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Atlantic Spiny Dogfish

2023 Management Track Assessment Report

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts

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This assessment of the Atlantic Spiny Dogfish (Squalus acanthias) stock is an update of the research track assessment completed in 2022, which used 2019 as the terminal year. This assessment updates commercial and recreational fishery catch data, research survey indices of abundance, and the analytical assessment models through 2022. Additionally, the initial year for this assessment is 1924 compared to 1989 for the research track assessment, and stock projections have been updated through 2026

State of Stock: Based on this updated assessment, the Atlantic Spiny Dogfish (*Squalus acanthias*) stock is not overfished and overfishing is not occurring (Figures 1-2). Retrospective adjustments were not made to the model results. Spawning Output in 2022 was estimated to be 190.8 (million pups) which is 101% of its target (SSB_{MSY} *proxy* = 188; Figure 1). The 2022 fully selected fishing mortality was estimated to be 0.02 which is 81% of the overfishing threshold proxy (F_{MSY} *proxy* = 0.0246; Figure 2).

Table 1: Catch and status table for Atlantic Spiny Dogfish. All weights are in (mt) recruitment is in (million pups) and F_{Full} is the fishing mortality on fully selected ages. Model results are from the current SS3 model with lambda=6.

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
					Data					
Commercial landings	7,373	10,734	8,687	12,158	8,789	6,923	7,947	8,828	4,780	4,969
Recreational landings	219	120	67	205	141	51	56	101	215	19
Commercial discards	10,226	10,368	6,803	7,078	6,609	5,402	6,964	7,422	5,955	3,884
Recreational discards	5,685	13,327	2,698	4,277	2,032	2,038	3,798	1,815	3,524	1,965
Catch for Assessment	13,222	18,242	12,350	16,289	12,403	9,854	12,059	12,683	8,490	7,122
					Model Results					
Spawning Output	311.4	283.3	253.8	233.5	212.6	200	193.6	188.9	186.6	190.8
F_{Full}	0.03	0.046	0.033	0.044	0.038	0.031	0.042	0.042	0.027	0.02
Recruits	81.8	230.7	70.4	99.5	104.1	78.3	193.5	189.3	186.6	136.2

Table 2: Comparison of reference points estimated in the research track assessment and from the current assessment update. A 60% SPR proxy was used for the overfishing threshold.

	2019	2023
F_{MSY} *proxy*	0.025	0.025
SSB_{MSY} (million pups)	371	188 (148- 227)
MSY (mt)	N/C	7134 (5631 - 8636)
Recruits (million pups)	N/C	109.9
Overfishing	Yes	No
Overfished	No	No

Projections: Short term projections of biomass were obtained using the SS3 forecast module.

Table 3: Short term projections of total fishery catch and spawning output for Atlantic Spiny Dogfish based on a harvest scenario of fishing at F_{MSY} *proxy* between 2024 and 2026. The catch in 2023, 7,751 (mt) is the 2023 ACL/ACT

Year	Catch (mt)	SSB (million pups)	F_{Full}
2023	7751	196.9 (167.6 - 226.3)	0.025

Year	Catch (mt)	SSB (million pups)	F_{Full}
2024	7818	202.8 (171.9 - 233.7)	0.025
2025	7956	208.3 (177 - 239.6)	0.025
2026	8085	212.5 (180.9 - 244)	0.025

Special Comments:

- What are the most important sources of uncertainty in this stock assessment? Explain, and describe qualitatively how they affect the assessment results (such as estimates of biomass, F, recruitment, and population projections).

  The lack of age and growth data induces considerable uncertainty, particularly when there is evidence that the growth parameters have changed over time. Spiny dogfish discards are uncertain, and are highly uncertain for the period before observer data was available as well as during the first years with observer data due to low sample sizes. Additionally, there is uncertainty in the assumed discard mortality rates. Results also depend on the value of weighting of the survey index (lambda), which also causes substantial uncertainty.

- Does this assessment model have a retrospective pattern? If so, is the pattern minor, or major? (A major retrospective pattern occurs when the adjusted SSB or F_{Full} lies outside of the approximate joint confidence region for SSB and F_{Full}).

  This assessment had only a minor retrospective pattern. No retrospective adjustment of spawning output or fishing mortality in 2022 was required.

- Based on this stock assessment, are population projections well determined or uncertain? If this stock is in a rebuilding plan, how do the projections compare to the rebuilding schedule?

  Population projections for Atlantic Spiny Dogfish, are reasonably well determined particularly because of the longevity and slow growth of this stock. This stock is not in a rebuilding plan.

- Describe any changes that were made to the current stock assessment, beyond incorporating additional years of data and the effect these changes had on the assessment and stock status.

  The data weighting for the survey index was increased to lambda = 6. This both induced a better fit to the survey data and also allowed the model to match the Albatross/Bigelow calibration at large sizes.

- If the stock status has changed a lot since the previous assessment, explain why this occurred.

  The overfishing status of Atlantic Spiny Dogfish changed because of reduced catches in 2022 compared to the previous terminal year of 2019. This caused F to be below the overfishing threshold in 2022. Overfishing was occuring in 2019 in both the previous and current models.

- Provide qualitative statements describing the condition of the stock that relate to stock status.

  Female Atlantic Spiny Dogfish have a truncated size structure, with large females being a much smaller percentage of the population than was observed historically. Although overfishing was not occurring in 2022, it was occurring during every year from 2012-2021. Because the ACL/ACT for 2023 was above the SS3 estimated OFL for that year, and projected discards are likely underestimated, it is probable that overfishing is occurring in 2023 as well.

- Indicate what data or studies are currently lacking and which would be needed most to improve this stock assessment in the future.

  The Atlantic Spiny Dogfish assessment could be improved with age and growth data, as well as more studies regarding discard mortality.

- Are there other important issues?

References:

Chang, J-H., Sosebee, K., Hart, D.R. 2023. Stock Synthesis For Atlantic Spiny Dogfish. Appendix to this report.

Spiny Dogfish Research Track Working Group. Research Track Assessment of Northwest Atlantic Spiny Dogfish. NEFSC Center Reference Document, in press.

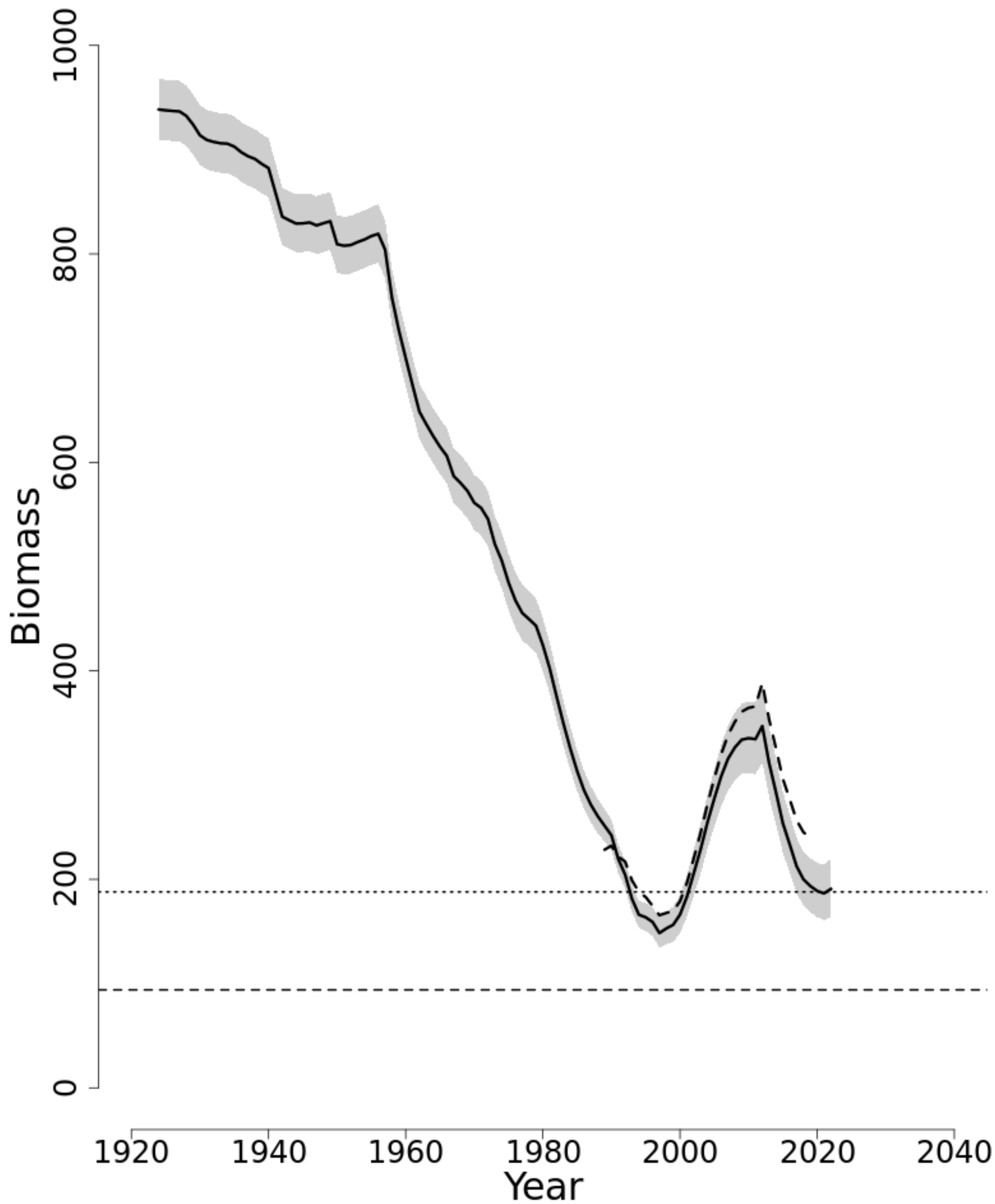

Figure 1: Trends in spawning output of Atlantic Spiny Dogfish between 1924 and 2022 from the current (solid line) and previous (dashed line) assessment and the corresponding $SSB_{Threshold}$ ($\frac{1}{2}$ SSB_{MSY} *proxy*; horizontal dashed line) as well as SSB_{Target} (SSB_{MSY} *proxy*; horizontal dotted line) based on the 2023 assessment. The approximate 95% gamma confidence intervals are shown.

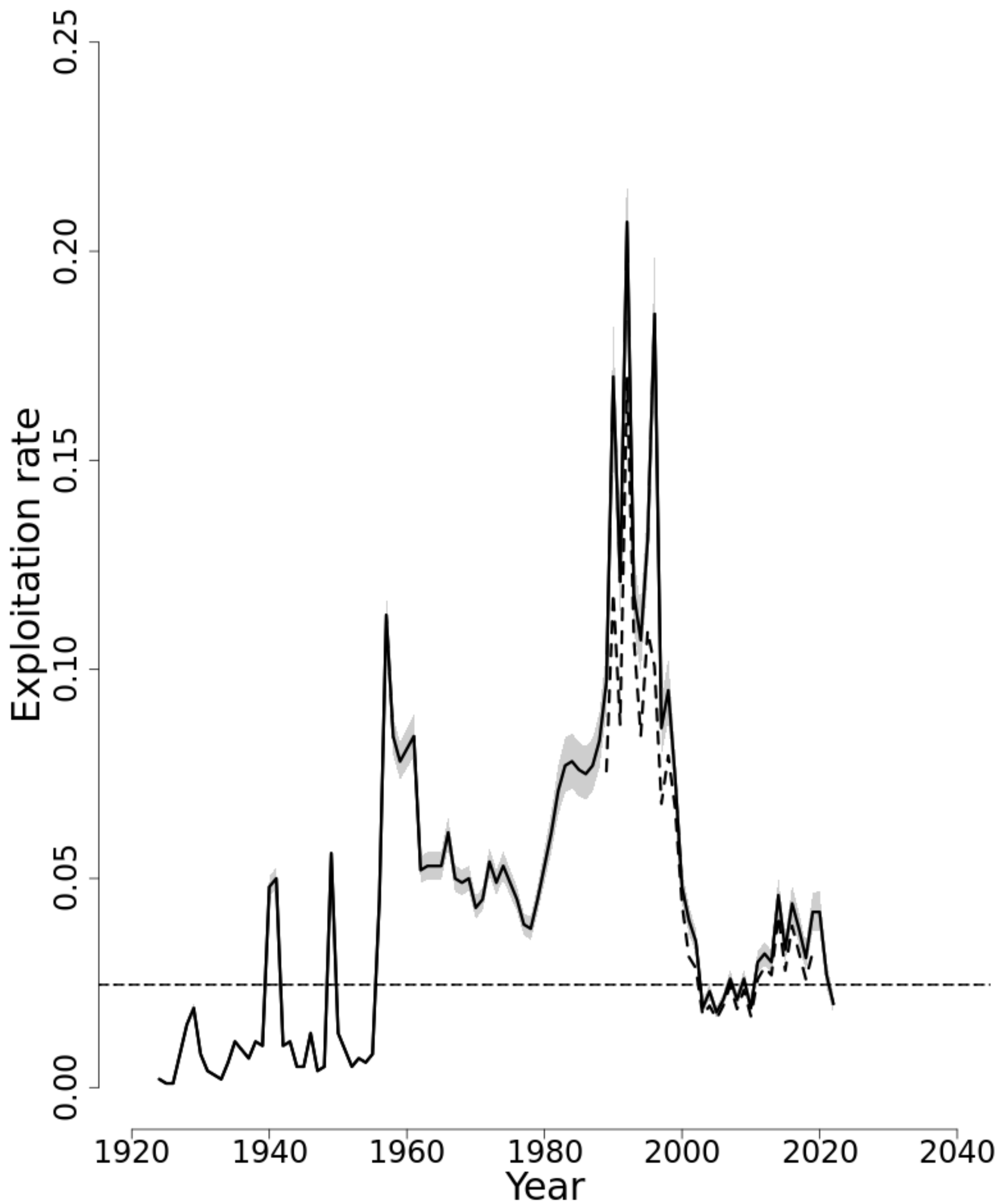

Figure 2: Trends in the fully selected fishing mortality (F_{Full}) of Atlantic Spiny Dogfish between 1924 and 2022 from the current (solid line) and previous (dashed line) assessment and the corresponding $F_{Threshold}$ (F_{MSY} *proxy*=0.0246; horizontal dashed line). based on the 2023 assessment. The approximate 95% gamma confidence intervals are shown.

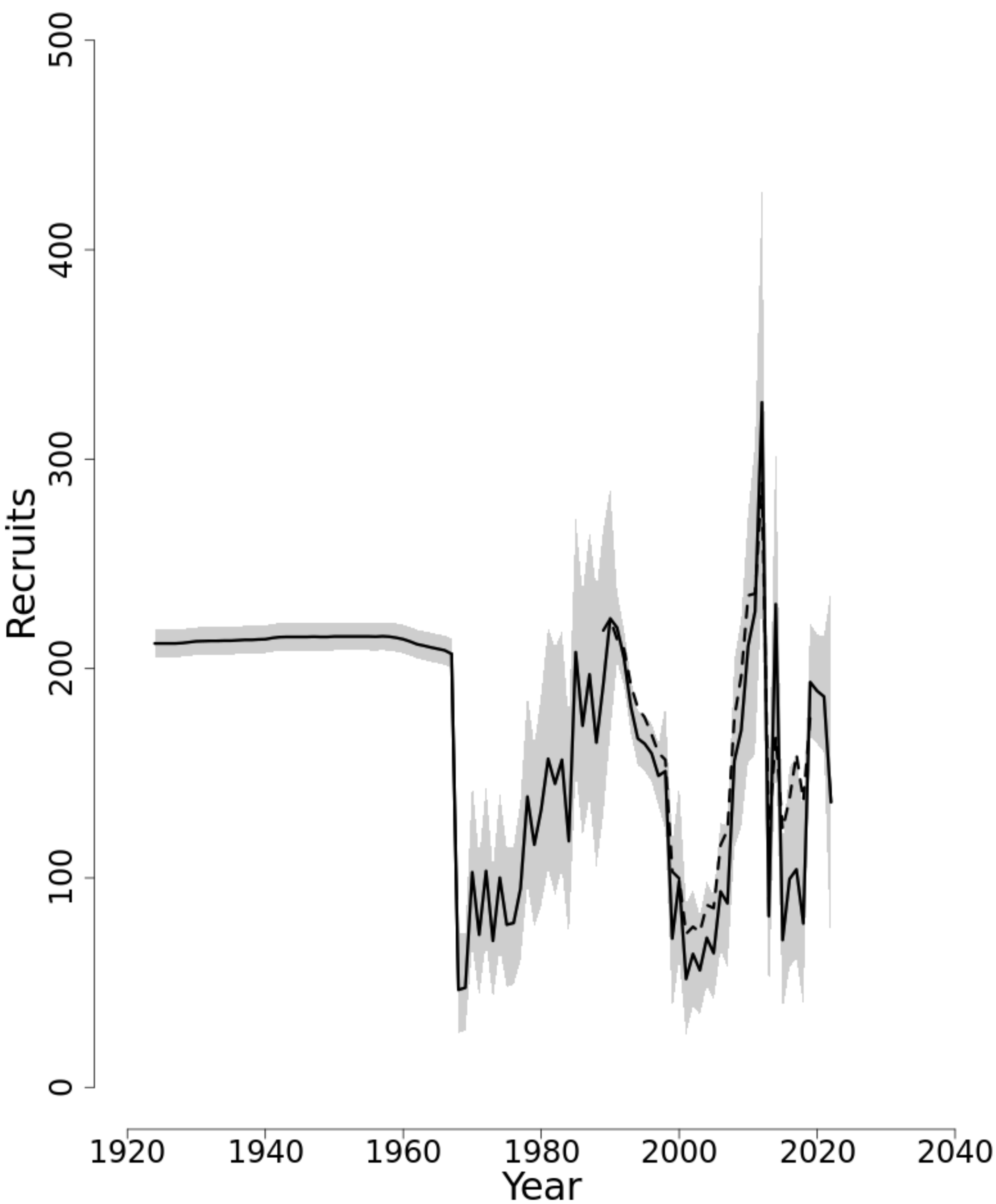

Figure 3: Trends in Recruits (million pups) of Atlantic Spiny Dogfish between 1924 and 2022 from the current (solid line) and previous (dashed line) assessment. The approximate 95% gamma confidence intervals are shown.

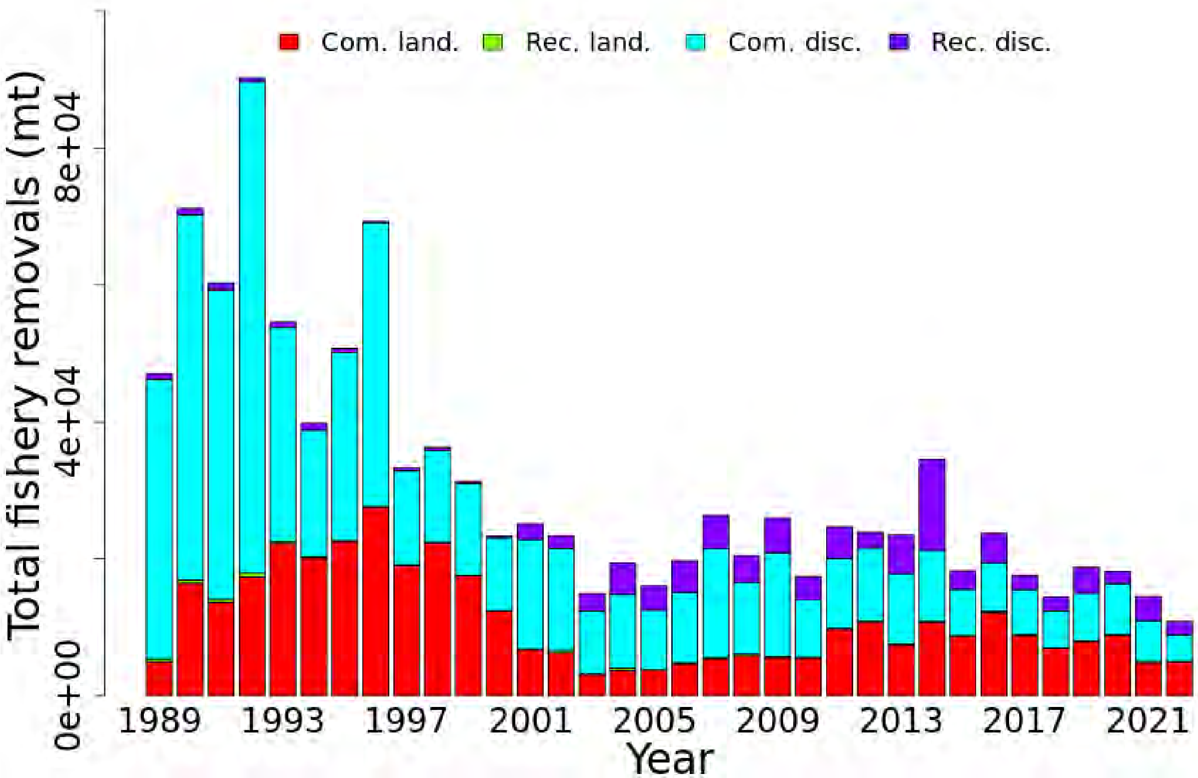

Figure 4: Total catch of Atlantic Spiny Dogfish between 1989 and 2022 by fleet (commercial, recreational, or Canadian) and disposition (landings and discards).

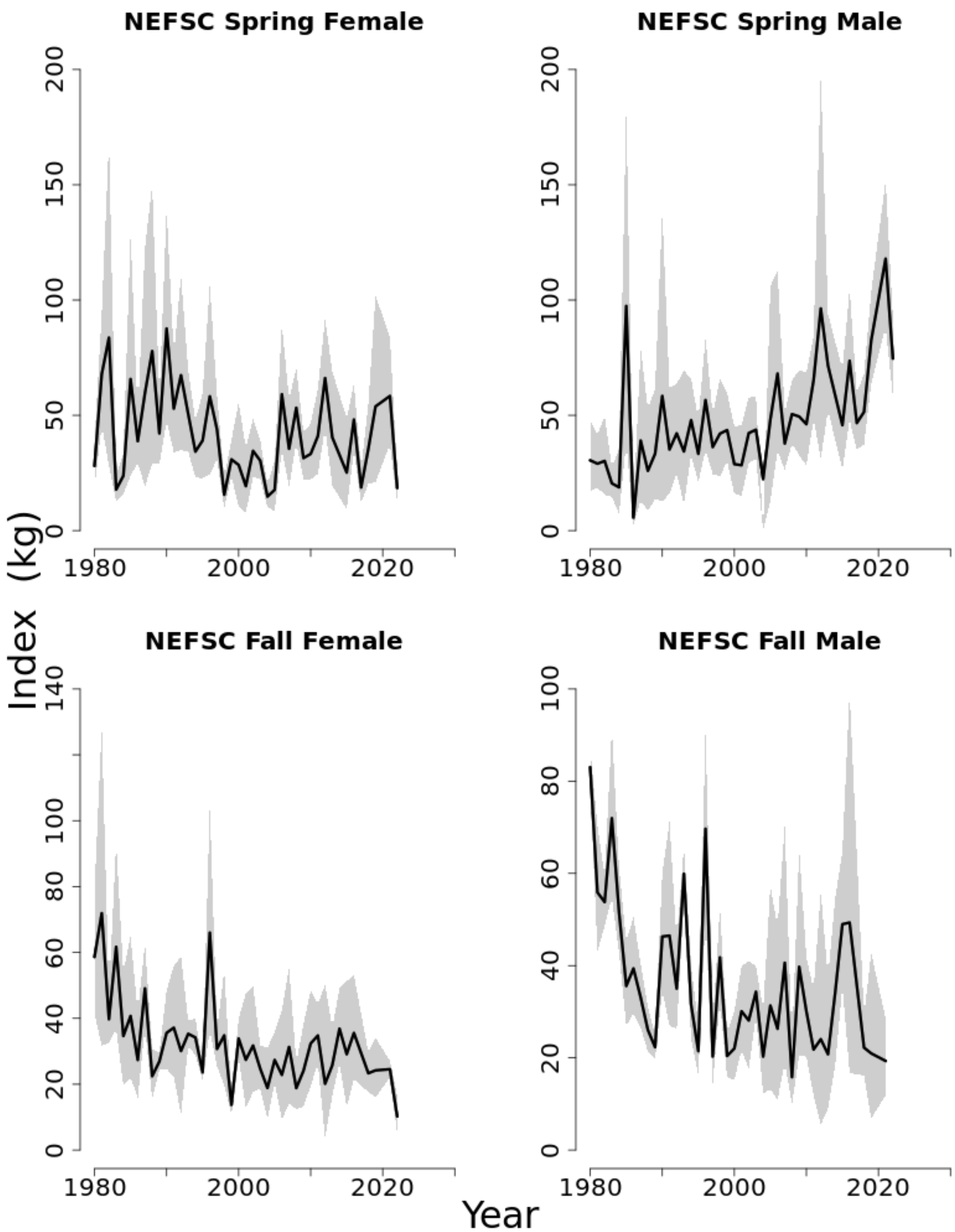

Figure 5: Indices of biomass for the Atlantic Spiny Dogfish between 1980 and 2022 for the Northeast Fisheries Science Center (NEFSC) spring and fall bottom trawl surveys; Females on the left, males on the right. The approximate 95% gamma confidence intervals are shown.

Stock Synthesis For Atlantic Spiny Dogfish

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Contents

1 Introduction

A sex-specific stock assessment model was constructed and implemented in Stock Synthesis version 3.30.21 (SS3; Methot and Wetzel 2013) for the 2023 Atlantic spiny dogfish management track assessment. This is an update of the SS3 model used during the 2022 spiny dogfish research track that is documented in NEFSC (2022). Updates on model configurations for this assessment are listed and discussed below:

- Model starting/ending year,
- Catch and survey data,
- Time blocks for biology, survey, and fishery
- Priors for selectivity parameters
- Likelihood weights for survey indices, and
- Spawner-recruitment relationship parameters.

2 Model Configuration

2.1 Model Starting/Ending Year

For the 2022 research track assessment, the SS3 model runs started in 1989, the first year quantitative discards information was available from the observer data. For this assessment, the model runs started in 1924, assuming the population was unfished before 1924. Despite the uncertainties in earlier years' catch, starting the model around the onset of the fishery is a more realistic model configuration than starting the model in 1989 with the assumption that the catch level was maintained at an initial equilibrium catch annually for 100+ years (R. Methot, NOAA Fisheries, personal communication). The terminal year for the SS3 runs is 2022 for the 2023 management track assessment. An SS3 run starting from 1989 using the 2022 research track assessment model was conducted in the sensitivity analysis.

2.2 Catch and Survey Data

Commercial catch time series data by gear were obtained from two sources: the research document from Fowler and Campana (2015) for landings from 1924 to 1961 (which was in turn based on Jensen et al. 1961) and discards from 1924 to 1988, and the Northeast Fisheries Science Center (NEFSC) database for later years. Sex-specific length composition data for catch by gear were obtained from the NEFSC database, and are available for landings from 1982 to 2022 and discards from 1989 to 2022. Like the 2022 research track assessment, the commercial data by gear were aggregated into five modeling fleets (two landings fleets and three discard fleets; Table 1 and Figures 1-2).

NEFSC spring bottom trawl survey data were used as the abundance index for the SS3 modeling. The survey index and sex-specific length composition data used in the 2022 research track assessment (offshore strata: 1-30, 34, 36-40, 61-76; inshore strata: 2, 5, 8, 11, 14, 17, 20, 23, 26, 29, 32, 35, 38, 41, 44-46, 56, 59-61, 64-66) were extended to 1982-2022 (besides 2014 and 2020 when data was not available). Following the research track assessment, survey selectivity time blocks were implemented to estimate different selectivities for the two different research vessels conducting the survey: RV *Albatross IV* (1982-2008) and FRV *Henry B. Bigelow* (2009-2022).

Additional NEFSC spring bottom trawl survey data from 1968 to 1981, which only covered the offshore strata (1-30, 34, 36-40, 61-76), were included in this assessment. The offshore strata surveyed in 1968-1981 is around half of the area size of the inshore+offshore strata surveyed in 1982-2022. The additional survey data were separated into two time series and modeled as different "fleets" in SS3 based on changes in the survey gear: Yankee 36 trawl net was used in 1968-1972, and Yankee 41 trawl net was used in 1973-1981 (Table 1). Sex-specific length composition data were available for all years except for 1973-1979, where only the unsexed data were available.

2.3 Time Blocks for Biology, Survey, and Fishery

Consistent with the 2022 research track assessment, survey time blocks (mentioned above), as well as biology time blocks, were used for this assessment. The time series was split into two biology time blocks with different growth, fecundity, and maturity for the years prior to 2012, and for 2012 and afterward.

New time blocks of selectivity for the landings fleets were introduced for this assessment. The 2022 research track assessment model showed some systematic poor fit to the landings' length composition data for large females in 1989-1993 (NEFSC 2022). Preliminary model runs for this assessment showed that the systematic poor fit persisted and extended to 1982 due to the sharp drop in proportions of large females for the landings fleets during the 1990s (Figure 3). Similar but less clear reductions were also observed for large males (Figure 4). Therefore, a time block of 1994-2022 (referred to as fishery block) on the peak value selectivity parameter (first size at maximum selectivity) for both sexes was implemented for this assessment to account for the shift in the length compositions for the two landings fleets. A sensitivity run was conducted to examine the fishery block assumption.

2.4 Prior for Selectivity Parameters

For this assessment, instead of non-informative priors, double normal selectivity parameters for all fleets utilize a diffuse symmetric beta prior (standard deviation = 0.05, scaled between parameter bounds) to impose a larger penalty near the parameter bounds. The diffuse symmetric beta prior provided only weak information about the parameters and helped the correlated selectivity parameters to avoid crashing into the bounds (Methot et al. 2021).

2.5 Likelihood Weights for Survey Indices

Preliminary model runs showed that the survey indices were not fitting well, similar to the 2022 research track model results. In order to fit the survey indices better, different likelihood weights (λ) for the three survey indices were explored during this assessment. Increasing λ changed the scale of the population and the female sex ratio of the estimated population by changing the survey catchability q and apical survey selectivity for females relative to males. $\lambda = 6$ was selected for this assessment so that the apical survey selectivity for females for the *Albatross* period is the same as the *Bigelow* period. This is a reasonable assumption, considering the substantial calibration data between these two vessels, and that the survey domain of the two periods is similar. The comparisons of model results with different λ for the survey indices are in the sensitivity analysis section.

2.6 Spawner-Recruitment Relationship Parameters

The survivorship spawner-recruitment (SR) parameters were updated based on a profile analysis and fixed at $Z_{frac} = 0.8$, $\beta = 1$, and $\sigma_R = 0.6$ (standard deviation of log recruitment deviations) for the final model for this assessment. Figure 5 compared the SR relationships from this assessment to that of the 2022 research track assessment.

3 Model Results

3.1 Convergence

The base case model converged (gradient 9.7×10^{-5}), and the Hessian matrix was positive definite. All parameters were estimated within their bounds, correlations between parameters were low (< 0.95), and all parameters were informative (correlation > 0.01).

3.2 Overall Goodness of Fit

The overall model fit to the abundance index and length composition data was evaluated using joint-index residual plots from the fit to the index data and the mean length of the length composition data (Carvalho et al. 2021). The residual plot for the three NEFSC spring bottom trawl survey indices showed a mild positive residual pattern around the end of the time series, with RMSE = 39.4% (Figure 6). The residual plot for the mean length of length composition data showed a good fit with RMSE = 8.7%. The loess-smoother of this plot showed a negative residual pattern in the early time series but no apparent residual pattern for recent years (Figure 7). The above analyses indicates a reasonably good overall fit to the data.

3.3 Growth

The time-varying growth curve by sex are shown in Figure 8. The estimated L_∞ for the biology block 2012-2022 were 88.52 cm for females and 79.74 cm for males. These estimates are similar to the 2022 research track assessment (female: 89.24 cm; male: 79.14 cm) and smaller than the estimates from Nammack et al. (1985; female: 100.5 cm; male: 82.49 cm). The reduction is more significant for females than males, likely reflecting the decrease of large females and males in both catch and survey data after 1995 (Figures 3 and 4).

3.4 Abundance Index

The observed and model-predicted NEFSC spring bottom trawl abundance indices are shown in Figure 9. The estimated survey catchabilities (q) were 0.17, 0.47, and 0.87 for fleets 6 (1968-1972), 7 (1973-1981), and 8 (1982-2022), respectively.

3.5 Selectivity

The estimated selectivities by sex and fleet are shown in Figure 10. The estimated selectivities were asymptotic (logistic) for all landings fleets and NEFSC spring bottom trawl survey fleets (fleets 1, 2, 6-8) and dome-shaped for all discard fleets (3-5). The estimated apical male selectivity was smaller than females for landings and discard fleets (1-5), which is reasonable for a female-targeted fishery. The estimated apical male selectivity was smaller than females for the two offshore surveys but similar to females for the inshore+offshore survey.

Time-varying selectivities showed a reduced peak value selectivity parameter for females and males for the two landings fleets in 1994-2022 (Figures 11 and 12). The peak value was reduced by 12.5 cm for fleet 1 and 9.9 cm for fleet 2 for both sexes. NEFSC spring bottom trawl survey showed increased selectivities for the median-size females and males during the *Bigelow* period (2009-2022; Figure 13).

3.6 Length Composition

The observed and model-predicted length compositions aggregated across time by fleet and sex are shown in Figure 14. The fits to the aggregated length compositions appear to be reasonably accurate. The observed and model-predicted annual length composition data and the residuals from the fits by fleet and sex are in Figures 15-30. Fits to the annual length composition were poor for the median size males for fleet 8 (Figure 30).

3.7 Recruitment

The fixed survivorship SR relationship, along with the estimated age-0 recruitment from both the SR relationship and recruitment deviations, are shown in Figure 31. The estimated age-0 recruitment has decreased slightly since 2019 (Table 2 and Figure 32).

3.8 Total Biomass, Spawning Output, and Fishing Mortality

The estimated time series of spawning output, fishing mortality, and sex-specific total biomass are provided in Table 2 and Figures 33 and 34. The estimated total biomass indicated significant changes in the population structure: the female-dominated population shifted to male domination around the 1980s (Figure 33). Females' weights at age are greater and have longer lifespans than males (Nammack et al. 1985); therefore, the estimated biomasses were higher than males early in the time series. This changed in the 1980s due to increasing fishing pressure on larger females (Figure 3). The estimated spawning output, i.e., the number of pups the mature females produced, had been dropping since 2012 but leveled off in the most recent years (Figure 34). The terminal spawning output is 190,771 (1,000s). The estimated fishing mortality decreased slightly since 2020. The terminal fishing mortality is 0.02.

4 Sensitivity Analysis

4.1 1989-2022 Research Track Model

Sensitivity runs were conducted to compare different model configurations:

- 2023 management track model (1924-2022),
- 2022 research track model (1989-2019), and
- 2022 research track model (1989-2022).

The estimated spawning output and fishing mortality from the 2022 research track model (1989-2019) are the highest and lowest, respectively, among the three models tested (Figures 35 and 36). However, the estimated spawning output, fishing mortality, and recruitment from the 2022 research track model with additional three years of data (1989-2022) and from the 2023 management track model (1924-2022) are very similar (1924-2022; Figures 35-37).

4.2 Fishery Block

A sensitivity run was conducted without the fishery block assumption. The fishery block assumption has minor influence on the estimated spawner output, fishing mortality, and recruitment (Figures 38-40) but improved the fits to the length compositions for large females and males in years prior to 1994 for the two landings fleets (Figures 41 and 42).

4.3 Likelihood Weights

Ten SS3 runs with λ increased from 1 to 10 for all three surveys were conducted, and the results were compared. Fits to the survey indices improved slightly with increasing *lambda*

(Figure 43). The improvement is mainly contributed by reducing survey catchability q and changes in female apical selectivity for the NEFSC spring bottom trawl survey (fleet 8). The survey q was reduced from 0.97 at $\lambda = 1$ to 0.84 at $\lambda = 10$. As a result, the estimated total population and recruitment increased with increasing λ (Figures 44 and 45).

A female apical selectivity smaller than 1 means fewer females were caught than males, and vice versa for the female apical selectivity larger than 1. The female apical selectivity was reduced from 1.1 to 0.91 for the *Albatross* period and increased from 0.82 to 0.99 for the *Bigelow* period with increasing λ. The influences of the female apical selectivity for the *Bigelow* period on the population estimates were more significant because the *Bigelow* survey caught more males than females for all years (Figure 46). The increases in apical female selectivity indicated that more females should be in the population than what was observed in the survey. As a result, the model increased the female sex ratio and estimated more females in the population with increasing λ (Figure 47).

The combination of increasing total population, recruitment, and female sex ratio results in an increase in spawning output and a decrease in fishing mortality with increasing λ (Figures 48 and 49). The final model was chosen so that the female apical selectivity from the *Albatross* and *Bigelow* period are the same.

5 Retrospective Analysis

A 7-year peel retrospective analysis was conducted for the base case model. The results indicated that the model has a minor retrospective pattern with Mohn's $\rho = -0.09$ for the spawning output and 0.06 for the fully recruited fishing mortality (Figures 50-51).

6 References

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Table 1: Summary of Atlantic spiny dogfish data by gear and fleet used in SS3.

Type	Gear	Fleet	Label in SS3
Landings	Sink Gill Net + Others Recreational	1	Landings_SGN_Rec_Others
Landings	Longline Otter Trawl + Foreign Fleet	2	Landings_LL_OT_Foreign
Discard	Sink Gill Net Scallop Dredge	3	Discard_SGN_SD
Discard	Longline Large Mesh Otter Trawl Recreational	4	Discard_LMOT_LL_Rec
Discard	Small Mesh Otter Trawl	5	Discard_SMOT
Survey	NEFSC Spring Bottom Trawl Offshore Yankee 36 1968-1972	6	NEFSC_Spring_BTS_OFFSHORE_Y36
Survey	NEFSC Spring Bottom Trawl Offshore Yankee 41 1973-1981	7	NEFSC_Spring_BTS_OFFSHORE_Y41
Survey	NEFSC Spring Bottom Trawl Inshore+Offshore 1982-2022	8	NEFSC_Spring_BTS

Table 2: Summary of total biomass by sex, spawning output (1,000s), recruitment (1,000s, age-0) and fishing mortality (age-12+) by year estimated by SS3 for Atlantic spiny dogfish.

Year	Total Biomass (mt) Female	Total Biomass (mt) Male	Spawning Output (1,000s)	Recruitment (1,000s)	F (age-12+)
1924	954497	718806	938549	211968	0.002
1925	953700	718429	937653	212007	0.001
1926	953202	718201	937050	212033	0.001
1927	952993	718117	936746	212046	0.008
1928	949227	716333	932441	212227	0.015
1929	941993	712922	924049	212567	0.019
1930	933378	708901	913746	212962	0.008
1931	930383	707639	909335	213122	0.004
1932	929636	707487	907355	213193	0.003
1933	929509	707650	906120	213237	0.002
1934	930012	708123	905687	213252	0.006
1935	928258	707497	902876	213349	0.011
1936	924278	705808	897597	213527	0.009
1937	921605	704771	893672	213654	0.007
1938	920154	704354	891071	213736	0.011
1939	916719	702975	886310	213881	0.010
1940	914004	701961	882309	213999	0.048
1941	893839	692417	858968	214597	0.050
1942	874495	683291	835712	215037	0.010
1943	873812	683477	832299	215088	0.011
1944	873079	683625	829054	215133	0.005
1945	875345	685248	829349	215129	0.005
1946	877641	686858	830088	215119	0.013
1947	876373	686700	827309	215156	0.004
1948	879377	688649	829392	215128	0.005
1949	881905	690322	831330	215102	0.056
1950	862225	680963	809296	215335	0.013
1951	862154	681401	807821	215345	0.009
1952	863836	682676	808464	215340	0.005
1953	867336	684813	811394	215319	0.007
1954	870027	686523	813818	215299	0.006
1955	873172	688380	817054	215270	0.008
1956	875117	689620	819247	215249	0.045
1957	860907	682821	803969	215367	0.113
1958	818991	662027	757841	215241	0.084
1959	792753	649005	726825	214714	0.078
1960	771379	638417	700114	213950	0.081
1961	750976	628227	673959	212903	0.084
1962	731536	618413	648588	211589	0.052
1963	724885	615370	636610	210860	0.053
1964	718473	612516	625317	210107	0.053
1965	712448	609819	615016	209364	0.053
1966	707080	607371	606055	208671	0.061
1967	694497	604780	586765	207033	0.050
1968	685363	597572	580230	46614	0.049
1969	671974	586702	572700	47586	0.050
1970	654261	574439	561184	102661	0.043
1971	637942	559865	556305	72874	0.045
1972	616318	544475	545625	103335	0.054

Table 2: Continued.

Year	Total Biomass (mt) Female	Male	Spawning Output (1,000s)	Recruitment (1,000s)	F (age-12+)
1973	583243	526877	521606	70014	0.049
1974	555238	509561	505930	100067	0.053
1975	522196	491259	484676	77715	0.049
1976	492086	473374	467611	78480	0.045
1977	466848	456265	455502	95015	0.039
1978	450117	441439	449478	138822	0.038
1979	437414	427072	443337	115873	0.045
1980	421395	414020	424748	132674	0.053
1981	407357	403103	402390	156920	0.061
1982	393064	394131	375491	145041	0.071
1983	381246	386259	349529	156367	0.077
1984	370941	378948	325501	117599	0.078
1985	365724	376141	303883	207773	0.076
1986	363641	375701	285493	172721	0.075
1987	365937	378077	271585	197177	0.077
1988	369535	381442	260582	164695	0.083
1989	374321	386505	251357	192450	0.097
1990	379180	393204	242328	223895	0.170
1991	372443	396547	219501	219511	0.121
1992	372006	404902	204436	204941	0.207
1993	360719	406672	181174	181659	0.118
1994	360177	415370	166107	166553	0.107
1995	364698	424688	163647	164083	0.131
1996	364350	431171	159114	159534	0.185
1997	354361	432972	148489	148789	0.086
1998	359672	439668	152866	150998	0.095
1999	358817	441577	156384	71060	0.074
2000	360517	442048	166173	98717	0.048
2001	363844	440117	183162	51845	0.040
2002	367828	435251	205654	63718	0.035
2003	368969	427999	228646	55935	0.019
2004	371831	420462	254648	71430	0.023
2005	371048	410777	277530	64146	0.018
2006	370265	401706	298808	93513	0.021
2007	366970	392134	315694	87945	0.026
2008	363098	384728	326579	155856	0.021
2009	361663	380745	334000	170601	0.026
2010	362053	379913	335360	210794	0.019
2011	367783	383971	334501	227210	0.030
2012	373941	393985	346988	327060	0.032
2013	358249	394338	311424	81819	0.030
2014	352166	399982	283295	230720	0.046
2015	340144	400850	253788	70414	0.033
2016	334098	402504	233505	99451	0.044
2017	325375	402434	212552	104129	0.038
2018	319616	400441	200023	78325	0.031
2019	319409	401465	193576	193546	0.042
2020	318821	402620	188899	189253	0.042
2021	318802	404738	186614	186614	0.027
2022	321401	406767	190771	136158	0.020

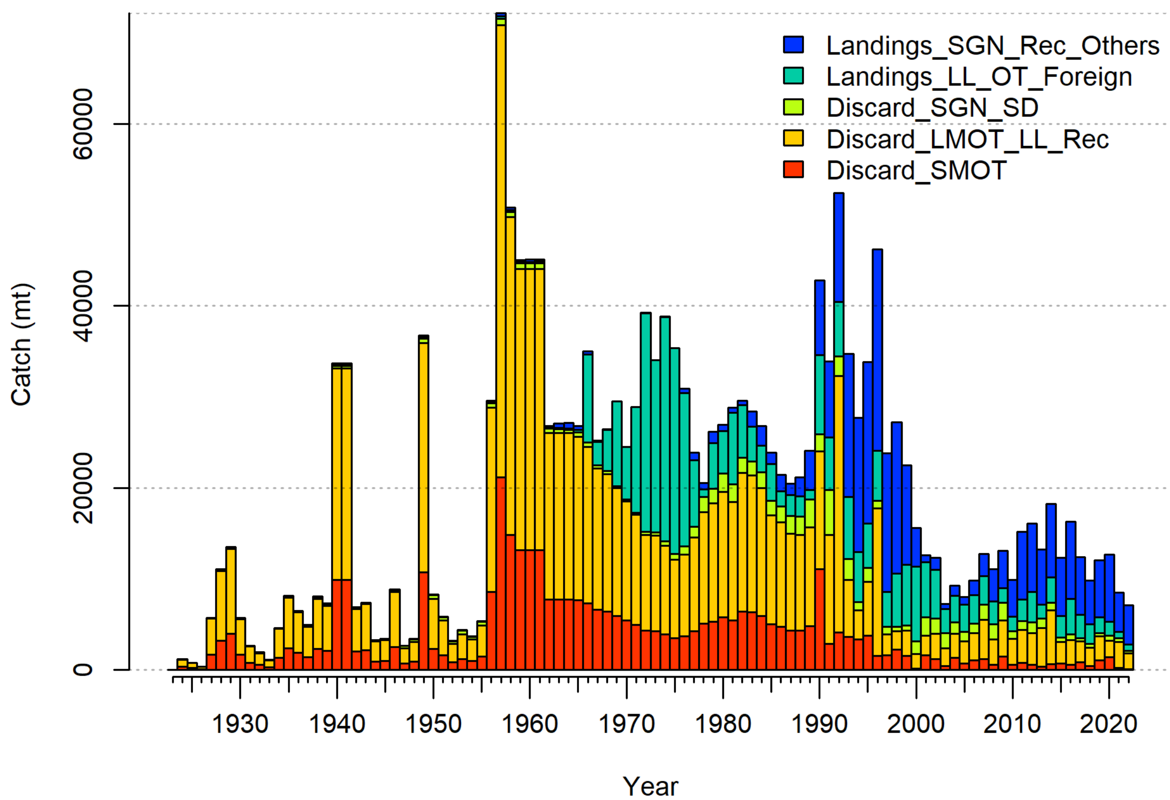


Figure 1: Time series of Atlantic spiny dogfish catch (landings plus dead discards) by fleet.

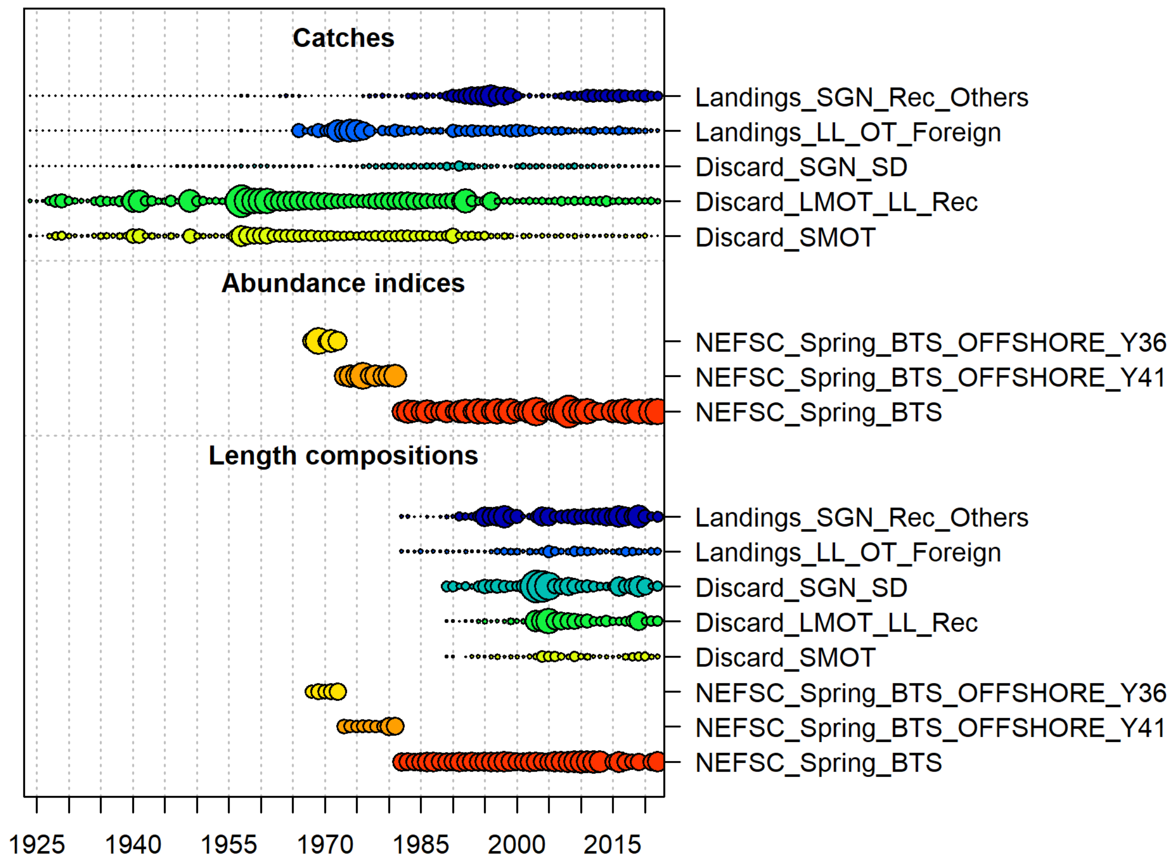


Figure 2: Catch and survey data by year for each fleet used in SS3. Circle area is relative within a data type. Circles are proportional to total catch for catches, to precision for indices, and to total sample size for length compositions. Note that since the circles are scaled relative to the maximum within each type, the scaling within separate plots should not be compared.

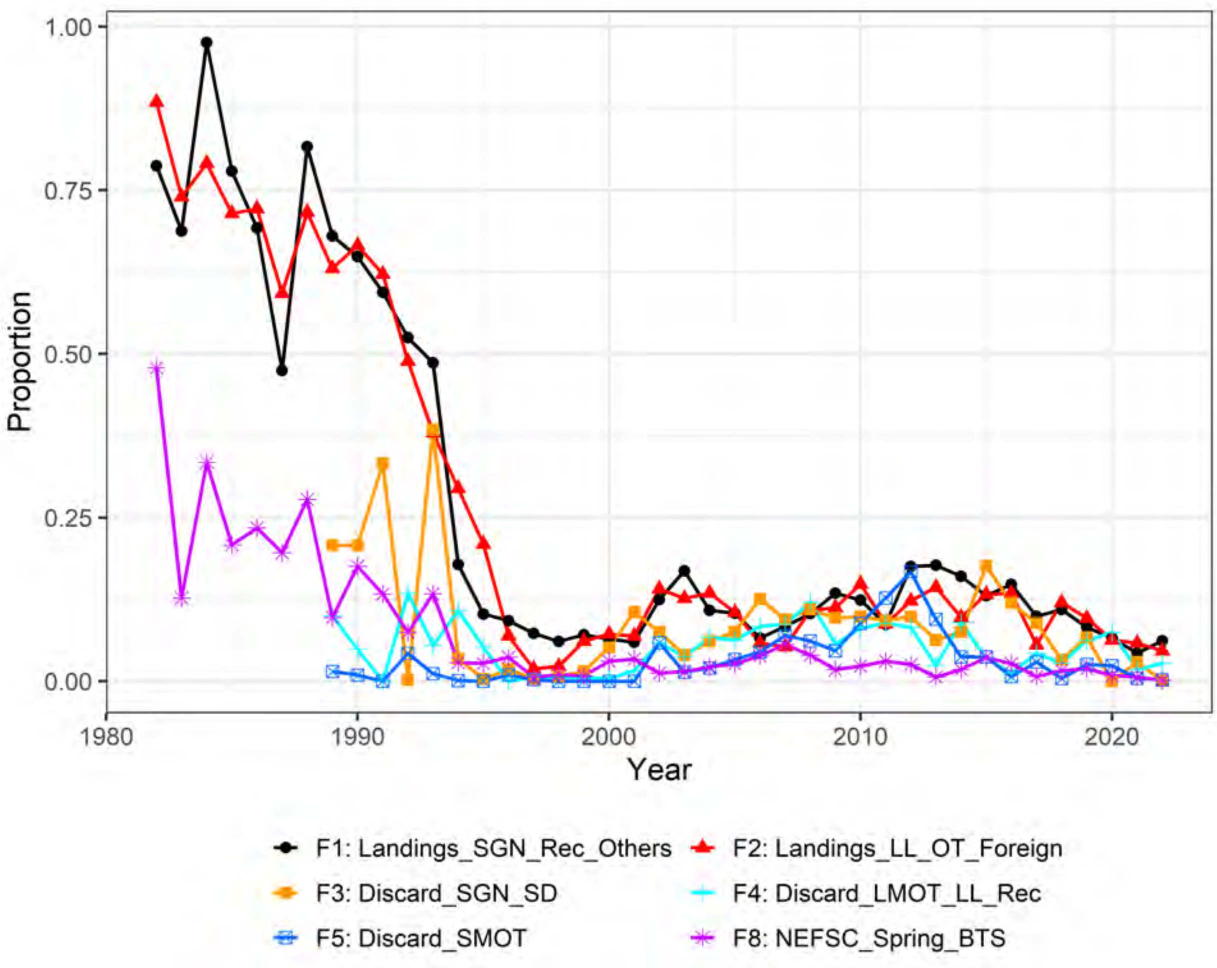


Figure 3: Proportions of 90+ cm females by fleet from 1982 to 2022.

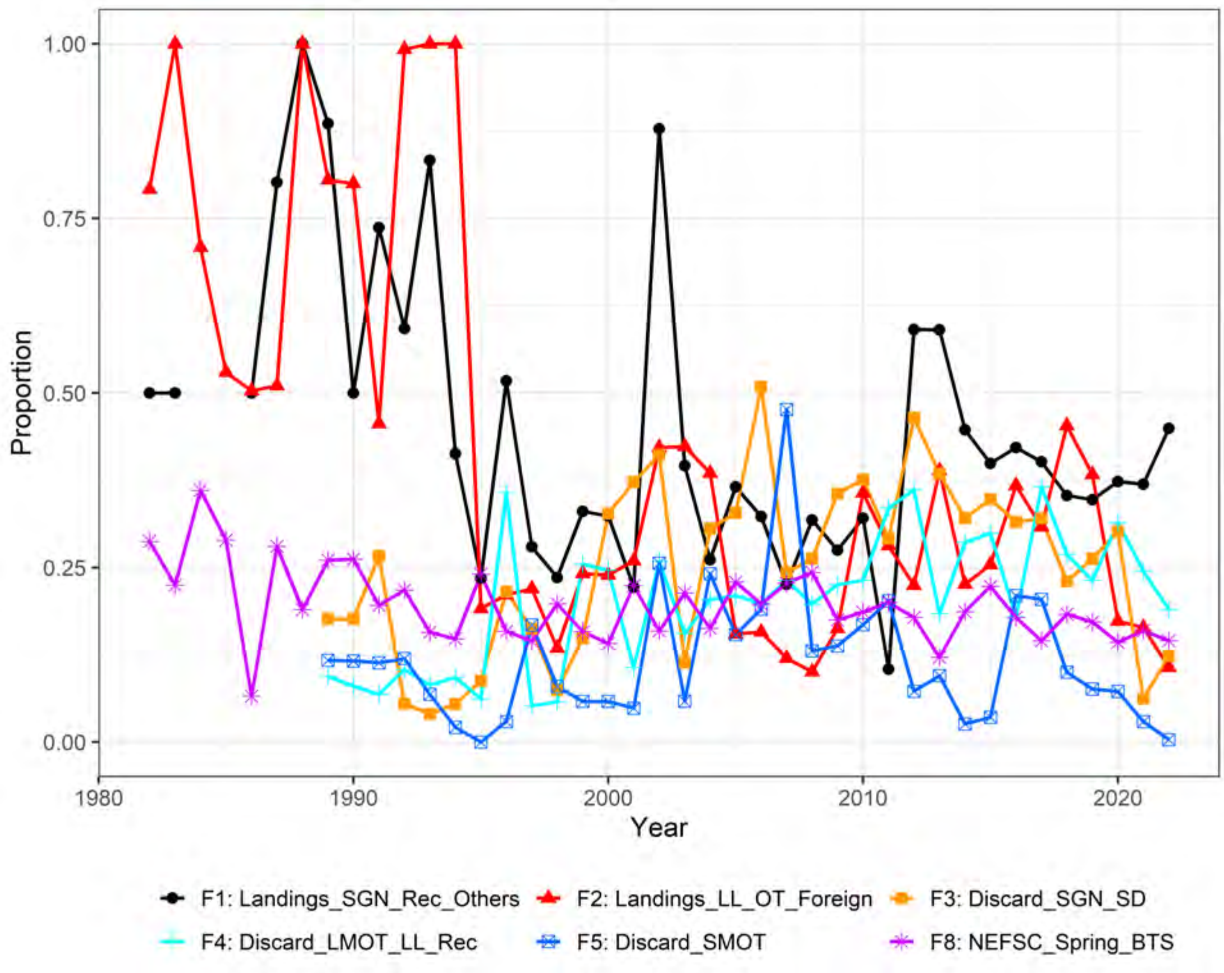


Figure 4: Proportions of 75+ cm males by fleet from 1982 to 2022.

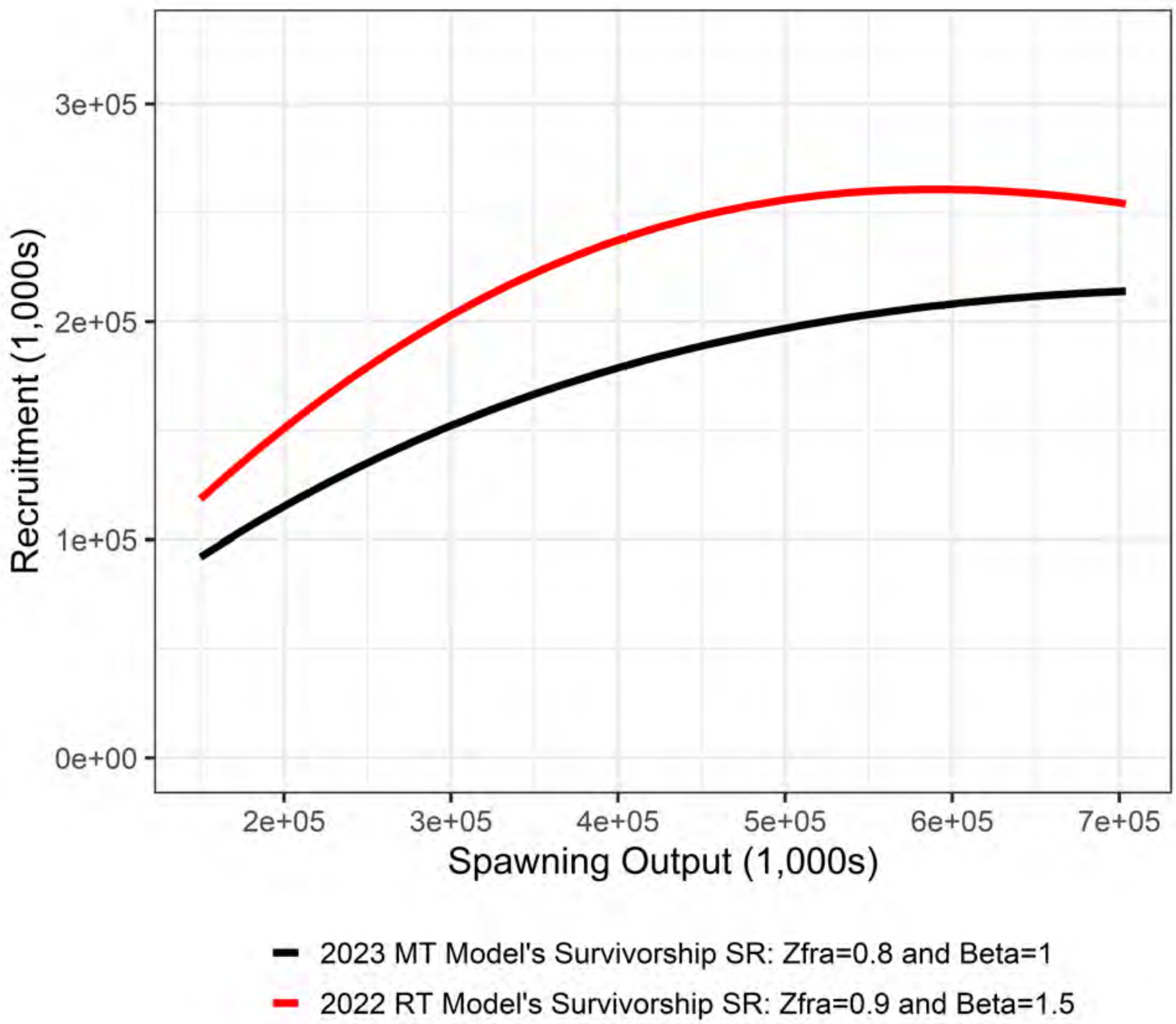


Figure 5: Comparison of survivorship spawner-recruitment relationships assumed in the 2022 research track and 2023 management track assessment model.

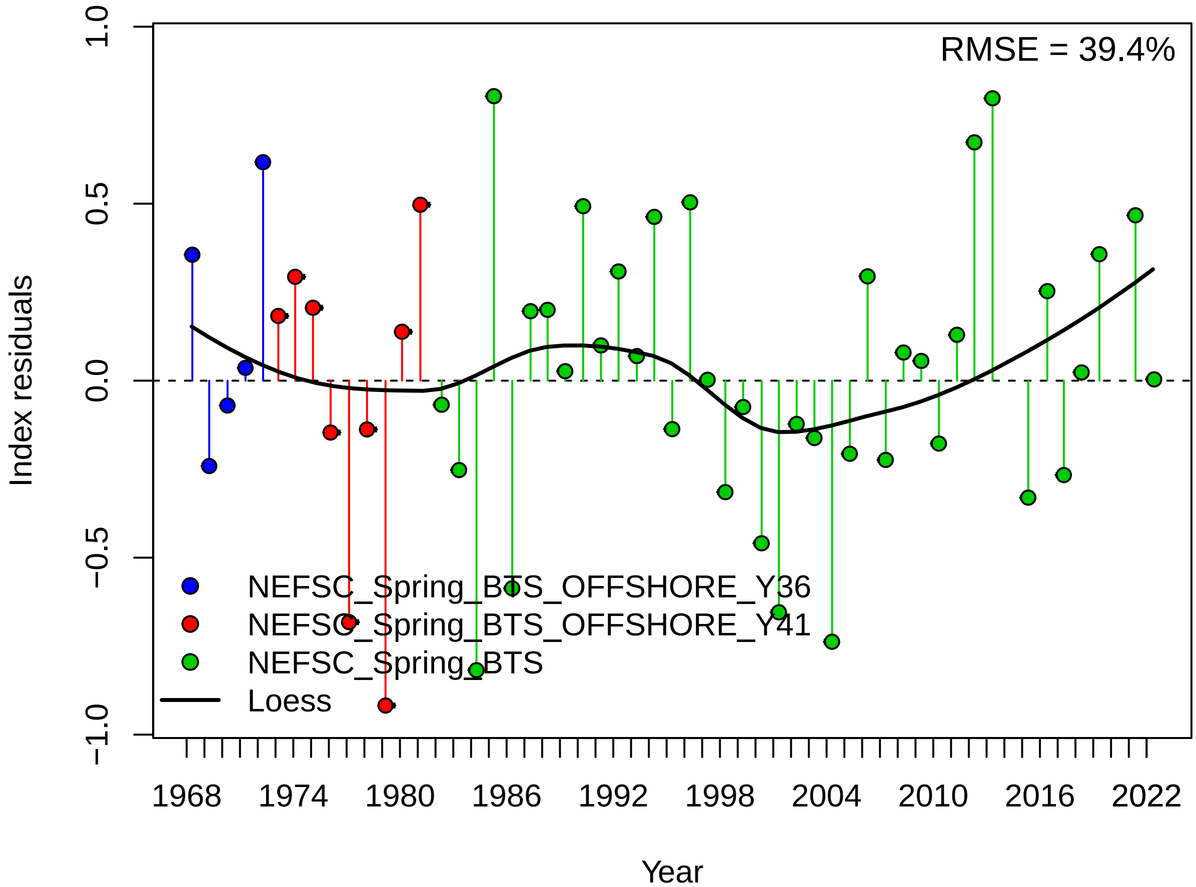


Figure 6: Joint residual plot from fit to annual survey index data.

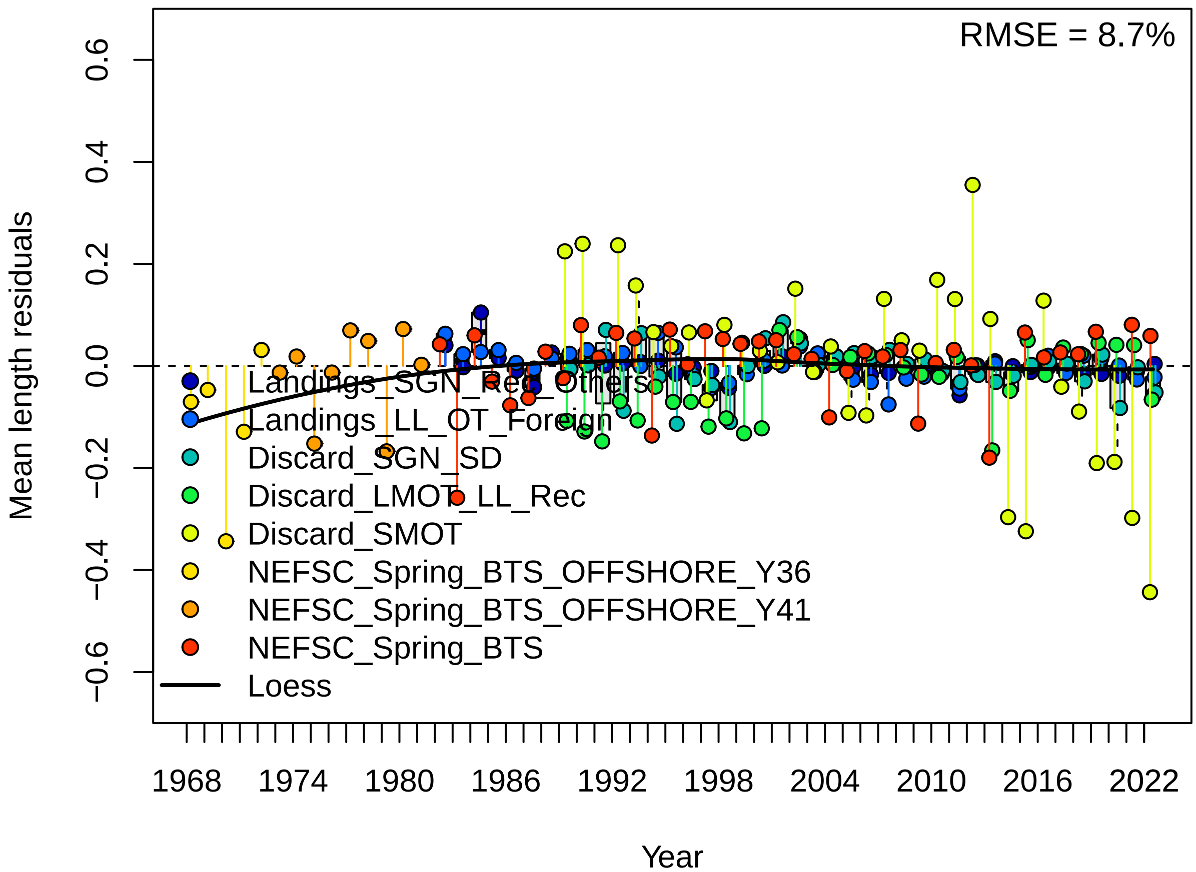


Figure 7: Joint residual plot from fit to annual mean length from length composition data.

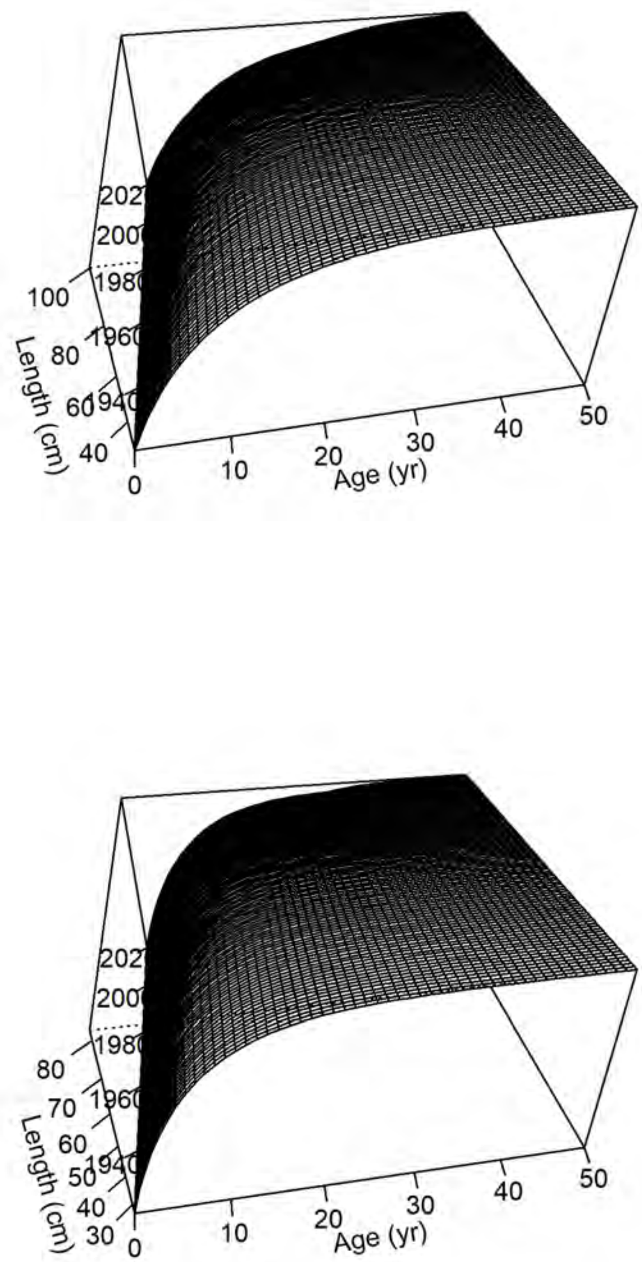


Figure 8: Surface plot of time-varying growth for females (top) and males (bottom) from 1924 to 2022.

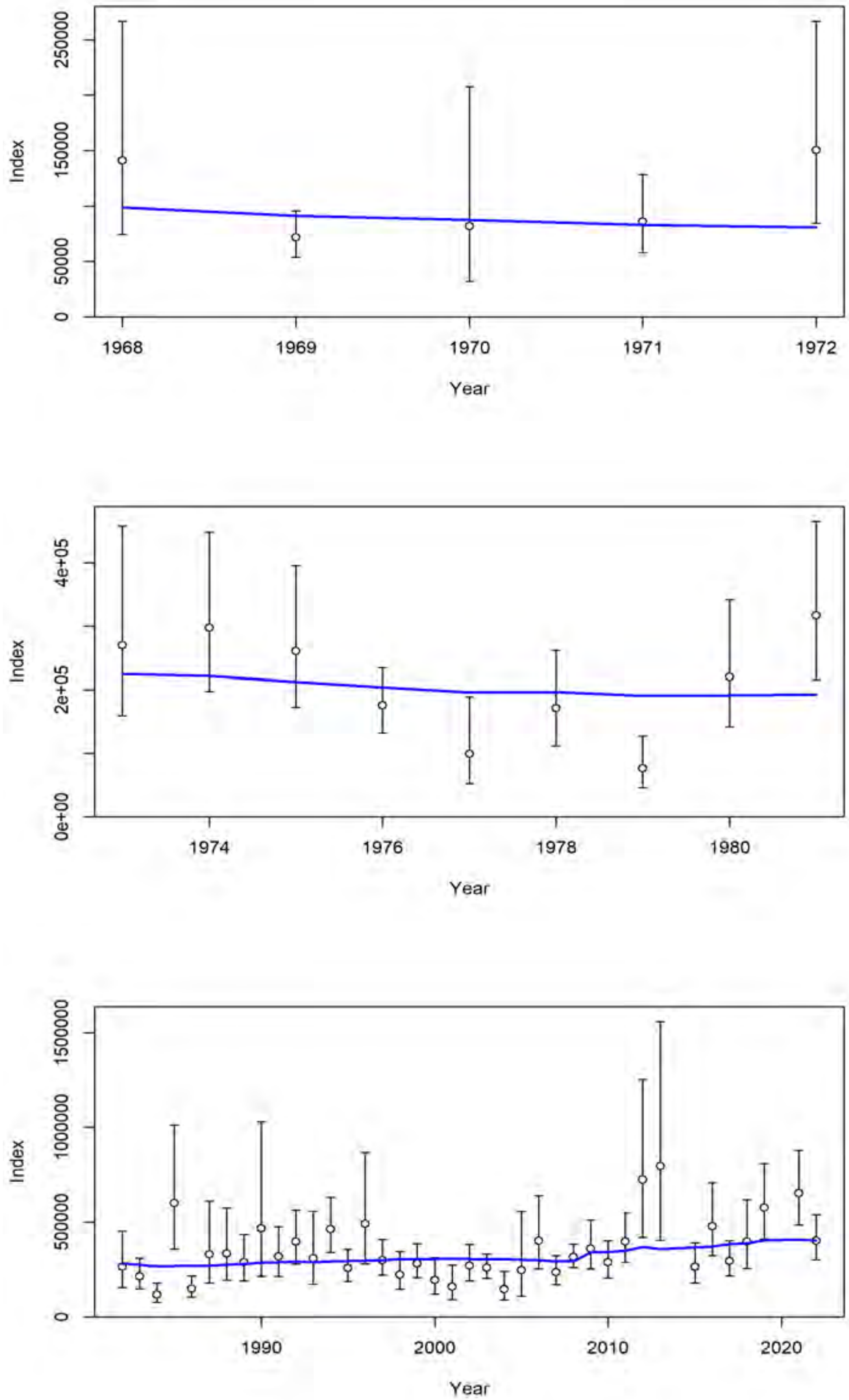


Figure 9: Observed and model-predicted abundance index (1,000s) for the NEFSC spring bottom trawl surveys. Lines indicate 95% uncertainty interval around index values based on the model assumption of lognormal error.

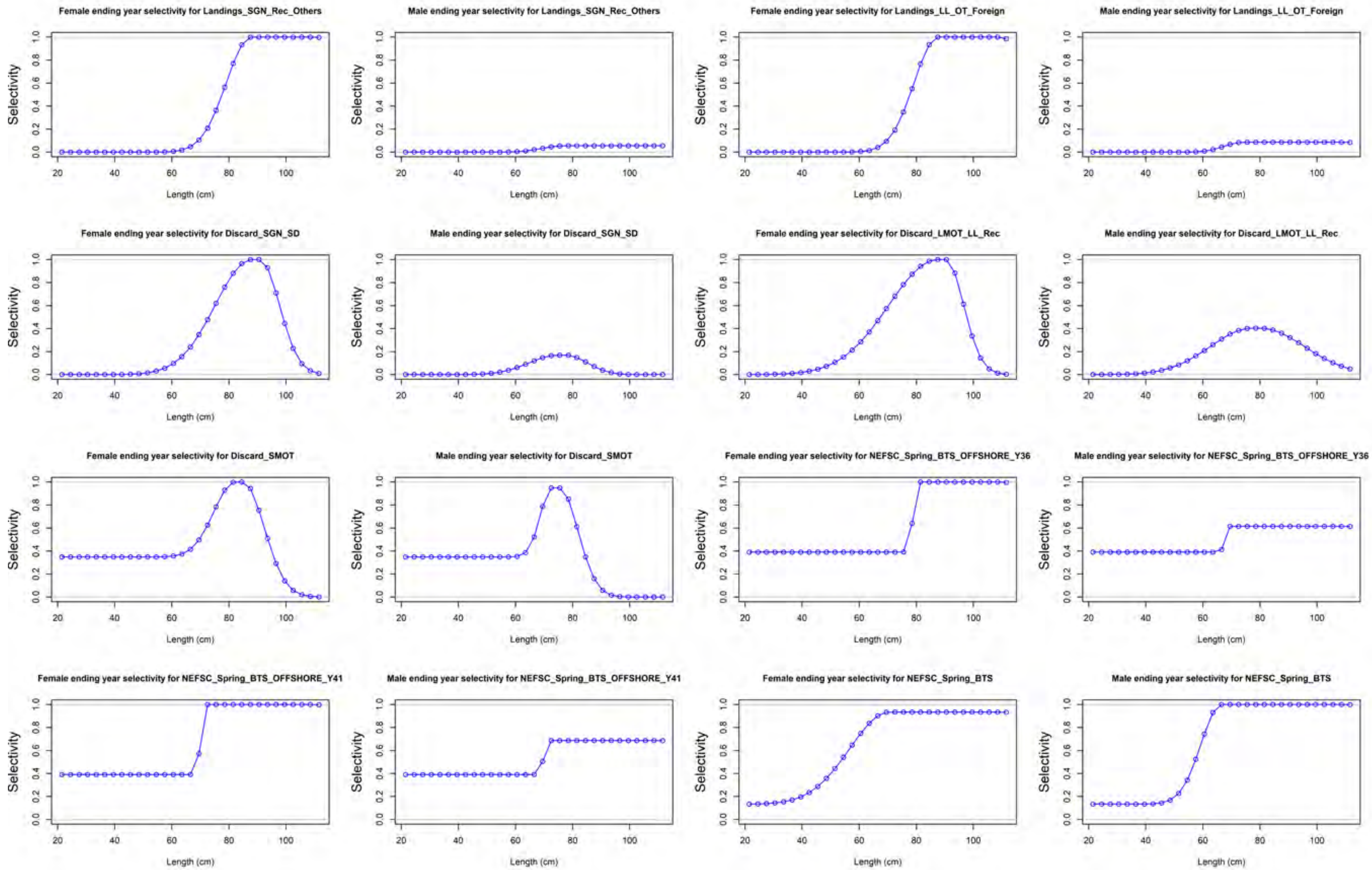
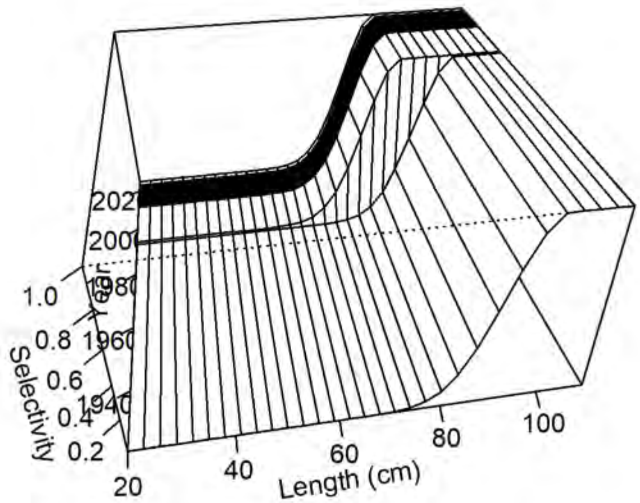


Figure 10: Estimated ending year selectivity for females and males for all fleets.



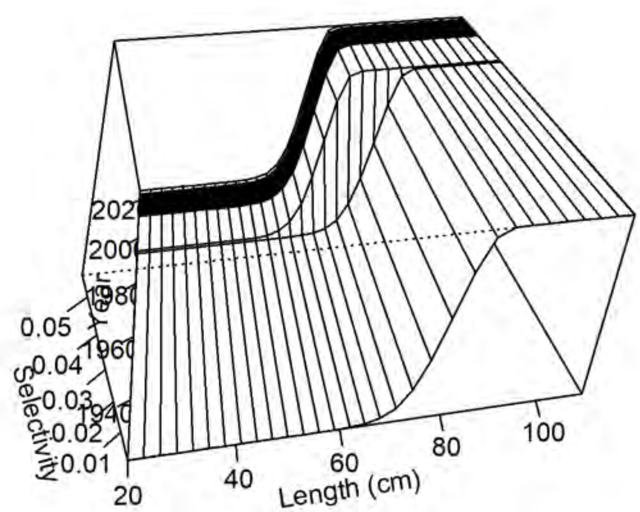
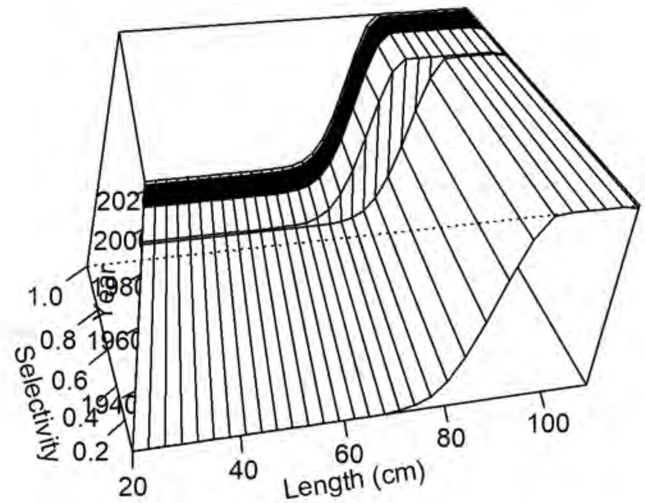


Figure 11: Surface plot of time-varying selectivity for females (top) and males (bottom) from 1982 to 2022 for fleet 1: Landings_SGN_Rec_Others.



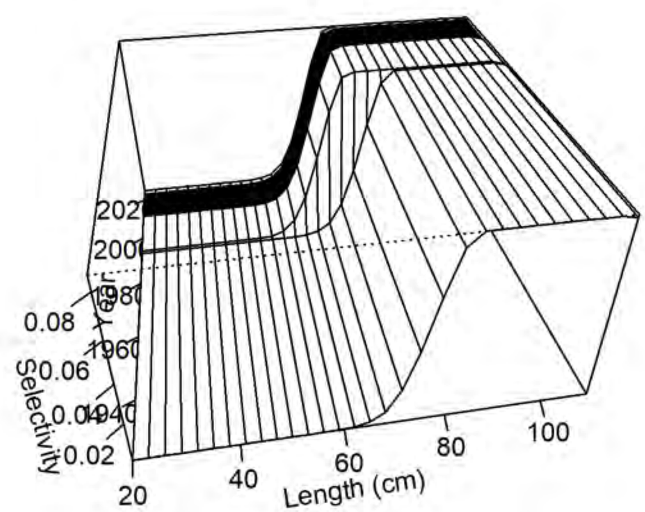


Figure 12: Surface plot of time-varying selectivity for females (top) and males (bottom) from 1982 to 2022 for fleet 2: Landings_LL_OT_Foreign.

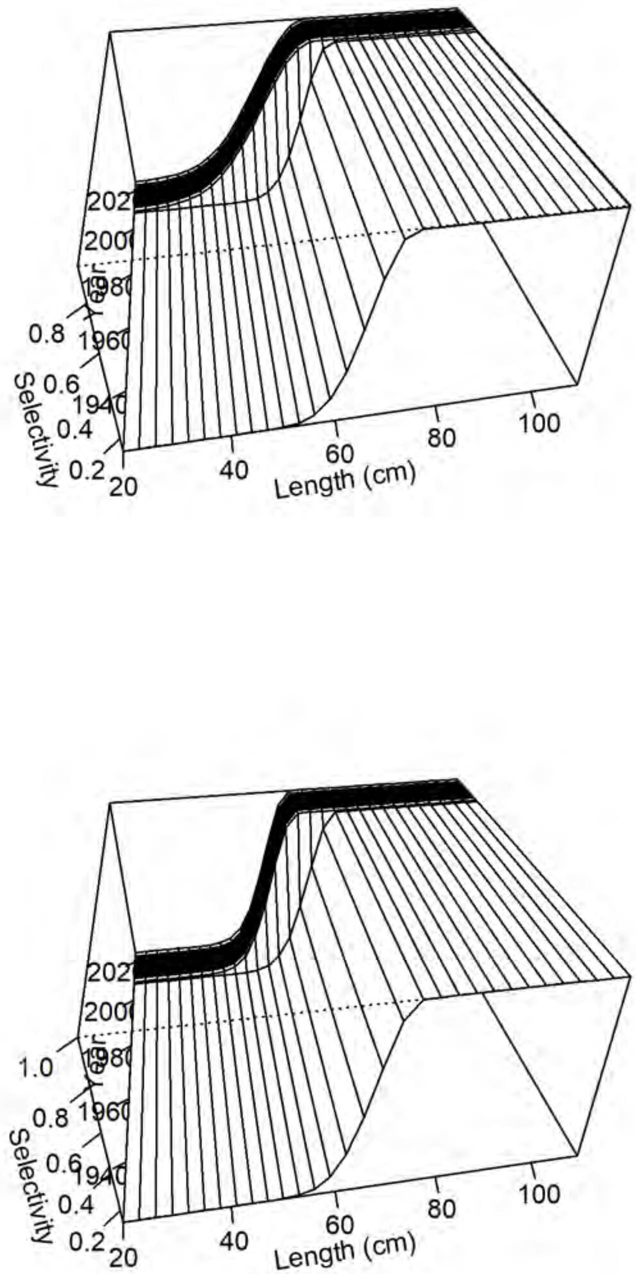


Figure 13: Surface plot of time-varying selectivity for females (top) and males (bottom) from 1982 to 2022 for fleet 8: NEFSC_Spring_BTS.

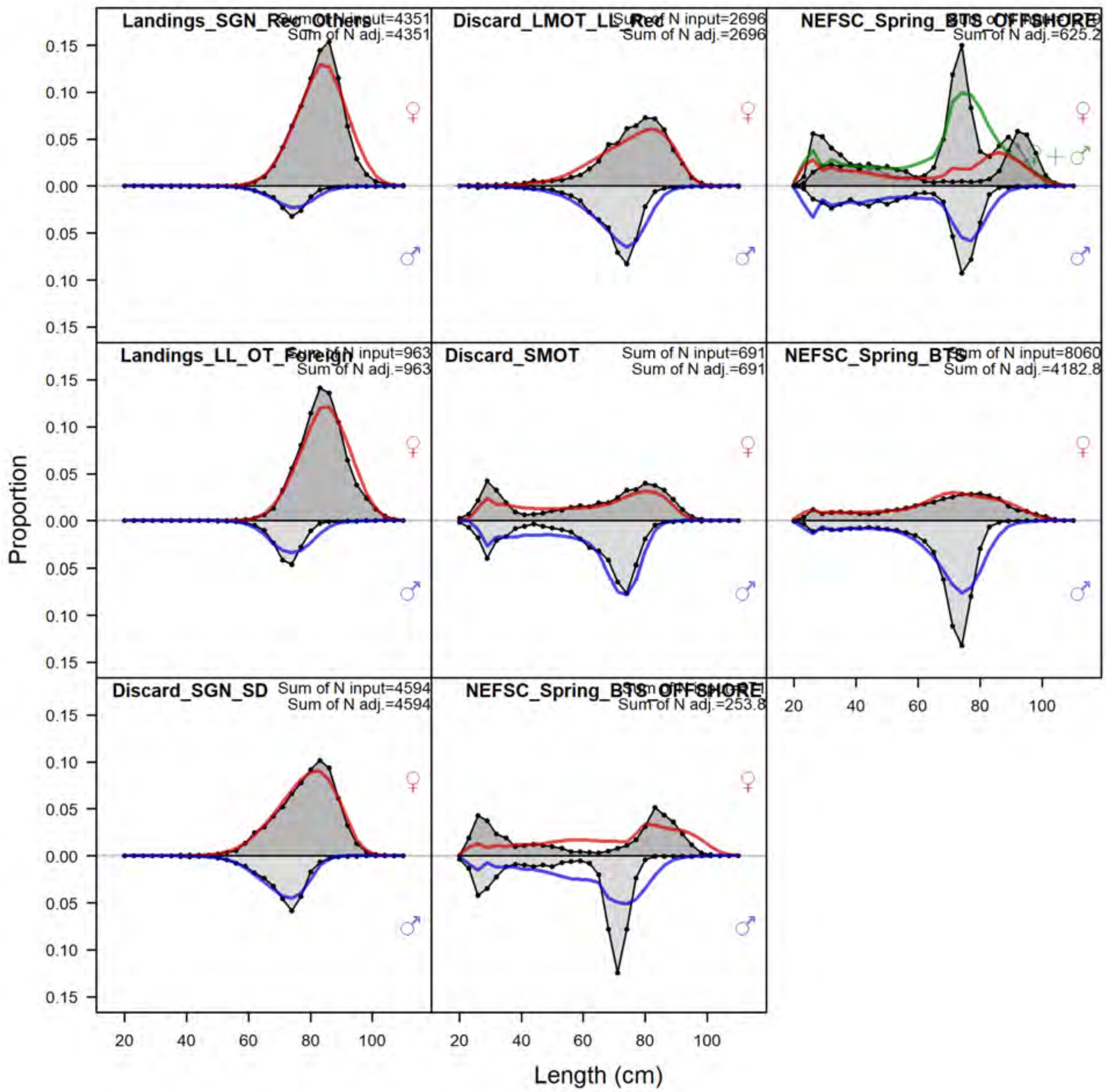


Figure 14: Observed (shaded) and model-predicted (line) length compositions, aggregated across time by fleet and sex.

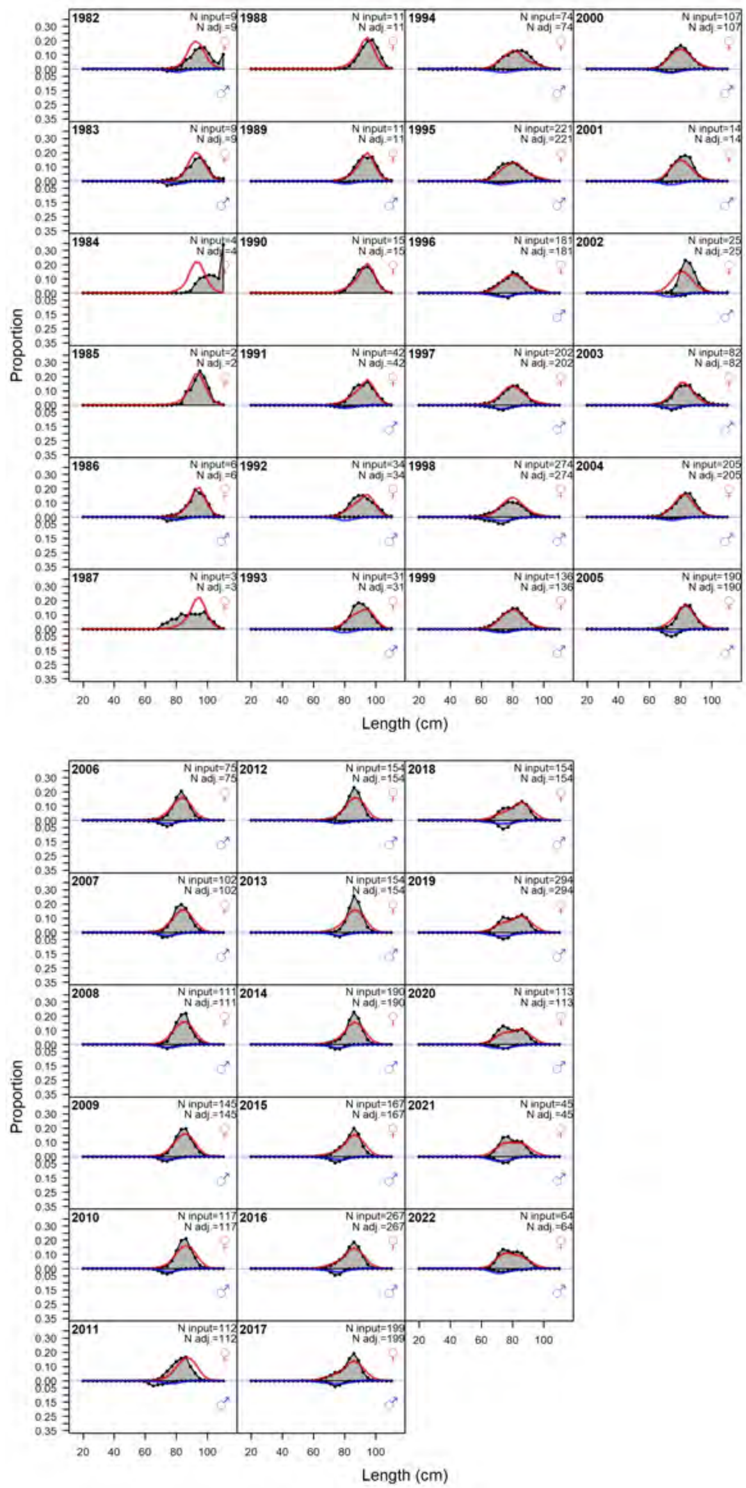


Figure 15: Fit to length compositions by year and sex for fleet 1: Landings_SGN_Rec_Others.

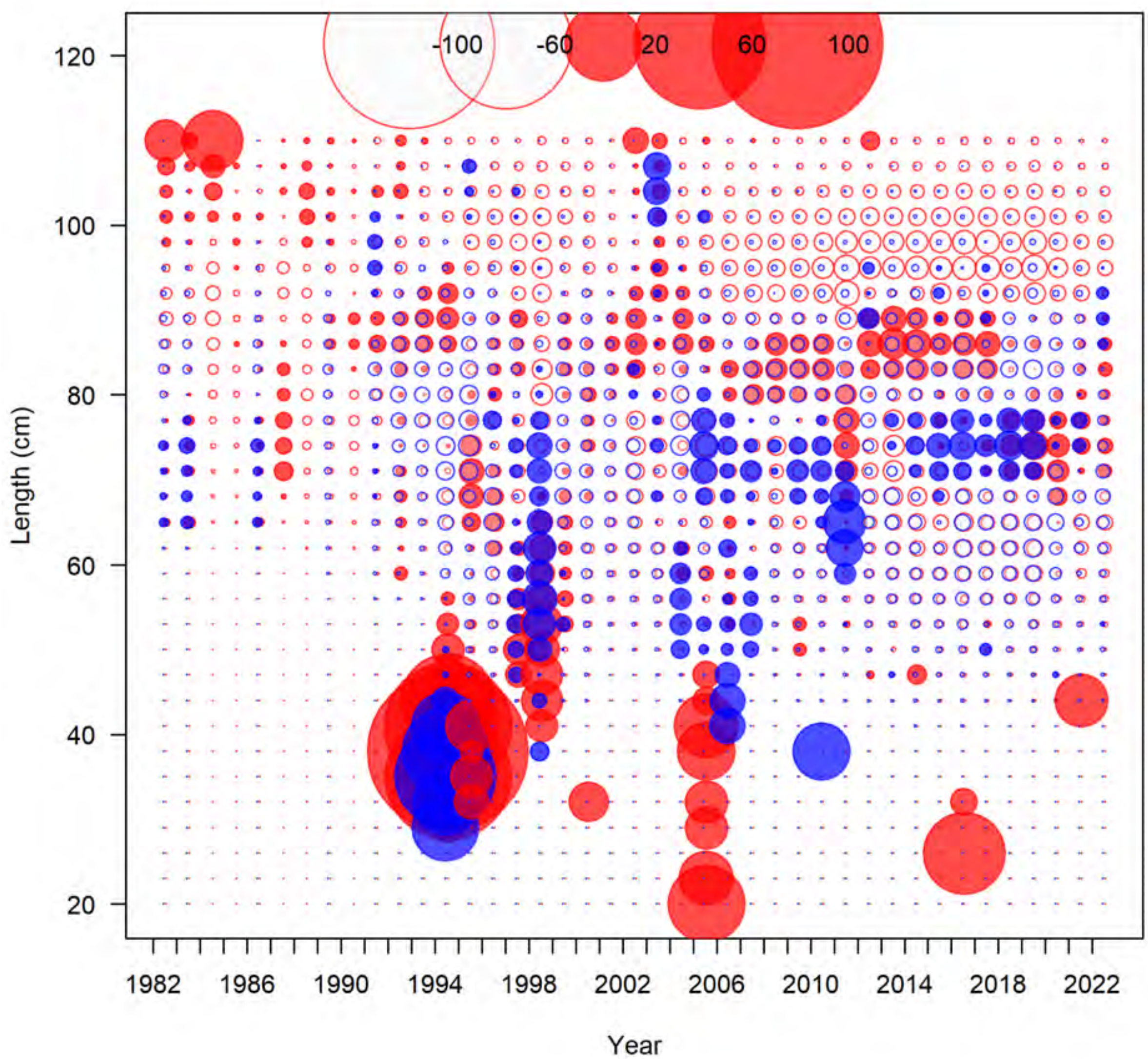


Figure 16: Pearson residuals for the fit to length compositions by year and sex for fleet 1: Landings_SGN_Rec_Others. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

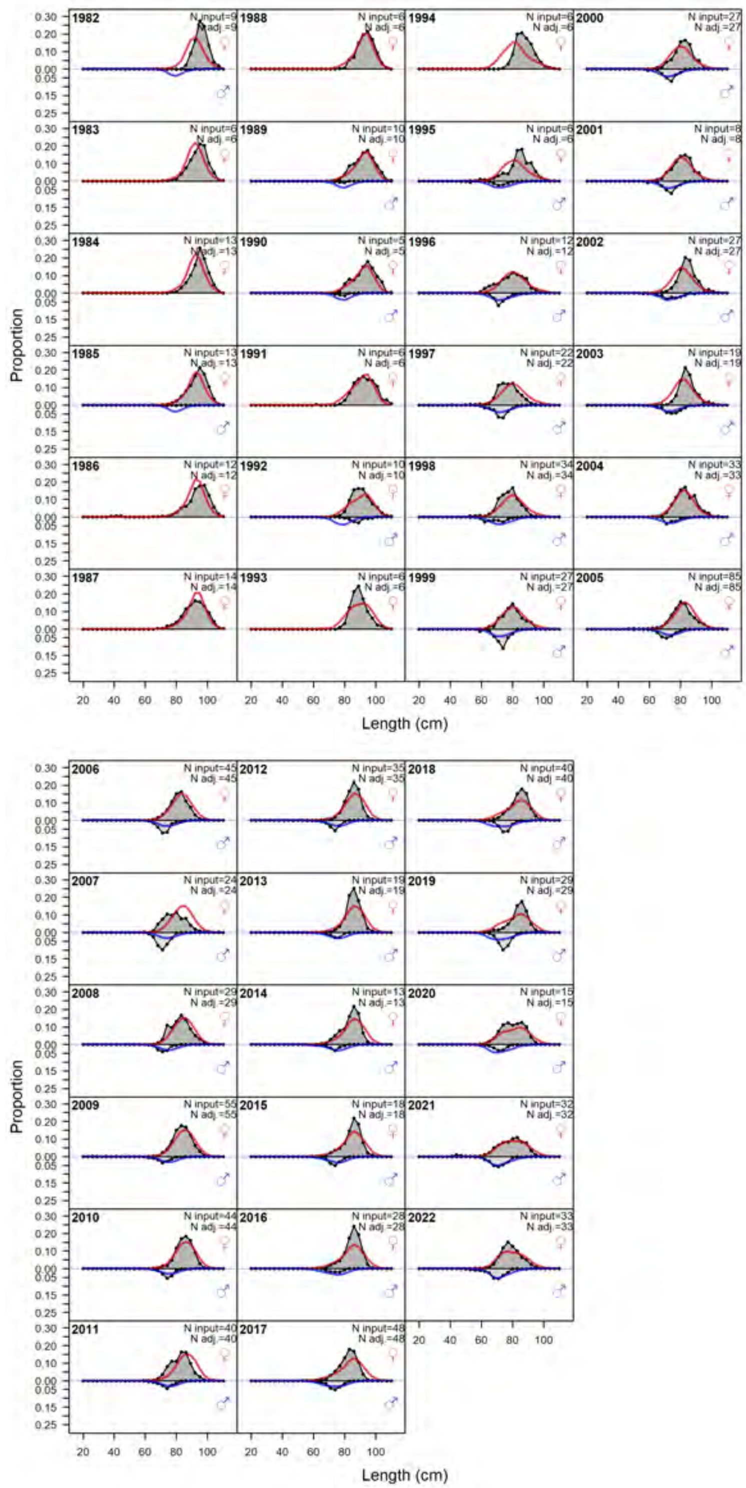


Figure 17: Fit to length compositions by year and sex for fleet 2: Landings_LL_OT_Foreign.

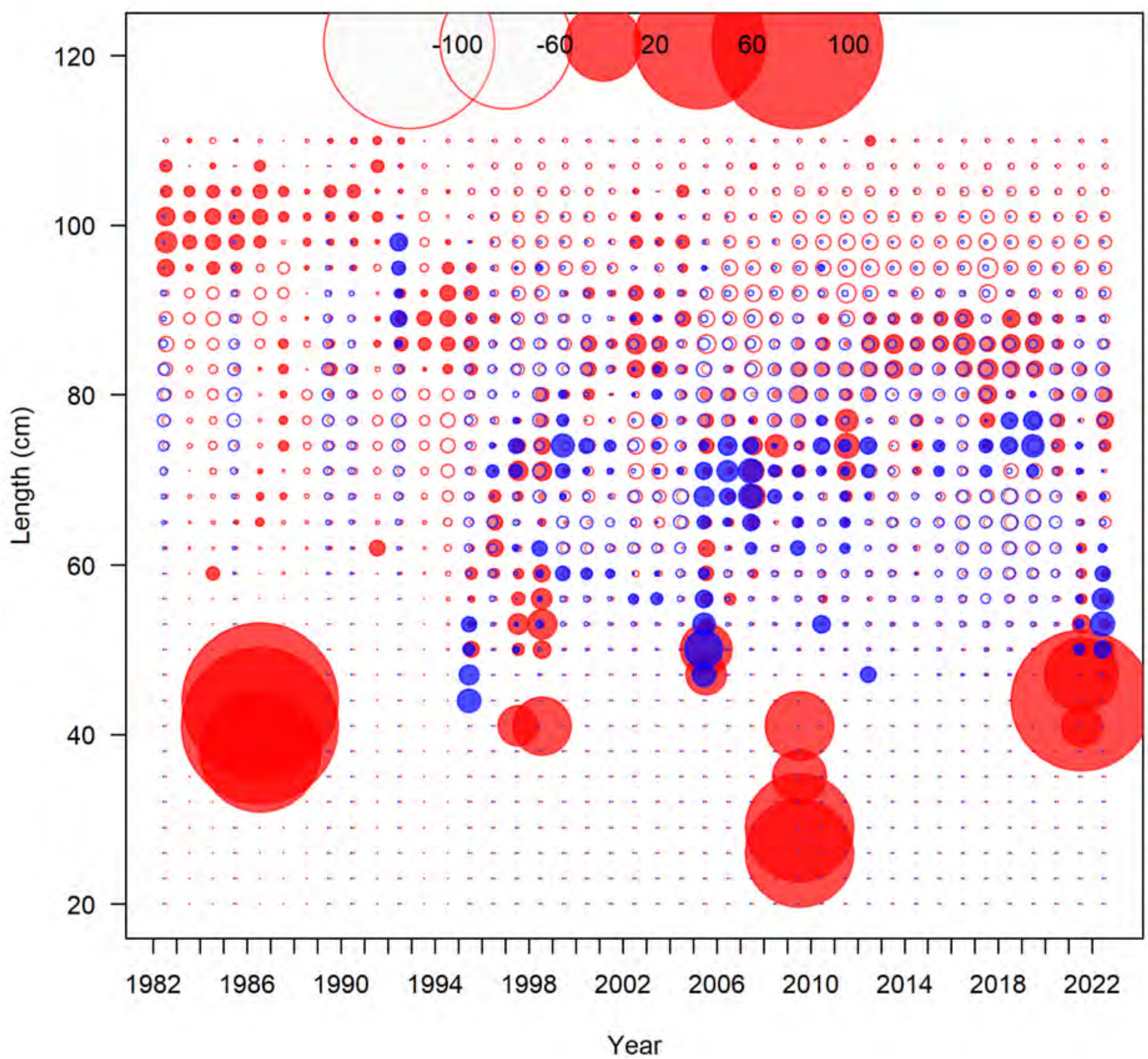


Figure 18: Pearson residuals for the fit to length compositions by year and sex for fleet 2: Landings_LL_OT_Foreign. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

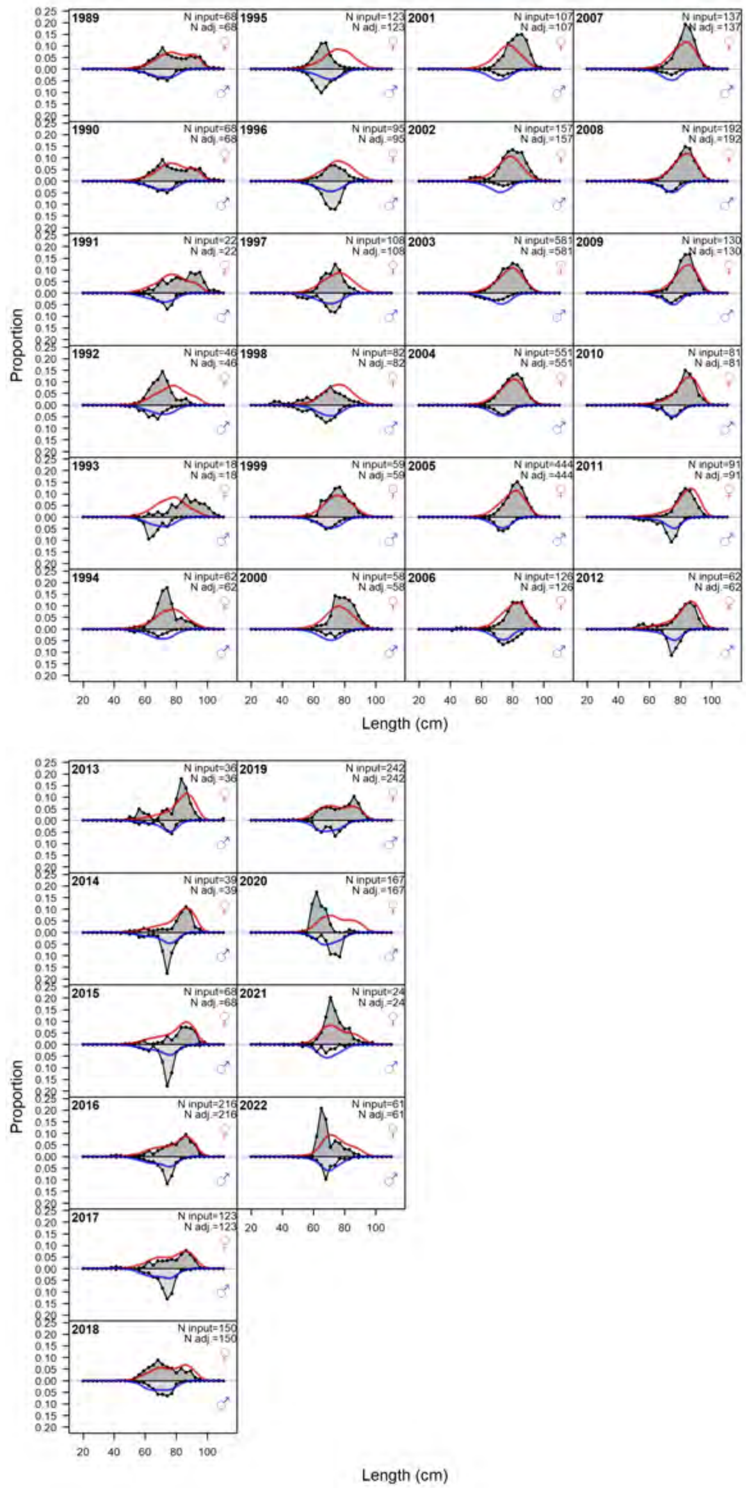


Figure 19: Fit to length compositions by year and sex for fleet 3: Discard_SGN_SD.

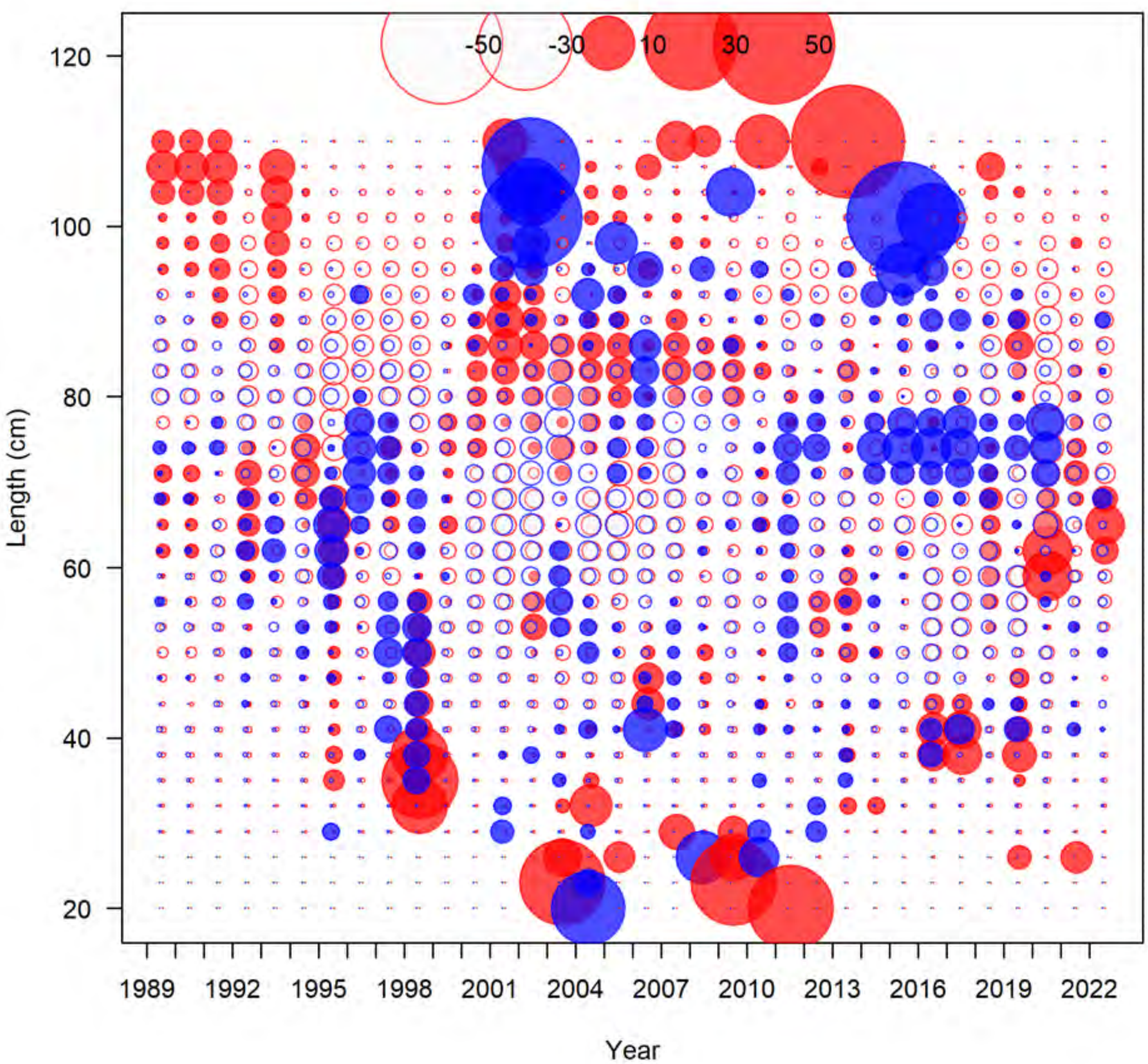


Figure 20: Pearson residuals for the fit to length compositions by year and sex for fleet 3: Discard_SGN_SD. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

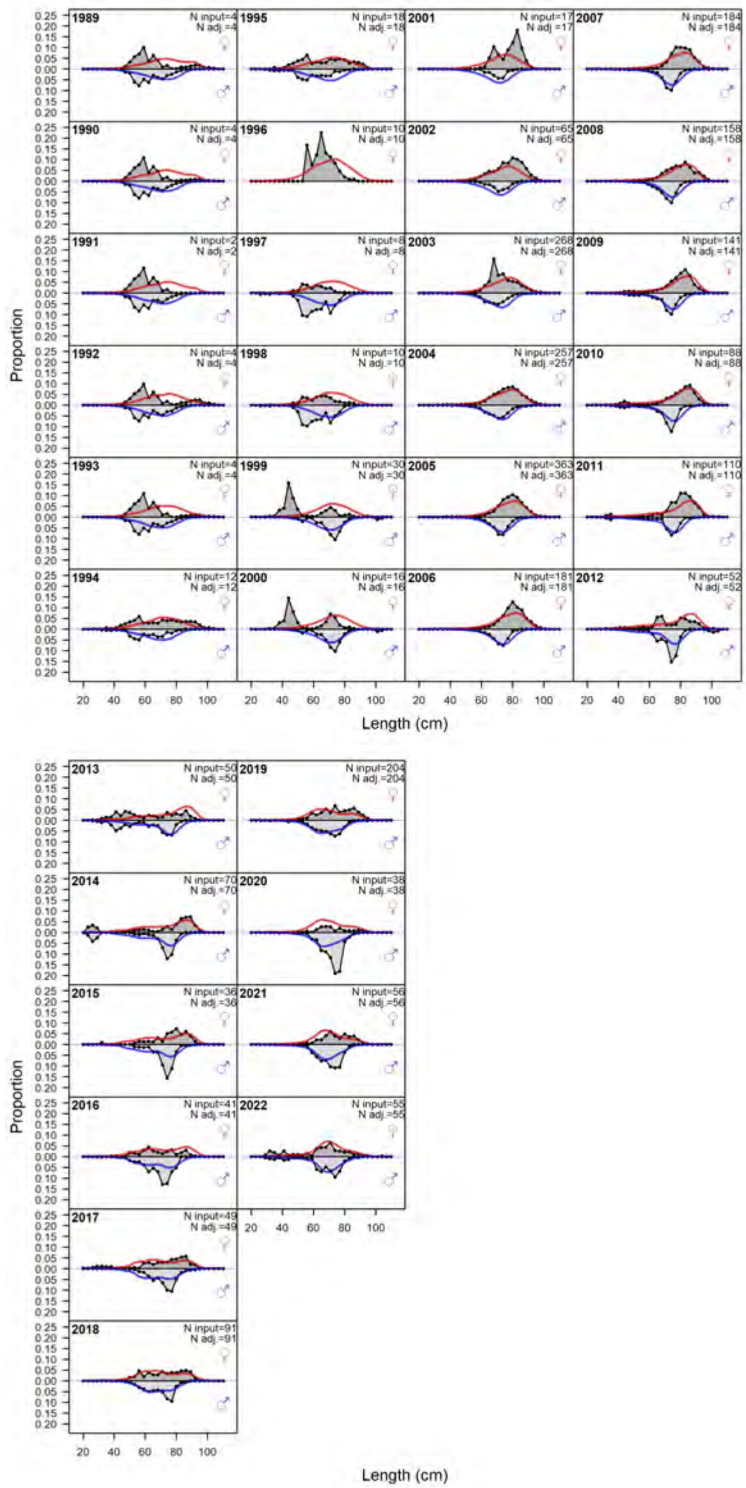


Figure 21: Fit to length compositions by year and sex for fleet 4: Discard_LMOT_LL_Rec.

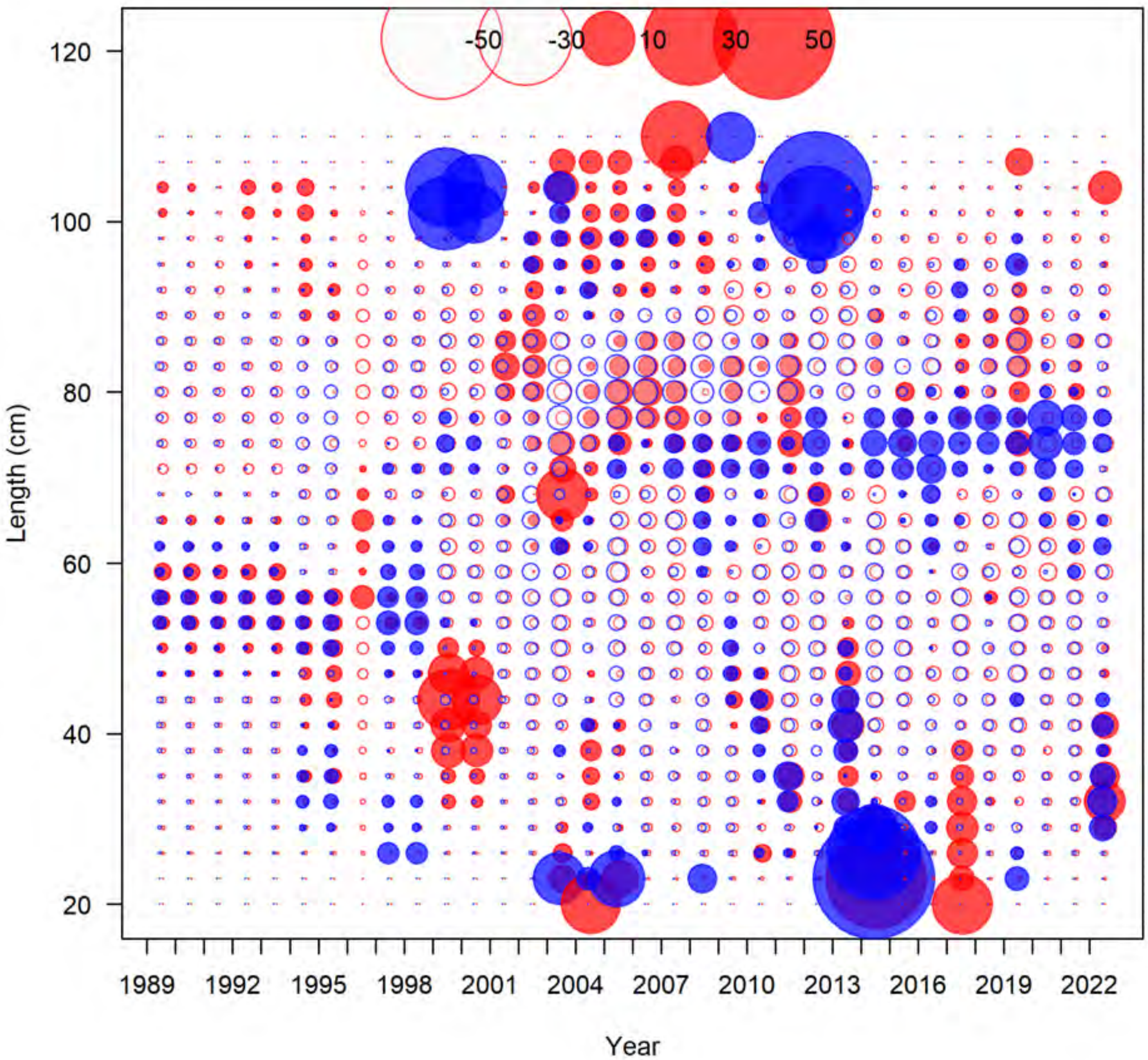
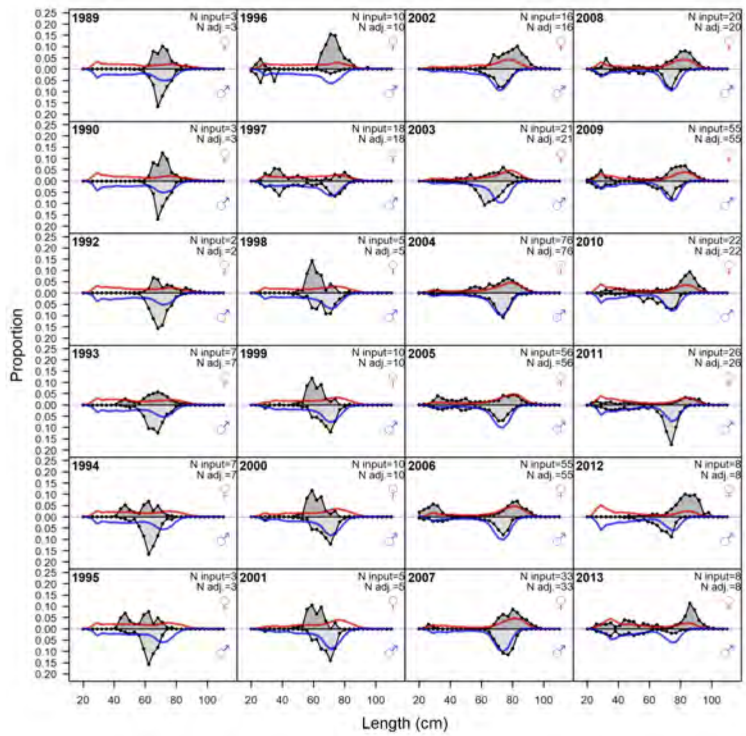


Figure 22: Pearson residuals for the fit to length compositions by year and sex for fleet 4: Discard_LMOT_LL_Rec. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).



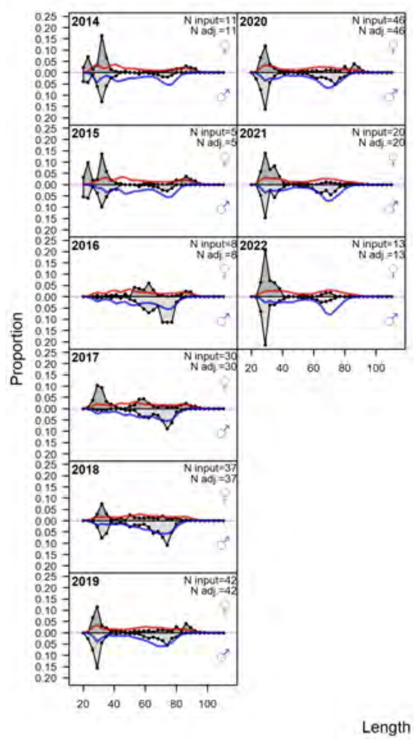


Figure 23: Fit to length compositions by year and sex for fleet 5: Discard_SMOT.

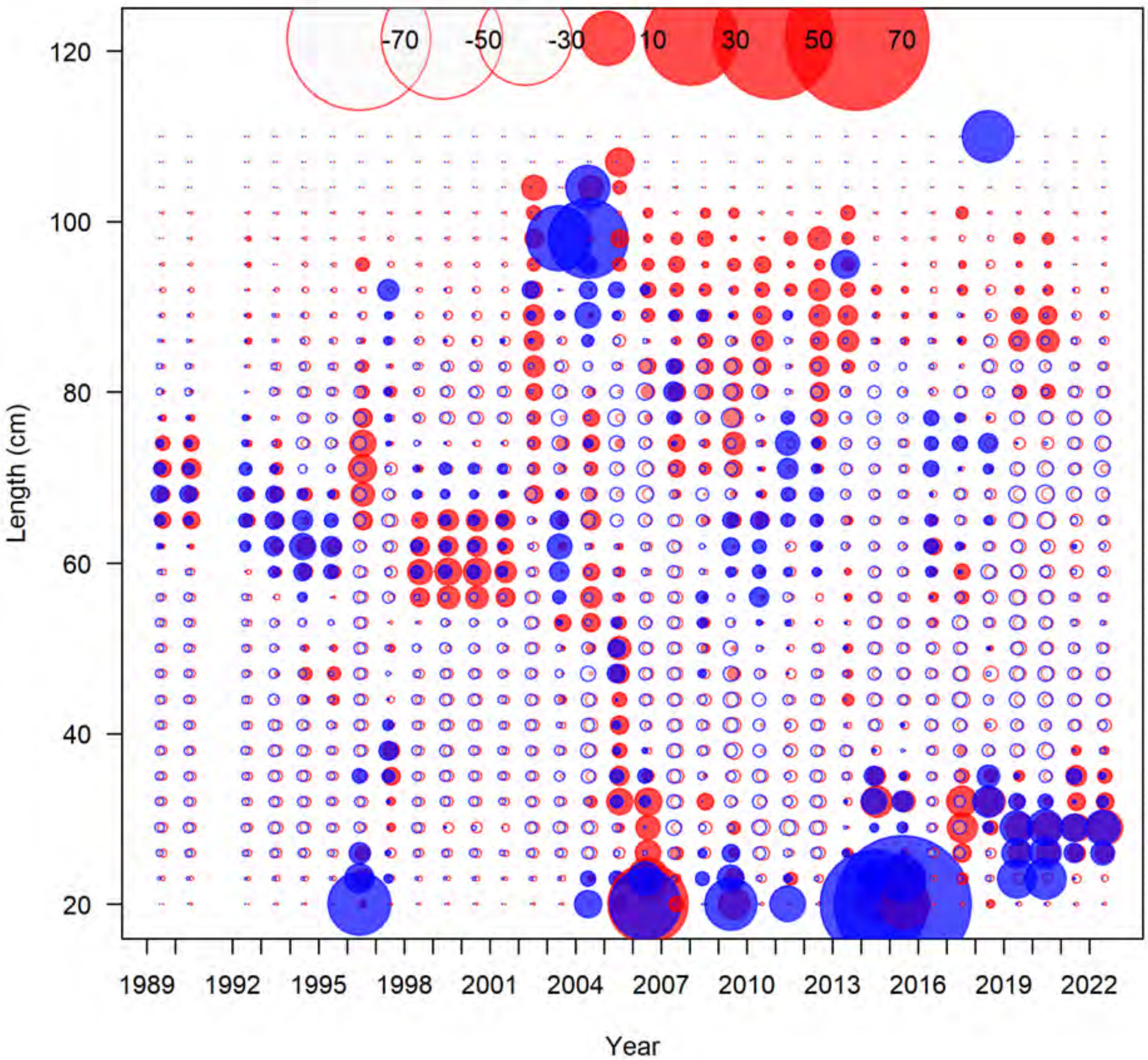


Figure 24: Pearson residuals for the fit to length compositions by year and sex for fleet 5: Discard_SMOT. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

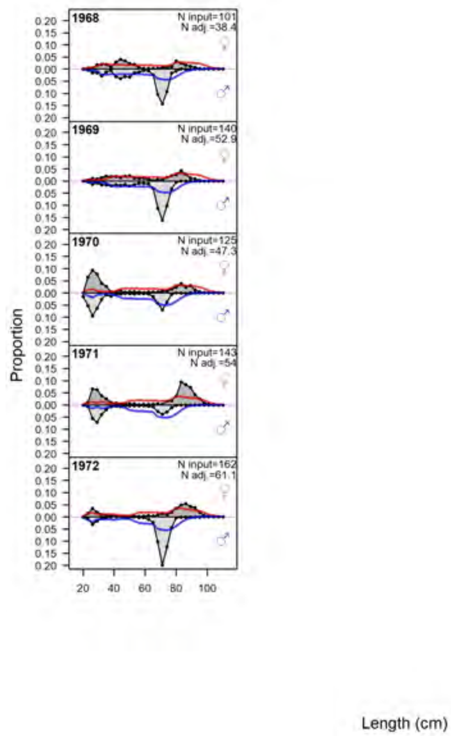


Figure 25: Fit to length compositions by year and sex for fleet 6: NEFSC_Spring_BTS_OFFSHORE_Y36.

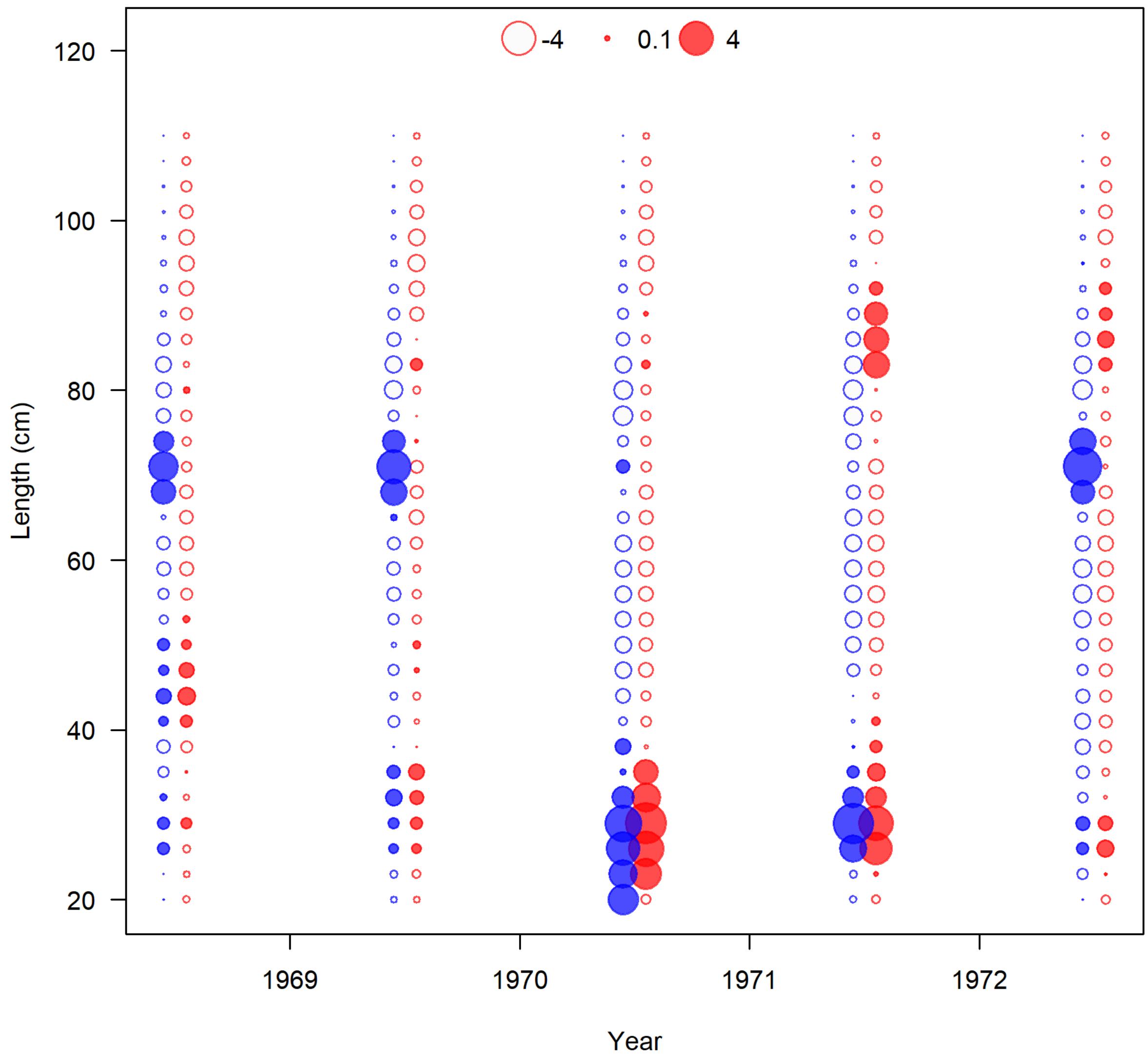


Figure 26: Pearson residuals for the fit to length compositions by year and sex for fleet 6: NEFSC_Spring_BTS_OFFSHORE_Y36. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

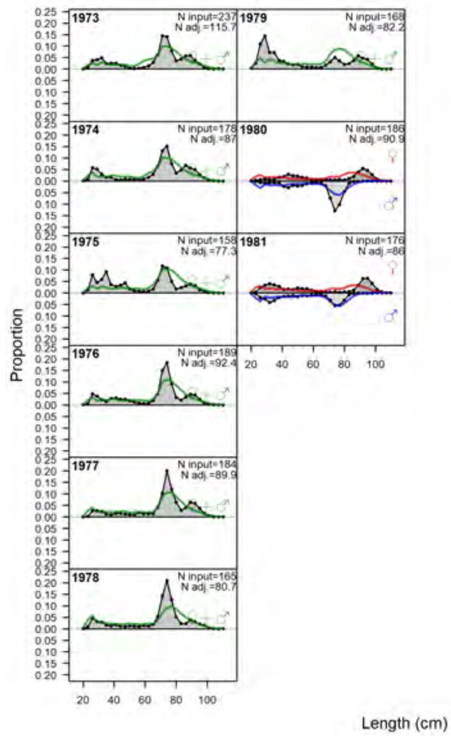


Figure 27: Fit to length compositions by year and sex for fleet 7: NEFSC_Spring_BTS_OFFSHORE_Y41.

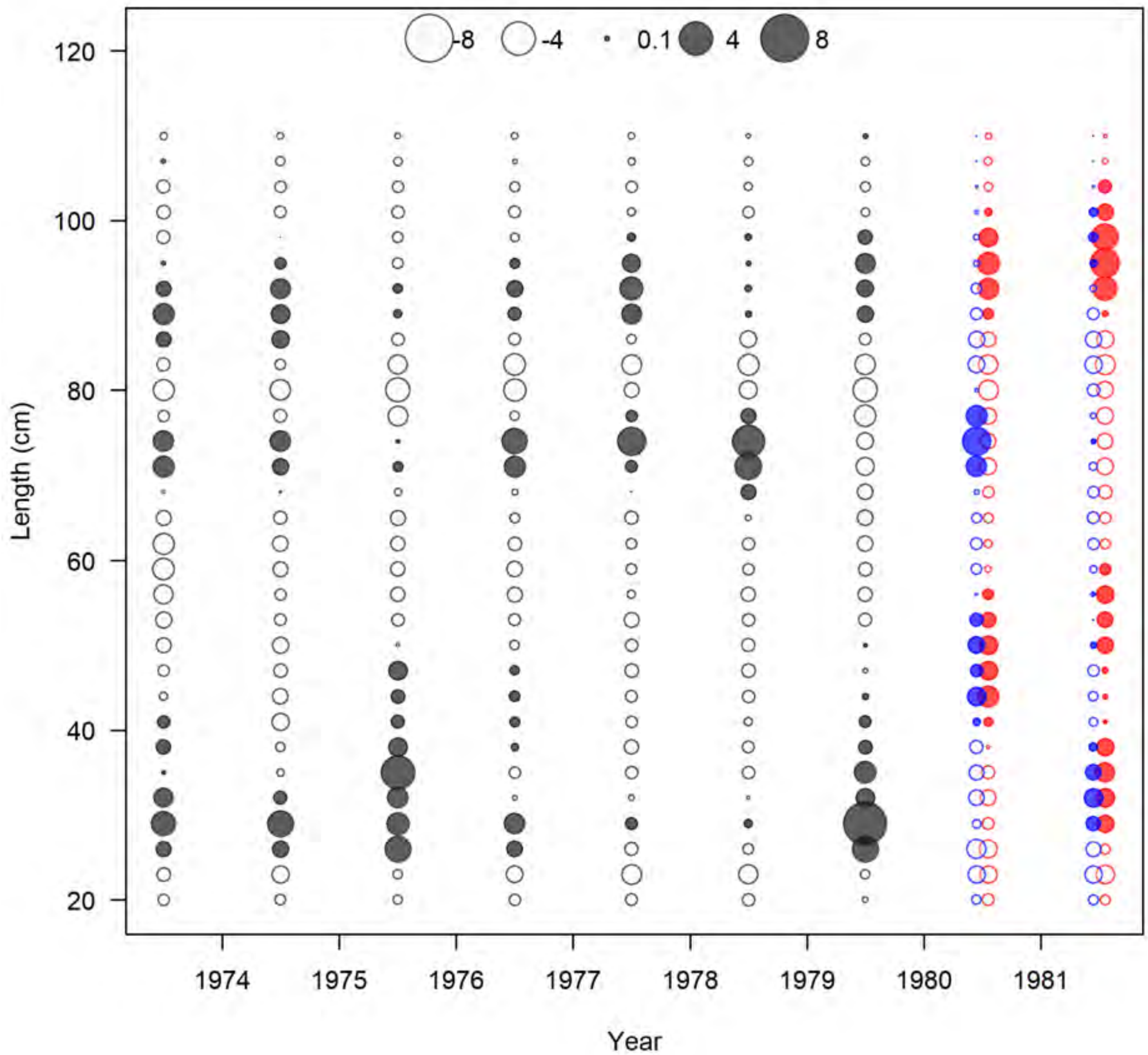


Figure 28: Pearson residuals for the fit to length compositions by year and sex for fleet 7: NEFSC_Spring_BTS_OFFSHORE_Y41. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

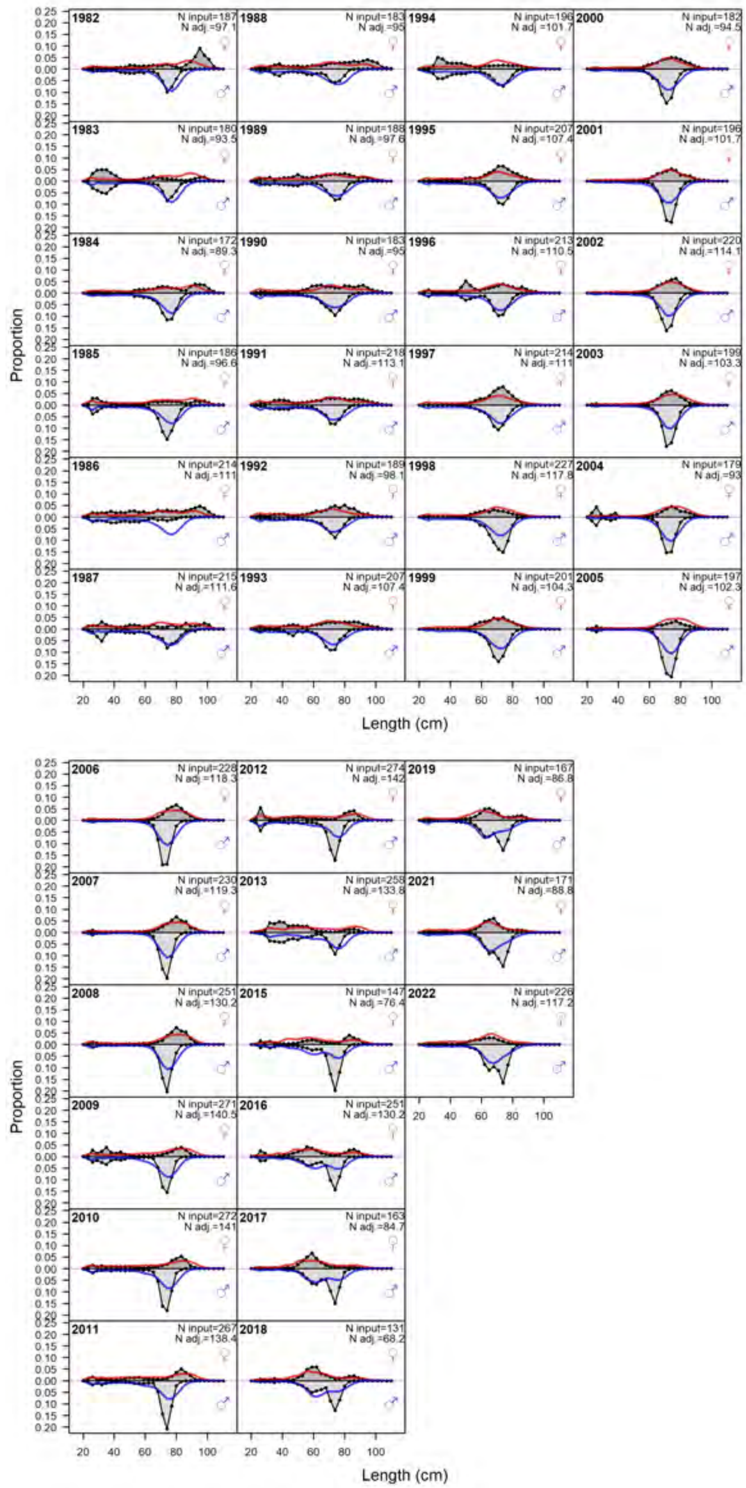


Figure 29: Fit to length compositions by year and sex for fleet 8: NEFSC_Spring_BTS.

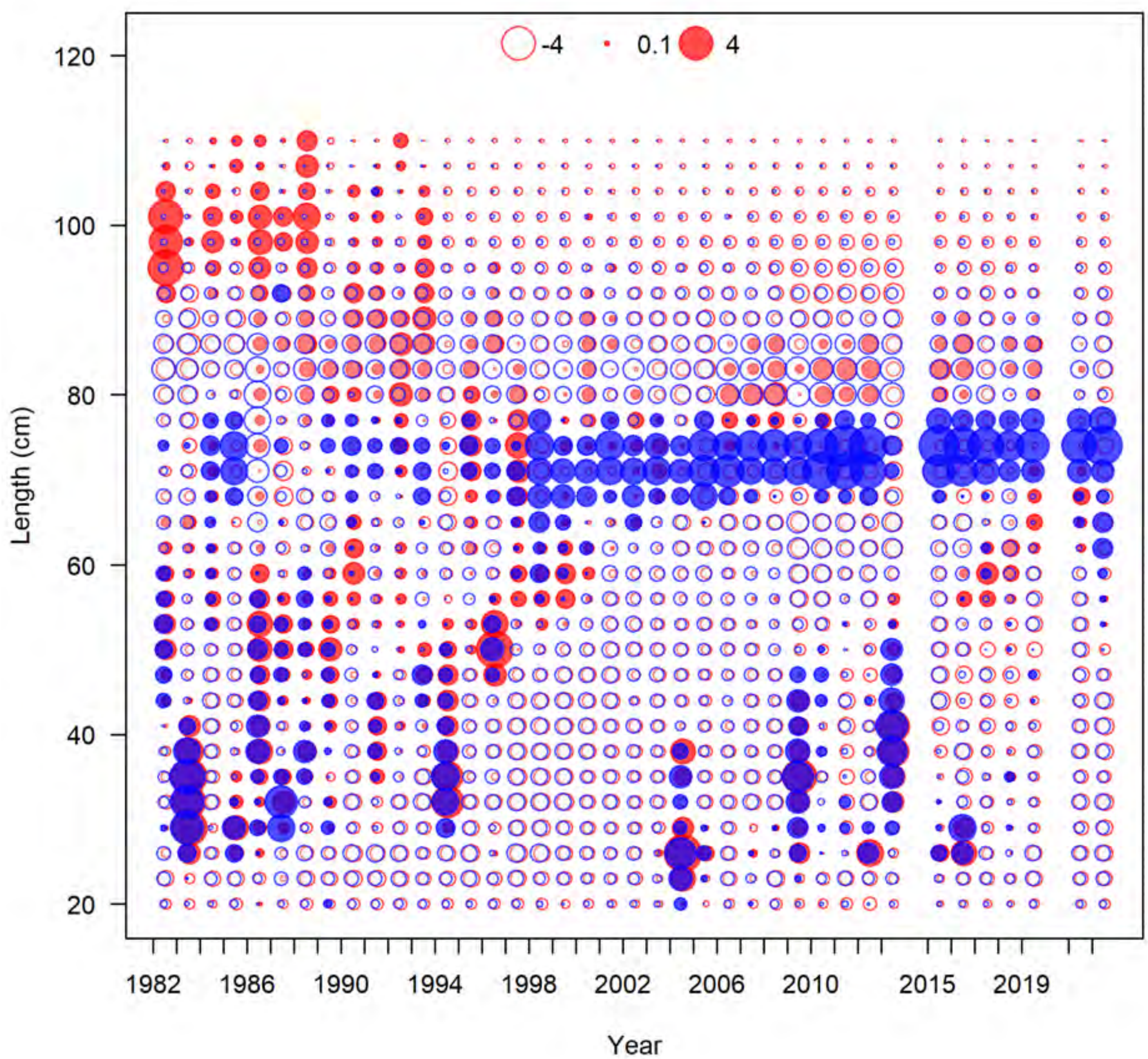


Figure 30: Pearson residuals for the fit to length compositions by year and sex for fleet 8: NEFSC_Spring_BTS. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

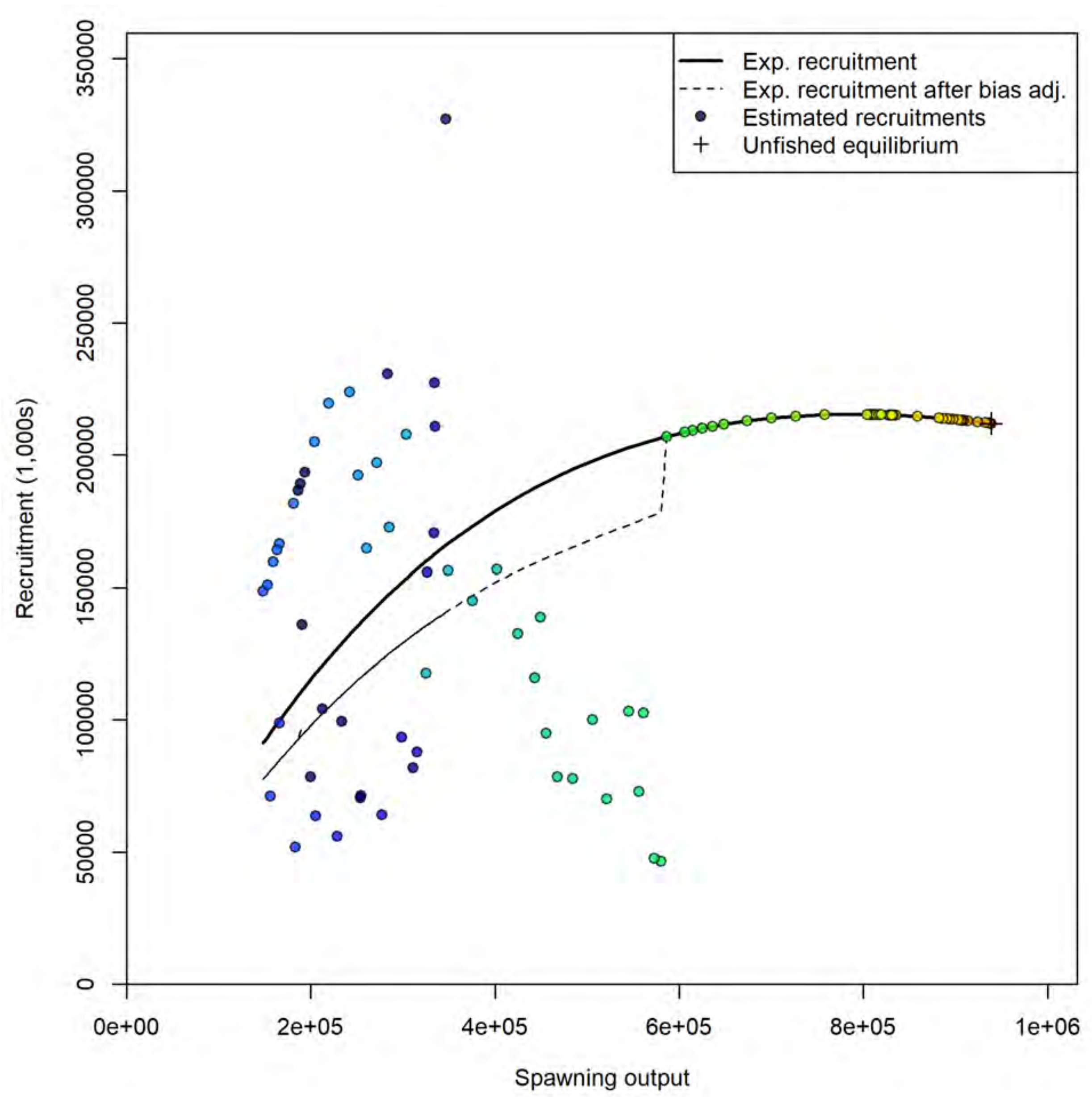


Figure 31: Fixed survivorship spawner-recruitment relationship, estimated age-0 recruitment (1,000s), and estimated spawning output (1,000s) for Atlantic spiny dogfish.

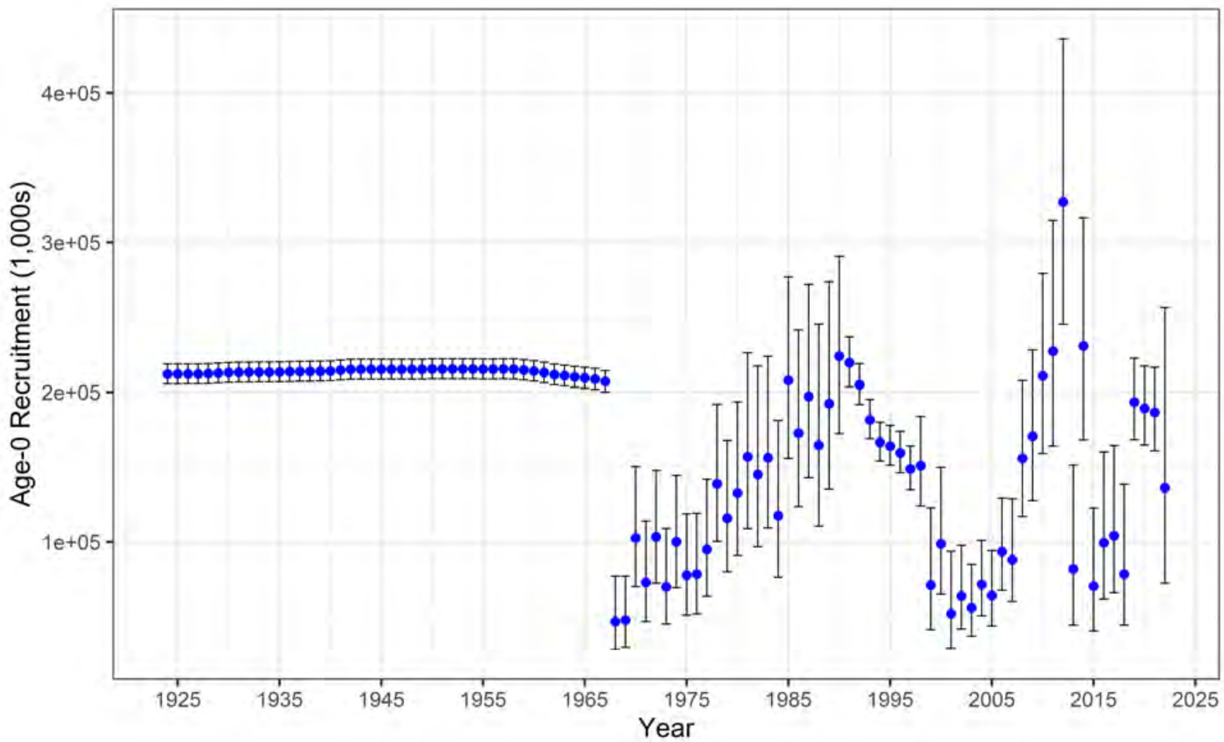


Figure 32: Estimated age-0 recruitment (1,000s) with $\sim$ 95% asymptotic intervals from 1924 to 2022 for Atlantic spiny dogfish.

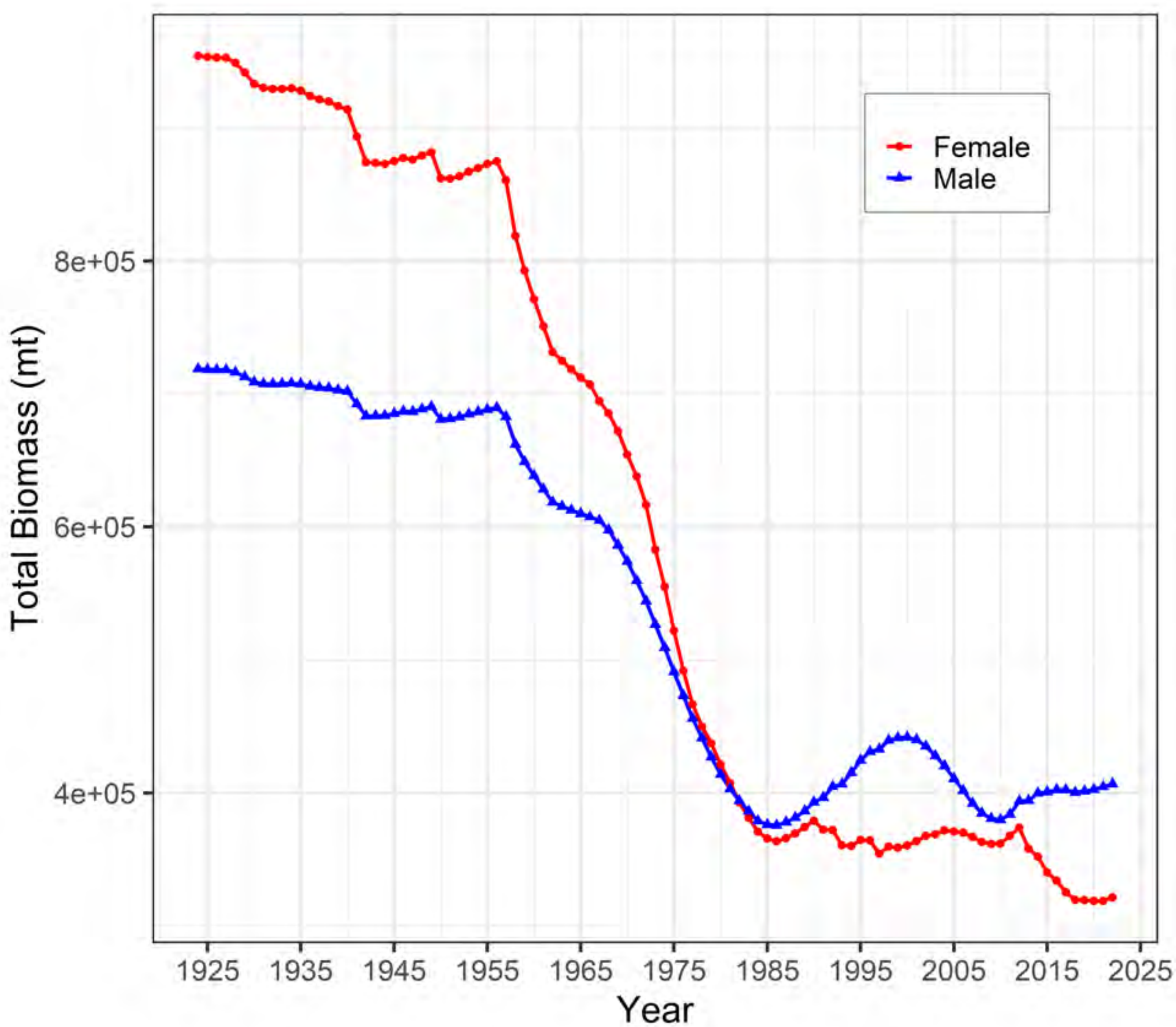


Figure 33: Estimated total biomass (mt) by sex from 1924 to 2022 for Atlantic spiny dogfish.

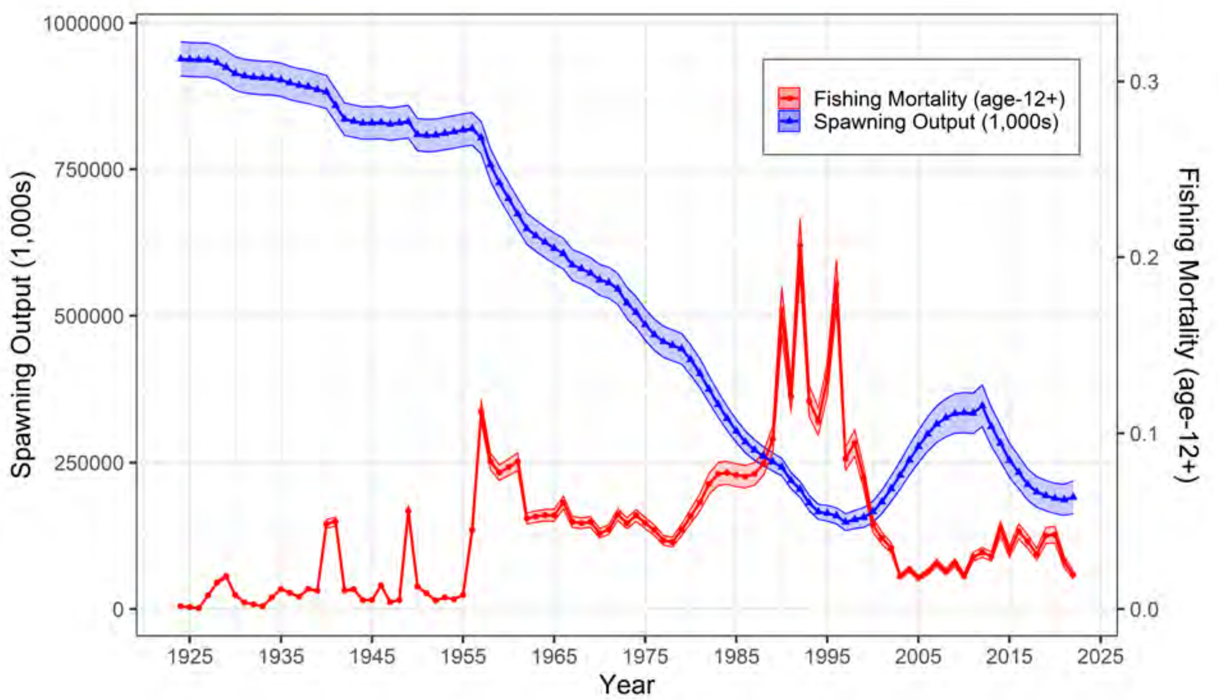


Figure 34: Estimated spawning output and fishing mortality (age-12+) with ∼ 95% asymptotic intervals from 1924 to 2022 for Atlantic spiny dogfish.

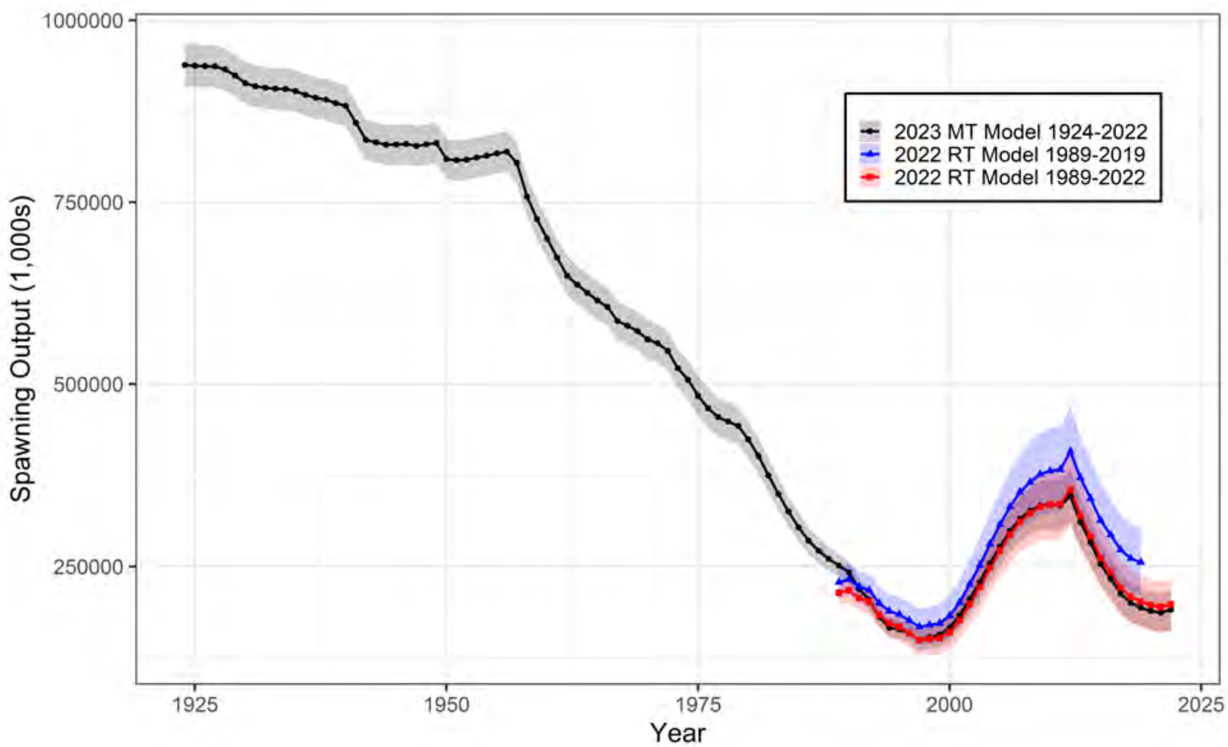


Figure 35: Spawning output (1,000s) with $\sim 95\%$ asymptotic intervals estimated using the original 2022 research track model (1989-2019), updated 2022 research track model (1989-2022), and 2023 management track model (1924-2022).

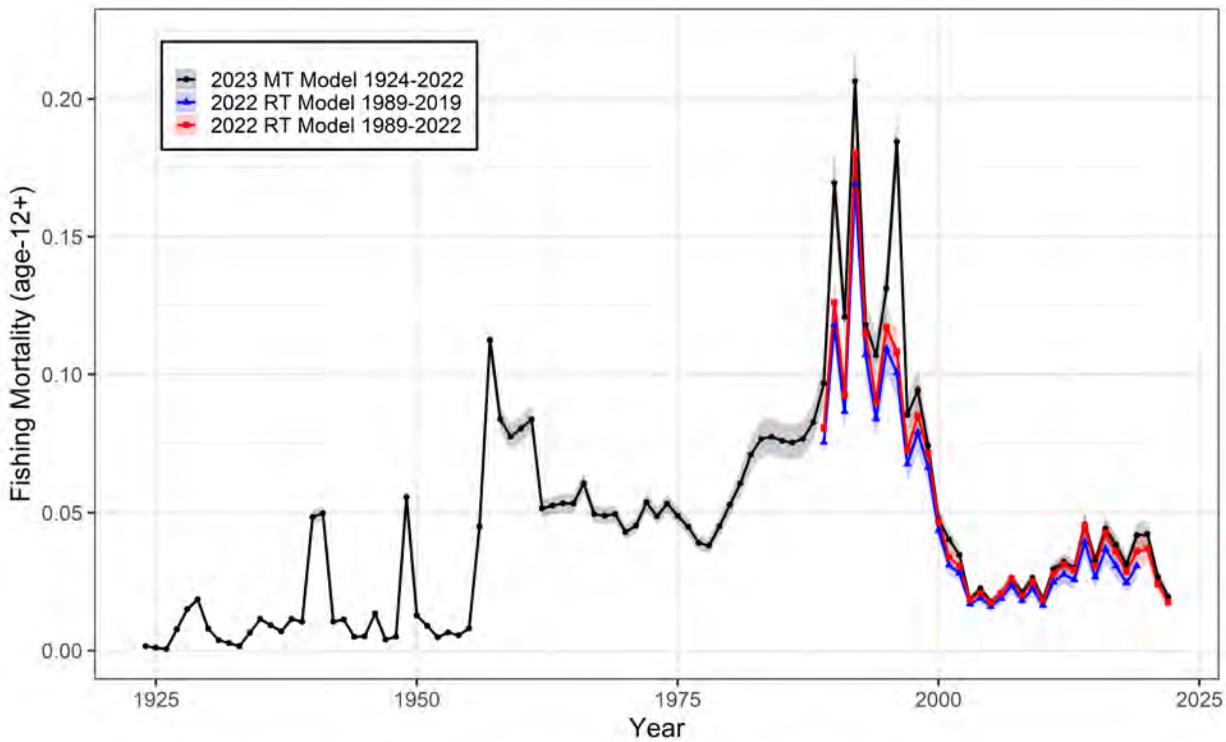


Figure 36: Fishing mortality (age-12+) with $\sim 95\%$ asymptotic intervals estimated using the original 2022 research track model (1989-2019), updated 2022 research track model (1989-2022), and 2023 management track model (1924-2022).

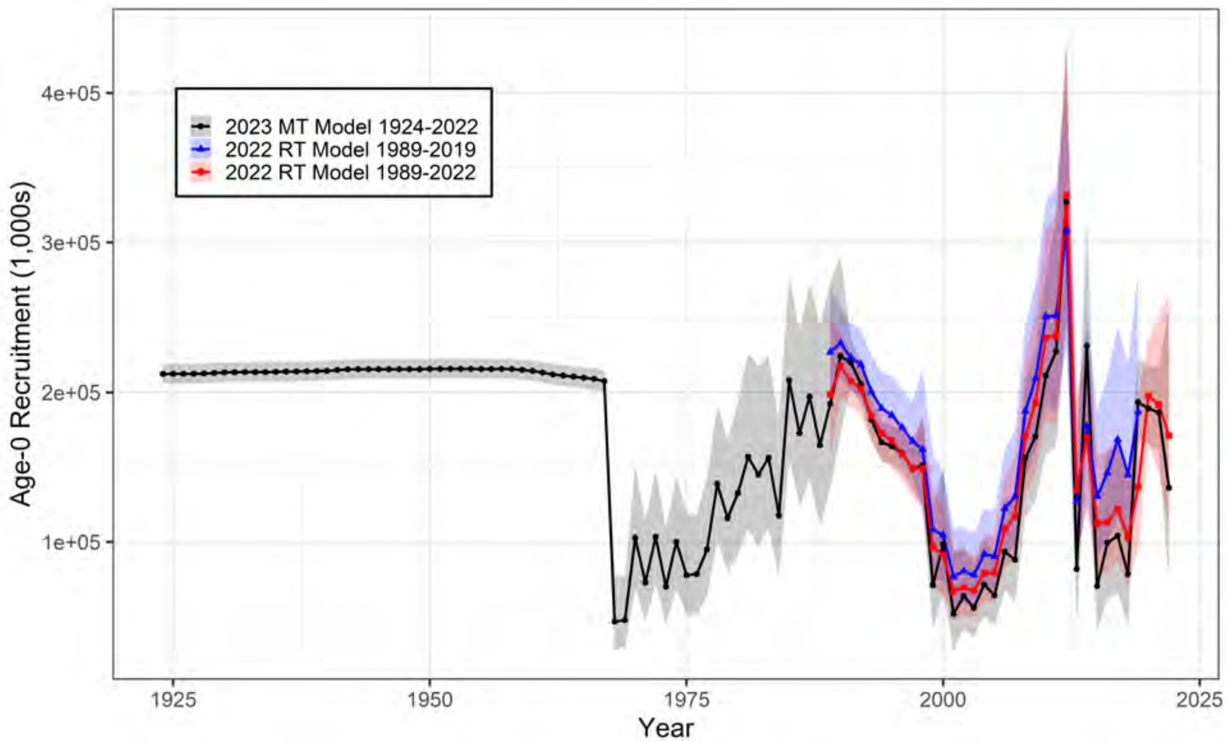


Figure 37: Age-0 recruitment (1,000s) with $\sim 95\%$ asymptotic intervals estimated using the original 2022 research track model (1989-2019), updated 2022 research track model (1989-2022), and 2023 management track model (1924-2022).

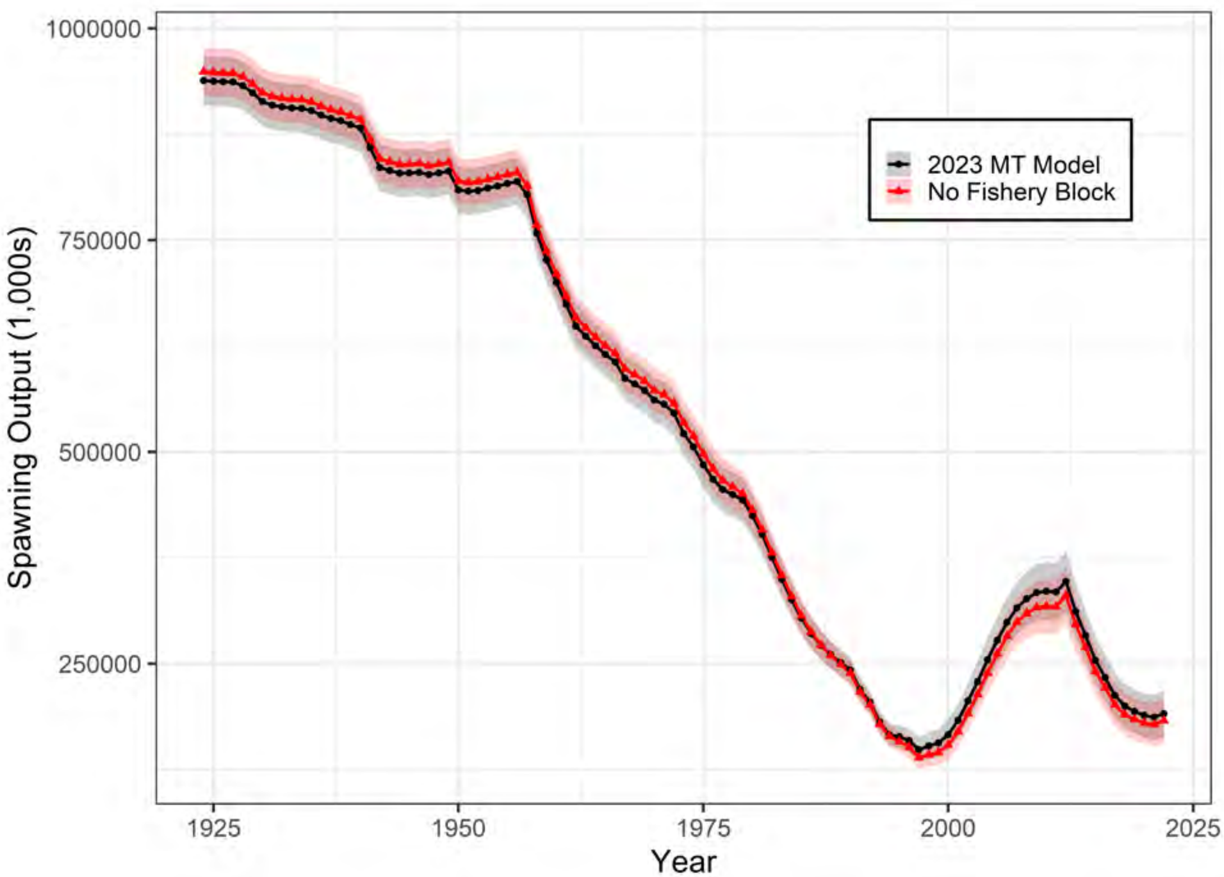


Figure 38: Spawning output (1,000s) with ∼ 95% asymptotic intervals estimated with and without the fishery block assumption.

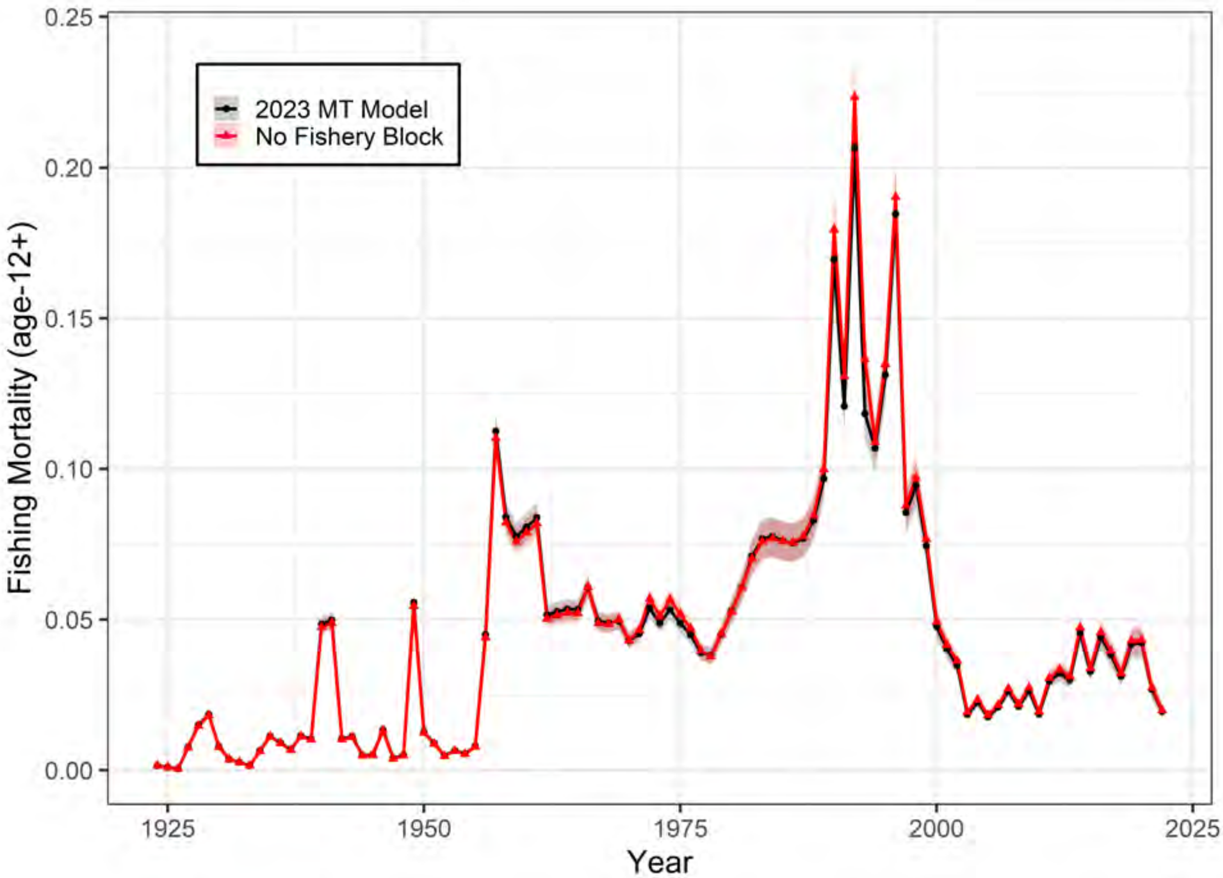


Figure 39: Fishing mortality (age-12+) with ∼ 95% asymptotic intervals estimated with and without the fishery block assumption.

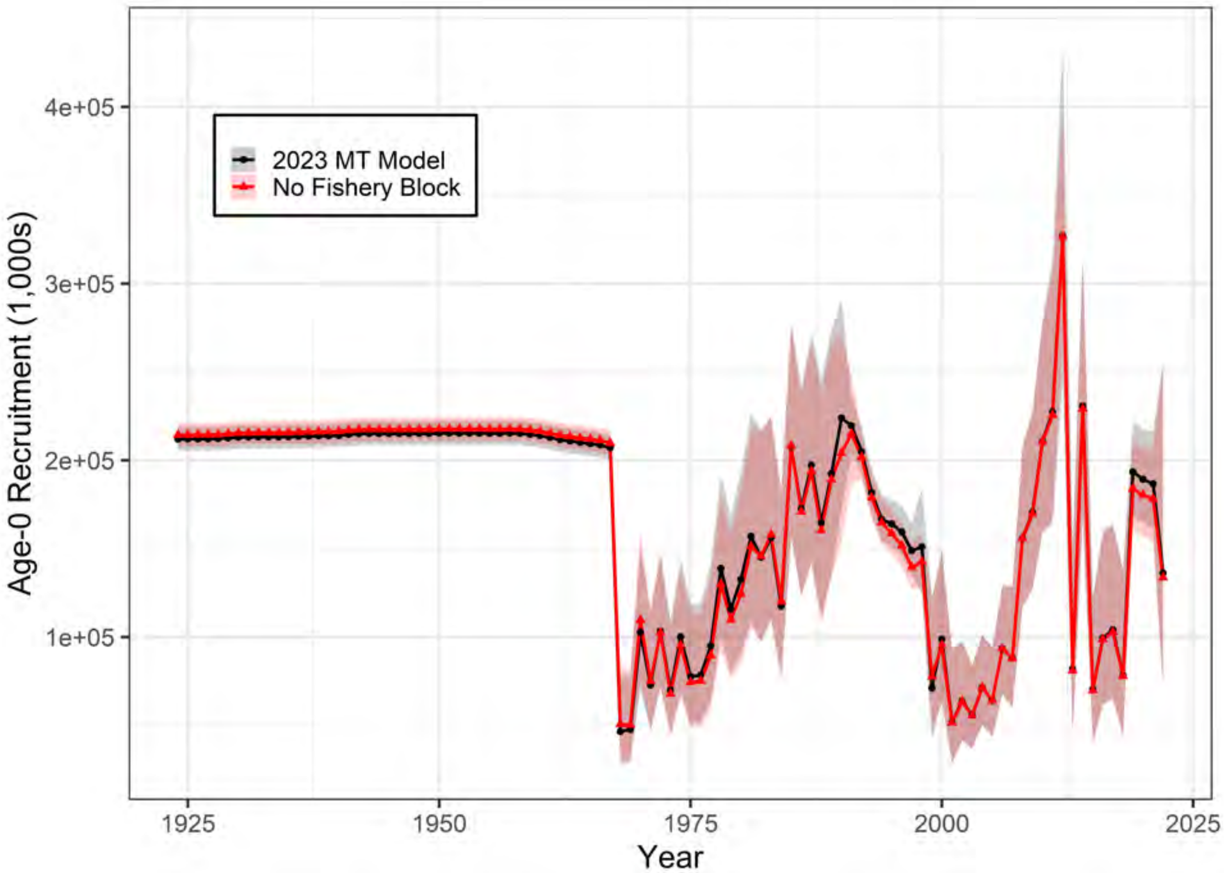


Figure 40: Age-0 recruitment (1,000s) with $\sim 95\%$ asymptotic intervals estimated with and without the fishery block assumption.

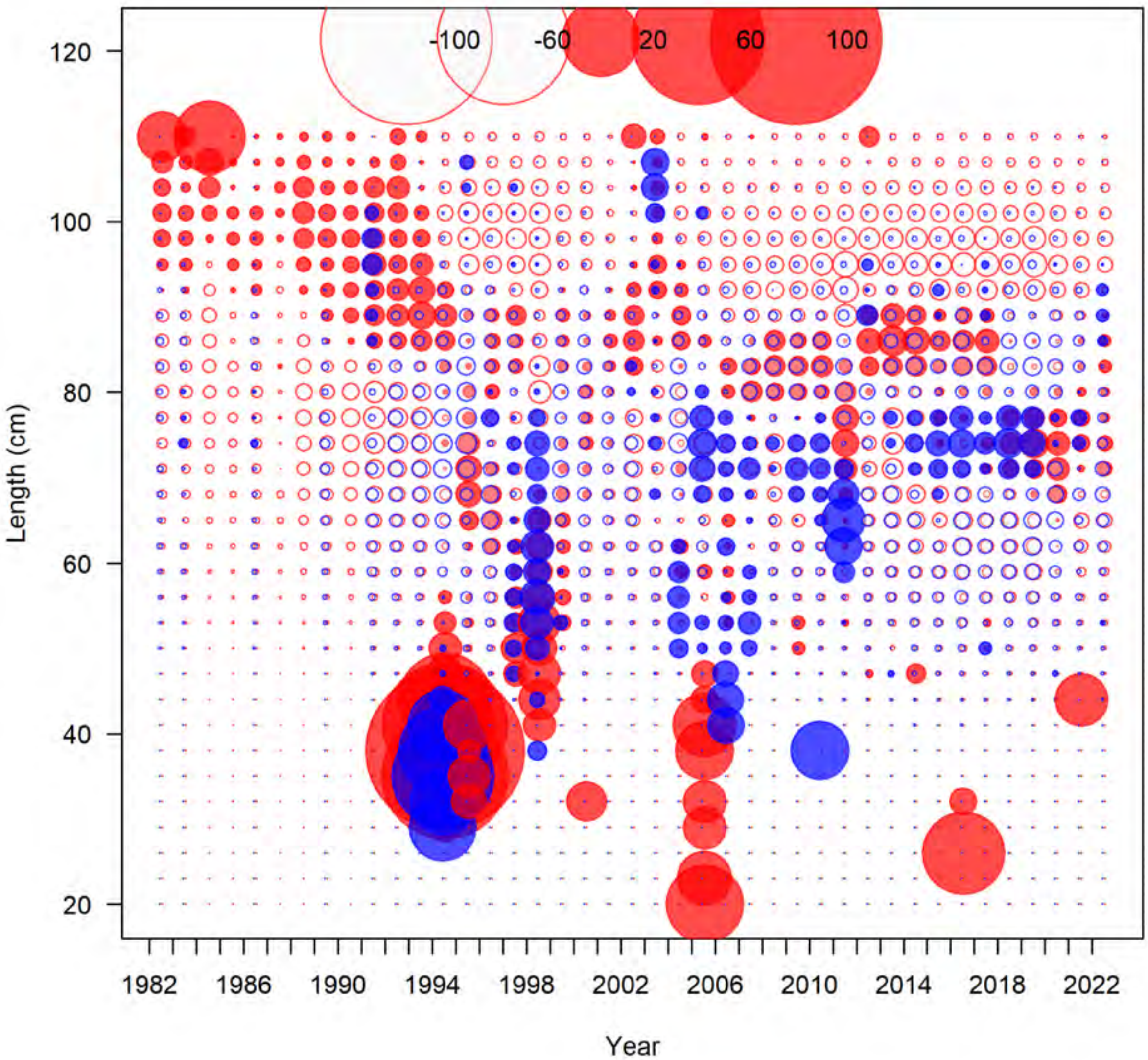


Figure 41: Pearson residuals for the fit to length compositions by year and sex for fleet 1: Landings_SGN_Rec_Others using the model without assuming a fishery block. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

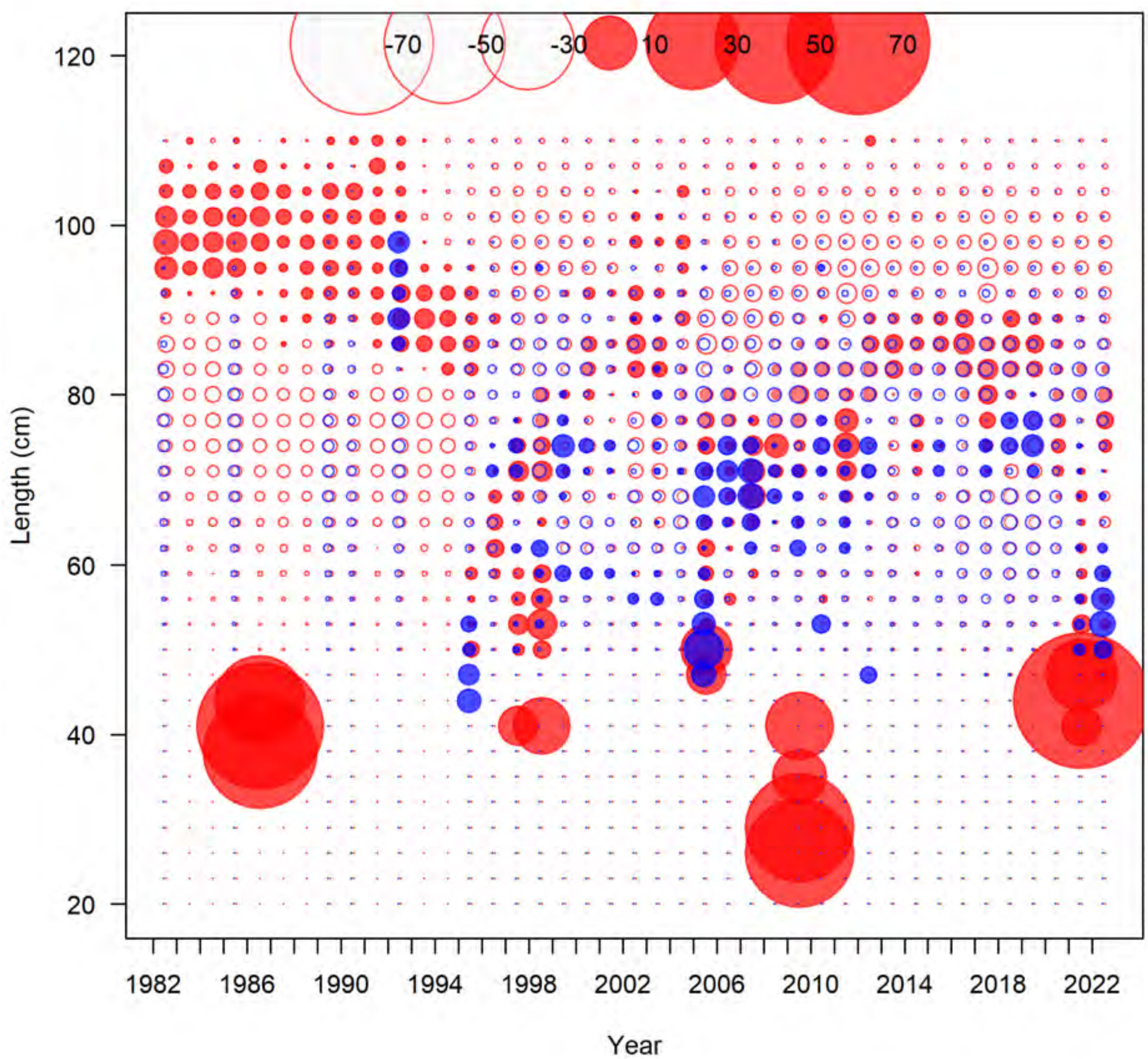


Figure 42: Pearson residuals for the fit to length compositions by year and sex for fleet 2: Landings_LL_OT_Foreign using the model without assuming a fishery block. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

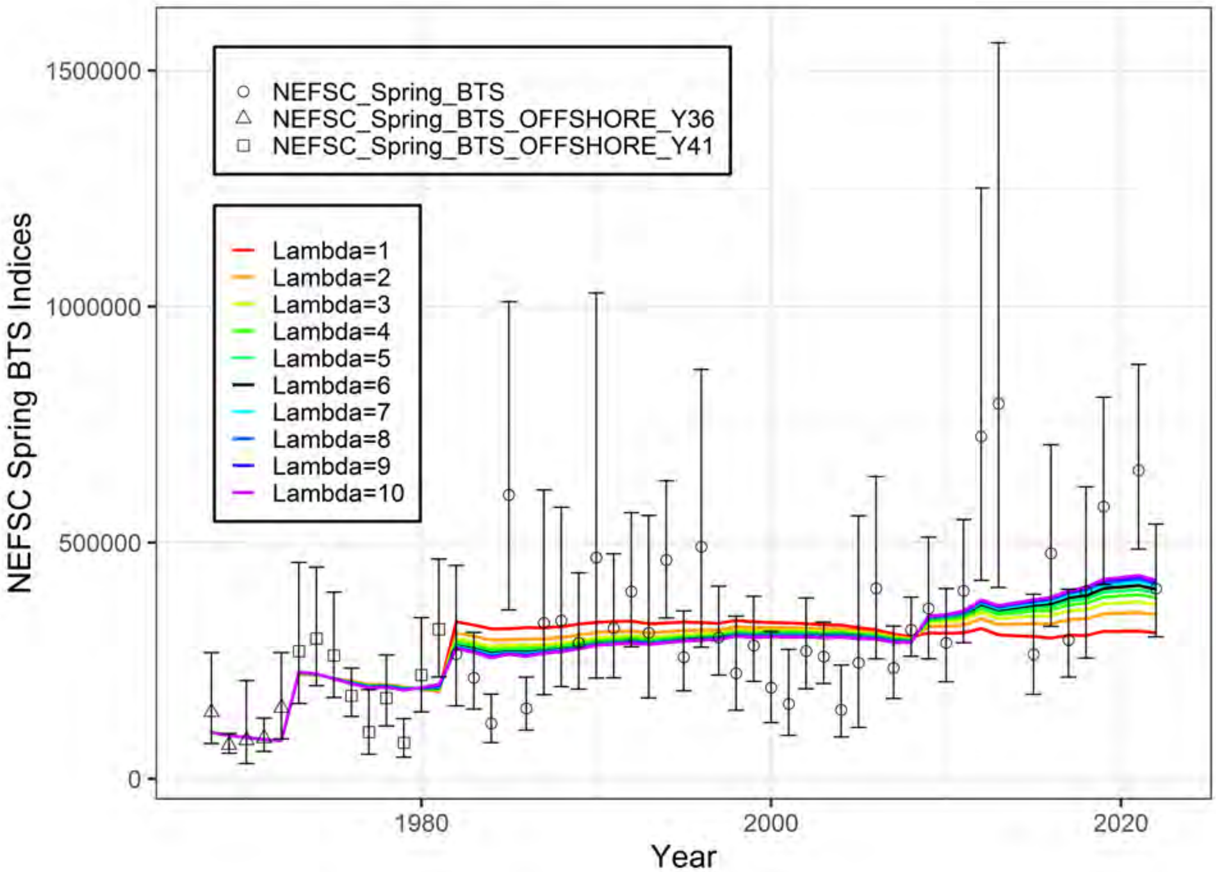


Figure 43: Survey indices with $\sim$ 95% asymptotic intervals for fleets 6-8 estimated with different likelihood weights for survey indices.

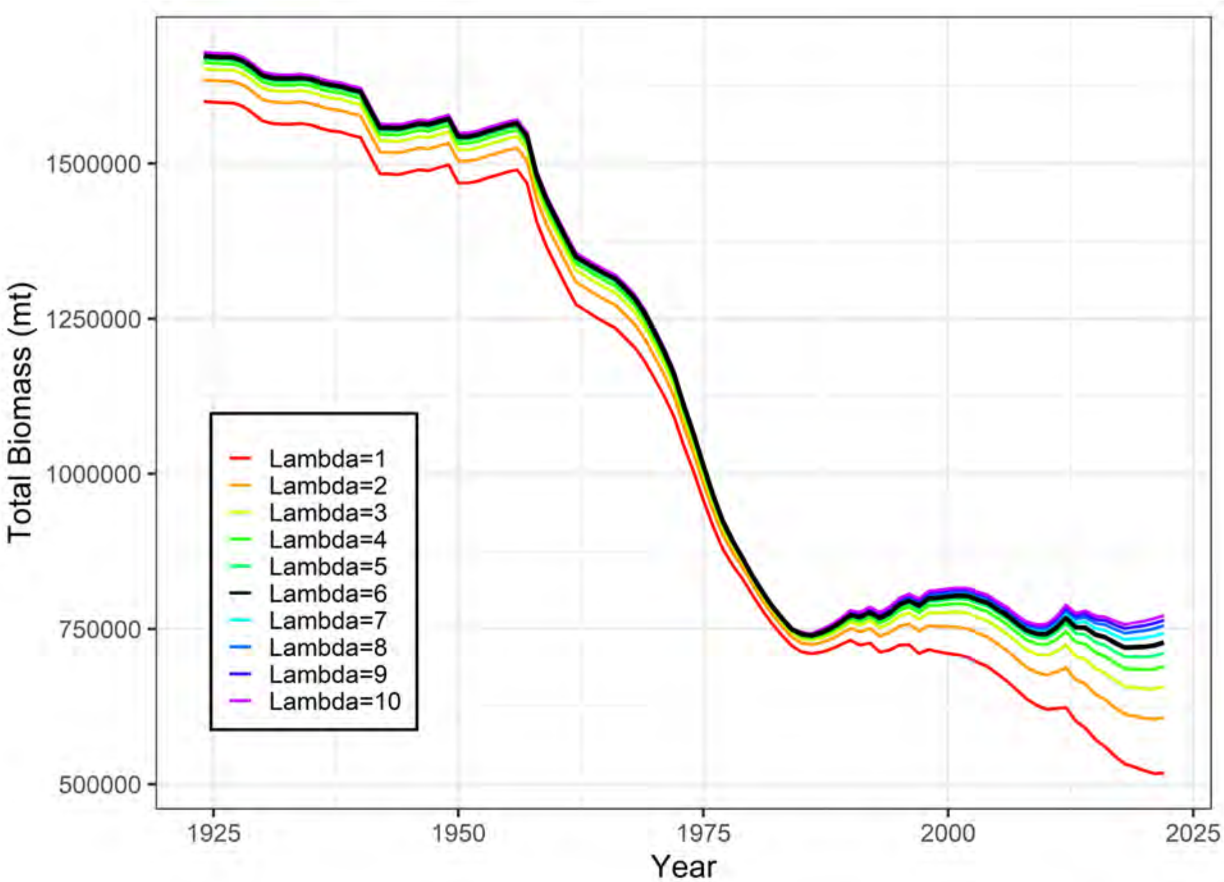


Figure 44: Total biomass (mt) estimated with different likelihood weights for survey indices.

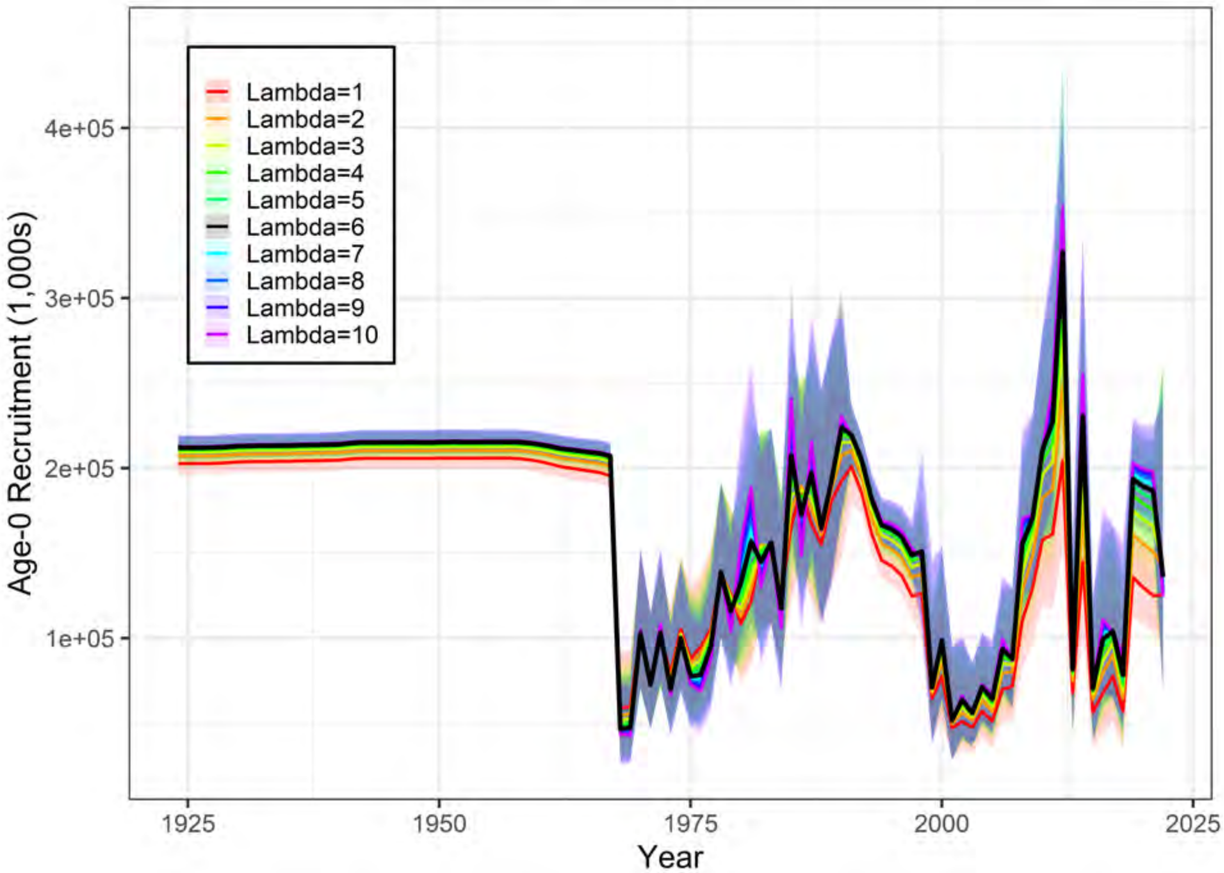


Figure 45: Age-0 recruitment (1,000s) with $\sim$ 95% asymptotic intervals estimated with different likelihood weights for survey indices.

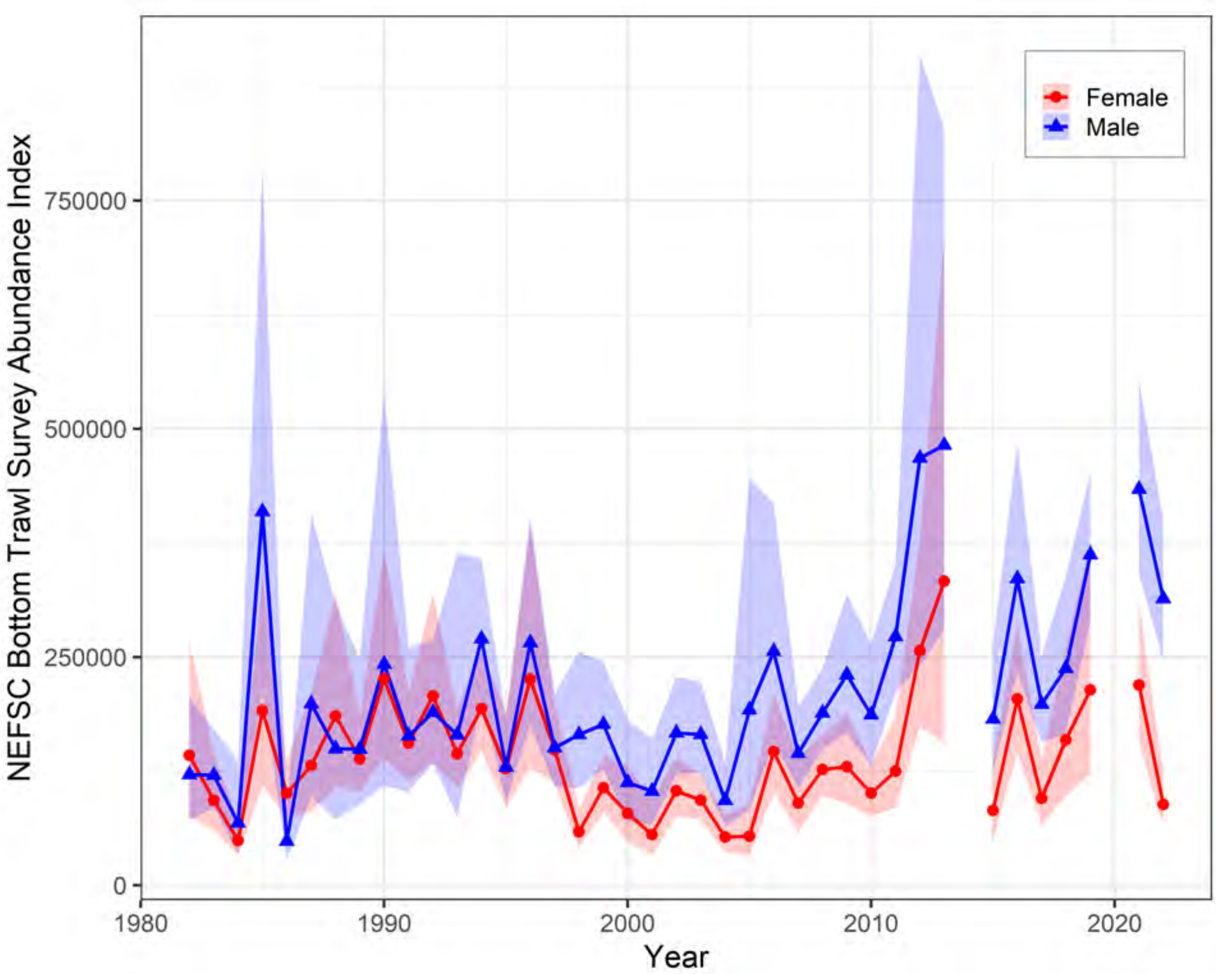


Figure 46: NEFSC spring bottom trawl survey abundance index with $\sim 95\%$ asymptotic intervals by sex for fleet 8.

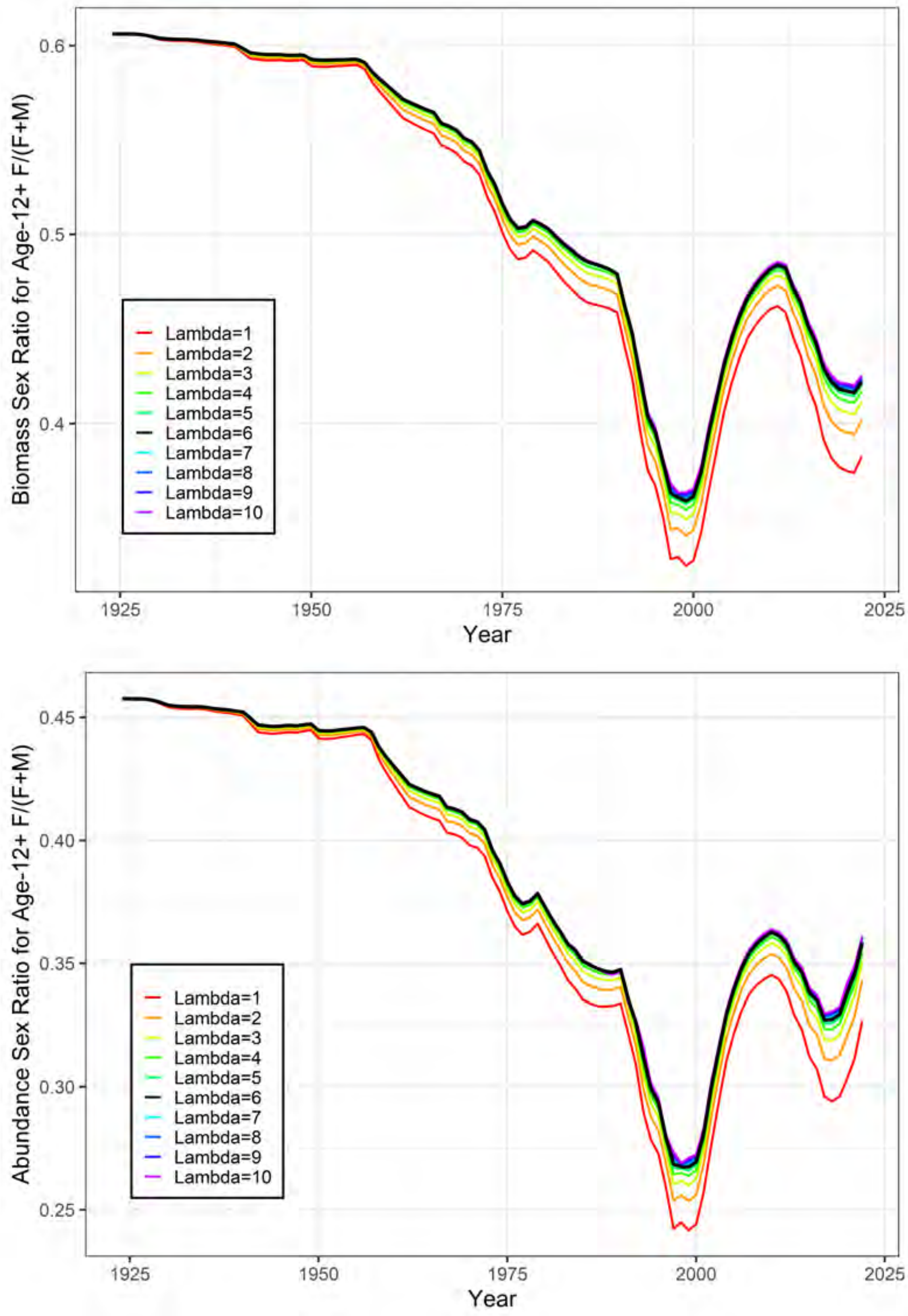


Figure 47: Female sex ratio (female/total) calculated using the estimated age-12+ numbers (top) and biomass (bottom) by likelihood weights for survey indices.

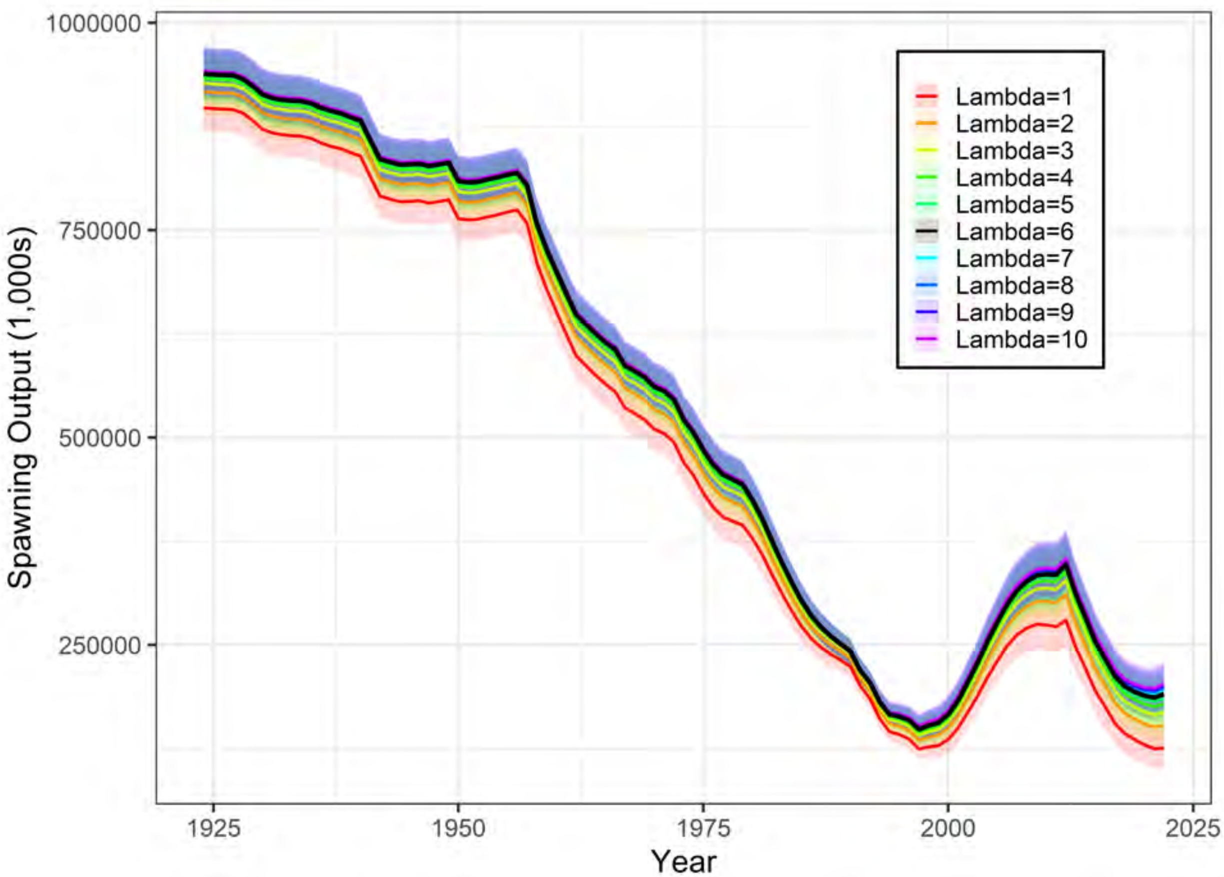


Figure 48: Spawning output (1,000s) with $\sim 95\%$ asymptotic intervals estimated with different likelihood weights for survey indices.

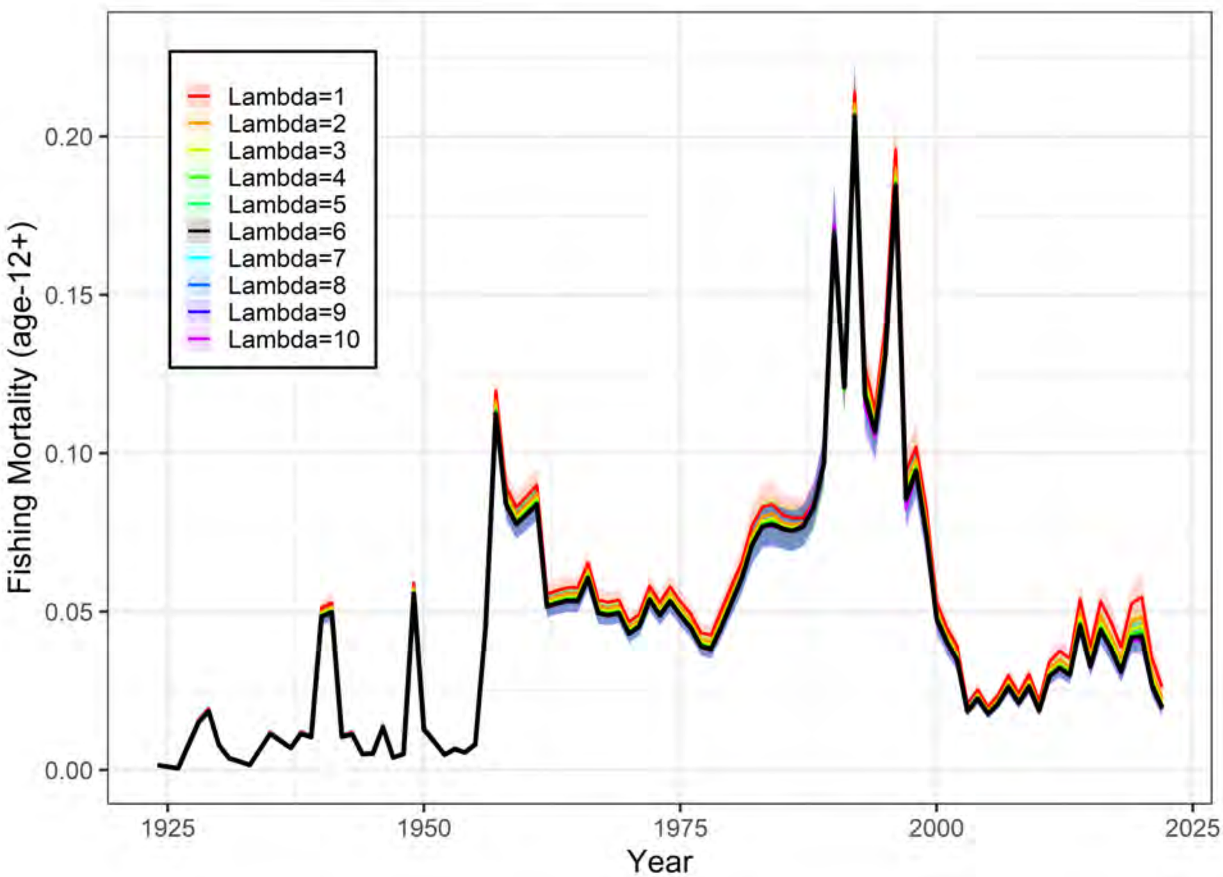


Figure 49: Fishing mortality (age-12+) with $\sim$ 95% asymptotic intervals estimated with different likelihood weights for survey indices.

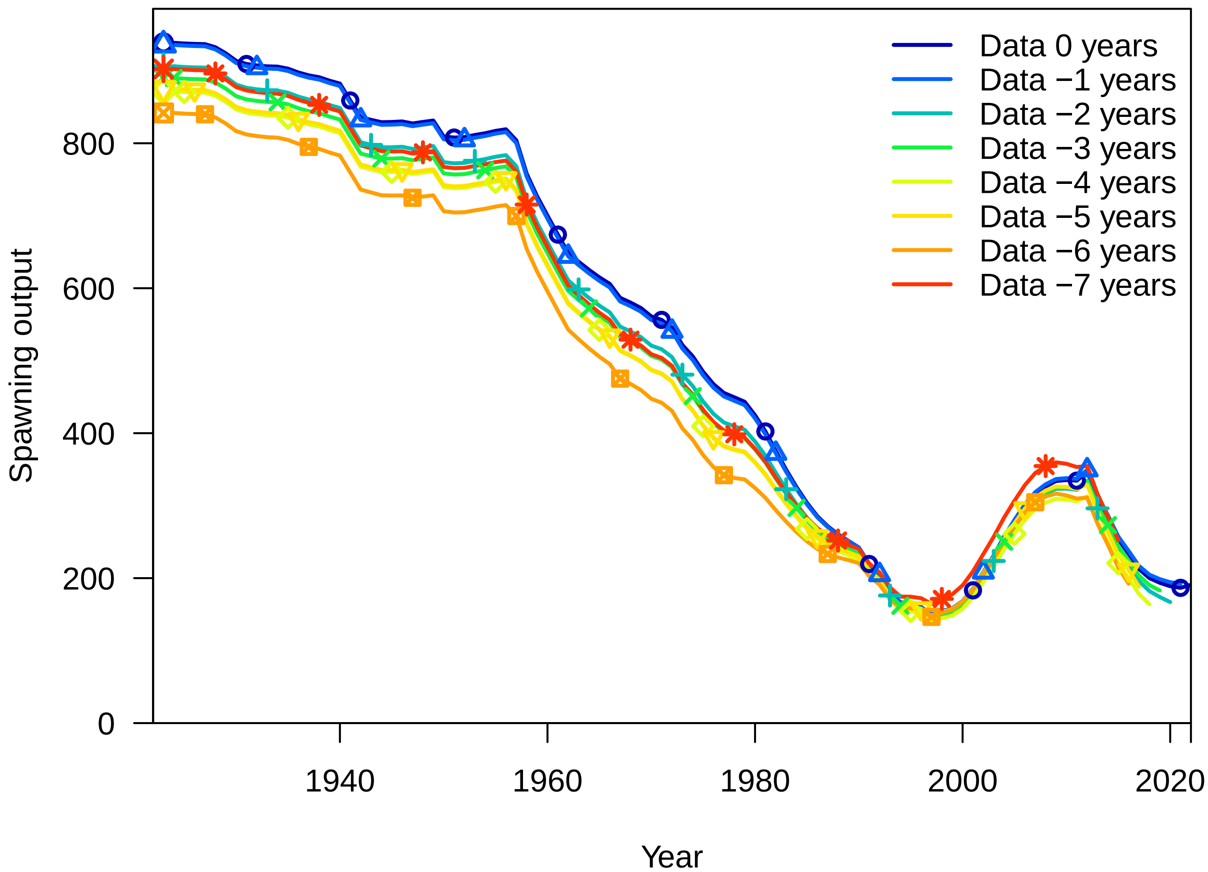


Figure 50: Retrospective plot for spawning output (1,000s).

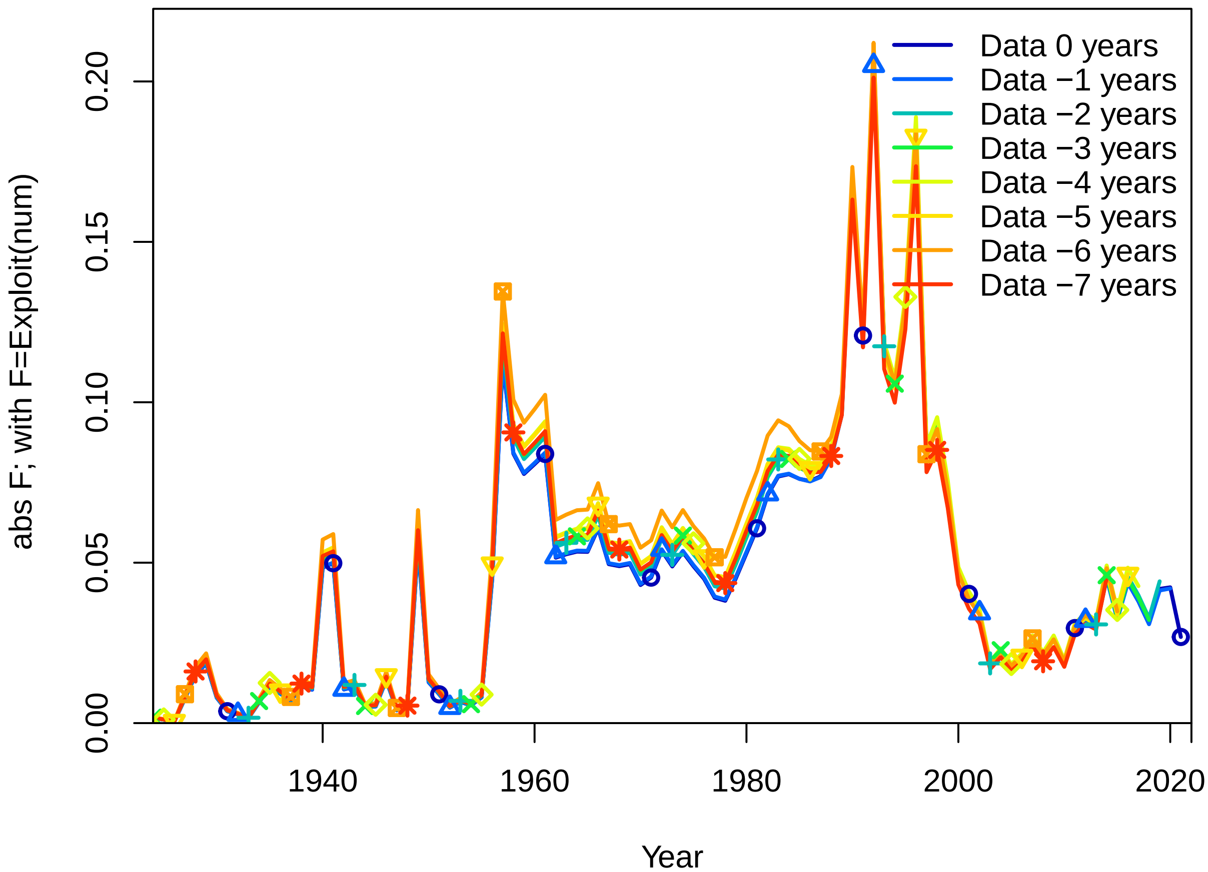


Figure 51: Retrospective plot for fishing mortality (age-12+).