**Northeast Fisheries Science Center Reference Document 15-06**

doi:10.7289/V5WM1BCT

# Butterfish 2014 Stock Assessment

by Charles F. Adams, Timothy J. Miller, John P. Manderson,
Dave E. Richardson, and Brian E. Smith

**Northeast Fisheries Science Center Reference Document 15-06**

doi:10.7289/V5WM1BCT

# Butterfish 2014 Stock Assessment

by Charles F. Adams, Timothy J. Miller, John P. Manderson,
Dave E. Richardson, and Brian E. Smith

NOAA Fisheries, Northeast Fisheries Science Center, 166 Water Street, Woods Hole, MA 02543

**U.S. DEPARTMENT OF COMMERCE**
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts
August 2015

## Northeast Fisheries Science Center Reference Documents

**This series is a secondary scientific series** designed to assure the long-term documentation and to enable the timely transmission of research results by Center and/or non-Center researchers, where such results bear upon the research mission of the Center (see the outside back cover for the mission statement). These documents receive internal scientific review, and most receive copy editing. The National Marine Fisheries Service does not endorse any proprietary material, process, or product mentioned in these documents.

All documents issued in this series since April 2001, and several documents issued prior to that date, have been copublished in both paper and electronic versions. To access the electronic version of a document in this series, go to *http://www.nefsc.noaa.gov/nefsc/publications/*. The electronic version is available in PDF format to permit printing of a paper copy directly from the Internet. If you do not have Internet access, or if a desired document is one of the pre-April 2001 documents available only in the paper version, you can obtain a paper copy by contacting the senior Center author of the desired document. Refer to the title page of the document for the senior Center author's name and mailing address. If there is no Center author, or if there is corporate (*i.e.*, non-individualized) authorship, then contact the Center's Woods Hole Laboratory Library (166 Water St., Woods Hole, MA 02543-1026).

**Information Quality Act Compliance**: In accordance with section 515 of Public Law 106-554, the Northeast Fisheries Science Center completed both technical and policy reviews for this report. These predissemination reviews are on file at the NEFSC Editorial Office.

This document may be cited as:

Adams CF, Miller TJ, Manderson JP, Richardson DE, Smith BE. 2015. Butterfish 2014 Stock Assessment. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 15-06; 110 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026, or online at http://www.nefsc.noaa.gov/publications/
doi:10.7289/V5WM1BCT

# TABLE OF CONTENTS



# LIST OF TABLES

# LIST OF FIGURES

# ABSTRACT/EXECUTIVE SUMMARY

A butterfish (*Peprilus triacanthus*) stock assessment was completed in January 2014. This document provides a summary of the data and results of the final model accepted by the Stock Assessment Review Committee panel. Commercial data used in the assessment consisted of US landings and discard estimates, and commercial mean weights at age, from 1989–2012. Survey data used in the assessment consisted of swept area abundances, and abundance indices (number/tow) by age from 1989–2012 Northeast Fisheries Science Center (NEFSC) fall surveys (inshore and offshore); and swept area abundances from the Northeast Area Monitoring and Assessment Program (NEAMAP) fall (2007–2012) survey. An augmented version of the age-structured assessment program (ASAP) catch at age model of Legault and Restrepo (1999) was used in the assessment. ASAP augmentations included: 1) reparameterization of catchability as the product of availability and efficiency; 2) estimation of natural mortality (*M*) made possible by fixing catchability, and 3) a length-based calibration of bottom trawl survey data in 2009–2012 was performed internal to the model. Catchability for the NEFSC fall offshore survey was reparameterized by using an average measure of availability based on bottom temperature, while efficiency was based on the relative efficiency of the *FRV* Albatross IV to the *FSV* Henry B. Bigelow, given the assumption that the Bigelow was 100% efficient for daytime tows. Results of the model include an estimate of $M = 1.22$ (CV = 0.05). The current fishing mortality ($F_{2012}$ = 0.02, CV = 0.33) is well below the accepted overfishing reference point ($F_{MSY}$ proxy = $2M/3 = 2 \times 1.22/3 = 0.81$). The accepted spawning stock biomass reference point $SSB_{MSY}$ proxy (median SSB based on a 50 year projection at the $F_{MSY}$) proxy is 45,616 mt (CV = 0.25). $SSB_{2012}$ is estimated to be 79,451 mt, which is well above the accepted $SSB_{MSY}$ proxy. The accepted maximum sustainable yield (MSY) proxy is 36,199 mt (CV = 0.20). $SSB_{threshold}$ is one half the $SSB_{MSY}$ proxy, or 22,808 mt. Overfishing is not occurring, and the stock is not overfished

# INTRODUCTION

Butterfish (*Peprilus triacanthus*) are distributed from Florida to Nova Scotia, occasionally straying as far north as Newfoundland, but are primarily found from Cape Hatteras to the Gulf of Maine, where the population is considered to be a unit stock (Collette and Klein-MacPhee 2002). Butterfish begin schooling around 6 cm. They are a fast growing species, overwintering offshore, and then moving inshore and northwards in the summer. Butterfish mature during their second summer (age 1) around 18 cm TL and are fully recruited by their third summer (age 2). Spawning occurs primarily during June–July. The diet consists primarily of tunicates (Larvacea, Ascidacea, Thaliacea), ctenophores and pelagic mollusks (*Clione*). They are preyed upon by a number of commercially important fishes such as bluefish (*Pomatomus saltatrix)*, spiny dogfish (*Squalus acanthias)*, silver hake (*Merluccius bilinearis)*, summer flounder (*Paralichthys dentatus)*, goosefish (*Lophius americanus)*, and swordfish (*Xiphias gladius*). Although it is generally thought that butterfish comprise a large part of the diet of longfin inshore squid (*Doryteuthis* (Amerigo) *pealeii*), recent stable isotope and fatty acid work suggests this is not the case (pers. comm., Olaf Jensen, 2013. Rutgers University, New Brunswick NJ 08901).

The last benchmark assessment for this stock was completed in 2009 (NEFSC 2010). The Stock Assessment Review Committee (SARC) accepted the trends in fishing mortality (F) and spawning stock biomass (SSB) but recommended that point estimates of F and SSB be interpreted with caution. In addition, the panel did not accept the redefined biological reference points (BRPs) or the reference points generated in the previous assessment (NEFSC 2004). Subsequent management advice was based on an “envelope analysis” which provided a bounded estimate of catch from an empirical analysis of commercial catch and Northeast Fisheries Science Center (NEFSC) survey data.

A new butterfish stock assessment was completed in January 2014 and reviewed by the SARC (NEFSC 2014). This document provides a summary of the data and results of the final model accepted by the review panel.

# METHODS

## Commercial Data

A variety of data sources were used to derive the catch time series. Landings prior to 1965 were obtained from Lyles (1967) as compiled by Murawski et al. (1978). Landings from 1965 to 1989 were obtained from the NEFSC commercial fisheries state canvas data table, while landings from 1990 to 2012 were obtained from the NEFSC commercial fisheries detail species data tables. Butterfish catch data for foreign fleets from 1963 to 1982, and 1983 to 1986, were obtained from Waring and Anderson (1983), and NEFSC (1990), respectively.

Two additional sources of data were used to estimate discards: the Greater Atlantic Regional Office Vessel Trip Report database; and the NEFSC Observer Database System. The observer database begins in 1989 which served as the beginning of the catch time series used in the assessment model.

## *Commercial landings*

During 1963 to 1986 landings of butterfish were reported by foreign fleets targeting longfin inshore squid in offshore areas. In many cases the reported catch included discards; thus, foreign landings are described below in the Total Catch section. Domestic landings of butterfish averaged 1,976 mt from 1965 to 1979 without any trend (Table 1; Figures 1 and 2). A domestic fishery was developed to supply the Japanese market, leading to peak landings of 11,715 mt in 1984, but then declined to 2,298 mt in 1990. From 1991 to 2001 landings ranged between 1,449 mt and 4,608 mt. From 2002 to 2012 there was no directed fishery, and landings, primarily as bycatch in the small mesh (< 10.2 cm) bottom trawl longfin squid fishery, ranged between 428 mt and 872 mt. A directed fishery was reestablished in January 2013, and landings for the year were 1,091 mt.

## *Commercial size composition*

Butterfish are sampled dockside as part of the National Marine Fisheries Service (NMFS) commercial sampling program. Samples, containing approximately 100 fish, are collected per market category, port and gear. Since 1989 an average of 28 butterfish samples per year have been collected, averaging 91 mt of landings per sample (range: 11–345 mt per sample). Sampling has resulted in an average of 2,864 length measurements per year, ranging from 688 in 1995 to 6,431 in 2007 (Table 2). Size composition from commercial samples of butterfish ranged from 7 to 29 cm during 1989 to 2012, with modal lengths from 14 to 17 cm (Figures 3–8).

## *Discard estimates*

Catch data from 1976 to 1986 as presented in historic assessment documents include discards, which were assumed to be 10% of landings (Waring and Anderson 1983; NEFSC 1990). In the previous assessment (NEFSC 2010) the portion of the annual total catches in these records attributable to discards was determined by subtracting the landings obtained from the NEFSC Commercial Fisheries State Canvas Data Table. These values are reproduced here as "historic discards" in Table 1. Foreign catch in Table 1 also includes discards, which were estimated by dividing longfin inshore squid catch by survey ratios to account for butterfish discards of countries reporting only longfin (Murawski and Waring 1979; NEFSC 1990).

The standardized bycatch reporting methodology (Wigley et al. 2007) combines landings, vessel trip report and observer sampling data to provide estimates of discard rates and total discards for specified stocks. Butterfish discard estimates from 1989 to 2012 were developed by using the combined ratio estimator (method 2 in Wigley et al. 2007). Strata were defined by quarter, gear type, and region (New England or Mid-Atlantic waters). Total discard estimates varied from just under 239 mt in 2007 to a high of 8,867 mt in 1999, but the precision of these estimates is generally poor (Table 3). In only 5 years is the estimated coefficient of variation ≤ 0.30.

Almost all estimated discards are attributable to bottom trawls; either in a single otter trawl configuration or a twin trawl configuration (Table 4). Details for these 2 gear types, with an additional stratification of small mesh (< 10.2 cm) vs. large mesh (≥ 10.2 cm), are shown in Tables 5 and 6. The number of observed trips for any stratum ranged from a low of 12 in 1994 for small mesh in the Mid-Atlantic (Table 5) to a high of 1,591 in 2011 for large mesh in New England (Table 6). The average number of observed trips was greater in New England (116 for small mesh and 450 for large mesh) relative to the Mid-Atlantic (88 for small mesh and 124 for large mesh size). Discards are roughly an order of magnitude higher with small mesh, averaging

1,151 mt in New England and 1,291 mt in the Mid-Atlantic; while large mesh discards averaged 259 mt and 144 mt in New England and Mid-Atlantic, respectively.

### *Discard size composition*

Data from observed trips in 1989 to 2012 were used to examine the size composition of the discarded and kept fraction of trips where butterfish were caught. The number of butterfish measured averaged 4,600, ranging from 1,176 in 1992 to 18,774 in 2011 (Figures 9–11). The size composition of discarded butterfish ranged from 3 to 34 cm, with modal lengths from 8 to 15 cm. The size composition of kept butterfish also ranged from 3 to 36 cm, with modal lengths from 15 to 19 cm.

### *Total commercial catch*

Total catches of butterfish increased from 15,167 mt in 1965 to a peak of 39,896 mt in 1973 and were dominated by catches from the offshore foreign fleets (Table 1; Figure 1). Total catches then declined to 11,863 mt in 1977, following the implementation of the Magnuson-Stevens Fishery Conservation and Management Act of 1976. Foreign landings were completely phased out by 1987. Butterfish catches by foreign fleets are likely underestimated because Spain and Italy did not report their butterfish bycatch from the squid fisheries from 1972 to 1976 (Murawski and Waring 1979).

A domestic fishery was developed to supply the Japanese market, leading to a peak catch of 22,401 mt in 1984, but then declined to 2,831 mt in 1990 (Table 1; Figures 1 and 2). From 1991 to 2001 catches ranged between 3,928 mt and 12,185 mt. Catches declined from 2002 to 2012 because of the lack of a directed fishery, ranging between 918 mt and 4,593 mt. Discards comprised a majority of the total butterfish catch, averaging 58% from 1989 to 2001, and 67% from 2002 to 2012. Total catch estimates were highly variable and imprecise, with coefficients of variation ranging from 0.07 – 1.43 (Table 3) because of the uncertain discard estimates.

Almost all of the total catch (not including landings by pound net and unknown gear types) was with single or twin bottom trawls, averaging 99% from 1989 to 2001, and 96% from 2002 to 2012 (Table 4).

### *Commercial catch at age*

Commercial landings were composed primarily of age 1 and age 2 butterfish (Table 7), discards were composed primarily of age 0 and age 1 fish (Table 8), and total catches were composed primarily of age 1, age 0 and age 2 fish (Table 9; Figure 12). Commercial mean weights at age are presented in Table 10.

### *Recreational catch*

Recreational catch was insignificant as measured by the Marine Recreational Information Program (MRIP).

## Survey Data

Research survey abundance and biomass indices for assessing the status of the butterfish resource are available from the NEFSC survey, as well as a number of state surveys. The accepted final model for this assessment used fall abundance indices from the NEFSC and

Northeast Area Monitoring and Assessment Program (NEAMAP) surveys. Thus, this section only describes abundance indices; details of biomass indices can be found in (NEFSC 2014).

### *NEFSC survey indices*

In spring 2009 the FSV *Henry B. Bigelow* (HBB) replaced the FRV *Albatross IV* (AIV). Because of the deeper draft of the HBB, the 2 innermost inshore strata have not been surveyed since 2008. Thus, the NEFSC strata were split as follows: the offshore series (Figure 13) consisted of the outermost of the 3 inshore strata (2, 5, 8, 11, 14, 17, 20, 23, 26, 29, 32, 35, 38, 41, 44–46, 56, 59–61 and 64–66) plus the offshore strata (1–14, 16, 19, 20, 23, 25 and 61–76); while the inshore series (Figure 14) consisted of the 2 innermost inshore strata (3, 4, 6, 7, 9, 10, 12, 13, 15, 16, 18, 19, 21, 22, 24, 25, 27, 28, 30, 31, 33, 34, 36, 37, 39, 40, 42, 43, 55, 58 and 63).

Offshore indices from the HBB for 2009 to 2012 presented below are converted to AIV units with the calibration coefficients in Table 11.

The NEFSC spring offshore abundance indices (stratified mean number per tow) averaged 58.0, ranging from 8.4 in 1990 to 142.6 in 2012 (Table 12; Figure 15). In general this index increased over the course of the time series. The inshore strata were not sampled during the spring in 1994–1996, while the highest abundance was observed in 1991. Although both indices were considered during development of the base model, only the offshore series was included in the base model presented to SARC 58.

The NEFSC fall offshore abundance indices averaged 186.3, ranging from 39.2 in 2005 to 510.4 in 1994 (Table 13; Figure 15). In general this index decreased over the course of the time series. The fall inshore abundance indices averaged 246.8, ranging from 39.5 in 1995 to 632.9 in 1997. Both indices were included in the base model presented to SARC 58.

The estimated precision of the NEFSC survey abundance indices are poorest for the spring series, with the coefficient of variation (CV) averaging 0.44 and 0.54 for the offshore and inshore, respectively (Table 12, Figure 16). The fall offshore CV averages 0.28 (Table 13; Figure 16) while the fall inshore CV is generally the lowest, averaging 0.25.

### *Aged NEFSC survey indices*

The number of stations where butterfish were sampled averaged 217 (or 45.0% of stations), ranging from 132 (or 32.7% of stations) in 1989 to 322 (or 62.3% of stations) in 2012 (Table 14). The number of butterfish aged averaged 1,061, ranging from 543 in 1989 to 1,771 in 2011. The number of butterfish measured averaged 1,105, ranging from 543 in 1989 to 1,861 in 2011.

The NEFSC spring offshore abundance at age indices show that this survey generally catches age groups 1–3 and usually some fish from age group 4 (Table 15; Figure 17). The same pattern holds for the spring inshore series, albeit with fewer butterfish (Table 16; Figure 18). Fall offshore abundance at age indices show that this survey generally catches age groups 0–3, with age 0 dominating the total catch (Table 17; Figure 19). The same pattern holds for the fall inshore series (Table 18; Figure 20).

### *NEAMAP survey*

The NEAMAP survey has covered inshore waters from Cape Cod to Cape Hatteras since fall 2007 and has used strata consistent with the NEFSC inshore strata.

The NEAMAP spring abundance indices (stratified mean number per tow) were higher than the comparable NEFSC spring inshore abundance indices, averaging 407.5, and ranging from 188.5 in 2009 to 525.6 in 2012 (Table 19; Figure 21). The fall abundance indices were generally an order of magnitude higher than the comparable NEFSC fall inshore abundance indices, averaging 1509.2, and ranging from 625.7 in 2012 to 3,600.8 in 2009. The CVs for NEAMAP abundance indices were ≤ 0.21 with the exception of 1 outlier each in the spring and fall series (Table 19; Figure 22). Both indices were included in the base model presented to SARC 58.

## *Aged NEAMAP survey indices*

NEAMAP does not yet have an age-length key for age 3+ butterfish. Thus, the NEFSC age-length keys were used to calculate NEAMAP abundance indices at age. The spring abundance indices at age show that this survey generally catches age groups 1–2 (Table 20; Figure 23); while the fall survey catch is dominated by age 0 butterfish (Table 21; Figure 24).

## *State Surveys*

Multiple surveys that capture butterfish have been conducted by individual states within inshore waters. The decision was made by the working group not to include these data in the base model as each survey only covers a small proportion of the butterfish stock area. However, the data are presented here to highlight the available information.

### Maine-New Hampshire survey

The Maine-New Hampshire survey began in fall 2000 (Table 22). There are gaps in the spring series during 2003–2005, and in 2009, while the highest abundance was observed in 2012 (Table 22; Figure 25). The fall abundance indices were higher, averaging 71.3, and ranging from 2.3 in 2000 to 303.6 in 2009. In general the fall index increased over the course of the time series. CVs for the spring and fall abundance indices averaged 0.41 and 0.29, respectively (Figure 25).

### Massachusetts Division of Marine Fisheries survey

The Massachusetts Division of Marine Fisheries (MADMF) survey began in spring 1978, although data presented are for 1989–2012 only. The MADMF spring abundance indices (stratified mean number per tow) averaged 9.9, ranging from 0.02 in 1989 to 46.1 in 2007 (Table 22; Figure 25). The fall abundance indices were higher, averaging 426.1, and ranging from 72.0 in 2001 to 979.2 in 2009. CVs for the spring and fall abundance indices averaged 0.62 and 0.25, respectively (Figure 25).

### Rhode Island Department of Environmental Management survey

The Rhode Island Department of Environmental Management (RIDEM) survey began in spring 1979, although data presented are for 1989–2012 only. The RIDEM spring abundance indices (stratified mean number per tow) averaged 21.3 and ranged from 0 butterfish in 1989, 1992 and 2005, to a maximum of 405.0 in 2006 (Table 22; Figure 25). The fall abundance indices were higher, averaging 468.1 and ranging from 42.7 in 2000 to 2507.7 in 2009. In general the fall index increased over the course of the time series. CVs for the spring and fall abundance indices averaged 0.71 and 0.38, respectively (Figure 25).

**Connecticut Department of Energy and Environmental Protection survey**

The Connecticut Department of Energy and Environmental Protection (CTDEEP) survey of Long Island Sound began in 1984, although data presented are for 1989–2012 only. There was no fall survey in 2010. The CTDEEP spring abundance indices (geometric mean number per tow) ranged from 0.5 in 1993 to 18.7 in 2006 (Table 22; Figure 26). The fall abundance indices were higher, ranging from 39.6 in 2011 to 477.9 in 1999.

**New York Department of Environmental Conservation survey**

The New York State Department of Environmental Conservation (NYSDEC) survey of Peconic Bay began in 1987. Sixteen stations are sampled weekly during May–October. The survey was not conducted in 2005. Data described below are annual means for 1989–2012 only. The NYSDEC abundance indices (mean number per tow) averaged 1.2 and ranged from 0.3 in 2007 to 5.2 in 2010 (Table 22; Figure 26).

**New Jersey Department of Environmental Protection survey**

The New Jersey Department of Environmental Protection (NJDEP) survey began in August 1988. Surveys are conducted in January, April, June, August and October. Data described below are annual means for 1989–2012 only. The NJDEP abundance indices (stratified mean number per tow) averaged 841.35 and ranged from 97.3 in 2012 to 2018.9 in 1994 (Table 22; Figure 26).

**Delaware Department of Natural Resources and Environmental Control surveys**

Bottom trawl surveys of Delaware Bay were conducted during 1966–1971 and 1979–1984; the Delaware Department of Natural Resources and Environmental Control (DDNREC) reinstated a 30-foot multispecies bottom trawl survey in 1990 (Table 22). The young-of-the-year seine survey in the estuaries of Delaware Bay began in 1980; in 1986 this was expanded to include Indian River and Rehoboth Bays (Table 22). Data described below are annual means for 1989–2012 only.

The trawl survey abundance indices (mean number per tow) averaged 16.4 and ranged from 3.6 in 1992 to 66.7 in 1993 (Table 22; Figure 26).

The seine survey abundance indices (mean number per tow) for estuaries ranged from 0.05 in 1994 and 2006 to 0.57 in 1999, while abundance indices for the bays ranged from 0 butterfish in 2001 to 2.27 in 2009 (Table 22; Figure 26).

**Chesapeake Bay Multispecies Monitoring and Assessment Program survey**

The Chesapeake Bay Multispecies Monitoring and Assessment Program (ChesMMAP) survey began in spring 2002. The ChesMMAP annual abundance indices (geometric mean number per tow) ranged from 13.6 in 2010 to 126.7 in 2005 (Table 22; Figure 27).

**Virginia Institute of Marine Science juvenile survey**

The Virginia Institute of Marine Science (VIMS) juvenile trawl survey began in 1988. Data presented below are annual means for 1989–2012 only. The VIMS juvenile abundance indices (geometric mean number per tow) ranged from 0.2 in 2007 to 2.3 in 1990 (Table 22; Figure 27).

**North Carolina Department of Environment and Natural Resources survey**

The North Carolina Department of Environment and Natural Resources (NCDENR) of Pamlico Sound began in 1990. The NCDENR annual abundance indices (weighted mean number per tow) ranged from 0.5 in 1997 to 7.8 in 2008 (Table 22; Figure 26).

### *Correlation coefficients*

Correlation coefficients for spring abundance indices considered for inclusion in the final model are shown in Table 23. The NEFSC offshore survey had a correlation coefficient of 0.49 with the MDMF survey. The NEAMAP survey had correlations > 0.4 with the Maine-New Hampshire survey, the MDMF survey, and the RIDEM survey. Standardized spring abundance indices are plotted in Figure 28.

Correlation coefficients for fall abundance indices considered for inclusion in the final model are shown in Table 24. The NEFSC offshore survey had a correlation coefficient of 0.54 with the NEAMAP survey. The NEAMAP survey had correlations > 0.4 with all the state surveys. The Maine-New Hampshire survey also had correlations > 0.4 with the 3 other state surveys. Standardized fall abundance indices are plotted in Figure 29.

NEFSC spring offshore, NEFSC fall offshore, NEFSC fall inshore, NEAMAP spring and fall survey data were included in the base model presented to SARC 58. NEFSC spring inshore data were not included because of the high CVs associated with this series. Other state survey data considered in this correlation analysis were not used as tuning indices in the base model.

## Consumptive removals by predators

Consumptive removals of butterfish by its predators were evaluated for possible inclusion in the assessment model to explain annual deviations in natural mortality (*M*). Briefly, fish diet data from NEFSC bottom trawl surveys were examined for a broad suite of butterfish predators. The total amount of food eaten and the type of food eaten were the primary diet data examined. From these basic food habits data, diet composition of butterfish, per capita consumption, total consumption, and the amount of butterfish removed by the fish predators were calculated. Combined with abundance estimates of these predators, butterfish consumption was summed across all predators for total butterfish consumption. Further details of this analysis can be found in (NEFSC 2014). Results are summarized here.

The top 6 finfish predators of butterfish are listed in Table 25. As in the previous assessment (NEFSC 2010), estimates of consumption by these 6 predators of butterfish appear low, generally between 1,000 and 8,000 mt/year (Figure 30). Based on a dynamic factor analysis, a single trend model fit the butterfish consumption data best, implying the trend in butterfish consumption was similar among these 6 predators. Additionally, for each predator, fitted consumption was generally constant relative to the time series mean (Figure 31). Annual CV estimates for total consumption across all fish predators were between 0.27 and 1.06, with a time series mean of 0.45. Although consumptive removals were not directly incorporated into the assessment model, the results of this analysis supported the estimation of a constant *M* in the model.

## ASAP Model

The age structured assessment program (ASAP) statistical catch at age model (Legault and Restrepo 1999) was used in this assessment. ASAP uses forward computations assuming the separability of fishing mortality into year and age components to estimate population sizes given observed catches, indices of abundance, and respective age compositions. The objective function is the sum of the likelihood components for aggregate annual catch, indices, and age composition data, and various penalties may be specified. Observations of proportions at age are modeled assuming a multinomial distribution, while all other model components are assumed to have a lognormal error distribution. Diagnostics include index fits, residuals in catch and catch-at-age, and effective sample size calculations. Weights can be specified for different components of the objective function and allow for relatively simple age-structured production models to fully parameterized statistical catch-at-age models. The standard ASAP (NFT 2013a) was used in the development of the base model; while an augmented version of ASAP (described below) was used both in the development of the base model and for the final model.

## *ASAP Augmentations*

### **Covariate Effects on Survey Catchability**

Survey catchability was reparameterized as a product of gear efficiency $E$ and availability to the gear $A$. Each of these components are bounded between 0 and 1, and $A$ is allowed to be functions of covariates $\boldsymbol{X}_A$,

$$\log\left(\frac{A}{1-A}\right) = \boldsymbol{X}_A^T \boldsymbol{\beta}_A \qquad (1)$$

Normal priors/penalties are allowed on $\log(E/(1-E))$ and average $\log(A/(1-A))$ across years as well.

A time varying estimate of $A$ was developed for possible inclusion in the assessment model. Briefly, this was done in 5 steps: 1) a thermal niche model was developed by using maximum likelihood to estimate parameters of a thermal reaction norm fit to catch and temperature data from federal and state fishery independent bottom trawl surveys conducted throughout the Northwest Atlantic; 2) a hindcast of bottom water temperature for the Northwest Atlantic was constructed by using historical climatology to remove systematic bias in the output from a numerical circulation model; 3) butterfish catch data was used to evaluate patterns of sample occupancy in relation to hindcasts of a thermal habitat suitability index (HSI), which was generated by coupling the thermal niche model to hindcast temperatures, as well as temperatures measured *in situ* with samples; 4) availability of the butterfish stock to surveys was calculated by using daily regional hindcasts of thermal habitat suitability and the locations and times of survey samples, as the proportion of available habitat suitability sampled in the region during the survey period; and 5) model based estimates of availability were compared with empirical estimates developed for simultaneous but nonoverlapping fall surveys and day:night differences in detectability. Further details of the time varying estimate of $A$ can be found in (NEFSC 2014).

For efficiency, an approach similar to that described in (NEFSC 2014) for estimating minimum bounds on biomass was used; the primary difference was that abundance indices were utilized in place of biomass indices. Briefly, the relative efficiency of the survey between day and night was used to scale the maximum efficiency of NEFSC fall offshore survey over the standard 24-hour operations. Night was defined as a solar zenith angle of ≥ 90° 50′ (Jacobson et al 2011). It was assumed daytime tows conducted by the HBB detected all available butterfish ($\delta_{day}$ = 1), and that average efficiency for the day and night tows combined was less than 1. The stratified mean day and night catch rates for 1989 to 2008 NEFSC fall offshore survey data from the AIV were calculated to obtain the nighttime efficiency:

$$\frac{\delta_{night,max}}{\delta_{day,max}} = \delta_{night,max} = \frac{Catch_{day}}{Catch_{night}} \quad (2)$$

and in turn a maximum value for the average efficiency for all tows combined:

$$\delta_{max} = \delta_{day,max} * Proportion\ day\ tows + \delta_{night,max} * Proportion\ night\ tows \quad (3)$$

Prior to retiring the AIV there was a large-scale paired gear experiment carried out with the new HBB. This paired-gear study indicated that the HBB was much more efficient than the AIV for most species (Miller et al. 2010). On average, the HBB was estimated to catch 1.935 times the butterfish in numbers per tow as the AIV during the fall survey. Additionally, the ratio of the average HBB and AIV wing swept area per tow is 0.024 $km^2$/0.038 $km^2$ = 0.63. Combining these 2 factors indicates that the efficiency per $km^2$ of the AIV is 0.33 that of the HBB, and combined with the maximum efficiency of the HBB, the maximum efficiency of the AIV is 0.2. This analysis assumes the HBB daytime tows are fully efficient and estimates the maximum efficiency for all HBB tows and a constant calibration factor from Miller et al. (2010) to provide an estimate of maximum efficiency for the AIV for the entire time series. Note that using an estimate of maximum efficiency is conservative since abundance estimates are inversely related to efficiency with all other parameters equal.

**Incorporation of Length-based Relative Catch Efficiency of HBB:AIV**

There are substantial size effects on this calibration factor for butterfish (Miller 2013). To incorporate uncertainty in size-based estimates of relative catch efficiency in the assessment model, a penalty was added to the likelihood for the estimates of the spline smoother coefficients $\boldsymbol{\beta}$ ($p$ = 10 is the number of coefficients) provided by Miller (2013),

$$f(\hat{\boldsymbol{\beta}}) = (2\pi)^{-\frac{\rho}{2}} \left|\boldsymbol{\Sigma}\right|^{-\frac{1}{2}} e^{-\frac{1}{2}(\boldsymbol{\beta}-\hat{\boldsymbol{\beta}})^T \Sigma^{-1} (\boldsymbol{\beta}-\hat{\boldsymbol{\beta}})} \quad (4)$$

where $\boldsymbol{\Sigma}$ is the estimated variance-covariance matrix from the fitted hierarchical generalized additive model. The data file includes the estimates of $\boldsymbol{\beta}$ and $\boldsymbol{\Sigma}$ as well as the design matrix for calculating the relative catch efficiency at length and, for the HBB surveys (2009–2012), the numbers-at-length indices and age-length keys. The calibrated (AIV scale) survey indices are calculated as

$$\hat{I}_A = \sum_{l=1}^{L} I_{H,l} \rho_l \quad (5)$$

where $I_{H,l}$ is the HBB numbers-at length $l$,

$$\rho_l = e^{-X_l^T \boldsymbol{\beta}} \quad (6)$$

is the relative catch efficiency (AIV:HBB) at length $l$ and $X_l$ is the row of the design matrix for the spline smoother associated with length $l$. The AIV proportions at age are calculated from the indices-at-age,

$$\hat{I}_{A,a} = \sum_{l=1}^{L} p(a \mid l) I_{H,l} \rho_l \quad (7)$$

where $p(a \mid l)$ is the proportion at age $a$ given length $l$ from the age length key. The indices $\hat{I}_A$ are used in the normal calculations of the survey likelihood components using the CVs supplied with the index data. Thus it is implicitly assumed that the CVs of the indices and effective sample sizes for the proportions-at-age are the same as if the AIV were being used in those years to conduct the bottom trawl survey. The calibrated indices and proportions at age also replace the normal index data for the calibrated years in the report file. Note that there will be $p$ more parameters estimated when calibrated indices are used so that deviations from $\boldsymbol{\beta}$ can be allowed. This approach allows the catchability in years when the HBB was used to differ from those years when the AIV was used, but in a way that is informed by the paired-gear experiment.

The final butterfish model included internal length-based calibration for the NEFSC fall offshore survey data from 2009 to 2012 (Table 26). The sizes observed in the data on butterfish from the paired gear study ranged from 2 to 21 cm, but there were some sizes observed in the 2009–2012 data outside of this range. Thus, for sizes > 21cm the same relative efficiency was assumed as that at 21 cm, and the relative efficiency at 2 cm was applied to any observations at 1 cm. Observations outside 2–21 cm are rare and this type of extrapolation has little effect on the calibrated aggregate indices or the age composition.

**Estimation of Natural Mortality effects**

There was also a change in the parameterization of natural mortality so that annual or age-specific effects of covariates on natural mortality could be specified or estimated. The annual and age-specific effects are linear on the log scale

$$\log M_{y,a} = \boldsymbol{X}_y^T \boldsymbol{\beta}_{M,y} + \boldsymbol{X}_a^T \boldsymbol{\beta}_{M,a}. \tag{8}$$

Estimating effects of covariates on $M$ by subsets of ages or years was accomplished by specifying appropriate design matrices.

Given the parameterization described above which constrains the catchability of the NEFSC fall offshore survey it was possible to estimate a constant $M$ in the final model.

# RESULTS

A final model, consisting of the NEFSC fall offshore, NEFSC fall inshore, and NEAMAP fall survey data, was chosen on the basis of better diagnostics and because most of the population is thought to be well distributed within the survey domain at this time. Specifications for the final model and swept area abundance inputs are shown in Tables 27 and 28, respectively.

The time varying HSI indicated that the NEFSC fall offshore survey sampled between 62% to 75% of thermal habitat suitable for butterfish (Figure 32). Preliminary runs with this covariate did not improve the model. Thus, a more parsimonious configuration, without the time varying HSI, was adopted. In this configuration, the median HSI over the time series ($A$ = 0.68) was used to estimate catchability for scaling the final model.

# Diagnostics for the Final Model

Objective function components for the final model are shown in Table 29. Root mean square error (MSE) for data components for the final model are generally close to 1 (Table 30).

Although there are more positive residuals in the mid part of the catch time series, the magnitude of these residuals is small in recent years (Figure 33). The NEFSC offshore survey has positive residuals early in the time series (Figure 34), while the NEFSC inshore survey has the reverse trend (Figure 35). No trends are apparent in the shorter NEAMAP time series (Figure 36). There is a predominance of negative residuals at age 2 and of positive residuals at age 3 in the catch age composition (Figure 37). No trends are apparent in the residuals for NEFSC survey age compositions (Figures 38 and 39), or NEAMAP survey age composition (Figure 40).

### Results for the Final Model

The peak in fishing mortality rate on fully selected ages (ages 2+) was F = 0.15, which occurred in 1993 (Tables 31 and 32; Figure 41). Fishing mortality ranged between 0.04 and 0.14 during 1994 to 2001, but has been ≤ 0.07 since 2002. Butterfish are fully selected by age 2 in the fishery (Figure 42). The model also provided a new estimate of $M = 1.22$.

Spawning stock biomass (Age 1+) averaged 79,410 mt during 1989 to 2012 (Table 31; Figures 43 – 45). Spawning stock biomass peaked in 2000 at 106,590 mt.

Recruitment averaged 8.5 billion fish during 1989 to 2012 (Table 31; Figures 45 – 47). The 1997 year class was the largest, at 14.8 billion fish, while the 2012 year class, estimated to be 2.4 billion fish, was the smallest of the time series. Estimated numbers at age are shown in Table 33 and Figure 48.

CVs for SSB and recruitment were ≤ 0.33 (Table 31; Figure 49), while CVs for F were variable, ranging from 0.22 to 1.00.

Index catchabilities and selectivities are shown in Figures 50 and 51, respectively.

## Sensitivities and Simulations

Sensitivities of annual estimates of spawning biomass, recruitment, and fishing mortality to various assumptions and augmentations of the ASAP model were explored during the Stock Assessment Workshop (SAW) 58 prior to the development of the final model. Further details of the HSI can be found in the SAW 58 report (NEFSC 2014). Similarly, a series of simulations were run prior to the development of the final model to evaluate the behavior of the model statistically with respect to the incorporation of the internal length-based calibration and estimation of natural mortality. The simulations showed no evidence of bias (NEFSC 2014).

## Retrospective patterns

A retrospective analysis of the final model using a 4 year peel was done for spawning biomass, recruitment and fishing mortality estimates. Four years was chosen as the break point between the AIV and HBB. There was no trend in terminal year estimates of SSB, recruitment and fishing mortality (Figure 52). Furthermore, the scale of the differences is relatively small based on calculated Mohn's rho (Mohn 1999) values.

## Biological Reference Points Based on the Final Model

Based on Patterson (1992), the overfishing reference point is $F = 2M/3 = 2 \times 1.22/3 = 0.81$ (CV = 0.05). The current fishing mortality ($F_{2012} = 0.02$, CV = 0.33) is well below the overfishing reference point (Figure 53). The biomass reference point $SSB_{MSY}$ proxy (median SSB based on a 50 year projection at the $F_{MSY}$ proxy) is 45,616 mt (CV = 0.25). $SSB_{2012}$ is estimated to be 79,451 mt, which is well above the $SSB_{MSY}$ proxy (Figure 54). The MSY proxy is 36,199 mt; CV = 0.20. $SSB_{threshold}$ is one half the $SSB_{MSY}$ proxy, or 22,808 mt.

## Stock Status

Fishing mortality was estimated to be 0.02 in 2012, which is well below the overfishing reference point $F_{MSY}$ proxy = 0.81 (Figure 54). There is a < 1% chance the estimated 2012 fishing mortality is above the $F_{MSY}$ proxy (Figure 55), and thus overfishing is not occurring.

$SSB_{2012}$ was estimated to be 79,451 mt, which is well above the accepted biomass reference point $SSB_{MSY}$ proxy = 45,616 mt. There is a < 1% chance the estimated SSB is below $SSB_{threshold}$ (Figure 56), thus the stock is not overfished.

## Projections

Stochastic projections were made to provide forecasts of stock size and catches in 2013–2014. The projections assume that recent patterns of fishery selectivity, discarding, maturity at age and mean weight at age will continue over the time span of the projections. One hundred projections were made for each of 1000 Markov Chain Monte Carlo (MCMC) realizations of 2012 stock sizes using AGEPRO (NFT, 2013b). Future recruitment at age 1 was generated randomly from the probability density function of the updated recruitment series for 1989–2012 (average recruitment = 8.1 billion fish).

If preliminary butterfish catch (landings plus discards) for 2013 (2,489 mt) is assumed, the median projection of SSB in 2013 is 51,746 mt, with 5% and 95% confidence limits of 32,489 mt and 81,073 mt, respectively (Figure 57). If the 2014 butterfish catch is assumed equal to the allowable biological catch (ABC) (9,100 mt), the median projection of SSB in 2014 is 53,580 mt, with 5% and 95% confidence limits of 38,365 mt and 73,885 mt, respectively (Figure 57).

# DISCUSSION

There were 3 augmentations to the standard ASAP (NFT 2013a) for the final model: 1) catchability was reparameterized as the product of availability and efficiency, with the former specified by using availability estimates based on bottom temperature; 2) length-based calibration of bottom trawl survey data in 2009–2012 was performed internal to the model; and 3) estimation of natural mortality. For the NEFSC fall offshore survey, an average measure of availability based on a bottom temperature was used, and the efficiency was based on the relative efficiency of the FRV *Albatross IV* to the FSV *Henry B. Bigelow* and an assumption that the Bigelow was 100% efficient for daytime tows. Additionally, by fixing catchability it was possible to estimate natural mortality. Ability to estimate parameters within the new model framework was confirmed through simulation.

Conflicting trends were observed between several survey abundance indices: the NEFSC offshore spring series has generally been increasing, while the NEFSC offshore fall series has been decreasing. While the spring series tracked cohorts more clearly through the age structure, butterfish are more widely distributed throughout the survey area during fall, and thus fall survey trends more accurately represent patterns in overall abundance. Research into the age structure and spatiotemporal distribution of butterfish may provide insights into these divergent trends. Two other clear contrasts with the NEFSC offshore fall series are the increasing trend in the Maine-New Hampshire and RIDEM fall surveys. It may be possible to address these discrepancies in future assessments with the inclusions of more state survey data, if methods can be developed to combine these data sources into a single series such that it is representative of the unit stock.

As in the previous assessment, estimates of consumption by the top 6 finfish predators of butterfish within the NEFSC food habits database appear to be very low and similar in magnitude to historic fishing mortality but well below the estimated natural mortality rate. The ratio of M/F ×1711 mt (2012 catch from Table 1) approximates a loss from natural mortality of 105,591 mt. However, only 2,093 mt were estimated for consumptive removals by the top 6 finfish predators in 2012 (Figure 30). Similarly, average estimates of biomass losses from natural mortality since 1989, based on the standard catch equation and model output, are 220,107 mt, whereas average consumptive removals over the same time period is only 3,056 mt. This discrepancy suggests potentially significant removals by other predators not available to the bottom trawl survey. Evidence was presented during the assessment that longfin inshore squid are not a major predator on butterfish (pers. comm., Olaf Jensen, 2013. Rutgers University, New Brunswick NJ 08901). Food habits of other potential predators, such as sharks, tuna, swordfish, marine mammals and seabirds are not adequately sampled by the NEFSC bottom trawl survey to determine total butterfish consumption. Elucidation of other sources of natural mortality is a priority research topic.

It is unclear why there was little variation in the HSI, given opposing trends in abundance indices between the NEFSC offshore survey and the NEFSC inshore survey to the north and east. One possibility is that changes in thermal habitat dynamics for butterfish during the fall do not completely account for the empirical trends. The other is that changes in thermal habitat dynamics do account for empirical trends, but the Regional Ocean Modeling System (NEFSC 2014) does not capture them well enough. This could occur because of misspecification of the niche model or because bias corrected model based temperatures did not capture real trends. The latter is possible because hindcast bottom temperatures were spatially bias corrected by using monthly bottom temperature from a long term climatology. This approach adjusted the model hindcast to match climatology[1] spatially and may have smoothed temperature variability on the edges of the ecosystem that may have increased over recent years. Research is ongoing to address these issues.

Two issues regarding the geographic extent of the butterfish stock need to be addressed. One is the possibility of spawning south of Cape Hatteras, NC, and the potential contribution to the northern stock. This consideration was put forward as a research recommendation by the working group. The other issue is the off-shelf density of butterfish. The latter could be addressed by a study with comparable HBB trawl gear and sampling protocols to depths of 367–700 m, from the southern Scotian Shelf to Cape Hatteras, concurrent with sampling of the deepest NEFSC strata during the spring and fall bottom trawl surveys. Swept area estimates of stock size for the off-shelf areas could be calculated to determine their effect on the NEFSC survey indices.

# Conclusions

In the previous butterfish assessment (NEFSC 2010) it was not possible to determine stock status relative to BRPs because of assessment uncertainties. Nevertheless the population was thought to be declining over time. The current assessment, which used a modified age-

[1] Climatology is commonly known as the study of climate, yet the term encompasses many other important definitions. Climatology is also defined as the long-term average of a given variable, often over time periods of 20-30 years. http://iridl.ldeo.columbia.edu/dochelp/StatTutorial/Climatologies/

structured catch at age model, as well as additional survey data from NEAMAP, yielded different insights into the butterfish stock. Fishing mortality has generally declined since 1989 but has always been low relative to natural mortality, which was estimated to be much higher than previously thought. Research on the estimation of catchability provided an improved basis for understanding the stock history and allowed estimation of BRPs. Although the accepted MSY proxy (36,199 mt) is high relative to recent catch limits, it is comparable to the peak historical catch observed in 1973 (Table 1; Figure 1). This result suggests that continued, judicious development of the recently reestablished directed butterfish fishery is reasonable.

## ACKNOWLEDGEMENTS

Thanks to Gary Shepherd for his help and guidance towards completing the assessment and to the rest of the Coastal Pelagic Working Group who contributed their advice and expertise throughout the assessment process. Thanks also to Josh Dayton for providing the age data. NEAMAP, ChesMMAP and VIMS data were provided by Chris Bonzek. Other state survey data were provided by: Sally Sherman (Maine-New Hampshire); Jeremy King (MADMF); Scott Olszewski (RIDEM); Kurt Gottschall (CTDEEP); John Maniscalco (NYSDEC); Linda Berry (NJDEP); Michael Greco (DDNREC); and Jason Rock (NCDENR).

## REFERENCES CITED


Collette BB, Klein-MacPhee G. 2002. Bigelow and Schroeder's Fishes of the Gulf of Maine, 3rd edn. Washington, DC: Smithsonian Institution Press.

Jacobson L, Seaver A, Tang J. 2011. AstroCalc4R: Software to calculate solar zenith angle; time at sunrise, local noon, and sunset; and photosynthetically active radiation based on date, time, and location. NEFSC Ref. Doc. 11-14. 16 p. http://www.nefsc.noaa.gov/publications/crd/crd1114/index.html.

Legault CM, Restrepo VR. 1999. A flexible forward age-structured assessment program. Col Vol Sci Pap ICCAT. 49(2):246–253.

Lyles CH. 1967. Fishery Statistics of the United States, 1965. US Fish Wildl Serv Stat Dig 59. 756 p.

Miller TJ. 2013. A comparison of hierarchical models for relative catch efficiency based on paired-gear data for US Northwest Atlantic fish stocks. Can J Fish Aquat Sci. 70(9):1306–1316.

Miller TJ, Das C, Politis PJ, Miller AS, Lucey SM, Legault CM, Brown RW, Rago PJ. 2010. Estimation of Albatross IV to Henry B. Bigelow calibration factors. NEFSC Ref. Doc. 10-05. 233 p. http://www.nefsc.noaa.gov/publications/crd/crd1005/.

Mohn R. 1999. The retrospective problem in sequential population analysis: an investigation using cod fishery and simulated data. ICES J Mar Sci. 56(4):473–488.

Murawski SA, Frank DG, Chang S. 1978. Biological and Fisheries Data on Butterfish, *Peprilus triacanthus* (Peck). Sandy Hook Laboratory Technical Series Report 6. 39 p. http://www.nefsc.noaa.gov/publications/series/shtsr/shltsr6.pdf.

Murawski SA, Waring GT. 1979. A population assessment of butterfish, *Peprilus triacanthus*, in the Northwestern Atlantic Ocean. Trans Am Fish Soc 108(5):427–539.

NEFSC. 1990. Report of the Spring 1990 NEFC Stock Assessment Workshop (Tenth SAW). NEFSC Ref Doc 90-07. 89 p. http://www.nefsc.noaa.gov/publications/crd/pdfs/crd9007.pdf.

NEFSC. 2004. 38th Northeast Regional Stock Assessment Workshop (38th SAW) *Stock Assessment Review Committee (SARC) Consensus Summary of Assessments*. NEFSC Ref Doc 04-03. 246 p. http://www.nefsc.noaa.gov/publications/crd/crd0403/.

NEFSC. 2010. 49th Northeast Regional Stock Assessment Workshop (49th SAW) *Assessment Report*. NEFSC Ref Doc 10-03. 383 p. http://www.nefsc.noaa.gov/publications/crd/crd1003/.

NEFSC. 2014. 58th Northeast Regional Stock Assessment Workshop (58th SAW) *Assessment Report*. NEFSC Ref Doc 14-04. 784 p. http://www.nefsc.noaa.gov/publications/crd/crd1404/.

NFT. 2013a. Age structured assessment program (ASAP) version 3.0.13. http://nft.nefsc.noaa.gov/ASAP.html.

NFT. 2013b. Age structured projection model (AGEPRO) version 4.2.2. http://nft.nefsc.noaa.gov/AGEPRO.html.

Patterson K.1992. Fisheries for small pelagic species: an empirical approach to management targets. Rev Fish Biol Fisher 2(4):321–338.

Waring GT, Anderson ED. 1983. Status of the northwestern Atlantic butterfish stock – 1983. Woods Hole Laboratory Ref Doc 83-41. 39 p. http://www.nefsc.noaa.gov/publications/series/whlrd/whlrd8341.pdf.

Wigley SE, Rago PJ, Sosebee KA, Palka DL. 2007. The analytic component to the standardized bycatch reporting methodology omnibus amendment: Sampling design and estimation of precision and accuracy, 2nd ed. NEFSC Ref Doc 07-09. 156 p. http://www.nefsc.noaa.gov/publications/crd/crd0709/.

**Table 1. Butterfish (*Peprilus triacanthus*) USA landings (mt), historic USA discards (mt), estimated USA discards (mt), foreign catch (mt), and total catch (mt), 1965–2012.**

| Year | USA Landings | Historic USA Discards | USA Discards | Foreign Catch | Total catch |
|---|---|---|---|---|---|
| 1965 | 2944 | | 11474 | 749 | 15167 |
| 1966 | 2461 | | 10997 | 3865 | 17323 |
| 1967 | 2245 | | 10174 | 2316 | 14735 |
| 1968 | 1585 | | 9856 | 5437 | 16878 |
| 1969 | 2198 | | 9421 | 15378 | 26997 |
| 1970 | 1731 | | 8760 | 12450 | 22941 |
| 1971 | 1566 | | 7977 | 8913 | 18456 |
| 1972 | 704 | | 6653 | 12221 | 19578 |
| 1973 | 1521 | | 6696 | 31679 | 39896 |
| 1974 | 1778 | | 6197 | 15465 | 23440 |
| 1975 | 1973 | | 5658 | 12764 | 20395 |
| 1976 | 1376 | 152 | 6193 | 14437 | 22006 |
| 1977 | 1296 | 152 | 7255 | 3312 | 11863 |
| 1978 | 3615 | 61 | 8675 | 1699 | 13989 |
| 1979 | 2646 | 185 | 9193 | 1107 | 12946 |
| 1980 | 5172 | 184 | 9956 | 1392 | 16520 |
| 1981 | 4855 | 0 | 9531 | 1400 | 15786 |
| 1982 | 8837 | 68 | 11098 | 1578 | 21513 |
| 1983 | 4743 | 162 | 10911 | 630 | 16284 |
| 1984 | 11715 | 257 | 10257 | 429 | 22401 |
| 1985 | 4633 | 106 | 8328 | 804 | 13765 |
| 1986 | 4418 | | 7936 | 164 | 12518 |
| 1987 | 4578 | | 7351 | | 11929 |
| 1988 | 2107 | | 7352 | | 9459 |
| 1989 | 3216 | | 4480 | | 7696 |
| 1990 | 2298 | | 533 | | 2831 |
| 1991 | 2189 | | 4887 | | 7076 |
| 1992 | 2754 | | 5025 | | 7779 |
| 1993 | 4608 | | 7577 | | 12185 |
| 1994 | 3634 | | 6694 | | 10328 |
| 1995 | 2067 | | 6353 | | 8420 |
| 1996 | 3555 | | 1049 | | 4604 |
| 1997 | 2794 | | 1134 | | 3928 |
| 1998 | 1966 | | 6412 | | 8378 |
| 1999 | 2110 | | 8867 | | 10977 |
| 2000 | 1449 | | 7044 | | 8493 |
| 2001 | 4404 | | 4969 | | 9373 |
| 2002 | 872 | | 2350 | | 3222 |
| 2003 | 536 | | 2088 | | 2624 |
| 2004 | 497 | | 1323 | | 1820 |
| 2005 | 428 | | 647 | | 1075 |
| 2006 | 555 | | 856 | | 1411 |
| 2007 | 679 | | 239 | | 918 |
| 2008 | 452 | | 1029 | | 1481 |
| 2009 | 435 | | 1079 | | 1514 |
| 2010 | 576 | | 4017 | | 4593 |
| 2011 | 664 | | 1612 | | 2276 |
| 2012 | 671 | | 1040 | | 1711 |

**Table 2. US commercial butterfish (*Peprilus triacanthus*) samples and lengths collected, 1989–2012.**

| | | Quarter | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | Total |
| 1989 | Total number of samples taken | 11 | 4 | 8 | 5 | 28 |
| | Total number of fish measured | 1115 | 399 | 800 | 504 | 2818 |
| 1990 | Total number of samples taken | 8 | 6 | 11 | 9 | 34 |
| | Total number of fish measured | 812 | 589 | 1103 | 901 | 3405 |
| 1991 | Total number of samples taken | 9 | 4 | 10 | 7 | 30 |
| | Total number of fish measured | 901 | 402 | 1002 | 700 | 3005 |
| 1992 | Total number of samples taken | 8 | 6 | 7 | 5 | 26 |
| | Total number of fish measured | 803 | 600 | 710 | 513 | 2626 |
| 1993 | Total number of samples taken | 2 | 6 | 4 | 9 | 21 |
| | Total number of fish measured | 206 | 539 | 451 | 969 | 2165 |
| 1994 | Total number of samples taken | | 3 | 4 | 7 | 14 |
| | Total number of fish measured | | 142 | 419 | 724 | 1285 |
| 1995 | Total number of samples taken | 1 | 3 | 2 | | 6 |
| | Total number of fish measured | 210 | 314 | 164 | | 688 |
| 1996 | Total number of samples taken | 3 | 1 | 5 | 7 | 16 |
| | Total number of fish measured | 400 | 115 | 421 | 791 | 1727 |
| 1997 | Total number of samples taken | 14 | 4 | 2 | 11 | 31 |
| | Total number of fish measured | 1499 | 413 | 199 | 964 | 3075 |
| 1998 | Total number of samples taken | 9 | 7 | 4 | 5 | 25 |
| | Total number of fish measured | 893 | 618 | 383 | 467 | 2361 |
| 1999 | Total number of samples taken | 12 | 8 | 5 | 3 | 28 |
| | Total number of fish measured | 1239 | 728 | 521 | 237 | 2725 |
| 2000 | Total number of samples taken | 3 | 3 | 1 | 3 | 10 |
| | Total number of fish measured | 345 | 280 | 108 | 295 | 1028 |
| 2001 | Total number of samples taken | 6 | 14 | 7 | 1 | 28 |
| | Total number of fish measured | 637 | 1446 | 714 | 114 | 2911 |
| 2002 | Total number of samples taken | 6 | 1 | 2 | 3 | 12 |
| | Total number of fish measured | 617 | 98 | 215 | 313 | 1243 |
| 2003 | Total number of samples taken | 9 | 9 | 7 | 3 | 28 |
| | Total number of fish measured | 930 | 931 | 774 | 312 | 2947 |
| 2004 | Total number of samples taken | 5 | 12 | 17 | 7 | 41 |
| | Total number of fish measured | 540 | 1117 | 1755 | 682 | 4094 |
| 2005 | Total number of samples taken | 11 | 9 | 9 | 10 | 39 |
| | Total number of fish measured | 1124 | 924 | 903 | 975 | 3926 |
| 2006 | Total number of samples taken | 10 | 17 | 7 | 16 | 50 |
| | Total number of fish measured | 988 | 1795 | 731 | 1638 | 5152 |
| 2007 | Total number of samples taken | 13 | 10 | 23 | 17 | 63 |
| | Total number of fish measured | 1433 | 1005 | 2232 | 1761 | 6431 |
| 2008 | Total number of samples taken | 13 | 10 | 12 | 7 | 42 |
| | Total number of fish measured | 1374 | 1043 | 980 | 694 | 4091 |
| 2009 | Total number of samples taken | 7 | 7 | 3 | 8 | 25 |
| | Total number of fish measured | 694 | 614 | 325 | 818 | 2451 |

**Table 2, continued. US commercial butterfish (*Peprilus triacanthus*) samples and lengths collected, 1989–2012.**

| | | | | | | |
|---|---|---|---|---|---|---|
| 2010 | Total number of samples taken | 5 | 11 | 9 | 7 | 32 |
| | Total number of fish measured | 563 | 1109 | 867 | 702 | 3241 |
| 2011 | Total number of samples taken | 13 | 4 | 1 | 6 | 24 |
| | Total number of fish measured | 1307 | 400 | 100 | 557 | 2364 |
| 2012 | Total number of samples taken | 11 | 5 | 2 | 4 | 22 |
| | Total number of fish measured | 1011 | 500 | 200 | 400 | 2111 |

**Table 3. Estimated USA butterfish (*Peprilus triacanthus*) discards (mt) and total catch (mt) from Table 1, and respective coefficients of variation (CV), 1989–2012.**

| Year | USA Discards | CV | Year | USA Catch | CV |
|---|---|---|---|---|---|
| 1989 | 4480 | 0.85 | 1989 | 7696 | 0.49 |
| 1990 | 533 | 0.37 | 1990 | 2831 | 0.07 |
| 1991 | 4887 | 0.99 | 1991 | 7076 | 0.68 |
| 1992 | 5025 | 0.54 | 1992 | 7779 | 0.35 |
| 1993 | 7577 | 0.32 | 1993 | 12185 | 0.20 |
| 1994 | 6694 | 0.41 | 1994 | 10328 | 0.26 |
| 1995 | 6353 | 0.49 | 1995 | 8420 | 0.37 |
| 1996 | 1049 | 0.71 | 1996 | 4604 | 0.16 |
| 1997 | 1134 | 0.84 | 1997 | 3928 | 0.24 |
| 1998 | 6412 | 1.87 | 1998 | 8378 | 1.43 |
| 1999 | 8867 | 0.36 | 1999 | 10977 | 0.29 |
| 2000 | 7044 | 0.23 | 2000 | 8493 | 0.19 |
| 2001 | 4969 | 0.54 | 2001 | 9373 | 0.29 |
| 2002 | 2350 | 1.25 | 2002 | 3222 | 0.91 |
| 2003 | 2088 | 1.38 | 2003 | 2624 | 1.10 |
| 2004 | 1323 | 0.28 | 2004 | 1820 | 0.20 |
| 2005 | 647 | 0.21 | 2005 | 1075 | 0.13 |
| 2006 | 856 | 0.71 | 2006 | 1411 | 0.43 |
| 2007 | 239 | 0.60 | 2007 | 918 | 0.16 |
| 2008 | 1029 | 0.64 | 2008 | 1481 | 0.44 |
| 2009 | 1079 | 0.30 | 2009 | 1514 | 0.22 |
| 2010 | 4017 | 0.33 | 2010 | 4593 | 0.29 |
| 2011 | 1612 | 0.15 | 2011 | 2276 | 0.10 |
| 2012 | 1040 | 0.35 | 2012 | 1711 | 0.22 |

**Table 4. Butterfish (*Peprilus triacanthus*) commercial catch (mt) by gear, 1989–2012. Otter trawl/twin trawl and other gear types include discards. Pound net and unknown gear types are landings only.**

| Year | Otter trawl/twin trawl | Pound net | Other gear types | Unknown gear types | Total |
|---|---|---|---|---|---|
| 1989 | 7545 | 86 | 52 | 0 | 7683 |
| 1990 | 2750 | 27 | 52 | 0 | 2830 |
| 1991 | 6996 | 12 | 66 | 0 | 7074 |
| 1992 | 7704 | 22 | 49 | 0 | 7775 |
| 1993 | 11969 | 131 | 84 | 0 | 12183 |
| 1994 | 10139 | 74 | 56 | 57 | 10326 |
| 1995 | 8236 | 57 | 52 | 71 | 8416 |
| 1996 | 4386 | 63 | 151 | 3 | 4603 |
| 1997 | 3680 | 67 | 172 | 11 | 3930 |
| 1998 | 8244 | 47 | 80 | 8 | 8378 |
| 1999 | 10844 | 66 | 66 | 0 | 10977 |
| 2000 | 8359 | 49 | 84 | 1 | 8493 |
| 2001 | 9242 | 43 | 87 | 0 | 9372 |
| 2002 | 3131 | 28 | 53 | 7 | 3219 |
| 2003 | 2563 | 16 | 41 | 0 | 2620 |
| 2004 | 1672 | 37 | 49 | 61 | 1819 |
| 2005 | 901 | 25 | 80 | 68 | 1074 |
| 2006 | 1276 | 0 | 62 | 72 | 1411 |
| 2007 | 742 | 7 | 74 | 94 | 917 |
| 2008 | 1344 | 2 | 45 | 84 | 1475 |
| 2009 | 1374 | 0 | 52 | 86 | 1512 |
| 2010 | 4427 | 0 | 76 | 118 | 4621 |
| 2011 | 2034 | 0 | 79 | 161 | 2274 |
| 2012 | 1462 | 0 | 108 | 140 | 1710 |

**Table 5. Total kept weight of all species, number of observed trips, discard rate (estimated from observed trips), estimated butterfish (*Peprilus triacanthus*) discards, and coefficient of variation (CV) for bottom trawl (Northeast Fisheries Science Center gear code = 050 and 053) and small mesh (< 10.2 cm) in New England and Mid-Atlantic waters, 1989–2012. Note that the kept weight all for trips with unknown mesh size are also included. Discard ratios are shown to 5 decimal places for consistency with Table 6.**

| | New England | | | | | Mid-Atlantic | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | Kept all (mt) | Obs. trips | Ratio | Discards (mt) | CV | Kept all (mt) | Obs. trips | Ratio | Discards (mt) | CV |
| 1989 | 50243.8 | 82 | 0.03061 | 1538.2 | 0.33 | 41179.1 | 32 | 0.02401 | 988.6 | 0.52 |
| 1990 | 58802.0 | 33 | 0.00544 | 320.0 | 1.68 | 42540.6 | 32 | 0.02589 | 1101.4 | 0.43 |
| 1991 | 60282.0 | 96 | 0.03191 | 1923.9 | 0.35 | 54585.1 | 70 | 0.03892 | 2124.4 | 0.37 |
| 1992 | 58985.4 | 61 | 0.07948 | 4688.2 | 0.56 | 60993.5 | 42 | 0.06455 | 3936.9 | 0.29 |
| 1993 | 55228.0 | 24 | 0.07214 | 3984.3 | 0.66 | 53899.8 | 31 | 0.02705 | 1457.9 | 0.71 |
| 1994 | 53374.0 | 37 | 0.05067 | 2704.3 | 0.89 | 53873.0 | 12 | 0.03075 | 1656.5 | 0.54 |
| 1995 | 36928.6 | 91 | 0.00546 | 201.8 | 0.91 | 39937.8 | 69 | 0.03398 | 1357.1 | 1.15 |
| 1996 | 43164.7 | 60 | 0.01053 | 454.3 | 0.72 | 44140.6 | 82 | 0.02427 | 1071.1 | 1.06 |
| 1997 | 36975.9 | 54 | 0.01564 | 578.4 | 0.68 | 45364.4 | 46 | 0.01060 | 480.7 | 2.11 |
| 1998 | 43587.3 | 18 | 0.01959 | 854.0 | 0.54 | 52020.5 | 36 | 0.00283 | 147.4 | 0.92 |
| 1999 | 38744.0 | 54 | 0.05833 | 2260.0 | 0.42 | 35266.2 | 45 | 0.10642 | 3753.1 | 0.82 |
| 2000 | 36838.8 | 62 | 0.07821 | 2881.0 | 0.41 | 33633.4 | 42 | 0.06130 | 2061.6 | 0.60 |
| 2001 | 39801.3 | 39 | 0.01316 | 523.7 | 3.24 | 22552.0 | 63 | 0.01137 | 256.4 | 1.68 |
| 2002 | 32708.4 | 111 | 0.00407 | 133.2 | 0.49 | 21027.5 | 33 | 0.04703 | 988.9 | 1.34 |
| 2003 | 33097.4 | 107 | 0.00970 | 320.9 | 0.59 | 21102.8 | 33 | 0.18842 | 3976.1 | 1.20 |
| 2004 | 48966.3 | 190 | 0.02269 | 1111.1 | 0.41 | 44612.8 | 150 | 0.01500 | 669.3 | 0.41 |
| 2005 | 30654.2 | 193 | 0.00587 | 179.8 | 0.32 | 28943.6 | 92 | 0.02360 | 683.2 | 0.32 |
| 2006 | 22857.4 | 91 | 0.00960 | 219.5 | 0.39 | 50379.5 | 117 | 0.01042 | 525.0 | 1.46 |
| 2007 | 24195.8 | 115 | 0.00421 | 101.8 | 0.43 | 21247.8 | 128 | 0.00243 | 51.6 | 3.26 |
| 2008 | 22415.0 | 92 | 0.03194 | 715.9 | 0.76 | 25240.4 | 98 | 0.01546 | 390.3 | 0.80 |
| 2009 | 25453.9 | 253 | 0.01980 | 504.1 | 0.31 | 29155.7 | 206 | 0.01830 | 533.5 | 0.60 |
| 2010 | 21369.0 | 341 | 0.04472 | 955.5 | 0.29 | 29775.9 | 219 | 0.02462 | 733.2 | 0.36 |
| 2011 | 15354.4 | 324 | 0.01186 | 182.1 | 0.25 | 30353.0 | 273 | 0.04526 | 1373.8 | 0.17 |
| 2012 | 16985.1 | 251 | 0.01651 | 280.5 | 0.24 | 26585.6 | 158 | 0.02547 | 677.0 | 0.49 |

**Table 6. Total kept weight of all species, number of observed trips, discard rate (estimated from observed trips), estimated butterfish (*Peprilus triacanthus*) discards, and coefficient of variation (CV) for bottom trawl (Northeast Fisheries Science Center gear code = 050 and 053) and large mesh (≥ 10.2 cm) in New England and Mid-Atlantic waters, 1989–2012. Discard ratios are shown to 5 decimal places to illustrate that all rates are greater than zero.**

| | New England | | | | | Mid-Atlantic | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | Kept all (mt) | Obs. trips | Ratio | Discards (mt) | CV | Kept all (mt) | Obs. trips | Ratio | Discards (mt) | CV |
| 1989 | 41411.8 | 68 | 0.00014 | 6.0 | 0.55 | 1463.4 | 21 | 0.00732 | 10.7 | 0.28 |
| 1990 | 55075.1 | 55 | 0.00214 | 117.7 | 0.85 | 1699.2 | 18 | 0.00092 | 1.6 | 0.64 |
| 1991 | 49171.0 | 91 | 0.00104 | 51.1 | 0.53 | 2161.1 | 22 | 0.00538 | 11.6 | 0.50 |
| 1992 | 39275.2 | 69 | 0.00015 | 5.8 | 0.76 | 2194.5 | 24 | 0.00683 | 15.0 | 0.87 |
| 1993 | 32234.4 | 54 | 0.06094 | 1964.3 | 0.48 | 2170.1 | 19 | 0.02464 | 53.5 | 0.45 |
| 1994 | 25936.9 | 40 | 0.00178 | 46.1 | 0.76 | 2683.8 | 29 | 0.00128 | 3.4 | 0.66 |
| 1995 | 30538.5 | 69 | 0.00535 | 163.3 | 1.07 | 5404.7 | 58 | 0.00469 | 25.4 | 1.02 |
| 1996 | 36679.1 | 45 | 0.00085 | 31.3 | 11.58 | 5838.5 | 27 | 0.00271 | 15.8 | 1.30 |
| 1997 | 32028.2 | 32 | 0.00130 | 41.6 | 0.58 | 5919.3 | 31 | 0.01428 | 84.5 | 0.78 |
| 1998 | 33224.9 | 28 | 0.02903 | 964.6 | 1.58 | 6866.9 | 17 | 0.12694 | 871.7 | 2.77 |
| 1999 | 32605.6 | 41 | 0.05569 | 1815.8 | 0.67 | 7794.3 | 43 | 0.12486 | 973.2 | 0.61 |
| 2000 | 36877.8 | 110 | 0.00354 | 130.4 | 0.84 | 6389.7 | 38 | 0.00061 | 3.9 | 0.55 |
| 2001 | 44410.8 | 168 | 0.01115 | 495.3 | 0.63 | 7285.3 | 63 | 0.14814 | 1079.2 | 0.81 |
| 2002 | 40569.8 | 246 | 0.00628 | 255.0 | 1.17 | 7292.8 | 111 | 0.00041 | 3.0 | 0.56 |
| 2003 | 42864.3 | 408 | 0.00075 | 32.3 | 0.93 | 6940.8 | 64 | 0.00006 | 0.4 | 0.66 |
| 2004 | 39100.5 | 605 | 0.00092 | 35.9 | 0.62 | 9446.1 | 249 | 0.00171 | 16.1 | 0.77 |
| 2005 | 34591.4 | 1497 | 0.00004 | 1.4 | 0.42 | 11538.0 | 194 | 0.00204 | 23.5 | 0.47 |
| 2006 | 27821.9 | 651 | 0.00015 | 4.1 | 0.79 | 9802.6 | 118 | 0.01690 | 165.7 | 0.20 |
| 2007 | 28541.1 | 638 | 0.00081 | 23.1 | 0.74 | 7327.9 | 273 | 0.00093 | 6.8 | 0.52 |
| 2008 | 30011.9 | 766 | 0.00024 | 7.1 | 1.07 | 6747.1 | 203 | 0.00335 | 22.6 | 0.93 |
| 2009 | 27999.5 | 893 | 0.00033 | 9.2 | 0.47 | 9523.5 | 265 | 0.00195 | 18.6 | 0.89 |
| 2010 | 26152.1 | 1053 | 0.00030 | 7.9 | 0.42 | 6300.2 | 438 | 0.00173 | 10.9 | 0.64 |
| 2011 | 32666.9 | 1591 | 0.00008 | 2.8 | 0.32 | 12875.6 | 385 | 0.00088 | 11.3 | 0.44 |
| 2012 | 35371.0 | 1573 | 0.00008 | 2.7 | 0.29 | 9463.0 | 269 | 0.00166 | 15.7 | 1.11 |

**Table 7. Butterfish (*Peprilus triacanthus*) commercial landings at age (numbers, 000s), 1989–2012.**

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4+ |
|---|---|---|---|---|---|
| 1989 | 519 | 14510 | 18229 | 7271 | 131 |
| 1990 | 1766 | 13052 | 10781 | 2953 | 261 |
| 1991 | 1139 | 10532 | 10133 | 3961 | 252 |
| 1992 | 298 | 13459 | 15746 | 3563 | 144 |
| 1993 | 5337 | 31738 | 17984 | 5391 | 0 |
| 1994 | 1359 | 11349 | 21275 | 8407 | 786 |
| 1995 | 374 | 7496 | 14411 | 2863 | 15 |
| 1996 | 2169 | 7205 | 21989 | 10732 | 956 |
| 1997 | 1139 | 18582 | 10847 | 2193 | 105 |
| 1998 | 209 | 6649 | 13783 | 2393 | 19 |
| 1999 | 815 | 6877 | 12115 | 3244 | 241 |
| 2000 | 539 | 5697 | 4469 | 1294 | 934 |
| 2001 | 959 | 9507 | 39195 | 3732 | 5 |
| 2002 | 1222 | 2714 | 3399 | 1998 | 251 |
| 2003 | 152 | 1118 | 1211 | 1812 | 743 |
| 2004 | 371 | 1710 | 2259 | 965 | 310 |
| 2005 | 259 | 751 | 1374 | 1603 | 802 |
| 2006 | 1569 | 3234 | 1822 | 802 | 302 |
| 2007 | 312 | 2670 | 3676 | 1211 | 123 |
| 2008 | 271 | 1332 | 2255 | 961 | 177 |
| 2009 | 672 | 1825 | 2293 | 877 | 178 |
| 2010 | 565 | 2496 | 2004 | 1580 | 180 |
| 2011 | 617 | 1868 | 2642 | 1387 | 1224 |
| 2012 | 511 | 3795 | 2553 | 1314 | 410 |

**Table 8. Butterfish (*Peprilus triacanthus*) commercial discards at age (numbers, 000s), 1989–2012.**

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4+ |
|---|---|---|---|---|---|
| 1989 | 43467 | 54831 | 22578 | 4748 | 109 |
| 1990 | 4892 | 6007 | 1404 | 241 | 27 |
| 1991 | 50316 | 64322 | 8207 | 2595 | 0 |
| 1992 | 38176 | 40354 | 24727 | 977 | 0 |
| 1993 | 30890 | 44222 | 25629 | 16008 | 0 |
| 1994 | 37253 | 74821 | 20033 | 4758 | 2159 |
| 1995 | 76725 | 78882 | 27475 | 3024 | 0 |
| 1996 | 6675 | 7890 | 6319 | 1572 | 25 |
| 1997 | 10713 | 14994 | 2102 | 173 | 0 |
| 1998 | 19040 | 68852 | 36428 | 1089 | 0 |
| 1999 | 48926 | 110810 | 24757 | 3444 | 2446 |
| 2000 | 105253 | 53089 | 22367 | 4353 | 2643 |
| 2001 | 57136 | 30651 | 22411 | 2160 | 728 |
| 2002 | 22996 | 21961 | 9224 | 1434 | 628 |
| 2003 | 15944 | 10468 | 5516 | 4899 | 816 |
| 2004 | 5939 | 14143 | 3532 | 1030 | 410 |
| 2005 | 1997 | 5120 | 4035 | 959 | 230 |
| 2006 | 7566 | 7931 | 1738 | 700 | 290 |
| 2007 | 654 | 2668 | 833 | 119 | 53 |
| 2008 | 10969 | 7409 | 4208 | 470 | 59 |
| 2009 | 7559 | 12156 | 3180 | 746 | 317 |
| 2010 | 23001 | 33742 | 16007 | 4800 | 326 |
| 2011 | 13229 | 15125 | 5905 | 1492 | 599 |
| 2012 | 3500 | 13248 | 3076 | 806 | 233 |

**Table 9. Butterfish (*Peprilus triacanthus*) commercial catch at age (numbers, 000s), 1989–2012.**

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4+ |
|---|---|---|---|---|---|
| 1989 | 43985 | 69341 | 40807 | 12020 | 240 |
| 1990 | 6658 | 19059 | 12185 | 3194 | 288 |
| 1991 | 51455 | 74854 | 18339 | 6557 | 252 |
| 1992 | 38474 | 53813 | 40473 | 4540 | 144 |
| 1993 | 36227 | 75960 | 43613 | 21399 | 0 |
| 1994 | 38612 | 86170 | 41308 | 13165 | 2945 |
| 1995 | 77100 | 86378 | 41886 | 5886 | 15 |
| 1996 | 8844 | 15095 | 28307 | 12303 | 981 |
| 1997 | 11853 | 11853 | 11853 | 11853 | 11853 |
| 1998 | 19249 | 75501 | 50211 | 3482 | 19 |
| 1999 | 49741 | 117687 | 36872 | 6688 | 2687 |
| 2000 | 105792 | 58786 | 26836 | 5647 | 3577 |
| 2001 | 58095 | 40158 | 61606 | 5892 | 732 |
| 2002 | 24218 | 24675 | 12623 | 3432 | 879 |
| 2003 | 16097 | 11586 | 6727 | 6711 | 1559 |
| 2004 | 6310 | 15853 | 5790 | 1995 | 720 |
| 2005 | 2256 | 5871 | 5409 | 2562 | 1032 |
| 2006 | 9135 | 11165 | 3560 | 1501 | 592 |
| 2007 | 967 | 5338 | 4509 | 1330 | 176 |
| 2008 | 11240 | 8741 | 6463 | 1431 | 237 |
| 2009 | 8232 | 13981 | 5474 | 1623 | 496 |
| 2010 | 23566 | 36238 | 18011 | 6380 | 506 |
| 2011 | 13846 | 16993 | 8548 | 2879 | 1822 |
| 2012 | 4011 | 17043 | 5629 | 2120 | 642 |

**Table 10. Butterfish (*Peprilus triacanthus*) commercial catch mean weight at age (kg), 1989–2012. Italicized values were originally missing; thus they were interpolated as the age 3 value plus the average difference between age 3 and age 4 for the entire time series.**

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4+ |
|---|---|---|---|---|---|
| 1989 | 0.02 | 0.04 | 0.06 | 0.09 | 0.21 |
| 1990 | 0.04 | 0.06 | 0.09 | 0.10 | 0.12 |
| 1991 | 0.03 | 0.04 | 0.09 | 0.10 | 0.17 |
| 1992 | 0.03 | 0.05 | 0.08 | 0.12 | 0.16 |
| 1993 | 0.04 | 0.06 | 0.09 | 0.12 | *0.16* |
| 1994 | 0.04 | 0.04 | 0.08 | 0.10 | 0.18 |
| 1995 | 0.02 | 0.04 | 0.07 | 0.11 | *0.15* |
| 1996 | 0.04 | 0.06 | 0.08 | 0.09 | 0.10 |
| 1997 | 0.03 | 0.07 | 0.09 | 0.11 | *0.16* |
| 1998 | 0.04 | 0.05 | 0.07 | 0.12 | *0.17* |
| 1999 | 0.03 | 0.04 | 0.08 | 0.09 | *0.14* |
| 2000 | 0.02 | 0.05 | 0.08 | 0.10 | 0.17 |
| 2001 | 0.03 | 0.04 | 0.08 | 0.13 | *0.17* |
| 2002 | 0.02 | 0.05 | 0.07 | 0.10 | *0.14* |
| 2003 | 0.04 | 0.05 | 0.08 | 0.10 | 0.13 |
| 2004 | 0.04 | 0.05 | 0.08 | 0.11 | 0.17 |
| 2005 | 0.05 | 0.04 | 0.06 | 0.10 | 0.12 |
| 2006 | 0.04 | 0.05 | 0.08 | 0.10 | 0.16 |
| 2007 | 0.05 | 0.06 | 0.08 | 0.12 | 0.19 |
| 2008 | 0.03 | 0.05 | 0.07 | 0.12 | *0.16* |
| 2009 | 0.04 | 0.04 | 0.07 | 0.09 | 0.17 |
| 2010 | 0.03 | 0.05 | 0.07 | 0.09 | 0.10 |
| 2011 | 0.03 | 0.05 | 0.07 | 0.09 | 0.11 |
| 2012 | 0.04 | 0.05 | 0.08 | 0.10 | 0.12 |

**Table 11. FSV *Henry B. Bigelow* to FRV *Albatross IV* mean calibration coefficients for butterfish (*Peprilus triacanthus*) from Miller et al. (2010).**

| | Number | | Weight | |
|---|---|---|---|---|
| | $\hat{\rho}$ | SE($\hat{\rho}$) | $\hat{\rho}$ | SE($\hat{\rho}$) |
| Spring | 1.487 | 0.220 | 2.356 | 0.332 |
| Fall | 1.935 | 0.172 | 1.808 | 0.184 |

**Table 12. Butterfish (*Peprilus triacanthus*) stratified mean number per tow from Northeast Fisheries Science Center spring surveys, and corresponding coefficients of variation (CV), for data collected in offshore strata 1989–2012 and inshore strata 1989–2008.**

| | Offshore | | | Inshore | |
|---|---|---|---|---|---|
| Year | Number | CV | Year | Number | CV |
| 1989 | 29.84 | 0.80 | 1989 | 0.42 | 0.85 |
| 1990 | 8.39 | 0.44 | 1990 | 0.44 | 0.57 |
| 1991 | 26.57 | 0.68 | 1991 | 47.19 | 0.25 |
| 1992 | 16.40 | 0.21 | 1992 | 0.31 | 0.40 |
| 1993 | 24.66 | 0.39 | 1993 | 0.32 | 0.08 |
| 1994 | 33.01 | 0.28 | 1994 | 0 | 0 |
| 1995 | 38.10 | 0.59 | 1995 | 0 | 0 |
| 1996 | 10.37 | 0.40 | 1996 | 0 | 0 |
| 1997 | 102.98 | 0.38 | 1997 | 1.98 | 0.24 |
| 1998 | 37.23 | 0.61 | 1998 | 0.12 | 0.81 |
| 1999 | 69.31 | 0.59 | 1999 | 0.02 | 1.00 |
| 2000 | 33.44 | 0.36 | 2000 | 0.05 | 1.00 |
| 2001 | 55.61 | 0.37 | 2001 | 0.03 | 1.00 |
| 2002 | 42.64 | 0.44 | 2002 | 2.92 | 0.60 |
| 2003 | 43.37 | 0.60 | 2003 | 0.03 | 1.00 |
| 2004 | 115.11 | 0.32 | 2004 | 0.06 | 0.83 |
| 2005 | 33.97 | 0.39 | 2005 | 0.02 | 1.00 |
| 2006 | 64.63 | 0.39 | 2006 | 12.41 | 0.04 |
| 2007 | 128.34 | 0.54 | 2007 | 0.22 | 0.78 |
| 2008 | 122.83 | 0.70 | 2008 | 2.59 | 0.30 |
| 2009 | 97.58 | 0.39 | | | |
| 2010 | 73.47 | 0.28 | | | |
| 2011 | 40.90 | 0.20 | | | |
| 2012 | 142.55 | 0.21 | | | |

**Table 13. Butterfish (*Peprilus triacanthus*) stratified mean number per tow from Northeast Fisheries Science Center fall surveys, and corresponding coefficients of variation (CV), for data collected in offshore strata 1989–2012 and inshore strata 1989–2008.**

| | Offshore | | | Inshore | |
|---|---|---|---|---|---|
| Year | Number | CV | Year | Number | CV |
| 1989 | 377.34 | 0.38 | 1989 | 594.95 | 0.52 |
| 1990 | 379.94 | 0.23 | 1990 | 63.71 | 0.32 |
| 1991 | 187.87 | 0.43 | 1991 | 172.60 | 0.24 |
| 1992 | 246.05 | 0.27 | 1992 | 107.53 | 0.12 |
| 1993 | 248.98 | 0.25 | 1993 | 292.31 | 0.25 |
| 1994 | 510.35 | 0.47 | 1994 | 303.32 | 0.12 |
| 1995 | 116.57 | 0.26 | 1995 | 39.52 | 0.35 |
| 1996 | 78.85 | 0.22 | 1996 | 157.52 | 0.32 |
| 1997 | 220.26 | 0.13 | 1997 | 632.94 | 0.10 |
| 1998 | 214.49 | 0.33 | 1998 | 112.32 | 0.37 |
| 1999 | 247.81 | 0.38 | 1999 | 185.17 | 0.30 |
| 2000 | 202.92 | 0.28 | 2000 | 312.86 | 0.27 |
| 2001 | 63.62 | 0.31 | 2001 | 368.50 | 0.24 |
| 2002 | 92.61 | 0.21 | 2002 | 225.53 | 0.34 |
| 2003 | 187.75 | 0.15 | 2003 | 267.15 | 0.19 |
| 2004 | 75.50 | 0.29 | 2004 | 317.13 | 0.29 |
| 2005 | 39.19 | 0.30 | 2005 | 228.52 | 0.07 |
| 2006 | 179.31 | 0.24 | 2006 | 202.04 | 0.23 |
| 2007 | 41.21 | 0.23 | 2007 | 220.95 | 0.14 |
| 2008 | 131.93 | 0.23 | 2008 | 131.67 | 0.14 |
| 2009 | 182.45 | 0.25 | | | |
| 2010 | 128.16 | 0.24 | | | |
| 2011 | 250.38 | 0.28 | | | |
| 2012 | 66.59 | 0.31 | | | |

**Table 14. Northeast Fisheries Science Center survey number of stations sampled in offshore and inshore strata, number of stations with butterfish (*Peprilus triacanthus*) sampled, butterfish aged, and lengths collected, 1989–2012.**

| | | Spring | Fall | Total |
|---|---|---|---|---|
| 1989 | Total number of stations sampled | 195 | 209 | 404 |
| | Total number of stations with butterfish | 27 | 105 | 132 |
| | Total number of fish aged | 98 | 445 | 543 |
| | Total number of fish measured | 98 | 445 | 543 |
| 1990 | Total number of stations sampled | 206 | 223 | 429 |
| | Total number of stations with butterfish | 27 | 119 | 146 |
| | Total number of fish aged | 128 | 552 | 680 |
| | Total number of fish measured | 128 | 552 | 680 |
| 1991 | Total number of stations sampled | 218 | 211 | 429 |
| | Total number of stations with butterfish | 49 | 153 | 202 |
| | Total number of fish aged | 201 | 771 | 972 |
| | Total number of fish measured | 201 | 771 | 972 |
| 1992 | Total number of stations sampled | 230 | 239 | 469 |
| | Total number of stations with butterfish | 45 | 197 | 242 |
| | Total number of fish aged | 218 | 964 | 1182 |
| | Total number of fish measured | 219 | 971 | 1190 |
| 1993 | Total number of stations sampled | 234 | 231 | 465 |
| | Total number of stations with butterfish | 41 | 161 | 202 |
| | Total number of fish aged | 190 | 791 | 981 |
| | Total number of fish measured | 190 | 806 | 996 |
| 1994 | Total number of stations sampled | 237 | 239 | 476 |
| | Total number of stations with butterfish | 33 | 184 | 217 |
| | Total number of fish aged | 187 | 910 | 1097 |
| | Total number of fish measured | 187 | 920 | 1107 |
| 1995 | Total number of stations sampled | 232 | 250 | 482 |
| | Total number of stations with butterfish | 48 | 165 | 213 |
| | Total number of fish aged | 253 | 782 | 1035 |
| | Total number of fish measured | 253 | 790 | 1043 |
| 1996 | Total number of stations sampled | 264 | 255 | 519 |
| | Total number of stations with butterfish | 34 | 142 | 176 |
| | Total number of fish aged | 146 | 684 | 830 |
| | Total number of fish measured | 147 | 688 | 835 |
| 1997 | Total number of stations sampled | 235 | 254 | 489 |
| | Total number of stations with butterfish | 77 | 157 | 234 |
| | Total number of fish aged | 416 | 742 | 1158 |
| | Total number of fish measured | 423 | 758 | 1181 |
| 1998 | Total number of stations sampled | 241 | 261 | 502 |
| | Total number of stations with butterfish | 48 | 174 | 222 |
| | Total number of fish aged | 192 | 846 | 1038 |
| | Total number of fish measured | 196 | 861 | 1057 |
| 1999 | Total number of stations sampled | 232 | 233 | 465 |
| | Total number of stations with butterfish | 39 | 150 | 189 |
| | Total number of fish aged | 188 | 729 | 917 |
| | Total number of fish measured | 193 | 737 | 930 |
| 2000 | Total number of stations sampled | 232 | 234 | 466 |
| | Total number of stations with butterfish | 53 | 123 | 176 |
| | Total number of fish aged | 218 | 561 | 779 |
| | Total number of fish measured | 228 | 590 | 818 |

**Table 14, continued. Northeast Fisheries Science Center survey number of stations sampled in offshore and inshore strata, number of stations with butterfish (*Peprilus triacanthus*) sampled, butterfish aged, and lengths collected, 1989–2012.**

| | | | | |
|---|---|---|---|---|
| 2001 | Total number of stations sampled | 234 | 232 | 466 |
| | Total number of stations with butterfish | 41 | 136 | 177 |
| | Total number of fish aged | 254 | 565 | 819 |
| | Total number of fish measured | 257 | 590 | 847 |
| 2002 | Total number of stations sampled | 236 | 238 | 474 |
| | Total number of stations with butterfish | 69 | 149 | 218 |
| | Total number of fish aged | 297 | 697 | 994 |
| | Total number of fish measured | 315 | 734 | 1049 |
| 2003 | Total number of stations sampled | 229 | 232 | 461 |
| | Total number of stations with butterfish | 35 | 173 | 208 |
| | Total number of fish aged | 167 | 805 | 972 |
| | Total number of fish measured | 179 | 851 | 1030 |
| 2004 | Total number of stations sampled | 234 | 227 | 461 |
| | Total number of stations with butterfish | 35 | 153 | 188 |
| | Total number of fish aged | 139 | 687 | 826 |
| | Total number of fish measured | 142 | 778 | 920 |
| 2005 | Total number of stations sampled | 234 | 239 | 473 |
| | Total number of stations with butterfish | 34 | 161 | 195 |
| | Total number of fish aged | 170 | 748 | 918 |
| | Total number of fish measured | 235 | 797 | 1032 |
| 2006 | Total number of stations sampled | 239 | 257 | 496 |
| | Total number of stations with butterfish | 57 | 206 | 263 |
| | Total number of fish aged | 263 | 996 | 1259 |
| | Total number of fish measured | 266 | 1017 | 1283 |
| 2007 | Total number of stations sampled | 263 | 249 | 512 |
| | Total number of stations with butterfish | 65 | 154 | 219 |
| | Total number of fish aged | 316 | 723 | 1039 |
| | Total number of fish measured | 324 | 746 | 1070 |
| 2008 | Total number of stations sampled | 241 | 247 | 488 |
| | Total number of stations with butterfish | 66 | 183 | 249 |
| | Total number of fish aged | 300 | 841 | 1141 |
| | Total number of fish measured | 316 | 875 | 1191 |
| 2009 | Total number of stations sampled | 274 | 252 | 526 |
| | Total number of stations with butterfish | 62 | 193 | 255 |
| | Total number of fish aged | 376 | 1042 | 1418 |
| | Total number of fish measured | 384 | 1070 | 1454 |
| 2010 | Total number of stations sampled | 270 | 262 | 532 |
| | Total number of stations with butterfish | 74 | 209 | 283 |
| | Total number of fish aged | 431 | 1178 | 1609 |
| | Total number of fish measured | 445 | 1204 | 1649 |
| 2011 | Total number of stations sampled | 254 | 258 | 512 |
| | Total number of stations with butterfish | 70 | 213 | 283 |
| | Total number of fish aged | 352 | 1419 | 1771 |
| | Total number of fish measured | 369 | 1492 | 1861 |
| 2012 | Total number of stations sampled | 260 | 257 | 517 |
| | Total number of stations with butterfish | 169 | 153 | 322 |
| | Total number of fish aged | 864 | 621 | 1485 |
| | Total number of fish measured | 1050 | 733 | 1783 |

**Table 15. Butterfish (*Peprilus triacanthus*) stratified mean number per tow at age from Northeast Fisheries Science Center spring surveys for data collected 1989–2012 in offshore strata.**

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4+ |
|---|---|---|---|---|---|
| 1989 | 0 | 24.27 | 4.70 | 0.87 | 0.01 |
| 1990 | 0.01 | 6.84 | 1.23 | 0.28 | 0.03 |
| 1991 | 0.02 | 24.63 | 1.35 | 0.57 | 0.02 |
| 1992 | 0 | 14.57 | 1.61 | 0.21 | 0.01 |
| 1993 | 0 | 21.51 | 2.67 | 0.47 | 0.00 |
| 1994 | 0 | 26.98 | 5.05 | 0.94 | 0.04 |
| 1995 | 0 | 24.00 | 11.74 | 2.37 | 0 |
| 1996 | 0 | 6.98 | 2.19 | 1.16 | 0.04 |
| 1997 | 0 | 98.19 | 4.15 | 0.64 | 0.00 |
| 1998 | 0 | 16.55 | 19.60 | 1.08 | 0 |
| 1999 | 0 | 57.44 | 10.09 | 1.78 | 0 |
| 2000 | 0 | 31.58 | 1.55 | 0.28 | 0.03 |
| 2001 | 0 | 44.78 | 10.12 | 0.72 | 0 |
| 2002 | 0 | 34.92 | 5.59 | 1.91 | 0.22 |
| 2003 | 0 | 35.80 | 4.99 | 2.42 | 0.16 |
| 2004 | 0 | 113.98 | 1.04 | 0.07 | 0.02 |
| 2005 | 0 | 25.60 | 7.02 | 0.91 | 0.44 |
| 2006 | 0 | 60.31 | 3.06 | 0.94 | 0.32 |
| 2007 | 0 | 109.78 | 15.47 | 2.90 | 0.19 |
| 2008 | 0 | 113.91 | 8.19 | 0.66 | 0.07 |
| 2009 | 0 | 92.76 | 3.86 | 0.79 | 0.17 |
| 2010 | 0 | 63.04 | 8.81 | 1.52 | 0.10 |
| 2011 | 0 | 33.68 | 5.19 | 1.43 | 0.60 |
| 2012 | 0 | 128.94 | 9.99 | 3.10 | 0.53 |

**Table 16. Butterfish (*Peprilus triacanthus*) stratified mean number per tow at age from Northeast Fisheries Science Center spring surveys for data collected 1989–2008 in inshore strata.**

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4+ |
|---|---|---|---|---|---|
| 1989 | 0.07 | 0 | 0.07 | 0.29 | 0 |
| 1990 | 0.19 | 0.25 | 0 | 0 | 0 |
| 1991 | 0 | 37.69 | 6.05 | 3.44 | 0.01 |
| 1992 | 0 | 0.14 | 0.14 | 0.02 | 0.02 |
| 1993 | 0 | 0.30 | 0.02 | 0 | 0 |
| 1994 | 0 | 0 | 0 | 0 | 0 |
| 1995 | 0 | 0 | 0 | 0 | 0 |
| 1996 | 0 | 0 | 0 | 0 | 0 |
| 1997 | 0 | 1.75 | 0.14 | 0.08 | 0 |
| 1998 | 0 | 0 | 0.09 | 0.03 | 0 |
| 1999 | 0 | 0 | 0 | 0.02 | 0 |
| 2000 | 0 | 0.03 | 0.03 | 0 | 0 |
| 2001 | 0 | 0.03 | 0 | 0 | 0 |
| 2002 | 0 | 0.72 | 1.76 | 0.17 | 0.28 |
| 2003 | 0 | 0.03 | 0 | 0 | 0 |
| 2004 | 0 | 0.06 | 0 | 0 | 0 |
| 2005 | 0 | 0 | 0 | 0.02 | 0 |
| 2006 | 0 | 2.93 | 7.68 | 1.57 | 0.23 |
| 2007 | 0 | 0.22 | 0 | 0 | 0 |
| 2008 | 0 | 2.01 | 0.46 | 0.06 | 0.06 |

**Table 17. Butterfish (*Peprilus triacanthus*) stratified mean number per tow at age from Northeast Fisheries Science Center fall surveys for data collected 1989–2012 in offshore strata.**

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4+ |
|---|---|---|---|---|---|
| 1989 | 325.84 | 39.43 | 11.45 | 0.62 | 0 |
| 1990 | 343.42 | 32.55 | 3.15 | 0.82 | 0 |
| 1991 | 167.26 | 18.37 | 2.21 | 0.02 | 0 |
| 1992 | 232.64 | 9.93 | 3.43 | 0.05 | 0 |
| 1993 | 195.92 | 46.58 | 6.07 | 0.42 | 0 |
| 1994 | 475.76 | 23.85 | 9.38 | 1.33 | 0.03 |
| 1995 | 41.44 | 48.16 | 26.91 | 0.07 | 0 |
| 1996 | 59.40 | 15.01 | 4.21 | 0.24 | 0 |
| 1997 | 204.14 | 13.81 | 2.14 | 0.19 | 0 |
| 1998 | 164.99 | 41.97 | 6.84 | 0.69 | 0 |
| 1999 | 241.17 | 4.92 | 1.72 | 0 | 0 |
| 2000 | 151.05 | 45.85 | 5.73 | 0.29 | 0 |
| 2001 | 38.53 | 15.20 | 9.66 | 0.22 | 0 |
| 2002 | 80.45 | 9.27 | 2.84 | 0.05 | 0 |
| 2003 | 175.45 | 10.38 | 1.69 | 0.11 | 0.12 |
| 2004 | 57.31 | 12.75 | 4.81 | 0.22 | 0.41 |
| 2005 | 33.92 | 3.17 | 1.52 | 0.58 | 0 |
| 2006 | 155.83 | 17.51 | 5.17 | 0.74 | 0.06 |
| 2007 | 26.03 | 13.65 | 1.51 | 0.02 | 0 |
| 2008 | 124.81 | 6.17 | 0.94 | 0.02 | 0 |
| 2009 | 158.32 | 20.06 | 3.88 | 0.17 | 0.01 |
| 2010 | 84.10 | 35.90 | 6.90 | 1.25 | 0 |
| 2011 | 218.27 | 26.86 | 4.76 | 0.42 | 0.06 |
| 2012 | 27.15 | 28.83 | 9.91 | 0.62 | 0.07 |

**Table 18. Butterfish (*Peprilus triacanthus*) stratified mean number per tow at age from Northeast Fisheries Science Center fall surveys for data collected 1989–2008 in inshore strata.**

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4+ |
|---|---|---|---|---|---|
| 1989 | 397.24 | 144.43 | 49.62 | 3.65 | 0 |
| 1990 | 38.02 | 11.54 | 11.86 | 2.29 | 0 |
| 1991 | 115.28 | 28.59 | 21.61 | 7.12 | 0 |
| 1992 | 89.42 | 7.40 | 10.30 | 0.40 | 0 |
| 1993 | 250.77 | 28.49 | 11.64 | 1.41 | 0 |
| 1994 | 291.99 | 7.04 | 3.43 | 0.85 | 0.01 |
| 1995 | 24.11 | 7.99 | 7.20 | 0.22 | 0 |
| 1996 | 130.65 | 23.71 | 2.77 | 0.39 | 0 |
| 1997 | 589.52 | 41.98 | 1.44 | 0 | 0 |
| 1998 | 66.98 | 38.05 | 6.80 | 0.48 | 0 |
| 1999 | 145.37 | 30.57 | 8.88 | 0.34 | 0 |
| 2000 | 305.24 | 6.38 | 0.55 | 0.67 | 0 |
| 2001 | 345.76 | 19.79 | 2.73 | 0.23 | 0 |
| 2002 | 185.27 | 30.25 | 9.12 | 0.88 | 0 |
| 2003 | 220.99 | 39.48 | 3.01 | 2.90 | 0.77 |
| 2004 | 184.48 | 65.98 | 58.96 | 4.55 | 3.16 |
| 2005 | 210.89 | 10.62 | 3.60 | 3.25 | 0.16 |
| 2006 | 176.14 | 19.40 | 4.81 | 1.45 | 0.23 |
| 2007 | 194.59 | 20.58 | 5.70 | 0.08 | 0 |
| 2008 | 119.82 | 9.76 | 1.83 | 0.25 | 0 |

**Table 19. Butterfish (*Peprilus triacanthus*) arithmetic mean number per tow from Northeast Area Monitoring and Assessment Program spring and fall surveys, and corresponding coefficients of variation (CV), for data collected 2007–2012.**

| | Spring | | | Fall | |
|---|---|---|---|---|---|
| Year | Number | CV | | Number | CV |
| | | | 2007 | 1061.01 | 0.36 |
| 2008 | 343.18 | 0.21 | 2008 | 1032.49 | 0.17 |
| 2009 | 188.48 | 0.12 | 2009 | 3600.76 | 0.14 |
| 2010 | 521.88 | 0.58 | 2010 | 1073.33 | 0.12 |
| 2011 | 458.63 | 0.15 | 2011 | 1661.64 | 0.17 |
| 2012 | 525.57 | 0.16 | 2012 | 625.73 | 0.21 |

**Table 20. Butterfish (*Peprilus triacanthus*) stratified mean number per tow at age from Northeast Area Monitoring and Assessment Program spring surveys for data collected 2008–2012.**

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4+ |
|---|---|---|---|---|---|
| 2008 | 9.11 | 316.12 | 16.03 | 1.64 | 0.27 |
| 2009 | 3.28 | 168.20 | 15.48 | 1.31 | 0.20 |
| 2010 | 9.97 | 408.85 | 98.44 | 4.21 | 0.41 |
| 2011 | 3.21 | 390.74 | 56.46 | 7.03 | 1.18 |
| 2012 | 5.45 | 369.49 | 146.20 | 3.83 | 0.61 |

**Table 21. Butterfish (*Peprilus triacanthus*) stratified mean number per tow at age from Northeast Area Monitoring and Assessment Program fall surveys for data collected 2007–2012.**

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4+ |
|---|---|---|---|---|---|
| 2007 | 991.54 | 52.62 | 14.44 | 2.18 | 0.23 |
| 2008 | 981.64 | 45.26 | 4.57 | 0.91 | 0.11 |
| 2009 | 3360.82 | 199.37 | 36.05 | 4.11 | 0.42 |
| 2010 | 860.64 | 164.43 | 40.66 | 6.90 | 0.71 |
| 2011 | 1443.41 | 174.90 | 37.87 | 4.91 | 0.55 |
| 2012 | 442.03 | 116.20 | 54.84 | 11.40 | 1.26 |

**Table 22. Butterfish (*Peprilus triacanthus*) mean number per tow for state surveys, 1989–2012. Empty cells indicate no survey was conducted. ME-NH = Maine New Hampshire, MADMF = Massachusetts Division of Marine Fisheries, RIDEM = Rhode Island Department of Environmental Management, CTDEEP = Connecticut Department of Energy and Environmental Protection, NYSDEC = New York State Department of Environmental Conservation, NJDFW = New Jersey Division of Fish and Wildlife.**

| Year | ME-NH Spring | ME-NH Fall | MADMF Spring | MADMF Fall | RIDEM Spring | RIDEM Fall | CTDEEP Spring | CTDEEP Fall | NYSDEC Peconic | NJDFW Annual |
|---|---|---|---|---|---|---|---|---|---|---|
| 1989 | | | 0.15 | 109.82 | 0 | 163.95 | 0.80 | 174.87 | 0.89 | 506.14 |
| 1990 | | | 8.82 | 297.93 | 0.02 | 497.84 | 1.60 | 154.65 | 1.38 | 356.26 |
| 1991 | | | 16.18 | 248.49 | 0.83 | 92.23 | 2.17 | 170.59 | 0.36 | 609.31 |
| 1992 | | | 0.64 | 660.11 | 0 | 277.94 | 2.60 | 301.72 | 0.90 | 2767.81 |
| 1993 | | | 1.06 | 731.89 | 27.35 | 688.06 | 0.48 | 87.73 | 0.40 | 214.66 |
| 1994 | | | 2.84 | 391.87 | 0.30 | 292.24 | 1.71 | 93.05 | 0.34 | 3220.32 |
| 1995 | | | 8.23 | 586.18 | 1.79 | 273.93 | 1.06 | 320.06 | 0.52 | 388.69 |
| 1996 | | | 2.59 | 337.35 | 3.71 | 281.52 | 3.22 | 173.74 | 0.36 | 1046.29 |
| 1997 | | | 5.14 | 401.52 | 1.73 | 1002.19 | 6.16 | 186.62 | 1.86 | 439.45 |
| 1998 | | | 3.05 | 921.22 | 3.73 | 399.59 | 6.51 | 355.49 | 0.75 | 233.08 |
| 1999 | | | 0.59 | 448.46 | 0.29 | 243.54 | 1.90 | 477.91 | 0.52 | 698.72 |
| 2000 | | 2.26 | 24.94 | 148.36 | 3.24 | 42.70 | 3.35 | 125.97 | 0.99 | 247.85 |
| 2001 | 0.03 | 11.73 | 11.01 | 71.97 | 11.22 | 165.02 | 2.94 | 142.89 | 0.69 | 308.36 |
| 2002 | 0.06 | 37.90 | 9.55 | 283.15 | 10.88 | 213.23 | 7.09 | 165.07 | 0.66 | 348.65 |
| 2003 | | 19.65 | 8.04 | 578.91 | 0.71 | 429.69 | 3.17 | 112.86 | 1.46 | 651.43 |
| 2004 | | 37.24 | 2.49 | 135.54 | 24.08 | 193.71 | 2.10 | 175.37 | 0.65 | 584.18 |
| 2005 | | 36.16 | 1.27 | 372.14 | 0 | 269.18 | 2.27 | 197.24 | | 412.00 |
| 2006 | 0.14 | 38.91 | 7.55 | 147.40 | 404.98 | 292.71 | 18.67 | 140.23 | 3.09 | 1477.43 |
| 2007 | 0.18 | 24.85 | 46.06 | 293.85 | 1.00 | 378.59 | 3.48 | 154.53 | 0.25 | 504.23 |
| 2008 | 0.04 | 112.10 | 5.98 | 531.96 | 0.10 | 590.48 | 4.64 | 181.71 | 1.78 | 2529.77 |
| 2009 | | 303.59 | 13.74 | 979.18 | 0.31 | 2507.67 | 9.44 | 409.75 | 2.33 | 1607.49 |
| 2010 | 0.39 | 63.24 | 26.45 | 129.26 | 0.51 | 437.07 | 1.99 | | 5.24 | 319.73 |
| 2011 | 0.34 | 108.94 | 2.44 | 833.27 | 1.14 | 920.81 | 15.64 | 39.62 | 1.97 | 603.91 |
| 2012 | 0.44 | 130.27 | 29.08 | 587.53 | 13.57 | 580.16 | 13.44 | 132.47 | 0.49 | 116.53 |

**Table 22, continued. Butterfish (*Peprilus triacanthus*) mean number per tow for state surveys, 1989–2012. Empty cells indicate no survey was conducted. Delaware Department of Natural Resources and Environmental Control (DDNREC), ChesMMAP = Chesapeake Bay Multispecies Monitoring and Assessment Program, VIMS = Virginia Institute of Marine Science, NCDMF = North Carolina Department of Environment and Natural Resources**

| Year | DDNREC 30 ft | DDNREC Estuary | DDNREC Bays | ChesMMAP | VIMS Juvenile | NCDMF Annual |
|---|---|---|---|---|---|---|
| 1989 | | 0.25 | 0.78 | | 1.86 | |
| 1990 | 8.02 | 0.41 | 0.51 | | 2.27 | 2.59 |
| 1991 | 6.72 | 0.13 | 0.62 | | 1.48 | 2.57 |
| 1992 | 3.60 | 0.19 | 0.32 | | 0.88 | 1.31 |
| 1993 | 66.67 | 0.22 | 0.20 | | 1.44 | 2.25 |
| 1994 | 5.68 | 0.05 | 0.31 | | 0.52 | 1.91 |
| 1995 | 9.08 | 0.13 | 0.15 | | 0.33 | 1.34 |
| 1996 | 12.64 | 0.06 | 0.04 | | 1.14 | 2.26 |
| 1997 | 23.93 | 0.41 | 0.33 | | 0.45 | 0.53 |
| 1998 | 35.41 | 0.36 | 0.07 | | 1.03 | 1.72 |
| 1999 | 16.23 | 0.57 | 0.44 | | 0.74 | 1.99 |
| 2000 | 9.83 | 0.46 | 0.07 | | 0.87 | 1.8 |
| 2001 | 12.01 | 0.14 | 0 | | 0.47 | 1.57 |
| 2002 | 10.90 | 0.10 | 0.25 | 31.16 | 0.40 | 1.49 |
| 2003 | 29.97 | 0.20 | 0.22 | 87.46 | 1.01 | 1.46 |
| 2004 | 32.02 | 0.24 | 0.33 | 59.34 | 0.86 | 1.38 |
| 2005 | 3.98 | 0.17 | 0.08 | 126.69 | 0.36 | 2.73 |
| 2006 | 8.34 | 0.05 | 0.77 | 81.79 | 1.26 | 1.96 |
| 2007 | 7.03 | 0.10 | 0.18 | 60.81 | 0.16 | 2.01 |
| 2008 | 14.62 | 0.17 | 0.44 | 73.82 | 0.98 | 7.79 |
| 2009 | 6.89 | 0.13 | 2.27 | 78.56 | 1.06 | 3.91 |
| 2010 | 14.98 | 0.41 | 0.42 | 13.62 | 1.45 | 5.18 |
| 2011 | 27.54 | 0.49 | 1.17 | 27.63 | 0.78 | 5.95 |
| 2012 | 9.98 | 0.21 | 0.13 | 15.12 | 0.27 | 2.54 |

**Table 23. Correlation coefficients between Northeast Fisheries Science Center (NEFSC), Northeast Area Monitoring and Assessment Program (NEAMAP), and state surveys for butterfish (*Peprilus triacanthus*) spring abundance indices (number per tow). Values > 0.4 are in bold. There is no correlation coefficient for NEFSC Inshore and NEAMAP because of the low sample size (*n* = 1 pair).**

| | NEFSC Offshore | NEFSC Inshore | ME-NH | MDMF | RIDEM | CTDEEP | NEAMAP |
|---|---|---|---|---|---|---|---|
| NEFSC Offshore | 1 | | | | | | |
| NEFSC Inshore | -0.11 | 1 | | | | | |
| ME-NH | 0.23 | 0.31 | 1 | | | | |
| MDMF | **0.49** | 0.16 | 0.37 | 1 | | | |
| RIDEM | 0.05 | 0.19 | -0.16 | -0.05 | 1 | | |
| CTDEEP | 0.32 | 0.15 | 0.29 | 0.10 | **0.60** | 1 | |
| NEAMAP | -0.09 | NA | **0.98** | **0.47** | **0.49** | 0.07 | 1 |

**Table 24. Correlation coefficients between Northeast Fisheries Science Center (NEFSC), Northeast Area Monitoring and Assessment Program (NEAMAP), and state surveys for butterfish (*Peprilus triacanthus*) fall abundance indices (number per tow). Values > 0.4 are in bold. Note the correlation coefficient for NEFSC Inshore and NEAMAP is due to the low sample size (*n* = 2 pairs).**

| | NEFSC Offshore | NEFSC Inshore | ME-NH | MDMF | RIDEM | CTDEEP | NEAMAP |
|---|---|---|---|---|---|---|---|
| NEFSC Offshore | 1 | | | | | | |
| NEFSC Inshore | 0.19 | 1 | | | | | |
| ME-NH | 0.27 | -0.78 | 1 | | | | |
| MDMF | 0.11 | -0.40 | **0.80** | 1 | | | |
| RIDEM | 0.04 | 0.23 | **0.96** | **0.63** | 1 | | |
| CTDEEP | -0.06 | -0.35 | **0.71** | 0.35 | 0.27 | 1 | |
| NEAMAP | **0.54** | **1** | **0.86** | **0.71** | **0.97** | **0.79** | 1 |

**Table 25. The top 6 fish predators of butterfish (*Peprilus triacanthus*) identified from Northeast Fisheries Science Center (NEFSC) bottom trawl survey food habits database.**

| Common Name | Species Name |
|---|---|
| Bluefish | *Pomatomus saltatrix* |
| Spiny dogfish | *Squalus acanthias* |
| Silver hake | *Merluccius bilinearis* |
| Summer flounder | *Paralichthys dentatus* |
| Goosefish | *Lophius americanus* |
| Smooth dogfish | *Mustelus canis* |

**Table 26. Estimated smoother coefficients and covariance matrix for butterfish (*Peprilus triacanthus*) length-based relative catch efficiency from Miller (2013) used to specify the penalty in the final model.**

| Coefficient | Covariance matrix | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| -1.231 | 0.018 | 0.003 | -0.006 | -0.010 | -0.012 | -0.012 | -0.010 | -0.003 | 0.008 | 0.020 |
| -0.102 | 0.003 | 0.059 | 0.009 | -0.020 | -0.034 | -0.041 | -0.041 | -0.031 | -0.026 | -0.028 |
| -1.047 | -0.006 | 0.009 | 0.090 | 0.091 | 0.100 | 0.103 | 0.097 | 0.057 | 0.005 | -0.018 |
| -0.838 | -0.010 | -0.020 | 0.091 | 0.129 | 0.145 | 0.153 | 0.141 | 0.085 | 0.018 | -0.015 |
| -0.764 | -0.012 | -0.034 | 0.100 | 0.145 | 0.183 | 0.193 | 0.179 | 0.110 | 0.027 | -0.012 |
| -0.753 | -0.012 | -0.041 | 0.103 | 0.153 | 0.193 | 0.217 | 0.202 | 0.126 | 0.036 | -0.007 |
| -0.807 | -0.010 | -0.041 | 0.097 | 0.141 | 0.179 | 0.202 | 0.203 | 0.132 | 0.047 | 0.008 |
| -0.468 | -0.003 | -0.031 | 0.057 | 0.085 | 0.110 | 0.126 | 0.132 | 0.114 | 0.073 | 0.057 |
| 0.222 | 0.008 | -0.026 | 0.005 | 0.018 | 0.027 | 0.036 | 0.047 | 0.073 | 0.180 | 0.311 |
| 0.737 | 0.020 | -0.028 | -0.018 | -0.015 | -0.012 | -0.007 | 0.008 | 0.057 | 0.311 | 0.949 |

**Table 27. Specifications for the final age-structured assessment program (ASAP) model. CV = coefficient of variation, RMSE = Root Mean Squared Error**

| | |
|---|---|
| Catch CVs | based on variance estimation for discards |
| Aggregate survey index CVs | design-based estimates were rescaled for RMSE diagnostics |
| Fishery effective sample size (input) | 27 |
| Starting value for fishery selectivity, Age 0 | 1 |
| Starting value for fishery selectivity, Age 1 | 1 |
| Starting value for fishery selectivity, Age 2 | 1 (fixed) |
| Starting value for fishery selectivity, Age 3 | 1 (fixed |
| Starting value for fishery selectivity, Age 4+ | 1 (fixed) |
| NEFSC fall offshore effective sample size (input) | 19 |
| NEFSC fall inshore effective sample size (input) | 14 |
| NEAMAP fall effective sample size (input) | 41 |
| Starting value for NEFSC fall offshore survey selectivity, Age 0 | 1 (fixed) |
| Starting value for NEFSC fall offshore survey selectivity, Age 1 | 0.58 |
| Starting value for NEFSC fall offshore survey selectivity, Age 2 | 0.632 |
| Starting value for NEFSC fall offshore survey selectivity, Age 3 | 0.632 (fixed) |
| Starting value for NEFSC fall offshore survey selectivity, Age 4+ | 0.632 (fixed) |
| Starting value for NEFSC fall inshore survey selectivity, Age 0 | 1 (fixed) |
| Starting value for NEFSC fall inshore survey selectivity, Age 1 | 0.461 |
| Starting value for NEFSC fall inshore survey selectivity, Age 2 | 0.657 |
| Starting value for NEFSC fall inshore survey selectivity, Age 3 | 0.349 |
| Starting value for NEFSC fall inshore survey selectivity, Age 4+ | 0.349 (fixed) |
| Starting value for NEAMAP fall survey selectivity, Age 0 | 1 (fixed) |
| Starting value for NEAMAP fall survey selectivity, Age 1 | 1 |
| Starting value for NEAMAP fall survey selectivity, Age 2 | 0.298 |
| Starting value for NEAMAP fall survey selectivity, Age 3 | 0.298 |
| Starting value for NEAMAP fall survey selectivity, Age 4+ | 0.298 |
| Fraction of year at NEFSC fall offshore survey | 0.75 |
| Fraction of year at NEFSC fall inshore survey | 0.75 |
| Fraction of year at NEAMAP fall survey | 0.67 |
| Fraction of year at spawning | 0.5 |

**Table 28. Swept area abundance (000s) inputs for the final model. Northeast Fisheries Science Center (NEFSC) survey areas used to derive these values were 42,945 nmi$^2$ (147,297 km$^2$) and 3,521 nmi$^2$ (12,077 km$^2$) for the offshore and inshore series, respectively; while swept area was assumed to be 0.0112 nmi$^2$ (0.0384 km$^2$). Northeast Area Monitoring and Assessment Program (NEAMAP) survey area and swept areas were assumed to be 11,868 km$^2$ and 0.025 km$^2$, respectively.**

| Year | NEFSC Fall Offshore | NEFSC Fall Inshore | NEAMAP Fall |
|---|---|---|---|
| 1989 | 1,446,871 | 187,037 | |
| 1990 | 1,456,820 | 20,029 | |
| 1991 | 720,360 | 54,262 | |
| 1992 | 943,447 | 33,805 | |
| 1993 | 954,693 | 91,896 | |
| 1994 | 1,956,873 | 95,355 | |
| 1995 | 446,988 | 12,423 | |
| 1996 | 302,335 | 49,521 | |
| 1997 | 844,577 | 198,979 | |
| 1998 | 822,423 | 35,309 | |
| 1999 | 950,207 | 58,213 | |
| 2000 | 778,073 | 98,354 | |
| 2001 | 243,934 | 115,849 | |
| 2002 | 355,108 | 70,900 | |
| 2003 | 719,912 | 83,986 | |
| 2004 | 289,500 | 99,699 | |
| 2005 | 150,261 | 71,842 | |
| 2006 | 687,532 | 63,517 | |
| 2007 | 158,014 | 69,462 | 488,812 |
| 2008 | 505,868 | 41,393 | 507,284 |
| 2009 | 699,575 | | 1,758,311 |
| 2010 | 491,395 | | 520,072 |
| 2011 | 960,040 | | 804,646 |
| 2012 | 255,318 | | 307,599 |

**Table 29. Objective function components for the final model.**

| Component | Objective Function |
|---|---|
| Aggregate catch | 189.851 |
| Aggregate survey indices | 659.819 |
| Catch age composition | 180.909 |
| Survey age composition | 161.395 |
| Relative catch efficiency penalty | -5.73728 |
| Total | 1186.24 |

**Table 30. Root Mean Squared Error (RMSE) for data components from the final model. NEFSC = Northeast Fisheries Science Center, NEAMAP = Northeast Area Monitoring and Assessment Program**

| Component | RMSE |
|---|---|
| Aggregate catch | 0.07 |
| Aggregate survey indices | 1.15 |
| NEFSC fall offshore indices | 0.98 |
| NEFSC fall inshore indices | 1.35 |
| NEAMAP fall indices | 1.00 |

**Table 31. Annual estimates of spawning biomass (mt), recruitment (millions), fully selected fishing mortality F (age 2+), and respective coefficient of variation (CV) from the final model.**

| Year | Spawning Biomass | CV | Recruitment | CV | Full F | CV |
|---|---|---|---|---|---|---|
| 1989 | 62,910 | 0.31 | 8,196 | 0.28 | 0.13 | 0.56 |
| 1990 | 89,052 | 0.27 | 9,030 | 0.24 | 0.03 | 0.29 |
| 1991 | 76,674 | 0.23 | 7,573 | 0.23 | 0.11 | 0.72 |
| 1992 | 77,013 | 0.21 | 7,175 | 0.21 | 0.10 | 0.41 |
| 1993 | 78,509 | 0.19 | 10,438 | 0.21 | 0.15 | 0.28 |
| 1994 | 69,763 | 0.19 | 11,587 | 0.20 | 0.14 | 0.33 |
| 1995 | 78,885 | 0.18 | 5,000 | 0.24 | 0.11 | 0.40 |
| 1996 | 75,485 | 0.19 | 9,403 | 0.22 | 0.06 | 0.26 |
| 1997 | 94,390 | 0.19 | 14,836 | 0.17 | 0.04 | 0.31 |
| 1998 | 103,490 | 0.16 | 8,873 | 0.23 | 0.08 | 1.00 |
| 1999 | 90,151 | 0.18 | 13,628 | 0.22 | 0.12 | 0.35 |
| 2000 | 106,590 | 0.18 | 10,586 | 0.22 | 0.09 | 0.28 |
| 2001 | 100,740 | 0.19 | 7,934 | 0.22 | 0.09 | 0.34 |
| 2002 | 85,021 | 0.19 | 8,044 | 0.21 | 0.04 | 0.78 |
| 2003 | 80,428 | 0.19 | 9,135 | 0.19 | 0.03 | 0.88 |
| 2004 | 85,343 | 0.17 | 5,126 | 0.22 | 0.02 | 0.28 |
| 2005 | 56,055 | 0.18 | 7,581 | 0.18 | 0.02 | 0.22 |
| 2006 | 67,460 | 0.17 | 7,397 | 0.20 | 0.02 | 0.45 |
| 2007 | 79,627 | 0.17 | 5,691 | 0.19 | 0.01 | 0.24 |
| 2008 | 62,643 | 0.18 | 7,595 | 0.19 | 0.02 | 0.47 |
| 2009 | 57,039 | 0.18 | 11,113 | 0.22 | 0.02 | 0.29 |
| 2010 | 77,877 | 0.20 | 6,546 | 0.24 | 0.07 | 0.36 |
| 2011 | 71,239 | 0.23 | 9,483 | 0.26 | 0.03 | 0.26 |
| 2012 | 79,451 | 0.25 | 2,432 | 0.33 | 0.02 | 0.33 |

**Table 32. Estimated fishing mortality at age from the final age-structured assessment program (ASAP) model.**

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4+ |
|---|---|---|---|---|---|
| 1989 | 0.005 | 0.040 | 0.132 | 0.132 | 0.132 |
| 1990 | 0.001 | 0.010 | 0.032 | 0.032 | 0.032 |
| 1991 | 0.004 | 0.032 | 0.107 | 0.107 | 0.107 |
| 1992 | 0.004 | 0.031 | 0.102 | 0.102 | 0.102 |
| 1993 | 0.005 | 0.045 | 0.150 | 0.150 | 0.150 |
| 1994 | 0.005 | 0.043 | 0.143 | 0.143 | 0.143 |
| 1995 | 0.004 | 0.033 | 0.109 | 0.109 | 0.109 |
| 1996 | 0.002 | 0.017 | 0.057 | 0.057 | 0.057 |
| 1997 | 0.002 | 0.013 | 0.044 | 0.044 | 0.044 |
| 1998 | 0.003 | 0.024 | 0.078 | 0.078 | 0.078 |
| 1999 | 0.004 | 0.035 | 0.116 | 0.116 | 0.116 |
| 2000 | 0.003 | 0.026 | 0.088 | 0.088 | 0.088 |
| 2001 | 0.003 | 0.027 | 0.091 | 0.091 | 0.091 |
| 2002 | 0.001 | 0.011 | 0.037 | 0.037 | 0.037 |
| 2003 | 0.001 | 0.009 | 0.030 | 0.030 | 0.030 |
| 2004 | 0.001 | 0.007 | 0.022 | 0.022 | 0.022 |
| 2005 | 0.001 | 0.005 | 0.017 | 0.017 | 0.017 |
| 2006 | 0.001 | 0.006 | 0.022 | 0.022 | 0.022 |
| 2007 | 0.000 | 0.004 | 0.012 | 0.012 | 0.012 |
| 2008 | 0.001 | 0.007 | 0.024 | 0.024 | 0.024 |
| 2009 | 0.001 | 0.007 | 0.025 | 0.025 | 0.025 |
| 2010 | 0.002 | 0.020 | 0.067 | 0.067 | 0.067 |
| 2011 | 0.001 | 0.009 | 0.031 | 0.031 | 0.031 |
| 2012 | 0.001 | 0.007 | 0.024 | 0.024 | 0.024 |

**Table 33. Estimated numbers at age (millions) on January 1 from the final age-structured assessment program (ASAP) model.**

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4+ |
|---|---|---|---|---|---|
| 1989 | 8,196 | 2,784 | 742 | 217 | 15 |
| 1990 | 9,030 | 2,397 | 786 | 191 | 60 |
| 1991 | 7,573 | 2,650 | 698 | 224 | 71 |
| 1992 | 7,175 | 2,217 | 754 | 184 | 78 |
| 1993 | 10,438 | 2,101 | 632 | 200 | 70 |
| 1994 | 11,587 | 3,051 | 590 | 160 | 68 |
| 1995 | 5,000 | 3,387 | 859 | 150 | 58 |
| 1996 | 9,403 | 1,463 | 963 | 226 | 55 |
| 1997 | 14,836 | 2,757 | 423 | 267 | 78 |
| 1998 | 8,873 | 4,352 | 799 | 119 | 97 |
| 1999 | 13,628 | 2,600 | 1,249 | 217 | 59 |
| 2000 | 10,586 | 3,988 | 738 | 327 | 72 |
| 2001 | 7,933 | 3,101 | 1,141 | 199 | 107 |
| 2002 | 8,044 | 2,324 | 886 | 306 | 82 |
| 2003 | 9,135 | 2,361 | 675 | 251 | 110 |
| 2004 | 5,126 | 2,681 | 687 | 192 | 103 |
| 2005 | 7,581 | 1,505 | 783 | 197 | 85 |
| 2006 | 7,397 | 2,226 | 440 | 226 | 82 |
| 2007 | 5,691 | 2,172 | 650 | 127 | 88 |
| 2008 | 7,595 | 1,672 | 636 | 189 | 62 |
| 2009 | 11,113 | 2,230 | 488 | 182 | 72 |
| 2010 | 6,546 | 3,263 | 650 | 140 | 73 |
| 2011 | 9,483 | 1,919 | 940 | 179 | 58 |
| 2012 | 2,432 | 2,783 | 559 | 268 | 68 |

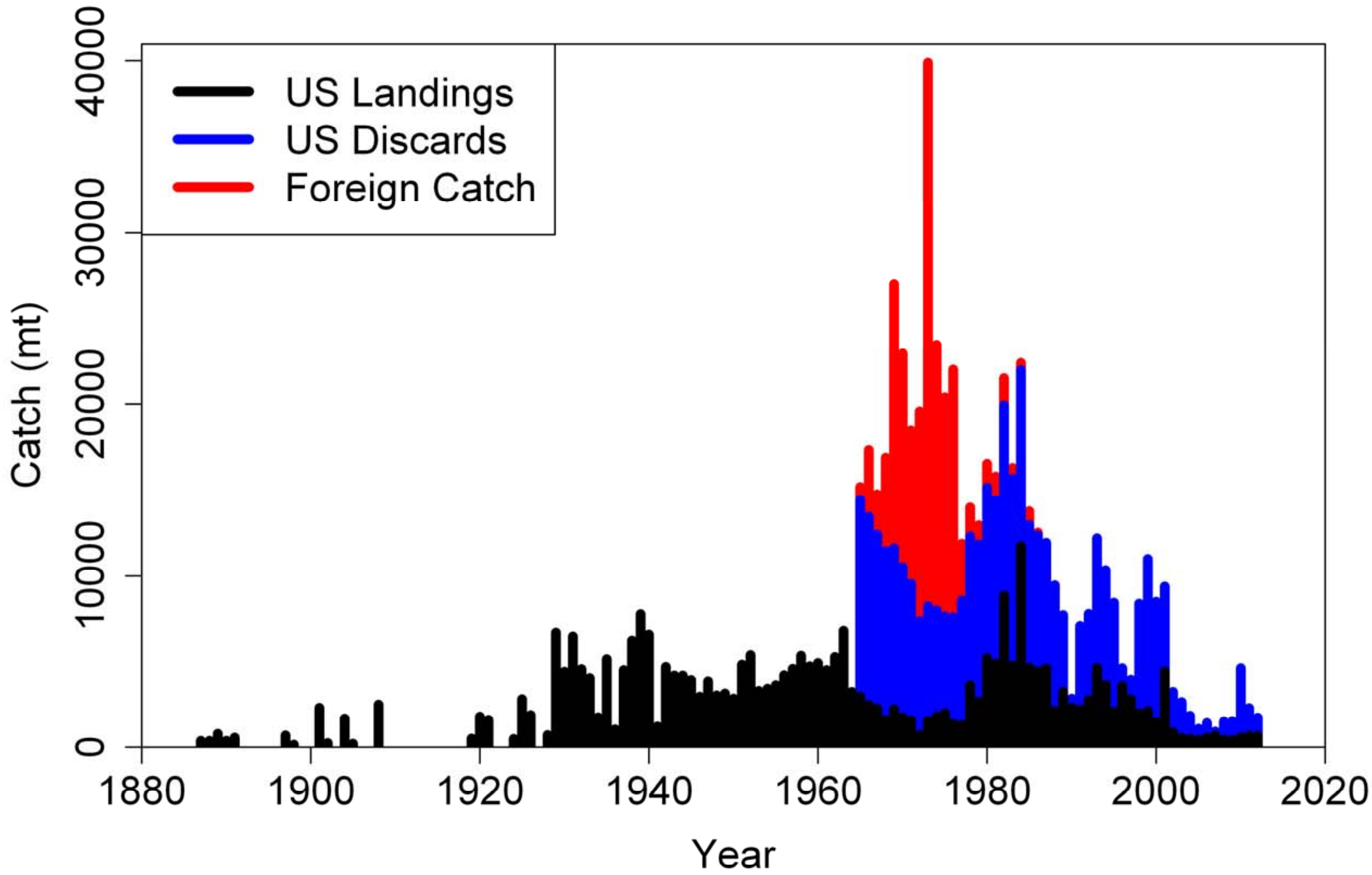


**Figure 1. Butterfish (*Peprilus triacanthus*) total catch, 1887–2012. Annual catch data are missing for some years prior to 1930. Discards are unavailable prior to 1965. Total catch 1965–1988 includes discards estimated by applying an average of discard rates for trawl gear 1989–1999 to annual landings of all species 1965–1988 by trawl gear.**

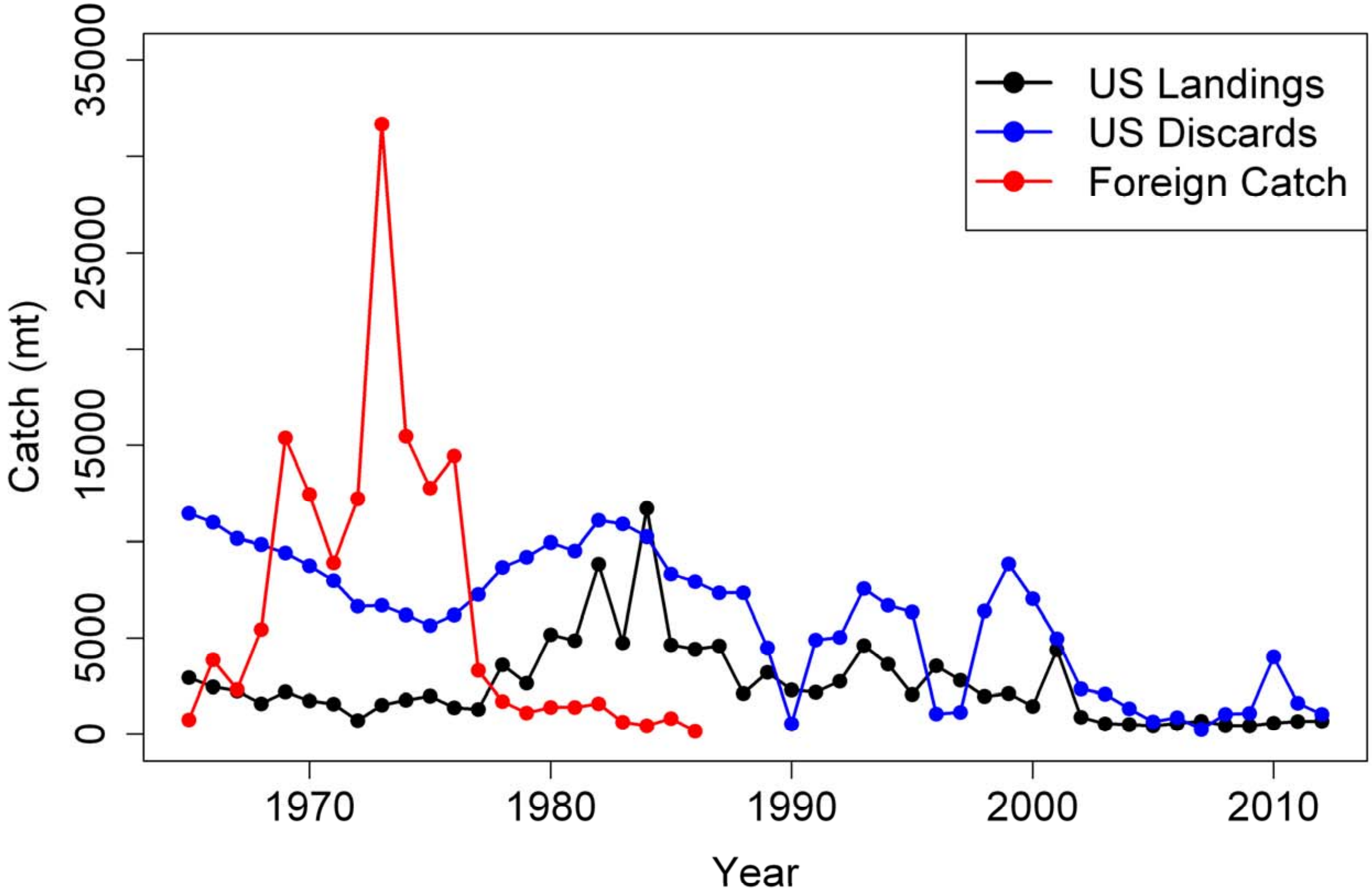


**Figure 2. USA landings, USA discards, and foreign catch of butterfish (*Peprilus triacanthus*), 1965–2012.**

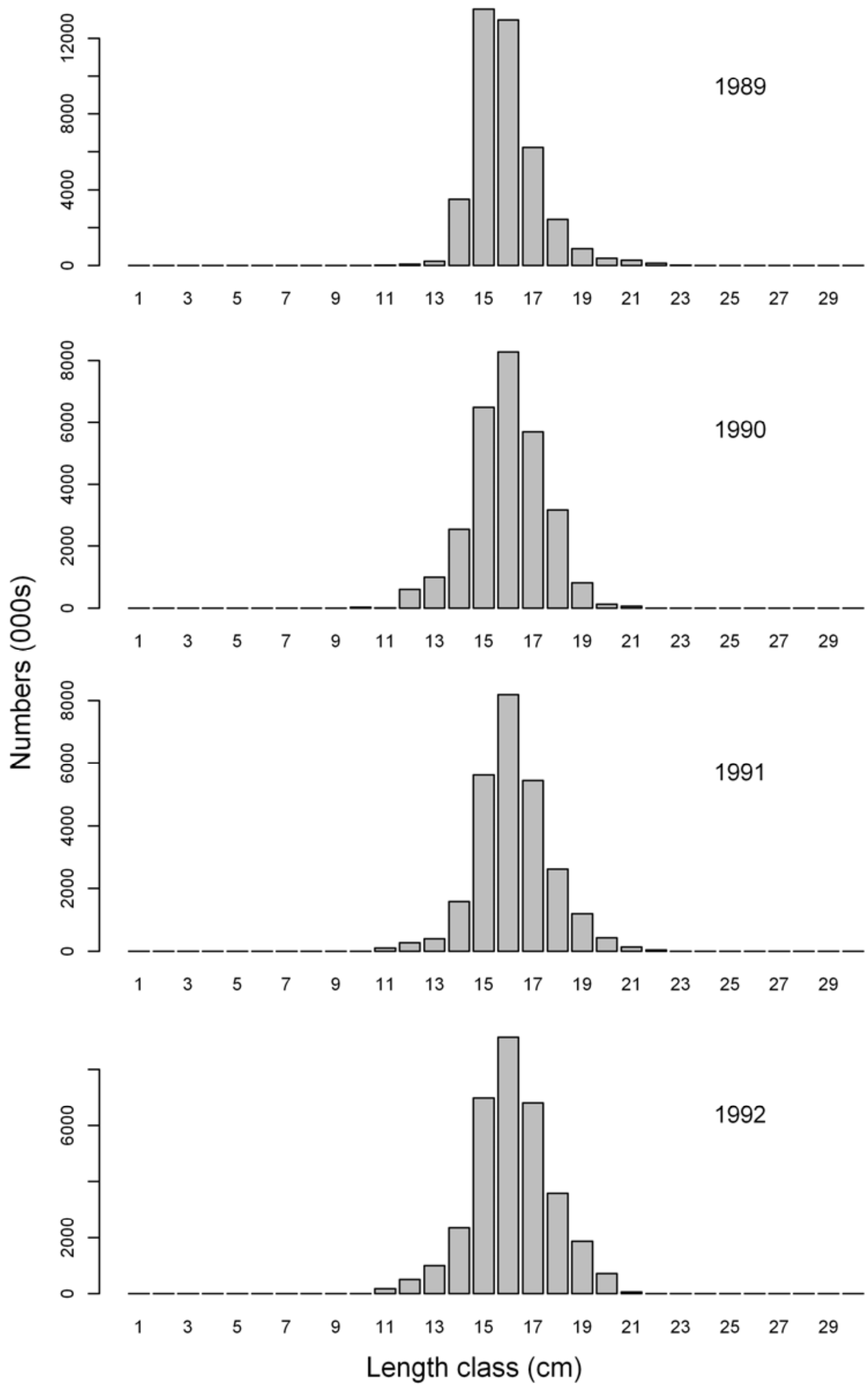


**Figure 3. Size composition data from New England and Mid-Atlantic commercial landings of butterfish (*Peprilus triacanthus*), 1989–1992. Note the Y-axis varies by year.**

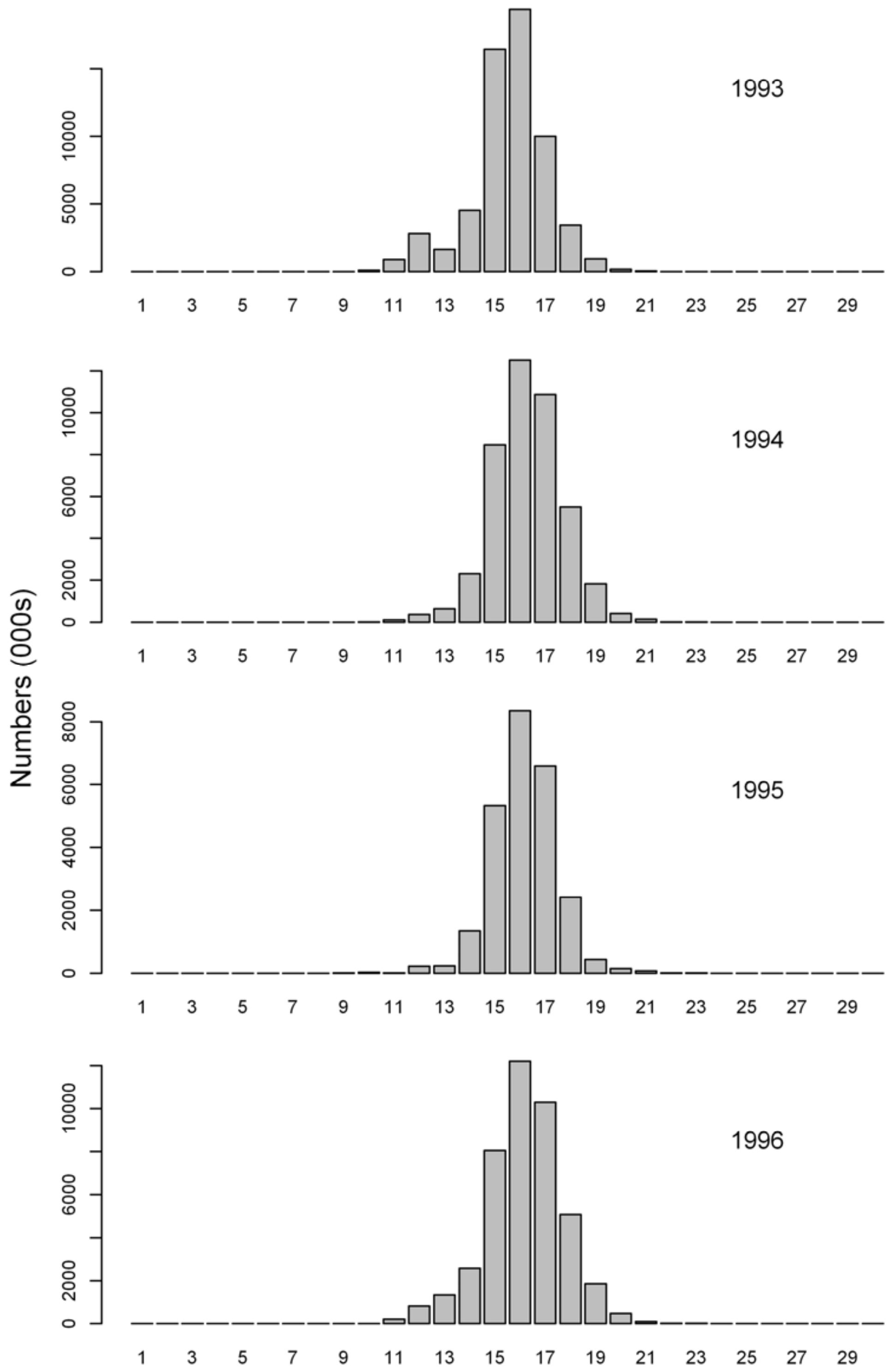


**Figure 4. Size composition data from New England and Mid-Atlantic commercial landings of butterfish (*Peprilus triacanthus*), 1993–1996. Note the Y-axis varies by year.**

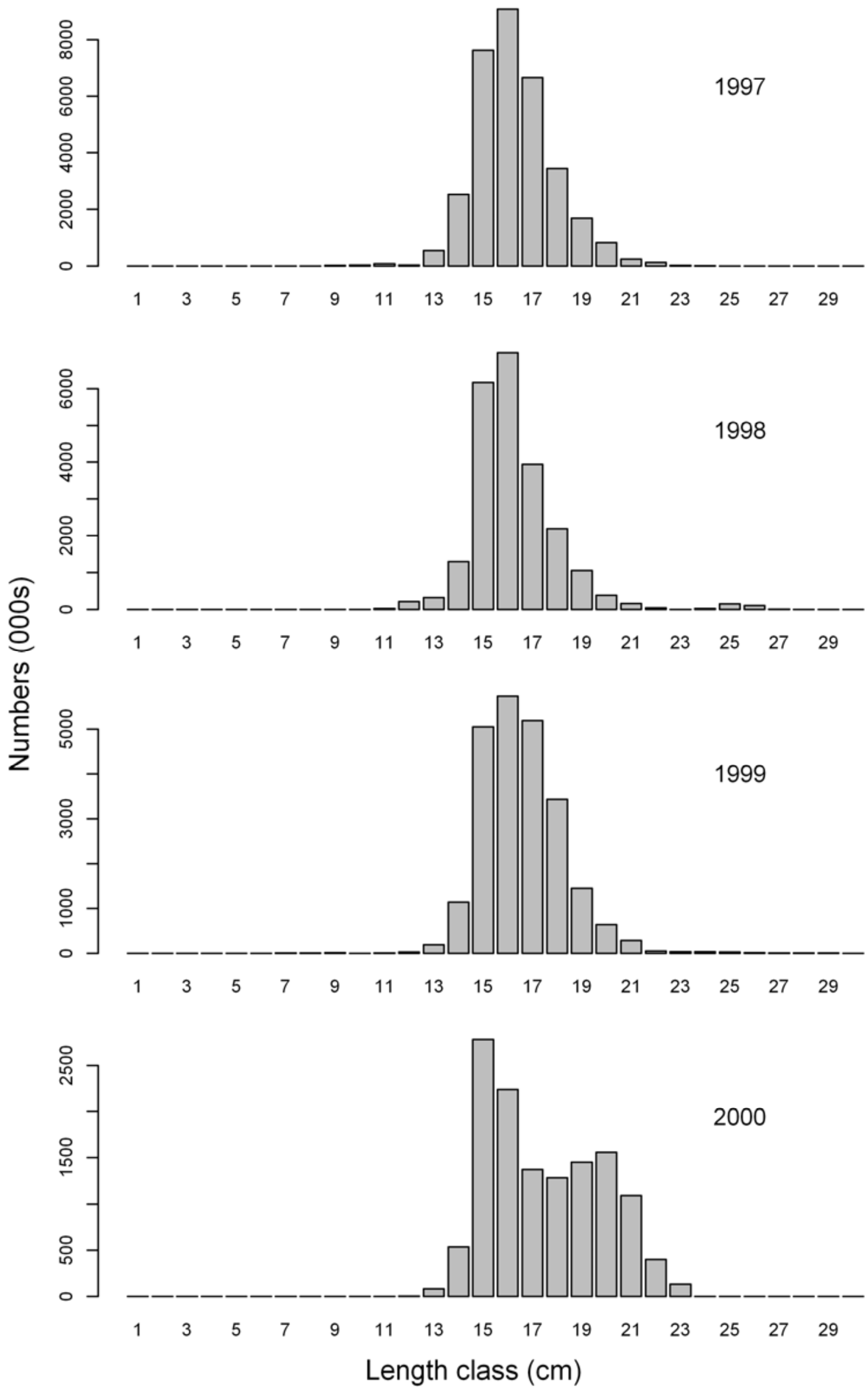


**Figure 5. Size composition data from New England and Mid-Atlantic commercial landings of butterfish (*Peprilus triacanthus*), 1997–2000. Note the Y-axis varies by year**.

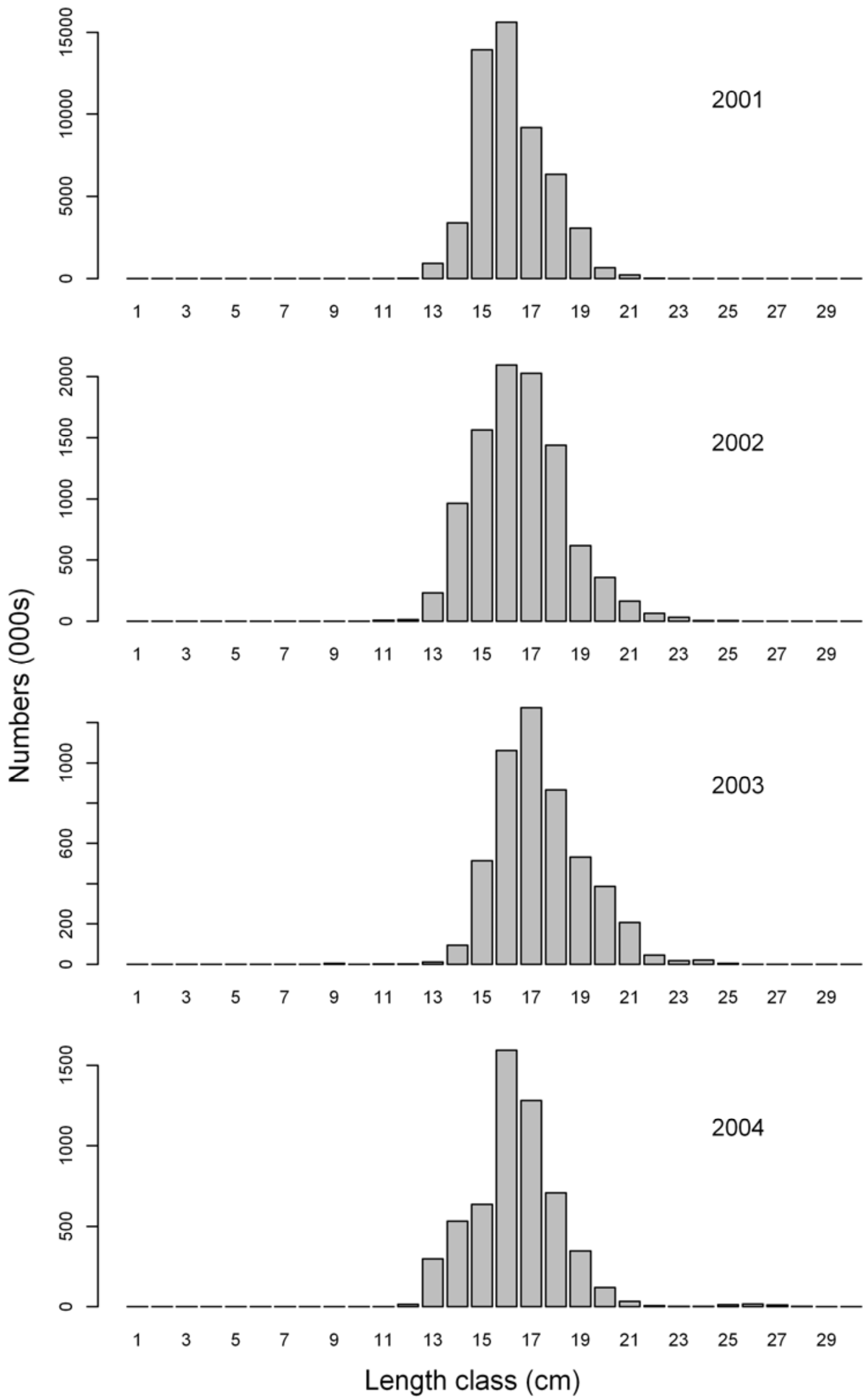


**Figure 6. Size composition data from New England and Mid-Atlantic commercial landings of butterfish (*Peprilus triacanthus*), 2001–2004. Note the Y-axis varies by year.**

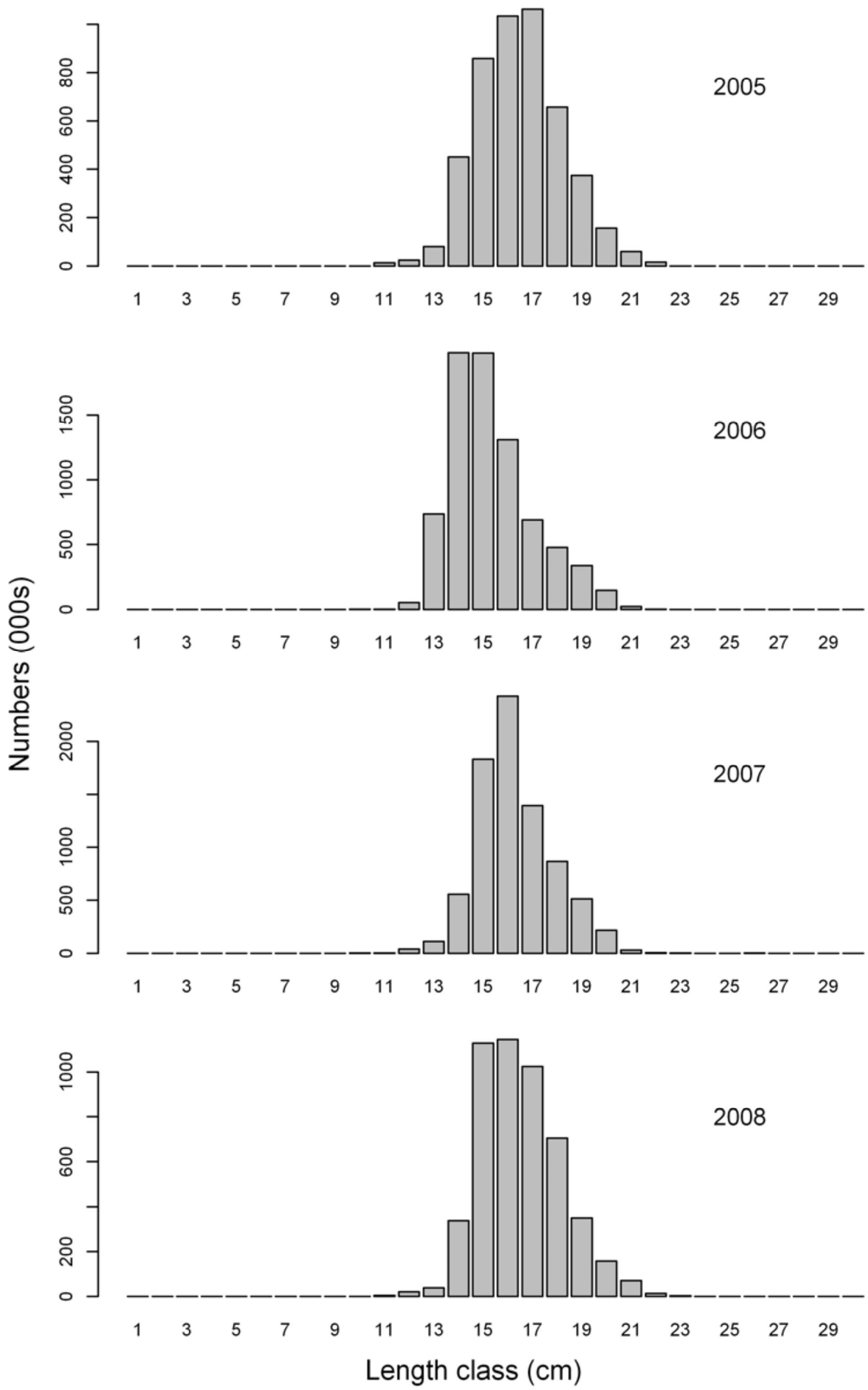


**Figure 7. Size composition data from New England and Mid-Atlantic commercial landings of butterfish (*Peprilus triacanthus*), 2005–2008. Note the Y-axis varies by year.**

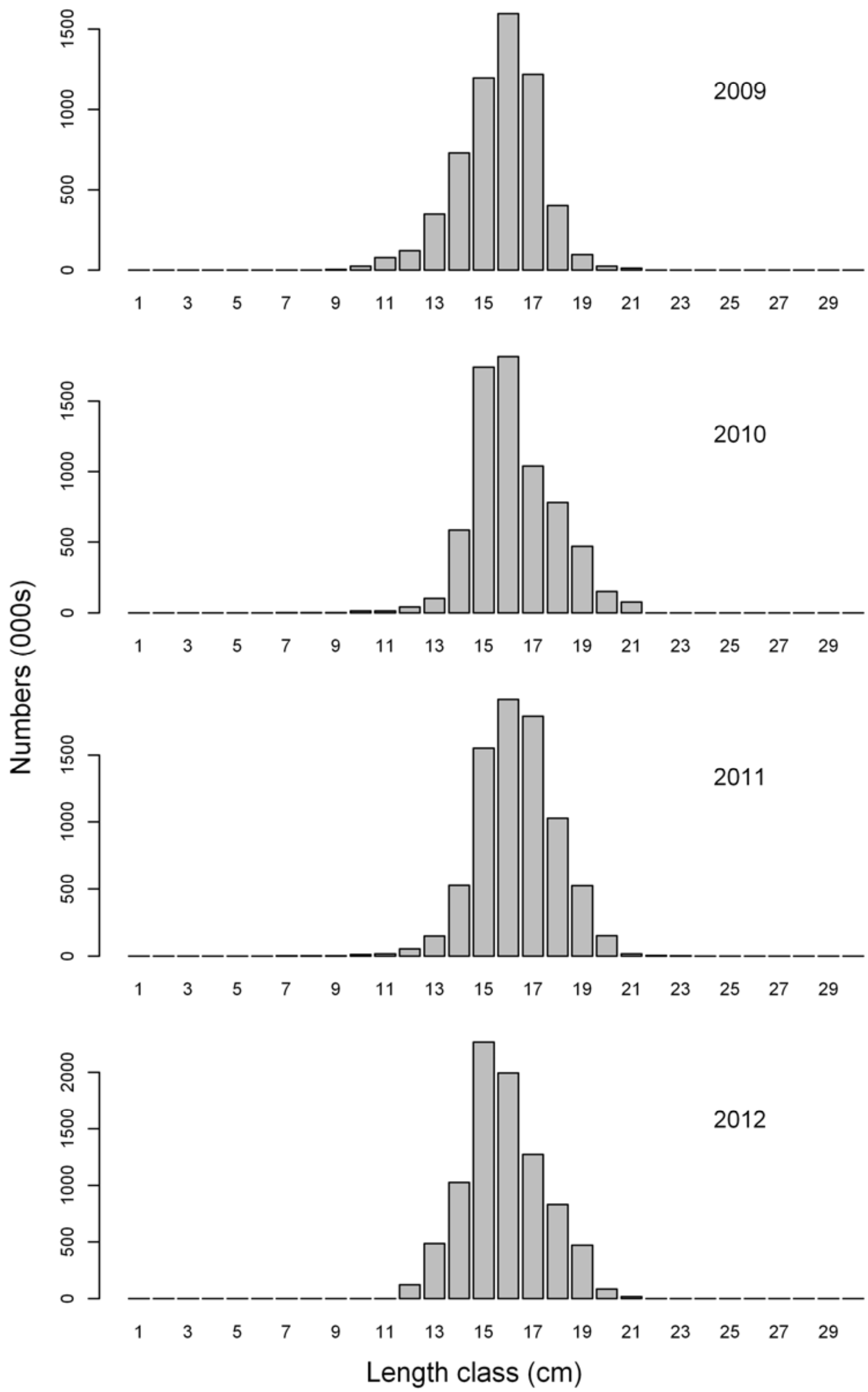


**Figure 8. Size composition data from New England and Mid-Atlantic commercial landings of butterfish (*Peprilus triacanthus*), 2009–2012. Note the Y-axis varies by year.**

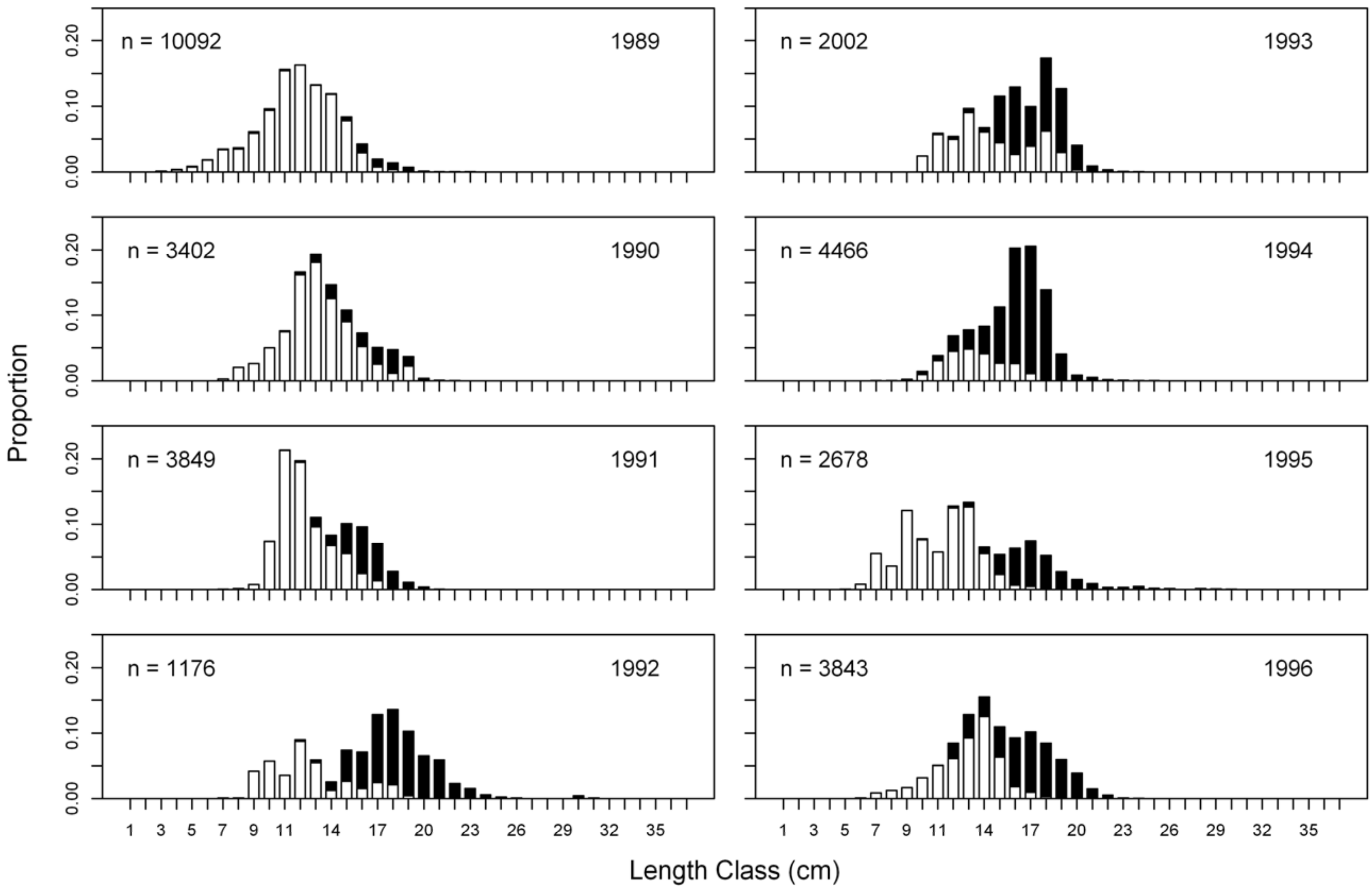


**Figure 9. Length composition of butterfish (*Peprilus triacanthus*) from National Marine Fisheries Service Observer Program, 1989–1996, with kept fish in black and discards in white. Bars are stacked. Size of a bar of a given color is the proportion of total length samples in the length interval and corresponding disposition.**

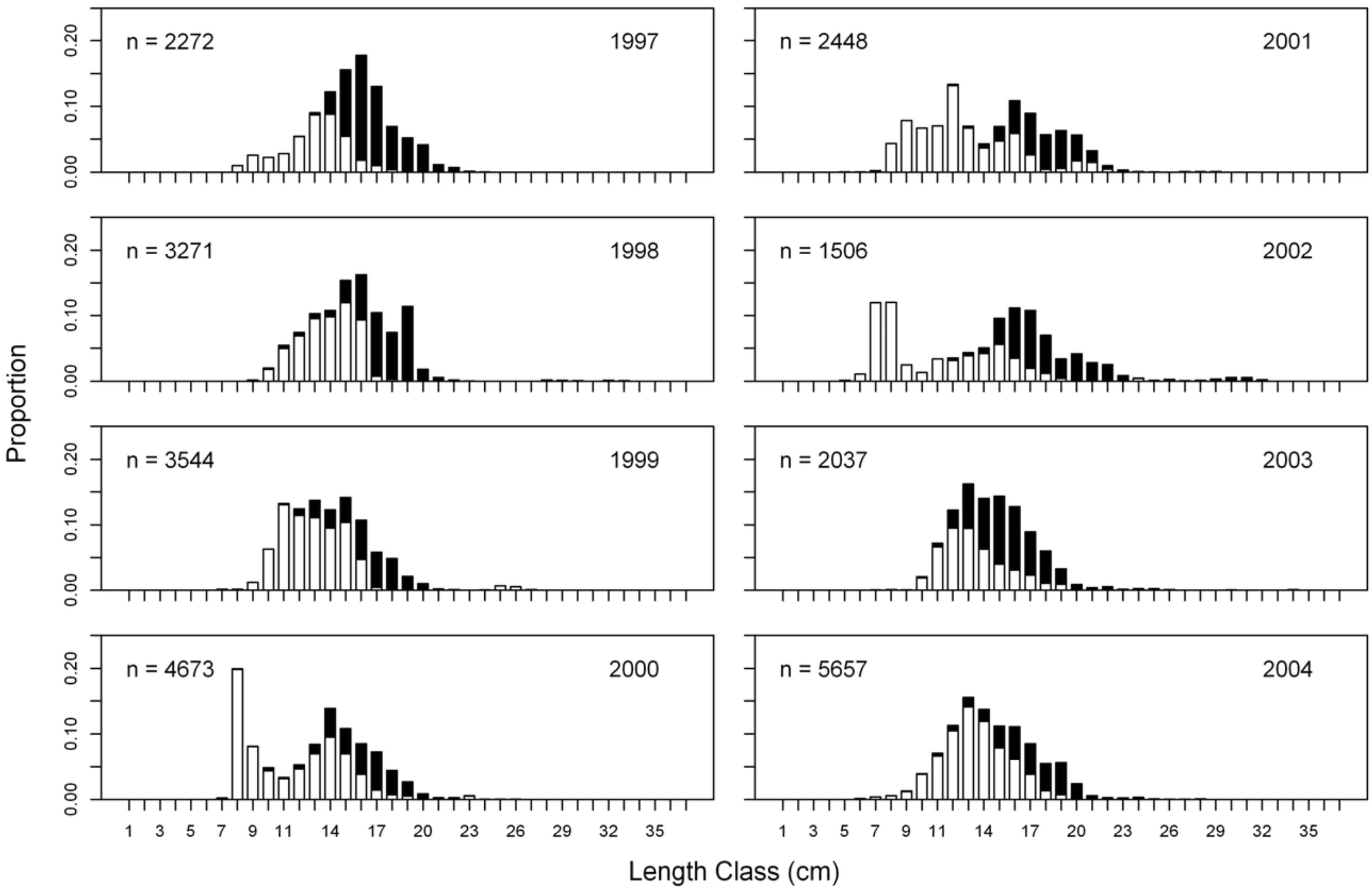


**Figure 10. Length composition of butterfish (*Peprilus triacanthus*) from National Marine Fisheries Service Observer Program, 1997–2004, with kept fish in black and discards in white. Bars are stacked. Size of a bar of a given color is the proportion of total length samples in the length interval and corresponding disposition.**

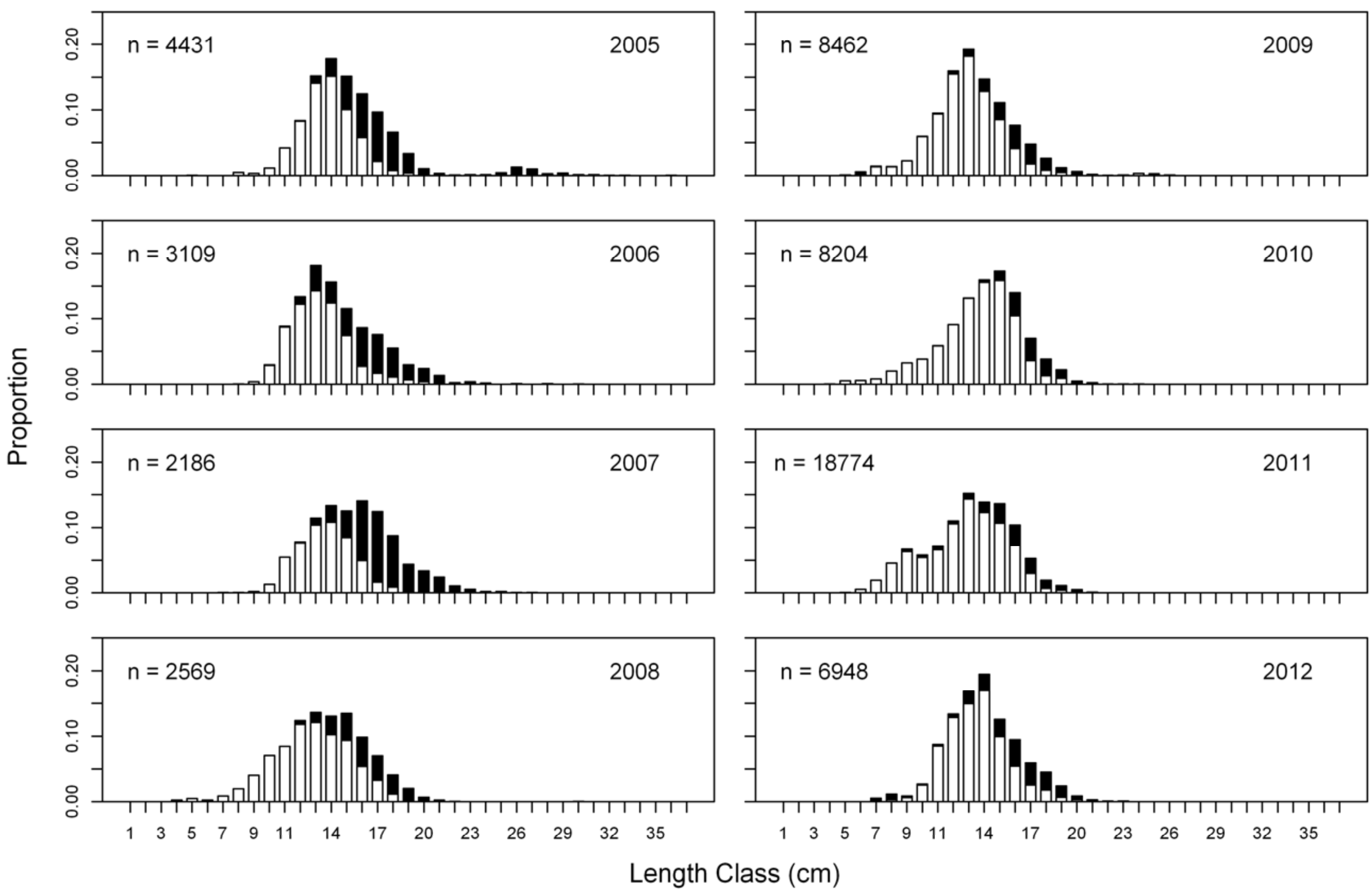


**Figure 11. Length composition of butterfish (*Peprilus triacanthus*) from National Marine Fisheries Service Observer Program, 2005–2012, with kept fish in black and discards in white. Bars are stacked. Size of a bar of a given color is the proportion of total length samples in the length interval and corresponding disposition.**

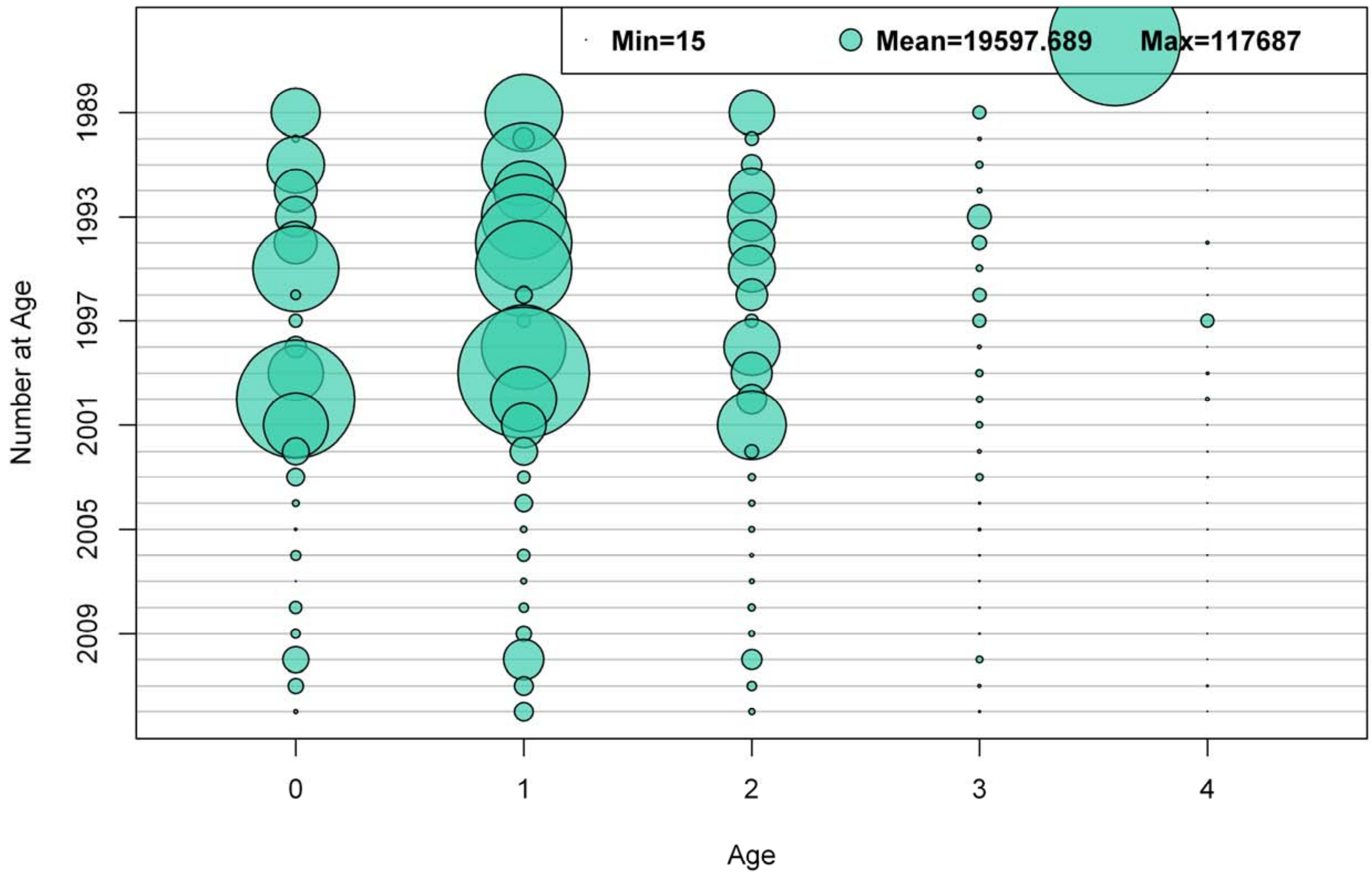


**Figure 12. Butterfish (*Peprilus triacanthus*) commercial catch (number) at age, 1989–2012.**

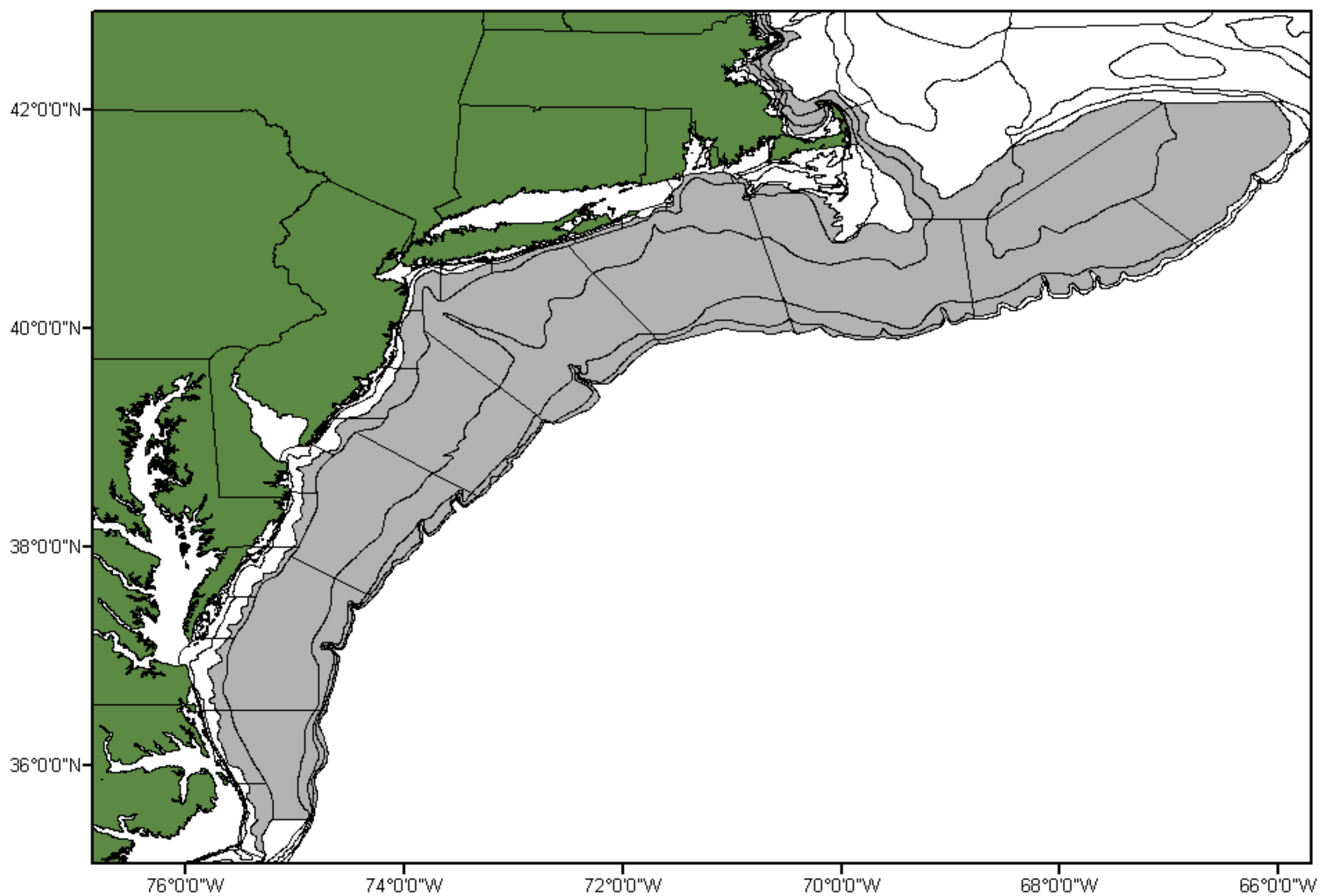


**Figure 13. Strata (in gray) used for Northeast Fisheries Science Center offshore indices for butterfish (*Peprilus triacanthus*), 1989–2012. Strata include the outermost inshore strata (2, 5, 8, 11, 14, 17, 20, 23, 26, 29, 32, 35, 38, 41, 44–46, 56, 59–61, and 64–66) and offshore strata (1–14, 16, 19, 20, 23, 25, and 61–76).**

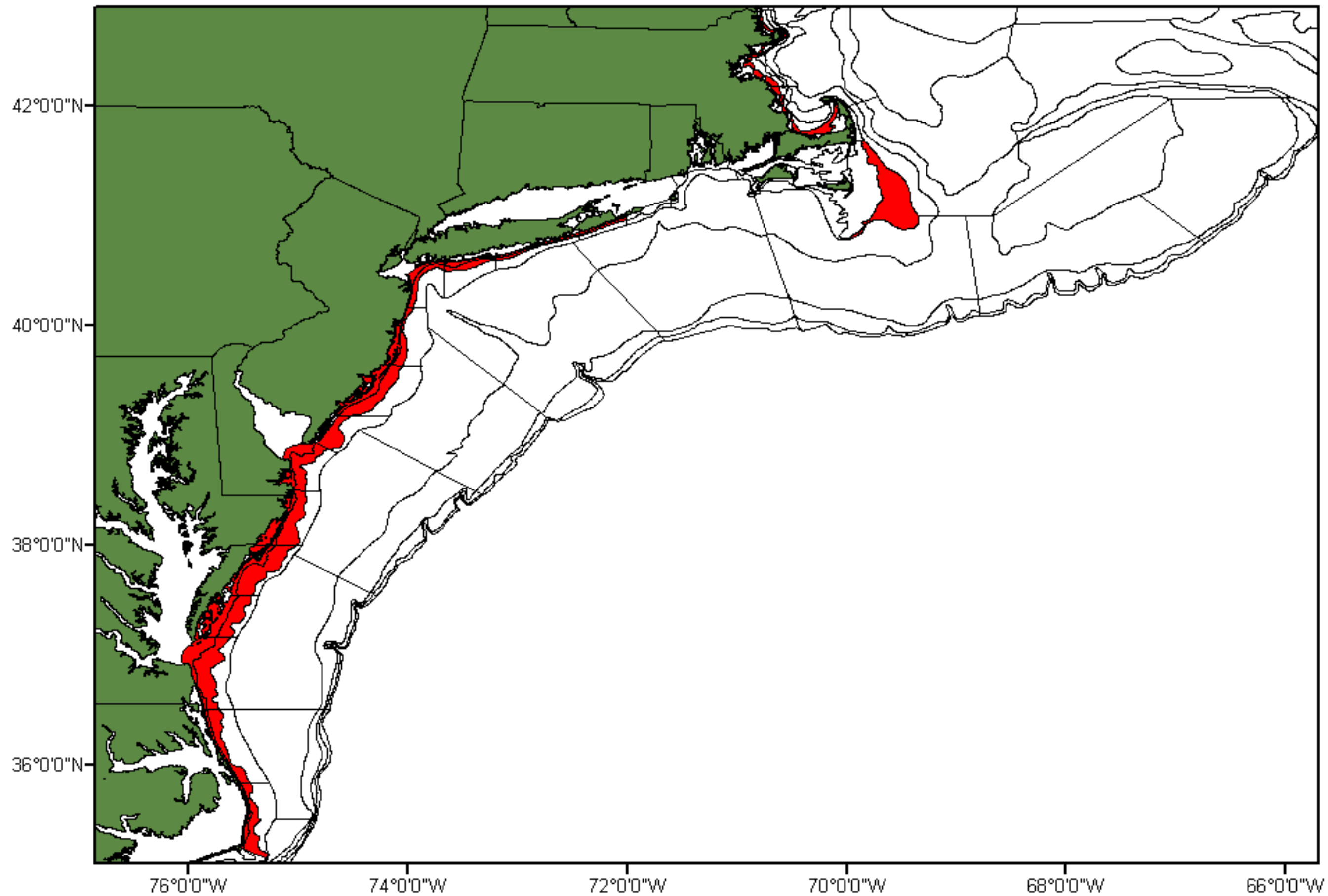


**Figure 14. Strata (in red) used for Northeast Fisheries Science Center inshore indices for butterfish (*Peprilus triacanthus*), 1989–2008. Strata include the 2 innermost inshore strata (3, 4, 6, 7, 9, 10, 12, 13, 15, 16, 18, 19, 21, 22, 24, 25, 27, 28, 30, 31, 33, 34, 36, 37, 39, 40, 42, 43, 55, 58, and 63).**

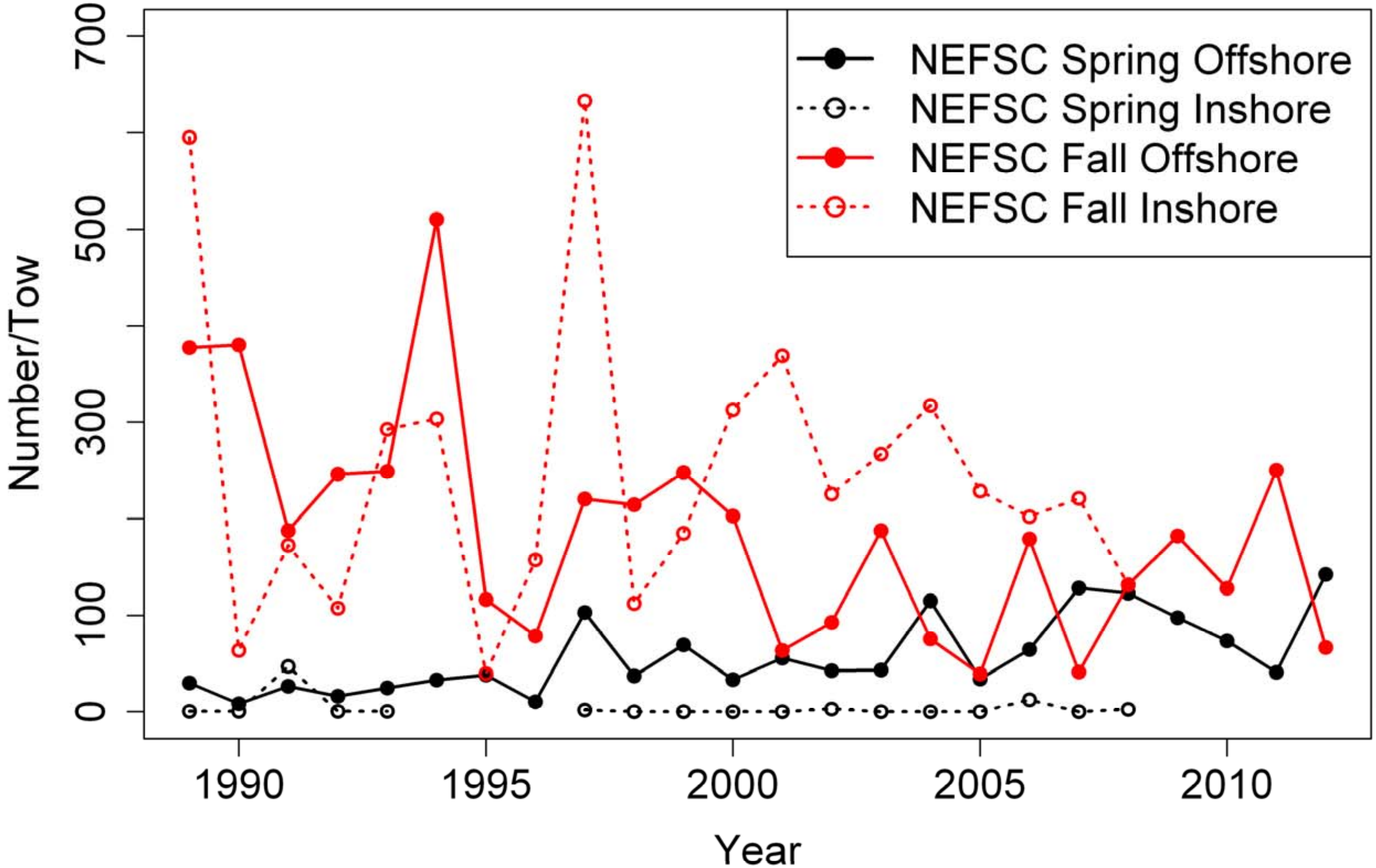


**Figure 15. Northeast Fisheries Science Center (NEFSC) spring offshore, spring inshore, fall offshore and fall inshore survey stratified mean number per tow for butterfish (*Peprilus triacanthus*).**

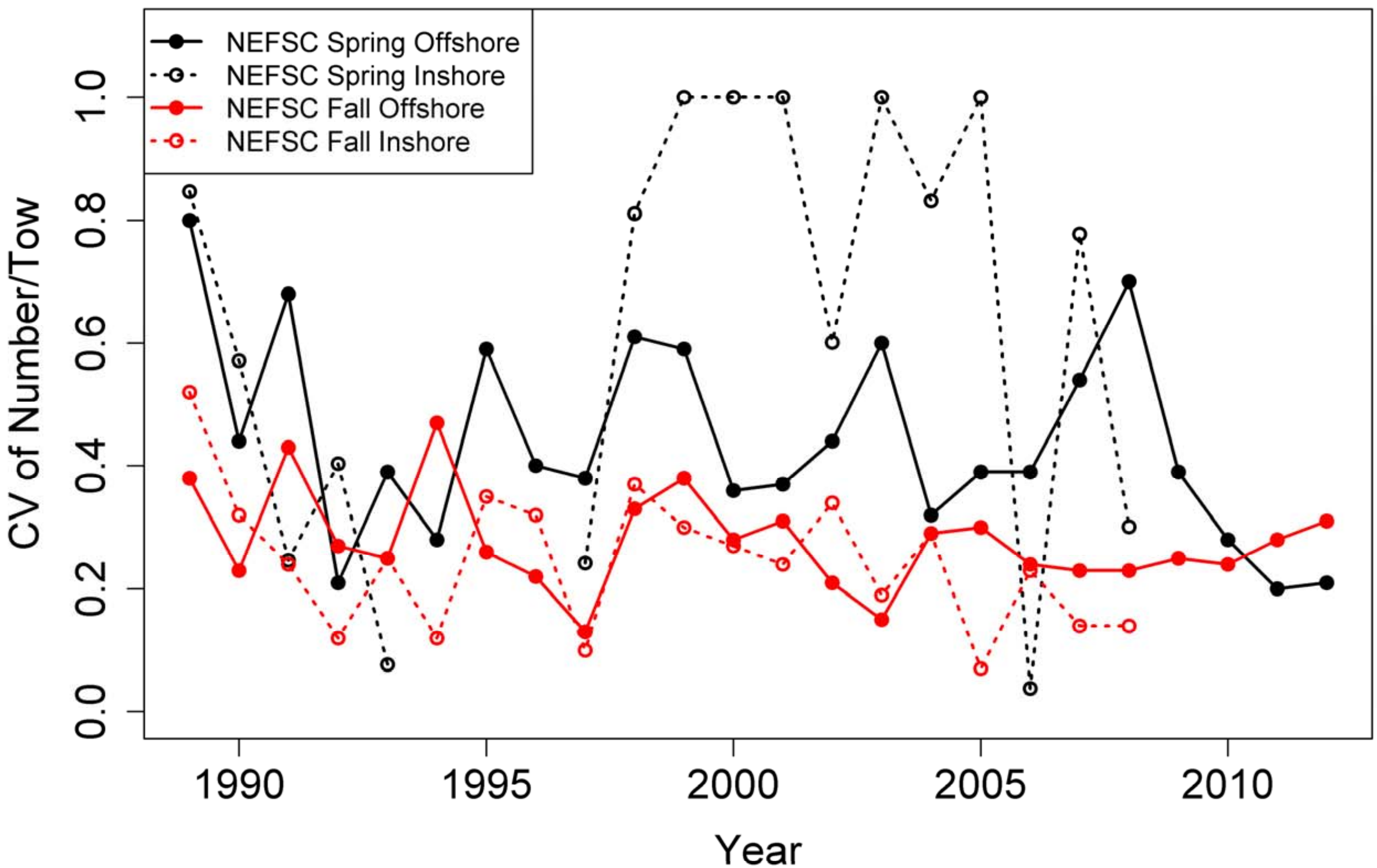


**Figure 16. Coefficient of variation (CV) for Northeast Fisheries Science Center (NEFSC) spring offshore, spring inshore, fall offshore, and fall inshore survey stratified mean number per tow for butterfish (*Peprilus triacanthus*).**

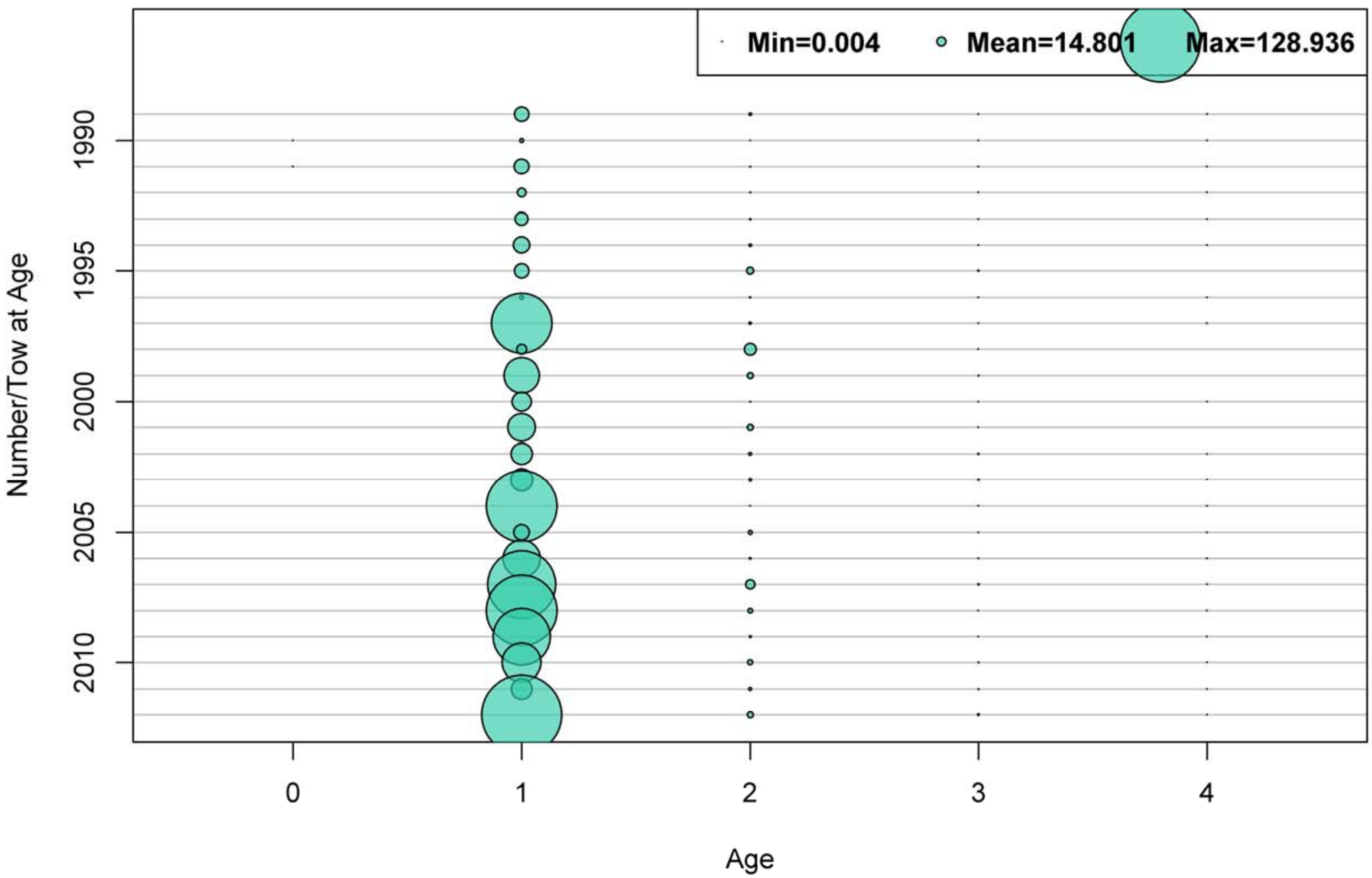


**Figure 17. Age composition of butterfish (*Peprilus triacanthus*) in Northeast Fisheries Science Center (NEFSC) spring offshore surveys, 1989–2012. Note: different scaling as compared with the other NEFSC age composition plots.**

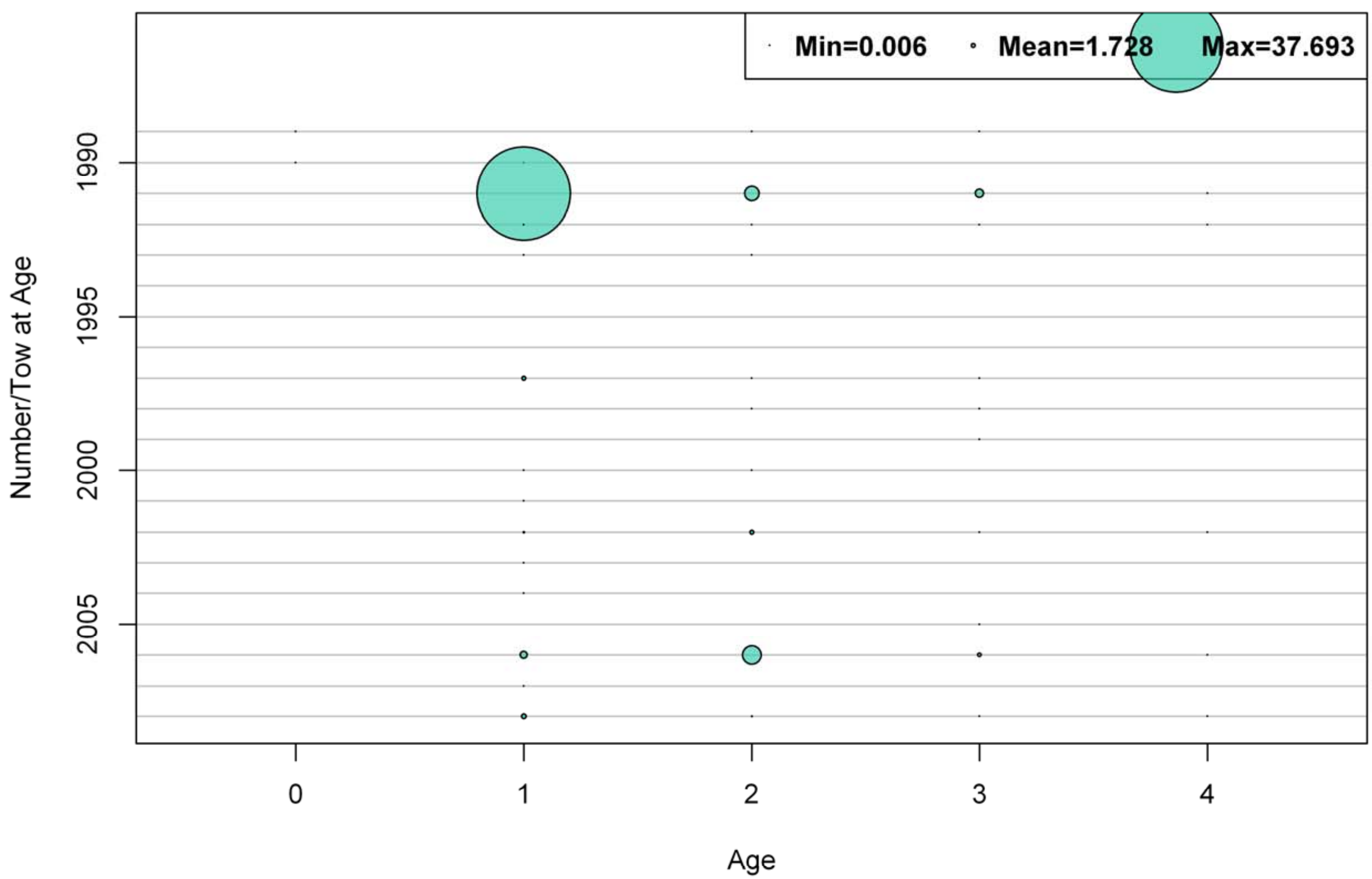


**Figure 18. Age composition of butterfish (*Peprilus triacanthus*) in Northeast Fisheries Science Center (NEFSC) spring inshore surveys, 1989–2008. Note: different scaling as compared with the other NEFSC age composition plots.**

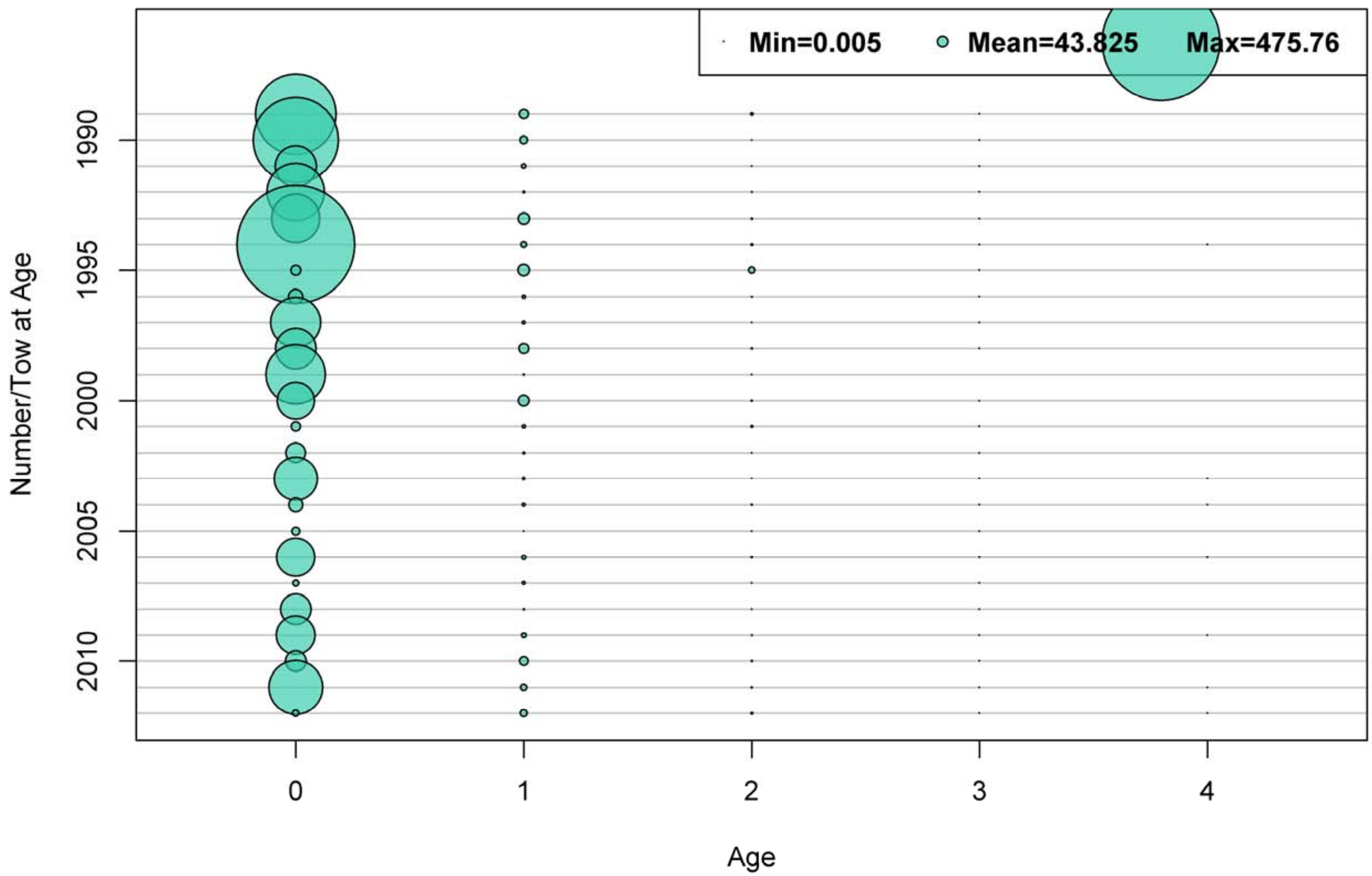


**Figure 19. Age composition of butterfish (*Peprilus triacanthus*) in Northeast Fisheries Science Center fall offshore surveys, 1989–2012.**

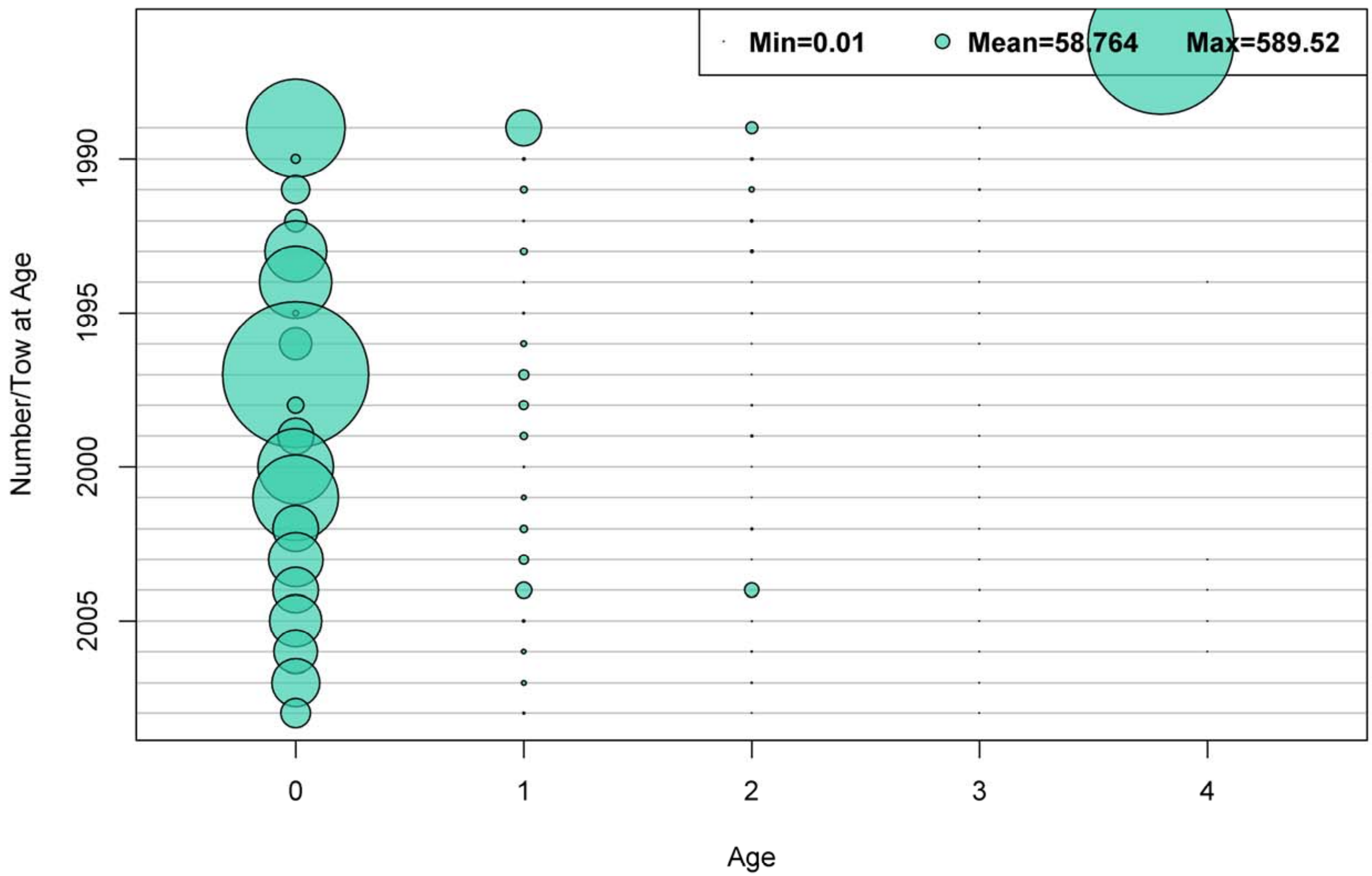


**Figure 20. Age composition of butterfish (*Peprilus triacanthus*) in Northeast Fisheries Science Center fall inshore surveys, 1989–2008.**

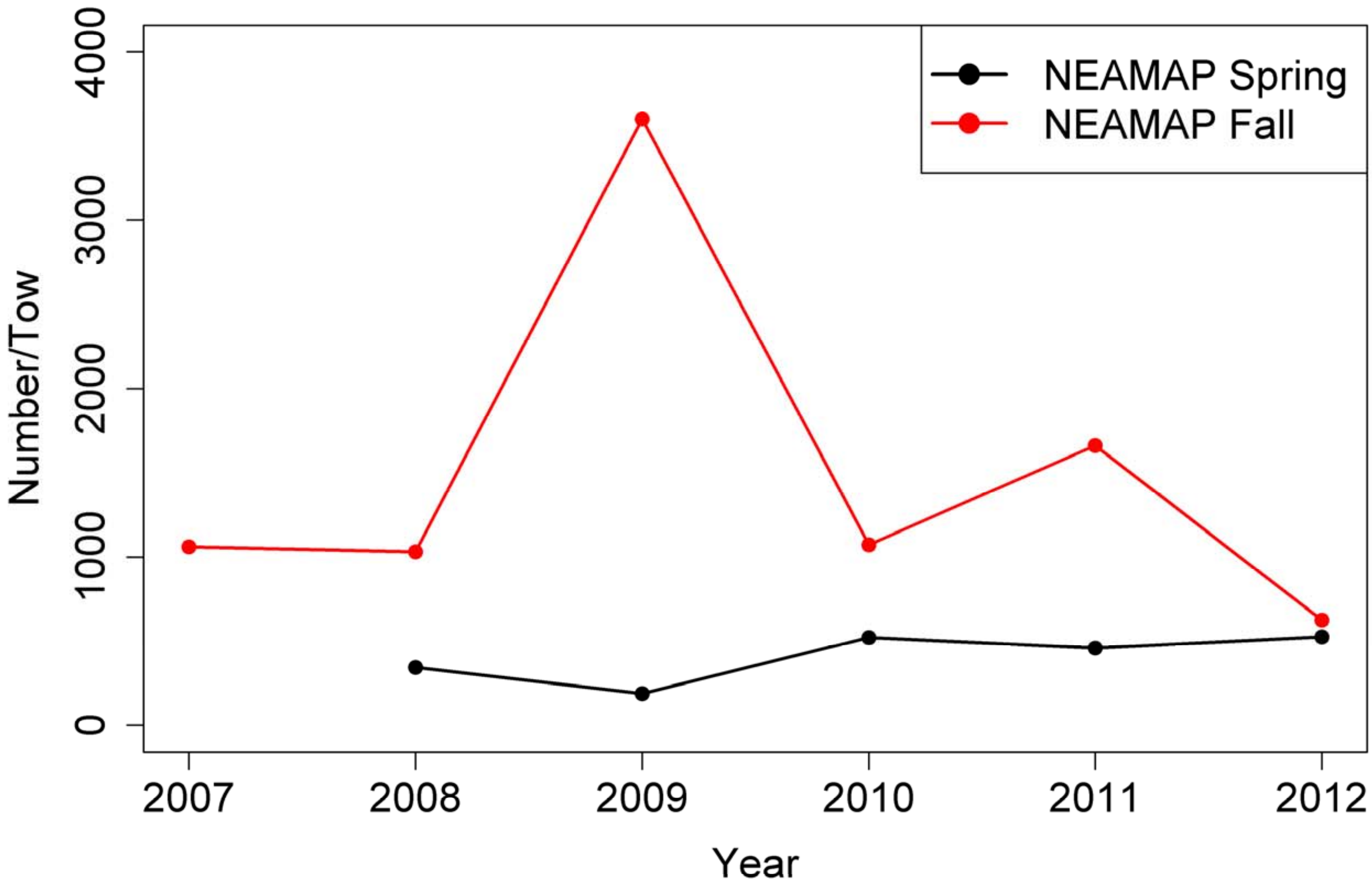


**Figure 21. Northeast Area Monitoring and Assessment Program (NEAMAP) spring and fall survey stratified arithmetic mean number per tow for butterfish (*Peprilus triacanthus*).**

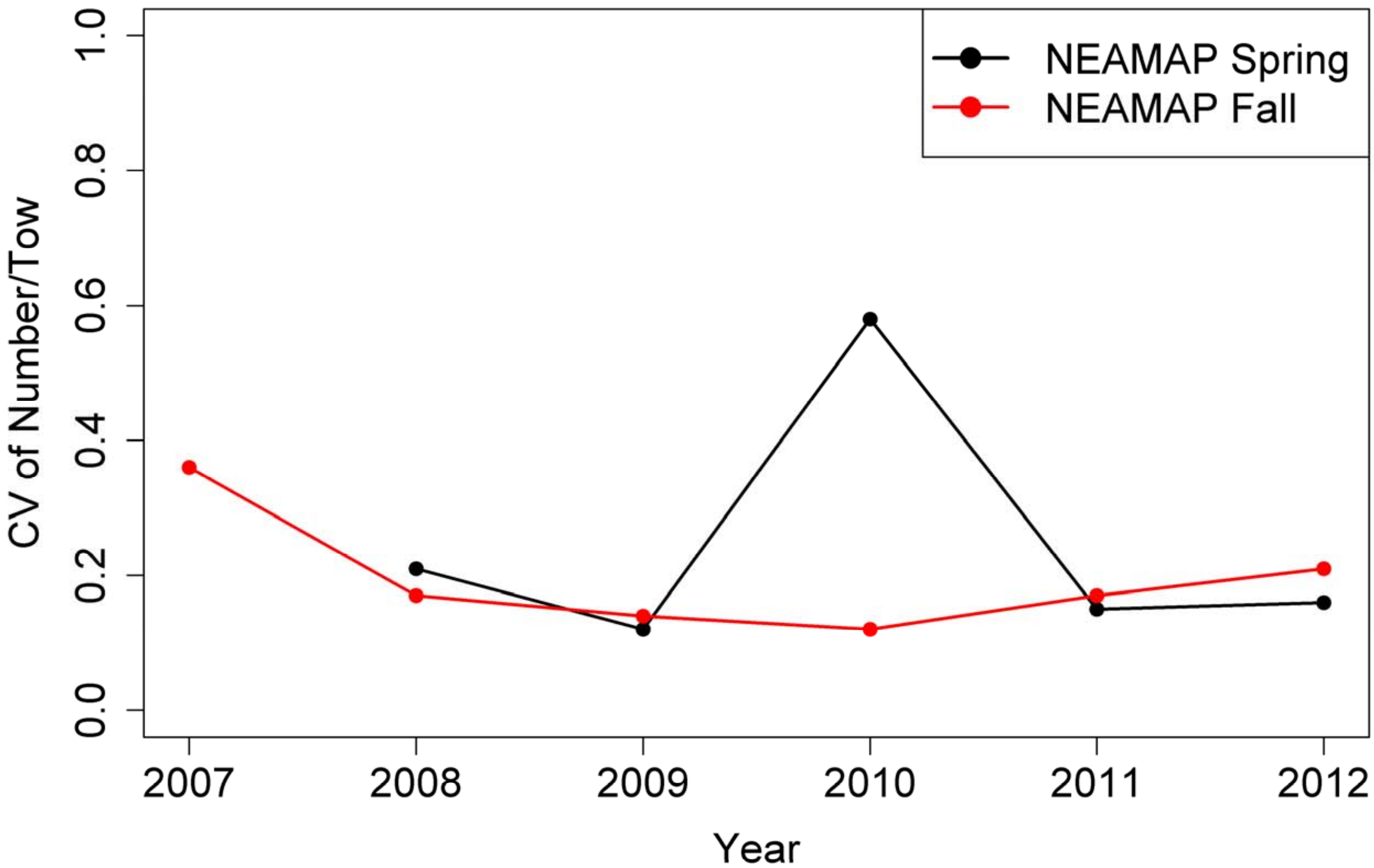


**Figure 22. Coefficient of variation (CV) for Northeast Area Monitoring and Assessment Program (NEAMAP) spring and fall survey stratified mean number per tow for butterfish (*Peprilus triacanthus*).**

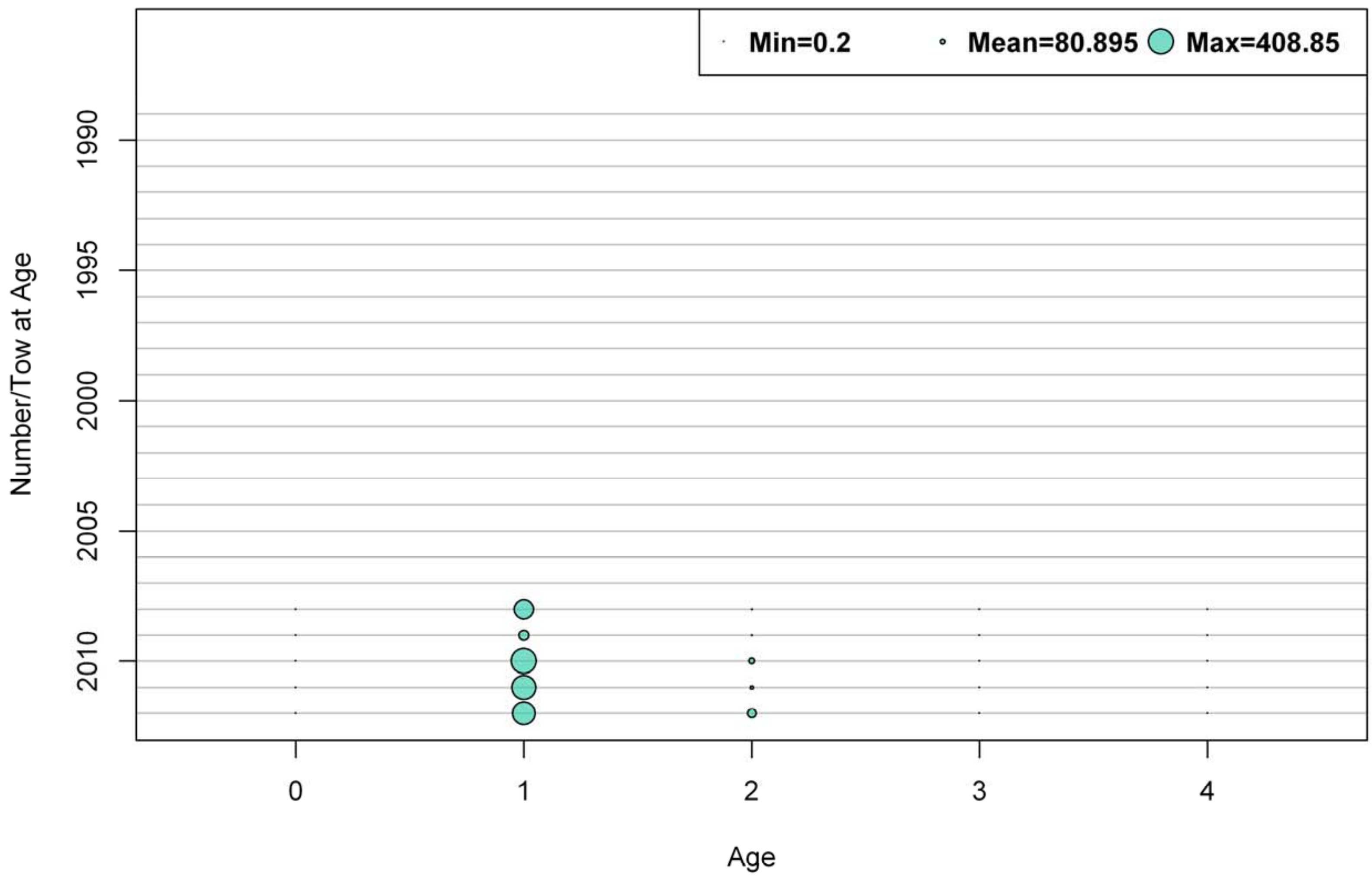


**Figure 23. Age composition of butterfish (*Peprilus triacanthus*) in Northeast Area Monitoring and Assessment Program (NEAMAP) spring surveys, 2008–2012.**

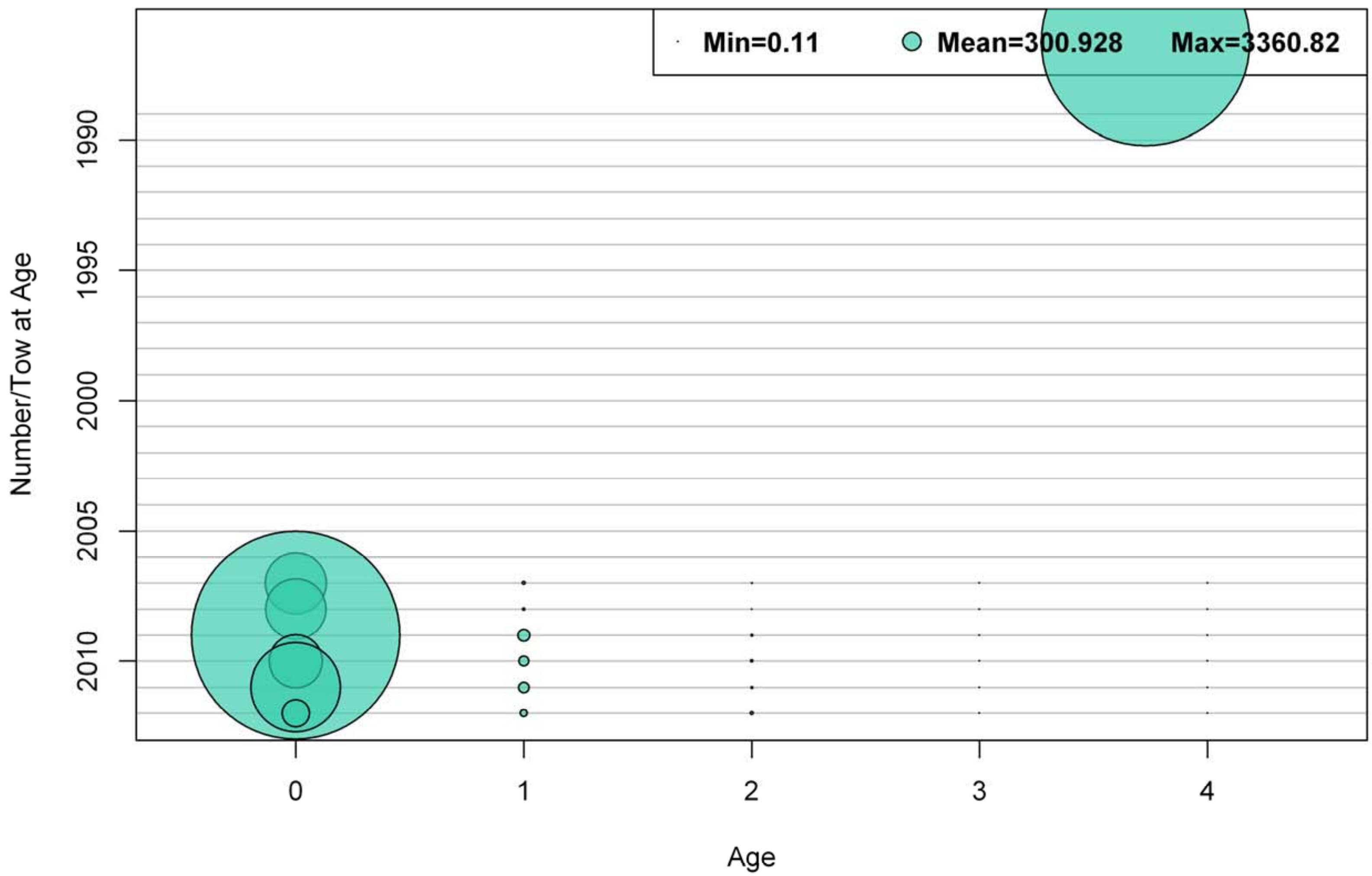


**Figure 24. Age composition of butterfish (*Peprilus triacanthus*) in Northeast Area Monitoring and Assessment Program (NEAMAP) fall surveys, 2007–2012.**

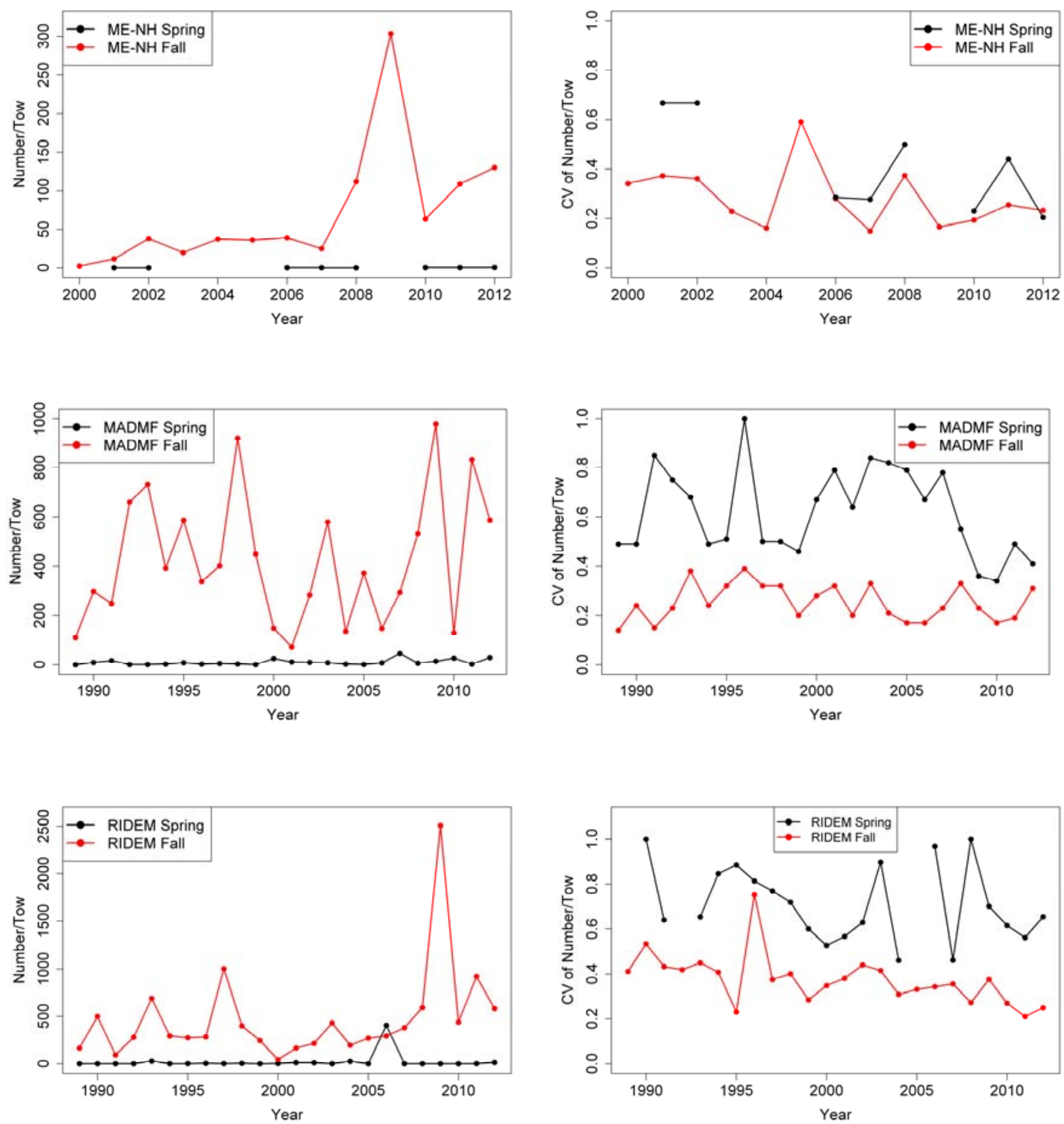


**Figure 25. Mean number per tow (left column) for butterfish (*Peprilus triacanthus*) and coefficient of variation (right column) for the Maine-New Hampshire (ME-NH) (top row), Massachusetts Division of Marine Fisheries (MADMF) (middle row), and Rhode Island Department of Environmental Management (RIDEM) (bottom row) surveys.**

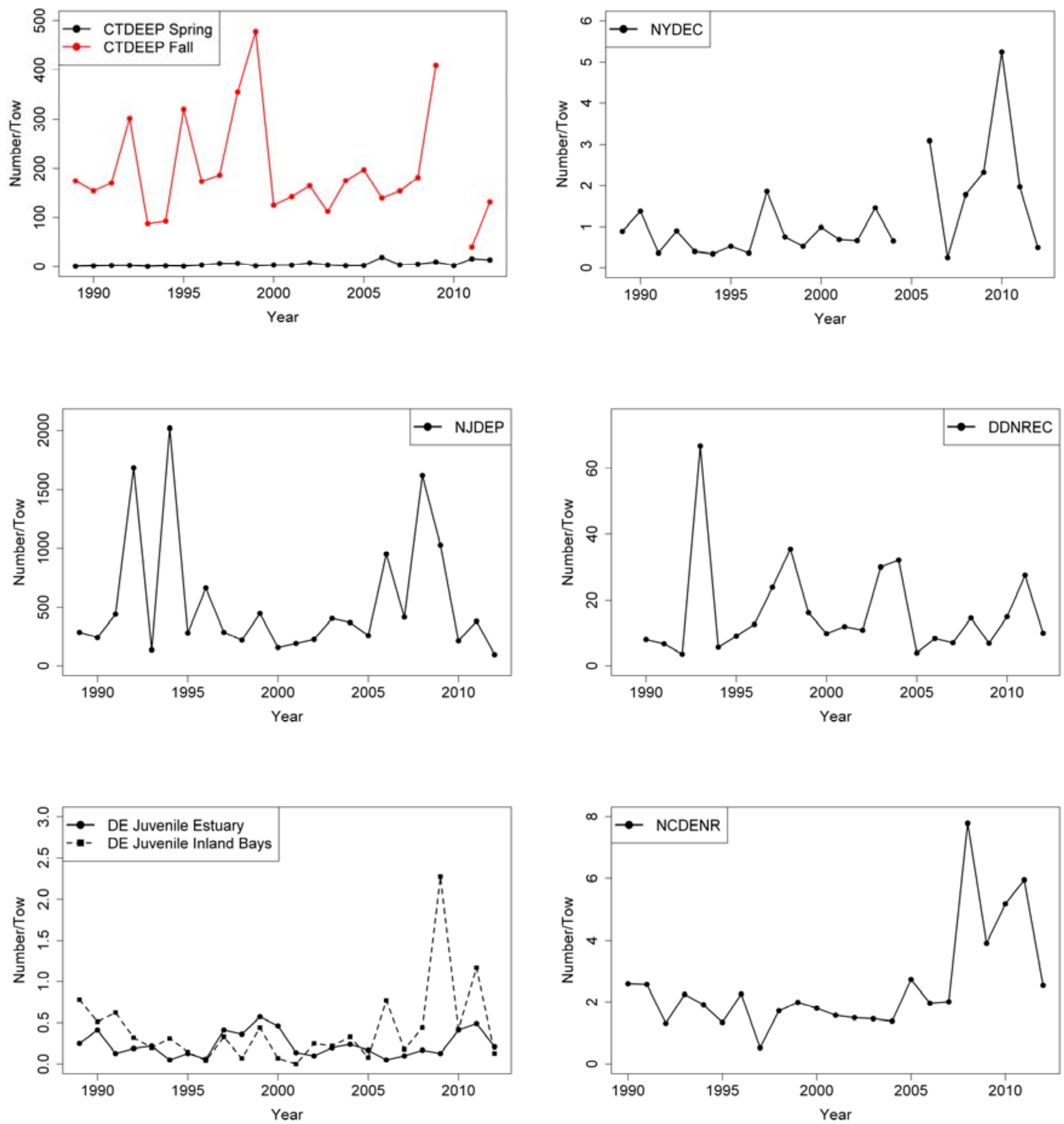


**Figure 26. Mean number per tow for butterfish (*Peprilus triacanthus*) the Connecticut Department of Energy and Environmental Protection (CTDEEP) (upper left), New York State Department of Environmental Conservation (NYSDEC) Peconic Bay (upper right), New Jersey Division of Fish and Wildlife (NJDEP) (middle left), Delaware Department of Natural Resources and Environmental Control (DDNREC) (middle right), DDNREC juvenile (bottom left), and North Carolina Department of Environment and Natural Resources (NCDENR) Pamlico Sound (bottom right) surveys. CTDEEP is the geometric mean. All others are annual means.**

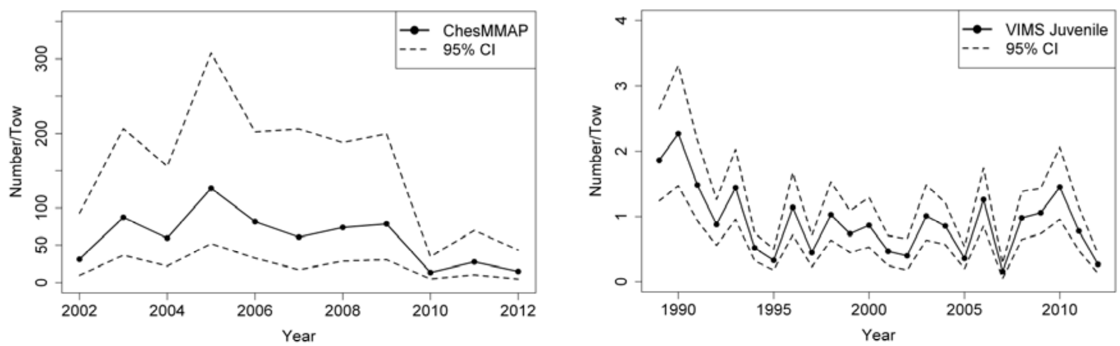


**Figure 27. Geometric mean number per tow for butterfish (*Peprilus triacanthus*) and 95% confidence interval for the Chesapeake Bay Multispecies Monitoring and Assessment Program (ChesMMAP) (right) and Virginia Institute of Marine Science (VIMS) juvenile (left) surveys.**

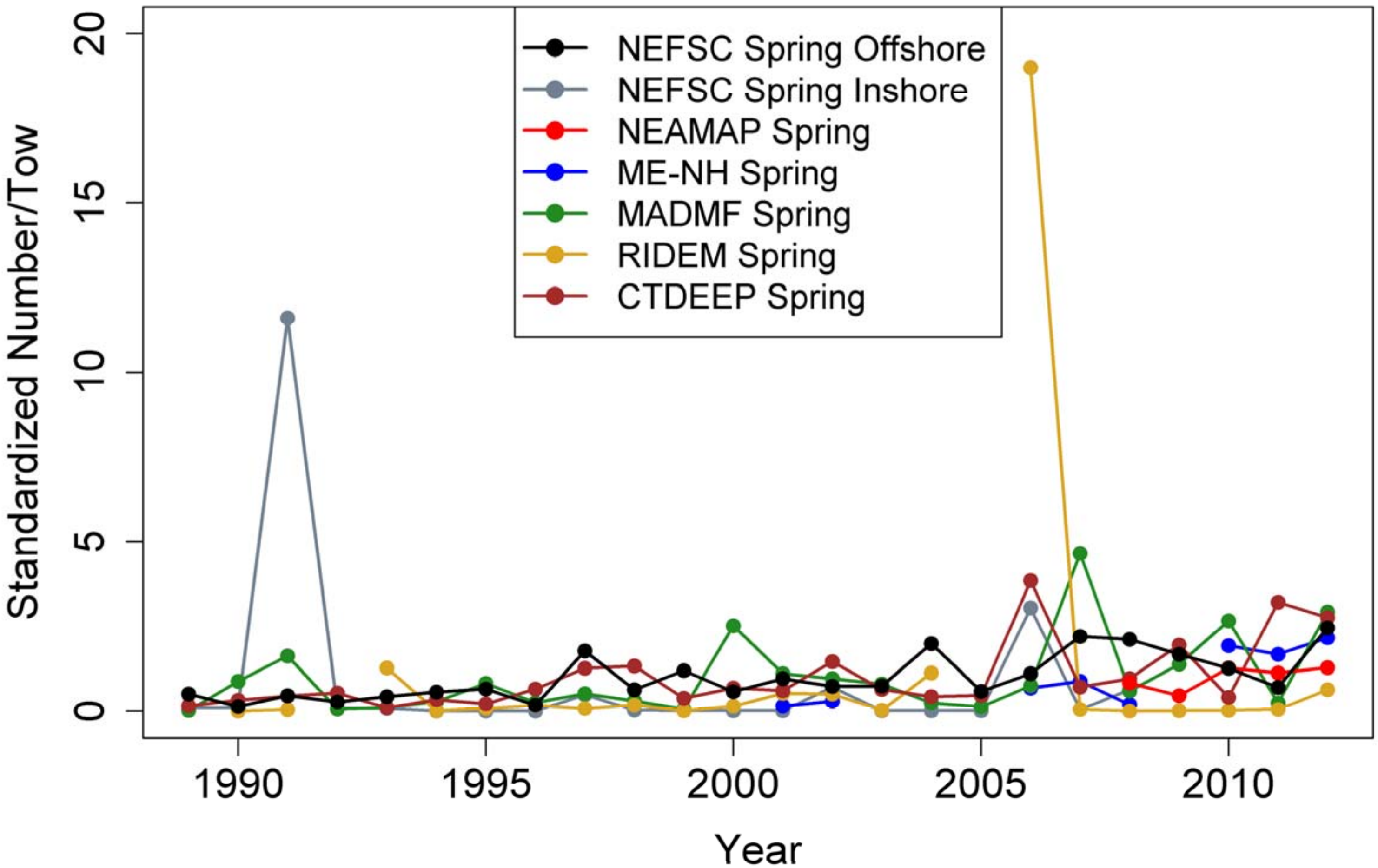


**Figure 28. Butterfish (*Peprilus triacanthus*) mean number per tow for Northeast Fisheries Science Center (NEFSC), Northeast Area Monitoring and Assessment Program (NEAMAP), and state surveys in spring, standardized to the mean of the respective time series. ME-NH = Maine New Hampshire, MADMF = Massachusetts Division of Marine Fisheries, RIDEM = Rhode Island Department of Environmental Management, CTDEEP = Connecticut Department of Energy and Environmental Protection.**

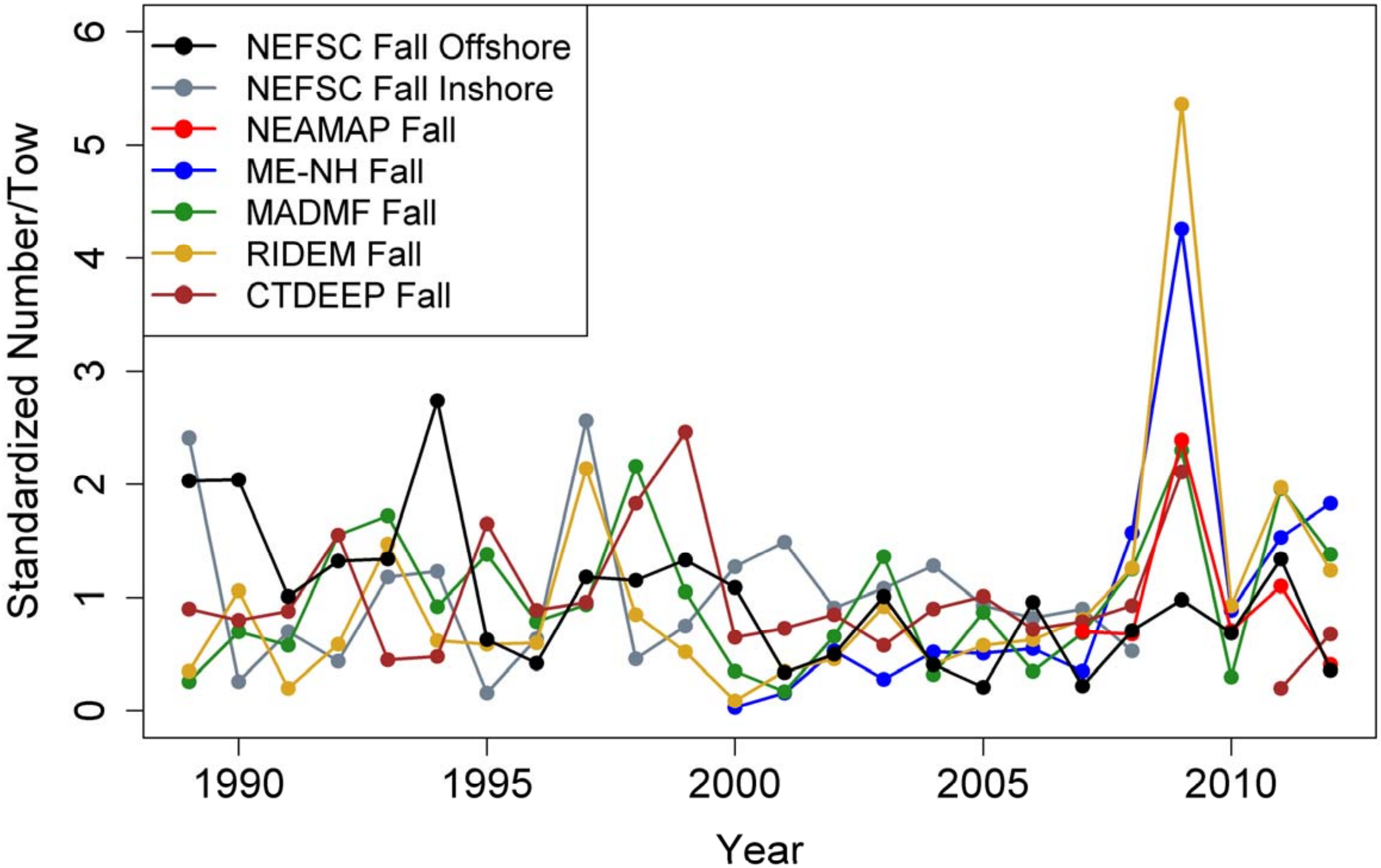


**Figure 29. Butterfish (*Peprilus triacanthus*) mean number per tow for Northeast Fisheries Science Center (NEFSC), Northeast Area Monitoring and Assessment Program (NEAMAP), and state surveys in fall, standardized to the mean of the respective time series. ME-NH = Maine New Hampshire, MADMF = Massachusetts Division of Marine Fisheries, RIDEM = Rhode Island Department of Environmental Management, CTDEEP = Connecticut Department of Energy and Environmental Protection.**

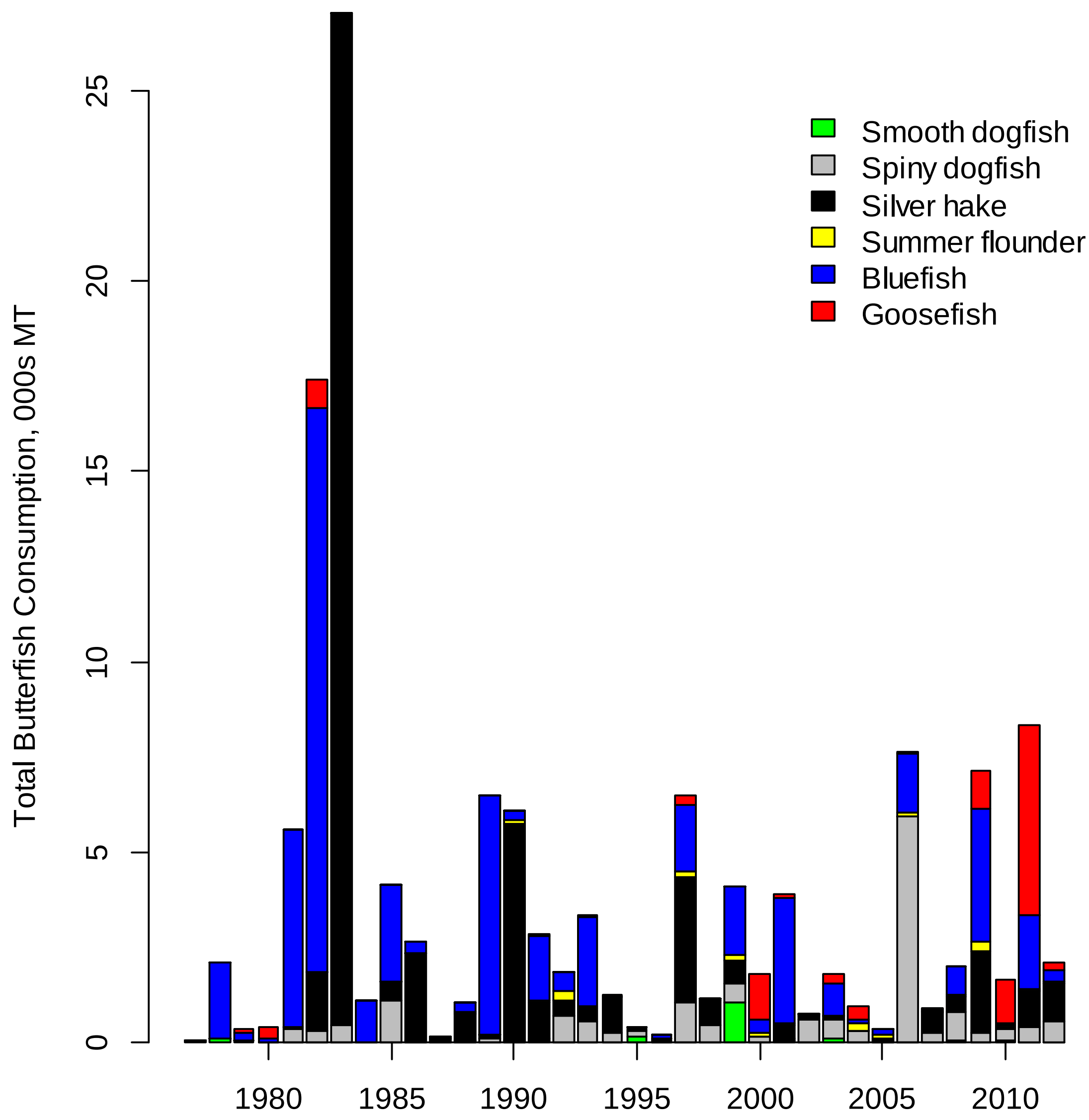


**Figure 30. Total consumption by the top 6 finfish predators of butterfish (*Peprilus triacanthus*), 1977–2012: Smooth dogfish (*Mustelus canis*), Spiny dogfish (*Squalus acanthias*), Silver hake (*Merluccius bilinearis*), Summer flounder (*Paralichthys dentatus*), Bluefish (*Pomatomus saltatrix*), Goosefish (*Lophius americanus*).**

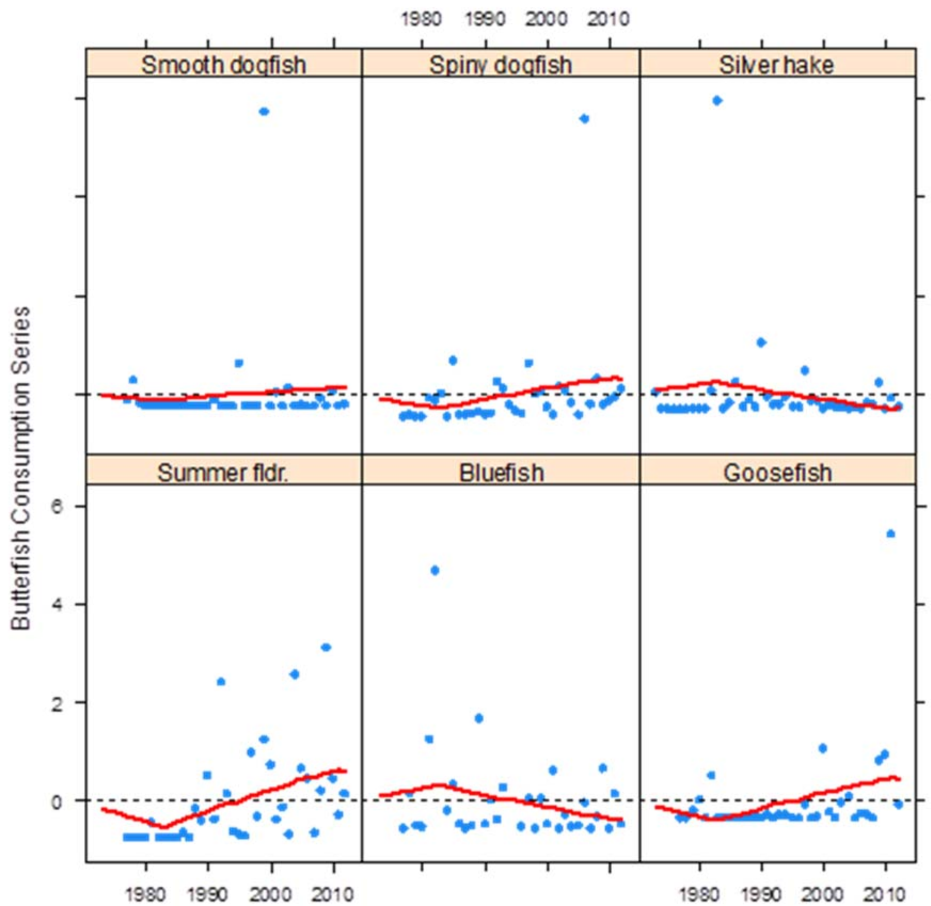


**Figure 31. Fitted values (red lines) for annual butterfish (*Peprilus triacanthus*) consumption data by predator (blue dots). Chosen model contains 1 trend and a diagonal and equal covariance matrix. Data were transformed with mean = 0 and standard deviation = 1.**

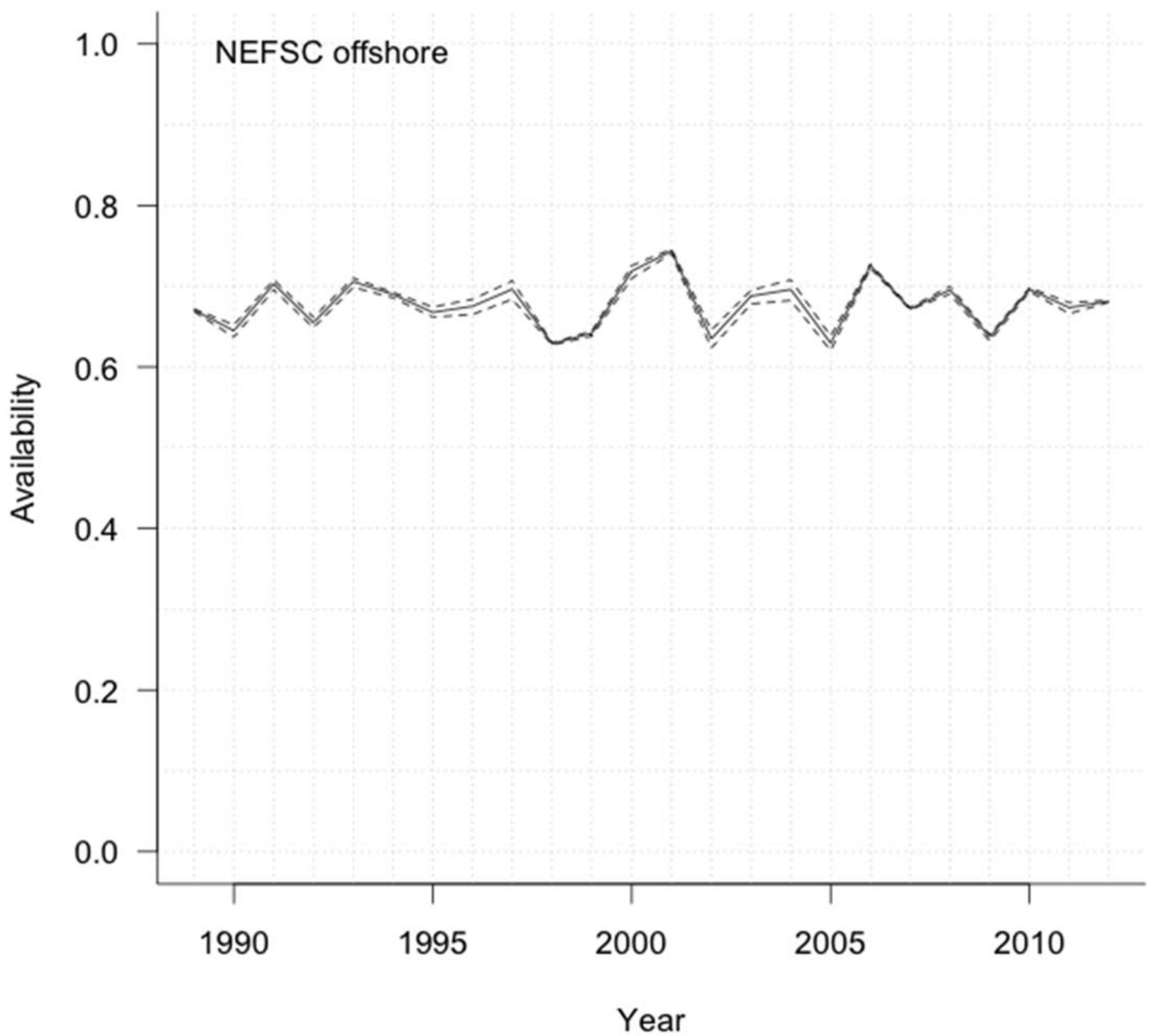


**Figure 32. Availability of butterfish (*Peprilus triacanthus*) to the Northeast Fisheries Science Center (NEFSC) offshore survey, 1989–2012. Solid line indicates availability *A*, while dashed lines show the 95% confidence interval. Median *A* = 0.68, with range from 0.62 to 0.75.**

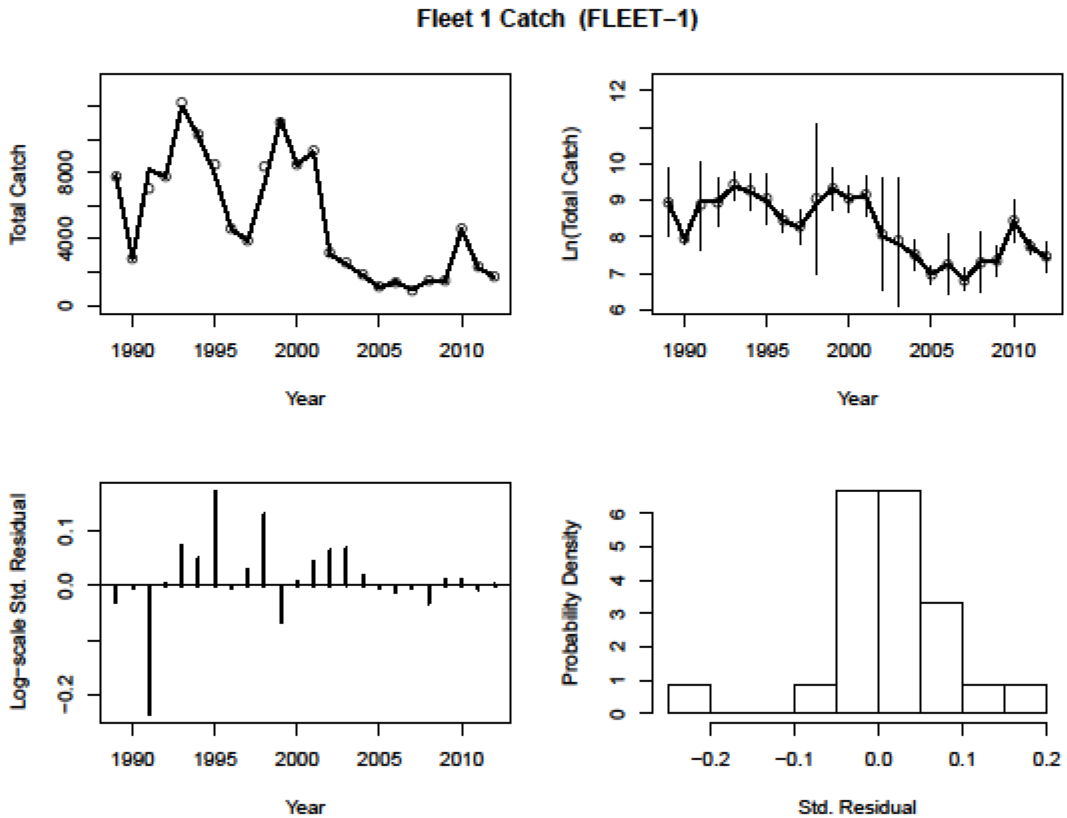


**Figure 33. Diagnostics for aggregate catch from the final model.**

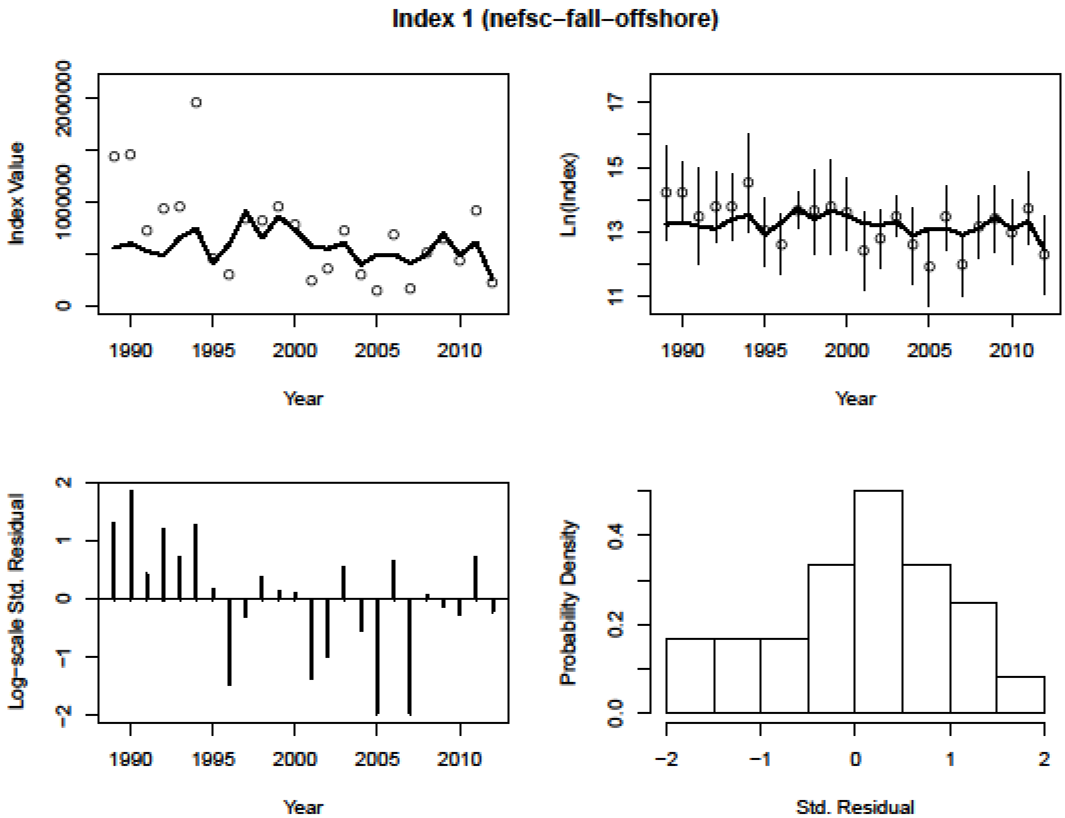


**Figure 34. Diagnostics for the Northeast Fisheries Science Center (NEFSC) fall offshore survey from the final model.**

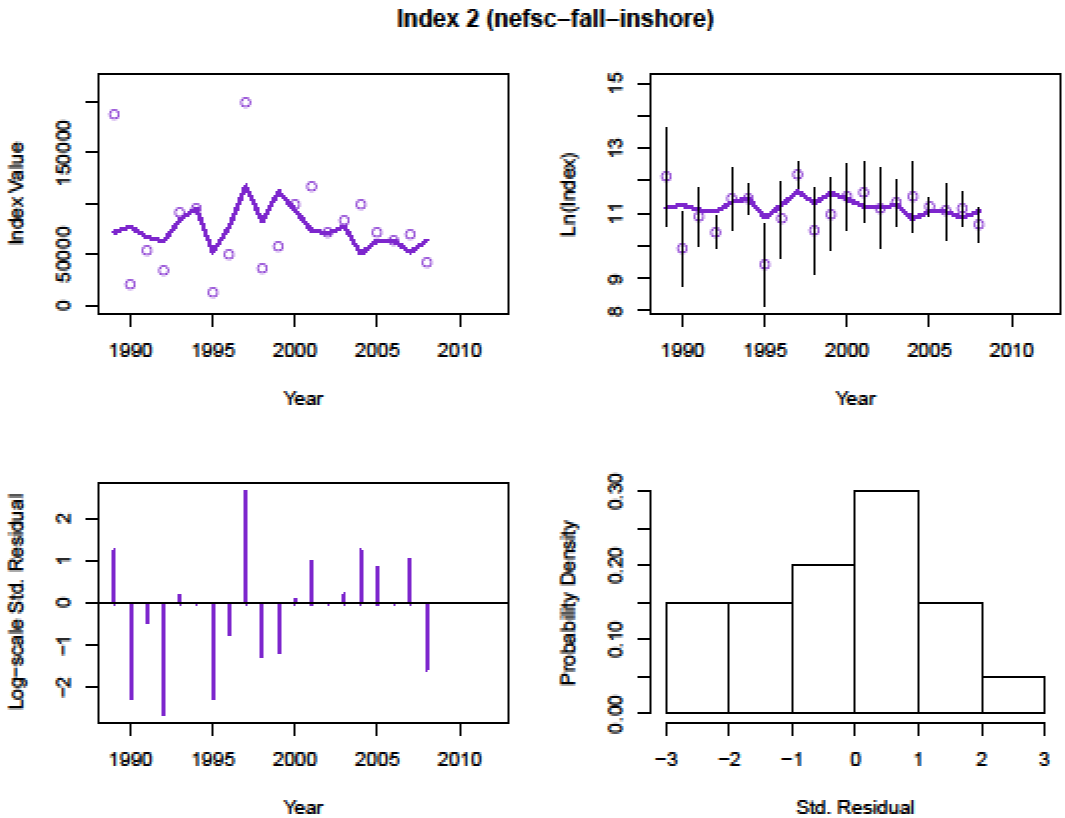


**Figure 35. Diagnostics for the Northeast Fisheries Science Center (NEFSC) fall inshore survey from the final model.**

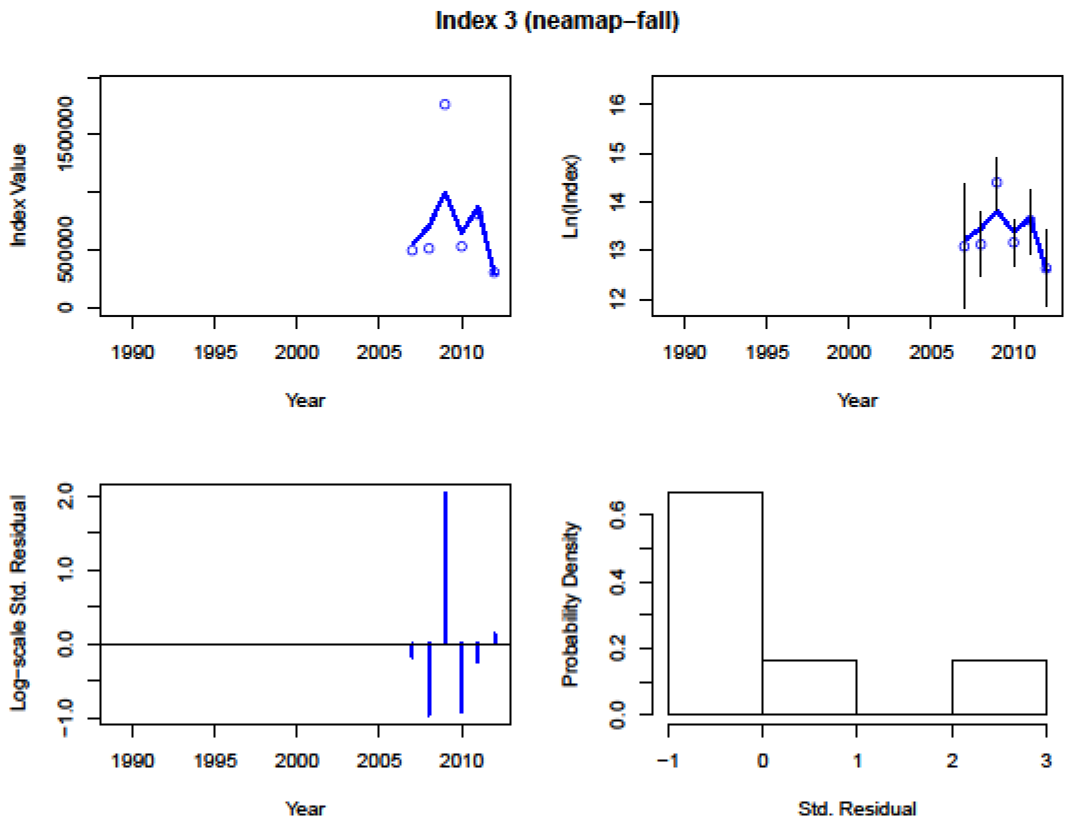


**Figure 36. Diagnostics for the Northeast Area Monitoring and Assessment Program (NEAMAP) fall survey from the final model.**

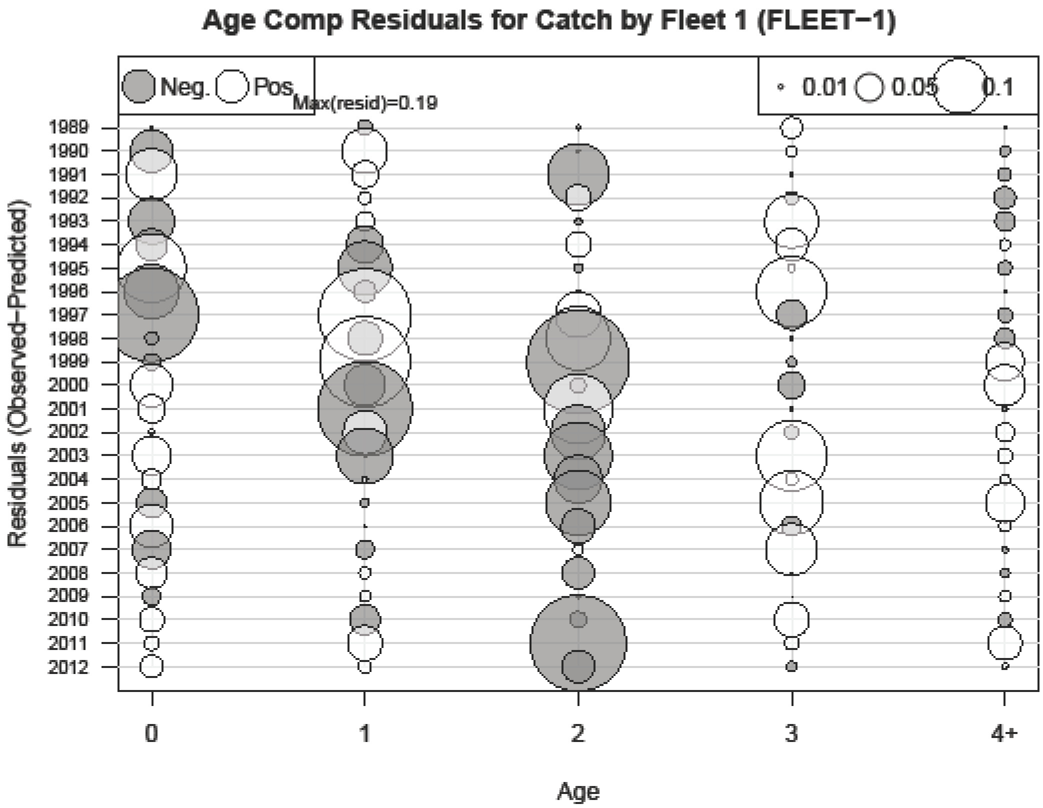


**Figure 37. Residuals for catch age composition from the final model.**

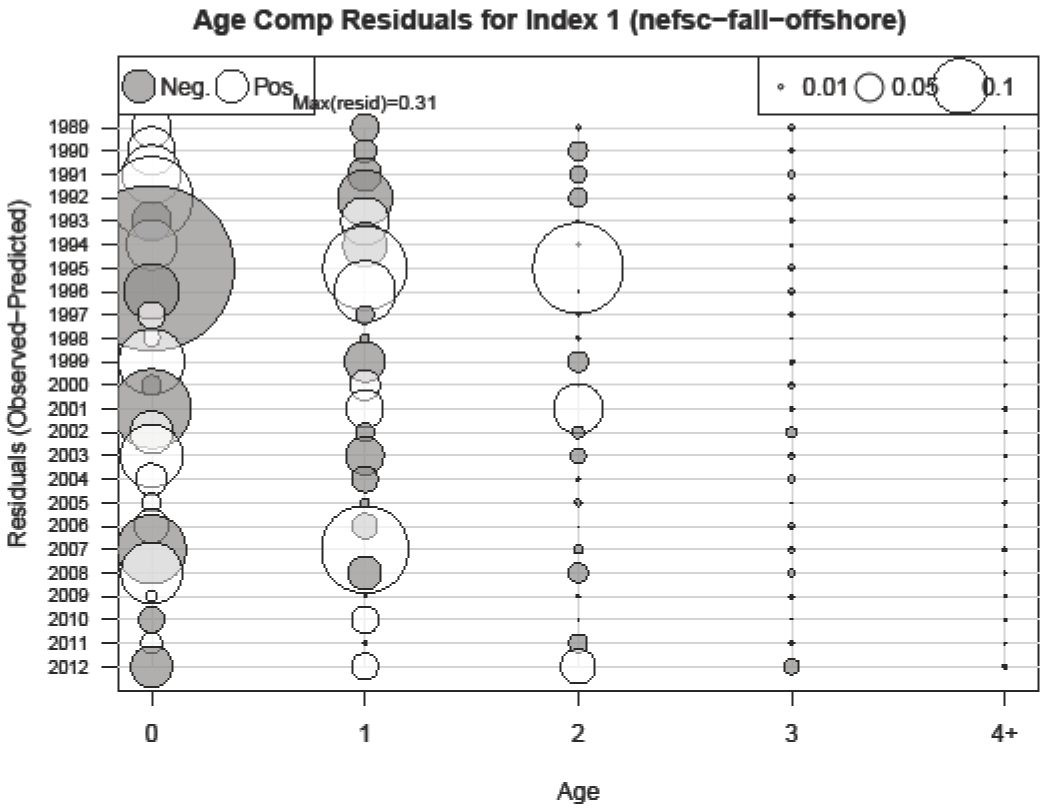


**Figure 38. Residuals for Northeast Fisheries Science Center (NEFSC) fall offshore age composition from the final model.**


**Figure 39. Residuals for Northeast Fisheries Science Center (NEFSC) fall inshore age composition from the final model.**

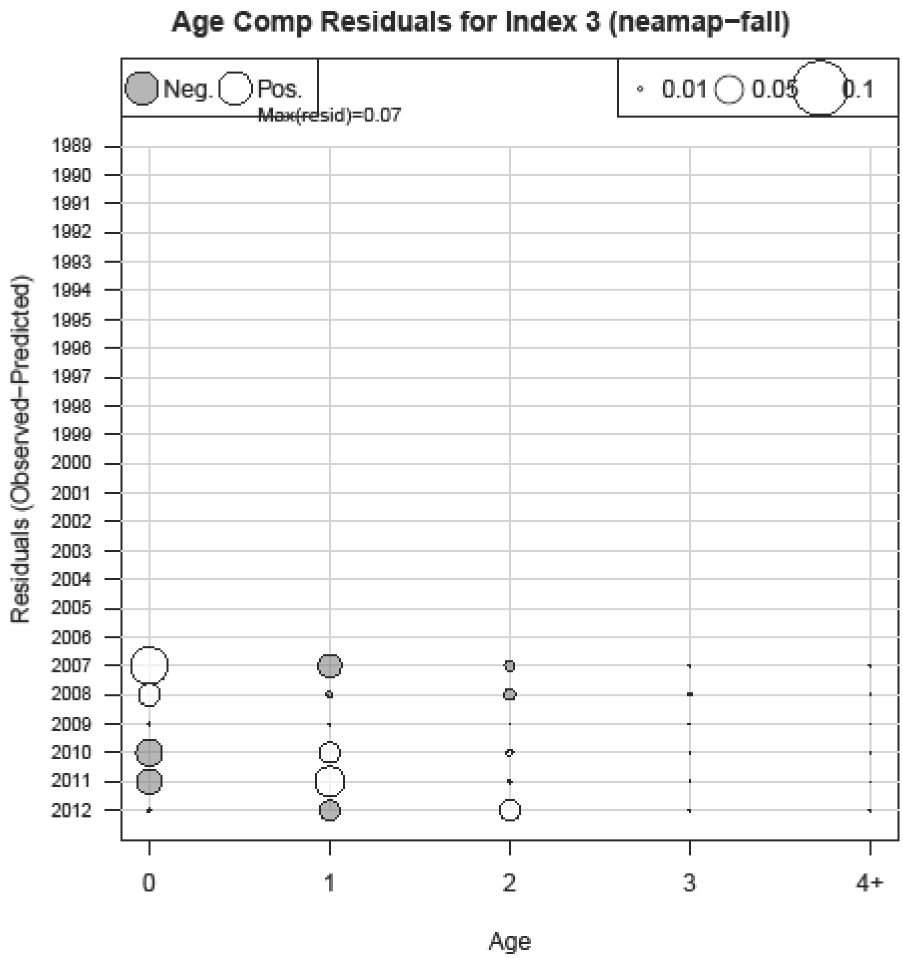


**Figure 40. Residuals for Northeast Area Monitoring and Assessment Program (NEAMAP) fall age composition from the final model.**

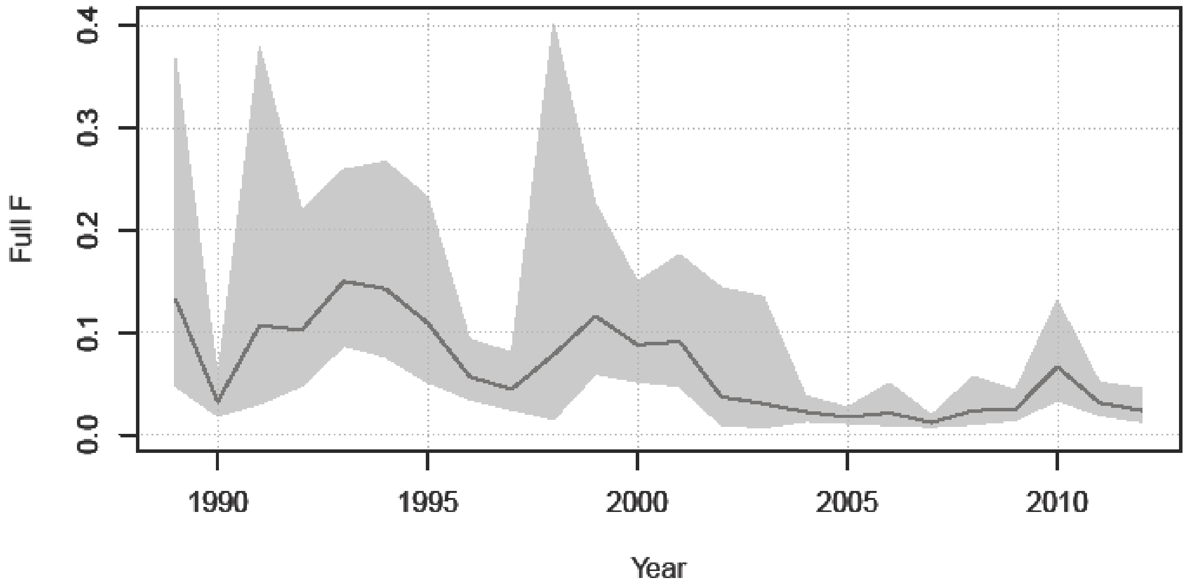


**Figure 41. Estimated fully selected fishing mortality (F) rate and 95% confidence interval from the final model.**


**Figure 42. Fleet selectivity at age from the final model.**

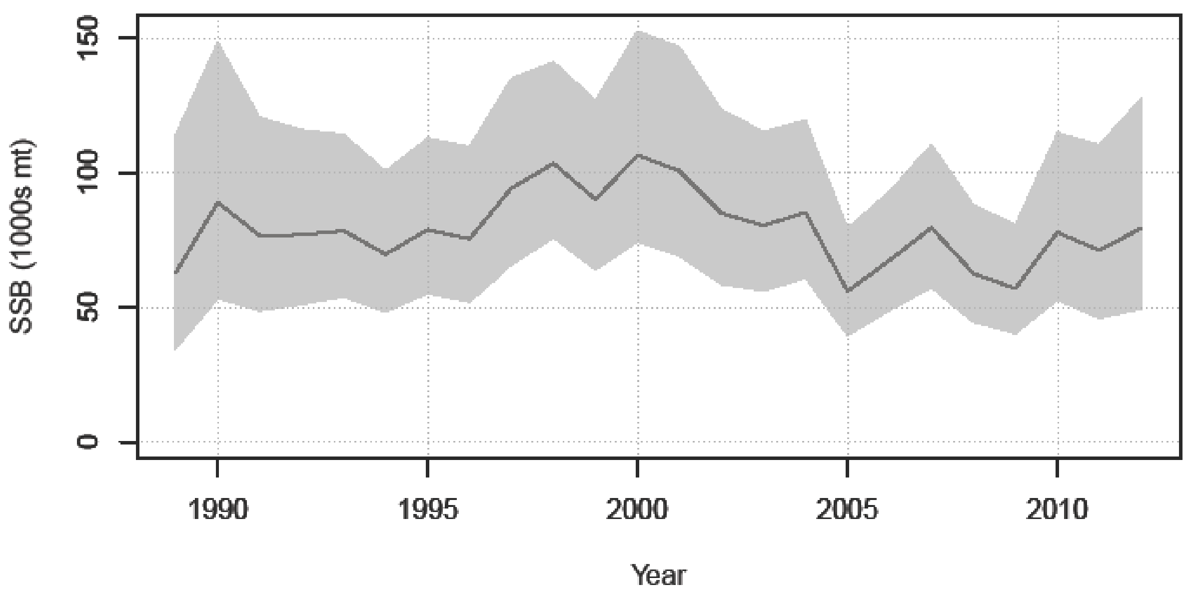


**Figure 43. Estimated spawning biomass and 95% confidence interval from the final model.**

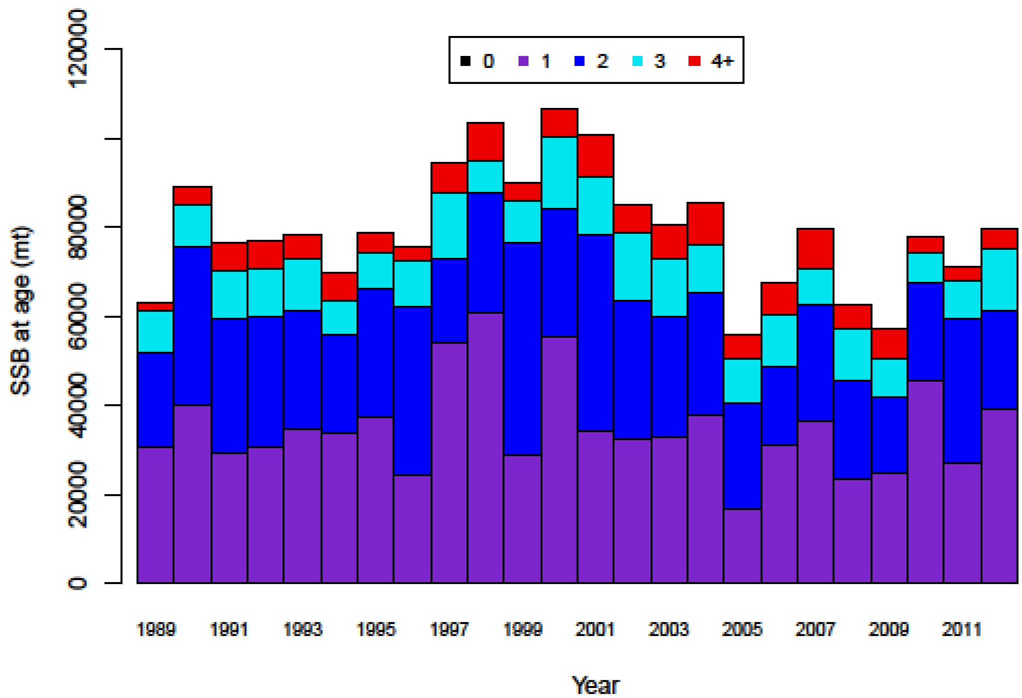


**Figure 44. Estimated annual spawning biomass at age (0, 1, 2, 3, 4+) from the final model.**

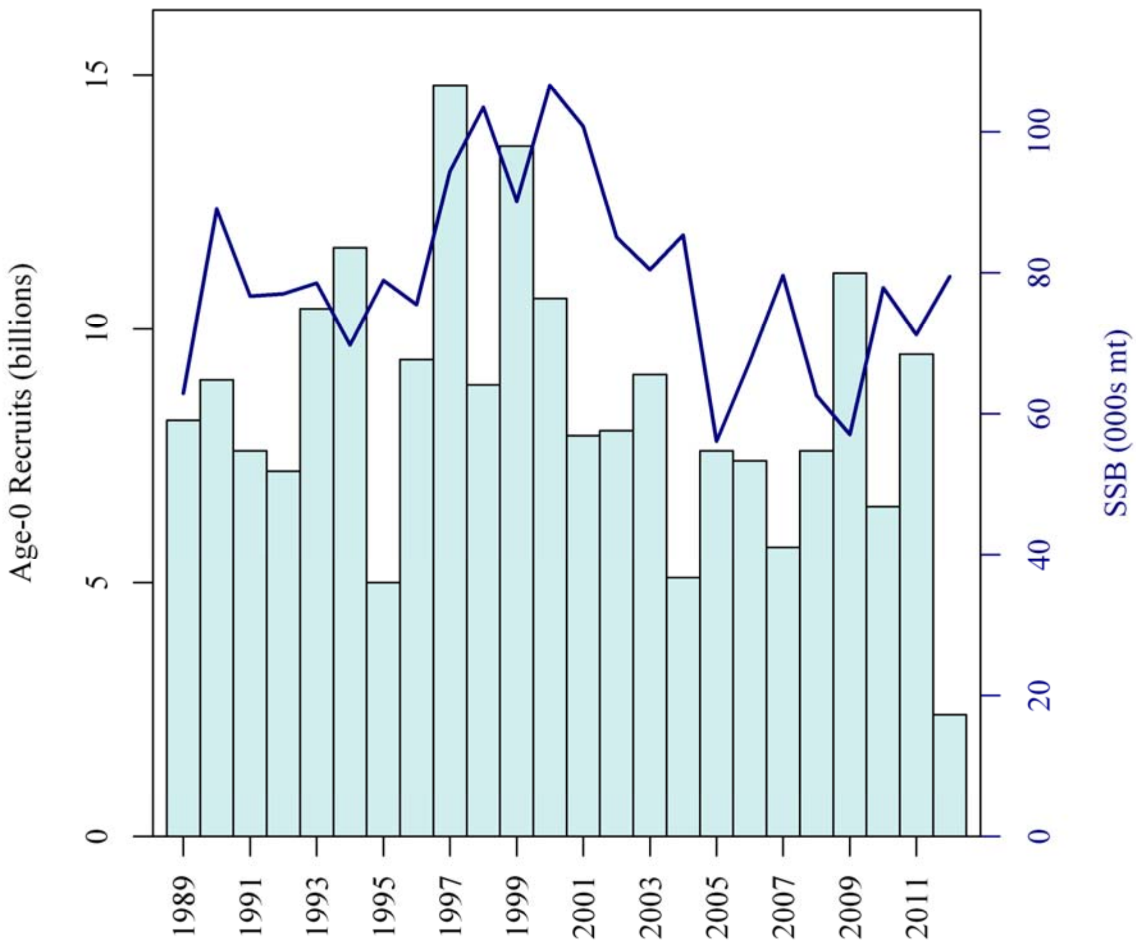


**Figure 45. Butterfish (*Peprilus triacanthus*) recruitment (vertical bars), and the spawning stock biomass (SSB) (blue line) that produced the corresponding recruitment. Year refers to spawning year.**

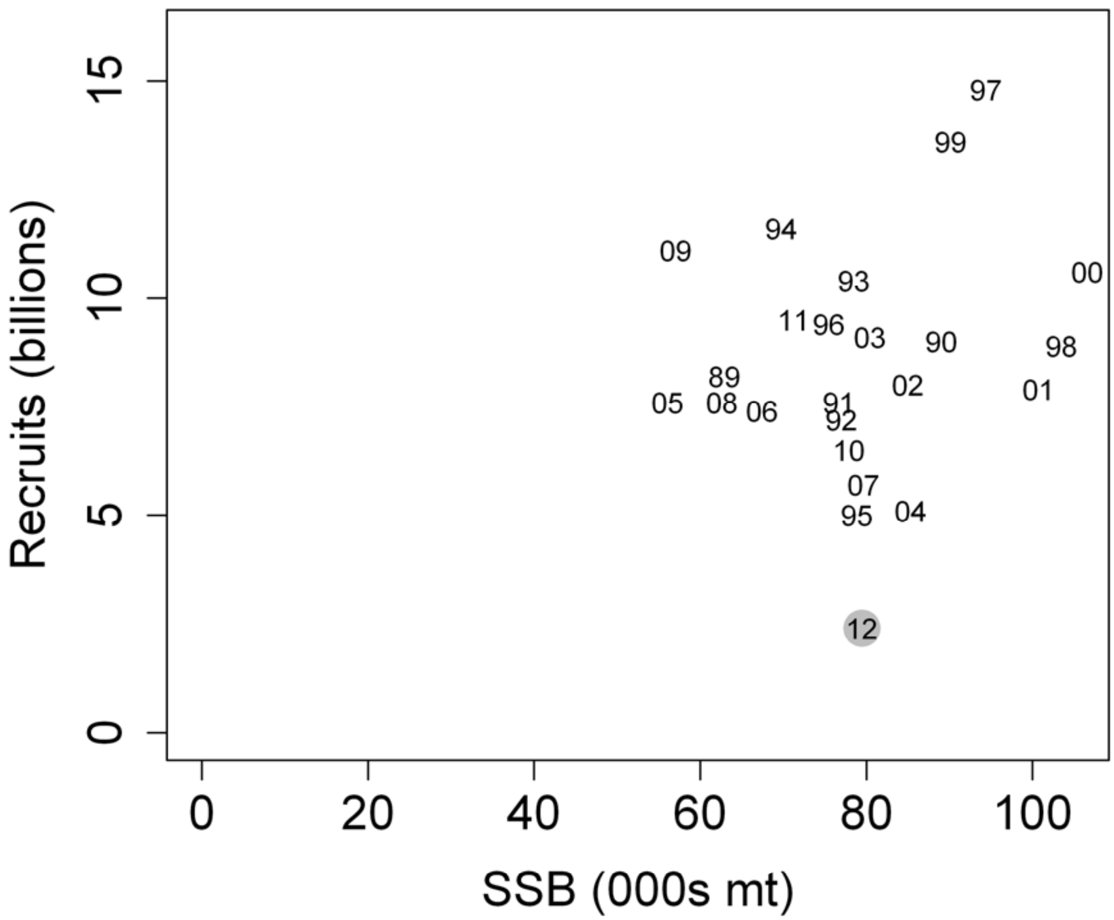


**Figure 46. Butterfish (*Peprilus triacanthus*) stock-recruitment scatter plot, with two digit indicator of model year.**

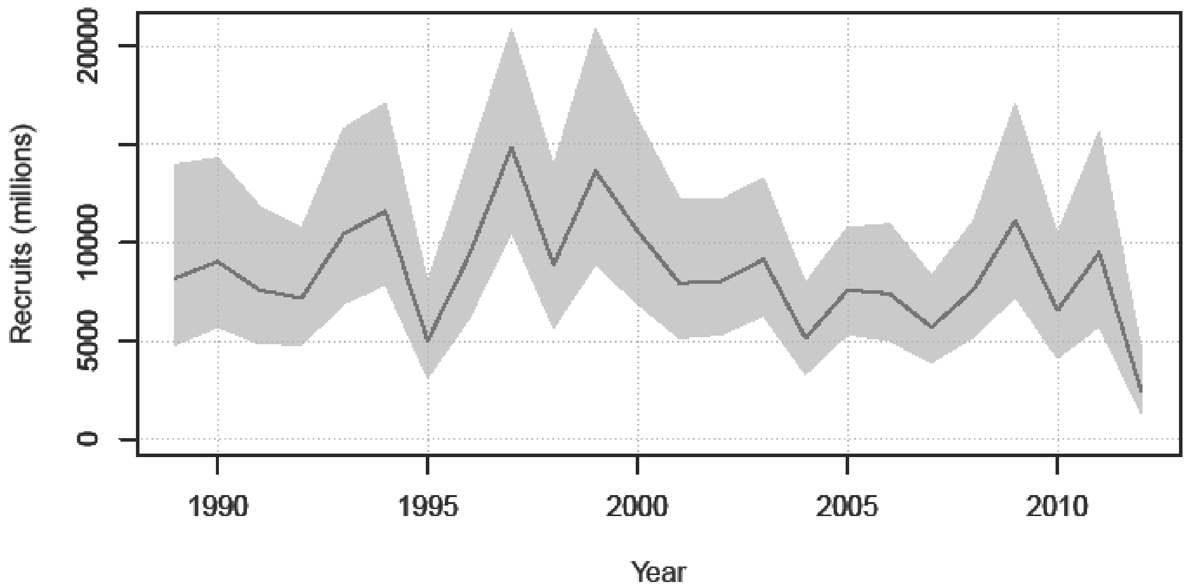


**Figure 47. Estimated recruitment and 95% confidence interval from the final age structured assessment program (ASAP) model.**

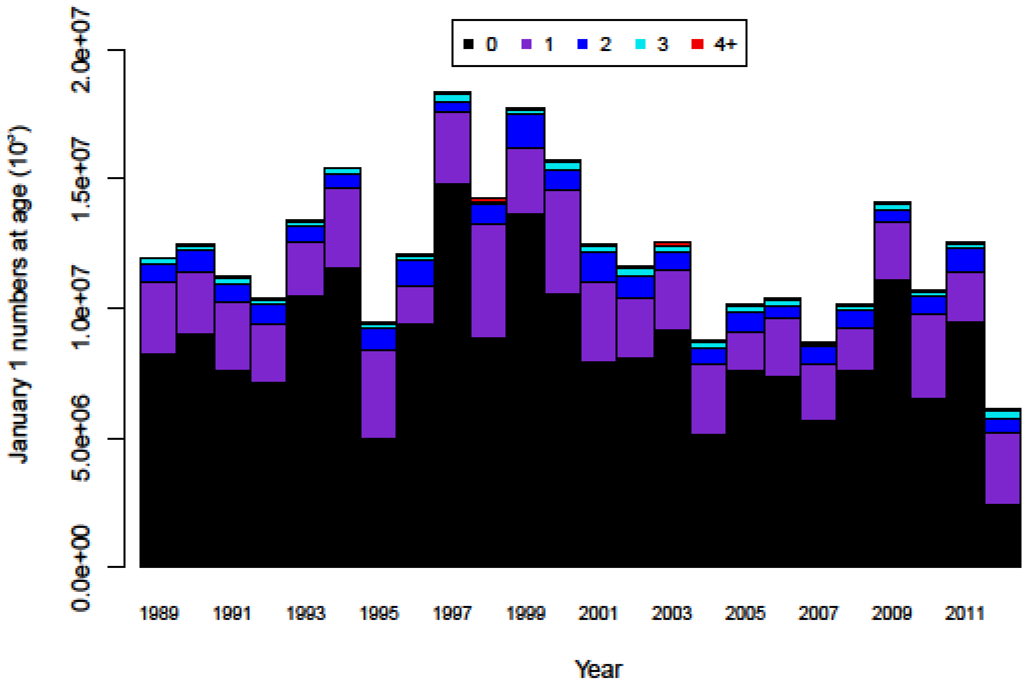


**Figure 48. Estimated numbers at age (0, 1, 2, 3, 4+) on January 1 from the final age structured assessment program (ASAP) model.**

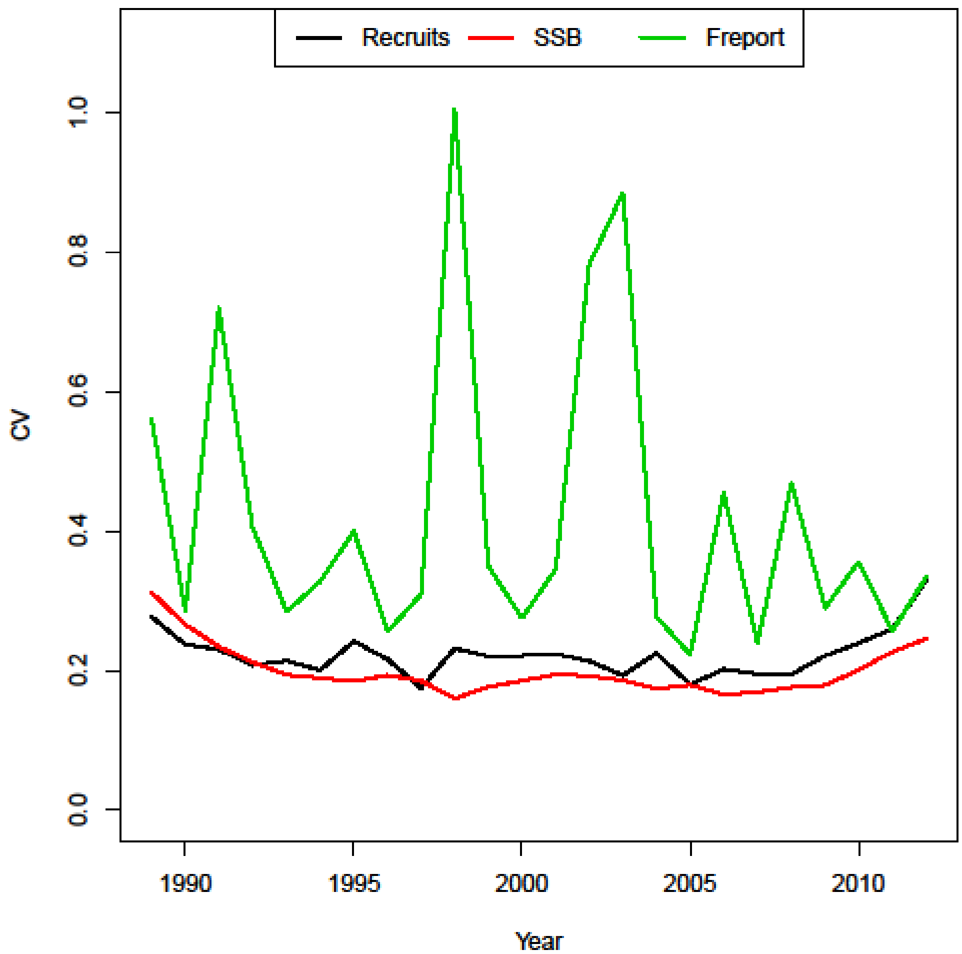


**Figure 49. Coefficients of variation for estimates of spawning stock biomass (SSB), recruits and fully selected fishing mortality from the final age structured assessment program (ASAP) model.**

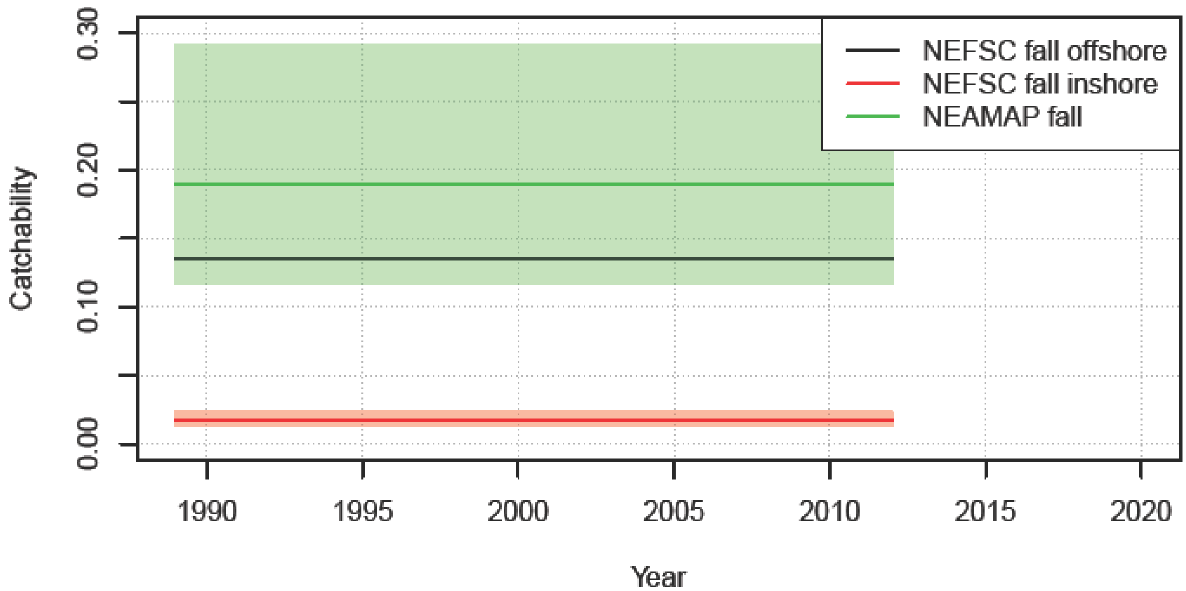


**Figure 50. Index catchability and 95% confidence interval from the final age structured assessment program (ASAP) model. NEFSC = Northeast Fisheries Science Center. NEAMAP = Northeast Area Monitoring and Assessment Program.**

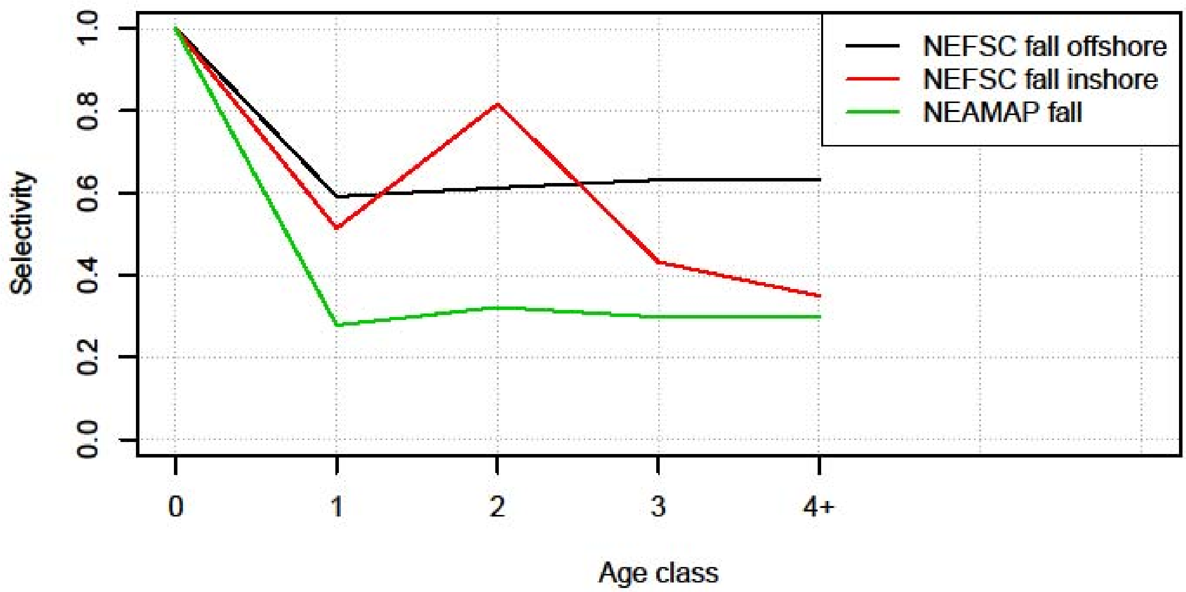


**Figure 51. Index selectivity from the final age structured assessment program (ASAP) model. NEFSC = Northeast Fisheries Science Center. NEAMAP = Northeast Area Monitoring and Assessment Program.**

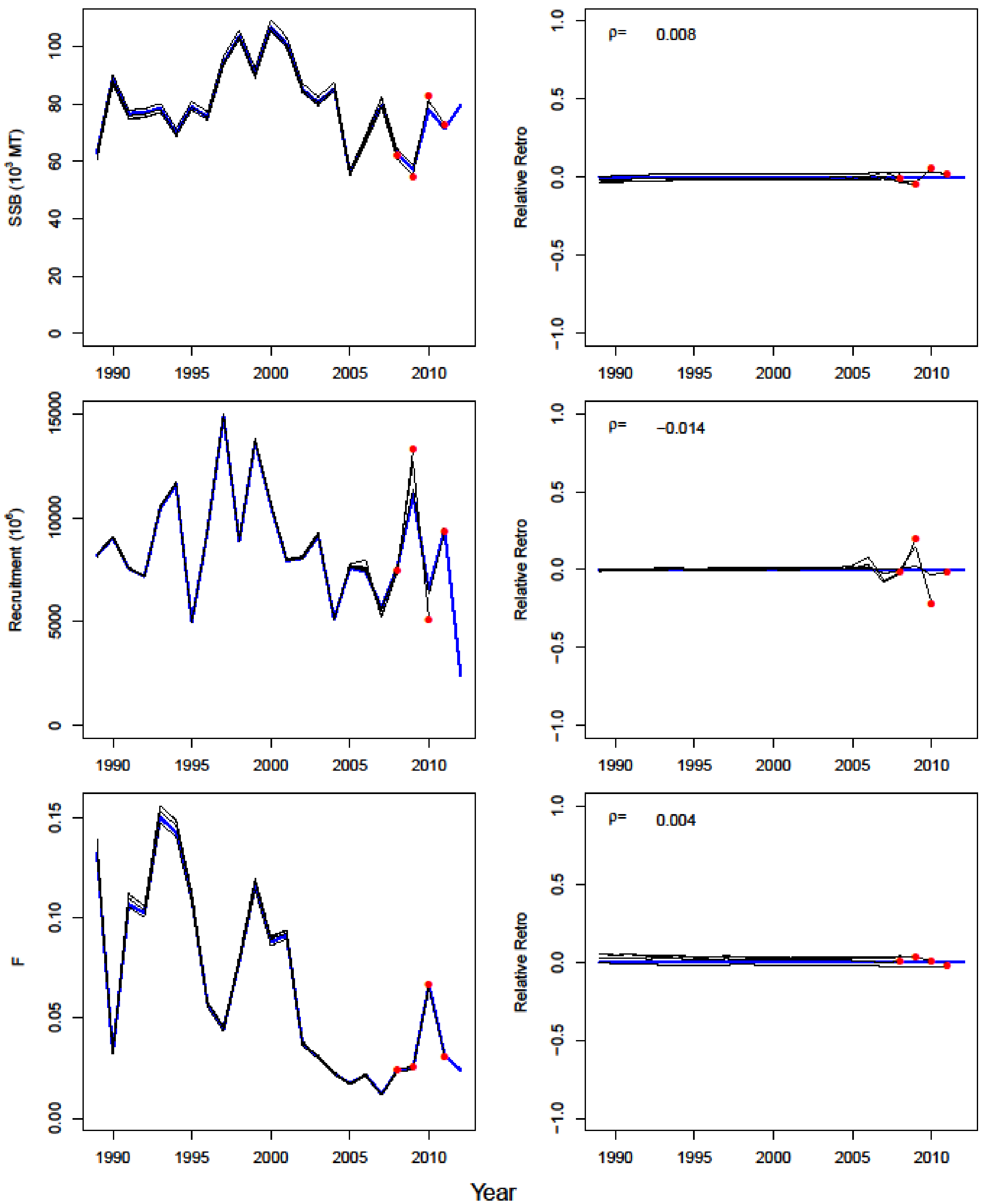


**Figure 52. Retrospective patterns for spawning biomass (SSB), recruitment, and fishing mortality (F) in the final age structured assessment program (ASAP) model. SSB = spawning stock biomass**

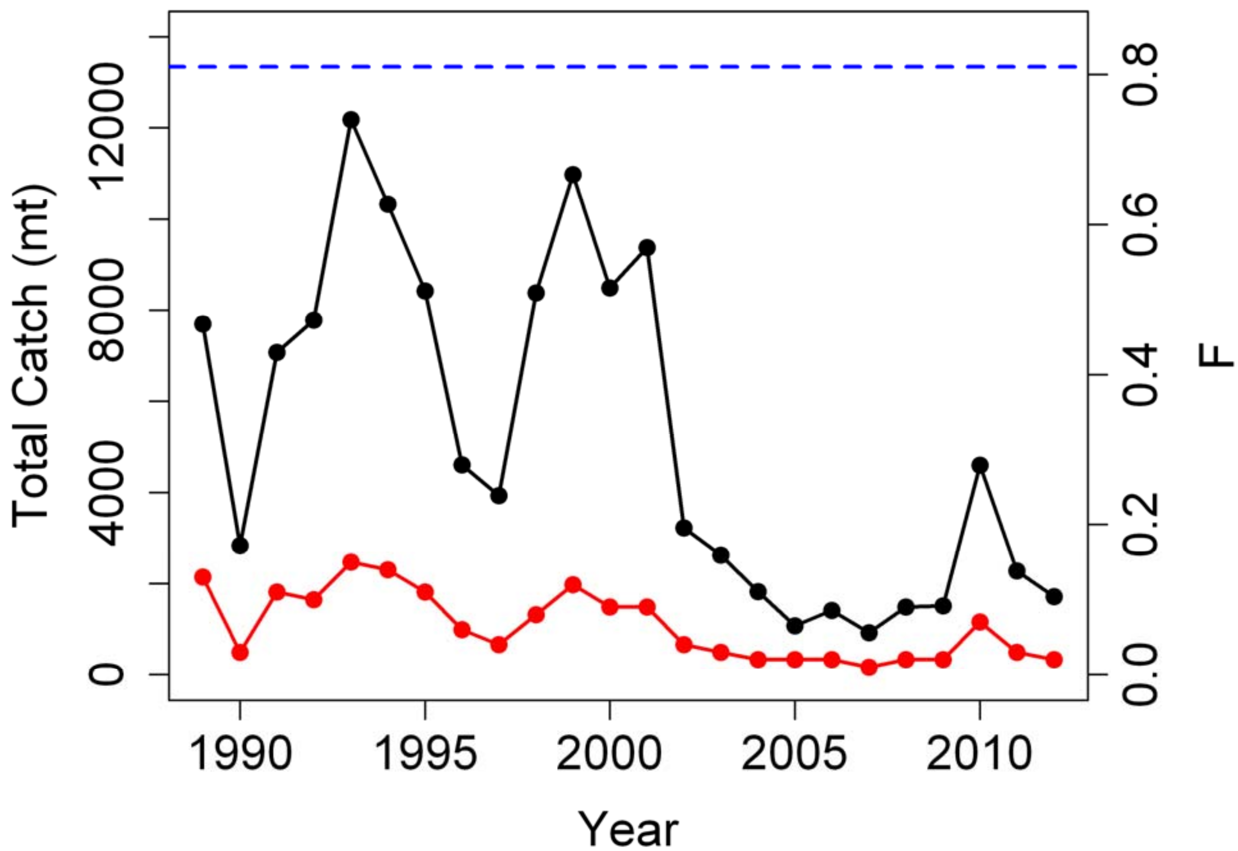


**Figure 53. Butterfish (*Peprilus triacanthus*) total catch (black line) and fishing mortality (F) (red line). Dashed blue line is the $F_{MSY}$ proxy = 0.81.**

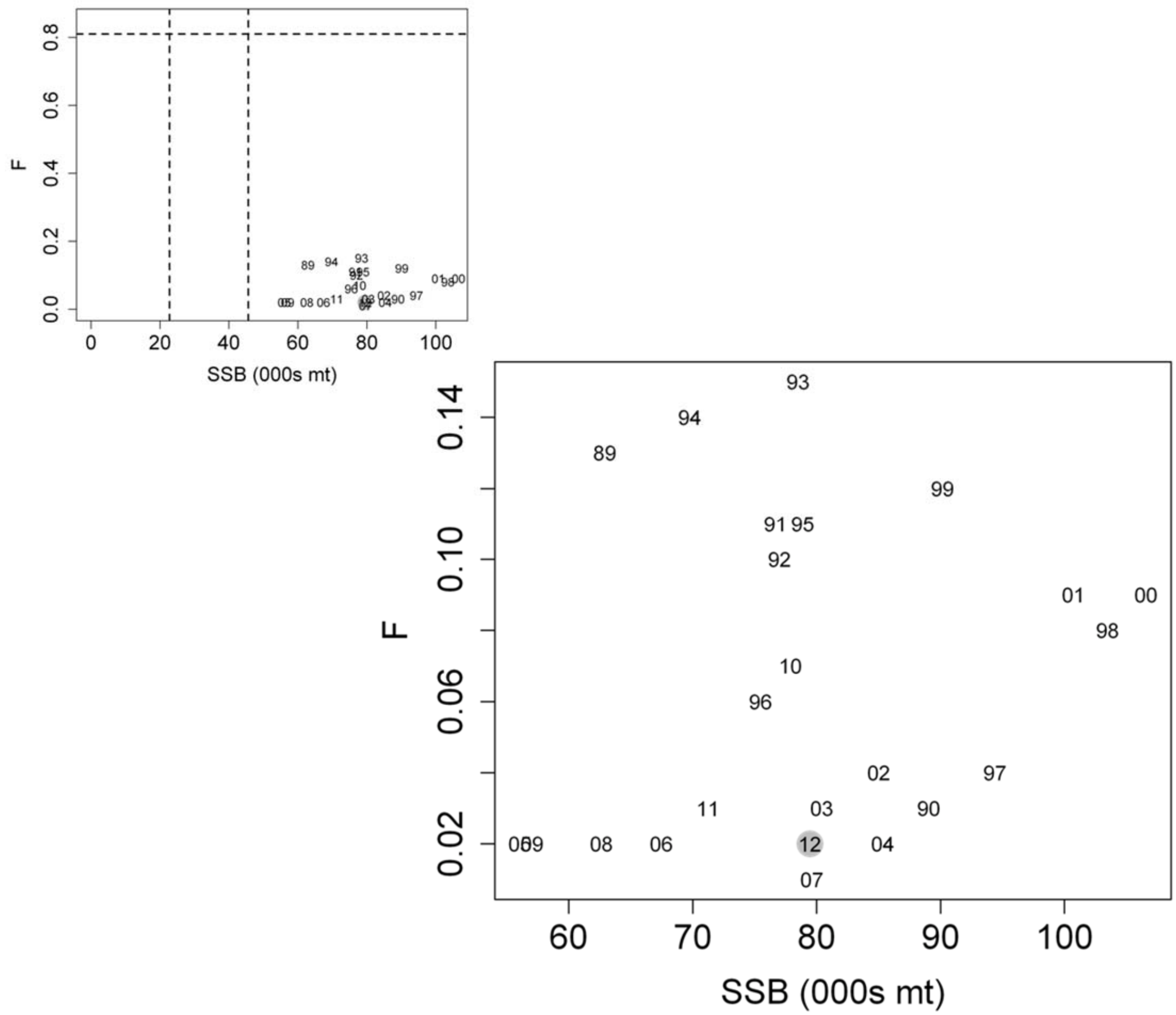


**Figure 54. Butterfish (*Peprilus triacanthus*) spawning stock biomass (SSB) and fishing mortality (F) relative to the biological reference points $SSB_{threshold}$ = 22,808 mt, $SSB_{MSY}$ proxy = 45,616 mt, and $F_{MSY}$ proxy = 0.81 (upper left panel). Plot is expanded for clarity in lower right panel.**

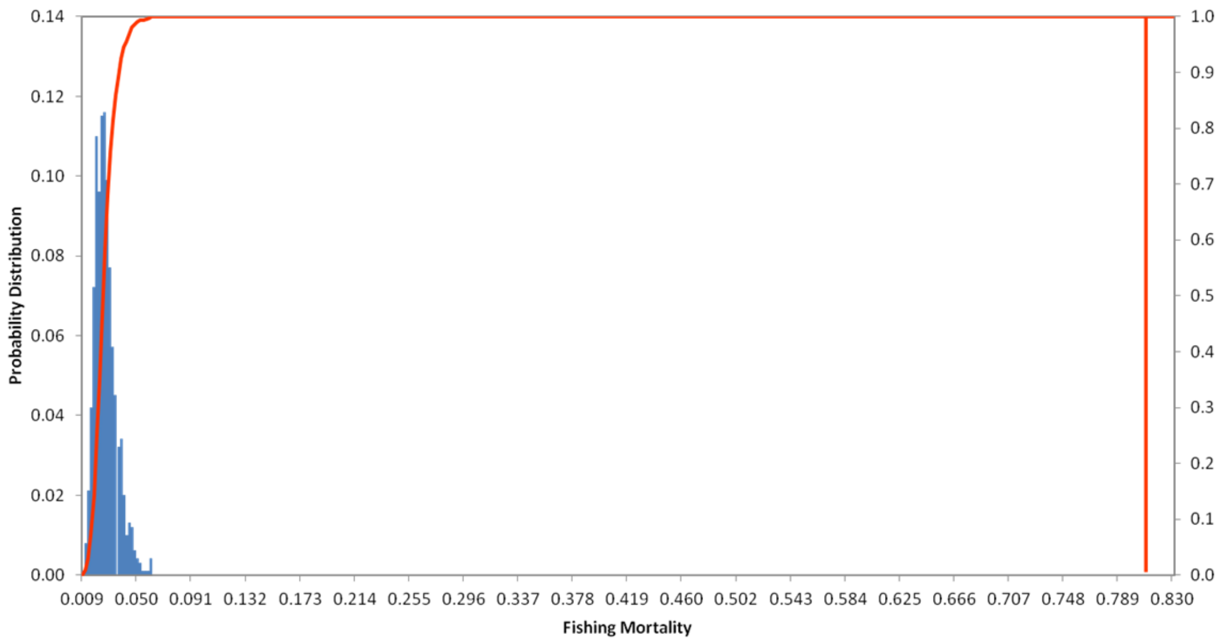


**Figure 55. Markov Chain Monte Carlo distribution plots for annual total fishing mortality (F). Vertical line shows $F_{MSY}$ proxy = 0.81.**

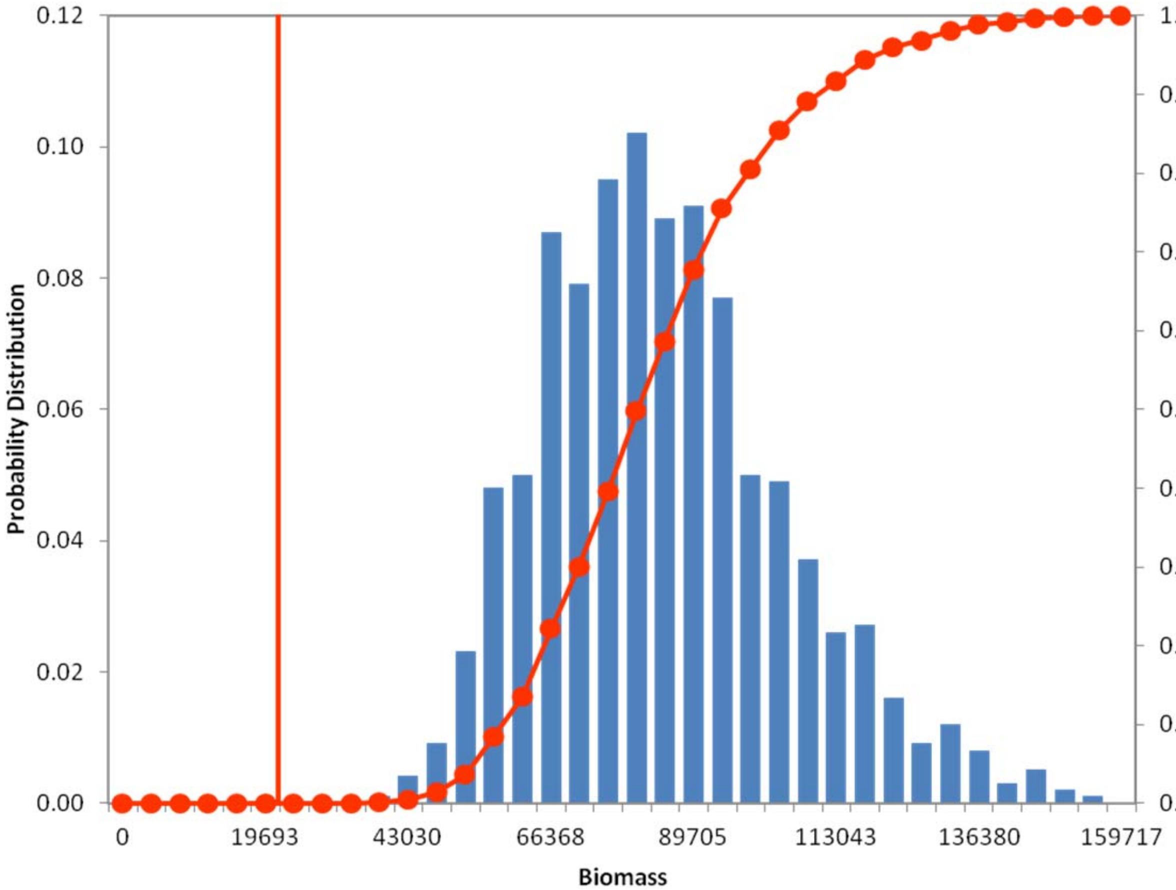


**Figure 56. Markov Chain Monte Carlo distribution plots for annual total spawning stock biomass (SSB). Vertical line shows $SSB_{threshold}$ = 22,808 mt.**

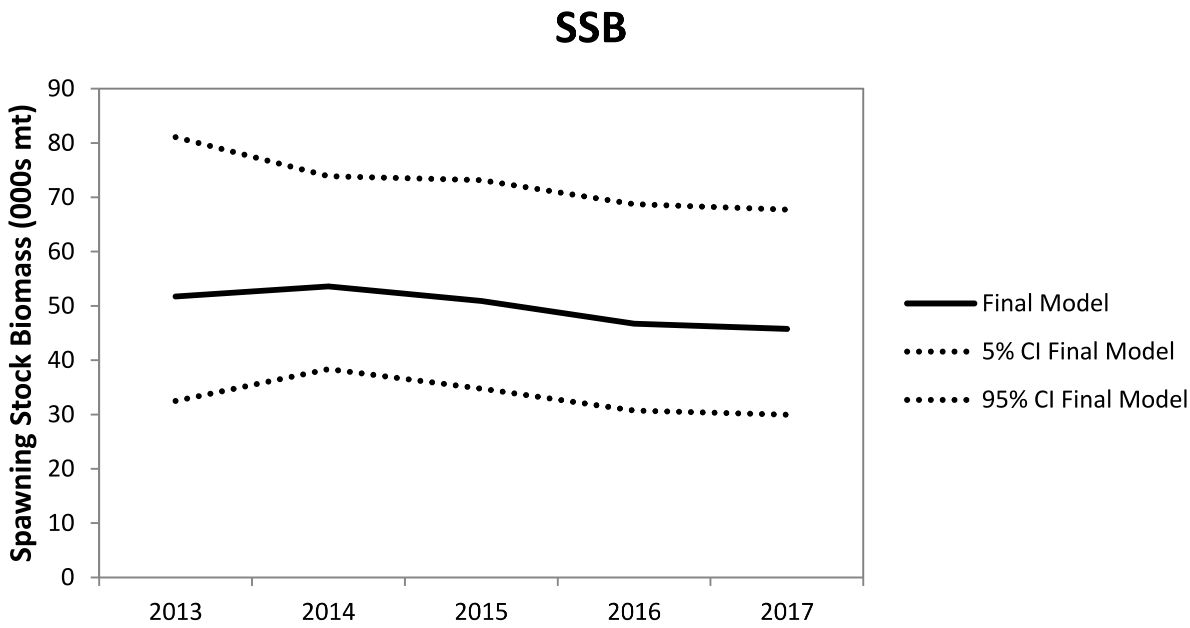


**Figure 57. Projection of median butterfish (*Peprilus triacanthus*) spawning stock biomass (SSB) and 95% confidence interval (CI) with preliminary 2013 catch (2,489 mt), 2014 ABC (9,100 mt), and $F_{MSY}$ proxy = 0.81 in 2015 and beyond.**

# Procedures for Issuing Manuscripts in the *Northeast Fisheries Science Center Reference Document* (CRD) Series

## Clearance

All manuscripts submitted for issuance as CRDs must have cleared the NEFSC's manuscript/abstract/webpage review process. If any author is not a federal employee, he/she will be required to sign an "NEFSC Release-of-Copyright Form." If your manuscript includes material from another work which has been copyrighted, then you will need to work with the NEFSC's Editorial Office to arrange for permission to use that material by securing release signatures on the "NEFSC Use-of-Copyrighted-Work Permission Form."

For more information, NEFSC authors should see the NEFSC's online publication policy manual, "Manuscript/abstract/webpage preparation, review, and dissemination: NEFSC author's guide to policy, process, and procedure," located in the Publications/Manuscript Review section of the NEFSC intranet page.

## Organization

Manuscripts must have an abstract and table of contents, and (if applicable) lists of figures and tables. As much as possible, use traditional scientific manuscript organization for sections: "Introduction," "Study Area" and/or "Experimental Apparatus," "Methods," "Results," "Discussion," "Conclusions," "Acknowledgments," and "Literature/References Cited."

## Style

The CRD series is obligated to conform with the style contained in the current edition of the United States Government Printing Office Style Manual. That style manual is silent on many aspects of scientific manuscripts. The CRD series relies more on the CSE Style Manual. Manuscripts should be prepared to conform with these style manuals.

The CRD series uses the American Fisheries Society's guides to names of fishes, mollusks, and decapod crustaceans, the Society for Marine Mammalogy's guide to names of marine mammals, the Biosciences Information Service's guide to serial title abbreviations, and the ISO's (International Standardization Organization) guide to statistical terms.

For in-text citation, use the name-date system. A special effort should be made to ensure that all necessary bibliographic information is included in the list of cited works. Personal communications must include date, full name, and full mailing address of the contact.

## Preparation

Once your document has cleared the review process, the Editorial Office will contact you with publication needs – for example, revised text (if necessary) and separate digital figures and tables if they are embedded in the document. Materials may be submitted to the Editorial Office as files on zip disks or CDs, email attachments, or intranet downloads. Text files should be in Microsoft Word, tables may be in Word or Excel, and graphics files may be in a variety of formats (JPG, GIF, Excel, PowerPoint, etc.).

## Production and Distribution

The Editorial Office will perform a copy-edit of the document and may request further revisions. The Editorial Office will develop the inside and outside front covers, the inside and outside back covers, and the title and bibliographic control pages of the document.

Once both the PDF (print) and Web versions of the CRD are ready, the Editorial Office will contact you to review both versions and submit corrections or changes before the document is posted online.

A number of organizations and individuals in the Northeast Region will be notified by e-mail of the availability of the document online.

**Research Communications Branch**
**Northeast Fisheries Science Center**
**National Marine Fisheries Service, NOAA**
**166 Water St.**
**Woods Hole, MA 02543-1026**

**MEDIA MAIL**

# Publications and Reports of the Northeast Fisheries Science Center

The mission of NOAA's National Marine Fisheries Service (NMFS) is "stewardship of living marine resources for the benefit of the nation through their science-based conservation and management and promotion of the health of their environment." As the research arm of the NMFS's Northeast Region, the Northeast Fisheries Science Center (NEFSC) supports the NMFS mission by "conducting ecosystem-based research and assessments of living marine resources, with a focus on the Northeast Shelf, to promote the recovery and long-term sustainability of these resources and to generate social and economic opportunities and benefits from their use." Results of NEFSC research are largely reported in primary scientific media (*e.g.*, anonymously-peer-reviewed scientific journals). However, to assist itself in providing data, information, and advice to its constituents, the NEFSC occasionally releases its results in its own media. Currently, there are three such media:

*NOAA Technical Memorandum NMFS-NE* -- This series is issued irregularly. The series typically includes: data reports of long-term field or lab studies of important species or habitats; synthesis reports for important species or habitats; annual reports of overall assessment or monitoring programs; manuals describing program-wide surveying or experimental techniques; literature surveys of important species or habitat topics; proceedings and collected papers of scientific meetings; and indexed and/or annotated bibliographies. All issues receive internal scientific review and most issues receive technical and copy editing.

*Northeast Fisheries Science Center Reference Document* -- This series is issued irregularly. The series typically includes: data reports on field and lab studies; progress reports on experiments, monitoring, and assessments; background papers for, collected abstracts of, and/or summary reports of scientific meetings; and simple bibliographies. Issues receive internal scientific review and most issues receive copy editing.

*Resource Survey Report* (formerly *Fishermen's Report*) -- This information report is a regularly-issued, quick-turnaround report on the distribution and relative abundance of selected living marine resources as derived from each of the NEFSC's periodic research vessel surveys of the Northeast's continental shelf. This report undergoes internal review, but receives no technical or copy editing.

**TO OBTAIN A COPY** of a *NOAA Technical Memorandum NMFS-NE* or a *Northeast Fisheries Science Center Reference Document*, either contact the NEFSC Editorial Office (166 Water St., Woods Hole, MA 02543-1026; 508-495-2350) or consult the NEFSC webpage on "Reports and Publications" (http://www.nefsc.noaa.gov/nefsc/publications/). To access *Resource Survey Report*, consult the Ecosystem Surveys Branch webpage (http://www.nefsc.noaa.gov/femad/ecosurvey/mainpage/).