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United States Research Report for 2022

by

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A. Status of the Fisheries (Subareas 3- 6 Inclusive)

Revised sampling and protocols were implemented in the Northeast Region in 1994, in 2004, in 2010 and in 2020. Auditing and allocation procedures have been used to prorate total reported landings by species among areas. However, these procedures are subject to change and the landings, by area, are still considered provisional.

Most spring and autumn survey indices for 2009-2022 were converted from the FSV *Henry B. Bigelow* catches (weights) to RV *Albatross IV* catches (weights) using either a single conversion factor or length-specific conversion factors which have only been estimated for some species. Consequently, 2009-2021 survey data points should be interpreted cautiously, and these values may change in the future as new methodologies are considered. The 2009-2022 data points have been plotted separately in the figures presenting spring and fall survey data. In 2014, the spring survey did not cover a large portion of the Mid-Atlantic region and this impacted the survey indices for summer flounder, southern red hake, Atlantic mackerel, Atlantic herring, spiny dogfish and little skate. The impact differs for each species and this is discussed in those sections. In 2017, the fall survey did not cover the Southern New England to Mid-Atlantic region and this has impacted the survey indices for Southern New England yellowtail flounder, southern windowpane flounder, southern silver hake, butterfish, longfin inshore squid, shortfin squid, winter skate, barndoor skate, thorny skate, smooth skate, clearnose skate, and rosette skate. The impact differs for each species and this is discussed in those sections. Additionally, the survey was conducted on a different vessel the FSV *Pisces*, which is considered a sister ship of the FSV *Henry B. Bigelow*. The impact of this change is unknown but should be minimal. The spring survey in 2020 was only partially conducted covering NAFO Subarea 6 aboard the FSV *Henry B. Bigelow*. Due to COVID-19 only 133 stations out of the normal 350-380 were successfully completed. No fall survey was conducted. Therefore, the survey data for all species sections do not include 2020 surveys.

Since 2012, the United States has been transferred quota for Div. 3LNO yellowtail flounder from Canada and, from 2012-2021 at least one vessel fished in the area. In 2022, the US did not have a vessel fish in the NAFO Regulatory Area.

1. **Atlantic Cod**

United States commercial landings of Atlantic cod (*Gadus morhua*) in 2022 were 506 mt, a 16% decrease from the 2021 landings of 601 mt.

Northeast Fisheries Science Center (NEFSC) research vessel survey biomass indices of Gulf of Maine cod remain below time series mean levels (Figure 1) and the stock continues to exhibit a truncated age structure and low recruitment. The NEFSC research vessel survey biomass indices for the Georges Bank stock remain low (Figure 2) and the stock continues to exhibit a truncated age structure and exhibit low recruitment.

2. **Haddock**

United States commercial landings of haddock (*Melanogrammus aeglefinus*) in 2022 were 5,057 mt, a 32% decrease from the 2021 landings of 7,413 mt.

Northeast Fisheries Science Center (NEFSC) research vessel survey biomass indices in the Gulf of Maine have declined from recent historical high levels and are below the time series average in the Fall survey, but above the average in the Spring survey (Figure 3). The NEFSC research vessel survey biomass indices for the Georges Bank stock have declined from recent historic high levels; both the fall and spring biomass indices are below the time series average (Figure 4).

3. **Redfish**

USA commercial landings of Acadian redfish (*Sebastes fasciatus*) decreased by 33% from 5,652 mt in 2021 to 3,791 mt in 2022. Fall research vessel survey biomass indices generally increased from the mid-1990s to a record-high index value of 77.05 kg/tow in 2010 (Figure 5). The survey biomass indices have generally decreased since the peak in 2010. Most recently, the survey biomass indices decreased by 4% from 23.70 kg/tow in 2021 to 22.80 kg/tow in 2022.

4. **Pollock (USA Waters of Areas 5&6 stock)**

USA commercial landings of pollock (*Pollachius virens*) decreased by 1% from 3,364 mt in 2021 to 3,331 mt in 2022. Fall research vessel survey biomass indices generally increased from the mid-1990s through 2005, before decreasing in 2006 (Figure 6). The survey biomass indices have been variable since 2006, reaching a record-low of 0.18 kg/tow in 2009. Most recently, the index increased by 555% from 0.34 kg/tow in 2021 to 2.24 kg/tow in 2022.

5. **White Hake**

Nominal USA landings of white hake (*Urophycis tenuis*) from NAFO Subareas 5 and 6 decreased by 13% from 2,101 mt in 2021 to 1,828 mt in 2022. Research vessel survey indices declined during the 1990s and increased in 2000 due to good recruitment of the 1998 year class. The indices have generally been variable since 2001. The indices have been stable since 2013 (Figure 7).

6. **Yellowtail Flounder**

USA landings of yellowtail flounder (*Limanda ferruginea*) from NAFO subareas 5 and 6 were 227 mt in 2022, a 23% decrease from 2021 landings of 294 mt.

The NEFSC autumn survey biomass index in the Gulf of Maine has generally been variable since 2008. Most recently, the index increased by 61% from 4.7 kg/tow in 2021 to 7.6 kg/tow in 2022 (Figure 8). On Georges Bank, the NEFSC autumn survey has remained low since 2010 and was the lowest in the time series in 2022. The Southern New England-Mid Atlantic yellowtail NEFSC autumn survey index is also at low levels and decreased further in 2022 compared to 2021 (0.0032 kg/tow in 2021 to 0.0027 kg/tow in 2022 - Figure 9).

7. Other Flounders

USA commercial landings of flounders (other than yellowtail flounder and Atlantic halibut) from Subareas 3-6 in 2022 totaled 7,487 mt, 11% higher than in 2021. Summer flounder (*Paralichthys dentatus*; 76%), witch flounder (*Glyptocephalus cynoglossus*; 10%), American plaice (*Hippoglossoides platessoides*; 10%), winter flounder (*Pseudopleuronectes americanus*; 4% comprising the Georges Bank, Southern New England, and Gulf of Maine stocks), and windowpane flounder (*Scophthalmus aquosus*; <1% comprising the Northern and Southern stocks) accounted for virtually all of the 'other flounder' landings in 2022. Compared to 2021, commercial landings in 2022 were lower for windowpane flounder (-41%), winter flounder (-29%), and witch flounder (-5%) but higher for summer flounder (18%) and American plaice (12%). In 2022, there was no catch from Div. 3N by US vessels.

Research vessel survey indices in 2022 increased for Georges Bank winter flounder, decreased for summer flounder while American plaice, witch flounder, northern windowpane and southern windowpane remained relatively unchanged (Figures 11-16).

8. Atlantic halibut

USA landings of Atlantic halibut (*Hippoglossus hippoglossus*) in the Gulf of Maine-Georges Bank region decreased 25% from 37.9 mt in 2021 to 28.5 mt in 2022. Research vessel survey indices have little trend and high interannual variability due to the low capture rate of Atlantic halibut (Figure 17). In some years there are no Atlantic halibut caught, indicating that abundance is close to being below the detectability level of the survey. Indices for 2009 – 2022 were converted from FSV *Henry .B. Bigelow* units to RV *Albatross IV* units using the mean calibration coefficient of other flounders.

9. Silver hake

USA landings of silver hake (*Merluccius bilinearis*) from NAFO subareas 5 and 6 increased compared to 2021. In 2022, US commercial landings of silver hake totaled 4,479 mt, a 2% difference compared to 2021 of 4,398 mt.

The NEFSC autumn research vessel survey biomass indices for northern silver hake have generally been increasing over the last ten years. Most recently, the NEFSC autumn survey biomass index increased by 157% from 16.05 kg/tow in 2021 to 41.00 kg/tow in 2022 (Figure 18). In the south, the NEFSC autumn survey index has also been increasing albeit with incomplete coverage in 2017. Most recently, the autumn index increased by 93% from 0.71 kg/tow in 2021 to 1.37 kg/tow in 2022 (Figure 19).

10. Red Hake

USA landings of red hake (*Urophycis chuss*) decreased for the 5th year in a row to just 179 mt in 2022, a more than 60% decline from 2018. Research vessel survey biomass indices for the Gulf of Maine - Northern Georges Bank stock increased after the early 1970s then declined in the early 2000s, but have increased in recent years (Figure 20). In 2022, the NEFSC spring biomass index was 6.5 kg/tow, the highest in the 1968-2022 time series. Indices for the Southern Georges Bank - Mid-Atlantic stock declined in the 1990s and in most years have remained below 1 kg/tow (Figure 21).

11. Butterfish

USA landings of butterfish (*Peprilus triacanthus*) decreased 30.9% from 3432 mt in 2019 to 2370 mt in 2020. Fall research vessel survey biomass indices have fluctuated since the 1970s, but were generally highest in the late 1970s to early 1990s. Since 1995, annual values have averaged 4.37 kg/tow. Biomass in 2017 was NA due to limited sampling of butterfish strata (Figure 22).

12. Atlantic Sea Scallops

USA Atlantic sea scallop (*Placopecten magellanicus*) landings in 2022 were 14,323 mt (meats), a decline of over 5000 mt from 2021. Ex-vessel value of the landings was about $476 million, a decline of over $190 million from 2021. These declines reflect the depletion of the large 2012 and 2013 year classes and the subsequent below average recruitment from 2014-2021.

Biomass in federally managed waters in 2022, based on dredge and optical surveys, was 56,116 mt (meats) on Georges Bank, 22,036 mt (meats) in the Mid-Atlantic Bight, and 1808 mt (meats) in the Gulf of Maine, for a total of 79,960 mt (meats). This is the lowest biomass observed since 1999. The stock has dropped below B_{MSY}, although it remains well above the overfished threshold of ½ B_{MSY}. Substantial recruitment was observed in deep water on the northern flank of Georges Bank and in the Great South Channel. Recruitment in the Mid-Atlantic was about average.

13. Northern Shrimp

The USA fishery for northern shrimp has been closed since 2014 due to extremely low abundance of all life stages based on fishery independent surveys of northern shrimp in the Gulf of Maine.

14. Spiny Dogfish

USA landings of spiny dogfish (*Squalus acanthias*) increased by 1.4% from 4,720 mt in 2021 to 4,786 mt in 2022. Survey indices of males and females combined, which are highly variable, generally declined between the early 1990s and 2005, but increased sharply in 2006 and have since generally remained high (Figure 23). The indices for males and females are also plotted separately and show diverging patterns. The male index has been stable and then increased in the last few years. The female index tends to drive the overall index showing a decline between the early 1990s and 2005 and then increasing. The 2022 index for females is the lowest in the time series.

15. Skates

USA nominal landings of skates increased 4.9% from 9,197 mt in 2021 to 9,645 mt in 2022. The landings are sold as wings for human consumption and as bait for the lobster fishery. Landings have increasingly been reported by species, however 732 mt were reported as unclassified in 2022, an increase from 4.3% to 7.6% of the total.

Winter Skate

Winter skate (*Leucoraja ocellata*) reported landings increased by 4.8% between 2021 and 2022 from 5,423 mt to 5,682 mt. For the survey, adjustment for the lack of coverage in the Southern New England and the Mid-Atlantic strata for fall 2017 was described in 2019 (SCS 19/15). A similar adjustment was made to account for missing strata in the north in 2018. Survey biomass indices for winter skate peaked in the mid-1980s (Figure 24) but then declined, possibly due to an increase in the directed fishery in the late 1980s and early 1990s. During the mid-1990s, the indices stabilized at an intermediate level, increased and generally remained at a slightly higher level with some peaks in 2009 and 2019.

Little Skate

Reported landings of little skate (*Leucoraja erinacea*) were similar between 2021 and 2022 at 2,923 mt and 2,929 mt. For the survey, the adjustment for the lack of coverage in the southern strata described above for spring 2014 was described in 2015 (SCS 15/09). Little skate survey indices have generally fluctuated without trend but the 2021-2022 values are lower than 2017-2019 (Figure 25).

Barndoor Skate

Landings of barndoor skate (*Dipturus laevis*) were allowed starting in 2018. Reported landings decreased 27% between 2021 and 2022 from 198 mt to 146 mt. The adjustment for the lack of coverage in the Southern New England strata was described in 2019 (SCS 19/15). In 2018, a similar adjustment was made to account for missing strata in the north. Survey indices declined markedly in the mid-1960s and remained very low through the late-1980s. Biomass indices subsequently increased to levels observed in the early1960s and were the highest in the time series in 2018 (Figure 26). While the subsequent years are lower than 2018, the values remain similar to those in the early 1960s.

Thorny Skate

There has been a possession prohibition on landings of thorny skate (*Amblyraja radiata*) in United States waters since 2003. Some landings still occur due to the high volume nature of the fishery. Reported landing increased from 0.003 mt in 2021 to 0.044 mt. in 2022. The adjustment for the lack of coverage in the Southern New England strata was described in 2019 (SCS 19/15). In 2018, a similar adjustment was made to account for missing strata in the north. Thorny skate survey indices have declined over the entire time series, and are currently near record lows (Figure 27).

Smooth Skate

There has been a possession prohibition on landings of smooth skate (*Malacoraja senta*) in the Gulf of Maine (NAFO Div. 5Y) since 2003 although landings are permitted in other parts of the United States. Smooth skate reported landings decreased by 40% between 2021 and 2022 from 239.7 mt to 144.0 mt. The adjustment for the lack of coverage in the Southern New England strata was described in 2019 (SCS 19/15). In 2018, a similar adjustment was made to account for missing strata in the north. Survey indices for smooth skate are highly variable, but were been generally stable from the 1980s through 201 (Figure 28). The last two years are lower than 2014-2019.

Clearnose Skate

Clearnose skate (*Raja eglanteria*) reported landings decreased by 12% between 2020 and 2021 from 14.6 mt to 12.8 mt. There were no indices available for 2017 since the strata set was not covered. Indices generally increased between 1995 and 2010 (Figure 29) but have been mostly stable over the last decade.

Rosette Skate

Rosette skate (*Leucoraja garmani*) reported landings were zero in 2021 and 2022. There were no indices available for 2017 since the strata set was not covered. Indices generally increased between 1995 and 2010 (Figure 30) but have been stable since.

B. Special Research Studies

1. Environmental Studies

A total of 1123 CTD (conductivity, temperature, depth) profiles were collected and processed by the Northeast Fisheries Science Center (NEFSC) in 2022 over the course of 9. Of this total, 1,012 CTD profiles were obtained within NAFO Subareas 5 and 6, and 55 profiles were collected in NAFO Subarea 4. These data are archived in an oracle database. Cruise reports, and annual hydrographic summaries are accessible at: https://www.fisheries.noaa.gov/new-england-mid-atlantic/science-data/ecosystem-monitoring-northeast-us-continental-shelf-survey. Data are publicly available from the World Ocean Database maintained by NOAA's National Centers for Environmental Information at: http://www.nodc.noaa.gov/OC5/SELECT/dbsearch/dbsearch.html

Hourly bottom temperature records were obtained by participants in the Environmental Monitors on Lobster Traps program at 17 fixed locations / depths around the Gulf of Maine and Southern New England Shelf. The results indicate that 2022 was, in general, warmer relative to the decades of data program participants have already collected. This trend is most pronounced in the second half of the year, with the majority of sites reporting significant annual increases (0.08 - 0.19 °C / year) in monthly average temperatures from July - November. Data are available via the NEFSC ERDDAP server. Real-time bottom temperatures have now been reported from over 60 vessels. Approximately 5700 haul-averaged bottom temperatures were automatically transmitted via satellite from a variety of locations and depths in 2022, bringing the program total to over 22,500 gear hauls. Observations from both fixed and mobile gear are compared to three different ocean models as well as empirically-derived climatology. The results are available in tabulated form and updated every 15 minutes. We continue our work to get the realtime data into an ERDDAP server to enable wider use of the data.

b) Plankton Studies

During 2022, field operations to monitor zooplankton community distribution and abundance returned to pre-covid levels of operation. 591 plankton tows were made over the course of 7 types of surveys, using 61 and 20 centimeter bongo nets. Each of these survey types covered a portion of the continental shelf between Cape Hatteras and the Gulf of Maine at different times of the year. These surveys included an East Coast Ocean Acidification (ECOA) cruise with 74 tows, North Atlantic Right Whale Surveys totaling 59 tows, a Spring Bottom Trawl Survey with 115 tows, a Fall Bottom Trawl Survey with 95 tows, the Spring Ecosystem Monitoring Survey with 138 tows, and a Fall Ecosystem Monitoring Survey with 86 tows. There was also a 7th category of Long Term Ecological Reserve (LTER) cruises that made 24 tows, done in conjunction with the Woods Hole Oceanographic Institution (WHOI) for the National Science Foundation (NSF), to study marine ecological processes over long time periods. All of these tows were made towing an array of 61 and 20 centimeter bongo nets simultaneously. The larger 61 centimeter diameter nets collected samples used for zooplankton and Ichthyoplankton distribution and abundance, while the smaller 20 centimeter nets provided plankton samples for the University of Connecticut and larval fish and eggs samples for the

NEFSC Oceans and Climate Branch. Operations with the Imaging FlowCytoBot from the Woods Hole Oceanographic Institute were continued in 2022 aboard both the Spring and Fall Ecosystem Monitoring (Ecomon) Surveys. The unit provided valuable data and plankton imagery during the Fall Ecomon Survey, but was inoperable for most of the Spring Ecomon Survey. Environmental DNA research continued in 2022 with a collection of environmental DNA samples on 32 water casts conducted during the Spring Ecosystem Monitoring Survey, for research being conducted at the NEFSC Milford Laboratory. In a continuation of a study that started in 2021, scientists aboard the 2022 Spring and Fall Ecosystem Monitoring Cruises collected pteropods from plankton samples at selected stations while at sea. By taking DIC water samples at these same stations, water acidity will be correlated to the pteropod shell thickness to explore the biogenic effects of increased acidity on calcium carbonate shell formation, in collaboration with researchers at the Bermuda Institute for Ocean Sciences (BIOS).

c) Benthic Studies

No field work done for 2022.

2. Biological Studies

a) Fish Species

Flatfishes: During 2015-2020, we implemented work on the plasticity of responses to high and variable thermal regimes and CO2, and the degree of intraspecific, inter-population differences in resilience to these climate-related environmental changes. We are interpreting these results in the context of differences in thermal and CO2 regimes between stocks that experience contrasting levels of environmental in situ. In 2019, we began a study of responses to elevated thermal and CO2 regimes for summer flounder (*Paralichthys dentatus*) offspring drawn from parents collected in New Jersey, near the northerly limits of its geographic range. The effort examined the early life-stage (ELS) responses to a large number of distinct thermal and CO2 regimes. Regarding thermal regimes, we used a large number of distinct constant thermal regimes on embryos (N=20 regimes) and larvae / young juveniles (N=11) as well as two seasonally varying regimes for larvae and young juveniles. Responses included effects on viability, growth, and development. Up to 12 different constant CO2 regimes were also evaluated under three different constant thermal regimes. A similar evaluation of effects of constant and variable thermal and CO2 regimes on winter flounder (*Psuedopleuronectes americanus*) was conducted in the winter 2019-2020.

Labrids: During 2022-2023 we initiated an aquaculture-related project on tautog (*Tautoga onitis*), funded by the Northeast Regional Aquaculture Center and Joint Project Agreement between the USA (NOAA) and the Republic of Korea (East Sea Fisheries Research Institute). Tautog is a candidate for aquaculture in the Northeast USA. It is a spring-spawning, cold-water wrasse (Labridae) that occupies inshore benthic waters with a high density of bottom structure. This research is addressing three fundamental questions about tautog ELS that are central to identifying optimal culture conditions for the production of juveniles. First, how does egg quality vary within the spawning season and among individual females? Second, what thermal regimes during the embryonic and larval life-periods maximize production of hatchlings and juveniles? Third, how does the density and quality (enrichment) of live feed, and the stocking density of larvae impact the number and quality of tautog entering the juvenile life stage? Three temporally displaced spawning tautog cohorts are being used to address these and related questions. To date, inter-female differences in egg sizes are being documented, and the thermal tolerances of their embryos, the functional form of embryonic period duration, the temperature-dependent size at hatch, and survival to hatch under a 14 °C temperature range have been described. Larval grow-out studies are currently underway. These data, collected by a team of government scientists and colleagues from the fish-farming industry, will be used as a basis of a bioeconomic model of tautog production in order to scope the feasibility of intensive tautog aquaculture.

Sturgeons: Macro-phenotypic data on effects of thermal regimes and of contaminants that were collected during 2014-2017 are being further analyzed for publication.

Forage fish: A set of studies on Atlantic silverside, *Menidia menidia*, continued through 2019. Those studies focus on effects of climate (thermal and CO2 variations), hypoxia, and parentage on key traits of the ELS. Those data are being further analyzed. An analogous system with a large number of treatment levels was developed in 2018 for dissolved oxygen and the first test used the fertilization rate of Atlantic silverside as the response variable. A clear, negative trend in fertilization rate occurred with increasing degrees of hypoxia.

Indicator species of toxicity: A study on the potential effects of contaminated sediments on finfish was initiated in 2020 and continued through 2022. Using white perch, *Morone americana*, as an indicator species but also an ecologically important one in estuaries and source river water in the Mid-Atlantic States, studies focused on evidence of reproductive impairment in fish inhabiting waterways of New Jersey known to have been subjected to contaminants. Adults are being assayed for evidence of impairment at the genetic to organismal levels. Sediments are being used for exposure experiments on the embryos and young larvae. The study includes fish populations and sediments from target (contaminated) and reference locations. The team participated with NYU colleagues in studies of per- and polyfluoroalkyl substances (PFAS). Using Atlantic silverside and mummichog (*Fundulus heteroclitus*) embryos as test subjects, the team compared the relative toxicities of three PFAS types among embryos from one (silverside) or three (mummichog) source populations.

b) Resource Survey Cruises

During 2022, personnel from the Ecosystems Surveys Branch (ESB) staged, staffed, and supported the spring and fall multi-species bottom trawl survey and the northern shrimp trawl survey. Additional staff and gear support was provided for the sea scallop dredge survey and the Atlantic surfclam dredge survey. In aggregate, the survey staff efforts totaled 162 research and charter vessel sea days. NOAA scientific and contract staff involvement in the various cruises totaled 1,933 person sea days. ESB cruises occupied 1,057 stations in an area extending from Cape Hatteras, North Carolina to Nova Scotia. A total of 412,720 length measurements were recorded, representing 1,659,100 individuals from 427 species during these cruises. Ecosystem survey data are used as fishery independent inputs for 48 single species stock assessments and for several ecosystem dynamics modeling efforts.

Significant effort was also expended in 2022 to fulfill special survey sampling requests from 40 NOAA and university investigators. This sampling included 12,800 feeding ecology observations, collection of 22,514 aging structures, and acquisition of 37,204 samples/specimens to support additional shore-based research. Additionally, the HabCam cruise tracks from the scallop survey completed 1,724 nm, collecting a total of 5.3 million image pairs.

c) Fishery Biology Program (https://www.fisheries.noaa.gov/new-england-mid-atlantic/science-data/age-and-growth-studies-northeast):

Fish age determinations by the Fishery Biology Program are used in age-structured single- and multi-species stock assessments for regions from the international (US-Canada) border regions in the Gulf of Maine and Georges Bank, south through the middle US Atlantic seaboard. These stock assessments serve as the basis for scientific advice to two federal fishery management councils (i.e., NEFMC, MAFMC).

In 2022, FBP staff provided ages for over 38,100 otoliths from 21 species. The top species by number aged were summer flounder (4,334), silver hake (3,833), and haddock (3,508). Large numbers of black sea bass, butterfish, white hake, scup, and winter flounder (combined total 13,576) were also aged. These data provide information on age composition, recruitment strength, and growth dynamics, which ultimately inform scientific determinations of stock status, biological reference points, and annual catch limits.

The FBP utilizes a robust set of QA/QC protocols to monitor and maintain 1) accuracy, 2) precision, and 3) inter-agency consistency in age determinations. Results of all these tests are posted publicly at https://fish.nefsc.noaa.gov/fbp/QA-QC/. The coefficient of variation is used to measure precision levels, with values under 5% deemed acceptable. Samples re-aged as part of this testing are not counted in the above totals.

1. Accuracy: Through the use of reference collections, personnel are regularly tested to measure whether there has been any deviation of their age estimates relative to a collection of consensus-aged samples. The Program currently has reference collections for 4 species and is currently working to build reference collections for additional species.

2. Precision: A subsample of recently-aged samples is re-aged blindly by personnel to quantify the random error of the age estimates. In addition, inter-reader precision tests are conducted when there is a change in the person responsible for ageing of a given species, and inter-structure tests are conducted when there is a change in the method for ageing. In 2022, 89 intra-reader precision tests were conducted across 20 species.

3. Inter-agency exchanges: For transboundary stocks, the FBP exchanges age structures with other laboratories. In 2022, 1 inter-agency exchange was conducted for haddock with the St. Andrews Biological Station (Fisheries and Oceans Canada),

d) <u>Food Web Dynamics</u>

The NEFSC collections of fish diet data as part of a long-term (since 1973) monitoring program continued in 2022 despite the COVID-19 pandemic. Along with these data, modeling and analytical efforts continued to focus on species interactions among small pelagics, flatfish, elasmobranchs, and gadiformes.

Fish diet samples were collected on the northeastern U.S. continental shelf (South-Atlantic Bight to Scotian shelf) during the NEFSC bottom trawl survey. Estimates of prey volume and composition were made primarily at sea for selected species. During 2022, stomachs from 6,953 individuals and 50 species were examined in the spring, and 5,897 individuals and 51 species were examined in the fall. Diet sampling emphasized gadiformes, elasmobranchs, small pelagics, flatfishes, and lesser-known species.

The time series of fish diet spans 50 years (1973-2022). The majority of the time series is available for analysis, including data from over 700,000 stomach samples and over 160 predators. Processing of the 2022 bottom trawl survey diet data is scheduled for completion in 2023.

These diet data undergo two rigorous data quality audits including initial checks at sea during sample collection, and secondary checks in the lab to ensure data quality. These checks consider the various facets of prey taxonomy, predator/prey mass, predator/prey length, and prevent missing information. In 2022, stomachs from juveniles (<=12 cm) routinely examined at sea were preserved for laboratory processing.

Since 2004, training workshops for identifying fish stomach contents and refreshing staff knowledge of marine invertebrate and fish taxonomy are offered once per year in the winter prior to the spring trawl survey. These workshops continued remotely in 2022 and provided class discussions and photos of specimens as aids for prey identification in association with the spring and autumn trawl surveys.

Staff prepared several papers and reports for publication and presentations on a wide range of trophic ecology issues in the Northwest Atlantic ecosystem. Since trophic interactions are central to food web and ecosystem considerations, research continues with respect to making fish diet metadata publically accessible; examining the trophic impact of species across estuarine, inshore, and offshore habitats; understanding the interaction of predation and bottom fishing effort on the seafloor relative to fish stock rebuilding; assessing trophic guilds across the North Atlantic; and incorporating fish consumption into stock assessments.

e) <u>Apex Predators Program</u>

Apex Predators Program (APP) research focused on determining migration patterns, age and growth, feeding ecology, reproductive biology, and relative abundance trends of highly migratory species, particularly Atlantic sharks. Members of the Cooperative Shark Tagging Program (CSTP), involving thousands of volunteer recreational and commercial fishers, scientists, and fisheries observers, continued to tag coastal and pelagic sharks and provide information to define essential fish habitat for shark species in U.S waters in 2022. Over 300,000 fish including more than 50 shark species have been tagged since this program was initiated in 1962 and recaptures include more than 30 of the shark species tagged. In 2022, CSTP movement and distribution data from spiny dogfish (*Squalus acanthias*) and shortfin mako (*Isurus oxyrinchus*) were used to inform the 2022 Research Track Assessment (RTA) for Northwest Atlantic Spiny Dogfish and a Species Review for the Endangered Species Act (ESA), respectively.

APP staff participated in the RTA process for northwest Atlantic spiny dogfish in 2022 and co-chaired the RTA Working Group. Staff provided data and analyses towards the RTA, presented on spiny dogfish movements during a stakeholder session, and presented two working papers on spiny dogfish age and growth from 2nd dorsal spines and distribution, movements, and growth from mark-recapture data. APP staff also participated in the Southeast Data Assessment and Review (SEDAR) 77 Assessment process in 2022. Staff presented updated discard mortality estimates for scalloped and smooth hammerheads (*Sphyrna lewini and S. zygaena*) using data from the Northeast Fisheries Observer Program and a spatiotemporal index of abundance for scalloped hammerhead from the NEFSC Coastal Shark Bottom Longline Survey. Additionally, staff presented a working paper on hierarchical recruitment indices of abundance for scalloped hammerheads in both the Atlantic and Gulf of Mexico (GOM) combined and separately for each area using data from the Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) surveys in the Atlantic and Gulf of Mexico Shark Pupping and Nursery (GULFSPAN) and the Texas Parks and Wildlife surveys in the GOM. APP staff also participated on the Shortfin Mako Extinction Risk Assessment Team in 2022 and contributed CSTP data and analyses for the Endangered Species Act Status Review for this species.

The NEFSC Coastal Shark Bottom Longline Survey began in 1986 and is conducted every two to three years. This survey is the longest running coast-wide (Florida to the Mid-Atlantic) fishery-independent shark survey in the U.S. Atlantic Ocean. The primary objective is to conduct a standardized, systematic survey of the shark populations off the U.S. Atlantic coast to provide unbiased indices of relative abundance. Additional survey objectives are to investigate the distribution, abundance, and species composition of sharks; tag sharks for migration studies; inject, with tetracycline, tagged sharks whenever feasible for age validation studies; collect biological samples for age and growth, food habits, and reproductive studies; and collect morphometric data.
A spatiotemporal index of scalloped hammerhead abundance from this survey was developed

during the SEDAR 77 Assessment process in 2022 for use in sensitivity analyses.

Since 1961, recreational shark tournament sampling has been conducted annually during the summer from New Jersey to Maine, until 2020 when the majority of tournaments were cancelled due to the COVID-19 pandemic. Tournaments have been a primary source of biological samples used in NEFSC shark food habits, reproduction, and age/growth studies that provide biological reference points used during the ICCAT pelagic shark assessments and SEDAR process. Many tournaments have not come back following initial cancellations in 2020. APP staff attended one tournament in 2022. Staff provided tags for sharks released during the tournament and examined 9 sharks (shortfin mako and common thresher). An additional 5 sharks (a white shark, common thresher, 2 porbeagles, and a tiger shark) were sampled from commercial incidental mortality and stranding events.

The NEFSC Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) Program continued to survey and monitor shark nursery habitat in nearshore waters along the U.S. Atlantic coast using federal, state, university, and commercial platforms. COASTSPAN surveys help determine the relative abundance, distribution, and migrations of sharks using coastal nursery habitat through longline and gillnet sampling and mark-recapture data. In 2022, our COASTSPAN participants were the Virginia Institute of Marine Science, South Carolina Department of Natural Resources (SCDNR), the University of North Florida (UNF), which conducted the survey in both Georgia and northern Florida waters, and Florida Atlantic University. Additionally, NEFSC staff conducted COASTSPAN surveys in Delaware Bay in 2022. Results from COASTSPAN surveys were provided to NMFS Highly Migratory Species Management Division for use in updating the EFH section of the annual Stock Assessment and Fisheries Evaluation (SAFE) Report in 2022. In addition, young-of-the-year catch-per-unit-effort data from COASTSPAN gillnet and longline surveys conducted by the SCDNR and UNF were used during the SEDAR 77 Assessment process to create a hierarchical recruitment index of abundance for the Atlantic and, including data from GOM surveys, for the Atlantic and GOM combined.

In 2022, APP staff with coauthors from the University of Miami, Mississippi State University, NOAA Fisheries Southwest Fisheries Science Center (SWFSC), and Rutgers University published a study in *Global Change Biology* on how ocean warming altered the distributional range, migratory timing, and spatial protections of tiger sharks (*Galeocerdo cuvier*). It is important to understand the responses of species to warming, especially in the case of apex predators that exhibit relatively high extinction risk and where changes to their distribution could impact predator–prey interactions that can initiate trophic cascades. A combined analysis of animal tracking, remotely sensed environmental data, habitat modeling, and capture data were used to evaluate the effects of climate variability and change on the distributional range and migratory phenology of this ectothermic apex predator. Tiger sharks satellite tracked in the western North Atlantic between 2010 and 2019 revealed significant annual variability in the geographic extent and timing of their migrations to northern latitudes from ocean warming. Specifically, migrations have extended farther poleward and arrival times to northern latitudes have occurred earlier in the year during periods with anomalously high sea-surface temperatures. A complementary analysis of nearly 40 years of tiger shark captures from the CSTP in the region revealed decadal-scale changes in the distribution and timing of shark captures in parallel with long-term ocean warming. Specifically, areas of highest catch densities have progressively increased poleward and catches have occurred earlier in the year off the North American shelf. During periods of anomalously high sea-surface temperatures, movements of tracked sharks shifted beyond spatial management zones that had been affording them protection from commercial fishing and bycatch. Taken together, these study results have implications for fisheries management, human–wildlife conflict, and ecosystem functioning.

APP staff worked in cooperation with staff from the Atlantic White Shark Conservancy and the University of Rhode Island to publish a study in *Fishery Bulletin* in 2022. This study was on the reproductive characteristics for the blue shark (*Prionace glauca*) in the North Atlantic Ocean, where the blue shark is caught in large numbers by commercial fisheries. Reproductive parameters, such as size and age at maturity, are important descriptors of life history characteristics essential for stock assessment and effective management, but had not been updated in this region since 1979. To address this gap in knowledge, 369 female and 488 male reproductive samples from 1971–2016 were used to examine whether maturity parameters have changed over time. A comparison of sex-specific fork length (FL) ($L50$) and weight ($W50$) at median maturity between 2 time periods (1971–1977 and 2003–2016) showed no evidence of change in females, but males had a statistically significant increase in both parameters, may be the result of differences in sample size range between the time periods. Thus, all data from 1971 through 2016 were combined to obtain new estimates of age and size at 50% maturity for both sexes. The $L50$ and $W50$ are 192.5 cm FL and 49.5 kg for male blue sharks and 190.9 cm FL and 50.1 kg for female blue sharks. These updated $L50$ and $W50$ increase reliability of data inputs for fisheries management.

In 2022, APP staff contributed to four publications studying the structure and mineralization of shark centra with coauthors from the Feinberg School of Medicine, Argonne National Laboratory, SWFSC, Duke University, and Stonybrook University. The centra of shark vertebrae consist of cartilage mineralized by a bioapatite similar to bone's carbonated hydroxyapatite, and, without a repair mechanism analogous to remodeling in bone, these structures still survive millions of cycles of high-strain loading. The main structures of the centrum are the corpus calcarea (an hourglass-shaped double cone) and the intermedialia, which supports the cones. Authors of the publication in the *Journal of the Royal Society Interface* studied bioapatite in shark centra using wide and small-angle X-ray scattering finding that crystallographic quantities from lamniform and carcharhiniform centra closely matched and were closely related to that in bone, but do possess differences, which probably affect mechanical property and warrant further study. The authors of the *Journal of Structural Biology* publication studied centra microanatomy and mineral density variation using microcomputed tomography and found that all lamniform and carcharhiniform centra contained growth bands which were visible as small changes in linear attenuation coefficient and these coefficients were the same in the corpus calcarea and intermedialia of the lamniforms, but were smaller in the intermedialia than in the corpus calcarea of the carcharhiniforms. In the *Journal of Medical Imaging* publication, the authors looked at the microstructure and energy dispersive diffraction reconstruction of 3D patterns of crystallographic texture in a blue shark centrum. This study determined that mineralized tissue samples can be mapped in 3D with energy dispersive x-ray diffraction and subsequently studied by destructive methods and that bioapatite in the cone walls and intermedialia wedges of a centrum is oriented to resist lateral and axial deflections, respectively. In the J*ournal of the Mechanical Behavior of Biomedical Materials* publication, the authors studied bioapatite structure in intact centra also using 3D mapping with energy dispersive diffraction. As in the previous study, the bioapatite structure is oriented laterally within the cone walls, but axially within the intermedialia wedges for the blue shark to resist lateral deformation and support axial loads, respectively. In the shortfin mako, there is some tendency for variation in orientation with position. Because bioapatite mineralized tissues vary significantly with both volume fraction of bioapatite and crystallographic texture, the present maps should inform future 3D numerical models of shark centra under applied load. The work from these four studies will help inform future age and growth studies as new methodologies are needed to improve age estimates.

f) <u>Marine Mammals</u>

Cetacean surveys:

Right whale cruises were conducted on the R/V Gloria Michelle to collect photo id, biological and physical oceanographic data in the area wind energy lease areas and near sighted right whales (*Eubalaena glacialis*). This is part of an effort to better understand right whale prey resources in southern New England. Zooplankton samples were collected with bongo nets and were processed at the Poland Sorting Center, returning species ID and abundance for zooplankton species, and as well as life stage information for *Calanus finmarchicus*. We also collected video plankton recorder (VPR) data to quantify zooplankton at particular depths in the water column. Lastly, we collected echosounding data over multiple frequencies to be paired with VPR and bongo net data to examine the preyscape over a larger time and area. Analysis of these data is ongoing and will be compared with similar data collected in 2020 and 2021. We are summarizing species abundance and distribution in southern New England, are collaborating with University of Massachusetts at Dartmouth to assess energy density of collected zooplankton, and have recently hired a contractor to assist in the analysis and processing of acoustic data collected.

A North Atlantic right whale research cruise was conducted aboard a contract research vessel. Semper Offshore provided the vessel Warren Junior for this effort. The cruise was conducted in offshore waters of New England and Canada during May and June of 2022. The research activities included: Suction-cup tagging to investigate the feeding ecology of right whales, zooplankton collection around feeding right whales to augment the study of feeding ecology, passive acoustics was used to help locate animals in the area or during night time hours, sUAS was utilized for photogrammetry which will be incorporated into a broad range of health assessment tools, photo-id for the ongoing contribution to the catalog, biopsy sampling that is contributed to the ongoing genetic assessment of the population, and dimethyl sulfide sampling which is being investigated as an indicator of right whale presence.

In 2022 Scientists participated in the WHOI Irminger oceanographic cruise aboard the R/V Neil Armstrong. The observer used the ship as a platform of opportunity to survey for North Atlantic right whales from Woods Hole to Iceland June 20 - July 17 2022.

Also as part of the Atlantic Marine Assessment Program for Protected Species (AMAPPS), the NEFSC conducted aerial abundance surveys during 1 November 2021 to February 2022 in the area extending from North Carolina to Maine. The main goal of this survey was to assess the feasibility of using hi-definition cameras in the belly window of the NOAA Twin Otter when flying at 1500 feet altitude. The target was to get as many images of marine mammals and sea turtles in the US Atlantic waters as possible and to develop the data collection protocols needed to utilize the cameras routinely in future flights.

The North Atlantic Right Whale Sighting Survey (NARWSS) is a NOAA Fisheries program that conducts aerial surveys for North Atlantic right whales off the northeastern coast of the United States and Canada. Images of individual whales are collected for mark-recapture models to monitor abundance and residency. In 2022, NARWSS flew 358 hours over 73 surveys in US waters from New Jersey to the Canadian border, and detected 198 right whales (including duplicates of the same individual). In Canada, NARWSS flew 87 hours over 17 surveys in 2022 in the Gulf of St Lawrence, and detected 77 right whales (including duplicates of the same individual).

During April and May 2022, research crews working from the NOAA research vessel Selkie (24' Safeboat) worked in Cape Cod Bay when right whales were in the area. All right whales encountered were photographed for the North Atlantic Right Whale catalog. Biopsy samples and unmanned aerial images for photogrammetry were also collected.

Work continued with the New England Aquarium and University of Rhode Island to update the North Atlantic Right Whale Individual ID catalog and right whale sightings databases.

Cetacean bycatch and other analyses:

Incidental bycatches of cetacean, turtle, and pinniped species were estimated based on observed takes in commercial fisheries from Maine to North Carolina. Fisheries observed during 2022 included gill nets, otter trawls, mid-water otter trawls, mid-water pair trawls, scallop trawls, scallop dredges, purse seines, and some pot traps.

Serious injury determinations were made on non-fatal large whale fishery interactions and vessel strikes, as well as bycaught small cetaceans and pinnipeds to determine causes and extents of injuries.

Gear Research - on-demand/ropeless

In 2022, the NEFSC Gear Research Team continued to test on-demand systems in the lobster fishery in an effort to reduce large whale and sea turtle entanglements. The risk of a large whale becoming entangled in the American lobster and Jonah crab fisheries is decreased by on-demand systems that remove the vertical line in the water column. In August of 2022, our science center was granted an exempted fishing permit allowing up to 100 vessels to assist in testing and improving on-demand gear systems. Our testing of these systems, which we have been developing in collaboration with fishermen and manufacturers, will continue and expand thanks to this effort. The Gear Lending Library, which we maintain to provide fishermen and researchers with on-demand systems to test and develop, has grown to include over 250 systems from eight different manufacturers aboard 35 different fishing vessels. The 2022 season completed 2,7990 hauls from 24 different fishermen. From February 1 through April 30, 2023, thirty of our federally permitted collaborating commercial fishermen completed more than 200 hauls of on-demand gear within the boundaries of the restricted areas that were subject to seasonal closures due to the presence of North Atlantic Right Whales. They fished in state and federal waters within the South Island Restricted Area and the Massachusetts Restricted Area, both of which prohibit vertical line fishing gear. Due to the absence of surface buoys on the on-demand gear, the bottom-set trap/pot gear was not marked at the surface of the water during this time. To aid in gear location and to let surrounding vessels know that gear is present on the bottom, we are also testing gear marking systems that make use of GPS points or other subsurface markings. On-demand gear hauls have improved over the past three fishing seasons, with greater success and fewer failures. The rate of successful on-demand gear hauls was 71% in 2020, 85% in 2021, and is now at 89% for the 2022 season. We are still receiving data from the 2022 season and anticipate that its success rate will increase. This steady increase in success suggests that on-demand solutions, with adequate training and monitoring, could reduce the entanglement of protected species in vertical lines and provide flexibility for fishing operations in locations with high whale abundance. This research would not have been possible without the collaboration of NEFSC, NGOs, state agencies, gear manufacturers, and, of course, fishermen. The Gear Lending Library's emphasis on collaboration is what makes it both accessible and successful.

Passive acoustics:

NEFSC researchers in the Passive Acoustics Group have been working to: (1) elucidate the basic acoustic behavior of various marine mammal and fish species and potential impacts of anthropogenic noise and offshore wind farm development; (2) monitor cetacean species presence using near real-time reporting from fixed and autonomous acoustic platforms; (3) improve the application of passive acoustics as a tool for monitoring and mitigation; and (4) set up a long term database for acoustic data collection and detection information.

Throughout 2022, 40 SoundTraps were deployed along the east coast from the Gulf of Maine to Florida Keys, including 11 sites (also deployed with FPODs) in the Southern New England Wind Energy Areas, covering Cox's Ledge and Nantucket Shoals to monitor for North Atlantic right whales, Atlantic Cod, Harbor Porpoises. Additional mysticete, odontocete, and fish species are analyzed, as time allows. Recorders deployed in three National Marine Sanctuaries (Stellwagen Bank, Gray's Reef, and Florida Keys), are part of a collaborate effort to evaluate sanctuary soundscapes throughout the U.S. Long-term NOAA Noise Reference Station recorders continue to collect data in the Stellwagen Bank National Marine Sanctuary and offshore of Georges Bank. In collaboration with colleagues at the Woods Hole Oceanographic Institution, gliders were deployed in the Gulf of Maine, Stellwagen Bank National Marine Sanctuary, and Cox Ledge; 7 real-time monitoring buoys operated by WHOI and colleagues are also active along the east coast. Detections from these real-time platforms are being used to trigger North Atlantic right whale Slow Zones; results can be found at http://dcs.whoi.edu. As part of the AMAPPS program, analyses of the distributions of sperm whales, beaked whales, members of the Kogiidae family, and baleen whales continued for data collected both on the towed array and bottom mounted recorders deployed in previous years. Finer-scale studies include improving classification methods of passive acoustic data, as well as describing acoustic and diving behavior of odontocetes. The NEFSC Passive Acoustics Research Group also works in collaboration on projects in Australia Marine Parks and Hong Kong Harbor to describe soundscapes and assess illegal vessel activity, and to apply these methods in Northeast U.S. waters, working with NOAA Office of Law Enforcement. Lastly, the group launched the Passive Acoustic Cetacean Map (PACM, https://apps-nefsc.fisheries.noaa.gov/pacm/#/), which gives public access to explore all acoustic detection data for all focal species, across different types of recording platforms, and from multiple organizations (displaying both NEFSC's and outside colleagues' analyses in the same portal). This website includes the development of templates for data submission to PACM, as well as our developing database. For more information on our projects and publications, please visit https://www.fisheries.noaa.gov/new-england-mid-atlantic/endangered-species-conservation/passive-acoustic-research-atlantic-ocean.

Pinnipeds:

The NEFSC conducts research on wild populations of gray and harbor seals in the Northwest Atlantic in collaboration with several other non-profit, academic, and government partners working under the NEFSC pinniped research permit. Research includes broad-based surveys to estimate population abundance as well as focused work on individual live or dead animals to study health, diet, movements, and behavior. In 2022 the NEFSC published an updated estimate of abundance of the Northwest Atlantic population of gray seals based on a survey completed in 2021 and estimated rates of increase in pup counts at various colonies. In collaboration with several other organizations, the NEFSC captured a total of 62 juvenile gray seals and 10 harbor seals of mixed age class for studies of health, diet, and movements. From each animal teams collected weight, morphometrics, swabs, whisker, lanugo, skin, blood, flipper tags, and if age-appropriate, a blubber biopsy. In addition, teams deployed a total of 24 satellite tags (n=14 gray seals and n=10 harbor seals) and 8 acoustic tags (gray seals). Some of these data were published in a manuscript describing phocine-distemper virus in seals; other samples and telemetry data are currently being analyzed.

Work continued in 2022 collecting diet data from harbor and gray seals using an interdisciplinary approach that includes the use of hard part remains, fatty acids and DNA methods. A draft manuscript was completed comparing the diet of harbor and gray seals using hard part remains recovered from the stomachs of fresh dead carcasses obtained from NEUS commercial fishery bycatch events (presently in review). In collaboration with researchers at the University of Dalhousie and Maritime Canada Department of Fisheries and Oceans, libraries of fatty acid signature (FAS) data obtained from blubber (predator) and various fish (prey) samples continued to be collated. Presently, the NEUS prey library includes 747 FAS records from 44 different species and the predator library includes 89 FAS records (34 harbor seal and 55 gray seal). Analysis of the NEUS prey FAS data will begin in 2023 and will be compared to the Canadian shelf FAS prey libraries. Preliminary results from a pilot DNA feasibility study utilizing meta-barcoding methods revealed encouraging results utilizing a set of primers restricted to bony fishes. Identified prey read counts were summarized from 24 sequenced samples that were extracted from 1) fecal matter recovered from the colon and 2) stomach contents from bycaught animals, 3) seal scat from haul out locations and 4) scat from rehabilitated animals held in captivity. There was a lot of overlap between recovered otoliths and DNA reads. Part III of the DNA feasibility study (in 2023) will test the same suite of samples against a set of primers that will include sharks and skates, taxonomic groups that are difficult to quantify from hard part remains. The long-term aim is to integrate results from the interdisciplinary seal diet research program to support a cross-validation study comparing results from the full array of biological samples obtained from the same individuals.

Bycatch estimation of harbor (*Phoca vitulina*), gray, harp (*Pagophilus groenlandicus*), and hooded (*Cystophora cristata*) seals in the Mid-Atlantic Gillnet, Northeast Sink Gillnet, and Northeast and mid-Atlantic bottom trawl fisheries was conducted in 2022 and reported in 2023 US Atlantic Marine Mammal Stock Assessment Reports..

g) Turtles

The NEFSC collaborated with academics, industry groups, and researchers from other NMFS science centers to (1) collect and assess data on sea turtles in the Greater Atlantic; and (2) assess and reduce sea turtle bycatch in U.S. commercial fisheries in the Northwest Atlantic Ocean.

During calendar year 2022, the Turtle Ecology team completed several field work trips. From August 22 - September 4, we collaborated with the broader Atlantic Marine Assessment Program for Protected Species (AMAPPS) team for leatherback satellite tagging, departing from Woods Hole, Massachusetts aboard M/V Warren Jr. with support from R/V Coriacea. Most of this trip was spent in waters south of Nantucket, where twelve leatherback sea turtles were successfully tagged. Flipper and PIT (microchip) tags were applied in addition to the satellite tag. Blood and tissue samples were taken for biochemistry and genetic analyses. The main goals of this cruise were to continue collecting leatherback surfacing behavior and build upon our knowledge of coastal leatherback sea turtle movements and habitat use. Understanding the proportion of time leatherbacks spend at the surface of the water and how that might vary seasonally and/or spatially provides necessary corrections for availability of the turtles to be counted during aerial surveys intended to estimate abundance. In addition, characterizing relative importance of different habitats and vertical use of the water column for leatherbacks in the region is essential for determining overlap with and impacts of wind energy development and fishing activities. We also assisted in satellite tagging efforts that will add data to our collaborative Oracle database. From April 14 to May 1, we joined the SEFSC off of Florida for leatherback satellite tagging aboard the R/V Coriacea with support from aircraft NOAA Twin Otter 56, and from May 23 - 28 we joined the Coonamessett Farm Foundation for loggerhead satellite tagging aboard the F/V Kathy Ann in the Mid-Atlantic Bight. In 2022, our collaborative team made progress on analysis and publication, with new publications on estimating the complex patterns of survey availability for loggerhead turtles (Hatch et al 2022) and preliminary estimates of surface availability for leatherback turtles tagged off North Carolina and Massachusetts (Rider et al 2022).

h) Environmental DNA

In 2022, Northeast Fisheries Science Center (NEFSC) continued eDNA research under the NMFS agency-wide genomics strategic initiative (SI). Under this SI, the following activities were conducted:

1.) The 2022 Northeast spring ecosystem monitoring survey aboard NOAA Ship Bigelow sampled 32 stations along the U.S. East Coast. During the 18-day research cruise (5/31 - 6/17/2022), 299 water samples including 16 negative field controls were filtered for eDNA metabarcoding analysis. Fieldwork is described in a science blog (https://www.fisheries.noaa.gov/science-blog/collecting-environmental-dna-samples-2022-spring-ecosystem-monitoring-survey). Lab processing of these samples are near completion. Samples will be sent out for next generation sequencing in 2023.

2.) We expanded the scope of a trial study conducted in 2021 using eDNA metabarcoding on 24 seal fecal samples by running additional PCR analysis to look for elasmobranchs in seal scats. Samples will be sent out for next generation sequencing in 2023.

3.) We dissected tissues and extracted DNA from 20 species including ray, sharks, and cephalopods. These will be used as positive controls for analysis of seal fecal samples and future work on cephalopods.

4.) A presentation titled Flatfish Distributions across the Northeast US Continental Shelf: Comparing Bottom Trawl and eDNA Metabarcoding Results for Fall, 2019 was made at the 17th Flatfish Biology Conference. Abstracts can be found here (https://repository.library.noaa.gov/view/noaa/48077).

3. Studies of Fishing Operations

In 2022, NEFSC Observers were deployed on 1,893 trips aboard commercial fishing vessels. The kept and discarded catch was weighed or estimated for all observed hauls. Estimated kept weights were obtained for all unobserved hauls. Length frequencies were recorded and age structures were collected from a portion of observed hauls. NEFSC Observers documented 137 marine mammal incidental takes, 406 seabird incidental takes and 14 sea turtle incidental takes. For most of these animals, the information recorded included animal condition, length and other relevant body measurements, as well as species identification characteristics. Tissue samples were also collected from many of these animals, and entire animals were retained if possible.

In addition, the Northeast Fisheries Observer Program deployed At-Sea Monitors on 1,580 trips aboard commercial fishing vessels in 2022. On these trips, there were 117 marine mammal and 142 seabird incidental takes documented.

a. New England and Mid-Atlantic Sink Anchored Gillnet Fishery

In the sink anchored gillnet fishery, 420 trips were observed with a total of 1,420 gear retrievals by Observers. There were 80 observed marine mammal takes (51 gray seals, eight harbor seals, eight unidentified seals, seven harbor porpoises, four common dolphins, one Risso's dolphin and one unidentified dolphin) and three sea turtle takes (two loggerhead turtles and one unidentified turtle) in this fishery. There were also 36 seabird takes (including 25 greater shearwaters) observed in this fishery.

At-Sea Monitors observed 370 trips in the sink anchored gillnet fishery with 1,396 gear retrievals. There were 90 marine mammal (40 gray seals, 27 harbor seals, 15 harbor porpoises, six unidentified seals, one common dolphin and one whitesided dolphin) and 129 seabird incidental takes (including 116 greater shearwaters) recorded in this fishery by Monitors.

b. Float Drift Gillnet Fishery

There were five floating drift gillnet trips with 53 gear retrievals observed in 2022. There were no marine mammal, sea turtle or seabird incidental takes observed.

No Monitors deployed on float drift gillnet trips in 2022.

c. Otter Trawl Fisheries

In the bottom otter trawl fishery 730 trips were observed with a total of 5,246 gear retrievals recorded by Observers. In addition, there were 18 midwater trawl trips with 84 gear retrievals, four haddock separator trawl trips with 137 gear retrievals, and 15 twin trawl trips with 110 gear retrievals observed in 2022. There were also five observed trips on vessels using large mesh belly panel trawl nets with 20 gear retrievals. There were no observed trips in the scallop or shrimp bottom otter trawl trips in 2022.

In the bottom otter trawl fishery, there were 50 observed marine mammal (31 common dolphins, six gray seals four unidentified pilot whales, four Risso's dolphins, two bottlenose dolphins, one unidentified dolphin, and one unidentified seal), 11 sea turtle (eight loggerhead, two leatherback and one Kemp's ridley) and 212 seabird takes in this fishery. On the midwater trawl trips there was one common dolphin take observed. There were no incidental takes documented in the haddock separator trawl, twin trawl or large mesh belly panel trawl fisheries in 2022.

At-Sea Monitors deployed on 1,173 bottom otter trawl trips with 11,531 gear retrievals and 24 haddock separator trawl trips with 669 gear retrievals, but no Ruhle trawl or twin trawl trips in 2022. There were 26 incidental takes documented on bottom otter trawl trips in 2022, including seven common dolphins, seven gray seals, four whitesided dolphins, two harbor porpoises, two harbor seals, two unidentified whales, one bottlenose dolphin, and one unidentified seal as well as 13 seabird takes by Monitors in the bottom otter trawl fishery. There were no incidental takes documented by Monitors on Ruhle trawl, twin trawl or haddock separator trawl trips in 2022.

d. Sea Scallop Dredge Fishery

In the sea scallop dredge fishery, 456 trips were observed with a total of 20,359 gear retrievals. There were 153 seabird takes (including 142 greater shearwaters) observed on these trips but no marine mammals or sea turtles in this fishery.

No Monitors deployed in the scallop dredge fishery in 2022.

e. Scottish Seine Fishery

No Scottish seine trips were covered by Observers or Monitors in 2022.

f. Drift Sink Gillnet Fishery

In the drift sink gillnet fishery in 2022, Observers deployed on 50 trips with a total of 241 gear retrievals. There were no incidental takes in this fishery.

Two drift sink gillnet trips with 15 gear retrievals were covered in 2022. There were no takes documented on these trips.

g. Anchored Floating Gillnet Fishery

One Observer deployed on an anchored floating gillnet trip documenting five gear retrievals in 2022.

No Monitors deployed on anchored floating gillnet trips in 2022.

h. Mid-water Pair Trawl Fishery

In 2022, there were two mid-water pair trawl trips observed but with no gear retrievals. There were no marine mammal, sea turtle or seabird takes observed in this fishery.

No Monitors deployed on mid-water pair trawl trips in 2022.

i. Bottom Longline Fishery

In the bottom longline fishery in 2022, there were 27 trips observed with a total of 219 gear retrievals. There were no marine mammal or sea turtle takes but four seabird takes observed in the bottom longline fishery.

At-Sea Monitors covered ten bottom longline trips with 30 gear retrievals in 2022. There was one gray seal documented but no sea turtle or seabird takes observed by Monitors.

j. Beach Haul Seine Fishery

No beach haul seine trips were covered by Observers or Monitors in 2022.

k. Pound Net Fishery

No pound net trips were covered by Observers or Monitors in 2022.

l. Handline/Trolling Fisheries

In 2022, there were 27 handline trips with 263 gear retrievals observed. There was one seabird take observed but there were no marine mammal or sea turtle takes in the handline fishery. There was one troll line trip with one gear retrieval and no incidental takes documented. And, there were no auto-jig handline trips observed in 2022.

Monitors did not deploy on handline, troll line or auto-jig trips in 2022.

m. Herring Purse Seine Fishery

In 2022, there were four herring purse seine trips with 11 gear retrievals observed. There were six gray seal takes but no sea turtle or seabird takes observed on these trips.

No herring purse seine trips were covered by Monitors in 2022.

n. Menhaden Purse Seine Fishery

Observers deployed on eight menhaden purse seine trips in 2022. No incidental takes were observed on these trips.

No menhaden purse seine trips were covered by Monitors in 2022.

o. Tuna Purse Seine Fishery

No tuna purse seine trips were covered by Observers or Monitors in 2022.

p. Pot / Trap Fisheries

In 2022, there were 38 lobster pot trips with 714 gear retrievals, 24 fish pot trips with 341 gear retrievals, 18 conch pot trips with 162 gear retrievals and 12 crab pot trips with 300 gear retrievals. There were no marine mammal, sea turtle or seabird takes in these fisheries. There were no hagfish pot, blue crab trap or whelk pot trips observed.

No lobster, fish, conch, hagfish, crab, blue crab or whelk pot trips were covered by Monitors in 2022.

q. Beam Trawl Fisheries

No beam trawl trips covered by Observers in 2022.

One beam trawl trip with one gear retrieval was documented by a Monitor in 2022. There were no takes documented on this trip.

r. Clam Dredge Fishery

There were 28 clam dredge trips with 923 gear retrievals in 2022. There were no observed takes of marine mammals, sea turtles or seabirds on these trips.

No clam dredge trips were covered by Monitors in 2022.

s. Other Dredge Fisheries

No other dredge trips were covered by Observers or Monitors in 2022.

4. Observer estimation of catch on NAFO Subarea 3 trips

The United States did not have any trips in NAFO Subarea 3.

5. Population Dynamics Research

a) Stock Assessments

Population dynamics research conducted within the NEFSC supports a number of domestic and international fisheries management authorities. Within the United States Northeast Region, management plans are developed by the New England (states of Maine through Connecticut) and Mid-Atlantic (New York through North Carolina) Fishery Management Councils, and the Atlantic States Marine Fisheries Commission (ASMFC). There are about four dozen managed species; all require periodic stock status updates as a basis for fishery management.

The Northeast Region recently revamped its stock assessment scheduling and review process system to better serve our management partners. The region has transitioned to a new stock assessment process that separates stock assessment development from operational stock assessments used to inform management. The Research Track Assessment Process is designed to develop, review and implement new stock assessment approaches for individual or groups of species. Results of the Research Track are not used directly in management, rather they establish the stock assessment approaches and methods that will be used in the Management Track process. The Management Track process is designed to develop, review and approve updated stock assessments for use in management (e.g. specification setting).

In 2022, Research Track Assessments were completed for haddock (Gulf of Maine, Georges Bank, and eastern Georges Bank), shortfin inshore squid (Georges Bank/Cape Hatteras), butterfish (Gulf of Maine/Cape Hatteras), American plaice (Gulf of Maine/Georges Bank), bluefish (Atlantic Coast), and spiny dogfish (Atlantic Coast). Research Track Assessment Working Groups continued their work on black sea Bass (Gulf of Maine/Cape Hatteras) and Atlantic cod (stock structure being revised).

In addition, the Management Track produced updated stock assessments in 2022 for Atlantic herring, winter flounder (southern New England/mid-Atlantic, Gulf of Maine, and Georges Bank), Atlantic halibut, haddock (Gulf of Maine and Georges Bank), white hake, monkfish, southern New England/mid-Atlantic yellowtail flounder, pollock, and American plaice. The U.S. also coordinated with Canada to develop and review stock assessments through the Transboundary Resources Assessment Committee (TRAC) process, including Eastern Georges Bank cod, Eastern Georges Bank haddock, and Georges Bank yellowtail flounder.

b) Atlantic Salmon Research

Atlantic salmon populations in eastern Maine are listed as endangered under the United States Endangered Species Act (ESA). Spawning populations have remained low with both smolt escapement and ocean survival rates challenging recovery of the species. Research programs conducted by the NEFSC, in conjunction with various agencies, private partners and international collaborators, are designed to better understand the factors contributing to these declines. Research activities include a variety of projects in natal rivers, estuaries, and at sea. The data from these studies support ESA, U.S. Atlantic Salmon Assessment Committee, International Council for the Exploration of the Seas (ICES) and North Atlantic Salmon Conservation Organization (NASCO) domestic and international science and management efforts.

Field research in 2022 focused on (1) monitoring the importance of diadromous fishes as prey for nearshore Gulf of Maine groundfish species; (2) monitoring of fishery removals on the high seas; (3) describing the marine migration of salmon from Greenland to natal rivers

Starting in 2012 a sampling program was initiated, in collaboration with the Maine Department of Marine Resources semi-annual nearshore groundfish surveys, to collect stomach samples from known diadromous fish predators. Sampling is continuing and analysis is being conducted to evaluate the contribution of diadromous fishes to the diets of captured nearshore predators. Monitoring the West Greenland fishery and collecting biological data and fishery statistics continued. These data are provided directly to ICES and are required for North American run-reconstruction modeling and for developing catch advice for the fishery to support NASCO management efforts. Lastly, starting in 2018, salmon have been captured, tagged with popoff satellite tags (PSAT) and released at their feeding grounds at West Greenland. To date over 200 PSAT tagged salmon have been released and data collected will allow researchers to describe migration pathways and the environmental conditions encountered en route to natal rivers to better understand the marine dynamics of the species.

c) Cooperative Research

Industry-Based Gulf of Maine Bottom Longline Survey

During 2022 staff from the NEFSC Cooperative Research Branch completed the Gulf of Maine bottom longline survey (BLLS) started in 2014. This survey was started in an effort to provide additional sampling in rocky and hard-bottom habitats and address concerns for some groundfish and data-poor species. The survey covers the western Gulf of Maine across the central Gulf to the US/Canada boundary. This includes all or portions of bottom trawl offshore survey strata 26-29, 36-37, and is further sub-stratified into smooth and rough bottom. The survey uses tub-trawl bottom longline gear similar to that used by commercial fishermen for groundfish. The biannual survey was conducted in 2022 completing 92 stations in total in the spring (April-May) and fall (Oct-Nov) with 46 vessel days at sea on two chartered commercial vessels. A total of 20,544 lengths were measured representing 22,434 individual organisms. Biological sampling of 1,498 organisms for samples such as age and maturity were collected, as well as tagging and other samples to support both NEFSC research studies and external investigators. The data collected on this survey will be used to support stock assessments, ecosystem and habitat studies, and management decisions for a range of fish, skates, and other species in the Gulf of Maine, and particularly beneficial for several data poor species.

Development of CPUE indices from fishery data

In the northeast US, the adoption of electronic logbook technology and the Northeast Fisheries Science Center's Cooperative Study Fleet Research Program have greatly enhanced the collection of high-resolution catch, effort, and environmental data by fishing captains. This has resulted in an extensive time series of fine-scale catch and effort information that has accumulated over the past fifteen years, providing a valuable resource for regional scientists and managers. This data set is similar to the information gathered by the NEFSC’s observer program and can be used to answer a variety of research questions related to catch rates, environmental drivers, and fishery dynamics. In 2022, our focus was on developing standardized CPUE time series to support the stock assessments of Spiny dogfish (*Squalus acanthias*) and Black sea bass (*Centropristis striata*). These efforts will continue in 2023 with the publication of peer-reviewed papers on the topic of commercial CPUE standardization. The fine-scale catch and effort data, combined with advancements in logbook hardware and software, enable us to study fishery dynamics and environmental impacts more accurately than ever before. With these tools, we can enhance ongoing science and management in the region.

Application of fishery data to evaluate operational conflicts with wind developments

In 2022, the Northeast Fisheries Science Center's Cooperative Study Fleet Research Program's fine-scale fishery data played a crucial role in improving our understanding of fishery footprints and potential spatial conflicts with planned offshore wind energy developments. Specifically, we explored the time series of fine-scale effort information for the longfin squid fishery (*Doryteuthis pealeii*), and the results indicated that the data set improved our ability to assess the impact of offshore wind energy development on fishing operations. By characterizing the true footprint of individual fishing trips and effort events and providing higher coverage in fisheries likely to be impacted (such as the longfin squid fishery), the fine-scale effort information collected by the Cooperative Study Fleet Research Program proved to be an important resource. For more information on this work, please see a recent peer-reviewed publication on the topic: Allen-Jacobson et al.'s (2023) 'Evaluating Potential Impacts of Offshore Wind Development on Fishing Operations by Comparing Fine-and Coarse-Scale Fishery-Dependent Data,' published in Marine and Coastal Fisheries (https://doi.org/10.1002/mcf2.10233). This paper provides a more detailed description of our methodology and findings and highlights the importance of fine-scale fishery data in understanding the potential impacts of offshore wind energy development on fisheries.

Engaging Shortfin Squid (*Illex illecebrosus*) Processors in Filling Biological Data Gaps Using Electronic Technology

The life history and population dynamics of the northern shortfin squid (*Illex illecebrosus*) are poorly understood due to a paucity of data, yet the species supports a productive fishery on the northwest Atlantic continental shelf. The Shortfin Squid Electronic Size Monitoring Project (ILXSM) was developed in 2021 to address the need for individual shortfin squid size and weights throughout the fishing season, which are key for understanding the ingress, egress, growth, and reproduction of this semelparous species. To achieve this goal, the ILXSM team developed an electronic data collection system that can be used by the region's shortfin squid processors to collect biological data during the vessel offload process. Six shortfin squid processors were provided with Big Fin Scientific electronic fish measuring boards, Marel digital Bluetooth scales, and a ruggedized Samsung tablets running the BioLogical Information System Software (BLISS) to efficiently collect paired mantle lengths and gram weights for a subsample of squid from each vessel offload. These data are uploaded to NEFSC databases for scientific analysis and downloaded by processors for use in sales and marketing. In 2021 and 2022, processors collected over 60,000 shortfin squid mantle lengths and weights. This project plays a critical role in documenting rapidly changing dynamics of the shortfin squid population and promotes long-term conservation of this valuable fishery resource.

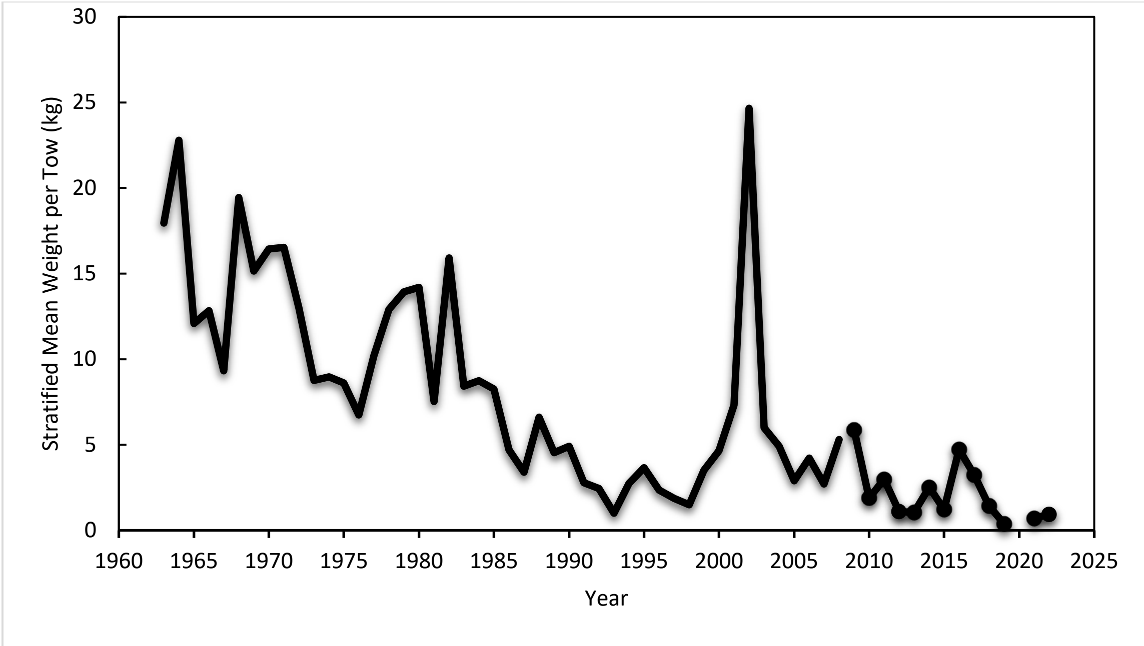

Figure 1. NEFSC autumn bottom trawl survey biomass indices for Gulf of Maine cod.

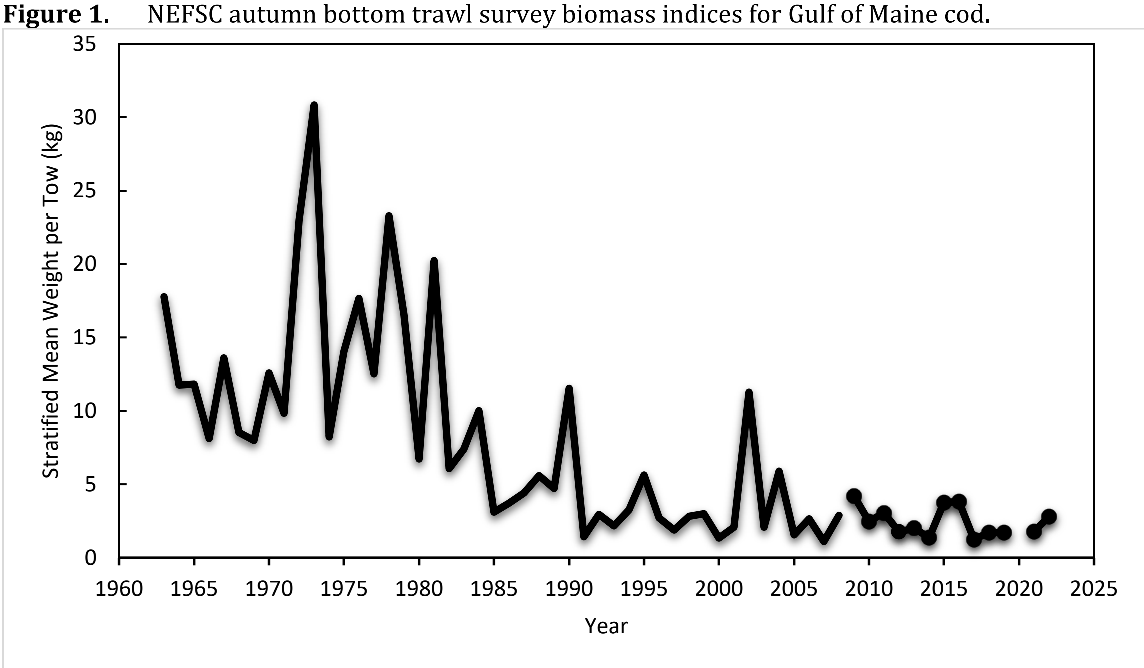

Figure 2. NEFSC autumn bottom trawl survey biomass indices for Georges Bank cod.

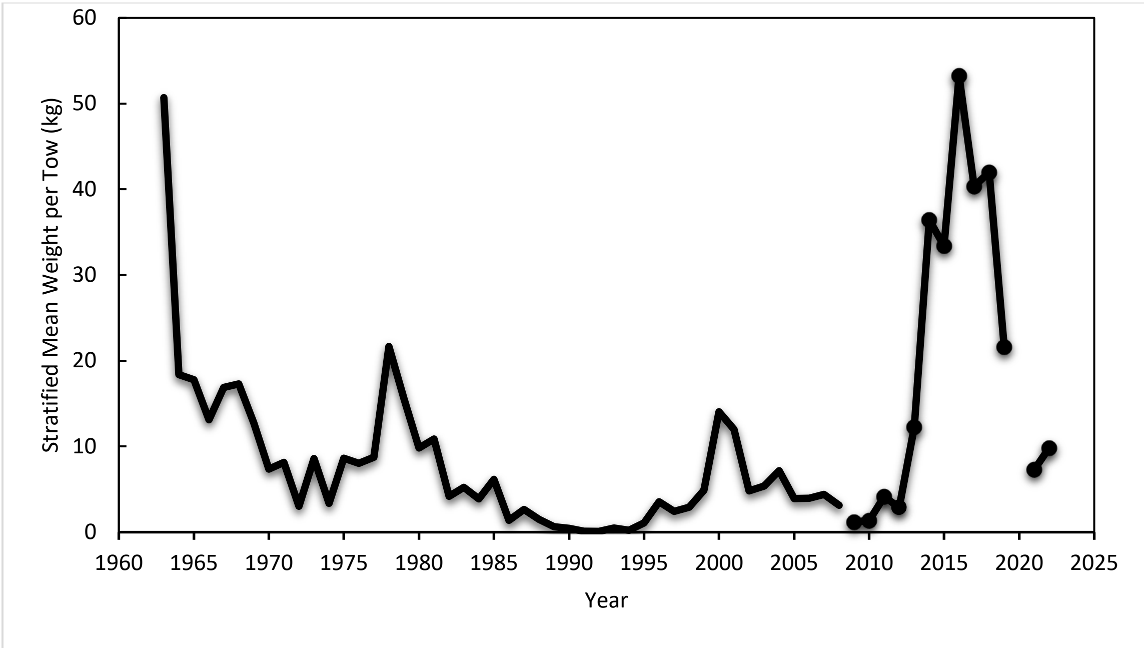

Figure 3. NEFSC autumn bottom trawl survey biomass indices for Gulf of Maine haddock.

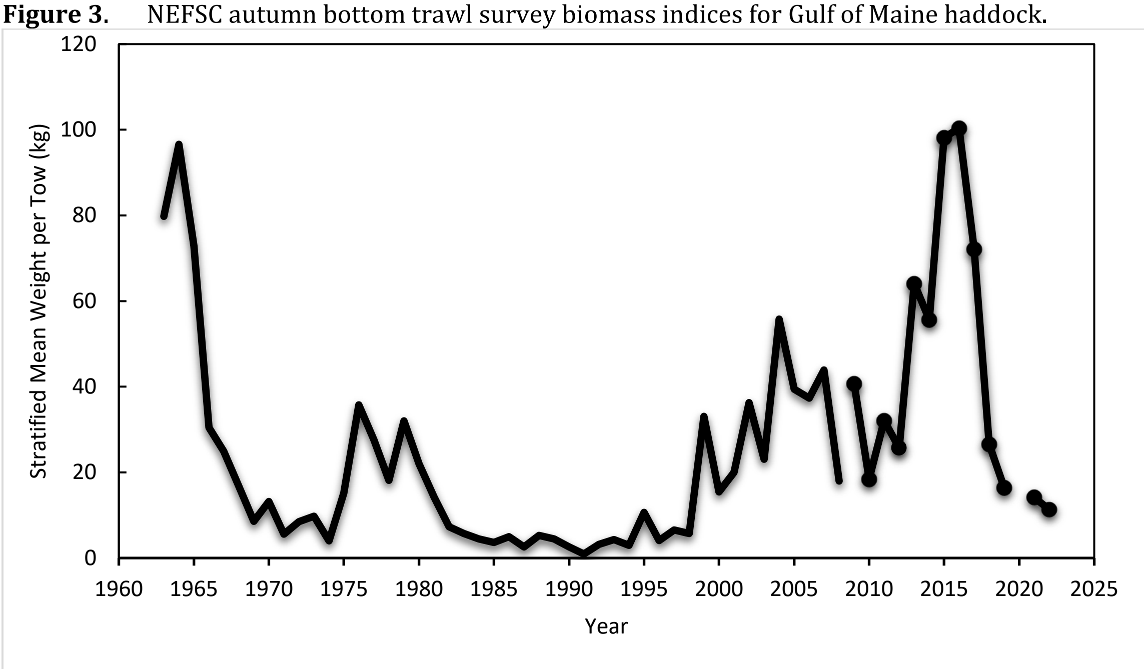

Figure 4. NEFSC autumn bottom trawl survey biomass indices for Georges Bank haddock.

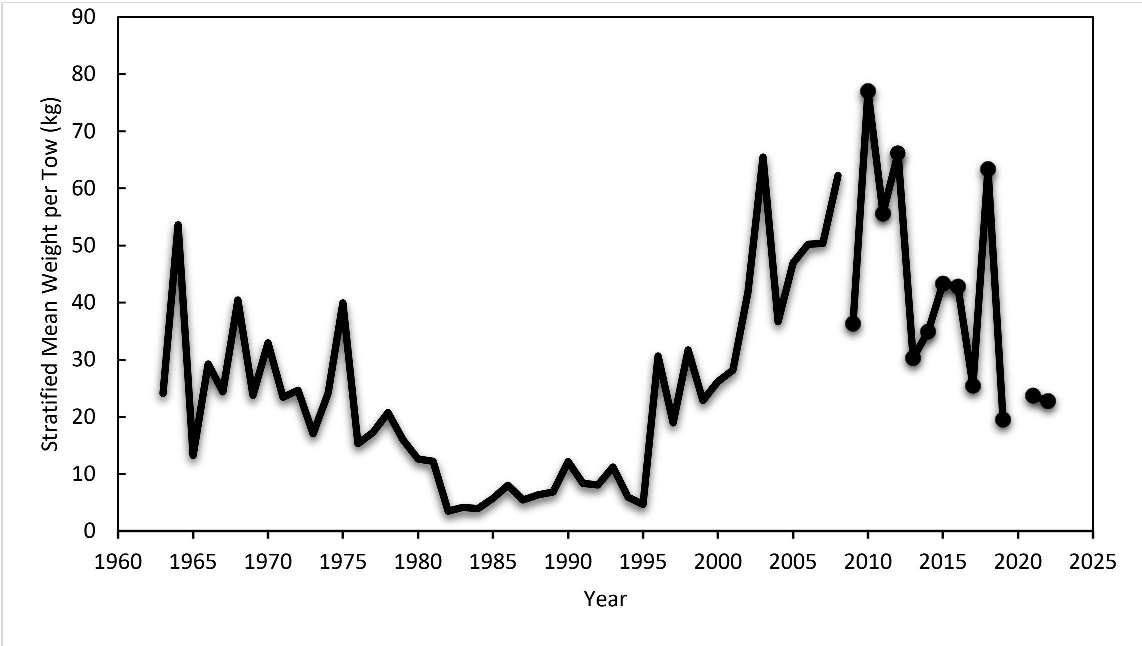

Figure 5. NEFSC autumn bottom trawl survey biomass indices for Acadian redfish.

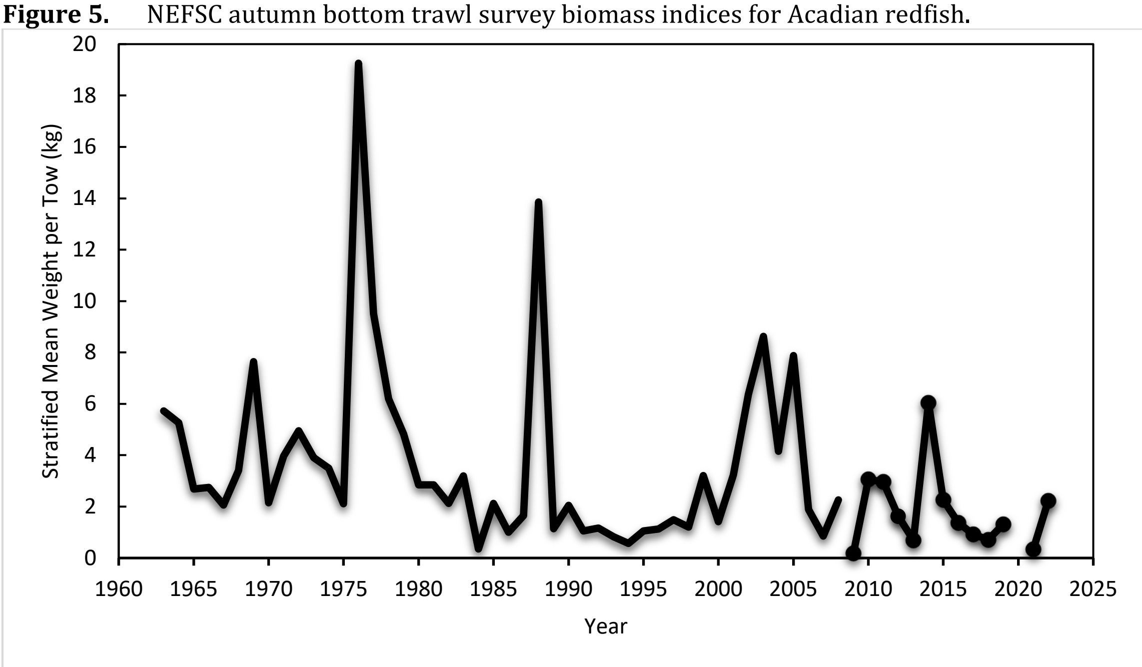

Figure 6. NEFSC autumn bottom trawl survey biomass indices for pollock.

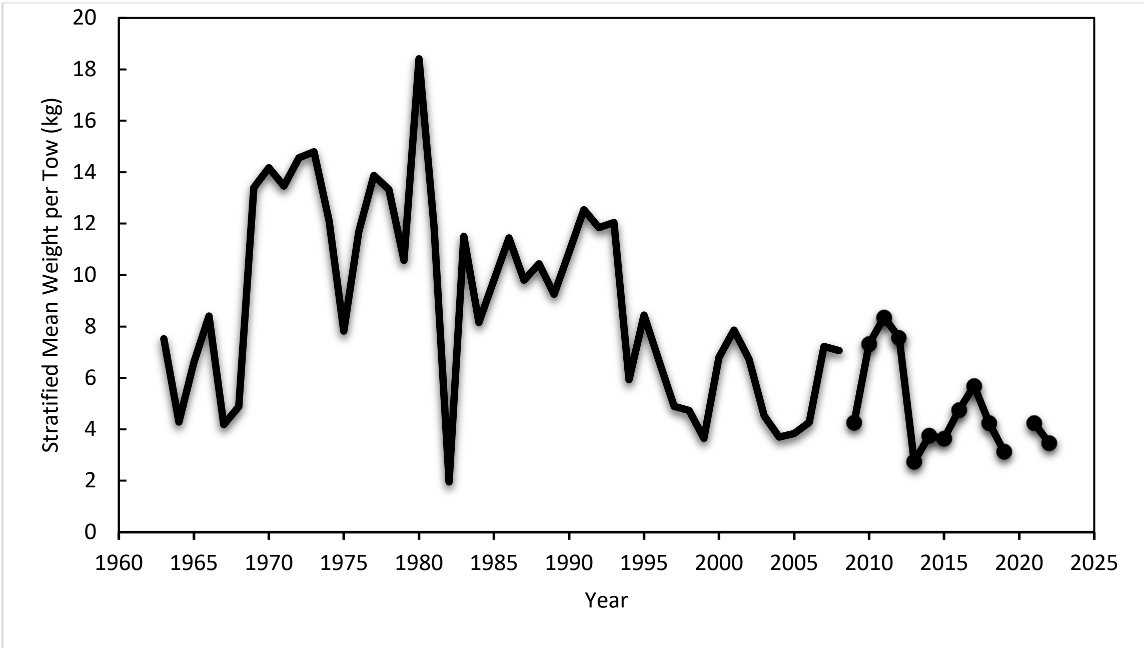

Figure 7. NEFSC autumn bottom trawl survey biomass indices for white hake.

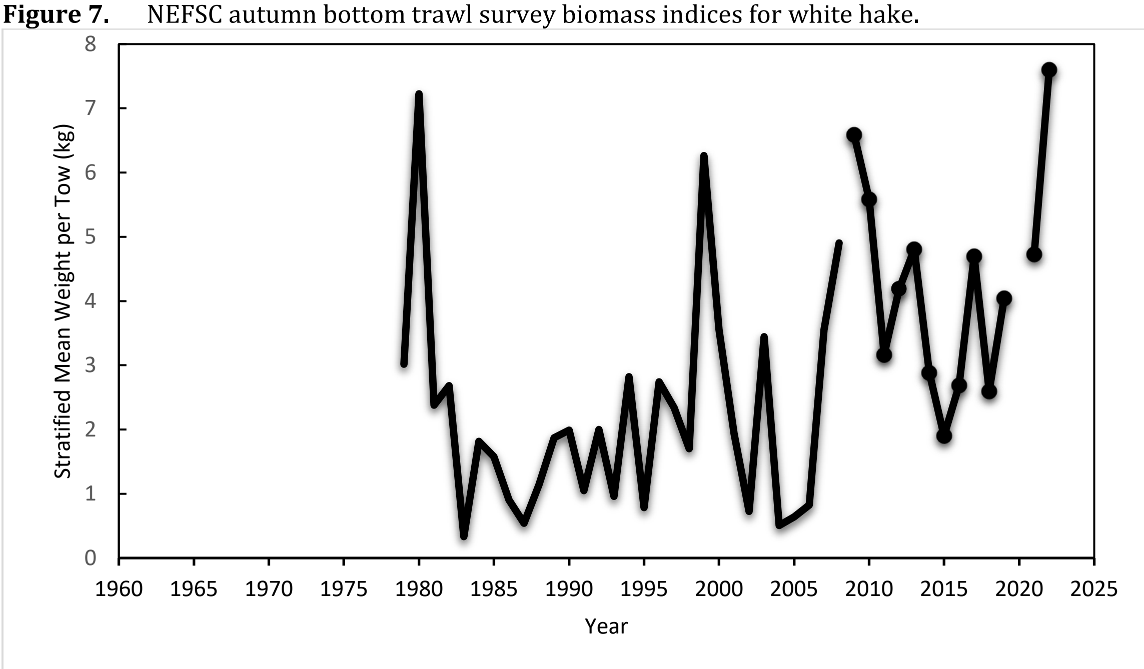

Figure 8. NEFSC autumn bottom trawl survey biomass indices for Cape Cod-Gulf of Maine yellowtail flounder.

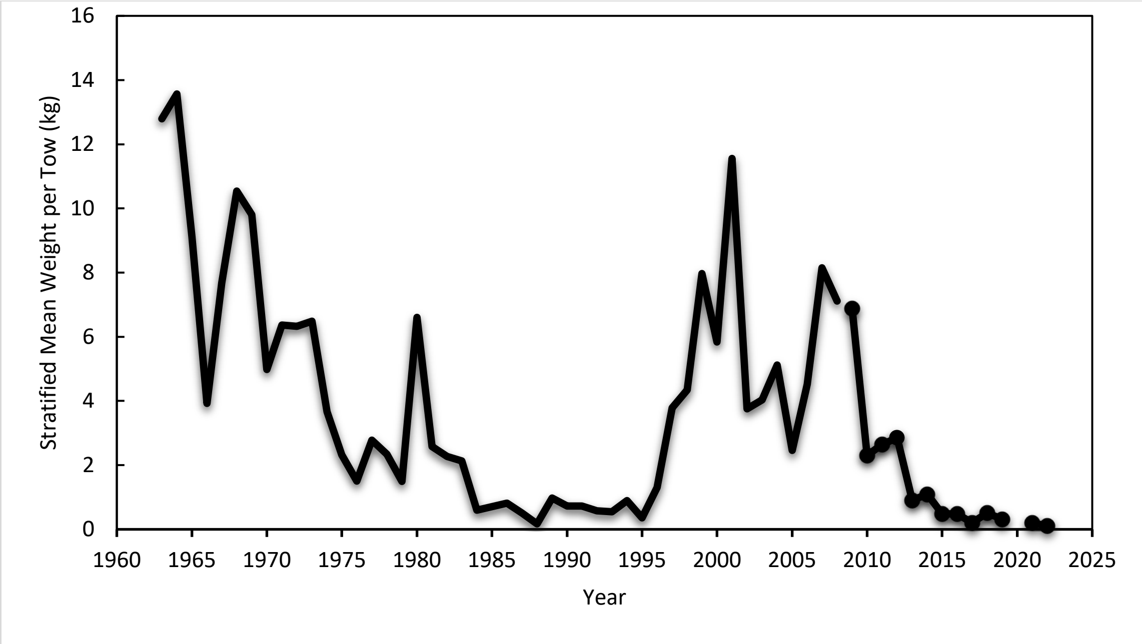

Figure 9. NEFSC autumn bottom trawl survey biomass indices for Georges Bank yellowtail flounder.

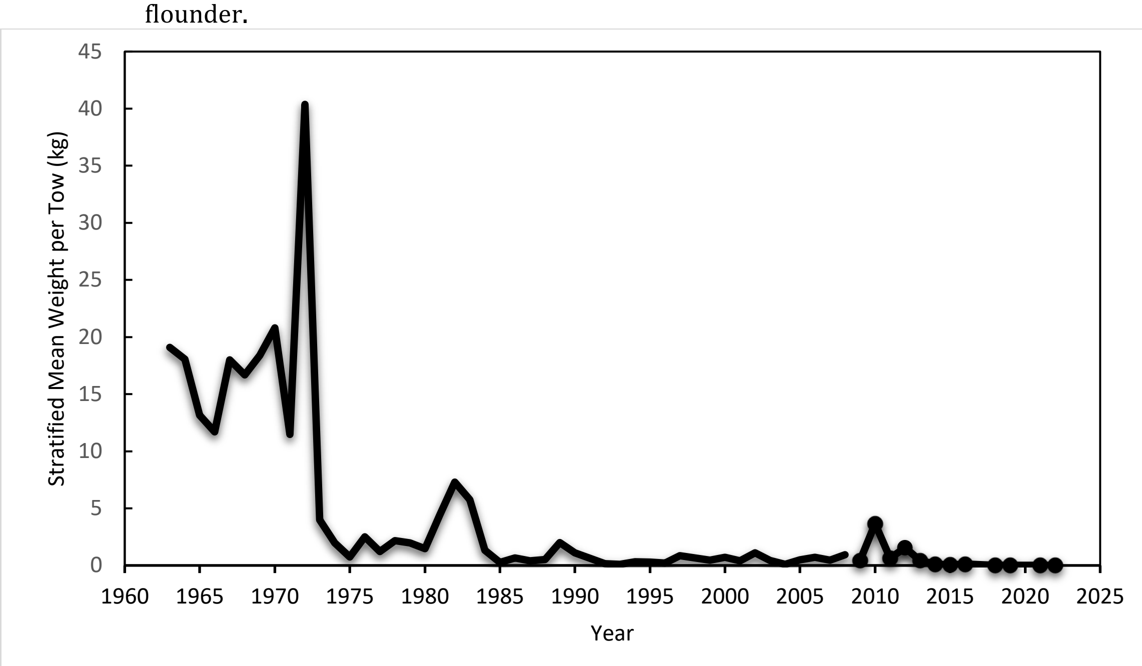

Figure 10. NEFSC autumn bottom trawl survey biomass indices for Southern New England-Mid-Atlantic yellowtail flounder.

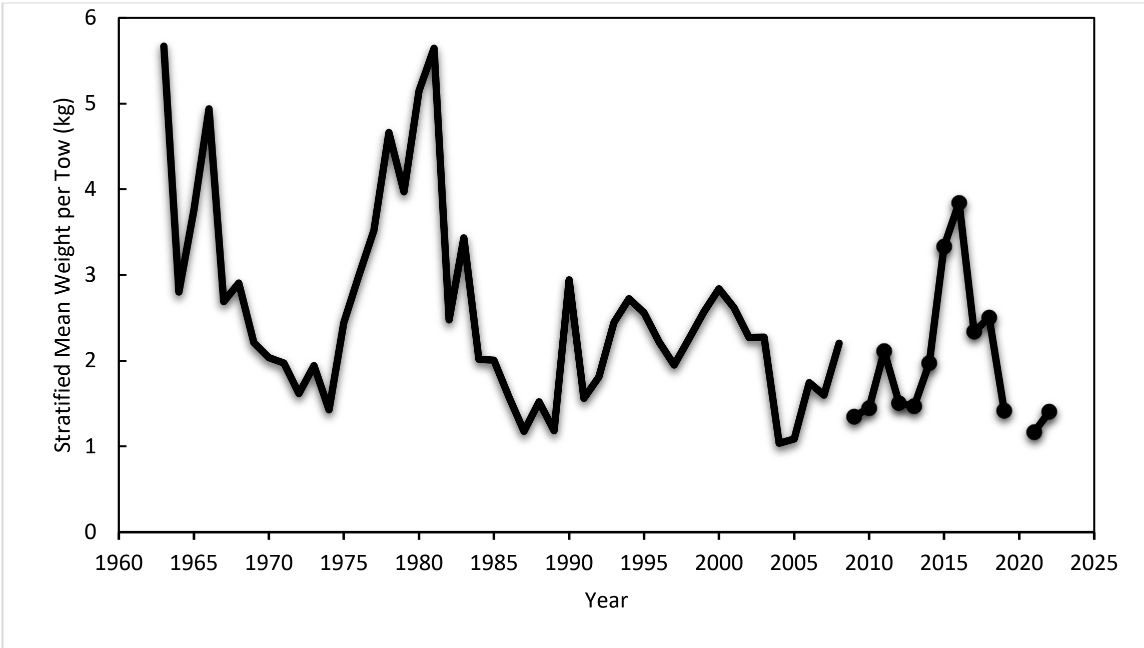

Figure 11. NEFSC autumn bottom trawl survey biomass indices for American plaice.

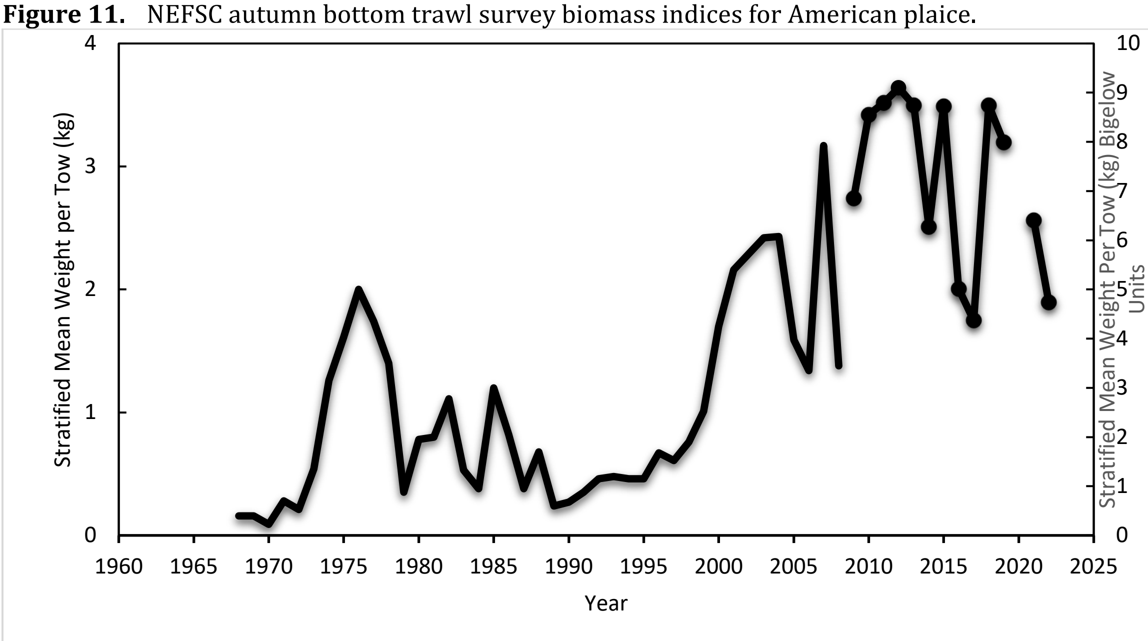

Figure 12. NEFSC spring bottom trawl survey biomass indices for summer flounder Data from 2009-2021 have not been calibrated to the earlier time series and are plotted on the right axis.

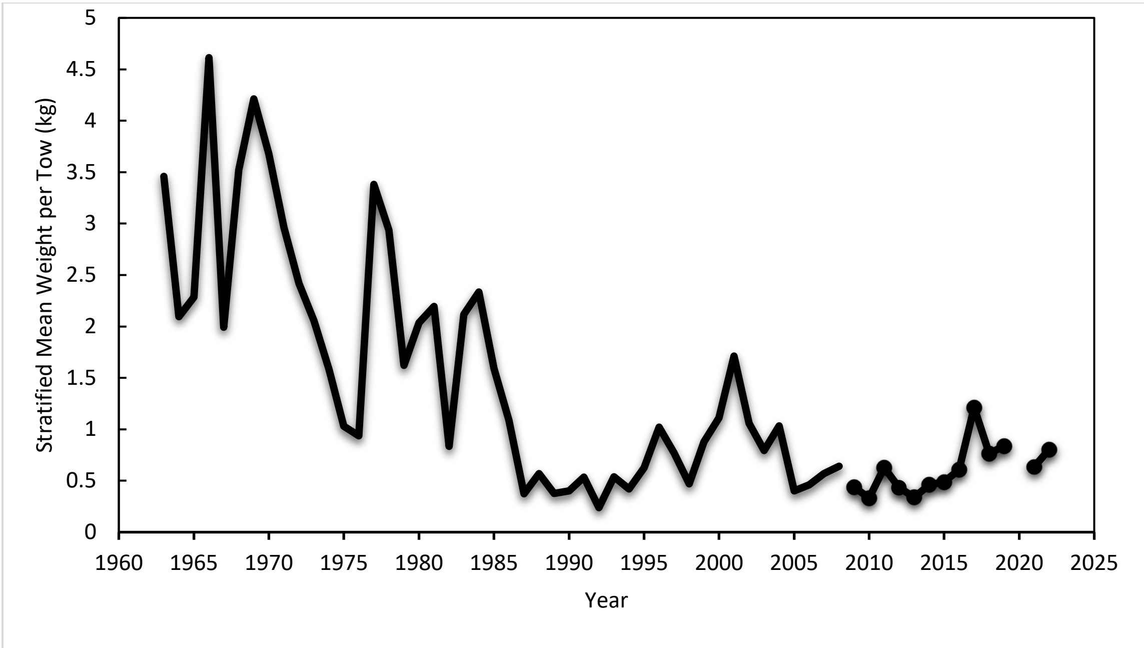

Figure 13. NEFSC autumn bottom trawl survey biomass indices for witch flounder.

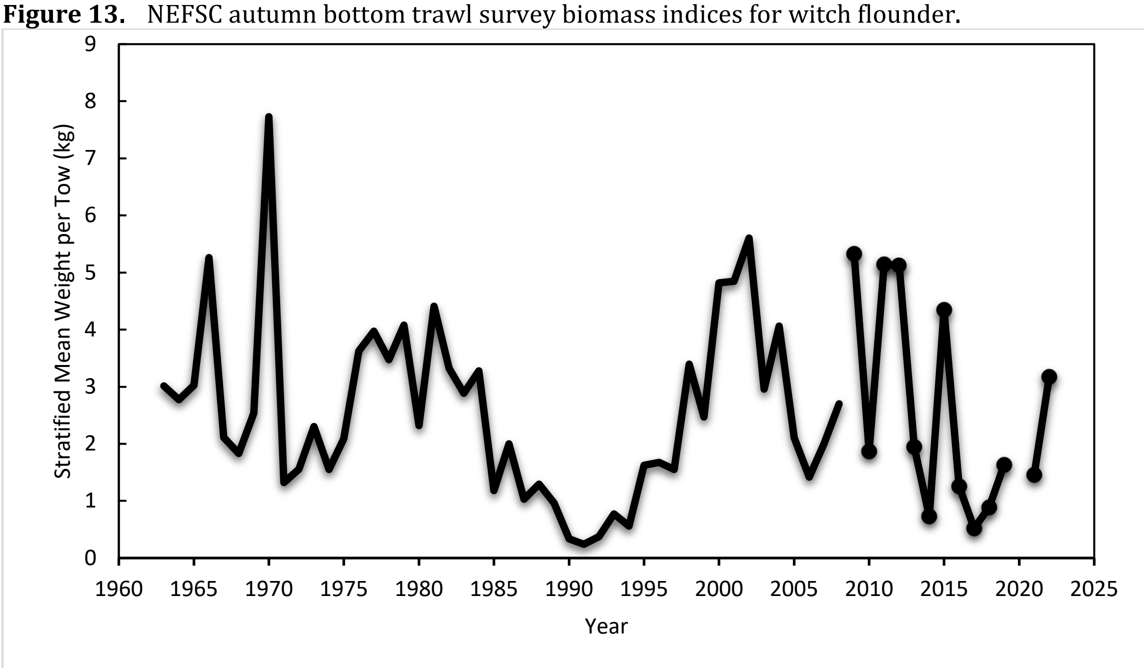

Figure 14. NEFSC autumn bottom trawl survey biomass indices for Georges Bank winter flounder.

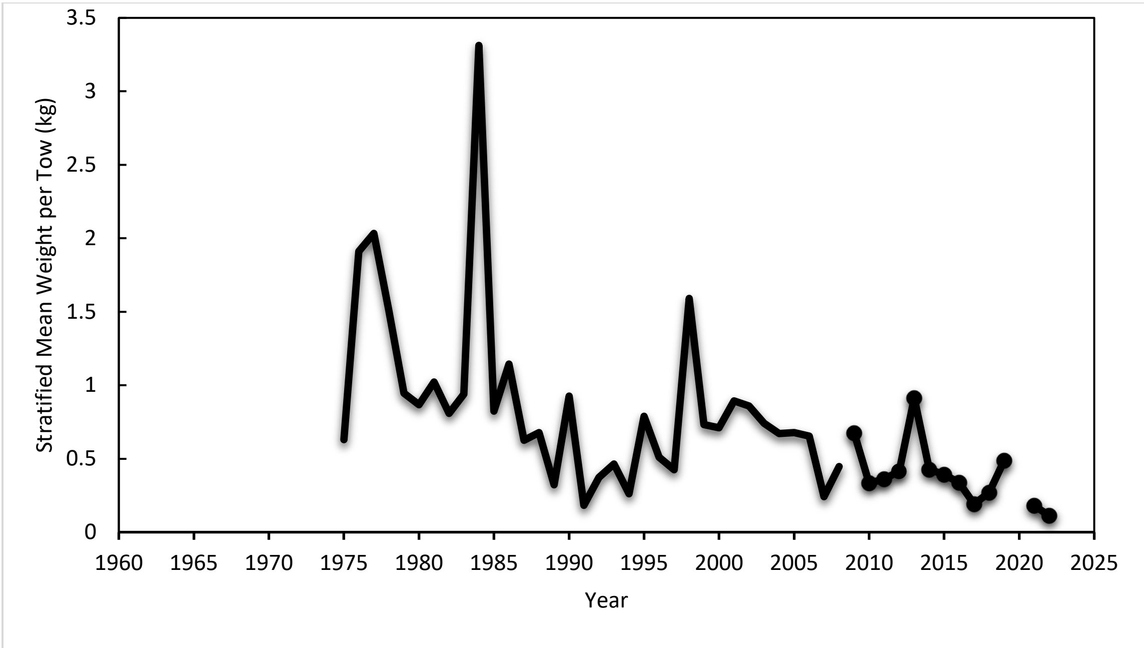

Figure 15. NEFSC autumn bottom trawl survey biomass indices for northern windowpane flounder.

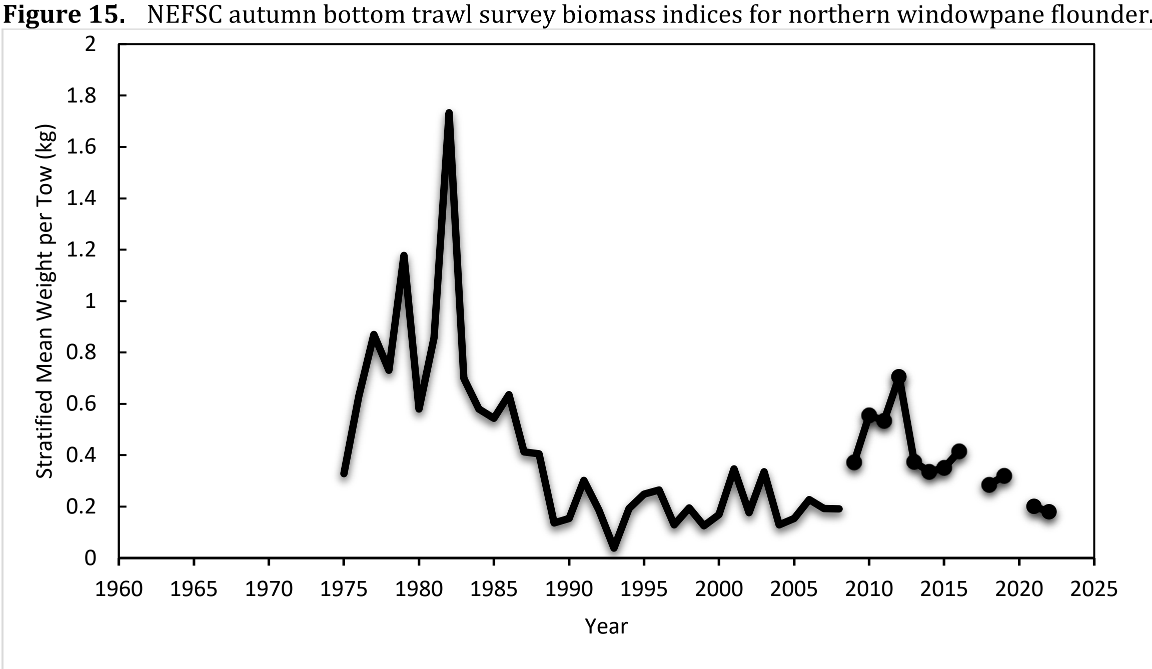

Figure 16. NEFSC autumn bottom trawl survey biomass indices for southern windowpane flounder.

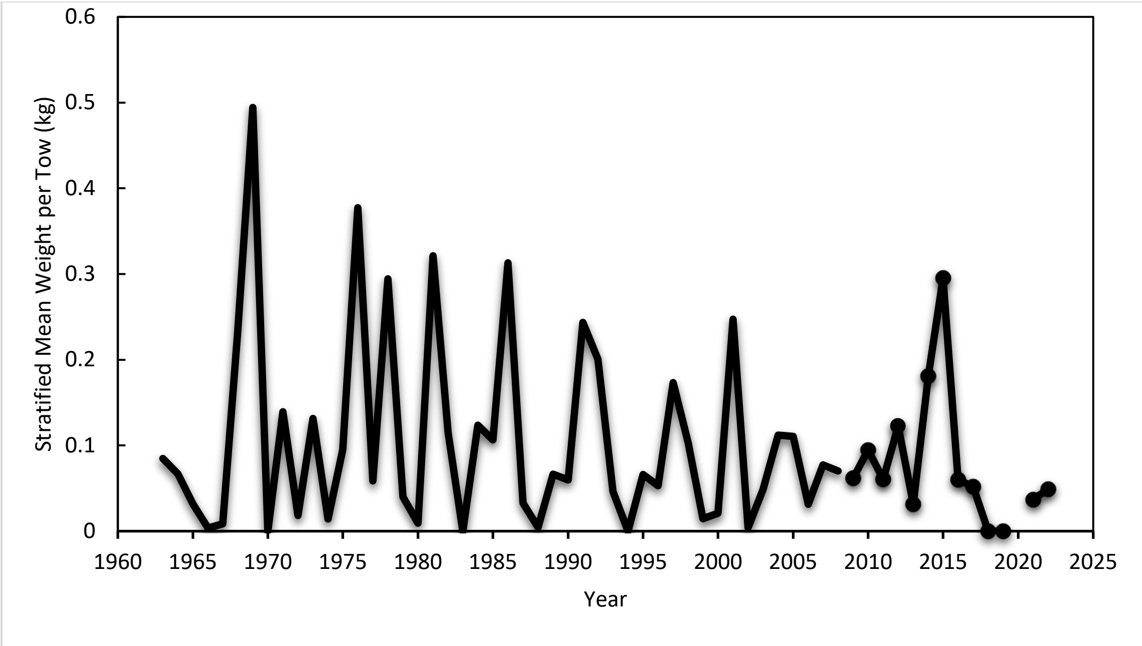

Figure 17. NEFSC autumn bottom trawl survey biomass indices for Atlantic halibut.

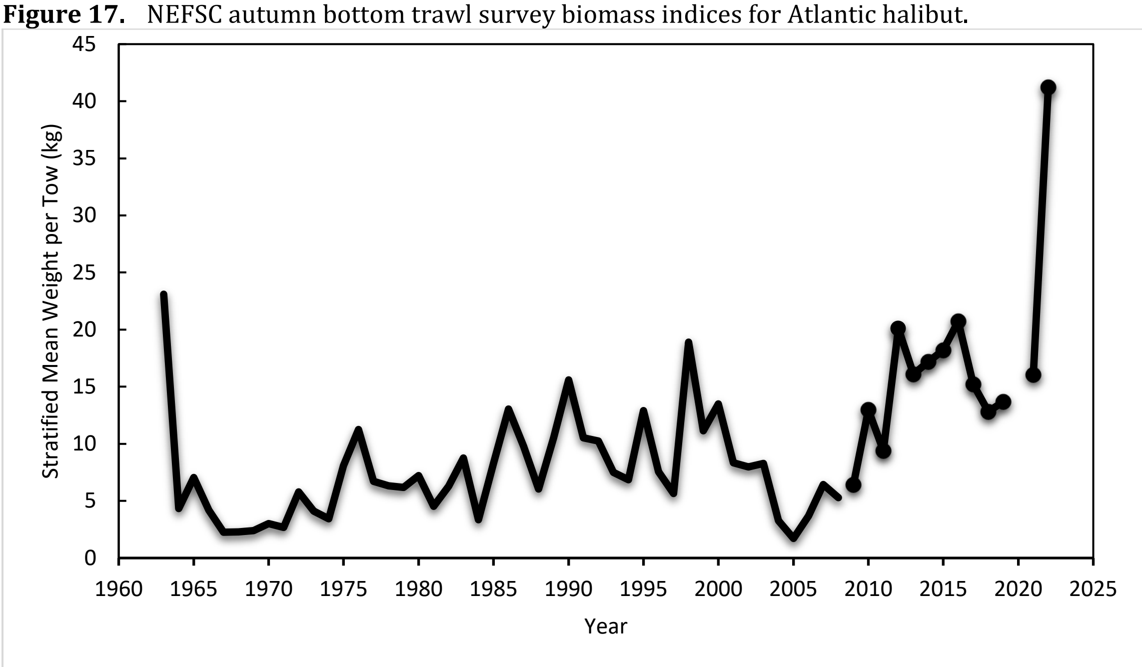

Figure 18. NEFSC autumn bottom trawl survey biomass indices for northern silver hake.

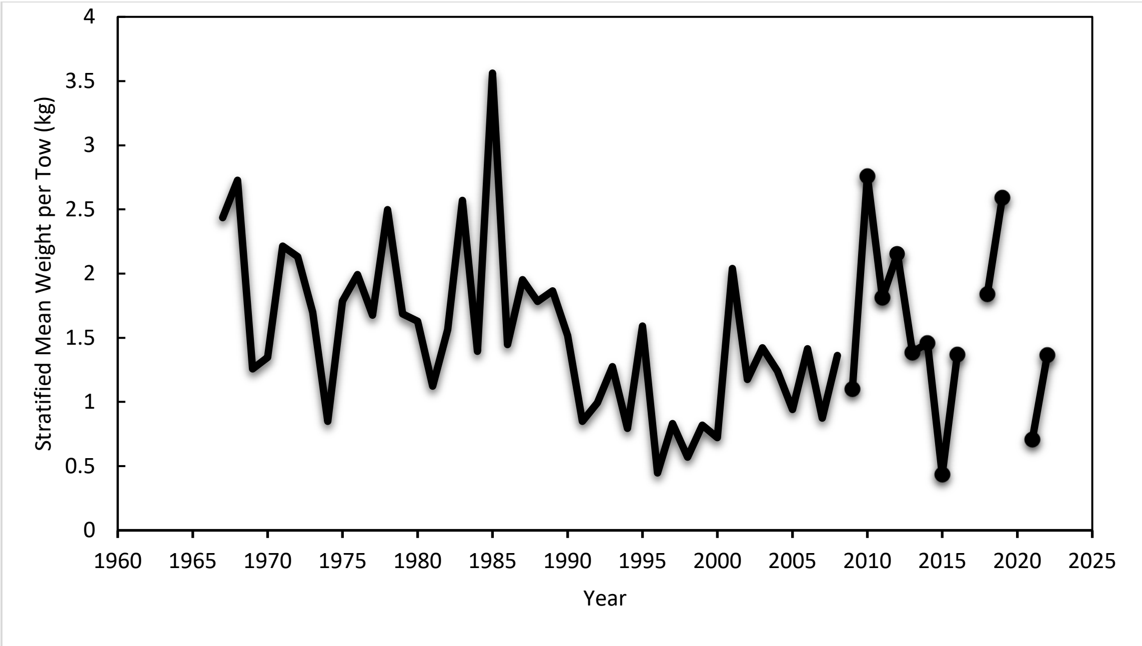

Figure 19. NEFSC autumn bottom trawl survey biomass indices for southern silver hake.

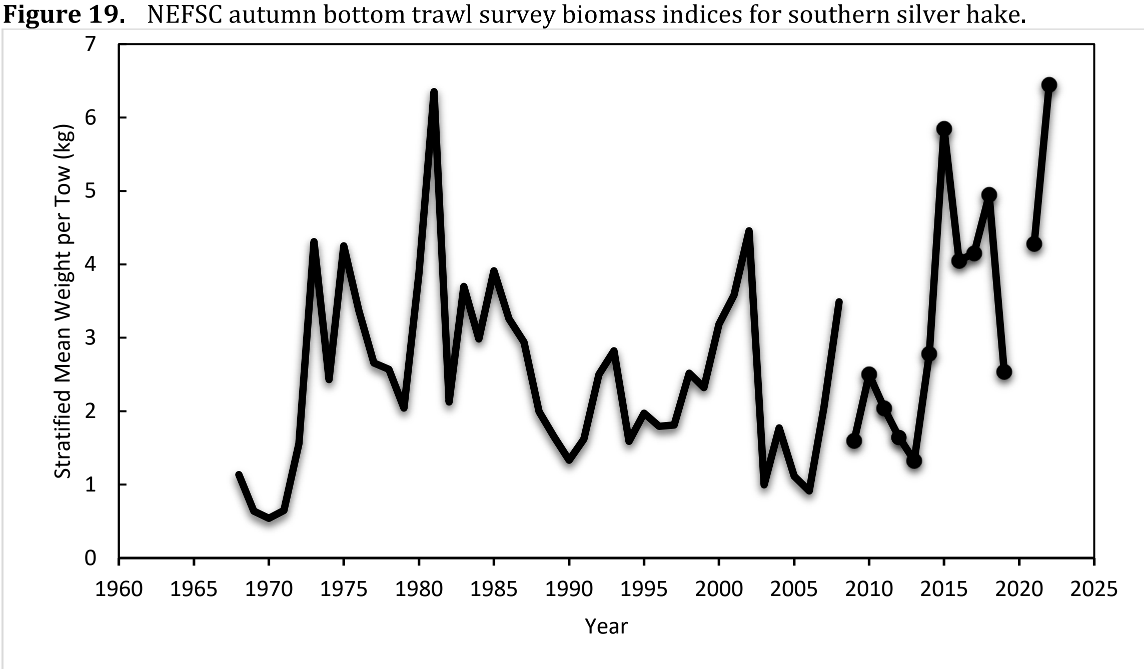

Figure 20. NEFSC spring bottom trawl survey biomass indices for northern red hake.

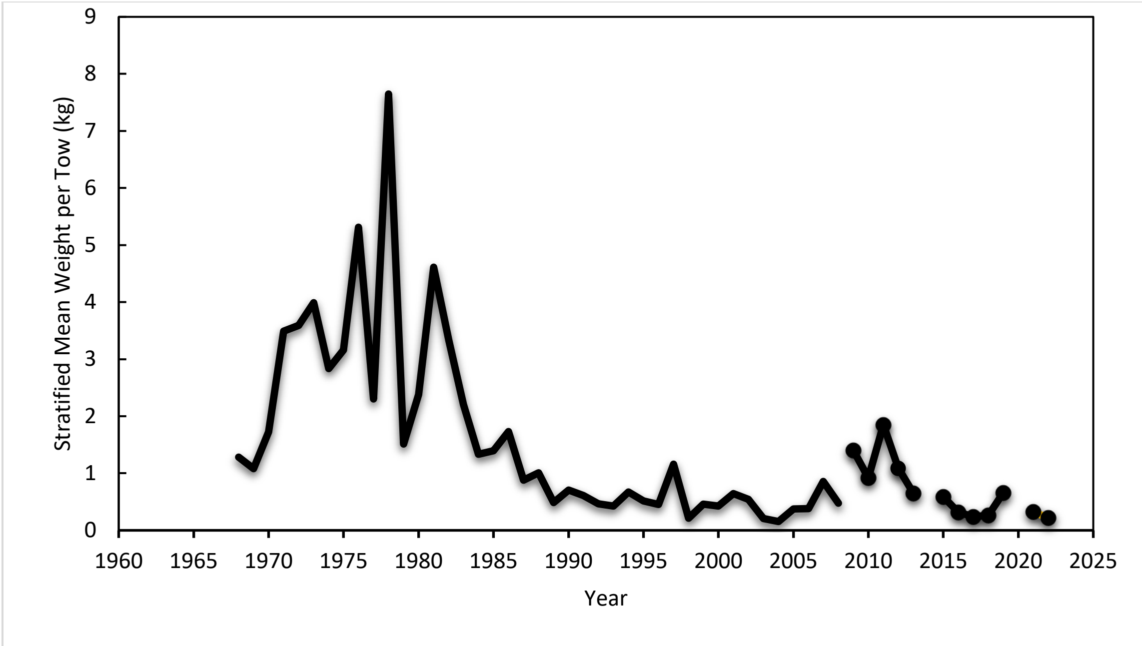

Figure 21. NEFSC spring bottom trawl survey biomass indices for southern red hake.

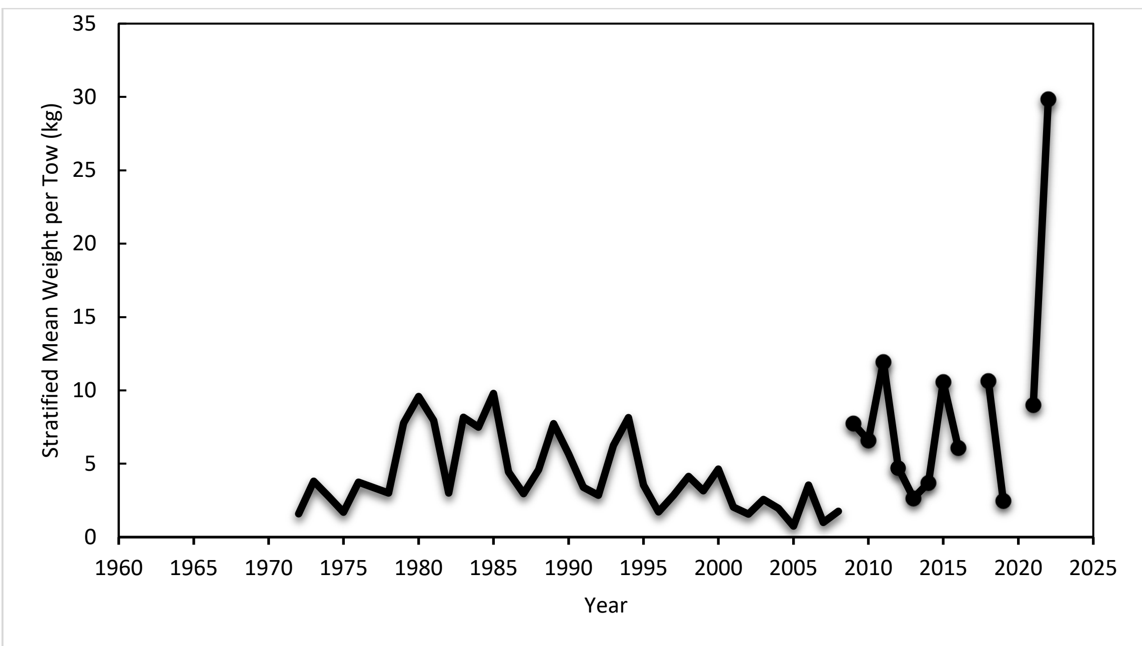

Figure 22. NEFSC autumn bottom trawl survey biomass indices for butterfish.

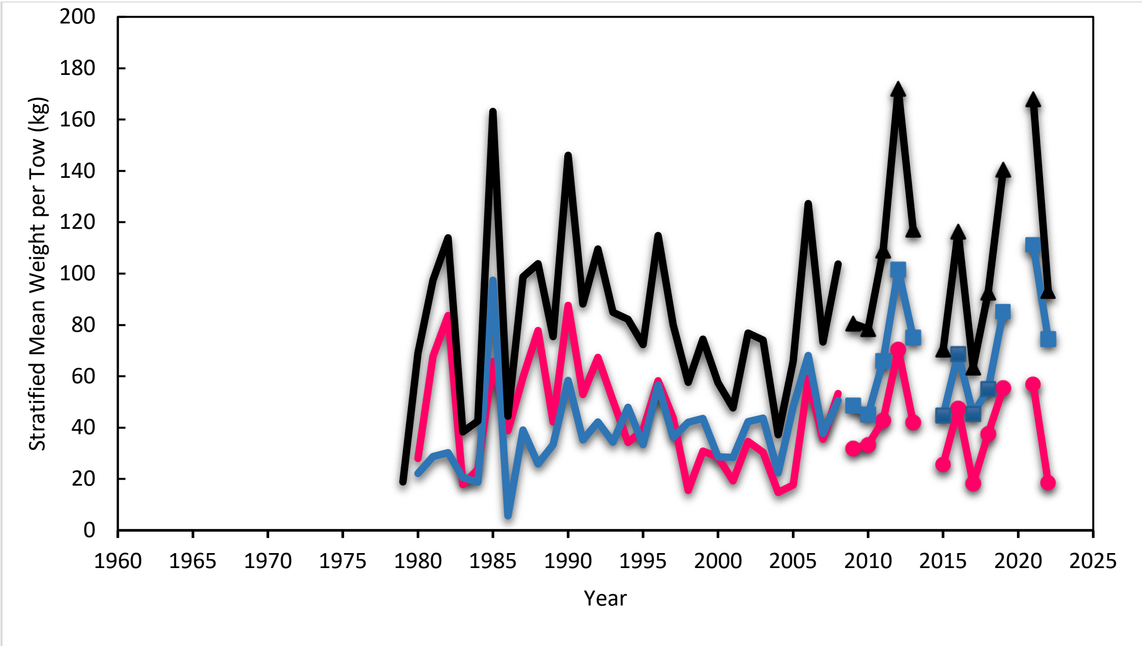

Figure 23. NEFSC spring bottom trawl survey biomass indices for spiny dogfish. The black line with triangles is the total biomass, the blue line with the squares is male biomass and the pink line with circles is female biomass.

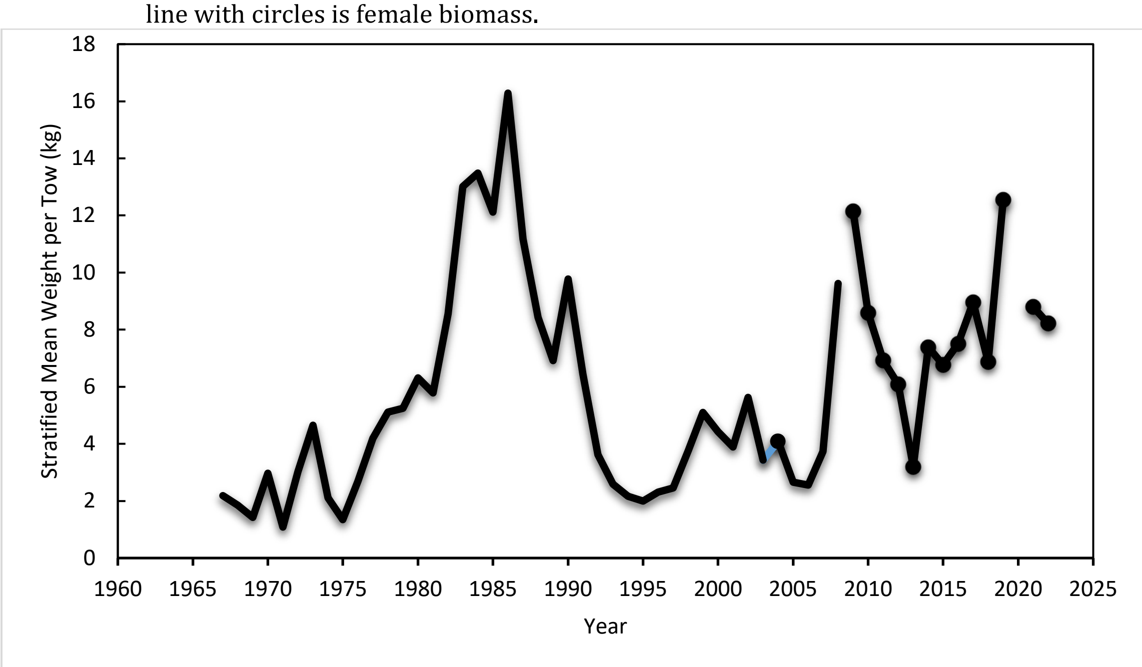

Figure 24. NEFSC autumn bottom trawl survey biomass indices for winter skate.

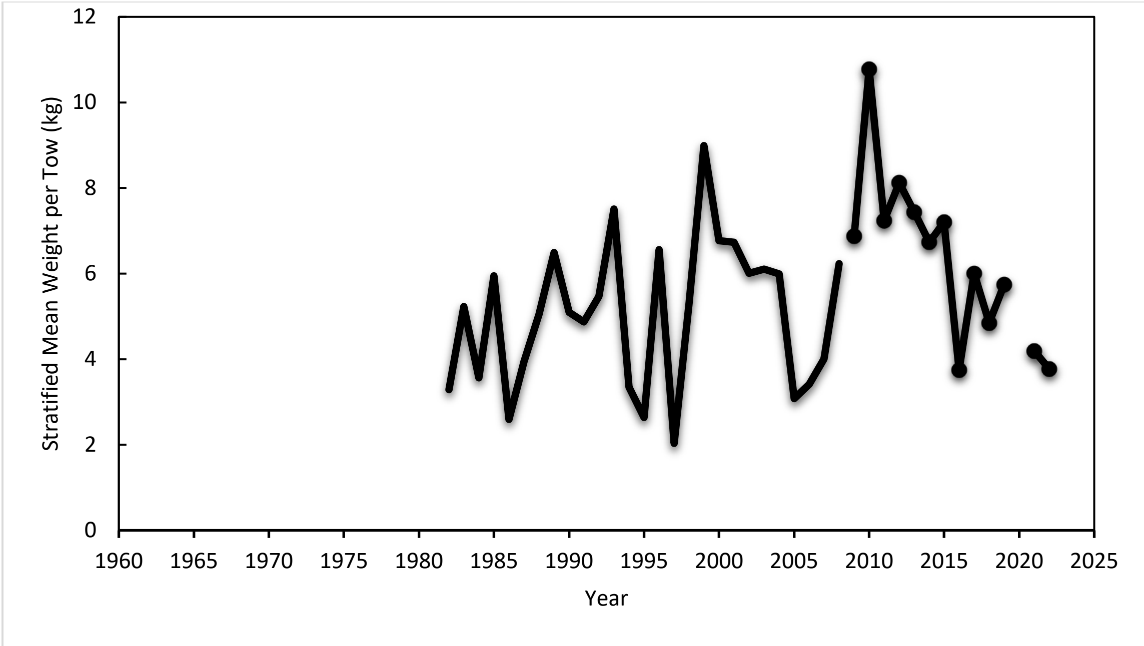

Figure 25. NEFSC spring bottom trawl survey biomass indices for little skate.

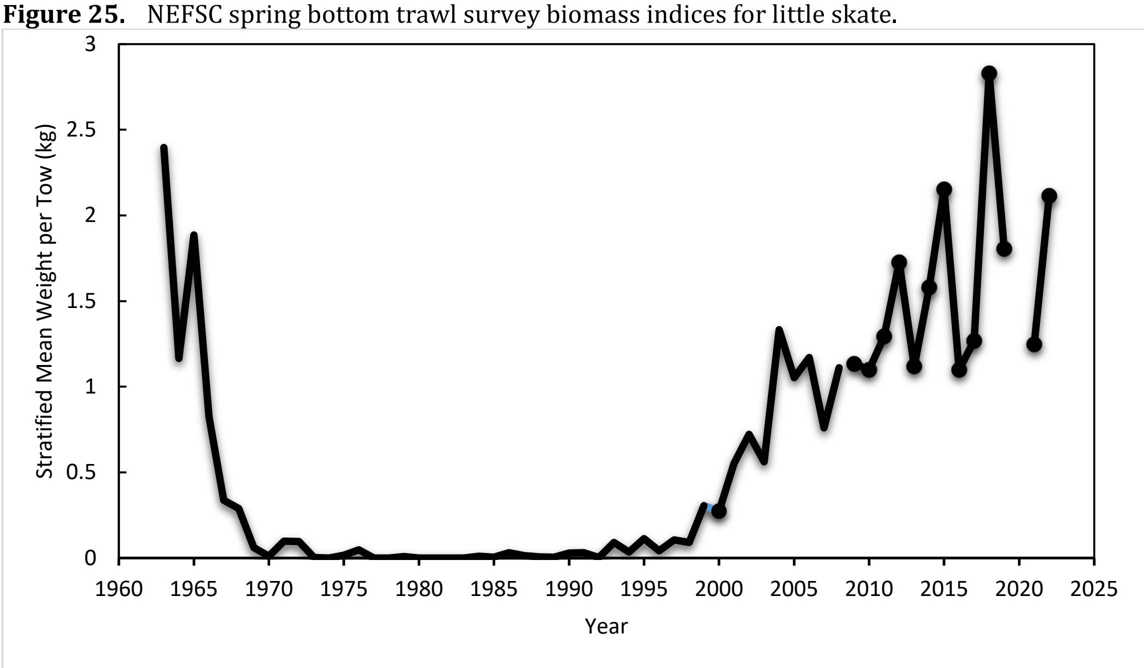

Figure 26. NEFSC autumn bottom trawl survey biomass indices for barndoor skate.

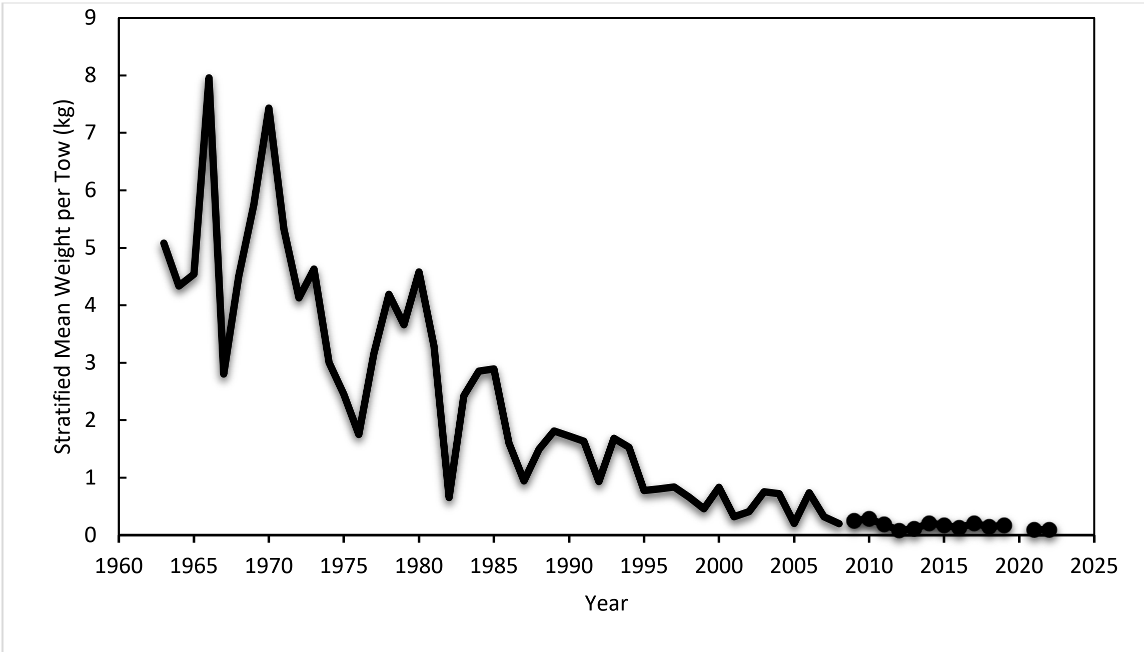

Figure 27. NEFSC autumn bottom trawl survey biomass indices for thorny skate.

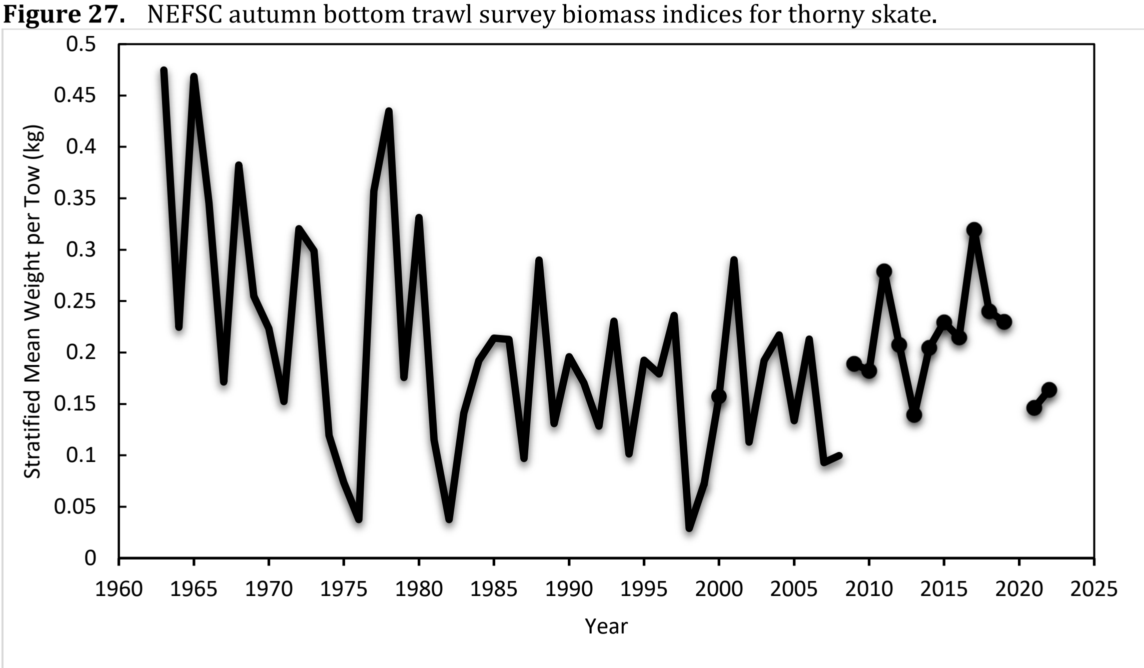

Figure 28. NEFSC autumn bottom trawl survey biomass indices for smooth skate.

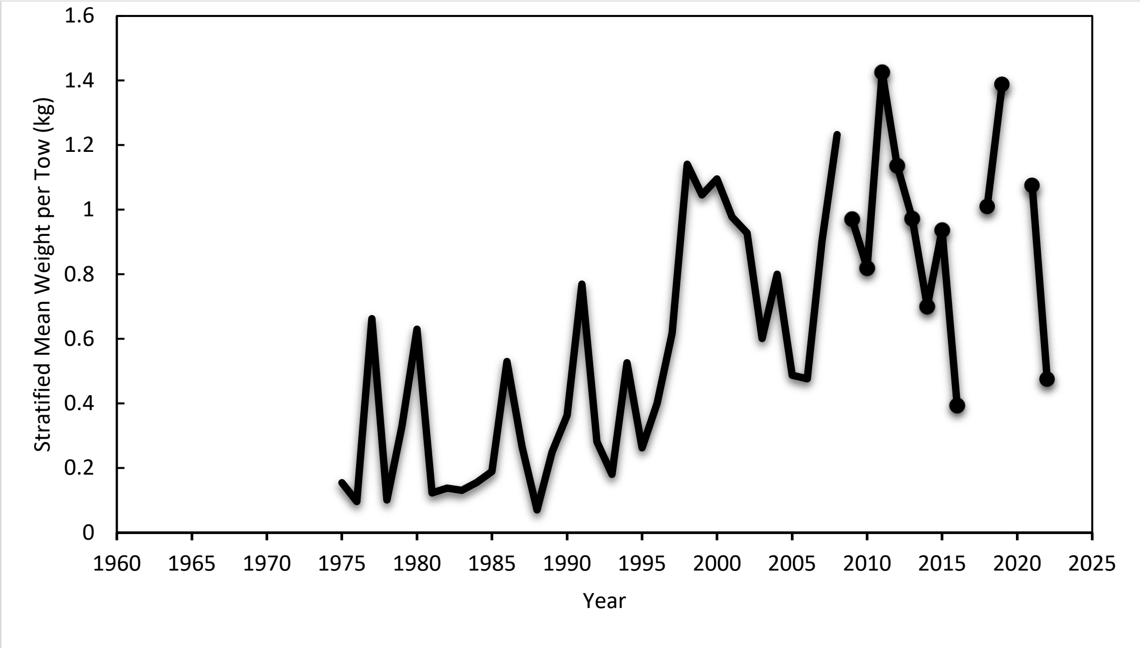

Figure 29. NEFSC autumn bottom trawl survey biomass indices for clearnose skate.

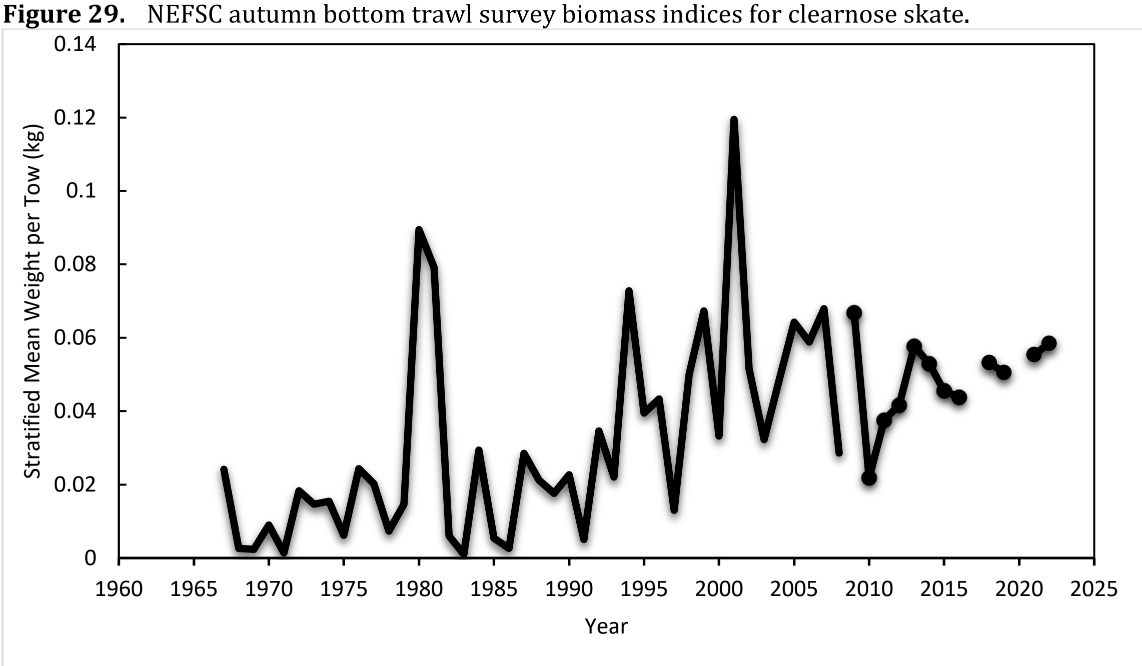

Figure 30. NEFSC autumn bottom trawl survey biomass indices for rosette skate.