C. RED HAKE STOCK ASSESSMENT FOR 2010

Executive Summary

Red hake, *Urophycis chuss*, is a demersal gadoid species distributed from the Gulf of St. Lawrence to North Carolina, and is most abundant from the western Gulf of Maine through Southern New England waters (Bigelow and Schroeder 1953). Red hake are separated into northern and southern stocks for management purposes. The northern stock is defined as the Gulf of Maine to Northern Georges Bank region, while the southern stock is defined as the Southern Georges Bank to Mid-Atlantic Bight region.

Nominal red hake commercial landings in the northern stock peaked at 15,000 mt in 1972 and 1973, followed by a sharp decline in 1977 corresponding to the departure of the distant water fleets. Landings then averaged 1000 mt from 1977-1994, but declined to average only 100 mt through 2009. In the southern stock, nominal landings peaked at over 100,000 mt in 1965 with a secondary peak of over 60,000 in 1972. Landings then averaged 2000 mt from 1977-1994, but declined to average 900 mt through 2009. Discards from the northern stock averaged 1300 mt in the early 1980s, declined to about 250 mt from 1995-2000 and have averaged 100 mt through 2009. Discards from the southern stock averaged 4000 mt in the 1980s, declined to about 1000 mt from 1995-2000 and have averaged 700 mt through 2009. Recreational landings were much more significant in the south with catch averaging 300 mt compared to less than 3 mt in the north through the time series.

Catch data are a major source of uncertainty for this stock assessment, because of potentially mixed reported landings with white hake and uncertain identification to species by observers. Therefore, a length-based model was developed to estimate the proportion of red hake caught from the total hake catch (red and white hake combined). The model estimates for the north were generally lower than the nominal and the large peak in landings in the 1970s is eliminated. The landings for the south were also lower but the trend was similar. The Hakes Working Group was not comfortable with the complete change in trend in the north, so nominal catch was used in the assessment.

For the northern stock, total biomass indices were derived for two time series. The fall survey shows an increase from 1970 through 2002 followed by a decline through 2005. The spring survey increases from 1970 through 1980, but declines through 1990, increases again through 2002 and then is consistent with the fall survey.For the southern stock, the spring survey increases from 1970 through 1980, but declines through 2005, with a slight increase through 2009.

Total consumptive removals by all consistent red hake predators, using swept area abundance estimates of the predators, were consistently around 5 thousand mt per year during the late 1970s to late 1990s; more recently these removals have averaged approximately 10 thousand mt in the 2000s. These minimum estimates of red hake consumed by the consistent fish predators in this study were compared to total catch. Catch and minimum swept area estimates of consumption were approximately equal for much of the time series, with landings a little higher earlier in the

time series (1970s), but with consumption the dominant source of removals more recently averaging more than five times higher than catch.

For the northern stock, exploitation indices were derived for two time series. The fall survey shows very high exploitation in the 1960s and early 1970s, followed by a drop to low values from 1977 through the rest of the time series. This coincides with the departure of the distant water fleet. The second time series for exploitation was derived using the spring survey and shows a similar trend.

There is only one time series for the southern stock and it is based on the spring survey. The same peak is evident in the 1960s-1970s followed by a decline. However, exploitation increased from the late 1970s through 2005, with a slight decline in 2002. Exploitation has declined since 2005.

Although some statistical catch at age models (SCALE and SS3) were attempted, the diagnostics were not adequate for stock status determination or fishery management. Therefore the assessment is based on An Index Method (AIM) analyses for the northern and southern stocks which use the catch and spring survey data from 1980-2009 and is the basis for proposed biological reference points.

Based on current biological reference points in the existing FMP, the northern stock of red hake is not overfished and overfishing is not occurring. The three year delta mean biomass index, based on NEFSC fall bottom trawl survey data for 2007-2009 (2.87 kg/tow), was above the management threshold level (1.6 kg/tow) and slightly below the target (3.1 kg/tow). The three year average exploitation index (landings divided by biomass index) for 2007-2009 (0.03) was below both the target (0.39) and the threshold (0.65).

Based on current biological reference points in the existing FMP, the southern stock of red hake is not overfished and overfishing is unknown. The three year delta individual mean weight index, based on NEFSC fall bottom trawl survey data for 2007-2009 (0.10 kg/individual), is below the management threshold (0.12 kg/individual) but the three year average recruitment index (5.95 num/tow) is above the threshold value (4.72 num/tow).

Based on new recommended biological reference points from SAW/SARC-51, the **northern** stock of red hake is not overfished and overfishing is not occurring. The three year arithmetic mean biomass index, based on NEFSC spring bottom trawl survey data in Albatross units for 2008-2010 (2.42 kg/tow), was above the proposed management threshold (1.27 kg/tow) and close to the target (2.53 kg/tow). The exploitation index (catch divided by biomass index) for 2009 (0.103 kt/kg) was below the threshold (0.163 kt/kg).

Based on new recommended biological reference points from SAW/SARC-51, the **southern** stock of red hake is not overfished and overfishing is not occurring. The three year arithmetic mean biomass index, based on NEFSC spring bottom trawl survey data in Albatross units for 2008-2010 (0.95 kg/tow), was above the proposed management threshold (0.51 kg/tow) and slightly below the target (1.02 kg/tow). The exploitation index (catch divided by biomass index) for 2009 (1.150 kt/kg) was below the threshold (3.038 kt/kg).

Stochastic projections were not performed for this assessment. However, applying the Relative F reference points to the three-year average biomass index allows catches of 394 mt in the north and 2897 mt in the south.

Terms of Reference

For each stock or combined,
1. Estimate catch from all sources including landings, discards, and effort. Characterize the uncertainty in these sources of data, and estimate LPUE. Analyze and correct for any species mis-identification in these data.
2. Present the survey data that are being used in the assessment (e.g., regional indices of abundance, recruitment, state surveys, age-length data, etc.). Characterize the uncertainty in these sources of data.
3. Evaluate the validity of the current stock definition, and determine whether this should be changed. Take into account what is known about migration among stock areas.
4. Estimate measures of annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series, and characterize their uncertainty. Include a historical retrospective analysis to allow a comparison with previous assessment results.
5. State the existing stock status definitions for the terms "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; estimates or proxies for BMSY, BTHRESHOLD, and FMSY; and estimates of their uncertainty). If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.
6. Evaluate stock status (overfished and overfishing) with respect to the existing BRPs, as well as with respect to the "new" BRPs (from Red hake TOR 5).
7. Develop and apply analytical approaches and data that can be used for conducting single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs).

   a. Provide numerical short-term projections (3 years). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions about the most important uncertainties in the assessment (e.g., terminal year abundance, variability in recruitment).
   b. Comment on which projections seem most realistic, taking into consideration uncertainties in the assessment.
   c. Describe this stock's vulnerability to becoming overfished, and how this could affect the choice of ABC.

8. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.

Hake Working Group (HWG) Meetings

Three meetings were held in preparation of the 2010 red hake assessment

1. Hake fishermen's/stakeholder's meeting – August 6, 2010 – UMASS School of Marine Science and Technology (SMAST), Fairhaven, MA. Participants include fishermen Dan Farnham and Bill Phoel. Also in attendance were David Goethel (Oversight Committee chair), Andrew Applegate (staff) Steve Cadrin (SSC and WG chair, SMAST), Pingguo He, Klondike Jonas, Yuying Zhang, Tony Wood, and Daniel Goethel (SMAST), Loretta O'Brien, Michele Traver, Katherine Sosebee and Larry Alade (NEFSC), and Dick Allen (advisor at large). A summary of the discussions is in Appendix A1.

2. Data Meeting – September 7-10, 2010, NEFSC Woods Hole MA. Participants included Steve Cadrin (WG Chair), Assessment leads (Larry Alade, Kathy Sosebee , Michele Traver), Rapporteurs (Jessica Blaylock and Julie Nieland), Mark Showell (DFO), Andy Applegate (NEFMC Staff), NEFSC (Loretta O'Brien, Mark Terceiro, Chris Legault, Tim Miller, Dave Richardson, Ayeisha Brinson, Jiashen Tang, Janet Nye, Mike Palmer, Paul Rago, Josef Idoine, Jon Hare), Moira Kelly (NERO), SMAST(Tony Wood, Yuying Zhang, Saang-Yoon Hyun)

3. Model Meeting – October 25-29, 2010, NEFSC, Woods Hole, MA. Participants included Steve Cadrin (WG chair), Assessment leads ((Larry Alade, Kathy Sosebee , Michele Traver), Rapporteurs (Jessica Blaylock and Julie Nieland), Mark Showell (DFO), Andy Applegate (NEFMC Staff), Dan Farnham (Fisherman and Industry Advisor), (Loretta O'Brien, Paul Nitschke, Mark Terceiro, Jay Burnett, Chris Legault, Tim Miller, Jon Deroba, Rich McBride, Jim Weinberg, Paul Rago, Josef Idoine, Jon Hare, Janet Nye, Dave Richardson, Laurel Col, Jason Link), SMAST(Tony Wood, Yuying Zhang, Dan Goethel). The groups met by correspondence after the meetings, including a WebEx meeting on November 5, 2010 to report updates on silver hake analyses, provide guidance on reference points and discuss plans for report development.

This Working Group (WG) report includes products from all three meetings and contributions from all participants.

Fishery Regulations

The following outlines the current small mesh multispecies regulations (based on the small mesh exemption program) for the New England whiting fishery to provide context for interpreting the fishery and model results.
1. 1994 & 2000 - Exempted fisheries allows vessels to fish for specific species such as whiting or northern shrimp in designated areas using mesh sizes smaller than the minimum mesh size allowed (Gulf of Maine, Georges Bank, Southern New England, Mid-Atlantic : 6.5-inch square or diamond) under the Regulated Mesh Area (RMA) regulations.

2. Permits

a. Open access Category K Multispecies

b. Limited Access Category A-F (non Days-at-Sea fishing)

3. No Size Limits

4. 500 lbs at sea transfer limit.

5. 2003 - Possession limits vary by exemption area

a. 3,500 lbs if mesh < 2.5 inches (63.5mm)

b. 7,500 lbs if mesh <=3.0 inches (76.2mm)

c. 30,000 lbs if mesh > 3.0 inches (76.2mm)

d. No Red Hake possession limit

Introduction

Red hake, *Urophycis chuss*, is a demersal gadoid species distributed from the Gulf of St. Lawrence to North Carolina, and is most abundant from the western Gulf of Maine through Southern New England waters. Red hake are separated into northern and southern stocks for management purposes. The northern stock is defined as the Gulf of Maine to Northern Georges Bank region, while the southern stock is defined as the Southern Georges Bank to Mid-Atlantic Bight region (Figure C1). Both red hake stocks were last assessed in the fall of 1990.

Red hake migrate seasonally, preferring temperatures between 5 and 12° C (41-54° F) (Grosslein and Azarovitz 1982). During the spring and summer months, red hake move into shallower waters to spawn, and during the winter months move offshore to deep waters in the Gulf of Maine and the edge of the continental shelf along Southern New England and Georges Bank. Spawning occurs from May through November, with primary spawning grounds on the southwest part of Georges Bank and in the Southern New England area off Montauk Point, Long Island (Colton and Temple 1961).

Red hake do not grow as large as white hake, and normally reach a maximum size of 50 cm (20 in.) and 2 kg (4.4 lbs.) (Musick 1967). However, females are generally larger than males of the same age, and reach a maximum length of 63 cm (25 in.) and a weight of 3.6 kg (7.9 lbs.) (Collette and Klein-MacPhee eds. 2002). Although they generally do not live longer than 8 years, red hake have been recorded up to 14 years old. In the northern stock, the age at 50% maturity is 1.4 years for males and 1.8 years for females, and the size at 50% maturity is 22 cm (8.7 in.) for males and 27 cm (10.6 in.) for females (O'Brien et al. 1993). In the southern red hake stock, the age at 50% maturity is 1.8 years for males and 1.7 years for females, and the size at 50% maturity is 24 cm (9.5 in.) for males and 25 cm (9.8 in.) for females (O'Brien et al. 1993).

Red hake prefer soft sand or muddy bottom, and feed primarily on crustaceans such as euphausiids, decapods, and rock crabs as well as fish such as haddock, silver hake, sea robins, sand lance, mackerel and small red hake (Bowman et al. 2000). Primary predators of red hake include spiny dogfish, cod, goosefish, and silver hake (Rountree 1999). As juveniles, red hake seek shelter from predators in scallop beds, and are commonly found in the mantle cavities of (or underneath) sea scallops. In the fall, red hake likely leave the safety of the scallop beds due to their increasing size and to seek warmer temperatures in offshore waters (Steiner et al. 1982).

TOR1. Estimate catch from all sources including landings, discards, and effort. Characterize the uncertainty in these sources of data, and estimate LPUE. Analyze and correct for any species mis-identification in these data.

Commercial Fishery Landings

Following the arrival of distant-water fleets in the early 1960s, nominal commercial landings from both stocks combined peaked at 113,500 mt in 1966 (Table C1, Figure C2). Nominal landings then declined sharply to 12,500 mt in 1970, increased to 76,200 mt in 1972, and then declined steadily with increased restrictions on distant-water fishing effort. Prior to implementation of the Magnuson Fisheries Conservation and Management Act (MFCMA) in 1977, distant-water fleets accounted for approximately 80-90% of the nominal landings from both stocks. Between 1977 and 1986, landings generally declined due to restrictions placed on distant water fleets, and foreign landings ceased in 1987 (Table C1, Figure C3). Red hake landings continued to decline afterwards, and averaged only 1,400 mt per year during 1996-2000. Nominal red hake landings then declined further to average 770 mt between 2001 and 2009. Red hake are often sold as bait over the side. These landings are not reported in the dealer database, but are supposed to be reported on Vessel Trip Reports (VTR). All the landings tables include whatever landings are reported in the totals. Due to some confidentiality issues, they are not reported separately.

The northern red hake stock had significantly lower commercial landings than the southern stock through the mid-1970s (Table C1, Figure C2). In 1973, total commercial landings peaked at 15,288 mt but have since declined progressively. After 1976, landings declined considerably due to the withdrawal of the distant water fleet. Commercial landings declined to less than 100 mt in 2005 and have remained low (Table C1, Figure C3).

During 1962 to 1976, landings from the southern red hake stock were much higher than those from the northern stock (Table 1, Figure C2). However, southern red hake landings decreased sharply after 1966 and also after 1976 due to restrictions on distant water fleets. The southern stock landings continued to decrease, and reached a record low of 356 mt in 2005 before increasing to 575 mt in 2009 (Table C1, Figure C3).

Commercial landings in the northern stock generally came from Massachusetts with smaller amounts landed in Maine and Rhode Island (Table C2). The primary states in which red hake were landed in the southern stock are Rhode Island, New Jersey, and New York (Table C3). Massachusetts was a historically important port, with some of the industrial fleet landings probably landed there.

Otter trawls in both regions accounted for the majority of the commercial landings of red hake, although the assumption was made that both the industrial fishery and the bait fishery are from otter trawl (Tables C4-C5). This assumption is likely valid since otter trawls were the main reported gear type throughout the history of the fishery.

Commercial landings from the northern stock are taken primarily in the summer months, mainly June through October (Table C6) although in the last five years, significant landings have only occurred in July, August and September. Commercial landings from the southern stock occur more evenly during the year (Table C7).

Species and Length Composition of Landings

Identification of hakes is uncertain in the commercial landings. An alternative method to estimate landings by species (red/white) was developed. Landings by region, half year, and, in the case of white hake, market category (Tables C8-C10) were converted to length composition. Market categories of white hake were aggregated as they were done in the white hake assessment (NEFSC 2001, 2008). The port samples by half year, region, and market were used (Tables C11-C13). In general, there were marginally adequate numbers of fish measured for red hake in the south and white hake in the north (Tables C14-C15). Pooling over years by species within a region was required to get an adequate number of fish, particularly for red hake in the north and white hake in the south (Table C16-C17). The length-weight equations by season from Wigley et al 2003 were applied to the samples and used to estimate the landings numbers at length for each market category.

Length compositions for each species for the two regions (GOM-NGBK Offshore strata 20-30, 36-40; SGBK-MA – Offshore strata 1-19, 61-76) were estimated for the spring and fall surveys. The species length-weight equations were then applied to determine weight-at-length by species. The proportions at length by species for both number and weight were applied to the commercial landings-at-length to estimate landings-at-length by species. The lengths had to be grouped into intervals to avoid zero cells in the survey. All fish greater than 70 cm were set to be white hake. Landings from 1964-2009 were hind-cast using the average proportion of red hake by region over the entire time series.

The landings that result from this method are very different than the nominal landings in the north (Table C18, Figure C4) but fairly similar for the southern landings (Table C18, Figure C5). The HWG decided that the hind-cast landings were too uncertain and that the increase seen in the northern stock disappears (and becomes white hake during that time). Therefore, nominal landings will be used for the assessment.

The length compositions from the raw length samples and the length-based model estimates show different patterns for the northern stock (Figures C6-C7). The raw data (only showing years which had red hake length samples) are noisy with some years having fairly small fish (i.e. 1992 and 2007). When the data are pooled to estimate the length compositions and split using survey proportions, trends of these small fish are evident from 1992-1996 and 2006-2009. In the southern stock, the length compositions are fairly similar (Figures C8-C9).

Commercial Fishery Discards

Discard estimates were calculated in this assessment. The ratio-estimator used in this assessment is based on the methodology described in Rago et al. (2005) and updated in Wigley et al 2007. It relies on a d/k ratio where the kept component is defined as the total landings of all species within a "fishery". A fishery is defined as a homogeneous group of vessels with respect to gear type (longline, otter trawl, shrimp trawl, sink gill net, and scallop dredge), quarter, and area fished (GOM-NGBK, SGBK-MA), and for otter trawls, mesh size (<= 5.49", > = 5.5 "). All trips were included if they occurred within this stratification regardless of whether or not they caught hakes.

The discard ratio for hakes in stratum h is the sum of discard weight over all trips divided by sum of kept weights over all trips:

$$\hat{R}_h = \frac{\sum_{i=1}^{n_h} d_{ih}}{\sum_{i=1}^{n_h} k_{ih}} \qquad (1)$$

where d_{ih} is the discards for hakes within trip i in stratum h and k_{ih} is the kept component of the catch for all species. R_h is the discard rate in stratum h. The stratum weighted discard to kept ratio is obtained by weighted sum of discard ratios over all strata:

$$\hat{R} = \sum_{h=1}^{H} \left(\frac{N_h}{\sum_{h=1}^{H} N_h} \right) \hat{R}_h \qquad (2)$$

The total discard within a strata is simply the product of the estimate discard ratio R and the total landings for the fishery defined as stratum h, i.e., $D_h = R_h K_h$.

Cells with < three trips were imputed using annual averages by gear type and region. To hind-cast the discards to 1981 (the first year in which there was no industrial fishery), discards/total landings by half year for the first three years (1989-1991 for otter trawl, sink gill net, and shrimp trawl; 1992-1994 for longline and scallop dredge) were averaged and the rate applied to the total landings from the dealer database. For the otter trawl fisheries, the mesh sizes were combined for the hind-cast.

The main sources of red hake discards in the north were the two small-mesh trawl fisheries, including the shrimp trawl fishery, at least until the early 1990s, with the implementation of the Nordmore grate in that fishery (Table C19). The small-mesh trawl fishery in the south is also the largest contributor to discards of red hake, with large-mesh trawl and scallop dredge catching some significant amounts (Table C20). Discards from the longline and sink gill net fisheries were minimal in both regions.

Discards from the northern stock averaged 1300 mt in the early 1980s, declined to about 250 mt from 1995-2000 and have averaged 100 mt through 2009 (Figure C10). Discards from the southern stock averaged 4000 mt in the 1980s, declined to about 1000 mt from 1995-2000 and have averaged 700 mt through 2009 (Figure C11).

Species and Length Composition of Discards

The same problem with species identification that exists in the landings is found in the Fisheries Observer Program data. The same length-based method used for commercial landings was used to split discards. Discards were estimated for white hake using the same method as for red hake (Tables C21-C22). Enough length samples were available for large and small mesh otter trawls in both regions and sink gill net and shrimp trawl in the north (Tables C23-26). Pooling over years was still required to get an adequate number of fish (Tables C27-30). To hind-cast the species proportions back to 1981, the average proportion of red hake for the time series was used and applied to the total red and white hake discards. This method resulted in slightly different discard estimates for the north (Table C31, Figure C10) and almost imperceptible differences in the south (Table C31, Figure C11). To be consistent with landings, the nominal discards were used for the assessment. The length compositions from the nominal discards and the length-based model estimates show very little difference in either stock (Figures C12-C15).

Recreational Catch

USA recreational landings of red hake were estimated by stock using data provided by NOAA MRFSS from 1981-2009 (Table C32). Landings prior to 1981 were hind-cast for the north using an average proportion of the total landings. The southern stock had estimates previously derived (NEFC 1990) and these were used directly. Recreational landings were much more significant in the south with catch averaging 300 mt compared to less than 3 mt in the north through the time series (Figure C16). The number of length samples taken in the recreational fishery is sparse for the northern stock, so the southern stock length frequencies were used for both stocks (Figure C17).

Commercial Fishing Effort and LPUE

There are currently no estimates of CPUE or effort for this species. Given the uncertainties given above with species identification and the major changes in management noted in the introduction, CPUE is not likely to be a good indicator of stock status. In particular, the fishery in the north has been limited in areas they can fish with small mesh. These are not necessarily areas for good red hake fishing. Over time, the fishery has also changed from one dominated by a distant water fleet that took substantial quantities of everything to a much smaller by-catch fishery that may be driven more by prices of silver hake and regulation than abundance.

TOR 2. Present the survey data that are being used in the assessment (e.g., regional indices of abundance, recruitment, state surveys, age-length data, etc.). Characterize the uncertainty in these sources of data.

Data Source: The primary sources of biological information for red hake are based on the annual fishery independent surveys conducted by the Northeast Fisheries Science Center (NEFSC). The surveys were conducted using a random stratified sampling design which allocates samples relative to the size of the strata, defined by depth. The surveys extend from the Gulf of Maine to Cape Hatteras, in offshore waters at depths 27-365 meters, and have been conducted in the fall since 1963 and in the spring since 1968. The winter bottom trawl survey began in 1992 and was specifically designed for flatfish, however, the deeper survey strata were not sampled until 1998 (Figure C18). The winter trawl survey does not cover the Georges Bank area because the survey was designed specifically for flatfish in the southern region. Details on the stratified random survey design and biological sampling methodology may be found in Grosslein (1969), Azarovitz (1981) and Sosebee and Cadrin (2006). Other surveys used in the analysis of silver hake are NEFSC shrimp survey (1985-2009), Massachusetts Division of Marine Fisheries (1978-2009) fall and spring surveys and Rhode Island (1979-2010), Connecticut (1984-2009), and Maine-New Hampshire (2000-2009) state surveys.

The NEFSC spring and fall survey estimates were calculated for northern, southern and combined management regions. The NEFSC strata used for the northern area are offshore strata 20-30 and 36-40. The NEFSC strata used for the southern management area are: offshore strata 1-19 and 61-76. The combined strata set is: offshore 1-30, 36-40, and 61-76.The strata set for the shrimp survey is shrimp strata 1-12. The strata set for the winter surveys is: offshore strata 1-3, 5-7, 9-11, 13-14, 61-63, 65-67, 69-71, and 73-75. Massachusetts Division of Marine Fisheries data was separated into northern and southern areas. The northern strata used were MADMF 18-36 and the southern strata used were 11-17 (Figure C19).

Minimum swept area abundance and biomass were calculated by using swept area conversions of 0.0112 for the NEFSC fall and spring surveys, 0.004 for NEFSC shrimp survey, 0.0131 for the NEFSC winter survey, and 0.003846208 for Massachusetts Division of Marine Fisheries (MADMF) fall and spring surveys. Swept area estimates were not calculated for the other state surveys

Transform: NEFSC spring and fall survey estimates were computed using both delta transformation and arithmetic means for numbers and weight. The Whiting Plan Development Team (PDT) has used the delta mean for assessing stock status. The delta transformation uses only the positive tows for log transformation:

$$
\hat{M}_\delta = \begin{cases} \dfrac{m}{n} e^{\bar{y}} \psi_m \left(\dfrac{1}{2} s_y^2 \right) & m > 1, \\ \dfrac{1}{n} x_1 & m = 1, \\ 0 & m = 0 \end{cases}
$$

$m =$ number of non - zero tows
$n =$ total number of tows

$$
\hat{V}_\delta = \begin{cases} \dfrac{m}{n} e^{2\bar{y}} \left[\psi(2s_y^2) - \dfrac{m-1}{n-1} \psi_m \left(\dfrac{m-2}{m-1} s_y^2 \right) \right] & m > 1, \\ \dfrac{1}{n} x_1^2 & m = 1, \\ 0 & m = 0 \end{cases}
$$

Examination of the differences between the delta and arithmetic means revealed that use of the delta transformation did not reduce the variability of the survey and may have increased the variability between years (Figure C20). If a survey has a high variance, the back-transformation may be biased high. The delta transformation was also more sensitive to the handling of missing weights. Prior to 2001, the data for weights were recorded to the nearest 0.1 kg and if a tow contained only a single small fish, the weight was entered into the data as zero. Since the delta transform uses the positive tow, how this is handled has an impact on the result. There are three options: taking out the zeros, leaving in the zeros, and filling in zeros using a length-weight equation. Since these options did not affect the arithmetic as much as the delta mean, the decision was made to use the arithmetic and length-weight options for any new analyses (Figure C21).

Calibration: In 2009 the *NOAA SHIP Henry B. Bigelow* replaced the *R/V Albatross IV* as the primary vessel for conducting spring and fall annual bottom trawl surveys for the Northeast Fisheries Science Center (NEFSC). There are many differences in the vessel operation, gear, and towing procedures between the new and old research platforms (NEFSC Vessel Calibration Working Group 2007). To merge survey information collected in 2009 onward with that collected previously, we need to be able to transform indices (perhaps at size and age) of abundance from the *Henry B. Bigelow* into those that would have been observed had the *Albatross IV* still been in service. The general method for merging information from these two time series is to calibrate the new information to that of the old (Pelletier 1998). Specifically we need to predict the relative abundance that would have been observed by the *Albatross IV* ($\hat{R}_A$) using the relative abundance from the *Henry B. Bigelow* (R_B) and a "calibration factor" (ρ),

$$
\hat{R}_A = \rho R_B . \qquad (3)
$$

To provide information from which to estimate calibration factors for a broad range of species, 636 paired tows were conducted with the two vessels during 2008. Paired tows occurred at many stations in both the spring and fall surveys. Paired tows were also conducted during the summer and fall at non-random stations to improve the number of non-zero observations for some species. Protocols for the paired tows are described in NEFSC Vessel Calibration Working Group (2007).

The methodology for estimating the calibration factors was proposed by the NEFSC and reviewed by a panel of independent scientists in 2009. The reviewers considered calibration factors that could potentially be specific to either the spring or fall survey (Miller et al. 2010). They recommended using a calibration factor estimator based on a beta-binomial model for the data collected at each station for most species, but also recommended using a ratio-type estimator under certain circumstances and not attempting to estimate calibration factors for species that were not well sampled.
Since the review, it has become apparent that accounting for size of individuals can be necessary for many species. When there are different selectivity patterns for the two vessels, the fraction of available fish of a given size taken by the two gears is different. Therefore, the ratio of the mean catches by the two vessels will change with size. Under these circumstances, the estimated calibration factor that ignores size reflects an average ratio weighted across sizes where the weights of each size class are at least in part related to the number of individuals at that size and the number of stations where individuals at that size were caught. Applying calibration factors that ignore size effects to surveys conducted in subsequent years when the size composition is unchanged should not produce biased predictions (eq. 1). However, when the size composition changes, the frequency of individuals and number of stations where individuals are observed at each size changes and the implicit weighting across size classes used to obtain the estimated calibration factor will not apply to the new data. Consequently, the predicted numbers per tow that would have been caught by the *Albatross IV* will be biased.

For red hake, we fit a suite of beta-binomial models that made different assumptions on the relationship of the calibration factor to length. The models ranged from those that were constant with respect to length to logistic and double-logistic functions of length. For red hake, the working group decided to use a season-specific double-logistic model relating the calibration factor to length due to it providing the best fit to the data with respect to AIC_c (Table C33-34, Figure C22). Note that the minima for both logistic components in the fall were assumed equal to 0 (e^{-100}) due to poorly estimated variance of model coefficients in the fully parameterized model. To estimate weight pre tow for the 2009 and 2010 surveys, the length-weight equations by season from Wigley et al 2003 were applied to the length frequencies.

Survey Data Results: Distribution maps for red hake show that there are higher concentrations of red hake by catch weight (kg) during the NEFSC spring surveys than the NEFSC fall surveys. There were less red hake caught in the middle of Georges Bank in the spring than the fall. They tended to be more in the Gulf of Maine and along the shelf, than in the middle of the bank. The maps are broken into 5-year blocks, by season, for the duration of the time series (Figures C23-C34).

<u>North</u>
The fall survey biomass steadily increased during the 1970s, spiked in 2000 at its highest of 12,118 metric tons and then decreased until 2005, where the stock declined to 2,486 metric tons. Biomass has increased the past few years and is currently at 5,086 metric tons in 2009, a 24% increase from 2008 (Table C35, Figure C35).

The spring survey biomass was variable during the 1970s, with many peaks and valleys. There was a large spike in 1981, where it increased to 13,594 metric tons. In 1982, the biomass index dropped sharply to 4,551 metric tons, a decline of 67%. The stock was quite low in 1990, and then increased until 2002, where the stock was at 9,543 metric tons and then considerably declined until 2006, with 1,952 metric tons. Since then, the minimum swept area biomass has increased again to 4,326 metric tons, a 122% increase over 2006 (Table C36, Figure C36).

The shrimp survey swept area biomass was quite low during the early part of the time series. The lowest point was in 1994, at 3,262 metric tons. Biomass continued to slowly increase, until it spiked in 2002 with an all time high of 64,925 metric tons. Then biomass declined by 74% to 17,194 metric tons in 2003. The 2009 estimate is currently at 13,164 metric tons (Table C37, Figure C37).

The lowest biomass estimate from the MADMF fall surveys was in 1987, where there were only 447 metric tons caught. Then biomass increased through the 1990s, where it hit a maximum value in 2000 of 3,842 metric tons. A decline occurred between 2002 and 2008, although 2009 increased by 83% over 2008 (Table C38, Figure C38).

The MADMF spring surveys have extremely low biomass estimates. There were two spikes early in the time series, in 1979 and 1981, with catches of 3,888 metric tons and 5,129 metric tons, respectively. The biomass declined considerably in 1982 and stayed low until a small bump in 2000 with 1,414 metric tons. The survey biomass then declined to its lowest value in 2004 of 75 metric tons. It increased by 226% in 2009, to 245 metric tons (Table C39, Figure C39).

The trends for all the fall surveys are in general agreement showing an increase through 2000, a decline through 2005 and an increase over the last few years (NH data in Table C40, Figure C40). The spring surveys also show a general agreement with higher values in the 1980s, declining through 1995, increasing through 2002, and followed by a decline until the last couple of years (NH data in Table C40, Figure C41).

South

The fall survey swept area biomass was higher during the 1970s and 1980s than any other part of the time series. Biomass peaked at 20,002 metric tons in 1983 before dropping drastically by 80% to 3,905 metric tons in 1984. The stock has continued to decline until 2005. Biomass has increased slightly and is currently at 3,368 metric tons (Table C41, Figure C42).

Similar to the fall survey, the spring survey swept area biomass was higher during the 1970s and early part of the 1980s. After 1981, when the biomass was 15,201 metric tons, it declined to reach a low value of 511 metric tons. Biomass continued to increase to 3,460 metric tons in 2010, a 577% increase since 2004 (Table C42, Figure C43).

The winter survey has a very short time series, 1992-2007. The swept area biomass was high during the early part of the time series, with 18,483 metric tons in 1993. The survey biomass then declined, hitting its lowest value in 2003 at only 159 metric tons. The biomass varied until the winter survey was discontinued in 2007 (Table C43, Figure C44).

The MADMF fall survey in the southern region has much smaller biomass than in the northern region. The survey was variable at best with many peaks and valleys throughout the time series. In 2004, the survey was at its lowest point with 0.22 metric tons of swept area biomass. In 2009, there was an increase of 645% to 1.64 metric tons than in 2004 (Table C44, Figure C45).

The MADMF spring survey has larger swept area biomass than the MADMF fall survey. The early part of the time series has greater values than the latter. The highest biomass was estimated in 1987 with 894 metric tons, where 2003 was the lowest, at 0.36 metric tons. In 2009, the swept area biomass was 6.92 metric tons (Table C45, Figure C46).

The trends for all the fall surveys are much noisier than in the northern area (RI and CT data in Table C46, Figure C47). The spring surveys also show great deal of noise (RI and CT data in Table C46, Figure C48).

Combined

The fall survey swept area biomass, combining both the northern and southern management areas, had a steep decline to 4,467 metric tons in 1974 from 17,737 metric tons in 1972. Then the biomass increased substantially to 28,807 metric tons in 1983. After a considerable drop in 1986, the biomass estimates were stable throughout the rest of the time series. The biomass in 2009 was 8,454 metric tons (Table C47, Figure C49).

In the spring survey, biomass peaked at 30,831 metric tons and 28,794 metric tons in 1978 and 1981, respectively. Biomass then declined until 1998, when biomass increased slightly. There was a 75% decline from 11,337 metric tons in 2002 to 2,812 metric tons in 2003. The stock increased since then and was 9,022 metric tons in 2009 (Table C48, Figure C50).

Length Composition

The length compositions from the fall survey show a large proportion of very small fish in the northern stock (Figure C51). There has also been a truncation of size of fish with very few fish caught that are greater than 40 cm. The spring survey length composition has many fewer small fish (except for 1974) but shows the same size truncation (Figure C52).

In the south, the young-of-the-year are very dominant in the length composition, but the size truncation is less noticeable, possibly since there may have already been truncation before the time series started (Figure C53). However, the spring survey shows some truncation occurring in the late 1980s and early 1990s, with fewer fish greater than 35 cm caught in the survey (Figure C54). The winter survey shows more young fish than the spring, possibly because the survey used a cookie sweep and was able to capture small fish and, more importantly, the scallops that they inhabit (Figure C55).

Estimates of Consumption of Red Hake

Every predator that contained red hake was identified from the NEFSC FHDBS. From that original list, a subset of predators (Table C49) was examined to elucidate which predators consistently ate red hake, determined by "rules of thumb" that include having a diet composition of >1% for any five year block, and with >5 tows for each two year block and > 10 stomachs for each three year block.

Annual consumption estimates were calculated on a seasonal basis (two 6 month periods) based on spring and fall bottom trawl surveys and for each predator species. Although the food habits data collections started quantitatively in 1973, not all species of red hake predators were sampled during the full extent of this sampling program, thus the time series used here begins in 1977 (Link and Almeida 2000). This sampling program was a part of the NEFSC bottom trawl survey program (Azarovitz 1981; NEFC 1988). There are various ways to integrate seasonally, but the simple sum of the two seasonal estimates was used in this analysis. The analyses were done for various size classes of predators, and then were integrated across all predator size classes to come up with a total consumption of red hake for each predator.

This approach followed previously established and described methods for estimating consumption, using an evacuation rate model methodology. For further details, see Durbin et al. (1983), Ursin et al. (1985), Pennington (1985), Overholtz et al. (1991, 1999, 2000, 2008), Tsou & Collie (2001a, 2001b), Link & Garrison (2002), Link et al. (2006, 2008, 2009), Methratta & Link (2006), Link & Sosebee (2008), Overholtz & Link (2007, 2009), Tyrrell et al. (2007, 2008), Link and Idoine (2009), Moustahfid et al. (2009a, 2009b), and NEFSC (e.g., 2006, 2007a, 2007b, 2008, 2010a, 2010b). The main data inputs are mean stomach contents (S_i) for each red hake predator *i*, diet composition (D_{ij}) where the subscript *j* refers to red hake as a prey item, and *T* is the bottom temperature taken from the bottom trawl surveys (Taylor et al. 2005). Units for stomach estimates are in g.

As noted, to estimate per capita consumption, the gastric evacuation rate method was used (Eggers 1977, Elliott and Persson 1978). There has been copious experience in this region using these models (see references listed above). The two main parameters, α and β, were set to 0.004 and 0.115 respectively based upon prior studies and sensitivity analyses (NEFSC 2007a, 2007b). The exception is that α was set to 0.002 for elasmobranch predators consistent with and to reflect their slightly lower metabolism than teleost fishes.

Using the evacuation rate model to calculate consumption requires two variables and two parameters. The per capita consumption rate, C_{it} is calculated as:

$$C_{it} = 24 \cdot E_{it} \cdot \overline{S_{it}}^{\gamma}$$

where 24 is the number of hours in a day and the evacuation rate E_{it} is:

$$E_{it} = \alpha e^{\beta T} \qquad ;$$

and is formulated such that estimates of mean stomach contents (S_{it}) and ambient temperature (*T*; here used as bottom temperature from the NEFSC bottom trawl surveys for either season (Taylor & Bascuñán 2000, Taylor et al. 2005)) are the only data required. This was done for each predator *i* (size and species) for each time period *t* (season and year). The parameters α and β are set as values chosen noted above. The parameter γ is a shape function is almost always set to 1 (Gerking 1994).

Once daily per capita consumption rates were estimated for each red hake predator, those estimates were then scaled up to a seasonal estimate. This was done by multiplying the number days in each half year, which were then multiplied by the diet composition D_{ij} that was red hake, to estimate the seasonal per capita consumption of red hake. That is, once per capita consumption rates were estimated for each red hake predator in a temporal period (t), those estimates were then scaled up to a seasonal estimate (C'_{it} = C_{fall} or C_{spr}) by multiplying the number days in each half year:

$$C'_{it} = C_{it} \cdot 182.5$$

These were then multiplied by the diet composition D_{ijt} that was red hake, to estimate the seasonal per capita consumption of this fish C_{ijt}:

$$C_{ijt} = C'_{it} \cdot D_{ijt}$$

These were then summed to provide an annual estimate, C'_{ij}:

$$C'_{ij} = C_{ij,fall} + C_{ij,spring}$$

Once these were summed to provide an annual estimate (or the following could be seasonally and the summed), they were then scaled by the total stock abundance of each predator to estimate the amount of red hake removed by any of the predators included in the study. Swept area estimates of abundance from bottom trawl survey estimates were used for all predators (Table C49). These consumption estimates were then scaled by the total stock abundance to estimate a total amount of red hake (j) removed by any predator i, C_{ij}:

$$C_{ij} = C'_{ij} \cdot N_i \quad ,$$

where N_i is the estimate of abundance for each predator for each year. These C_{ij} were then summed across all i predators to obtain an estimate a total amount of red hake removed by these red hake predators, C_j:

$$C_j = \sum_i C_{ij} \quad .$$

Total consumptive removals by all consistent red hake predators, using swept area abundance estimates of the predators, were consistently around 5 thousand mt per year during the late 1970s to late 1990s; more recently these removals averaged approximately 10 thousand mt in the 2000s (Figure C56). For more explicit presentation of the step-by-step data series used to derive the consumptive removal results, please contact the working group, as has been done for similar prior assessments (e.g., NEFSC 2007a, 2007b).

These minimum estimates of red hake consumed by the consistent fish predators in this study were compared to total catch (Figure C56). Catch and minimum swept area estimates of consumption were approximately equal for much of the time series, with landings a little higher earlier in the time series (1970s), but with consumption the dominant source of removal more recently averaging more than five times than catch (Figure C57).

Estimates of predatory removal of red hake via consumption are likely conservative given nature of these consumption estimates. These consumption estimates should be useful to inform both the scaling of biomass estimates and the magnitude of mortalities for red hake. The estimates of consumption also imply that there has been a change in natural mortality over time. This is likely to be important in any model attempts.

There were enough red hake measured in the stomachs of the predators to pool over the entire time series (n=612). In the future, it may be useful to break into time periods. More than half of the fish measured are between 3 and 8 cm with the mode at 4 cm (Figure C58).

TOR 3. Evaluate the validity of the current stock definition, and determine whether this should be changed. Take into account what is known about migration among stock areas.

Two subpopulations of red hake are assumed to exist within the U.S. EEZ based largely by analogy with silver hake (NEFC 1986). No morphometric or genetic analyses of the population structure have been conducted. The northern red hake stock inhabits Gulf of Maine - Northern Georges Bank waters, and the southern red hake stock inhabits Southern Georges Bank - Middle Atlantic Bight waters (Figure C1). These boundaries were established at SAW 2.

Distribution

While it is likely that the northern and the southern stocks mix on Georges Bank, the degree of mixing and movement among the management areas are unknown. NEFSC trawl surveys indicate a generally continuous distribution of silver hake from the Gulf of Maine to the southern New England/Mid-Atlantic Bight (Figures C23 and C24). However, the relative density of red hake has varied through time between the northern and southern management areas. Population density as measured by the NEFSC fall bottom trawl survey increased in northern area during the mid-1980's and then declined in the 2000's (Figure C35). In contrast southern area showed stability through 1982 with a drop in 1983 and a progressive decline through 2004. Since 2004, there has been a slight increase (Figure C42). The spring trends indicate a stable biomass through 1987 followed by a decline through 1995 (Figure C36). Biomass increased through 2000 followed by a decline. The southern trends in the spring are similar to that of the fall survey (Figure C43). The proportion of the total biomass in each area has changed from 80% in the 1960s to 60-80% in the north in the last decade (Figure C59). This could indicate movement, differential mortality, or both.

Growth and Maturity

In addition to morphology, genetics, and recruitment trends, growth is often a factor in deciding whether to assess adjacent populations as separate stocks or as one combined stock. Comparisons of growth parameters k and L_∞ (Roomian and Jamili 2011, for example) and growth plots (Brooks and Ortiz 2004, for example) may be confounded by the covariance between these two parameters when simultaneously fitted to size at age data. Similar data can be fit equally well with Von Bertalanffy growth parameters having a low k and high L_∞, and vice versa, unless there are sufficient age samples for old fish. Comparison of plots with associated age data to demonstrate variance around the fitted curves can also lead to subjective mis-interpretation (e.g. determination that growth is not different when in fact it is).

A plot of mean size at age with confidence intervals, one population along the abscissa and one along the ordinate is an alternative and possibly more informative way of comparing growth characteristics between two populations. Similarities in size at age will appear along a slope=1, while differences in growth are readily identifiable as horizontal or vertical deviations from the slope=1 line and the confidence intervals show whether that deviation is significantly different from the other population. Distance between successive ages represents the annual growth increment, which of course declines with age as the fish size approaches L_{∞}. Another advantage of this approach is that it can be readily applied to cohorts and grouped by time frame, examining the growth of fish that have experienced similar environmental characteristics and food availability.

Age determination of red hake by reading otoliths is described in Penttila and Dery 1988, Chapter 9. Dery's otolith analysis concluded that red hake otoliths in the northern stock area were considerably more difficult to interpret than those from red hake captured in the southern stock area, due to "numerous and sometimes prominent checks", factors that "blur the [sic] distinction between annular zones".

The analysis also indicates that otoliths from red hake captured in the northwestern and eastern part of the Bay of Fundy (Gulf of Maine) varied from the otolith morphology for red hake captured elsewhere and had intermediate characteristics with white hake, suggesting the possible existence of hybridization in that area.

Red hake from the spring and fall surveys have been aged from 1970 to 1985. Before 1975 (1957-1974 cohorts), age 1 to 3 red hake appear to have the same growth rates in the northern and southern stock areas. Then age 4+, growth appears to slow in the southern area and continue to a higher L_{∞} in the northern stock area (Figure C60a, Figure C61a). Age 4 to 10 red hake are always larger in the north than in the south.

This general pattern of large, old red hake in the northern stock area persists for the 1975-1985 cohorts (Figure C60b, Figure C61b)). Size at age is also relatively consistent between the two cohort time series.

There are also slight differences in size at maturity between stocks although the differences are in one direction for males and the opposite for females (Figure C62).

Although the large, older fish in the northern stock area would argue for separate population modeling and stock dynamics, there appears to be considerable uncertainty in the interpretation of red hake ages in the northern stock area, due to the aforementioned otolith anomalies, potential hybridization with white hake, and possible differential exploitation patterns between the two areas. It is equivocal whether not there are two stocks, one stock or more. There is not enough information to come to a definitive conclusion.

TOR 4. Estimate measures of annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series, and characterize their uncertainty. Include a historical retrospective analysis to allow a comparison with previous assessment results.

Historical Retrospective

The last assessments for these stocks were conducted in 1990 and at the time both stocks were considered to be “under-exploited”.

In this assessment, three models were attempted. They were An Index Method (AIM), Stock Synthesis (SS3) and Statistical Catch-at-Length (SCALE). While all three had problems, AIM was considered to be most useful for guidance on reference points and stock status. The other models needed more time to be developed properly.

AIM model

> **[SAW51 Editor’s Note, Aug. 11, 2011: The AIM method described in this section mentions using a three-year centered average of the abundance index. This is just one possible way that AIM can be applied. Depending on model performance and diagnostics, the survey index averages used in AIM might instead be based on longer or shorter time series, or even based on single point estimates from individual survey abundance indices. In the 2011 red hake stock assessment, the AIM analysis and relative F were based on survey indices from single years, and not on the three-year average described in Equation 1 (below). Following the SARC51 peer review, analyses by Dr. Paul Rago demonstrated that, for red hake, the AIM model performed better using the one-year approach than with smoothed three-year averages.]**

The AIM model is a simple approach for examining the relationship between survey data and catch in data poor stock assessments. AIM is designed to address the question of whether a given rate of fishing mortality is likely to increase or decrease the population size. Survey data are used to define a relative rate of increase and the ratio of catch to survey indices provides a measure of relative fishing mortality. Theoretically the model can identify a stable point about which the stock will neither increase nor decrease in response to a fixed harvest rate. The model assumes that the resource dynamics are approximately linear with relatively minor influence of density dependent effects or variable environmental or ecological factors. Such conditions often typify stocks that have been historically harvested at high fishing rates and are therefore at low population sizes. AIM is both an analytic and graphing approach. The analytical methods can be used to define relative Fs for replacement and the graphical methods can be used to identify transient conditions that are relevant to implementation of any model. The details of the methodology are described below.

- ✓ Population biomass at time t can be written as a linear combination of historical population biomasses
- ✓ Recruitment is proportional to population biomass

- ✓ Fishing mortality is proportional to catch divided by an index of population size (relative F).
- ✓ The rate of change in population biomass is a monotonically decreasing function of relative F.
- ✓ Smoothing methods can be used to identify underlying trends.
- ✓ Randomization methods can be used to develop sampling distributions of test statistics
- ✓ Graphical methods can help identify linkages among variables

Relative F is defined as the ratio of catch to an index of population abundance. A three-year centered average of the abundance index is chosen as the measure of average stock size.

$$relF_{j,s,t} = \left(\frac{C_{s,t}}{\frac{I_{j,s,t-1} + I_{j,s,t} + I_{j,s,t+1}}{3}} \right) \qquad (1)$$

Where $relF_{j,s,t}$ = relative F for relative index j for stock s at time t
$C_{s,t}$ = catch or landings of stock s at time t (in units of weight)
$I_{j,s,t}$= Index of abundance j for stock s at time t expressed in terms of average weight per tow

The population size at any given time can be viewed as a weighted sum of previous recruitment events. For a population with a maximum age of A years, the population in year t consists of the recruits from year t-1, t-2, …t-A. At high levels of total mortality, the contributions from the earliest recruitments, say t-k-1 to t-A will diminish in importance such that the population can be viewed as the sum of recruitments from t-1 to t-k years.

Using the linearity assumption defined above, we can employ basic life history theory to write abundance at time t as a function of the biomasses in previous time periods. The number of recruits at time t (R_t) is assumed to be proportional to the biomass at time t (B_t). More formally,

$$R_t = S_o\, Egg\, B_t \qquad (2)$$

where **Egg** is the number of eggs produced per unit of biomass, and $\mathbf{S_o}$ is the survival rate between the egg and recruit stages. Survival for recruited age groups at age a and time t ($S_{a,t}$) is defined as

$$S_{a,t} = e^{-F_{a,t} - M_{a,t}} \qquad (3)$$

where F and M refer to the instantaneous rates of fishing and natural mortality, respectively. We also need to consider the weight at age a and time t ($W_{a,t}$) and the average longevity (A) of the species.

Using these standard concepts we now write the biomass at time t as a linear combination of the A previous years. Without loss of generality, we can drop the subscripts on the survival terms and assume that average weight at age is invariant with respect to time. Further, set the product S_o Egg equal to the coefficient α. The biomass at time t can now be written as

$$B_t = R_{t-1} S^1 W_1 + R_{t-2} S^2 W_2 + R_{t-3} S^3 W_3 + .. + .R_{t-(A-1)} S^{A-1} W_{A-1} + R_{t-A} S^A W_A \quad (4)$$

Substituting Eq. (2) into Eq. (4) leads to

$$B_t = \alpha B_{t-1} S^1 W_1 + \alpha B_{t-2} S^2 W_2 + \alpha B_{t-3} S^3 W_3 + .. + .\alpha B_{t-(A-1)} S^{A-1} W_{A-1} + \alpha B_{t-A} S^A W_A \quad (5)$$

If the population is replacing itself, then the left hand side of Eq. 5 will equal the right hand side. The replacement ratio can then be defined as

$$\Psi_t = \frac{B_t}{\alpha B_{t-1} S^1 W_1 + \alpha B_{t-2} S^2 W_2 + \alpha B_{t-3} S^3 W_3 + .. + .alphaB_{t-(A-1)} S^{A-1} W_{A-1} + \alpha B_{t-A} S^A W_A} \quad (6)$$

Substituting observed values of abundance indices into Eq 6 leads to

$$\Psi_t = \frac{\frac{I_t}{q}}{\alpha \frac{I_{t-1}}{q} S^1 W_1 + \alpha \frac{I_{t-2}}{q} S^2 W_2 + \alpha \frac{I_{t-3}}{q} S^3 W_3 + .. + \alpha \frac{I_{t-(A-1)}}{q} S^{A-1} W_{A-1} + \alpha \frac{I_{t-A}}{q} S^A W_A} \quad (7)$$

By noting that the q's cancel out, and letting $\varphi_j = \alpha S^j W_j$, Eq. 6 simplifies to

$$\Psi_t = \frac{I_t}{\sum_{j=1}^{A} \phi_j \quad I_{t-j}} \qquad (8)$$

All of the I_t and φ_j are positive, and at equilibrium $I_t = I_{t+1}$ and $I_t = \sum \varphi_j I_{t-j}$ both hold. Therefore $\sum \varphi_j = 1$. When the population is not at equilibrium the parameter Ψ becomes a measure of the non equilibrium state of the population and a measure of whether the population is increasing or decreasing relative to prevailing fishery and ecosystem conditions.

It would be desirable to express the parameters of φ_j weighting terms as function of the underlying parameters. Analyses of other stocks with more detailed information, such as Georges Bank haddock, have suggested that setting the φ_j to 1/A is a reasonable approximation.

Equations 2 to 8 are a long way of justifying that the ratio of current stock size to a moving average of the previous A years of stock size can be used as a measure of population growth rate. This ratio embeds some life history theory into the basis for the ratio and simultaneously provides a way of damping the variations in abundance owing to measurement error. A ratio defined as I_t/I_{t-1} has been found, as expected to be much more noisy measure of population change.

Further details on the AIM methodology may be found in Working Group (2002) and the NOAA Fisheries Toolbox 3.1 (2010a) software package http://nft.nefsc.noaa.gov/AIM.html. The relationship between $\mathbf{\Psi_t}$ and $\mathbf{relF_t}$ can be expressed as

$$\ln(\Psi_t) = a + b\ln(relF_t) \quad (9)$$

The usual tests of statistical significance do not apply for the model described in Eq. 9. The relation between $\mathbf{\Psi_t}$ and $\mathbf{relF_t}$ is of the general form of Y/X vs X where X and Y are random variables. The expected correlation between Y/X and X is less than zero and is the basis for the oft stated criticism of spurious correlation. To test for spurious correlation we developed a sampling distribution of the correlation statistic using a randomization test. The randomization test is based on the null hypothesis that the catch and survey time series represent a random ordering of observations with no underlying association. The randomization test was developed as follows:

1. Create a random time series of length **T** of $\mathbf{C_{r,t}}$ from the set $\{\mathbf{C_t}\}$ and $\mathbf{I_{r,t}}$ from the set $\{\mathbf{I_t}\}$ by sampling with replacement.
2. Compute a random time series of relative F ($\mathbf{relF_{r,t}}$) and replacement ratios ($\mathbf{\Psi_{r,t}}$)
3. Compute the r-th correlation coefficient, say $\boldsymbol{\rho_r}$ between ln($\mathbf{relF_{r,t}}$) and ln($\mathbf{\Psi_{r,t}}$).
4. Repeat steps 1 to 3 K times.
5. Compare the observed correlation coefficient $\mathbf{r_{obs}}$ with the sorted set of $\boldsymbol{\rho_r}$
6. The approximate significance level of the observed correlation coefficient $\mathbf{r_{obs}}$ is the fraction of values of $\boldsymbol{\rho_r}$ less than $\mathbf{r_{obs}}$

It should be emphasized that relF is not necessarily an adequate proxy for Fmsy, since this parameter only estimates the average mortality rate at which the stock was capable of replacing itself. Thus, while relF defined as average replacement fishing mortality is a necessary condition for an F_{msy} proxy, it is not sufficient, since the stock could theoretically be brought to the stable point under an infinite array of biomass states. The relF at replacement does however provide some guidance on the contemporary rate of harvesting and its potential impact on future stock abundance.

AIM was applied to northern and southern stocks of red hake using 1963-2009 catches which include commercial landings and discards described as “Raw C2”. An alternative catch series from 1980 to 2009, which includes recreational catch, described as “Catch 3” was also applied to both northern and southern red hake. Results of these analyses are described separately in subsequent sections. Each section consists of two tables and three graphs. For all applications Relative F was defined as the ratio of catch to 1-year average of survey abundance (Eq. 1) and the replacement ratio was defined as a 5-year moving average of previous stock sizes (Eq. 8). The relationship between catch, survey, relative F and the replacement ratio for the fall and spring survey indices are depicted for each scenario. Although none of the randomization tests resulted in significant statistical relationship between the replacement ratio and relative F, The HWG decided that the results of the shorter series were considered “best” for purposes of reference point proxies and stock status. This was instead of any more subjective look at the survey and catch data.

Application of AIM to Red Hake, Northern Stock, catch series “Raw C2”

AIM was applied to northern red hake using catches derived from the method denoted as “Raw C2”, and the NEFSC fall and spring bottom trawl survey indices (Table C50). Randomization tests for the fall and spring surveys revealed no significant statistical relationship between the replacement ratio and relative F (Table C51). In fact the randomization test suggested a low probability of obtaining test statistics greater than those observed. Relative F at replacement was poorly specified for both the fall (Figure C63) and spring surveys (Figure C64). The 90% confidence intervals for both surveys (Table C51, Figure C65) were very wide suggesting no information about the relationship between population growth rate and relative F. The six panel plots for the fall and spring surveys (Figures C63 and C64, respectively) suggest that despite a continuously decreasing relative F neither the replacement ratio nor the surveys have any consistent trends. The relationship between the relative F and survey indices suggests that the surveys appear to be changing over time. The large pulse in landings during the early 1970s followed by relatively low catches resulted in about a 3 fold increase in stock size by the early 1980s but the absence of population response in the following three decades since then suggests that factors other than fishing mortality may be responsible.

Application of AIM to Red Hake, Southern Stock, catch series “Raw C2”

AIM was applied to southern red hake using catches derived from the method denoted as “Raw C2”, and the NEFSC fall and spring bottom trawl survey indices (Table C52). Randomization tests for the fall and spring surveys revealed no significant statistical relationship between the replacement ratio and relative F (Table C53).

Trends in relative F for the fall (Figure C66) and spring (Figure C67) surveys are remarkably similar owing to similar trends in survey abundance. Abundance indices in both fall and spring surveys show increases since 2000 but remain well below rates observed before 1980. Estimated relative F at replacement for both fall and spring surveys is about 2,200 mt/kg/tow. Bootstrap estimates suggested about a 3-fold range of estimates in the 90% confidence interval (Figure C68)

Relative F at replacement was poorly specified for both the fall (Figure C66) and spring surveys (Figure C67). The 90% confidence intervals for both surveys (Table C53, Figure C68) were very wide suggesting relatively little information about the relationship between population growth rate and relative F. The relationship between the relative F and survey indices suggests that the functional relationship appears to be changing over time. The large pulse in landings during the late 1960s and early 1970s, followed by relatively low catches, was matched with consistently low survey indices. The phase plane plot of survey indices and relative F (left middle panel

Figures C66-C67) suggests three separate stanzas wherein the survey declined by similar ranges while the relative F varied by progressively smaller ranges (1967-1976, 1977-1994, 1995-2009). Such changes in the southern stock suggest that factors other than fishing mortality may be responsible for the declines in abundance.

[SAW51 Editor's Note, Aug. 11, 2011: In the 2011 red hake stock assessment for the N and S stocks, the AIM analysis and relative F's were based on survey indices from single years, and not based on the three-year average described in the AIM Methods (e.g., Equation 1).]

Application of AIM to Red Hake, Northern Stock, catch series "Catch3 short"

In the preceding sections analyses of the relationship between the replacement ratio and relative F suggested nonstationarity. More specifically, the rate of increase in stock size with respect to relative F appeared to be decreasing over time. The reduced duration of the time series for catch was designed to address the potential changes in natural mortality suggested by the consumption estimates. The working group considered another catch estimate, denoted as "Catch 3" for the period 1980-2009 for both the Northern and Southern stocks of red hake.

For northern red hake the continuous declines in landings and relatively small range of change in survey abundance resulted in a steady decline in relative F in the fall survey (Table C54, Figure C69). The replacement ratio varied about 1.0 until 2000 when it fell to low levels before rising sharply in 2009. A similar response was observed in the spring survey (Figure C70). The estimated relative Fs at replacement were nearly identical (162 and 163.1 mt/kg or 0.162 and 0.163 kt/kg; Table C55) but the spring survey estimate had a slightly smaller confidence interval. Bootstrap estimates of relF at replacement had some extreme values (Figure C71). Randomization tests suggest that the probability of observing correlations less than the observed value were 26 to 38% (Table C55).

Application of AIM to Red Hake, Southern Stock, catch series "Catch3 short"

The truncated catch time series was also considered for the southern stock of red hake (Tables C56-C57, Figures C72-C74). Catch estimates for the southern red hake stock consist of two stanzas of landings of about 5000 mt before 1994 and roughly half as much annually since then (Table C56, Figures C72-C73). Both the fall and spring surveys declined consistently during the high catch stanza and have recently increased since the early 2000s. The increase in replacement ratio since 2000 was preceded by near halving of relative F in the late 1990s from its peak value (Figures C72-C73).

The phase plane plots of survey and relative F again suggest similar population responses to exploitation but differing slopes before and after 1994. Fall and spring relative fishing mortalities at replacement are similar, 2300 vs 3038 mt/kg (2.300 vs 3.038 kt/kg; Table C57). The relative F at replacement for the fall and spring surveys have overlapping confidence intervals but randomization tests suggest that the degree of association between relative F and the replacement ratio is not significant.

AIM Model Choice

Although none of the randomization tests resulted in significant statistical relationship between the replacement ratio and relative F, the HWG decided that the results of the shorter series were considered "best" for purposes of reference point proxies and stock status. This was instead of any more subjective look at the survey and catch data at least until an analytical assessment can be developed in the future.

[SAW51 Editor's Note: The red hake SCALE and SS3 model description and results, which are described below, are included in the report mainly to document the modeling that the Red Hake Working Group provided to the SARC-51 for peer review. The results from these two models were not accepted as a basis for providing management advice.]

Stock Synthesis Model (SS3)

A forward-projecting statistical catch-at age model (Stock Synthesis 3 version 3.11c, NOAA Fisheries Toolbox (NFT) 3.1 (2010c)) was attempted to be used to estimate fishing mortality rates and stock sizes for the northern stock, southern stock and combined areas. The first attempts at modeling used the length-based model estimated catches and fit stock-recruitment relationships using both Ricker and Beverton-Holt. The results were promising, but the stock-recruitment relationships caused some problems including some negative SSBmsy estimates). After the HWG decided to use the nominal catch in the models, there were no improvements to the fits of any of the models with stock-recruitment relationships. Therefore, the SR alternative to not fit a SR relationship was used for the remainder of the models.

Other issues involved fits to the length compositions (Figure C75), particularly the fall survey in which the small fish are under-estimated in the model. The HWG decided that this may be due to a peculiarity of red hake. The survey may be catching more small fish before they settle and inhabit scallop shells. This may result in an unusual selectivity pattern not available in any current model. So the Age-0 fish were removed from the fall survey and used as a recruitment index as well as the Age-1 spring survey data.

Another length fitting problem was initially thought to be a major model problem (Figure C76). In all the model runs, there is a knife-edge increase at 55 cm. On further inspection, it was due to the binning of length data above 55 cm. The length bins above 5 cm were single cm intervals until 55 cm at which time a 5 cm and then a 10 cm bin was used. After this was changed to cm intervals through 80 cm, the fits were better, although in recent years there is some problem with the model estimating more large fish than in any of the data (Figure C77).

One of the final model runs used four fleets of catch data (landings, discards, recreational catch and consumption) and four survey indices (spring, fall, spring recruitment and fall recruitment). The fits to the survey data were not very good and showed some patterning in the residuals (Figure C78). The main problem was in the fit to the length composition of the consumption data. The single length composition did not fit the model predicted length composition (Figure C79). Several tweaks were attempted to solve this, including changing the size at age 1, moving the time of consumption from mid-year to the beginning of the year, and removing consumption to be replaced with an age-varying natural mortality. None of these options were successful and most of the variations did not converge. Therefore, no SS3 models were accepted at this time, although the HWG thought that it was worthwhile to pursue for the next assessment.

Statistical Catch-at-Length Model (SCALE)

<u>Introduction</u>

Incomplete or lack of age-specific catch and survey indices often limits the application of a full age-structured assessment (e.g. Virtual Population Analysis and many forward projecting age-structured models). Stock assessments will often rely on the simpler size/age aggregated models (e.g. surplus production models) when age-specific information is lacking. However the simpler size/age aggregated 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 large fish in a survey can provide insights on population status using a simple model framework.

The Statistical Catch At LEngth (SCALE,NOAA Fisheries Toolbox (NFT) 3.1 (2010b)) 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 (Fstart), 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 model with the sexes combined. The SCALE model will allow for missing data.

<u>Model Configuration</u>

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 and therefore population mean length/weight at age are 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 account for the 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 populations numbers at age starting with age-1 recruitment get normally distributed at one cm length intervals using the 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 (Fstart) 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 of the estimated abundance at age getting 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

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

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 a do not alter the mean length of fish at age a+1. However, it does more 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. Like 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 $\sum(\text{Vrec})^2$ 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 (Fstart), 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 comprised of 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} calculations of the sum of length are 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 and in L_{adult} and L_{lf} the input survey specified lengths up to the maximum length are 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.

<u>Application to red hake</u>

Various model formulations were attempted for the northern stock, southern stock and combined stocks. These included different natural mortalities, the alternative catch series, and different time series. All models had issues with the absence of older ages (sizes) at the end of the time series and lack of fit to the catch at the beginning of the time series. The model run done starting the time series in 1980, but the model does not fit to the declining trend in catch. The model also had a very strong retrospective pattern (Figures C80a-c). Since consumption cannot be added to SCALE as it is configured, it will no longer be considered as a potential candidate model for this red hake assessment.

5. ***State the existing stock status definitions for the terms "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; estimates or proxies for BMSY, BTHRESHOLD, and FMSY; and estimates of their uncertainty). If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.***

The overfishing definitions are taken from NEFMC (2000, 2003) and are as follows:

*The northern stock of red hake is overfished when the three-year moving average of stock biomass, derived from the fall survey, is below **1.6 kg/tow**. If an analytical assessment is available for northern red hake, then the three-year moving average will be replaced with the terminal year biomass estimate and compared with the biomass reference points.*

*Overfishing occurs when the ratio between catch and survey biomass exceeds **0.65**, the proxy for FMSY. When biomass is less than 3.1 kg/tow (the biomass target), the stock is overfished when fishing mortality is above a rate that declines linearly to zero when biomass equals the minimum biomass threshold (1.6 kg/tow).*

In 1998 the Overfishing Definition Review Panel (Applegate et al. 1998) concluded that MSY and F reference points could not be determined for southern red hake because the time series of landings and survey biomass indices did not include a period of stable landings at high biomass levels. The Panel noted that discarding could be significant, especially in the scallop and trawl fisheries. Habitat destruction was also thought to be prohibiting stock recovery since juveniles rely on intact scallop beds for shelter. However, in recent years the scallop stock has been recovering, but red hake biomass indices have not increased.

*The southern stock of red hake is in an overfished condition when the three-year moving average weight per individual in the fall survey falls below the 25th percentile of the average weight per individual from the fall survey time series 1963-1997 (0.12) **AND** when the three-year moving average of the abundance of immature fish less than 25 cm falls below the median value of the 1963-1997 fall survey abundance of fish less than 25 cm (4.72).*

In previous SAFE Reports, the Whiting Monitoring Committee (WMC) noted problems associated with the overfishing definition for southern red hake. Although the current definition is intended to identify overfished (i.e. low biomass) stock conditions, it is a better indication of overfishing (high exploitation rate) conditions. The WMC recommends that the overfishing definition for the southern stock of red hake be revisited after a benchmark stock assessment is completed.

The Hake Working Group examined both the fall and spring surveys and decided that the spring had more consistency in the AIM results (smaller confidence intervals for the relative F). The Hake Working Group also agreed with the WMC about the problems associated with the existing biomass reference point for the southern stock of red hake. Therefore the HWG proposes new BRPs (in kg/tow in Albatross units) for both northern and southern red hake stocks as follows:

> *Red hake is overfished when the three-year moving average of the spring survey weight per tow (i.e., the biomass threshold) is less than one half of the BMSY proxy, where the BMSY proxy is defined as the average observed from 1980 – 2010. The current estimates of Bthreshold for the northern and southern stocks are 1.27 kg/tow and 0.51 kg/tow, respectively.*

Overfishing occurs when the ratio between catch and survey biomass exceeds 0.163 kt/kg and 3.038 kt/kg, respectively, derived from AIM analyses from 1980-2009.

Applying the BMSY proxy to the replacement F allows for an MSY of 412 mt and 3086 mt for the northern and southern stocks, respectively.

The biomass reference points could be considerably different depending on the time series used to develop the average. For instance, if the entire time series was used, the B*MSY proxy* would be 2.43 kg/tow for the north and 1.61 for the south. If a shorter time series was chosen, for example 1990-2010, the two reference points would be 2.17 and 0.58, respectively. Other stocks have used the entire time series, but instead of the average, used the 75^{th} percentile of the series (NEFSC 2007b). This would also change the reference points to 3.22 and 2.25 kg/tow, respectively. The Working Group chose the intermediate to reflect the potential increase in natural mortality suggested by the consumption estimates.

The 80% confidence intervals around the Freplacement for the north are from 0.062-0.240 kt/kg/tow (Figure C71) and for the south are 2.240 -3.700 kt/kg/tow (Figure C74).

6. Evaluate stock status (overfished and overfishing) with respect to the existing BRPs, as well as with respect to the "new" BRPs (from Red hake TOR 5).

Based on current biological reference points in the existing FMP, the northern stock of red hake is not overfished and overfishing is not occurring. The three year delta mean biomass index (Figure C81), based on NEFSC fall bottom trawl survey data for 2007-2009 (2.87 kg/tow), was above the management threshold level (1.6 kg/tow) and slightly below the target (3.1 kg/tow). The three year average exploitation index (landings divided by biomass index, Figure C82) for 2007-2009 (0.03) was below both the target (0.39) and the threshold (0.65).

Based on current biological reference points in the existing FMP, the southern stock of red hake is not overfished and overfishing is unknown. The three year delta individual mean weight index (Figure C83), based on NEFSC fall bottom trawl survey data for 2007-2009 (0.10 kg/individual), is below the management threshold (0.12 kg/individual) but the three year average recruitment index (5.95 num/tow) is above the threshold value (4.72 num/tow).

Based on new recommended biological reference points from SARC 51, the northern stock of red hake is not overfished and overfishing is not occurring. The three year arithmetic mean biomass index (Figure C84), based on NEFSC spring bottom trawl survey data in Albatross units for 2008-2010 (2.42 kg/tow), was above the proposed management threshold (1.27 kg/tow) and slightly below the target (2.53 kg/tow). The exploitation index (catch divided by biomass index, Figure C85) for 2009 (0.103 kt/kg) was below the threshold (0.163 kt/kg).

Based on new recommended biological reference points from SARC 51, the southern stock of red hake is not overfished and overfishing is not occurring. The three year arithmetic mean biomass index (Figure C86), based on NEFSC spring bottom trawl survey data in Albatross units for 2008-2010 (0.95 kg/tow), was above the proposed management threshold (0.51 kg/tow) and slightly below the target (1.02 kg/tow). The exploitation index (catch divided by biomass index,

Figure C87) for 2009 (1.150 kt/kg) was below the threshold (3.038 kt/kg).

7. Develop and apply analytical approaches and data that can be used for conducting single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs).
a. Provide numerical short-term projections (3 years). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions about the most important uncertainties in the assessment (e.g., terminal year abundance, variability in recruitment).
b. Comment on which projections seem most realistic, taking into consideration uncertainties in the assessment.
c. Describe this stock's vulnerability to becoming overfished, and how this could affect the choice of ABC.

Stochastic projections were not performed for this assessment. However, applying the Relative F reference points to the three-year average biomass index allows catches of 394 mt in the north and 2897 mt in the south.

8. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.

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1. Updated VPA based on new stock boundaries will be undertaken
   Attempted several analytical models with no success.

2. A re-analysis of growth rate
   This assessment estimated growth parameters for the "new" stock definitions as well as smaller regions.

3. Predator/prey considerations for red hake are important
   This assessment estimated consumption of red hake by the major predators.

4. CPUE indices need to be re-calculated given new stock boundaries
   CPUE is no longer considered a valid abundance index for this species due to the management changes that have occurred in the last twenty-five years.

New Research Recommendations

- Studies to estimate discard mortality should be conducted.
- Develop explicit process and criteria for the application of length-based (vs. constant) calibration coefficients (other than purely statistical criteria such as AIC, etc.). It may be useful, if enough data exist, to attempt a cross validation with a subset of data.
- Information on consumption by more predators (including mammals, highly migratory species (HMS)) needs to be included.

- Diel (day/night) variation in consumption of hakes.
- Validation of the ageing method for red hake via tagging, radiocarbon, or tetracyclin research.
- More comprehensive analysis of red hake stock structure based on DNA (expanded genetic analysis).
- Perform a stock reduction analysis
- Continue developing an analytical assessment with Stock Synthesis or ASAP as more age data are available.
- Continue ageing the available samples.

Sources of Uncertainty

8. Catch data are uncertain given the identification issues between red and white hake, as well as possible hybridization between the two species.
9. Stock structure is not known and has been assumed by analogy with silver hake.
10. Growth estimates are from a time of assumed high mortality and should be revisited when data become available.
11. Natural mortality is unknown.
12. Consumption
    a. Minimum swept area estimates for some predator abundance does not account for q for all predators; these are likely lower estimates of predator abundance and thus these consumption estimates should be viewed as conservative estimates. Although stock assessment estimates of abundance were used for some predators, using a full range of abundance estimates from stock assessments for more predators would also likely increase the estimates noted here.
    b. Is the α too low compared to literature? These too may be somewhat conservative, but are within the range of those generally reported. Again, these should be viewed as conservative estimates.
    c. Some fish predators that did not consistently eat red hake (e.g. some of the skates, other gadids) were not included in the analysis.
    d. Also, these estimates did not include a wide range of other (non-fish) predators known to consume red hake (e.g., seabirds, squids, marine mammals), nor did they include red hake cannibalism, which is suspected to be significant. Collectively this relatively limited set of predators thus may result in these being fairly conservative estimates of overall predatory removals of red hake.
    e. Spatio-temporal overlap considerations between predators and red hake were assumed. This work was done for both red hake stocks combined and could be reevaluated for both stocks separately.

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C. Red Hake-Tables

Table C1. Nominal commercial landings of red hake (mt) from the northern stock from 1960-2009. US landings from 1994-2009 include landings reported as bait on Vessel Trip Reports.

	Northern Stock			Southern Stock			Combined Stock		
Year	US	DWF	Total	US	DWF	Total	US	DWF	Total
1960	3,792		3,792	4,286		4,286	8,078		8,078
1961	3,276		3,276	8,105		8,105	11,381		11,381
1962	1,911		1,911	11,865		11,865	13,776		13,776
1963	1,225	2,056	3,281	29,712	2,189	31,901	30,937	4,245	35,182
1964	288	1,121	1,409	32,622	10,751	43,373	32,910	11,872	44,782
1965	200	2,573	2,773	25,246	67,744	92,990	25,446	70,317	95,763
1966	885	4,690	5,575	3,985	103,937	107,922	4,870	108,627	113,497
1967	577	1,286	1,863	6,764	52,019	58,783	7,341	53,305	60,646
1968	552	2,075	2,627	7,001	11,137	18,138	7,553	13,212	20,765
1969	146	1,875	2,021	5,539	47,389	52,928	5,685	49,264	54,949
1970	261	771	1,032	4,679	6,775	11,454	4,940	7,546	12,486
1971	377	4,428	4,805	3,227	31,907	35,134	3,604	36,335	39,939
1972	538	14,488	15,026	1,995	59,199	61,194	2,533	73,687	76,220
1973	362	14,926	15,288	3,603	47,759	51,362	3,965	62,685	66,650
1974	891	6,332	7,223	2,183	24,460	26,643	3,074	30,792	33,866
1975	450	8,251	8,701	2,065	17,911	19,976	2,515	26,162	28,677
1976	653	5,684	6,337	3,905	18,560	22,465	4,558	24,244	28,802
1977	889	2	891	2,522	4,540	7,062	3,411	4,542	7,953
1978	1,223		1,223	3,327	2,136	5,463	4,550	2,136	6,686
1979	1,523		1,523	6,624	968	7,592	8,147	968	9,115
1980	1,029		1,029	3,927	155	4,082	4,956	155	5,111
1981	1,246		1,246	2,124	196	2,320	3,370	196	3,566
1982	1,210		1,210	2,993	177	3,170	4,203	177	4,380
1983	895		895	1,334	107	1,441	2,229	107	2,336
1984	1,059		1,059	1,214	57	1,271	2,273	57	2,330
1985	992		992	827	76	903	1,819	76	1,895
1986	1,457		1,457	644	50	694	2,101	50	2,151
1987	1,013		1,013	943		943	1,956		1,956
1988	862		862	871		871	1,733		1,733
1989	776		776	931		931	1,707		1,707
1990	826		826	798		798	1,624		1,624
1991	743		743	925		925	1,668		1,668
1992	918		918	1,245		1,245	2,163		2,163
1993	768		768	924		924	1,693		1,693
1994	727		727	983		983	1,710		1,710
1995	186		186	1,428		1,428	1,613		1,613
1996	409		409	700		700	1,109		1,109
1997	338		338	999		999	1,337		1,337
1998	187		187	1,154		1,154	1,342		1,342
1999	220		220	1,351		1,351	1,571		1,571
2000	197		197	1,417		1,417	1,614		1,614
2001	222		222	1,469		1,469	1,691		1,691
2002	275		275	663		663	938		938
2003	210		210	623		623	832		832
2004	103		103	588		588	691		691
2005	96		96	356		356	452		452
2006	96		96	375		375	471		471
2007	69		69	470		470	539		539
2008	52		52	580		580	632		632
2009	85		85	575		575	659		659

Table C2. US landings of red hake (mt) from the northern region by state. Unknown state landings include landings reported as bait on Vessel Trip Reports as well as industrial fishery landings.

Year	CT	ME	MD	MA	NH	NJ	NY	RI	Unknown	Total
1964				144					144	288
1965		<1		200						200
1966				371					514	885
1967		<1		118					459	577
1968				92					460	552
1969				134					12	146
1970				261					<1	261
1971		12		363					2	377
1972				538						538
1973		39		323						362
1974		17		469				<1	405	891
1975		1		448				1		450
1976		3		650				<1		653
1977		25		864				1		889
1978		18		1205				<1	<1	1,223
1979		12		1509				1	1	1,523
1980		26		1000				1	2	1,029
1981		83		1162	1			1		1,246
1982		70		1073	61	6		1		1,210
1983		56		839	<1			<1		895
1984		47		1011	1			<1		1,059
1985		77		909	<1			5		992
1986		190		1265	<1			2		1,457
1987		132		877	1			4		1,013
1988		34		763	7	<1		58		862
1989		20		675	1			79		776
1990		5	<1	719	<1			100		826
1991		4		712	<1			27		743
1992		13		818	22			65		918
1993		<1		686	21			62		768
1994		37		631	30			16	13	727
1995	7	<1	<1	122	14		2	1	40	186
1996	5			360			<1	13	31	409
1997	5	<1		309	<1	1	2	6	15	338
1998	6	<1		136			21	10	14	187
1999	23	<1		162		<1	12	7	16	220
2000	13	<1		151		<1		8	25	197
2001	22	<1		154	<1		10	15	21	222
2002	20	<1		197	<1		5	22	31	275
2003	3	<1		141	<1		7	34	25	210
2004	21			50	<1		1	2	29	103
2005	16			47	<1		1	<1	32	96
2006	12			55	<1		2	6	21	96
2007	<1	<1	<1	31			1	3	33	69
2008	<1	<1		9		<1	<1	<1	43	52
2009	1	<1		10	<1		<1	<1	74	85

Table C3. US landings of red hake (mt) from the southern region by state. Unknown state landings include landings reported as bait on Vessel Trip Reports as well as industrial fishery landings.

Year	CT	DE	ME	MD	MA	NH	NJ	NY	NC	RI	VA	Unknown	Total
1964					1160					67		31395	32,622
1965					880					119		24247	25,246
1966					39					77		3869	3,985
1967										40		6724	6,764
1968										155		6846	7,001
1969					<1					266		5273	5,539
1970										330		4349	4,679
1971					2					142		3083	3,227
1972					<1					216		1779	1,995
1973					<1					182		3421	3,603
1974					<1					193		1990	2,183
1975					<1					411		1654	2,065
1976					1					594		3310	3,905
1977					5					243		2274	2,522
1978					3		592			130		2602	3,327
1979					7		958			247		5412	6,624
1980					<1		787			317		2823	3,927
1981					5		732			184		1203	2,124
1982				12	2		427			378	7	2166	2,993
1983				15	1		439			587	16	276	1,334
1984				24	1		403			617	26	143	1,214
1985				8	1		276			418	9	115	827
1986				3	2		225	61		350	3		644
1987				8	1		171	210		548	5		943
1988				13	1		233	180		440	4		871
1989	11			21	1		319	239		337	4		931
1990	12	<1		12	2		332	96		338	6		798
1991	52	<1		5	2		274	147		441	3		925
1992	134	1		5	2		195	319		588	1		1,245
1993	149	2		5	1		234	199		333	2		924
1994	92	1		4	4		225	235		415	2	5	983
1995	418	1	<1	3	1	<1	186	272		539	1	7	1,428
1996	100		<1	2	14		61	196		324	1	2	700
1997	169			4	4		104	275	<1	430	1	12	999
1998	114			2	8		111	373	<1	544	2		1,154
1999	141			3	22		112	428	<1	641	<1	4	1,351
2000	159			<1	29		153	398	<1	676	<1	2	1,417
2001	129		1	12	15		145	451	<1	688	<1	28	1,469
2002	132	<1		<1	15	<1	61	186	<1	244	1	24	663
2003	186			<1	54		14	119	<1	249	<1	1	623
2004	169	<1		<1	77		18	98	<1	210	1	15	588
2005	156			<1	18		21	47		102	<1	12	356
2006	108	<1		1	47		19	19		174	<1	6	375
2007	121	<1		1	43		53	46		170	<1	36	470
2008	64	<1		1	30		47	73		273	2	89	580
2009	87	<1		1	45		81	74		175		113	575

Table C4. US landings of red hake (mt) from the northern region by gear. Landings reported as bait on Vessel Trip Reports and industrial fishery landings are assumed to be otter trawl.

Year	LL	OTF	OTS	SGN	OTH	Total
1964	<1	288			<1	288
1965	<1	199			<1	200
1966	<1	885				885
1967	<1	577			<1	577
1968	<1	552			<1	552
1969	1	145			<1	146
1970	1	260				261
1971	1	376				377
1972	1	538				538
1973	1	339		23	<1	362
1974	<1	890		1		891
1975	8	397	36	6	3	450
1976	41	589	4	19	1	653
1977	24	824	15	26	<1	889
1978	28	1190		4	1	1,223
1979	<1	1516	4	2	<1	1,523
1980	1	1021	1	4	1	1,029
1981	5	1140	6	95	1	1,246
1982	<1	1148	21	39	1	1,210
1983	1	866	22	4	2	895
1984	<1	1038	17	2	1	1,059
1985	3	920	44	24	<1	992
1986	<1	1174	269	5	9	1,457
1987	1	815	171	4	22	1,013
1988	1	793	46	5	16	862
1989	2	690	47	34	2	776
1990	2	720	76	22	4	826
1991	5	642	64	30	3	743
1992	4	861	22	25	6	918
1993	3	729	<1	5	32	768
1994	2	690	1	8	26	727
1995	1	171		2	12	186
1996	2	404	1	1	1	409
1997	3	323	1	2	9	338
1998	1	184		1	1	187
1999	<1	215		4	1	220
2000	<1	191		2	4	197
2001	<1	208		2	12	222
2002	<1	273		2	<1	275
2003	<1	206		1	3	210
2004	<1	100		<1	3	103
2005	<1	95		<1	1	96
2006		96		<1	<1	96
2007		69		<1	<1	69
2008	<1	52		<1	<1	52
2009		85		<1	<1	85

Table C5. US landings of red hake (mt) from the southern region by gear. Landings reported as bait on Vessel Trip Reports and industrial fishery landings are assumed to be otter trawl.

Year	LL	OTF	SGN	OTH	Total
1964		32622			32,622
1965		25246			25,246
1966		3985			3,985
1967		6764			6,764
1968		7001			7,001
1969		5539		<1	5,539
1970		4679		<1	4,679
1971		3227			3,227
1972		1983	<1	12	1,995
1973		3603			3,603
1974	<1	2183		<1	2,183
1975		2065		<1	2,065
1976		3903	<1	2	3,905
1977		2520		2	2,522
1978		3269		58	3,327
1979		6526	<1	98	6,624
1980	<1	3885	<1	42	3,927
1981		2076	<1	48	2,124
1982		2928	<1	64	2,993
1983		1265	4	65	1,334
1984		1102	1	111	1,214
1985		772	2	53	827
1986	<1	601	<1	44	644
1987	<1	889	<1	54	943
1988	<1	800	<1	70	871
1989		838	1	92	931
1990	<1	741	1	56	798
1991	<1	868	3	54	925
1992	15	1185	1	44	1,245
1993	<1	849	2	73	924
1994	<1	853	3	127	983
1995	<1	992	1	435	1,428
1996	<1	693	1	6	700
1997	<1	984	1	14	999
1998	1	1141	1	11	1,154
1999	1	1337	<1	13	1,351
2000	<1	1399	3	15	1,417
2001	1	1443	10	15	1,469
2002	<1	654	1	8	663
2003	<1	620	<1	2	623
2004	<1	576	2	10	588
2005	<1	349	<1	6	356
2006	<1	369	<1	6	375
2007		460	<1	10	470
2008	2	567	3	8	580
2009		550	<1	25	575

Table C6. US landings of red hake (mt) from the northern region by month. Landings reported as bait on Vessel Trip Reports and industrial fishery landings are included as unknown month.

Year	Unk	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1964	144	1	2	1	1	<1	6	9	17	34	48	25	2	288
1965		2	1	3	1	31	2	8	19	18	39	61	15	200
1966	514	2	2	3	3	1	4	67	93	56	54	73	13	885
1967	459	2	1	3	<1	1	23	11	9	3	24	21	21	577
1968	460	1	1	1	<1		4	5	1	5	28	42	4	552
1969	12	1	<1	1	<1	1	1	4	4	22	58	32	12	146
1970	<1	2	4	11	28	7	10	25	22	53	55	39	5	261
1971	2	4	4	8	4	6	18	32	54	75	86	61	23	377
1972		7	4	3	7	2	23	82	97	85	125	71	31	538
1973		8	3	4	12	4	10	41	56	41	81	59	45	362
1974	405	22	9	8	34	16	23	65	84	85	79	40	22	891
1975		17	6	8	19	26	43	86	51	77	58	43	16	450
1976		7	15	6	14	25	73	125	99	105	91	58	36	653
1977		20	17	42	28	48	74	154	124	105	137	79	63	889
1978	<1	17	17	19	29	33	99	255	248	211	165	90	40	1,223
1979	1	27	8	16	30	78	191	403	271	205	169	87	37	1,523
1980	2	10	7	7	15	41	133	218	176	184	130	73	32	1,029
1981		44	24	25	25	59	143	182	233	195	212	80	25	1,246
1982		29	20	14	26	44	110	175	179	193	263	100	59	1,210
1983		24	10	10	15	35	153	169	145	134	122	57	21	895
1984		20	8	4	5	18	106	199	219	185	176	79	40	1,059
1985		14	4	12	11	41	74	169	173	205	166	70	52	992
1986		18	72	65	47	75	134	146	172	156	179	217	176	1,457
1987		22	12	29	47	92	120	126	137	133	94	109	92	1,013
1988		16	7	27	14	33	61	148	160	115	145	97	38	862
1989		7	2	8	14	29	147	108	141	110	127	58	23	776
1990		18	9	6	18	23	60	170	198	97	133	49	42	826
1991		28	10	8	14	18	39	156	122	72	154	90	30	743
1992		16	8	4	2	56	66	148	144	122	175	146	31	918
1993		20	<1	<1	1	63	59	120	150	114	145	70	25	768
1994	13	5	<1	<1	16	13	39	143	155	132	127	62	23	727
1995	40	<1	1	<1	1	1	1	30	58	33	19	2	1	186
1996	31	<1	<1	<1	<1	14	89	36	79	64	81	11	2	409
1997	15	1	<1	1.3	2	12	5	27	48	53	142	28	3	338
1998	14	<1	<1	<1	6	<1	2	21	41	34	55	10	2	187
1999	16	<1	<1	<1	<1	1	4	35	44	64	47	7	4	220
2000	25	5	3	6.8	1	<1	7	24	35	26	54	8	2	197
2001	21	4	2	2.1	4	2	5	35	25	34	50	33	5	222
2002	31	2	4	<1	<1	1	3	36	43	67	64	17	5	275
2003	25	2	<1	<1	<1	1	2	40	52	42	26	15	5	210
2004	29	1	1	0.9	<1	1	<1	4	12	35	15	3	<1	103
2005	32	<1	<1	<1		<1		13	45	4	1	1	<1	96
2006	21		1	<1	<1		<1	12	41	19	1	<1	<1	96
2007	33	<1		1	<1	<1	<1	6	15	4	7	1	<1	69
2008	43	<1	<1	<1	<1	<1	<1	<1	3	1	1	2	1	52
2009	74		<1	<1		<1	<1	5	3	2	<1	1	<1	85

Table C7. US landings of red hake (mt) from the southern region by month. Landings reported as bait on Vessel Trip Reports and industrial fishery landings are included as unknown month.

Year	Unk	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1964	31395	<1	2	<1	114	899	173	6	3	1	4	8	16	32,622
1965	24247	2	2	11	50	724	102	43	24	2	14	23	3	25,246
1966	3869	1	8	9	8	2	45	8	6	5	2	5	16	3,985
1967	6724	1	<1	2	3	<1	2	2	6	<1	8	8	7	6,764
1968	6846	2	1	3	<1	5	14	15	34	14	14	31	22	7,001
1969	5273	<1	2	7	19	23	44	48	26	10	11	39	38	5,539
1970	4349	11	4	8	14	22	77	61	35	20	9	26	42	4,679
1971	3083	2	1	8	8	9	23	21	18	2	4	4	43	3,227
1972	1779	24	5	2	2	12	22	26	25	22	<1	24	54	1,995
1973	3421	47	7	6	6	13	23	9	17	2	2	16	33	3,603
1974	1990	24	12	24	44	30	12	3	1	<1	<1	11	33	2,183
1975	1654	41	12	4	14	50	17	21	2	4	13	43	189	2,065
1976	3310	110	15	25	85	34	12	8	10	14	19	152	111	3,905
1977	2274	21	1	7	4	24	18	12	21	17	8	42	73	2,522
1978	2602	92	14	50	142	180	54	29	24	13	14	54	60	3,327
1979	5412	167	162	60	272	164	86	33	21	23	47	80	96	6,624
1980	2823	150	70	52	174	147	104	36	20	25	52	116	158	3,927
1981	1203	45	7	18	196	165	48	26	24	15	35	105	237	2,124
1982	2166	74	32	61	137	124	41	24	34	38	30	78	154	2,993
1983	276	231	42	61	99	227	86	35	54	38	19	28	139	1,334
1984	143	134	47	128	117	182	129	42	61	47	46	46	92	1,214
1985	115	90	17	38	113	170	83	35	29	27	32	9	69	827
1986		56	37	55	120	131	77	37	19	14	18	16	66	644
1987		71	86	107	80	170	122	70	54	38	8	35	101	943
1988		100	51	86	172	145	73	24	9	10	14	47	141	871
1989		62	48	26	109	141	99	58	20	30	34	42	108	931
1990		40	21	45	221	177	43	45	32	38	47	20	41	798
1991		64	44	43	168	143	56	19	53	71	28	86	94	925
1992		142	125	99	170	241	52	29	61	72	47	24	47	1,245
1993		74	80	67	75	76	108	37	40	49	40	49	77	924
1994	5	64	86	98	152	126	82	29	34	44	77	46	49	983
1995	7	87	112	97	137	108	117	113	97	152	106	165	128	1,428
1996	2	66	50	55	84	83	50	71	28	30	44	69	66	700
1997	12	121	87	125	112	94	127	77	40	66	43	27	70	999
1998		102	109	84	86	79	153	122	42	141	84	73	80	1,154
1999	4	119	146	131	88	206	123	74	91	75	106	76	111	1,351
2000	2	79	158	120	120	150	187	69	123	165	113	61	68	1,417
2001	28	123	139	218	163	234	175	124	87	42	51	38	46	1,469
2002	24	54	56	60	52	54	99	62	36	55	31	38	42	663
2003	1	56	51	60	53	61	52	40	16	52	60	61	60	623
2004	15	36	49	54	59	74	38	52	72	42	39	39	19	588
2005	12	41	27	32	47	27	39	33	20	29	15	17	18	356
2006	6	18	24	37	37	40	38	54	40	15	24	15	27	375
2007	36	23	25	30	27	49	32	61	50	54	26	23	32	470
2008	89	29	34	29	26	46	59	43	50	47	65	22	38	580
2009	113	44	22	39	42	44	88	31	27	46	36	19	25	575

Table C8. Nominal landings of red hake (mt) by region and half year. Landings reported as bait on Vessel Trip Reports and industrial fishery landings are included as unknown half.

	Northern Stock				Southern Stock			
Year	1	2	Unknown	Total	1	2	Unknown	Total
1964	11	134	144	288	1188	39	31395	32,622
1965	39	161		200	890	109	24247	25,246
1966	15	356	514	885	74	42	3869	3,985
1967	28	90	459	577	9	31	6724	6,764
1968	7	86	460	552	25	130	6846	7,001
1969	3	131	12	146	96	171	5273	5,539
1970	61	200	<1	261	137	194	4349	4,679
1971	44	331	2	377	52	92	3083	3,227
1972	47	491		538	66	150	1779	1,995
1973	40	323		362	102	80	3421	3,603
1974	112	374	405	891	145	48	1990	2,183
1975	118	331		450	139	272	1654	2,065
1976	140	514		653	281	314	3310	3,905
1977	227	662		889	75	173	2274	2,522
1978	214	1009	<1	1,223	531	193	2602	3,327
1979	349	1173	1	1,523	912	300	5412	6,624
1980	213	813	2	1,029	697	408	2823	3,927
1981	320	926		1,246	478	443	1203	2,124
1982	243	967		1,210	469	358	2166	2,993
1983	247	648		895	746	312	276	1,334
1984	161	897		1,059	736	334	143	1,214
1985	157	835		992	511	201	115	827
1986	412	1045		1,457	475	169		644
1987	323	690		1,013	637	306		943
1988	158	704		862	626	245		871
1989	208	567		776	484	292		931
1990	134	689		826	547	224		798
1991	118	624		743	518	350		925
1992	152	766		918	830	280		1,245
1993	143	625		768	480	293		924
1994	73	641	13	727	607	279	5	983
1995	4	143	40	186	658	762	7	1,428
1996	104	274	31	409	390	309	2	700
1997	21	301	15	338	666	321	12	999
1998	8	164	14	187	612	542		1,154
1999	5	200	16	220	814	532	4	1,351
2000	22	150	25	197	816	600	2	1,417
2001	20	183	21	222	1052	388	28	1,469
2002	11	232	31	275	375	264	24	663
2003	5	180	25	210	333	290	1	623
2004	3	70	29	103	310	263	15	588
2005	<1	64	32	96	213	132	12	356
2006	1	73	21	96	194	175	6	375
2007	2	33	33	69	186	247	36	470
2008	<1	9	43	52	223	266	89	580
2009	<1	10	74	85	278	184	113	575

Table C9. Nominal landings of white hake (mt) by market and half year for the northern region.

	Unclassified			Small			Large		
Year	1	2	Total	1	2	Total	1	2	Total
1985	794	2009	2803	418	705	1123	633	1751	2385
1986	873	1690	2563	359	312	672	651	1245	1896
1987	517	985	1502	448	1449	1897	473	1312	1785
1988	155	557	712	812	1657	2469	449	1013	1462
1989	206	870	1076	453	944	1397	645	1364	2010
1990	187	744	931	733	1796	2529	446	911	1358
1991	366	824	1190	692	2324	3016	337	861	1199
1992	246	1367	1612	1193	3690	4883	499	1063	1562
1993	493	1372	1865	1229	2205	3434	564	1193	1757
1994	370	663	1033	566	971	1537	554	951	1505
1995	285	732	1017	383	1157	1540	504	952	1456
1996	214	484	698	333	921	1253	505	694	1199
1997	39	46	85	269	764	1033	289	772	1061
1998	38	37	76	183	590	773	442	945	1387
1999	11	34	46	296	568	864	734	881	1614
2000	10	21	31	421	642	1062	775	1036	1811
2001	9	64	73	453	857	1310	895	1119	2014
2002	10	20	30	662	470	1132	810	1205	2015
2003	4	33	37	288	362	650	1887	1801	3688
2004	57	174	231	211	374	584	1469	1134	2603
2005	388	231	619	201	339	540	792	662	1454
2006	231	108	339	140	178	319	483	519	1003
2007	134	90	224	97	217	314	416	532	949
2008	41	24	65	119	295	414	294	501	794
2009	41	24	65	201	368	569	463	552	1015

Table C10. Nominal landings of white hake (mt) by market and half year for the southern region.

	Unclassified			Small			Large		
Year	1	2	Total	1	2	Total	1	2	Total
1985	40	6	46	15	5	20	36	7	43
1986	34	10	43	9	2	11	44	8	52
1987	43	14	58	12	14	26	24	4	28
1988	51	15	65	26	13	39	17	7	24
1989	19	2	21	11	10	21	13	9	22
1990	22	15	36	35	13	49	19	5	24
1991	46	32	78	72	12	84	30	10	40
1992	95	23	118	162	16	179	83	7	90
1993	65	36	102	162	42	204	86	18	104
1994	174	45	219	106	57	163	133	142	275
1995	74	40	113	76	16	92	92	14	106
1996	48	23	71	25	2	28	31	2	33
1997	22	5	28	8	4	12	2	1	4
1998	13	11	25	35	10	45	29	33	61
1999	13	7	20	25	8	33	38	6	44
2000	18	10	28	23	7	31	15	6	21
2001	23	5	28	15	15	30	15	11	27
2002	7	2	9	36	8	44	24	11	35
2003	4	1	5	12	4	16	30	8	37
2004	1	15	16	19	6	25	41	11	52
2005	26	8	35	5	5	10	10	3	12
2006	9	5	14	9	6	14	5	7	12
2007	1	1	2	19	3	22	13	4	18
2008	11	2	14	9	14	23	5	9	14
2009	6	3	8	12	9	20	14	5	18

Table C11. Summary of number of red hake measured by port samplers by region and half.

	North			South		
Year	1	2	Total	1	2	Total
1975					206	206
1976					103	103
1977				159		159
1979					94	94
1980				318		318
1981		101	101			
1982		431	431			
1983	125	1232	1357	182		182
1984	209	546	755	982	200	1182
1985	43	914	957	1139	599	1738
1986	335	1227	1562	948	320	1268
1987		967	967	786	213	999
1988	666	1172	1838	612	100	712
1989	111	410	521	201	309	510
1990	242	607	849	518	275	793
1991	826	214	1040	701	299	1000
1992		111	111	400	404	804
1993		95	95	303	100	403
1994				419	356	775
1995				1067	62	1129
1996					193	193
1997				1730	246	1976
1998		138	138	904	309	1213
1999		47	47	748	795	1543
2000				250	388	638
2001		99	99	1010	720	1730
2002				432	406	838
2003		345	345	1068	509	1577
2004		370	370	755	1195	1950
2005				1030	1208	2238
2006		93	93	1255	1146	2401
2007		37	37	2819	1758	4577
2008			957	2560	2183	4743
2009			1562	1139	599	1738

Table C12. Summary of number of white hake measured by port samplers by market category and half in the northern region.

	Uncl			Small			Large		
Year	1	2	Total	1	2	Total	1	2	Total
1985	101	397	498	356	640	996	509	790	1299
1986	215	398	613	686	668	1354	332	221	553
1987	245	237	482	443	998	1441	111	754	865
1988	100	41	141	1414	823	2237	233	299	532
1989	100	106	206	185	511	696		410	410
1990		101	101	613	749	1362	214	306	520
1991	207	94	301	674	1118	1792	474	728	1202
1992	97	237	334	1177	1423	2600	94	622	716
1993	214	293	507	1097	616	1713	361	851	1212
1994	236	697	933	397	1063	1460	303	667	970
1995	100		100	191	535	726	221	103	324
1996	199	546	745	101	976	1077	202	1210	1412
1997		58	58	1634	2455	4089	1166	1574	2740
1998		118	118	500	886	1386	897	1226	2123
1999				213	640	853	831	425	1256
2000				1172	1146	2318	229	336	565
2001				881	887	1768	784	1457	2241
2002				1171	1746	2917	1055	761	1816
2003				1637	1500	3137	1945	3285	5230
2004				988	978	1966	3536	1646	5182
2005	28	61	89	1203	1760	2963	1849	1711	3560
2006				1467	1936	3403	1922	1748	3670
2007				1524	1759	3283	1469	1489	2958
2008				1226	1857	3083	1698	1467	3165
2009				981	1691	2672	1248	1920	3168

Table C13. Summary of number of white hake measured by port samplers by market category and half in the southern region.

	Uncl			Small			Large		
Year	1	2	Total	1	2	Total	1	2	Total
1985									
1986									
1987	113		113						
1988				100		100			
1989									
1990				104		104			
1991				151		151			
1992				52	55	107	100		100
1993				50		50	100		100
1994									
1995									
1996									
1997									
1998				100		100			
1999					107	107		104	104
2000									
2001									
2002							85		85
2003				92	96	188			
2004				96		96			
2005	111		111	61		61	106		106
2006									
2007	201		201						
2008				142		142	5		5
2009					101	101	28		28

Table C14. Sampling intensity (mt/100 lengths) of red hake by region and half.

	North		South	
Year	1	2	1	2
1975				132
1976				304
1977			47	
1978				
1979				320
1980			219	
1981		917		
1982		224		
1983	198	53	410	
1984	77	164	75	167
1985	364	91	45	34
1986	123	85	50	53
1987		71	81	144
1988	24	60	102	245
1989	187	138	241	95
1990	55	114	106	82
1991	14	292	74	117
1992		690	207	69
1993		658	158	293
1994			145	78
1995			62	1228
1996				160
1997			38	131
1998		119	68	175
1999		425	109	67
2000			326	155
2001		184	104	54
2002			87	65
2003		52	31	57
2004		19	41	22
2005			21	11
2006		79	15	15
2007		91	7	14
2008			9	12
2009			24	31

Table C15. Sampling Intensity (mt/100 lengths) of white hake by market category and half in the northern region.

	Uncl		Small		Large	
Year	1	2	1	2	1	2
1985	786	506	118	110	124	222
1986	406	425	52	47	196	563
1987	211	416	101	145	426	174
1988	155	1358	57	201	193	339
1989	206	820	245	185		333
1990		737	120	240	209	298
1991	177	877	103	208	71	118
1992	253	577	101	259	531	171
1993	230	468	112	358	156	140
1994	157	95	143	91	183	143
1995	285		201	216	228	925
1996	108	89	329	94	250	57
1997		80	16	31	25	49
1998		32	37	67	49	77
1999			139	89	88	207
2000			36	56	338	308
2001			51	97	114	77
2002			57	27	77	158
2003			18	24	97	55
2004			21	38	42	69
2005	1387	378	17	19	43	39
2006			10	9	25	30
2007			6	12	28	36
2008			10	16	17	34
2009			20	22	37	29

Table C16. Pooling of red hake port length samples to estimate length and species composition of the commercial landings by region and half.

	North			South	
	Half 1	Half 2		Half 1	Half 2
1985					
1986					
1987					
1988					
1989					
1990					
1991					
1992					
1993					
1994					
1995					
1996					
1997					
1998					
1999					
2000					
2001					
2002					
2003					
2004					
2005					
2006					
2007					
2008					
2009					

Table C17. Pooling of white hake port length samples to estimate length and species composition of the commercial landings by region, market category and half.

	North							South					
	Uncl		Small		Large			Uncl		Small		Large	
	Half 1	Half 2	Half 1	Half 2	Half 1	Half 2		Half 1	Half 2	Half 1	Half 2	Half 1	Half 2
1985													
1986													
1987													
1988													
1989													
1990													
1991													
1992													
1993													
1994													
1995													
1996													
1997													
1998													
1999													
2000													
2001													
2002													
2003													
2004													
2005													
2006													
2007													
2008													
2009													

Table C18. Comparison of nominal landings (mt) with the length-based model-estimated landings (mt) by stock.

	Northern Stock		Southern Stock	
Year	Nominal	Length-Based Model Estimate	Nominal	Length-Based Model Estimate
1960	3792		4286	
1961	3276		8105	
1962	1911		11865	
1963	3281		31901	
1964	1409	272	43373	30087
1965	2773	338	92990	64462
1966	5575	442	107922	74815
1967	1863	191	58783	40755
1968	2627	237	18138	12612
1969	2021	206	52928	36725
1970	1032	172	11454	8003
1971	4805	452	35134	24428
1972	15026	1111	61194	42484
1973	15288	1133	51362	35652
1974	7223	674	26643	18496
1975	8701	701	19976	13861
1976	6337	575	22465	15584
1977	891	274	7062	4914
1978	1223	291	5463	3809
1979	1523	269	7592	5273
1980	1029	264	4082	2854
1981	1246	437	2320	1668
1982	1210	454	3170	2253
1983	895	449	1441	1052
1984	1059	478	1271	959
1985	992	827	903	739
1986	1457	557	694	502
1987	1013	452	943	755
1988	862	598	871	656
1989	776	486	931	637
1990	826	601	798	480
1991	743	321	925	593
1992	918	456	1245	684
1993	768	302	924	865
1994	727	391	983	924
1995	186	296	1428	1381
1996	409	183	700	654
1997	338	179	999	827
1998	187	118	1154	1075
1999	220	141	1351	1084
2000	197	105	1417	1413
2001	222	195	1469	1381
2002	275	240	663	592
2003	210	149	623	537
2004	103	40	588	278
2005	96	23	356	298
2006	96	67	375	338
2007	69	40	470	357
2008	52	7	580	489
2009	85	37	575	431

Table C19. Red hake discards (mt) from the northern region by gear and half. The discards from 1981-1988 (1991 for scallop dredge and longline) are hind-cast using the first three years of available data. The otter trawl discards are hind-cast combining mesh-sizes.

	Longline			Large Mesh Otter Trawl			Small Mesh Otter Trawl			Sink Gill Net			Scallop Dredge			Shrimp Trawl		
	1	2	Total	1	2	Total	1	2	Total	1	2	Total	1	2	Total	1	2	Total
1981	3.1	1.8	4.8	269.8	921.1	1190.9	Na			2.1	4.0	6.1	6.9	8.1	15.0	107.2	0.5	107.7
1982	2.8	1.5	4.3	265.9	1026.5	1292.4	Na			0.9	3.6	4.5	4.1	6.2	10.4	135.4	12.9	148.3
1983	4.0	1.7	5.8	293.1	865.3	1158.4	Na			1.0	3.0	3.9	3.5	4.9	8.4	137.1	39.5	176.7
1984	2.7	0.3	3.1	244.8	795.7	1040.5	Na			0.9	3.9	4.8	2.0	2.9	4.9	178.9	95.1	274.0
1985	2.5	0.8	3.4	211.5	671.4	882.9	Na			1.0	3.3	4.3	1.4	2.8	4.2	249.7	125.5	375.2
1986	3.6	1.1	4.7	181.8	538.3	720.2	Na			1.2	3.5	4.7	2.6	3.0	5.6	304.7	148.7	453.4
1987	6.3	3.3	9.6	154.7	483.8	638.5	Na			1.1	3.6	4.6	3.1	5.8	8.9	308.6	82.2	390.9
1988	6.7	4.2	10.8	144.7	461.3	606.0	Na			1.2	3.6	4.8	3.9	7.4	11.3	182.4	81.6	264.0
1989	6.2	3.3	9.5	301.2	94.2	395.3	4.2	687.9	692.0	2.5	4.9	7.4	4.4	8.5	12.9	259.4	70.5	329.9
1990	4.9	3.3	8.2	30.8	112.0	142.8	10.2	101.6	111.8	1.1	3.6	4.7	3.3	9.7	13.0	194.0	120.5	314.5
1991	31.2	17.9	49.2	7.7	214.8	222.5	17.8	309.4	327.2	0.7	3.2	3.9	1.2	1.6	2.8	168.6	44.0	212.5
1992	0.4	0.2	0.6	54.9	93.0	147.9	69.4	417.5	486.9	0.5	0.4	0.9	0.2	2.2	2.4	77.1	10.5	87.6
1993	0	0	0	17.6	3.1	20.7	5.1	27.5	32.6	0.4	0.4	0.8	9.2	15.4	24.5	4.4	0.2	4.6
1994	0	0	0	8.9	0	8.9	3.0	49.8	52.8	0.1	3.7	3.8	1.6	2.1	3.7	3.0	4.5	7.5
1995	3.6	4.5	8.1	2.5	13.0	15.5	3.2	22.9	26.1	0.9	0.7	1.6	0.3	0.8	1.0	3.8	6.9	10.7
1996	3.3	3.5	6.9	11.8	0	11.8	25.1	498.9	524.0	0.8	2.9	3.7	0.1	3.7	3.8	74.8	31.0	105.8
1997	3.5	3.6	7.1	3.7	8.5	12.2	0.5	3.6	4.0	0.8	0.2	1.1	0.2	5.5	5.7	84.8	10.2	95.0
1998	2.7	4.1	6.8	5.5	2.5	8.0	7.5	87.4	94.8	0.4	1.1	1.5	0	0	0	17.7	1.0	18.7
1999	2.7	3.6	6.3	6.7	304.7	311.4	6.6	128.4	135.1	0.6	2.3	2.8	1.7	1.9	3.7	8.1	0.2	8.2
2000	1.6	3.8	5.4	0	27.0	27.0	0.1	0.4	0.4	2.1	1.6	3.7	2.2	4.1	6.2	11.9	0.2	12.1
2001	2.2	2.6	4.9	40.0	7.6	47.6	0.2	65.2	65.4	7.6	4.2	11.8	2.7	2.1	4.8	0.7		0.7
2002	0.8	0.5	1.3	4.1	31.1	35.2	0	53.7	53.7	0.5	2.7	3.2	3.1	4.1	7.2	0.2		0.2
2003	0	0	0	10.0	18.5	28.5	0.0	27.8	27.8	0.9	1.3	2.3	0	28.6	28.6	0.4		0.4
2004	0.0	1.7	1.7	10.4	15.9	26.3	0	25.6	25.6	0.9	1.0	1.8	0.8	0.4	1.2	0.8	0.0	0.8
2005	0.5	2.4	2.9	5.3	30.8	36.1	0.2	10.8	10.9	0.1	0.4	0.5	0.2	6.6	6.8	0.2	0.0	0.2
2006	0.2	1.3	1.5	3.4	38.4	41.8	0.0	124.6	124.6	0.4	8.4	8.9	0.6	0.6	1.1	0.1	3.3	3.3
2007	0	0.9	0.9	6.6	14.8	21.3	4.6	72.7	77.3	0.0	0.1	0.1	2.3	18.1	20.4	5.9	1.4	7.4
2008	0.0	2.2	2.2	5.6	28.6	34.2	2.1	16.4	18.5	2.4	0.2	2.6	0.2	0.4	0.6	0.8	0.5	1.3
2009	0.2	0.4	0.6	7.8	37.3	45.2	5.6	39.4	45.0	0.2	0.8	1.0	0.3	1.7	2.0	0.3	0.9	1.2

Table C20. Red hake discards (mt) from the southern region by gear and half. The discards from 1981-1988 (1991 for scallop dredge and longline) are hind-cast using the first three years of available data. The otter trawl discards are hind-cast combining mesh-sizes.

	Longline			Large Mesh Otter Trawl			Small Mesh Otter Trawl			Sink Gill Net			Scallop Dredge		
	1	2	Total	1	2	Total	1	2	Total	1	2	Total	1	2	Total
1981	0.4	1.0	1.4	1592.0	1113.4	2705.4	Na			0	0.003	0.003	3.4	4.6	8.0
1982	0.3	0.5	0.8	1806.3	1959.1	3765.3	Na			0	0.003	0.003	4.4	5.3	9.7
1983	0.2	0.5	0.7	1958.6	1918.1	3876.7	Na			0	0.005	0.005	5.8	5.6	11.4
1984	0.2	0.3	0.5	2132.9	1764.5	3897.4	Na			0	0.008	0.008	6.9	5.3	12.2
1985	0.1	0.5	0.7	1741.8	1214.9	2956.7	Na			0	0.004	0.004	6.0	5.1	11.1
1986	0.1	0.5	0.6	1724.9	1650.1	3375.1	Na			0	0.007	0.007	6.0	6.9	12.9
1987	0.2	0.6	0.8	1787.8	1503.9	3291.7	Na			0	0.008	0.008	10.7	9.9	20.6
1988	0.1	0.1	0.2	2002.2	1439.3	3441.5	Na			0	0.008	0.008	11.0	9.1	20.0
1989	0.07	0.15	0.21	39.4	19.5	58.9	1875.0	3047.6	4922.6	0	0	0	15.0	8.8	23.8
1990	0.05	0.21	0.26	1112.1	226.0	1338.1	1717.4	1634.8	3352.2	0	0	0	18.8	38.3	57.0
1991	0.83	0.47	1.30	380.9	65.2	446.1	1439.0	704.8	2143.8	0	0	0	13.6	7.2	20.8
1992	0	1.96	1.96	595.9	172.9	768.9	3542.2	2009.1	5551.4	0.033	0.144	0.177	14.7	5.9	20.6
1993	0	0	0	53.5	0.5	54.1	2089.5	3146.7	5236.3	0.064	0.111	0.175	7.1	10.0	17.2
1994	0	0	0	38.5	1.1	39.6	1187.7	442.1	1629.9	0	0.012	0.012	7.2	43.1	50.3
1995	0	0	0	38.7	1.7	40.5	718.3	542.6	1260.8	0.007	0	0.007	19.5	8.0	27.5
1996	1.06	0.75	1.82	4.8	8.1	12.9	325.6	20.6	346.2	0	0	0	8.2	10.5	18.7
1997	1.21	1.04	2.25	0.4	290.9	291.3	2062.4	0.2	2062.6	0.056	0	0.056	43.1	23.2	66.3
1998	1.17	0.80	1.97	0.3	0	0.3	199.6	534.1	733.7	0.015	0	0.015	2.7	1.5	4.3
1999	0.90	0.42	1.31	0	0	0	985.9	4.9	990.8	0.148	0	0.148	24.1	43.9	68.0
2000	0.60	0.52	1.11	11.2	1.5	12.8	108.6	9.7	118.3	0.032	0	0.032	77.9	39.7	117.6
2001	0.84	0.84	1.68	0.0	0	0.0	76.6	22.4	99.0	0.076	0	0.076	17.3	19.6	36.9
2002	0	0	0	0.6	0.8	1.4	6.5	292.7	299.2	0.148	0	0.148	3.0	23.2	26.2
2003	0	0	0	10.3	37.8	48.1	272.0	14.9	286.9	0	0	0	1.6	8.4	10.0
2004	0.01	0.01	0.01	22.2	91.4	113.6	213.3	259.5	472.8	0	0	0	12.0	17.3	29.4
2005	0.03	0.01	0.04	56.0	75.0	131.0	232.1	581.7	813.9	0	0	0	7.0	55.3	62.3
2006	0.01	0.08	0.09	43.6	56.4	99.9	378.6	95.3	473.9	0	0	0	27.4	72.5	99.9
2007	3.20	4.35	7.55	85.5	45.8	131.3	1188.7	196.6	1385.3	0	0	0	9.3	12.0	21.3
2008	3.78	3.64	7.42	96.6	16.7	113.3	488.4	150.3	638.7	0	0	0	17.4	37.0	54.4
2009	2.76	4.77	7.53	105.0	36.8	141.7	110.1	548.2	658.4	0	0	0	33.6	27.7	61.3

Table C21. White hake discards (mt) from the northern region by gear and half. The discards from 1981-1988 (1991 for scallop dredge and longline) are hind-cast using the first three years of available data. The otter trawl discards are hind-cast combining mesh-sizes.

	Longline			Large Mesh Otter Trawl			Small Mesh Otter Trawl			Sink Gill Net			Scallop Dredge			Shrimp Trawl		
	1	2	Total	1	2	Total	1	2	Total	1	2	Total	1	2	Total	1	2	Total
1981	1.2	0.8	2.0	106.0	537.6	643.6	Na			18.6	65.6	84.2	8.9	127.1	136.0	6.9	0.1	7.0
1982	1.1	0.6	1.8	104.5	599.2	703.6	Na			8.1	59.1	67.2	5.3	98.2	103.5	8.7	3.7	12.4
1983	1.6	0.8	2.4	115.2	505.0	620.1	Na			8.6	49.1	57.7	4.5	77.0	81.5	8.8	11.3	20.2
1984	1.1	0.1	1.3	96.2	464.4	560.6	Na			8.2	64.6	72.8	2.6	46.2	48.8	11.5	27.3	38.8
1985	1.0	0.4	1.3	84.1	418.2	502.2	Na			8.8	55.3	64.1	1.8	44.3	46.1	16.1	36.0	52.1
1986	1.4	0.5	1.9	73.5	328.4	401.9	Na			10.8	57.9	68.7	3.4	47.5	50.9	19.6	42.7	62.3
1987	2.5	1.4	4.0	61.8	292.1	353.9	Na			9.7	58.8	68.5	4.0	91.3	95.3	19.9	23.6	43.5
1988	2.6	1.8	4.4	57.6	278.1	335.7	Na			10.8	59.9	70.8	5.0	116.3	121.3	11.8	23.4	35.2
1989	2.48	1.45	3.93	70.7	288.8	359.4	49.94	86.52	136.46	11.6	22.3	33.9	5.61	133.97	139.58	9.78	17.42	27.20
1990	1.98	1.43	3.40	16.1	79.8	95.9	1.04	268.18	269.22	8.5	124.3	132.8	2.02	144.98	147.00	8.65	3.73	12.39
1991	1.22	0.70	1.93	6.5	132.3	138.8	1.82	31.57	33.38	18.3	46.4	64.7	7.85	10.07	17.91	21.63	46.26	67.89
1992	11.49	7.25	18.74	42.7	219.8	262.5	33.59	0	33.59	34.4	94.2	128.5	3.92	11.86	15.78	71.90	1.01	72.91
1993	0	0	0	28.8	62.8	91.5	14.52	276.75	291.27	62.8	167.4	230.2	1.93	278.97	280.90	3.37	0.54	3.91
1994	0	0	0	14.9	0	14.9	3.93	64.31	68.24	1.7	19.0	20.7	0.99	1.31	2.29	5.43	6.02	11.45
1995	4.23	5.28	9.52	27.3	88.0	115.2	0.74	5.01	5.76	2.0	43.3	45.3	0.50	1.50	2.00	12.34	1.00	13.34
1996	3.89	4.13	8.02	17.4	0.5	18.0	1.22	8.24	9.46	7.1	73.2	80.3	0.04	2.83	2.87	15.69	1.64	17.33
1997	4.12	4.24	8.36	3.6	13.8	17.4	4.10	31.67	35.76	17.0	23.0	40.0	0.03	0.65	0.68	2.31	0.28	2.58
1998	3.13	4.84	7.97	25.5	21.5	47.0	0.24	2.80	3.04	2.2	2.3	4.5	22.47	24.89	47.36	5.46	0.30	5.75
1999	3.22	4.17	7.38	3.8	106.2	110.0	0	0	0	8.9	4.6	13.6	1.16	1.38	2.53	2.48	0.06	2.54
2000	1.82	4.49	6.31	40.6	73.1	113.7	0.25	1.34	1.59	5.8	8.9	14.7	1.43	2.66	4.08	3.65	0.06	3.71
2001	2.62	3.10	5.72	55.2	139.0	194.2	2.68	0	2.68	1.3	47.0	48.2	0.69	0.53	1.22	0		0
2002	1.27	0.82	2.09	49.1	51.5	100.7	0	0.17	0.17	1.4	2.7	4.1	0.31	0.41	0.72	0.06		0.06
2003	0	0	0	30.4	26.5	56.9	0.02	0	0.02	7.3	8.0	15.2	0.09	0.46	0.55	0.21		0.21
2004	0	2.02	2.02	6.7	31.5	38.2	0.00	0.85	0.85	1.2	10.0	11.2	0.00	0.00	0.01	0.33	0.01	0.34
2005	0.11	3.08	3.19	5.4	14.9	20.3	0.06	0.49	0.56	2.6	13.1	15.7	0	0.77	0.77	0.40	0.02	0.42
2006	0.05	2.51	2.55	7.0	15.7	22.7	0.01	0.09	0.11	1.8	12.5	14.3	0.13	0.19	0.32	1.00	0	1.00
2007	0	0.77	0.77	3.9	5.6	9.5	0.03	0.48	0.51	2.5	2.1	4.6	0.25	0.13	0.38	3.54	0.85	4.39
2008	0.03	3.13	3.16	2.6	8.3	10.9	0.09	0.73	0.82	3.3	8.8	12.1	0.04	0.13	0.17	3.29	0.82	4.11
2009	0.04	0.26	0.30	8.0	13.7	21.6	0.17	1.21	1.39	2.4	4.9	7.3	0	0.86	0.86	2.54	1.83	4.38

Table C22. White hake discards (mt) from the southern region by gear and half. The discards from 1981-1988 (1991 for scallop dredge and longline) are hind-cast using the first three years of available data. The otter trawl discards are hind-cast combining mesh-sizes.

	Longline			Large Mesh Otter Trawl			Small Mesh Otter Trawl			Sink Gill Net			Scallop Dredge		
	1	2	Total	1	2	Total	1	2	Total	1	2	Total	1	2	Total
1981	0.4	1.0	1.4	1592.0	1113.4	2705.4	Na			0	0.003	0.003	3.4	4.6	8.0
1982	0.3	0.5	0.8	1806.3	1959.1	3765.3	Na			0	0.003	0.003	4.4	5.3	9.7
1983	0.2	0.5	0.7	1958.6	1918.1	3876.7	Na			0	0.005	0.005	5.8	5.6	11.4
1984	0.2	0.3	0.5	2132.9	1764.5	3897.4	Na			0	0.008	0.008	6.9	5.3	12.2
1985	0.1	0.5	0.7	1741.8	1214.9	2956.7	Na			0	0.004	0.004	6.0	5.1	11.1
1986	0.1	0.5	0.6	1724.9	1650.1	3375.1	Na			0	0.007	0.007	6.0	6.9	12.9
1987	0.2	0.6	0.8	1787.8	1503.9	3291.7	Na			0	0.008	0.008	10.7	9.9	20.6
1988	0.1	0.1	0.2	2002.2	1439.3	3441.5	Na			0	0.008	0.008	11.0	9.1	20.0
1989	0	0	0	6.4	9.0	15.3	10.8	142.9	153.8	0	0	0	9.8	111.4	121.3
1990	0	0	0	238.3	40.7	279.0	185.1	12.9	198.0	0	0	0	10.3	188.9	199.3
1991	0	0	0	0.7	1.0	1.7	7.0	87.4	94.3	0	0	0	8.0	4.3	12.3
1992	0	0	0	4.0	0	4.0	247.5	9.7	257.2	0	0	0	6.9	4.8	11.7
1993	0	0	0	20.2	0	20.2	2.4	0	2.4	0.128	0.037	0.165	8.2	284.6	292.7
1994	0	0	0	165.4	10.6	176.0	78.9	99.3	178.1	0.085	0.004	0.088	0.8	1.8	2.7
1995	0	0	0	24.5	0.1	24.6	2.8	0	2.8	0	0	0	68.3	62.5	130.8
1996	0.134	0.095	0.229	1.8	0.1	1.9	6.5	0.4	6.9	0	0	0	0.0	1.2	1.2
1997	0.153	0.131	0.284	23.7	27.0	50.7	18.4	0	18.4	0.195	0.266	0.461	0.3	1.9	2.2
1998	0.148	0.101	0.249	0	0	0	0	0	0	0	0	0	0.4	43.7	44.0
1999	0.113	0.053	0.166	0	7.6	7.6	0.3	576.8	577.1	0	0	0	0	7.7	7.7
2000	0.076	0.065	0.141	1.6	0.7	2.3	32.0	1.4	33.4	1.622	0	1.622	25.8	15.2	41.0
2001	0.106	0.106	0.212	0	0	0	0.2	0	0.2	0	0	0	3.5	1.4	4.9
2002	0	0	0	0	0.4	0.4	0	1.9	1.9	0	0	0	1.0	3.0	4.0
2003	0	0	0	0.2	1.6	1.8	0	378.3	378.3	0.538	0	0.538	0.3	1.5	1.7
2004	0.025	0.021	0.047	2.6	25.1	27.7	35.1	9.3	44.4	0.605	0	0.605	0.9	4.9	5.9
2005	0	0.051	0.051	2.1	3.6	5.7	5.1	86.8	92.0	0.918	0	0.918	0.5	2.5	3.0
2006	0	0.608	0.608	4.8	12.0	16.8	6.0	0.2	6.2	0.112	0	0.112	0.3	3.0	3.3
2007	0	0	0	10.3	5.0	15.3	2.9	0.0	2.9	1.196	0	1.196	0.7	1.9	2.6
2008	0	0	0	5.0	5.3	10.4	117.4	30.9	148.3	0	0	0	5.4	7.0	12.4
2009	0	0	0	8.0	0.4	8.3	0.2	14.7	14.9	0	0	0	7.0	2.2	9.2

Table C23. Number of discarded red hake sampled from the FOP in the northern region by gear type.

	Large Mesh				Small Mesh				Sink Gill Net				Scallop Dredge				Shrimp Trawl			
	Half 1		Half 2		Half 1		Half 2		Half 1		Half 2		Half 1		Half 2		Half 1		Half 2	
	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len
1989	4	557	4	167	2	273	6	627	-	-	1	1	-	-	-	-	11	1815	-	-
1990	-	-	1	44	-	-	4	711	-	-	-	-	-	-	-	-	2	160	-	-
1991	-	-	1	1	-	-	6	429	1	2	6	7	-	-	-	-	-	-	-	-
1992	2	72	-	-	2	535	4	463	2	4	1	1	-	-	-	-	7	39	2	152
1993	-	-	-	-	2	650	-	-	-	-	1	1	-	-	-	-	1	2		
1994	-	-	-	-	-	-	-	-	1	1	1	2	-	-	1	27	1	1	3	116
1995	-	-	1	22	-	-	1	3	-	-	-	-	-	-	-	-	12	136	1	3
1996	-	-	-	-	-	-	10	750	2	2	2	4	-	-	-	-	7	151	1	32
1997	-	-	1	61	-	-	-	-	-	-	-	-	-	-	-	-	6	104	-	-
1998	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1999	-	-	2	152	-	-	1	43	1	2	3	5	-	-	1	7	-	-	-	-
2000	-	-	1	4	-	-	-	-	3	22	1	1	-	-	-	-	-	-	-	-
2001	1	1	-	-	-	-	-	-	1	3	2	4	-	-	-	-	-	-	-	-
2002	-	-	7	136	-	-	9	198	2	2	2	6	-	-	1	1	-	-	-	-
2003	12	89	10	261	-	-	3	116	9	12	4	7	-	-	1	103	2	7	-	-
2004	4	37	20	210	-	-	9	316	9	12	21	40	-	-	1	1	3	48	-	-
2005	23	126	19	86	2	5	8	63	1	1	6	10	-	-	2	2	1	1	-	-
2006	12	105	6	65	-	-	3	274	-	-	2	2	-	-	4	17	1	1	-	-
2007	13	175	6	25	-	-	3	1079	-	-	-	-	-	-	1	2	2	30	-	-
2008	2	2	26	183	-	-	-	-	1	1	1	2	2	3	1	16	1	16	-	-
2009	7	27	10	210	-	-	2	85	1	1	2	3	-	-	-	-			-	-

Table C24. Number of discarded red hake sampled from the FOP in the southern region by gear type.

	Large Mesh					Small Mesh					Scallop Dredge			
	Half 1		Half 2			Half 1		Half 2			Half 1		Half 2	
	trips	len	trips	len		trips	len	trips	len		trips	len	trips	len
1989	1	9	1	10		5	460	-	-		-	-	-	-
1990	-	-	-	-		4	383	-	-		-	-	-	-
1991	-	-	-	-		1	45	3	193		-	-	-	-
1992	-	-	-	-		9	1583	1	73		-	-	-	-
1993	-	-	-	-		-	-	1	110		1	4	-	-
1994	-	-	-	-		1	29	3	27		-	-	2	24
1995	2	13	1	3		2	89	1	14		1	2	-	-
1996	-	-	-	-		-	-	1	11		-	-	2	7
1997	-	-	1	482		4	203	3	3		1	184	1	7
1998	-	-	-	-		-	-	-	-		-	-	-	-
1999	-	-	-	-		-	-	3	67		1	1	2	29
2000	-	-	-	-		1	87	1	2		4	202	2	3
2001	-	-	-	-		-	-	-	-		-	-	-	-
2002	-	-	-	-		-	-	1	92		-	-	2	114
2003	-	-	-	-		1	107	-	-		2	3	2	104
2004	4	255	13	690		3	152	12	832		2	28	9	185
2005	15	365	14	498		13	525	14	1219		-	-	6	217
2006	10	40	4	279		9	353	10	502		-	-	3	4
2007	4	135	12	114		8	630	4	45		-	-	4	20
2008	7	29	5	42		6	290	3	47		5	51	7	53
2009	4	71	4	27		2	2	17	922		7	31	2	14

Table C25. Number of discarded white hake sampled from the FOP in the northern region by gear type.

	Large Mesh				Small Mesh				Sink Gill Net				Scallop Dredge				Shrimp Trawl			
	Half 1		Half 2		Half 1		Half 2		Half 1		Half 2		Half 1		Half 2		Half 1		Half 2	
	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len
1989	3	217	7	709	1	472	6	583	0	0	1	2	-	-	-	-	-	-	-	-
1990	2	8	1	9	-	-	4	303	0	0	1	32	-	-	-	-	-	-	-	-
1991	-	-	1	43	-	-	-	-	1	135	7	30	-	-	-	-	-	-	-	-
1992	-	-	1	86	-	-	-	-	0	0	4	4	-	-	-	-	6	17	3	58
1993	2	29	1	14	-	-	1	30	1	1	10	13	-	-	-	-	17	282	-	-
1994	4	26	-	-	-	-	-	-	0	0	2	4	-	-	1	1	30	517	4	256
1995	10	146	5	163	-	-	3	106	1	1	7	30	-	-	1	7	37	958	-	-
1996	5	56	-	-	2	145	8	309	2	12	2	3	-	-	-	-	9	325	2	15
1997	2	6	5	47	-	-	-	-	0	0	2	4			-	-	4	25	-	-
1998	2	11	1	2	-	-	-	-	0	0	1	1	1	5	-	-	0	0	-	-
1999	-	-	4	31	-	-	-	-	0	0	3	20			-	-	0	0	-	-
2000	3	12	-	-	-	-	2	10	2	9	0	0			-	-	0	0	-	-
2001	-	-	-	-	3	42	-	-	1	4	2	2			-	-	0	0	-	-
2002	-	-	9	126	-	-	2	14	0	0	1	2			-	-	0	0	-	-
2003	8	23	11	172	1	1	-	-	3	7	12	52			-	-	1	1	-	-
2004	13	125	30	392	2	4	5	92	4	6	19	69			-	-	0	0	-	-
2005	43	454	45	660	3	4	4	12	2	3	16	35			-	-	5	28	-	-
2006	21	280	20	346	-	-	-	-	1	1	3	4			-	-	4	131	-	-
2007	18	163	29	209	-	-	1	3	2	7	1	5	1	1	-	-	3	43	-	-
2008	14	118	50	465	-	-	1	5	1	3	4	6	2	3	-	-	2	31	1	25
2009	22	99	23	214	-	-	2	12	2	2	2	3	-	-	-	-	1	13	1	1

Table C26. Number of discarded white hake sampled from the FOP in the southern region by gear type.

	Large Mesh				Small Mesh				Sink Gill Net				Scallop Dredge			
	Half 1		Half 2		Half 1		Half 2		Half 1		Half 2		Half 1		Half 2	
	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len
1989	-	-	-	-	-	-	3	115	-	-	-	-	-	-	-	-
1990	-	-	-	-	-	-	0	0	-	-	-	-	-	-	-	-
1991	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-
1992	-	-	-	-	-	-	0	0	-	-	-	-	-	-	-	-
1993	-	-	-	-	-	-	0	0	-	-	-	-	1	1	-	-
1994	-	-	-	-	-	-	1	2	-	-	-	-	1	1	2	2
1995	-	-	-	-	-	-	0	0	-	-	-	-	2	51	1	66
1996	-	-	-	-	-	-	1	26	-	-	-	-	-	-	1	1
1997	2	33	2	17	1	29	-	-	-	-	-	-	-	-	0	0
1998	0	0	0	0	0	0	-	-	-	-	-	-	-	-	3	41
1999	0	0	2	11	0	0	-	-	-	-	-	-	-	-	3	32
2000	0	0	0	0	2	107	-	-	-	-	-	-	-	-	0	0
2001	0	0	0	0	0	0	-	-	-	-	-	-	-	-	0	0
2002	0	0	2	3	0	0	-	-	-	-	-	-	-	-	0	0
2003	1	1	1	24	0	0	-	-	-	-	-	-	-	-	0	0
2004	6	65	8	215	3	89	-	-	-	-	-	-	-	-	6	212
2005	9	40	14	114	6	87	-	-	-	-	-	-	-	-	4	60
2006	12	220	5	69	2	19	-	-	-	-	-	-	-	-	1	4
2007	4	46	4	10	2	39	-	-	-	-	-	-	-	-	1	15
2008	5	9	4	32	3	6	-	-	-	-	-	-	-	-	4	42
2009	1	1	1	3	1	1	-	-	-	-	-	-	1	1	1	1

Table C27. Pooling of red hake observer length samples to estimate length and species composition of the commercial discards by gear from the north.

	Red North			Red North			Red North			Red North	
	Large Mesh			Small Mesh			Shrimp Trawl			Sink Gill Net	
	Half1	Half2		Half1	Half2		Half1	Half2		Half1	Half2
1989											
1990											
1991											
1992											
1993											
1994											
1995											
1996											
1997											
1998											
1999											
2000											
2001											
2002											
2003											
2004											
2005											
2006											
2007											
2008											
2009											

Table C28. Pooling of red hake observer length samples to estimate length and species composition of the commercial discards by gear from the south.

	Red South			Red South	
	Large Mesh			Small Mesh	
	Half1	Half2		Half1	Half2
1989					
1990					
1991					
1992					
1993					
1994					
1995					
1996					
1997					
1998					
1999					
2000					
2001					
2002					
2003					
2004					
2005					
2006					
2007					
2008					
2009					

Table C29. Pooling of white hake observer length samples to estimate length and species composition of the commercial discards by gear from the north.

	White North		White North		White North		White North	
	Large Mesh		Small Mesh		Shrimp Trawl		Sink Gill Net	
	Half1	Half2	Half1	Half2	Half1	Half2	Half1	Half2
1989								
1990								
1991								
1992								
1993								
1994								
1995								
1996								
1997								
1998								
1999								
2000								
2001								
2002								
2003								
2004								
2005								
2006								
2007								
2008								
2009								

Table C30. Pooling of white hake observer length samples to estimate length and species composition of the commercial discards by gear from the south.

	White South			White South	
	Large Mesh			Small Mesh	
	Half1	Half2		Half1	Half2
1989					
1990					
1991					
1992					
1993					
1994					
1995					
1996					
1997					
1998					
1999					
2000					
2001					
2002					
2003					
2004					
2005					
2006					
2007					
2008					
2009					

Table C31. Comparison of nominal discards (mt) with the length-based model-estimated discards (mt) by stock.

	Northern Stock		Southern Stock	
Year	Nominal	Length-Based Model Estimate	Nominal	Length-Based Model Estimate
1981	1324	1230	2715	2680
1982	1460	1315	3776	3709
1983	1353	1195	3889	3824
1984	1327	1148	3910	3844
1985	1270	1084	2968	2938
1986	1189	993	3389	3362
1987	1052	906	3313	3325
1988	897	820	3462	3462
1989	1447	1308	5006	4737
1990	595	647	4748	4441
1991	818	531	2612	2334
1992	726	639	6343	5887
1993	83	380	5308	5509
1994	77	115	1720	1818
1995	63	109	1329	1386
1996	656	602	380	377
1997	125	141	2422	2251
1998	130	184	740	629
1999	468	381	1060	1483
2000	55	110	250	299
2001	135	239	138	136
2002	101	116	327	333
2003	88	90	345	650
2004	57	42	616	546
2005	57	37	1007	1077
2006	181	134	674	677
2007	127	112	1545	1532
2008	59	49	814	896
2009	95	74	869	862

Table C32. Estimates of nominal recreational catch (mt) by stock.

Year	North	South
1960	13.82	317
1961	11.94	612
1962	6.97	892
1963	4.47	770
1964	1.05	848
1965	0.73	634
1966	3.23	94
1967	2.10	165
1968	2.01	575
1969	0.53	489
1970	0.95	410
1971	1.37	287
1972	1.96	177
1973	1.32	317
1974	3.25	191
1975	1.64	52
1976	2.38	645
1977	3.24	750
1978	4.46	971
1979	5.55	245
1980	3.75	144
1981	30.89	176
1982	2.94	29
1983	0.03	135
1984	1.36	548
1985	0.00	29
1986	0.47	205
1987	0.25	472
1988	4.10	251
1989	0.48	436
1990	4.10	514
1991	1.60	285
1992	0.67	194
1993	0.97	89
1994	1.70	69
1995	1.01	45
1996	5.37	19
1997	0.83	173
1998	0.01	53
1999	0.06	53
2000	0.06	44
2001	0.48	24
2002	0.28	10
2003	0.13	18
2004	0.02	10
2005	0.02	55
2006	0.05	53
2007	0.21	20
2008	0.22	74
2009	0.43	100

Table C33. Minimized negative log-likelihood, number of model parameters, AIC_c measures for beta-binomial models with the specified relationship of the calibration factor to length fit to **red hake** catch data from the 2008 *Albatross IV*/*Henry B. Bigelow* calibration experiment.

Model	Model	-LL	# parameters	AIC_c	Δ (AIC_c)	AIC_c Weights
1	Constant	4791.267	2	9586.536	303.482	0
2	Survey, S-S, constant	4787.159	4	9582.327	299.2727	0
3	S,F,S-S, constant model	4781.916	6	9575.853	292.7986	0
4	All stations, logistic model	4670.32	5	9350.655	67.6003	0
5	Survey, S-S logistic	4658.74	10	9337.532	54.4778	0
6	S, F, S-S, logistic	NA	NA	NA	NA	NA
7	All stations, double logistic model[1]	4649.882	6	9311.784	28.7294	0
8	Survey, S-S, double-logistic model[2]	4638.766	14	9305.632	22.5777	0
9	S,F,S-S, double-logistic model[3]	4619.406	22	9283.054	0	1

1 Minima for both ascending and descending logistic components were assumed equal to 0 (exp(-100)) to allow variance estimation.
2 Minima for both ascending and descending logistic components were assumed equal to 0 (exp(-100)) for the survey data to allow variance estimation.
3 Minima for both ascending and descending logistic components were assumed equal to 0 (exp(-100)) for the fall data to allow variance estimation.

Table C34. Resulting length-based calibration factors for red hake by season.

Length	Spring	Fall
1	2.855	0.001
2	2.855	0.003
3	2.855	0.011
4	2.855	0.036
5	2.854	0.115
6	2.853	0.357
7	2.853	0.977
8	2.888	2.065
9	3.225	3.114
10	5.457	3.679
11	12.282	3.892
12	12.930	3.960
13	7.305	3.979
14	4.455	3.983
15	3.532	3.982
16	3.263	3.978
17	3.186	3.974
18	3.164	3.967
19	3.158	3.960
20	3.157	3.950
21	3.156	3.938
22	3.156	3.923
23	3.156	3.905
24	3.156	3.883
25	3.156	3.855
26	3.156	3.821
27	3.156	3.780
28	3.156	3.730
29	3.156	3.669
30	3.156	3.596
31	3.156	3.510
32	3.156	3.407
33	3.156	3.288
34	3.156	3.150
35	3.156	2.994
36	3.156	2.820
37	3.156	2.630
38	3.156	2.426
39	3.156	2.212
40	3.156	1.993
41	3.156	1.775
42	3.156	1.561
43	3.156	1.358
44	3.156	1.169
45	3.156	0.996
46	3.156	0.841
47	3.156	0.704
48	3.156	0.586
49	3.156	0.484
50	3.156	0.398

Table C35. Swept area abundance and biomass and upper and lower confidence intervals for red hake from the NEFSC fall bottom trawl surveys in the northern management region (strata 20-30, 36-40). Estimates for 2009 were converted to Albatross units using the calibration factors at length in Table C34.

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1963	23966	24.57	30.67	18.46	10371.71	14147.00	6596.43
1964	23966	7.98	11.72	4.25	2811.73	3566.44	2057.01
1965	23966	5.84	8.43	3.25	2603.09	3735.70	1470.27
1966	23966	5.01	6.63	3.39	1976.34	2658.73	1293.74
1967	23966	2.93	4.66	1.20	1045.30	1552.01	538.59
1968	23966	2.13	3.22	1.03	548.65	791.52	305.57
1969	23966	9.24	13.43	5.06	1433.47	2098.31	768.41
1970	23966	9.95	14.45	5.46	1284.32	1733.26	835.39
1971	23966	13.96	22.86	5.06	2851.10	3505.24	2196.95
1972	23966	20.63	27.14	14.11	4998.41	6708.55	3288.48
1973	23966	15.64	23.03	8.26	3342.62	4711.89	1973.34
1974	23966	6.33	8.27	4.38	1444.81	1824.41	1065.20
1975	23966	17.59	22.54	12.63	3771.65	4629.08	2914.44
1976	23966	15.52	20.10	10.94	3631.92	4639.99	2623.64
1977	23966	28.56	33.93	23.18	7458.99	8774.34	6143.43
1978	23966	30.76	38.95	22.58	6543.36	8118.70	4968.02
1979	23966	14.58	18.09	11.08	3900.89	4833.21	2968.57
1980	23966	36.25	48.66	23.84	8042.09	10563.87	5520.53
1981	23966	38.41	66.71	10.10	6007.33	7245.86	4768.81
1982	23966	16.29	23.40	9.18	3575.21	5269.10	1881.12
1983	23966	22.91	27.67	18.14	8804.72	10655.03	6954.42
1984	23966	22.43	28.66	16.20	7578.61	9535.90	5621.52
1985	23966	39.02	48.32	29.73	10130.34	11882.86	8377.61
1986	23966	18.44	21.70	15.17	6077.73	7146.58	5009.11
1987	23966	18.46	24.31	12.61	4818.88	5971.17	3666.58
1988	23966	14.55	18.01	11.10	5443.71	6764.40	4122.79
1989	23966	60.03	90.17	29.89	9995.75	13533.09	6458.62
1990	23966	30.94	45.93	15.96	7104.64	9402.16	4807.32
1991	23966	28.60	46.18	11.01	5473.02	7860.85	3085.19
1992	23966	22.94	31.72	14.16	4898.48	6147.07	3649.89
1993	23966	25.67	43.32	8.01	4259.96	6810.62	1709.29
1994	23966	47.05	66.45	27.65	7904.07	11461.53	4346.62
1995	23966	53.99	69.48	38.50	7009.84	8223.76	5795.92
1996	23966	28.11	33.41	22.81	5421.02	6421.82	4420.23
1997	23966	27.49	32.66	22.32	6242.07	7512.91	4971.45
1998	23966	45.62	55.49	35.75	10361.44	12258.82	8464.06
1999	23966	35.87	42.56	29.17	7107.20	8417.63	5796.56
2000	23966	53.05	65.01	41.09	12117.81	14917.34	9318.49
2001	23966	46.89	58.90	34.87	10453.24	12160.18	8746.52
2002	23966	52.29	61.25	43.33	11498.97	13983.95	9013.78
2003	23966	33.54	39.47	27.61	7593.58	9003.30	6183.87
2004	23966	20.66	24.97	16.36	3328.06	4099.26	2557.09
2005	23966	25.62	36.01	15.23	2485.62	3040.69	1930.76
2006	23966	51.31	67.74	34.89	4679.36	5775.16	3583.34
2007	23966	39.66	53.38	25.93	5184.15	6394.86	3973.65
2008	23966	27.35	33.18	21.51	4087.49	5000.55	3174.43
2009	23966	26.67			5085.50		

Table C36. Swept area abundance and biomass and upper and lower confidence intervals for red hake from the NEFSC spring bottom trawl surveys in the northern management region (strata 20-30, 36-40). Estimates for 2009 and 2010 were converted to Albatross units using the calibration factors at length in Table C34.

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1968	23966	5.17	6.64	3.69	2434.90	3200.74	1669.27
1969	23966	5.09	6.95	3.23	1367.99	2024.27	711.92
1970	23966	3.12	4.13	2.11	1157.22	1629.26	684.96
1971	23966	5.92	7.97	3.88	1386.60	1888.18	885.03
1972	23966	15.25	20.48	10.02	3338.98	4202.18	2475.56
1973	23966	34.98	57.00	12.95	9225.63	13956.99	4494.27
1974	23966	21.01	28.03	14.00	5201.91	6682.23	3721.36
1975	23236	29.87	34.75	24.98	8824.49	10584.21	7064.57
1976	23966	30.23	35.52	24.95	7213.55	9164.86	5262.25
1977	23966	20.52	24.55	16.48	5682.94	7075.11	4290.77
1978	23966	18.63	22.23	15.03	5501.05	6534.16	4468.16
1979	23966	19.27	26.97	11.58	4366.73	5981.66	2752.02
1980	23966	30.87	40.52	21.23	8308.71	10350.74	6266.68
1981	23966	57.82	89.12	26.52	13594.07	19459.11	7729.25
1982	23966	18.30	24.88	11.71	4551.40	5832.94	3270.08
1983	23966	28.09	39.79	16.39	7913.92	11193.62	4634.43
1984	23966	20.50	24.77	16.22	6381.16	7696.30	5065.81
1985	23966	21.88	26.41	17.36	8373.34	10285.05	6461.40
1986	23966	21.76	25.96	17.57	6974.75	8556.93	5392.56
1987	23966	25.01	29.52	20.49	6293.21	7447.65	5139.00
1988	23966	15.64	19.89	11.38	4271.51	5320.67	3222.14
1989	23966	17.11	21.16	13.07	3533.49	4439.27	2627.91
1990	23966	13.24	16.33	10.14	2848.32	3386.05	2310.37
1991	23966	16.97	22.84	11.10	3469.29	4665.45	2272.92
1992	23966	20.17	25.61	14.74	5351.91	7026.96	3677.07
1993	23966	27.31	34.07	20.55	6042.43	7244.79	4840.06
1994	23966	17.31	21.52	13.09	3403.17	4252.04	2554.52
1995	23966	17.98	21.31	14.66	4221.87	5043.56	3400.18
1996	23966	21.15	26.40	15.90	3834.77	4689.63	2979.70
1997	23966	23.51	29.35	17.67	3875.00	4670.16	3079.84
1998	23966	25.68	29.48	21.88	5389.78	6150.70	4628.65
1999	23966	24.37	29.36	19.39	4969.31	6098.28	3840.55
2000	23966	34.27	39.81	28.73	6818.33	7989.24	5647.42
2001	23966	40.77	48.94	32.59	7659.06	8941.89	6376.03
2002	23966	47.06	53.34	40.78	9542.75	10587.41	8498.09
2003	23966	12.35	14.18	10.53	2131.26	2464.22	1798.31
2004	23966	21.05	27.70	14.41	3791.55	4807.96	2775.13
2005	23966	13.64	16.78	10.51	2347.81	2779.41	1916.42
2006	23966	13.50	15.84	11.16	1952.16	2229.91	1674.20
2007	23966	34.04	43.97	24.11	4399.90	5586.86	3212.94
2008	23966	48.92	58.54	39.30	7464.55	9179.19	5750.13
2009	23966	24.18			3740.11		
2010	23966	26.82			4326.30		

Table C37. Swept area abundance and biomass and upper and lower confidence intervals for red hake from the NEFSC shrimp trawl surveys (strata -12).

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1985	9675	35.44	49.81	21.07	10948.96	14769.13	7129.02
1986	12022	32.38	42.23	22.53	11030.49	14657.52	7403.75
1987	11595	67.48	77.05	57.91	18964.78	21544.38	16385.47
1988	6574	24.32	29.15	19.49	8548.50	10208.11	6888.73
1989	9167	33.32	36.84	29.81	7563.46	8300.03	6826.89
1990	9167	31.60	38.40	24.81	10288.81	13032.95	7544.67
1991	10401	65.96	94.78	37.15	16716.75	22794.31	10639.44
1992	8983	37.89	48.26	27.51	10817.33	13639.11	7995.54
1993	10629	41.20	50.45	31.94	13543.74	16983.81	10103.66
1994	6574	12.27	15.06	9.48	3261.53	3887.86	2635.35
1995	6147	30.89	35.60	26.17	4824.63	5546.13	4102.97
1996	6574	78.94	95.44	62.45	10073.18	11794.41	8351.94
1997	6147	44.64	51.67	37.61	8796.36	10312.51	7280.20
1998	7241	32.15	43.13	21.17	6906.65	9766.84	4046.63
1999	8195	57.68	73.67	41.69	9216.30	10608.22	7824.18
2000	8195	104.36	134.79	73.93	18844.61	22430.33	15258.89
2001	7749	120.34	137.57	103.11	22746.41	25921.95	19571.07
2002	8500	271.96	435.27	108.64	64924.91	107687.35	22162.48
2003	9167	70.30	81.75	58.85	17193.85	20037.46	14350.25
2004	10788	88.93	103.62	74.23	17285.61	20197.83	14373.12
2005	10788	43.79	51.34	36.24	8889.31	10395.05	7383.58
2006	7241	51.81	58.55	45.06	8560.49	9769.01	7352.15
2007	9370	84.43	98.02	70.84	9015.58	10069.00	7962.39
2008	9370	93.14	111.49	74.79	14413.17	16642.06	12184.05
2009	9370	76.77	85.81	67.73	13164.38	14861.99	11466.77

Table C38. Swept area abundance and biomass and upper and lower confidence intervals for red hake from Massachusetts Division of Marine Fisheries fall north survey (strata 18-36).

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1978	948	4.25	4.99	3.50	1427.07	1635.40	1218.78
1979	969	5.64	7.50	3.78	1292.13	1584.58	999.66
1980	969	8.28	15.39	1.17	1638.04	2626.21	649.90
1981	969	12.42	15.87	8.97	2369.36	2823.30	1915.45
1982	969	7.56	9.06	6.05	1569.36	1925.80	1212.95
1983	969	11.94	18.38	5.50	2789.64	4424.86	1154.45
1984	969	3.89	4.78	3.01	1219.57	1518.30	920.85
1985	948	10.38	15.88	4.88	2494.86	3267.44	1722.28
1986	969	8.13	9.48	6.77	1650.91	1979.39	1322.44
1987	933	2.66	3.28	2.04	446.75	554.14	339.39
1988	933	3.89	5.68	2.09	862.92	1168.10	557.71
1989	875	3.94	5.32	2.55	757.29	1178.32	336.26
1990	969	4.48	5.67	3.28	1309.44	1640.06	978.82
1991	914	10.64	12.16	9.12	1660.65	1795.32	1525.98
1992	969	8.13	9.98	6.28	926.22	1117.84	734.60
1993	969	4.30	5.56	3.05	733.24	982.22	484.27
1994	969	4.73	5.84	3.61	1083.86	1364.34	803.40
1995	969	13.23	16.26	10.21	1486.15	1884.23	1088.06
1996	969	11.03	12.87	9.18	1927.19	2423.78	1430.62
1997	969	4.74	5.54	3.94	912.01	1031.10	792.89
1998	969	8.77	10.76	6.78	1282.00	1804.87	759.11
1999	969	21.98	36.00	7.95	2307.39	2780.98	1833.80
2000	969	21.95	28.03	15.87	3841.93	4891.75	2792.11
2001	969	7.42	10.99	3.84	1313.92	1658.77	969.07
2002	969	12.07	21.60	2.54	2021.49	3597.25	445.73
2003	969	7.19	11.66	2.72	940.88	2074.02	-192.25
2004	969	4.48	5.78	3.18	644.10	750.72	537.51
2005	969	4.44	5.23	3.65	617.92	735.20	500.67
2006	969	5.50	7.54	3.46	562.52	725.05	400.02
2007	948	3.01	3.92	2.09	484.03	586.89	381.18
2008	969	5.13	6.27	3.98	673.20	851.04	495.36
2009	948	10.87	13.07	8.68	1232.85	1557.19	908.51

Table C39. Swept area abundance and biomass and upper and lower confidence intervals for red hake from Massachusetts Division of Marine Fisheries spring north survey (strata 18-36).

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1978	930	0.82	0.90	0.73	87.00	112.02	62.00
1979	969	10.69	41.33	-19.95	3887.58	15468.92	-7693.76
1980	969	4.56	6.58	2.54	964.61	1264.49	664.71
1981	969	12.70	37.99	-12.60	5128.72	18529.83	-8272.38
1982	969	2.04	4.82	-0.74	712.27	1847.95	-423.43
1983	969	3.83	4.40	3.26	928.16	1199.55	656.80
1984	969	2.38	3.04	1.72	444.49	587.26	301.72
1985	969	5.10	6.94	3.25	877.82	1349.65	405.97
1986	969	8.20	11.56	4.84	1270.11	1811.98	728.22
1987	969	2.44	3.08	1.80	582.48	950.83	214.10
1988	969	1.77	2.33	1.21	284.81	359.64	210.01
1989	969	3.61	4.54	2.67	454.01	588.80	319.20
1990	969	1.58	2.34	0.82	362.76	479.69	245.84
1991	969	3.42	6.94	-0.10	332.86	444.26	221.45
1992	969	3.85	5.47	2.22	335.81	440.23	231.35
1993	969	0.74	0.92	0.56	107.32	152.07	62.58
1994	969	2.24	4.02	0.45	277.28	390.53	164.04
1995	969	4.06	5.08	3.05	246.19	298.82	193.54
1996	969	3.80	6.93	0.67	150.48	203.54	97.42
1997	969	6.18	7.53	4.84	832.25	1065.59	598.90
1998	969	3.53	5.19	1.87	719.96	1124.85	315.07
1999	969	4.61	6.68	2.53	721.42	1145.15	297.71
2000	969	7.14	8.86	5.41	1414.04	1904.64	923.42
2001	969	4.15	6.59	1.70	888.71	1929.66	-152.25
2002	969	3.34	4.65	2.03	635.43	783.09	487.75
2003	969	1.12	1.36	0.88	142.12	188.40	95.81
2004	969	0.86	1.10	0.62	75.08	96.26	53.89
2005	969	4.96	7.61	2.31	149.57	210.77	88.38
2006	969	5.18	6.95	3.40	347.14	457.11	237.17
2007	969	1.17	1.62	0.72	133.40	215.83	50.97
2008	969	0.98	1.29	0.66	180.94	263.35	98.53
2009	969	3.16	4.92	1.39	244.66	358.43	130.88

Table C40. Stratified mean number and weight per tow (kg) for red hake from the fall and spring Maine-New Hampshire state surveys, 2000-2009.

	MENH Fall	MENH Fall	MENH Spring	MENH Spring
Year	Stratified Mean Number/Tow	Stratified Mean Weight/Tow (Kg)	Stratified Mean Number/Tow	Stratified Mean Weight/Tow (Kg)
2000	25.78	2.70		
2001	31.33	4.34	5.30	0.22
2002	17.92	2.51	9.08	1.00
2003	29.38	5.43	9.45	0.78
2004	15.30	2.91	3.21	0.31
2005	13.41	1.37	6.74	0.71
2006	11.18	1.37	2.56	0.10
2007	25.86	3.35	9.70	0.46
2008	35.07	4.16	11.82	0.57
2009	30.43	3.41	23.89	0.78

Table C41. Swept area abundance and biomass and upper and lower confidence intervals for red hake from the NEFSC fall bottom trawl surveys in the southern management region (strata 1-19, 61-76). Estimates for 2009 were converted to Albatross units using the calibration factors at length in Table C34.

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1967	37081	26.06	36.15	15.98	5601.55	7555.92	3647.51
1968	37081	49.14	62.91	35.37	10172.78	13136.94	7208.28
1969	37081	58.22	75.34	41.10	11761.30	15180.03	8342.56
1970	37081	50.23	60.59	39.88	7471.49	8940.16	6002.49
1971	37081	57.72	70.61	44.83	8502.47	10424.73	6579.89
1972	37081	84.47	112.47	56.47	12739.31	16307.69	9170.59
1973	37081	63.56	88.28	38.84	7785.35	10573.38	4997.33
1974	37081	73.00	92.27	53.73	3022.43	4394.76	1650.10
1975	37081	112.16	142.02	82.30	16169.96	20158.49	12181.11
1976	37081	66.05	82.64	49.45	11047.16	13842.14	8252.18
1977	37081	42.09	53.86	30.33	8319.72	10941.54	5697.56
1978	37081	38.82	47.96	29.68	6219.68	7779.73	4659.62
1979	37081	56.00	67.10	44.90	7879.71	9766.21	5993.55
1980	37021	80.00	100.65	59.36	10359.93	13498.78	7220.75
1981	37081	61.95	76.52	47.38	7676.10	9955.92	5396.28
1982	37081	51.83	68.60	35.06	10247.93	13423.98	7071.88
1983	37081	97.56	134.36	60.77	20001.56	27804.79	12198.32
1984	36995	25.21	38.27	12.15	3904.95	6048.02	1762.22
1985	37081	134.25	200.35	68.14	6582.54	9071.60	4093.81
1986	37081	24.73	39.22	10.23	3171.75	5036.73	1306.77
1987	37029	18.05	25.93	10.16	2511.36	3399.06	1623.66
1988	37081	26.58	42.51	10.65	2549.65	4063.68	1035.62
1989	37081	31.46	47.09	15.84	3908.73	5739.28	2077.86
1990	36976	33.54	51.72	15.36	4017.51	5958.75	2075.94
1991	37081	38.12	59.42	16.82	5324.43	8306.81	2342.06
1992	36924	14.59	18.97	10.21	2075.33	2756.77	1393.88
1993	37021	32.90	42.13	23.67	2986.14	4111.64	1860.64
1994	37081	33.81	54.63	13.00	2658.24	4003.09	1313.73
1995	37081	30.91	44.75	17.07	1537.87	2120.24	955.83
1996	37081	10.93	15.56	6.30	1305.78	1885.83	726.06
1997	37081	13.39	22.15	4.64	1980.19	3753.79	206.93
1998	37081	13.13	16.54	9.71	1655.73	2258.96	1052.50
1999	37081	59.12	106.03	12.21	1787.17	3196.91	377.43
2000	37081	8.70	11.60	5.81	1576.94	2400.00	753.54
2001	37021	37.18	56.03	18.34	1822.62	2399.75	1245.49
2002	37081	28.33	35.91	20.76	1990.79	2480.79	1500.46
2003	37021	22.49	28.80	16.17	1833.20	2463.22	1202.85
2004	37081	21.69	26.56	16.82	1326.64	1628.25	1025.02
2005	36916	34.51	48.16	20.87	2089.71	2948.34	1231.08
2006	37029	33.26	45.18	21.33	2704.44	4703.67	705.53
2007	37081	46.75	63.43	30.08	1821.94	2532.76	1111.11
2008	37081	22.36	31.37	13.35	2408.61	3332.99	1484.23
2009	37081	30.33			3368.29		

Table C42. Swept area abundance and biomass and upper and lower confidence intervals for red hake from the NEFSC spring bottom trawl surveys in the southern management region (strata 1-19, 61-76). Estimates for 2009 and 2010 were converted to Albatross units using the calibration factors at length in Table C34.

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1968	37081	20.66	28.71	12.62	4255.38	5837.28	2673.80
1969	37081	18.89	23.77	14.01	3582.95	4552.35	2613.55
1970	37081	31.48	37.24	25.72	5704.85	6855.02	4554.67
1971	37081	80.99	114.98	47.01	11549.41	15652.82	7446.33
1972	37081	59.23	87.88	30.57	11885.12	17216.18	6553.74
1973	37081	70.98	87.06	54.90	13218.05	16203.07	10232.70
1974	37081	46.87	58.56	35.17	9395.07	11808.31	6982.15
1975	35374	42.63	63.22	22.04	10039.58	14482.81	5596.04
1976	37081	78.15	136.55	19.75	17592.95	33299.40	1886.16
1977	37081	39.93	48.93	30.94	7616.17	9202.71	6029.64
1978	37081	110.37	151.64	69.09	25319.70	32988.18	17651.55
1979	37081	28.72	40.72	16.72	5011.56	6798.40	3224.39
1980	37081	48.96	60.50	37.41	7878.72	10112.85	5644.59
1981	36909	91.24	127.92	54.56	15200.58	20687.49	9713.66
1982	37081	58.50	80.31	36.69	11065.04	16856.63	5273.45
1983	37081	40.04	53.42	26.67	7306.28	9845.34	4767.23
1984	37081	24.32	38.39	10.25	4406.02	7141.40	1670.30
1985	37081	23.49	31.18	15.79	4609.63	6232.26	2986.68
1986	37081	37.45	53.45	21.46	5740.60	8417.06	3064.15
1987	37081	14.65	21.47	7.84	2905.23	4190.82	1619.31
1988	36976	20.14	27.48	12.81	3320.91	4619.03	2022.79
1989	37081	12.98	16.97	8.98	1613.35	2213.27	1013.11
1990	36909	15.85	21.15	10.55	2329.55	3095.08	1563.69
1991	37081	15.75	20.86	10.64	2022.24	2693.67	1351.14
1992	36845	10.64	15.28	6.00	1529.07	2395.25	662.88
1993	36845	10.91	13.22	8.60	1393.20	1846.20	940.53
1994	36905	19.58	30.66	8.50	2223.20	3280.92	1165.14
1995	37081	10.89	14.31	7.46	1707.05	2250.68	1163.09
1996	37081	11.31	19.19	3.43	1499.46	2899.93	98.99
1997	36800	25.60	46.86	4.34	3814.39	6946.99	681.46
1998	37021	6.08	7.09	5.08	706.04	845.86	566.55
1999	37081	10.71	14.49	6.92	1505.42	2082.16	928.68
2000	37081	11.41	14.52	8.30	1400.14	1958.34	841.94
2001	37081	13.38	16.86	9.89	2125.20	2758.89	1491.85
2002	37081	12.25	18.38	6.11	1794.46	2797.30	791.61
2003	37081	6.18	8.15	4.21	680.70	874.71	486.69
2004	37081	5.74	8.66	2.83	511.19	818.43	203.95
2005	37081	9.65	12.01	7.29	1245.19	1587.53	902.86
2006	37021	10.92	13.85	7.98	1256.07	1712.88	799.59
2007	37081	25.33	33.99	16.68	2838.68	3710.75	1966.29
2008	37081	13.73	19.38	8.07	1567.33	2233.80	900.54
2009	36995	29.84			4433.65		
2010	37081	26.45			3459.51		

Table C43. Swept area abundance and biomass and upper and lower confidence intervals for red hake from the NEFSC winter flatfish surveys in the southern management region (strata 1-3, 5-7, 9-11, 13-14, 61-63, 65-67, 69-71, 73-75).

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1992	30014	107.45	174.39	40.51	15311.03	26314.03	4307.81
1993	29928	126.71	196.99	56.44	18482.71	29030.39	7935.03
1994	30014	73.83	123.70	23.95	6571.00	10607.77	2534.46
1995	30014	17.00	28.11	5.89	1711.94	2676.74	746.91
1996	30014	5.90	7.71	4.10	768.91	1061.95	475.87
1997	30014	23.91	35.89	11.94	2674.91	4014.54	1335.28
1998	30014	13.92	17.22	10.61	1399.43	1903.25	895.61
1999	30014	35.79	58.39	13.19	5108.57	8330.83	1886.07
2000	30014	45.65	58.99	32.31	4298.88	6195.49	2402.04
2001	30014	31.22	41.37	21.07	3999.65	5543.20	2456.34
2002	30014	15.43	22.01	8.85	1278.69	1834.29	723.09
2003	26984	7.46	11.97	2.94	159.23	237.91	80.54
2004	30014	57.02	96.82	17.23	5327.60	9446.16	1208.81
2005	29358	7.65	9.52	5.79	315.54	425.35	205.95
2006	30014	20.56	25.70	15.41	1490.39	2164.44	816.33
2007	26984	5.44	7.06	3.83	263.66	360.89	166.44

Table C44. Swept area abundance and biomass and upper and lower confidence intervals for red hake from Massachusetts Division of Marine Fisheries fall south survey (strat 11-17).

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1978	864	0.08	0.10	0.06	13.46	20.06	6.83
1979	864	0.13	0.25	0.01	6.54	17.86	-4.76
1980	864	0.02	0.03	0.00	2.36	4.94	-0.20
1981	864	0.05	0.06	0.04	2.34	6.33	-1.66
1982	864	0.23	0.37	0.08	26.10	41.76	10.47
1983	864	0.01	0.02	-0.01	0.52	2.11	-1.08
1984	864	0.04	0.15	-0.07	5.66	22.42	-11.10
1985	864	0.03	0.06	0.01	0.09	0.18	0.02
1986	864	0.44	0.86	0.01	14.40	27.77	1.01
1987	864	0.04	0.06	0.01	0.81	1.62	0.02
1988	864	0.02			2.88		
1989	864	0.12	0.33	-0.08	14.71	45.24	-15.79
1990	864	0.20	0.42	-0.02	1.57	3.14	0.00
1991	864	0.29	0.53	0.05	2.34	3.84	0.83
1992	864	0.01	0.02	0.00	0.58	2.16	-0.99
1993	864	0.20	0.51	-0.11	1.42	3.53	-0.72
1994	864	0.12	0.33	-0.08	7.97	31.07	-15.10
1995	864	1.03	1.66	0.40	9.39	13.14	5.64
1996	864	0.04	0.07	0.02	7.10	12.87	1.33
1997	864	0.05	0.10	0.00	2.02	4.13	-0.09
1998	864	0.04	0.07	0.02	0.34	0.70	0.00
1999	864	1.38	2.69	0.07	13.59	22.49	4.69
2000	864	0.03			2.63	10.54	-5.26
2001	864	0.00	0.01	-0.01	0.27	1.06	-0.54
2002	864	0.21	0.44	-0.03	0.61	1.17	0.02
2003	864	0.13	0.24	0.02	0.29	0.56	0.02
2004	864	0.12	0.21	0.04	0.22	0.43	0.02
2005	864	0.32	0.69	-0.04	1.03	2.43	-0.38
2006	864	0.94	1.69	0.20	2.25	3.80	0.70
2007	864	0.19	0.36	0.01	1.06	2.00	0.11
2008	864	0.24	0.52	-0.03	7.64	30.84	-15.57
2009	864	0.17	0.34	0.01	1.64	2.94	0.34

Table C45. Swept area abundance and biomass and upper and lower confidence intervals for red hake from Massachusetts Division of Marine Fisheries spring south survey (strata 11-17).

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1978	864	0.11	0.18	0.04	5.10	9.82	0.38
1979	864	6.22	11.71	0.73	2093.08	3843.67	342.50
1980	864	0.86	1.47	0.24	230.34	506.33	-45.67
1981	864	1.63	2.90	0.35	565.30	1054.65	75.97
1982	864	1.52	3.77	-0.74	696.33	1913.68	-521.02
1983	864	2.84	5.63	0.05	592.08	1209.58	-25.43
1984	864	2.12	4.11	0.12	420.52	794.07	46.97
1985	864	0.57	0.97	0.17	71.41	133.01	9.84
1986	864	0.64	0.74	0.53	76.06	111.08	41.06
1987	864	5.08	7.08	3.08	893.83	1423.59	364.07
1988	864	0.15	0.29	0.00	18.67	35.85	1.51
1989	864	2.14	3.17	1.11	581.54	924.67	238.38
1990	864	2.60	4.82	0.37	753.09	1514.12	-7.91
1991	864	0.01	0.02	0.00	1.17	2.67	-0.36
1992	864	1.18	1.77	0.58	262.08	509.97	14.17
1993	864	0.29	0.44	0.14	35.58	46.63	24.53
1994	864	4.33	7.92	0.74	757.18	1316.64	197.70
1995	864	1.86	5.92	-2.20	86.19	320.65	-148.26
1996	864	0.34	0.60	0.09	29.97	61.06	-1.12
1997	864	1.72	2.76	0.69	230.68	364.54	96.82
1998	864	0.28	0.87	-0.30	28.35	111.46	-54.74
1999	864	0.59	2.15	-0.98	100.68	381.75	-180.41
2000	864	0.71	1.94	-0.52	210.33	579.11	-158.46
2001	864	0.25	0.69	-0.20	40.70	160.66	-79.23
2002	864	0.40	1.47	-0.66	124.34	497.21	-248.54
2003	864	0.04	0.09	-0.02	0.36	1.08	-0.34
2004	864	0.20	0.38	0.03	1.06	2.04	0.09
2005	864	1.40	1.76	1.04	42.16	98.91	-14.60
2006	864	0.11	0.15	0.06	3.35	5.30	1.42
2007	864	0.35	0.61	0.08	36.08	67.75	4.40
2008	864	0.14	0.24	0.05	1.80	4.31	-0.74
2009	864	0.72	1.03	0.41	6.92	20.80	-6.94

Table C46. Stratified mean number and weight (kg) per tow for red hake from Rhode Island and Connecticut state surveys in the southern management area for both fall and spring.

	RI Fall	RI Fall	RI Spring	RI Spring	CT Fall	CT Fall	CT Spring	CT Spring
Year	Stratified Mean Number/Tow	Stratified Mean Weight/Tow (Kg)	Stratified Mean Number/Tow	Stratified Mean Weight/Tow (Kg)	Stratified Mean Number/Tow	Stratified Mean Weight/Tow (Kg)	Stratified Mean Number/Tow	Stratified Mean Weight/Tow (Kg)
1979	2.91	0.22	5.72	0.55				
1980	0.71	0.09	8.75	0.48				
1981	2.60	0.24	1.43	0.24				
1982	1.84	0.15	1.37	0.07				
1983	0.61	0.09	8.00	1.14				
1984	3.00	0.43	14.26	2.84	0.74		15.04	
1985	3.16	0.22	2.67	0.15	0.33		3.02	
1986	12.47	0.75	19.25	1.37	1.00		4.67	
1987	2.24	0.26	34.34	1.77	0.37		3.84	
1988	1.93	0.40	9.42	1.06	0.75		3.64	
1989	2.91	0.34	12.57	0.87	1.14		13.12	
1990	0.36	0.03	2.12	0.19	0.44		4.75	
1991	0.00	0.00	9.30	0.63	0.33		4.35	
1992	0.32	0.04	0.17	0.00	0.39	0.11	4.83	0.78
1993	0.54	0.05	0.83	0.01	1.81	0.34	6.00	0.85
1994	0.56	0.07	0.39	0.04	0.59	0.19	0.89	0.14
1995	0.20	0.02	7.39	0.11	0.20	0.04	4.12	0.66
1996	0.58	0.10	2.01	0.13	1.62	0.48	1.49	0.21
1997	3.35	0.23	16.87	1.79	0.89	0.18	1.41	0.33
1998	0.15	0.02	2.39	0.25	0.53	0.10	6.28	0.94
1999	0.26	0.02	4.15	0.26	0.29	0.06	7.21	1.05
2000	0.46	0.06	5.87	0.40	1.20	0.32	4.01	0.59
2001	0.31	0.03	0.82	0.18	0.41	0.07	2.64	0.45
2002	0.10	0.01	1.04	0.27	0.15	0.02	5.11	0.96
2003	1.45	0.19	4.20	0.04	0.73	0.19	1.18	0.13
2004	1.33	0.09	2.04	0.08	0.76	0.14	1.37	0.20
2005	2.84	0.20	1.51	0.01	0.45	0.10	1.06	0.22
2006	0.49	0.03	1.51	0.10	0.33	0.06	1.30	0.25
2007	0.14	0.01	0.60	0.02	0.54	0.12	3.85	0.67
2008	0.33	0.03	1.01	0.01	0.41	0.09	3.37	0.61
2009	0.63	0.07	0.43	0.02	0.90	0.13	1.48	0.23
2010			1.03	0.02				

Table C47. Swept area abundance and biomass and upper and lower confidence intervals for red hake from the NEFSC fall bottom trawl surveys in the northern and southern management regions combined (strata 1-30, 36-40, 61-76). Estimates for 2009 were converted to Albatross units using the calibration factors at length in Table C34.

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1967	61047	29.00	39.18	18.81	6647.04	8648.51	4645.57
1968	61047	51.27	65.07	37.47	10721.38	13692.52	7750.24
1969	61047	67.46	84.94	49.98	13194.87	16659.84	9729.37
1970	61047	60.19	71.33	49.04	8755.88	10278.79	7232.98
1971	61047	71.68	86.86	56.50	11353.65	13375.29	9332.02
1972	61047	105.10	133.74	76.46	17737.42	21625.90	13849.49
1973	61047	79.20	104.73	53.67	11128.00	14159.09	8096.36
1974	61047	79.32	98.67	59.97	4467.33	5882.31	3052.35
1975	61047	129.75	159.92	99.57	19941.66	24006.73	15876.58
1976	61047	81.57	98.70	64.44	14679.08	17627.87	11730.29
1977	61047	70.65	83.41	57.88	15778.47	18667.30	12889.64
1978	61047	69.59	81.72	57.45	12763.18	14942.89	10582.93
1979	61047	70.58	82.17	58.99	11780.98	13856.58	9704.84
1980	60987	116.25	139.67	92.83	18401.74	22294.02	14510.01
1981	61047	100.36	130.20	70.51	13683.25	16244.50	11122.55
1982	61047	68.12	85.98	50.27	13822.79	17331.90	10314.22
1983	61047	120.47	157.50	83.44	28806.55	36780.27	20832.29
1984	60961	47.64	61.86	33.42	11483.53	14312.23	8655.37
1985	61047	173.27	239.86	106.68	16712.71	19717.64	13708.32
1986	61047	43.16	57.94	28.38	9249.71	11359.65	7139.77
1987	60995	36.51	45.89	27.12	7330.29	8736.44	5924.14
1988	61047	41.13	57.30	24.96	7993.34	9917.96	6068.73
1989	61047	91.49	123.91	59.07	13904.54	17744.51	10064.58
1990	60942	64.48	86.81	42.15	11121.92	14013.40	8230.98
1991	61047	66.72	92.93	40.50	10797.14	14428.89	7165.94
1992	60890	37.53	47.01	28.04	6973.54	8371.83	5575.78
1993	60987	58.57	77.64	39.50	7246.02	9938.70	4553.33
1994	61047	80.86	108.07	53.66	10562.77	14247.39	6877.60
1995	61047	84.90	104.96	64.83	8547.67	9883.07	7212.81
1996	61047	39.04	45.92	32.16	6727.16	7864.16	5589.62
1997	61047	40.88	50.73	31.04	8222.27	10322.39	6122.69
1998	61047	58.75	69.07	48.42	12016.99	13987.39	10047.14
1999	61047	94.99	142.25	47.72	8894.33	10539.33	7249.33
2000	61047	61.75	73.99	49.51	13694.70	16591.70	10797.69
2001	60987	84.07	105.60	62.55	12275.81	14064.04	10487.59
2002	61047	80.63	92.14	69.11	13489.75	16000.85	10978.10
2003	60987	56.03	64.53	47.53	9426.85	10949.34	7903.81
2004	61047	42.35	48.75	35.96	4654.83	5471.34	3838.33
2005	60882	60.14	76.76	43.52	4575.39	5582.66	3568.66
2006	60995	84.57	104.27	64.87	7383.66	9593.64	5174.23
2007	61047	86.41	107.40	65.42	7006.23	8383.61	5628.32
2008	61047	49.71	60.13	39.29	6496.05	7751.88	5240.23
2009	61047	57.00			8453.82		

Table C48. Swept area abundance and biomass and upper and lower confidence intervals for red hake from the NEFSC spring bottom trawl surveys in the northern and southern management regions combined (strata 1-30, 36-40, 61-76). Estimates for 2009 and 2010 were converted to Albatross units using the calibration factors at length in Table C34.

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1968	61047	25.83	33.98	17.68	6690.64	8420.13	4960.61
1969	61047	23.98	29.15	18.82	4950.80	6104.15	3798.00
1970	61047	34.60	40.44	28.76	6861.79	8087.09	5636.49
1971	61047	86.92	120.95	52.89	12935.97	17062.64	8809.85
1972	61047	74.48	103.49	45.47	15223.60	20610.99	9836.74
1973	61047	105.95	130.04	81.87	22443.49	27805.27	17081.71
1974	61047	67.88	81.29	54.46	14597.32	17390.22	11803.87
1975	58610	72.49	93.49	51.50	18864.05	23568.55	14159.02
1976	61047	108.38	166.94	49.83	24806.34	40570.64	9042.04
1977	61047	60.45	70.20	50.70	13298.98	15376.76	11221.20
1978	61047	128.99	170.40	87.59	30821.10	38546.82	23094.84
1979	61047	47.99	62.01	33.98	9378.35	11723.75	7032.94
1980	61047	79.83	94.57	65.09	16187.27	19172.57	13202.50
1981	60875	149.06	194.77	103.35	28794.42	36579.35	21010.03
1982	61047	76.80	99.39	54.21	15616.59	21514.71	9717.92
1983	61047	68.13	85.31	50.96	15220.33	19203.10	11237.01
1984	61047	44.82	59.38	30.25	10786.79	13766.10	7808.02
1985	61047	45.37	54.14	36.60	12982.84	15427.45	10538.24
1986	61047	59.22	75.66	42.77	12715.22	15755.58	9674.86
1987	61047	39.66	47.70	31.62	9198.47	10889.26	7507.69
1988	60942	35.78	44.14	27.42	7592.18	9227.82	5956.54
1989	61047	30.09	35.52	24.66	5147.03	6184.28	4109.23
1990	60875	29.08	35.10	23.07	5177.64	6093.48	4261.79
1991	61047	32.72	40.18	25.26	5491.50	6820.91	4162.10
1992	60811	30.82	37.79	23.84	6880.87	8726.38	5035.91
1993	60811	38.22	45.29	31.15	7435.77	8706.29	6165.26
1994	60871	36.89	48.57	25.21	5626.22	6945.82	4306.62
1995	61047	28.87	33.51	24.22	5928.64	6891.77	4965.52
1996	61047	32.46	40.93	23.99	5333.98	6780.58	3887.39
1997	60766	49.11	70.55	27.68	7689.07	10857.04	4521.64
1998	60987	31.76	35.67	27.86	6095.98	6867.57	5323.84
1999	61047	35.08	41.22	28.93	6474.80	7724.08	5225.51
2000	61047	45.68	51.93	39.44	8218.45	9479.18	6957.72
2001	61047	54.14	62.91	45.38	9784.42	11197.22	8371.61
2002	61047	59.31	67.83	50.78	11337.30	12747.92	9926.13
2003	61047	18.53	20.99	16.08	2811.98	3179.89	2444.06
2004	61047	26.80	33.74	19.85	4302.72	5342.70	3262.74
2005	61047	23.29	27.06	19.52	3593.05	4125.03	3061.62
2006	60987	24.42	28.11	20.72	3208.35	3735.45	2681.25
2007	61047	59.37	71.52	47.22	7238.43	8591.82	5885.04
2008	61047	62.65	73.58	51.72	9031.69	10840.20	7223.17
2009	60961	54.02			8173.75		
2010	61047	62.67			9022.02		

Table C49. Species of consistent red hake predators. Whether abundances where estimated from recent stock assessments (SA) or swept area (SWA) from surveys are noted, as is the resolution of the diet data (annual, 2 yr, or 3 yr).

Common Name	Species Name	Assessment or Swept Area	Diet Resolution
Spiny dogfish	*Squalus acanthias*	SWA	Annual
Little skate	*Raja ocellata*	SWA	Annual
Winter skate	*Raja erinacea*	SWA	3 yr
Thorny skate	*Raja radiata*	SWA	2 yr
Silver Hake	*Merluccius bilinearis*	SWA	Annual
Atlantic cod	*Gadus morhua*	SWA	Annual
White hake	*Urophycis tenuis*	SWA	Annual
Fourspot flounder	*Paralichthys oblongus*	SWA	3 yr
Summer Flounder	*Paralichthys dentatus*	SWA	3 yr
Windowpane	*Scophthalmus aquosus*	SWA	3 yr
Sea raven	*Hemitripterous americanus*	SWA	3 yr
Goosefish	*Lophius americanus*	SWA	3 yr

Table C50. Summary of catch, NEFSC fall and spring bottom trawl survey indices, replacement ratios and relative fishing mortality rates for red hake, northern stock. Catch is based on method "Raw C2". Estimates for 2009 were converted to Albatross units using the calibration factors at length in Table C34.

		NEFSC Survey		Replacement Ratio		Relative Fishing Mortality	
Year	Catch(mt)	Fall (kg/tow)	Spring (kg/tow)	Fall	Spring	Relative F Fall (mt/kg)	Relative F Spring (mt/kg)
1963	3281.0	4.85	-999			676.5	
1964	1409.0	1.31	-999			1075.6	
1965	2773.0	1.22	-999			2273.0	
1966	5575.0	0.92	-999			6059.8	
1967	1863.0	0.49	-999			3802.0	
1968	2627.0	0.26	1.14	0.1479		10103.8	2304.4
1969	2021.0	0.67	0.64	0.7976		3016.4	3157.8
1970	1032.0	0.6	0.54	0.8427		1720.0	1911.1
1971	4805.0	1.33	0.65	2.2619		3612.8	7392.3
1972	15026.0	2.34	1.56	3.4925		6421.4	9632.1
1973	15288.0	1.56	4.31	1.5000	4.7572	9800.0	3547.1
1974	7223.0	0.68	2.43	0.5231	1.5779	10622.1	2972.4
1975	8701.0	1.76	4.25	1.3518	2.2392	4943.8	2047.3
1976	6337.0	1.7	3.37	1.1082	1.2765	3727.6	1880.4
1977	891.0	3.49	2.66	2.1704	0.8354	255.3	335.0
1978	1223.0	3.06	2.57	1.6649	0.7550	399.7	475.9
1979	1523.0	1.82	2.04	0.8513	0.6675	836.8	746.6
1980	1029.0	3.76	3.88	1.5892	1.3029	273.7	265.2
1981	2570.5	2.81	6.35	1.0159	2.1866	914.8	404.8
1982	2669.9	1.67	2.13	0.5589	0.6086	1598.7	1253.5
1983	2248.1	4.11	3.7	1.5663	1.0902	547.0	607.6
1984	2386.3	3.54	2.98	1.2491	0.8232	674.1	800.8
1985	2262.4	4.73	3.91	1.4884	1.0268	478.3	578.6
1986	2645.9	2.84	3.26	0.8422	0.8547	931.6	811.6
1987	2065.7	2.25	2.94	0.6661	0.9199	918.1	702.6
1988	1758.7	2.54	2	0.7270	0.5956	692.4	879.4
1989	2223.0	4.67	1.65	1.4686	0.5467	476.0	1347.3
1990	1420.6	3.32	1.33	0.9748	0.4833	427.9	1068.2
1991	1561.4	2.56	1.62	0.8195	0.7245	609.9	963.8
1992	1643.9	2.29	2.5	0.7464	1.3103	717.9	657.6
1993	851.6	1.99	2.82	0.6469	1.5495	428.0	302.0
1994	804.2	3.69	1.59	1.2441	0.8014	217.9	505.8
1995	248.9	3.28	1.97	1.1841	0.9990	75.9	126.3
1996	1064.8	2.53	1.79	0.9160	0.8524	420.9	594.8
1997	463.0	2.92	1.81	1.0595	0.8482	158.6	255.8
1998	316.9	4.84	2.52	1.6794	1.2625	65.5	125.8
1999	687.1	3.32	2.32	0.9618	1.1983	207.0	296.2
2000	251.7	5.66	3.19	1.6755	1.5322	44.5	78.9
2001	357.2	4.89	3.58	1.2688	1.5391	73.0	99.8
2002	375.7	5.37	4.46	1.2413	1.6617	70.0	84.2
2003	297.1	3.55	1	0.7371	0.3111	83.7	297.1
2004	160.0	1.56	1.77	0.3423	0.6082	102.6	90.4
2005	153.2	1.16	1.1	0.2758	0.3929	132.1	139.3
2006	276.8	2.19	0.91	0.6624	0.3820	126.4	304.2
2007	196.6	2.42	2.06	0.8749	1.1147	81.2	95.4
2008	111.6	1.91	3.49	0.8778	2.5512	58.4	32.0
2009	180.0	12.46	1.75	6.7424	0.9378	14.4	102.8

Table C51. Summary of AIM results for northern red hake for NEFSC fall and spring bottom trawl surveys and catch estimation method "raw C2" for 1963-2009.

Red Hake, North, RawC2	***Fall Survey***	***Spring Survey***
Critical value (observed correlation between replacement ratio and relative F	-0.208518	0.006928
Probability of observing correlation < Critical Value	0.9775	0.996
Relative F at Replacement (mt/kg)	607.85	7973.31
90% Confidence Interval for RelF at replacement	(14.29,37701)	(0.066,11261)

Table C52. Summary of catch, NEFSC fall and spring bottom trawl survey indices , replacement ratios and relative fishing mortality rates for red hake, southern stock. Catch is based on method "Raw C2". Estimates for 2009 were converted to Albatross units using the calibration factors at length in Table C34.

		NEFSC Survey		Replacement Ratio		Relative Fishing Mortality	
Year	Catch(mt)	Fall (kg/tow)	Spring (kg/tow)	Fall	Spring	Relative F Fall (mt/kg)	Relative F Spring (mt/kg)
1963	31901.0	-999	-999				
1964	43373.0	-999	-999				
1965	92990.0	-999	-999				
1966	107922.0	-999	-999				
1967	58783.0	1.69	-999			34782.8	
1968	18138.0	3.07	1.29			5908.1	14060.5
1969	52928.0	3.55	1.08			14909.3	49007.4
1970	11454.0	2.26	1.72			5068.1	6659.3
1971	35134.0	2.57	3.49			13670.8	10067.0
1972	61194.0	3.85	3.59	1.4650		15894.5	17045.7
1973	51362.0	2.35	3.99	0.7680	1.7860	21856.2	12872.7
1974	26643.0	0.91	2.84	0.3121	1.0238	29278.0	9381.3
1975	19976.0	4.88	3.18	2.0436	1.0173	4093.4	6281.8
1976	22465.0	3.34	5.31	1.1470	1.5535	6726.0	4230.7
1977	7062.0	2.51	2.3	0.8187	0.6081	2813.5	3070.4
1978	5463.0	1.88	7.65	0.6719	2.1708	2905.9	714.1
1979	7592.0	2.38	1.51	0.8802	0.3548	3189.9	5027.8
1980	4082.0	3.13	2.38	1.0440	0.5965	1304.2	1715.1
1981	5034.8	2.32	4.61	0.8761	1.2037	2170.2	1092.1
1982	6945.9	3.1	3.34	1.2684	0.9051	2240.6	2079.6
1983	5329.8	6.04	2.21	2.3575	0.5670	882.4	2411.7
1984	5181.2	1.18	1.33	0.3477	0.4733	4390.8	3895.6
1985	3871.4	1.99	1.39	0.6309	0.5011	1945.4	2785.2
1986	4082.6	0.96	1.73	0.3281	0.6716	4252.7	2359.9
1987	4256.3	0.76	0.88	0.2864	0.4400	5600.4	4836.7
1988	4332.6	0.77	1.01	0.3522	0.6698	5626.7	4289.7
1989	5936.9	1.18	0.49	1.0424	0.3864	5031.3	12116.1
1990	5545.9	1.22	0.71	1.0777	0.6455	4545.9	7811.2
1991	3536.8	1.61	0.61	1.6462	0.6328	2196.8	5798.0
1992	7588.0	0.63	0.46	0.5686	0.6216	12044.5	16495.8
1993	6231.8	0.9	0.42	0.8318	0.6402	6924.2	14837.7
1994	2702.8	0.8	0.67	0.7220	1.2454	3378.5	4034.1
1995	2756.5	0.46	0.52	0.4457	0.9059	5992.3	5300.9
1996	1079.5	0.39	0.45	0.4432	0.8396	2768.0	2399.0
1997	3421.5	0.6	1.16	0.9434	2.3016	5702.4	2949.5
1998	1894.8	0.5	0.21	0.7937	0.3261	3789.6	9022.8
1999	2411.6	0.54	0.45	0.9818	0.7475	4466.0	5359.2
2000	1667.2	0.48	0.42	0.9639	0.7527	3473.3	3969.5
2001	1606.3	0.55	0.64	1.0956	1.1896	2920.5	2509.8
2002	990.0	0.6	0.54	1.1236	0.9375	1650.0	1833.3
2003	967.9	0.55	0.21	1.0300	0.4646	1759.8	4609.0
2004	1203.9	0.4	0.15	0.7353	0.3319	3009.7	8025.8
2005	1363.5	0.63	0.38	1.2209	0.9694	2164.3	3588.1
2006	1049.2	0.82	0.38	1.5018	0.9896	1279.5	2760.9
2007	2015.0	0.55	0.86	0.9167	2.5904	3663.6	2343.0
2008	1393.5	0.73	0.47	1.2373	1.1869	1908.9	2964.8
2009	1443.5	1.02	1.34	1.6294	2.9911	1415.2	1077.2

Table C53. Summary of AIM results for southern red hake for NEFSC fall and spring bottom trawl surveys and catch estimation method "raw C2" for 1963-2009.

Red Hake, South, RawC2	***Fall Survey***	***Spring Survey***
Critical value (observed correlation between replacement ratio and relative F	-0.461619	-0.45839
Probability of observing correlation < Critical Value	0.4755	0.745
Relative F at Replacement (mt/kg)	2201.7	2304.1
90% Confidence Interval for RelF at replacement	1027.9,3251.9	(1087.4, 3128.7)

Table C54. Summary of catch, NEFSC fall and spring bottom trawl survey indices, replacement ratios and relative fishing mortality rates for red hake, northern stock. Catch is based on method "Raw C3", 1980-2009. Estimates for 2009 were converted to Albatross units using the calibration factors at length in Table C34.

		NEFSC Survey		Replacement Ratio		Relative Fishing Mortality	
Year	Catch(mt)	Fall (kg/tow)	Spring (kg/tow)	Fall	Spring	Relative F Fall (mt/kg)	Relative F Spring (mt/kg)
1963							
1964							
1965							
1966							
1967							
1968							
1969							
1970							
1971							
1972							
1973							
1974							
1975							
1976							
1977							
1978							
1979							
1980	1032.8	3.76	3.88			274.7	266.2
1981	2601.4	2.81	6.35			925.8	409.7
1982	2672.8	1.67	2.13			1600.5	1254.8
1983	2248.2	4.11	3.7			547.0	607.6
1984	2387.7	3.54	2.98			674.5	801.2
1985	2262.4	4.73	3.91	1.4884	1.0268	478.3	578.6
1986	2646.4	2.84	3.26	0.8422	0.8547	931.8	811.8
1987	2065.9	2.25	2.94	0.6661	0.9199	918.2	702.7
1988	1762.8	2.54	2	0.7270	0.5956	694.0	881.4
1989	2223.5	4.67	1.65	1.4686	0.5467	476.1	1347.6
1990	1424.8	3.32	1.33	0.9748	0.4833	429.1	1071.2
1991	1563.0	2.56	1.62	0.8195	0.7245	610.6	964.8
1992	1644.6	2.29	2.5	0.7464	1.3103	718.2	657.8
1993	852.6	1.99	2.82	0.6469	1.5495	428.4	302.3
1994	805.9	3.69	1.59	1.2441	0.8014	218.4	506.9
1995	249.9	3.28	1.97	1.1841	0.9990	76.2	126.9
1996	1070.1	2.53	1.79	0.9160	0.8524	423.0	597.8
1997	463.8	2.92	1.81	1.0595	0.8482	158.8	256.2
1998	317.0	4.84	2.52	1.6794	1.2625	65.5	125.8
1999	687.2	3.32	2.32	0.9618	1.1983	207.0	296.2
2000	251.8	5.66	3.19	1.6755	1.5322	44.5	78.9
2001	357.7	4.89	3.58	1.2688	1.5391	73.1	99.9
2002	376.0	5.37	4.46	1.2413	1.6617	70.0	84.3
2003	297.2	3.55	1	0.7371	0.3111	83.7	297.2
2004	160.1	1.56	1.77	0.3423	0.6082	102.6	90.4
2005	153.3	1.16	1.1	0.2758	0.3929	132.1	139.3
2006	276.9	2.19	0.91	0.6624	0.3820	126.4	304.3
2007	196.8	2.42	2.06	0.8749	1.1147	81.3	95.5
2008	111.8	1.91	3.49	0.8778	2.5512	58.5	32.0
2009	180.4	12.46	1.75	6.7424	0.9378	14.5	103.1

Table C55. Summary of AIM results for northern red hake for NEFSC fall and spring bottom trawl surveys and catch estimation method "Catch 3" for 1980-2009.

Red Hake, North, Catch3 short	***Fall Survey***	***Spring Survey***
Critical value (observed correlation between replacement ratio and relative F	-0.424471	-0.474634
Probability of observing correlation < Critical Value	0.379	0.2595
Relative F at Replacement (mt/kg)	162	163.1
90% Confidence Interval for RelF at replacement	(51.9, 407.0)	(42.9,260.3)

Table C56. Summary of catch, NEFSC fall and spring bottom trawl survey indices , replacement ratios and relative fishing mortality rates for red hake, southern stock. Catch is based on method "Raw C3", 1980-2009. Estimates for 2009 were converted to Albatross units using the calibration factors at length in Table C34.

		NEFSC Survey		Replacement Ratio		Relative Fishing Mortality	
Year	Catch(mt)	Fall (kg/tow)	Spring (kg/tow)	Fall	Spring	Relative F Fall (mt/kg)	Relative F Spring (mt/kg)
1963							
1964							
1965							
1966							
1967							
1968							
1969							
1970							
1971							
1972							
1973							
1974							
1975							
1976							
1977							
1978							
1979							
1980	4226.0	3.13	2.38			1350.2	1775.6
1981	5210.7	2.32	4.61			2246.0	1130.3
1982	6975.3	3.1	3.34			2250.1	2088.4
1983	5464.8	6.04	2.21			904.8	2472.7
1984	5729.5	1.18	1.33			4855.5	4307.9
1985	3900.8	1.99	1.39	0.6309	0.5011	1960.2	2806.3
1986	4288.1	0.96	1.73	0.3281	0.6716	4466.7	2478.6
1987	4728.4	0.76	0.88	0.2864	0.4400	6221.6	5373.2
1988	4583.5	0.77	1.01	0.3522	0.6698	5952.6	4538.1
1989	6372.4	1.18	0.49	1.0424	0.3864	5400.3	13004.9
1990	6059.9	1.22	0.71	1.0777	0.6455	4967.2	8535.1
1991	3821.5	1.61	0.61	1.6462	0.6328	2373.6	6264.8
1992	7782.3	0.63	0.46	0.5686	0.6216	12352.9	16918.1
1993	6321.2	0.9	0.42	0.8318	0.6402	7023.5	15050.4
1994	2771.7	0.8	0.67	0.7220	1.2454	3464.7	4136.9
1995	2801.4	0.46	0.52	0.4457	0.9059	6090.0	5387.3
1996	1098.8	0.39	0.45	0.4432	0.8396	2817.4	2441.8
1997	3594.9	0.6	1.16	0.9434	2.3016	5991.5	3099.0
1998	1947.6	0.5	0.21	0.7937	0.3261	3895.1	9274.0
1999	2464.6	0.54	0.45	0.9818	0.7475	4564.0	5476.8
2000	1711.6	0.48	0.42	0.9639	0.7527	3565.8	4075.1
2001	1630.2	0.55	0.64	1.0956	1.1896	2964.1	2547.2
2002	1000.3	0.6	0.54	1.1236	0.9375	1667.2	1852.4
2003	985.7	0.55	0.21	1.0300	0.4646	1792.1	4693.6
2004	1214.4	0.4	0.15	0.7353	0.3319	3035.9	8095.7
2005	1418.5	0.63	0.38	1.2209	0.9694	2251.6	3732.9
2006	1102.7	0.82	0.38	1.5018	0.9896	1344.7	2901.7
2007	2034.6	0.55	0.86	0.9167	2.5904	3699.3	2365.8
2008	1467.1	0.73	0.47	1.2373	1.1869	2009.8	3121.6
2009	1543.4	1.02	1.34	1.6294	2.9911	1513.1	1151.8

Table C57. Summary of AIM results for southern red hake for NEFSC fall and spring bottom trawl surveys and catch estimation method “Catch 3” for 1980-2009.

Red Hake, South, Catch3 short	***Fall Survey***	***Spring Survey***
Critical value (observed correlation between replacement ratio and relative F	-0.565693	-0.665111
Probability of observing correlation < Critical Value	0.7015	0.6485
Relative F at Replacement (mt/kg)	2306.9	3038.2
90% Confidence Interval for RelF at replacement	(1313.8, 2982.0)	(2134.8, 3730.9)

C. Red Hake - Figures

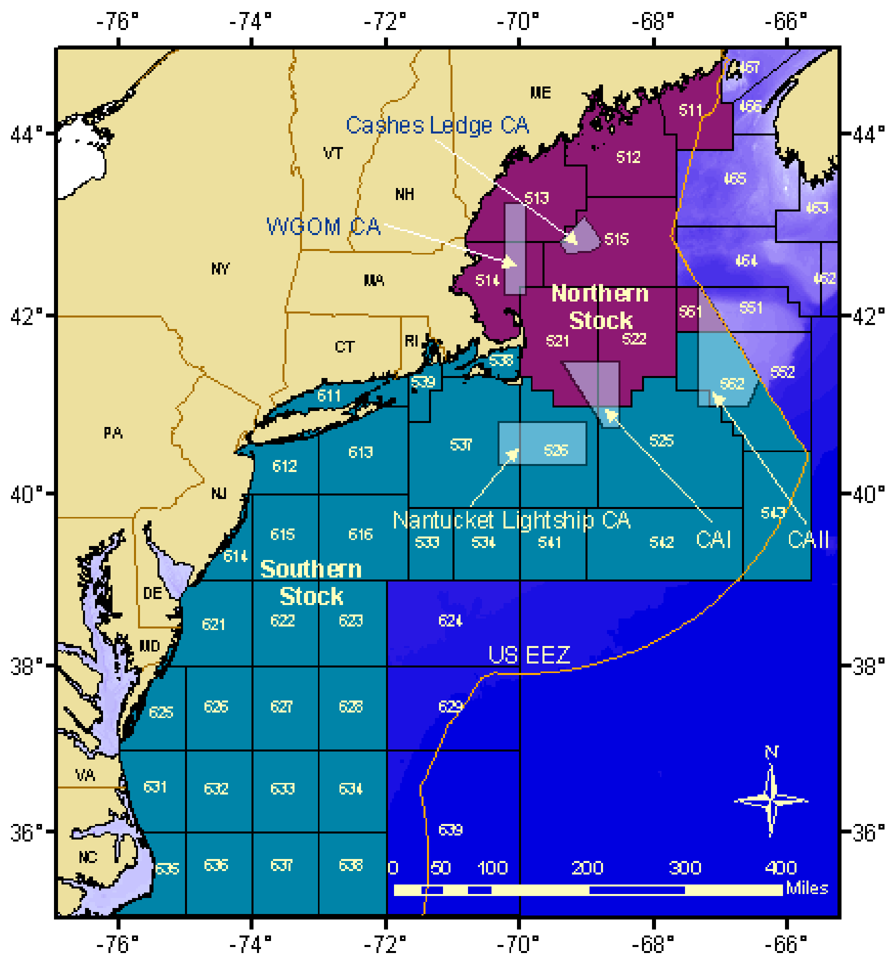


Figure C1. Statistical areas used to define the northern and southern red hake stocks.

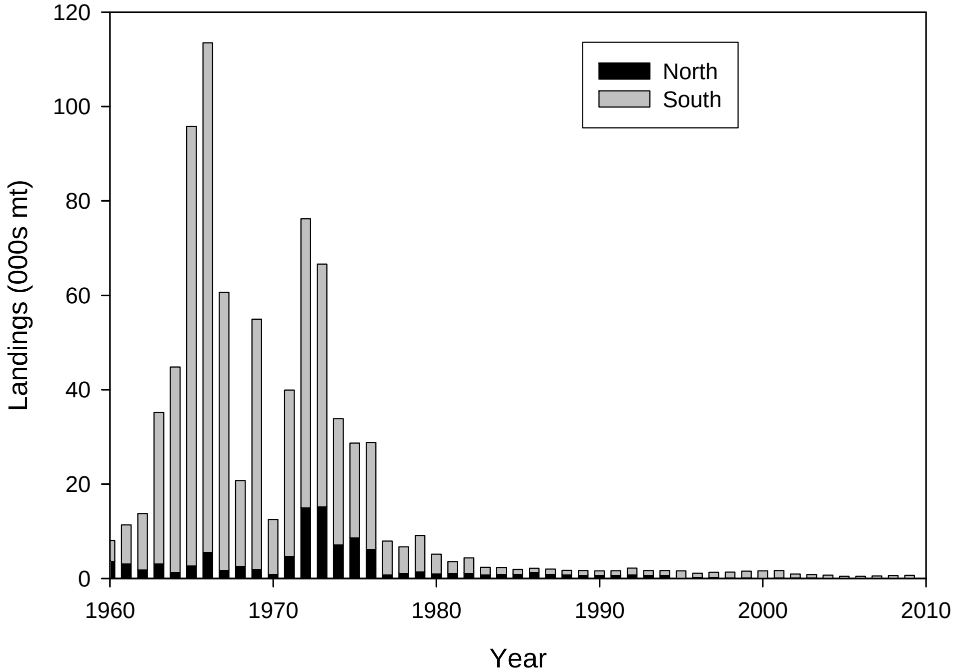


Figure C2. Nominal commercial landings (000s mt) by stock area for red hake, 1960-2009.

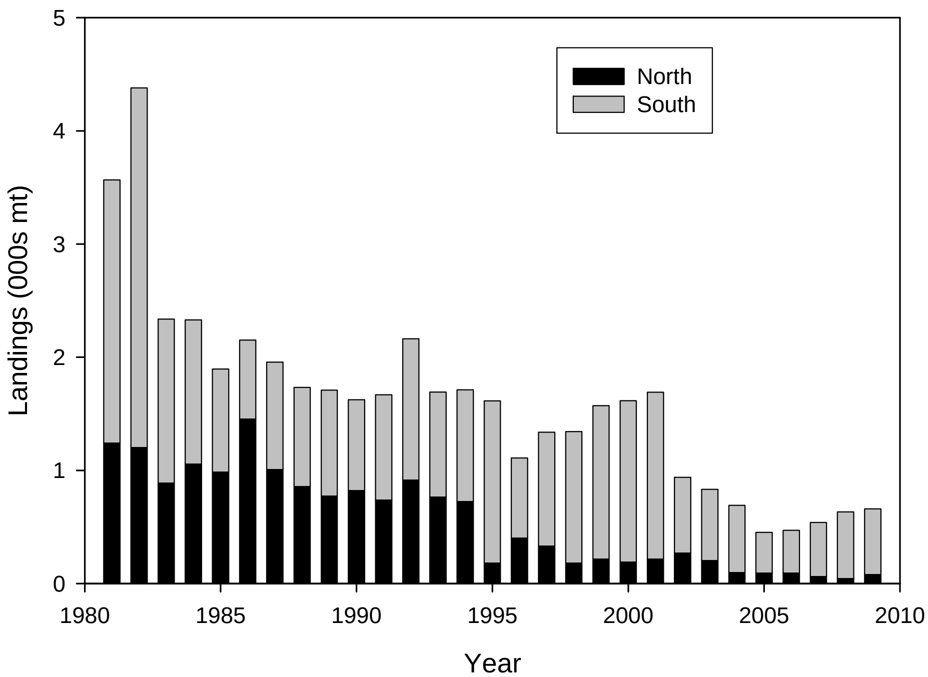


Figure C3. Nominal commercial landings (000s mt) by stock area for red hake, 1981-2009.

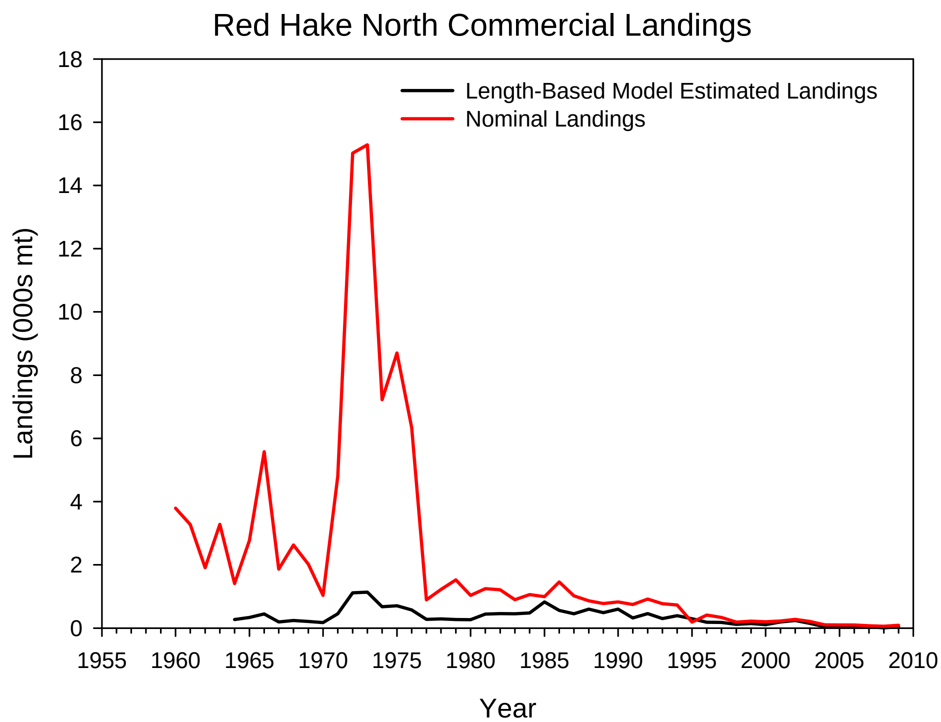


Figure C4. Comparison of nominal landings (000s mt) of red hake with length-based model estimated landings from the northern stock.

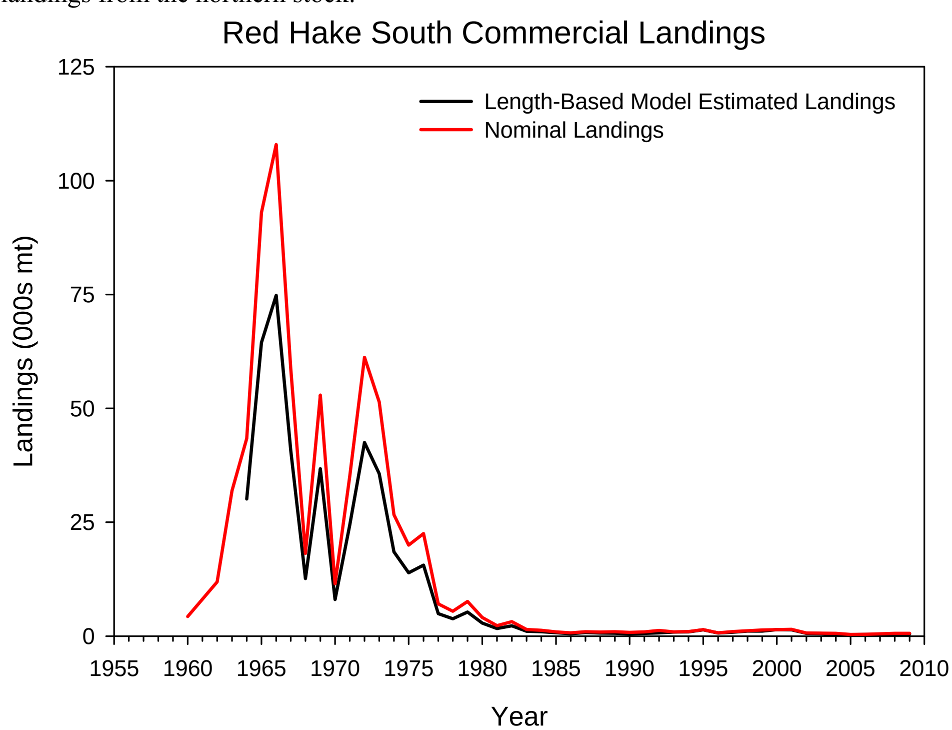
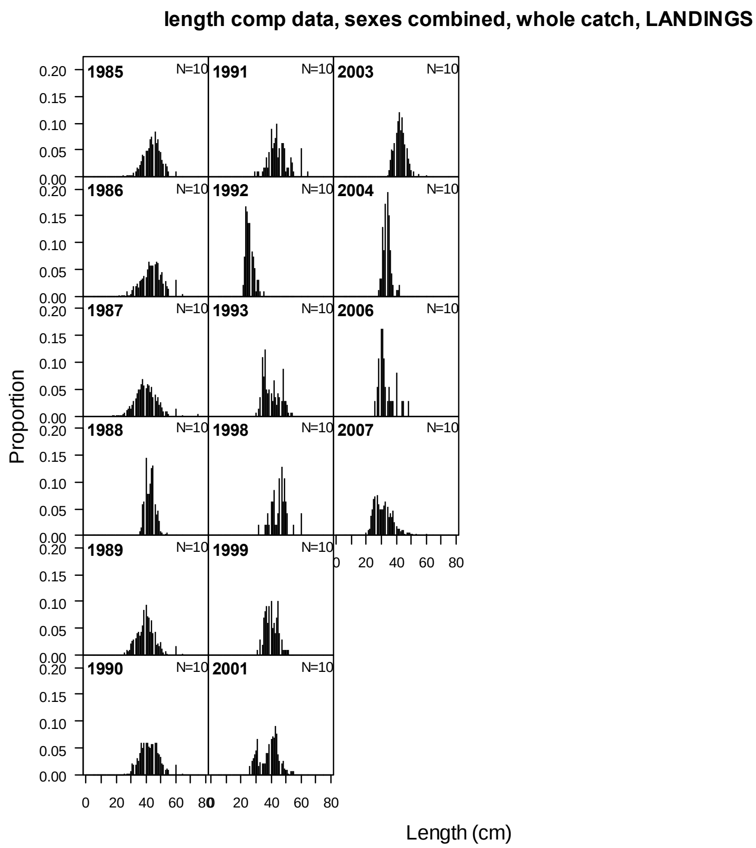


Figure C5. Comparison of nominal landings (000s mt) of red hake with length-based model estimated landings from the southern stock.



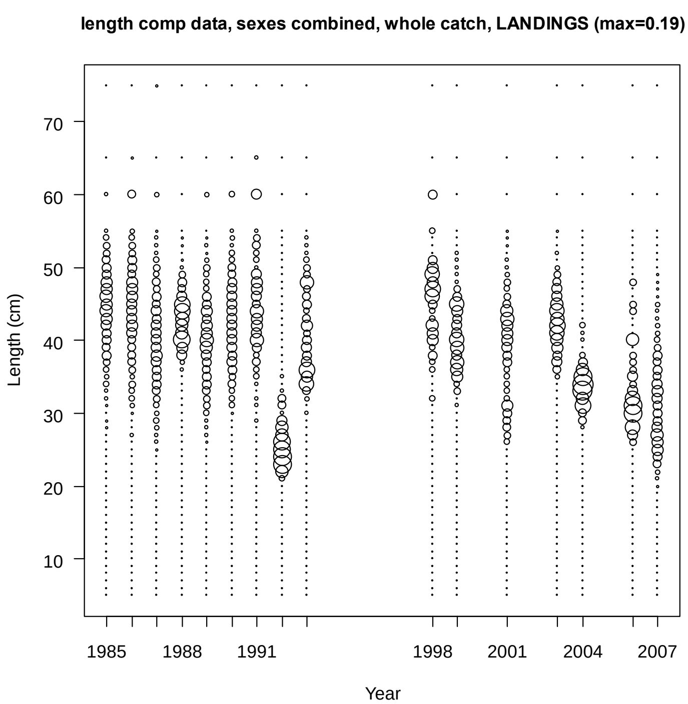
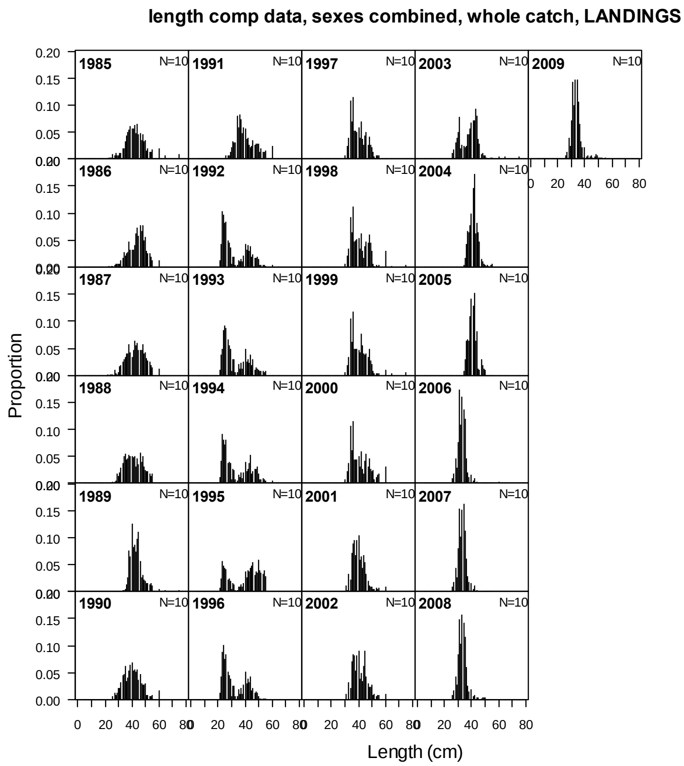


Figure C6. Length composition of nominal commercial landings from the northern stock.



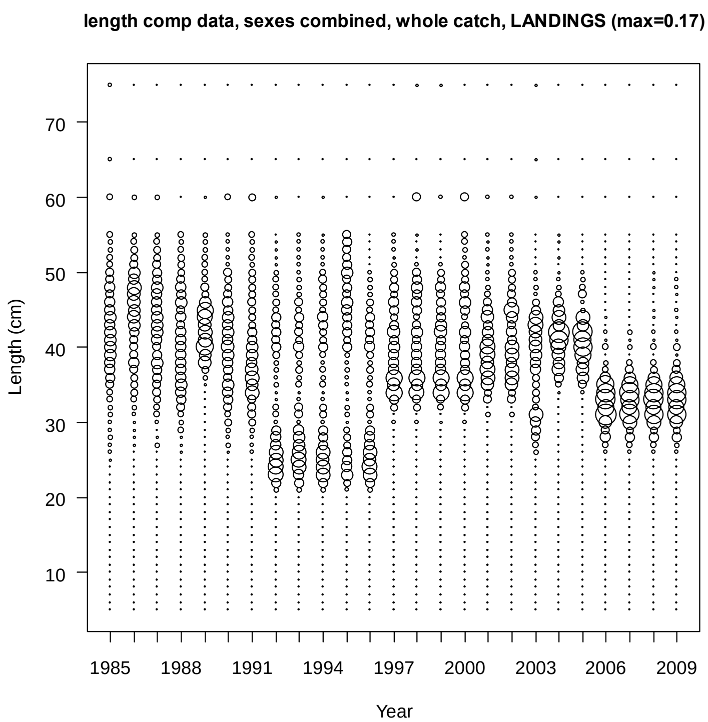
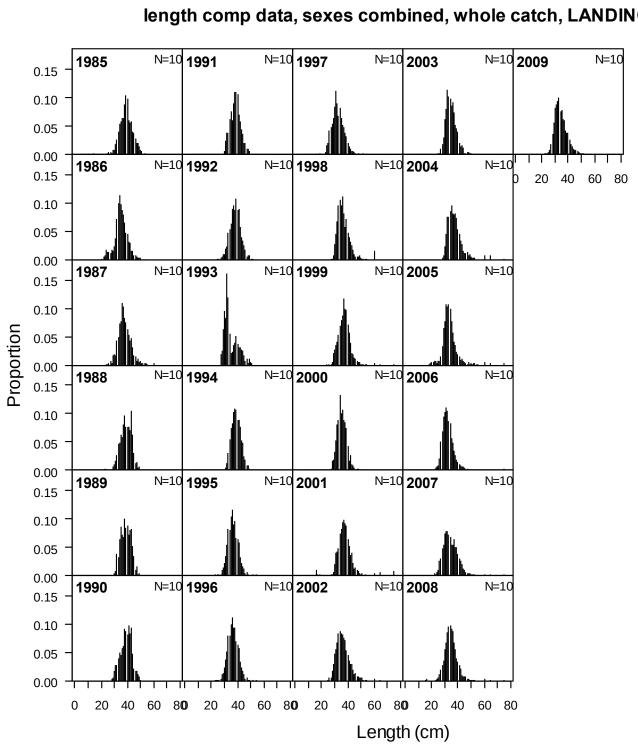


Figure C7. Length composition of length-based model estimated commercial landings from the northern stock.



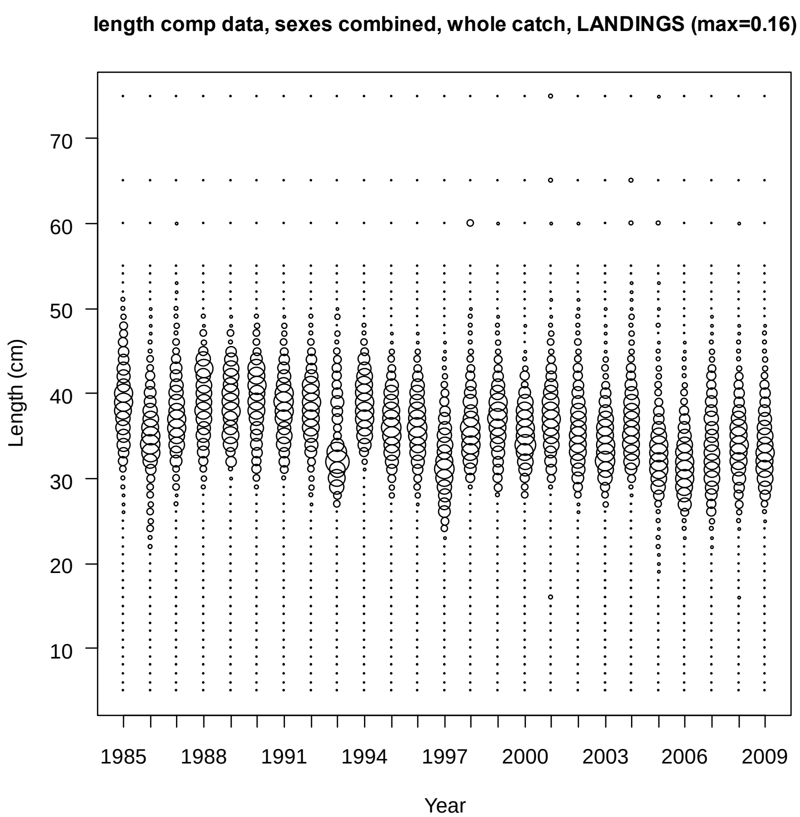
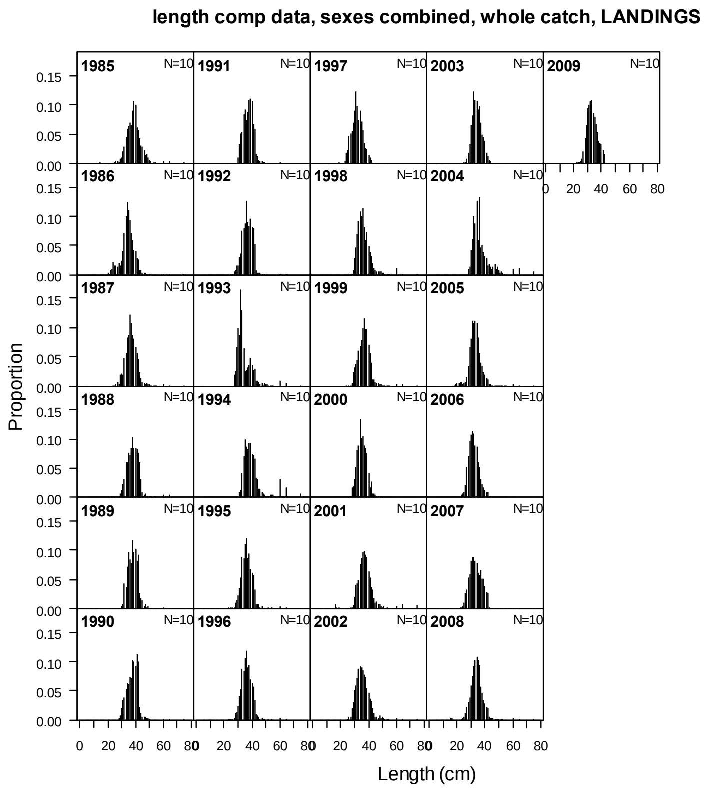


Figure C8. Length composition (proportion) of nominal commercial landings from the southern stock.



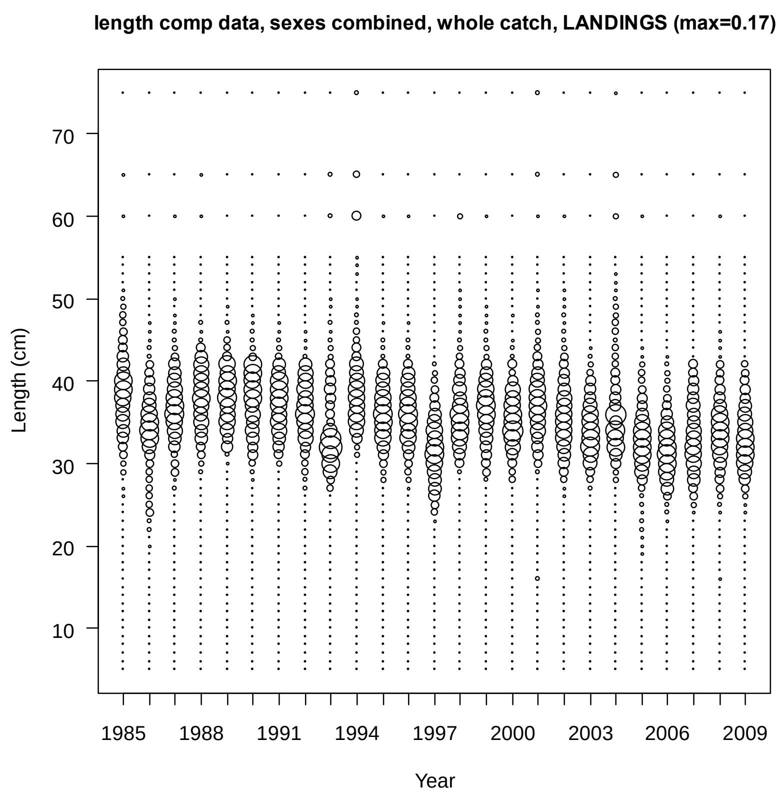


Figure C9. Length composition of length-based model estimated commercial landings from the northern stock.

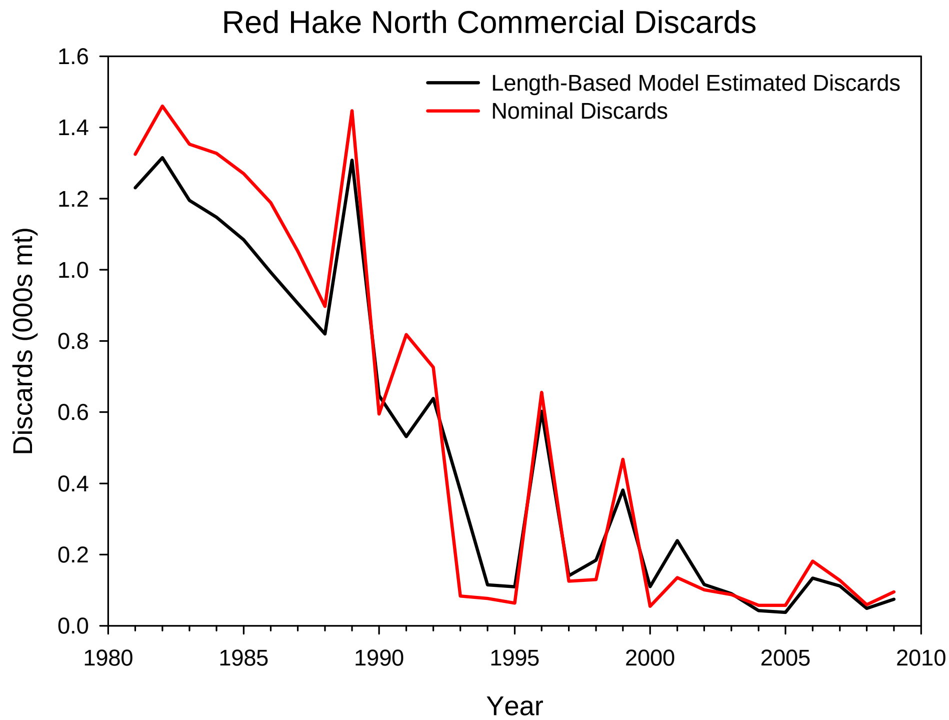


Figure C10. Comparison of nominal discards (000s mt) of red hake with length-based model estimated landings from the northern stock.

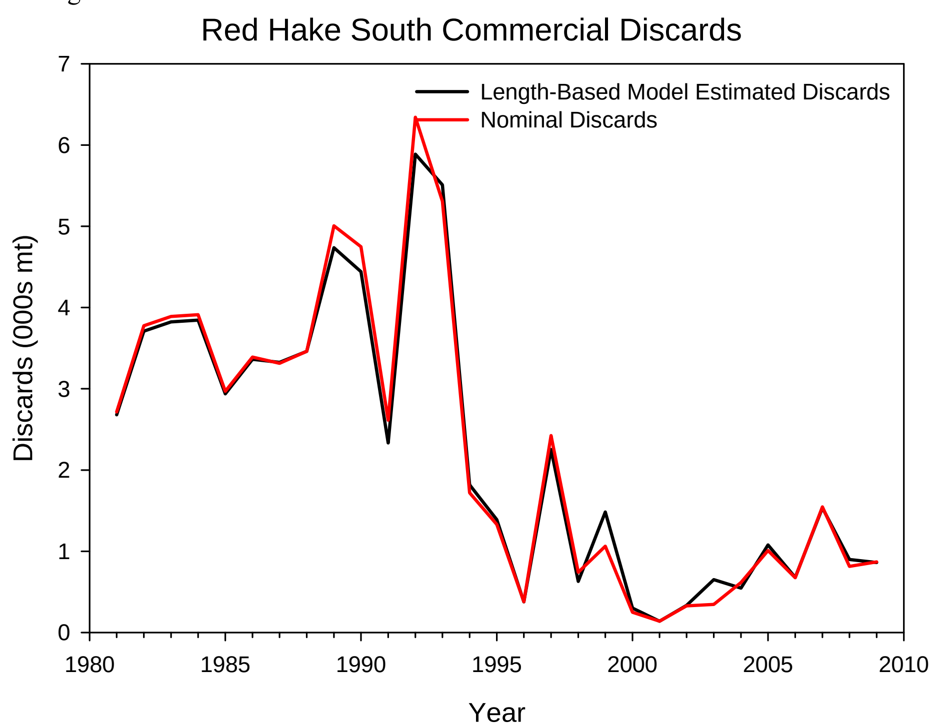
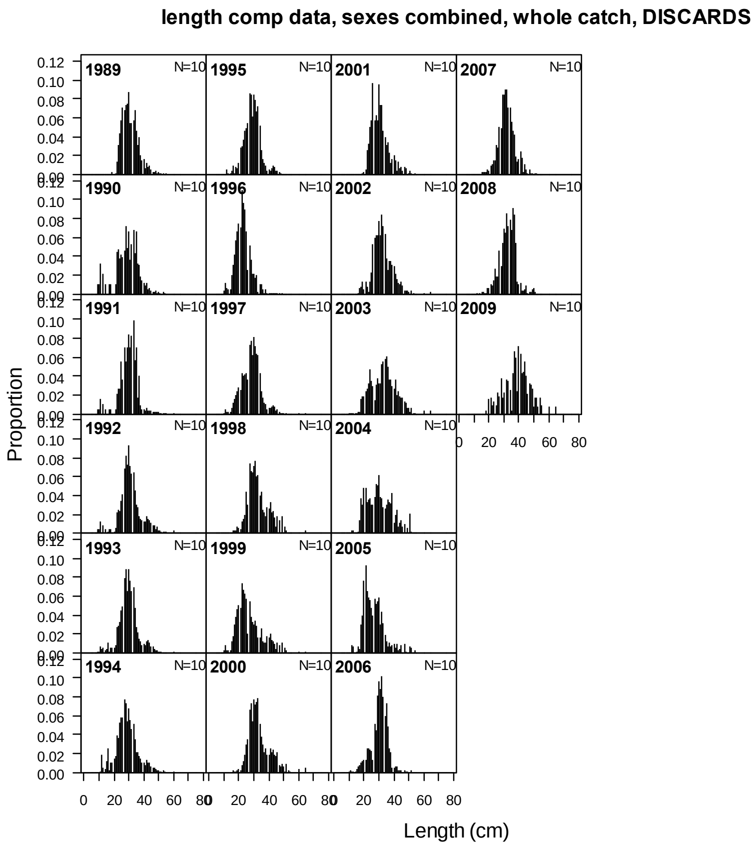


Figure C11. Comparison of nominal discards (000s mt) of red hake with length-based model estimated landings from the southern stock.



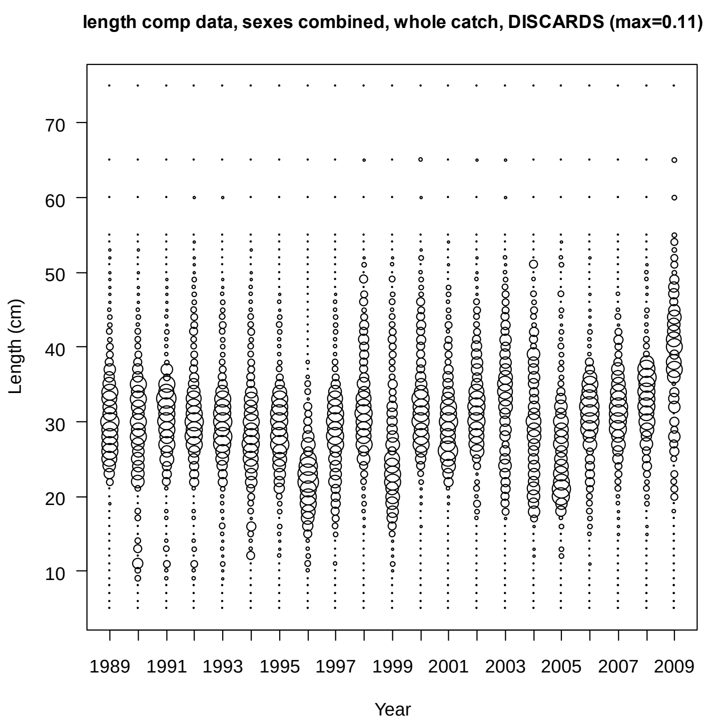


Figure C12. Length composition of nominal red hake commercial discards from the northern stock.

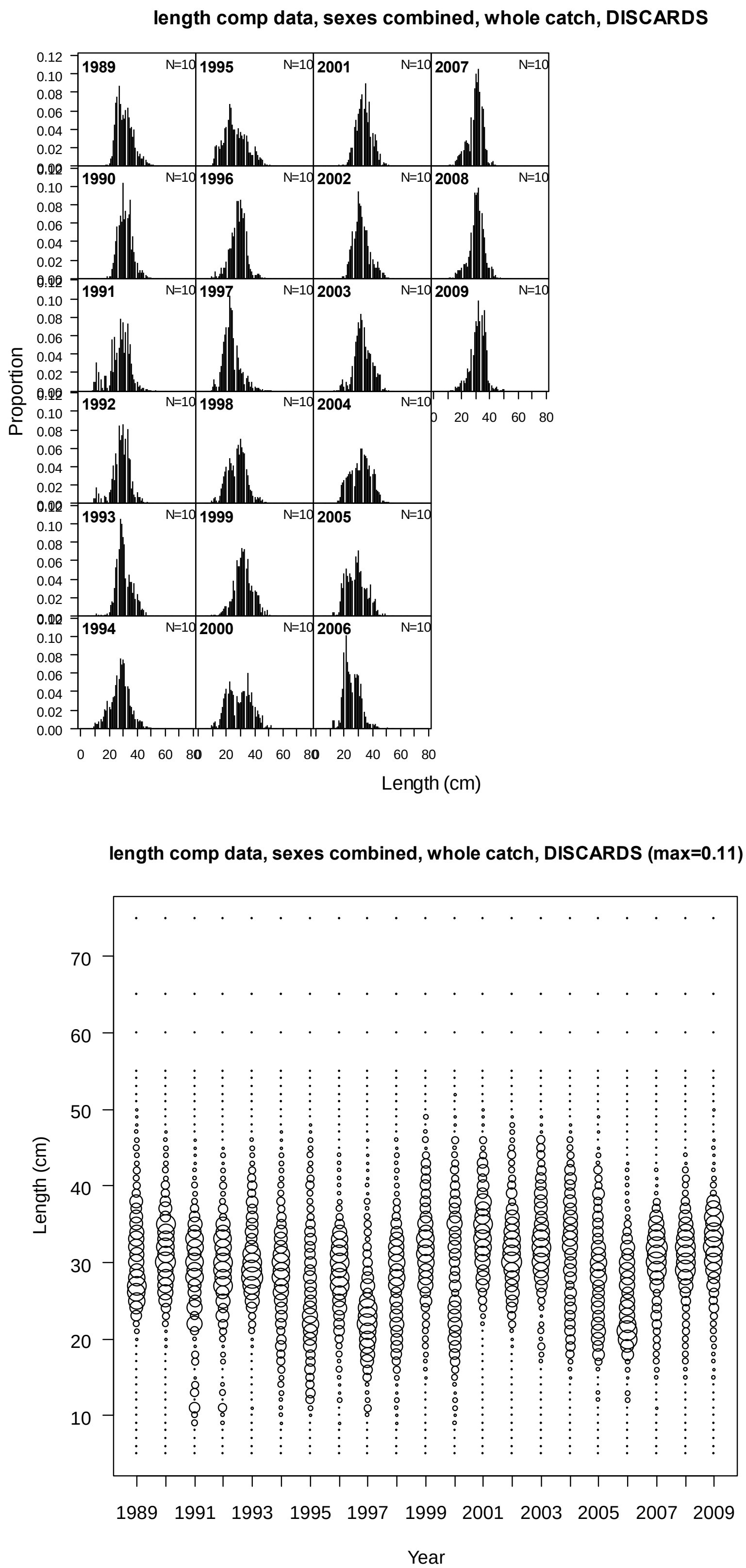
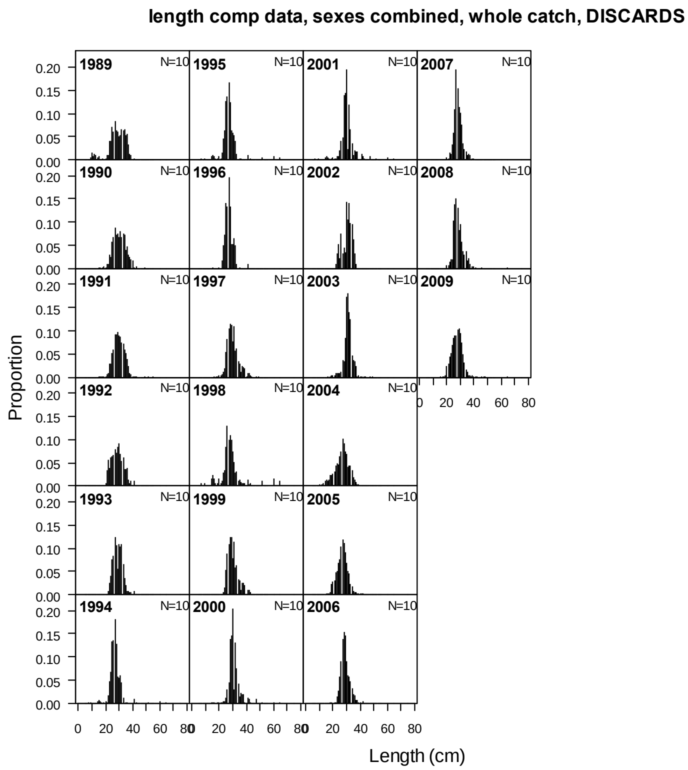


Figure C13. Length composition of length-based model estimated commercial discards from the northern stock.



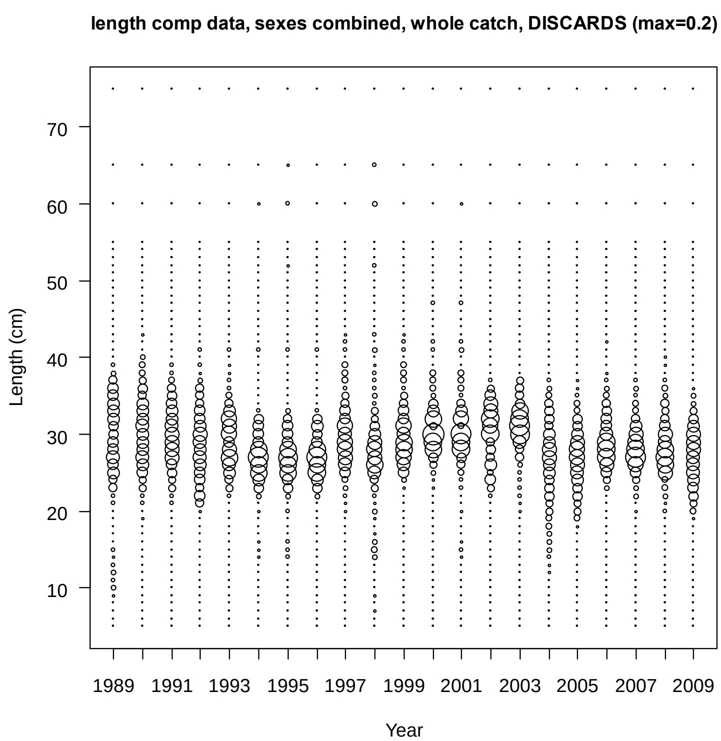
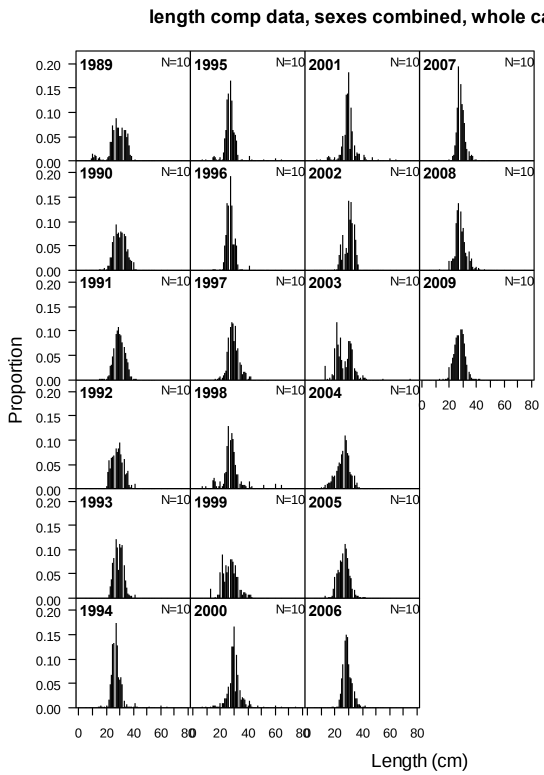


Figure C14. Length composition of nominal red hake commercial discards from the southern stock.



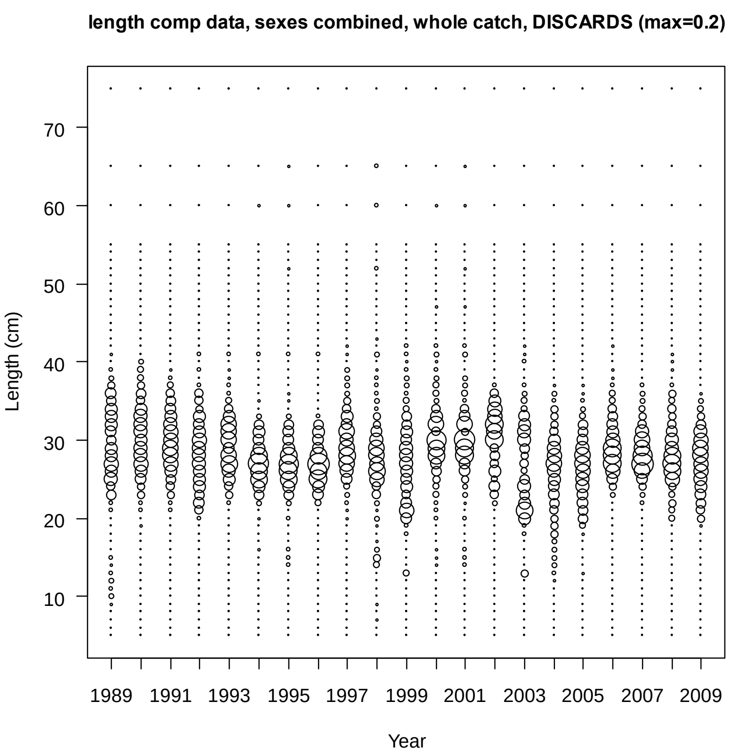


Figure C15. Length composition of length-based model estimated commercial discards from the southern stock.

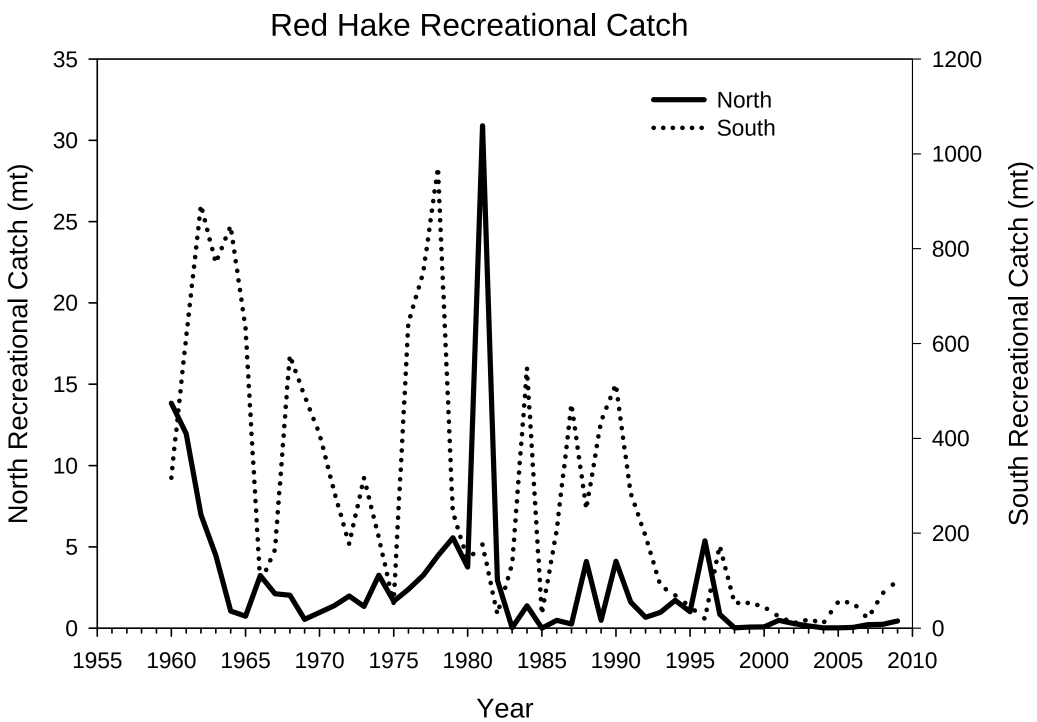
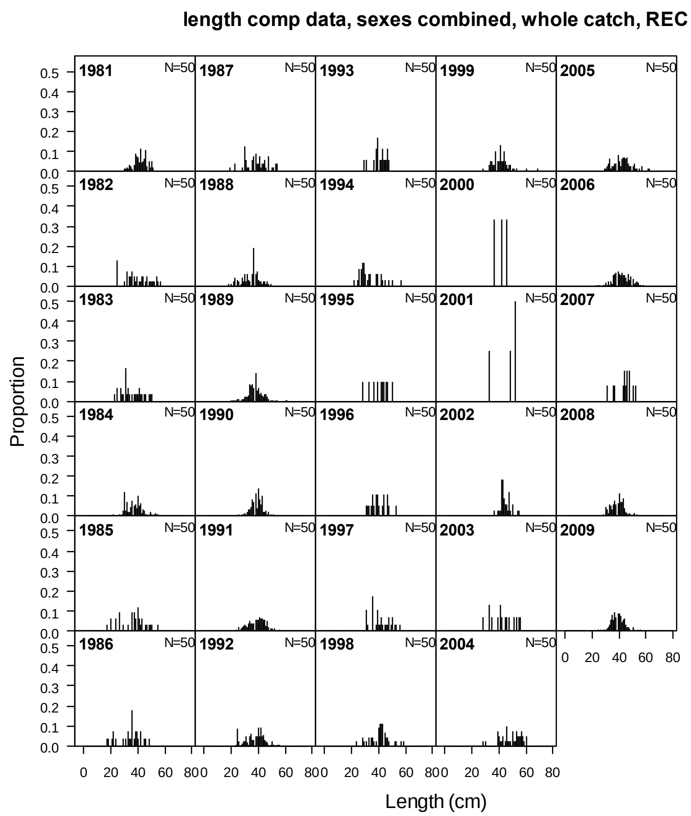


Figure C16. Recreational catch (mt) of red hake by stock. Note the southern stock is plotted against the right-hand axis.



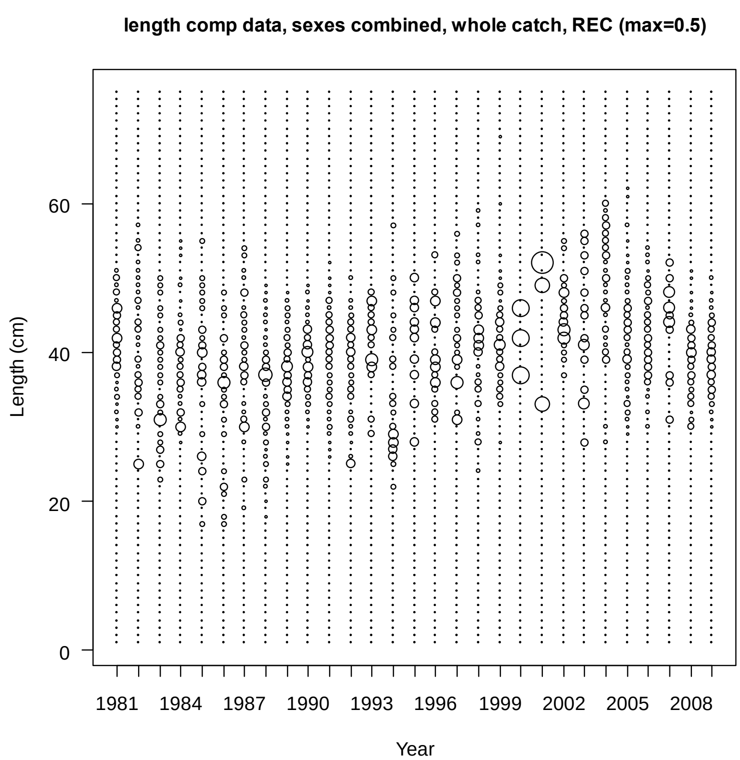


Figure C17. Length composition of recreational catch from the combined stock (mostly southern).

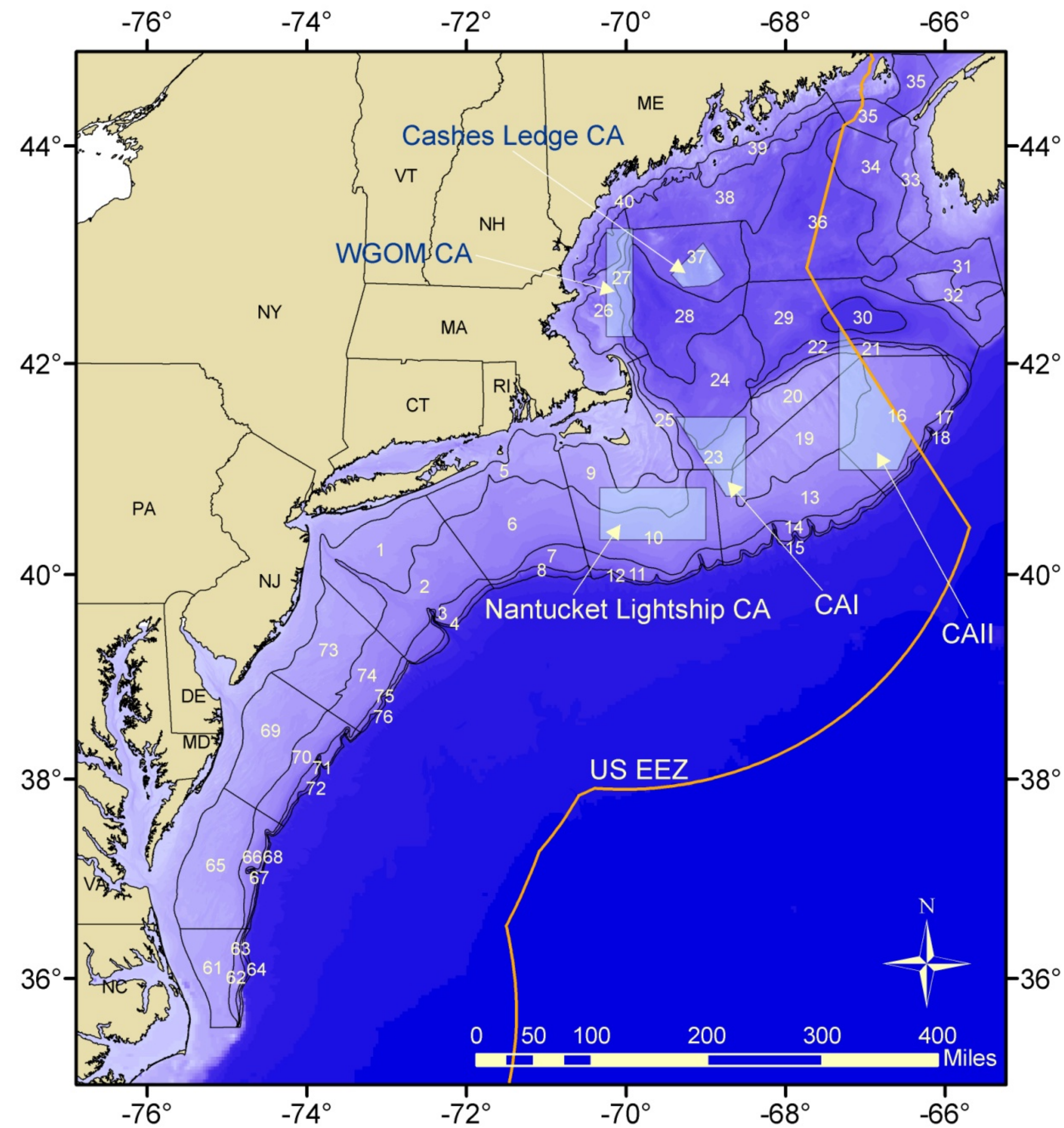


Figure C18. NEFSC survey strata.

Region	Stratum	Area(nm^2)
1. Buzzards Bay Vineyard Sd & coastal water south of Marthas Vineyard	11	102
	12	160
	13	88
	14	16
2. Nantucket Sound	15	190
	16	212
3. East of Cape Cod Race Point to Muskeget Island	17	85
	18	88
	19	39
	20	24
	21	40
4. Cape Cod Bay	25	47
	26	87
	27	94
	28	93
	29	103
	30	32
5. Massachusetts Bay north to N.H. border	31	41
	32	49
	33	78
	34	38
	35	174
	36	33

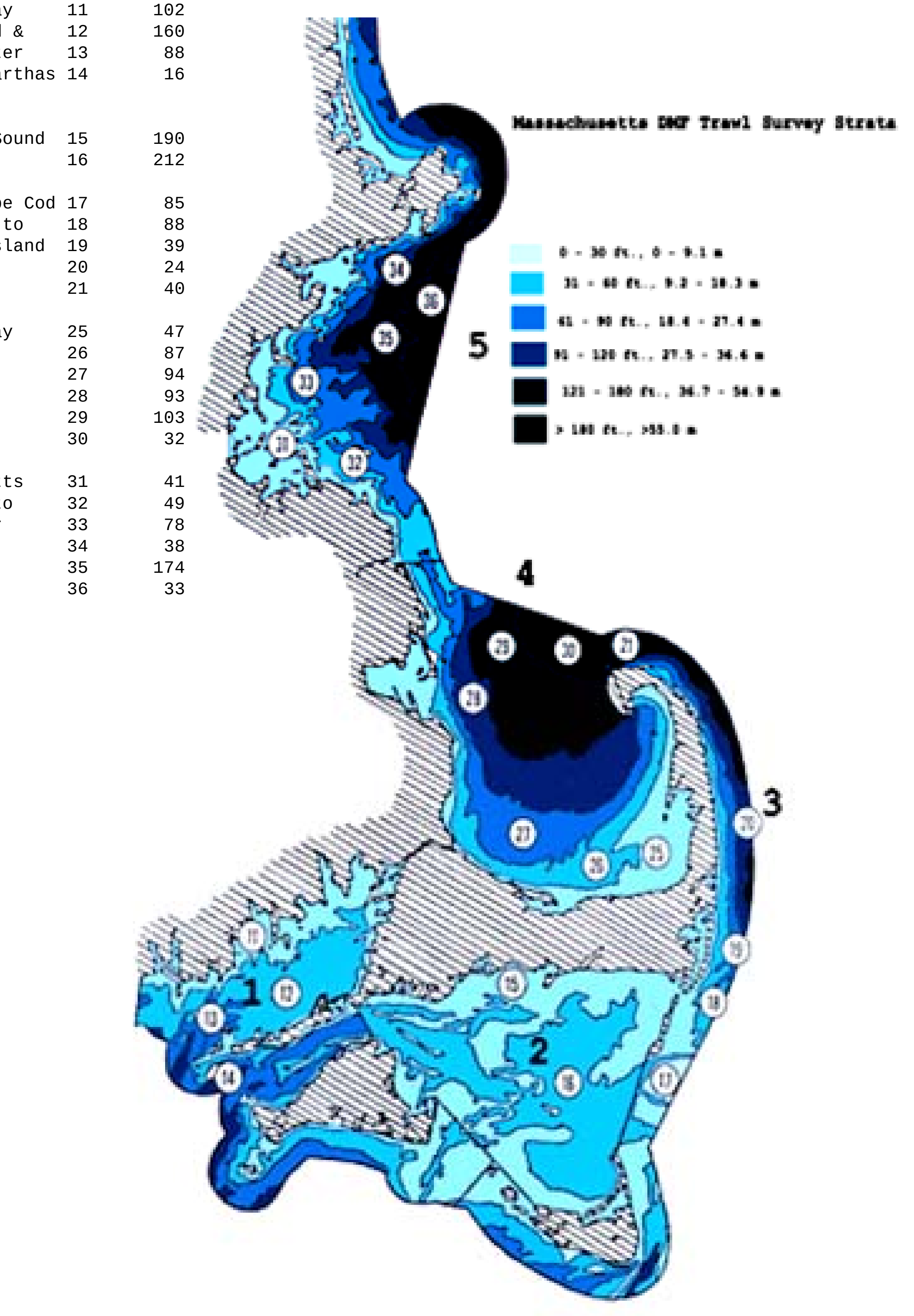


Figure C19. MADMF survey strata.

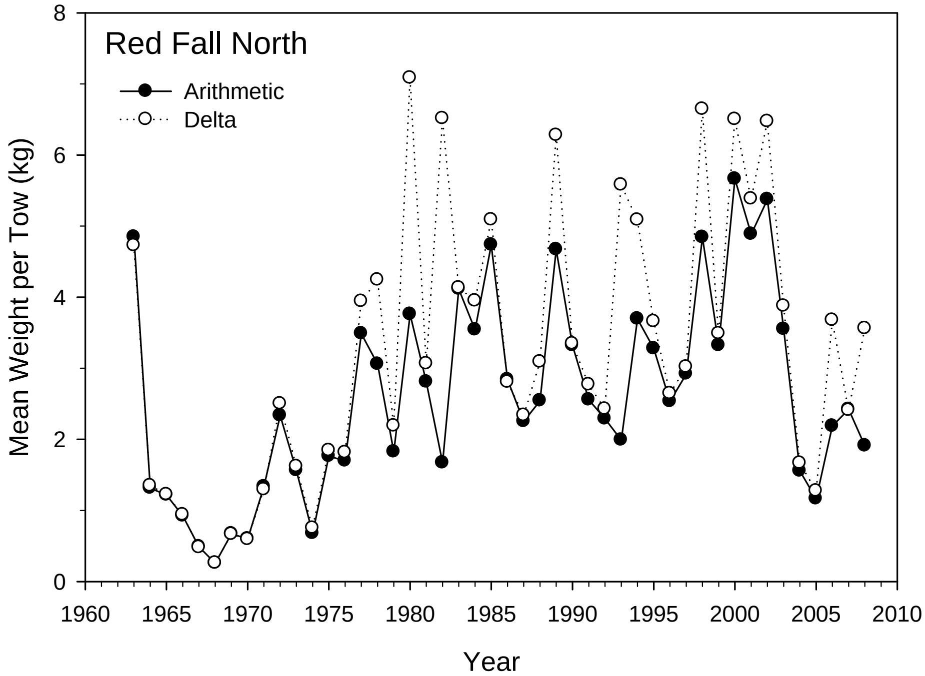
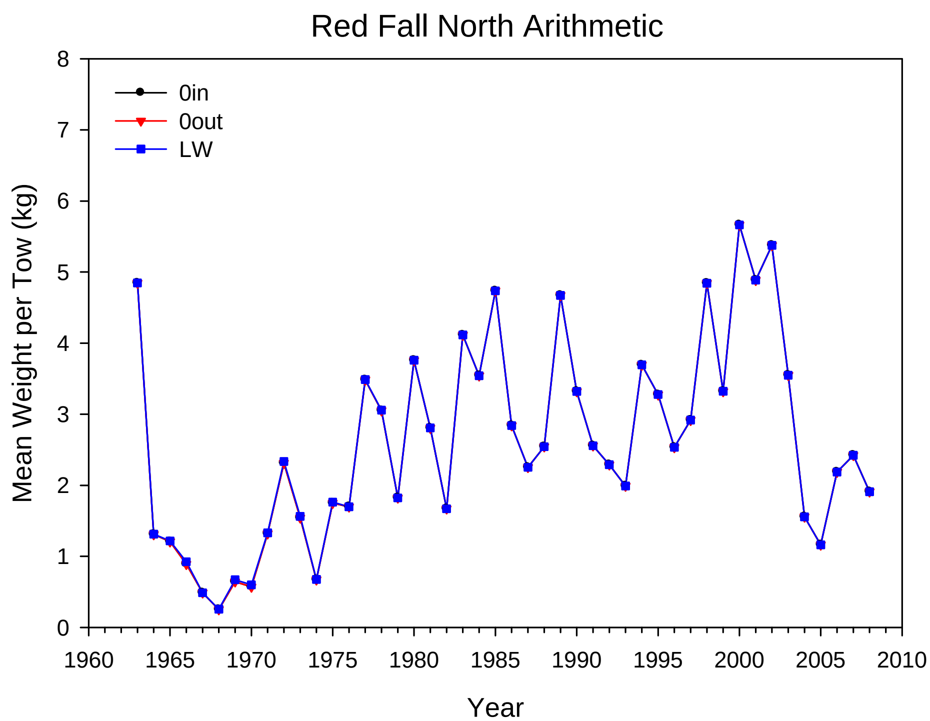


Figure C20.Comparison of the arithmetic and delta transformed mean weight per tow from the fall survey.



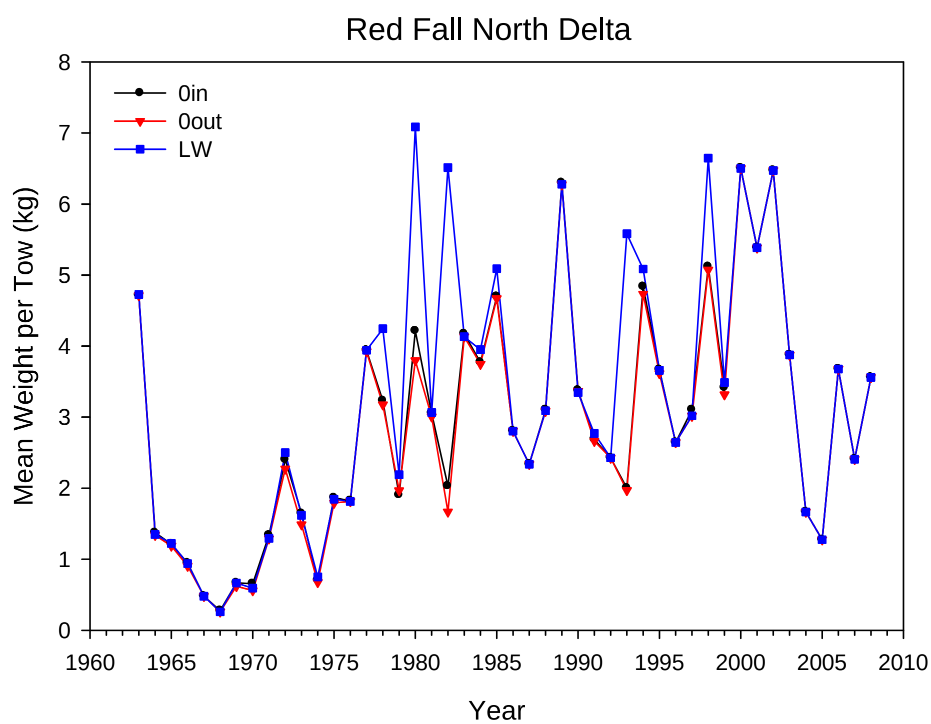


Figure C21. Comparison of the arithmetic and delta transformed mean weight per tow from the fall survey with three methods of handling missing weight data.

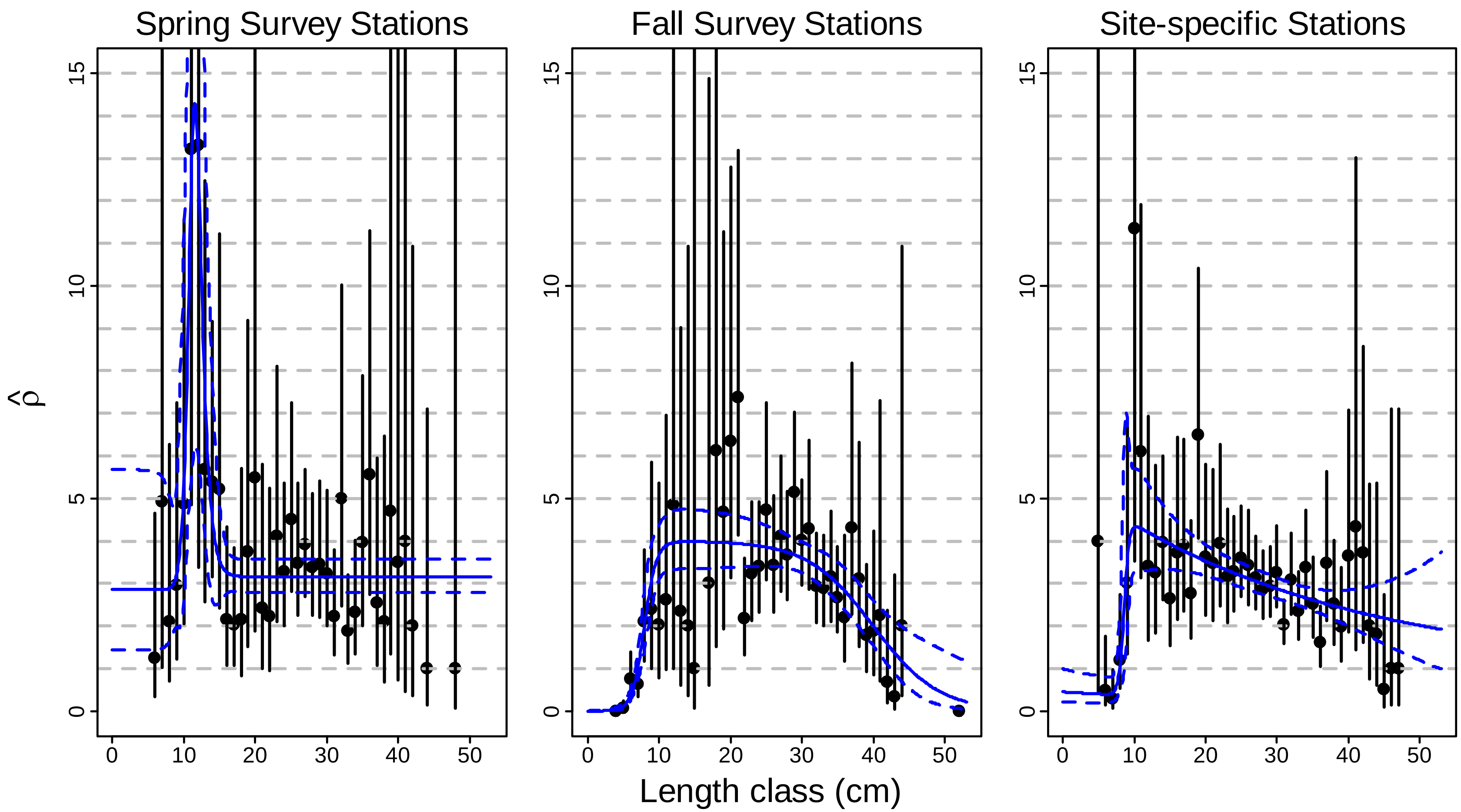


Figure C22. Beta-binomial based estimates of calibration factors and corresponding 95% confidence intervals by length class (1 cm bins) for **red hake**. The black points and vertical bars represent results where different calibration factors are estimated for each length class. The blue lines represent results from double-logistic models. For the fall, the double logistic model has with no minima (assumed equal to 0) for the ascending or descending logistic function.

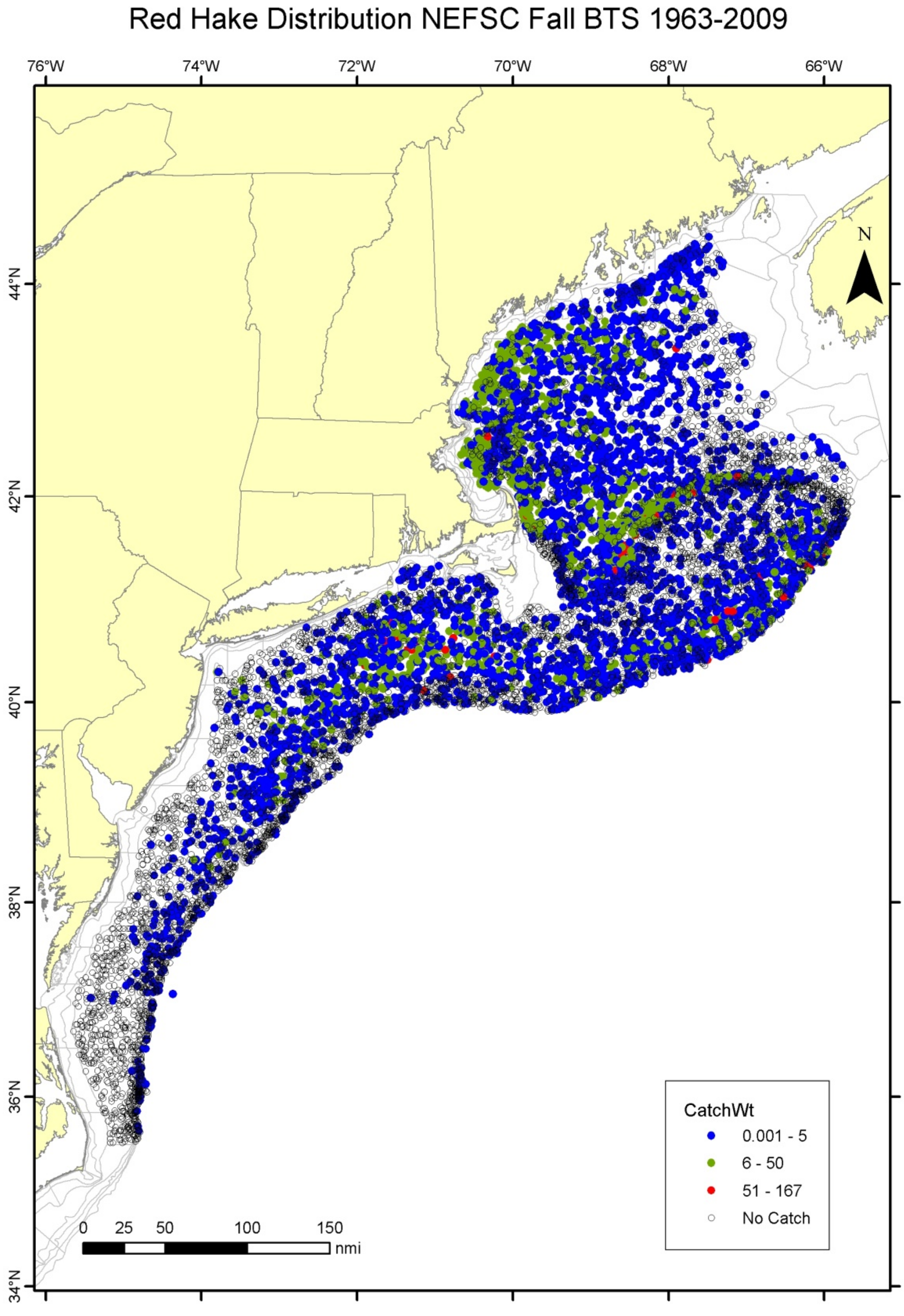


Figure C23. NEFSC distribution maps for red hake during the fall bottom trawl surveys, 1963-2009.

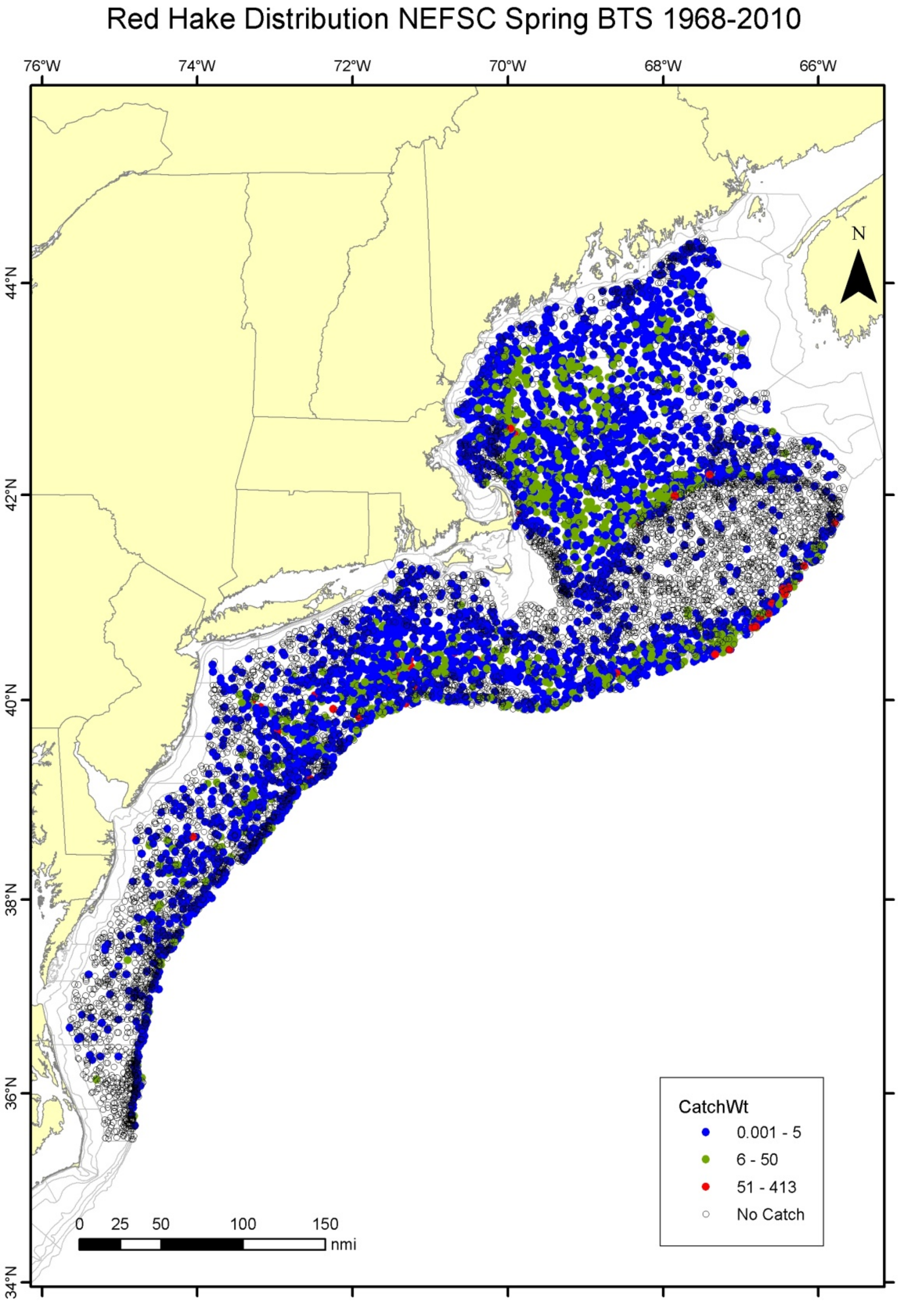


Figure C24. NEFSC distribution maps for red hake during the spring bottom trawl surveys, 1968-2010.

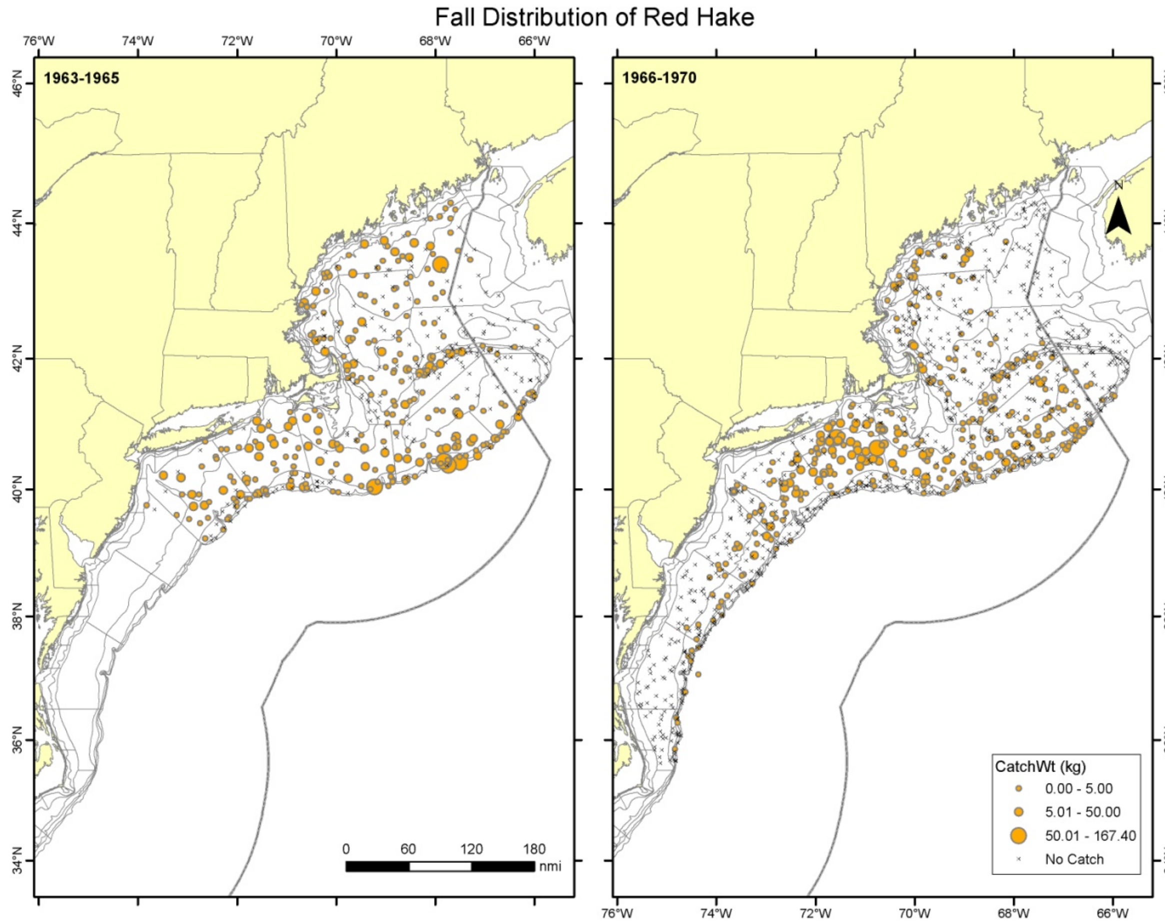


Figure C25. NEFSC distribution maps for red hake during the fall bottom trawl surveys, 1963-1970.

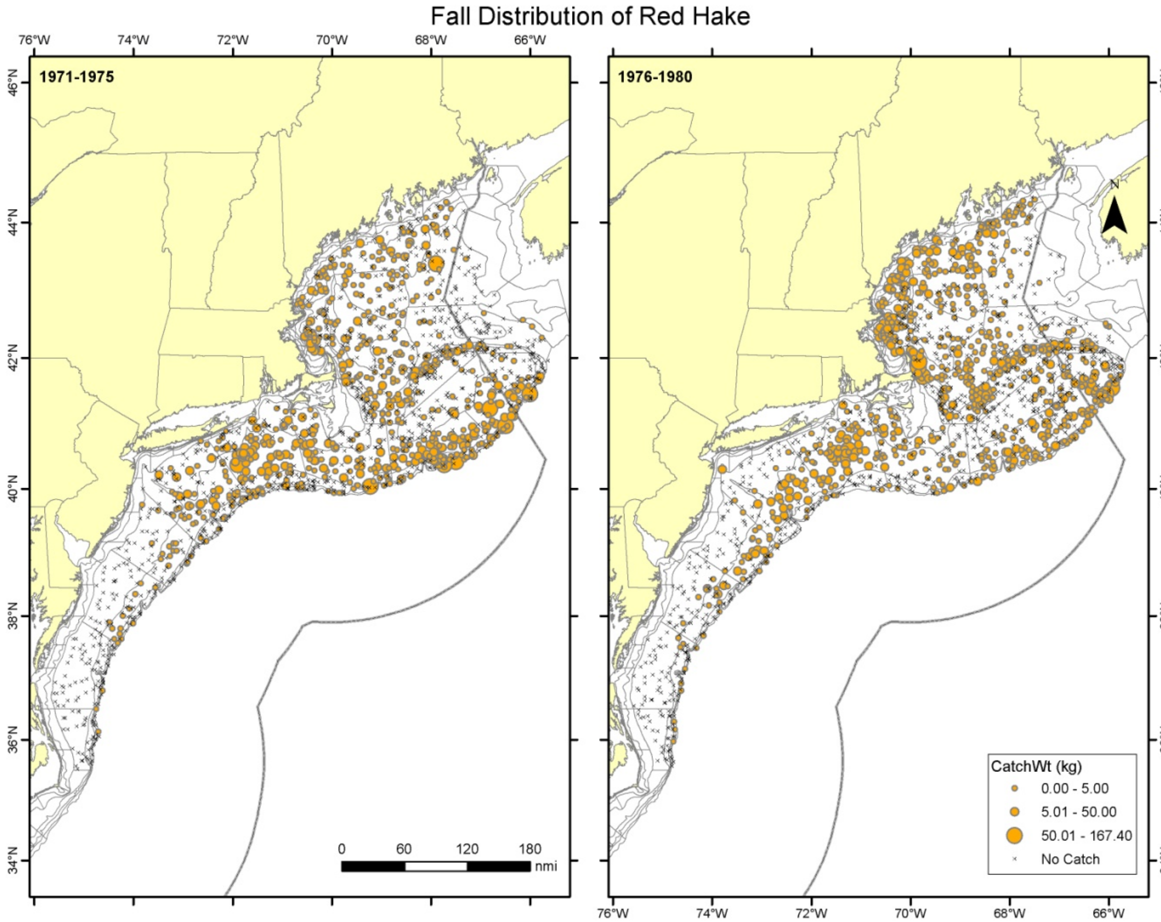


Figure C26. NEFSC distribution maps for red hake during the fall bottom trawl surveys, 1971-1980.

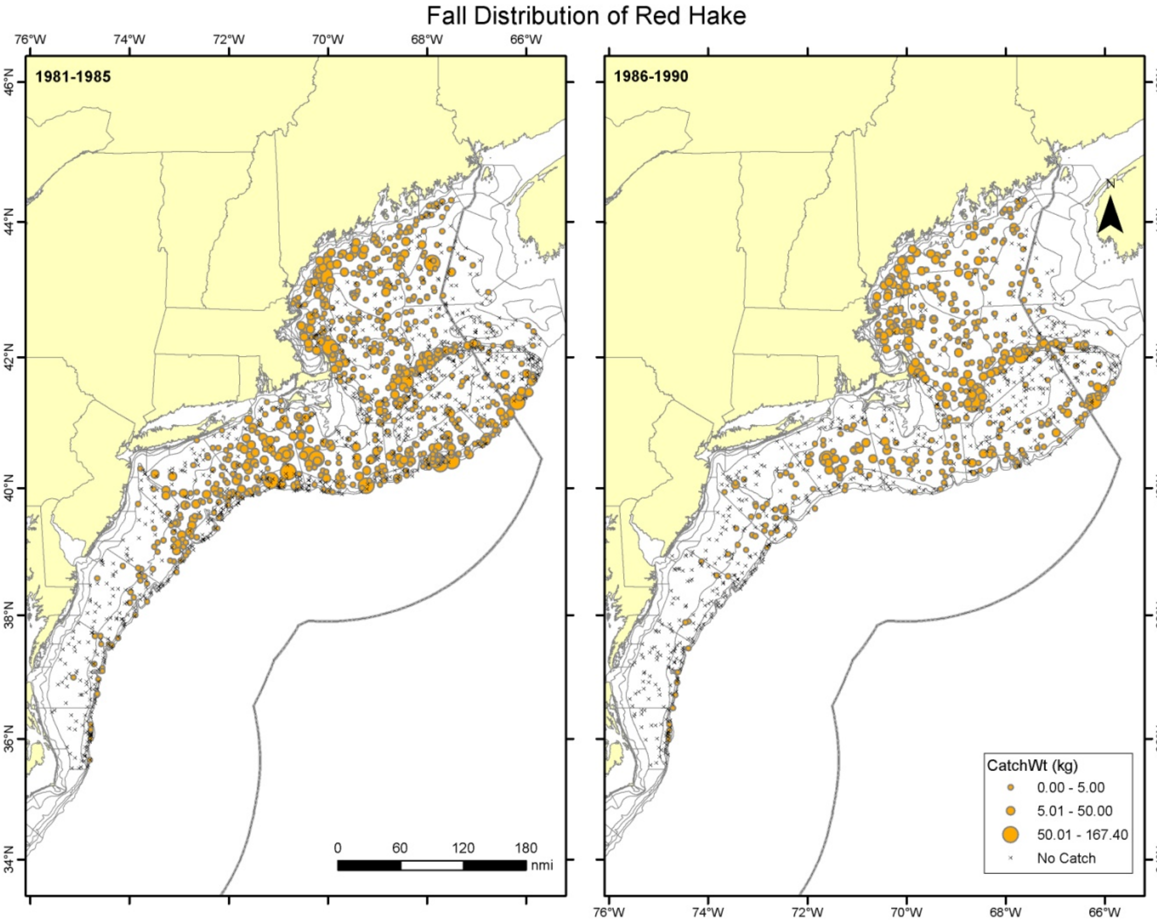


Figure C27. NEFSC distribution maps for red hake during the fall bottom trawl surveys, 1981-1990.

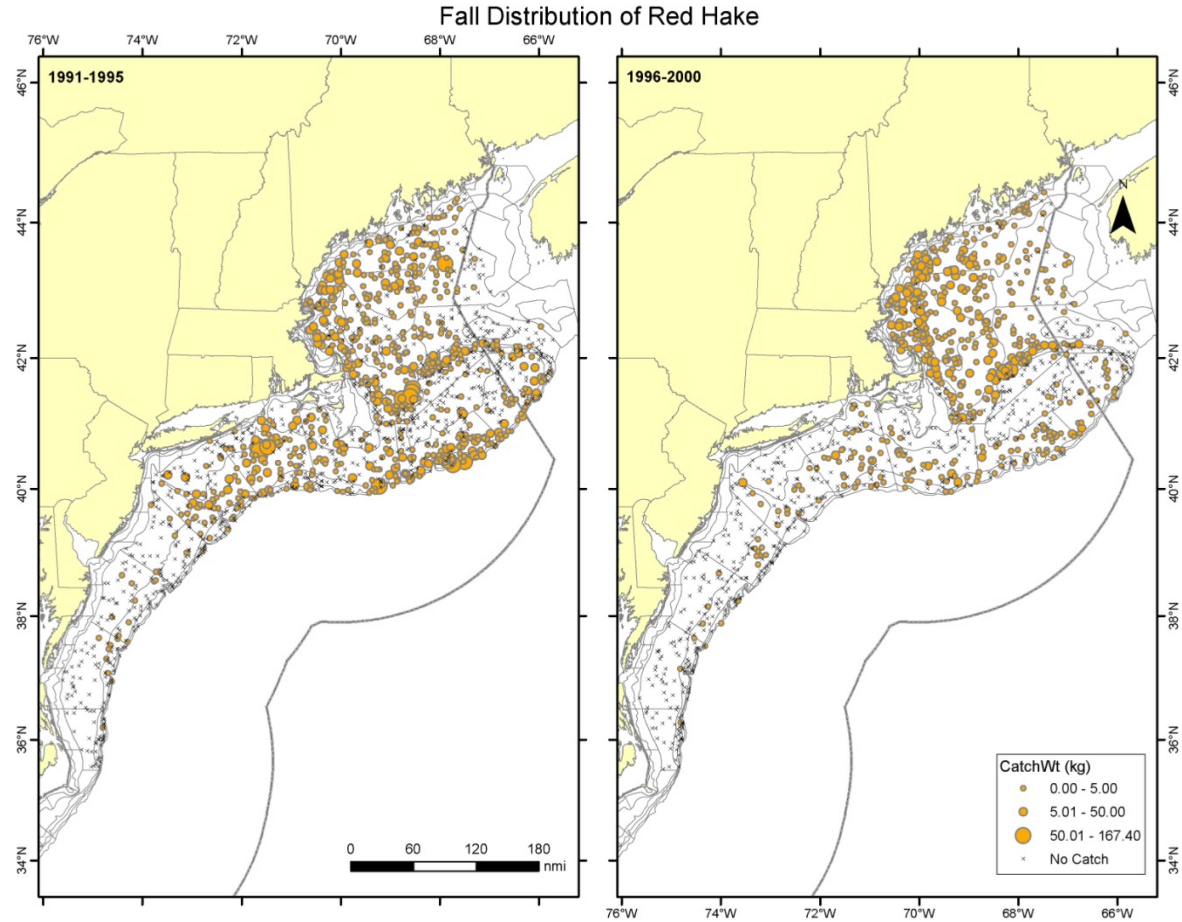


Figure C28. NEFSC distribution maps for red hake during the fall bottom trawl surveys, 1991-2000.

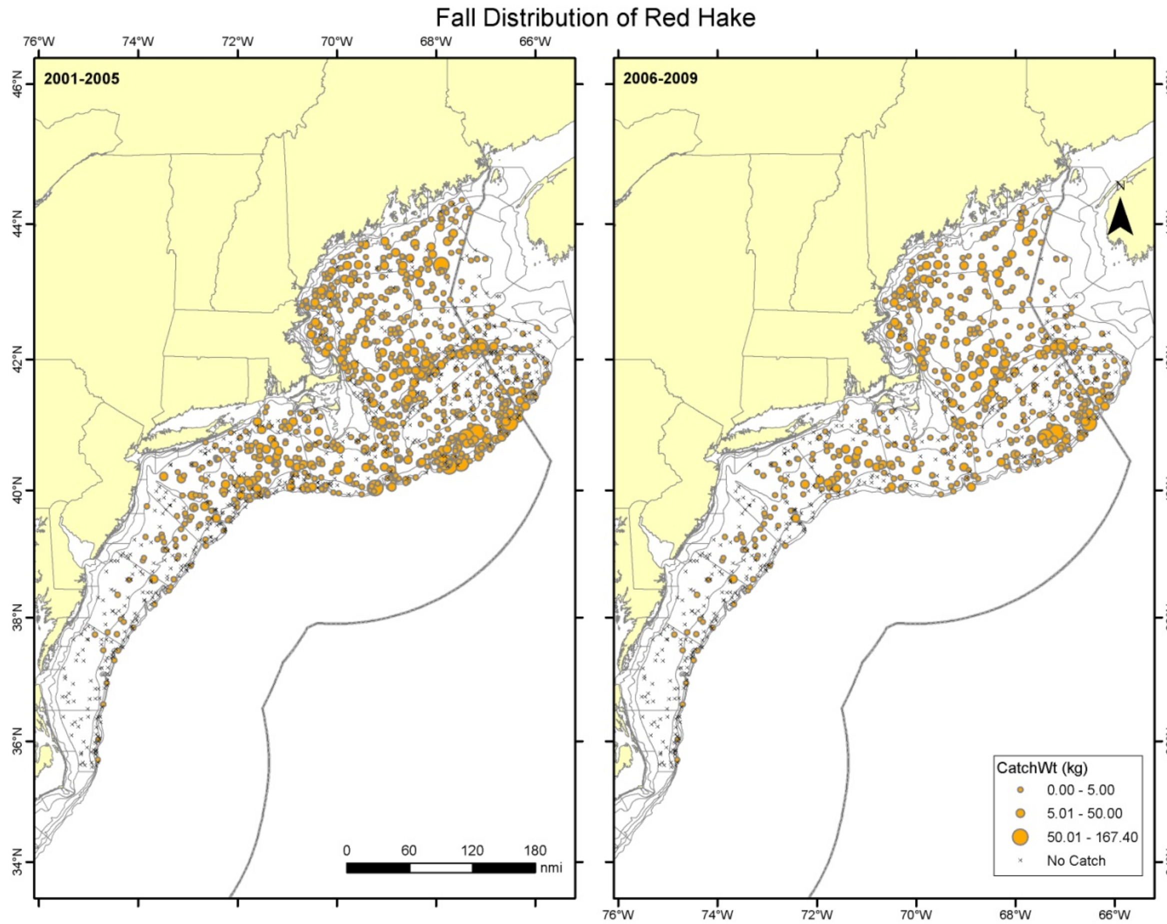


Figure C29. NEFSC distribution maps for red hake during the fall bottom trawl surveys, 2001-2009.

Spring Distribution of Red Hake

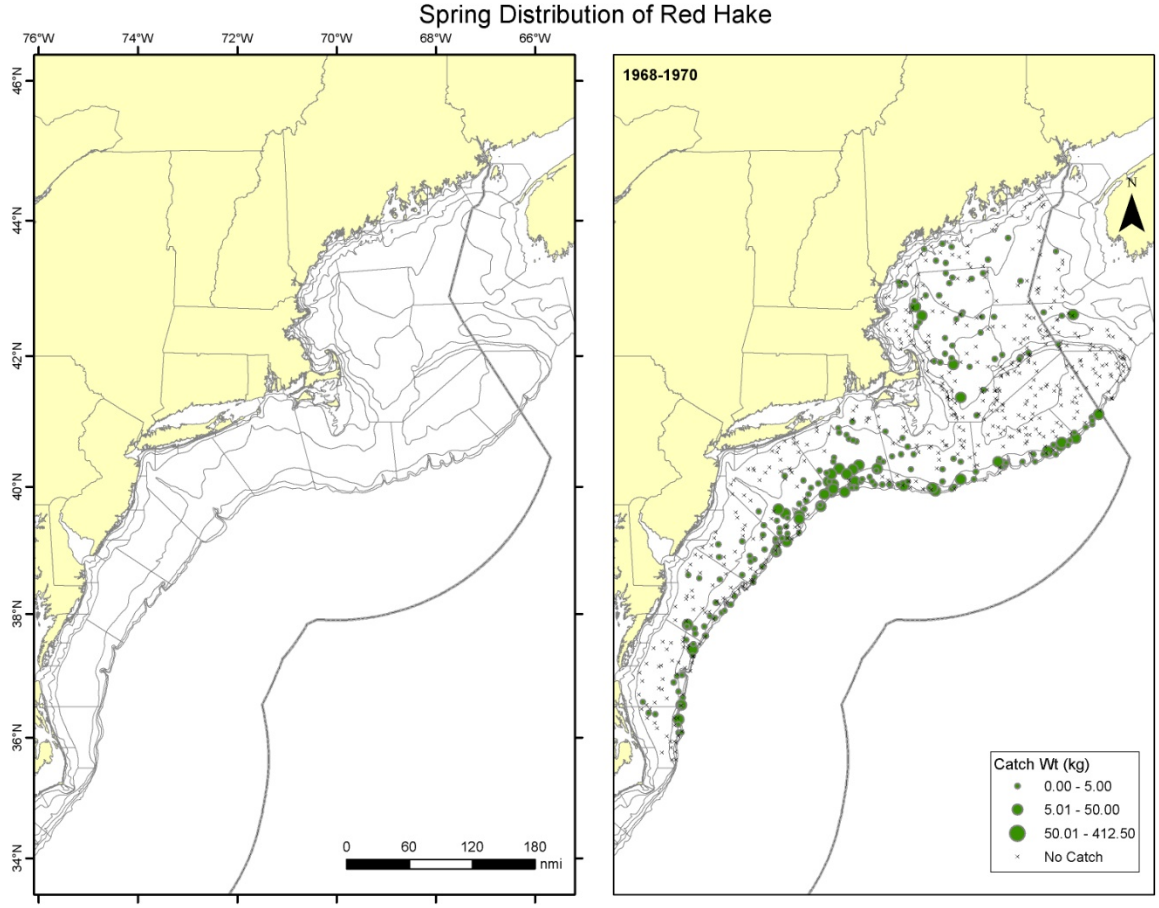


Figure C30. NEFSC distribution maps for red hake during the spring bottom trawl surveys, 1968-1970.

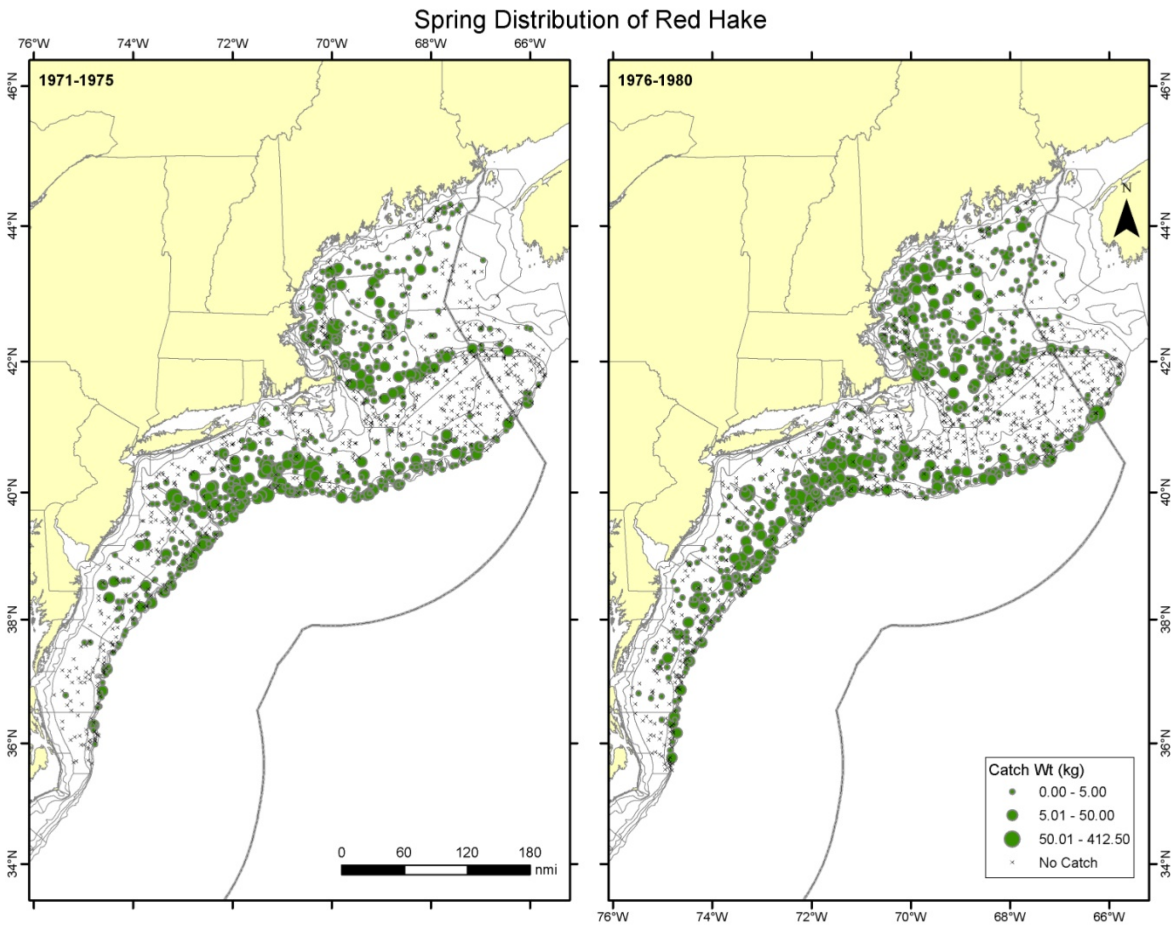


Figure C31. NEFSC distribution maps for red hake during the spring bottom trawl surveys, 1971-1980.

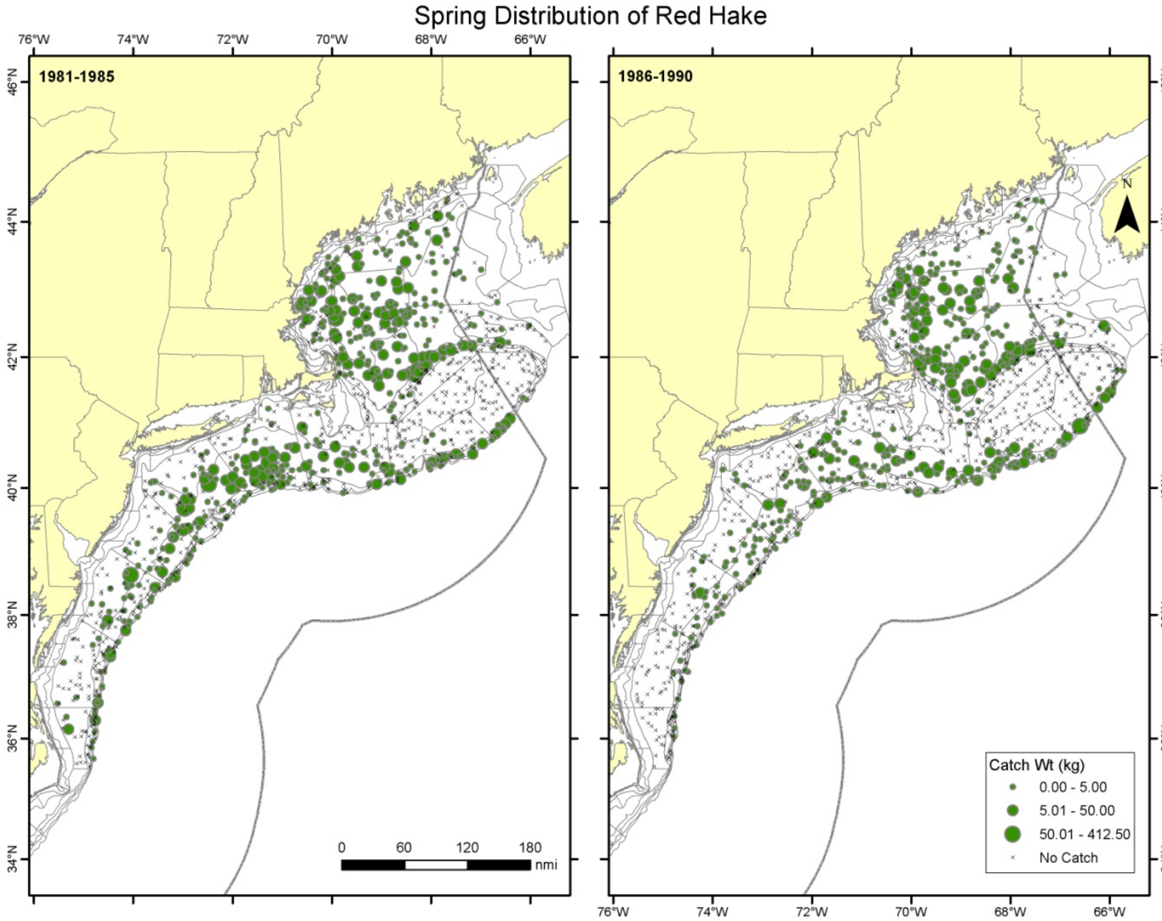


Figure C32. NEFSC distribution maps for red hake during the spring bottom trawl surveys, 1981-1990.

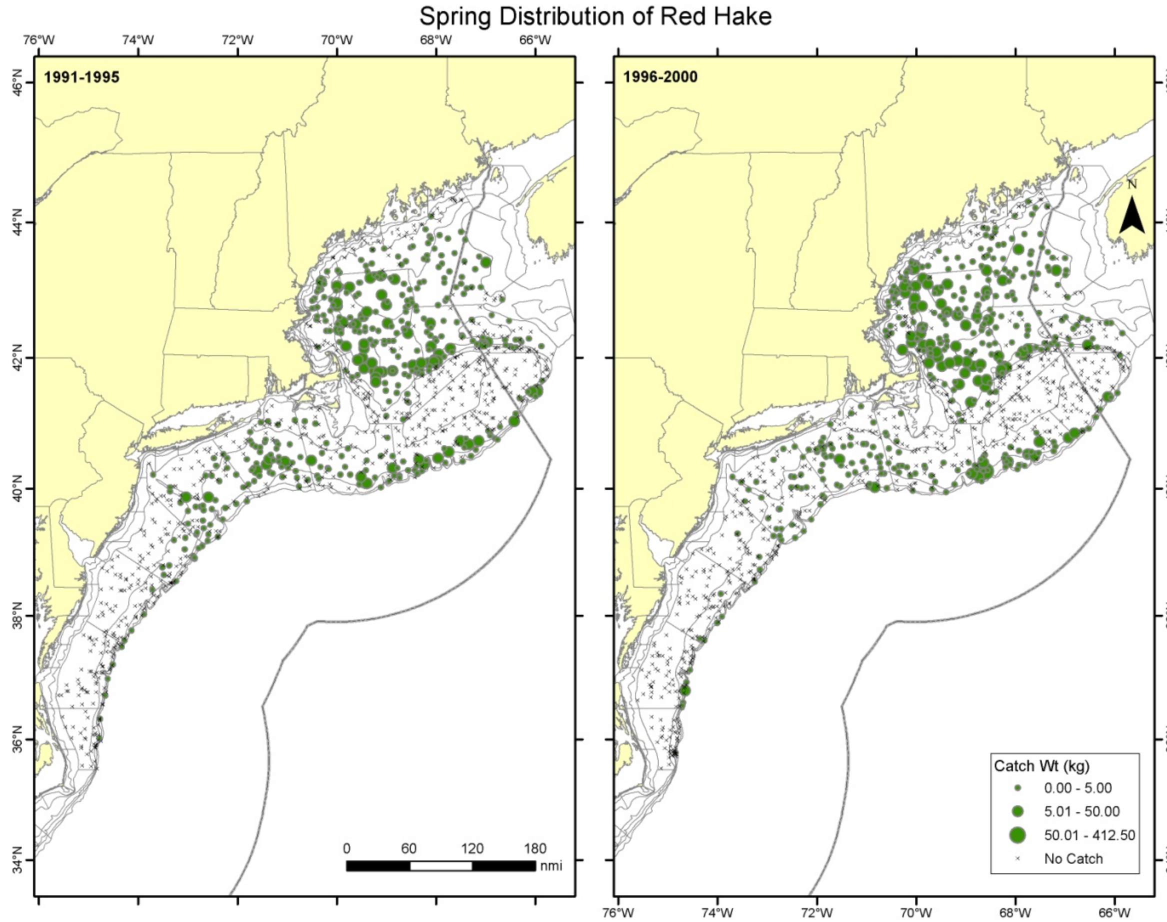


Figure C33. NEFSC distribution maps for red hake during the spring bottom trawl surveys, 1991-2000.

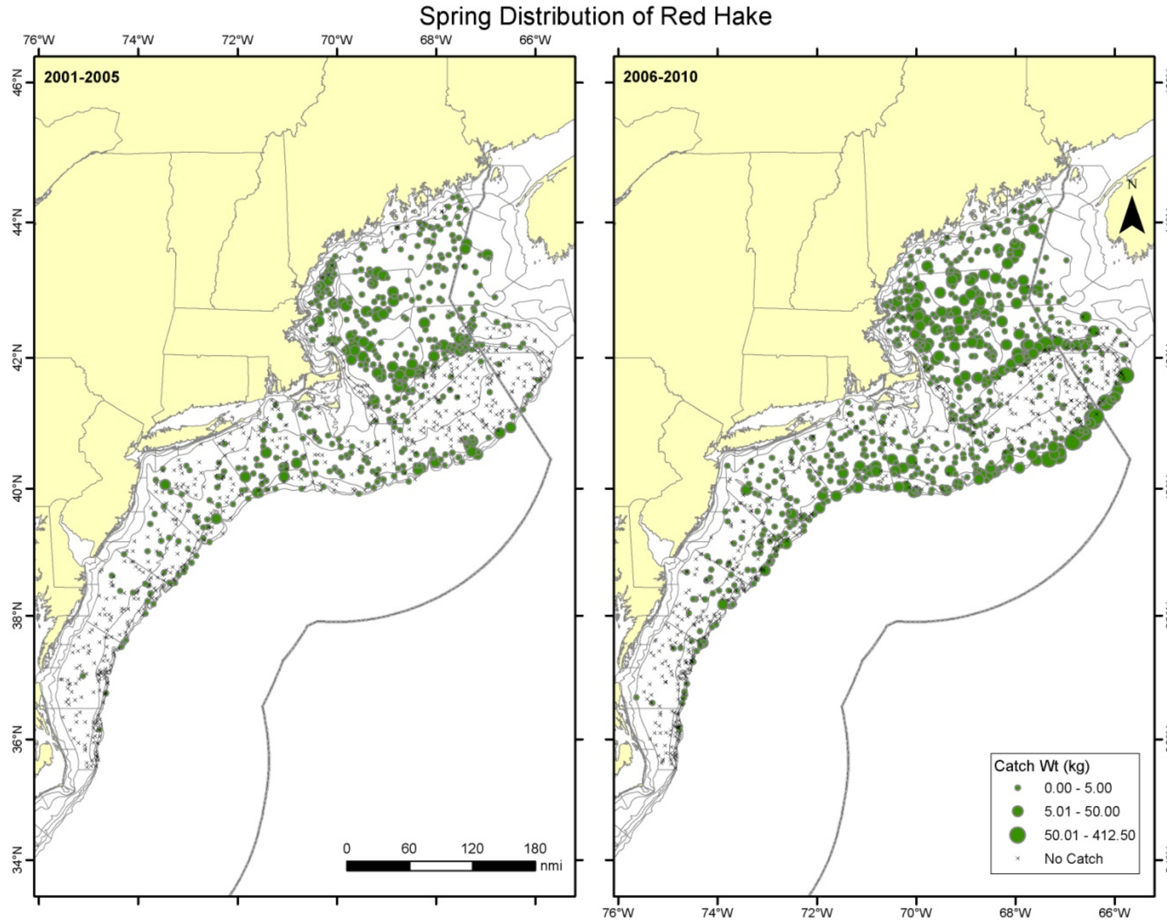
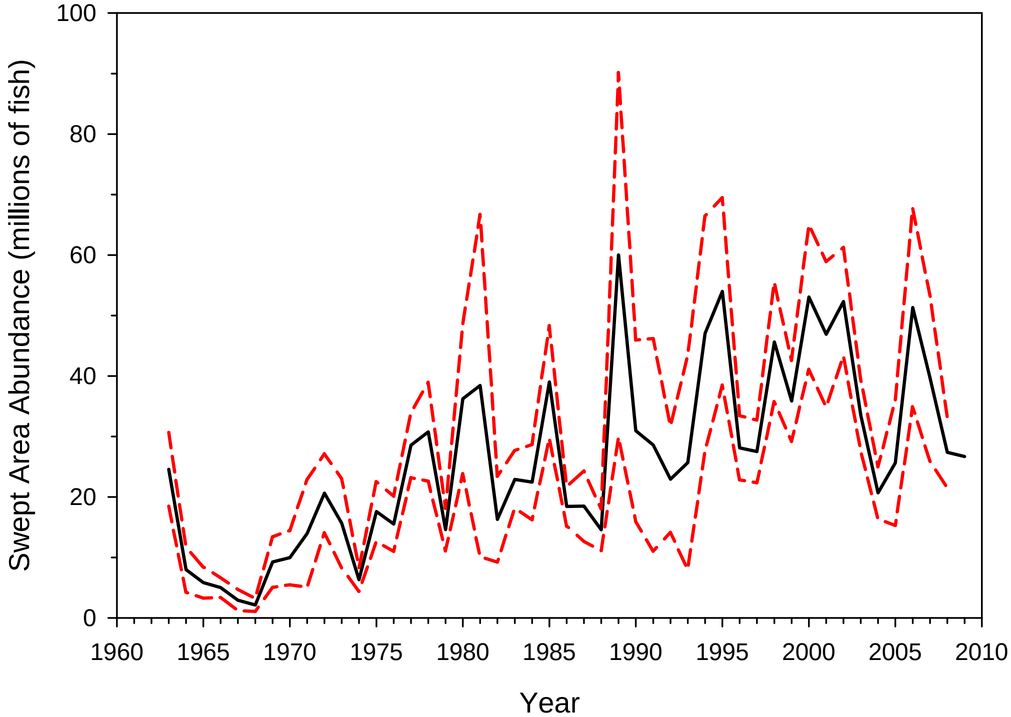


Figure C34. NEFSC distribution maps for red hake during the spring bottom trawl surveys, 2001-2010.

NORTH FALL



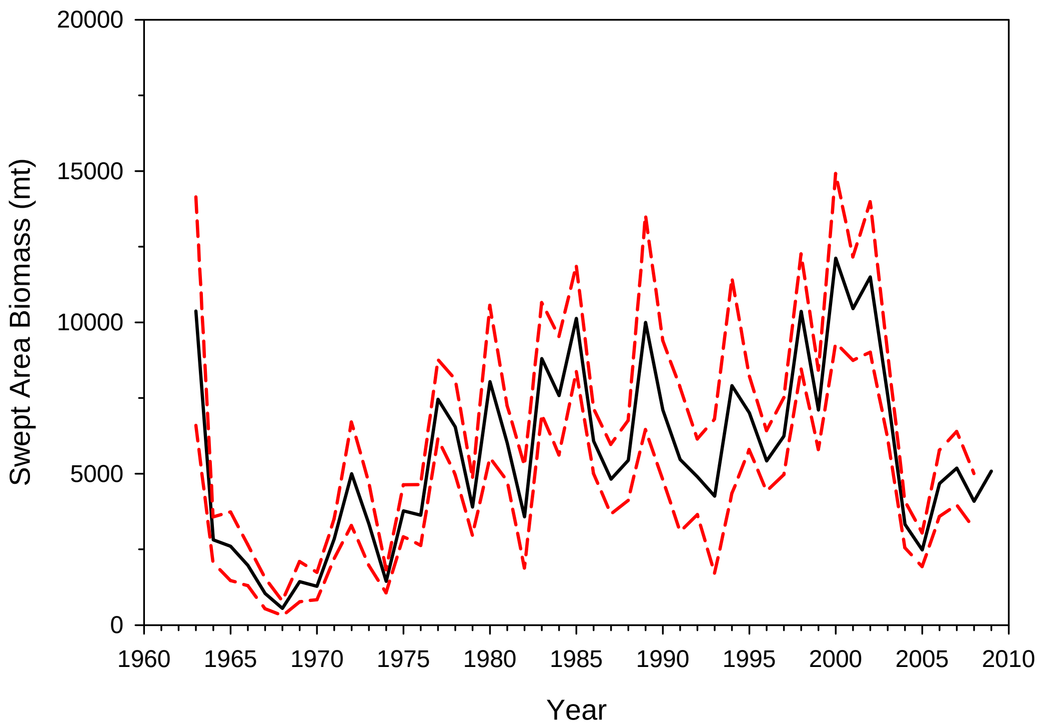
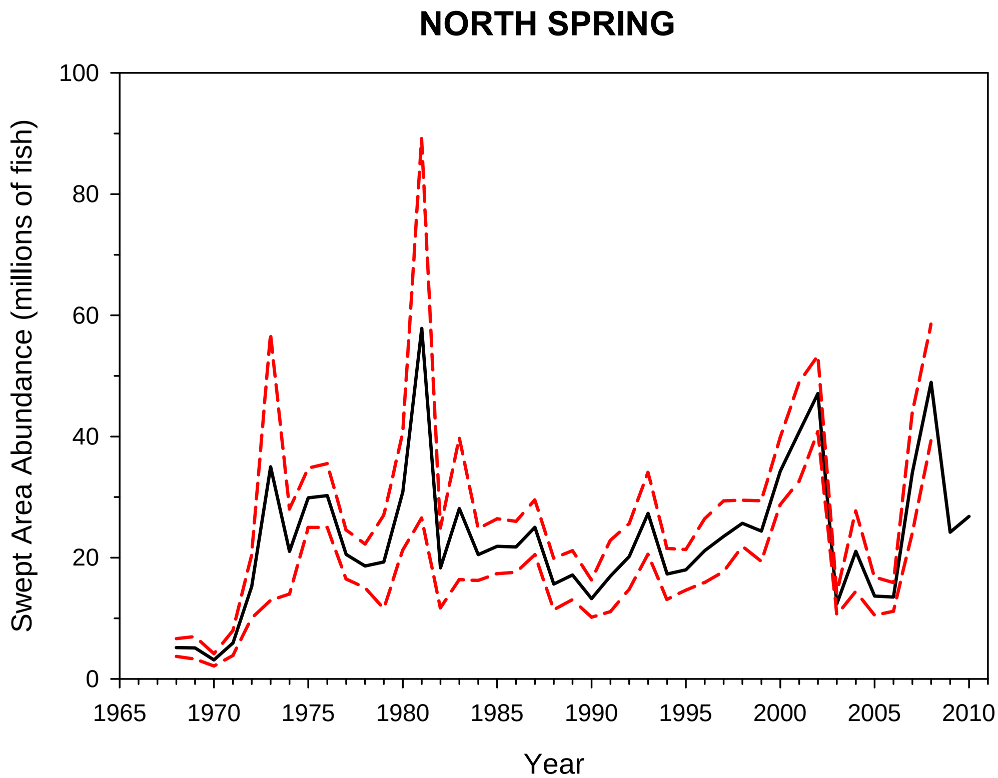


Figure C35. Swept area abundance (top) and biomass (bottom) with confidence intervals for the NEFSC fall survey in the northern management region. Estimates for 2009 were converted to Albatross units using the calibration factors at length in Table C34.



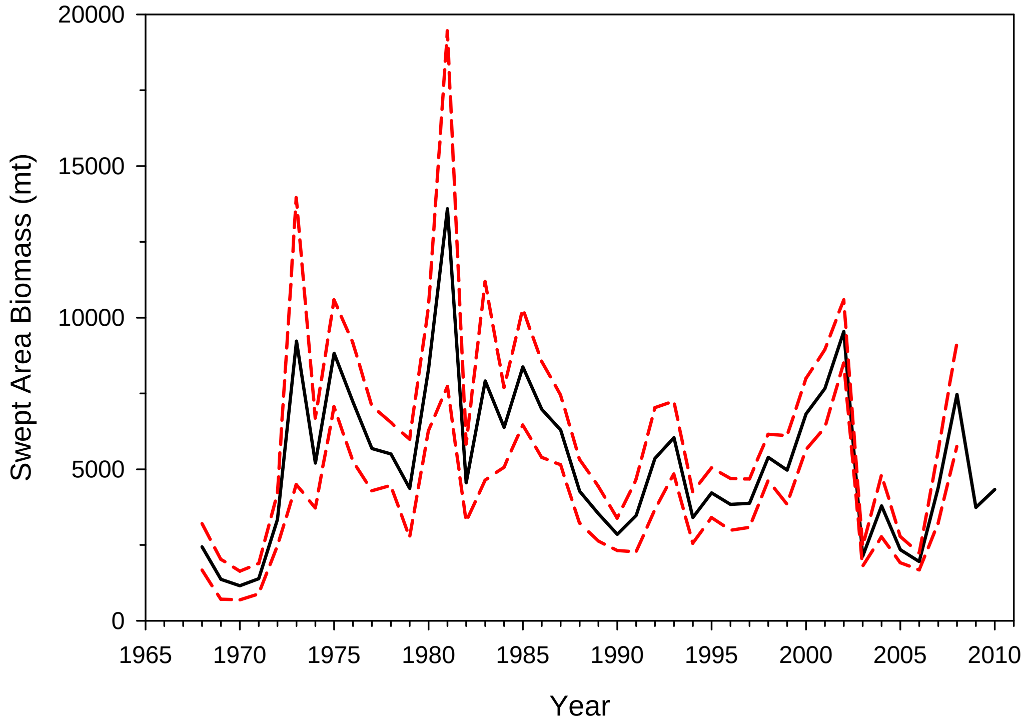


Figure C36. Swept area abundance (top) and biomass (bottom) with confidence intervals for the NEFSC spring survey in the northern management region. Estimates for 2009 and 2010 were converted to Albatross units using the calibration factors at length in Table C34.

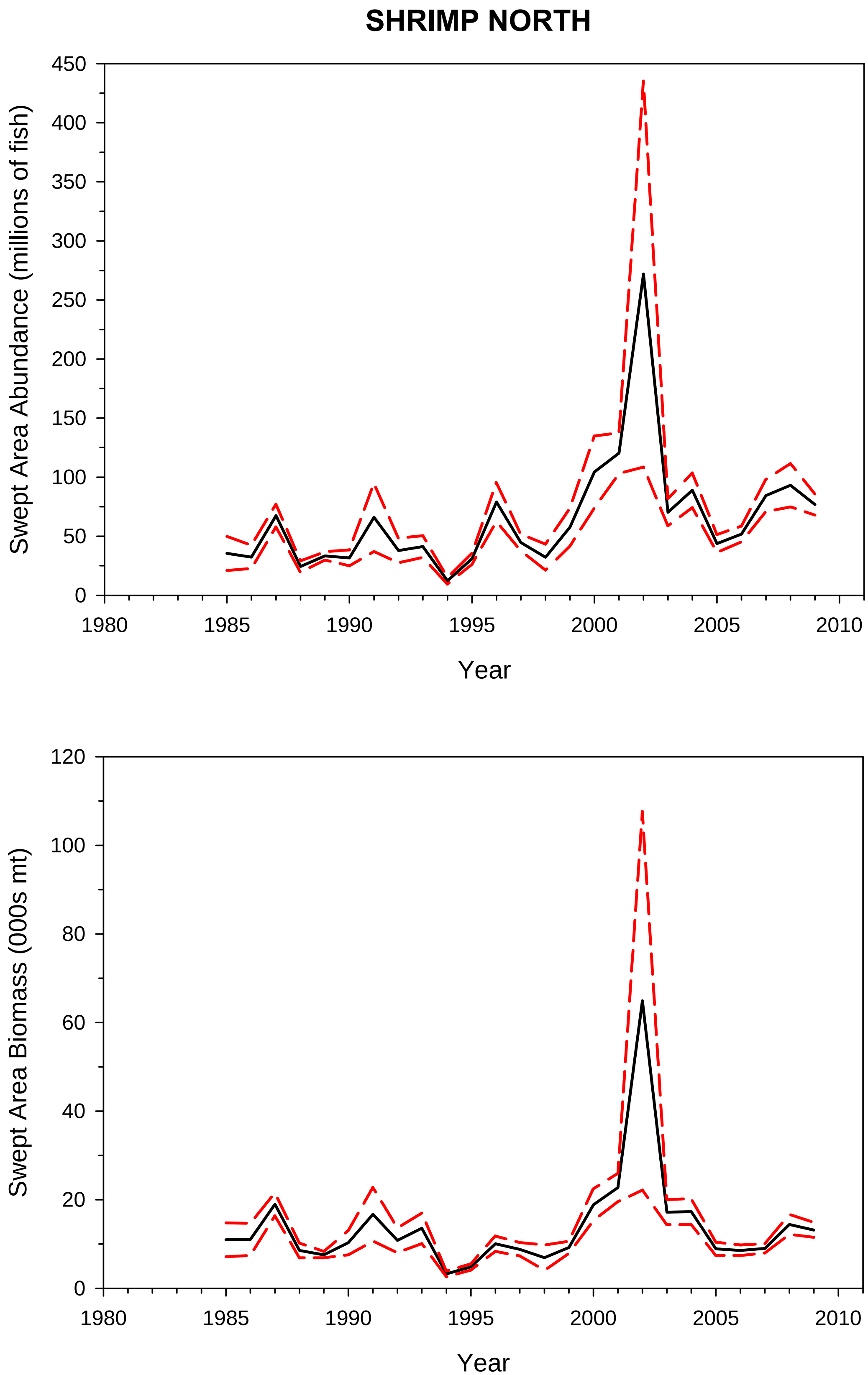
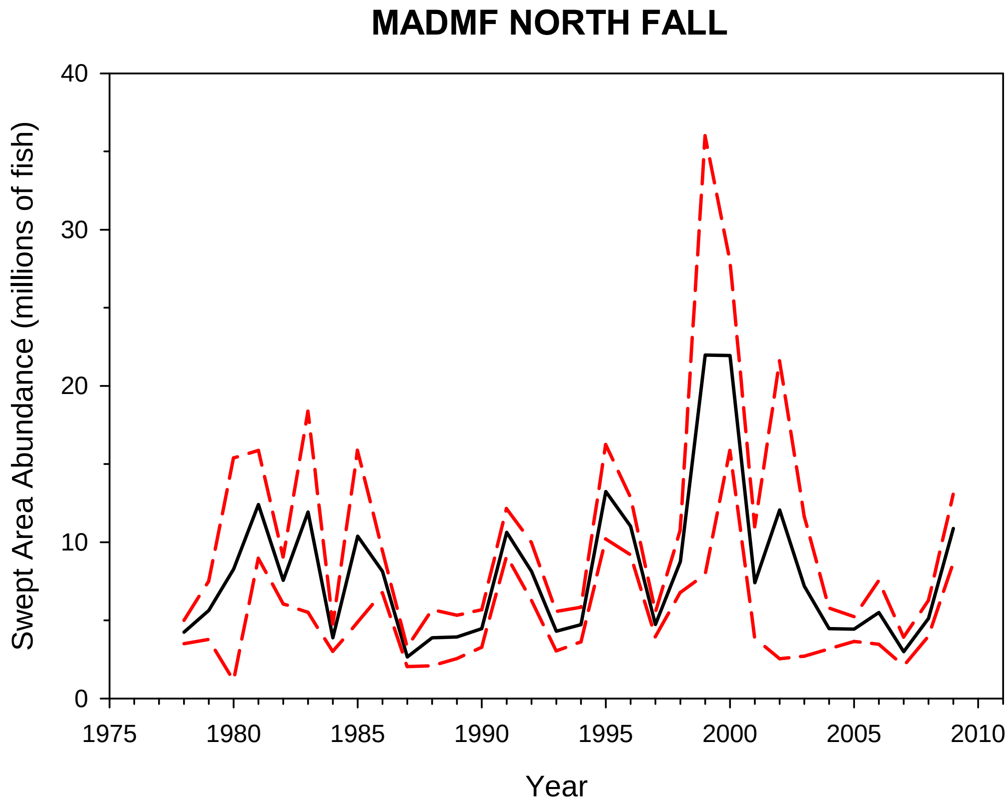


Figure C37. Swept area abundance (top) and biomass (bottom) with upper and lower confidence intervals for red hake from the NEFSC shrimp trawl surveys (strata 1-12).



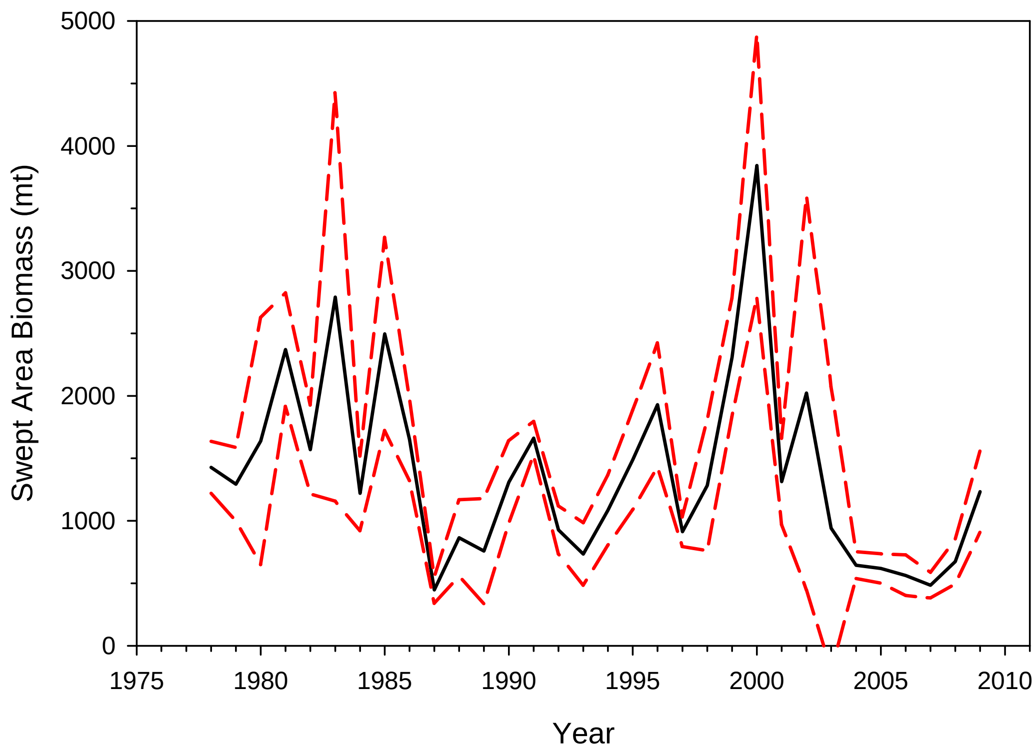


Figure C38. Swept area abundance (top) and biomass (bottom) with upper and lower confidence intervals for red hake from Massachusetts Division of Marine Fisheries fall north survey (strata 18-36).

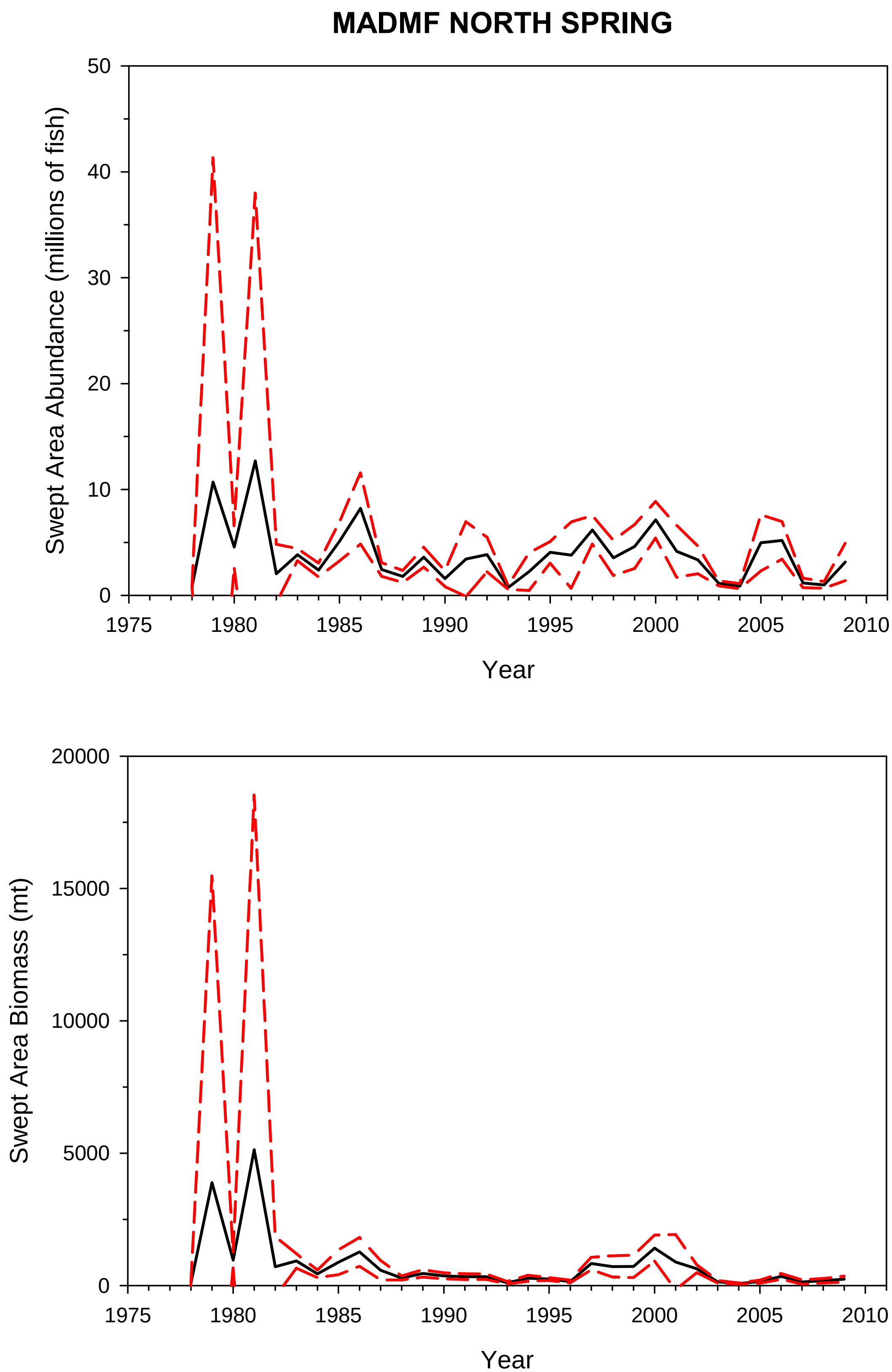


Figure C39. Swept area abundance (top) and biomass (bottom) with upper and lower confidence intervals for red hake from Massachusetts Division of Marine Fisheries spring north survey (strata 18-36).

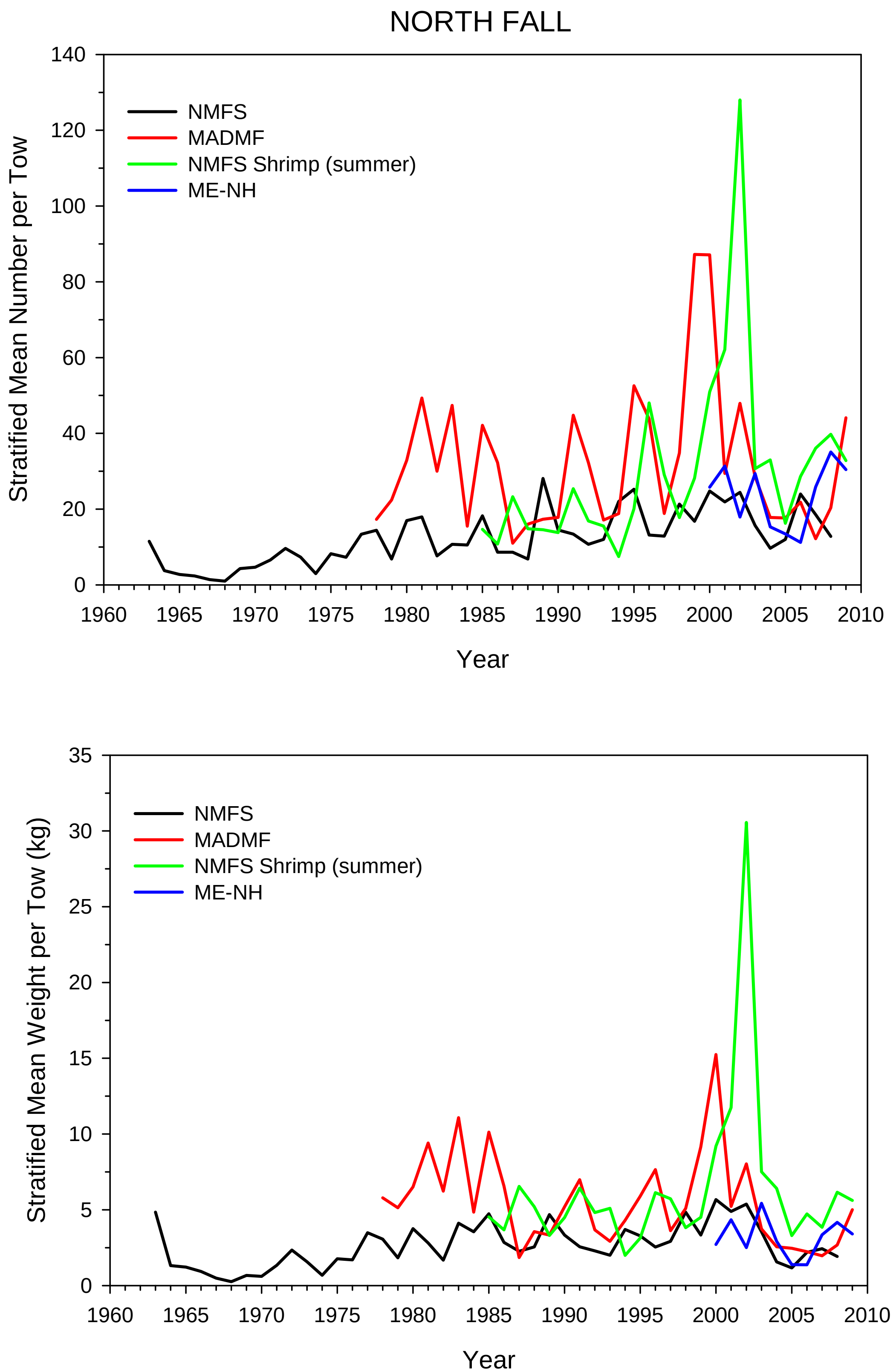
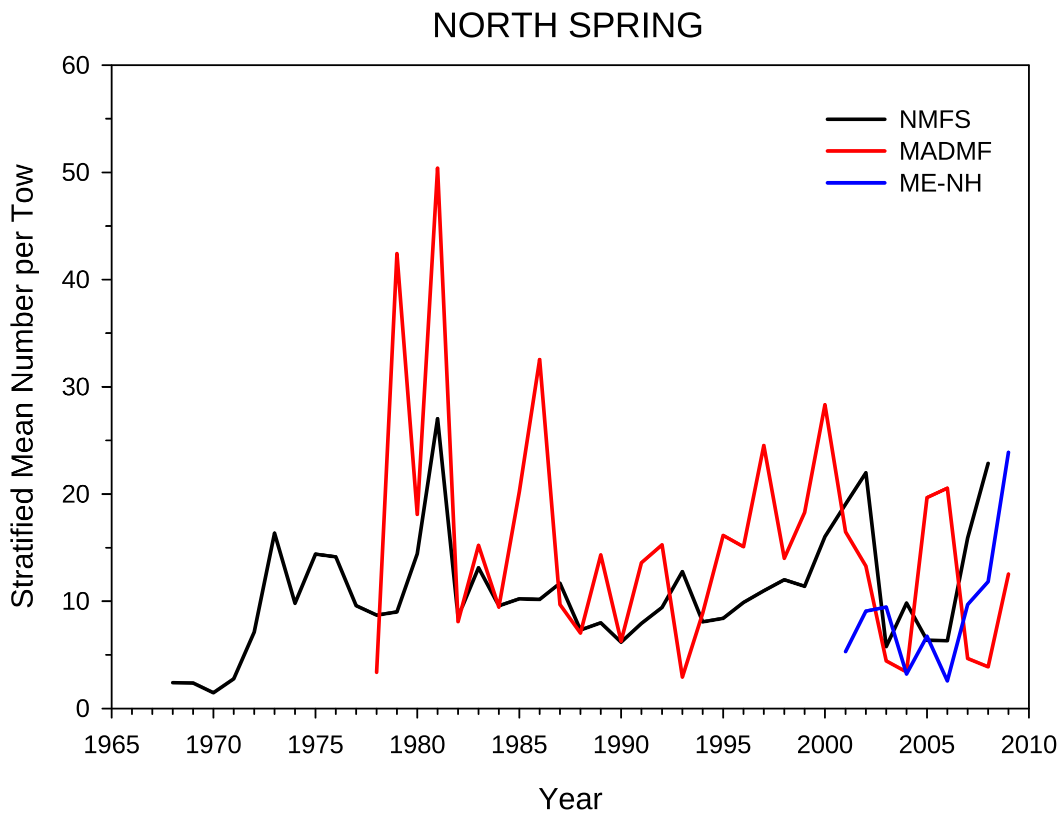


Figure C40. Stratified mean number and weight per tow (kg) for red hake from the all the fall north surveys: NEFSC, MADMF, shrimp and Maine-New Hampshire state surveys.



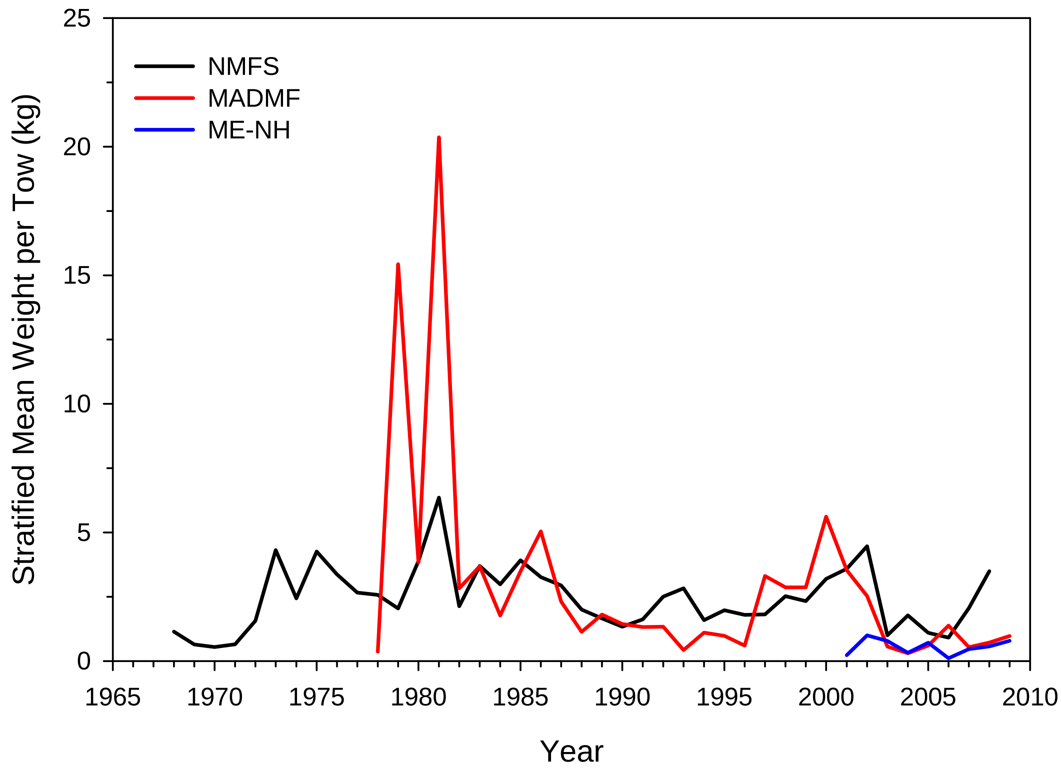


Figure C41. Stratified mean number and weight per tow (kg) for red hake from the all the spring north surveys: NEFSC, MADMF, and Maine-New Hampshire state surveys.

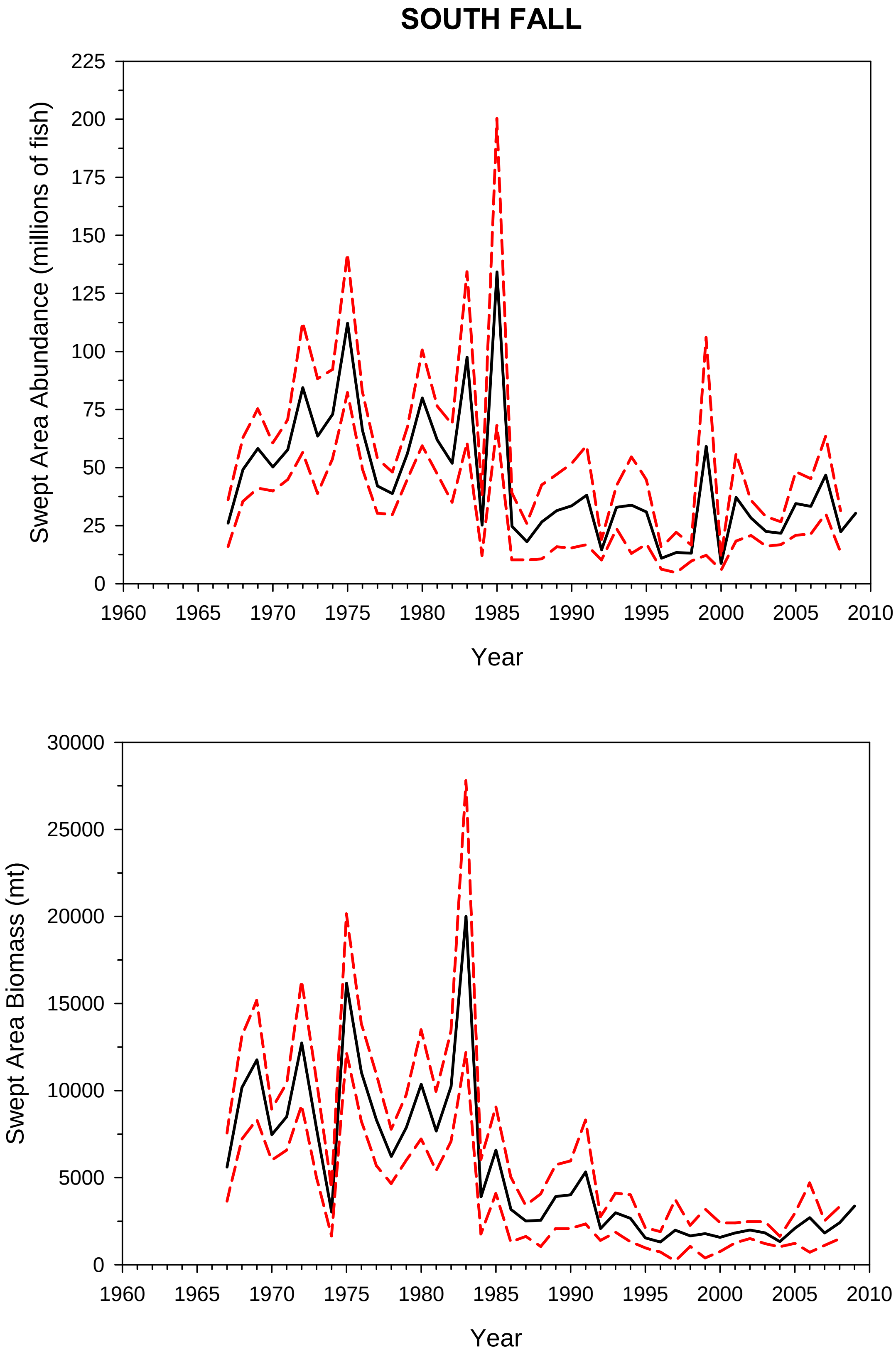


Figure C42. Swept area abundance (top) and biomass (bottom) with confidence intervals for the NEFSC fall survey in the southern management region. Estimates for 2009 were converted to Albatross units using the calibration factors at length in Table C34.

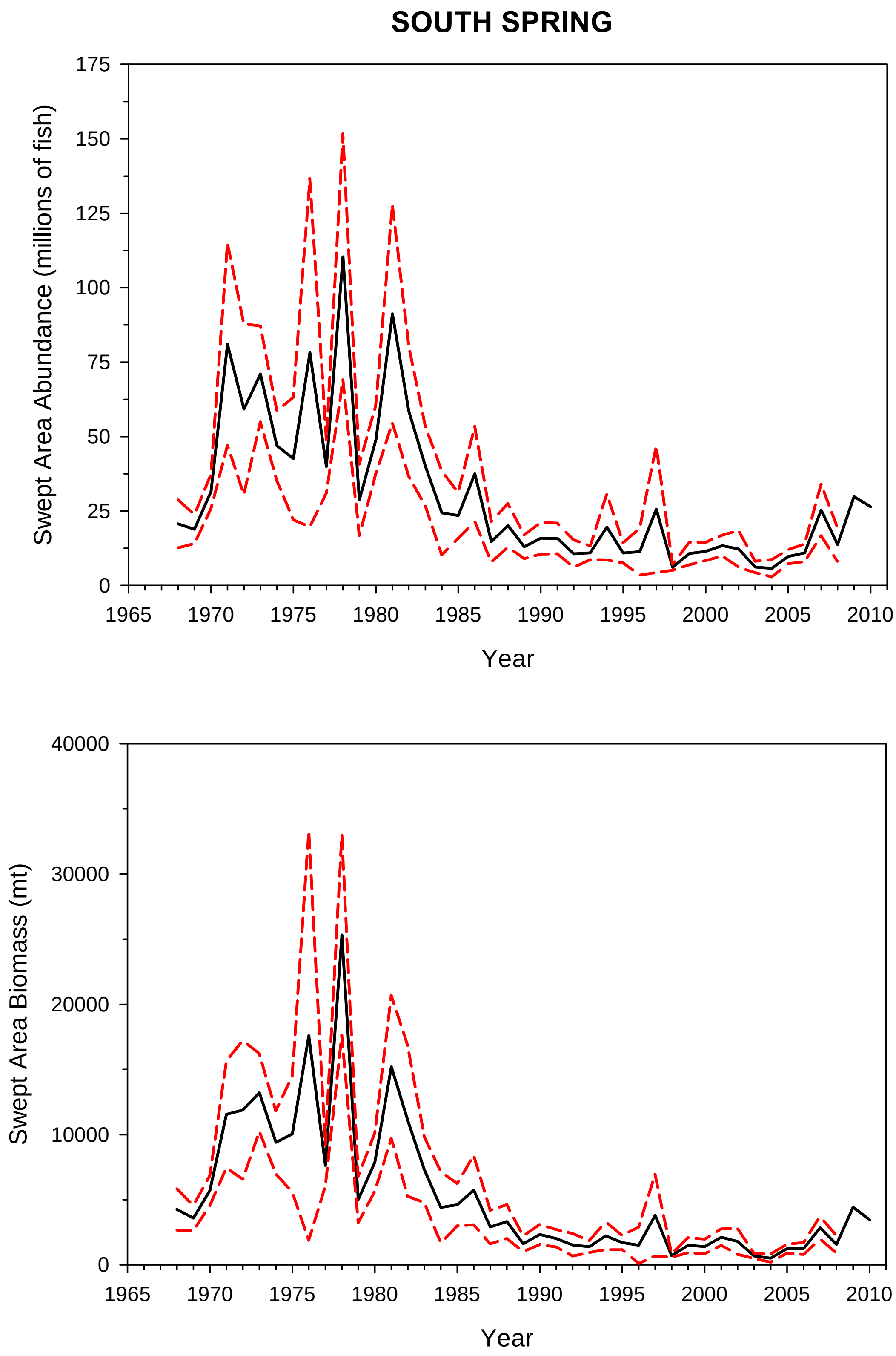


Figure C43. Swept area abundance (top) and biomass (bottom) with confidence intervals for the NEFSC spring survey in the southern management region. Estimates for 2009 and 2010 were converted to Albatross units using the calibration factors at length in Table C34.

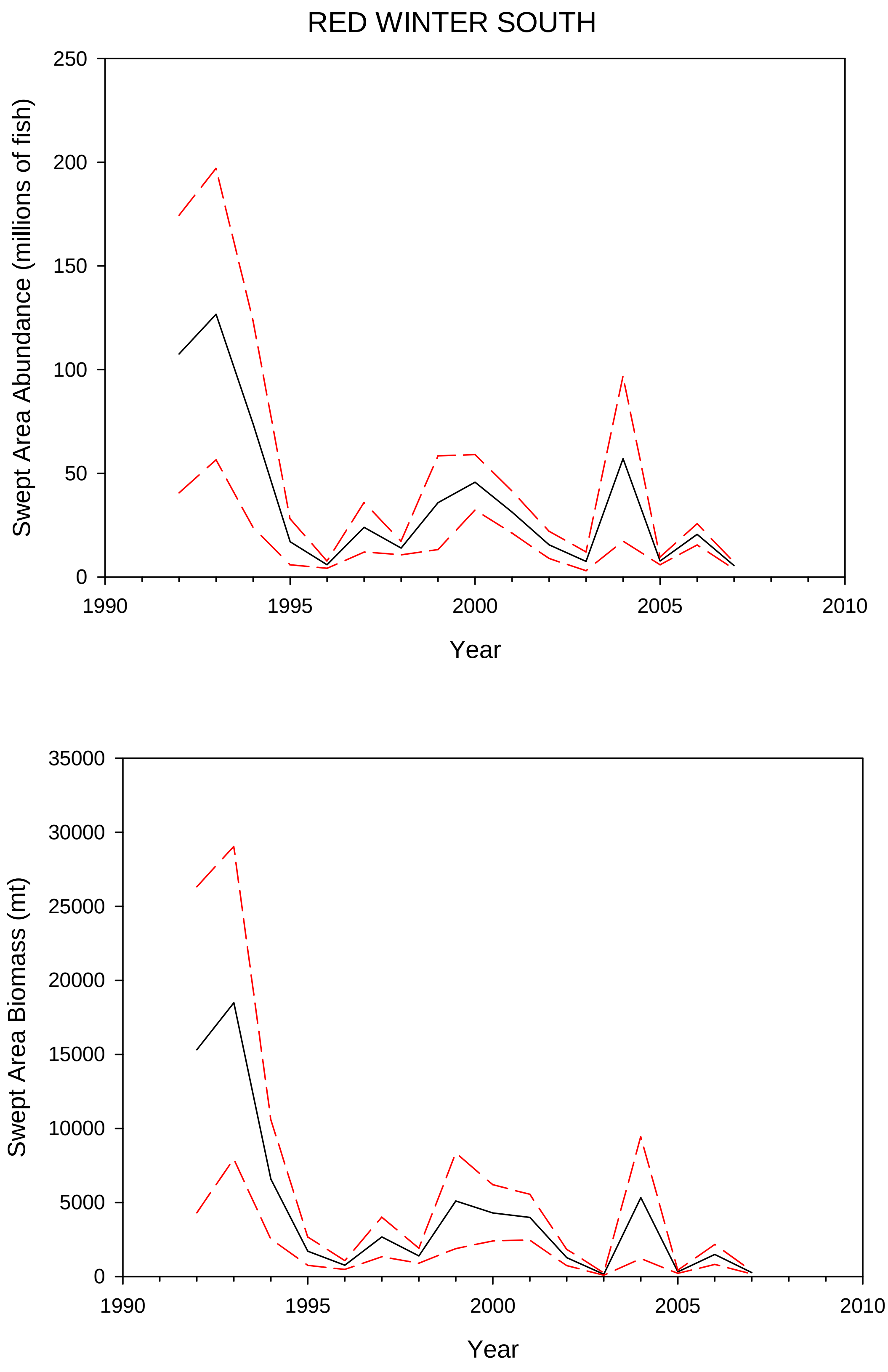
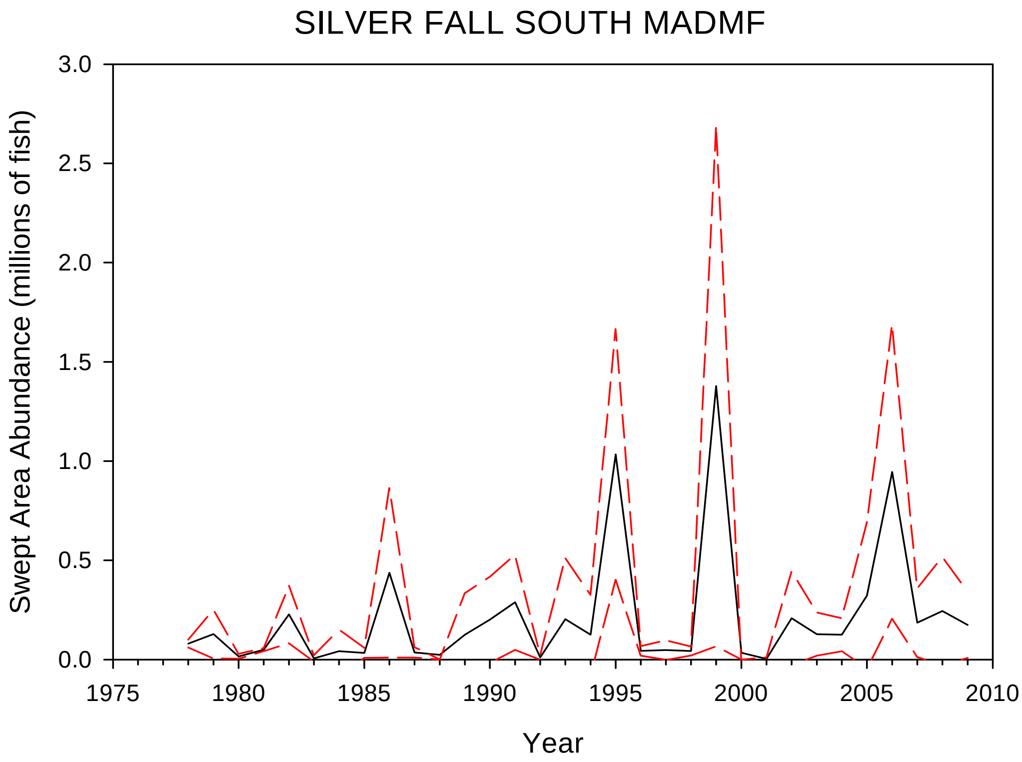


Figure C44. Swept area abundance and biomass and upper and lower confidence intervals for red hake from the NEFSC winter flatfish surveys in the southern management region (strata 1-3, 5-7, 9-11, 13-14, 61-63, 65-67, 69-71, 73-75).



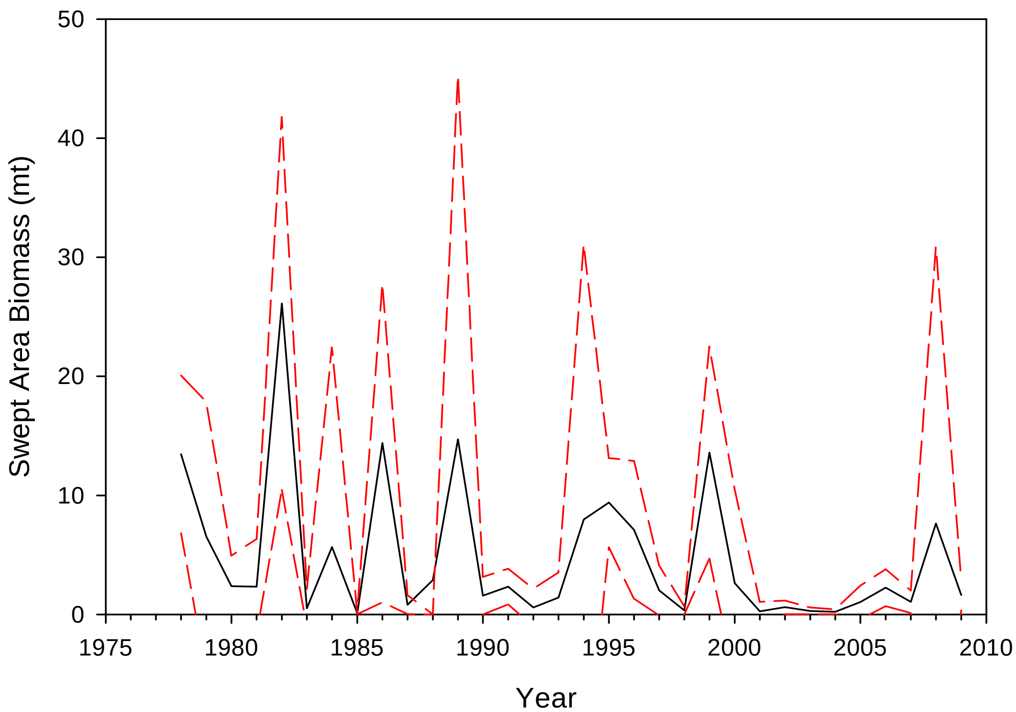
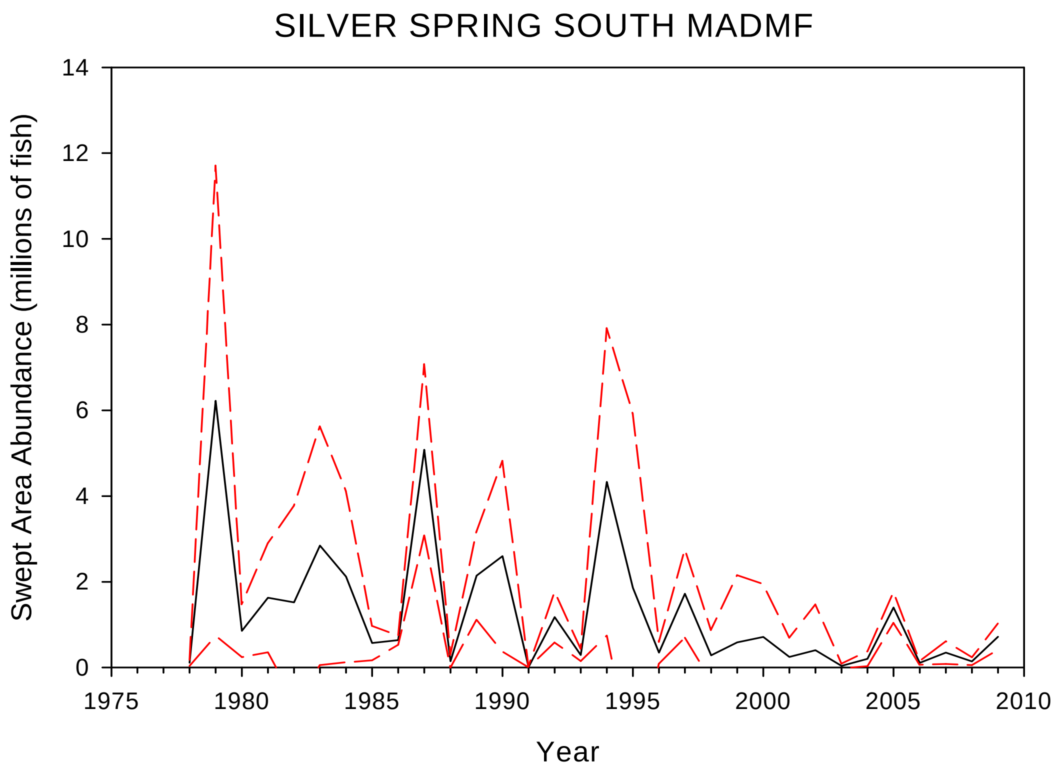


Figure C45. Swept area abundance (top) and biomass (bottom) with upper and lower confidence intervals for red hake from Massachusetts Division of Marine Fisheries fall south survey (strata 11-17).



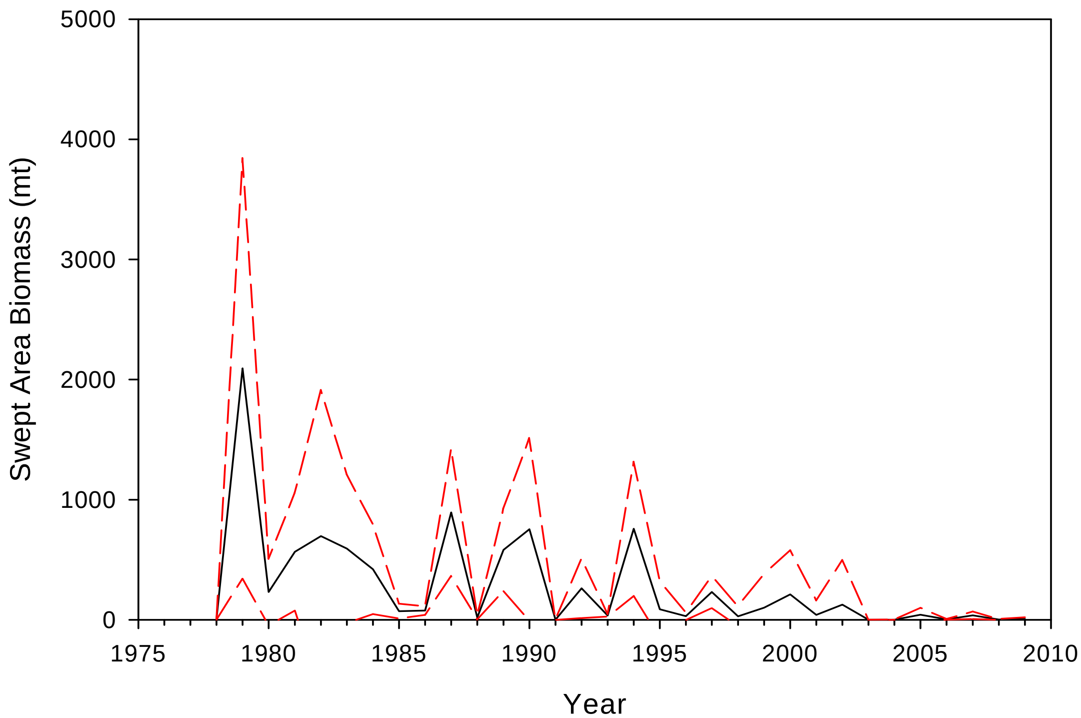
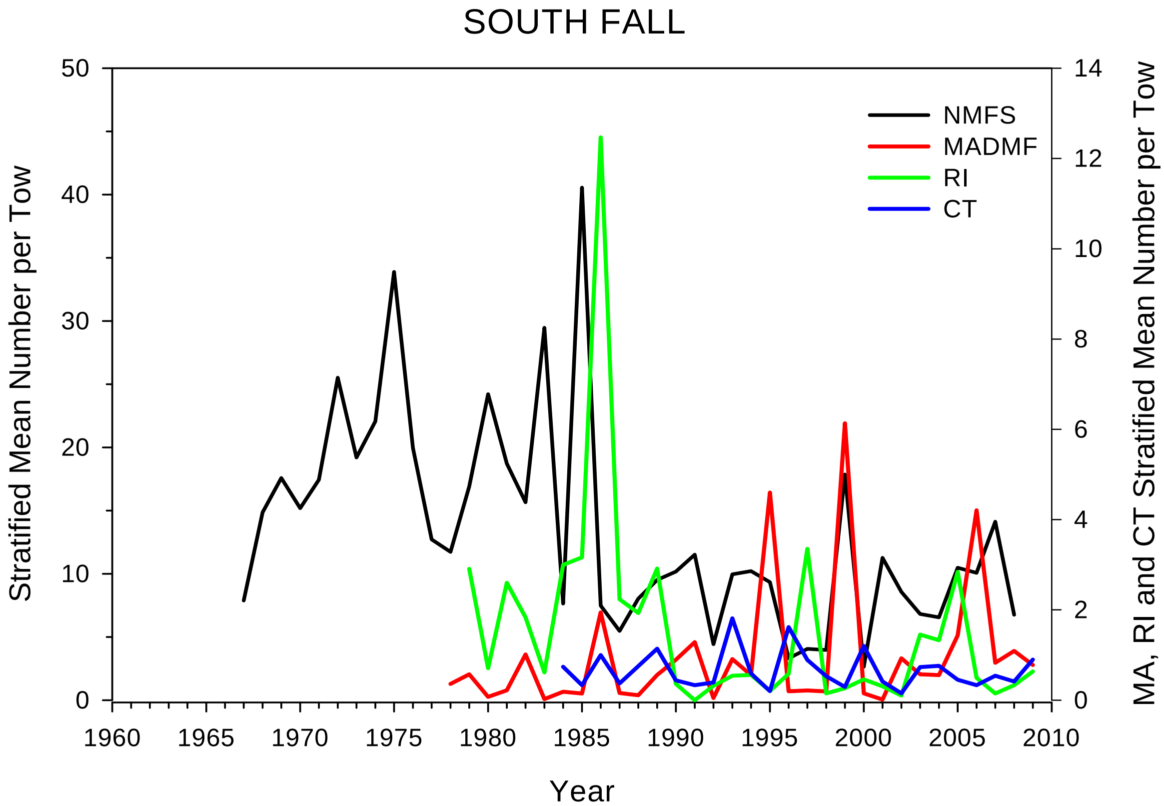


Figure C46. Swept area abundance (top) and biomass (bottom) with upper and lower confidence intervals for red hake from Massachusetts Division of Marine Fisheries spring south survey (strata 11-17).



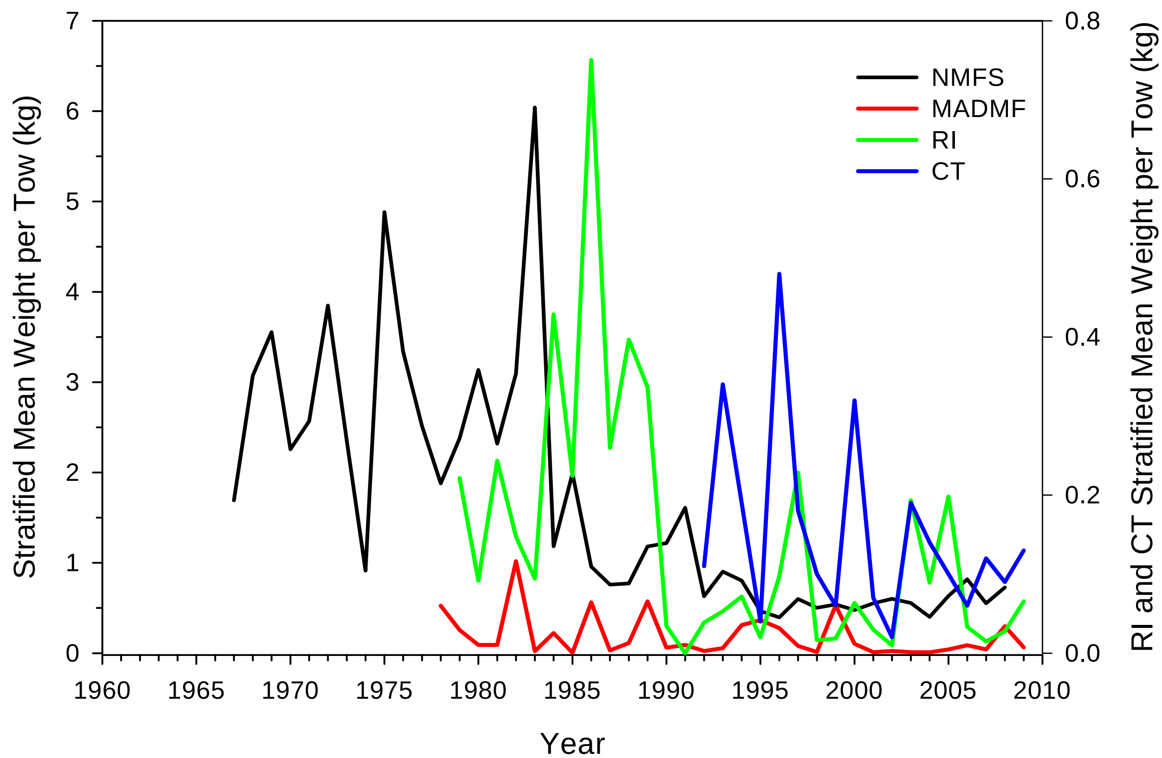


Figure C47. Stratified mean number and weight (kg) per tow for red hake from all the fall surveys in the southern management area: NEFSC, MADMF, RI and CT.

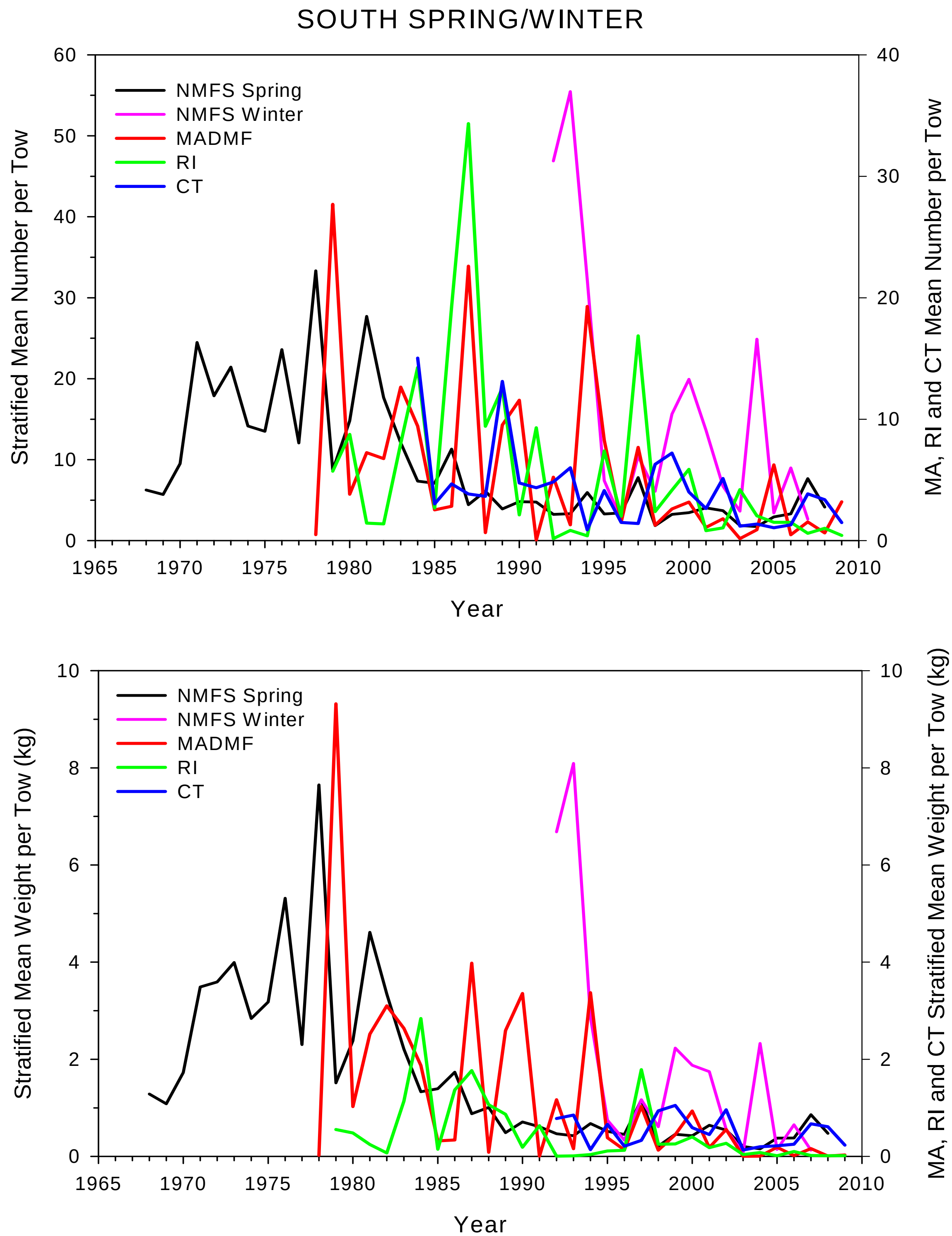
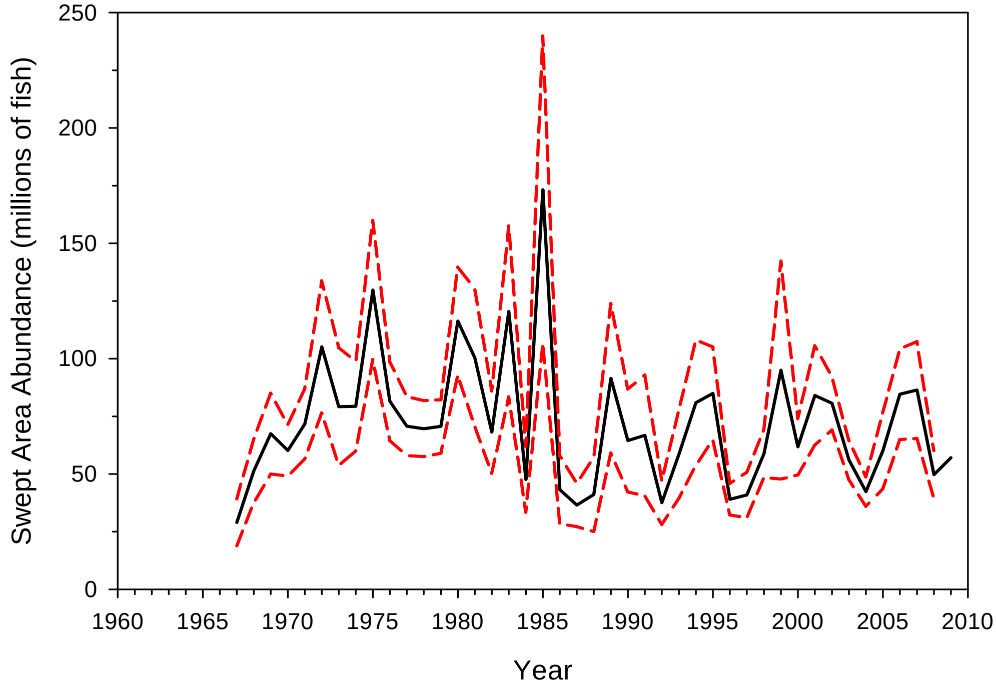


Figure C48. Stratified mean number and weight (kg) per tow for red hake from all the spring surveys in the southern management area: NEFSC, MADMF, RI and CT.

COMBINED FALL



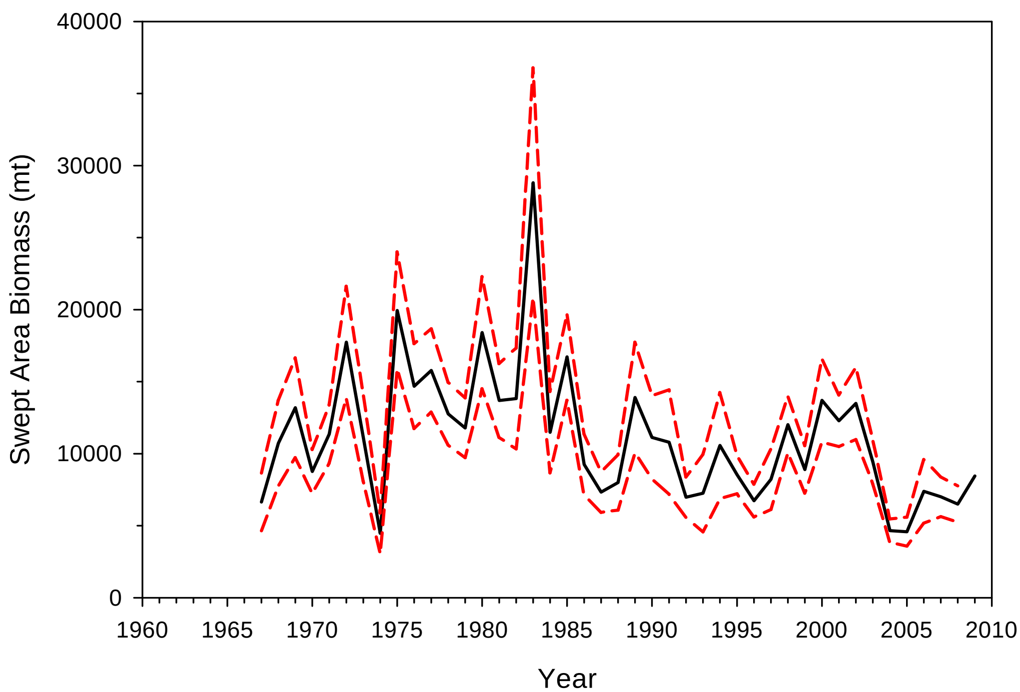
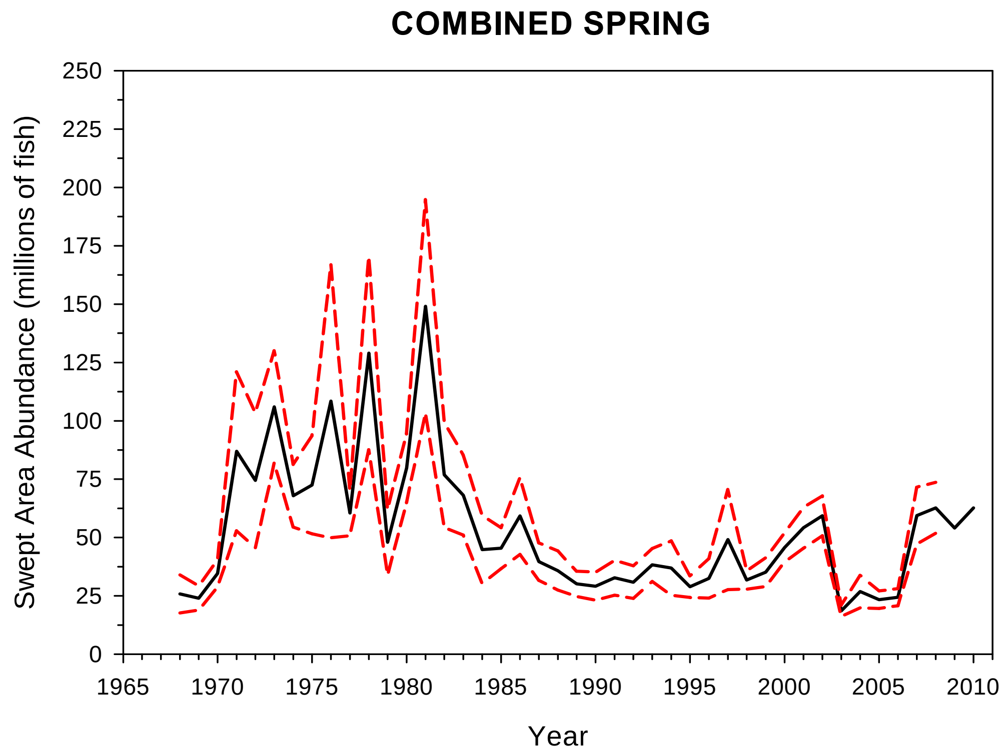


Figure C49. Swept area abundance (top) and biomass (bottom) with upper and lower confidence intervals for red hake from the NEFSC fall bottom trawl surveys in the northern and southern management regions combined (strata 1-30, 36-40, 61-76). Estimates for 2009 were converted to Albatross units using the calibration factors at length in Table C34.



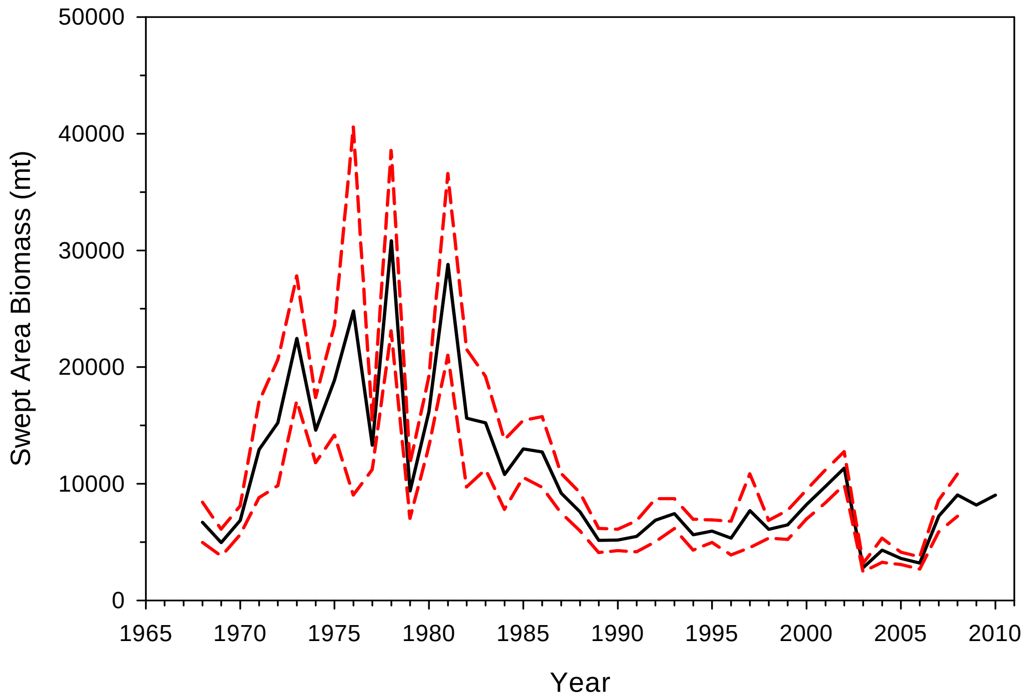
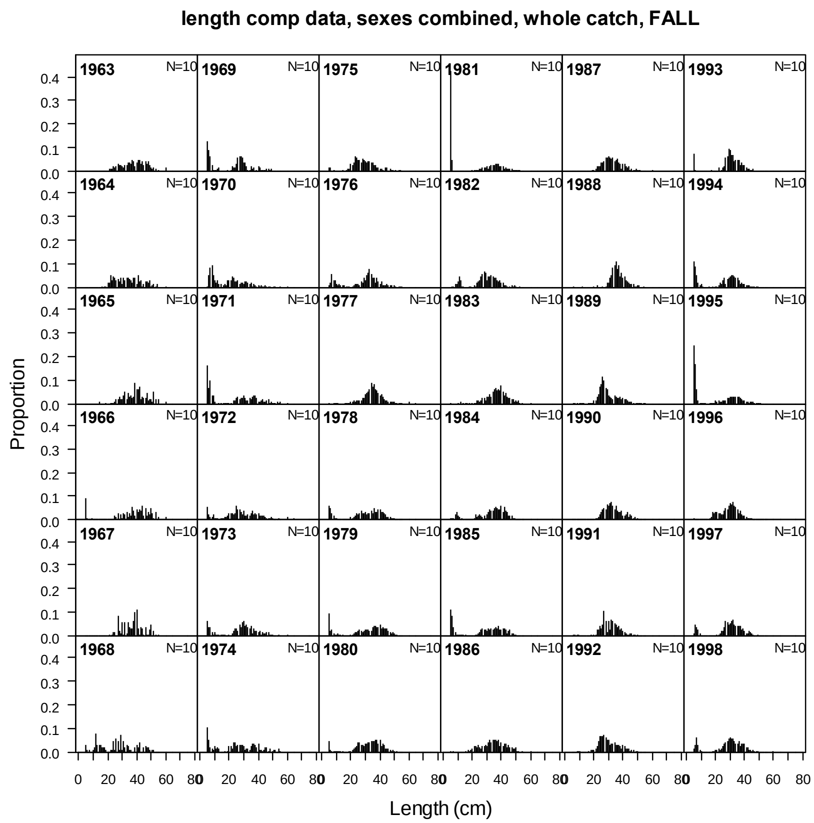


Figure C50. Swept area abundance (top) and biomass (bottom) with upper and lower confidence intervals for red hake from the NEFSC spring bottom trawl surveys in the northern and southern management regions combined (strata 1-30, 36-40, 61-76). Estimates for 2009 and 2010 were converted to Albatross units using the calibration factors at length in Table C34.



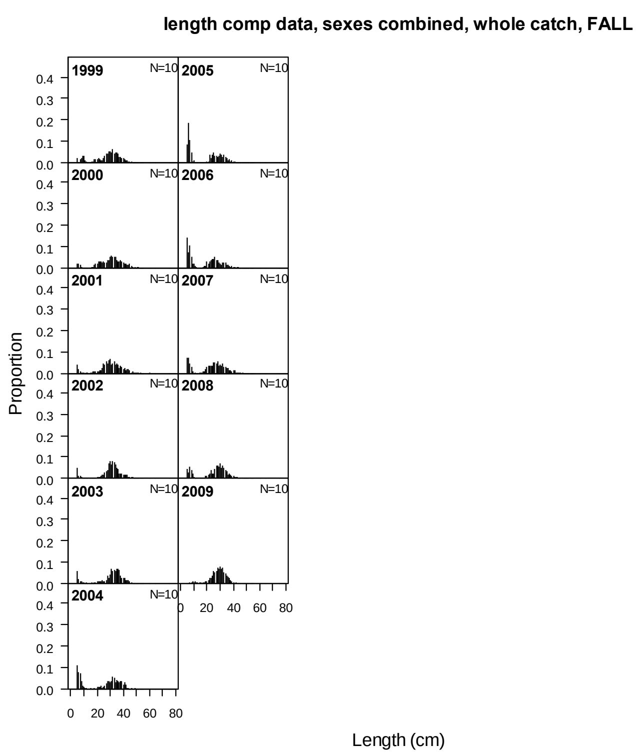


Figure C51. Length composition of red hake from the fall survey for the northern stock.

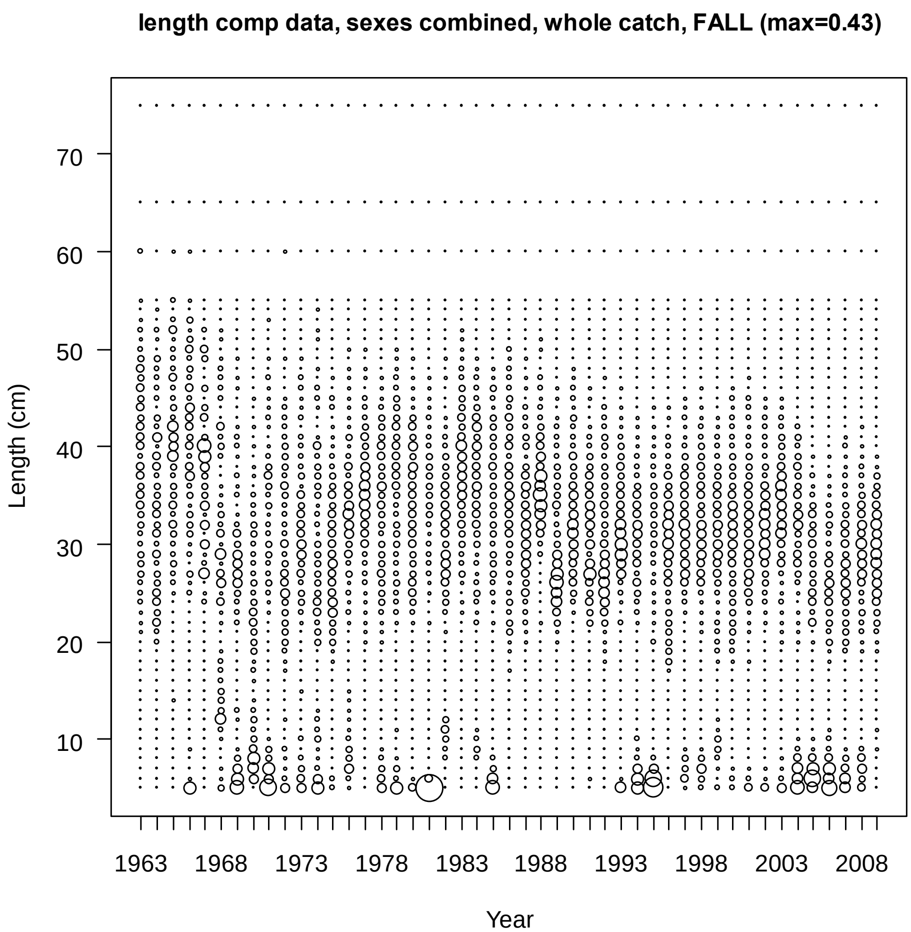
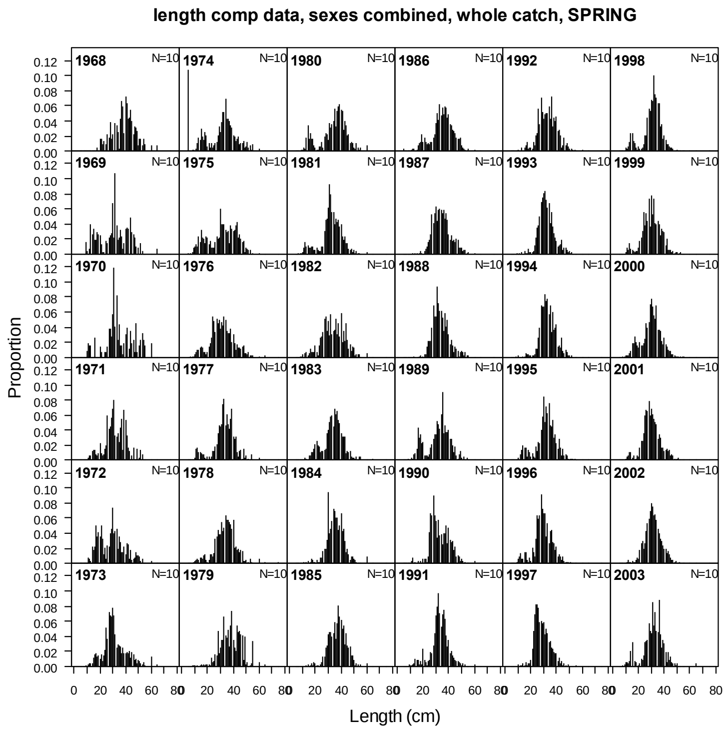


Figure C51 cont. Length composition of red hake from the fall survey for the northern stock.



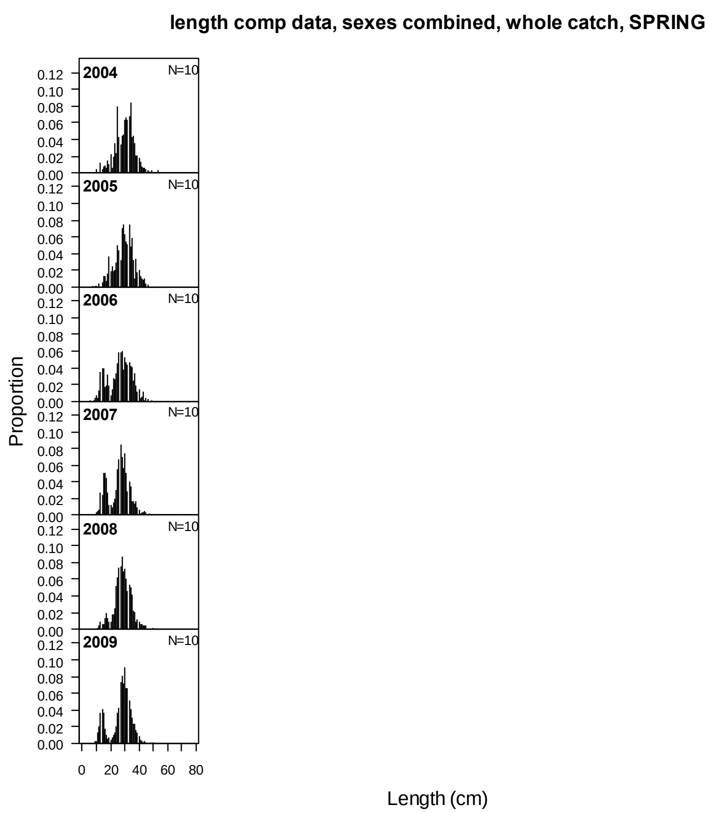


Figure C52. Length composition of red hake from the spring survey for the northern stock.

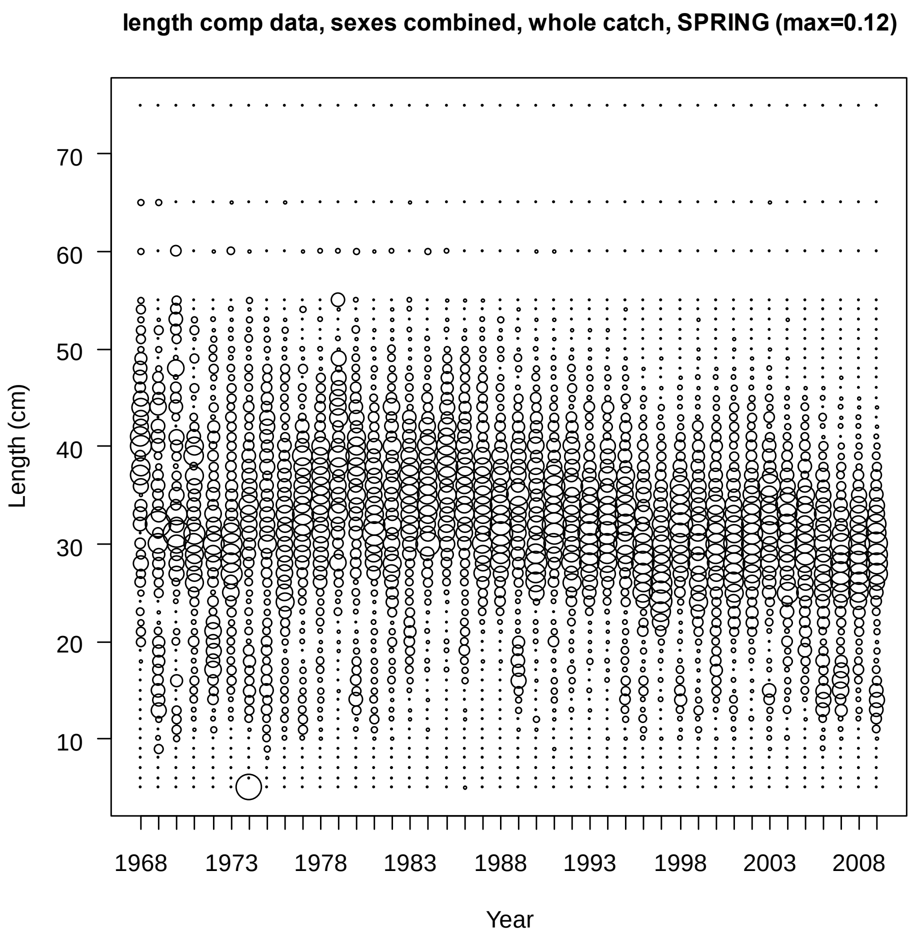
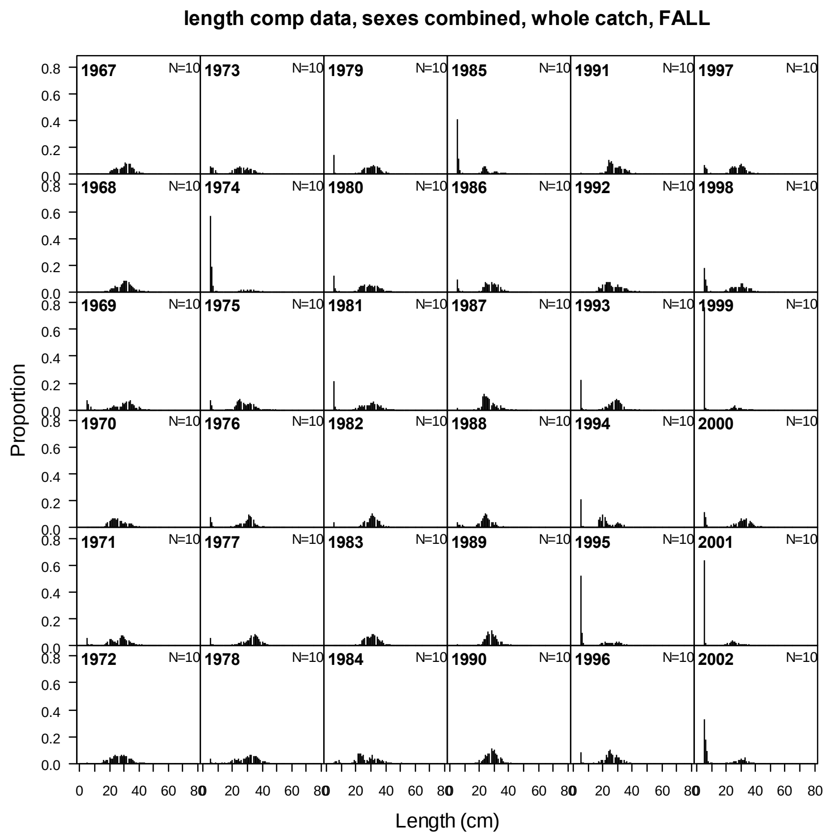


Figure C52 cont. Length composition of red hake from the spring survey for the northern stock.



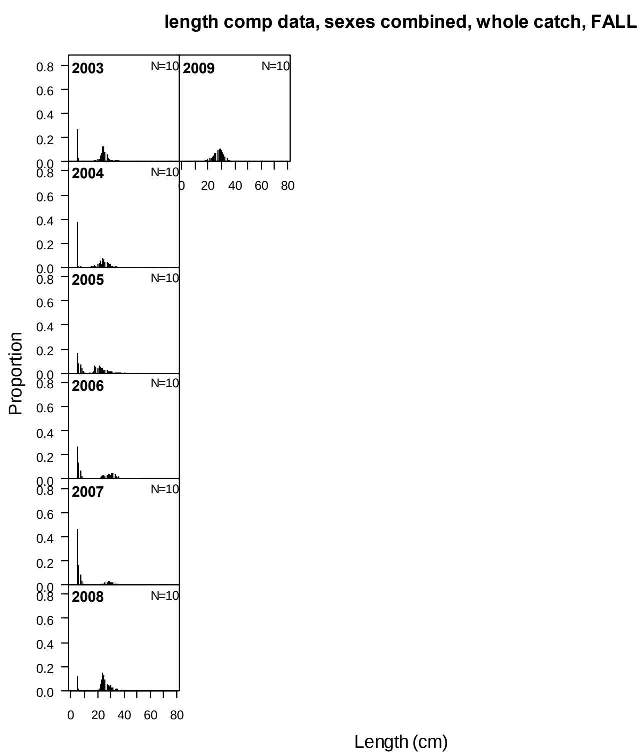


Figure C53. Length composition of red hake from the fall survey for the southern stock.

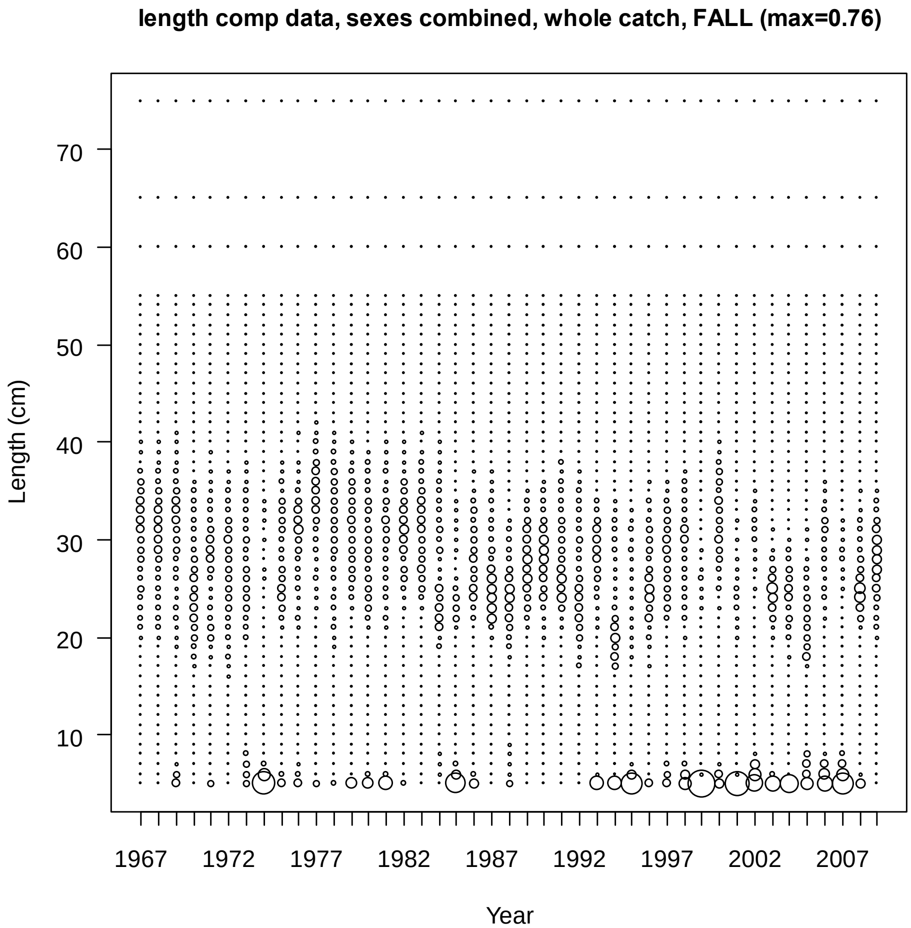
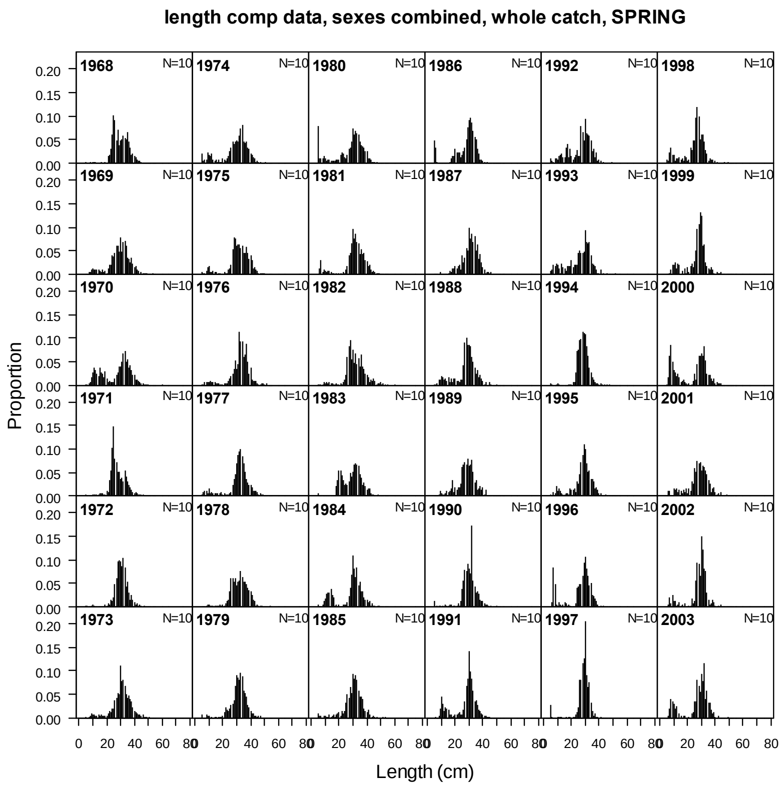


Figure C53 cont. Length composition of red hake from the fall survey for the southern stock.



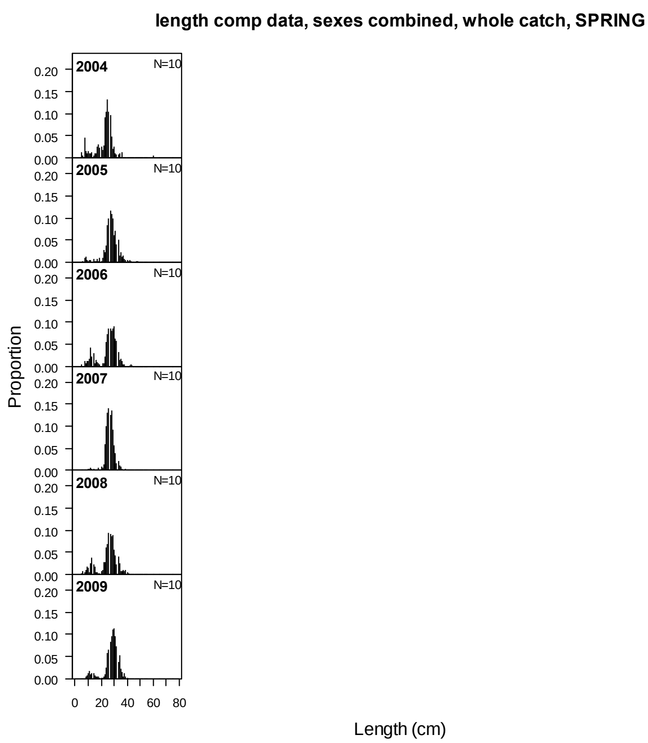


Figure C54. Length composition of red hake from the spring survey for the southern stock.

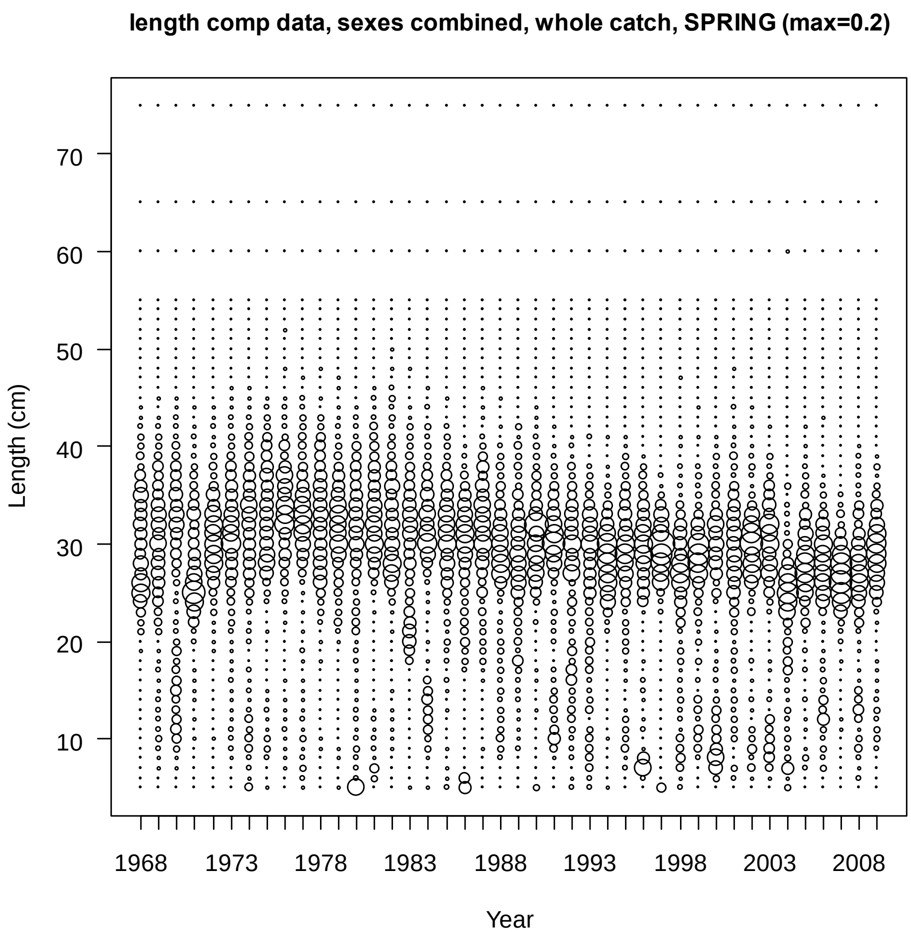
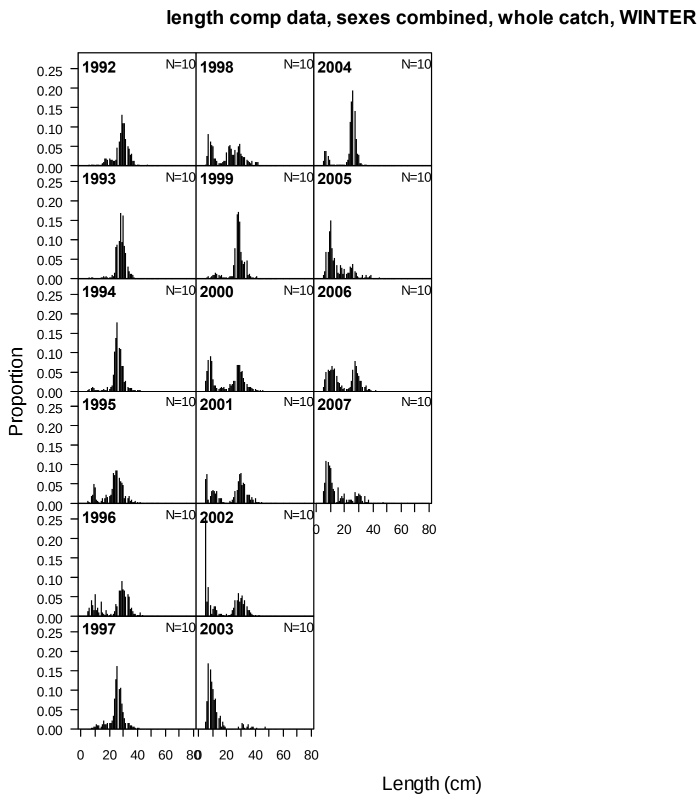


Figure C54 cont. Length composition of red hake from the spring survey for the southern stock.



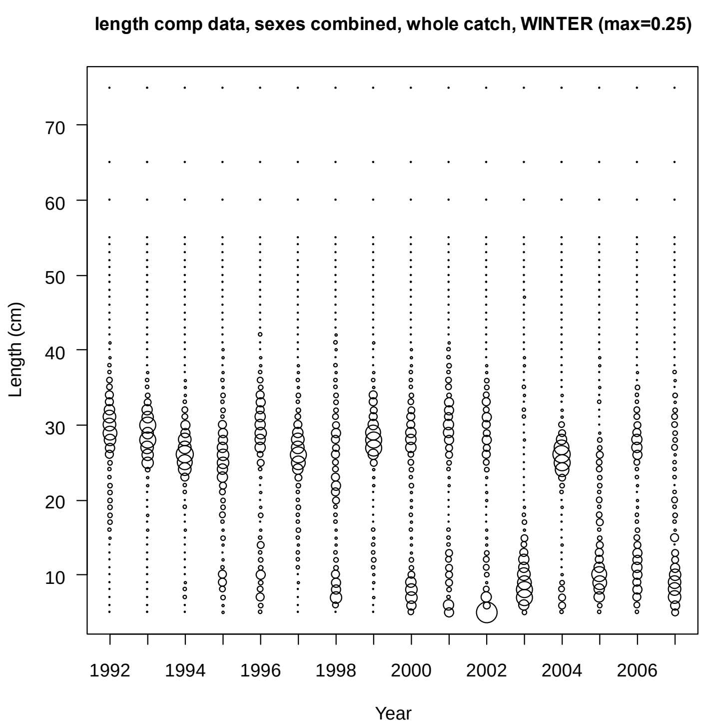


Figure C55. Length composition of red hake from the winter survey for the southern stock.

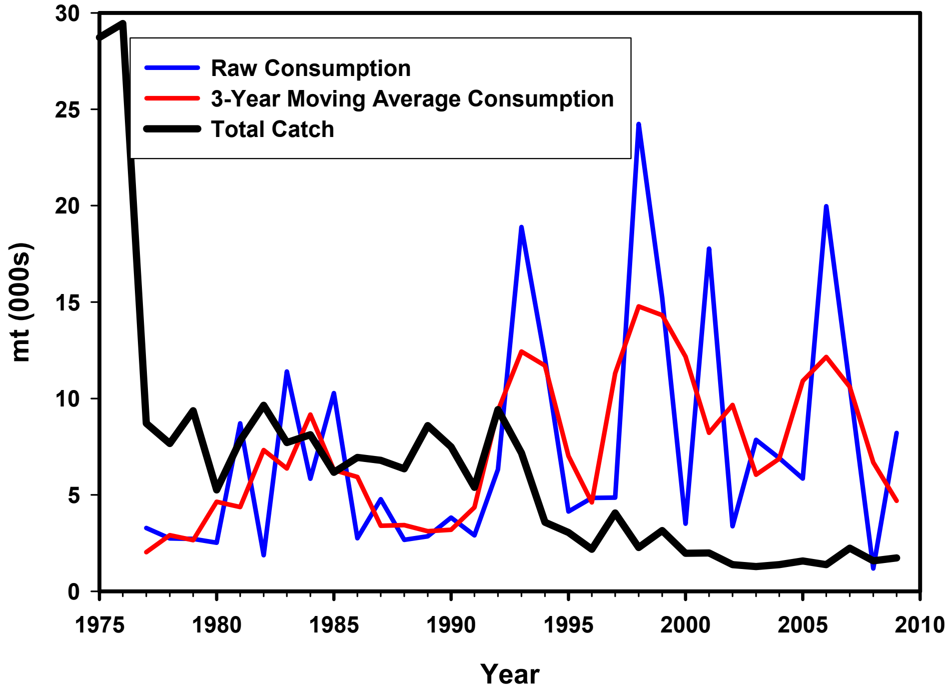


Figure C56. Minimal estimates of total red hake biomass removed by consumption by major fish predators compared to total catch.

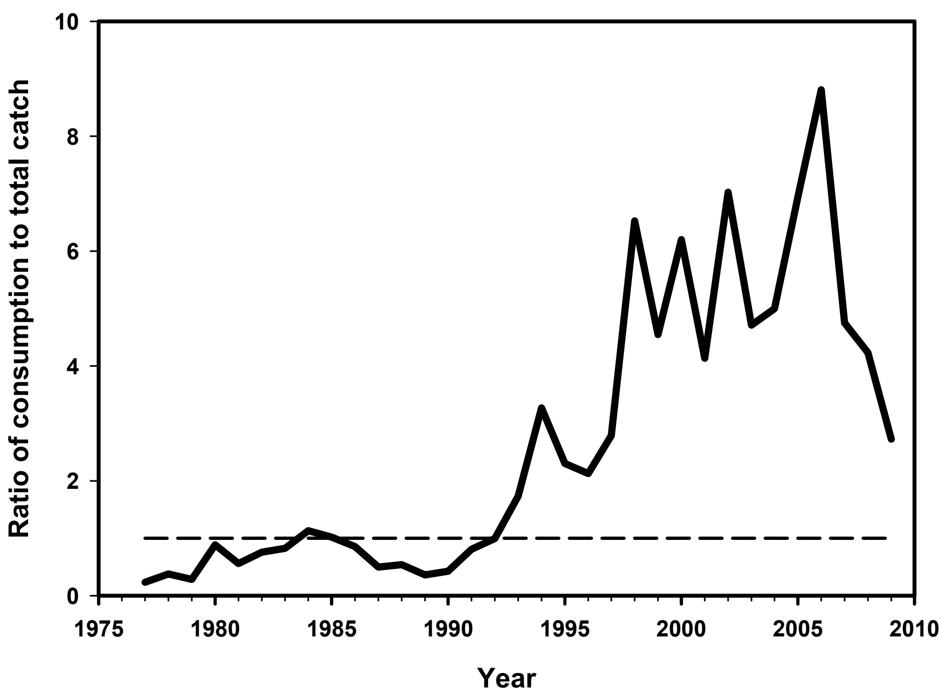
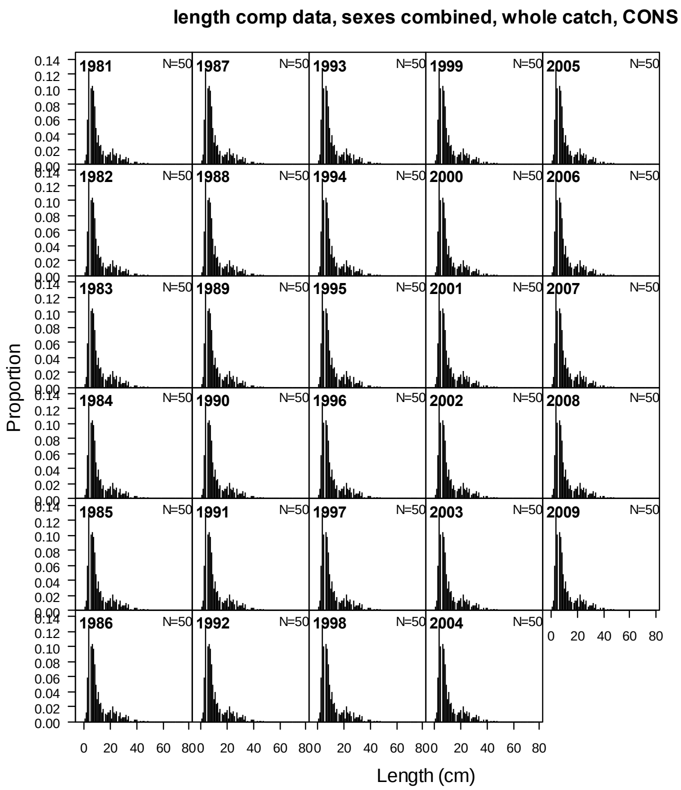


Figure C57. Ratio of consumption to total catch of red hake over the time series. The constant line represents a ratio of unity.



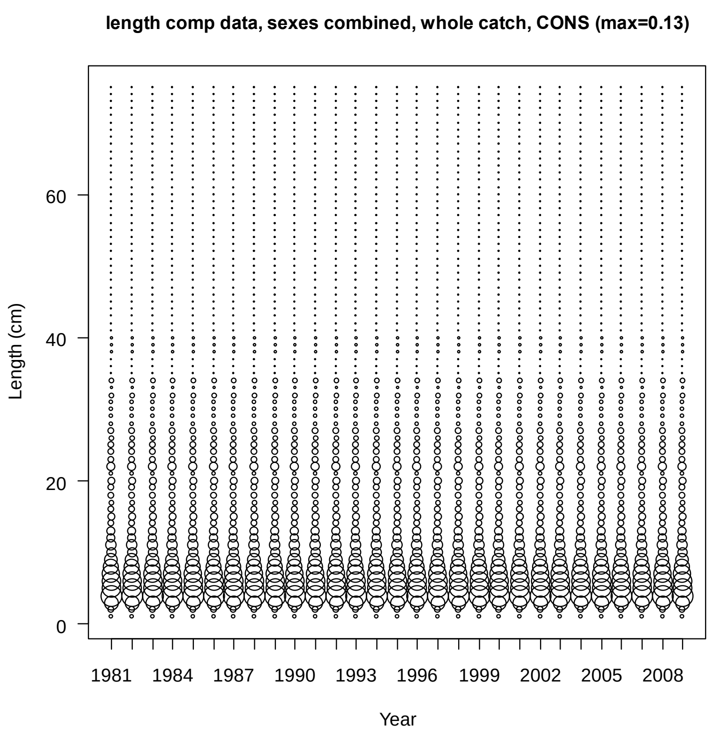
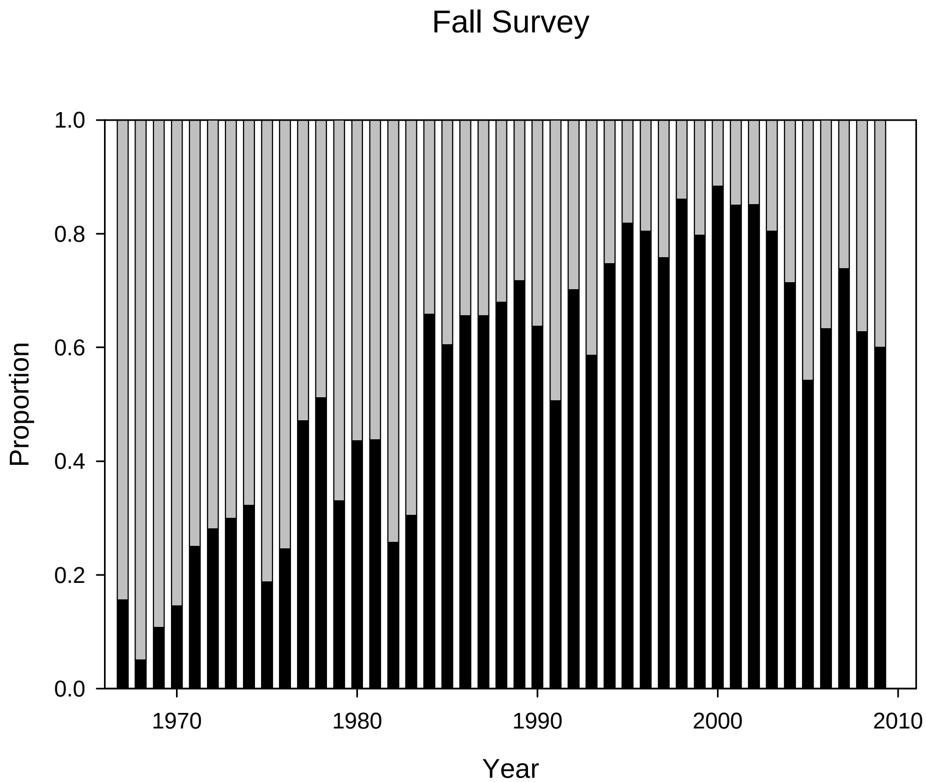


Figure C58. Length composition of red hake consumed by major predators from the NEFSC surveys for the northern and southern stocks combined.



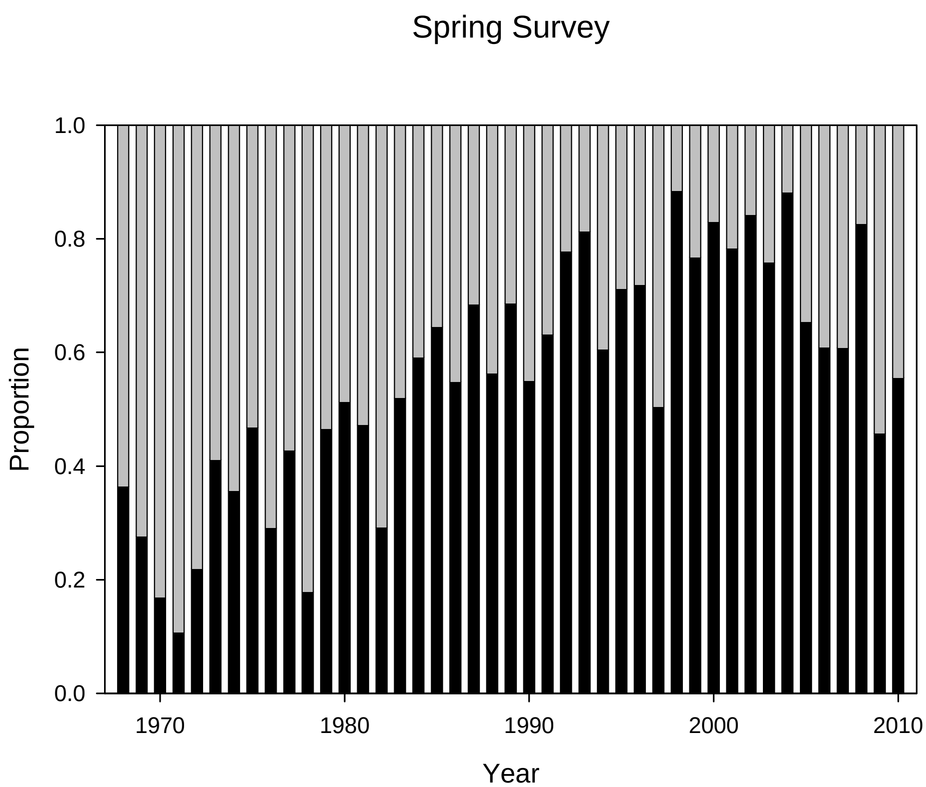


Figure C59. Proportion of swept area biomass found in the northern area (black) and the southern area (gray bars).

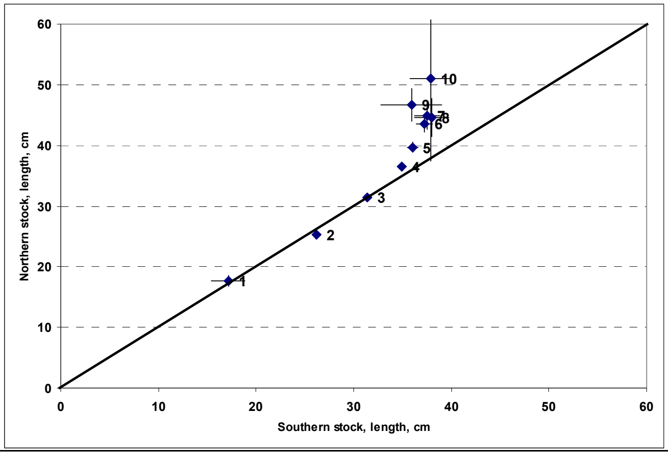
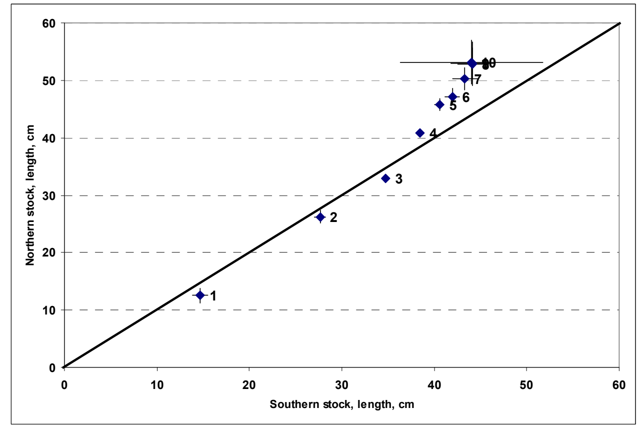
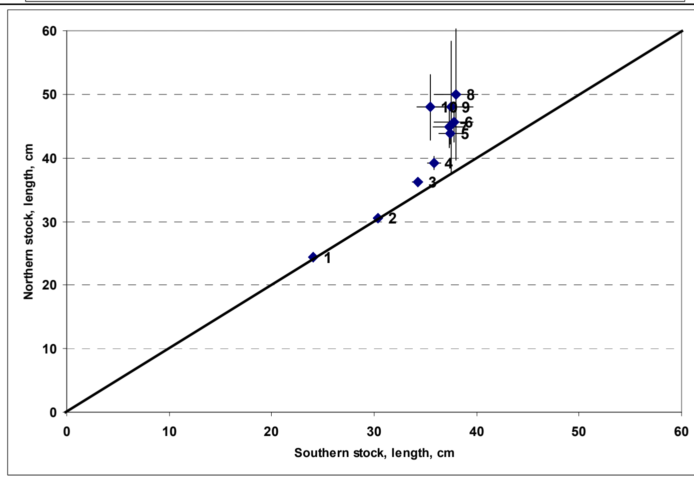
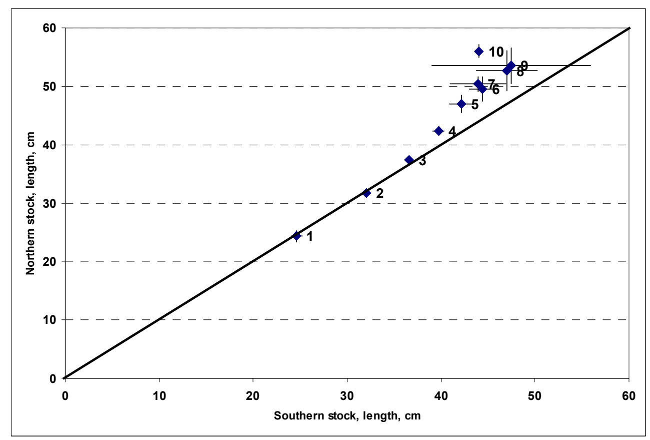
Red hake	Males	Females
Spring		
Fall		

Figure C60a. Size (cm total length) at age comparison between red hake caught in strata 1-19, 61-76 (Southern stock) and strata 20-40 (Northern stock) for 1957-1974 cohorts.

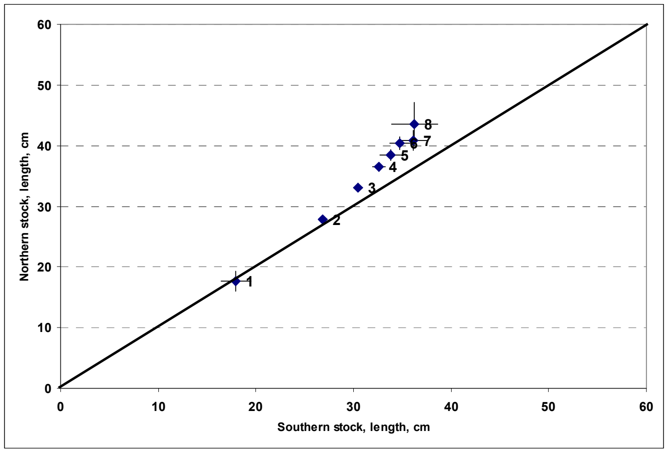
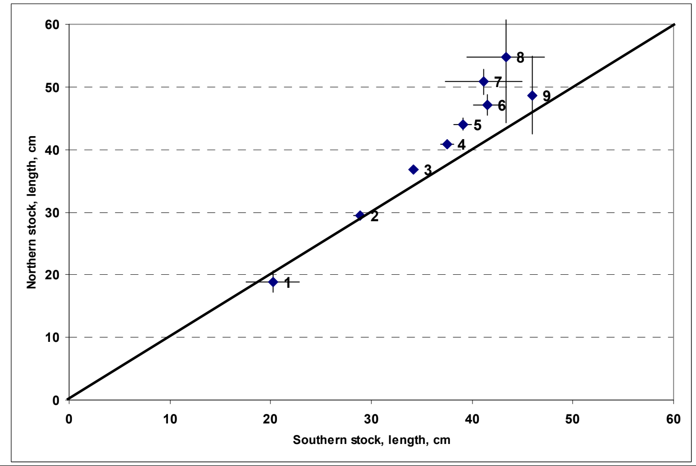
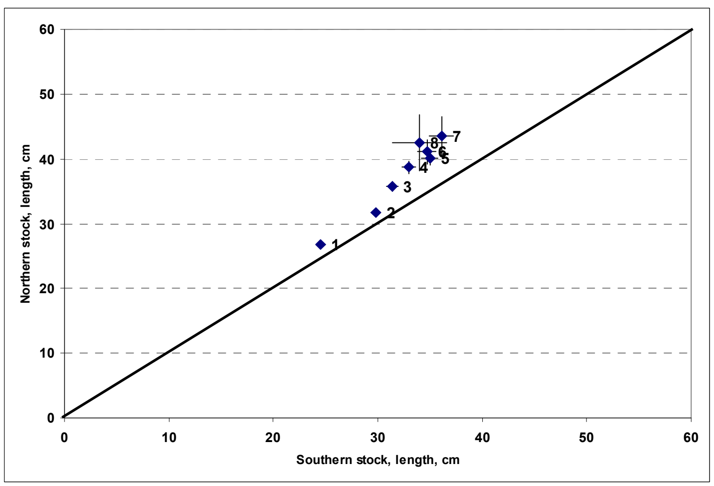
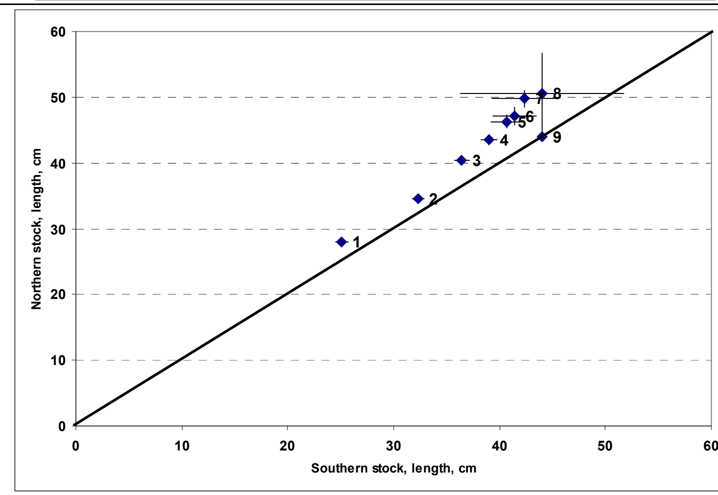
<table>
<tr><th>Red hake</th><th>Males</th><th>Females</th></tr>
<tr><td>Spring</td><td>
</td><td>
</td></tr>
<tr><td>Fall</td><td>
</td><td>
</td></tr>
</table>

Figure C60b. Size (cm total length) at age comparison between red hake caught in strata 1-19, 61-76 (Southern stock) and strata 20-40 (Northern stock) for 1975-1985 cohorts.

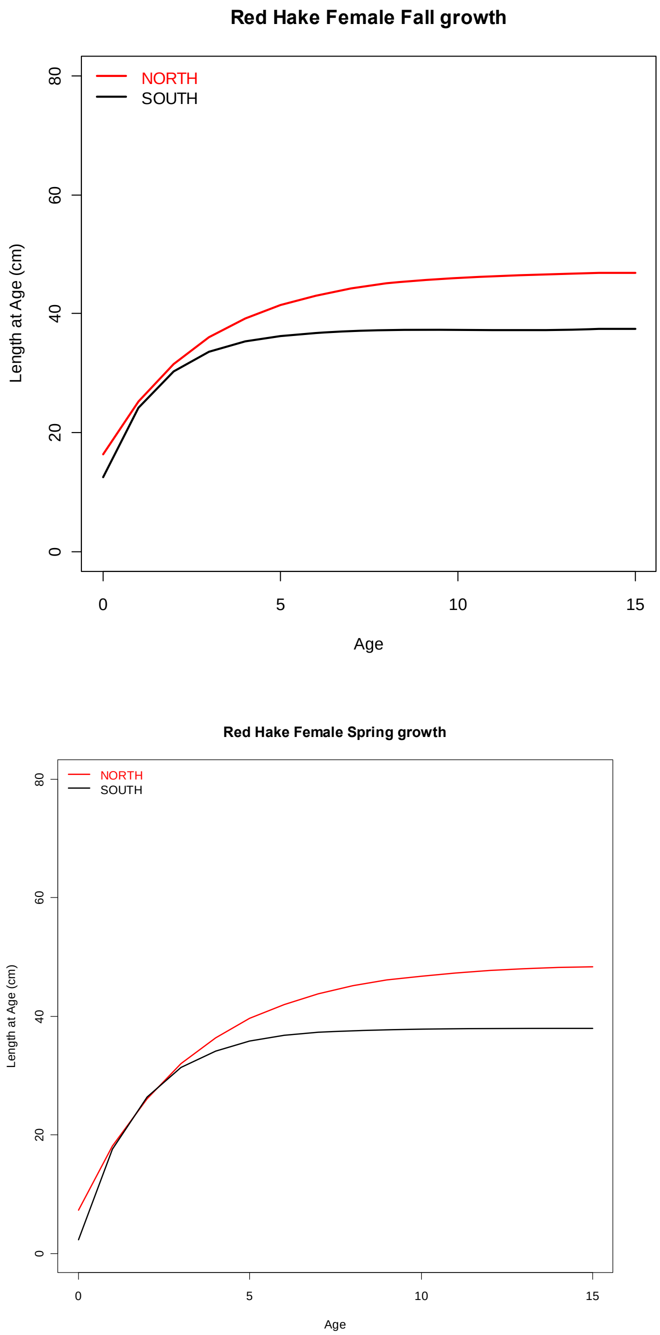
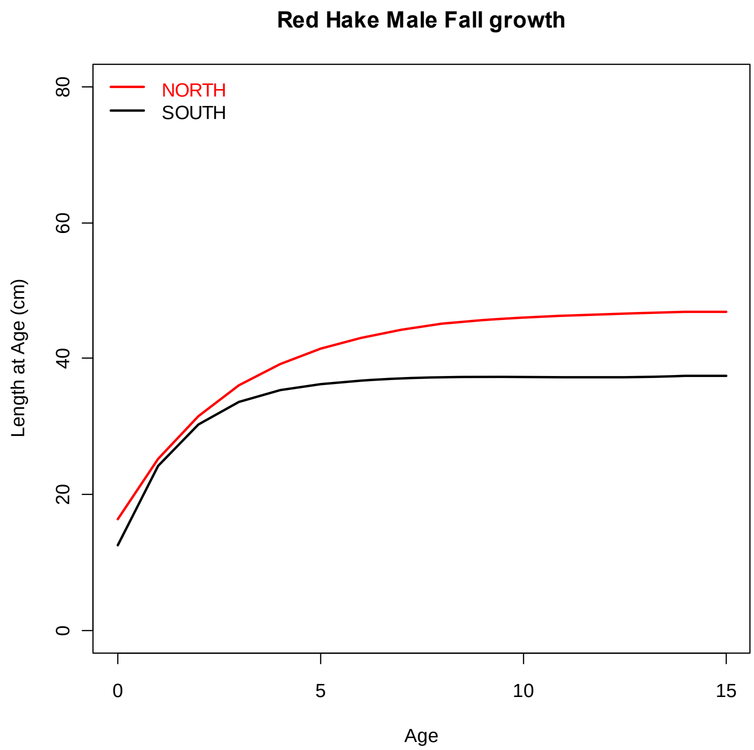


Figure C61a. Growth curves for female red hake by stock area.



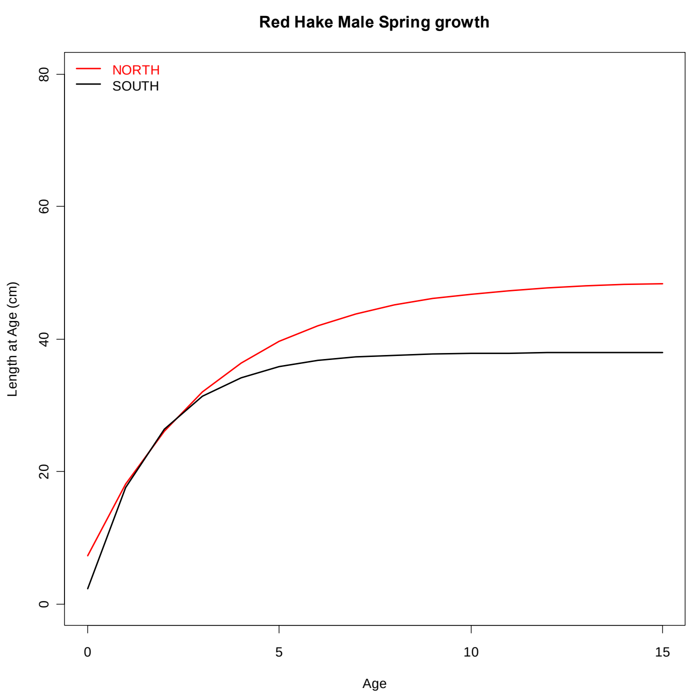


Figure C61a. Growth curves for male red hake by stock area.

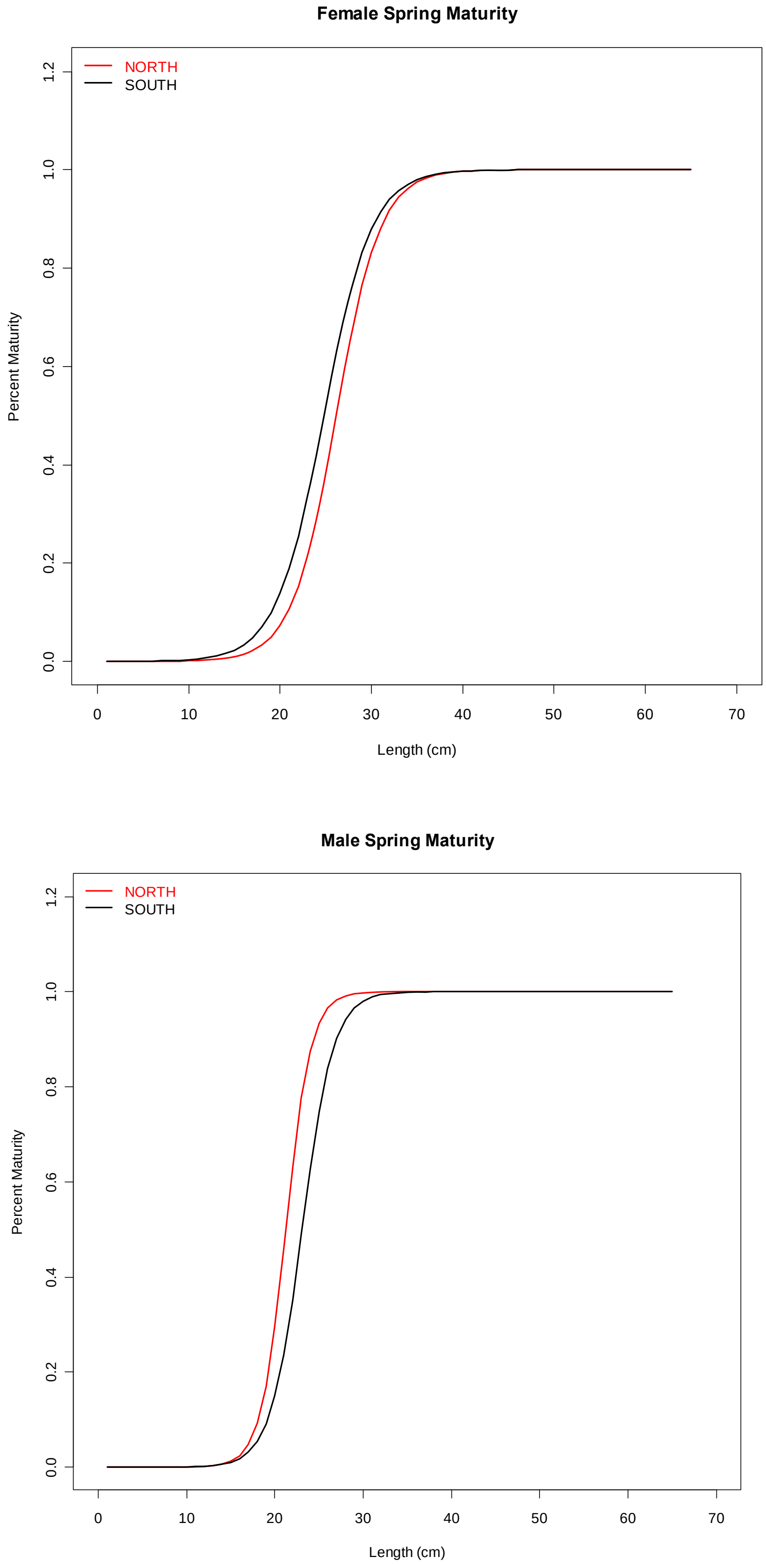


Figure C62. Maturity ogives for red hake by stock and sex.

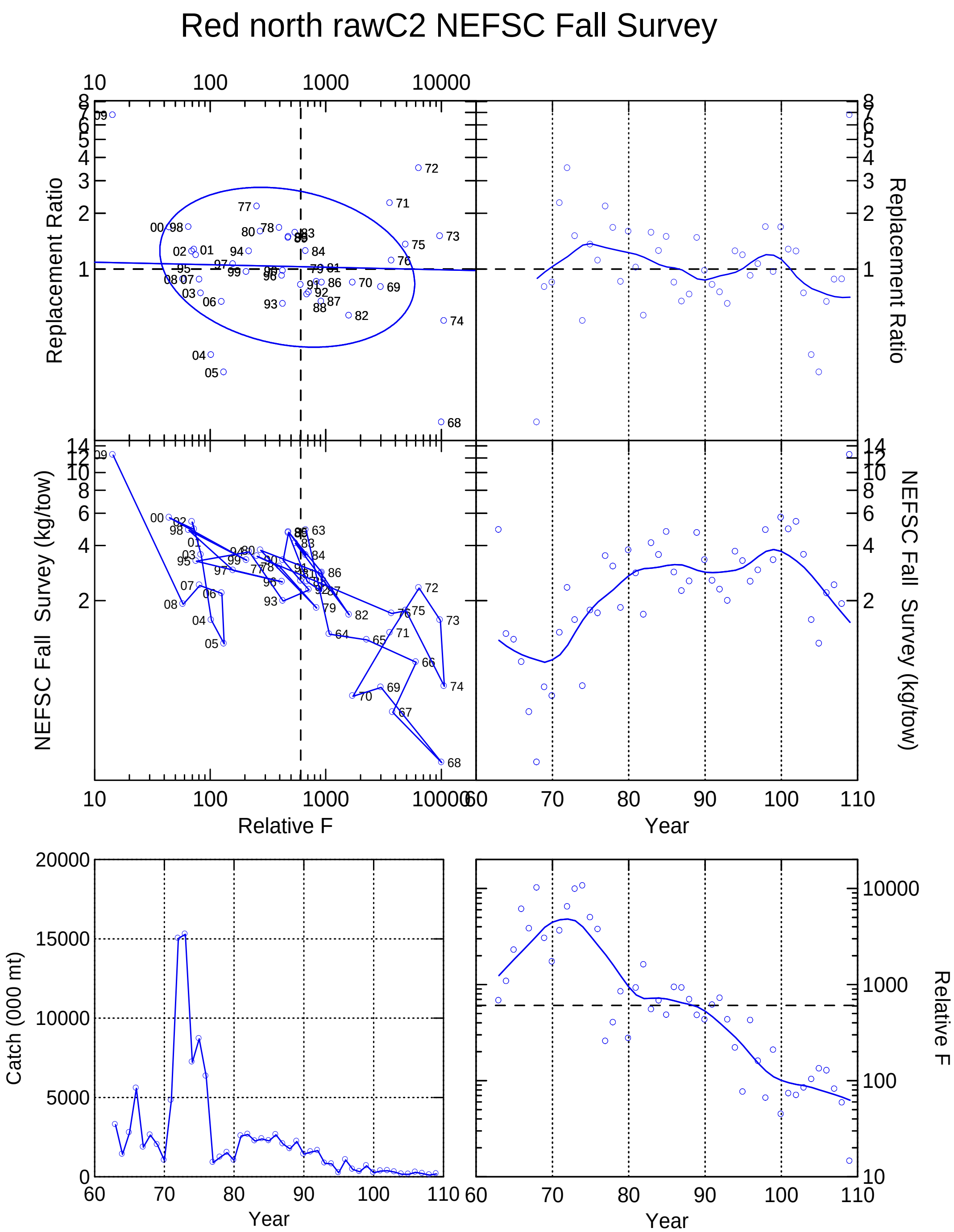


Figure C63. Six panel plot for northern red hake depicting trends in relative biomass, landings, relative fishing mortality and replacement ratios for the NEFSC fall survey index and landings based on catch method "raw C2". Horizontal dashed lines (---) represent replacement ratios in the top two panels and the replacement F in the lower right panel. Smooth lines represent Lowess smooths (tension =0.3). The confidence ellipse in the top left panel has a nominal probability level of 0.68. The regression line in the top left panel is a robust regression using bisquare downweighting of residuals.

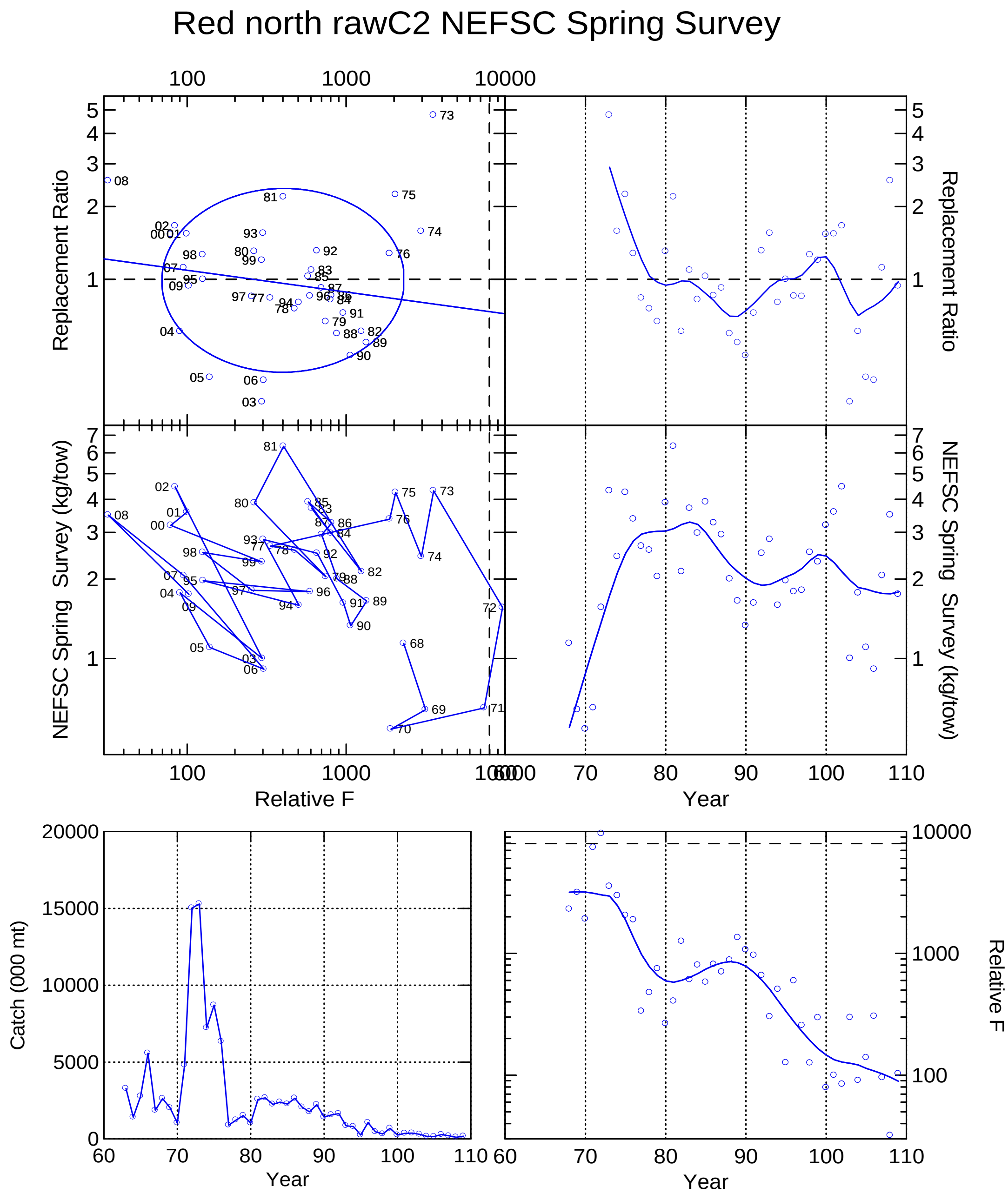


Figure C64. Six panel plot for northern red hake depicting trends in relative biomass, landings, relative fishing mortality and replacement ratios for the NEFSC spring survey index and landings based on catch method “raw C2”. Horizontal dashed lines (---) represent replacement ratios in the top two panels and the replacement F in the lower right panel. Smooth lines represent Lowess smooths (tension =0.3). The confidence ellipse in the top left panel has a nominal probability level of 0.68. The regression line in the top left panel is a robust regression using bisquare downweighting of residuals.

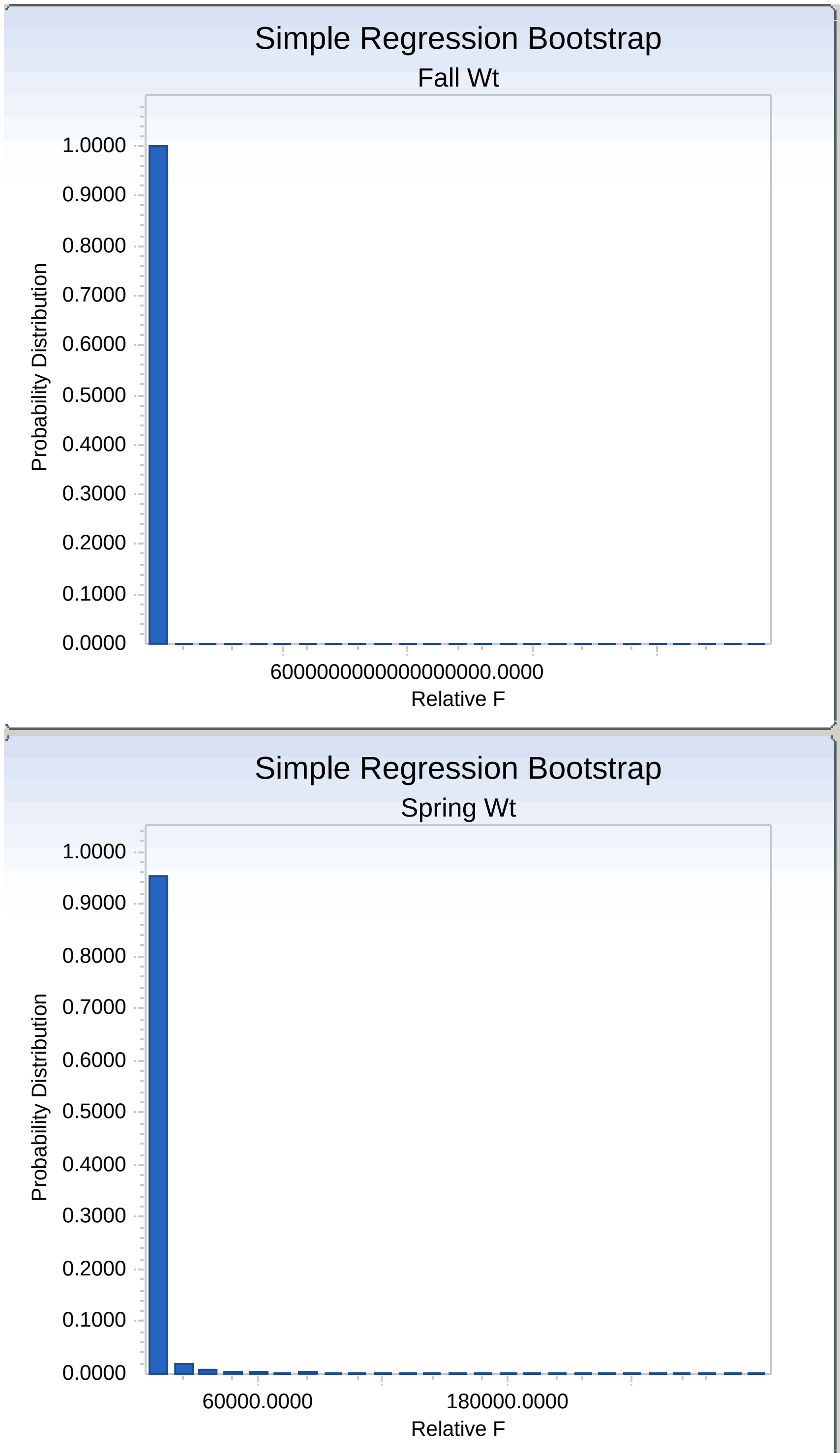


Figure C65.Randomization tests summary of sampling distribution of correlation coefficient between replacement ratio and relative F for fall (top) and spring (bottom) survey indices for northern red hake, using catch estimation method “raw C2”, 1963-2009.

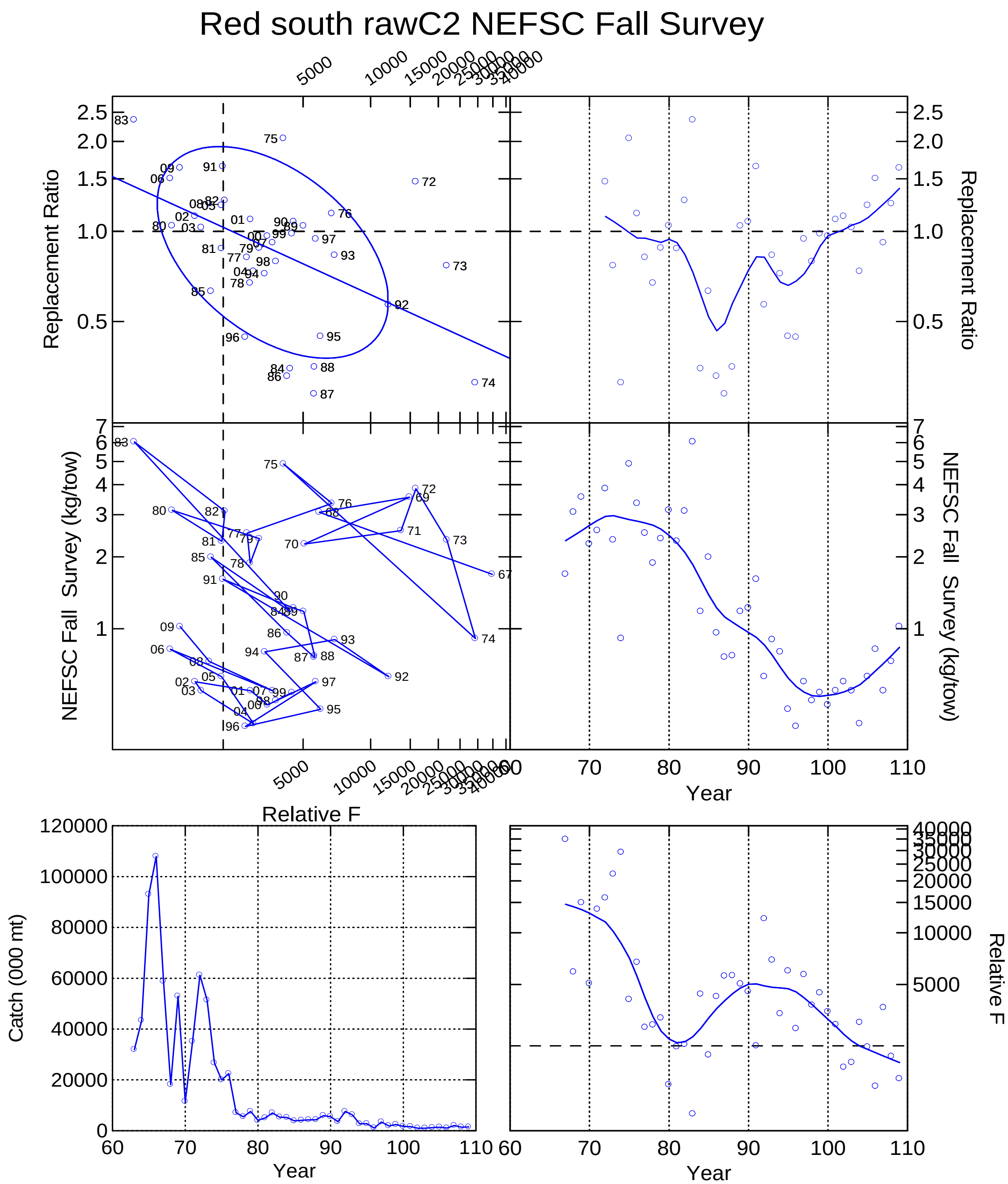


Figure C66. Six panel plot for southern red hake depicting trends in relative biomass, landings, relative fishing mortality and replacement ratios for the NEFSC fall survey index and landings based on catch method "raw C2". Horizontal dashed lines (---) represent replacement ratios in the top two panels and the replacement F in the lower right panel. Smooth lines represent Lowess smooths (tension =0.3). The confidence ellipse in the top left panel has a nominal probability level of 0.68. The regression line in the top left panel is a robust regression using bisquare downweighting of residuals.

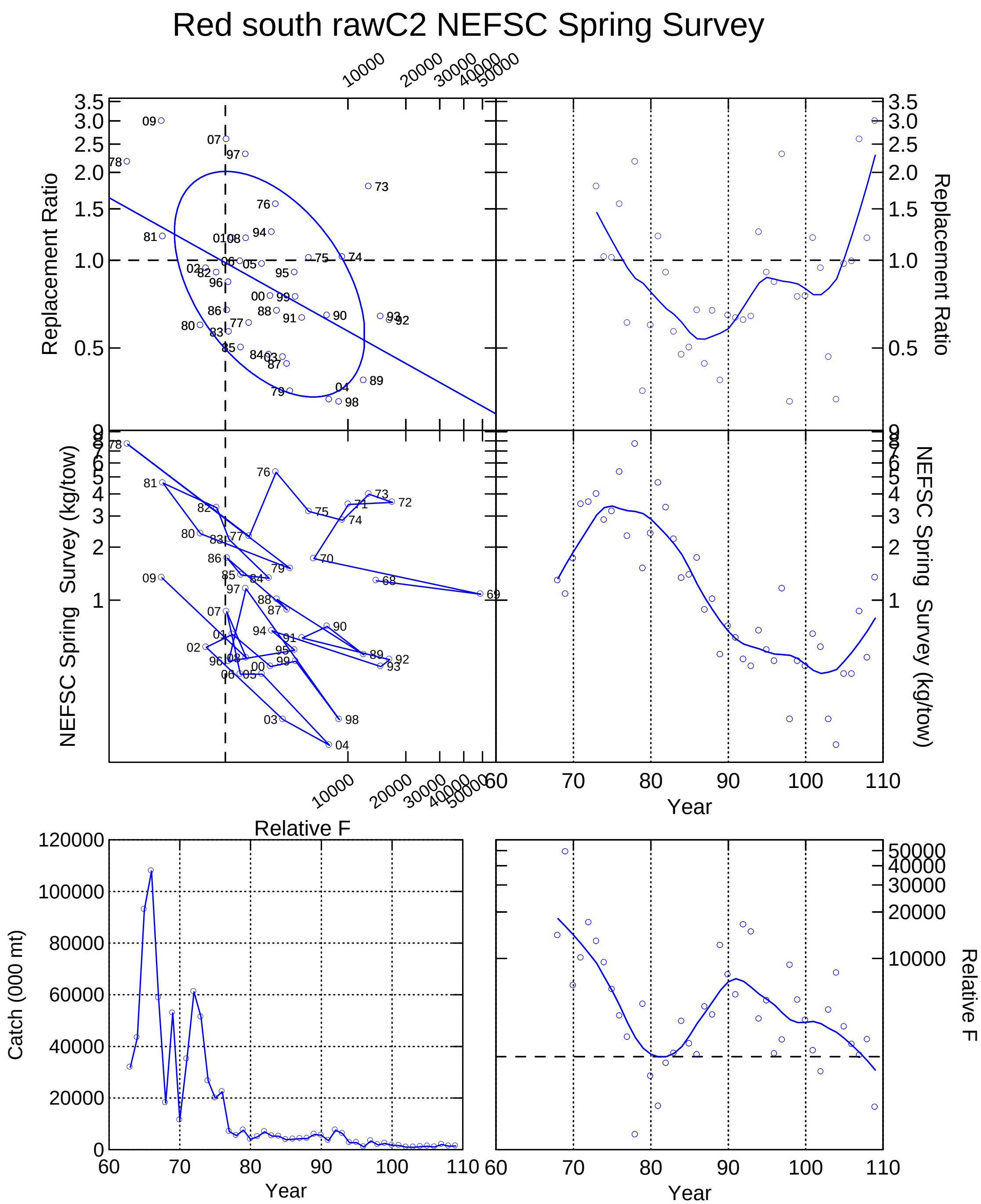
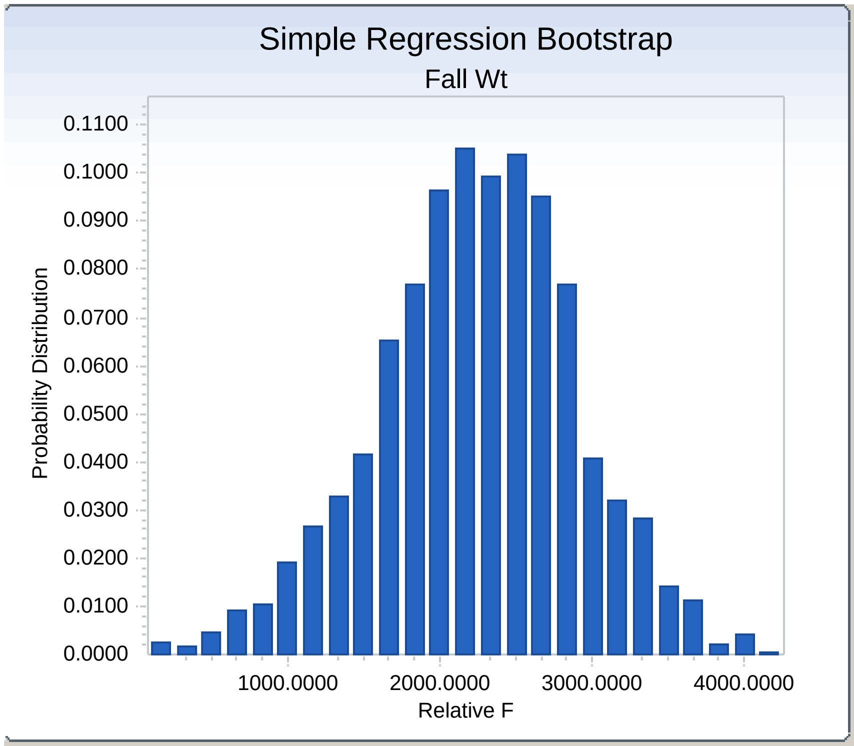


Figure C67. Six panel plot for southern red hake depicting trends in relative biomass, landings, relative fishing mortality and replacement ratios for the NEFSC spring survey index and landings based on catch method "raw C2". Horizontal dashed lines (---) represent replacement ratios in the top two panels and the replacement F in the lower right panel. Smooth lines represent Lowess smooths (tension =0.3). The confidence ellipse in the top left panel has a nominal probability level of 0.68. The regression line in the top left panel is a robust regression using bisquare downweighting of residuals.



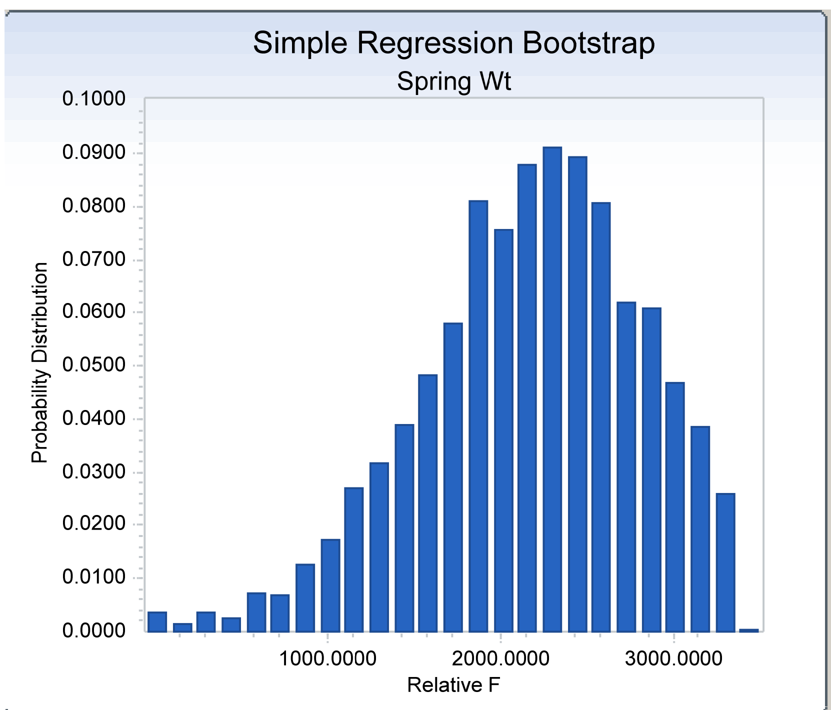


Figure C68. Randomization tests summary of sampling distribution of correlation coefficient between replacement ratio and relative F for fall (top) and spring (bottom) survey indices for southern red hake, using catch estimation method “raw C2”, 1963-2009.

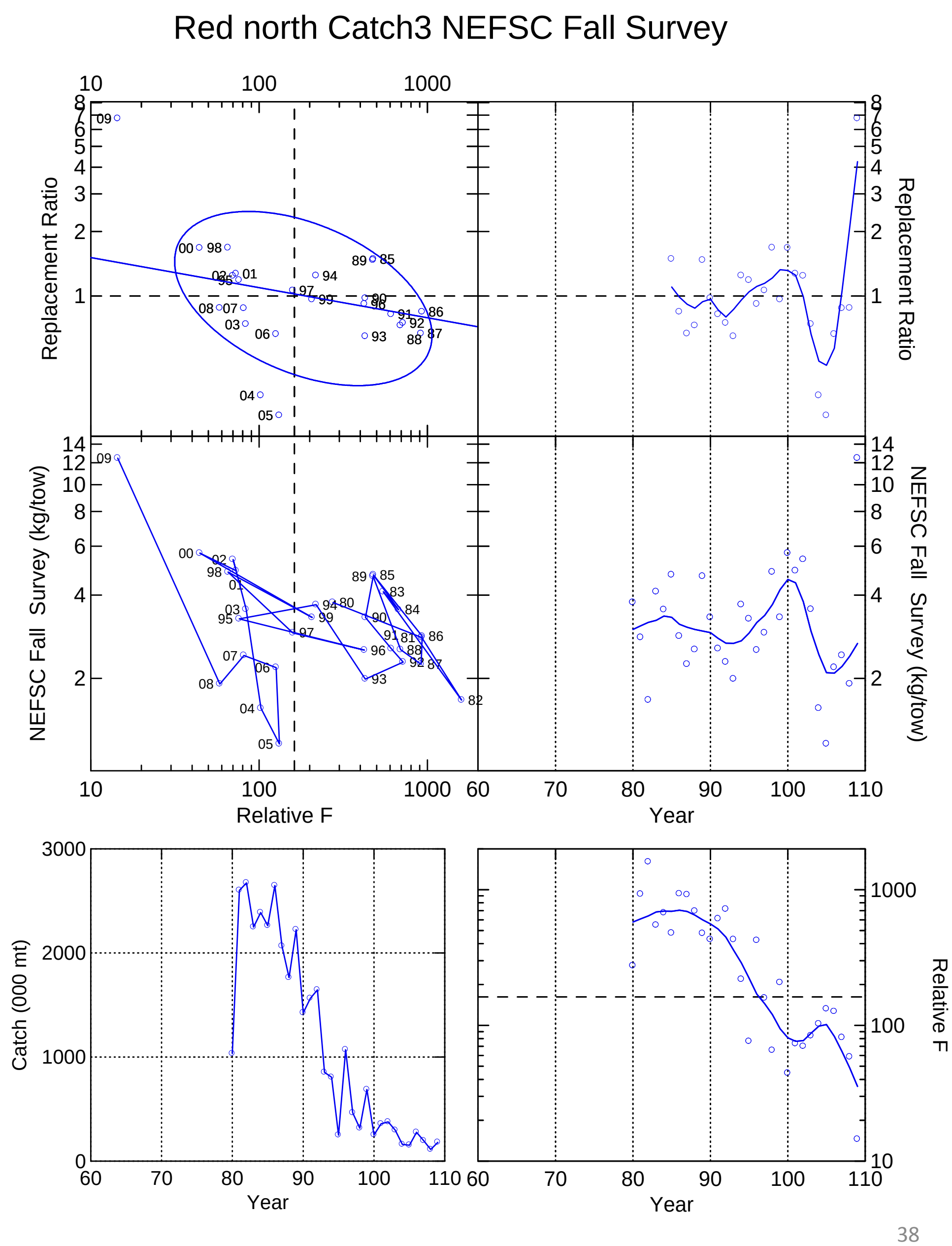


Figure C69. Six panel plot for northern red hake depicting trends in relative biomass, landings, relative fishing mortality and replacement ratios for the NEFSC fall survey index and landings based on catch method “Catch 3”, 1980-2009. Horizontal dashed lines (---) represent replacement ratios in the top two panels and the replacement F in the lower right panel. Smooth lines represent Lowess smooths (tension =0.3). The confidence ellipse in the top left panel has a nominal probability level of 0.68. The regression line in the top left panel is a robust regression using bisquare downweighting of residuals.

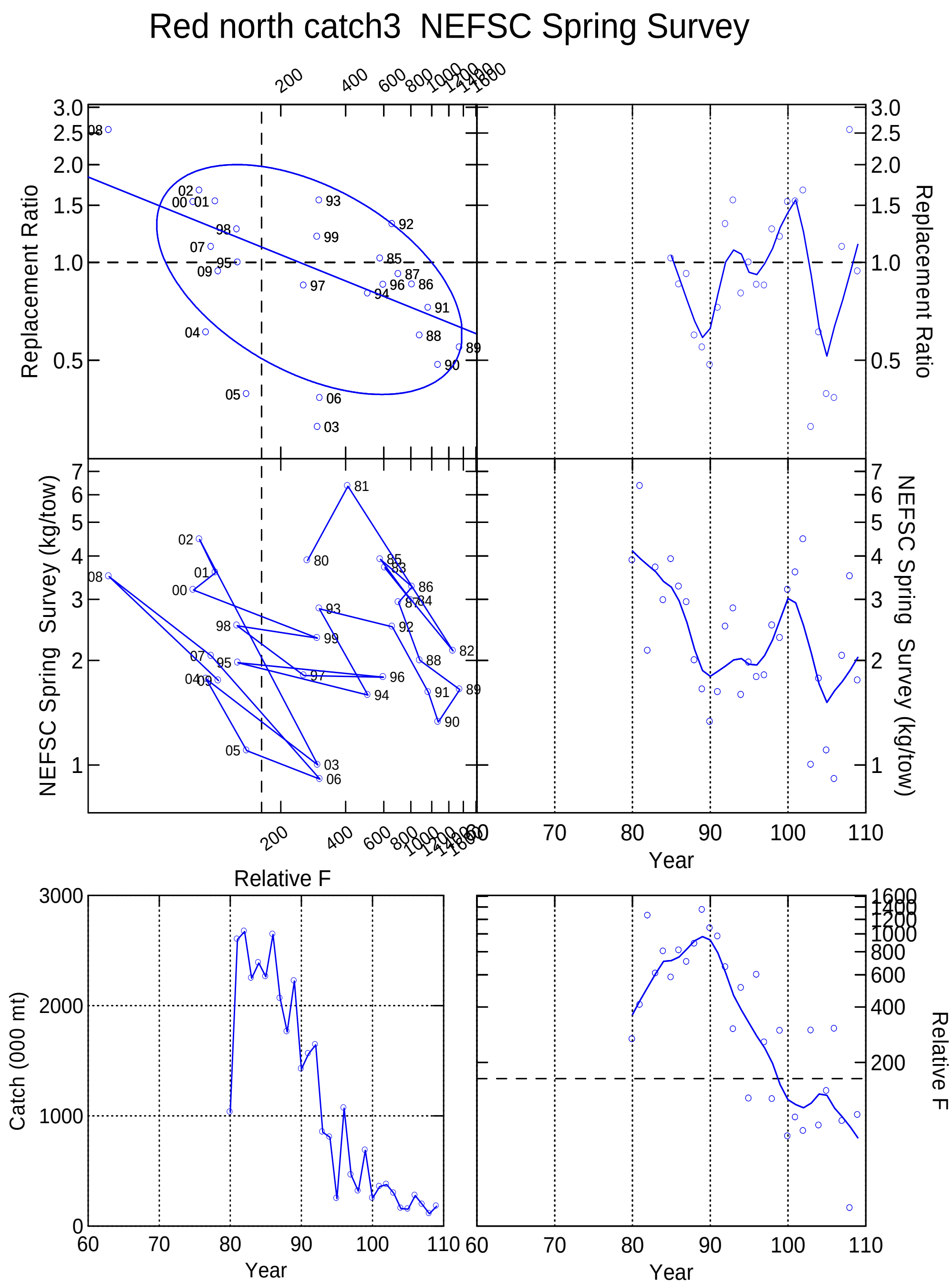
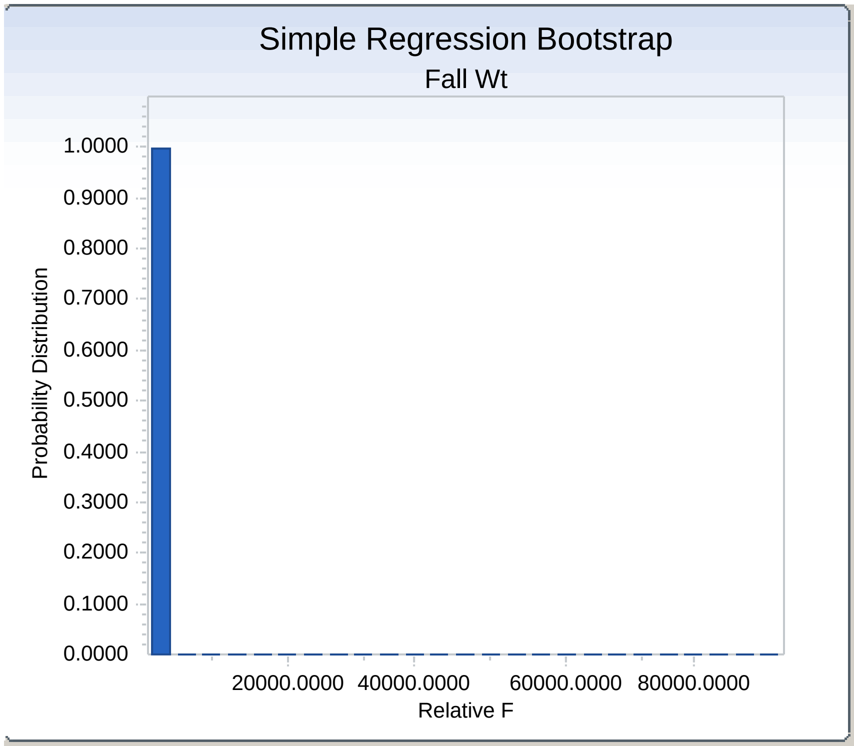


Figure C70. Six panel plot for northern red hake depicting trends in relative biomass, landings, relative fishing mortality and replacement ratios for the NEFSC springl survey index and landings based on catch method "Catch 3", 1980-2009. Horizontal dashed lines (---) represent replacement ratios in the top two panels and the replacement F in the lower right panel. Smooth lines represent Lowess smooths (tension =0.3). The confidence ellipse in the top left panel has a nominal probability level of 0.68. The regression line in the top left panel is a robust regression using bisquare downweighting of residuals.



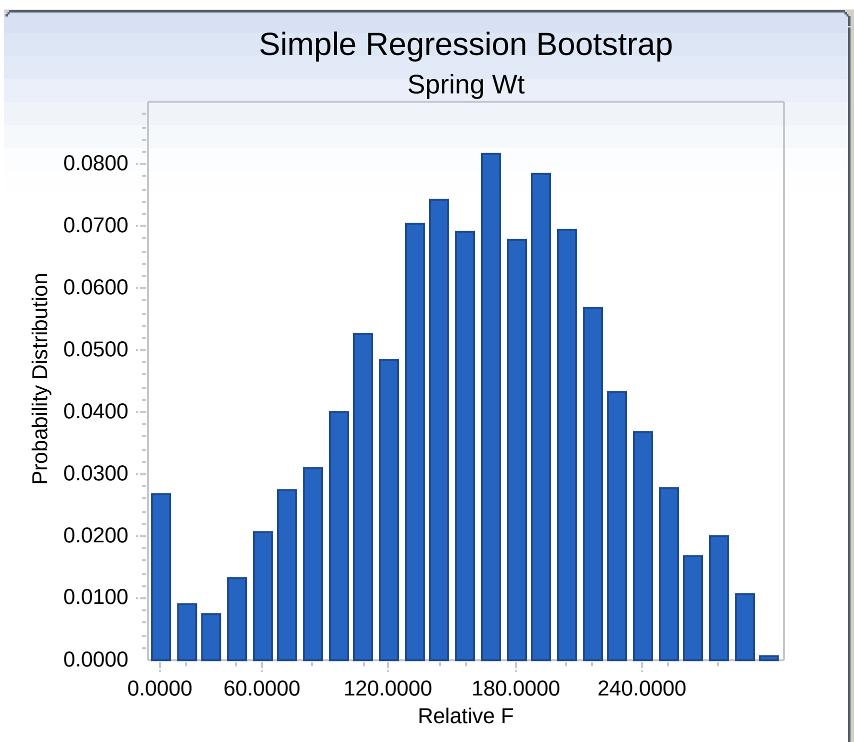


Figure C71. Randomization tests summary of sampling distribution of correlation coefficient between replacement ratio and relative F for fall (top) and spring (bottom) survey indices for northern red hake, using catch estimation method "Catch 3", 1980-2009.

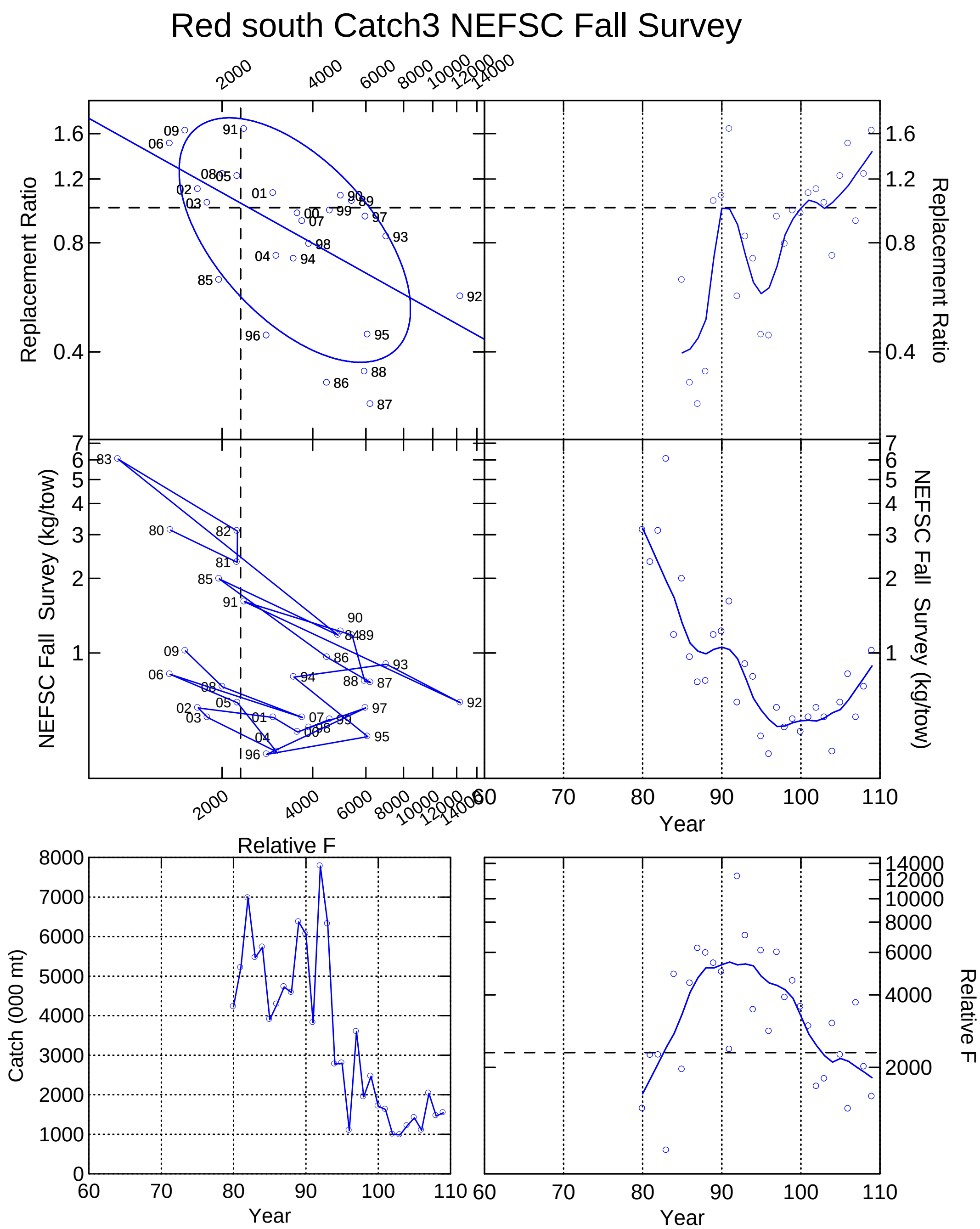


Figure C72. Six panel plot for southern red hake depicting trends in relative biomass, landings, relative fishing mortality and replacement ratios for the NEFSC fall survey index and landings based on catch method "Catch 3", 1980-2009. Horizontal dashed lines (---) represent replacement ratios in the top two panels and the replacement F in the lower right panel. Smooth lines represent Lowess smooths (tension =0.3). The confidence ellipse in the top left panel has a nominal probability level of 0.68. The regression line in the top left panel is a robust regression using bisquare downweighting of residuals.

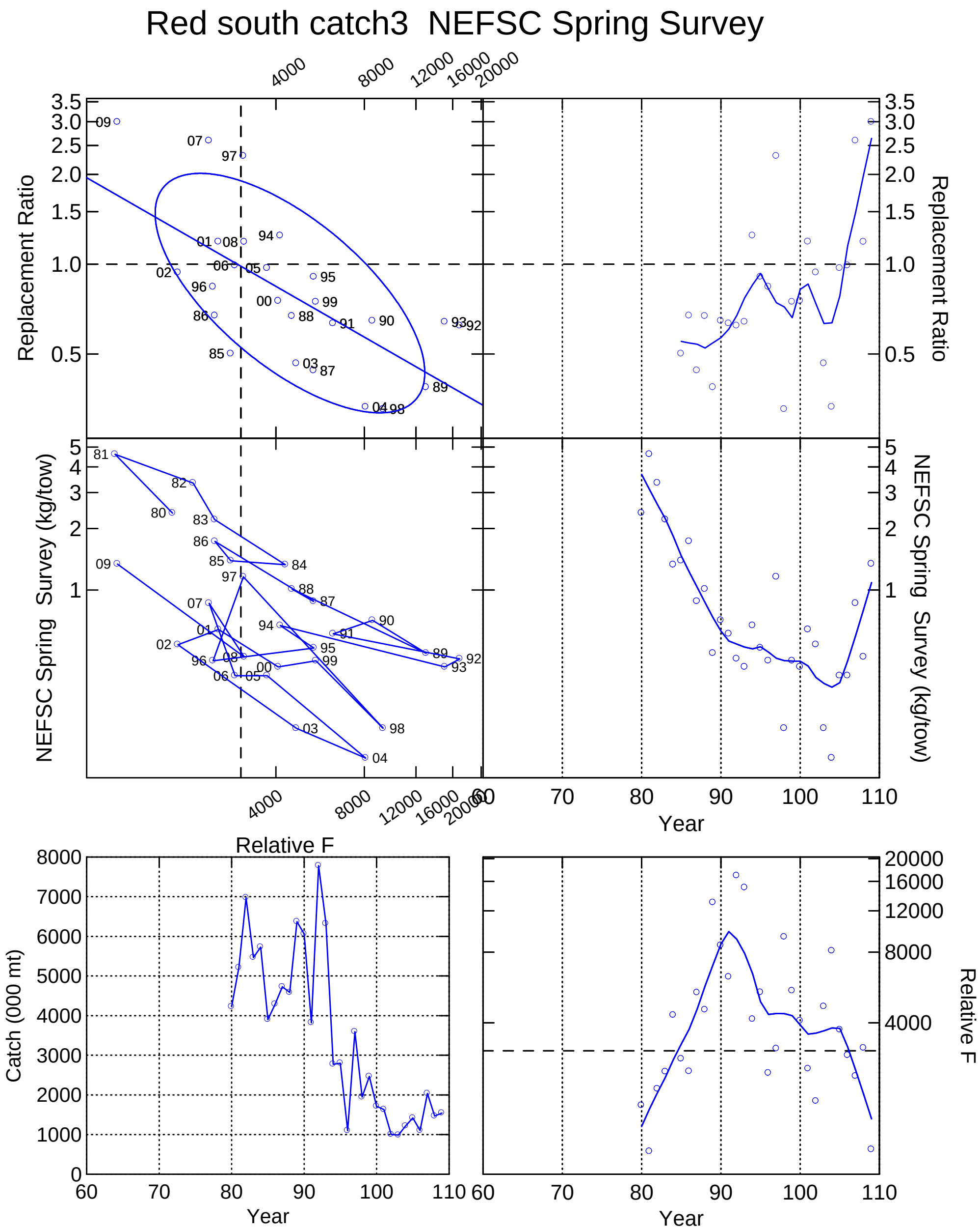
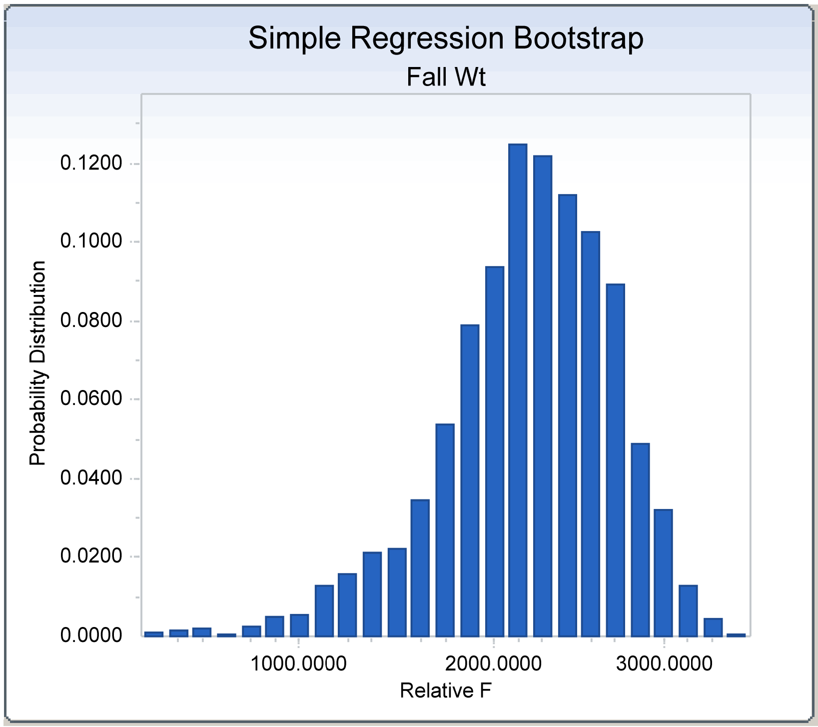


Figure C73. Six panel plot for southern red hake depicting trends in relative biomass, landings, relative fishing mortality and replacement ratios for the NEFSC spring survey index and landings based on catch method "Catch 3", 1980-2009. Horizontal dashed lines (---) represent replacement ratios in the top two panels and the replacement F in the lower right panel. Smooth lines represent Lowess smooths (tension =0.3). The confidence ellipse in the top left panel has a nominal probability level of 0.68. The regression line in the top left panel is a robust regression using bisquare downweighting of residuals.



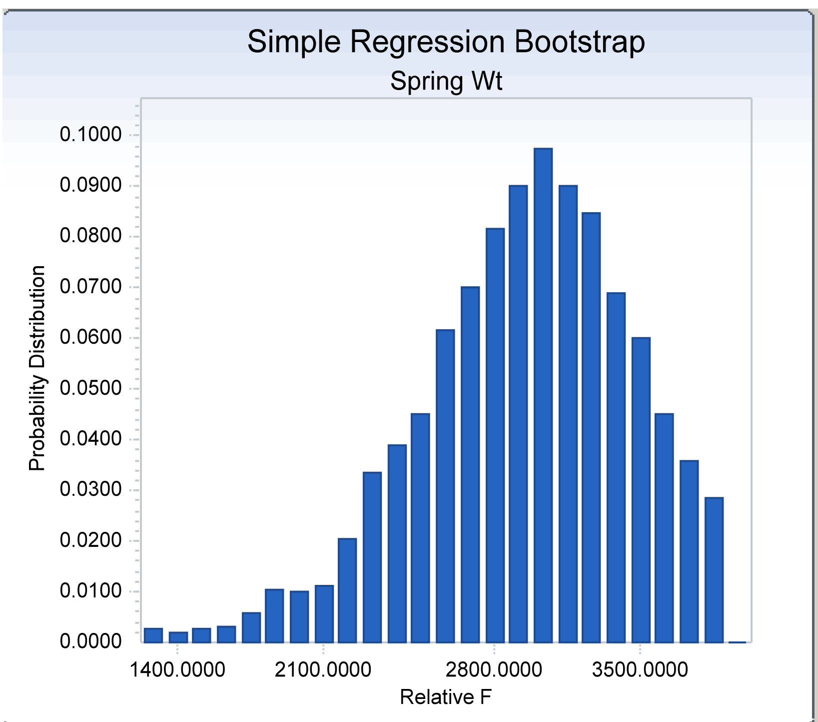


Figure C74. Randomization tests summary of sampling distribution of correlation coefficient between replacement ratio and relative F for fall (top) and spring (bottom) survey indices for southern red hake, using catch estimation method "Catch 3", 1980-2009.

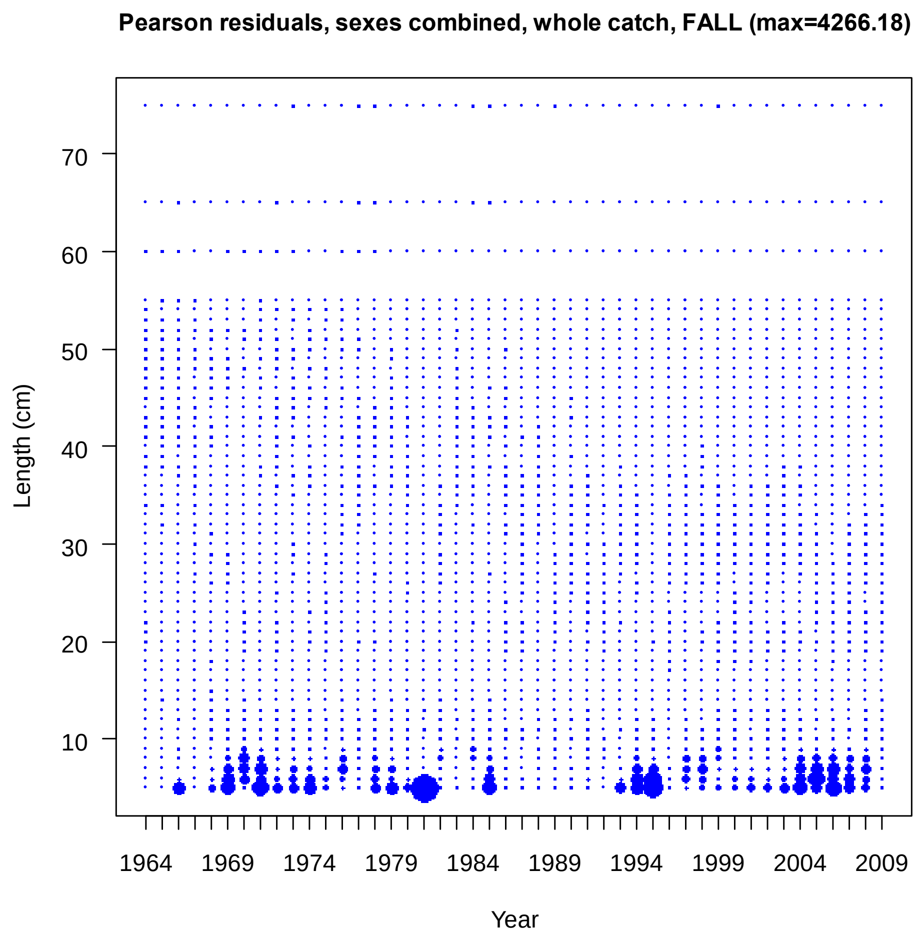


Figure C75. Residuals from SS3 run with the entire length composition for the fall survey.

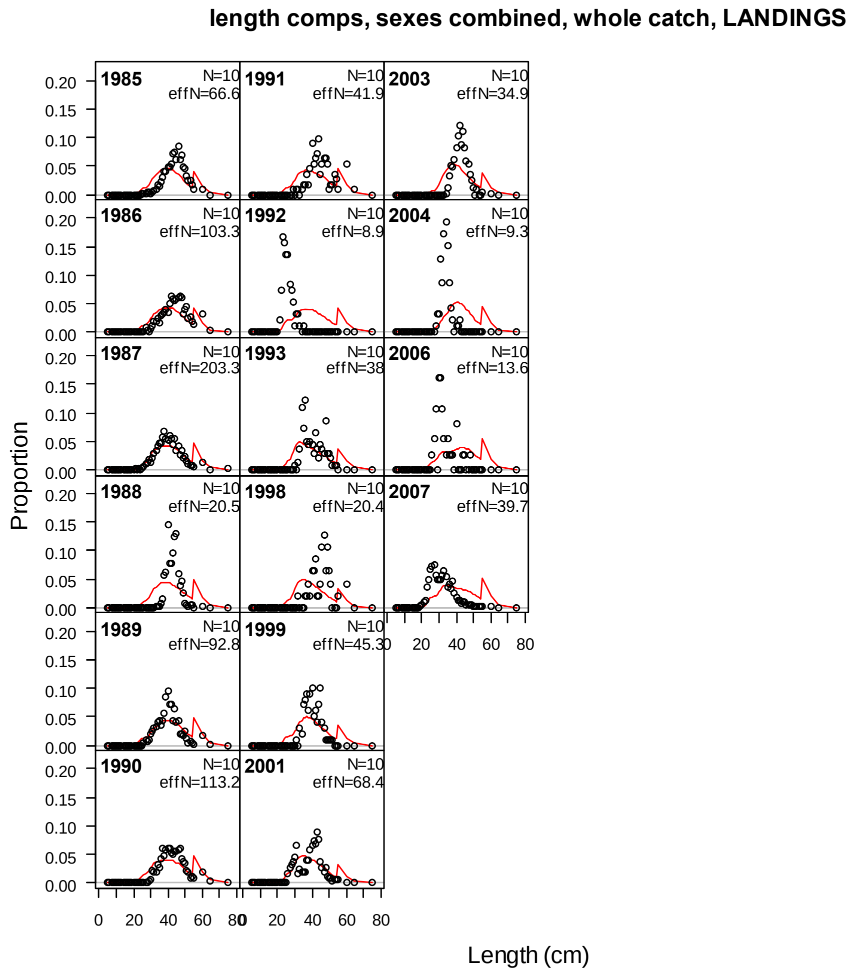


Figure C76. Fits to the length composition of the commercial landings with data pooled above 55 cm.

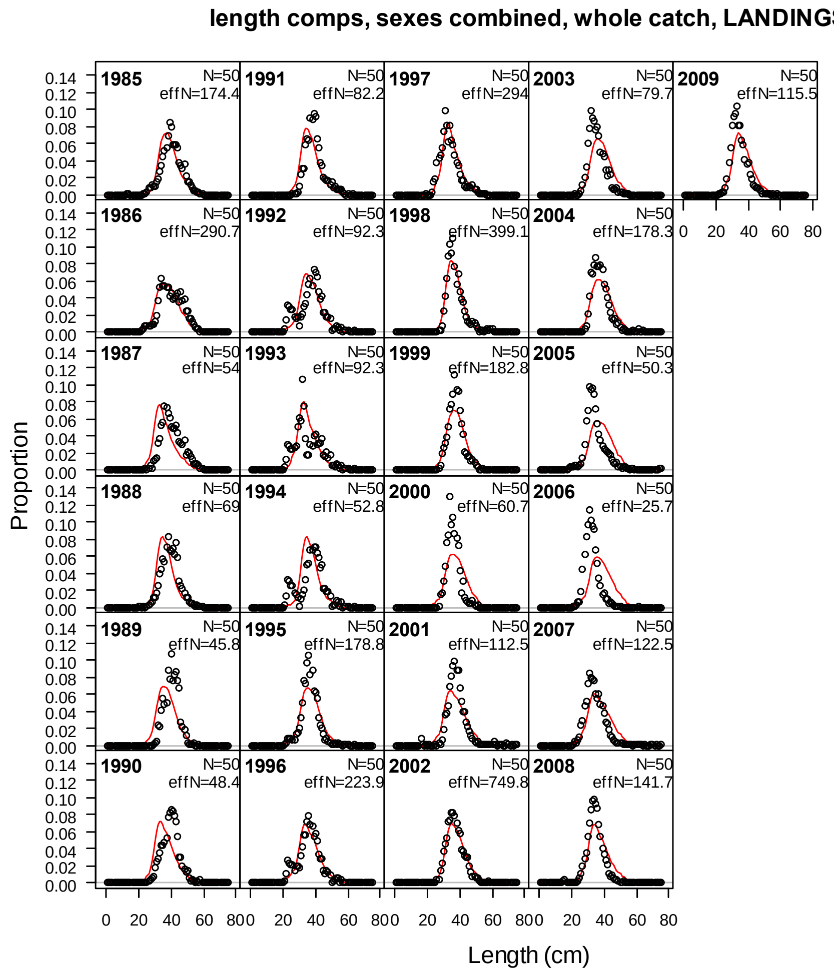


Figure C77. Fits to the length composition of the commercial landings data unpooled.

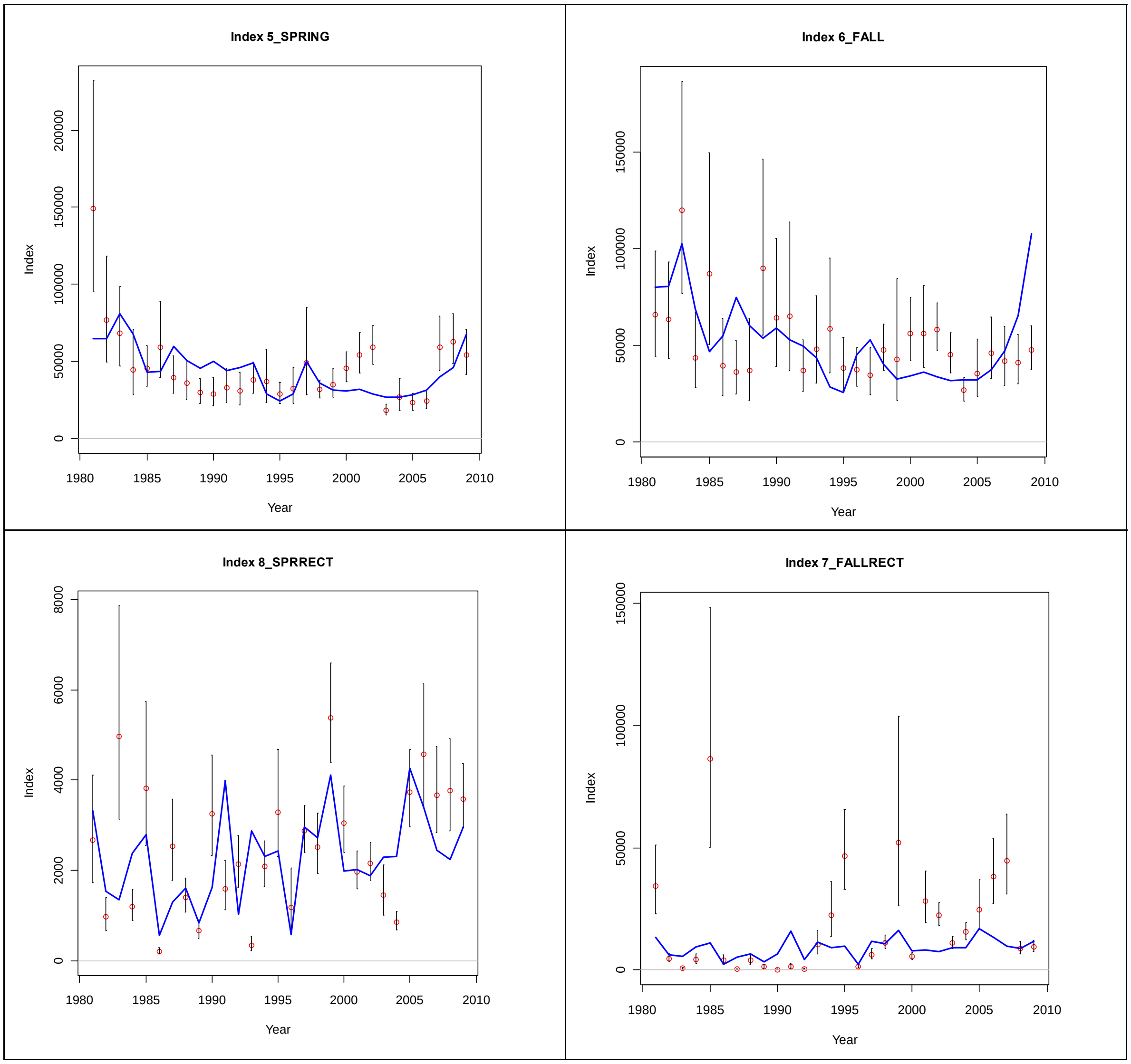


Figure C78. Fits to the survey indices from a final model run.

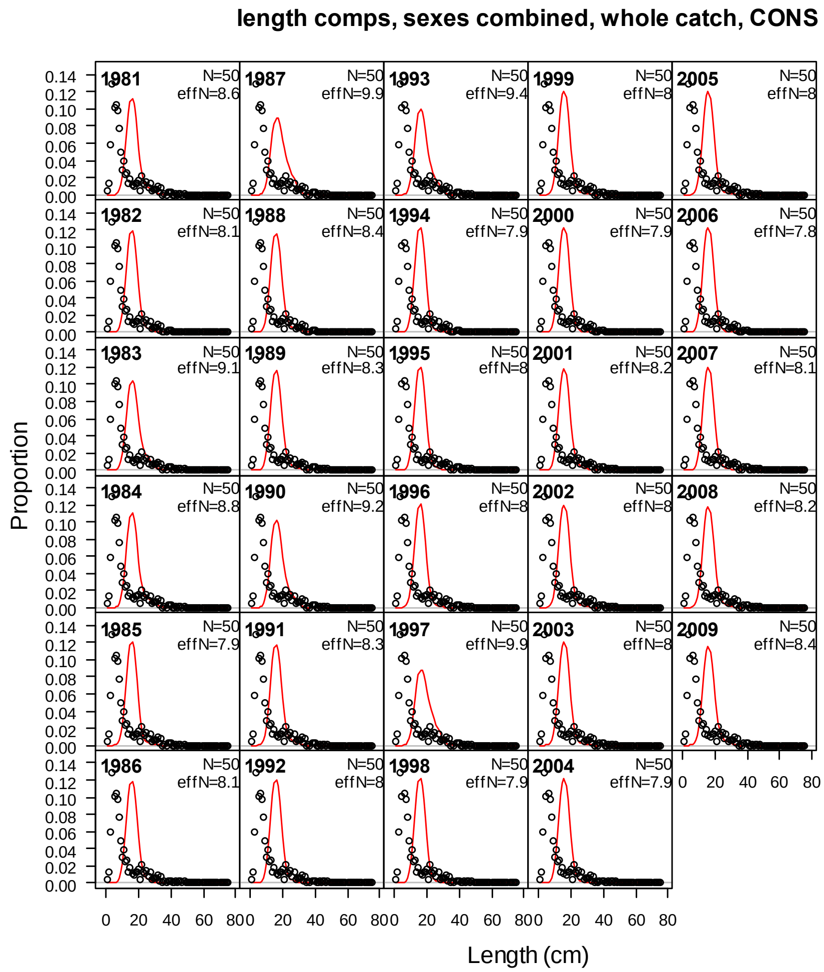
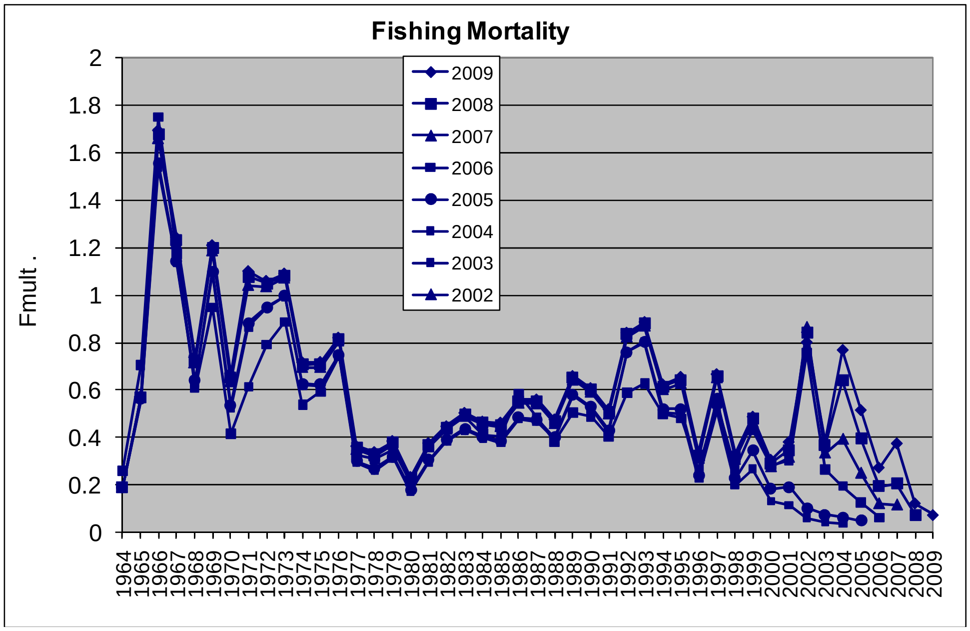


Figure C79. Fits to the length composition of the consumption.



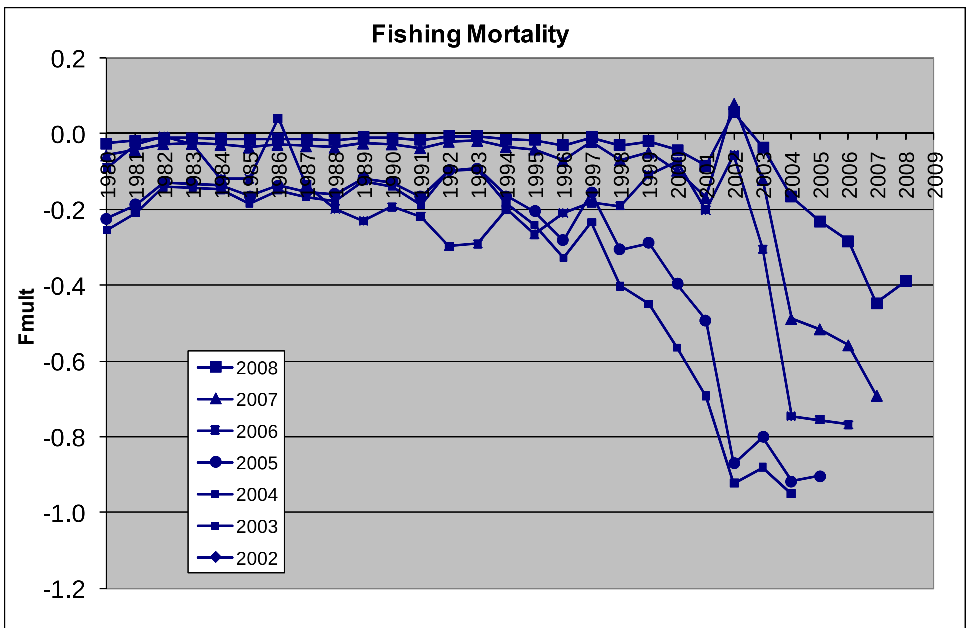
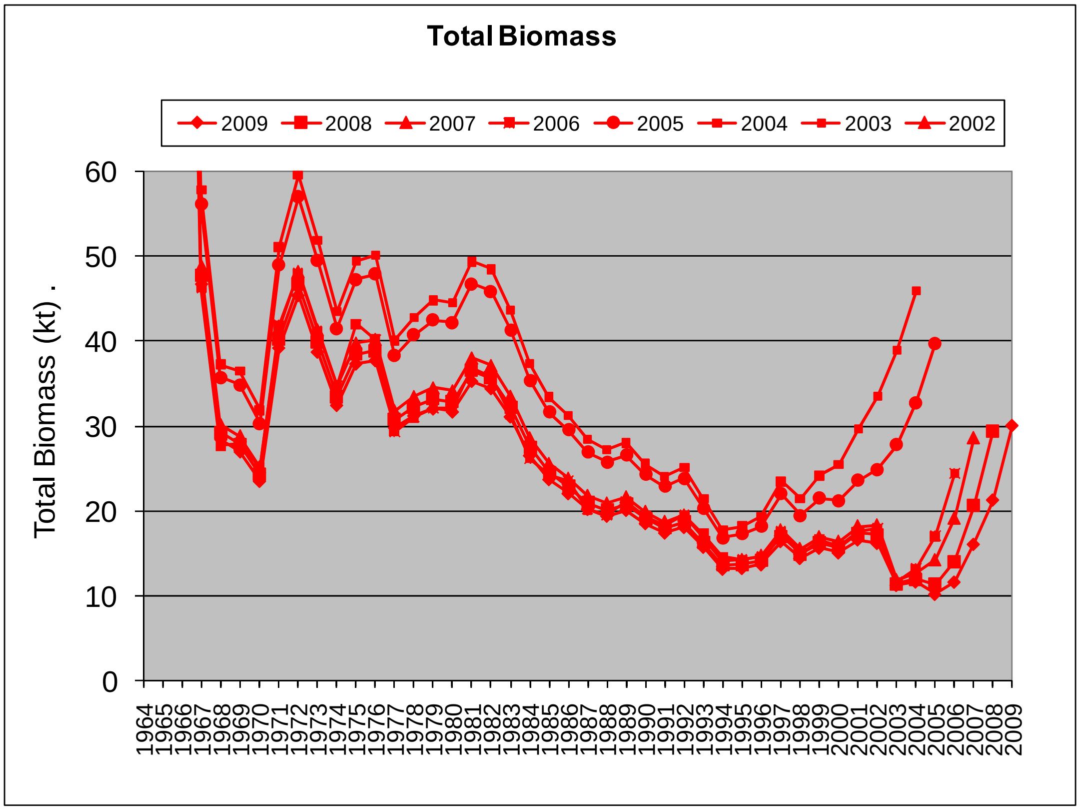


Figure C80a. Fishing mortality retrospective pattern of final SCALE model run.



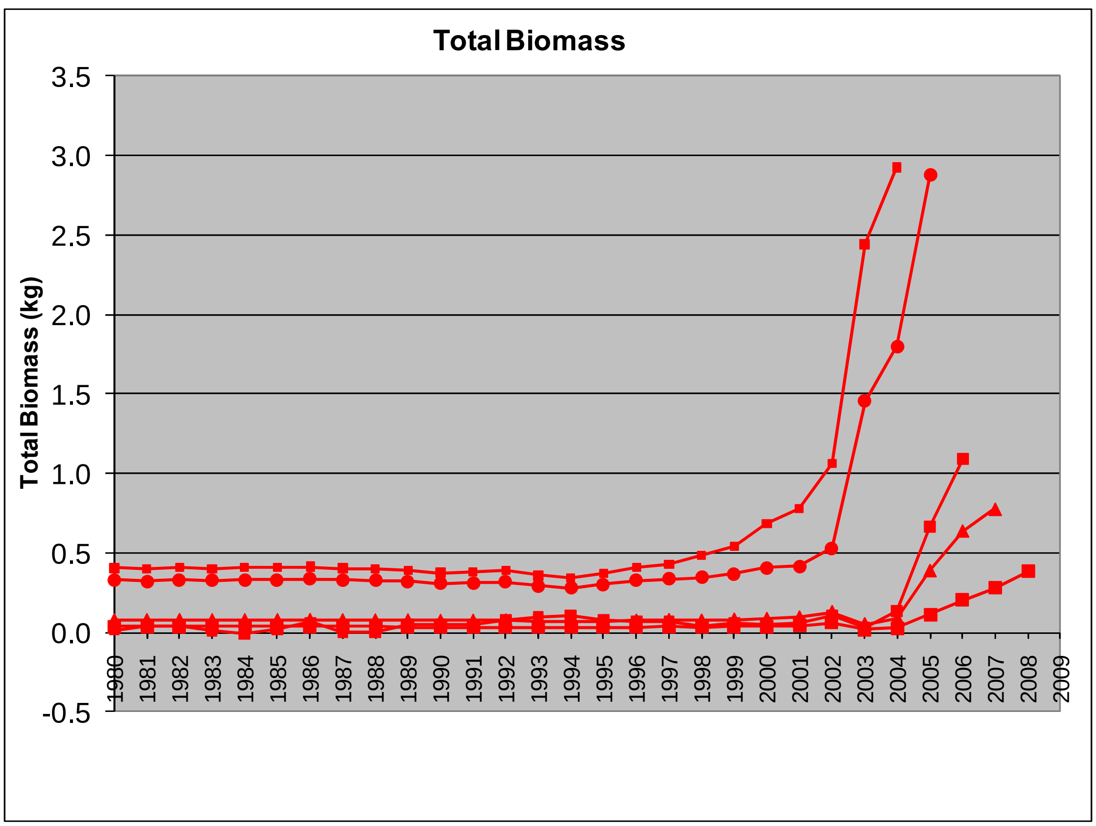
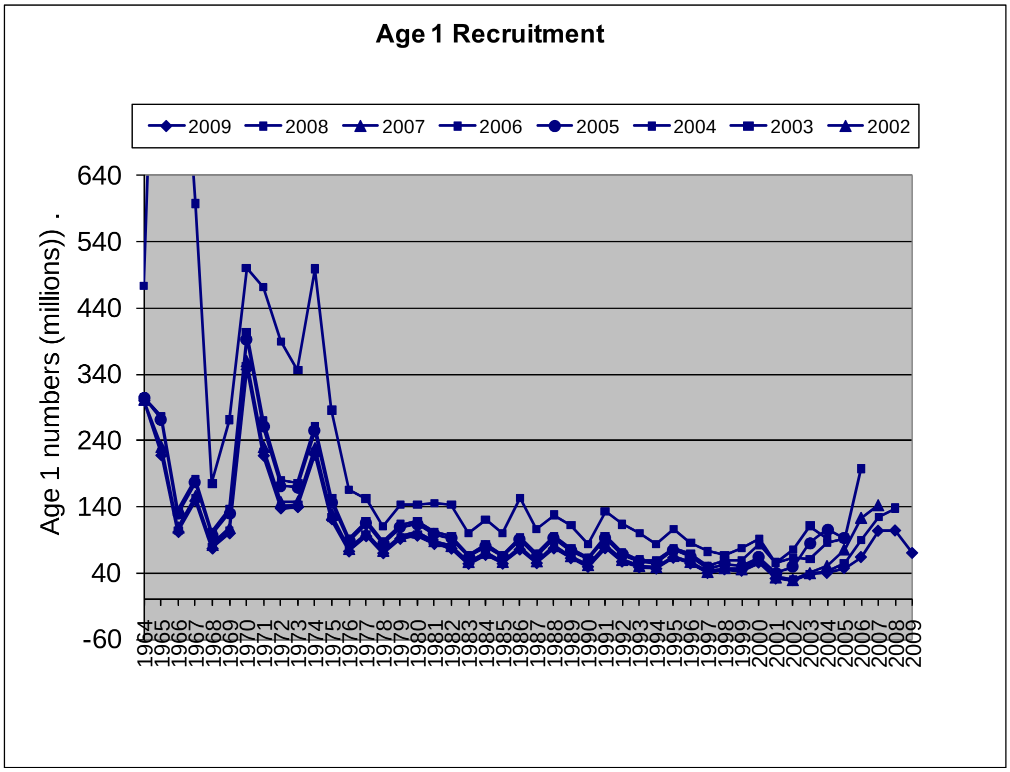


Figure C80b. Total biomass retrospective pattern of final SCALE model run.



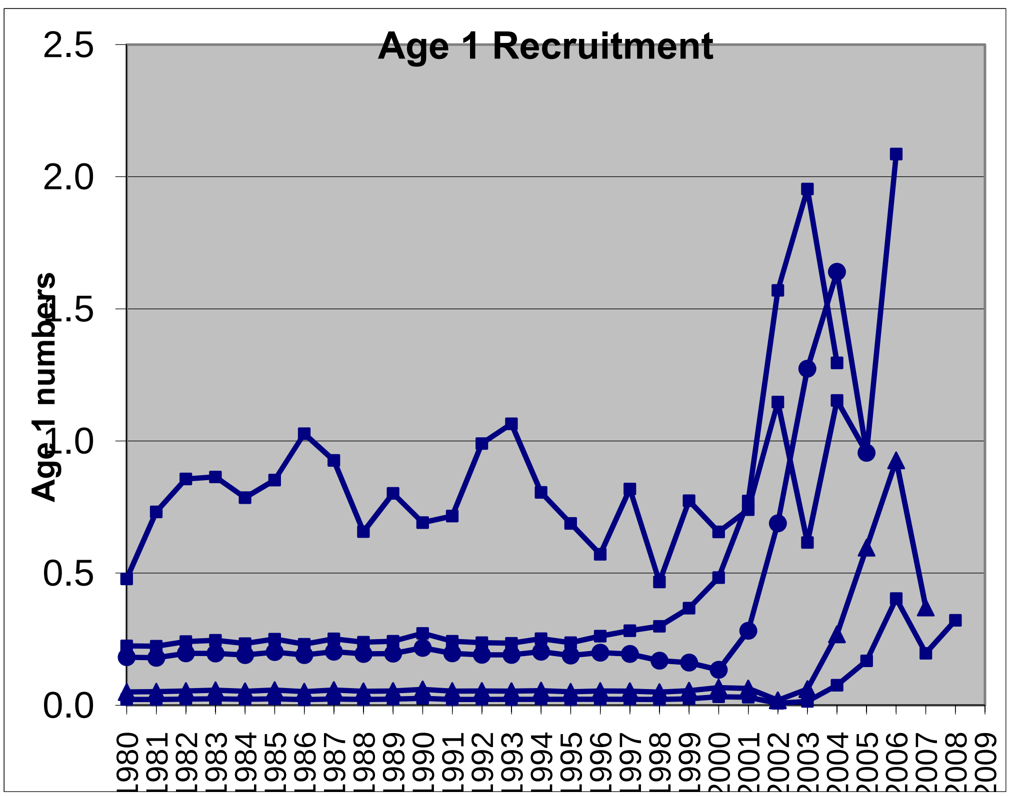


Figure C80c. Recruitment retrospective pattern of final SCALE model run.

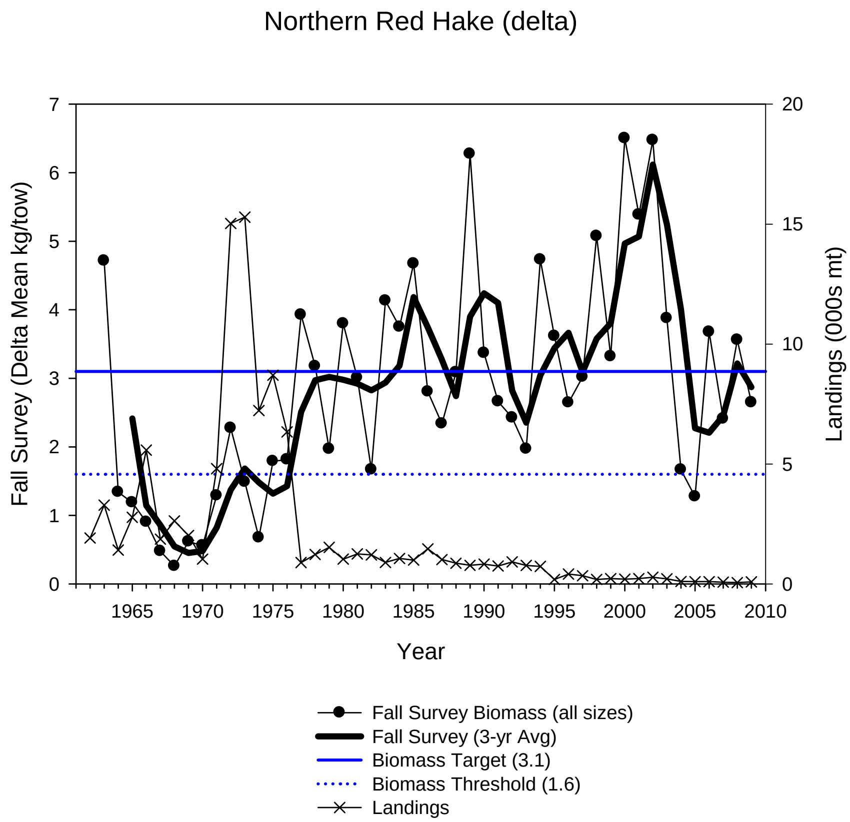


Figure C81. Fall survey biomass (delta transformation) and current BRPs (as opposed to "proposed" BRPs) for the northern stock of red hake.

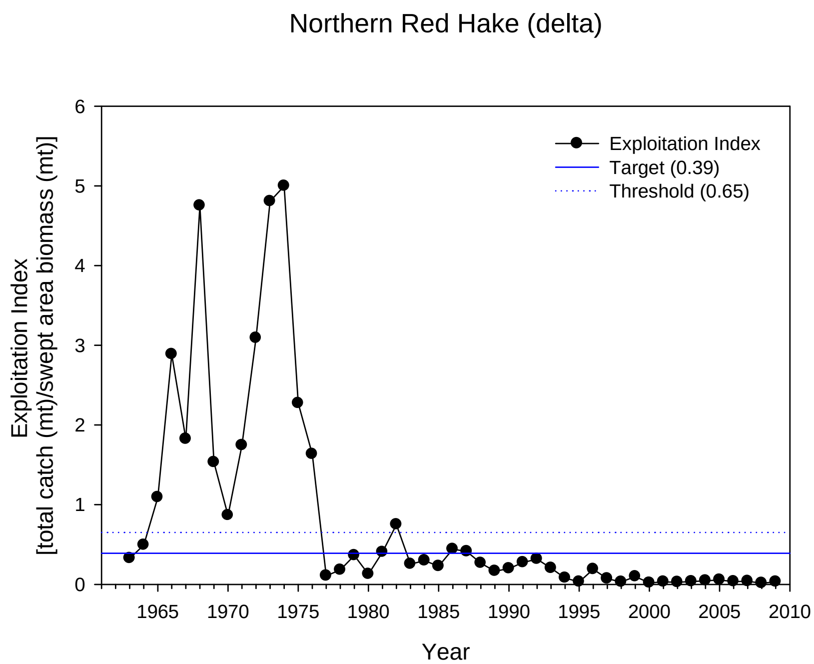


Figure C82. Exploitation Indices (delta transformation of fall survey) and current BRPs BRPs (as opposed to "proposed" BRPs) for the northern stock of red hake.

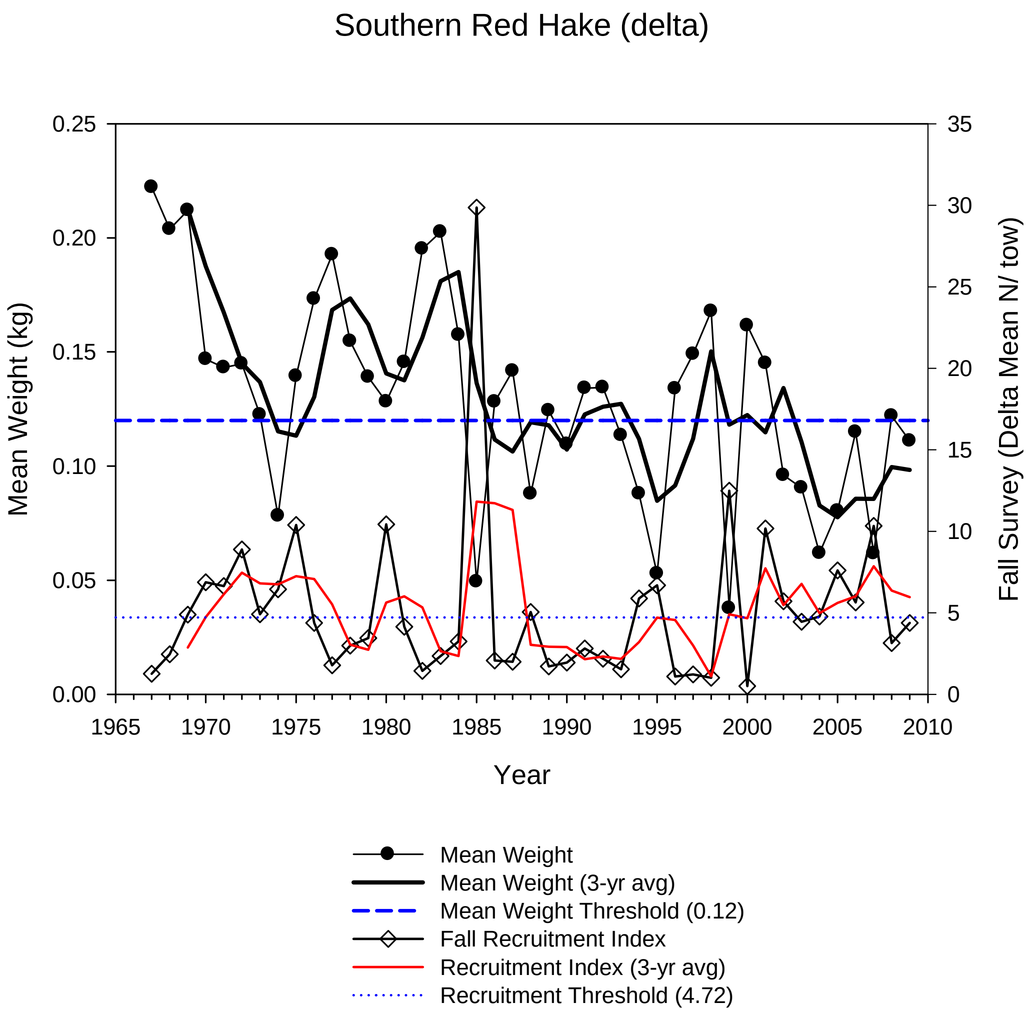


Figure C83. Mean individual weight (kg)/tow and recruitment index (Number of fish <25cm) from the NEFSC fall survey for the southern stock of red hake. Also shown are current BRP thresholds.

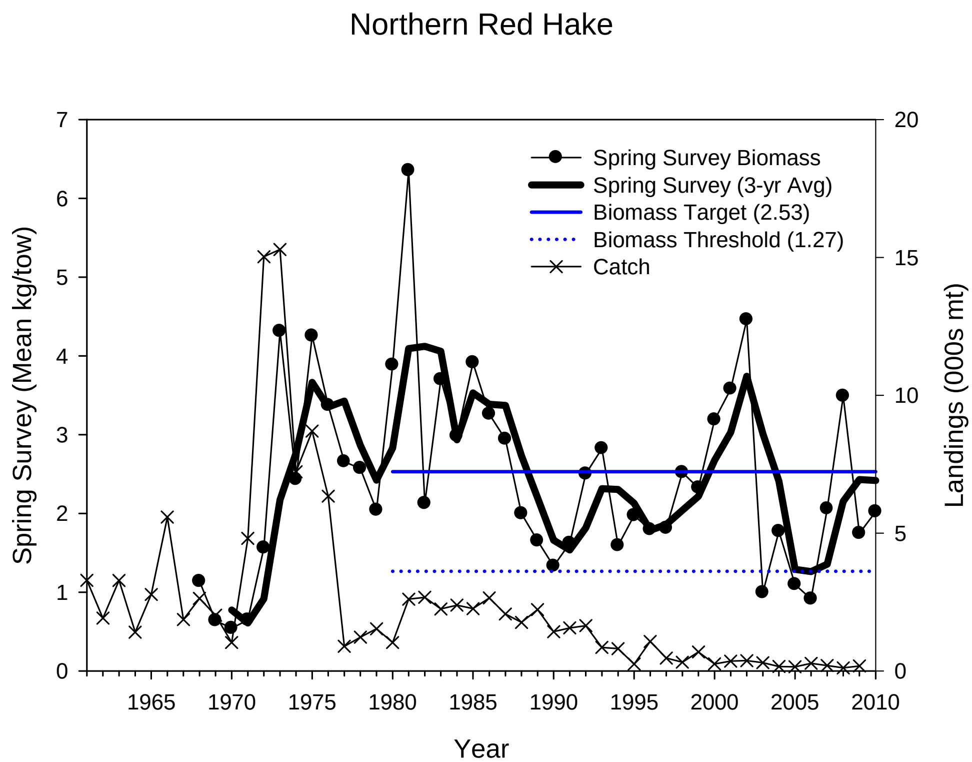


Figure C84. Spring survey biomass and newly proposed BRPs for the northern stock of red hake.

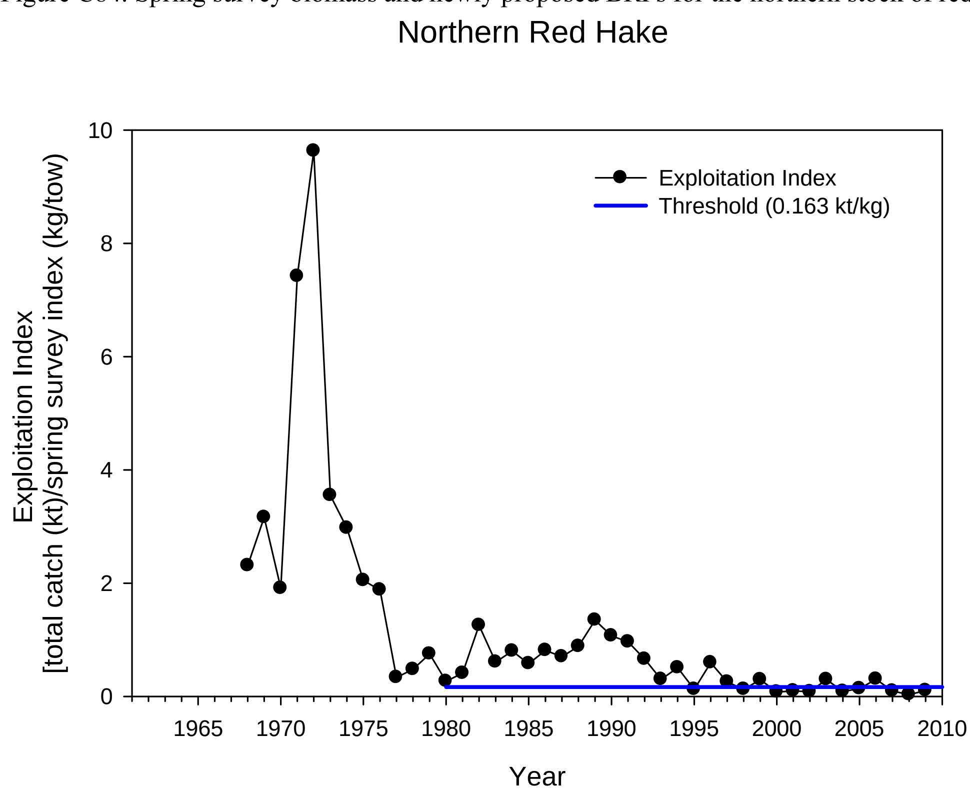


Figure C85. Exploitation indices (spring survey) and newly proposed overfishing threshold for the northern stock of red hake.

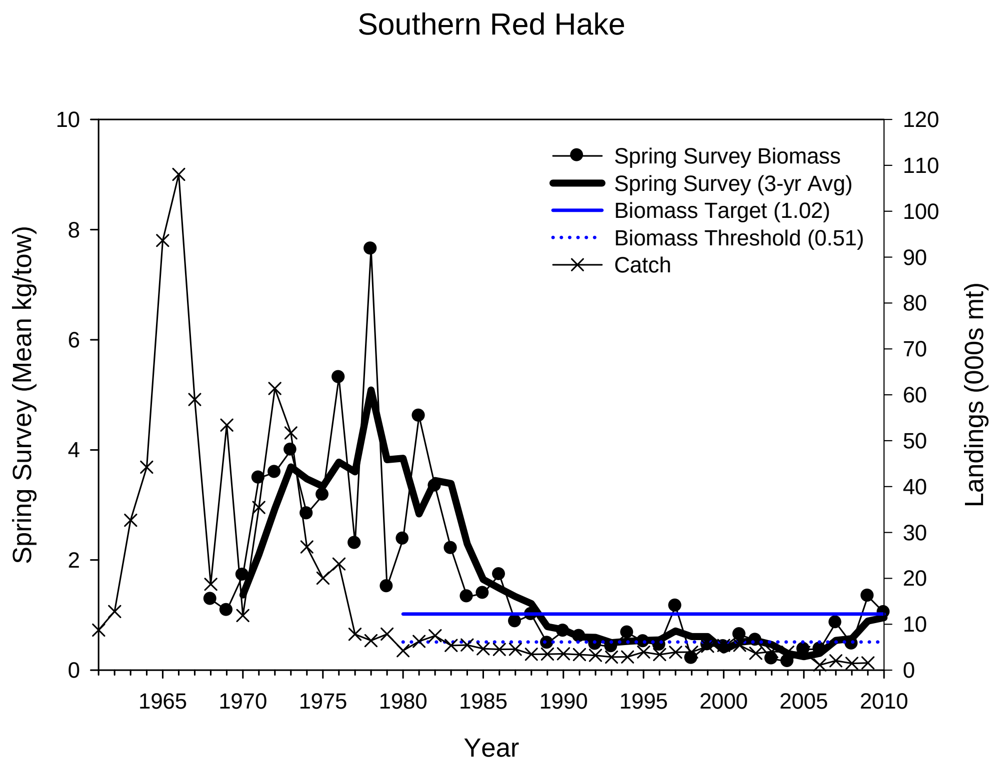
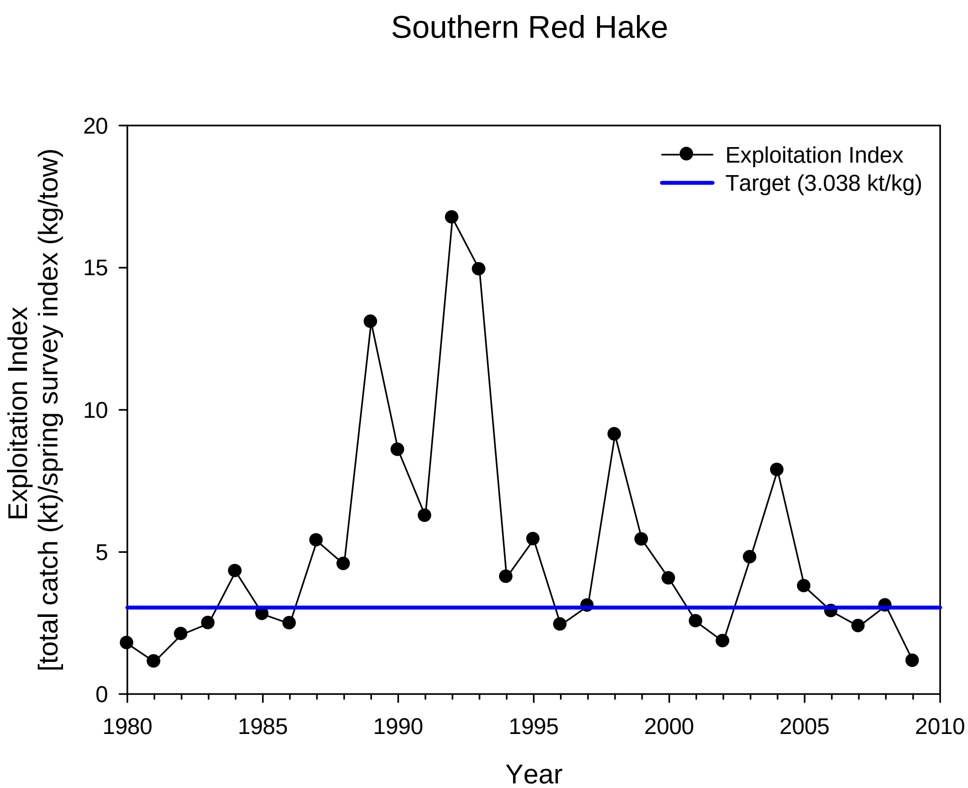


Figure C86. Spring survey biomass and newly proposed BRPs for the southern stock of red hake.



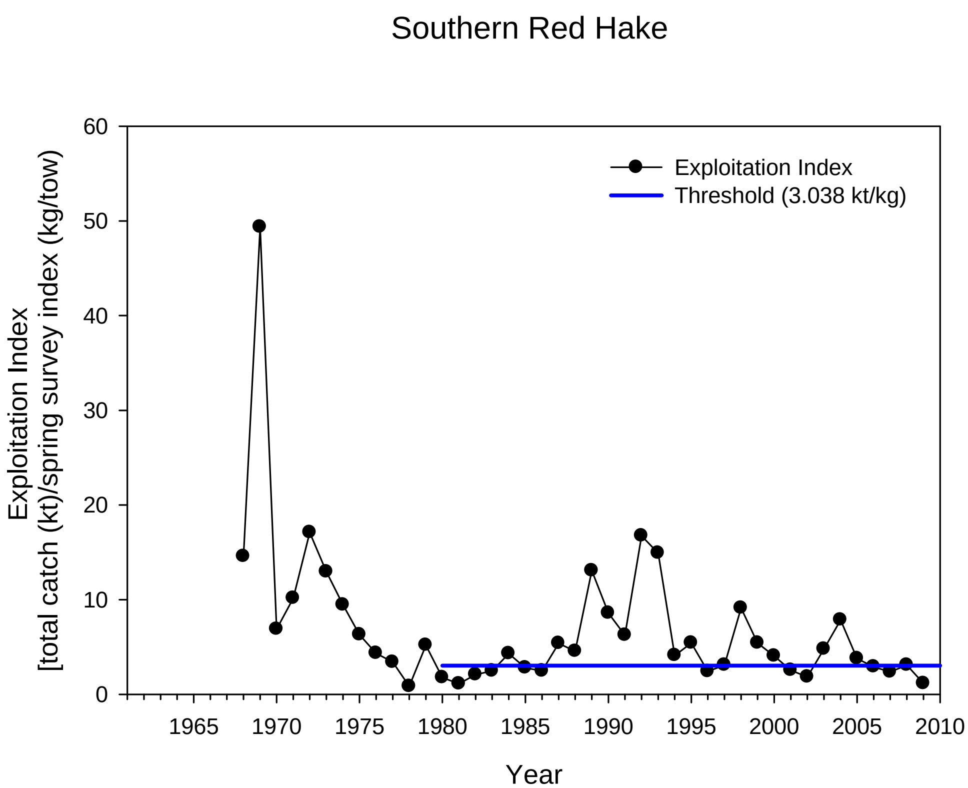


Figure C87. Exploitation indices (spring survey) and newly proposed overfishing threshold for the southern stock of red hake.