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United States Research Report for 2017

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, and in 2010. 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 therefore still considered provisional.

Most spring and autumn survey indices for 2009-2017 were converted from the FSV *Henry B. Bigelow* catches (weights) to RV *Albatross IV* catches (weights) using a either single conversion factor or length-specific conversion factors which have only been estimated for some species. Consequently, 2009-2017 survey data points should be interpreted cautiously, and these values may change in the future as new methodologies are considered. The 2009-2017 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 has 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 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 is discussed in those sections. Additionally, the survey was conducted on a different vessel the FSV *Pisces*, which is considered ti be a sister ship the the FSV *Henry B. Bigelow*. The impact of this change is unknown but should be minimal.

For the last few years, the United States has been allocated quota for Div. 3LNO yellowtail flounder and, from 2012-2017, a vessel fished in the area. An additional vessel fished in area for Atlantic halibut in 2014, while two additional vessels were added in 2017, one for yellowtail and one for Atlantic halibut. The sections for cod, haddock, pollock, yellowtail flounder, white hake, halibut, other flounders, and skates contain the landings and the discards of these species. The landings and discards of species not included below are summarized in Table 1.

1. Atlantic Cod

United States commercial landings of Atlantic cod (Gadus morhua) in 2017 were 842 mt, a 41% decrease from the 2016 landings of 1,432 mt. In addition, 1.8 mt were landed from Div. 3N and 29.2 mt were discarded. In Div. 3M 0.3 mt were discarded while in Div. 3L 0.8 mt were discarded.

Northeast Fisheries Science Center (NEFSC) research vessel survey biomass indices in the Gulf of Maine 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 2017 were 5,490mt, a 9% increase from the 2016 landings of 5,023 mt. In addition, <0.1 mt of haddock were landed in Div. 3N and <0.1 mt were discarded.

Northeast Fisheries Science Center (NEFSC) research vessel survey biomass indices in the Gulf of Maine are near time series highs (Figure 3) due to the presence of several strong year classes. The NEFSC research vessel survey biomass indices for the Georges Bank stock are near the highest levels in the time series due to several recent exceptionally strong year classes (Figure 4).

3. Redfish

USA landings of Acadian redfish (*Sebastes fasciatus*) increased by 33% from 3,889 mt in 2016 to 5,172 mt in 2017. Fall research vessel survey biomass indices generally increased from the mid-1990s through 2010, with the 2010 index value of 83.47 kg/tow being the highest on record, before generally decreasing through 2017 (Figure 5). Most recently, the survey biomass indices decreased by 42% from 45.22 kg/tow in 2016 to 26.20 kg/tow in 2017.

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

USA landings of pollock (*Pollachius virens*) increased by 26% from 2,582 mt in 2016 to 3,249 mt in 2017. In addition < 0.1 mt of Pollock were discarded in NAFO Div. 3N. Fall research vessel survey indices reflected a general increase in pollock biomass from the mid-1990s through 2005, before declining in 2006 (Figure 6). The survey biomass indices have been variable since 2006, reaching a record-low of 0.19 kg/tow in 2009. Most recently, the index decreased by 28% from 1.30 kg/tow in 2016 to 0.94 kg/tow in 2017.

5. White Hake

Nominal USA landings of white hake (*Urophycis tenuis*) from NAFO Subareas 5 and 6 increased by 49% from 1,325 mt in 2016 to 1,978 mt in 2017. Landings from Div. 3N were 46 mt while <0.1 mt were discarded in Div 3M and 15 mt in Div. 3N. Research vessel survey indices declined during the 1990s and increased in 2000 and 2001 due to good recruitment of the 1998 year class. The indices have generally been variable since 2001. The indices have increased from a low value in 2013 (Figure 7).

6. Yellowtail Flounder

USA landings of yellowtail flounder (*Limanda ferruginea*) from NAFO subareas 5 and 6 were 397 mt in 2017, a 12.6% decrease from 2016 landings of 454 mt. In Div. 3N, landings decreased by approximately 13% from 897 mt in 2016 to 782 mt in 2017. Additionally, 11.3 mt of yellowtail flounder were discarded in Div. 3N bringing the total catch of yellowtail flounder in Div. 3N to 793 mt in 2017.
The NEFSC autumn research vessel survey biomass index in the Gulf of Maine has been steadily increasing in the recent three years (Figure 8). Incomplete survey coverage in the

inshore habitat for the autumn survey in 2017 was analyzed to account examine the differences between including and excluding survey strata on the estimate of mean biomass. A linear relationship between survey estimates that excludes missing strata to survey estimates with the full strata values was applied to the observed 2017 autumn survey value of 4.41kg/tow, and resulted in an upward scaling of the fall survey estimate by approximately 14% (5.023 kg/tow). Relative to 2016, the 2017 NEFSC autumn survey biomass increased from 2.47 kg/tow in 2016, to 4.41 kg/tow for unaccounted missing strata or 5.023 kg/tow when adjusted for missing strata (Figure 8).

The NEFSC autumn research vessel survey biomass indices on Georges Bank have been declining over the last nine years. In 2017, the NEFSC autumn survey biomass is second lowest of the time series. The 2017 autumn survey was 0.20 kg/tow compared to 0.44 kg/tow in 2016 (Figure 9).

The 2017 biomass index for the NEFSC autumn survey was not computed for Southern New England-Mid Atlantic yellowtail because the primary habitat for this stock was not sampled due to mechanical problems with the survey vessel.

7. Other Flounders

USA commercial landings of flounders (other than yellowtail flounder and Atlantic halibut) from Subareas 3-6 in 2017 totaled 5,407 mt, 13% lower than in 2016. Summer flounder (*Paralichthys dentatus*; 49%), winter flounder (*Pseudopleuronectes americanus*; 20% comprising the Georges Bank, Southern New England, and Gulf of Maine stocks), American plaice (*Hippoglossoides platessoides*; 23%), witch flounder (*Glyptocephalus cynoglossus*; 8%), and windowpane flounder (*Scophthalmus aquosus*; <1% comprising the Northern and Southern stocks) accounted for virtually all of the 'other flounder' landings in 2017. Compared to 2016, commercial landings in 2017 were lower for summer flounder (-25%) and winter flounder (-8%), but higher for witch flounder (12%), American plaice (11%), and windowpane flounder (2%). The American plaice landings from Div. 3N were 77 mt. In addition, 40.3 mt of American plaice were discarded in Div. 3N bringing the total catch of American plaice in Div. 3N in 2017 to 117.3 mt. The witch flounder landings from Div. 3N were < 1 mt while witch flounder discards were 2.6 mt.

Research vessel survey indices in 2017 increased for witch flounder, decreased for American plaice, Georges Bank winter flounder, northern windowpane, and summer flounder (Figures 11-16). The 2017 research vessel survey index for southern windowpane is not available due to insufficient sampling of the standard strata set.

8. Atlantic halibut

USA landings of Atlantic halibut (*Hippoglossus hippoglossus*) in the Gulf of Maine-Georges Bank region decreased 6% from 68 mt in 2016 to 64 mt in 2015. In addition, 42.6 mt of halibut were landed in NAFO Div. 3N and 18.3 mt of halibut were discarded. In Div. 3M and 3L, 9.2 and 10.5 mt were landed, respectively and 0.5 and 1.9 mt discarded. 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 – 2017 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 were 5,351 mt in 2017, a 15% decrease from 2016 landings of 6,332 mt.

The NEFSC autumn research vessel survey biomass indices for northern silver hake have generally been increasing over the last ten years. In 2017, the NEFSC autumn survey biomass was 15.76 kg/tow, a decrease from the 2016 survey value of 21.51 kg/tow (Figure 18).

The NEFSC autumn survey in the south has been relatively stable in the recent five years with the exception of the 2015 survey value estimated lowest in the time series. Due to mechanical issues of the vessel, survey coverage of primary habitat for this stock was incomplete. Stratum level average catches of unsampled strata in the autumn of 2017 were then recalculated using the recent three year averages (2014-2016) of mean stratum catches. The stratified mean biomass was then recalculated to account for the incomplete coverage in the south. The recalculated 2017 NEFSC autumn survey resulted in downward scaling of the observed survey value of 1.14 kg/tow by approximately 13% to 0.99 kg/tow. (Figure 19)

10. Red Hake

USA landings of red hake (*Urophycis chuss*) decreased 20% from 490 mt in 2016 to 394 mt in 2017. Research vessel survey biomass indices for the Gulf of Maine - Northern Georges Bank stock increased after the early 1970s, markedly declined in 2003, stable through 2014, and increased in 2015 to the second highest value in the time series but has since declined again. The 2017, the NEFSC spring biomass index was 4.66 kg/tow, a 5% increase from the 2016 value of 4.46 kg/tow (Figure 20). Indices for the Southern Georges Bank - Mid-Atlantic stock declined in the 1990s and remained low through 2017(Figure 21).

11. Atlantic Herring

Nominal preliminary USA landings of Atlantic herring (*Clupea harengus*) declined, equaling 67,574 mt in 2016 and 50,250 mt in 2017, which continues a decline that began in 2014. Spring survey indices generally declined slightly during 2010-2017 and averaged 10.92 kg/tow (Figure 22). The 2017 spring survey index was 5.49 kg/tow. Based on a 2015 update to the 2012 assessment, spawning biomass generally increased from 1982 to 1997, declined from 1998 to 2009, and increased through 2014. The 2008 year class was estimated to be the largest on record and the 2011 cohort the second largest. A retrospective pattern reemerged in the 2015 update assessment that had been largely resolved using time varying natural mortality in the 2012 assessment. While time varying natural mortality was still applied in 2015, this feature no longer appears sufficient to remove the retrospective pattern. Age composition data show that the 2008 cohort has persisted and still significantly contributes to the fishery, but the 2011 cohort also comprises a large proportion of survey and fishery catches in recent years. A benchmark Atlantic herring assessment will be conducted in summer of 2018. The consequences of the transition to a new survey vessel (i.e., the Bigelow) that began in 2009 and time-varying natural mortality are likely to continue to be of interest at the benchmark assessment.

12. Atlantic Mackerel

USA commercial landings of Atlantic mackerel (*Scomber scombrus*) increased 21.0% from 5,687 mt in 2016 to 6,882 mt in 2017. Recreational catches decreased 20.8% from 1,611 mt in 2016 to 1,275 mt in 2017.

Northwest Atlantic mackerel in NAFO subareas 3-6 was last assessed in the U.S. in 2017 through the Northeast Stock Assessment Workshop (SAW) process. This assessment recommended that Atlantic mackerel be considered overfished with overfishing occurring. A rebuilding plan is currently being developed by the U.S.'s Mid Atlantic Fishery Management Council (MAFMC).

For the recent U.S. assessment, a range-wide spawning stock biomass (SSB) index was developed by combining estimates from Canada's dedicated Atlantic mackerel egg survey and estimates from the U.S.'s ichthyoplankton surveys. The combined SSB index showed a general decline over the time series from a maximum of 1,846,983 mt in 1986 to 29,256 mt in 2010, beyond which SSB increased slightly to 55,805 mt in 2016 (Figure 23). This general trend was also observed in the time series of both individual spawning contingents. The proportion of the total spawning biomass represented by the southern contingent varied over time from a maximum of 43% in 1983 to a minimum of 1% in 2005 and averaged 6.6% since 2010. Accordingly, trends in the combined SSB index closely followed those of the northern contingent. The strong increases in the combined SSB index around 1986 and 2002 were thought to be due to the arrival of the 1982 and 1999 dominant year-classes, respectively.

13. Butterfish

USA landings of butterfish (*Peprilus triacanthus*) increased 207.0% from 1194 mt in 2016 to 3665 mt in 2017. Fall research vessel survey biomass indices have fluctuated substantially since the 1970s, but were generally highest in the late 1970s to early 1990s. Since 1995, annual values have typically been less than the long-term average (mean = 6.21 kg/tow). Biomass in 2017 is NA due to limited sampling of butterfish strata (Figure 24).

14. Squids

The USA small-mesh bottom trawl fishery for longfin inshore squid, *Doryteuthis (Amerigo) pealeii,* began in 1987. During 1987-2016, landings averaged 15,457 mt, with a low of 6,913 in 2010 and a peak of 23,733 mt in 1989. In addition to other factors, landings have been affected by in-season quotas, since 2000, which have been trimester-based since 2007. During 2007-2016 landings were below the 1987-2016 mean and averaged 11,569 mt. Landings during 2017 (8,176 mt) were the lowest since 2010.

Fall survey relative abundance indices of longfin inshore squid (derived using only daytime tows) declined from the third highest point in the time series during 2006 (1,778 squid per tow) to 339 squid/tow in 2011 (Figure 25). During 2012-2014, relative abundance increased and was above the 1975-2016 median of 638 squid per tow but then declined to 536 squid per tow in 2016. Abundance indices were not computed for 2017 because there were mechanical problems with the survey vessel and the primary longfin squid habitat was not sampled.

The USA small-mesh bottom trawl fishery for Northern shortfin squid (*Illex illecebrosus*) began in 1987. During 1987-2016, landings averaged 11,914 mt, with a low of 1,958 mt in 1988 and a peak of 26,097 mt in 2004. In recent years, landings declined from 18,797 mt in 2011 to 2,422 mt in 2015 then increased to 6,682 mt in 2016. Landings during 2017 totaled 22,516 mt and were the third highest amount since 1987.

Fall survey relative abundance indices of Northern shortfin squid attained a record-high in 2006 (29.5 squid/tow) then steadily declined below the 1967-2016 median (8.0 squid per tow) to 4.7 squid/tow in 2013. Thereafter, relative abundance increased and was slightly above the median through 2015, but then declined to 7.6 squid per tow in 2016 (Figure 26). Abundance indices were not computed for 2017 because there were mechanical problems with the survey vessel and the primary *Illex* habitat was not sampled.

15. Atlantic Sea Scallops

USA Atlantic sea scallop (*Placopecten magellanicus*) landings in 2017 were 23,466 mt (meats), an increase of about 4,940 mt over 2016. The ex-vessel value of the landings was $509 million, about $23 million higher than 2016. Landings are expected to increase further during 2018-2019 as the very strong 2012 Georges Bank and 2013 Mid-Atlantic year classes enter the fishery.

The total biomass in 2017, based on dredge and optical surveys, was about 275,000 mt (meats), the highest on record, with about 173,000 mt on Georges Bank and 102,000 mt in the Mid-Atlantic.

16. 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. Recruitment indices have been at lowest observed values in four of the six years since 2011 (the time series began in 1984). Warming temperatures, increased predation pressure and overexploitation are factors thought to have been responsible for the collapse. Recruitment improved slightly in 2016, but was at its lowest level in 2017, and the fishery remains closed.

17. Small Elasmobranchs

USA landings of spiny dogfish (*Squalus acanthias*) decreased 9.5% from 12,097 mt in 2016 to 10,949 mt in 2017. In addition, <0.1 mt were discarded in Div. 3N. Survey indices, which are highly variable, generally declined between the early 1990s and 2005, but increased sharply in 2006 and have since remained high (Figure 28). The 2014 data point is plotted, although the comparability with previous years has not been evaluated. The area not covered by the survey generally had a large proportion of the spiny dogfish biomass. The survey index remained high in 2016, although the survey was a month later than normal and may have impacted the comparability of the estimate. The 2017 survey index declined although the survey was conducted at the normal time of the year.

USA nominal landings of skates (most species are still landed as unclassified) decreased 5% between 2016 and 2017 from 15,379 mt to 14,580 mt. The landings are sold as wings for human consumption and as bait for the lobster fishery. In addition, 56.9, 0.8 and 1.2 mt of thorny skate were discarded in Div. 3N, 3M and 3L, respectively. Barndoor skate were also discarded in 3N (<0.1 mt). An additional 1.2, 0.8 and 6.4 mt of spinytail skate were discarded in Div 3L, 3M and 3N, respectively. Less than 0.1 mt was discarded each of shorttail skate, smooth skate, soft skate and skate, unclassified in Subarea 3.

For winter skate, the lack of coverage in the Southern New England and the Mid-Atlantic strata described above for fall 2017 was analyzed for the entire time series to show the difference between including and excluding these strata on the estimate of mean biomass.. In general, winter skate are more abundant in the northern strata. Thus relative biomass estimates (catch per tow) based on the northern strata only will be higher than estimates based on the entire strata set. Over the entire time series (1967-2016) the ratio of the time series without the southern strata to the full strata set is 1.729. To adjust the observed 2017 value for this average ratio, the 2017 value of 14.464 was divided by 1.729 yielding a value of 8.36. Survey biomass indices for winter skate (*Leucoraja ocellata*) peaked in the mid-1980s (Figure 29) but then declined, possibly due to an increase in the directed fishery in the late 1980s and early1990s. During the mid-1990s, the indices stabilized at an intermediate level, increased through 2009, declined through 2013, but increased in 2014 and remained above 2012-2013 values through 2017.

For little skate, the lack of coverage in the southern strata described above for spring 2014 was analyzed for the entire time series to show the difference between including and excluding these strata on the estimate of mean abundance.. In general, little skate are more abundant in the northern strata. Thus relative abundance estimates (catch per tow) based on the northern strata only will be higher than estimates based on the entire strata set. Over the entire time series (1968-2013) the ratio of the time series without the southern strata to the full strata set is 1.091. To adjust the observed 2014 value for this average ratio, the 2014 value of 7.14 was divided by 1.091 yielding a value of 6.54. Little skate (*Leucoraja erinacea*) survey indices have generally fluctuated without trend (Figure 30).

For barndoor skate, thorny skate and smooth skate, the lack of coverage in the Southern New England strata described above for fall 2017 was analyzed for the entire time series to show the difference between including and excluding these strata on the estimate of mean biomass.. In general, all three species of skate are more abundant in the northern strata. Thus relative biomass estimates (catch per tow) based on the northern strata only will be higher than estimates based on the entire strata set. Over the entire time series (1963-2016) the ratios of the time series for the three species without the southern strata to the full strata set are 1.251, 1.458, and 1.382, respectively. To adjust the observed 2017 values for these average ratios, the 2017 values of 1.983, 0.299, and 0.454 were divided by 1.251, 1.458, and 1.382 yielding a values of 1.58, 0.21, and 0.33. Survey indices for barndoor skate (*Dipturus laevis*) declined markedly in the mid-1960s, remained very low through the late-1980s, and subsequently increased to levels observed in the mid-1960s (Figure 31). Thorny skate (*Amblyraja radiata*) survey indices have declined over the entire time series, and are currently near record lows (Figure 32). Survey indices for smooth skate (*Malacoraja senta*) are highly variable, but have been generally stable for the last 20 years (Figure 33) with an increase over the last several years. For clearnose and rosette skate, there are no indices available for 2017 since the entire strata set was not covered. Indices for both clearnose skate (*Raja eglanteria*) and rosette skate (*Leucoraja garmani*) generally increased over the time series (Figures 34 and 35) with a decrease over the last couple of years.

B. Special Research Studies

1. <u>Environmental Studies</u>

a) <u>Hydrographic Studies</u>

A total of 1146 CTD (conductivity, temperature, depth) profiles were collected and processed by the Northeast Fisheries Science Center (NEFSC) in 2017 over the course of 8 cruises. Of this total, 1085 CTD profiles were obtained within NAFO Subareas 4, 5, and 6. These data are archived in an oracle database. Cruise reports, annual hydrographic summaries, and data are accessible at: http://www.nefsc.noaa.gov/epd/ocean/MainPage/index.html.

Hourly bottom temperature records obtained by participants of the Environmental Monitors on Lobster Trap Project (see emolt.org) at approximately 50 fixed locations/depths around the Gulf of Maine and Southern New England Shelf indicate that 2017 was a year of extremes. Relative to the seasonal average, it started out warm, got cold in late Spring, and ended very warm. The 17-year time series of hourly bottom temperatures at many locations are now being compared to multiple ocean models and, in some cases, being assimilated into hindcast runs.

Realtime bottom temperature is now being reported from more than a dozen Study Fleet Trawlers when the fishermen haul their gear. Beginning in May 2015, approximately 4000 trawl-averaged bottom temperatures have been automatically transmitted via satellite from a variety of locations and depths. Funding is available for a few dozen more boats in 2018. A pilot study is underway to send weather data as well.

Approximately 80 satellite-tracked surface drifters were deployed off the coast of New England in 2017 (see http://www.nefsc.noaa.gov/drifter). The collective archive helps resolve the transport pathways of coastal currents in shelf waters. The drifter project is promoted as an educational tool where students are involved with both the construction of the instruments and the processing, plotting, and analysis of the data. Sensor packages are now being developed and housed on these drifters and a few dozen unmanned sailboats (see http://educationalpassages.org) deployed annually.

b) Plankton Studies

During 2017, zooplankton community distribution and abundance were monitored using 575 bongo net tow samples taken on 7 surveys. Six of the seven surveys covered all or part of the continental shelf region from Cape Hatteras northeastward into the Gulf of Maine, including Georges Bank. One survey, designated as the Tuna / Slope Water Survey, concentrated on sampling the slope water region of the Mid-Atlantic Bight to collect tuna larvae. Part of this survey used slightly different towing protocols from conventional Ecosystem Monitoring Surveys in that 134 of the bongo net tows were done as tow-yos instead of double obliques to focus on the upper 25 meters of the water column to increase the chances of capturing Bluefin or Yellowfin tuna larvae. The remaining 100 tows carried out on the Tuna / Slope Water Survey were done in a conventional double oblique manner down to 200 meters.

2017 was the fourth year where the Imaging FlowCytoBot unit from the Woods Hole Oceanographic Institute was used to collect images of phytoplankton from the scientific seawater flow-through system on the three Ecosystem Monitoring Surveys. In addition, these three ecosystem monitoring cruises conducted water casts, collecting a total of 156 nutrient samples in collaboration with the University of Maine to monitor levels of nutrients in the euphotic zone. While the water casts collecting nutrient samples were being conducted, 102 chlorophyll samples were taken along with 114 dissolved inorganic carbon samples. The three dedicated ecosystem monitoring surveys also collected 62 plankton samples for the Census of Marine Zooplankton Program, based at the University of Connecticut. These samples, collected with a set of smaller (20 cm diameter) bongo nets, having 165 micron mesh, were for genetic analysis of the planktonic organisms to supplement identifications made by traditional visual taxonomic means. These same three surveys also collected 198 plankton samples using the same smaller (20 cm diameter) bongo nets equipped with 335 micron mesh for larval fish and egg sample genetic studies.

c) Benthic Studies

No field work done for 2017

2. Biological Studies

a) Fish Species

Flatfishes: The team of researchers at the NOAA NMFS Howard Laboratory (Highlands, New Jersey), along with collaborators within the Northeast Fisheries Science Center and in academia, continue to implement experimental studies designed to evaluate the potential effects of future ocean conditions (elevated CO_2 and water temperature) on early life-stages of marine fishes. The key elements of this approach are that it uses i) multiple species that differ in their ecologies and resource values, ii) wide yet realistic ranges of environmental conditions (e.g., concurrent manipulation of CO_2 levels and water temperatures), and iii) diverse, ecologically relevant response variables. The research team has grown by bringing in colleagues and collaborators with different skills with respect to the set of biotic response variables to be included in the analyses. To date, we have completed seven experiments that evaluate the effects of high CO_2 seawater on the early life-stages of finfish important to the NW Atlantic. Two experiments have been conducted on summer flounder, *Paralichthys dentatus*, and four on winter flounder, *Pseudopleuronectes americanus*. The first experiment on summer flounder, a one-way experimental design with CO_2 levels as the factor (at 3 levels) is complete and published (Chambers et al. 2014. *Biogeosciences*, 11, 1613-1626, doi:10.5194/bg-11-1613-2014, 2014.). The rates of growth and development of larvae in the two-way experiments are currently being analyzed. The responses scored in these experiments include fertilization rates, embryo viability, survival, developmental rate, growth rate, histological changes, otolith allometry, biochemical measures of fish condition, and differential gene expression. Our results from the summer flounder one-way design showed a significant negative affect of increased CO_2 on embryo survival and on larval growth and development. Larvae were initially larger, develop more quickly but metamorphosed at smaller sizes at high CO_2 levels. Results from the 2-way experiments on both flounder species show significant though opposite effects of CO_2 on fertilization rates with a negative impact of increasing CO_2 on fertilization in summer flounder but a positive one in winter flounder. Both species exhibited significant interactions in responses to CO_2, temperature, and parentage. In 2015 - 2017 we implemented OA work on two fronts: 1) the potential for transgenerational effects on the resiliency of offspring to high CO_2, and 2) intraspecific, inter-population differences in resilience to high CO_2 between stocks that experience contrasting levels of environmental variance in CO_2 *in situ*. For the former study we are evaluating responses in small-bodied forage species that can be housed and accommodated by our in-house CO_2 delivery system. The focal species is Atlantic silverside (*Menidia menidia*) and results are discussed below. Winter flounder is our experimental model for the inter-population contrasts. In early 2016, we collected and spawn adults, and compared responses of offspring derived from parents collected inshore at two latitudes (New Jersey, New Hampshire) with those from an offshore spawning population (Stellwagen Bank offshore from Massachusetts).

<u>Sturgeons</u>: During 2014-16 we conducted multiple experiments on habitat constraints in shortnose and Atlantic sturgeons (*Acipenser brevirostrum* and *A. oxyrhynchus*, respectively) that built upon our earlier pilot eco-toxicological studies (summarized in Chambers et al. 2012, *Environmental Toxicology and Chemistry* 31:2324-2337). Our earlier work evaluated the toxic responses of embryos and larvae after aqueous exposures to PCB 126 and TCDD (dioxin). Rates of uptake of radiolabelled PCB126 were also quantified. We measured viability, macro-phenotypic characters (e.g., days to hatch, morphometrics of recently hatched larvae, and starvation resistance), and molecular responses (CYP1A1). Uptake was a linear function of exposure doses, and lethal and sublethal toxicities to both contaminants were expressed in both species in responses including survival of early life-stages, the size and shape of larvae, and the development of key organs. Our new work, funded for two years by the Hudson River Foundation, the NOAA National Ocean Service Office, and the Delaware River Basin Commission (DRBC) evaluated the separate and combined effects of toxins and climate change on early life-stages of both sturgeon species. The toxins used in 2014 were four congeners of PCBs (77, 81, 126, and 169), an Aroclor mixture, and dioxin. We also challenged embryos of both sturgeon species to the entire thermal tolerance range with up to 40 different constant temperatures. This allowed a clear depiction of the functional form of phenotypic plasticity. In 2015 we conducted 2-way designs (toxin × temperature) in order to evaluate the interactive effects of these co-stressors. In addition, the DRBC-funded component evaluated the role of dissolved oxygen (hypoxia) with thermal warming as a co-stressor in Atlantic sturgeon. Sturgeon larvae were exposed to acute (22-hr) reductions in DO from 10 mg/L to 8, 6, 4, and 3 mg/L and scored for mortality, activity (based on video tracking), and prey consumption (maximum intake and attack rate inferred through functional response trials). Those data were presented at a USGS-NOAA workshop in May 2016, the Annual American Fisheries Society Meeting in August 2016, and the Hudson River Symposium in May 2018. Analyses and summary of gene expression data (AHR2, CYP1A) and TEFs appear in Roy

et al (2017. doi.org/10.1016/j.aquatox.2018.01.017). Macro-phenotypic data are being further analyzed for publication.

Codfish: During 2016 we conducted multiple experiments on habitat constraints in Atlantic tomcod (*Microgadus tomcod*) that built upon our earlier eco-toxicological studies. Our earlier work evaluated the toxic responses of embryos and larvae after aqueous exposures to PCB 126 and TCDD (dioxin). Rates of uptake of radiolabelled PCB126 were also quantified. We measured viability, macro-phenotypic characters (e.g., days to hatch, morphometrics of recently hatched larvae, and starvation resistance), and molecular responses (CYP1A1). Uptake was a linear function of exposure doses, and lethal and sublethal toxicities to both contaminants were expressed in responses of both species including survival of early life-stages, the size and shape of larvae, and the development of key organs. Some of these results are summarized in Wirgin et al. 2014 (*Science* 331: 1322-1325). Our new work, funded for two years by the Hudson River Foundation evaluates the separate and combined effects of toxins and climate change on early life-stages of tomcod. The toxins used in 2016 were four congeners of PCBs (77, 81, 126, and 169), an Aroclor mixture, and dioxin. We challenged embryos to the entire thermal tolerance range of each species with up to 40 different constant temperatures which allowed us to clearly depict the functional form of phenotypic plasticity. In 2016, we also conducted 2-way designs (toxin × temperature) in order to evaluate the interactive effects of these co-stressors. In addition, the role of dissolved oxygen (hypoxia) with summer thermal regimes as a co-stressor after exposure of Atlantic tomcod to these contaminants. Those data are being further analyzed. These effects of these stressors were also evaluated from differences in gene expression among toxins, and novel results were revealed (*Genome Biology and Evolution* 2017 9(9):2251–2264. doi:10.1093/gbe/evx159).

Forage fish. A new set of studies on Atlantic silverside, *Menidia menidia*, was initiated in 2016 and continues into 2018. Those studies focus on effects of climate (thermal and CO2 variations) and parentage on key early life-stage traits (ELS). The 2016 silverside work focused on baseline information on phenotypic variation and the environmental (thermal), maternal, and genetic contributions to that variance. In 2016-2017, a new CO_2 delivery system was developed that allows us to expose test subjects to up to 14 constant or fluctuating CO_2 regimes. Initial evaluations of the system look very promising and this high-frequency CO_2 system (HFCO2) will allow us to quantitatively characterize the shape of responses to elevated CO_2. Experiments in 2017 tested the effects of a wide range of pCO_2 levels (485 to 2,500 µatm) on ELS. Results were presented at 2018 Ocean Sciences Meeting and the Effects of Climate Change on World's Oceans. Those data are being further analyzed. We anticipate using this HFCO2 system to explore CO_2-driven reaction norms, interactions between CO_2 and other environmental co-stressors, and the role of parentage in affecting the sensitivity / resilience of early life stages to elevated CO_2 levels. An analogous HF system is being developed for dissolved oxygen.

b) Resource Survey Cruises

During 2017, 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. In aggregate, the survey staff efforts totaled 126 research and charter vessel sea days. NOAA scientific and contract staff involvement in the various cruises totaled of 1,226 person sea days, and volunteers contributed another 371 person sea days. ESB cruises occupied 729 stations in an area extending from Cape Hatteras, North Carolina to Nova Scotia. A total of 95,644 length measurements were recorded, representing 975,148 individuals from 231 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 2017 to fulfill special survey sampling requests from

69 NOAA and University investigators. This sampling included 9,878 feeding ecology observations, collection of 21,529 aging structures, and acquisition of 19,978 samples/specimens to support additional shore-based research.

c) Fishery Biology Program (http://www.nefsc.noaa.gov/fbp/)

Fish age determinations by the Fishery Biology Program are used in stock assessments and integrated ecosystem research plans for regions from the shared (US-Canada) boundary areas of the Gulf of Maine and Georges Bank, south through the middle US Atlantic seaboard. In 2017, the Program provided ages for over 66,000 otoliths and other hard structures from 21 species. The top species by number aged were haddock (9,738), Atlantic cod (9,030), silver hake (5,713), winter flounder (5,512), and American plaice (5,187). Large numbers of yellowtail flounder, scup, golden tilefish, black sea bass, white hake, pollock, and Atlantic mackerel were also aged (combined total 19,084). Most of this effort was production ages in support of age-structured stock assessments that serve as the basis for scientific advice to two federal fishery management councils (i.e., NEFMC, MAFMC). These data provide information on age compositions, recruitment strength and growth dynamics, which ultimately inform the scientific basis for determination of stock status, biological reference points and annual catch limits.

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

1. Accuracy: Through the use of reference collections, personnel regularly test to measure whether there has been any deviation of their age estimates relative to a collection of consensus-aged samples.

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.

The Fishery Biology Program also partners with other agencies by exchanging age structures. In 2017, 491 haddock and 393 Atlantic cod age structures were exchanged with age readers from the St. Andrews Biological Station (Fisheries and Oceans Canada).

Related research for 2017:

1. Published estimates of monkfish fecundity and spawning frequency (southern management unit), with implications for population reproductive potential. DOI: 10.1111/jfb.13272.

2. Completed field sampling of wolffish for a life history study, in partnership with the NEFSC Cooperative Research Branch, the Massachusetts Division of Marine Fisheries, the University of New Hampshire, and cooperating fishermen.

3. Completed 1 of 2 years of field sampling Atlantic halibut for a life history study, in partnership with the NEFSC Cooperative Research Branch, the Massachusetts and Maine Divisions of Marine Fisheries, the Nature Conservancy, and cooperating fishermen.

4. Continued sampling and measurement for an age validation study of monkfish (southern management unit), with monthly collections of the strong 2015 strong year-class and

sampling of various potential age structures.

5. Continued sampling of windowpane flounder to develop a marginal increment analysis to validate age estimates, with support from the Study Fleet Biosampling Program.

6. Continued analysis to decipher population structure for cod using growth pattern differences.

7. Partnering with Atlantic States Marine Fisheries Commission to create an aging manual that will standardize processing and aging for species of the western North Atlantic.

8. Continued a project on white hake life history, in partnership with the State of Maine.

9. Continued enhanced biological sampling of selected groundfishes to examine fecundity dynamics.

10. Continued calibration of macroscopic gonad staging performed during research vessel survey cruises by validating against an independent gonad histology method.

11. Continued analysis of environmental effects on haddock growth and reproduction.

12. Continued to investigate the feasibility of measuring bioelectrical impedance (BIA) as a predictor of fish condition and reproductive potential.

13. Continued a reproductive study of maturation, sex change, and reproductive seasonality of the migratory black sea bass population from the mid-Atlantic states and southern New England.

d) Food Web Dynamics

The NEFSC continued studies of fish trophic dynamics based on an integrated program of long-term (since 1973) monitoring and process-oriented predation studies. Modeling and analytical efforts focused on species interactions among small pelagics, flatfish, elasmobranchs, and gadiformes.

Fish food habits samples were collected on the northeastern U.S. continental shelf (South-Atlantic Bight to Scotian shelf) during NEFSC spring and autumn bottom trawl surveys. Estimates of prey volume and composition were made at sea for selected species. During 2017, stomachs from 8,017 individuals and 51 species were examined in the spring, and stomachs from 1,773 individuals and 15 species were examined in the autumn (reduction in autumn sampling due to survey vessel repairs). In the spring, diet sampling emphasized gadiformes, elasmobranchs, small pelagics, flatfishes, and lesser known species. In the fall, an emphasis was placed on piscivores encountered in the Gulf of Maine and Georges Bank where sampling occurred.

The collection of food habits data continued during NEFSC trawl surveys, creating a 45-year time series (1973-2017). The majority of the time series is now available for analysis, including data from over 650,000 stomach samples and over 160 predators. The processing of the 2017 bottom trawl survey food habits data is scheduled for completion in 2018.

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 2017, stomachs from juveniles (<=12 cm) of predators 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 in 2017 and provided class discussions and 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 general diet information, multispecies functional feeding responses, incorporating fish consumption into stock assessments, and evaluating fisheries reference points.

e) Apex Predators Program

Apex Predators research focused on determining migration patterns, age and growth, feeding ecology, and reproductive biology of highly migratory species, particularly large Atlantic sharks. Members of the Cooperative Shark Tagging Program (CSTP), involving over 6,000 volunteer recreational and commercial fishermen, scientists, and fisheries observers continued to tag coastal and pelagic sharks and provide information to define essential fish habitat for shark species in US waters in 2017. Information was received on ~5,000 tagged and 400 recaptured fish bringing the total numbers tagged to 290,000 fish of more than 50 species and 17,800 recaptured of 33 species.

APP staff analyzed mark-recapture data from the CSTP and catch data from multiple surveys for use in the SEDAR (Southeast Data Assessment and Review) 54 standard assessment of U.S. Atlantic sandbar sharks. Length data and indices of abundance were updated for the following surveys: Southeast Area Monitoring and Assessment Program (SEAMAP) Longline Surveys from the South Carolina and Georgia Departments of Natural Resources (SCDNR, GADNR), NEFSC Coastal Shark Bottom Longline Survey, and NEFSC Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) surveys in Delaware Bay, South Carolina, Georgia, and northern Florida.

Since 1961, recreational shark tournament sampling has been conducted annually during the summer from New Jersey to Maine. Tournaments are 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. APP staff provided tags for sharks released during the tournaments and examined 73 sharks at six tournaments in 2017.

The NEFSC COASTSPAN program continued to investigate known and putative shark nursery areas along the US east coast to describe their species composition, habitat preferences, and determine the relative abundance, distribution and migration of sharks through longline and gillnet sampling and mark-recapture data. In 2017, our COASTSPAN participants were the Massachusetts Division of Marine Fisheries (MDMF), Virginia Institute of Marine Science, SCDNR, the University of North Florida, which conducted the survey in both Georgia and northern Florida waters, and Florida Atlantic University. MDMF staff conducts a survey in the U.S. Virgin Islands using COASTSPAN gear and methods. The NEFSC staff conducts the survey in Narragansett and Delaware Bays. In 2017, data from these COASTSPAN surveys were analyzed for use in the standard assessment for U.S. Atlantic sandbar sharks during SEDAR 54. Data were also provided to NMFS Highly Migratory Species Management Division for use in updating the Essential Fish Habitat designations for all managed shark species. Additionally, shark length and community composition data from the SCDNR COASTSPAN survey were analyzed for a presentation at the American Elasmobranch Society annual meeting held in Austin, Texas in 2017 on the importance of sampling gear in identifying what species are present in coastal communities as the susceptibility of species to different gear types varies by species and size class.

APP staff and the NEFSC Cooperative Research Program published a study on the gestation period and pupping seasonality of spiny dogfish in Southern New England in *Fishery Bulletin* in 2017. Mature female spiny dogfish were collected monthly from July 2013 to June 2015 and data on 2545 embryos from 622 females were obtained. Recent postpartum females and females with candled embryos appeared in January through April indicating parturition, followed closely by mating. Vitellogenesis is concurrent with embryo growth, thus ova are ready for fertilization immediately after pupping. Visible embryos were observed in June and growth continued until the external and internal yolks were absorbed and the umbilical scar was partially healed. Gestation period was approximately 23 months. No individual was observed with first and second year embryos. Average fecundity was estimated from the largest group of oocytes (5.3), and free (4.3), and total (4.5) embryos. These values are similar to previous studies, but average fecundity by maternal size class has decreased from previous studies and is negatively correlated with spawning stock biomass, providing supporting evidence for density dependent fecundity.

f) Marine Mammals

Cetacean surveys:

In 2017, NEFSC continued work on the Atlantic Marine Assessment Program for Protected Species (AMAPPS), which is a partnership with the Bureau of Ocean Energy Management (BOEM), the US Navy, and the US Fish and Wildlife Service. As part of this program, NMFS is conducting seasonal surveys of protected species along the Atlantic coast through the next several years. The goal of the program is to provide a better understanding of the distribution and abundance of sea turtle, marine mammal, and seabird populations, and to develop a decision-support tool for use in evaluating the likely impacts of various industrial, military, and development activities within U.S. Atlantic waters.

Two aerial abundance surveys were conducted on the NOAA Twin Otter during 2017, one during 10 June–09 July and the other during 23 November–30 December. The southwestern extent was New Jersey and the northeastern extent was the southern tip of Nova Scotia, Canada. These surveys covered waters from the coastline to about the 100 m depth contour with a higher coverage over the New York State Offshore Planning Area. Track lines were flown 183 m (600 ft) above the water surface, at about 200 kph (110 knots). The two-independent team methodology was used to collect data. In these two surveys sightings of over 7,000 individual marine mammals were recorded in approximately 842 groups.

During April 14–19, 2017, the National Science Foundation ship *R/V Endeavor* operated by the University of Rhode Island conducted a Rhode Island Endeavor Program research cruise intended to explore marine mammal distribution relative to prey layers and physical oceanography while also deploying instrumentation examining carbon export to the deep sea. NEFSC staff led the marine mammal, zooplankton, and active acoustic portions of the cruise. The study area was continental shelf and shelf edge south of Narragansett Bay, Rhode Island. The visual observers detected 51 marine mammal sightings. In addition, 10 CTD casts and 9 bongo nets were deployed, and 64 hours of EK60 data and 12 hours of passive acoustic data from a buoy were recorded.

In September, the NEFSC conducted a 10-day survey for beaked whales in the western North Atlantic on the UNOLS vessel the *R/V Hugh R. Sharp*, focusing primarily on the Georges Bank region. The scientific crew included a visual observation team scanning for marine mammals and sea turtles using line-transect sampling techniques, a single observer targeting sea birds using strip transect sampling techniques, and an acoustic team monitoring a towed hydrophone array. In addition, small boat work was conducted when conditions were feasible to collect identification photographs, water samples for eDNA testing, and to attempt deployment of suction cup tags on beaked whales. Approximately 800 km of trackline were surveyed by the marine mammal visual team, with 570 km of effort also targeted for seabirds. The passive acoustic team surveyed approximately 2053 km (including both daytime and nighttime recording effort), collecting over 167 hours of passive acoustic data. An estimated 160 groups of cetaceans were sighted (1259 individuals), 1 loggerhead sea turtle, and 259 groups (417 individuals) of birds. Beaked whales were the most commonly sighted cetacean taxa, followed by pilot whales (*Globicephala spp.*). Three CTD casts were conducted in areas where beaked whales were presumed to be foraging (based on dive times and the occurrence of echolocation clicks), and active acoustic (EK60) data were collected during one night to map prey distribution in an area associated with beaked whale foraging activity. In addition, 14 water samples were collected from several groups of Cuvier's (*Ziphius cavirostris)* and True's (*Mesoplodon mirus*) beaked whales for eDNA testing.

The North Atlantic Right Whale Sighting Survey (NARWSS) is a NOAA Fisheries program which locates and records the seasonal distribution of North Atlantic right whales off the northeastern coast of the United States. Images of individual whales are also collected for mark-recapture models to monitor the population. NARWSS flights conducted in 2017 followed systematic tracklines with randomized starting locations within 7 primary survey blocks: Cashes Ledge, Franklin Basin, Georges Basin, Great South Channel, Jeffreys Ledge, Martha's Vineyard and Nantucket, and Stellwagen Bank. During 2017, NARWSS flew 97.9 hours over 22 surveys, including 3 directed flights around reported aggregations in New York Bight. NARWSS detected 243 right whales (including possible duplicate sightings of the same individual), with 238 right whales sighted within survey blocks and 5 right whales sighted during transit to or from survey areas.

During April and May 2017, research crews working from the NOAA research vessel Selkie (24' Safeboat) or the R/V Nicholas (25' Safeboat) worked nine days in Cape Cod Bay and three days in waters south of Martha's Vineyard when right whales were in these areas. All right whales encountered were photographed for the North Atlantic Right Whale catalog. Additionally, eleven biopsy samples were collected from right whales that had never previously been sampled. This included two calves that had not been sighted (and therefore not sampled) in the Southeast U.S. calving grounds. One of these mothers is a whale sighted in Iceland and had never been seen or photographed from a vessel prior to this 2017 CCB sighting. These two mothers were not seen in the calving grounds and likely gave birth outside of that area. The DNA in right whale skin can be used to determine sex, and to create a genetic "fingerprint" for future re-identification. This is very important for estimating calf survival rates. When calves are not photographed well at 8 or 9 months of age, when they are still with their mothers, matching young juveniles to these calves over the next few years is near impossible. The shift in summer habitat use by right whales has hindered the photographic capture of young during this vital stage (stable callosity pattern while still with their mother). Therefore, without genetic sampling to make the link between unknown juveniles with their mother, survival information is lost. During these spring trips, sei whale genetic samples were collected and photographs taken. We hope to investigate stocks of sei whales in our local waters.

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 2017 included gill nets, otter trawls, mid-water otter trawls, mid-water pair trawls, scallop trawls, scallop dredges, purse seines, and some pot and traps. Cetaceans observed taken included harbor porpoises, Risso's dolphins (*Grampus griseus*), short-beaked common dolphins, Atlantic white-sided dolphins (*Lagenorhynchus acutus*), and bottlenose dolphins. To support Atlantic Take Reduction Teams (e.g., harbor porpoise and Atlantic trawl teams), the observer data were analyzed to identify environmental factors, fishing practices, and gear characteristics associated with the bycatches.

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.

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

Cetacean 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; (2) monitor baleen whale presence using real time reporting from fixed and autonomous glider platforms; and (3) improve the application of passive acoustics as a tool for monitoring and mitigation.

In June/July 2017, 8 high-frequency recording packages (HARPs) were recovered and redeployed along the U.S. east coast shelf break, from the waters off New England to Georgia. These units will record continuously for approximately one year. Additionally, a multi-year effort consisting of the deployment of Marine Autonomous Recording Units (MARUs) in five lines across the continental shelf (off Nantucket, Cape Hatteras, Cape Fear, Charleston and Brunswick) was continued. These units are recovered and redeployed approximately every 6 months, and are aimed at monitoring changes in migratory movements of baleen whales. The mid-Atlantic region is covered by existing BOEM and NY State projects. Acoustic recorders were also deployed seasonally in four National Marine Sanctuaries (Stellwagen Bank, Gray's Reef, Florida Keys, and Flower Garden Banks), as part of a collaborative effort to evaluate sanctuary soundscapes. Long-term NOAA Noise Reference Station recorders continue to collect data in the Stellwagen Bank National Marine Sanctuary and offshore of Georges Bank. Gliders were deployed south of Cape Cod and in the Gulf of Maine, and a real-time monitoring buoy is active in the New York Bight. These projects are aimed at evaluating the efficacy of using real-time information about baleen whale presence for management and mitigation; results from these projects can be found at http://dcs.whoi.edu/. Towed hydrophone array data were collected in conjunction with an AMAPPS shipboard survey in September. Over 150h of array data resulted in the real-time detection and tracking of multiple species of beaked whales. Finally, 10 acoustic recorders were recovered from six sites throughout the Caribbean, as part of the Caribbean Humpback Acoustic Monitoring Program (CHAMP). CHAMP is an international collaboration involving researchers from the Dominican Republic, Saint Martin, Guadeloupe, Martinique, Aruba and Bonaire.

Archival acoustic data from 2006 to present continue to be analyzed for right, fin, sei, blue and humpback whale presence. A manuscript on the patterns of distribution of North Atlantic right whales before and after 2010 was published. Two manuscripts from AMAPPS work on beaked whales were published, one on
a new approach for 3D localization using towed hydrophone arrays, and another on the effects of shipboard echosounders on beaked whale detection rates. In addition, a manuscript on the effects of vessel noise on communication ranges for cod and haddock was published. A number of additional manuscripts involving colleagues from the Passive Acoustics Group were published in 2017 see our website for more details (https://www.nefsc.noaa.gov/psb/acoustics/psbAcousticPubs.html).

Pinnipeds:

In 2017, the NEFSC conducted unmanned aerial surveys (UAS) of gray seal (*Halichoerus grypus*) pupping colonies on Muskeget Island, Massachusetts, as well as UAS surveys over other haul-out sites on Cape Cod to monitor entanglement rates. In addition, a diverse group of researchers collaborated on a gray seal pup capture project on Muskeget and South Monomoy Islands, Massachusetts. Partners included NEFSC's Protected Species Branch, Atlantic Marine Conservation Society, Tufts University, Marine Mammals of Maine, the University of New England, the Woods Hole Oceanographic Institution, and the University of Connecticut. Close to 100 gray seal pups were captured, sampled, and flipper-tagged; a portion were also tagged with satellite and acoustic tags. Samples contributed to Tuft's work on influenza in migratory wild populations among other projects.

Work began in 2017 to study pinniped diet from fatty acids in blubber (predator) and various fish (prey) samples, in collaboration with researchers at University of Dalhousie, Canada. In addition, work continued on stomach content analysis of bycaught harbor and gray seals.

Bycatch estimation of harbor (*Phoca vitulina*), gray, harp (*Pagophilus groenlandicus*), and hooded (*Cystophora cristata*) seals was conducted based on observed takes in the Mid-Atlantic Gillnet, Northeast Sink Gillnet, and Northeast and mid-Atlantic bottom trawl fisheries.

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 U.S. Mid-Atlantic waters; and (2) assess and reduce sea turtle bycatch in U.S. commercial fisheries in the Northwest Atlantic Ocean.

From 06 July 6–19 July 2017, the NEFSC and partners conducted a Cetacean and Turtle cruise aboard the NOAA Ship R/V Henry B. Bigelow. This survey occurred in shelf and shelf break waters off of the Northeast United States and Canada. The southwestern extent was the shelf waters off of New Jersey and the northeastern extent was Canadian waters near the Northeast Channel. The cruise accomplished objectives related to loggerhead sea turtle ecology, maintenance (exchange) of fixed acoustic recording devices, and zooplankton, turtle, and cetacean distribution. We deployed 5 satellite related data loggers to collect information on loggerhead sea turtles. We retrieved and re-deployed acoustic devices at three locations. We collected temperature, depth, and salinity, and documented the distribution of zooplankton, turtles, and cetaceans. Throughout the cruise, we documented 2521 animals across 25 taxonomic groups.

In 2017 the NEFSC conducted research related to turtle bycatch assessment. This included estimating turtle mortality rates in commercial gears using serious injury guidelines. The NEFSC also continues to develop quantitative methods for assessing anthropogenic threats to sea turtles.

In 2017, the NEFSC conducted three gear-related projects investigating methods to reduce sea turtle bycatch in fishing gear. The first was a comparative study of the ability of a large 12" (30.5 cm) mesh low profile gillnet to reduce sea turtle bycatch. We compared two different tie-down configurations: standard (12 meshes with 48 in (1.2 m) tie-downs) and low profile (eight meshes with 24 in (0.6 m) tie-downs) using the same experimental protocol. Previously this configuration proved successful at reducing the bycatch of Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*) with little effect on the targeted catch of monkfish (*Lophius americanus*) and winter skate (*Leucoraja ocellata*). Sixty paired sets (120 hauls) were completed in waters off Cape Hatteras, NC, an area chosen because of the high densities of sea turtles in the winter months. Results are being analyzed but there was no significant difference in the capture of loggerhead sea turtles between treatments. Fourteen loggerheads were captured in the control nets and eight were captured in the experimental nets ($P = 0.125$). It is interesting to note that during the first seven trips of the study, ten loggerhead turtles were captured in the control nets while none were captured in the experimental nets. During the final five trips of the study, eight loggerheads were captured in the experimental nets and four were captured in the control nets. We are looking at environmental changes that may have caused these results.

The second study was a test of a cable-sorting grid to reduce turtle bycatch in the summer flounder fishery. Previous studies comparing catch rates of Turtle Excluder Device (TED)-equipped trawls and standard flatfish trawls found an average of 25-30% loss in targeted summer flounder (*Paralichthys dentatus*) catch in the TED equipped trawl. As such, additional bycatch reduction devices (e.g., topless trawls, cable grids) have been investigated. In 2016 the NESC was funded to run a comparative study of a NETIII (a type of cable grid)-equipped trawl to that of a standard flatfish trawl in the summer flounder trawl fishery. The study documented operational issues and compared the catch data aboard two commercial fishing vessels. Aboard the FV Darana R, significant reductions (29-45%) in summer flounder catch were observed during leg 1 and 2 of the project. Aboard the FV Jersey Cape, a modified configuration was used and no significant reduction in summer flounder catch was observed. In total, four configurations were tested throughout the study in an attempt to improve target catch efficiency. From an operational and safety standpoint, the NETIII system was a substantial improvement from previous research using rigid grid TEDs. Because these studies proved to be a proof of concept for this gear, in 2017 we did a full study of the NETIII system in the most successful configuration form 2016 using a twin trawl out of Point Judith, RI. The vessel was able to complete 49-paired tows. The results, which were highly significant, showed that the NETIII Cable TED reduced that catch of the targeted summer flounder by almost 53% and reduced the targeted skate catch by almost 42%. These results suggest that this TED in this configuration was unsuccessful at maintaining the targeted catch.

The third study was another comparative cable TED study in the longfin inshore squid (*Loligo pealeii*) fishery. The cable TED [TI] tested is similar to a cable TED successfully tested in the croaker fishery. This work occurred in the southern New England waters in October of 2017. The vessel was able to complete 38-paired tows in six days. Results from this work, using a twin trawl configuration, showed that the cable equipped net caught similar quantities of longfin squid compared to an identical net without the cable TED attached. A modification was made to the floatation used to address an increase in benthic species encountered. The change reduced the catch of benthic species.

Reports on PSB gear projects are located at: http://www.nefsc.noaa.gov/read/protspp/PR_gear_research/.

3. Studies of Fishing Operations

In 2017, NEFSC Observers were deployed on 4,961 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 recorded 352 marine mammal incidental takes, 21 sea turtle incidental takes, and 1,233 seabird 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 405 trips aboard commercial fishing vessels in 2017. On these trips there were 34 marine mammal and 12 seabird incidental takes documented.

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

In the sink anchored gillnet fishery, 1,282 trips were observed with a total of 5,615 gear retrievals by Observers. There were 255 observed marine mammal takes in this fishery (145 gray seals, 52 harbor seals, 21 common dolphins, 13 harbor porpoises, 13 unidentified seals, six harp seals, three unidentified dolphins and two bottlenose dolphins). There were also two Kemp's ridley turtles, one loggerhead turtle, one green turtle and 1,064 seabird takes observed in this fishery (including 918 greater shearwater).

At-Sea Monitors observed 82 trips in the sink anchored gillnet fishery with 356 gear retrievals. There were 32 marine mammal (13 gray seals, 12 harbor seals, five harbor porpoises and two unidentified seals) and 11 seabird (nine greater shearwaters and two unidentified shearwaters) incidental takes recorded in this fishery by Monitors.

b. Float Drift Gillnet Fishery

There were 65 floating drift gillnet trips with 240 gear retrievals observed in 2017. There was one common dolphin but no sea turtle or seabird incidental takes observed.

No Monitors deployed on float drift gillnet trips in 2017.

c. Otter Trawl Fisheries

In the bottom otter trawl fishery 2,218 trips were observed with a total of 13,128 gear retrievals recorded by Observers. In addition, there were 24 midwater trawl trips with 44 gear retrievals, 16 scallop trawl trips with 86 gear retrievals, two shrimp bottom otter trawl trips with 27 gear retrievals, 15 twin trawl trips with 144 gear retrievals, four haddock separator trawl trips with 161 gear retrievals, three Ruhle trawl trip with 16 gear retrievals, eight shrimp twin trawl trips with 924 gear retrievals and two large mesh belly panel trawl trips with 21 gear retrievals observed in 2017.

In the bottom otter trawl fishery, there were 90 observed marine mammal takes (68 common dolphins, seven Risso's dolphins, six gray seals, three bottlenose dolphins, one whitesided dolphin, one harbor seal, one pilot whale, one unidentified dolphin, one unidentified seal and one unidentified marine mammal). There were also seven loggerhead turtles, two Kemp's ridley turtles, one leatherback turtle and 18 seabird takes in this fishery. There were no incidental takes observed in the mid-water trawl, scallop trawl, shrimp bottom otter trawl, twin trawl, haddock separator trawl, Ruhle trawl or large mesh belly panel trawl trips in 2017. On the 2017 shrimp twin trawl trips there were two Kemp's ridley and one green sea turtle and 17 seabird takes observed.

At-Sea Monitors deployed on 272 bottom otter trawl trips with 2,937 gear retrievals, four haddock separator trawl trips with 91 gear retrievals, one twin trawl trip with two gear retrievals and no Ruhle trawl trips in 2017. There were two marine mammal (one whitesided dolphin and one gray seal) and one seabird take recorded by Monitors in the bottom otter trawl fishery. There were no incidental takes documented by Monitors on either the haddock separator trawl or twin trawl trips in 2017.

d. Sea Scallop Dredge Fishery

In the sea scallop dredge fishery, 680 trips were observed with a total of 35,704 gear retrievals. There was one gray seal, one loggerhead turtle, one unidentified turtle and 48 seabird takes observed in this fishery.

No Monitors deployed in the scallop dredge fishery in 2017.

e. Scottish Seine Fishery

No Scottish seine trips were covered by Observers or Monitors in 2017.

f. Drift Sink Gillnet Fishery

In the drift sink gillnet fishery in 2017, Observers were deployed on 275 trips with a total of 1,986 gear retrievals. There were two bottlenose dolphin, two harbor porpoise, one leatherback turtle and three seabird takes in this fishery.

Monitors did not deploy on any drift sink gillnet trips in 2017.

g. Anchored Floating Gillnet Fishery

There were 22 anchored floating gillnet trips with 49 gear retrievals observed in 2017. There were no marine mammal, sea turtle or seabird takes observed in this fishery.

No Monitors deployed on anchored floating gillnet trips in 2017.

h. Mid-water Pair Trawl Fishery

In 2017 there were 38 mid-water pair trawl trips observed with a total of 95 gear retrievals. There were no marine mammal or sea turtle takes observed in this fishery. There were 54 northern gannets documented.

No Monitors deployed on mid-water pair trawl trips in 2017.

i. Bottom Longline Fishery

In the bottom longline fishery in 2017 there were 51 trips observed with a total of 276 gear retrievals. There were no marine mammal or sea turtle takes observed but there were 29 seabird takes observed in the bottom longline fishery.

At-Sea Monitors covered a total of ten bottom longline trip with 42 gear retrievals in 2017. There were no marine mammal, 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 2017.

k. Pound Net Fishery

No pound net trips were covered by Observers or Monitors in 2017.

l. Handline/Trolling Fisheries

In 2017 there were 67 handline trips and 577 gear retrievals, three auto-jig handline trips and 28 gear retrievals, and two troll line trips with eight gear retrievals observed. No marine mammals, sea turtles or seabirds were taken in these fisheries.

Monitors covered 29 handline trips and 424 gear retrievals and six auto-jig handline trips and 40 gear retrievals observed in 2017. There were no documented takes in this fishery in 2017.

m. Herring Purse Seine Fishery

In 2017 there were 14 herring purse seine trips with 22 gear retrievals observed. There were no marine mammal, sea turtles or seabirds were observed.

No herring purse seine trips were covered by Monitors in 2017.

n. Menhaden Purse Seine Fishery

No menhaden purse seine trips were covered by Observers or Monitors in 2017.

o. Tuna Purse Seine Fishery

No tuna purse seine trips were covered by Observers or Monitors in 2017.

p. Pot / Trap Fisheries

In 2017 there were 44 lobster pot trips with 620 gear retrievals, 26 fish pot trips with 184 gear retrievals, 45 conch pot trips with 463 gear retrievals, one hagfish pot trip with 14 gear retrievals, 20 crab pot trips with 283 gear retrievals, three blue crab trips with six gear retrievals and one whelk pot trip with two gear retrievals observed. There were no marine mammal, sea turtle or seabird takes in these fisheries.

No lobster, fish, conch, hagfish, crab, blue crab or whelk pot trips were covered by Monitors in 2017.

q. Beam Trawl Fisheries

One beam trawl trip with four gear retrievals and one scallop beam trawl trip with two gear retrievals were observed in 2017. There were no marine mammal, sea turtle or seabird takes documented in this fishery in 2017.

One beam trawl trip with three gear retrievals was covered by a Monitor in 2017. There were no incidental takes on this trip.

r. Clam Dredge Fishery

There were 25 clam dredge trips with 1,187 gear retrievals observed in 2017. No marine mammals, sea turtles or seabirds were documented in 2017.

s. Other Dredge Fisheries

Two crab dredge trips with 40 gear retrievals and one horseshoe crab dredge trip with eight gear retrievals were covered by Observers in 2017. There were no takes in these fisheries.

No other dredge trips were covered by Monitors in 2017.

4. Observer estimation of catch on NAFO Div 3 trips

a. The checker pen is measured and total volume is calculated prior to the catch being dumped onboard (The F/V Titan uses varying size checker pens as they can change the size by adding or removing pen boards).

b. Once the catch is dumped the observer takes the depth of the checker pen (filled with catch) in 10 random locations within it using a measuring stick. The average depth of the fish in the checker pen is then calculated. The total volume of the catch is then calculated by multiplying the length times the width of the checker pen times the depth of the catch.

c. The observer then fills (depending on amount of catch) 1.47 cu. ft. baskets with the catch from random locations throughout the checker pen. The number of baskets varies from 8 to 15 (unless the catch is very low it could be less). The number of baskets used is then multiplied by the volume of one basket to obtain the Total Volume Subsampled. The fish are then separated by species and whether they are kept or discarded. The discard size is determined by the observer according to the legal U.S. fisheries regulations. The kept and discards of each species are weighed and recorded.

d. The kept and discarded catch weights are then calculated by the following formula:

1) A Sample Multiplier is calculated by (Total Volume (see # 2 above / total Subsample Volume (see # 3 above)

2) The weight of each species Subsampled is then multiplied by the Sample Multiplier to calculate the Estimated Total Weight for that species and catch disposition.

3) The percent Subsampled can be calculated by dividing the Total Subsample Volume by the Total Volume of the catch.

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 three dozen managed species; all require stock status updates as a basis for fishery management. Stock assessments are routinely reviewed in a peer review process termed the Stock Assessment Workshop (SAW). Stocks assessments conducted and reviewed through this process in 2017 included Atlantic mackerel and ocean quahog.

Not all assessments conducted by the NEFSC are vetted at the SAW. Some are developed and reviewed in the US/Canada Transboundary Resources Assessment Committee (TRAC). In 2017, stock assessments conducted and reviewed through the TRAC process included Eastern Georges Bank cod, Eastern Georges Bank haddock, and Georges Bank yellowtail flounder. Twenty stocks were updated through a separate process (operational assessments) and included Gulf of Maine cod, Georges Bank cod, Gulf of Maine haddock, Georges Bank haddock, white hake, pollock, Cape Cod/Gulf of Maine yellowtail flounder, Georges Bank yellowtail flounder, Southern New England/ Mid-Atlantic yellowtail flounder, American plaice, witch flounder, Gulf of Maine winter flounder, Georges Bank winter flounder, Southern New England winter flounder, Gulf of Maine/ Georges Bank windowpane flounder, Southern New England/Mid-Atlantic windowpane flounder, Acadian redfish, Atlantic halibut, Atlantic wolfish, and ocean pout. Other stock assessments or data updates in 2017 vetted in regional bodies included summer flounder, bluefish, spiny dogfish, butterfish, Loligo and Illex squids, skates, scup, surf clam, tow red hake stocks, two silver hake stocks, offshore hake sea scallops, and golden tilefish.

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 dwindled over the years, and both smolt escapement and ocean survival rates have declined. 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 are used to provide information for local, national, and international stock assessment activities. These assessments support ESA and North Atlantic Salmon Conservation Organization (NASCO) management efforts.

Field research in 2017 focused on (1) a fish community survey within the Penobscot River estuary; (2) monitoring the importance of diadromous fishes as prey for nearshore Gulf of Maine groundfish species; (3) modeling the impacts of hydroelectric facilities on diadromous fish productivity; (4) optimizing stocking dates of age 1 hatchery smolts (5) monitoring of fishery removals on the high seas; and (6) describing the ecosystem processes and connections that govern the productivity of Atlantic salmon in the marine environment. Through the application of active (pelagic trawling) and passive (multi-frequency split-beam hydroacoustics) techniques, estimates of biomass and habitat use for various commercially important fish species (e.g. Atlantic herring, alewife, blueback herring, American shad) are being developed for the Penobscot Estuary. Documentation of American shad spawning, the presence of multiple size classes of river herring utilizing the upper estuary and the detection of significant juvenile Atlantic herring biomass in the lower estuary highlights the importance of this estuarine nursery. 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. Analysis will be conducted to evaluate the contribution of diadromous fishes to the diets of captured nearshore predators. Life history modeling is being conducted on a number of different diadromous species and river systems to evaluate the impacts that hydroelectric facilities are having on the productivity of these species. Results are being used to support federal permitting efforts and to guide restoration programs for these species. The initial year of a two year acoustic telemetry investigation was undertaken on the Narraguagus River to describe differences in survival between stock groups of age 1 hatchery smolts to evaluate performance through river, estuary and bay environments. Defining this relationship will help hatchery managers optimize time of stocking to improve survival of restoration smolts. 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. Finally, modeling efforts evaluating how ecosystem changes are affecting energy flow to Atlantic salmon and the impacts of those changes on salmon growth, survival, and productivity are underway. All of these studies will contribute to recommendations for additional measures to be considered to halt the decline of USA Atlantic salmon stocks and help restore these populations.

c) Cooperative Research

The Northeast Cooperative Research Program (NCRP) began in 1999 and in 2016 became the Cooperative Research Branch (CRB) under the Fisheries Monitoring and Research Division (FMRD) in the NOAA Fisheries Northeast Fisheries Science Center (NEFSC). The CRB supports collaborations among fishermen and scientists with the goal of enhancing marine fisheries science used to improve stock assessments, reduce bycatch, and provide important information to fishery managers and the industry. Increased communications and shared learning among fishermen, scientists and managers is an important objective. Cooperative research is supported by the United States Federal Budget and fishery resource allocations that are ‘set-aside’ and harvested to fund research programs (Research Set-Aside or RSA). Cooperative research occurs among NEFSC, states’ marine fishery agencies, academic and non-governmental research institutions, and commercial fishing enterprises. Cooperative studies span research themes such as fishery dependent data development, fishery independent surveys, fishery biology and oceanography, and bycatch reduction through marine resource education and outreach. CRB work that occurred in 2017 is described below. Many of these projects will continue into 2018.

Projects focused on Fishery Dependent Data: Northeast and mid-Atlantic multispecies

Core Study Fleet

Fishermen collaborated with the NEFSC to develop a Fisheries Logbook Data Recording System (FLDRS) used by Study Fleet participants in the Northeast and mid-Atlantic regions to collect information on fishing effort and catch by recording haul-by-haul data and to provide more detailed record keeping than is currently required by NOAA using paper or electronic Vessel Trip Reports (VTR and eVTR, respectively). The current core group of 43 Study Fleet vessels participates in diverse fisheries such as trawl and gillnet fisheries for groundfish and monkfish, small mesh fisheries targeting squid, herring, and mackerel, and scallop dredge fisheries. An additional 19 vessels outside of the formal Study Fleet contribute data to fishery-dependent cooperative research projects in the Northeast region. An onboard computer, with FLDRS software installed, and integrated to the vessel’s Global Positioning System (GPS), Vessel Monitoring System (VMS), depth sounder, and temperature/depth sensors attached to fishing gear allows fishermen to easily capture these data along with fishing effort and catch information. Data are then transmitted to the NEFSC through either dockside wireless transmission, or through satellite transmissions while still at sea.

Study Fleet data advance fisheries science, monitoring, and management by allowing fine-scale analyses of species overlap to reduce accidental catch or “bycatch,” and by helping create temperature-based habitat modeling. The effort also facilitates comparisons among Study Fleet data, at-sea observer data, and discard estimation models, and helps refine the assignment of harvest to stock area algorithms. The Study Fleet also provides practical advice to help shape enhancements to the FLDRS data capture system and provides feedback to fishermen so they can interpret their own data. A significant product for 2017 & 2018 is the development of the Study Fleet Data Dashboard. This system allows fishing captains to use their previously reported tow-by-tow catch and discard data, along with temperature, spatial and temporal information to analyze their historical fishing patterns, make important business decisions, and fish more efficiently, including avoiding areas where previous catch rates of non-target species were high. The dashboard has the potential to align reporting accuracy with improved profitability and reduced effort. Also, Study Fleet data are also used to develop habitat-based tools to estimate the availability of fish populations to fisheries and fisheries-independent surveys. These tools are being used to study climate-driven shifts in fish distribution that may help improve survey designs and inform stock assessments while developing practical management strategies in a dynamic and changing ocean.

Confirming the Accuracy of Study Fleet Self-Reported Discard Data

Cooperative research scientists are comparing discard estimates for selected species using both the Study Fleet and at-sea observer data to determine if they can complement one another in calculating discard estimates used in stock assessments. These studies serve as a critical evaluation of the use of fishermen’s self-reported data, and may improve the understanding of the potential success of electronic monitoring (video cameras recording at-sea fishing operations). Our June 2017 publication in the North American Journal of Fisheries Management included comparisons between at-sea observers and Study Fleet self-reported data on retained and discarded fish for six species from 2007 to 2014. Though statistical differences were discernible, due to the large differences in number of samples between the observer and Study Fleet efforts, results demonstrate that within gear types and for the species studied, that industry can accurately self-report discard information for many fisheries. This study determined, under the right circumstances using robust quality control, training, and oversight, that confidence in self-reported data may be achieved for assessment, monitoring, and management purposes.

Study of Processed to Unprocessed Conversion Factors for Groundfish

This integrated Study Fleet project is aiding in the validation and updating of processed-weight to round-weight conversion factors for groundfish. Fishery scientists and managers use these factors to calculate the total weight of a species removed from a population based on the weight of processed fish landed and sold. Initial analyses of 3,656 fish (1,896 Atlantic cod, 646 monkfish, 686 haddock, 264 Atlantic pollock, 66 winter skate, and 98 white hake) is complete with seasonal conversion factors estimated. Results show that previous processed-weight to round-weight conversion factors used by stock assessment scientists and state agencies were out of date. This information is being used as part of an Atlantic Coastal Cooperative Statistics Program (ACCSP) effort to update conversion factors coast-wide for commercially important species. The ACCSP is a cooperative state-federal program established to be the key source of fisheries-dependent information on the U.S. Atlantic Coast.

River Herring Bycatch Reduction

The Study Fleet and other commercial vessels are providing data to help the small-mesh bottom- trawl herring fishery avoid river herring bycatch by examining small-scale variations in river herring distribution and abundance. Without mitigation, bycatch caps of river herring could have serious financial impacts on this fishery. The NEFSC collaborates with the Massachusetts Division of Marine Fisheries and University of Massachusetts Dartmouth School of Marine Science and Technology on this project. A sampling grid was created along coastal river estuaries to monitor river herring bycatch and Study Fleet and other participating vessels fishing in these areas report river herring bycatch through FLDRS. The reports are transmitted in real-time to shore-side facilities where bycatch rates are plotted within the grid and high bycatch grid cells are reported back out to active fishing vessels. This allows fishing captains to avoid those cells, thereby reducing bycatch of river herring.

Collaborative Research to Inform 2017 Atlantic Mackerel Benchmark Stock Assessment

Since 2015, Cooperative Research staff have led the development of an Atlantic Mackerel Working Group (AMWG) composed of industry, NEFSC assessment scientists, and academic experts. The AMWG's goals were to better understand socio-ecological factors affecting the Atlantic mackerel population and fishery, and to develop information to increase the accuracy of the 2017 stock assessment. After the 2010 assessment failed to pass the Center for Independent Experts (CIE) review, the official status of the Atlantic mackerel stock was unknown. This group applied a transdisciplinary, collaborative approach to fill knowledge gaps in collaboration with the Mid-Atlantic Fishery Management Council. This partnership helped support AMWG meetings as well as a collaborative two-year field study collecting data from the Study Fleet and other commercial fishing vessels to examine the winter and spring habitat ecology of mackerel. The project used real-time habitat forecasting with the industry to develop a dynamic winter habitat model for mackerel. This accounted for changes in the availability of the stock to the NEFSC spring survey and the winter fishery. A time-varying index of availability was then applied to the spring NEFSC bottom trawl survey data that was traditionally used in the assessment to determine the population trend. This work is also providing information for the development of adaptive surveys that include areas outside of areas traditionally sampled in fishery independent surveys, and to estimate changes in the potential availability of mackerel to the fishery. This resulted from the interaction of changes in habitat due to climate change and space-based fishery management strategies that do not account for dynamic changes in the ocean. The work of the AMWG and constructive engagement with members of the mackerel fishery has allowed cooperative research staff in the Northeast to lead the development of working papers describing the socio-economic factors affecting mackerel and the U.S. fishery. This provided valuable context for interpretation of the data and improved the 2017 stock assessment, which successfully passed CIE review on December 1, 2017.

Commercial Fishing Vessels Collecting Weather Data Offshore
In 2016, the Study Fleet began work on a collaborative project with the NEFSC's Oceanography Branch and NOAA's National Weather Service to gather important weather and climate-related data from mini-weather stations mounted on fishing vessels. The Weather Service provided funding and equipment while the CRB assisted with outreach to participating fishing vessels and installing the equipment. The weather stations include a barometer to measure atmospheric pressure, anemometer to measure wind speed and direction, and a thermometer to measure air temperature. The stations are equipped with a built-in computer, which factors out the ship's motion to derive a true wind speed and direction and can automatically report, via satellite, every hour and continuously on a display on the ships dashboard. In a 2017 pilot, two commercial fishing vessels were equipped with these weather stations. This project was valuable for enhancements and gathering data by observation to check the accuracy of NOAA Weather Service atmospheric circulation models, offshore forecasts, and integration of weather data into other oceanographic modeling. These offshore weather observations also may improve fisheries science through models of catch rate differences in fishery independent surveys during calm versus turbulent oceans (resulting from low versus high-pressure cells). The National Weather Service recently asked for a proposal to equip more vessels.

Supporting Electronic Vessel Trip Reporting (eVTR) and Environmental & Oceanographic Data Capture

FLDRS software is the primary program used for Electronic Vessel Trip Reporting (eVTR) on the East Coast, accounting for 83 percent of all electronic report submissions by commercial fishermen. The CRB leveraged multiple funding sources in support of expanding the eVTR reporting. NEFSC and cooperative research branch staff collaborated with many industry and management partners to expand and support eVTR in the Northeast and Mid-Atlantic in squid, mackerel, herring, flatfish, monkfish, surf clam, ocean quahog, and sea scallop fisheries. The collaborative eVTR effort includes developing and testing additional reporting software for the clam industry (eCLAMS), and new equipment for wireless data transmission of eVTRs from selected Northeast dock sites.

In 2017, vessels enrolled in eVTR included 49 cooperative research vessels (30 of which participate in Study Fleet), 38 non-cooperative research vessels using FLDRS, and 16 vessels using eCLAMS. The NEFSC-developed FLDRS and eCLAMS software packages are available free to the industry. However, CRB financial support remains important for industry transition to eVTR to provide software training, technical field support, troubleshooting, and continued software advancements. Building on the eVTR coverage already established through cooperative research, the CRB continues to expand electronic reporting and improvements in fishery dependent monitoring and research data. In FY 2017, approximately 101 vessels reported via eVTR, but this number fluctuates seasonally and by fishery. The development of an enhanced version of FLDRS (Version 5) continues to advance the goals of electronic reporting and real-time fishery dependent data (FDD) capture.

Fishery Independent Data Research and Development

2017 Sweep Efficiency Study Targeting Summer Flounder
The 2017 twin trawl study aboard a commercial vessel from Point Judith, RI focused on testing the efficiency of different sweep types on fishing nets. Trawl nets use various configurations of foot-rope gear at the opening, called sweeps. Sweeps with large rubber disks called rockhoppers are used on federal fisheries surveys on the NOAA ship Henry B. Bigelow and allow nets to be towed over many of the diverse bottom types of the Atlantic continental shelf

for the broad ecosystem survey. Commercial fishermen use smaller foot-rope configurations with added chains to fish in smoother bottom habitats. These different types of foot-rope gears help determine the efficiency of nets to target different types of species and on different types of seabeds. Chain sweeps, for example, allow the net to remain directly on the ocean floor, thus they are most efficient for flatfish and other bottom-dwelling species. This configuration cannot be towed over complex rocky bottoms as they often get hung up on bottom structures.

Target species for this study included summer flounder, red hake and winter flounder, some of which tend to stay on the ocean bottom and may be less available to the NEFSC bottom-trawl survey. NEFSC scientists and the fishing industry are both intent on enhancing the understanding of the catch efficiency of standard bottom trawl survey gear to improve stock assessments. For this twin trawl study, two Bigelow survey nets were towed through the same areas at the same time, with a rockhopper sweep used as a control and a chain sweep as the experimental gear. A team of fishermen and NEFSC staff collaborated to design and conduct this study, and included scientists from the CRB, the Fisheries Ecology Branch, and the Oceans and Climate Branch. The team targeted summer flounder in Southern New England from Montauk, Long Island to Nantucket, and red hake in the western Gulf of Maine off Cape Ann. In total, 103 tows were conducted that collected over 73,000 fish of the seven species targeted by the study. The results of this experiment provided analytical refinements to the standard NOAA ecosystem survey and improvements to summer flounder population abundance estimates. Results are being used in the upcoming 2018 benchmark summer flounder stock assessment. This sweep efficiency experiment, like those recently conducted on yellowtail flounder, winter flounder and American plaice, was recommended by the Northeast Trawl Advisory Panel (NTAP), which is a joint advisory panel for the Mid-Atlantic and New England Fishery Management Councils, and is composed of fishermen, scientists, and managers. The NTAP seeks to capture input from stakeholders on how best to incorporate industry vessels and fishermen's participation in the NEFSC survey process, and has outlined a wide array of near- and long-term alternatives. This includes presenting the cooperative sweep comparison studies at the 2017 Operational Assessment of 19 groundfish species. See: Operational Assessments.

Support for NEFSC Apex Predator COASTSPAN Shark Survey, Tagging, & Research

The NEFSC Apex Predator Program's Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) survey is an ongoing investigation of known and potential shark nursery grounds along the East Coast of the United States. The objectives are to determine the location of shark nursery grounds, to describe species composition and habitat preferences using presence/absence data, estimate relative abundance, monitor distribution and migration of sharks utilizing these nursery grounds. Survey methods include longline and gillnet sampling and a mark-recapture tagging program.

Delaware Bay COASTSPAN sampling encompasses the entire bay from the mouth of the Delaware River to the mouth of the bay using a random stratified design using spatial-bathometric criteria. Sampling also is conducted at historical fixed stations throughout the bay. Results show that Delaware Bay continues to provide important nursery habitat for sandbar sharks, smooth dogfish and sand tigers. The extensive use of the bay by all life stages of sand tigers and smooth dogfish in all life stages continues to highlight the seasonal importance of this essential shark habitat. In 2017, data from the 2016 survey were provided to NMFS Highly Migratory Species Management Division for use in updating Essential Fish Habitat for these shark species and for use in the annual Stock Assessment and Fisheries Evaluation (SAFE) Report. Additionally, data through 2015 were modeled to create standardized indices of abundance for use in the 2017 standard stock assessment update for the sandbar shark during the Southeast Data Assessment and Review (SEDAR) 54 process.

<u>Cooperative Gulf of Maine Bottom Longline Survey</u>

Industry and other external constituents have expressed concern that the NEFSC bottom trawl survey lacks sufficient sampling in rocky hard-bottom habitats. This could hamper assessments for several economically and ecologically important Gulf of Maine stocks that typically inhabit this complex rocky habitat, including Atlantic cod, haddock, cusk and white hake. Since 2013, the CRB has conducted a bottom longline survey (BLLS) designed to sample in complex rocky habitat of the western and central Gulf of Maine. The survey is conducted with two commercial fishing vessels during the spring and fall periods that the NEFSC bottom trawl survey operates in the same areas. This will allow for comparisons of species diversity and abundance estimates between the two different survey methodologies. With four full years completed, the BLLS has begun determining species diversity and relative abundance in rocky habitats, comparisons of catchability differences among rocky, sand, and mud bottom types, and is providing more information on several data-poor species, some of which are species of concern or candidates for listing under the Endangered Species Act (Atlantic wolffish, Atlantic halibut, cusk, and thorny skate). BLLS data contributed to the determination to not list cusk as an endangered species.

Seventeen other species caught in this survey are considered data-rich species, seven of which are being caught in sufficient numbers to provide indices of abundance to tune and improve stock assessments. Additional years of the survey are needed to establish time series sufficient to be used by assessment modelers. These species include cod, haddock, little skate, pollock, red hake, spiny dogfish, and white hake. In 2017, the survey team collaborated with staff from the Protected Resources Division and the New England Aquarium to further work on the effects of barotrauma on bottom-dwelling species such as cusk. Cooperative Research staff also conducted a pioneering study to test the effect of current and tide on the bait used in the BLLS and its attraction to fish. The ‘plume’ effect of bait scent affects catch per unit of effort (CPUE), and this study focused on quantifying effects on catch rates due to current and tide velocity, direction, and habitat type. An underwater video camera arrangement was also designed and used to assist in habitat classification.

Products from the Bottom Longline survey include:

- Supplemental age and maturity sampling for Enhanced Biosampling (EBS),
- Supplemental age-length keys for EBS,
- Supporting detailed life-history studies such as habitat use, temporal and spatial spawning characteristics and trophic dynamics,
- Water current velocity meters that provide data to validate bottom currents used in statistical models by oceanography and stock assessment scientists,
- Studies to determine the effect of current and tides on bait and how it attracts target species to the gear as well as the effects on CPUE,
- Bottom Longline Survey current velocity data, are also used in an oceanographic model created by University of Massachusetts-Dartmouth, School for Marine and Science Technology (SMAST), which estimates currents at multiple depth layers,
- The BLLS also supports research with external partners including the New England Aquarium, University of Massachusetts-Dartmouth & Boston, and the University of Maine, and
- An NEFSC technical memorandum currently under peer review.

<u>Enhancing Oceanographic Data and Data Telemetry</u>

This collaboration with the NEFSC Oceanography Branch is assisting with the development and testing of affordable wireless temperature-depth probe systems that record ocean bottom temperatures. This information fills a major gap in oceanography data and is important because it can help improve the understanding of fish distribution and bycatch avoidance strategies. Accounting for environmental factors in fisheries science requires an understanding of the way they vary both at fine and broad scales. Ocean circulation models can estimate this, but current models in use now contain biases due to inaccurate measurements and uncertainty in estimating ocean mixing processes. Because of this, it is important to compare and correct model estimates using real observations. The updated models can then provide more accurate estimates for assessment and management. Through cooperative research projects, the Cooperative Research Branch has shared more than 5 million bottom temperatures with modelers from the NEFSC, University of Massachusetts Dartmouth-School for Marine Science and Technology (SMAST), Rutgers University, and the Mid-Atlantic and Northeast Regional Ocean Observation Systems to help improve oceanographic models. Temperature data shared with SMAST were used to evaluate the bottom temperature hindcast model (a model using historical data) to develop habitat-based estimates of scup and bluefish availability to the NEFSC and Northeast surveys in the SAW/SARC 60 assessment process in 2016. The validated and improved hindcast model was also used in the 2017 update stock assessment for butterfish.

Collaborating vessels also helped to test low-cost methods for transmission of oceanography and catch data in real time, allowing immediate feedback to fishermen that they can use to fish more selectively and avoid accidental catch of prohibited or protected species. The telemetry technology used combines modifications to commonly used ocean drifter transmitters with wireless temperature depth recorders. As fishermen haul gear with the wireless temperature sensor attached, an onboard computer automatically sends time, latitude and longitude, and average temperature and depth for the tow to the GLOBALSTAR satellite system. Within minutes, the data reaches arrives to an NEFSC lab, which posts it on a website for the participating fishermen and collaborating scientists. Data from over 1,650 hauls has been telemetered to date. Additional sensors are being developed, including some that report directly to a smartphone instead of a shipboard computer. Participants are now testing a second-generation of affordable, more easily accessible equipment.

Ecosystems Fishery Science, General Biological Studies, Bycatch Reduction, and Outreach/Education

<u>Enhanced Biological Sampling for Age and Growth, Maturation, Fecundity of Commercially Important Marine Finfish</u>

A critical factor in determining how much fish can be sustainability removed from a stock is how fast they replace themselves. The CRB supports the work of the Population Biology Branch through the Enhanced Biological Sampling (EBS) Program to examine fish tissue samples to better understand their reproductive biology. This effort has resulted in profound and valuable stock assessment science improvements for several flounder stocks. Using EBS data, stock assessment scientists have improved age and growth keys resulting in better informed stock assessments for winter and summer flounder. Additionally, revised estimates of reproductive age for these species have improved the understanding of the effects of human activities and climate change on fish stocks. Opportunistic sampling during collaborative projects increases the data available for many important commercial and recreational stocks.

Through 2017, CRB projects provided more than 10,000 reproductive samples from industry-based surveys, gear comparison studies and Study Fleet. Biological samples provided in 2017 include: 381 winter flounder, 302 yellowtail flounder, 131 haddock, 22 wolffish, 31 cusk, and 6 Atlantic halibut. Samples from flounders and haddock were used in histological studies to determine maturity status, which have led to insights into the maturation size/age and fecundity of yellowtail, winter, and summer flounders, halibut, cusk, haddock, and wolffish. Winter and summer flounder were shown to have different length-at-age keys from previous assessments and were shown to mature at smaller sizes, resulting in improved spawning stock biomass estimates. Ongoing work aims to better understand the environmental and energetic factors that influence the potential of these flatfishes to reproduce effectively and sustainably. Herring samples are also collected to get more information on what proportion of fish skip spawning in a given year, as well as the timing and success of spring spawning.

Georges Bank haddock, which has shown extreme fluctuation in how many young fish grow large enough to become legal targets for the fishery, are also being collected to compare changes in spawning sizes through time, space and varying levels of exploitation. The collection of samples on species lacking robust data, such as cusk, is highly valuable. Little or antiquated data on life-history information for cusk in the western North Atlantic are available. Most of these data are more than 35 years old. This work is attempting to address the need for more reproductive and other life-history data needs to support assessments and status evaluations for an Endangered Species List candidate species on cusk and wolffish. Several peer-reviewed publications from the Enhanced Biological Sampling program support and improve stock assessments for flatfish. The EBS program documented changes in female reproductive potential among three stocks of winter flounder. New microscopic techniques were tested to examine development of mature gonads collected during cooperative research survey cruises. These data and new techniques demonstrated that some species of fish are maturing at different ages and sizes than previously known.

Testing Hook Gear Fisheries in Gulf of Maine Closed Areas

The highly regulated commercial fishing industry constantly looks for opportunities to fish in sustainable and emerging fisheries. The GARFO Sustainable Fisheries Division (SFD) was approached by the industry and asked to consider allowing hook and line fishing targeting pollock and haddock (both rebuilt fisheries but quota-limited by Atlantic cod accidental catch or "bycatch" limits) in two areas closed to fishing in the Gulf of Maine. These three species of groundfish often co-exist on the same grounds and it is difficult to harvest only pollock and haddock using mobile gear. Staff from CRB and fishery at-sea observers monitor these fishing activities to determine if pollock and/or haddock can be efficiently and economically targeted with hook and line gear in the Western Gulf of Maine and Cashes Ledge closed areas, with minimal bycatch of cod. The CRB and Fisheries Sampling Branch (FSB) collaborated with SFD to provide data collection design and the field staff coverage required by the project's Exempted Fishing Permit (EFP). If successful, this project has the potential to provide alternative fishing opportunities for fishery sectors. Commercial vessels are participating fishing with rod and reel gear and with electronic jigging machines. Preliminary results (not statistically determined) from 35 monitored trips showed that earlier in the summer, mixing of cod and pollock made it difficult to avoid cod, though total catch rates (kept and discarded) were 7.7 times greater for pollock than cod. Later in the summer, pollock catch rates appeared to increased by 17 to 18 times greater than cod. Additionally, the time of day and tide cycle appeared to influence pollock catch. Sharks often attack fish being landed by hook and line fishing, this is known as depredation. Some depredation occurred (approximately 10 percent) in this study, thereby potentially reducing landings and income.

Table 1. Catches of species not included in the Status of the Fisheries Section by NAFO Div in Subarea 3.

	3L		3M		3N		Total		
Species	Ret.	Disc.	Ret.	Disc.	Ret.	Disc.	Ret.	Disc.	Total
Anthomastus spp		<0.1						<0.1	<0.
Atlantic wolffish						1.3		1.3	1.3
black dog		2.1		3.1		2.1		7.3	7.3
blue antimora				<0.1				<0.1	<0.1
blue ling						<0.1		<0.1	<0.1
blue shark						<0.1		<0.1	<0.1
crabs				<0.1		1.0		1.0	1.0
crustacean						0.2		0.2	0.2
cusk	<0.1		<0.1		0. 5	0.6	0.5	0.6	1. 2
Duva florida						<0.1		<0.1	<0.1
European ling				<0.1				<0.1	<0.1
Greenland halibut	0.6	<0.1	0.8	<0.1	1.1	0.4	2.5	0.5	3.0
Greenland shark		0.6		3.2		15.6		19.4	19.4
groundfish						0.8		0.8	0.8
Halipteris finmarchia		<0.1						<0.1	<0.1
invertebrates		<0.1		<0.1	<0.1	6.7	<0.1	6.7	6.7
longfin hake						<0.1		<0.1	<0.1
lumpfish						<0.1		<0.1	<0.1
northern wolffish		13.9		12.8		4.7		31.4	31.4
porbeagle						1.3		1.3	1.3
redfishes		<0.1		<0.1	0.1	0.2	0.1	0.2	0.3
roughhead grenadier		0.5		0.8		7.0		8.3	8.3
sandlance						<0.1		<0.1	<0.1
sculpin						3.1		3.1	3.1
scup						0.2		0.2	0.2
spotted wolffish		0.1		0.1		1.6		1.8	1.8
urchin						0.2		0.2	0.2

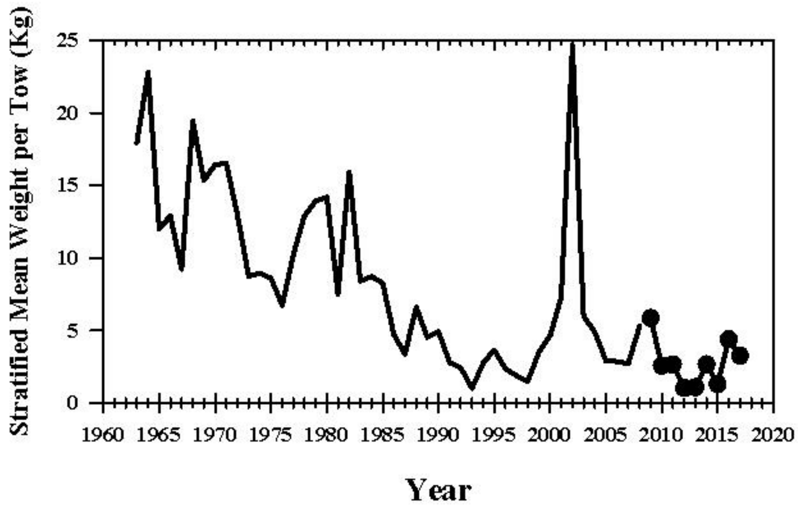

Fig. 1. NEFSC autumn bottom trawl survey biomass indices for Gulf of Maine cod.

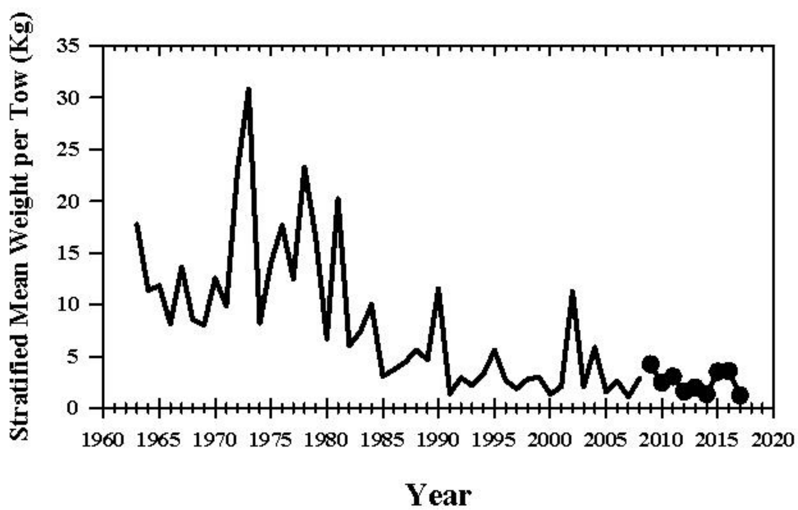

Fig. 2. NEFSC autumn bottom trawl survey biomass indices for Georges Bank cod.

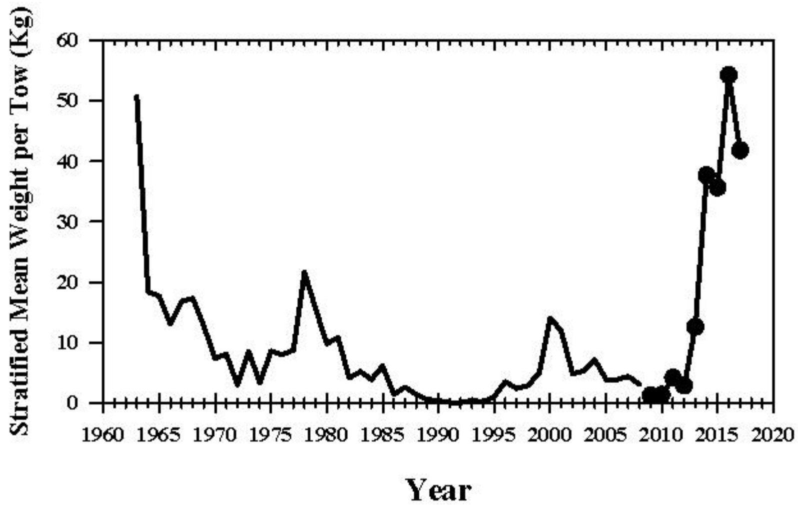

Fig. 3. NEFSC autumn bottom trawl survey biomass indices for Gulf of Maine haddock.

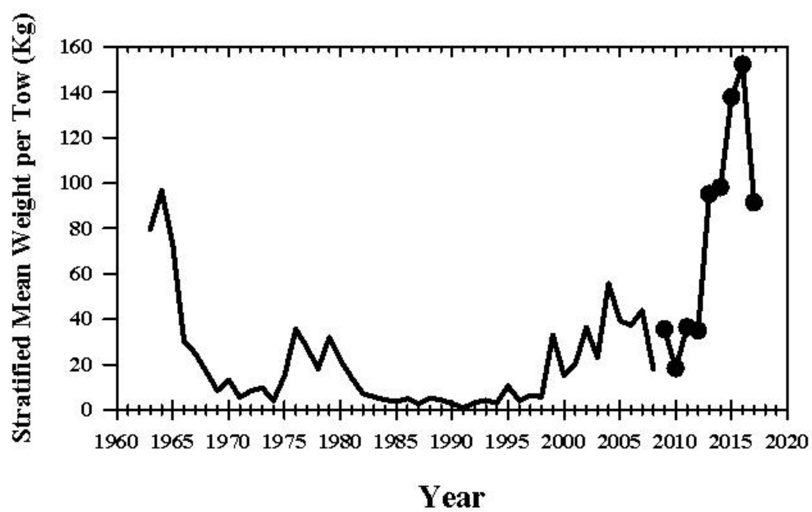

Fig. 4. NEFSC autumn bottom trawl survey biomass indices for Georges Bank haddock.

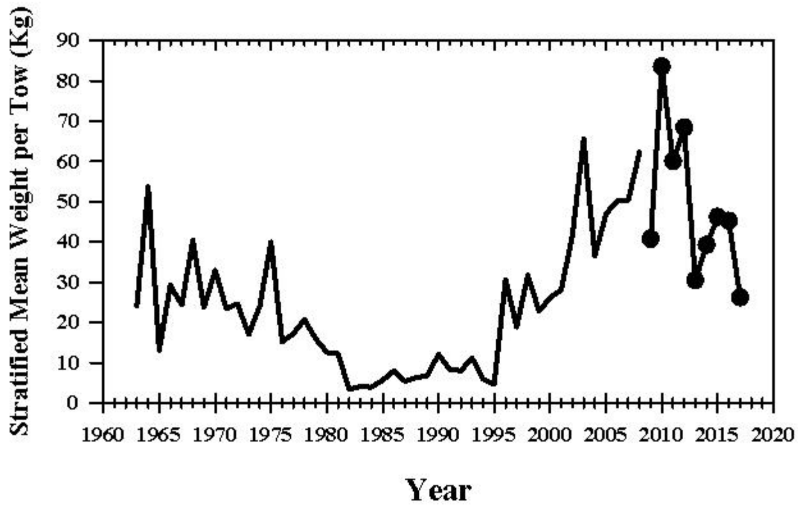

Fig. 5. NEFSC autumn bottom trawl survey biomass indices for Acadian redfish.

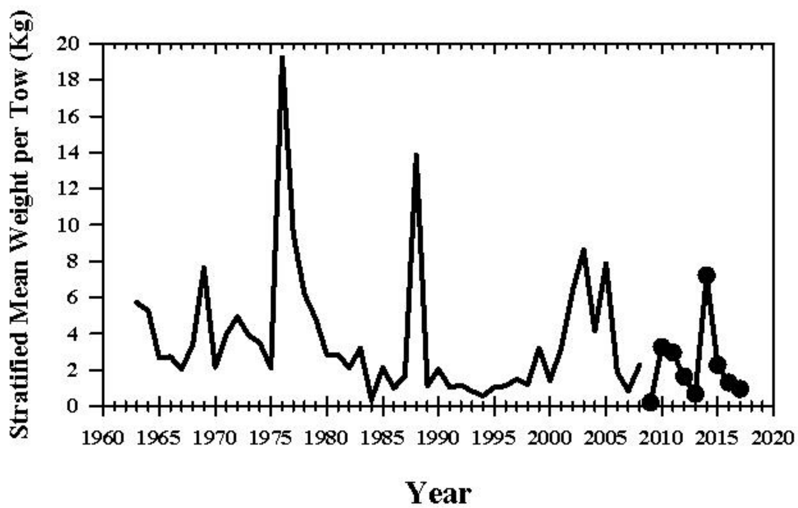

Fig. 6. NEFSC autumn bottom trawl survey biomass indices for pollock.

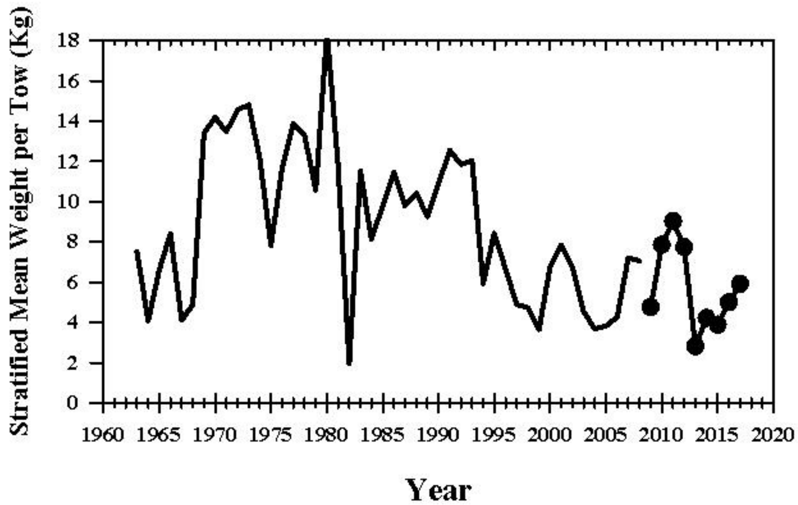

Fig. 7 NEFSC autumn bottom trawl survey biomass indices for white hake.

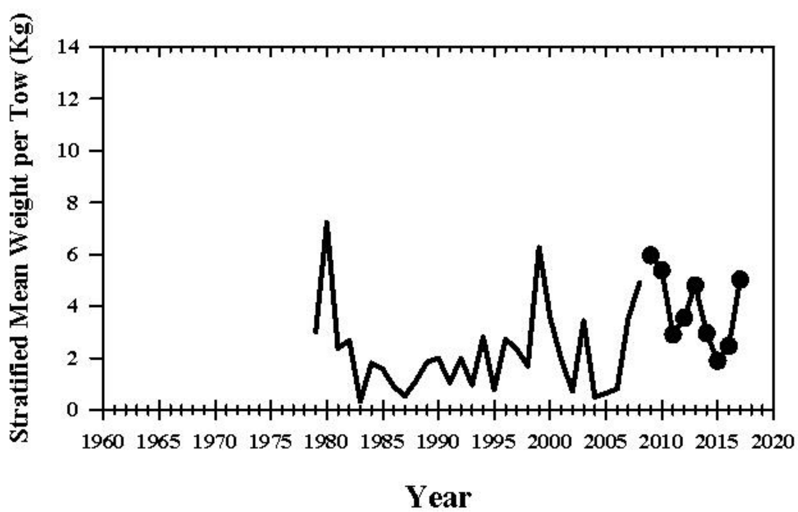

Fig. 8. NEFSC autumn bottom trawl survey biomass indices for Cape Cod-Gulf of Maine yellowtail flounder.

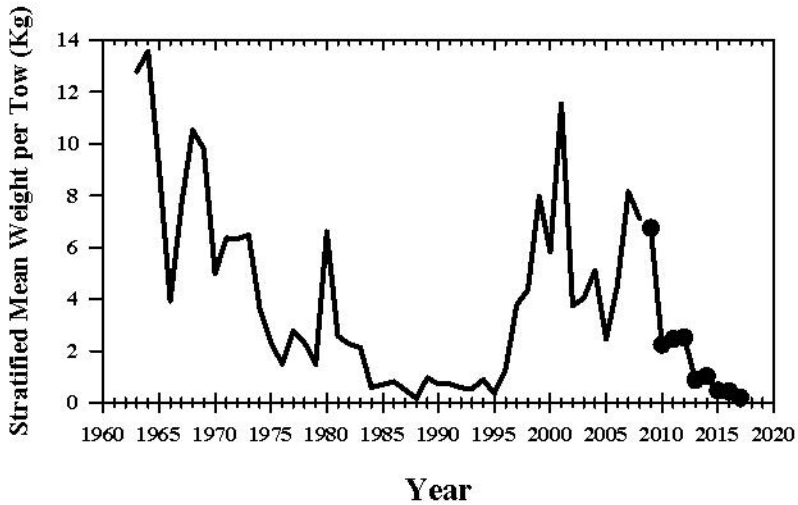

Fig. 9. NEFSC autumn bottom trawl survey biomass indices for Georges Bank yellowtail flounder.

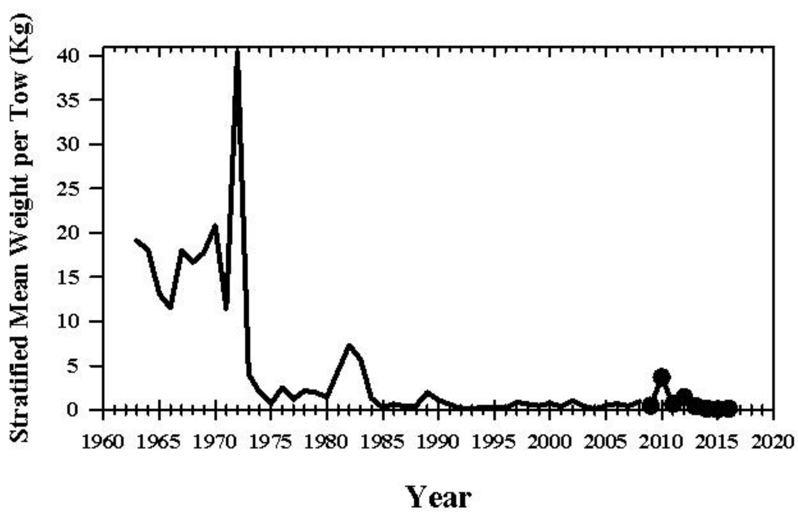

Fig. 10. NEFSC autumn bottom trawl survey biomass indices for Southern New England-Mid-Atlantic yellowtail flounder.

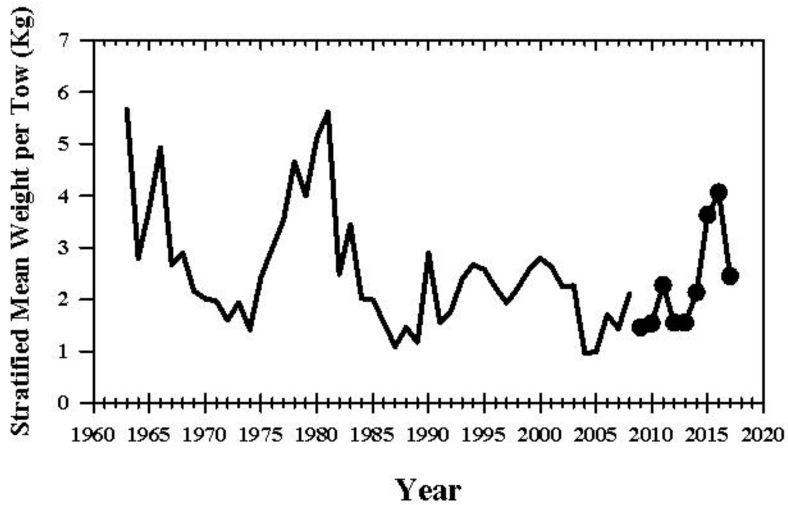

Fig. 11. NEFSC autumn bottom trawl survey biomass indices for American plaice.

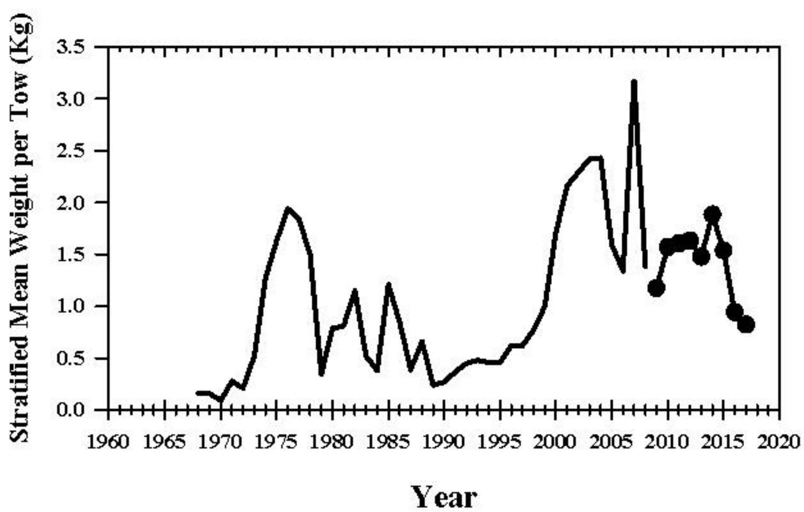

Fig. 12. NEFSC spring bottom trawl survey biomass indices for summer flounder.

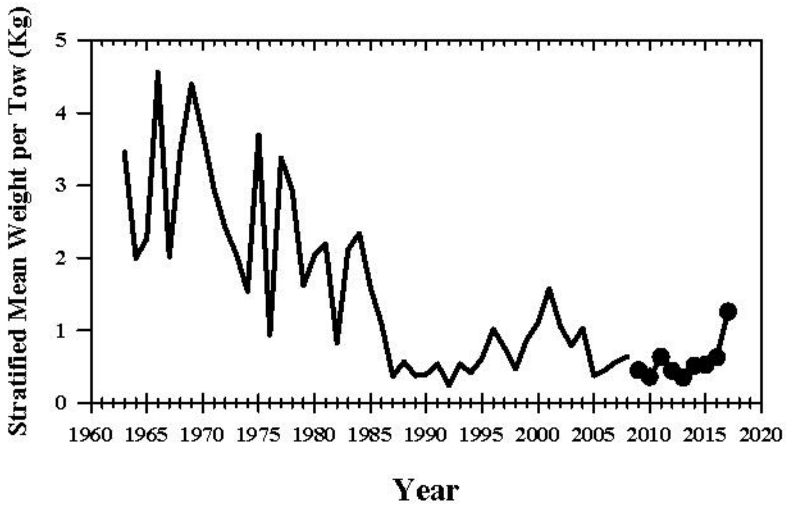

Fig.13. NEFSC autumn bottom trawl survey biomass indices for witch flounder.

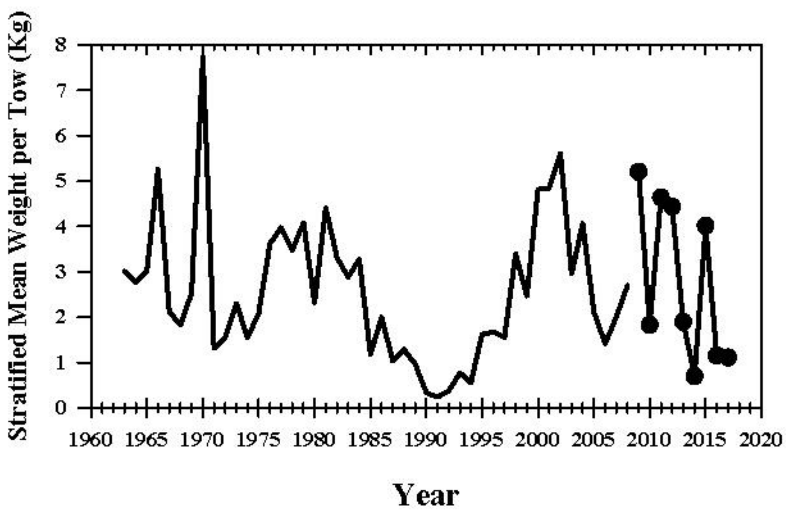

Fig. 14. NEFSC autumn bottom trawl survey biomass indices for Georges Bank winter flounder.

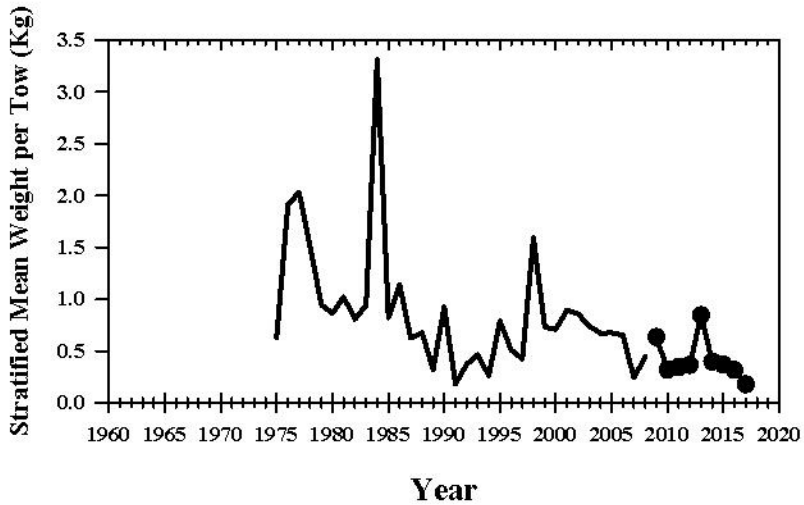

Fig. 15. NEFSC autumn bottom trawl survey biomass indices for northern windowpane flounder.

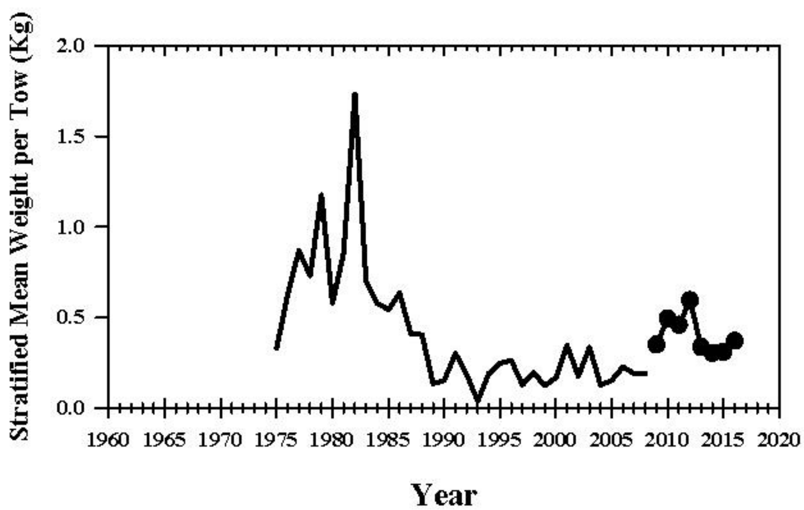

Fig. 16. NEFSC autumn bottom trawl survey biomass indices for southern windowpane flounder.

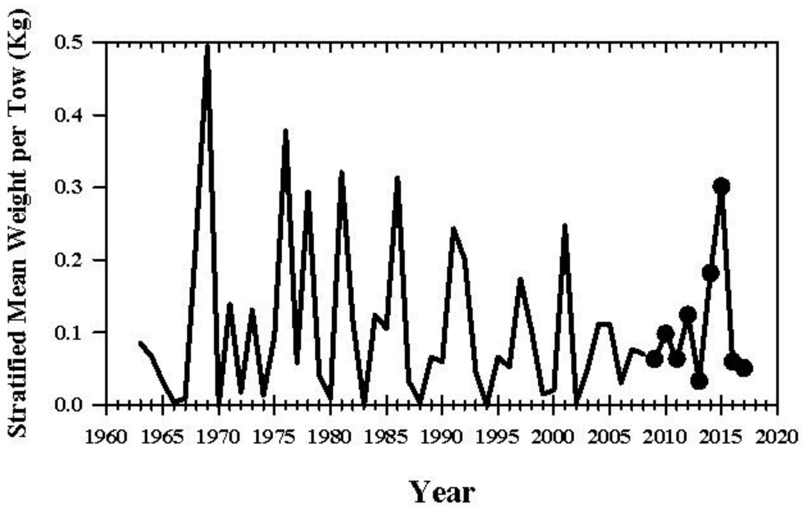

Fig. 17. NEFSC autumn bottom trawl survey biomass indices for Atlantic halibut.

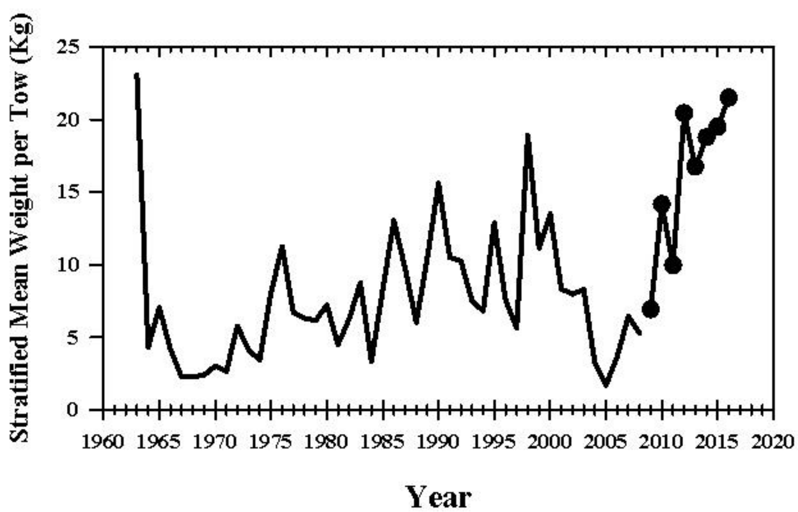

Fig.18. NEFSC autumn bottom trawl survey biomass indices for northern silver hake.

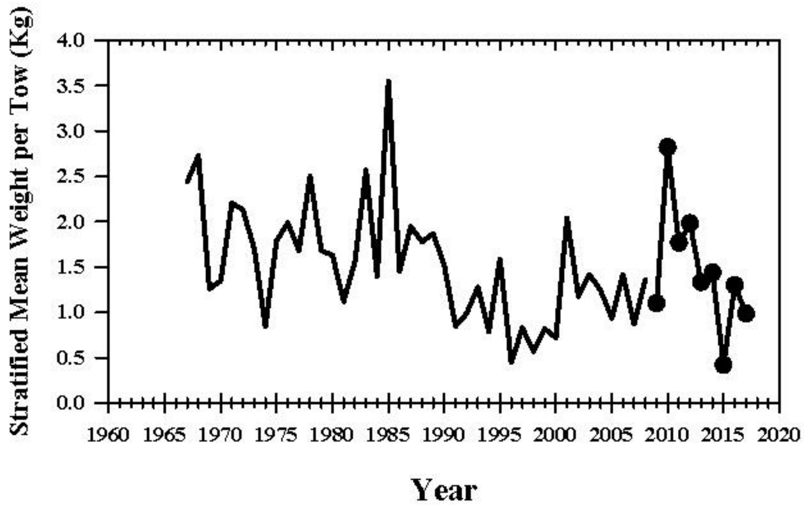

Fig. 19 NEFSC autumn bottom trawl survey biomass indices for southern silver hake.

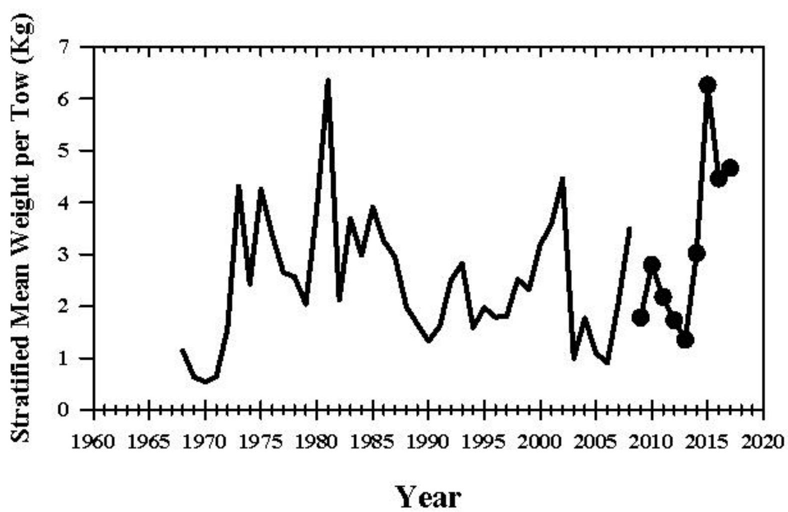

Fig. 20. NEFSC spring bottom trawl survey biomass indices for northern red hake.

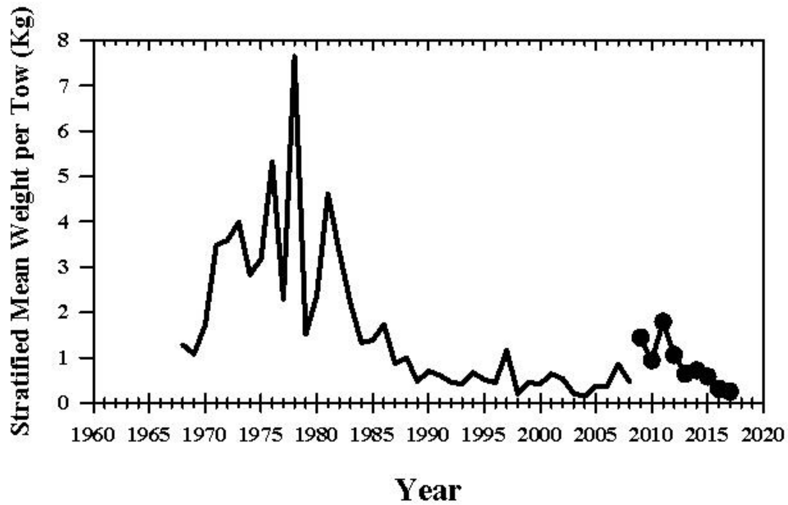

Fig. 21. NEFSC spring bottom trawl survey biomass indices for southern red hake.

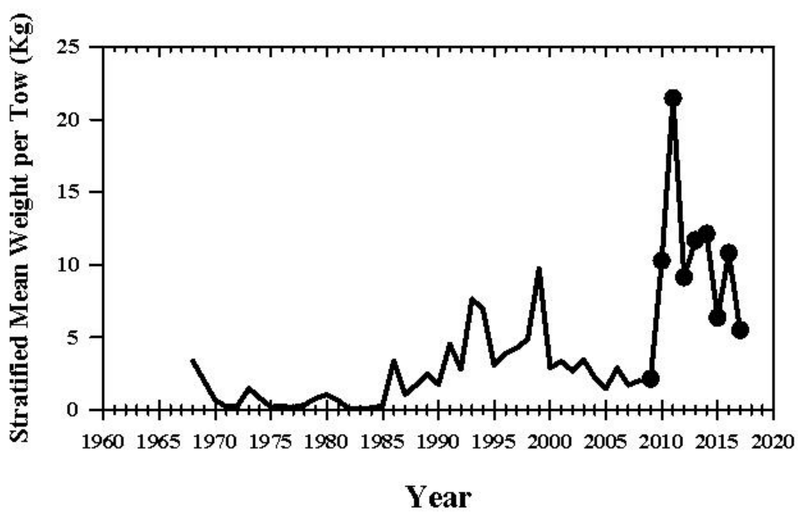

Fig. 22. NEFSC spring bottom trawl survey biomass indices for Atlantic herring.

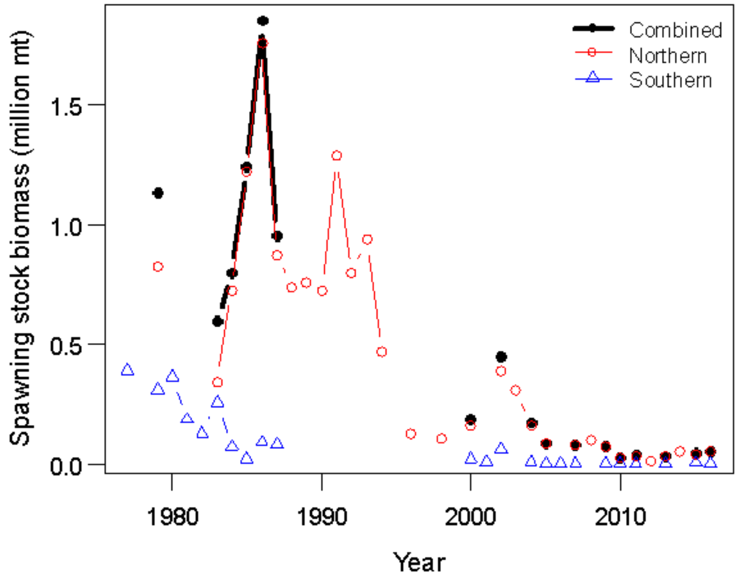

Fig 23. NEFSC spring bottom trawl survey biomass indices for Atlantic mackerel.

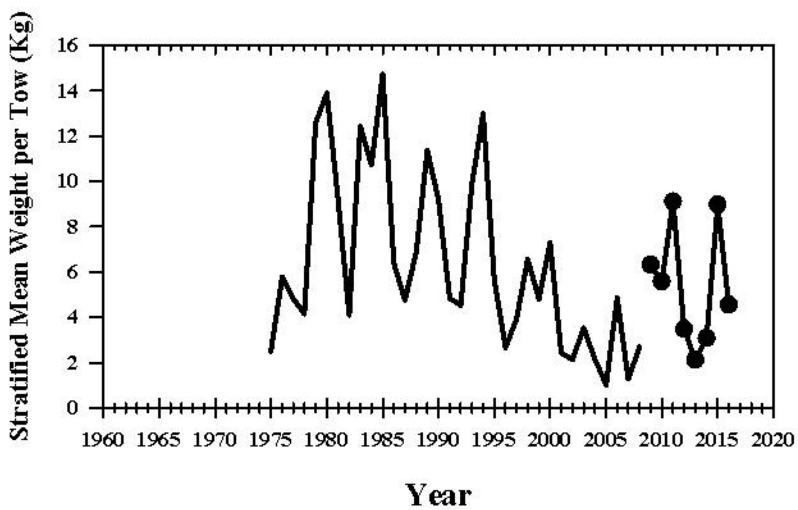

Fig. 24. NEFSC autumn bottom trawl survey biomass indices for butterfish.

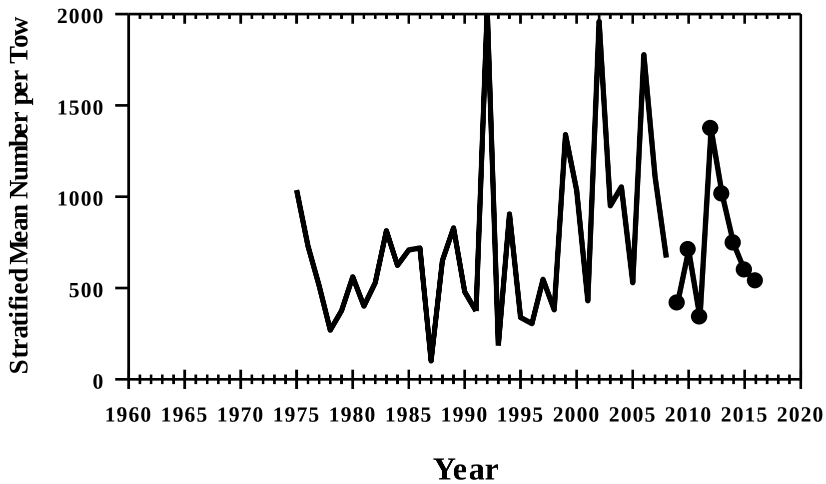

Fig. 25. NEFSC autumn bottom trawl survey abundance indices for longfin inshore squid.

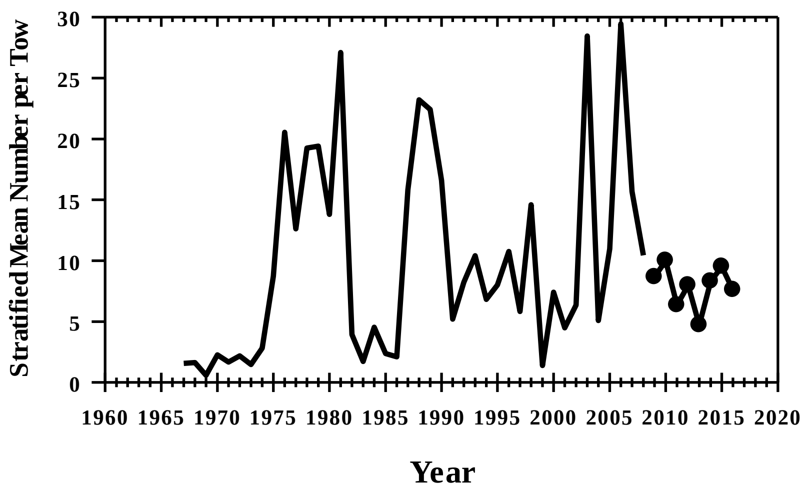

Fig. 26. NEFSC autumn bottom trawl survey abundance indices for northern shortfin squid.

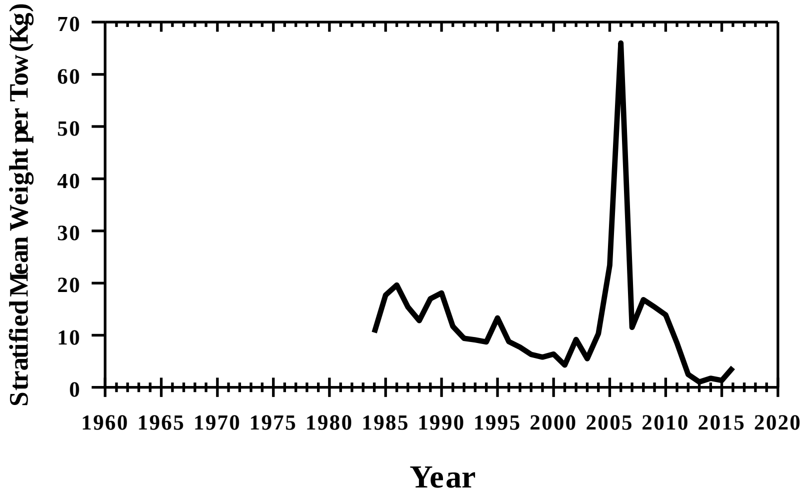

Fig. 27. ASMFC summer shrimp survey biomass indices for northern shrimp.

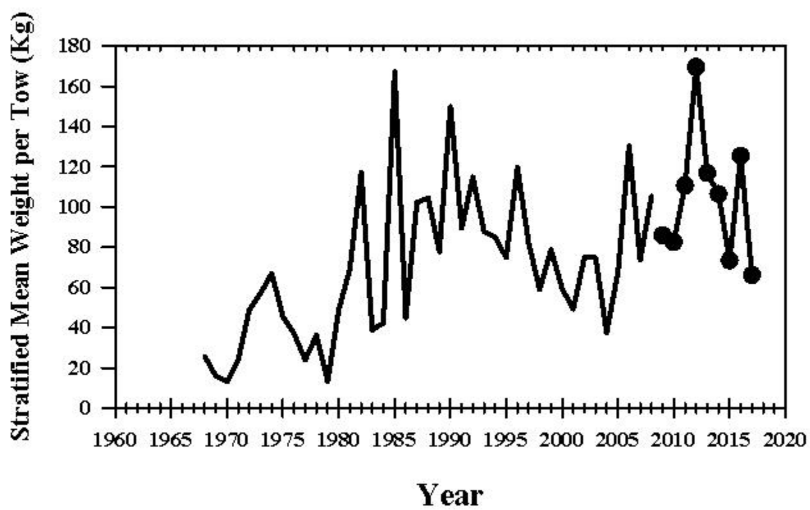

Fig. 28. NEFSC spring bottom trawl survey biomass indices for spiny dogfish.

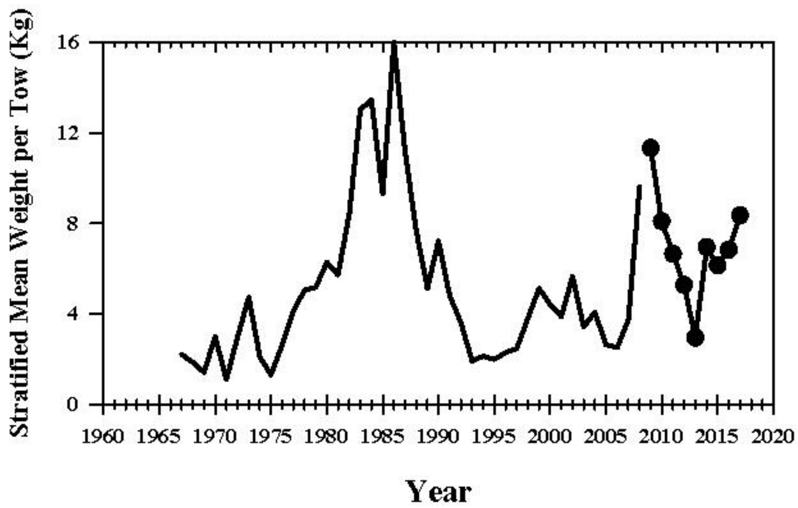

Fig. 29. NEFSC autumn bottom trawl survey biomass indices for winter skate.

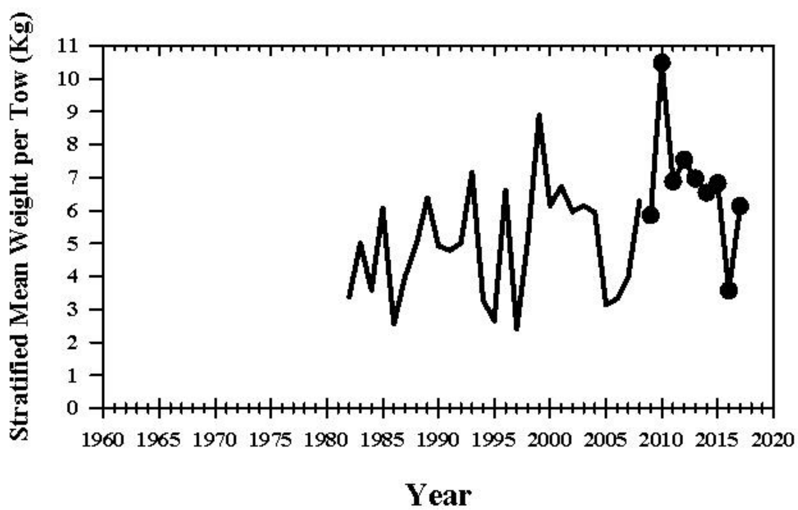

Fig. 30. NEFSC spring bottom trawl survey biomass indices for little skate.

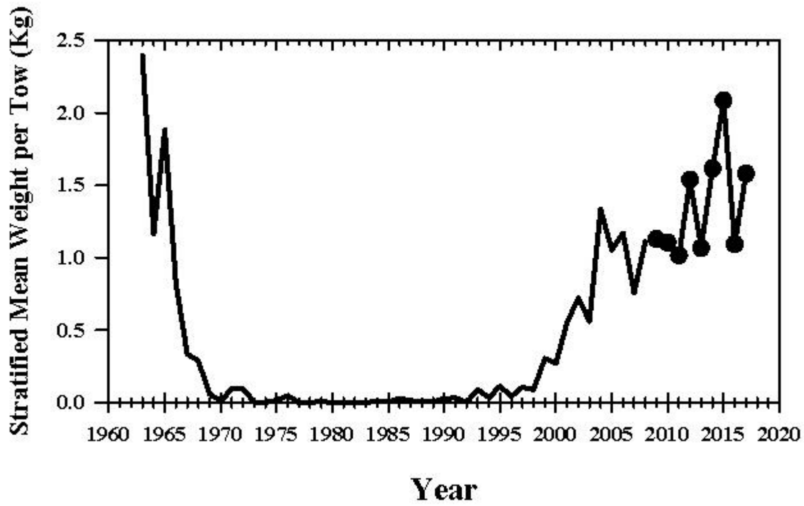

Fig. 31. NEFSC autumn bottom trawl survey biomass indices for barndoor skate.

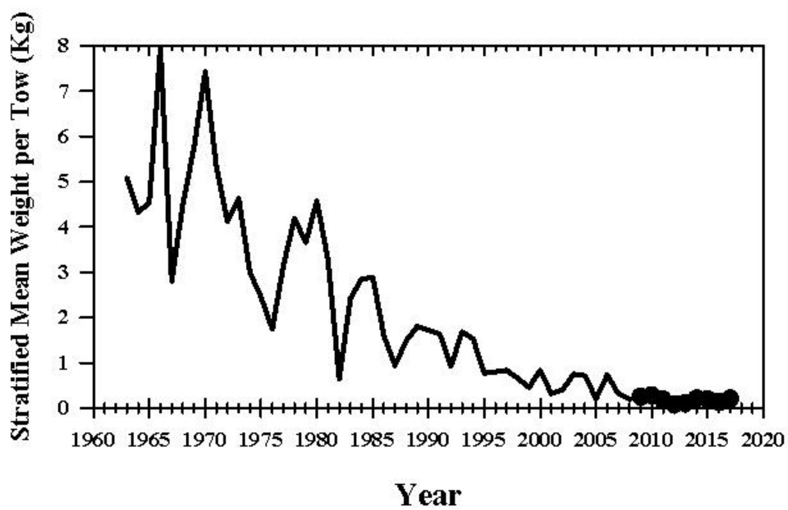

Fig. 32. NEFSC autumn bottom trawl survey biomass indices for thorny skate.

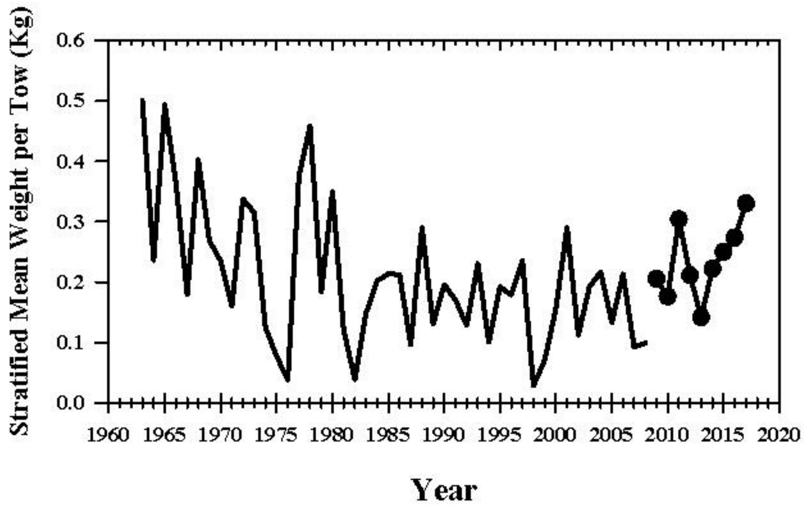

Fig. 33. NEFSC autumn bottom trawl survey biomass indices for smooth skate.

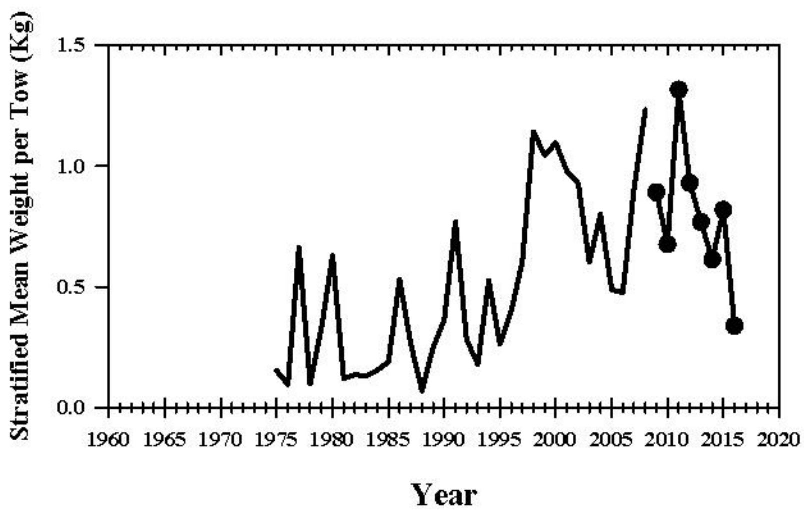

Fig. 34. NEFSC autumn bottom trawl survey biomass indices for clearnose skate.

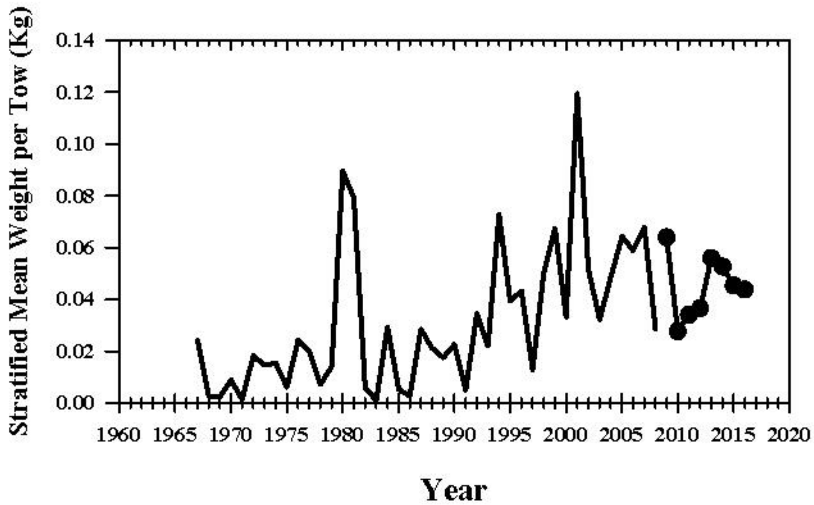

Fig. 35. NEFSC autumn bottom trawl survey biomass indices for rosette skate.