Research Track Assessment of Northwest Atlantic

Spiny Dogfish

Spiny Dogfish Research Track Working Group

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EXECUTIVE SUMMARY

A research track assessment for spiny dogfish was planned for peer review in 2022, with several terms of reference (TORs) established to be addressed. This is the Spiny Dogfish Working Group's report to fulfill the TORs.

Terms of Reference (TOR) 1: "*Identify relevant ecosystem and climate influences on the stock. Characterize the uncertainty in the relevant sources of data and their link to stock dynamics. Consider findings, as appropriate, in addressing other TORs. Report how the findings were considered under impacted TORs.*"

Ecosystem and climate influences on the Northwest Atlantic spiny dogfish stock (simply "spiny dogfish" hereafter) were assessed by the Working Group in the context of their distribution and life history processes. The literature on spiny dogfish distribution was reviewed to provide context on its historical range, migration patterns, and perceived stock structure. Spatial distribution of the species was described specifically for within the Northeast U.S. Continental Shelf, and the geographic, climate, and environmental variables that have been known to influence spiny dogfish. To assess how climate has influenced the stock's abundance and distribution, a Vector Autoregressive Spatiotemporal (VAST) model was developed from the Northeast Fisheries Science Center (NEFSC) spring bottom trawl survey to calculate the center of gravity and effective area occupied for male and female dogfish. Largely, these metrics suggested that the annual distribution of dogfish has not changed significantly over time. Temperature and depth were explored as covariates in the VAST model, as they were the most common variables associated with spiny dogfish abundance and distribution from the literature. Results indicated that depth was the only significant factor in predicting occurrence and abundance.

The Working Group also discussed the environment and potential effects on life history characteristics: recruitment, growth, maturity, and diet. The Working Group explored the correlation between environmental conditions (e.g., spring bottom temperature, the North Atlantic Oscillation) on recruitment and recruits per spawner indices from the NEFSC spring bottom trawl survey, with little correspondence. Temperature was also evaluated in the context of a stock-recruit relationship, which indicated no statistical improvement over a non-environmentally explicit relationship. While environmental and climate influences on growth may be occurring, the lack of time series growth information prevented the Working Group from conducting related formal analyses. Updated maturity time-series data indicated a decline in maturity over time, but several causes are possible, including either harvest or environmental forcings. As such, better understanding the drivers in the declining maturity over time is considered a research recommendation.

TOR 2: Estimate catch from all sources including landings and discards. Describe the spatial and temporal distribution of landings, discards, and fishing effort. Characterize the uncertainty in these sources of data.

Commercial and recreational landings and discards are estimated over time, with methods for deriving them presented. Commercial landings increased rapidly from the late 1960s to 1974, with substantial spiny dogfish harvest by foreign trawling fleets beginning in 1966. After 1978, landings by foreign fleets were curtailed, and landings by U.S. and Canadian vessels increased. The U.S. commercial fishery intensified in 1990, and landings were reduced in the 2000s due to restrictions imposed by federal and interstate fisheries management plans. When the stock was declared rebuilt in 2009, the allowed biological catch, trip limits and landings increased. Otter trawl and gill nets have been the primary U.S. commercial gears used to harvest spiny dogfish. Estimation of discards was uncertain prior to establishment of the at-sea observer program in 1989, which informed the starting year of the assessment model. There is some uncertainty in landings and discards for each fleet's size and sex composition information based on the available data and thus associated assumptions made to produce catch information for the assessment model. Catch per unit effort indices were developed for the U.S. commercial otter trawl fleet to assess prospective correspondence to fisheries independent surveys.

TOR 3: Present the survey data used in the assessment (e.g., indices of relative or absolute abundance, recruitment, state surveys, age-length data, application of catchability and calibration studies, etc.) and provide a rationale for which data are used. Describe the spatial and temporal distribution of the data. Characterize the uncertainty in these sources of data.

The Working Group evaluated several fisheries-independent surveys within the stock boundaries to inform modeling efforts of TOR 4: NEFSC Bottom Trawl Surveys, NEFSC

Bottom Long Line Survey, Northeast Area Monitoring and Assessment Program (NEAMAP) Inshore Trawl Survey, Massachusetts Division of Marine Fisheries (MADMF) Bottom Trawl Survey, Atlantic States Marine Fisheries Commission (ASMFC) Shrimp Survey, Rhode Island Coastal Trawl Surveys, the Maine-New Hampshire (ME-NH) Inshore Groundfish Trawl Survey, and Canadian Bottom Trawl Surveys. Where available, indices were evaluated for both male and female spiny dogfish by season. Concerns as to whether surveys that only sampled a portion of the stock unit adequately track temporal population changes led the Working Group to only use the NEFSC spring bottom trawl survey for modeling purposes. Of the available data, this survey best samples the entirety of the stock. Fall indices are not optimal for assessing annual changes because substantial portions of the stock are outside the survey domain during that season.

VAST models were developed to integrate multiple surveys' information and produce a single index and associated length composition for each sex in a given season. VAST models for this exercise included the NEFSC Bottom Trawl Survey, NEAMAP Inshore Trawl Survey, MADMF Bottom Trawl Survey, and ME-NH Inshore Groundfish Trawl Survey. A comparison of NEFSC spring bottom trawl relative abundances indices and the VAST model spring indices indicated similar patterns over time. Abundance indices produced by VAST were developed for spiny dogfish by season and sex for use in the assessment model as a sensitivity run. However, VAST model fitting proved challenging for the length composition data and the Working Group was unable to get a converged model at the resolution of the length bins used by the assessment model. Model sensitivity analyses included testing the NEFSC fall bottom trawl survey indices, NEFSC spring and fall bottom long line survey indices, as well as the VAST spring index with interpolated length compositions.

TOR 4: Use appropriate assessment approach to estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series, and estimate their uncertainty. Compare the time series of these estimates with those from the previously accepted assessment(s). Evaluate a suite of model fit diagnostics (e.g., residual patterns, sensitivity analyses, retrospective patterns), and (a) comment on likely causes of problematic issues, and (b), if possible and appropriate, account for those issues when providing scientific advice and evaluate the consequences of any correction(s) applied.

Stock Synthesis 3 (SS3) was chosen as the primary assessment tool, due to its ability to model sexes separately, and to accommodate length-based approaches. The SS3 base case model ran from 1989-2019 because the sea sampling data used to estimate discards was not available prior to 1989. Input data to the model included the NEFSC spring trawl survey, landings, discards, and length compositions for all of these data sources. Growth was modeled as von Bertalanffy, using the parameters estimated by Nammack et al. (1985), except that L_∞ for 2012-2019 was estimated within the model; the estimated female L_∞ for that period (89.24 cm) is considerably smaller than that used for 1989-2011 (100.50 cm). Natural mortality was taken to decline with age (Lorenzen 1996), and was assumed to average 0.102 over the 50 year potential lifespan of Atlantic spiny dogfish. The survival spawner-recruitment relationship was used, which was specifically designed for low fecundity species such as spiny dogfish (Taylor et al. 2013). Alternative stock-recruit models (Beverton-Holt and Ricker) were tested in SS3, but output from these runs appeared to be much less credible than that from the survival spawner-recruitment relationship.

The base case SS3 run showed declines in spawning output from 1989 to 1997; these quantities increased until 2012, then declined again. The estimated base case spawning output trends reasonably matched survey trends during 2000-2019 and exhibited almost no retrospective pattern (Mohn's $\rho = 0.06$). However, the base case estimated smaller declines in spawning output during 1989-1997 than those observed in the NEFSC spring trawl survey. Estimated female fishing mortality (numbers based, age 12+) peaked in 1992 at about 0.17, declined to less than 0.025 between 2002-2010, and averaged about 0.033 during the most recent period (2014-19).

The SS3 base case run was compared to the output from the Stochastic Estimator, the model used in previous spiny dogfish assessments. The Stochastic Estimator is based on swept area calculations under the assumption that the survey trawl efficiency is one, and uses bootstrapping to quantify the uncertainties. The SS3 model generally estimated somewhat higher biomass and spawning output and lower fishing mortality than the Stochastic Estimator because it estimated a slightly lower survey efficiency ($q = 0.83$). The Stochastic Estimator estimated much higher F and a larger decline in female biomass and spawning output in the early portion of the time series.

TOR 5: Update or redefine status determination criteria (SDC; point estimates or proxies for BMSY, BTHRESHOLD, FMSY and MSY reference points) and provide estimates of those criteria and their uncertainty, along with a description of the sources of uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for reference points. Compare estimates of current stock size and fishing mortality to existing, and any redefined, SDCs.

Per recruit calculations indicate that both yield-per-recruit (YPR) and pups-per-recruit (PPR) calculations are highly sensitive to growth assumptions. Maximum YPR occurred around $F = 0.15$, but using the estimates of L_∞ from the most recent period (89.24 cm for females), fishing above $F = 0.03$ produced less than two pups per recruit, and thus was unsustainable. The Working Group evaluated three SS3 estimated spawners-per-recruit (SPR) reference points: SPR50%, SPR60% and SPR70%. The fishing mortality associated with SPR50% (0.037) would produce less than two PPR. Furthermore, mean fishing mortality was below this value during 2013-2019, but nonetheless, female biomass and spawning output substantially declined during this period. By contrast, these quantities increased when fishing mortality was below $F = 0.025$, the fishing mortality associated with SPR60%, and decreased when $F > 0.025$ during the most recent period. For these reasons, the Working Group recommended adopting the SPR60% reference points: a spawning output target of 370.8 million pups and $F = 0.025$. This spawning output target corresponds to a considerably higher spawning biomass than previous reference points (SSB_{MAX} = 159,288 or 189,553 mt). However, reestimation of the previous reference points using updated data and parameters produced estimates similar to SPR60% (SSB_{MAX} = 445,349 mt and $F = 0.03$, McManus et al. 2022).

TOR 6: Define appropriate methods for producing projections; provide justification for assumptions of fishery selectivity, weights at age, maturity, and recruitment; and comment on the reliability of resulting projections considering the effects of uncertainty and sensitivity to projection assumptions.

The Working Group used the projection tool internal to SS3 for this assessment. The continuity of both the assessment model and projections being conducted with the same software allowed for effective and efficient application of the projection tool. Short-term projections were conducted (2020-2022) under four different fishing mortality rates: one under zero harvest and at $F = 0.017$, 0.025, and 0.037, corresponding to the SPR reference points SPR70%, SPR60%, and SPR50% respectively. Projections indicated a decline in spawning output from 2019 to 2020, and then increases in spawning output under all four alternatives, likely due to maturation of many females in the large 2009-2012 year classes.

TOR 7: "Review, evaluate, and report on the status of research recommendations from the last assessment peer review, including recommendations provided by the prior assessment working group, peer review panel, and SSC. Identify new recommendations for future research, data collection, and assessment methodology. If any ecosystem influences from TOR 2 could not be considered quantitatively under that or other TORs, describe next steps for development, testing, and review of quantitative relationships and how they could best inform assessments. Prioritize research recommendations."

The Working Group reviewed the research recommendations presented in the last benchmark stock assessment for spiny dogfish (43rd SAW Stock Assessment Report, NEFSC 2006), and those most recent from the Mid-Atlantic Fisheries Management Council and its Scientific and Statistical Committee. Individual responses were provided to each recommendation on how the work conducted during this assessment addressed them. New research recommendations were also put forth by the Working Group; the highest priority recommendation is in regard for consistent ageing analyses. Movement from data-limited approaches to more sophisticated models often depends on available age or growth information. Aging programs should be established to allow for the continuous inclusion of such data and better inform growth in the assessment model, which can have significant impacts on model performance. Age samples should be collected across the spectrum of significant variables: by sex, across the size spectrum, by season, and over various areas of the stock bounds.

TOR 8: Develop a backup assessment approach to providing scientific advice to managers if the proposed assessment approach does not pass peer review or the approved approach is rejected in a future management track assessment. A backup assessment approach is required to be in place as a hedge against a scenario where the primary catch-at-age model is not suitable for providing management advice.

The Working Group evaluated several backup approaches, including the Stochastic Estimator, Depletion-Based Stock Reduction Analysis, Depletion-Corrected Average Catch, and the index-based method Ismooth. Each method uses various data streams (e.g., fisheries-independent indices, landings or catch information, life history parameters) to provide inferences on population size and/or stock status. Of the methods reviewed, the Working Group recommended the Stochastic Estimator be used as the backup approach to providing scientific advice to managers if the preferred SS3 assessment model approach does not pass peer review or if SS3 is rejected in a future management track assessment.

WORKING GROUP PROCESS

A research track assessment for Spiny dogfish was planned for peer review in July 2022, to be followed by a management track assessment in fall 2022. However, the peer review was rescheduled to allow for data streams for the assessment to become available (of which included new ageing data and analyses for spiny dogfish). The peer review was rescheduled for December 2022, with an anticipated management track assessment in 2023. The Working Group was formed in June 2021 and met over a series of virtual meetings. Working Group meeting agendas were developed prior based on feedback of the Working Group and non-Working Group members. The Working Group met during the following meetings:

1. July 30, 2021 – Kickoff meeting
2. September 22, 2021 – TORs 2, 3, 4
3. October 12, 2021 – TORs 2, 3, 4
4. November 15, 2021 – TORs 1, 2, 3, 4, 5
5. December 21, 2021 – TORs 2, 3, 4
6. January 19, 2022 – TORs 1, 2, 3, 4
7. February 15, 2022 – Stakeholder session
8. March 9, 2022 – TORs 1, 3, 4, 8
9. April 5, 2022 – TORs 4, 8
10. April 19, 2022 – TORs 2, 3, 4
11. May 2, 2022 – TORs 1, 3, 4, 8
12. May 11, 2022 – TORs 4, 8
13. June 15, 2022 – TOR 4
14. June 29, 2022 – TORs 4, 5, 8
15. August 23, 2022 – TORs 1, 2, 3

16. September 8, 2022 – TORs 1, 3, 4
17. September 22, 2022 – TORs 3, 4
18. October 4, 2022 – TOR 4
19. October 11, 2022 – TORs 4, 5, 6, 7
20. October 24, 2022 - TORs 4, 5, 6
21. November 1, 2022 - TORs 4, 5, 6
22. November 4, 2022 - TORs 1-8
23. November 15, 2022 - TOR 5, Assessment Document
24. November 16, 2022 - Assessment Document
25. November 17, 2022 - Assessment Document

Working Group members met through additional sub-TOR meetings to discuss finer details of various research to support individual TORs, of which discussions and recommendations were brought before the Working Group for consensus. Working Group materials (presentations, agendas, meeting minutes, literature, data, model runs, working papers, and assessment document drafts) were shared using a Google Drive folder. Working Group Co-Chairs and TOR Leads produced the report by compiling information from working papers, meeting minutes and presentations, and the draft report was reviewed and edited by Working Group members.

INTRODUCTION

Atlantic spiny dogfish (*Squalus acanthias*) is a schooling shark that is widely distributed across both sides of the North Atlantic. It is closely related to Pacific spiny dogfish, which previously was considered a subspecies of *Squalus acanthias,* but recently has been reclassified as its own species, *Squalus suckleyi* (Ebert et al. 2010). This assessment is for the Northwest Atlantic spiny dogfish stock (hereafter spiny dogfish refers to the Northwest Atlantic stock unless otherwise indicated).

Spiny dogfish are considered one of the most migratory shark species in the northwest Atlantic (Compagno 1984). It has a wide-ranging diet consisting of fish, such as herring, mackerel and sand lance, as well as invertebrates including ctenophores, squid, crustaceans and bivalves. Spiny dogfish are live bearers with a very long gestation period (18-24 months), and are slow growing with late maturation. Females grow larger than males and as a result, the fishery primarily targets females. In the northwest Atlantic, spiny dogfish occur from Florida to Canada, with highest concentrations from Cape Hatteras to Nova Scotia. In the winter and spring, they are found primarily in Mid-Atlantic waters, and tend to migrate north in the summer and fall, with concentrations in southern New England, Georges Bank, and the Gulf of Maine (though a recent study has created some uncertainty regarding the established migration paradigm, Carlson 2014).

Fishery and Management History

The management unit for spiny dogfish is the northwest Atlantic coast of the United States. Canadian landings are also accounted for by management. The management objectives of the Spiny Dogfish Fishery Management Plan (FMP) can be summarized as avoiding overfishing, avoiding management or regulatory conflicts, facilitating enforcement, and contributing to the protection of biodiversity and ecosystem structure and function.

The fishery was essentially unmanaged before 2000. Prior to about 1979, landings of spiny dogfish by U.S. and Canadian vessels were very low, with most catch likely being discarded. However, there were substantial landings by foreign trawlers, with landings peaking in the early 1970s at about 20,000 mt per year. A domestic fishery began to develop between 1979-1989, with annual landings averaging around 4,000 mt. Landings increased in the 1990s as other groundfish stocks declined, averaging over 20,000 mt per year from 1993-1998.

Observations of declining numbers and sizes of mature females as well as reduced recruitment (Rago et al. 1998) led to a determination in 1998 that this stock was overfished (NEFSC 1998). This led the Mid-Atlantic and New England Fishery Management Councils to develop a joint management plan that initially curtailed most directed fishing in order to rebuild the spiny dogfish stock. Low trip limits and catch reductions in the 2000s led to increases in spawning stock biomass and recruitment. The fishery was declared rebuilt in 2010, which allowed for the resumption of a directed fishery. Current management includes a 7,500 lb (3,402 kg) trip limit and an overall quota of 29.56 million lbs (13,408 mt), although a substantial decrease in the quota is likely for 2023. Table 1 describes the history of quotas and trip limits.

The Atlantic States Marine Fisheries Commission (ASMFC) approved an Interstate FMP to complement the federal plan in 2003, and ASMFC management sets regional and/or state allocations and trip limits. These allocations can restrict fishing at times even if the full quota has not been attained, though late 2019 ASMFC changes have facilitated state transfers that reduce (but do not eliminate) the state allocation constraint on total landings. Boats without federal spiny dogfish permits are not bound by the federal trip limit in state waters, but cannot retain spiny dogfish in federal waters. The federal spiny dogfish permit is not "limited access," so it can be added and/or dropped by fishery participants as they deem the ability to fish either federal waters, or state waters with higher trip limits, to be more advantageous.

Table 1. History of spiny dogfish quotas and trip limits. Note: The Councils have not always agreed on catch limits or trip limits - those listed here are as implemented by NMFS. States can also set their own trip limits for state waters.

Fishing Year	NMFS Commercial quota (mt)	Federal Trip Limit (pounds)	Notes
2000	1,814	600/300	Initially two seasonal quotas and trip limits. 5/1-10/31 and 11/1-4/30
2001	1,814	600/300	
2002	1,814	600/300	
2003	1,814	600/300	
2004	1,814	600/300	
2005	1,814	600/300	
2006	1,814	600	Trip limits for both periods or just annual hereafter
2007	1,814	600	
2008	1,814	600	
2009	5,443	3,000	Closed 9/26-10/31, 2009, and 1/26-4/30, 2010. ASMFC removes seasonal quotas
2010	6,803	3,000	Closed 8/27-10/31, 2010, and April 2011
2011	9,072	3,000	Closed 8/26-10/ 31, 2011, and 1/13-4/30, 2012
2012	16,191	3,000	
2013	18,526	4,000	New trip limit effective May 3, 2013
2014	22,243	5,000	New trip limit effective Sept 8; federal seasonal allocation ends Aug 2014
2015	22,957	5,000	
2016	18,307	6,000	New trip limit effective Aug 15, 2016
2017	17,735	6,000	
2018	17,325	6,000	
2019	9,309	6,000	
2020	10,521	6,000	
2021	13,408	6,000	
2022	13,408	7,500	New trip limit effective May 1, 2022

Assessment History

The following presents the chronology of spiny dogfish benchmark assessments with brief summaries regarding the findings:

Anthony and Murawski (1985): During Stock Assessment Workshop (SAW) 1, several notes were made regarding key spiny dogfish uncertainties including discard mortality, data confidentiality limitations on calculating catch per unit effort (one company), growth rates, survey variability, predator/prey interactions, and harvest implications of the stock's low mean fertility, natural mortality rate, and long life span.

NEFSC (1990): During SAW 11, spiny dogfish were assessed as part of the small elasmobranchs group, which included skates and dogfish species. Landings, life history, trawl survey and reference points based yield per recruit analyses were presented. General conclusions were that the population has substantially increased since the 1960s. To better understand the dynamics of spiny dogfish and its response to exploitation, future research recommended included: better evaluation of the Northeast Fisheries Science Center (NEFSC) survey indices as an indicator of stock abundance and biomass and means to estimate absolute population size; evaluating changes in population demographics over time, including size, age, and sex composition, and population fecundity, evaluation of stock recruitment relationships from survey data, better understanding of the trophic dynamics of spiny dogfish in the ecosystem, and investigation of discard data to clarify the removals from the stock.

NEFSC (1994): During SAW 18, the assessment scientists addressed terms of references regarding patterns of landings and fishery dependent data, fishery independent abundance data, and biological reference points. Data suggested that the spiny dogfish stock in the Northwest Atlantic had begun to decline as a consequence of the recent increase in exploitation. Pups per recruit and biomass dynamic models were used to derive reference points and understand the population size. Swept-area estimates of the fishable biomass increased threefold from 1968 to 1988, but then declined by over 10%. It was recommended that a management program with appropriate management targets for stock biomass and fishing mortality rates be quickly established.

NEFSC (1998): During SAW 26, the assessment from SAW 18 was updated with data through 1997. Several analyses were presented as part of the assessment: trends in length composition of landings and surveys, trends in recruitment, application of a Beverton and Holt mortality estimator, comparison of observed length-specific sex ratios and predictions of a mechanistic life history model, and revisions to the previous yield-per-recruit estimates. New biological reference points based on pups per recruit necessary for equilibrium was proposed. Although the stock was deemed to be at a moderate biomass level, a severe reduction in the mature component of the fishery was apparent, which can affect recruitment, and the stock was over-exploited.

NEFSC (2003): During SAW 37, the Beverton-Holt mortality estimator was again applied to derive mortality rates. Fishery selectivity was further explored, and stochastic estimates of fishing mortality and biomass for the stock were conducted for the first time. Fishery-dependent, fishery independent, and life history information were evaluated. Poor recruitment was identified, with an apparent recruitment failure from 1997-2003.

NEFSC (2006): During SAW 43, the Stochastic Estimator of fishing mortality (*F*) and biomass (*B*), the primary model used in the assessment, was updated to include uncertainty in recreational catch and discarded catch by gear type. Despite lower landings since 2001, fishing mortality rates on the fully recruited female stock component were above the rebuilding target. An analytical model (LTM) was used to express survey indices of biomass in absolute scale and in turn to provide estimates of fishing mortality rates. New biological reference points for spawning stock biomass based on the Ricker stock-recruitment model were developed. At this time, however, recent recruitment patterns did not conform to the Ricker model, soliciting a more detailed consideration of reproductive biology in the future. As such, the existing *F* and *B* reference points were retained. The stock was found to be not overfished and overfishing not occurring. Projections indicated that if recruitment returns to levels consistent with expected size-specific reproduction, the biomass would rebound by 2015.

O’Brien and Worcester (2010), TRAC (2010): Two models were attempted using different stock units and growth estimates. Scientists from Fisheries and Oceans Canada (DFO) presented a two area, two half year (Nov-Apr, May-Oct) time step model that allowed for migration in both directions over the Hague line (Haist et al. 2010). The model deficiencies identified included no recruitment being estimated for the Canadian side of the stock, and poor fits to length and survey data. NEFSC scientists attempted a one stock, annual Stock Synthesis 3 model (Sosebee et al. 2010). The model included both sexes and used <= 35 cm individuals as a recruitment index, and females >= 80 cm as a spawning stock biomass (SSB) index. However, the model did not provide reasonable population estimates for the stock, and also had issues with fit to survey abundance indices and length data. From this assessment, both proposed DFO and NEFSC models were rejected.

TOR1: ECOSYSTEM AND CLIMATE INFLUENCES

"*Identify relevant ecosystem and climate influences on the stock. Characterize the uncertainty in the relevant sources of data and their link to stock dynamics. Consider findings, as appropriate, in addressing other TORs. Report how the findings were considered under impacted TORs.*"

Distribution and Habitat Use

Spiny dogfish (*Squalus* spp.) are distributed worldwide in boreal and temperate continental shelves as far from shore as the 900 m contour (Stehlik 2007; Dell'Appa et al. 2015). Spiny dogfish can be found throughout the North Atlantic, but the northwest Atlantic Ocean population is not believed to mix with populations from across the Atlantic or other oceans of the world (Stehlik 2007). Although it is not considered the norm, there is evidence of transatlantic migration by individuals, with historic records spanning from off Newfoundland, Canada to southwest of Iceland and north of Scotland (Holden 1967, Templeman 1976) and a recent record from Georges Bank to just south of Ireland (McCandless 2022). Genetic findings have suggested that North Pacific spiny dogfish are distinct from the South Pacific and Atlantic regions (Verissimo et al. 2010). The general distribution of northwest Atlantic spiny dogfish is considered to be from Florida to Greenland, with most concentrated from Cape Hatteras, North Carolina, to Nova Scotia (Rago et al. 1998). Spiny dogfish have been found in water temperatures between 1 and 20°C, but are most often between 6 and 15°C (Dell'Appa et al. 2015, references therein).

The species seasonally migrates north and south on the northwest Atlantic shelf, as well as inshore and offshore with changes in water temperature (Garrison 2000; Dell'Apa et al. 2015). In U.S. waters, mature females typically will overwinter in waters off North Carolina, move north to southern New England and the Gulf of Maine in the spring, with migrations occurring south toward the Carolinas again in the fall (O'Brien and Worcester 2010). A satellite tag study has created some uncertainty regarding this established migration paradigm, suggesting movements may occur more regionally (Carlson et al. 2014). Conventional tagging studies have suggested the northwest Atlantic spiny dogfish population may be comprised of multiple stocks, principally separate U.S. and Canadian stocks, given limited intermixing (between 10 and 38.4 % intermixing rate) along the New England coast (Campana et al. 2007; O'Brien and Worcester 2010; Rulifson et al. 2012). These tagging studies have been used to understand prospective population structure for northwest Atlantic spiny dogfish (Figure 1.1, O'Brien and Worcester 2010). However, these studies primarily consisted of mature females and genetic studies on the species are lacking to determine the true distinctions between U.S. and Canadian Atlantic spiny dogfish.

Spiny dogfish distributions vary with sex (Haugen et al. 2017, McCandless 2022). Mature males overwinter on the outer continental shelf and slope off southern New England and down to the Delaware and Maryland border, whereas females tend to stay further inshore whether traveling down the coast to North Carolina or remaining in the Gulf of Maine (McCandless 2022). Male dogfish can be found with little female presence in the spring along the continental shelf (Chesapeake Bay to Long Island) between depth ranges of 70–80 m and 300–330 m (~ 90–150 km or 240–270 km from shore, Haugen et al. 2017). Male-skewed catches have also been observed in the fall in the western Gulf of Maine and on Georges Bank at depths of 80–250 m. Depth has been found to be the greatest environmental variable in predicting male-skewed dogfish locations (Haugen et al. 2017).

Previous work has suggested little or no distributional shifts over time (Nye et al. 2009). However, recent data from the NEFSC Bottom Trawl Survey indicate that the center of abundance of spiny dogfish has moved 1.42 degrees (157.98 km) south, its range has expanded by 0.21 degrees (23.79 km), and has moved 18 meters shallower from 1974-1977 to 2017-2019 (NOAA Fisheries 2022a). The Fall Bottom Trawl Survey data indicate that spiny dogfish has moved 0.61 degrees (68.36 km) north, its range has contracted by 0.37 degrees (41.05 km), and has moved 32.8 meters deeper from 1974-1977 to 2017-2019 (NOAA Fisheries 2022a).

Species distribution modeling using NEFSC Bottom Trawl Survey data has also been used to understand spiny dogfish distributions and their changes over time (NOAA Fisheries 2022b). Spring survey indices are greater than those in the fall, at least in part due migrations into Canada in the summer and fall. Over time, the probability of occurrence in the spring has increased in areas such as the Gulf of Maine, and coastal and shelf break waters in the Mid-Atlantic Bight, whereas it has decreased on Georges Bank. In the fall, increasing habitat trends predicting probability of occurrence have increased in large regions of Southern New

England, Mid-Atlantic Bight, Georges Bank, and Gulf of Maine, except it has decreased in waters in eastern Gulf of Maine and coastal areas of southern Massachusetts and Rhode Island. Friedland et al. (2020) reported that over the Northeast U.S. Continental Shelf, occupancy habitat area has decreased in the spring over time, and increased in the fall. From a suite of environmental (e.g., physical, primary and secondary productivity, benthic) variables, bottom temperature appeared to be the most important covariate in determining the presence of spiny dogfish. In a similar analysis conducted in nearshore waters from North Carolina and southern New England using the NEAMAP Bottom Trawl survey data, Dell'Apa et al. (2017) identified several variables were significant in predicting catch, including bathymetry, sea surface temperature, salinity, chlorophyll-a (chl-a) concentration, season, and time of survey. Females were predicted to occur more inshore than males, inhabiting warmer, less saline, and higher chl-a waters. Females were also in greater abundance in the spring and morning, with males more abundant in the fall and afternoon times.

Spiny dogfish has been characterized as having an overall low climate vulnerability rank, with high exposure to climate changes and low biological sensitivity (Hare et al. 2016). Correspondence between spiny dogfish distribution and environmental conditions have been identified. Using the NEFSC Bottom Trawl Survey data, Sagarese et al. (2014b) found patterns specific to ontogenetic stages. Neonate, immature, and mature dogfish selected warmer, more saline waters. In the fall, the authors found that larger dogfish occupied relatively warmer, shallower, and less saline waters and that neonates selected higher salinities. Using generalized additive models, seasonal occurrences for various stages of spiny dogfish have been linked to depth, bottom temperature, and prey species (e.g., Atlantic herring, Atlantic mackerel, *Doryteuthis* spp.; Sagarese et al. 2014a). Using these models to forecast distributions under a warming scenario suggest that higher regional probabilities of occurrence for most dogfish stages could result.

As part of the Stakeholder Session held during the Research Track Assessment, several participants described their perspectives on ecosystem drivers for spiny dogfish (Appendix A). With warming waters, a prospective indirect effect of increasing seal populations on spiny dogfish natural mortality was mentioned. The impact of groundfish on the spiny dogfish population was recommended to be investigated, which has since been explored through evaluating a suite of drivers on the retrospective patterns of groundfish stocks (Kerr et al. 2022). A spatial and temporal shift in spiny dogfish abundance and distribution was noted to have occurred over time, which has impacted the distance that harvesters need to travel now to catch the species (Appendix A). Aligning with previous studies (Sagarese et al. 2014a; Sagarese et al. 2016), stakeholders noted similar prey items of significance for spiny dogfish that may influence their distribution such as squid and herring (Appendix A). Although, studies have shown that spiny dogfish are opportunistic predators that prey on more abundant species and will shift their diet when these prey are not readily available, as seen with herring (Overholtz and Link 2006) and ctenophores (Link and Ford 2005). This may also be the case if prey distributions shift, unless those factors affecting the prey distribution, such as temperature, also influence spiny dogfish distribution.

As part of this assessment, catch per unit effort (CPUE) was also analyzed to determine whether ecological and economic conditions influence the catch rates (Jones et al. 2022). An inverse relationship between catch rate and depth was identified, with little variation in this effect between years when models were fit with an explicit year by depth interaction. This consistent relationship suggests that catch rates are consistently higher in shallow areas. A unimodal relationship between catch rate and the hour of the day emerged as well, perhaps either due to increased availability to the gear in this time period. Models also indicated a significant, cyclical relationship between CPUE and month, where there was an increase in CPUE early in the year followed by a decrease.

The Working Group explored the relationship between spiny dogfish abundance and distribution with the environment through species distribution modeling (Hansell and McManus 2022). A vector auto-regressive spatiotemporal model (VAST, Thorson 2015) was used to model the distribution of spiny dogfish over time using the NEFSC bottom trawl survey. VAST is a delta or hurdle model, where the probability of occurrence and positive catch rates are modeled separately as generalized linear mixed models, with resulting predictions integrated. Two seasonal models (spring and fall) were fit to sex specific catch rates from the NEFSC bottom trawl survey to estimate changes in spiny dogfish distribution. Models were only fit to strata that were consistently sampled and explored the influence of local environmental variables. While several environmental variables have been used to describe spiny dogfish abundance and distribution, for these analyses, only bottom temperature and depth were tested. Both seasonal models successfully converged, with depth proving to be a significant variable in the models, and thus it was included as a covariate influencing spiny dogfish abundance (Hansell and McManus 2022). Spatial estimates of probability of occurrence and abundance when present highlighted some degree of interannual variability (Hansell and McManus 2022). From these predictions, the center of gravity and effective area occupied were estimated. For both male and female spiny dogfish in the fall, center of gravity estimates were variable with no clear distribution shifts north/south or east/west (Figures 1.2). In the spring however, it appeared that the center of gravity for both sexes shifted east since the early 2000s (Figure 1.2). Effective areas occupied for both sexes and seasons were variable with no clear indication of a significant change over time (Figure 1.3).

Life History Processes and Rates

Several species' recruitment patterns in the Northeast U.S. Shelf have been found to change over time in concert with environmental changes (e.g., Perretti et al. 2017). The Working Group evaluated whether similar changes have occurred over time, and whether such changes may be driven by the environment. The goal of this exercise was to determine whether environmental influences on recruitment and recruitment per spawner have occurred, and if so, should such considerations be carried forward into the assessment model. As previously examined by Rago and Sosebee (2010), spiny dogfish recruitment and spawning females were analyzed from the NEFSC spring bottom trawl survey (McManus et al. 2022) These analyses were intended to use similar methods and definitions as Rago and Sosebee (2010) for comparability; as such, recruitment was defined here as fish ≤ 35cm, and spawning females were defined as ≥80 cm. Change point analyses on recruits and recruits per spawner did not identify any meaningful regimes over time (McManus et al. 2022). Recruitment correspondence to annual spring mean bottom temperature and the North Atlantic Oscillation (NAO) were also explored to determine if a significant relationship existed between the variables, despite there not having been a dramatic change over time. Both of these environmental indices indicated very little correlation to recruitment or recruits per spawner (McManus et al. 2022). Lastly, the impact of spring bottom temperature on the stock-recruit relationship was also tested using a Ricker model (Figure 1.4). While a model was successfully fit which incorporated temperature and highlighted its influence of recruits per spawning, this model was not a statistical improvement over a model without incorporating the environment, suggesting temperatures impact on the relationship was not significant. Based on these findings, the Working Group did not pursue investigation of environmental drivers on recruitment or the stock-recruit relationship within the assessment model.

Given marine species' growth rates and maturity schedules can be influenced by environmental conditions, the Working Group discussed evaluating such interactions for spiny dogfish. As part of the Research Track Assessment, spiny dogfish spines were aged to determine whether growth has changed in recent years compared to previous growth rates (Passerotti and McCandless 2022). While more recent growth rates were available, age and growth information was only available for select years over the last several decades and substantial uncertainties in the contemporary growth estimates persisted (Passerotti and McCandless 2022). Therefore, the Working Group determined that there was not enough time series information to test whether environmental conditions have changed growth over time. Growth was also investigated using mark-recapture data from fish tagged between 2011 and 2012, with the majority of recaptures within the first couple of years (McCandless 2022). A lower estimate for both L_{∞} and k were seen for females when compared to estimates used in past assessments based on ageing data from 1980 - 1981 (Nammack et al. 1985). Male growth parameters did not decrease, indicating the changes seen in females would be more likely due to fishing pressure. Although the estimates from this study were not appropriate for incorporation into the assessment model due to the low sample size, lack of small-sized fish, and measurement error, these estimates do provide supporting evidence of a decrease in large females.

The maturity and fecundity analyses presented in Sosebee (2005) were also updated for this assessment (Sosebee 2022a), particularly for informing the assessment model. The Working Group did not explore whether time series trends in maturity patterns were driven by environmental conditions primarily because the temporal patterns seemed to align with changes in the relative abundance, with the hypothesis that declines in maturity concurrent with abundance were the result of fishing mortality more so than the environment. However, these relationships warrant further investigation.

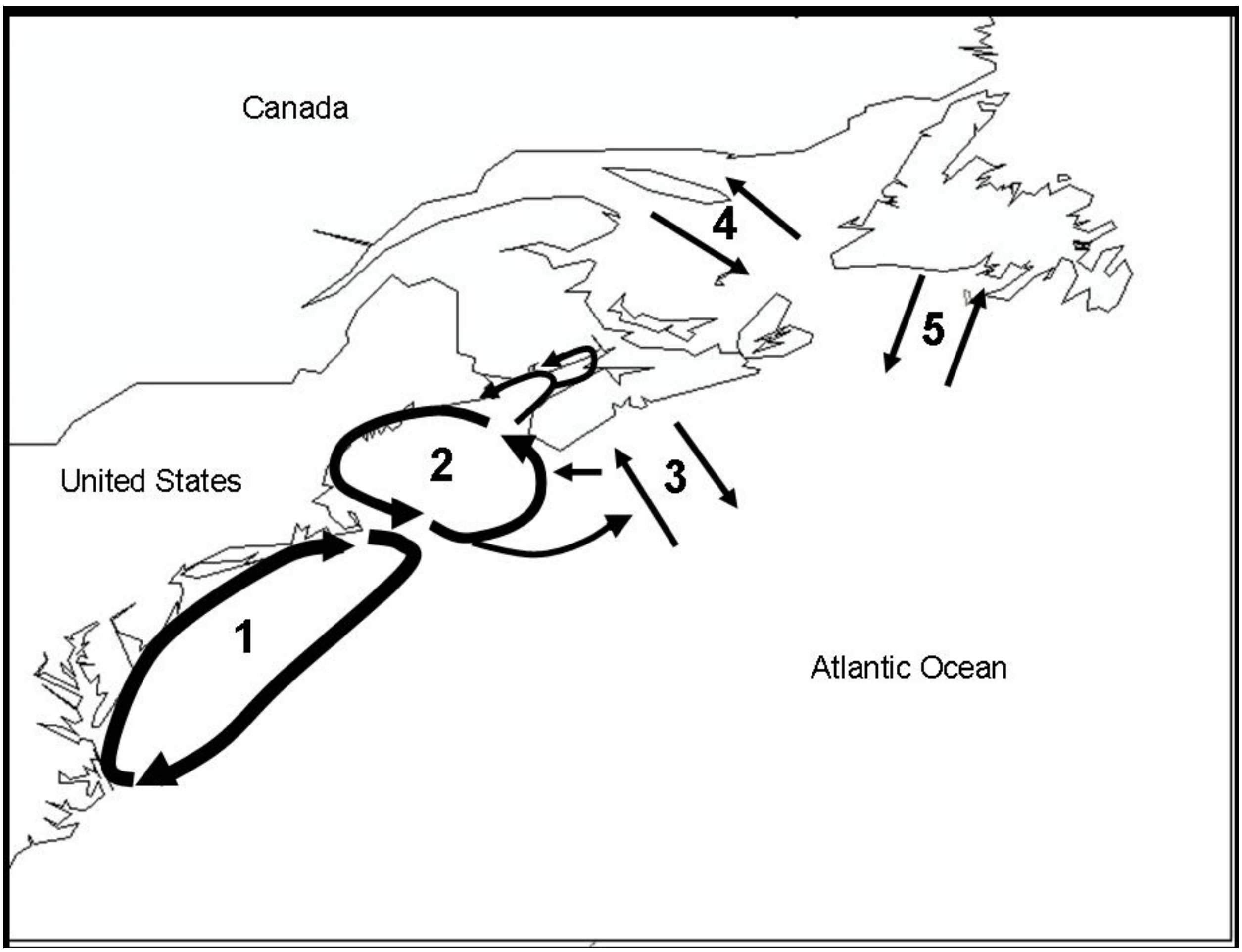


Figure 1.1. Spiny dogfish movements based on tagging data assessed during that most recent Transboundary Resources Assessment Committee benchmark assessment for Northwest Atlantic spiny dogfish (TRAC 2010).

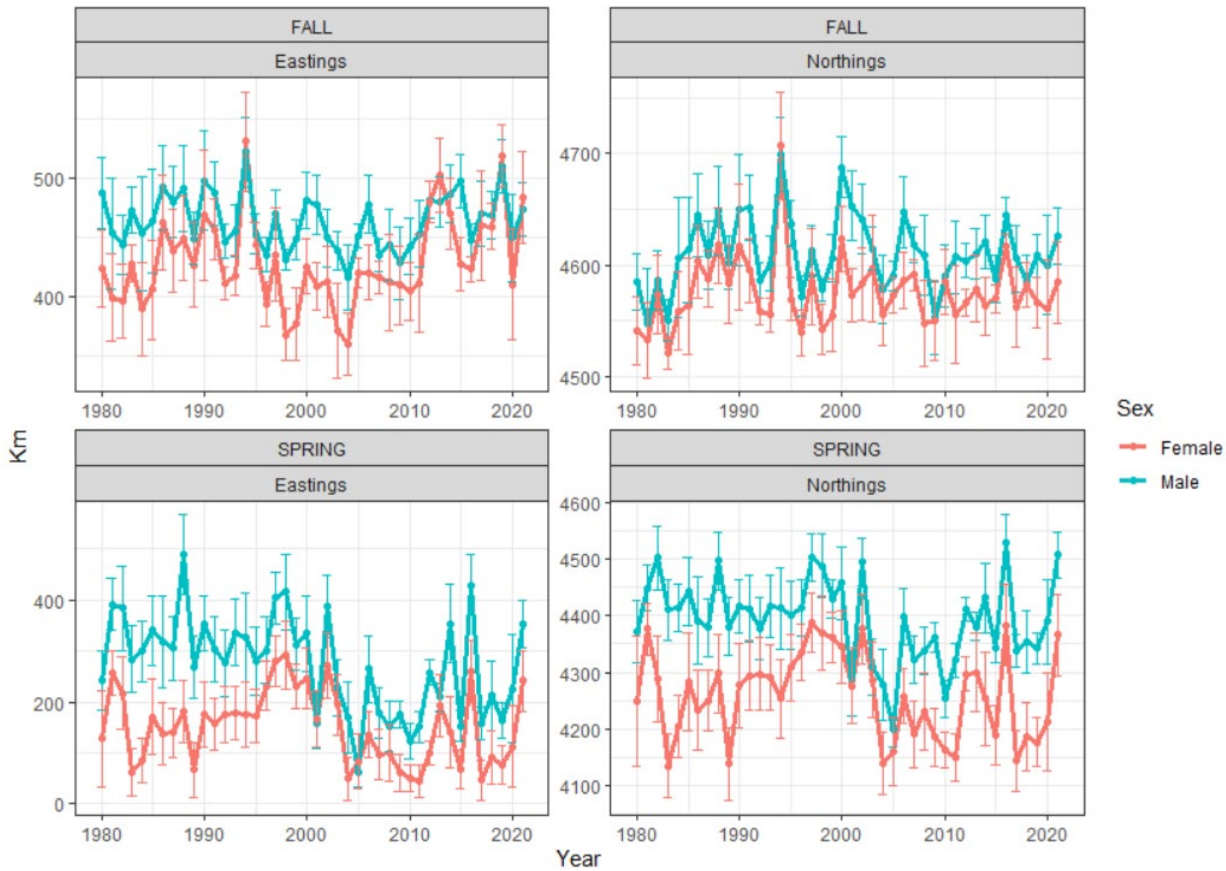


Figure 1.2. Center of gravity estimates from the VAST model for spiny dogfish. Results are presented by season and sex. Higher eastings values indicate the center of gravity is further east whereas higher northings values indicate the center of gravity is further north. Similarly, lower eastings values indicate the center of gravity is further west whereas lower northings values indicate the center of gravity is further south.

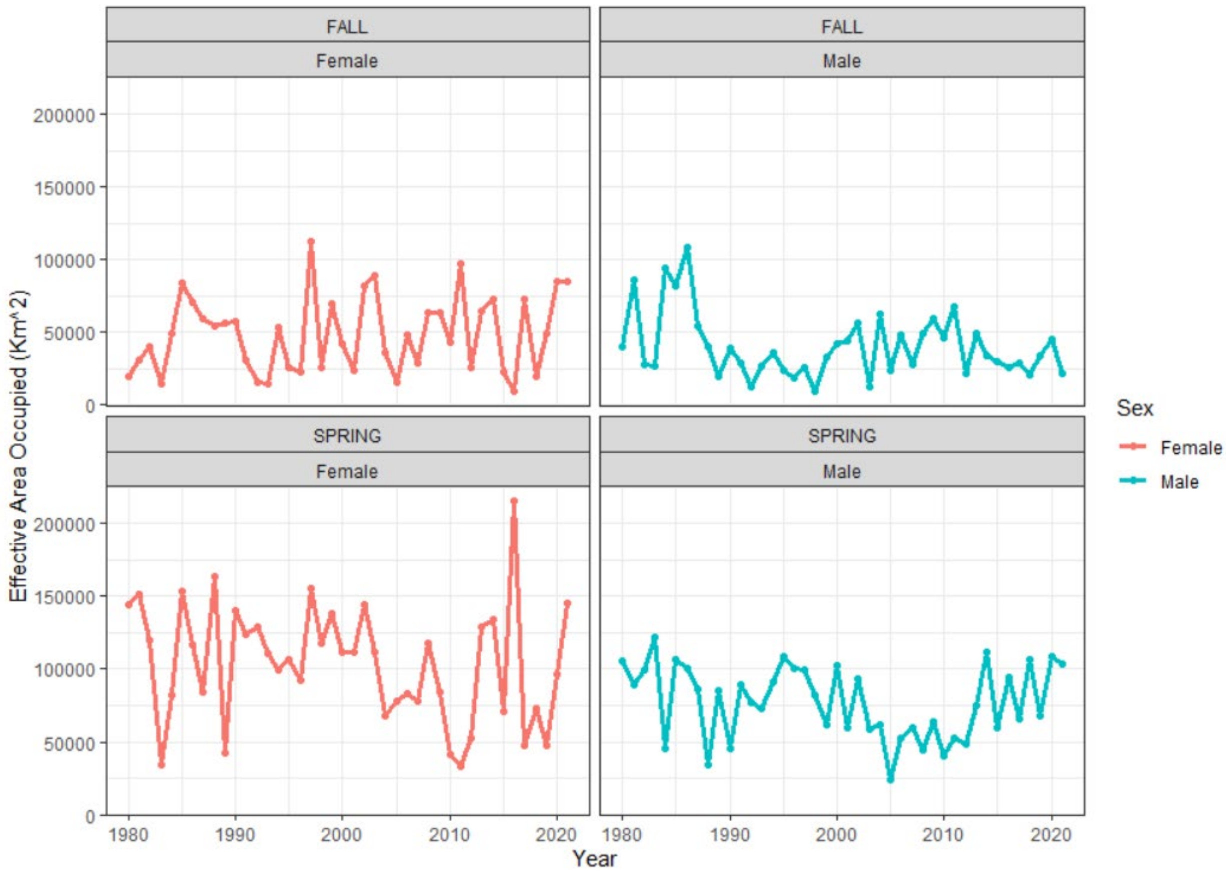


Figure 1.3: Effective area occupied estimates from the VAST model for spiny dogfish. Results are presented by season and sex.

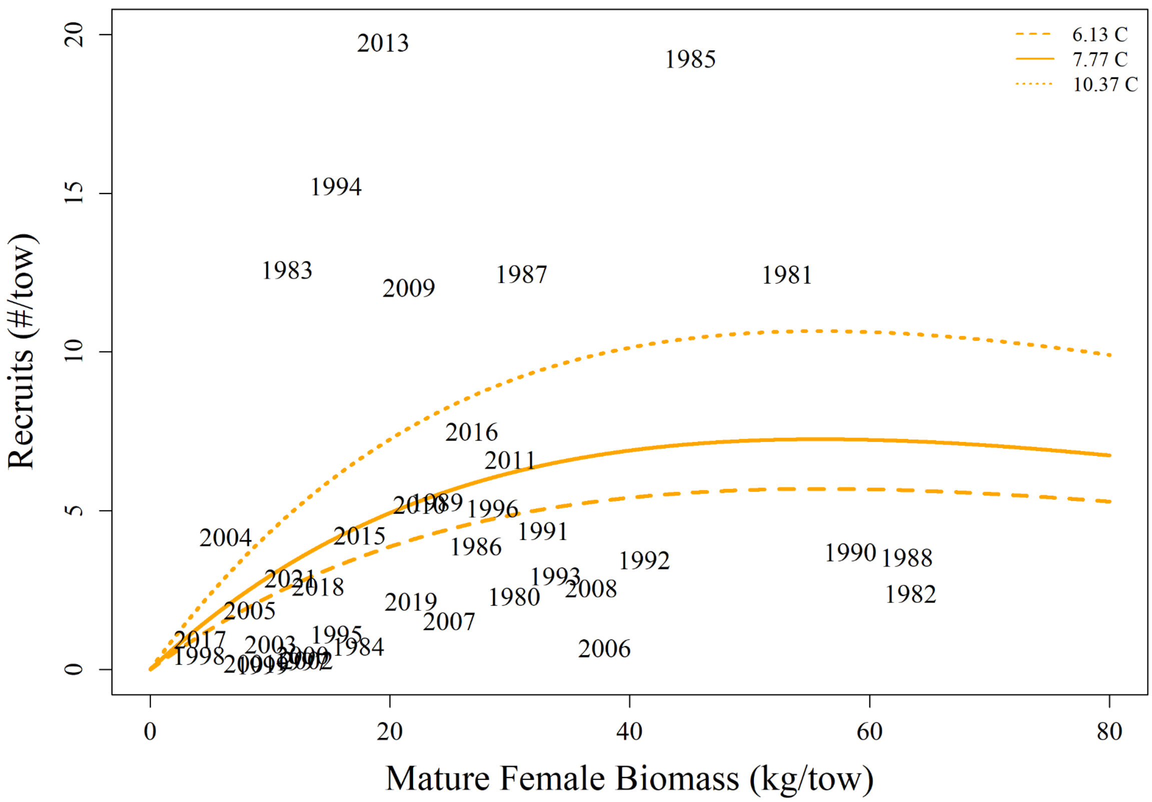


Figure 1.4. Ricker model fit to the mature female index and recruit index from the NEFSC spring bottom trawl survey, as defined in Rago and Sosebee (2010, with mean annual spring bottom temperature as a covariate in the model. Years represent annual data points. The solid line represents model predictions using the 50th percentile of the spring bottom temperature time series, whereas the dotted and dashed lines represent the minimum and maximum time series values, respectively.

TOR2: FISHERY DATA

"*Estimate catch from all sources including landings and discards. Describe the spatial and temporal distribution of landings, discards, and fishing effort. Characterize the uncertainty in these sources of data.*"

Commercial Landings

Commercial landings data were obtained from the NEFSC commercial fisheries databases (General Canvass, Weighout and logbook), the Northwest Atlantic Fisheries Organization (NAFO) database (https://www.nafo.int/Data/STATLANT), Department of Fisheries and Oceans Canada, and the State of North Carolina for both spiny dogfish and unclassified dogfishes. The tables in the Appendix of NEFSC 1998 show which database (General Canvass or Weighout) the landings came from by state for 1962-1988 for unclassified dogfish and for spiny dogfish. Historical records dating back to 1931 indicate that U.S. commercial landings of dogfish in Subareas 5 and 6 were less than 100 mt in most years prior to 1960 (NEFSC 1990). Total commercial landings of spiny dogfish in NAFO Subareas 2-7 by all fisheries increased rapidly from the late 1960s to a peak of about 25,000 mt in 1974 (Table 2.1, Figure 2.1). Substantial harvests of dogfish by foreign trawling fleets began in 1966 in Subareas 5 and 6 and continued through 1977. After 1978, landings by foreign fleets were curtailed, and landings by U.S. and Canadian vessels increased. A sharp intensification of the U.S. commercial fishery began in 1990; estimated landings in 1996, in excess of 27,000 mt, were about five times greater than the 1980-1989 average. Landings between 1997 and 1999 averaged about 20,000 mt. Landings in 2001 and 2002 dropped dramatically due to restrictions imposed by federal and interstate fisheries management plans. Total landings further declined for the next couple of years, until the ASMFC increased the state quotas for 2006-2008 and landings increased slightly. When the stock was declared rebuilt in 2009, landings increased in response to increases in the allowed biological catch (ABC) and trip limits. Landings from 2011-2016 averaged nearly 10,000 mt but have been lower from 2017-2019.

United States Landings

U.S. commercial landings of dogfish from NAFO Subareas 2-6 were around 500 mt in the early 1960s, dropped to levels as low as 70 mt during 1963-1975 while averaging about 90 mt, and remained below 1,000 mt until the late 1970s (Table 2.1). Landings increased to about 4,800 mt in 1979 and remained fairly steady for the next ten years at an annual average of about 4,500 mt. Landings increased sharply to 14,900 mt in 1990, dropped slightly in 1991, but continued a rapid expansion from 18,987 mt in 1992 to over 28,000 mt in 1996. Landings in 1996 were the highest recorded. Landings declined in 1997 and 1998 to around 20,000 mt. In 1999, the last full year unaffected by spiny dogfish regulations, the landings declined to 14,860 mt. U.S. landings dropped to about 981 mt in 2004 in response to quota restrictions. The U.S. landings trend followed the total landings trend described above and in 2019 the landings were 7,910 mt.

The primary gears used by U.S. fishermen to catch spiny dogfish have been otter trawls and sink gill nets (Table 2.2, Figure 2.2). The latter accounted for over 50% of the total U.S. landings during the 1960s, while the former was the predominant gear through the 1970s and into the early 1980s. During the peak period of exploitation in the 1990s, sink gill nets were the dominant gear. Over the last nine years the landings by line gear have averaged almost 2,000 mt, otter trawls have averaged only 500 mt and sink gill nets averaged nearly 6,000 mt.

Since 1979, the bulk of the landings have occurred in Massachusetts (Sosebee 2022b). Landings at the height of the fishery (1991-2000) averaged nearly 20,000 mt. Other states with significant landings include New Jersey, Maryland, and Virginia. Landings in North Carolina peaked in 1996 at 5,992 mt, about half of the Massachusetts landings, but dropped sharply to about 1,300 mt between 1997 and 2000. North Carolina landings in 2001-2002 were negligible. In 2001 and 2002, virtually all of the landings were taken north of Rhode Island since the fishing year is May-April and the fish have migrated north in May. As the quotas increased, so did the landings in most states.

The temporal and spatial pattern of dogfish landings were closely tied to the north-south migration patterns of the stock. Peak landings from May through October coincide with residency of dogfish along the southern flank of Georges Bank, the Gulf of Maine, and the near shore waters around Massachusetts. As the population migrates to the south in late fall and early winter, landings increase in the southern states, especially North Carolina. U.S. dogfish landings have been reported in all months of the year, but most have traditionally occurred from June through September (Sosebee 2022b). During the peak years of the domestic fishery, substantial harvest was also taken during autumn and winter months. When the directed fishery was severely curtailed in 2001, landings by statistical area indicate that most landings during the 1980s originated from statistical area 514 (Massachusetts Bay; Figure 2.3; Sosebee 2022b) and continue to occur in this statistical area. Following the intensification of the fishery in 1990, statistical areas 537 (Southern New England) and 621 (off Delmarva and southern New Jersey) produced substantial quantities. In 1992 and 1993, large landings were reported from statistical areas 631 and 635 (North Carolina). When the directed fishery was reduced, the landings remained around Massachusetts (513, 514 and 521). In more recent years, landings have increased in more southern areas such as 614, 625, and 631.

The spatial distribution of commercial fishing landings and trips were assessed from vessel trip report data by year blocks and gear type (Jones 2022). In recent years (2010-2021), commercial landings from otter trawls were greatest from coastal Gulf of Maine and northern Georges Bank (514, 521, 522), southern New England (537, 539) and the northern Mid-Atlantic Bight (612, 613, 617). Recent gillnet catch was also spread across the northeast US, but much more in coastal waters and extending farther south (621, 625, 631). Long line catches have been more restricted to coastal waters off Massachusetts, and portions of the shelf break in southern New England. For more information on the spatial distribution of commercial effort on spiny dogfish, see Jones (2022). Overtime, the spatial distribution of the commercial fishery has been found to increasingly overlap with the center of abundance, and that increasing availability of the stock to the fishery has been more pronounced in the fall than spring (Sagarese et al. 2015).

Foreign Landings

A substantial foreign harvest of dogfish occurred mainly during 1966-1977 in Subareas 5 and 6, of which were taken primarily by the former USSR. Foreign landings averaged 13,000 mt per year during this time, and reached peaks of approximately 24,000 mt in 1972 and 1974 (Table 2.1). In addition to the former USSR, other countries that reported significant amounts of landings included Poland, the former German Democratic Republic, Japan, and Canada. Since 1978, foreign landings have averaged only about 900 mt annually and, except for those taken by Japan and Poland, have come primarily from Subareas 4 and 3. Canadian landings were low until 1979 when 1,300 mt were landed, and averaged 233 mt until 1990. Canadian landings increased about nine-fold between 1996 and 2001, and from 3,755 mt in 2001 to an average around 2055 mt from 2003-2008. Spiny dogfish taken by the distant water fleets were caught almost entirely by otter trawl, whereas Canadian landings were mainly harvested by gill nets and longlines. In the last ten years, the landings from Canada have been substantially reduced to an annual average of 42 mt.

Commercial Discards

Discard estimates were re-calculated as part of this assessment. The ratio-estimator used in this assessment is based on the methodology described in Rago et al. (2005) and updated in Wigley et al. (2007). It relies on a discard/kept (d/k) ratio, where the kept component is defined as the total landings of all species within a 'fishery.' A fishery is defined as a homogeneous group of vessels with respect to gear type (longline, otter trawl, sink gill net, and scallop dredge), quarter, region (New England, Mid-Atlantic), and by mesh size for otter trawls (<= 5.49", > = 5.5"). All trips were included if they occurred within this stratification, regardless of whether they caught spiny dogfish.

The discard ratio (R_h) for dogfish in stratum h is the sum of discard weight over all trips divided by sum of kept weights over all trips:

$$\hat{R}_h = \frac{\sum_{i=1}^{n_h} d_{ih}}{\sum_{i=1}^{n_h} k_{ih}} \qquad (1)$$

where d_{ih} is the discards for dogfish within trip i in stratum h and k_{ih} is the kept component of the catch for all species. R_h is the discard rate in stratum h. The stratum weighted discard to kept ratio is obtained by weighted sum of discard ratios over all strata:

$$\hat{R} = \sum_{h=1}^{H} \left(\frac{N_h}{\sum_{h=1}^{H} N_h} \right) \hat{R}_h \qquad (2)$$

The total discards within a strata is simply the product of the estimated discard ratio R and the total landings for the fishery defined as stratum h, i.e., $D_h = R_h K_h$.

Cells (area/quarter/gear/mesh) with less than or equal to three trips were imputed using the sum of discards divided by the sum of kept. The order of imputation was half year within region, annual within region and then across region. For longline gear, there were many missing years. To estimate these, the sum of discards divided by the sum of kept over 1993-2003 was used (for 1993-2001). In 2002, there were two longline trips with a large amount of discards that gave an anomalously high value of total discards. For this year, those trips were omitted to derive the d/r ratio. For scallop dredge (1989-1991) and longline (1989-1990) trips, the average d/k ratio for the first three years for scallop dredge (1992-1994) and for longline (1991-1993) was used to derive the discards. Discards and number of trips by half year and gear type are shown in Tables 2.3-2.5 along with coefficients of variation (CVs) by gear type. The discard mortalities vary by gear type (Table 9 in NEFSC 2006).

Commercial discard estimates over the time series were generally higher than those estimated in the last assessment particularly in the early part of the time series when more imputation was required (NEFSC 2006; Sosebee 2022b). Additionally, some commercial data were revised since the previous assessment, which caused some years to previously have higher discards than this revised version. Discards declined from 1993 through 2000, were stable until 2010, and slowly declined to the lowest value in the time series in 2019 (Figure 2.4).

Size and Sex Composition of Commercial Landings and Discards

The sex of commercial landings was not recorded routinely until 1982 and discards until 1991. For details on the commercial landings sampling program, see Burns et al. (1983). The estimated sex composition of the landings from previous assessments was based on pooled samples over the entire year. For this assessment, the Working Group estimated the sex and size composition by gear type and by half year. The details are given in Sosebee 2022b.

Recreational Landings and Discards

Recreational landings and discards were obtained from the Marine Recreational Information Program (MRIP) http://www.st.nmfs.noaa.gov/recreational-fisheries/access-data/run-a-data-query/index. Descriptions of the program are in Van Voorhees et al. (1992) and Papacostas and Foster (2021). Of note, recreational catch since 2018 uses a mail-based survey for total effort to improve response rates and reduce bias, and catch before 2018 is calibrated from effort estimates from a telephone-based survey (Breidt et al. 2017).

The MRIP estimates are partitioned into three categories of numbers caught: A, B1, and B2. Type A catches represent landed fish enumerated by the interviewer, while B1 are landed catches reported by the angler. Type B2 catches are those fish caught and returned to the water. Biological information on recreationally caught dogfish is generally scant and the data are not collected by sex.

Recreational landings in number ranged between 1,736 and 806,857 over the entire time period with no observable trend (Table 2.6, Figure 2.5). The total discards are a larger fraction of the catch ranging from 128,652 to over 7 million fish in 2014, with the largest discards occurring from 2004-2019. Recreational discard mortality was assumed to be 20%, which is at the high end of published studies of other fish (NEFSC 2006). This makes the range of dead discards 25,730 to over 1 million fish.

Size and Sex Composition of Recreational Landings and Discards

The previous assessments assumed an average weight of 2.5 kg per fish based on limited length information to convert numbers of fish to metric tons. This assessment is using a different method based on the average length composition (Details in Sosebee 2022b). The range of landings in mt is 4 to 2,837 mt (Figure 2.6) with the majority of the time series < 500 mt and less than 250 mt from 2005-2019. Discards increased between 2000 and 2009, peaked at just over 2,700 mt in 2014, and averaged almost 600 mt between 2016 and 2019.

Discard Mortality

The Working Group reviewed the literature to determine if new research has been conducted to inform inferences in discard mortality in the commercial and recreational fisheries. Several papers were examined by the Working Group (Rago et al. 1998; Mandleman and Farrington 2007a; Mandleman and Farrington 2007b; Rulifson 2007; Courtney and Mathers 2019; Courtney et al. 2021). The Working Group did not find new research quantifying discard mortalities rates for Atlantic spiny dogfish in either the commercial or recreational fisheries As such, the Working Group used discard mortality rates that were previously used during the NEFSC (2006) assessment. Discard mortality rates for the recreational fishery was assigned as 0.20, whereas those for commercial fisheries were designated by gear type: otter trawl (0.50), sink gillnet (0.30), scallop dredge (0.70), longline (0.10; Sosebee 2022b).

Overall Sex Composition

The number of females landed by all gears combined increased between 1989 and 1996 to about 10.5 million fish (Figure 2.7). The same increase occurred with males but on a much smaller scale (average of 2 million fish between 1996 and 1999). Since 2005, females have averaged around 3 million fish while males averaged around 500,000 fish. The sex ratio of the discards was closer to 0.5 over the time series (Figure 2.8). Overall catch of females averaged nearly 12 million fish from 1989-1999 and decreased to just over 4 million fish from 2005-2019 (Figure 2.9). Males decreased from an average of 5 million fish to 1.7 million over the same time periods.

Commercial Trawl Catch Per Unit Effort

Evaluating CPUE information in the stock assessment process can provide additional information on stocks' interannual changes, particularly when the spatiotemporal patterns of existing fisheries-independent surveys do not adequately capture the species spatial and temporal distribution (Cadrin et al. 2020). CPUE metrics can use various metrics of effort to standardize the catch rates to evaluate the performance of a fishery. During the Stakeholder Session Meeting, harvesters inquired about the utility of deriving CPUE indices to evaluate the fishery and stock (Appendix A). As part of the assessment, CPUE indices were derived by combining existing data from two of the region's fine-scale fishery dependent data sets: NEFSC Study Fleet Program and Northeast Fisheries Observer Program (Jones et al. 2022). Integrating bottom trawl gear observations from these datasets, which represent the largest sample of records by gear type and avoid issues related to targeting, both nominal and model-based CPUE annual indices were derived to understand the efficacy of CPUE in tracking changes in the stock. The model-based approaches used Generalized Additive Models (GAMs) with a suite of ecological and economic covariates that were hypothesized to influence CPUE. From 2007 through 2021, the nominal CPUE index was highlighted by variability over time, with either a stable or slightly declining trend. The model-based indices accounting for significant covariates produced smaller confidence intervals around the annual indices than the nominal index, but a stronger decline from the early 2010s through 2021 (Figure 2.10). Correlations between the CPUE indices and NEFSC bottom trawl survey indices varied in the relationship and significance; spring bottom trawl indices tended to be negatively correlated with the CPUE indices, and positively correlated with the fall indices (Jones et al. 2022).

During the Stakeholder Session, harvesters noted recent lower yields and attributed them to not being able to get away from smaller fish, and the challenges of needing to find the marketable big fish within small fish schools (Appendix A). Others noted that the past year was one of the first where medium to large females were found. Another consideration for the changes in CPUE indices over time are gear and management changes. While gillnet gear was not included in these CPUEs, for example, one person during the Stakeholder Session noted that when approximately four years ago, gillnet gear changed from 6.5” to 7” mesh, catch decreased due to extrusion through the mesh (Appendix A).

Table 2.1. Total spiny dogfish commercial landings (mt, live) in NAFO Subareas 2 to 7, 1962-2019 by country.

Year	United States	Canada	Distant Water Fleets	Total Landings
1962	235	0	0	235
1963	610	0	1	611
1964	730	0	16	746
1965	488	9	198	695
1966	578	39	9,389	10,006
1967	278	0	2,436	2,714
1968	158	0	4,404	4,562
1969	113	0	9,190	9,303
1970	106	19	5,640	5,765
1971	73	4	11,566	11,643
1972	69	3	23,991	24,063
1973	89	20	18,793	18,902
1974	127	36	24,513	24,676
1975	147	1	22,523	22,671
1976	550	3	16,788	17,341
1977	931	1	7,199	8,131
1978	828	84	622	1,534
1979	4,753	1,331	187	6,271
1980	4,085	660	599	5,344
1981	6,865	564	974	8,403
1982	5,411	389	364	6,164
1983	4,897	0	464	5,361
1984	4,450	2	391	4,843
1985	4,028	13	1,012	5,053
1986	2,748	20	368	3,136
1987	2,703	281	139	3,123
1988	3,105	1	647	3,753

1989	4,492	167	256	4,915
1990	14,729	1,309	393	16,431
1991	13,104	307	234	13,645
1992	16,427	868	67	17,362
1993	20,777	1,435	27	22,239
1994	18,305	1,820	2	20,127
1995	21,588	956	14	22,558
1996	26,926	431	236	27,593
1997	18,351	446	214	19,011
1998	20,628	1,055	607	22,290
1999	14,855	2,091	554	17,500
2000	9,257	2,741	402	12,400
2001	2,294	3,820	677	6,791
2002	2,199	3,584	474	6,257
2003	1,170	1,302	643	3,115
2004	981	2,362	330	3,673
2005	1,146	2,270	330	3,746
2006	2,248	2,439	10	4,697
2007	3,008	2,384	31	5,423
2008	4,135	1,572	131	5,838
2009	5,392	113	82	5,587
2010	5,440	6	127	5,573
2011	9,479	125	143	9,747
2012	10,595	65	137	10,797
2013	7,312	5	61	7,378
2014	10,649	54	31	10,734
2015	8,663	1	23	8,687
2016	12,097	32	24	12,153
2017	8,735	54	0	8,789
2018	6,878	45	0	6,923
2019	7,910	36	1	7,947

Table 2.2. United States spiny dogfish commercial landings (mt, live) by gear type, 1962-2019. Other gear includes seines, dredges, pots, and unknown.

Year	Line Trawl	Otter Trawl	Sink Gill Net	Other	Total
1962	18.7	78.3	129.4	8.4	234.9
1963	49.8	85.5	435.5	38.8	609.6
1964	12.5	75.4	619.0	23.4	730.4
1965	55.1	52.3	358.4	22.2	488.0
1966	84.7	95.2	358.0	40.1	578.1
1967	23.9	110.8	98.0	44.9	277.5
1968	2.5	78.0	54.3	23.2	158.0

1969	1.9	88.4	6.4	16.7	113.4
1970	1.8	80.5	12.4	11.0	105.7
1971	0.0	53.0	4.1	16.2	73.3
1972	0.6	53.5	0.7	14.4	69.2
1973	0.5	76.7	6.3	5.8	89.4
1974	1.9	79.2	11.3	34.9	127.3
1975	0.3	89.4	14.4	42.8	146.9
1976	5.2	71.6	438.3	34.5	549.6
1977	2.8	102.6	798.9	27.2	931.4
1978	3.4	121.4	687.1	16.6	828.4
1979	17.7	3517.6	1199.8	17.6	4752.7
1980	12.1	3370.1	638.2	64.7	4085.1
1981	1.0	6287.1	568.1	8.7	6865.0
1982	2.9	5065.6	320.1	22.0	5410.6
1983	0.2	3367.5	1523.7	5.1	4896.5
1984	0.9	2486.0	1955.6	7.9	4450.4
1985	158.7	2844.4	1017.4	7.6	4028.0
1986	2.6	1258.1	1470.3	16.7	2747.6
1987	7.8	1848.1	814.6	32.8	2703.4
1988	4.7	1589.5	1502.1	9.0	3105.2
1989	144.5	486.5	3859.8	1.3	4492.0
1990	17.7	7010.8	7698.3	1.7	14728.5
1991	31.5	5199.5	7849.7	23.0	13103.6
1992	28.9	4978.9	11388.6	30.7	16427.1
1993	259.7	5087.8	15417.1	11.9	20776.5
1994	853.5	2844.2	14467.3	139.7	18304.6
1995	1725.5	2194.6	17402.4	265.5	21588.0
1996	1650.1	3136.7	22051.4	87.4	26925.6
1997	1423.4	1786.4	15080.9	60.6	18351.2
1998	1503.5	2656.7	16427.8	39.7	20627.6
1999	1760.6	2269.7	10597.2	227.1	14854.6
2000	1835.0	3175.3	4235.5	10.9	9256.7
2001	1328.4	239.8	717.1	8.3	2293.6
2002	1074.4	236.6	885.0	2.9	2198.9
2003	664.7	38.0	409.5	57.8	1170.0
2004	45.0	150.6	760.7	24.7	981.0
2005	149.1	251.5	694.0	51.2	1145.7
2006	263.1	469.4	1349.3	166.4	2248.2
2007	484.7	201.7	1891.0	430.0	3007.6
2008	533.9	269.7	2928.2	403.0	4134.8
2009	595.3	809.1	3792.3	195.7	5392.3
2010	754.2	666.6	3880.7	138.8	5440.2
2011	1006.2	1082.8	7049.5	341.0	9479.4
2012	2298.6	809.6	7065.3	421.9	10595.3
2013	943.8	550.0	5566.0	252.5	7312.3

2014	2194.2	531.6	7650.2	272.8	10648.7
2015	1897.7	390.8	6261.4	113.0	8662.9
2016	3376.3	445.4	8114.1	161.0	12096.9
2017	2045.2	466.7	6015.9	207.2	8734.9
2018	1836.3	288.2	4514.5	239.3	6878.3
2019	1445.8	220.5	5887.4	356.7	7910.3

Table 2.3. Discard estimates of spiny dogfish in the large mesh (>= 5.5 inches) and small mesh (<= 5.49 inches) otter trawl (OT) fleets from the Northeast Fisheries Observer Program from 1989-2019.

	Large Mesh							Small Mesh							Overall
	Half 1		Half 2		Total			Half 1		Half 2		Total			OT
Year	trips	discards	trips	discards	trips	discards	CV	trips	discards	trips	discards	trips	discards	CV	CV
1989	31	8433.6	30	6568.3	61	15001.9	29.9	45	9423.8	75	3979.0	120	13402.8	39.5	24.4
1990	26	6965.5	28	18270.1	54	25235.6	38.4	41	7553.3	43	6974.6	84	14527.9	29.1	26.6
1991	31	4279.4	51	9232.2	82	13511.5	20.6	61	3117.5	113	3860.8	174	6978.3	23.5	15.7
1992	64	40401.9	18	14873.9	82	55275.8	30.5	52	6231.3	52	3374.6	104	9605.9	44.7	26.8
1993	26	4875.3	30	7872.1	56	12747.4	31.6	27	3466.1	20	4278.2	47	7744.3	19.5	21.0
1994	42	4903.1	15	528.7	57	5431.9	26.5	13	645.6	20	6563.1	33	7208.7	55.8	33.8
1995	56	8574.5	67	4253.1	123	12827.7	37.1	26	971.7	77	6977.6	103	7949.3	27.7	25.2
1996	32	2118.7	30	1037.7	62	3156.4	36.4	36	6979.0	94	410.7	130	7389.7	22.3	19.0
1997	23	2342.5	15	539.8	38	2882.3	34.1	48	2337.7	22	272.7	70	2610.4	36.6	24.9
1998	21	1806.4	5	641.9	26	2448.4	22.0	15	2794.2	23	1966.0	38	4760.2	29.8	21.1
1999	17	1749.3	32	3104.8	49	4854.1	30.2	22	170.5	32	3021.7	54	3192.1	31.0	22.0
2000	77	1802.0	52	320.9	129	2122.9	26.0	29	203.5	27	594.6	56	798.1	36.7	21.4
2001	71	1492.1	136	1307.6	207	2799.6	23.8	38	300.1	36	714.1	74	1014.2	19.3	18.2
2002	47	1932.4	212	1510.5	259	3443.0	22.7	27	209.6	70	1483.6	97	1693.2	10.1	15.5
2003	196	972.6	207	1224.6	403	2197.1	14.5	67	632.5	80	1135.4	147	1767.9	27.4	14.6
2004	227	855.2	413	1816.1	640	2671.2	12.8	149	1309.5	281	1238.8	430	2548.3	24.0	13.4
2005	670	1014.5	773	1719.6	1443	2734.1	20.5	181	684.1	244	1427.7	425	2111.9	18.4	14.1
2006	415	870.1	275	3344.0	690	4214.1	33.6	126	1183.8	110	1063.4	236	2247.2	17.8	22.8
2007	332	2441.7	449	2356.5	781	4798.2	19.6	126	1924.8	168	2195.8	294	4120.7	18.0	13.4
2008	412	1058.4	473	1413.7	885	2472.0	11.4	106	1208.9	107	797.5	213	2006.4	24.2	12.5
2009	479	2163.5	567	1100.6	1046	3264.2	15.1	199	3389.6	306	1395.5	505	4785.1	14.4	10.5
2010	523	2435.1	807	1390.9	1330	3825.9	8.4	313	1062.9	294	640.2	607	1703.1	16.6	7.7
2011	898	1990.2	953	2144.8	1851	4135.0	9.0	255	1816.7	302	593.1	557	2409.8	19.7	9.2
2012	977	2653.6	743	1681.1	1720	4334.7	7.8	185	1520.8	201	843.2	386	2364.0	21.3	9.0
2013	789	2169.3	557	3172.5	1346	5341.9	8.0	279	931.9	358	648.4	637	1580.4	16.6	7.3
2014	706	3435.7	761	1816.4	1467	5252.1	10.3	321	2250.6	441	736.1	762	2986.7	11.1	7.7
2015	609	1754.0	519	1296.5	1128	3050.4	11.6	280	1592.4	369	489.6	649	2082.1	14.3	9.0
2016	455	1684.2	463	1348.6	918	3032.8	9.4	374	1080.3	629	967.5	1003	2047.8	13.9	7.9
2017	444	1686.4	521	935.7	965	2622.1	9.7	681	2096.7	971	732.0	1652	2828.7	11.5	7.6
2018	486	1009.3	468	1175.5	954	2184.8	12.6	441	1088.2	788	656.4	1229	1744.6	15.2	9.7
2019	595	1037.5	758	1650.1	1353	2687.7	7.1	484	1912.9	632	837.6	1116	2750.5	9.7	6.0

Table 2.4. Discard estimates of spiny dogfish in the sink gill net and longline fleets from the Northeast Fisheries Observer Program from 1989-2019.

	SGN							Longline						
	Half 1		Half 2		Total			Half 1		Half 2		Total		
Year	trips	discards	trips	discards	trips	discards	CV	trips	discards	trips	discards	trips	discards	CV
1989	1	3042.0	106	4995.7	107	8037.7	14.0		707.6		429.0		1136.7	
1990	75	1501.4	78	2447.9	153	3949.2	28.0		566.4		445.1		1011.5	
1991	194	5277.6	763	8983.0	957	14260.7	8.6	1	529.6	17	414.9	18	944.5	4.3
1992	497	1844.5	690	3734.9	1187	5579.4	10.1	32	833.3		643.8	32	1477.1	9.5
1993	348	1637.4	422	5478.9	770	7116.2	19.5	3	3333.4	1	2209.1	4	5542.5	
1994	188	343.8	216	1058.2	404	1402.1	23.5	2	2612.0		2201.4	2	4813.4	
1995	298	1119.8	239	3124.8	537	4244.7	31.1	1	2359.5		2384.3	1	4743.8	
1996	254	916.4	168	1587.1	422	2503.5	21.3		2215.1		2067.9		4283.0	
1997	257	1066.2	132	1010.4	389	2076.6	24.8		2401.4		2310.6		4712.0	
1998	267	552.9	136	942.2	403	1495.1	24.5		1995.8	1	2408.7	1	4404.5	
1999	88	1243.9	101	647.0	189	1890.8	26.9		1845.0		1893.7		3738.7	
2000	118	2003.2	108	2710.2	226	4713.4	29.1		1105.8		2082.4		3188.2	
2001	98	1810.4	69	4905.7	167	6716.0	30.2		1578.0		1761.1		3339.1	
2002	67	1522.7	106	3830.1	173	5352.8	20.9		1677.0	9	1012.9	9	2689.9	95.2
2003	162	1110.6	330	4137.9	492	5248.5	12.4	17	6.9	2	9.9	19	16.8	7.9
2004	289	899.4	800	3202.0	1089	4101.5	7.7	9	117.8	113	474.4	122	592.3	10.6
2005	260	1265.9	744	2168.2	1004	3434.2	12.8	88	231.5	204	242.2	292	473.7	12.5
2006	136	930.1	115	2040.1	251	2970.2	19.3	46	471.7	56	661.9	102	1133.5	21.1
2007	100	3076.8	234	1943.6	334	5020.4	22.9	24	142.8	69	1798.9	93	1941.7	39.7
2008	115	2068.1	194	2769.8	309	4837.9	18.2	27	114.7	52	150.5	79	265.2	11.6
2009	190	1098.9	226	4143.7	416	5242.5	14.1	35	129.5	55	599.0	90	728.5	19.8
2010	419	1002.8	1460	1383.2	1879	2386.0	9.3	72	228.8	120	168.7	192	397.5	23.8
2011	733	747.5	1326	2092.5	2059	2840.1	5.4	77	80.5	41	248.5	118	329.0	17.2
2012	755	1112.1	933	1894.8	1688	3007.0	6.4	107	57.3	112	113.2	219	170.6	7.9
2013	233	1177.3	601	1898.9	834	3076.2	9.5	32	37.2	4	55.0	36	92.2	18.9
2014	410	946.9	962	1458.2	1372	2405.2	9.4	26	10.4	18	6.7	44	17.2	51.4
2015	315	758.5	750	916.0	1065	1674.5	23.7	8	23.9	4	27.8	12	51.7	30.1
2016	443	1213.2	543	728.8	986	1942.0	23.0	15	38.9	9	236.0	24	274.9	24.0
2017	485	323.1	622	558.0	1107	881.2	13.7	27	23.2	35	176.7	62	199.9	24.6
2018	374	606.0	456	505.7	830	1111.6	18.4	23	2.4	52	98.3	75	100.7	17.9
2019	586	414.0	584	504.3	1170	918.3	17.5	29	5.9	37	83.6	66	89.4	22.5

Table 2.5. Discard estimates of spiny dogfish in the scallop dredge fleet from the Northeast Fisheries Observer Program from 1989-2019.

	Scallop						
	Half 1		Half 2		Total		
Year	trips	discards	trips	discards	trips	discards	CV
1989		584.6		293.9		878.6	
1990		556.7		357.0		913.7	
1991		633.6		282.9		916.6	
1992	8	364.4	10	334.1	18	698.5	63.6
1993	14	219.4	8	8.1	22	227.5	40.0
1994	11	350.1	12	271.0	23	621.1	41.0
1995	15	223.0	12	142.2	27	365.2	18.4
1996	22	96.1	18	43.5	40	139.7	31.7
1997	19	117.0	10	81.1	29	198.1	20.6
1998	9	44.4	17	71.2	26	115.6	11.7
1999	15	13.7	56	9.6	71	23.2	40.9
2000	38	17.1	218	26.3	256	43.4	40.4
2001	58	6.3	48	19.2	106	25.5	30.5
2002	34	36.8	66	37.7	100	74.5	18.3
2003	50	63.2	74	51.9	124	115.1	21.7
2004	85	67.6	212	28.4	297	96.0	13.1
2005	128	32.5	206	24.4	334	56.9	17.9
2006	45	75.7	183	95.4	228	171.1	23.2
2007	158	158.2	202	72.5	360	230.7	11.2
2008	385	172.4	257	86.0	642	258.4	11.8
2009	373	334.3	117	123.0	490	457.3	12.1
2010	145	134.6	194	59.2	339	193.8	10.9
2011	177	122.5	216	103.6	393	226.1	16.7
2012	237	337.3	186	87.5	423	424.8	8.8
2013	245	82.5	234	47.9	479	130.4	9.7
2014	233	86.9	250	21.1	483	108.0	10.4
2015	288	26.7	245	14.3	533	41.0	14.5
2016	362	80.4	271	39.2	633	119.7	14.0
2017	377	57.3	269	17.3	646	74.6	12.0
2018	275	71.0	282	63.6	557	134.6	14.4
2019	281	54.4	282	79.2	563	133.5	17.1

Table 2.6. Summary of spiny dogfish landings and discards based on Marine Recreational Information Program estimates. Discard mortality is assumed to be 20%.

Year	Observed Harvest (A)	PSE	Reported Harvest (B1)	PSE	Released Alive (B2)	PSE	Total Landings A+B1 (number)	Dead Discards B2 (number)
1981	1,540	56.5	805,317	65.9	128,652	26.2	806,857	25,730
1982	13,193	55.5	9,398	33.6	161,147	43.4	22,591	32,229
1983	14,579	50.4	29,826	48.4	294,107	21.1	44,405	58,821
1984	17,680	73.1	23,124	40.7	994,439	67.6	40,804	198,888
1985	24,512	86.4	34,792	55	167,371	32.5	59,304	33,474
1986	13,036	33	81,888	40.6	564,352	24.7	94,924	112,870
1987	64,431	78.1	64,119	50.6	373,458	42	128,550	74,692
1988	56,212	40.4	87,845	37.7	545,672	23.6	144,057	109,134
1989	49,649	57.6	72,777	28.3	794,579	28.5	122,426	158,916
1990	55,501	41.6	71,655	35.2	753,649	20.3	127,156	150,730
1991	81,441	29.6	53,394	35.9	1,040,163	18.4	134,835	208,033
1992	123,555	48.6	32,165	27.4	523,665	16	155,720	104,733
1993	38,093	34.3	40,403	42.4	778,604	19.7	78,496	155,721
1994	13,890	40.4	44,574	58.6	593,746	22.4	58,464	118,749
1995	19,030	30.4	16,562	47.2	356,311	25.3	35,592	71,262
1996	6,753	44	4,365	68.8	186,192	19.4	11,118	37,238
1997	31,872	48.1	12,055	70.1	487,269	20.3	43,927	97,454
1998	21,530	41.4	44,432	94.1	417,596	22.4	65,962	83,519
1999	21,757	63.3	13,231	74.5	362,473	19.7	34,988	72,495
2000	1,640	44	96	85.7	335,904	24.6	1,736	67,181
2001	6,751	56.3	3,352	68.5	1,153,341	12.5	10,103	230,668
2002	3,000	37.6	140,033	66.1	997,419	15	143,033	199,484
2003	15,581	42	8,584	56.6	1,584,326	14.1	24,165	316,865
2004	75,946	49.1	71,732	50.2	2,705,518	13.8	147,678	541,104
2005	8,811	41.4	10,001	42.8	1,983,774	19.3	18,812	396,755
2006	7,980	40.1	23,195	61.2	2,336,176	13.9	31,175	467,235
2007	3,319	62	48,365	63.3	2,413,174	14	51,684	482,635
2008	25,731	36.9	68,959	48.3	2,216,029	13.3	94,690	443,206
2009	9,216	42.2	33,972	39	2,885,331	14.8	43,188	577,066
2010	5,112	42	10,637	66.5	1,936,270	19.9	15,749	387,254
2011	16,750	39.9	17,716	54.7	2,372,432	15.8	34,466	474,486
2012	6,629	68.7	12,719	81.7	1,726,341	27.6	19,348	345,268
2013	20,326	56.2	55,131	73	4,803,736	19	75,457	960,747
2014	5,159	56.6	39,952	25.5	7,008,107	43	45,111	1,401,621
2015	9,173	56.7	16,379	62.9	1,711,330	22.3	25,552	342,266
2016	35,052	80.7	43,877	62.6	3,630,248	26.1	78,929	726,050
2017	19,524	60.8	35,806	37.4	1,435,399	20.9	55,330	287,080
2018	4604	69.8	16,864	53.1	1490265	19.5	21,468	298,053
2019	17352	52	6899	60.2	2318948	17.6	24,251	463,790

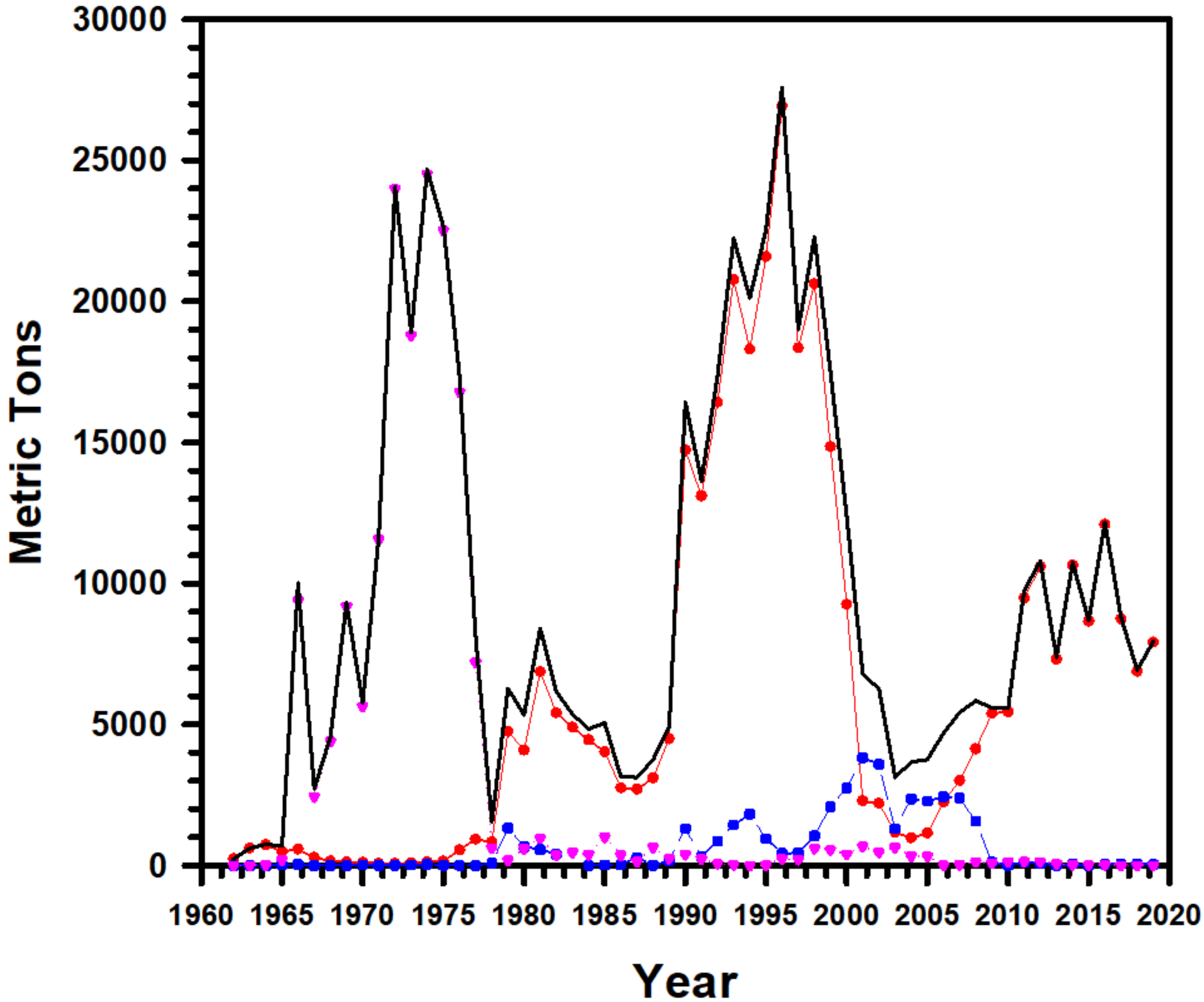


Figure 2.1. Commercial landings (metric tons) from the United States (red circles), Canada (blue squares) and other foreign (pink triangles) and total (black solid line) in NAFO Subareas 2-7 from 1962-2019.

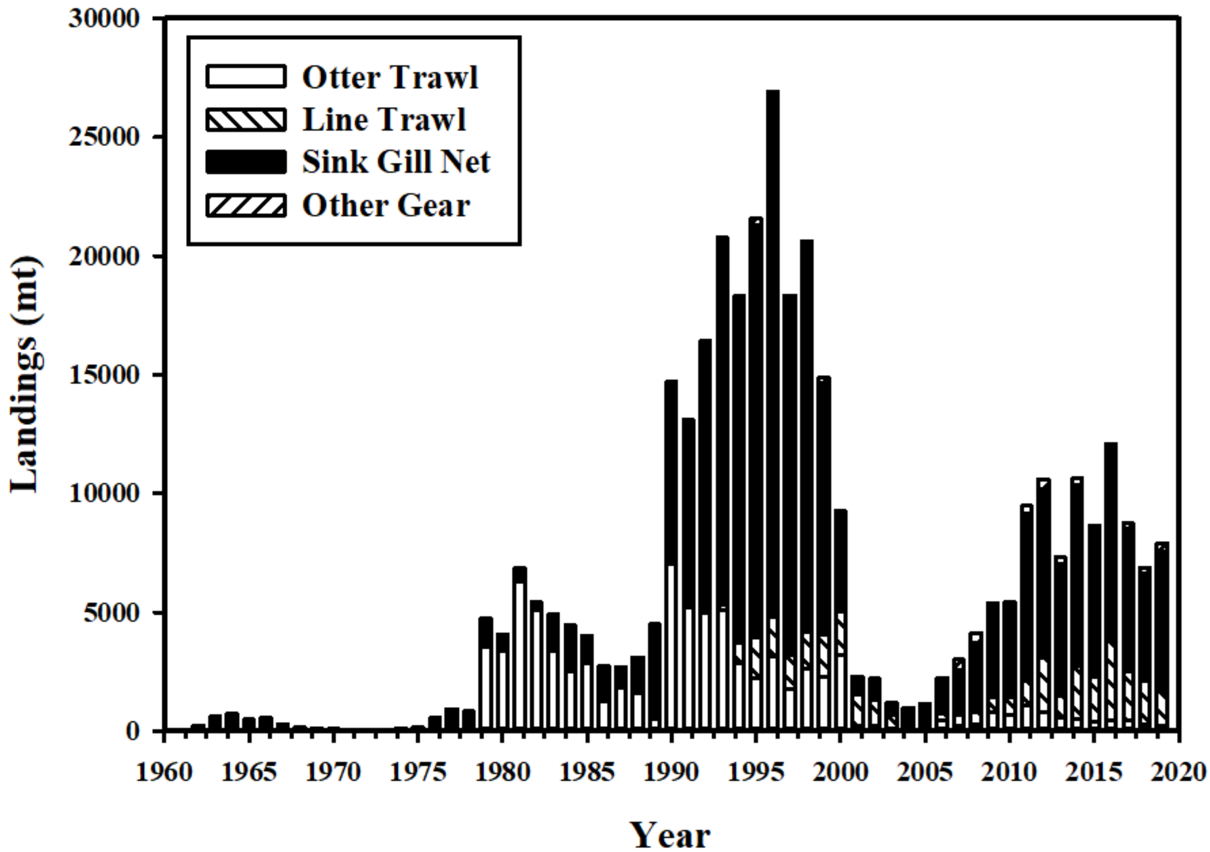


Figure 2.2. U.S. landings (metric tons) of spiny dogfish from NAFO subareas 2-7 by gear type, 1962-2019.

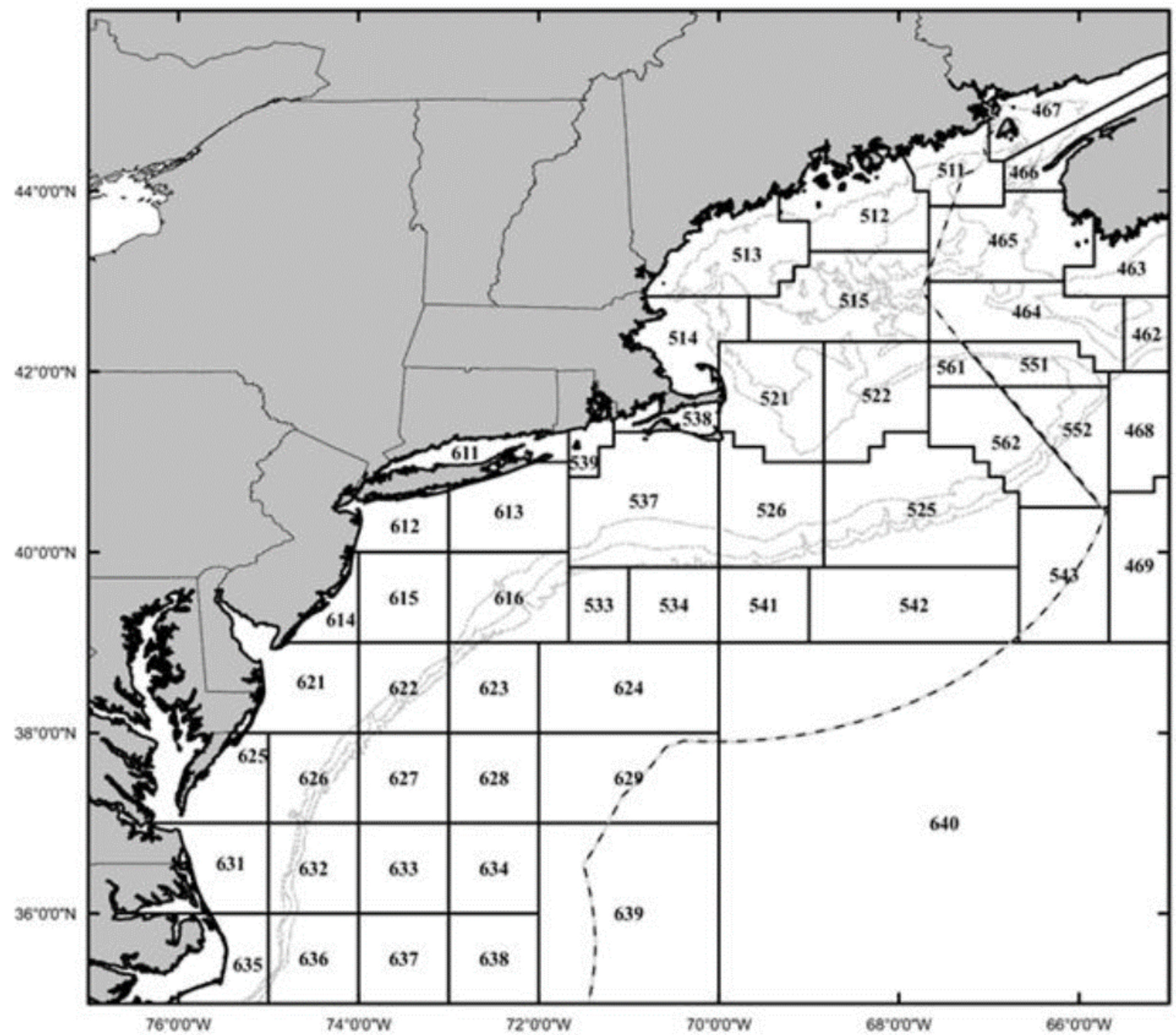


Figure 2.3 Map of fishing statistical areas as defined by the NOAA Fisheries.

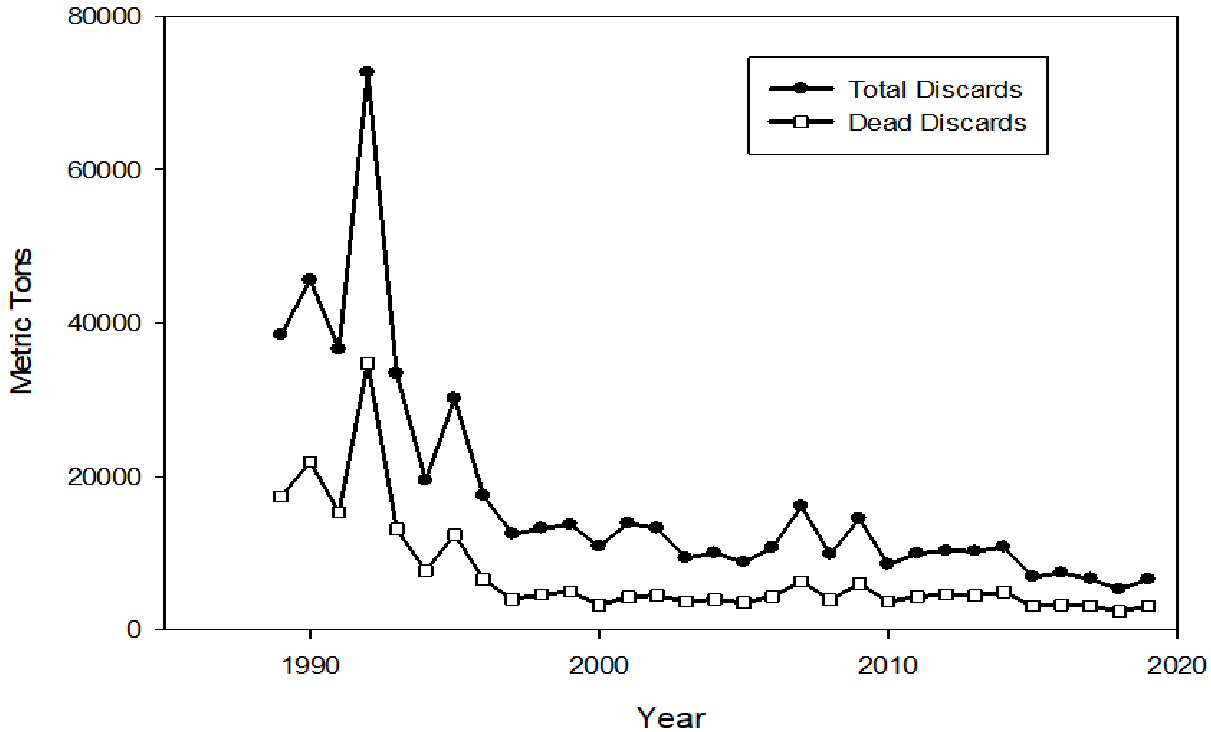


Figure 2.4. Total discards (closed circles) and dead discards (open squares) estimated for spiny dogfish using the methodology developed in this report from 1989-2019.

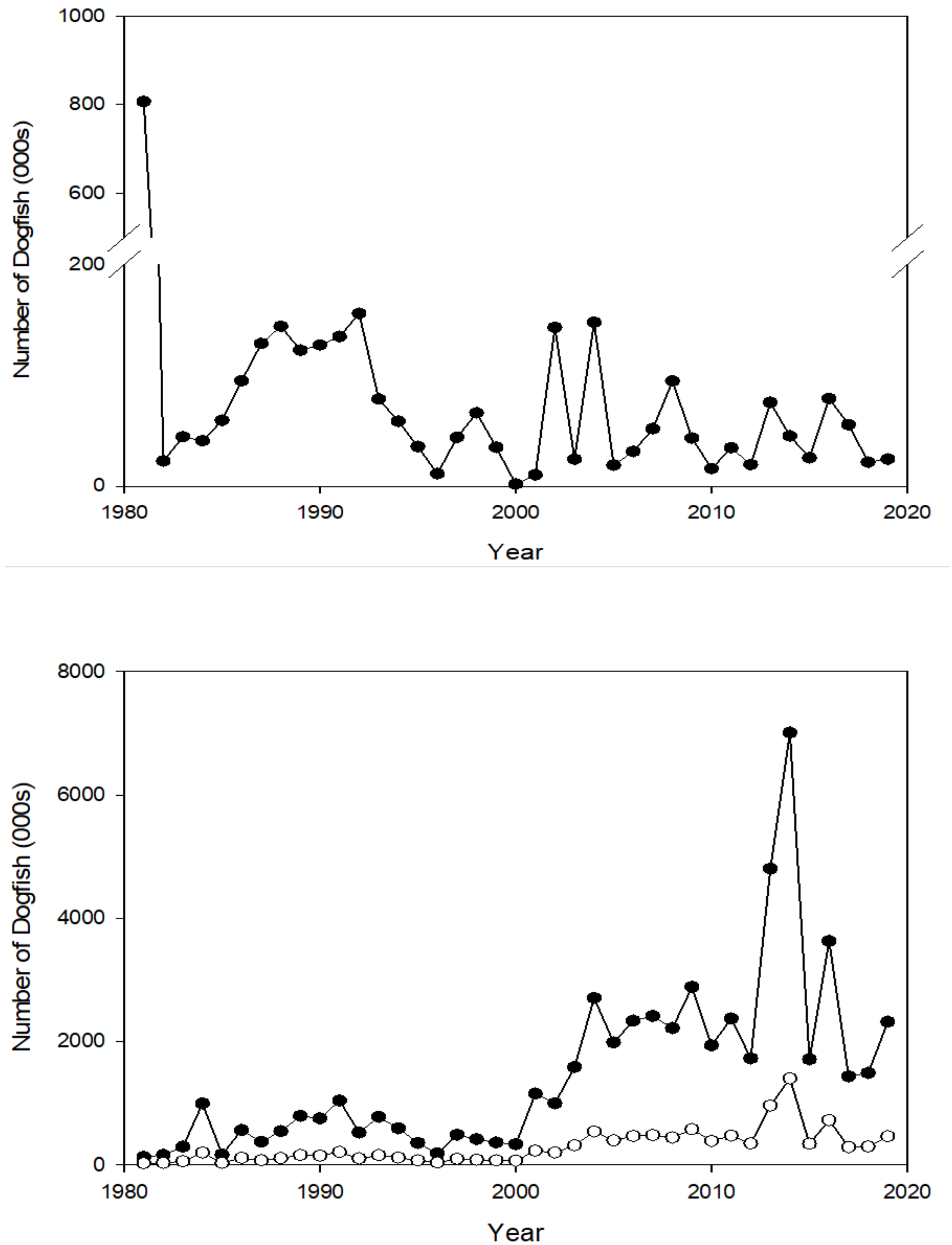


Figure 2.5. Estimates of recreational landings (top panel) and discards (bottom panel, total = black circles, dead = open circles) from 1981-2019 in number.

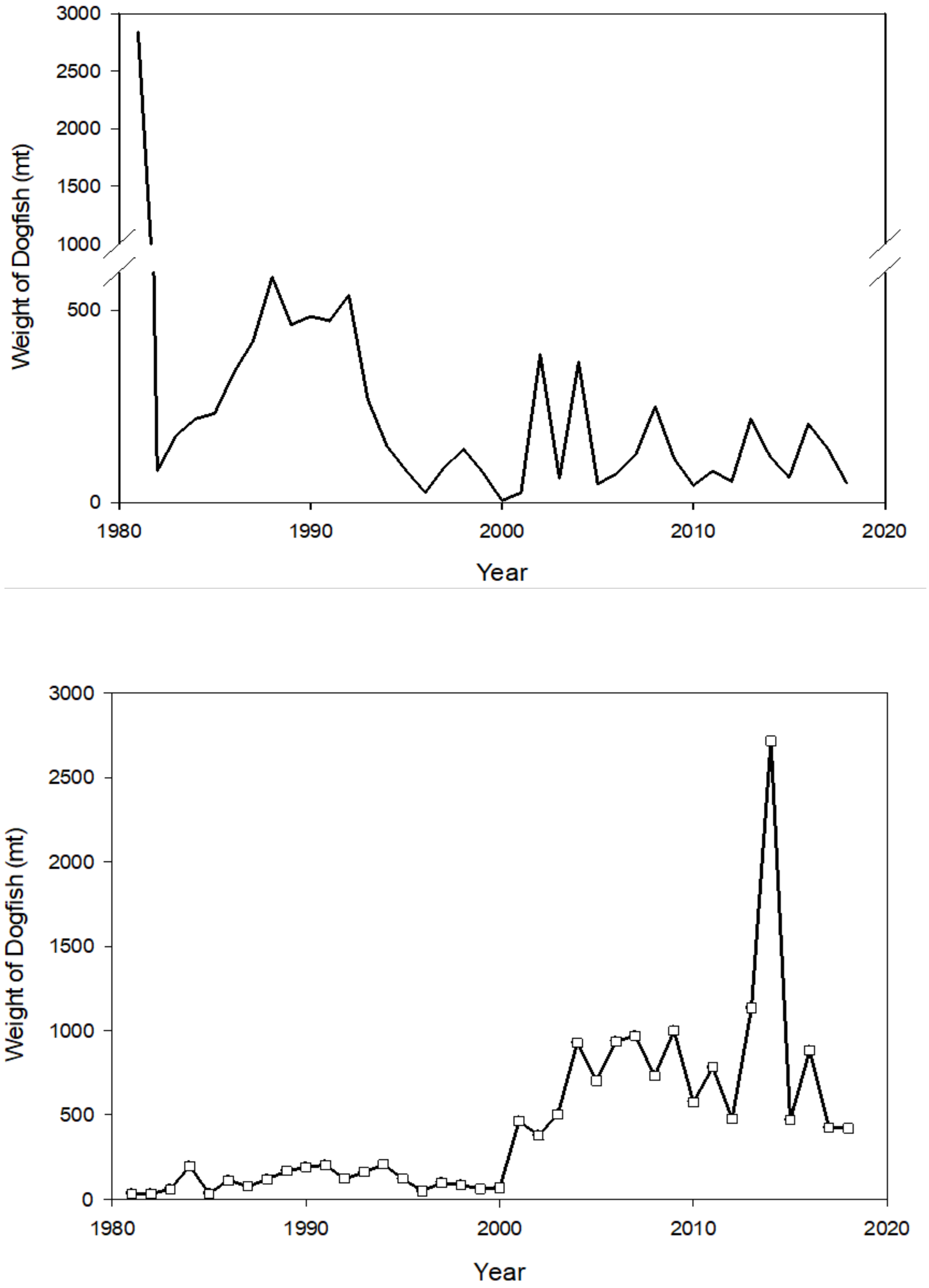
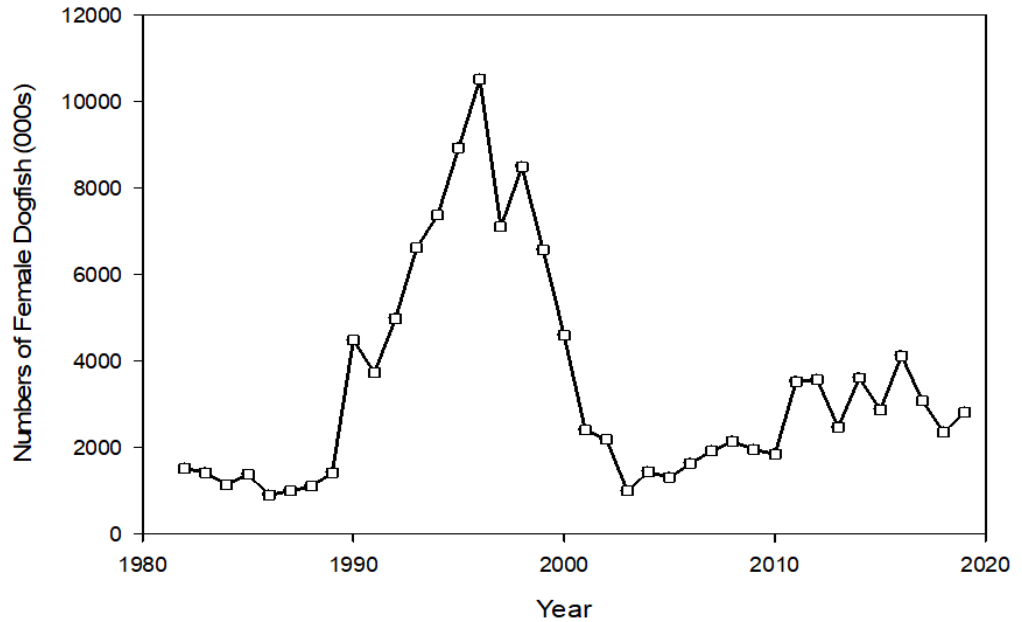


Figure 2.6. Estimates of recreational landings (top panel) and dead discards (bottom panel) from the new length-based method.



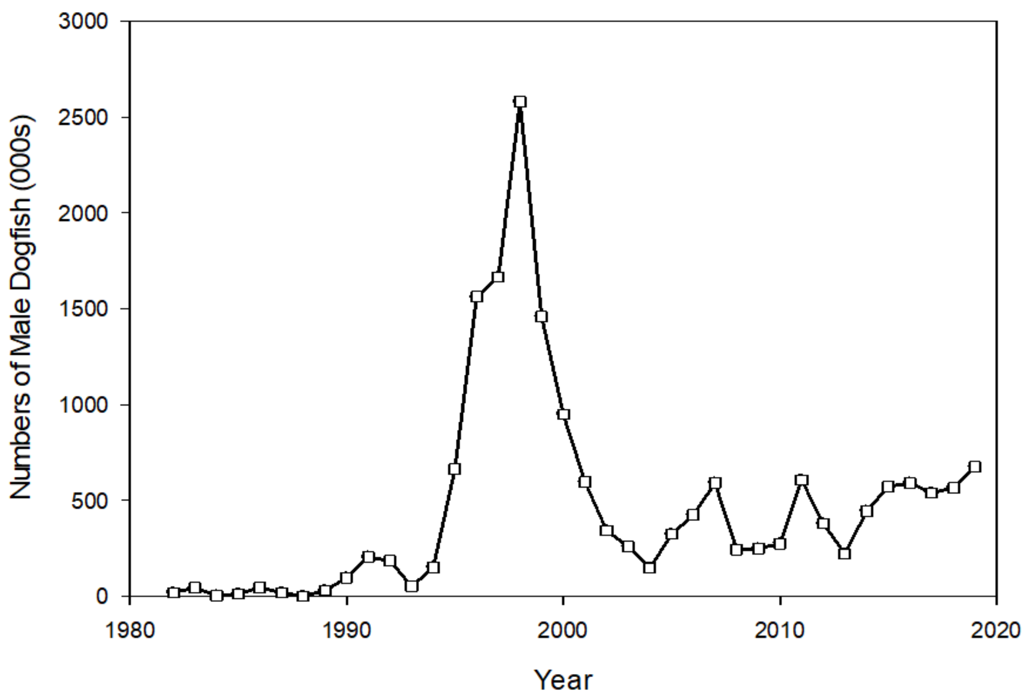


Figure 2.7. Estimates of total landings of females (top panel) and males (bottom panel) in 000s of fish from the new length-based method.

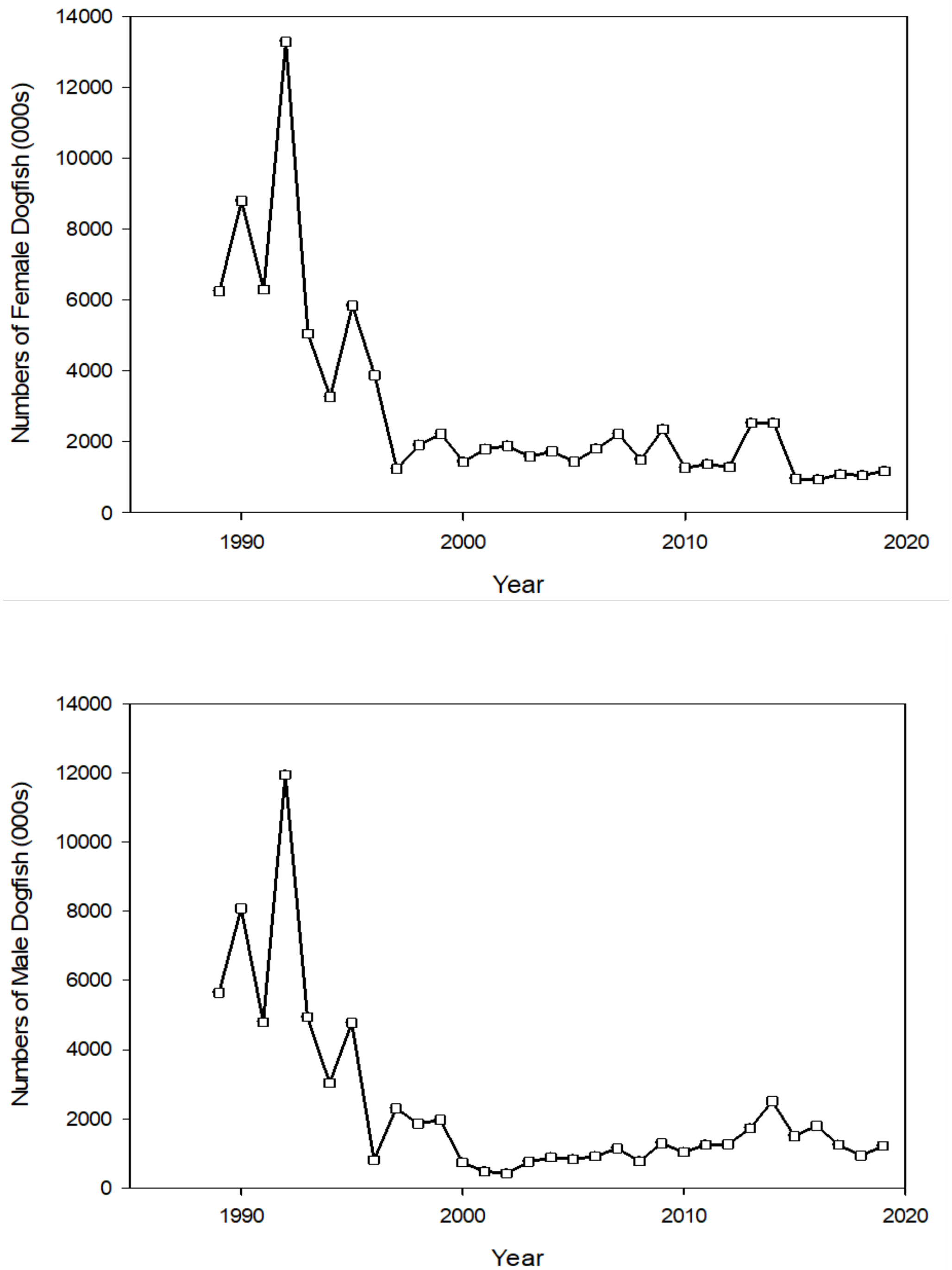


Figure 2.8. Estimates of dead discards of females (top panel) and males (bottom panel) in 000s of fish from the new length-based method.

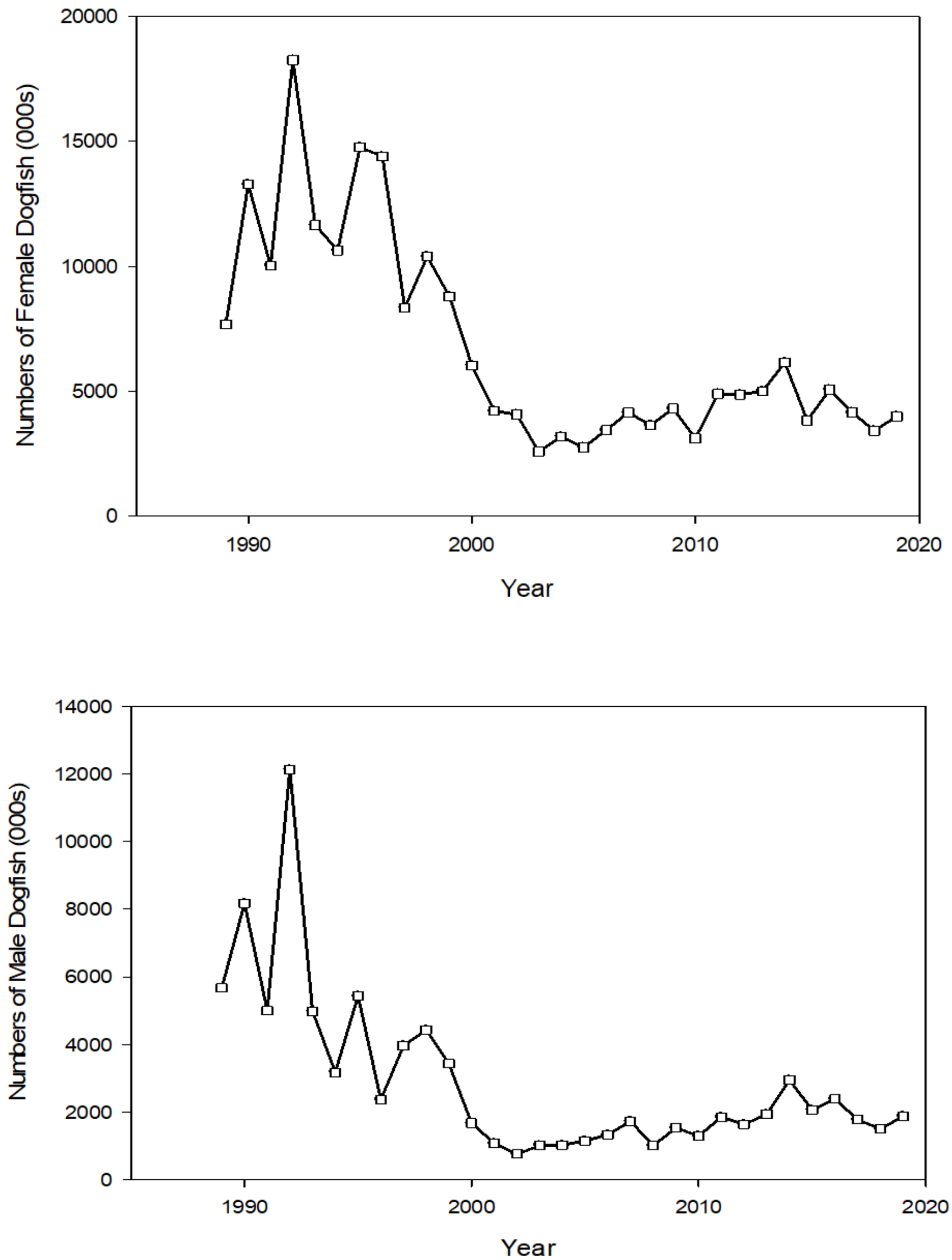


Figure 2.9. Estimates of total catch (landings plus dead discards) of females (top panel) and males (bottom panel) in 000s of fish from the new length-based method.

Figure 2.10. Catch rate (CPUE) trends through time for the nominal and standardized methods. The mean survey index (fall and spring combined) is shown in orange as well. The survey catches represent a combination of both male and female dogfish (similar to the CPUEs). The ribbon associated with each blue series approximates a confidence interval. Values are derived from the coefficient values for each year term in each model (Maunder and Punt 2004).

TOR3: SURVEY DATA

"*Present the survey data used in the assessment (e.g., indices of relative or absolute abundance, recruitment, state surveys, age-length data, application of catchability and calibration studies, etc.) and provide a rationale for which data are used. Describe the spatial and temporal distribution of the data. Characterize the uncertainty in these sources of data.*"

Fishery independent surveys considered for use in this research track assessment included NEFSC, state, and Canadian trawl surveys and the NEFSC bottom longline survey in the Gulf of Maine. The state surveys considered are more temporally and/or spatially limited when compared with the NEFSC Bottom Trawl Survey, which has the greatest spatial coverage. NEFSC Spring Bottom Trawl Survey data were used to estimate stock biomass in previous assessments and, once management measures went into place, to update biological reference points in between assessments. Studies comparing the seasonal relative abundance and distribution from NEFSC and Canadian trawl surveys indicated that the spring trawl surveys provide the best representation of spiny dogfish abundance in the northwest Atlantic (NEFSC 1994; Campana et al. 2007). Additionally, VAST estimates of encounter probability from 1980-2021, using four biannual trawl surveys, indicated higher encounter rates throughout the surveys' combined range during the spring (Figures 3.1 and 3.2; Hansell and McManus 2022). For these reasons, the Working Group recommended the NEFSC Spring Bottom Trawl Survey for use in the base run of this assessment and all other indices were reviewed for potential use in sensitivity runs.

NEFSC Surveys

Fall and Spring Bottom Trawl Surveys

The NEFSC has conducted both the fall and spring multispecies bottom trawl surveys annually since 1968 as a random stratified survey with coverage from the Gulf of Maine to Cape Hatteras, North Carolina (Figures 3.3 and 3.4). Exploratory analyses of survey data indicated inconsistent sampling in Gulf of Maine stratum 35 (Figure 3.3), including the splitting of the stratum into two sections in 1985 with sampling only occurring in the southern portion of the stratum. This stratum was eliminated from index development. Two vessels, the RV *Albatross IV* and the FRV *Henry B. Bigelow*, have conducted the majority of the surveys with the former vessel used prior to 2009 and the latter vessel used from 2009 to present. When the survey platform changed in 2009, stations less than 18 m in depth were excluded, eliminating many of the shallow inshore stations. Inshore strata retained for index development, given consistent sampling across platforms, were strata 2, 5, 8, 11, 14, 17, 20, 23, 26, 29, 32, 35, 38, 41, 44-46, 56, 59-61, and 64-66 (Figure 3.4). Survey timing remained relatively consistent across years during the spring survey, but in the fall tended to extend later in the year as the time series progressed (Figure 3.5). Sex was recorded for spiny dogfish caught during the survey starting in 1980. For details on changes in survey coverage, vessels, timing, design, and gear throughout the history of the survey see Johnston and Sosebee (2014).

The Working Group recommended application of the seasonal vessel calibration factors from Miller et al. (2010) to account for the vessel/gear change in 2009. Other available calibration factors were not applicable during this assessment process because the factors were not found to be significant or did not apply to the temporal or spatial scale of the survey used for this assessment. Relative abundance indices using mean numbers and weight per tow were developed for both the spring and fall survey by sex and combined sex from 1980 to 2021 (Tables 3.1 - 3.4). Design based total biomass estimates were developed for both the fall and spring surveys (Figures 3.6 and 3.7)

The Working Group recommended using the spring index in the base run and the fall index as a sensitivity. Both indices were also recommended for use in spatiotemporal habitat modeling (VAST) to explore distribution shifts and to develop an integrated survey index.

Winter Bottom Trawl Survey

The NEFSC initiated an offshore winter bottom trawl survey in 1992 to target flatfish and provide better estimates of their abundance than produced from the spring and fall surveys (Terceiro 2003). The winter bottom trawl survey ended in 2007 based on the new vessel (FRV *Henry B. Bigelow*) and gear changes planned for the spring and fall surveys likely improving flatfish catches (Johnston and Sosebee 2014). This survey was conducted in February and timing was consistent across years (Figure 3.8). Survey coverage generally ranged from Georges Bank to the mid-Atlantic, with consistent coverage only occurring off southern New England and the Mid-Atlantic (Figure 3.3, strata 1-12 and 61-76). Two different vessels were used to conduct this survey, but not during consistent time frames and no conversion factors were developed for the two vessel/gear combinations. For additional information on the survey design, coverage, and vessels see Johnston and Sosebee (2014). Both flatfish and elasmobranch (including spiny dogfish) catchability for this survey were high (NEFSC 2000, 2003). Stratified mean number per tow estimates for spiny dogfish declined across the time series in the regions consistently sampled (Figure 3.9).

The Working Group did not recommend the use of the winter survey index for this assessment due to the short time series, limited consistent spatial coverage, and lack of a conversion factor or consistent time frames for the different vessel/gear combinations.

Gulf of Maine Bottom Longline Survey

The NEFSC Gulf of Maine Bottom Longline Survey was initiated in 2014 and has occurred in the spring and fall concurrently with the NEFSC Bottom Trawl Survey. The NEFSC Bottom Trawl Survey cannot efficiently sample very complex, rough-bottom areas. This bottom longline survey was designed to increase sampling of several data-poor groundfish stocks that are associated specifically with rough-bottom habitat (McElroy et al. 2019). Survey coverage included six offshore strata in the Gulf of Maine: 26, 27, 37, and portions of 28, 29, and 36, all with sub-stratification by bottom type (Figure 3.10, Nieland and McElroy 2022). For more details on the gear and survey design see McElroy et al. (2019). Stratified mean numbers and weight per set were developed for spiny dogfish by season, bottom type, and sex for the survey from 2014 through 2021 (Figures 3.11 and 3.12). No significant differences were found between longline catches by sex or combined sex with bottom type based on an ANOVA test ($P<.05$; Nieland and McElroy 2022). Additionally, visual and regression analyses comparing combined bottom type longline and trawl indices from the same strata by sex and season indicated general agreement among survey trends with number derived indices showing better agreement (Nieland and McElroy 2022).

Lengths of spiny dogfish caught in the bottom longline and trawl surveys (only for the six strata covered by the longline survey) were compared by proportions at length (Figure 3.13). A Kolmogorov-Smirnov test was performed to determine if the proportions at length from the longline and trawl surveys by sex, season, and year came from the same distribution. The proportions at length for females during the spring surveys in 2017, 2018, and all years combined and the fall surveys in 2014, 2018, and all years combined had significantly different length distributions ($P<.05$, Nieland and McElroy 2022).

The Working Group recommended sensitivity runs using the stratified mean numbers per set index for the spring and fall longline surveys with combined bottom types.

U.S. State and Interstate Fishery Independent Surveys

ASMFC Northern Shrimp Trawl Survey

The ASMFC Northern Shrimp Trawl Survey is a random stratified bottom trawl survey that began in 1983 with limited sampling in the first year. The survey covers Gulf of Maine waters stratified by depth and area with core coverage in strata 04010, 04030, and 04050-04080 each year except the initial survey year (Figure 3.14; Johnston and Sosebee 2014). The survey takes about two weeks to complete and is conducted during the summer months anytime between July and August with timing trending later in the year across the survey time frame (Figure 3.15). For details on survey design and gear see Johnston and Sosebee (2014). Stratified mean numbers and weight per tow indices show an increasing trend with high variability in recent years, primarily driven by males (Figure 3.16).

The Working Group did not recommend this index for use given the timing of the survey, as the NEFSC Spring Bottom Trawl Survey may account for some of these fish before they migrate into the Gulf of Maine. Additionally, the large increase in abundance in the later years could be partially attributed to the gradual shift in survey timing to later in the summer or warming ocean temperatures altering migration timing.

NEAMAP Trawl Survey

The Northeast Area Monitoring and Assessment Program (NEAMAP) Trawl Survey began sampling the coastal ocean from Martha's Vineyard, Massachusetts, to Cape Hatteras, North Carolina, since the fall of 2007 (Figure 3.17). The survey area is stratified by latitudinal/longitudinal region and depth. A four-seam, three-bridle, 400x12 cm bottom trawl is towed for 20 minutes at each sampling site with a target speed-over-ground of 3.0 kts. The net is outfitted with a 2.54 cm knotless nylon liner to retain the early life stages of the various fishes and invertebrates sampled by the trawl. The survey conducts two cruises a year, one in the spring (April-May) and one in the fall (September-November). NEAMAP catches mainly adult spiny dogfish, although some years and seasons also encounter juveniles based on the length frequencies (Figure 3.18. and 3.19). Female and male spiny dogfish were caught more often in the spring (77% and 33% positive tows, respectively) than in the fall (52% and 15% positive tows, respectively).

After reviewing the geometric means provided by NEAMAP, nominal and model based indices were developed for this survey by sex and season (Figures 3.20 and 3.21). Model based indices explored used a variety of generalized models. A full model that predicted catch as a linear function of year, water temperature, salinity, dissolved oxygen, depth, depth stratum, and station was compared with nested submodels using AIC. Based on several diagnostics (AIC, dispersion, percent deviance explained, and resulting coefficients of variation), the model chosen was a negative binomial that included year and station for females in the spring and year and depth strata for males in the spring (Figure 3.21). For females in the fall, the model chosen was a negative binomial that included year, temperature, and depth strata and for males in the fall, year and depth strata (Figure 3.21). Fall nominal and model based indices for both sexes indicate that the survey does not encounter spiny dogfish regularly with only a few peaks in the time series, notably in 2016 (Figures 3.20 and 3.21).

The Working Group recommended that seasonal indices for this survey be used in spatiotemporal habitat modeling (VAST) to explore distribution shifts and to develop an integrated survey index.

MADMF Inshore Bottom Trawl Survey

The Massachusetts Division of Marine Fisheries (MADMF) began a biannual (spring and fall) bottom trawl survey in 1978 in coastal state waters. The survey area is stratified by both bio-geographic region and depth (Figure 3.22). A ¾ Yankee trawl net is used with a 39 ft headrope, 51 ft footrope, 0.25 in codend, 3.5 in cookie sweep, low aspect Tomkiewicz doors (wooden, 325 lb; 72x40 in), 63 ft of ⅜ chain in bottom legs, and 60 ft of ⅜ wire in top legs. The net is towed for 20 minutes at each sampling site with a target speed-over-ground of 2.5 kts. Two vessels have been used to conduct this survey, the F/V *Frances Elizabeth* from 1978 - 1981 and the R/V *Gloria Michelle* from 1982 to present. MADMF catches mainly large juvenile and adult spiny dogfish, although young juveniles are encountered based on the length frequencies (Figure 3.23. and 3.24).

Abundance (mean numbers per tow) and biomass (kg per tow) indices for spiny dogfish from Massachusetts spring and fall inshore bottom trawl surveys were developed for 1980-2021 (Figures 3.25 and 3.26). The spring survey usually occurs before the major influx of dogfish to Massachusetts waters. In the fall, catches tend to be an order of magnitude larger, as much of the dogfish stock is concentrated near the Massachusetts coast. Wide variations in availability result in highly variable survey indices. High variability in this survey is also a reflection of the seasonal use by dogfish of the area surveyed.

The Working Group recommended that seasonal indices for this survey be used in spatiotemporal habitat modeling (VAST) to explore distribution shifts and to develop an integrated survey index.

ME-NH Inshore Groundfish Trawl Survey

The Maine-New Hampshire Inshore Groundfish Trawl Survey is a biannual (spring and fall) random stratified survey by depth (5-20, 21-35, 36-55, and 55+ fathoms) and area based on geologic, oceanographic, geographic, and biologic factors that started in 2000. Sex data was not recorded until 2005. Survey coverage is in the shallow waters along the Maine and New Hampshire coast within the Gulf of Maine (Figure 2.27). For details on survey design and gear see Sherman et al. (2005).

Abundance (mean numbers per tow) and biomass (kg per tow) indices for spiny dogfish from the ME-NH spring and fall inshore bottom trawl surveys were developed for 1980-2021 (Figures 3.28 and 3.29). Similar to what was seen in the MADMF survey, catches were greater in the fall than in the spring, with the exception of a notable peak in mean numbers per tow during the spring in 2016. This peak was not seen in the weight per tow plot and can be explained by the size distribution of the catches during the spring in 2016, which was skewed towards young-of-the-year sized fish (Figure 3.30). There also appears to be an overall declining trend during the fall survey, although there is high interannual variability across the time series. There is no discernable trend during the spring season. These trends are also apparent in the mean catch at length plots (Figures 3.30 and 3.31).

The Working Group recommended that seasonal indices for this survey be used in spatiotemporal habitat modeling (VAST) to explore distribution shifts and to develop an integrated survey index.

Rhode Island Coastal Trawl Surveys

The Rhode Island Department of Environmental Management's Division of Marine Fisheries conducts two coastal bottom trawl surveys in Rhode Island waters, the Monthly (1990-present) and Seasonal (1979 - present) Trawl Surveys. The Monthly Trawl Survey has 13 fixed stations located in Narragansett Bay (12) and in Rhode Island Sound (1) surveyed in the middle of each month (Figure 3.32). The Seasonal Survey occurs during the Spring (April-May) and Fall (September-October) with a combination of fixed (12) and random (14) stations in Narragansett Bay and 18 fixed stations in Rhode Island and Block Island Sound (Figure 3.33). For details on survey design and gear see Parkins and Olszewski (2021).

The majority of spiny dogfish encountered during the Rhode Island bottom trawl surveys are over 75 cm stretched total length with a female to male ratio of approximately 4:1. Abundance (mean numbers per tow) and biomass (kg per tow) indices for spiny dogfish for both spring and fall seasonal and the monthly trawl surveys were developed for 1979-2021 and 1990-2021, respectively (Figures 3.34 and 3.35). Catches were low throughout the time series for each survey with the exception of a peak in the mid-2000s that was associated with high coefficients of variation (Figures 3.34 and 3.35).

The Working Group did not recommend this index for use given the low encounter rates and the limited spatial coverage of the surveys.

Canada DFO Bottom Trawl Surveys

Canada Department of Fisheries and Oceans (DFO) Bottom Trawl surveys were designed to provide abundance trends for fish and invertebrates and use Northwest Atlantic Fisheries Organization (NAFO) Divisions to define area coverage (Figure 3.36).

Scotian Shelf Trawl Survey (NAFO Divisions 4VWX)

The Canada DFO Scotian Shelf survey was initiated in 1970 as a summer survey with coverage in NAFO Divisions 4VWX (Figure 3.36). For information on survey design, gear, and vessels see Fowler and Showell (2009) and DFO (2020). The design based biomass index developed for this survey shows high inter-annual variability with an increasing trend in catches through 2002 followed by a decreasing trend for the remainder of the time series (Figure 3.37). Although sex data was not available at the time of analyses, previous assessment reports indicated that the adult females were not encountered on this summer survey (TRAC 2010) and the male biomass was nearly 2.8 times greater than female biomass estimated from this survey (NEFSC 2006). Length frequency data indicate no young of the year caught during this survey, only larger juveniles and likely adult males (Figure 3.38)

The Working Group did not recommend this index for use in the assessment due to the high inter-annual variability. The Working Group also cited the need to review the catch per set information by sex and combined, which was not possible during the assessment time frame. Spatiotemporal modeling would also be beneficial in the future to investigate potential shifts in distribution or migration timing.

Eastern Georges Bank (NAFO Division 5Ze)

The Canada DFO Eastern Georges Bank survey was initiated in 1987 as a winter (February) survey with coverage in NAFO Division 5Ze (Figure 3.36). For information on survey design, gear, and vessels see Stone and Gross (2012). The design based biomass index developed for this survey shows a steep increase with high interannual variability followed by a sharp decline and in the mid 1990s remaining at low levels until drops to zero in 2003 and basically stays there except for a minor blip in 2008 (Figure 3.39). Comparison to NEFSC Spring Bottom Trawl Survey data in the same region shows a similar trend with the drop in the mid 1990s but with more variability after it drops off (Figure 3.40).

The Working Group did not recommend this index for use in the assessment model given they would need to review the catch per set information by sex and combined sex for this assessment, data which were not available during the assessment time frame and the trend from this survey is already seen within the NEFSC Spring Bottom Trawl Survey data. The Working Group did highlight a future need for spatiotemporal modeling to help determine what is behind the declining trends seen in this region.

Southern Gulf of St Lawrence

The Canada DFO Southern Gulf of St Lawrence survey was initiated in 1971 as an annual survey conducted each September (Figure 3.41). For information on survey design, gear, and vessels see Hurlbut and Clay (1990). Abundance (mean numbers per tow) and biomass (kg per tow) indices and spatiotemporal plots of biomass were developed (Figures 3.42 and 3.43). There were no spiny dogfish catches during the first 12 years of the survey and then there was a large spike in the late 1980s (Figures 3.42 and 3.43). This was followed by a decline with high inter-annual variability until spiny dogfish disappeared from the survey again in 2003 (Figures 3.42 and 3.43). These trends are similar to what was seen in Canadian and U.S. surveys on eastern Georges Bank (Figures 3.39 and 3.40).

Campana et al. (2007) reported on this abrupt appearance of spiny dogfish in the southern part of the Gulf of St. Lawrence suggesting it is a sink population and that there had been no immigration or recruitment, slowed individual growth due to the colder temperatures, and a gradual reduction in numbers.

The Working Group did not recommend this index for use in the assessment model, but did highlight the need to do some future spatiotemporal modeling to help determine what is behind the declining trends seen in this region.

Spring Grand Banks (NAFO Divisions 3LNOP)

The Canada DFO Spring Grand Banks survey was initiated in 1996 with coverage in NAFO Divisions 3LNOP (Figure 3.36). For information on survey design, gear, and vessels see Rideout and Ings (2020). Abundance and biomass indices for spiny dogfish were developed for the Spring Grand Banks Survey and catch distribution was plotted for the last year in the time series (Figure 3.44). Catches were low across the time series with an increase during the last few years of the survey. The estimates at the end of the time series had large error bars and high inter-annual variability.

The Working Group did not recommend these indices for use in the assessment due given the low encounter rates throughout the majority of the time series and the uncertainty in the estimates in recent years. The Working Group did highlight a future need for spatiotemporal modeling to help determine what is behind the increasing trend seen at the end of the time series.

Fall Grand Banks and Labrador (NAFO Divisions 2HJ3KVLNO)

The Canada DFO Fall Grand Banks and Labrador survey was initiated in 1995 with coverage in NAFO Divisions 2HJ3KVLNO (Figure 3.36). For information on survey design, gear, and vessels see Rideout and Ings (2020). Abundance and biomass indices for spiny dogfish were developed for the Fall Grand Banks Survey and catch distribution was plotted for the last year in the time series (Figure 3.45 and 3.46). As seen in the spring survey, catches were low across the time series with an increase during the last few years of the survey. The estimates at the end of the time series had large error bars and high inter-annual variability.

The Working Group did not recommend these indices for use in the assessment due given the low encounter rates throughout the majority of the time series and the uncertainty in the estimates in recent years. The Working Group did highlight a future need for spatiotemporal modeling to help determine what is behind the increasing trend seen at the end of the time series.

Integrated Survey Indices

A model based approach to deriving a spring index of abundance and length composition was pursued by the Working Group with two objectives: account for survey or environmental considerations that may influence catchability, and integrate multiple surveys into a single index to better describe the population. Spatiotemporal models have the ability to account for spatial shifts and can yield more precise/accurate indices (Shelton et al. 2014). Fitting assessments to these models can also lead to less retrospective bias and outperform assessments with design-based indices (Cao et al. 2017). Previous research has shown how diel effects can influence spiny dogfish catch from fisheries-independent surveys (Sagarese et al. 2016), warranting evaluation in a model-based index approach for inclusion in the assessment model.

A VAST model was developed to both include explanatory covariates and integrate survey information. As described in TOR1, the VAST model represents a delta-model that predicts the probability of an encounter and the positive catch rate as two separate generalized linear mixed models. A Bernoulli distribution was assumed for probability of a positive catch and a Poisson distribution for positive catch. Time of day, bottom temperature and depth associated with each tow were explored as covariates. For both the spring and fall model configurations, AIC, and model diagnostics supported including depth as a modulate of density (Hansell and McManus 2022). In deriving the single model-based index of abundance, the VAST model incorporated data from four biannual trawl surveys (Figure 3.47): the Northeast Fisheries Science Center (1980 – 2021); Massachusetts Division of Marine Fisheries (1980 – 2021); Maine/New Hampshire (2005 – 2021); and Northeast Area Monitoring and Assessment Program (2007 – 2021; Hansell and McManus 2022).

In the spring, encounter probability and abundance are high in the mid-Atlantic (Figures 3. 1 and 3.48). In contrast, in the fall encounter probability and abundance are estimated to be lower in the mid-Atlantic and higher in the Gulf of Maine (Figures 3.2 and 3.49). For the spring and fall, VAST estimates of relative abundance for male and female dogfish are similar to the NEFSC designed based estimates (Figures 3.50 - 3.53). In the spring, VAST estimates differ from designed based estimates for the inshore surveys (menh, madmf, and neamap; Figures 3.50

and 3.51). In the fall, VAST estimates were more similar to design based estimates from the inshore surveys (Figures 3.52 and 3.53)

A multivariate VAST model was fit to length to produce standardized length composition data. The model fit to spring inshore (Maine-New Hampshire, Massachusetts Division of Marine Fisheries, and NEAMAP) and offshore surveys (NEFSC). The model failed to converge using 3 cm length bins so length bins were increased to 6 cm bins and the model successfully converged (Figures 3.54). The model estimates of length composition are similar to design based estimates of length composition (Figures 3.55 and 3.56).

The Working Group recommended using the spring VAST index as a sensitivity run in the model.

Table 3.1. Annual NEFSC Fall Bottom Trawl Survey mean numbers per tow and coefficients of variation (CV).

Year	Female	CV	Male	CV	Unsexed	CV	Total	CV
1980	3.83	72.81	1.35	60.38	0.03	46.44	5.21	58.64
1981	38.65	68.16	35.03	76.73	0.02	54.20	73.70	71.91
1982	6.68	38.92	6.69	43.74	0.00		13.37	39.74
1983	18.01	65.81	13.75	56.77	0.00	100.00	31.76	61.69
1984	14.51	38.63	10.59	30.73	0.00		25.11	34.63
1985	20.17	36.33	17.96	48.37	0.08	78.70	38.21	40.71
1986	15.22	29.94	12.43	28.43	0.00		27.65	27.36
1987	16.77	49.40	16.31	48.95	0.00		33.09	49.07
1988	13.60	23.98	10.47	22.72	0.00		24.07	22.44
1989	5.43	29.20	6.53	27.70	0.00		11.95	26.91
1990	11.72	34.74	13.91	44.10	0.00		25.63	35.58
1991	13.77	43.96	19.37	36.25	0.00		33.13	37.14
1992	25.85	33.50	12.47	38.08	0.00		38.32	30.09
1993	4.10	47.84	4.36	34.98	0.00		8.46	35.30
1994	9.06	33.17	11.65	37.56	0.00		20.71	34.17
1995	7.36	27.79	12.92	23.18	0.00		20.28	23.62
1996	19.80	70.86	12.93	58.97	0.00		32.73	66.00
1997	9.57	25.51	15.02	40.51	0.00		24.59	30.72
1998	16.76	42.22	10.50	26.50	0.00		27.26	34.81
1999	8.12	18.46	8.98	12.88	0.17	100.00	17.28	13.74
2000	5.25	22.79	11.37	40.94	0.00		16.63	33.85
2001	21.69	31.65	12.34	33.89	0.00		34.03	27.41
2002	15.48	29.23	15.10	37.73	0.00		30.59	31.72

2003	6.76	31.11	5.65	26.42	0.00		12.41	24.69
2004	16.45	22.10	17.32	19.89	0.01	100.00	33.78	18.85
2005	8.18	31.45	24.41	28.26	0.00		32.59	27.35
2006	20.34	25.97	26.57	25.68	0.00		46.91	22.84
2007	18.29	43.29	22.24	22.93	0.00		40.54	31.30
2008	13.22	19.58	18.11	20.14	0.00		31.33	18.82
2009	19.74	34.87	24.31	20.66	0.00		44.04	24.08
2010	24.07	35.36	24.03	28.50	0.00		48.10	32.37
2011	24.18	41.61	32.20	29.51	0.00		56.38	34.78
2012	60.37	19.62	62.27	20.53	0.00		122.64	20.14
2013	50.17	27.89	59.12	24.20	3.69	83.63	112.97	25.78
2014	28.93	39.32	36.74	34.71	0.00		65.67	36.85
2015	23.51	29.81	16.77	31.79	0.00		40.28	29.11
2016	20.95	40.54	35.61	35.05	12.91	100.00	69.47	35.55
2017								
2018	17.96	24.99	17.87	20.94	0.00		35.84	23.33
2019	26.32	24.90	43.43	26.20	0.00		69.75	24.19
2020								
2021	9.20	25.50	20.37	26.42	0.00		29.57	24.55

Table 3.2. Annual NEFSC Fall Bottom Trawl Survey mean weight (kg) per tow and coefficients of variation (CV).

Year	Female	CV	Male	CV	Unsexed	CV	Total	CV
1980	16.48	83.02	2.43	64.94	0.03	60.99	18.94	75.11
1981	34.64	55.87	12.39	33.47	0.02	81.40	47.04	44.21
1982	9.69	53.79	5.10	35.13	0.00		14.78	44.32
1983	23.43	71.96	13.08	61.85	0.00	100.00	36.50	68.12
1984	25.45	51.56	9.05	32.89	0.00		34.50	45.92
1985	26.93	35.54	13.20	42.90	0.09	73.24	40.22	33.35
1986	24.45	39.38	13.55	28.73	0.00		38.00	33.06
1987	13.14	33.09	10.64	41.29	0.00		23.79	36.18
1988	17.12	26.04	9.59	20.18	0.00		26.71	21.07
1989	4.85	22.31	5.89	30.64	0.00		10.74	23.19
1990	17.15	46.30	14.07	51.91	0.00		31.22	35.93
1991	23.29	46.51	24.37	31.69	0.00		47.66	35.23
1992	41.17	35.02	13.68	51.95	0.00		54.85	32.84
1993	5.66	59.91	4.97	32.73	0.00		10.63	37.63
1994	8.31	31.53	12.88	41.11	0.00		21.19	35.59
1995	5.23	21.46	12.98	22.36	0.00		18.21	20.90
1996	26.62	69.67	14.78	60.49	0.00		41.40	66.20
1997	9.10	20.30	16.27	53.42	0.00		25.37	37.25
1998	25.69	41.77	12.42	25.01	0.00		38.11	34.76
1999	12.06	20.25	12.21	12.63	0.28	100.00	24.55	13.80
2000	8.85	22.02	17.21	41.47	0.00		26.07	33.06
2001	32.57	30.10	15.43	32.60	0.00		48.00	26.51
2002	26.00	28.11	21.22	39.77	0.00		47.22	31.57
2003	13.56	34.33	8.09	26.54	0.00		21.65	26.91

2004	29.25	20.28	22.71	18.06	0.00	100.00	51.96	15.42
2005	14.53	31.33	36.29	29.33	0.00		50.82	28.00
2006	37.61	26.31	36.72	24.40	0.00		74.33	21.55
2007	33.87	40.60	32.55	23.14	0.00		66.43	31.37
2008	19.16	15.82	20.95	19.72	0.00		40.11	16.07
2009	26.63	39.74	28.93	22.02	0.00		55.56	26.87
2010	22.86	30.09	18.31	15.60	0.00		41.17	22.61
2011	13.37	21.80	27.04	22.78	0.00		40.41	22.09
2012	60.43	24.04	54.78	25.26	0.00		115.21	22.92
2013	20.25	19.04	35.29	17.58	4.11	77.67	59.65	17.84
2014	15.77	34.17	27.16	33.16	0.00		42.93	32.00
2015	33.80	48.98	15.28	37.15	0.00		49.08	39.84
2016	22.71	42.78	43.39	36.10	12.00	100.00	78.10	35.77
2017								
2018	13.35	22.21	14.95	20.09	0.00		28.30	20.10
2019	19.12	20.97	44.31	31.89	0.00		63.42	26.91
2020								
2021	5.22	19.32	22.15	34.66	0.00		27.37	31.20

Table 3.3. Annual NEFSC Spring Bottom Trawl Survey mean numbers per tow and coefficients of variation (CV).

Year	Female	CV	Male	CV	Unsexed	CV	Total	CV
1980	13.63	22.38	17.46	24.44	8.29	68.61	39.38	22.71
1981	31.26	20.58	24.79	21.97	0.63	69.32	56.68	19.81
1982	27.09	33.38	23.05	27.50	0.00		50.15	27.95
1983	17.71	22.60	22.91	18.01	0.01	100.00	40.62	19.13
1984	9.31	18.66	12.95	36.27	0.00		22.26	21.96
1985	36.41	29.33	77.83	33.79	0.00	100.00	114.24	26.96
1986	19.14	15.44	9.17	28.67	0.00		28.31	18.91
1987	24.92	24.85	37.80	37.69	0.00		62.72	32.28
1988	35.26	28.18	28.39	38.38	0.02	77.04	63.67	28.12
1989	26.35	19.14	28.35	29.44	0.00		54.70	21.43
1990	43.00	31.12	46.05	52.59	0.00		89.05	41.80
1991	29.57	18.04	31.10	28.51	0.00		60.67	20.66
1992	39.42	24.05	36.02	21.00	0.00		75.44	18.02
1993	27.40	16.56	31.34	45.86	0.00		58.74	30.81
1994	36.80	17.31	51.30	16.66	0.00		88.10	15.85

1995	24.29	22.67	24.65	19.31	0.00		48.94	16.59
1996	42.91	37.92	50.49	26.50	0.00		93.41	29.58
1997	28.26	16.06	28.62	18.06	0.00		56.87	15.89
1998	11.10	20.30	31.37	25.13	0.00		42.47	22.33
1999	20.22	15.46	33.41	18.02	0.00		53.63	16.13
2000	15.00	31.58	21.42	26.54	0.27	100.00	36.69	25.03
2001	10.57	33.94	19.58	27.38	0.00		30.15	28.41
2002	19.66	19.84	31.70	18.61	0.00		51.36	17.95
2003	17.75	13.46	31.42	15.33	0.00		49.17	12.74
2004	10.06	26.93	17.69	26.96	0.00		27.75	25.94
2005	10.23	30.13	36.51	48.97	0.00		46.73	43.60
2006	27.86	21.53	48.70	28.77	0.06	100.00	76.61	23.92
2007	17.11	25.03	27.46	16.84	0.00		44.57	16.53
2008	24.12	14.20	35.87	13.49	0.00		59.99	10.08
2009	24.76	21.09	44.78	17.78	0.00		69.54	18.02
2010	19.48	16.37	36.50	19.88	0.00		55.98	17.30
2011	23.36	23.15	51.69	15.15	0.00		75.05	16.54

2012	47.60	21.65	85.55	37.33	0.00	76.38	133.15	28.39
2013	59.94	43.08	86.03	29.82	0.01	72.43	145.98	35.43
2014								
2015	15.43	28.73	34.95	21.28	0.00	100.00	50.39	20.18
2016	35.48	19.06	60.21	20.89	0.00	100.00	95.70	20.25
2017	18.78	21.39	38.99	14.03	0.00		57.77	16.03
2018	28.71	28.22	42.39	19.68	0.08	56.09	71.18	22.82
2019	39.85	34.91	67.18	12.37	0.00		107.03	17.37
2020								
2021	43.23	18.72	87.42	13.78	0.00		130.65	15.14

Table 3.4. Annual NEFSC Spring Bottom Trawl Survey mean weight (kg) per tow and coefficients of variation (CV).

Year	Female	CV	Male	CV	Unsexed	CV	Total	CV
1980	28.06	18.72	22.13	25.72	18.95	63.03	69.14	21.71
1981	67.85	18.22	28.76	20.37	0.91	35.47	97.53	15.56
1982	83.68	43.71	30.21	28.94	0.00		113.89	36.27
1983	17.82	15.89	20.50	15.96	0.00	100.00	38.33	12.10
1984	23.78	18.77	18.77	38.75	0.00		42.55	19.15
1985	65.73	41.24	97.43	38.37	0.00	100.00	163.16	28.73
1986	38.80	12.98	5.65	32.76	0.00		44.45	14.12
1987	59.66	45.12	39.04	43.89	0.00		98.70	44.28
1988	77.85	40.12	25.94	44.18	0.03	83.60	103.81	35.28
1989	42.18	17.50	33.31	36.97	0.00		75.49	22.11
1990	87.64	26.84	58.40	56.25	0.00		146.04	36.71
1991	52.93	20.47	35.19	33.53	0.00		88.12	22.09
1992	67.39	28.81	42.17	23.61	0.00		109.56	21.41
1993	50.56	17.88	34.34	43.65	0.00		84.90	23.29
1994	34.27	18.36	47.92	17.81	0.00		82.19	14.57
1995	39.08	24.27	33.31	20.97	0.00		72.40	17.81
1996	58.22	36.45	56.61	21.95	0.00		114.83	24.87
1997	43.81	16.11	36.25	18.22	0.00		80.06	15.50
1998	15.57	21.50	42.05	25.84	0.00		57.62	22.48
1999	30.89	12.99	43.60	17.29	0.00		74.49	14.03
2000	28.49	41.08	28.64	25.90	0.40	100.00	57.53	29.39
2001	19.30	37.33	28.37	27.57	0.00		47.67	29.98
2002	34.57	18.68	42.29	17.29	0.00		76.87	16.22
2003	30.34	13.95	43.76	15.41	0.00		74.10	12.28

2004	14.78	17.20	22.40	19.86	0.00		37.18	14.34
2005	17.68	31.64	48.17	50.36	0.00		65.85	43.08
2006	59.14	23.53	68.10	29.47	0.00	100.00	127.24	24.23
2007	35.51	27.39	37.78	16.73	0.00		73.29	18.52
2008	53.26	15.49	50.52	13.76	0.00		103.78	10.21
2009	31.47	16.45	49.47	19.10	0.00		80.94	15.95
2010	33.27	18.67	46.17	22.36	0.00		79.44	18.30
2011	41.04	23.07	65.17	14.12	0.00		106.21	15.04
2012	66.15	18.30	96.32	44.81	0.01	80.31	162.48	29.30
2013	40.45	31.52	71.58	14.84	0.01	82.00	112.04	18.33
2014								
2015	25.18	40.38	45.00	24.30	1.15	99.81	71.33	24.39
2016	48.15	15.30	73.64	19.71	0.01	100.00	121.80	17.12
2017	18.73	20.07	46.67	13.57	0.00		65.40	14.90
2018	35.41	25.01	51.46	15.11	0.01	54.06	86.88	18.61
2019	53.86	38.82	82.52	12.37	0.00		136.38	19.05
2020								
2021	58.40	20.38	117.92	13.69	0.00		176.31	15.72

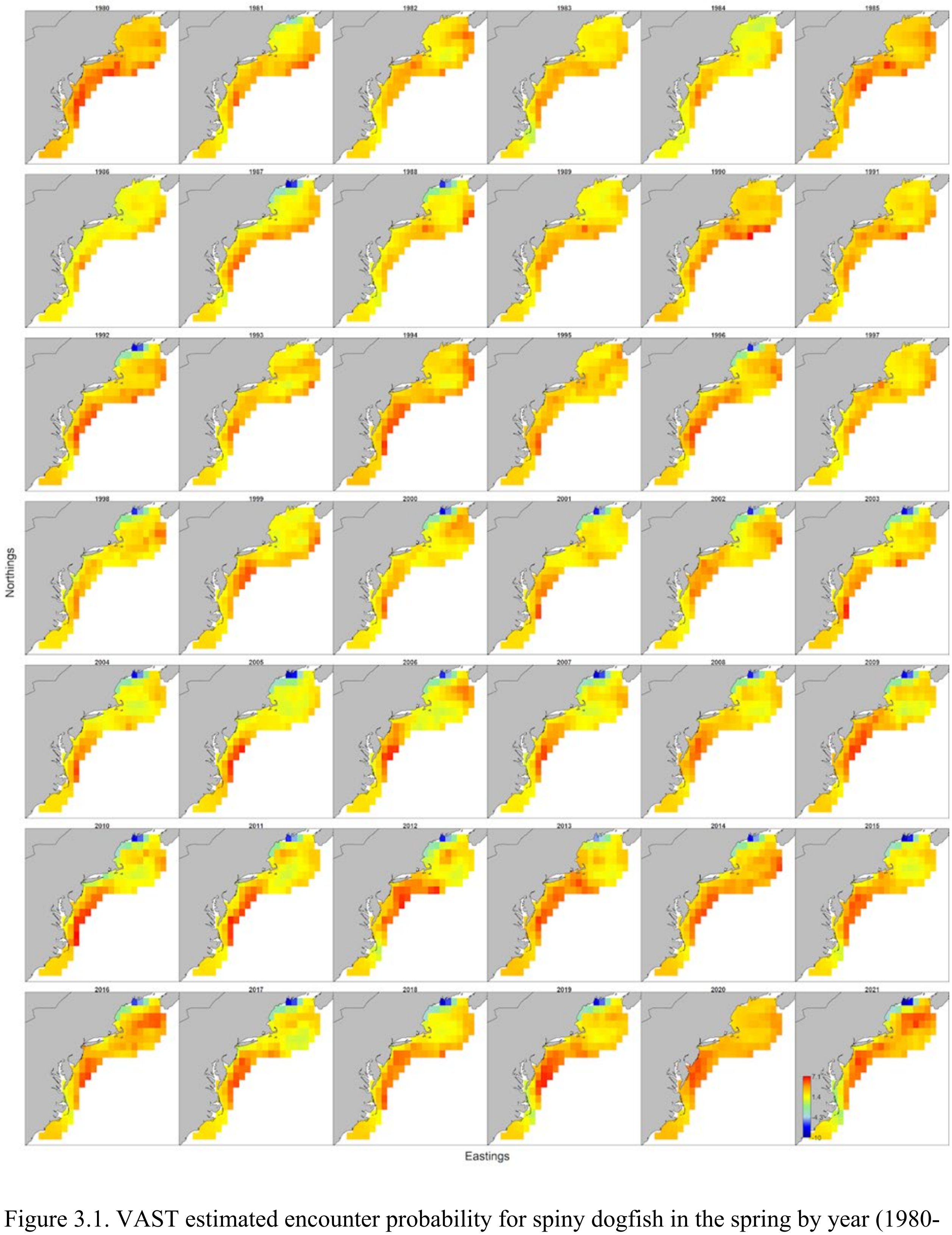


Figure 3.1. VAST estimated encounter probability for spiny dogfish in the spring by year (1980-2021).

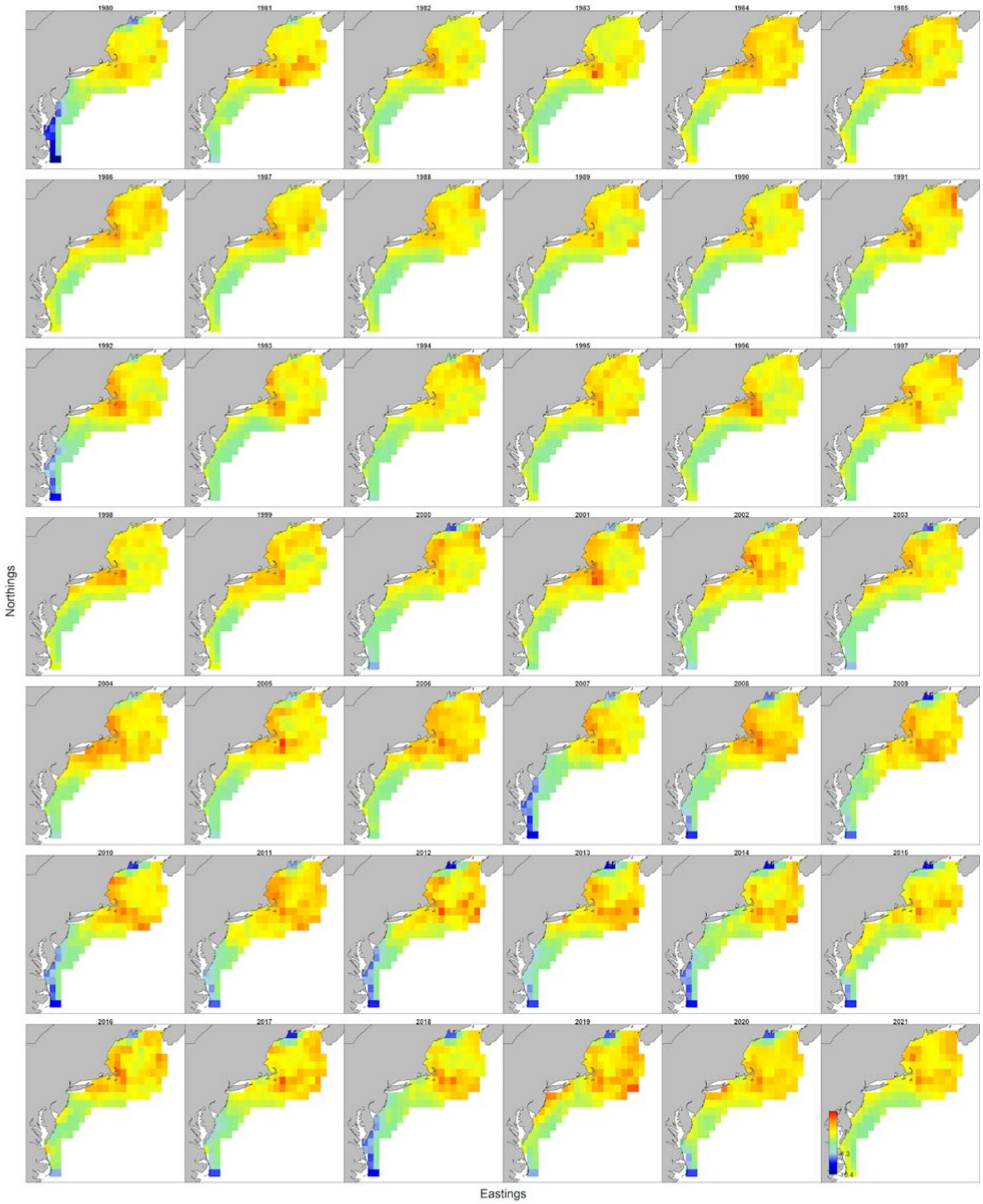


Figure 3.2. VAST estimated encounter probability for spiny dogfish in the fall by year (1980-2021).

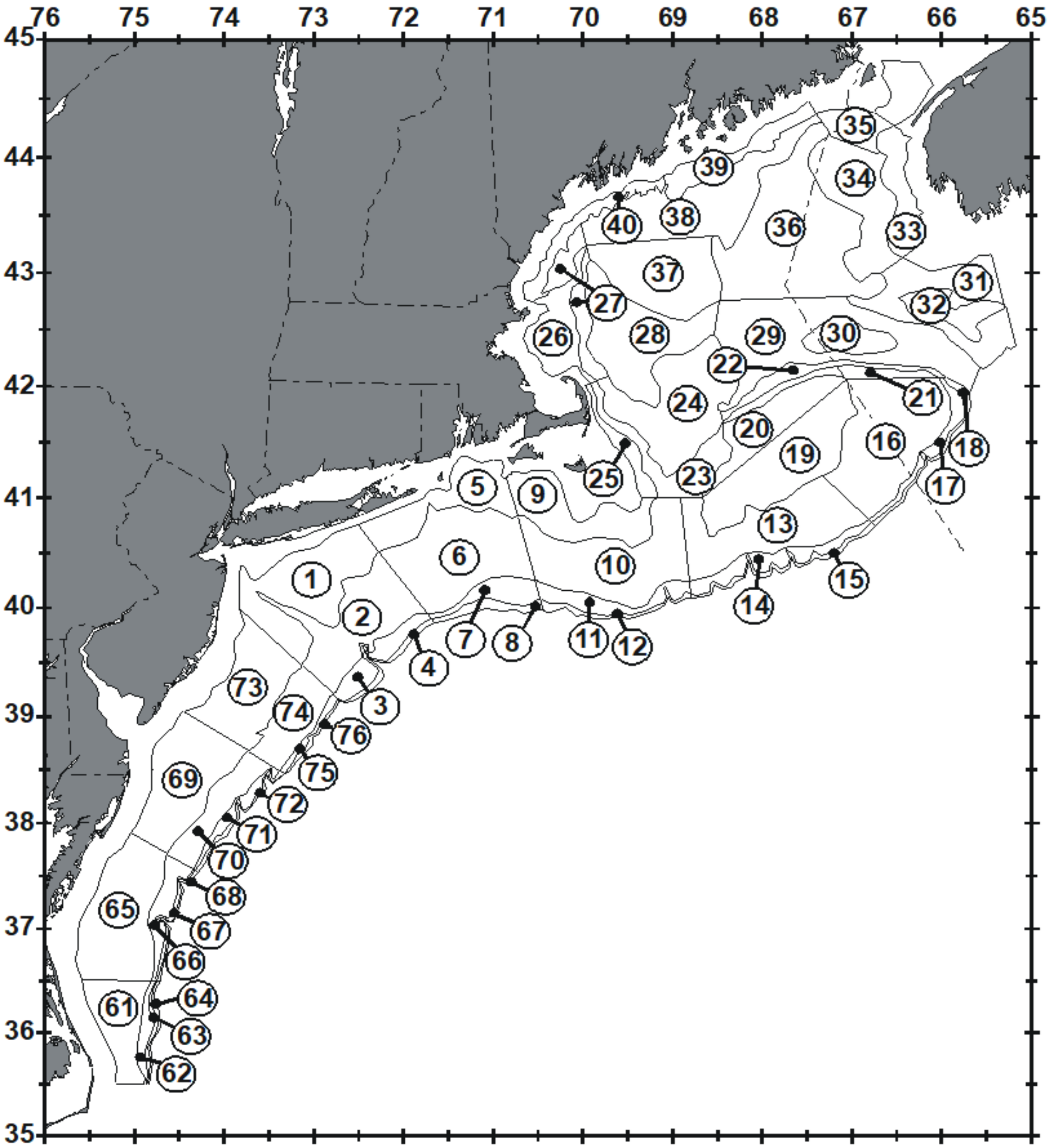


Figure 3.3. NEFSC Fall, Spring, and Winter Bottom Trawl Survey offshore stations.

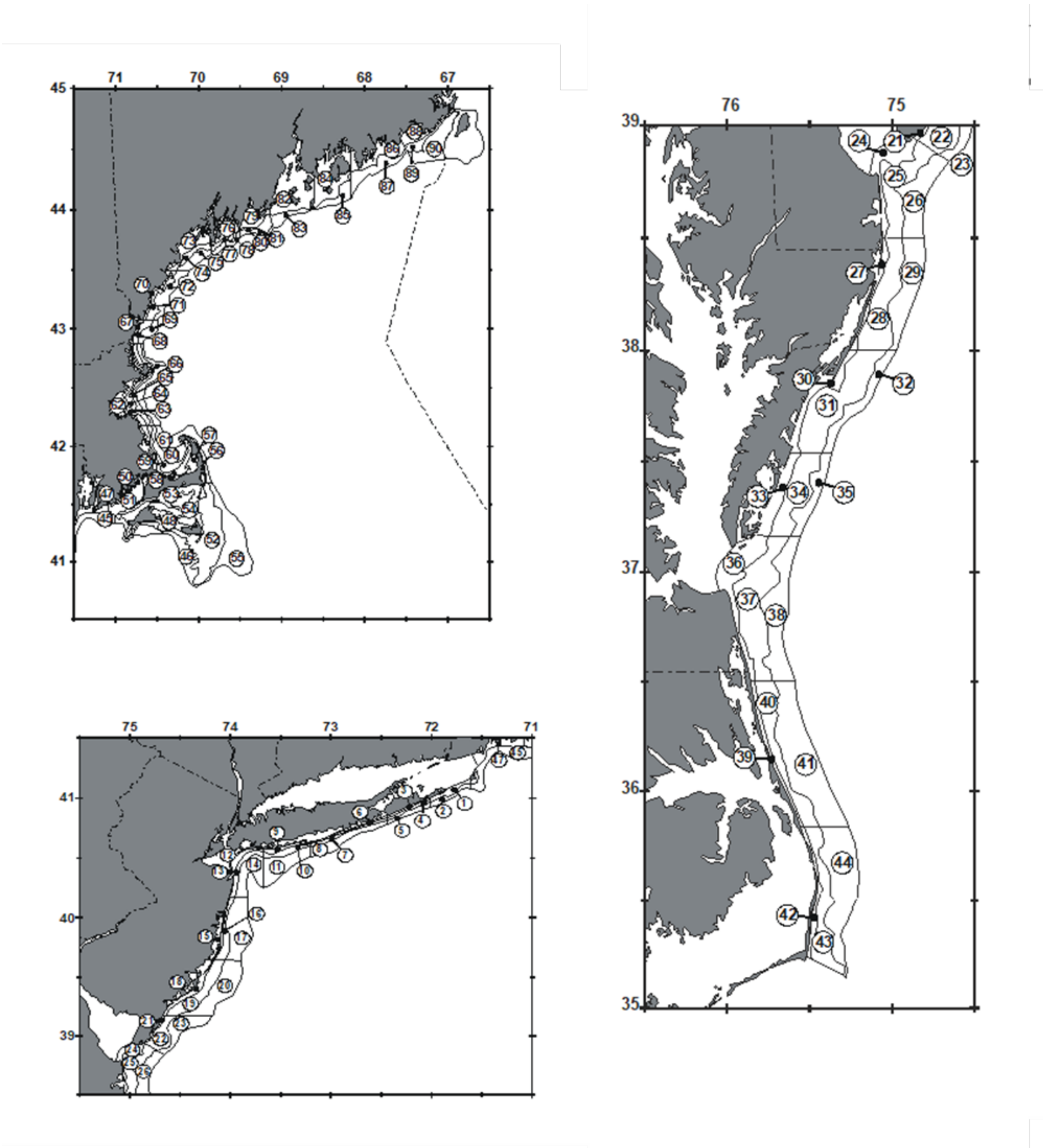


Figure 3.4. NEFSC Fall and Spring Bottom Trawl Survey inshore stations.

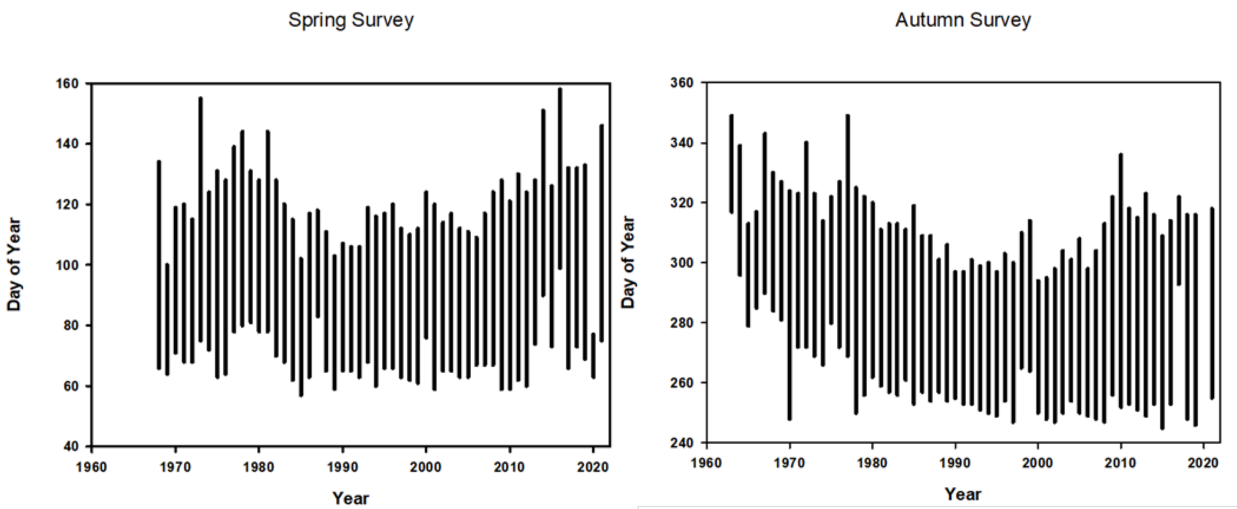


Figure 3.5. NEFSC Spring and Fall Bottom Trawl Survey annual timing.

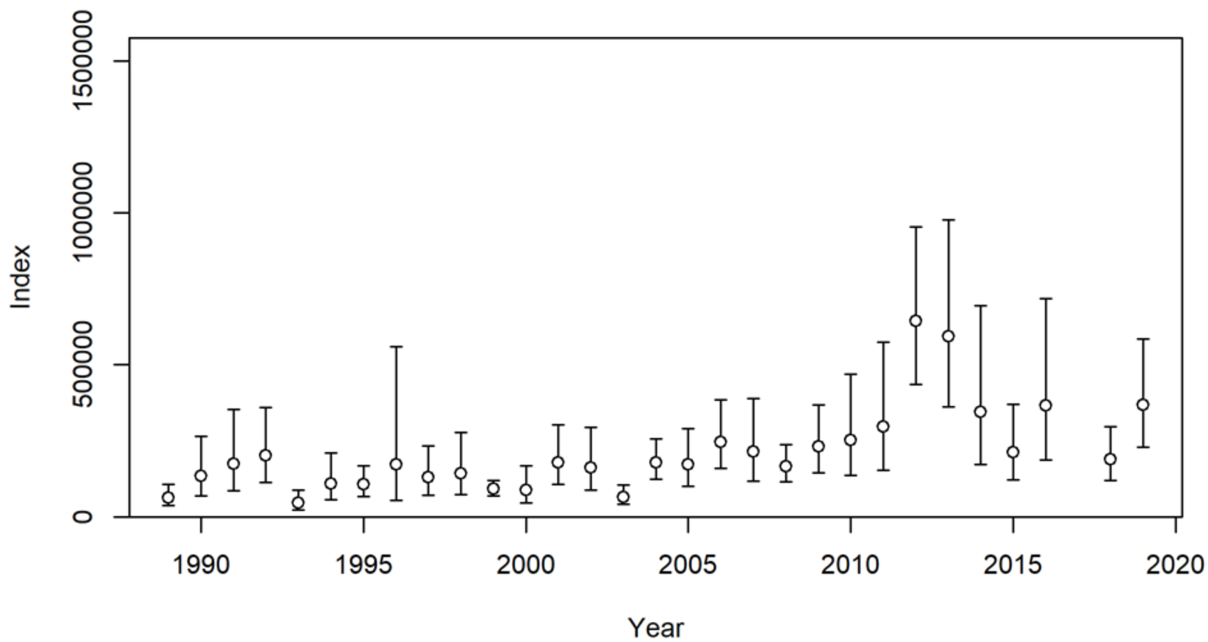


Figure 3.6. Annual NEFSC Fall Bottom Trawl Survey design based estimates of total biomass.

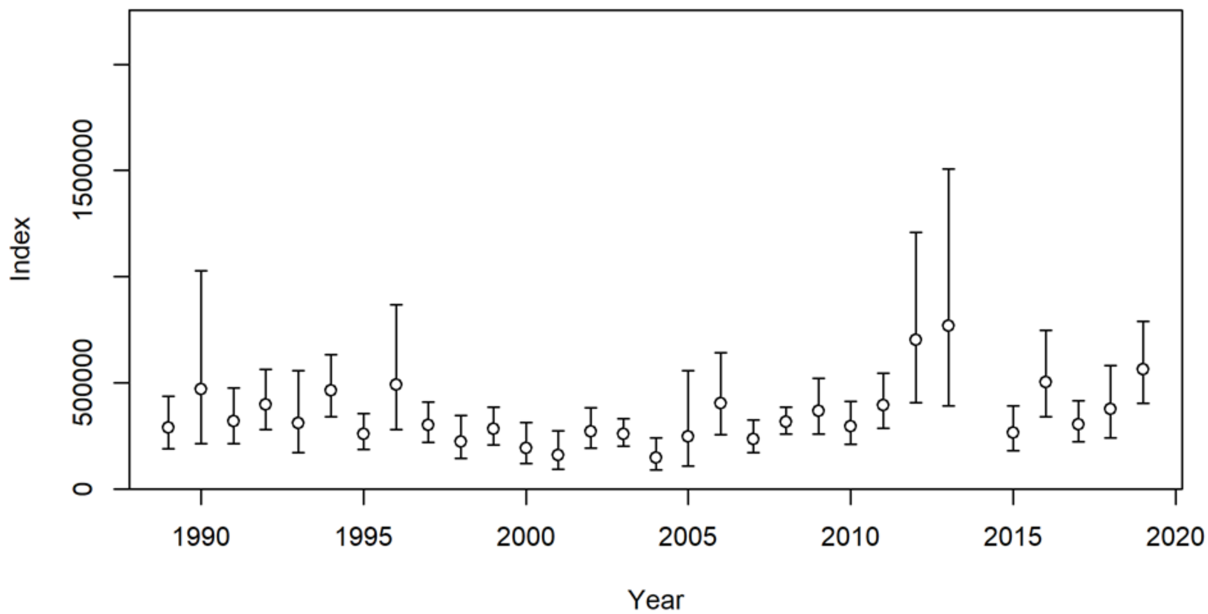


Figure 3.7. Annual NEFSC Spring Bottom Trawl Survey design based estimates of total biomass.

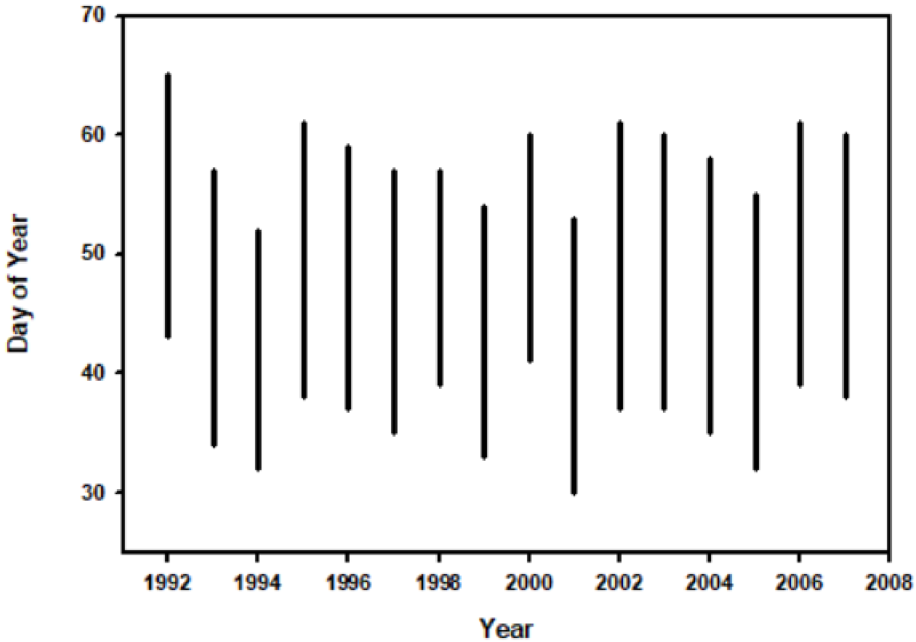


Figure 3.8. NEFSC Winter Bottom Trawl Survey annual timing.

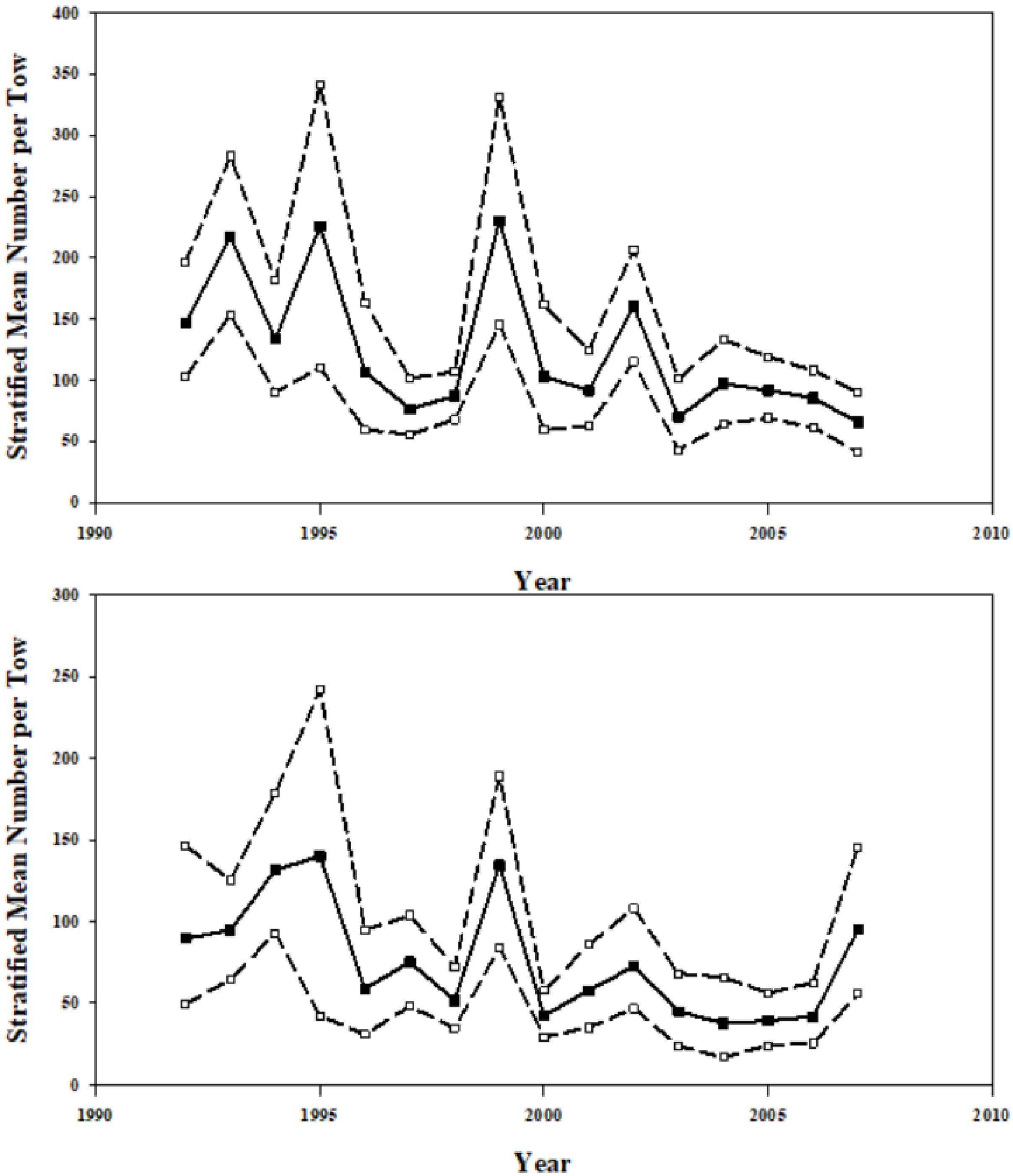


Figure 3.9. Annual NEFSC Winter Bottom Trawl Survey stratified mean number per tow (solid circles and line) and 95% upper and lower confidence limits (open circles and dashed lines) for the strata off southern New England (strata 01010-01120, top) and mid-Atlantic (strata 0610-01760, bottom) regions.

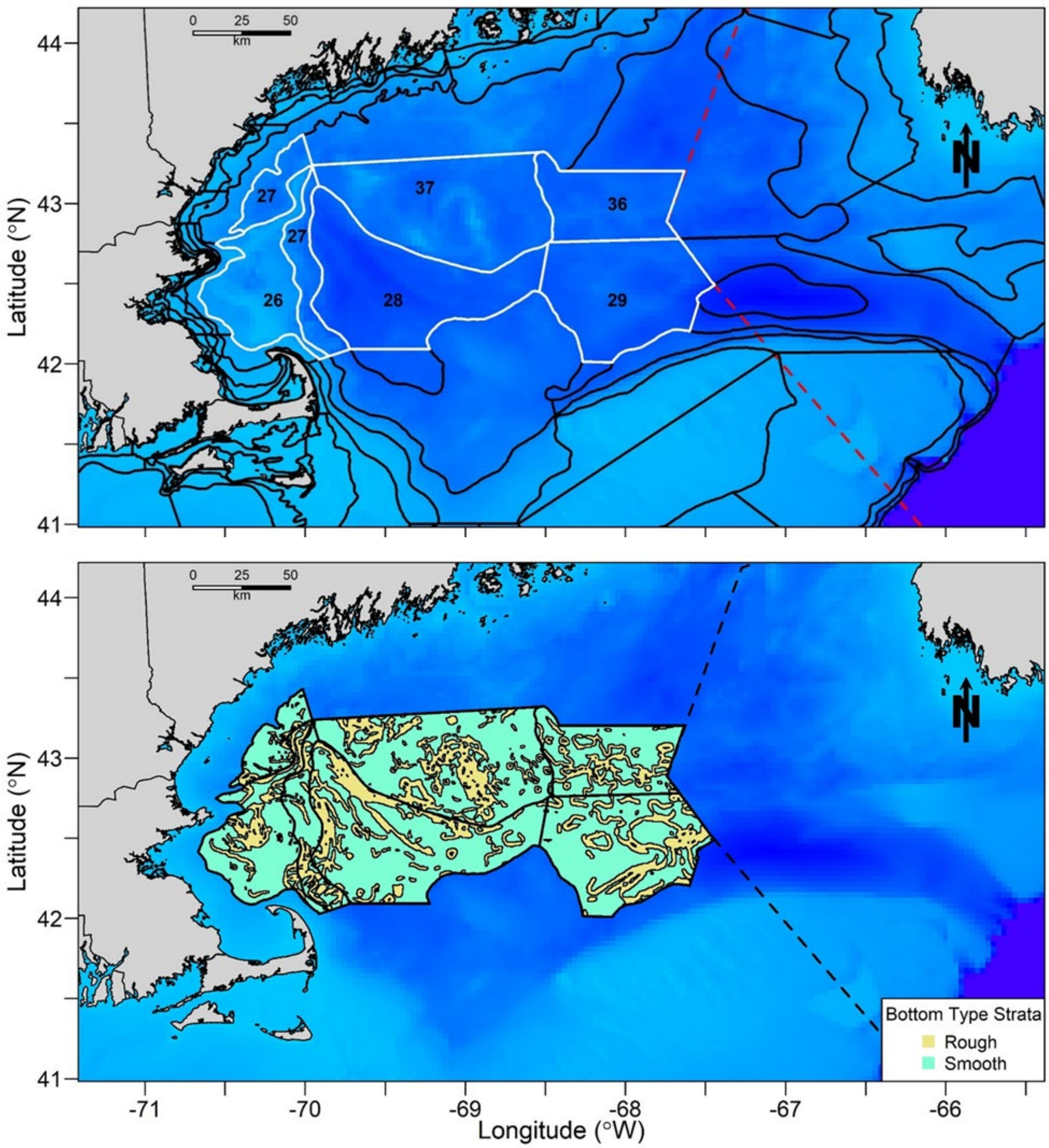


Figure 3.10. Northeast Fisheries Science Center Gulf of Maine Bottom Longline Survey strata (black lines, top panel) and their sub-stratification (bottom panel) by rough (yellow) and smooth (green) bottom types. The dashed line is the Exclusive Economic Zone boundary.

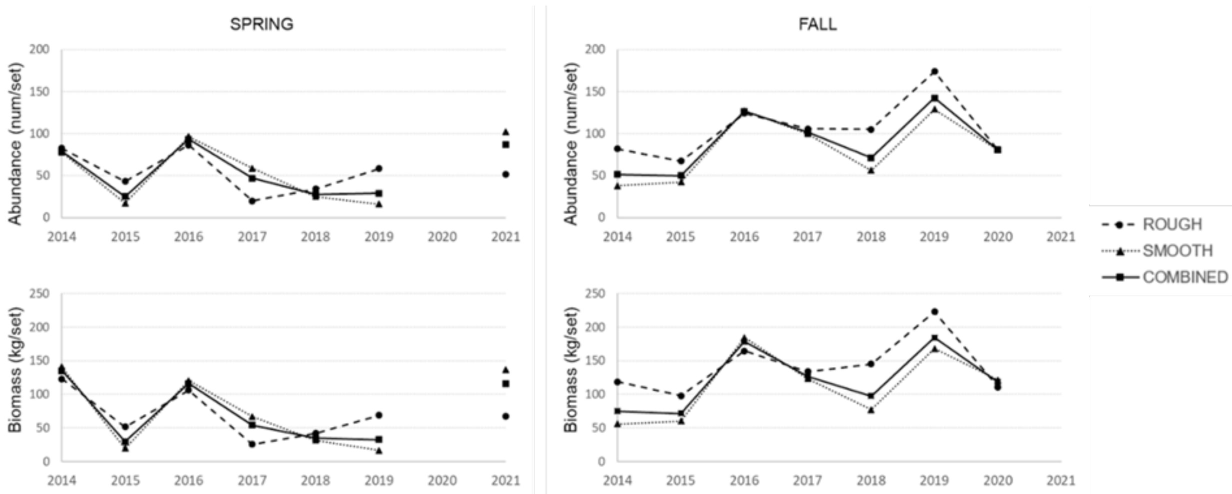


Figure 3.11. NEFSC Gulf of Maine Bottom Longline Survey Stratified mean numbers/set (top row) and kg/set (bottom row) index estimates for male spiny dogfish for the spring (a) and fall (b) by year and bottom type (Rough (circle with dashed line), Smooth (triangle with dotted line), and Combined (square with solid line)).

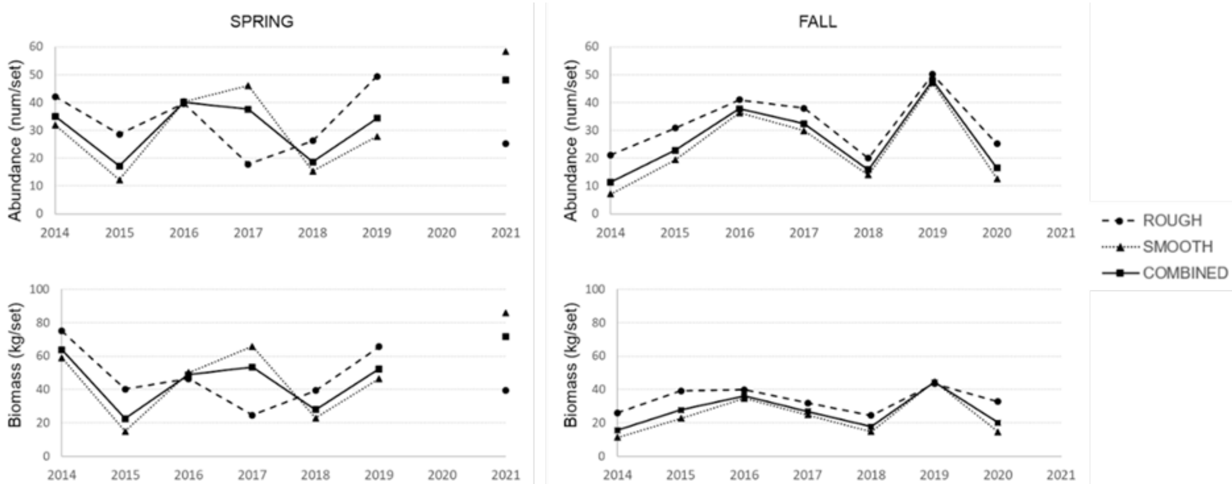
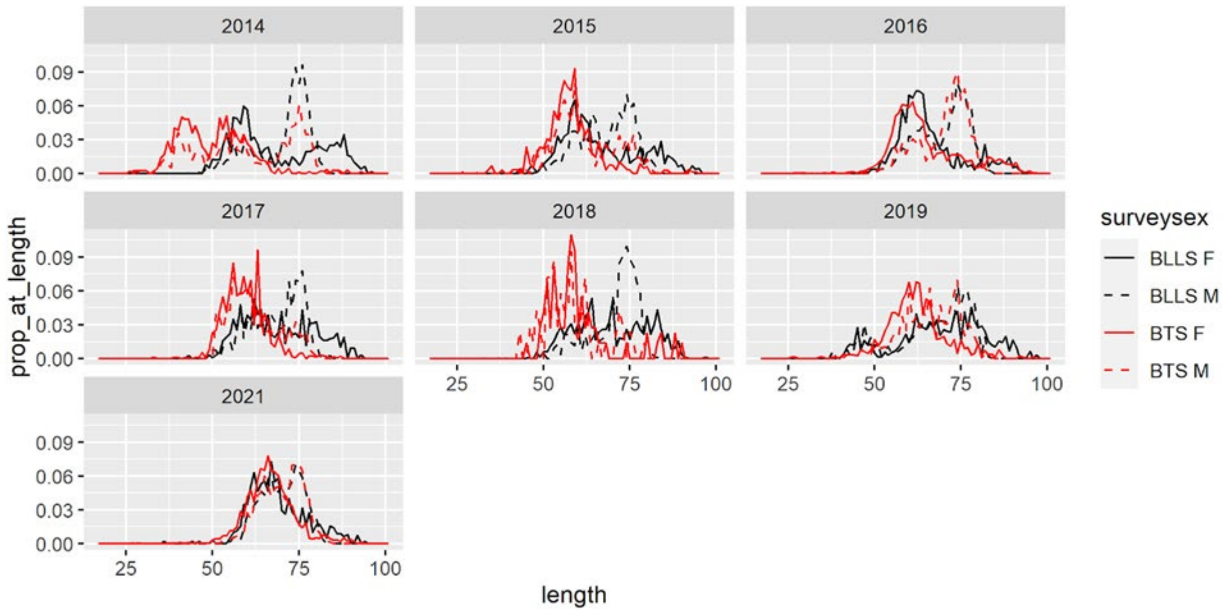


Figure 3.12. NEFSC Gulf of Maine Bottom Longline Survey Stratified mean numbers/set (top row) and kg/set (bottom row) index estimates for female spiny dogfish for the spring (a) and fall (b) by year and bottom type (Rough (circle with dashed line), Smooth (triangle with dotted line), and Combined (square with solid line)).



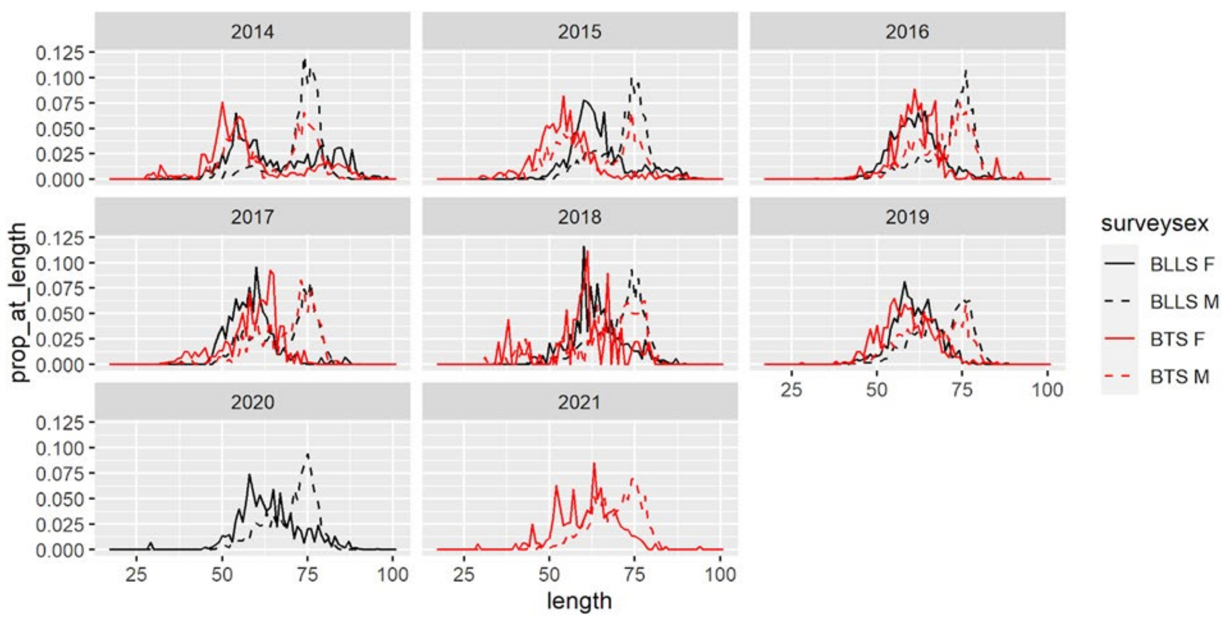


Figure 3.13. Spiny dogfish proportions at length (cm) by season (spring = top, fall = bottom), sex (females = solid lines, males = dashed lines), and year in the Northeast Fisheries Science Center Gulf of Maine Bottom Longline Survey (BLLS; black lines) and the Northeast Fisheries Science Center Bottom Trawl Survey (BTS; red lines) during 2014 – 2021. BTS lengths were only for the 6 strata covered by the BLLS.

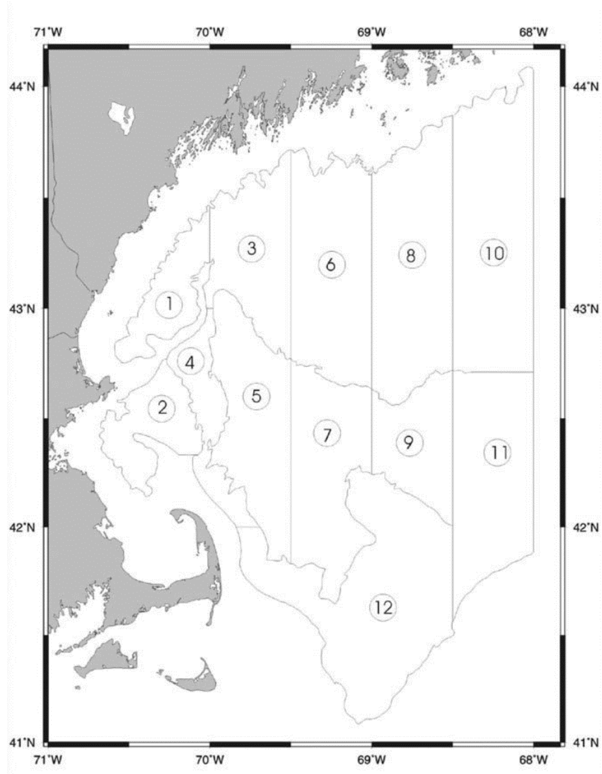


Figure 3.14. Strata used for the ASMFC Northern Shrimp Bottom Trawl Survey.

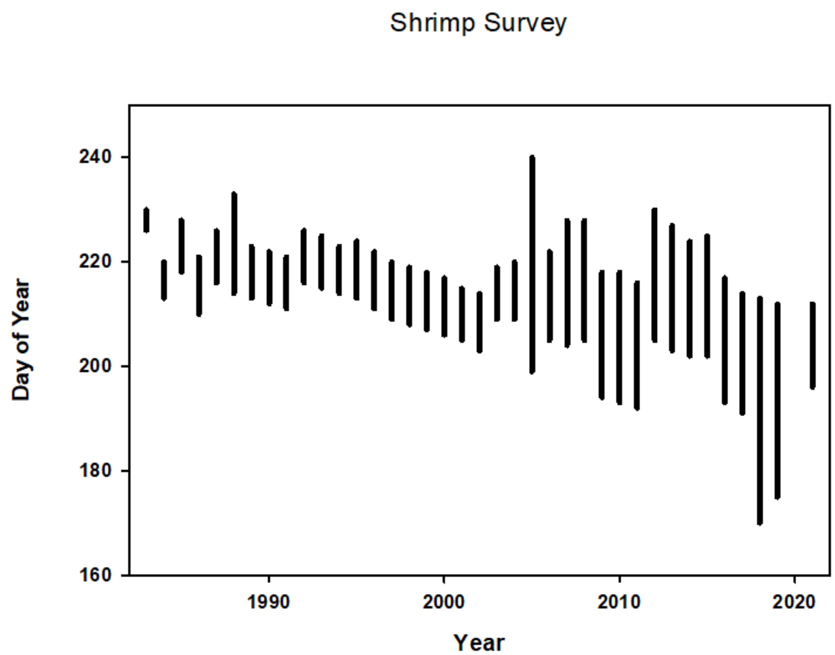


Figure 3.15. Timing of the ASMFC Northern Shrimp Bottom Trawl Survey from 1983-2021.

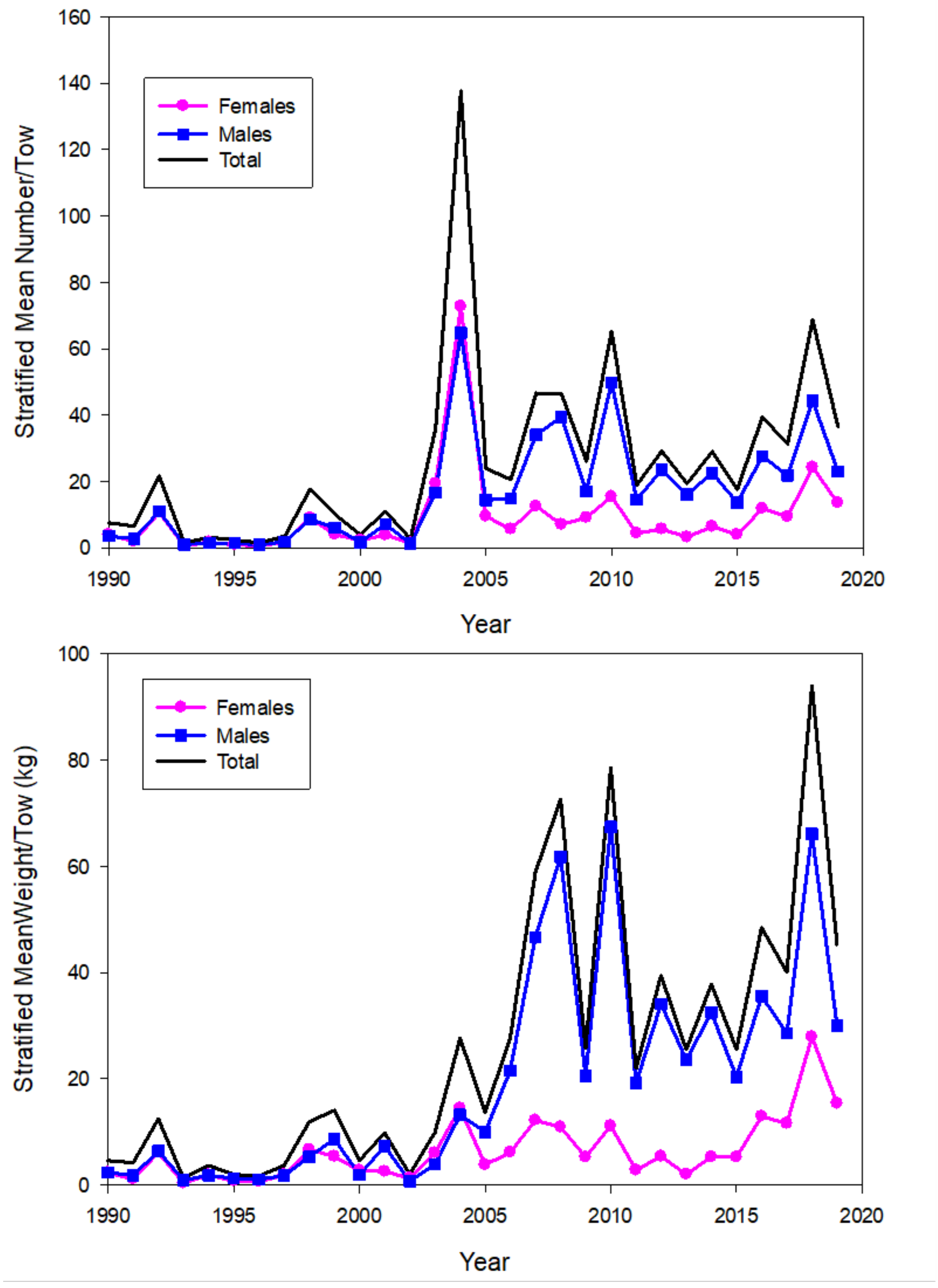


Figure 3.16. Stratified mean numbers (top panel) and weight (bottom panel) per tow from the ASMFC Northern Shrimp Bottom Trawl Survey from 1990-2019.

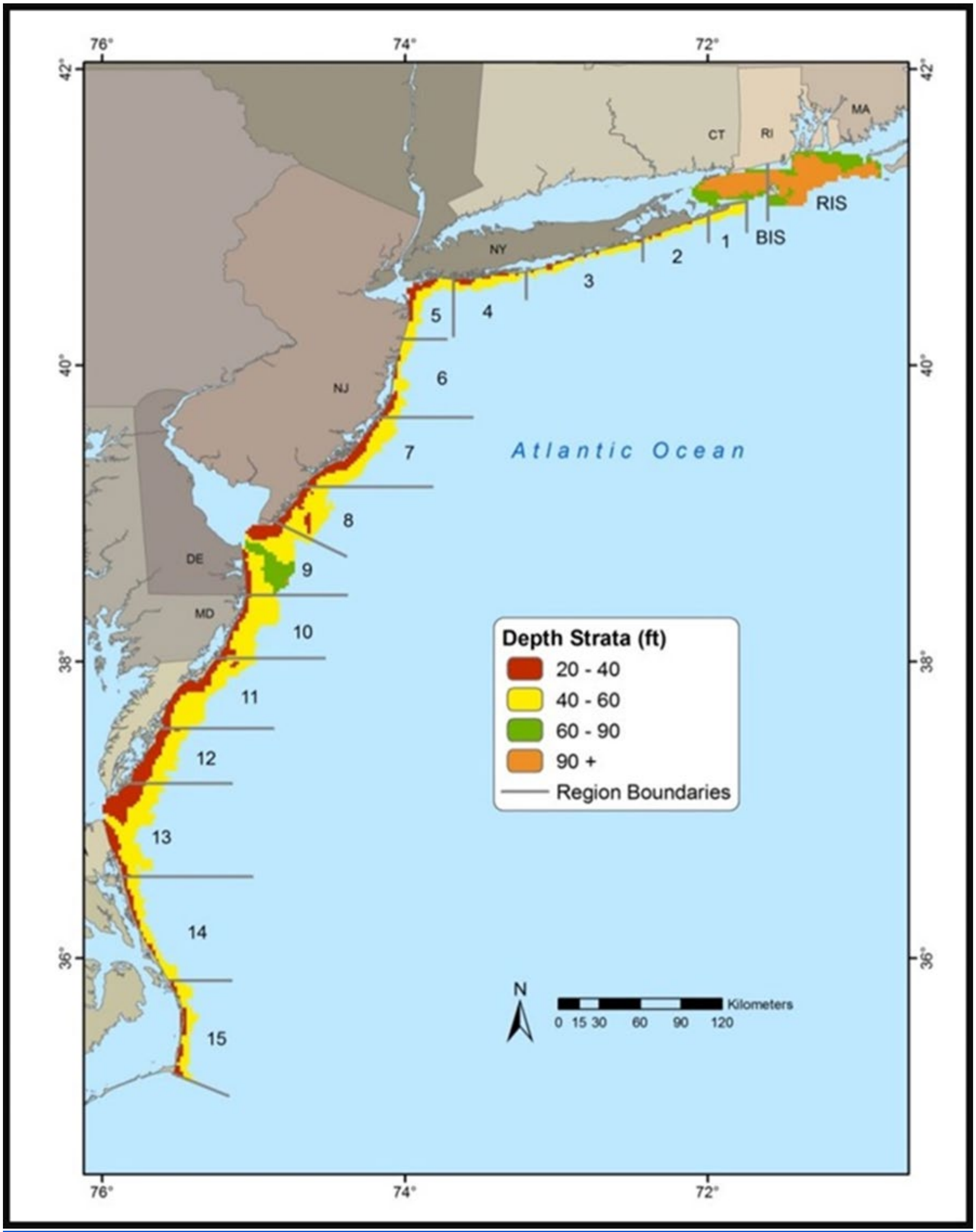


Figure 3.17. Sampling strata used in the NEAMAP survey. Map provided by NEAMAP and available here: http://www.neamap.net/index.html.

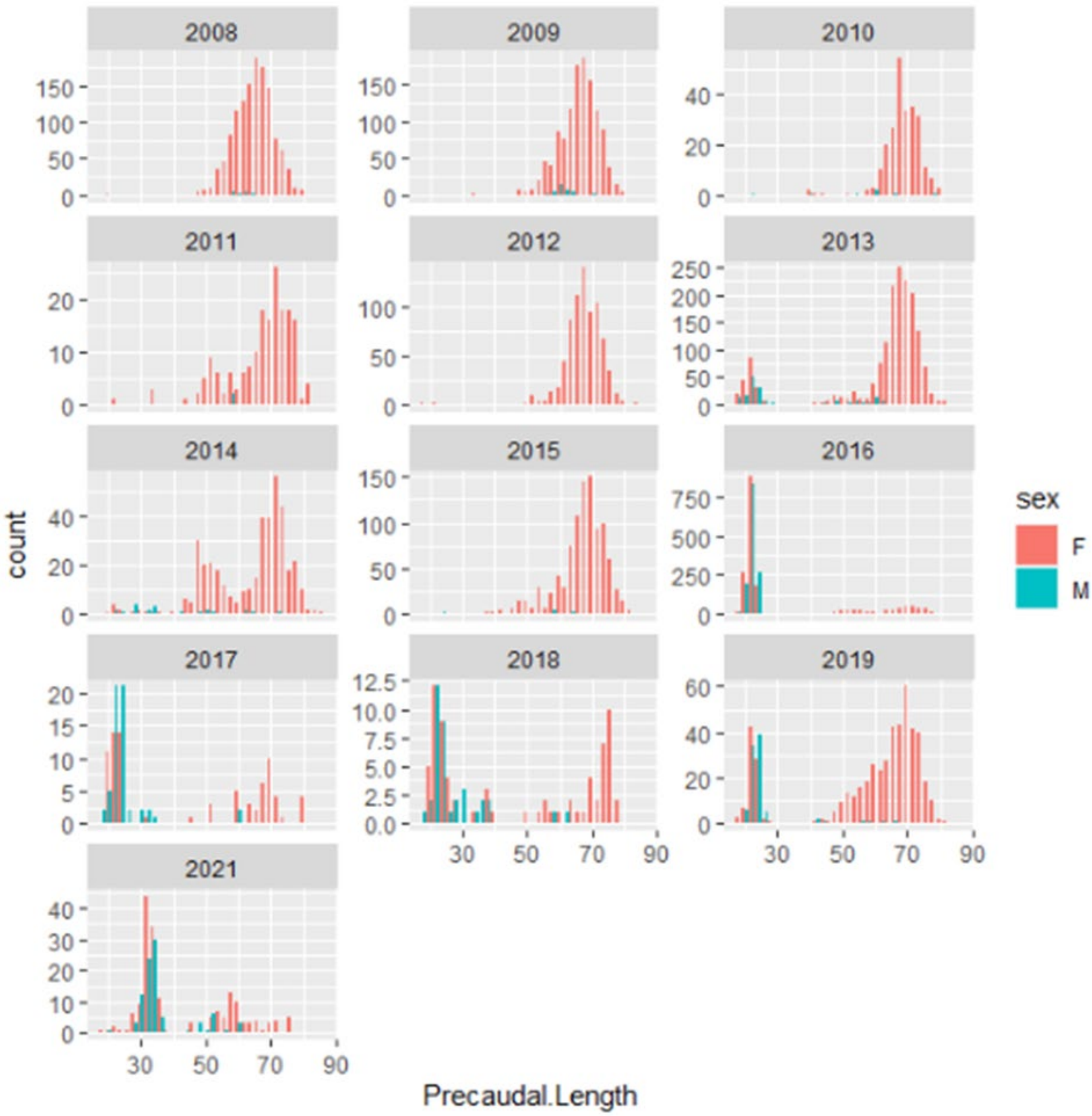


Figure 3.18. NEAMAP precaudal length (cm) frequencies of male and female spiny dogfish by year for the spring tows.

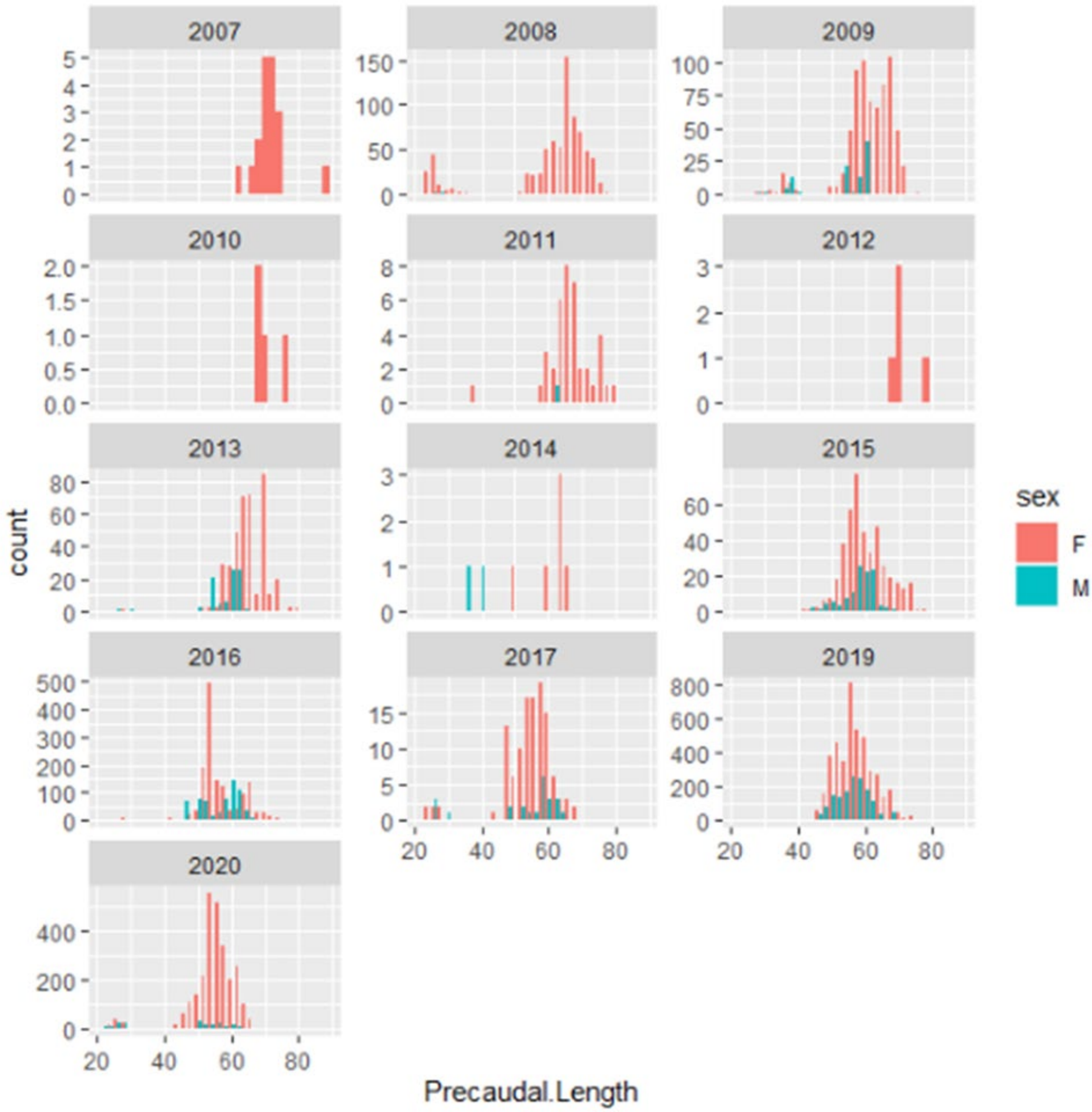


Figure 3.19. NEAMAP precaudal length (cm) frequencies of male and female spiny dogfish by year for the fall tows.

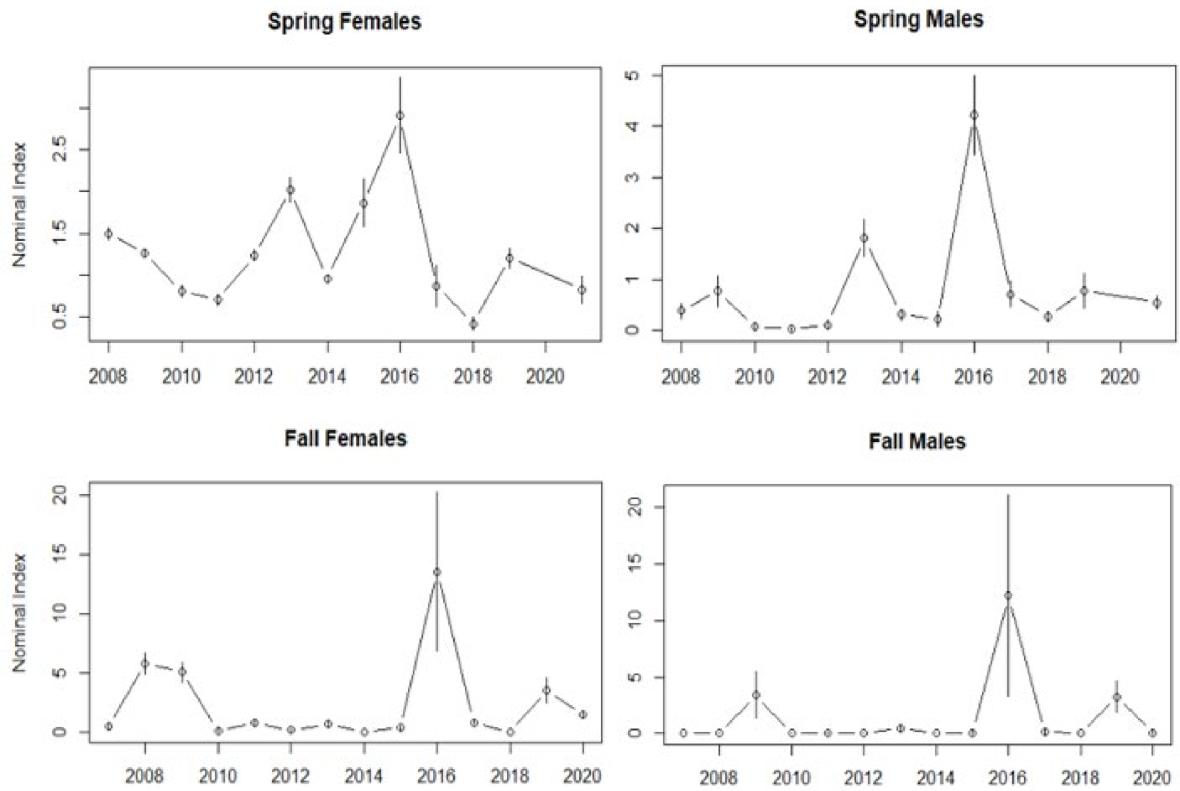


Figure 3.20. NEAMAP nominal (arithmetic mean) indices by season and sex with 95% confidence intervals.

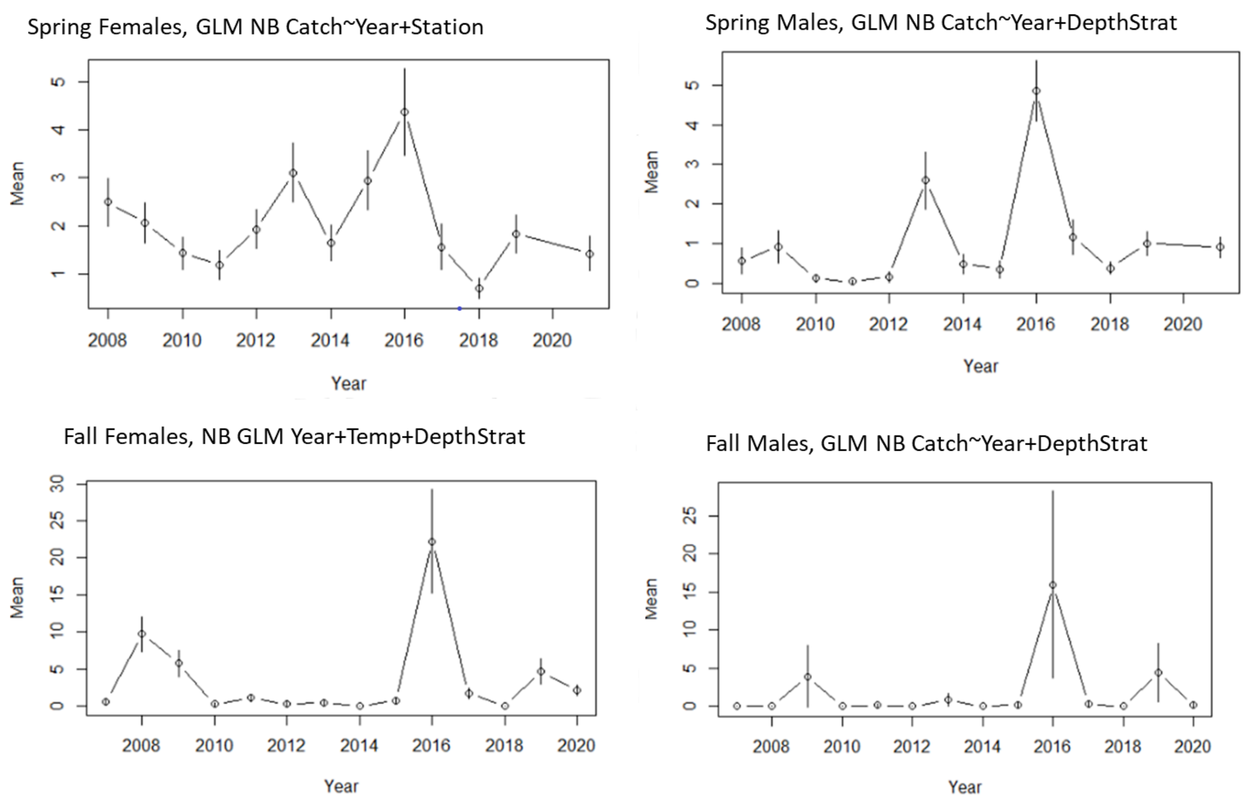


Figure 3.21. NEAMAP standardized indices of abundance by season and sex with 95% confidence intervals.

MADMF TRAWL SURVEY

STATION ASSIGNMENT BY STRATUM

REGION	STRATUM	DEPTH (METERS)	DEPTH (FEET)	SUBSTRATUM A	SUBSTRATUM B	# STATIONS ASSIGNED
5	31	0 - 9.1	0 - 30	2	1	3
	32	9.2 - 18.3	31- 60	1	2	3
	33	18.4 - 27.4	61 - 90	2	2	4
	34	27.5 - 36.6	91 - 120	2	2	4
	35	36.7 - 54.9	121 - 180	2	3	5
	36	>=55.0	>180	1	1	2
4	25	0 - 9.1	0 - 30	2	2	4
	26	9.2 - 18.3	31- 60	3	2	5
	27	18.4 - 27.4	61 - 90	3	2	5
	28	27.5 - 36.6	91 - 120	3	2	5
	29	36.7 - 54.9	121 - 180	3	2	5
	30	>=55.0	>180	0	2	2
3	17	0 - 9.1	0 - 30	2	3	5
	18	9.2 - 18.3	31- 60	2	3	5
	19	18.4 - 27.4	61 - 90	1	1	2
	20	27.5 - 36.6	91 - 120	2	0	2
	21	36.7 - 54.9	121 - 180	2	0	2
2	15	0 - 9.1	0 - 30	10		10
	16	9.2 - 18.3	31- 60	11		11
1	11	0 - 9.1	0 - 30	3	2	5
	12	9.2 - 18.3	31- 60	5	2	7
	13	18.4 - 27.4	61 - 90	3	2	5
	14	27.5 - 36.6	91 - 120	1	1	2
TOTAL STATION ASSIGNMENT						103

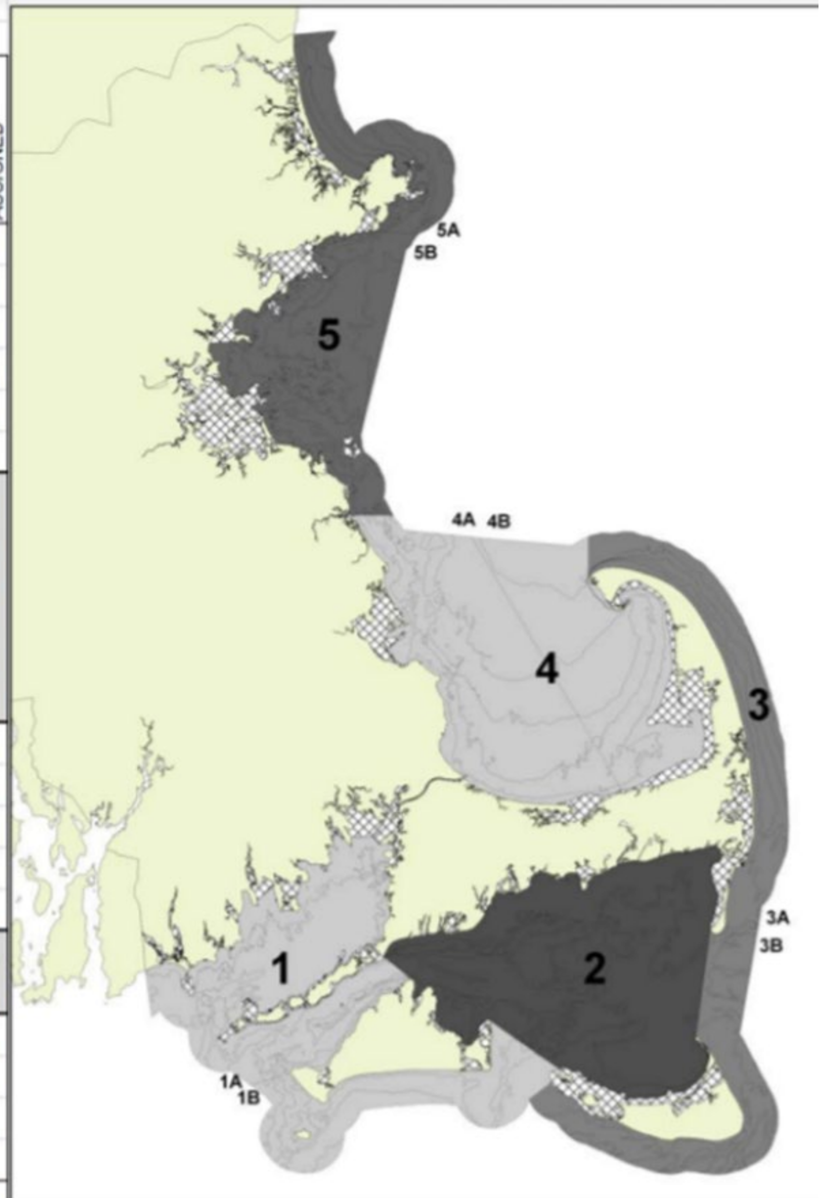


Figure 3.22 MADMF biannual bottom trawl survey strata.

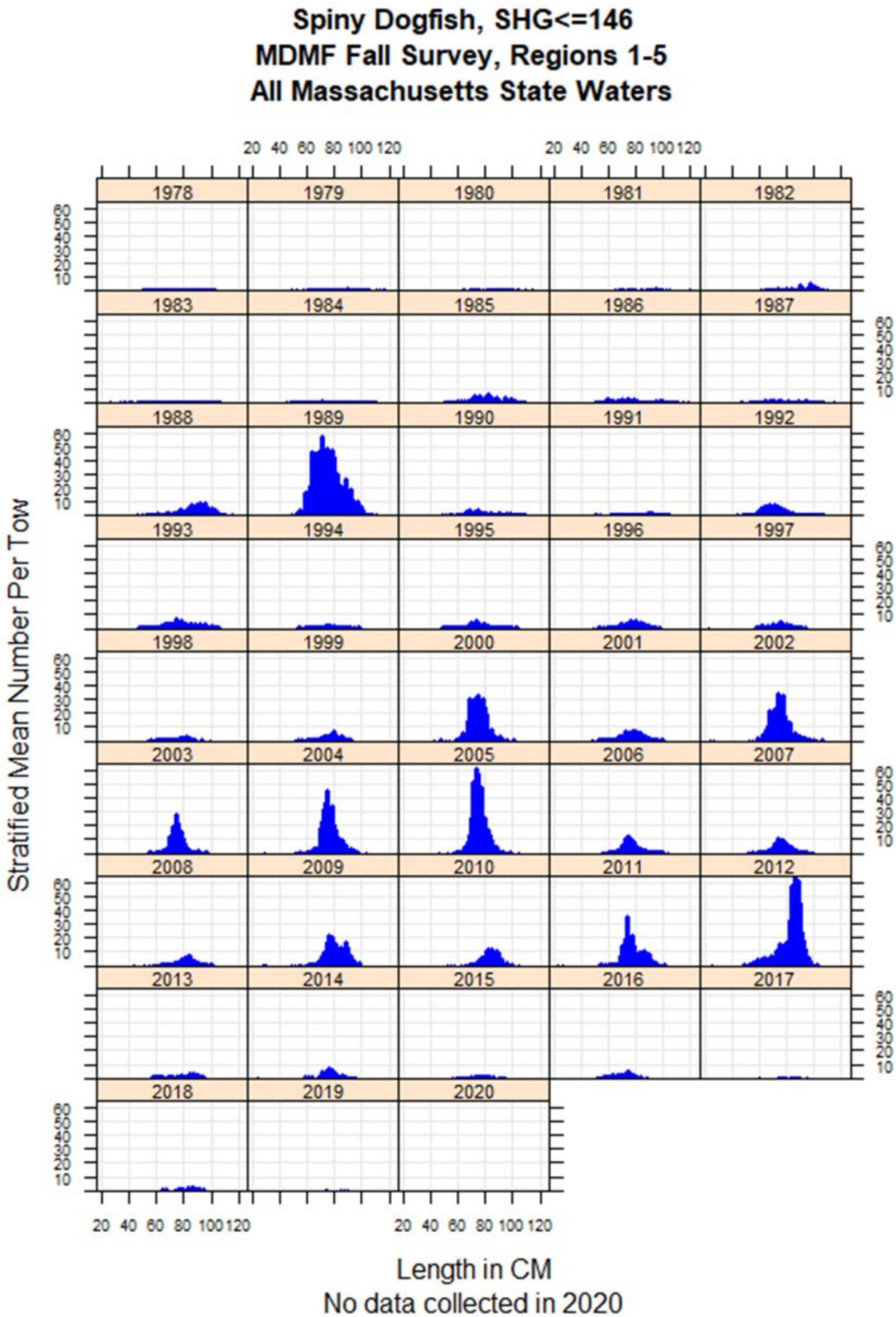


Figure 3.23. MADMF fall bottom trawl survey length composition by year.

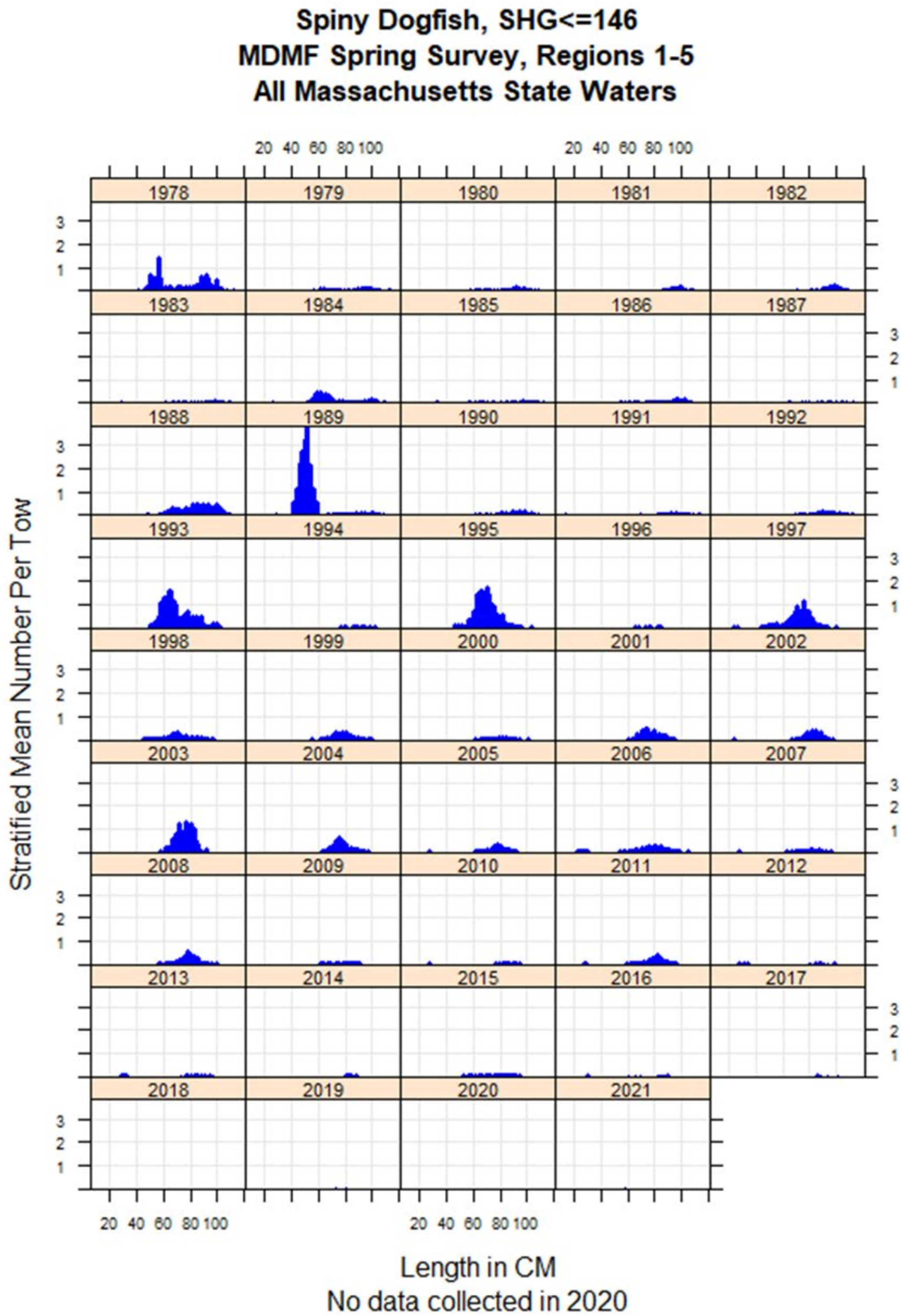


Figure 3.24. MDMF spring bottom trawl survey length composition by year.

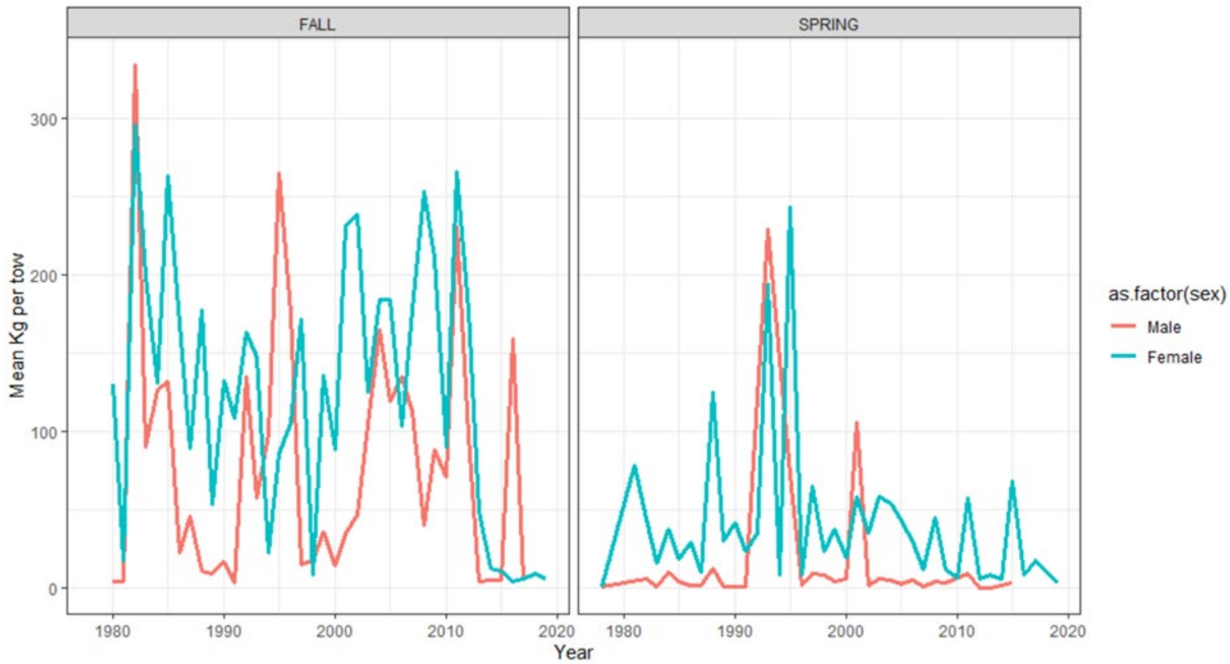


Figure 3.25. MADMF fall and spring survey mean kg/tow.

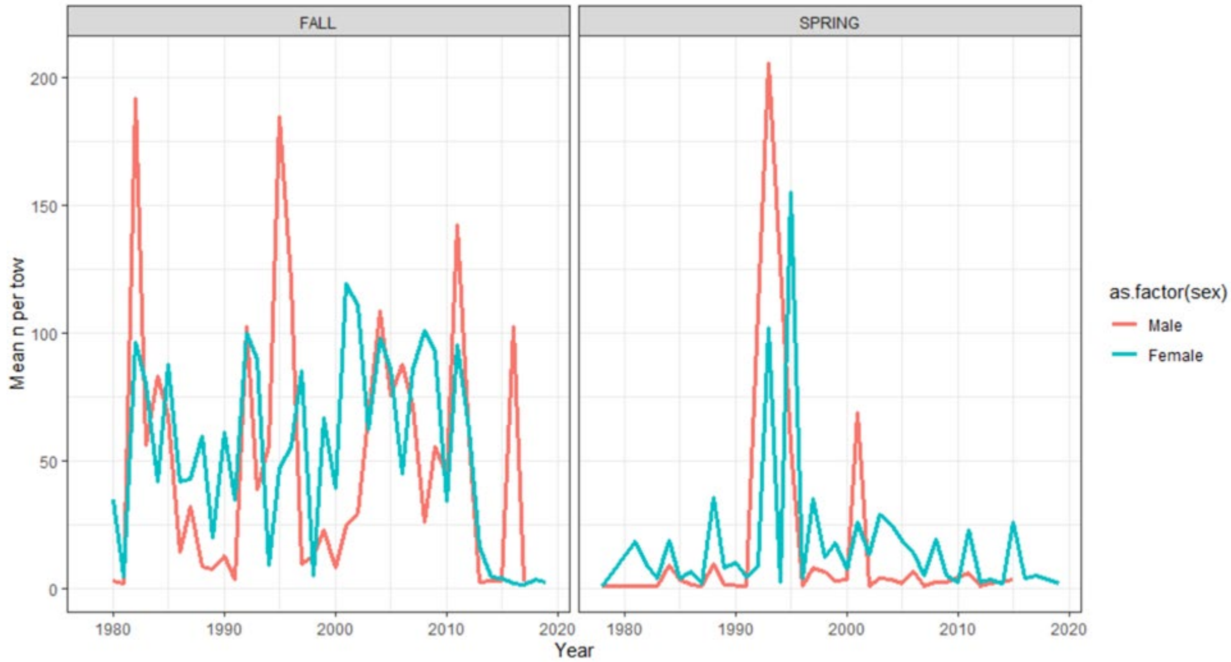


Figure 3.26. MADMF fall and spring survey mean numbers/tow.

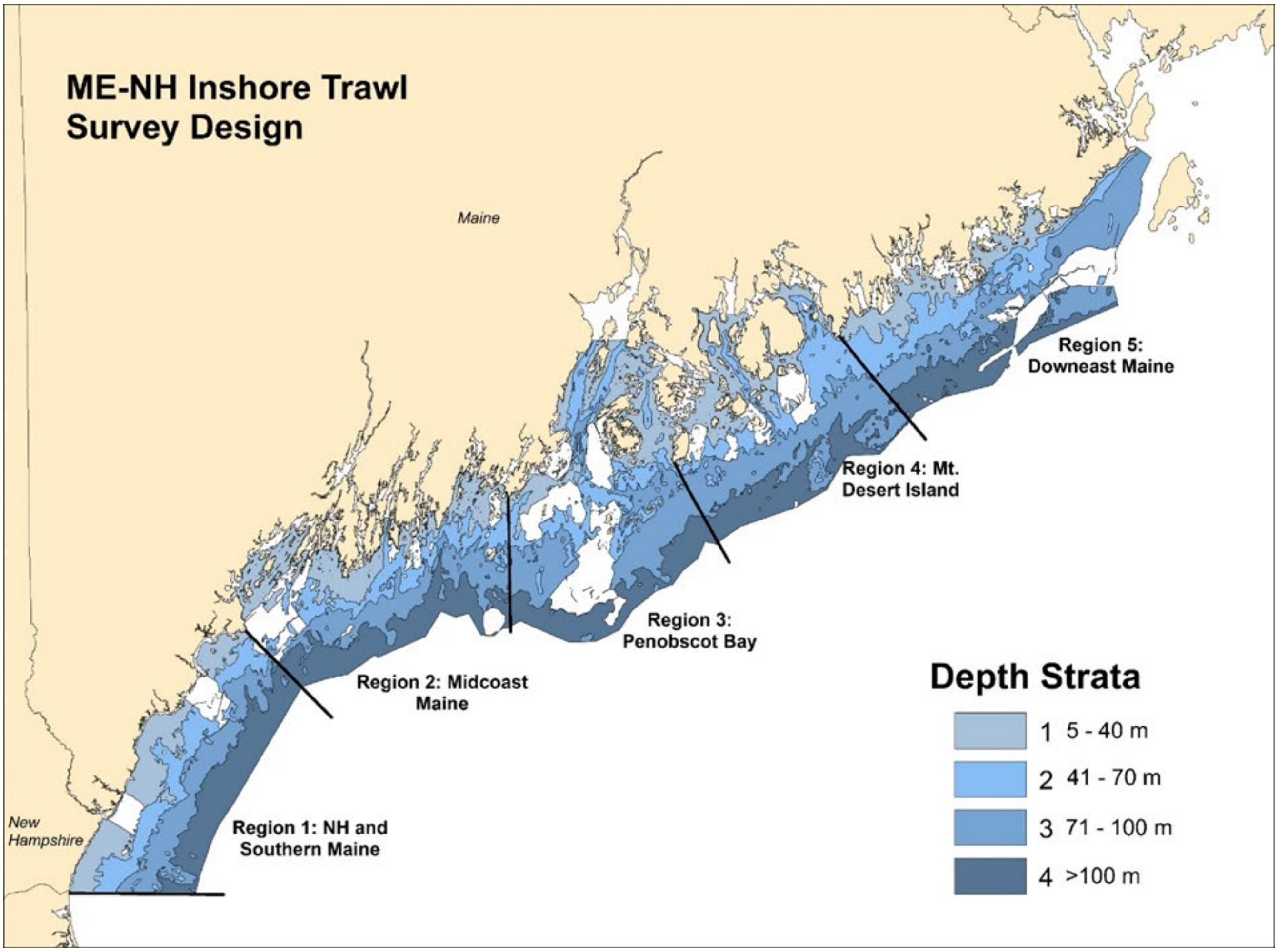


Figure 3.27. ME-NH Inshore Trawl Survey Strata.

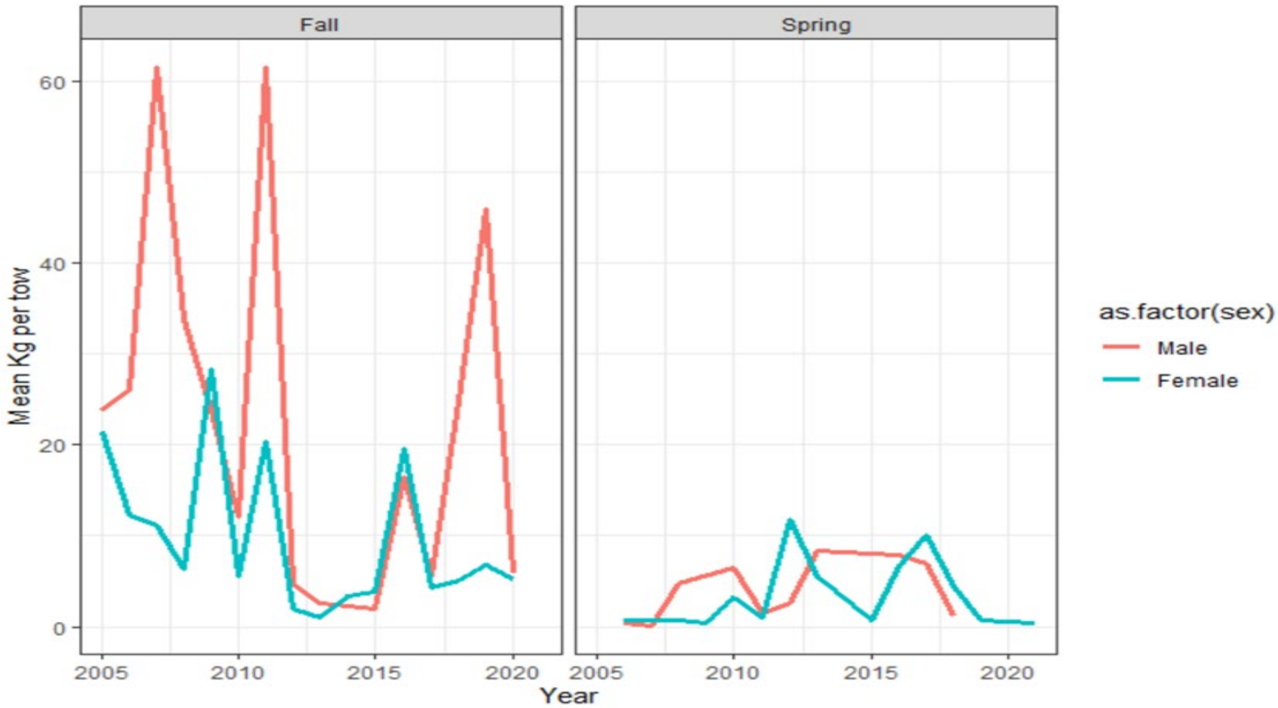


Figure 3.28. ME-NH Inshore Trawl fall and spring survey mean kg/tow.

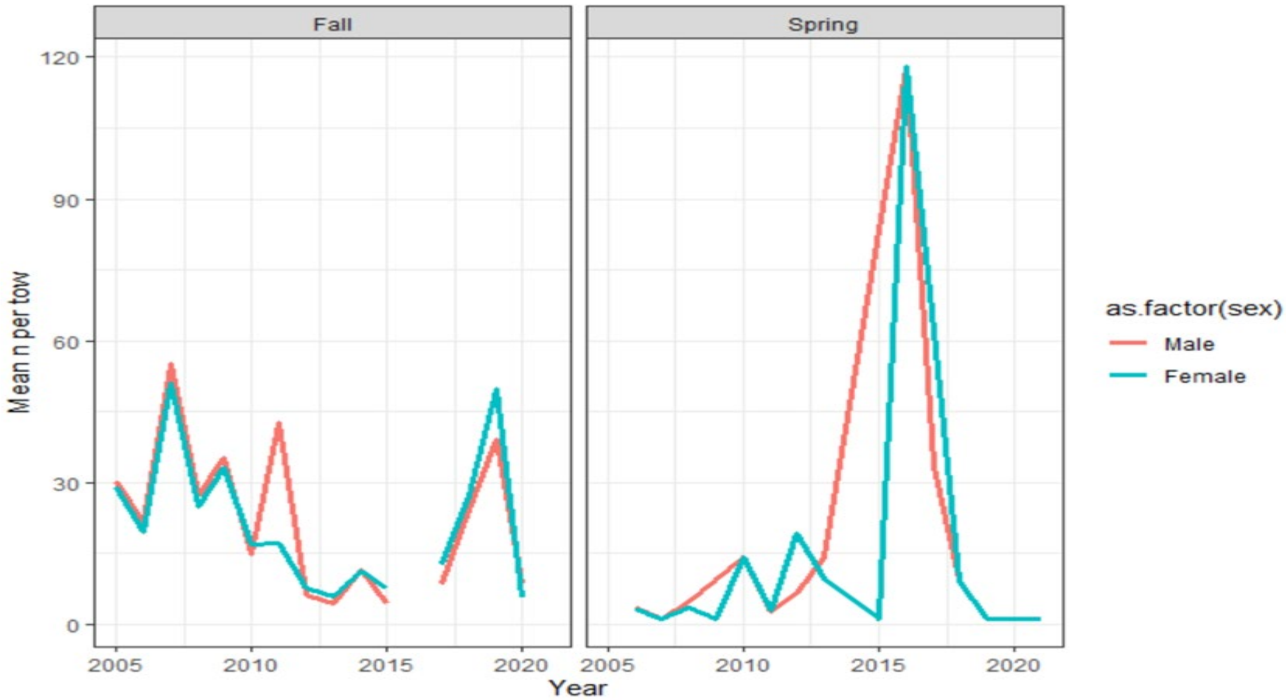


Figure 3.29. ME-NH Inshore Trawl fall and spring survey mean numbers/tow.

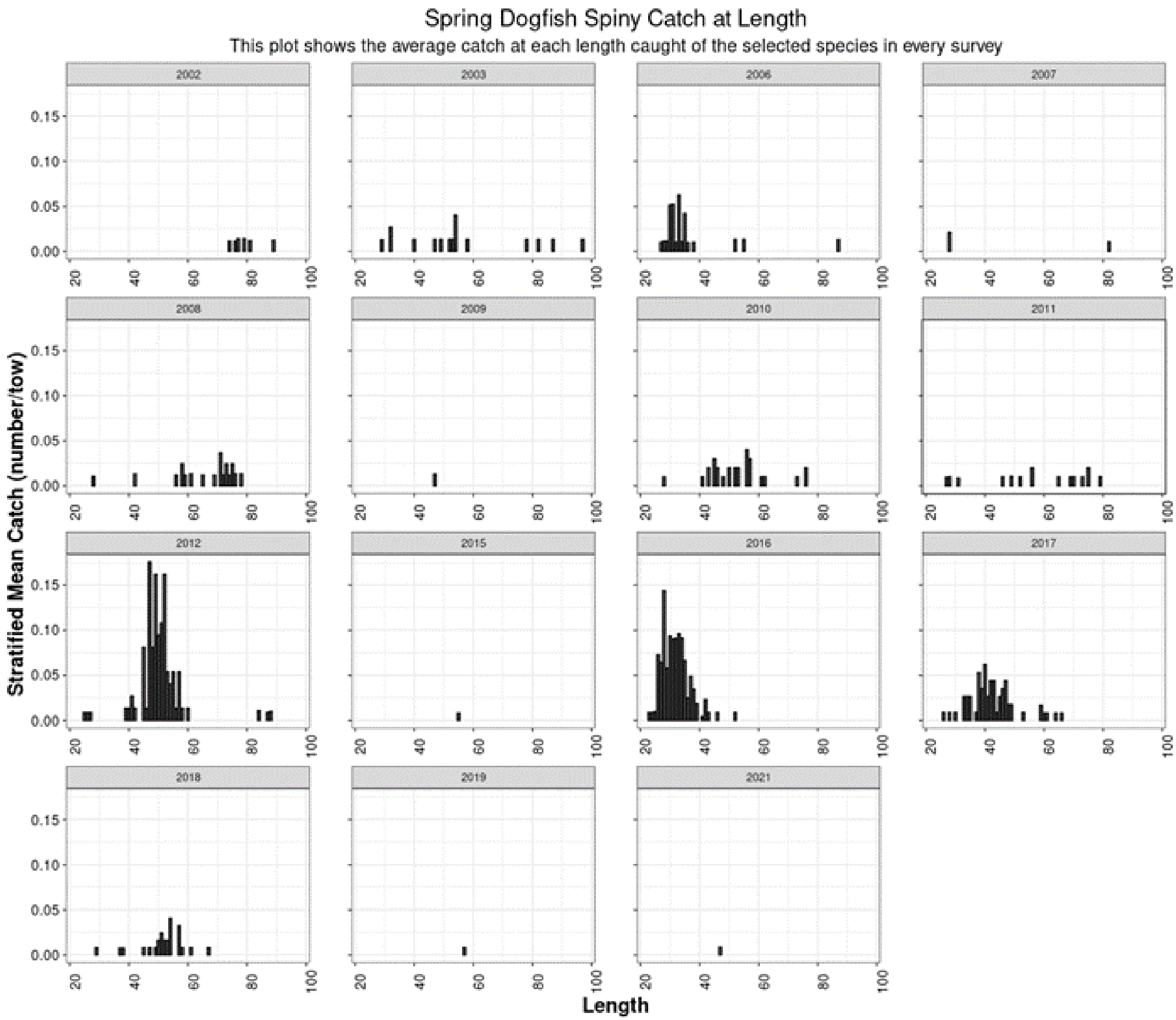


Figure 3.30. ME-NH spring bottom trawl survey length composition by year.

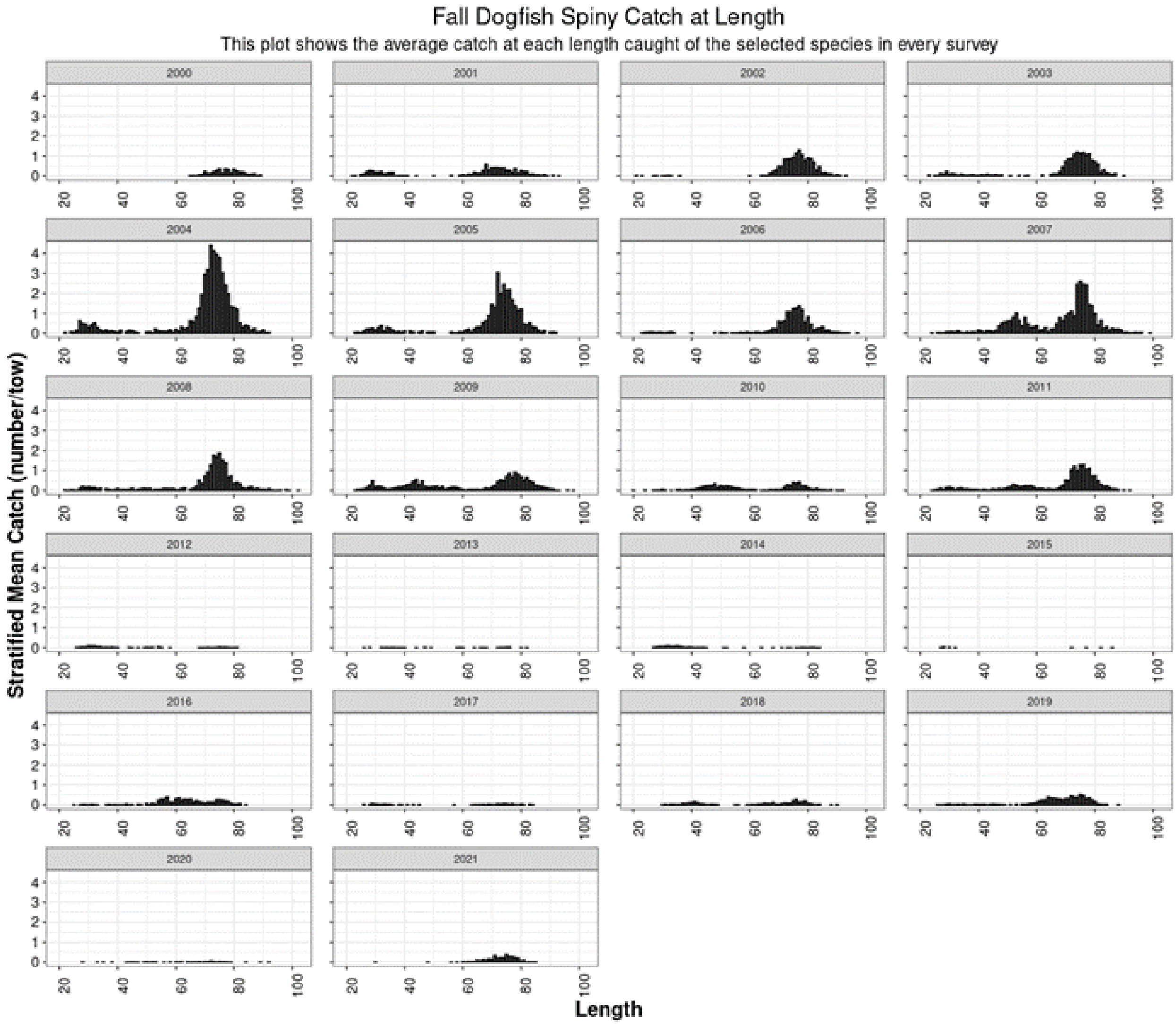


Figure 3.31. ME-NH fall bottom trawl survey length composition by year.

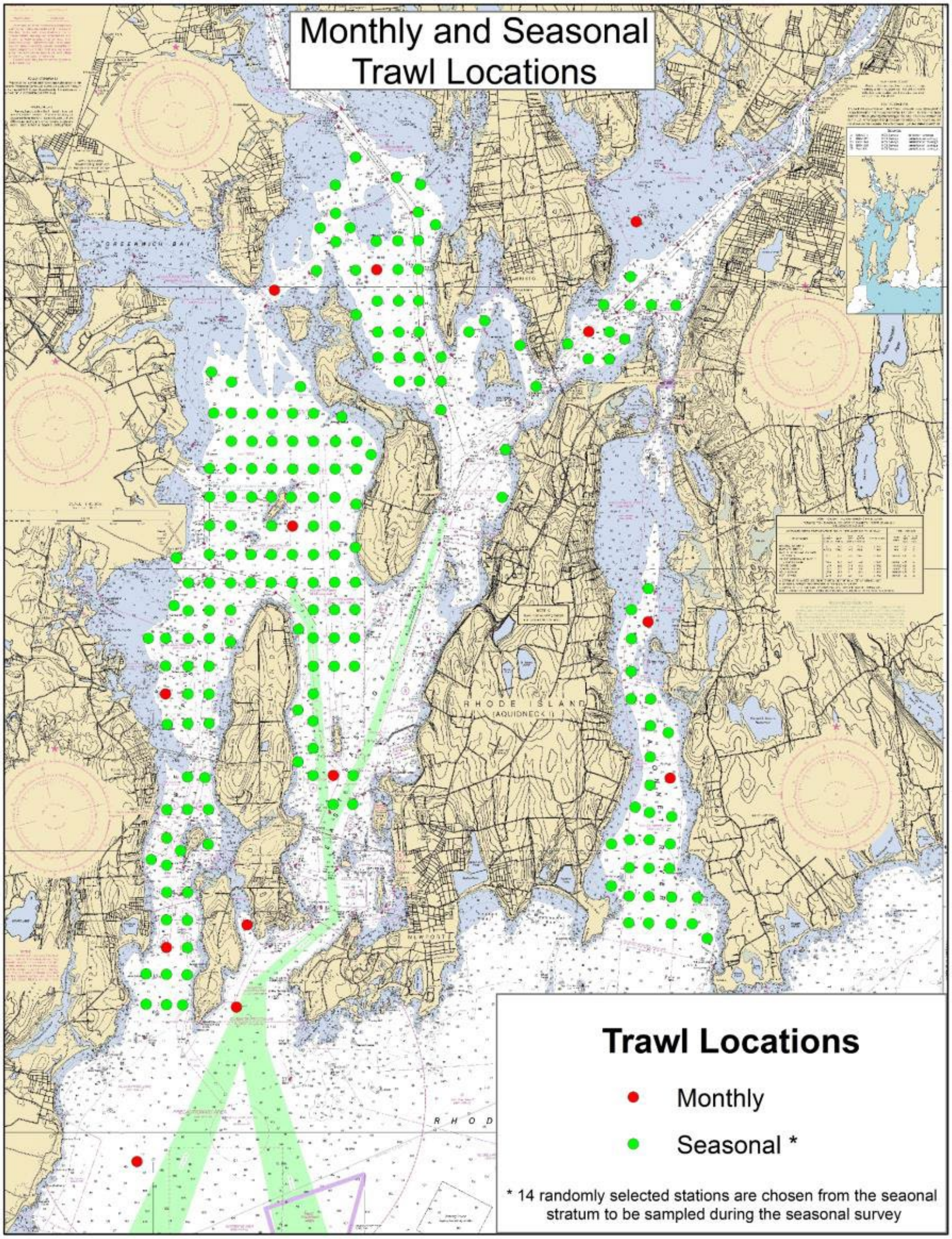


Figure 3.32. RI DEM Monthly and Seasonal Bottom Trawl locations in Narragansett Bay.

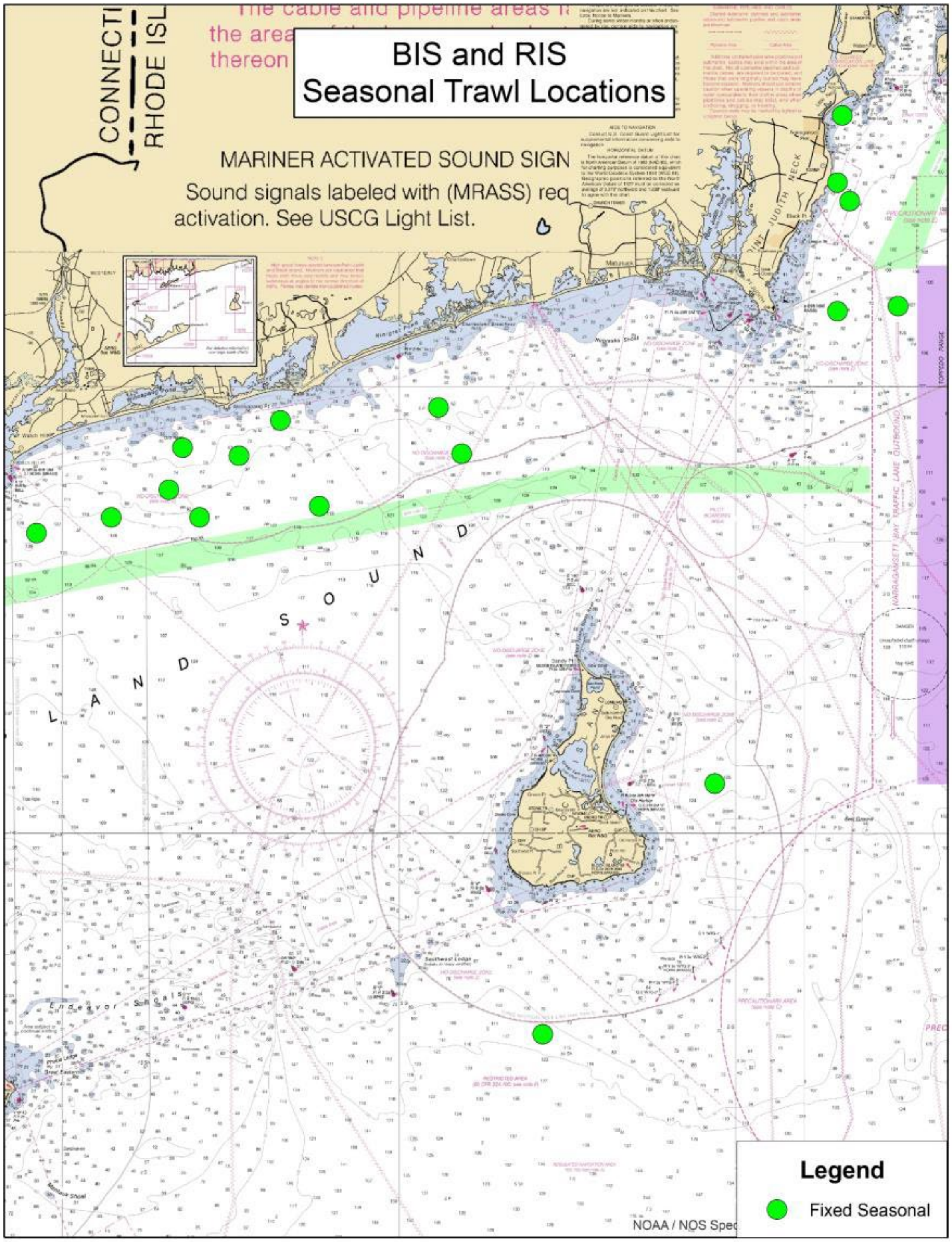


Figure 3.33. RI DEM Seasonal Bottom Trawl locations in Rhode Island and Block Island Sounds.

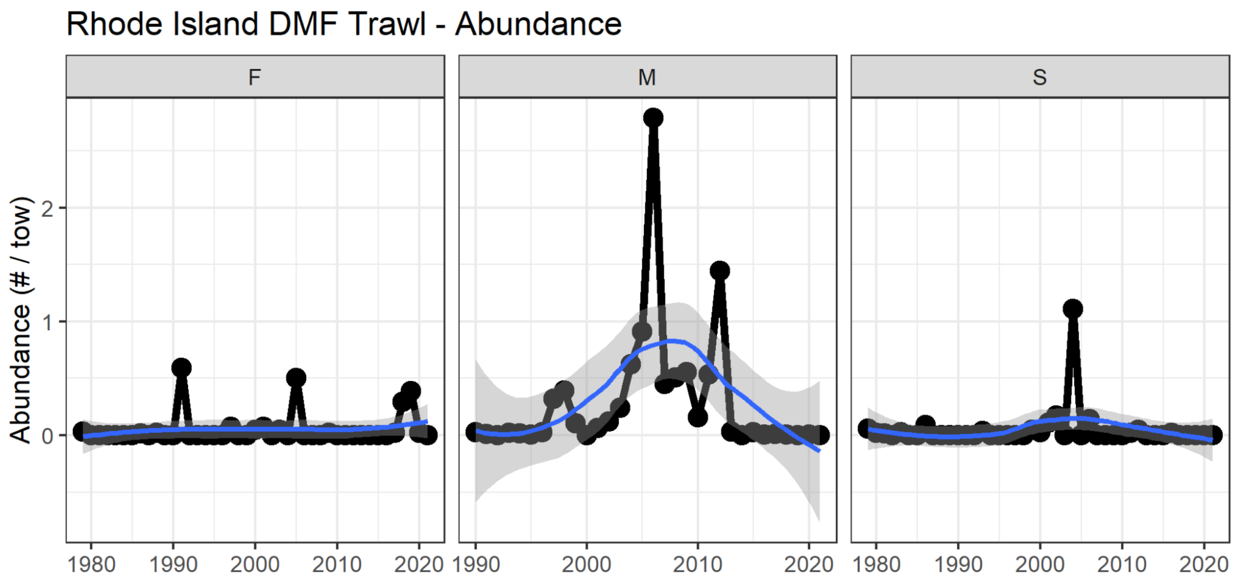


Figure 3.34. Rhode Island Fall (F) and Spring (S) Seasonal and Monthly (M) surveys mean numbers/tow.

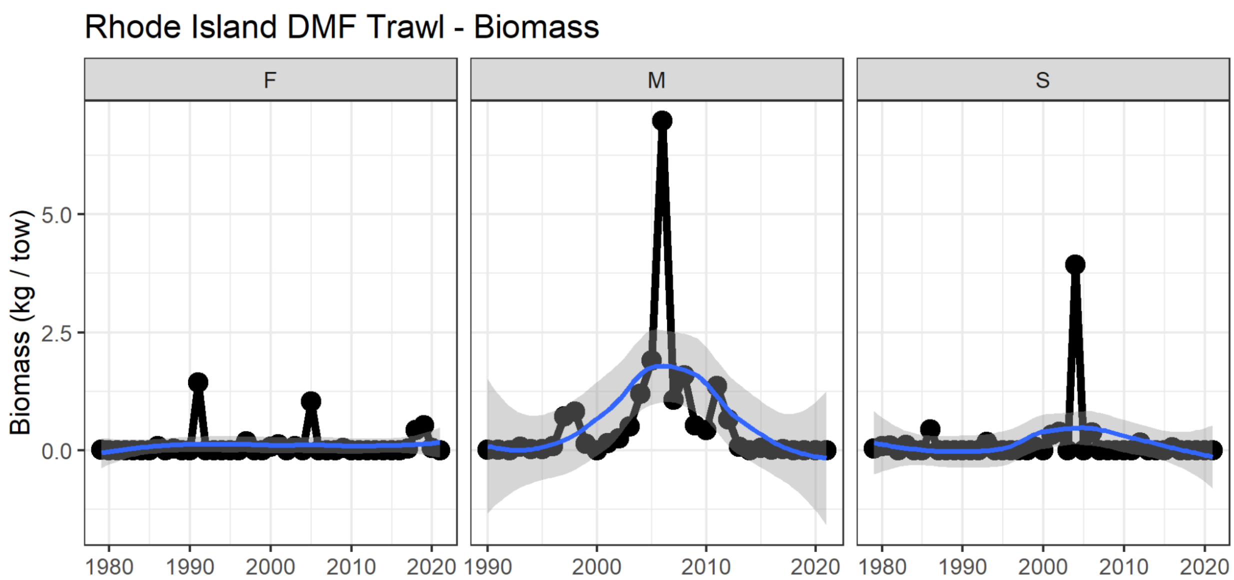


Figure 3.35. Rhode Island Fall (F) and Spring (S) Seasonal and Monthly (M) surveys mean kg/tow.

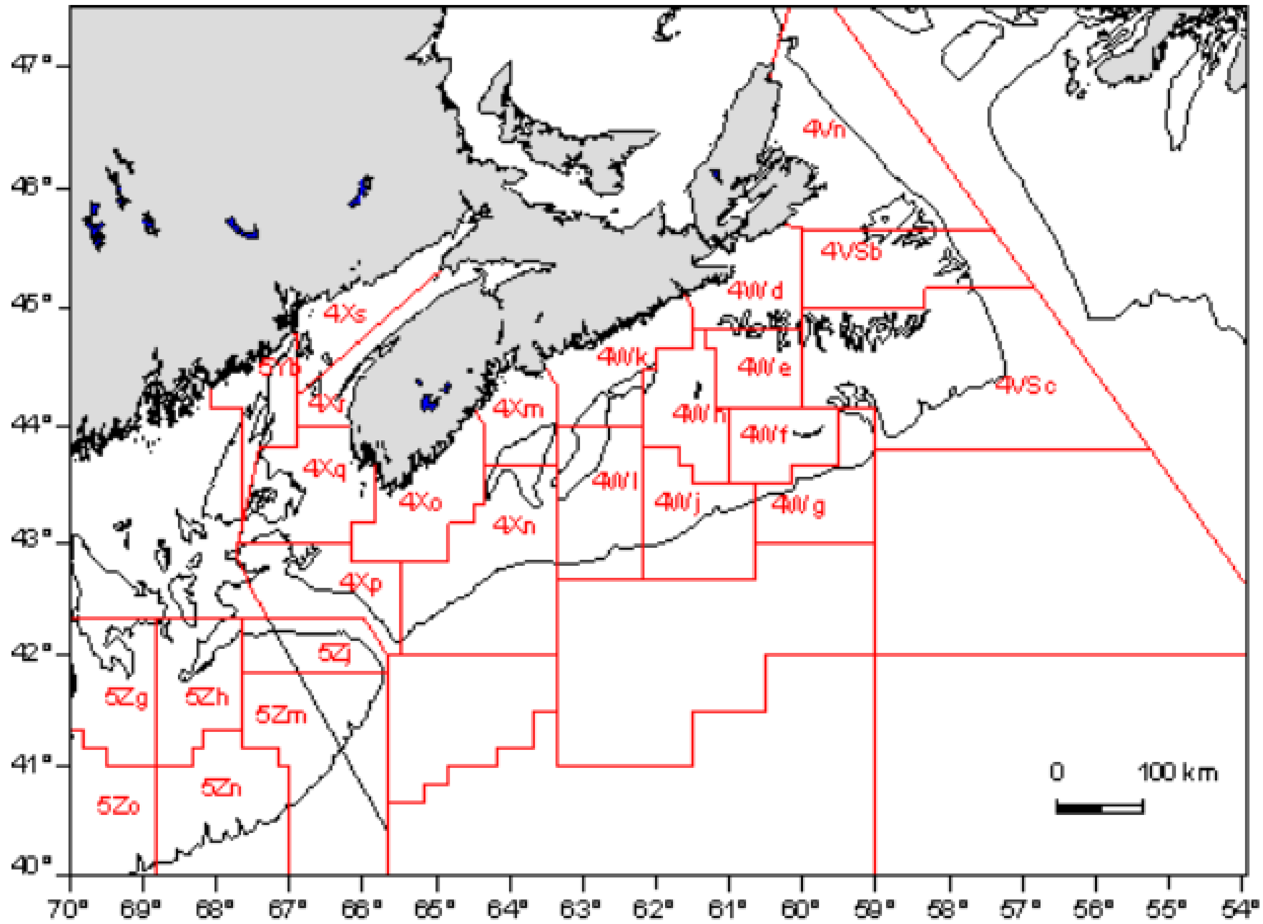


Figure 3.36. Northwest Atlantic Fisheries Organization Divisions

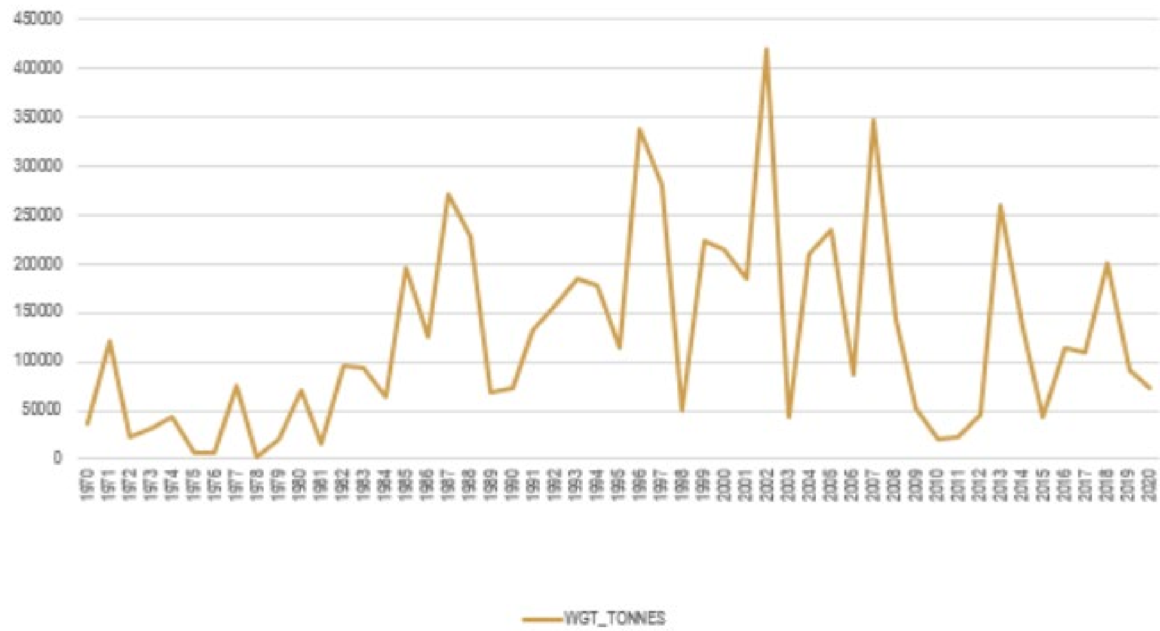


Figure 3.37. Design based biomass index for the Canada DFO Scotian Shelf Summer Survey.

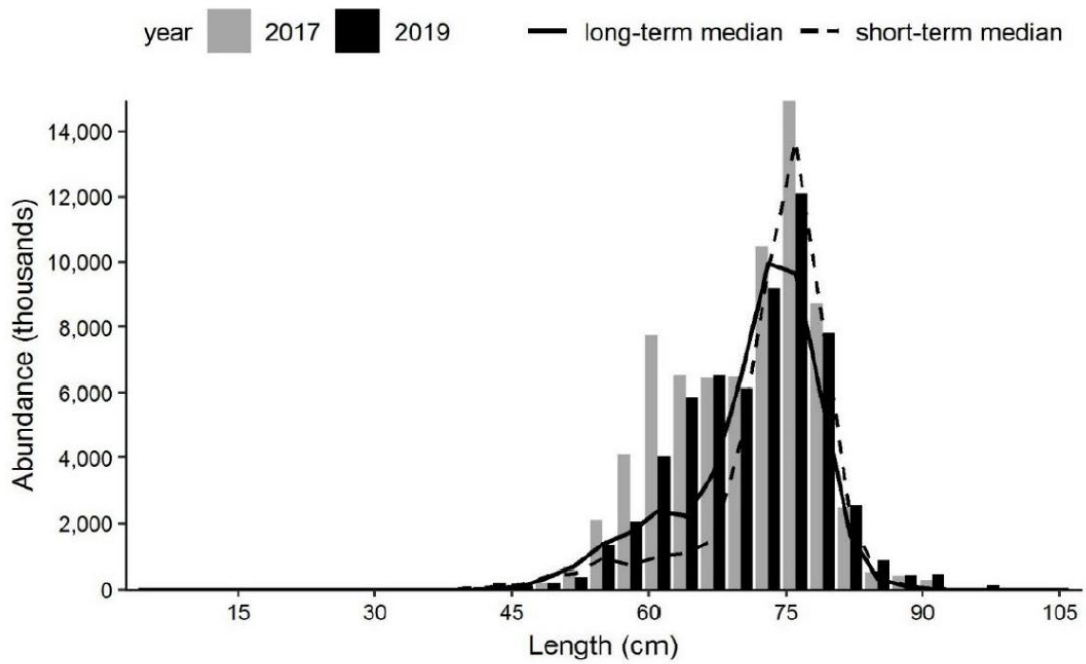


Figure 3.38. Scotian Shelf Survey length frequency indices. Gray and black bars represent the number in thousands at length for 2017 and 20197, respectively. The solid and dashed black lines represent the median in thousands at length for 1970–2017 and 2008-2017, respectively.

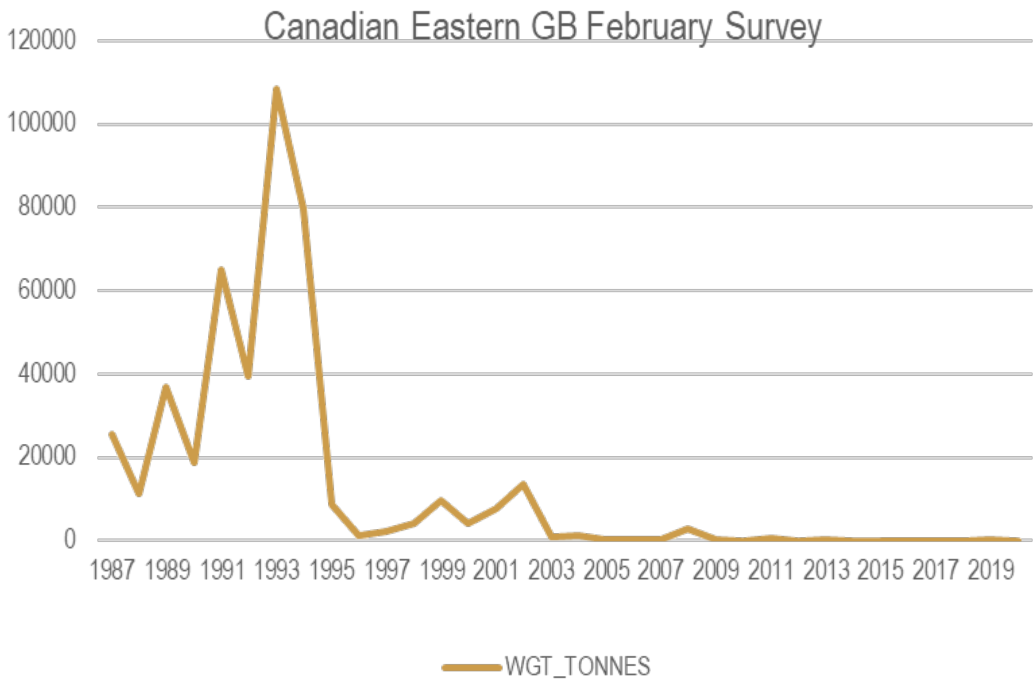


Figure 3.39. Design based biomass index for the Canada DFO Eastern Georges Bank Survey.

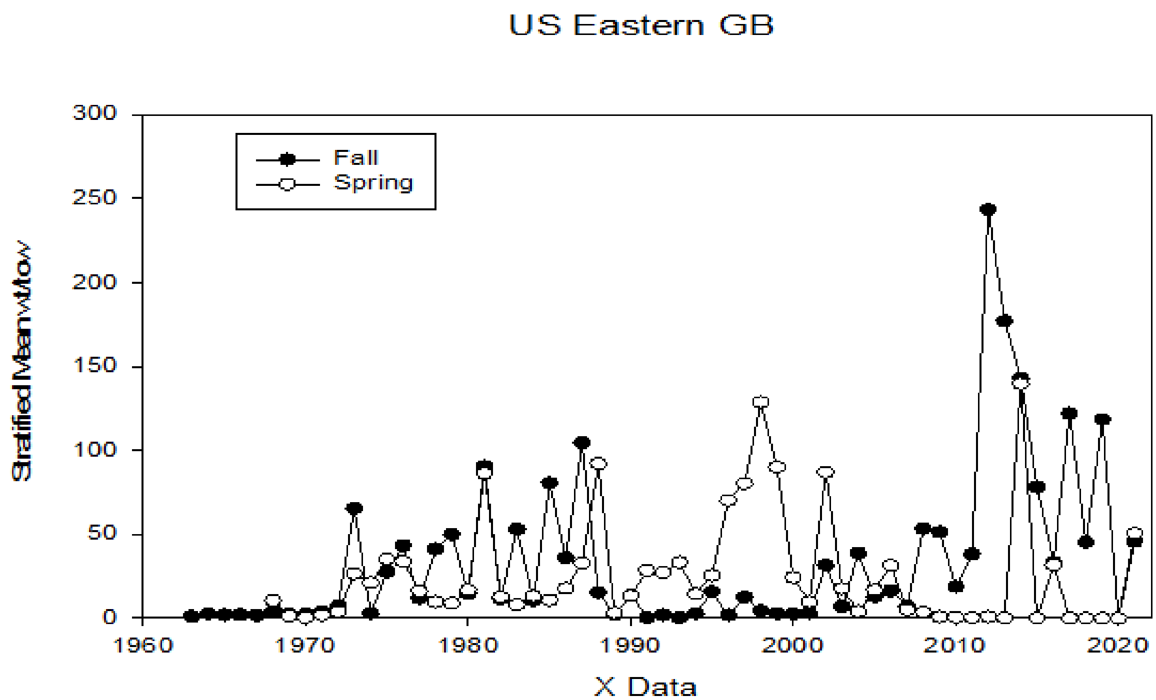


Figure 3.40. NEFSC Fall and Spring Bottom Trawl Survey stratified mean/tow for the US Eastern Georges Bank.

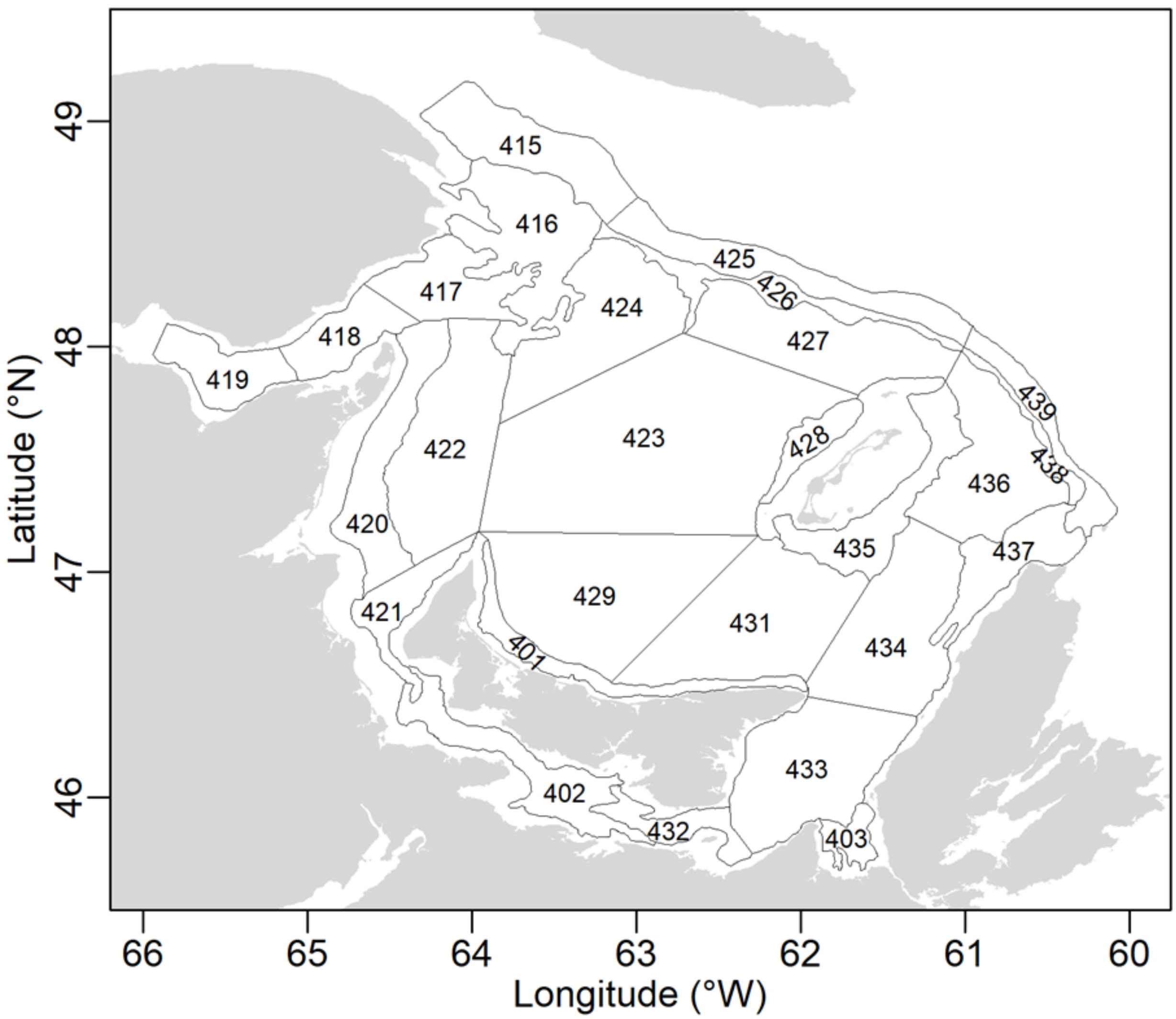


Figure 3.41. Canada DFO Southern Gulf of St. Lawrence survey strata.

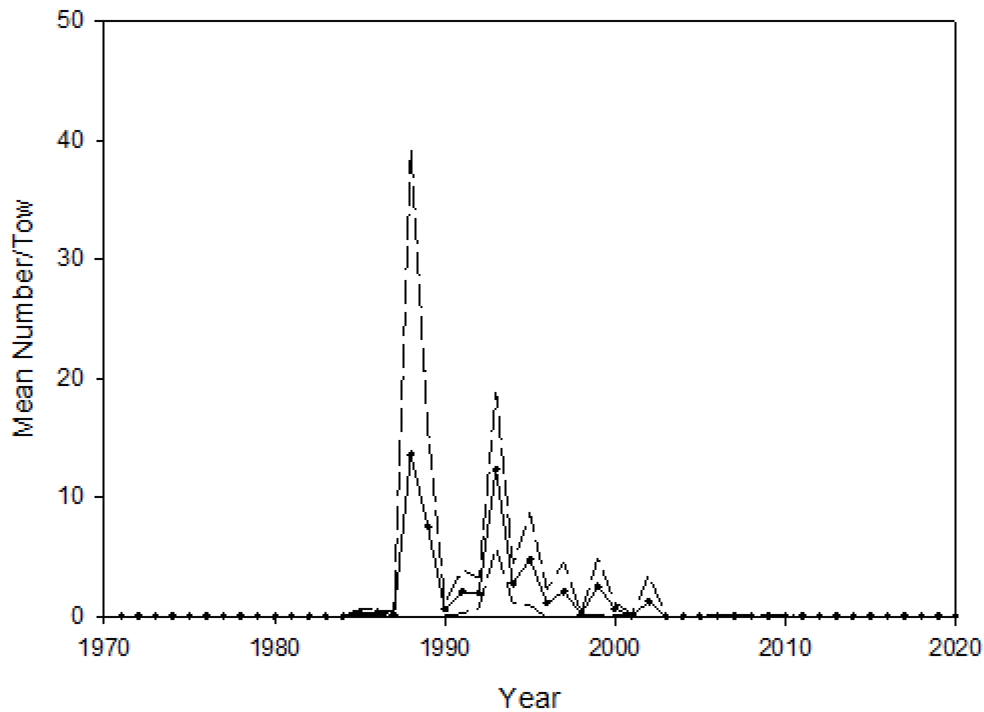


Figure 3.42. Annual mean numbers per tow for the Southern Gulf of St. Lawrence Survey

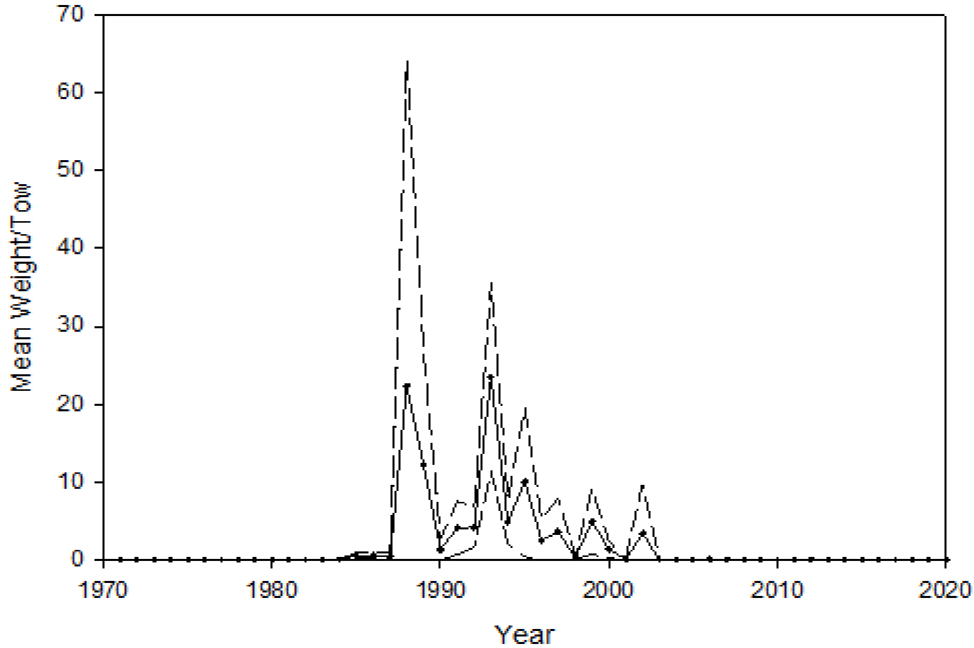


Figure 3.43. Annual mean weight (kg) per tow for the Southern Gulf of St. Lawrence Survey

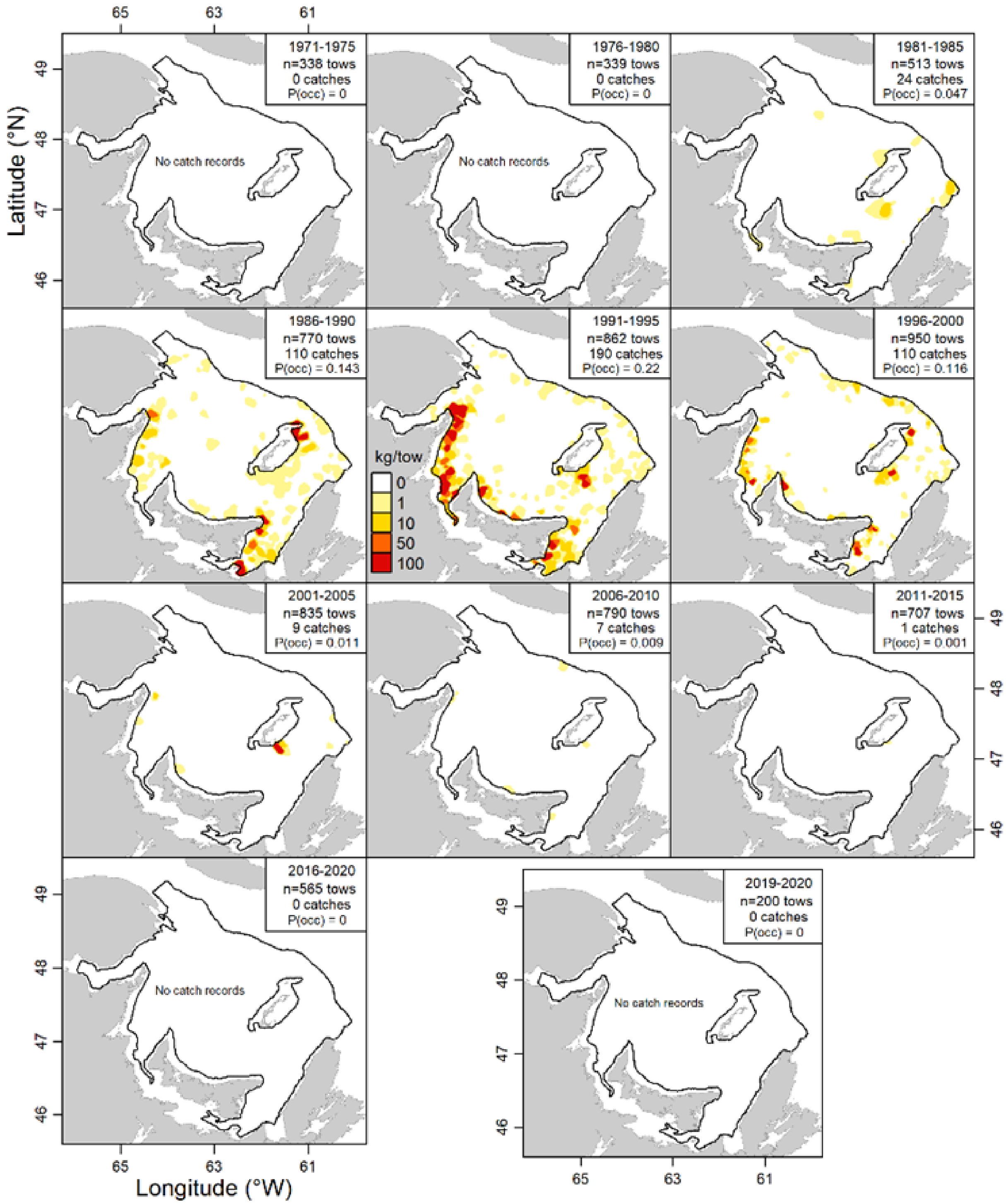


Figure 3.44. Distribution of survey mean weight (kg) per tow within the Southern Gulf of St Lawrence.

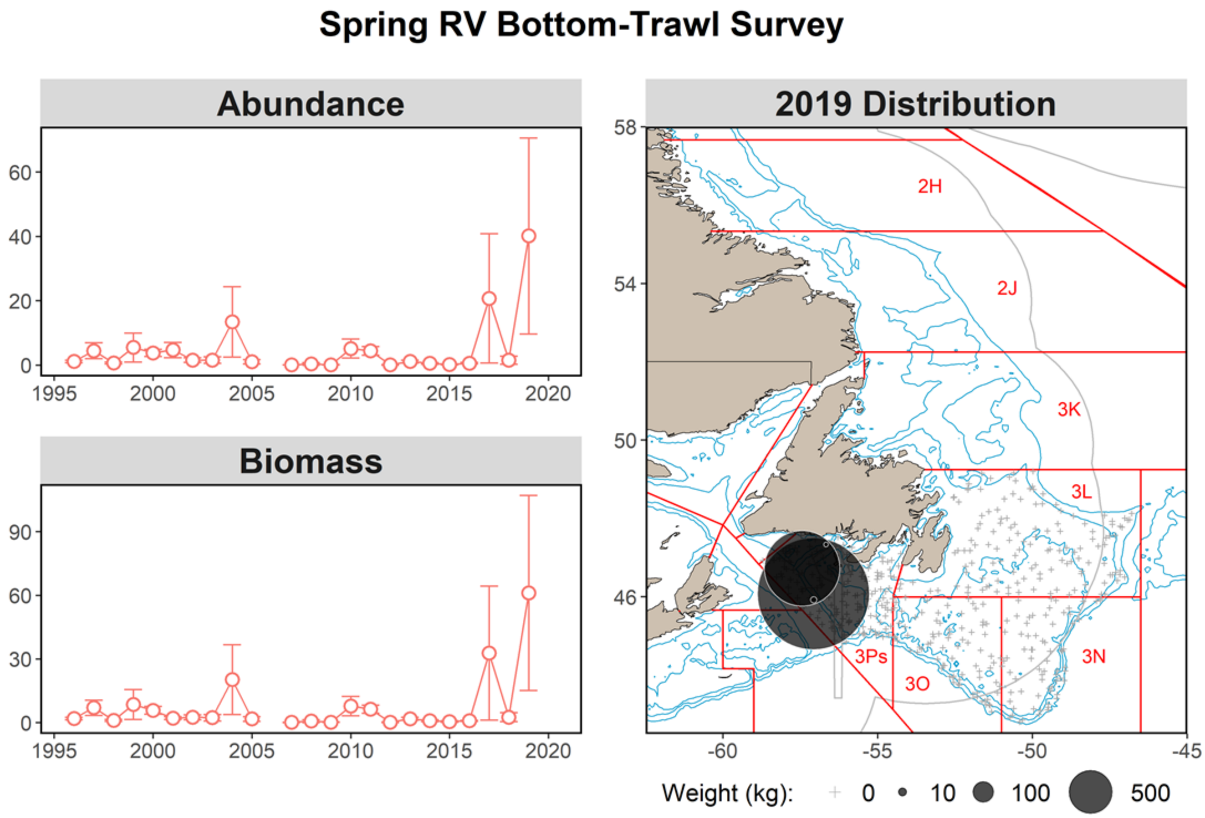


Figure 3.45. Canada DFO Spring Grand Banks abundance and biomass from 1996 - 2019 with 95% confidence intervals and weight (kg) per tow plotted within the survey area for the last year of the survey (2019).

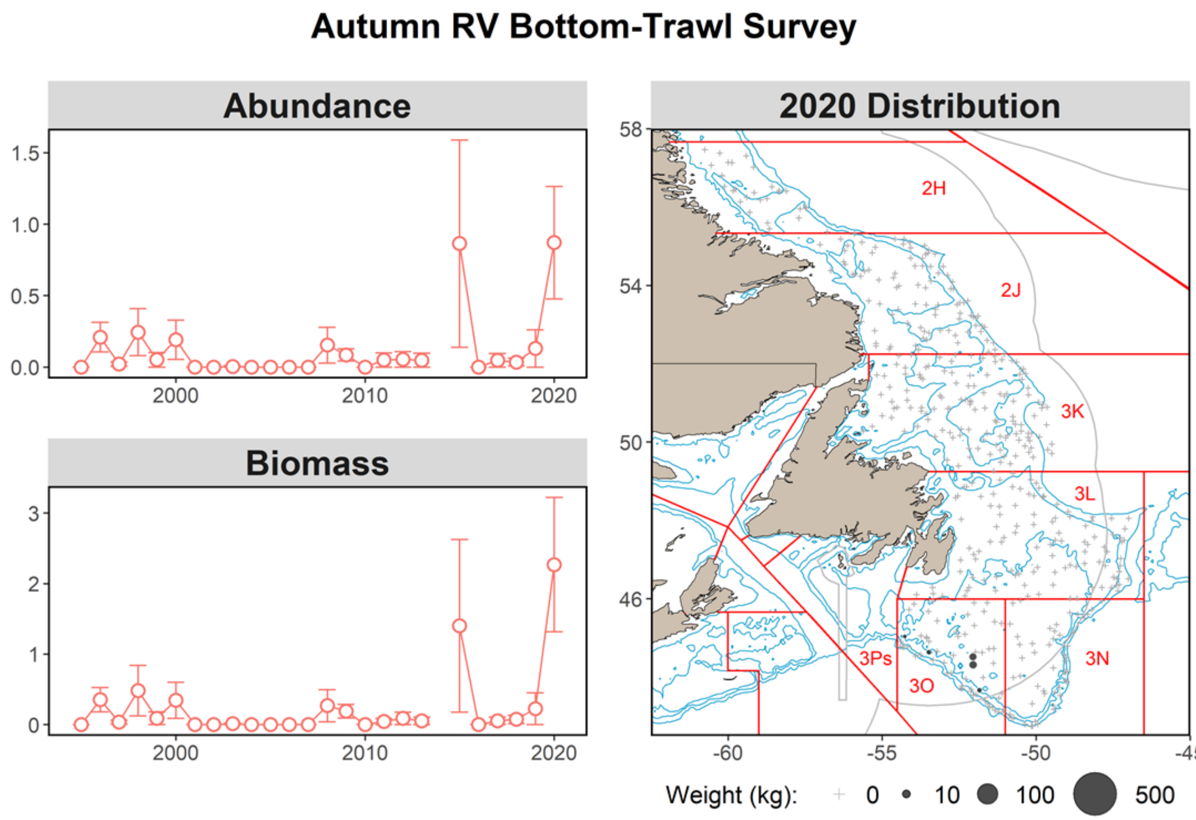


Figure 3.46. Canada DFO Fall Grand Banks and Labrador abundance and biomass from 1996 - 2020 with 95% confidence intervals and weight (kg) per tow plotted within the survey area for the last year of the survey (2020).

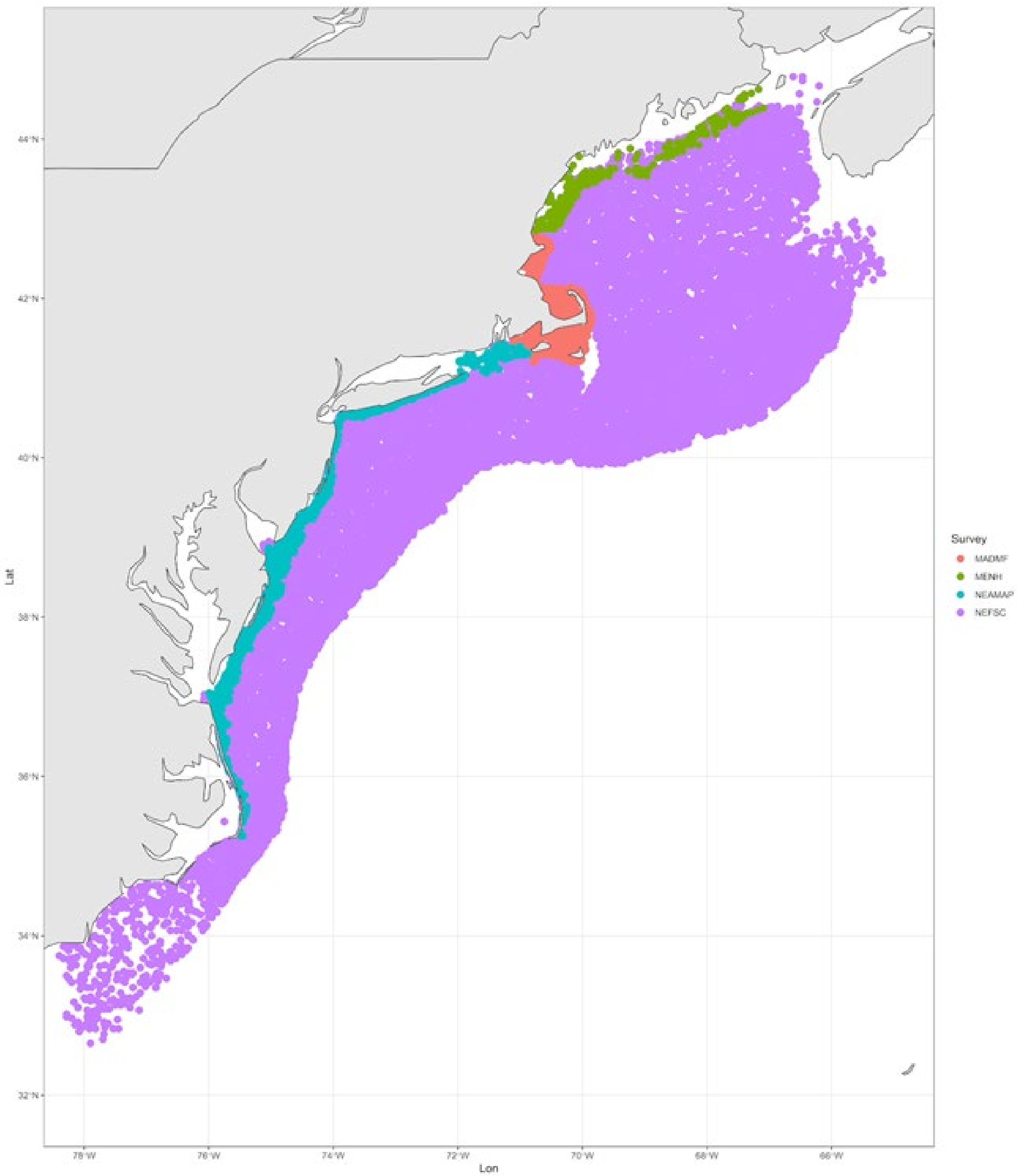


Figure 3.47: Survey data explored in VAST models for spiny dogfish.

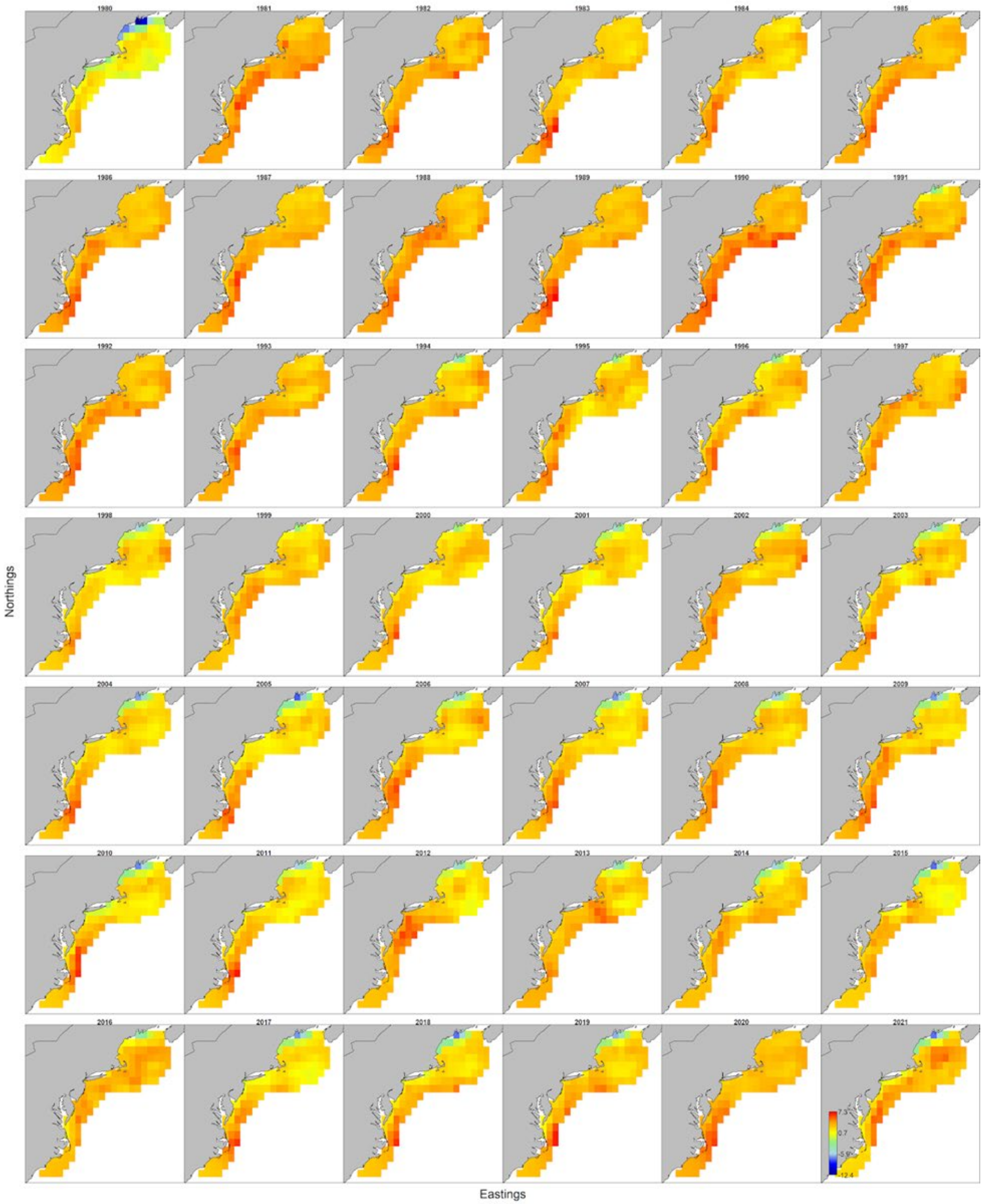


Figure 3.48: VAST estimated abundance for spiny dogfish in the spring.

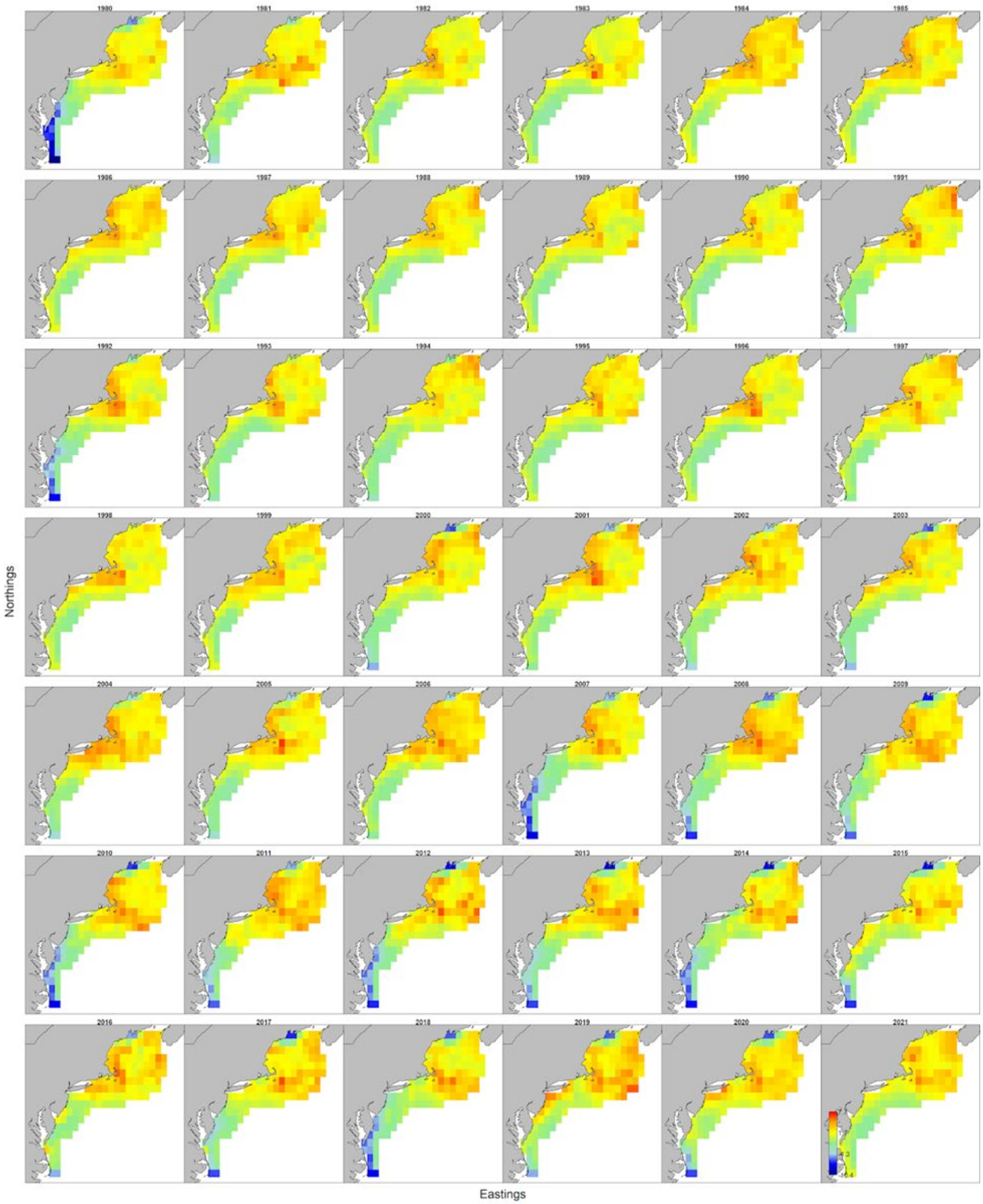


Figure 3.49: VAST estimated abundance for spiny dogfish in the fall.

Figure 3.50: Spring comparison of male relative abundance estimates produced by VAST and design based estimates for inshore and offshore surveys.

Figure 3.51: Spring comparison of female relative abundance estimates produced by VAST and design based estimates for inshore and offshore surveys.

Figure 3.52: Fall comparison of male relative abundance estimates produced by VAST and design based estimates for inshore and offshore surveys.

Figure 3.53: Fall comparison of female relative abundance estimates produced by VAST and design based estimates for inshore and offshore surveys.

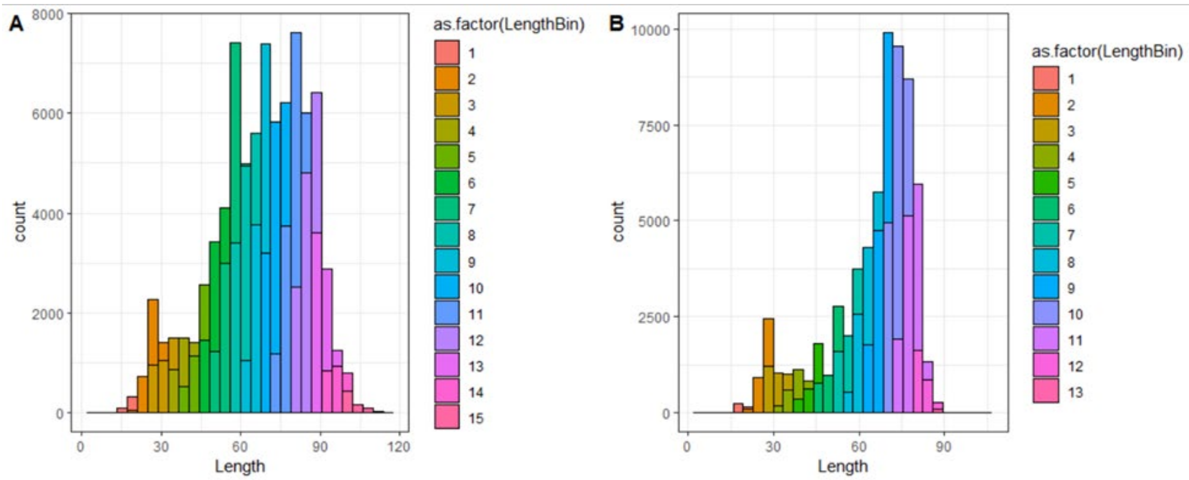


Figure 3.54: Spring length distribution and size bins used in VAST for female (A) and male (B) spiny dogfish

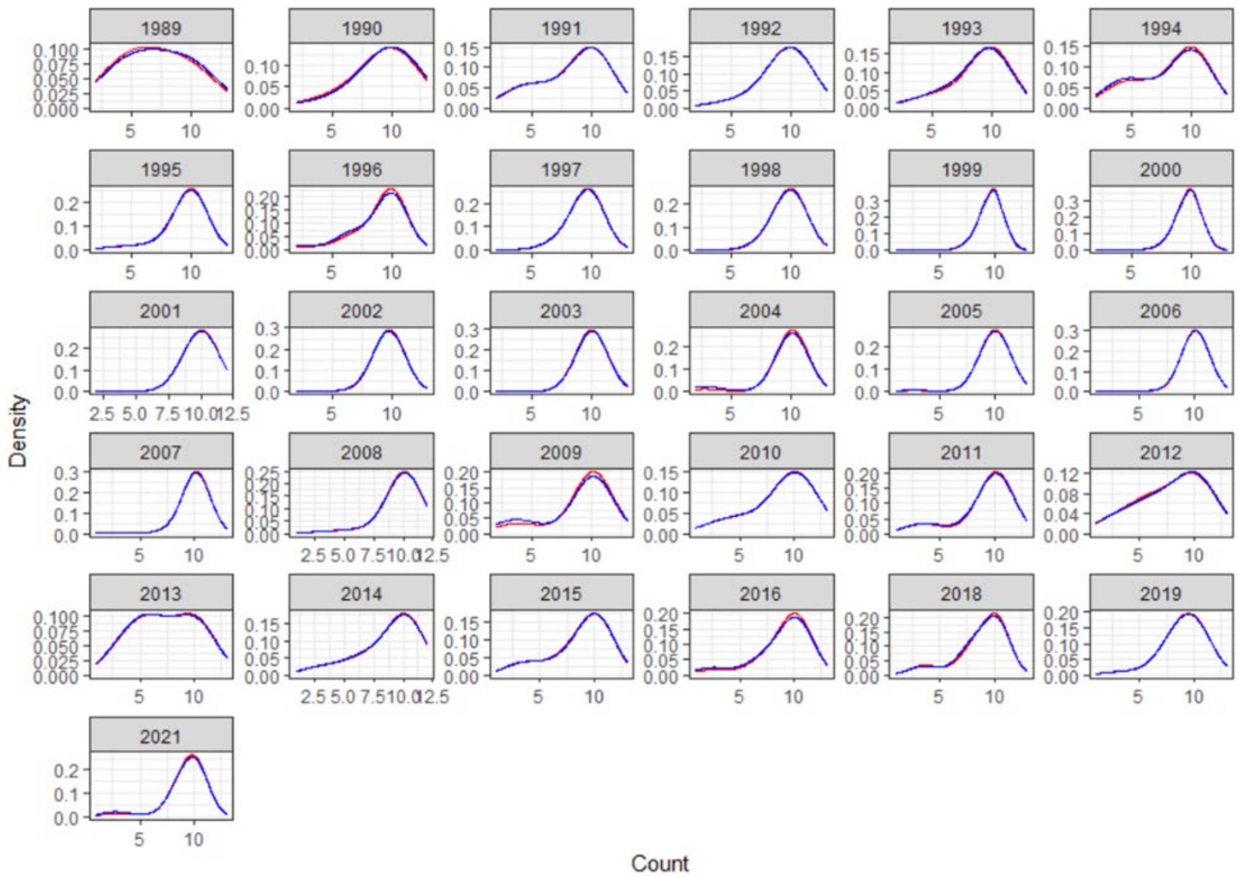


Figure 3.55: Comparison between design and VAST estimates of length composition for male spiny dogfish.

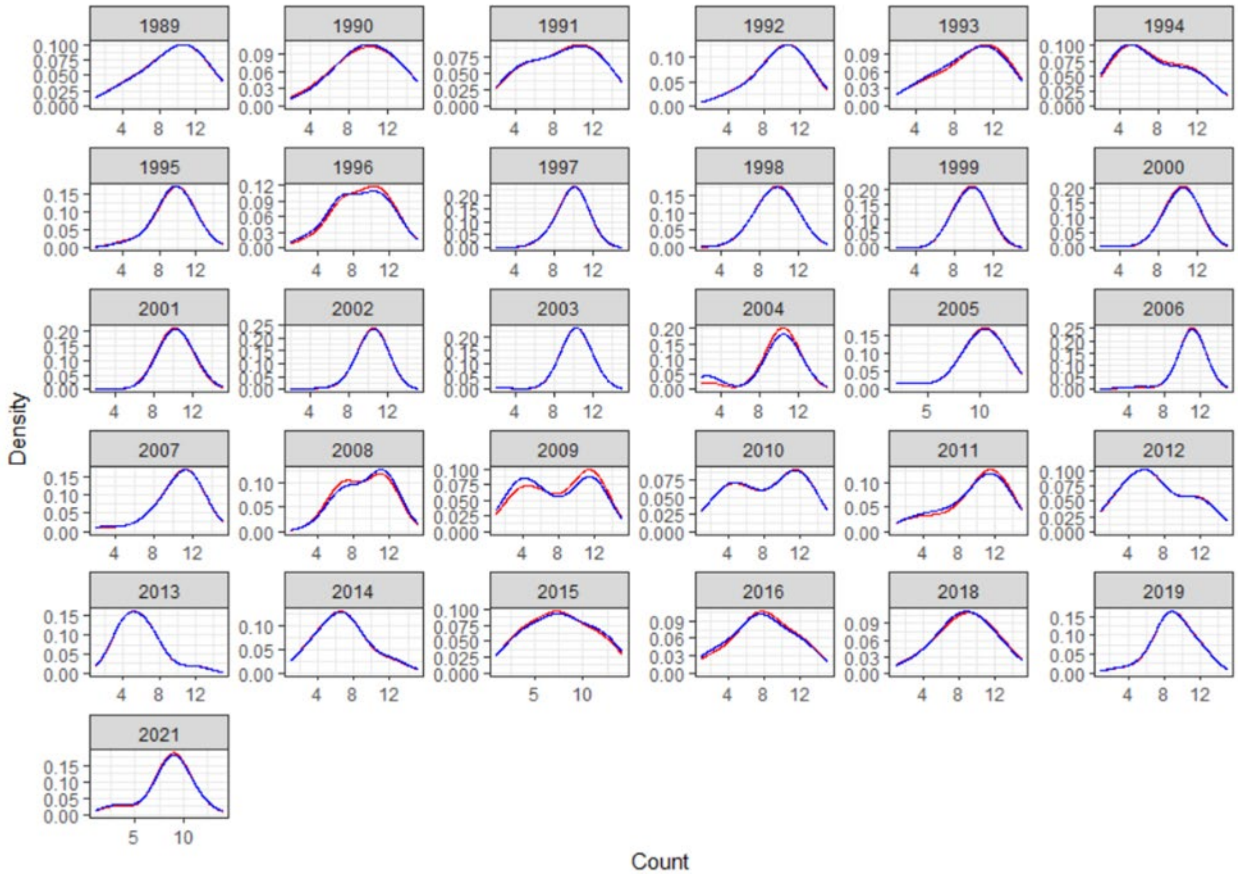


Figure 3.56: Comparison between design and VAST estimates of length composition for female spiny dogfish.

TOR4: ESTIMATE STOCK SIZE AND FISHING MORTALITY

"*Use appropriate assessment approach to estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series, and estimate their uncertainty. Compare the time series of these estimates with those from the previously accepted assessment(s). Evaluate a suite of model fit diagnostics (e.g., residual patterns, sensitivity analyses, retrospective patterns), and (a) comment on likely causes of problematic issues, and (b), if possible and appropriate, account for those issues when providing scientific advice and evaluate the consequences of any correction(s) applied.*"

Several approaches to stock assessment modeling were evaluated for this research track assessment. Ultimately, the Working Group proposed Stock Synthesis 3 (SS3) as the basis for status determination and fishery management advice (Chang et al. 2022). SS3 provides an analytical advancement over previous spiny dogfish assessments, because it incorporates biological characteristics and rates of the stock, as well as fishery dynamics into estimating stock conditions (e.g., spawning stock biomass, recruitment, fishing mortality).

A number of important life history processes and parameters were investigated and re-estimated in this assessment. These include length-weight relationships, maturity and pups at length for females, and natural mortality (Figure 4.1; see Anstead 2022a, Hart and Sosebee 2022, and Sosebee 2022a for details). Of particular interest is that the mean length at maturity has declined from around 80 cm in 1998 to 73 cm during 2012-2019 (Sosebee 2022a). This decline could be due to earlier maturation or slower growth or both. Natural mortality was chosen to decline with age (Lorenzen 1996), with a 50 year mean averaging 0.102 (Anstead 2022a).

There were also new investigations into growth using mark-recapture (McCandless 2022) and ageing (Passerotti and McCandless 2022) methods. The mark-recapture estimates were not appropriate for use in the assessment model, but provided supporting evidence concerning the decrease in length at maturity (McCandless 2002). Additionally, new ages were produced using the 2nd dorsal spine, but questions regarding the age estimates and uncertainties in the growth estimates prevented the Working Group from using these estimates directly in SS3 at this time (Passerotti and McCandless 2022).

Stock Synthesis

Model Configuration

An Atlantic spiny dogfish stock assessment model was developed in Stock Synthesis version 3.30.18 (SS3; Methot and Wetzel 2013) to provide an alternative to the index-based approach (Stochastic Estimator; NEFSC 2006) that was used in the previous assessments. SS3 is a statistical length-based age-structured population modeling framework. It is one of the most widely used stock assessment packages in the U.S. and globally (Dichmont 2016, 2021) and has many essential features of next-generation stock assessment models (Punt et al. 2020). Unlike most age-structured stock assessment models, SS3 can tune directly to length data, which is necessary when age data are lacking, as in Atlantic spiny dogfish. Additionally, SS3 can model sexes separately, an essential feature for a sexually dimorphic species such as spiny dogfish where the fishery targets only females. SS3 was recently used to assess Pacific spiny dogfish (Gertseva et al. 2021).

A sex-specific SS3 model was constructed for the Atlantic spiny dogfish to account for the life history and fishing differences between sexes. The SS3 runs were conducted solely on length data with assumed/estimated growth parameters within the model. While there was an effort to age Atlantic spiny dogfish and provide up-to-date age information for this assessment, due to several potential issues for the new age data, the Working Group decided not to use it for this assessment (Passerotti and McCandless 2022). Due to the uncertainty associated with growth, extensive sensitivity and profile analyses on various growth assumptions were conducted.

Catch data for the model included: commercial landings (metric tons) for U.S. and distant water commercial fisheries, U.S. recreational landings from 1962 to 2019, and discards from U.S. commercial fisheries and U.S. recreational landings from 1989 to 2019 (see TOR2). Both landings and discards data are available by gear type and summarized in Table 4.1. The discards were converted into dead discards using gear-specific discard mortalities and modeled as “catch” in SS3 (see TOR2). The commercial data by gear were aggregated into five modeled fleets (two fleets for landings and three fleets for discards) based on examining the similarities of their length compositions (Table 4.1 and Figures 4.2-4.3).

Spring NEFSC bottom trawl survey data were used as the primary abundance index for the SS3 modeling because that survey best covers the range of the stock (see TOR3). The survey has operated in the spring and fall since 1968. Fall data were not used because a greater portion of dogfish is outside of the bottom trawl survey domain in the fall due to seasonal migrations. The 2014 spring bottom trawl survey data were excluded from SS3 modeling because of missing data from critical survey strata in the Mid-Atlantic region. The annual stratified mean number per tow index was expanded using a factor of 5,260,450, the ratio of the total area surveyed divided by the swept area of a tow (wings only), the same expansion factor used in the Stochastic Estimator. This expansion allows the survey catchability (q) estimated in SS3 to be interpretable as gear efficiency combined with availability.

Additional abundance/biomass indices considered in SS3 modeling were the NEFSC bottom longline survey data (2014-2021; Nieland and McElroy 2022) and a vector auto-regressive spatio-temporal model-based index (VAST) that combined four trawl surveys from NEFSC (1980-2021), Massachusetts Division of Marine Fisheries (1980-2021); Maine/New Hampshire (2005-2021); and Northeast Area Monitoring and Assessment Program (NEAMAP; 2007-2021; Hansell and McManus 2022; see TOR3). These abundance/biomass indices, along with the NEFSC fall bottom trawl survey index, were included in SS3 as sensitivity runs.

The abundance/biomass indices are assumed to have a lognormal error structure, and the standard error of $\sqrt{ln\ (1 + CV^2)}$ where CV is the coefficient of variation. A constant parameter added to the inputted standard error of the survey indices was estimated in SS3 for each survey.

Sex-specific length composition data from catch and survey for all fleets and years, except for the 2014 NEFSC spring bottom trawl survey, were available for this assessment. Total length data were partitioned into 31 length bins, from 20 to 110+ cm with a 3 cm increment. SS3 estimated population numbers at length (population length bins), structured the same as the length composition data. Length composition data were excluded and not used in the modeling when the effective sample size was one, or the number of length bins covered was less than five, as they are less credible (Figure 4.3). Comparing preliminary model runs using the complete data versus the reduced data showed no difference in population estimates, suggesting that the excluded data were not informative.

SS3 model runs started in 1989, the first year quantitative discards information was available from observer data. Discards before 1989 are a significant source of mortality for spiny dogfish (NEFSC 1994); thus, the Working Group was reluctant to start the model before 1989. Since fishing for dogfish occurred before 1989, an initial equilibrium catch was assumed, and initial fishing mortality was estimated for each fleet in SS3. The initial equilibrium catch by fleet was estimated using an average of the 1962-1988 catch data. Total landings from 1962 to 1988 were obtained from Sosebee (2019). Total discards from 1962 to 1988 were hindcasted using the observed ratio of discarded dogfish to landings of all species in 1989 from otter trawl and gill nets fishery (NEFSC 2006). Hindcasted total discards are likely underestimated because they only rely on two types of gears. Total landings and hindcasted total discards were assigned to each fleet using the averaged by-fleet proportion from the 1989-1993 catch data. An SS3 run of starting the model from 1962 and assuming fishing morality to be negligible prior to 1962 was conducted in the sensitivity analysis.

Life history characteristics, including the sex-specific length-weight relationship, female maturity, and fecundity relationship, were updated using NEFSC bottom trawl survey data during this assessment and fixed at the updated values in SS3 (Hart and Sosebee 2022; Sosebee 2022a). During the preliminary model explorations, the Working Group found evidence of changing life history characteristics, including growth, maturity, and fecundity for Atlantic spiny dogfish in recent years. In particular, the estimated length at 50% maturity declined from 80 cm in 1998- 2011 to 73 cm during 2012-2019 (Figure 4.1; see Sosebee 2022a, Figure 1). Therefore, time blocks of 1989-2011 and 2012-2019 (referred to as biology blocks) were implemented in SS3 to allow growth, maturity, and fecundity to vary through time. Different growth, maturity, and fecundity parameter values were assumed/estimated for each block in SS3. Several sensitivity runs were conducted to examine the biology block assumption.

In the past assessments, the sex-specific growth for Atlantic spiny dogfish was assumed to follow a von Bertalanffy (VB) relationship estimated by Nammack et al. (1985; Table 4.2). A new growth study was conducted during this assessment to provide up-to-date growth information (Passerotti and McCandless 2022). During the preliminary model explorations, the new age data was compiled as conditional distributions of age-at-length, and VB growth parameters were estimated for each sex in SS3 (Figure 4.4). However, due to the high variability in length by age classes, especially for older females (Figure 4.4), the estimated standard deviations around the estimated growth curve were unrealistically large. As a result, the estimated selectivities for landings and surveys became dome-shaped, which the Working Group found unreasonable. SS3 runs that fixed the growth parameters at the values estimated by Passerotti and McCandless (2022) using the new growth data were also conducted. However, the results were similarly unrealistic. Given the uncertainties of the new growth data identified in Passerotti and McCandless (2022) and the unrealistic SS3 model results, the new growth data were not used in this assessment. Performances of the model using Nammack et al. (1985) growth and models with time-varying growth where the VB parameters were estimated for the biology block 2012-2019 were examined during the preliminary model explorations. The results showed a significant improvement in Akaike information criterion (AIC), resulting from the reduced VB asymptotic length (L_∞), especially for the females (Table 4.2-4.3). The reduction of L_∞ reflects the absence of large females in both catch and survey data for recent years (Figure 4.5). The Working Group decided to estimate L_∞ for both sexes in SS3 for the 2012-2019 period but fix the VB length at age-0 (L_{Amin}) and growth coefficient (k) at the values of Nammack et al. (1985) for the base case model. Sensitivity and profile analyses with various growth assumptions were conducted. The maximum age in SS3 was fixed at 50 years based on the approximate maximum age observed (Passerotti and McCandless 2022).

Sex-specific length-weight relationships in SS3 were estimated using NEFSC bottom trawl survey data from 1993 to 2019 from generalized linear mixed-effects models (Hart and Sosebee 2022; Figure 4.6):

$$W = 1.899348e-06L^{3.188} \text{ for females,} \qquad (1)$$

$$W = 3.656515e-06L^{3.006} \text{ for males,} \qquad (2)$$

where W is total weight (kg) and L is total length (cm).

Female maturity relationships were estimated for 1998-2011 and 2012-2019, respectively, using NEFSC bottom trawl survey data and used in SS3 (Sosebee 2022a; Figure 4.7):

$$Mat = \frac{1}{1+exp(0.4098361(79.9-L))} \text{ for biology block: 1989-2011,} \quad (3)$$

$$Mat = \frac{1}{1+exp(0.2832861(73.1-L))} \text{ for biology block: 2012-2019,} \quad (4)$$

where *Mat* is proportion mature and *L* is total length (cm).

Fecundity relationships were estimated for 1998-2011 and 2012-2019, respectively, using the pups/embryo data found in a subsample of female dogfish in the NEFSC bottom trawl survey and used in SS3 (Hart and Sosebee 2022; Figure 4.8):

$$P = 5.525074e - 06L^{3.046335} \text{ for biology block: 1989-2011,} \quad (5)$$

$$P = 7.893089e - 06L^{2.950182} \text{ for biology block: 2012-2019,} \quad (6)$$

where *P* is number of pups (age-0) and *L* is total length (cm).

The past Atlantic spiny dogfish assessments assumed a natural mortality (*M*) of 0.092 (Hoenig 1983; Rago et al. 1998). Several age-constant and age-varying *M* estimator approaches were evaluated for this assessment. Each approach required different life history parameters as inputs (see Anstead 2022a, Table 1). Many approaches were age-constant or time-invariant, providing one *M* estimate for all ages or lengths of spiny dogfish. Several age-constant approaches were revised and updated by Then et al. (2015), which were considered in this assessment. Two age-varying approaches were also used to consider different values of *M* by either age or length for spiny dogfish. All approaches were done by sex.

Life history parameters used in the *M* estimator approaches were tabulated by sex for spiny dogfish using various sources (see Anstead 2022a, Table 2). While the Working Group recommended the values in Table 2 in Anstead (2022a), other values were considered, including those for maximum age (Nammack et al. 1985), VB growth parameters (Campana et al. 2009;

Bubley et al. 2012), and length-weight relationship parameters (Wigley et al. 2003). As part of the 2022 assessment, the growth and length-weight relationship were re-estimated using updated data (Hart and Sosebee 2022; Passerotti and McCandless 2022). Several issues were identified in the growth analysis, so the values from Nammack et al. (1985) were used for the *M* estimators that use growth parameters, although the revised length-weight parameters were used.

The Working Group decided that approaches that rely heavily on the VB growth rate coefficient, *k*, should not be used for spiny dogfish (e.g., Alverson and Carney 1975, Jensen 1996). The Working Group supported the length-varying Lorenzen (1996) estimates by sex that were scaled to the average Then et al. (2015) estimate ($M = 0.102$) being used for the base case model (Figure 4.9). Sensitivity runs were conducted to examine various *M* assumptions.

~~Stock-recruit (S~~R) relationship in SS3 models the relationships between age-0 fish and spawning output, i.e., the number of pups the mature females produced (1,000s) at the beginning of each year (Methot et al. 2021). Ricker, Beverton-Holt, and survival SR relationships were explored during this assessment. The survival SR relationship developed by Taylor et al. (2013) is an SR model that explicitly models the survival between embryos and age-0 recruits, which is particularly useful for low fecundity species that produce fewer offspring per litter and exhibit a more direct relationship between spawning output and recruitment (Taylor et al. 2013; Methot et al. 2021). The survival SR relationship was assumed for the Pacific spiny dogfish assessment (Gertseva et al. 2021) and is parameterized as (Taylor et al. 2013):

$$R_y = SSB_y e^{ln(S_0)(1-Z_{frac}(1-\frac{SSB_y}{SSB_0}^{\beta}))} \qquad (7)$$

where R_y is recruitment in year *y*, SSB_y is spawning output in year *y*, $S_0 = \frac{R_0}{SSB_0}$ is survival of per-recruit individuals at unfished equilibrium, R_0 is unexploited equilibrium recruitment, SSB_0 is the corresponding equilibrium spawning output, β is a shape parameter controlling the shape of the density-dependent relationship between $\frac{SSB_y}{SSB_0}$ and S_0 (with limit $\beta > 1$), and Z_{frac} is a fraction of pre-recruit instantaneous mortality rate at equilibrium ($-\ ln\ (S_0)$) and range $0 < Z_{frac} < 1$.

During the preliminary model explorations, the parameters for all three SR models were estimated within SS3, and model results were compared. The SS3 model with the Beverton- Holt SR relationship failed to converge, and the models that assumed Ricker and survivorship SR relationships showed very differently estimated stock trajectories. Thus, the Working Group decided to estimate the SR relationship outside of SS3, fix the SR parameters in SS3 at these values, and then compare their model performances.

The Ricker and Beverton-Holt SR relationships parameterized by *a* and *b* were estimated using the NEFSC bottom trawl survey data (McManus et al. 2022). The survivorship SR relationship was explored using the same data set (with S_0 and SSB_0 estimated by averages of various SS3 preliminary runs) but failed to converge because the two parameters Z_{frac} and β are highly correlated. Therefore, the survivorship SR parameters estimated in a preliminary model run (Z_{frac} = 0.93 and β = 1.6) were assumed for exploratory SS3 runs.

In SS3, the Ricker and Beverton-Holt SR models were parameterized using $ln\ (R_0)$, the steepness parameter (*h*; Methot and Wetzel 2013). To estimate the Ricker and Beverton-Holt steepness from the *a* and *b* form models, S_0 is required (Miller and Brooks 2021):

$$h = \frac{a\phi_0}{4+a\phi_0} \text{ for Beverton-Holt SR model,} \qquad (8)$$

$$h = \frac{(a\phi_0)^{\frac{4}{5}}}{5} \text{ for Ricker SR model,} \qquad (9)$$

where $\phi_0 = \frac{1}{S_0}$ can be interpreted as unexploited spawning per recruit. The survivorship SR relationship is not parameterized in the form of steepness in SS3, but steepness was calculated for comparison purposes. S_0 is also required to estimate steepness for the survivorship SR parameters (Taylor et al. 2013):

$$h = 0.2e^{S_0 Z_{frac}(1-0.2^{\beta})} \qquad (10)$$

To get an estimate of S_0 , various preliminary SS3 runs were examined. The estimated S_0 in SS3 is invariant with different model settings, e.g., ~~growth,~~ maturity, fecundity, SR relationships, but varies with natural mortality. Therefore, three S_0 values derived using three *M* assumptions, static *M* = 0.092 (Hoenig 1983), static *M* = 0.102 (Then et al. 2015), and Lorenzen (1996) *M* scaled to an average of 0.102 were assumed, steepness were estimated from these values for the Ricker and Beverton-Holt SR models, and SS3 runs were conducted with the fixed steepness values. For the survivorship SR relationship, parameters were fixed at Z_{frac} = 0.93 and β = 1.6, and model runs were conducted with three different M assumptions.

The estimated steepness was around 0.4 for *M* = 0.092, around 0.3 for *M* = 0.102, and around 0.2 for scaled Lorenzen (1996) *M* for both Ricker and Beverton-Holt SR models. However, the steepness is around 1 for *M* = 0.092, around 0.8 for *M* = 0.102, and around 0.6 for scaled Lorenzen *M* for the survivorship SR models. AIC values from these runs suggested that survivorship SR outperformed Ricker and Beverton-Holt models regardless of *M* assumptions; the survivorship SR model coupled with *M* = 0.102 performed the best, followed by the scaled Lorenzen (1996) *M*. These conclusions were the same with or without estimating recruitment deviations in the model.

Because assuming *M* = 0.102 resulted in an unrealistically high steepness/productivity for spiny dogfish, a long-lived and low fecundity stock, the Working Group decided to assume a survivorship SR relationship, coupled with the Lorenzen (1996) *M* scaled to an average of 0.102 as the base case model configuration. The survivorship SR parameters were updated based on a profile analysis and fixed at Z_{frac} = 0.9, β = 1.5, and σ_R = 0.3 (standard deviation of log recruitment deviations) for the base case model. Recruitment deviations were estimated for the entire time series and bias-adjusted so that the estimated recruitments are mean unbiased (Methot and Taylor 2011; Methot et al. 2021). Uncertainty of the SR relationship assumptions were further explored in the sensitivity and profile analysis.

A double normal selectivity function was assumed for all six fleets in SS3 to fit the length composition data for its ability to estimate either an asymptotic or a domed-shaped selectivity pattern from data (Methot and Wetzel 2013; Methot et al. 2021). The double normal selectivity function has six parameters: p1 - peak value, p2 - top logistic, p3 - ascending width, p4 - descending width, p5 - selectivity at first length bin, and p6 - selectivity at last length bin. The sex-specific selectivity was estimated using a parameter offset approach with a maximal selectivity greater than or equal to one for the dominant sex and an additional parameter to determine the relative apical selectivity value for the offset sex. The selectivity parameters allowed to be offset in SS3 are p1, p3, p4, and p6. For the catch fleets 1-5, male selectivity was estimated as an offset from the female parameters, so the maximum selectivity for both sexes is one; thus, the resulting apical fishing mortality is comparable among fleets. The shape of the selectivities was freely estimated in SS3 for all fleets. Parameters p5 and p6 were skipped for all fleets, except for p5 for the discard fleet 5 and survey because they caught small dogfish. The offset of descending parameter p4 for landings fleets and the survey was turned off because it was estimated at zero during the preliminary model explorations. Selectivity time blocks were implemented for the NEFSC spring bottom trawl survey to estimate different selectivities for the two different research vessels conducting the survey: RV *Albatross IV* (1989-2008) and FRV *Henry B. Bigelow* (2009-2019). A sensitivity run was conducted to examine the selectivity time block assumption.

Three data weighting approaches were explored to rescale the effective sample size to reduce conflicts between data sources during the preliminary model exploration: McAllister-Ianelli, Francis, and Dirichlet-Multinomial (McAllister and Ianelli 1997; Francis and Hilborn 2011; Thorson et al. 2017). The scalers estimated using McAllister-Ianelli and Francis data weighting approach significantly down-weighted the survey length composition data relative to the catch length composition data. Thus, the Working Group decided to use the Dirichlet-Multinomial data weighting approach, which involves estimating a parameter (θ) to scale each fleet's inputted effective sample size. For comparison purposes, the θ parameter was fixed at the base case value for the jitter and profile analysis but re-estimated for the retrospective analysis. Sensitivity analysis was conducted without weighting the length composition data.

In summary, the parameters fixed in SS3 include length-weight, maturity, fecundity, SR relationships, growth for the first biology block, and the fixed p4-6 parameters mentioned in the selectivity paragraph above. Within the estimated parameters, the peak, ascending, and apical selectivity parameters were time-varying for fleet 6, and L_{∞} for both sexes were estimated for biology block 2012-2019. Non-informative priors were used for all the parameters except for the θ parameter for the Dirichlet-Multinomial error distribution used to weight the length data. A

Normal N(0, 1.813) prior was assumed for $ln\ (\theta)$ to counteract the log transformation effect between θ and data weighting (Methot et al. 2021).

The model convergence was evaluated based on whether the final gradient is < 0.0001 and whether the Hessian matrix for the parameter estimates is positive definite. Parameters estimated at a bound were examined, and correlations between estimated parameters were produced to see if highly correlated parameter pairs or non-informative parameters exist for possible unstable model or model misspecification. The residual analysis proposed by Carvalho et al. (2021) was performed on indices and length composition data to check for model fits. Profile of R_0, jitter, and retrospective analyses were also conducted to check for data consistency and model stability (Carvalho et al. 2021).

Model Results

The base case model converged (gradient 2.3 x 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). The 100 iterations of jittering the starting values by 10% resulted in 60% of the runs converging at the total likelihood value of the base case (-23409.9) and above the base case total likelihood value for the rest of the runs with a maximum change of 36.6 in likelihood. This result indicated that the base case model is slightly sensitive to starting values but stable and is likely to converge at a global rather than a local minimum.

The overall model fit of the abundance index data 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 NEFSC spring bottom trawl survey index showed a residual pattern where the residuals are positive during the 1990s, negative during the 2000s, and positive in recent years, with RMSE = 39.6% (Figure 4.10). The residual plot for mean length of the length composition data showed a good fit with RMSE = 6.3%. The loess-smoother of this plot indicated a positive residual pattern at the beginning of the time series but no apparent residual pattern for recent years (Figure 4.11). The above analysis indicated a reasonably good overall fit to the data for the base case model.

The time-varying growth curve and the assumed/estimated VB growth parameters by sex are shown in Table 4.2 and Figure 4.12. The estimated L_∞ for the biology block 2012-2019 were smaller than those estimated by Nammack et al. (1985) for both sexes. The reduction is more significant for females (11.26 cm) than males (3.35 cm) and is likely reflecting the absence of large females in both catch and survey data (Figure 4.5).

The observed and model-predicted NEFSC spring bottom trawl abundance index is shown in Figure 4.13. The predicted index is within the 95% uncertainty level, except for 2004. The estimated catchability q was 0.83 for this survey.

The estimated selectivities by sex and fleet are shown in Figures 4.14-4.19. The estimated selectivities were asymptotic (logistic) for all landings fleets and NEFSC spring bottom trawl survey (fleets 1, 2, and 6) and dome-shaped for all discard fleets (3-5; Table 4.1). Estimated apical male selectivity was smaller than females for landings and discard fleets (1-5; Table 4.1), which is reasonable for a female-targeted fishery. Time-varying selectivity for the NEFSC spring bottom trawl survey showed an increased selectivity for small dogfish and reduced selectivity for the ~~large~~ females during the *Bigelow* period (2009-2019), which is consistent with the survey data. Figure of length compositions from 2005 to 2012 showed systematic changes between the *Albatross* to *Bigelow* period for both sexes (Figure 4.20).

The observed and model-predicted length compositions aggregated ~~by fleet, year,~~ and sex are shown in Figure 4.21. The fits to the aggregated length compositions appear to be fairly accurate, suggesting that the estimated fisheries and survey selectivities are reasonable. The observed and model-predicted annual length composition data and the residuals from the fits by fleet and sex are shown in Figures 4.22-4.33. Fit to the annual length composition data showed some systematic poor fit for the large females for the landings fleets (1 and 2) and the survey, as well as the median size males for the survey. There were large residuals for small (around 30 cm) dogfish for fleets 1, 3, and 4 and large dogfish for fleets 3 and 4. The fixed survivorship SR relationship, along with the estimated recruitment from both the SR relationship and recruitment deviations, are shown in Figure 4.34. The estimated recruitment decreased from 1989 to the early 2000s, when the lowest recruitments of the entire time series were estimated, followed by a large increase through 2010, and then dropped to half of the peak value and stayed stable since (Table

4.4 and Figure 4.35). The estimated time series of total biomass by sex and spawning output are provided in Table 4.4 and Figure 4.36. The estimated spawning output declined during the beginning of the time series, increased starting in the early 2000s, peaked in 2012, and then decreased since. The estimated annual fishing mortality, which is defined as the number-based exploitation rate for age 12+ dogfish (roughly age at 50% fishery selectivity), peaked around 1989 to ~~199~~ decreased to the lowest point in ~~200~~, and stayed ~~below 0.02 since 2003, except for 2014, which is slightly above 0.02~~ (Table 4.4 and Figure 4.36).

Sensitivity Analysis

For the base case model, L_∞ was the only growth parameter estimated for the biology block 2012-2019. The sensitivity of this assumption was examined with three additional runs:

- estimating L_∞ and k but fixing L_{Amin} at the Nammack et al. (1985) values,
- estimating all three growth parameters L_∞, k, and L_{Amin}, and
- fixing L_∞, k, and L_{Amin} at the Nammack et al. (1985) values

for both sexes for the biology block 2012-2019. The estimated spawning output from the two growth scenarios with estimating two or all three VB parameters are similar to the estimates from the base case model, with slightly higher terminal spawning outputs (Figure 4.37). However, the run assuming Nammack et al. (1985) growth produced a very different spawning output trajectory than the base case model (Figure 4.37). The estimated L_∞ is similar with or without estimating k and L_{Amin} (Table 4.2). The estimated k is slightly higher than that estimated by the Nammack et al. (1985) study. Although runs estimating two or all three VB parameters performed better than the base-case model, the differences in AIC were small (Table 4.3). When the VB growth parameters were fixed at the Nammack et al. (1985) values, the AIC was much worse. These results support the Working Group's decision on estimating the L_∞ for the biology block 2012-2019 for the base case model.

Sensitivity runs were performed assuming:

- M = 0.092 (Hoenig 1983) for all ages and sexes, as used in the previous assessments,

- M = 0.102 for all ages and sexes derived using Then et al. (2015) method, and
- the sex- and age-specific Lorenzen (1996) M scaled to asymptote at 0.102.

These were compared to the base case model where the sex- and age-specific Lorenzen (1996) M was scaled to an average of 0.102. A summary of performance statistics and several critical parameter estimates for these runs can be found in Table 4.3. The two static natural mortality runs performed better than the base case in AIC, likely contributed by the higher M for older dogfish (Figure 4.38). However, the estimated NEFSC spring bottom trawl survey q and steepness h were both over 1 for the static natural mortality runs, indicating possible model misspecifications. This supports the Working Group's decision not to use static natural mortality for the base case model. The run with Lorenzen (1996) M scaled to asymptote at 0.102, which assumed the highest natural mortality at age of all the runs, performed worse than the base case. The estimated spawning output for this run is much higher than the two static M runs and the base case model (Figure 4.39).

The performance of the base case model with a fixed survivorship SR relationship and estimated recruitment deviations was compared to two additional sensitivity runs:

- fixed Ricker SR parameters with recruitment deviations and
- fixed Beverton-Holt SR parameters with recruitment deviations.

The Ricker and Beverton-Holt SR relationship parameters were derived from the NEFSC bottom trawl survey and translated into steepness using the ϕ_0 estimated from the base case model. The estimated steepness was 0.28 for both Ricker and Beverton-Holt SR and 0.68 for the survivorship SR from the base case model. Different SR assumptions resulted in different trajectories of spawning output and likely different management advice (Figure 4.40). These two SR sensitivity runs performed worse than the base case model in terms of AIC (Table 4.3). The recruitment likelihood increased when assuming a Ricker (recruitment likelihood = 126.99) or a Beverton-Holt (recruitment likelihood = 107.97) SR relationship, reflecting a poorer fit to the recruitment data compared to the base case model (recruitment likelihood = 0.24). The recruitment time series estimated from the Ricker and Beverton-Holt models were far from what was observed in the NEFSC spring bottom trawl survey (Figure 4.41; see McManus et al. 2022,

Figure 1). In both cases, the estimated NEFSC spring bottom trawl survey q was over 1, which indicated possible model misspecifications (Table 4.3).

Sensitivity runs were conducted with different time block assumptions:

- biology block 2011-2019,
- biology block 2013-2019,
- no biology block, and
- no survey block.

These were compared to the base case model where the biology block 2012-2019 and survey block 2009-2019 was assumed. For the runs with plus and minus one year of the base case biology block (2012-2019), the maturity and fecundity relationships remain the same as the base case model, and L_{∞} was estimated for both sexes within the model. The run with no biology block, maturity, fecundity, and growth was assumed to be the same as the settings for the biology block 1989-2011 in the base case model. The model run with no biology block could not track the large population increases observed in surveys around 2010, and performed worse in terms of AIC (Table 4.3 and Figure 4.42; see TOR3). Assuming different lengths of the biology block only affected the earlier years' spawning output and did not change the terminal estimates (Figure 4.42). Therefore, even though the 2011-2019 biology block slightly outperformed the base case model, given that the terminal year estimates are insensitive to this assumption, the Working Group decided to proceed with the base case model configuration. The fit for length composition data was worse with no survey blocks in the model (Table 4.3).

A sensitivity run was conducted that examined a longer time series 1962-2019. The population is assumed to be unfished prior to 1962. Landings and discards from 1962 to 1988 were estimated using the same method used to derive the initial equilibrium catch for each fleet in the base case model. NEFSC spring bottom trawl survey time series data were available from 1979 for this run. The estimated spawning output is smaller for the 1962-2019 model; however, the trend is similar to the base case model (Figure 4.43).

Sensitivity runs were conducted using different survey data:

- NEFSC fall bottom trawl survey (as an additional abundance index),
- NEFSC spring longline survey (as an additional abundance index),
- NEFSC fall longline survey (as an additional abundance index), and
- VAST spring index (as the sole biomass index).

These were compared to the base case model that used only the NEFSC spring bottom trawl survey index. The estimated spawning output trend is similar to the base case model in all cases (Figure 4.44). The NEFSC fall bottom trawl survey was split into *Albatross* and *Bigelow* time series and entered as separate fleets in the model because their length composition is distinctly different (see TOR3). The estimated survey q for the NEFSC fall bottom trawl is much smaller than the spring survey (Table 4.3), reflecting the seasonal migration of dogfish out of the survey domain in the fall. The estimated selectivity for the NEFSC fall bottom trawl survey is logistic for the *Albatross years* but flat domed-shaped for the *Bigelow* period. Further investigations regarding the fall survey data and the model are required to examine whether this result is reasonable. Adding the NEFSC longline survey to the model did not change the spawning output (Figure 4.44). The model constructed using the model-based VAST index performed worse than the base case model in AIC (Table 4.3). The VAST length composition was estimated at a 6 cm length bin and was interpolated to a 3 cm length bin using a moving average method. It is not clear whether this mismatch is the cause of its low performance. The Working Group suggested continuing to develop the VAST index, and this index should be reevaluated in future assessments.

Profile and Retrospective Analysis

For the R_0 profile analysis, the $ln\ (R_0)$ parameter was fixed at values above and below the value estimated by the base case model (9 to 15 with an increment of 0.5, base case $ln\ (R_0)$ = 12) and the models were refitted. The results indicated that the length composition data was the most informative and the survey index was the least informative for estimating R_0 (Figure 4.45). Among the length composition data, the catch data support the base case R_0; however, the survey data slightly favored a smaller R_0 value (Figure 4.46). This result indicated a slight conflict between catch and survey length composition data and that the maximum likelihood estimate of R_0 landed at the spot where conflicts between different sources of data were balanced (Figure 4.46).

Likelihood profiling was conducted over a wide range of values for the female VB growth parameters L_∞ and k while the rest of the VB parameters were fixed at the Nammack et al. (1985) values. The model had a tendency to favor smaller L_∞ and slightly larger k values compared to Nammack et al. (1985; Figure 4.47). The run with the smallest total likelihood was L_∞ = 88 and k = 0.12, which is close to the maximum likelihood estimates (Tables 4.2-3 and Figure 4.47), suggesting that the estimated growth parameters in the base case model or sensitivity analysis are likely global instead of local minimums.

The survivorship SR parameters, Z_{frac}, β, and σ_R were profiled over a wide range of values, and the resulting total likelihoods are in Figure 4.48. Among the combination of parameters tested, the parameter values fixed in the base case model (Z_{frac} = 0.9, β = 1.5, and σ_R = 0.3) produced the smallest total likelihood. The β parameter is the least influential to the model, which is likely why this parameter is hard to estimate in SS3. The model performance is the most sensitive to Z_{frac}, where larger Z_{frac} values were favored.

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 ρ= 0.06 for the spawning output and -0.05 for the fully recruited fishing mortality (Figures 4.49-4.50).

Stochastic Estimator

In addition to SS3, the Working Group used the Stochastic Estimator model to estimate the spiny dogfish population size and fishing mortality rates. The Stochastic Estimator uses swept area calculations based on the NEFSC spring bottom trawl survey and catch (landings and mortal discard) data to estimate biomass and fishing mortality, under the assumption that survey efficiency (between the wingtips) is 1. It uses bootstrapping to better quantify the uncertainties of these quantities. It was the primary method used in recent previous assessments; a full description can be found in NEFSC (2006), pages 35-42.

Only minor changes to the Stochastic Estimator were done for this assessment. These include updating length-weight, maturity, and fecundity relationships, and changing the assumed logistic (landed) fishery selectivity curve to better match that from SS3 (in particular, the L_{50} for the selectivity curve was reduced from 80 to 73 cm). Spawning stock biomass (females greater than 80 cm) were replaced by spawning output (pups); these quantities are strongly correlated. Additionally, a call to a proprietary subroutine that calculates normal quantiles was replaced by public code, so the Fortran source code can be compiled using the 'gfortran' open source compiler.

The Stochastic Estimator was run for the 1989-2019 time series using spring trawl survey, landings, and discard data. Results show high fishing mortality on females, a decline in total and exploitable female biomass and spawning output during 1989-2000, a recovery after fishing mortality was reduced during 2000-2010, and a more modest decline in biomass and spawning output in the last years of the time series as fishing mortality increased somewhat (Figure 4.51). Fishing mortality for males has remained low.

The results from the Stochastic Estimator can be compared to those from the SS3 base run (Figure 4.52). These estimates are strongly correlated during 2000-2019, with SS3 estimating somewhat higher biomass and lower fishing mortality due to its lower survey efficiency estimate (q). In the early portion of the time series (1989-2009), the Stochastic Estimator shows greater declines in spawning output and much higher fishing mortalities than SS3. It is likely that this is due to some misspecification in life history parameters (e.g., growth, natural mortality) or in catch data (e.g., discards, discard mortality) in SS3 during that period.

Table 4.1. Summary of Atlantic spiny dogfish data by gear and fleet used in SS3.

Type	Gear	Fleet	Label
Landings	Sink Gill Net + Others Recreational	1	Landings_SGN_Rec_Others
Landings	Longline Otter Trawl + Foreign	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	6	NEFSC_Spring_BTS

Table 4.2. Summary of von Bertalanffy (VB) growth parameters assumed/estimated in SS3 for Atlantic spiny dogfish. Shaded cell indicated an estimated value.

Sex	VB Parameters	Base Case 1989-2011 Nammack et al. (1985)	Base Case 2012-2019 Est. $L\infty$	Sensitivity	
				Est. $L\infty$, k	Est. $L\infty$, k, L_{Amin}
Female	$L\infty$	100.50	89.24	88.64	88.67
	k	0.1057	0.1057	0.1258	0.1259
	L_{Amin}	26.53	26.53	26.53	27.33
Male	$L\infty$	82.49	79.14	78.02	78.02
	k	0.1481	0.1481	0.1657	0.1666
	L_{Amin}	26.94	26.94	26.53	27.46

Table 4.3. Summary of Atlantic spiny dogfish SS3 model runs.

Version	Sensitivity Category	Scenario	AIC	Delta AIC	Catchability (q)	Steepness (h)
3.6.2 1.5	Base Case	Dirichlet-Multinomial Data Weighting	-46624	-	0.83	0.68
3.6.2 1		No Data Weighting	5504	0	0.88	0.68
3.6.2_2	Growth	Nammack et al. (1985)/Est L_∞, and k	5488	-17	0.85	0.68
3.6.2_3		Nammack et al. (1985)/Est L_∞, k, and L_{Amin}	5485	-19	0.85	0.68
3.6.2_4		Nammack et al. (1985)	5931	427	1.03	0.68
3.6.2 8.1	Natural Mortality	M=0.092 (Hoenig 1983)	5108	-396	1.11	1.23
3.6.2 8		M=0.102 (Then et al. 2015)	5059	-446	1.13	1.01
3.6.2 8.2		Lorenzen (1996) scaled asymptote 0.102	5938	433	0.47	0.36
3.6.2 6	SR Relationship	Ricker SR with recruitment deviation	5833	328	1.21	0.28
3.6.2 5		Beverton-Holt SR with recruitment deviation	5804	300	1.18	0.28
3.6.2 10	Time Block	Biology Block 2011-2019	5387	-117	0.86	0.68
3.6.2 11		Biology Block 2013-2019	5601	69	0.89	0.68
3.6.2 1.2		No Biology Block	5938	434	1.02	0.68
3.6.2 9		No Survey Block	5648	143	0.95	0.68
3.6.2 13.1	Model Starting Year	1962-2019 Model	6974	-	0.87	0.68
3.6.2 14	Survey Data	Additional NEFSC fall bottom trawl survey	7202	-	0.94/0.33/0.48	0.68
3.6.2 15		Additional NEFSC spring longline survey	5606	-	0.89/0.0004	0.68
3.6.2 16		Additional NEFSC fall longline survey	5590	-	0.89/0.0002	0.68
3.6.2 18		VAST spring index	5778	274	0.03	0.68

Table 4.4. Summary of total biomass by sex, spawning output, recruitment (in 1,000, age 0+) and fishing mortality (age 12+) by year estimated by SS3 for Atlantic spiny dogfish.

Year	Total Biomass		Spawning Output	Recruitment (1,000s)	F
	Female	Male			
1989	379,672	432,328	228,469	218,249	0.076
1990	386,663	437,351	232,245	223,706	0.118
1991	382,068	440,461	221,779	213,925	0.087
1992	384,717	447,807	217,034	209,429	0.17
1993	373,117	447,218	199,000	192,048	0.107
1994	371,731	453,841	187,884	181,317	0.084
1995	376,160	461,839	183,010	176,608	0.109
1996	375,467	466,877	174,570	168,454	0.101
1997	373,842	472,231	165,600	159,660	0.068
1998	380,404	478,322	167,817	156,426	0.079
1999	381,356	480,471	169,694	102,990	0.067
2000	384,201	480,566	178,975	99,774	0.044
2001	389,329	478,825	196,331	73,343	0.031
2002	395,526	474,807	219,984	76,663	0.029
2003	398,997	468,448	244,437	74,109	0.017
2004	403,791	461,401	271,988	87,065	0.02
2005	405,289	452,780	296,758	85,641	0.016
2006	406,741	444,746	319,904	115,680	0.02
2007	406,047	436,859	338,467	122,918	0.024
2008	404,749	431,073	351,125	176,522	0.019

2009	406,500	429,058	360,845	196,595	0.023
2010	410,016	430,333	364,526	234,935	0.017
2011	418,240	435,756	365,877	235,805	0.026
2012	425,115	444,996	388,326	288,488	0.029
2013	409,991	443,991	353,179	120,648	0.027
2014	401,195	445,024	325,491	167,354	0.041
2015	389,002	444,033	296,337	123,237	0.028
2016	383,112	444,474	276,850	137,889	0.039
2017	375,398	444,646	256,708	159,111	0.032
2018	371,603	444,323	245,197	136,947	0.026
2019	371,635	445,385	239,877	176,963	0.032

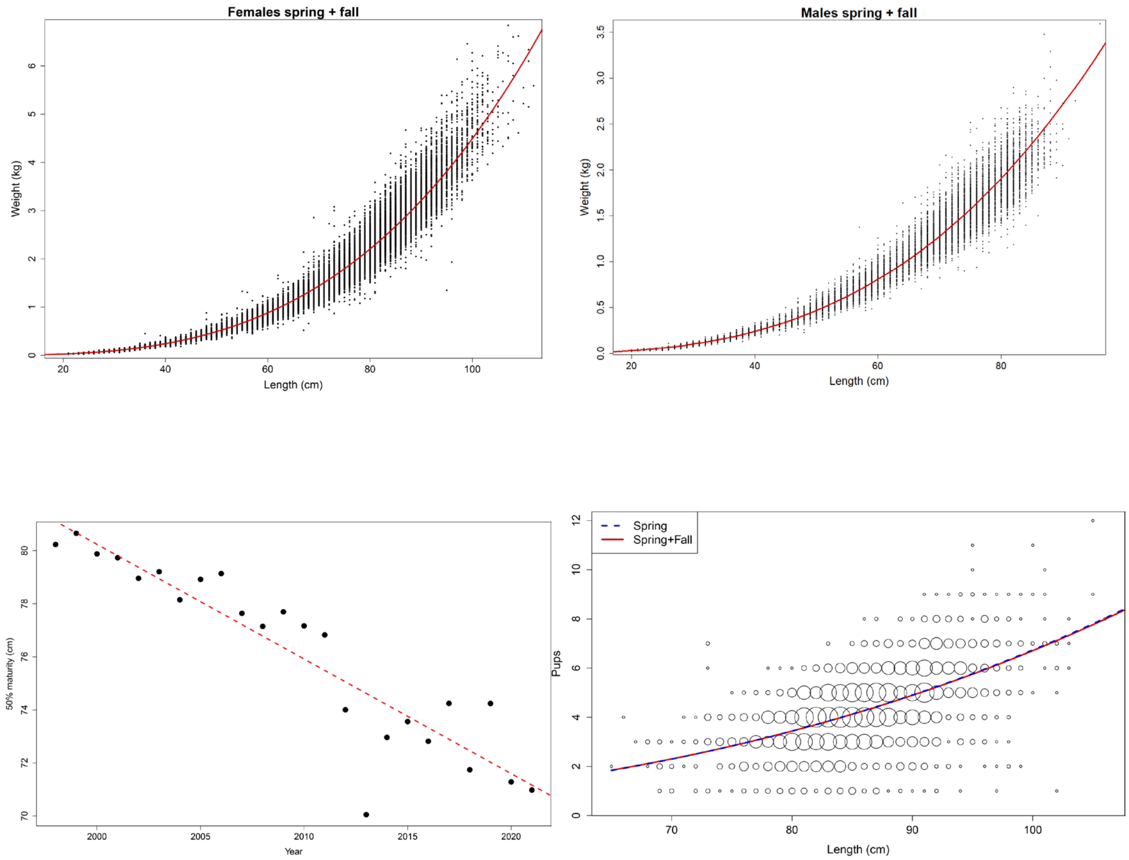


Figure 4.1. Plots of female and male length-weight relationships (top left and right), 50% (L_{50}) maturity at length over time (bottom left), and pups at length (bottom right).

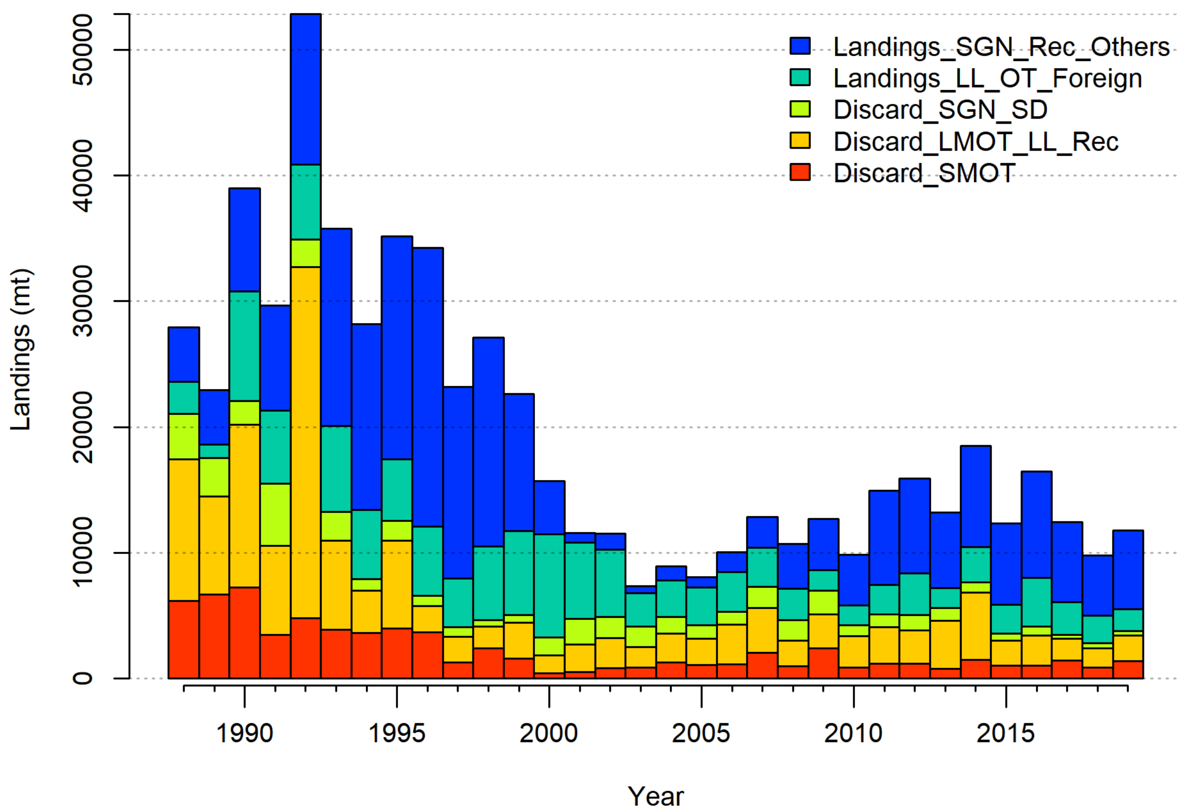


Figure 4.2. Time series of Atlantic spiny dogfish catch by fleet.

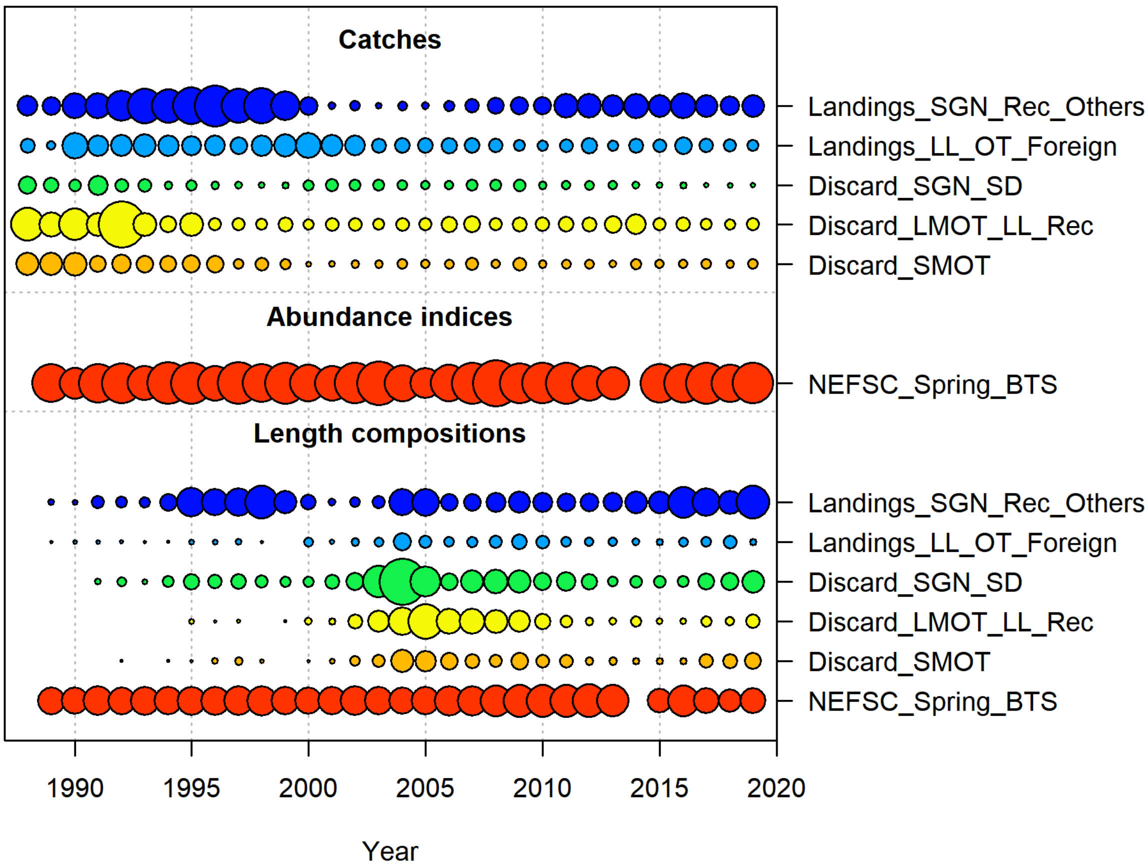


Figure 4.3. Catch and survey data by year for each fleet used in SS3. Circle area is relative within a data type. Circles are proportional to total catch for catches, to precision for indices, and to total sample size for length compositions. Note that since the circles are scaled relative to the maximum within each type, the scaling within separate plots should not be compared.

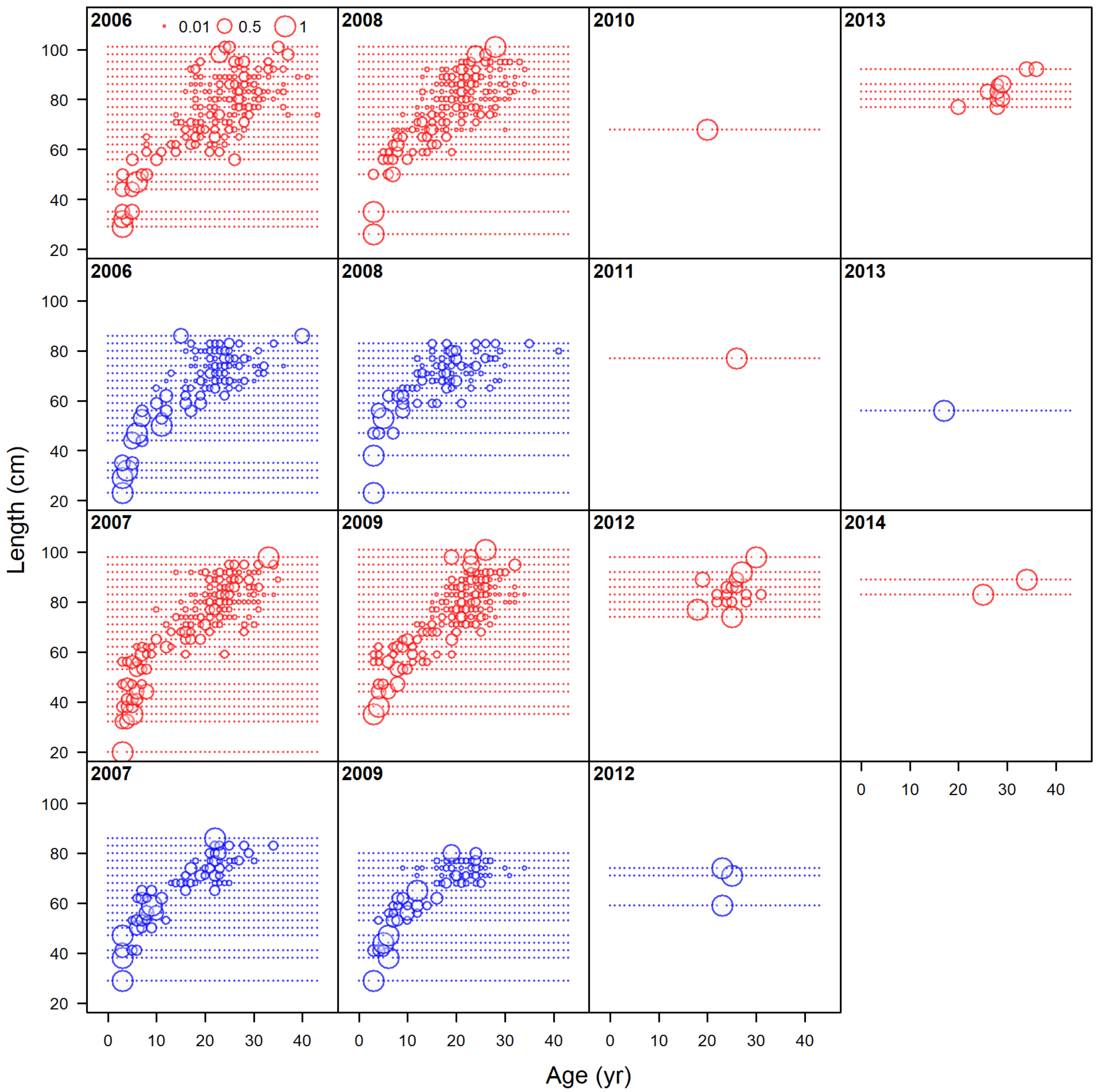


Figure 4.4. Conditional age-at-length data from NEFSC spring bottom trawl survey.

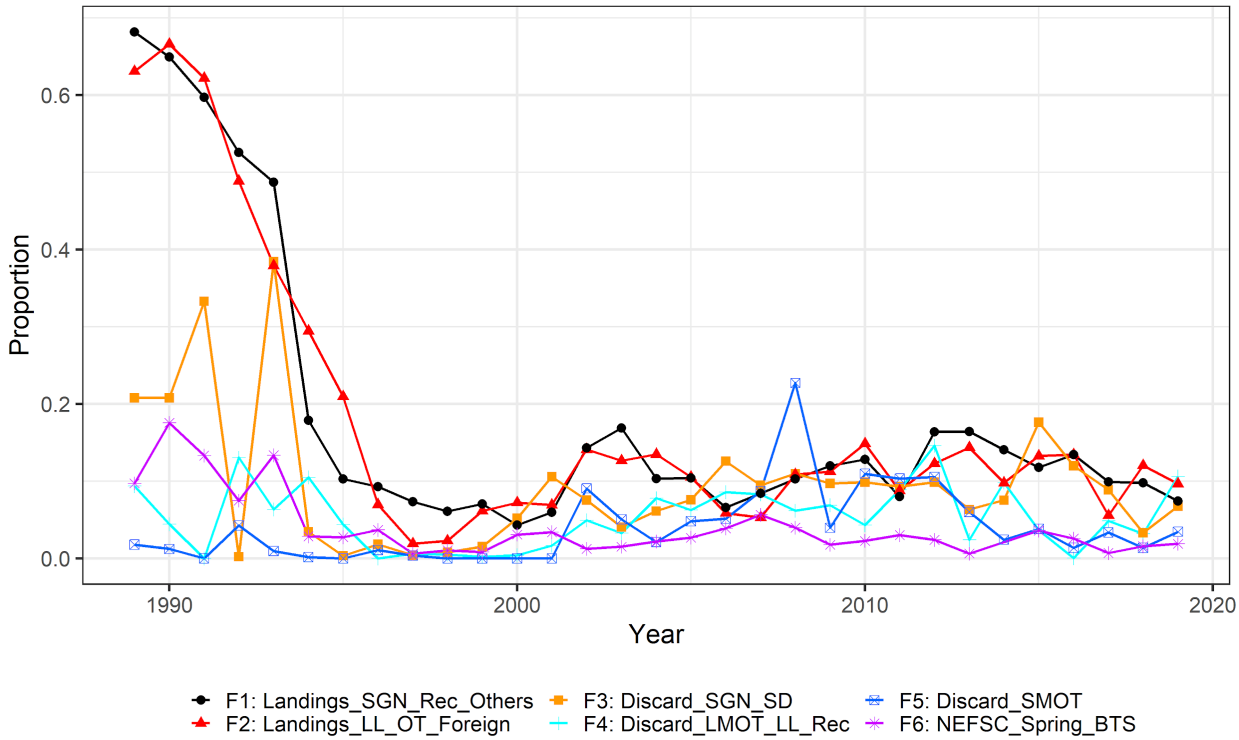


Figure 4.5. Proportion of 90+ cm females by fleet and year.

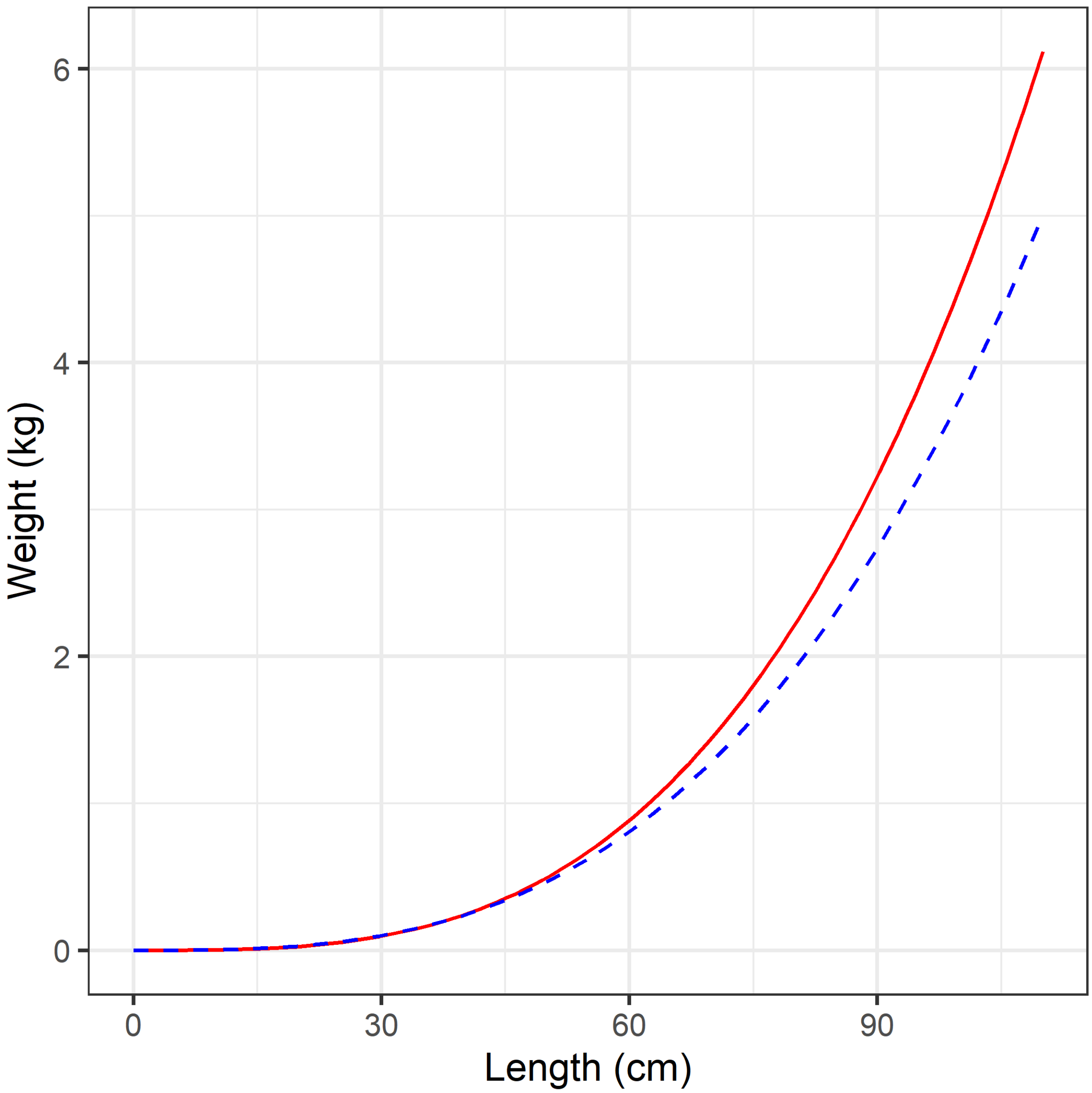


Figure 4.6. Length-weight relationships for females (red solid line) and males (blue dash line).

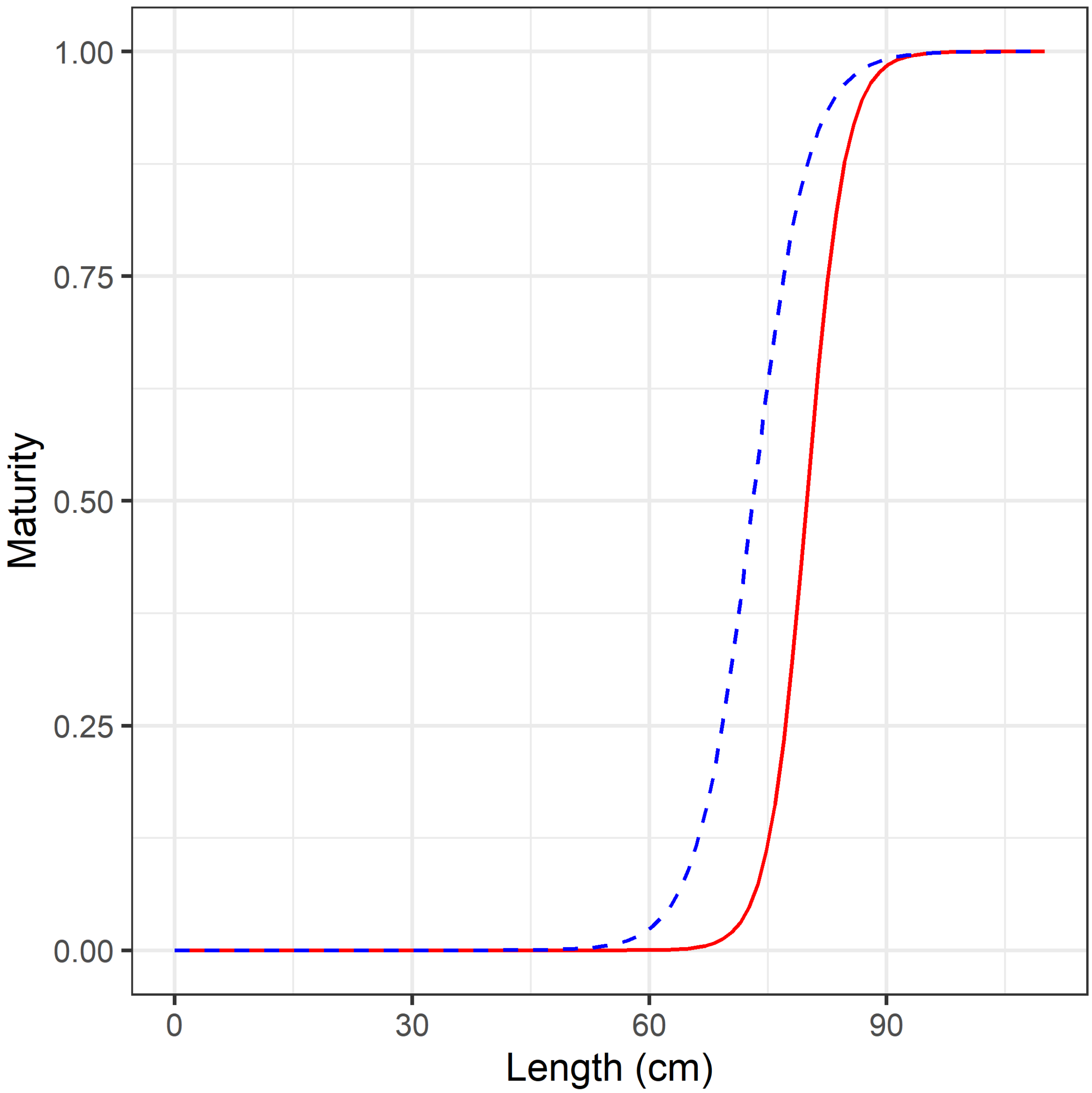


Figure 4.7. Maturity at length for biology blocks 1989-2011 (red solid line) and 2012-2019 (blue dash line).

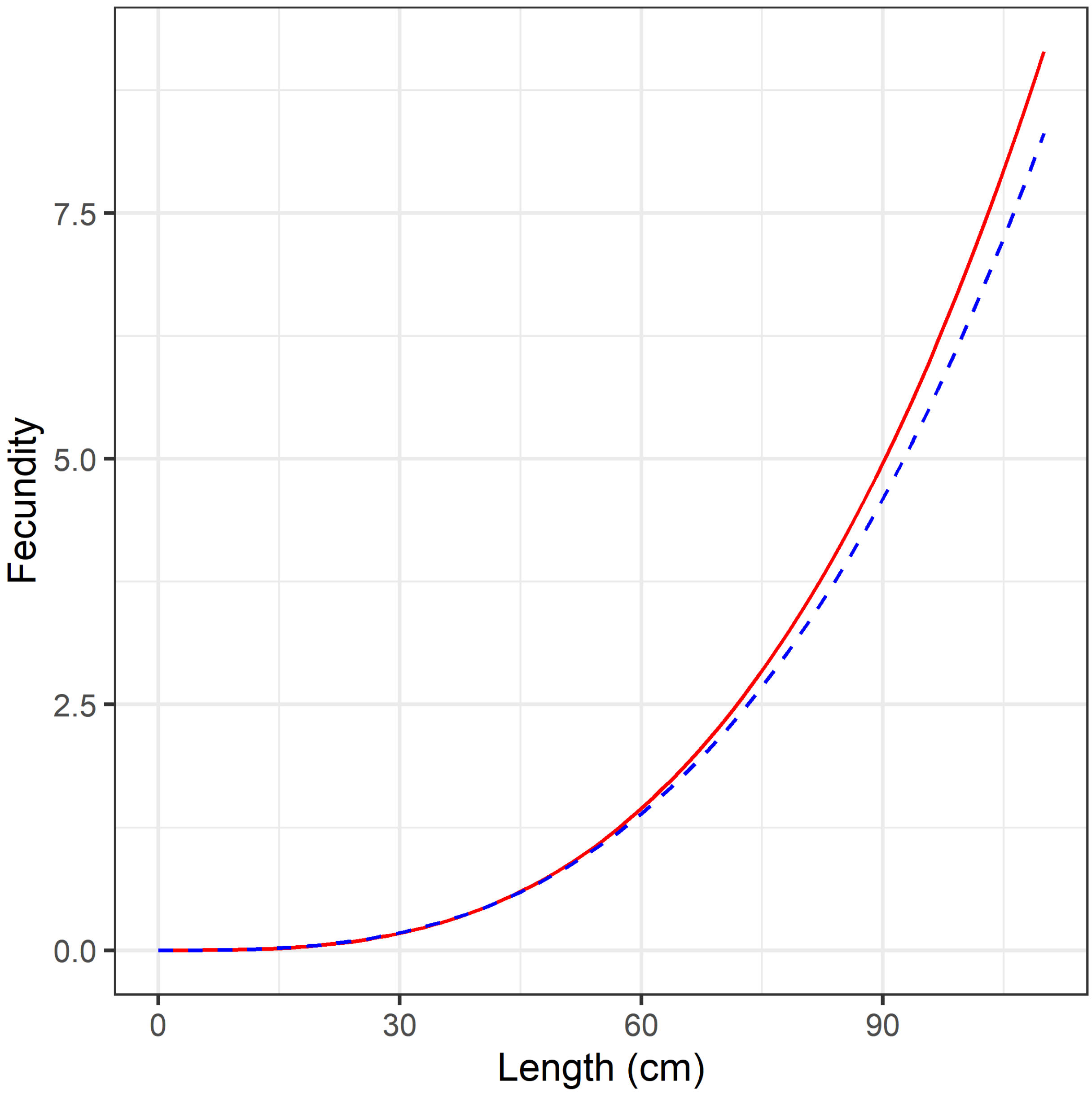


Figure 4.8. Fecundity at length for biology blocks 1989-2011 (red solid line) and 2012-2019 (blue dash line).

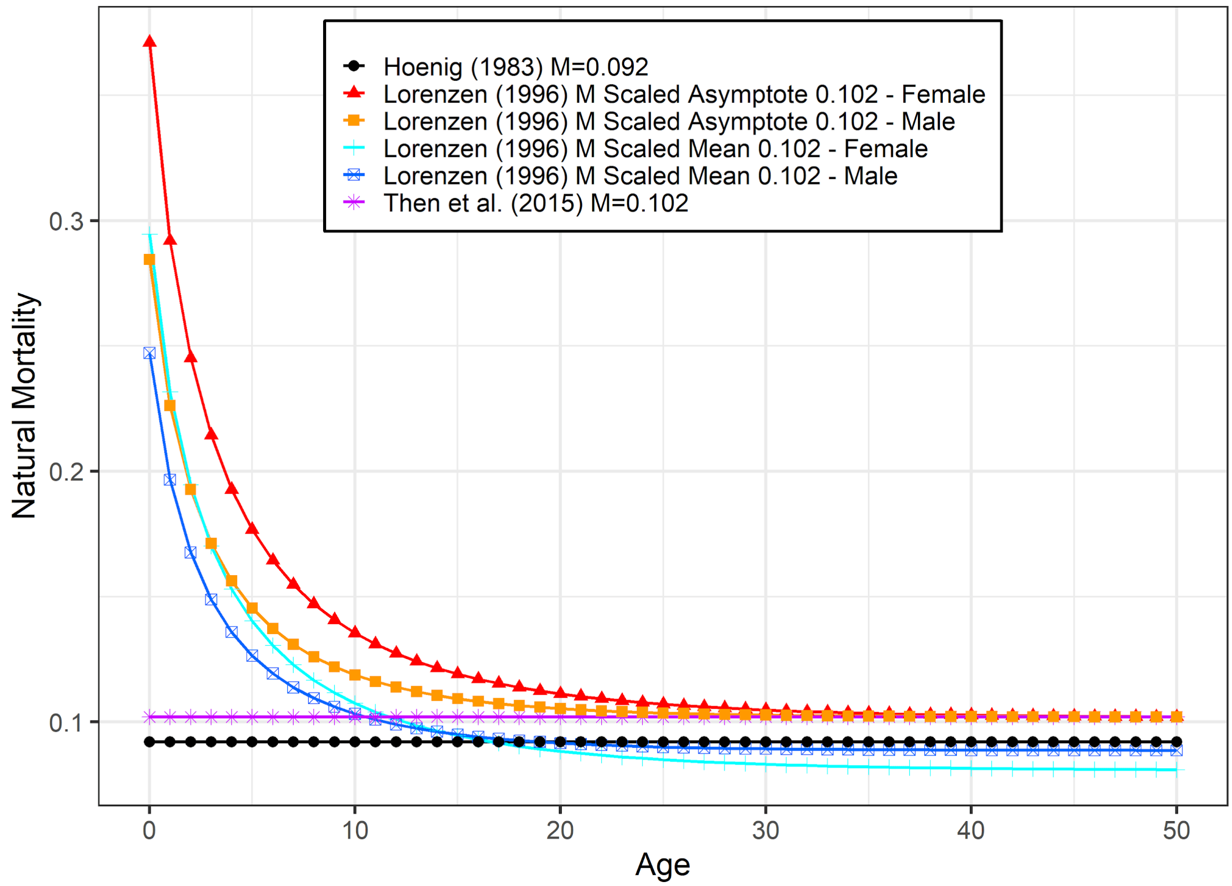


Figure 4.9. Natural mortality estimates explored in SS3 for Atlantic spiny dogfish.

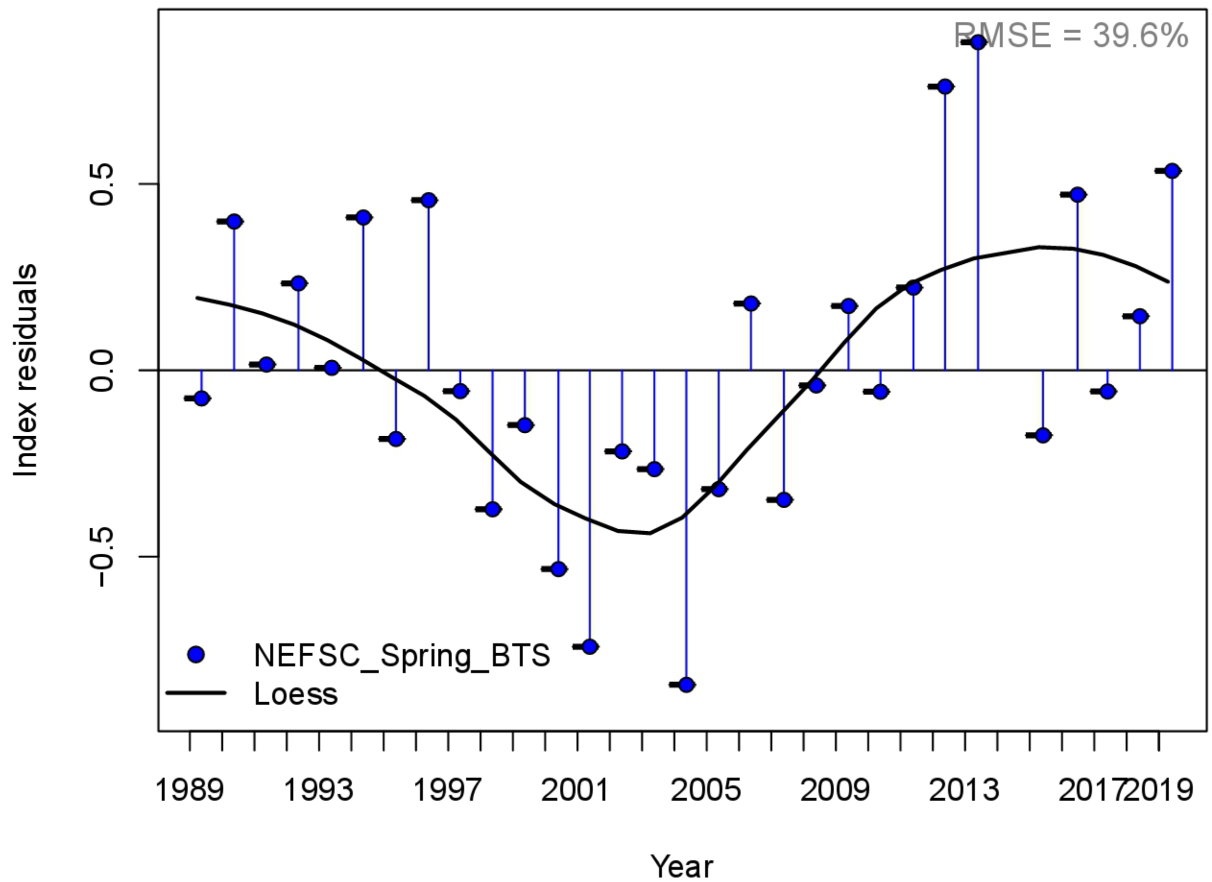


Figure 4.10. Joint residual plot from fit to annual index data.

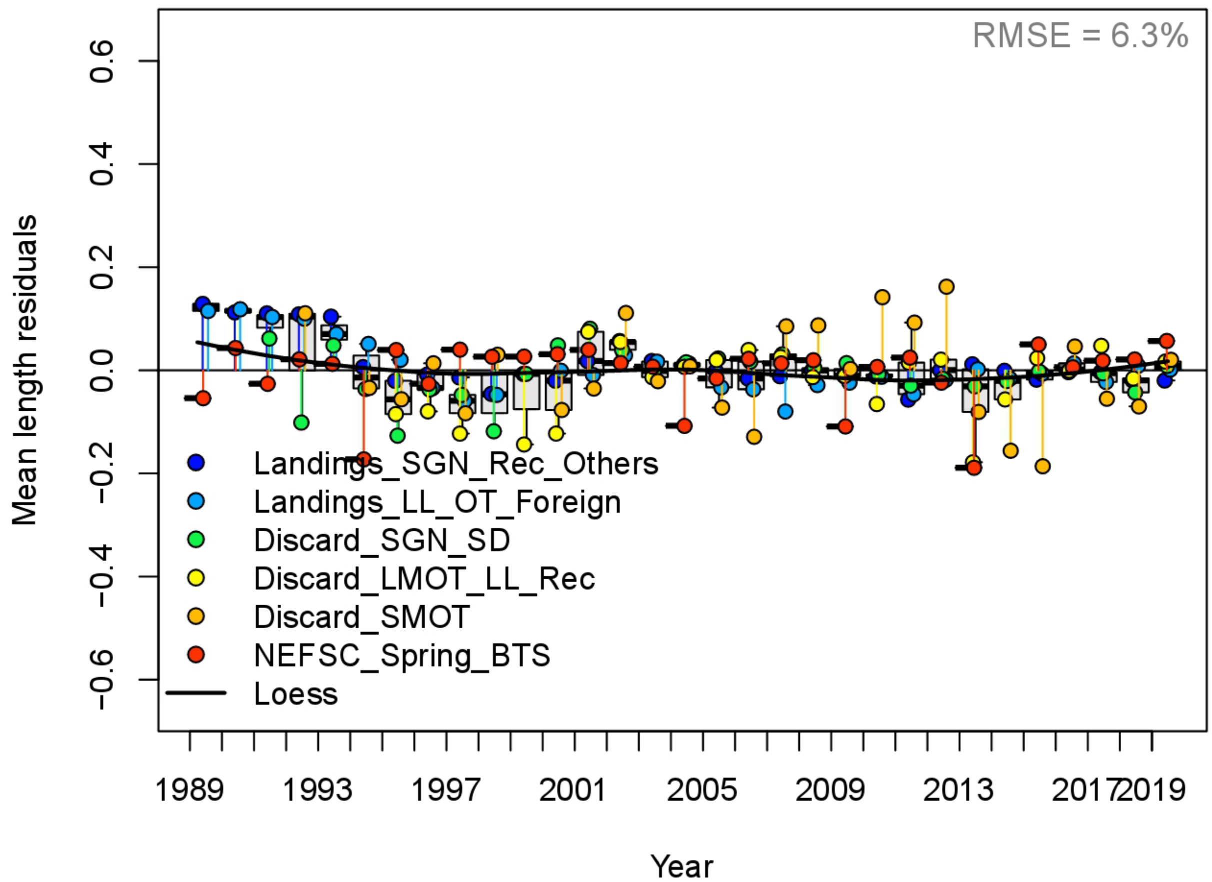


Figure 4.11. Joint residual plot from fit to annual mean length from length composition data.

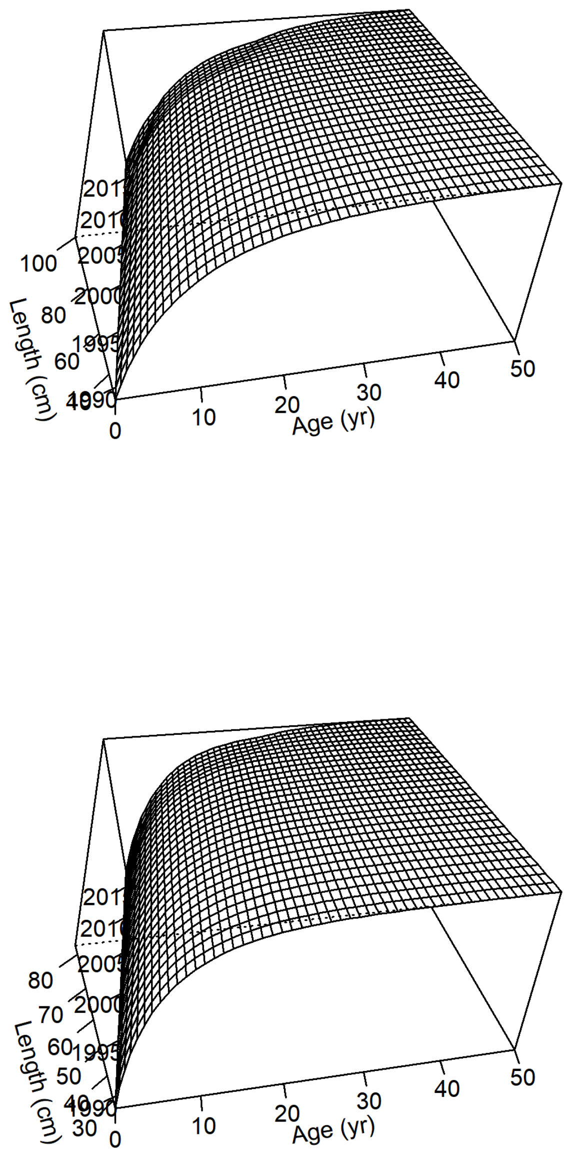


Figure 4.12. Surface plot of time-varying growth for females (top) and males (bottom) from 1989 to 2019.

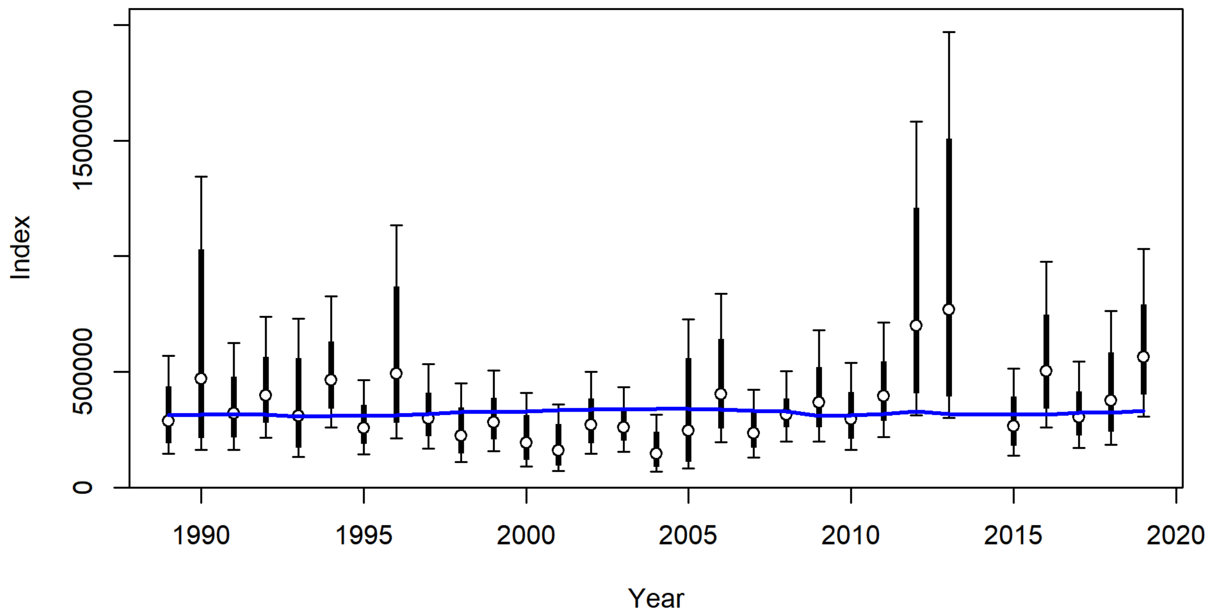


Figure 4.13. Observed and model-predicted abundance index (1,000s) for the NEFSC spring bottom trawl survey. Lines indicate 95% uncertainty interval around index values based on the model assumption of lognormal error. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

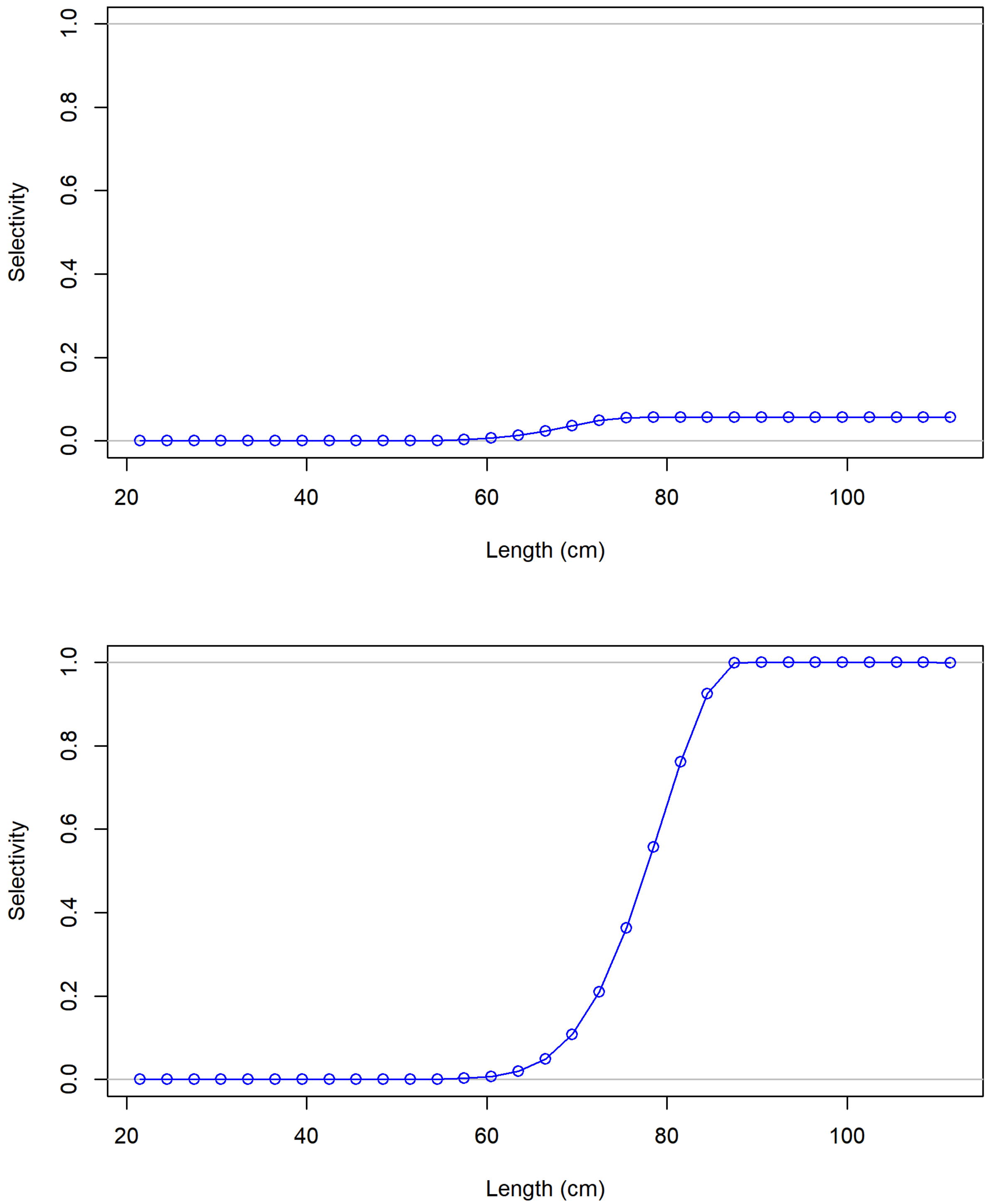


Figure 4.14. Estimated selectivity for females (top) and males (bottom) for fleet 1: Landings_SGN_Rec_Others.

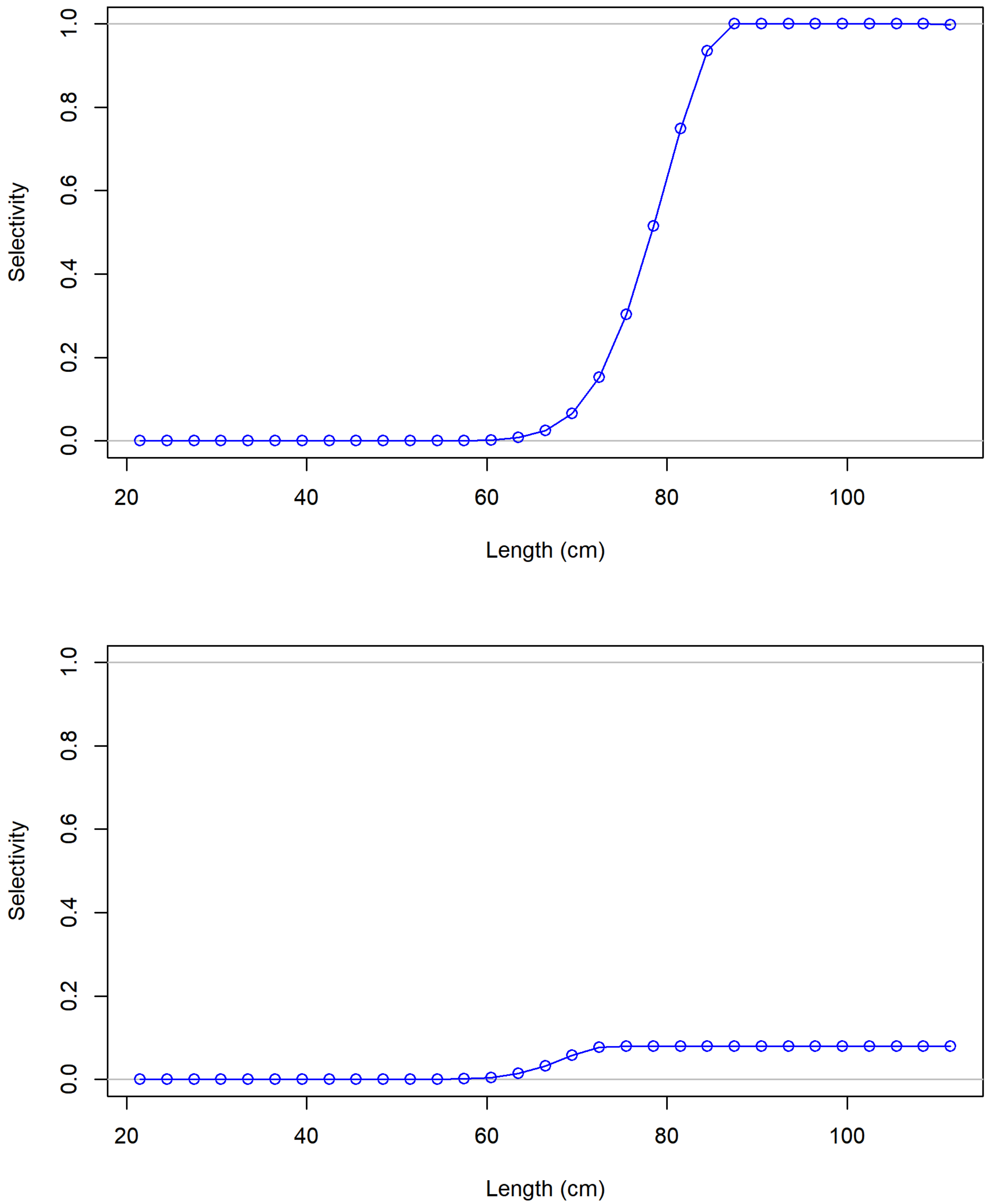


Figure 4.15. Estimated selectivity for females (top) and males (bottom) for fleet 2: Landings_LL_OT_Foreign.

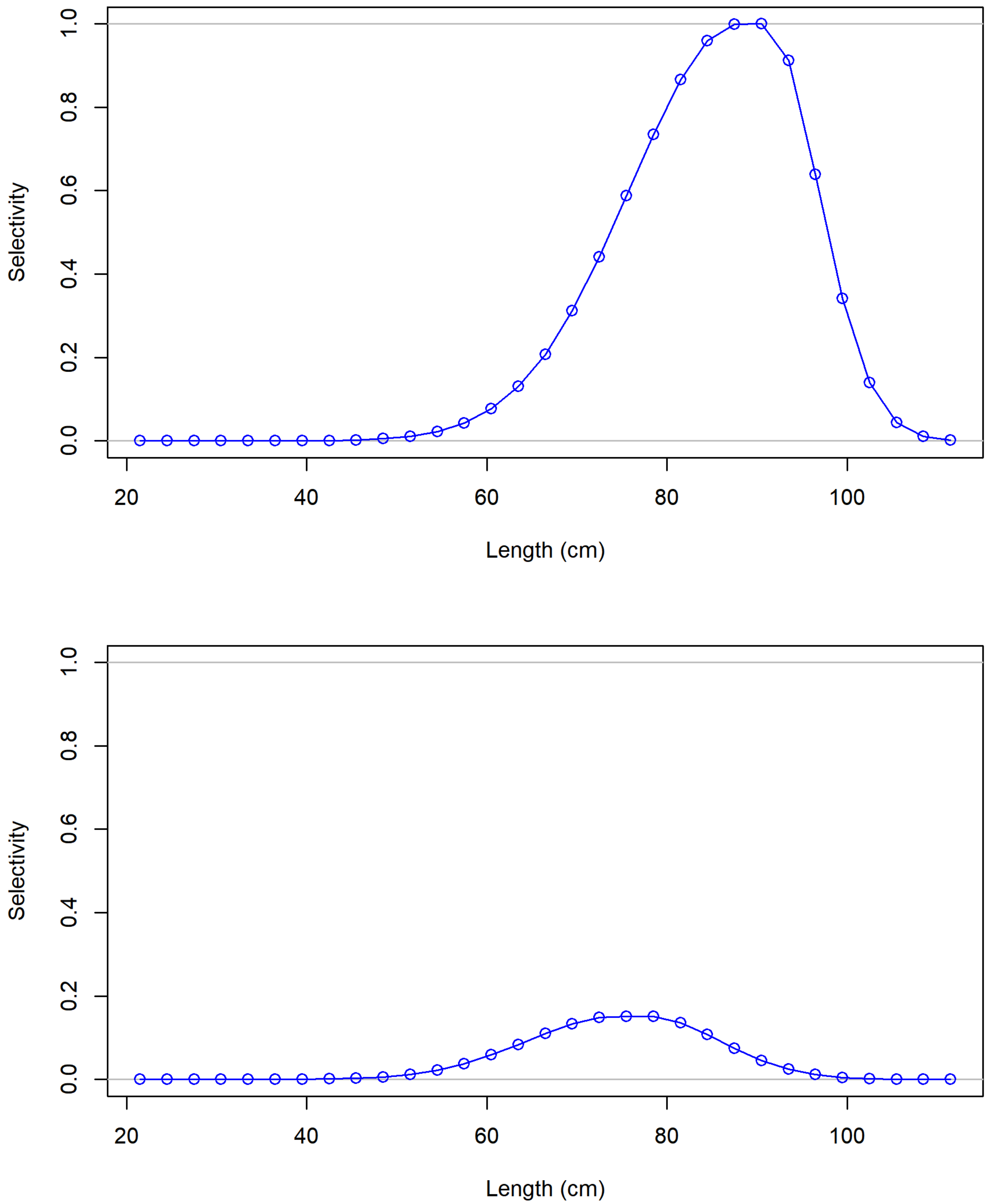


Figure 4.16. Estimated selectivity for females (top) and males (bottom) for fleet 3: Discard_SGN_SD.

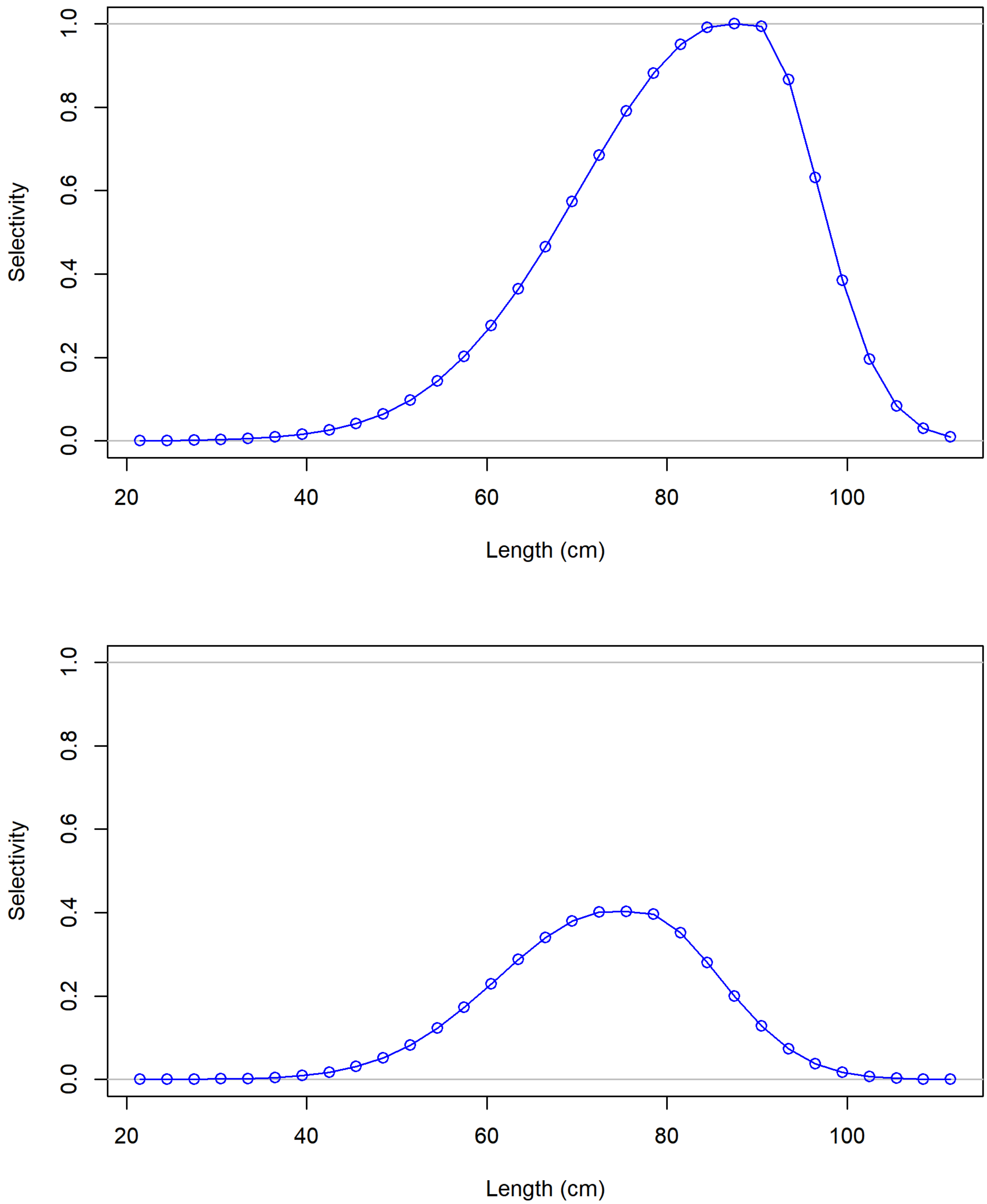


Figure 4.17. Estimated selectivity for females (top) and males (bottom) for fleet 4: Discard_LMOT_LL_Rec.

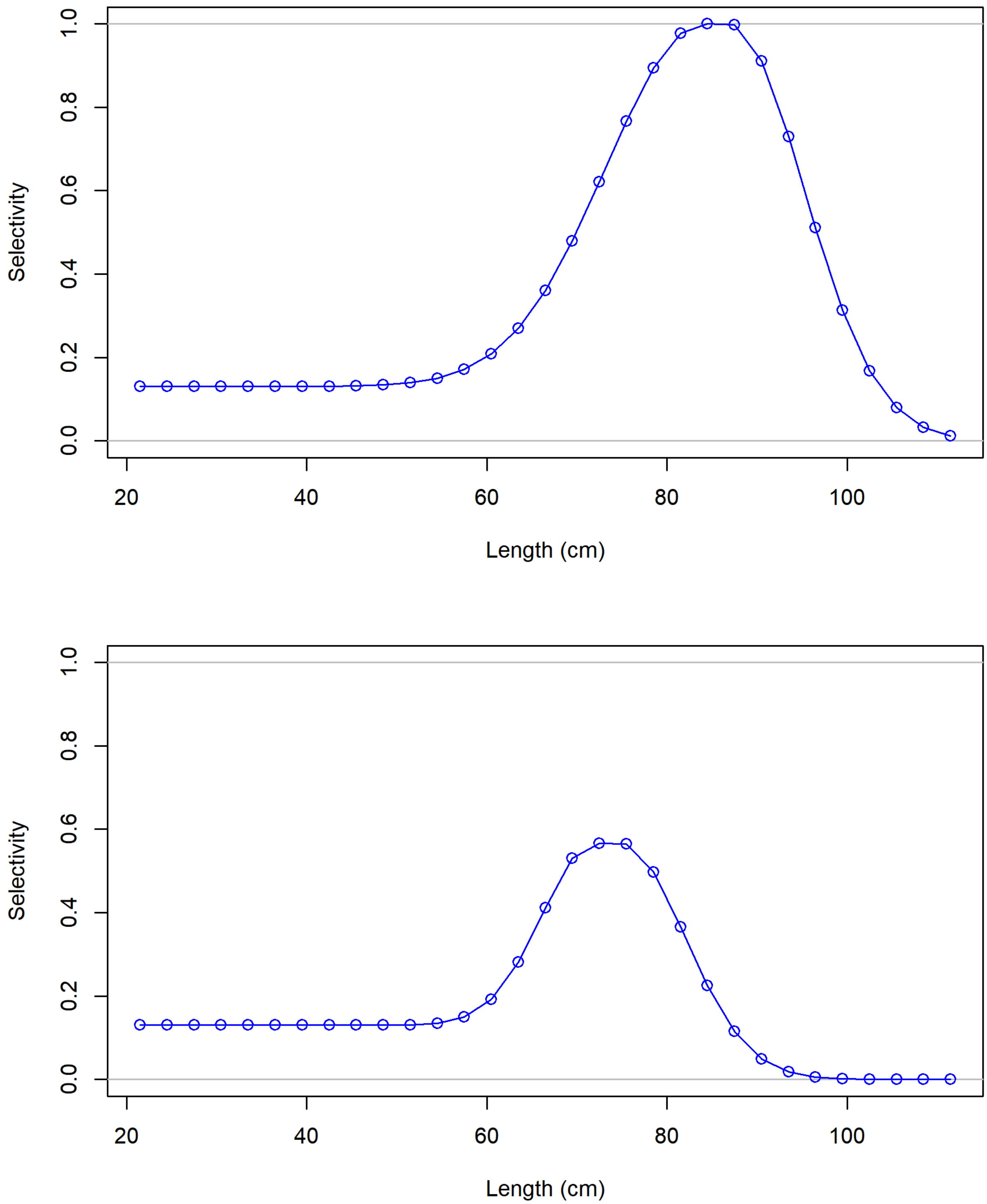
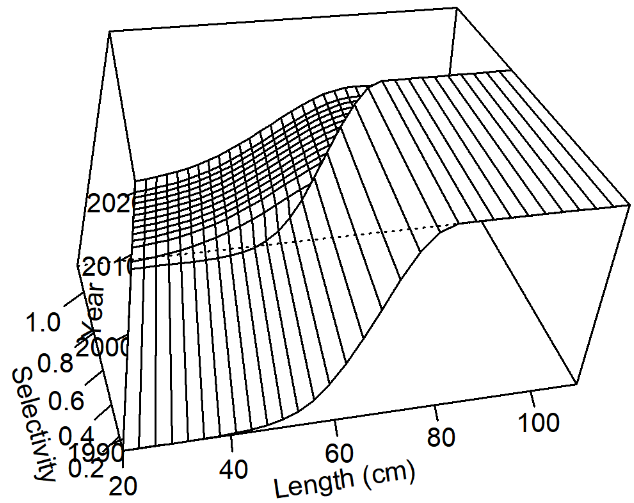


Figure 4.18. Estimated selectivity for females (top) and males (bottom) for fleet 5: Discard_SMOT.



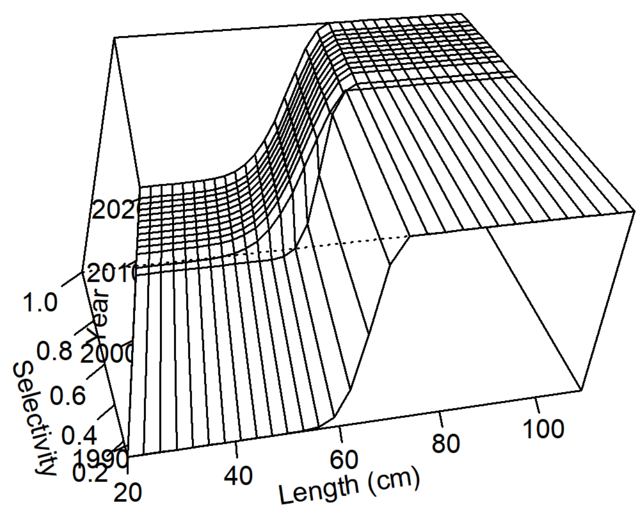


Figure 4.19. Surface plot of time-varying selectivity for females (top) and males (bottom) from 1989 to 2019 for NEFSC spring bottom trawl survey.

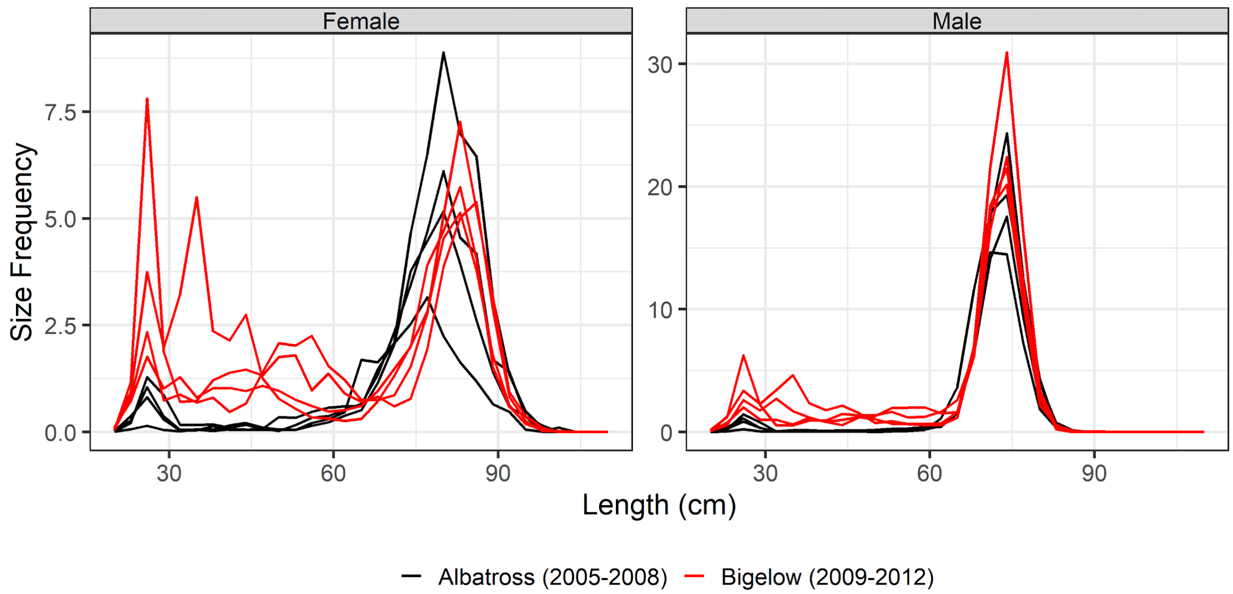


Figure 4.20. Observed length composition data from 2005 to 2012 for NEFSC spring bottom trawl survey by *Albatross* and *Bigelow* period.

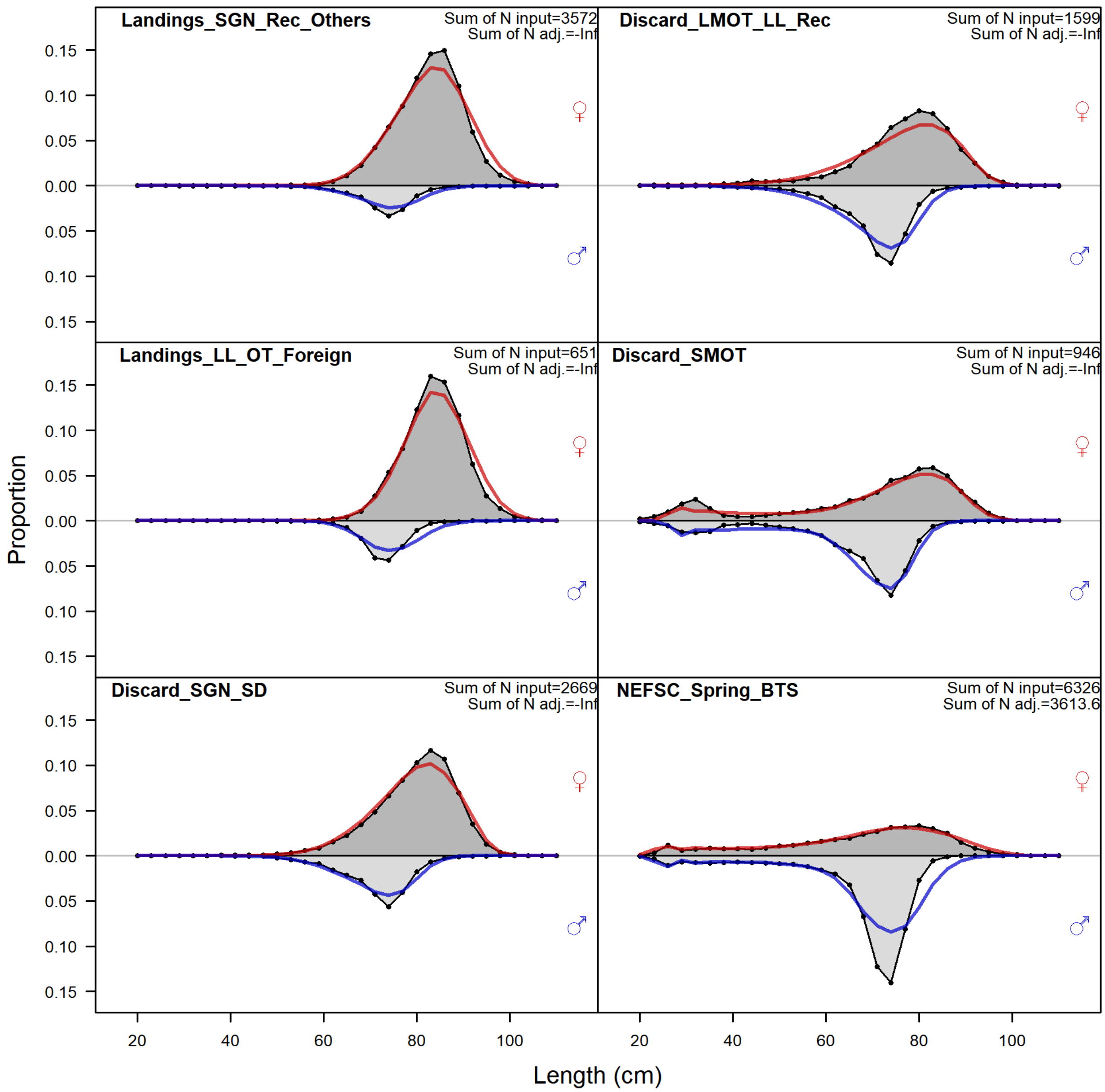


Figure 4.21. Observed (shaded) and model-predicted (line) length compositions, aggregated across time by fleet and sex.

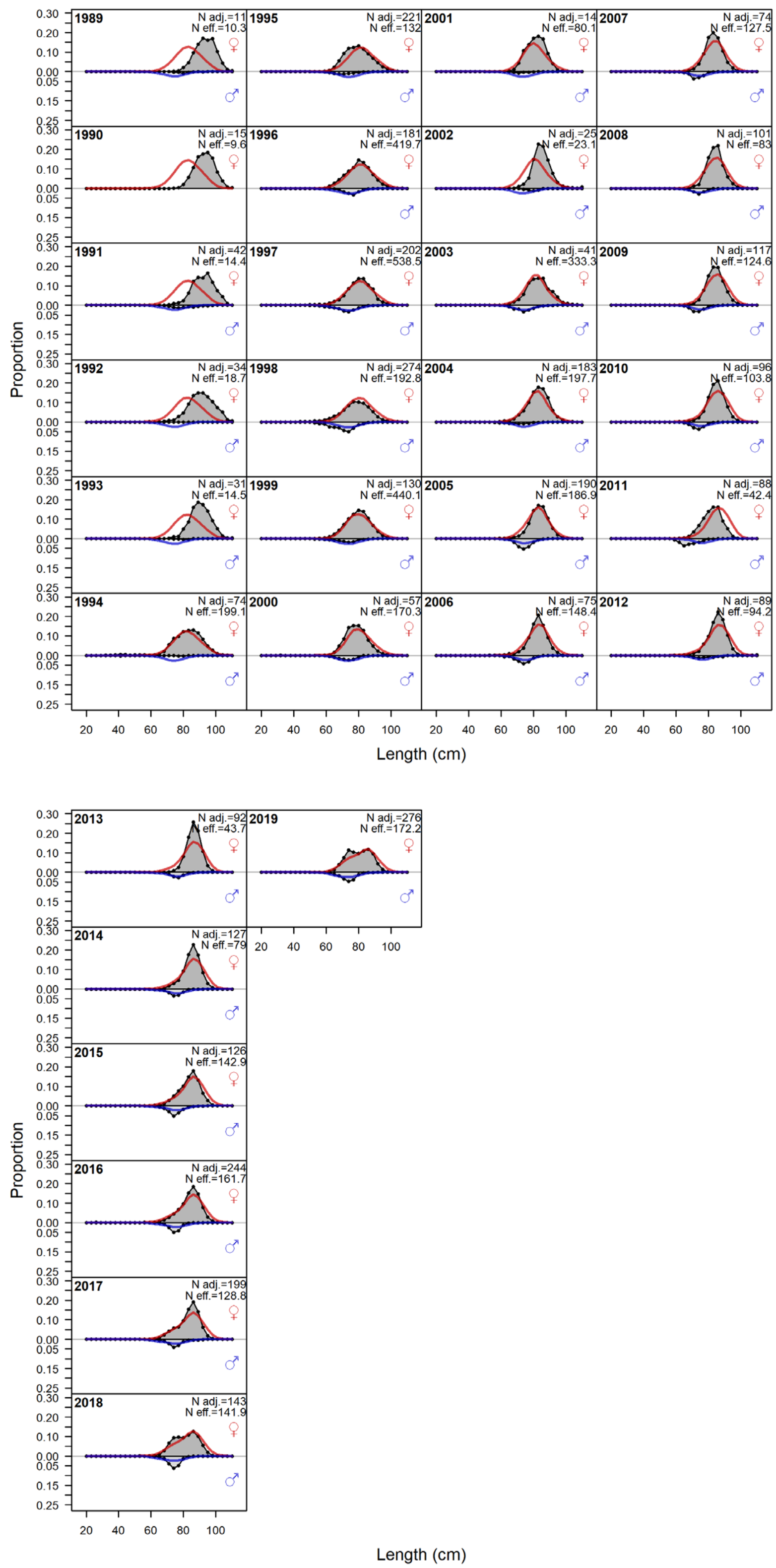


Figure 4.22. Fit to length compositions by year and sex for fleet 1: Landings_SGN_Rec_Others.

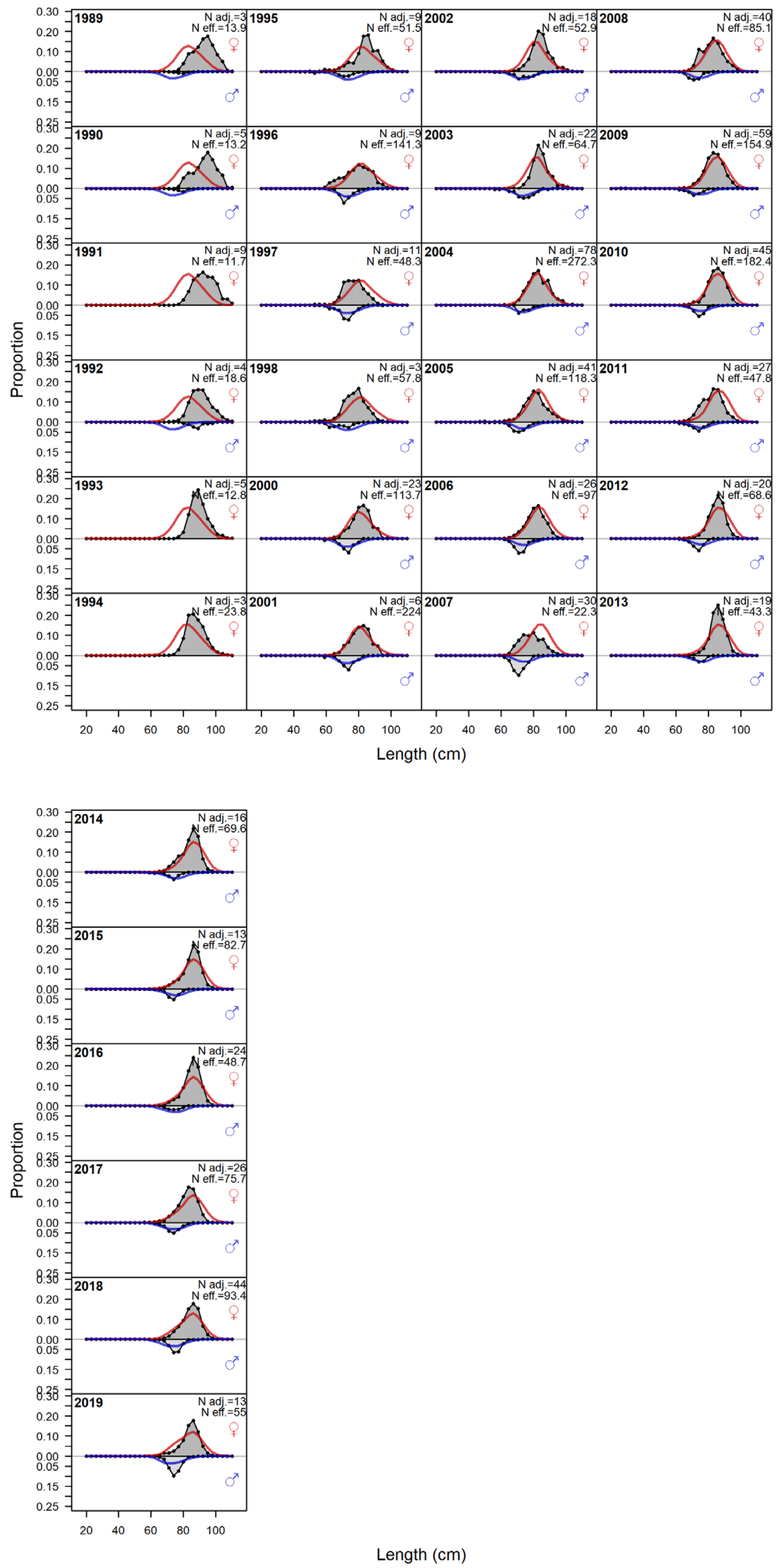


Figure 4.23. Fit to length compositions by year and sex for fleet 2: Landings_LL_OT_Foreign.

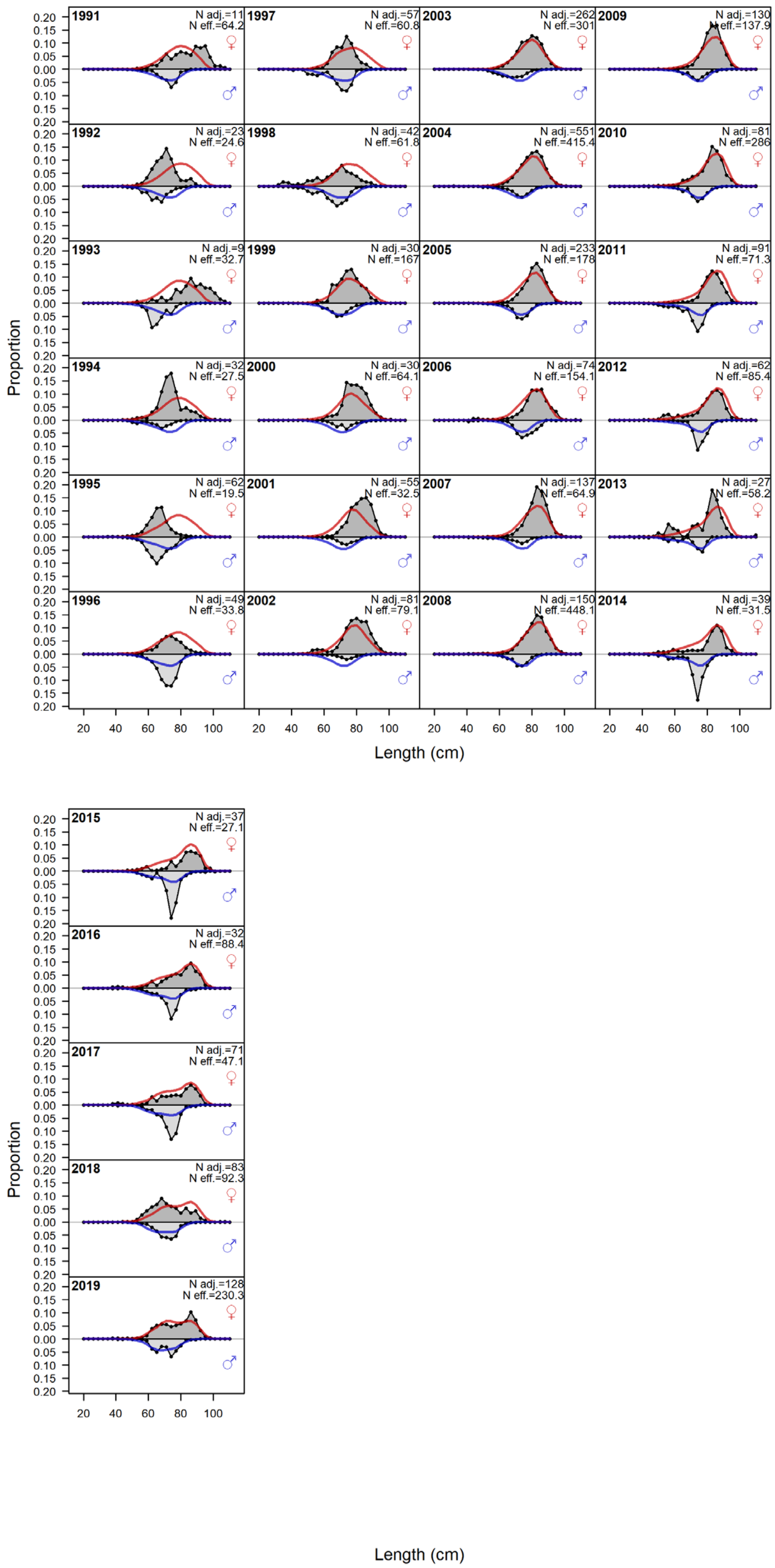


Figure 4.24. Fit to length compositions by year and sex for fleet 3: Discard_SGN_SD.

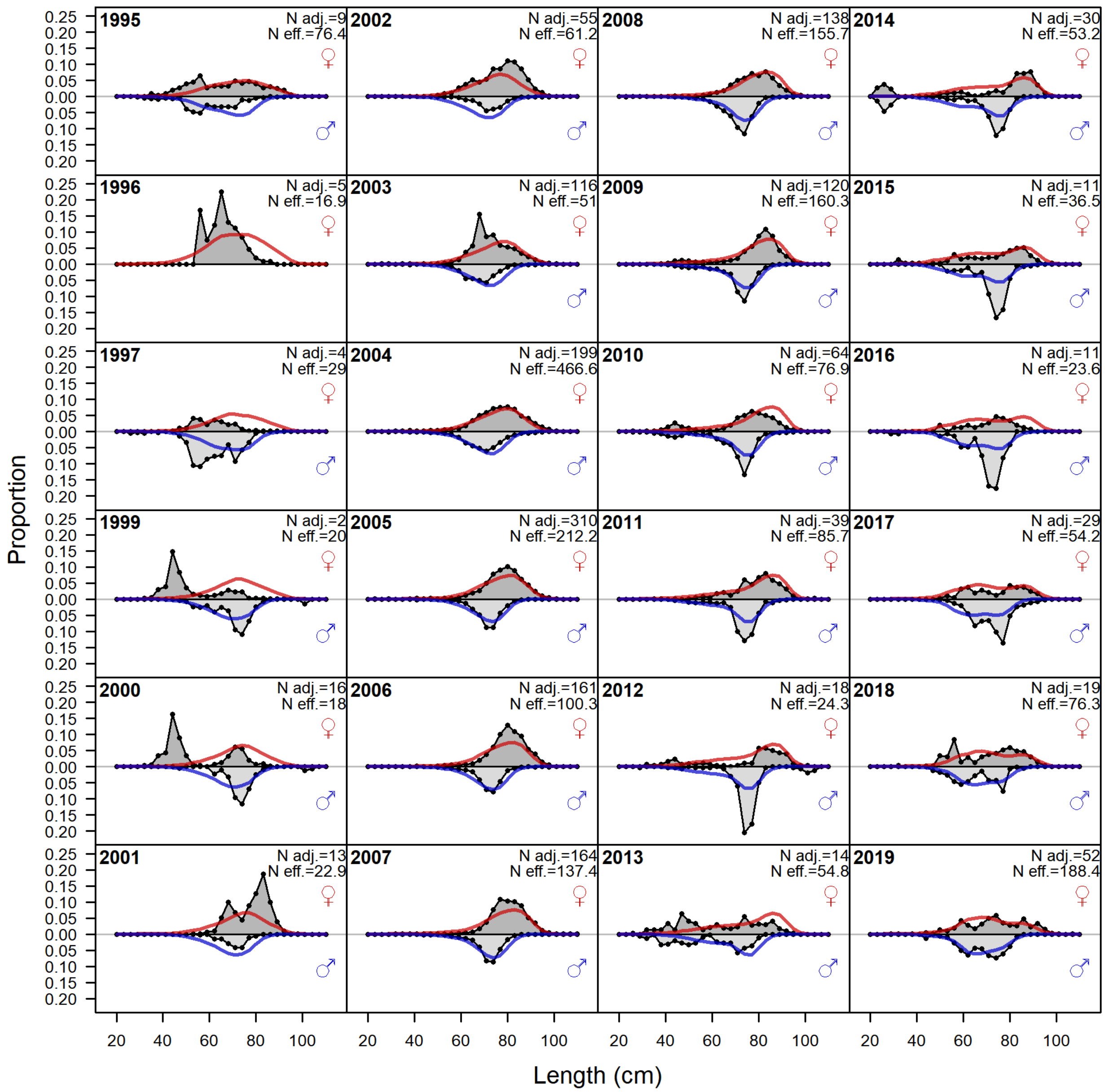
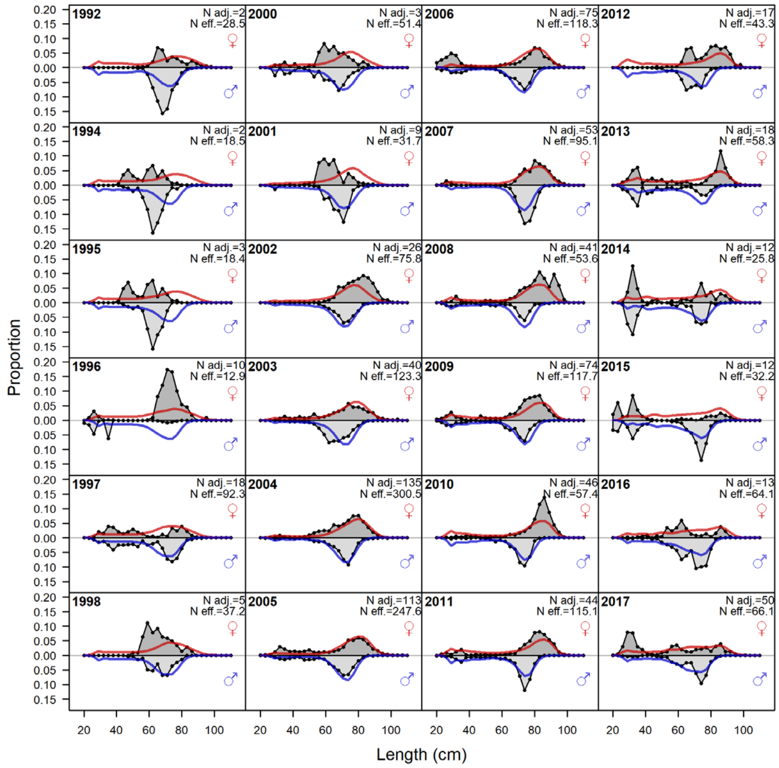


Figure 4.25. Fit to length compositions by year and sex for fleet 4: Discard_LMOT_LL_Rec.



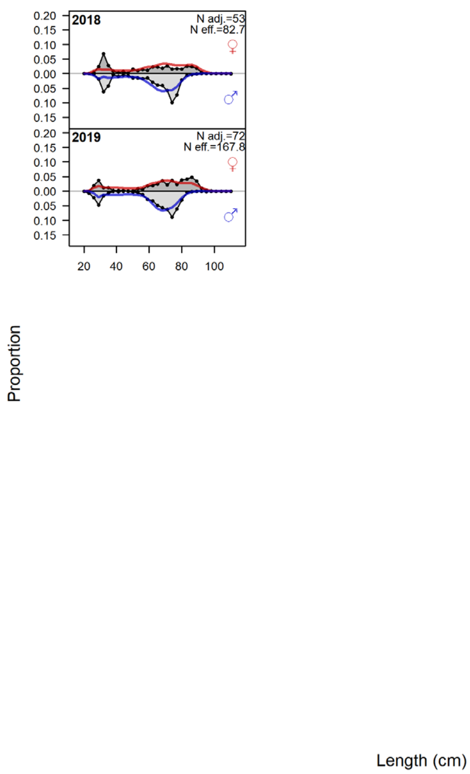


Figure 4.26. Fit to length compositions by year and sex for fleet 5: Discard_SMOT.

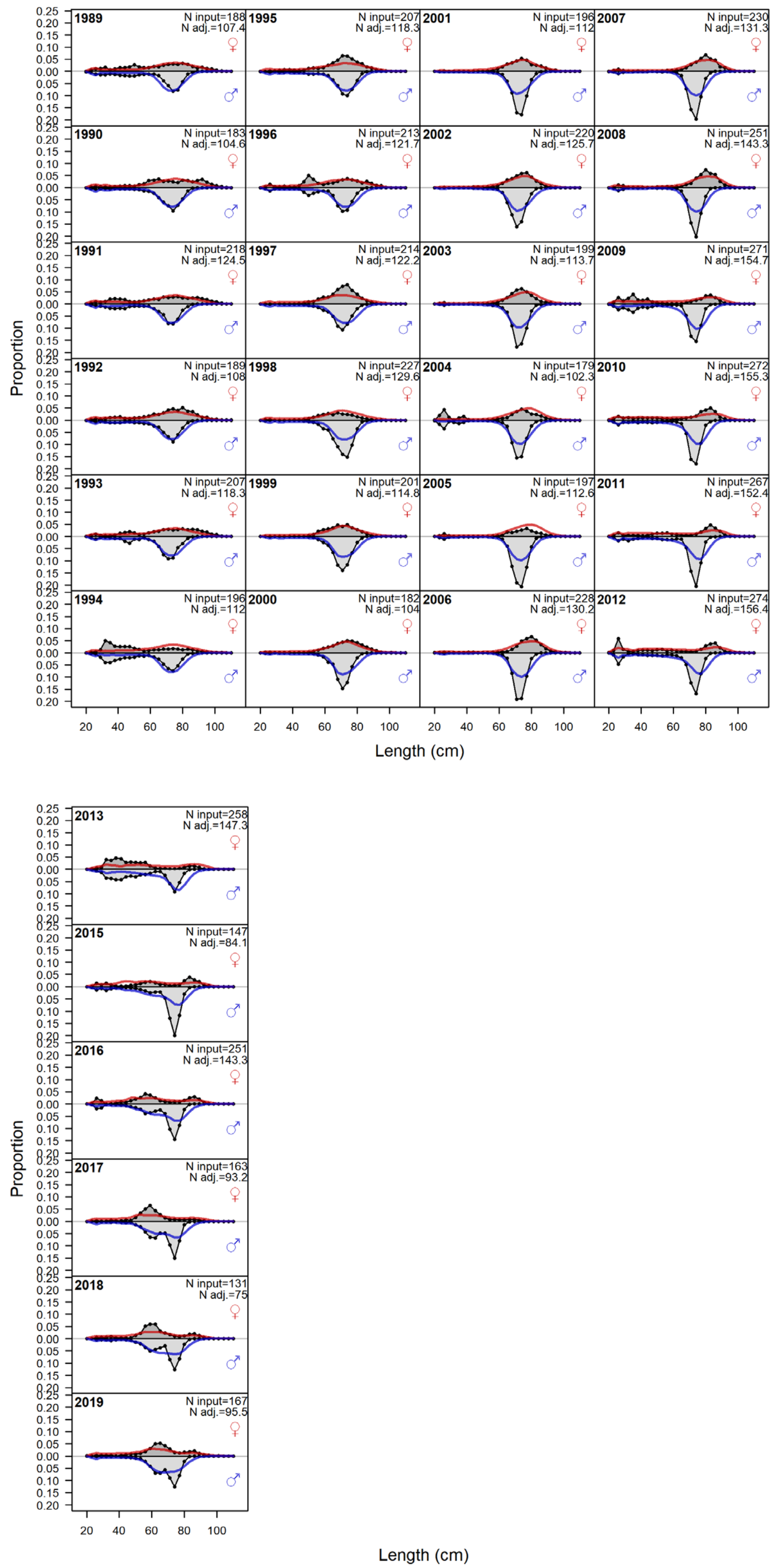


Figure 4.27. Fit to length compositions by year and sex for NEFSC spring bottom trawl survey.

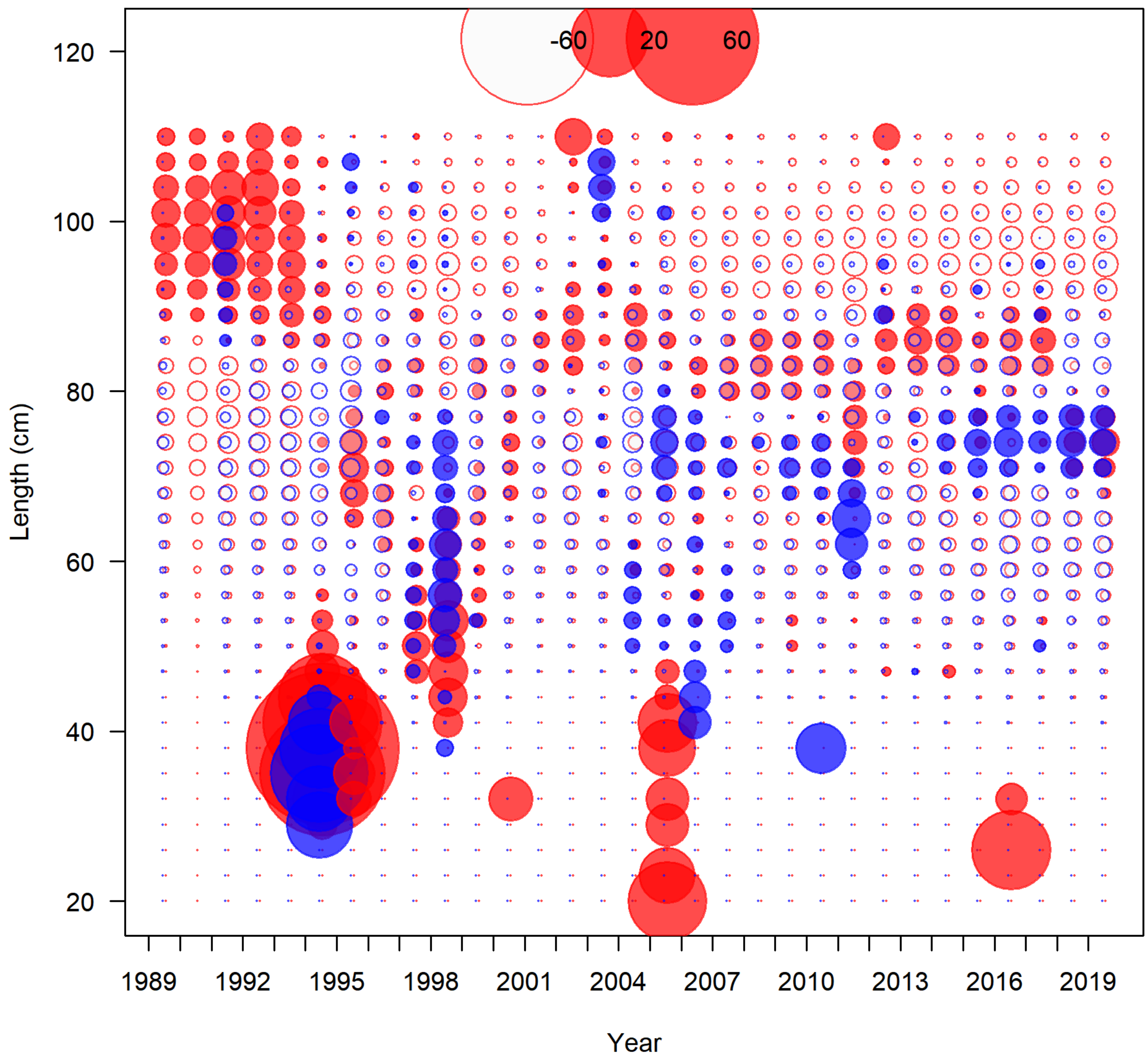


Figure 4.28. Pearson residuals for the fit to length compositions by year and sex for fleet 1: Landings_SGN_Rec_Others. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

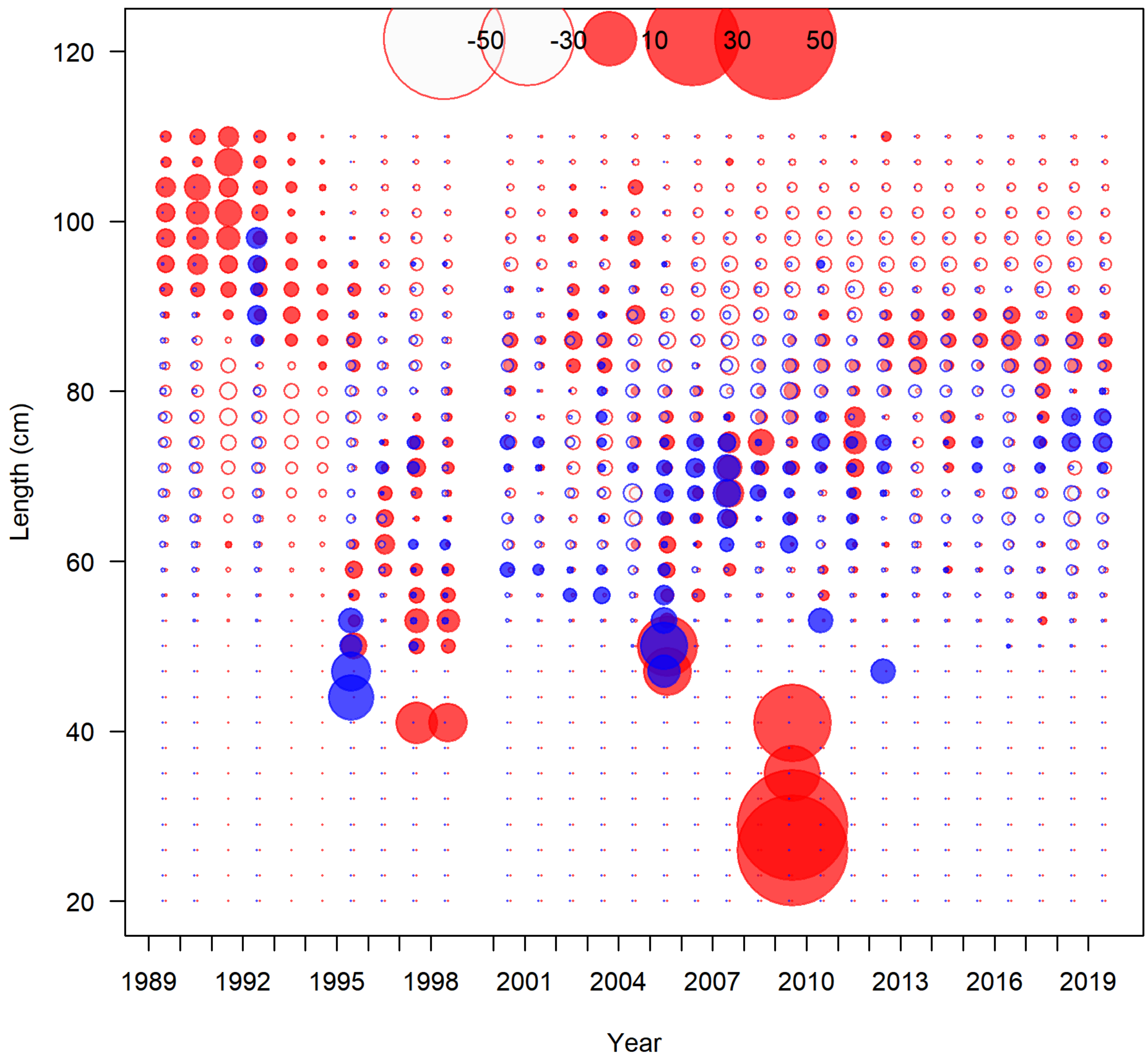


Figure 4.29. Pearson residuals for the fit to length compositions by year and sex for fleet 2: Landings_LL_OT_Foreign. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

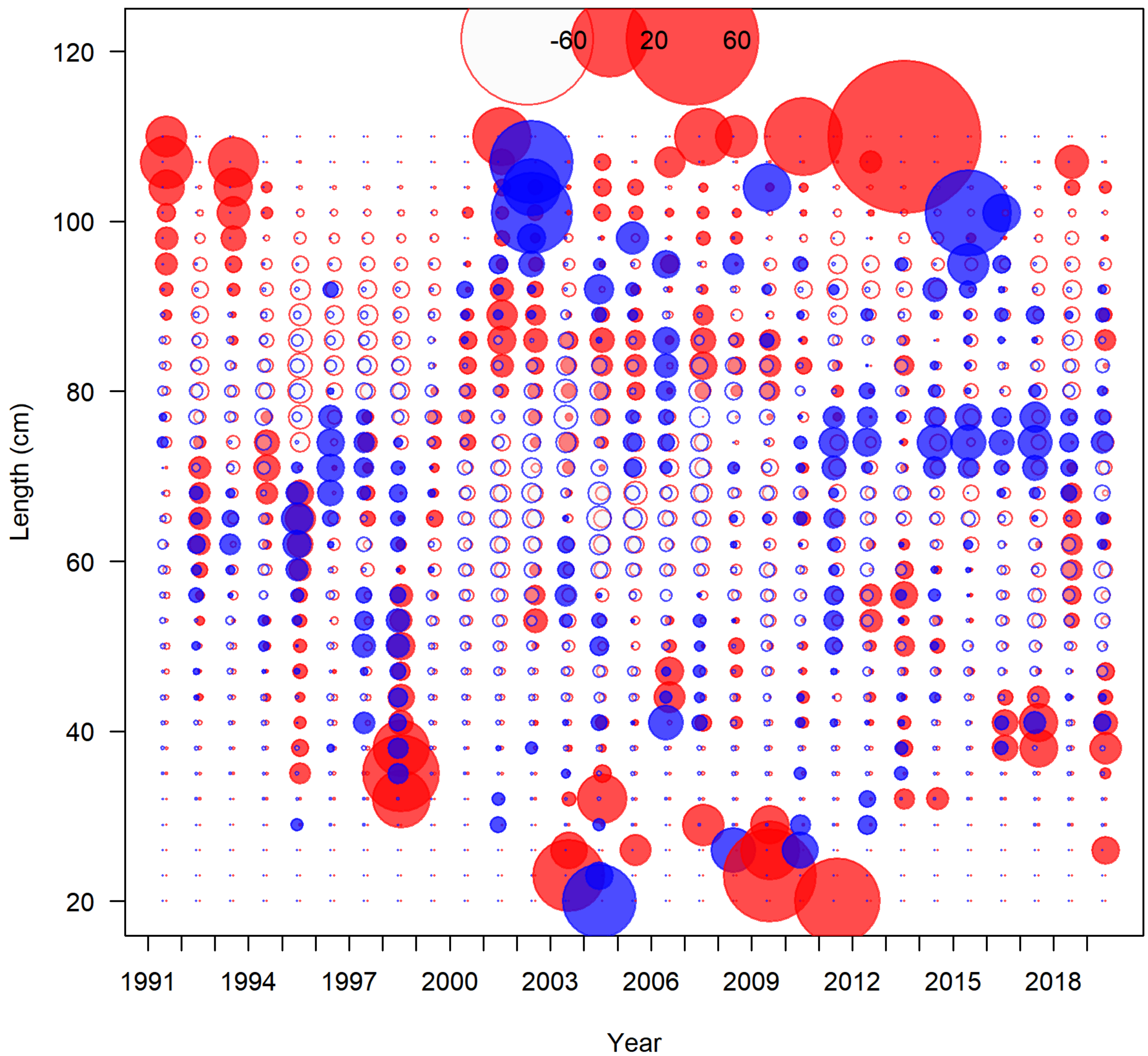


Figure 4.30. Pearson residuals for the fit to length compositions by year and sex for fleet 3: Discard_SGN_SD. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

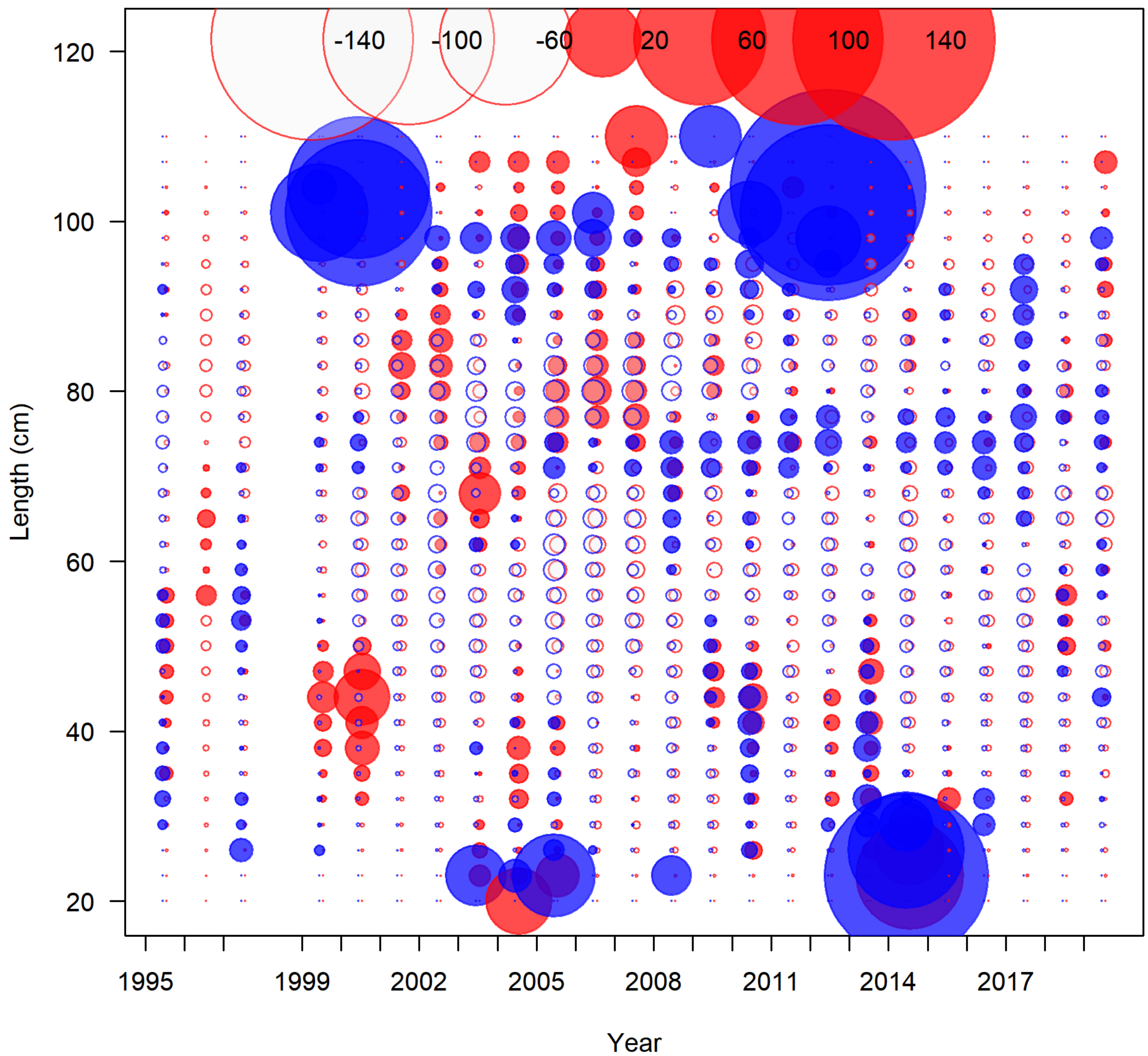


Figure 4.31. Pearson residuals for the fit to length compositions by year and sex for fleet 4: Discard_LMOT_LL_Rec. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

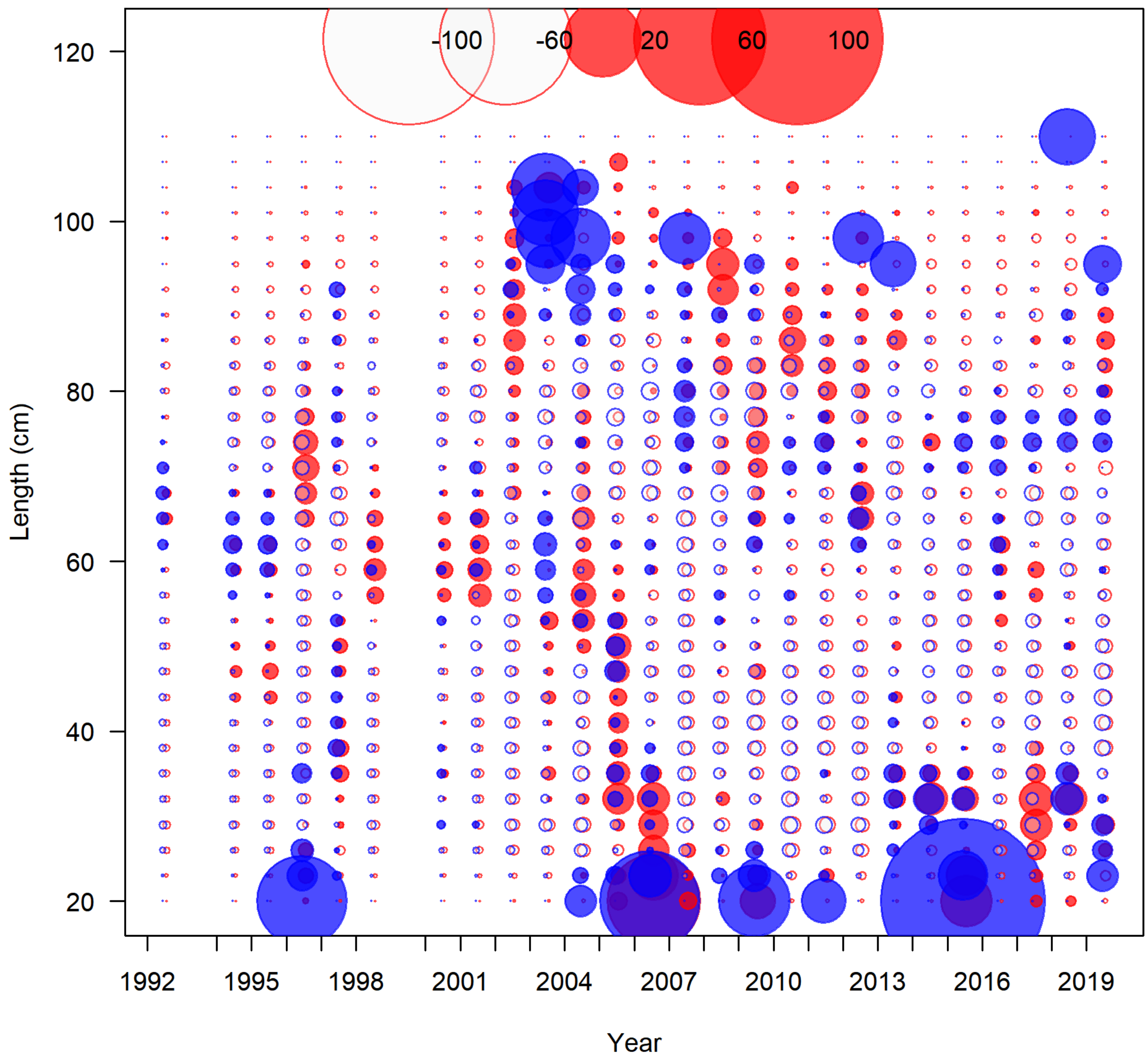


Figure 4.32. Pearson residuals for the fit to length compositions by year and sex for fleet 5: Discard_SMOT. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

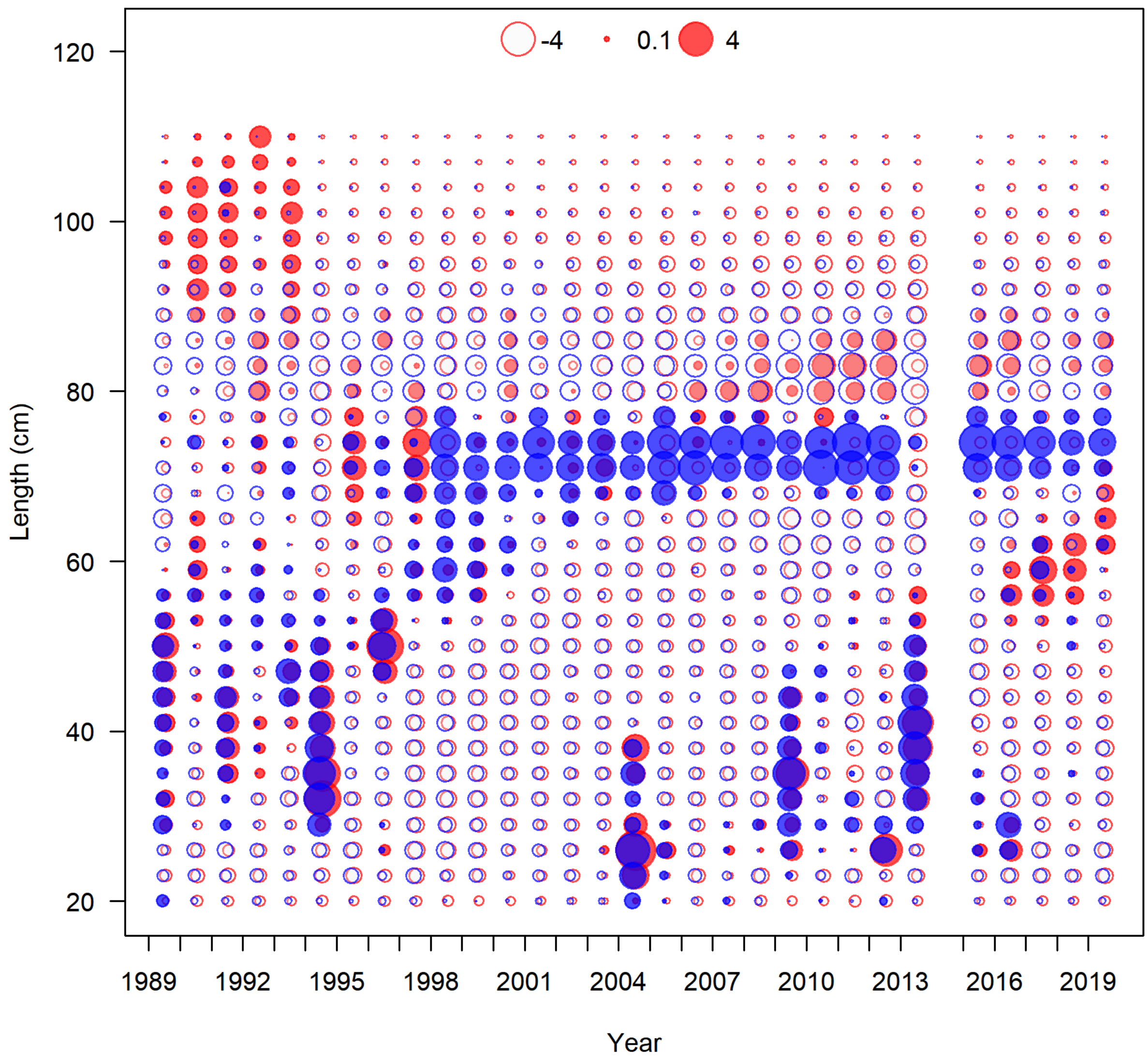


Figure 4.33. Pearson residuals for the fit to length compositions by year and sex for NEFSC spring bottom trawl survey. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

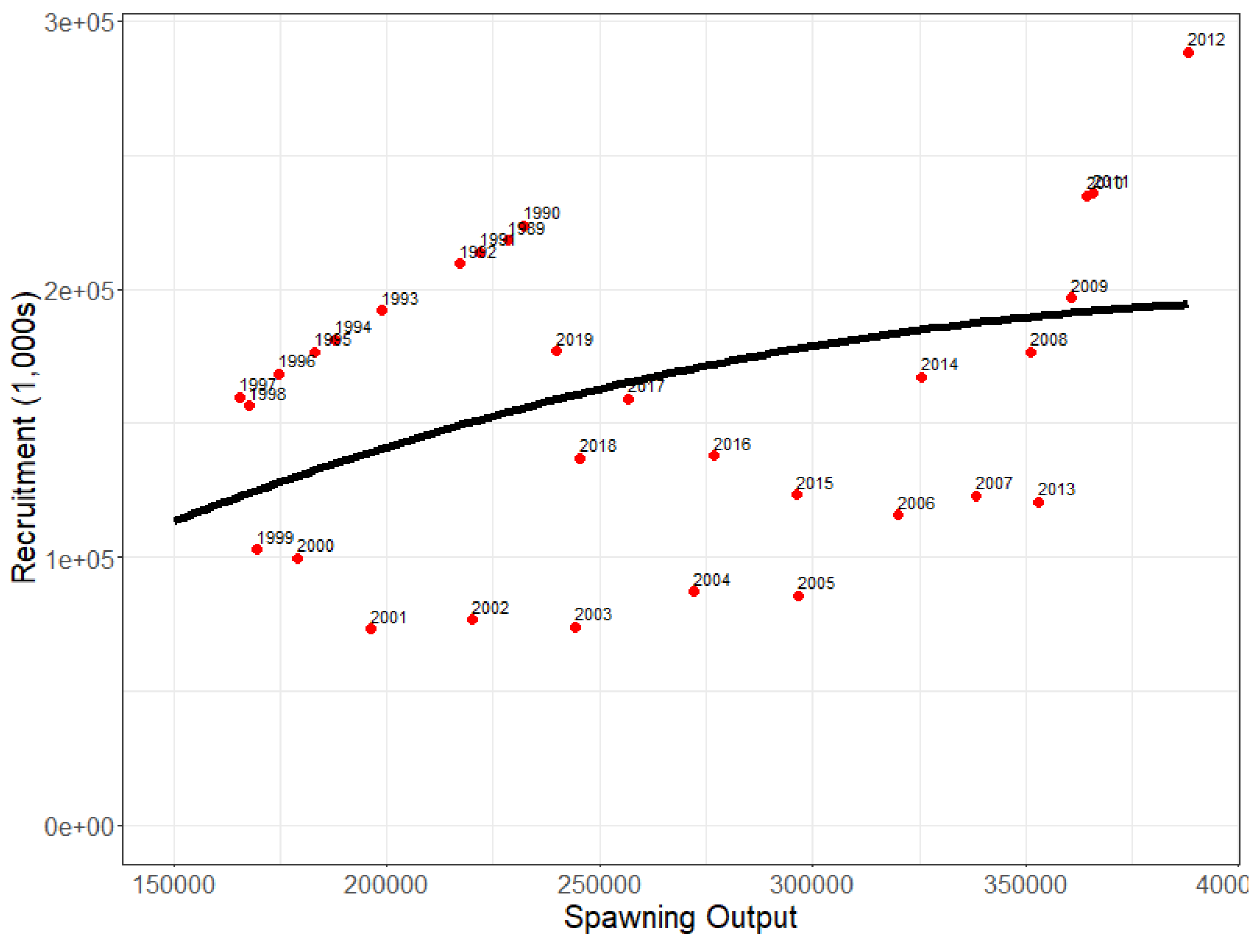


Figure 4.34. Fixed survivorship spawner-recruitment relationship, estimated age-0 recruitment (1,000s), and estimated spawning output by year for Atlantic spiny dogfish.

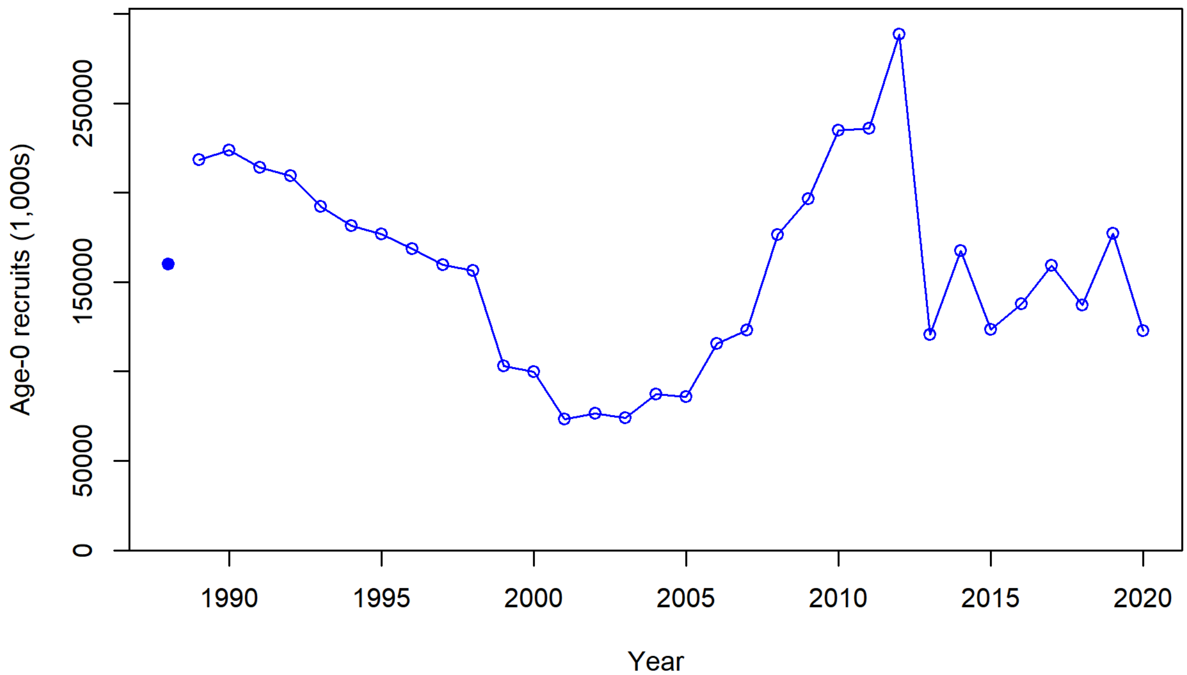


Figure 4.35. Estimated age-0 recruitment (1,000) by year for Atlantic spiny dogfish.

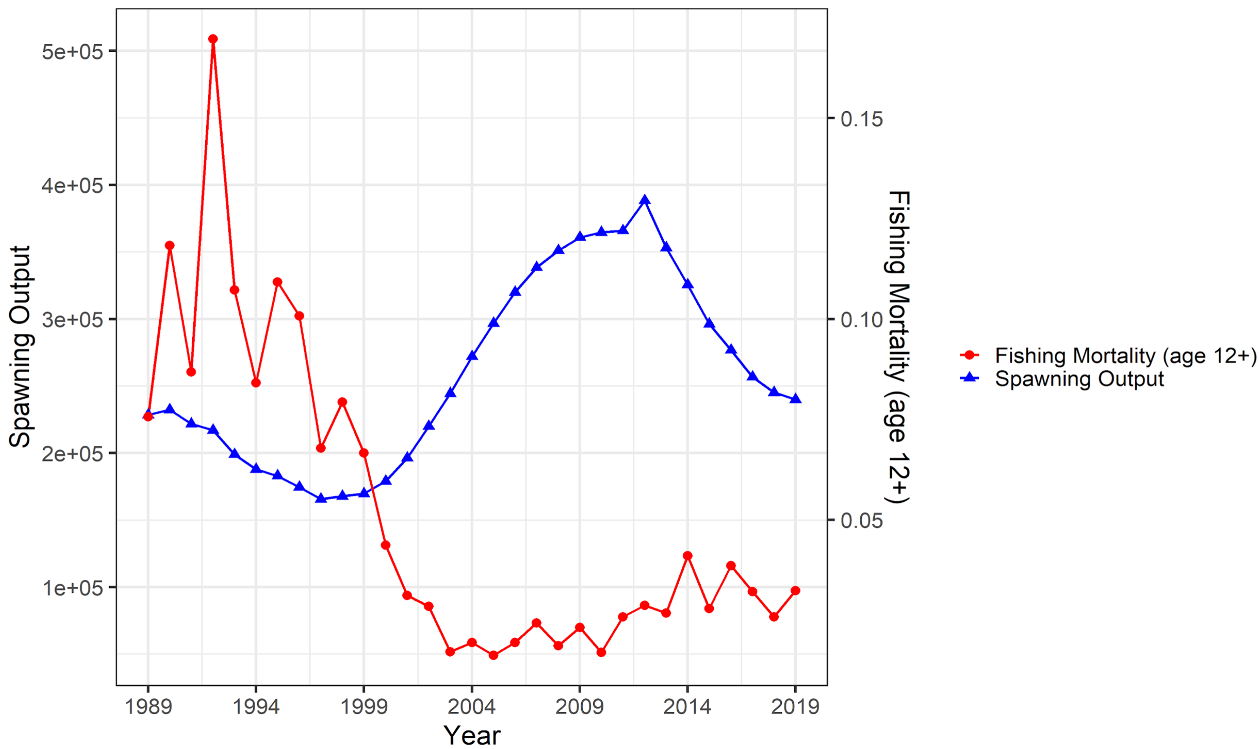


Figure 4.36. Estimated spawning output and fishing mortality (age 12+) by year for Atlantic spiny dogfish.

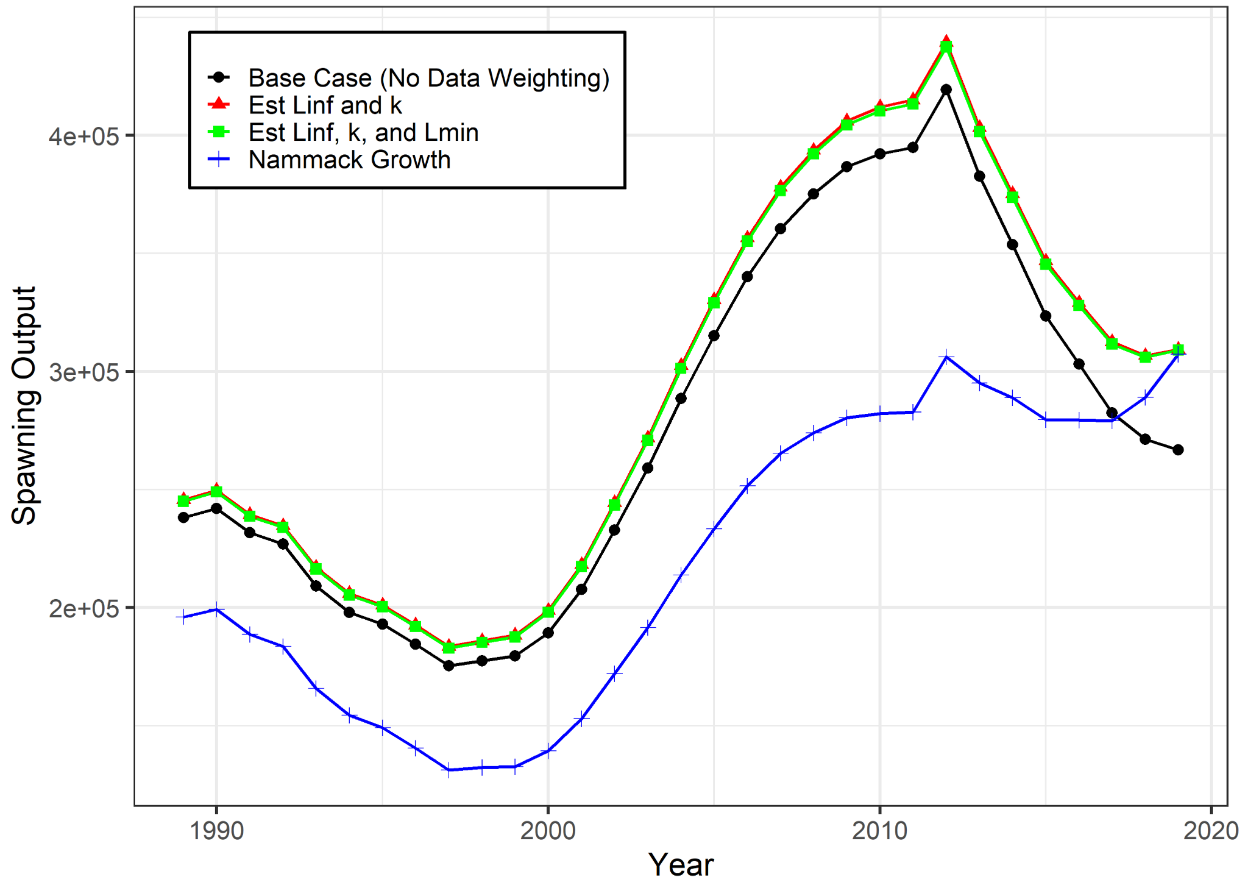


Figure 4.37. Spawning output estimated using different growth assumptions.

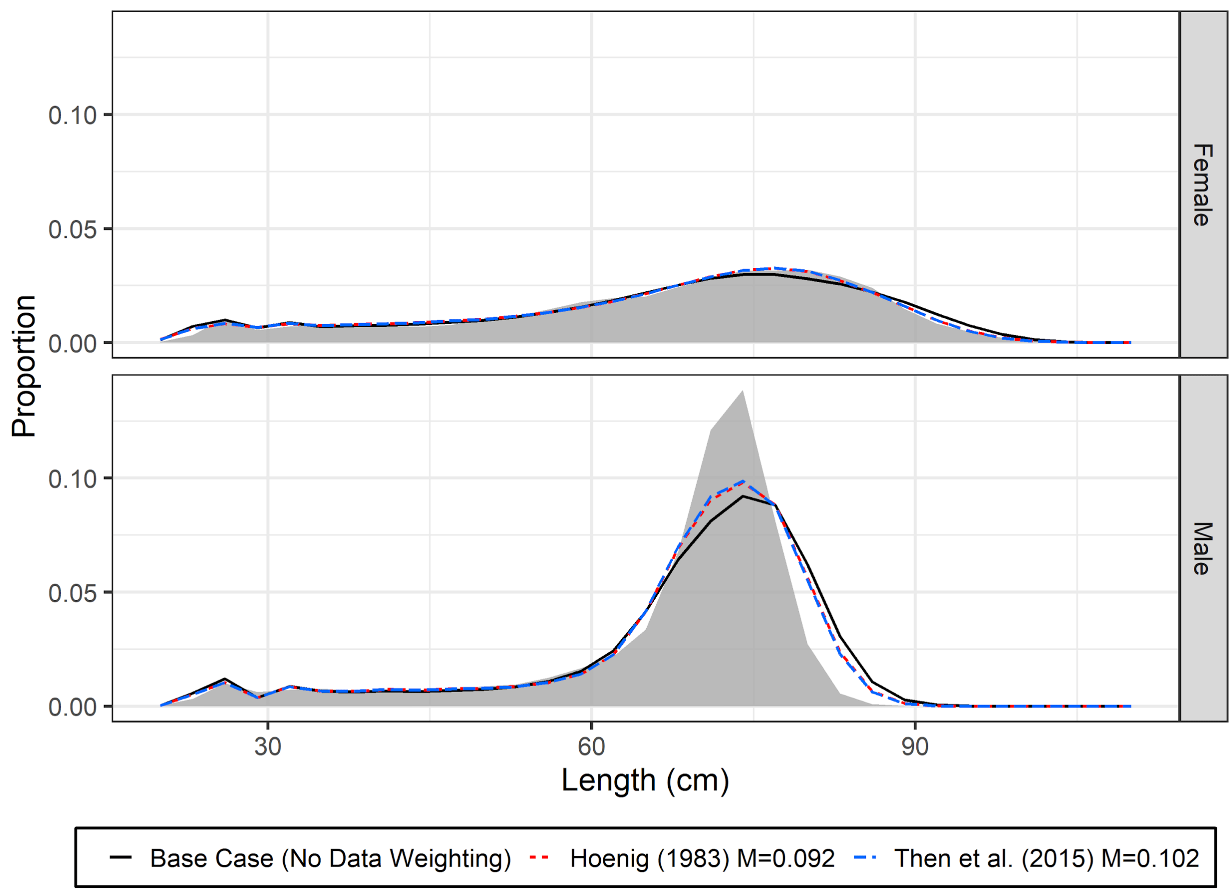


Figure 4.38. Observed (shaded) and model-predicted (line) length compositions by sex and natural mortality assumptions, aggregated across time.

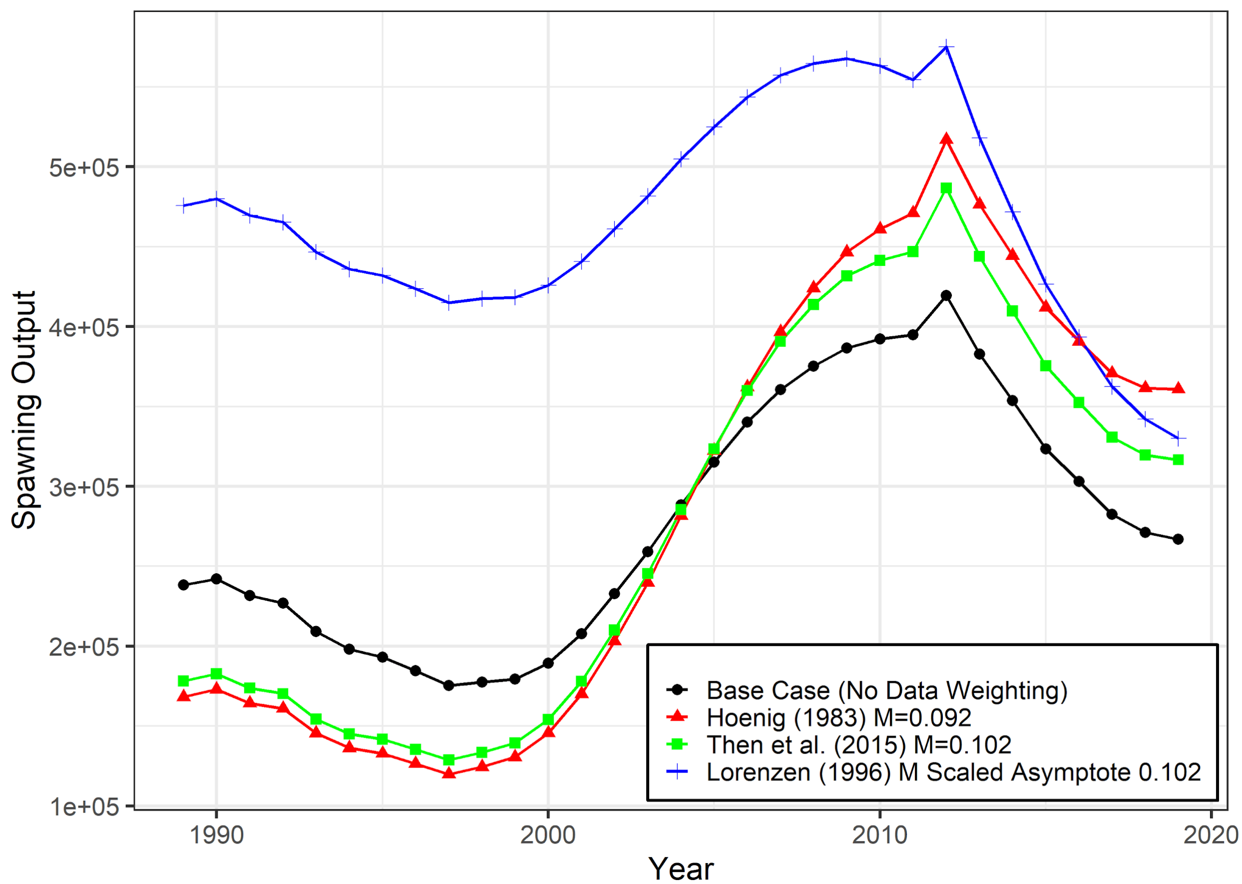


Figure 4.39. Spawning output estimated using different natural mortality assumptions.

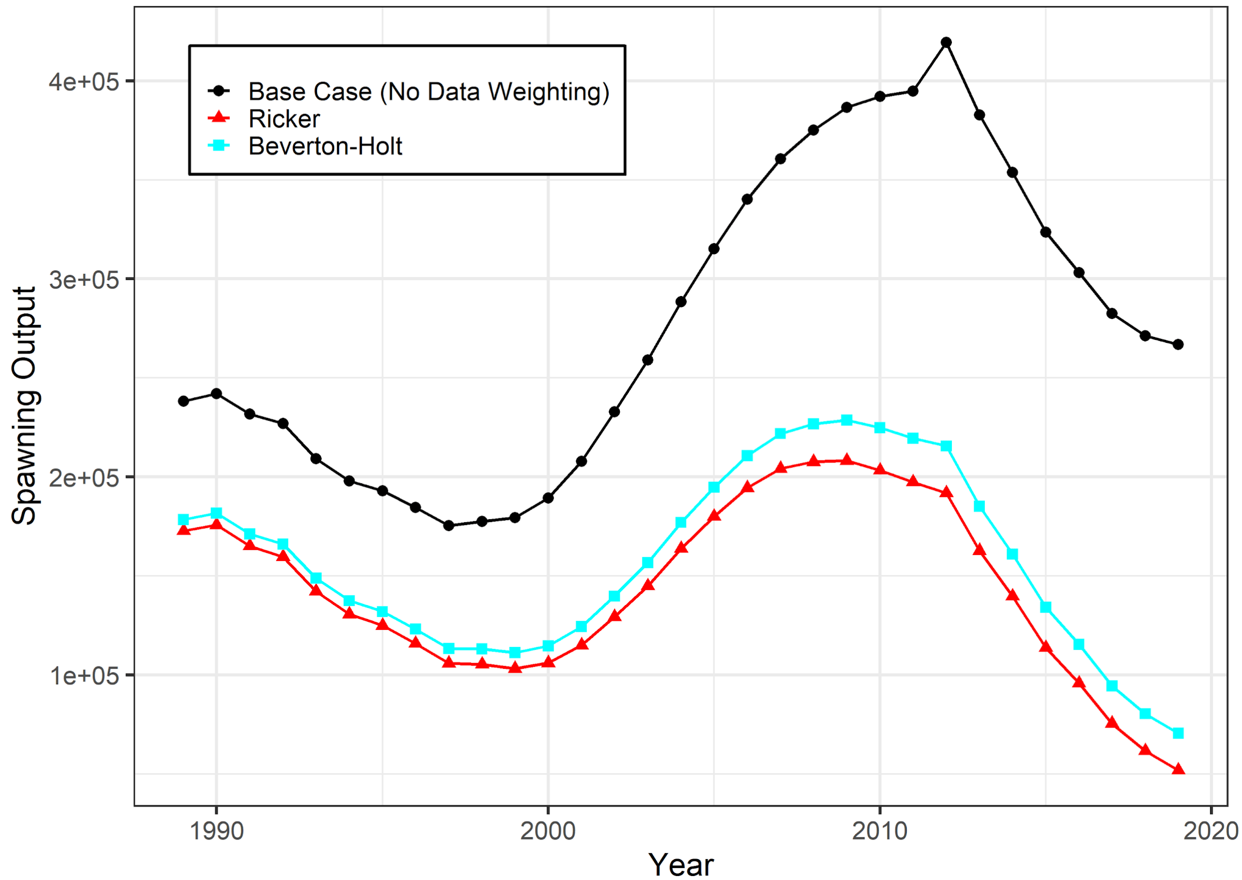


Figure 4.40. Spawning output estimated using different spawner-recruitment relationship assumptions.

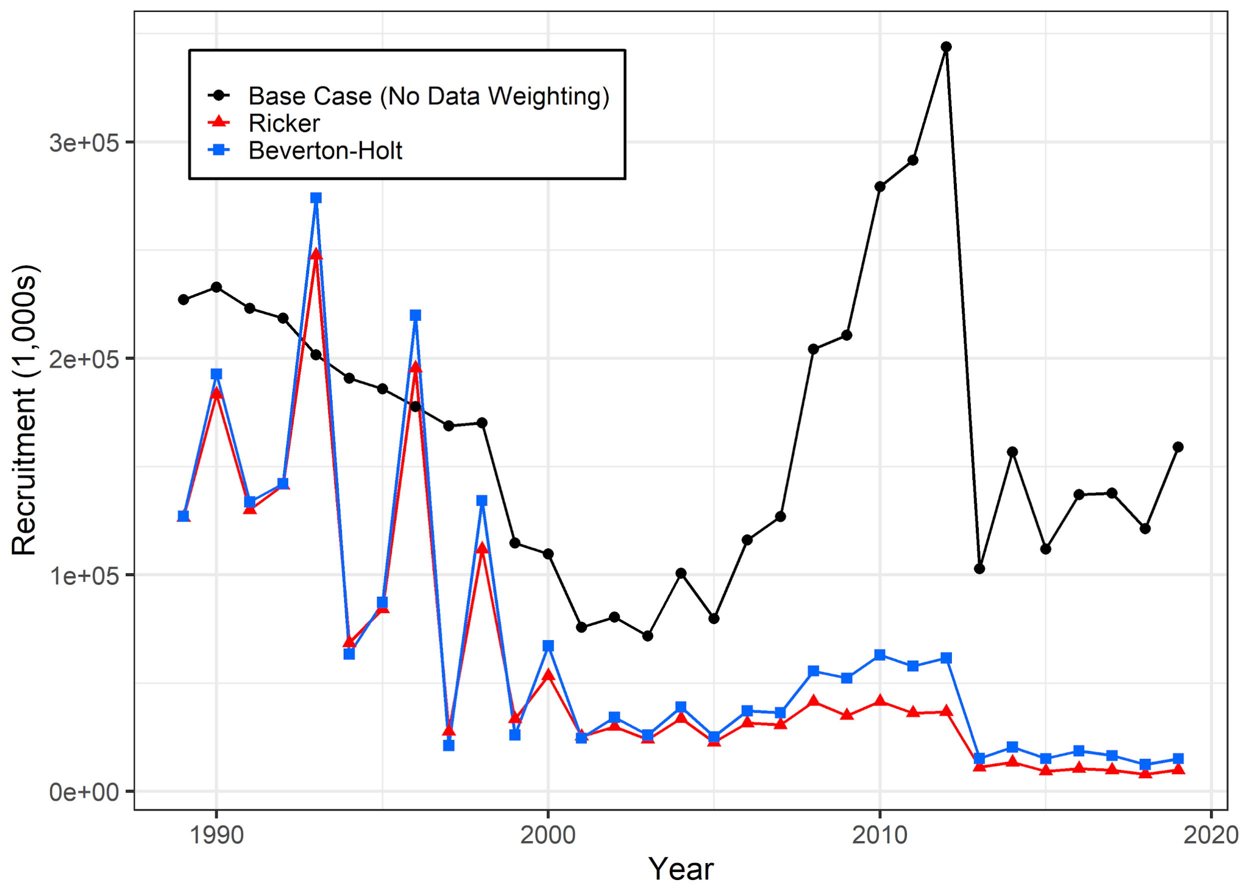


Figure 4.41. Recruitment (1,000) estimated using different spawner-recruitment relationship assumptions.

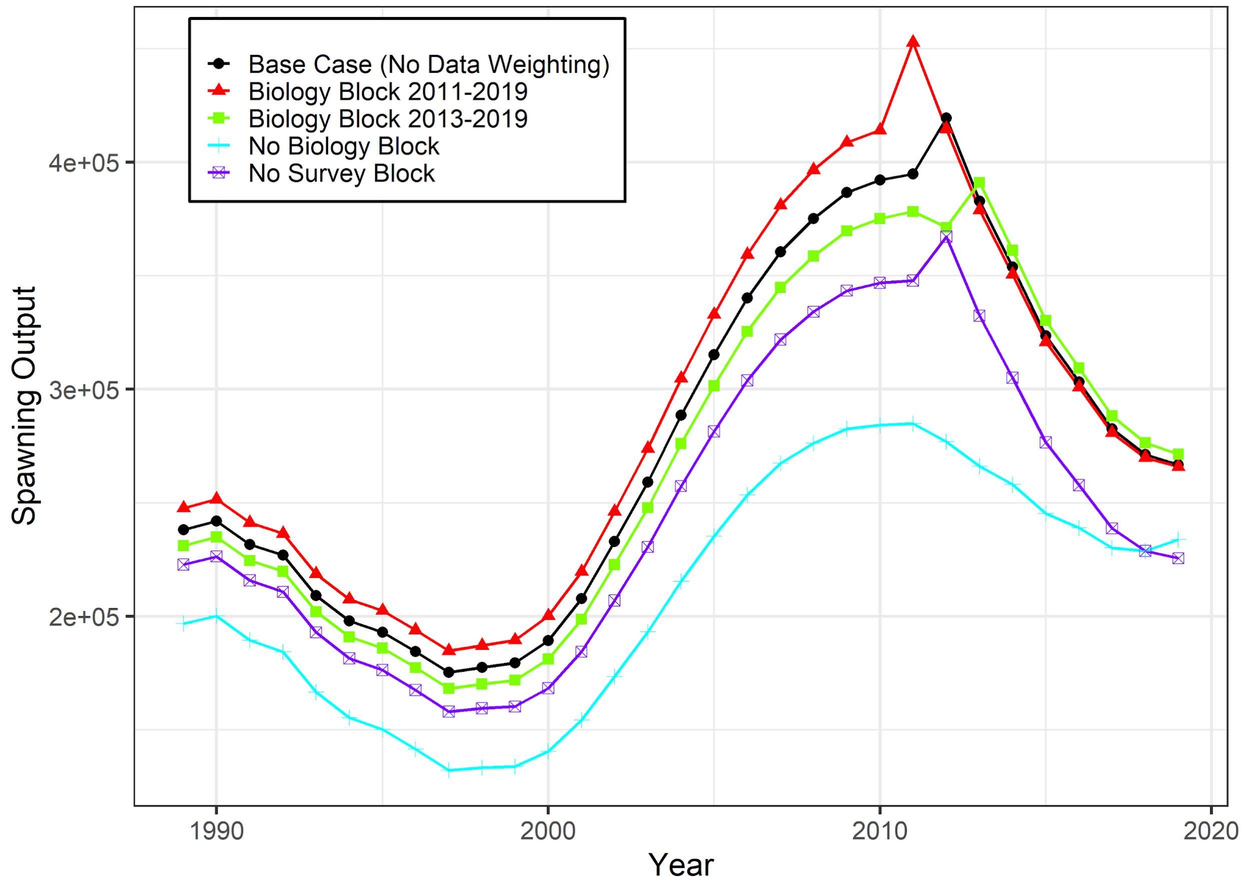


Figure 4.42. Spawning output estimated using different time block assumptions.

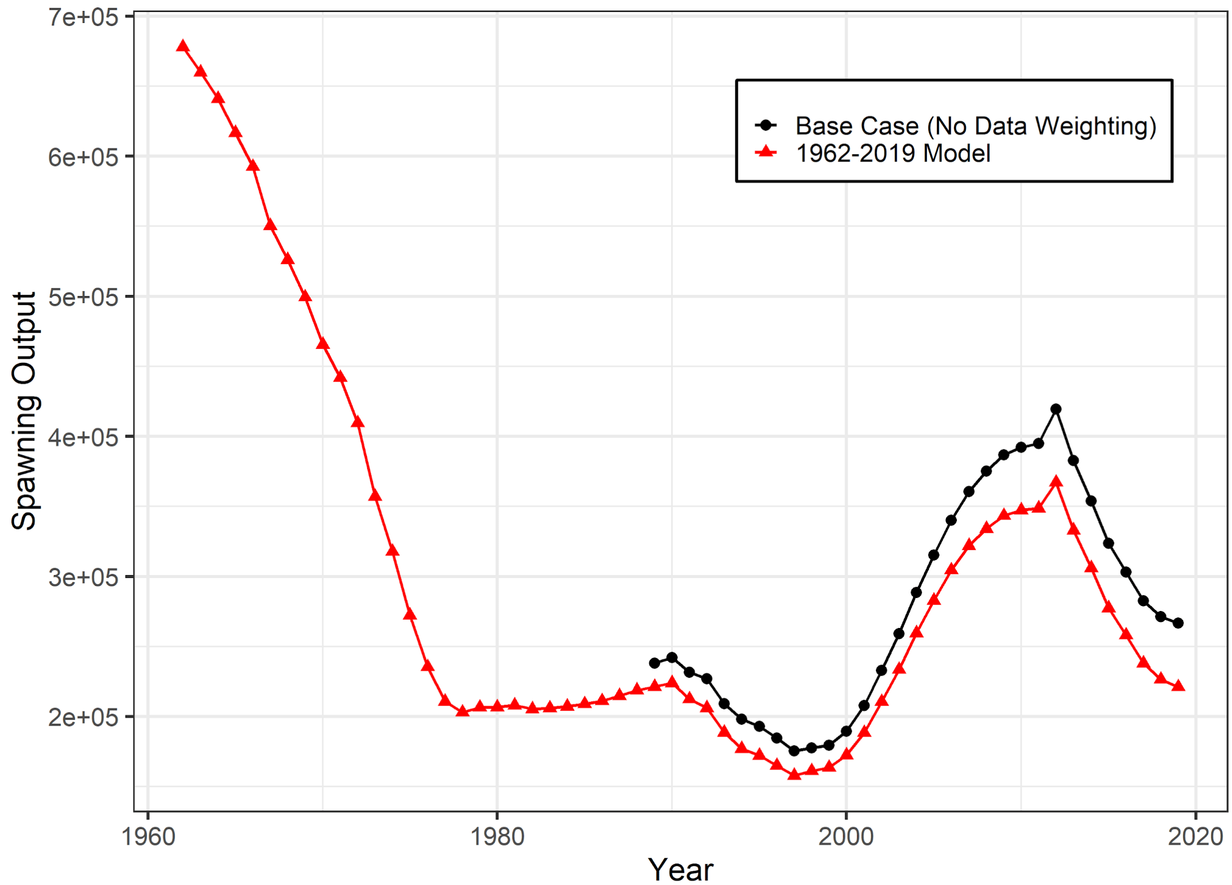


Figure 4.43. Spawning output estimated using different starting year assumptions.

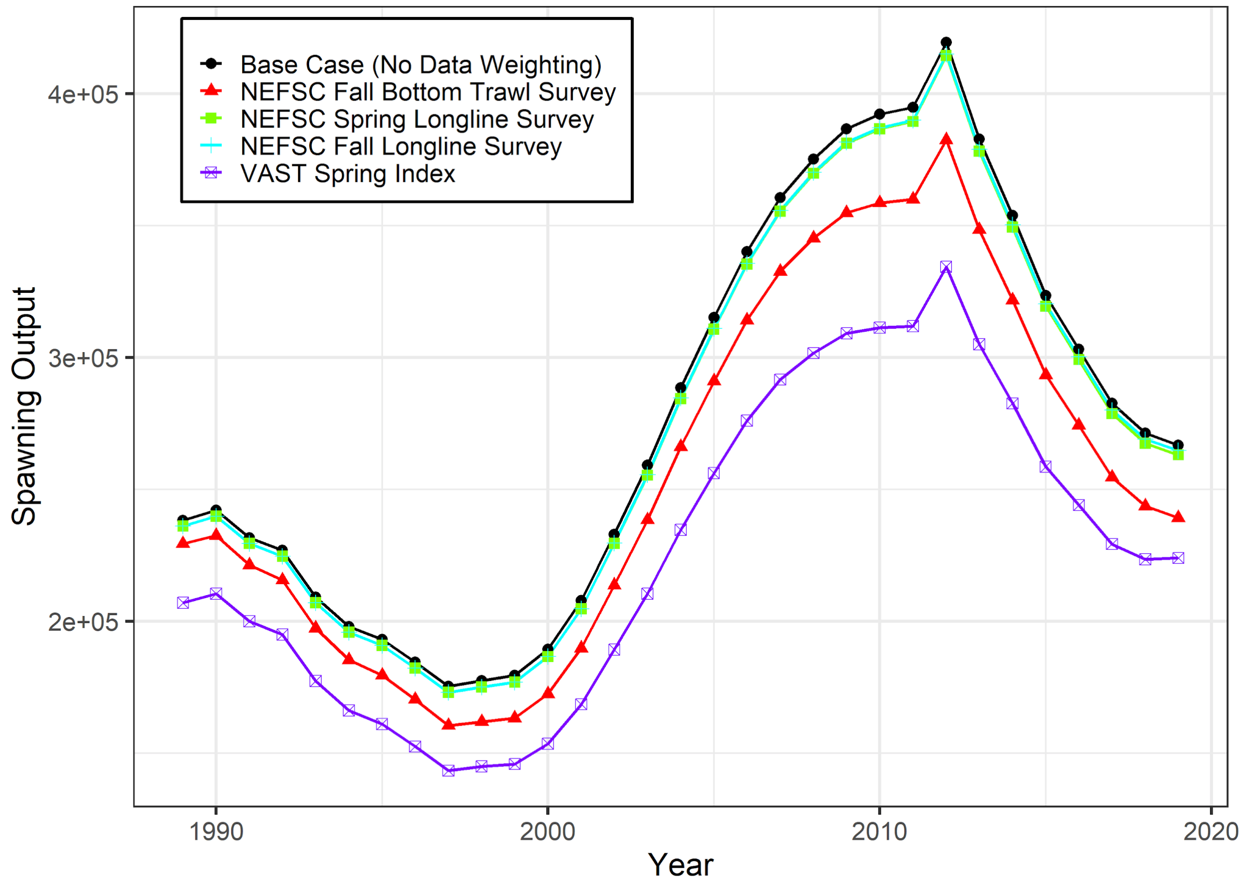


Figure 4.44. Spawning output estimated using different survey data.

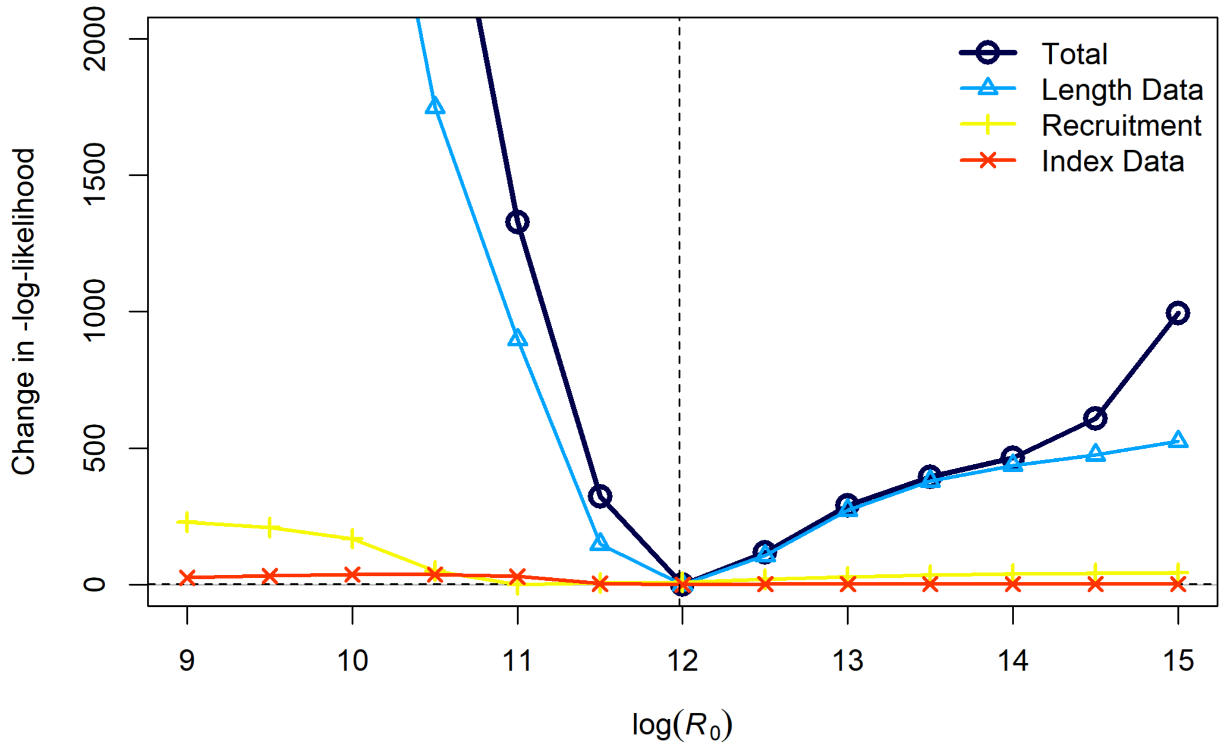


Figure 4.45. Log-likelihood profiles for R_0 for various data components.

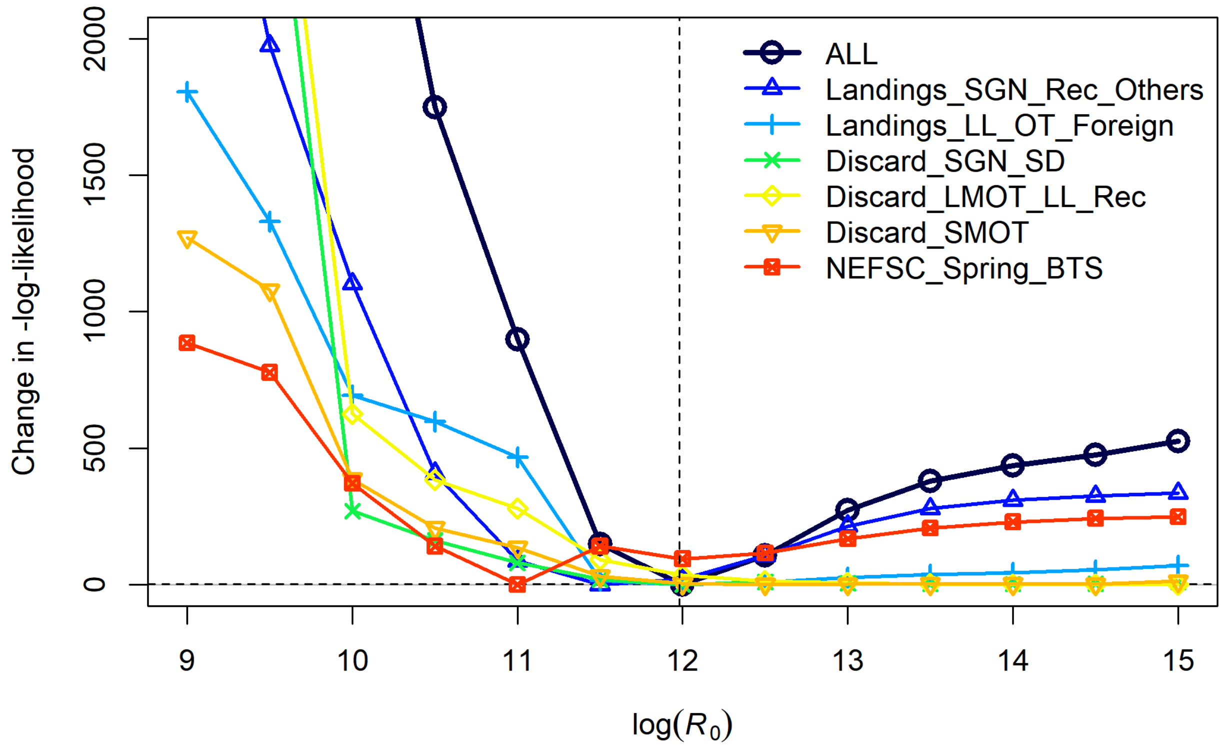


Figure 4.46. Log-likelihood profiles for R_0 for various source of length composition data.

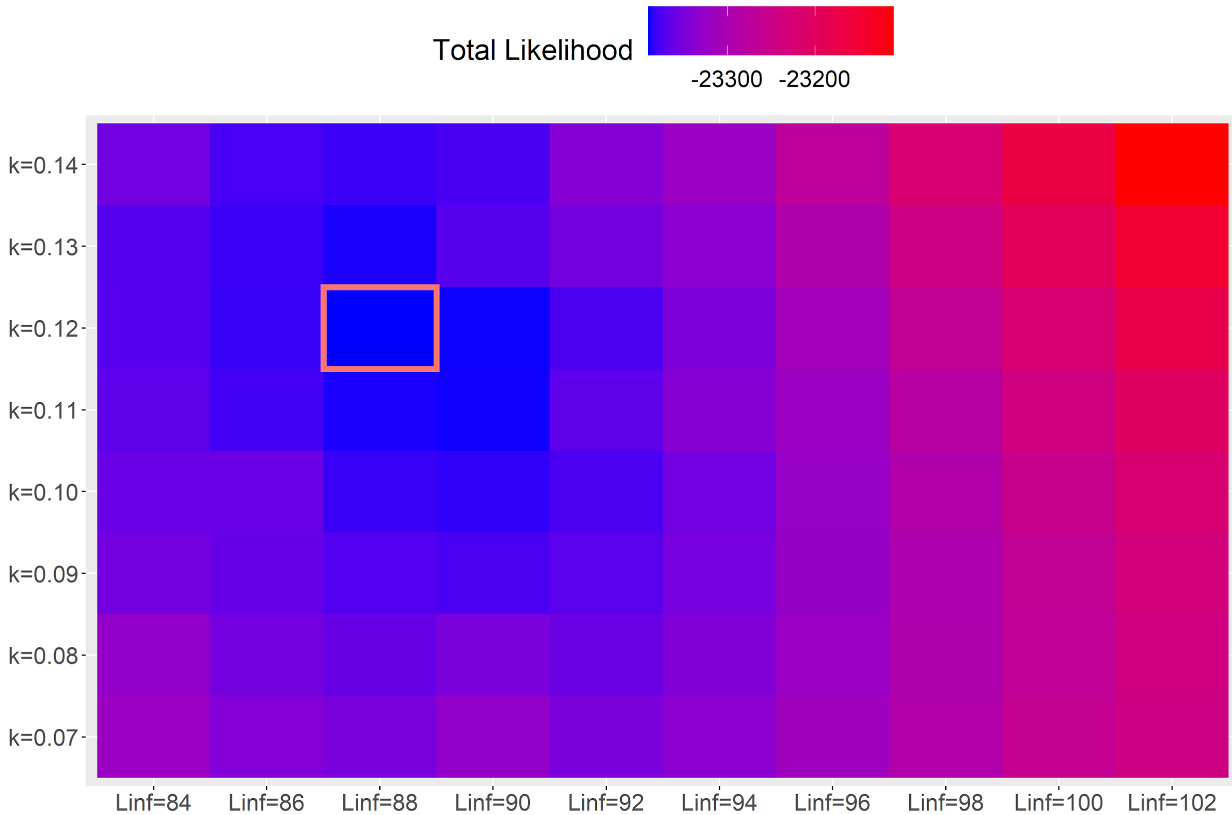


Figure 4.47. Total log-likelihood surface from profiling female L_∞ and k von Bertalanffy growth parameters. The box indicated the run with the smallest total likelihood.

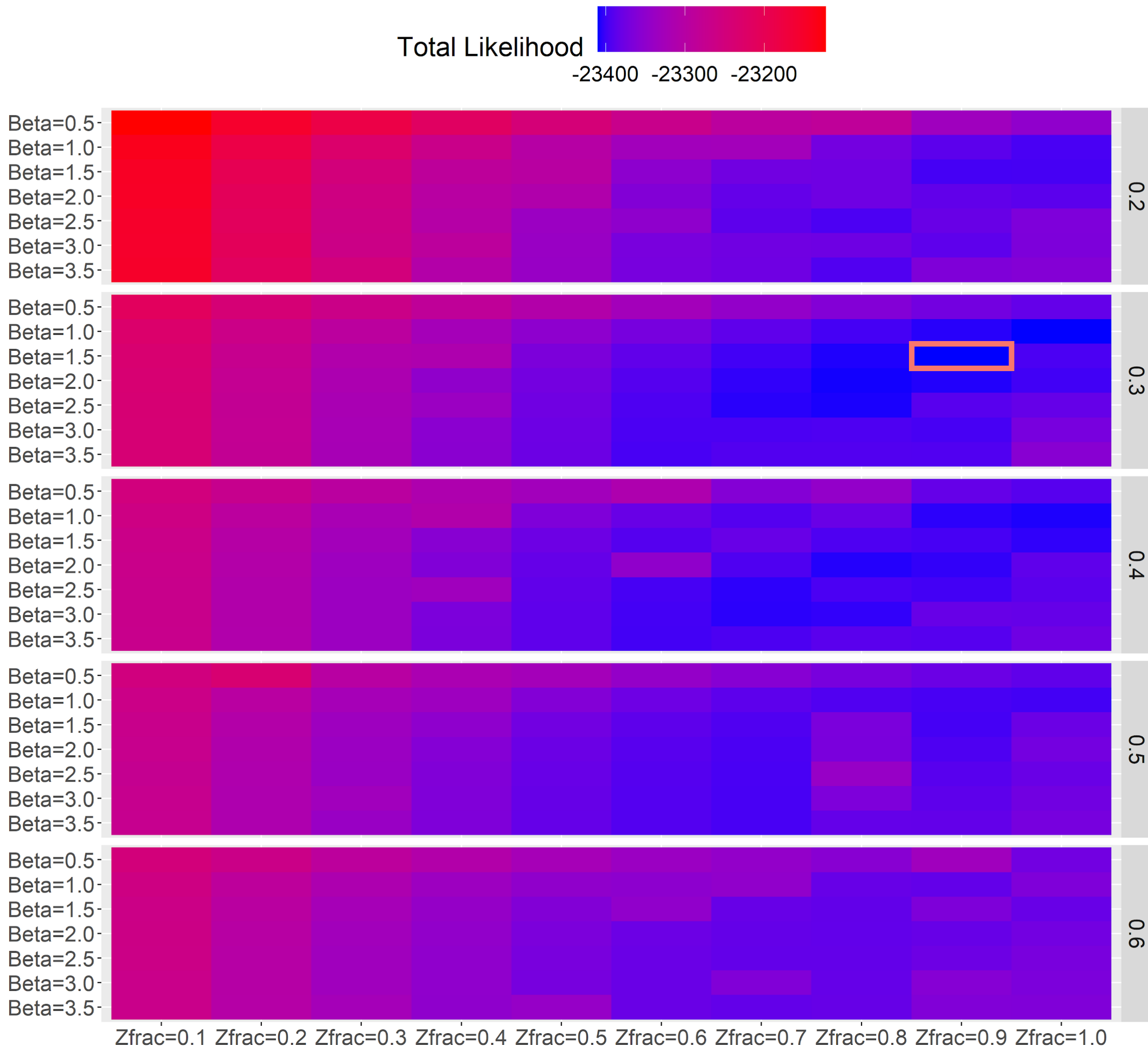


Figure 4.48. Total log-likelihood surface from profiling survivorship spawner-recruitment parameters Z_{frac}, β, and σ_R. The box indicated the run with the smallest total likelihood.

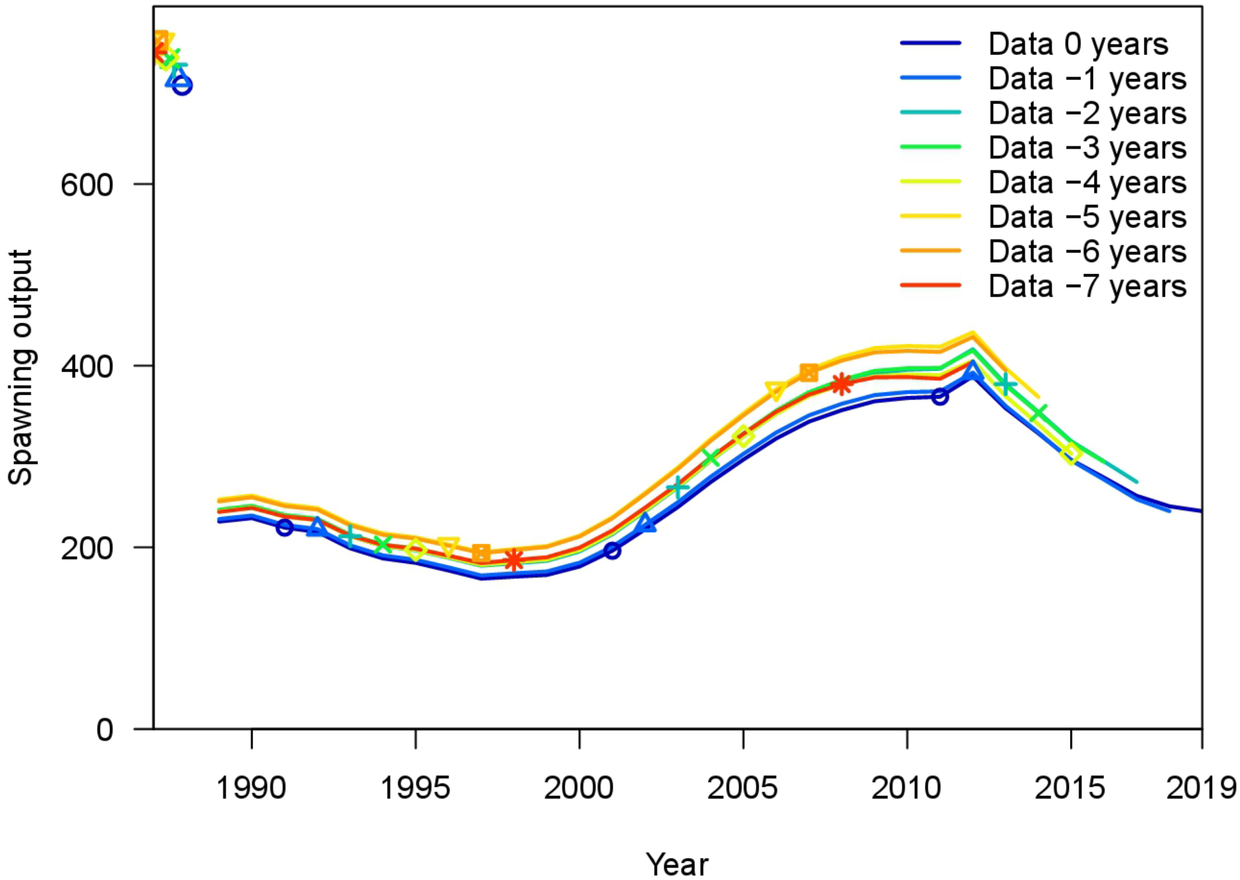


Figure 4.49. Retrospective plot for spawning output.

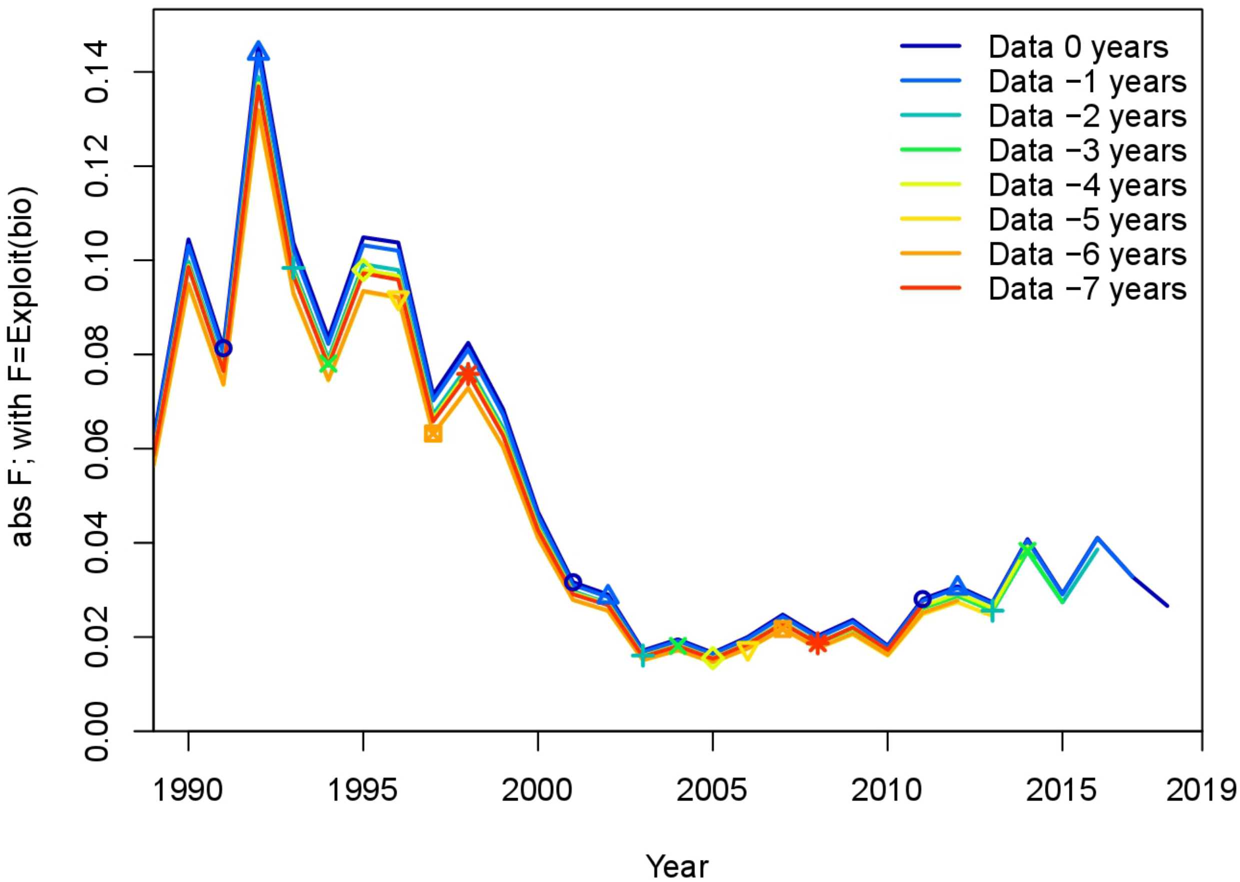


Figure 4.50. Retrospective plot for fishing mortality (age 12+).

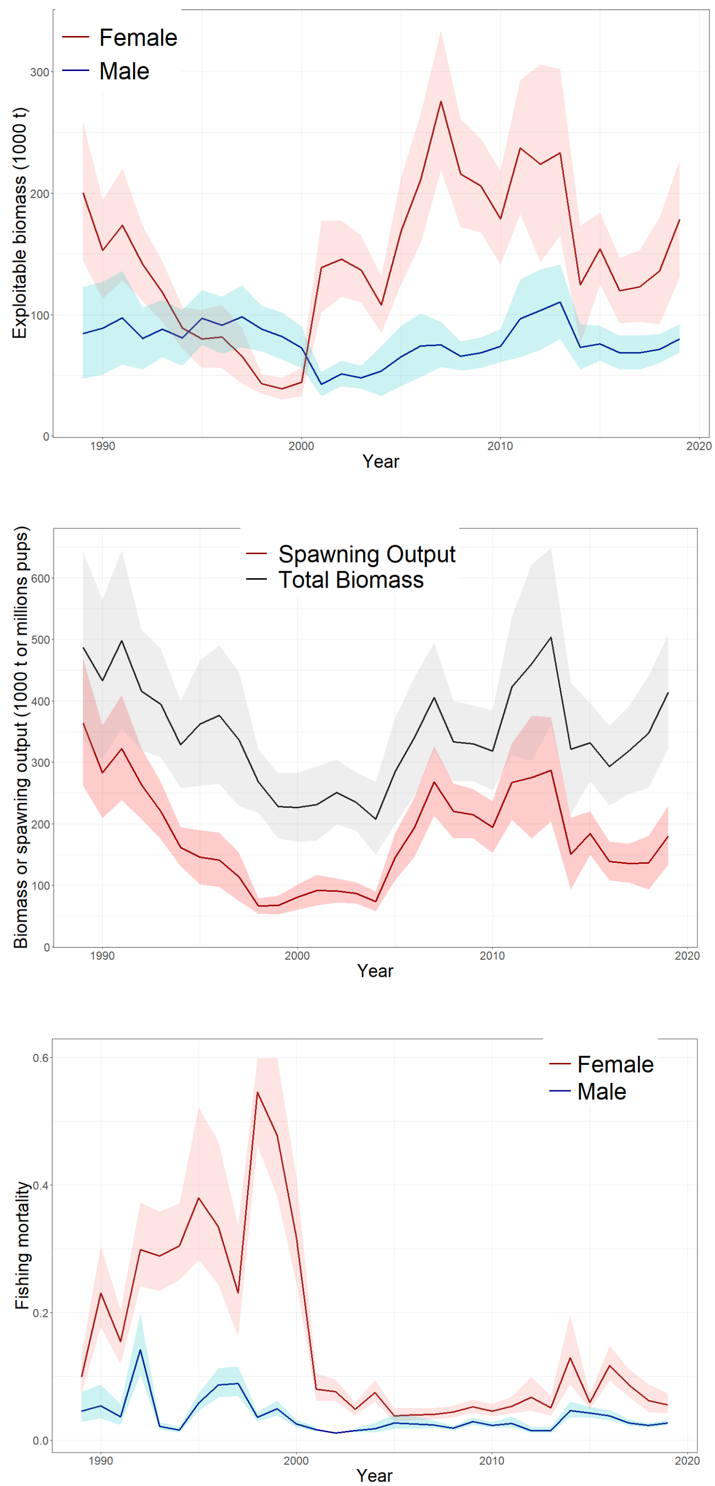


Figure 4.51. Exploitable biomass by sex (top), total biomass and spawning output (middle), and fishing mortality by sex (bottom), from the Stochastic Estimator with 90% confidence intervals.

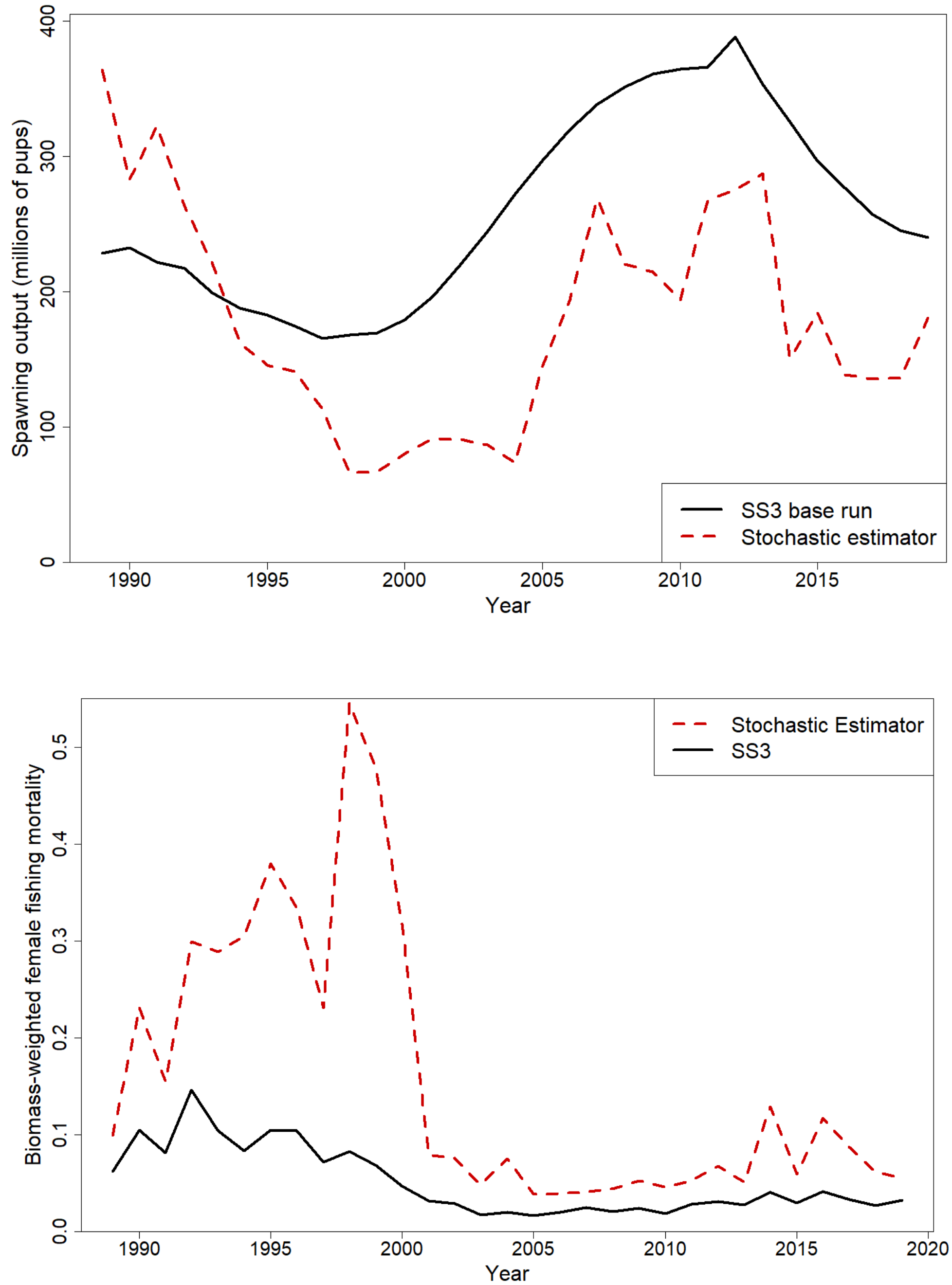


Figure 4.52. Comparison of estimates for spawning output (top) and fishing mortality (bottom) from the SS3 base run and the Stochastic Estimator.

TOR5: STATUS DETERMINATION CRITERIA

"*Update or redefine status determination criteria (SDC; point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, F_{MSY} and MSY reference points) and provide estimates of those criteria and their uncertainty, along with a description of the sources of uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for reference points. Compare estimates of current stock size and fishing mortality to existing, and any redefined, SDCs.*"

Per Recruit Analysis

A length-based per recruit analysis was performed for spiny dogfish; methods and details can be found in Hart and Chang (2022). Figure 5.1 shows yield- and pups-per-recruit at three different L_∞ values, and otherwise with parameters as in the SS3 base run. The fishing mortality that maximizes yield-per-recruit, F_{MAX}, ranges between 0.148 to 0.158. Pups-per-recruit is more constraining, and for the base case growth (L_∞ = 89.24 cm), $F > 0.03$ results in less than two pups-per-recruit. Therefore, fishing mortality needs to be below 0.03 to be sustainable.

Figure 5.2 shows the equilibrium fraction female in the population at F from the per recruit analysis. This can be compared to the observed fraction females observed on the spring trawl survey (Figure 5.3). This fraction, both by numbers and biomass, started out in 1980 at about its unfished equilibrium value, and then declined due to the relatively heavy fishing in the 1990s. The numbers-based fraction then leveled off at about 0.35, whereas the fraction by biomass continued to decline, likely as a reflection of slower growth.

SPR Reference Points

The Working Group examined three putative spawners per recruit (SPR) reference points from the SS3 base model: SPR50%, SPR60% and SPR70% (Table 5.1). The fishing mortality associated with SPR50% is 0.037, which produces less than two pups per recruit. Moreover, the mean fishing mortality between 2012-2019 was below 0.037, but nonetheless the stock rapidly decreased during that time (Figure 5.4).

By contrast, the fishing mortality associated with SPR60% (0.025) gives more than two pups per recruit. During the period when F was below this level, the stock increased, but it then decreased in 2012-2019 when F was above 0.025 (Figure 5.4). The SPR70% reference points would suggest that overfishing was occurring during the period that the stock was rapidly increasing (2000-2012) and thus is less credible than SPR60%. Based on the combination of theoretical and empirical evidence, the Working Group recommended the SPR60% reference points: a spawning output (analogous to spawning biomass) target of 370.8 million pups and F = 0.025. Based on these reference points, and assuming that the overfishing threshold is half the target, the stock was not overfished, but overfishing was occurring in 2019.

Comparison with Previous Reference Points

Previous assessments used a biomass target of SSB_{MAX}, the SSB that produces the maximum recruitment according to the Ricker stock recruit relationship (Rago and Sosebee 2010). A reanalysis of this approach (McManus et al. 2022) estimated SSB_{MAX} = 445,349 mt. Note that this analysis considered spawning biomass to be female biomass greater than 80 cm, consistent with Rago and Sosebee (2010), which is shifted to the right compared to the maturity curve for the latest period. Per recruit analysis indicates that 445,349 mt SSB corresponds to slightly under F = 0.03 (Hart and Chang 2022, Table 2), similar to the recommended SPR60% reference points, and would lead to the same status determination. However, both the updated SSB_{MAX} and SPR60% reference points are much greater than those calculated in Rago and Sosebee (2010), who estimated SSB_{MAX} to be 159,288 or 189,553 mt, depending on the assumed area swept by the survey trawl.

The evidence that Atlantic spiny dogfish follows a Ricker model has weakened, based on the updated stock-recruit fits. Additionally, the survival stock-recruit relationship (Taylor et al. 2013) produced a superior fit and more credible results in the SS3 model. The Working Group therefore concluded that the Ricker-based SSB_{MAX} may not be the most appropriate proxy reference point.

Table 5.1. SPR reference points: Target spawning output (thousands of pups), target fishing mortality, and equilibrium catch (mt, including mortal discards).

	SPR50%	SPR60%	SPR70%
Eq. Spawning Output	268,707	370,799	457,116
F	0.037	0.025	0.017
Eq. Catch	18,876	16,792	12,657

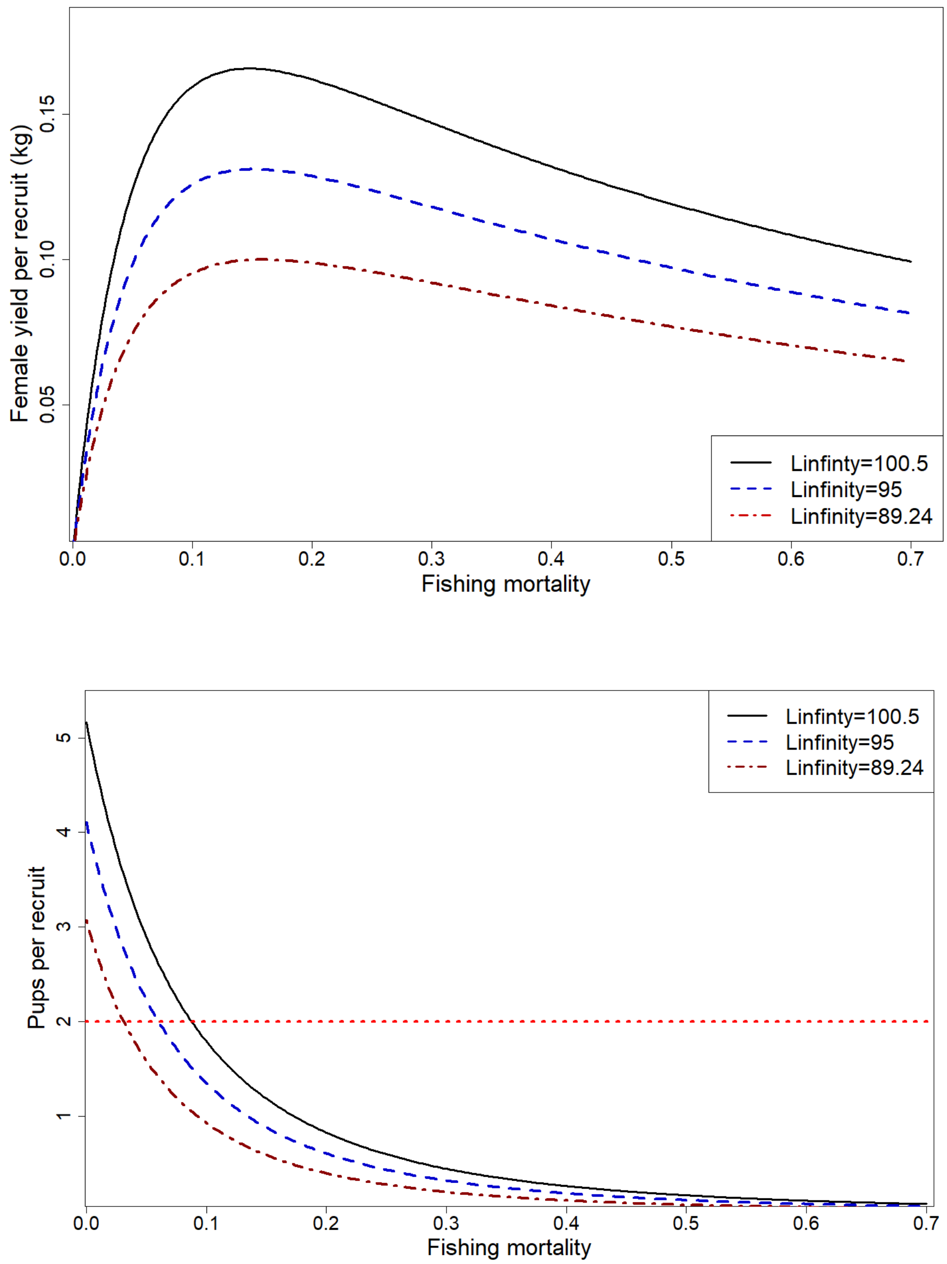


Figure 5.1. Yield and pups per recruit (top and bottom, respectively) assuming Lorenzen natural mortality at three different growth rates.

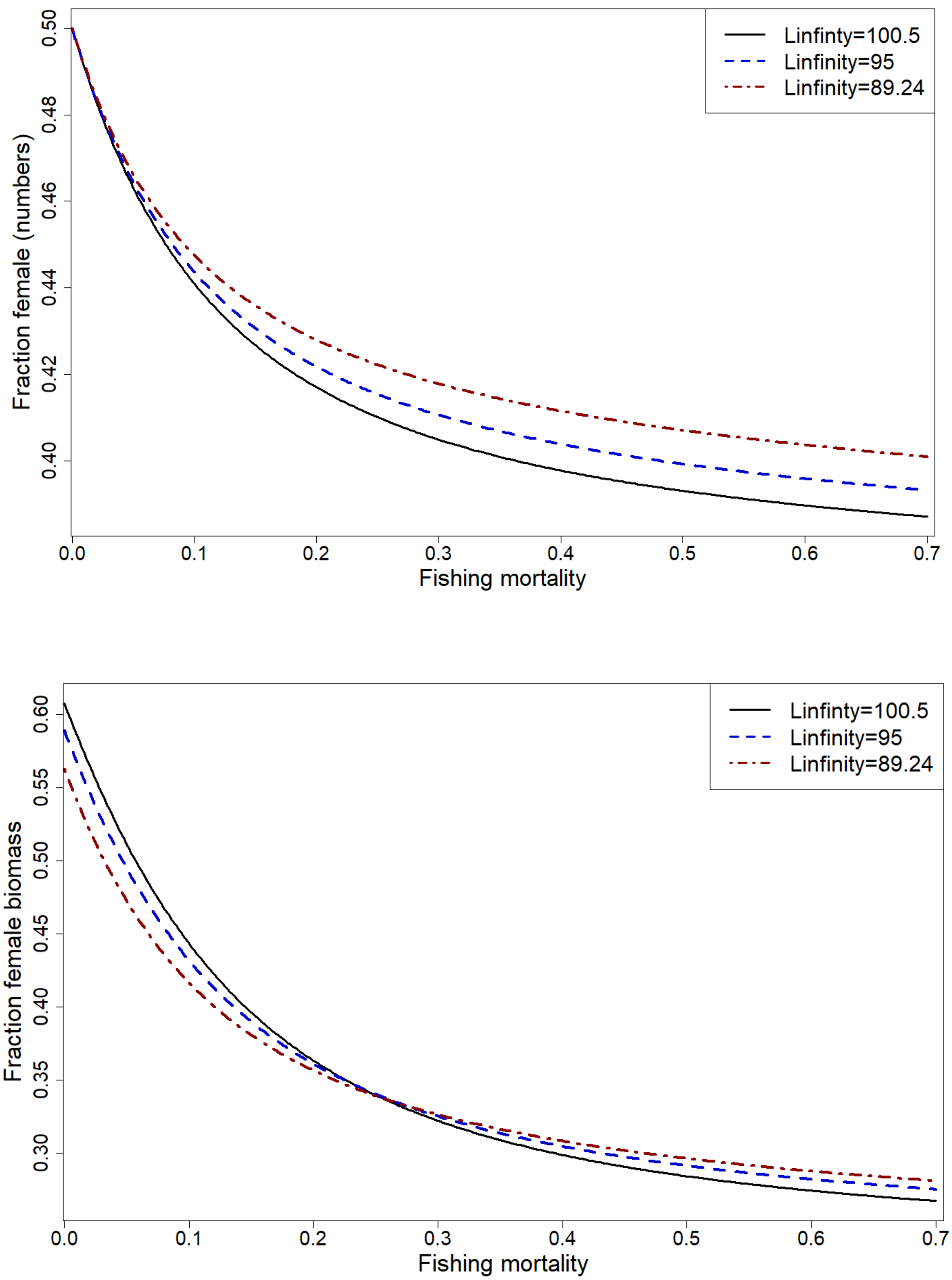


Figure 5.2. Fraction of spiny dogfish that are female (top) and the fraction of female biomass (bottom) from per recruit analysis.

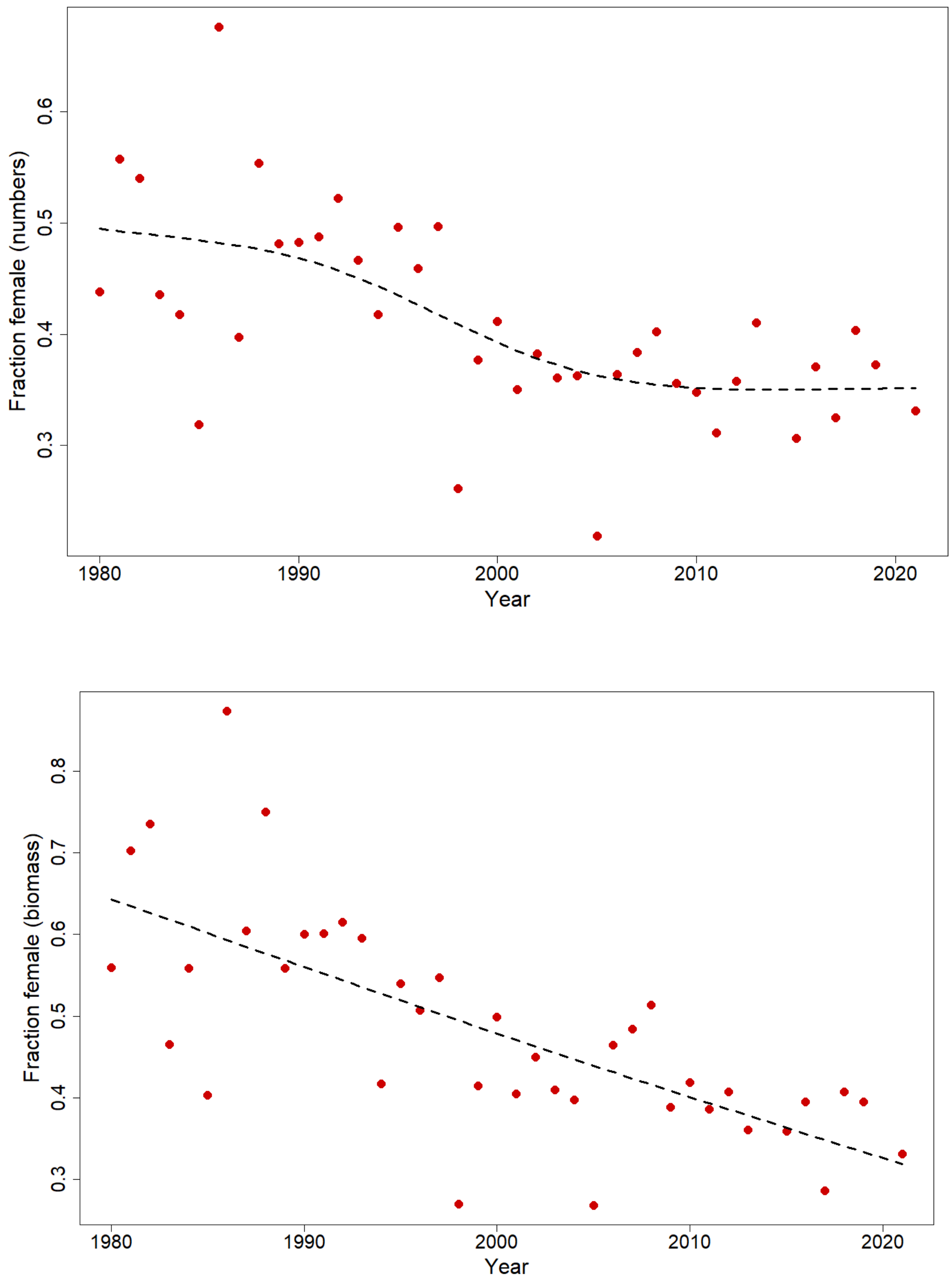


Figure 5.3. Fraction females in terms of numbers (top) and biomass (bottom) from the spring trawl survey. Dashed lines represent GAM smoothers.

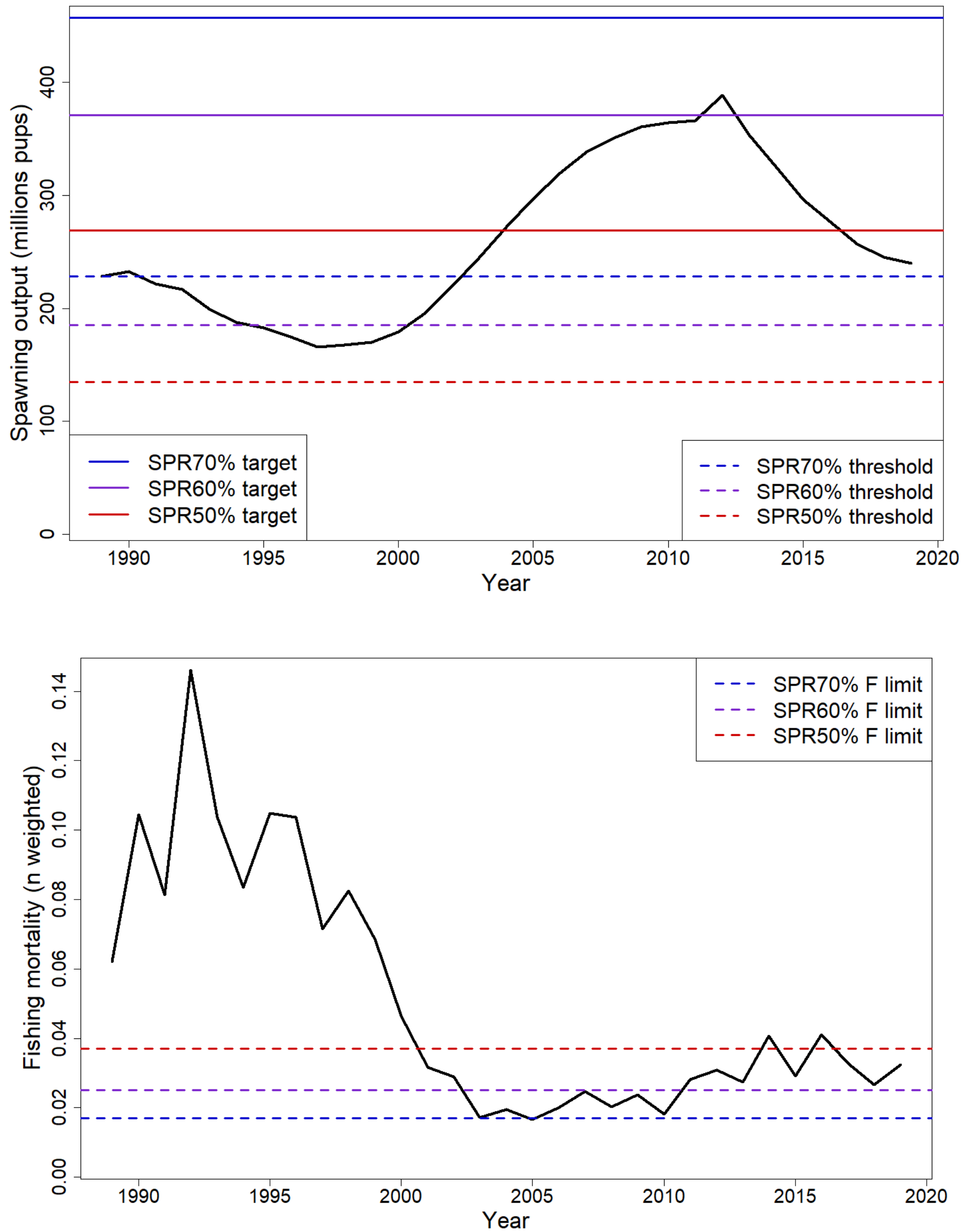


Figure 5.4. Time series of spawning output (top) and fishing mortality (bottom), from the SS3 base model, together with biomass and fishing mortality reference points at SPR50%, SPR60% and SPR70%.

TOR6: PROJECTION METHODS

"Define appropriate methods for producing projections; provide justification for assumptions of fishery selectivity, weights at age, maturity, and recruitment; and comment on the reliability of resulting projections considering the effects of uncertainty and sensitivity to projection assumptions"

The Working Group used SS3 as the preferred projection tool for this assessment. The continuity of both the assessment model and projections being conducted with the same software allowed for effective and efficient application of the projection tool. The Working Group conducted three-year projections (2020-2022) under four different fishing mortality rates: $F = 0$, 0.017, 0.025, and 0.037. The latter three figures are the F values associated with the spawner per recruit reference points SPR70%, SPR60% and SPR50%, respectively (Table 6.1, Figure 6.1). Spawning output is projected to decrease between 2019-2020, then increase under all four alternatives, likely due to ongoing maturation of the large 2009-2012 year classes.

These projections use the same biological and fishery assumptions employed in the SS3 estimation model for the 2012-2019 period of reference points, such as fishery fleet selectivity, maturity-at-age, natural mortality, and length compositions. The greatest uncertainties are assumptions regarding growth. Other uncertain assumptions include the amounts of discards, discard mortality, and the selectivities of the various fleets, as well as the uncertainties associated with the terminal year (2019) estimate.

Since the current dogfish fishery is female-targeted, the forecasted catch from SS3 is female-targeted as well. To get a potential male catch for a hypothetical male-targeted fishery, a reasonable potential removal rate for males will have to be assumed and applied to the forecasted male population. Time constraints precluded exploring this possibility during this assessment.

Table 6.1. Projected spawning output (thousands of pups) and catch (mt) under four potential *F* values (0, 0.017, 0.025, 0.037) for years 2020-2022.

Year	Quantity	*F*=0	*F*=0.017	*F*=0.025	*F*=0.037
2020	Spawning Output	165,541	165,541	165,541	165,541
2021	Spawning Output	185,599	181,608	179,460	176,500
2022	Spawning Output	211,191	202,404	197,805	191,618
2020	Catch	0	6,034	9,291	13,790
2021	Catch	0	6,649	10,156	14,905
2022	Catch	0	7,323	11,099	16,122

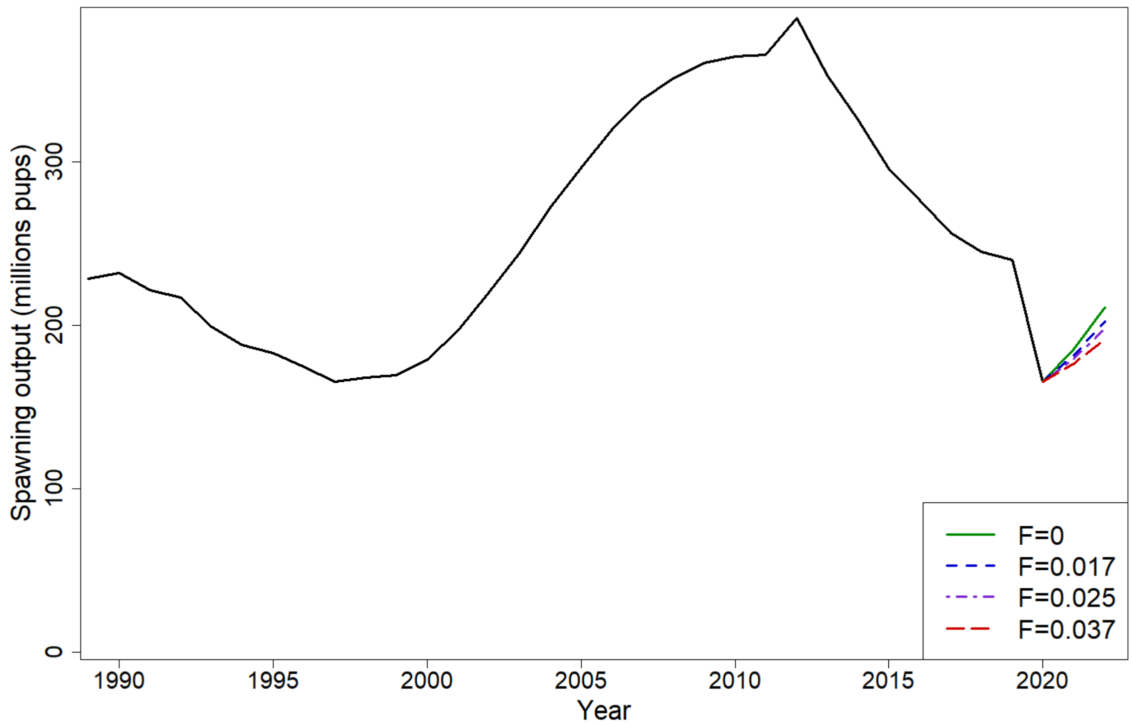


Figure 6.1. Estimated spawning output (1989-2019) from the SS3 base case model, with projected spawning output from 2020-2022 at four different values of *F*: *F*=0, 0.017, 0.025,0.037.

TOR7: RESEARCH RECOMMENDATIONS

"*Review, evaluate, and report on the status of research recommendations from the last assessment peer review, including recommendations provided by the prior assessment working group, peer review panel, and SSC. Identify new recommendations for future research, data collection, and assessment methodology. If any ecosystem influences from TOR 2 could not be considered quantitatively under that or other TORs, describe next steps for development, testing, and review of quantitative relationships and how they could best inform assessments. Prioritize research recommendations.*"

Status of Previous Research Recommendations

Most recent research recommendations were evaluated by the Working Group, with responses provided.

43rd SAW Stock Assessment Report (NEFSC 2006)

1. "*Incorporate Canadian commercial fishery sample data into the assessment when it is made available (expected in 2007).*" – While commercial landings from Canada are included in the assessment, fishery sampling data were not incorporated into this assessment. Several attempts were made to retrieve available data from Canadian scientists, but such efforts were not successful. It appears that few samples, if any, are collected in Canada given the landings are at very low levels.
2. "*Conduct an ageing workshop for spiny dogfish, encouraging participation by NEFSC, NCDMF, Canada DFO, other interested state agencies, academia, and other international investigators with an interest in dogfish ageing (US and Canada Pacific Coast, ICES).*" – While a workshop was not conducted as part of this assessment, extensive work was conducted between NEFSC and Washington Department of Fish and Wildlife (WDFW) scientists on ageing spines for new growth estimates. There has been communication between the entities on methodologies, quality assurance and control of samples, and data analysis.

3. “*Examine observer data to calculate a weighted average discard mortality rate based on an assumption that the rate increases with catch size.*” – The Working Group did not address this during the assessment.
4. “*Develop experimental estimates of discard mortality in the New England and Mid-Atlantic commercial fisheries.*” – Experimental estimates of discard mortality were not developed during this assessment. Because there has not been research advancements in discard mortality since the last benchmark assessment, discard mortality assumptions were maintained for this assessment. The Working Group is aware of several proposals in recent years to do such work, but those were not funded.
5. “*Conduct a coast-wide tagging study for spiny dogfish to explore stock structure, migration patterns, and mixing rates.*” – Although a coast-wide study has not been funded, there was a new conventional tagging study conducted on a commercial platform since the last assessment that focused on distribution and movements by sex and life stage and movements between the US and Canada from southern New England, the Gulf of Maine, and Georges Bank. The Working Group reviewed this data and results from previously published conventional and high technology tagging studies.

Mid-Atlantic Fishery Management Council Comprehensive Five Year (2020–2024) Research Priorities (2019)

1. “*Integrate recent information on the efficiency of the NEFSC survey gear as it relates to: distribution of spiny dogfish beyond the current NEFSC trawl survey geographic footprint (including inter annual differences); gear efficiency; depth utilization within the footprint; distribution within the survey footprint under different environmental conditions.*” - VAST modeling allowed for the consideration of changing environmental conditions. While recent research has demonstrated presence in waters deeper than the survey, information to standardize survey indices for off-shelf habitat usage was not available for deeper waters. VAST models account for shifting spatial distributions of dogfish as well as produce standardized indices that account for changes in depth selection.

2. “*Explore model-based methods to derive survey indices for spiny dogfish.*” – Model-based methods (VAST) were used to derive spring relative abundance spiny dogfish indices that considered spatiotemporal changes and incorporated multiple surveys into a single index.

3. “*Investigate alternative stock assessment modeling frameworks that evaluate: the effects of stock structure; distribution; updated biological information such as sex ratio and spiny dogfish productivity; state-space models; and sex-specific models.*” – A new length-based assessment model (SS3) was developed for peer review consideration. Additionally, multiple data-limited tools new to spiny dogfish consideration were included (DCAC, DBSRA, PlanB Smooth).

4. “*Evaluate the utility of the study fleet information as it relates to issues identified under priority (1) above.*” – Fishery-dependent data from the Study Fleet and Observer Programs were integrated into deriving catch-per-unit-effort indices from the fishery using model-based approaches that tested environmental data (such as depth, year, month, area) for inclusion in the models. These analyses also suggest that there is a substantive overlap between the survey and Observer/Study Fleet Program. Recent research has also supported this overlap (Sagarese et al. 2015).

5. “*Research opportunities to increase domestic and/or international market demand.*” – Work regarding this recommendation was not conducted as part of this assessment because it is outside of the scope of its terms of reference.

6. “*Expand information on the efficiency of the NEFSC survey gear as it relates to: distribution of spiny dogfish beyond the current NEFSC trawl survey geographic footprint (including inter annual differences); gear efficiency; depth utilization within the footprint; distribution within the survey footprint under different environmental conditions.*”
See the response to recommendation #1 above.

7. “*Continue ageing studies for spiny dogfish age structures (e.g., fins, spines) obtained from all sampling programs (include additional age validation and age structure exchanges), and conduct an ageing workshop for spiny dogfish, encouraging participation by NEFSC, Canada DFO, other interested state agencies, academia, and other international investigators with an interest in dogfish ageing (US and Canada Pacific Coast, ICES).*” – New ageing analyses were conducted as part of the assessment to understand how growth has

changed in recent years, with the hope of incorporating this new growth information into the assessment model.

8. "*Evaluate ecosystem effects on spiny dogfish acting through changes in dogfish vital rates*" – Environmental variables were incorporated into the VAST modeling to understand environmental drivers on the stock. While this work did not directly address specific vital rates, the modeling is done under the theory that the relationships reflect spiny dogfish habitat needs to maintain vital rates.

Mid-Atlantic Fisheries Management Council Scientific and Statistical Committee Research Recommendations (2020)

1. "*Revise the assessment model to investigate the effects of stock structure, distribution, sex ratio, and size of pups on birth rate and first year survival of pups.*" The development of the SS3 model allowed for improved population dynamics modeling of the species. The SS3 model allows for estimating sex ratios and pups (age-0) stock abundance. The SS3 framework also allows for incorporating stock structure and distribution changes in various ways, although this was not including the present model. Spiny dogfish is currently managed as one stock and distributional changes were evaluated in TOR1, with data products from this informing the model through VAST indices. Pup size is not a model input into SS3 at this time.
2. "*Explore model-based methods to derive survey indices for spiny dogfish.*" Model-based methods (i.e., VAST) were used to derive relative abundance indices for use in the assessment model. Additional model indices were explored for the NEAMAP survey.
3. "*Consider development of a state-space assessment model.*" New stock assessment modeling frameworks have been built to allow for state-space modeling of biological processes within the model, most notably used in the region being the Woods Hole Assessment Model (WHAM, Stock and Miller 2021). However, WHAM is presently an age-structured model that requires annual ageing information. Because this information is lacking for spiny dogfish, this recommendation was not possible to pursue at this time, and developing a SS3 model was prioritized instead. Additionally, there is a State-Space Modeling Research Track Assessment Working Group underway that will explore the

application and use of state-space models across a wide range of stocks in the Greater Atlantic Region. The State-Space Research Track is also working on creating a model framework that fits to length composition data, which could be explored on dogfish in the future.

4. "*Compile and examine the available data from large scale (international) tagging programs, including conventional external tags, data storage tags, and satellite pop-up tags, and evaluate their use for clarifying movement patterns and migration rates.*" A synthesis of tagging information currently available was conducted as part of the assessment, including a review of new NEFSC tagging results since the last assessment.

5. "*Investigate the distribution of spiny dogfish beyond the depth range of current NEFSC trawl surveys, possibly by using experimental research or supplemental surveys.*" The Working Group reviewed available fishery independent data that may be able to address this question, but none were identified. Analyses from the Study Fleet and Observer Program datasets (specifically modeled CPUE from covariates) indicated depth was negatively correlated to CPUE, including some data points that were at depths greater than 200m. VAST models did not indicate a significant shift to deeper water or outside the survey range.

6. "*Continue ageing studies for spiny dogfish age structures (e.g., fins, spines) obtained from all sampling programs (include additional age validation and age structure exchanges), and conduct an ageing workshop for spiny dogfish, encouraging participation by NEFSC, Canada DFO, other interested state agencies, academia, and other international investigators with an interest in dogfish ageing (US and Canada Pacific Coast, ICES).*" New ageing analyses were conducted as part of the assessment.

7. "*Evaluate the ecosystem context of spiny dogfish including quantifying their role as predator and prey, and effects of climatic factors such as changes in temperature and salinity on the distribution, growth and survival, as they impact both population dynamics and reference points.*" A new study on the effects of groundfish on the spiny dogfish population was recently published and was reviewed by the Working Group. The Working Group also conducted a literature review of spiny dogfish diet. The VAST modeling also considered several environmental variables to understand their impact on spiny dogfish abundance.

2022 Research Track Stock Assessment Working Group Recommendations

1. Develop a consistent sampling program for ageing Atlantic spiny dogfish. Sampling should occur at minimum annually, and ideally include samples from both spring and fall seasons. Fish over the species' entire size range should be sampled. This includes near-term embryos, in order to assess timing, identification criteria, and spine base diameter at first annulus deposition to better inform ageing of young fish. It is also imperative to ensure that large spiny dogfish are obtained to get a better sense of maximum ages and inform parameterization (e.g., L_∞ estimates). Lacking appropriate growth information will result in increased uncertainty in the assessment model's estimates of stock size and mortality rates. Such growth investigations should include size at birth and maturity, as those are intricately related to growth. Investigation into alternate ageing methods should continue, owing to the large uncertainty inherent in ages estimated from worn spines using current methods. Finally, improve routine cleaning protocols for spine sampling in order to reduce potential damage to spine enamel and enable more accurate ageing.
2. Continue exploration into the spatial distribution of spiny dogfish. Such work should expand upon the analyses discussed and presented herein regarding the environmental drivers on spiny dogfish movement by sex and size, and whether such relationships have resulted in changes in distribution over time. Directed research should also be conducted on the seasonal or intra-annual movement of spiny dogfish. Questions remain regarding what component of the spiny dogfish population exists outside of the federal trawl survey bounds off the shelf, and whether such biomass varies seasonally or interannually. Such knowledge will allow for informing survey catchability. If possible, exploring environmental correlations to the degree of on- and off-shelf distribution may allow for predicting this dynamic over time, and provide a catchability time series for stock assessment model use.
3. Further explore the sensitivity of the SS3 model parameterization and configuration.
4. Conduct directed studies that estimate discard mortality rates for spiny dogfish by commercial and recreational harvesting gear type.
5. Develop state-space models that can tune to lengths. Such a model is worth considering if/when the tools are developed within SS3. When available, a review of results from the

State-Space Research Track Working Group should be conducted to evaluate the efficacy of developed tools for spiny dogfish.

6. Investigate prospective contributors to the decline in maturity over time for female spiny dogfish. Analyses could include but are not limited to assessing environmental drivers and harvest effects.
7. Coordinate a biological sampling program targeting spiny dogfish from additional locations and habitats outside those sampled by the NEFSC trawl surveys to understand the various factors that influence their life history (e.g., growth, maturity, fecundity)
8. Continue developing the VAST models presented to assess additional environmental variables that may influence abundance and distribution, and better predict the size composition for models that include multiple datasets.
9. Investigate datasets enumerating the abundance or diet of known spiny dogfish predators for comparison to natural mortality assumptions, and as potential proxies for dogfish natural mortality rates.

TOR8: BACKUP ASSESSMENT APPROACH

"Develop a backup assessment approach to providing scientific advice to managers if the proposed assessment approach does not pass peer review or the approved approach is rejected in a future management track assessment."

In the event the proposed assessment method fails peer review in the research track process or subsequently fails peer review in the routine management track process, the Working Group explored several assessment methods to serve contingency plans. The Working Group recommends that if the proposed assessment approach (SS3) does not pass peer review or is rejected in a future management track assessment, that the Stochastic Estimator approach be used in its place. The Stochastic Estimator has been used as the primary assessment tool for Atlantic spiny dogfish and has been previously considered sufficient for guiding catch advice. However, the Stochastic Estimator has many limitations that were noted previously, as it lacks the inclusion of life history information, and ability to use multiple fleets and surveys. If the Stochastic Estimator is considered a preferable modeling approach by the peer-reviewers, future application of the Stochastic Estimator should consider additional advancements to the data inputs that would address previous concerns. For example, future applications of the Stochastic Estimator should consider using model-based fisheries-independent indices that can integrate multiple surveys and address concerns regarding missed or incomplete sampling for a given year. Specifically, the Working Group recommends testing the VAST indices or a modified version presented as part of this assessment (Hansell and McManus 2022).

Other data-limited approaches were also evaluated as part of the research track. The Depletion-Corrected Average Catch (DCAC; MacCall 2009) model was applied to female Atlantic spiny dogfish to calculate a sustainable yield (Anstead 2022b). DCAC adjusts the average catch over the available time series based on an assumed depletion in the stock relative to its unfished biomass. Depletion-Based Stock Reduction Analysis (DB-SRA; Dick and MacCall 2011) was also implemented, which uses a flexible production model with a lumped biomass population dynamics model (Anstead 2022b). Both methods require similar input parameters (e.g., natural mortality, ratio of fishing mortality at maximum sustainable yield to natural mortality) and user-specified distributions (e.g., lognormal, uniform). Monte Carlo resampling is used to sample from the input parameters. DCAC recommends a sustainable yield whereas DB-SRA solves for the initial biomass that fits the specified inputs and, using the catch history, calculates catch limits and reference points. Catch advice for female spiny dogfish from both the DCAC and DB-SRA were consistent with each other (Figures 8.1 - 8.3), and both recommend a female harvest that is somewhat below the current coastwide total quota. When reviewing the methods, the Working Group believed the DCAC method provided more realistic catch advice over the DB-SRA method given it does not rely on a production function. However, the overall consensus of the Working Group was that since these methods ignore the size and age structure of the population, they did not provide a greater benefit over the Stochastic Estimator. Additionally, the biomass estimates and increasing trend from DB-SRA in recent years was not consistent with the results derived from SS3 and the Stochastic Estimator.

The Working Group also applied the Ismooth method (formerly known as the PlanB Smooth method) for Atlantic spiny dogfish to evaluate its performance (NEFSC 2020). The Ismooth method uses a LOESS-smoothed average index of abundance. A log linear regression on the last three years of the LOESS-smoothed index is conducted to derive the slope, which is used as a multiplier on recent catch to provide revised catch advice. This tool was evaluated as the backup model due to its performance during the Index Based Model Working Group (NEFSC 2020), and its use as the primary assessment model for stocks within the region. Simulation testing of the Ismooth method has indicated that it can be useful in the absence of an age-structured assessment depending on the given stock's biomass and exploitation in relation to its current status relative to its reference points (Legault et al. 2022). Application of the Ismooth highlights the decline that is observed in the standard NEFSC spring bottom trawl indices, and can be run to provide sex-specific catch multipliers (Figure 8.4). Given it also does not include the population dynamics or age information, the Working Group does not recommend this method as a contingency plan over the stochastic estimator.

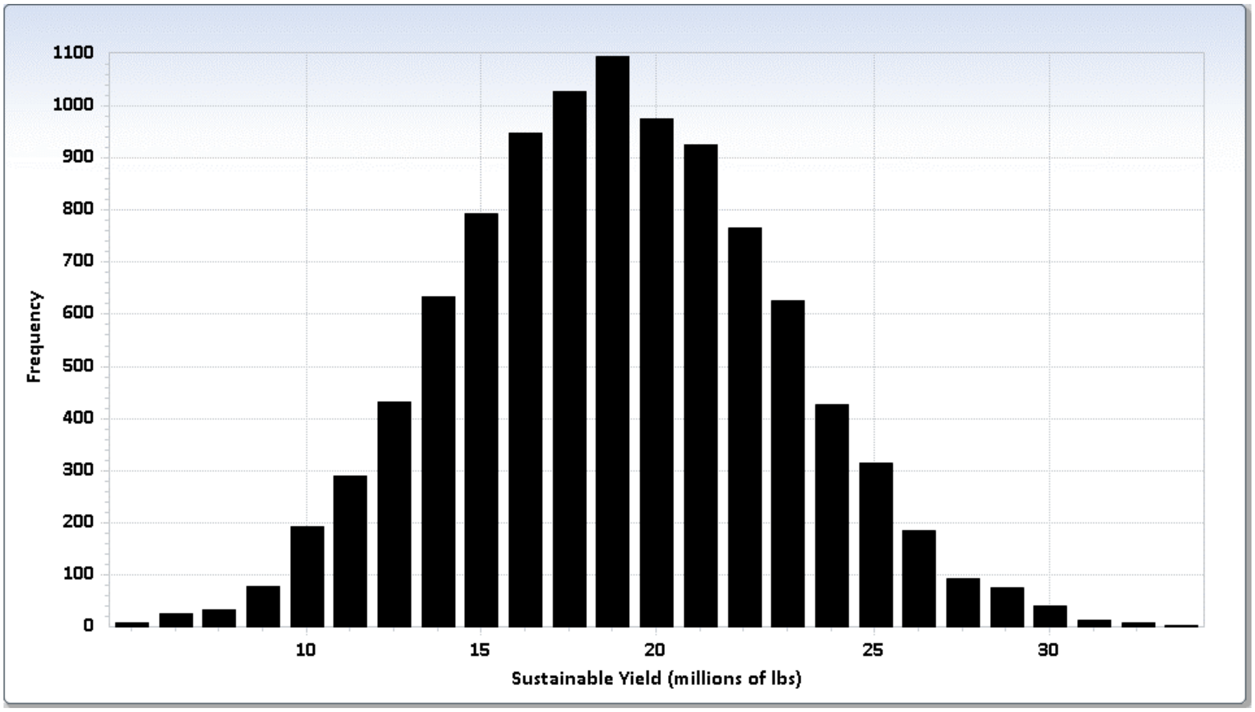


Figure 8.1 Distribution of sustainable yield estimates from the DCAC base configuration for female spiny dogfish.

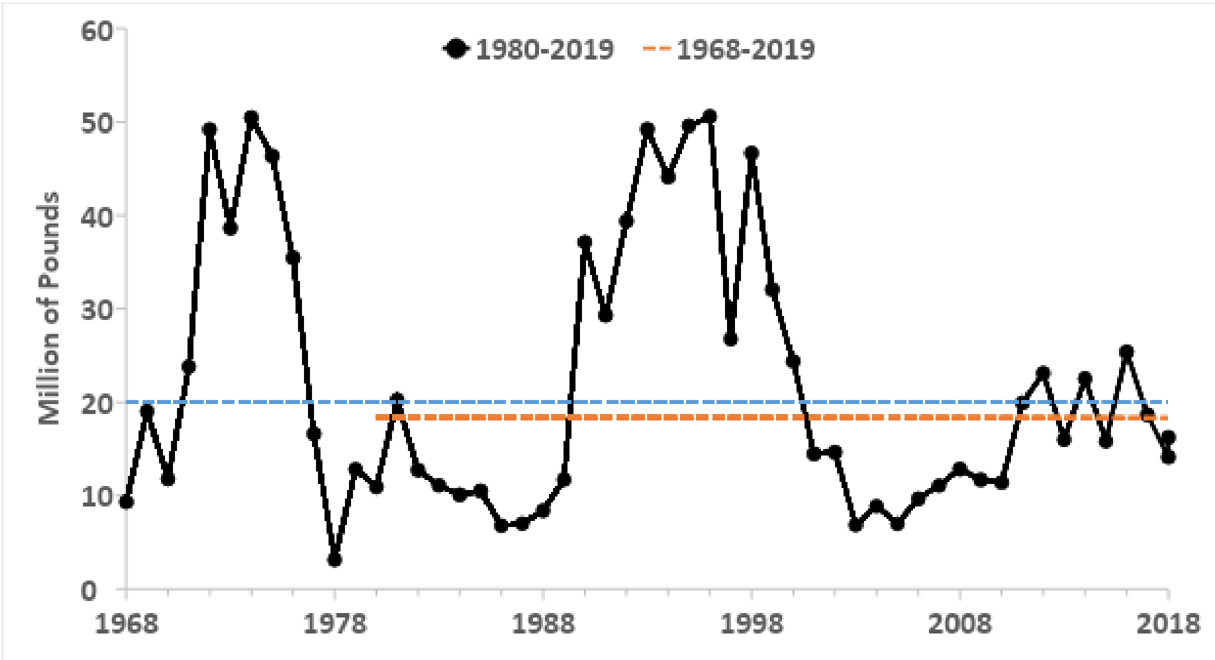


Figure 8.2. Female spiny dogfish removals in millions of pounds (black line) and the median sustainable yield estimate (18.36; dashed orange line) from the DCAC base configuration. A longer time series was also explored and the median sustainable yield from that sensitivity run was included (20.02; dashed blue line).

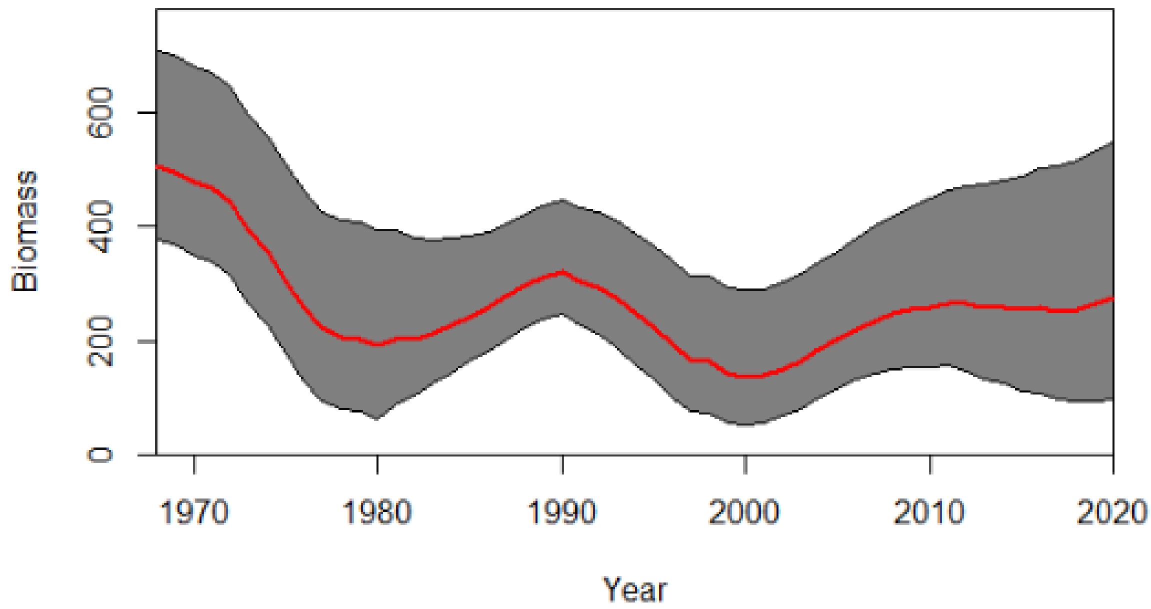


Figure 8.3. Estimated female spiny dogfish biomass (millions of pounds) from the DB-SRA model with 95% confidence intervals. Red line indicates the median biomass values.

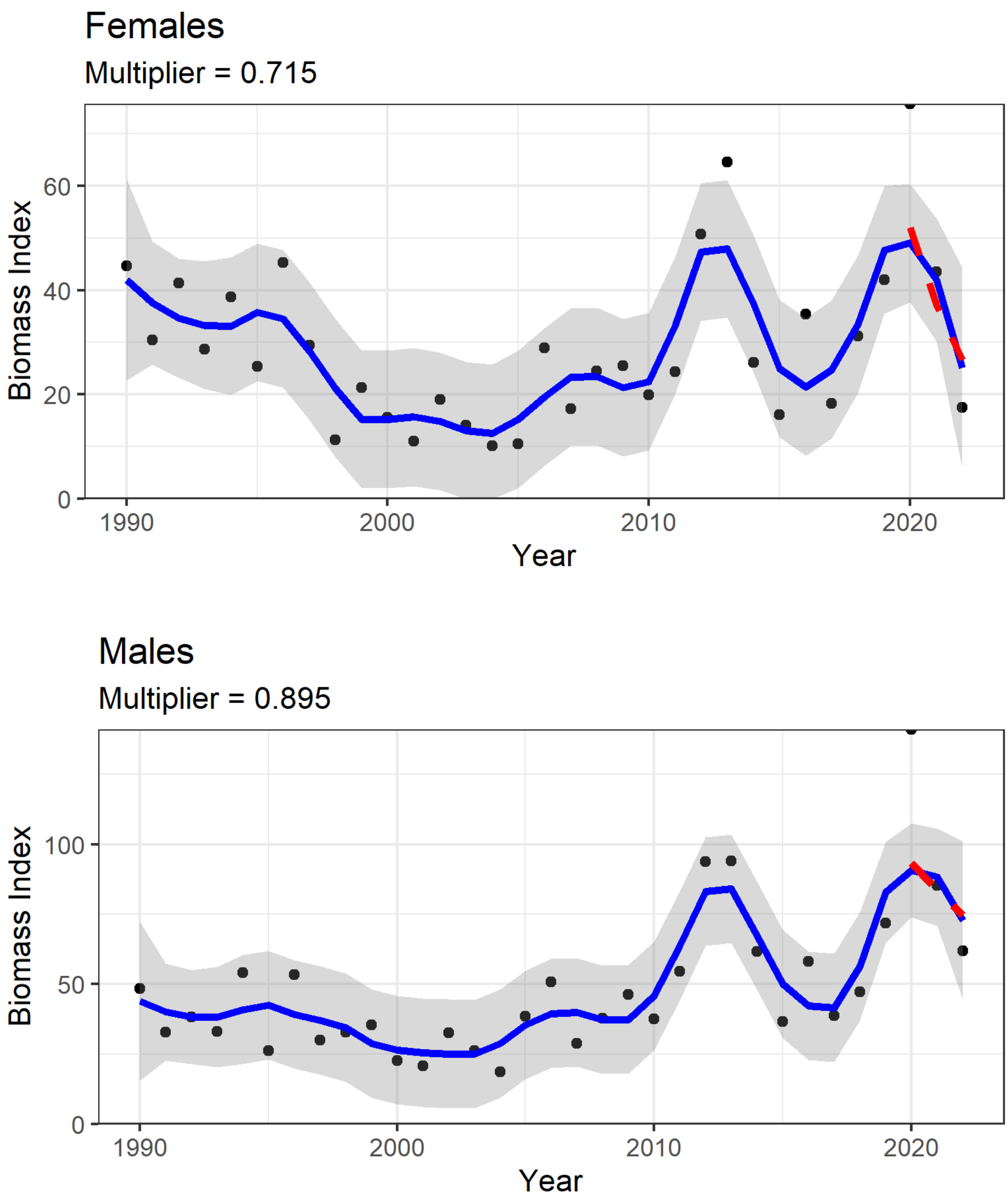


Figure 8.4. Female (top) and male (bottom) spiny dogfish NEFSC bottom trawl survey indices with the Ismooth approach applied. Loess fits (blue lines) and the associated confidence interval (gray areas) and the fit to the terminal years for deriving the multiplier (dashed red lines) are presented. Indices were derived from Stock SMART.

ACKNOWLEDGMENTS

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APPENDIX A. STAKEHOLDER SESSION MEETING NOTES

Stakeholder Session Meeting Summary
Tuesday, February 15, 2022
3:02PM-5:06PM

*Please note that **public questions/comments/input is bolded** to distinguish from working group presentation summaries and responses*

An introduction to the research track and terms of reference

Presenter: Conor McManus-RIDEM
Provided background on the Spiny Dogfish Research Track Stock Assessment process and Work Group.

Discussion summary: No discussion

The assessment model

Presenter: Jui-Han Chang-NEFSC
Provided background on Stock Synthesis 3 (SS3), a stock assessment-modeling program, which will be evaluated for use in the stock assessment.

Discussion summary

- **What will be the terminal year for the research track?**
    - As of now, the assessment will run through 2019 as 2020-2021 catch data is still under analysis.
    - Terminal year is considered so that GARFO and NEFSC will use the same set of data.

- **Clarification of the current working model and the final model**
    - The current working model is not an SS3 model.
    - As part of this research track assessment, the WG has developed a SS3 model for spiny dogfish using data through 2008, but will be updating data through 2019 for the assessment. At this point the WG will evaluate the model's performance.

Ecosystem drivers and influences

Presenter: Alex Hansell-NEFSC
Provided background and efforts addressing Terms of Reference 1 regarding environmental drivers for the stock.

Discussion summary

- Ecological and/or climate influences on abundance and the effects of environmental influences on catch?
    - **The water is now warmer, seal population is increasing which could be influencing numbers.**

- **Are seals eating dogfish and if so, how does this impact the dogfish population? The relationship between dogfish and groundfish needs to be considered.**

- Shifts in spatial distribution over time
    - **Fishers must travel further offshore to encounter and get the same biomass as in the past**
    - **Pockets of no fish up to 20 miles offshore**
    - **Travel distance has increased every year.**
    - **In 2008-2010, trip limits were 2000lbs and they used smaller skiffs. These limits were easier to fill the boat, gaffing the fish from the boat a half mile from the beach. Now traveling 10-20 miles offshore to catch that same biomass. Fishers are traveling much greater distances offshore. Within that subset of time, within 3-4 years ago they had state permits within state waters, sometime in 2015-2016, fishers were required to go outside state waters and with each subsequent year, fishers travel distance increased. This previous year was extra challenging because the fish were not even offshore at the fishing grounds. The fish are pushing offshore, and they seem to have pockets of no fish whatsoever. Groups of fishers would go up and down the coast searching for spiny dogfish.**
    - **Travel distance has increased every year; as of 3 years ago "no fish inshore", especially this past year 0 catch.**

- Timing of location over time
    - **In 2014-2015 they were reliable to predict, at the end of June spiny dogfish would move inshore and into November, they would move offshore again. The start and end dates have moved "closer". Instead of June moving inshore, they were moving inshore in July, the catchability window of inshore dogfish has shortened.**
    - **The time frame from maxing out on trip limit, the shoulders are getting larger where folks aren't maxing out, July-August guys are maxing out. The time is there but the biomass isn't in the Gulf of Maine.**
    - **Because the start and end of the availability has moved closer together, there is a shorter window of economic viability.**

- Changes in the size of fish or sex ratios
    - **This year, spiny dogfish were smaller, and it was more difficult to catch big fish.**
    - **Lower yields because fishermen couldn't get out of the small fish, the "art" of fishing is finding the big fish within smaller fish schools.**
    - **This year was one of the first that females were in the 4-5lb range (medium large females) something they rarely see. Normally females are 6+lbs.**
    - **Four years ago gear switched from 6.5" to 7" gear, this year he couldn't catch a fish because they all swam through the mesh.**

- Prey

- **Squid, sand eels, and herring sometimes**

Movement ecology as related to tagging data

Presenter: Cami McCandless-NEFSC
Provided background on all tagging data that is being reviewed and/or analyzed by the Working Group.

Discussion summary

- **Why is a recapture rate of 3% considered good for sharks? Is this from tag retention or a catchability index?**
    - It is probably a little bit of both.
    - Catchability: the size of the ocean and their highly migratory spatial dynamics means few are encountered and of those not all are reported
    - The highest recapture rate is about 13% (shortfin mako) and 9% (blue).

- **We release spiny dogfish without tagging them with the NMFS M-dart tags from the Cooperative Tagging Program. It looks like you're not in strong need for tagging of spiny dogfish with these tags. Is that a correct interpretation?**
    - That is correct. Spiny dogfish are typically tagged with the roto tags instead of the dart tags due to concerns with tag retention.
    - **Over the years 42,000 spiny dogs tagged with Stainless Steel single barbed shark tags from floy tag company, and we have had tag retention for decades. One of the reasons we didn't use roto tags was we were concerned about the catch in gillnets. The other thing is that we saw most of our tag returns coming from the inner continental shelf where most of the fishery is taking place, most of those came within a year, but there was something very strange, we started getting tags returned 10 years later, those had been released from NC waters and showing up in MA fisheries 10 years later, I think they went offshore from any harvest and stayed there for a long time before they returned to the continental shelf. I haven't published that but that's what we are seeing in the data.**

- **How is the study fleet data being used?**
    - Vessels used for tagging were part of the study fleet.
    - Tagging data is not regularly received from the study fleet currently, only a handful a year. When tags were originally put out there was a high return.
    - NOAA is investigating further/increased use of the study fleet data for answering directed questions.

- **Where do the off the shelf tag returns come from?**
    - All but 1 are summer recaptures.
    - **There was one recapture of a stainless-steel barbed tag from Iceland.**
    - **We see more male fish(undesirable) every summer off cape cod and less large females. We also see a lot of mixed sized fish of both sexes.**

Survey and catch information
Presenter: Kathy Sosebee-NEFSC

Provided background on the NEFSC Bottom Trawl Survey data being used in the assessment currently, and reviewed the other survey data that will be evaluated as part of the assessment. Landings information was also reviewed.

Discussion summary

- **Where does the catch data come from?**
  - Refer to vessel/trip reports to derive landings information.

- **Are the surveys indicating that numbers are going down?**
  - The trawl survey numbers are down slightly with 2017 being a strange year. The numbers are not down to the extent they were 20 years ago. Currently, 2020 and 2021 are not included.

- **What is the method and format of the recreational landing survey?**
  - The method has changed overtime, used to be a combination of phone survey and mail survey. Now it is a mail survey combined with an intercept survey where they get information, just not many spiny dogfish encountered.
  - The success of the survey has been reviewed by the National Academy of Sciences.
  - Participation in the intercept survey is high and the mail survey is higher than the phone survey. Jason Didden can be contacted for more information (jdidden@mafmc.org).

- **Is catch taking into account effort metrics? Seeing a decline in landing component but Gulf of Maine probably ever contributed much in the first place, but the effort has decreased? Is this being accounted for? Decreases in catch from Gulf of Maine could lead to erroneous conclusions if decrease in effort is not considered.**
  - CPUE issue when there is only one processor which is in an early stock assessment report; unsure if CPUE can be looked at if there is only 1 processor; the Working Group will investigate further.
  - CPUE must account for changes in the number of participants.

- **What is the rush in raising the trip limits? Concern that raising trip limits is a push from processors and could negatively impact stock size and push mid-size vessels out of the fishery. Industry participation has already declined significantly.**
  - The trip limit is a management question rather than a question that will be addressed as part of the assessment. The working group does not have final estimates or inferences on current stock size. When the assessment is complete with updated modeling, we will have a better understanding of the stock size, and assuming it passes peer-review, will be available for future management considerations.
  - In terms of current management, GARFO is working on trip limit revisions for May of 2022. The reason we are changing this year is from industry requests and

looking at the data. Trip limits limit the people's ability to run their operations as they would like to, and it's causing many discards and they aren't able to meet the quotas they have by the end of the year. It's not a significant increase either, so it's largely by industry request. It's related but not directly involved with the research assessment.

- **What efforts have been made to increase the value of dogfish?**
    - Several projects have been funded to increase dogfish market value.
    - Varying degrees of success in these efforts.

Closing

The next Working Group meeting is scheduled for February 24 from 10-1PM. The link to the meeting can be found on the assessment's homepage: https://www.fisheries.noaa.gov/event/research-track-working-group-2022-improving-assessments-spiny-dogfish.