Atlantic States Marine Fisheries Commission

2024 Atlantic Sturgeon Stock Assessment Update

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Sustainable and Cooperative Management of Atlantic Coastal Fisheries

Atlantic Sturgeon Stock Assessment Update

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EXECUTIVE SUMMARY

The purpose of this assessment was to update the 2017 Atlantic Sturgeon Benchmark Stock Assessment and Peer Review Report (ASMFC 2017) with recent data from 2016-2022. Data from a variety of fisheries-dependent and independent sources were used to develop bycatch, effective population size, and mortality estimates.

Several states closed their Atlantic sturgeon fisheries in the mid to late 1990s, and a coastwide moratorium was implemented in 1998, ending the directed Atlantic sturgeon landings time series. For this assessment, bycatch in other fisheries was quantified from federal observer programs from Maine to North Carolina and in North and South Carolina from other fishery programs. Bycatch data begins in the 2000s and estimates of Atlantic sturgeon bycatch have generally been decreasing in recent years, with the exception of estimates from gill nets from the federal program.

Nine fishery-independent surveys were developed into indices of relative abundance for Atlantic sturgeon. Most indices either had no trend over the time series or were increasing. The individual indices were combined to develop a coastwide index of relative Atlantic sturgeon abundance. The coastwide index is variable from 1990-2022 but has been steadily increasing since 2013.

Estimates of total mortality (Z) produced from an acoustic tagging model were compared to total mortality thresholds defined as the value of total mortality, Z, that results in an egg-per-recruit (EPR) that is 50% of the EPR of an unfished stock, $Z_{50\%EPR}$, at both the coastwide and DPS-level. Total mortality was low for the coastwide population. For individual DPSs, the Gulf of Maine had the highest Z estimates whereas the Chesapeake Bay had the lowest Z estimates.

Stock status determination was made qualitatively relative to historical abundance and quantitatively relative to 1998 (or, for surveys that started after 1998, the first year of the survey), the start of the coastwide moratorium when more quantitative datasets were available. The terminal year index values of the selected fisheries-independent surveys were compared to the index value that occurred during 1998 to evaluate whether abundance was higher or lower than at the start of the moratorium. At the coastwide level, while Atlantic sturgeon remain depleted relative to historic levels, the composite index had a 100% probability of being above the 1998 value and a significant positive trend over the time series, and the probability of total mortality being above the total mortality threshold was less than 2%.

At the individual DPS level, results were more mixed. Individual indices varied, with slightly more than half having a greater than 50% chance of being above the reference year value; most indices showed a positive or no significant trend. The average probability of being above the reference year was greater than 50% for the New York Bight and the Carolina indices, and less than 50% for the other indices, similar to the results of the 2017 assessment. The Gulf of Maine

DPS had a 56% probability of annual *Z* being above the *Z* threshold, but all other DPSs had a less than 50% probability of exceeding the *Z* threshold.

Population	**Mortality Status**	**Biomass/Abundance Status**		
	P(Z)>$Z_{50\%EPR}$ Reference Point	**Relative to Historical Levels**	**NOAA Designation**	**Average probability of terminal year of indices > reference year***
Coastwide	2%	Depleted		100%
Gulf of Maine	56%	Depleted	Threatened	45%
New York Bight	20%	Depleted	Endangered	59%
Chesapeake Bay	14%	Depleted	Endangered	27%
Carolina	18%	Depleted	Endangered	77%
South Atlantic	27%	Depleted	Endangered	31%

***Reference year is 1998, or the first year of the survey for indices that started after 1998**

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INTRODUCTION

This terms of reference (TOR) report describes the update to the most recent benchmark stock assessment for Atlantic sturgeon (ASMFC 2017). This assessment extends the fishery-independent and –dependent data for Atlantic sturgeon through 2022, reruns the tagging, autoregressive integrated moving average (ARIMA), and egg-per-recruit models and estimates annual bycatch and total mortality. Stock status is determined using the total mortality reference point defined and accepted for management use in 2017.

Atlantic sturgeon are categorized into five distinct population segments (DPS): Gulf of Maine, New York Bight, Chesapeake Bay, Carolina, and South Atlantic (Figure 1). The DPSs have different physical, genetic, and physiological characteristics (NOAA 2012a). The SAS note that while surveys used in this assessment are categorized by DPS, they are likely catching a mixed population. The SAS is making the assumption, based on genetic work (Kazyak et al. 2021), that the surveys encounter predominantly Atlantic sturgeon from populations which spawn nearby, but some Atlantic sturgeon from other DPSs may be mixed in as well.

TOR 1. Fishery-Dependent Data

Update fishery-dependent data (landings, discards, catch-at-age, etc.) that were used in the previous peer-reviewed and accepted benchmark stock assessment.

Several states closed their Atlantic sturgeon fisheries in the mid to late 1990s, and a coastwide moratorium was implemented in 1998, ending the directed Atlantic sturgeon landings time series. Historical commercial landings are available in ASMFC 2017.

However, Atlantic sturgeon are still caught as bycatch in fisheries for other species. Estimates of Atlantic sturgeon bycatch are available from federal and state data collection programs and were updated for this assessment.

a. Northeast Fishery Observer Program Bycatch Estimates

Following the approach used by Miller and Shepherd (2011), Miller (2015), Curti (2016), and Boucher and Curti (2023), the same generalized linear model (GLM) framework with quasi-poisson assumption was used for modeling Atlantic sturgeon takes as a function of the trip-specific species mix, year, and quarter factors. In Miller and Shepherd (2011), the “species mix” was comprised of those species currently managed with federal fishery management plans. In this analysis, the modifications applied in ASMFC 2017 were followed, where the “species mix” covariates were those species caught most on observed hauls encountering Atlantic sturgeon.

The selected model for each gear type was applied to vessel trip reports to predict Atlantic sturgeon take for all trips. The new NEFSC/GARFO Catch Accounting and Monitoring System (CAMS) was not used to develop the estimates, to be more consistent with the methods used in the 2017 benchmark assessment. The total bycatch of Atlantic sturgeon from bottom otter trawls ranged between 478 – 1,187 fish over the time series (Table 1). The proportion of the encountered Atlantic sturgeon recorded as dead ranged between 0 – 18% and averaged 4%. This resulted in annual dead discards ranging from 0 – 212 fish. Likewise, the total bycatch of Atlantic sturgeon from sink and drift gillnets ranged from 281 – 1,583 fish (Table 2). The proportion of Atlantic sturgeon recorded as dead ranged between 12 – 51% and averaged 30%, resulting in annual dead discards ranging from123 – 594 fish. The estimates from the updated model for this assessment were very similar to the estimates from the benchmark model for both gears (Figure 3). The percent of dead sturgeon in both otter trawls and gillnets was higher in 2021-2022 than it was in earlier years, but observer coverage was lower in 2021-2022, resulting in higher uncertainty around the estimates.

b. North Carolina Atlantic Sturgeon Bycatch Estimates from the Estuarine Gill Net Fishery

A GLM framework was used to predict Atlantic sturgeon interactions in North Carolina's estuarine gill net fishery based on data collected during 2013-2022 using the same methods as ASMFC 2017 although the time period of data has changed. Since 2017, the bycatch database in North Carolina has improved and their Protected Resources Section no longer recommends using the data from 2004-2012 as was done in the benchmark. For this update, only the data from 2013-2022 was used. The best-fitting GLM was a zero-inflated Poisson model with an offset for trips that used year, season, management unit, and mesh size in the count part and year, management unit, and mesh size in the zero-inflated part. Atlantic sturgeon bycatch in North Carolina's estuarine gill net fishery reached a high of 1,413 Atlantic sturgeon in 2015 and a low of 119 in 2019 (Table 3). In general, the Atlantic sturgeon bycatch in this fishery has decreased over time, due in part to additional regulations on the gillnet fishery to minimize bycatch of Atlantic sturgeon as a result of the ESA listing.

c. South Carolina Atlantic Sturgeon Bycatch Estimates from the American Shad Fishery

Following the methods of ASMFC 2017, Atlantic sturgeon bycatch estimates in South Carolina were estimated. Between years 2000-2022, a total of 1,728 Atlantic sturgeon were reported in the Winyah Bay and Waccamaw, Great Pee Dee, and Santee Rivers American shad fisheries (Table 4). Previous observer coverage indicated that the vast majority of sturgeon caught in this fishery are alive when released, as the fishery occurs in the spring when the water temperatures are cooler. Therefore, all sturgeon reported as bycatch are assumed to be released alive unless specifically reported dead. Based on genetic makeup and ecological groupings included in the recent 2012 listing of the Atlantic sturgeon to the Endangered Species List, these rivers are part of the Carolina DPS (NOAA 2012a). Average effort during the same time series equaled 3,342,073 net yard hours with an average catch per unit effort (CPUE) of 0.0000035 Atlantic sturgeon per net yard hours. It is also important to note, since shad regulation changes in 2013 as part of requirements of South Carolina's Shad Sustainably Plan, reported numbers of Atlantic sturgeon for Carolina DPS rivers decreased by 30% and CPUE decreased by 38%. These are notable decreases to already low levels of overall impact.

Between years 2000-2022 a total of 69 Atlantic sturgeon were reported in the Edisto, Combahee, and Savannah Rivers shad fisheries (Table 4). Based on genetic makeup and ecological groupings included in the recent 2012 listing of the Atlantic sturgeon to the Endangered Species List, these rivers are part of the South Atlantic DPS (NOAA 2012a). Average effort during the same time series equaled 261,195 net yard hours with an average CPUE of 0.0000016 Atlantic sturgeon per net yard hours. It is important to note, since shad regulation changes in 2013 as part of requirements of South Carolina's Shad Sustainably Plan, reported numbers of Atlantic sturgeon for South Atlantic DPS rivers was one fish. These are also notable decreases to already low levels of overall impact. This combined with overall declining effort suggests by-catch in this fishery may not be a concern to sturgeon populations in these rivers.

TOR 2. Fishery-Independent Data

Update fishery-independent data (abundance indices, age-length data, etc.) that were used in the previous peer-reviewed and accepted benchmark stock assessment.

As noted in ASMFC 2017, Atlantic sturgeon are not often encountered by fishery-independent surveys. Nine surveys were developed into indices of relative abundance and were standardized using generalized linear models. Because of low positive tows, several surveys used a binomial error structure as recommended by the Peer Review Panel (Table 5). Indices were combined for a coastwide index of relative Atlantic sturgeon abundance using the Conn method (Conn 2010). The coastwide index is variable from 1990-2022 but has been steadily increasing since 2013 (Figure 4). Individual survey plots can be found in the Appendix (Figure A6 - Figure A22).

A power analysis was completed on the abundance indices (ASMFC 2017; Gerrodette 1987). Median coefficients of variation (CVs), or proportional standard error, ranged from 0.14–1.15 for the surveys analyzed and power values ranged from 0.13 to 1.00 (Table 6). The Maine-New Hampshire Trawl had the lowest power and the South Carolina Edisto Sturgeon Monitoring Project Survey had the highest power to detect a 50% increase or decrease in abundance. The results were similar to the benchmark (ASMFC 2017).

TOR 3. Life History Information

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

The life history information used to parameterize the eggs-per-recruit (EPR) reference point model was the same as used in the benchmark. The median life history information is presented in Table 7.

TOR 4. Models

Update accepted model(s) or trend analyses and estimate uncertainty. Include sensitivity runs and retrospective analysis if possible and compare with the benchmark assessment results. Include bridge runs to sequentially document each change from the previously accepted model to the updated model.

a. Tagging Model

The tagging analysis from ASMFC (2017) was repeated to estimate annual survival of telemetry tagged Atlantic sturgeon. The dataset consisted of tag detection data for Atlantic sturgeon tagged and observed on receiver arrays across the Atlantic coast. Detection data from the 2017 assessment was updated to included additional detections and tags through the time period ending in 2022. Tagged Atlantic sturgeon were individually assigned a DPS based on genetics if a genetic assignment was available, then location of tagging if genetics were unavailable (Table 8). Tagged individuals were separated into two groups for size-at-tagging, subadults (<1,300 mm) and adults (>1,300 mm), with the break approximating size at maturation. The benchmark assessment only looked at parameter estimates over a single block of time, but for this update both single and dual time stanzas were evaluated. Based on the pattern in tag detections, representing shifts in effort across DPSs, a cutoff date of December 2015 was used to split detections into early (2006-2015) and late periods (2016-2022).

The Cormack-Jolly-Seber model and estimated parameters, detection probability (P) and annual survival (S), were the same as in the benchmark model. Similarly, scenario runs used 2,500 burn-in and 10,000 model iterations and best performing models were selected using Deviance Information Criterion (DIC). The scenarios evaluated by the model included those from the benchmark assessment and the additional early and late time blocks.

The best model for each DPS and size group varied, with a single estimate of P performing better for certain DPSs, while monthly DPS estimates were better for others. Size groups showed less of a pattern for P. Models using the early and late S blocks were less supported than those using single blocks, and the S estimates did not vary greatly between times. The peer review from the benchmark assessment recommended presenting the median, instead of mean, value of the posterior distribution for estimates, due to skewing in the distributions related to sample size.

Total mortality (Z) was calculated from survival using the equation:

$$Z = -\ln(S)$$

Overall, estimates of Z were similar to those in the benchmark assessment, in most cases equal or lower. Across DPSs, Z was also similar, although the Gulf of Maine DPS was somewhat higher (Table 9; Figure 5-Figure 10). Atlantic sturgeon migrate over large areas throughout their subadult and adult stages (Kazyak et al. 2021) and mortalities may occur beyond the geographic area associated with a specific DPS. Therefore, the DPS-specific estimates represent estimates for individuals originating from the DPS, rather than the conditions within the geographic area associated with the DPS itself. Subadult *Z* was also generally higher than adult *Z*; see Appendix A for more detailed results.

The number of tags available were greatly increased over the benchmark, improving estimates, but the tagging model was still sensitive to sample size, notably in the results for the Gulf of Maine DPS. Importantly, many tagged Atlantic sturgeon originate through shorter-term studies that are focused on answering specific research questions and may not have steady funding. Continued application of this model will require continued operation of acoustic telemetry arrays and ongoing deployment of acoustic tags. Improved tagging and detection data could also lead to future model improvements as additional modeling aspects, such as covariates, or finer resolution temporal or spatial parameter estimates can be developed.

b. Stochastic Eggs-per-Recruit (EPR) Model

During the update, a revision was made to how uncertainty was parameterized for the stochastic EPR model used to estimate the *Z* reference point. This revision made the standard deviation of the drawn parameters align more closely with the published values where available when parameters were drawn from a lognormal distribution. Otherwise, the parameterization of the model was the same as in the benchmark assessment. Median selectivity values for the bycatch and ship strike fleets are presented in Table 7.

The adjustment to the uncertainty parameterization had a negligible effect on the overall distribution for the $Z_{50\%EPR}$ reference point compared to the benchmark values. The 80th percentile of the $Z_{50\%EPR}$ distribution is used as the reference point and was equal to 0.14.

c. Mann-Kendall Test

Analyses from ASMFC (2017) were repeated with raw updated indices. For ASMFC (2017), only one index, North Carolina Program 135's (NC p135) spring index for juveniles, had a significant (increasing) trend ($\alpha = 0.05$). For the present report, the following raw indices had increasing trends: New Jersey Ocean Trawl, NC p135's spring index for young-of-the-year (YOY) and juveniles, NC p135's spring index for juveniles, NC p135's fall index for YOY and juveniles, NC p135's fall index for juveniles, and the Conn index (Table 12). No survey had a significant declining trend.

d. ARIMA

The fishery-independent indices were analyzed using the autoregressive integrated moving average (ARIMA) methods described in ASMFC (2017) with the following changes:

- In 2017, only contiguous years of a survey index with no missing index values were used in ARIMAs (Figure 11); due to COVID and other reasons (e.g., vessel mechanical issues), sampling for several surveys was suspended during at least 2020 and so for the present assessment, the ARIMA code (the *surveyfit* and *surveyref* functions from the *fishmethods* package) was modified to allow missing values; the bootstrapping routine within *surveryref* was also modified so that missing years of data always had missing data and no additional missing years were added via re-sampling.

- Given the variability in available terminal years relative to ASMFC 2017 (Figure 11), the data was not subset to a common set of years as a sensitivity analysis. The goal of this sensitivity analysis in 2017 was to determine whether the comparison of the terminal year to the 25th percentile of the time series was sensitive to the specific years over which the 25th percentile was calculated. For the present analyses, due to COVID and other issues, surveys have variable terminal years and years missing adjacent to terminal years, and so the SAS found this sensitivity analysis to be less relevant (i.e., trimming surveys to a common terminal year would only add four additional years to ASMFC (2017), resulting in a terminal year of 2019, approximately 5 years ago – this was judged to be of little use).

Consistent with ASMFC (2017), probabilities greater than or equal to 0.50 were considered credible evidence that an index value was greater than a reference point.

Descriptive statistics for all model runs are provided in Table 11. When adjusted for multiple tests (Holm 1979; RCT 2017), residuals from all model fits were normally distributed, except for the South Carolina Edisto Sturgeon Monitoring Project Survey (SC Edisto).

Fitted indices, grouped by DPS, are plotted in Figure 13 - Figure 15. Plots of ARIMA fits with reference values are provided in the Appendix (Figure A1). Significant trends (Holm-adjusted *p*-values ≤ 0.05) are summarized in Table 12 and reported below.

Comparison of ARIMA fits from 2024 with those generated in 2017 are provided in Figure 16. Direct comparison of index fits is complicated by index model structures changing in some instances (e.g., GLM vs generalized additive model, or GAM, for New York State Department of Environmental Conservation Juvenile Atlantic Sturgeon Abundance Monitoring Program, or NY JASAMP) and additional years of data becoming available (e.g., Connecticut Long Island Sound Trawl Survey, or CT LIST, in the spring) due to changes in ARIMA methodology from ASMFC (2017; e.g., allowance for missing years of data).

All ARIMAs were credibly above their respective 25th percentiles of abundance except for the CT LIST for the index using all months and the Virginia Institute of Marine Science (VIMS) Shad and River Herring Monitoring Survey in the James River in the spring (Table 12). The situation was more mixed when considering terminal year fits compared to the fitted index from 1998 (or the first year of the survey). When including all indices, the terminal year for 7 of 18 indices were not above the 1998 (or surrogate) value. As was done in ASMFC (2017), because some survey indices, when subset to different ages or months, are strongly correlated with each other, 'duplicative' surveys were removed for final status determination. In this case, for the group of NC p135 spring indices, the juvenile index was strongly correlated with both the YOY and the YOY and juvenile indices (while those two indices were not strongly correlated with each other). Since the indices are not lagged, only the YOY and juvenile index was removed, since similar information is contained in the individual indices. For the group of NC p135 fall indices, all three indices were strongly correlated with each other. Following the reasoning for NC p135 spring indices, YOY and juvenile indices was removed. With these adjustments, 7 of 16 indices were not above their respective fitted 1998 (or surrogate) index value. See Table 13 for results summarized by DPS, or Table 12 for individual survey results.

Results from the reverse retrospective analysis are provided in Figure 17 - Figure 18. Figure 17 suggests that the terminal year comparisons with the 25th percentile of the CT LIST index for all months, CT LIST spring index, NY JASAMP, and VIMS (James River only) indices are all somewhat sensitive to the start year of the survey. In each of those surveys, except for NY JASAMP, the probability of being above the 25th percentile of abundance tends to increase with later starts in the survey – this is an intuitive result as early years of these surveys tended to have relatively high index values, and so as those years are sequentially removed, the 25th percentile of the time series drops, making it more likely that the terminal year will exceed that value.

Figure 18 suggests that the conclusions with respect to comparisons with the index value in 1998 (or start year of the survey for surveys that began after 1998) for CT LIST index using all months, CT LIST index in the spring, Maine-New Hampshire Inshore Groundfish Trawl Survey (ME-NH Trawl), SC Edisto, US Fish and Wildlife Cooperative Tagging Cruise (USFWS), and both VIMS indices are all somewhat sensitive to the start year of the survey. The reasons for this may be similar to those stated above – early years of these indices tend to have comparatively large values with wide swings in abundance, the removal of which can have a strong influence on the ARIMA trend.

A correlation matrix of all ARIMA fits is provided in Figure 19. Index fits in the New York Bight DPS are uncorrelated or negatively correlated with each other. Index fits in the Chesapeake Bay DPS are uncorrelated with each other. Index fits in the Carolina DPS are uncorrelated or positively correlated with each other. The Northeast Area Monitoring and Assessment Program Trawl Survey (NEAMAP), which corresponds to the New York Bight, Chesapeake Bay, and Carolina DPSs, is uncorrelated with all index fits, save CT LIST index for the fall; the Conn index fit is positively correlated with all Carolina DPS index fits, and the New Jersey Ocean Trawl fit, but uncorrelated or negatively corelated to the remainder of the index fits. See Figure 19 for relationships among all survey fits.

For detailed DPS- and index-specific results, see Appendix C.

TOR 5. Stock Status

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

Atlantic sturgeon was designated as a federally endangered species in 2012 (Federal Register 2012). However, there remains no estimates of unexploited biomass or abundance at the coastwide or DPS-level against which to evaluate Atlantic sturgeon status, and estimates of current abundance are limited to a few rivers. Also, for a species that has been under a moratorium for nearly twenty years, the traditional "overfished" and "overfishing" status designations are not as meaningful.

For this assessment, quantitative stock status was determined from the probability of the estimate of total mortality from the tagging model being greater than the $Z_{50\%EPR}$ reference point and the probability that the terminal year of the indices for a given DPS was greater than the reference year for each index, as evaluated by the ARIMA analysis. Because the available indices only cover the most recent time period, long after the height of exploitation, metrics like trends in landings and consideration of anecdotal reports of historical distribution and abundance were used to determine a qualitative biomass or abundance status relative to historical levels.

For total mortality, the distributions of the annual estimate of Z from the tagging model were compared to the total mortality EPR reference point to determine the probability of total mortality for the coast and for each DPS being above the reference point. The 80th percentile of the stochastic $Z_{50\%\mathrm{EPR}}$ estimate for the coast was used as the reference point. Total mortality was low for the coastwide population; median annual Z was estimated to be 0.01 for 2006-2022, with only a 1.8% chance that Z was higher than the Z reference point (Table 9, Figure 5).

At the individual DPS level, estimates of survival were lower and estimates of Z were higher, due to the lower sample size and the broader parameter distributions (Table 9, Figure 6 -Figure 10). The Gulf of Maine had the highest median annual Z at 0.15, with a 55.5% probability of being above the Z threshold. The New York Bight DPS median annual Z was 0.06, with a 20.2% probability of being above the Z threshold. The Chesapeake Bay DPS had a median annual Z of 0.05, with a 14.1% probability of being above the Z threshold. The Carolina DPS had a median annual Z of 0.05, with an 18.2% probability of being above the Z threshold. The South Atlantic DPS had a median annual Z of 0.07 with a 26.5% probability of being above the Z threshold. Overall, the probability of exceeding the Z threshold was lower for the coast and for all DPSs than was estimated for the 2017 benchmark assessment. The two time-block model had less statistical support than the single time-block model, so this lower probability may result from an improved ability to estimate Z in the update, with the larger sample size and longer time series, rather than a reduction in Z in recent years. In all DPSs and at the coastwide level, Atlantic sturgeon were determined to be depleted relative to historical levels, a term that acknowledges the impact of not just directed fishing mortality, which has ceased since 1998, but other factors such as bycatch mortality, ship strikes, and reductions in productivity due to habitat loss.

At the coastwide level, while Atlantic sturgeon remain depleted relative to historic levels, the composite index had a 100% probability of being above the 1998 value and a significant positive trend over the time series, and the probability of total mortality being above the total mortality threshold was less than 2% (Table 14).

At the individual DPS level, results were more mixed (Table 14). Individual indices varied, with slightly more than half having a greater than 50% chance of being above the reference year value; most indices showed a positive or no significant trend (Table 13). The average probability of being above the reference year was greater than 50% for the New York Bight and the Carolina DPSs, and less than 50% for the other DPSs, similar to the results of the 2017 assessment. The Gulf of Maine DPS had a 55.5% probability of annual Z being above the Z threshold, but all other DPSs had a less than 50% probability of exceeding the Z threshold (Table 14).

Atlantic sturgeon is a data-limited species, and there are several limitations and sources of uncertainty in the datasets used in this assessment that should be taken into account when evaluating stock status. Even though Z has a low probability of exceeding the Z reference point at the coastwide level, sources of mortality like bycatch and ship strike mortality may not be affecting each DPS or even each river within a DPS equally. Only half of the tagged fish were able to be assigned to a DPS based on genetics; the rest were assigned based on where they were tagged. This makes the estimates of Z at the DPS level less reliable, as fish from other DPSs are likely mixed with the true DPS fish in the analysis. In addition, the tagging model is predominately measuring Z on adult fish, based on the size of the fish in the model and the time at large, and mortality on juveniles may be higher. For abundance trends, the probability of a DPS being above or below the reference level is based on a limited number of surveys for each DPS. Indices are assigned to a DPS based on where the survey occurs, not on the genetics of the fish caught by that survey. While genetic work (Kazyak et al. 2021) suggests that the surveys encounter predominantly Atlantic sturgeon from populations which spawn nearby, some Atlantic sturgeon from other DPSs may be mixed in as well, potentially confounding some of the trends reported for each DPS.

In addition, tag data and indices were not available for all rivers within each DPS, so the results reported here represent only the component of each DPS, and the coastwide population, that are represented in the available data.

TOR 6. Projections

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

Projections cannot be conducted with the models used in this assessment.

TOR 7. Research Recommendations

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

a. Progress on Benchmark Research Recommendations

Since the 2017 Atlantic sturgeon Benchmark Assessment, research and management information has been published on a variety of topics that help address research priorities. Appendix D lists the complete list of research recommendations from ASMFC 2017.

High Priority Recommendations

> *Identify spawning units along the Atlantic coast at the river or tributary and coast-wide level.*

Significant progress has been made towards identifying and characterizing extant spawning units along the Atlantic Coast since the last benchmark stock assessment. Two studies found evidence of small breeding populations in rivers that had not been documented prior. Savoy et al. (2017) found evidence of breeding in the Connecticut River by a limited number of breeders, which appear to have originated from much more southern locations. These results indicate that re-colonizers of extirpated populations may not necessarily come from nearby populations. Secor et al. (2022) studied spawning in the Nanticoke River-Marshyhope Creek (Chesapeake Bay), finding a small adult population with a small effective population size genetically (N_e = 12.2, 95% CI = 6.7-21.9) and small spawning runs (<100 adults; Coleman et al. 2024). In addition to these field studies, molecular analysis found evidence of distinct spring- and fall- spawning populations in the Pee Dee and Ogeechee Rivers (White et al. 2021). Despite this progress, there are likely still additional spawning populations which have not yet been formally documented, particularly within the Carolina DPS.

> *Expand and improve the genetic stock definitions of Atlantic sturgeon, including developing an updated genetic baseline sample collection at the coast-wide, DPS, and river-specific level for Atlantic sturgeon, with the consideration of spawning season-specific data collection.*

Several studies have advanced our knowledge of genetic stocks of Atlantic sturgeon. Farrae et al. (2017) found that fall- and spring-spawned Atlantic sturgeon in the Edisto River are genetically distinct but both with high genetic diversity indicating lack of inbreeding and lack of recent bottlenecks. White et al. (2021) published a genetic baseline for Atlantic sturgeon, consisting of representative individuals from 18 genetically distinct groups collected in 13 rivers and one estuary. This baseline includes discrete spring- and fall-spawning populations from four rivers. In most cases, genetic differentiation was lower within DPSs versus among populations from separate DPSs. A notable finding from White et al. (2021) was that populations that spawn in the same season (i.e., spring or fall) are often more similar than populations which spawn within the same river. The White et al. (2021) baseline is currently being used by the U.S. Geological Survey, NOAA Fisheries, and US Army Corps of Engineers to allocate take to specific DPSs to support federal management of Atlantic sturgeon under the Endangered Species Act. The U.S. Geological Survey is continuing to expand and augment this genetic baseline, with ongoing efforts to improve stock characterization in the South Atlantic and Carolina DPSs, as well as populations which spawn in Canadian rivers. Wirgin et al. (2023) used microsatellite analysis to estimate the genetic population structure of Atlantic sturgeon from 13 spawning rivers from St. Lawrence River, Quebec, to Satilla River, Georgia, and found two distinct genetic clusters of juveniles in Ogeechee River, Georgia (spring- and fall-spawned) differing significantly in mean total length and evidence that one cluster is resident while the other is highly migratory. The Savannah and Altamaha River populations showed no such partitioning.

Our enhanced understanding of genetic population structure in Atlantic sturgeon has been leveraged to improve our characterization of stock composition in habitats where mixing may occur. For example, Wirgin et al. (2018) studied the genetics of 148 subadult Atlantic sturgeon collected in the tidal Hudson River estuary and 8 dead specimens found floating (likely victims of vessel strikes) and found 142 live and all 8 dead were Hudson River (New York Bight DPS), 2 Kennebec River (Gulf of Maine DPS), 2 Delaware River (New York Bight DPS), 1 Ogeechee River (South Atlantic DPS) and one James River (Chesapeake Bay DPS). This result does not differ markedly from the retrospective mixed-stock analysis on the New York Bight fishery fin spines collected 30 years ago which suggest the fishery primarily harvested individuals from the Hudson River population, with a few from at least eight other populations (White et al. 2021).

Kazyak et al.'s (2021) mixed-stock microsatellite analysis of 1,704 Atlantic sturgeon found extensive stock mixing in the mid-Atlantic with individuals from all five regions were commonly observed (north of Cape Cod, Massachusetts, and south of Cape Hatteras, North Carolina, stocks were dominated by individuals from regional stocks). Subadults and adults encountered in offshore environments had moved 277 km on average from their natal source with 23% being found over 500km from their natal source.

Wirgin et al. (2023) conducted individual-based assignment testing on 1,512 Atlantic sturgeon from coastal environments, focusing their analysis on individuals which demonstrated affinity to the South Atlantic DPS. Their analysis found a disproportionate contribution from one of the genetic groups from the Ogeechee River, which the authors interpreted to suggest significantly different migratory strategies (i.e., resident and highly migratory).

White et al. (2023) reported individual-based assignment testing results for 329 Atlantic sturgeon which were encountered as mortalities or taken during federally-permitted activities. The majority of these animals assigned to the Hudson River population, with substantial additional contributions from the James River (fall-spawning) and Delaware River populations. Nonetheless, a considerable number of individuals originated from distant populations from the southeastern United States.

White et al. (2024) examined the composition of >500 juvenile and subadult Atlantic sturgeon captured during monitoring surveys at Haverstraw Bay from 2017-2022. The majority of these fish assigned to the Hudson River population, and there were no patterns of natal origin with respect to sex, size, or age. This work indicates that the long-term survey data collected at this location primarily reflects demographic trends in the Hudson River population.

> *Determine habitat use by life history stage including adult staging, spawning, and early juvenile residency; expand the understanding of migratory ingress of spawning adults and egress of adults and juveniles along the coast.*

The frequency of spawning and spawning population abundance has been examined to further our understanding since 2017. Breece et al. (2021) found that females spawn at much shorter mean intervals than historical literature suggests in the Hudson River with mean intervals between spawning periods 1.66 years for females and 1.28 years for males. Additionally, they found significantly longer occupancy in the spawning grounds for males (45 days) than females (21 days). The authors documented that fish returned in September when water temperatures are 20 - 27°C and departed as fall temperatures declined below 20°C. They preferred hard bottom and spawned mostly on sand-cobble and cobble. Movement was higher at night and fish covered multiple spawning regions. Kazyak et al. (2020) integrated side-scan sonar with acoustic telemetry to estimate size of the 2014 spawning run for the Hudson River (N=466, 95% confidence interval = 310-745). If reported spawning intervals were taken into account, the estimate appears similar to the historical total adult population estimate by Kahnle et al. (2007). Vine et al. (2019a and 2019b) examined spawning abundance and migration cues in the Savannah River in South Carolina and Georgia using side-scan monitoring as an alternative to traditional mark-recapture techniques and found maximum daily spawner abundance between 35 and 55 individuals in the fall spawning season. Their conclusion is that directed flow regulation (e.g., intermittent flood pulsing) during key temperature thresholds may facilitate upriver movement and aid in the conservation of sturgeon. Acoustic monitoring and mixed-effects models in the Great Pee Dee River, North Carolina (Denison et al. 2023), indicated that discharge affected water temperature influencing migration initiation and upriver movement. Spring runs cued on rising temperature and high discharge, while fall runs cued on falling temperatures and low discharge. Analogously, in spring Atlantic sturgeon travelled further upriver when discharge was decreasing, while in the fall they travelled upriver when discharge was increasing. They migrated significantly further upstream in fall than spring.

Recent work by White et al. (2024) highlights the extent to which adult sturgeon utilize non-natal rivers. In the Delaware River, a significant proportion of sturgeon which are in freshwater reaches during the spawning season appear to be from other populations. However, despite the physical presence of non-natal adults in spawning reaches, the observed levels of genetic differentiation among population indicate that little effective gene flow is occurring.

Rulifson et al. (2020) tracked Atlantic sturgeon in a strategically placed acoustic array just south of Cape Hatteras where the continental shelf area is naturally constricted finding presence in fall, winter, and spring at approximately the same time as spiny dogfish which could be a problem for bycatch in the spiny dogfish fishery.

Collect DPS-specific age, growth, fecundity, and maturity information.

Several studies address Atlantic sturgeon growth. Kehler et al. (2018) observed hatchery fish marked with an oxytetracycline (OTC) marker and seven recaptures of wild fish and found that growth was different between spring and fall collections with two-part zone for each year of growth. They found mean growth rates of 0.3 mm/day and 2.4 g/day and were unable to effectively estimate fork lengths of age classes. Markin and Secor (2019), through a lab experiment, determined the strain (river of origin) does not support the existence of latitudinal counter gradient growth variation and growth differences are due to the thermal environment alone. They found that spring and fall spawning impacts to growth vary by latitude, predicting that fall spawning should not occur north of the Chesapeake DPS owing to a curtailed fall-winter growth season. They conclude that conservation success is “most sensitive to factors that influence first-year survival.”

The Southern Division American Fisheries Society (SDAFS) held a workshop on Atlantic and Gulf sturgeon ageing as part of their 2024 Annual Meeting, which provided a forum for researchers to discuss their experience and challenges with ageing sturgeon. ASMFC is planning an ageing workshop and exchange for Atlantic sturgeon to develop a standardized protocol for processing and reading Atlantic sturgeon hard parts. The project has recently been revived to build on the discussions at the SDAFS meeting. The workshop is being planned for later in 2024 followed by a hard part exchange. This will provide better, more consistent life history information for the next benchmark, helping to address this research recommendation.

> *Collect more information on regional vessel strike occurrences, including mortality estimates. Identify hot spots for vessel strikes and develop strategies to minimize impacts on Atlantic sturgeon.*

Since 2017 several authors investigated ship strikes as a threat to Atlantic sturgeon. Fox et al. (2020) placed 164 carcasses along the shoreline of the Delaware River Estuary to estimate reporting rates and found overall reporting rate was 4.8% and only included areas easily accessible to the general public, such as beaches. Additionally, they found there was little movement of carcasses and no trends in number of carcasses along the shoreline from 2005-2019. They concluded that because reporting rates of Atlantic sturgeon carcasses are low, the magnitude of vessel strikes may be unsustainably high and directly impeding recovery. In related work, Fox and Madsen (2020) determined that sturgeon use the mouth of Delaware Bay heavily and could be directly (vessel strikes) or indirectly (disruption to foraging habitats) impacted by an increase in vessel traffic. DiJohnson (2019) investigated the influence of vessels on Atlantic sturgeon movement and found no evidence that Atlantic sturgeon behavior is affected by commercial shipping, but is more influenced by sediment type. Recent work by White et al. (2024) highlights the prevalence of non-natal sturgeon throughout the Delaware River and its estuary, suggesting that ship strikes in these areas may be impacting populations from a broad area of the coast.

Despite suggesting areas of focus for ship strike mortality, Kahn et al. (2023) estimated adult annual survival of 99.2% (95% confidence interval: 97.9-99.7%) in the York River, Chesapeake Bay, with 80% of the suspected mortalities’ last detections occurring in a shipping channel.

Atlantic sturgeon are highly migratory with complex and not fully understood movement patterns. Two recent papers studied regional movement. Melnychuk et al. (2017) analyzed movement using acoustic telemetry and survival patterns with multi-state mark-recapture models finding that late spring is particularly sensitive period for Atlantic sturgeon along the coast of Long Island, New York. The authors suggest that managers could use real-time observations from acoustic telemetry to implement short fishery closures to reduce incidental mortality. Rothermel et al. (2020) used a gradient-based array of acoustic telemetry receivers on or near wind-farm lease areas off the coast of Maryland and Delaware to study both Atlantic sturgeon and striped bass movement. The highest incidence of Atlantic sturgeon was in spring and fall biased toward shallow regions. The incidence was often transient (mean =~2 days) with increased residency (>2 days) during autumn and winter, often concentrated in the lease areas during the winter. No diel pattern among seasons was noted. Atlantic sturgeon appeared to select areas based on temperature and depth rather than specific benthic characteristics.

> *Establish regional (river or DPS-specific) fishery-independent surveys to monitor Atlantic sturgeon abundance or expand existing regional surveys to include annual Atlantic sturgeon monitoring. Estimates of abundance should be for both spawning adults and early juveniles at age. See Table 8 for a list of surveys considered by the SAS.*

Abundance estimates have been developed for several populations. White et al. (2022) investigated genetic-based estimates of breeding population size and how genotyping and sampling effort influence bias and precision. As an example, they evaluated the number of successful spawners (N_S) for the Delaware River breeding population of Atlantic sturgeon resulting in a breeding population three orders of magnitude below historic sizes (N_S likely between 125 and 250 adults). The pedigree-based approach to estimating breeding populations has several strengths including using juvenile genotypes which may be easier to obtain than adult and simulation analysis to objectively evaluate magnitude and direction of bias which can be used to optimize sampling and genotyping strategies.

Kazyak et al. (2020) integrated side-scan sonar with acoustic telemetry to estimate size of the 2014 spawning run for the Hudson River (N=466, 95% CRI = 310-745). If reported spawning intervals were taken into account, the estimate appears to similar to the historical total adult population estimate by Kahnle et al. (2007).

Coleman et al. (2024) developed a similar integrated side-scan sonar and acoustic approach to estimate spawning runs in the Marshyhope-Nanticoke River system (Chesapeake DPS), relying on an extensive telemetry array. Estimates were 32 (95% CRI=23-47) and 70 (95% CRI=49-105), respectively in 2020 and 2021. Both the Marshyhope Creek and upper Nanticoke River were extensively occupied by these spawning runs.

Kahn et al. (2019) used a suite of mark-recapture models to estimate the abundance of adult Atlantic sturgeon in the York River population. This study presents a series of annual abundance estimates from 2013-2018. The most recent population estimate (2018) using the Schumacher-Eschmeyer model indicated an abundance of 145 adults (95% CI: 89-381).

Vine et al. (2019) used *N*-mixture models to estimate the abundance of Atlantic sturgeon in the Savannah River using side-scan sonar and estimated the maximum daily spawner abundance (95% CI:35-55) within a portion of the river. However, this estimate is not a full census of spawning run size or overall adult abundance for this population.

> *Encourage data sharing of acoustic tagged fish, particularly in underrepresented DPSs, and support programs that provide a data sharing platform such as The Atlantic Cooperative Telemetry Network. Data sharing would be accelerated if it was required or encouraged by funding agencies.*

The Bureau of Ocean Energy Management funded a large collaborative synthesis of existing acoustic telemetry data (led by Matthew Breece, David Kazyak, and Dewayne Fox, in partnership with many researchers) for Atlantic sturgeon which will wrap up in 2024. This effort helped to foster collaborative relationships among researchers, and also provided each participating researcher with a list of their tag detections from across a vast area.

> *Maintain and support current networks of acoustic receivers and acoustic tagging programs to improve the estimates of total mortality. Expand these programs in underrepresented DPSs.*

Although the number of tools which can leverage acoustic telemetry to provide management relevant insights into Atlantic sturgeon continue to grow (e.g., ASMFC 2017, Kazyak et al. 2020), the distribution of telemetry receivers continues to be ad hoc, and some important arrays have not been maintained. Many arrays are funded by specific grants and research questions, and consequently there are often not resources to main longer-term continuity. Maintenance and continued support of these arrays (and ongoing deployment of acoustic transmitters) is critical to enable continued application of mortality and abundance models used in the ASMFC Atlantic sturgeon assessment.

Moderate Priority Recommendations

> *Evaluate the effects of predation on Atlantic sturgeon by invasive species (e.g., blue and flathead catfish).*

Using a DNA-based approach, Bunch et al. (2021) examined the factors that influence first-year survival. Using gut contents to assess consumption of Atlantic sturgeon early life stages, they found eggs or days-old larvae in 4% of the samples from 23 fish species collected during September and October in the Pamunkey River, Virginia. The highest percent were found in common carp (*Cyprinus carpio*) and striped bass (*Morone saxatilis*). Six percent of blue catfish (*Ictalurus furcatus*) samples had target DNA.

> *Evaluate methods of imputation to extend time series with missing values. ARIMA models were applied only to the contiguous years of surveys due to the sensitivity of model results to missing years observed during exploratory analyses.*

The SAS considered the research recommendation from ASMFC 2017 to evaluate methods of imputation to extend time series with missing values. Imputation methods were explored but those methods were deprioritized once the ARIMA code was modified to allow for missing values (see TOR 3). The SAS might consider further exploration of imputation methods for comparison to results of ARIMAs with missing values.

b. New Research Recommendations

- Improve understanding of offshore habitat use, particularly in areas where offshore energy development and mineral removal are planned or occurring.

- Leverage species distribution models and acoustic telemetry data to identify key areas of occupancy along the coast throughout the year (for the species overall, and specific to each spawning population and DPS).

- Monitor for the potential presence of non-native sturgeon taxa throughout the native range of Atlantic sturgeon and evaluate potential risk of captive sturgeons to wild populations.

- Characterize the degree to which vessel strikes in specific rivers and estuaries may be impacting populations which spawn in other locations.

- Develop cost-effective strategies for long-term monitoring of Atlantic sturgeon.

- Evaluate strategies to reduce or mitigate mortalities from ship strikes. Improve understanding of how dredging may concentrate Atlantic sturgeon within high-traffic shipping channels and elevate risk of adverse interactions.

- If the NC p135 surveys are no longer being conducted, there would be no surveys in the Carolina DPS to characterize trends or status after 2019. Finding alternative surveys for this region will be important.

- Further explore uncertainty in ARIMA results (e.g., consider incorporating reverse retrospective results into survey-specific probabilities of exceeding reference points, what role lags in recruitment can play in interpretation of results or selection of reference points, whether autocorrelated models are appropriate for sturgeon YOY surveys).

- Explore the application of alternative ageing approaches such as DNA methylation-based methods (e.g., Mayne et al. 2021, Weber et al. 2024) to Atlantic sturgeon.

- Prioritize the genetic assignment of tagged fish, including the processing of archived samples, to improve the estimates of *Z* at the DPS-level.

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TABLES

Table 1. Annual sturgeon bycatch estimates for otter trawl gear based on application of the best performing model to otter trawl vessel trip records.

Year	Total Bycatch Estimate	Standard Error	Percent Dead	Dead Bycatch Estimate
2006	1,187	103	18%	212
2007	1,099	105	9%	95
2008	1,033	156	16%	167
2009	1,025	116	2%	21
2010	986	96	1%	9
2011	922	97	0%	0
2012	848	85	0%	0
2013	892	96	0%	0
2014	789	79	0%	0
2015	735	72	0%	0
2016	759	71	0%	0
2017	723	72	0%	0
2018	684	69	8%	54
2019	835	94	0%	0
2020				
2021	633	64	6%	40
2022	478	52	9%	43

Table 2. Annual sturgeon bycatch estimates for gillnet gear based on application of the best performing model to gillnet vessel trip records.

Year	Total Bycatch Estimate	Standard Error	Percent Dead	Dead Bycatch Estimate
2006	1,512	332	12%	187
2007	1,506	386	20%	301
2008	813	495	28%	227
2009	1,151	561	13%	148
2010	281	84	51%	143
2011	442	228	44%	195
2012	281	81	44%	123
2013	1,583	620	38%	594
2014	668	199	33%	223
2015	711	112	28%	197
2016	1,209	151	32%	382
2017	1,276	215	22%	276
2018	1,049	149	27%	278
2019	1,029	132	20%	206
2020				
2021	1,077	375	46%	497
2022	561	108	33%	183

Table 3. Estimated numbers of Atlantic sturgeon bycatch from the North Carolina's Atlantic sturgeon bycatch data.

Year	Total Bycatch	Percent Dead	Number Dead
2013	508	7%	34
2014	1,104	3%	37
2015	1,413	4%	57
2016	998	6%	58
2017	765	6%	44
2018	365	8%	30
2019	119	25%	30
2020	388	0%	0
2021	406	23%	94
2022	498	17%	85

Table 4. Number of Atlantic sturgeon reported as incidental bycatch by commercial American shad fisherman in South Carolina, 2000-2022. The Carolina DPS includes the Waccamaw, Pee Dee, Winyah, and Santee Rivers. The South Atlantic DPS includes the Edisto, Combahee, and Savannah Rivers.

Year	Carolina DPS			South Atlantic DPS		
	# Atlantic Sturgeon	Effort (Net Yard Hours)	CPUE (#Atlantic Sturgeon/Net Yard Hours)	# Atlantic Sturgeon	Effort (Net Yard Hours)	CPUE (#Atlantic Sturgeon/Net Yard Hours)
2000	40	2,284,770	0.0000175	5	559,575	0.0000089
2001	128	3,339,789	0.0000383	20	493,149	0.0000406
2002	74	4,222,339	0.0000175	5	301,618	0.0000166
2003	16	3,881,793	0.0000041	3	425,421	0.0000071
2004	11	4,094,782	0.0000027	0	527,201	0.0000000
2005	0	3,963,111	0.0000000	1	367,849	0.0000027
2006	226	6,607,328	0.0000342	2	389,517	0.0000051
2007	162	2,562,688	0.0000632	6	384,197	0.0000156
2008	76	4,070,683	0.0000187	0	270,265	0.0000000
2009	186	5,110,128	0.0000364	3	276,875	0.0000108
2010	12	3,357,022	0.0000036	3	221,982	0.0000135
2011	173	5,818,003	0.0000297	8	240,967	0.0000332
2012	194	5,617,356	0.0000345	11	260,664	0.0000422
2013	157	3,457,182	0.0000454	1	214,095	0.0000047
2014	15	2,876,558	0.0000052	0	163,182	0.0000000
2015	10	3,207,376	0.0000031	0	148,910	0.0000000
2016	15	1,782,507	0.0000084	0	126,589	0.0000000
2017	66	2,486,297	0.0000265	0	122,626	0.0000000
2018	138	2,436,613	0.0000566	0	108,405	0.0000000
2019	19	1,529,485	0.0000124	0	189,697	0.0000000
2020	2	1,777,785	0.0000011	0	80,115	0.0000000
2021	4	1,235,016	0.0000032	0	71,515	0.0000000
2022	4	1,149,057	0.0000035	1	63,061	0.0000016

Table 5. Fishery-independent surveys used to develop indices of relative abundance. The months and model used for the index are listed in addition to the start and end year of the survey. A length cutoff was used for determining if surveys catch predominantly young-of-the-year (YOY; <500 mm), juveniles (500-1300 mm), or adults (>1300 mm).

Survey	Months/Season	Model	Stage	Start Year	End Year
Maine-New Hampshire Trawl (ME-NH Trawl)	May, Sept, Nov	Binomial	Juveniles and Adults	2000	2022
Connecticut Long Island Sound Trawl Survey (CT LISTS)	Fall	Binomial	Juveniles	1992	2021
CT LISTS	Spring	Binomial	Juveniles	1992	2021
CT LISTS	All	Binomial	Juveniles	1992	2021
Northeast Area Monitoring and Assessment Program Trawl Survey (NEAMAP)	Fall	Binomial	Juveniles	2007	2021
New York State Department of Environmental Conservation Juvenile Atlantic Sturgeon Abundance Monitoring Program (NY JASAMP)	Spring	GAM	Juveniles	2004	2022
New Jersey Ocean Trawl Survey (NJ OT)	Jan, Apr, Jun, Oct	GLM	Juveniles	1990	2022
Virginia Institute of Marine Science Shad and River Herring Monitoring Survey (VIMS)	Spring	Binomial	Juveniles	1998	2019
VIMS James River Only	Spring	Binomial	Juveniles	1998	2019
North Carolina Program 135 (NC p135)	Spring	GLM	YOY and Juveniles	1991	2019
NC p135	Spring	GLM	YOY	1991	2019
NC p135	Spring	GLM	Juveniles	1991	2019
NC p135	Fall	GLM	YOY and Juveniles	1990	2019
NC p135	Fall	GLM	YOY	1990	2019
NC p135	Fall	GLM	Juveniles	1990	2019
South Carolina Edisto River Sturgeon Monitoring Project Survey (SC Edisto)	All Months	GLM	Juveniles	2004	2022
US Fish and Wildlife Cooperative Tagging Cruise (USFWS Coop)	Winter	GLM	Juveniles and Adults	1988	2010

Table 6. Results of the power analysis by survey for linear and exponential trends in Atlantic sturgeon abundance indices over a 20-year period. Power was calculated as the probability of detecting a 50% change. Time series length, life stage, and median coefficient of variation (CV) is reported for each index. Survey name abbreviations can be found in Table 5.

Survey	DPS	Index Timeseries	Life Stage	Median CV	Linear Trend		Exponential Trend	
					+50%	-50%	+50%	-50%
ME-NH Trawl	Gulf of Maine	2000-2022	Juvenile & Adult	1.154	0.13	0.16	0.15	0.22
CT LISTS	New York Bight	1992-1998, 2000-2009, 2011-2019, 2021	Juvenile	0.694	0.21	0.29	0.23	0.35
CT LISTS	New York Bight	1992-1998, 2000-2009, 2011-2019, 2021	Juvenile	0.722	0.20	0.27	0.22	0.33
CT LISTS	New York Bight	1992-1998, 2000-2009, 2011-2019, 2021	Juvenile	0.455	0.36	0.50	0.38	0.55
NY JASAMP	New York Bight	2004-2022	Juvenile	0.190	0.92	0.99	0.93	0.99
NJ OT	New York Bight	1990-2019, 2022	Juvenile & Adult	0.401	0.43	0.59	0.44	0.63
VIMS	Chesapeake Bay	1998-2019	Juvenile	0.518	0.30	0.48	0.32	0.48
VIMS James only	Chesapeake Bay	1998-2019	Juvenile	0.403	0.42	0.59	0.44	0.63
NEAMAP	New York Bight-Carolina	2007-2019, 2021	Juvenile	0.444	0.37	0.52	0.39	0.57
USFWS Coop	Carolina	1988-2010	Juvenile & Adult	0.506	0.31	0.44	0.33	0.49
NC p135	Carolina	1990-2019	YOY & Juveniles	0.182	0.94	0.99	0.94	0.99
NC p135	Carolina	1990-2019	YOY	0.258	0.73	0.90	0.74	0.91
NC p135	Carolina	1990-2019	Juveniles	0.289	0.65	0.83	0.66	0.85
NC p135	Carolina	1991-2019	YOY & Juveniles	0.317	0.58	0.77	0.59	0.79
NC p135	Carolina	1991-2019	YOY	0.423	0.40	0.55	0.41	0.60
NC p135	Carolina	1991-2019	Juveniles	0.407	0.42	0.58	0.44	0.62
SC Edisto	South Atlantic	2004-2022	Juvenile	0.138	1.00	1.00	1.00	1.00

Table 7. Median life history information used in the $Z_{50\%EPR}$ reference point. Table continues on the next page.

Age	Length (cm)	Proportion Mature	Bycatch Selectivity	Ship-Strike Selectivity	Weight (kg)	*M*	Fecundity
1	32.1	0.00	0.08	0.00	0.2	0.31	90995.9
2	50.8	0.00	0.23	0.00	0.8	0.21	90995.9
3	67.1	0.00	0.50	0.00	1.9	0.17	90995.9
4	81.9	0.00	0.79	1.00	3.5	0.14	90995.9
5	95.1	0.01	0.93	1.00	5.6	0.12	90995.9
6	106.8	0.01	0.98	1.00	8.0	0.11	90995.9
7	117.5	0.02	0.99	1.00	10.6	0.10	91335.2
8	127.3	0.03	1.00	1.00	13.4	0.09	92520.9
9	136.2	0.05	1.00	1.00	16.6	0.09	96470.8
10	144.4	0.08	1.00	1.00	19.7	0.08	104291.7
11	152.0	0.12	1.00	1.00	23.1	0.08	115423.8
12	158.9	0.19	1.00	1.00	26.4	0.08	135527.6
13	165.2	0.27	1.00	1.00	29.8	0.07	183316.7
14	171.1	0.38	1.00	1.00	33.3	0.07	339359.8
15	176.7	0.50	1.00	1.00	36.5	0.07	490655.7
16	181.9	0.63	1.00	1.00	39.9	0.07	629404.6
17	186.7	0.74	1.00	1.00	43.2	0.07	770975.8
18	191.3	0.82	1.00	1.00	46.4	0.06	903715.8
19	195.4	0.89	1.00	1.00	49.6	0.06	1024231.2
20	199.4	0.93	1.00	1.00	52.7	0.06	1139715.1
21	202.9	0.96	0.99	1.00	55.7	0.06	1241324.0
22	206.4	0.97	0.97	1.00	58.8	0.06	1344861.1
23	209.6	0.98	0.91	1.00	61.6	0.06	1439418.1
24	212.8	0.99	0.77	1.00	64.4	0.06	1530709.6
25	215.6	0.99	0.50	1.00	67.2	0.06	1612340.4
26	218.3	1.00	0.21	1.00	70.0	0.06	1693249.2
27	220.9	1.00	0.06	1.00	72.4	0.06	1769304.0
28	223.3	1.00	0.02	1.00	74.9	0.06	1837289.8
29	225.5	1.00	0.01	1.00	77.1	0.05	1903293.5
30	227.7	1.00	0.00	1.00	79.2	0.05	1964925.8
31	229.4	1.00	0.00	1.00	81.4	0.05	2015602.3
32	231.4	1.00	0.00	1.00	83.5	0.05	2075587.8
33	233.2	1.00	0.00	1.00	85.2	0.05	2126190.9
34	234.8	1.00	0.00	1.00	87.2	0.05	2174873.7
35	236.5	1.00	0.00	1.00	88.7	0.05	2223011.3
36	238.0	1.00	0.00	1.00	90.4	0.05	2266675.2
37	239.4	1.00	0.00	1.00	91.9	0.05	2309000.0
38	240.7	1.00	0.00	1.00	93.4	0.05	2346197.8

Age	Length (cm)	Proportion Mature	Bycatch Selectivity	Ship-Strike Selectivity	Weight (kg)	*M*	Fecundity
39	241.9	1.00	0.00	1.00	94.9	0.05	2380814.5
40	243.0	1.00	0.00	1.00	96.3	0.05	2411883.3
41	244.3	1.00	0.00	1.00	97.6	0.05	2449495.1
42	245.5	1.00	0.00	1.00	99.0	0.05	2484347.2
43	246.4	1.00	0.00	1.00	100.1	0.05	2512884.9
44	247.3	1.00	0.00	1.00	101.1	0.05	2539675.2
45	248.3	1.00	0.00	1.00	102.5	0.05	2567953.4
46	249.0	1.00	0.00	1.00	103.3	0.05	2588918.2
47	249.7	1.00	0.00	1.00	104.5	0.05	2609761.0
48	250.6	1.00	0.00	1.00	105.6	0.05	2635485.3
49	251.4	1.00	0.00	1.00	106.5	0.05	2658257.6
50	252.2	1.00	0.00	1.00	107.5	0.05	2682246.7
51	252.8	1.00	0.00	1.00	108.3	0.05	2699340.3
52	253.4	1.00	0.00	1.00	109.1	0.05	2716885.6
53	254.0	1.00	0.00	1.00	110.1	0.05	2733578.0
54	254.7	1.00	0.00	1.00	111.0	0.05	2755329.4
55	254.3	1.00	0.00	1.00	110.9	0.05	2742443.5
56	254.9	1.00	0.00	1.00	111.5	0.05	2761337.8
57	255.4	1.00	0.00	1.00	112.3	0.05	2775846.9
58	255.9	1.00	0.00	1.00	112.8	0.05	2788317.5
59	256.5	1.00	0.00	1.00	113.7	0.05	2805446.1
60	256.9	1.00	0.00	1.00	114.3	0.05	2818772.7

Table 8. Number of acoustically tagged Atlantic sturgeon by DPS and size group.

	Total	< 1300 mm	> 1300 mm
Gulf of Maine	224	55	169
NY Bight	534	144	390
Chesapeake Bay	464	74	390
Carolina	489	208	281
South Atlantic	364	133	231

Table 9. Estimates of annual survival, total mortality, and the probability of Z being above the Z threshold for the coastwide population and for each individual DPS.

Population	Median Annual Survival Rate, S (2.5th-97.5th percentiles)	Median Annual Total Mortality, Z (2.5th-97.5th percentiles)	$Z_{50\%\ \mathrm{EPR}}$ reference point	Probability that Z is greater than the $Z_{50\%\mathrm{EPR}}$ reference point
Coast	0.99 (0.89-1.00)	0.01 (0.001-0.11)	0.14	1.8%
Gulf of Maine	0.86 (0.34-0.98)	0.15 (0.018-1.08)		55.5%
NY Bight	0.94 (0.63-1.00)	0.06 (0.005-0.46))		20.2%
Chesapeake Bay	0.95 (0.67-1.00)	0.05 (0.003-0.41)		14.1%
Carolina	0.95 (0.63-1.00)	0.05 (0.003-0.46)		18.2%
South Atlantic	0.93 (0.60-1.00)	0.07 (0.004-0.51)		26.5%

Table 10. Probability that Z is greater than the $Z_{50\%\mathrm{EPR}}$ reference point from the 2024 update and the 2017 benchmark.

Population	2024 Update	2017 Benchmark
Coast	1.8%	6.5%
Gulf of Maine	55.5%	73.5%
NY Bight	20.2%	31.2%
Chesapeake Bay	14.1%	30.0%
Carolina	18.2%	75.4%
South Atlantic	26.5%	40.2%

Table 11. Summary statistics for ARIMA model results. n = number of years in time series, W = Shapiro-Wilk statistic for normality, adj p = Holm-adjusted probability of rejecting the null hypothesis regarding normality of model residuals, r1, r2, and r3 = the first three sample autocorrelations for the first differenced logged series, (θ) = moving average parameter, SE = standard error of theta, σ^2_c = variance of index. JYR = James, York, Rappahannock.

DPS	Survey	Years avail	n	W	adj p	r_1	r_2	r_3	θ	SE	σ^2_c
GOM	ME-NH Trawl	2000-2022	23	0.96	0.37	-0.54	-0.1	0.41	1.00	0.13	0.22
NYB	CT LISTS Fall	1992-2021	30	0.98	1.00	-0.65	0.46	-0.29	0.55	0.22	0.31
NYB	CT LISTS Spring	1992-2021	30	0.96	1.00	-0.23	-0.44	0.1	0.92	0.12	0.39
NYB	CT LISTS All Months	1992-2021	30	0.98	1.00	-0.43	-0.1	-0.09	1.00	0.12	0.19
NYB	NY JASAMP	2004-2022	19	0.97	1.00	-0.3	-0.08	-0.06	0.47	0.29	0.49
NYB	NJ Ocean Trawl	1990-2022	33	0.98	1.00	-0.35	0.08	-0.12	0.40	0.17	0.36
CB	VIMS-JYR	1998-2019	22	0.91	0.12	0.19	-0.32	-0.33	0.39	0.29	0.71
CB	VIMS-J Spring	1998-2019	22	0.93	0.12	-0.17	-0.23	-0.03	1.00	0.14	1.3
C	NC p135 Spring YOY + Juv	1991-2019	29	0.98	1.00	-0.18	-0.28	-0.12	0.63	0.25	0.37
C	NC p135 Spring YOY	1991-2019	29	0.97	1.00	-0.36	-0.17	0.12	1.00	0.31	0.25
C	NC p135 Spring Juv	1991-2019	29	0.93	0.31	-0.18	-0.33	-0.29	0.66	0.13	0.13
C	NC p135 Fall YOY+Juv	1990-2019	30	0.97	1.00	-0.26	-0.28	0.12	0.74	0.15	0.56
C	NC p135 Fall YOY	1990-2019	30	0.96	1.00	-0.37	-0.28	0.22	0.92	0.13	0.93
C	NC p135 Fall Juv	1990-2019	30	0.96	1.00	-0.26	-0.31	0.2	0.55	0.17	0.1
C	USFWS	1988-2010	23	0.94	1.00	-0.54	0.31	-0.37	1.00	1.6	0.5
SA	SC Edisto	2004-2022	19	0.88	0.02	-0.52	0.1	0.27	0.77	0.33	0.33
NYB-CB-C	NEAMAP Fall	2007-2021	15	0.96	0.71	-0.43	-0.16	0.26	0.59	0.29	0.21
Coast	Conn	1990-2022	33	0.95	0.11	-0.44	0.04	0.12	0.53	0.15	0.06

Table 12. ARIMA and trend analysis results for Atlantic sturgeon indices of abundance. Shown are the probabilities that the terminal year (ty) of an index is greater than the 25th percentile of a time series and the probabilities that the terminal year of an index is greater than the index value in 1998 (or surrogate reference year if survey started after 1998); green shading indicates ≥ 50% probability. The Mann Kendall tau (τ) statistic, Holm-adjusted probability of the Mann-Kendall time series trend being significant, and whether the trend is increasing (+), decreasing (-), or not significant (n.s.). Light grey font indicates a strong (0.60) within survey correlation. JYR = James, York, Rappahannock. Underlined probabilities are those values represented in the DPS tallies and averages presented Table 13.

										Trend analysis results **ARIMA fits**			Trend analysis results **Raw index**		
DPS	Survey	Months	Ages	P(ty > 25th pctl)	P(ty > yrAsRefPt)	n	First yr	Terminal yr	yrAsRefPt	M-K τ	M-K p_{adj}	Trend	M-K τ	M-K p_{adj}	Trend
GOM	ME-NH Trawl	5, 10, 11	Juveniles and Adults	0.59	0.45	23	2000	2022	2000	-0.45	0.00	-	-0.08	0.63	n.s.
NYB	CT LISTS Fall	Fall	Juveniles	0.96	0.97	30	1992	2021	1998	0.09	0.53	n.s.	0.07	0.65	n.s.
NYB	CT LISTS Spring	Spring	Juveniles	0.51	0.29	30	1992	2021	1998	-0.74	0.00	-	-0.22	0.44	n.s.
NYB	CT LISTS All Months	All	Juveniles	0.43	0.12	30	1992	2021	1998	-0.62	0.00	-	-0.14	0.57	n.s.
NYB	NY JASAMP	Spring	Juveniles	0.65	0.57	19	2004	2022	2004	0.36	0.08	n.s.	0.24	0.49	n.s.
NYB	NJ Ocean Trawl	1, 4, 6, 10	Juveniles	1.00	1.00	33	1990	2022	1998	0.52	0.00	+	0.38	0.02	+
CB	VIMS-JYR	Spring	Juveniles	0.97	0.38	22	1998	2019	1998	-0.13	0.40	n.s.	-0.02	1.00	n.s.
CB	VIMS-J Spring	Spring	Juveniles	0.45	0.15	22	1998	2019	1998	-0.45	0.00	-	0.07	1.00	n.s.
C	NC p135 Spring YOY + Juv	Spring	YOY+Juveniles	1.00	0.99	29	1991	2019	1998	0.79	0.00	+	0.44	0.00	+
C	NC p135 Spring YOY	Spring	YOY	0.82	0.82	29	1991	2019	1998	0.52	0.00	+	0.18	0.51	n.s.
C	NC p135 Spring Juv	Spring	Juveniles	1.00	1.00	29	1991	2019	1998	0.93	0.00	+	0.60	0.00	+
C	NC p135 Fall YOY+Juv	Fall	YOY+Juveniles	0.99	0.99	30	1990	2019	1998	0.76	0.00	+	0.37	0.02	+
C	NC p135 Fall YOY	Fall	YOY	0.66	0.63	30	1990	2019	1998	0.67	0.00	+	0.17	0.51	n.s.
C	NC p135 Fall Juv	Fall	Juveniles	1.00	1.00	30	1990	2019	1998	0.90	0.00	+	0.55	0.00	+
C	USFWS	Winter	Juveniles and Adults	0.53	0.42	23	1988	2010	1998	0.09	0.56	n.s.	0.17	0.51	n.s.
SA	SC Edisto	5-9	Juveniles	0.76	0.31	19	2004	2022	2004	0.38	0.03	+	0.19	0.26	n.s.
NYB-CB-C	NEAMAP Fall	Fall	Juveniles	0.93	0.84	15	2007	2021	2007	0.32	0.13	n.s.	0.27	0.19	n.s.
Coast	Conn	All Months	YOY, Juv, Adult	1.00	1.00	33	1990	2022	1998	0.67	0.00	+	0.55	0.00	+

Table 13. Summary of tally and percentage of surveys, by DPS, where terminal year index (ty) is greater than the reference value, either the 25th percentile of a given time series or the index value in 1998 (or start year of survey, whichever is later) for a given index (a). See columns 1 and 2 of Table 12 for list of surveys included in each DPS. Results from ASMFC (2017) are provided for comparative purposes. Plot of (a) mean, by DPS and assessment year. * = 1998 or first year of survey, whichever is more recent (b).

(a)

		ASMFC (2024)			ASMFC (2017)	
	DPS	P (ty > 25th pctl)	P (ty > 1998*)	DPS	P (ty > 25th pctl)	P (ty > 1998*)
Tally	GOM	1 of 1	0 of 1	GOM	1 of 1	1 of 1
	NYB	4 of 5	3 of 5	NYB	4 of 4	3 of 4
	CB	1 of 2	0 of 2	CB	1 of 1	0 of 1
	C	5 of 5	4 of 5	C	5 of 5	3 of 5
	SA	1 of 1	0 of 1	SA	1 of 1	0 of 1
	NYB-CB-C	1 of 1	1 of 1	NYB-CB-C	0 of 1	0 of 1
	Coast	1 of 1	1 of 1	Coast	1 of 1	1 of 1

	DPS	P (ty > 25th pctl)	P (ty > 1998*)	DPS	P (ty > 25th pctl)	P (ty > 1998*)
Pct	GOM	100%	0%	GOM	100%	100%
	NYB	80%	60%	NYB	100%	75%
	CB	50%	0%	CB	100%	0%
	C	100%	80%	C	100%	60%
	SA	100%	0%	SA	100%	0%
	NYB-CB-C	100%	100%	NYB-CB-C	0%	0%
	Coast	100%	100%	Coast	100%	100%

	DPS	P (ty > 25th pctl)	P (ty > 1998*)	DPS	P (ty > 25th pctl)	P (ty > 1998*)
Mean	GOM	0.59	0.45	GOM	0.61	0.51
	NYB	0.71	0.59	NYB	0.80	0.75
	CB	0.71	0.27	CB	0.96	0.36
	C	0.80	0.77	C	0.72	0.67
	SA	0.76	0.31	SA	0.51	0.28
	NYB-CB-C	0.93	0.84	NYB-CB-C	0.49	0.33
	Coast	1.00	1.00	Coast	0.95	0.95

(b)

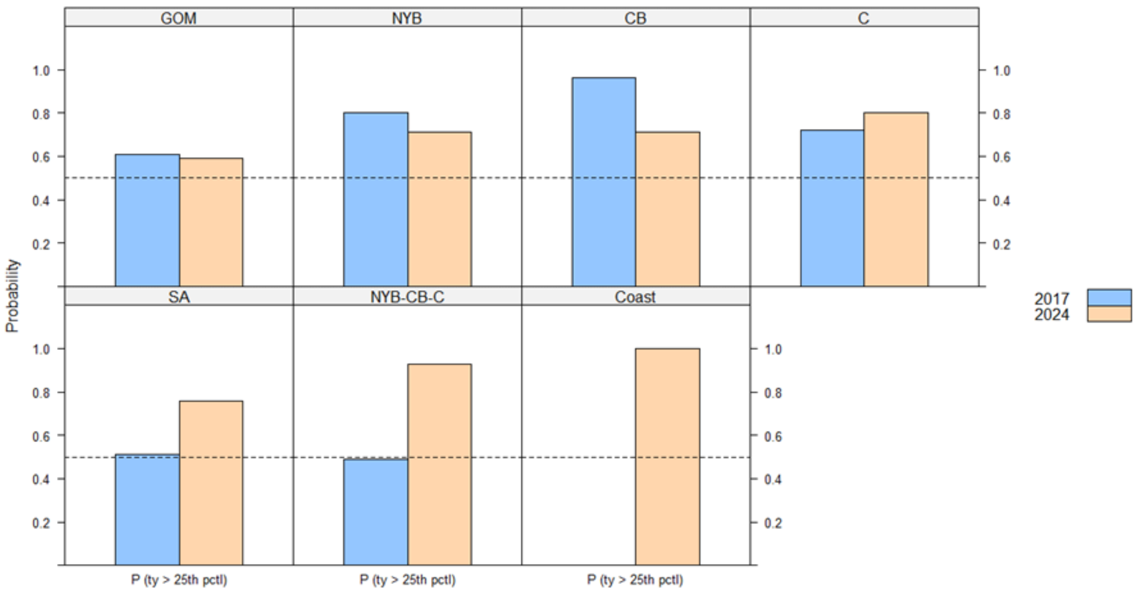


Table 14. Stock status determination for the coastwide stock and individual DPSs based on morality estimates and biomass/abundance status relative to historic levels and the terminal year of indices relative to the start of the moratorium as determined by the ARIMA analysis.

Population	Mortality Status	Biomass/Abundance Status		
	P(Z)>$Z_{50\%EPR}$ Reference Point	Relative to Historical Levels	NOAA Designation	Average probability of terminal year of indices > reference year*
Coastwide	1.80%	Depleted		100%
Gulf of Maine	55.50%	Depleted	Threatened	45%
New York Bight	20.20%	Depleted	Endangered	59%
Chesapeake Bay	14.10%	Depleted	Endangered	27%
Carolina	18.20%	Depleted	Endangered	77%
South Atlantic	26.50%	Depleted	Endangered	31%

***Reference year is 1998, or the first year of the survey for indices that started after 1998**

FIGURES

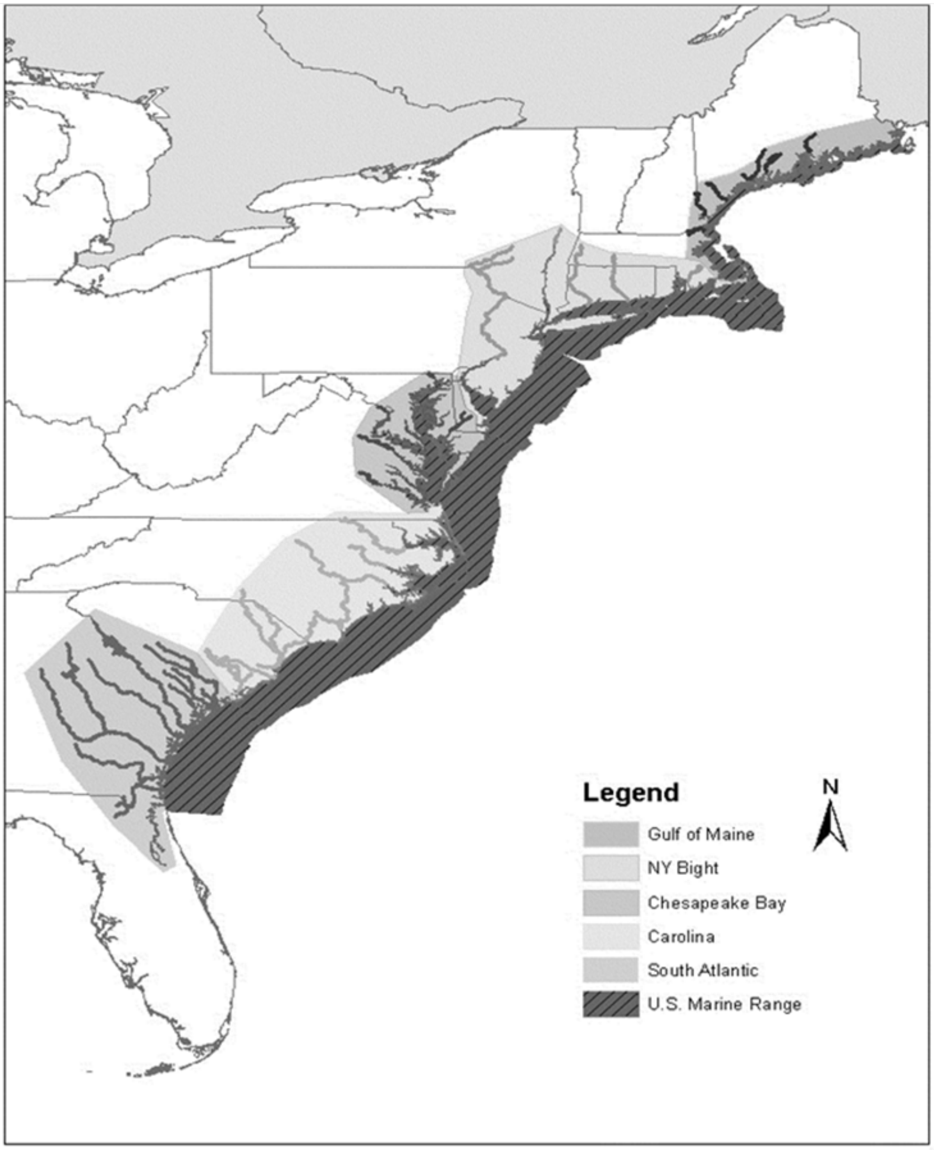


Figure 1. The five distinct population segments (DPS) for the Atlantic sturgeon. Source: NOAA Fisheries Final Rule, 77 FR 5880.

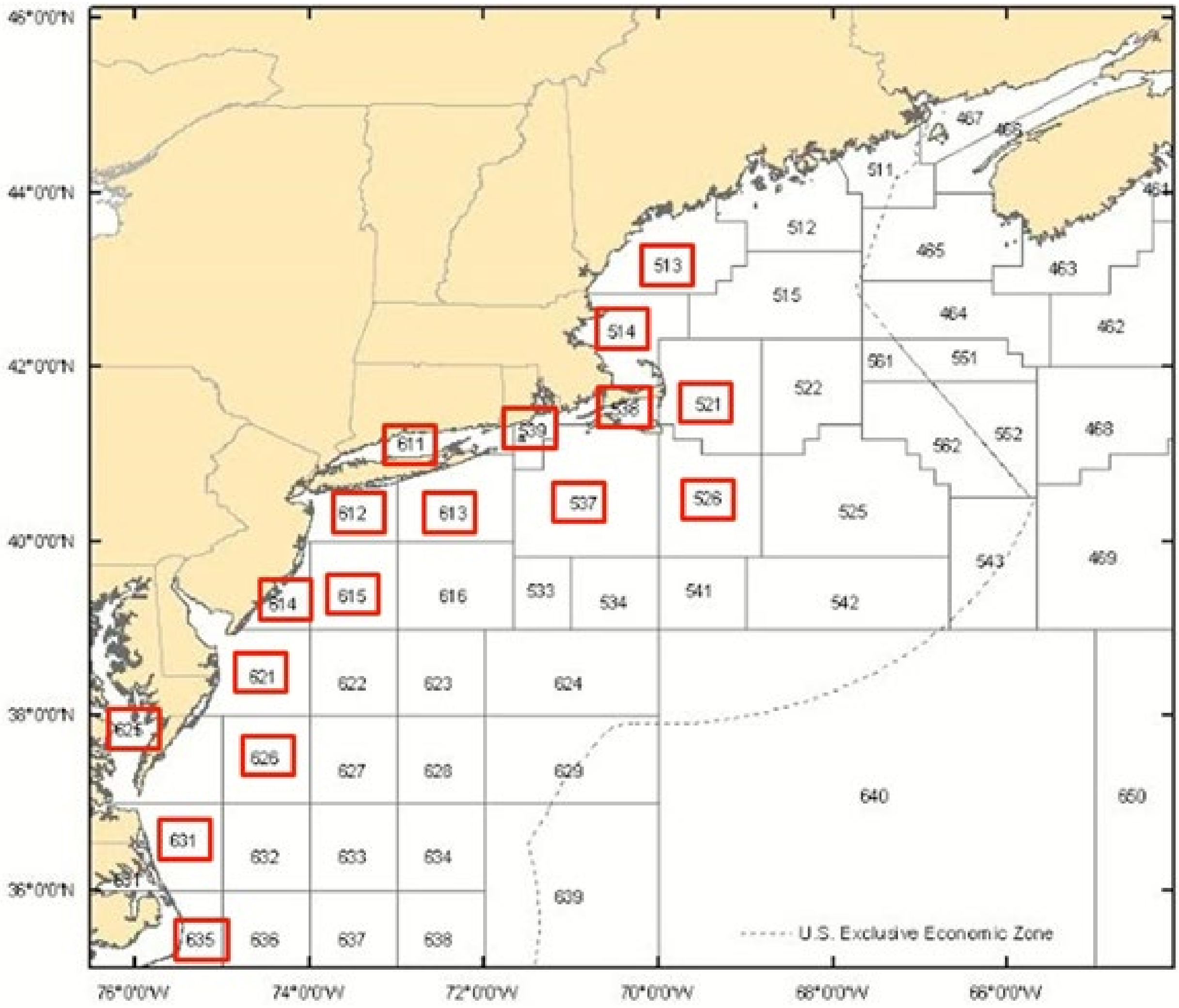


Figure 2. **Observed trips used in the estimation of bycatch included coastal statistical areas 513, 514, 521, 526, 537, 538, 539, 611, 612, 613, 614, 615, 621, 625, 626, 631, and 635.**

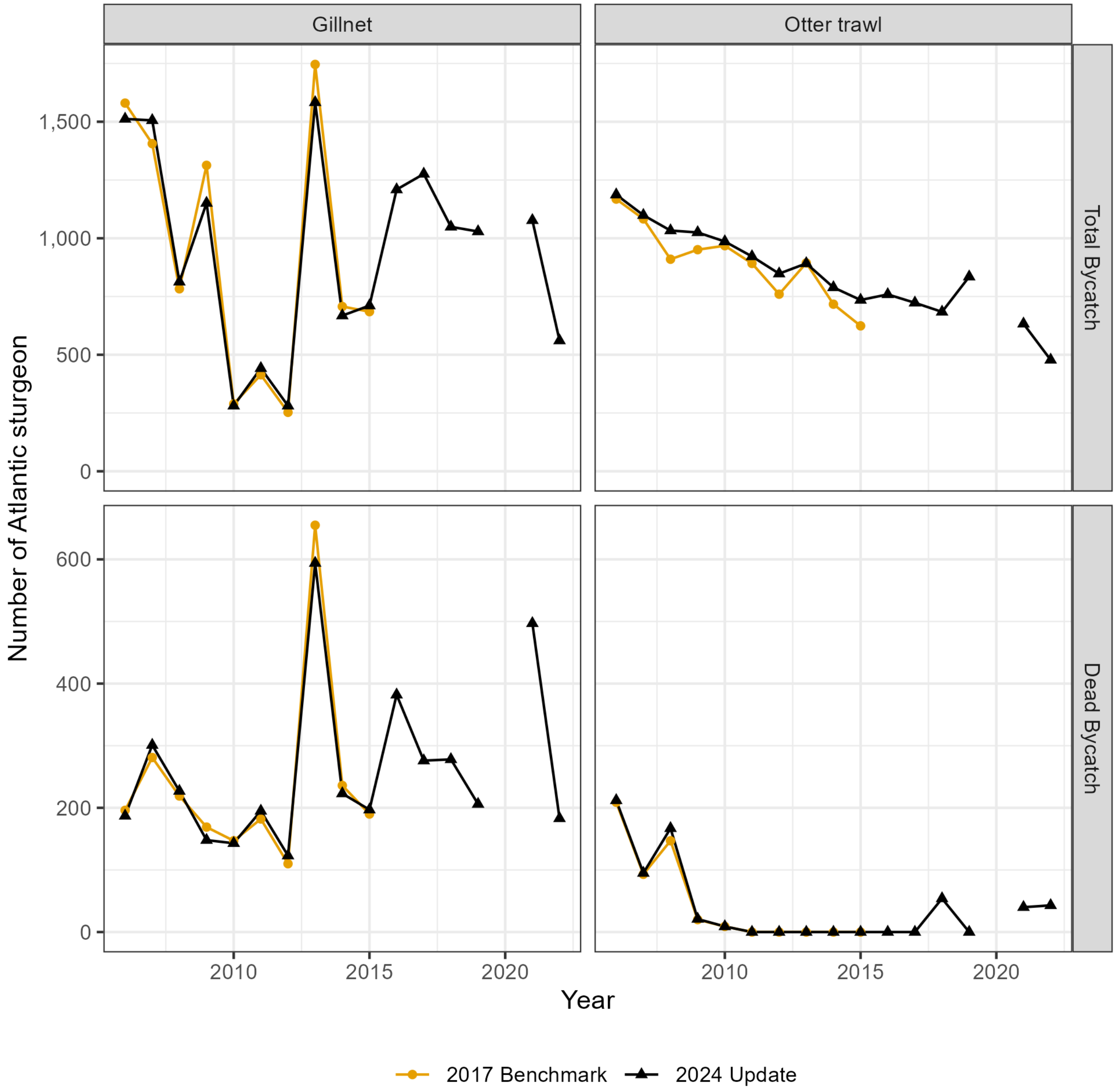


Figure 3. Estimates of total Atlantic sturgeon bycatch and dead bycatch by gear from the 2024 update compared to the 2017 benchmark assessment.

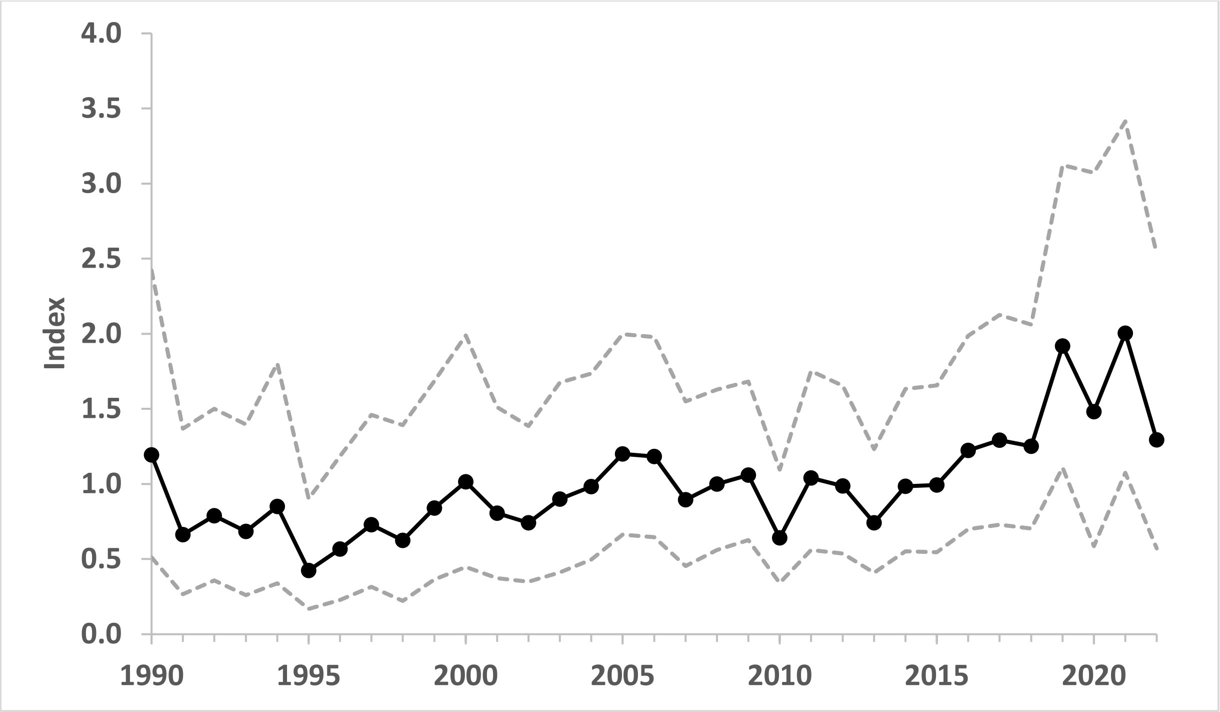


Figure 4. Time series of coastwide juvenile and adult Atlantic sturgeon relative abundance using Conn (2010) with 95% credible intervals.

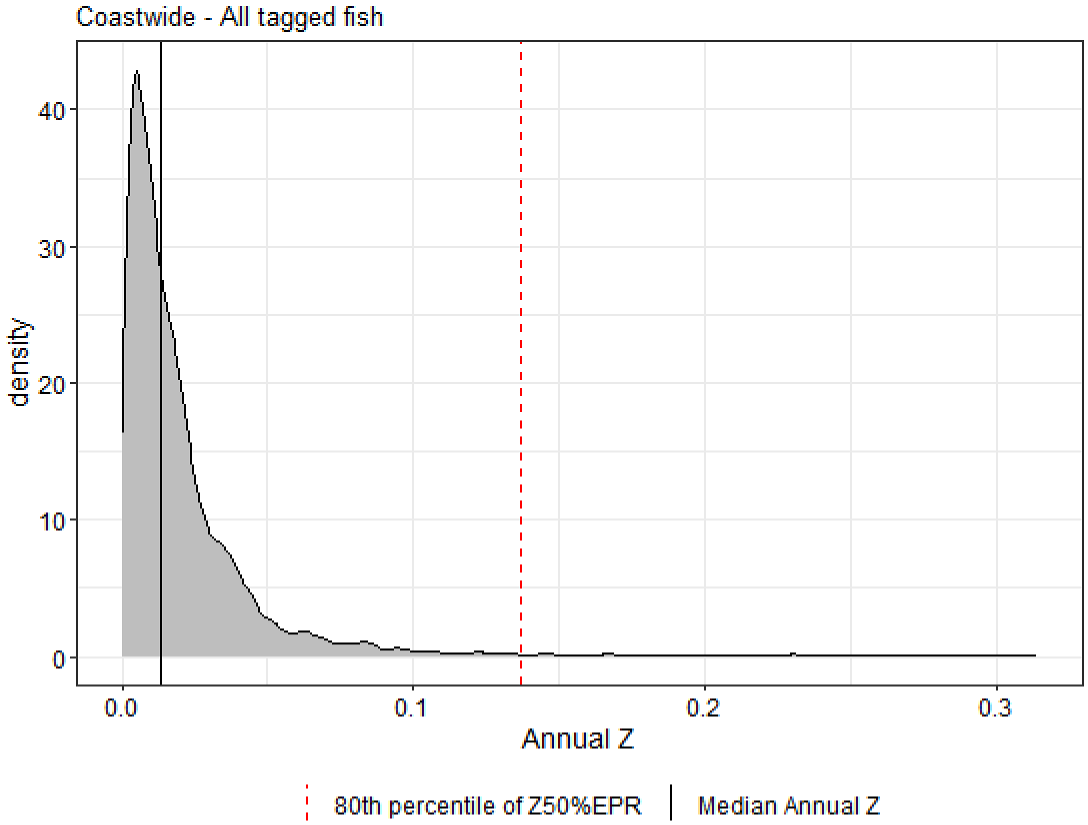


Figure 5. Distribution of annual *Z* estimate from the tagging model for the coastwide population (all tagged fish), plotted with the median annual *Z* and the *Z* reference point. The x-axis has been truncated to exclude the highest 0.5% of *Z* estimates to show detail.

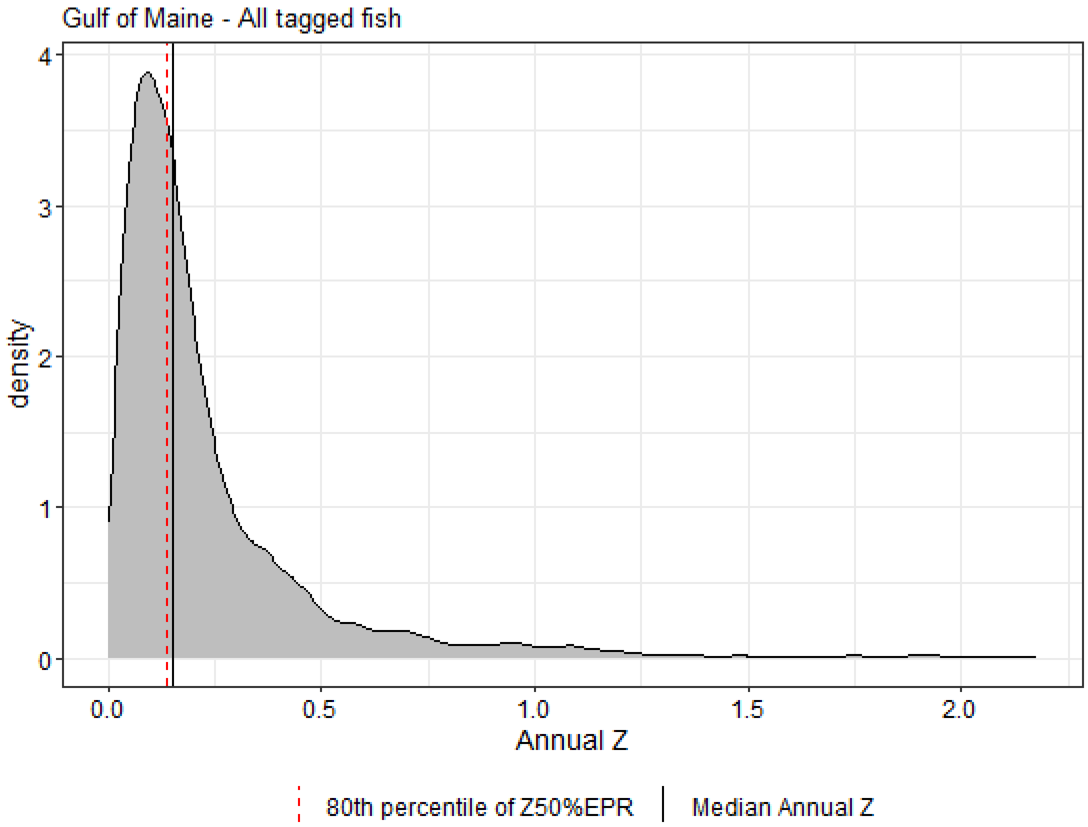


Figure 6. **Distribution of annual *Z* estimate from the tagging model for all tagged fish assigned to the Gulf of Maine DPS, plotted with the median annual *Z* and the *Z* reference point. The x-axis has been truncated to exclude the highest 0.5% of *Z* estimates to show detail.**

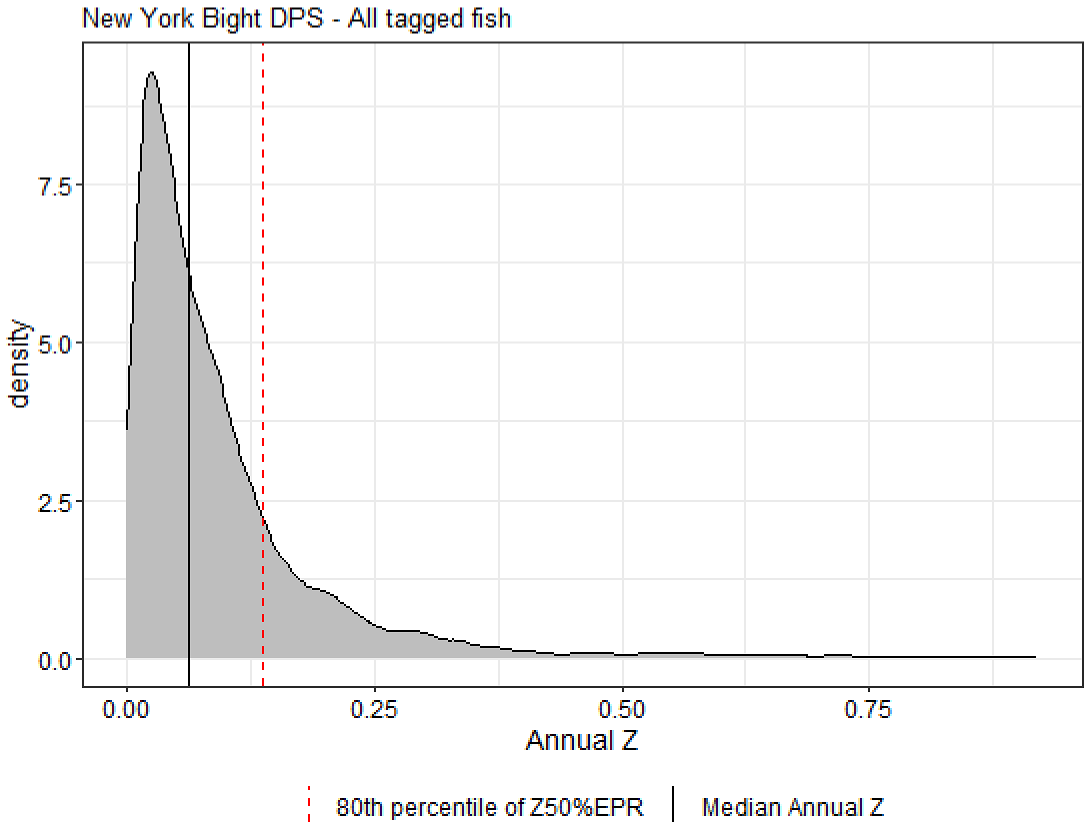


Figure 7. Distribution of annual *Z* estimate from the tagging model for all tagged fish assigned to the New York Bight DPS, plotted with the median annual *Z* and the *Z* reference point. The x-axis has been truncated to exclude the highest 0.5% of *Z* estimates to show detail.

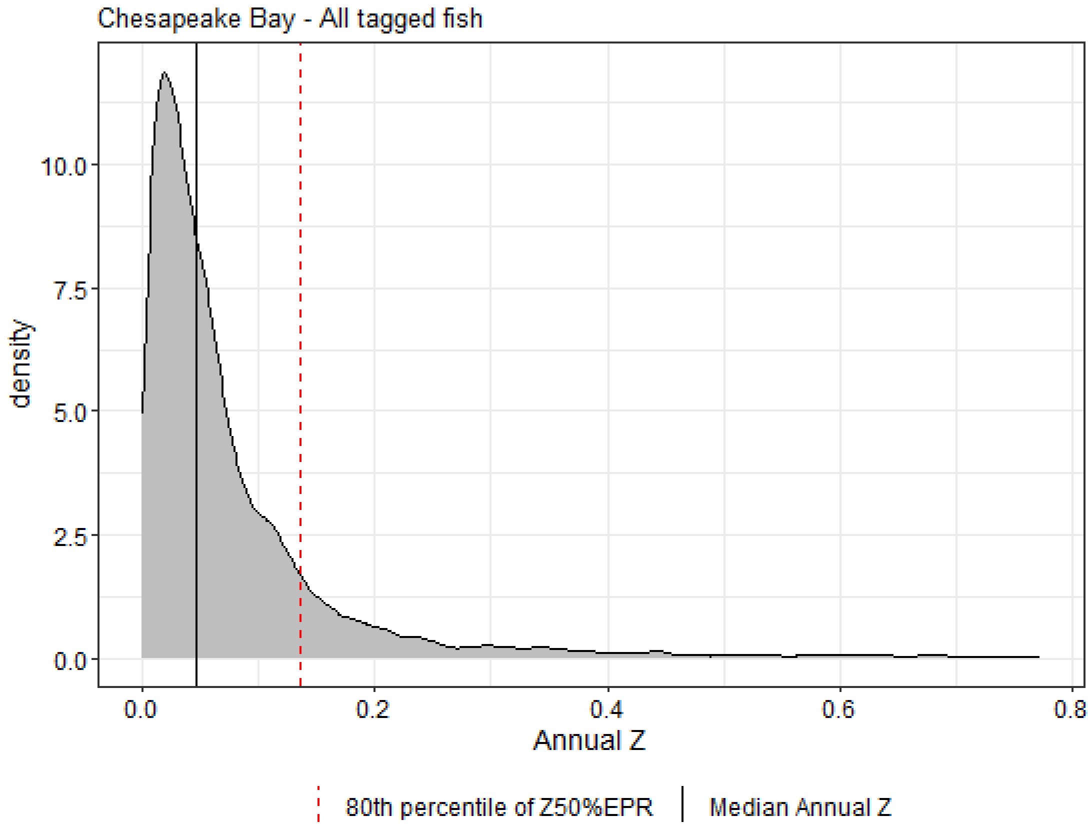


Figure 8. **Distribution of annual *Z* estimate from the tagging model for all tagged fish assigned to the Chesapeake Bay DPS, plotted with the median annual *Z* and the *Z* reference point. The x-axis has been truncated to exclude the highest 0.5% of *Z* estimates to show detail.**

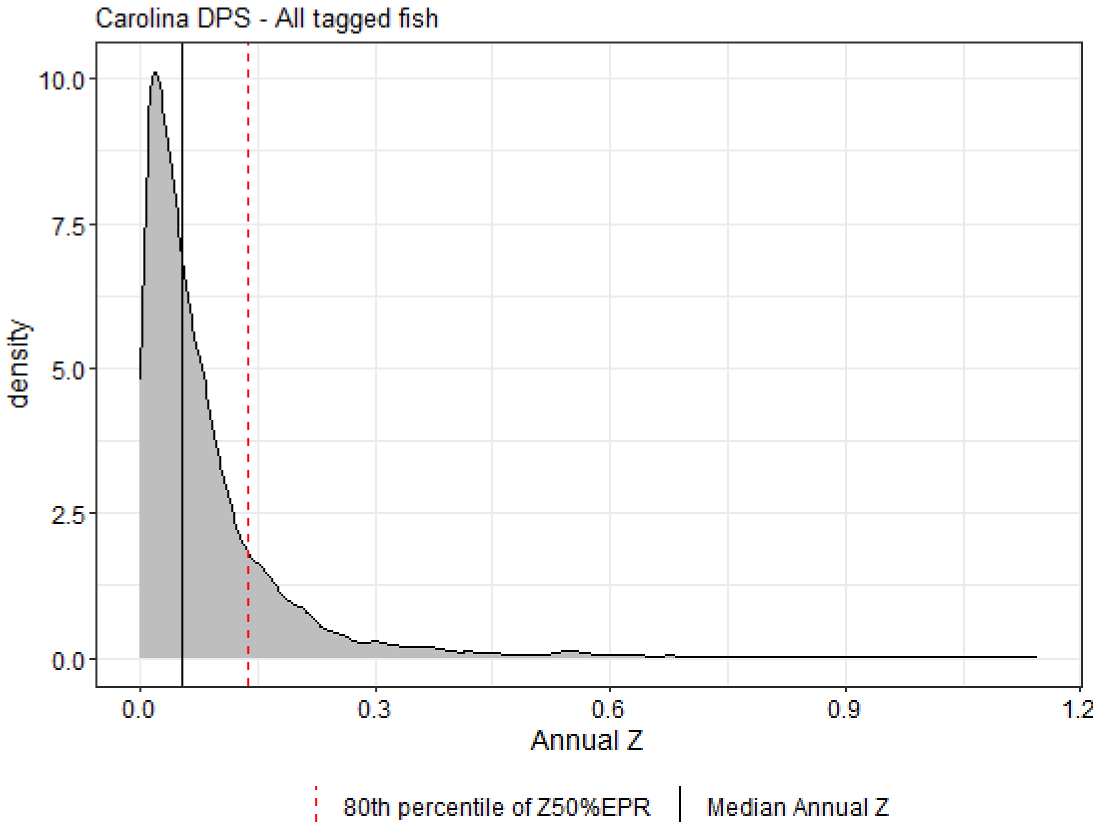


Figure 9. Distribution of annual *Z* estimate from the tagging model for all tagged fish assigned to the Carolina DPS, plotted with the median annual *Z* and the *Z* reference point. The x-axis has been truncated to exclude the highest 0.5% of *Z* estimates to show detail.

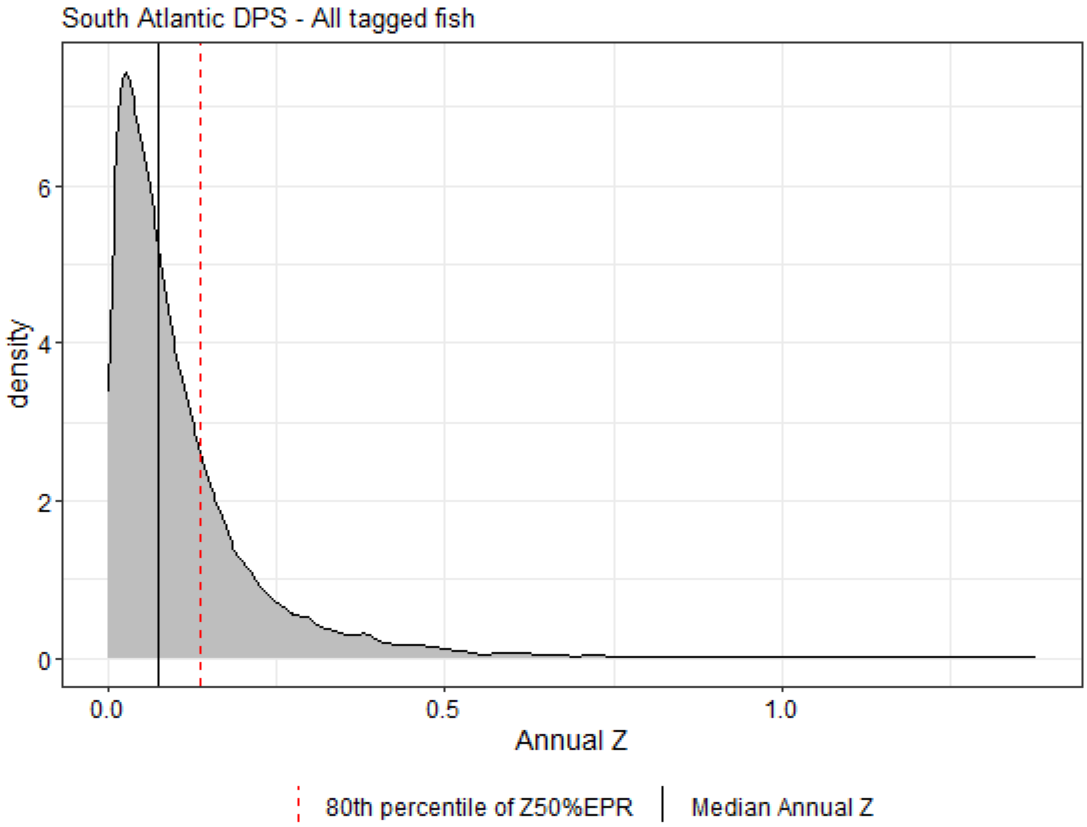


Figure 10. Distribution of annual *Z* estimate from the tagging model for all tagged fish assigned to the South Atlantic DPS, plotted with the median annual *Z* and the *Z* reference point. The x-axis has been truncated to exclude the highest 0.5% of *Z* estimates to show detail.

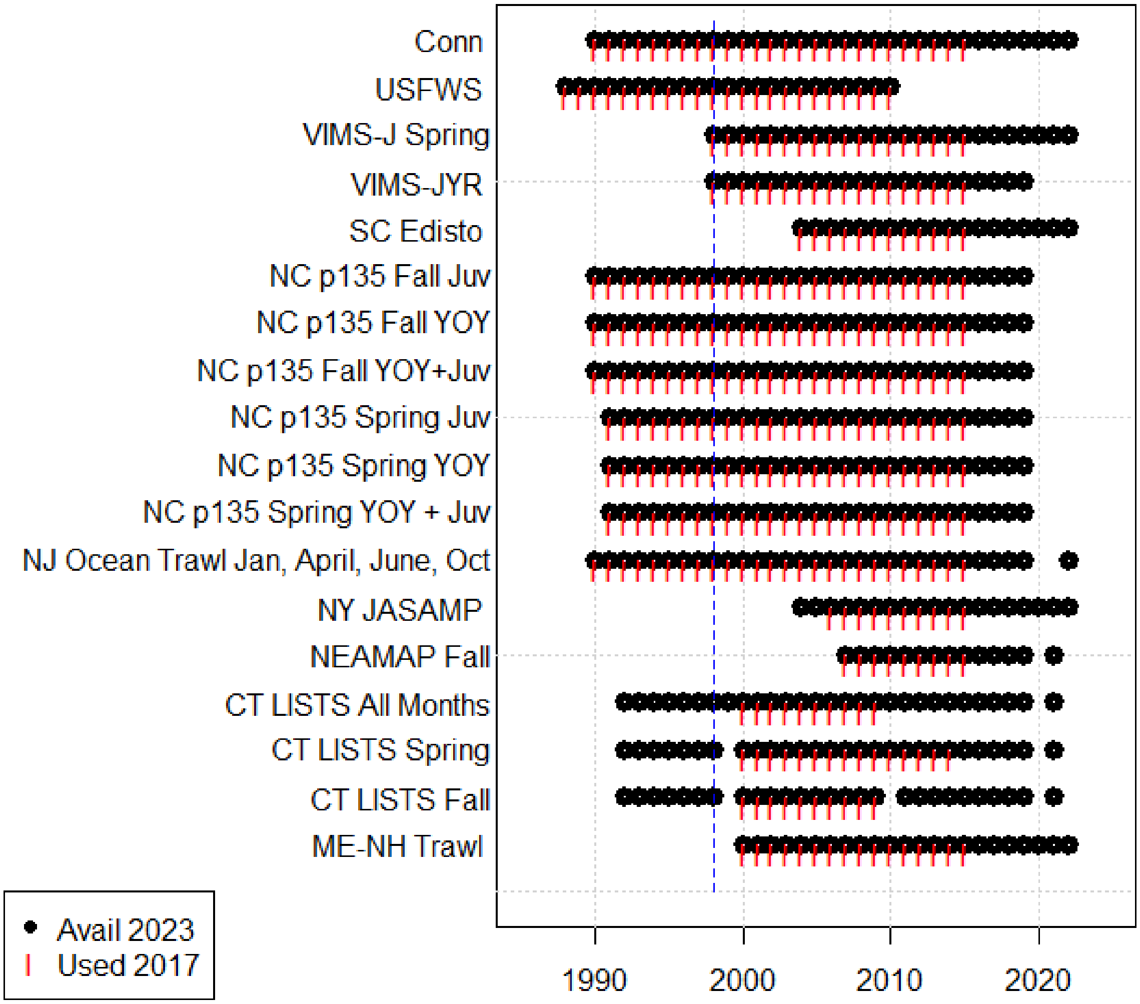


Figure 11. Visualization of the years of data available for 2023/2024 ARIMAs and those used for 2017 ARIMAs (ASMFC 2017). A blue vertical dashed line is added at 1998. Index values for the VIMS survey was not used in the final ARIMAs due to changes in the gear, net location, and effort.

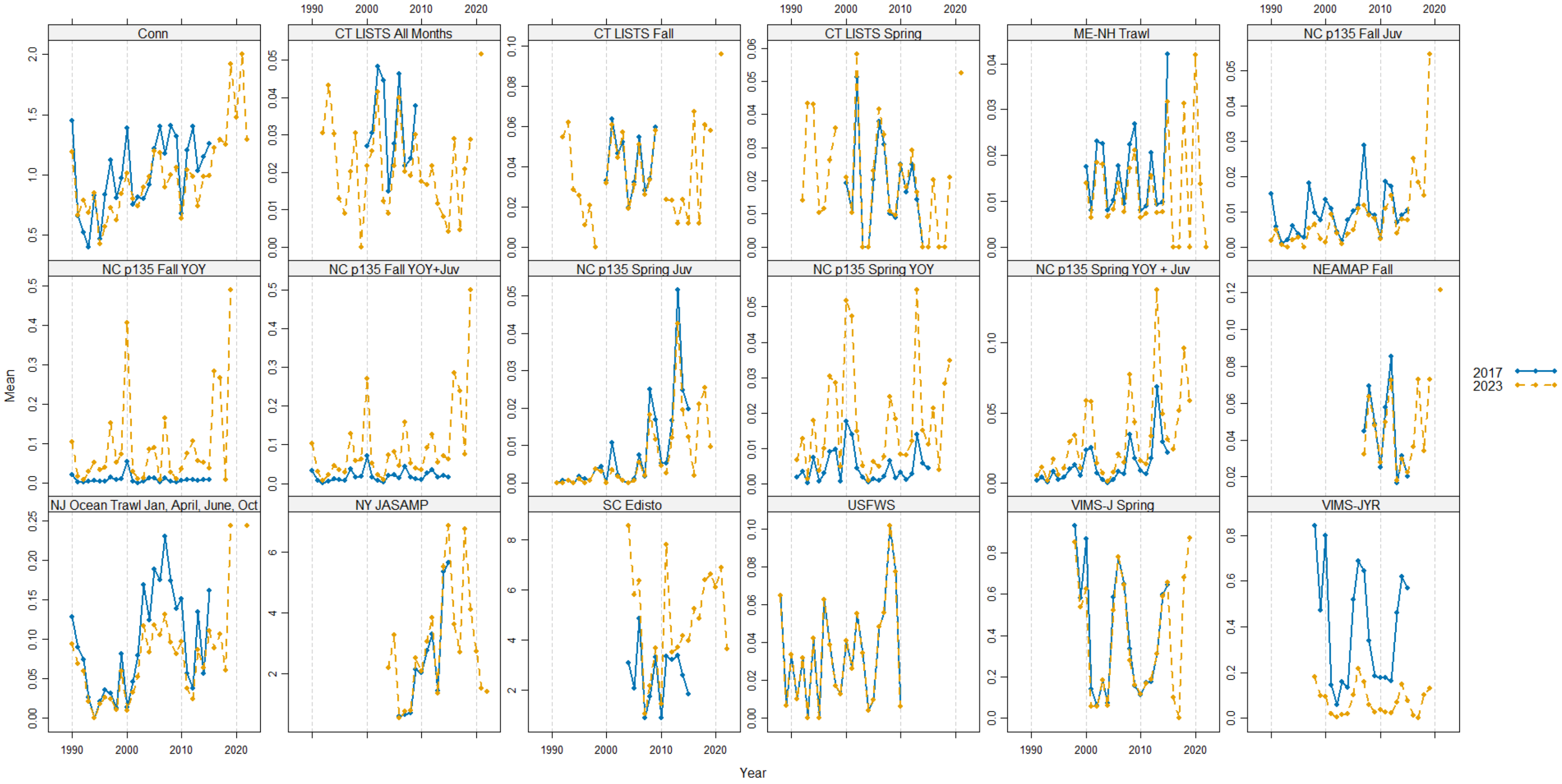


Figure 12. Plot of raw indices used in 2017 and 2023 ARIMAs.

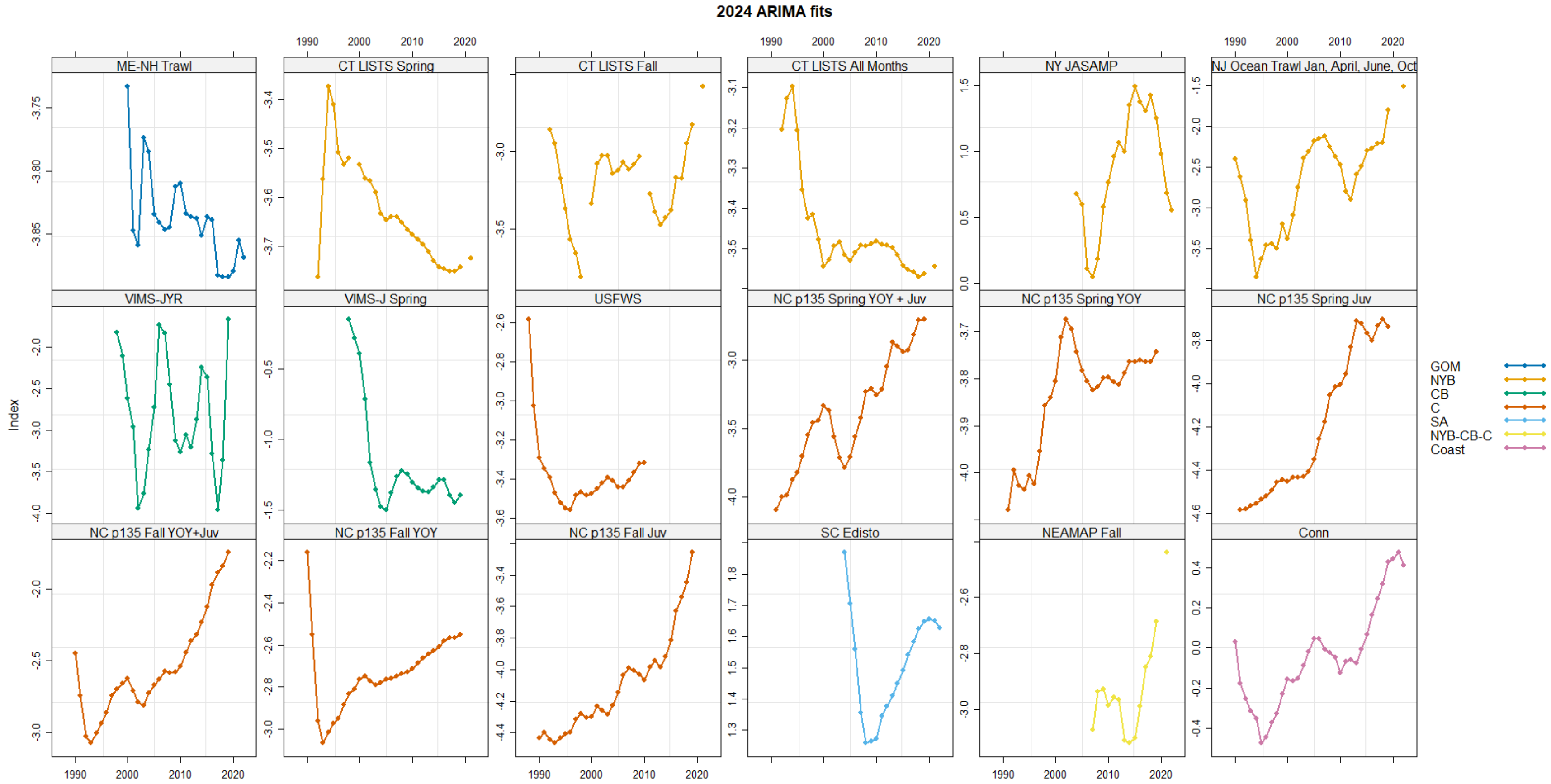


Figure 13. ARIMA fitted indices plotted on individualized y-axes. See Table 12 for results of trend analysis.

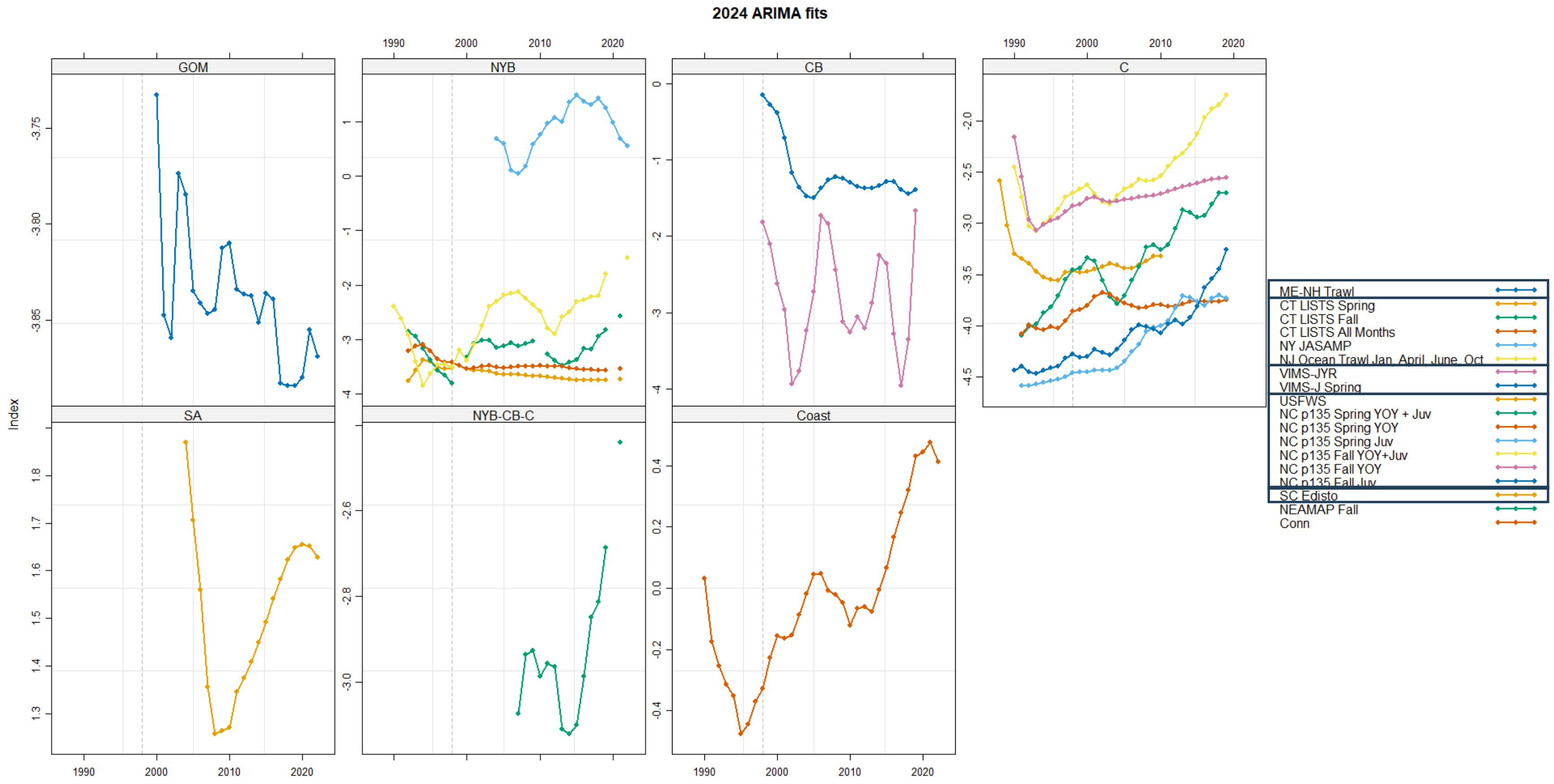


Figure 14. ARIMA fitted indices grouped by DPS plotted on separate y-axes. Boxes are drawn around surveys within DPSs. See Table 12 for results of trend analysis.

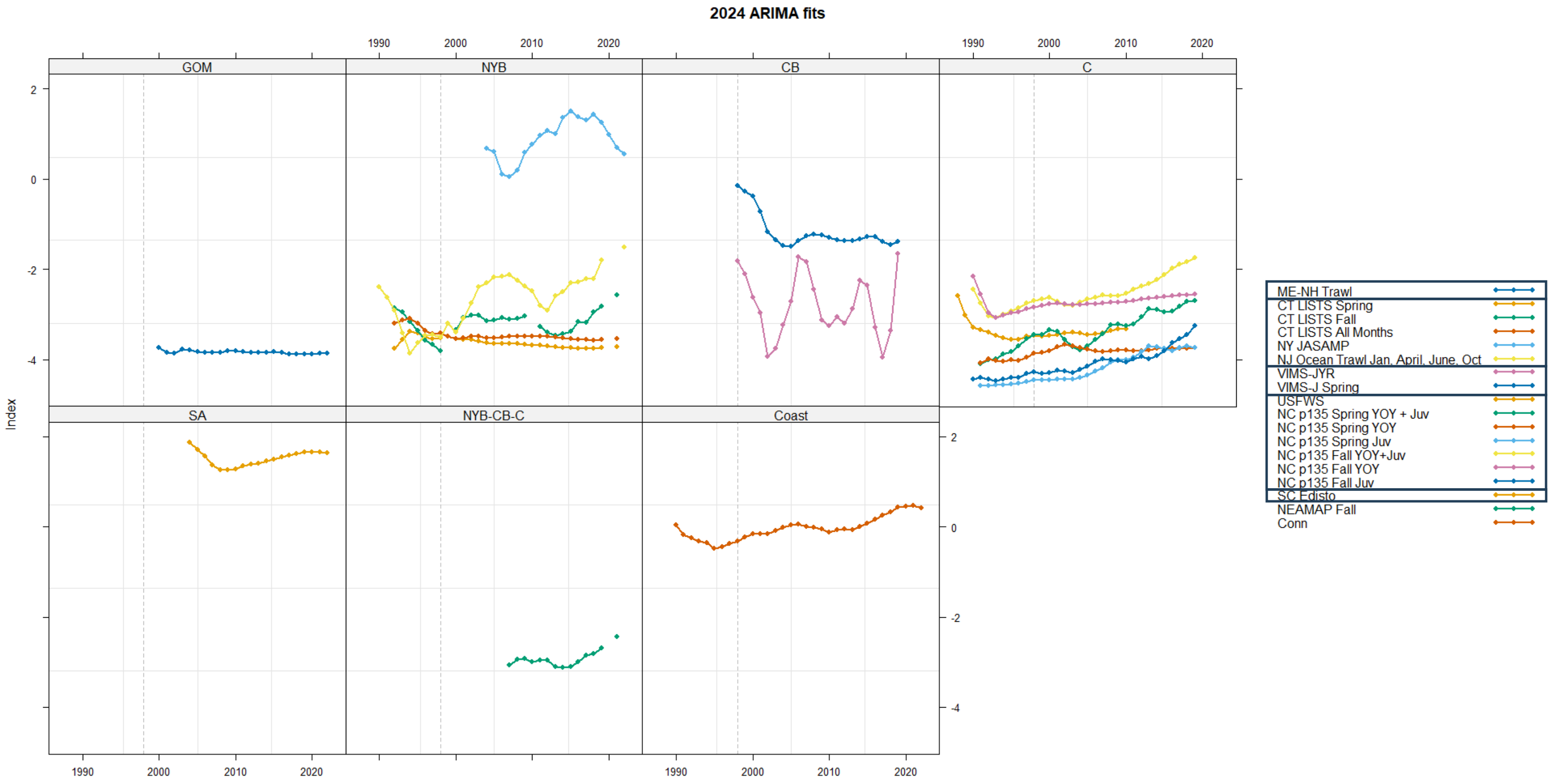


Figure 15. ARIMA fitted indices grouped by DPS plotted on a common y-axis. Boxes are drawn around surveys within DPSs. See Table 12 for results of trend analysis.

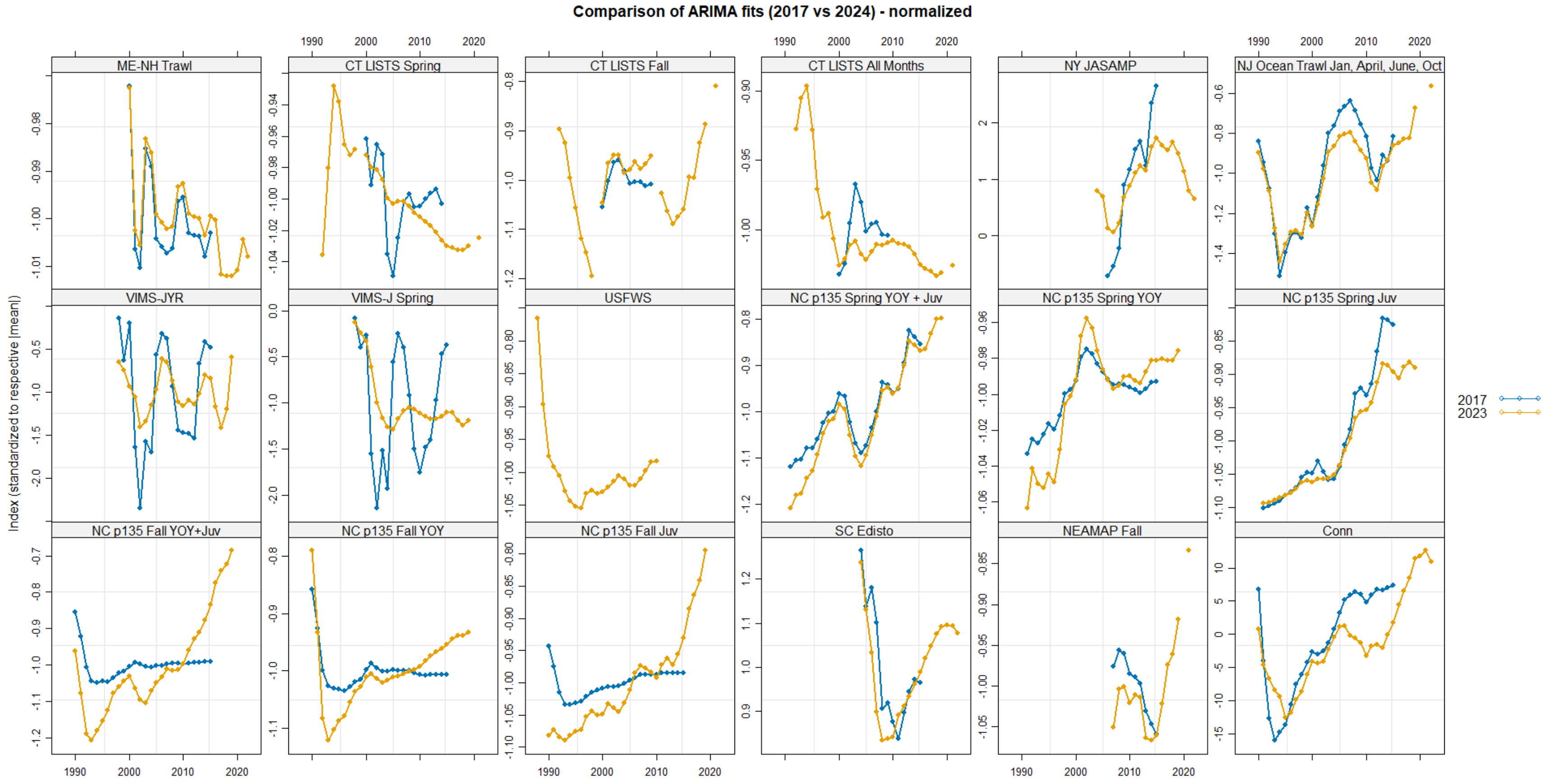


Figure 16. ARIMA fits from indices fit in ASMFC (2017) with those fit in 2024 (labelled 2023). Indices have been scaled to the absolute value of their respective mean. Note that USFWS index was 100% unchanged from ASMFC (2017) due to the termination of that timeseries in 2010.

Figure 17. Probabilities that the terminal year of a given index is greater than the 25th percentile of its time series. The plotted point represents the probability that the terminal year of the index is greater than the 25th percentile of the index assuming the survey started in the plotted year. A dotted horizontal line is added at probability = 0.50 (min credible probability). A red box is drawn around indices where credibility of terminal year being above the 25th percentile of a given time series changes with start year, suggesting some sensitivity of the results to the survey start year.

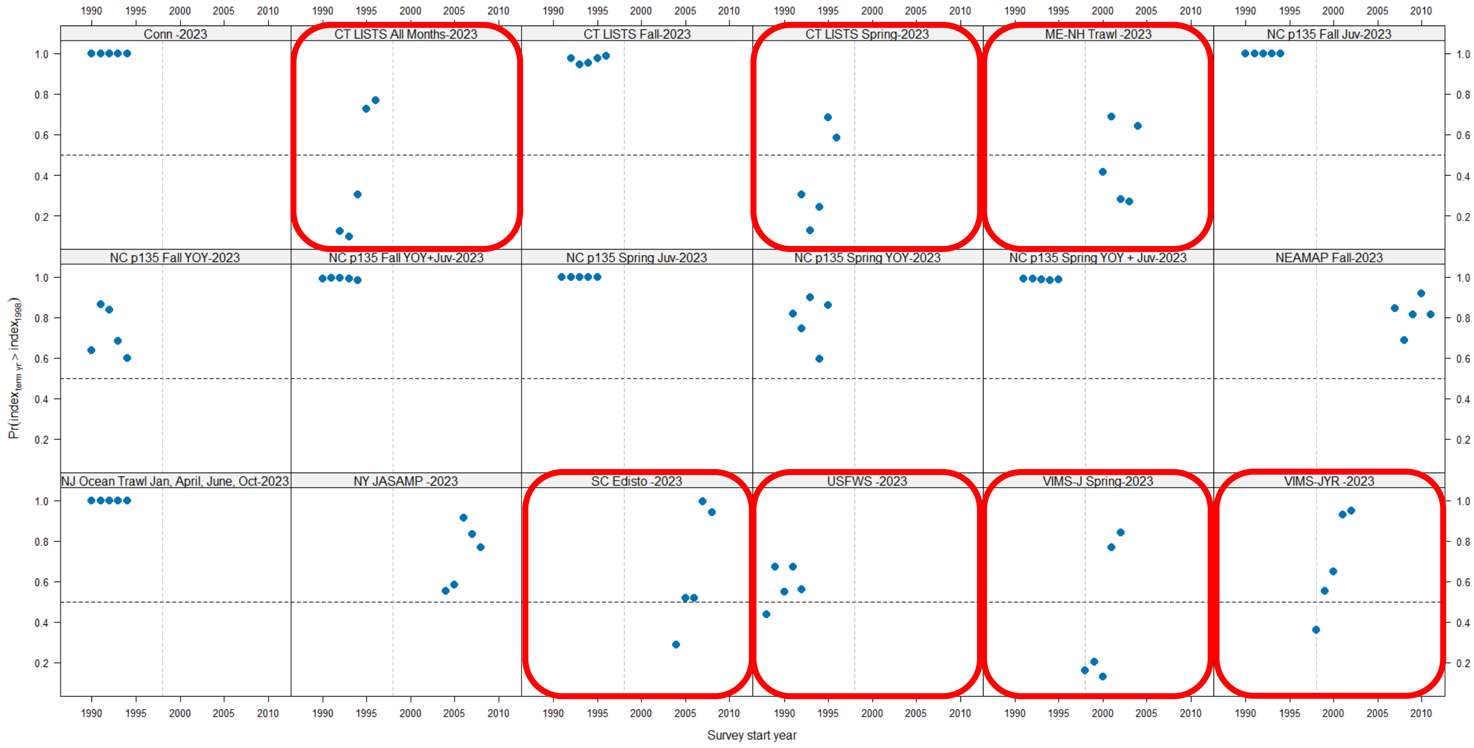


Figure 18. Probabilities that the terminal year of a given index is greater than the index value in 1998*; a vertical dotted line is added at 1998. The plotted point represents the probability that the terminal year of the index is greater than the index value in 1998* assuming the survey started in the plotted year. A dotted horizontal line is added at probability = 0.50 (min credible probability). A red box is drawn around indices where credibility of terminal year being above the 1998 index value of a given time series changes with start year, suggesting some sensitivity of the results to the survey start year. * For surveys that started after 1998, what is plotted is the probability that the terminal year is greater than the index in the plotted year, so that in those cases, the comparisons are against a moving set of years [e.g., SC Edisto: Pr(2023 index > 2004 index = 0.29 (assuming index started in 2004), …, Pr(2023 index > 2007 index = 0.94 (assuming index started in 2007)].

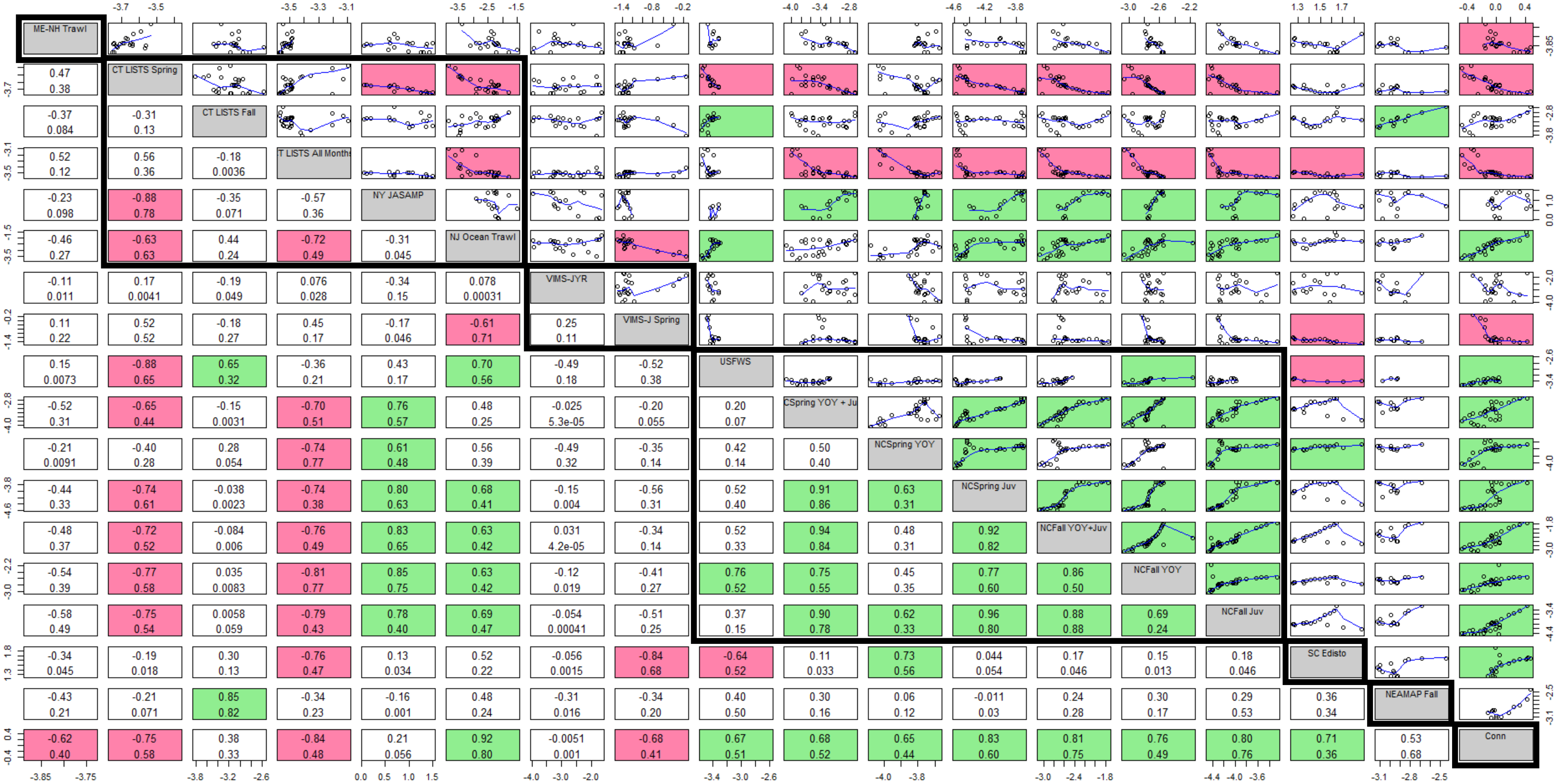


Figure 19. Correlation matrix of ARIMA fits to surveys. Spearman correlations below diagonal (top row), notable correlations (≥ 0.60 or ≤ -0.60) are indicated in green or red, respectively; r^2 below diagonal (bottom row). Lowess smoother added to scatterplots above the diagonal. Index name along the diagonal. Black boxes are drawn around surveys within a single DPS to help illustrate trends within a DPS or regional index (e.g., NEAMAP, Conn).

APPENDICES

a. Tagging Model Supplemental Results

Table A1. Results of Cormack-Jolly Seber model for all size Atlantic sturgeon for all DPSs. The mean and percentile *S* values are presented, along with mean *P* estimates. The mean *S* estimates were reported for the benchmark assessment, but due to skewness in the posterior distributions, the peer review panel recommended using median values for the *S* estimates (bold). Estimate of *P* are the mean or range of monthly means depending on if the preferred model for that DPS used the single or monthly *P* estimate.

DPS	N	TL Range (cm)	Mean	sd	2.50%	25%	50%	75%	97.50%	*P*
GM	224	29-237	0.81	0.16	0.34	0.76	**0.86**	0.92	0.98	0.02-0.34
NY	534	26-268	0.91	0.10	0.63	0.88	**0.94**	0.97	1.00	0.31
CH	464	25-240	0.93	0.09	0.67	0.91	**0.95**	0.98	1.00	0.09-0.49
CA	489	30-265	0.92	0.10	0. 63	0.90	**0.95**	0.98	1.00	0.42
SA	364	28-267	0.90	0.12	0.60	0.87	**0.93**	0.97	1.00	0.12-0.54
All	2,075	25-268	0.98	0.03	0.89	0.98	**0.99**	0.99	1.00	0.11-0.47

Table A2. Results of Cormack-Jolly Seber model for Atlantic sturgeon < 1300 mm for all DPSs. The mean and percentile *S* values are presented, along with mean *P* estimates. The mean *S* estimates were reported for the benchmark assessment, but due to skewness in the posterior distributions, the peer review panel recommended using median values for the *S* estimates (bold). Estimate of *P* are the mean or range of monthly means depending on if the preferred model for that DPS used the single or monthly *P* estimate.

DPS	N	TL Range (cm)	Mean	sd	2.50%	25%	50%	75%	97.50%	*P*
GM	55	29-129	0.56	0.25	0.09	0.37	**0.58**	0.76	0.96	0.29
NY	144	26-129	0.82	0.16	0.41	0.75	**0.86**	0.93	0.99	0.33
CH	74	25-128	0.77	0.18	0.27	0.69	**0.82**	0.90	0.98	0.15-0.50
CA	208	30-129	0.86	0.13	0.47	0.82	**0.90**	0.95	0.99	0.37
SA	133	28-124	0.81	0.17	0.33	0.74	**0.86**	0.93	0.99	0.21-0.51
All	614	25-129	0.94	0.08	0.71	0.92	**0.96**	0.98	1.00	0.34

Table A3. Results of Cormack-Jolly Seber model for Atlantic sturgeon > 1300 mm for all DPSs.The mean and percentile *S* values are presented, along with mean *P* estimates. The mean *S* estimates were reported for the benchmark assessment, but due to skewness in the posterior distributions, the peer review panel recommended using median values for the *S* estimates (bold). Estimate of *P* are the mean or range of monthly means depending on if the preferred model for that DPS used the single or monthly *P* estimate.

DPS	N	TL Range (cm)	Mean	sd	2.50%	25%	50%	75%	97.50%	*P*
GM	169	130-237	0.77	0.19	0.22	0.69	**0.82**	0.91	0.98	0.04-0.31
NY	390	130-268	0.86	0.13	0.55	0.81	**0.89**	0.94	0.99	0.30
CH	390	130-240	0.90	0.10	0.60	0.87	**0.93**	0.97	1.00	0.33
CA	281	130-265	0.87	0.12	0. 57	0.82	**0.90**	0.95	0.99	0.47
SA	231	130-267	0.83	0.16	0.38	0.77	**0.88**	0.94	0.99	0.09-0.55
All	1,461	130-268	0.96	0.05	0.83	0.96	**0.98**	0.99	1.00	0.31

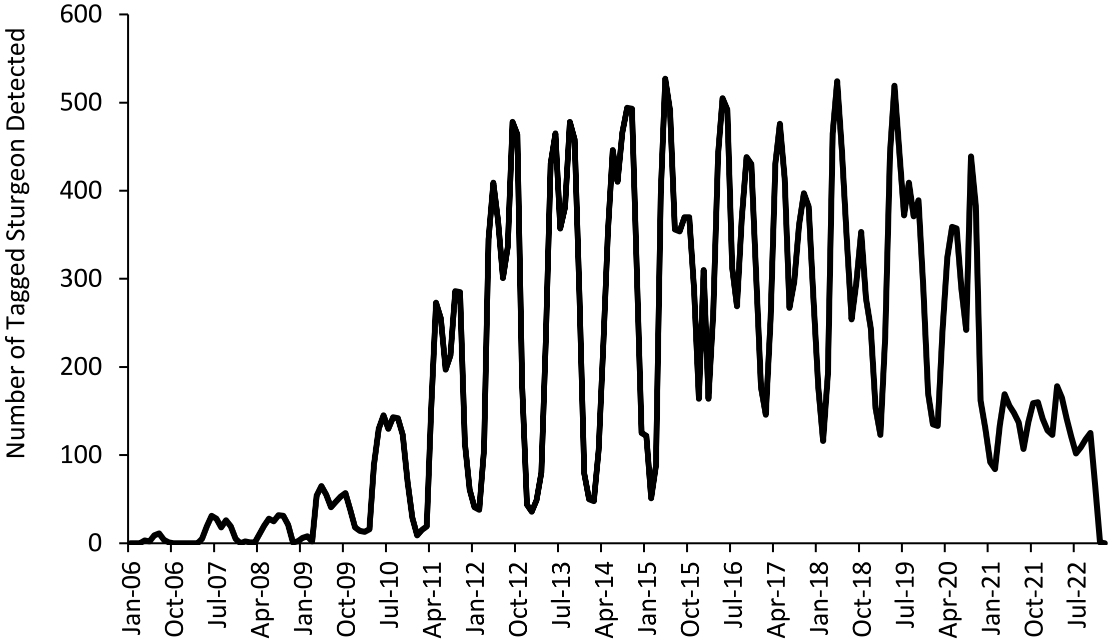


Figure A1. Total number of tagged sturgeon detected weekly over time for all DPSs.

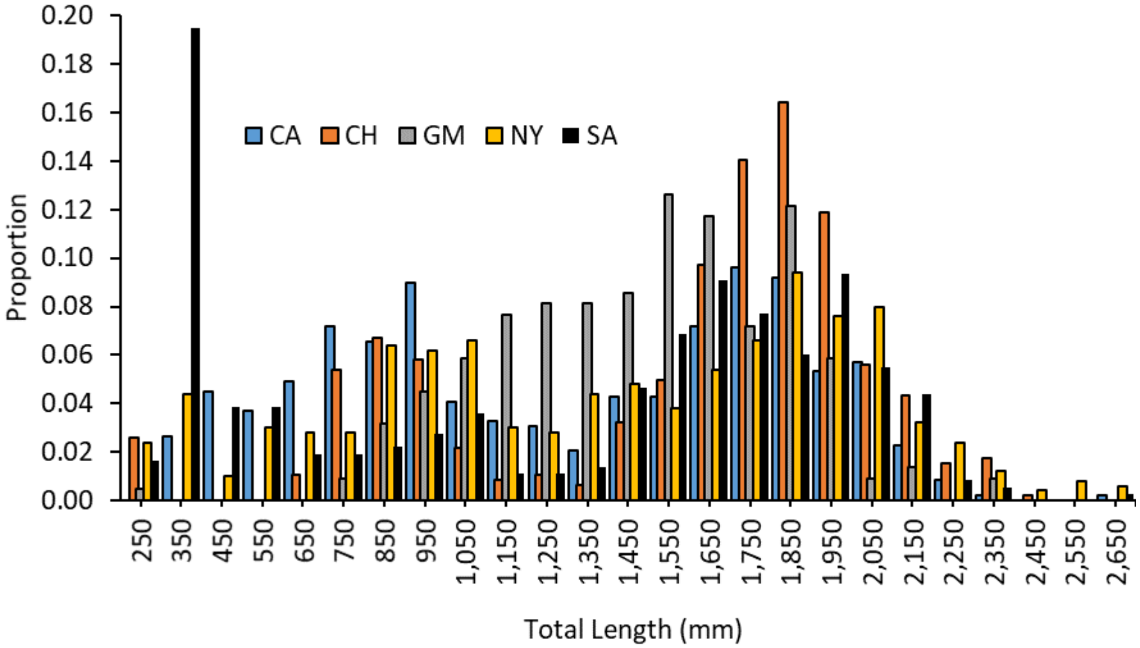


Figure A2. Length-frequency of all tagged Atlantic sturgeon by assigned DPS.

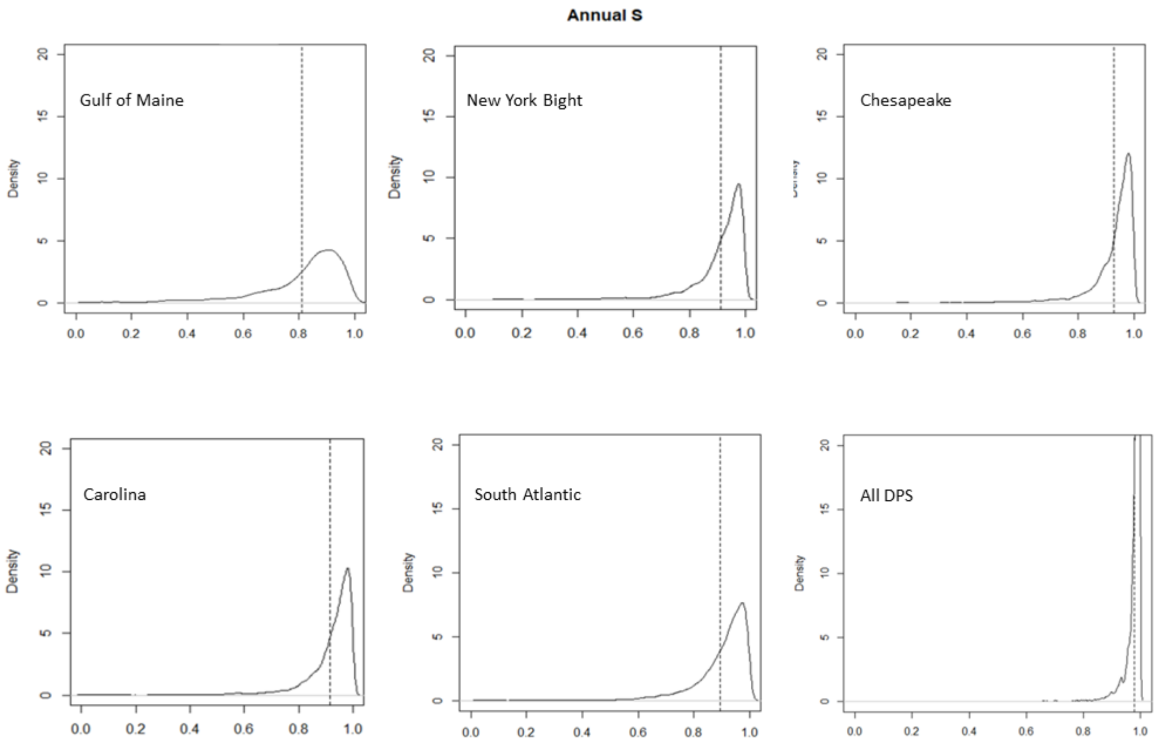


Figure A3. Posterior distributions for estimates of *S* for all sized tagged Atlantic sturgeon. Results are for the best model for each DPS. Dotted vertical line represents the mean *S* estimate.

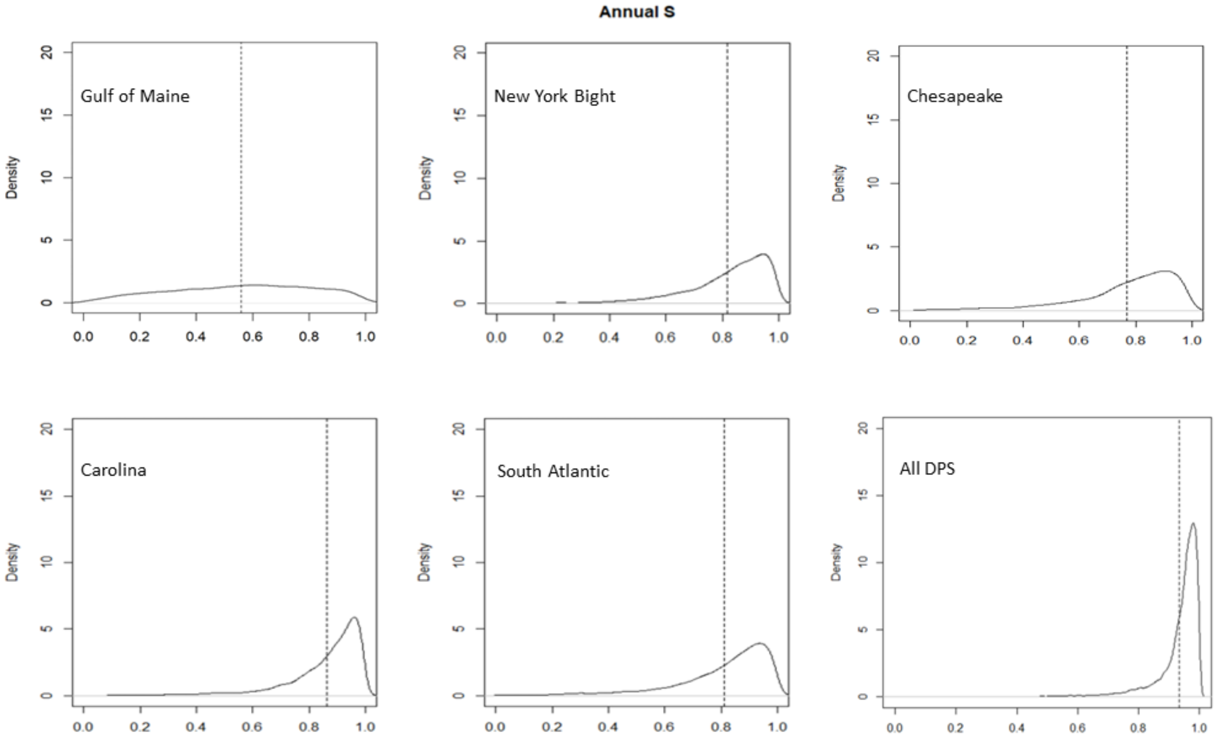


Figure A4. **Posterior distributions for estimates of *S* for tagged Atlantic sturgeon < 1300 mm. Results are for the best model for each DPS. Dotted vertical line represents the mean *S* estimate.**

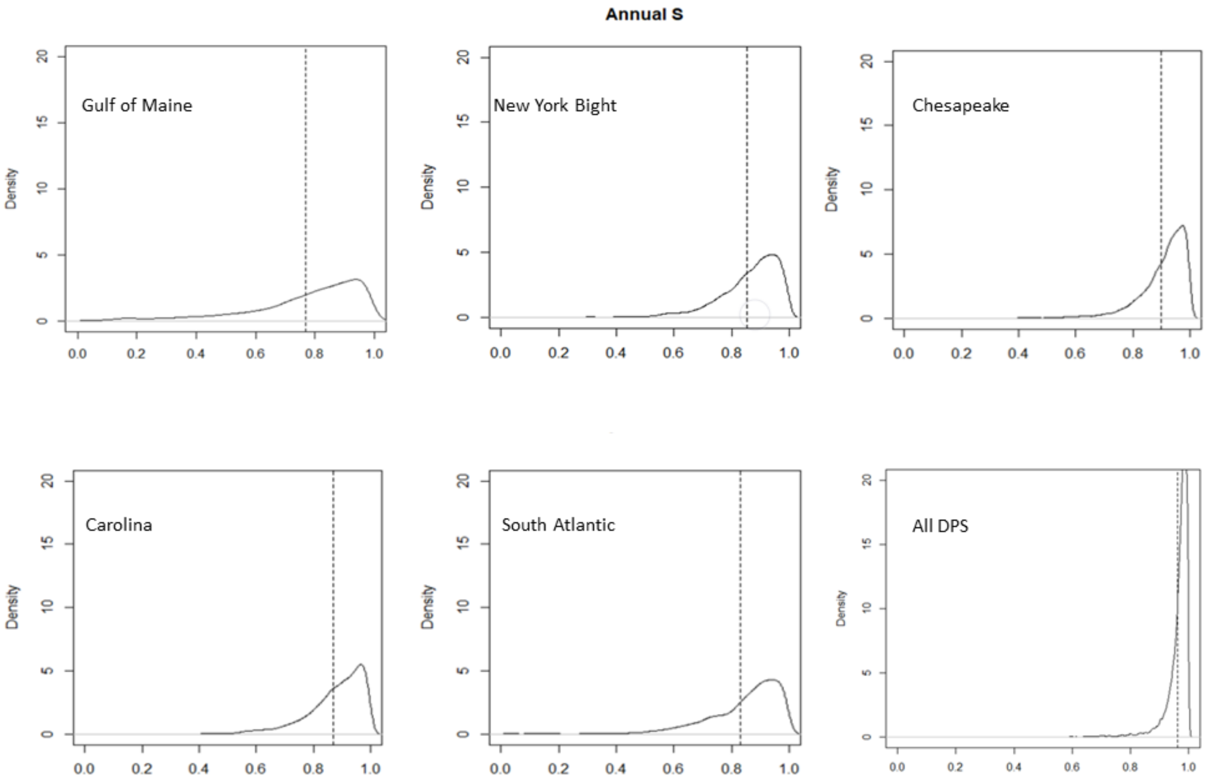


Figure A5. Posterior distributions for estimates of *S* for tagged Atlantic sturgeon >1300 mm. Results are for the best model for each DPS. Dotted vertical line represents the mean *S* estimate.

b. Standardized Indices of Abundance

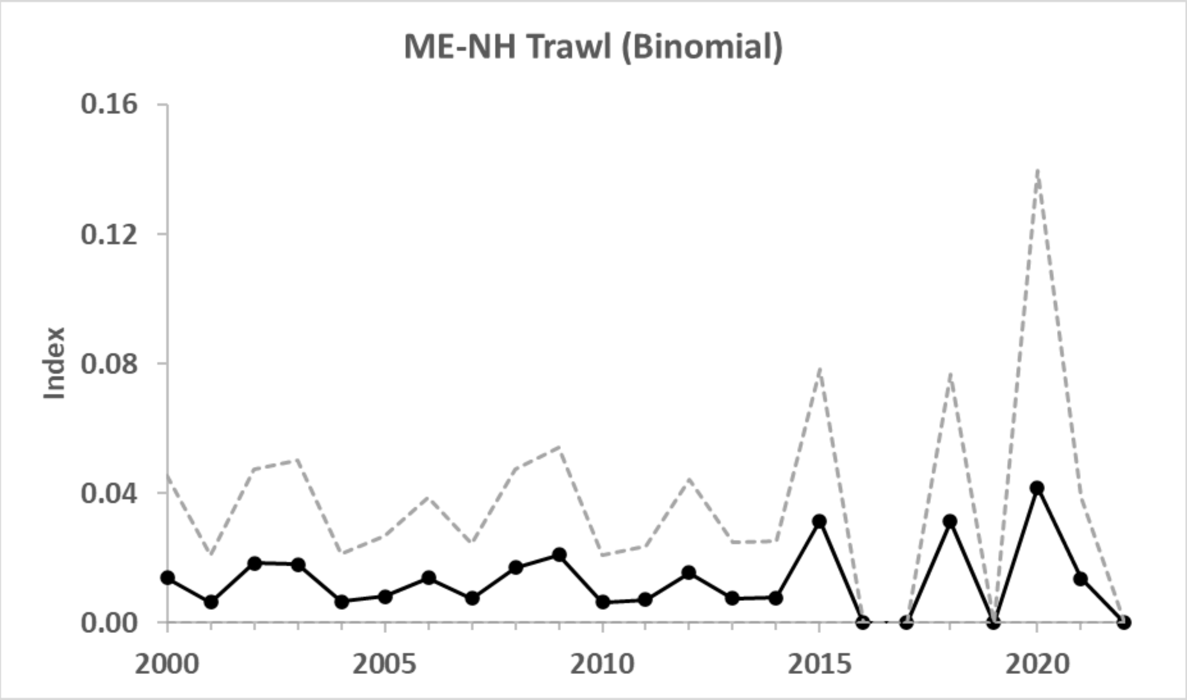


Figure A6. Standardized index of relative abundance of Atlantic sturgeon developed from the Maine-New Hampshire Trawl Survey with 95% confidence intervals.

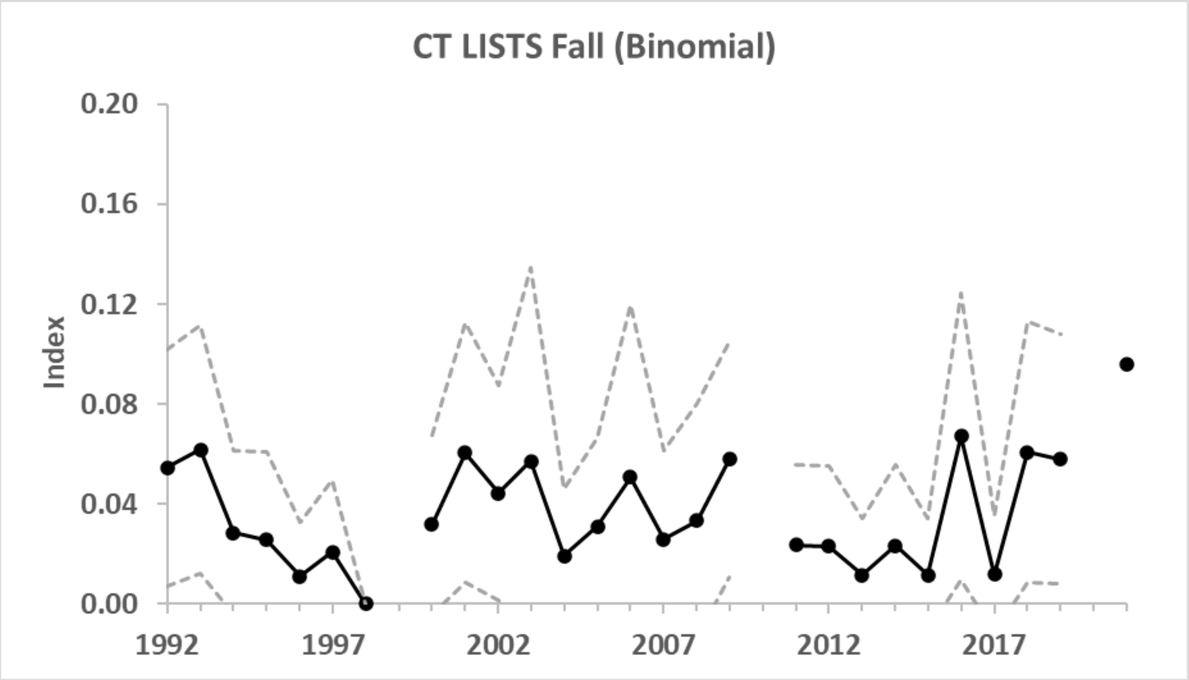


Figure A7. Standardized index of relative abundance of Atlantic sturgeon developed from the Connecticut Long Island Sound Trawl Survey in the fall with 95% confidence intervals.

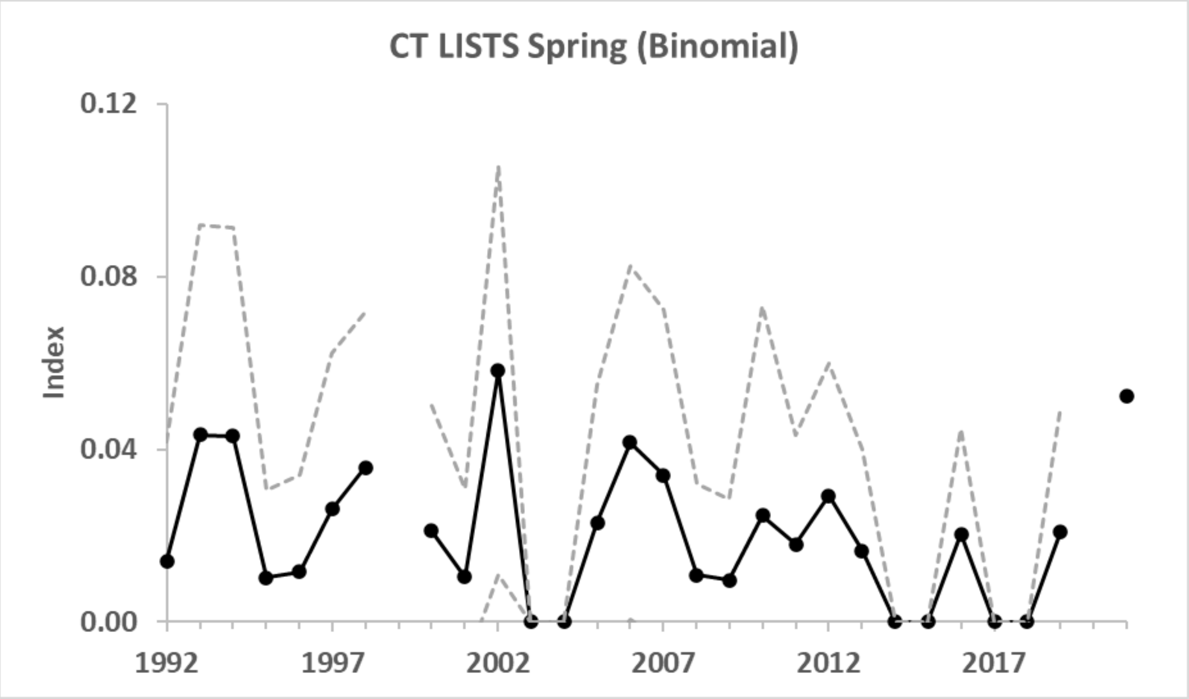


Figure A8. Standardized index of relative abundance of Atlantic sturgeon developed from the Connecticut Long Island Sound Trawl Survey in the spring with 95% confidence intervals.

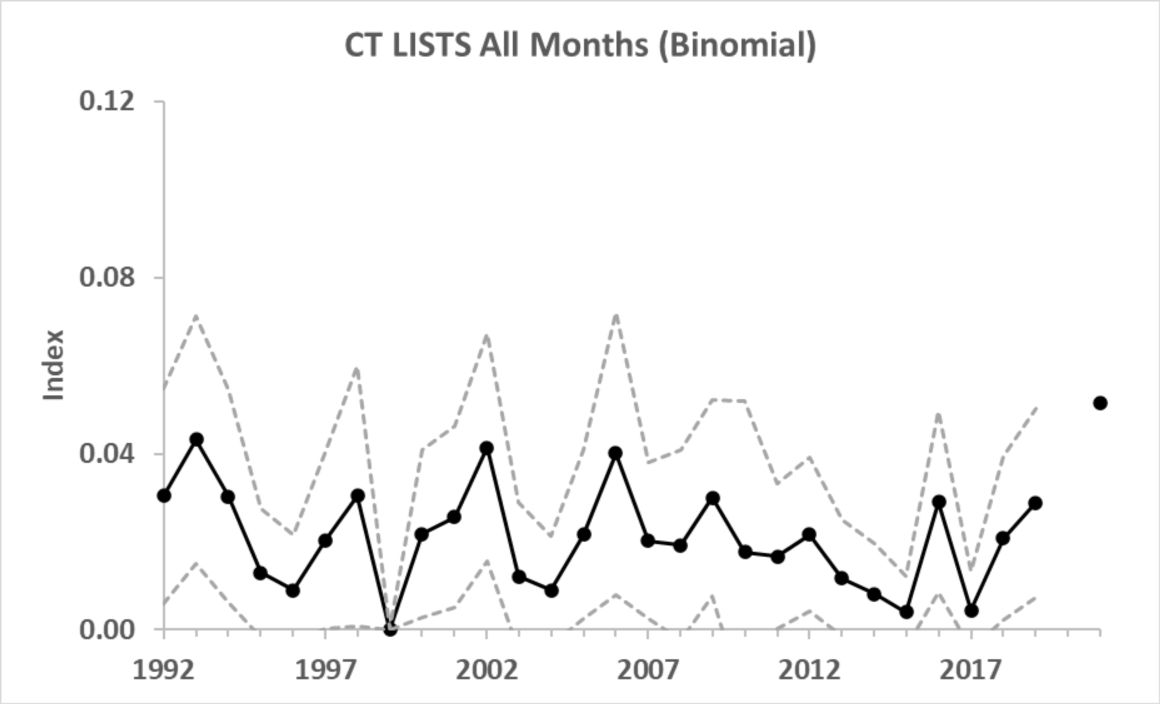


Figure A9. Standardized index of relative abundance of Atlantic sturgeon developed from the Connecticut Long Island Sound Trawl Survey for all months with 95% confidence intervals.

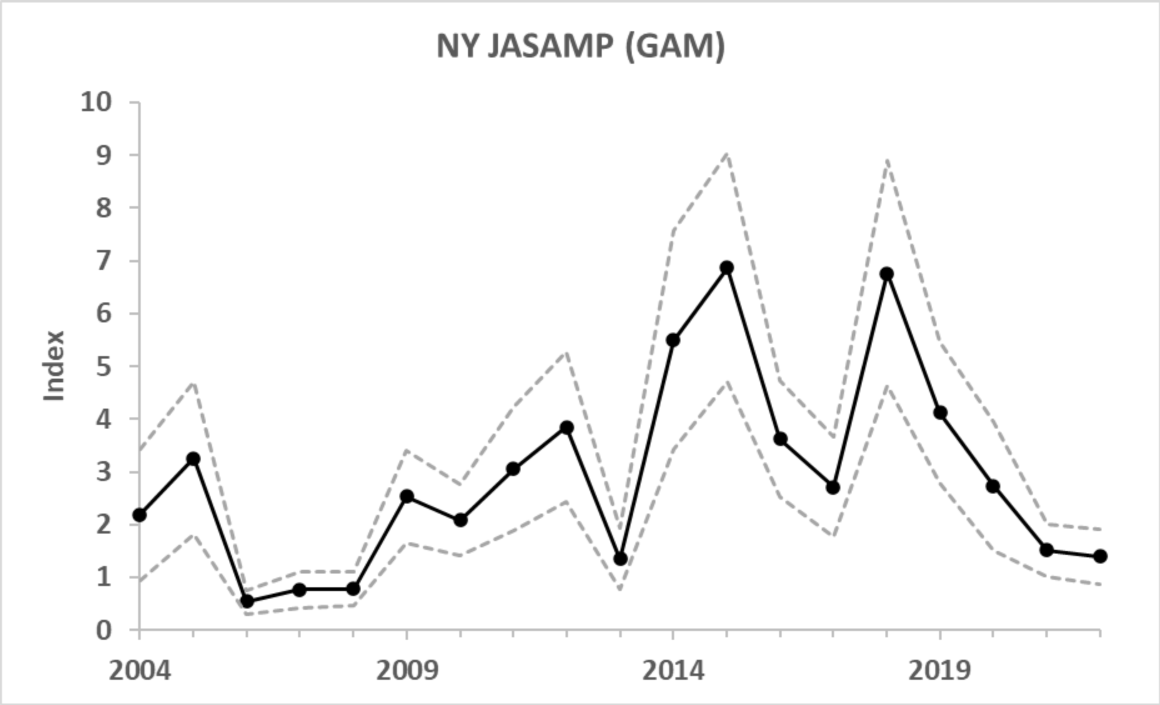


Figure A10. Standardized index of relative abundance of Atlantic sturgeon developed from the NYDEC JASAMP survey with 95% confidence intervals.

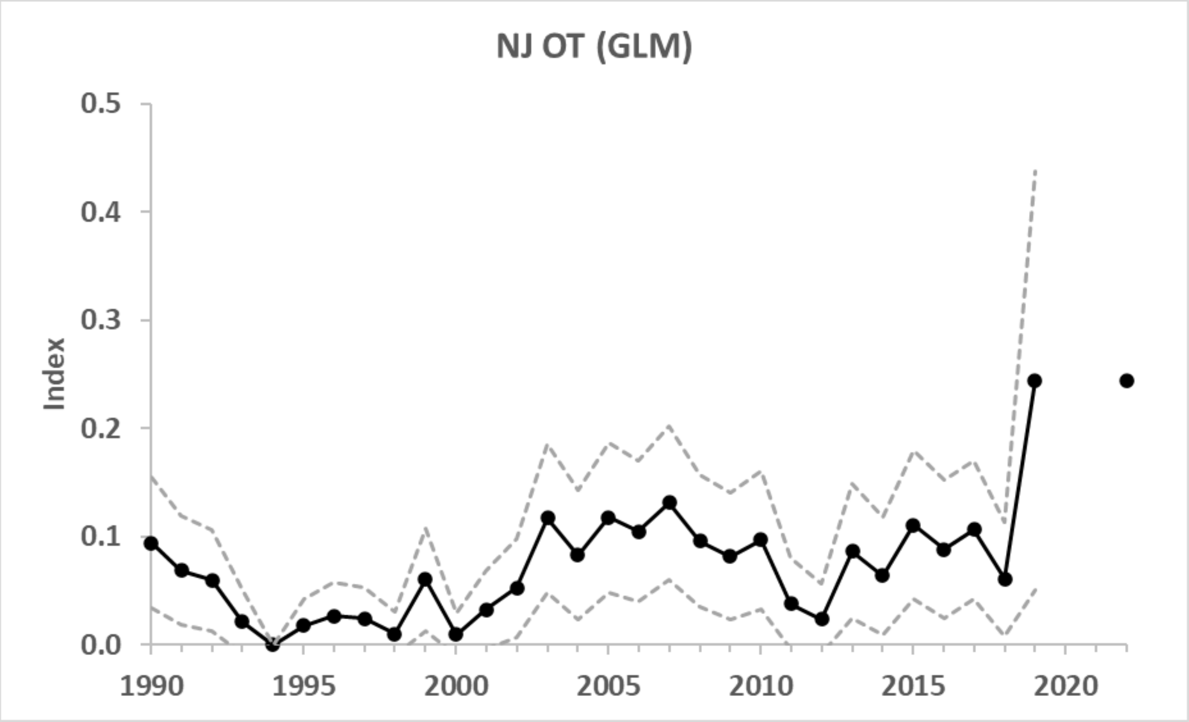


Figure A11. Standardized index of relative abundance of Atlantic sturgeon developed from the New Jersey Ocean Trawl Survey with 95% confidence intervals.

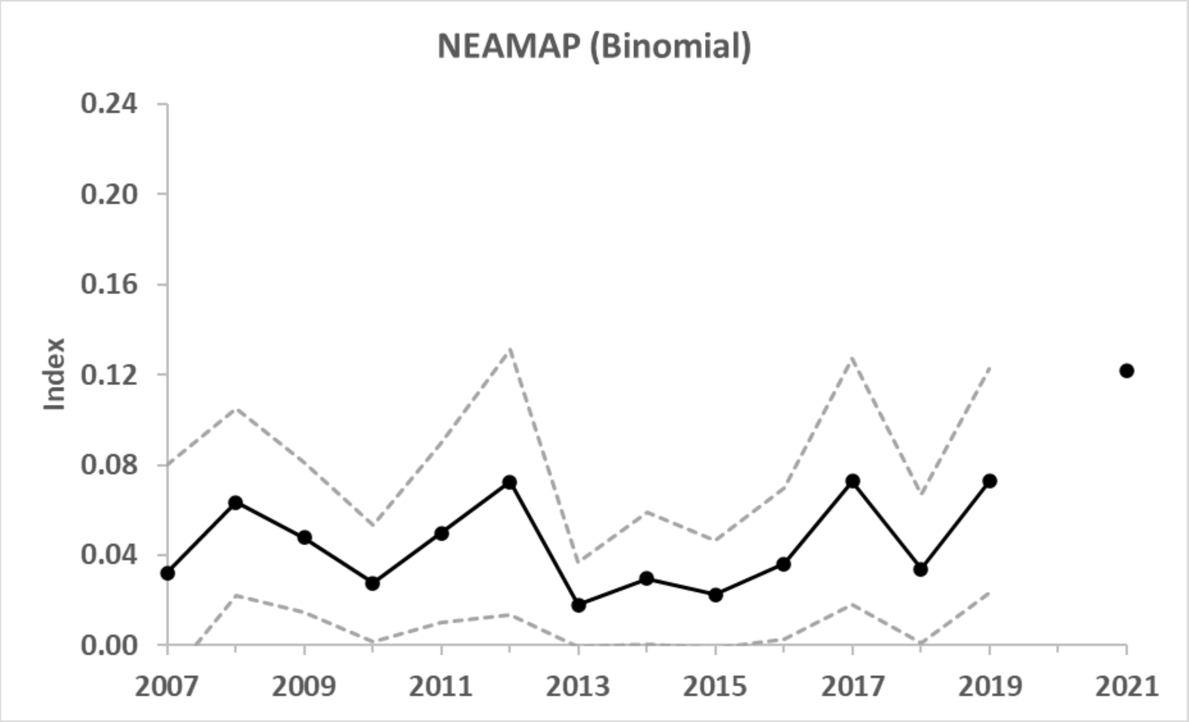


Figure A12. Standardized index of relative abundance of Atlantic sturgeon developed from the NEAMAP Survey in the fall with 95% confidence intervals.

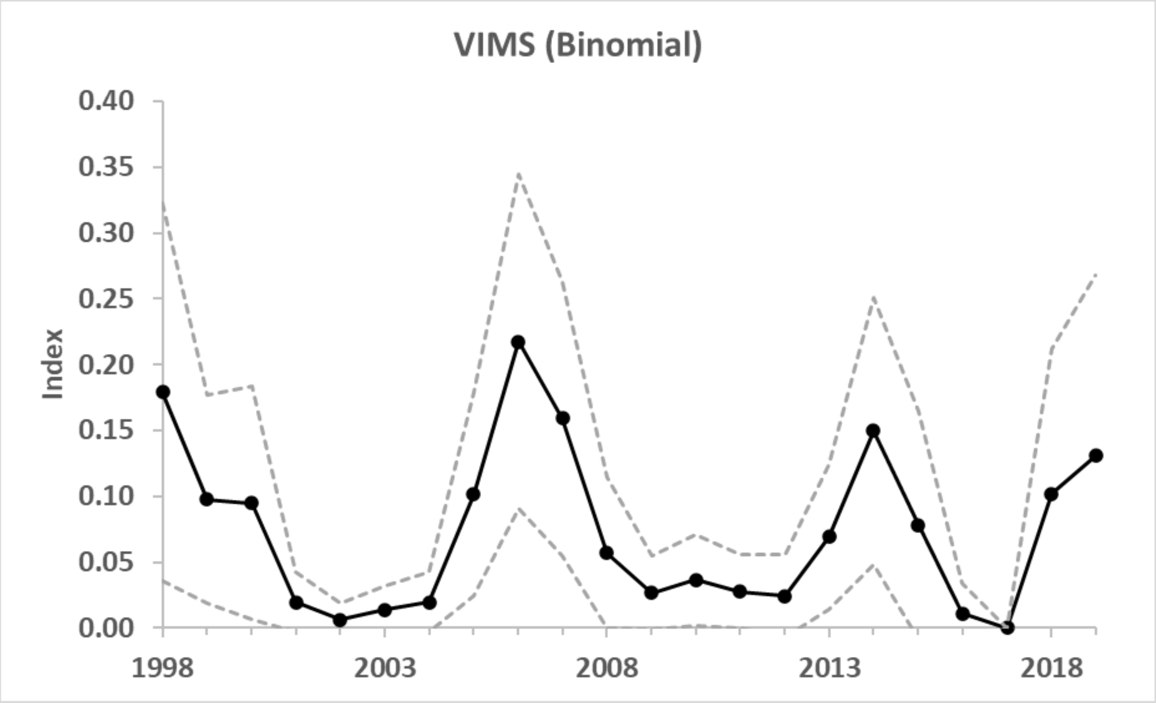


Figure A13. Standardized index of relative abundance of Atlantic sturgeon developed from the VIMS Shad and River Herring Monitoring Survey with 95% confidence intervals.

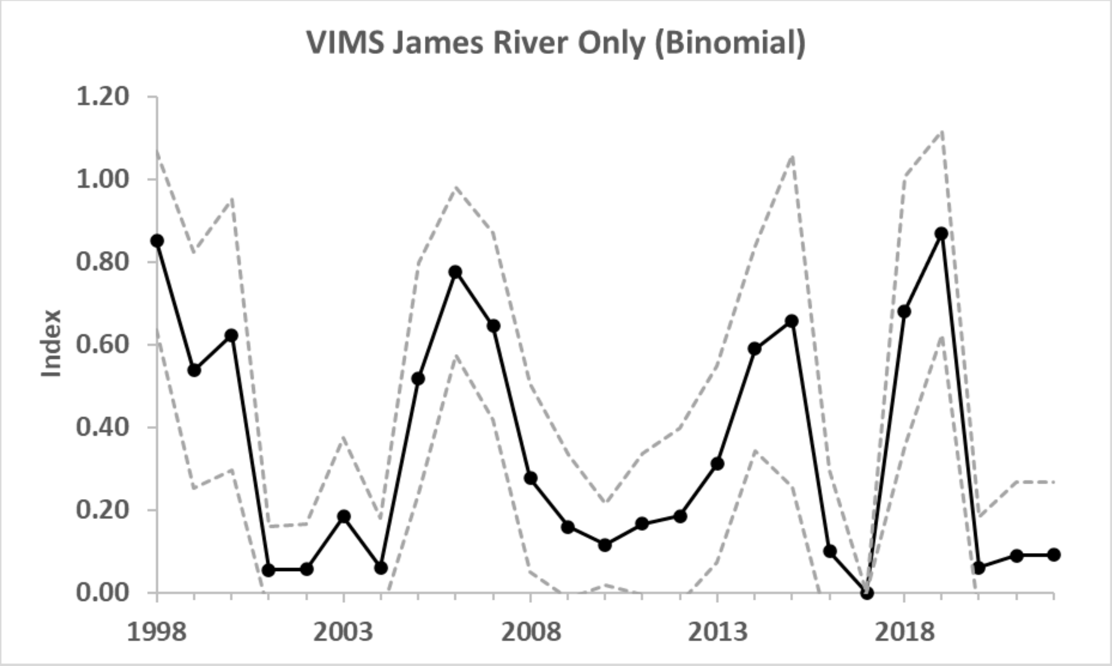


Figure A14. Standardized index of relative abundance of Atlantic sturgeon developed from the VIMS Shad and River Herring Monitoring Survey for the James River only with 95% confidence intervals.

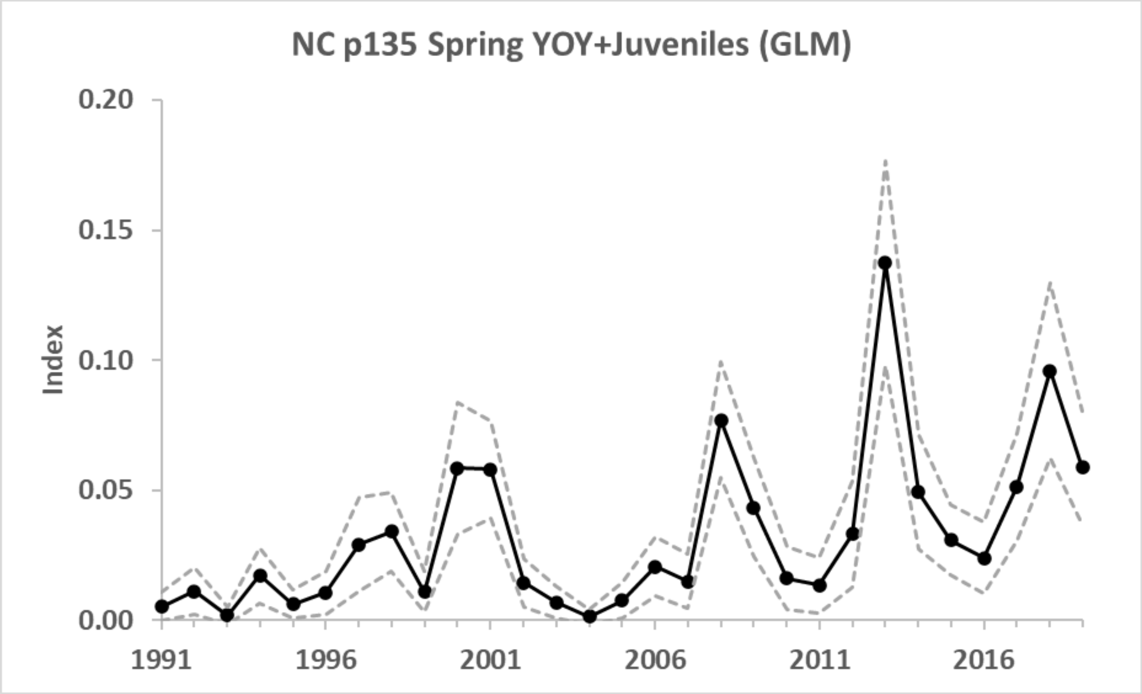


Figure A15. **Standardized index of relative abundance of Atlantic sturgeon developed from the spring component of the NC p135 Survey for YOY and juveniles with 95% confidence intervals.**

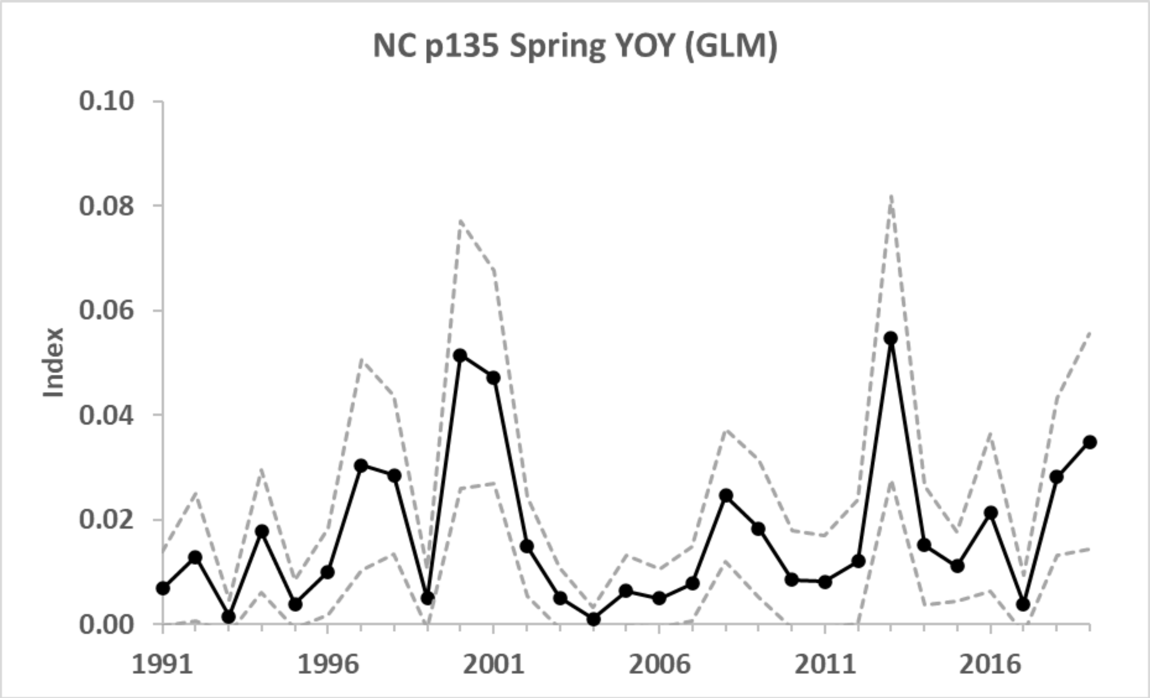


Figure A16. **Standardized index of relative abundance of Atlantic sturgeon developed from the spring component of the NC p135 Survey for YOY with 95% confidence intervals.**

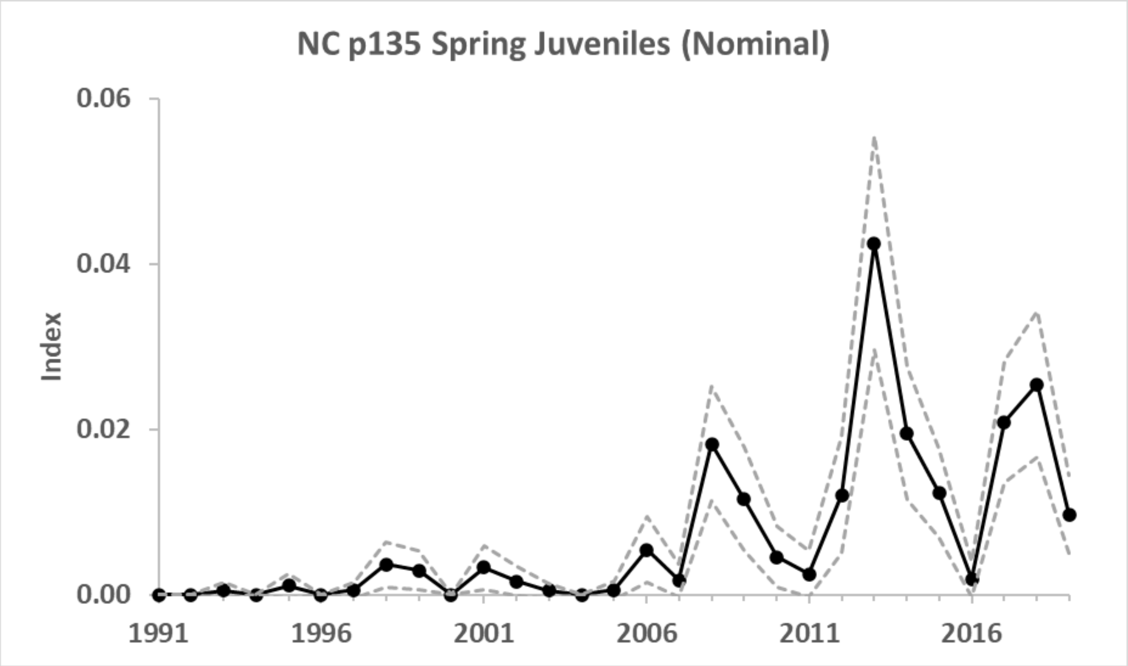


Figure A17. Standardized index of relative abundance of Atlantic sturgeon developed from the spring component of the NC p135 Survey for juveniles with 95% confidence intervals.

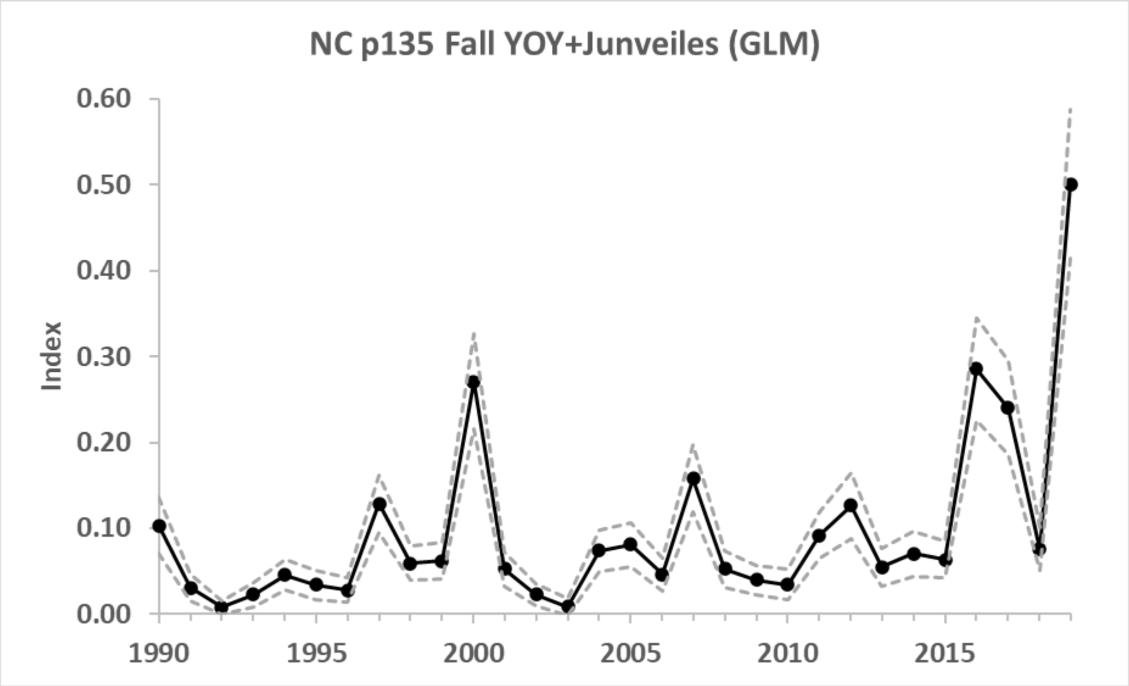


Figure A18. Standardized index of relative abundance of Atlantic sturgeon developed from the fall component of the NC p135 Survey for YOY and juveniles with 95% confidence intervals.

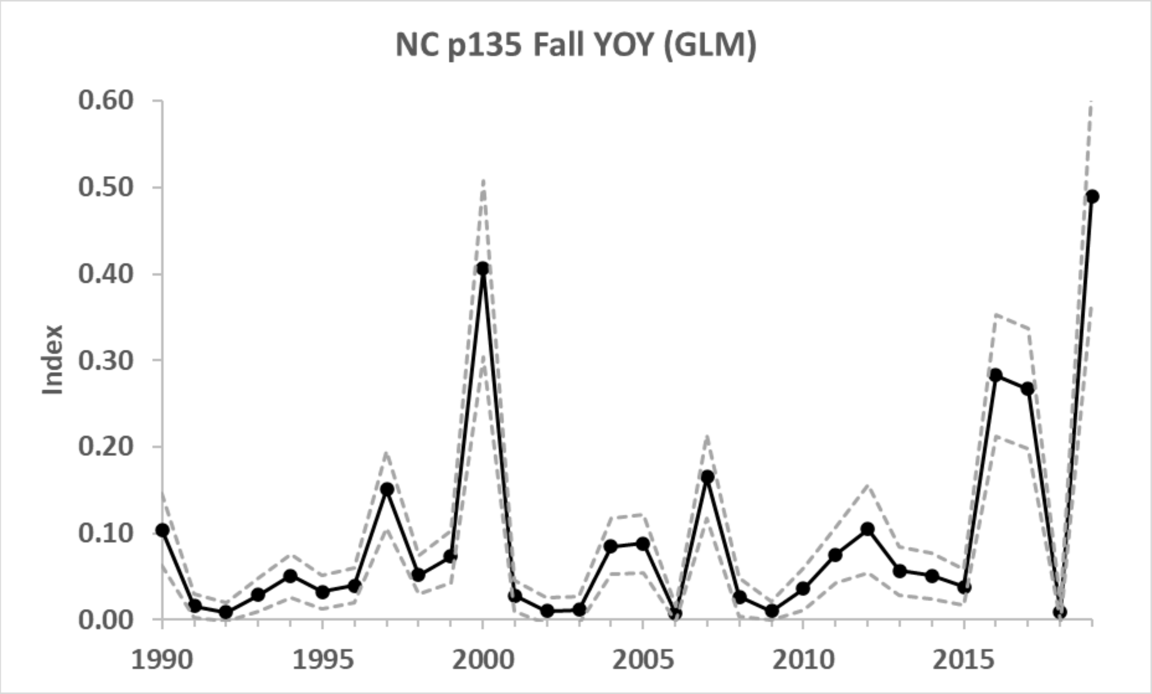


Figure A19. Standardized index of relative abundance of Atlantic sturgeon developed from the fall component of the NC p135 Survey for YOY with 95% confidence intervals.

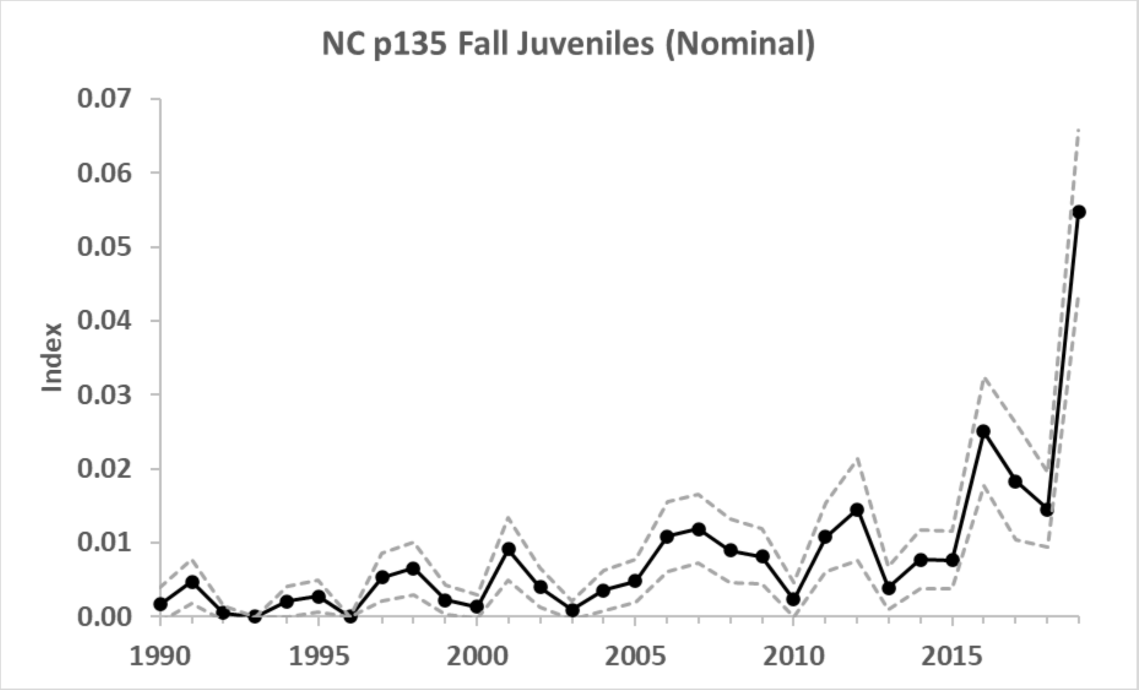


Figure A20. Standardized index of relative abundance of Atlantic sturgeon developed from the fall component of the NC p135 Survey for juveniles with 95% confidence intervals.

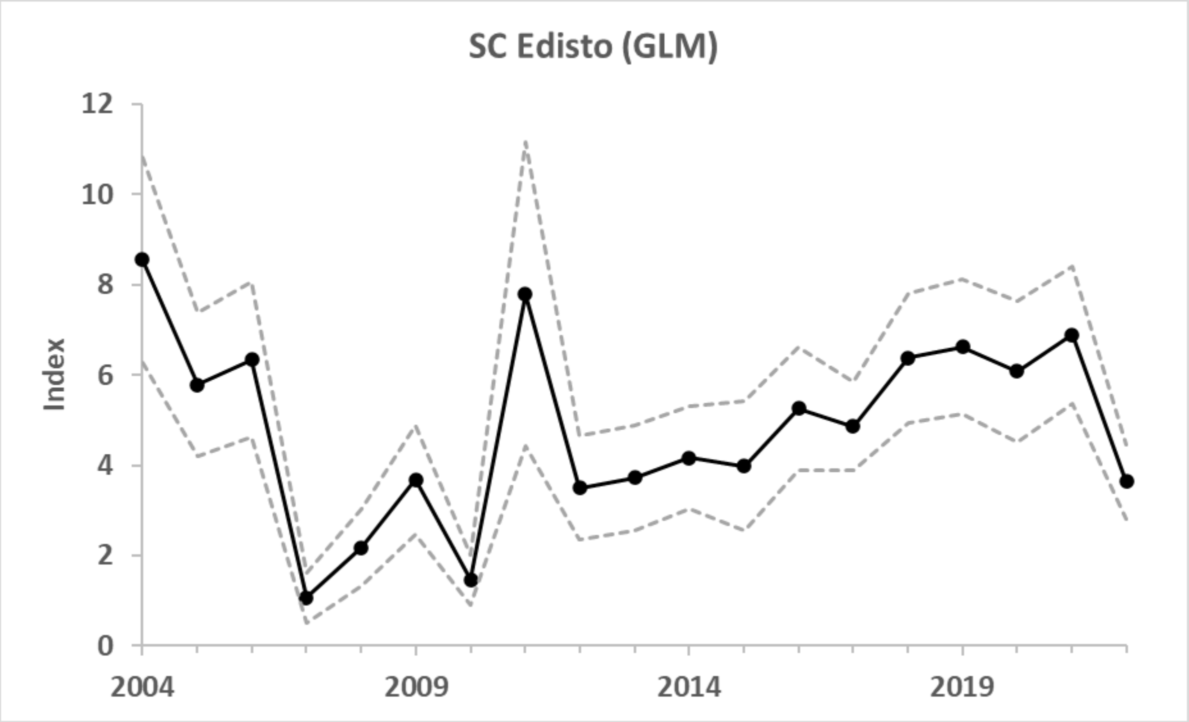


Figure A21. Standardized index of relative abundance of Atlantic sturgeon developed from the SC Edisto Survey with 95% confidence intervals.

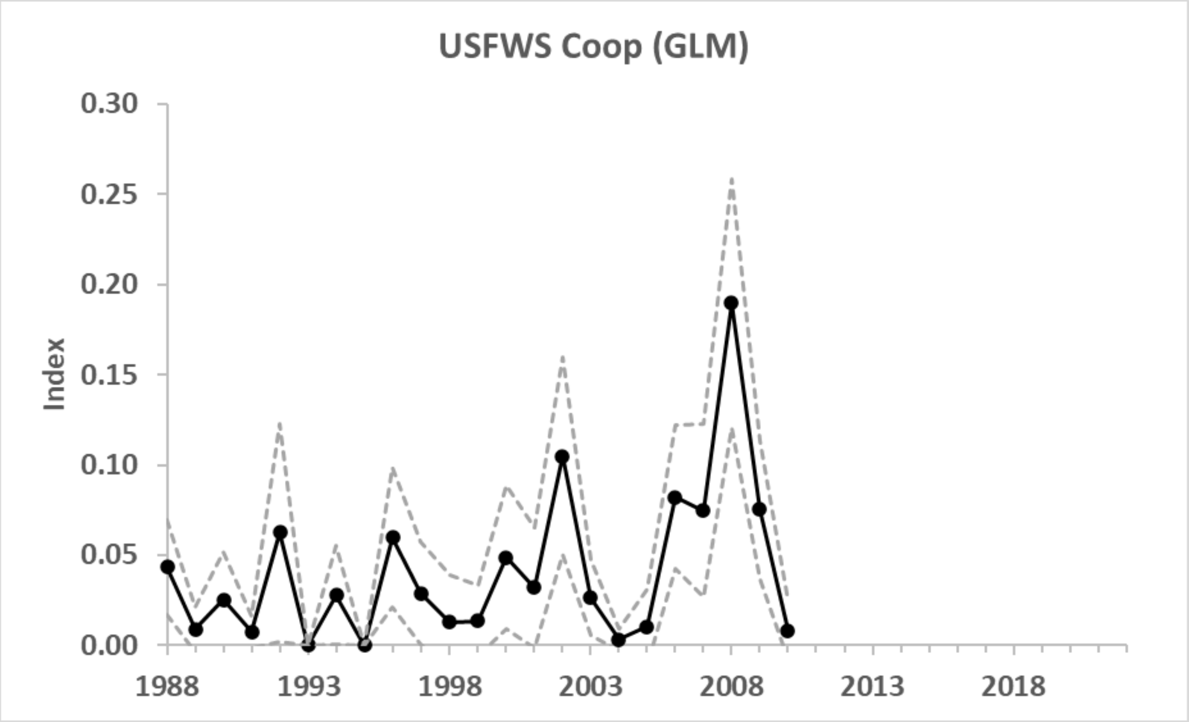


Figure A22. Standardized index of relative abundance of Atlantic sturgeon developed from the USFWS Cooperative Cruise with 95% confidence intervals.

c. Supplemental ARIMA Results

Gulf of Maine DPS

Maine-New Hampshire Trawl Survey

Descriptive statistics for the ME-NH Trawl Survey ARIMA are provided in Table 11. The fitted index started at the time series high value, has oscillated over time, generally decreasing, and ended the time series at a comparatively low level (Figure 13-Figure 15). The Mann-Kendall test did detect a significant (α = 0.05) declining trend in the time series. The terminal year index is credibly above the 25th percentile of the timeseries, but not the index value at the start of the timeseries (Table 12). The retrospective analysis suggests that conclusions regarding comparisons between terminal year and start year are sensitive to the start year of the survey, but not against the 25th percentile of the time series (Figure 17-Figure 18).

New York Bight DPS

Connecticut Long Island Sound Trawl Survey (Fall)

Descriptive statistics for the CT LIST Survey (fall) ARIMA are provided in Table 11. The fitted index starts the time series at a comparatively high level, oscillated over time and in recent years is trending upwards, with the terminal year at a time series high (Figure 13-Figure 15). The Mann-Kendall test did not detect a significant (α = 0.05) trend in the time series. The terminal year index is credibly above the 25th percentile of the timeseries and the fitted value in 1998 (Table 12). The retrospective analysis suggests that these conclusions are not sensitive to the start year of the survey (Figure 17-Figure 18).

Connecticut Long Island Sound Survey (Spring)

Descriptive statistics for the CT LIST Survey (spring) ARIMA are provided in Table 11. The fitted index starts at the time series low, increased rapidly, peaking in 1994, declined over time through about 2015, before starting a modest upward trend (Figure 13-Figure 15). The Mann-Kendall test detected a significant (α= 0.05) downward trend in the time series. The terminal year index is credibly above the 25th percentile of the time series, but not the fitted index value in 1998 (Table 12). The retrospective analysis suggests that these conclusions are sensitive to the start year of the survey (Figure 17-Figure 18).

Connecticut Long Island Sound Survey (All Months)

Descriptive statistics for the CT LIST Survey (all months) ARIMA are provided in Table 11. The fitted index starts near the time series high, increased for 2 years before declining markedly through the late 1990s, after which the index stabilized through about 2013. The index declined after 2013 but has increased slightly in the most recent 2 years available (Figure 13-Figure 15). The Mann-Kendall test detected a significant (α = 0.05) downward trend in the time series. The terminal year index is not credibly above the 25th percentile of the time series or the fitted index value in 1998 (Table 12). The retrospective analysis suggests that these conclusions are sensitive to the start year of the survey (Figure 17-Figure 18).

New York JASAMP

Descriptive statistics for the JASAMP Survey ARIMA are provided in Table 11. The fitted index has oscillated over time, with a declining trend in the most recent several years, ending the time series at a value near where it began (Figure 13-Figure 15). The Mann-Kendall test did not detect a significant (α = 0.05) trend in the time series. The terminal year index is credibly above the 25th percentile of the time series and the fitted index value from the start of the time series (Table 12). Figure 13 shows that the point estimate of the terminal year index is below the index value from the first year of the survey, but the distribution of bootstrapped values validates the Table 12 conclusion. The retrospective analysis suggests that these conclusions are sensitive to the start year of the survey with respect to comparison against the 25th percentile, but not against the start year of the survey (Figure 17-Figure 18).

New Jersey Ocean Trawl

Descriptive statistics for the NJ Ocean Trawl Survey ARIMA are provided in Table 11. The fitted index declined through the mid-1990s (the time of commercial fishery closure in NJ) after which it increased, initially peaking in the mid-2000s, before dipping slightly and again rising to a time series high (Figure 13-Figure 15). The Mann-Kendall test detected a significant (α = 0.05) increasing trend in the time series. The terminal year index is credibly above the 25th percentile of the time series and the fitted index value in 1998 (Table 12). The retrospective analysis suggests that these conclusions are not sensitive to the start year of the survey (Figure 17-Figure 18).

Chesapeake Bay DPS

VIMS-James, York, and Rappahannock Rivers (Spring)

Descriptive statistics for the VIMS-JYR Survey (spring) ARIMA are provided in Table 11. The fitted index has oscillated over time, starting near the time series high, reaching a comparable level near the middle of the time series, and ending at the time series high (Figure 13-Figure 15). The Mann-Kendall test did not detect a significant (α = 0.05) trend in the time series. The terminal year index is credibly above the 25th percentile of the time series but not the fitted index value in 1998 (Table 12). The retrospective analysis suggests that conclusions regarding comparisons between terminal year and 1998 are sensitive to the start year of the survey, but not against the 25th percentile of the time series (Figure 17-Figure 18).

VIMS-James River (Spring)

Descriptive statistics for the VIMS-J Survey (spring) ARIMA are provided in Table 11. The fitted index started at the time series high, decreased dramatically through 2005, after which it varied without trend for the remainder of the time series (Figure 13-Figure 15). The Mann-Kendall test detected a significant (α = 0.05) downward trend in the time series. The terminal year index is not credibly above the 25th percentile of the time series or the fitted index value in 1998 (Table 12). The retrospective analysis suggests that these conclusions are sensitive to the start year of the survey (Figure 17-Figure 18).

Carolina DPS

North Carolina p135 (YOY and Juvenile; Spring)

Descriptive statistics for this survey ARIMA are provided in Table 11. The fitted index started at the time series low value but has generally increased over time (save a relatively steep decline between 2001-2004), ending at time series high value (Figure 13-Figure 15). The Mann-Kendall test detected a significant (α = 0.05) increasing trend in the time series. The terminal year index is credibly above the 25th percentile of the time series and the fitted index value in 1998 (Table 12). The retrospective analysis suggests that these conclusions are not sensitive to the start year of the survey (Figure 17-Figure 18).

North Carolina p135 (YOY; Spring)

Descriptive statistics for this survey ARIMA are provided in Table 11. The fitted index started at the time series low value, generally increased through 2002, subsequently decline through 2007, before generally gradually increasing (Figure 13-Figure 15). The Mann-Kendall test detected a significant (α = 0.05) increasing trend in the time series. The terminal year index is credibly above the 25th percentile of the time series and the fitted index value in 1998 (Table 12). The retrospective analysis suggests that these conclusions are not sensitive to the start year of the survey (Figure 17-Figure 18).

North Carolina p135 (Juvenile; Spring)

Descriptive statistics for this survey ARIMA are provided in Table 11. The fitted index started at the time series low value, increased through 2013, and has since oscillated (Figure 13-Figure 15). The Mann-Kendall test detected a significant (α = 0.05) increasing trend in the time series. The terminal year index is credibly above the 25th percentile of the time series and the fitted index value in 1998 (Table 12). The retrospective analysis suggests that these conclusions are not sensitive to the start year of the survey (Figure 17-Figure 18).

North Carolina p135 (YOY and Juvenile; Fall)

Descriptive statistics for this survey ARIMA are provided in Table 11. The fitted index declined over the first several years of the survey before generally increasing over time, ending at a time series high value (Figure 13-Figure 15). The Mann-Kendall test detected a significant (α = 0.05) increasing trend in the time series. The terminal year index is credibly above the 25th percentile of the time series and the fitted index value in 1998 (Table 12). The retrospective analysis suggests that these conclusions are not sensitive to the start year of the survey (Figure 17-Figure 18).

North Carolina p135 (YOY; Fall)

Descriptive statistics for this survey ARIMA are provided in Table 11. The fitted index started at the time series high value, declined dramatically through 1993 before generally increasing over the remainder of the time series (Figure 13-Figure 15). The Mann-Kendall test detected a significant (α = 0.05) increasing trend in the time series. The terminal year index is credibly above the 25th percentile of the timeseries and the fitted index value in 1998 (Table 12). The retrospective analysis suggests that these conclusions are not sensitive to the start year of the survey (Figure 17-Figure 18).

North Carolina p135 (Juvenile; Fall)

Descriptive statistics for this survey ARIMA are provided in Table 11. The fitted index started near the time series low value, but generally increased over time, ending at a time series high value (Figure 13-Figure 15). The Mann-Kendall test detected a significant (α = 0.05) increasing trend in the time series. The terminal year index is credibly above the 25th percentile of the time series and the fitted index value in 1998 (Table 12). The retrospective analysis suggests that these conclusions are not sensitive to the start year of the survey (Figure 17-Figure 18).

USFWS

Descriptive statistics for this survey ARIMA are provided in Table 11. No additional years of data are available since ASMFC (2017), and so the results are identical to those reported there. In short, the fitted index started at the time series high value, decreased through 2006 before generally increasing over the remainder of the time series (Figure 13-Figure 15). The Mann-Kendall test did not detect a significant (α = 0.05) trend in the time series. The terminal year index is credibly above the 25th percentile of the timeseries but not the fitted index value in 1998 (Table 12). The retrospective analysis suggests that conclusions regarding comparisons between terminal year and 1998 are sensitive to the start year of the survey, but not against the 25th percentile of the time series (Figure 17-Figure 18).

South Atlantic DPS

SC Edisto

Descriptive statistics for this survey ARIMA are provided in Table 11. The fitted index started at the time series high value, decreased through 2008 before increasing through 2020; the index has since declined slightly (Figure 13-Figure 15). The Mann-Kendall test detected a significant (α = 0.05) increasing trend in the time series. The terminal year index is credibly above the 25th percentile of the time series but not the fitted index value from the start of the survey (Table 12). The retrospective analysis suggests that conclusions regarding comparisons between terminal year and start year are sensitive to the start year of the survey, but not against the 25th percentile of the time series (Figure 17-Figure 18).

NYB-CB-C DPSs

NEAMAP

Descriptive statistics for this survey ARIMA are provided in Table 11. The fitted index oscillated over the first decade of the time series and has been increasing since, ending at a time series high value (Figure 13-Figure 15). The Mann-Kendall test did not detect a significant ($\alpha = 0.05$) trend in the time series. The terminal year index is credibly above the 25th percentile of the time series and the fitted index value from the start of the survey (Table 12). The retrospective analysis suggests that these conclusions are not sensitive to the start year of the survey (Figure 17-Figure 18).

Coastwide (All DPSs)

Conn Index

Descriptive statistics for this survey ARIMA are provided in Table 11. The fitted index declined over the first several years before increasing through 2005; the index declined slightly for several years afterwards, before increasing to a time series high in 2021, and declined slightly in 2022 (Figure 13-Figure 15). The Mann-Kendall test detected a significant ($\alpha = 0.05$) increasing trend in the time series. The terminal year index is credibly above the 25th percentile of the time series and the fitted index value from the start of the survey (Table 12). The retrospective analysis suggests that these conclusions are not sensitive to the start year of this index (Figure 17-Figure 18).

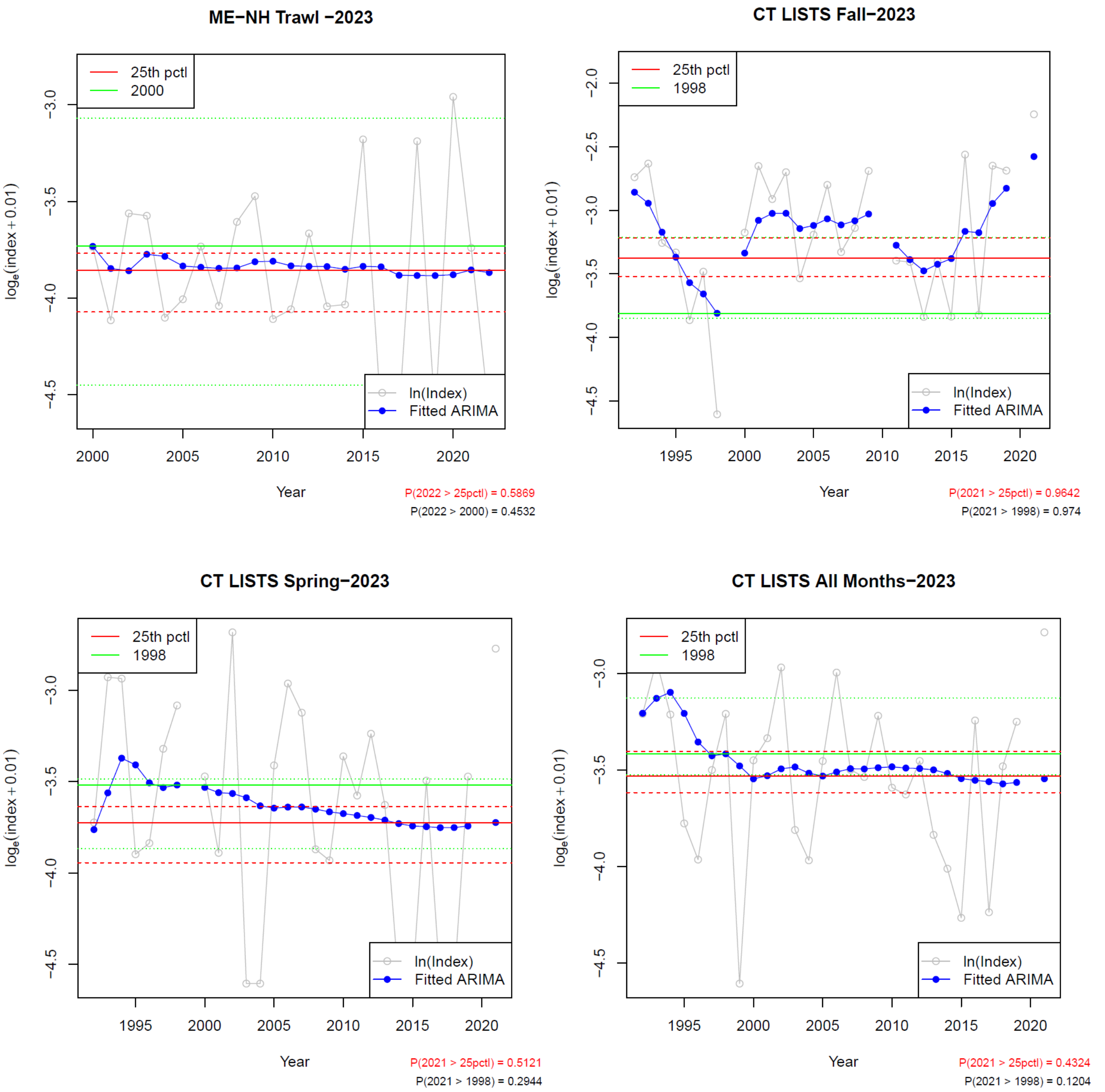


Figure A1. ARIMA-fitted indices used to establish stock status (solid blue line) plotted with the reference values. The dashed red and green lines represent the 80% confidence intervals around the reference values. The grey line with circles is the raw index input to ARIMA. Probability of exceeding reference points is provided in bottom-right margin of plots. Figures continue on the following pages.

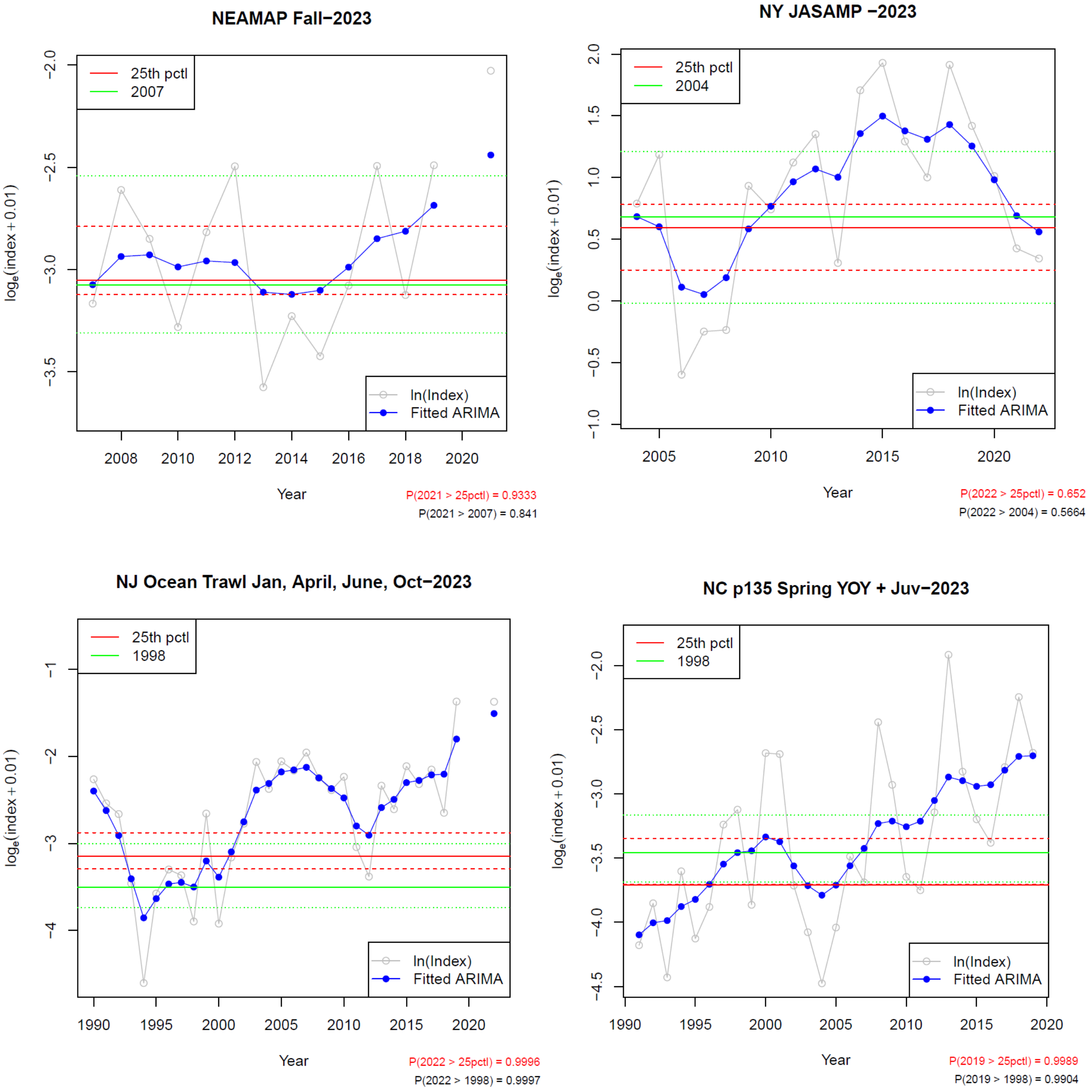
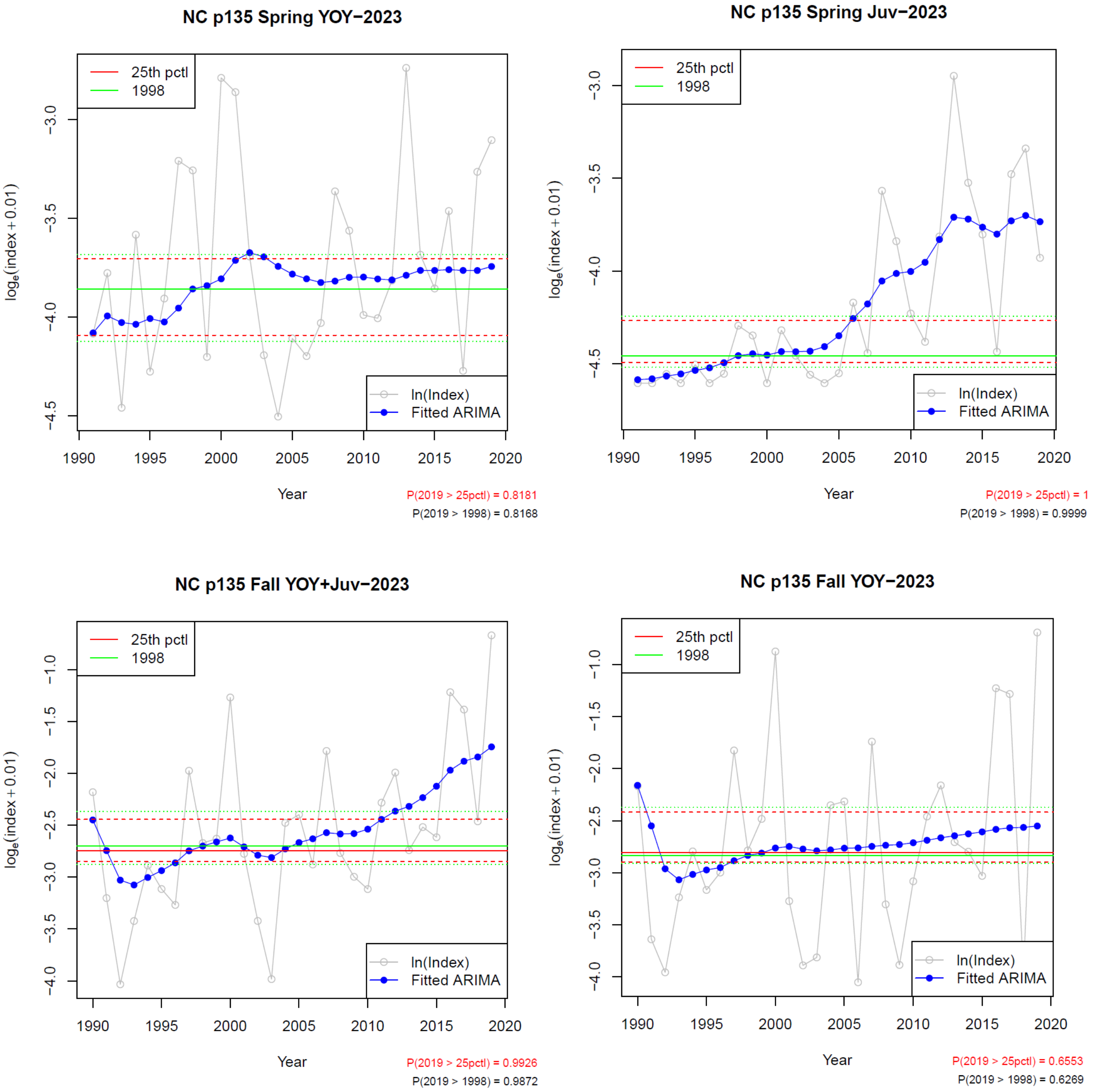


Figure A18 Continued.



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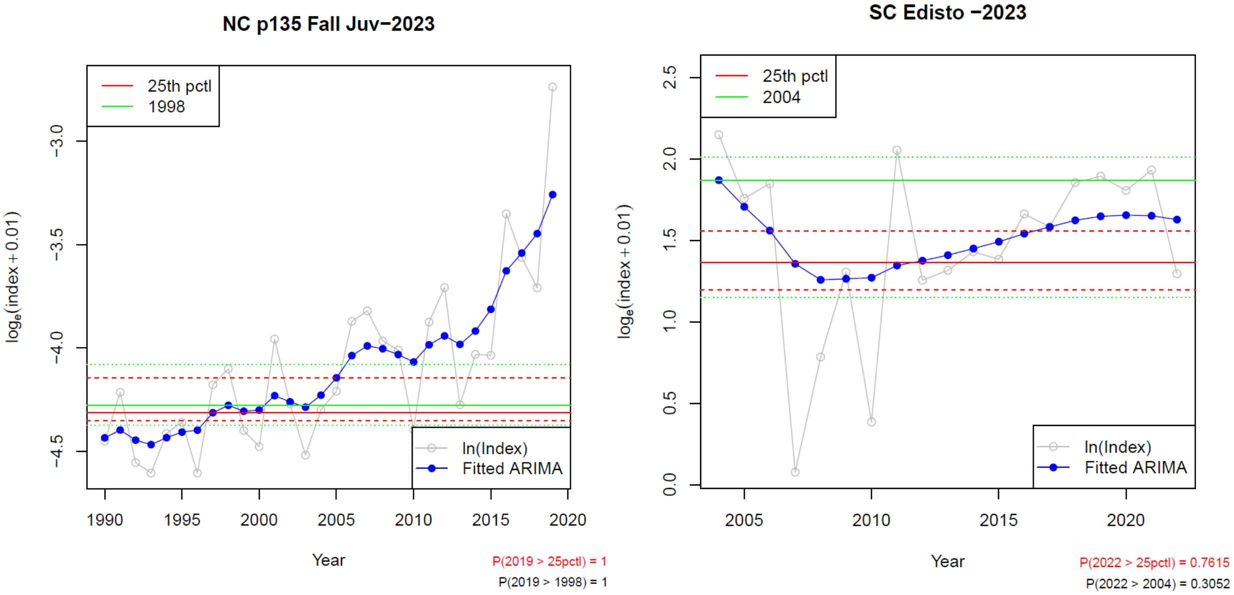

Figure A18 Continued.

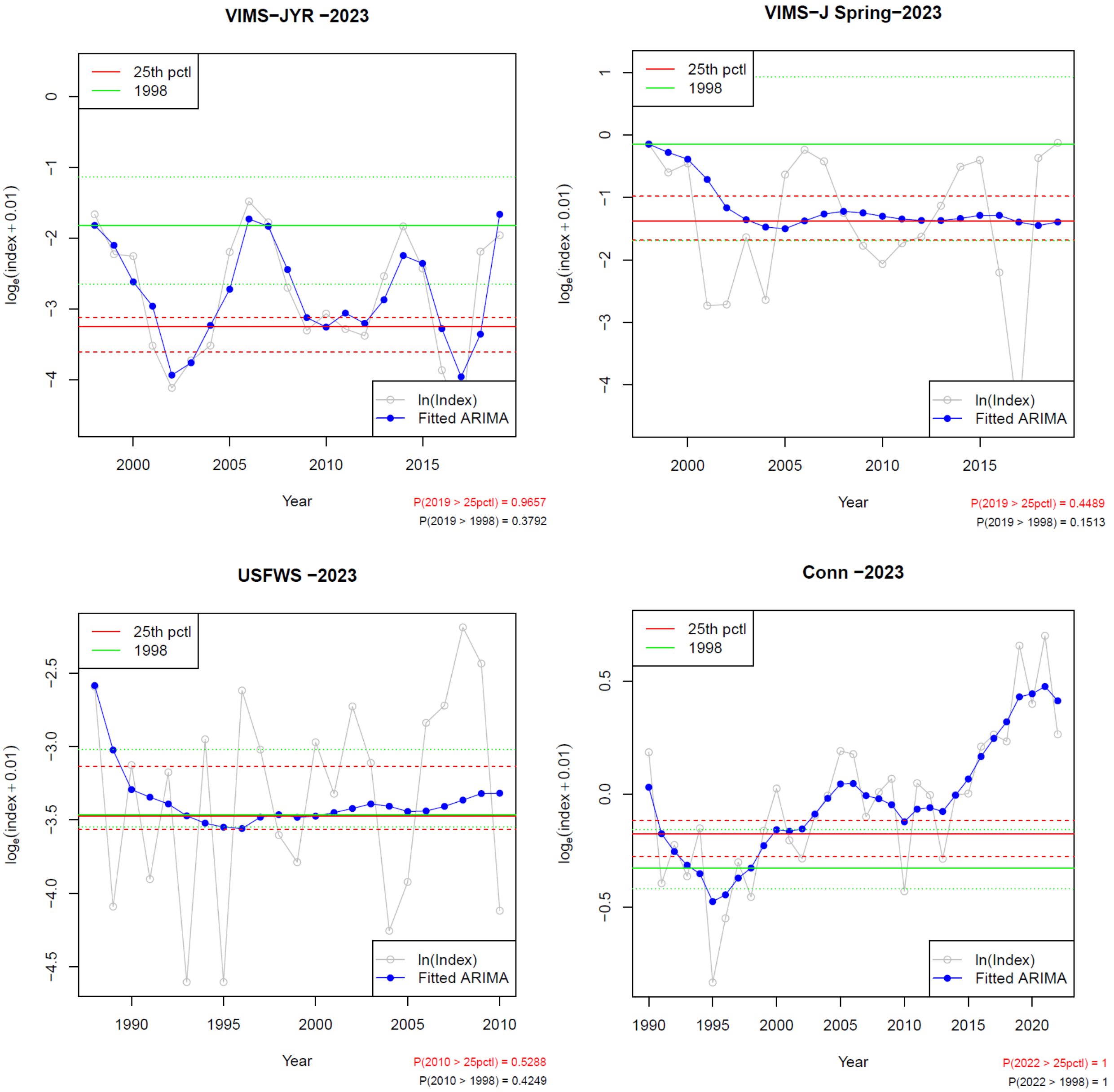

Figure A18 Continued.

d. 2017 Benchmark Research Recommendations

The following is the complete list of research recommendations from the benchmark assessment (ASMFC 2017).

Research recommendations have been categorized as future research, data collection, and assessment methodology and ranked as high or moderate priority. Recommendations with asterisks (**) indicate improvements that should be made before initiating another benchmark stock assessment.

Future Research

High Priority

Identify spawning units along the Atlantic coast at the river or tributary and coast-wide level.

**Expand and improve the genetic stock definitions of Atlantic sturgeon, including developing an updated genetic baseline sample collection at the coast-wide, DPS, and river-specific level for Atlantic sturgeon, with the consideration of spawning season-specific data collection.

Determine habitat use by life history stage including adult staging, spawning, and early juvenile residency.

Expand the understanding of migratory ingress of spawning adults and egress of adults and juveniles along the coast.

Identify Atlantic sturgeon spawning habit through the collection of eggs or larvae.

Investigate the influence of warming water temperatures on Atlantic sturgeon, including the effects on movement, spawning, and survival.

Moderate Priority

Evaluate the effects of predation on Atlantic sturgeon by invasive species (e.g., blue and flathead catfish).

Data Collection

High Priority

**Establish regional (river or DPS-specific) fishery-independent surveys to monitor Atlantic sturgeon abundance or expand existing regional surveys to include annual Atlantic sturgeon monitoring. Estimates of abundance should be for both spawning adults and early juveniles at age. See Table 8 in ASMFC 2017 for a list of surveys considered by the SAS.

**Establish coast-wide fishery-independent surveys to monitor Atlantic sturgeon mixed stock abundance or expand existing surveys to include annual Atlantic sturgeon monitoring. See Table 8 in ASMFC 2017 for a list of surveys considered by the SAS.

**Continue to collect biological data, PIT tag information, and genetic samples from Atlantic sturgeon encountered on surveys that require it (e.g., NEAMAP). Consider including this level of data collection from surveys that do not require it.

**Encourage data sharing of acoustic tagged fish, particularly in underrepresented DPSs, and support programs that provide a data sharing platform such as The Atlantic Cooperative Telemetry Network. Data sharing would be accelerated if it was required or encouraged by funding agencies.

**Maintain and support current networks of acoustic receivers and acoustic tagging programs to improve the estimates of total mortality. Expand these programs in underrepresented DPSs.

**Collect DPS-specific age, growth, fecundity, and maturity information.

**Collect more information on regional vessel strike occurrences, including mortality estimates. Identify hot spots for vessel strikes and develop strategies to minimize impacts on Atlantic sturgeon.

**Monitor bycatch and bycatch mortality at the coast-wide level, including international fisheries where appropriate (i.e., the Canadian weir fishery). Include data on fish size, health condition at capture, and number of fish captured.

Assessment Methodology

High Priority

**Establish recovery goals for Atlantic sturgeon to measure progress of and improvement in the population since the moratorium and ESA listing.

**Expand the acoustic tagging model to obtain abundance estimates and incorporate movement.

Moderate Priority

Evaluate methods of imputation to extend time series with missing values. ARIMA models were applied only to the contiguous years of surveys due to the sensitivity of model results to missing years observed during exploratory analyses.