass retrospective − absolute
Spawning Stock Biomass (mt)
9,000
6,000
3,000
0
1990
2000
2010
2020
Year
Terminal Year
2023
2022
2021
2020
2019
2018
Mohn's rho = 0.025

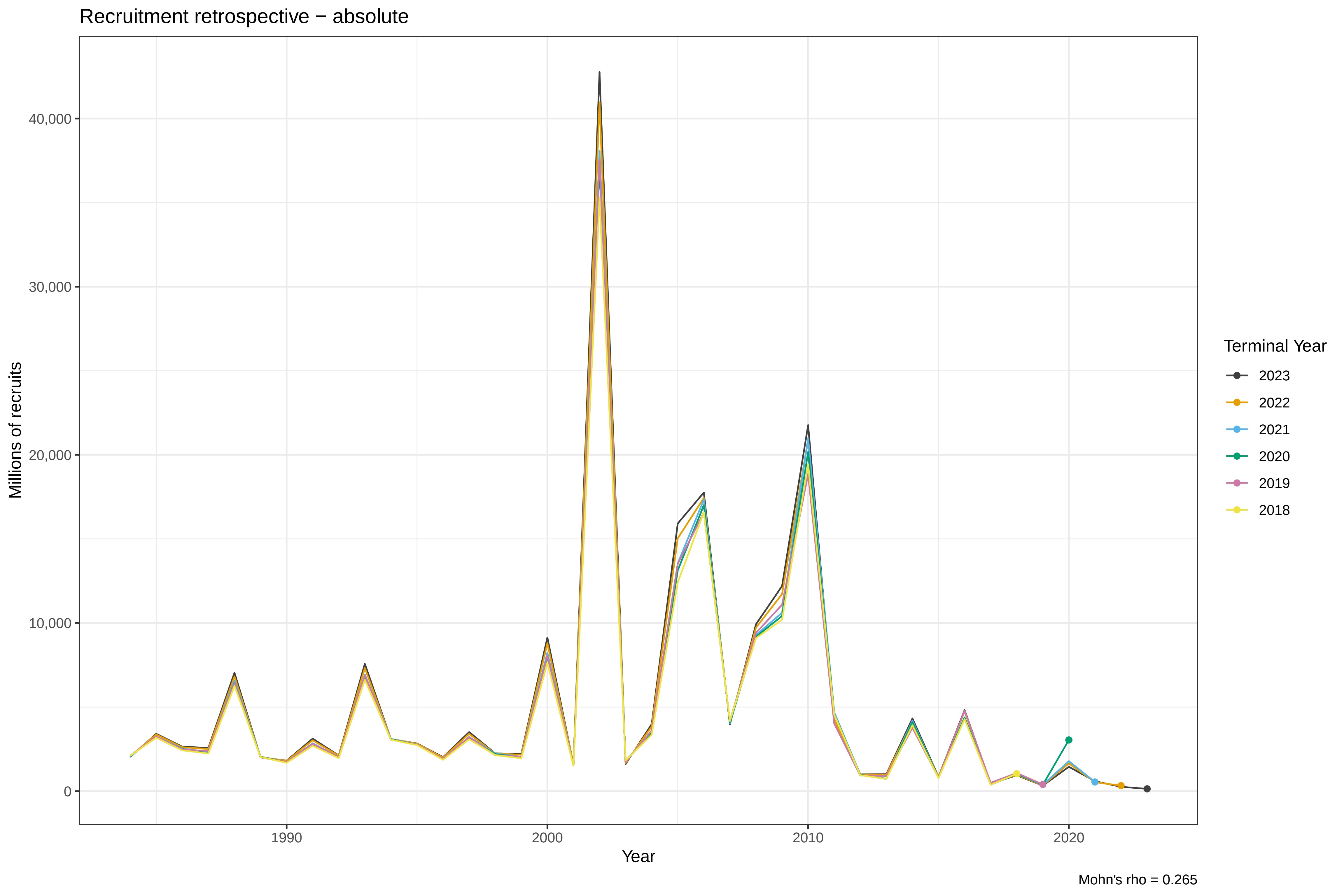


Spawning stock biomass retrospective − relative
0.50
0.25
0.00
−0.25
−0.50
(SSB − SSB 2023)/SSB2023
1990
2000
2010
2020
Year
Terminal Year
2023
2022
2021
2020
2019
2018
Mohn's rho = 0.025

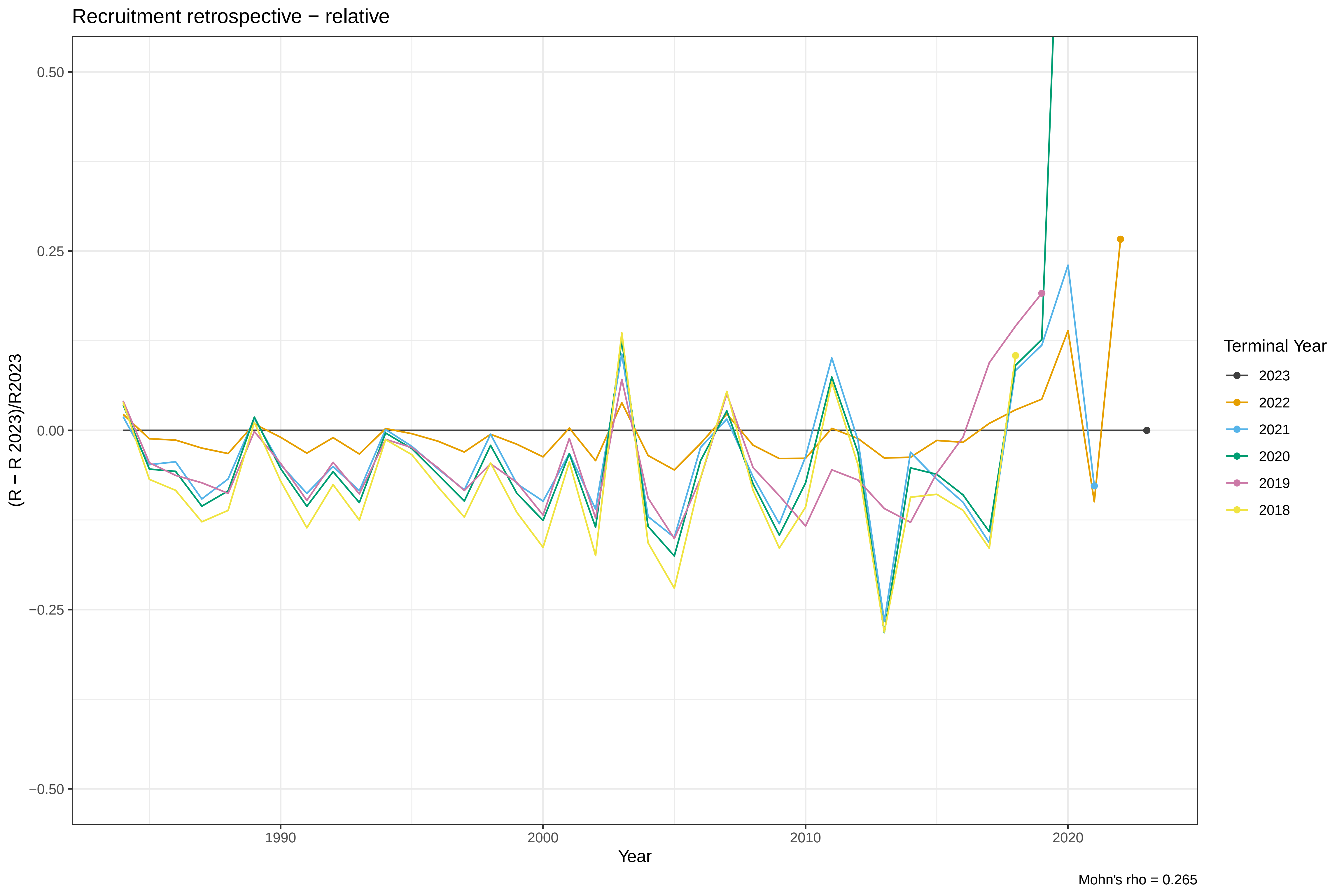


Exploitation rate retrospective − absolute
Exploitation rate
0.0
0.1
0.2
1990
2000
2010
2020
Year
Terminal Year
2023
2022
2021
2020
2019
2018
Mohn's rho = −0.041


Exploitation rate retrospective − relative
0.50
0.25
0.00
−0.25
−0.50
(u − u 2023)/u2023
1990
2000
2010
2020
Year
Terminal Year
2023
2022
2021
2020
2019
2018
Mohn's rho = −0.041



Recruitment retrospective − absolute
Millions of recruits
40,000
30,000
20,000
10,000
0
1990
2000
2010
2020
Year
Terminal Year
2023
2022
2021
2020
2019
2018
Mohn's rho = 0.265



Recruitment retrospective − relative
0.50
0.25
0.00
−0.25
−0.50
(R − R 2023)/R2023
1990
2000
2010
2020
Year
Terminal Year
2023
2022
2021
2020
2019
2018
Mohn's rho = 0.265