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ABSTRACT

Silver hake (*Merluccius bilinearis*) is a short-lived gadid that ranges from Newfoundland to South Carolina. This species is an important component of the food web in the northeast continental shelf ecosystem. In the U.S. EEZ, the silver hake population was intensively harvested by distant water fleets during the 1960s and 1970s with peak annual landings of over 300,000 mt. Since 1980, annual landings have remained stable at roughly 20,000 mt in what is now an entirely domestic fishery.

Two subpopulations of silver hake are assumed to exist within the US EEZ. For the purpose of assessment, the northern stock is assigned to areas of northern Georges Bank and the Gulf of Maine and the southern stock is assigned to areas of southern Georges Bank, southern New England, and the Mid-Atlantic Bight. While it is recognized that the northern and southern stocks mix on Georges Bank, the amount of mixing and movement among northern and southern areas are unknown.

Proxies for determining whether northern and southern silver hake are overfished were put forward in 1998 by a panel that reviewed overfishing definitions for northeast groundfish stocks. In 1999, the survey index for the northern stock was above its biomass target while the survey index for the southern stock was below its biomass threshold for SFA determination using the best available survey data. Therefore, the northern stock is considered not overfished while the southern stock is considered to be overfished.

An age-structured sequential population analysis was conducted for the entire silver hake population from Cape Hatteras to the Gulf of Maine using NEFSC autumn and spring numbers-at-age indices and time-varying survey catchability. Another set of population analyses were conducted for the northern stock, the southern stock, and the entire silver hake population using NEFSC autumn and spring biomass indices in a Bayesian surplus production model. In addition, analyses of research vessel survey indices were used to quantify biomass and exploitation rate.

The population dynamics of silver hake in the US EEZ have changed through time. In particular, patterns of growth and spatial distribution have changed substantially over the past 40 years. Age structure of the silver hake population appears to be truncated at about age-6 in recent years whereas historically, silver hake of age-6 and older were much more frequently observed. Older silver hake may be less vulnerable to the fishery and survey in recent years because their spatial distribution has changed. Alternatively, continued high fishing mortality rates may have precluded the rebuilding of age structure following the cessation of the foreign distant water fleet fishery. Survey data indicate that biomass in the northern stock area is high and that biomass in the southern stock area is low. For the combined stock area, biomass is likely near carrying capacity and harvest rates appear to be low.

INTRODUCTION

Silver hake (*Merluccius bilinearis*) is a short-lived gadid that ranges from Newfoundland to South Carolina. This species is an important component of the food web in the northeast continental shelf ecosystem (Sissenwine and Cohen 1991), and according to Bigelow and Schroeder (1953), "*Silver hake are strong swift swimmers, well armed and extremely voracious*". In the U.S. EEZ, the silver hake population was intensively harvested by distant water fleets during the 1960s and 1970s with peak annual landings of over 300,000 mt. Since 1980, annual landings have remained stable at roughly 20,000 mt in what is now an entirely domestic fishery. Silver hake was last assessed in 1993 at SAW 17. In that assessment, an age-structured analysis of the population in two stock areas was attempted, but results were not considered to be reliable. As a result, the previous assessment was index-based and current overfishing thresholds for silver hake are based on research survey information. The current assessment was undertaken for SAW 32 (2001), where stock assessments for sea scallops, American plaice, Gulf of Maine haddock, and silver hake were reviewed. An *Advisory Report on Stock Status* and a *Consensus Summary of Assessments* have been published in draft form as a result of that meeting (NEFSC 2001a, 2001b). This report is intended to serve as a detailed description of the assessment accepted and reviewed by the SAW.

STOCK STRUCTURE AND DISTRIBUTION

Two subpopulations of silver hake are assumed to exist within the US EEZ (Almeida 1987a). Analyses of morphometric characters (Conover et al. 1961, Almeida 1987a) are the primary basis for this delineation. Recent analyses of otolith microconstituent data are also consistent with the existence of two or more stocks (Bolles and Begg 2000). However, genetic analyses of population structure have been inconclusive (Schenk 1981). For the purpose of assessment, the northern stock is assigned to areas of northern Georges Bank and the Gulf of Maine and the southern stock is assigned to areas of southern Georges Bank, southern New England, and the Mid-Atlantic Bight (Figure 1 and Figure 2). These boundaries were established at SAW 11.

While it is likely that the northern and southern stocks mix on Georges Bank, the amount of mixing and movement among northern and southern areas are unknown (Almeida 1987a, Helser et al. 1995, Helser 1996). Silver hake spawn in the Gulf of Maine, southern New England, and on the southern flank of Georges Bank. Silver hake larvae entrained in the clockwise gyre of Georges Bank may settle in either the southern or northern stock areas (see Distribution of Eggs and Larvae below). As a result, reproductive isolation of the two stocks is unlikely. However, it is unknown to what extent the northern and southern stocks have independent demographic and genetic trajectories. If gene flow is high between northern and southern stocks, on the order of a few migrants per generation, genetic analyses may be of limited utility to separate the subpopulations in areas of mixing (Waples 1998).

Analyses of silver hake size-at-age data show that growth has varied in time and among areas. In particular, recent growth analyses (Helser 1996) indicate that there are consistent differences between silver hake growth in the Gulf of Maine and southern New England/Mid-Atlantic Bight areas. Helser also shows that growth patterns on Georges Bank and the Gulf of Maine were indistinguishable during 1988-1992 and that growth rate changes dynamically on Georges Bank. Growth analyses conducted for this assessment show that there are very minor differences in growth between northern and southern stock areas during the 1990s (see Growth below). In general, differences in silver hake growth between northerly and southerly areas can be expected if there is limited movement between areas based on differences in primary productivity and water temperature between the Gulf of Maine and the continental shelf areas of southern New England and Georges Bank.

The spatial distribution of silver hake has changed through time. Population density, as measured by the NEFSC fall bottom trawl survey has been increasing in northern stock areas (Gulf of Maine: offshore strata 24, 26-30, and 36-40, northern Georges Bank: offshore strata 20-23 and 25) since the late 1960s (Figure 3A). Density in southern stock areas has decreased (Figure 3B) since the 1960s in southern New England (offshore strata 1-12) and Mid-Atlantic Bight waters (offshore strata 61-76, note that 1963-1966 indices are based on average proportion during 1967-1999, see STOCK ABUNDANCE AND BIOMASS INDICES below) while density in southern Georges Bank waters (offshore strata 13-19) increased in the 1980s and subsequently decreased in the 1990s. In contrast, spring survey information on density is highly variable (Figure 4) and likely provides less information on trend in comparison to the fall survey.

In terms of the spatial distribution of total population biomass, there has been an increasing trend in the population biomass index in northern stock areas and a decrease in southern stock areas (Figure 5A). The total population biomass index has increased since the historic lows of the late 1960s, while the proportion of total biomass in the Gulf of Maine has increased from about 50% in the late 1960s to over 80% in the late 1990s (Figure 5B). In contrast, the proportion of total biomass in southern New England has decreased from about 40% in the late 1960s to about 10% in the late 1990s. As with the density data, the spring survey total biomass information is highly variable by stock area (Figure 6) and likely provides less information on trend in comparison to the fall survey. Overall, the Gulf of Maine has consistently had the highest density and proportion of biomass through time and this suggests that the Gulf of Maine is the best habitat for silver hake among northern and southern stock areas.

Changes in oceanographic conditions of shelf waters have likely affected silver hake distribution. Near-bottom water temperatures, as indexed during the NEFSC fall and spring bottom trawl surveys, in the northern and southern stock areas (Figure 7) show that the 1960s was a relatively cool time period and also show that temperatures have increased in recent years. In particular, water temperatures on northern and southern Georges Bank have slowly increased through time, relative to the Gulf of Maine. The ratio of population density of silver hake to temperature has also changed in both northern and southern stock areas (Figure 8). Density per degree has increased in northern areas (Figure 8A,C) and decreased in southern areas (Figure 8B,D). Overall, changes in temperature may have altered the spatial distribution of the two stock components.

Changes in broad-scale oceanographic conditions may also have affected silver hake distribution. NEFSC bottom trawl survey data collected during fall, winter, and spring (Figure 9) show that a portion of the population is consistently present in deeper waters of the upper continental slope at depths of 100-300 m. This depth range represents the boundary of the NEFSC bottom trawl surveys ,which are primarily designed to sample continental shelf waters. Near the shelf/slope break, warm slope waters impinge upon the upper continental slope and provide year-round habitat for silver hake. In fact, the USSR fishery for silver hake documented this feature of silver hake distribution in the 1960s (Figure 10). The association of a fraction of the silver hake population with slope waters suggests that changes in the slope water mass between the Gulf Stream and the continental shelf water probably affects the offshore distribution of silver hake. In particular, changes in the position of the shelf/slope front (Drinkwater et al. 2000) and Gulf Stream position alter slope water characteristics and may influence silver hake distribution in deeper water at the shelf/slope break. One broad-scale feature that has been correlated with changes in Gulf Stream position is the North Atlantic Oscillation (NAO) index (Jones et al. 1997, Taylor and Stephens 1998). The NAO index has trended up sharply since the 1960s (Figure 11) and this trend may have affected the amount of habitat available to silver hake in offshore waters of the upper continental slope.

In summary, four additional pieces of information on silver hake stock structure have been examined for this assessment. First, the density and proportion of population biomass has decreased in the southern area and increased in the northern area. Second, growth patterns have changed through time and have been similar in northern and southern areas during the 1990s. Third, ichthyoplankton data show that silver hake eggs are continuously distributed over Georges Bank. Fourth, changes in oceanographic conditions over the past 40 years may have influenced the spatial distribution of stock components.

THE FISHERY

The silver hake fishery has changed through time from an inshore fishery prosecuted with pound and trap nets to an otter trawl fishery (Fritz 1960). During the 1960s, landings of silver hake increased substantially (Table 1 and Figure 12). Most of the increase in harvest was due to directed fishing for silver hake by the distant water fleet of the former USSR. During the 1980s and 1990s, total silver hake landings have remained low in comparison to historic yields.

Recreational Fishery

Silver hake once supported a recreational fishery in the Mid-Atlantic Bight (Fritz 1960) with annual landings of around 1,000 mt (2.2 million pounds) in the southern stock area. Recreational fishery landings decreased substantially in the 1970s and 1980s and are currently very low. Recreational landings of silver hake collected by MRFSS have averaged only 18,000 fish per year during 1995-1999.

Commercial Fishery

Directed commercial fishing for silver hake began in the 1920s. The domestic commercial fishery has been relatively stable since the late 1970s. Market demand for silver hake does not appear to have changed much over the past two decades, and landings have remained at roughly 15,000 to 20,000 mt per year.

Commercial Landings

Commercial landings of silver hake during 1993-1999 were collected from the NEFSC weigh-out database. During 1994-1999, the area where silver hake were captured was not recorded for many trips in the weigh-out database due to changes in the reporting system for fishery statistics. As a result, the unknown-area landings were prorated to the northern and southern stock areas based on fishing location information stored in the vessel-trip reporting database (e.g., fishery logbook data). These prorated landings by stock area for 1994-1999 are considered to be provisional until a final evaluation of the fishery logbook data has been completed.

Silver hake are landed in three commercial market categories: small, large, and unclassified. The vast majority of landings are reported as unclassified (Table 2).

Sampling Intensity

The adequacy of length frequency sampling of commercial silver hake landings has varied during 1993-1999 (Table 3). Sampling has generally been adequate for the unclassified market category but has been poor for the large and small market categories in several years. Sampling in the northern stock area has generally been lower than in the southern area (Figure 13). Most commercial fishery length samples collected in port during 1994-1996 had an unknown stock area in the commercial fishery length database (Figure 13). These unknown-area samples were assigned to northern and southern stock areas by identifying each sample with the corresponding vessel trip in the fishery logbook database, wherever possible.

The length samples by market category were evaluated for use in constructing commercial fishery catch at age during 1993-1999. Mean lengths of commercial fishery length samples from the 1st and 2nd half of the year were generally similar for the southern stock (Table 3). Few comparisons between 1st and 2nd half samples were possible in the north but the available data suggested that mean lengths were similar within a market category during the year. As a result, length frequency data from the 1st and 2nd half of each year were combined by market category. Similarly, comparisons of mean lengths of unclassified samples from northern and southern stock areas suggested that there was no practical difference between unclassified silver hake from the two areas. For the small and large market categories, there were few data for comparison and it was inconclusive whether differences existed for these minor categories. Because northern and southern samples were similar for the predominant unclassified category, commercial length frequency samples from the two stock areas were combined by market category to derive the length frequency of the landings.

Sampling intensities (1 sample consists of 100 fish lengths) for annual landings combined by half-year and stock area for small, unclassified, and large categories were: 623, 487, and 275 mt per sample in 1993; 377, 234, and 352 mt per sample in 1994; 371, 376, and 146 mt per sample in 1995; 306, 709, and 453 mt per sample in 1996; 215, 277, and 57 mt per sample in 1997; 238, 177, and 90 mt per sample in 1998; 163, 224, and 79 mt per sample in 1999 (Tables 2 and 3). Overall, sampling intensities for the silver hake fishery have improved in the last couple of years.

Length distributions of commercial fishery landings were computed as a catch-weighted average of the length distributions by market category (Figure14). Mean length of commercial landings ranged from a high of 31 cm in 1995 to a low of 28 cm in 1999 and averaged 29 cm during 1993-1999.

Commercial Landings at Age

Commercial landings at age data for 1955-1992 were based on the previous silver hake assessment (NEFSC 1994). Commercial landings at age during 1993-1999 were derived from commercial length frequency data, research survey age-length keys, and length-weight relationships derived from research survey data. Commercial length frequency distributions were derived from market category samples as described above. The silver hake age-length key for each year was calculated as the average of the age-length keys from the spring and fall NEFSC bottom trawl surveys during each year because no commercial fishery age data are available for silver hake. The length-weight relationship for each year was calculated as the average of the length-weight relationships from the spring and fall NEFSC bottom trawl surveys. The spring survey age-length keys were not available for 1998-1999 and the age-length keys in 1998 and 1999 were derived from the spring 1997 age-length key and the fall age-length key for that year.

Commercial landings at age have varied substantially through time (Table 4 and Figure 15). During 1955-1959, roughly 300 million silver hake were landed each year. Landings peaked at an average over 1 billion silver hake per year in the late 1960s. Landings of silver hake have decreased since then and now average roughly 85 million fish per year, less than one-tenth of the peak value. The age composition of silver hake landings has also changed substantially through time. In the late 1950s to 1960s, age-4 and older silver hake comprised almost half of the landed catch. In contrast, during the 1990s, age-4 and older silver hake account for less than 20% of the landed catch. Similarly, age-6 and older silver hake accounted for 5% or more of the landed catch during 1955-1974, but these age classes were very rare in the sampled catch during the 1990s.

Bycatch and Discards

Bycatch and discard of silver hake occurs in directed and non-directed fisheries. Several sources of information were used to examine patterns of discarding. These were weigh-out interview data for 1983-1993, sea sampling data for 1989-1999, and fishing vessel logbook data for 1994-1999. Data on discarding patterns prior to 1983 were very limited and no estimates of the magnitude of discarding were attempted for this assessment.

Weigh-out interview data were screened to include only trips that were also recorded in the commercial weigh-out database. This was done to ensure that ratios of discarded catch weight to kept catch were accurate. The weigh-out interview data for otter trawl fishing operations indicated that discard to kept ratios ranged from 10% to 80% during 1983-1993. Based on the interview data, the average discard to kept ratio was roughly 30%.

Sea sampling data collected during 1989-1999 showed that discarding of silver hake captured by otter trawls occurred throughout the northern and southern stock areas (Figure 16). Discarding of silver hake by scallop dredges also occurred in both northern and southern stock areas (Figure 17) while discarding by sink gill nets occurred primarily in the northern stock area (Figure 18). Discard to kept ratios by weight, summarized by year, quarter, gear-type, and stock area (Table 5), varied through time and ranged from 0% to over 100% for the directed silver hake fishery (small mesh otter trawl, codend mesh 3" or less) and for the non-directed fisheries (large mesh otter trawl, shrimp trawl, sink gill net, and scallop dredge). Overall, it is unknown whether the variability in the discard ratios was due to non-random coverage of the fleet, small sample sizes, or inherent variation in discard rates and practices.

Fishery logbook data collected during 1994-1999 also show that silver hake discarding practices varied through time and differed between directed and non-directed fisheries. Discard to kept ratios in the logbook data, summarized by year, quarter, gear-type, and stock area (Table 6) represent a fraction of all fishing operations and range from 0% to over 100%. For scallop dredges, there were no records of discarding although some silver hake are discarded in the sea scallop fishery.

STOCK ABUNDANCE AND BIOMASS INDICES

Research Survey Indices

Research survey indices for relative biomass and population numbers at age were recomputed for the combined stock area using NEFSC spring and fall survey data. This was done for three reasons: (i) to improve the precision of the southern area indices, (ii) to ensure that the southern area was consistently sampled through time, and (iii) to correct a minor error in the value of the 1992 autumn biomass index for the southern stock. First, to improve precision of the southern area indices, the delta-distribution was used to compute southern area abundance indices (stratified mean kg or numbers/tow). In general, use of the delta-distribution gives higher precision than use of the arithmetic mean (see Pennington 1986). In the previous assessment, stratified means were based on the delta-distribution for the northern stock and were based on the arithmetic mean for the southern stock. Second, to ensure that the southern area was consistently sampled through time (1963-1999), inshore survey strata were excluded from the southern survey index calculations. This was done because inshore survey strata were not sampled until 1972. As a result, southern silver hake indices from the 1963-1971 period were not directly comparable to indices from 1973-present because different geographic areas were surveyed. In addition, the inshore survey strata were sampled using a different vessel (R/V Atlantic Twin) with different survey gear during 1972-1974 compared to the 1975-1999 period when the R/V Albatross IV and R/V Delaware II were used. These inconsistencies were resolved by excluding inshore survey strata for the southern area in the current assessment. It should be noted that inshore survey strata contain a very small proportion of silver hake biomass in the southern area (<0.01% in all years). Third, the 1992 autumn survey biomass index was reported as 0.72 in the previous assessment while the correct value, using the arithmetic average, was 0.85. Overall, these improvements altered the survey time series for the southern area but did not affect the northern area time series.

The recomputation of the autumn survey indices also altered the values of the survey biomass threshold and survey biomass target for the southern stock. According to the overfishing definition for the southern stock, the survey biomass target for the southern stock is computed as one-half of the arithmetic average of the NEFSC autumn survey biomass indices (kg/tow) during 1973-1982. Under this definition, the survey biomass threshold for the southern stock changed from 0.78 kg/tow, using data from the previous assessment (see Table B5 in NEFSC 1994 [SARC 17]), to 0.89 kg/tow using data from the current assessment (see Table 7). Coincidentally, the 1999 biomass index for overfishing status determination in the southern stock (computed as three-year average of the 1997-1999 biomass indices in Table 7), as recomputed in this assessment, was 0.78 kg/tow (see Table 14). It is important to note that the 1999 biomass index (0.78) must be compared to the revised survey biomass threshold (0.89) to be logically consistent. Similarly, the survey biomass target for the southern stock changed from 1.56 kg/tow based on data from the previous assessment to 1.78 kg/tow using the current data.

No attempt was made to adjust survey data for possible day-night variation in silver hake distribution in the water column. Although day-night differences in catchability might be expected for this species (Bowman and Bowman 1980), the NEFSC surveys operate continuously through day and night and no systematic bias would be expected since allocation of a tow location to day or night is random. On the other hand, use of survey catch information from day and night time periods can be expected to increase the variability of calculated indices.

During 1963-1966, survey strata in the Mid-Atlantic Bight (offshore strata 61-76) were not sampled. To calculate the survey biomass time series of the southern stock for 1963-1966, it was assumed that the proportion of total silver hake biomass in the Mid-Atlantic Bight during these years was equal to the long-term average of 1.8%. Given this assumption, the fall biomass index for the southern area was extended to 1963-1966. This was important for population modeling because the largest silver hake catches occurred during the 1963-1966 period.

Biomass indices for northern and southern stock areas show differing trends (Table 7). Biomass indices for the northern stock area show an increasing trend while biomass indices for the southern stock area show a decreasing trend (Figure 19). Biomass indices for the combined stock area show an increasing trend in the fall (Figure 20) and vary without trend in the spring.

Numbers-at-age indices from the NEFSC spring and fall bottom trawl surveys were computed for the combined stock area using all available age-length data (Tables 8 and 9, Figures 21, 22, and 23). For the spring survey, there were no ageing data collected prior to 1973. It was assumed that the average of the spring age-length keys during 1973-1975 was an adequate representation of silver hake size-at-age during 1968-1972. In addition, there were no age-length data available for spring during 1998-1999 and here it was assumed that the 1997 spring age-length key was an adequate representation of silver hake size-at-age during 1998-1999. Similarly, for the fall survey, there were no age data collected prior to 1973 and no age data collected in 1974. The average of the 1973 and 1975 age-length keys was used to represent silver hake size at age during 1963-1972 and 1974, when no age data were collected.

LIFE HISTORY PARAMETERS

Recent research on silver hake life history parameters includes studies of larval settlement and growth (Steves and Cowen 2000), variation in otolith morphometrics (Bolles and Begg 2000), growth variation of larvae in relation to water masses (Jeffrey and Taggart 2000), acoustic measurements of the distribution of silver hake and euphausiid prey (Cochrane et al. 2000), spatial and temporal patterns of growth (Helser 1996), and potential effects of density-dependent growth and maturation on population dynamics (Helser and Brodziak 1998). Together, these studies have expanded the information base on silver hake population dynamics.

Distribution of Eggs and Larvae

Silver hake have a protracted spawning period that lasts from late-spring through autumn. Spawning occurs during May-October on Southern Georges Bank, during June-October in the Gulf of Maine and northern Georges Bank, and during June-December in the Mid-Atlantic Bight (Colton et al. 1979). Silver hake larvae are widely distributed in continental shelf waters during summer and early autumn. Silver hake has been classified as a ubiquitous, extended spawner by Sherman et al. (1984) based on the broad distribution of its larvae and its protracted spawning period. Ichthyoplankton surveys conducted from 1977-1987 show the extensive distribution of silver hake eggs during May to October (Figures 24 and 25). This broad distribution may be in part due to multiple spawnings by individual fish; Fahay (1974) reported that silver hake can spawn up to three times per year. In addition, Fahay (1974) observed that larger females tend to mature and spawn earlier in the season compared to smaller mature females. More recently, Steves and Cowen (2000) investigated settlement patterns and habitat use of juvenile silver hake and reported that the outer continental shelf was an important nursery habitat for silver hake in the Southern New England/Mid-Atlantic Bight region. Because most of these observations are based on data that were collected over a decade ago, it is unclear whether these distributional patterns have persisted in recent years.

Growth

Helser (1996) investigated dynamic changes in growth rates of silver hake from Cape Hatteras to the Gulf of Maine during 1975-1992. He found that there were spatial and temporal patterns in growth among four areas: the Mid-Atlantic Bight/Southern New England area (MAB, offshore strata 1-12, 61-76), Southern Georges Bank (SGB, offshore strata 13-19), Northern Georges Bank (NGB, offshore strata 20-23, 25), and the Gulf of Maine (GM, offshore strata 24, 26-30, 36-40). In particular, there were three distinct area growth patterns during 1975-1980: MAB, SGB/NGB, and GM. During 1982-1987, there were four distinct growth patterns: MAB, SGB, NGB, and GM. More recently, there were only two distinct area growth patterns: MAB and SGB/NGB/GM. This shows that silver hake growth changes in space and time and suggests that growth on Georges Bank is influenced by stock mixing. In addition, the study by Helser and Brodziak (1998) shows that density-dependent changes in growth rates can have a substantial impact on management advice for silver hake.

Growth analyses conducted for this assessment were based on NEFSC survey size-at-age data from the spring and fall surveys. Growth curves were computed for the early 1970s (1973-1974) and the 1990s (1993-1999) to investigate time periods not covered in Helser's study. Schnute's (1981) growth model was fit to mean size-at-age data for these analyses. As in Helser (1996), growth curves were computed for size at age on January 1st, where spring survey data were assigned ages of observed year plus 3 months and fall survey data were assigned ages of observed year plus 8 months. Results showed a substantial change in growth between the early 1970s and the 1990s for the northern and southern stock areas and the combined stock area (Figure 26). During the early 1970s the average silver hake growth pattern conformed to a von Bertalanffy model while during the 1990s the average growth pattern has been nearly linear with age. The recent change in growth pattern was not expected to be a result of errors in age determinations because quality control measures are in place to ensure consistent age readings. For example, paired comparisons of otolith readings from the fall 1998 survey show 92% agreement between age readers. One implication of recent increases in growth rate is that the mean weights at capture of some age classes have increased during the 1990s (Table 10).

Natural Mortality

Silver hake are assumed to have a relatively high natural mortality rate consistent with their lifespan. The assumed natural mortality rate of 0.4 is generally consistent with estimates derived from life history parameters (Table 11, for details of estimation methods, see Hoeing (1983) and

Quinn and Deriso (1999)). Regardless, there is probably age-specific, geographic, and temporal variation in the natural mortality rate of silver hake in the northwest Atlantic.

The maximum age of silver hake in NEFSC surveys has changed dramatically through time (Figure 27). Maximum ages averaged 9.5 y during 1963-1988 and subsequently decreased to an average of 5.6 y during 1989-1999 based on spring and fall survey data. The important question raised by this truncation of age structure is, what has happened to the older fish? One possibility is that natural mortality on older ages changed substantially in the late 1980s due to environmental changes. Another possibility is that the availability of older silver hake to the NEFSC surveys has changed due to a shift in their spatial distribution. Another possibility is that fishing mortality from directed and non-directed fisheries has been too high to allow the age structure to rebuild. Unfortunately, this important question is unlikely to be answered through age-structured modeling because estimation of natural mortality and survey selectivity parameters determining capture probabilities at older ages are probably confounded (Thompson 1994). As a result, further field investigation will be needed to determine the most likely cause of the truncation of age structure.

Silver hake are an important component of the northeast continental shelf food web. Silver hake diet primarily consists of euphausiids, shrimp, fish, and other hakes (Garrison and Link 2000a,2000b). Smaller silver hake feed intensively on euphausiids. Silver hake undergo an ontogenetic shift to increased piscivory (Garrison and Link 2000b,2000c). Fish has been a consistent component of silver hake diet through time, although fish consumption by silver hake was relatively lower in the 1980s. There has been a shift in diet in recent years from sand lance to herring (Pers. comm. Jason Link, NEFSC, unpublished data). Silver hake exhibit a higher frequency of cannibalism than other gadids in the northwest Atlantic, with medium-sized adults (age-2 and age-3) preying heavily upon age-0 and age-1 juveniles (Pers. comm., Jason Link, NEFSC). Predation by silver hake on groundfish is also substantial and may be on the order of 100,000 mt per year (Overholtz et al. 1999, Overholtz et al. 2000).

Length-Weight Relationship

Length-weight relationships of silver hake for northern, southern, and combined stock areas during 1992-1999 were estimated using methods described in Hayes et al. (1995). For each year, to determine the number of fish landed at age the estimated curves for the spring and fall were averaged to predict the mean weight at length at the midpoint of the year. In addition, possible changes in condition factor, as indexed by predicted mean weight at 25 cm, were investigated to see whether there had been declines in weight at length similar to those observed in the Scotian Shelf silver hake population (Hunt 1997, Showell and Fanning 1998). Results showed that there has been no apparent decline in silver hake condition factor in either northern or southern stock areas during the 1990s (Figure 28). Thus, the Scotian Shelf silver hake population appears to have a different trend in condition factor compared to the population in the US EEZ.

Maturity and Fecundity

Density-dependence in fraction of silver hake mature at age has been suggested for the northern and southern stock areas (see Helser and Brodziak 1998, and references therein). These density-dependent maturity models were not used in this assessment because of their dependence upon absolute estimates of stock sizes. Instead, maturity ogives from the most recent assessment reported in Helser and Mayo (1994) were used to characterize population percent mature at age. In particular, percent mature at ages 1 through 6 and older were: 10%, 75%, 100%, 100%, 100%, and 100%, where the age-1 and age-2 values were the average of northern and southern stock values to the nearest 5%. These values of fraction mature at age were used in age-structured population modeling to provide an index of spawning biomass through time.

ESTIMATION OF FISHING MORTALITY RATES AND STOCK SIZE

Brief History of Assessments

The first preliminary assessment of silver hake in Subarea 5 (Georges Bank and the Gulf of Maine) is given in Gulland (1968) in the form of a series of interpretations of the likely sustainability of catches from the early 1960s. The foundation for the present VPA assessment framework was laid down in a series of papers by Anderson (1975a, 1975b, 1977), and a description of changes in ageing techniques is provided in (Anderson and Nichy 1975). Since the late 1970s, the assessment has been performed by several individuals in the form of multi-year updates (Anderson 1977, Anderson and Almeida 1979, Anderson and Almeida 1981, Almeida 1987b, NEFC 1990a, NEFC 1990b).

There are 4 major events in the evolution of the catch at age data which has formed the basis of the assessment of the silver hake stocks:

1) Pooled age-length keys from USA and USSR ageing based on whole otoliths were used to derive the 1955-1972 catch at age.
2) Thin sectioned otoliths were used for ageing beginning in 1973 and this practice continues to present.
3) Discard estimates were included in the initial catch at age matrix for Division 5Y and Subdivision 5Ze silver hake assessments in the 1975 assessments. Discards primarily consisted of age 0 and 1 fish. Discards were excised from the catch at age data in all subsequent assessments.
4) A change in the assumed stock structure from 3 stocks to 2 stocks was implemented in the 1987 assessment.

VPAs were tuned using age-aggregated *ad hoc* techniques prior to 1990. In 1990 (SAW 11) both Laurec-Shepherd and ADAPT tuning methods were attempted. VPAs for both silver hake stocks were accepted with reservation at SAW 11, but the subsequent VPA assessments were rejected at SAW 17, due to a high degree of uncertainty and instability in parameter estimates.

Exploitation Rate Indices

Indices of relative exploitation rate were computed for northern and southern stock areas based on the ratio of landings to fall survey biomass index (Figure 29). The exploitation rate index for the northern stock area shows high values for 1963-1975 followed by low values since 1976. The index for the southern stock is higher than for the northern stock throughout the time series. The southern exploitation rate index shows high values during 1963-1977 followed by a period of low values during 1978-1993. Since 1994, the southern exploitation rate index appears to be increasing. Together, the exploitation rate indices suggest that exploitation rates in recent years are much lower than during the 1960s and 1970s when foreign distant water fleets intensively harvested silver hake.

Age-specific exploitation rate indices were calculated for the combined stock area using NEFSC spring and fall survey data. The age-specific indices were examined to see whether the ratio of landings at age to survey numbers at age has changed through time. Substantial changes in age-specific exploitation rate indices were apparent (Figure 30). Some of the changes in the early 1970s coincide with prohibitions on fishing for silver hake in southern New England waters during January-March in 1970-1972 and during April 1973-1974 (Anderson et al. 1980). The age-specific exploitation rate indices were very high for ages 4, 5, and 6+ during the late 1960s and early 1970s. Between 1974 and 1975 there was a reduction in exploitation rate indices for the fall survey to low values that have persisted to the present. For the spring survey, there was a gradual reduction in the exploitation rates from 1975 to 1980 after which the indices were low and stable. Thus, the age-specific exploitation rate indices show that exploitation rates were higher in the 1960s through early 1970s, especially for older ages, and have remained low since around 1980.

Total Mortality Indices from Research Surveys

Estimates of instantaneous total mortality were computed for the combined stock area using NEFSC spring and fall numbers-at-age data and Heincke's method as used in the most recent assessment (NEFSC 1994). Results indicated that total mortality was high during the 1960s and that there has been an increasing trend in total mortality since the early 1980s (Table 12 and Figure 31). If natural mortality has been constant and equal to 0.4, then the increasing trend in total mortality implies that fishing mortality has increased and is currently very high ($F>1$). This increase in F appears to contradict the trend in exploitation rate indices.

Sequential Age-Structured Population Analyses

An age-structured population analysis was conducted to estimate stock size and fishing mortality for silver hake in the combined stock area. This approach contrasts the approach taken in the most recent assessment where separate analyses were attempted for northern and southern stock areas. There were six reasons why separate age-structured analyses were not conducted for the northern and southern stock areas. First, catch-at-age data from the stock mixing area of Georges Bank likely contain errors in allocation to northern and southern components due to stock mixing and also due to errors in reporting catch amount and location, especially during the 1960s when distant water fleets intensively harvested silver hake on Georges Bank. Second, the commercial length frequency sampling of the northern stock area has been poor in the 1990s and was considered to be inadequate to characterize this component in isolation. Third, there has been a south to north shift in distribution of population biomass in recent years with the possible implication that silver hake stock components do not have the same spatial distribution through time. Fourth, there have been spatial changes in silver hake growth through time (see Helser 1996) and these changes in growth are not consistent with two distinct subpopulations separated by a boundary across Georges Bank. Fifth, analyses of silver hake growth data from the 1990s show that growth rates in northern and southern stock areas are very similar and therefore, silver hake from the two stock areas are currently exhibiting similar growth dynamics. Sixth, the most recent age-structured assessment based on two stocks was rejected because the models did not fit the data. Thus, it was expected that similar two-stock analyses would reproduce this lack of fit and provide no technical improvement over an index-based assessment of population status.

The ADAPT tuned-VPA model was applied to conduct age-structured analyses of the combined silver hake population using derived input data for catch at age (Table 4), survey numbers at age (Tables 8 and 9), catch weight at age (Table 10), and assumed natural mortality of 0.4. There were multiple model formulations examined. Of these, output for two model formulations that represent the baseline model with a very poor fit to the data and the best fit model were examined in detail at SAW32 whereas key features of other model formulations were summarized (Table 13).

Residual patterns for model predictions of age-specific survey indices were very poor in the baseline model. There was a clear non-random trend in residuals across all age indices that went from low to high values (Figure 32). As a result, the baseline model was not considered to be reliable.

The best fit model was a model with 3 time periods of constant catchability for the spring and fall survey indices. These time periods were 1963-1974, 1975-1980, and 1981-1999. These periods were chosen based on observed residual patterns, changes in age-specific exploitation rate indices in 1974/75 for the fall survey and 1980/81 for the spring survey, possible changes in silver hake distribution associated with changes in the position of the shelf/slope front and the northern edge of the Gulf Stream (see Drinkwater et al. 2000), as well as reduced landings by the foreign fishery. The residuals for the 3-period catchability model were satisfactory (Figure 33), although some indications of low or high residuals were apparent. Estimated catchabilities for the 3-period catchability model showed an increasing trend through time for both spring and fall surveys (Figure 34), with the exception of the age-1 index during 1975-1980. This implied that the spatial distribution of the population had changed and was more available to both spring and fall surveys since 1980. Overall, recent outputs of the best fit ADAPT model (Figure 35) appeared to be inconsistent with the long-term trend in exploitation rate indices and for this reason, the model was discounted by both the Northern Demersal Working Group and the SARC in their reviews of the silver hake assessment.

Biomass Dynamics Population Analyses

A Bayesian state-space formulation of the Schaefer surplus production model was developed by Meyer and Millar (1999) and an extension of their model forms the basis for biomass dynamics analyses of silver hake in the northern, southern, and combined stock areas. We briefly describe the model, the Northern Demersal Groups' consensus on the most appropriate model structure and priors, and then show the surplus production results for the northern, southern, and combined silver hake stock areas.

The Bayesian surplus production (BSP) model uses a reparameterized form of the Schaefer surplus production model. The standard form of the Schaefer model relates stock biomass in year t (B_t) to biomass the previous year, intrinsic growth rate (r), carrying capacity (K) and catch the previous year (C_{t-1}) as

$$B_t = B_{t-1} + rB_{t-1}\left(1 - \frac{B_{t-1}}{K}\right) - C_{t-1}$$

The reparameterized form relates the fraction of carrying capacity (P_t=B_t/K) to intrinsic growth rate, carrying capacity, and the catch time series as

$$P_t = P_{t-1} + rP_{t-1}\left(1 - P_{t-1}\right) - \frac{C_{t-1}}{K}$$

This relationship is the basis of the state equations for the state-space model.

Stock biomass changes through time due to harvest and biomass production. The state equations determine changes in relative stock biomass through time (t=1,...,N) via:

$$P_1 = \exp\left(u_1\right)$$

$$P_t = \left(P_{t-1} + rP_{t-1}(1 - P_{t-1}) - \frac{C_{t-1}}{K}\right)\exp\left(u_t\right) \ for\ t \geq 2$$

$$C_t \sim Uniform[C_{L(t)}, C_{U(t)}]$$

where the independent lognormal process errors for relative biomass are exp(u_t) with $u_t \sim N(0,\sigma^2)$ and the annual catch error distribution is a uniform distribution with time-varying upper ($C_{U(t)}$) and lower ($C_{L(t)}$) bounds.

Relative abundance in year t is measured by the mean weight per tow index (I_t) from the NEFSC autumn and/or spring bottom trawl surveys. In the simplest form, the survey index is assumed to be proportional to stock biomass with constant survey catchability (q) throughout the assessment time horizon

$$I_t = qB_t$$

This relationship is the basis of the observation equations for the state-space model. Stock biomass is measured by the time series of survey indices. The observation equations relate the observed survey indices to model parameters via:

$$I_t = qKP_t \cdot \exp(v_t) \ for \ t = 1,\ldots,N$$

where the independent lognormal observation errors are $\exp(v_t)$ with $v_t \sim N(0,\tau^2)$.

In the simplest form for two surveys with constant catchability, the BSP model has eight parameters (r, K, q_{FALL}, fall_σ^2, fall_τ^2, q_{SPR},spr_σ^2,spr_τ^2), N unknown relative biomasses (P_t), and N unknown catches (C_t) for a total of 2N+8 unknowns. To describe the Bayesian estimation procedure, let the joint prior of the parameters and unobservables be p(r,K,q_{FALL},fall_σ^2,fall_τ^2, q_{SPR},spr_σ^2,spr_τ^2, P_t, C_t) ≡ p(Θ). Further, let the joint likelihood of the survey indices given the parameters and unobserved states be p(I_t | r,K,q_{FALL},fall_σ^2,fall_τ^2, q_{SPR},spr_σ^2,spr_τ^2, P_t, C_t) ≡ p(Data | Θ) and the joint posterior distribution of the unobservables be p(r,K,q_{FALL},fall_σ^2,fall_τ^2, q_{SPR},spr_σ^2,spr_τ^2 P_t, C_t | I_t) ≡ p(Θ | Data).

Bayes' theorem determines the posterior as a function of the prior and likelihood via

$$p(\Theta \mid Data) = \frac{p(Data|\Theta)\,p(\Theta)}{\int_{\Theta} p(Data|\Theta)\,p(\Theta)\,d\Theta}$$

Direct calculation of the posterior distribution is not possible for the BSP model because the integral in the denominator of the right hand side is not tractable. As a result, Markov chain Monte Carlo (MCMC) methods were used to obtain samples from the posterior distribution of a Bayesian model (Gilks et al. 1996, Brooks 1998). Gibbs sampling is one type of MCMC algorithm that can be readily applied using the BUGS software (Gilks et al. 1994; Meyer and Millar 1999). Computer code to fit the BSP model was implemented using the WINBUGS1.3 software.

Several candidate versions of the three BSP models (northern, southern, and combined silver hake) were evaluated by the Northern Demersal Working Group during their review of the silver hake assessment. These included models that used the fall survey biomass index alone with constant catchability, as well as models that included both surveys with 2 time periods of catchability and population dynamics. The single index models did not perform well and had moderate to strong residual patterns for the predicted survey indices. The Working Group concluded that the single index models had less information than the two index model, and as a result, the single index models were not used in further analyses. The 2-period catchability models using both survey indices were fit for 1963-1974 and 1975-1999 time periods with separate values of catchability, intrinsic growth rate, and carrying capacity for each time period. The 2-period, 2-index models had adequate residual patterns but did not have plausible biological parameters; these models implied marked changes in carrying capacity that were considered to be unrealistic. As a result, the Northern Demersal Working Group chose to use BSP models with a single catchability using both spring and fall survey indices as the basis for assessing stock status.

Initial choices of prior distributions for parameters and unobservables were refined for northern, southern, and combined silver hake BSP models following discussions of the Northern Demersal Working Group. The prior distribution for carrying capacity was a lognormal distribution with parameters chosen to set the 10^{th} and 90^{th} percentiles of the distribution. These percentiles were: combined area (700,000 mt, 2,000,000 mt), northern area (200,000 mt, 1,000,000 mt), southern area (400,000 mt, 2,000,000 mt). The prior distribution for intrinsic growth rate was a broad uniform distribution for each model with r~Uniform[0.01, 1.99].

The prior distribution for the inverse of survey catchability was chosen to be a high-variance gamma distribution as described in Meyer and Millar (1999). That is, the inverse of q was assumed to be distributed as Gamma(0.001,0.001). This choice gives a vague prior for q, p(q), that is approximately proportional to 1/q, that is, $p(q) \propto 1/q$. In addition, the range of possible values of q was bounded to fall within the interval [0.001, 10]. In effect, the bounding of q ensured that model predictions of survey biomass indices (qKP_t) were also bounded. The prior for process error variance parameter (σ^2) was also chosen to be an inverse gamma distribution for both northern and southern monkfish. The inverse of σ^2 was distributed as Gamma(4.00, 0.01). This choice led to a 10% and 90% quantiles for σ of 0.04 and 0.08, respectively. Similarly, the prior for observation error variance parameter (τ^2) was chosen to be an inverse gamma distribution for both northern and southern monkfish. The inverse of τ^2 was distributed as Gamma(2.00, 0.01). This choice led to a 10% and 90% quantiles for τ of 0.05 and 0.14, respectively. Also note that the prior distribution for process error variance parameter was stochastically dominated by the prior for observation error variance parameter. That is, observation error was assumed to be somewhat larger than process error.

The prior distributions for the relative biomasses (P_t) were lognormal distributions for each BSP model. The prior distribution for relative biomass in the initial year of the assessment time horizon was $P_1 \sim \text{Lognormal}(0, \sigma^2)$. For subsequent years, the conditional prior distribution of P_t (conditioned on values of P_{t-1}, K, r, and σ^2) was

$$P_t \sim Lognormal\left(P_{t-1} + rP_{t-1}(1 - P_{t-1}) - \frac{C_t}{K} , \sigma^2 \right)$$

Thus, the prior distribution for relative biomass in year t was dependent upon the previous year's relative biomass, intrinsic growth rate, carrying capacity, and the process error parameter.

Uniform error distributions were assumed for total annual catch of northern, southern, and combined silver hake models during two time periods, 1963-1976 and 1977-1999. These time periods were based on the Northern Demersal Working Group discussion of the reliability of the time series of annual catches $\{C_t\}$ for each stock area. In particular, the accuracy of reported catches of silver hake by distant water fleets was raised. It was pointed out that there was a potential for under-reporting or over-reporting of silver hake catches during the 1960s and 1970s. Thus, catches were initially modeled during 1963-1976 as being Uniform[$C_{L(t)}$, $C_{U(t)}$] = [$0.5C_t$, $1.5C_t$], where C_t was the reported landings (Table 1). This implied that the catch error was up to 50% during 1963-1976. After viewing the posterior distribution of total catches, the Working Group concluded that there was no information to estimate the total catch during this time period and chose to set the catch error distribution to be Uniform[$C_{L(t)}$, $C_{U(t)}$] = [$0.9C_t$, $1.1C_t$]. This implied that the catches were likely measured with error but were unbiased. For the 1977-1999 period, it was assumed that total catch was under-reported due to discarding. The Working Group concluded that discard rates were not well-known and decided that a uniform catch error distribution of Uniform[$C_{L(t)}$, $C_{U(t)}$] = [C_t , $1.1C_t$] for the period 1977-1999 was the most appropriate prior. This implied that the mean discard rate was 5% of reported catch since 1977.

Residual patterns of the three BSP models as well as convergence diagnostics were examined by the Working Group. The distribution of model predictions for the spring and fall survey indices were generally adequate and appeared randomly distributed for the combined (Figure 36), northern (Figure 37), and southern (Figure 38) BSP models. For each parameter, convergence of the MCMC samples to the stationary posterior distribution was also evaluated using the corrected ratio (R_C) of mixture-of-sequences variance (V) to the within-sequence variance (W) as defined by German and Rubin (1992) and generalized by Brooks and German (1998). At convergence, the R_C is expected to be near 1. For each of the three models, the convergence diagnostics generally indicated that the model parameters had converged. In contrast, the extremely low intrinsic growth rate (r=3%) for the southern stock led the Northern Demersal Working Group to discount this model. Overall, given the uncertainties about misallocation of catches to northern and southern stocks and the north-south changes in the spatial distribution of the silver hake population, the Working Group recommended that the combined BSP model be used for management advice.

Summary statistics and marginal densities of model parameters of interest (r, K, q_{FALL},fall_σ^2,fall_τ^2, q_{SPR},spr_σ^2,spr_τ^2) were computed for each model (Appendix 1). In addition, several derived parameters were also summarized: stock biomass (thousand mt) at the beginning of the each year; the annual exploitation rate, the exploitation rate that would produce maximum surplus production (HMSP), the ratio of the exploitation rate in 1999 to HMSP, and the maximum surplus production (thousand mt) from the stock. Time series of stock biomass (Figure 39) and exploitation rate (Figure 40) were also computed.

BIOLOGICAL REFERENCE POINTS AND HARVEST CONTROL RULE

Age-Based Biological Reference Points

Yield- and spawning biomass per recruit analyses were conducted for both areas. Catch weights at age were the 7-year average of observed catch weights at age. The growth curve for 1993-1998 was used to compute stock weights at age, except for ages 5 and 6 where the catch weights were used. The fraction mature at age and natural mortality rate were the same as used in the ADAPT analyses.

Analyses were conducted for two partial recruitment patterns: dome-shaped and flat topped selectivity at older ages. For the dome-shaped analysis, partial recruitment values were the 7-year average of most recent values taken from the best fit ADAPT model. For spawning biomass per recruit analyses, the value of 40% of unfished spawning potential was chosen as a target based on Clark's (1993) paper and based on previous values used for northern and southern silver hake stocks. Results show that F40%=0.49 and F0.1= 0.38 for dome-shaped selectivity while F40%=0.40=M and F0.1=0.34 for flat-topped selection.

Index-Based Biological Reference Points

Proxies for determining whether northern and southern silver hake are overfished were put forward in 1998 by a panel that reviewed overfishing definitions for northeast groundfish stocks (NEFMC 1999). In 1999, the survey index for the northern stock was above its biomass target while the survey index for the southern stock was below its biomass threshold using the best available survey data (Table 14). Therefore, the northern stock is considered to be not overfished while the southern stock is considered to be overfished.

Biomass-Based Biological Reference Points

The biomass dynamics models provide estimates of the biomass that would produce maximum surplus production, BMSP, the harvest rate that would produce maximum surplus production, HMSP, and the amount of maximum surplus production, MSP, for the combined, northern, and southern stock areas (Table 15). As noted in the section on Biomass Dynamics Analyses, the Northern Demersal Working Group recommended that the combined silver hake analyses be used for management advice given the changes in spatial distribution of the resource and the potential misallocation of catches to northern and southern components.

Harvest Control Rule

Hypothetical harvest control rules were developed for northern, southern, or combined silver hake stock areas using information from the surplus production model. The target harvest rate was proposed to be 60% of the median of the distribution of exploitation rate that would produce maximum surplus production for the stock unit. The limit harvest rate was proposed to be the median of the distribution of exploitation rate that would produce maximum surplus production. A value of 60% was chosen for the uncertainty reduction in the target harvest rate to account for the importance of silver hake within the northeast continental shelf food web as well as to account for uncertainties due to misallocation of catch to stock unit and also due to discarding of silver hake.

CONCLUSIONS

The population dynamics of silver hake in the US EEZ have changed through time. In particular, patterns of growth and spatial distribution have changed substantially over the past 40 years. Age structure of the silver hake population appears to be truncated at about age-6 in recent years whereas historically, silver hake of age-6 and older were much more frequently observed. Older silver hake may be less vulnerable to the fishery and survey in recent years because their spatial distribution has changed. Alternatively, continued high fishing mortality rates may have precluded the rebuilding of age structure following the cessation of the foreign distant water fleet fishery. Survey data indicate that biomass in the northern stock area is high and that biomass in the southern stock area is low. For the combined stock area, biomass is likely near carrying capacity and harvest rates appear to be low. Regardless of uncertainties about the status of northern and southern components, the silver hake population constitutes an important link in the food web and increases in exploitation rate should be made with due caution.

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BACK MATTER

Table 1. Silver hake landings (mt) by area, 1955-1999 (prorations to area during 1994-99 area provisional).

Year	Foreign Total Northern Stock Area	US Total Northern Stock Area	Total Landings Northern Stock Area	Foreign Total Southern Stock Area	US Total Southern Stock Area	Total Landings Southern Stock Area	Unreported Stock Area	Total Landings
1955		53,361	53,361		13,842	15,717		69,078
1956		42,150	42,150		14,871	16,564		58,714
1957		62,750	62,750		17,153	17,153		79,903
1958		49,903	49,903		13,473	13,473		63,376
1959		50,608	50,608		17,112	17,112		67,720
1960		45,543	45,543		9,206	9,206		54,749
1961		39,688	39,688		13,209	13,209		52,897
1962	36,575	42,427	79,002	5,325	13,408	18,733		97,735
1963	37,525	36,399	73,924	74,023	19,359	93,382		167,306
1964	57,240	37,222	94,462	127,036	26,518	153,584		248,046
1965	15,793	29,449	45,242	283,366	23,765	307,131		352,373
1966	14,239	33,477	47,716	200,058	11,212	211,270		258,986
1967	6,882	26,489	33,371	81,749	9,500	91,249		124,620
1968	10,506	30,873	41,379	49,422	9,074	58,496		99,875
1969	8,047	15,917	23,964	67,396	8,165	75,561		99,525
1970	12,305	15,223	27,528	20,633	6,879	27,512		55,040
1971	25,243	11,158	36,401	66,344	5,546	71,890		108,291
1972	18,784	6,440	25,224	88,381	5,973	94,396		119,620
1973	18,086	13,997	32,083	97,989	6,604	104,593		136,676
1974	13,775	6,905	20,680	102,112	7,751	109,863		130,543
1975	27,308	12,566	39,874	65,812	8,441	74,253		114,127
1976	151	13,483	13,634	58,307	10,434	68,741		82,375
1977	2	12,455	12,457	47,850	11,458	59,308		71,765
1978		12,609	12,609	14,353	12,779	27,132		39,741
1979		3,415	3,415	4,877	13,498	18,375		21,790
1980		4,730	4,730	1,698	11,848	13,546		18,276
1981		4,416	4,416	3,043	11,783	14,826		19,242
1982		4,656	4,656	2,397	12,164	14,561		19,217
1983		5,310	5,310	620	11,520	12,140		17,450
1984		8,289	8,289	412	12,731	13,143		21,432
1985		8,297	8,297	1,321	11,843	13,164		21,461
1986		8,502	8,502	550	9,573	10,123		18,625
1987		5,658	5,658	2	10,121	10,121		15,779
1988		6,767	6,767		9,195	9,194		15,961
1989		4,646	4,646		13,169	13,169		17,815
1990		6,379	6,379		13,615	13,615		19,994
1991		6,053	6,053		10,093	10,093		16,146
1992		5,302	5,302		10,288	10,288		15,590
1993		4,360	4,360		12,912	12,912		17,272
1994		103	103		7,039	7,039	8,916	16,058
1995		245	245		2,728	2,728	11,755	14,727
1996		318	318		3,082	3,082	12,799	16,199
1997		133	133		2,416	2,416	13,036	15,585
1998		118	118		1,849	1,849	12,992	14,959
1999		540	540		2,422	2,422	11,139	14,100

Silver hake landings (mt) prorated to area, 1994-1999

Year		Prorated Northern Area			Prorated Southern Area			Prorated Total
1994			4,053			12,004		16,058
1995			2,706			12,021		14,727
1996			3,919			12,280		16,199
1997			2,827			12,757		15,584
1998			2,526			12,433		14,959
1999			4,042			10,059		14,100

Table 2. Silver hake landings (mt) by market category and period.				
Annual Total Landings (mt)				
	Market Category			
Year	Small	Unclassified	Large	Total
1993	1,320	15,598	387	17,306
1994	5,567	10,067	423	16,058
1995	2,269	11,700	759	14,727
1996	3,348	12,145	707	16,199
1997	4,660	9,903	1,022	15,585
1998	3,694	10,199	1,067	14,959
1999	3,664	9,626	811	14,100
Average	3,503	11,320	739	15,562
1st Half of Year Total Landings (mt): January-June				
	Market Category			
Year	Small	Unclassified	Large	Total
1993	1	7,692	125	7,819
1994	2,949	4,311	233	7,493
1995	1,418	5,280	389	7,087
1996	1,514	6,091	337	7,941
1997	2,741	4,864	621	8,226
1998	1,622	5,471	560	7,653
1999	2,362	4,960	426	7,748
Average	1,801	5,524	384	7,710
2nd Half of Year Total Landings (mt): July-December				
	Market Category			
Year	Small	Unclassified	Large	Total
1993	1,319	7,906	262	9,487
1994	2,618	5,756	190	8,564
1995	851	6,420	370	7,641
1996	1,834	6,054	370	8,258
1997	1,919	5,039	401	7,359
1998	2,072	4,728	506	7,306
1999	1,301	4,667	385	6,353
Average	1,702	5,796	355	7,852
Landings (mt) with Half of Year Not Reported				
	Market Category			
Year	Small	Unclassified	Large	Total
1993		1,091		1,091
1994		857		857

Table 3. Silver hake commercial length frequency samples by time period, area, and market category , 1993-1999.

1993			Northern Area			Southern Area	
Half of Year		Small	Unclassified	Large	Small	Unclassified	Large
1st Half	Number of Fish					1414	41
	Avg Length (cm)					29.5	39
2nd Half	Number of Fish		886		212	900	100
	Avg Length (cm)		28.1		26.3	31.4	43.3
1994			Northern Area			Southern Area	
Half of Year		Small	Unclassified	Large	Small	Unclassified	Large
1st Half	Number of Fish		297		762	1593	120
	Avg Length (cm)		29.6		27.9	31	43.4
2nd Half	Number of Fish		612		617	1605	
	Avg Length (cm)		29.7		27.4	30.7	
1995			Northern Area			Southern Area	
Half of Year		Small	Unclassified	Large	Small	Unclassified	Large
1st Half	Number of Fish	202	348		409	2226	337
	Avg Length (cm)	28.1	35.4		28	31.7	43.2
2nd Half	Number of Fish		252	92		285	88
	Avg Length (cm)		28.8	50.4		30	34.6
1996			Northern Area			Southern Area	
Half of Year		Small	Unclassified	Large	Small	Unclassified	Large
1st Half	Number of Fish				821	299	
	Avg Length (cm)				26.1	33.2	
2nd Half	Number of Fish		601	56	274	698	100
	Avg Length (cm)		27.9	38.3	27	28.6	39.1
1997			Northern Area			Southern Area	
Half of Year		Small	Unclassified	Large	Small	Unclassified	Large
1st Half	Number of Fish				1426	3034	1553
	Avg Length (cm)				27.9	29.9	34.3
2nd Half	Number of Fish	209	207		533	236	157
	Avg Length (cm)	27.2	27.3		24.2	30.2	33.3
1998			Northern Area			Southern Area	
Half of Year		Small	Unclassified	Large	Small	Unclassified	Large
1st Half	Number of Fish				1117	3143	736
	Avg Length (cm)				26.6	28.7	36.2
2nd Half	Number of Fish		710	42	434	1615	410
	Avg Length (cm)		28.7	42.5	26.2	27	33.3
1999			Northern Area			Southern Area	
Half of Year		Small	Unclassified	Large	Small	Unclassified	Large
1st Half	Number of Fish		170		1347	3055	626
	Avg Length (cm)		29		26	27.7	36.6
2nd Half	Number of Fish		147	113	895	932	291
	Avg Length (cm)		31.6	50.1	26.3	27.8	37.9

Table 4. Silver hake landings (millions of fish) at age for combined stock area.							
	Number of Fish Landed by Age (millions)						
Year	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6+	Total
1955	34.4	29.5	70.2	90.9	39.1	28.0	292.1
1956	78.1	59.3	56.9	76.4	31.8	19.4	321.9
1957	55.2	41.7	90.1	107.4	51.2	33.0	378.6
1958	41.5	48.0	64.9	73.1	33.8	29.2	290.5
1959	21.9	41.4	94.8	78.9	35.5	26.2	298.7
1960	16.4	54.7	88.9	63.8	25.7	19.7	269.2
1961	1.5	29.4	85.9	73.0	24.4	17.8	232.0
1962	3.1	40.1	158.9	157.4	57.5	25.9	442.9
1963	21.4	82.1	308.6	299.2	82.7	31.1	825.1
1964	19.8	111.9	419.9	394.9	135.3	75.5	1157.3
1965	50.9	227.6	985.9	607.0	93.4	41.4	2006.2
1966	24.0	380.1	590.2	360.6	97.6	55.0	1507.5
1967	16.4	126.8	248.8	209.8	51.1	21.4	674.3
1968	11.0	28.5	169.2	140.3	65.5	39.2	453.7
1969	4.9	30.6	127.8	121.9	56.9	45.5	387.6
1970	66.6	41.1	49.7	66.7	36.5	30.0	290.6
1971	12.0	65.6	166.1	128.8	64.2	62.8	499.5
1972	212.2	218.6	130.1	37.2	7.2	4.1	609.4
1973	106.2	416.5	137.1	33.8	6.7	2.5	702.8
1974	95.3	255.0	163.6	83.3	19.9	13.5	630.6
1975	14.2	166.7	212.7	71.3	27.7	7.4	500.0
1976	9.3	105.8	167.4	103.9	13.3	3.0	402.7
1977	4.4	42.7	155.2	83.7	14.2	6.3	306.5
1978	4.9	35.0	27.5	38.8	26.0	6.5	138.7
1979	8.8	25.5	19.6	9.4	12.2	10.8	86.3
1980	4.7	29.2	31.5	11.5	4.9	7.6	89.4
1981	22.5	32.4	35.8	20.1	5.6	4.1	120.5
1982	18.3	41.8	15.1	12.3	10.3	4.7	102.5
1983	11.0	37.1	20.7	7.8	6.0	4.5	87.1
1984	10.2	67.0	32.8	8.7	1.9	1.5	122.1
1985	18.0	32.9	37.0	11.5	1.9	1.2	102.5
1986	14.4	42.2	26.4	9.1	2.1	1.1	95.3
1987	6.1	38.3	28.9	7.5	5.4	0.3	86.5
1988	4.1	28.2	40.1	10.3	1.8	0.2	84.7
1989	6.0	32.0	49.0	12.0	1.0	0.0	100.0
1990	4.2	38.8	39.3	16.0	2.7	0.2	101.2
1991	2.6	24.6	36.0	19.7	2.8	0.5	86.2
1992	3.5	29.9	37.6	12.8	0.7	0.0	84.5
1993	8.7	36.9	31.7	16.5	2.3	0.1	96.1
1994	2.0	37.0	37.8	10.8	0.4	0.0	88.1
1995	5.5	22.8	26.6	11.9	1.0	0.2	67.9
1996	3.5	34.6	41.9	11.9	0.7	0.0	92.6
1997	6.8	37.7	36.3	6.1	0.3	0.0	87.3
1998	8.0	41.6	32.6	5.9	0.4	0.1	88.5
1999	12.7	43.0	27.0	5.0	0.4	0.2	88.4
	Combined Silver hake average landings at age by time period (millions)						
	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6+	Total
Avg 55-59	46.2	44.0	75.4	85.3	38.3	27.2	316.4
Avg 60-64	12.4	63.6	212.4	197.7	65.1	34.0	585.3
Avg 65-69	21.4	158.7	424.4	287.9	72.9	40.5	1005.9
Avg 70-74	98.5	199.4	129.3	70.0	26.9	22.6	546.6
Avg 75-79	8.3	75.1	116.5	61.4	18.7	6.8	286.8
Avg 80-84	13.3	41.5	27.2	12.1	5.7	4.5	104.3
Avg 85-89	9.7	34.7	36.3	10.1	2.4	0.6	93.8
Avg 90-94	4.2	33.4	36.5	15.2	1.8	0.2	91.2
Avg 95-99	7.3	35.9	32.9	8.2	0.6	0.1	84.9
Avg 55-92	24.6	76.3	121.2	83.1	25.8	15.1	346.1

Table 5a. Kept(mt) and discarded (mt) silver hake from sea sampling trips in the northern stock area that caught silver hake.

		Otter Trawl				Otter Trawl															
North		SMALL MESH				LARGE MESH				SHRIMP				SINK GILL NET				SCALLOP DREDGE			
	Qtr	ntrips	kept	discarded	ratio	ntrips	kept	discarded	ratio	ntrips	kept	discarded	ratio	ntrips	kept	discarded	ratio	ntrips	kept	discarded	ratio
1989	1	2	15.42	4.72	0.306					10	0.27	0.92	3.361								
	2	18	3.32	2.05	0.617					12	0.75	2.98	3.955								
	3	43	231.64	48.71	0.210	1	0.00	0.00	0.450					33	0.30	0.10	0.331				
	4	20	22.76	10.14	0.446					8	0.37	0.99	2.710	45	0.42	0.22	0.527				
1990	1	2	0.00	0.42						16	1.20	1.48	1.232	5	0.00	0.01					
	2	7	0.31	1.05	3.409					4	0.12	0.44	3.749	14	0.00	0.03	12.950				
	3	15	80.02	9.67	0.121									18	0.06	0.23	4.215				
	4	15	15.90	0.78	0.049	2	0.02	0.32	16.711	4	0.09	0.67	7.185	33	0.38	0.27	0.705				
1991	1	4	0.00	0.01	2.725	2	0.00	0.05		28	0.56	1.45	2.608	4	0.04	0.01	0.221				
	2	5	0.01	0.01	1.073					11	0.09	0.75	8.572	69	0.19	0.14	0.734				
	3	23	143.40	18.06	0.126	5	28.75	0.05	0.002					319	2.51	2.52	1.004				
	4	45	31.45	4.77	0.152	2	0.00	0.01		7	0.23	0.26	1.162	246	1.89	0.85	0.449				
1992	1	21	0.44	0.60	1.359	2	0.00	0.07		54	0.87	3.91	4.504	23	0.01	0.03	4.200	1	0.01	0.00	0.000
	2	11	0.29	0.07	0.231	2	0.10	0.41	3.977	5	0.02	0.25	13.733	140	0.41	0.24	0.581	1	0.00	0.00	
	3	20	79.98	8.74	0.109									222	0.75	1.38	1.831	2	0.00	0.01	
	4	19	43.79	9.54	0.218					7	0.05	0.60	13.119	201	1.44	0.42	0.289	2	0.00	0.00	
1993	1	3	0.00	0.05	23.087	2	0.01	0.08	7.530	40	0.14	0.93	6.424	8	0.00	0.02	42.800	2	0.00	0.00	
	2	9	1.46	0.35	0.240	4	0.00	0.20	45.044	6	0.00	0.08		45	0.08	0.10	1.276	1	0.00	0.00	
	3	9	84.36	7.65	0.091									102	1.75	0.79	0.451	2	0.00	0.01	20.800
	4	11	4.86	1.05	0.215	1	0.00	0.03		6	0.03	0.70	20.665	149	1.17	0.32	0.276	2	0.00	0.18	
1994	1	6	0.03	0.14	4.290	2	0.00	0.05		31	0.01	0.44	32.250	9	0.08	0.01	0.094	1	0.00	0.00	
	2	4		0.10		1	0.00	0.05	36.286	2	0.00	0.00		42	0.22	0.00	0.008	1	0.00	0.00	
	3	2	0.01	0.01	1.396									84	1.22	0.08	0.065				
	4	6	1.95	0.13	0.068					9	0.10	0.57	5.554	378	6.20	0.12	0.020	4	0.00	0.01	
1995	1	13	0.04	0.27	7.675	3	0.00	0.06		49	0.00	1.57		7	0.02	0.00	0.137	1	0.00	0.00	
	2	2	0.00	0.05		7	0.04	0.42	10.635	6	0.00	0.23		46	0.58	0.02	0.041				
	3	23	16.46	0.41	0.025	3	0.00	0.05						87	1.96	0.07	0.035	1	0.00	0.03	
	4	20	18.07	0.19	0.010	4	0.00	0.18		10	0.13	2.09	15.895	122	1.77	0.09	0.052	2	0.00	0.01	2.863
1996	1					4	0.00	0.13		29	0.05	0.71	13.096	4	0.01	0.01	0.978				
	2	5	0.71	0.17	0.235	6	0.00	0.21	235.367	8	0.04	1.01	26.866	29	0.19	0.01	0.040	1	0.00	0.00	
	3	27	39.03	0.18	0.005									70	1.08	0.15	0.142	3	0.00	0.01	
	4	18	34.87	0.21	0.006	3	0.00	0.01	1.711	7	0.21	0.59	2.835	98	1.62	0.11	0.068	1	0.00	0.00	
1997	1	6	0.02	0.06	3.362	3	0.00	0.07		19	0.38	0.37	0.977	5	0.02	0.05	2.398	2	0.00	0.00	
	2									1	0.00	0.30		45	0.28	0.01	0.036				
	3	1	0.00	0.03		3	0.00	0.10						81	0.62	0.02	0.030	2	0.00	0.04	
	4	1	0.00	0.02		2	0.00	0.05		1	0.03	0.03	1.000	42	0.55	0.03	0.054	2	0.00	0.00	3.214
1998	1					2	0.00	0.20		3	0.00	0.02		8	0.04	0.00	0.053				
	2	2	0.00	0.00	0.439	1	0.00	0.00						37	0.24	0.04	0.165	1	0.00	0.04	
	3					2	0.00	0.00						57	0.33	0.02	0.058	2	0.00	0.01	
	4													85	0.63	0.03	0.049	2	0.00	0.05	
1999	1									5	0.09	0.41	4.715	7	0.03	0.07	2.653				
	2	1	0.00	0.00	0.000	1	0.06	0.03	0.484	1	0.00	0.16		22	0.03	0.02	0.715				
	3	2	0.00	0.00	0.600	12	0.10	0.14	1.365					34	0.34	0.07	0.209				
	4	15	20.47	2.99	0.146	4	0.00	0.48						49	0.51	0.12	0.240	1	0.00	0.08	

Table 5b. Kept(mt) and discarded (mt) silver hake from sea sampling trips in the southern stock area that caught silver hake.																	
			Otter Trawl				Otter Trawl										
South			SMALL MESH				LARGE MESH			SINK GILL NET				SCALLOP DREGDE			
	Qtr	ntrips	kept	discarded	ratio	ntrips	kept	discarded	ratio	ntrips	kept	discarded	ratio	ntrips	kept	discarded	ratio
1989	1	15	22.87	5.59	0.244												
	2	22	65.29	30.47	0.467												
	3	19	70.33	5.37	0.076												
	4	22	28.62	5.61	0.196												
1990	1	18	32.34	6.06	0.187												
	2	21	29.73	20.36	0.685												
	3	4	9.40	4.37	0.465												
	4	12	3.55	2.98	0.839												
1991	1	34	69.30	4.90	0.071												
	2	23	21.58	4.35	0.202					1	0.00	0.00					
	3	17	12.67	26.58	2.097	1	0.01	3.73	266.714	1	0.01	0.00	0.233				
	4	36	29.24	10.16	0.348									2	0.00	0.00	
1992	1	34	71.26	2.41	0.034	3	6.06	0.42	0.069					2	0.01	0.00	0.000
	2	7	8.25	0.98	0.119					22	0.02	0.02	1.000	2	0.00	0.01	
	3	8	73.30	8.02	0.109					7	0.01	0.00	0.200	3	0.00	0.01	
	4	18	9.60	10.96	1.141					24	0.03	0.07	2.214	1	0.00	0.00	
1993	1	17	67.34	13.65	0.203	1	0.85	7.06	8.284	3	0.00	0.00	0.278	2	0.00	0.00	
	2	8	3.35	4.42	1.320	2	0.00	0.32		13	0.01	0.02	2.740	4	0.00	0.02	
	3	7	33.38	26.98	0.808					3	0.00	0.00	2.000	2	0.00	0.88	
	4	16	16.38	34.15	2.085	1	9.10	0.01	0.001	39	0.14	0.08	0.581	2	0.00	0.00	7.200
1994	1	17	17.53	7.68	0.438	1	1.02	0.08	0.080	7	0.00	0.02	5.406	5	0.00	0.03	
	2	9	9.08	5.03	0.554									4	0.00	0.06	
	3	6	0.18	1.90	10.422					1	0.00	0.00		2	0.00	0.01	
	4	12	1.04	3.52	3.391	1	0.00	0.00	1.511	8	0.03	0.01	0.365	4	0.01	0.05	3.401
1995	1	14	9.17	0.85	0.093	2	0.00	0.09	67.071	10	0.01	0.00	0.045	9	0.02	0.37	17.305
	2	8	0.05	0.47	9.812	2	0.00	0.00	0.360	7	0.01	0.01	1.008	5	0.02	0.09	5.434
	3	9	1.02	0.75	0.735	2	0.00	0.01	4.339	2	0.00	0.01		4	0.00	0.24	
	4	13	2.20	3.58	1.626	6	0.06	0.05	0.953	1	0.00	0.00					
1996	1	9	4.55	1.79	0.394	2	0.00	0.01		6	0.00	0.00	1.911	5	0.00	0.03	
	2	16	1.37	1.73	1.263	1	0.00	0.00		11	0.00	0.01	1.789	6	0.00	0.12	32.003
	3	15	0.39	0.57	1.459	2	0.00	0.58	160.203					6	0.00	0.05	
	4	15	11.94	0.96	0.080	1	0.00	0.00	0.000	1	0.00	0.00	0.000	5	0.00	0.05	
1997	1	28	54.34	10.88	0.200	2	0.00	0.01		16	0.01	0.01	1.721	6	0.00	0.05	15.000
	2	4	13.63	0.04	0.003	1	0.01	0.09	17.780	15	0.01	0.04	7.623	5	0.00	0.24	
	3	9	6.86	15.69	2.286	3	0.00	0.40		1	0.00	0.01		7	0.00	0.09	
	4	1	0.00	11.11		1	0.01	0.03	6.130	1	0.00	0.00	0.000				
1998	1	14	20.48	7.80	0.381	3	1.04	0.29	0.282	13	0.05	0.00	0.047	1	0.00	0.00	
	2	3	0.00	0.25	502.600	1	2.83	0.02	0.006	8	0.01	0.01	0.625	5	0.00	0.01	
	3	4	14.42	17.33	1.202	1	0.00	0.00		7	0.03	0.00	0.040	2	0.00	0.06	
	4	10	3.45	0.06	0.018	1	0.15	0.00	0.009	3	0.00	0.00	0.217	3	0.00	0.01	
1999	1	6	17.79	6.01	0.338	3	2.14	3.28	1.533	2	0.00	0.00	1.929				
	2	7	8.71	6.04	0.693	4	13.06	0.27	0.021	1	0.01	0.00	0.000	5	0.02	0.10	6.739
	3	5	0.00	0.15										14	0.00	0.23	452.000
	4	7	0.36	0.42	1.183	3	0.18	0.03	0.176					2	0.00	0.01	

Table 6a. Fishery logbook records of silver hake discarded (mt) and kept (mt) catches in the northern stock area.

North		Otter Trawl					Otter Trawl								
		SMALL MESH					LARGE MESH					SINK GILL NET			
	Qtr	ntrips	kept	discarded	ratio		ntrips	kept	discarded	ratio		ntrips	kept	discarded	ratio
1994	2	77	66.67	4.76	0.071		132	10.40	0.47	0.045		98	9.42	0.04	0.004
	3	831	724.68	38.50	0.053		117	21.92	1.66	0.076		263	15.00	0.35	0.023
	4	604	244.06	24.08	0.099		123	13.22	0.16	0.012		362	12.79	0.52	0.041
1995	1	753	2.27	16.98	7.467		12	3.15	0.74	0.235		28	0.73	0.03	0.043
	2	138	0.19	5.76	30.758		135	1.55	0.21	0.135		151	13.64	0.29	0.021
	3	872	546.09	11.23	0.021		139	12.37	0.53	0.043		272	11.44	1.18	0.104
	4	409	154.19	18.11	0.117		94	7.45	0.21	0.028		225	7.32	0.78	0.106
1996	1	537	8.03	6.68	0.832		28	3.61	0.39	0.109		24	0.21	0.01	0.046
	2	127	21.82	10.69	0.490		102	5.81	0.21	0.036		153	2.30	0.08	0.033
	3	664	1039.19	27.51	0.026		154	59.00	0.35	0.006		206	3.10	0.32	0.102
	4	469	315.42	23.52	0.075		126	15.13	1.00	0.066		141	3.58	0.04	0.011
1997	1	491	17.75	9.56	0.538		39	8.10	0.16	0.020		11	0.06	0.00	0.007
	2	225	29.16	19.01	0.652		135	2.02	4.61	2.284		95	1.17	0.08	0.069
	3	369	502.52	16.15	0.032		127	5.55	3.33	0.600		147	2.08	0.15	0.071
	4	489	462.03	15.53	0.034		51	3.83	0.10	0.026		86	1.82	0.03	0.017
1998	1	195	0.05	3.97	85.019		16	1.14	0.05	0.048					
	2	51	1.78	10.37	5.837		153	3.13	0.09	0.030		132	1.17	0.14	0.123
	3	374	194.95	8.50	0.044		134	3.80	0.17	0.045		111	1.23	0.15	0.120
	4	196	118.35	10.93	0.092		73	1.46	0.14	0.094		83	0.45	0.07	0.153
1999	1	170	5.23	6.94	1.328		12	1.38	1.16	0.837		13	0.26	0.00	0.018
	2	76	0.13	9.69	75.762		258	4.22	0.79	0.187		108	4.12	0.13	0.032
	3	365	220.21	21.02	0.095		397	15.00	0.94	0.062		190	8.06	1.27	0.158
	4	154	270.14	25.21	0.093		100	11.25	0.55	0.049		113	1.34	0.25	0.187

Table 6b. Fishery logbook records of silver hake discarded (mt) and kept (mt) catches in the southern stock area.

South		Otter Trawl					Otter Trawl								
		SMALL MESH					LARGE MESH				SINK GILL NET				
	Qtr	ntrips	kept	discarded	ratio		ntrips	kept	discarded	ratio		ntrips	kept	discarded	ratio
1994	2	519	894.44	79.32	0.089		15	5.43	4.63	0.852					
	3	266	451.78	35.28	0.078		3	7.85	0.95	0.121					
	4	449	529.00	16.24	0.031		24	18.08	0.60	0.033		4	0.02	0.00	0.000
1995	1	345	973.99	31.28	0.032		41	47.09	2.95	0.063		14	0.13	0.02	0.177
	2	195	726.29	17.72	0.024		33	28.82	2.18	0.076					
	3	160	3459.55	37.23	0.011		32	29.19	1.67	0.057					
	4	250	326.62	35.59	0.109		29	37.24	1.43	0.038					
1996	1	269	594.79	49.52	0.083		9	6.45	0.07	0.011					
	2	178	594.95	30.15	0.051		22	3.63	0.01	0.003		1	0.00	0.00	0.000
	3	145	416.64	21.31	0.051		20	8.46	0.34	0.040		1	0.05	0.00	0.047
	4	306	713.79	21.89	0.031		47	10.57	0.22	0.021		1	0.00	0.00	0.000
1997	1	260	649.86	20.75	0.032		26	8.72	0.05	0.006		4	0.10	0.00	0.000
	2	246	476.42	13.13	0.028		77	7.22	0.23	0.032		3	0.01	0.00	0.000
	3	143	457.91	25.09	0.055		31	13.64	0.64	0.047					
	4	300	302.05	13.36	0.044		52	2.98	0.70	0.234		4	0.15	0.02	0.138
1998	1	216	348.25	14.91	0.043		41	23.28	1.44	0.062					
	2	143	296.26	32.86	0.111		49	11.38	0.14	0.012					
	3	107	334.80	20.76	0.062		26	26.04	10.78	0.414					
	4	270	271.04	8.55	0.032		67	10.55	0.68	0.064		1	0.00	0.00	0.500
1999	1	155	257.52	20.08	0.078		49	8.89	0.34	0.038					
	2	122	331.47	10.45	0.032		59	7.18	0.69	0.097					
	3	71	110.05	5.81	0.053		17	13.80	0.28	0.021		4	0.03	0.02	0.600
	4	245	139.31	6.69	0.048		43	14.13	0.56	0.040					

Table 7. Silver hake biomass indices from NEFSC fall and spring surveys for northern, southern, and combined stock areas.

	Northern Area Fall		Northern Area Spring		Southern Area Fall		Southern Area Spring		Combined Area Fall		Combined Area Spring	
Year	Mean Weight (kg) Per Tow	Stderr	Mean Weight (kg) Per Tow	Stderr	Mean Weight (kg) Per Tow	Stderr	Mean Weight (kg) Per Tow	Stderr	Mean Weight (kg) Per Tow	Stderr	Mean Weight (kg) Per Tow	Stderr
1963	25.418	6.200			3.418	0.840			12.081	2.528		
1964	4.415	0.878			2.908	0.525			3.499	0.471		
1965	6.475	1.802			3.773	0.653			4.834	0.818		
1966	4.124	0.765			1.760	0.274			2.688	0.346		
1967	2.158	0.576			2.186	0.303			2.175	0.291		
1968	2.048	0.546	0.036	0.017	2.693	0.341	3.756	1.615	2.439	0.298	2.296	0.981
1969	2.635	0.583	0.192	0.053	1.256	0.171	2.202	0.430	1.797	0.251	1.413	0.262
1970	3.034	0.798	14.133	13.352	1.332	0.174	1.233	0.176	2.000	0.331	6.297	5.243
1971	2.466	0.498	0.406	0.125	2.210	0.363	2.192	0.301	2.310	0.295	1.491	0.190
1972	6.085	0.947	1.702	0.649	2.000	0.437	1.399	0.209	3.603	0.457	1.518	0.285
1973	4.150	0.575	3.126	0.980	1.699	0.297	4.968	0.710	2.661	0.289	4.245	0.578
1974	3.764	1.034	2.682	0.504	0.862	0.177	3.474	0.552	2.001	0.420	3.163	0.389
1975	8.234	1.127	9.720	2.769	1.840	0.299	6.486	1.372	4.350	0.478	7.768	1.375
1976	12.632	2.762	8.829	1.702	2.062	0.279	4.110	0.724	6.211	1.097	5.963	0.800
1977	7.593	2.474	3.699	0.626	1.773	0.431	4.553	0.713	4.058	1.006	4.217	0.498
1978	7.072	0.970	0.813	0.145	2.931	0.698	5.307	0.932	4.556	0.570	3.542	0.569
1979	6.651	0.974	1.617	0.314	1.741	0.205	2.342	0.562	3.669	0.402	2.058	0.363
1980	6.655	1.205	4.151	0.638	2.122	0.734	2.779	0.474	3.903	0.650	3.318	0.382
1981	4.057	1.024	2.269	0.380	1.166	0.166	3.761	0.557	2.301	0.415	3.174	0.369
1982	5.450	3.063	1.346	0.272	1.651	0.329	2.018	0.459	3.143	1.219	1.754	0.299
1983	9.205	1.884	1.507	0.332	3.200	1.124	1.376	0.241	5.558	1.006	1.428	0.196
1984	3.621	0.783	1.090	0.174	1.558	0.470	2.209	0.549	2.369	0.419	1.770	0.340
1985	8.583	1.406	2.645	0.742	3.907	1.926	2.642	0.464	5.743	1.294	2.643	0.405
1986	14.194	2.324	3.247	0.802	1.388	0.240	2.672	0.475	6.415	0.924	2.898	0.427
1987	9.836	1.375	3.802	0.675	1.619	0.381	3.617	0.881	4.848	0.588	3.690	0.597
1988	6.312	1.229	1.256	0.217	1.830	0.421	1.709	0.340	3.590	0.546	1.531	0.223
1989	12.549	3.221	3.566	0.861	2.120	0.539	2.316	0.554	6.214	1.306	2.806	0.477
1990	15.246	3.805	1.623	0.443	1.645	0.277	3.869	2.400	6.994	1.506	2.985	1.465
1991	11.889	3.480	1.381	0.200	0.907	0.197	1.459	0.355	5.219	1.371	1.428	0.230
1992	14.245	5.407	5.655	1.722	0.978	0.137	0.528	0.185	6.200	2.130	2.549	0.688
1993	8.117	1.565	2.497	0.601	1.329	0.254	1.362	0.493	3.996	0.634	1.809	0.381
1994	6.925	0.977	7.319	3.849	0.799	0.129	2.278	0.793	3.204	0.391	4.263	1.590
1995	13.161	1.953	3.485	0.821	1.641	0.561	0.999	0.400	6.164	0.839	1.975	0.404
1996	7.886	1.233	3.463	1.121	0.431	0.070	6.216	5.698	3.358	0.486	5.135	3.489
1997	5.638	1.113	1.188	0.185	0.842	0.160	0.684	0.113	2.725	0.448	0.883	0.100
1998	21.966	6.752	4.446	0.763	0.620	0.110	0.686	0.190	9.000	2.652	3.435	0.743
1999	11.636	1.142	4.234	0.837	0.870	0.352	1.774	0.679	5.097	0.497	2.415	0.696
2000			10.002	1.583			1.049	0.369			4.909	0.885
Average	8.274		3.348		1.813		2.718		4.351		2.996	

Table 8. Silver hake combined area number per tow at age, autumn survey, delta-distribution.

Year	Age-0	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6+	Age-2+	Age-3+
1963	9.050	70.097	34.382	15.339	3.973	1.414	0.417	55.525	21.144
1964	0.218	15.596	9.763	2.894	0.997	0.350	0.108	14.112	4.349
1965	0.594	15.472	24.784	6.498	1.135	0.388	0.241	33.045	8.261
1966	0.000	12.859	27.095	17.811	4.448	1.707	0.724	51.785	24.690
1967	0.972	9.066	3.099	0.439	0.135	0.069	0.026	3.768	0.670
1968	5.923	14.892	12.396	4.342	1.430	0.535	0.099	18.802	6.406
1969	16.782	3.450	1.952	0.231	0.036	0.009	0.002	2.231	0.279
1970	3.041	14.910	6.660	0.645	0.143	0.048	0.043	7.539	0.879
1971	24.403	10.200	9.255	1.715	0.378	0.138	0.028	11.514	2.260
1972	4.845	30.489	15.654	1.347	0.312	0.137	0.053	17.503	1.849
1973	9.510	4.596	5.566	2.203	0.453	0.249	0.084	8.556	2.989
1974	49.134	22.469	18.078	4.780	1.674	0.750	0.458	25.740	7.662
1975	36.131	14.267	9.579	3.598	1.287	0.466	0.328	15.259	5.679
1976	62.159	5.383	12.602	9.556	3.463	0.672	0.776	27.068	14.466
1977	79.725	6.061	4.626	7.662	4.110	0.836	0.217	17.450	12.825
1978	46.105	10.660	4.900	3.124	3.590	3.546	0.888	16.048	11.148
1979	12.983	13.317	7.233	1.732	0.861	0.781	1.001	11.607	4.375
1980	27.857	5.308	6.353	8.717	2.268	0.922	2.182	20.443	14.089
1981	31.545	6.210	2.582	3.228	2.540	0.462	0.547	9.357	6.775
1982	40.194	9.059	5.557	1.908	1.292	0.948	0.290	9.995	4.438
1983	17.891	25.662	13.715	1.696	0.579	0.495	0.302	16.786	3.071
1984	18.214	5.838	4.794	1.596	0.400	0.093	0.053	6.935	2.141
1985	75.643	28.159	3.897	4.960	1.314	0.183	0.126	10.480	6.583
1986	11.598	35.081	10.083	1.712	1.203	0.198	0.000	13.196	3.114
1987	21.144	2.330	4.331	3.503	0.266	0.028	0.013	8.141	3.810
1988	2.454	13.078	38.834	8.183	1.214	0.736	0.084	49.052	10.217
1989	17.897	22.804	11.819	7.062	0.694	0.054	0.030	19.660	7.841
1990	24.994	7.312	24.781	6.370	2.428	0.425	0.033	34.037	9.256
1991	49.547	12.946	13.839	5.362	0.867	0.050	0.000	20.118	6.279
1992	54.518	19.480	20.854	5.236	0.221	0.000	0.000	26.311	5.457
1993	5.066	23.488	15.037	2.120	0.448	0.023	0.000	17.627	2.591
1994	12.818	8.164	18.670	1.488	0.078	0.000	0.000	20.236	1.566
1995	52.622	39.939	19.031	4.066	0.162	0.000	0.000	23.259	4.228
1996	2.139	6.880	15.011	3.696	0.351	0.022	0.008	19.090	4.078
1997	43.196	9.704	12.301	2.898	0.219	0.014	0.007	15.438	3.137
1998	23.942	99.721	22.674	2.461	0.328	0.015	0.015	25.493	2.819
1999	62.057	24.966	16.780	0.797	0.157	0.031	0.021	17.786	1.006
Average	25.862	18.376	13.205	4.351	1.228	0.454	0.249	19.486	6.282

Table 9. Silver hake combined area number per tow at age, spring survey, delta distribution.

Year	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6+	Age-2+	Age-3+
1968	13.458	5.335	2.745	0.626	0.166	0.038	8.910	3.575
1969	4.492	4.580	2.665	0.945	0.283	0.086	8.560	3.980
1970	19.558	2.994	2.000	1.197	0.457	0.214	6.862	3.868
1971	9.405	5.857	2.331	0.513	0.163	0.066	8.930	3.073
1972	18.621	3.507	1.133	0.379	0.124	0.043	5.185	1.678
1973	6.859	10.711	3.282	0.920	0.134	0.092	15.139	4.428
1974	39.916	3.706	3.701	1.896	0.627	0.301	10.230	6.524
1975	33.037	41.183	10.718	2.589	0.742	0.080	55.311	14.128
1976	14.000	16.416	8.850	2.150	0.558	0.279	28.253	11.837
1977	3.687	3.421	5.443	2.735	0.549	0.399	12.547	9.127
1978	4.638	3.107	1.521	1.992	1.086	0.352	8.057	4.950
1979	7.804	6.898	0.884	0.371	0.542	0.446	9.141	2.243
1980	5.208	10.499	4.216	0.715	0.207	0.491	16.127	5.628
1981	7.878	3.825	3.722	2.075	0.722	0.593	10.937	7.112
1982	5.472	4.298	1.180	0.907	0.749	0.465	7.601	3.302
1983	6.212	6.025	0.926	0.510	0.266	0.279	8.005	1.981
1984	3.071	5.709	2.093	0.461	0.129	0.173	8.565	2.857
1985	21.241	4.376	3.868	1.387	0.304	0.194	10.129	5.753
1986	35.614	9.921	1.988	1.686	0.288	0.089	13.972	4.051
1987	4.345	21.487	4.978	1.022	0.542	0.055	28.084	6.596
1988	3.561	2.157	6.137	0.817	0.079	0.022	9.213	7.056
1989	49.274	5.194	4.919	1.695	0.086	0.012	11.906	6.711
1990	9.381	14.843	5.388	0.984	0.225	0.037	21.477	6.634
1991	19.065	3.562	3.325	1.774	0.372	0.104	9.137	5.576
1992	58.078	20.520	3.993	1.233	0.067	0.000	25.814	5.294
1993	18.089	16.362	3.612	0.976	0.141	0.000	21.091	4.729
1994	3.933	35.884	13.688	0.921	0.033	0.005	50.531	14.647
1995	22.590	22.799	5.644	1.277	0.037	0.005	29.762	6.963
1996	2.660	17.345	31.833	1.320	0.043	0.011	50.551	33.206
1997	2.281	3.299	3.056	0.368	0.027	0.007	6.758	3.458
1998	111.241	56.314	1.303	0.322	0.000	0.000	57.939	1.624
1999	5.983	36.378	1.853	0.443	0.098	0.000	38.772	2.394
2000	42.365	78.073	6.120	0.997	0.179	0.051	85.419	7.346
Average	18.576	14.745	4.822	1.158	0.304	0.151	21.179	6.434

Table 10. Silver hake average landed weight at age (kg) for the combined stock area.						
Year	Age-1	Age-2	Age-3	Age-4	Age-5	Age6+
1955	0.045	0.122	0.189	0.249	0.326	0.481
1956	0.038	0.086	0.186	0.253	0.324	0.465
1957	0.064	0.101	0.180	0.252	0.323	0.434
1958	0.052	0.104	0.188	0.268	0.336	0.450
1959	0.042	0.122	0.177	0.256	0.344	0.483
1960	0.052	0.112	0.169	0.230	0.319	0.500
1961	0.068	0.137	0.179	0.233	0.309	0.501
1962	0.069	0.130	0.169	0.226	0.302	0.482
1963	0.079	0.114	0.168	0.216	0.294	0.520
1964	0.058	0.114	0.159	0.216	0.307	0.540
1965	0.063	0.107	0.155	0.202	0.304	0.512
1966	0.060	0.092	0.149	0.211	0.308	0.525
1967	0.046	0.095	0.158	0.220	0.307	0.499
1968	0.049	0.105	0.151	0.224	0.318	0.478
1969	0.064	0.126	0.191	0.251	0.313	0.510
1970	0.053	0.103	0.173	0.221	0.282	0.461
1971	0.064	0.106	0.158	0.207	0.274	0.496
1972	0.091	0.200	0.279	0.378	0.409	0.587
1973	0.103	0.168	0.253	0.315	0.414	0.626
1974	0.077	0.183	0.229	0.303	0.357	0.538
1975	0.105	0.150	0.211	0.340	0.473	0.715
1976	0.071	0.167	0.201	0.234	0.446	0.616
1977	0.088	0.169	0.214	0.261	0.382	0.590
1978	0.099	0.193	0.272	0.325	0.331	0.488
1979	0.083	0.177	0.238	0.283	0.389	0.378
1980	0.101	0.170	0.194	0.253	0.312	0.490
1981	0.072	0.145	0.213	0.247	0.262	0.492
1982	0.110	0.158	0.208	0.252	0.296	0.432
1983	0.117	0.170	0.215	0.265	0.292	0.416
1984	0.068	0.150	0.201	0.326	0.366	0.413
1985	0.120	0.158	0.230	0.344	0.497	0.573
1986	0.092	0.160	0.217	0.313	0.465	0.557
1987	0.117	0.140	0.212	0.237	0.485	0.467
1988	0.068	0.151	0.178	0.316	0.482	0.777
1989	0.098	0.152	0.193	0.243	0.364	0.606
1990	0.112	0.154	0.209	0.263	0.344	0.432
1991	0.089	0.151	0.187	0.224	0.315	0.415
1992	0.067	0.152	0.195	0.250	0.303	0.492
1993	0.037	0.095	0.158	0.263	0.490	0.791
1994	0.032	0.087	0.158	0.249	0.568	0.836
1995	0.037	0.076	0.162	0.318	0.692	0.842
1996	0.041	0.100	0.154	0.349	0.761	0.841
1997	0.040	0.104	0.166	0.298	0.546	0.922
1998	0.047	0.084	0.194	0.299	0.471	0.745
1999	0.030	0.087	0.197	0.341	0.566	0.942
Averages						
1955-1992	0.077	0.139	0.196	0.261	0.349	0.512
1993-1999	0.038	0.091	0.170	0.303	0.585	0.846
Decadal Averages of Mean Weights at Age (kg)						
Decade	Age-1	Age-2	Age-3	Age-4	Age-5	Age6+
1955-59	0.048	0.107	0.184	0.256	0.331	0.462
1960-69	0.061	0.113	0.165	0.223	0.308	0.507
1970-79	0.083	0.162	0.223	0.287	0.376	0.550
1980-89	0.096	0.155	0.206	0.280	0.382	0.522
1990-99	0.053	0.109	0.178	0.285	0.506	0.726

Table 11. Two alternative approaches to estimating natural mortality of silver hake.

Hoenig's regression model (1983) based on maximum observed age Tmax.					
Fish:	ln(Z) = 1.46-1.01*ln(Tmax)				
a	b				
1.46	-1.01				
Time Period	**Tmax**	**ln(Z)**	**Z**		
1960s-1980s	9.5	-0.81719	0.44		
1990s	5.6	-0.28156	0.75		
Value for 0.4	10.5	-0.91629	0.4		

Pauly's regression model (Quinn and Deriso 1999) using growth parameters from Helser (1996) and near-bottom temperatures from the NEFSC autumn survey

ln(M) = -0.0152-0.279*ln(Linf)+0.6543*ln(k)+0.4634*ln(C)

MAB is Mid-Atlantic Bight, SGB is southern Georges Bank, NGB is northern Georges Bank, and GOM is Gulf of Maine.

REGION	**Linf**	**k**	**Fall Survey Temperature (C)**	**M**	**M Using 0.5*C**
MAB75-80	49.44	0.307	12.423	0.49	0.36
MAB82-87	38.51	0.763	12.615	0.96	0.70
MAB88-92	41.25	0.472	12.27	0.68	0.49
SGB75-80	42.23	0.369	12.61	0.58	0.42
SGB82-87	35.74	0.737	12.267	0.95	0.69
SGB88-92	39.71	0.425	12.25	0.64	0.47
NGB75-80	45.13	0.323	10.666	0.49	0.35
NGB82-87	38.82	0.621	11.248	0.80	0.58
NGB88-92	42.47	0.399	10.371	0.56	0.41
GOM75-80	51.48	0.254	7.59	0.34	0.25
GOM82-87	44.31	0.401	7.866	0.49	0.35
GOM88-92	44.88	0.354	7.228	0.43	0.31

Table 12. Estimates of average instantaneous total mortality (Z) and fishing mortality (F) for combined area silver hake based on NEFSC survey numbers-at-age data and an assumed natural mortality of 0.4.

	Spring Survey		Fall Survey	
Time Period	Z	F	Z	F
1964-1967	-	-	1.40	1.00
1969-1972	-	-	2.03	1.63
1974-1977	1.13	0.73	0.63	0.23
1979-1982	0.83	0.43	0.66	0.26
1984-1987	1.09	0.69	1.11	0.71
1989-1992	1.41	1.01	1.45	1.05
1994-1998	2.87	2.47	1.80	1.40

Estimates for 1964-1972 are based on survey numbers-at-age data computed with an average of age-length keys for 1973-1975.

Survey Z for the fall is computed as the natural logarithm of the ratio of the sum from year j-1 to k-1 of age 2+ abundance to the sum from year j to k of age 3+ abundance

Survey Z for the spring is computed as the natural logarithm of the ratio of the sum from year j to k of age 3+ abundance to the sum from year j+1 to k+1 of age 4+ abundance

The estimate of spring survey Z during 1969-1972 was not feasible

Table 13. Summary of ADAPT model formulations for combined silver hake.

Model Identifier	Main Feature	Survey Indices	Residual Patterns	Precision of Estimates	Selectivity Pattern for Older Ages	Comments on model fit relative to baseline
Run 11	Use all data	Fall:1-5 Spr:1-5	Very poor low to high patterns across ages	High CVs on population size estimates	Dome-shaped selectivity	Baseline model
Run 12	Catchability change in 1980-81	Fall:1-5 Spr:1-5	Low to high patterns across ages	High CVs on population size estimates	Dome-shaped selectivity	Little improvement to model fit
Run 13	Set F-ratio on plus-group to be 1/2	Fall:1-5 Spr:1-5	Low to high patterns across ages	High CVs on population size estimates	Dome-shaped selectivity	Better residual patterns for ages 4 & 5
Run 14	Catchability changes in 1974-75 and 1980-81	Fall:1-5 Spr:1-5	Moderate low to high patterns across ages	High CVs on population size estimates	Dome-shaped selectivity	Better fit to data
Run 15	Same as Run 14 with F-ratio set to be 1/2	Fall:1-5 Spr:1-5	Moderate low to high patterns across ages	High CVs on population size estimates	Dome-shaped selectivity	Best fit to data
Run 16	Hyperdepletion: SQRT transform age-4,-5 indices	Fall:1-5 Spr:1-5	Low to high patterns across ages	High CVs on population size estimates	Dome-shaped selectivity	No improvement to model fit
Run 17	Hyperstable: SQR transform age-1 to age-5 indices	Fall:1-5 Spr:1-5	Low to high patterns across ages	High CVs on population size estimates	Dome-shaped selectivity	Modest improvement to model fit
Run 18	Exclude noisy age-1 index	Fall:2-5 Spr:2-5	Low to high patterns across ages	High CVs on population size estimates	Dome-shaped selectivity	No improvement to model fit
Run 19	Use only fall survey data	Fall:1-5	Low to high patterns across ages	Very high CVs on population size estimates	Dome-shaped selectivity	No improvement to model fit
Run 20	Use only spring survey data	Spr:1-5	Low to high patterns across ages	Very high CVs on population size estimates	Dome-shaped selectivity	No improvement to model fit
Run 23	Increase M on ages 1 and 2	Fall:1-5 Spr:1-5	Low to high patterns across ages	High CVs on population size estimates	Dome-shaped selectivity	Modest improvement to model fit
Run 24	Use only 1967-1999 data	Fall:1-5 Spr:1-5	Low to high patterns across ages	High CVs on population size estimates	Dome-shaped selectivity	Modest improvement to model fit
Run 25	Use only 1981-1999 data	Fall:1-5 Spr:1-5	Moderate low to high patterns across ages	High CVs on population size estimates	Dome-shaped selectivity, except for 1997-1999	Better fit to data

Table 14. Amendment 12 criteria for determining whether northern and southern silver hake are overfished based on NEFSC autumn survey biomass indices, delta-distribution.						
Northern Silver Hake Overfishing Status Evaluation						
Year	Autumn Index	Autumn Index 3-Year Moving Average	3-Year Average Index Above BMSY?	3-Year Average Index Above Biomass Threshold?	BMSY Proxy	Biomass Threshold
1990	15.246	11.369	Yes	Yes	6.626	3.313
1991	11.889	13.228	Yes	Yes		
1992	14.245	13.793	Yes	Yes		
1993	8.117	11.417	Yes	Yes		
1994	6.925	9.762	Yes	Yes		
1995	13.161	9.401	Yes	Yes		
1996	7.886	9.324	Yes	Yes		
1997	5.638	8.895	Yes	Yes		
1998	21.966	11.830	Yes	Yes		
1999	11.636	13.080	Yes	Yes		
Southern Silver Hake Overfishing Status Evaluation						
Year	Autumn Index	Autumn Index 3-Year Average	3-Year Average Index Above BMSY?	3-Year Average Index Above Biomass Threshold?	BMSY Proxy	Biomass Threshold
1990	1.645	1.865	Yes	Yes	1.785	0.892
1991	0.907	1.557	No	Yes		
1992	0.978	1.177	No	Yes		
1993	1.329	1.071	No	Yes		
1994	0.799	1.035	No	Yes		
1995	1.641	1.256	No	Yes		
1996	0.431	0.957	No	Yes		
1997	0.842	0.971	No	Yes		
1998	0.620	0.631	No	No		
1999	0.870	0.777	No	No		

Table 15. Estimates of silver hake biological reference points for combined, northern, and southern stock areas from the Northern Demersal Working Groups preferred Bayesian surplus production models. Table entries are biomass in 1999 (B_{1999}, kt), biomass that would produce maximum surplus production (B_{MSP}, kt), maximum surplus production (MSP, kt), exploitation rate to produce maximum surplus production at B_{MSP} (H_{MSP}, fraction of stock biomass), and ratio of exploitation rate in 1999 to H_{MSP} (H_{Ratio} , fraction of H_{MSP}). Northern and southern area values do not sum to combined area values because the input data are not additive and the analytical models are nonlinear.

Stock Unit	B_{1999}	B_{MSP}	MSP	H_{MSP}	H_{Ratio}
Combined Area	1,180	603	201	0.34	0.04
Northern Area	202	102	45	0.44	0.05
Southern Area	561	990	17	0.02	1.11

Figure 1. NEFSC survey strata for northern (offshore strata 20-30 and 36-40) and southern (offshore strata 1-19 and 61-76) silver hake in the northwest Atlantic.

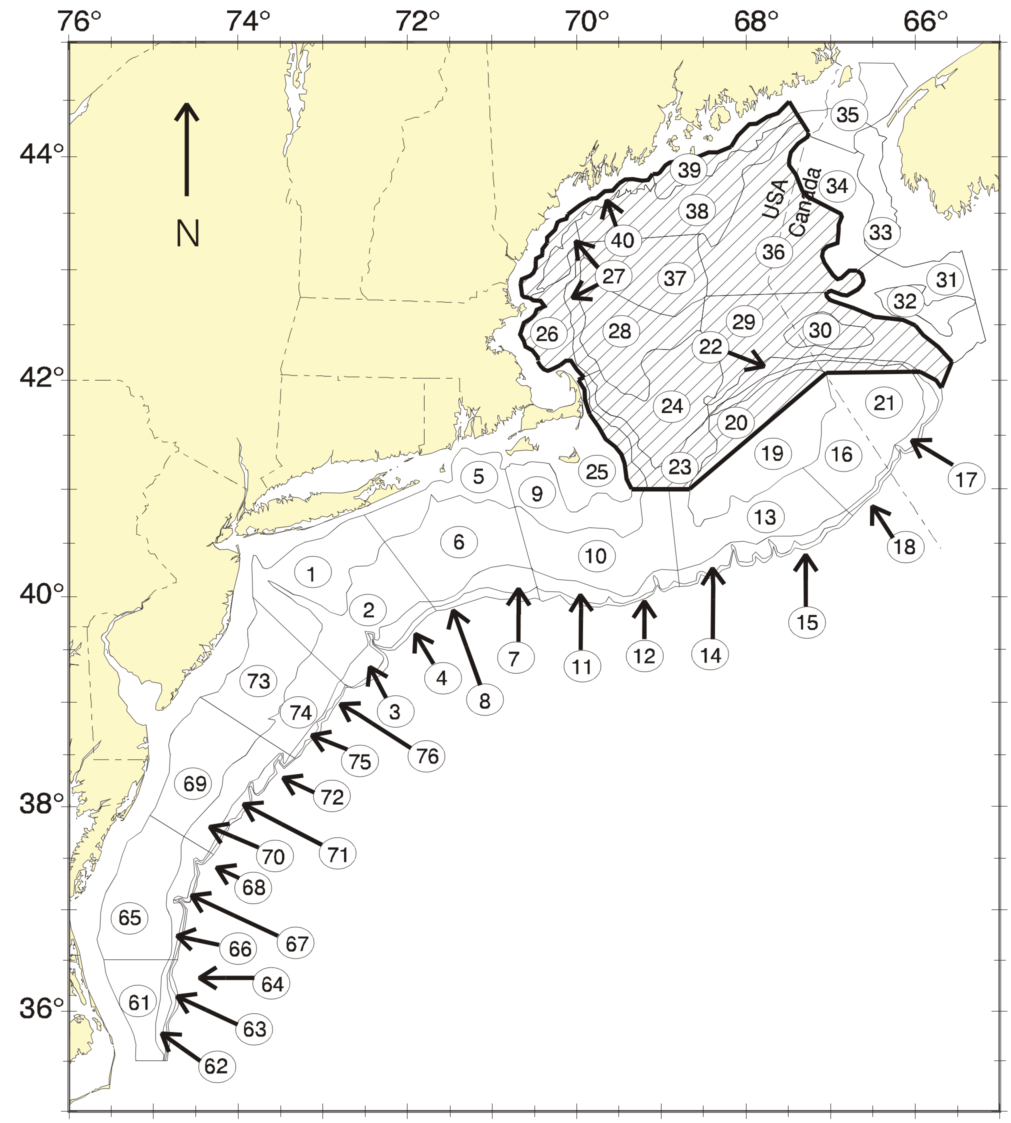


Figure 2. Commercial fishery statistical areas for northern (SA 511-515, 521, 522, 551, and 561) and southern (SA 525, 526, 533-539, 541-543, 552, 562, 611-639) silver hake in the northwest Altantic.

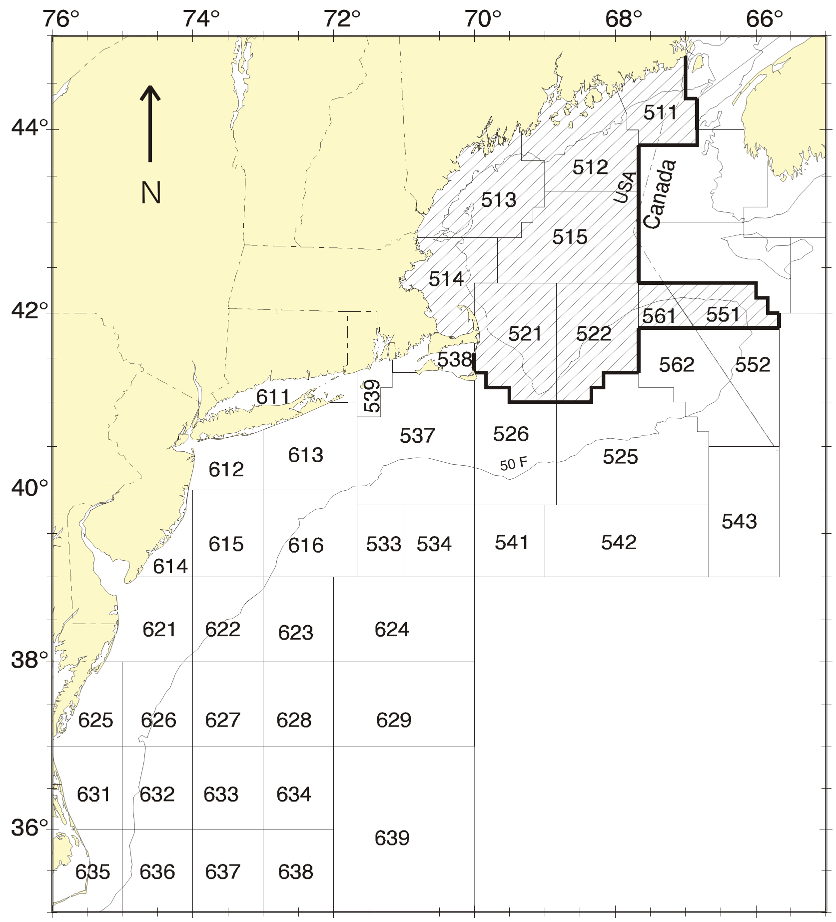


Figure 3. Silver hake density from the NEFSC fall survey.

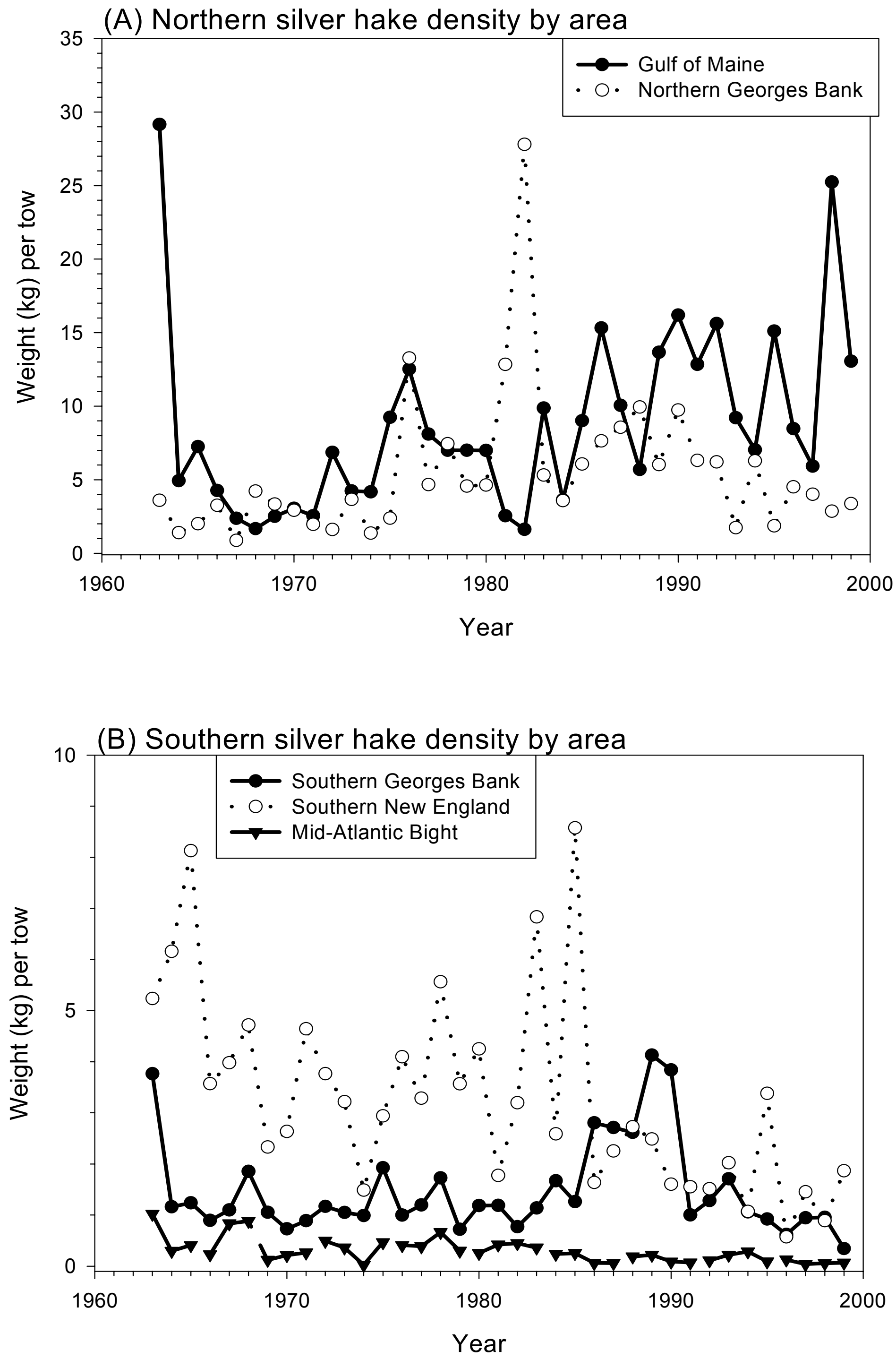
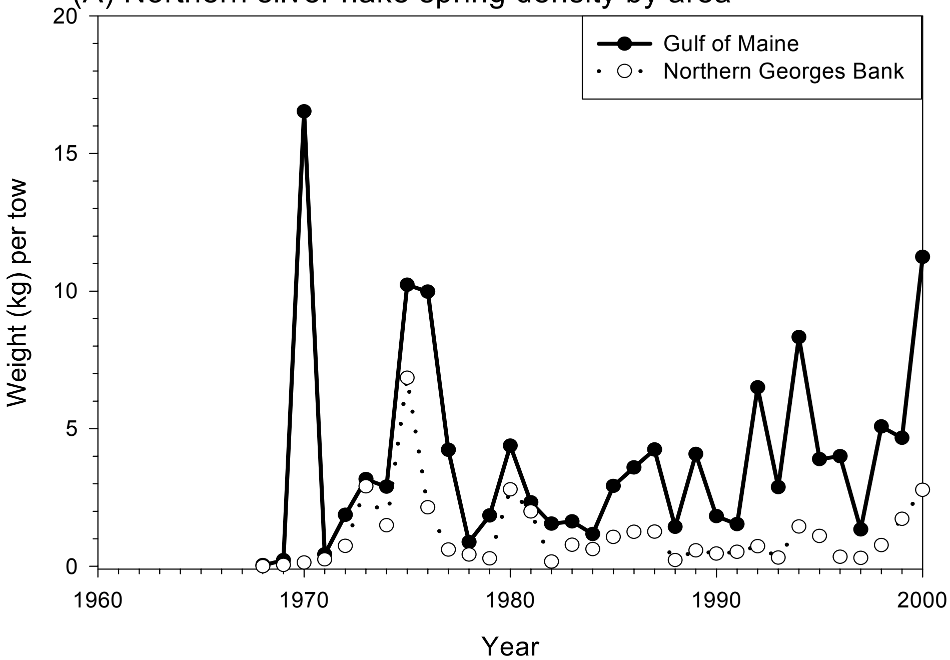


Figure 4. Silver hake density from the NEFSC spring survey.

(A) Northern silver hake spring density by area



(B) Southern silver hake spring density by area

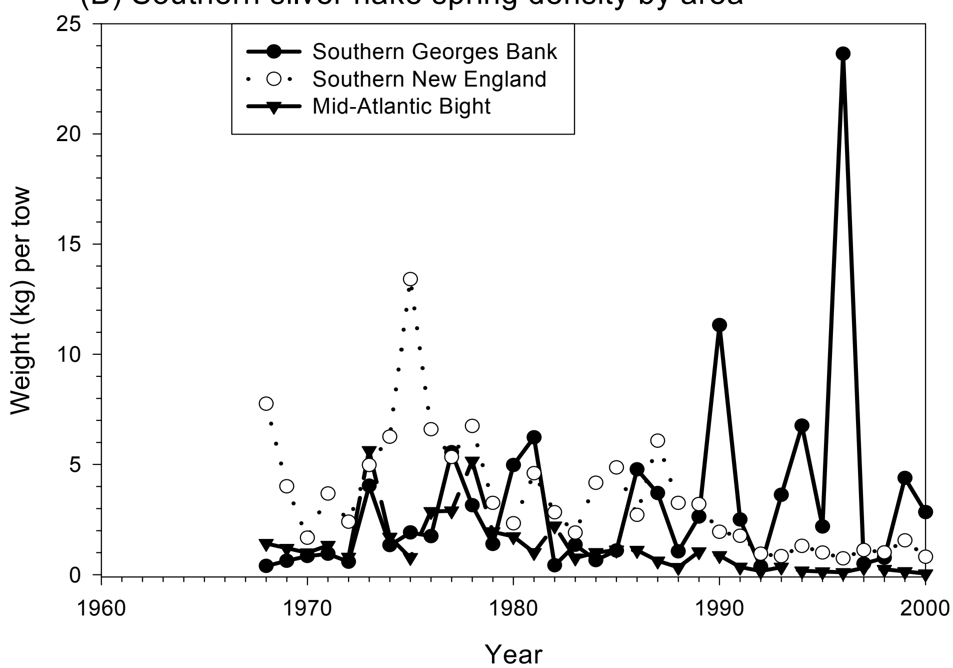


Figure 5. Autumn survey distribution of silver hake biomass by area.

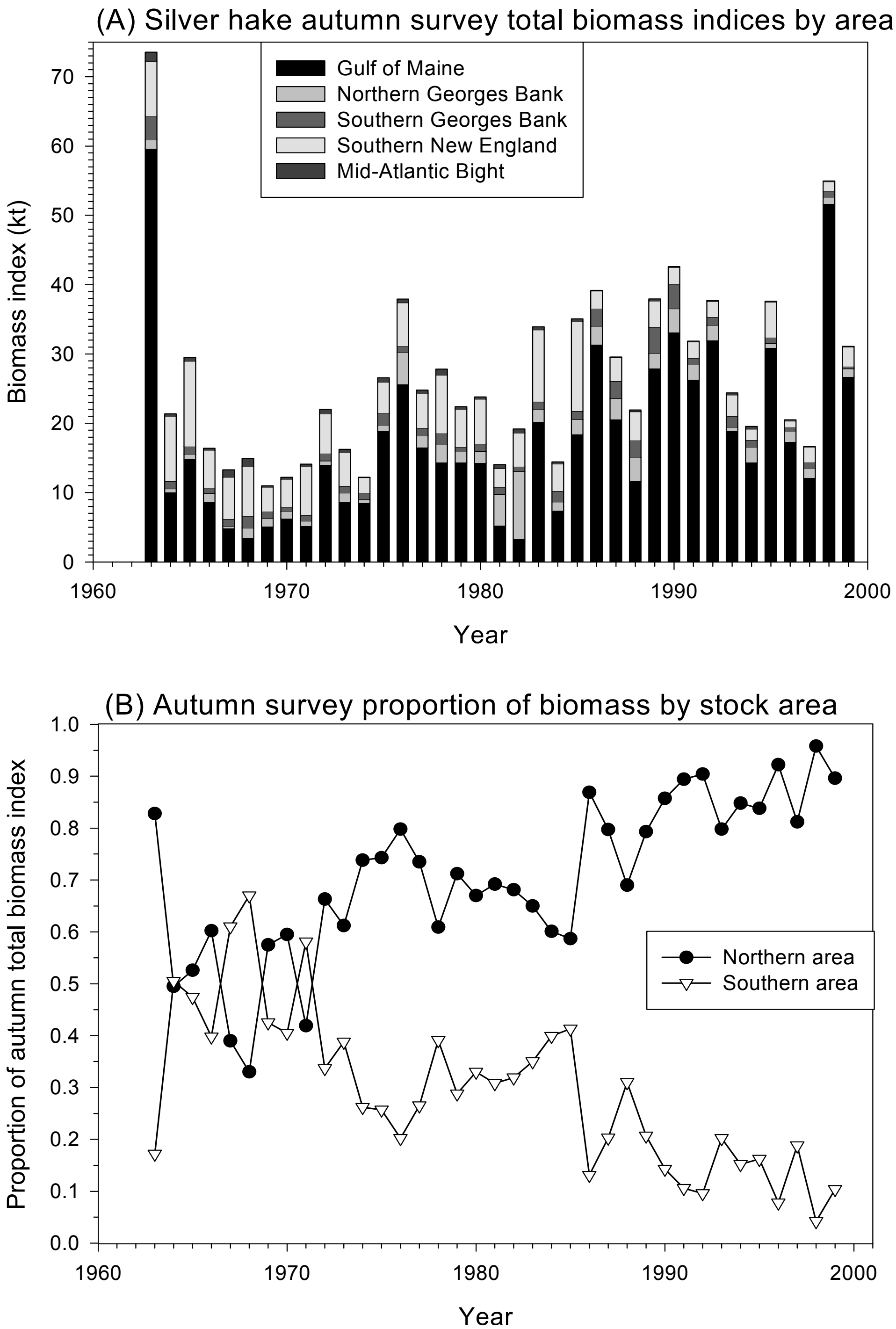
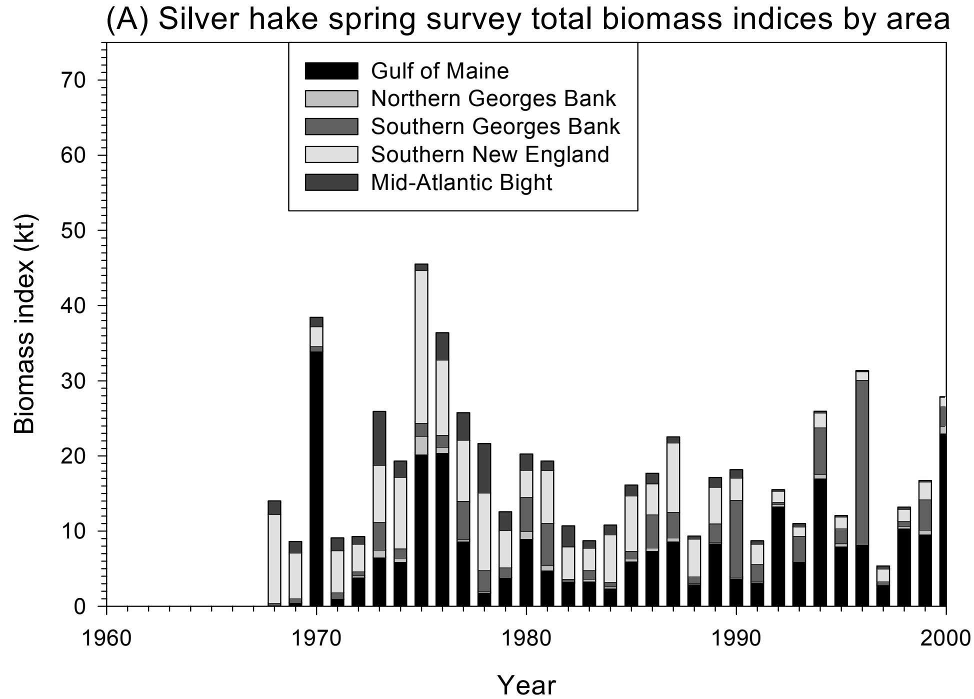


Figure 6. Spring survey distribution of silver hake biomass by area.



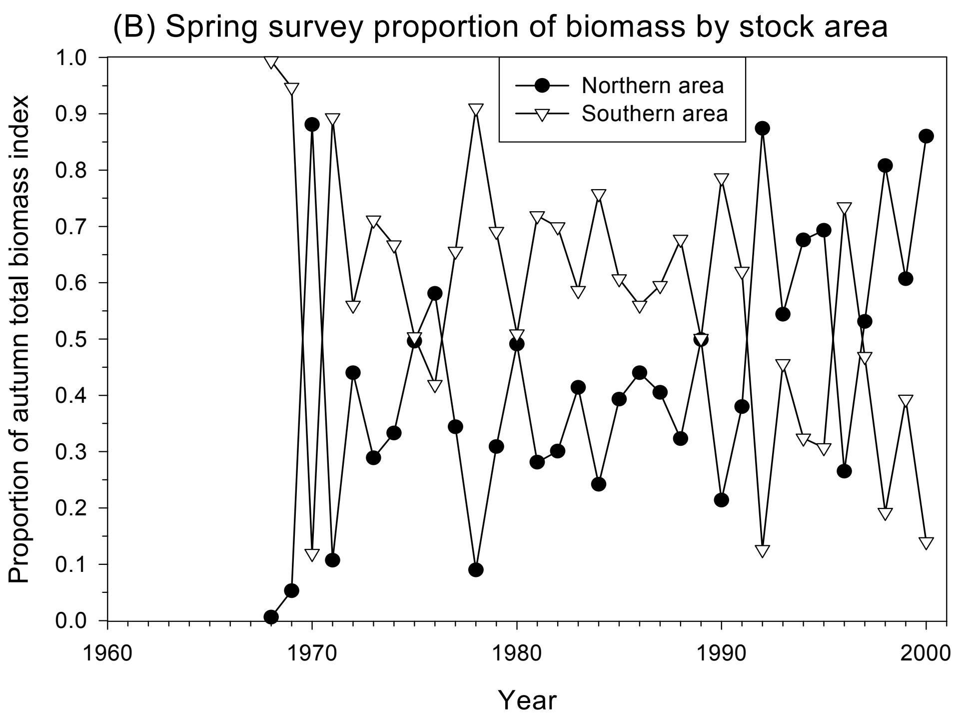
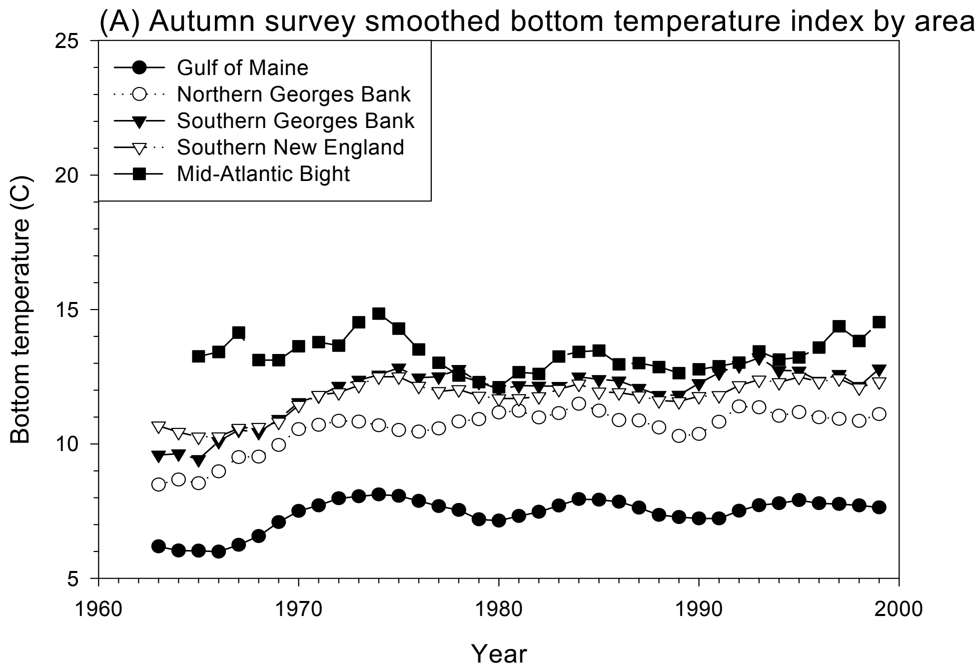


Figure 7. Trends in near-bottom temperatures by area during autumn and spring.



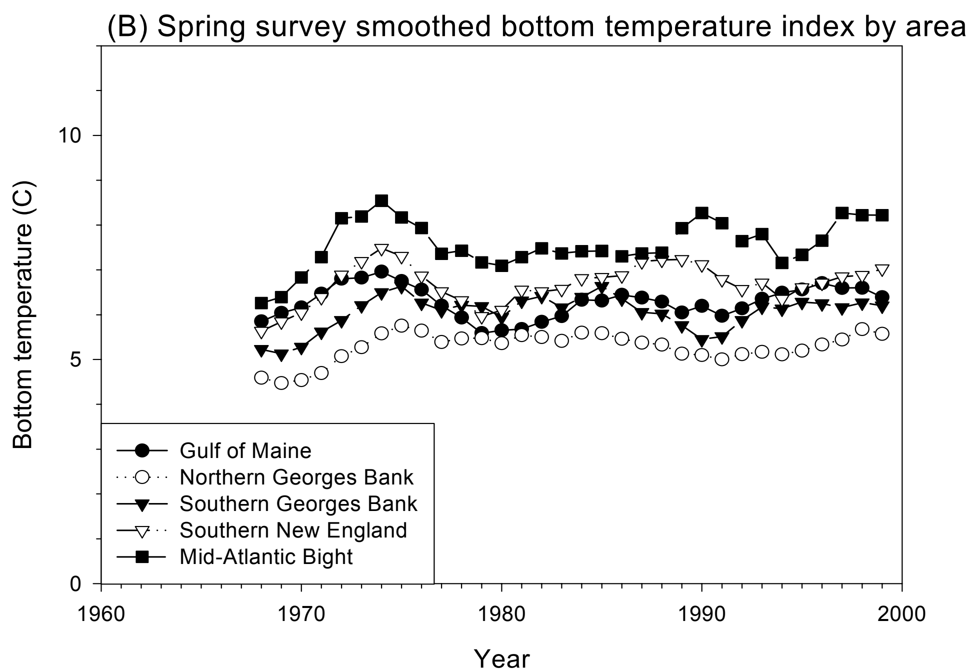
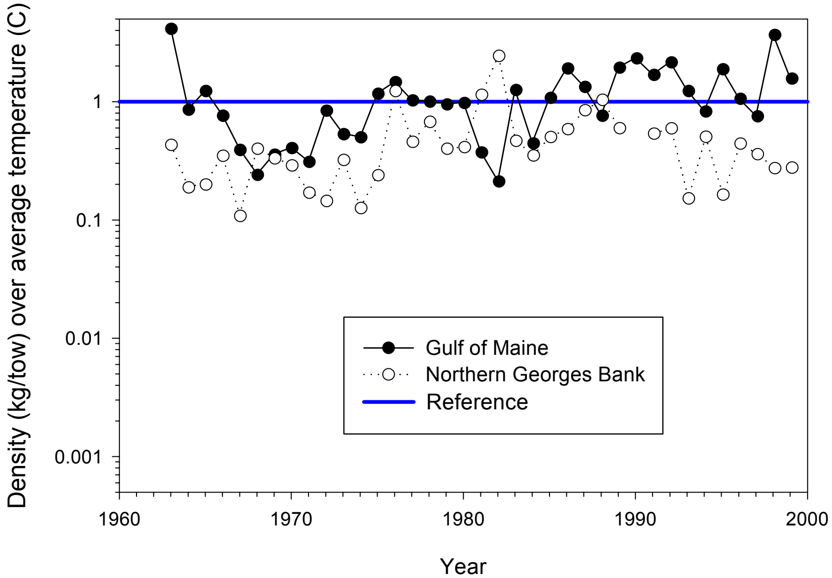
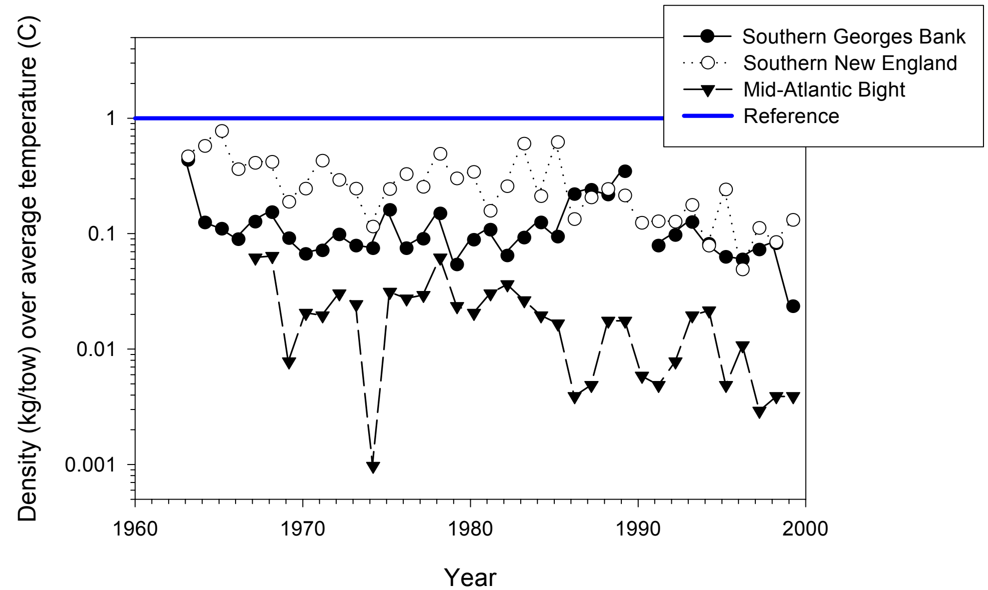


Figure 8. Silver hake density (kg/tow) per degree of bottom temperature by area during the NEFSC autumn and spring surveys.

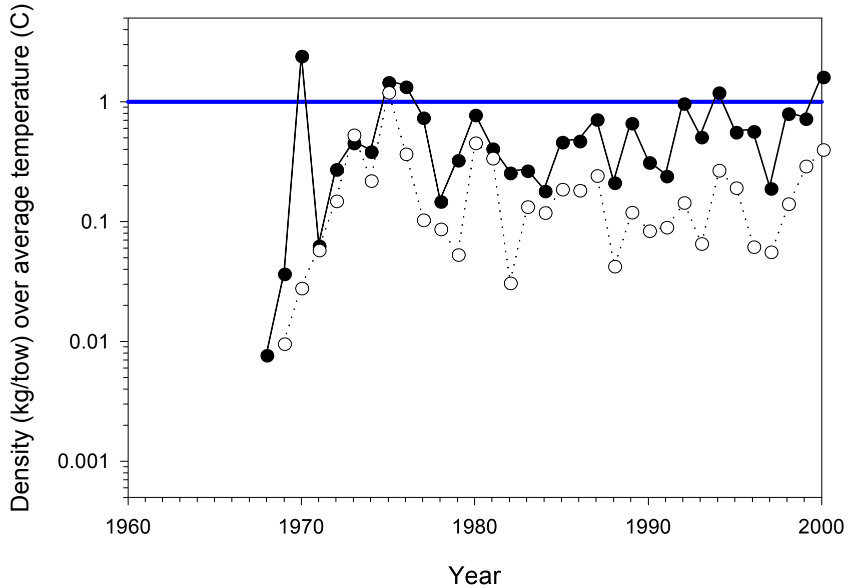
(A) Northern silver hake density to temperature in autumn



(B) Southern silver hake density to temperature in autumn



(C) Northern silver hake spring density to temperature in spring



(D) Southern silver hake spring density to temperature in spring

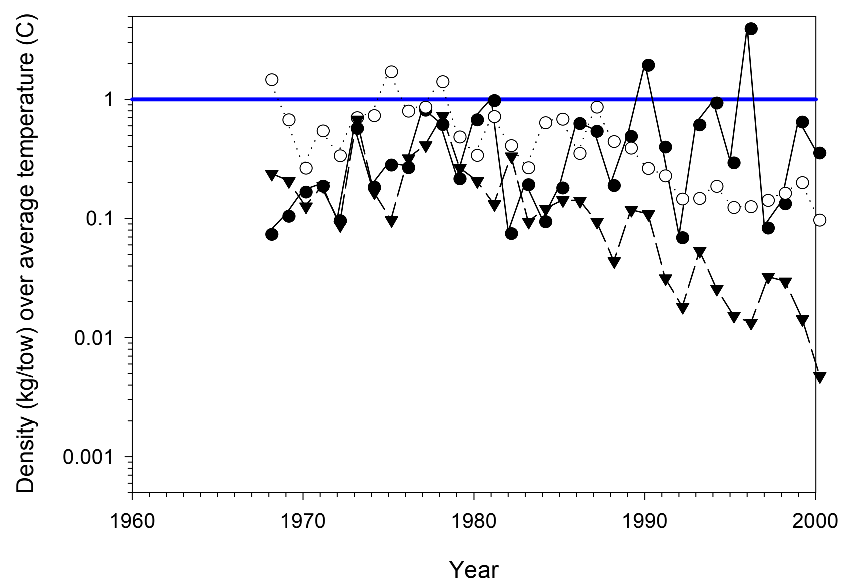
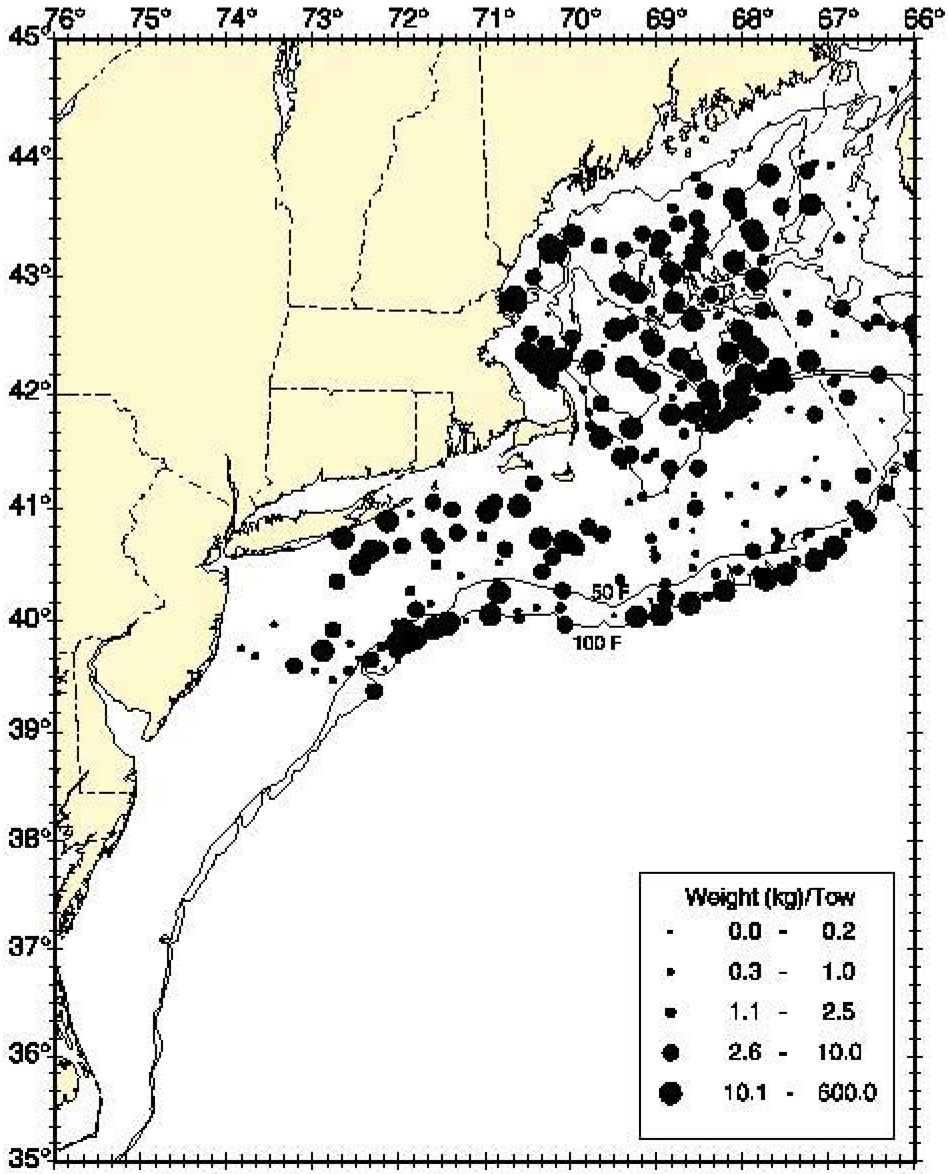
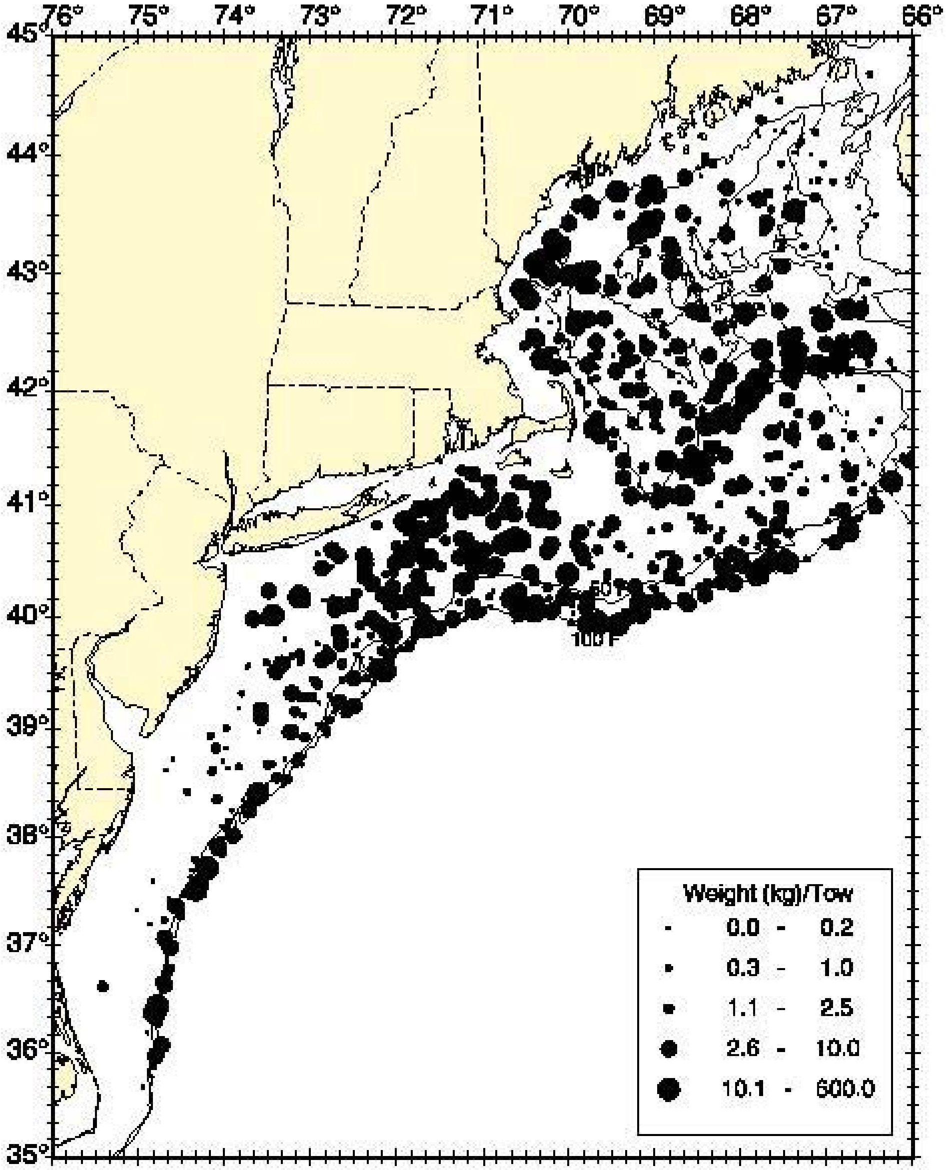


Figure 9A. Silver hake autumn distribution, 1963-64.



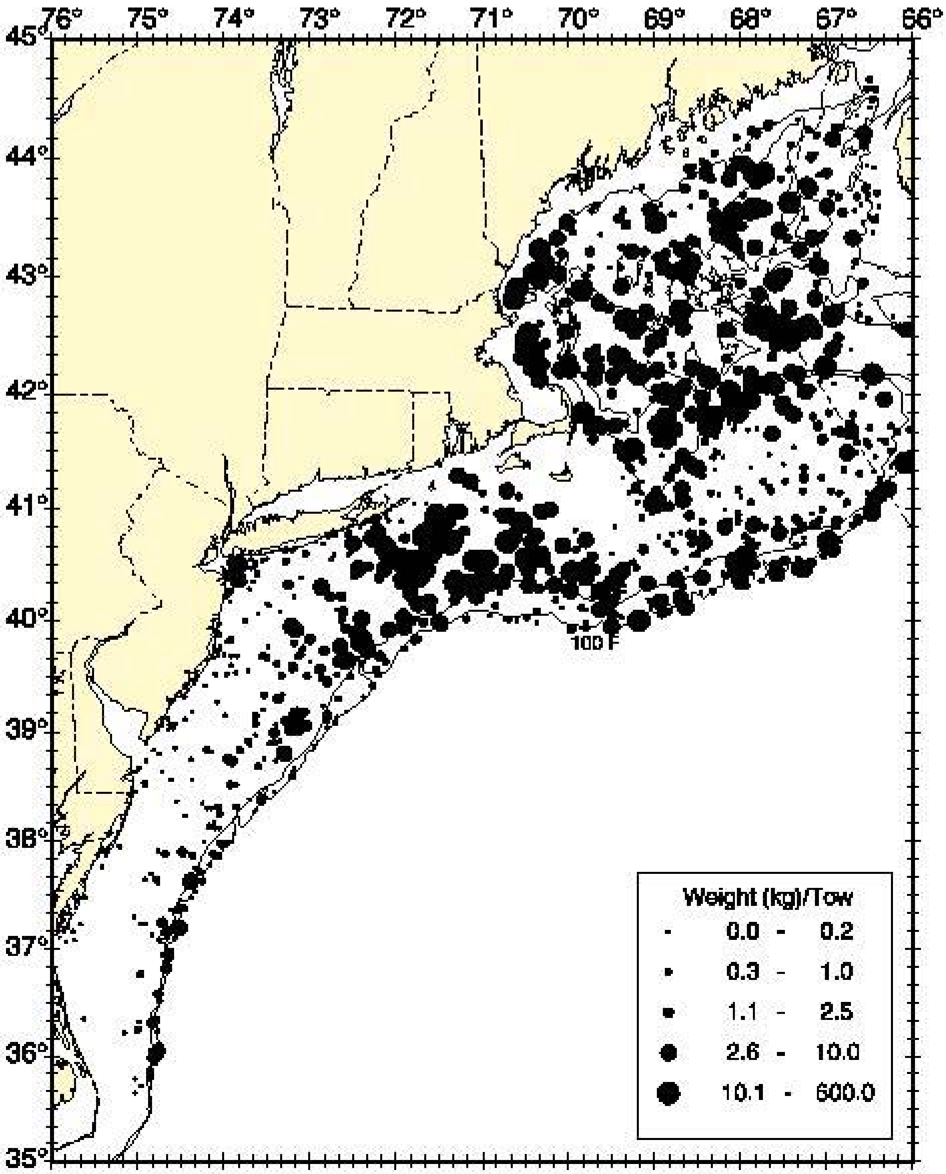
Distribution of Silver Hake during the NEFSC Autumn Bottom Trawl Surveys, 1963-1964.

Figure 9B. Silver hake autumn distribution, 1965-69.



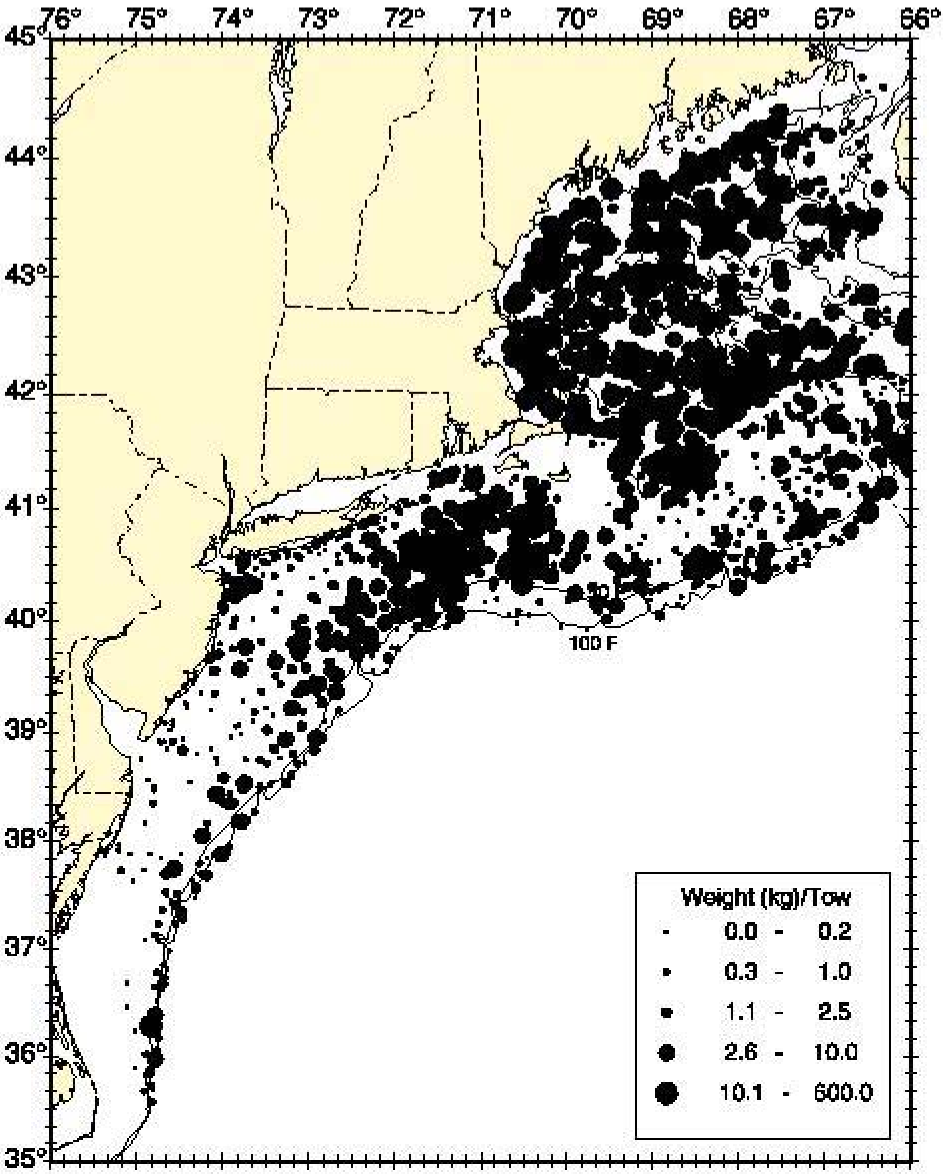
Distribution of Silver Hake during the NEFSC Autumn Bottom Trawl Surveys, 1965-1969.

Figure 9C. Silver hake autumn distribution, 1970-74.



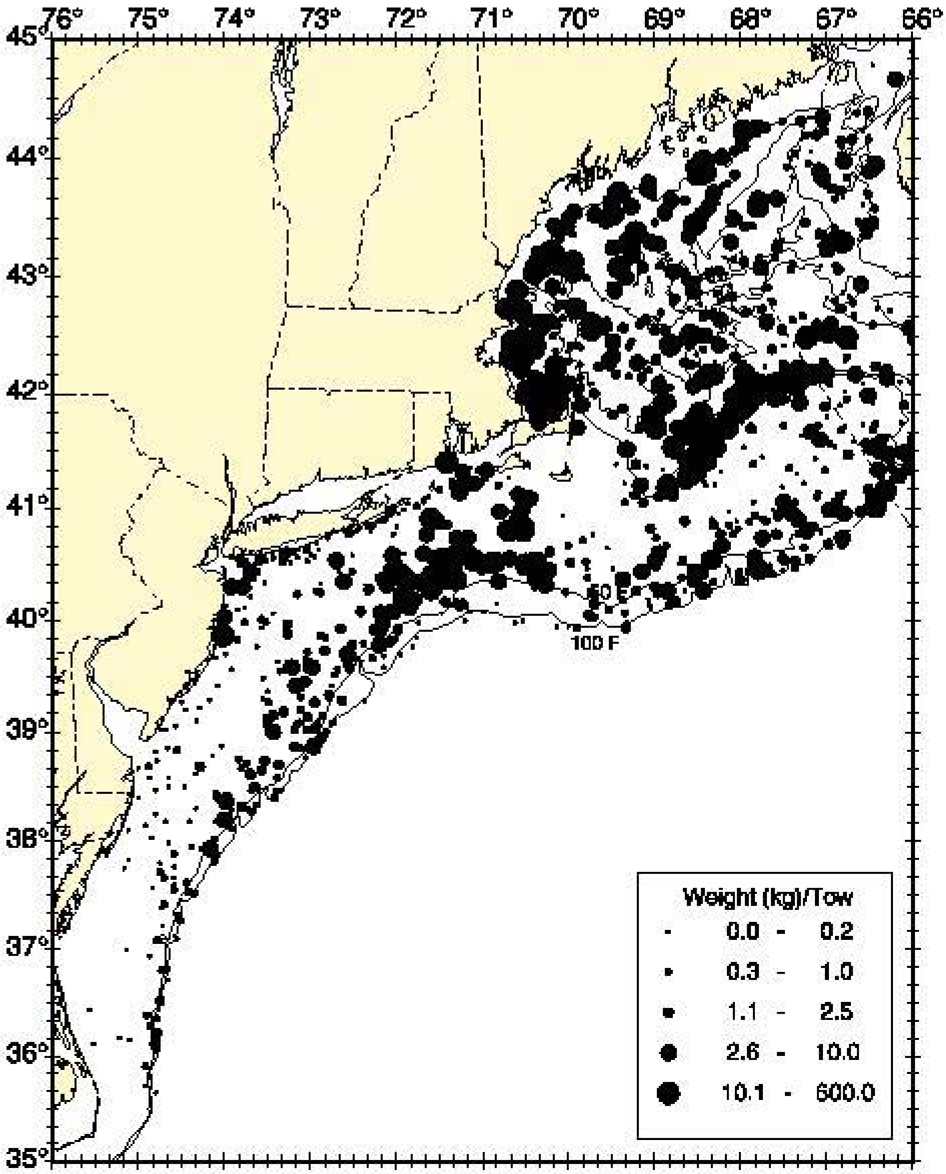
Distribution of Silver Hake during the NEFSC Autumn Bottom Trawl Surveys, 1970-1974.

Figure 9D. Silver hake autumn distribution, 1975-79.



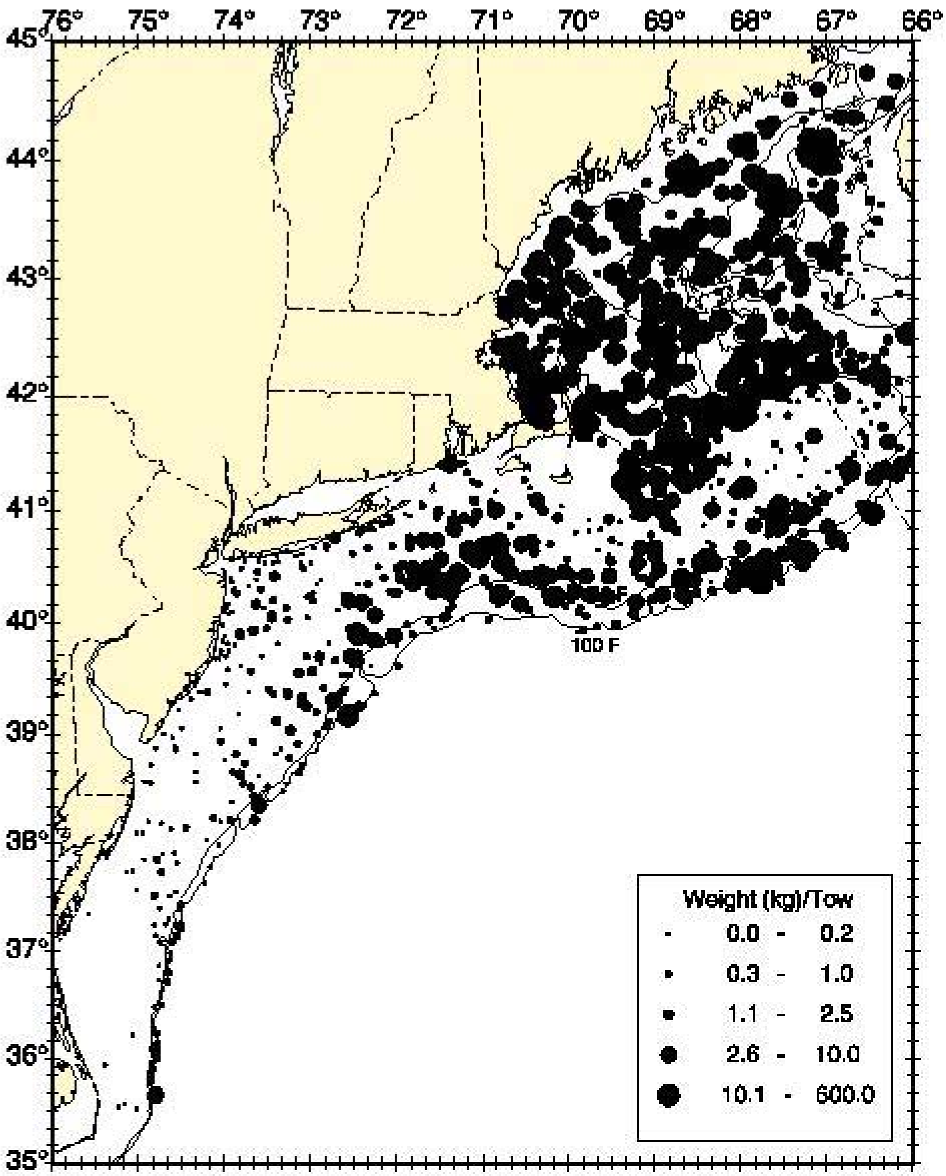
Distribution of Silver Hake during the NEFSC Autumn Bottom Trawl Surveys, 1975-1979.

Figure 9E. Silver hake autumn distribution, 1980-84.



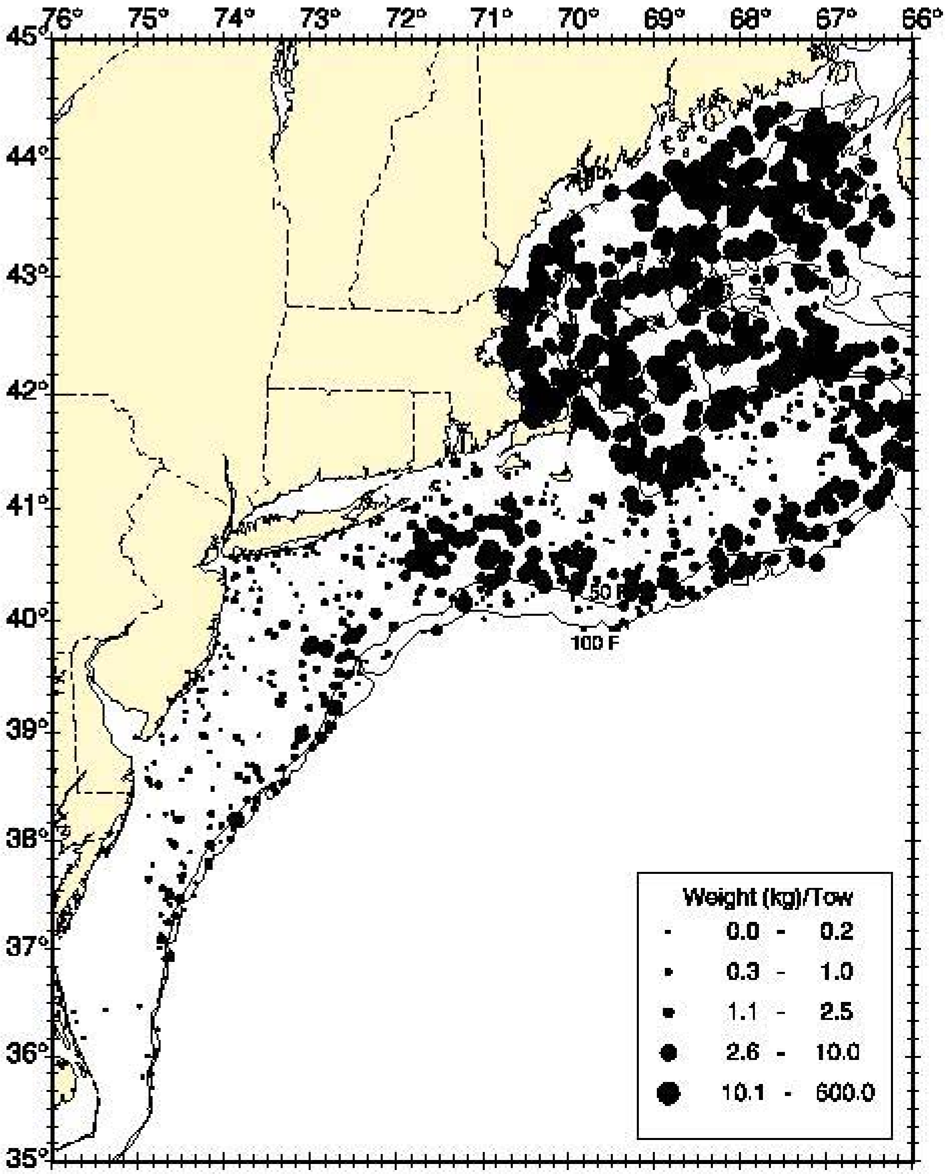
Distribution of Silver Hake during the NEFSC Autumn Bottom Trawl Surveys, 1980-1984.

Figure 9F. Silver hake autumn distribution, 1985-89.



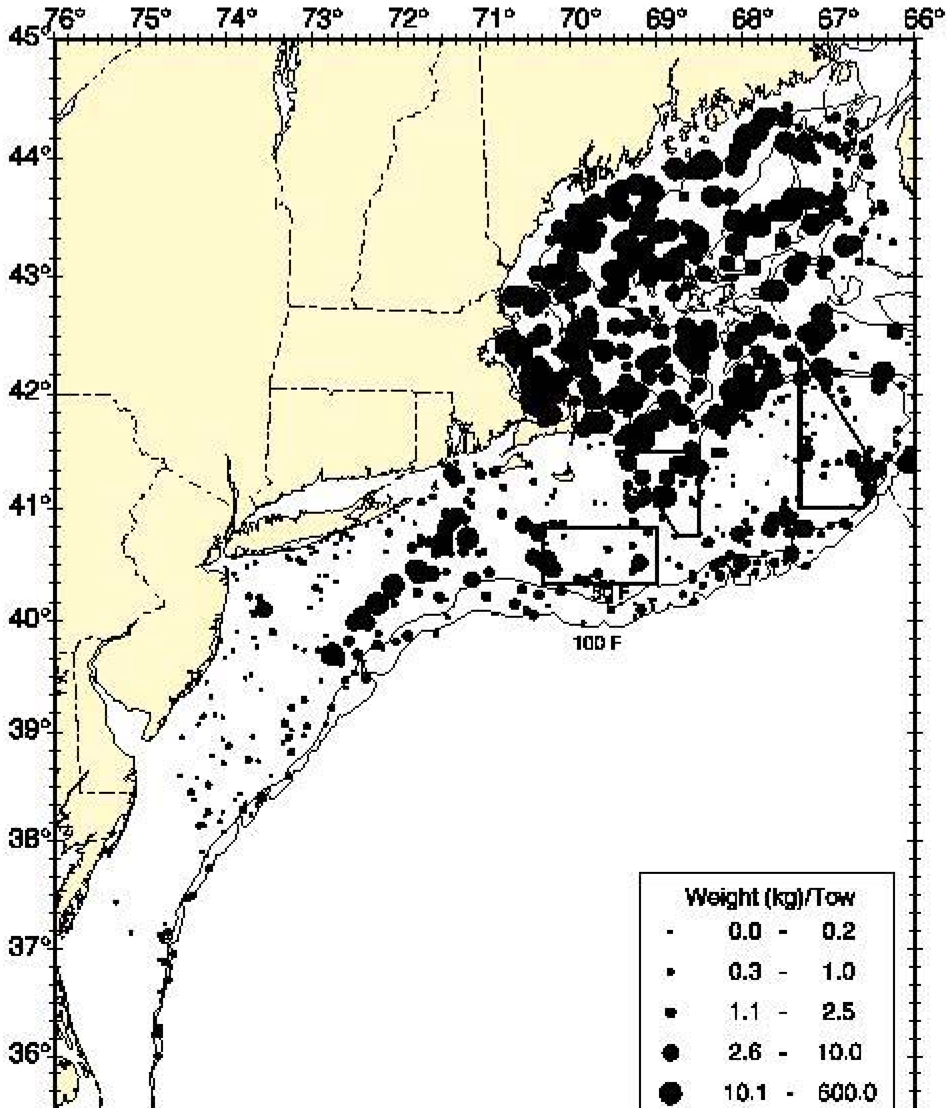
Distribution of Silver Hake during the NEFSC Autumn Bottom Trawl Surveys, 1985-1989.

Figure 9G. Silver hake autumn distribution, 1990-94.



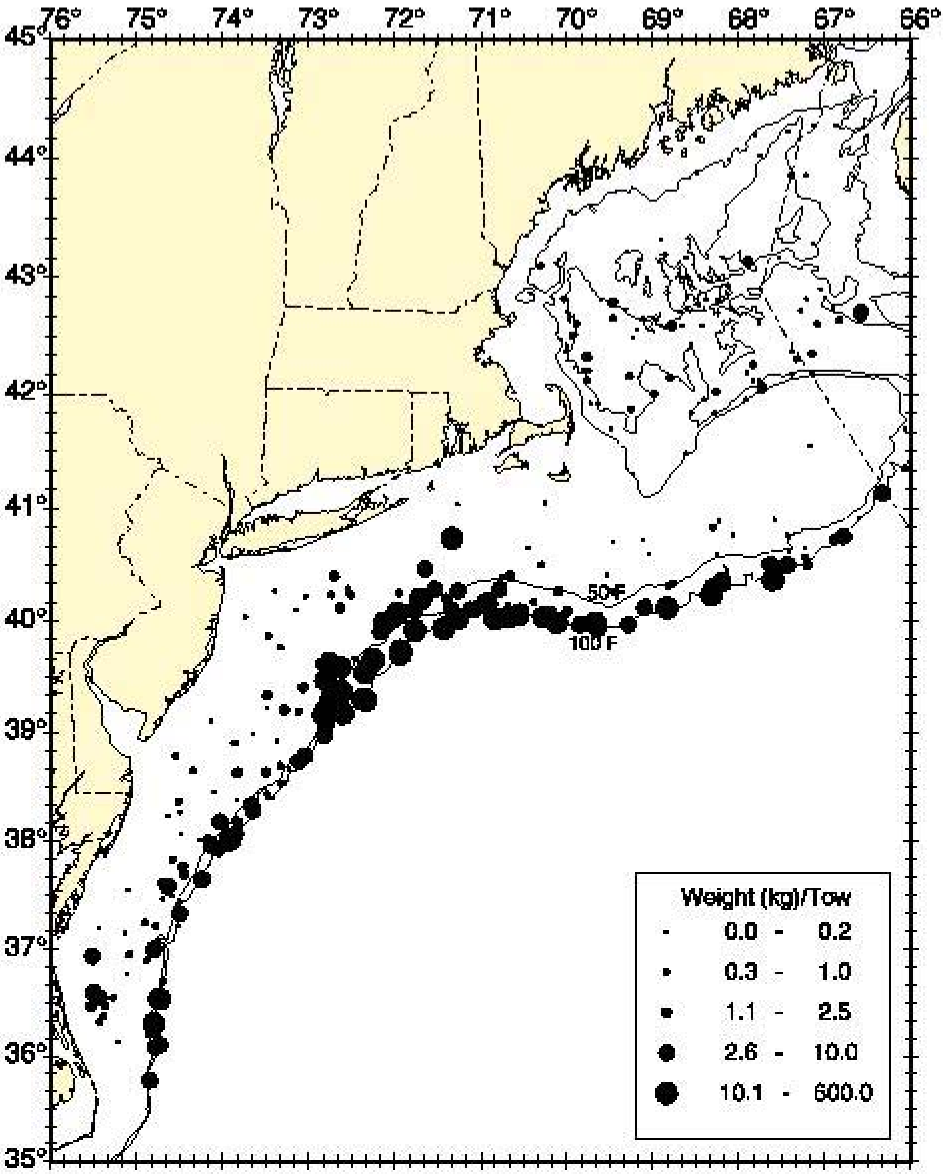
Distribution of Silver Hake during the NEFSC Autumn Bottom Trawl Surveys, 1990-1994.

Figure 9H. Silver hake autumn distribution, 1995-98, in relation to groundfish closed areas.



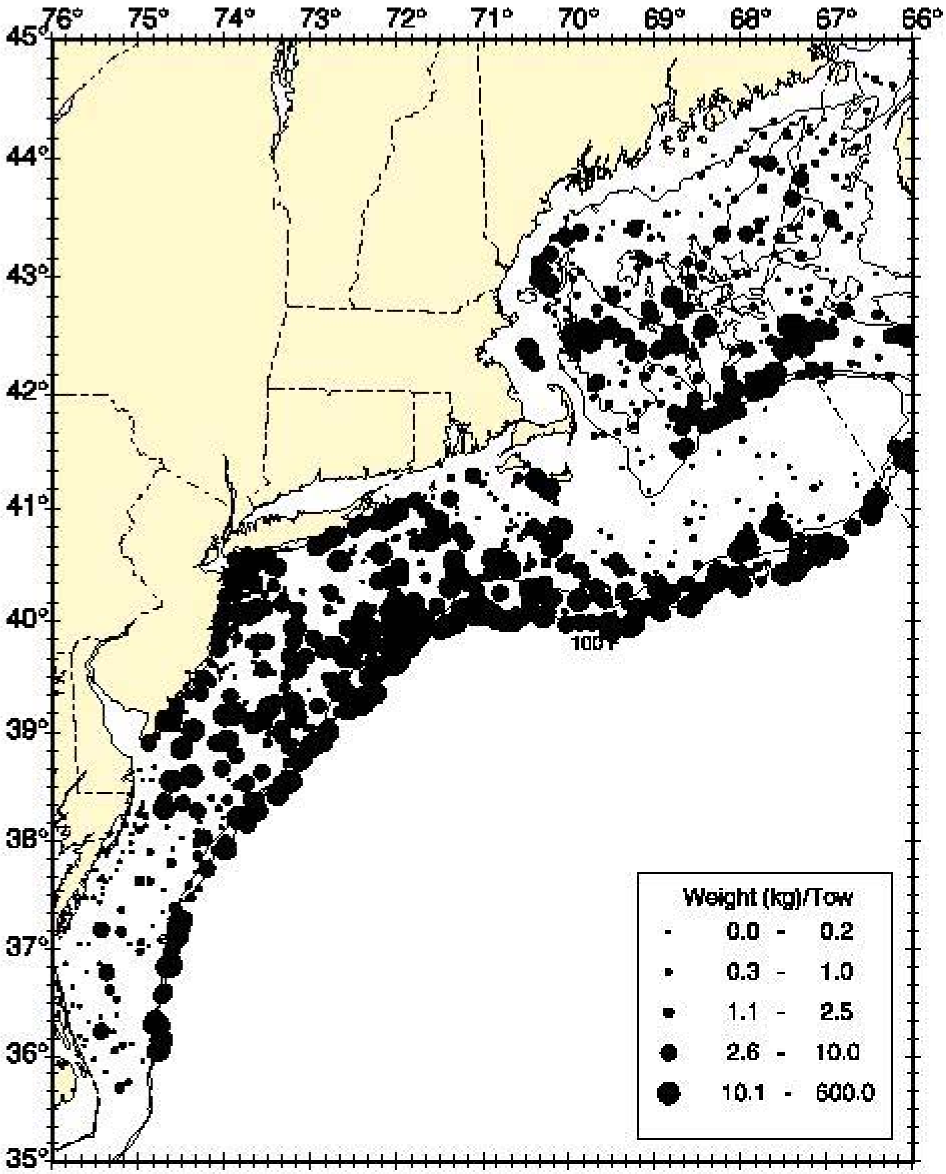
Distribution of Silver Hake during the NEFSC Autumn Bottom Trawl Surveys, 1995-1998.

Figure 9I. Silver hake spring distribution, 1968-69.



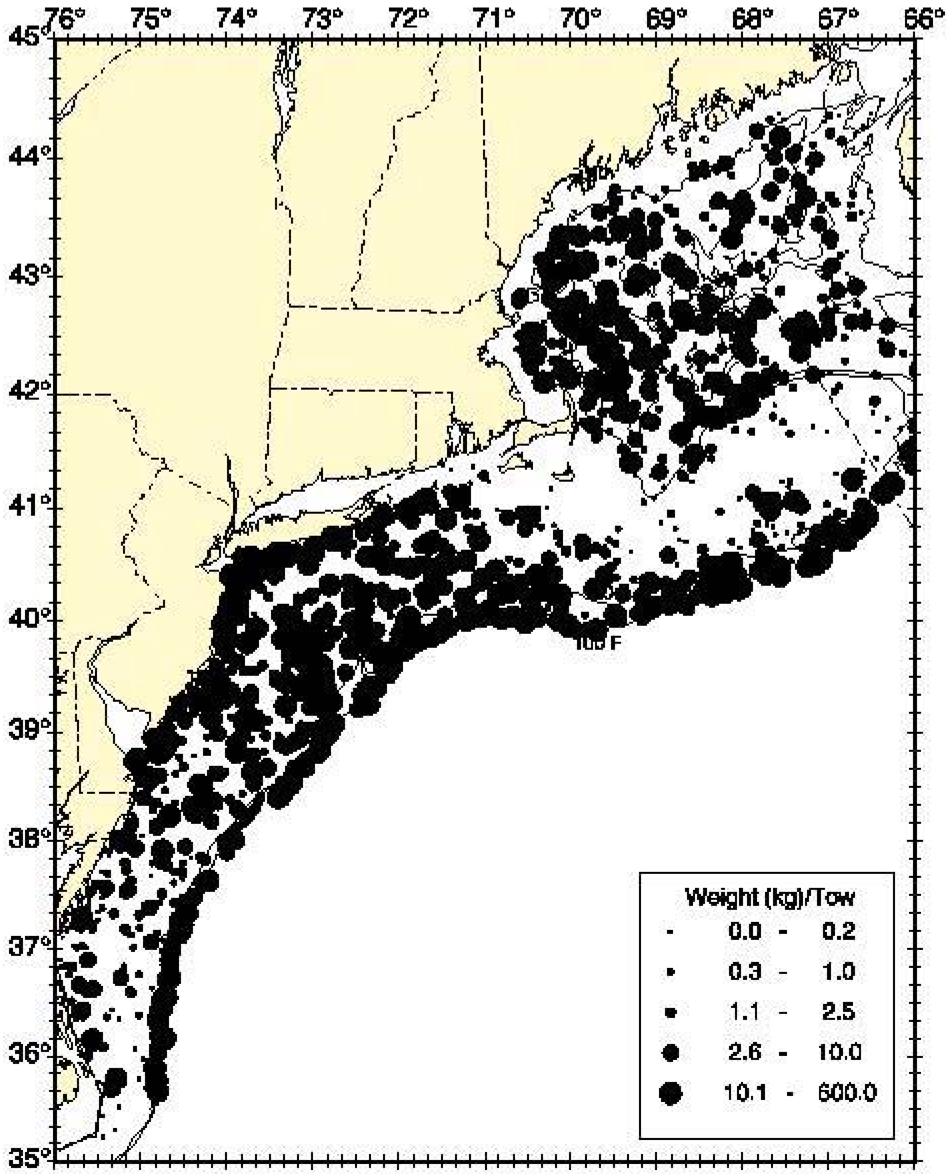
Distribution of Silver Hake during the NEFSC Spring Bottom Trawl Surveys, 1968-1969.

Figure 9J. Silver hake spring distribution, 1970-74.



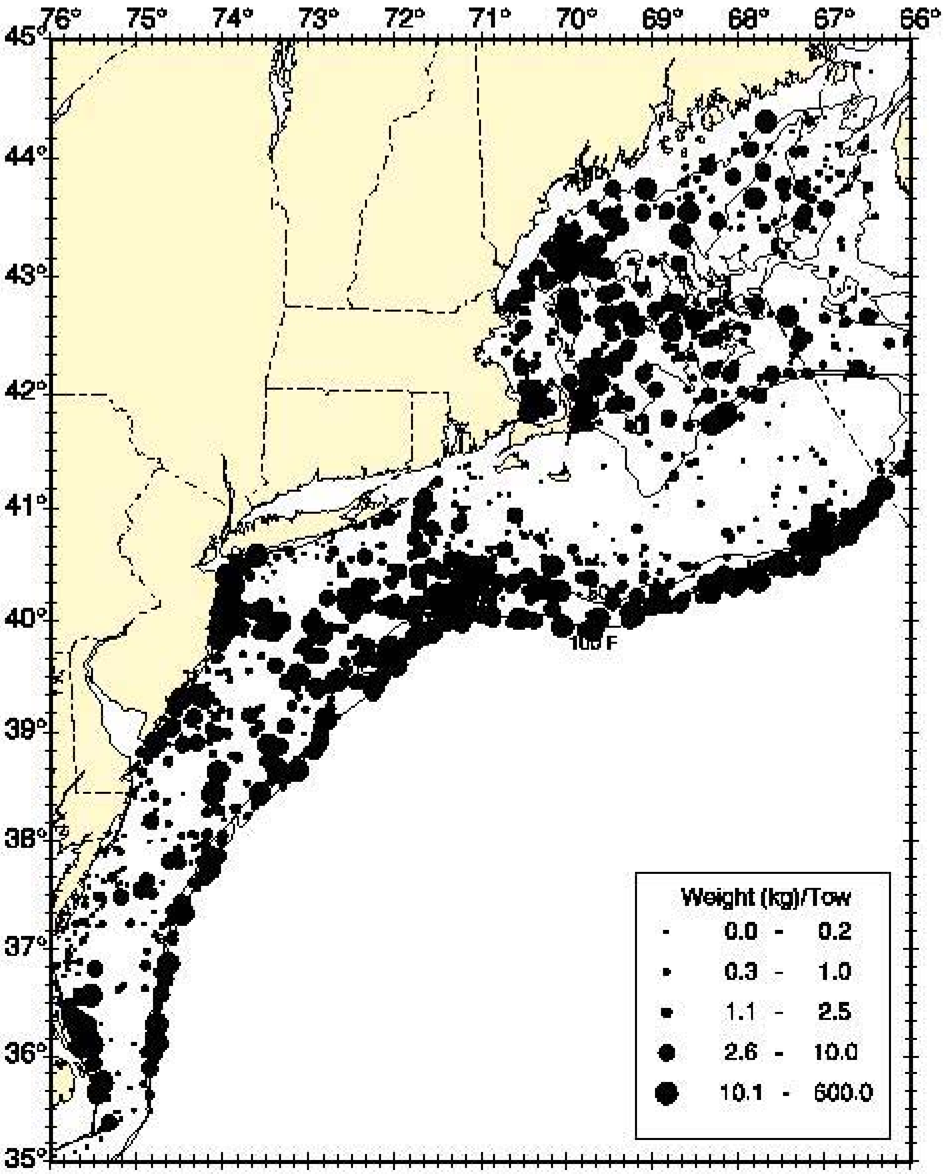
Distribution of Silver Hake during the NEFSC Spring Bottom Trawl Surveys, 1970-1974.

Figure 9K. Silver hake spring distribution, 1975-79.



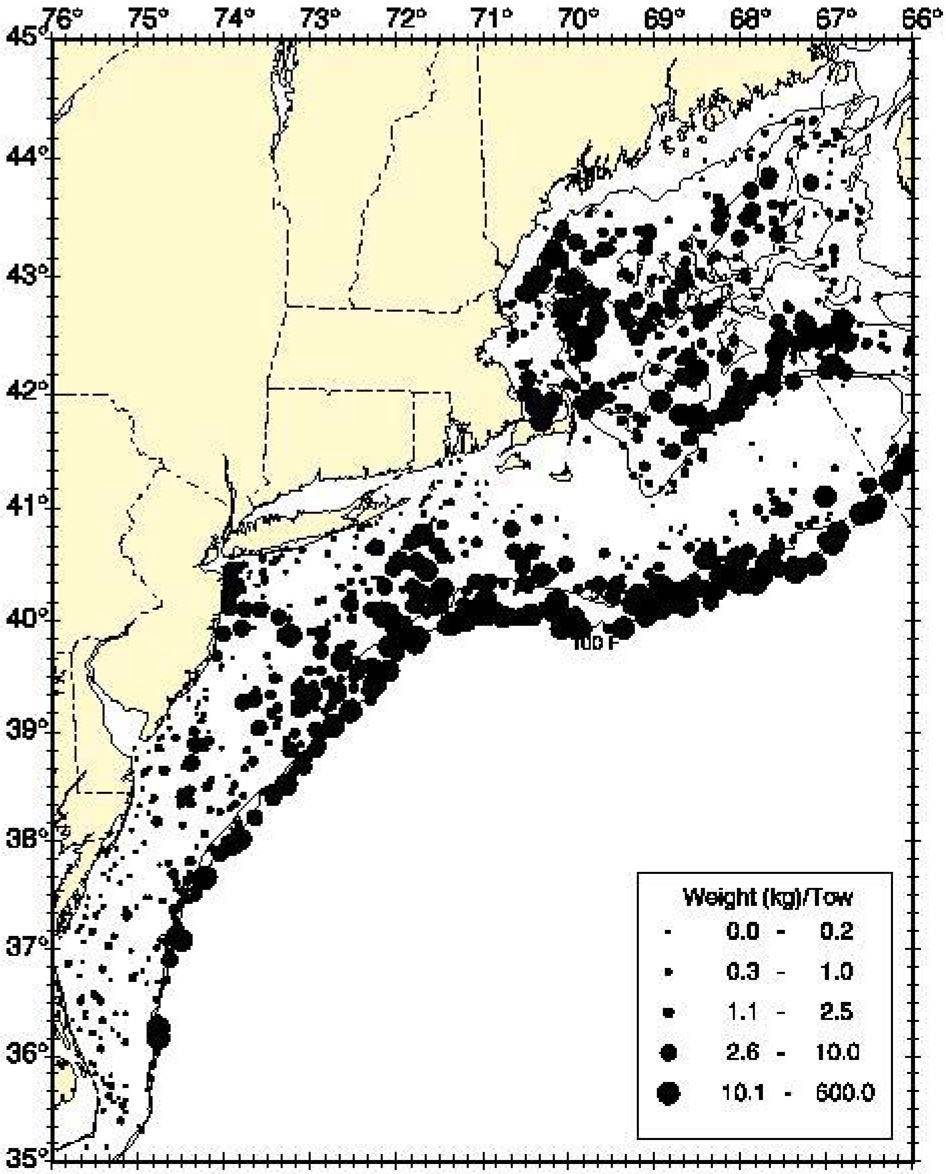
Distribution of Silver Hake during the NEFSC Spring Bottom Trawl Surveys, 1975-1979.

Figure 9L. Silver hake spring distribution, 1980-84.



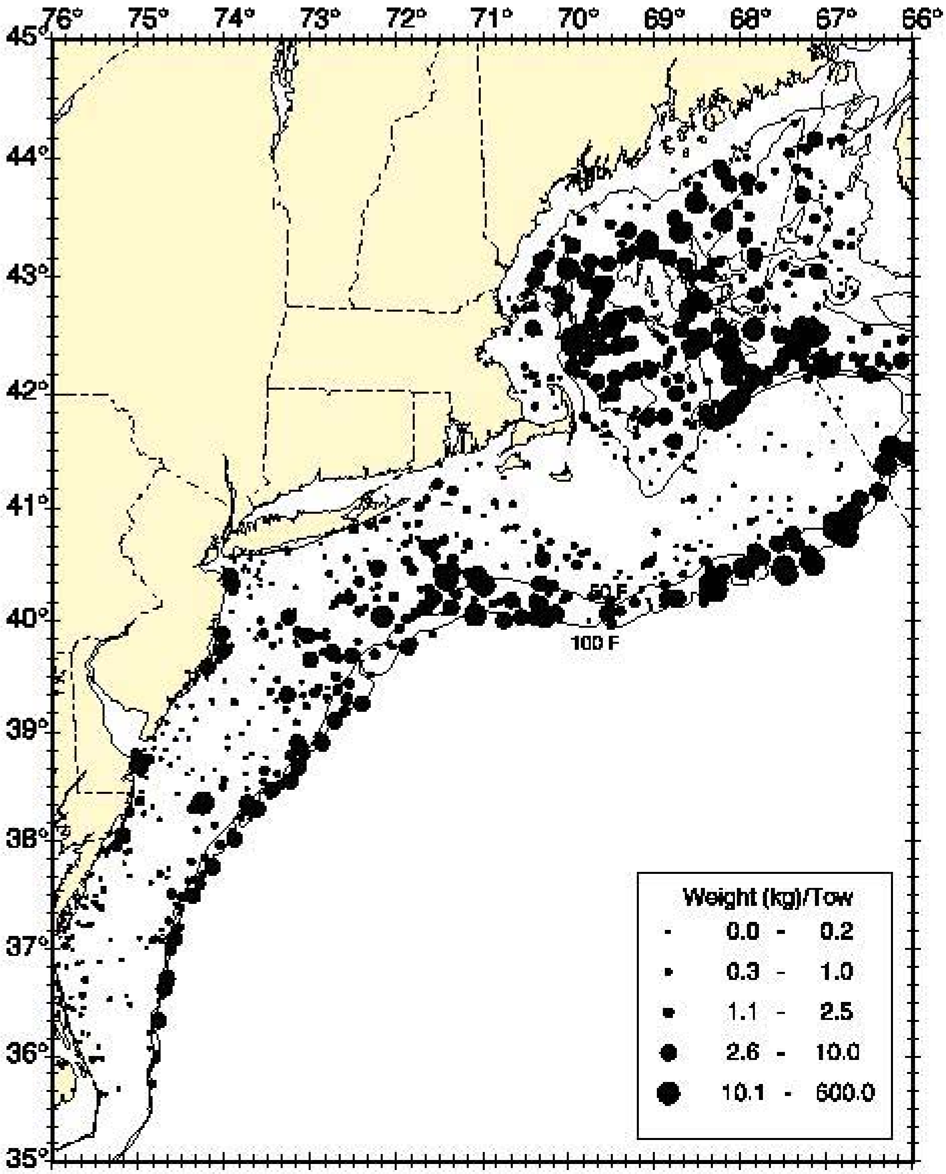
Distribution of Silver Hake during the NEFSC Spring Bottom Trawl Surveys, 1980-1984.

Figure 9M. Silver spring hake distribution, 1985-89.



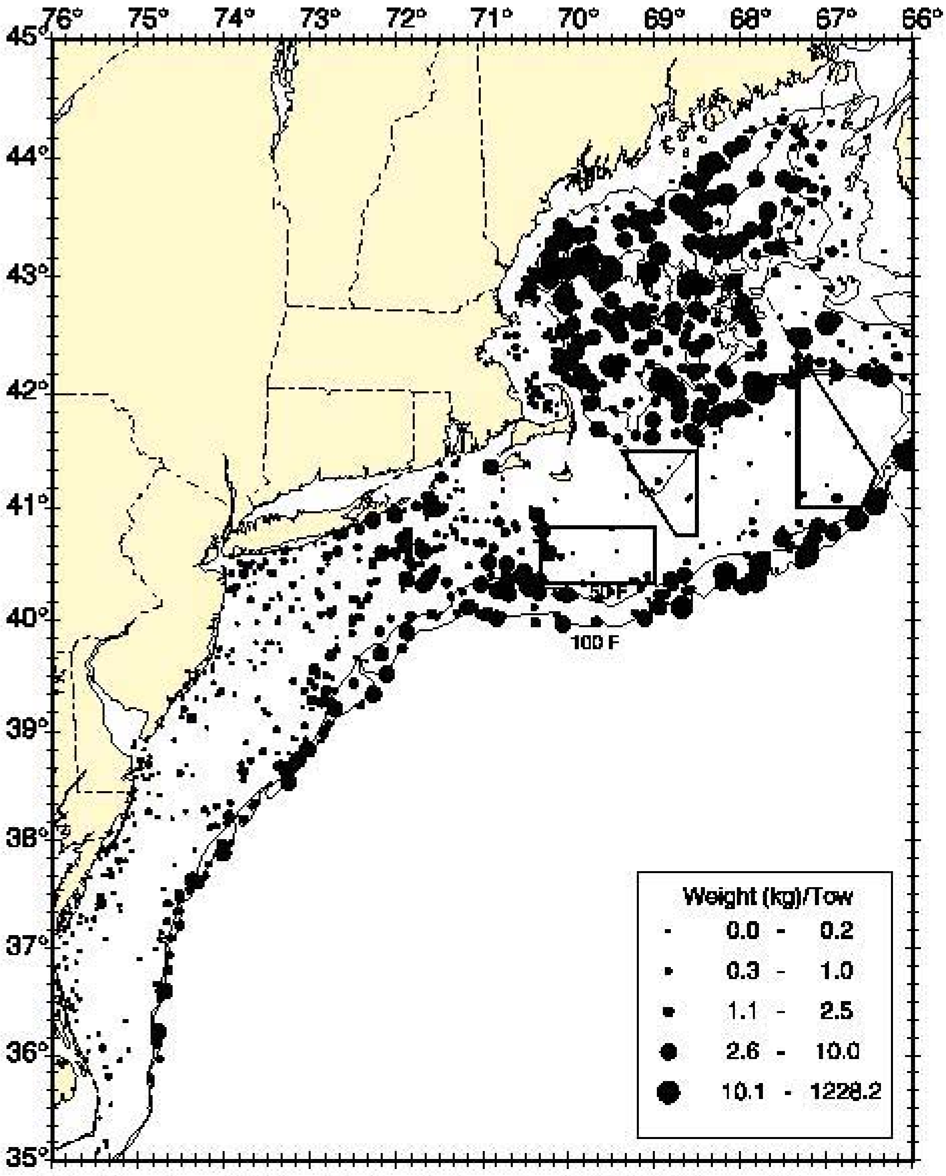
Distribution of Silver Hake during the NEFSC Spring Bottom Trawl Surveys, 1985-1989.

Figure 9N. Silver hake spring distribution, 1990-94.



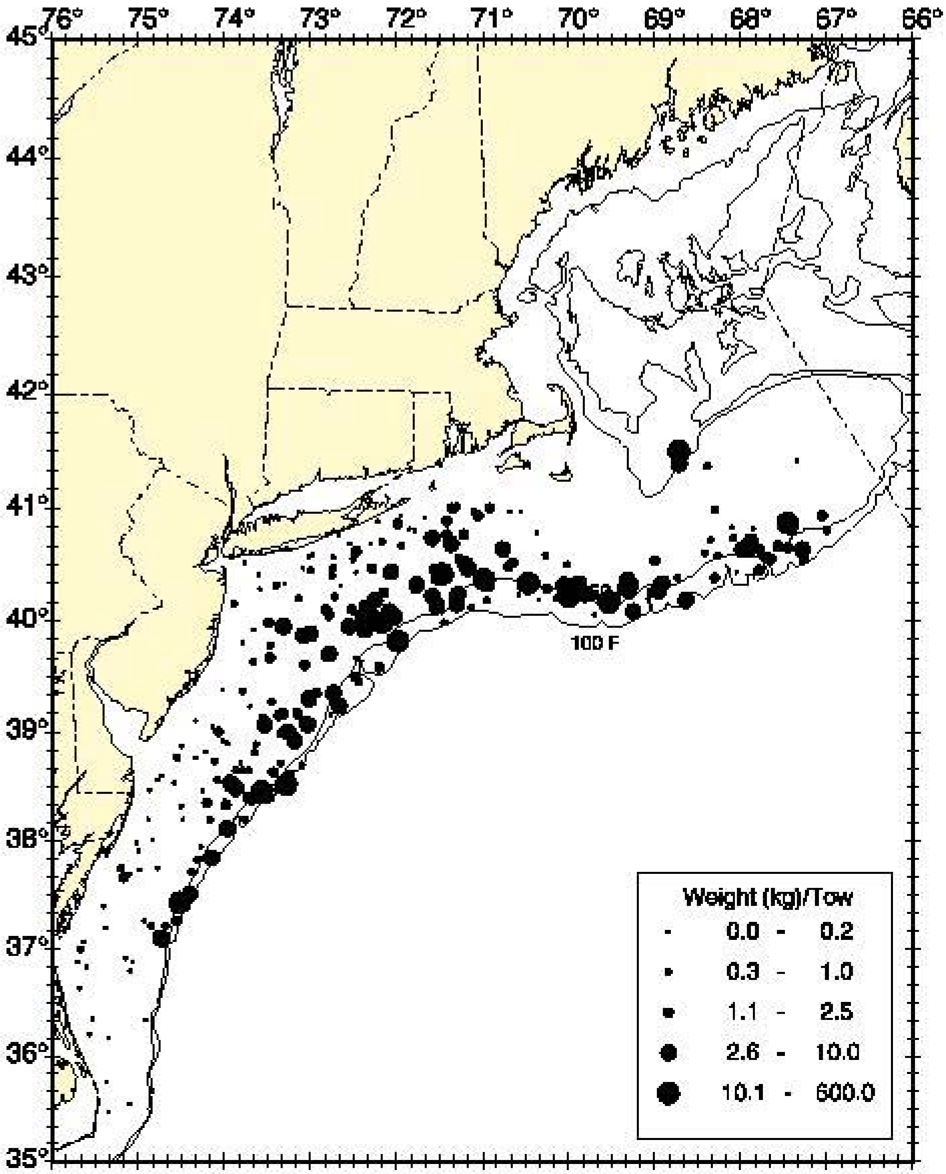
Distribution of Silver Hake during the NEFSC Spring Bottom Trawl Surveys, 1990-1994.

Figure 9O. Silver hake spring distribution, 1995-99, in relation to groundfish closed areas.



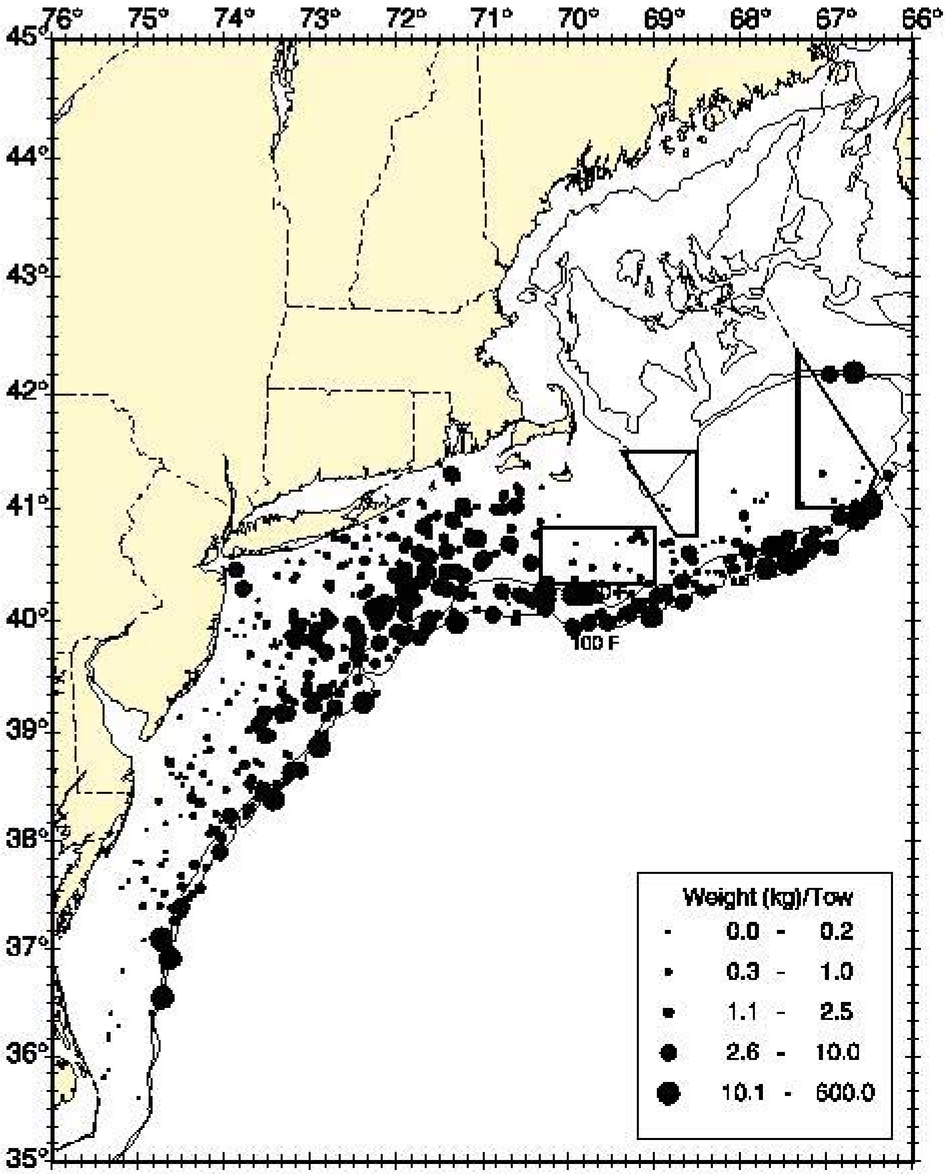
Distribution of Silver Hake during the NEFSC Spring Bottom Trawl Surveys, 1995-1999.

Figure 9P. Silver hake winter distribution, 1992-94.



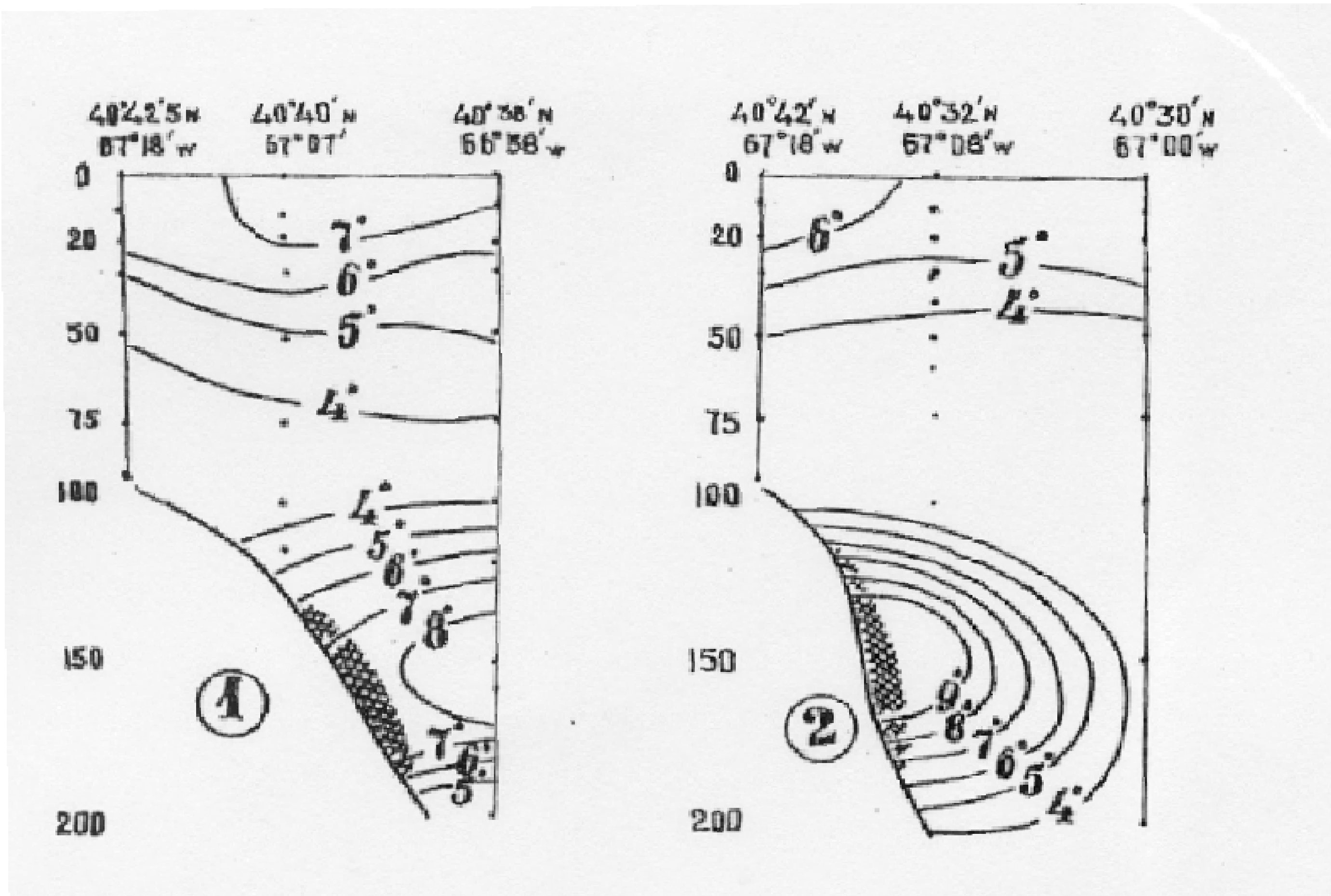
Distribution of Silver Hake during the NEFSC Winter Bottom Trawl Surveys, 1992-1994.

Figure 9Q. Silver hake winter distribution, 1995-99, in relation to groundfish closed areas.



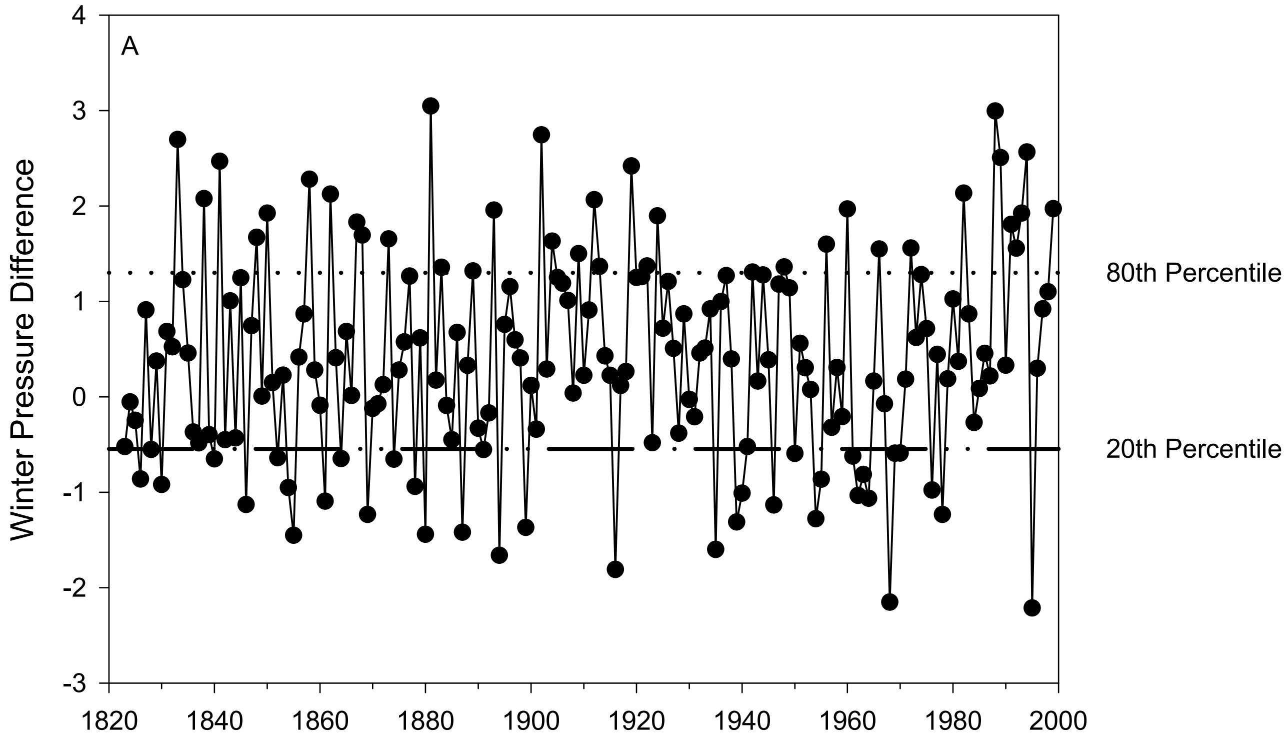
Distribution of Silver Hake during the NEFSC Winter Bottom Trawl Surveys, 1995-1999.

Figure 10. Water temperature distribution at depth (m) near silver hake concentrations (dark circles) at Lydonia Canyon during May 1964 from Sarnits and Sauskan (1966).



USSRG4_FIG 8

Figure 11. North Atlantic Oscillation index (A) and smoothed index (B), 1823-1999, derived from Jones et al. (1997).



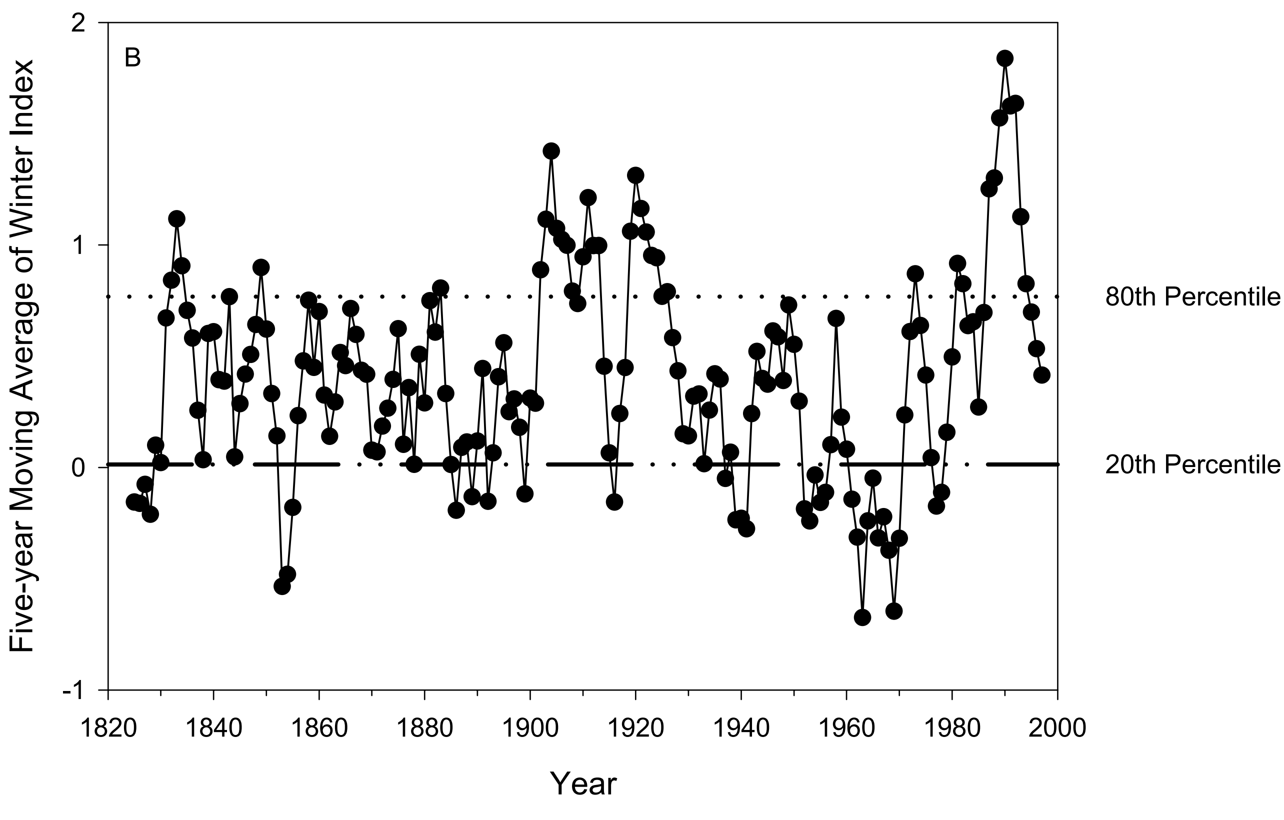


Figure 12. Silver hake fishery yields by stock area, 1955-1999.

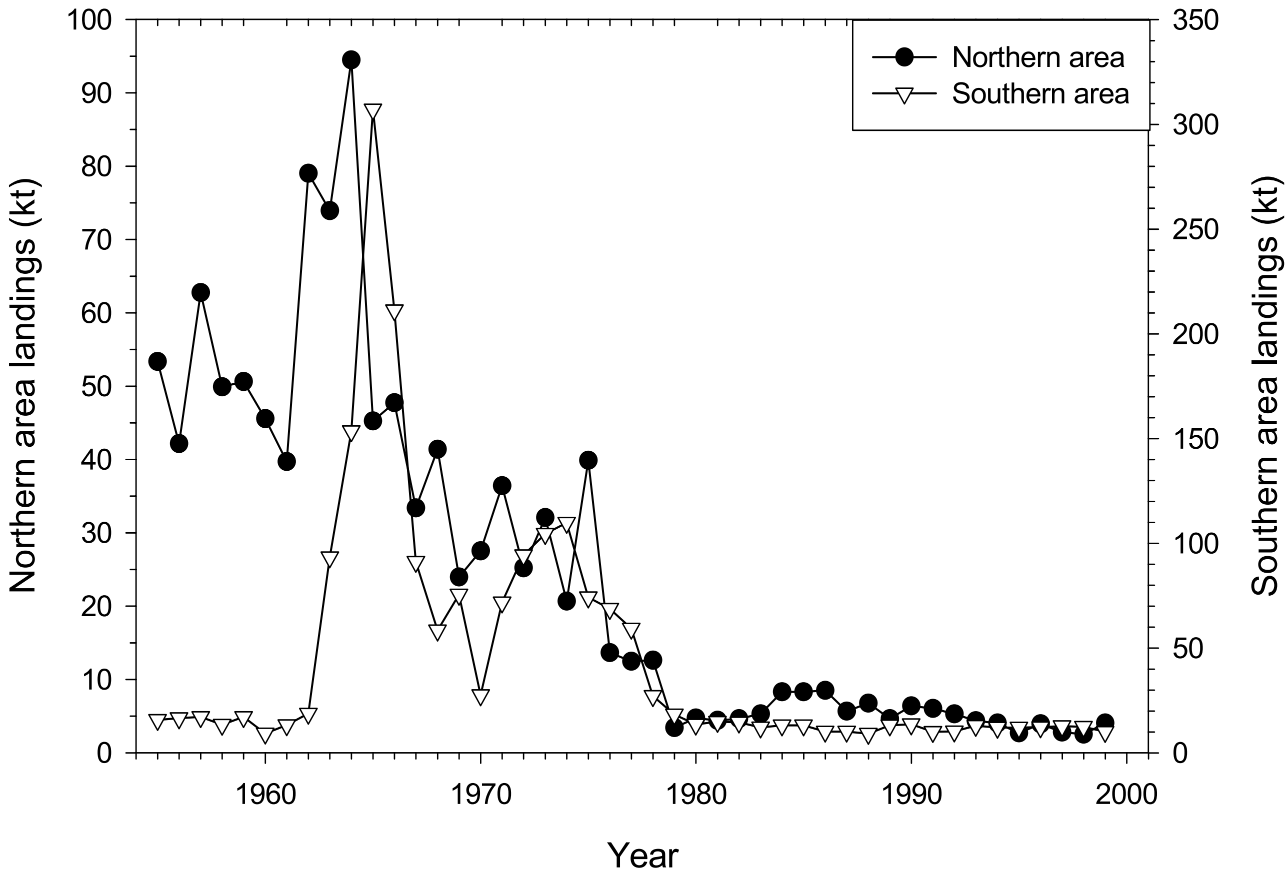


Figure 13. Mean lengths of silver hake in commercial market category samples, 1993-1999.

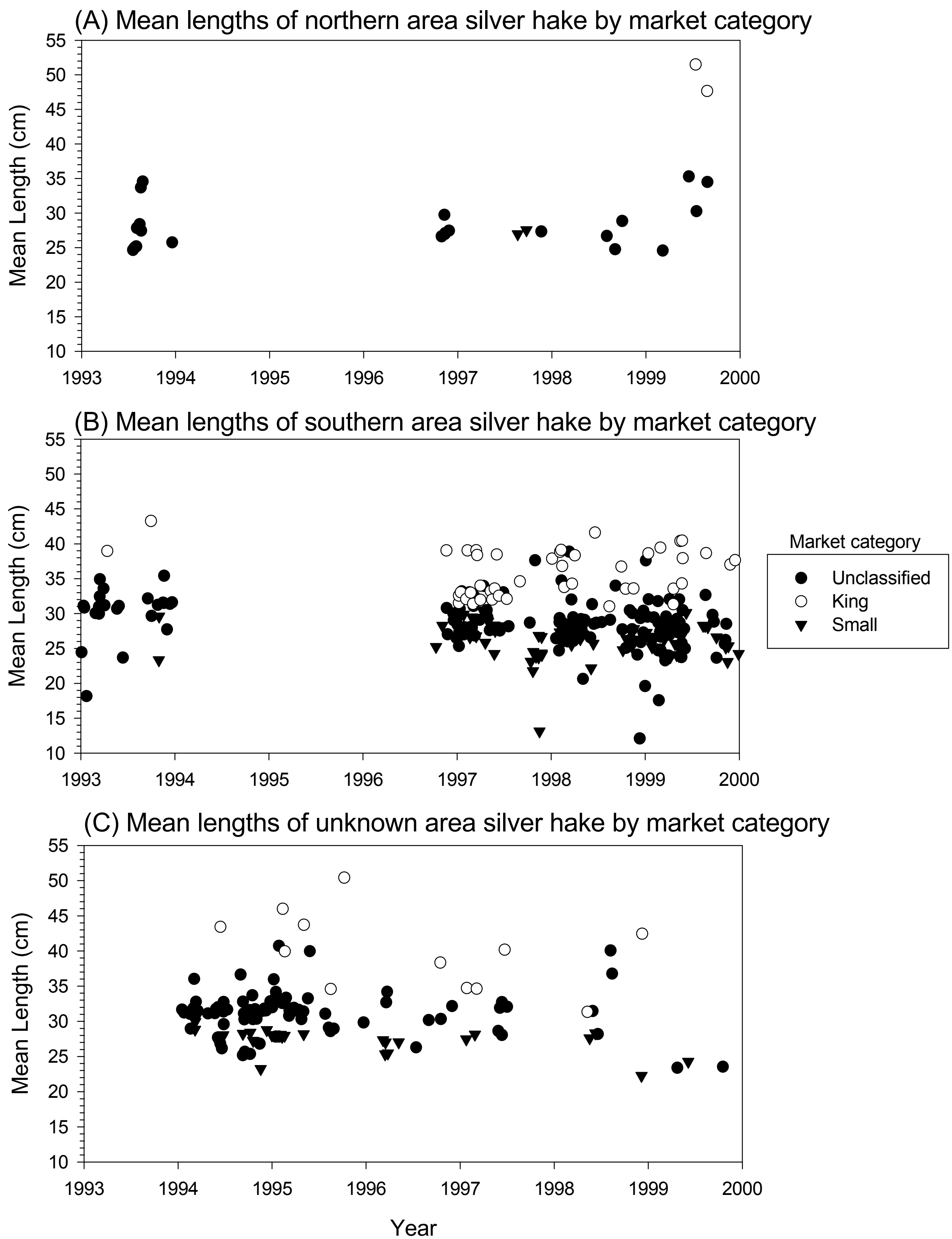


Figure 14. Length frequency distributions of silver hake landings, 1993-1999.

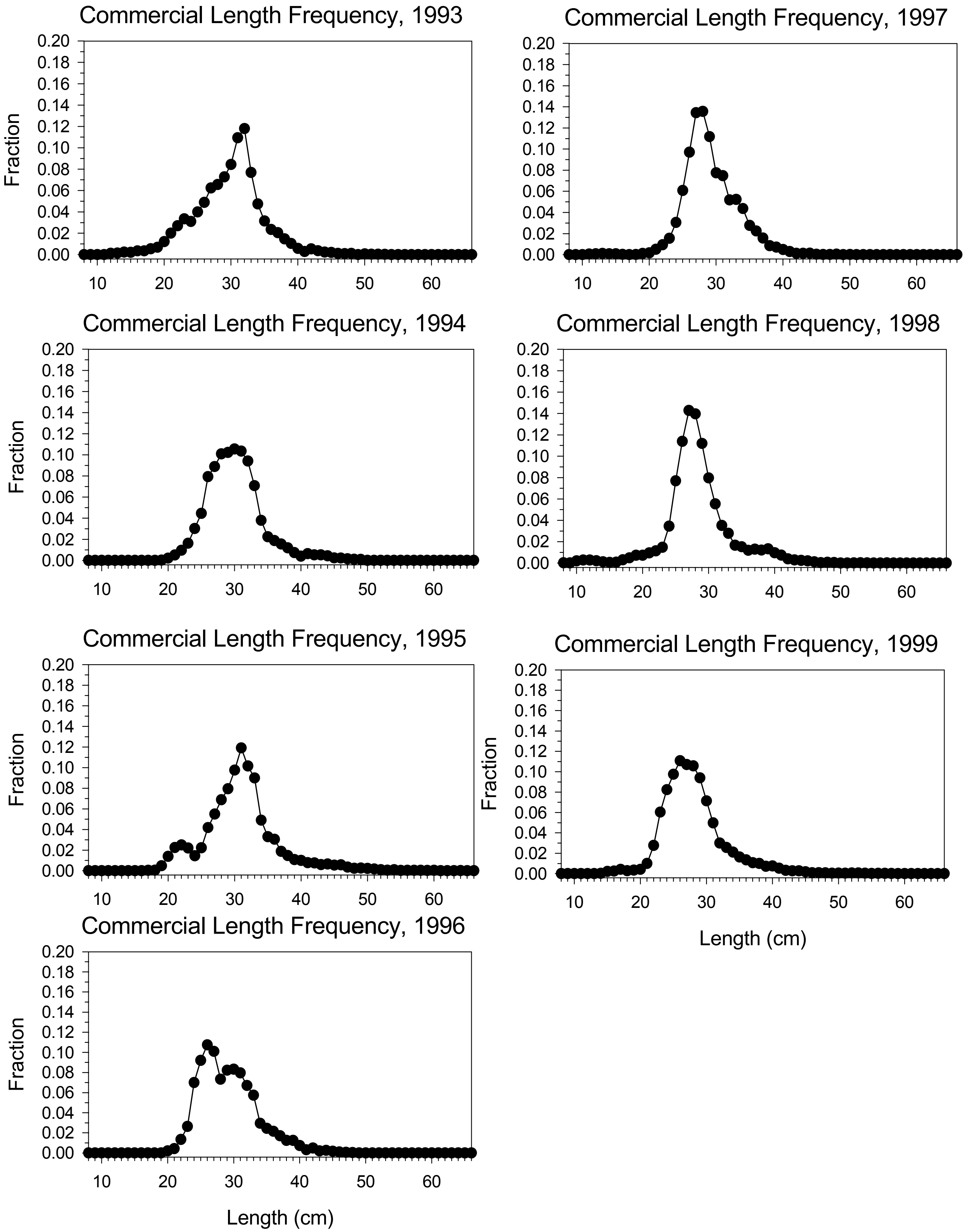


Figure 15. Silver Hake Landings at Age, 1955-1999.

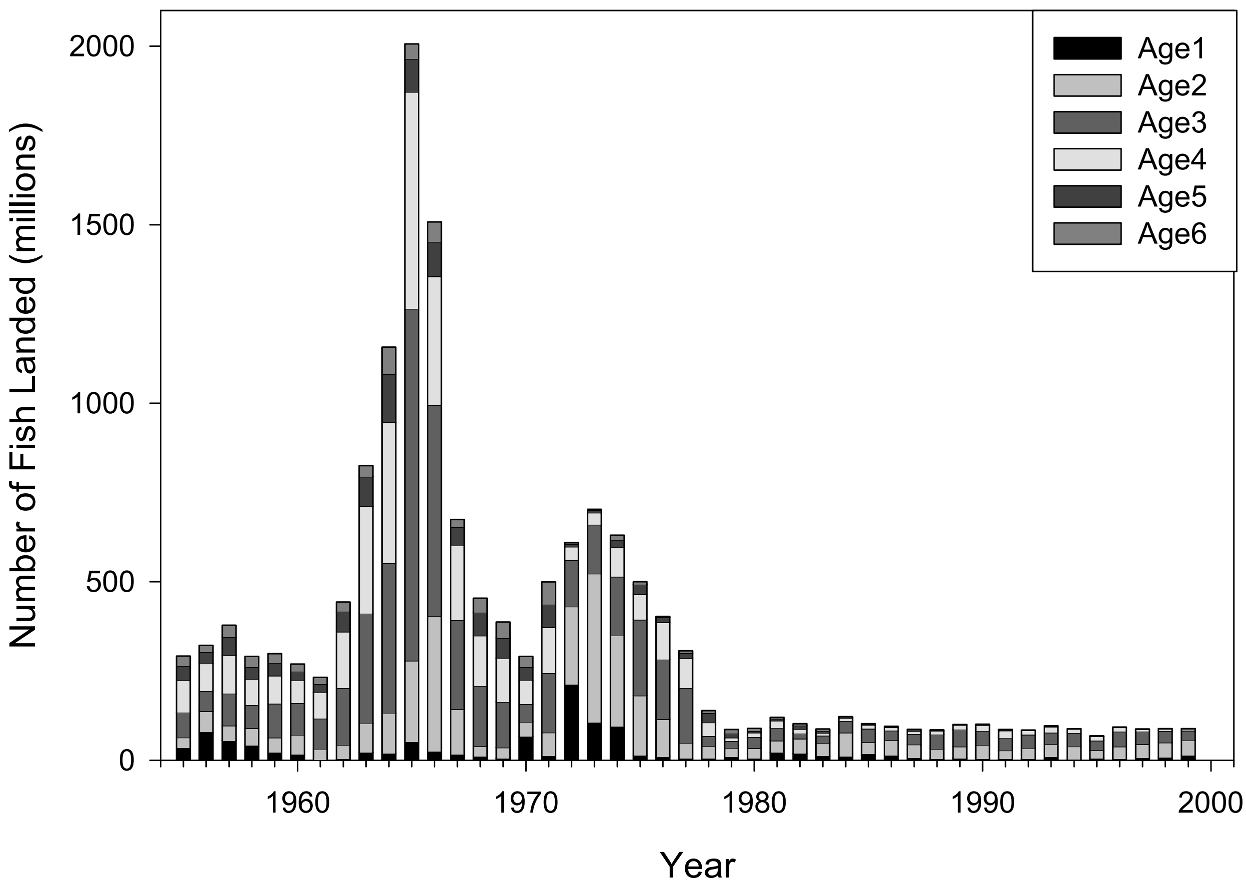
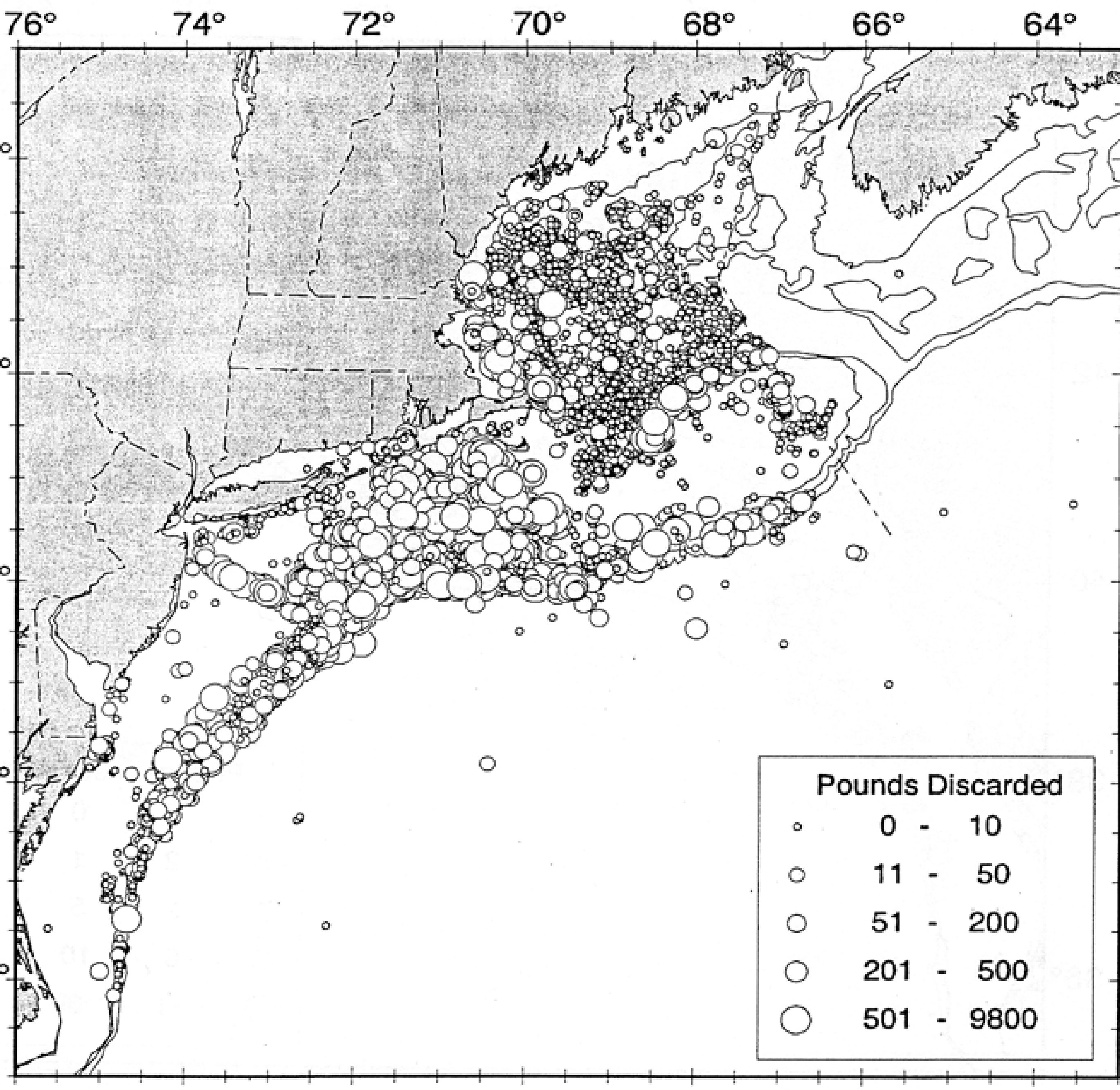


Figure 16. Spatial pattern of silver hake discard by otter trawls, 1989-1999.



Silver Hake
Otter Trawl Discards 1989-1999

Figure 17. Spatial pattern of silver hake discard by scallop dredges, 1989-1999.

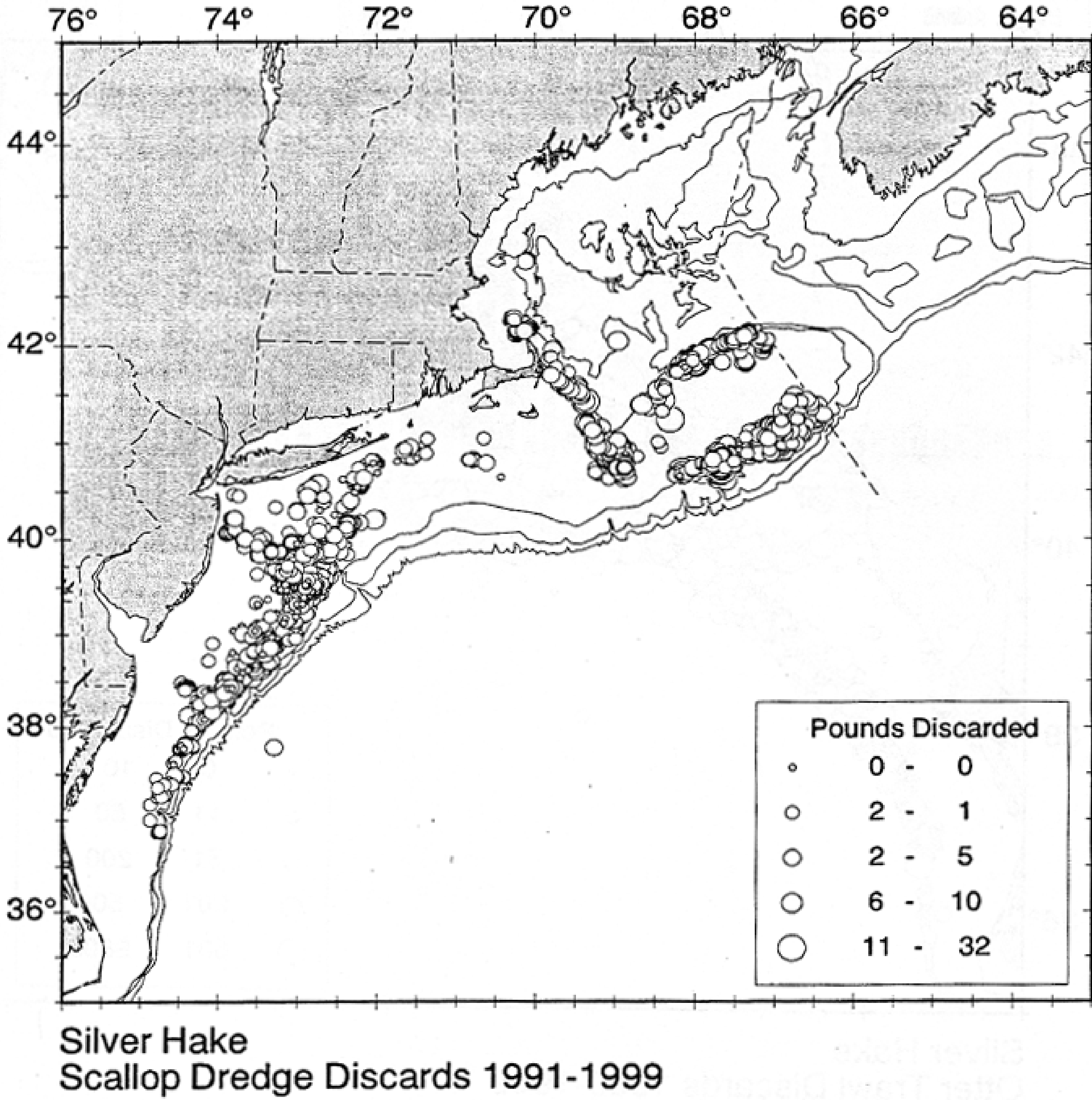
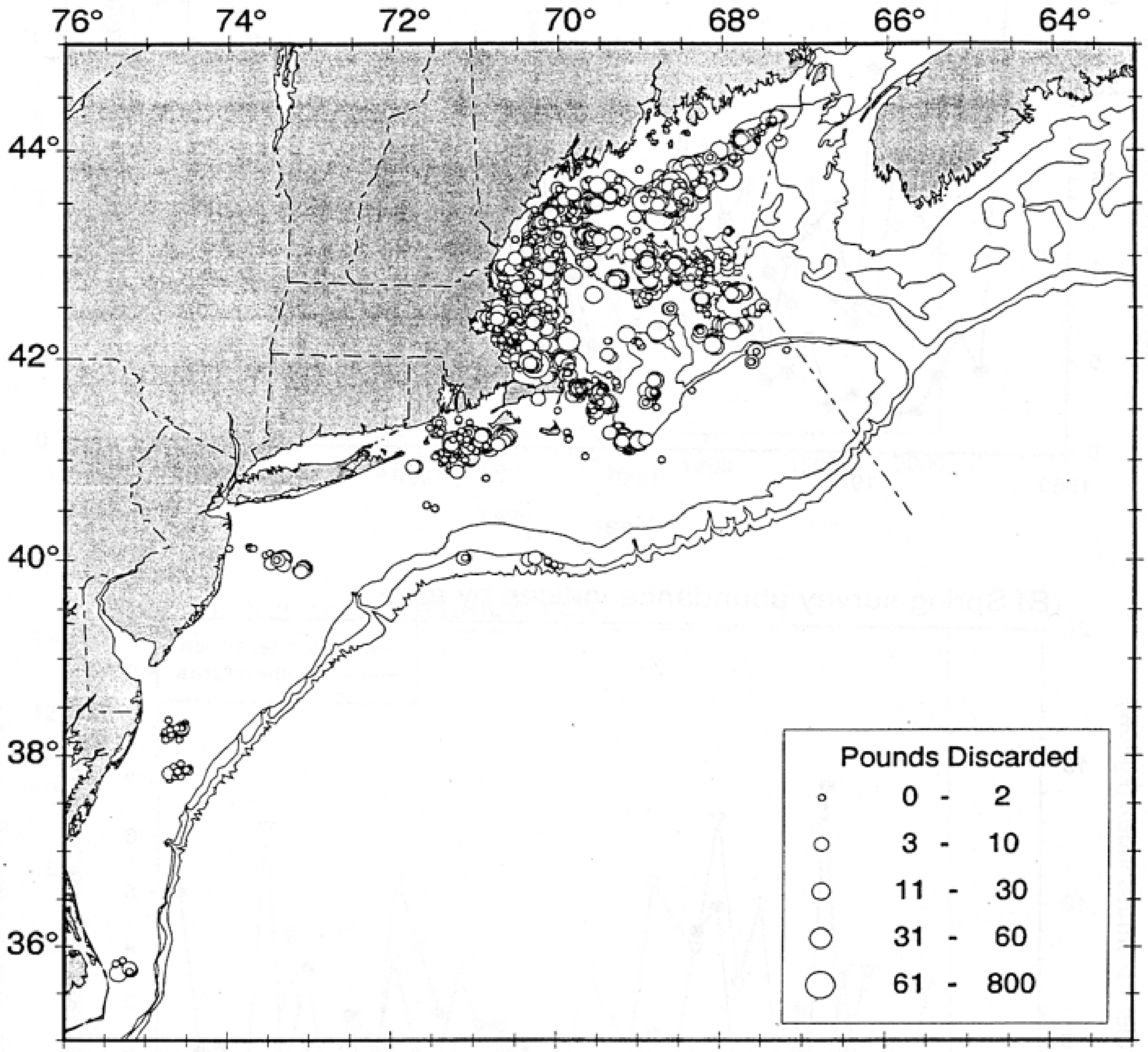
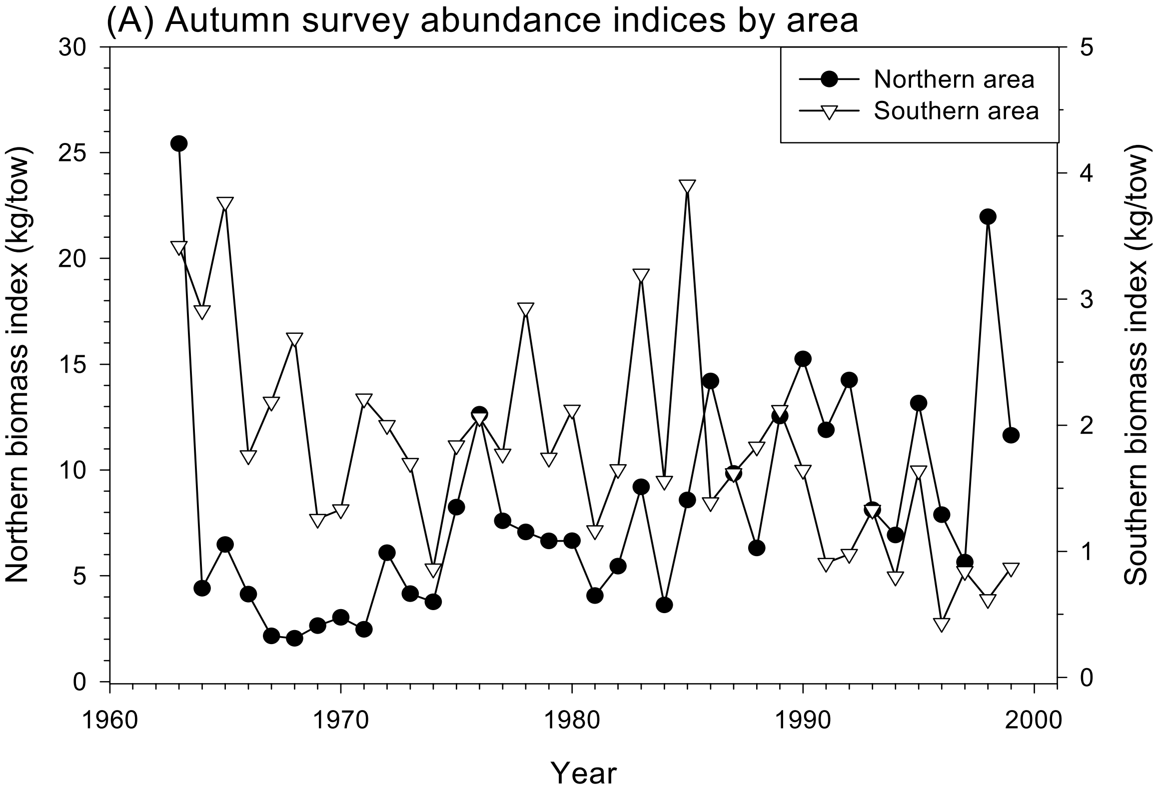


Figure 18. Spatial pattern of silver hake discard by sink gill nets, 1989-1999.



Silver Hake
Sink Gill Net Discards 1989-1999

Figure 19. Silver hake survey biomass indices by area.



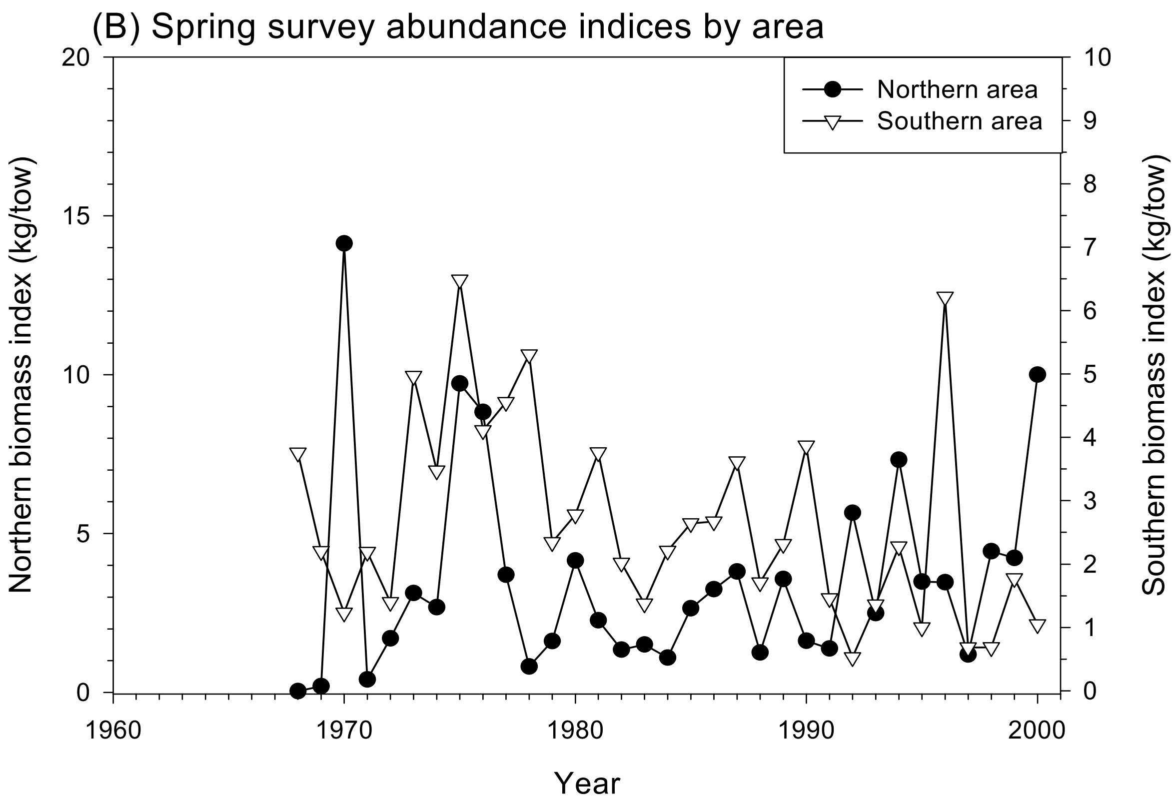


Figure 20. Silver hake survey biomass indices for the combined stock area.

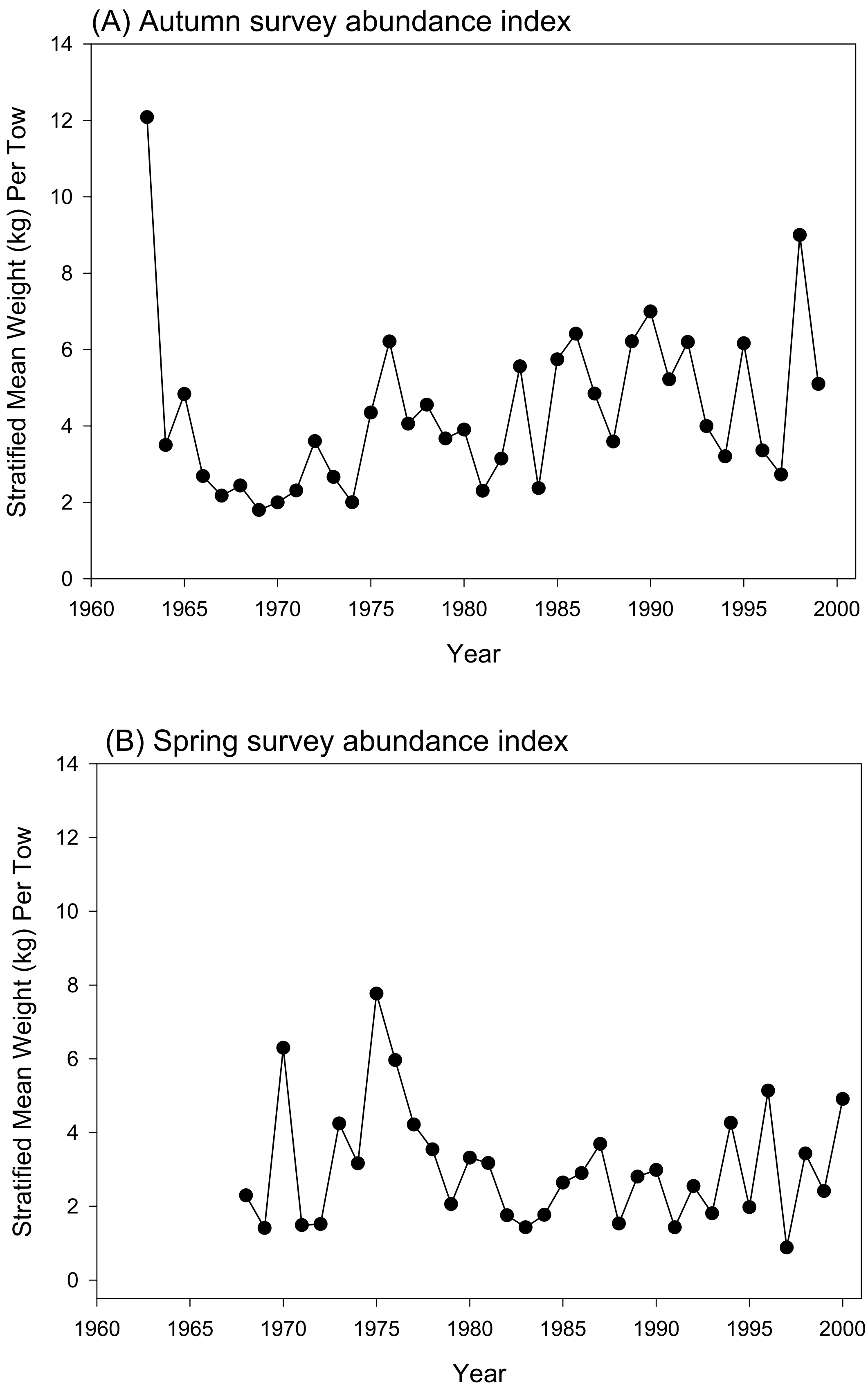
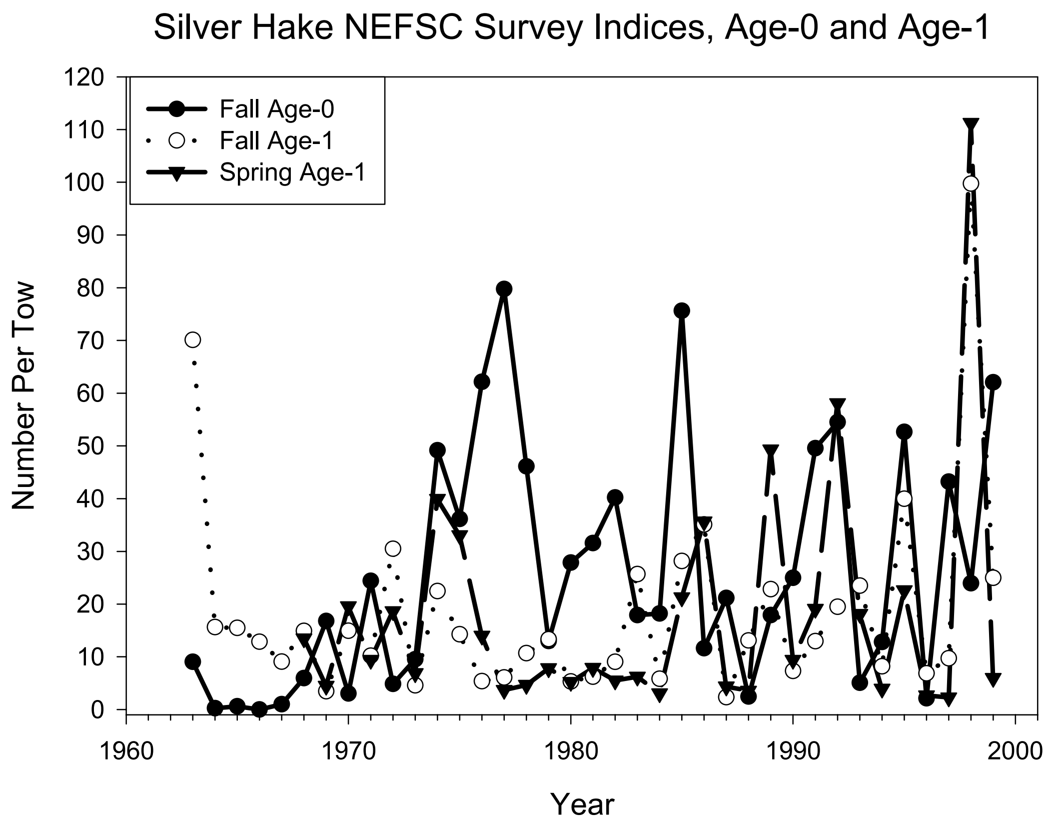


Figure 21. Silver hake survey indices, age-0, age-1, and age-2.



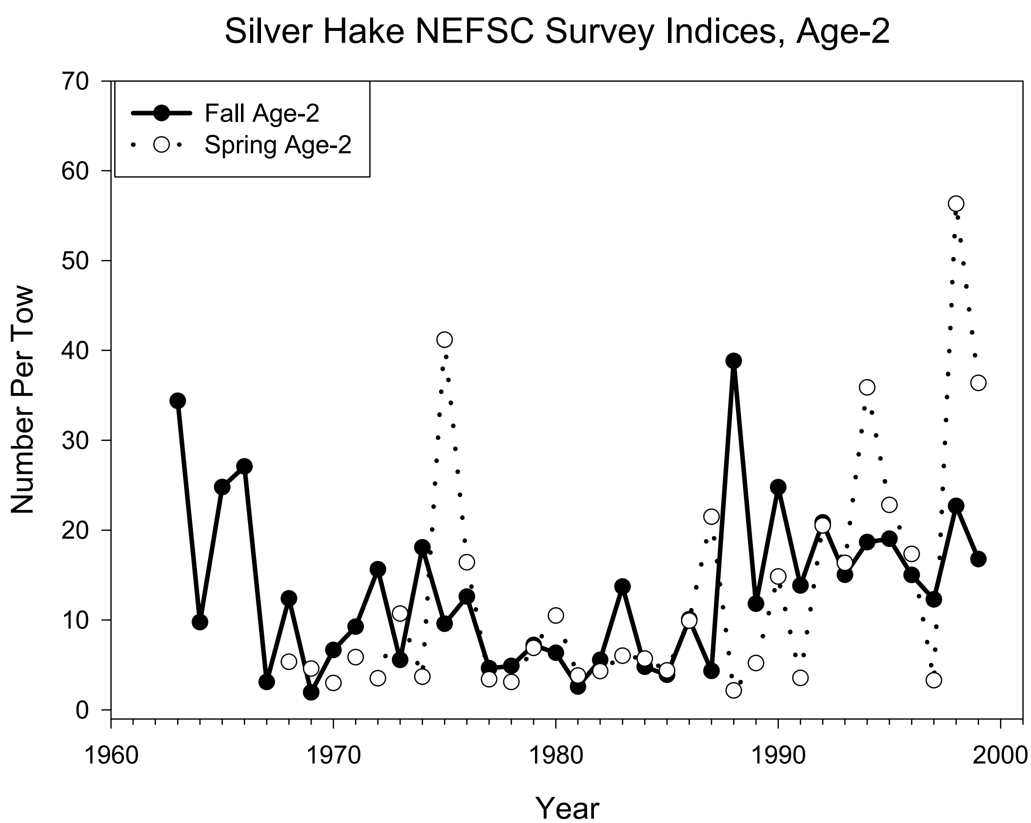
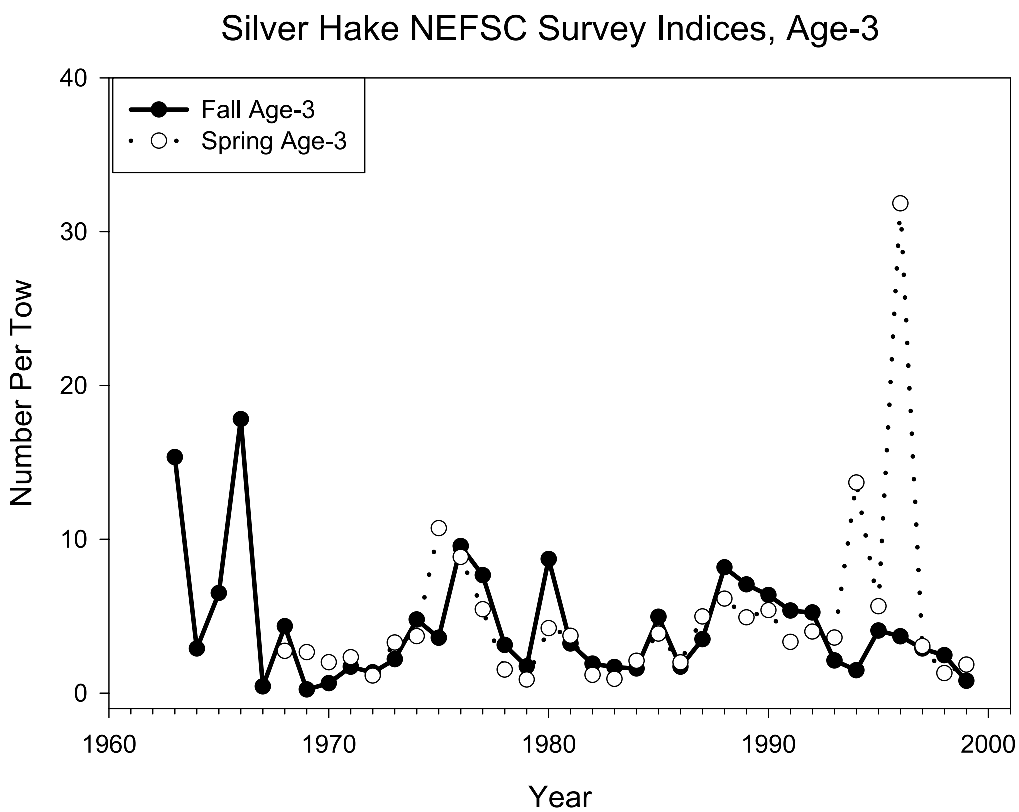


Figure 22. Silver hake abundance indices, age-3 and age-4.



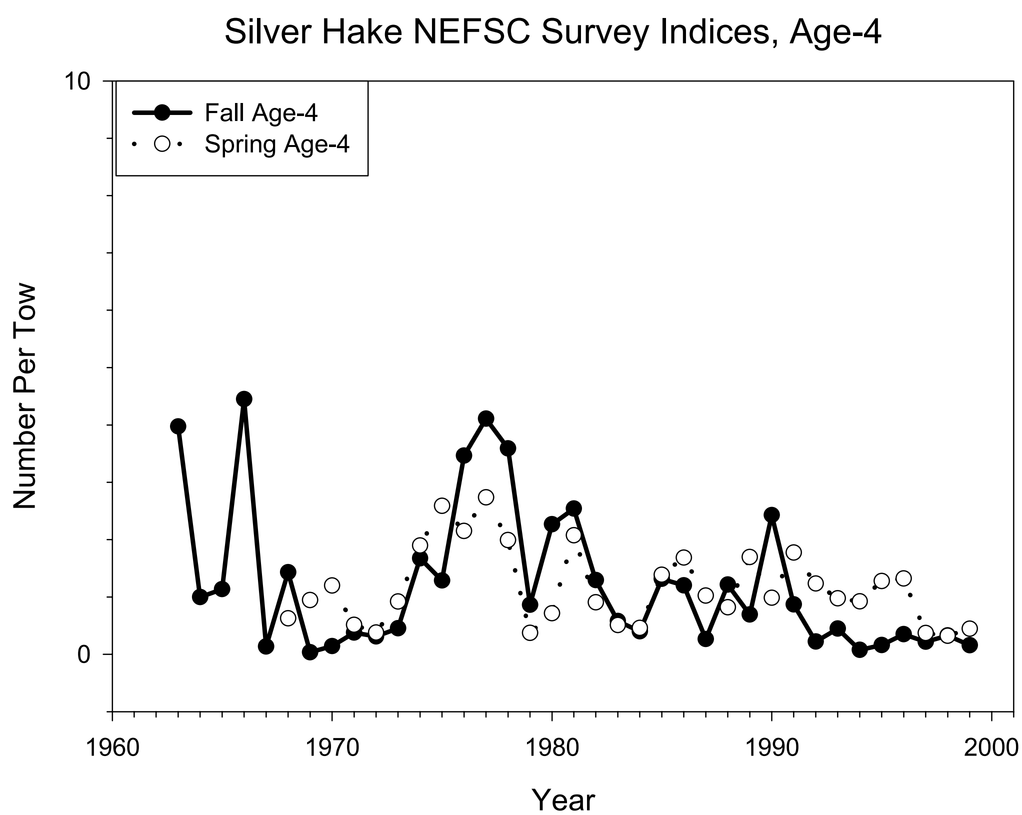
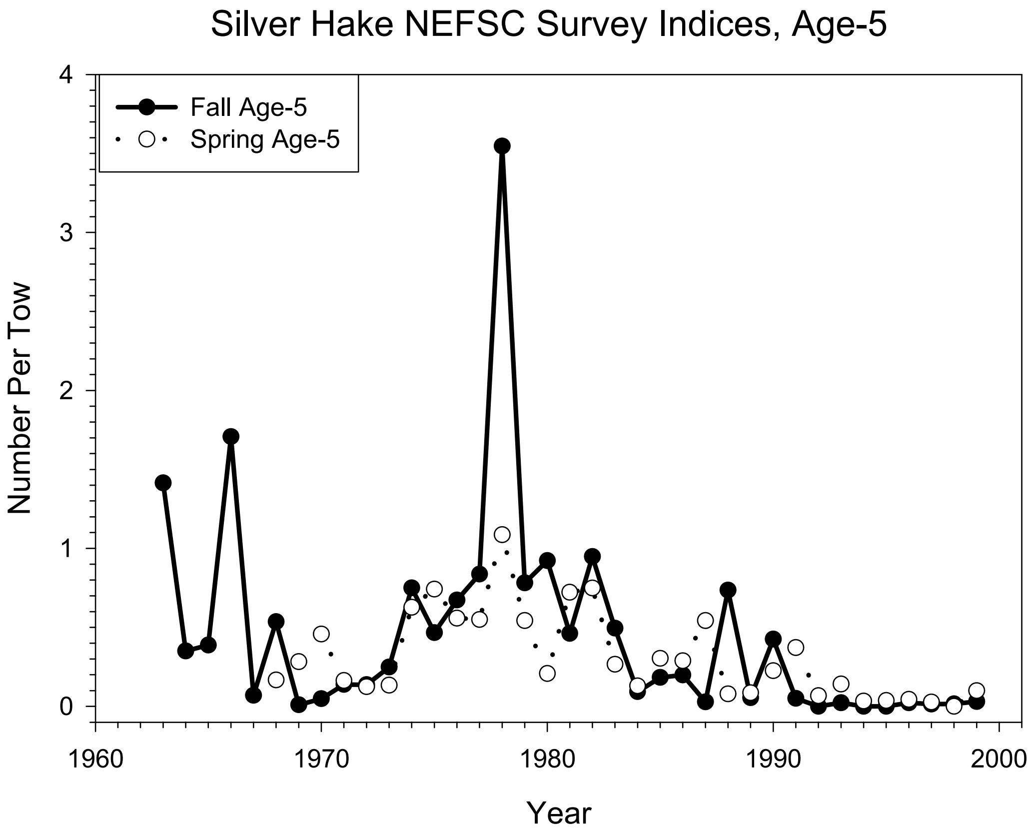


Figure 23. Silver hake abundance indices, age-5 and age-6.



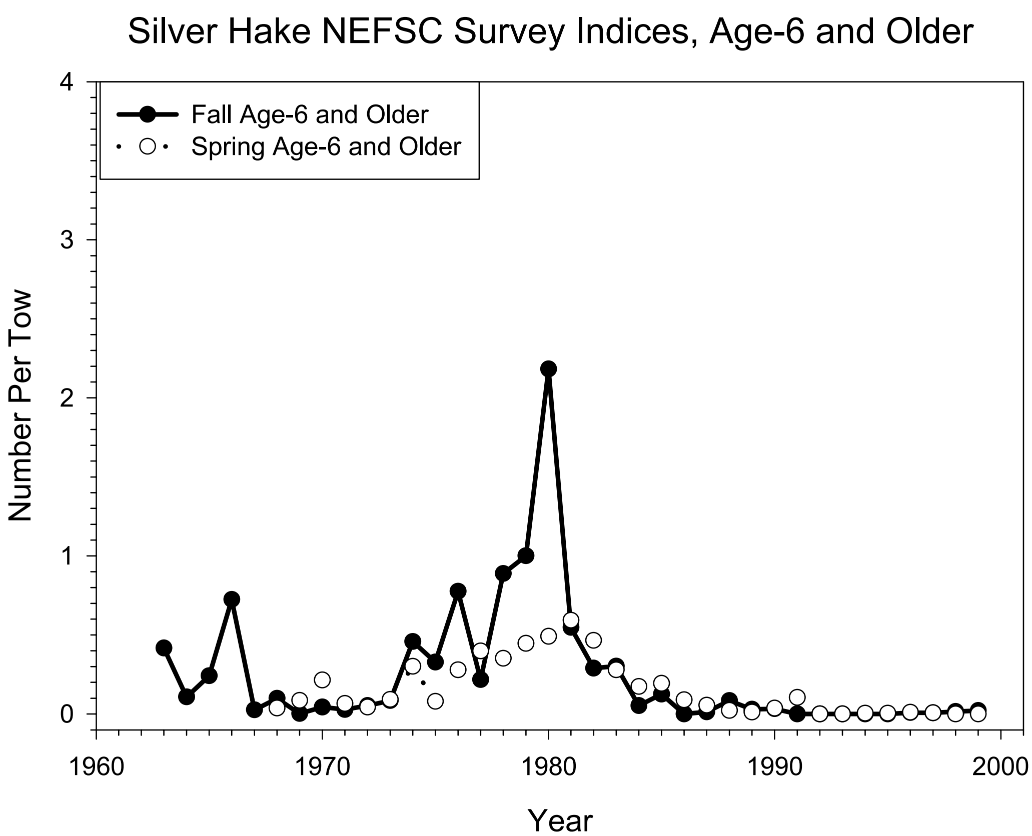


Figure 24. Monthly distribution of silver hake eggs from MARMAP ichthyoplankton surveys during January through June of 1977-1987 from Berrien and Sibunka (1999).

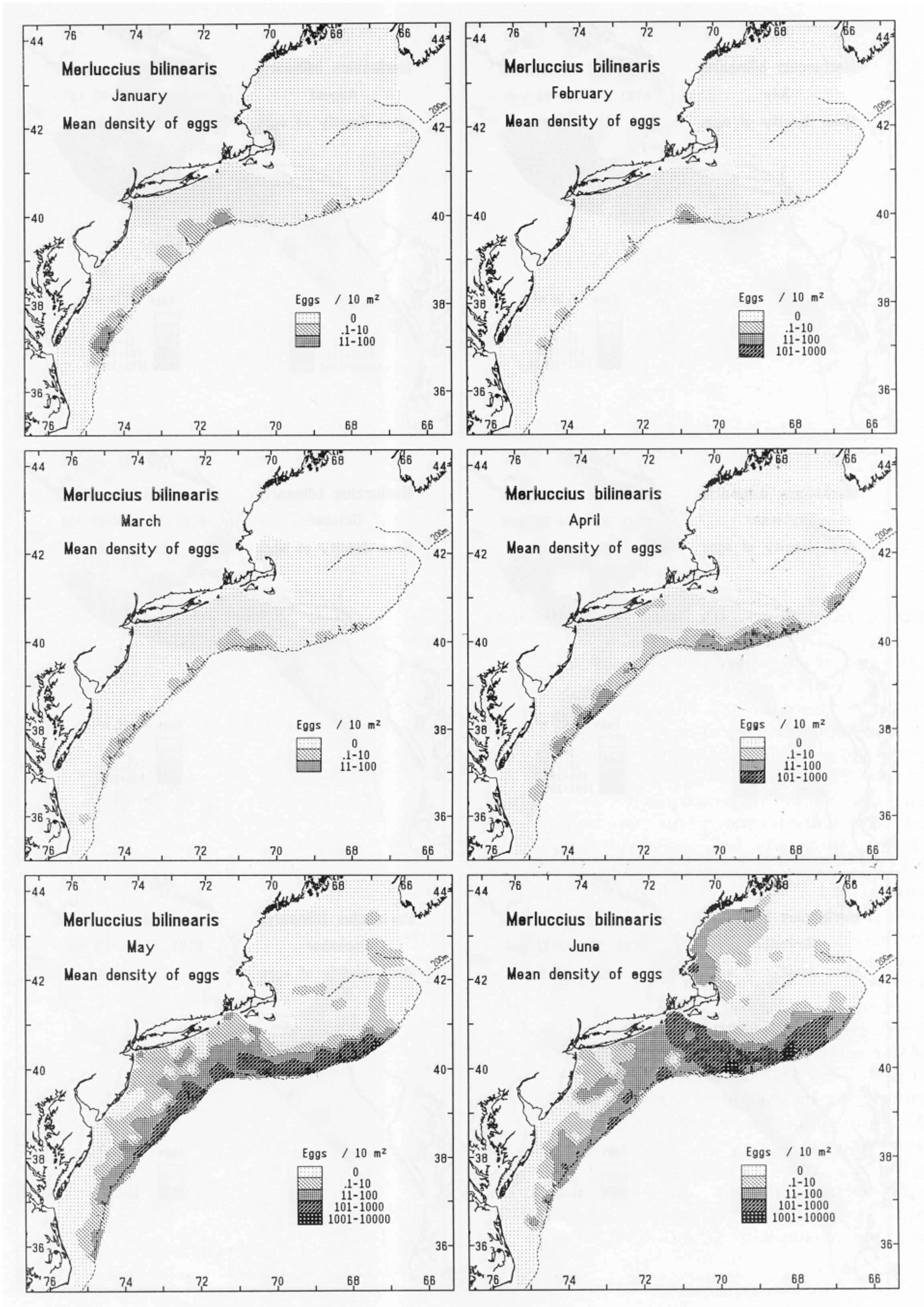


Figure 25. Monthly distribution of silver hake eggs from MARMAP ichthyoplankton surveys during July through December of 1977-1987 from Berrien and Sibunka (1999).

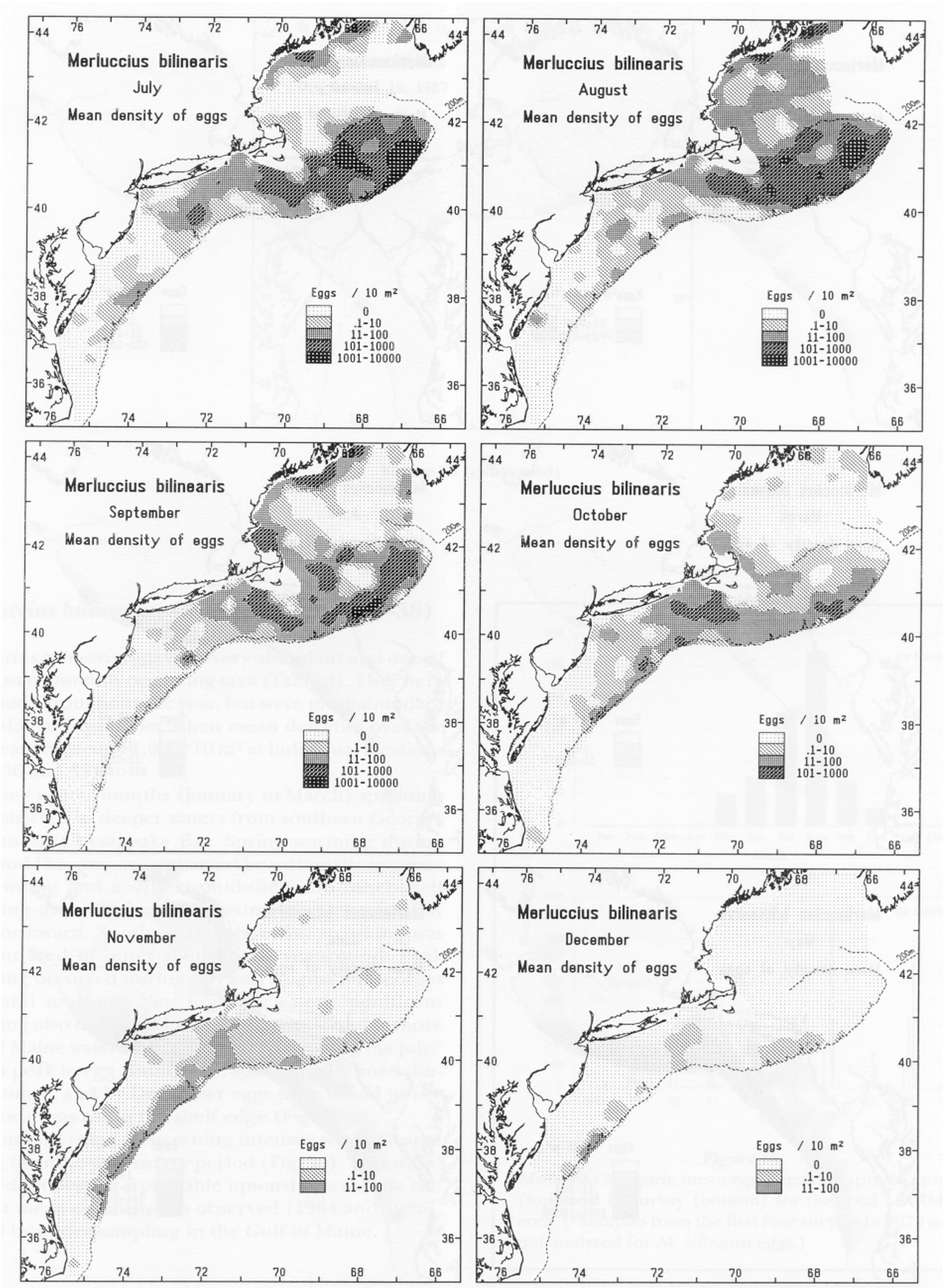


Figure 26. Silver hake growth curves for the early 1970s and the 1990s calculated from NEFSC spring and fall survey size-at-age data.

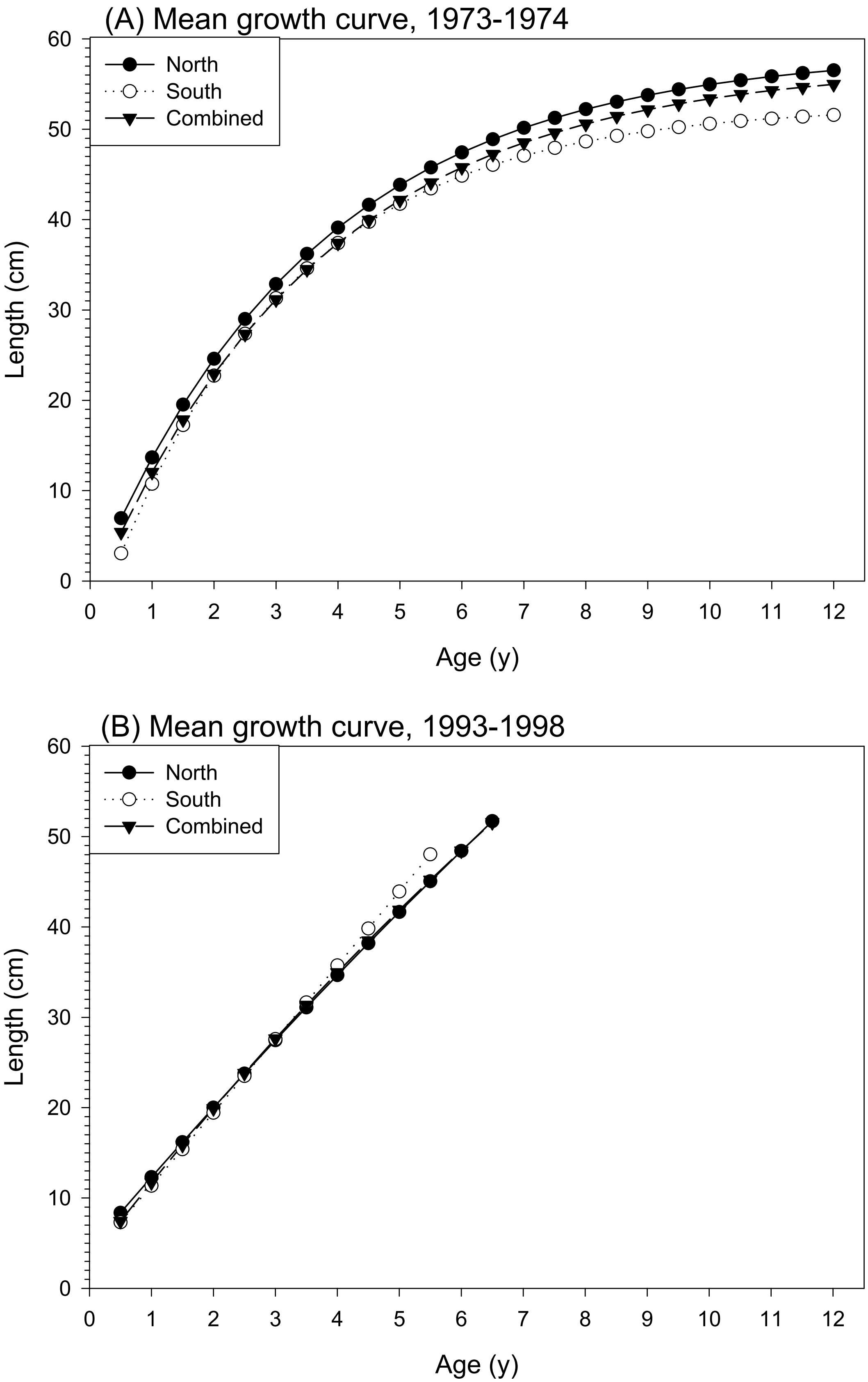


Figure 27. Maximum ages of silver hake from NEFSC survey data.

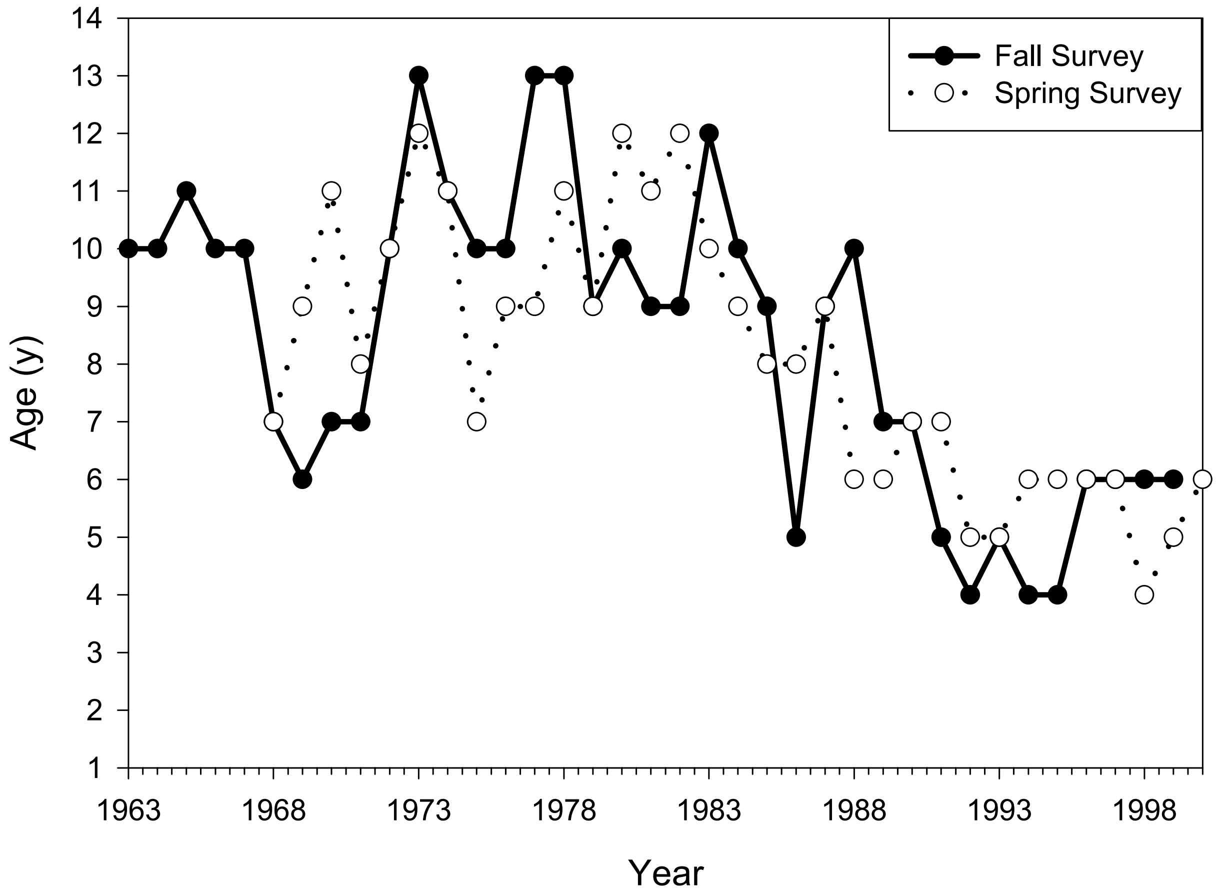
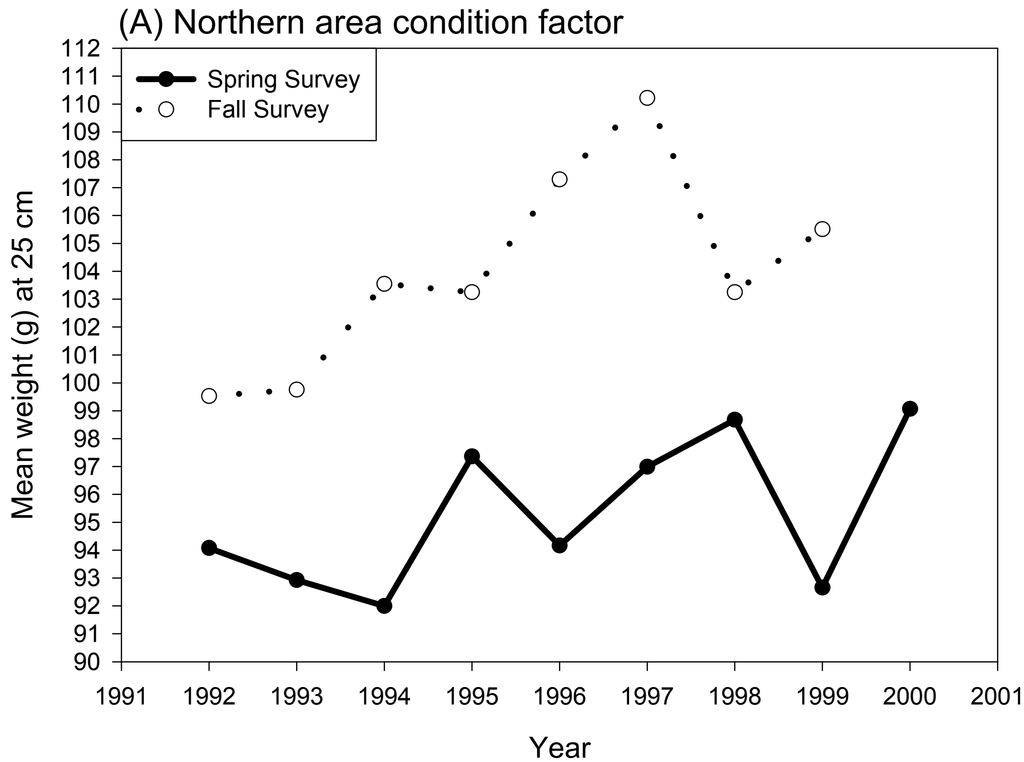


Figure 28. Silver hake condition factor during NEFSC surveys by stock area, 1992-2000.



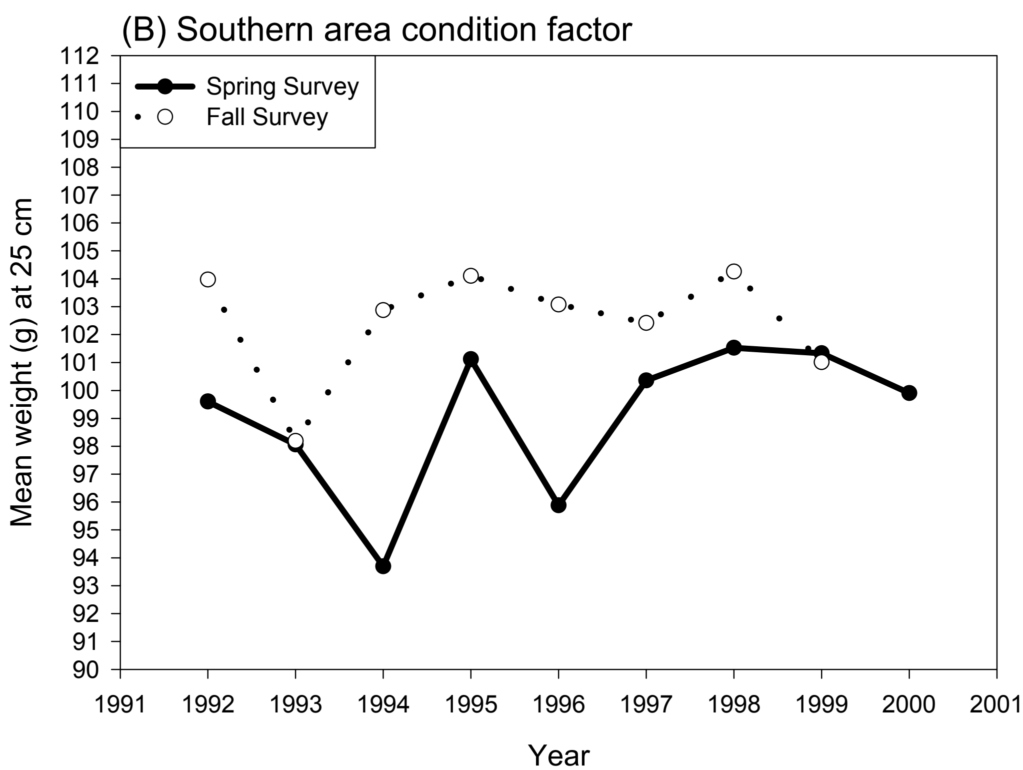


Figure 29. Silver hake exploitation rate indices by stock area, 1963-1999.

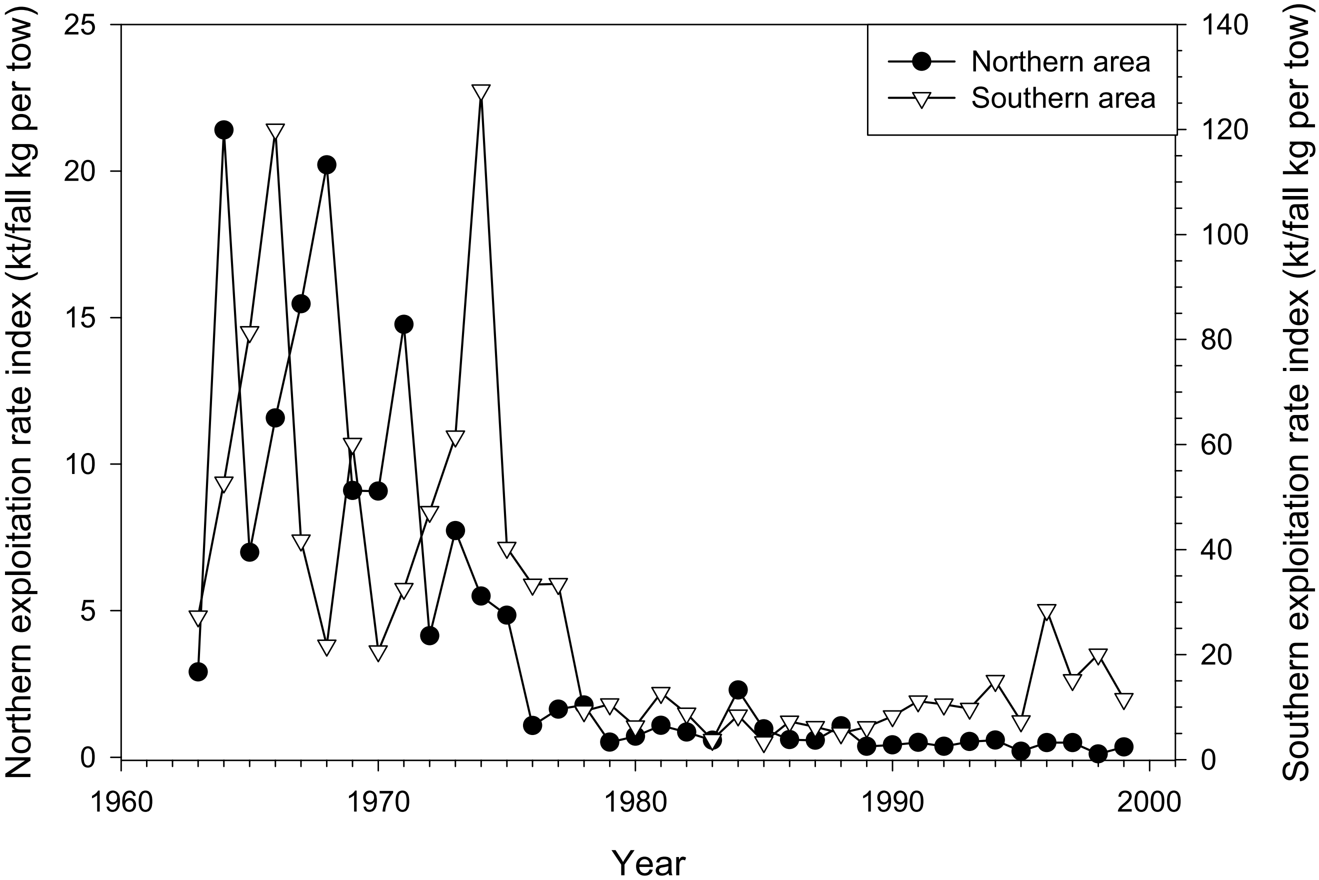


Figure 30. Age-specific exploitation rate indices for combined area silver hake from NEFSC autumn and spring surveys.

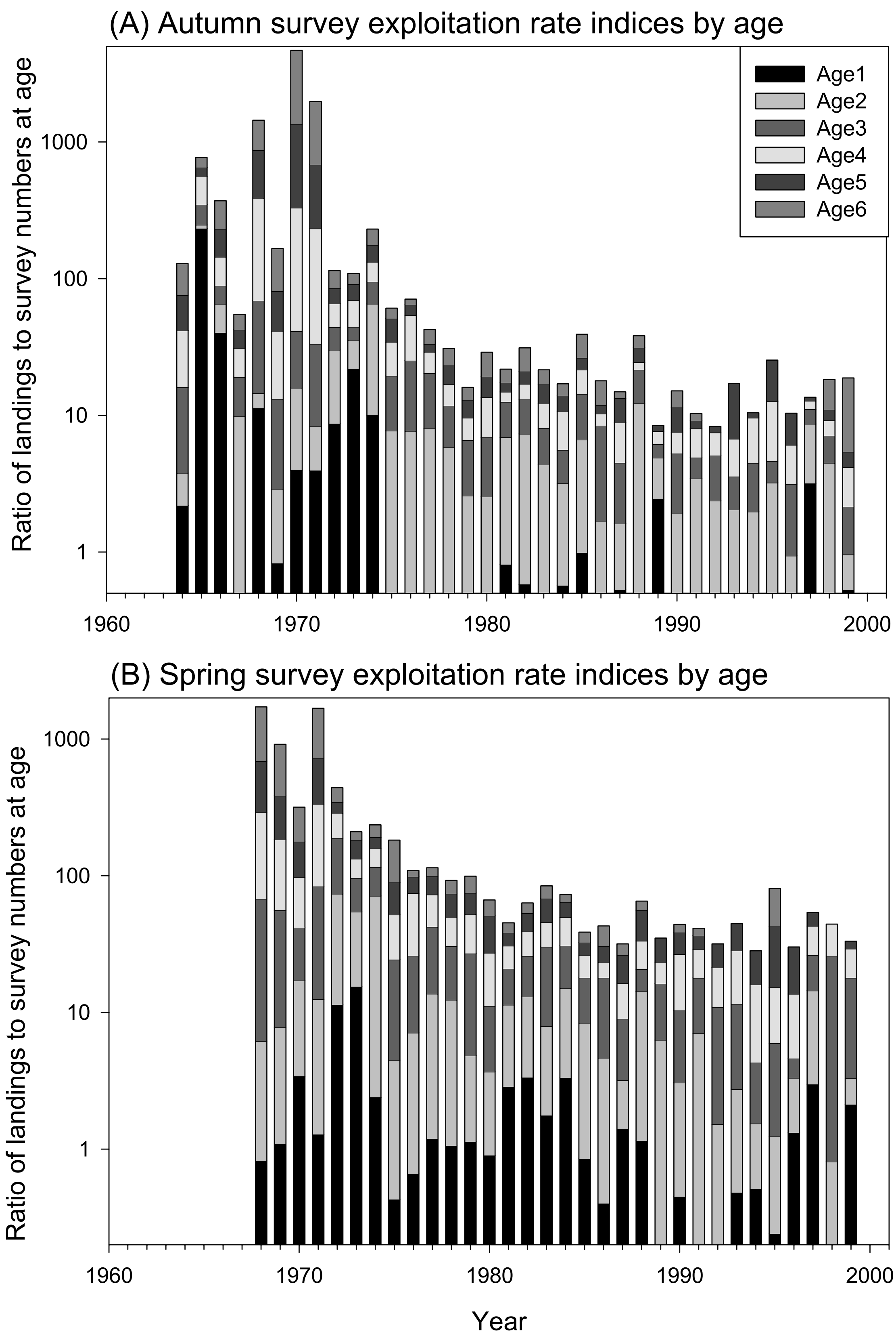


Figure 31. Silver hake average total mortality for the combined stock area from NEFSC spring and autumn survey data using Heincke's method.

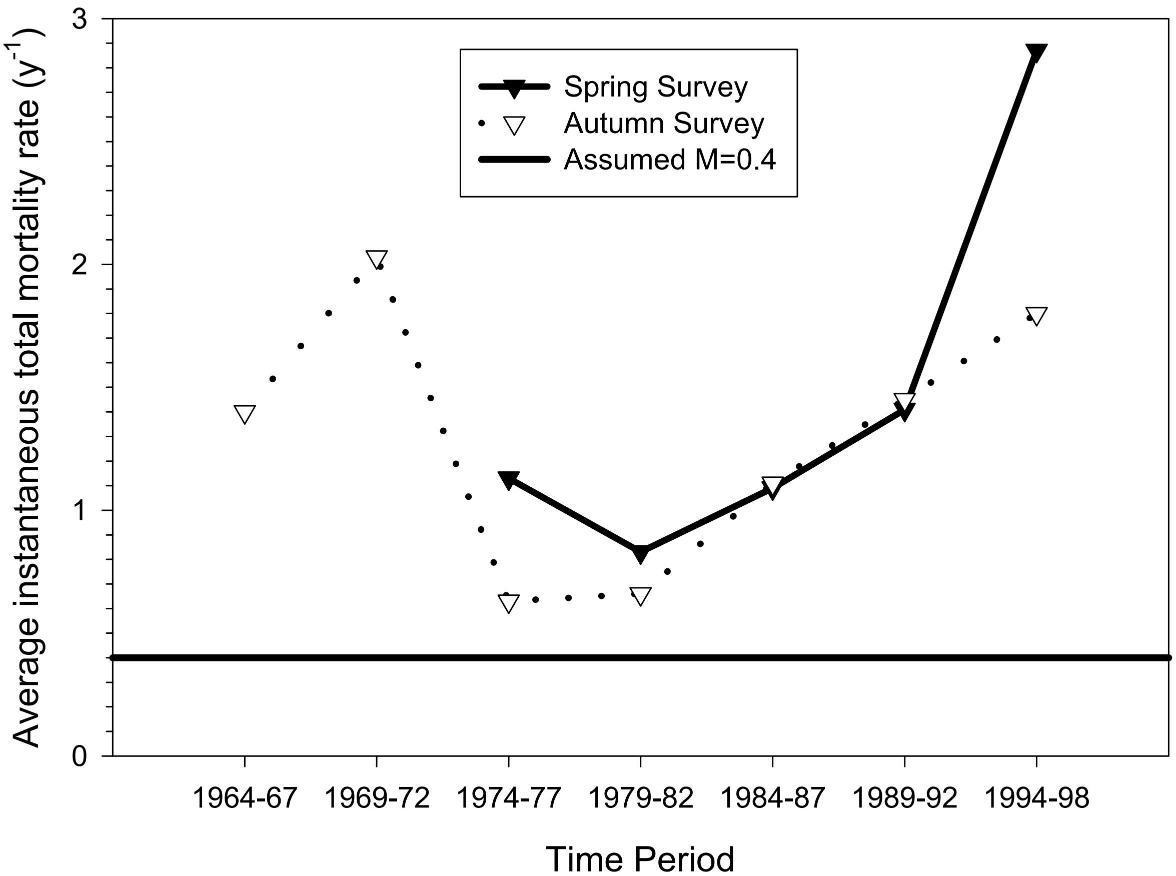


Figure 32. Silver hake ADAPT residuals for baseline model (Run 11).

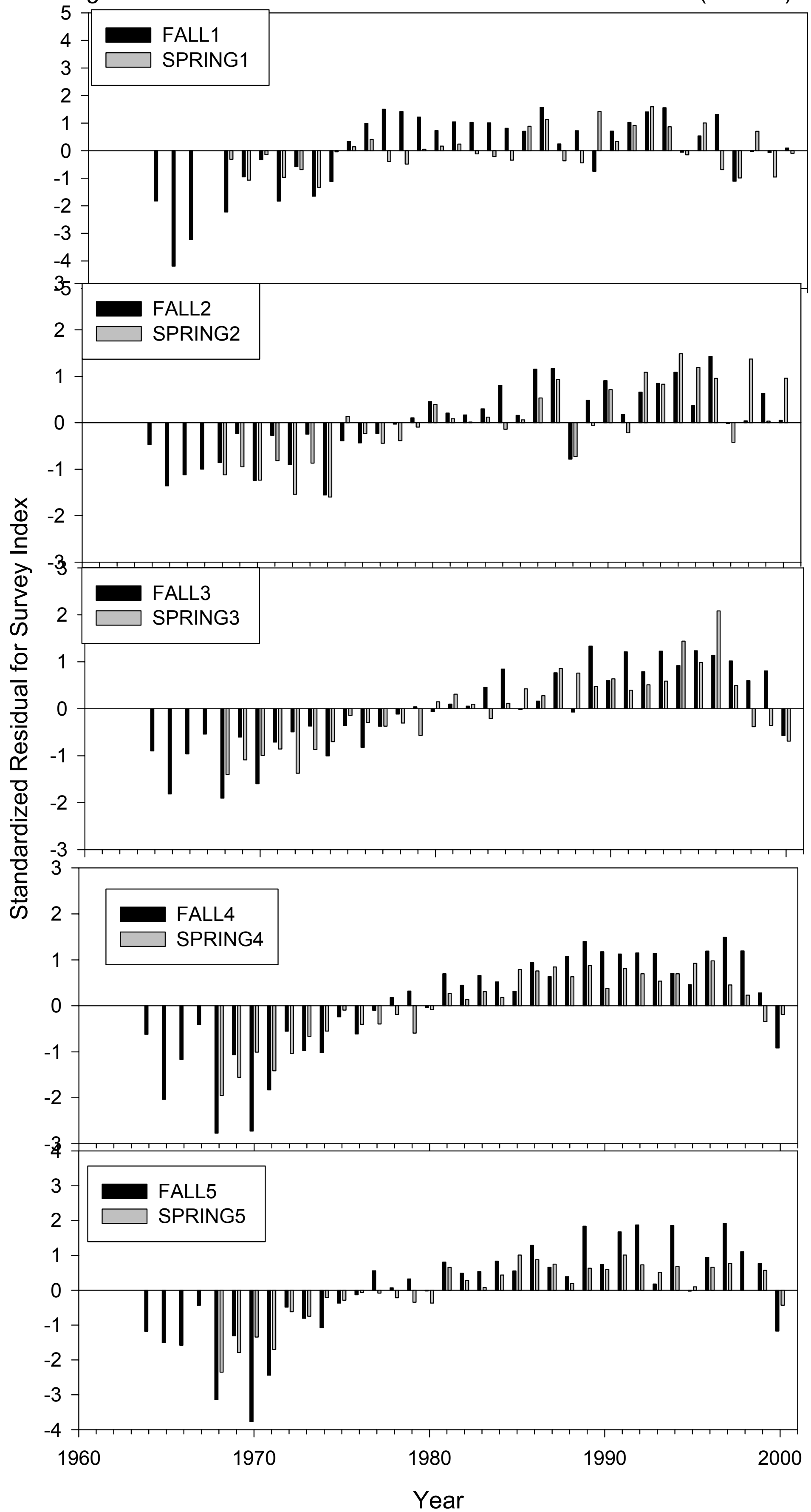


Figure 33. Silver hake ADAPT residuals for best fit model (Run 15).

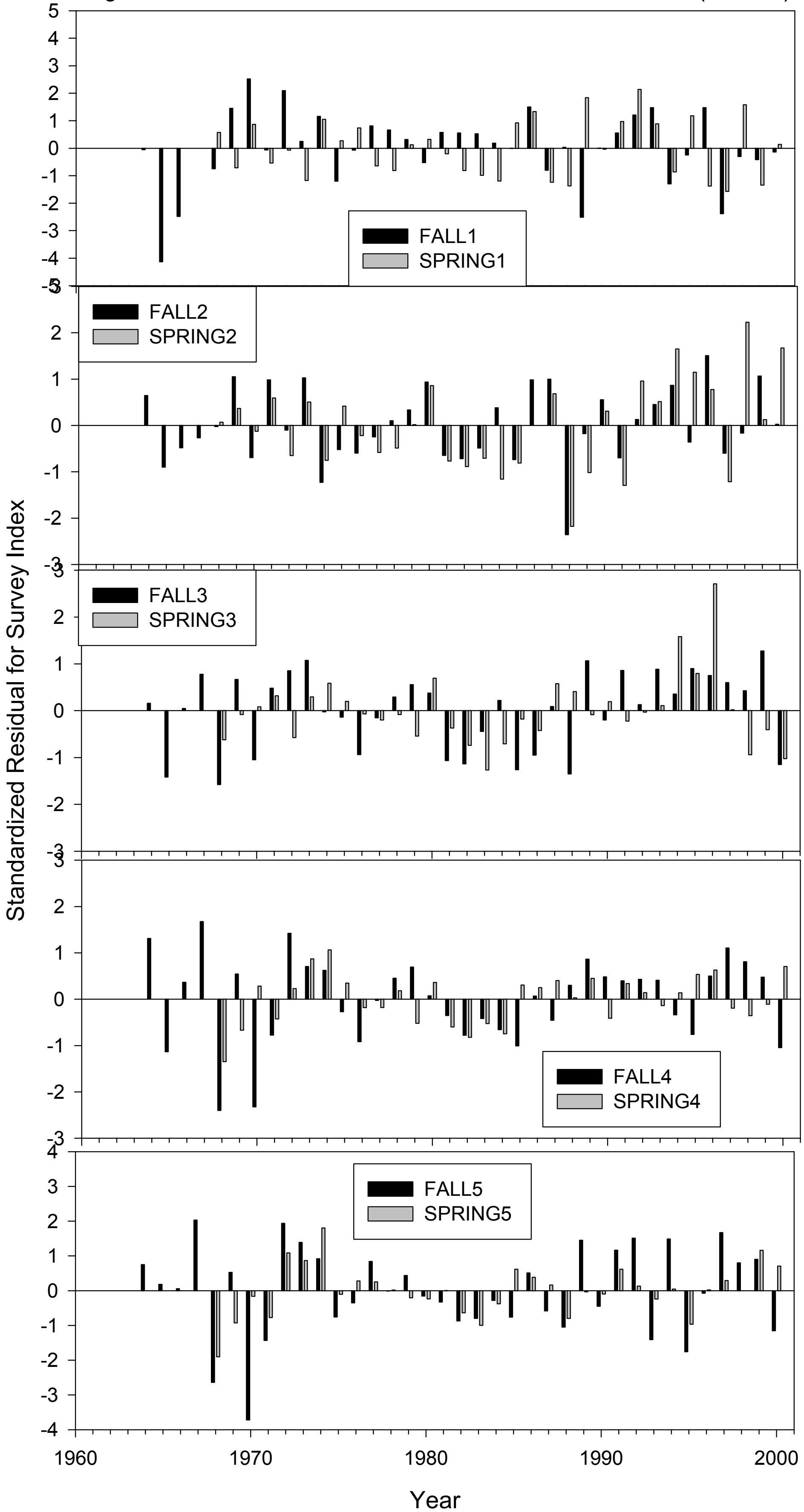


Figure 34. Trends in silver hake survey catchability at age for the best fit ADAPT model.

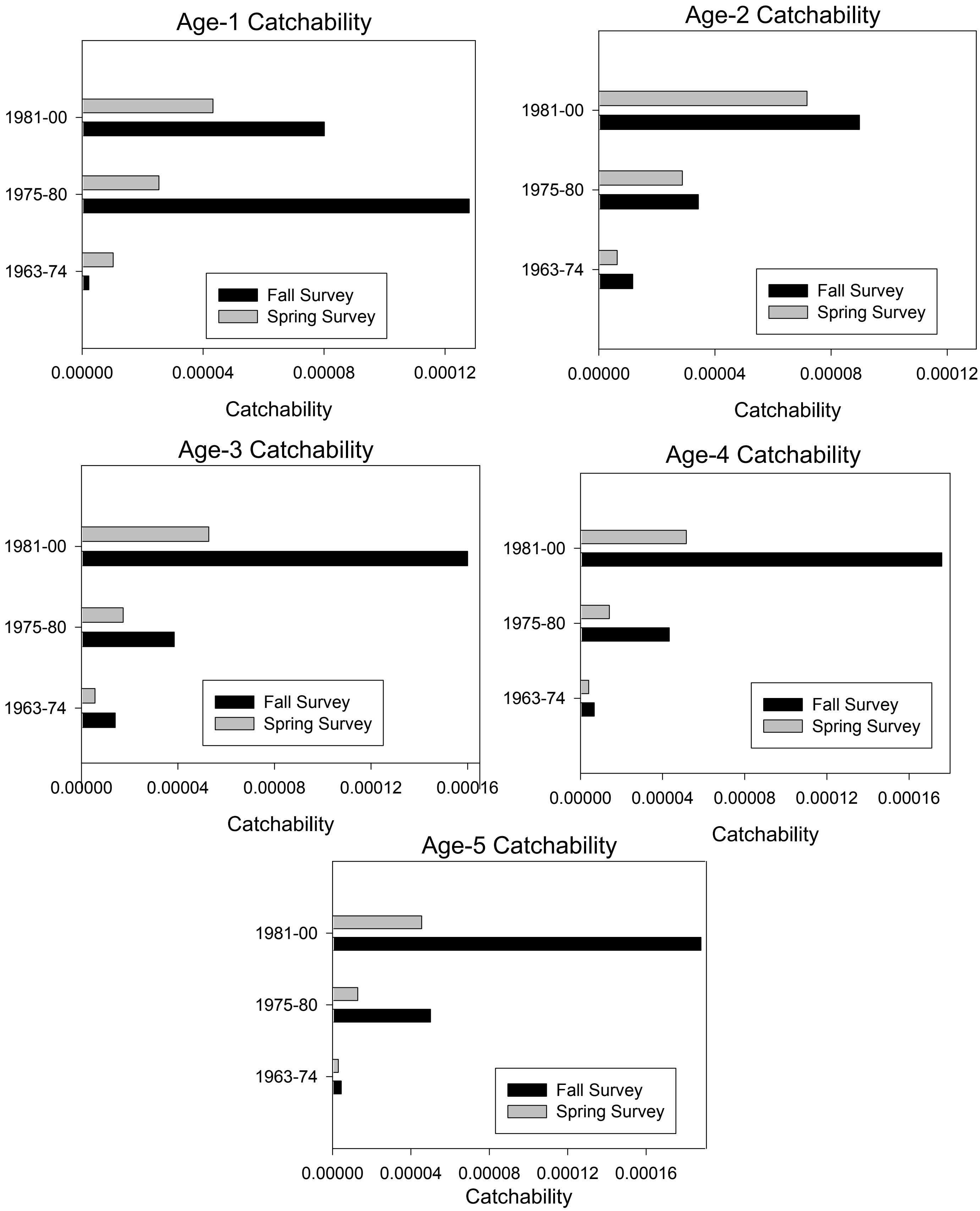


Figure 35. Estimated fishing mortality and spawning biomass for combined area silver hake from best fit ADAPT model.

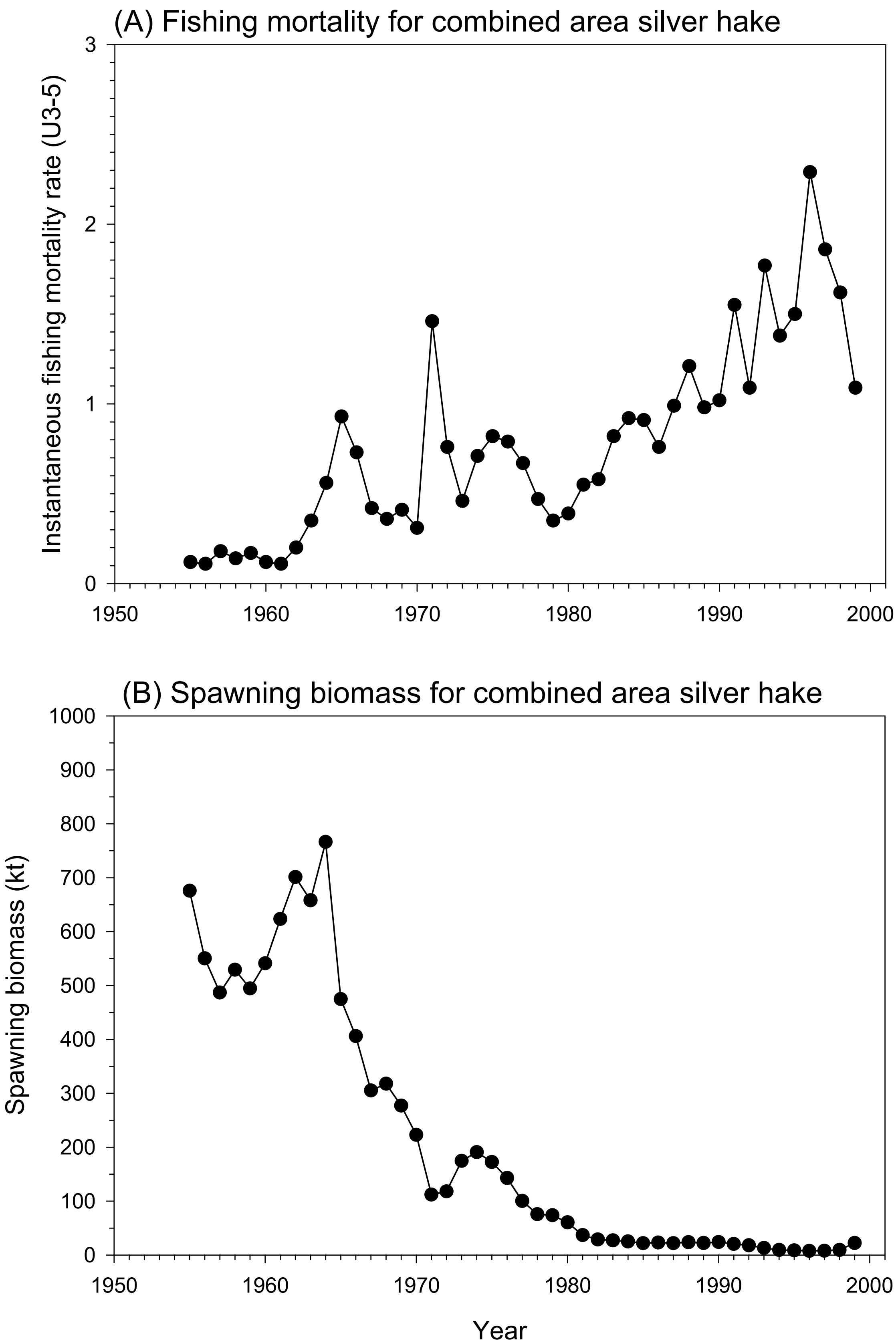


Figure 36. Median residuals for combined silver hake BSP model

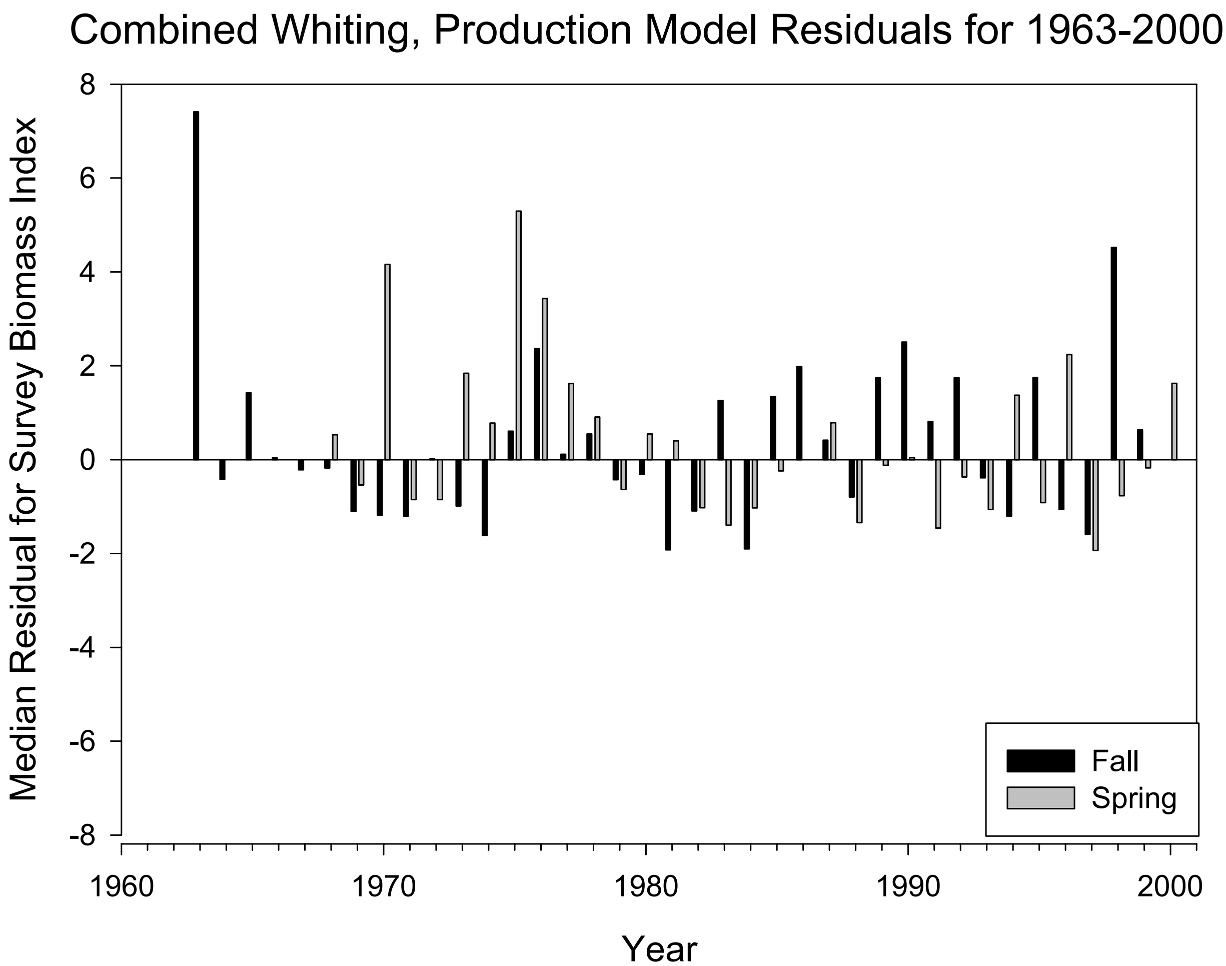


Figure 37. Median residuals for northern silver hake BSP model

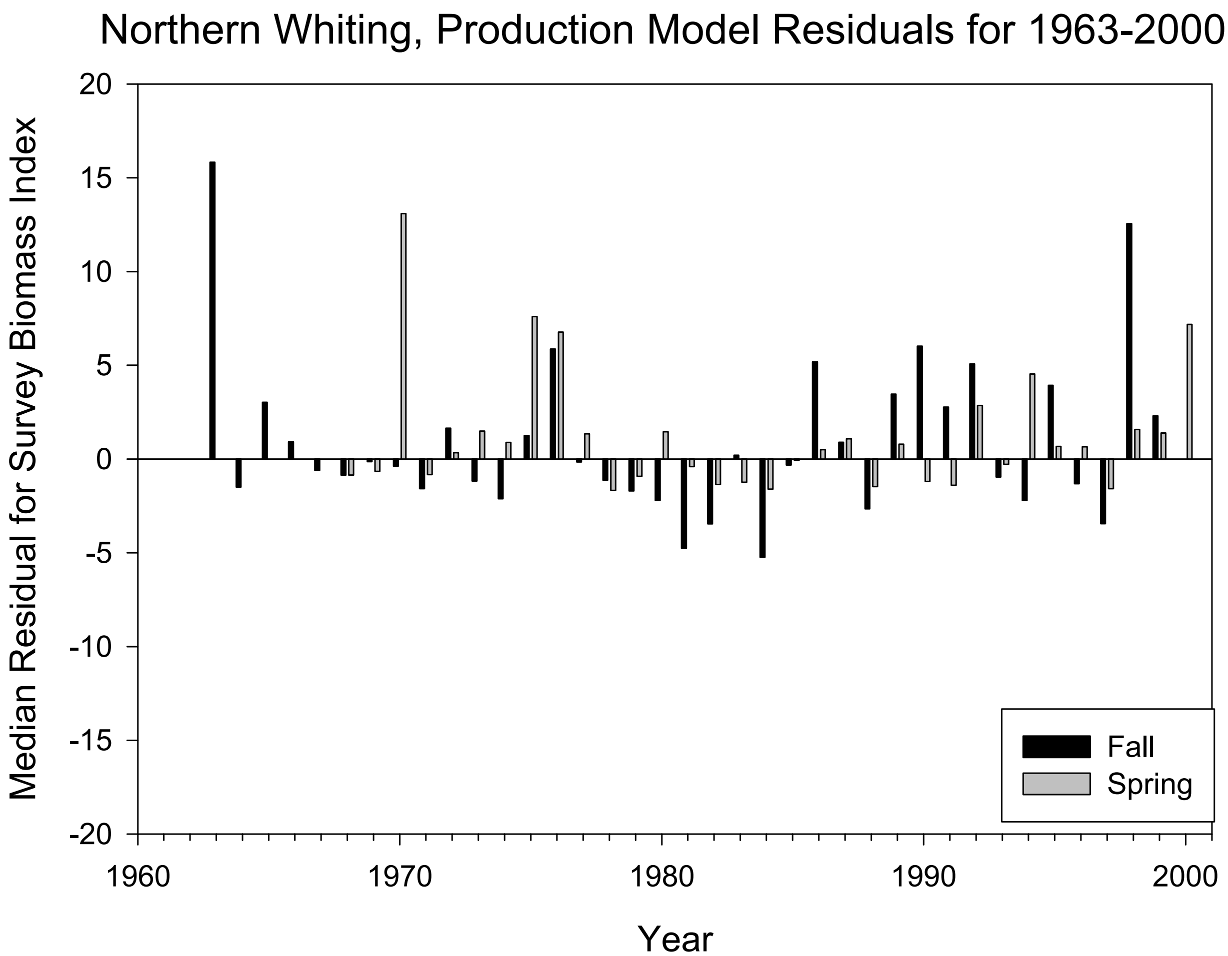


Figure 38. Median residuals for the southern silver hake BSP model

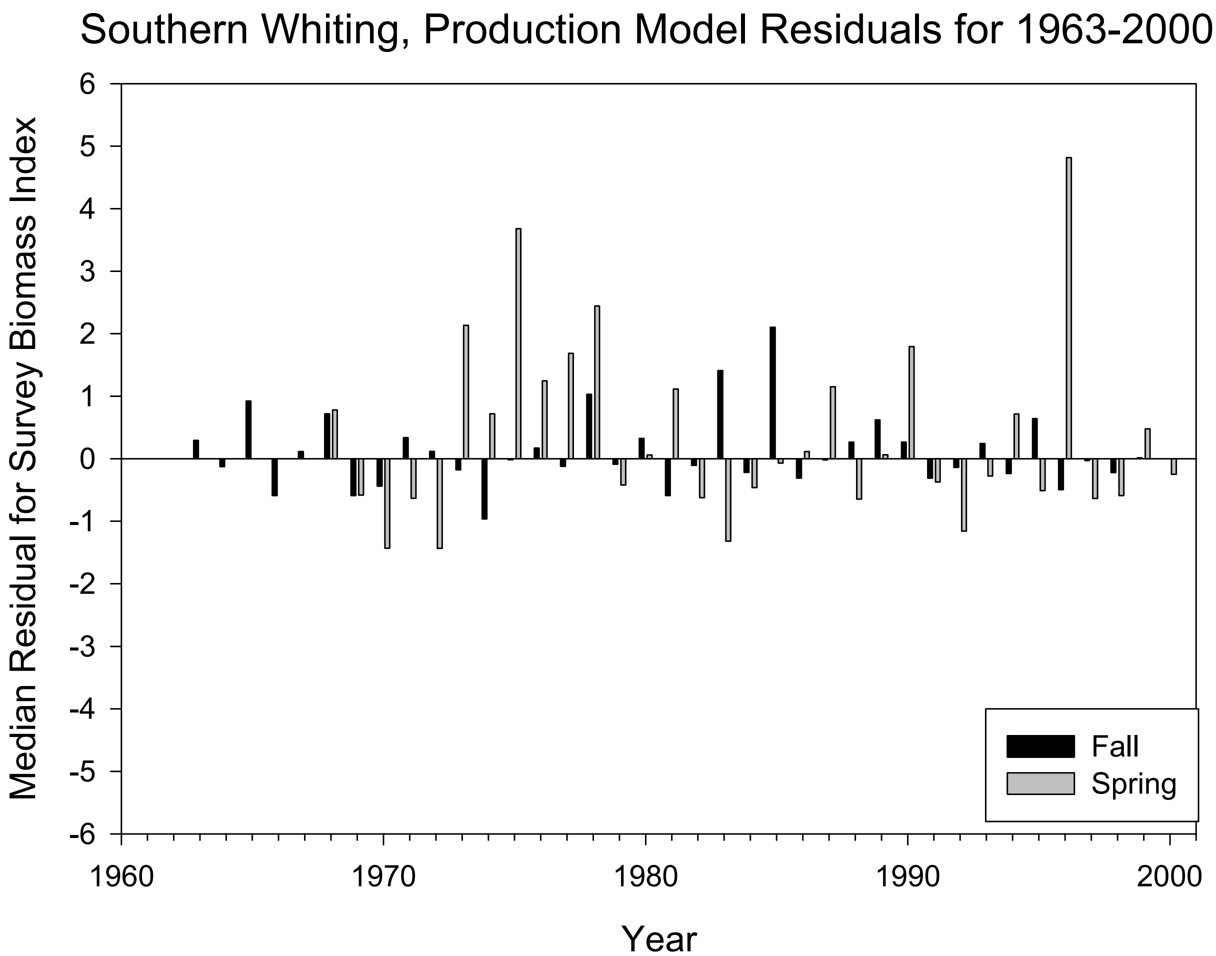


Figure 39. Biomass estimates for combined, northern, and southern silver hake from Bayesian surplus production model.

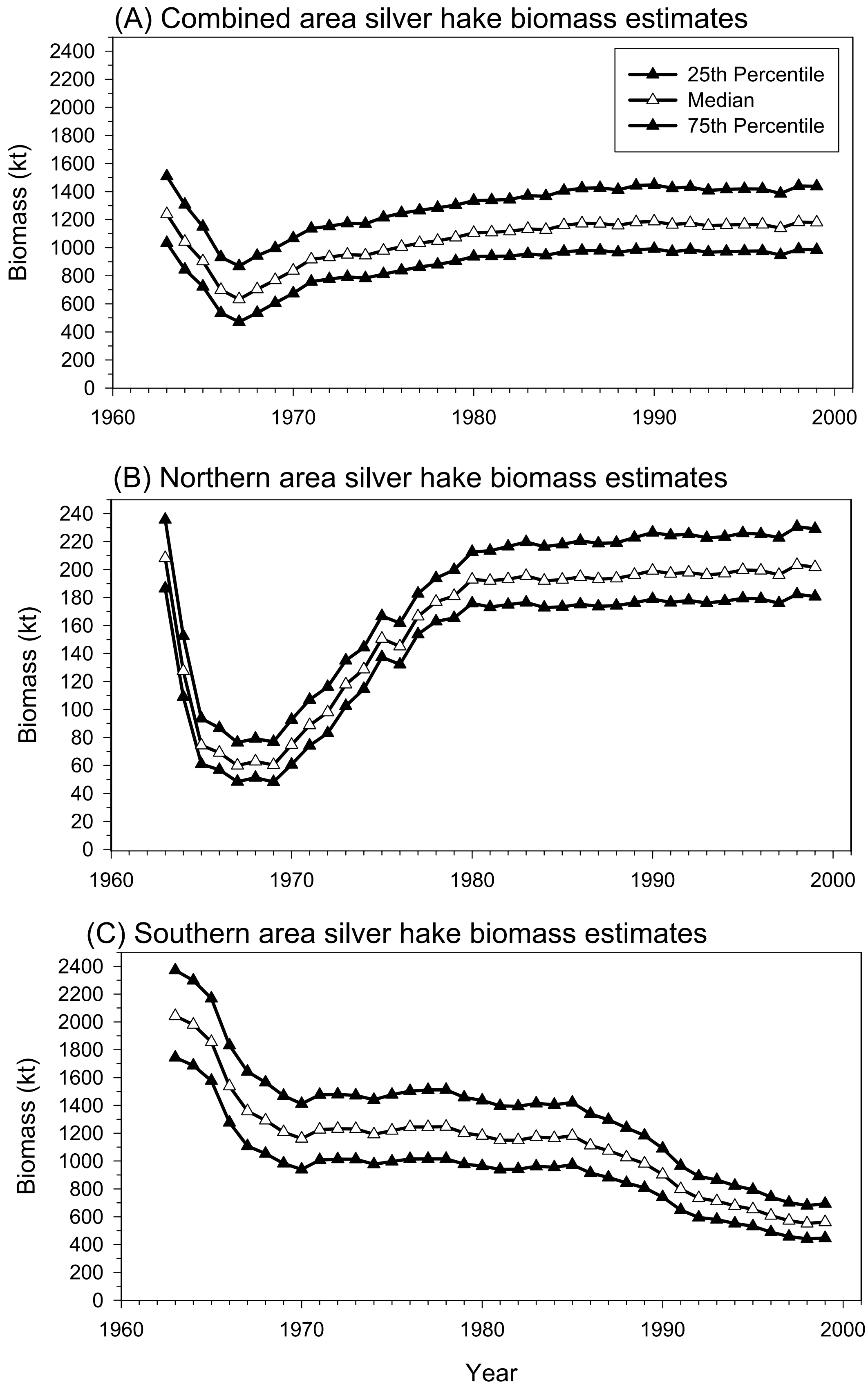
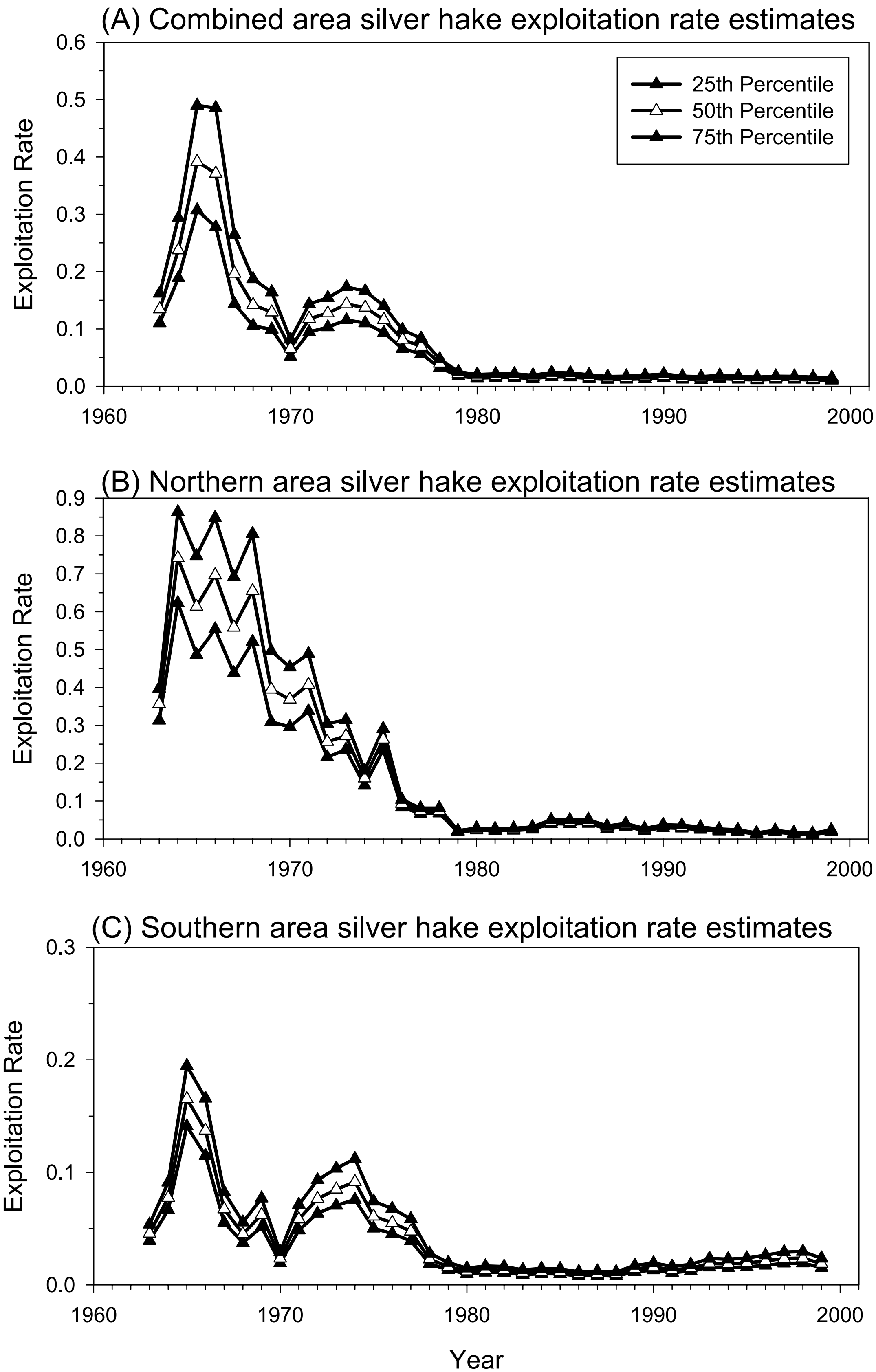


Figure 40. Exploitation rate estimates for combined, northern, and southern silver hake from Bayesian surplus production model.



Appendix 1. Combined stock area BSP model for silver hake.

```
# Implementation of the surplus production model for combined whiting
# Jon Brodziak, NEFSC Nov-7-00
# LOGNORMAL OBSERVATION ERRORS
########################################################################

model CombinedFS6300

{
# PRIOR DISTRIBUTIONS
#########################################

# PRIOR FOR K
# Lognormal with 10%Q at 700 kt and 90%Q at 2000 kt
################################################

K ~ dlnorm(7.07599,5.94623)

# PRIOR FOR R
# Uniform from [0.01,1.99]
################################################

r ~ dunif(0.01,1.99)

# PRIOR FOR Q
# Inverse gamma with a=b=0.001
##############################

iqFALL ~ dgamma(0.001,0.001)I(0.01,10000);
qFALL <- 1/iqFALL;
iqSPR ~ dgamma(0.001,0.001)I(0.01,10000);
qSPR <- 1/iqSPR;

# PRIOR FOR SIGMA2 - PROCESS ERROR VARIANCE
######################################################

isigma2 ~ dgamma(a0,b0);
sigma2 <- 1/isigma2;

# PRIOR FOR TAU2FALL/SPR - OBSERVATION ERROR VARIANCE
#########################################################

itau2FALL   ~ dgamma(c0FALL,d0FALL);
tau2FALL   <- 1/itau2FALL;
itau2SPR   ~ dgamma(c0SPR,d0SPR);
tau2SPR   <- 1/itau2SPR;

# CONDITIONAL PRIORS FOR PROPORTIONS P
# Lognormal bounded as (0.001,3)
########################################

Pmean[1] <- 0;
P[1] ~ dlnorm(Pmean[1],isigma2) I(0.001,3)
dlow[1] <- dlowpre*L[1]
dup[1] <- duppre*L[1]
# Catch error during 1963
C[1] ~ dunif(dlow[1],dup[1])

# Catch error during 1964-1977
for (i in 2:15) {
   Pmean[i] <- log(max(P[i-1] + r*P[i-1]*(1-P[i-1]) - C[i-1]/K,0.001))
   P[i]  ~ dlnorm(Pmean[i],isigma2)I(0.001,3)
```

```
   dlow[i] <- dlowpre*L[i]
   dup[i] <- duppre*L[i]
   C[i] ~ dunif(dlow[i],dup[i])
   }
# Catch error during 1978-2000
for (i in 16:38) {
   Pmean[i] <- log(max(P[i-1] + r*P[i-1]*(1-P[i-1]) - C[i-1]/K,0.001))
   P[i]      ~ dlnorm(Pmean[i],isigma2)I(0.001,3)
   dlow[i] <- dlowcur*L[i]
   dup[i] <- dupcur*L[i]
   C[i] ~ dunif(dlow[i],dup[i])
   }


# LIKELIHOOD OF SAMPLING DISTRIBUTION
######################################
# FALL SURVEY LIKELIHOOD & RESIDUALS
for (i in 1:N) {
    ImeanFALL[i] <- log(qFALL*K*P[i])
    IFALL[i] ~ dlnorm(ImeanFALL[i],itau2FALL)
    RESIDFALL[i] <- IFALL[i] - qFALL*K*P[i]
    }
# SPRING SURVEY LIKELIHOOD & RESIDUALS
for (i in 1:NSPR) {
    ImeanSPR[i] <- log(qSPR*K*P[i+5])
    ISPR[i] ~ dlnorm(ImeanSPR[i],itau2SPR)
    RESIDSPR[i] <- ISPR[i] - qSPR*K*P[i+5]
   }
# MANAGEMENT PARAMETERS
MSP <- r*K/4
INDEXMSPFALL <- qFALL*K/2
INDEXMSPSPR <- qSPR*K/2
HMSP <- r/2
HRATIO <- H[37]/HMSP

#  COMPUTE BIOMASS AND HARVEST RATE TRAJECTORIES
for (i in 1:N) {
    B[i] <- P[i]*K
    H[i] <- C[i]/B[i]
   }

# PROJECT YEAR 2001
P2001 <- P[N+1]+r*P[N+1]*(1-P[N+1])-C[N+1]/K
B2001 <- P2001*K
H2000 <- min(C[N+1]/(P[N+1]*K),1.0)

# END OF CODE
}
```

Data

```
# Vector L() is discard-adjusted total catch
# Vector IFALL() is autumn kg/tow index
# Vector ISPR is spring kg/tow index
# N is number of years
# Sigma is state equation error with parameters a0,b0
# TauFALL is autumn observation equation error with parameters c0FALL,d0FALL
# TauSPR is autumn observation equation error with parameters c0SPR,d0SPR
# Vector C() is discard-adjusted catch with error multiplier
# Error multiplier is bounded by [dlowpre,duppre] for 1963-1976
# and is bounded by [dlowcur,dupcur] for 1976-2000

list(
```

```
L=c(167.306,248.046,352.373,258.986,124.620,99.875,99.525,55.040,
108.291,119.620,136.676,130.543,114.127,82.375,71.765,39.741,
21.790,18.276,19.242,19.217,17.450,21.432,21.461,18.625,15.779,
15.961,17.815,19.994,16.146,15.590,17.272,16.058,14.727,16.199,
15.585,14.959,14.100,15.000),
IFALL=c(12.081,3.499,4.834,2.688,2.175,2.439,1.797,2.000,2.310,3.603,2.661,
2.001,4.350,6.211,4.058,4.556,3.669,3.903,2.301,3.143,5.558,2.369,
5.743,6.415,4.848,3.590,6.214,6.994,5.219,6.200,3.996,3.204,6.164,
3.358,2.725,9.000,5.097),
ISPR=c(2.296,1.413,6.297,1.491,1.518,4.245,3.163,7.768,5.963,4.217,
3.542,2.058,3.318,3.174,1.754,1.428,1.770,2.643,2.898,3.690,1.531,
2.806,2.985,1.428,2.549,1.809,4.263,1.975,5.135,0.883,2.164,2.740,4.564),
N=37,
NSPR=33,
a0=4.0,b0=0.01,
c0FALL=2.0,d0FALL=0.01,
c0SPR=2.0,d0SPR=0.01,
dlowpre=0.90,duppre=1.10,
dlowcur=1.00,dupcur=1.10)
```

Inits

```
# Initial Condition 1
list(
P=c(0.9,0.3,0.4,0.2,0.2,0.2,0.1,0.2,0.2,0.3,0.2,0.2,0.4,
0.5,0.3,0.4,0.3,0.3,0.2,0.3,0.5,0.2,0.5,0.5,0.4,0.3,0.5,
0.6,0.4,0.5,0.3,0.3,0.5,0.3,0.2,0.7,0.4,0.5),
C=c(167.306,248.046,352.373,258.986,124.620,99.875,99.525,55.040,
108.291,119.620,136.676,130.543,114.127,82.375,71.765,39.741,
21.790,18.276,19.242,19.217,17.450,21.432,21.461,18.625,15.779,
15.961,17.815,19.994,16.146,15.590,17.272,16.058,14.727,16.199,
15.585,14.959,14.100,15.000),
r=0.4,
K=1500,
iqFALL=100,iqSPR=100,
isigma2=1000,
itau2FALL=100,itau2SPR=100)

# Initial Condition 2
list(
P=c(0.9,0.3,0.4,0.2,0.2,0.2,0.1,0.2,0.2,0.3,0.2,0.2,0.4,
0.5,0.3,0.4,0.3,0.3,0.2,0.3,0.5,0.2,0.5,0.5,0.4,0.3,0.5,
0.6,0.4,0.5,0.3,0.3,0.5,0.3,0.2,0.7,0.4,0.5),
C=c(167.306,248.046,352.373,258.986,124.620,99.875,99.525,55.040,
108.291,119.620,136.676,130.543,114.127,82.375,71.765,39.741,
21.790,18.276,19.242,19.217,17.450,21.432,21.461,18.625,15.779,
15.961,17.815,19.994,16.146,15.590,17.272,16.058,14.727,16.199,
15.585,14.959,14.100,15.000),
r=0.3,
K=1800,
iqFALL=100,iqSPR=100,
isigma2=1000,
itau2FALL=100,itau2SPR=100)
```

Results

Summary of Posterior Distribution

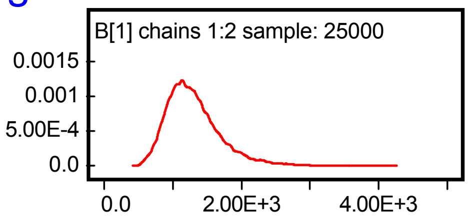
node	mean	sd	MC error	10.0%	25.0%	median	75.0%	90.0%	start	sample
B[1]	1308.0	397.1	13.18	874.8	1032.0	1247.0	1508.0	1819.0	5000	25000
B[2]	1111.0	388.4	13.03	688.2	842.7	1049.0	1306.0	1609.0	5000	25000
B[3]	978.9	363.5	12.34	598.1	726.5	908.7	1151.0	1443.0	5000	25000
B[4]	781.2	344.3	11.88	431.0	542.9	707.0	936.6	1222.0	5000	25000
B[5]	726.2	349.6	12.43	376.6	484.5	648.6	878.9	1177.0	5000	25000
B[6]	800.0	360.8	13.15	437.8	548.5	720.1	956.8	1265.0	5000	25000
B[7]	860.2	348.3	12.55	509.4	621.2	783.3	1012.0	1304.0	5000	25000
B[8]	927.2	349.7	12.47	576.9	687.4	851.2	1079.0	1368.0	5000	25000
B[9]	1002.0	338.8	11.81	663.8	770.8	927.8	1148.0	1428.0	5000	25000
B[10]	1014.0	338.3	11.57	674.8	783.1	941.4	1165.0	1440.0	5000	25000
B[11]	1030.0	341.7	11.61	686.7	797.1	956.4	1183.0	1464.0	5000	25000
B[12]	1024.0	345.7	11.65	675.6	787.9	950.3	1180.0	1457.0	5000	25000
B[13]	1061.0	355.7	11.91	700.2	815.8	986.0	1222.0	1507.0	5000	25000
B[14]	1089.0	360.3	12.0	722.5	840.3	1013.0	1251.0	1545.0	5000	25000
B[15]	1112.0	357.7	11.88	750.5	869.0	1039.0	1273.0	1566.0	5000	25000
B[16]	1128.0	355.2	11.76	765.7	886.2	1057.0	1290.0	1580.0	5000	25000
B[17]	1149.0	350.5	11.61	788.9	912.0	1080.0	1308.0	1593.0	5000	25000
B[18]	1179.0	353.2	11.74	814.6	941.7	1112.0	1339.0	1622.0	5000	25000
B[19]	1180.0	351.8	11.67	812.8	941.2	1116.0	1344.0	1625.0	5000	25000
B[20]	1185.0	356.7	11.85	808.6	942.6	1120.0	1353.0	1636.0	5000	25000
B[21]	1203.0	358.8	11.92	826.1	957.0	1141.0	1373.0	1656.0	5000	25000
B[22]	1196.0	363.4	12.02	810.6	946.8	1134.0	1372.0	1657.0	5000	25000
B[23]	1231.0	373.3	12.35	833.6	973.8	1168.0	1413.0	1706.0	5000	25000
B[24]	1241.0	379.3	12.57	833.4	980.3	1177.0	1427.0	1724.0	5000	25000
B[25]	1245.0	380.7	12.59	838.8	982.1	1179.0	1433.0	1725.0	5000	25000
B[26]	1229.0	379.1	12.56	820.3	966.8	1166.0	1417.0	1714.0	5000	25000
B[27]	1254.0	386.2	12.78	839.5	986.1	1188.0	1443.0	1746.0	5000	25000
B[28]	1259.0	387.5	12.85	841.3	991.5	1192.0	1456.0	1749.0	5000	25000
B[29]	1237.0	384.0	12.65	824.0	974.0	1173.0	1428.0	1724.0	5000	25000
B[30]	1250.0	381.7	12.59	843.3	983.8	1184.0	1437.0	1740.0	5000	25000
B[31]	1229.0	378.8	12.53	820.9	966.3	1165.0	1416.0	1705.0	5000	25000
B[32]	1235.0	376.3	12.52	833.2	973.9	1170.0	1418.0	1713.0	5000	25000
B[33]	1236.0	380.0	12.55	829.2	975.9	1173.0	1421.0	1719.0	5000	25000
B[34]	1239.0	376.5	12.49	838.3	979.6	1172.0	1418.0	1718.0	5000	25000
B[35]	1206.0	377.0	12.45	805.1	947.1	1144.0	1392.0	1678.0	5000	25000
B[36]	1256.0	381.9	12.63	848.1	991.3	1190.0	1442.0	1741.0	5000	25000
B[37]	1249.0	387.4	12.77	833.4	983.0	1183.0	1439.0	1735.0	5000	25000
C[1]	167.4	9.634	0.06066	154.0	159.1	167.2	175.7	180.7	5000	25000
C[2]	247.7	14.29	0.0926	228.1	235.3	247.6	259.9	267.7	5000	25000
C[3]	352.8	20.38	0.1349	324.5	335.2	352.9	370.6	380.9	5000	25000
C[4]	259.6	14.99	0.09832	238.5	246.6	260.0	272.6	280.1	5000	25000
C[5]	124.8	7.171	0.04626	114.7	118.6	124.8	131.0	134.6	5000	25000
C[6]	100.1	5.752	0.03622	92.08	95.2	100.3	105.1	108.0	5000	25000
C[7]	99.55	5.767	0.03682	91.58	94.57	99.54	104.6	107.5	5000	25000
C[8]	55.08	3.196	0.02048	50.62	52.3	55.13	57.88	59.44	5000	25000
C[9]	108.3	6.238	0.04093	99.61	102.8	108.2	113.7	116.9	5000	25000
C[10]	119.5	6.902	0.04778	110.0	113.5	119.5	125.5	129.1	5000	25000
C[11]	136.5	7.877	0.04712	125.6	129.7	136.4	143.3	147.5	5000	25000
C[12]	129.9	7.531	0.04683	119.8	123.4	129.6	136.4	140.7	5000	25000
C[13]	113.8	6.569	0.04465	104.8	108.1	113.7	119.5	123.0	5000	25000
C[14]	82.32	4.731	0.02803	75.78	78.24	82.29	86.41	88.95	5000	25000
C[15]	71.77	4.145	0.02643	66.0	68.19	71.76	75.35	77.52	5000	25000
C[16]	41.72	1.152	0.007406	40.13	40.72	41.72	42.73	43.32	5000	25000
C[17]	22.88	0.6256	0.004216	22.01	22.34	22.88	23.42	23.75	5000	25000
C[18]	19.19	0.5255	0.003199	18.46	18.74	19.2	19.65	19.92	5000	25000
C[19]	20.2	0.5559	0.003493	19.43	19.71	20.2	20.68	20.97	5000	25000
C[20]	20.18	0.5547	0.003396	19.4	19.7	20.18	20.66	20.94	5000	25000
C[21]	18.32	0.5044	0.003276	17.62	17.89	18.33	18.76	19.02	5000	25000
C[22]	22.5	0.618	0.003979	21.65	21.96	22.5	23.04	23.36	5000	25000
C[23]	22.53	0.6166	0.003904	21.68	22.0	22.53	23.07	23.39	5000	25000
C[24]	19.55	0.5388	0.003301	18.81	19.08	19.54	20.02	20.31	5000	25000

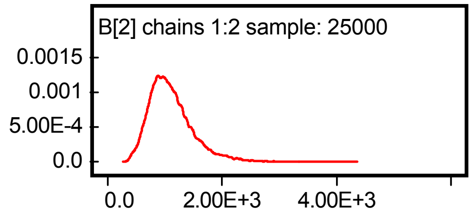
C[25]	16.56	0.4537	0.00276	15.93	16.17	16.56	16.95	17.2	5000	25000
C[26]	16.76	0.4616	0.002943	16.12	16.36	16.76	17.15	17.4	5000	25000
C[27]	18.7	0.5137	0.003108	17.99	18.26	18.71	19.14	19.42	5000	25000
C[28]	21.0	0.5774	0.00339	20.2	20.5	21.0	21.49	21.8	5000	25000
C[29]	16.95	0.4666	0.003191	16.31	16.55	16.95	17.36	17.6	5000	25000
C[30]	16.37	0.4506	0.002864	15.74	15.98	16.37	16.76	16.99	5000	25000
C[31]	18.13	0.4999	0.003073	17.44	17.7	18.13	18.56	18.83	5000	25000
C[32]	16.86	0.4638	0.003017	16.22	16.46	16.85	17.26	17.51	5000	25000
C[33]	15.46	0.424	0.0027	14.88	15.1	15.46	15.83	16.05	5000	25000
C[34]	17.01	0.4653	0.00296	16.37	16.61	17.01	17.41	17.65	5000	25000
C[35]	16.36	0.452	0.002825	15.74	15.97	16.36	16.75	16.99	5000	25000
C[36]	15.71	0.4336	0.00284	15.11	15.33	15.71	16.08	16.31	5000	25000
C[37]	14.81	0.4084	0.002749	14.24	14.45	14.8	15.16	15.37	5000	25000
C[38]	15.75	0.4349	0.002651	15.15	15.37	15.75	16.12	16.35	5000	25000
H[1]	0.1391	0.04102	0.001415	0.09153	0.1102	0.1342	0.1625	0.1926	5000	25000
H[2]	0.2495	0.08707	0.003059	0.1533	0.1889	0.2357	0.2943	0.3607	5000	25000
H[3]	0.4059	0.1402	0.00499	0.2442	0.3056	0.388	0.4849	0.5896	5000	25000
H[4]	0.3917	0.1603	0.005785	0.2118	0.2766	0.3664	0.4788	0.6023	5000	25000
H[5]	0.209	0.09411	0.00343	0.1054	0.1416	0.1923	0.258	0.3316	5000	25000
H[6]	0.1485	0.06183	0.002256	0.07864	0.1043	0.1388	0.1825	0.2304	5000	25000
H[7]	0.1326	0.04849	0.001737	0.07598	0.0979	0.1267	0.1606	0.1964	5000	25000
H[8]	0.06671	0.02225	7.851E-4	0.03982	0.0508	0.06465	0.08032	0.09607	5000	25000
H[9]	0.1185	0.03492	0.001196	0.07515	0.09378	0.1163	0.1406	0.1644	5000	25000
H[10]	0.1292	0.03811	0.001288	0.0822	0.1023	0.1267	0.153	0.1792	5000	25000
H[11]	0.1449	0.04233	0.001438	0.09238	0.1148	0.1421	0.1717	0.2	5000	25000
H[12]	0.1393	0.04163	0.001413	0.08859	0.1096	0.1361	0.1648	0.1932	5000	25000
H[13]	0.1177	0.03493	0.001191	0.07509	0.09273	0.1151	0.1394	0.1633	5000	25000
H[14]	0.08281	0.02442	8.242E-4	0.05291	0.06525	0.08098	0.09809	0.1148	5000	25000
H[15]	0.07032	0.02026	6.833E-4	0.0454	0.05603	0.0689	0.0828	0.09662	5000	25000
H[16]	0.04019	0.01125	3.839E-4	0.02641	0.03229	0.03952	0.04702	0.05452	5000	25000
H[17]	0.02154	0.005852	1.997E-4	0.01434	0.01746	0.02119	0.02511	0.02908	5000	25000
H[18]	0.01758	0.004767	1.627E-4	0.0118	0.01429	0.01725	0.02038	0.0236	5000	25000
H[19]	0.01848	0.005032	1.718E-4	0.01241	0.01502	0.01807	0.02149	0.02487	5000	25000
H[20]	0.01843	0.005145	1.759E-4	0.01233	0.01488	0.018	0.02139	0.02498	5000	25000
H[21]	0.01645	0.004503	1.544E-4	0.01102	0.01333	0.01606	0.01913	0.02223	5000	25000
H[22]	0.02042	0.005847	2.008E-4	0.01355	0.01638	0.01983	0.02378	0.02779	5000	25000
H[23]	0.01984	0.005593	1.929E-4	0.01321	0.01594	0.0193	0.02314	0.0271	5000	25000
H[24]	0.01713	0.004975	1.725E-4	0.01132	0.01368	0.01659	0.01995	0.02352	5000	25000
H[25]	0.01445	0.004121	1.424E-4	0.009577	0.01156	0.01403	0.01688	0.01975	5000	25000
H[26]	0.01485	0.004336	1.497E-4	0.00978	0.01181	0.01438	0.01735	0.02044	5000	25000
H[27]	0.01623	0.004685	1.625E-4	0.01072	0.01295	0.01574	0.01898	0.02228	5000	25000
H[28]	0.01815	0.005286	1.835E-4	0.01198	0.01442	0.01758	0.0212	0.02497	5000	25000
H[29]	0.01494	0.004398	1.515E-4	0.009806	0.01188	0.01445	0.01743	0.02058	5000	25000
H[30]	0.01422	0.004038	1.396E-4	0.009405	0.01137	0.01382	0.01662	0.01944	5000	25000
H[31]	0.01607	0.004707	1.624E-4	0.01059	0.0128	0.01555	0.01876	0.02207	5000	25000
H[32]	0.01481	0.004196	1.455E-4	0.009813	0.01187	0.01439	0.01731	0.02028	5000	25000
H[33]	0.01361	0.003969	1.366E-4	0.00899	0.01085	0.01317	0.01587	0.01864	5000	25000
H[34]	0.01488	0.00417	1.434E-4	0.009882	0.01198	0.0145	0.01737	0.02028	5000	25000
H[35]	0.01482	0.004509	1.533E-4	0.009717	0.01173	0.01429	0.01727	0.02036	5000	25000
H[36]	0.01357	0.00383	1.326E-4	0.009003	0.01087	0.01318	0.01584	0.01856	5000	25000
H[37]	0.01293	0.003814	1.316E-4	0.008481	0.01027	0.01252	0.01508	0.0178	5000	25000
HMSP	0.4034	0.196	0.007461	0.2088	0.265	0.3477	0.488	0.7106	5000	25000
HRATIO	0.03638	0.01274	4.448E-4	0.02024	0.02867	0.0367	0.04364	0.05055	5000	25000
INDEXMSPFALL	2.273	0.1936	0.005373	2.03	2.142	2.268	2.398	2.52	5000	25000
INDEXMSPSPR	1.502	0.1633	0.003561	1.305	1.388	1.49	1.601	1.715	5000	25000
K	1274.0	380.5	12.88	862.1	1009.0	1211.0	1463.0	1758.0	5000	25000
MSP	239.5	112.9	4.095	153.0	173.8	204.6	260.0	373.8	5000	25000
RESIDFALL[1]	7.41	0.4991	0.0119	6.778	7.111	7.44	7.752	8.015	5000	25000
RESIDFALL[2]	-0.4176	0.4627	0.01194	-1.005	-0.7113	-0.4071	-0.1085	0.1591	5000	25000
RESIDFALL[3]	1.403	0.3739	0.00738	0.9167	1.174	1.426	1.662	1.858	5000	25000
RESIDFALL[4]	-0.001479	0.4045	0.01173	-0.5329	-0.2604	0.0273	0.2863	0.4952	5000	25000
RESIDFALL[5]	-0.3101	0.515	0.01805	-1.021	-0.6104	-0.2464	0.05686	0.2927	5000	25000
RESIDFALL[6]	-0.3377	0.6034	0.02233	-1.228	-0.6674	-0.2272	0.0927	0.3389	5000	25000
RESIDFALL[7]	-1.223	0.5521	0.01972	-2.004	-1.595	-1.156	-0.8118	-0.5561	5000	25000

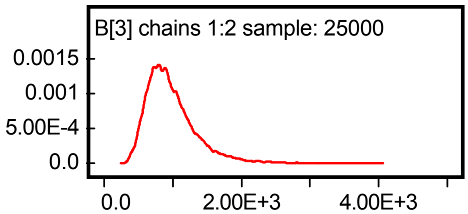
RESIDFALL[8]	-1.278	0.5416	0.01847	-2.015	-1.652	-1.23	-0.871	-0.6133	5000	25000
RESIDFALL[9]	-1.258	0.478	0.01411	-1.886	-1.586	-1.236	-0.9155	-0.6531	5000	25000
RESIDFALL[10]	-3.182E-4	0.3965	0.008779	-0.5115	-0.2631	0.005313	0.2719	0.5067	5000	25000
RESIDFALL[11]	-1.001	0.3763	0.007359	-1.483	-1.243	-0.9924	-0.7444	-0.5263	5000	25000
RESIDFALL[12]	-1.631	0.3539	0.005124	-2.083	-1.854	-1.62	-1.392	-1.189	5000	25000
RESIDFALL[13]	0.5872	0.3783	0.004855	0.1045	0.3568	0.6103	0.8427	1.043	5000	25000
RESIDFALL[14]	2.345	0.3927	0.004594	1.844	2.11	2.369	2.611	2.812	5000	25000
RESIDFALL[15]	0.09854	0.3853	0.004198	-0.3967	-0.1391	0.1213	0.3604	0.5647	5000	25000
RESIDFALL[16]	0.5344	0.3878	0.004381	0.03384	0.2936	0.553	0.7976	1.009	5000	25000
RESIDFALL[17]	-0.4364	0.3929	0.005166	-0.9407	-0.6884	-0.424	-0.1683	0.05158	5000	25000
RESIDFALL[18]	-0.3159	0.4093	0.005825	-0.8364	-0.5771	-0.3045	-0.03935	0.1993	5000	25000
RESIDFALL[19]	-1.922	0.4116	0.005936	-2.448	-2.19	-1.912	-1.646	-1.412	5000	25000
RESIDFALL[20]	-1.092	0.4126	0.006306	-1.616	-1.358	-1.082	-0.8155	-0.582	5000	25000
RESIDFALL[21]	1.253	0.4179	0.006392	0.7187	0.9848	1.267	1.533	1.769	5000	25000
RESIDFALL[22]	-1.901	0.4211	0.007491	-2.435	-2.176	-1.897	-1.624	-1.372	5000	25000
RESIDFALL[23]	1.346	0.4231	0.007297	0.8025	1.081	1.361	1.637	1.869	5000	25000
RESIDFALL[24]	1.986	0.4472	0.009121	1.415	1.703	2.003	2.289	2.534	5000	25000
RESIDFALL[25]	0.4043	0.4389	0.00814	-0.1603	0.1289	0.417	0.7079	0.9511	5000	25000
RESIDFALL[26]	-0.791	0.4405	0.009039	-1.349	-1.076	-0.7807	-0.4937	-0.2419	5000	25000
RESIDFALL[27]	1.743	0.4461	0.008926	1.167	1.461	1.761	2.047	2.293	5000	25000
RESIDFALL[28]	2.502	0.4565	0.009411	1.919	2.223	2.522	2.81	3.065	5000	25000
RESIDFALL[29]	0.809	0.4524	0.009774	0.2318	0.5257	0.8244	1.112	1.368	5000	25000
RESIDFALL[30]	1.739	0.4389	0.008248	1.174	1.465	1.761	2.037	2.275	5000	25000
RESIDFALL[31]	-0.3852	0.439	0.008732	-0.9539	-0.6649	-0.376	-0.0889	0.1618	5000	25000
RESIDFALL[32]	-1.205	0.4245	0.007445	-1.755	-1.474	-1.19	-0.9178	-0.6718	5000	25000
RESIDFALL[33]	1.754	0.443	0.009067	1.187	1.469	1.769	2.047	2.306	5000	25000
RESIDFALL[34]	-1.066	0.4326	0.00692	-1.612	-1.336	-1.049	-0.7746	-0.5343	5000	25000
RESIDFALL[35]	-1.573	0.4547	0.009785	-2.143	-1.864	-1.572	-1.286	-1.015	5000	25000
RESIDFALL[36]	4.515	0.4434	0.008314	3.942	4.245	4.538	4.818	5.059	5000	25000
RESIDFALL[37]	0.6448	0.4672	0.01026	0.05262	0.3482	0.6593	0.9573	1.221	5000	25000
RESIDSPR[1]	0.4601	0.4242	0.01514	-0.145	0.2176	0.5282	0.7679	0.9416	5000	25000
RESIDSPR[2]	-0.5825	0.3905	0.01325	-1.12	-0.8459	-0.5417	-0.2899	-0.1076	5000	25000
RESIDSPR[3]	4.132	0.3831	0.01228	3.619	3.873	4.158	4.416	4.608	5000	25000
RESIDSPR[4]	-0.8646	0.3459	0.009172	-1.315	-1.097	-0.852	-0.6191	-0.4273	5000	25000
RESIDSPR[5]	-0.8614	0.3008	0.005738	-1.248	-1.061	-0.8537	-0.6533	-0.4842	5000	25000
RESIDSPR[6]	1.827	0.2919	0.004827	1.451	1.641	1.838	2.026	2.19	5000	25000
RESIDSPR[7]	0.7645	0.2806	0.003527	0.3993	0.5871	0.7777	0.9547	1.109	5000	25000
RESIDSPR[8]	5.283	0.2985	0.003478	4.899	5.097	5.298	5.488	5.645	5000	25000
RESIDSPR[9]	3.409	0.3094	0.003209	3.013	3.225	3.43	3.621	3.779	5000	25000
RESIDSPR[10]	1.602	0.3057	0.002674	1.206	1.414	1.62	1.81	1.976	5000	25000
RESIDSPR[11]	0.8863	0.3067	0.002551	0.4899	0.6964	0.906	1.096	1.262	5000	25000
RESIDSPR[12]	-0.6529	0.3099	0.002673	-1.051	-0.8474	-0.6373	-0.4412	-0.2719	5000	25000
RESIDSPR[13]	0.5324	0.32	0.003025	0.1191	0.3305	0.5484	0.753	0.9252	5000	25000
RESIDSPR[14]	0.3853	0.3215	0.003243	-0.03009	0.1828	0.4017	0.6017	0.78	5000	25000
RESIDSPR[15]	-1.043	0.3239	0.003767	-1.462	-1.245	-1.027	-0.8217	-0.6458	5000	25000
RESIDSPR[16]	-1.415	0.3279	0.003738	-1.842	-1.615	-1.396	-1.189	-1.014	5000	25000
RESIDSPR[17]	-1.05	0.3341	0.004764	-1.48	-1.256	-1.033	-0.826	-0.6408	5000	25000
RESIDSPR[18]	-0.261	0.3376	0.004604	-0.6961	-0.4711	-0.24	-0.02736	0.1506	5000	25000
RESIDSPR[19]	-0.02667	0.3502	0.005937	-0.4838	-0.2401	-0.001852	0.2142	0.3948	5000	25000
RESIDSPR[20]	0.755	0.35	0.005353	0.299	0.5404	0.7829	0.9959	1.177	5000	25000
RESIDSPR[21]	-1.363	0.3513	0.00596	-1.819	-1.576	-1.34	-1.121	-0.9372	5000	25000
RESIDSPR[22]	-0.1472	0.355	0.005938	-0.6063	-0.36	-0.1222	0.09692	0.2812	5000	25000
RESIDSPR[23]	0.01804	0.3638	0.006224	-0.454	-0.1995	0.04536	0.2724	0.4526	5000	25000
RESIDSPR[24]	-1.485	0.3584	0.006494	-1.949	-1.706	-1.459	-1.241	-1.051	5000	25000
RESIDSPR[25]	-0.3971	0.3497	0.005308	-0.8507	-0.6111	-0.371	-0.1534	0.02863	5000	25000
RESIDSPR[26]	-1.085	0.3483	0.005735	-1.538	-1.301	-1.064	-0.8439	-0.661	5000	25000
RESIDSPR[27]	1.351	0.3386	0.00474	0.9136	1.139	1.374	1.585	1.763	5000	25000
RESIDSPR[28]	-0.9376	0.3506	0.005904	-1.391	-1.151	-0.9157	-0.6956	-0.51	5000	25000
RESIDSPR[29]	2.213	0.3439	0.004355	1.77	2.003	2.238	2.45	2.628	5000	25000
RESIDSPR[30]	-1.956	0.3553	0.006486	-2.406	-2.174	-1.937	-1.72	-1.531	5000	25000
RESIDSPR[31]	-0.7985	0.3532	0.005435	-1.254	-1.008	-0.7715	-0.5543	-0.3763	5000	25000
RESIDSPR[32]	-0.2002	0.3632	0.006786	-0.6725	-0.4229	-0.177	0.04899	0.2389	5000	25000
RESIDSPR[33]	1.596	0.3647	0.006092	1.124	1.378	1.624	1.849	2.034	5000	25000
qFALL	0.00387	0.001132	4.01E-5	0.002506	0.003072	0.003769	0.004549	0.005342	5000	25000

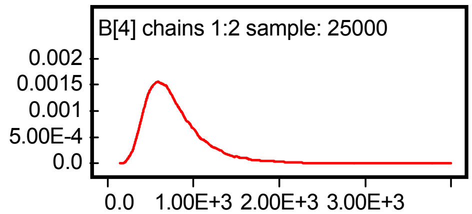
qSPR	0.002549	7.413E-4	2.515E-5	0.00166	0.002029	0.002482	0.002991	0.003513	5000	25000
r	0.8068	0.392	0.01492	0.4176	0.5299	0.6954	0.9759	1.421	5000	25000
sigma2	0.003697	0.002791	4.496E-5	0.001561	0.002068	0.002928	0.004397	0.00657	5000	25000
tau2FALL	0.1429	0.03933	8.201E-4	0.09823	0.1149	0.1373	0.1647	0.1946	5000	25000
tau2SPR	0.2723	0.07275	8.992E-4	0.1916	0.2212	0.261	0.311	0.3664	5000	25000

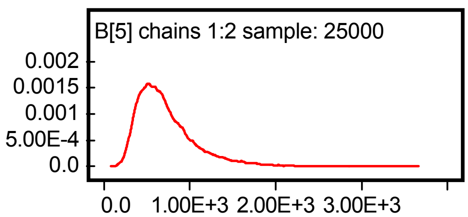
Marginal Plots

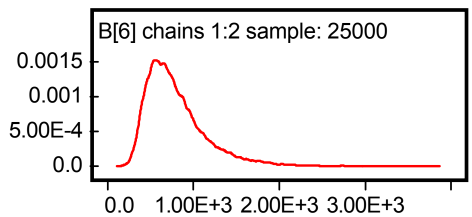


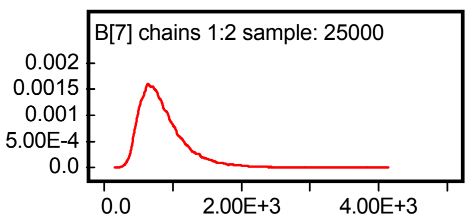


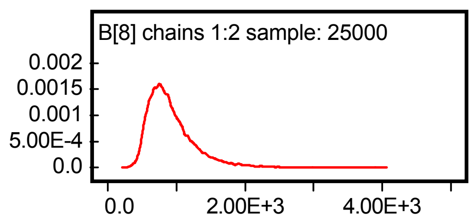


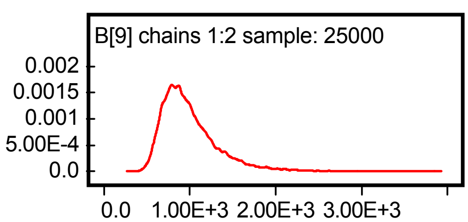


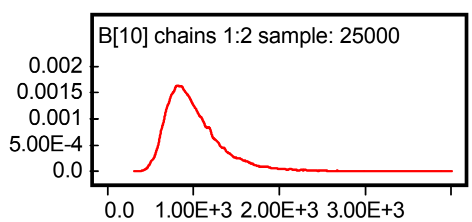


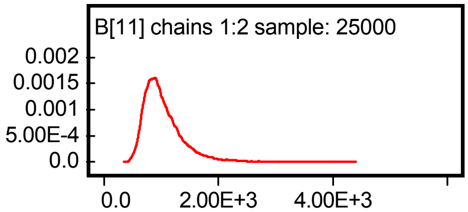


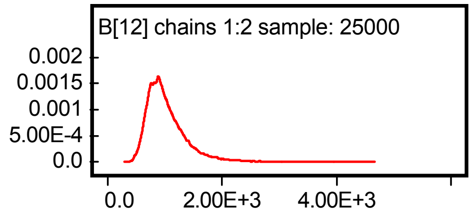









B[11] chains 1:2 sample: 25000
0.002
0.0015
0.001
5.00E-4
0.0
0.0
2.00E+3
4.00E+3


B[12] chains 1:2 sample: 25000
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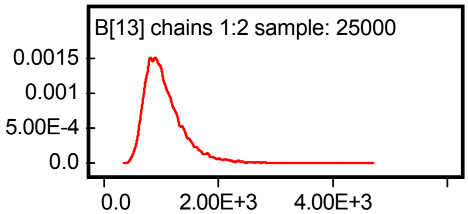
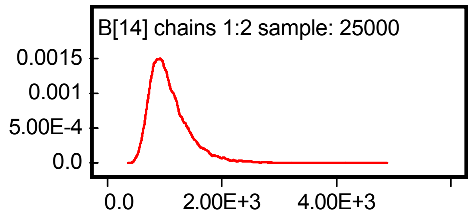
0.0015
0.001
5.00E-4
0.0
0.0
2.00E+3
4.00E+3


B[13] chains 1:2 sample: 25000
0.0015
0.001
5.00E-4
0.0
0.0
2.00E+3
4.00E+3


B[14] chains 1:2 sample: 25000
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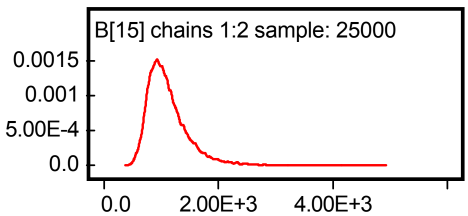
5.00E-4
0.0
0.0
2.00E+3
4.00E+3


B[15] chains 1:2 sample: 25000
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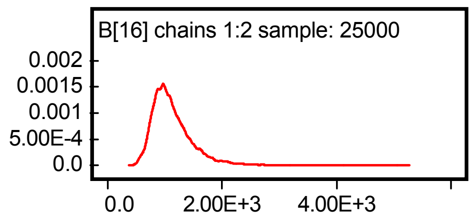
0.001
5.00E-4
0.0
0.0
2.00E+3
4.00E+3


B[16] chains 1:2 sample: 25000
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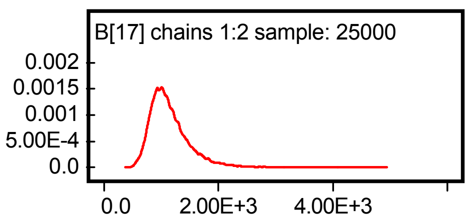
0.001
5.00E-4
0.0
0.0
2.00E+3
4.00E+3


B[17] chains 1:2 sample: 25000
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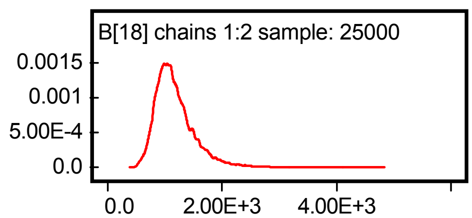
0.0015
0.001
5.00E-4
0.0
0.0
2.00E+3
4.00E+3


B[18] chains 1:2 sample: 25000
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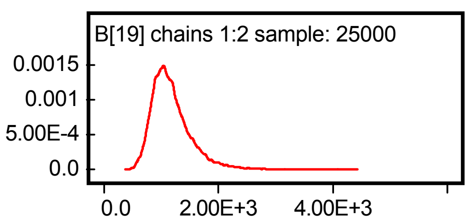
0.001
5.00E-4
0.0
0.0
2.00E+3
4.00E+3


B[19] chains 1:2 sample: 25000
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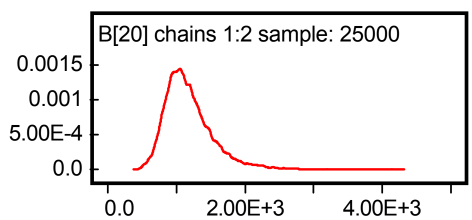
0.001
5.00E-4
0.0
0.0
2.00E+3
4.00E+3


B[20] chains 1:2 sample: 25000
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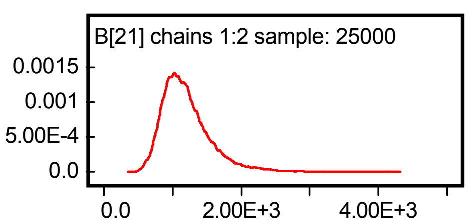
5.00E-4
0.0
0.0
2.00E+3
4.00E+3


B[21] chains 1:2 sample: 25000
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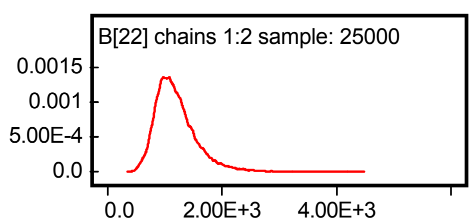
0.0
0.0
2.00E+3
4.00E+3


B[22] chains 1:2 sample: 25000
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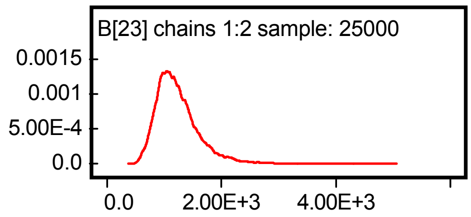
0.001
5.00E-4
0.0
0.0
2.00E+3
4.00E+3


B[23] chains 1:2 sample: 25000
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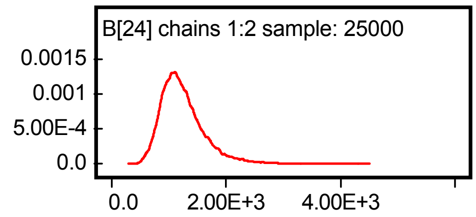
0.001
5.00E-4
0.0
0.0
2.00E+3
4.00E+3


B[24] chains 1:2 sample: 25000
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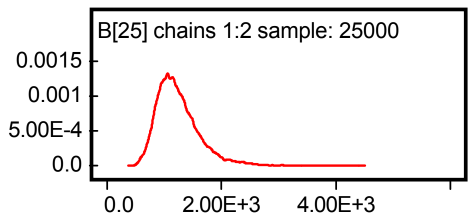
0.0
2.00E+3
4.00E+3


B[25] chains 1:2 sample: 25000
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0.001
5.00E-4
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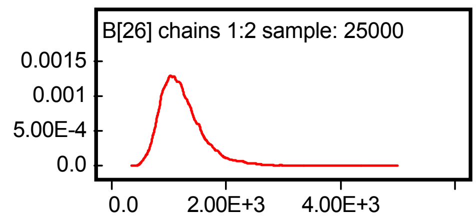
0.0
2.00E+3
4.00E+3


B[26] chains 1:2 sample: 25000
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0.001
5.00E-4
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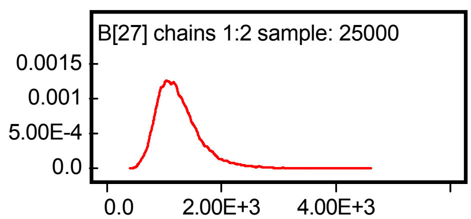
0.0
2.00E+3
4.00E+3


B[27] chains 1:2 sample: 25000
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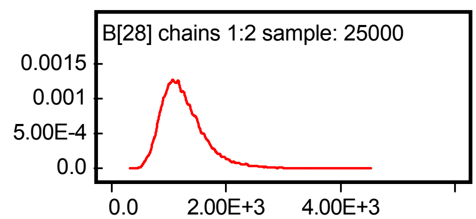
5.00E-4
0.0
0.0
2.00E+3
4.00E+3


B[28] chains 1:2 sample: 25000
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5.00E-4
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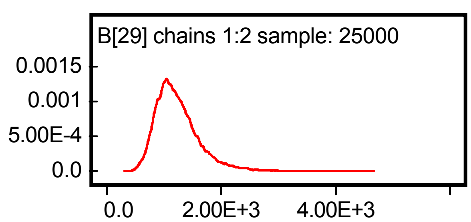
0.0
2.00E+3
4.00E+3


B[29] chains 1:2 sample: 25000
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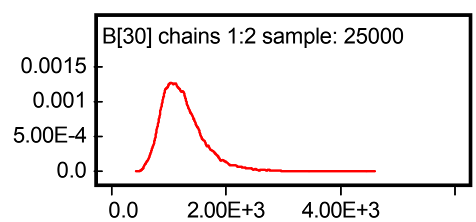
0.0
2.00E+3
4.00E+3


B[30] chains 1:2 sample: 25000
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5.00E-4
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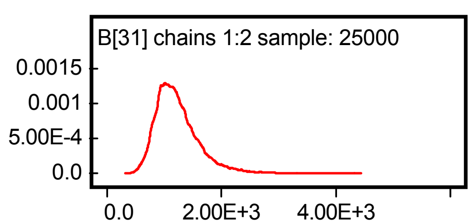
0.0
2.00E+3
4.00E+3


B[31] chains 1:2 sample: 25000
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5.00E-4
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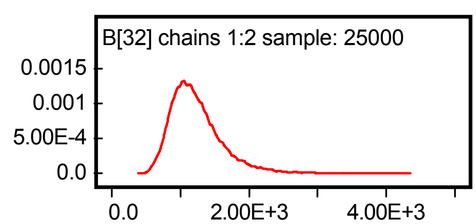
0.0
2.00E+3
4.00E+3


B[32] chains 1:2 sample: 25000
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5.00E-4
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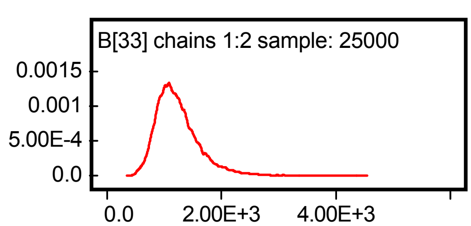
0.0
2.00E+3
4.00E+3


B[33] chains 1:2 sample: 25000
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0.001
5.00E-4
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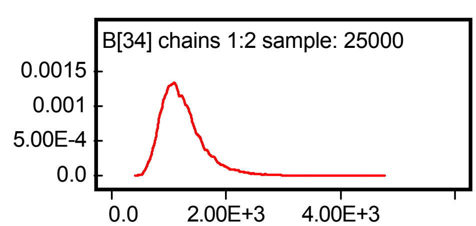
0.0
2.00E+3
4.00E+3


B[34] chains 1:2 sample: 25000
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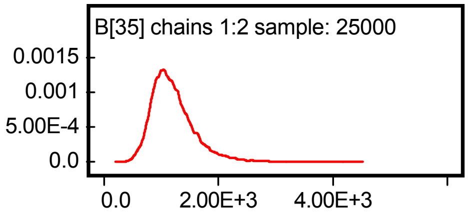
0.0
2.00E+3
4.00E+3


B[35] chains 1:2 sample: 25000
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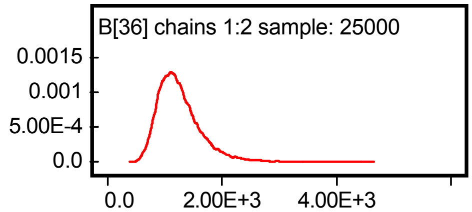
0.0
2.00E+3
4.00E+3


B[36] chains 1:2 sample: 25000
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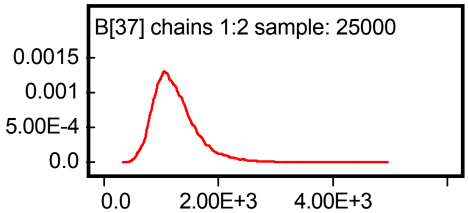
0.0
2.00E+3
4.00E+3


B[37] chains 1:2 sample: 25000
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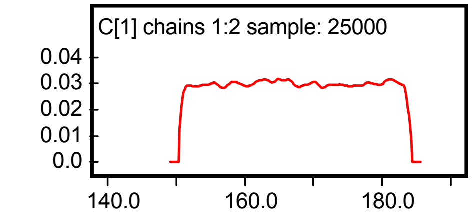
0.0
2.00E+3
4.00E+3


C[1] chains 1:2 sample: 25000
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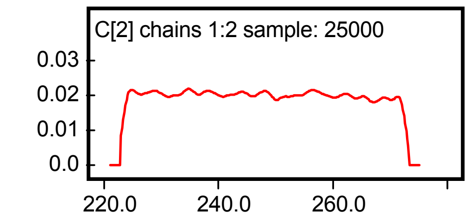
0.03
0.02
0.01
0.0
140.0
160.0
180.0


C[2] chains 1:2 sample: 25000
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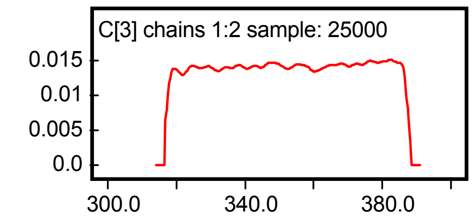
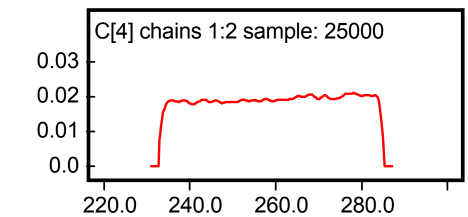
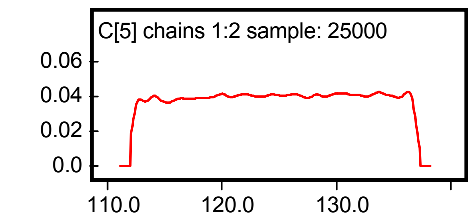
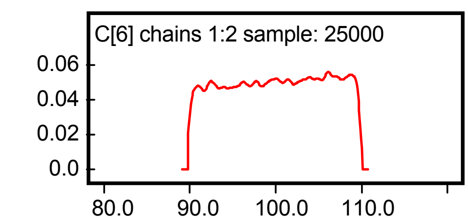
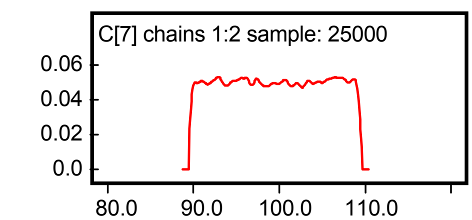
0.02
0.01
0.0
220.0
240.0
260.0

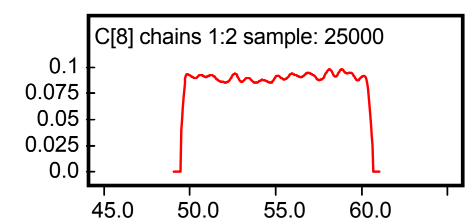

C[3] chains 1:2 sample: 25000
0.015
0.01
0.005
0.0
300.0
340.0
380.0

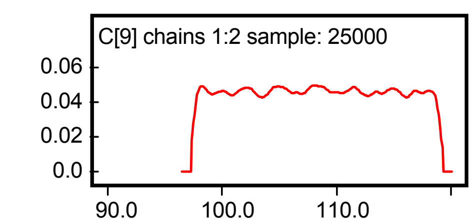

C[4] chains 1:2 sample: 25000
0.03
0.02
0.01
0.0
220.0
240.0
260.0
280.0

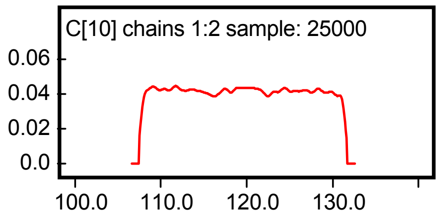

C[5] chains 1:2 sample: 25000
0.06
0.04
0.02
0.0
110.0
120.0
130.0

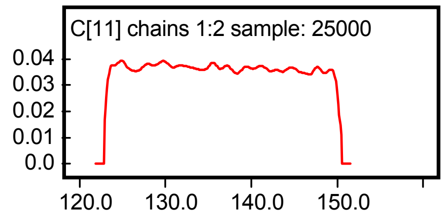

C[6] chains 1:2 sample: 25000
0.06
0.04
0.02
0.0
80.0
90.0
100.0
110.0

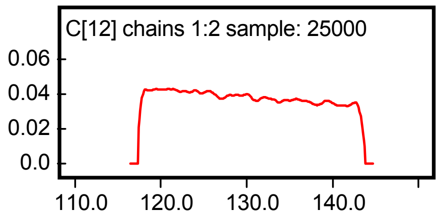

C[7] chains 1:2 sample: 25000
0.06
0.04
0.02
0.0
80.0
90.0
100.0
110.0

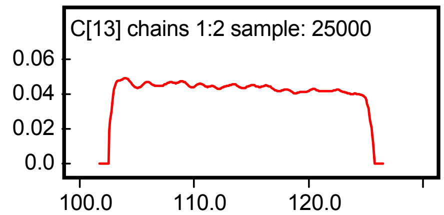

C[8] chains 1:2 sample: 25000
0.1
0.075
0.05
0.025
0.0
45.0
50.0
55.0
60.0

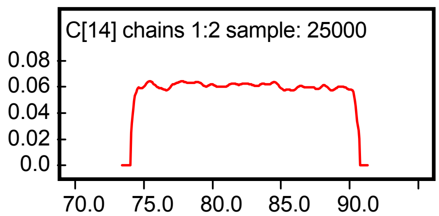

C[9] chains 1:2 sample: 25000
0.06
0.04
0.02
0.0
90.0
100.0
110.0

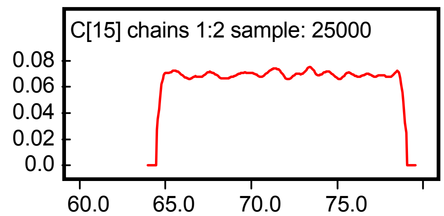

C[10] chains 1:2 sample: 25000
0.06
0.04
0.02
0.0
100.0
110.0
120.0
130.0

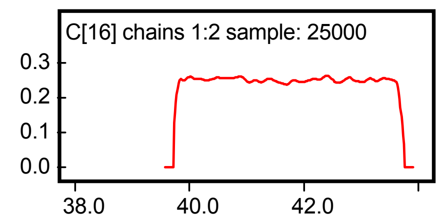

C[11] chains 1:2 sample: 25000
0.04
0.03
0.02
0.01
0.0
120.0
130.0
140.0
150.0

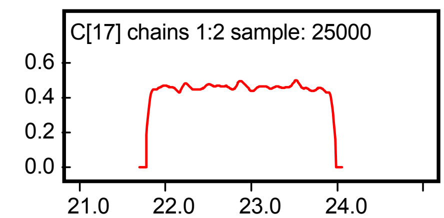

C[12] chains 1:2 sample: 25000
0.06
0.04
0.02
0.0
110.0
120.0
130.0
140.0

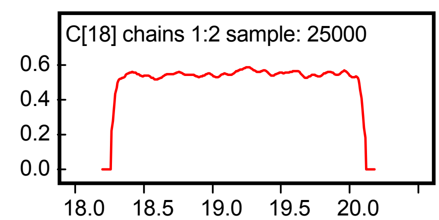

C[13] chains 1:2 sample: 25000
0.06
0.04
0.02
0.0
100.0
110.0
120.0

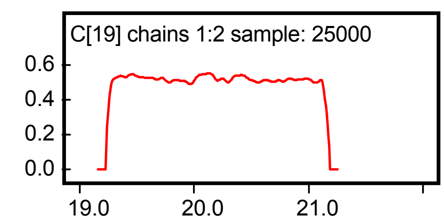

C[14] chains 1:2 sample: 25000
0.08
0.06
0.04
0.02
0.0
70.0
75.0
80.0
85.0
90.0

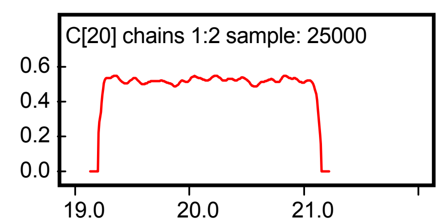

C[15] chains 1:2 sample: 25000
0.08
0.06
0.04
0.02
0.0
60.0
65.0
70.0
75.0

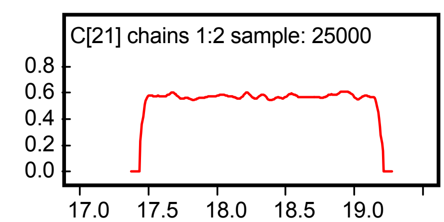

C[16] chains 1:2 sample: 25000
0.3
0.2
0.1
0.0
38.0
40.0
42.0

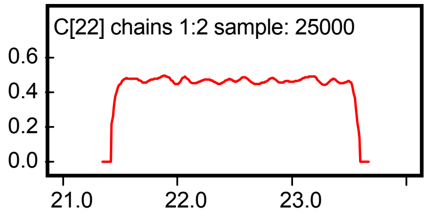

C[17] chains 1:2 sample: 25000
0.6
0.4
0.2
0.0
21.0
22.0
23.0
24.0

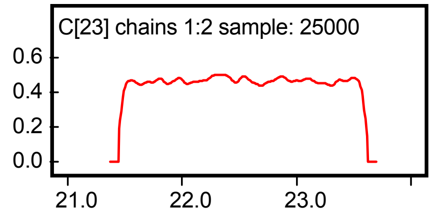

C[18] chains 1:2 sample: 25000
0.6
0.4
0.2
0.0
18.0
18.5
19.0
19.5
20.0

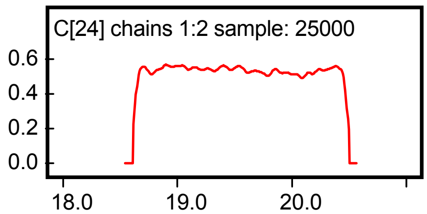

C[19] chains 1:2 sample: 25000
0.6
0.4
0.2
0.0
19.0
20.0
21.0

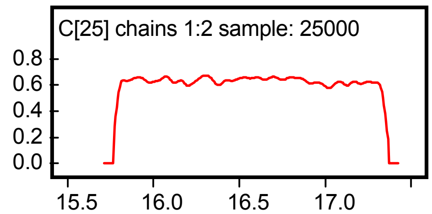

C[20] chains 1:2 sample: 25000
0.6
0.4
0.2
0.0
19.0
20.0
21.0

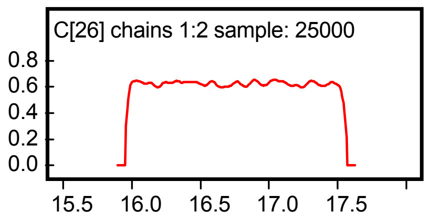

C[21] chains 1:2 sample: 25000
0.8
0.6
0.4
0.2
0.0
17.0
17.5
18.0
18.5
19.0

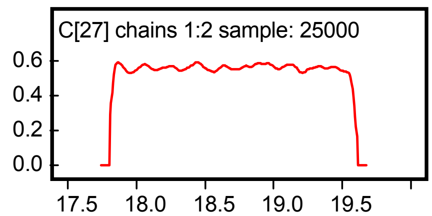

C[22] chains 1:2 sample: 25000
0.6
0.4
0.2
0.0
21.0
22.0
23.0

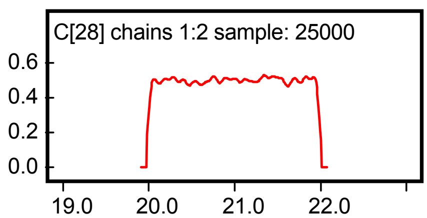

C[23] chains 1:2 sample: 25000
0.6
0.4
0.2
0.0
21.0
22.0
23.0

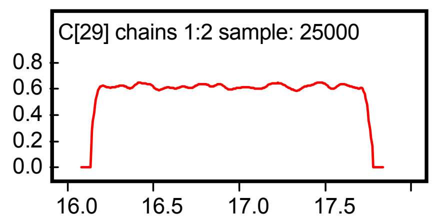

C[24] chains 1:2 sample: 25000
0.6
0.4
0.2
0.0
18.0
19.0
20.0

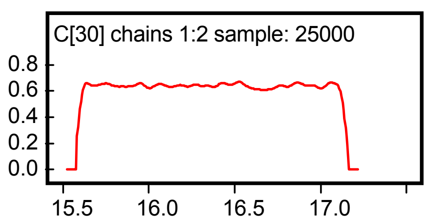

C[25] chains 1:2 sample: 25000
0.8
0.6
0.4
0.2
0.0
15.5
16.0
16.5
17.0

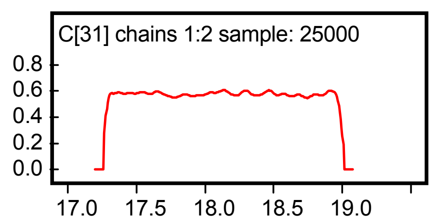

C[26] chains 1:2 sample: 25000
0.8
0.6
0.4
0.2
0.0
15.5
16.0
16.5
17.0
17.5

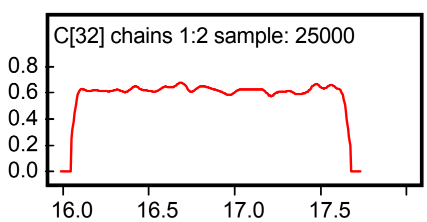

C[27] chains 1:2 sample: 25000
0.6
0.4
0.2
0.0
17.5
18.0
18.5
19.0
19.5

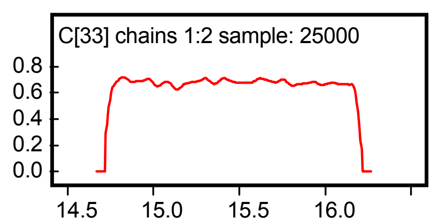

C[28] chains 1:2 sample: 25000
0.6
0.4
0.2
0.0
19.0
20.0
21.0
22.0

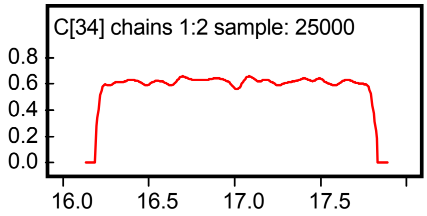

C[29] chains 1:2 sample: 25000
0.8
0.6
0.4
0.2
0.0
16.0
16.5
17.0
17.5

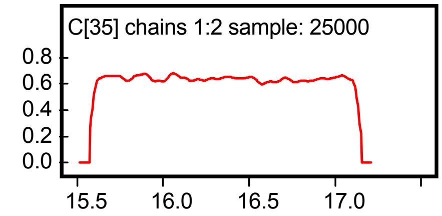

C[30] chains 1:2 sample: 25000
0.8
0.6
0.4
0.2
0.0
15.5
16.0
16.5
17.0

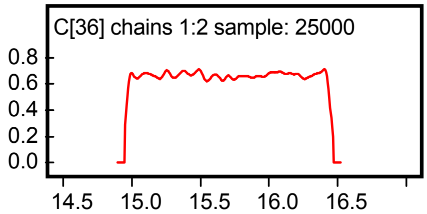

C[31] chains 1:2 sample: 25000
0.8
0.6
0.4
0.2
0.0
17.0
17.5
18.0
18.5
19.0

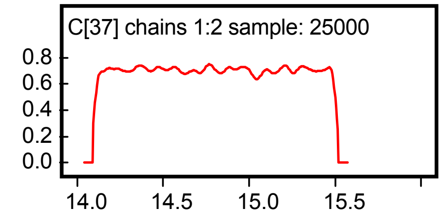

C[32] chains 1:2 sample: 25000
0.8
0.6
0.4
0.2
0.0
16.0
16.5
17.0
17.5

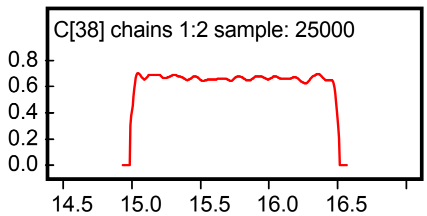

C[33] chains 1:2 sample: 25000
0.8
0.6
0.4
0.2
0.0
14.5
15.0
15.5
16.0

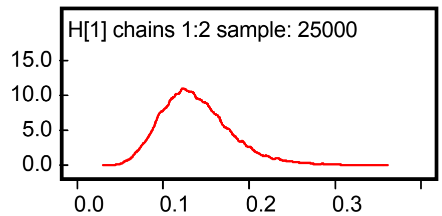

C[34] chains 1:2 sample: 25000
0.8
0.6
0.4
0.2
0.0
16.0
16.5
17.0
17.5

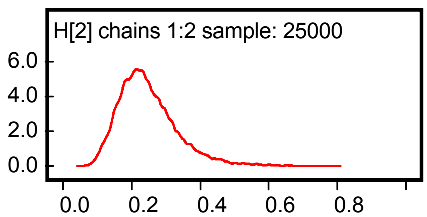

C[35] chains 1:2 sample: 25000
0.8
0.6
0.4
0.2
0.0
15.5
16.0
16.5
17.0

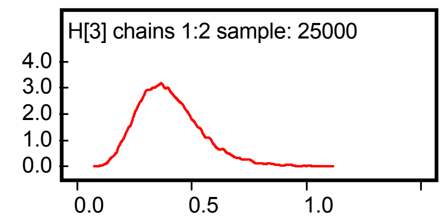

C[36] chains 1:2 sample: 25000
0.8
0.6
0.4
0.2
0.0
14.5
15.0
15.5
16.0
16.5

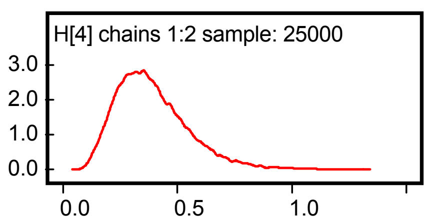

C[37] chains 1:2 sample: 25000
0.8
0.6
0.4
0.2
0.0
14.0
14.5
15.0
15.5

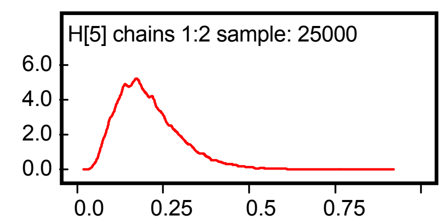

C[38] chains 1:2 sample: 25000
0.8
0.6
0.4
0.2
0.0
14.5
15.0
15.5
16.0
16.5

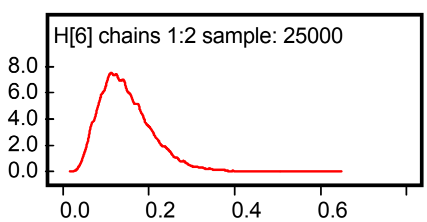

H[1] chains 1:2 sample: 25000
15.0
10.0
5.0
0.0
0.0
0.1
0.2
0.3

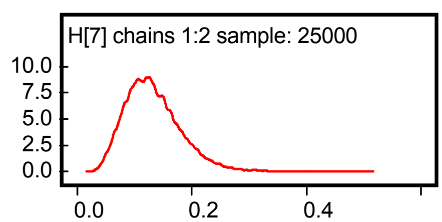

H[2] chains 1:2 sample: 25000
6.0
4.0
2.0
0.0
0.0
0.2
0.4
0.6
0.8

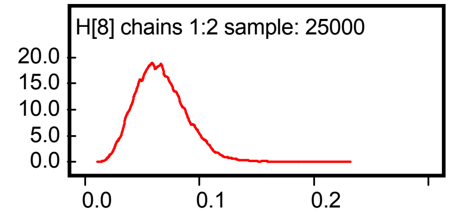

H[3] chains 1:2 sample: 25000
4.0
3.0
2.0
1.0
0.0
0.0
0.5
1.0

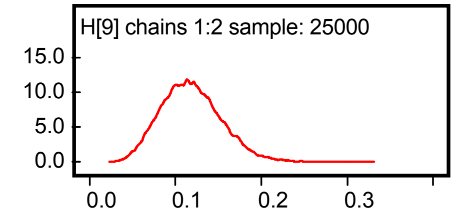

H[4] chains 1:2 sample: 25000
3.0
2.0
1.0
0.0
0.0
0.5
1.0

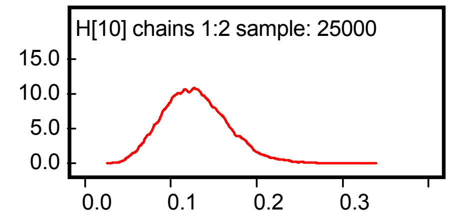

H[5] chains 1:2 sample: 25000
6.0
4.0
2.0
0.0
0.0
0.25
0.5
0.75

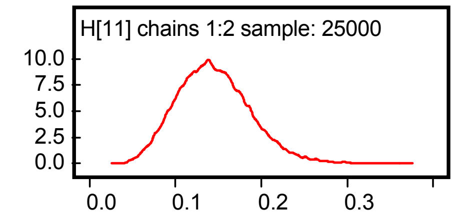

H[6] chains 1:2 sample: 25000
8.0
6.0
4.0
2.0
0.0
0.0
0.2
0.4
0.6

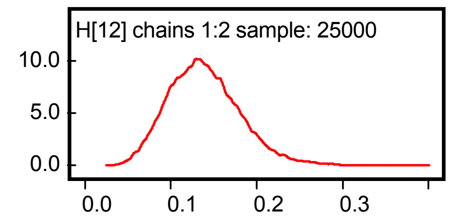

H[7] chains 1:2 sample: 25000
10.0
7.5
5.0
2.5
0.0
0.0
0.2
0.4

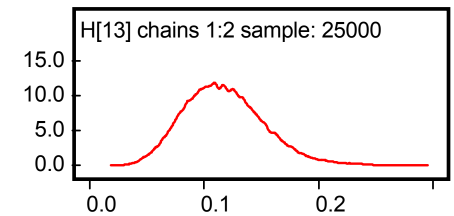

H[8] chains 1:2 sample: 25000
20.0
15.0
10.0
5.0
0.0
0.0
0.1
0.2

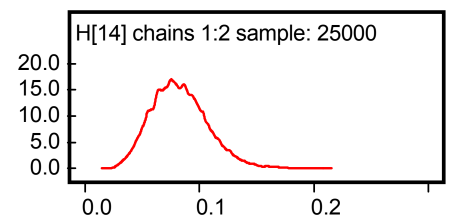

H[9] chains 1:2 sample: 25000
15.0
10.0
5.0
0.0
0.0
0.1
0.2
0.3

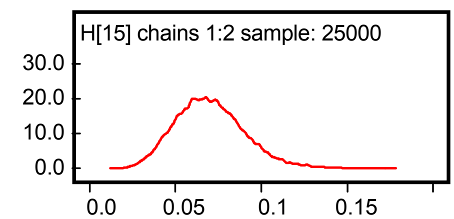

H[10] chains 1:2 sample: 25000
15.0
10.0
5.0
0.0
0.0
0.1
0.2
0.3

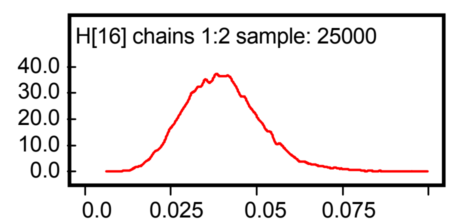

H[11] chains 1:2 sample: 25000
10.0
7.5
5.0
2.5
0.0
0.0
0.1
0.2
0.3

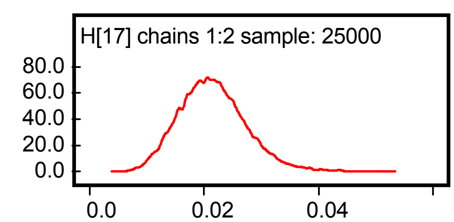

H[12] chains 1:2 sample: 25000
10.0
5.0
0.0
0.0
0.1
0.2
0.3

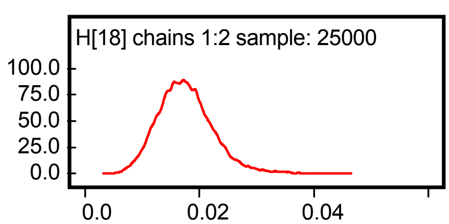

H[13] chains 1:2 sample: 25000
15.0
10.0
5.0
0.0
0.0
0.1
0.2

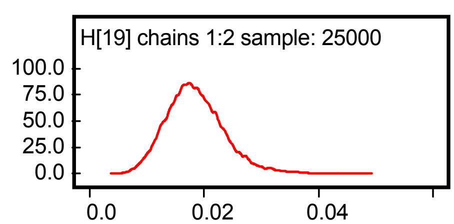

H[14] chains 1:2 sample: 25000
20.0
15.0
10.0
5.0
0.0
0.0
0.1
0.2

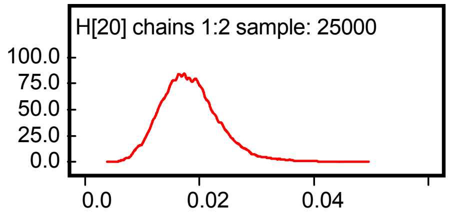
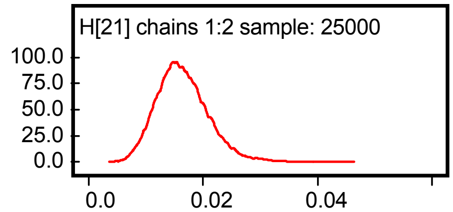
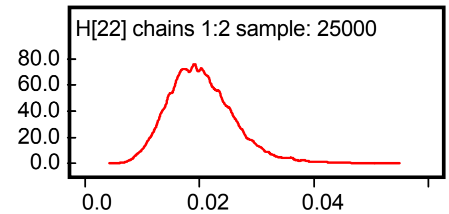
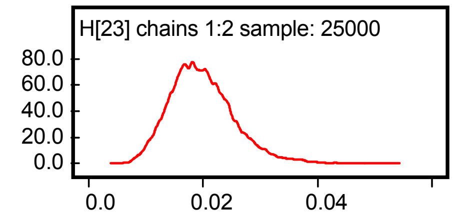
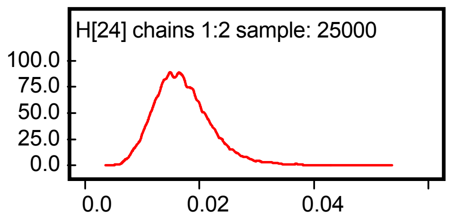
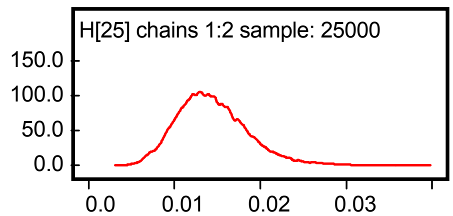
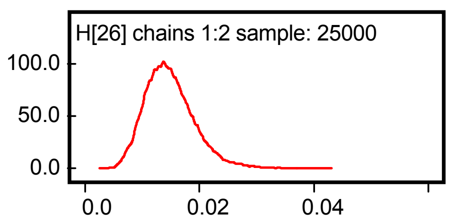
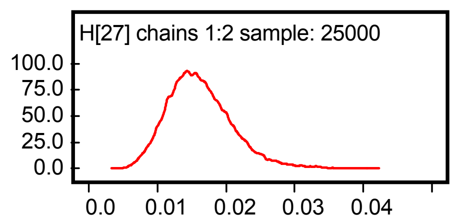
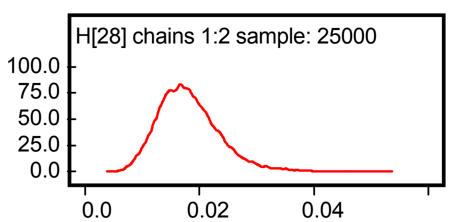
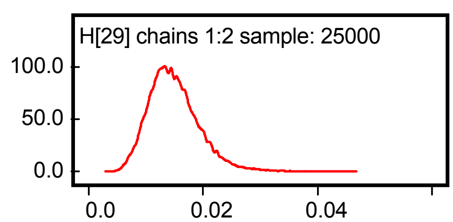
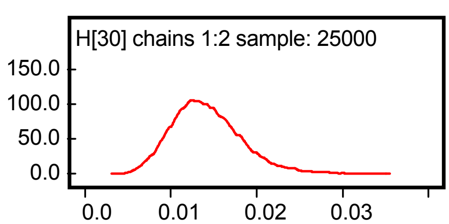
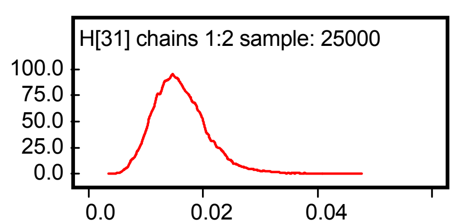

H[15] chains 1:2 sample: 25000
30.0
20.0
10.0
0.0
0.0
0.05
0.1
0.15

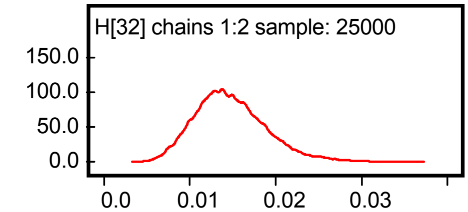

H[16] chains 1:2 sample: 25000
40.0
30.0
20.0
10.0
0.0
0.0
0.025
0.05
0.075

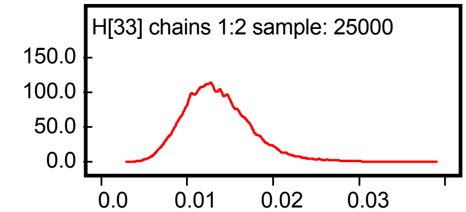

H[17] chains 1:2 sample: 25000
80.0
60.0
40.0
20.0
0.0
0.0
0.02
0.04

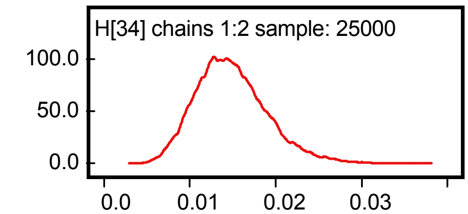

H[18] chains 1:2 sample: 25000
100.0
75.0
50.0
25.0
0.0
0.0
0.02
0.04

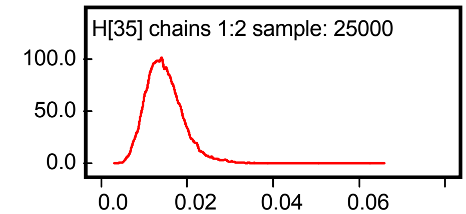

H[19] chains 1:2 sample: 25000
100.0
75.0
50.0
25.0
0.0
0.0
0.02
0.04

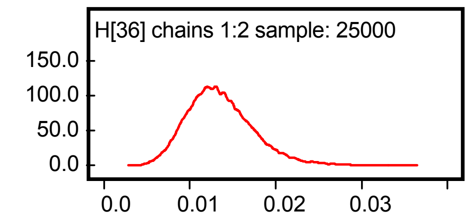

H[20] chains 1:2 sample: 25000
100.0
75.0
50.0
25.0
0.0
0.0
0.02
0.04

H[21] chains 1:2 sample: 25000
100.0
75.0
50.0
25.0
0.0
0.0
0.02
0.04

H[22] chains 1:2 sample: 25000
80.0
60.0
40.0
20.0
0.0
0.0
0.02
0.04

H[23] chains 1:2 sample: 25000
80.0
60.0
40.0
20.0
0.0
0.0
0.02
0.04

H[24] chains 1:2 sample: 25000
100.0
75.0
50.0
25.0
0.0
0.0
0.02
0.04

H[25] chains 1:2 sample: 25000
150.0
100.0
50.0
0.0
0.0
0.01
0.02
0.03

H[26] chains 1:2 sample: 25000
100.0
50.0
0.0
0.0
0.02
0.04

H[27] chains 1:2 sample: 25000
100.0
75.0
50.0
25.0
0.0
0.0
0.01
0.02
0.03
0.04

H[28] chains 1:2 sample: 25000
100.0
75.0
50.0
25.0
0.0
0.0
0.02
0.04

H[29] chains 1:2 sample: 25000
100.0
50.0
0.0
0.0
0.02
0.04

H[30] chains 1:2 sample: 25000
150.0
100.0
50.0
0.0
0.0
0.01
0.02
0.03

H[31] chains 1:2 sample: 25000
100.0
75.0
50.0
25.0
0.0
0.0
0.02
0.04

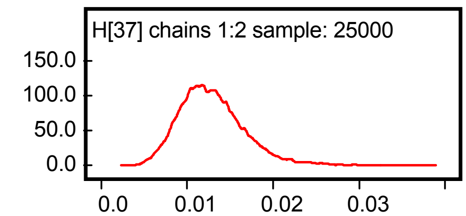

H[32] chains 1:2 sample: 25000
150.0
100.0
50.0
0.0
0.0
0.01
0.02
0.03

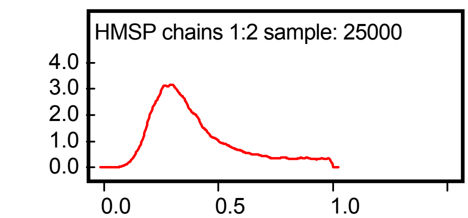

H[33] chains 1:2 sample: 25000
150.0
100.0
50.0
0.0
0.0
0.01
0.02
0.03

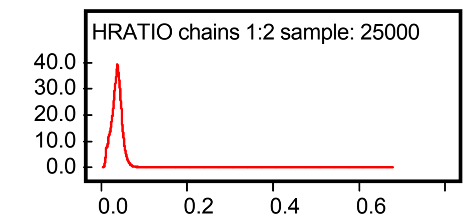

H[34] chains 1:2 sample: 25000
100.0
50.0
0.0
0.0
0.01
0.02
0.03

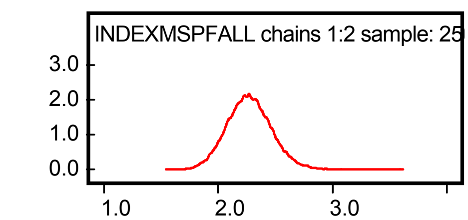

H[35] chains 1:2 sample: 25000
100.0
50.0
0.0
0.0
0.02
0.04
0.06

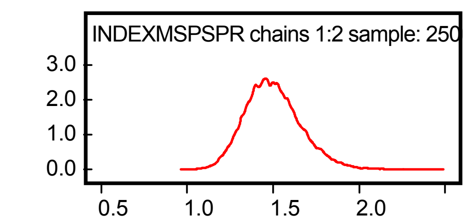

H[36] chains 1:2 sample: 25000
150.0
100.0
50.0
0.0
0.0
0.01
0.02
0.03

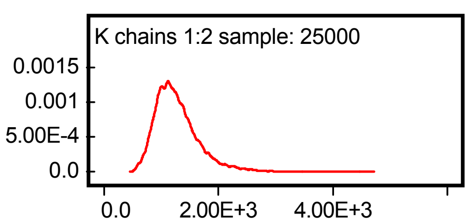

H[37] chains 1:2 sample: 25000
150.0
100.0
50.0
0.0
0.0
0.01
0.02
0.03

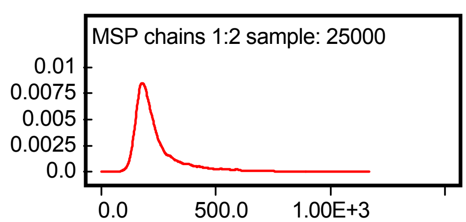

HMSP chains 1:2 sample: 25000
4.0
3.0
2.0
1.0
0.0
0.0
0.5
1.0

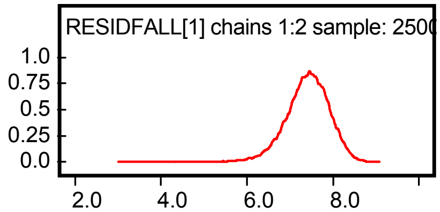

HRATIO chains 1:2 sample: 25000
40.0
30.0
20.0
10.0
0.0
0.0
0.2
0.4
0.6

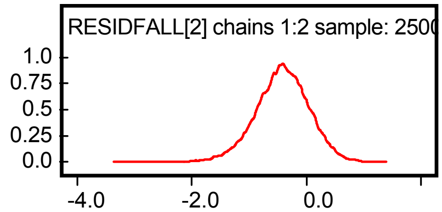

INDEXMSPFALL chains 1:2 sample: 25
3.0
2.0
1.0
0.0
1.0
2.0
3.0

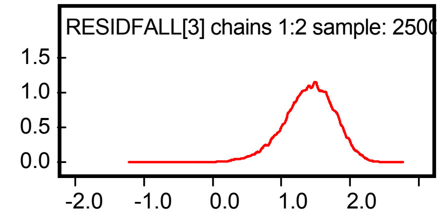

INDEXMSPSPR chains 1:2 sample: 250
3.0
2.0
1.0
0.0
0.5
1.0
1.5
2.0

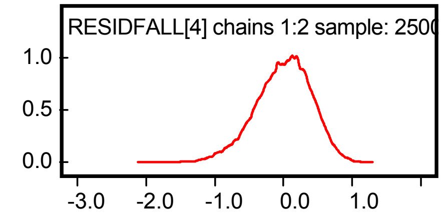

K chains 1:2 sample: 25000
0.0015
0.001
5.00E-4
0.0
0.0
2.00E+3
4.00E+3

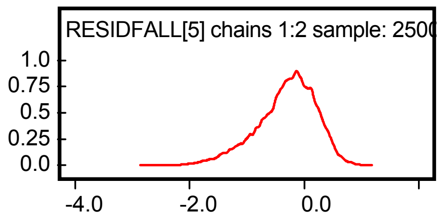

MSP chains 1:2 sample: 25000
0.01
0.0075
0.005
0.0025
0.0
0.0
500.0
1.00E+3

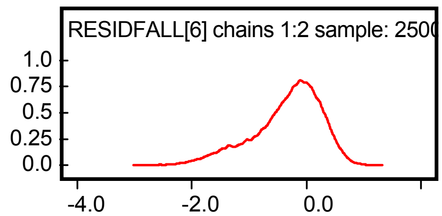

RESIDFALL[1] chains 1:2 sample: 2500
1.0
0.75
0.5
0.25
0.0
2.0
4.0
6.0
8.0

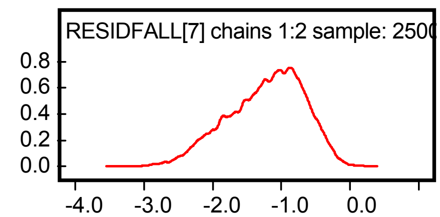

RESIDFALL[2] chains 1:2 sample: 2500
1.0
0.75
0.5
0.25
0.0
-4.0
-2.0
0.0

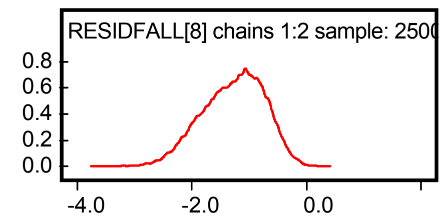

RESIDFALL[3] chains 1:2 sample: 2500
1.5
1.0
0.5
0.0
-2.0
-1.0
0.0
1.0
2.0

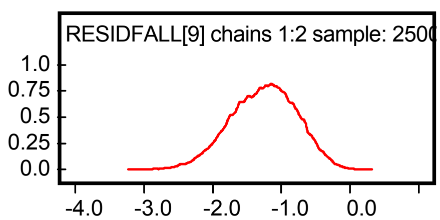

RESIDFALL[4] chains 1:2 sample: 2500
1.0
0.5
0.0
-3.0
-2.0
-1.0
0.0
1.0

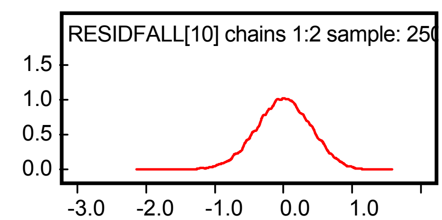

RESIDFALL[5] chains 1:2 sample: 2500
1.0
0.75
0.5
0.25
0.0
-4.0
-2.0
0.0

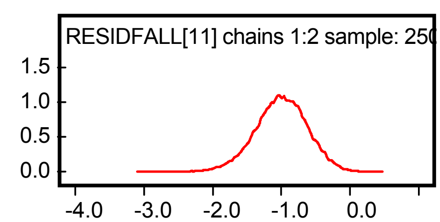

RESIDFALL[6] chains 1:2 sample: 2500
1.0
0.75
0.5
0.25
0.0
-4.0
-2.0
0.0

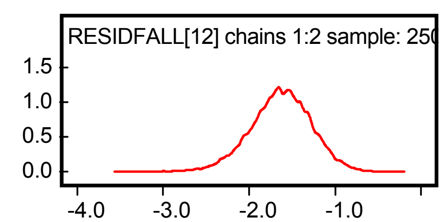

RESIDFALL[7] chains 1:2 sample: 2500
0.8
0.6
0.4
0.2
0.0
-4.0
-3.0
-2.0
-1.0
0.0

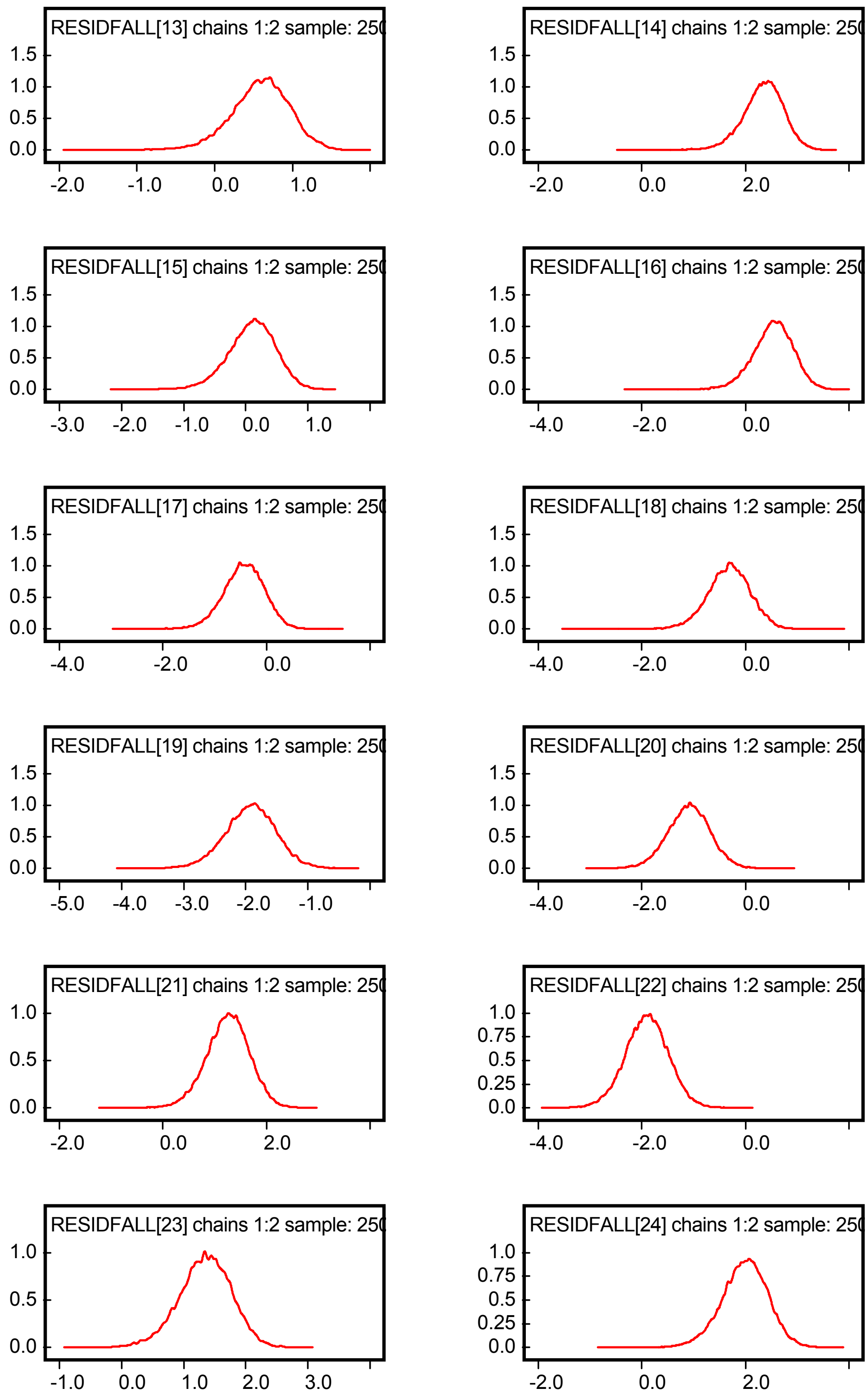

RESIDFALL[8] chains 1:2 sample: 2500
0.8
0.6
0.4
0.2
0.0
-4.0
-2.0
0.0

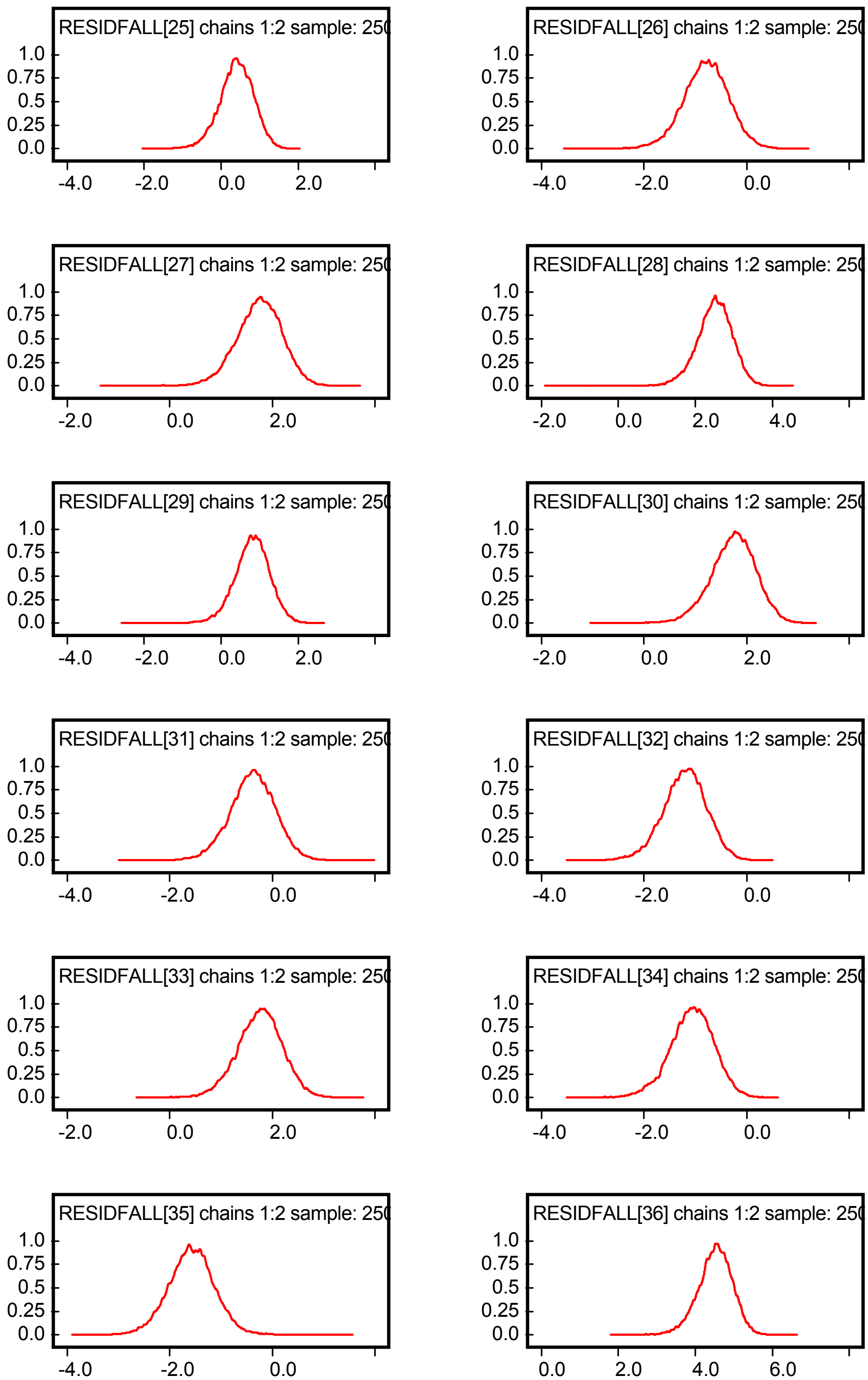

RESIDFALL[9] chains 1:2 sample: 2500
1.0
0.75
0.5
0.25
0.0
-4.0
-3.0
-2.0
-1.0
0.0

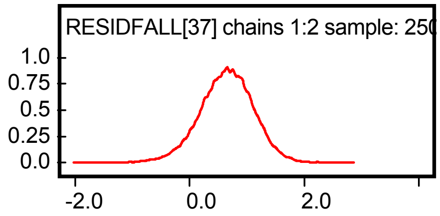

RESIDFALL[10] chains 1:2 sample: 25
1.5
1.0
0.5
0.0
-3.0
-2.0
-1.0
0.0
1.0

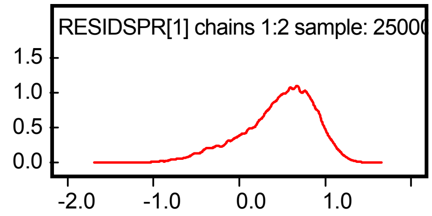

RESIDFALL[11] chains 1:2 sample: 25
1.5
1.0
0.5
0.0
-4.0
-3.0
-2.0
-1.0
0.0

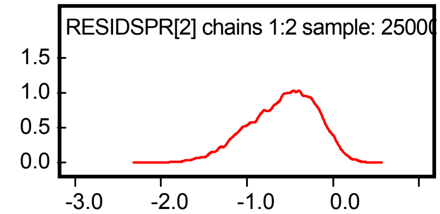

RESIDFALL[12] chains 1:2 sample: 25
1.5
1.0
0.5
0.0
-4.0
-3.0
-2.0
-1.0

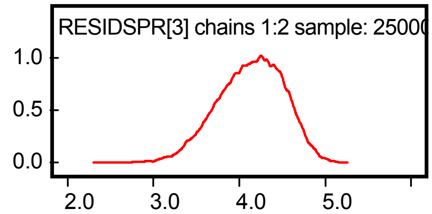

RESIDFALL[13] chains 1:2 sample: 250
1.5 1.0 0.5 0.0
-2.0 -1.0 0.0 1.0
RESIDFALL[14] chains 1:2 sample: 250
1.5 1.0 0.5 0.0
-2.0 0.0 2.0
RESIDFALL[15] chains 1:2 sample: 250
1.5 1.0 0.5 0.0
-3.0 -2.0 -1.0 0.0 1.0
RESIDFALL[16] chains 1:2 sample: 250
1.5 1.0 0.5 0.0
-4.0 -2.0 0.0
RESIDFALL[17] chains 1:2 sample: 250
1.5 1.0 0.5 0.0
-4.0 -2.0 0.0
RESIDFALL[18] chains 1:2 sample: 250
1.5 1.0 0.5 0.0
-4.0 -2.0 0.0
RESIDFALL[19] chains 1:2 sample: 250
1.5 1.0 0.5 0.0
-5.0 -4.0 -3.0 -2.0 -1.0
RESIDFALL[20] chains 1:2 sample: 250
1.5 1.0 0.5 0.0
-4.0 -2.0 0.0
RESIDFALL[21] chains 1:2 sample: 250
1.0 0.5 0.0
-2.0 0.0 2.0
RESIDFALL[22] chains 1:2 sample: 250
1.0 0.75 0.5 0.25 0.0
-4.0 -2.0 0.0
RESIDFALL[23] chains 1:2 sample: 250
1.0 0.5 0.0
-1.0 0.0 1.0 2.0 3.0
RESIDFALL[24] chains 1:2 sample: 250
1.0 0.75 0.5 0.25 0.0
-2.0 0.0 2.0

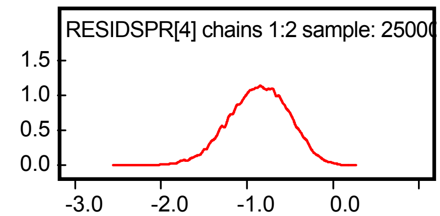

RESIDFALL[25] chains 1:2 sample: 25(
1.0
0.75
0.5
0.25
0.0
-4.0
-2.0
0.0
2.0
RESIDFALL[26] chains 1:2 sample: 25(
1.0
0.75
0.5
0.25
0.0
-4.0
-2.0
0.0
RESIDFALL[27] chains 1:2 sample: 25(
1.0
0.75
0.5
0.25
0.0
-2.0
0.0
2.0
RESIDFALL[28] chains 1:2 sample: 25(
1.0
0.75
0.5
0.25
0.0
-2.0
0.0
2.0
4.0
RESIDFALL[29] chains 1:2 sample: 25(
1.0
0.75
0.5
0.25
0.0
-4.0
-2.0
0.0
2.0
RESIDFALL[30] chains 1:2 sample: 25(
1.0
0.75
0.5
0.25
0.0
-2.0
0.0
2.0
RESIDFALL[31] chains 1:2 sample: 25(
1.0
0.75
0.5
0.25
0.0
-4.0
-2.0
0.0
RESIDFALL[32] chains 1:2 sample: 25(
1.0
0.75
0.5
0.25
0.0
-4.0
-2.0
0.0
RESIDFALL[33] chains 1:2 sample: 25(
1.0
0.75
0.5
0.25
0.0
-2.0
0.0
2.0
RESIDFALL[34] chains 1:2 sample: 25(
1.0
0.75
0.5
0.25
0.0
-4.0
-2.0
0.0
RESIDFALL[35] chains 1:2 sample: 25(
1.0
0.75
0.5
0.25
0.0
-4.0
-2.0
0.0
RESIDFALL[36] chains 1:2 sample: 25(
1.0
0.75
0.5
0.25
0.0
0.0
2.0
4.0
6.0

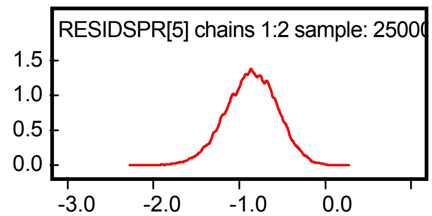

RESIDFALL[37] chains 1:2 sample: 25(
1.0
0.75
0.5
0.25
0.0
-2.0
0.0
2.0

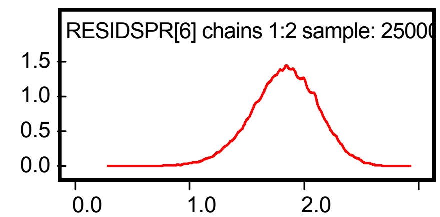

RESIDSPR[1] chains 1:2 sample: 2500(
1.5
1.0
0.5
0.0
-2.0
-1.0
0.0
1.0

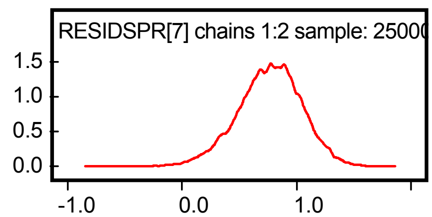

RESIDSPR[2] chains 1:2 sample: 2500(
1.5
1.0
0.5
0.0
-3.0
-2.0
-1.0
0.0

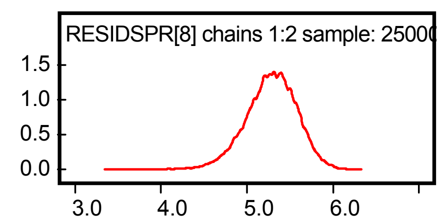

RESIDSPR[3] chains 1:2 sample: 2500(
1.0
0.5
0.0
2.0
3.0
4.0
5.0

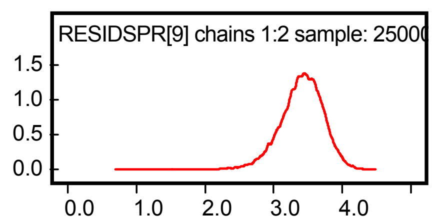

RESIDSPR[4] chains 1:2 sample: 2500(
1.5
1.0
0.5
0.0
-3.0
-2.0
-1.0
0.0

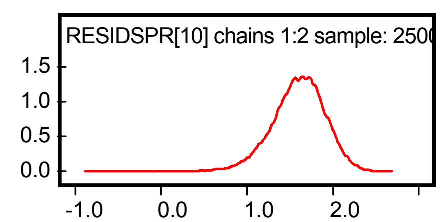

RESIDSPR[5] chains 1:2 sample: 2500(
1.5
1.0
0.5
0.0
-3.0
-2.0
-1.0
0.0

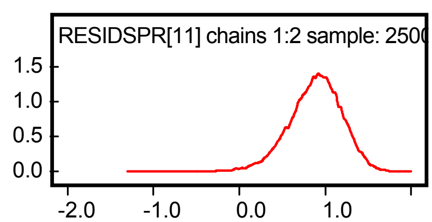

RESIDSPR[6] chains 1:2 sample: 2500(
1.5
1.0
0.5
0.0
0.0
1.0
2.0

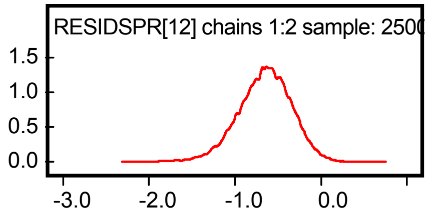

RESIDSPR[7] chains 1:2 sample: 2500(
1.5
1.0
0.5
0.0
-1.0
0.0
1.0

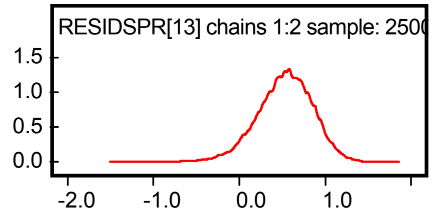

RESIDSPR[8] chains 1:2 sample: 2500(
1.5
1.0
0.5
0.0
3.0
4.0
5.0
6.0

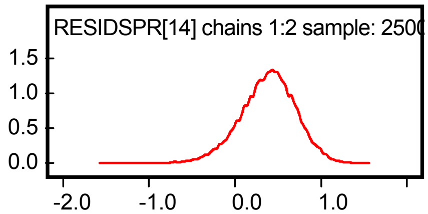

RESIDSPR[9] chains 1:2 sample: 2500(
1.5
1.0
0.5
0.0
0.0
1.0
2.0
3.0
4.0

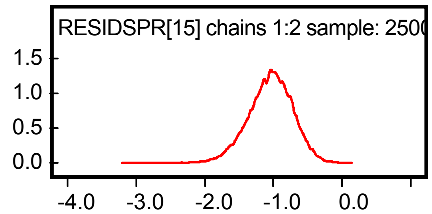

RESIDSPR[10] chains 1:2 sample: 250(
1.5
1.0
0.5
0.0
-1.0
0.0
1.0
2.0

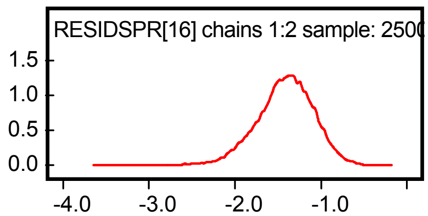

RESIDSPR[11] chains 1:2 sample: 250(
1.5
1.0
0.5
0.0
-2.0
-1.0
0.0
1.0

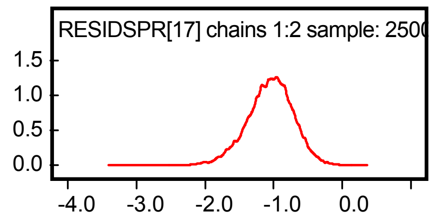

RESIDSPR[12] chains 1:2 sample: 2500
1.5
1.0
0.5
0.0
-3.0
-2.0
-1.0
0.0

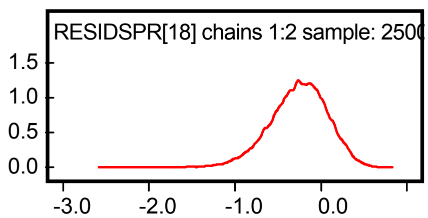

RESIDSPR[13] chains 1:2 sample: 2500
1.5
1.0
0.5
0.0
-2.0
-1.0
0.0
1.0

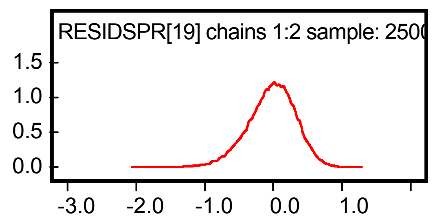

RESIDSPR[14] chains 1:2 sample: 2500
1.5
1.0
0.5
0.0
-2.0
-1.0
0.0
1.0

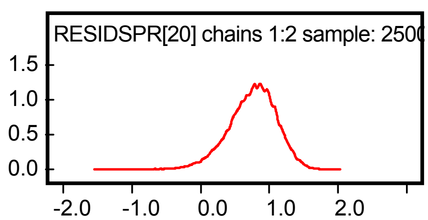

RESIDSPR[15] chains 1:2 sample: 2500
1.5
1.0
0.5
0.0
-4.0
-3.0
-2.0
-1.0
0.0

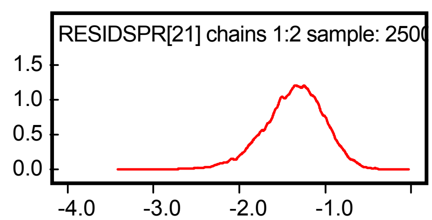

RESIDSPR[16] chains 1:2 sample: 2500
1.5
1.0
0.5
0.0
-4.0
-3.0
-2.0
-1.0

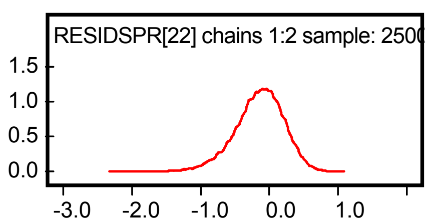

RESIDSPR[17] chains 1:2 sample: 2500
1.5
1.0
0.5
0.0
-4.0
-3.0
-2.0
-1.0
0.0

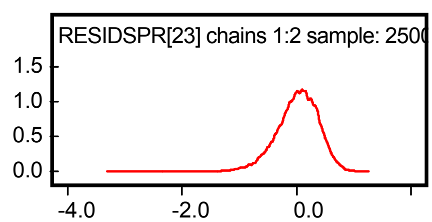

RESIDSPR[18] chains 1:2 sample: 2500
1.5
1.0
0.5
0.0
-3.0
-2.0
-1.0
0.0

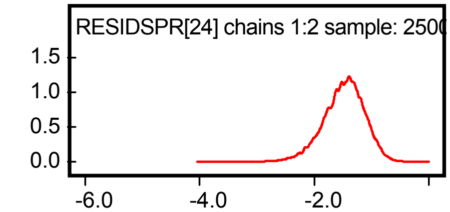

RESIDSPR[19] chains 1:2 sample: 2500
1.5
1.0
0.5
0.0
-3.0
-2.0
-1.0
0.0
1.0

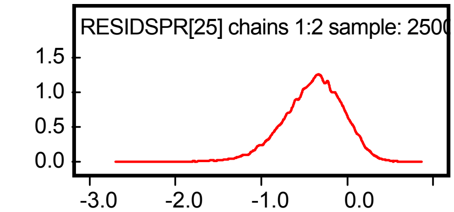

RESIDSPR[20] chains 1:2 sample: 2500
1.5
1.0
0.5
0.0
-2.0
-1.0
0.0
1.0
2.0

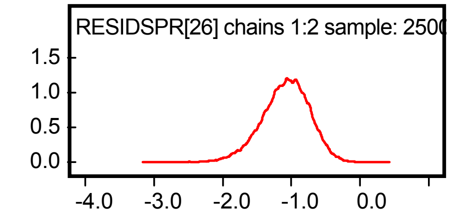

RESIDSPR[21] chains 1:2 sample: 2500
1.5
1.0
0.5
0.0
-4.0
-3.0
-2.0
-1.0

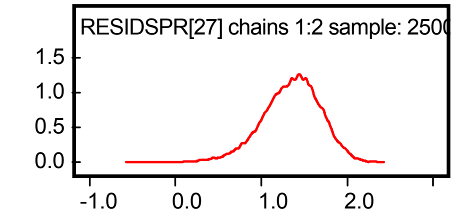

RESIDSPR[22] chains 1:2 sample: 2500
1.5
1.0
0.5
0.0
-3.0
-2.0
-1.0
0.0
1.0

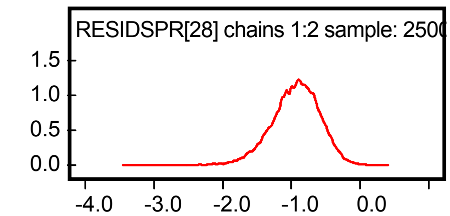

RESIDSPR[23] chains 1:2 sample: 2500
1.5
1.0
0.5
0.0
-4.0
-2.0
0.0

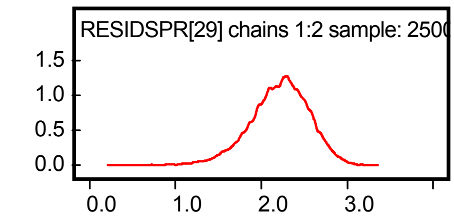

RESIDSPR[24] chains 1:2 sample: 2500
1.5 1.0 0.5 0.0
-6.0 -4.0 -2.0

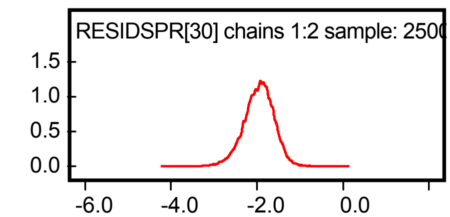

RESIDSPR[25] chains 1:2 sample: 2500
1.5 1.0 0.5 0.0
-3.0 -2.0 -1.0 0.0

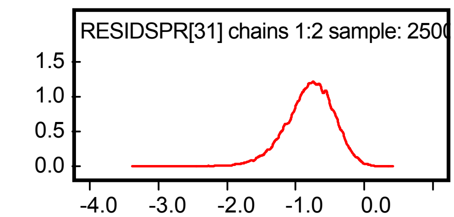

RESIDSPR[26] chains 1:2 sample: 2500
1.5 1.0 0.5 0.0
-4.0 -3.0 -2.0 -1.0 0.0

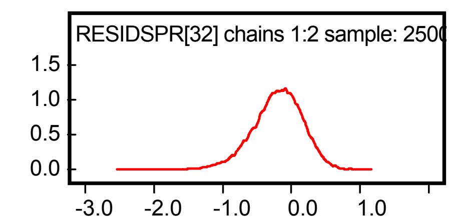

RESIDSPR[27] chains 1:2 sample: 2500
1.5 1.0 0.5 0.0
-1.0 0.0 1.0 2.0

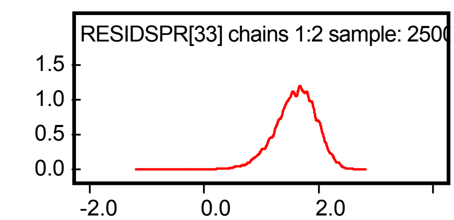

RESIDSPR[28] chains 1:2 sample: 2500
1.5 1.0 0.5 0.0
-4.0 -3.0 -2.0 -1.0 0.0

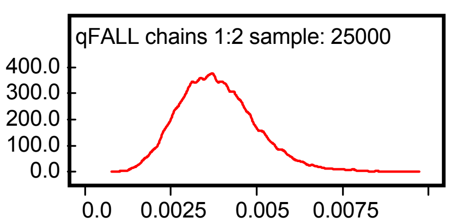

RESIDSPR[29] chains 1:2 sample: 2500
1.5 1.0 0.5 0.0
0.0 1.0 2.0 3.0

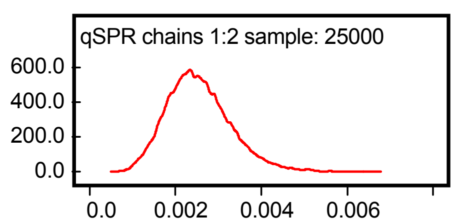

RESIDSPR[30] chains 1:2 sample: 2500
1.5 1.0 0.5 0.0
-6.0 -4.0 -2.0 0.0

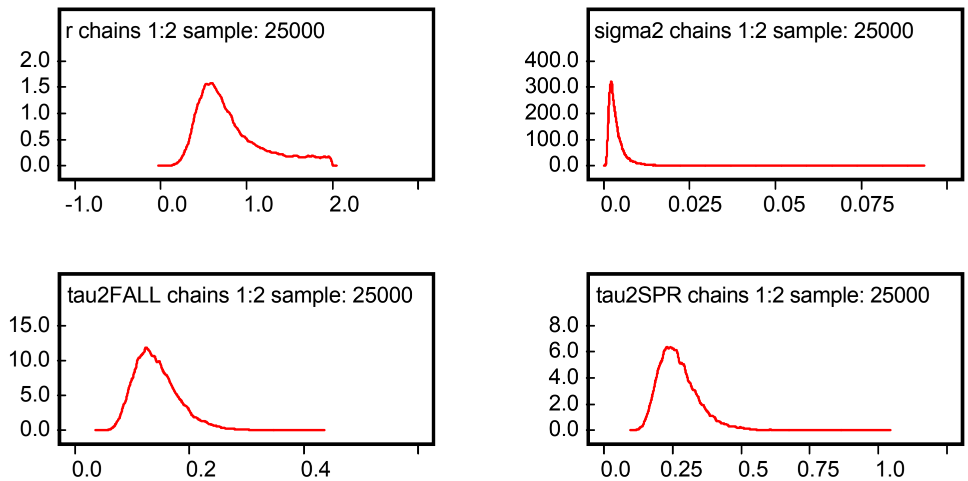

RESIDSPR[31] chains 1:2 sample: 2500
1.5 1.0 0.5 0.0
-4.0 -3.0 -2.0 -1.0 0.0


RESIDSPR[32] chains 1:2 sample: 2500
1.5 1.0 0.5 0.0
-3.0 -2.0 -1.0 0.0 1.0


RESIDSPR[33] chains 1:2 sample: 2500
1.5 1.0 0.5 0.0
-2.0 0.0 2.0


qFALL chains 1:2 sample: 25000
400.0 300.0 200.0 100.0 0.0
0.0 0.0025 0.005 0.0075


qSPR chains 1:2 sample: 25000
600.0 400.0 200.0 0.0
0.0 0.002 0.004 0.006


r chains 1:2 sample: 25000
2.0
1.5
1.0
0.5
0.0
-1.0
0.0
1.0
2.0
sigma2 chains 1:2 sample: 25000
400.0
300.0
200.0
100.0
0.0
0.0
0.025
0.05
0.075
tau2FALL chains 1:2 sample: 25000
15.0
10.0
5.0
0.0
0.0
0.2
0.4
tau2SPR chains 1:2 sample: 25000
8.0
6.0
4.0
2.0
0.0
0.0
0.25
0.5
0.75
1.0

Appendix 1. Northern stock area BSP model for silver hake.

```
# Implementation of the surplus production model for combined whiting
# Jon Brodziak, NEFSC Nov-7-2000
# LOGNORMAL OBSERVATION ERRORS
################################################################################

model NorthFS6300

{
# PRIOR DISTRIBUTIONS
##############################################

# PRIOR FOR K
# Lognormal with 10%Q at 200 kt and 90%Q at 1000 kt
######################################################

K ~ dlnorm(6.10304,2.53004)I(10,5000)

# PRIOR FOR R
# Uniform from [0.01,1.99]
######################################################

r ~ dunif(0.01,1.99)

# PRIOR FOR Q
# Inverse gamma with a=b=0.001
# and bounded as (0.001,10)
##################################

iqFALL ~ dgamma(0.001,0.001)I(0.1,1000);
qFALL <- 1/iqFALL;
iqSPR ~ dgamma(0.001,0.001)I(0.1,1000);
qSPR <- 1/iqSPR;


# PRIOR FOR SIGMA2 - PROCESS ERROR VARIANCE
#############################################################

isigma2 ~ dgamma(a0,b0);
sigma2 <- 1/isigma2;

# PRIOR FOR TAU2FALL/SPR - OBSERVATION ERROR VARIANCE
#################################################################

itau2FALL   ~ dgamma(c0FALL,d0FALL);
tau2FALL   <- 1/itau2FALL;
itau2SPR   ~ dgamma(c0SPR,d0SPR);
tau2SPR   <- 1/itau2SPR;

# CONDITIONAL PRIORS FOR PROPORTIONS P
# Lognormal bounded as (0.001,3)
#############################################

Pmean[1] <- 0;
P[1] ~ dlnorm(Pmean[1],isigma2) I(0.001,3)
dlow[1] <- dlowpre*L[1]
dup[1] <- duppre*L[1]
# Low precision catch error during 1963
C[1] ~ dunif(dlow[1],dup[1])

# Low precision catch error during 1964-1977
for (i in 2:15) {
```

```
   Pmean[i] <- log(max(P[i-1] + r*P[i-1]*(1-P[i-1]) - C[i-1]/K,0.001))
   P[i]  ~ dlnorm(Pmean[i],isigma2)I(0.001,3)
   dlow[i] <- dlowpre*L[i]
   dup[i] <- duppre*L[i]
   C[i] ~ dunif(dlow[i],dup[i])
   }
# High precision catch error during 1978-2000
for (i in 16:38) {
   Pmean[i] <- log(max(P[i-1] + r*P[i-1]*(1-P[i-1]) - C[i-1]/K,0.001))
   P[i]      ~ dlnorm(Pmean[i],isigma2)I(0.001,3)
   dlow[i] <- dlowcur*L[i]
   dup[i] <- dupcur*L[i]
   C[i] ~ dunif(dlow[i],dup[i])
   }


# LIKELIHOOD OF SAMPLING DISTRIBUTION
######################################
# FALL SURVEY LIKELIHOOD & RESIDUALS
for (i in 1:N) {
    ImeanFALL[i] <- log(qFALL*K*P[i])
    IFALL[i] ~ dlnorm(ImeanFALL[i],itau2FALL)
    RESIDFALL[i] <- IFALL[i] - qFALL*K*P[i]
    }
# SPRING SURVEY LIKELIHOOD & RESIDUALS
for (i in 1:NSPR) {
    ImeanSPR[i] <- log(qSPR*K*P[i+5])
    ISPR[i] ~ dlnorm(ImeanSPR[i],itau2SPR)
    RESIDSPR[i] <- ISPR[i] - qSPR*K*P[i+5]
   }
# MANAGEMENT PARAMETERS
MSP <- r*K/4
INDEXMSPFALL <- r/(2*qFALL)
INDEXMSPSPR <- r/(2*qSPR)
HMSP <- r/2
HRATIO <- H[37]/HMSP

#  COMPUTE BIOMASS AND HARVEST RATE TRAJECTORIES
for (i in 1:N) {
    B[i] <- P[i]*K
    H[i] <- C[i]/B[i]
   }

# PROJECT YEAR 2001
P2001 <- P[N+1]+r*P[N+1]*(1-P[N+1])-C[N+1]/K
B2001 <- P2001*K
H2000 <- min(C[N+1]/(P[N+1]*K),1.0)

# END OF CODE
}
```

Data

```
# Vector L() is discard-adjusted total catch
# Vector IFALL() is autumn kg/tow index
# Vector ISPR is spring kg/tow index
# N is number of years
# Sigma is state equation error with parameters a0,b0
# TauFALL is autumn observation equation error with parameters c0FALL,d0FALL
# TauSPR is autumn observation equation error with parameters c0SPR,d0SPR
# Vector C() is discard-adjusted catch with error multiplier
# Error multiplier is bounded by [dlowpre,duppre] for 1963-1976
# and is bounded by [dlowcur,dupcur] for 1976-1999
```

```
list(
L=c(73.924,94.462,45.242,47.716,33.371,41.379,23.964,27.528,36.401,
25.224,32.083,20.680,39.874,13.634,12.457,12.609,3.415,4.730,4.416,
4.656,5.310,8.289,8.297,8.502,5.658,6.767,4.646,6.379,6.053,5.302,
4.360,4.053,2.706,3.919,2.827,2.526,4.042,4.000),
IFALL=c(25.418,4.415,6.475,4.124,2.158,2.048,2.635,3.034,2.466,6.085,
4.150,3.764,8.234,12.632,7.593,7.072,6.651,6.655,4.057,5.450,9.205,3.621,
8.583,14.194,9.836,6.312,12.549,15.246,11.889,14.245,8.117,6.925,13.161,
7.886,5.638,21.966,11.636),
ISPR=c(0.036,0.192,14.133,0.406,1.702,3.126,2.682,9.720,8.829,3.699,0.813,
1.617,4.151,2.269,1.346,1.507,1.090,2.645,3.247,3.802,1.256,3.566,1.623,
1.381,5.655,2.497,7.319,3.485,3.463,1.188,4.446,4.234,10.002),
N=37,
NSPR=33,
a0=4.0,b0=0.01,
c0FALL=2.0,d0FALL=0.01,
c0SPR=2.0,d0SPR=0.01,
dlowpre=0.9,duppre=1.10,
dlowcur=1.00,dupcur=1.10)
```

Inits

```
# Initial Condition 1
list(
P=c(0.9,0.2,0.3,0.2,0.1,0.1,0.1,0.1,0.1,0.2,0.2,0.1,0.3,0.5,0.3,0.3,0.3,
0.3,0.2,0.2,0.4,0.1,0.3,0.6,0.4,0.2,0.5,0.6,0.5,0.6,0.3,0.3,0.5,0.3,0.2,0.9,0.5,0.5),
C=c(73.924,94.462,45.242,47.716,33.371,41.379,23.964,27.528,36.401,
25.224,32.083,20.680,39.874,13.634,12.457,12.609,3.415,4.730,4.416,
4.656,5.310,8.289,8.297,8.502,5.658,6.767,4.646,6.379,6.053,5.302,
4.360,4.053,2.706,3.919,2.827,2.526,4.042,4.000),
r=0.4,
K=400,
iqFALL=10,iqSPR=20,
isigma2=100,
itau2FALL=100,itau2SPR=100)
# Initial Condition 2
list(
P=c(0.9,0.2,0.3,0.2,0.1,0.1,0.1,0.1,0.1,0.2,0.2,0.1,0.3,0.5,0.3,0.3,0.3,
0.3,0.2,0.2,0.4,0.1,0.3,0.6,0.4,0.2,0.5,0.6,0.5,0.6,0.3,0.3,0.5,0.3,0.2,0.9,0.5,0.5),
C=c(73.924,94.462,45.242,47.716,33.371,41.379,23.964,27.528,36.401,
25.224,32.083,20.680,39.874,13.634,12.457,12.609,3.415,4.730,4.416,
4.656,5.310,8.289,8.297,8.502,5.658,6.767,4.646,6.379,6.053,5.302,
4.360,4.053,2.706,3.919,2.827,2.526,4.042,4.000),
r=0.3,
K=600,
iqFALL=10,iqSPR=20,
isigma2=100,
itau2FALL=100,itau2SPR=100)
```

Results

Summary of Posterior Distribution

node	mean	sd	MC error	10.0%	25.0%	median	75.0%	90.0%	start	sample
B[1]	220.1	69.15	2.671	169.9	186.5	208.2	235.7	272.8	5000	25000
B[2]	136.4	43.14	1.682	94.9	109.1	127.6	152.6	185.2	5000	25000
B[3]	82.79	36.12	1.446	51.38	60.95	74.38	93.59	120.4	5000	25000

B[4]	76.32	31.17	1.245	48.06	56.83	69.12	86.75	110.6	5000	25000
B[5]	66.33	28.17	1.114	40.44	48.4	59.9	76.43	97.76	5000	25000
B[6]	68.92	27.39	1.09	43.01	51.21	62.88	79.18	100.3	5000	25000
B[7]	66.18	27.52	1.098	39.63	48.15	60.36	76.79	97.97	5000	25000
B[8]	80.21	29.3	1.151	50.96	60.7	74.68	92.64	114.2	5000	25000
B[9]	93.81	29.67	1.12	63.37	74.2	88.74	107.0	128.4	5000	25000
B[10]	102.9	31.37	1.156	71.15	83.12	97.99	116.1	137.1	5000	25000
B[11]	121.7	30.61	1.04	89.68	102.5	117.9	135.1	154.8	5000	25000
B[12]	132.7	30.2	0.9732	102.8	114.7	128.7	144.4	164.1	5000	25000
B[13]	156.4	34.71	1.154	126.4	137.4	150.6	166.8	188.5	5000	25000
B[14]	152.6	41.28	1.441	122.1	132.2	145.1	161.8	184.1	5000	25000
B[15]	172.7	34.05	1.088	143.8	153.8	166.6	182.8	203.9	5000	25000
B[16]	182.3	33.27	1.079	151.6	163.0	177.0	193.9	215.4	5000	25000
B[17]	186.3	34.27	1.143	152.5	165.4	181.1	199.8	222.2	5000	25000
B[18]	197.9	34.99	1.175	162.5	175.9	192.9	212.6	236.2	5000	25000
B[19]	196.8	36.4	1.255	158.8	173.2	192.0	213.5	238.6	5000	25000
B[20]	199.5	37.94	1.325	160.5	174.9	193.2	216.6	243.8	5000	25000
B[21]	202.6	40.59	1.458	162.2	176.5	195.5	219.7	248.8	5000	25000
B[22]	198.9	40.56	1.437	158.1	172.9	192.0	216.3	245.8	5000	25000
B[23]	201.2	44.65	1.64	158.9	173.3	192.8	218.0	250.4	5000	25000
B[24]	204.9	51.83	1.962	160.4	175.2	194.8	220.6	255.3	5000	25000
B[25]	202.9	48.64	1.803	159.2	173.8	193.2	218.8	253.2	5000	25000
B[26]	202.8	46.03	1.666	160.1	174.3	193.7	219.2	252.8	5000	25000
B[27]	206.9	52.22	1.978	161.5	176.3	196.3	222.9	259.3	5000	25000
B[28]	210.5	56.18	2.133	164.0	178.9	199.2	226.5	262.9	5000	25000
B[29]	207.6	53.06	2.001	161.1	176.5	197.1	224.5	261.0	5000	25000
B[30]	209.3	55.79	2.133	163.1	178.0	197.9	225.3	261.9	5000	25000
B[31]	206.1	49.09	1.816	161.6	176.2	196.2	222.7	258.1	5000	25000
B[32]	206.9	47.75	1.744	162.7	177.5	197.3	223.4	258.7	5000	25000
B[33]	210.2	52.57	1.991	164.7	179.5	199.7	226.1	262.0	5000	25000
B[34]	208.5	47.63	1.761	163.8	179.0	199.3	225.3	260.6	5000	25000
B[35]	205.7	47.55	1.737	160.9	176.0	196.3	222.8	258.3	5000	25000
B[36]	215.7	64.5	2.516	167.1	182.3	203.3	230.6	269.8	5000	25000
B[37]	212.7	54.17	2.048	165.0	180.7	201.8	229.1	267.7	5000	25000
C[1]	74.13	4.25	0.03111	68.15	70.5	74.22	77.79	79.95	5000	25000
C[2]	94.64	5.458	0.05112	86.98	89.93	94.75	99.38	102.1	5000	25000
C[3]	45.59	2.592	0.01745	41.84	43.42	45.77	47.85	49.03	5000	25000
C[4]	48.15	2.725	0.01835	44.17	45.9	48.35	50.54	51.71	5000	25000
C[5]	33.48	1.929	0.01282	30.76	31.82	33.53	35.17	36.1	5000	25000
C[6]	41.2	2.379	0.01681	37.97	39.14	41.1	43.22	44.57	5000	25000
C[7]	23.88	1.384	0.008796	22.0	22.68	23.83	25.06	25.84	5000	25000
C[8]	27.51	1.594	0.01069	25.31	26.12	27.5	28.88	29.73	5000	25000
C[9]	36.21	2.101	0.01346	33.4	34.39	36.11	38.02	39.22	5000	25000
C[10]	25.2	1.451	0.009123	23.21	23.95	25.18	26.45	27.23	5000	25000
C[11]	32.04	1.852	0.01094	29.5	30.43	32.03	33.64	34.63	5000	25000
C[12]	20.62	1.19	0.007581	19.0	19.58	20.6	21.64	22.29	5000	25000
C[13]	39.71	2.307	0.01509	36.6	37.68	39.64	41.69	42.97	5000	25000
C[14]	13.65	0.7838	0.004789	12.55	12.98	13.65	14.32	14.73	5000	25000
C[15]	12.46	0.7207	0.004474	11.46	11.84	12.46	13.09	13.46	5000	25000
C[16]	13.24	0.3646	0.002284	12.73	12.93	13.24	13.56	13.75	5000	25000
C[17]	3.586	0.09903	6.456E-4	3.45	3.499	3.586	3.673	3.723	5000	25000
C[18]	4.968	0.137	8.489E-4	4.779	4.848	4.968	5.087	5.158	5000	25000
C[19]	4.639	0.127	7.961E-4	4.462	4.53	4.64	4.75	4.814	5000	25000
C[20]	4.889	0.1346	8.742E-4	4.703	4.772	4.891	5.005	5.075	5000	25000
C[21]	5.576	0.1539	9.875E-4	5.362	5.442	5.577	5.711	5.788	5000	25000
C[22]	8.702	0.2396	0.001591	8.372	8.495	8.701	8.911	9.036	5000	25000
C[23]	8.714	0.239	0.001488	8.382	8.507	8.715	8.92	9.043	5000	25000
C[24]	8.927	0.2448	0.001524	8.588	8.714	8.928	9.138	9.265	5000	25000
C[25]	5.942	0.1631	0.001047	5.715	5.8	5.942	6.083	6.167	5000	25000
C[26]	7.107	0.1957	0.001271	6.836	6.937	7.107	7.277	7.379	5000	25000
C[27]	4.879	0.1343	8.451E-4	4.693	4.763	4.88	4.995	5.066	5000	25000
C[28]	6.697	0.1842	0.001216	6.442	6.536	6.697	6.856	6.952	5000	25000
C[29]	6.355	0.1751	0.001091	6.114	6.202	6.355	6.507	6.598	5000	25000
C[30]	5.568	0.1532	9.827E-4	5.354	5.437	5.567	5.701	5.779	5000	25000

C[31]	4.578	0.1264	8.077E-4	4.403	4.467	4.577	4.688	4.753	5000	25000
C[32]	4.256	0.1172	7.079E-4	4.093	4.153	4.256	4.359	4.417	5000	25000
C[33]	2.841	0.07793	4.458E-4	2.733	2.774	2.842	2.909	2.949	5000	25000
C[34]	4.114	0.1134	7.542E-4	3.957	4.016	4.114	4.212	4.273	5000	25000
C[35]	2.967	0.08195	5.278E-4	2.855	2.896	2.967	3.038	3.082	5000	25000
C[36]	2.653	0.07343	4.572E-4	2.551	2.589	2.654	2.717	2.754	5000	25000
C[37]	4.244	0.1162	6.905E-4	4.083	4.144	4.243	4.344	4.405	5000	25000
C[38]	4.2	0.1155	7.897E-4	4.04	4.1	4.2	4.301	4.36	5000	25000
H[1]	0.3537	0.06831	0.002574	0.2701	0.313	0.3563	0.3974	0.4365	5000	25000
H[2]	0.7461	0.186	0.007714	0.5137	0.6234	0.7418	0.8634	0.9832	5000	25000
H[3]	0.6234	0.2	0.008395	0.3757	0.4862	0.6135	0.7473	0.8849	5000	25000
H[4]	0.708	0.2216	0.009357	0.4332	0.5538	0.6967	0.8482	0.9993	5000	25000
H[5]	0.5731	0.1911	0.008034	0.3407	0.4379	0.5588	0.6916	0.8292	5000	25000
H[6]	0.6702	0.213	0.00893	0.4096	0.5207	0.6546	0.8056	0.9556	5000	25000
H[7]	0.4108	0.1421	0.005884	0.2428	0.3092	0.3952	0.4959	0.6044	5000	25000
H[8]	0.3807	0.1199	0.004796	0.2394	0.2958	0.3684	0.4536	0.5413	5000	25000
H[9]	0.4186	0.1172	0.004451	0.2799	0.3375	0.4073	0.4887	0.5733	5000	25000
H[10]	0.2638	0.07112	0.002539	0.1815	0.2159	0.2568	0.3044	0.3566	5000	25000
H[11]	0.2773	0.06312	0.00207	0.2044	0.2357	0.2716	0.3138	0.3589	5000	25000
H[12]	0.1618	0.03255	9.959E-4	0.1238	0.1411	0.1599	0.1807	0.203	5000	25000
H[13]	0.2626	0.04622	0.001356	0.2077	0.2351	0.2627	0.2908	0.3187	5000	25000
H[14]	0.09315	0.01697	5.146E-4	0.07282	0.08326	0.09367	0.1038	0.1136	5000	25000
H[15]	0.07411	0.01158	3.235E-4	0.06009	0.06733	0.07453	0.08149	0.08799	5000	25000
H[16]	0.07448	0.01109	3.48E-4	0.06129	0.0681	0.07468	0.08137	0.08773	5000	25000
H[17]	0.01977	0.003067	1.008E-4	0.01605	0.01788	0.01978	0.02173	0.02358	5000	25000
H[18]	0.02575	0.003964	1.319E-4	0.02093	0.02332	0.02577	0.02828	0.03064	5000	25000
H[19]	0.02427	0.004094	1.421E-4	0.01937	0.02166	0.02413	0.02682	0.0293	5000	25000
H[20]	0.02527	0.004255	1.493E-4	0.01996	0.02254	0.02527	0.02798	0.03059	5000	25000
H[21]	0.02843	0.004874	1.739E-4	0.02238	0.0253	0.02848	0.03163	0.03451	5000	25000
H[22]	0.0453	0.008138	2.921E-4	0.03527	0.04012	0.0453	0.0504	0.05519	5000	25000
H[23]	0.04498	0.008159	3.014E-4	0.03471	0.03986	0.04516	0.05036	0.05505	5000	25000
H[24]	0.04547	0.00846	3.158E-4	0.03487	0.04039	0.0458	0.051	0.05576	5000	25000
H[25]	0.03051	0.005653	2.09E-4	0.02337	0.02704	0.03073	0.03423	0.03741	5000	25000
H[26]	0.03642	0.006618	2.432E-4	0.02803	0.03237	0.03664	0.04077	0.04447	5000	25000
H[27]	0.02463	0.004648	1.743E-4	0.01885	0.02184	0.02481	0.02771	0.03033	5000	25000
H[28]	0.0333	0.006322	2.359E-4	0.02535	0.02954	0.03359	0.03745	0.04098	5000	25000
H[29]	0.03202	0.006155	2.313E-4	0.02426	0.02825	0.03222	0.03606	0.03956	5000	25000
H[30]	0.02785	0.005299	2.003E-4	0.0212	0.02466	0.0281	0.03133	0.03424	5000	25000
H[31]	0.02315	0.004333	1.61E-4	0.01767	0.02049	0.02331	0.02598	0.02839	5000	25000
H[32]	0.02141	0.003949	1.462E-4	0.0164	0.01898	0.02154	0.024	0.02624	5000	25000
H[33]	0.01411	0.002634	9.832E-5	0.0108	0.01253	0.01422	0.01583	0.01729	5000	25000
H[34]	0.02052	0.003781	1.406E-4	0.01569	0.01822	0.02064	0.023	0.02519	5000	25000
H[35]	0.01503	0.00282	1.047E-4	0.01144	0.01328	0.0151	0.01686	0.0185	5000	25000
H[36]	0.01293	0.002487	9.398E-5	0.009797	0.01147	0.01305	0.01456	0.01593	5000	25000
H[37]	0.02088	0.004041	1.524E-4	0.01579	0.01848	0.02102	0.02352	0.02581	5000	25000
HMSP	0.4457	0.1158	0.00479	0.3028	0.3681	0.4424	0.5192	0.5941	5000	25000
HRATIO	0.04804	0.006704	2.002E-4	0.04051	0.04371	0.04739	0.05162	0.05626	5000	25000
INDEXMSPFALL	9.631	1.384	0.0385	7.959	8.745	9.586	10.47	11.33	5000	25000
INDEXMSPSPR	31.99	7.124	0.1464	23.41	27.0	31.42	36.37	41.28	5000	25000
K	214.0	49.3	1.932	169.8	184.1	203.7	229.7	265.6	5000	25000
MSP	45.34	5.428	0.191	38.92	42.0	45.25	48.54	51.65	5000	25000
RESIDFALL[1]	15.7	1.364	0.03794	14.43	15.14	15.82	16.46	17.0	5000	25000
RESIDFALL[2]	-1.538	0.7623	0.02021	-2.509	-1.994	-1.487	-1.015	-0.6265	5000	25000
RESIDFALL[3]	2.931	0.676	0.02436	2.075	2.578	3.024	3.391	3.687	5000	25000
RESIDFALL[4]	0.8448	0.583	0.02064	0.0846	0.5224	0.9164	1.25	1.513	5000	25000
RESIDFALL[5]	-0.6842	0.5559	0.02025	-1.411	-0.9918	-0.6127	-0.2929	-0.04708	5000	25000
RESIDFALL[6]	-0.919	0.5396	0.01926	-1.63	-1.233	-0.8541	-0.5393	-0.2912	5000	25000
RESIDFALL[7]	-0.2042	0.5715	0.02065	-0.9635	-0.5432	-0.1408	0.2057	0.4695	5000	25000
RESIDFALL[8]	-0.4414	0.6174	0.01969	-1.257	-0.813	-0.3829	-0.003383	0.2982	5000	25000
RESIDFALL[9]	-1.643	0.6871	0.01901	-2.55	-2.059	-1.582	-1.16	-0.8221	5000	25000
RESIDFALL[10]	1.557	0.7861	0.02066	0.5204	1.075	1.639	2.122	2.49	5000	25000
RESIDFALL[11]	-1.266	0.9239	0.02536	-2.483	-1.828	-1.172	-0.6024	-0.1706	5000	25000
RESIDFALL[12]	-2.168	0.9464	0.02647	-3.409	-2.782	-2.124	-1.497	-0.9914	5000	25000
RESIDFALL[13]	1.231	1.058	0.02995	-0.135	0.5481	1.256	1.957	2.567	5000	25000

RESIDFALL[14]	5.839	1.007	0.02666	4.685	5.265	5.864	6.464	7.021	5000	25000
RESIDFALL[15]	-0.1548	1.078	0.03081	-1.503	-0.8502	-0.1488	0.5481	1.198	5000	25000
RESIDFALL[16]	-1.105	1.036	0.02781	-2.388	-1.766	-1.12	-0.4386	0.1965	5000	25000
RESIDFALL[17]	-1.689	0.9956	0.02438	-2.922	-2.327	-1.694	-1.061	-0.431	5000	25000
RESIDFALL[18]	-2.212	1.065	0.02633	-3.525	-2.896	-2.215	-1.529	-0.8943	5000	25000
RESIDFALL[19]	-4.747	1.043	0.02401	-6.026	-5.406	-4.758	-4.115	-3.506	5000	25000
RESIDFALL[20]	-3.46	1.012	0.02183	-4.709	-4.102	-3.453	-2.818	-2.227	5000	25000
RESIDFALL[21]	0.1731	0.9862	0.01856	-1.064	-0.4464	0.1963	0.8183	1.373	5000	25000
RESIDFALL[22]	-5.243	0.9954	0.02072	-6.468	-5.858	-5.241	-4.641	-4.072	5000	25000
RESIDFALL[23]	-0.3525	0.9233	0.01424	-1.537	-0.937	-0.3146	0.275	0.7797	5000	25000
RESIDFALL[24]	5.119	0.9973	0.01838	3.901	4.545	5.188	5.781	6.275	5000	25000
RESIDFALL[25]	0.8431	0.9337	0.0144	-0.349	0.2645	0.8952	1.479	1.971	5000	25000
RESIDFALL[26]	-2.692	0.9333	0.01486	-3.883	-3.275	-2.66	-2.066	-1.542	5000	25000
RESIDFALL[27]	3.391	0.9793	0.01666	2.154	2.809	3.459	4.049	4.564	5000	25000
RESIDFALL[28]	5.939	1.049	0.02013	4.678	5.359	6.021	6.627	7.139	5000	25000
RESIDFALL[29]	2.706	0.9809	0.0163	1.465	2.119	2.775	3.365	3.877	5000	25000
RESIDFALL[30]	4.99	1.035	0.01997	3.743	4.418	5.073	5.668	6.186	5000	25000
RESIDFALL[31]	-1.017	0.9469	0.01405	-2.234	-1.602	-0.957	-0.3792	0.1309	5000	25000
RESIDFALL[32]	-2.254	0.9544	0.01471	-3.469	-2.84	-2.207	-1.613	-1.087	5000	25000
RESIDFALL[33]	3.853	0.9993	0.01702	2.602	3.256	3.924	4.522	5.044	5000	25000
RESIDFALL[34]	-1.369	0.9745	0.01431	-2.608	-1.971	-1.324	-0.7075	-0.1758	5000	25000
RESIDFALL[35]	-3.484	0.9574	0.01483	-4.698	-4.09	-3.45	-2.851	-2.317	5000	25000
RESIDFALL[36]	12.45	1.208	0.03101	11.19	11.88	12.55	13.17	13.7	5000	25000
RESIDFALL[37]	2.231	1.007	0.01605	0.9684	1.642	2.298	2.907	3.44	5000	25000
RESIDSPR[1]	-0.8847	0.2384	0.006688	-1.199	-1.015	-0.8495	-0.7159	-0.6151	5000	25000
RESIDSPR[2]	-0.689	0.2405	0.007061	-1.007	-0.8231	-0.6544	-0.518	-0.4149	5000	25000
RESIDSPR[3]	13.06	0.2684	0.006805	12.7	12.9	13.09	13.25	13.37	5000	25000
RESIDSPR[4]	-0.8661	0.3004	0.006385	-1.259	-1.042	-0.8327	-0.6518	-0.5122	5000	25000
RESIDSPR[5]	0.3011	0.3328	0.00657	-0.1353	0.1059	0.3378	0.5376	0.6941	5000	25000
RESIDSPR[6]	1.452	0.3876	0.007422	0.9465	1.22	1.494	1.728	1.91	5000	25000
RESIDSPR[7]	0.8486	0.4079	0.007489	0.3184	0.598	0.8859	1.138	1.339	5000	25000
RESIDSPR[8]	7.556	0.4696	0.008341	6.94	7.273	7.595	7.885	8.124	5000	25000
RESIDSPR[9]	6.729	0.458	0.007879	6.156	6.473	6.771	7.041	7.261	5000	25000
RESIDSPR[10]	1.304	0.5026	0.008454	0.6496	1.006	1.346	1.652	1.91	5000	25000
RESIDSPR[11]	-1.715	0.5118	0.007578	-2.381	-2.02	-1.672	-1.362	-1.1	5000	25000
RESIDSPR[12]	-0.9617	0.5129	0.006647	-1.63	-1.267	-0.9181	-0.6041	-0.3488	5000	25000
RESIDSPR[13]	1.409	0.5488	0.007146	0.6938	1.086	1.461	1.792	2.056	5000	25000
RESIDSPR[14]	-0.4539	0.5446	0.006859	-1.161	-0.7763	-0.4084	-0.08205	0.1894	5000	25000
RESIDSPR[15]	-1.41	0.5439	0.006202	-2.119	-1.727	-1.359	-1.031	-0.7677	5000	25000
RESIDSPR[16]	-1.287	0.5467	0.005293	-1.995	-1.606	-1.236	-0.9055	-0.6397	5000	25000
RESIDSPR[17]	-1.652	0.5424	0.006202	-2.36	-1.973	-1.602	-1.279	-1.017	5000	25000
RESIDSPR[18]	-0.12	0.5352	0.004402	-0.8241	-0.4374	-0.06624	0.2584	0.5117	5000	25000
RESIDSPR[19]	0.4381	0.5585	0.006206	-0.2847	0.1208	0.4992	0.827	1.088	5000	25000
RESIDSPR[20]	1.018	0.545	0.004793	0.312	0.6988	1.078	1.398	1.659	5000	25000
RESIDSPR[21]	-1.53	0.5418	0.004688	-2.237	-1.849	-1.473	-1.153	-0.8929	5000	25000
RESIDSPR[22]	0.7311	0.5605	0.005862	0.005683	0.4027	0.7941	1.126	1.388	5000	25000
RESIDSPR[23]	-1.258	0.5813	0.006954	-2.004	-1.584	-1.189	-0.8584	-0.5817	5000	25000
RESIDSPR[24]	-1.461	0.5617	0.005838	-2.192	-1.792	-1.402	-1.067	-0.8071	5000	25000
RESIDSPR[25]	2.79	0.572	0.006852	2.051	2.465	2.854	3.187	3.459	5000	25000
RESIDSPR[26]	-0.3304	0.5535	0.004733	-1.055	-0.6486	-0.2767	0.05621	0.3275	5000	25000
RESIDSPR[27]	4.478	0.5532	0.004832	3.756	4.149	4.534	4.867	5.128	5000	25000
RESIDSPR[28]	0.604	0.5682	0.00575	-0.1336	0.2763	0.6636	0.9996	1.27	5000	25000
RESIDSPR[29]	0.5995	0.5563	0.004714	-0.1258	0.2759	0.6581	0.9885	1.252	5000	25000
RESIDSPR[30]	-1.635	0.553	0.005015	-2.359	-1.958	-1.581	-1.249	-0.9827	5000	25000
RESIDSPR[31]	1.499	0.6204	0.01051	0.7435	1.175	1.576	1.914	2.189	5000	25000
RESIDSPR[32]	1.322	0.5777	0.005773	0.5681	0.9906	1.386	1.727	1.997	5000	25000
RESIDSPR[33]	7.113	0.593	0.007156	6.372	6.789	7.179	7.518	7.786	5000	25000
qFALL	0.04607	0.00921	3.525E-4	0.03447	0.04018	0.04615	0.05213	0.05763	5000	25000
qSPR	0.01422	0.003544	1.008E-4	0.009921	0.01178	0.01398	0.01641	0.01883	5000	25000
r	0.8915	0.2317	0.00958	0.6055	0.7362	0.8848	1.038	1.188	5000	25000
sigma2	0.00475	0.01176	4.411E-4	0.001567	0.002085	0.002979	0.004527	0.007287	5000	25000
tau2FALL	0.1886	0.04904	6.777E-4	0.1347	0.1554	0.182	0.2152	0.2509	5000	25000
tau2SPR	1.038	0.2644	0.002523	0.7435	0.8537	0.9999	1.179	1.384	5000	25000

Appendix 1. Southern stock area BSP model for silver hake.

```
# Implementation of the surplus production model for southern whiting
# Jon Brodziak, NEFSC Nov-7-00
# LOGNORMAL OBSERVATION ERRORS
################################################################################

model South_FS_6300

{
# PRIOR DISTRIBUTIONS
##############################################

# PRIOR FOR K
# Lognormal with 10%Q at 400 kt and 90%Q at 2000 kt
######################################################

K ~ dlnorm(6.79618,2.53004)I(10,5000)

# PRIOR FOR R
# Uniform from [0.01,1.99]
######################################################

r ~ dunif(0.01,1.99)

# PRIOR FOR Q
# Inverse gamma with a=b=0.001
# and bounded as (0.001,10)
##################################

iqFALL ~ dgamma(0.001,0.001)I(0.1,1000);
qFALL <- 1/iqFALL;
iqSPR ~ dgamma(0.001,0.001)I(0.1,1000);
qSPR <- 1/iqSPR;

# PRIOR FOR SIGMA2 - PROCESS ERROR VARIANCE
############################################################

isigma2 ~ dgamma(a0,b0);
sigma2 <- 1/isigma2;

# PRIOR FOR TAU2FALL/SPR - OBSERVATION ERROR VARIANCE
###############################################################

itau2FALL   ~ dgamma(c0FALL,d0FALL);
tau2FALL   <- 1/itau2FALL;
itau2SPR   ~ dgamma(c0SPR,d0SPR);
tau2SPR   <- 1/itau2SPR;

# CONDITIONAL PRIORS FOR PROPORTIONS P
# Lognormal bounded as (0.001,3)
#############################################

Pmean[1] <- 0;
P[1] ~ dlnorm(Pmean[1],isigma2) I(0.001,3)
dlow[1] <- dlowpre*L[1]
dup[1] <- duppre*L[1]
# Low precision catch error during 1963
C[1] ~ dunif(dlow[1],dup[1])

# Low precision catch error during 1964-1977
for (i in 2:15) {
  Pmean[i] <- log(max(P[i-1] + r*P[i-1]*(1-P[i-1]) - C[i-1]/K,0.001))
```

```
   P[i]  ~ dlnorm(Pmean[i],isigma2)I(0.001,3)
   dlow[i] <- dlowpre*L[i]
   dup[i] <- duppre*L[i]
   C[i] ~ dunif(dlow[i],dup[i])
   }
# High precision catch error during 1978-2000
for (i in 16:38) {
   Pmean[i] <- log(max(P[i-1] + r*P[i-1]*(1-P[i-1]) - C[i-1]/K,0.001))
   P[i]      ~ dlnorm(Pmean[i],isigma2)I(0.001,3)
   dlow[i] <- dlowcur*L[i]
   dup[i] <- dupcur*L[i]
   C[i] ~ dunif(dlow[i],dup[i])
   }


# LIKELIHOOD OF SAMPLING DISTRIBUTION
####################################
# FALL SURVEY LIKELIHOOD & RESIDUALS
for (i in 1:N) {
    ImeanFALL[i] <- log(qFALL*K*P[i])
    IFALL[i] ~ dlnorm(ImeanFALL[i],itau2FALL)
    RESIDFALL[i] <- IFALL[i] - qFALL*K*P[i]
    }
# SPRING SURVEY LIKELIHOOD & RESIDUALS
for (i in 1:NSPR) {
    ImeanSPR[i] <- log(qSPR*K*P[i+5])
    ISPR[i] ~ dlnorm(ImeanSPR[i],itau2SPR)
    RESIDSPR[i] <- ISPR[i] - qSPR*K*P[i]
   }
# MANAGEMENT PARAMETERS
MSP <- r*K/4
INDEXMSPFALL <- r/(2*qFALL)
INDEXMSPSPR <- r/(2*qSPR)
HMSP <- r/2
HRATIO <- H[37]/HMSP

#  COMPUTE BIOMASS AND HARVEST RATE TRAJECTORIES
for (i in 1:N) {
    B[i] <- P[i]*K
    H[i] <- C[i]/B[i]
   }

# PROJECT YEAR 2001
P2001 <- P[N+1]+r*P[N+1]*(1-P[N+1])-C[N+1]/K
B2001 <- P2001*K
H2000 <- min(C[N+1]/(P[N+1]*K),1.0)

# END OF CODE
}
```

Data

```
# Vector L() is discard-adjusted total catch
# Vector IFALL() is autumn kg/tow index
# Vector ISPR is spring kg/tow index
# N is number of years
# Sigma is state equation error with parameters a0,b0
# TauFALL is autumn observation equation error with parameters c0FALL,d0FALL
# TauSPR is autumn observation equation error with parameters c0SPR,d0SPR
# Vector C() is discard-adjusted catch with error multiplier
# Error multiplier is bounded by [dlowpre,duppre] for 1963-1976
# and is bounded by [dlowcur,dupcur] for 1976-2000
```

```
list(
L=c(93.382,153.584,307.131,211.270,91.249,58.496,75.561,27.512,71.890,
94.396,104.593,109.863,74.253,68.741,59.308,27.132,18.375,13.546,14.826,
14.561,12.140,13.143,13.164,10.123,10.121,9.194,13.169,13.615,10.093,
10.288,12.912,12.004,12.021,12.280,12.757,12.433,10.059,11.000),
IFALL=c(3.418,2.908,3.773,1.760,2.186,2.693,1.256,1.332,2.210,2.000,
1.699,0.862,1.840,2.062,1.773,2.931,1.741,2.122,1.166,1.651,3.200,1.558,
3.907,1.388,1.619,1.830,2.120,1.645,0.907,0.978,1.329,0.799,1.641,0.431,
0.842,0.62,0.87),
ISPR=c(3.756,2.202,1.233,2.192,1.399,4.968,3.474,6.486,4.11,4.553,5.307,
2.342,2.779,3.761,2.018,1.376,2.209,2.642,2.672,3.617,1.709,2.316,3.869,
1.459,0.528,1.362,2.278,0.999,6.216,0.684,0.686,1.774,1.049),
N=37,
NSPR=33,
a0=4.0,b0=0.01,
c0FALL=2.0,d0FALL=0.01,
c0SPR=2.0,d0SPR=0.01,
dlowpre=0.90,duppre=1.10,
dlowcur=1.00,dupcur=1.10)
```

Inits

```
# Initial Condition 1
list(
P=c(0.9,0.7,0.7,0.5,0.6,0.7,0.3,0.3,0.6,0.5,0.4,0.2,0.5,0.5,0.5,0.8,0.4,
0.5,0.3,0.4,0.8,0.4,1.0,0.4,0.4,0.5,0.5,0.4,0.2,0.3,0.3,0.2,0.4,0.1,0.2,
0.2,0.2,0.2),
C=c(93.382,153.584,307.131,211.270,91.249,58.496,75.561,27.512,71.890,
94.396,104.593,109.863,74.253,68.741,59.308,27.132,18.375,13.546,14.826,
14.561,12.140,13.143,13.164,10.123,10.121,9.194,13.169,13.615,10.093,
10.288,12.912,12.004,12.021,12.280,12.757,12.433,10.059,11.000),
r=0.4,
K=600,
iqFALL=10,iqSPR=20,
isigma2=100,
itau2FALL=100,itau2SPR=100)

# Initial Condition 2
list(
P=c(0.9,0.7,0.7,0.5,0.6,0.7,0.3,0.3,0.6,0.5,0.4,0.2,0.5,0.5,0.5,0.8,0.4,
0.5,0.3,0.4,0.8,0.4,1.0,0.4,0.4,0.5,0.5,0.4,0.2,0.3,0.3,0.2,0.4,0.1,0.2,
0.2,0.2,0.2),
C=c(93.382,153.584,307.131,211.270,91.249,58.496,75.561,27.512,71.890,
94.396,104.593,109.863,74.253,68.741,59.308,27.132,18.375,13.546,14.826,
14.561,12.140,13.143,13.164,10.123,10.121,9.194,13.169,13.615,10.093,
10.288,12.912,12.004,12.021,12.280,12.757,12.433,10.059,11.000),
r=0.3,
K=600,
iqFALL=10,iqSPR=20,
isigma2=100,
itau2FALL=100,itau2SPR=100)
```

Results

Summary of Posterior Distribution

node	mean	sd	MC error	10.0%	25.0%	median	75.0%	90.0%	start	sample
B[1]	2068.0	459.6	10.02	1494.0	1744.0	2043.0	2371.0	2670.0	5000	25000
B[2]	2004.0	444.1	9.509	1452.0	1687.0	1980.0	2298.0	2593.0	5000	25000
B[3]	1886.0	423.1	9.263	1360.0	1577.0	1856.0	2169.0	2453.0	5000	25000
B[4]	1563.0	395.3	9.11	1069.0	1278.0	1538.0	1832.0	2092.0	5000	25000
B[5]	1385.0	376.6	9.026	917.1	1108.0	1358.0	1643.0	1890.0	5000	25000
B[6]	1320.0	358.9	8.929	872.4	1053.0	1292.0	1566.0	1805.0	5000	25000
B[7]	1233.0	341.3	8.728	803.4	983.8	1209.0	1470.0	1696.0	5000	25000
B[8]	1184.0	332.5	8.65	767.7	939.9	1162.0	1412.0	1637.0	5000	25000
B[9]	1250.0	329.2	8.616	834.4	1008.0	1227.0	1476.0	1699.0	5000	25000
B[10]	1254.0	326.1	8.559	846.0	1014.0	1232.0	1480.0	1697.0	5000	25000
B[11]	1252.0	326.6	8.614	842.3	1013.0	1231.0	1472.0	1698.0	5000	25000
B[12]	1217.0	325.6	8.643	810.4	977.3	1193.0	1440.0	1655.0	5000	25000
B[13]	1246.0	336.6	9.027	828.2	997.4	1219.0	1477.0	1706.0	5000	25000
B[14]	1270.0	344.4	9.302	844.1	1015.0	1245.0	1503.0	1739.0	5000	25000
B[15]	1275.0	350.1	9.389	841.5	1016.0	1245.0	1511.0	1750.0	5000	25000
B[16]	1279.0	354.2	9.446	844.6	1016.0	1247.0	1512.0	1759.0	5000	25000
B[17]	1229.0	339.8	9.07	807.3	977.8	1202.0	1457.0	1691.0	5000	25000
B[18]	1209.0	331.6	8.958	797.0	964.5	1182.0	1436.0	1656.0	5000	25000
B[19]	1177.0	323.0	8.719	776.2	939.3	1150.0	1397.0	1616.0	5000	25000
B[20]	1176.0	319.9	8.655	779.0	941.4	1150.0	1393.0	1609.0	5000	25000
B[21]	1200.0	324.3	8.658	800.7	962.4	1174.0	1415.0	1636.0	5000	25000
B[22]	1191.0	320.0	8.484	795.7	955.6	1165.0	1405.0	1625.0	5000	25000
B[23]	1210.0	324.9	8.564	812.5	973.7	1182.0	1421.0	1647.0	5000	25000
B[24]	1138.0	304.5	8.1	761.5	914.5	1113.0	1339.0	1548.0	5000	25000
B[25]	1099.0	293.7	7.802	736.4	882.2	1075.0	1297.0	1495.0	5000	25000
B[26]	1050.0	280.6	7.406	703.5	843.5	1027.0	1238.0	1431.0	5000	25000
B[27]	1004.0	267.6	7.113	673.3	807.8	982.0	1184.0	1369.0	5000	25000
B[28]	923.7	247.0	6.571	617.5	740.8	903.9	1091.0	1257.0	5000	25000
B[29]	813.9	224.2	6.006	532.5	649.0	798.8	966.5	1117.0	5000	25000
B[30]	748.4	208.7	5.581	485.6	594.9	734.0	890.8	1033.0	5000	25000
B[31]	727.5	200.1	5.369	477.4	579.3	712.7	864.1	999.6	5000	25000
B[32]	693.6	192.2	5.165	453.2	552.3	678.8	823.1	956.1	5000	25000
B[33]	668.7	185.7	5.025	437.7	532.0	654.3	793.9	921.4	5000	25000
B[34]	622.1	179.1	4.867	400.4	489.0	608.7	741.3	864.8	5000	25000
B[35]	587.2	173.4	4.668	374.4	457.9	572.2	701.4	823.6	5000	25000
B[36]	568.4	172.7	4.633	357.5	441.2	551.6	680.4	803.4	5000	25000
B[37]	578.5	176.9	4.663	362.5	447.2	561.1	693.4	820.1	5000	25000
C[1]	93.36	5.394	0.03647	85.93	88.68	93.33	98.06	100.9	5000	25000
C[2]	153.4	8.847	0.05794	141.3	145.8	153.3	161.1	165.8	5000	25000
C[3]	307.1	17.76	0.1034	282.5	291.7	307.2	322.5	331.8	5000	25000
C[4]	211.1	12.2	0.07261	194.2	200.5	211.1	221.5	228.0	5000	25000
C[5]	91.24	5.29	0.03406	83.88	86.7	91.23	95.84	98.53	5000	25000
C[6]	58.51	3.377	0.02272	53.83	55.59	58.54	61.45	63.17	5000	25000
C[7]	75.53	4.361	0.02817	69.48	71.75	75.52	79.3	81.57	5000	25000
C[8]	27.48	1.585	0.009923	25.3	26.1	27.45	28.85	29.69	5000	25000
C[9]	71.78	4.15	0.02536	66.07	68.17	71.7	75.38	77.57	5000	25000
C[10]	94.22	5.471	0.03682	86.71	89.47	94.05	98.94	101.9	5000	25000
C[11]	104.4	5.998	0.03785	96.2	99.24	104.3	109.5	112.8	5000	25000
C[12]	109.4	6.358	0.03987	100.8	103.9	109.2	114.9	118.4	5000	25000
C[13]	74.11	4.265	0.02603	68.23	70.41	74.08	77.77	80.09	5000	25000
C[14]	68.65	3.97	0.02397	63.21	65.17	68.6	72.08	74.17	5000	25000
C[15]	59.26	3.422	0.02072	54.53	56.29	59.24	62.23	64.0	5000	25000
C[16]	28.49	0.7837	0.004844	27.4	27.8	28.49	29.17	29.57	5000	25000
C[17]	19.3	0.5288	0.003239	18.56	18.84	19.29	19.76	20.03	5000	25000
C[18]	14.22	0.393	0.002382	13.68	13.88	14.22	14.57	14.77	5000	25000
C[19]	15.57	0.4289	0.002644	14.97	15.2	15.57	15.95	16.16	5000	25000
C[20]	15.29	0.4193	0.002728	14.71	14.93	15.29	15.65	15.87	5000	25000
C[21]	12.75	0.3502	0.002097	12.26	12.44	12.75	13.05	13.23	5000	25000
C[22]	13.8	0.3796	0.002468	13.27	13.47	13.8	14.13	14.33	5000	25000
C[23]	13.82	0.3787	0.002392	13.3	13.49	13.82	14.15	14.35	5000	25000
C[24]	10.63	0.2922	0.001826	10.22	10.37	10.63	10.88	11.03	5000	25000
C[25]	10.63	0.2928	0.001914	10.22	10.37	10.63	10.88	11.03	5000	25000

C[26]	9.654	0.2657	0.00172	9.286	9.425	9.655	9.884	10.02	5000	25000
C[27]	13.83	0.3802	0.002399	13.3	13.5	13.84	14.16	14.36	5000	25000
C[28]	14.3	0.3913	0.002172	13.75	13.96	14.3	14.63	14.84	5000	25000
C[29]	10.6	0.292	0.001977	10.19	10.35	10.6	10.85	11.0	5000	25000
C[30]	10.81	0.2959	0.001859	10.4	10.55	10.81	11.06	11.21	5000	25000
C[31]	13.56	0.3721	0.002125	13.04	13.23	13.56	13.88	14.07	5000	25000
C[32]	12.61	0.345	0.00224	12.13	12.31	12.61	12.9	13.09	5000	25000
C[33]	12.62	0.3458	0.002082	12.14	12.32	12.63	12.92	13.1	5000	25000
C[34]	12.9	0.3533	0.002032	12.4	12.59	12.9	13.2	13.38	5000	25000
C[35]	13.39	0.3678	0.002351	12.88	13.08	13.39	13.71	13.9	5000	25000
C[36]	13.05	0.3582	0.002359	12.56	12.74	13.05	13.36	13.55	5000	25000
C[37]	10.56	0.2915	0.00179	10.16	10.31	10.56	10.81	10.97	5000	25000
C[38]	11.55	0.3168	0.002038	11.11	11.28	11.55	11.83	11.99	5000	25000
H[1]	0.04754	0.01174	2.669E-4	0.03453	0.03924	0.04568	0.05379	0.06296	5000	25000
H[2]	0.0806	0.01985	4.482E-4	0.05861	0.06645	0.0774	0.09111	0.1064	5000	25000
H[3]	0.1716	0.04214	9.728E-4	0.1244	0.141	0.1653	0.1948	0.2265	5000	25000
H[4]	0.1445	0.04121	0.001008	0.1	0.1149	0.1372	0.1657	0.1984	5000	25000
H[5]	0.07138	0.02241	5.635E-4	0.04784	0.05541	0.06719	0.08245	0.09964	5000	25000
H[6]	0.04806	0.01506	3.932E-4	0.03212	0.03723	0.0452	0.05563	0.06724	5000	25000
H[7]	0.06664	0.02153	5.808E-4	0.04419	0.05126	0.06231	0.07703	0.09439	5000	25000
H[8]	0.02535	0.008485	2.308E-4	0.01666	0.01941	0.02362	0.02924	0.03603	5000	25000
H[9]	0.06195	0.01881	5.119E-4	0.04207	0.04853	0.05836	0.07124	0.08621	5000	25000
H[10]	0.08087	0.02412	6.569E-4	0.05507	0.06347	0.07641	0.0932	0.1121	5000	25000
H[11]	0.08974	0.02668	7.298E-4	0.06107	0.07057	0.08481	0.1034	0.1246	5000	25000
H[12]	0.0972	0.02979	8.263E-4	0.06569	0.07577	0.09152	0.112	0.1357	5000	25000
H[13]	0.06434	0.01973	5.498E-4	0.04313	0.05014	0.06083	0.07431	0.0901	5000	25000
H[14]	0.05845	0.01789	5.004E-4	0.03915	0.04554	0.05518	0.06773	0.08169	5000	25000
H[15]	0.05034	0.01543	4.276E-4	0.03359	0.03909	0.0475	0.05846	0.07076	5000	25000
H[16]	0.02416	0.007342	2.063E-4	0.01616	0.01884	0.0228	0.02803	0.03384	5000	25000
H[17]	0.01703	0.005226	1.465E-4	0.01139	0.01324	0.01605	0.01971	0.02395	5000	25000
H[18]	0.01276	0.003915	1.111E-4	0.008575	0.009905	0.01204	0.01474	0.01787	5000	25000
H[19]	0.01435	0.00445	1.266E-4	0.009606	0.01113	0.01353	0.0166	0.02006	5000	25000
H[20]	0.01408	0.004305	1.228E-4	0.009483	0.01098	0.01327	0.01621	0.01971	5000	25000
H[21]	0.01147	0.003424	9.654E-5	0.007763	0.008997	0.01084	0.01325	0.01595	5000	25000
H[22]	0.01252	0.003746	1.051E-4	0.008473	0.009814	0.01184	0.01445	0.0174	5000	25000
H[23]	0.01232	0.003611	1.003E-4	0.008369	0.00971	0.01172	0.0142	0.01703	5000	25000
H[24]	0.01008	0.002977	8.404E-5	0.006851	0.00793	0.009558	0.01162	0.01399	5000	25000
H[25]	0.01043	0.003068	8.706E-5	0.007083	0.008189	0.009898	0.01205	0.01442	5000	25000
H[26]	0.009923	0.002941	8.262E-5	0.006742	0.00779	0.009411	0.01144	0.01374	5000	25000
H[27]	0.01485	0.004349	1.218E-4	0.01009	0.01166	0.01408	0.01717	0.02059	5000	25000
H[28]	0.01671	0.004968	1.39E-4	0.01136	0.01311	0.01582	0.01933	0.02319	5000	25000
H[29]	0.01415	0.004455	1.258E-4	0.009458	0.01095	0.01327	0.01635	0.01992	5000	25000
H[30]	0.01574	0.00509	1.435E-4	0.01044	0.01211	0.01473	0.01818	0.02224	5000	25000
H[31]	0.02024	0.006332	1.782E-4	0.01353	0.01567	0.01901	0.02337	0.02841	5000	25000
H[32]	0.01976	0.00621	1.746E-4	0.01317	0.01529	0.01857	0.02283	0.02784	5000	25000
H[33]	0.02052	0.006406	1.819E-4	0.01367	0.01588	0.0193	0.02372	0.02893	5000	25000
H[34]	0.02268	0.007414	2.114E-4	0.01486	0.01736	0.02121	0.02641	0.03222	5000	25000
H[35]	0.02507	0.008422	2.392E-4	0.01624	0.01907	0.02338	0.0292	0.03584	5000	25000
H[36]	0.02537	0.00874	2.46E-4	0.01624	0.01916	0.02367	0.0296	0.03649	5000	25000
H[37]	0.02017	0.006899	1.896E-4	0.01286	0.01523	0.01883	0.02363	0.02919	5000	25000
HMSP	0.02241	0.01794	2.985E-4	0.006983	0.01023	0.01713	0.02866	0.04381	5000	25000
HRATIO	1.386	0.9786	0.01367	0.4326	0.6712	1.109	1.842	2.76	5000	25000
INDEXMSPFALL	14.28	11.43	0.1991	4.714	6.857	11.17	17.93	27.04	5000	25000
INDEXMSPSPR	9.547	7.804	0.1381	3.089	4.501	7.383	11.93	18.26	5000	25000
K	2012.0	475.0	11.88	1429.0	1677.0	1980.0	2313.0	2625.0	5000	25000
MSP	20.97	14.5	0.1602	7.305	10.67	17.15	27.0	39.18	5000	25000
RESIDFALL[1]	0.2507	0.5033	0.01615	-0.4063	-0.05379	0.2932	0.6019	0.8516	5000	25000
RESIDFALL[2]	-0.1559	0.4488	0.01194	-0.7428	-0.4265	-0.125	0.1582	0.383	5000	25000
RESIDFALL[3]	0.895	0.3978	0.008776	0.3761	0.6576	0.9243	1.172	1.374	5000	25000
RESIDFALL[4]	-0.6068	0.3168	0.005437	-1.02	-0.8045	-0.589	-0.3878	-0.219	5000	25000
RESIDFALL[5]	0.09995	0.2824	0.003845	-0.2638	-0.07656	0.1159	0.2923	0.4488	5000	25000
RESIDFALL[6]	0.707	0.2596	0.003109	0.3732	0.5422	0.718	0.8871	1.032	5000	25000
RESIDFALL[7]	-0.5977	0.2466	0.003206	-0.9132	-0.7564	-0.5885	-0.4285	-0.2913	5000	25000
RESIDFALL[8]	-0.4453	0.2415	0.003114	-0.758	-0.5995	-0.4363	-0.2792	-0.146	5000	25000

RESIDFALL[9]	0.3264	0.2334	0.002522	0.02666	0.1782	0.3363	0.4865	0.6158	5000	25000
RESIDFALL[10]	0.1089	0.2292	0.002304	-0.1853	-0.03555	0.1193	0.2665	0.3911	5000	25000
RESIDFALL[11]	-0.1894	0.2288	0.00206	-0.4852	-0.3329	-0.1767	-0.03381	0.09308	5000	25000
RESIDFALL[12]	-0.9696	0.2254	0.002054	-1.259	-1.111	-0.96	-0.8145	-0.6927	5000	25000
RESIDFALL[13]	-0.03503	0.2348	0.002502	-0.3421	-0.1776	-0.01626	0.1288	0.247	5000	25000
RESIDFALL[14]	0.1494	0.2475	0.003083	-0.1732	0.001005	0.1714	0.3242	0.445	5000	25000
RESIDFALL[15]	-0.1466	0.2593	0.003634	-0.4853	-0.3008	-0.1221	0.03503	0.1629	5000	25000
RESIDFALL[16]	1.006	0.2742	0.004112	0.6483	0.846	1.032	1.197	1.33	5000	25000
RESIDFALL[17]	-0.1077	0.2464	0.003234	-0.426	-0.2558	-0.08743	0.06318	0.1886	5000	25000
RESIDFALL[18]	0.3039	0.2354	0.003004	-0.003716	0.1613	0.3229	0.4671	0.59	5000	25000
RESIDFALL[19]	-0.6033	0.2238	0.002591	-0.8922	-0.7408	-0.5875	-0.4497	-0.3298	5000	25000
RESIDFALL[20]	-0.1186	0.2241	0.002596	-0.4075	-0.2544	-0.1038	0.03762	0.1526	5000	25000
RESIDFALL[21]	1.391	0.2397	0.003036	1.078	1.248	1.411	1.557	1.68	5000	25000
RESIDFALL[22]	-0.2372	0.2367	0.002962	-0.5422	-0.381	-0.2184	-0.07389	0.0481	5000	25000
RESIDFALL[23]	2.08	0.2605	0.003675	1.746	1.928	2.105	2.262	2.389	5000	25000
RESIDFALL[24]	-0.3275	0.2256	0.00283	-0.6196	-0.4635	-0.3086	-0.1722	-0.05427	5000	25000
RESIDFALL[25]	-0.03789	0.2176	0.002549	-0.3222	-0.17	-0.01928	0.1129	0.223	5000	25000
RESIDFALL[26]	0.2472	0.2072	0.00231	-0.02281	0.121	0.266	0.3931	0.4948	5000	25000
RESIDFALL[27]	0.605	0.1998	0.002278	0.3451	0.4856	0.6227	0.7451	0.8428	5000	25000
RESIDFALL[28]	0.2533	0.1765	0.001794	0.02377	0.148	0.2661	0.3751	0.4664	5000	25000
RESIDFALL[29]	-0.3158	0.1527	0.001496	-0.5124	-0.4114	-0.3089	-0.2111	-0.128	5000	25000
RESIDFALL[30]	-0.1454	0.1437	0.001549	-0.3306	-0.2367	-0.1402	-0.04717	0.03289	5000	25000
RESIDFALL[31]	0.2359	0.1368	0.001504	0.05936	0.1492	0.2428	0.3299	0.4052	5000	25000
RESIDFALL[32]	-0.2429	0.1322	0.001542	-0.4148	-0.3266	-0.2351	-0.1527	-0.08032	5000	25000
RESIDFALL[33]	0.6364	0.1288	0.001615	0.4702	0.5548	0.6436	0.726	0.7947	5000	25000
RESIDFALL[34]	-0.5019	0.1284	0.00184	-0.6686	-0.5828	-0.4951	-0.4122	-0.3452	5000	25000
RESIDFALL[35]	-0.03761	0.1279	0.001955	-0.2041	-0.1178	-0.02909	0.05118	0.1189	5000	25000
RESIDFALL[36]	-0.2309	0.134	0.002104	-0.4053	-0.3129	-0.2212	-0.1372	-0.06793	5000	25000
RESIDFALL[37]	0.003198	0.1438	0.00208	-0.1842	-0.08634	0.01458	0.1041	0.178	5000	25000
RESIDSPR[1]	-1.045	0.9137	0.02745	-2.241	-1.591	-0.9521	-0.4022	0.03523	5000	25000
RESIDSPR[2]	-2.442	0.8344	0.02102	-3.536	-2.947	-2.364	-1.851	-1.444	5000	25000
RESIDSPR[3]	-3.129	0.7528	0.01606	-4.112	-3.581	-3.06	-2.605	-2.231	5000	25000
RESIDSPR[4]	-1.394	0.5984	0.01047	-2.173	-1.764	-1.345	-0.9778	-0.6648	5000	25000
RESIDSPR[5]	-1.76	0.5215	0.007596	-2.445	-2.081	-1.719	-1.4	-1.124	5000	25000
RESIDSPR[6]	1.962	0.4775	0.006224	1.345	1.665	1.993	2.297	2.545	5000	25000
RESIDSPR[7]	0.6688	0.445	0.00603	0.08935	0.3917	0.6948	0.9802	1.214	5000	25000
RESIDSPR[8]	3.797	0.4288	0.005571	3.24	3.53	3.824	4.097	4.322	5000	25000
RESIDSPR[9]	1.261	0.4228	0.00489	0.7087	0.994	1.291	1.555	1.773	5000	25000
RESIDSPR[10]	1.692	0.4166	0.004526	1.148	1.434	1.719	1.982	2.202	5000	25000
RESIDSPR[11]	2.451	0.4113	0.003877	1.918	2.193	2.475	2.737	2.955	5000	25000
RESIDSPR[12]	-0.4278	0.4013	0.00366	-0.9499	-0.68	-0.4034	-0.1491	0.06555	5000	25000
RESIDSPR[13]	-0.05601	0.4125	0.003738	-0.5965	-0.3096	-0.02524	0.2309	0.4423	5000	25000
RESIDSPR[14]	0.8694	0.4294	0.004421	0.3061	0.6103	0.909	1.17	1.384	5000	25000
RESIDSPR[15]	-0.8837	0.4433	0.005091	-1.463	-1.148	-0.842	-0.5751	-0.3568	5000	25000
RESIDSPR[16]	-1.535	0.4633	0.005774	-2.144	-1.803	-1.487	-1.212	-0.9863	5000	25000
RESIDSPR[17]	-0.5853	0.4201	0.004432	-1.132	-0.8388	-0.5492	-0.2935	-0.08251	5000	25000
RESIDSPR[18]	-0.1064	0.4079	0.003973	-0.6397	-0.3543	-0.07218	0.1773	0.3861	5000	25000
RESIDSPR[19]	-0.002592	0.3889	0.003377	-0.5061	-0.24	0.02592	0.2709	0.4667	5000	25000
RESIDSPR[20]	0.9419	0.3906	0.003446	0.4347	0.7041	0.9734	1.215	1.411	5000	25000
RESIDSPR[21]	-1.026	0.414	0.004246	-1.563	-1.271	-0.99	-0.7331	-0.5304	5000	25000
RESIDSPR[22]	-0.3981	0.4102	0.004226	-0.9308	-0.6435	-0.363	-0.1108	0.09424	5000	25000
RESIDSPR[23]	1.107	0.4446	0.005326	0.5283	0.8468	1.149	1.417	1.632	5000	25000
RESIDSPR[24]	-1.135	0.392	0.004018	-1.655	-1.37	-1.101	-0.8603	-0.6634	5000	25000
RESIDSPR[25]	-1.977	0.3777	0.003614	-2.475	-2.207	-1.945	-1.712	-1.524	5000	25000
RESIDSPR[26]	-1.031	0.3608	0.003314	-1.501	-1.248	-0.9984	-0.7785	-0.5996	5000	25000
RESIDSPR[27]	-0.01257	0.3466	0.0033	-0.463	-0.218	0.02069	0.2297	0.3999	5000	25000
RESIDSPR[28]	-1.105	0.3079	0.002635	-1.504	-1.291	-1.081	-0.8899	-0.7343	5000	25000
RESIDSPR[29]	4.368	0.2662	0.002137	4.024	4.205	4.384	4.55	4.695	5000	25000
RESIDSPR[30]	-1.014	0.2483	0.00229	-1.338	-1.17	-0.9972	-0.8442	-0.7077	5000	25000
RESIDSPR[31]	-0.9661	0.2365	0.002189	-1.274	-1.114	-0.951	-0.8008	-0.6776	5000	25000
RESIDSPR[32]	0.1994	0.2266	0.002199	-0.09408	0.05926	0.2127	0.3564	0.4771	5000	25000
RESIDSPR[33]	-0.4694	0.2214	0.002262	-0.7574	-0.607	-0.4552	-0.3157	-0.1989	5000	25000
qFALL	0.001605	4.437E-4	1.308E-5	0.00112	0.001274	0.001522	0.001836	0.002187	5000	25000
qSPR	0.002433	7.211E-4	2.095E-5	0.001658	0.001908	0.002297	0.002812	0.003379	5000	25000

r	0.04481	0.03588	5.97E-4	0.01397	0.02046	0.03427	0.05732	0.08762	5000	25000
sigma2	0.01122	0.007507	1.548E-4	0.004377	0.006287	0.009359	0.01389	0.02017	5000	25000
tau2FALL	0.1141	0.03085	3.14E-4	0.07932	0.09224	0.1094	0.1309	0.1542	5000	25000
tau2SPR	0.2885	0.07484	5.137E-4	0.2042	0.2359	0.2769	0.3291	0.3861	5000	25000

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Northeast Fisheries Science Center
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**STANDARD
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Publications and Reports of the Northeast Fisheries Science Center

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