Northeast Fisheries Science Center Reference Document 13-23

2013 Monkfish Operational Assessment

by Northeast Fisheries Science Center

August 2013

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NOAA's National Marine Fisheries Serv., 166 Water St., 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 2013

Northeast Fisheries Science Center Reference Documents

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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:

Northeast Fisheries Science Center. 2013. 2013 monkfish operational assessment. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 13-23; 116 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026, or online at http://nefsc.noaa.gov/publications/

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MONKFISH REVIEW PANEL SUMMARY

The Panel reviewed the 2013 monkfish operational stock assessment on April 8-9, 2013 in Woods Hole, Massachusetts. The model configuration has not changed substantively since the last peer review by the SARC 50 in 2010. The model has been updated with two years of data and revisions of discard estimates for 1980-2011 based on new methodology (SBRM approach). Changes in the discard estimates resulted in a minor reduction in the number of selectivity blocks in the southern stock model. Projections of biomass and catch are likely over-optimistic due to the retrospective patterns in both stocks. The Review Panel agreed that the assessment team met all Terms of Reference.

Model results indicate that the North and South, monkfish stocks are not over-fished and overfishing is not occurring. Nevertheless, both stocks demonstrate retrospective patterns in fishing mortality and biomass with fishing mortality consistently being under-estimated and biomass being over-estimated. This pattern was stronger for the Northern Management Area stock component. Potential causes of these retrospective patterns include misspecification of growth and natural mortality. The Review Panel recommends that a new benchmark assessment not proceed until new information on age, growth, longevity, and natural mortality is obtained. Potential differences by sex would need to be addressed. Notwithstanding these concerns, regular assessment updates might be needed to meet management requirements.

The panel noted that a number of key uncertainties remain unresolved since 2010 SARC. These include uncertainties in landings, discards, commercial length frequencies, aging methods, life history, growth, and natural mortality. These uncertainties are propagated through the SCALE assessment model and lead to greater uncertainties in estimates of stock size, recruitment, fishing mortality, biological reference points, and stock projections. The compounding nature of these uncertainties implies increased risk of not achieving the biological reference points. Despite these uncertainties, the work presented represents the best available scientific information and modeling approach for assessing the status of monkfish, and is accepted by the Review Panel for determining the stock status and providing catch advice.

The Review Panel examined projections for initial conditions of population sizes with and without correction for retrospective patterns. In both instances, the probability of becoming overfished in the short term is negligible. Considering consistency of retrospective pattern demonstrated in 2010 and 2013 assessments, the Panel agreed that an adjustment for the retrospective pattern should be made. However, the Panel expressed concern that the adjustment to the initial stock size for projections without change to reference points creates an inconsistency in determination of stock status. The Panel agreed that the correction for retrospective pattern did not address fully the sources of unresolved uncertainty detailed above.

The Review Panel discussed and recommended the following research priorities:

1) resolution of age, growth, and natural mortality issues

2) determination of movement patterns in relation to stock areas
3) development of a one stock model given evidence of movement between the two areas and existing genetic information (on-going genetics work may resolve the two stock-area issue)
4) development of a two-sex model depending on the results of aging work (would require estimation of sex ratios in catch and survey data)

2013 Monkfish Assessment Update

Executive Summary

Assessments of the northern and southern management units of monkfish were updated with minmal changes to methodological approaches and data of the previous assessments (NEFSC 2010).

TOR 1. Update catch estimates from all sources including landings and discards. Characterize the uncertainty in these sources of data.

Data for 2010 and 2011 were added to the catch time series in the assessment (complete data for 2012 were not yet available). Due to changes in software and data, the previous time series (1980-2009) of discard estimates for both areas were revised. The revisions resulted in higher estimates of discards in the south and an increase in the proportion of small fish in the discard and catch in the south during 2000-2009. Changes to the historical data in the north were minimal.

Landings and catch during 2010 and 2011 remained at relatively low levels in the north and increased slightly in the south. The catch-length frequency in recent years did not expand to larger sizes, which might have been expected while catches have been relatively low.

Estimation of total catch for monkfish has several sources of uncertainty. Before 1980, fishery removals were primarily bycatch, but most were unreported. Therefore, evaluation of fishery development is difficult, leading to problems interpreting the state of the resource in the early years of the marketed fishery. Since 1980, the quality of landings estimates generally increased, but the series includes under-reporting and difficulties converting landed products to live weight.

There is no information on the magnitude of discards prior to 1989. Recent assessments have assumed that discard rates before 1989 were similar to discard:kept ratios observed in later years; this may be problematic if discard rates were lower in later years because markets had developed. The quality of discard data generally increased in the 1989-2009 observer time series as a result of increasingly greater coverage of fleets and improved protocols, but there were some unsampled portions of the fishery (e.g., some half-year periods in which entire gear-types were not sampled).

TOR 2. Update fishery-independent indices used as inputs in the last assessment model. Characterize uncertainty and any bias in these sources of data.

All survey series used in the assessment models were updated through 2011, which was the most recent year with complete data available.

Within the northern management area, broad trends in stock size were consistent among the five surveys conducted there. Biomass fluctuated without trend from 1963 to the early 1980s, but declined thereafter to near historic lows during the 1990s, when landings reached their peak. Biomass indices increased from 2000 to 2004, but then decreased and have remained at lower levels since then. Abundance indices in the north fluctuated without trend during 1963-1998 but spiked during 2000-2002, reflecting a strong 1999 year class.

General trends in survey indices in the southern area are also consistent among surveys. Survey biomass and abundance indices were high during the mid-1960s, fluctuated around an intermediate level during the 1970s and mid-1980s, then declined to low levels since the late 1980s. Biomass indices increased slightly around 2002 but have returned to lower levels since then.

Size-based indices of abundance indicate relatively strong recruitment in the northern area during the 1990s and in several recent years, and variable but stable recruitment in the south. Length distributions gradually became truncated from the 1960s to early 1990s, and the median size of monkfish in survey catches has remained fairly constant since the early 1990s.

TOR 3. Update the SCALE model for monkfish to estimate fishing mortality, recruitment and stock biomass (total and spawning stock) and their uncertainty. Include a historical retrospective analysis to allow a comparison with previous assessment results.

The SCALE models for both management areas were updated with two additional years of data and the revised catch data for 1980-2009. The basic configuration of the models was not changed. Retrospective patterns were estimated based on 7 peels.

The SCALE models for the north changed little with the revised data and additional years of data. For the north, estimated F in 2011was 0.08 (retrospective bias -54%, corrected F_{2011}=0.16), estimated total biomass was 60,500 mt (retrospective bias +87%, corrected total biomass = 32,390 mt). Estimated age-1 recruitment in 2011 was 11.7 million fish, near the time series low (retrospective bias +23%, corrected age-1 recruitment = 9.5 million). Spawning biomass continued to increase in the northern management area.

The SCALE model for the south changed somewhat with the revised data and additional two years. The increased proportion of small fish in the revised catch data caused a shift in estimated selectivity so that the final model estimated only one selectivity time block (vs. two blocks in the 2010 SAW 50 assessment). The re-estimated time series of F, biomass, and recruitment using the single selectivity block in the south were similar to the estimates from SAW 50. For the south, estimated F in 2011was 0.11 (retrospective bias -22%, corrected F_{2011}=0.14), estimated total biomass was 111,100 mt (retrospective bias +24%, corrected total biomass=88,806 mt). Estimated age-1 recruitment in 2011 was 23.3 million fish, near the time series low (retrospective bias +50%, corrected age-1 recruitment=15.3 million). Spawning biomass continued to increase through 2010, but in 2011 showed a slight downturn.

The SCALE model results for monkfish continue to be subject to high levels of uncertainty due to weaknesses in input data, such as under-reported landings and unknown discards during the 1980s; incomplete understanding of key biological parameters such as age and growth, longevity, natural mortality, sex ratios and stock structure; and the relatively short reference time frame of the model (no information prior to 1980). Further, both models have difficulty fitting the catch-length frequencies in some years, with substantial overestimates of the numbers of large fish in the stock. The recent retrospective patterns have improved in the north since the 2010 assessment, but optimistic retrospective patterns remain in both areas (F underestimated, biomass overestimated) and are pronounced in the northern area.

TOR 4. Update biological reference points as needed and evaluate stock status to determine if the stock is overfished and if overfishing is occurring. Provide estimates of uncertainty.

Reference points were updated using the revised selectivity estimates from the SCALE models. The following table gives the reference points for each management area. Reference points were not adjusted for retrospective patterns.

North	BRP	Basis	SAW 50 (2010)	2013 Update
	Fmax	Age-based YPR	0.43	0.44
	Bthreshold	0.5*Bmax Projected	26,465	23,037
	Btarget	Bmax Projected	52,930	46,074
	MSY	Fmax Projected	10,745	9,383
South				
	Fmax	Age-based YPR	0.46	0.37
	Bthreshold	0.5*Bmax Projected	37,245	35,834
	Btarget	Bmax Projected	74,490	71,667
	MSY	Fmax Projected	15,279	14,328

In the north, F_{max} (F threshold) changed only slightly (SAW 50 F_{max}=0.43, 2013 update F_{max}=0.44). In the south, F_{max} under the single selectivity block was estimated as 0.37 (SAW 50

F_{max}=0.46). Given the current estimates of F from the SCALE models, overfishing is not occurring in either management area.

Biomass reference points based on long-term projections of total biomass at F_{max} were recommended in the SAW 50 assessment, adopted for management in 2012, and updated in the current assessment. Given the current estimates of biomass from the SCALE models, monkfish are not overfished in either management area.

The BRPs for monkfish are based on output from the SCALE model, which is subject to high levels of uncertainty as discussed under TOR 3; therefore the BRPs are also highly uncertain.

TOR 5. Summarize sources of data, model and reference point uncertainty relevant to setting Acceptable Biological Catch limits.

The SCALE model results for monkfish continue to be subject to high levels of uncertainty due to weaknesses in input data such as: under-reported landings and unknown discards during the 1980s; incomplete understanding of key biological parameters such as age and growth, longevity, natural mortality, sex ratios and stock structure; and the relatively short reference time frame (1980-2011) of the model. Further, both models have difficulty fitting the catch length frequencies in some years, with substantial overestimates of the numbers of large fish in the stock. The retrospective patterns have improved in the north since the 2010 assessment, but optimistic retrospective patterns remain in both areas (F underestimated, biomass overestimated).

The BRPs use output from the SCALE model, which is subject to high levels of uncertainty as discussed under TOR 3; therefore the BRPs are also highly uncertain.

TOR 6. Perform short-term (3 year) projections for stock biomass under alternative harvest strategies.

SCALE model results and AGEPRO projections were used to predict stock trends during 2014-2016 under two scenarios: F=$F_{threshold}$ assuming stochastic long-term recruitment (using both unadjusted and retrospective-adjusted SCALE outputs), and status quo F (unadjusted 2011 F estimated from SCALE) assuming stochastic long-term recruitment.

For both areas, fishing at $F_{threshold}$ led to declines in total stock biomass in the unadjusted and retrospective-adjusted runs. In the north, total stock biomass increased during 2012-2016 under $F_{status\ quo}$, while in the south, total stock biomass decreased during 2012-2016 under $F_{status\ quo}$.

The projections for both areas have a high degree of uncertainty due to uncertainty in the starting conditions (output from the SCALE model).

TOR 7. Should the baseline model fail when applied in the operational assessment, provide guidance on how stock status might be evaluated. Should an alternative assessment approach not be readily available, provide guidance on the type of scientific and management advice that can be. An underlying premise of operational assessment

is to minimize the number of significant changes in methodology that would likely require a more detailed peer review.

The baseline model performed similarly to previously accepted versions of the model; therefore, despite its high uncertainty, it was not considered to have failed.

TOR 8. If feasible, present preliminary results from ongoing research projects and indicate how they could impact future assessments.

Studies are currently underway to investigate growth and migration patterns of monkfish. Results are too preliminary and incomplete to include in depth.

Introduction

Life History

Monkfish (*Lophius americanus*), also called goosefish, are distributed in the Northwest Atlantic, from the Grand Banks and northern Gulf of St. Lawrence south to Cape Hatteras, North Carolina (Collette and Klein-Macphee 2002). Monkfish may be found from inshore areas to depths of at least 900 m (500 fathoms). Seasonal onshore-offshore migrations occur and appear to be related to spawning and possibly food availability (Collette and Klein-MacPhee 2002).

Monkfish rest partially buried on soft bottom substrates, and attract prey using a modified first dorsal fin ray that resembles a fishing pole and lure. Monkfish are piscivorous and commonly eat prey as large as themselves. Despite the behavior of monkfish as a demersal 'sit-and-wait' predator, recent information from electronic tagging suggests seasonal off-bottom movements (Rountree et al. 2006). Growth is rapid at about 10 cm per year, and is similar for both sexes up to age 6 and lengths of around 60 cm (Richards et al. 2008). Few males are found older than age 7, but females can live to 12-14 years or older. Tagging studies underway suggest that growth patterns may differ between males and females (Richards et al. 2012); however, relatively few tags have been recaptured to date, and the information is insufficient to support revising the growth assumptions in the assessment at this time. Monkfish as large as 138 cm have been captured in NEFSC bottom trawl surveys.

Female monkfish begin to mature at age 4 and 50% of females are mature by age 4.7 (about 41 cm). Males mature at slightly younger ages and smaller sizes (50% maturity at age 4.2 or 37 cm (NEFSC 2002; Richards et al. 2008). Spawning takes place from spring through early autumn, progressing from south to north, with most spawning occurring during the spring and early summer. Females lay a buoyant mucoid egg raft or veil which can be as large as 12 m long and 1.5 m wide and only a few mm thick. The eggs are arranged in a single layer in the veil, and the larvae hatch after about 1-3 weeks, depending on water temperature. The larvae and juveniles spend several months in a pelagic phase before settling to a benthic existence at a size of about 8 cm (Collette and Klein-MacPhee 2002).

Stock Identification

The Fishery Management Plan (FMP) defines two management areas for monkfish (northern and southern), divided roughly by a line bisecting Georges Bank (Figure 1). The two assessment and management areas for monkfish were defined in the 1999 FMP based on differences in temporal patterns of recruitment (estimated from NEFSC surveys), perceived differences in growth patterns, and differences in the contribution of fishing gear types (mainly trawl, gill net, and dredge) to the landings.

Genetic studies suggest a homogeneous population of monkfish off the U.S. east coast (Chikarmane et al. 2000). Monkfish larvae are distributed over deep (< 300 m) offshore waters of the Mid-Atlantic Bight in March-April, and across the continental shelf (30 to 90 m) later in the year, but relatively few larvae have been sampled in the northern management area (Steimle et al. 1999). NEFSC surveys continue to indicate different recruitment patterns in the two management units in recent years.

The perceived differences in growth in the two management areas were based on studies about 10 years apart and under different stock conditions (Armstrong et al. 1992: Georges Bank to Mid-Atlantic Bight, 1982-1985; Hartley 1995: Gulf of Maine, 1992-1993). Age, growth, and maturity information from the NEFSC surveys and the 2001, 2004, and 2009 cooperative monkfish surveys indicated only minor differences in age, growth, and maturity between the areas (Richards et al. 2008; Johnson et al. 2008). The recent biological evidence (growth, maturity, and genetic information) suggests that use of a single stock hypothesis in the assessment might be appropriate. However, substantial differences in the fisheries exist, and current management maintains separate regulatory areas to accommodate these differences.

The southern deepwater extent of the range of American monkfish (*L. americanus*) overlaps with the northern extent of the range of blackfin monkfish (*L. gastrophysus*; Caruso 1983). These two species are morphologically similar, which may create a problem in identification of survey catches and landings from the southern extent of the range of monkfish. The potential for a problem, however, is believed to be small. The NEFSC closely examined winter and spring 2000 survey catches for the presence of blackfin monkfish and found none. The cooperative monkfish survey conducted in 2001 caught only eight blackfin monkfish of a total of 6,364 monkfish captured in the southern management area.

Fisheries Management

Commercial fisheries for monkfish occur year-round using gillnets, trawls, and scallop dredges. No significant recreational fishery exists. The primary monkfish products are tails, livers and whole gutted fish. Peak fishing activity occurs during November through June, and value of the catch is highest in the fall due to the high quality of livers during this season.

U.S. fisheries for monkfish are managed in the Exclusive Economic Zone (EEZ) through a joint New England Fishery Management Council - Mid-Atlantic Fishery Management Council Monkfish Fishery Management Plan (FMP). The primary goals of the Monkfish FMP are to end and prevent overfishing and to optimize yield and economic benefits to various fishing sectors involved with the monkfish fisheries (NEFMC and MAFMC 1998; Haring and Maguire 2008). Current regulatory measures vary with type of permit but include limited access, limitations on days at sea, mesh size restrictions, trip limits, minimum size limits, and annual catch limits (Tables 1 and 2).

Biological reference points for monkfish were established in the original Fishery Management Plan (FMP), but were revised after SAW 34 (NEFSC 2002), after the Data Poor Stocks Working Group (DPSWG) in 2007 (NEFSC 2007a), and after SAW 50 in 2010. The overfishing definition is F_{max}. Prior to 2007, $B_{threshold}$ was defined as one-half of the median of the 1965-1981 3-year average NEFSC autumn trawl survey catch (kg) per tow. After acceptance of an analytical assessment in 2007 (NEFSC 2007a), B_{target} was redefined as the average of total biomass for the model time period (1980-2006), and $B_{threshold}$ as the lowest observed value in the total biomass time series from which the stock had then increased (termed "B_{Loss}"). According to the earlier (survey index-based) reference points, monkfish were overfished and overfishing status could not be determined (NEFSC 2005); however, with adoption of the analytical assessment in 2007, monkfish status was changed to no longer overfished and overfishing was not occurring. SAW 50 in 2010 also concluded that both stocks were not overfished and overfishing was not occurring, while recognizing the continuing significant uncertainty in the determination.

2007 DPSWG Assessment

The DPSWG accepted a length-tuned analytical model (SCALE) for monkfish assessment and status determination, and adopted a value for natural mortality (M) of M=0.3. However, the WG emphasized that the assessment was highly uncertain due to under-reported landings; unknown discards during the 1980s; incomplete understanding of key biological parameters such as age and growth, longevity, natural mortality, and stock structure; the shorter reference time frame (1980-2006) than in previous assessments (1963-2006); and the relatively recent development of the assessment model. The WG also concluded that uncertainties in historical catch data precluded application of long-term models that rely on episodes of depletion and recovery to estimate stock size.

2010 SAW 50 Assessment

The 2010 Southern Demersal Working Group (SDWG) updated the SCALE model to assess the status of monkfish using data through 2009. Further developments included examination of retrospective patterns in the SCALE estimates, and development of short-term stochastic age-based projections. Data from a cooperative monkfish survey conducted during winter/spring of 2009 were analyzed and included in the assessment model, along with data collected on the new NEFSC survey vessel, starting in spring 2009, which was adjusted using calibration coefficients developed for monkfish. Length frequency composition data from the 2009 cooperative survey were included in the final SCALE assessment model. The SARC 50 panel decided against making an adjustment for the retospective pattern in the assessment.

TOR 1. Update catch estimates from all sources including landings and discards. Characterize the uncertainty in these sources of data.

Landings

Landings statistics for monkfish are sensitive to conversion from landed weight to live weight, because a substantial fraction of the landings occur as tails only (or other parts). The conversion of landed weight of tails to live weight of monkfish in the NEFSC weigh-out database is made by multiplying landed tail weight by a factor of 3.32. In 2012, the dealer database for 2005-2011 was corrected because some dealers were reporting ‘head-on, gutted’ monkfish (conversion factor of 1.14) as ‘round’ (no conversion). This resulted in a 1.5% overestimate of monkfish landings (live weight) during those years (all years combined), which has now been corrected. Early catch statistics (before ~1980) are uncertain, because much of the monkfish catch was sold outside of the dealer system or used for personal consumption until the mid-1970s. For 1964 through 1989, there are two potential sources of landings information for monkfish: the NEFSC ‘weigh-out’ database, which consists of fish dealer reports of landings; and the ‘general canvass’ database, which contains landings data collected by NMFS port agents (for ports not included in the weigh-out system) or reported by states not included in the weigh-out system (Table 3). All landings of monkfish are reported in the general canvass data as ‘unclassified tails.’ Consequently, some landed weight attributable to livers or whole fish in the canvass data may be inappropriately converted to live weight. This is not an issue for 1964-1981, when only tails were recorded in both databases. For 1982-1989, the weigh-out database contains market category information that allows for improved conversions from landed to live weight. The two data sources produce the same trends in landings, with general canvass landings slightly greater than weigh-out landings. It is not known which of the two measures more accurately reflects landings, but the additional data sources suggest that the general canvass is most reliable for 1964-1981 landings, whereas the availability of market category details suggests that the weigh-out database is most reliable for 1982-1989.

Beginning in 1990, most of the extra sources of landings in the general canvass database were incorporated into the NEFSC weigh-out database. However, North Carolina reported landings of monkfish to the Southeast Fisheries Science Center, and until 1997 these landings were not added to the NEFSC general canvass database. Since these landings most likely come from the southern management area, they have been added to the weigh-out data for the southern management area for 1977-1997 for the landings statistics used for stock assessment.

Beginning in July 1994, the NEFSC commercial landings data collection system was redesigned to consist of vessel trip reports (VTR) and dealer weigh-out records. The VTRs include area fished for each trip, which is used to apportion dealer-reported landings to statistical areas. The northern management area includes statistical areas 511-515, 521-523, and 561; the southern management area includes areas 525-526, 562, 537-543, and 611-636 (Figure 1). Each VTR trip should have a direct match in the dealer data base, but this is not always true. VTR records with no matching dealer landings were excluded, but dealer landings with no matching VTR were included in landings statistics, apportioning the unmatched landings to management area using proportions calculated from matched trips pooled over gear, state, and quarter.

Total U.S. landings (live weight) remained at low levels until the middle 1970s, increasing less than 1,000 mt to around 6,000 mt in 1978 (Table 3; Figure 2). Annual landings remained stable at between 8,000 and 10,000 mt until the late 1980s. Landings increased from the late 1980s to over 20,000 mt per year 1992-2004, peaking at 28,500 mt in 1997. Landings declined steadily after 2003, and stabilized around an average of 8,300 mt during 2009-2011. During recent years (2008-2011 North; 2009-2011 South), fishing year landings have been below the TAC (Table 2).

By region, landings began to increase in the north in the mid-1970s, and began to increase in the south in the late 1970s. Most of the increase in landings during the late 1980s through mid-1990s was from the southern area. Historical under-reporting of landings shold be considered in the interpretation of this series.

Trawls, scallop dredges and gill nets are the primary gear types that land monkfish (Table 4; Figure 3). Trawls have contributed approximately half of the landings since 1964. Prior to 1994, gillnets contributed less than 10% of total landings, but landings from gillnets have generally increased, and accounted for almost 40% of landings in the past decade (2002-2011). Monkfish landings from the scallop dredge fishery have declined to about 9% in the past decade, primarily due to regulatory changes.

Until the late 1990s, total landings were dominated by landings of monkfish tails. From 1964 to 1980 landings of tails rose from 19mt to 2,302mt, and peaked at 7,191mt in 1997 (Table 5). Landings of tails declined after 1997, but are still an important component of the landings. Landings of gutted whole fish have increased steadily since the early 1990s, and are now the largest market category on a landed-weight basis. On a regional basis, more tails were landed from the northern area than the southern area prior to the late 1970s (Tables 5 and 6). From 1979 to 1989, landings of tails were about equal from both areas. In the 1990s, landings of tails from the south predominated, but since 2000, landings of tails have been greater in the north.

Beginning in 1982, several market categories were added to the system (Table 5). Tails were broken down into large (> 2.0 lbs), small (0.5 to 2.0 lbs), and unclassified categories, and the liver market category was added. In 1989, unclassified round fish were added; in 1991, peewee tails (<0.5 lbs) and cheeks; in 1992, belly flaps; and in 1993, whole gutted fish were added. Monkfish livers have become a very valuable product. Landings of livers increased from 10mt in 1982 to an average of over 600mt during 1998-2000. During 1982-1994, ex-vessel prices for livers rose from an average of $0.97/lb to over $5.00/lb, with seasonal variations as high as $19.00/lb. Landings of unclassified round (whole) or gutted whole fish jumped in 1994 to 2,045mt and 1,454mt, respectively; landings of gutted fish continued to increase through 2003. The tonnage of peewee tails landed increased through 1995 to 364mt and then declined to 153mt in 1999 and 4mt in 2000 when the category was essentially eliminated by regulations.

Foreign Landings

Landings (live wt) from NAFO areas 5 and 6 by countries other than the US are shown in Table 3 and Figure 2. Reported landings were high but variable in the 1960s and 1970s, with a peak in 1973 of 6,818mt. Landings were low but variable in the 1980s, declined in the early 1990s, and have generally been below 300mt in recent years. There were no updated NAFO data available for monkfish for this assessment update.

Discard Estimates

Catch data from the fishery observer, dealer, and VTR databases were used to investigate discarding frequencies and rates. The number of trips with monkfish discards available for analysis varied widely among management areas and gear types (Tables 7 and 8). As in previous monkfish assessments (NEFSC 2007a; NEFSC 2010), monkfish discards were estimated on a gear, half-year, and management area basis, using observed discard-per-kept-monkfish to expanded to total discards for otter trawls and gillnets, and observed discard-per-all-kept-catch to expanded for scallop dredges and shrimp trawls. As before, discards for 1980-1988 (before observer sampling) were estimated by applying average discard ratios by management area and gear type (trawl, shrimp trawl, gillnet, dredge) from 1989-1991 to landings for 1980-1988 as follows:

Area	**Shrimp Trawls**	**Trawls**	**Gillnets**	**Dredges**
North				
Years included	1989-1991	1989-1991	1989-1991	1992-1997
Number of trips	124	253	1191	54
South				
Years included	n/a	1989-1991	1991-1992	1991-1993
Number of trips		334	177	32

Methods for estimating discards were changed slightly from previous assessments, and the time series of estimates for all gears in both areas were re-estimated. The revisions were prompted by advances in standardized SBRM methodology (Rago et al. 2005; Wigley et al. 2007), which have rendered obsolete the earlier SAS programs used for monkfish. In the current assessment, dealer landings were used to expand the d/k ratios; assessements in 2007 and 2010 used landings from vessel trip reports (VTRs). Some additional program and gear codes were included in the current assessment (e.g. observer training trips, haddock separator trawl, Rhule trawl). The most significant impacts of the changes were the inclusion of more observed trips since 2004 for trawlers, and changes to the estimated kept-all (raising factor) for scallop dredges in both areas (see Figures 1 and 2 in Appendix I). In general, d/k ratios remained similar to previous estimates despite the higher sample sizes. Revised estimates of discards were slightly lower in the north and slightly higher in the south (Appendix I, Figures 3 and 4) during 1980-2002, but were higher thereafter in the south due primarily to the change in raising factor for scallop dredges.

The proportion of discards in the northern area catch was about 13% in the 1980s, 7% during 2002-2006, became slightly higher on average (12%) during 2007-2009, and was 14% for 2010-2011 (Table 9; Figures 4 and 5). The proportion of discards in the southern area catch generally increased since the 1980s (average 16% 1980-1989), with an annual average of 29% during 2002-2006, 24% during 2007-2009, and 28% in 2010-2011 (Table 9; Figures 4 and 5). Gill nets consistently have had the lowest discard ratios. Some of the trends in discarding may reflect imposition of size limits starting in 2000 and decreased trip limits in the south starting in 2002. The DPWG (NEFSC 2007a) noted a potential bias in discard estimates due to increased observer sampling in the multispecies groundfish fishery. Monkfish discard rates may differ between the directed monkfish fisheries and bycatch fisheries. The most frequent discard reasons were that fish were too small for regulations or the market. The estimates of total catch for 1980-2011 are shown in Figure 5 and Table 9.

Size Composition of U.S. Catch

Tail lengths were converted to total lengths using relations developed by Almeida et al. (1995). As in NEFSC (2007a), length composition of landings and discard were estimated from fishery observer samples by management area, year, gear-type (trawls, dredges and gillnets), and catch disposition (kept or discarded). Landings in unknown gear categories were allocated proportionately to the 3 major gear types before assigning lengths. The stratification used for assigning lengths within area and gear type is shown in Table 10. The estimated length composition of landings and discard is shown in Figures 6-9. Size composition was re-estimated for 1994-2009 (all available years) because of the updates to the discard estimates. There were minor changes in the estimated length composition for 1994-2006 due to an error discovered after the SAW 50 review (NEFSC 2007a) (gillnet discard lengths in the south characterized using kept lengths) and because different blocks of years/areas were used in some cases when data were sparse. Length composition was estimated for 2010-2011 using the same methods applied to the earlier data.

Age composition of the catch was not estimated due to uncertainties in the aging method that were highlighted in previous assessments (NEFSC 2007a; NEFSC 2010) and because the operational model for monkfish (SCALE) is length-based.

Effort and CPUE

Evaluating trends in effort or catch rates in the monkfish fishery is difficult for several reasons. Much of the catch is taken in multi-species fisheries, and defining targeted monkfish trips is difficult. There have been programmatic changes in data collection from port interviews (1980-1993) to logbooks (1994-2009), and comparison of effort statistics among programs is difficult. Catch rates may not reflect patterns of abundance, because they have been affected by regulatory changes (e.g., 1994 - closed areas; 2000 - trip limits; 2006 - reductions in trip limits).

CPUE data have not been used in the assessment model for monkfish, therefore they were not examined for this assessment update.

TOR 2. Update fishery-independent indices used as inputs in the last assessment model. Characterize uncertainty and any bias in these sources of data.

Resource surveys used in the 2010 assessment models were updated. Surveys included in the 2013 assessment update were 2001, 2004, and 2009 cooperative monkfish surveys; NEFSC winter, spring, and autumn offshore surveys; NEFSC scallop surveys (SFMA only); Northern Shrimp Technical Committee (NSTC) shrimp surveys (NFMA only); and ME/NH inshore surveys.

The NEFSC survey strata used to define the northern and southern management areas are:

Survey	Northern Area	Southern Area
NEFSC Offshore bottom trawl	20-30, 34-40	1-19, 61-76
NSTC Shrimp	1,3,5-8	
Shellfish		6,7,10,11,14,15,18,19,22-31,33-35,46,47,55,58-61,621,631

NEFSC spring and autumn bottom trawl survey indices for 1963-2008 were standardized to adjust for statistically significant effects of trawl type (Sissenwine and Bowman 1977) on catch rates. The trawl conversion coefficients apply only to the spring survey during 1973-1981.

NEFSC indices derived from surveys on the FSV *Henry B. Bigelow* (starting spring 2009) were adjusted using calibration coefficients estimated during experimental work (Miller et al. 2009). The FSV *Henry B. Bigelow*, which became the main platform for NEFSC research surveys in spring 2009, has significantly different size, towing power, and fishing gear characteristics than the previous survey platform (R/V *Albatross IV)*, resulting in different fishing power and catchability for most species. Calibration experiments to estimate these differences were conducted during 2008 (Brown 2009; NEFSC 2007b), and were peer reviewed by a panel of three non-NMFS scientists during the summer of 2009 (Anonymous 2009). The objective was to develop specific protocols for guidance in the selection and use of appropriate estimators based on the amount of data available and the relative performance of two candidate estimators. The Panel developed general guidance on which estimator to use given sample sizes for each species. Following these guidelines, monkfish catches were converted using a simple ratio estimator without a seasonal (spring vs. fall) or length-specific correction. The low catch rates of monkfish in the *Albatross* series made development of more detailed coefficients infesible. The overall coefficients for monkfish were 7.1295 for numbers and 8.0618 for biomass (kg) (Anonymous 2009; Miller et al. 2009).

Coefficients of variation and confidence intervals for all survey indices are given in the tables for each survey and region discussed below.

Northern Area

Biomass indices from NEFSC autumn research trawl surveys fluctuated without trend between 1963 and 1975, increased briefly in the late 1970s, but declined thereafter to near historic lows during the 1990s (Table 11; Figure 10). From 2000 to 2003 the index increased, reflecting recruitment of a relatively strong 1999 yearclass. Subsequently, the biomass index declined and has remained low since. In the unconverted *Bigelow* time series (2009-2012, Figure 11), biomass and abundance indices in the north have generally increased.

Indices from the NEFSC spring research trawl surveys reflect similar trends of relatively high biomass levels in the mid 1970s (but with possible declines in the late 1970s); a declining trend from the early 1980s to the lowest values in the time series in 1998; an increase to relatively high biomass from 2001 to 2005; and somewhat lower levels since then (Table 12, Figure 10). The spring *Bigelow* indices (Figure 11) increased during 2009-2011, but declined in 2012.

Survey length distributions have become increasingly truncated over time (Figure 12). By 1990, fish greater than 60 cm long were uncommon. The minimum, median, and maximum lengths in the trawl surveys declined during the 1980s and have fluctuated around smaller sizes since ~1990 (Figure 13). Several modes potentially representing strong yearclasses have appeared in survey length distributions in recent years (Figure 12). However, despite relatively low exploitation in recent years, there is little evidence of increased abundance of large individuals in the survey catches.

Abundance indices were estimated for monkfish of lengths corresponding to ages 1 and 2 for input to the assessment model (Figure 19). To the extent that these indices reflect recruitment, recruitment in the northern area has increased in the past decade. Survey abundance at length and at age suggests relatively strong 1993, 1999 and possibly 2006 yearclasses in the northern area. Survey age data are available for 1993-2006 from the autumn trawl survey and for 1995-2006 for the spring trawl survey (NEFSC 2007a).

Other surveys which catch monkfish in portions of the northern area include the ASMFC shrimp survey, the Massachusetts Division of Marine Fisheries fall and spring surveys, and ME/NH inshore surveys (Figures 10, 14, and 15). The shrimp survey samples the western Gulf of Maine during summer and caught more monkfish than the spring or fall surveys prior to 2009 (when the FSV *Bigelow* survey series began) (Table 13; Figure 10). Patterns of abundance and biomass have been relatively consistent among the spring, fall, ME-NH, and shrimp surveys (Figure 10). The Massachusetts surveys catch few monkfish and were not considered to reflect patterns of abundance for the entire management area (NEFSC 2007a); therefore they have not been used in recent assessments.

Southern Area

Biomass indices from the NEFSC autumn research survey were high during the mid-1960s, fluctuated around an intermediate level during the 1970s-mid 1980s, then declined to consistently low levels since the late 1980s (Table 15; Figure 16). NEFSC spring surveys reflect similar trends as the autumn series: biomass remained fairly high during the mid 1970s-early 1980s, but fluctuated around lower levels thereafter (Table 16; Figure 16). A spike in biomass was observed in 2003, but subsequent indices have returned to lower values. Biomass and abundance indices based on the NEFSC winter flatfish survey (conducted during 1992-2007) fluctuated without trend (Table 17; Figure 16). Although the winter survey series had a short duration, the gear used in the winter survey was more effective for capturing monkfish than the gear used in autumn or spring surveys. Abundance indices based on the NEFSC sea scallop survey have fluctuated widely and have been at relatively low levels since 2007 (Table 18; Figure 16).

Inconsistent geographic coverage should be considered in the interpretation of southern survey indices. For example, the fall survey did not sample southern strata until 1967. The winter survey sampled Georges Bank inconsistently and did not sample deep strata before 1998. The scallop survey does not currently sample the entire southern management area, and the timing of this survey has shifted in recent years from mid-summer to late spring.

Abundance (numbers per tow) shows trends similar to biomass, with a spike in 1972, fluctuations around a relatively low level since the mid-1970s, and a slight increase in 2002 and 2003 followed by a return to lower levels. Length distributions from the southern area showed truncation over time but somewhat less dramatically than in the north (Figure 17). As in the northern area, fish greater than 60 cm have been rare since the 1980s, especially when compared to the 1960s. Any recent strong recruitment does not appear to remain in the system long enough to contribute substantially to increased stock biomass. Survey age data are available for 1993-2006 from the autumn trawl survey, 1995-2006 for the spring trawl survey, and 1997-2007 for the winter trawl survey (NEFSC 2007a). Age samples collected since 2006 survey have not been processed due to uncertainties regarding validity of the aging method (NEFSC 2007a).

TOR 3. Update the SCALE model for monkfish to estimate fishing mortality, recruitment and stock biomass (total and spawning stock) and their uncertainty. Include an historical retrospective analysis to allow a comparison with previous assessment results.

Several modeling approaches were investigated by the Data Poor Stocks Working Group (NEFSC 2007a), but the only approach considered suitable was a relatively new one called SCALE (for Statistical Catch-At-Length Analysis). SCALE models were used in 2007 to estimate fishing mortality, recruitment and stock biomass, and to re-define reference points. The SCALE models were updated for SAW 50 (NEFSC 2010) and are updated again for the current assessment.

Monkfish SCALE Model

Introduction

Incomplete or lacking age-specific catch data and survey indices often limit the application of a full age-structured assessment (e.g. Virtual Population Analysis and many forward-projecting age-structured models). Stock assessments often rely on the simpler size/age aggregated models (e.g. surplus production models) when age-specific information is lacking. However, these models may not utilize all of the available information for a stock assessment. Knowledge of a species growth and lifespan, along with total catch data, size composition of the removals, recruitment indices, and indices on numbers and size composition of the recruited fish in a survey, can provide insights on population status using a simple model framework.

The Statistical Catch At Length (SCALE) model, is a forward-projecting age-structured model tuned with total catch (mt), catch at length or proportional catch at length, recruitment at a specified age (usually estimated from first length mode in the survey), survey indices of abundance of the larger/older fish (usually adult fish), and the survey length frequency distributions. The SCALE model was developed in the AD model builder framework. The model parameter estimates are fishing mortality and recruitment in each year, fishing mortality to produce the initial population (F_{start}), logistic selectivity parameters for each year or blocks of years, and Qs for each survey index.

The SCALE model was developed as an age-structured model that does not rely on age-specific information on a yearly basis. The model is designed to fit length information, abundance indices, and recruitment at age which can be estimated by using survey length slicing. However, the model does require an accurate representation of the average overall growth of the population, which is input to the model as mean lengths at age. Growth can be modeled as sex-specific growth and natural mortality, or growth and natural mortality can be modeled with the sexes combined. The SCALE model will allow for missing data.

Model Configuration

The SCALE model assumes growth follows the mean input length at age with predetermined input error in length at age. Therefore, a growth model or estimates of the average mean length at age is essential for reliable results. The model assumes static growth; therefore, population mean length/weight at age is assumed constant over time.

The SCALE model estimates logistic parameters for a flattop selectivity curve at length in each time block specified by the user for the calculation of population and catch age-length matrices, or the user can input fixed logistic selectivity parameters. Presently the SCALE model cannot accommodate a dome shaped selectivity pattern.

The SCALE model computes an initial age-length population matrix in year one of the model as follows. First, the estimated population numbers at age starting with age-1 recruitment are normally distributed at 1 cm length intervals, using mean length at age with the assumed standard deviation. Next, the initial population numbers at age are calculated from the previous age at length abundance using the survival equation. An estimated fishing mortality (F_{start}) is also used to produce the initial population. This F can be thought of as the average fishing mortality that occurred before the first year in the model. Now the process repeats itself, with the total estimated abundance at age being redistributed according to the mean length at age and standard deviation in the next age (age+1).

This two-step process is used to incorporate the effects of length-specific selectivities and fishing mortality. The initial population length and age distribution is constructed by assuming population equilibrium with an initial value of F, called F_{start}. Length-specific mortality is estimated as a two-step process in which the population is first decremented for the length specific effects of mortality as follows:

$$N^{*}_{a,len,y_1} = N_{a-1,len,y_1} e^{-\left(PR_{len}F_{start}+M\right)}$$

In the second step, the total population of survivors is then redistributed over the lengths at age *a* by assuming that the proportions of numbers at length at age *a* follow a normal distribution with a mean length derived from the input growth curve (mean lengths at age).

$$N_{a,len,y_1} = \pi_{len,a} \sum_{len=0}^{L_\infty} N^{*}_{a,len,y_1}$$

where

$$\pi_{len,a} = \Phi\left(len+1 \mid \mu_a, \sigma_a^2\right) - \Phi\left(len \mid \mu_a, \sigma_a^2\right)$$

where

$$\mu_a = L_\infty\left(1 - e^{-K\left(a-t_0\right)}\right)$$

Mean lengths at age can be calculated from a von Bertalanffy model from a prior study as shown in the equation above, or mean lengths at age can be calculated directly from an age-length key. Variation in length at age a = σ_s^2 can often be approximated empirically from the growth study used for the estimation of mean lengths at age. If large differences in growth exist between the sexes, then growth can be input as sex-specific growth with sex-specific natural mortality. However, catch and survey data are still fitted with sexes combined.

This SCALE model formulation does not explicitly track the dynamics of length groups across age, because the consequences of differential survival at length at age do not alter the mean length of fish at age a+1. However, it does realistically account for the variations in age-specific partial recruitment patterns by incorporating the expected distribution of lengths at age.

In the next step, the population numbers at age and length for years after the calculation of the initial population use the previous age and year for the estimate of abundance. Here, the calculations are done on a cohort basis. As in the previous initial population survival equation, the partial recruitment is estimated on a length vector.

$$N^{*}_{a,len,y} = N_{a-1,len,y-1} e^{-\left(PR_{len} F_{y-1} + M\right)}$$

Second stage:

$$N_{a,len,y} = \pi_{len,a} \sum_{len=0}^{L_\infty} N^{*}_{a,len,y}$$

Constant M is assumed along with an estimated length-weight relationship to convert estimated catch in numbers to catch in weight. The standard Baranov's catch equation is used to remove the catch from the population in estimating fishing mortality.

$$C_{y,a,len} = \frac{N_{y,a,len} F_y PR_{len} \left(1 - e^{-\left(F_y PR_{len} + M\right)}\right)}{(F_y \; PR_{len}) + M}$$

Catch is converted to yield by assuming a time invariant average weight at length.

$$Y_{y,a,len} = C_{y,a,len} W_{len}$$

The SCALE model results in the calculation of population and catch age-length matrices for the starting population and then for each year thereafter. The model is programmed to estimate recruitment in year 1 and estimate variation in recruitment relative to recruitment in year 1 for each year thereafter. Estimated recruitment in year one can be thought of as the estimated average long term recruitment in the population since it produces the initial population. The residual sum of squares of the variation in recruitment $\sum(\mathrm{Vrec})^2$ is then used as a component of the total objective function. The weight on the recruitment variation component of the objective function (Vrec) can be used to penalize the model for estimating large changes in recruitment relative to estimated recruitment in year one.

The model requires an age-1 recruitment index for tuning, or the user can assume relatively constant recruitment over time by using a high weight on Vrec. Usually there is little overlap in ages at length for fish that are one and/or two years of age in a survey of abundance. The first mode in a survey can generally index age-1 recruitment using length slicing. In addition, numbers and the length frequency of the larger fish (adult fish) in a survey where overlap in ages at a particular length occurs can be used for tuning population abundance. The model tunes to the catch and survey length frequency data using a multinomial distribution. The user specifies the minimum size (cm) for the model to fit. Different minimum sizes can be fit for the catch and survey data length frequencies.

The number of parameters estimated is equal to the number of years in estimating F and recruitment plus one for the F to produce the initial population (F_{start}), logistic selectivity parameters for each year or blocks of years, and for each survey Q. The total likelihood function to be minimized is made up of likelihood components comprising fits to the catch, catch length frequencies, the recruitment variation penalty, each recruitment index, each adult index, and adult survey length frequencies:

$$\mathrm{L}_{\mathrm{catch}} = \sum_{years}\left(l\,\mathrm{n}(Y_{\mathrm{obs,y}} + 1) - \ln\left(\sum_{a}\sum_{len} \mathrm{Y}_{\mathrm{pred,len,a,y}} + 1 \right) \right)^2$$

$$L_{catch\_lf} = -N_{eff} \sum_{y} \left(\sum_{inlen}^{L_\infty} \left(\left(C_{y,len} + 1\right) \ln\left(1 + \sum_{a} C_{pred,y,a,len} \right) - \ln\left(C_{y,len} + 1\right) \right) \right)$$

$$\mathrm{L}_{\mathrm{vrec}} = \sum_{y=2}^{Nyears} \left(Vrec_y\right)^2 = \sum_{y=2}^{Nyears} \left(R_1 - R_y\right)^2$$

$$\sum L_{rec} = \sum_{i=1}^{Nrec} \left[\sum_{y}^{Nyears} \left(\ln\left(I_{rec_i,inage_i,y}\right) - \ln\left(\sum_{len}^{L_\infty} N_{y,inage_i,len} * q_{rec\,i} \right) \right)^2 \right]$$

$$\sum L_{adult} = \sum_{i=1}^{Nadult} \left[\sum_{y}^{Nyears} \left(\ln\left(I_{adult_i, inlen+_i, y} \right) - \left(\sum_{a} \sum_{inlen_i}^{L_\infty} \ln\left(N_{pred,y,a,len} * q_{adult\,i} \right) \right) \right)^2 \right]$$

$$\sum L_{lf} = \sum_{i=1}^{Nlf} \left[-N_{eff} \sum_{y} \left(\sum_{inlen_i}^{L_\infty} \left(\left(I_{lf_i,y,len} + 1 \right) \ln\left(1 + \sum_{a} N_{pred,y,a,len} \right) - \ln\left(I_{lf_i,y,len} + 1 \right) \right) \right) \right]$$

In equation L_{catch_lf}, calculation of the sum of length is made from the user input specified catch length to the maximum length for fitting the catch. Input user-specified fits are indicated with the prefix “in” in the equations. LF indicates fits to length frequencies. In equation L_{rec}, the input specified recruitment age; in L_{adult} and L_{lf}, the input survey specified lengths up to the maximum length is used in the calculation.

$$Obj\ \ fcn = \sum_{i=1}^{N} \lambda_i L_i$$

Lambdas represent the weights to be set by the user for each likelihood component in the total objective function.

Monkfish SCALE Model Configuration and Results

The SCALE model was updated in the current assessment using revised catch numbers and catch weights in both management areas for 1994-2009 (see Appendix I for detailed discussion of data revisions), and two additional years of data (2010, 2011). Complete data for 2012 were not available for this assessment update, so the terminal year was 2011.

No conclusive new information on growth and natural mortality was available for this assessment, and assumptions of growth, variation in mean length at age, and natural mortality (M=0.3) were the same as those used in the 2007 and 2010 assessments (NEFSC 2007a; NEFSC 2010). Mean and variance in monkfish length at age were estimated from industry-based surveys (2001 and 2004), and NEFSC winter, spring, and fall surveys for management areas combined (Table 19). No significant differences in growth were observed between the management units in the 2001 and 2004 cooperative surveys. The standard deviation for age 1 was 2.9; for older ages a standard deviation of 4.5 was assumed. The overall standard deviation on mean lengths at age was estimated directly from the age data. The oldest aged fish from surveys and commercial samples was age 12. Mean lengths at age for the older fish (10-12) was supplemented with data collected from a study of large monkfish (Johnson et al. 2008).

Age modes in the predicted length frequencies are seen for most ages, due to the linear nature of monkfish growth and the model structure that uses a single annual growth time step. The absence of a decline in growth with age in monkfish produces this process error in the SCALE model fits. This can be concealed by increasing the variance on mean lengths at age by increasing the assumed variance on the mean lengths at age. However, as in the previous assessments, an increase in the variance on the mean lengths at age beyond what is supported by the raw growth data was avoided due to concerns about its effect on the estimated selectivity.

Relative abundance trends for recruits (ages 1, 2, and/or 3) and adults (40+ cm) in each management unit were updated and are shown in Figure 20. For both management units, the model was fit to spring, fall, and industry-based survey length frequencies (30+ cm), 40+ cm adult indices, and recruitment indices at age. The northern area had additional inputs from the ASMFC summer shrimp trawl survey (1991-2011) and the ME-NH fall inshore trawl survey (2000-2011). The southern area had additional information from the NEFSC winter trawl (1992-2007) and NEFSC scallop dredge (1984-2011) surveys (Figure 20). Survey abundance indices were scaled using the approximate size (nm^2) of the survey area divided by the average coverage of the survey's tow (Table 20). The survey catchability estimates from the model were used as a diagnostic check for the interpretation of survey efficiencies. Survey indices from the R/V *Bigelow* (2009-2011) were converted to *Albatross* units by dividing *Bigelow* numbers per tow by the conversion coefficient described above (7.2).

For this assessment update, the model configurations used in SAW 50 (NEFSC 2010) were adhered to as closely as possible. For the northern stock, two runs are described (Table 21; Figures 21-26). Run 1 is a repeat of the 2010 model (1980-2009) using the revised catch data to show the impact of the data revisions (Figure 21). Run 2 uses the revised catch data plus an additional two years of data (1980-2011, Figure 22), and is considered the final run for the north. In the south (Table 22; Figures 27-33), run 1 was also a repeat of the 2010 model using revised data and run 2 used the revised data plus two new years of data. Run 3 in the south estimated only one selectivity block (vs. two blocks estimated in 2010) and is considered the final run for the south.

In the past and in the current assessments using SCALE, a single selectivity block was estimated for the northern management unit. In the south, three selectivity blocks were estimated in 2007, two blocks in 2010, and in the current assessment only one block in the final run. The change from three to two blocks in 2010 provided a better fit to the catch length frequency data and corresponded to a shift to more gillnet gear in the southern fishery. One selectivity block was used in the current assessment because the revised data for the catch time series showed more small fish than in the earlier data, and the most recent two years of data (2010, 2011) have relatively high numbers of small fish in the catch (Figure 9) primarily from discards in the scallop dredge sector (Figure 7c). The change in the selectivity due to the revised data is shown in Figure 27, and the change due to revised data plus two additional years of data is shown in Figure 28. The difference in selectivity blocks 1 and 2 in the south was minimal, with the revised data and 2 additional years (Figure 29).

As in previous SCALE-based assessments, models for both the north and south had difficulty in fitting the catch length frequency data, and in particular overestimated the abundance of larger fish. This pattern was seen in the final few years in the north, and more persistently in the south (Figures 25 and 32). A possible explanation for this might be a mis-specification of growth. Currently accepted growth models are linear (Richards et al 2008) and linear growth is used in SCALE. However, there are suggestions from tagging studies that growth may slow at older ages, at least for males (Richards et al. 2012). If growth does slow, using a constant growth increment would lead to overestimation of numbers at length of large fish by SCALE. A further factor may be the recent decline in catches in both areas without a concomitant expansion of length frequencies in the catch or surveys. The model may not have been able to reconcile the effects of a decline in catch with the lack of a corresponding shift in the length distributions.

The final run for the north (run 2) estimated higher F and lower biomass than the SAW 50 assessment did, but very little change in selectivity (Table 22; Figure 22). For 2004-2009, the annual F estimate was on average 47% higher than was estimated in 2010 and total biomass was on average 20% lower. Some of this is likely due to the strong retrospective pattern observed in 2010 (see below for further discussion). Regardless, the model for the north estimates terminal F to be near the lowest in the model time series, and terminal biomass to be increasing from a low point in 2006. The estimates of age 1 recruitment suggest strong recruitment pulses in 1993 and 2000 (1992 and 1999 yearclasses), but no major recruitment events since then. The northern model estimated lower total biomass in the terminal year than was projected for 2011 from the 2010 assessment: 81,900 tons projected in 2010 versus 60,500 tons estimated for 2011 in the current assessment.

The final run for the south (run 3) (Table 23) estimated similar F and biomass as the SAW 50 assessment, despite the revised data and change from two to one selectivity block (Figure 29). For 2006-2009, the annual F estimate was on average 12% higher than estimated in 2010 and total biomass was on average 3% lower. The model for the south estimates terminal F to be increasing slightly and terminal biomass to be decreasing slightly. The estimates of age 1 recruitment have fluctuated widely, but have been near the time series low since 2005, with a slight increase in the 2011 estimate. The southern model estimated lower total biomass in the terminal year than was projected for 2011 from the 2010 assessment: 132,200 tons projected in 2010 versus 111,100 tons estimated for 2011 in the current assessment.

Monkfish SCALE Model Uncertainty

Assessment of monkfish is difficult because of the often poor quality of data or lack of data. Survey data provide a long-term picture, but there is high variability in the survey trends due to the low numbers of fish caught in many of the surveys. Landings were historically under-reported, and discard data were not available until relatively recently, and length composition of discards even more recently. Age samples were not taken in surveys until 1994 and from landings until 2000; landings are sparsely sampled for age because removing vertebrae compromises product quality, and even if there were samples, significant questions have been raised about the aging method, which has not been validated using known-age individuals. Important aspects of monkfish biology are poorly understood, including stock structure and movement patterns, growth rates, and longevity. Effects of process error within the model due to the linear growth trend are unknown. Uncertainty surrounds the lack of an explanation for the consistent sex ratio patterns that occur with size in multiple surveys (Richards et al. 2008).

Given the litany of data limitations, it is not surprising that most of the assessment approaches applied during the 2007 Data Poor Stocks Working Group assessment were not successful. The SCALE model was considered useful at that assessment because it integrated the available information and the resulting estimates appeared reasonable (e.g. biomass estimates consistent with empirically-estimated biomass from industry-based surveys). This remained true in the 2010 assessment and the current assessment. However, substantial uncertainty remains surrounding the lack of evidence for rebuilding of the size structure with the observed decline in the catch.

Retrospective patterns in the current model for the north are somewhat less severe than in previous assessments (Figure 26), suggesting that the strong 1999 yearclass may have contributed to the retrospective pattern in the north. However, retrospective underestimation of F and overestimation of biomass continues to be severe, based on the average of 7 peels. If the fishing mortality estimated for 2011 is adjusted upward to account for the average retrospective under-estimation of -54% for the 2004-2010 terminal years, the estimate for 2011 changes from 0.08 to 0.16. If the total biomass estimated for 2011 is adjusted downward to account for the average retrospective overestimation of 87% for the 2004-2010 terminal years, the estimate for 2011 changes from 60,485 mt to 32,390 mt.

The model for the southern area exhibits less severe retrospective patterns than the north; however, the retrospective errors in fishing mortality and stock size increased slightly for the south with this model update (Figure 33). If the fishing mortality estimated for 2011 is adjusted upward to account for the average retrospective underestimation of -23% for the 2004-2010 terminal years, the estimate for 2011 changes from 0.11 to 0.14. If the total biomass estimated for 2011 is adjusted downward to account for the average retrospective overestimation of +25% for the 2004-2010 terminal years, the estimate for 2011 changes from 111,100 mt to 88,806 mt. Age-specific retrospective adjustments using seven peels are summarized in Table 24.

As a further diagnostic, estimates of total biomass based on converting SCALE output numbers at length (30+ cm) to biomass using the length-weight relationship were compared with biomass estimated by applying the length composition from NEFSC *Bigelow* fall and spring surveys to the estimated total number (30+) from SCALE and then converting to biomass. In the north, the estimates from the two methods did not diverge greatly (Figure 34A.); however, in the south the biomass estimates derived by applying the survey length were about half that estimated using the model-estimated length composition (Figure 34B). In a similar analysis of the 2011 estimated and observed catch in the south, 33% of the estimated catch (mt) was over 90 cm, whereas only 3% of the observed catch was over 90 cm (Figure 34C).

Potential explanations for the lack of fit and/or retrospective pattern in the SCALE model were explored in SAW 50. The explanations deemed most likely to cause underlying problems with the model were (1) the growth model being incorrect (i.e., if growth is not linear with age) and (2) setting M=0.3 may be inappropriate (i.e., monkfish longevity may be greater than currently assumed). Although studies are underway to investigate growth and migration of monkfish, there are insufficient results at present to provide further clarification on these issues.

Improvements to the SCALE model since 2007 allow for estimation of within-model uncertainty on fishery selectivity and stock numbers through the MCMC procedure. However, uncertainty in F could not be estimated with the MCMC for monkfish because fishing mortality is set equal to model results in the MCMC. Therefore, all of the within-model uncertainty is not accounted for in the MCMC results. The high uncertainty surrounding this assessment will be largely underestimated by within model uncertainty estimates and probably should not be solely used for the determination of the uncertainty in setting ABCs.

Spawning biomass is not output directly by the SCALE model, but was estimated as the product of population numbers at length (SCALE), maturity at length (Richards et al. 2008), weight at length (SCALE), and fraction female at length (based on data in Richards et al. 2008). Trends in spawning biomass are shown in Figure 35. In the north, estimates of spawning biomass have been increasing since 2006, while in the south spawning biomass had been increasing since the late 1990s but showed a slight downturn in the terminal year of the model (2011).

TOR 4. Update biological reference points as needed and evaluate stock status to determine if the stock is overfished and if overfishing is occurring. Provide estimates of uncertainty.

Overfishing Reference Points

SAW 34 (NEFSC 2002) and Framework 2 of the Monkfish FMP established the overfishing definition as F_{max} and estimated it be equal to 0.2 for both management areas (assuming M=0.2). NEFSC (2007a) examined length-based and age-based YPR models and concluded that the length-based approach was not appropriate as it assumes a von Bertalanffy growth model which does not fit currently understood monkfish growth patterns. NEFSC (2007a and 2010) used the age-based YPR model to update the value of F_{max} assuming M=0.3, and Framework Adjustment 7 of the monkfish FMP adopted this approach for use in management in 2011 (Table 1). The current assessment updates the age-based YPR model using revised selectivity patterns output from SCALE. F_{target} was not defined in the original monkfish FMP or in Framework Adjustments 2 or 7. The DPWSG (NEFSC 2007a) recommended that $F_{40\%}$ be used to define $F_{target;}$ however, this has not yet been formally adopted by management.

Age-based YPR was calculated for each management region using the approach of NEFSC (2007a). This assumed a constant natural mortality M=0.3 and applied selectivity at age approximated from SCALE output selectivity at length for each area. Mean weights at age for the catch and stock were from SCALE output, and maturity ogives were from the 2001 Cooperative Monkfish Survey data (NEFSC 2002), which were very similar to other estimates of maturity (NEFSC 2007a). The estimates from NEFSC (2007a; 2010) and the current assessment are shown in Table 25, and the updated yield curves in Figure 36. The difference in estimates for the two areas reflects differing selectivity estimated for the two areas. The differences between years reflect the changes in selectivity patterns estimated by the SCALE model, especially in the south.

The updated estimates of F_{max} are 0.44 in the northern area and 0.37 in the southern area. Unadjusted estimates of current F (2011) are 0.08 in the northern area and 0.11 in the southern area, both less than the respective overfishing thresholds (Figure 37).

Biomass Reference Points

In the 2010 assessment, recommended biomass reference points were estimated based on long-term projected biomass corresponding to F_{MSY} or its proxy (= F_{max} for monkfish). The recommended reference points were subsequently adopted in Framework Adjustment 7 to the Monkfish FMP. Total biomass targets (i.e., B_{max} at F_{max}) and thresholds (0.5*B_{max}) calculated in 2010 and from the current assessment are shown in Table 26. Current estimates of B_{target} are 46,074 mt in the northern area and 71,667 mt in the southern area, and estimates of $B_{threshold}$ are 23,037 mt in the northern area and 35,834 mt in the southern area. The total catch produced from the long-term B_{target} at the respective values of F_{max} (i.e., proxy for F_{MSY}) is 9,383 mt for the northern area and 14,328 mt for the southern area.

All of the BRPs are based on results of the SCALE model (including F reference points from the YPR which uses selectivity curves estimated by SCALE); therefore, the BRPs are subject to the same high level of uncertainty that surrounds the SCALE model results. Further, the BRPs based on projected biomass at F_{max} are subject to high uncertainty, due to reliance on projections of SCALE model results and the high estimate of F_{max} due to the assumption of M=0.3 in the YPR model.

Using the biological reference points recommended in the 2010 stock assessment and adopted in 2011, the current assessment indicates that monkfish are not overfished with no overfishing occurring in both the northern and southern stock management areas (Figure 37). These determinations are considered highly uncertain due to the many uncertainties in the assessment model upon which they are based. A comparison of the current estimates of reference points with those estimated in the last two assessments is given in Table 26.

TOR 5. Summarize sources of data, model and reference point uncertainty relevant to setting Acceptable Biological Catch limits.

The assessment results for monkfish continue to be uncertain, due to likely under-reported landings and unknown discards during the 1980s and incomplete understanding of key biological parameters such as age and growth, longevity, natural mortality, and stock structure. The population models for both areas exhibit retrospective patterns which are stronger in the north than the south (Figures 26 and 33); however, there appears to be stronger bias in the results in the south than in the north (Figure 34). The BRPs are based on output from the SCALE model; therefore, the BRPs are also highly uncertain.

TOR 6. Perform short-term (3 year) projections for stock biomass under alternative harvest strategies.

SCALE model results and AGEPRO projections were used to predict stock trends during 2013-2016 under two scenarios: $F=F_{threshold}$ assuming stochastic long-term recruitment (using both unadjusted and adjusted SCALE outputs); and status quo F (unadjusted 2011 F estimated from SCALE) assuming stochastic long-term recruitment (Table 27).

For both areas, fishing at $F_{threshold}$ led to declines in total stock biomass in the unadjusted and retrospective-adjusted runs. In the north, total stock biomass increased during 2013-2016 under $F_{status\ quo}$, while in the south, total stock biomass decreased during 2013-2016 under $F_{status\ quo}$.

The projections for both areas have a high degree of uncertainty due to uncertainty in the starting conditions (output from the SCALE model).

Table 28 compares the projected biomass from the SAW 50 models (ACT scenarios) to the current model estimates of biomass for 2010 and 2011 for both management areas.

TOR 7. Should the baseline model fail when applied in the operational assessment, provide guidance on how stock status might be evaluated. Should an alternative assessment approach not be readily available, provide guidance on the type of scientific and management advice that can be. An underlying premise of operational assessment is to minimize the number of significant changes in methodology that would likely require a more detailed peer review.

The baseline models for both monkfish management areas performed similarly to the two previous assessments that were accepted for use in management. Therefore the baseline model was expected to be adequate to guide management under the same terms as in previous years (i.e., with great caution considering the uncertainties underlying the model).

TOR 8. If feasible, present preliminary results from ongoing research projects and indicate how they could impact future assessments.

Figure 40 shows preliminary results from an ongoing archival tagging study of monkfish in which recaptured fish with tags are returned to the investigators (Richards et al. 2012). The recaptured monkfish were 54-77 cm TL at release. The tag returns are few, but suggest the possibility of differences in growth between male and female monkfish. The two females that ‘shrank’ were at large for a short time and the apparent shrinkage may represent measurement error on the live fish (and poor health of one of the recaptured fish).

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Table 1. Timeline of events influencing fishery management of monkfish.

Month/Year	Regulatory Action
Nov. 1999	FMP implemented - Included a multi-level limited access program; two management areas; target TACs; effort limitations (DAS); Year 3 default measures (0 DAS); trip limits for limited access vessels; bycatch allowances; minimum fish sizes; minimum mesh sizes; gear restrictions; spawning season restrictions; a framework adjustment process; annual review requirements; permitting and reporting requirements; and other measures for administration and enforcement.
Nov. 1999	Amendment 1 effective – EFH Omnibus Amendment
May. 2000	DAS implemented
Jul. 2000	SAW 31
Spring 2001	Cooperative Survey
Fall 2001	Hall v. Evans decision - trip limit on gillnet vessels set equal to trawls, based on permit category.
Jan. 2002	SAW 34
Spring 2002	Councils submit Framework 1 – Proposes to fix landings at existing levels and postpone default measures for 1 year while Councils develop Amendment 2.
May. 2002	Emergency Rule – Framework 1 disapproved for non-compliance with Fthreshold in the original plan (which was invalidated by SAW 31 and SAW 34). Implemented a revision to the OFD based on SAW 34 recommendations, and management measures in FW 1.
May. 2003	Framework 2 - Modified the OFD reference points recommended by SAW 34; established an index- and landings-based method for setting TACs to achieve annual rebuilding goals; contained a method for calculating DAS and trip limits; and eliminated the default measures.
Spring 2004	Cooperative Survey
May. 2005	Amendment 2 - Made minimum fish size in SFMA equivalent to that in NFMA (11-inch tail/17-inch whole); established a 6-inch roller gear restriction in the SFMA, implemented two canyon closure areas; removed the 20-day spawning block requirement; established a research set-aside program; established an Offshore Fishery Program in the SFMA; modified some incidental catch limits; and modified the monkfish limited entry program to include vessels that had historically fished off of VA and NC.
Spring 2007	Councils submit Framework 4 - Would establish target TACs, trip limits, and DAS requirements for final 3 years of rebuilding plan; would require use of DAS in NFMA; contains backstop measures if target TACs exceeded; would revise incidental catch limits for NFMA and scallop access areas; and would adjust boundary line applicable to Category H vessels.
May. 2007	Interim Rule - Tempoarily implemented target TAC, DAS, and trip limits recommended in Framework 4 for the NFMA (except does not include the at-sea declaration provision); continues FY 2006 target TAC, DAS, and trip limits for the SFMA; and prohibits the use of carryover DAS. Also temporarily implements other measures contained in Framework 4: Revision to border applicable to Category H vessels and revisions to incidental catch limits in NFMA and scallop access areas.
Autumn 2007	Framework 4 implemented.
Apr. 2008	Framework 5 - Adopted DPWG (2007) reference point definitions, tightened loopholes (e.g. reduced DAS carryover days allowed, tightened effort accounting methods)
Oct. 2008	Framework 6 - removed backstop provision of Framework 4.
May, 2011	Amendment 5 -implemented ACLs and AMs, and set specifications of DAS, trip limits and other management measures to replace those adopted in Framework 4.
Oct., 2011	Framework 7- Revised the catch target, DAS and trip limits for the northern management area and management reference points for both areas in response to SARC 50
2010- present	Amendment 6 in development to consider modifications to the management system, including possible DAS leasing, sectors or ITQs

Table 2. Management measures for monkfish, fishing years 2000-2013 (note that regulations pertain to fishing years (May 1- April 30), and do not correspond to calendar year landings in Table 3.

North

Target TACs, trip limits, DAS restrictions, and landings for the Northern Fishery Management Area

			Trip Limits*	Trip Limits*				
Fishing Year	Target TAC (lbs)	Target TAC/TAL (mt)	Cat. A & C	Cat. B & D	DAS Restrictions**	Landings (lbs)	Landings (mt)	Percent of TAC
2000	12,507,000	5,673	n/a	n/a	40	26,145,000	11,859	209%
2001	12,507,000	5,673	n/a	n/a	40	32,745,000	14,853	262%
2002	25,737,000	11,674	n/a	n/a	40	31,947,000	14,491	124%
2003	39,039,000	17,708	n/a	n/a	40	31,207,000	14,155	80%
2004	37,408,000	16,968	n/a	n/a	40	25,905,000	11,750	69%
2005	29,012,834	13,160	n/a	n/a	40	21,016,667	9,533	72%
2006	17,057,165	7,737	n/a	n/a	40	14,720,265	6,677	86%
2007	11,023,100	5,000	1,250	470	31	11,133,344	5,050	101%
2008	11,023,100	5,000	1,250	470	31	7,777,909	3,528	71%
2009	11,023,100	5,000	1,250	470	31	7,372,258	3,344	67%
2010	11,023,100	5,000	1,250	470	31	6,247,901	2,834	57%
2011	12,905,845	5,854	1,250	600	40	8,153,433	3,699	63%
2012	12,905,845	5,854	1,250	600	40			
2013	12,905,845	5,854	1,250	600	40			

* Trip limits in pounds tail weight per DAS

** Excluding up to 10 DAS carryover, became 4 DAS carryover in FY2007

In 2011, the target TAC became a target TAL

South

Target TACs, trip limits, DAS restrictions, and landings for the Southern Fishery Management Area

			Trip Limits*	Trip Limits*				
Fishing Year	Target TAC (lbs)	Target TAC/TAL (mt)	Cat. A & C	Cat. B, D, H	DAS Restrictions**	Landings (lbs)	Landings (mt)	Percent of TAC
2000	13,281,000	6,024	1,500	1,000	40	17,549,000	7,960	132%
2001	13,281,000	6,024	1,500	1,000	40	24,404,000	11,069	184%
2002	17,463,000	7,921	550	450	40	16,487,000	7,478	94%
2003	22,511,000	10,211	1,250	1,000	40	26,891,000	12,198	119%
2004	14,929,704	6,772	550	450	28	13,719,000	6,223	92%
2005	21,325,315	9,673	700	600	39.3	21,287,811	9,656	100%
2006	8,084,351	3,667	550	450	12	13,027,100	5,909	161%
2007	11,243,562	5,100	550	450	23	15,829,172	7,180	141%
2008	11,243,562	5,100	550	450	23	14,883,407	6,751	132%
2009	11,243,562	5,100	550	450	23	10,582,189	4,800	94%
2010	11,243,562	5,100	550	450	23	9,885,528	4,484	88%
2011	19,676,234	8,925	550	450	28	12,789,016	5,801	65%
2012	19,676,234	8,925	550	450	28			
2013	19,676,234	8,925	550	450	28			

* Trip limits in pounds tail weight per DAS

** Excluding up to 10 DAS carryover, became 4 DAS carryover in FY2007

In 2011, the target TAC became a target TAL

Table 3. Landings (calculated live weight, mt) of monkfish as reported in NEFSC weighout data base (1964-1993) and vessel trip reports (1994-2009) (North = SA 511-523, 561; South = SA 524-639 excluding 551-561 plus landings from North Carolina for years 1977-1995); General Canvas database (1964-1989, North = ME, NH, northern weigh out proportion of MA; South = Southern weigh out proportion of MA, RI-VA); Foreign landings from NAFO database areas 5 and 6. Shaded cells denote suggested source for landings which are used in the total column at the far right (see text for details).

	Weigh Out Plus NC			General Canvas				
Year	US North	US South	US Total	US North	US South	US Total	Foreign	Total
1964	45	19	64	45	61	106	0	106
1965	37	17	54	37	79	115	0	115
1966	299	13	312	299	69	368	2,397	2,765
1967	539	8	547	540	59	598	11	609
1968	451	2	453	449	36	485	2,231	2,716
1969	258	4	262	240	43	283	2,249	2,532
1970	199	12	211	199	53	251	477	728
1971	213	10	223	213	53	266	3,659	3,925
1972	437	24	461	437	65	502	4,102	4,604
1973	710	139	848	708	240	948	6,818	7,766
1974	1,197	101	1,297	1,200	183	1,383	727	2,110
1975	1,853	282	2,134	1,877	417	2,294	2,548	4,842
1976	2,236	428	2,663	2,256	608	2,865	341	3,206
1977	3,137	830	3,967	3,167	1,314	4,481	275	4,756
1978	3,889	1,384	5,273	3,976	2,073	6,049	38	6,087
1979	4,014	3,534	7,548	4,068	4,697	8,765	70	8,835
1980	3,695	4,232	7,927	3,623	6,035	9,658	132	9,790
1981	3,217	2,380	5,597	3,171	4,142	7,313	381	7,694
1982	3,860	3,722	7,582	3,757	4,492	8,249	310	7,892
1983	3,849	4,115	7,964	3,918	4,707	8,624	80	8,044
1984	4,202	3,699	7,901	4,220	4,171	8,391	395	8,296
1985	4,616	4,262	8,878	4,452	4,806	9,258	1,333	10,211
1986	4,327	4,037	8,364	4,322	4,264	8,586	341	8,705
1987	4,960	3,762	8,722	4,995	3,933	8,926	748	9,470
1988	5,066	4,595	9,661	5,033	4,775	9,809	909	10,570
1989	6,391	8,353	14,744	6,263	8,678	14,910	1,178	15,922
1990	5,802	7,204	13,006				1,557	14,563
1991	5,693	9,865	15,558				1,020	16,578
1992	6,923	13,942	20,865				473	21,338
1993	10,645	15,098	25,743				354	26,097
1994	10,950	12,126	23,076				543	23,619
1995	11,970	14,361	26,331				418	27,075
1996	10,791	15,715	26,507				184	26,978
1997	9,709	18,462	28,172				189	28,517
1998	7,281	19,337	26,618				190	26,866
1999	9,128	16,085	25,213				151	25,364
2000	10,729	10,147	20,876				176	21,052
2001	13,341	9,959	23,301				142	23,450
2002	14,011	8,884	22,896				294	23,189
2003	14,991	11,095	26,086				309	26,375
2004	13,209	7,978	21,186				166	21,352
2005	10,140	9,177	19,317				206	19,523
2006	6,974	7,980	14,955				279	15,234
2007	4,953	7,388	12,341				8	12,349
2008	3,942	7,250	11,192				2	11,194
2009	3,210	5,532	8,742					8,742
2010	2,424	4,996	7,420					7,420
2011	2,362	6,344	8,707					8,707

Table 4. U.S. landings of monkfish (calculated live weight, mt) by gear type.

	North					South					Regions Combined				
Year	Trawl	Gill Net	Scallop Dredge	Other	Total	Trawl	Gill Net	Scallop Dredge	Other	Total	Trawl	Gill Net	Scallop Dredge	Other	Total
1964	45	0			45	19				19	64	0			64
1965	36	0			37	17				17	53	0			53
1966	299	0		0	299	13			0	13	311	0		0	312
1967	532		8		539	8				8	540		8		547
1968	447		4		451	2				2	449		4		453
1969	253	1	4		258	4				4	257	1	4		262
1970	198	0		0	199	12				12	210	0		0	211
1971	213		0		213	10				10	223		0		223
1972	426	8	1	2	437	24				24	451	8	1	2	461
1973	661	29	12	8	710	132		5	1	137	794	29	17	9	848
1974	1,060	105	7	25	1,197	98			0	98	1,160	105	7	25	1,297
1975	1,712	123	10	9	1,853	265	0	2	2	269	1,990	123	12	10	2,135
1976	2,031	143	47	15	2,236	333		7	0	340	2,459	143	54	15	2,670
1977	2,737	230	142	28	3,137	508		57	26	591	3,487	230	202	53	3,973
1978	3,255	368	212	54	3,889	605	0	507	26	1,138	4,016	368	774	80	5,238
1979	2,967	393	584	71	4,014	944	6	1,015	16	1,981	3,989	399	2,070	87	6,545
1980	2,526	518	596	56	3,696	1,139	10	1,274	7	2,429	3,723	528	2,276	62	6,589
1981	2,266	461	443	47	3,217	1,100	16	782	105	2,003	3,483	477	1,399	152	5,512
1982	3,040	421	367	32	3,860	1,806	12	1,507	27	3,352	4,998	433	2,061	60	7,551
1983	3,233	314	266	37	3,849	1,819	11	2,119	17	3,966	5,166	325	2,431	56	7,977
1984	3,648	315	196	43	4,202	1,714	15	1,704	18	3,452	5,513	330	1,968	61	7,871
1985	3,982	315	264	55	4,616	1,739	17	2,347	3	4,106	5,757	332	2,611	58	8,758
1986	3,412	326	553	36	4,327	1,841	32	2,068	12	3,954	5,318	358	2,621	48	8,345
1987	3,853	374	695	38	4,960	1,680	26	1,997	3	3,707	5,561	400	2,692	41	8,694
1988	3,554	304	1,172	36	5,066	1,828	58	2,594	3	4,483	5,399	363	3,765	39	9,567
1989	3,429	349	2,584	30	6,391	3,240	17	5,036	3	8,297	6,679	366	7,620	33	14,698
1990	3,298	338	2,141	25	5,802	2,361	32	4,744	5	7,142	5,697	372	6,885	30	12,984
1991	3,299	338	2,033	24	5,694	5,515	363	3,907	16	9,800	8,847	700	5,941	39	15,528
1992	4,330	359	2,211	24	6,923	6,528	977	6,409	11	13,925	10,860	1,336	8,619	35	20,850
1993	5,890	695	4,034	26	10,645	5,987	1,722	7,158	192	15,059	11,879	2,417	11,192	218	25,707
1994	7,574	1,571	1,808	86	11,039	5,233	2,342	3,995	556	12,126	12,707	3,884	5,759	638	22,988
1995	9,119	1,531	1,266	54	11,970	5,785	3,800	4,030	746	14,361	14,905	5,331	5,296	800	26,331
1996	8,445	1,389	913	45	10,791	7,141	4,211	4,330	33	15,715	15,586	5,599	5,243	78	26,507
1997	7,363	988	1,318	40	9,709	8,161	5,203	4,890	208	18,462	15,524	6,192	6,208	249	28,172
1998	5,421	885	948	27	7,281	7,815	6,198	5,190	134	19,337	13,236	7,083	6,138	161	26,618
1999	7,037	1,470	598	24	9,128	6,364	6,187	3,481	54	16,085	13,401	7,656	4,079	78	25,213
2000	8,234	2,102	316	76	10,729	4,018	4,005	1,975	150	10,147	12,252	6,107	2,291	226	20,876
2001	9,990	2,959	381	11	13,341	3,091	5,119	1,719	30	9,959	13,081	8,078	2,100	41	23,301
2002	10,839	2,978	181	13	14,011	1,584	5,410	1,847	43	8,884	12,423	8,389	2,028	56	22,896
2003	12,028	2,488	222	254	14,991	2,034	7,262	1,717	83	11,095	14,062	9,750	1,939	336	26,086
2004	9,918	2,866	14	411	13,209	1,228	4,605	671	1,474	7,978	11,145	7,471	685	1,885	21,186
2005	6,876	2,567	99	598	10,140	1,706	4,673	1,581	1,216	9,177	8,582	7,241	1,680	1,814	19,317
2006	5,054	1,573	185	162	6,974	1,457	3,970	1,532	1,022	7,980	6,511	5,542	1,717	1,184	14,955
2007	3,482	1,172	243	56	4,953	1,084	3,782	1,594	928	7,388	4,566	4,954	1,837	984	12,341
2008	3,055	802	52	34	3,942	1,041	4,098	1,370	741	7,250	4,095	4,900	1,422	775	11,192
2009	2,491	651	21	47	3,210	721	3,117	826	868	5,532	3,212	3,768	847	915	8,742
2010	1,947	460	12	6	2,424	590	2,738	579	1,089	4,996	2,537	3,198	590	1,094	7,420
2011	1,790	516	26	30	2,362	776	3,269	468	1,831	6,344	2,566	3,785	494	1,861	8,707

Table 5. Landed weight (mt) of monkfish by market category for 1964-2011 for northern assessment area.

Year	Belly Flaps	Cheeks	Livers	Head on, Gutted	Round	Dressed	Heads	Tails Unc.	Tails Large	Tails Small	Tails Peewee	All Tails
1964	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.5	0.0	0.0	0.0	13.5
1965	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.0	0.0	0.0	0.0	11.0
1966	0.0	0.0	0.0	0.0	0.0	0.0	0.0	90.1	0.0	0.0	0.0	90.1
1967	0.0	0.0	0.0	0.0	0.0	0.0	0.0	162.5	0.0	0.0	0.0	162.5
1968	0.0	0.0	0.0	0.0	0.0	0.0	0.0	135.9	0.0	0.0	0.0	135.9
1969	0.0	0.0	0.0	0.0	0.0	0.0	0.0	77.8	0.0	0.0	0.0	77.8
1970	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59.8	0.0	0.0	0.0	59.8
1971	0.0	0.0	0.0	0.0	0.0	0.0	0.0	64.1	0.0	0.0	0.0	64.1
1972	0.0	0.0	0.0	0.0	0.0	0.0	0.0	131.6	0.0	0.0	0.0	131.6
1973	0.0	0.0	0.0	0.0	0.0	0.0	0.0	213.8	0.0	0.0	0.0	213.8
1974	0.0	0.0	0.0	0.0	0.0	0.0	0.0	360.4	0.0	0.0	0.0	360.4
1975	0.0	0.0	0.0	0.0	0.0	0.0	0.0	558.0	0.0	0.0	0.0	558.0
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	673.4	0.0	0.0	0.0	673.4
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	944.7	0.0	0.0	0.0	944.7
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1171.4	0.0	0.0	0.0	1171.4
1979	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1209.1	0.0	0.0	0.0	1209.1
1980	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1113.1	0.0	0.0	0.0	1113.1
1981	0.0	0.0	0.0	0.0	0.0	0.0	0.0	969.0	0.0	0.0	0.0	969.0
1982	0.0	0.0	10.0	0.0	0.0	0.0	0.0	1145.6	15.0	2.0	0.0	1162.6
1983	0.0	0.0	9.3	0.0	0.0	0.0	0.0	1152.3	4.8	2.4	0.0	1159.4
1984	0.0	0.0	14.7	0.0	0.0	0.0	0.0	1261.9	3.7	0.0	0.0	1265.6
1985	0.0	0.0	11.4	0.0	0.0	0.0	0.0	1385.9	1.6	2.6	0.0	1390.2
1986	0.0	0.0	13.7	0.0	0.0	0.0	0.0	1302.7	0.3	0.2	0.0	1303.2
1987	0.0	0.0	24.0	0.0	0.0	0.0	0.0	1491.5	1.7	0.7	0.0	1493.9
1988	0.0	0.0	47.4	0.0	0.0	0.0	0.0	1516.9	5.6	3.3	0.0	1525.8
1989	0.0	0.0	58.7	0.0	11.2	0.0	0.0	1464.5	327.0	130.2	0.0	1921.6
1990	0.0	0.0	77.9	0.0	30.3	0.0	0.0	1173.7	410.7	154.0	0.0	1738.4
1991	0.0	3.3	70.0	0.0	0.3	0.0	0.0	1013.9	538.6	153.2	9.1	1714.8
1992	0.0	0.7	83.0	0.0	0.1	0.0	0.0	910.5	589.9	505.4	79.4	2085.3
1993	0.0	0.6	208.3	98.2	350.6	0.0	0.0	1034.3	867.9	1061.8	102.9	3067.0
1994	0.0	1.4	207.6	532.7	981.3	0.0	0.0	403.0	1205.7	1074.8	136.2	2819.7
1995	0.0	0.7	45.7	1223.7	1113.3	0.0	0.0	361.7	1180.4	1003.3	304.4	2849.9
1996	0.3	0.2	65.1	1115.7	745.4	0.0	0.0	89.8	930.4	1398.6	223.9	2642.7
1997	0.0	0.1	50.9	634.3	244.3	0.0	0.0	26.4	1126.1	1361.5	119.1	2633.1
1998	0.0	0.0	24.0	550.9	143.9	0.0	0.0	16.3	1054.9	810.1	79.2	1960.5
1999	0.0	0.1	39.8	1700.8	510.6	0.0	0.0	28.3	995.5	848.4	139.4	2011.6
2000	0.0	0.0	93.9	3213.4	912.1	0.0	0.0	17.5	782.9	1050.4	2.7	1853.4
2001	0.0	0.0	93.5	3084.2	231.1	0.0	0.0	128.5	1114.6	1646.7	0.0	2889.8
2002	0.0	0.1	75.3	3788.7	24.1	0.0	0.0	79.6	1055.3	1777.2	0.0	2912.0
2003	0.0	0.0	60.6	2363.9	13.7	0.0	0.0	94.7	1572.5	2032.2	0.0	3699.5
2004	0.0	0.0	55.8	646.7	959.9	0.0	0.0	3.0	1882.5	1580.3	1.4	3467.3
2005	0.0	0.0	41.8	1705.6	22.0	0.1	0.0	3.3	1440.1	1017.0	1.6	2462.0
2006	0.0	0.0	22.5	1621.9	19.6	0.0	0.0	8.9	899.3	626.9	2.6	1537.8
2007	0.0	0.1	13.2	682.0	0.0	0.1	0.6	8.9	869.6	378.4	0.8	1257.7
2008	0.0	0.0	4.5	390.7	0.0	3.9	0.0	1.4	738.9	310.6	0.0	1050.9
2009	0.0	0.0	1.8	289.6	0.0	10.7	0.0	1.9	560.0	299.0	0.0	860.9
2010	0.0	0.0	1.1	208.3	0.0	0.5	0.0	2.2	395.6	260.6	0.0	658.3
2011	0.0	0.0	2.4	249.0	0.0	0.0	0.0	3.4	375.4	247.2	0.0	626.0

Table 6. Landed weight (mt) of monkfish by market category for 1964-2011 for southern assessment area.

Year	Belly Flaps	Cheeks	Livers	Head on, Gutted	Round	Dressed	Heads	Tails Unc.	Tails Large	Tails Small	Tails Peewee	All Tails
1964	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.7	0.0	0.0	0.0	5.7
1965	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	5.0
1966	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9	0.0	0.0	0.0	3.8
1967	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	2.3
1968	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.6
1969	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	1.2
1970	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	0.0	0.0	0.0	3.7
1971	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	3.0
1972	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.4	0.0	0.0	0.0	7.4
1973	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.7	0.0	0.0	0.0	41.7
1974	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.3	0.0	0.0	0.0	30.3
1975	0.0	0.0	0.0	0.0	0.0	0.0	0.0	84.8	0.0	0.0	0.0	84.8
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	128.8	0.0	0.0	0.0	128.8
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	249.6	0.0	0.0	0.0	249.6
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.0	403.1	0.0	0.0	0.0	403.1
1979	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1015.6	0.0	0.0	0.0	1015.6
1980	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1189.3	0.0	0.0	0.0	1189.3
1981	0.0	0.0	0.0	0.0	0.0	0.0	0.0	685.0	0.0	0.0	0.0	685.0
1982	0.0	0.0	0.2	0.0	0.0	0.0	0.0	912.4	138.1	51.3	0.0	1101.8
1983	0.0	0.0	2.3	0.0	0.0	0.0	0.0	857.7	236.6	136.2	0.0	1230.5
1984	0.0	0.0	10.3	0.0	0.0	0.0	0.0	859.7	183.1	44.5	0.0	1087.3
1985	0.0	0.0	16.7	0.0	0.0	0.0	0.0	1081.1	85.1	70.8	0.0	1236.9
1986	0.0	0.0	22.6	0.0	0.0	0.0	0.0	1062.6	76.1	52.0	0.0	1190.8
1987	0.0	0.0	330.2	0.0	0.0	0.0	0.0	972.2	138.2	6.0	0.0	1116.4
1988	0.0	0.0	65.4	0.0	0.0	0.0	0.0	1129.3	189.5	31.5	0.0	1350.4
1989	0.0	0.0	87.6	0.0	4.5	0.0	0.0	2037.4	230.4	229.8	0.0	2497.5
1990	0.0	0.0	101.8	0.0	187.3	0.0	0.0	1428.1	443.4	223.4	0.0	2094.9
1991	0.0	5.2	200.2	0.0	415.1	0.0	0.0	1215.2	1123.3	460.9	27.5	2826.8
1992	0.2	3.0	238.5	0.0	385.9	0.0	0.0	1868.2	1318.3	787.6	103.9	4077.9
1993	0.0	1.1	251.5	0.0	178.1	0.0	0.0	2468.9	1065.1	789.3	159.4	4482.8
1994	0.0	3.8	250.5	921.0	1063.5	0.0	0.0	853.9	1025.0	988.5	121.8	2989.2
1995	2.3	0.3	451.3	1528.7	1539.1	0.0	0.0	518.0	1341.0	1419.3	58.9	3337.2
1996	0.4	0.5	504.4	2352.1	317.6	0.0	0.0	996.3	1159.7	1628.6	45.6	3830.2
1997	0.1	0.0	577.1	2559.4	550.9	0.0	0.0	647.2	1924.0	1912.6	32.4	4516.2
1998	0.0	0.5	581.9	3036.0	438.0	0.0	0.0	841.9	1952.0	1839.7	16.3	4649.9
1999	0.1	0.1	557.6	4047.4	620.9	0.0	0.0	508.9	1392.8	1352.4	14.1	3268.1
2000	0.0	3.7	530.1	3700.7	178.9	0.0	0.0	276.2	797.1	656.9	1.6	1731.8
2001	0.5	0.0	465.9	3944.0	300.3	0.0	0.0	216.8	844.3	493.6	0.4	1555.1
2002	0.2	0.0	433.3	4012.9	551.3	0.0	0.0	167.0	628.6	336.1	0.2	1132.0
2003	0.0	0.9	425.7	4958.8	667.2	0.0	0.0	242.4	790.1	405.1	0.7	1438.3
2004	0.3	2.1	354.9	2758.0	1066.1	7.8	0.0	185.6	670.8	273.6	0.1	1130.1
2005	0.3	54.9	330.1	3694.7	187.4	17.7	0.0	105.1	770.6	550.5	2.1	1428.3
2006	0.2	108.4	293.2	3350.8	26.6	20.4	4.8	68.5	658.1	505.6	0.7	1232.8
2007	0.2	43.6	258.0	3030.2	107.1	12.2	0.1	88.4	726.9	328.9	0.9	1145.1
2008	0.2	4.8	252.6	3007.5	43.5	13.4	1.1	61.2	768.2	300.3	0.0	1129.7
2009	0.8	0.0	198.9	2539.5	3.9	8.7	11.4	47.1	505.2	235.2	0.3	787.8
2010	0.4	0.0	188.2	2116.9	9.4	4.3	27.4	61.4	476.0	234.9	0.0	772.3
2011	0.1	16.9	224.1	2693.0	2.3	5.8	38.9	44.4	574.5	363.1	0.0	982.0

Table 7. Revised discard estimates, monkfish live weight, northern management region. Dredge and shrimp trawl are based on SBRM d/k all species, live weight; trawl and gillnet based on d/k monk.

North		Trawl					Gillnet					Scallop Dredge					Shrimp Trawl				
Year	Half	No. trips	D/K ratio	CV	Dlr monk (mt)	Discard (mt)	No. trips	D/K ratio	CV	Dlr monk (mt)	Discard (mt)	No. trips	D/K ratio	CV	Dlr all spp (mt)	Discard (mt)	No. trips	D/K ratio	CV	Dlr all spp (mt)	Discard (mt)
1989	1	30	0.037	0.58	1,550	58	1	0.036		84	3		0.001		18,213	17	31	0.002	0.33	3,412	5.5
	2	63	0.141	0.44	1,830	257	103	0.027	0.32	265	7		0.008		24,053	185	9	0.001	0.62	931	1.2
1990	1	16	0.082	0.60	1,562	128	73	0.036	0.41	121	4		0.001		9,864	9	27	0.002	0.34	4,494	8.1
	2	36	0.039	0.45	1,690	66	65	0.029	0.37	219	6		0.008		19,293	149	4	0.058	1.01	620	35.8
1991	1	27	0.042	0.45	1,233	52	191	0.030	0.47	120	4		0.001		16,608	16	46	0.004	0.19	3,536	12.8
	2	81	0.167	0.25	1,999	334	758	0.036	0.10	213	8	1	0.002		21,312	40	7	0.046	0.40	340	15.7
1992	1	51	0.122	0.30	1,674	203	403	0.065	0.16	105	7	3	0.000	0.98	14,179	1	76	0.003	0.23	3,285	9.6
	2	35	0.224	0.43	2,624	587	618	0.040	0.24	248	10	6	0.001	0.41	20,033	26	6	0.003	0.28	161	0.4
1993	1	19	0.067	0.30	2,821	189	271	0.086	0.21	119	10	7	0.002	0.26	13,702	25	78	0.001	0.26	1,890	2.5
	2	19	0.084	0.26	3,032	254	338	0.032	0.24	560	18	4	0.018	0.45	12,674	230	4	0.001	0.70	316	0.3
1994	1	18	0.035	0.29	3,273	115	65	0.065	0.29	270	18	2	0.001	1.21	5,486	5	71	0.002	0.38	2,443	5.9
	2	6	0.024	0.59	4,385	107	44	0.055	0.19	779	43	5	0.010	0.38	6,230	59	6	0.001	0.44	906	0.7
1995	1	30	0.164	0.36	4,643	762	38	0.141	0.30	469	66	1	0.014		2,318	32	64	0.000	0.23	4,452	1.8
	2	48	0.090	0.31	4,478	403	69	0.088	0.23	1,023	90	5	0.018	0.50	6,544	119	9	0.001	0.43	1,377	0.7
1996	1	21	0.190	0.23	4,294	814	28	0.137	0.43	340	47	8	0.003	0.94	5,338	14	30	0.000	0.34	7,580	0.8
	2	49	0.132	0.57	4,057	534	34	0.132	0.19	934	123	5	0.022	0.40	11,375	246	5	0.000	0.79	1,418	0.4
1997	1	13	0.100	0.49	3,795	378	19	0.036	0.32	329	12	4	0.004	0.48	10,567	42	17	0.000	0.61	5,416	0.9
	2	7	0.076	0.23	3,225	244	26	0.194	0.84	742	144	4	0.020	0.76	9,148	180		0.001		649	0.4
1998	1	7	0.124	0.37	3,150	392	39	0.028	0.41	238	7	2	0.004	0.32	7,482	28		0.001		3,095	2.7
	2	3	0.093	0.10	2,398	223	72	0.043	0.28	606	26	7	0.014	0.16	6,400	90		0.001		168	0.1
1999	1	3	0.098	0.04	3,947	388	36	0.067	0.65	282	19	2	0.004	0.65	8,347	29		0.001		1,407	1.2
	2	42	0.069	0.21	3,011	207	66	0.036	0.51	1,051	38	6	0.004	0.44	6,797	30		0.001		33	0.0
2000	1	80	0.069	0.32	3,916	271	58	0.041	0.30	501	21		0.004		6,993	31		0.001		2,068	1.8
	2	61	0.088	0.31	3,798	333	65	0.077	0.24	2,033	157	95	0.004	0.13	13,019	56		0.001		35	0.0
2001	1	61	0.102	0.20	5,088	518	41	0.061	0.69	880	53	17	0.003	0.42	14,926	41	3	0.000	0.14	813	0.1
	2	113	0.066	0.10	4,588	303	33	0.108	0.93	2,208	238		0.005		11,525	60		0.001			0.0
2002	1	47	0.076	0.25	5,634	428	33	0.045	0.39	760	34		0.005		8,712	45		0.001		308	0.3
	2	274	0.100	0.10	4,532	455	67	0.053	0.27	2,230	118	10	0.008	0.97	11,533	88		0.001			0.0
2003	1	206	0.101	0.14	6,642	671	112	0.037	0.24	628	23	5	0.001	0.89	16,053	9	15	0.000	1.01	855	0.0
	2	218	0.055	0.12	4,721	261	273	0.058	0.13	1,570	91	8	0.015	0.41	10,361	157		0.001			0.0
2004	1	163	0.042	0.12	5,307	225	212	0.021	0.22	739	16	3	0.000	0.69	5,633	0	12	0.000	0.25	1,069	0.1
	2	377	0.036	0.10	4,039	147	728	0.059	0.09	1,788	105	19	0.096	0.48	3,705	355		0.001		44	0.0
2005	1	500	0.047	0.07	3,971	187	153	0.098	0.26	516	51	20	0.001	0.57	5,745	6	17	0.000	0.52	836	0.1
	2	601	0.057	0.10	3,038	174	660	0.074	0.12	1,450	108	39	0.008	0.21	23,131	184		0.001		40	0.0
2006	1	292	0.055	0.08	2,852	158	93	0.063	0.41	262	17	5	0.001	0.42	20,833	14	17	0.000	0.56	847	0.0
	2	201	0.071	0.11	2,285	162	80	0.080	0.17	1,025	82	39	0.021	0.32	14,291	305	3	0.000	0.10	449	0.2
2007	1	221	0.050	0.10	2,075	104	42	0.061	0.32	228	14	28	0.002	0.22	11,600	26	14	0.001	0.72	1,899	1.0
	2	303	0.072	0.10	1,448	104	190	0.062	0.16	693	43	68	0.021	0.18	23,644	487		0.001		333	0.2
2008	1	277	0.088	0.10	1,821	160	61	0.076	0.28	141	11	25	0.001	0.22	7,065	11	16	0.000	0.77	1,834	0.9
	2	383	0.082	0.10	1,045	86	156	0.051	0.22	541	28	22	0.011	0.34	3,696	42	3	0.001	0.90	167	0.1
2009	1	351	0.166	0.13	1,666	276	129	0.209	0.46	149	31	7	0.001	0.47	1,960	3	7	0.001	0.61	998	0.8
	2	408	0.079	0.11	832	66	195	0.119	0.27	467	55	22	0.003	0.26	11,642	34	5	0.000	0.92	347	0.0
2010	1	339	0.097	0.08	1,537	149	305	0.056	0.15	112	6	16	0.001	0.80	3,350	4	11	0.000	1.00	2,911	0.1
	2	671	0.090	0.07	857	77	1364	0.102	0.07	303	31	25	0.003	0.31	15,930	50	4	0.000	0.91	780	0.0
2011	1	671	0.120	0.07	1,461	175	554	0.050	0.10	120	6	23	0.002	0.80	6,660	16	1	0.000		3,745	0.0
	2	743	0.058	0.08	1,174	69	1244	0.080	0.10	361	29	81	0.004	0.13	35,600	158		0.001		78	0.0

Table 8. Revised discard estimates, monkfish live weight, southern management region. Dredge and shrimp trawl are based on SBRM d/k all species, live weight; trawl and gillnet based on d/k monk.

South		Trawl					Gillnet					Scallop Dredge				
Year	Half	No. trips	D/K ratio	CV	Dlr monk (mt)	Discard (mt)	No. trips	D/K ratio	CV	Dlr monk (mt)	Discard (mt)	No. trips	D/K ratio	CV	Dlr all spp (mt)	Discard (mt)
1989	1	46	0.709	0.50	2,195	1,556		0.031		12	0		0.010	0.010	59,696	577
	2	53	0.169	0.59	733	124	3	0.054		5	0		0.015	0.015	35,498	528
1990	1	50	0.064	0.26	1,567	100	1	0.031		14	0		0.010		64,314	622
	2	35	0.118	0.32	759	90	13	0.054		18	0		0.015		53,040	789
1991	1	73	0.258	0.30	1,257	324	3	0.031		209	2		0.010		67,829	656
	2	77	0.020	0.39	3,831	78	8	0.000		154	0	2	0.001	0.07	36,015	19
1992	1	62	0.061	0.38	3,947	239	94	0.011	0.31	786	8	7	0.001	0.69	48,686	29
	2	41	0.028	0.83	2,135	60	72	0.020	0.20	176	3	7	0.012	0.50	39,126	460
1993	1	40	0.092	0.68	2,598	238	78	0.034	0.70	1,306	44	12	0.008	0.30	23,971	197
	2	34	0.028	0.49	1,301	36	87	0.061	0.20	341	21	4	0.032	0.53	18,379	587
1994	1	43	0.095	0.29	2,925	277	124	0.079	0.33	1,565	124	10	0.020	0.26	26,657	538
	2	30	0.323	0.56	2,027	655	173	0.056	0.18	967	55	10	0.015	0.29	24,222	370
1995	1	61	0.175	0.55	2,789	488	260	0.044	0.20	2,758	121	14	0.030	0.17	34,108	1,011
	2	103	0.115	0.57	2,946	340	170	0.050	0.34	1,172	59	9	0.050	0.45	18,456	917
1996	1	56	0.164	0.36	3,187	523	226	0.077	0.27	2,615	202	19	0.020	0.23	27,505	547
	2	85	0.095	0.18	4,021	380	134	0.052	0.28	1,434	75	15	0.029	0.26	19,621	562
1997	1	60	0.025	0.47	4,130	102	238	0.067	0.34	3,089	206	16	0.028	0.18	19,067	543
	2	29	0.089	0.15	4,215	374	106	0.015	0.34	1,313	20	8	0.041	0.39	14,997	612
1998	1	31	0.108	0.33	3,991	431	228	0.070	0.20	3,606	252	8	0.008	0.24	17,094	136
	2	28	0.027	0.52	3,946	108	64	0.062	0.44	2,053	128	15	0.012	0.57	15,300	177
1999	1	39	0.045	0.30	4,370	195	52	0.052	0.34	4,207	220	13	0.010	0.26	30,059	291
	2	34	0.214	0.57	2,306	494	35	0.046	0.57	1,917	88	56	0.004	0.16	34,102	150
2000	1	67	0.786	0.32	2,255	1,773	60	0.063	0.30	2,683	170	38	0.014	0.16	47,847	666
	2	47	0.107	0.62	1,709	182	44	0.051	0.81	1,157	59	133	0.009	0.16	43,879	382
2001	1	61	0.946	0.47	1,703	1,611	57	0.030	0.42	2,248	67	42	0.015	0.11	64,029	972
	2	96	0.404	0.73	1,348	545	35	0.033	0.38	2,788	92	48	0.014	0.15	70,044	973
2002	1	50	0.338	0.38	1,123	379	34	0.017	0.80	3,590	61	34	0.019	0.09	83,888	1,571
	2	94	0.327	0.39	566	185	40	0.063	0.44	1,967	124	61	0.018	0.10	81,620	1,475
2003	1	120	0.331	0.36	1,172	388	50	0.016	0.35	4,452	69	46	0.014	0.15	82,660	1,192
	2	99	0.406	0.45	1,177	478	56	0.070	0.31	2,849	199	71	0.017	0.12	91,638	1,542
2004	1	237	0.240	0.44	1,012	243	78	0.073	0.22	3,441	252	82	0.014	0.08	107,728	1,543
	2	436	0.300	0.31	733	220	74	0.089	0.22	1,043	93	193	0.015	0.10	95,117	1,432
2005	1	534	0.175	0.14	945	165	100	0.104	0.22	3,217	334	108	0.014	0.18	99,628	1,419
	2	654	0.064	0.11	1,588	102	82	0.081	0.20	1,372	111	174	0.019	0.19	67,548	1,290
2006	1	327	0.180	0.19	1,008	181	43	0.054	0.19	2,865	155	43	0.009	0.31	87,842	767
	2	277	0.055	0.15	1,010	56	35	0.082	0.32	967	79	166	0.022	0.14	99,456	2,210
2007	1	335	0.125	0.25	741	93	59	0.220	0.37	2,139	471	138	0.010	0.14	103,992	1,083
	2	420	0.159	0.40	657	104	45	0.054	0.33	1,569	84	156	0.013	0.15	68,914	920
2008	1	343	0.098	0.19	744	73	54	0.108	0.25	2,882	311	374	0.006	0.11	106,134	686
	2	316	0.017	0.31	594	10	39	0.104	0.29	993	104	245	0.010	0.13	74,506	717
2009	1	414	0.080	0.30	646	52	62	0.052	0.19	2,438	128	370	0.006	0.08	122,576	725
	2	529	0.088	0.31	280	25	32	0.074	0.24	610	45	103	0.009	0.15	73,175	652
2010	1	569	0.248	0.24	474	118	114	0.060	0.21	2,034	122	132	0.010	0.11	108,617	1,098
	2	545	0.190	0.51	369	70	95	0.077	0.18	695	54	174	0.008	0.12	81,139	648
2011	1	573	0.123	0.13	634	78	178	0.078	0.12	2,357	185	156	0.010	0.13	107,870	1,132
	2	601	0.088	0.11	598	53	84	0.122	0.19	1,066	130	150	0.010	0.12	62,873	623

Table 9. Annual catch using (mt monks discarded / mt kept of all species) to estimate discards for dredges and shrimp trawls and (mt monks discarded / mt monks kept) to estimate discards for trawls and gillnets.

	North			South			Areas Combined				
Year	Landings	Discard	Total (mt)	Landings	Discard	Total (mt)	Landings	Discard	Total (mt)	Foreign	Total (mt)
1980	3,623	635	4258	6,035	563	6598	9,658	1,197	10,855	132	10,987
1981	3,171	754	3925	4,142	451	4593	7,313	1,204	8,517	381	8,898
1982	3,860	699	4559	3,722	586	4308	7,582	1,285	8,867	310	9,177
1983	3,849	664	4513	4,115	659	4774	7,964	1,323	9,287	80	9,367
1984	4,202	616	4818	3,699	684	4383	7,901	1,301	9,202	395	9,597
1985	4,616	640	5256	4,262	636	4898	8,878	1,276	10,154	1,333	11,487
1986	4,327	548	4875	4,037	618	4655	8,364	1,166	9,530	341	9,871
1987	4,960	766	5726	3,762	1039	4801	8,722	1,805	10,527	748	11,275
1988	5,066	784	5850	4,595	1030	5625	9,661	1,814	11,475	909	12,384
1989	6,391	534	6925	8,353	2,786	11139	14,744	3,320	18,064	1,178	19,242
1990	5,802	406	6208	7,204	1,602	8806	13,006	2,008	15,014	1,557	16,571
1991	5,693	481	6174	9,865	1,080	10945	15,558	1,561	17,119	1,020	18,139
1992	6,923	844	7767	13,942	801	14743	20,865	1,644	22,509	473	22,982
1993	10,645	730	11375	15,098	1,123	16221	25,743	1,853	27,596	354	27,950
1994	10,950	353	11303	12,126	2,019	14145	23,076	2,372	25,448	543	25,991
1995	11,970	1475	13445	14,361	2,935	17297	26,331	4,410	30,741	418	31,159
1996	10,791	1780	12572	15,715	2,289	18004	26,507	4,069	30,576	184	30,760
1997	9,709	1002	10712	18,462	1,856	20318	28,172	2,858	31,030	189	31,219
1998	7,281	769	8050	19,337	1,231	20568	26,618	2,000	28,618	190	28,808
1999	9,128	713	9841	16,085	1,438	17523	25,213	2,151	27,364	151	27,515
2000	10,729	871	11599	10,147	3,232	13379	20,876	4,103	24,979	176	25,155
2001	13,341	1213	14554	9,959	4,260	14219	23,301	5,473	28,773	142	28,915
2002	14,011	1169	15180	8,884	3,796	12680	22,896	4,964	27,860	294	28,154
2003	14,991	1212	16203	11,095	3,869	14964	26,086	5,080	31,167	309	31,476
2004	13,209	847	14056	7,978	3,782	11760	21,186	4,629	25,816	166	25,982
2005	10,140	711	10851	9,177	3,421	12597	19,317	4,132	23,449	206	23,655
2006	6,974	738	7712	7,980	3,448	11428	14,955	4,186	19,140	279	19,419
2007	4,953	778	5732	7,388	2,755	10143	12,341	3,533	15,875	8	15,883
2008	3,942	338	4280	7,250	1,901	9151	11,192	2,240	13,432	2	13,434
2009	3,210	465	3675	5,532	1,626	7158	8,742	2,092	10,833		10,833
2010	2,424	317	2741	4,996	2,109	7105	7,420	2,426	9,846		9,846
2011	2,362	452	2814	6,344	2,200	8545	8,707	2,652	11,359		11,359

Table 10. Temporal stratification used in expanding landings and discard to length composition of the monkfish catch. Unless otherwise indicated, sampling was expanded within gear type and area.

	Trawl		Gillnet		Dredge	
North	Kept	Discarded	Kept	Discarded	Kept	Discarded
1994	annual	annual	1994-1999	1994-1999	1994-1999	1994-1999
1995	annual	annual	1994-1999	1994-1999	1994-1999	1994-1999
1996	annual	annual	1994-1999	1994-1999	1994-1999	1994-1999
1997	annual	annual	1994-1999	1994-1999	1994-1999	1994-1999
1998	annual	annual	1994-1999	1994-1999	1994-1999	1994-1999
1999	annual	annual	1994-1999	1994-1999	1994-1999	1994-1999
2000	annual	annual	annual	2000-2002 N+S	annual N+S	annual N+S
2001	annual	annual	annual	2000-2002 N+S	annual N+S	annual N+S
2002	annual	annual	annual	2000-2002 N+S	annual N+S	annual N+S
2003	half-year	half-year	annual	annual N+S	annual N+S	annual N+S
2004	half-year	half-year	annual	annual N+S	annual N+S	annual N+S
2005	half-year	half-year	annual	annual N+S	annual N+S	annual N+S
2006	half-year	half-year	annual	2006-2008 N+S	annual N+S	annual N+S
2007	half-year	half-year	annual	2006-2008 N+S	annual N+S	annual N+S
2008	half-year	half-year	annual	2006-2008 N+S	annual N+S	annual N+S
2009	half-year	half-year	annual	2009-2011 N+S	annual N+S	annual N+S
2010	half-year	half-year	annual	2009-2011 N+S	annual N+S	annual N+S
2011	half-year	half-year	annual	2009-2011 N+S	annual N+S	annual N+S
South						
1994	annual		annual	annual	annual	annual
1995	annual		annual	annual	annual	annual
1996	annual		annual	annual	annual	annual
1997	annual		annual	annual	annual	annual
1998	annual		annual	annual	annual	annual
1999	annual		annual	annual	annual	annual
2000	annual N+S	annual N+S	annual	2000-2002 N+S	annual	annual
2001	annual N+S	annual N+S	annual	2000-2002 N+S	2000-2002	2000-2002
2002	annual N+S	annual N+S	annual	2000-2002 N+S	2000-2002	2000-2002
2003	annual	half-year	annual	annual N+S	annual	annual
2004	annual	half-year	annual	annual N+S	annual	annual
2005	annual	half-year	annual	annual N+S	annual	annual
2006	annual	half-year	annual	2006-2008 N+S	annual	annual
2007	annual	half-year	annual	2006-2008 N+S	annual	annual
2008	annual	half-year	annual	2006-2008 N+S	annual	annual
2009	annual	half-year	annual	2009-2011 N+S	annual	annual
2010	annual	half-year	annual	2009-2011 N+S	annual	annual
2011	annual	half-year	annual	2009-2011 N+S	annual	annual

Table 11. Survey results from NEFSC offshore autumn bottom trawl surveys in the northern management region (strata 20-30, 34-40). Indices are delta distribution stratified means.

	Biomass Index				Abundance Index				Mean	Length						Number	Number	Number of	Proportion
	Mean	CV	L95%	U95%	Mean	CV	L95%	U95%	Ind wt	Min	5%	50%	Mean	95%	Max	of Fish	of Tows	Non-zero Tows	Non-zero
1963	3.82	27.3	2.34	5.30	0.80	18.4	0.51	1.09	4.7	11	14	59	58.3	103	111	86	90	39	0.43
1964	1.89	23.2	1.03	2.75	0.39	22.5	0.22	0.56	4.8	21	21	58	59.4	92	102	32	87	23	0.26
1965	2.54	22.7	1.41	3.67	0.35	17.1	0.23	0.46	7.3	28	36	70	71.6	96	110	40	88	30	0.34
1966	3.38	18.4	2.16	4.60	0.51	16.7	0.34	0.68	6.5	37	48	73	73.1	90	96	55	86	33	0.38
1967	1.23	34.2	0.40	2.05	0.19	26.7	0.09	0.29	6.5	48	48	69	70.3	91	92	18	86	14	0.16
1968	2.05	37.8	0.53	3.57	0.29	30.5	0.12	0.46	7.2	11	26	72	71.4	105	106	32	86	16	0.19
1969	3.76	26.3	1.82	5.69	0.42	17.2	0.28	0.56	8.8	13	41	78	78.8	101	110	39	88	30	0.34
1970	2.28	29.1	0.98	3.58	0.40	22.4	0.22	0.57	5.8	22	36	67	67.2	90	98	41	92	21	0.23
1971	2.93	25.9	1.45	4.41	0.49	18.6	0.31	0.67	5.9	15	22	69	67.0	97	101	44	94	27	0.29
1972	1.42	27.3	0.67	2.17	0.32	19.8	0.19	0.44	4.4	21	21	61	56.9	97	99	29	94	22	0.23
1973	3.18	26.7	1.77	4.59	0.51	19.3	0.32	0.71	6.0	16	16	58	65.2	109	112	63	92	29	0.32
1974	2.06	23.5	1.11	3.01	0.31	20.1	0.19	0.44	6.4	13	13	69	64.9	109	111	37	97	23	0.24
1975	1.73	21.1	1.02	2.43	0.30	20.5	0.18	0.42	5.7	11	11	60	62.9	97	102	40	106	27	0.25
1976	3.39	27.6	1.55	5.22	0.42	21.6	0.24	0.60	7.6	29	30	71	72.1	106	121	32	87	24	0.28
1977	5.57	19.0	3.49	7.65	0.63	13.7	0.46	0.79	7.2	21	35	73	71.1	107	119	112	126	56	0.44
1978	5.11	16.1	3.50	6.72	0.58	13.2	0.43	0.73	6.7	10	24	70	67.6	104	116	146	201	78	0.39
1979	5.12	16.9	3.57	6.67	0.47	12.0	0.36	0.58	8.9	15	19	77	73.5	103	115	125	211	78	0.37
1980	4.46	25.5	2.23	6.68	0.53	16.0	0.37	0.70	6.3	6	16	66	63.9	101	111	65	97	39	0.40
1981	2.00	27.8	0.34	1.53	0.41	15.4	0.07	0.22	4.4	9	13	55	57.5	93	101	46	93	30	0.32
1982	0.94	30.3	0.38	1.49	0.14	25.7	0.07	0.21	6.6	29	29	71	68.9	97	100	17	95	14	0.15
1983	1.62	21.8	0.93	2.31	0.47	20.2	0.28	0.66	3.4	13	17	54	53.0	88	96	38	82	27	0.33
1984	3.01	27.1	1.41	4.61	0.48	13.7	0.35	0.61	5.8	11	26	63	62.7	102	106	36	88	29	0.33
1985	1.44	36.2	0.42	2.46	0.37	24.6	0.19	0.55	4.0	12	15	55	53.1	101	102	32	88	23	0.26
1986	2.35	27.2	1.10	3.61	0.60	18.9	0.38	0.83	3.7	19	23	52	53.8	82	100	46	90	26	0.29
1987	0.87	36.1	0.26	1.49	0.26	28.6	0.12	0.41	3.3	15	15	53	52.2	92	96	22	87	15	0.17
1988	1.52	34.8	0.48	2.57	0.31	29.7	0.13	0.50	4.9	11	11	53	57.1	92	93	26	89	17	0.19
1989	1.40	40.2	0.50	2.31	0.43	19.3	0.27	0.59	2.6	9	9	39	40.8	93	96	39	87	25	0.29
1990	1.06	28.7	0.50	1.62	0.59	18.1	0.38	0.80	1.4	9	10	25	32.3	72	89	55	89	35	0.39
1991	1.25	29.4	0.60	1.91	0.58	17.1	0.38	0.77	1.7	9	10	31	38.3	83	95	62	88	33	0.38
1992	1.12	28.6	0.57	1.66	0.94	18.3	0.60	1.27	1.2	9	9	26	33.0	79	86	78	86	37	0.43
1993	1.13	44.1	0.51	1.75	0.99	15.4	0.69	1.29	0.9	6	9	20	27.1	71	94	103	86	45	0.52
1994	1.05	31.3	0.45	1.65	1.35	14.4	0.97	1.73	0.7	9	9	19	24.9	55	98	110	87	51	0.59
1995	1.71	31.2	0.66	2.76	0.92	12.9	0.69	1.16	1.7	10	12	34	39.6	84	91	87	93	40	0.43
1996	1.09	27.3	0.52	1.67	0.63	18.1	0.41	0.85	1.7	8	11	38	40.3	63	95	51	88	30	0.34
1997	0.75	26.6	0.40	1.10	0.50	19.9	0.30	0.69	1.3	8	9	35	35.4	70	86	39	90	27	0.30
1998	1.02	23.7	0.57	1.47	0.61	17.7	0.40	0.82	1.5	10	10	30	35.5	68	77	56	104	38	0.37
1999	0.90	32.2	0.37	1.42	1.08	16.3	0.74	1.43	0.7	8	8	22	25.7	58	81	111	106	44	0.42
2000	2.53	25.1	1.32	3.74	2.40	17.7	1.56	3.23	1.0	9	11	25	30.3	70	88	165	87	43	0.49
2001	2.07	23.0	1.14	3.01	1.62	12.8	1.21	2.03	1.1	8	12	31	34.7	65	93	145	90	50	0.56
2002	2.32	27.1	1.09	3.55	1.28	14.4	0.92	1.64	1.4	9	9	34	35.1	65	93	114	86	45	0.52
2003	2.72	31.3	1.05	4.39	1.07	13.8	0.78	1.36	1.7	8	8	40	37.8	73	88	90	88	39	0.44
2004	0.63	29.6	0.26	0.99	0.52	20.1	0.31	0.72	1.2	8	8	21	29.8	68	89	36	85	24	0.28
2005	1.62	46.2	0.15	3.09	0.59	20.2	0.36	0.83	1.7	8	8	24	34.3	79	88	46	87	29	0.33
2006	1.04	25.2	0.53	1.56	0.76	16.4	0.52	1.01	1.3	6	7	33	33.2	69	86	56	94	37	0.39
2007	1.20	32.7	0.43	1.97	0.64	16.5	0.43	0.84	1.7	9	17	31	37.5	77	81	63	90	32	0.36
2008	0.99	31.8	0.37	1.61	0.78	22.7	0.43	1.13	1.2	9	9	27	31.6	68	85	60	90	27	0.30
Bigelow, no calibration coefficient applied:																			
2009	4.33	21.4	2.51	6.15	2.97	11.6	2.29	3.64	1.4	9	9	32	34.4	69	101	255	90	61	0.68
2010	7.12	30.1	2.91	11.32	3.53	12.4	2.68	4.39	1.4	7	8	36	37.3	66	95	313	88	62	0.70
2011	6.58	19.1	3.35	5.21	4.28	11.1	3.35	5.21	1.5	7	8	37	35.4	69	91	295	80	59	0.74
2012	8.86	29.8	3.691	14.02	4.73	9.2	3.882	5.58	1.3	6	8	33	34.3	65.0	97	433	101	80	0.79
Bigelow, calibration coefficient applied:																			
2009	0.54				0.42														
2010	0.88				0.50														
2011	0.82				0.60														
2012	1.10				0.66														

Table 12. Survey results from NEFSC offshore spring bottom trawl surveys in the northern management region (strata 20-30, 34-40). Indices are delta distribution stratified means.

	Biomass Index				Abundance Index					Length						Number of	Number	Number of Nonzero	Proportion
	Mean	CV	L95%	U95%	Mean	CV	L95%	U95%	Ind wt	Min	5%	50%	Mean	95%	Max	Fish	of Tows	Tows	Non-zero
1968	1.01	35.9	0.30	1.72	0.17	31.3	0.07	0.27	6.0	50	51	68	70.4	89	90	13	86	11	0.13
1969	1.34	44.9	0.16	2.52	0.18	38.3	0.05	0.32	7.5	33	33	71	71.5	99	100	15	87	10	0.11
1970	2.02	30.9	0.80	3.25	0.34	19.0	0.22	0.47	5.9	30	30	62	65.4	98	99	32	90	22	0.24
1971	1.04	29.4	0.44	1.64	0.16	27.9	0.07	0.24	6.5	45	53	69	72.6	99	100	20	96	15	0.16
1972	4.68	18.1	3.05	6.31	0.64	15.0	0.45	0.83	7.1	13	39	74	72.7	100	105	59	96	38	0.40
1973	1.91	25.5	0.96	2.86	0.43	29.5	0.18	0.69	4.3	17	26	68	65.7	99	106	91	87	36	0.41
1974	1.48	21.2	0.86	2.09	0.44	14.4	0.31	0.56	3.4	20	23	58	58.3	97	111	86	83	41	0.49
1975	0.94	18.6	0.60	1.28	0.34	16.7	0.23	0.45	2.8	16	19	53	54.0	87	109	73	87	36	0.41
1976	2.83	20.5	1.69	3.96	0.67	15.5	0.47	0.88	3.8	14	20	60	61.5	95	106	158	99	52	0.53
1977	1.03	22.7	0.58	1.48	0.26	19.7	0.16	0.36	3.6	10	31	66	63.4	93	106	61	107	37	0.35
1978	0.63	23.3	0.34	0.91	0.14	16.4	0.10	0.19	4.0	15	19	73	65.5	89	92	37	113	30	0.27
1979	0.90	36.8	0.28	1.52	0.14	14.5	0.10	0.19	4.7	12	14	67	62.5	100	118	48	139	40	0.29
1980	1.62	26.3	0.79	2.46	0.38	14.9	0.27	0.49	3.7	17	22	43	53.3	98	107	84	85	38	0.45
1981	1.74	24.3	0.91	2.58	0.38	12.8	0.28	0.47	4.4	11	21	52	57.7	95	120	95	87	42	0.48
1982	3.02	29.5	1.27	4.76	0.35	28.1	0.16	0.54	8.6	25	36	61	68.8	105	108	33	92	22	0.24
1983	1.59	34.0	0.53	2.64	0.42	27.7	0.19	0.64	3.7	12	13	49	49.9	96	112	34	90	22	0.24
1984	1.70	33.1	0.60	2.80	0.33	22.9	0.18	0.47	4.7	17	19	62	60.8	93	100	26	86	19	0.22
1985	2.11	24.6	1.09	3.13	0.35	21.6	0.20	0.49	6.1	13	13	68	66.9	104	108	25	81	21	0.26
1986	2.16	29.5	0.96	3.37	0.34	21.1	0.20	0.48	6.2	11	14	63	65.4	109	121	30	90	22	0.24
1987	1.73	29.6	0.73	2.73	0.24	22.1	0.14	0.35	7.1	16	16	66	64.2	99	100	21	83	16	0.19
1988	2.11	29.1	0.91	3.31	0.61	17.8	0.40	0.82	3.3	10	20	49	49.8	89	110	43	90	26	0.29
1989	1.64	32.0	0.64	2.63	0.62	24.8	0.32	0.93	2.6	10	11	40	43.2	80	94	48	85	24	0.28
1990	1.00	32.4	0.37	1.64	0.28	22.6	0.16	0.41	3.6	15	18	47	49.1	106	107	25	90	17	0.19
1991	1.83	37.7	0.48	3.18	0.59	18.8	0.37	0.81	2.7	12	15	35	42.3	78	100	48	86	28	0.33
1992	0.91	63.3	-0.19	2.01	0.49	34.6	0.16	0.83	1.8	16	17	35	40.6	82	101	36	83	20	0.24
1993	1.20	22.7	0.74	1.67	0.68	15.6	0.48	0.89	1.7	10	11	44	41.0	71	90	59	87	27	0.31
1994	0.95	34.1	0.40	1.50	0.45	20.0	0.28	0.63	2.2	10	13	40	41.0	83	89	45	88	24	0.27
1995	1.75	37.7	0.81	2.70	0.98	16.7	0.66	1.31	1.8	15	16	33	39.9	73	97	83	88	39	0.44
1996	1.01	28.2	0.45	1.56	0.67	24.7	0.34	0.99	1.5	15	17	41	43.0	60	70	49	82	20	0.24
1997	0.56	37.0	0.17	0.95	0.34	27.2	0.16	0.52	1.6	9	9	36	39.4	75	89	34	89	19	0.21
1998	0.49	29.3	0.23	0.74	0.41	15.5	0.29	0.54	1.1	11	11	19	31.3	67	78	46	115	33	0.29
1999	1.22	24.5	0.65	1.80	0.82	17.2	0.55	1.10	1.4	9	14	31	35.5	71	97	62	87	33	0.38
2000	1.44	21.1	0.85	2.03	1.13	12.9	0.84	1.41	1.2	15	17	29	34.5	75	87	99	89	42	0.47
2001	1.97	33.1	0.69	3.25	1.69	14.1	1.22	2.15	1.1	9	11	24	31.4	75	86	151	89	50	0.56
2002	2.00	16.8	1.34	2.66	1.76	12.3	1.33	2.18	1.1	12	15	34	36.6	60	73	155	91	50	0.55
2003	2.38	33.5	0.82	3.95	0.81	20.9	0.48	1.14	2.3	10	13	42	44.2	69	95	79	86	30	0.35
2004	2.29	30.7	0.91	3.66	0.91	18.7	0.58	1.24	2.5	9	11	48	46.7	81	85	69	88	36	0.41
2005	2.06	38.5	0.51	3.61	0.71	15.9	0.49	0.93	2.1	11	13	48	45.1	68	75	52	87	31	0.36
2006	0.93	40.9	0.18	1.67	0.37	28.7	0.16	0.57	2.5	15	13	43	44.8	72	105	33	95	23	0.24
2007	1.65	70.1	-0.61	3.91	0.56	28.3	0.25	0.86	1.9	11	10	32	36.8	78	85	43	86	19	0.22
2008	1.78	45.8	0.18	3.38	0.68	21.7	0.39	0.97	1.9	8	16	35	40.8	73	85	61	86	24	0.28
Bigelow, no calibration coefficient applied:																			
2009	4.26	17.3	2.82	5.71	2.27	11.6	1.75	2.78	1.7	11	12	36	39.4	77	93	245	116	63	0.54
2010	4.96	18.2	3.19	6.73	2.48	12.5	1.87	3.09	1.9	10	14	40	42.3	70	115	222	104	54	0.52
2011	6.77	18.2	4.35	9.19	3.12	13.5	2.29	3.95	2.1	10	13	44	45.6	75	91	250	91	58	0.64
2012	5.84	23.7	3.13	8.55	3.58	13.9	2.61	4.56	1.5	10	13	36	38.5	66	97	360	110	72	0.65
Bigelow, calibration coefficient applied:																			
2009	0.53				0.32														
2010	0.61				0.35														
2011	0.84				0.44														
2012	0.72				0.50														

Table 13. Survey results from ASMFC summer shrimp surveys in the northern management region (strata 1, 3, 5, 6-8). Indices are delta distribution stratified means.

	Biomass Index				Abundance Index								Length						
	Mean	CV	L95%	U95%	Mean	CV	L95%	U95%	Ind wt	Min	5%	50%	Mean	95%	Max	Number of Fish	Number of Tows	Number of Nonzero Tows	Proportion of Nonzero Tows
1991	1.96	20.6	1.17	2.75	2.90	11.2	2.27	3.54	0.65	11	15	24	27.5	59	96	125	43	39	0.91
1992	2.92	26.5	1.40	4.43	2.91	11.2	2.27	3.54	0.93	11	13	28	31.5	56	78	135	45	40	0.89
1993	3.34	31.7	1.39	5.30	3.76	14.4	2.70	4.81	0.83	7	9	23	27.6	59	102	170	46	42	0.91
1994	1.64	25.5	0.84	2.45	3.48	15.3	2.43	4.52	0.48	5	10	19	24.1	48	95	166	43	37	0.86
1995	1.64	28.3	0.73	2.54	2.09	21.3	1.22	2.96	0.75	11	19	26	31.2	67	76	83	35	24	0.69
1996	3.43	31.2	1.33	5.53	2.97	14.8	2.11	3.83	1.12	13	14	34	34.4	63	90	107	32	30	0.94
1997	2.08	25.5	1.04	3.12	1.58	16.5	1.07	2.09	1.32	11	16	32	37.7	62	73	72	40	31	0.78
1998	2.30	35.2	0.71	3.89	2.12	14.9	1.50	2.74	1.07	12	16	23	31.3	61	77	84	35	31	0.89
1999	6.35	19.8	4.77	7.93	7.02	12.4	5.31	8.73	0.93	8	9	28	30.9	65	82	301	42	39	0.93
2000	4.12	25.1	2.09	6.15	5.76	14.7	4.10	7.41	0.67	11	15	28	30.2	51	82	215	35	30	0.86
2001	8.55	24.5	4.44	12.66	11.12	12.2	8.46	13.79	0.67	11	13	26	29.5	51	85	442	36	36	1.00
2002	12.86	14.6	9.18	16.54	11.79	10.4	9.38	14.20	1.07	11	17	32	35.3	59	94	493	38	38	1.00
2003	8.24	30.2	4.47	12.02	5.86	14.6	4.17	7.54	1.27	3	13	38	37.4	63	87	236	37	36	0.97
2004	4.60	12.6	3.46	5.74	3.39	10.9	2.66	4.11	1.32	11	11	34	35.7	66	75	142	35	33	0.94
2005	7.60	16.6	5.13	10.06	5.25	10.4	4.19	6.32	1.38	9	14	34	37.4	66	89	271	46	44	0.96
2006	7.36	22.2	3.81	10.91	4.34	8.8	3.09	5.60	1.52	7	11	30	37.2	70	89	143	29	29	1.00
2007	5.13	32.7	1.84	8.42	4.39	13.0	3.26	5.51	0.92	9	11	19	28.2	64	79	218	43	36	0.84
2008	3.90	23.3	2.12	5.67	2.85	13.8	2.08	3.62	1.35	10	14	32	36.1	67	82	116	37	31	0.84
2009	4.23	32.7	1.52	6.94	3.10	12.1	2.36	3.84	1.03	11	13	30	32.7	60	80	159	49	45	0.92
2010	3.11	24.8	1.60	4.62	2.57	15.9	1.77	3.37	1.09	9	16	33	35.1	58	90	132	49	43	0.88
2011	2.71	18.5	1.72	3.69	2.25	10.3	1.80	2.71	1.18	13	13	37	36.2	59	77	124	47	38	0.81
2012	3.71	23.4	2.01	5.41	3.65	14.5	2.61	4.68	0.89	4	10	26	30.8	56	92	192	49	41	0.84

Table 14. Monkfish indices from Maine-New Hampshire inshore surveys, strata 1-4, regions 1-5.

Year	Fall Stratified Mean Number	SE	Fall Stratified Mean Weight	SE
2000	4.8	0.61	1.6	0.28
2001	11.1	1.56	4.8	0.50
2002	4.1	1.13	3.5	1.14
2003	3.7	0.64	3.6	0.80
2004	3.0	0.52	3.6	0.84
2005	1.8	0.25	2.0	0.47
2006	2.9	0.31	1.8	0.20
2007	3.1	0.43	2.1	0.35
2008	4.1	0.70	3.0	0.41
2009	2.0	0.41	1.9	0.52
2010	1.1	0.17	0.7	0.13
2011	1.0	0.17	1.1	0.20
2012				

Year	Spring Stratified Mean Number	SE	Spring Stratified Mean Weight	SE
2001	6.0	0.91	1.0	0.15
2002	2.4	0.33	1.1	0.17
2003	1.0	0.14	0.6	0.18
2004	1.4	0.17	0.4	0.12
2005	1.1	0.16	0.8	0.15
2006	0.3	0.06	0.1	0.03
2007	1.1	0.18	0.4	0.10
2008	1.4	0.19	0.5	0.08
2009	0.8	0.11	0.2	0.04
2010	0.6	0.10	0.2	0.04
2011	0.3	0.05	0.2	0.07
2012	0.4	0.06	0.3	0.11

Table 15. Survey results from NEFSC offshore autumn bottom trawl surveys in the southern management region (strata 1-19, 61-76). Indices are delta distribution stratified means.

	Biomass Index				Abundance Index					Length						Number of		Number of	Proportion
	Mean	CV	L95%	U95%	Mean	CV	L95%	U95%	Ind wt	Min	5%	50%	Mean	95%	Max	Fish	Number of Tows	Nonzero Tows	Nonzero Tows
1963	3.64	26.5	1.82	5.47	1.20	19.6	0.74	1.66	3.0	7	17	53	50.4	91	97	102	73	36	0.49
1964	6.14	57.2	2.67	9.61	1.64	22.7	0.91	2.37	3.5	14	21	53	52.0	86	101	132	83	34	0.41
1965	5.09	22.8	2.91	7.28	1.15	16.4	0.78	1.52	4.2	10	15	59	56.3	91	104	83	85	39	0.46
1966	7.06	14.5	5.06	9.06	1.93	14.9	1.36	2.49	3.6	7	7	51	49.6	87	98	101	87	56	0.64
1967	1.15	26.3	0.62	1.68	0.52	19.2	0.32	0.71	2.2	14	19	31	40.6	83	100	98	163	42	0.26
1968	0.90	25.7	0.46	1.35	0.40	24.2	0.21	0.59	2.2	12	17	45	46.3	75	86	77	164	39	0.24
1969	1.36	32.3	0.51	2.21	0.54	21.8	0.31	0.77	2.5	10	14	41	45.4	88	96	101	163	43	0.26
1970	1.34	27.2	0.64	2.04	0.35	16.8	0.23	0.47	3.6	4	13	55	53.3	84	104	58	161	35	0.22
1971	0.71	32.8	0.28	1.14	0.28	23.8	0.15	0.41	2.8	5	8	39	42.3	95	98	55	168	28	0.17
1972	5.05	18.6	3.37	6.72	4.11	35.1	1.28	6.94	1.3	12	16	23	31.8	74	99	604	161	85	0.53
1973	2.03	25.5	1.04	3.02	1.18	13.8	0.86	1.49	1.6	13	14	32	37.7	77	93	280	154	70	0.45
1974	0.71	27.8	0.32	1.10	0.22	23.8	0.12	0.32	3.3	14	16	54	52.9	81	101	56	153	26	0.17
1975	2.05	17.9	1.33	2.77	0.65	17.2	0.43	0.87	2.7	8	17	45	46.3	87	105	127	158	51	0.32
1976	1.09	25.7	0.55	1.64	0.31	20.2	0.19	0.44	3.2	11	11	51	50.7	77	95	60	165	34	0.21
1977	1.88	18.5	1.20	2.56	0.37	14.6	0.27	0.48	4.2	5	16	55	53.1	95	106	94	172	50	0.29
1978	1.39	18.7	0.88	1.91	0.26	16.0	0.18	0.34	4.5	13	17	61	56.5	87	101	68	219	39	0.18
1979	2.28	22.4	1.28	3.27	0.69	15.5	0.48	0.90	2.3	7	16	34	40.5	84	109	182	205	70	0.34
1980	1.88	19.2	1.18	2.58	0.73	21.0	0.43	1.02	2.2	3	16	34	41.6	85	104	113	159	42	0.26
1981	2.86	34.5	0.89	4.84	0.97	20.4	0.58	1.35	2.0	6	17	38	40.7	71	99	176	146	59	0.40
1982	0.66	23.3	0.36	0.95	0.61	19.8	0.37	0.85	1.1	13	15	26	32.5	66	73	98	143	42	0.29
1983	2.16	34.6	0.70	3.61	0.78	20.1	0.47	1.08	2.3	7	16	45	44.4	72	100	109	146	49	0.34
1984	0.75	40.8	0.16	1.34	0.31	32.4	0.11	0.51	2.4	5	13	47	45.7	68	93	42	146	25	0.17
1985	1.33	21.9	0.76	1.89	0.52	16.5	0.36	0.69	2.1	17	17	40	42.0	72	96	100	145	46	0.32
1986	0.56	29.1	0.24	0.88	0.33	23.6	0.17	0.48	1.5	7	14	34	37.6	68	78	60	146	33	0.23
1987	0.28	29.3	0.12	0.43	0.48	18.5	0.31	0.66	0.6	12	13	20	25.0	56	61	67	132	27	0.20
1988	0.55	31.7	0.21	0.90	0.23	29.4	0.10	0.36	2.4	19	27	36	45.1	87	91	27	129	19	0.15
1989	0.64	42.0	0.30	0.98	0.38	26.7	0.18	0.58	1.4	7	7	42	38.0	57	77	57	129	23	0.18
1990	0.45	47.5	0.05	0.84	0.29	31.0	0.12	0.47	1.1	9	13	24	33.1	61	81	47	136	22	0.16
1991	0.80	35.9	0.24	1.35	0.69	32.7	0.25	1.13	0.9	14	15	23	30.8	57	81	106	131	27	0.21
1992	0.32	34.5	0.19	0.44	0.34	17.7	0.22	0.46	0.9	8	11	30	32.2	54	74	46	129	21	0.16
1993	0.29	41.2	0.06	0.53	0.29	27.0	0.14	0.44	0.8	10	13	32	30.4	52	68	46	130	24	0.18
1994	0.62	35.9	0.19	1.05	0.60	20.9	0.35	0.84	0.9	8	12	25	29.2	59	83	85	135	31	0.23
1995	0.41	29.7	0.19	0.64	0.49	24.2	0.26	0.73	0.8	11	13	25	29.4	54	66	72	129	29	0.22
1996	0.39	22.4	0.22	0.56	0.23	22.4	0.13	0.34	1.6	18	19	42	42.3	62	68	31	131	21	0.16
1997	0.59	20.5	0.35	0.83	0.31	18.2	0.20	0.42	1.9	9	9	49	44.6	70	71	43	131	24	0.18
1998	0.50	26.1	0.24	0.76	0.33	28.0	0.15	0.51	1.5	11	11	36	37.0	68	87	45	131	20	0.15
1999	0.30	18.2	0.20	0.41	0.45	14.9	0.32	0.58	0.7	12	14	27	29.2	52	55	109	106	44	0.42
2000	0.48	62.2	0.27	0.70	0.42	18.4	0.27	0.57	1.1	5	15	33	34.3	63	70	64	132	30	0.23
2001	0.71	24.3	0.37	1.05	0.38	18.8	0.24	0.52	1.7	4	11	39	41.7	70	80	51	130	30	0.23
2002	1.32	20.6	0.78	1.85	0.83	16.2	0.57	1.09	1.5	6	14	41	39.1	61	81	110	130	47	0.36
2003	0.83	17.6	0.54	1.11	0.95	17.4	0.63	1.28	0.9	6	7	18	28.3	59	70	128	130	41	0.32
2004	0.97	33.5	0.33	1.61	0.47	24.5	0.25	0.70	1.6	7	15	45	40.4	64	78	67	133	32	0.24
2005	0.80	25.0	0.41	1.20	0.58	20.9	0.34	0.81	1.3	7	13	42	38.5	57	67	76	123	34	0.28
2006	0.83	27.8	0.38	1.29	0.45	19.5	0.28	0.62	1.7	6	12	44	40.6	65	77	83	151	36	0.24
2007	0.51	26.1	0.25	0.76	0.20	23.2	0.11	0.28	2.6	25	25	51	50.1	68	69	27	142	19	0.13
2008	0.41	37.2	0.11	0.71	0.20	26.4	0.10	0.30	2.1	4	4	45	38.6	69	88	39	142	20	0.14
Bigelow, no calibration coefficient applied:																			
2009	1.87	15.2	1.32	2.43	1.57	13.9	1.14	2.00	1.2	6	7	26	33.3	62	77	346	177	84	0.47
2010	3.52	24.6	1.83	5.22	2.71	20.9	1.60	3.83	1.1	5	9	23	32.0	61	80	492	183	91	0.50
2011	2.65	24.0	1.40	3.89	3.23	16.2	2.20	4.25	0.6	4	7	19	26.1	53	76	575	170	96	0.56
2012	2.83	15.9	1.95	3.71	1.77	16.1	1.21	2.3	1.6	4	23	39	41.6	62	82	340	173	80	0.46
Bigelow, calibration coefficient applied:																			
2009	0.23				0.22														
2010	0.44				0.38														
2011	0.33				0.45														
2012	0.35				0.25														

Table 16. Survey results from NEFSC offshore spring bottom trawl surveys in the southern management region (strata 1-19, 61-76). Indices are delta distribution stratified means.

	Biomass Index				Abundance Index					Length						Number of	Number of Nonzero	Number
	Mean	CV	L95%	U95%	Mean	CV	L95%	U95%	Ind wt	Min	5%	50%	Mean	95%	Max	Fish	Tows	of Tows
1968	1.16	26.0	0.57	1.75	0.21	20.6	0.13	0.30	5.41	21	23	63	62.5	94	95	65	31	150
1969	0.96	27.6	0.44	1.47	0.22	19.2	0.14	0.30	4.10	7	25	47	54.3	91	111	41	31	155
1970	1.01	27.6	0.46	1.55	0.18	20.9	0.10	0.25	5.65	22	22	65	63.9	102	108	40	31	166
1971	0.77	30.0	0.32	1.22	0.20	24.8	0.10	0.30	3.68	13	16	50	53.3	101	115	42	24	160
1972	1.89	19.5	1.17	2.61	0.36	13.7	0.27	0.46	5.17	14	22	59	59.1	103	123	79	48	165
1973	1.90	13.8	1.54	2.25	1.05	9.3	0.85	1.25	2.17	11	19	32	41.1	80	110	589	128	187
1974	1.16	18.1	0.77	1.56	0.49	12.3	0.37	0.60	3.24	14	21	44	49.1	93	117	201	70	132
1975	0.95	20.4	0.57	1.32	0.45	13.8	0.33	0.57	2.80	10	22	44	47.6	87	107	169	61	134
1976	1.21	15.9	0.83	1.59	0.40	12.0	0.31	0.50	3.34	13	22	48	51.5	91	110	259	78	162
1977	1.21	18.2	0.77	1.64	0.30	11.3	0.23	0.37	4.61	16	21	51	56.8	95	116	173	75	160
1978	0.75	16.9	0.52	0.97	0.33	10.7	0.26	0.40	2.99	11	17	39	45.9	90	104	196	66	161
1979	0.76	26.2	0.46	1.05	0.28	21.2	0.16	0.40	2.94	10	14	37	44.4	98	124	125	50	194
1980	0.80	19.5	0.49	1.10	0.45	10.8	0.35	0.55	1.93	18	21	34	40.8	83	106	346	99	204
1981	1.82	18.5	1.16	2.47	0.78	15.8	0.54	1.03	2.56	12	22	40	44.6	89	113	345	74	141
1982	2.81	22.2	1.59	4.03	0.94	15.4	0.66	1.23	2.32	11	14	38	42.4	89	104	251	68	150
1983	0.95	28.5	0.42	1.49	0.27	17.8	0.18	0.36	3.51	24	24	47	51.8	97	112	55	36	147
1984	0.75	35.8	0.22	1.27	0.18	25.9	0.09	0.27	4.07	21	21	47	50.9	96	97	35	22	149
1985	0.33	36.9	0.09	0.57	0.16	28.0	0.07	0.25	2.05	22	22	39	42.3	85	90	31	21	147
1986	0.83	29.7	0.35	1.31	0.28	28.5	0.12	0.44	2.92	15	24	43	48.7	90	102	65	36	149
1987	0.50	52.4	-0.01	1.01	0.11	25.6	0.05	0.16	4.61	15	15	59	52.7	102	103	30	21	150
1988	0.43	15.0	0.30	0.55	0.44	17.9	0.29	0.60	0.97	17	18	30	34.0	61	82	67	33	132
1989	0.36	17.9	0.24	0.49	0.20	25.3	0.10	0.30	1.50	15	24	41	41.4	69	79	36	18	129
1990	1.00	22.3	0.57	1.44	0.21	13.2	0.15	0.26	4.03	16	21	53	56.5	86	93	39	23	128
1991	0.59	29.2	0.32	0.86	0.32	28.0	0.14	0.49	1.51	15	23	33	37.6	69	101	61	31	132
1992	0.21	34.1	0.07	0.35	0.18	25.5	0.09	0.27	1.24	14	19	28	35.0	69	85	28	17	128
1993	0.26	32.1	0.10	0.43	0.20	25.1	0.10	0.29	1.32	17	19	38	38.6	56	72	29	18	128
1994	0.32	29.1	0.14	0.50	0.11	24.9	0.06	0.17	2.38	13	13	41	44	91	93	24	18	131
1995	0.53	47.9	0.03	1.02	0.20	22.6	0.11	0.28	2.64	18	19	38	46	80	81	32	20	129
1996	0.29	25.1	0.15	0.43	0.14	22.9	0.07	0.20	2.08	9	9	44	44	80	81	27	20	143
1997	0.13	23.6	0.07	0.19	0.12	22.1	0.07	0.18	1.06	18	18	37	36	58	75	38	14	130
1998	0.28	16.7	0.19	0.37	0.25	15.9	0.17	0.33	1.11	12	16	35	36	64	77	40	30	131
1999	0.63	20.6	0.37	0.88	0.33	16.1	0.23	0.44	1.90	16	19	41	43	74	94	63	32	131
2000	0.29	19.8	0.18	0.41	0.24	18.3	0.15	0.33	1.22	14	14	38	38	61	78	32	25	131
2001	0.24	31.3	0.09	0.39	0.23	21.4	0.14	0.33	1.09	11	15	34	36	57	68	44	50	89
2002	0.37	32.8	0.13	0.62	0.32	35.6	0.10	0.54	1.18	22	23	37	39	53	62	50	50	91
2003	1.42	19.0	0.89	1.95	0.31	17.8	0.20	0.42	3.72	15	29	57	57	80	87	65	30	86
2004	0.19	34.9	0.06	0.32	0.12	27.1	0.05	0.18	1.57	22	21	37	40	61	62	24	36	88
2005	0.37	18.7	0.23	0.50	0.26	29.1	0.11	0.41	1.42	20	20	36	39	61	68	41	26	131
2006	0.54	30.6	0.22	0.86	0.17	22.3	0.10	0.25	3.14	24	15	37	53	80	80	28	20	132
2007	0.56	24.1	0.29	0.82	0.26	17.0	0.17	0.34	2.14	20	23	48	46	69	75	77	30	158
2008	0.39	32.9	0.14	0.64	0.19	31.3	0.07	0.30	2.06	17	17	41	46	64	84	32	19	140

Bigelow, no calibration coefficient applied:

2009	2.97	26.8	1.41	4.53	1.15	16.5	0.78	1.53
2010	1.80	21.3	1.05	2.55	1.08	21.0	0.63	1.52
2011	3.27	14.7	2.33	4.21	1.83	16.0	1.26	2.41
2012	2.97	12.6	2.24	3.70	2.17	11.0	1.70	2.64

Bigelow, calibration coefficient applied:

2009	0.37	0.16
2010	0.22	0.15
2011	0.41	0.26
2012	0.37	0.30

Table 17. Survey results from NEFSC offshore winter bottom trawl surveys in the southern management region (strata 1-19, 61-76). Indices are delta distribution stratified means. The winter survey was discontinued after 2007.

	Biomass Raw Index			Abundance Raw Index				Length						Number of Fish	Number of Tows	Number of Nonzero Tows
	Mean	L95%	U95%	Mean	L95%	U95%	Ind wt	Min	5%	50%	Mean	95%	Max			
1992	6.314	4.160	8.468	5.234	3.854	6.614	1.139	11	22	33	36.0	51	95	582	100	66
1993	6.357	4.563	8.150	4.952	3.898	6.005	1.193	9	21	36	37.7	53	98	555	108	77
1994	3.321	2.372	4.270	2.484	1.870	3.097	1.298	8	16	31	35.1	61	78	278	77	56
1995	3.774	2.472	5.076	3.137	2.104	4.170	1.209	19	21	35	37.4	57	101	365	106	76
1996	4.496	3.435	5.557	3.438	2.662	4.213	1.294	10	22	37	39.1	57	100	456	119	87
1997	4.460	3.190	5.731	2.976	2.323	3.629	1.456	10	18	39	39.8	59	82	359	107	89
1998	2.849	1.997	3.701	1.494	1.150	1.838	1.876	10	20	41	44.1	69	103	203	114	77
1999	4.090	3.066	5.114	3.068	2.370	3.767	1.319	10	17	34	37.8	61	87	362	115	83
2000	5.690	4.023	7.356	4.428	3.166	5.689	1.265	11	24	103	39.2	103	96	616	118	93
2001	7.182	4.501	9.863	4.380	2.997	5.762	1.383	8	24	103	39.3	103	84	729	142	115
2002	6.235	4.794	7.675	3.474	2.737	4.212	1.744	15	30	103	44.5	103	86	550	143	113
2003	5.482	3.491	7.473	2.258	1.580	2.937	2.418	12	25	103	45.5	103	85	316	86	72
2004	7.171	4.308	10.034	4.397	2.836	5.957	1.568	13	23	103	41.2	103	88	682	123	103
2005	4.531	2.657	6.405	2.972	2.043	3.902	1.497	13	23	103	40.0	103	90	313	91	59
2006	5.481	4.022	6.939	3.082	2.327	3.837	1.743	22	31	103	44.7	103	92	430	114	78
2007	3.395	2.586	4.205	1.472	1.212	1.732	2.251	14	23	42	48.3	103	91	217	118	83

Table 18. Survey results from NEFSC offshore scallop dredge surveys in the southern management region (shellfish strata 6, 7, 10, 11, 14, 15, 18, 19, 22-31, 33-35, 46, 47, 55, 58-61, 621, 631). Indices are delta distribution stratified means.

	Abundance Index				Length						Number of Fish	Number of Tows	Number of Nonzero Tows	Proportion Nonzero Tows
	Mean	CV	L95%	U95%	Min	5%	50%	Mean	95%	Max				
1984	1.29	7.0	1.11	1.46	6	11	28	29.5	54	82	410	254	165	0.65
1985	1.52	8.9	1.26	1.79	7	9	25	28.7	53	84	493	282	183	0.65
1986	1.25	8.2	1.05	1.45	8	10	15	22.9	54	95	431	296	183	0.62
1987	3.15	6.2	2.77	3.54	8	9	13	18.6	51	90	1253	315	255	0.81
1988	1.67	8.6	1.39	1.95	7	12	28	29.8	49	97	572	316	187	0.59
1989	1.00	8.3	0.83	1.16	6	10	31	31.9	53	101	303	304	147	0.48
1990	1.53	6.5	1.34	1.73	6	10	18	24.4	54	94	563	303	205	0.68
1991	2.28	6.5	1.99	2.57	7	9	14	21.0	45	94	808	315	241	0.77
1992	1.94	7.3	1.66	2.22	5	9	25	27.3	52	97	644	316	235	0.74
1993	2.85	5.0	2.57	3.12	8	10	15	21.8	48	73	995	301	258	0.86
1994	3.40	5.9	3.01	3.80	8	10	15	22.2	51	87	1145	314	265	0.84
1995	2.26	6.6	1.97	2.56	7	9	27	29.6	57	92	764	314	243	0.77
1996	2.01	6.6	1.75	2.27	7	9	23	29.9	59	81	638	298	226	0.76
1997	1.11	7.2	0.95	1.27	7	13	33	36.7	65	76	388	313	196	0.63
1998	1.01	7.0	0.88	1.15	6	11	20	30.2	61	79	371	319	183	0.57
1999	2.59	8.5	2.16	3.02	6	10	16	23.5	55	84	856	306	248	0.81
2000	2.24	6.1	1.97	2.51	8	9	18	27.3	54	87	832	315	240	0.76
2001	1.71	6.7	1.48	1.94	7	8	35	36.0	64	77	549	334	233	0.70
2002	1.71	6.6	1.49	1.93	7	11	35	34.2	60	86	598	310	203	0.65
2003	2.78	7.1	2.39	3.17	6	9	15	24.4	58	87	819	294	211	0.72
2004	2.88	6.5	2.51	3.24	9	11	26	29.8	61	83	860	348	290	0.83
2005	2.01	6.6	1.75	2.27	8	10	28	31.3	56	83	859	344	265	0.77
2006	1.45	6.1	1.27	1.62	7	7	29	31.1	61	83	571	327	230	0.70
2007	0.83	8.2	0.69	0.96	7	12	39	40.2	69	84	366	336	183	0.54
2008	1.00	8.9	0.83	1.18	7	7	26	31.3	68	75	350	285	162	0.57
2009	0.79	9.8	0.64	0.94	6	10	25	30.9	65	80	248	269	133	0.49
2010	0.74	9.9	0.59	0.88	7	8	35	35.9	59	77	213	275	135	0.49
2011	0.93	12.5	0.70	1.16	8	10	29	32.6	57	75	204	203	112	0.55
2012	1.32	8.4	1.10	1.54	6	8	32	33.0	55	70	170	132	84	0.64

Table 19. Age length key used for estimating mean lengths at age and variation from ages in the spring, winter, 2001 & 2004 cooperative, and fall surveys.

	age										
length	1	2	3	4	5	6	7	8	9	10	total
8	1										1
9	4										4
10	19										19
11	25	3									28
12	26	9									35
13	23	21									44
14	24	18									42
15	27	28									55
16	15	48									63
17	22	43									65
18	26	56	2								84
19	8	54	16								78
20	4	50	34								88
21		25	72								97
22		29	82								111
23		32	81	1							114
24		22	120								142
25		23	127								150
26		27	149								176
27		22	174	5							201
28		20	140	53							213
29		6	89	130							225
30		4	46	163							213
31		3	26	178							207
32			26	183							209
33			22	154							176
34		1	19	192							212
35			23	203							226
36			25	184							209
37			20	197	6						223
38			20	173	31						224
39			11	104	84						199
40			8	63	140						211
41			3	29	171						203
42				26	200						226
43			1	22	209						232
44				26	197						223
45				19	200						219
46				24	179						203
47				28	184	4					216
48				17	197	32					246
49				12	123	81					216
50				13	98	141					252
51				2	33	157					192
52				1	28	186					215
53					24	186					210
54					20	184					204
55					19	198					217
56					15	191	1				207
57					12	179	1				192
58					20	143	3				166
59					19	117	25				161
60					8	68	87				163
61					2	37	99				138
62						19	113				132
63					1	13	81				95
64						9	101				110
65						12	86				98
66						7	60				67
67						5	63				68
68						3	66				69
69						8	53	2			63
70						3	38	23			64
71						3	27	32			62
72							16	52			68
73							2	52			54
74							4	51			55
75							1	38			39
76							4	42			46
77							4	31			35
78							2	41			43
79							1	26			27
80							3	40	9		52
81							2	18	9		29
82							1	18	20		39
83								5	20		25
84								2	25		27
85								2	18		20
86								3	10	1	14
87								1	15		16
88								4	12		16
89								2	7		9
90									2	1	3
91									7		7
92									3	2	5
93									4		4
94									2		2
95								1	2	2	5
96									1	2	3
97									2		2
98									1	1	2
102										2	2
103										1	1
105										2	2
107										1	1
110										1	1
total	224	544	1336	2202	2220	1986	944	486	169	16	10127

Table 20. Area swept expansions used for scaling the stratified number per tow indices for input to SCALE. Nm^2 represents the square nautical miles covered by the survey.

Survey	nm^2	footprint	expansions
Shrimp North	6,147	0.00350	1,756,286
Winter South	30,014	0.01270	2,363,307
Scallop South	13,204	0.00110	12,003,636
Fall & Spring North	26,265	0.01120	2,345,089
Fall & Spring South	37,081	0.01120	3,310,804
Fall and spring combine albatross	63,346	0.01120	5,655,893
Fall and spring combine Bigelow	63,346	0.00700	9,049,429
ME/NH Fall North	4,517	0.00462	977,324
MDMF Fall North	1,055	0.00385	274,311

Table 21. Northern area SCALE model runs summaries: residual sums of squares, input weights, effective sample sizes, and parameter estimates.

Run:	2007 Final Run		2010 Final Run		2013 run 1		2013 Final (run 2)	
	Data Poor WG		SAW 50		Revised data 1980-2009		Revised + new data (1980-2011)	
	Weight	RSS	Weight	RSS	Weight	RSS	Weight	RSS
Total Objective Function		241.34		291.22		290.22		320.36
Residuals from Catch Weight	10	0.68	10	3.57	10	3.43	10	5.08
Residuals from Catch Length Frequency	400	9.57	400	12.35	400	12.21	400	14.26
Residuals from Variation in Recruitment Penalty (Vrec)	5	24.93	5	28.02	5	29.04	5	31.29
Residuals from Recruitment Index 1 North Fall age 1	2	32.41	2	34.69	2	33.96	2	34.79
Residuals from Recruitment Index 2 North Spring age 2	2	29.45	2	29.35	2	28.18	2	28.51
Residuals from Recruitment Index 3 North Spring age 3	2	30.78	2	32.16	2	30.66	2	31.75
Residuals from Recruitment Index 4 North Shrimp age 1	2	21.54	2	26.49	2	26.09	2	26.37
Residuals from Recruitment Index 5 North Shrimp Age 2	2	6.52	2	6.35	2	10.57	2	10.22
Residuals from Recruitment Index 6 ME-NH Fall age1			2	15.76	2	13.23	2	22.38
Residuals from Adult Index 1 North Fall 40+	3	15.96	3	15.17	3	14.74	3	14.33
Residuals from Adult Index 2 North Spring 40+	3	12.84	3	14.32	3	14.62	3	14.73
Residuals from Adult Index 3 North Shrimp 40+	3	15.11	3	18.60	3	18.80	3	19.28
Residuals from Adult Index 4 ME-NH Fall 40+			3	3.35	3	3.33	3	11.00
Residuals from Survey Length Frequency Fall Albatross	25	13.82	25	14.96	25	14.97	25	15.01
Residuals from Survey Length Frequency Spring Albatross	25	13.18	25	14.40	25	14.43	25	14.48
Residuals from Survey Length Frequency Shrimp	75	14.28	75	15.95	75	16.18	75	17.67
Residuals from Survey Length Frequency Coop Monkfish	100	0.26	100	0.58	100	0.59	100	0.61
Residuals from Survey Length Frequency Fall Bigelow			100	0.79	100	0.81	100	1.75
Residuals from Survey Length Frequency Spring Bigelow			100	0.55	100	0.53	100	1.46
Residuals from Survey Length Frequency ME-NH Fall			50	3.81	50	3.83	50	5.39
Q for Recruitment Index 1 North Fall age 1		0.024		0.010		0.011		0.012
Q for Recruitment Index 2 North Spring age 2		0.036		0.009		0.010		0.010
Q for Recruitment Index 3 North Spring age 3		0.049		0.016		0.014		0.014
Q for Recruitment Index 4 North Shrimp age 1		0.025		0.040		0.041		0.042
Q for Recruitment Index 5 North Shrimp Age 2		0.038		0.112		0.070		0.071
Q for Recruitment Index 6 ME-NH Fall age1				0.014		0.019		0.015
Q for Adult Index 1 North Fall 40+		0.041		0.048		0.052		0.053
Q for Adult Index 2 North Spring 40+		0.044		0.052		0.056		0.057
Q for Adult Index 3 North Shrimp 40+		0.130		0.134		0.144		0.147
Q for Adult Index 4 ME-NH Fall 40+				0.054		0.058		0.051
Fstart		0.01		0.01		0.01		0.01
Recruitment year 1 (millions)		20.5		16.1		14.9		14.3
Alpha Selectivity Parameter for block 1		42.7		48.9		50.1		48.7
Beta Selectivity Parameter for block 1		0.16		0.13		0.14		0.14

Table 22. Southern area SCALE model runs summaries: residual sums of squares, input weights, effective sample sizes, and parameter estimates.

Run:	DPWG Final Run (2007)		SAW 50 Final Run (2010)		2013 run 1		2013 run 2		2013 run 3 - Final run	
					Revised data 1980-2009		Revised+new data (1980-2011)		1 Selectivity block 1980-2011	
	Weight	RSS	Weight	RSS	Weight	RSS	Weight	RSS	Weight	RSS
Total Objective Function		287.71		358.8		383.4		419.88		420.1
Resid from Catch Weight	10	0.93	10	0.91	10	0.96	10	1.22	10	1.26
Resid from Catch LF	400	9.22	400	12.09	400	11.79	400	13.86	400	13.58
Resid from Var in Recruit Penalty (Vrec)	5	13.59	5	22.00	5	24.48	5	26.64	5	26.59
Resid from South Fall age 1	2	29.50	2	49.34	2	49.11	2	55.76	2	55.76
Resid from South Spring age 2	2	16.95	2	33.79	2	34.02	2	37.90	2	37.91
Resid from South Spring Age 3	2	36.32	2	40.00	2	58.45	2	59.62	2	59.55
Resid from South Winter age 2	2	6.85	2	6.67	2	6.66	2	6.64	2	6.62
Resid from South Winter Age 3	2	12.27	2	13.03	2	12.17	2	12.11	2	12.08
Resid from South Scallop age 1	3	29.31	3	32.55	3	43.71	3	53.61	3	53.61
Resid from South Scallop age 2	3	13.56	3	15.95	3	9.89	3	14.44	3	14.42
Resid from Adult South Fall 40+	3	20.74	3	24.44	3	24.28	3	24.39	3	24.73
Resid from Adult South Spring 40+	3	27.87	3	28.82	3	29.13	3	31.03	3	31.19
Resid from Adult South Winter 40+	3	4.08	3	5.25	3	5.14	3	5.07	3	5.11
Resid from Adult South Scallop 40+	3	16.66	3	17.36	3	17.22	3	16.91	3	17.04
Resid from Survey LF Fall Albatross	25	12.60	25	13.91	25	13.89	25	13.89	25	13.89
Resid from Survey LF Spring Albatross	25	16.84	25	17.97	25	17.93	25	17.95	25	17.95
Resid from Survey LF Winter	75	5.64	75	6.43	75	6.44	75	6.42	75	6.41
Resid from Survey LF Coop Monkfish	100	0.33	100	0.72	100	0.71	100	0.72	100	0.71
Resid from Survey LF Scallop	75	14.46	75	16.40	75	16.34	75	17.85	75	17.84
Resid from Survey LF Fall Bigelow			100	0.70	100	0.69	100	2.09	100	2.09
Resid from Survey LF Spring Bigelow			100	0.43	100	0.40	100	1.77	100	1.77
Q for Recruit Idx 1 Fall age 1		0.024		0.006		0.006		0.007		0.007
Q for Recruit Idx 2 Spring age 2		0.045		0.002		0.002		0.002		0.002
Q for Recruit Idx 3 Spring age 3		0.045		0.009		0.007		0.007		0.007
Q for Recruit Idx 4 Winter age 2		0.038		0.010		0.009		0.009		0.009
Q for Recruit Idx 5 Winter age 3		0.046		0.083		0.069		0.072		0.072
Q for Recruit Idx 6 Scallop age 1		0.026		0.281		0.193		0.184		0.182
Q for Recruit Idx 7 Scallop age 2		0.040		0.168		0.200		0.199		0.198
Q for Adult Idx 1 Fall 40+		0.027		0.023		0.022		0.023		0.023
Q for Adult Idx 2 Spring 40+		0.018		0.016		0.015		0.016		0.016
Q for Adult Idx 3 Winter 40+		0.249		0.155		0.143		0.153		0.152
Q for Adult Idx 4 Scallop 40+		0.510		0.187		0.174		0.186		0.184
Fstart		0.2		0.2		0.2		0.2		0.2
Recruitment year 1 (millions)		31.1		28.1		30.4		28.2		28.5
Alpha Selectivity Parameter for Block 1	1980-1995	40.24	1980-2001	45.59	1980-2001	43.47	1980-2001	44.11	1980-2011	42.59
Beta Selectivity Parameter for Block 1		0.13		0.15		0.15		0.15		0.15
Alpha Selectivity Parameter for Block 2	1996-2003	48.32	2002-2009	50.69	2002-2009	44.06	2002-2011	40.83		
Beta Selectivity Parameter for Block 2		0.15		0.13		0.13		0.15		
Alpha Selectivity Parameter for Block 3	2004-2007	50.98								
Beta Selectivity Parameter for Block 3		0.13								

Table 23. Estimates of age-1 recruitment, biomass and fishing mortality rates from SCALE model final runs.

North				
Year	Age-1 Recruitment (millions)	Exploitable Biomass (kt)	Total Biomass (kt)	F
1980	14.29	73.37	89.11	0.07
1981	10.24	69.73	85.10	0.07
1982	11.45	66.84	81.79	0.08
1983	10.49	63.83	78.10	0.08
1984	9.31	61.34	74.63	0.09
1985	7.10	58.59	70.69	0.11
1986	11.09	55.20	66.46	0.11
1987	9.62	51.91	62.52	0.13
1988	12.68	47.49	57.74	0.15
1989	14.90	42.70	53.23	0.20
1990	19.62	36.96	48.61	0.21
1991	16.17	32.80	45.92	0.23
1992	16.68	30.12	44.92	0.32
1993	26.93	28.46	45.16	0.55
1994	25.46	24.78	42.77	0.58
1995	10.96	23.46	41.98	0.74
1996	14.89	21.13	39.91	0.89
1997	26.46	19.36	38.20	0.71
1998	30.94	21.18	39.70	0.43
1999	39.27	25.47	45.31	0.43
2000	42.06	27.74	51.52	0.47
2001	27.46	29.31	57.87	0.64
2002	17.96	30.00	61.08	0.82
2003	15.99	30.60	60.77	1.21
2004	17.42	26.79	51.74	1.12
2005	12.27	24.32	43.66	0.88
2006	18.59	22.92	39.11	0.58
2007	16.33	23.78	39.14	0.37
2008	15.68	26.74	42.26	0.23
2009	13.67	31.41	47.34	0.16
2010	8.36	37.33	53.46	0.09
2011	11.72	44.73	60.48	0.08

South				
Year	Age-1 Recruitment (millions)	Exploitable Biomass (kt)	Total Biomass (kt)	F
1980	28.49	81.94	103.62	0.09
1981	31.25	89.48	111.69	0.06
1982	24.05	99.01	121.44	0.05
1983	18.52	108.43	130.46	0.05
1984	22.53	116.36	137.51	0.05
1985	22.83	123.47	143.18	0.05
1986	29.15	127.28	145.83	0.05
1987	36.13	127.80	146.82	0.05
1988	9.22	125.77	145.32	0.05
1989	27.80	121.70	142.07	0.12
1990	35.08	112.10	132.75	0.10
1991	40.42	107.43	128.09	0.13
1992	36.23	99.85	121.91	0.20
1993	45.67	88.64	114.14	0.26
1994	30.55	81.53	109.24	0.23
1995	30.91	82.05	110.42	0.27
1996	22.53	81.96	109.07	0.28
1997	25.51	83.33	107.95	0.29
1998	45.07	82.38	105.14	0.28
1999	44.11	80.31	103.08	0.24
2000	33.88	81.79	106.32	0.18
2001	17.24	84.17	110.81	0.19
2002	35.10	87.59	114.86	0.17
2003	39.99	93.89	119.77	0.20
2004	25.67	97.07	120.76	0.15
2005	18.65	99.98	123.17	0.16
2006	15.39	102.32	124.95	0.15
2007	14.17	105.34	125.26	0.12
2008	17.08	109.01	125.39	0.11
2009	16.01	109.91	123.76	0.08
2010	13.12	105.80	118.42	0.08
2011	23.32	98.43	111.10	0.11

Table 24. (A). Mohn's rho statistic for SCALE model retrospective patterns based on 7 peels. (B.) Adjustment factors for estimated population numbers at age based on age-specific retrospective patterns based on 7 peels.

A. North

Relative Change in Estimate			
Terminal Year	F	Total B	Age 1 Rcrt
2010	-0.03	0.03	-0.03
2009	-0.25	0.21	0.04
2008	-0.44	0.43	0.13
2007	-0.57	0.65	0.24
2006	-0.77	1.36	0.30
2005	-0.84	1.77	0.27
2004	-0.85	1.62	0.65
Mohn's Rho	-0.54	0.87	0.23

South

Relative Change in Estimate			
Terminal Year	F	Total B	Age 1 Rcrt
2010	-0.03	0.03	0.29
2009	-0.10	0.10	0.33
2008	-0.21	0.20	0.08
2007	-0.27	0.27	0.21
2006	-0.36	0.41	1.49
2005	-0.34	0.42	0.60
2004	-0.27	0.33	0.70
Mohn's Rho	-0.23	0.25	0.53

B.

Age	North	South
1	0.81	0.65
2	0.77	0.84
3	0.79	0.87
4	0.76	0.88
5	0.76	0.88
6	0.66	0.85
7	0.48	0.82
8	0.31	0.80
9	0.20	0.78
10	0.14	0.75
11	0.11	0.72
12	0.09	0.69

Table 25. Results of age-based yield-per-recruit analysis using M=0.3 and area-specific selectivity patterns estimated by SCALE model in 2007 (NEFSC 2007a), 2010 (NEFSC 2010), and 2013.

North	DPWG (2007)				SAW50 (2010)				2013 Update			
Reference Point	F	YPR	SSBR	Total B / R	F	YPR	SSBR	Total B / R	F	YPR	SSBR	Total B / R
Fzero	0.00	0.00	7.97	9.94	0.00	0.00	5.39	6.41	0.00	0.00	5.39	6.41
F-01	0.18	0.56	3.22	4.81	0.27	0.51	2.55	3.46	0.27	0.51	2.55	3.46
F-Max	0.31	0.60	2.06	3.51	0.43	0.54	1.85	2.69	0.44	0.54	1.84	2.68
F at 40% MSP	0.18	0.56	3.19	4.77	0.35	0.54	2.15	3.03	0.35	0.54	2.15	3.03

South	DPWG (2007)				SAW50 (2010)				2013 Update			
Reference Point	F	YPR	SSBR	Total B / R	F	YPR	SSBR	Total B / R	F	YPR	SSBR	Total B / R
Fzero	0.00	0.00	5.32	6.41	0.00	0.00	5.39	6.41	0.00	0.00	5.39	6.41
F-01	0.25	0.50	2.43	3.39	0.28	0.52	2.59	3.51	0.24	0.48	2.45	3.33
F-Max	0.40	0.53	1.72	2.61	0.46	0.55	1.88	2.73	0.37	0.51	1.76	2.56
F at 40% MSP	0.31	0.52	2.13	3.06	0.38	0.55	2.15	3.04	0.29	0.50	2.15	3.00

Table 26. Estimated biological reference points, biomass and F for monkfish in northern and southern management regions. Biomass BRPs in metric tons. Reference points for DPWG (2007) are provided for historical reference only; reference points were re-defined in Framework 7 (2012) based on methodology accepted at the SAW 50 review.

North	BRP	Basis	DPWG (2007)	SAW 50 (2010)	2013 Update
	Fmax	YPR	0.31	0.43	0.44
	Bthreshold	Bloss (1980-final yr)	65,200	41,238	38,196
	Bthreshold	0.5*Bmax Proj		26,465	23,037
	Btarget	Bavg (1980-final yr)	92,200	61,991	55,009
	Btarget	Bmax Proj		52,930	46,074
	MSY	Fmax Proj		10,745	9,383
South					
	Fmax	YPR	0.40	0.46	0.37
	Bthreshold	Bloss (1980-final yr)	96,400	99,181	103,082
	Bthreshold	0.5*Bmax Proj		37,245	35,834
	Btarget	Bavg (1980-final yr)	122,500	121,313	121,696
	Btarget	Bmax Proj		74,490	71,667
	MSY	Fmax Proj		15,279	14,328

Table 27. Projected catch and biomass (mt) for the northern and southern monkfish management regions under A. $F_{threshold}$, B. $F_{threshold}$ based on retrospective-adjusted SCALE model outputs, C. $F_{status\ quo}$ (F_{2011} estimated by SCALE model, no retrospective adjustment). Catch and biomass in mt; annual P is relative to BRPs.

North

A. $F_{threshold}$

Year	F	Total Catch	Total Biomass	P < $B_{threshold}$	P > F_{max}
2012	0.44	16,385	66,605	0%	0%
2013	0.44	13,768	56,660	0%	0%
2014	0.44	11,336	48,970	0%	0%
2015	0.44	9,481	44,003	0%	0%
2016	0.44	8,449	41,848	0%	0%

B. $F_{threshold}$, retro adjusted

Year	F	Total Catch	Total Biomass	P < $B_{threshold}$	P > F_{max}
2012	0.44	6,770	32,152	0%	0%
2013	0.44	6,869	32,243	0%	0%
2014	0.44	6,567	31,973	0%	0%
2015	0.44	6,187	32,412	0%	0%
2016	0.44	6,196	34,236	0%	0%

C. $F_{status\ quo}$

Year	F	Total Catch	Total Biomass	P < $B_{threshold}$	P > F_{max}
2012	0.08	3,274	66,605	0%	0%
2013	0.08	3,685	72,275	0%	0%
2014	0.08	3,929	76,450	0%	0%
2015	0.08	4,041	79,597	0%	0%
2016	0.08	4,123	82,262	0%	0%

South

A. $F_{threshold}$

Year	F	Total Catch	Total Biomass	P < $B_{threshold}$	P > F_{max}
2012	0.37	25,751	108,139	0%	0%
2013	0.37	19,748	86,915	0%	0%
2014	0.37	15,453	72,803	0%	0%
2015	0.37	13,054	65,778	0%	0%
2016	0.37	12,267	63,756	0%	0%

B. $F_{threshold}$, retro adjusted

Year	F	Total Catch	Total Biomass	P < $B_{threshold}$	P > F_{max}
2012	0.37	19,786	84,003	0%	0%
2013	0.37	15,530	69,136	0%	0%
2014	0.37	12,370	59,430	0%	0%
2015	0.37	10,540	55,299	0%	0%
2016	0.37	10,219	55,791	0%	0%

C. $F_{status\ quo}$

Year	F	Total Catch	Total Biomass	P < $B_{threshold}$	P > F_{max}
2012	0.11	8,258	108,139	0%	0%
2013	0.11	7,984	106,639	0%	0%
2014	0.11	7,632	104,601	0%	0%
2015	0.11	7,399	104,201	0%	0%
2016	0.11	7,467	106,145	0%	0%

Table 28. Comparison of biomass projected under SAW 50 ACT scenario in 2010 with estimated biomass (2010, 2011) and projected biomass (2013-2016) from updated SCALE models (unadjusted for retrospective) under $F_{status\ quo}$ scenarios.

North	SAW 50 (2010)		2013 Assessment Update				
	F_{INPUT}	B_{PROJ}	$F_{status\ quo}$	B_{EST}	B_{PROJ}	Δ	% Over-estimated
2010	0.10	74.1	0.08	53.5		20.6	38.5%
2011	0.22	81.9	0.08	60.5		21.4	35.4%
2012	0.22	81.2	0.08		66.6	14.6	
2013	0.22	80.2	0.08		72.4	7.8	
2014	0.23	79	0.08		76.6	2.4	
2015	0.24	77.5	0.08		79.7	-2.2	
2016	0.24	76.4	0.08		82.6	-6.2	

South	SAW 50 (2010)		2013 Assessment Update				
	F_{INPUT}	B_{PROJ}	$F_{status\ quo}$	B_{EST}	B_{PROJ}	Δ	% Over-estimated
2010	0.07	131.3	0.11	118.4		12.9	10.9%
2011	0.13	132.2	0.11	111.1		21.1	19.0%
2012	0.14	126.3	0.11		108.1	18.2	
2013	0.15	121.1	0.11		106.6	14.5	
2014	0.16	116.7	0.11		104.6	12.1	
2015	0.17	114.0	0.11		104.2	9.8	
2016	0.17	113.8	0.11		106.1	7.7	

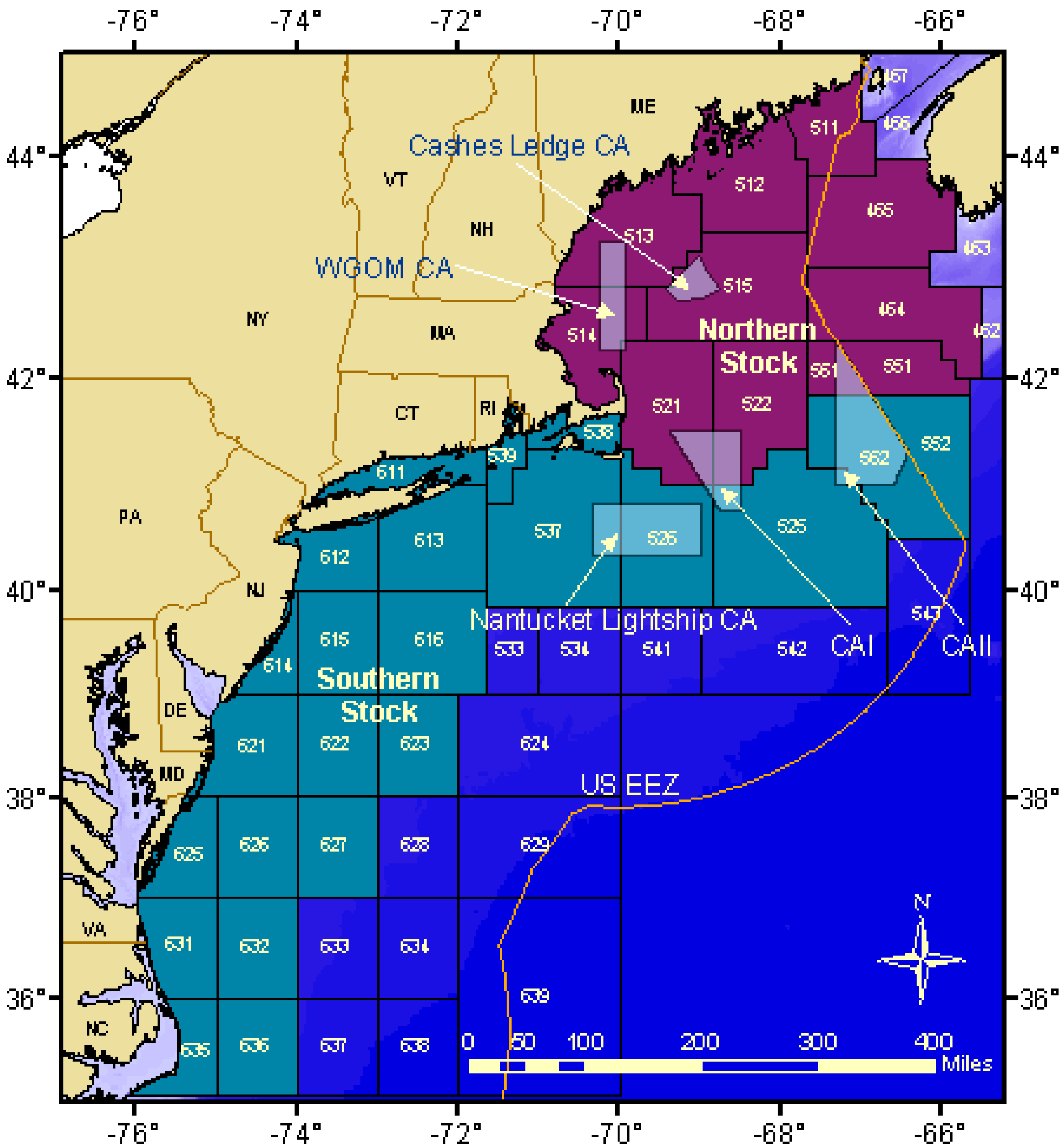


Figure 1. Fishery statistical areas used to define northern and southern monkfish management areas.

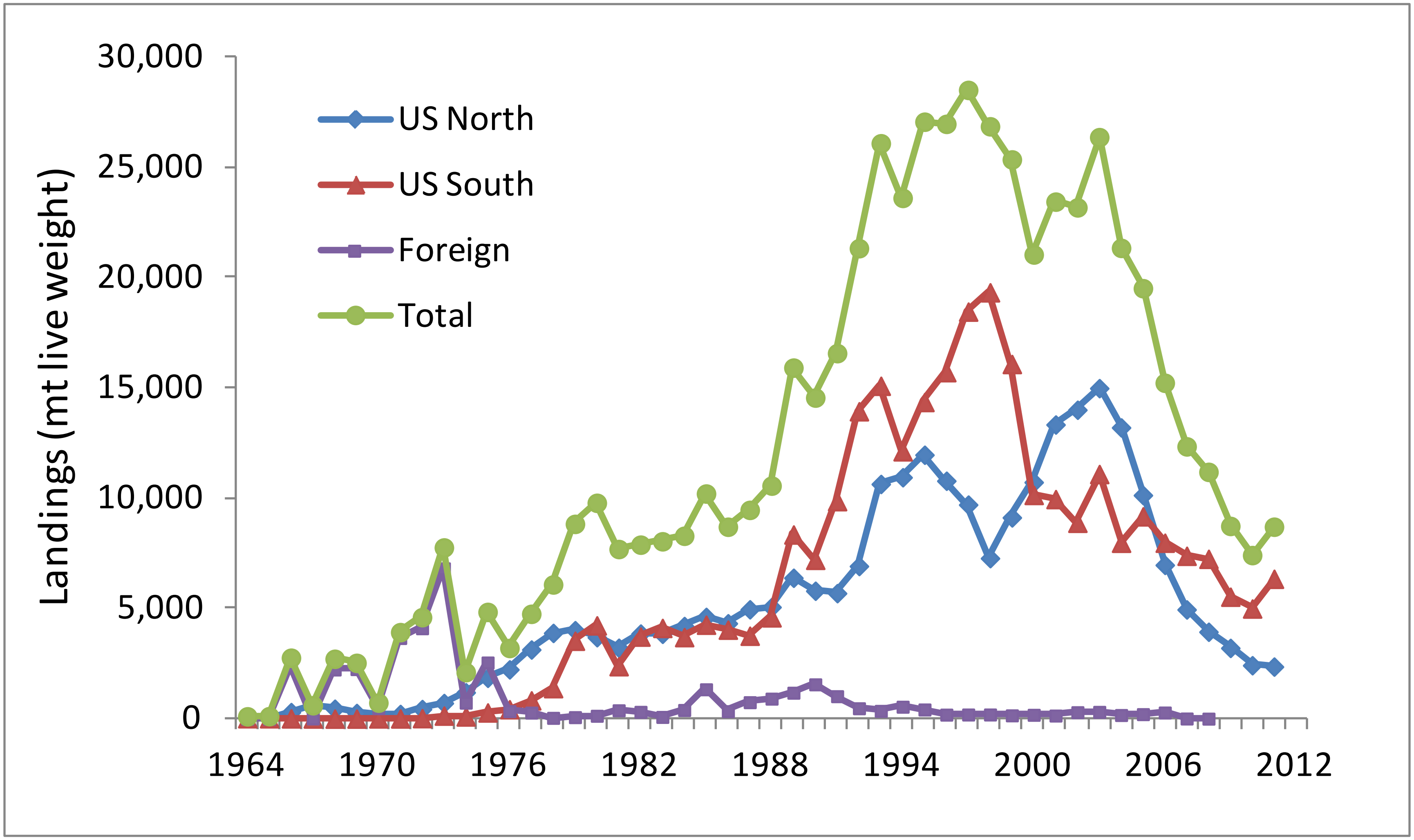


Figure 2 . Monkfish landings by management area and combined areas, 1964-2011.

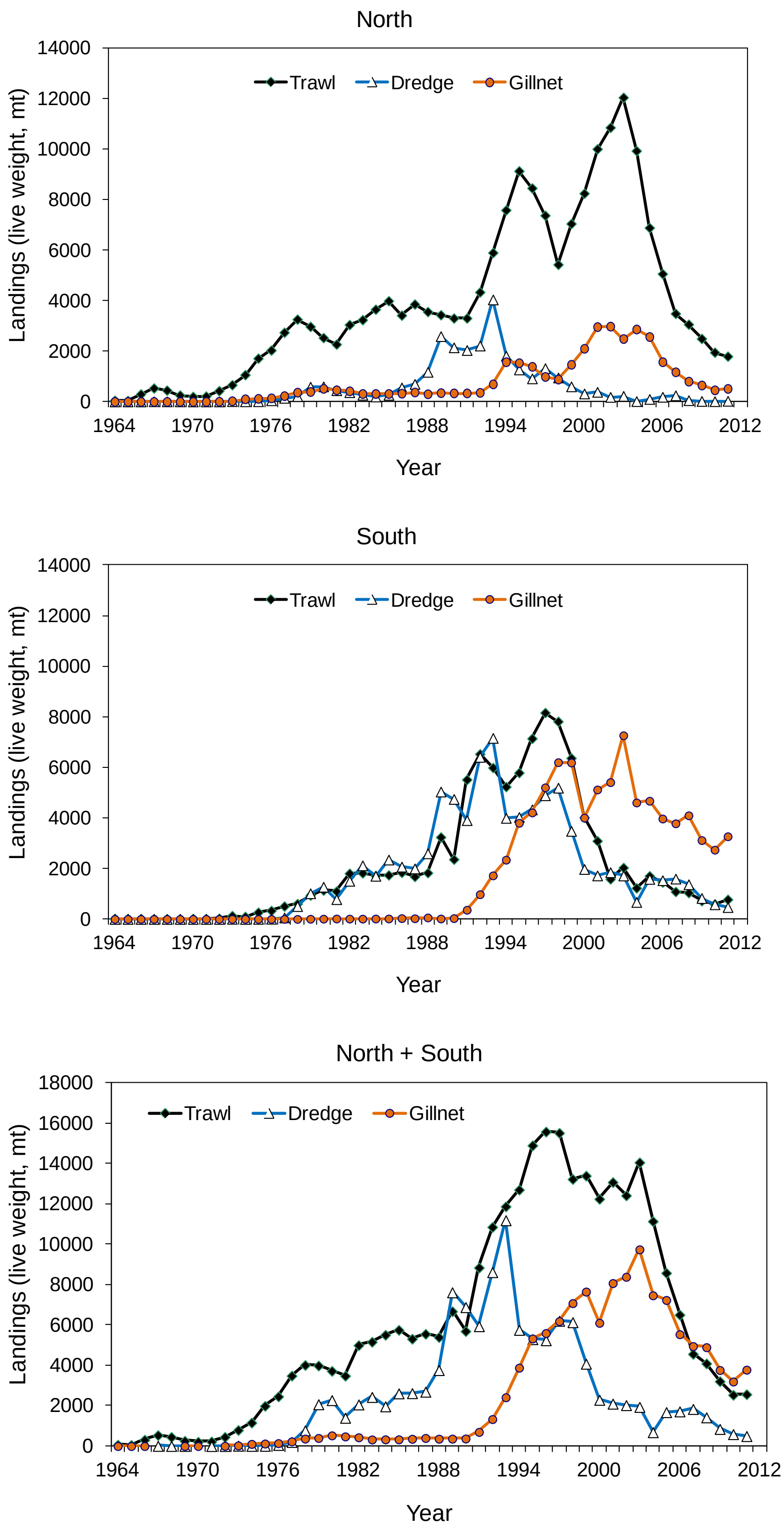


Figure 3. Commercial landings of monkfish by gear type and management region.

NORTH

SOUTH

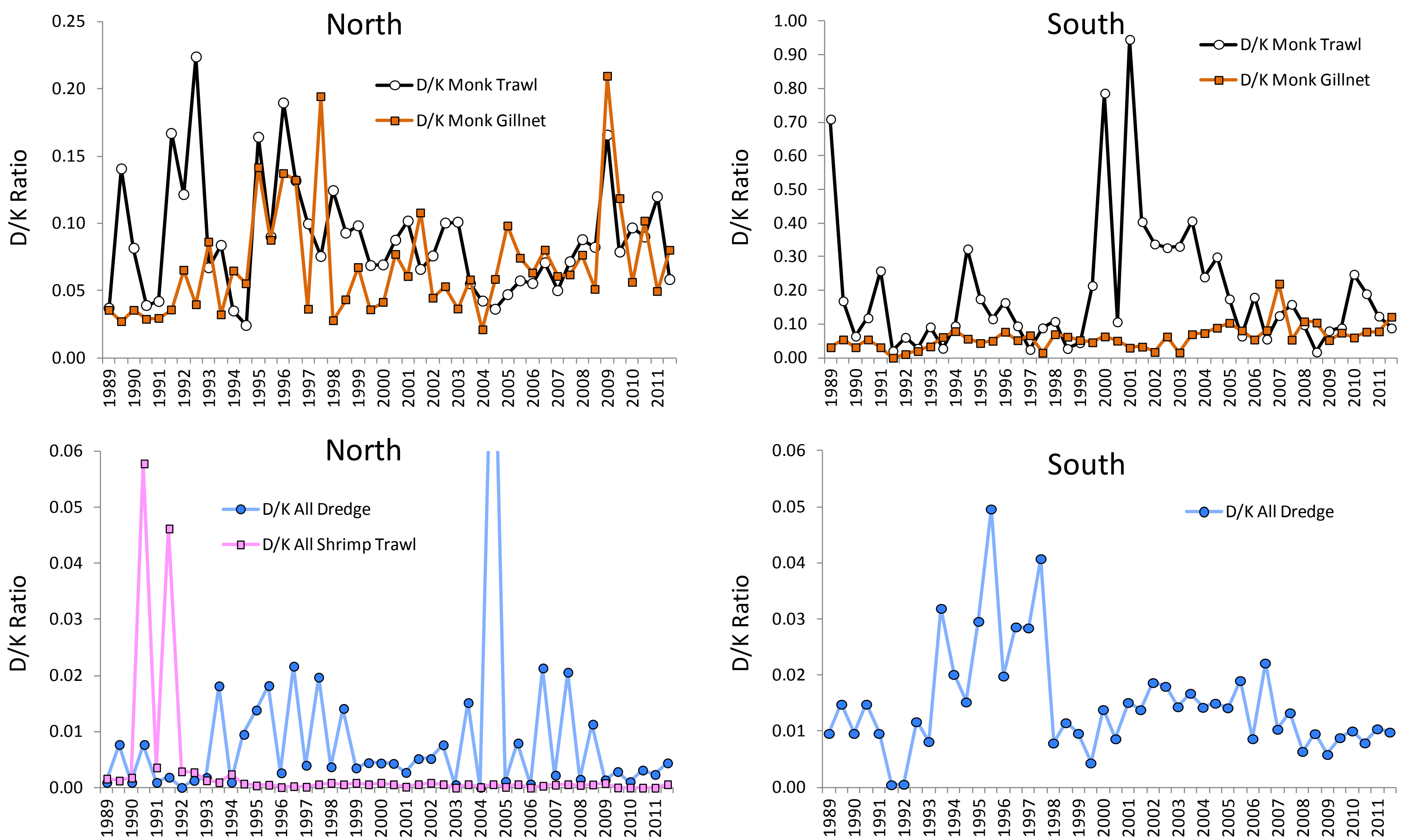


Figure 4. Discard ratios by half year for trawls and gillnets (top panels) and dredges and shrimp trawls (bottom panels) for North (left column) and South (right column). Trawls and gillnets ratios were based on kept monkfish; dredge and shrimp trawl were based on kept of all species.

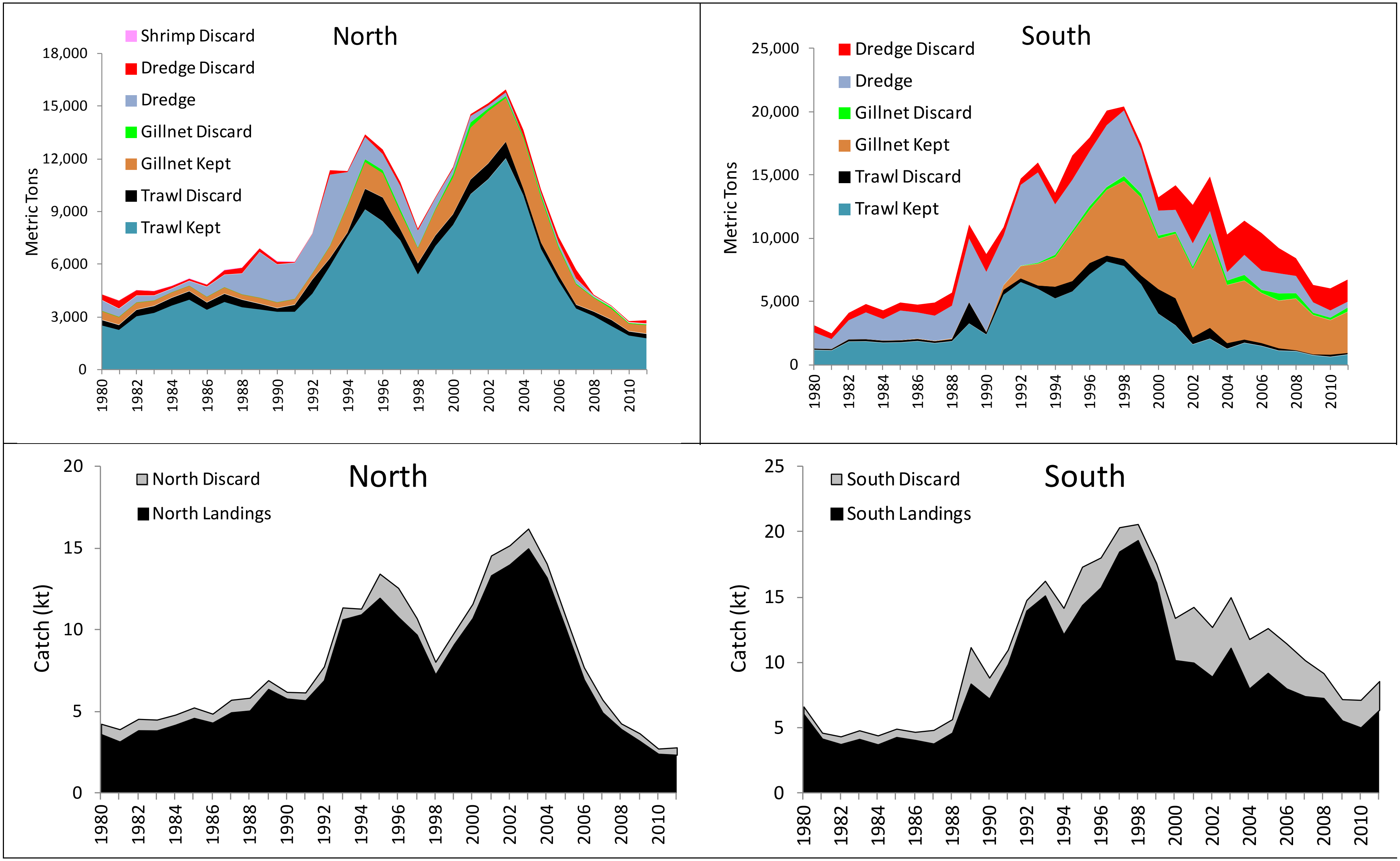


Figure 5. Monkfish landings and discard by gear type (top panels) and total (bottom panels) for North (left) and South (right).

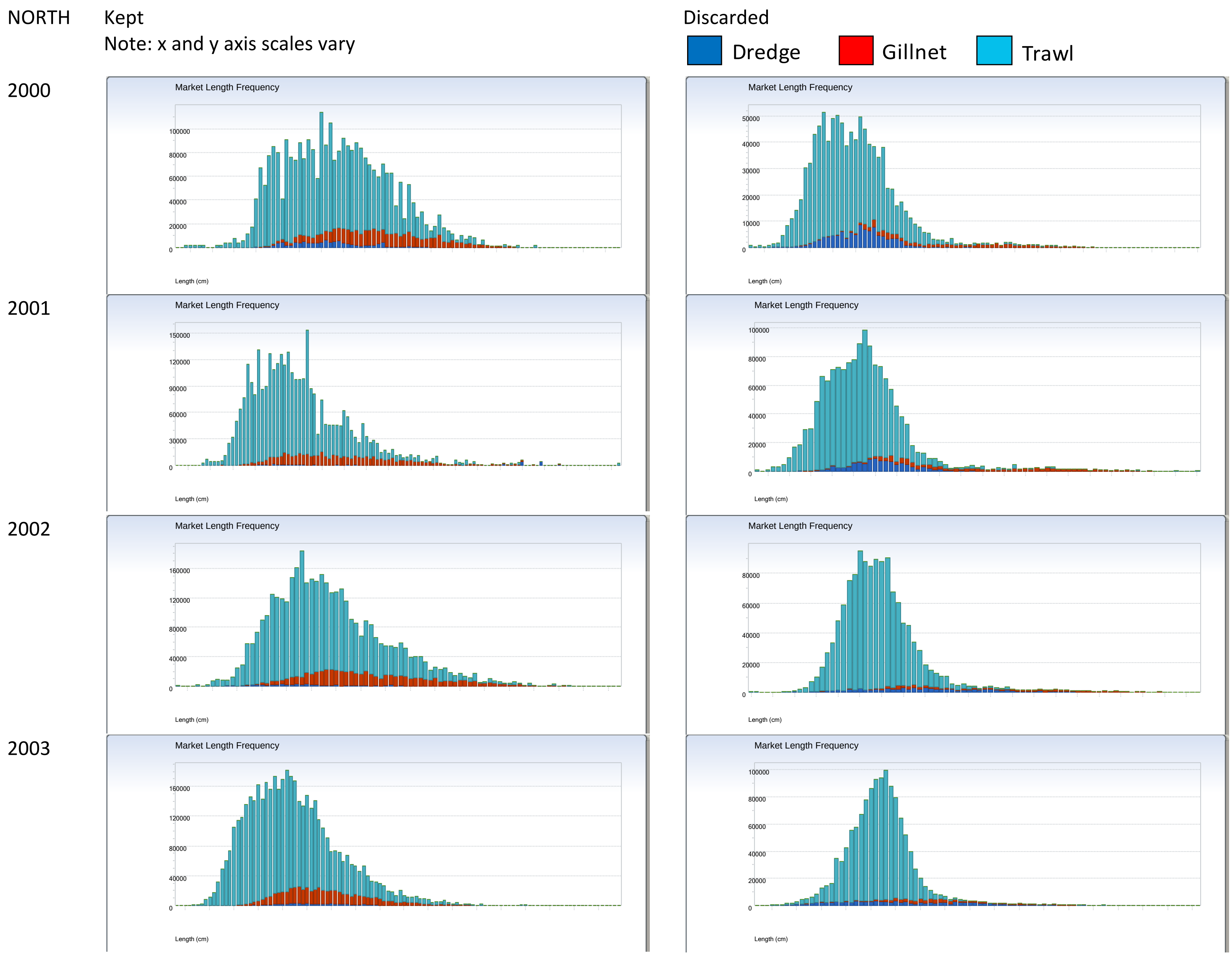


Figure 6. Estimated length composition of kept and discarded monkfish in the North, by gear type.

NORTH

Kept
Note: x and y axis scales vary

Discarded

Dredge Gillnet Trawl

2004
2005
2006
2007

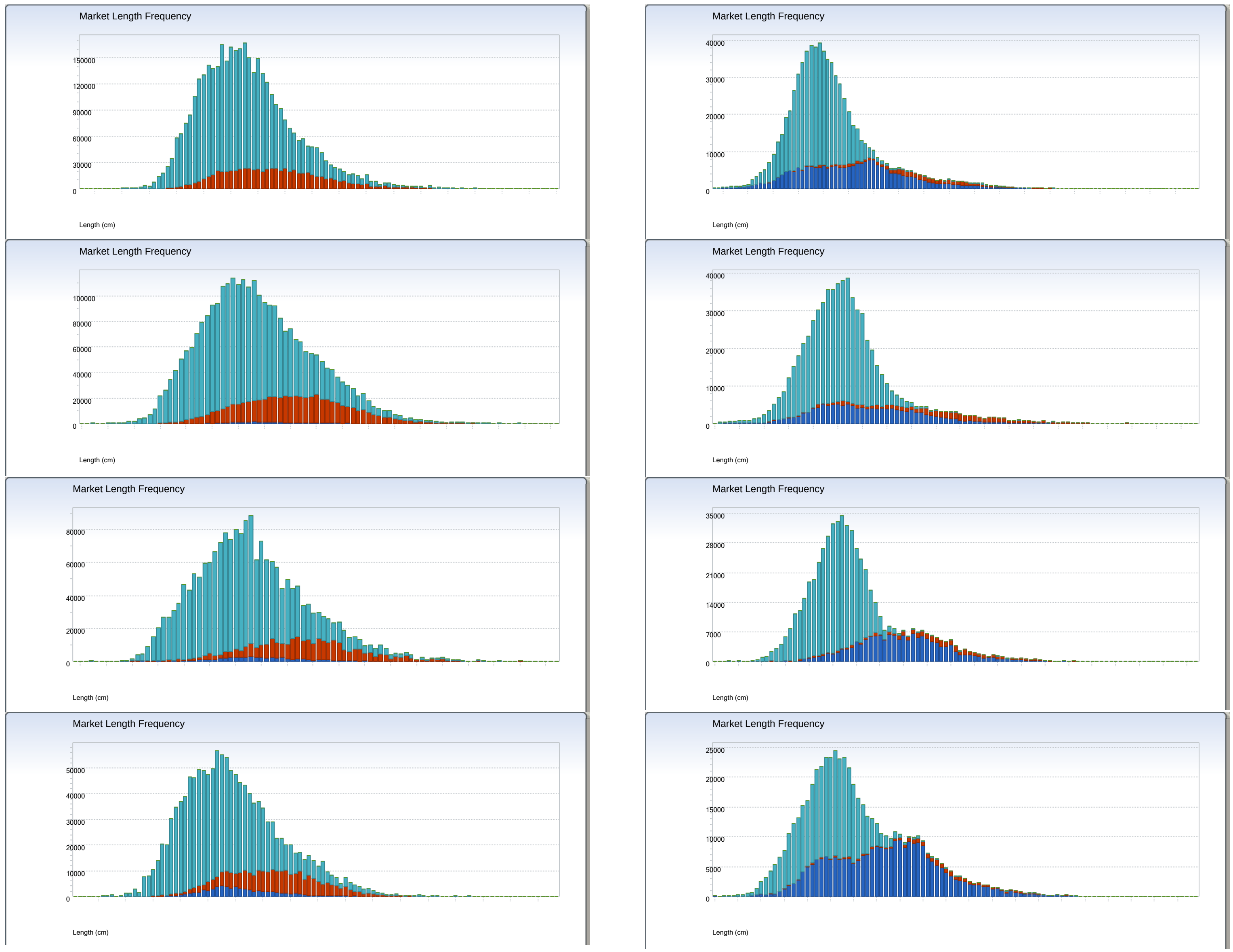


Figure 6, continued

NORTH Kept

Note: x and y axis scales vary

Discarded

Dredge Gillnet Trawl

2008

2009

2010

2011

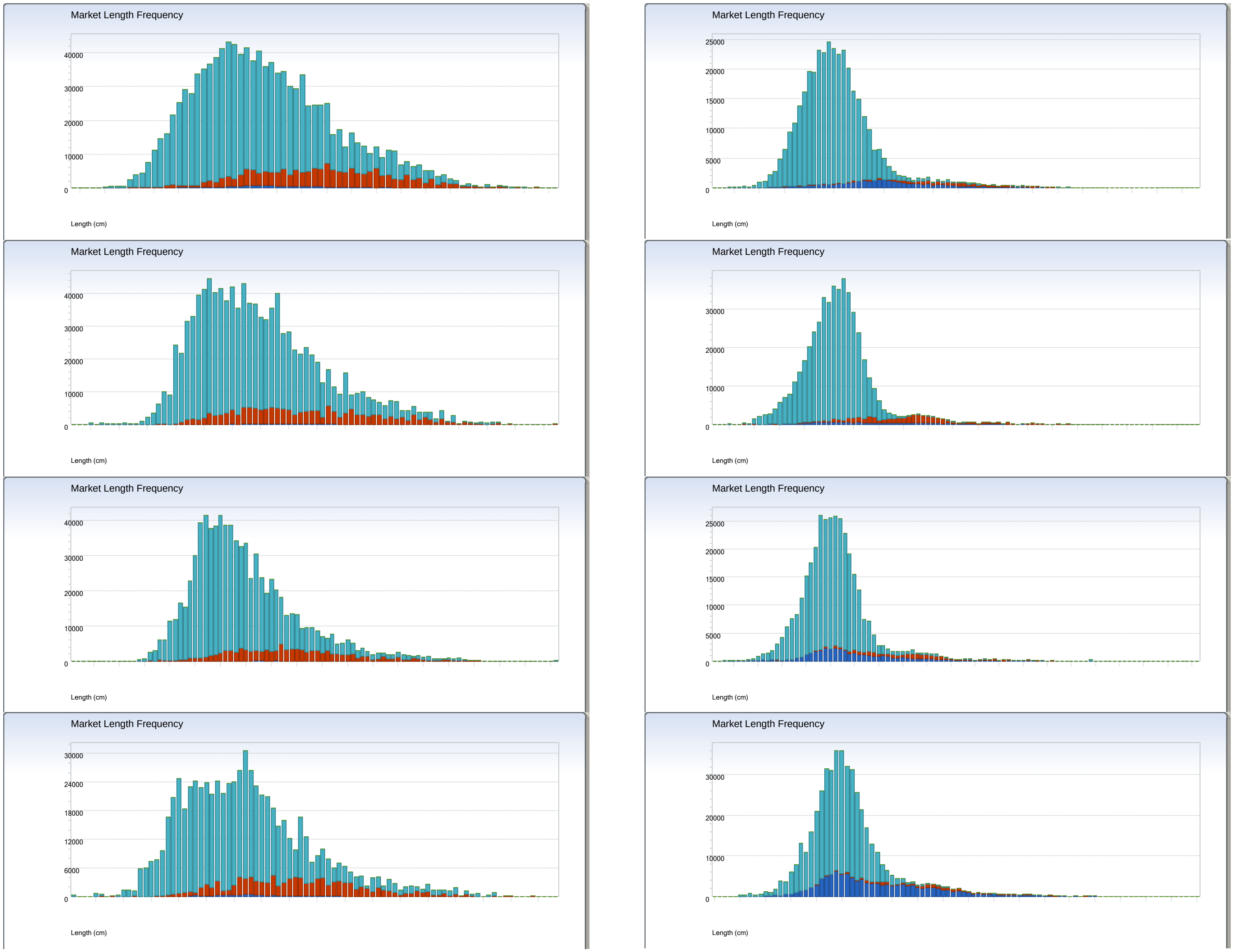


Figure 6, continued

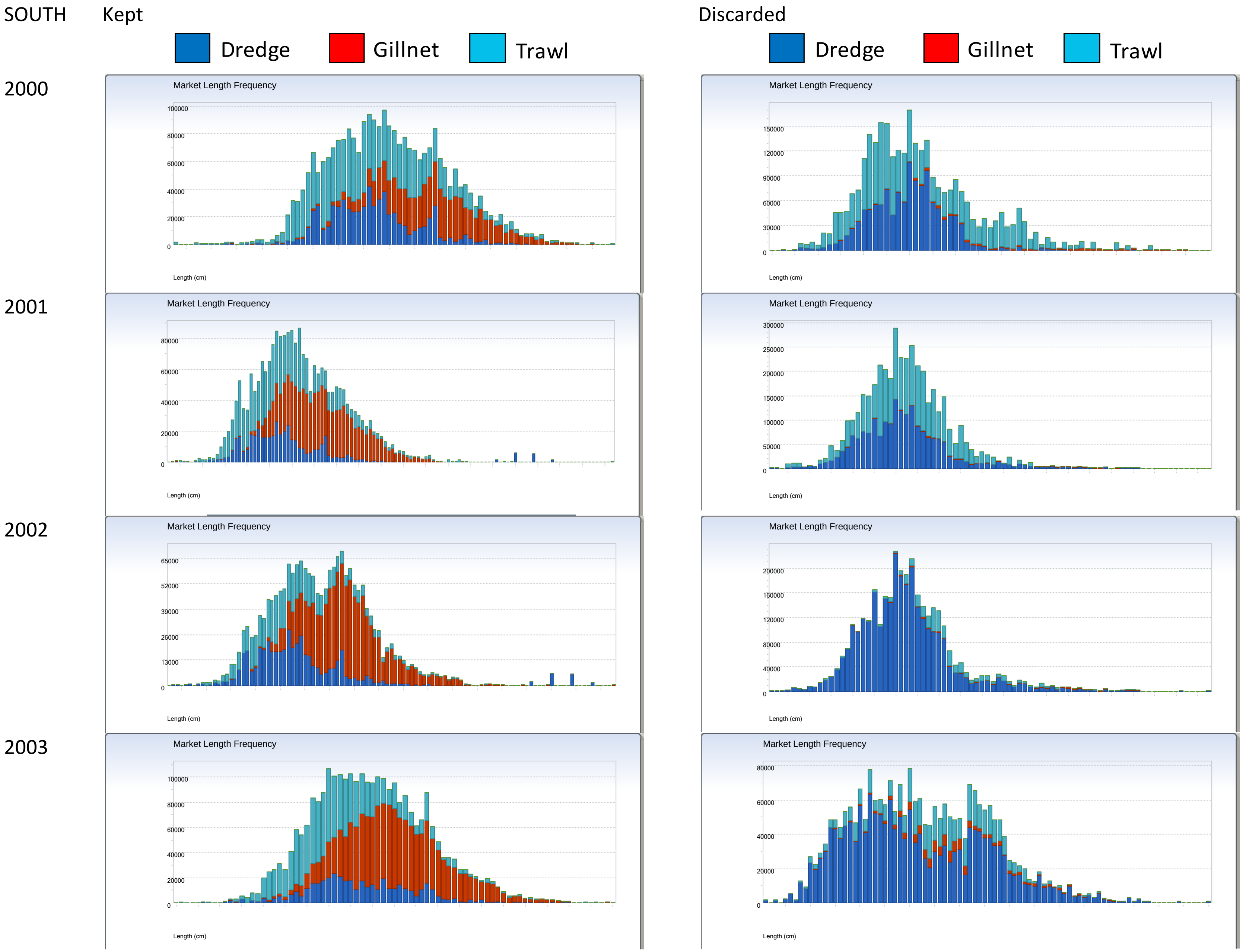


Figure 7. Estimated length composition of kept and discarded monkfish in the South, by gear type.

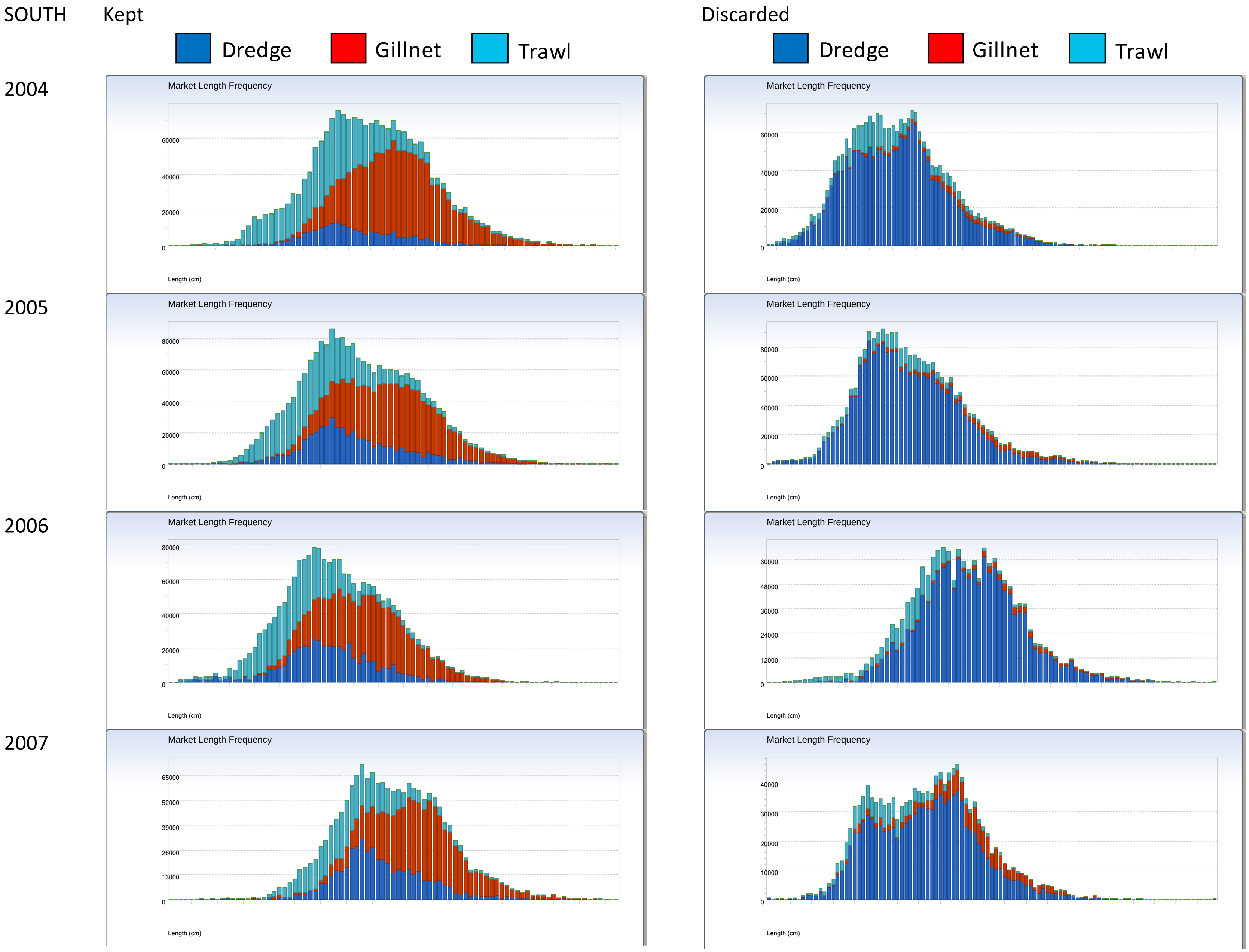


Figure 7, continued.

SOUTH Kept Discarded

2008

2009

2010

2011

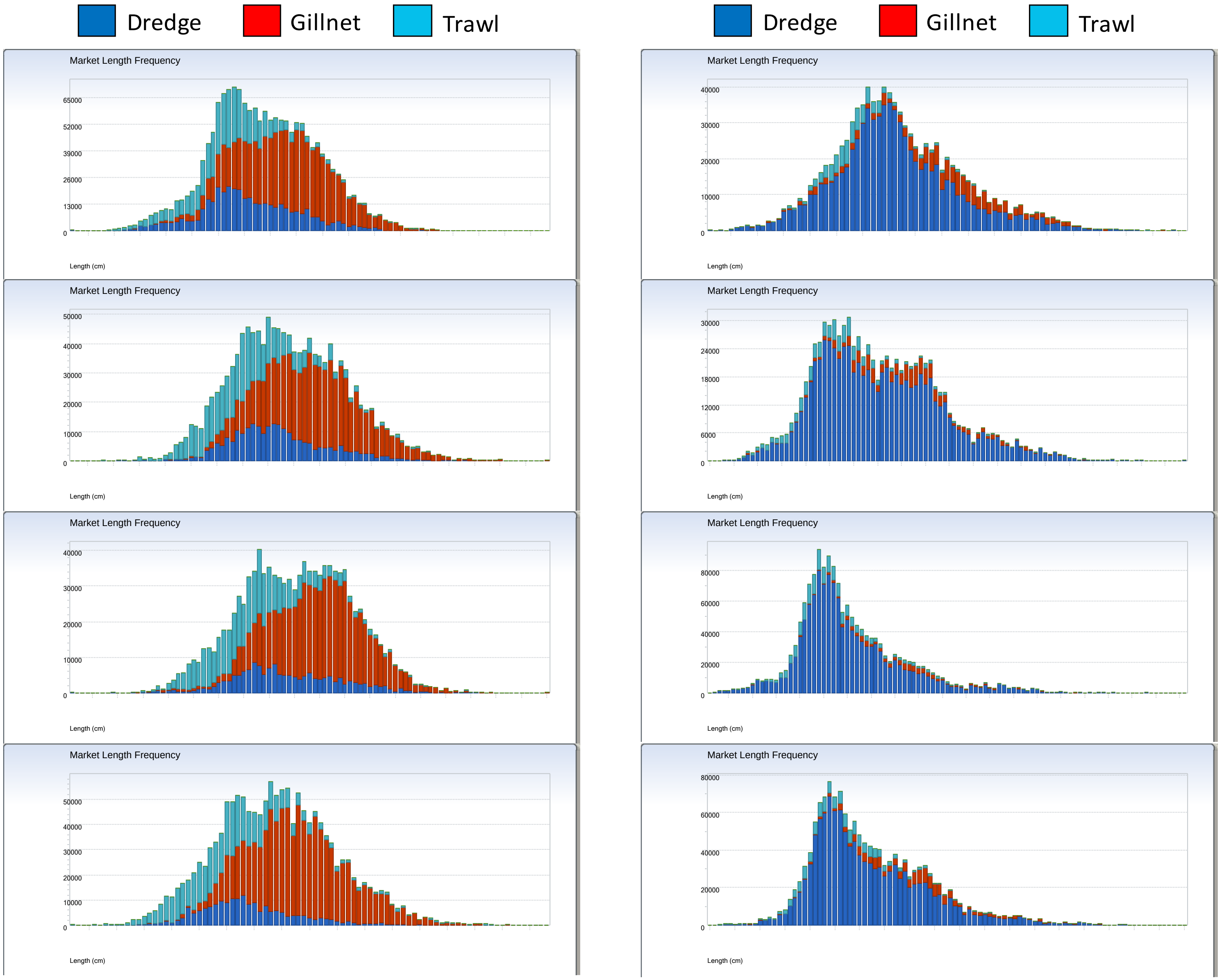


Figure 7, continued.

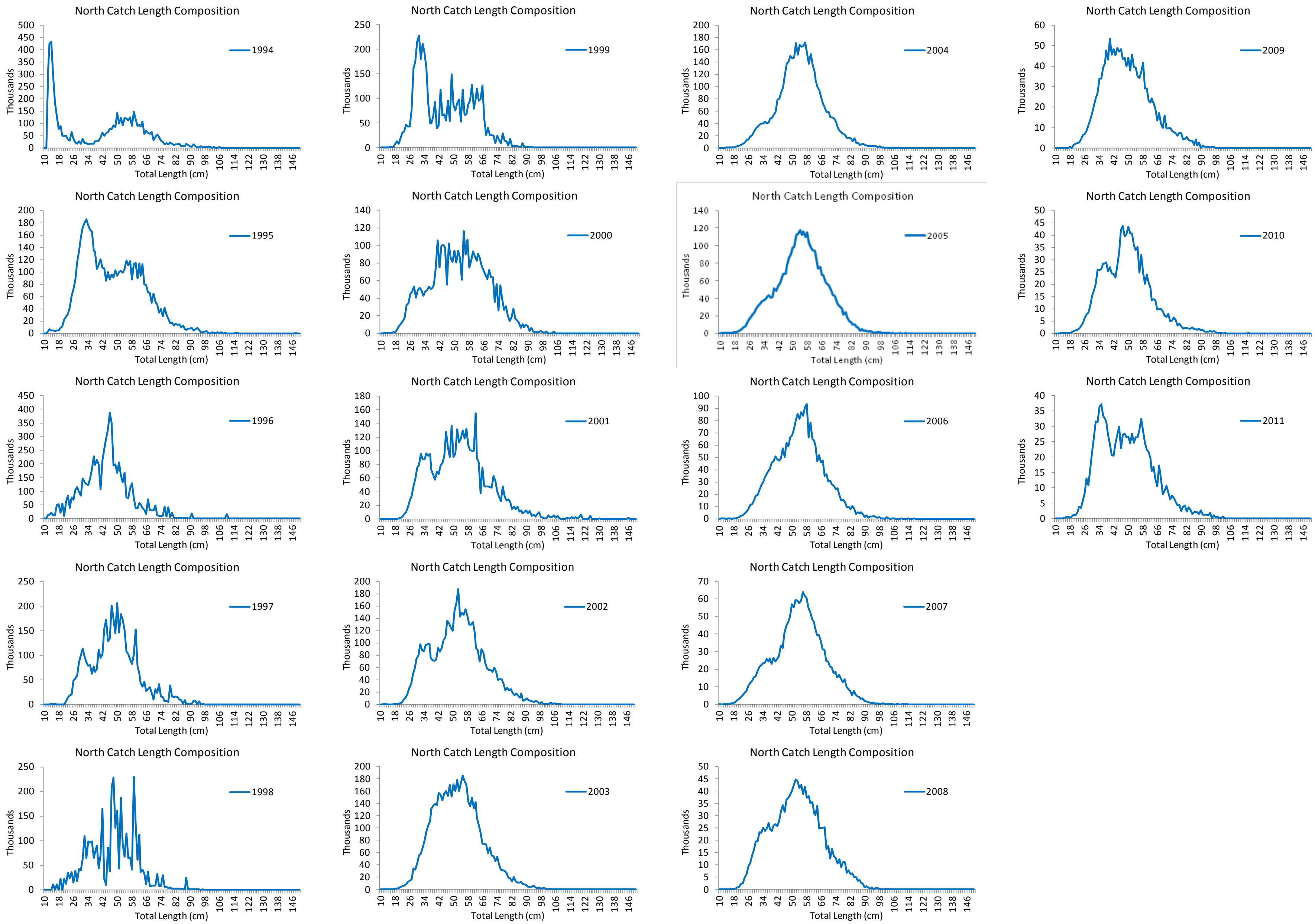


Figure 8. Length composition of monkfish commercial catch estimated using length frequency data collected by fishery observers in the northern management region.

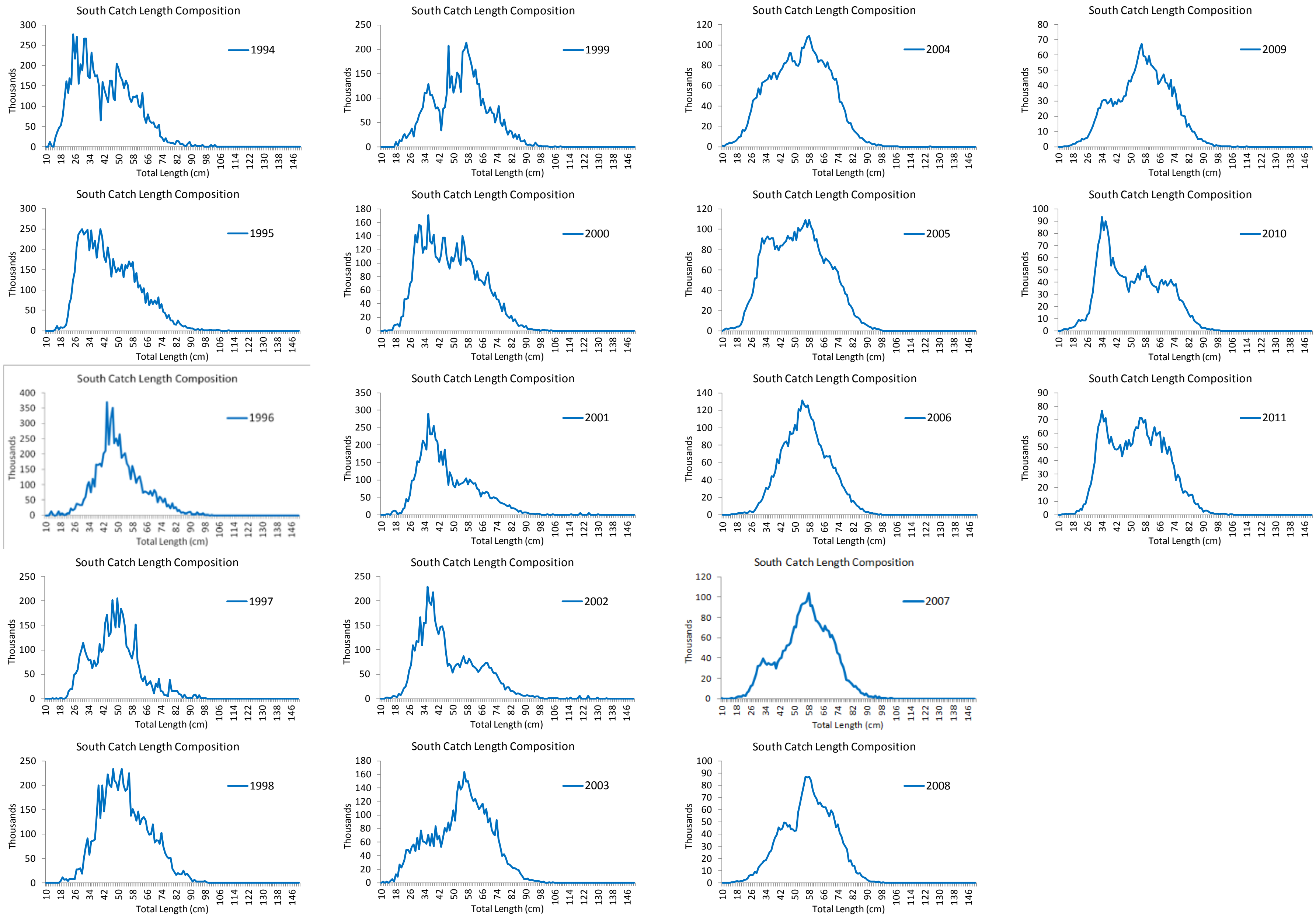


Figure 9. Length composition of monkfish commercial catch estimated using length frequency data collected by fishery observers in the southern management region.

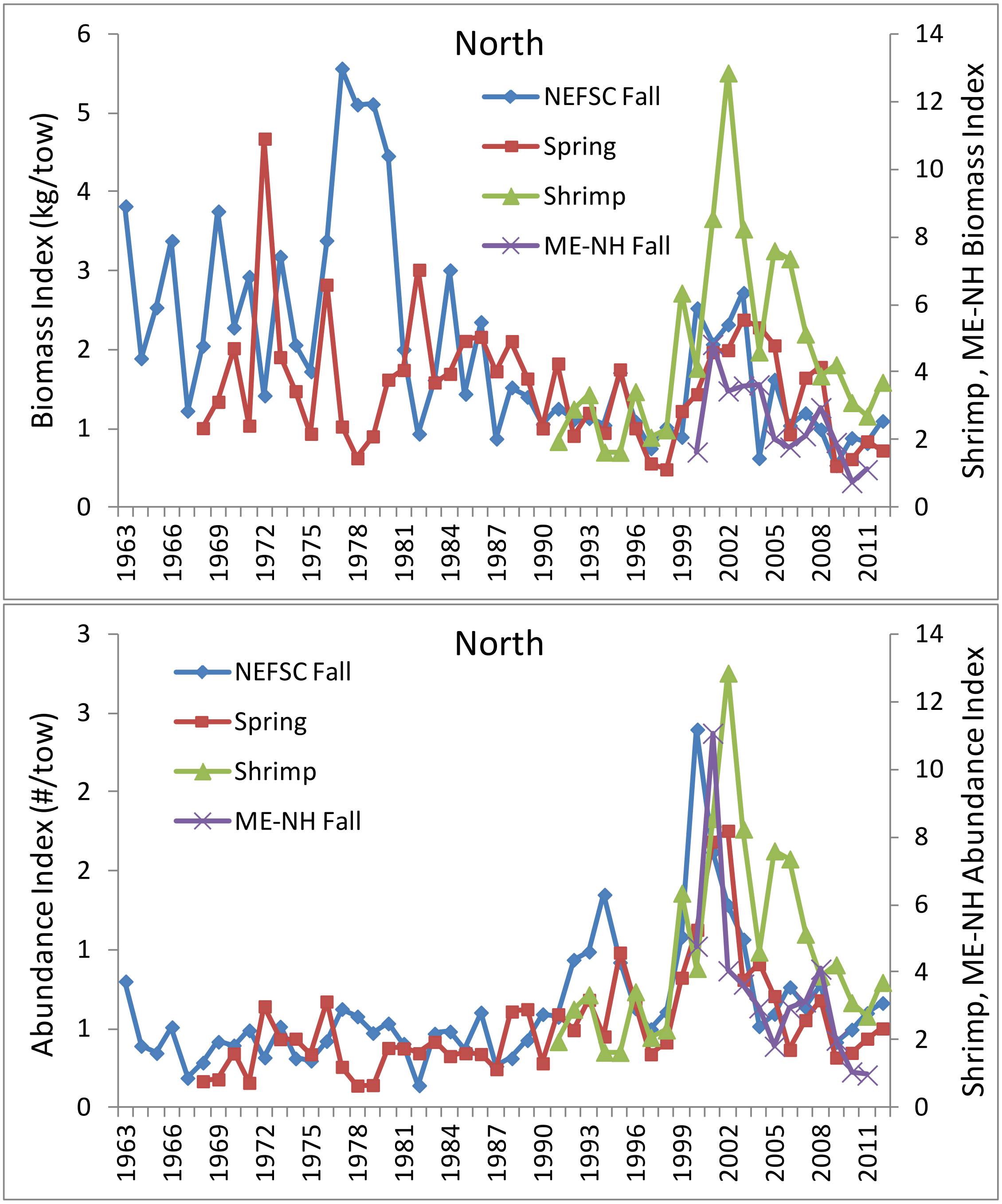


Figure 10. Survey indices for monkfish in the northern management area. Top panel biomass, bottom panel abundance.

North

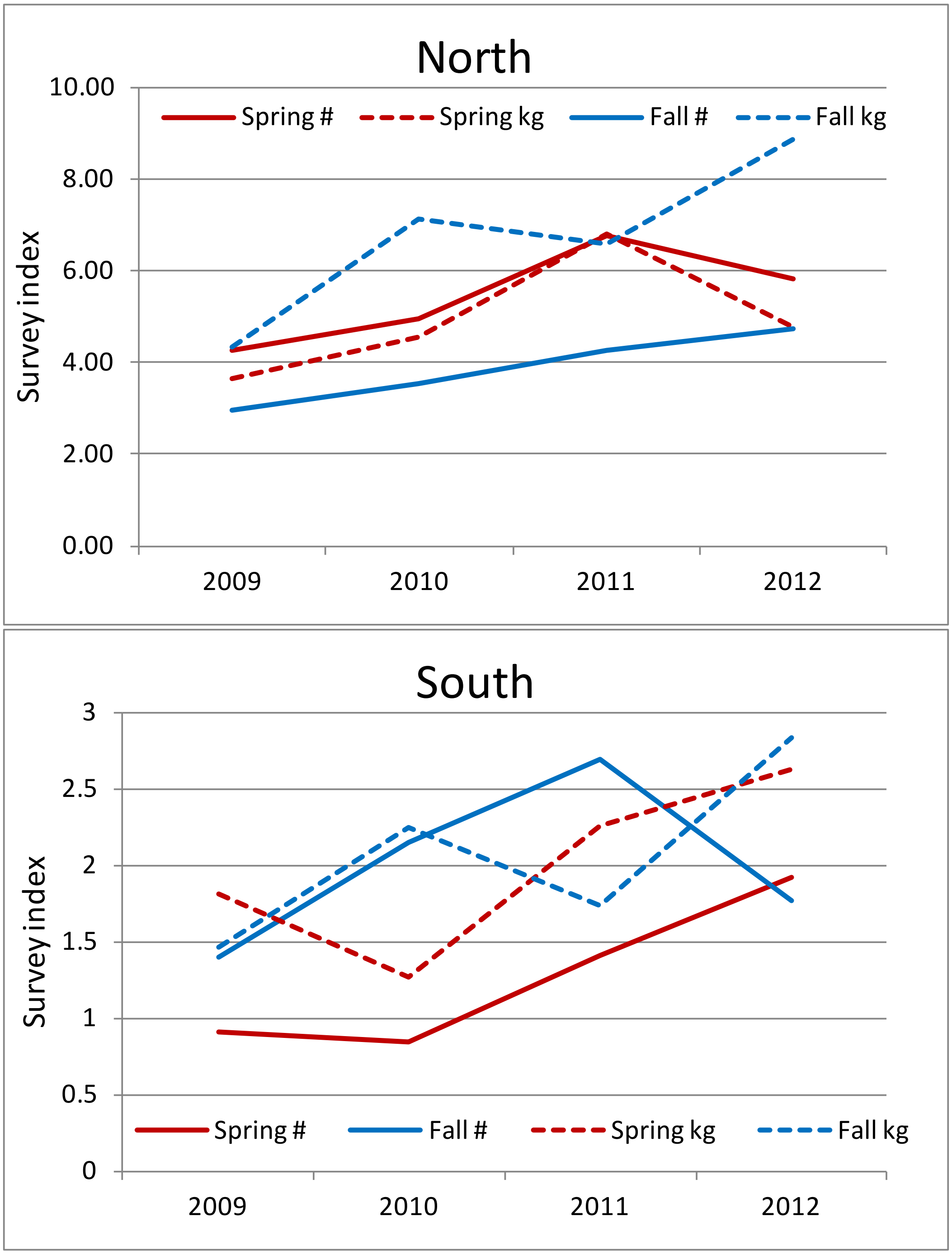


Figure 11. NEFSC autumn and spring survey indices for monkfish in the northern and southern management areas for 2009-2012, not converted to Albatross units.

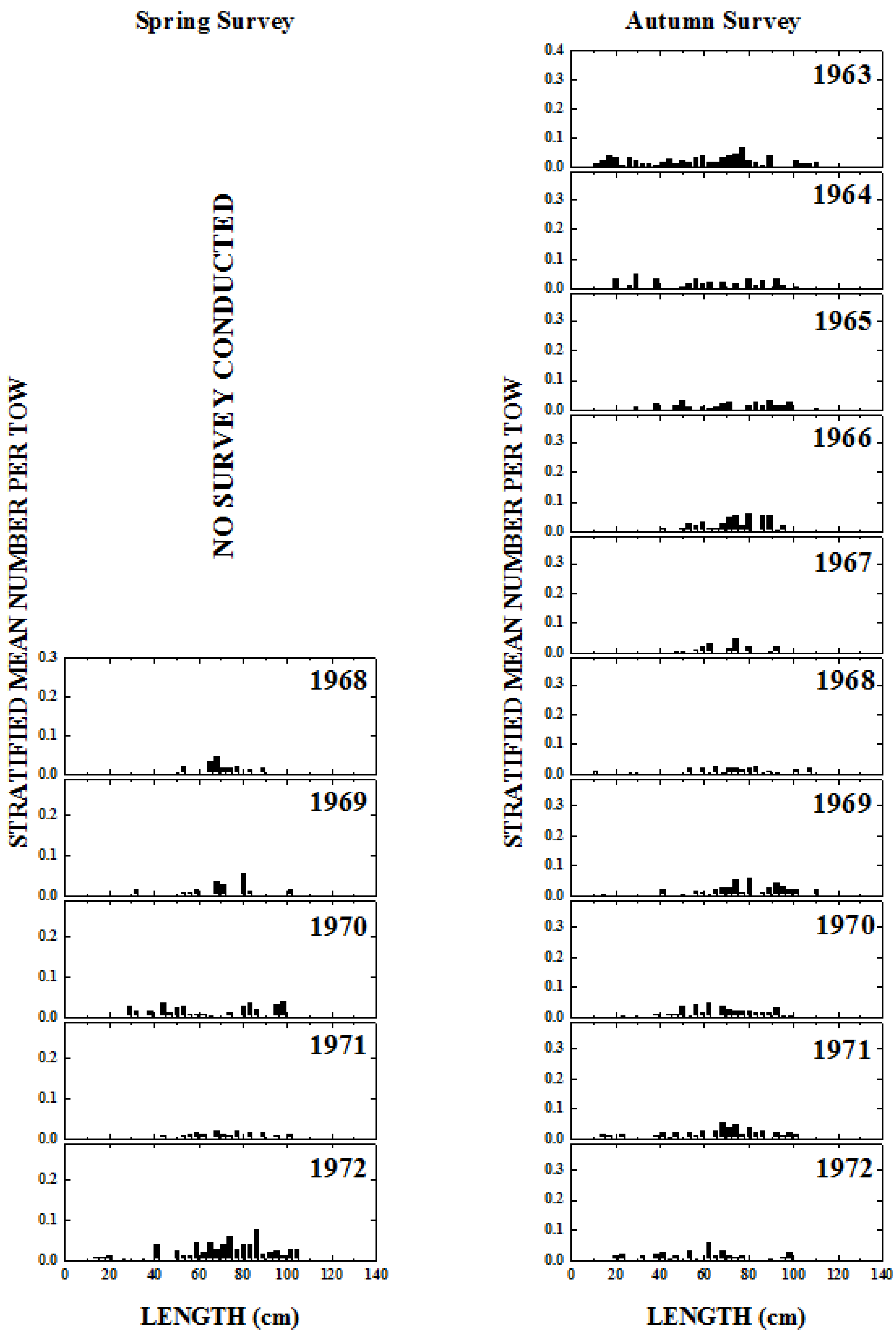


Figure 12. Goosefish length composition from the NEFSC spring and autumn bottom trawl surveys in the northern management region.

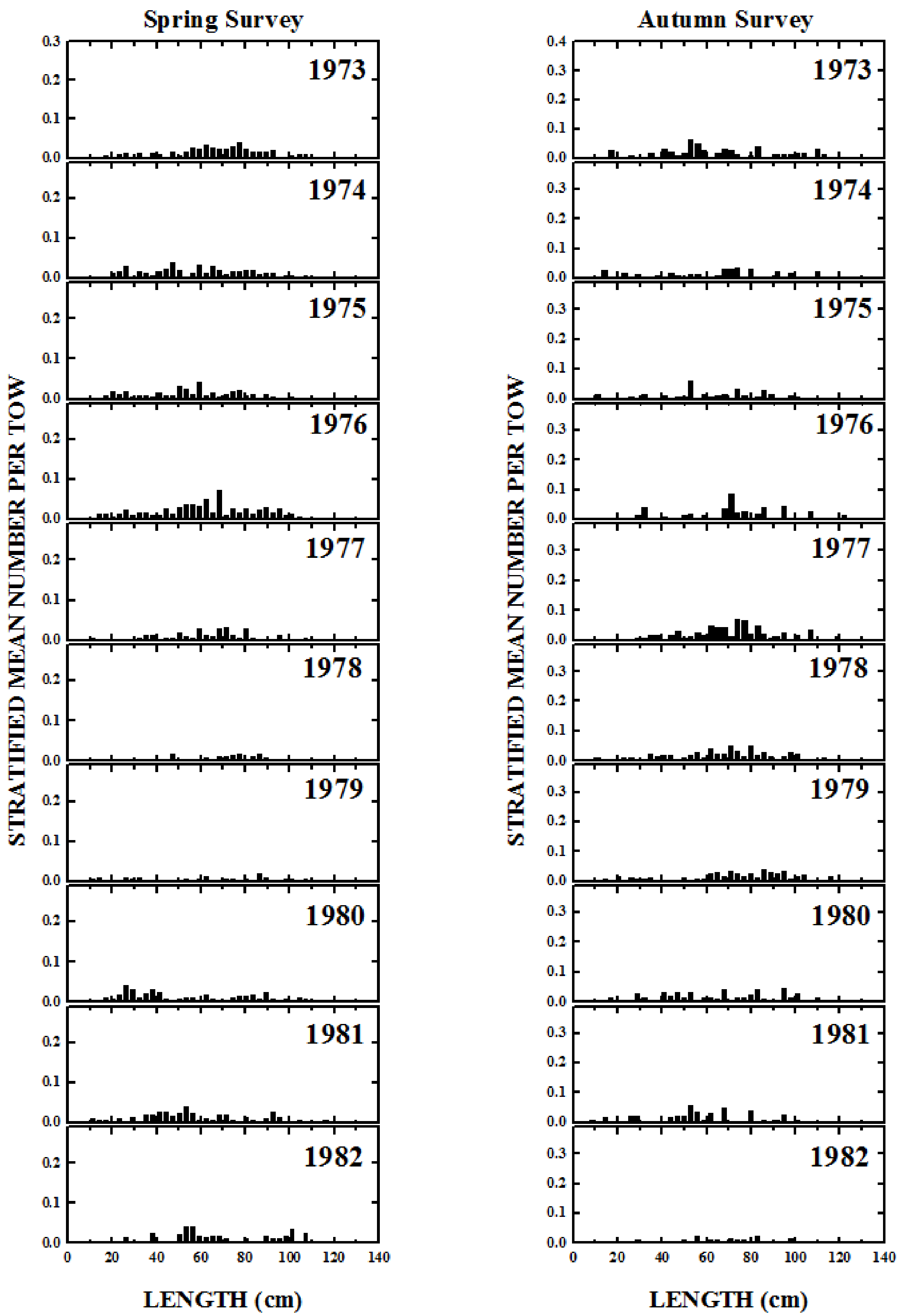


Figure 12, continued. Goosefish length composition from the NEFSC spring and autumn bottom trawl surveys in the northern management region.

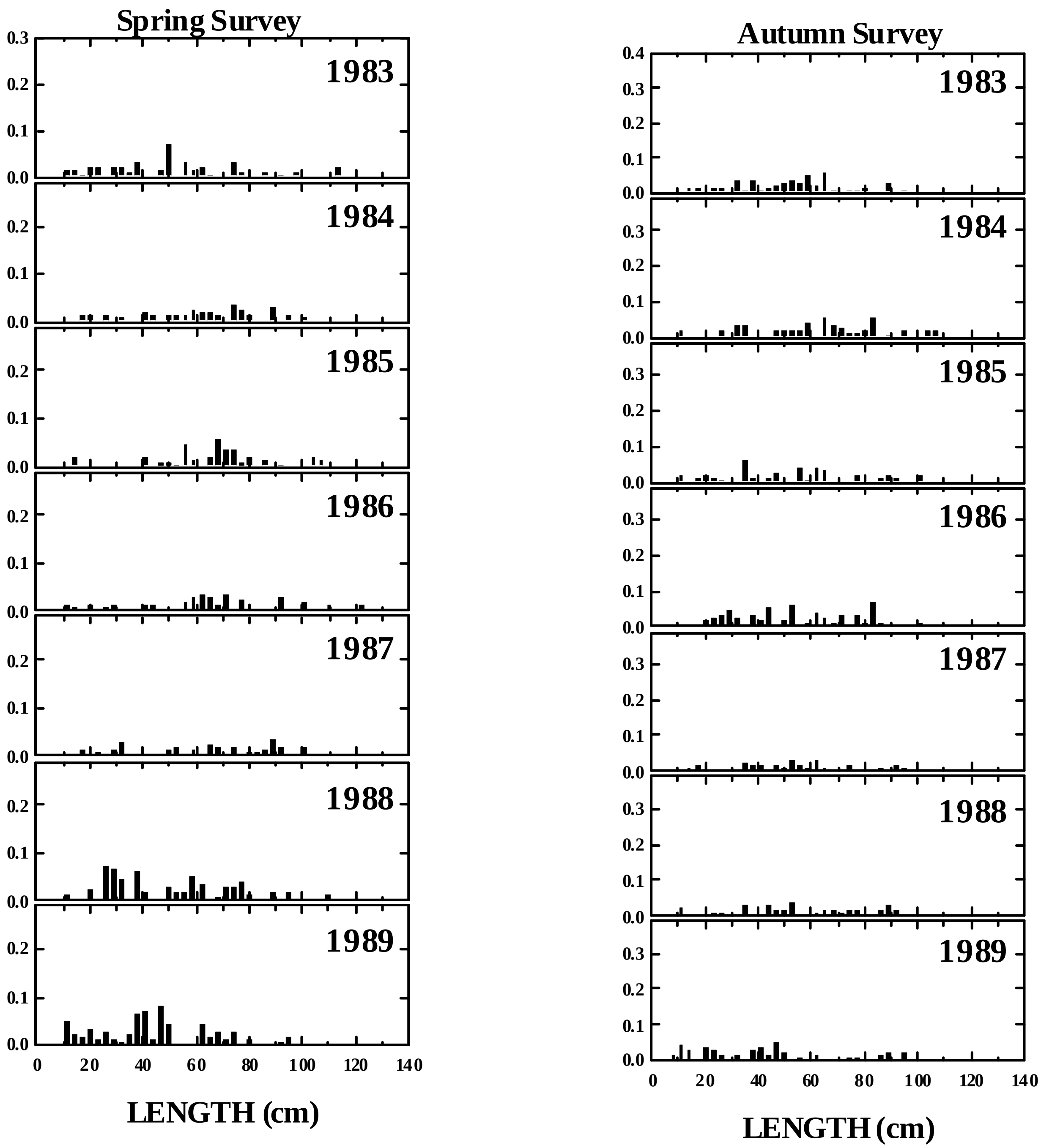


Figure 12, continued. Goosefish length composition from the NEFSC spring and autumn bottom trawl surveys in the northern management region.

NOTE: Y-AXIS SCALE CHANGES ON THIS PAGE

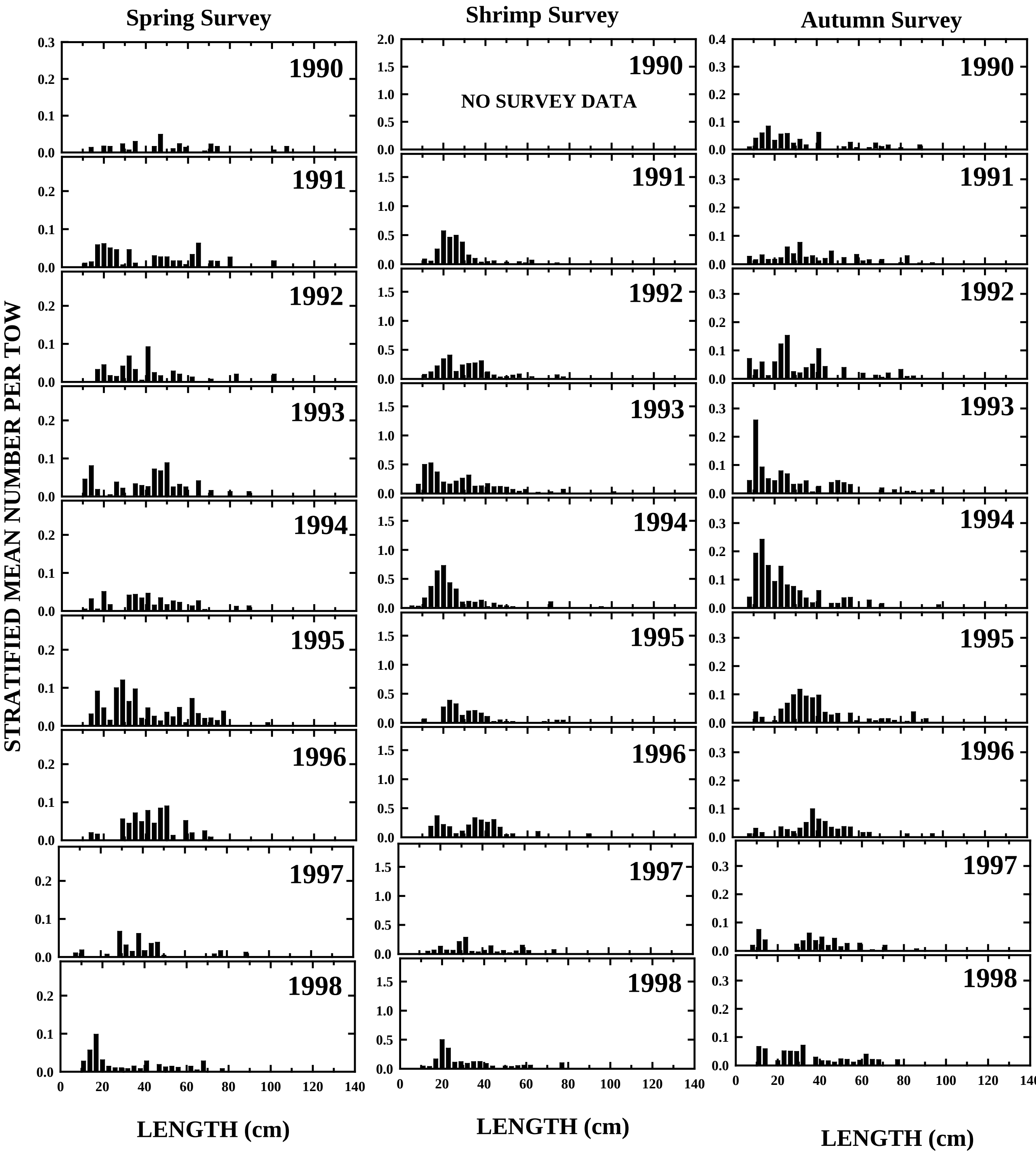


Figure 12, continued. Goosefish length composition from the NEFSC spring and autumn bottom trawl survey, and ASMFC summer shrimp survey in the northern management region.

NOTE: Y-AXIS SCALE CHANGES ON THIS PAGE

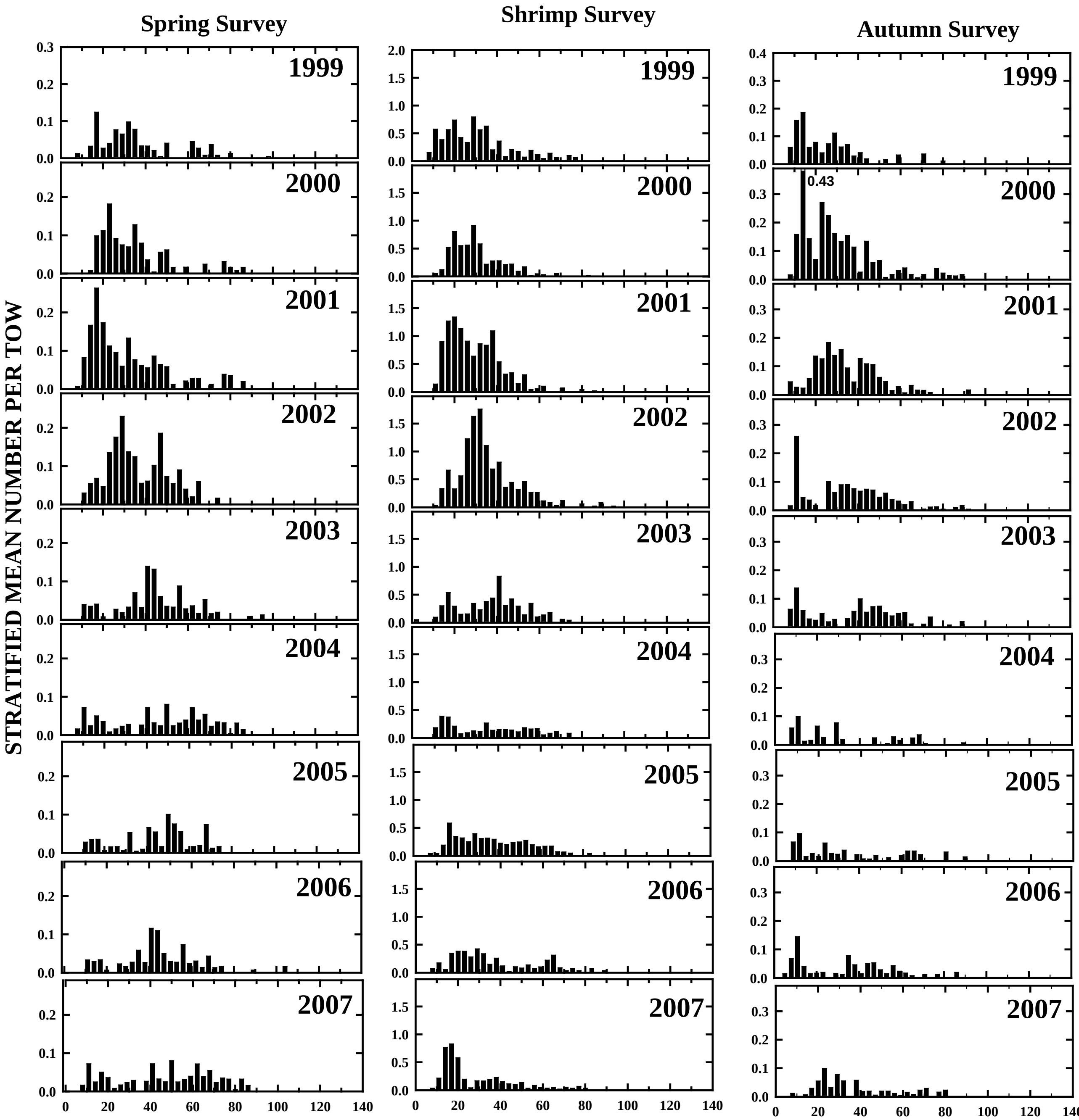
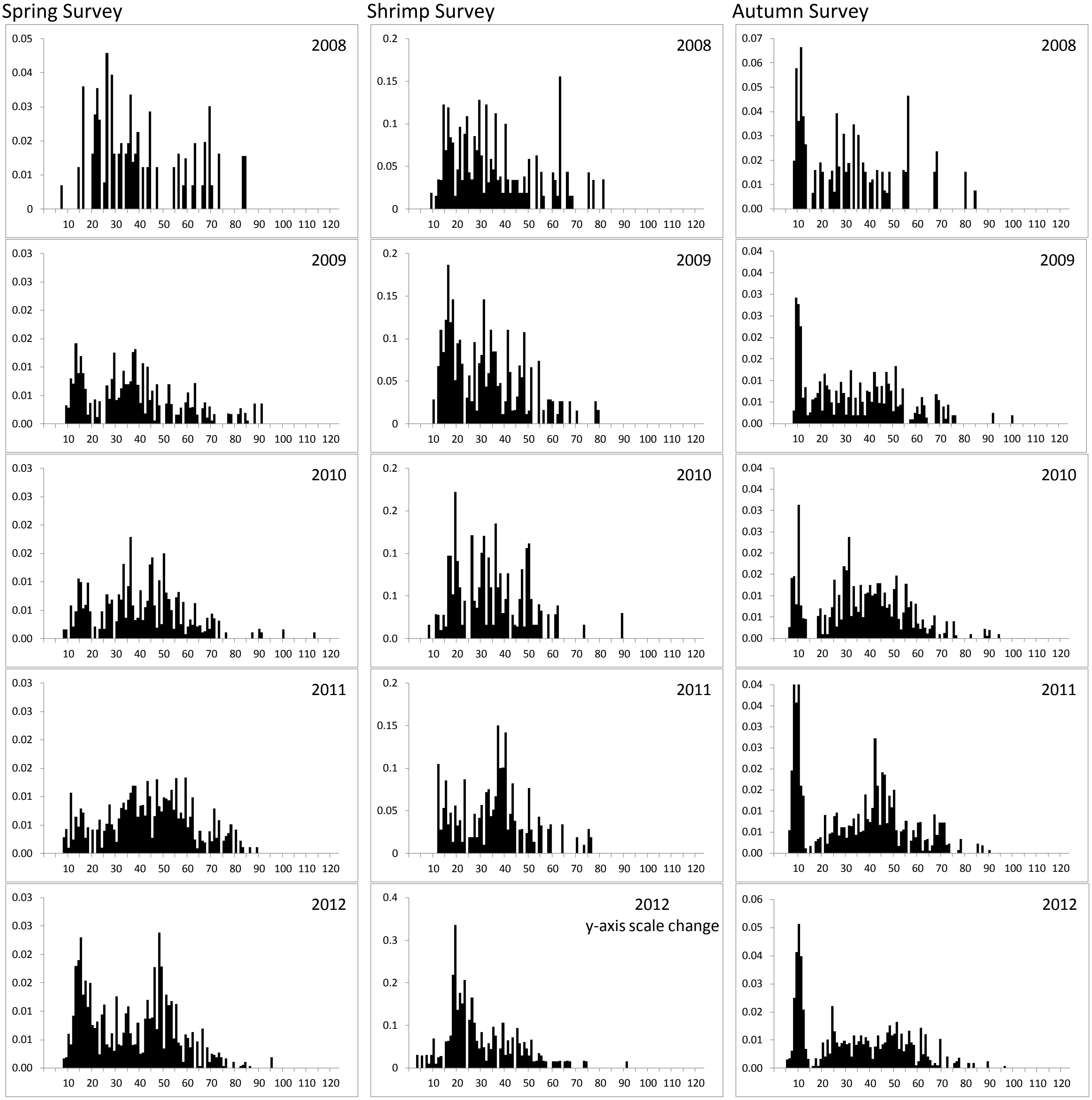


Figure 12, continued. Goosefish length composition from the NEFSC spring and autumn bottom trawl survey, and ASMFC summer shrimp survey in the northern management region.



Note: axis scales change from previous page

Figure 12, continued. Goosefish length composition from the NEFSC spring and autumn bottom trawl survey, and ASMFC summer shrimp survey in the northern management region. 2009-2012 indices have been converted to *Albatross* units. Note axis changes this page due to plotting options (bars are 3-cm groups in previous plots, 1-cm groups here).

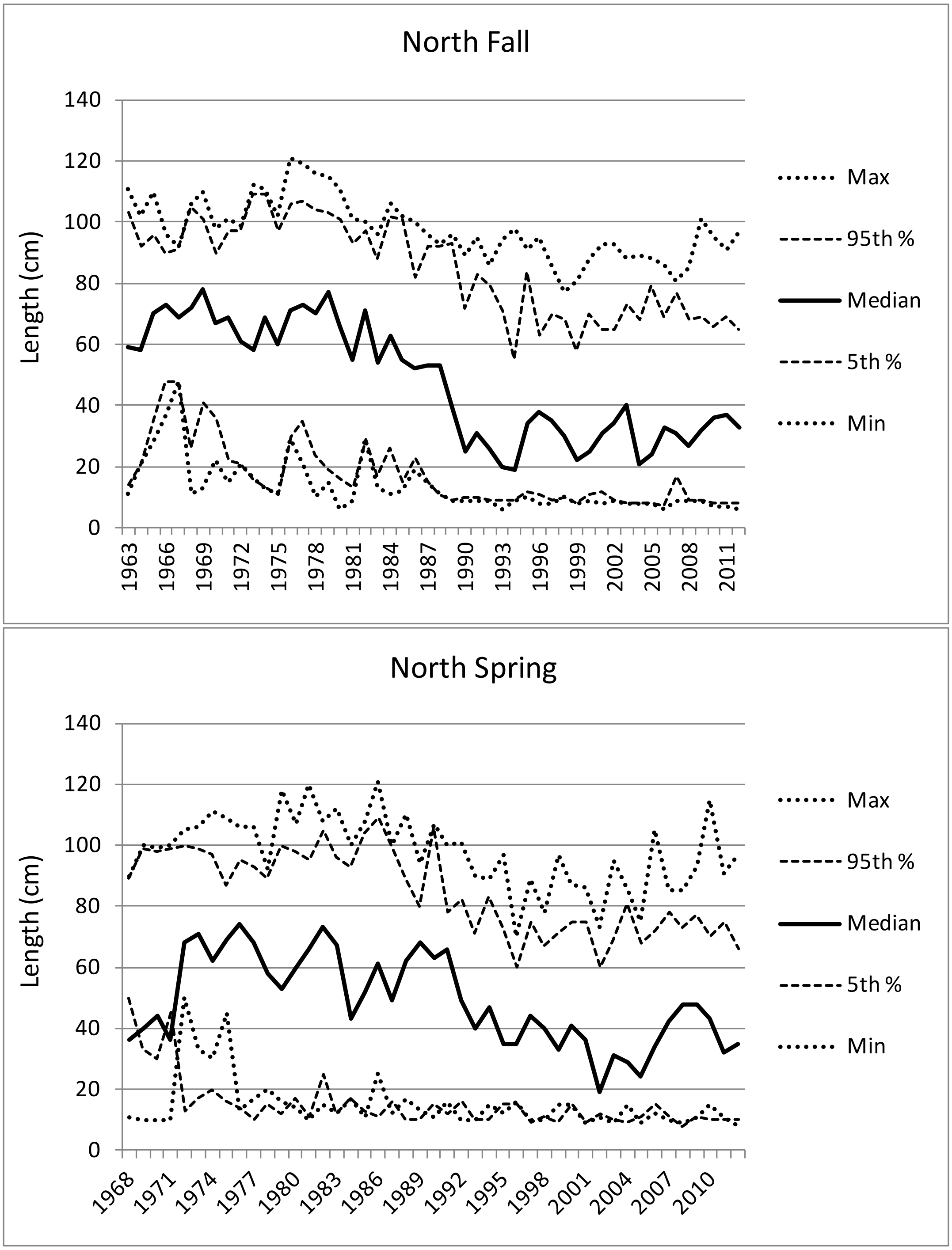


Figure 13. Length quantiles for monkfish over time from NEFSC autumn and spring surveys.

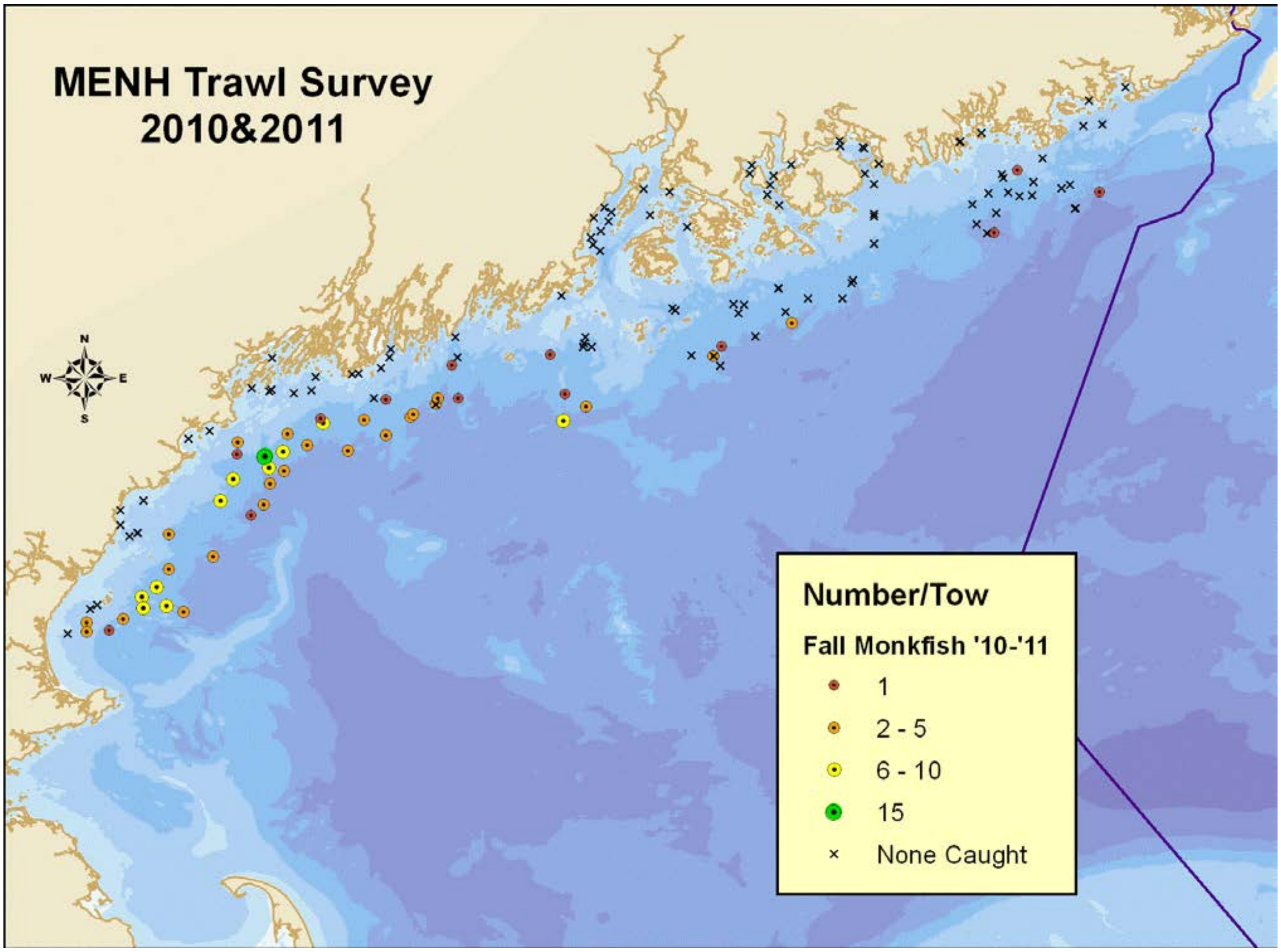


Figure 14. Distribution of monkfish in ME-NH fall survey, 2010-2011.

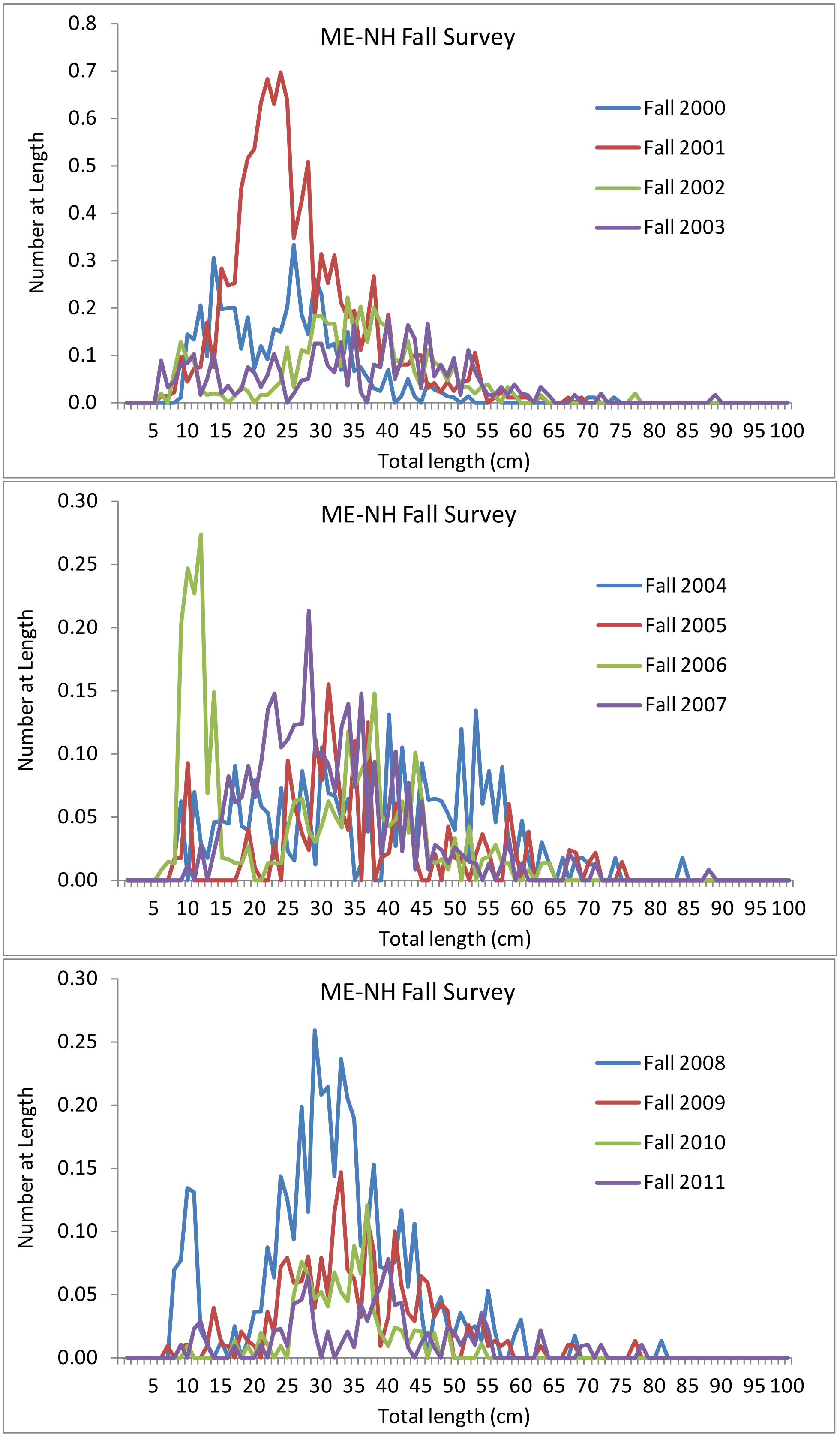


Figure 15. Length frequencies from Maine-New Hampshire fall inshore survey, 2000-2011.

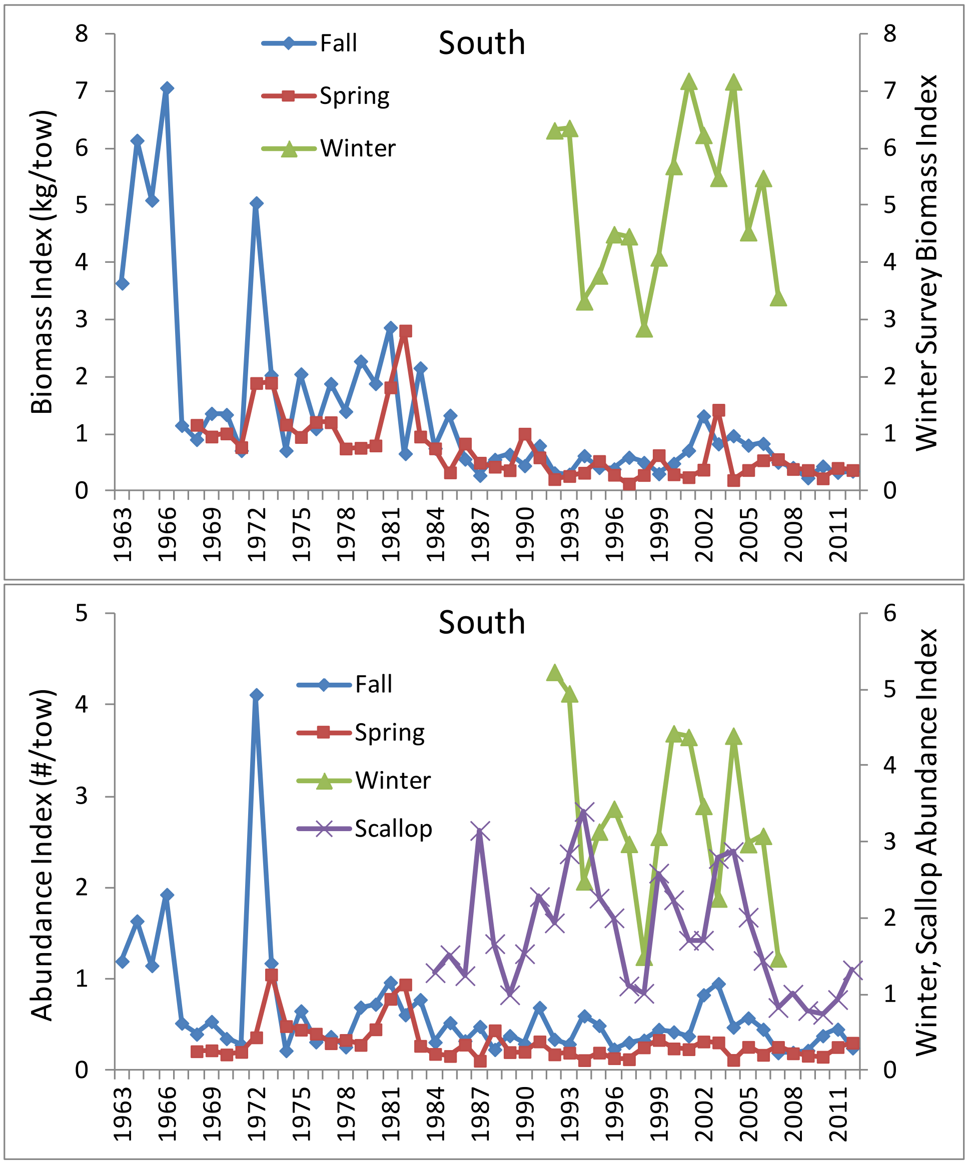


Figure 16. Survey indices for monkfish in the southern management area. Top panel biomass, bottom panel abundance.

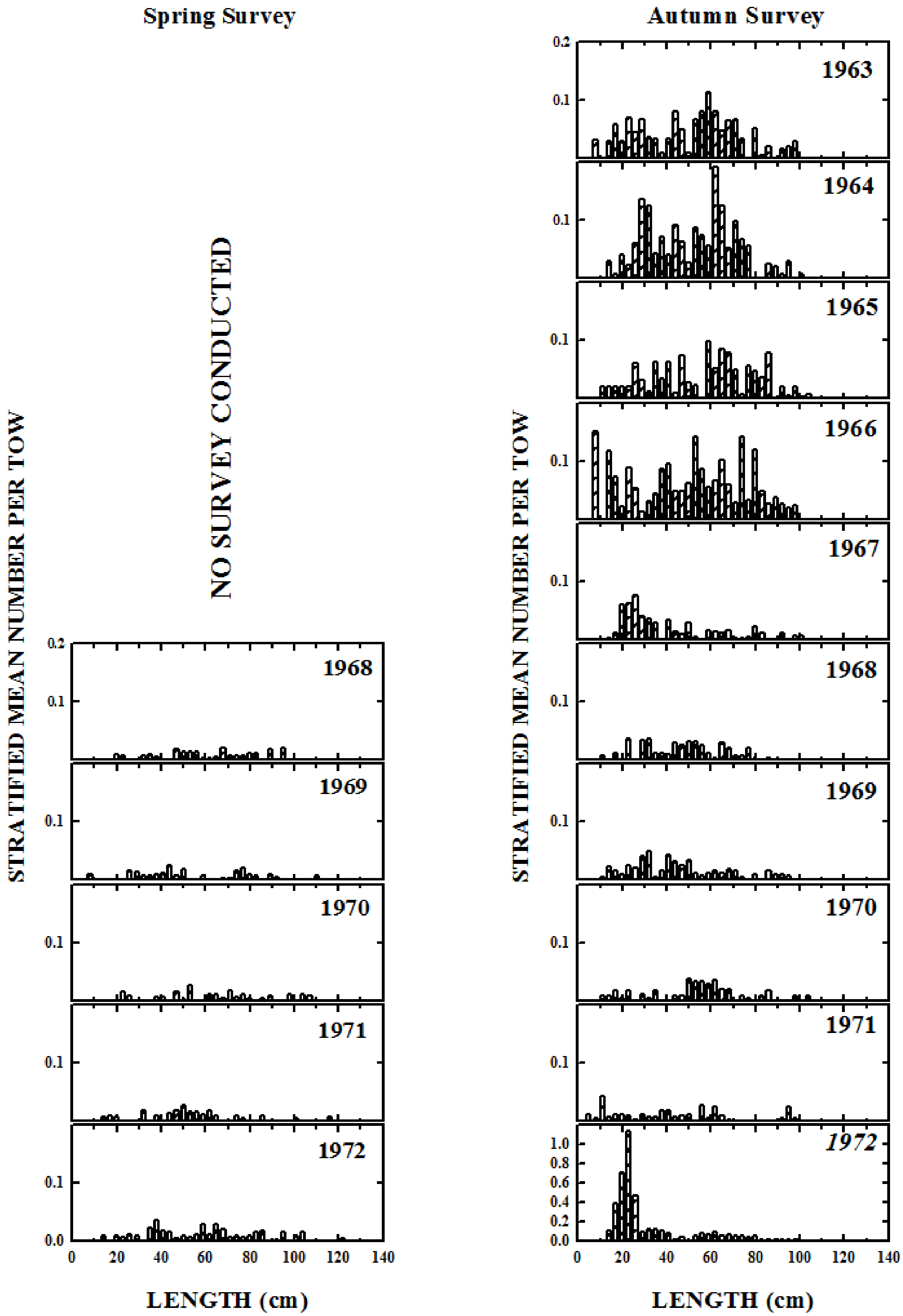


Figure 17. Goosefish length composition from the NEFSC spring bottom trawl (March-April), winter flatfish (February), summer scallop (July-August), and autumn (September-October) bottom trawl surveys in the southern management region, 1963-2009. Note: 1963-1966 sampled reduced strata set.

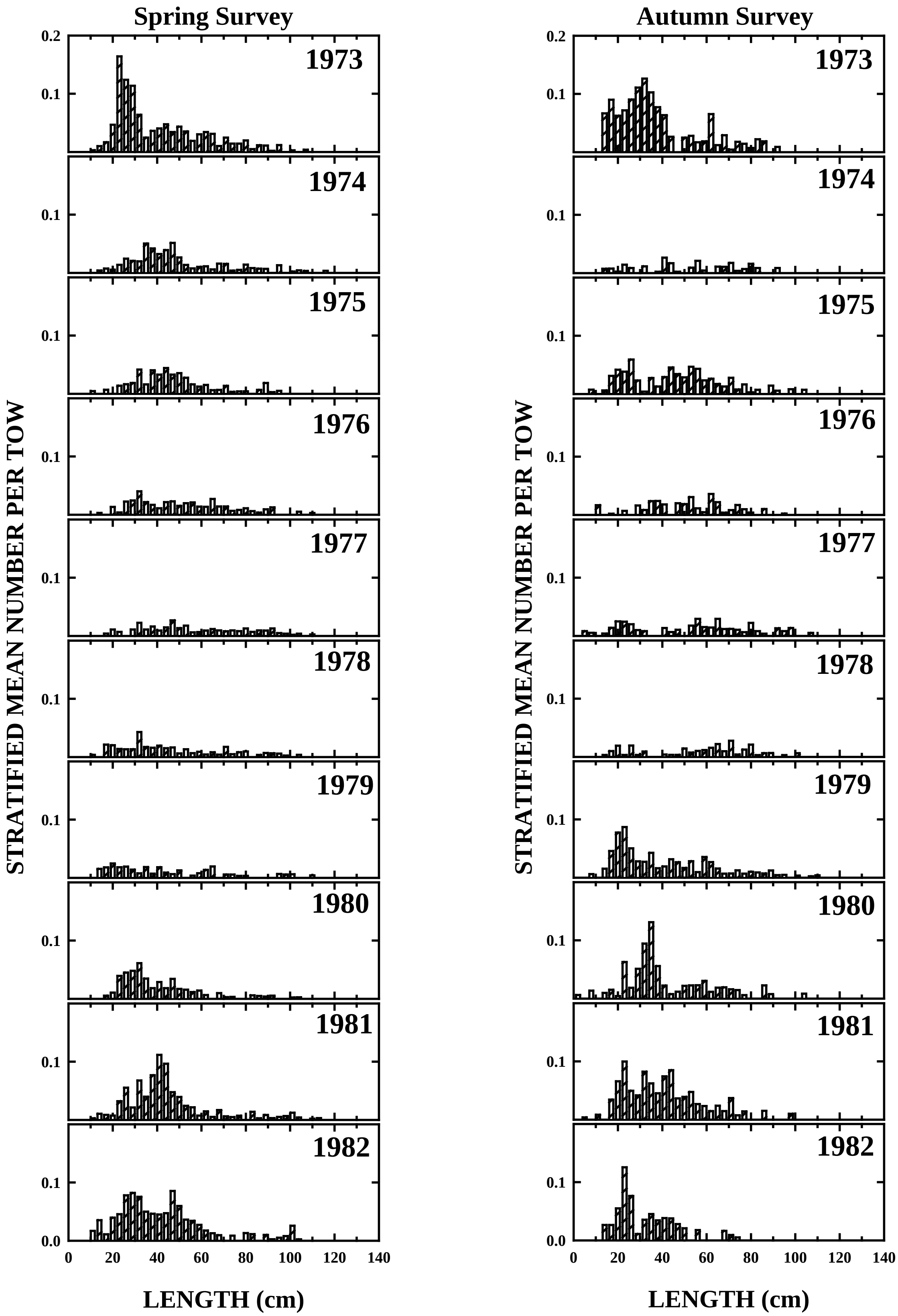


Figure 17, continued (South).

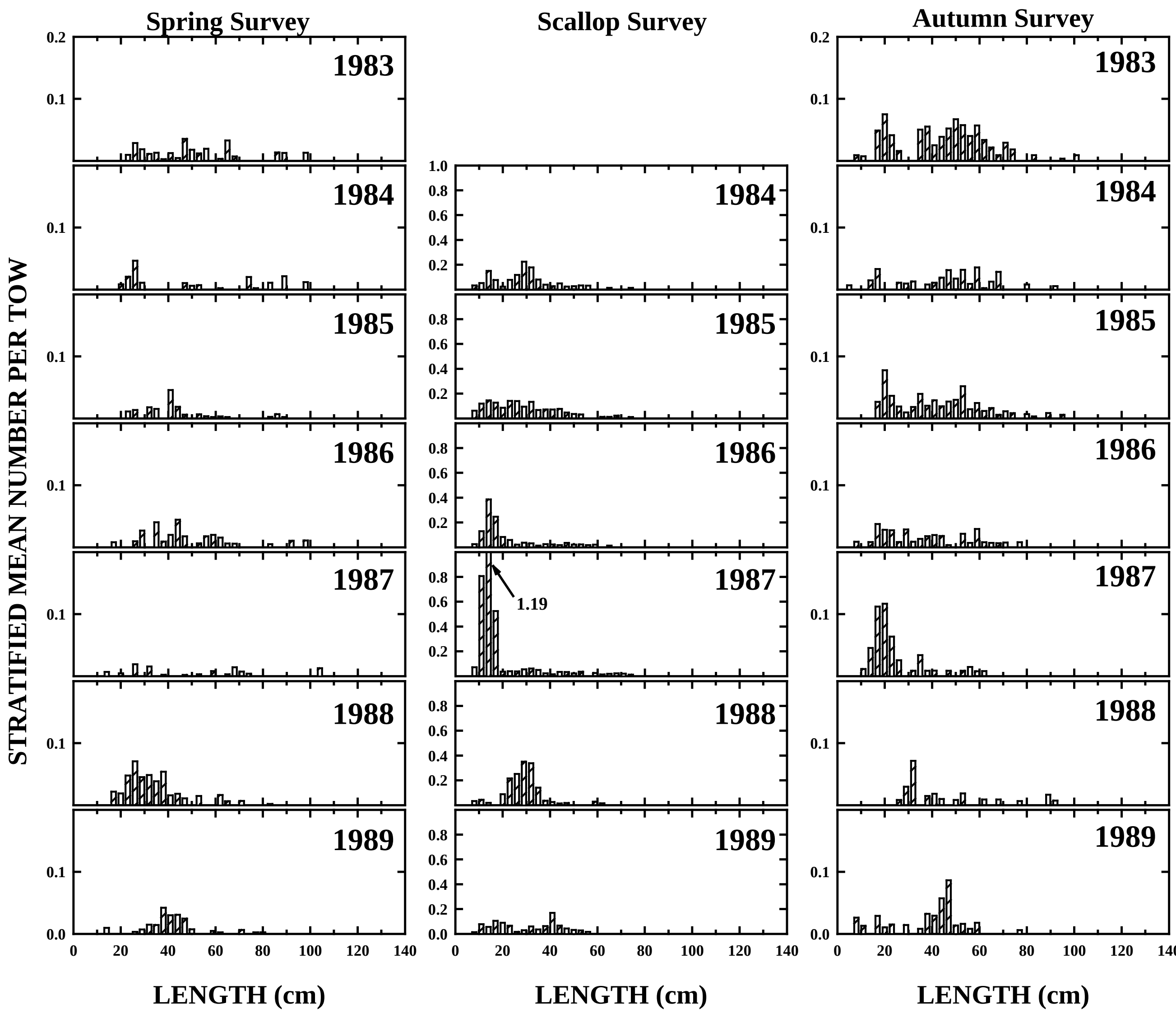


Figure 17, continued (South).

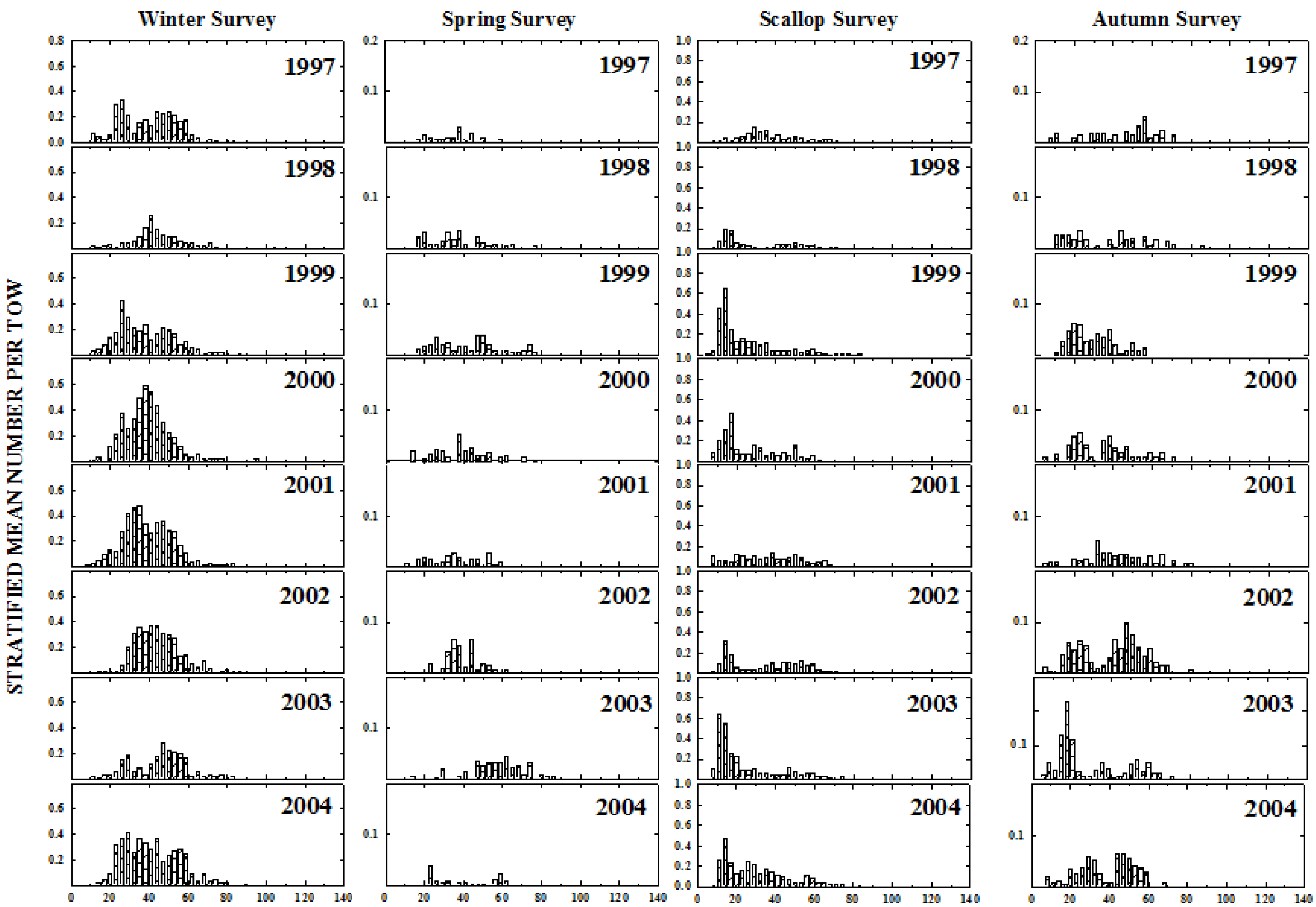


Figure 17, continued (South).

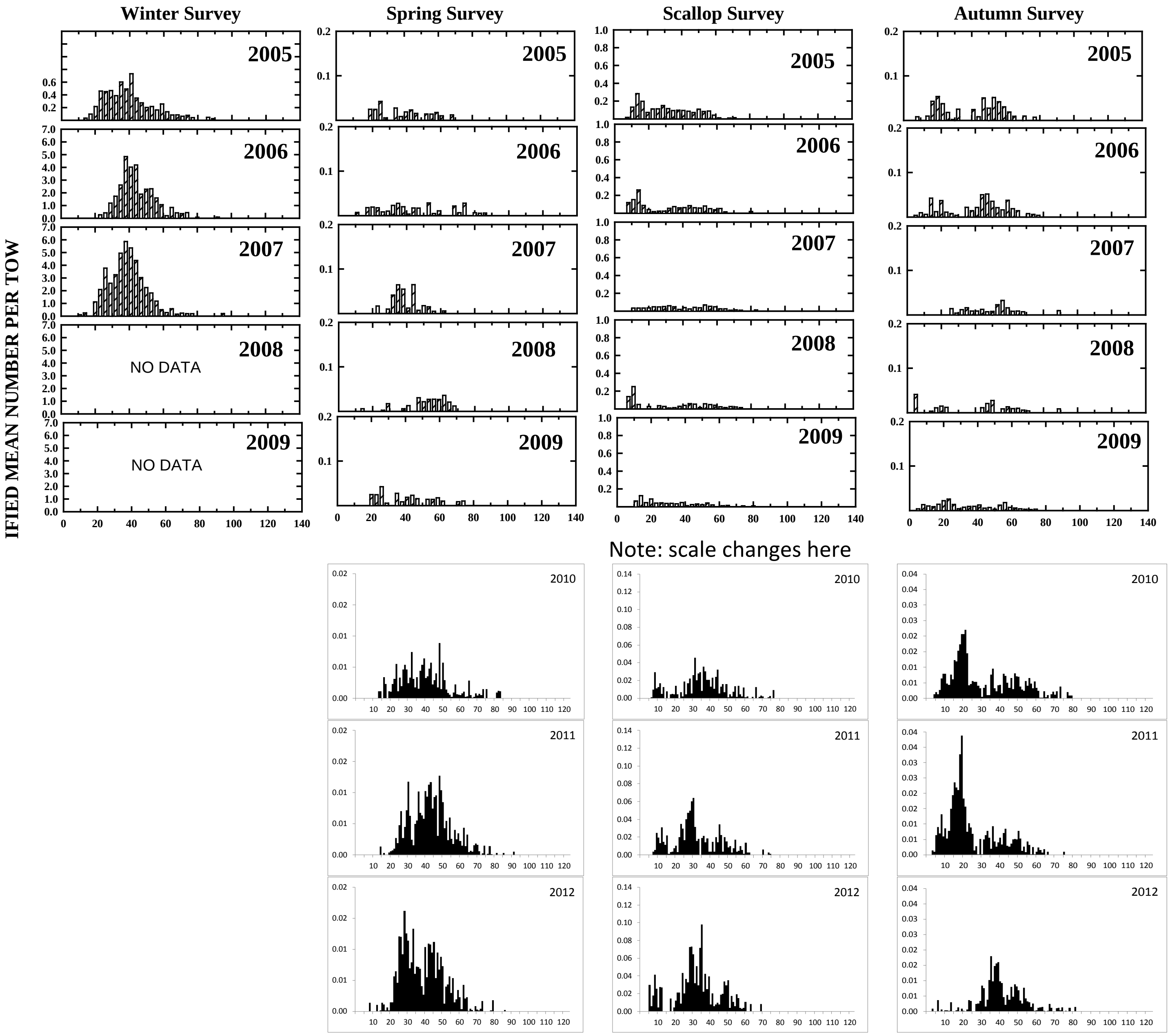


Figure 17, continued (South).

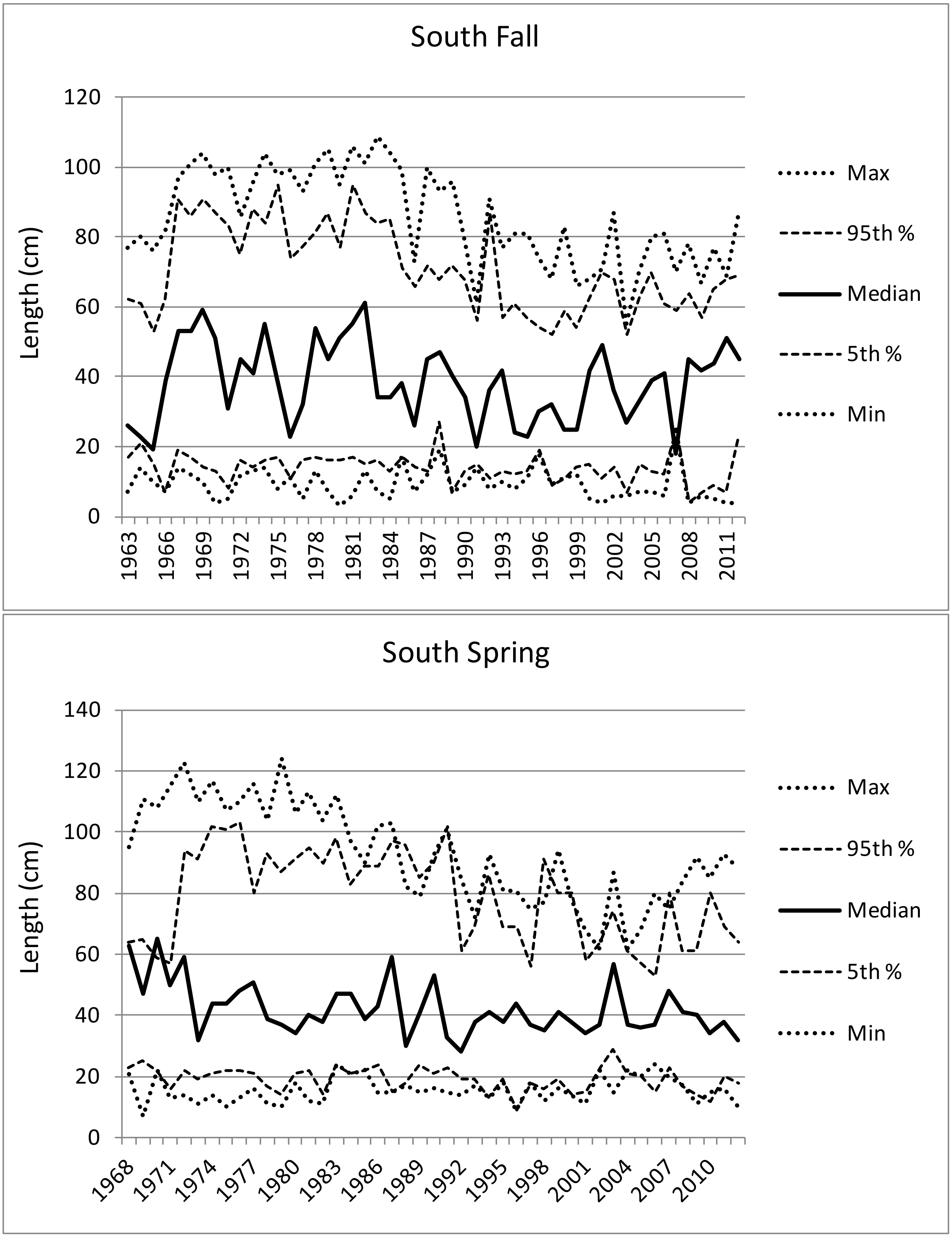


Figure 18. Length quantiles for monkfish over time from NEFSC autumn and spring surveys.

North SCALE- survey inputs

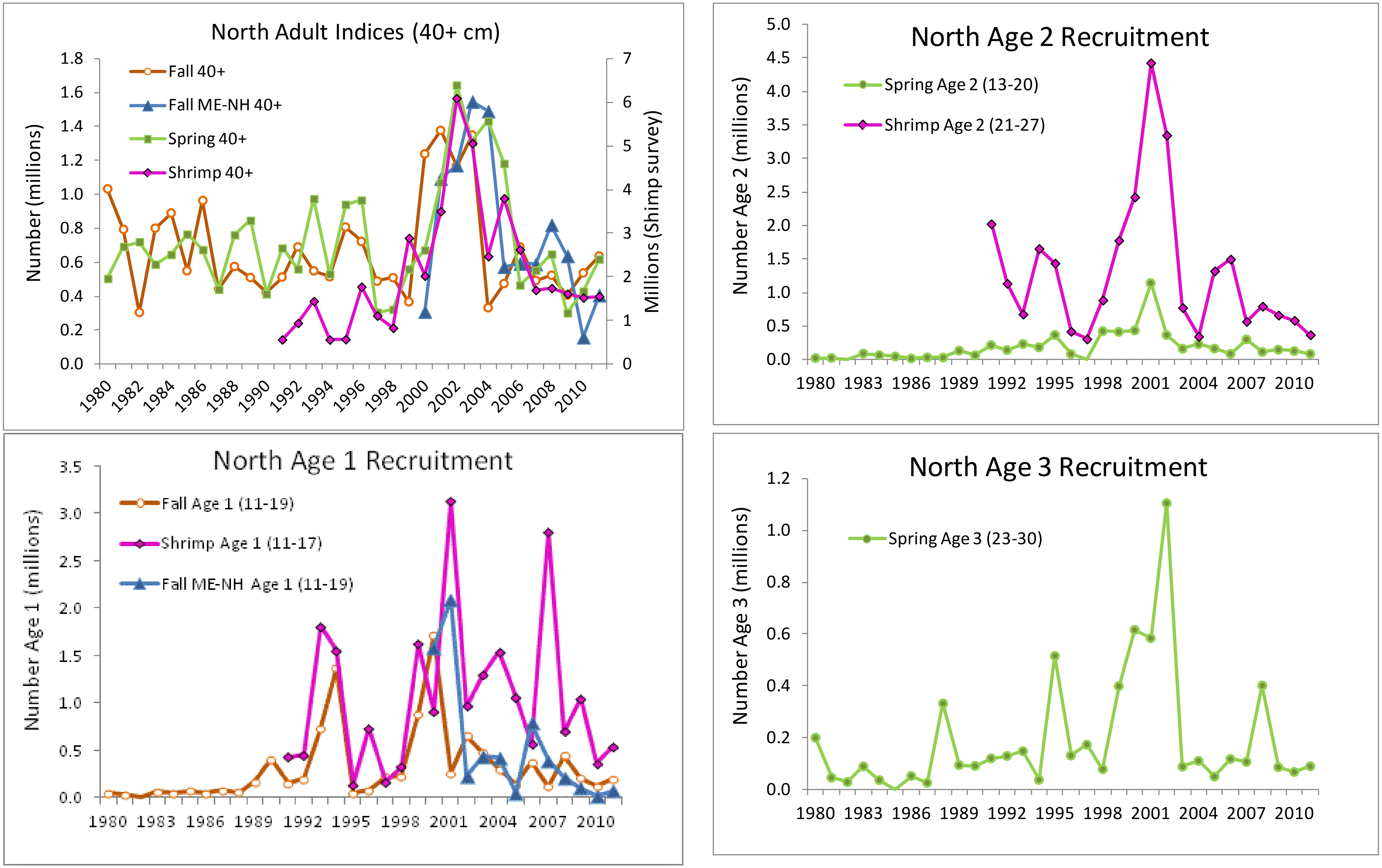


Figure 19. Survey inputs for the SCALE model for the northern management region.

South SCALE- survey inputs

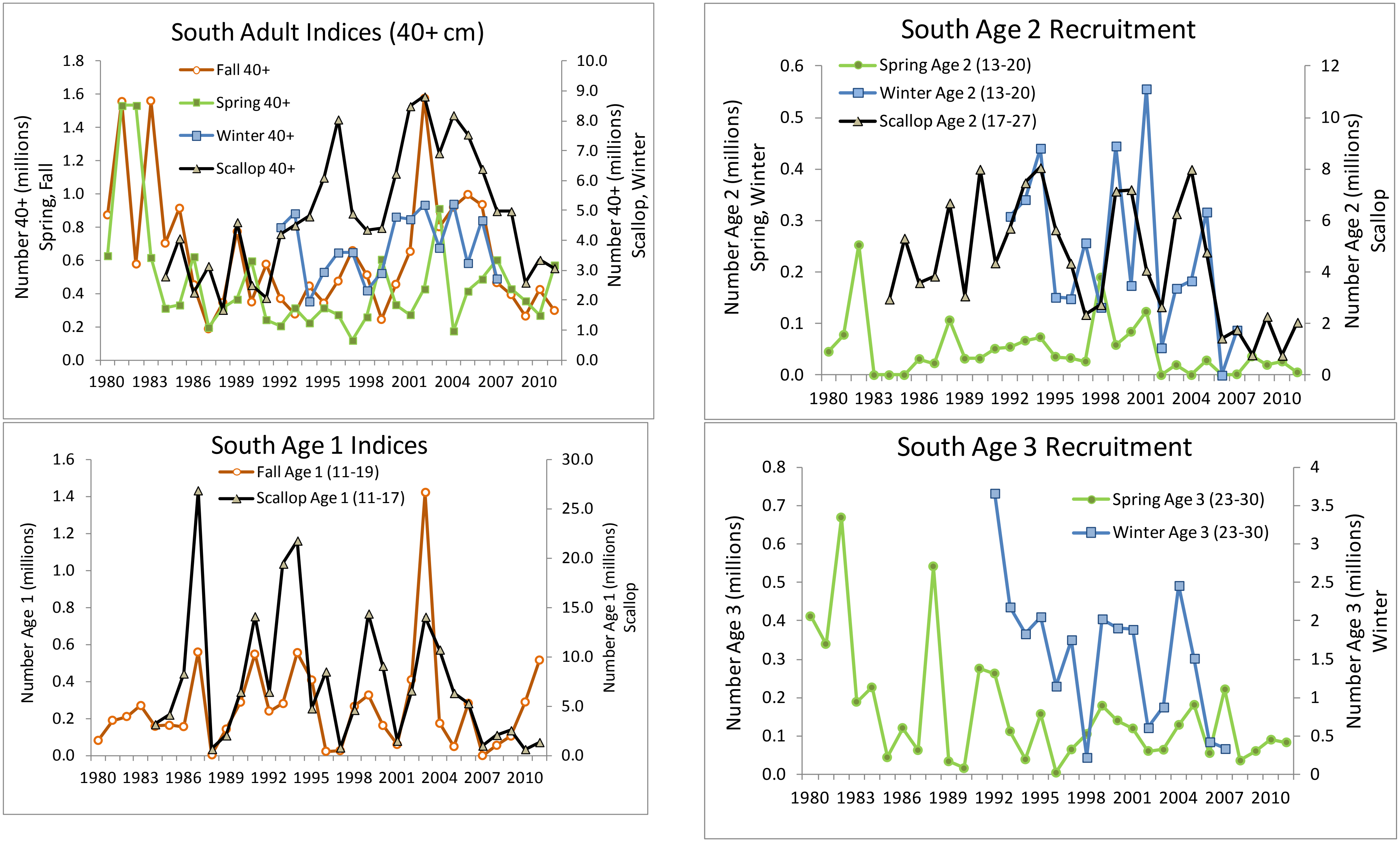


Figure 20. Survey inputs for the SCALE model for the southern management region.

North Run 1 – Revised Data, 1980-2009

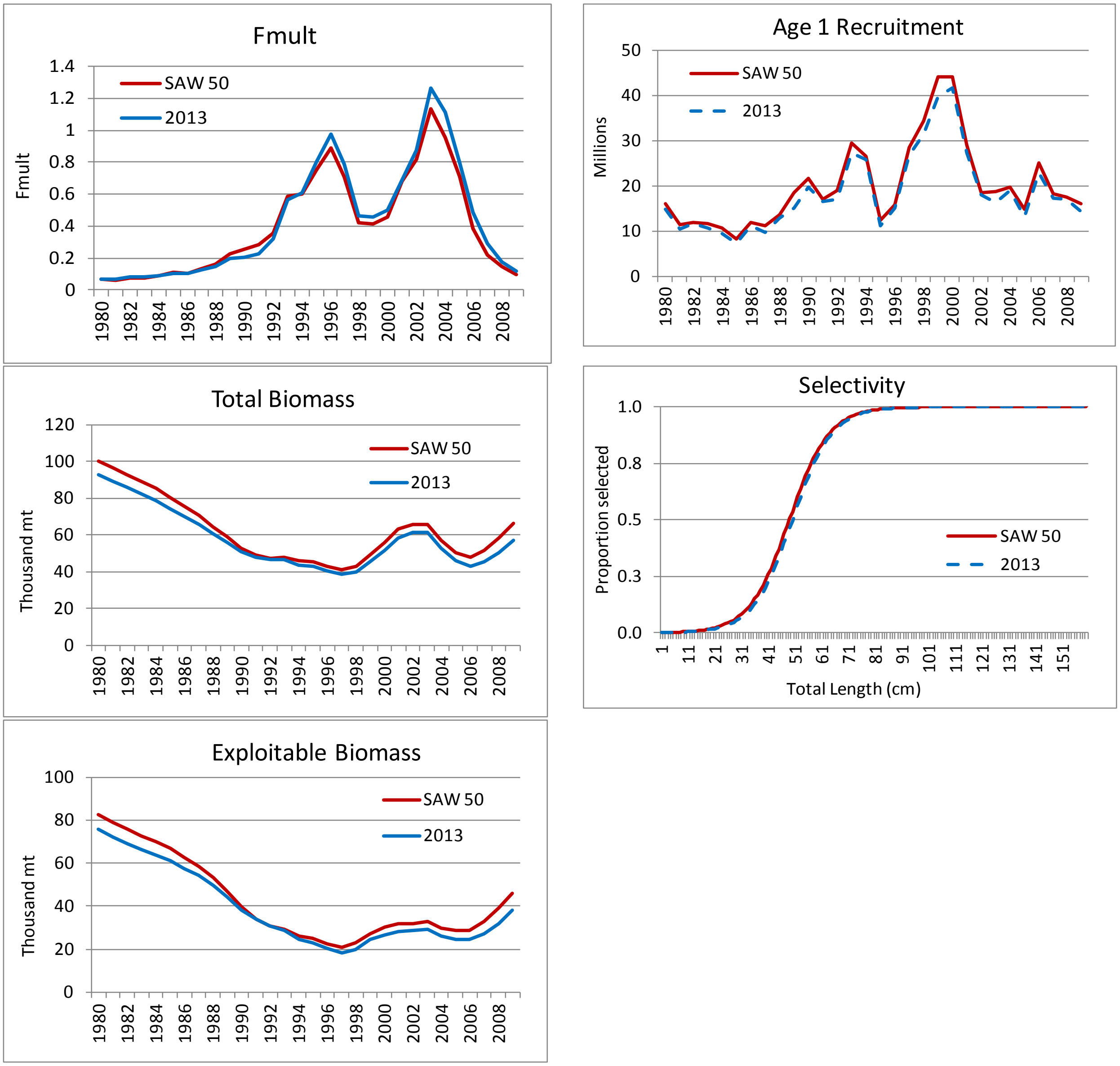


Figure 21. Comparison of SAW 50 SCALE model results for the North with results of same model using revised data for 1980-2009.

North Run 2 (Final run) – Revised + New Data (1980-2011)

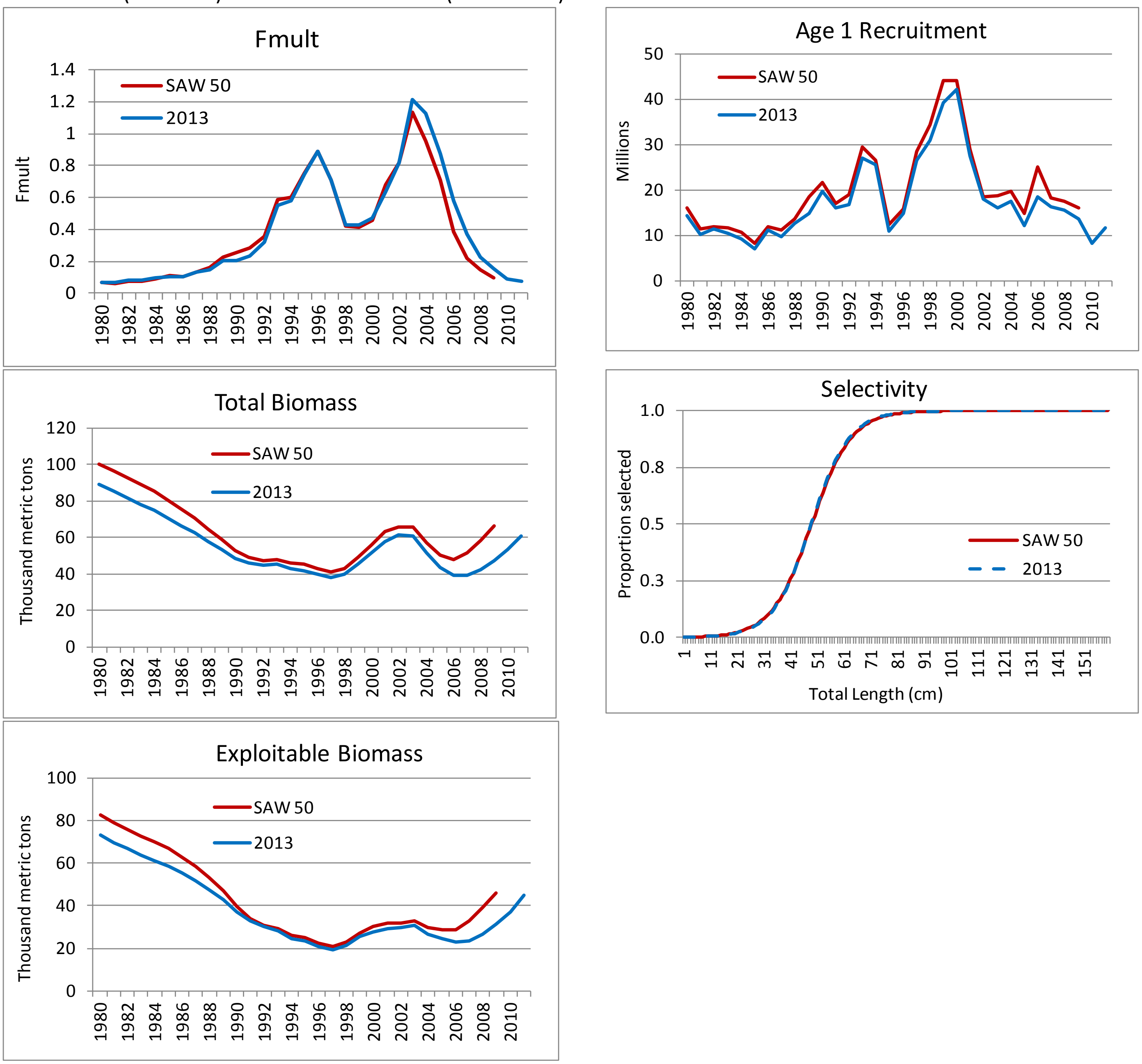


Figure 22. Comparison of SAW 50 SCALE model results for the North with results of same model using revised data (1980-2009) plus two additional years of data (2010-2011, final model for the North).

North

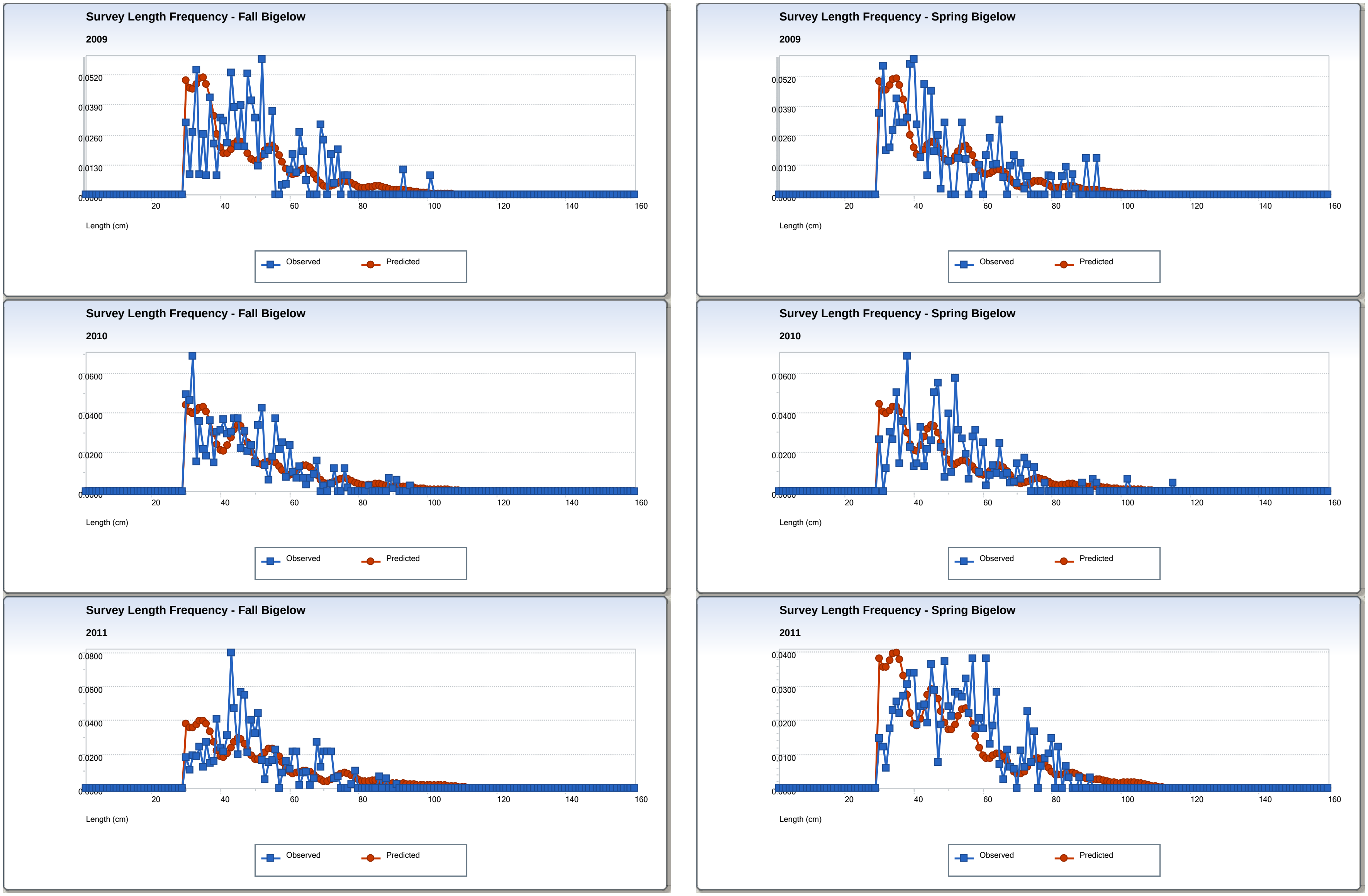


Figure 23. North SCALE final model fits to Bigelow survey length frequencies, 2009-2011.

North

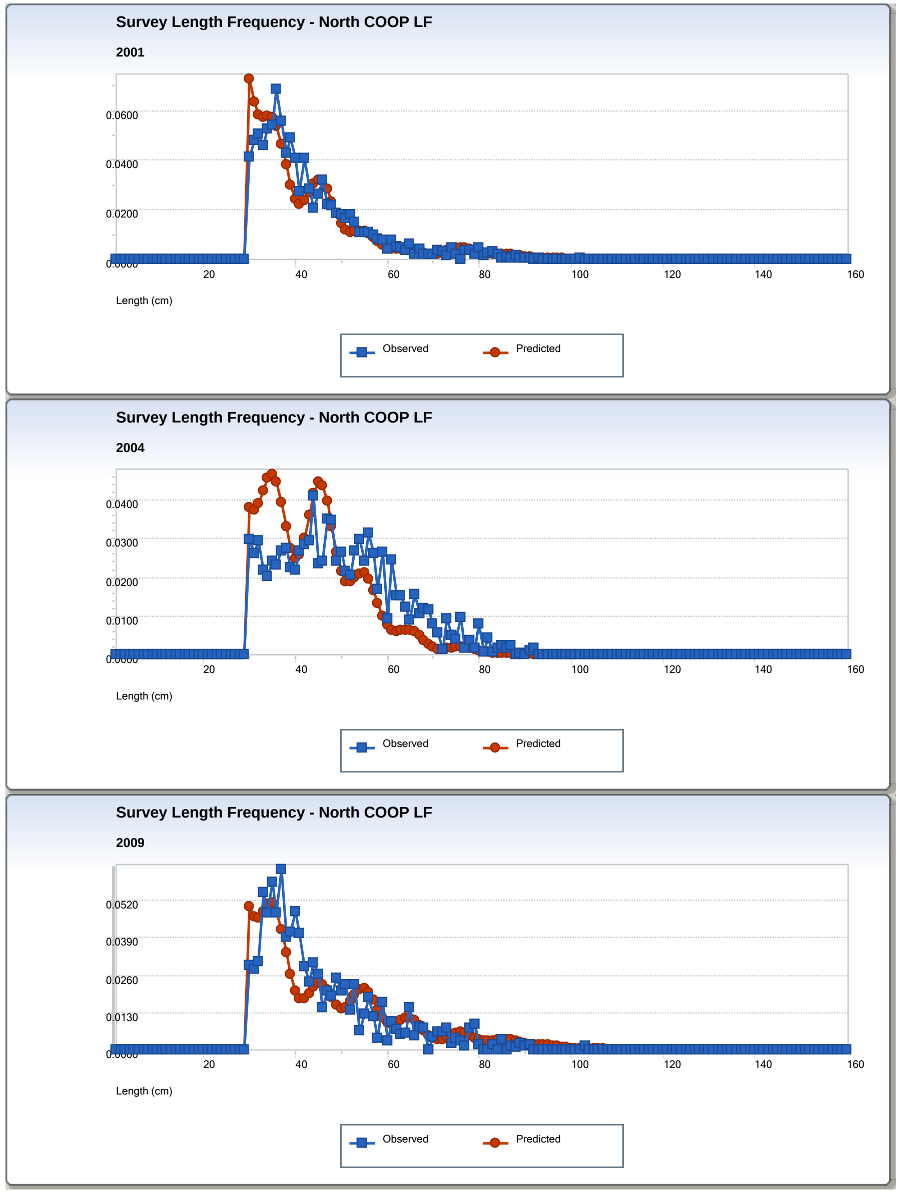


Figure 24. North SCALE model fits to Cooperative Monkfish Survey length frequencies, 2001, 2004, 2009.

North

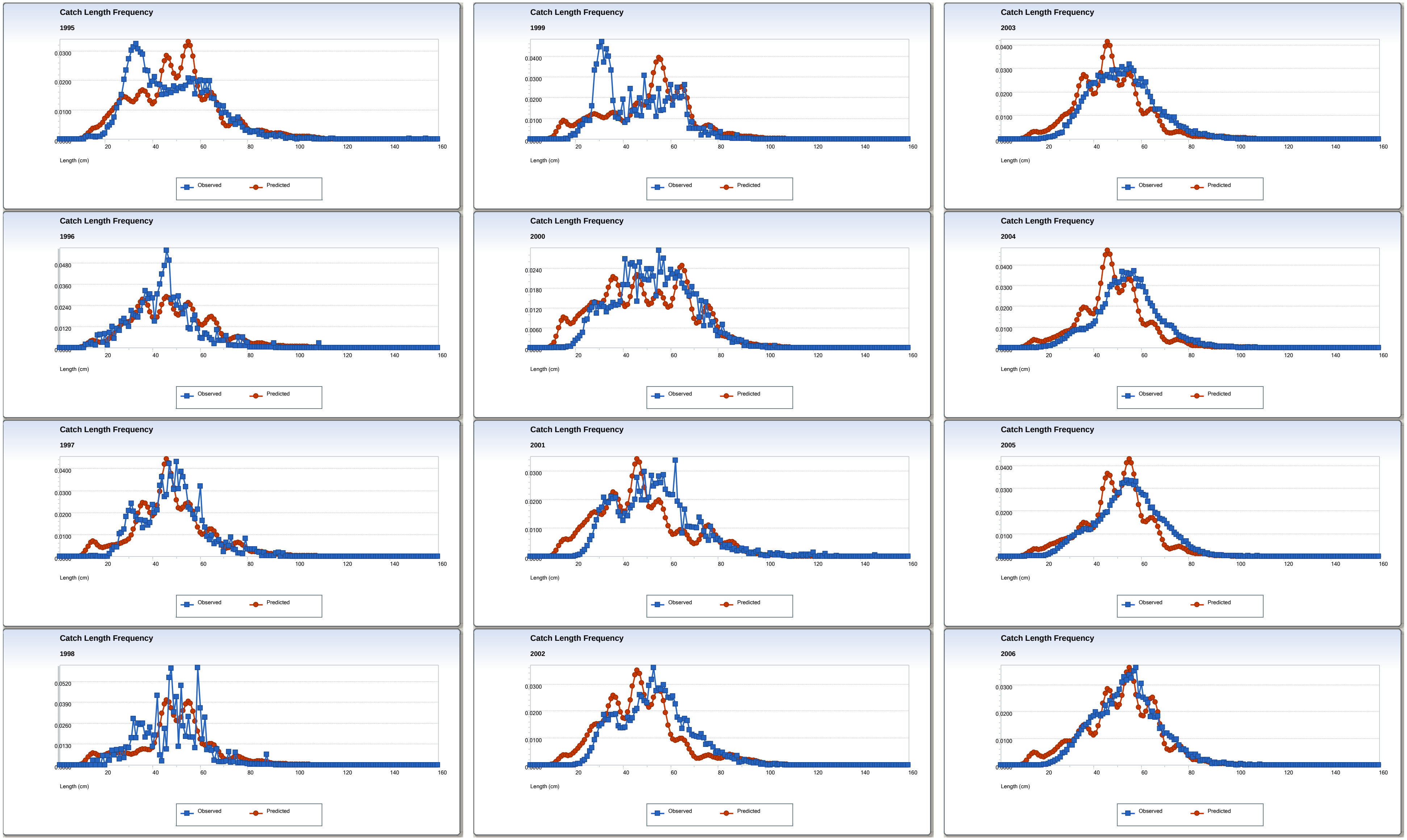


Figure 25. North SCALE model fits to catch length frequencies, 1994-2011.

North

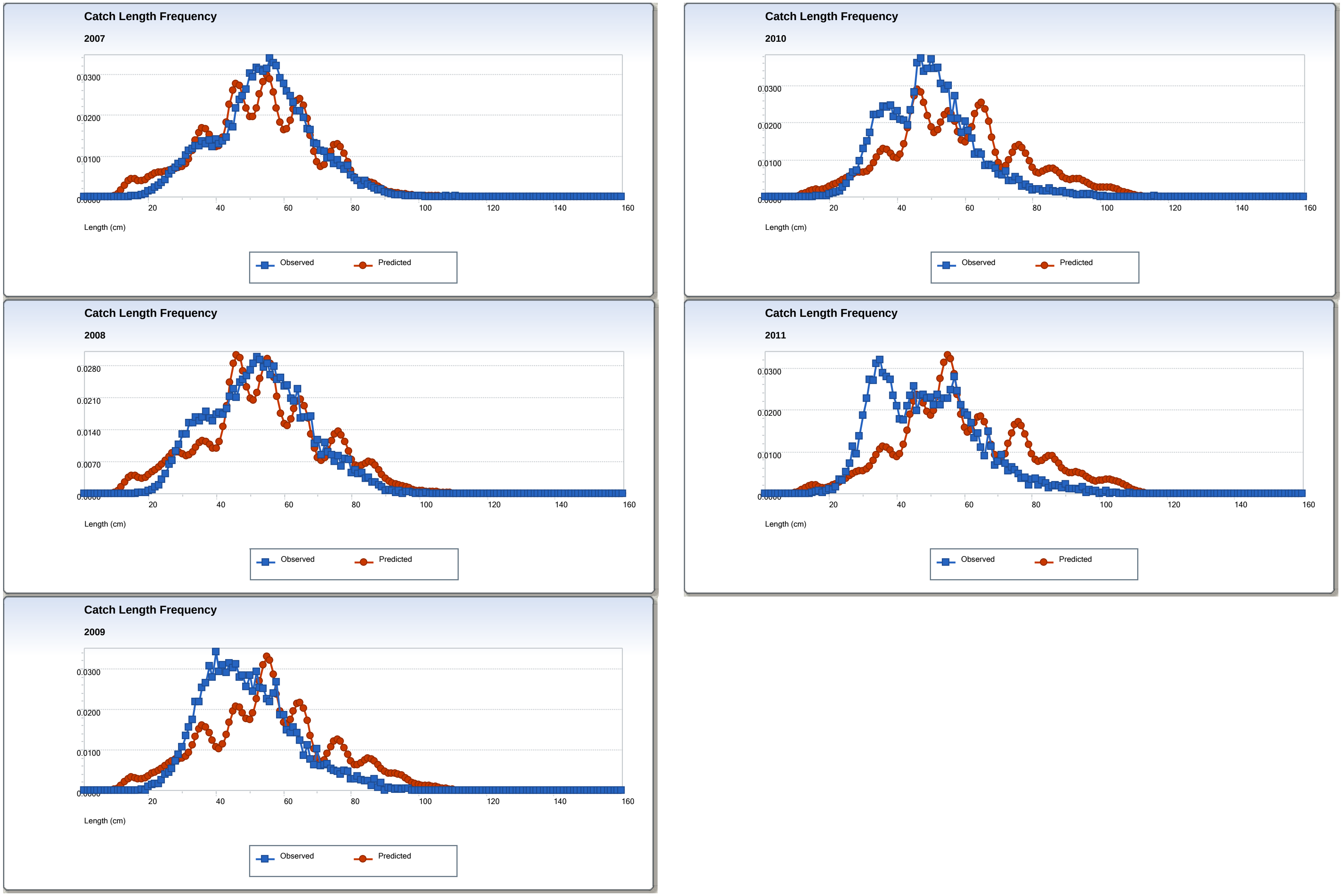


Figure 25, continued.

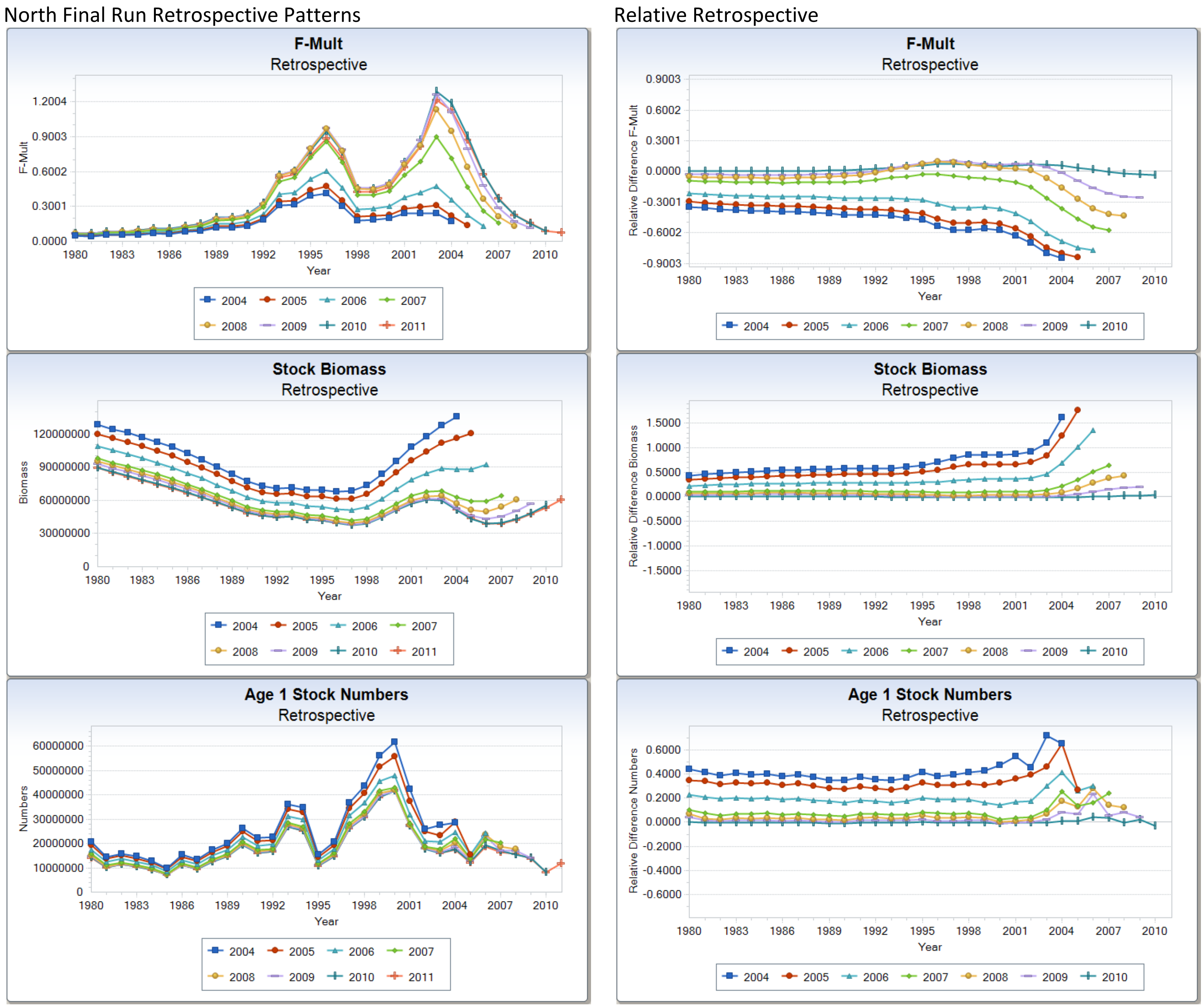


Figure 26. Retrospective patterns in final SCALE model for the north, 7 peels.

South Run 1–SAW 50 model using revised data (1980-2009)

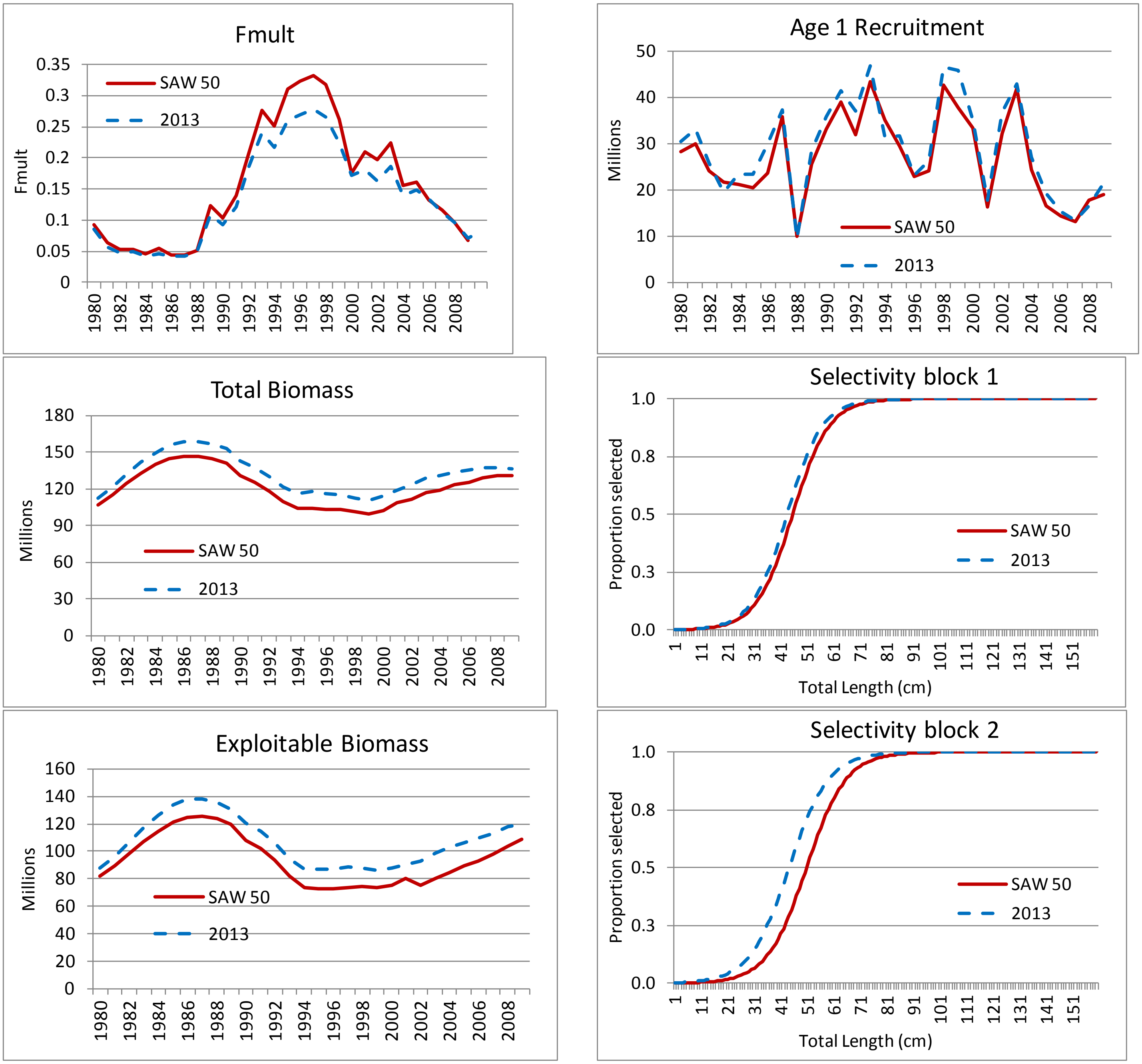


Figure 27. Comparison of SAW 50 SCALE model results for the South with results of same model using revised data for 1980-2009.

South Run 2 – Revised + New Data (1980-2011)

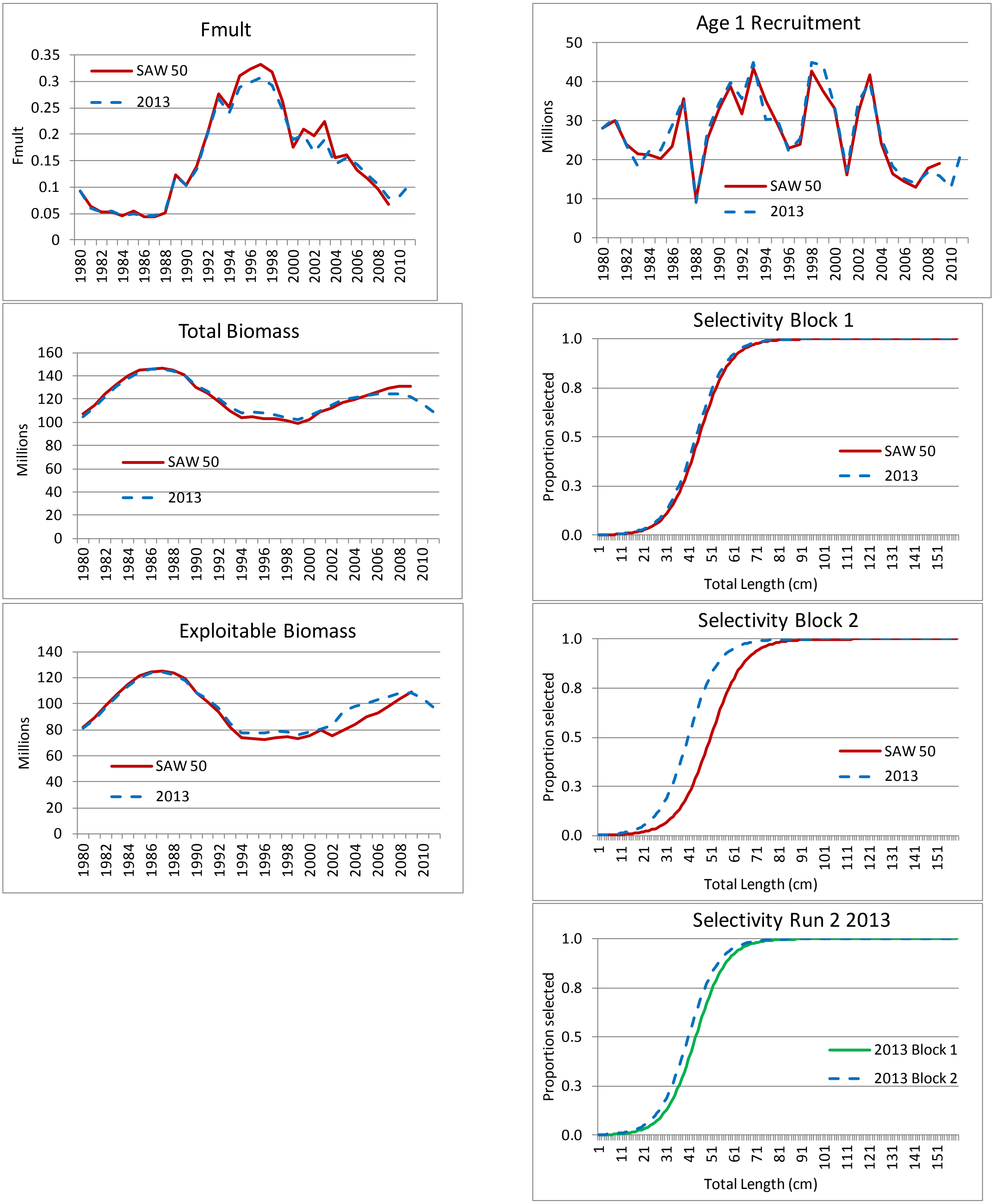


Figure 28. Comparison of SAW 50 SCALE model results for the South with results of same model using revised data (1980-2009) plus new data (2010-2011).

South Run 3 (Final) – 1 Selectivity Block, 1980-2011

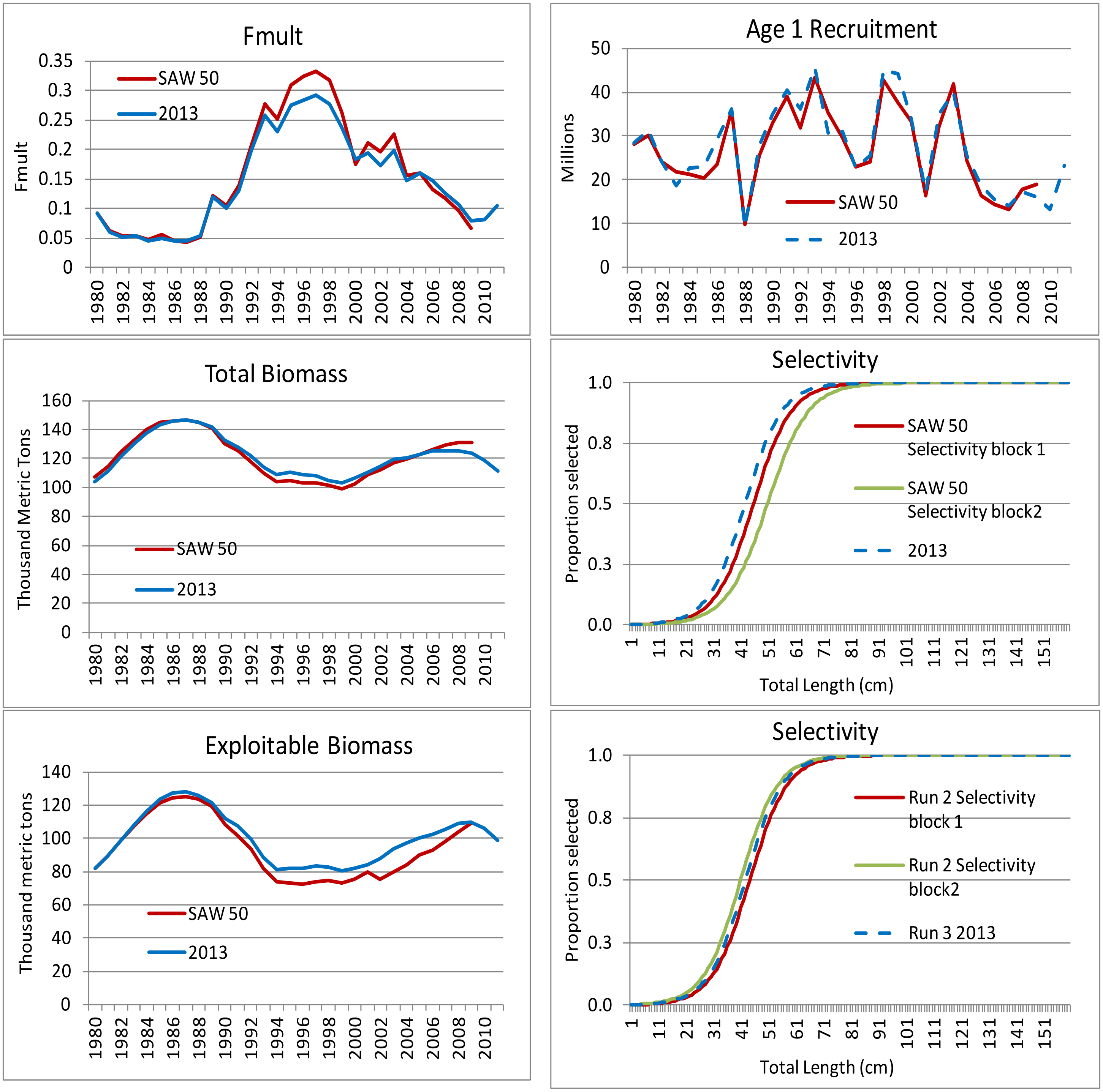


Figure 29. Comparison of SAW 50 SCALE model results for the South with results using revised data (1980-2009) plus new data (2010-2011) using only one selectivity block (final run for 2013 south).

South

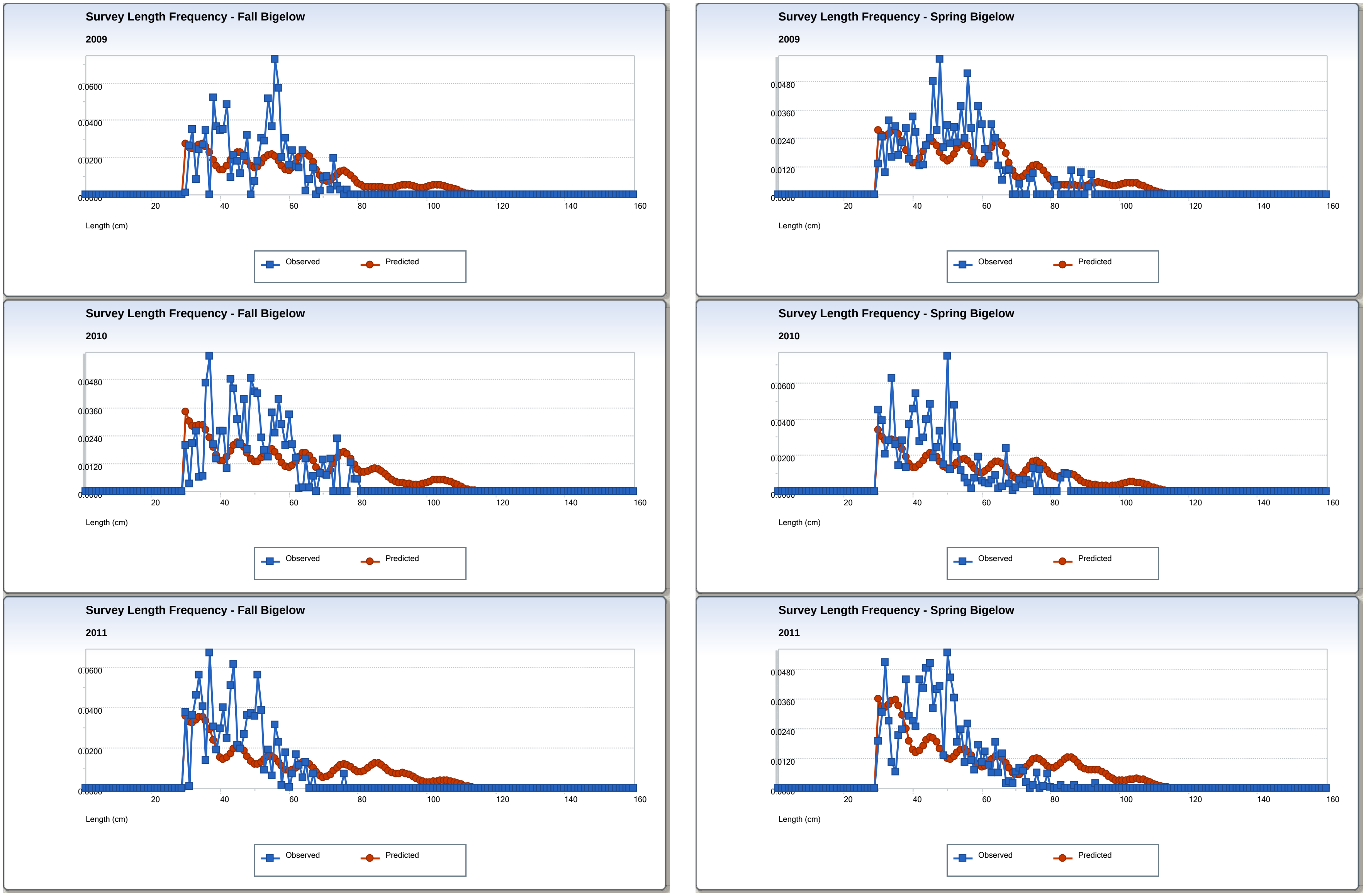


Figure 30. South SCALE final model fits to Bigelow survey length frequencies, 2009-2011

South

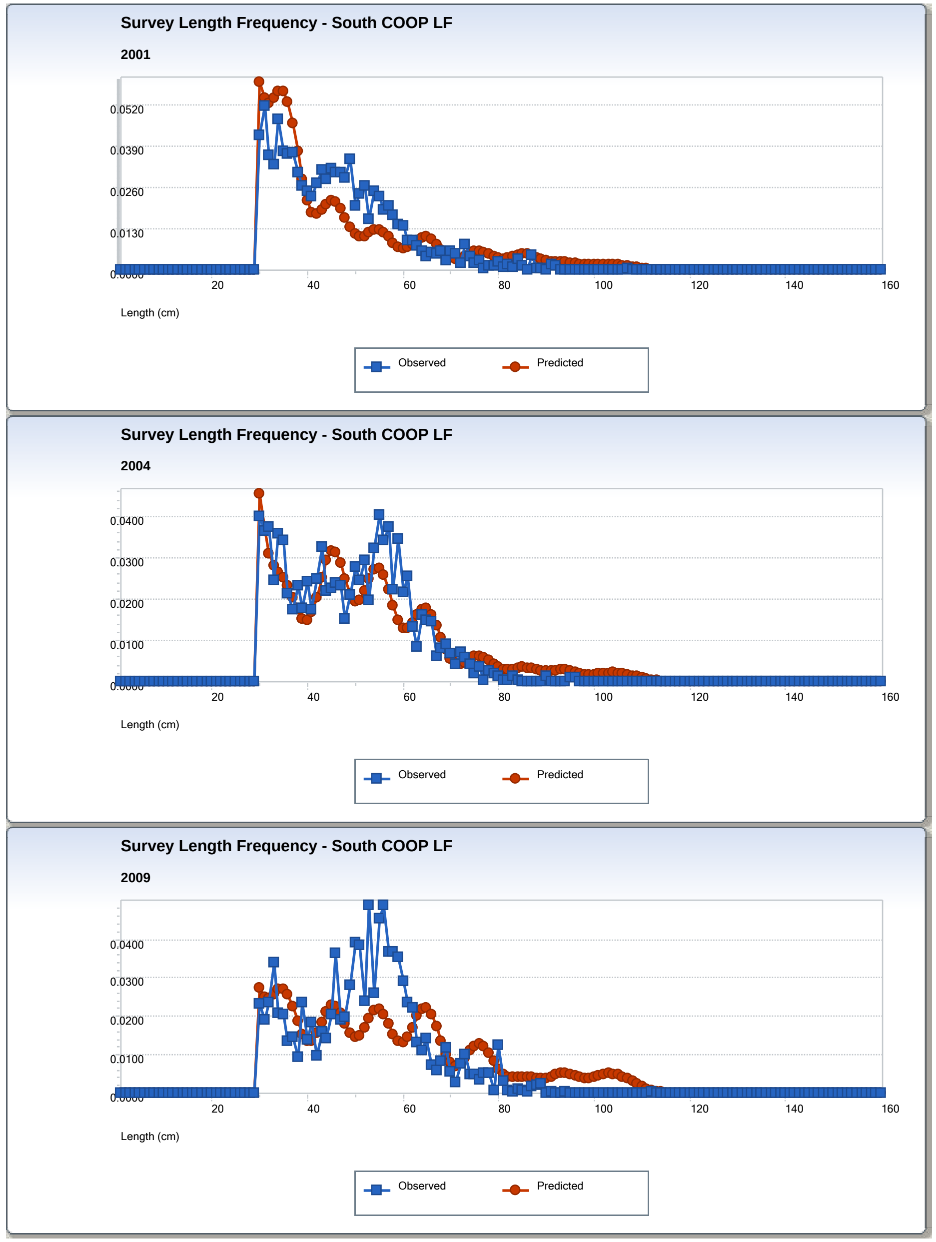


Figure 31. South SCALE model fits to Cooperative Monkfish Survey length frequencies, 2001, 2004, 2009.

South

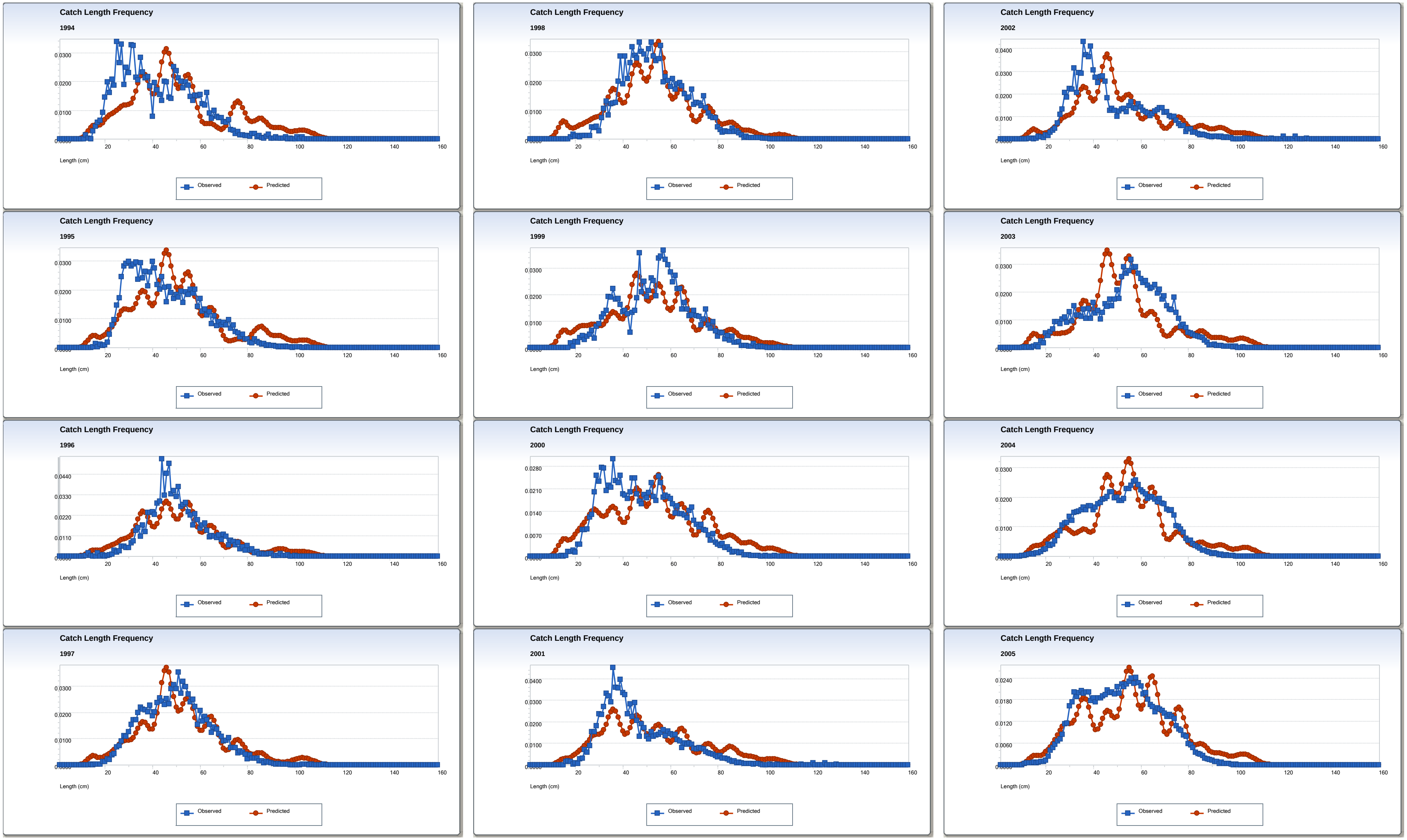


Figure 32. South SCALE final model fits to catch length frequencies, 1994-2011.

South

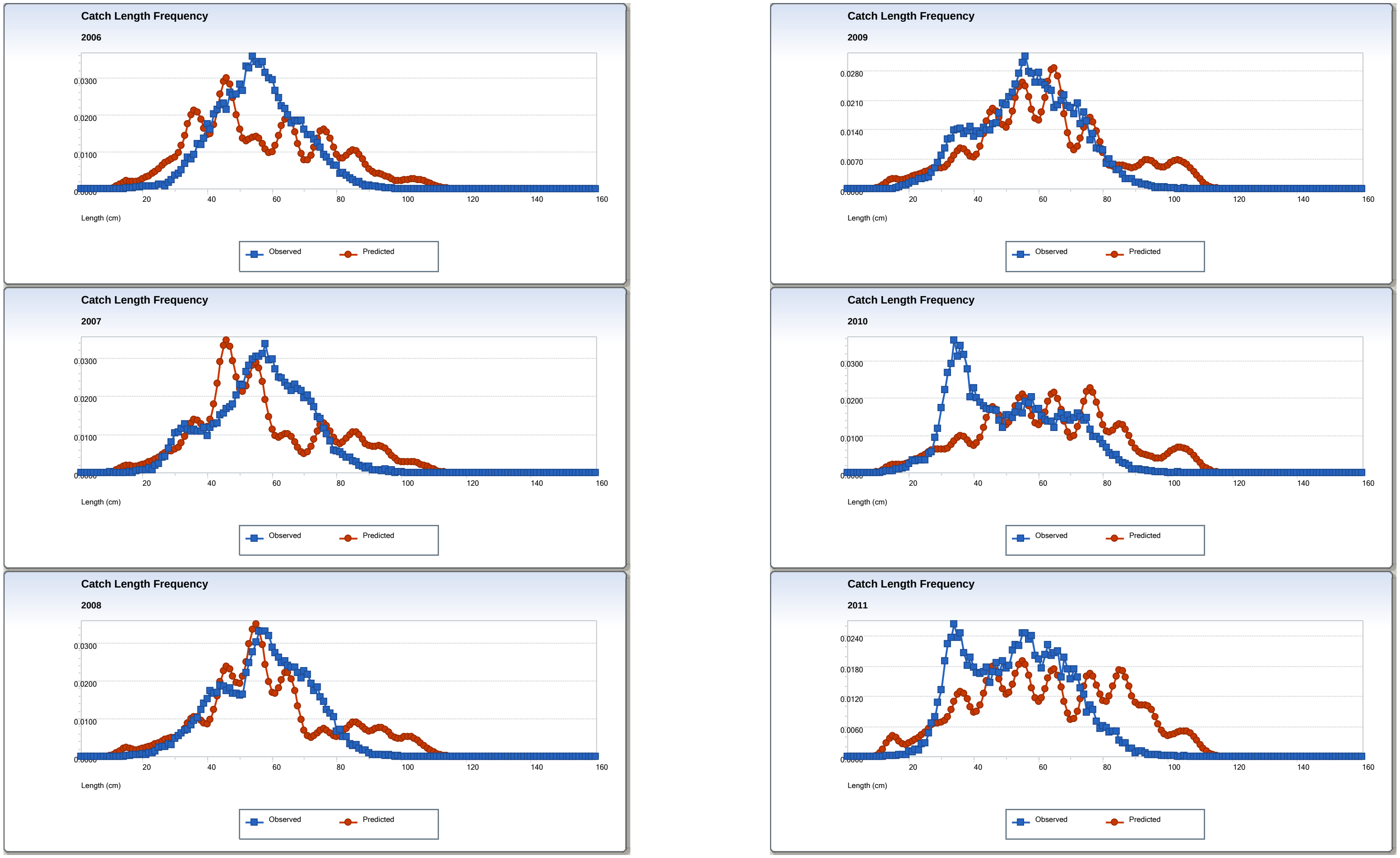
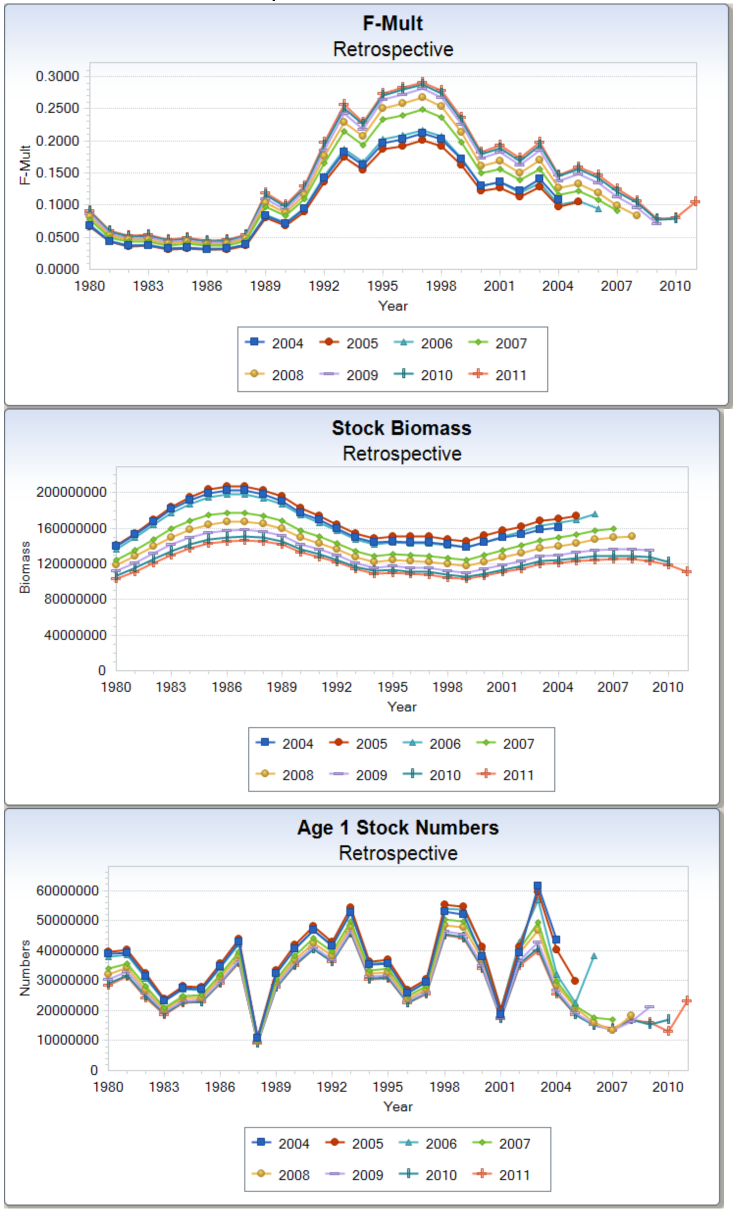


Figure 32, continued.

South Final Run Retrospective Patterns



Relative Retrospective

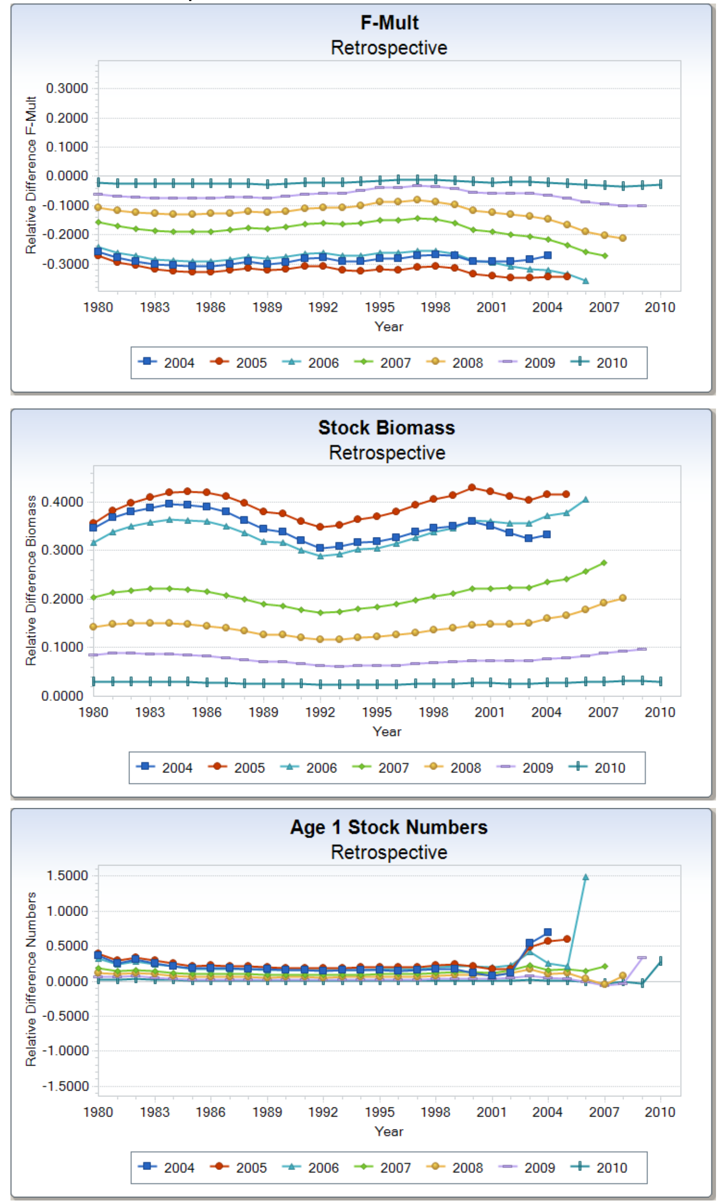


Figure 33. Retrospective patterns in the final SCALE model for the south, 7 peels.

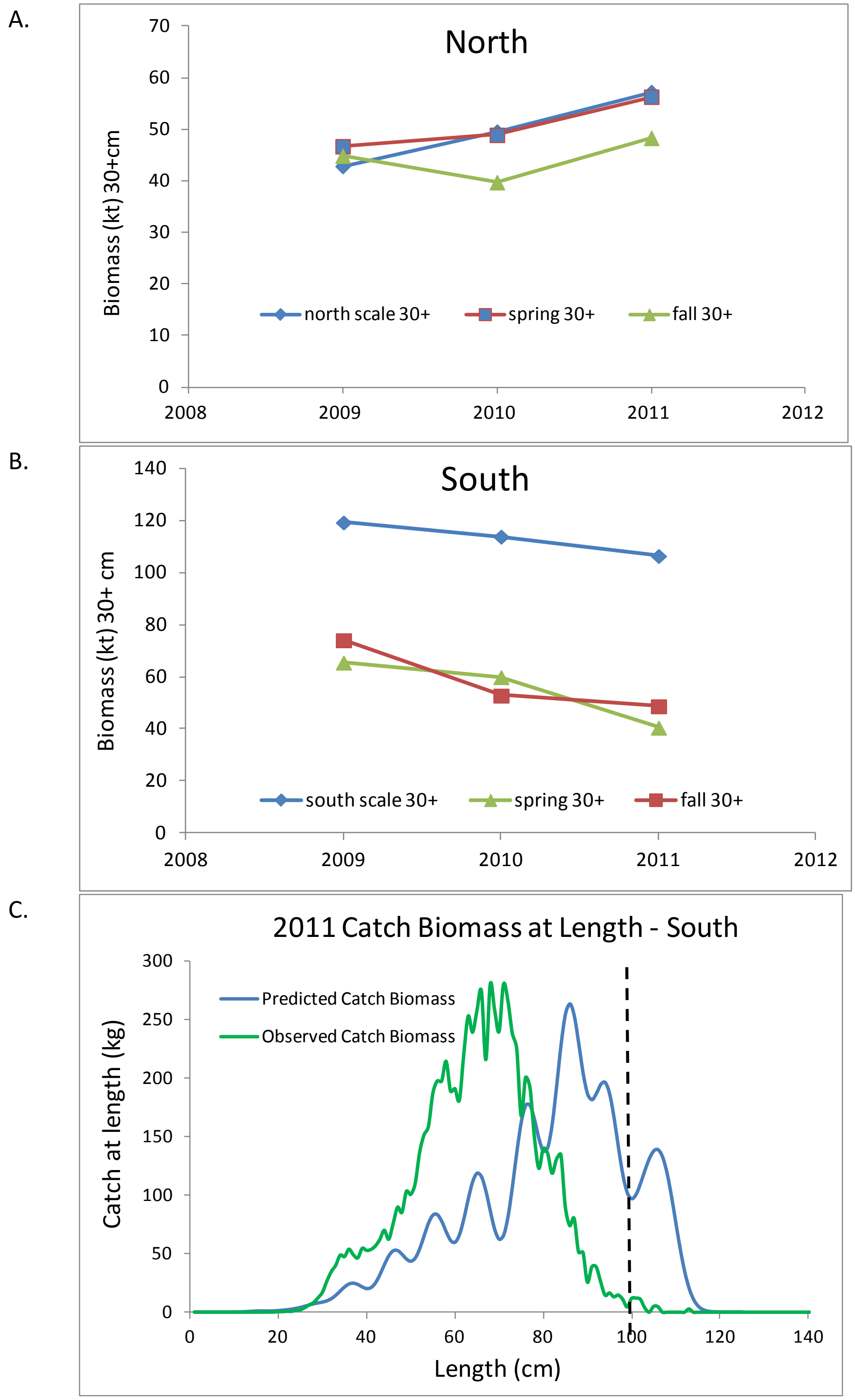


Figure 34. Estimates of total biomass at length (from converting SCALE output numbers at length (30+ cm) to biomass) compared with biomass at length estimated from length composition from NEFSC surveys applied to the estimated total number (30+) from SCALE and converted to biomass (A, B). (C) similar analysis comparing predicted and observed catch weight by length for 2011 in the southern management region. Vertical line indicates approximate maximum size in observed catch

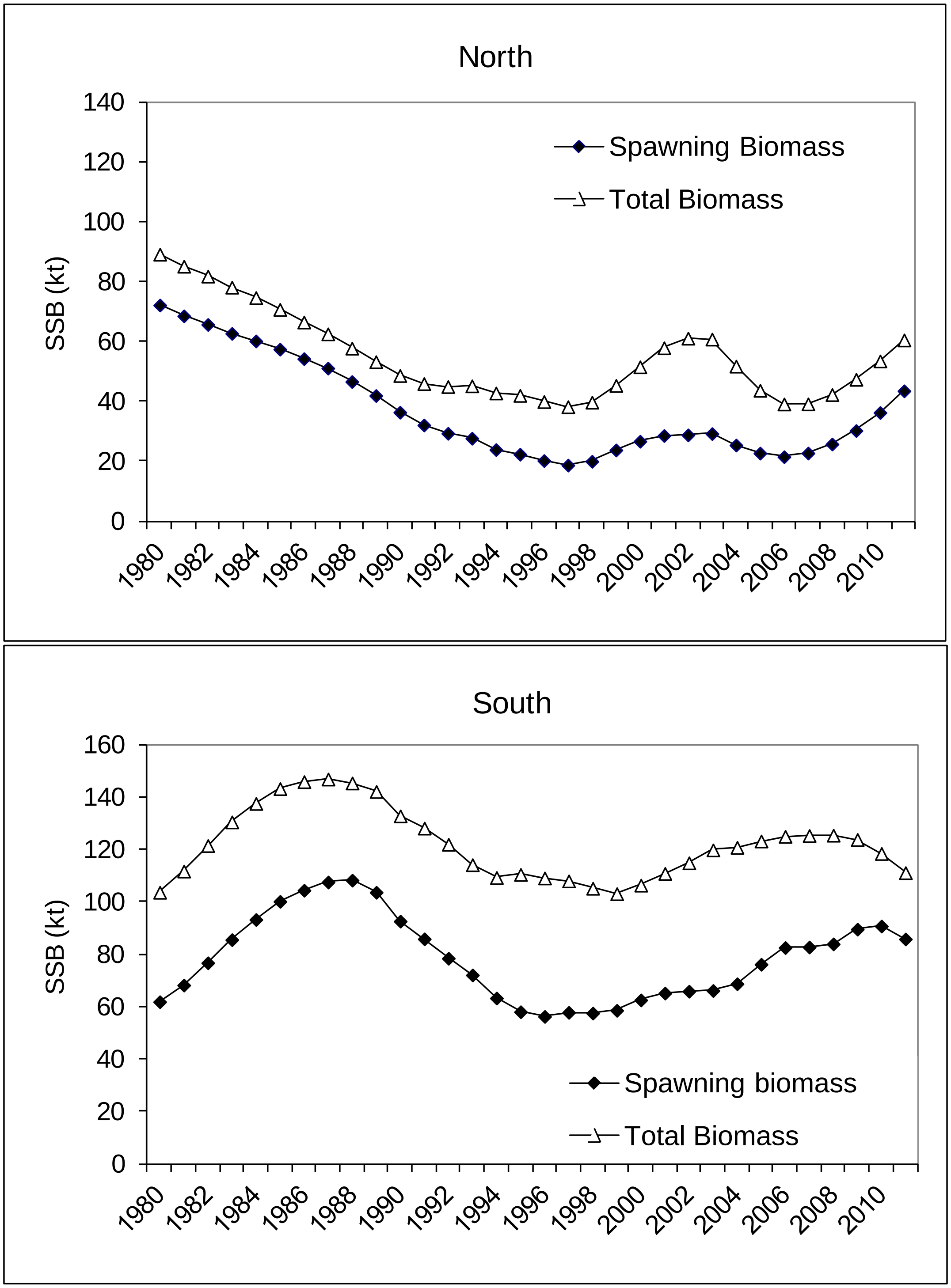
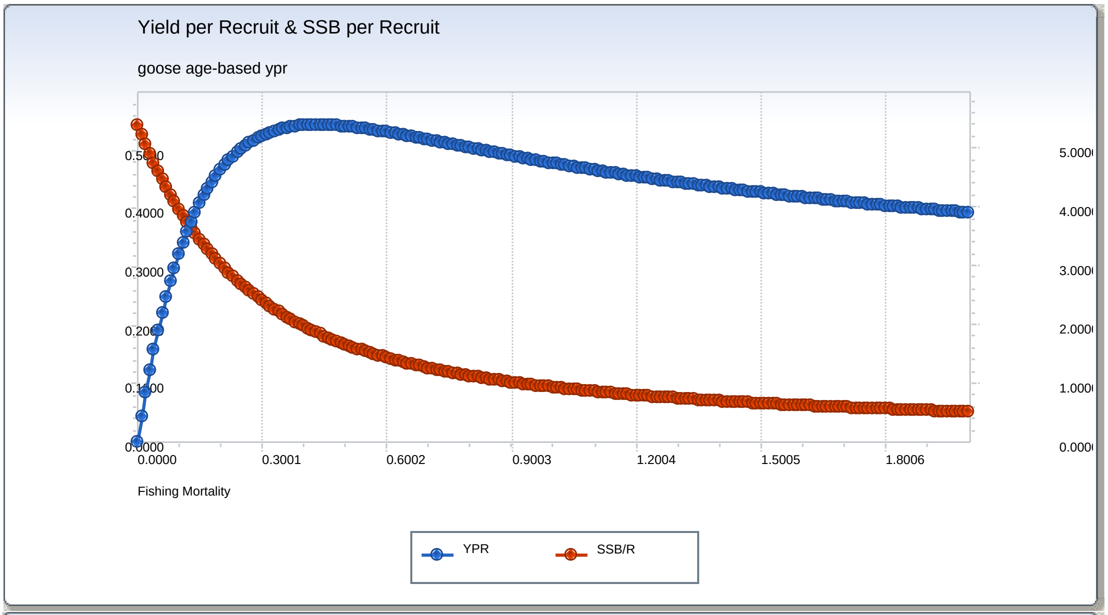


Figure 35. Trends in spawning stock biomass estimated from SCALE output of numbers at length as described in the text.

North



South

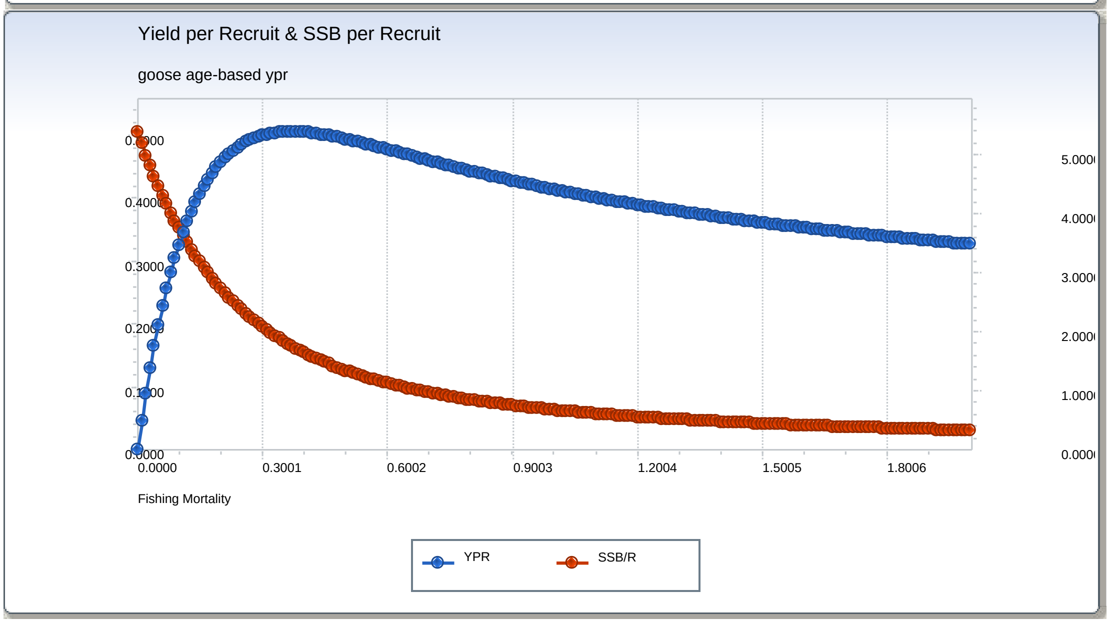


Figure 36. Yield per recruit and spawning stock biomass per recruit curves using selectivity patterns from 2013 SCALE models for north (top) and south (bottom).

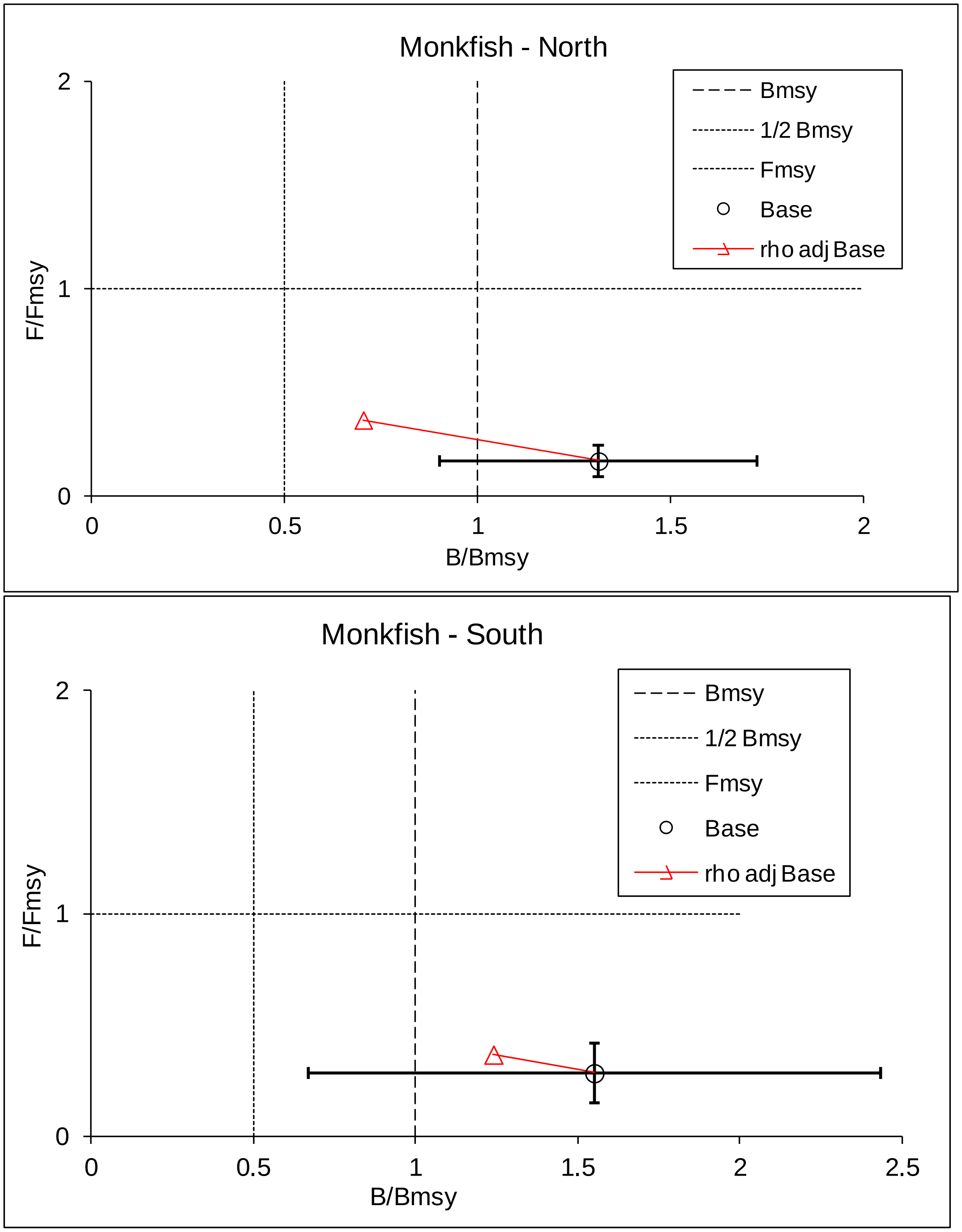


Figure 37. Current stock status evaluation for monkfish in the northern and southern management areas. Error bars are +/- 1 standard error, biomass standard error is weighted mean coefficient of variation of predicted numbers at age converted to biomass (weighting factor).

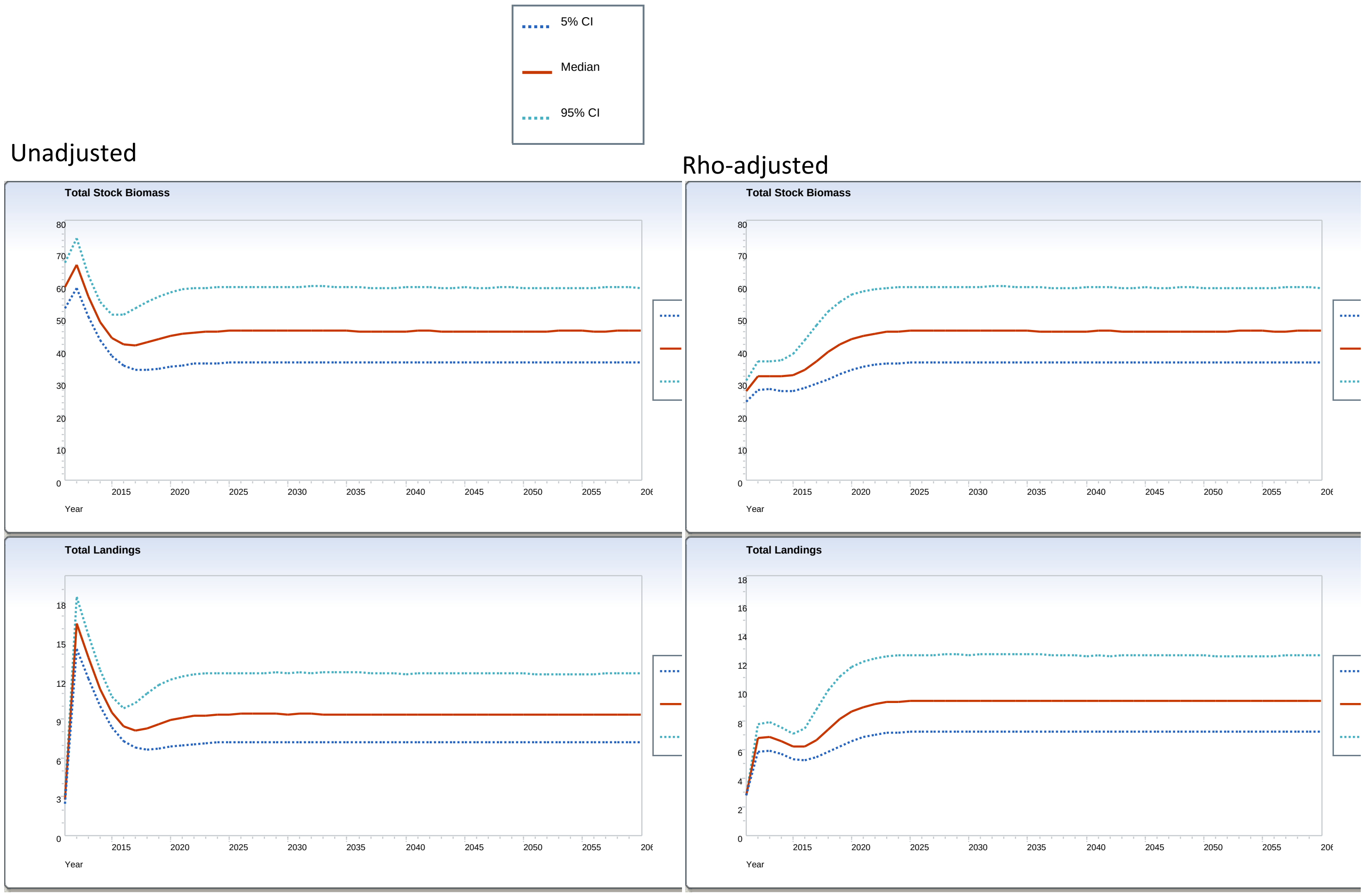


Figure 38. Northern management area projected total biomass (top) and catch (bottom) under the Fmax scenario, unadjusted (left) and adjusted for age-specific retrospective patterns (right).

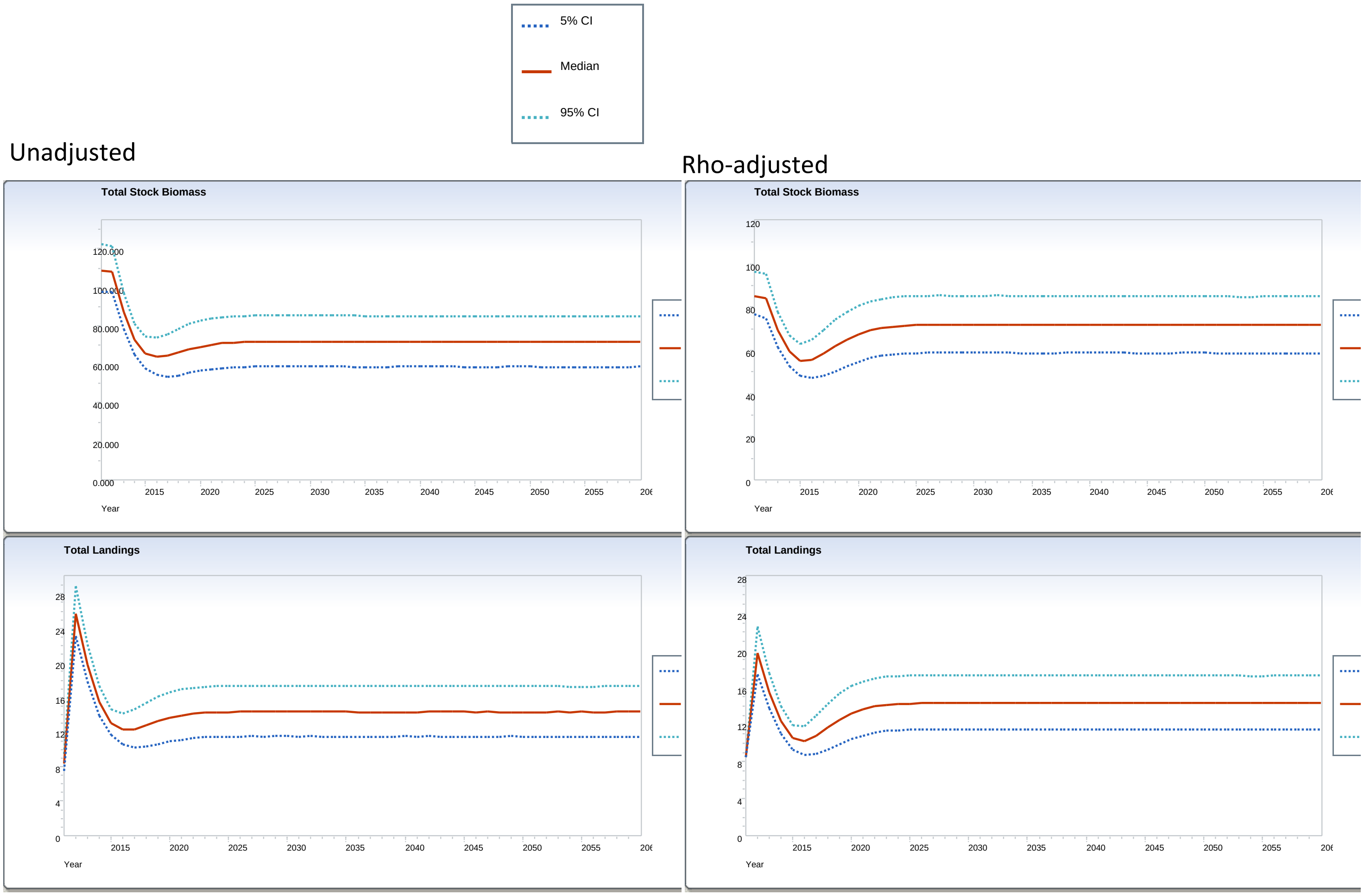


Figure 39. Southern management area projected total biomass (top) and catch (bottom) under the Fmax scenario, unadjusted (left) and adjusted for age-specific retrospective patterns (right).

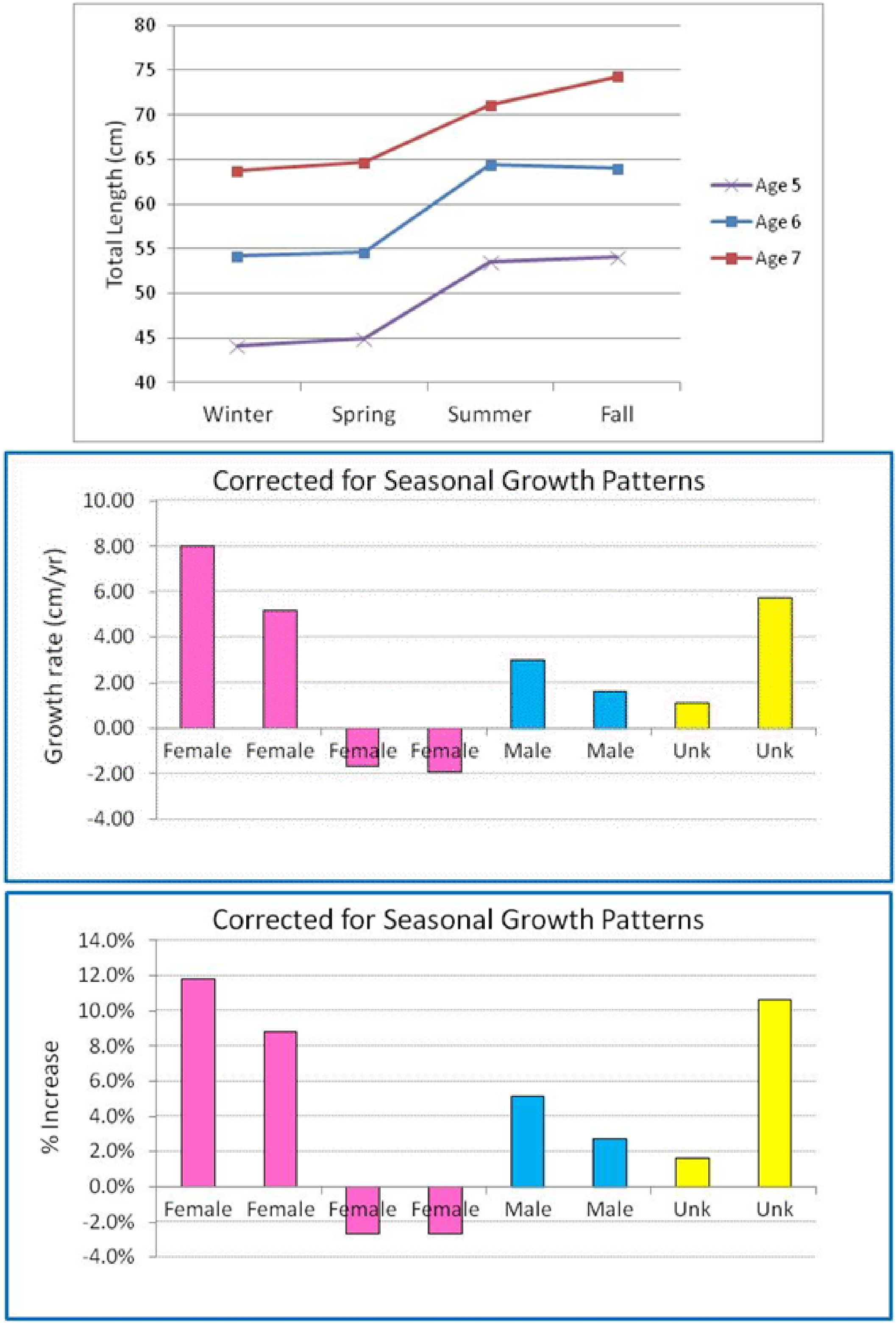


Figure 40. (A) Seasonal variation in growth based on survey length at age data (from Richards et al. 2008), (B) Annual growth increment of recaptured fish adjusted for seasonal growth rates while fish was at large, (C) Annual growth increment as percent of length at release. Unk = sex unknown. Source: Richards et al. (2012).

Appendix I: Updates to Historical Monkfish Data

Fishery data were updated in this assessment to reflect changes to databases, finalization of standardized methods (SBRM discards), and correction of errors. The most significant changes occurred in data for the South and were primarily related to changes in the expansion factor for the discard estimates, particularly in the scallop dredge. The changes are discussed in detail below.

Changes to Commercial Catch Estimates

There were no significant changes to the kept component of the commercial catch, however discard estimates were revised in both areas, and changes were more pronounced in the South. The revisions were the result of two main factors: (1) using the finalized version of the SBRM software to retrieve observer data and develop the d/k ratios, and (2) using dealer landings as the expansion factor to estimate mt of discards (vs. VTR landings, as had been used in the past). The changes to the data used to estimate discards (mt) are shown in Figures 1 and 2, and reflect both changes in software and changes to the observer database (e.g. additional sampling programs included). In both areas, more observed trips were included, especially for trawls; however, this had little impact on d/k ratios aside from generally smoothing out some spikes. Using the dealer landings for expanding the d/k ratios had little effect in the trawl and gillnet sectors, but had a substantial effect on the dredge estimates, especially in the South. The revised raising factor (dealer landings of all kept species in scallop dredges) corresponded closely to scallop landings, as would be expected, whereas the VTR dredge landings from previous monkfish assessments were substantially lower. These changes resulted in an average increase of 53% in estimated discards (mt) and 10% in estimated catch (mt) in the South during 2000-2009 (Figure 4). In the north, the impact was much lower (-0.5% in discards mt, -0.6% in catch mt) (Figure 3).

Because of the changes to the discard estimates, the entire time series of catch estimates (1980-2009) was revised for both areas. The same methods were applied as in earlier assessments. The d/k ratios used to estimate discards prior to 1989 (when observer coverage began) changed slightly (Figure 5), but resulted in relatively little change to the early catch data (Figures 3 and 4).

Changes to Commercial Catch Length Composition

An error was discovered in assigning length composition to gillnet discards in previous assessments. Due to a programming error, discard lengths for gillnets were characterized using length samples from landings rather than from discards. Figures 6 and 7 show the length composition of kept and discarded monkfish from gillnets for 2000-2009. The impact of this error was minor because gillnet discards are very low relative to the total catch (<2% by weight in both areas).

The overall change in the catch length composition is shown in Figures 8 and 9. The differences are greater in the South primarily because of the increase in estimated discards in the dredge, which tends to discard relatively small individuals.

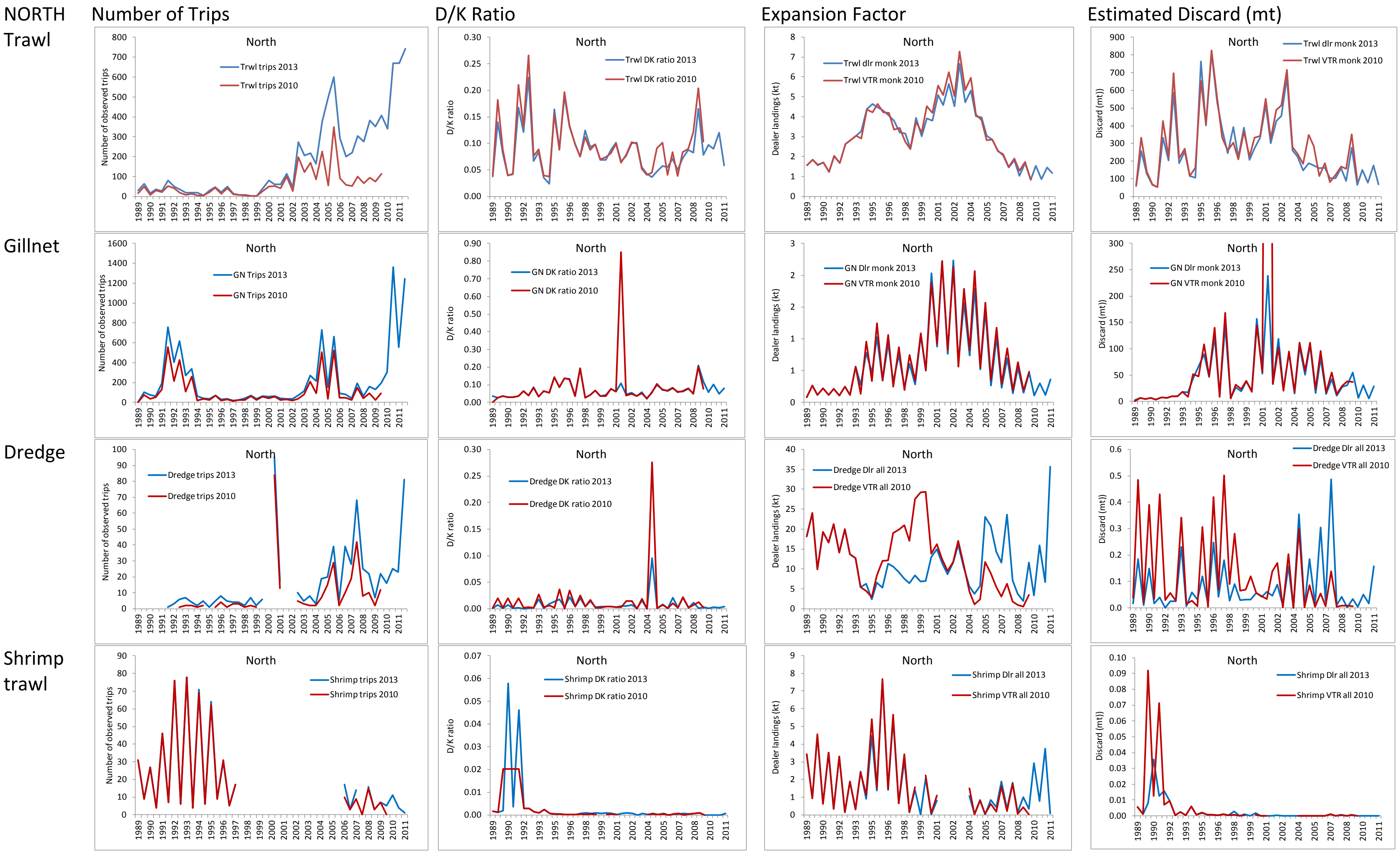


Figure 1. Changes to data used to estimate discards (mt) of monkfish in the North. Data is shown on a half-year basis.

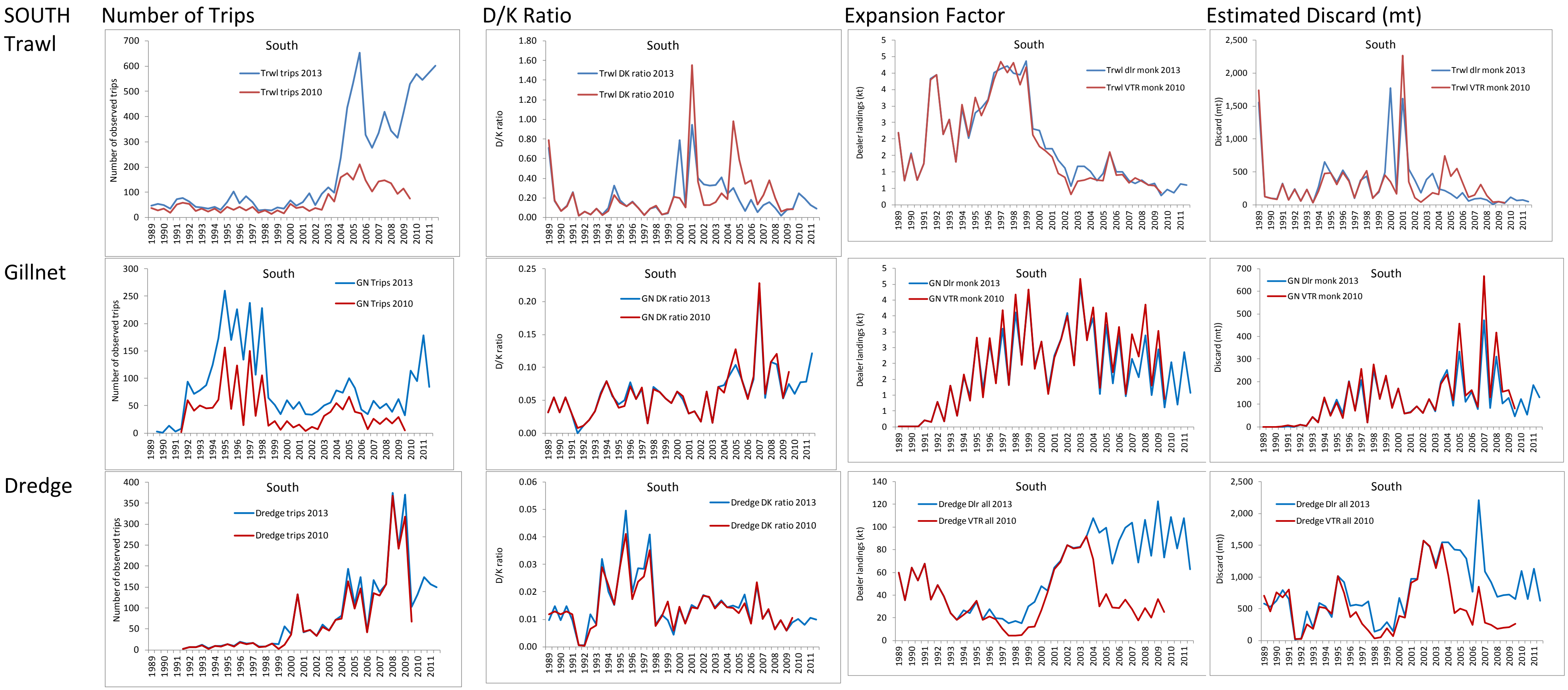


Figure 2. Changes to data used to estimate discards (mt) of monkfish in the South. Data is shown on a half-year basis.

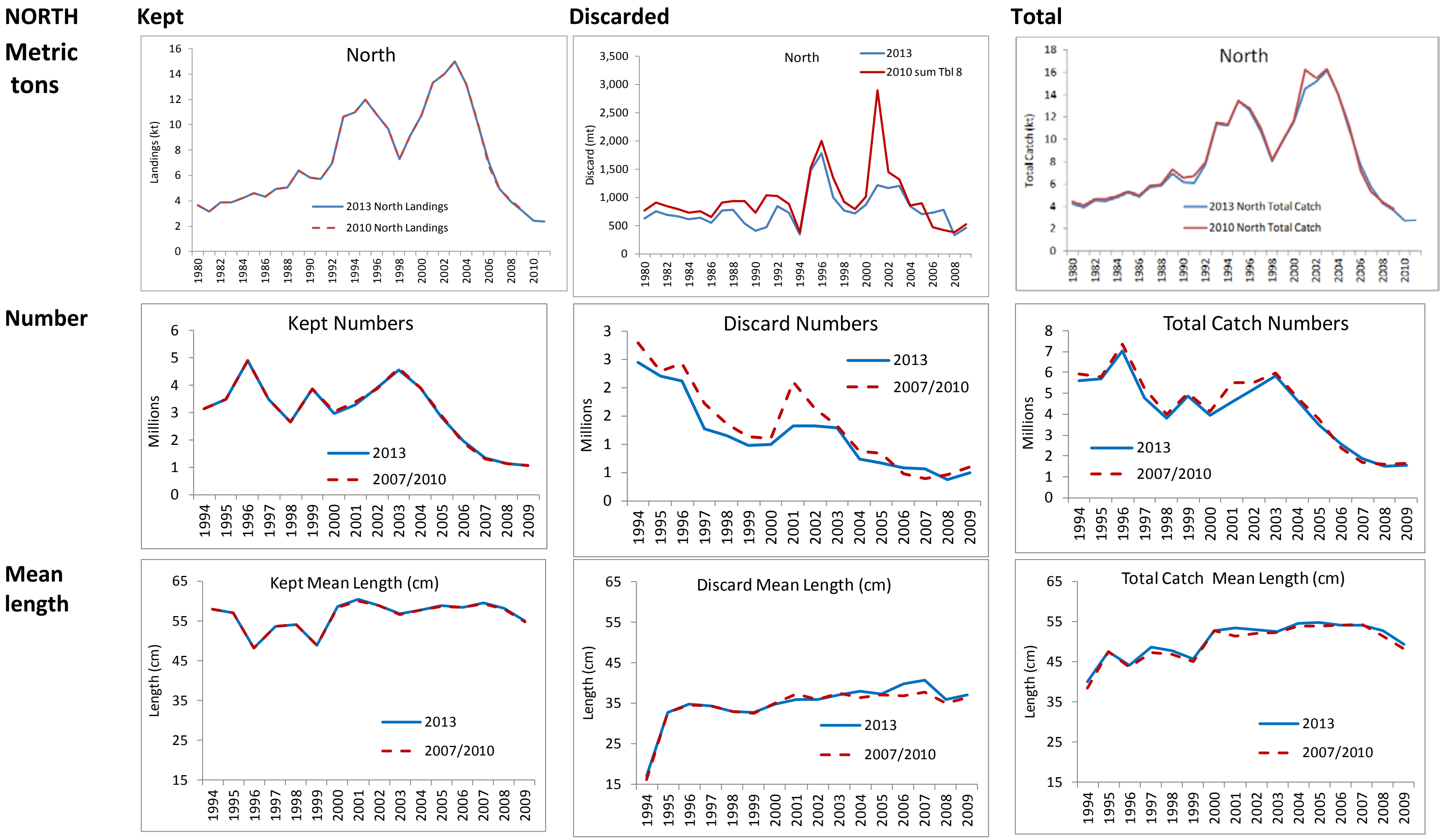


Figure 3. Comparison of revised and previous estimates of catch (mt, numbers) and mean length in the catch in the North.

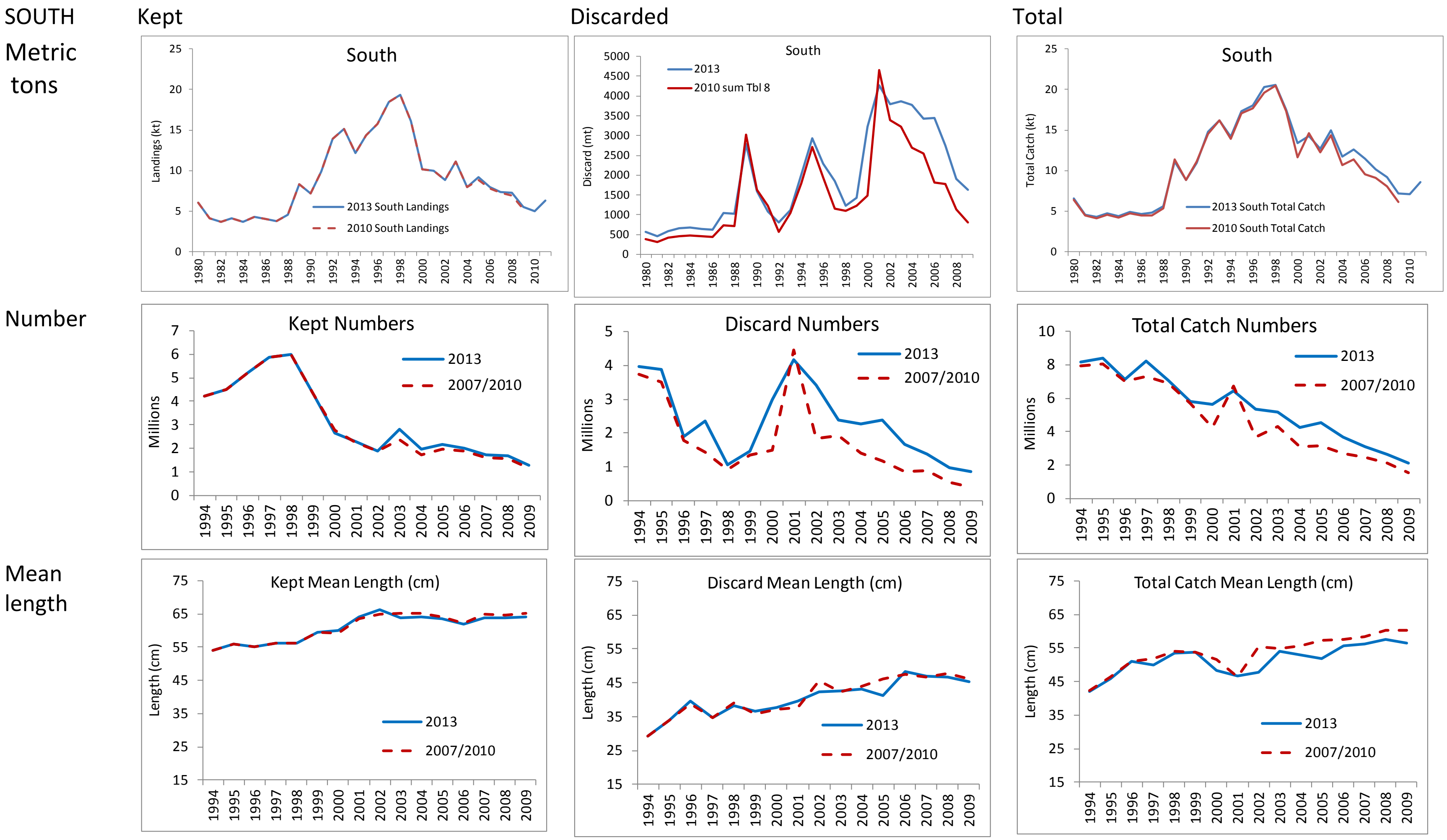


Figure 4. Comparison of revised and previous estimates of catch (mt, numbers) and mean length in the catch in the South.

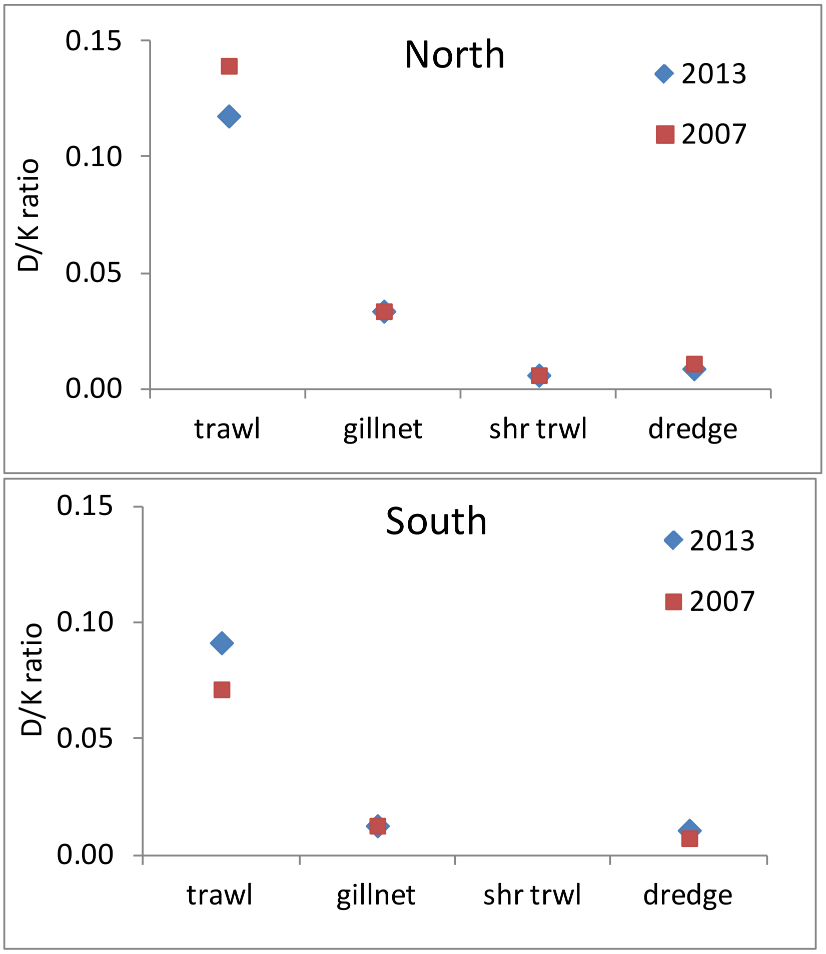


Figure 5. Change in d/k ratios used to estimate discards for 1980-1988.

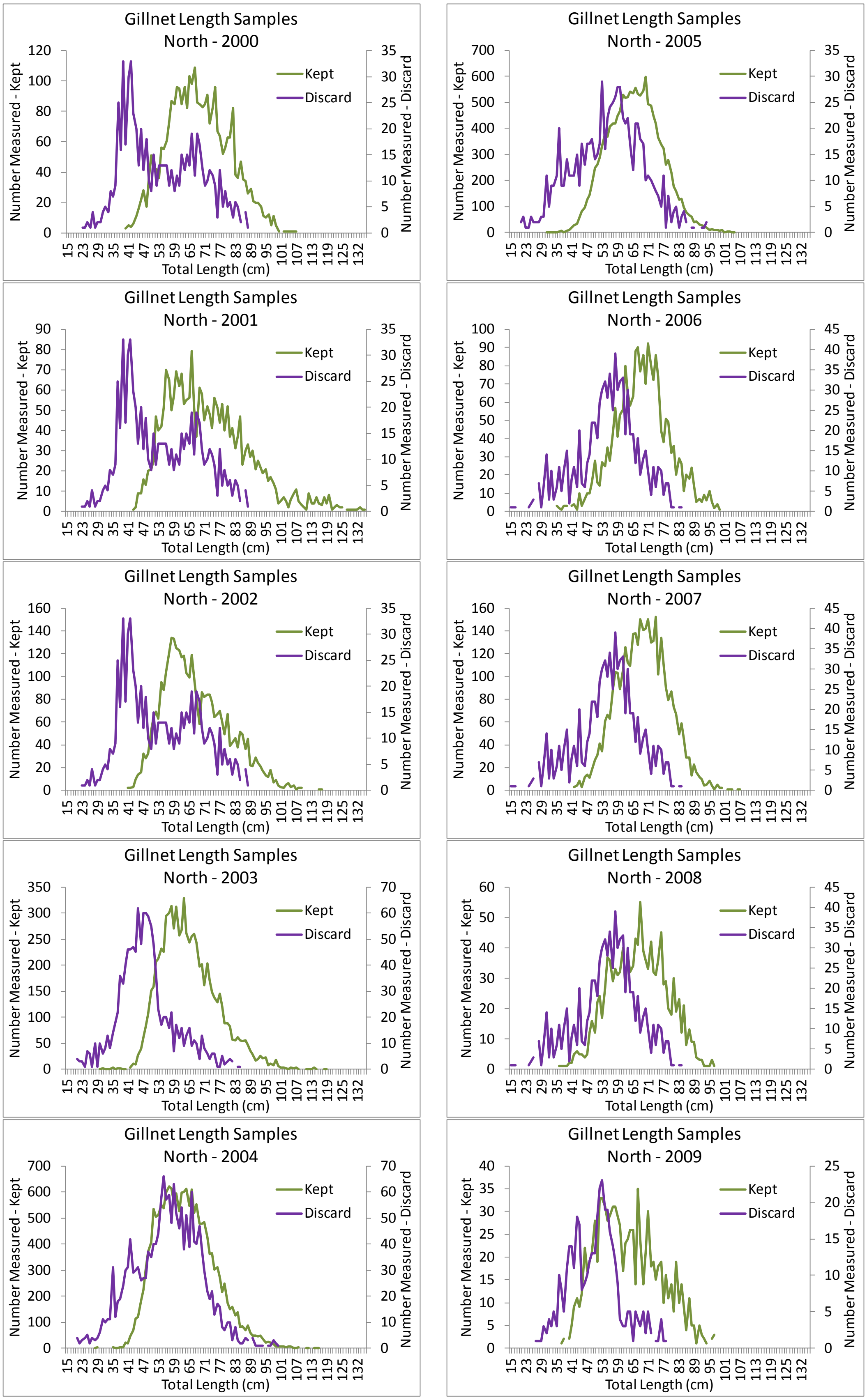


Figure 6. Comparison of kept and discard length compositions for gillnets using 2013 assessment data, North.

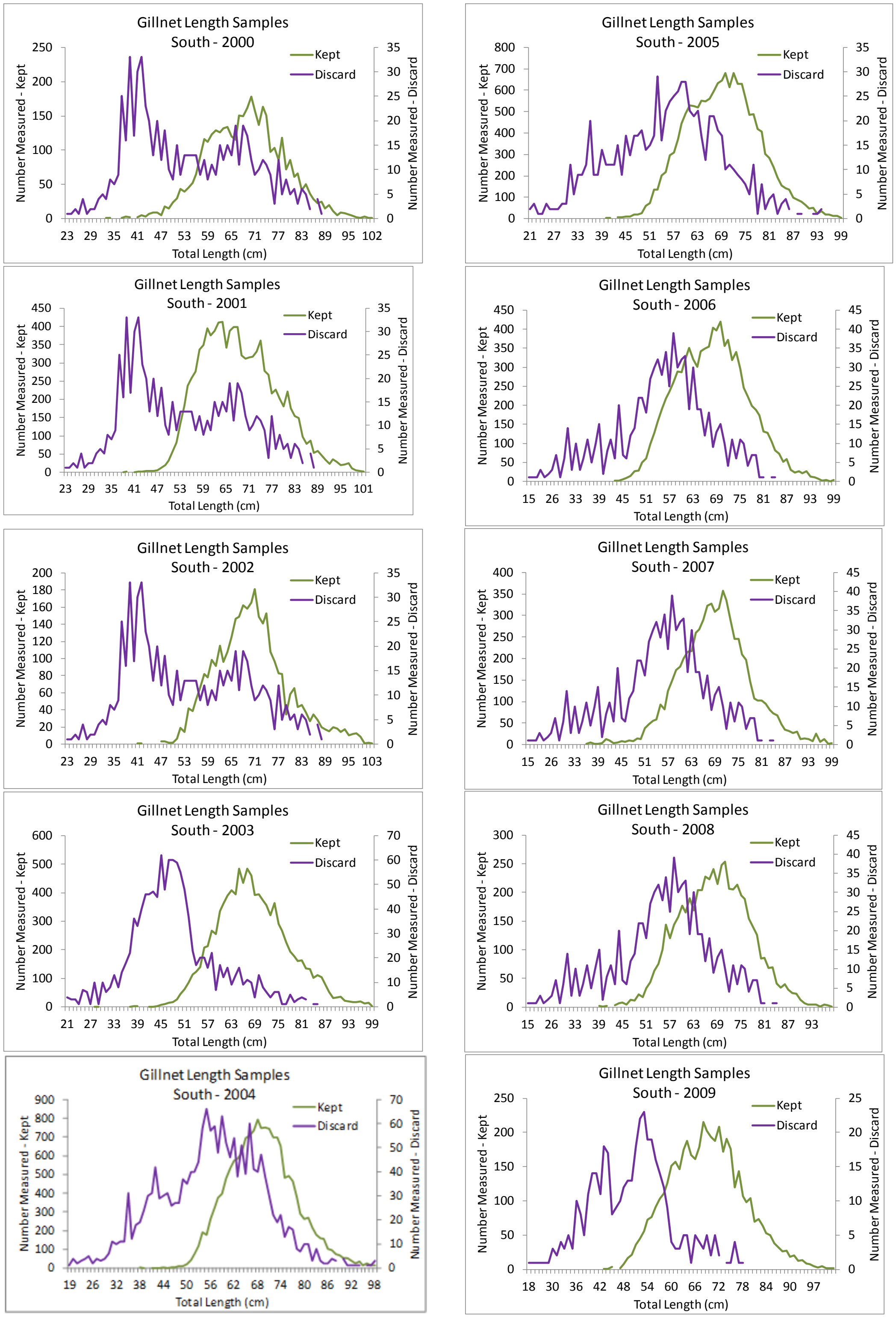


Figure 7. Comparison of kept and discard length compositions for gillnets using 2013 assessment data, South.

NORTH

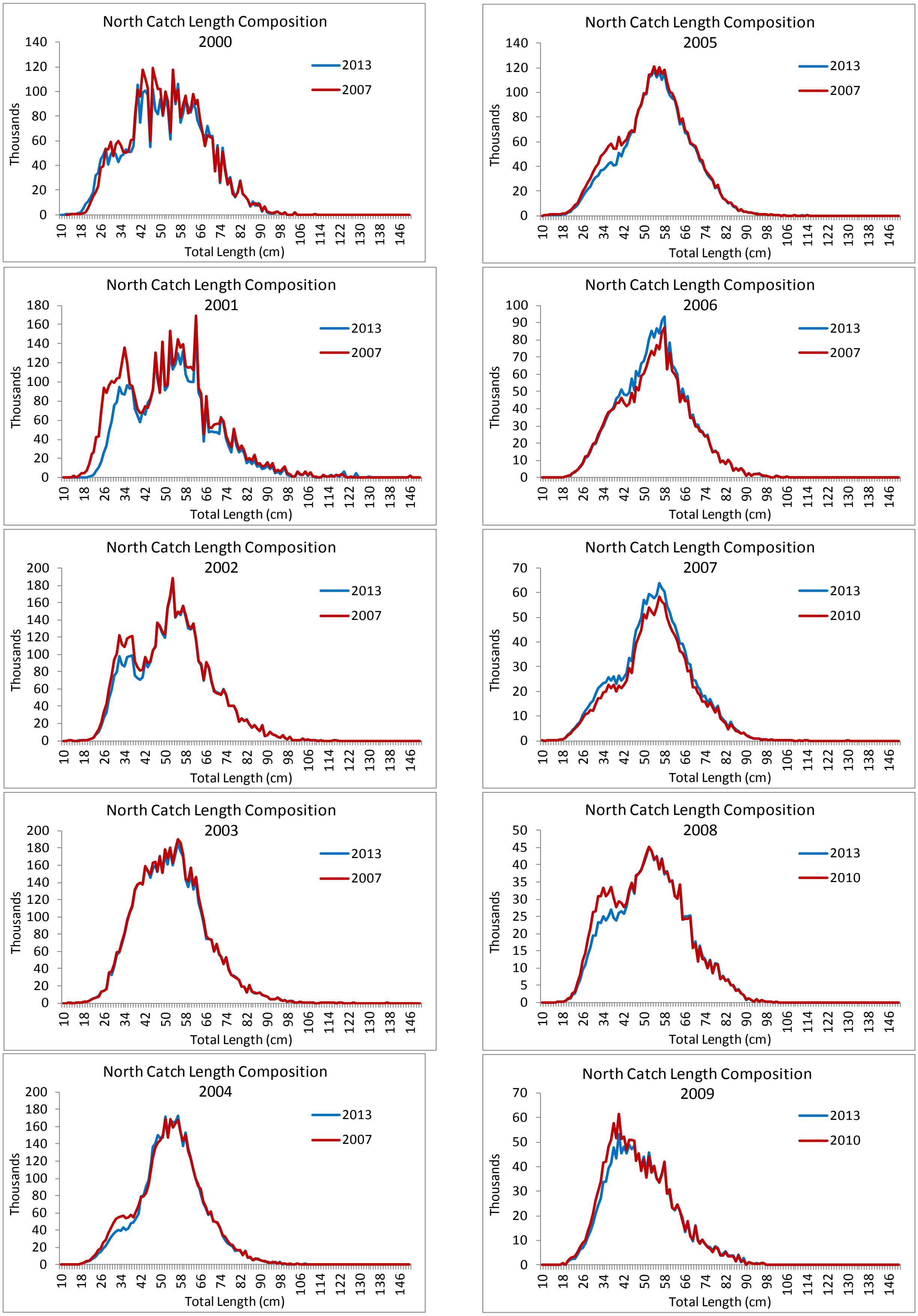


Figure 8. Revisions to catch length composition, North.

SOUTH

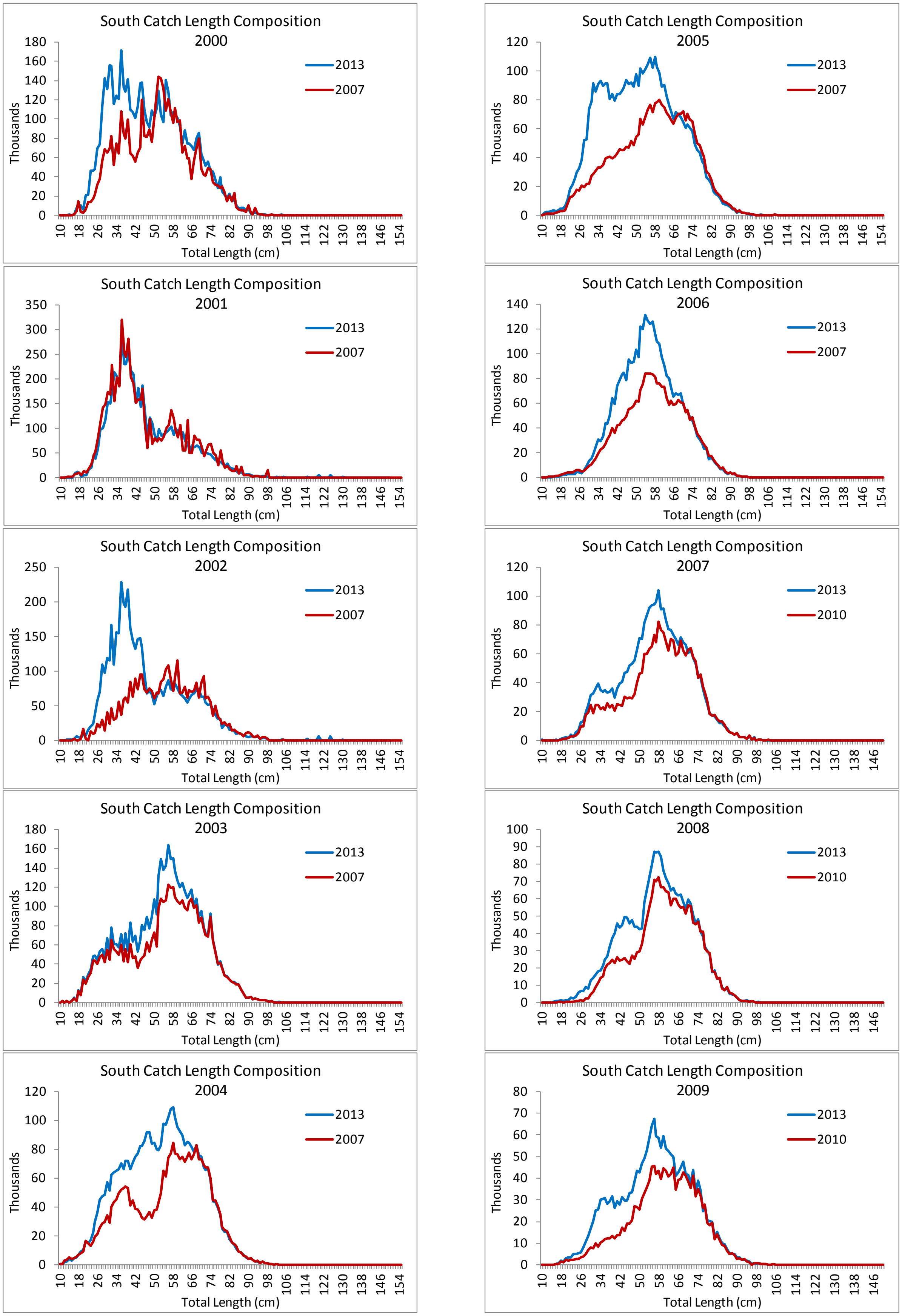


Figure 9. Revisions to catch length composition, South.

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