Northeast Fisheries Science Center Reference Document 02-05

Biological Characteristics, Population Dynamics, and Current Status of Redfish, *Sebastes fasciatus* Storer, in the Gulf of Maine - Georges Bank Region

by

Ralph K. Mayo, Jon K.T. Brodziak,
Michele Thompson, Jay M. Burnett,
and Steven X. Cadrin

April 2002

Recent Issues in This Series:

01-07 **Proceedings of the 14th Canada-USA Scientific Discussions, January 22-25, 2001, MBL Conference Center, Woods Hole, Massachusetts.** By S. Clark and R. O'Boyle, convenors. May 2001.

01-08 **TRAC Advisory Report on Stock Status: A Report of the Fourth Meeting of the Transboundary Resources Assessment Committee (TRAC), St. Andrews Biological Station, St. Andrews, New Brunswick, April 17-20, 2001.** [By the 4th Transboundary Resources Assessment Committee Meeting.] July 2001.

01-09 **Results of a Field Collection of Biopsy Samples from Coastal Bottlenose Dolphin in the Mid-Atlantic.** By J. Nicolas, D.C. Potter, C.W. Potter, and P.E. Rosel. July 2001.

01-10 **Assessment of the Georges Bank Atlantic Cod Stock for 2001.** By L. O'Brien and N.J. Munroe. [A report of the 4th Transboundary Resources Assessment Committee Meeting.] July 2001.

01-11 **Protocol and Guide for Estimating Nucleic Acids in Larval Fish Using a Fluorescence Microplate Reader.** By E.M. Caldarone, M. Wagner, J. St. Onge-Burns, and L.J. Buckley. July 2001.

01-12 **Northeast Fisheries Science Center Publications, Reports, and Abstracts for Calendar Year 2000.** By L. Garner and J.A. Gibson. August 2001.

01-13 **Elemental Composition of Fish Otoliths: Results of a Laboratory Intercomparison Exercise.** By V.S. Zdanowicz. September 2001.

01-14 **Identification of Seasonal Area Management Zones for North Atlantic Right Whale Conservation.** By R.L. Merrick, P.J. Clapham, T.V.N. Cole, P. Gerrior, and R.M. Pace, III. October 2001.

01-15 **Bycatch Estimates of Coastal Bottlenose Dolphin (*Tursiops truncatus*) in U.S. Mid-Atlantic Gillnet Fisheries for 1996 to 2000.** By D.L. Palka and M.C. Rossman. November 2001.

01-16 **Causes of Reproductive Failure in North Atlantic Right Whales: New Avenues for Research -- Report of a Workshop Held 26-28 April 2000, Falmouth, Massachusetts.** By R.R. Reeves, R. Roland, and P.J. Clapham, editors. November 2001.

01-17 **Collected Abstracts of the Northeast Fisheries Science Center's Seventh Science Symposium, Westbrook, Connecticut, December 11-13, 2001.** By R. Mercaldo-Allen, J. Choromanski, M.S. Dixon, J.B. Hughes, D.R. Lanyon, C.A. Kuropat, C. Martin, and J.J. Ziskowski, compilers. December 2001.

01-18 **Report of the 33rd Northeast Regional Stock Assessment Workshop (33rd SAW): Stock Assessment Review Committee (SARC) Consensus Summary of Assessments.** [By Northeast Regional Stock Assessment Workshop No. 33.] December 2001.

01-19 **Report of the 33rd Northeast Regional Stock Assessment Workshop (33rd SAW): Public Review Workshop.** [By the 33rd Northeast Regional Stock Assessment Workshop.] December 2001.

01-20 **Assessment of 19 Northeast Groundfish Stocks through 2000: A Report to the New England Fishery Management Council's Multi-Species Monitoring Committee.** By Northern Demersal and Southern Demersal Working Groups, Northeast Regional Stock Assessment Workshop. December 2001.

02-01 **Workshop on the Effects of Fishing Gear on Marine Habitats off the Northeastern United States, October 23-25, 2001, Boston, Massachusetts.** By Northeast Region Essential Fish Habitat Steering Committee. February 2002.

02-02 **The 2001 Assessment of the Gulf of Maine Atlantic Cod Stock.** By R.K. Mayo, E.M. Thunberg, S.E. Wigley, and S.X. Cadrin. [A report of the 33rd Northeast Regional Stock Assessment Workshop.] March 2002.

02-03 **An Age-Structured Assessment Model for Georges Bank Winter Flounder.** By J.K.T. Brodziak. [A report of the 34th Northeast Regional Stock Assessment Workshop.] March 2002.

02-04 **Re-Evaluation of Biological Reference Points for New England Groundfish.** By Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish. March 2002.

Northeast Fisheries Science Center Reference Document 02-05

A Report of the 33rd Northeast Regional Stock Assessment Workshop

Biological Characteristics, Population Dynamics, and Current Status of Redfish, *Sebastes fasciatus* Storer, in the Gulf of Maine - Georges Bank Region

by

Ralph K. Mayo, Jon K.T. Brodziak, Michele Thompson, Jay M. Burnett, and Steven X. Cadrin

National Marine Fisheries Serv., 166 Water St., Woods Hole, MA 02543-1026

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

April 2002

Northeast Fisheries Science Center Reference Documents

This series is a secondary scientific series designed to assure the long-term documentation and to enable the timely transmission of research results by Center and/or non-Center researchers, where such results bear upon the research mission of the Center (see the outside back cover for the mission statement). These documents receive internal scientific review but no technical or copy editing. The National Marine Fisheries Service does not endorse any proprietary material, process, or product mentioned in these documents.

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

This document's publication history is as follows: manuscript submitted for review--December 18, 2001; manuscript accepted through technical review--February 15, 2002; manuscript accepted through policy review--March 1, 2002; and camera-ready copy submitted for publication--April 3, 2002. This document may be cited as:

Mayo, R.K.; Brodziak, J.K.T.; Thompson, M.; Burnett, J.M.; Cadrin, S.X. 2002. Biological characteristics, population dynamics, and current status of redfish, *Sebastes fasciatus* Storer, in the Gulf of Maine - Georges Bank region. *Northeast Fish. Sci. Cent. Ref. Doc.* 02-05; 130 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026.

TABLE OF CONTENTS

ABSTRACT

The status of the Gulf of Maine/Georges Bank redfish (*Sebastes fasciatus*) stock through 2000 is reviewed, and the current status of the stock is compared on a relative basis to revised estimates MSY-based reference points. The 2001 assessment is based on several sources of information including: the age composition of USA commercial landings, Northeast Fisheries Science Center (NEFSC) spring and autumn research vessel survey data, and standardized USA commercial fishing effort data. This assessment updates the analyses presented in the 1993 assessment of the Gulf of Maine/Georges Bank redfish stock as well as that prepared in 2000 by the Northern Demersal Working Group.

Information on the size and age structure of the redfish stock is presented including: age composition of the commercial landings (1969-1985), length composition of inshore and offshore components of the stock based on NEFSC spring (1968-2000) and autumn (1963-2000) research vessel surveys, and age composition of the stock based on NEFSC spring and autumn research vessel surveys (1975-2000). Several aspects of the biology of the redfish stock are also presented including patterns in diurnal catchability, length-weight relationships, analyses of maturity at length, and inshore/offshore biomass comparisons.

The assessment of current status is based on several analyses including trends in catch/survey biomass exploitation ratios; a yield and biomass per recruit analysis; an age-structured dynamics model which incorporates information on the age composition of the landings, size and age composition of the population, and trends in relative abundance derived from commercial CPUE and research vessel survey biomass indices; and an age-aggregated biomass dynamics model. Surplus production estimates were derived from the age-structured production model, and information on current status of biomass and fishing mortality relative to MSY-based reference points is also provided by the biomass dynamics model.

The fishery on this stock developed during the 1930s. Landings rose rapidly from less than 100 mt in the early 1930s to over 20,000 mt in 1939, peaking at 56,000 mt in 1942, then declined throughout the 1940s and 1950s. Redfish have been harvested primarily by domestic vessels, although distant water fleets took considerable quantities for a brief period during the early 1970s. The distant water fleet effort, combined with increased domestic fishing effort, resulted in a brief increase in total catch to about 20,000 mt during the early 1970s. Landings declined throughout the 1980s and have averaged less than 500 mt per year during the 1990s.

Exploitation ratios (catch/survey biomass) suggest that fishing mortality has been very low since the mid-1980s compared to previous periods. Estimates of fishing mortality derived from the age-structured dynamics model and the age-aggregated biomass model are similar, both indicating that current fishing mortality is low relative to past decades and with respect to Fmsy (<5%). Stock biomass has increased since the mid-1990s, and is presently estimated to be about 33% of Bmsy due, in large part, to recruitment of one or more strong year classes from the early 1990s.

INTRODUCTION

Redfish, *Sebastes fasciatus* Storer, have supported a substantial domestic fishery in the Gulf of Maine and the Georges Bank (Great South Channel) regions off the northeast coast of the U.S. (Northwest Atlantic Fisheries Organization [NAFO] Subarea 5) since the late 1930s when the development of freezing techniques enabled a widespread distribution of the frozen product throughout the country. Landings by domestic vessels rose rapidly, peaking at 56,000 mt in 1942 in Subarea 5, then declined throughout the 1940s and 1950s (Table 1, Figure 1). As landings declined in local waters, U.S. fishing effort began to expand to the Scotian Shelf and the Gulf of St. Lawrence (NAFO Subarea 4), and finally to the Grand Bank of Newfoundland (NAFO Subarea 3). This expansion continued throughout the 1940s and early 1950s, culminating with a peak U.S catch of 130,000 mt in 1952 (Figure 1). By the mid-1950s, redfish stocks throughout the Northwest Atlantic were heavily exploited by U.S and Canadian fleets (Atkinson 1987), and total landings began to decline in all Subareas.

During the 1960s and early to mid-1970s, catches by distant water fleets were substantial, at times accounting for 25-30% of the total Subarea 5 redfish catch (Table 1). With the declaration of exclusive economic zones by the U.S. and Canada in 1977, U.S. vessels were prohibited from fishing in all but a small portion of Subarea 4 off Southwest Nova Scotia. Landings from the Gulf of Maine subsequently increased temporarily during the late 1970s, but have been declining throughout the 1980s, and have remained below 1,000 mt per year throughout the 1990s. Recent landings from this stock are at their lowest level since the directed fishery commenced in 1934.

The status of this stock has been assessed since the 1970s with a variety of techniques including production models (Schaefer 1954, 1957; Pella and Tomlinson 1969; Fox 1975), yield per recruit (Thompson and Bell 1934; Beverton and Holt 1957) and virtual population analysis (VPA). A preliminary production model estimate suggested a long-term potential yield of 20,000 mt from this stock (Mayo 1975) but this was revised to 14,000 mt when non-equilibrium conditions were taken into account (Doubleday 1976, Walter 1976), irrespective of the growth model (exponential or logistic) employed (Mayo 1980). A yield per recruit analysis performed with M=0.05 and partial recruitment of 50% at age 6 and full recruitment at age 9, indicated Fmax at 0.13 and $F_{0.1}$ at 0.06 (Mayo 1993, NEFSC 2001). Virtual population analysis, which was first performed on this stock using catch at age data from 1969-1980, indicated that age 9+ fishing mortality rates, in the range of 0.18 to 0.28 throughout most of the 1970s, were accompanied by a 62% decline in exploitable biomass (age 5+) between 1969 and 1980 (Mayo *et al.* 1983). A subsequent analysis which included additional catch at age data through 1983 indicated that, although F had begun to decline from a maximum value of 0.28 in 1979 to 0.17 in 1983, exploitable biomass had been reduced by 75% from the 1969 level by 1984 (NEFC 1986). The VPA was discontinued after 1986, but further declines in redfish landings since then suggest that F is now likely to be rather low (at or below M), rendering the convergence of VPAs somewhat unlikely.

Previous stock assessments were reviewed at the 2nd and 15th Northeast Regional Stock Assessment Workshops (NEFC 1986, NEFSC 1993) and by the Northern/Southern Demersal Working Group (NEFSC 2001). The potential for this stock to return to conditions observed in the 1960s is limited, in part, by the combination of slow growth and low fecundity of redfish. Even at relatively low levels of F, ranging from 0.03 to 0.05, restoration of the 1969 age structure is not likely to occur except under extremely favorable recruitment conditions over several decades (Mayo 1987).

COMMERCIAL FISHERY

Commercial Catch and Effort

Landings of redfish from Subarea 5 from 1934 through 2000 are given in Table 1 and Figure 1. Landings by domestic vessels rose rapidly from less than 100 mt in the early 1930s to over 20,000 mt in 1939, peaking at 56,000 mt in 1942, then declined throughout the 1940s and 1950s. Redfish have been harvested primarily by domestic vessels, although distant water fleets took considerable quantities for a brief period during the early 1970s (Table 1). The distant water fleet effort, combined with increased domestic fishing effort, resulted in a brief increase in total catch to about 20,000 mt during the early 1970s. Landings declined throughout the 1980s and have averaged less than 500 mt per year during the 1990s. Landings in 2000 (319 mt) remain close to an historic low. Redfish have been harvested almost exclusively by otter trawlers fishing out of Maine and Massachusetts ports.

Commercial catch per unit effort (CPUE) indices for directed redfish trips, standardized by vessel tonnage class as described by Mayo *et al*. (1979), are listed in Table 1 and illustrated in Figure 2a. The resulting calculated fishing effort values were derived by dividing total annual landings by the directed CPUE index. Directed CPUE has declined steadily from over 10 tons per day fished during the late 1960s to less than 2 tons per day fished since 1984 (Table 1, Figure 2a). This 70-80% decline is consistent with the 60-70% decline in exploitable biomass estimated by previous VPAs (Mayo *et al*. 1983; NEFC 1986). Total fishing effort, after peaking during the late 1970s (coincident with the highest estimates of fishing mortality [NEFC 1986]), appeared to stabilize during the mid-1980s before declining precipitously through 1989.

A depiction of the available effort data is presented in Figure 2b. Historically, 80-90% of the total redfish catch and 20-40% of the total number of trips on which redfish were taken were accounted for in the directed CPUE calculation (50% redfish trips). These percentages declined sharply between 1979 and 1982, and are now at levels which preclude any definitive interpretation of the CPUE and effort trends.

Commercial Length Composition

The available commercial length and age sample data are summarized in Table 2. Commercial length sampling for redfish has generally been sufficient to allow quarterly pooling until the 1990s. Sampling during most years since 1994 has been insufficient to characterize the length composition of the landings. The apparent improvement in sampling intensity in recent years is an artifact of the rapid decline in landings. Even with very low landings, sampling must be maintained at relatively high levels in order to reflect the age structure of the population. Age samples have been routinely collected since the 1960s but production ageing ceased after 1985 (Table 2).

Estimates of numbers landed at length were derived from 1969 through 2000 when sample data permitted. In most years prior to 1991, sampling was sufficient to allow pooling of length data on a quarterly, and in a few cases, semi-annual basis. However, from 1991 to 2000, pooling of samples was required on a semi-annual, and in several cases, an annual basis. Due to the differences in growth between males and females, sampling for redfish is conducted separately by sex, and estimates of numbers landed are also derived separately for males and females. The overall length composition is then obtained by addition of the estimates by sex.

Changes in the length composition of the landings between 1969 and 2000 are illustrated in Figure 3. In 1978, the landings still reflected a fairly broad age structure in the population of both males and females with the 1971 year class accounting for the mode between 20 and 30 cm. With the decline in subsequent recruitment, modes shifted toward larger sizes until fish from the 1978 year class appeared in 1983 and 1984. As landings continued to decrease throughout the 1980s, modal lengths shifted further until few fish between 20 and 25 cm could be seen recruiting to the fishery.

Shifts in modal lengths are reflected in annual changes in mean length of the landings as illustrated in Figure 4. Increases in mean length occur during periods of poor recruitment (such as 1965-1976) while sharp decreases generally signify the appearance of a strong year class entering the fishery. The declines which began in 1976 and 1983 indicate recruitment of the 1971 and 1978 year classes entering the fishery at age 5. The subsequent overall increasing trend indicates a gradual ageing of the population as recruitment has declined over the past 30 years. Mean lengths of the landings have become extremely variable in recent years as landings have become extremely low and sampling has deteriorated.

Commercial Age Composition

Estimates of numbers landed at age were also derived from the biological sampling data for the period 1969 through 1985. With the sharp decline in landings evident during the 1980s, ageing of commercial samples was discontinued after 1985. For the period 1969-1985, however, estimates of numbers landed at age were derived by applying quarterly age/length keys, separately by sex, to the estimated numbers landed at length by sex. The overall age composition was then obtained by addition of the estimates by sex.

Catch at age and mean weight at age matrices based on all available commercial length and age data from 1969 through 1985 are given in Table 3, and trends in the age composition of the landings are illustrated in Figure 5 . The sharp discontinuity in the age structure of the population created by poor recruitment since the 1960s can be inferred from the age composition of the landings. The most striking feature is the singular presence of the 1971 year class advancing through the fishery since 1976, followed by the entrance of the 1978 year class during 1983-1985. By the early 1980s, the fishery had become dependent on a few relatively strong year classes and recruitment appeared to have collapsed.

RESEARCH VESSEL SURVEYS

Bottom trawl surveys have been conducted by the Northeast Fisheries Science Center in the Gulf of Maine - Georges Bank region since autumn 1963 and spring 1968 (Azarovitz 1981). The NEFSC spring and autumn bottom trawl survey data were analyzed to evaluate trends in total abundance and biomass of redfish, diurnal effects on catchability, differences in density between inshore and offshore regions of the Gulf of Maine, trends in the size and age composition of the population, total mortality, relationships between length and weight, and changes in maturation at length.

Trends in Total Abundance and Biomass

Abundance (stratified mean number per tow) and biomass (stratified mean weight per tow) indices have been calculated from NEFSC spring and autumn surveys based on strata encompassing the Gulf of Maine and portions of the Great South Channel (strata 24, 26-30, 36-40; Tables 4 and 5; Figures 6a and 6b). Trends in total abundance and biomass are similar in both spring and autumn surveys. Relative abundance of redfish has declined sharply in both survey series, from peak levels over of 100 fish per tow in the late 1960s and early 1970s to generally less than 10 fish per tow during the mid-1980s through mid-1990s. The decline in biomass has been of the same order (Figures 6a and 6b). Both series suggest a slight increase in abundance and biomass between the mid-1980s and 1990s followed by a sharp increase in autumn 1996 and spring 1997.

Day/Night Comparisons

Redfish have been observed to exhibit consistent diurnal patterns in their vertical distribution. Although Kelly and Barker (1961) concluded that there is little evidence of diurnal movement of planktonic larvae, they also noted a significant decrease in catches of larval redfish by an Issacs-Kidd midwater trawl during daylight. This was attributed to possible gear avoidance by larval redfish. Adult redfish, however, are thought to exhibit very pronounced diurnal movement patterns. Templeman (1959) noted that, off Newfoundland, redfish catches from sets made more than one hour before sunrise or after sunset were negligible compared to those from daytime sets. Catches were also related to the season, with good catches extending over a longer part of the day in the brightest months with the longest period of daylight. This pattern was well known in the commercial redfish fishery as vessels would often lay to during the night.

In an earlier paper on redfish biology, Steele (1957) noted the same overall diurnal pattern in redfish catches. In this study, Steele provided evidence of a 2-3 fold difference in average catch rates over a 24-hour period. This pattern was correlated , in part, with the vertical movement of the euphausiid, *Meganyctiphanes norvegica*, a major prey item of redfish in the North Atlantic. Steele (1957) also observed seasonal departures from the general pattern, and speculated that these differences may be related to the sexual maturation cycle of males and females. The diurnal response of males and females differed among seasons.

The presence of a diurnal pattern in redfish activity in the Gulf of Maine was examined over the period 1992-2000. NEFSC spring and autumn survey catch data were partitioned into six 4-hour time blocks as follows: 0001-0400 hr (night2), 0401-0800 hr (dawn), 0801-1200 hr (day1), 1201-1600 hr (day2), 1601-2000 hr (dusk), and 2001-2400 hr (night1). Catch data for valid survey tows within the total Gulf of Maine strata set as above were selected from the spring, summer, and autumn surveys. Summer surveys were conducted only in 1992, 1993 and 1994 and the number of tows in the Gulf of Maine which contained redfish (n=85) was relatively small.

The catch data were analyzed for seasonal and diurnal effects by ANOVA using PROC GLM (SAS, 1990). Initial analyses indicated that seasonal effects were not significant; however, based on the observations of Steele (1957) regarding different seasonal responses by males and females, further analyses were conducted separately for spring and autumn data, with summer excluded. In the analyses of diurnal effects, the last time block (2001-2400 hr) was elected to represent unity and each of the 5 remaining blocks were related to the last block. The factors for each time block were re-transformed from log scale to linear scale.

In the overall analysis, catch rates from periods 2 (0401-0800 hr), 3 (0801-1200 hr) and 4 (1201-1600 hr) were significantly different ($p < 0.05$) from period 6 (2001-2400 hr). These represent dawn and the 2 daytime periods. Catch rates from the remaining periods (1 and 5), representing dusk (1601-2000 hr) and night (2001-2400 hr) were not significantly different from period 6. Analyses of the spring and autumn data revealed possible seasonal differences (Figure 7). During spring, catch rates from time periods 2, 3, and 4 were significantly different ($p < 0.05$) from those of period 6, but during autumn, none of the time periods exhibited statistically significant differences in catch rates, although the general pattern was similar to spring. These differences between spring and autumn were not due to any pronounced bias in survey station coverage by time period as the number of stations in both spring and autumn were almost evenly distributed (Figures 8a and 8b).

In fact, the seasonal differences obtained for the Gulf of Maine are consistent with the observations of Steele (1957) and Templeman (1959). When the timing of the NEFSC survey in the Gulf of Maine is taken into account (spring survey in late April, autumn survey in late October), it can be seen that this portion of the spring survey occurs during a period of considerably longer daylight relative to autumn. There is a 2-month absolute difference in the timing of the spring and autumn surveys with respect to the corresponding vernal and autumnal equinoxes. These results are consistent with Templeman's (1959) observation that good catches occur over a longer part of the day in the brightest months. The results also seem to corroborate Steele's (1957) observation that seasonal differences may be related to the reproductive cycle where females may be more pelagic during the larval extrusion stage in spring whereas both sexes may occupy bottom during a greater period of time during the copulation stage in autumn.

Despite the large diurnal differences in catch rates derived from these analyses, abundance and biomass indices are not likely to exhibit any substantial bias given the even distribution of occupied stations over time. It is likely, however, that annual departures from an even distribution among the six time periods may impart a degree of inter-annual variability which may partially explain some of the large year effects exhibited in these data. However, if the redfish survey indices were to form the basis of an estimate of absolute biomass, the diurnal differences noted herein must be taken into account before any estimation is made.

Inshore/Offshore Comparisons

Indices were also computed for inshore (strata 26, 27, 39, and 40; area: 3,042 square miles) and offshore (strata 24, 28-30, 36-38; area: 17,419 square miles) subsets of the data (Figures 9a and 9b). When two or more strata sets of unequal area are compared in this manner, the stratified mean catch per tow indices must be considered to represent the density of fish (index of number or biomass per unit area) rather than actual abundance or biomass (index of population size). The inshore Gulf of Maine area from Massachusetts Bay to the eastern coast of Maine has generally contained higher densities of redfish compared to the offshore regions, particularly in terms of numbers (Figure 9a). These fish are generally smaller than those in the offshore regions, and the index from the inshore area may be used as a measure of recruitment (Mayo 1980). Trends in these indices have been consistent with trends in the overall combined indices (Figures 6a and 6b).

Trends in mean length and weight of redfish from inshore and offshore strata sets during autumn are illustrated in Figures 10a and 10b. As with commercial mean lengths, sharp declines indicate the appearance of a relatively strong year class. This is most evident in the autumn series of inshore data which has provided the most consistent indicator of recruitment patterns over time. The sharp declines which occur immediately after 1971, 1978, and 1984 reflect the initial appearance and subsequent increased influence of these year classes in the inshore bottom trawl survey indices. The 1991 year class is reflected in the offshore mean length and weight patterns.

To compare trends in actual abundance and biomass between regions, the indices must be weighted by the area of each strata set. This approach provides indices of population size within each strata set which can be directly compared on the same basis. When viewed in this manner, it is clear that the greatest fraction of the redfish population has historically been found in the offshore region of the Gulf of Maine (Figures 11a and 11b).

Size Composition

Length composition data from spring, autumn and shrimp surveys (Figures 12 and 12a) simultaneously illustrate the changes in relative abundance and size structure of the population which resulted from the decline in recruitment over time. The redfish population was composed of a relatively broad range of sizes in the 1960s resulting from consistent recruitment of year classes from the 1950s and 1960s. By the mid-1970s, however, abundance of large fish had declined substantially and only the 1971 year class remained a dominant feature in the demographics of the population. The consistency of the survey indices had begun to erode by the beginning of the 1980s and, throughout this decade, only sporadic indications of the 1978 and subsequent year classes were evident.

During the 1990s, however, substantial numbers of redfish, generally between 20 and 25 cm, began to appear, first in spring 1992, then in autumn 1995 and 1996. These data likely reflect the strength of one or more year classes from the mid-1980s and early 1990s. In autumn 1999, a mode at 5 cm could indicate a potentially strong 1999 year class. By 1997, large numbers of redfish up to 30 cm and larger were appearing consistently. However, the size structure of the population remains truncated compared to the 1960s and early 1970s. The same pattern appears in the shrimp survey.

Age Composition

Age composition estimates are available from NEFSC autumn surveys from 1975 through 2000 and from NEFSC spring surveys from 1975 through 1990 with some exceptions. The survey otolith collection is routinely aged to the maximum possible age. For this analysis and the subsequent analysis of mortality rates, all ages greater than 50 years were binned at 50+. As the autumn survey has provided the most consistent set of abundance and biomass indices, priority was given to ageing of the autumn survey otolith collection. Annual trends are illustrated in Figure 13. The age composition data clearly illustrate recruitment patterns and changes in age structure of the population that are suggested by the length composition data. In 1975 the population still appeared to exhibit a relatively broad age structure. The 1971 year class is prominently featured in 1975 followed by the 1978 year class in the early 1980s; these two year classes continued to dominate the demographics of the population through the 1980s.

More recently, the 1985 and 1991 year classes appear most prominent. As indicated by the length composition estimates, the age structure of the population during the late 1990s remains truncated compared to the 1975 and earlier period.

Total Mortality Estimates

Estimates of instantaneous total mortality were computed from the age composition data derived from NEFSC autumn surveys from 1975-1996. Annual Z estimates, based on the annual survival rate from ages 6 and older to ages 7 and older, were highly variable, ranging between -1.6 to + 1.6. These estimates reflect the high degree of variability in year class strength evident in the survey abundance indices at age presented in Figure 13. Therefore, an alternate approach was attempted.

The 1975-1996 autumn survey age composition data contain information on cohorts spanning 1925 to as recently as 1995. To minimize the variability induced by variation in year class strength, separate catch curves were constructed for each cohort. Since the time span represented in the age composition data covers the years 1975-1996, cohorts from years prior to the mid-1970s become truncated at the younger ages whereas cohorts from years after 1975 become progressively truncated at the older ages. When combined in a single plot, the mortality on by various ages spanning the period 1925-1995 is visually represented (Figure 14). This provides a general indication of the average mortality sustained by the population over this 70 year period. It is evident that, in most cases, redfish are incompletely recruited until ages 5 or 6. However, mortality rates appear to be relatively consistent for most cohorts after age 6. No attempt was made at this stage to derive mortality estimates for individual cohorts.

Length-Weight Analyses

The relationship between length (cm) and weight (kg) of redfish was examined by season and sex using linear regression (PROC REG, SAS 1990) of the form:

$$\text{Ln Weight} = a + b^{*} \text{ Ln Length.}$$

The analysis is based on 8,567 individual length and weight measurements collected during NEFSC spring and autumn surveys since 1992. There are no significant differences (p=0.800) in the length-weight relationship between spring and autumn. However, differences between males and females are highly significant ($P< 0.01$) (Figure 15), with females considerably heavier at a given length.

Maturation Analyses

Redfish are relatively long-lived, slow growing fish with an extremely low natural mortality rate compared to most highly exploited species. Growth studies have indicated maximum ages ranging from 50-60 years at lengths of 45-50 cm (Mayo *et al*. 1990). Perlmutter and Clark (1949) provided early evidence that immature redfish in the Gulf of Maine exhibited extremely slow growth and that maturation was delayed until about age 9. Kelly and Wolf (1959) further demonstrated the extremely slow growth of adult redfish up to age 20. More recently, Mayo *et al*. (1981) provided further validation of the slow growth rates for redfish up to age 7 based on length mode progression and otolith edge formation. Consequently, an instantaneous natural mortality rate of 0.05 has been employed in age-structured models, consistent with the longevity of this species. Moreover, growth and maturation appear to be linked. The most recent estimates of redfish maturation suggest a median age of about 5.5 years (Mayo *et al*. 1990; O'Brien *et al*. 1993) compared to the 9-10 years indicated by Perlmutter and Clark (1949).

In this analysis, the relationship between maturation (Pm) and length is examined within 3 time periods using logistic regression (PROC LOGISTIC, SAS 1990) of the form:

$$Pm = e^{(a + b^{*}Len)} / (1 + e^{(a + b^{*}Len)}).$$

The analysis is based on 3,728 individual maturity stage observations from 1975 through 2000 within the following periods: 1975-1981, 1982-1991, and 1992-2000. There are 6 maturation stages for male redfish and 7 stages (including eyed larvae) for females. The development and present basis for the NEFSC maturity stages are described by Burnett *et al*. (1989).

In general, redfish maturation at length remained relatively constant over the 25 year period analyzed. A slight trend towards decreasing size at maturity is evident in both the spring and autumn results (Figure 16). Estimates of median length at maturation (L50) for females varied between 20.3 cm and 22.6 cm. The slightly higher values occurred in the earliest period. Estimates of L50 for males ranged from 20.2 to 21.3 cm and the higher values also correspond to the 1975-1981 period (Figure 17).

ASSESSMENT OF CURRENT STATUS

Yield and SSB per Recruit

Yield and spawning stock biomass (SSB) per recruit were calculated according to the methods described by Thompson and Bell (1934) and Gabriel *et al*. (1989). Natural mortality was assumed to be 0.05. Mean weights at age for the yield per recruit calculations were taken as the 1969-1984 mean of the commercial mean weights at age (Table 3). Partial recruitment was based on the fishery selectivity pattern derived from the age-structured model presented below. This pattern was similar to that employed in the previously published VPA (Mayo 1993) which was taken from the most recently published VPA (NEFC 1986) which reflects the recruitment of the 1971 year class. Growth and maturation data for SSB/R analysis were taken from the female data presented by Mayo *et al*. (1990).

Estimates of $F_{0.1}$ (0.06) and F_{max} (0.13) (Table 6, Figure 18) are identical to those derived by Mayo (1993); these estimates were similar to those reported by Mayo (1980) using the Beverton-Holt approach with the same value of M (0.05) for 89mm mesh (males) and 102 mm mesh (females). F at 30% of Maximum Spawning Potential was estimated as 0.07, slightly above the estimate of $F_{0.1}$.

Index of Exploitation

An index of exploitation (Table 7; Figure 19) was derived for the period 1963-2000, expressed as the ratio of the autumn NEFSC biomass index (Table 5) to total fishery removals (Table 1). The index fluctuated considerably during the 1960s and 1970s, generally increased until 1982, then declined sharply during the 1980s. Since 1990, the index of exploitation has remained at an extremely low level as landings remained low despite the recent increase in the survey biomass index. However, in contrast to the 1960s and 1970s, where a substantial portion of the stock persisted in the 30-40 cm range (Figure 12), during the 1990s, almost all of the redfish were less than 25 cm, and almost none were larger than 30 cm. This suggests that, given the present demographics of the stock, only a small fraction of the biomass would be considered exploitable. Thus, the exploitation ratio based on the total biomass index, tends to under-estimate current exploitation relative to the earlier period in the series.

Age-structured Dynamics Model

In this section, an age-structured assessment model is developed for redfish. Age-structured population dynamics of redfish are modeled in a standard manner using forward-projection methods for statistical catch-at-age analyses (Fournier and Archibald 1982, Methot 1990, Ianelli and Fournier 1998, Restrepo and Legault 1998). The population dynamics model, statistical estimation approach, model diagnostics, and model results are described in sequence below.

Population dynamics model

The age-structured model is based on forward projection of population numbers at age. This modeling approach is based on the principle that population numbers through time are determined by recruitment and total mortality at age through time. The population numbers at age matrix $N=(N_{y,a})_{YxA}$ has dimensions Y by A, where Y is the number of years in the assessment time horizon and A is the number of age classes modeled. The oldest age (A) comprises a plus-group consisting of all fish age-A and older. The time horizon for redfish is 1934-2000 (Y=67). The number of age classes is 26, representing ages 1 through 26+.

Recruitment (numbers of age-1 fish) in year y (R_y) is modeled as a lognormal deviation from average recruitment (μ_R), where V_y are iid normal random variables with zero mean and constant variance.

$$R_y = \mu_R e^{V_y}$$

For all years y from 1935-2000, $R_y = N_{y1}$ is estimated from the recruitment deviation and average recruitment.

Initial population abundance at age in 1934 is based on recruitment deviations from average recruitment for 1909-1934 and natural mortality. For all ages a < A, the numbers at age in the first year (ystart=1) are estimated as lognormal deviations from average recruitment as reduced by natural mortality

$$N_{1,a} = \mu_R e^{V_{ystart-a+1}} e^{-(a-1)M}$$

For the plus group, the initial numbers at age is the sum of numbers at ages 26 and older based on an equilibrium recruitment deviation for ages 26 and older and natural mortality.

$$N_{1,A} = \frac{\mu_R e^{V_{ystart-A+1}} e^{-(A-1)M}}{1-e^{-M}}$$

The total instantaneous mortality at age matrix $Z=(Z_{y,a})_{YxA}$ and the instantaneous fishing mortality at age matrix $F=(F_{y,a})_{YxA}$ both have dimensions Y by A. Instantaneous natural mortality at age is assumed to be constant (M) and for all years, y and ages, a

$$Z_{y,a} = F_{y,a} + M$$

Population numbers at age through time are computed from the initial population numbers at age, recruitment through time, and total mortality at age through time. For all ages, a that are younger than the plus group (a < A), the number at age are sequentially determined using

$$N_{y,a} = N_{y-1,a-1} e^{-Z_{y-1,a-1}}$$

For the plus group, numbers at age are the sum of survivors at age A-1 and plus group survivors

$$N_{y,A} = N_{y-1,A-1} e^{-Z_{y-1,A-1}} + N_{y-1,A} e^{-Z_{y-1,A}}$$

Fishing mortality at age a in year y is modeled as a separable process, where S_a is selectivity at age a and F_y is fully-recruited fishing mortality in year y

$$F_{y,a} = S_a F_y$$

Fully-recruited fishing mortality in each year is modeled as a lognormal deviation from average fishing mortality (μ_F),where U_y are iid normal random variables with zero mean and constant variance

$$F_y = \mu_F e^{U_y}$$

Fishery selectivity at age is modeled as being time-invariant throughout the assessment time horizon. This approach was chosen for parsimony. In particular, redfish catch-at-age data to estimate fishery selectivity are limited to 1969-1985, a period when the fishery practices are believed to have been relatively stable. Fishery selectivity at age is estimated for ages 1 through 9. For ages older than 9 years, fishery selectivity is assumed to be equal to the age-9 selectivity value. This approach was chosen to reflect the asymptotic selectivity pattern from previous VPA-based assessments of redfish, wherein age 9 was the age of full selectivity. Two constraints are applied to the estimated selectivity at age coefficients. First, the selectivities are constrained to average 1 for estimated ages. This forces the scale of each coefficient to be near unity. Second, a constraint is applied to ensure that estimated selectivities change smoothly between adjacent ages. Details of the implementation of both constraints are described in the section on statistical estimation approach. Last, for each year the selectivity at age values are scaled so that the maximum selectivity at age value is unity. This ensures that estimated fully-recruited fishing mortality rates are directly comparable to biological reference points such as $F_{0.1}$.

The fishery catch numbers at age matrix $C=(C_{y,a})_{YxA}$ and the fishery catch biomass at age (yield) matrix $Y=(Y_{y,a})_{YxA}$ both have dimensions Y by A. Fishery catch at age in each year is computed from Baranov's catch equation using population numbers, fishing mortality, and total mortality at age

$$C_{y,a} = \frac{N_{y,a} F_{y,a} \left(1 - e^{-Z_{y,a}}\right)}{Z_{y,a}}$$

Catch biomass at age in each year is the product of catch numbers at age and mean weight at age, where W_a is the mean weight at age computed as the average of mean redfish weights at age from fishery sampling during 1969-1985

$$Y_{y,a} = C_{y,a} W_a$$

Total fishery catch biomass in year y (Y_y) is the sum of yields by age class

$$Y_y = \sum_{a=1}^{A} Y_{y,a}$$

The total fishery catch biomass time series is compared to observed values using a lognormal probability model.

The proportion of fishery catch at age a in year y ($P_{y,a}$) is computed from estimated catch numbers

$$P_{y,a} = \frac{C_{y,a}}{\sum_a C_{y,a}}$$

The time series of fishery proportions at age are fitted to observed fishery values using a multinomial probability model.

Fishery catch-per-unit effort in year y ($CPUE_y$) is modeled as a catchability coefficient (Q_{CPUE}) times exploitable biomass raised to a power (β_{CPUE}), where exploitable biomass is computed at the midpoint of the year

$$CPUE_y = Q_{CPUE} \left(\sum_a S_a W_a N_{y,a} e^{-Z_{y,a}} \right)^{\beta_{CPUE}}$$

This model for CPUE coincides with the proportionality model when $\beta_{CPUE} = 1$. The estimated CPUE time series is fitted to observed values using a lognormal probability model.

The survey biomass index in year y (I_y) for either the NEFSC autumn or spring survey is modeled as a catchability coefficient (Q_{SURVEY}) times the population biomass that is vulnerable to the survey, where $S_{SURVEY,a}$ is survey selectivity at age a and p_{SURVEY} is the fraction of annual total mortality that occurs prior to the survey

$$I_y = Q_{SURVEY} \sum_a S_{SURVEY,a} W_a N_{y,a} e^{-p_{SURVEY} Z_{y,a}}$$

The survey biomass index time series are fitted to observed values using a lognormal probability model.

Survey selectivity at age is modeled using Thompson's exponential-logistic model (Thompson 1994), where α, β, and γ are parameters and survey selectivity for redfish is assumed to be time invariant.

$$S_{SURVEY,a} = \frac{1}{1-\gamma}\left(\frac{1-\gamma}{\gamma}\right)^{\gamma}\left(\frac{e^{\alpha\gamma(\beta-a)}}{1+e^{\alpha(\beta-a)}}\right)$$

This model has the useful property that the maximum selectivity value is unity. For values of $\gamma>0$ survey selectivity is dome-shaped, while survey selectivity is flat-topped when $\gamma=0$.

Survey catch proportion at age a in year y ($P_{SURVEY,\, y,\, a}$) is computed from survey selectivity, the fraction of mortality occurring prior to the survey, and population numbers at age

$$P_{SURVEY,y,a} = \frac{S_{SURVEY,a} N_{y,a} e^{-p_{SURVEY} Z_{y,a}}}{\sum_a S_{SURVEY,a} N_{y,a} e^{-p_{SURVEY} Z_{y,a}}}$$

The time series of survey proportions at age are fitted to observed fishery values using a multinomial probability model.

Statistical estimation approach

The population dynamics model is fit to observed data using an iterative maximum likelihood estimation approach. The statistical model consists of nine likelihood components (L_j) and two penalty terms (P_k). The model objective function (Λ) is the weighted sum of the likelihood components and penalties where each summand is multiplied by an emphasis coefficient (λ_j) that reflects the relative importance of the data.

$$\Lambda = \sum_j \lambda_j L_j + \sum_k \lambda_k P_k$$

Each likelihood component is written as a negative log-likelihood so that the maximum likelihood estimates of model parameters are obtained by minimizing the objective function. The Automatic Differentiation Model Builder software is used to estimate a total of 179 model parameters. The likelihood components and penalty terms are described below.

1. Recruitment

Recruitment strength is modeled by lognormal deviations from average recruitment for the period 1909-2000. A total of 92 recruitment deviation parameters (V_y) and one average recruitment parameter (μ_R) are estimated based on the objective function minimization. The recruitment likelihood component (L_1) is

$$L_1 = \sum_y V_y^2$$

where

$$V_y = \ln(R_y) - \ln(\mu_R)$$

2. Fishery CPUE

Fishery CPUE is modeled by lognormal deviations of predicted values from observed values, denoted with a superscript "OBS" for all variables, during 1942-1989, where W_y are iid normal random variables with zero mean and constant variance

$$CPUE_y^{OBS} = CPUE_y e^{W_y}$$

A total of 2 parameters (Q_{CPUE} and β_{CPUE}) are estimated based on the objective function minimization. The fishery CPUE likelihood component (L_2) is

$$L_2 = \sum_y W_y^2$$

3. Fishery age composition

Fishery age composition is modeled as a multinomial distribution for sampling catch numbers at age. The constant $N_{E,FISHERY,y}$ denotes the effective sample size for the multinomial distribution for year y and is assumed to be constant across time for the years 1969-1985 when redfish catch-at-age data are available. The observed number of fish at age in the fishery samples is computed as the effective sample size times the observed proportion at age. The effective sample size was assumed to be 200 fish in each year during 1969-1985. The negative log-likelihood of the multinomial sampling model for the fishery ages (L_3) is

$$L_3 = -\sum_y N_{E,FISHERY,y} \sum_a \left(P_{y,a}^{OBS} \ln P_{y,a} - P_{y,a}^{OBS} \ln P_{y,a}^{OBS} \right)$$

The second term in summation over a is a constant that scales L_3 to be zero if observed and predicted proportions were identical. Nine fishery selectivity coefficients (S_1 through S_9) are estimated based on the objective function minimization.

4. Autumn survey age composition

Autumn survey age composition is also modeled as a multinomial distribution for sampling survey catch numbers at age. The constant $N_{E,AUTUMN,y}$ denotes the effective sample size for the multinomial distribution for year y and is assumed to be constant across time for the years 1975-2000 when redfish autumn survey catch-at-age data are available. The observed number of fish at age in the survey samples is computed as the effective sample size times the observed proportion at age. The effective sample size was assumed to be 100 fish in each year during each year. The negative log-likelihood of the multinomial sampling model for the autumn survey ages (L_4) is

$$L_4 = -\sum_y N_{E,AUTUMN,y} \sum_a \left(P^{OBS}_{AUTUMN,y,a} \ln P_{AUTUMN,y,a} - P^{OBS}_{AUTUMN,y,a} \ln P^{OBS}_{AUTUMN,y,a} \right)$$

As with the fishery age composition, the second term in the summation over a is a constant that scales L_4 to be zero if observed and predicted proportions were identical. Three autumn survey selectivity coefficients (α_{AUTUMN}, β_{AUTUMN}, γ_{AUTUMN}) are estimated based on the objective function minimization.

5.Autumn survey biomass index

The autumn survey biomass index is modeled by lognormal deviations of predicted values from observed values during 1963-2000, where $D_{AUTUMN,\,y}$ are i.i.d. normal random variables with zero mean and constant variance

$$I^{OBS}_{AUTUMN,y} = I_{AUTUMN,y} e^{D_{AUTUMN,y}}$$

The autumn survey biomass likelihood component (L_5) is

$$L_5 = \sum_y D^2_{AUTUMN,y}$$

One autumn survey catchability (Q_{AUTUMN}) coefficient is estimated based on the objective function minimization.

6. Spring survey age composition

Spring survey age composition is also modeled as a multinomial distribution for sampling survey catch numbers at age. The constant $N_{E,SPRING\,y}$ denotes the effective sample size for the multinomial distribution for year y and is assumed to be constant across time for the years 1975-1980 and 1984-1990 when redfish spring survey catch-at-age data are available. The observed number of fish at age in the survey samples is computed as the effective sample size times the observed proportion at age. The effective sample size was assumed to be 100 fish in each year during each year.The negative log-likelihood of the multinomial sampling model for the autumn survey ages (L_6) is

$$L_6 = -\sum_y N_{E,SPRING,y} \sum_a \left(P^{OBS}_{SPRING,y,a} \ln P_{SPRING,y,a} - P^{OBS}_{SPRING,y,a} \ln P^{OBS}_{SPRING,y,a} \right)$$

Three spring survey selectivity coefficients (α_{SPRING}, β_{SPRING}, γ_{SPRING}) are estimated based on the objective function minimization.

7. Spring survey biomass index

The spring survey biomass index is also modeled by lognormal deviations of predicted values from observed values during 1968-2000, where $D_{SPRING,\,y}$ are i.i.d. normal random variables with zero mean and constant variance

$$I^{OBS}_{SPRING,y} = I_{SPRING,y}\, e^{D_{SPRING,y}}$$

The spring survey biomass likelihood component (L_7) is

$$L_7 = \sum_y D^2_{SPRING,y}$$

One spring survey catchability (Q_{SPRING}) coefficient is estimated based on the objective function minimization.

8. Catch biomass

Catch biomass is modeled by lognormal deviations of predicted values from observed values during 1934-1999, where T_y are iid normal random variables with zero mean and constant variance

$$Y^{OBS}_y = Y_y e^{T_y}$$

The catch biomass likelihood component (L_8) is

$$L_8 = \sum_y T^2_y$$

9. Fishing mortality

Fishing mortality on fully-selected ages is modeled by lognormal deviations from average fishing mortality for the period 1934-1999. A total of 66 recruitment deviation parameters (U_y) and one average fishing mortality parameter (μ_F) are estimated based on the objective function minimization. The fishing mortality likelihood component (L_9) is

$$L_9 = \sum_y U^2_y$$

where

$$U_y = \ln(F_y) - \ln(\mu_F)$$

10. Fishery selectivity

Two constraints on fishery selectivity are included in a penalty function. The fishery selectivity penalty function (P_1) is

$$P_1 = \left(\tfrac{1}{9} \sum_{a=1}^{9} S_a - 1 \right)^2 + \sum_{a=1}^{7} \left(S_a - 2S_{a+1} + S_{a+2} \right)^2$$

The first term constrains the fishery selectivity coefficients to scale to an average of 1. The second term constrains the fishery selectivity coefficient of age a+1 to be near to the linear prediction of this value interpolated from age a and age a+2 selectivities over the range of estimated selectivity coefficients.

11. Fishing mortality penalty

One constraint on fishing mortality is imposed to ensure that during the early phases of the iterative estimation process that the observed catch is not generated by an extremely small F on an extremely large population size. The fishing mortality penalty function (P_2) is

$$P_2 = 10 \sum_y \left(F_y - 0.1 \right)^2 \Leftrightarrow \; phase < 3$$

$$P_2 = \tfrac{1}{1000} \sum_y \left(F_y - 0.1 \right)^2 \Leftrightarrow \; phase \geq 3$$

The constraint is weighted with a value of 10 for the initial estimation phases and is weighted with a value of 0.001 for the latter and final estimation phases. The value of 0.1 was used because this is near the maximum computed in previous VPA-based analyses of the redfish stock. Sensitivity analyses that changed 0.1 to either 0.05 or 0.2 showed virtually no difference in parameter estimates.

Initial values are input for all parameters before the estimation phases are conducted. A total of seven estimation phases were used for the iterative minimization of the objective function. The first phase estimates average recruitment. The second phase estimates average fishing mortality and fishing mortality deviations. The third phase estimates recruitment deviations. The fourth phase estimates fishery and survey selectivity coefficients. The fifth and sixth phases are placeholders left open for additional parameters, if needed, while the seventh phase estimates the fishery CPUE catchability and beta parameters.

The eleven emphasis values used for the baseline analysis were: 10 (recruitment), 10 (fishery CPUE), 1 (fishery age composition), 1 (autumn survey age composition), 1000 (autumn survey biomass index), 1 (spring survey age composition), 1000 (spring survey biomass index), 1000 (catch biomass), 1 (fishing mortality), 100 (fishery selectivity penalty), 1 (fishing mortality penalty).

Model diagnostics

Model diagnostics were the discrepancies between observed data and predicted values for the catch biomass series (Figure 20), the autumn survey biomass series (Figure 21), the spring survey biomass series (Figure 22), the fishery CPUE series (Figure 23), fishery age composition series (Figure 24), autumn survey age composition series (Figure 25), and spring survey age composition series (Figure 26).

Model results

Key model results of spawning biomass, fishing mortality, recruitment, and population biomass for the period 1963-2000 are listed in Table 8 and a full listing of the code to fit the model, the model output, and the standard deviation of parameters and other assigned output variables are provided in Appendix 1.

Fishery and survey selectivity estimates at age are shown in Figure 27. Fishery selectivity was flat-topped with full selectivity at age 9. While it was assumed that selectivity for ages 10 and older was equal to age-9 selectivity, this did not mean that the age-9 fish had to be fully-selected. The autumn survey selectivity pattern was moderately dome-shaped with full selection at age 5. In contrast, spring survey selectivity was dome-shaped with full selection at age 9. The Northern Demersal Working Group (NDWG) noted that the spring survey selectivity pattern was robust but the autumn survey selectivity pattern was sensitive to the inclusion of recent autumn survey age composition data. In particular, autumn survey selectivity was flat-topped in an initial model run that included the 1996-1998 and 1981-1983 autumn survey age composition data but did not include the 1999-2000 data.

Recruitment estimates are shown in Figure 28 (see also Table 8). Strong year classes have been sporadic in recent years with the 1971 and 1992 year classes being very large. Recruitment was higher, on average, in the 1950s-1960s than in recent years. Overall, the model's ability to resolve which year class(es) in the early 1990s were strong was dependent on the recent autumn survey age composition data, in part due to the lack of commercial fishery age composition data since 1985. The NDWG noted that the earliest recruitment values in the time series (1934-1962) were not reliable as absolute measures of recruitment strength by year because these values were sensitive to assumptions about how to estimate the initial population size at age in 1934. This sensitivity was a natural consequence of having little information on annual recruitment variation at the beginning of the time series. In particular, the extremely large recruitment estimate in 1942 was sensitive to model assumptions about initial population size.

Population biomass estimates are shown in Figure 29 (see also Table 8). Population biomass declined from the 1950s to the late-1980s and has increased since then. The NDWG noted that the early portion of the population biomass time series (1934-1951) was less reliable because there was no relative abundance information during that time period, i.e., the model was only tuned to catch biomass in the 1930s-1940s. The NDWG also noted that population biomass estimates in the 1970s-1980s were very similar to those obtained with an untuned VPA conducted for SAW 2.
Spawning biomass estimates (at start of the spawning season) are shown in Figure 30 (see also Table

8). Spawning biomass declined from the 1950s to the late-1980s and has increased throughout the 1990s. The NDWG noted that the current population biomass estimate was sensitive to the size of the strong year class(es) of the early-1990s which could start to appear in fishery catches.

Fishing mortality estimates are shown in Figure 31 (see also Table 8). Annual estimates of fishing mortality early in the time series (1934-62) were not considered to be reliable because they were sensitive to assumptions about initial population size. Instead, the early estimates of F provide information on the average fishing mortality that was experienced by the redfish population as the fishery began. Fishing mortality increased from 0.05-0.1 in the early 1960s to over 0.20 in the late-1970s to early-1980s. Since then, fishing mortality has declined and is currently below 0.01 in 2000.

Stock-recruitment data are shown in Figure 32. Recruitment was below-average throughout 1963-2000, with the exception of a few strong year classes; for example, the 1971 and 1992 year classes.

Surplus production implied by the age-structured estimates of exploitable biomass and observed catches is shown in Figure 33. Surplus production was above 10 kt per year during the 1960s and then declined to very low levels in the 1980s because recruitment was very low. The recent increase in surplus production is due to strong recruitment in the early 1990s. The trajectory of surplus production shows the decline from 1963 to 1990 followed by a sharp increase in recent years.

Model sensitivity to the assumption that natural mortality is 0.05 is shown in Figure 34. The likelihood profile for natural mortality shows that there are values of M from 0.025 to 0.045 that produce a higher value of the total model likelihood than M=0.05. The biomass time series shows the consequence of higher or lower values of M on estimated population biomasses.

Model sensitivity to the assumption that each of the relative abundance indices (autumn and spring survey biomass indices and CPUE) provides useful information on population trend is shown in Figure 35. The delete one index sensitivity analysis shows that the model is robust to the exclusion of one index. The delete two indices sensitivity analysis shows that the model is robust to the use of only the autumn or the spring survey series. However, use of only the CPUE series would produce a substantially different population biomass trajectory.

Biomass Dynamics Model

MSY-based reference points

The current overfishing definition and targets for redfish are based on an MSY estimate from surplus production analysis (MSY=14,000 mt, Mayo 1980), supplemented with an F_{MSY} proxy from a dynamic pool model ($F_{20\%}$=0.12), to derive a proxy B_{MSY} (14,000/0.12=60,500 mt, Applegate *et al*. 1998). As calculated, the current B_{MSY} proxy is in units of exploitable biomass.

The age-structured model provides some information on the likely range of MSY based on average recruitment and yield-per-recruit values. If $F_{0.1}$=0.06 is assumed to be a suitable proxy for F_{MSY}, then the average recruitment of 27,954 thousand age-1 recruits would produce an MSY of roughly 4,562 mt. Based on the 95% confidence interval for the point estimate of average recruitment and a fixed yield-per-recruit value of 0.1632 at $F_{0.1}$=0.06, the 95% confidence interval for MSY would be (4,401 mt - 4,729 mt). In contrast, if one assumed that F_{MAX}=0.13 was a suitable proxy for F_{MSY}, the point estimate of MSY would be 5,048 mt with a 95% confidence interval of (4,870 mt - 5,234 mt). Thus, the age-structured model suggests that MSY may be on the order of 4,400-5,200 mt, a much lower value than that suggested by surplus production analyses. However, these estimates of recruitment depend considerably on the average recruitment applied to the yield per recruit estimates. Since the mid-1960s, recruitment has been extremely low in most years with the exception of a few very large year classes. Thus, an average value which captures the observed recruitment pattern is difficult to calculate for this stock. For similar reasons, these data provide little evidence of a stock-recruitment relationship. Therefore, an age-disaggregated approach, in which natural mortality, growth and recruitment are subsumed into a single parameter, the intrinsic rate of growth (r), may provide additional insight into the past trajectory of biomass and fishing mortality for this stock.

A biomass dynamics model (ASPIC, Prager 1994, 1995) was developed to revise the MSY estimate and replace proxies with direct estimates of MSY reference points that include all available information on trends in biomass and catch. The analysis includes the entire time series of catch since the beginning of the fishery (1934-2000), NEFSC spring and fall survey biomass indices (1968-2000 and 1963-2000, respectively), and the standardized CPUE series (1952-1990, Figure 36). The three biomass indices are moderately correlated (correlation ranged from 0.42-0.63: Appendix 2). Initial attempts to fit ASPIC had problems with convergence and sensitivity to starting values and random number seeds. In order to reduce the number of estimated parameters, biomass in 1934 was set equal to K and therefore removed from estimation (Appendix 2). Initial trials that estimated B1R indicated that biomass in 1934 was near K. The assumption that the stock was at virgin biomass in 1934 is justified, because there was no fishery prior to 1934 and incidental catch of redfish in other fisheries was negligible. Furthermore, life history characteristics of redfish such as long lifespan, slow growth, slow maturity, and internal fertilization suggest that the population is “K-selected” and will maintain a relatively stable stock size near its carrying capacity in the absence of fishing.

Model results

The model fit the biomass indices well (R^2=0.71 for CPUE, 0.59 for the fall survey, and 0.37 for the spring survey; Figures 37-39). Although the observed data represents a large dynamic range (Figure 40), biomass dynamics parameters (r: intrinsic rate of increase and K: carrying capacity) are largely influenced by a few observations. For example, r is largely influenced by the large rate of increase in recent years from strong recruitment, and K is largely determined by estimates from the early years in the time series, which are not calibrated with biomass indices (Figure 40).

The estimate of MSY is 20,000 mt (Figure 41) with an 80% confidence limit of 19,000-22,000 mt, which is similar to a previous estimate from production modeling (Mayo 1975). The estimate of F_{MSY} (0.09 on total biomass, with an 80% CI of 0.08-0.10) is consistent with life history and relatively low productivity of redfish. The estimate of B_{MSY} is 226,000 with an 80% CI of 211,000-244,000 mt. However, estimates of absolute biomass from ASPIC are commonly misleading, and ratios of biomass or F to MSY conditions are more reliable (Prager 1994). Comparisons of biomass estimates from ASPIC, the historical VPA (NEFSC 1986) and the present age-based dynamics model suggest that ASPIC underestimates redfish biomass (Figure 42). Therefore, only relative biomass and F estimates from ASPIC (Figures 43 and 44) should be considered to be reliable. The estimate of biomass in 2001 is 33% of B_{MSY} with an 80% CI of 27-40%, and the estimate of F on biomass in 2000 is estimated as 5% of Fmsy with an 80% CI of 4-7% (Table 9, "REDFISH3" in Table 10).

Sensitivity of ASPIC results to excluding the CPUE series and estimating biomass in 1934 was assessed with alternative analyses. Results from sensitivity analyses suggest that estimates are relatively robust to both decisions (Table 10). Estimates of MSY, F_{MSY}, and B_{MSY} and B_{2001}/B_{MSY} had less than 3% difference in estimates among alternative runs, but estimates of F_{2000}/F_{MSY} had slightly greater sensitivity (9% difference). However, alternative runs that estimated B1R had problems converging on a solution. No solution could be found when CPUE was included and B1R was estimated. Many bootstrap trials could not converge when B1R was estimated without including CPUE ("REDFISH2"), and results were sensitive to random number seeds. Including CPUE in the analysis appears to reduce variance of parameter estimates, and therefore "REDFISH3" was chosen as the best run.

An additional analysis was performed to assess sensitivity of model parameter estimates to the recently observed strong recruitment by truncating the analysis to 1934-1995 ("REDFISHT" in Table 10). Results indicate that the stock is less productive (i.e., a 34% decrease in Fmsy) when recent observations are excluded from the model. Therefore, when the entire time series is included in the model, there is an explicit assumption that the recently observed high recruitment is consistent with the long-term reproductive capacity of the stock.

The capacity of the redfish stock to rebuild to B_{MSY} was assessed using ten-year stochastic projections from "REDFISH3" assuming F=0 from 2001 to 2010. Results indicate that the stock can rebuild to B_{MSY} in 2010 in the absence of fishing (Figure 45). However, the projection implicitly assumes the higher productivity indicated by analysis of the entire time series (i.e., including the recently observed strong recruitment). As demonstrated in the sensitivity analyses, the estimate of intrinsic growth rate (r) is sensitive to recent recruitment observations.

CONCLUSIONS

The biomass of redfish in the Gulf of Maine-Georges Bank region has increased considerably during the past decade, due primarily to improved recruitment from several year classes of the early 1990s. Despite this, total stock biomass is still relatively low and the age structure remains truncated compared to earlier periods. Biomass in 2000 was approximately 1/3 of the estimated Bmsy. Catches from this stock have been minimal since the late 1980s and have averaged less than 500 mt per yr during the 1990s. As such, the current exploitation rate is extremely low.

Exploitation ratios (catch/NEFSC autumn survey biomass index) suggest that fishing mortality has been very low since the mid-1980s compared to previous periods. Fully recruited fishing mortality (ages 9+) in 2000 was less than 0.01, well below any Fmsy reference point. This is in contrast to the late 1970s and early 1980s when F ranged between 0.2 and 0.3. These high fishing mortality rates coincided with a 75% decline in exploitable biomass and a 90% decline in relative abundance and biomass indices derived from NEFSC bottom trawl surveys between the early 1970s and the late1980s. The existing proxy for Fmsy ($F_{20\%}$) is 0.12, a relatively high value considering the life history of the species. Other more appropriate proxies for Fmsy are $F_{0.1}$ (0.06) and $F_{50\%}$ (0.04) (Ralston *et al.* 1998; Dorn 2002).

ACKNOWLEDGMENTS

We are indebted to members of the Northern Demersal Working Group who provided a thorough, constructive review of the initial version of this assessment, and to several members of the Stock Assessment Review Committee review panel of the 33rd Stock Assessment Workshop who contributed additional analyses not provided in the initial assessment.

REFERENCES

Applegate, A., S. Cadrin, J. Hoenig, C. Moore, S. Murawski, and E. Pikitch. 1998. Evaluation of existing overfishing definitions and recommendations for new overfishing definitions to comply with the Sustainable Fisheries Act. New England Fishery Management Council Report.

Atkinson, D.B. 1987. The redfish resources off Canada's east coast. Proc. Int. Rockfish Symp., Oct. 1986, Anchorage, Alaska. Alaska Sea Grant Report No. 87-2, p. 15-34.

Azarovitz, T.R. 1981. A brief historical review of the Woods Hole Laboratory trawl survey time series. In: W.G. Doubleday and D. Rivard (ed.). 1981. Bottom Trawl Surveys. Can. Spec. Publ. Fish. Aquat. Sci. 58: 62-67.

Beverton, R.J.H. and S.J. Holt. 1957. On the Dynamics of Exploited Fish Populations. Fish. Invest. Lond.(2) 19: 533p.

Burnett, J., L. O'Brien, R.K. Mayo, J. Darde and M. Bohan. 1989. Finfish maturity sampling and classification schemes used during Northeast Fisheries Center bottom trawl surveys, 1963-1989. NOAA Tech. Mem NMFS-F/NEC-76, 14 p.

Dorn, M. W. 2002. Advice on west coast rockfish harvest rate from Bayesian meta-analysis of stock-recruit relationships. N. Am. J. Fish. Management. 21: 000-000.

Doubleday, W.G. 1976. Environmental fluctuations and fisheries management. Int. Comm. Northw. Atl. Fish. Sel Papers, No. 1: 141-150.

Fournier, D. A., and C. P. Archibald. 1982. A general theory for analyzing catch at age data. Can. J. Fish. Aquat. Sci. 39:1195-1207.

Fox, W.W. 1975. Fitting the generalized stock production model by least squares and equilibrium approximation. Fish Bull, U.S., 73(1): 23-27.

Ianelli, J. N., and D. A. Fournier. 1998. Alternative age-structured analyses of NRC simulated stock assessment data. NOAA Tech. Memo. NMFS-F/SPO-30. pp. 81-96.

Gabriel, W.L. , M.P. Sissenwine, and W.J. Overholtz. 1989. Spawning stock biomass per recruit analysis: an example for Georges Bank haddock. North Am. J. Fish. Management 9:383-391.

Kelly, G.F. and R.S. Wolf. 1959. Age and growth of the redfish, Sebastes marinus, in the Gulf of Maine. Fish. Bull., U.S., 60: 1-31.

Kelly, G.F. and A. Barker. Vertical distribution of young redfish in the Gulf of Maine. Int. Comm. Northw. Atl. Fish. Special Publ. No. 3: 220-233.

Mayo, R.K. 1976. Update of redfish status for 1975 in ICNAF Subarea 5. Int. Comm. Northw. Atl. Fish. Res. Doc. No. 76/VI/43, 9p.

Mayo, R.K. 1980. Exploitation of redfish, Sebastes marinus (L.), in the Gulf of Maine-Georges Bank region, with particular reference to the 1971 year class. J. Northw. Atl. Fish. Sci., Vol. 1: 21-37.

Mayo, R.K. 1987. Recent exploitation patterns and future stock rebuilding strategies for Acadian redfish, Sebastes fasciatus Storer, in the Gulf of Maine-Georges Bank region of the Northwest Atlantic. Proc. Int. Rockfish Symp., Oct. 1986, Anchorage, Alaska. Alaska Sea Grant Report No. 87-2, p. 335-353.

Mayo, R.K. 1993. Historic and recent trends in the population dynamics of redfish, Sebastes fasciatus Storer, in the Gulf of Maine-Georges Bank region. Northeast Fisheries Science Center, Reference Doc. No. 93-03, 24 p.

Mayo, R.K., E. Bevacqua, V.M. Gifford, and M.E. Griffin. 1979. An assessment of the Gulf of Maine redfish, Sebastes marinus (L.), stock in 1978. Nat. Mar. Fish. Serv., NEFC, Woods Hole Laboratory Ref. Doc. No. 79-20, 64p.

Mayo, R.K., V.M. Gifford, and A. Jearld Jr. 1981. Age validation of redfish, Sebastes marinus (L.), from the Gulf of Maine-Georges Bank region. J. Northw. Atl. Fish. Sci., Vol 2: 13-19.

Mayo, R.K., U.B. Dozier, and S.H. Clark. 1983. An assessment of the redfish, Sebastes fasciatus, stock in the Gulf of Maine-Georges Bank region. Nat. Mar. Fish. Serv., NEFC, Woods Hole Laboratory Ref. Doc. No. 83-22, 55 p.

Mayo, R.K., J. Burnett, T.D. Smith, and C.A. Muchant. 1990. Growth-maturation interactions of Acadian redfish (Sebastes fasciatus Storer) in the Gulf of Maine-Georges Bank region of the Northwest Atlantic. J. Cons. int. Explor. Mer, 46: 287-305.

Methot, R. D. 1990. Synthesis model: an adaptive framework for analysis of diverse stock assessment data. Int. North Pac. Fish. Comm. Bull. 50:259-277.

NEFC. 1986. Report of the Second NEFC Stock Assessment Workshop (Second SAW). National Marine Fisheries Service, NEFC, Woods Hole Laboratory Ref. Doc. No. 86-09, 114p.

NEFSC. 1993. Report of the Fifteenth Northeast Regional Stock Assessment Workshop (15th SAW). Stock Assessment Review Committee (SARC) Consensus Summary of Assessments. National Marine Fisheries Service, NEFSC Ref. Doc. No. 93-06, 108p.

NEFSC. 2001. Assessment of 19 Northeast Groundfish Stocks. Report of the Northern and Southern Demersal Working Groups, Northeast Regional Stock Assessment Workshop. National Marine Fisheries Service, NEFSC Ref. Doc. No. 01-20, 217p.

O'Brien, L, J. Burnett and R.K. Mayo. 1993. Maturation of 19 species of finfish off the northeast coast of the United States, 1985-1990. NOAA Tech Report NMFS 113, 66p.

Pella, J.J. and P.K. Tomlinson. 1969. A generalized stock production model. Bull. Inter.-Amer. trop. Tuna Comm., 13(3): 419-496.

Perlmutter, A. and G.M. Clarke. 1949. Age and growth of immature rosefish (Sebastes marinus) in the Gulf of Maine and off Nova Scotia. Fish. Bull., U.S., 51: 207-228.

Prager, M.H. 1994. A suite of extensions to a non-equilibrium surplus-production model. Fish. Bull. 92: 374-389.

Prager, M.H. 1995. Users's manual for ASPIC: A Stock Production Model Incorporating Covariates, program version 3.6x. Miami Laboratory Document MIA-92/93-55, National Marine Fisheries Service. 29p.

Ralston, R, J.R. Bence, W.G. Clark, R.J. Conser, T. Jagielo and T.J. Quinn II. 2000. Panel Report: West Coast Groundfish Harvest Rate Policy Workshop. Sponsored by Scientific and Statistical Committee, PFMC. Alaska Fisheries Science Center, Seattle, WA: March 20-23, 2000.

Restrepo, V. R., and C. M. Legault. 1998. A stochastic implementation of an age-structured production model. University of Alaska Sea Grant College Program, Report Number 98-01: 435-450.

SAS 1990. SAS/STAT User's Guide, Version 6, Fourth Edition. SAS Institute, Inc., Cary, NC.

Schaefer, M.B. 1954. Some aspects of the dynamics of populations important to the management of the commercial marine fisheries. Bull. Inter.-Amer. trop. Tuna Comm., 1(2): 25-56.

Schaefer, M.B. 1957. A study of the dynamics of the fishery for yellowfin tuna in the eastern tropical Pacific Ocean. Bull. Inter.-Amer. trop. Tuna Comm., 2(6): 245-285.

Steele, D.H. 1957. The Redfish (Sebastes marinus L.) In the western Gulf of St. Lawrence. J. Fish. Res. Bd. Canada, 14: 899-924.

Templeman, W. 1959. Redfish Distribution in the North Atlantic. Bull. Fish. Res. Bd. Canada, No. 120: 1-173.

Thompson, G. G. 1994. Confounding of gear selectivity and the natural mortality rate in cases where the former is a nonmonotone function of age. Can. J. Fish. Aquat. Sci. 51:2654-2664.

Thompson, W.F. and F.H. Bell. 1934. Biological statistics of the Pacific halibut fishery. 2. Effect of changes in intensity upon total yield and yield per unit of gear. Rep. Int. Fish. (Pacific Halibut) Comm. 8: 49p.

Walter, G.G. 1976. Non-equilibrium regulation of fisheries. Int. Comm. Northw. Atl. Fish., Sel. Papers, No. 1: 129-140.

Table 1. Nominal redfish catches (metric tons), actual and standardized catch per unit effort, and calculated standardized USA and total effort for the Gulf of Maine-Georges Bank redfish fishery.

	Nominal Catch (Metric tons)			USA Catch per Unit Effort (tons/day)		Calculated Standard Effort (days fished)	
Year	USA	Others	Total	Actual	Standard	USA	Total
1934	519		519				
1935	7549		7549				
1936	23162		23162				
1937	14823		14823				
1938	20640		20640				
1939	25406		25406				
1940	26762		26762				
1941	50796		50796				
1942	55892		55892	6.9	6.9	8100	8100
1943	48348		48348	6.7	6.7	7216	7216
1944	50439		50439	5.4	5.4	9341	9341
1945	37912		37912	4.5	4.5	8425	8425
1946	42423		42423	4.7	4.7	9026	9026
1947	40160		40160	4.9	4.9	8196	8196
1948	43631		43631	5.4	5.4	8080	8080
1949	30743		30743	3.3	3.3	9316	9316
1950	34307		34307	4.1	4.1	8368	8368
1951	30077		30077	4.1	4.1	7336	7336
1952	21377		21377	3.5	3.4	6287	6287
1953	16791		16791	3.8	3.6	4664	4664
1954	12988		12988	3.4	3.1	4190	4190
1955	13914		13914	4.5	4.0	3479	3479
1956	14388		14388	4.4	3.8	3786	3786
1957	18490		18490	4.3	3.6	5136	5136
1958	16043	4	16047	4.4	3.6	4456	4458
1959	15521		15521	4.3	3.5	4435	4435
1960	11373	2	11375	3.8	3.0	3791	3792
1961	14040	61	14101	4.6	3.5	4011	4029
1962	12541	1593	14134	5.4	4.0	3135	3534
1963	8871	1175	10046	4.1	3.0	2957	3349
1964	7812	501	8313	4.3	2.9	2694	2867
1965	6986	1071	8057	7.0	4.4	1588	1831
1966	7204	1365	8569	11.7	6.4	1126	1339
1967	10442	422	10864	12.4	5.6	1865	1940
1968	6578	199	6777	14.7	6.1	1078	1111
1969	12041	414	12455	11.4	4.9	2457	2542
1970	15534	1207	16741	9.0	4.0	3884	4185
1971	16267	3767	20034	7.0	3.2	5083	6261
1972	13157	5938	19095	5.7	2.9	4537	6584
1973	11954	5406	17360	5.3	2.9	4122	5986
1974	8677	1794	10471	5.0	2.6	3337	4027
1975	9075	1497	10572	4.0	2.2	4125	4805
1976	10131	565	10696	4.6	2.3	4405	4650
1977	13012	211	13223	4.9	2.5	5205	5289
1978	13991	92	14083	4.8	2.4	5830	5868
1979	14722	33	14755	3.6	1.9	7748	7766
1980	10085	98	10183	3.2	1.6	6303	6364
1981	7896	19	7915	2.7	1.4	5640	5654
1982	6735	168	6903	2.7	1.5	4490	4602
1983	5215	113	5328	2.1	1.2	4346	4440
1984	4722	71	4793	1.9	1.1	4293	4357
1985	4164	118	4282	1.4	0.9	4627	4758
1986	2790	139	2929	1.0	0.6	4650	4882
1987	1859	35	1894	1.1	0.7	2656	2706
1988	1076	101	1177	0.9	0.5	2152	2354
1989	628	9	637	1.1	0.6	1047	1062
1990	588	13	601	**	**		
1991	525		525	**	**		
1992	849		849	**	**		
1993	800		800	**	**		
1994*	440		440	**	**		
1995*	440		440	**	**		
1996*	322		322	**	**		
1997*	251		251	**	**		
1998*	320		320	**	**		
1999*	353		353	**	**		
2000*	319		319	**	**		

* Preliminary
** CPUE and effort not calculated due to sharp reduction in directed redfish trips

Table 2. Commercial length and age sampling summary for Gulf of Maine - Georges Bank Redfish, 1969-2000.

Year	Landings (tons)	Number of Samples	Number of tons/sample	Number of Length Measurements	Number of Ages Collected	Number of Ages Available
1969	12455	14	890	3,200	?	616
1970	16741	18	930	2,300	600	461
1971	20034	34	589	7,796	963	963
1972	19095	16	1193	5,085	?	1,066
1973	17360	23	755	6,246	1,120	1,027
1974	10471	34	308	7,945	2,170	1,011
1975	10572	27	392	6,761	2,912	1,147
1976	10696	24	446	8,094	3,700	1,028
1977	13223	31	427	8,495	3,688	863
1978	14083	30	469	5,493	2,352	1,012
1979	14755	35	422	8,975	3,866	1,122
1980	10183	21	485	4,858	2,210	1,110
1981	7915	21	377	3,718	1,718	851
1982	6903	27	256	4,216	1,734	849
1983	5328	31	172	5,100	2,416	995
1984	4793	26	184	4,603	2,275	1,018
1985	4282	37	116	5,775	2,962	1,464
1986	2929	38	77	6,063	3,102	N/A
1987	1894	29	65	4,633	2,290	N/A
1988	1177	21	56	2,487	1,258	N/A
1989	637	17	37	1,921	958	N/A
1990	601	12	51	1,338	692	N/A
1991	525	10	52	1,136	?225	N/A
1992	849	11	77	1,354	?	N/A
1993	800	5	160	528	?	N/A
1994	440	2	220	226	?	N/A
1995	440	3	147	303	?	N/A
1996	322	1	322	113	?	N/A
1997	251	3	84	343	?	N/A
1998	320	0	–	0	?	N/A
1999	353	1	353	111	?	N/A
2000	319	1	319	110	?	N/A

Table 3. Total catch at age and mean weights at age for Gulf of Maine - Georges Bank redfish, 1969-1985.

Year	Age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26+
Number landed (000s)																										
1969	-	-	-	22	421	439	1008	6065	2513	6717	2660	3975	3287	2221	2820	1348	751	526	606	426	451	345	469	38	100	847
1970	-	-	-	-	146	4055	4048	1060	9692	3221	8351	2734	4702	2672	2302	3489	1778	1640	393	662	368	529	572	488	64	1743
1971	-	-	-	-	-	72	1941	4430	1536	7907	2767	6504	3088	4267	3680	2895	2206	2765	1347	1163	560	1048	559	282	138	2439
1972	-	-	-	-	-	-	933	3296	7401	1712	7580	2782	2884	1994	3531	2449	1205	1276	2245	734	1011	1172	718	538	1280	2874
1973	-	-	-	-	-	-	235	2463	7938	8391	2201	7337	2078	3100	2376	2024	1799	1380	864	933	411	590	426	295	289	1977
1974	-	-	308	105	-	17	8	174	1886	4724	2945	2435	1709	1115	1302	935	1454	910	640	661	589	730	271	285	250	1755
1975	-	-	4	695	72	11	-	30	124	1944	4360	2154	1932	1442	1009	1344	1360	1235	945	1116	608	887	492	294	298	1282
1976	-	-	-	196	8961	439	-	-	21	48	467	2706	3375	1702	1725	1388	1233	1166	1424	608	769	681	323	672	94	2011
1977	-	-	-	-	234	16747	311	-	-	-	81	2127	1262	4012	1823	2747	1466	1190	1064	461	706	541	117	571	1013	2157
1978	-	-	-	-	-	271	24569	215	-	34	33	182	1689	1484	2948	1748	1310	866	899	1283	895	734	500	192	530	2220
1979	-	-	-	-	25	205	849	23729	152	117	48	168	541	1228	1972	1299	1580	983	845	1008	798	594	532	538	427	2506
1980	-	-	-	-	-	132	175	1110	16900	208	44	46	217	491	830	1221	860	664	564	452	473	370	349	294	265	1308
1981	-	-	23	-	77	40	57	47	223	12380	84	22	-	44	317	364	1274	506	534	396	318	381	306	326	350	1540
1982	-	-	3	271	123	60	92	30	-	15	7268	56	32	21	128	185	582	452	840	324	501	484	301	134	104	2270
1983	-	-	-	11	1687	159	46	43	86	49	141	4959	58	106	64	42	85	319	270	551	169	224	314	195	131	1817
1984	-	-	46	11	51	6674	-	20	40	-	35	15	3571	-	44	49	34	92	210	166	324	215	144	157	162	1807
1985	-	-	27	146	33	31	3818	-	28	11	13	40	12	3202	-	25	11	101	116	260	230	187	197	142	107	1489
Mean weight (kg)																										
1969	.010	.020	.052	.113	.115	.142	.169	.195	.219	.260	.320	.339	.366	.404	.425	.473	.495	.457	.589	.497	.515	.594	.589	.705	.708	.591
1970	.010	.020	.052	.092	.172	.168	.170	.189	.221	.236	.290	.339	.356	.367	.340	.418	.427	.438	.523	.579	.505	.450	.464	.476	.345	.541
1971	.010	.020	.052	.092	.135	.172	.242	.244	.265	.304	.333	.369	.399	.437	.445	.468	.435	.449	.541	.553	.514	.544	.581	.481	.473	.540
1972	.010	.020	.052	.092	.135	.171	.197	.240	.257	.289	.334	.367	.399	.427	.451	.472	.490	.515	.509	.562	.581	.565	.604	.489	.560	.668
1973	.010	.020	.052	.092	.135	.171	.162	.213	.257	.281	.343	.341	.384	.402	.482	.454	.500	.492	.523	.525	.529	.641	.633	.568	.653	.620
1974	.010	.020	.064	.080	.135	.195	.150	.233	.270	.326	.331	.378	.399	.427	.449	.442	.503	.527	.540	.565	.525	.578	.585	.641	.633	.642
1975	.010	.020	.039	.098	.161	.221	.195	.383	.349	.317	.342	.394	.399	.420	.460	.469	.533	.527	.522	.550	.600	.547	.595	.607	.663	.662
1976	.010	.020	.052	.076	.135	.199	.195	.245	.345	.278	.296	.347	.395	.389	.405	.427	.511	.469	.542	.517	.518	.552	.645	.577	.628	.630
1977	.010	.020	.052	.092	.090	.173	.288	.245	.277	.297	.350	.413	.412	.408	.433	.454	.462	.534	.537	.610	.466	.595	.611	.544	.552	.605
1978	.010	.020	.052	.092	.135	.135	.209	.300	.277	.311	.383	.468	.402	.433	.423	.458	.551	.504	.526	.547	.523	.537	.633	.551	.606	.641
1979	.010	.020	.052	.092	.135	.200	.191	.251	.304	.295	.248	.402	.508	.472	.474	.564	.526	.543	.551	.617	.664	.597	.567	.605	.567	.647
1980	.010	.020	.052	.092	.135	.108	.175	.188	.283	.371	.421	.362	.424	.454	.506	.478	.499	.518	.554	.595	.647	.664	.629	.599	.681	.695
1981	.010	.020	.080	.092	.117	.150	.143	.195	.247	.318	.374	.466	.404	.532	.592	.543	.528	.499	.537	.550	.594	.617	.560	.633	.552	.650
1982	.010	.020	.052	.142	.203	.256	.242	.252	.277	.383	.395	.491	.563	.383	.544	.475	.540	.504	.564	.583	.592	.563	.621	.499	.535	.699
1983	.010	.020	.052	.107	.172	.198	.249	.329	.252	.368	.396	.425	.381	.471	.504	.595	.494	.579	.639	.580	.614	.647	.622	.630	.589	.682
1984	.010	.020	.110	.092	.206	.197	.195	.311	.252	.297	.333	.377	.403	.420	.497	.630	.569	.529	.519	.499	.610	.547	.568	.600	.517	.619
1985	.010	.020	.092	.146	.154	.177	.239	.245	.279	.345	.421	.362	.595	.443	.441	.591	.494	.545	.599	.552	.603	.635	.605	.699	.624	.692

Table 4. Spring NEFSC bottom trawl survey stratified mean catch per tow indices, average weights and average lengths of redfish in the Gulf of Maine - Georges Bank region.

	INSHORE 1				OFFSHORE 2				COMBINED 3	
	Stratified Mean Catch per Tow		Avg. Wt.	Avg. Length	Stratified Mean Catch per Tow		Avg. Wt.	Avg. Length	Stratified Mean Catch per Tow	
Year	Number	kg	kg	cm	Number	kg	kg	cm	Number	kg
1968	7.9	1.2	0.152	17.9	51.7	19.8	0.383	26.4	45.2	17.0
1969	59.0	8.3	0.141	20.3	44.2	21.7	0.491	30.6	46.4	19.7
1970	29.7	9.3	0.313	24.4	59.1	20.6	0.349	26.4	54.7	18.9
1971	49.9	13.3	0.267	24.9	176.0	81.7	0.464	29.8	157.2	71.6
1972	23.8	4.6	0.193	18.6	114.7	51.3	0.447	28.9	101.2	44.4
1973	14.4	4.6	0.319	22.0	49.6	28.9	0.583	31.4	44.4	25.3
1974	25.7	6.1	0.237	19.7	35.8	21.0	0.587	31.5	34.3	18.8
1975	50.9	18.9	0.371	25.5	37.4	17.4	0.465	28.5	38.9	17.6
1976	45.9	6.4	0.139	19.8	65.1	29.6	0.455	29.2	62.2	26.2
1977	79.1	24.0	0.303	25.3	15.6	9.4	0.603	32.1	25.1	11.6
1978	33.7	10.4	0.309	25.0	22.3	12.5	0.561	30.2	24.0	12.2
1979	27.5	8.5	0.309	25.4	67.5	36.4	0.539	30.0	61.6	32.3
1980	8.5	2.2	0.259	25.3	33.5	23.5	0.701	32.4	29.8	20.3
1981	3.0	1.0	0.333	22.5	38.9	21.7	0.558	30.5	33.6	18.6
1982	5.0	1.4	0.280	24.7	19.0	10.8	0.568	30.1	16.9	9.4
1983	4.8	0.9	0.188	21.6	10.7	7.0	0.654	31.0	9.9	6.1
1984	5.4	1.6	0.296	25.1	4.9	2.9	0.592	30.2	5.0	2.7
1985	1.2	0.4	0.333	24.8	13.6	7.7	0.566	30.1	11.7	6.6
1986	9.5	5.4	0.568	29.9	4.5	2.8	0.622	31.4	5.3	3.2
1987	5.5	1.4	0.255	23.9	27.8	14.9	0.536	30.5	24.5	12.9
1988	11.7	2.6	0.222	23.0	7.5	3.4	0.453	28.4	8.1	3.3
1989	17.6	2.7	0.153	17.6	6.5	3.0	0.462	27.8	7.6	2.9
1990	0.8	0.2	0.250	23.1	14.4	8.0	0.556	30.2	12.3	6.8
1991	5.5	0.8	0.145	19.4	10.2	4.9	0.480	28.0	9.5	4.3
1992	77.0	15.8	0.205	23.4	31.0	9.8	0.316	26.1	37.9	10.7
1993	12.4	2.2	0.182	22.6	39.5	20.2	0.510	29.7	35.5	7.5
1994	16.6	2.5	0.152	19.6	16.1	4.2	0.259	24.2	16.1	3.9
1995	11.8	2.1	0.176	20.7	6.4	1.9	0.293	23.6	7.2	1.9
1996	16.4	2.2	0.137	20.0	30.9	13.6	0.439	27.8	28.7	11.9
1997	1235.2	175.8	0.142	20.7	33.3	9.3	0.278	24.6	212.0	34.0
1998	13.6	2.0	0.145	20.4	38.4	8.9	0.231	23.6	4.7	7.8
1999	50.8	6.3	0.125	19.9	80.5	21.2	0.264	24.4	76.0	19.0
2000	12.0	2.9	0.238	23.8	209.4	65.3	0.312	25.9	180.1	56.0

Table 5. Autumn NEFSC bottom trawl survey stratified mean catch per tow indices, average weights and average lengths of redfish in the Gulf of Maine - Georges Bank region.

	INSHORE 1				OFFSHORE 2				COMBINED 3	
	Stratified Mean Catch per Tow		Avg. Wt.	Avg. Length	Stratified Mean Catch per Tow		Avg. Wt.	Avg. Length	Stratified Mean Catch per Tow	
Year	Number	kg	kg	cm	Number	kg	kg	cm	Number	kg
1963	86.3	7.6	0.088	17.4	87.5	27.0	0.309	26.4	87.3	24.1
1964	81.3	13.5	0.166	20.2	122.3	61.8	0.505	30.8	116.3	54.6
1965	189.5	22.3	0.118	17.7	33.9	11.5	0.339	25.3	57.0	13.1
1966	172.8	17.0	0.098	16.2	77.8	31.2	0.401	27.4	91.9	29.1
1967	62.9	5.3	0.084	17.7	107.1	27.6	0.258	23.6	100.5	24.3
1968	41.1	4.7	0.114	18.3	161.3	46.6	0.289	25.1	143.4	40.4
1969	105.9	16.0	0.151	20.7	65.2	24.8	0.380	27.4	71.2	23.5
1970	18.2	2.8	0.154	20.3	107.2	38.2	0.356	26.3	94.0	32.9
1971	20.7	4.7	0.227	21.8	52.8	26.7	0.506	29.7	48.0	23.4
1972	36.4	6.6	0.181	20.8	58.9	27.8	0.472	29.2	55.6	24.6
1973	26.2	2.1	0.080	15.6	41.4	19.7	0.476	29.7	39.2	17.0
1974	44.4	4.7	0.106	18.0	49.0	27.6	0.563	30.1	48.3	24.2
1975	45.7	6.0	0.131	19.6	79.9	45.9	0.574	30.6	74.8	39.9
1976	11.6	2.5	0.216	22.6	31.9	17.5	0.549	30.2	28.9	15.3
1977	54.6	12.3	0.225	23.4	37.9	18.1	0.478	28.5	40.4	17.3
1978	20.4	5.5	0.270	24.6	49.5	23.4	0.473	29.0	45.2	20.7
1979	6.2	2.1	0.339	26.5	32.8	18.4	0.561	30.5	28.9	16.0
1980	20.6	6.2	0.301	24.6	20.6	13.8	0.670	31.8	20.6	12.6
1981	6.8	1.9	0.279	24.9	22.7	14.0	0.617	31.8	20.4	12.2
1982	28.2	4.6	0.163	21.2	5.6	3.2	0.571	31.5	9.0	3.4
1983	30.2	8.7	0.288	24.8	6.5	3.3	0.508	29.1	10.0	4.1
1984	7.7	3.2	0.416	27.9	7.8	4.1	0.526	29.0	7.8	3.9
1985	7.2	2.1	0.292	24.8	14.0	6.3	0.450	28.0	13.0	5.7
1986	67.6	15.3	0.226	23.3	18.8	6.7	0.356	26.1	26.1	8.0
1987	26.5	4.8	0.181	21.9	11.5	5.6	0.487	29.2	13.7	5.5
1988	18.5	5.1	0.276	21.9	11.4	6.5	0.570	29.1	12.4	6.3
1989	14.0	2.9	0.207	22.6	21.3	7.5	0.352	25.9	20.3	6.8
1990	57.6	14.5	0.252	23.8	31.7	11.7	0.369	26.7	35.5	12.2
1991	7.2	1.1	0.153	20.4	21.1	9.6	0.455	28.5	19.1	8.4
1992	7.8	1.2	0.147	20.0	24.9	9.3	0.374	27.3	22.4	8.1
1993	53.7	7.4	0.137	20.0	32.5	11.9	0.366	26.3	35.6	11.2
1994	31.5	5.4	0.171	21.7	19.0	6.0	0.317	25.0	20.9	5.9
1995	109.7	11.1	0.102	18.5	19.9	3.5	0.177	21.3	33.2	4.7
1996	53.8	9.1	0.169	21.5	189.9	34.4	0.181	21.8	169.6	30.6
1997	105.6	15.7	0.149	20.3	57.9	19.5	0.337	26.0	65.0	18.9
1998	48.7	10.7	0.219	20.4	128.9	35.4	0.275	23.6	117.0	31.7
1999	164.2	35.1	0.214	23.2	68.2	20.7	0.304	25.6	82.5	22.9
2000	133.3	22.0	0.165	21.6	99.4	26.9	0.271	24.8	104.4	26.2

Table 6. Yield and spawning stock biomass per recruit analysis for Gulf of Maine - Georges Bank redfish.

The NEFC Yield and Stock Size per Recruit Program - PDBYPRC
PC Ver.2.0 [Method of Thompson and Bell (1934)] 1-Jan-1999

Run Date: 10- 5-2001; Time: 10:04:15.27

REDFISH UPDATED AVE WTS & FPAT, MAT VECTOR (MAYO ET AL. 1990)

Proportion of F before spawning: .4000
Proportion of M before spawning: .4000
Natural Mortality is Constant at: .050
Initial age is: 1; Last age is: 26
Last age is a PLUS group;
Original age-specific PRs, Mats, and Mean Wts from file:
==> d:\assess\redf\yrred.dat

Age-specific Input data for Yield per Recruit Analysis

Age	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Weights Catch	Average Weights Stock
1	.0138	1.0000	.0100	.010	.002
2	.0312	1.0000	.0200	.020	.012
3	.0697	1.0000	.0500	.059	.033
4	.1507	1.0000	.1500	.099	.064
5	.2999	1.0000	.3600	.145	.103
6	.5084	1.0000	.6400	.178	.148
7	.7291	1.0000	.8500	.201	.196
8	.9289	1.0000	.9500	.250	.246
9	1.0000	1.0000	.9800	.272	.295
10	1.0000	1.0000	.9900	.310	.343
11	1.0000	1.0000	1.0000	.348	.388
12	1.0000	1.0000	1.0000	.391	.430
13	1.0000	1.0000	1.0000	.423	.469
14	1.0000	1.0000	1.0000	.429	.505
15	1.0000	1.0000	1.0000	.463	.537
16	1.0000	1.0000	1.0000	.495	.566
17	1.0000	1.0000	1.0000	.503	.592
18	1.0000	1.0000	1.0000	.508	.615
19	1.0000	1.0000	1.0000	.548	.636
20	1.0000	1.0000	1.0000	.558	.654
21	1.0000	1.0000	1.0000	.565	.669
22	1.0000	1.0000	1.0000	.581	.683
23	1.0000	1.0000	1.0000	.595	.696
24	1.0000	1.0000	1.0000	.583	.706
25	1.0000	1.0000	1.0000	.581	.716
26+	1.0000	1.0000	1.0000	.637	.750

Summary of Yield per Recruit Analysis for:
REDFISH UPDATED AVE WTS & FPAT, MAT VECTOR (MAYO ET AL. 1990)

Slope of the Yield/Recruit Curve at F=0.00: --> 7.5310
F level at slope=1/10 of the above slope (F0.1): -----> .059
Yield/Recruit corresponding to F0.1: -----> .1632
F level to produce Maximum Yield/Recruit (Fmax): -----> .127
Yield/Recruit corresponding to Fmax: -----> .1806
F level at 30 % of Max Spawning Potential (F30): -----> .075
SSB/Recruit corresponding to F30: --------> 2.6312

Listing of Yield per Recruit Results for:
REDFISH UPDATED AVE WTS & FPAT, MAT VECTOR (MAYO ET AL. 1990)

	FMORT	TOTCTHN	TOTCTHW	TOTSTKN	TOTSTKW	SPNSTKN	SPNSTKW	% MSP
	.00	.00000	.00000	20.5042	9.1737	15.7030	8.7760	100.00
	.05	.38712	.15522	12.7649	3.9263	8.0041	3.5674	40.65
F0.1	.06	.41925	.16317	12.1227	3.5252	7.3690	3.1719	36.14
F30%	.07	.46461	.17220	11.2165	2.9757	6.4750	2.6312	29.98
	.10	.51797	.17890	10.1507	2.3604	5.4286	2.0284	23.11
Fmax	.13	.55860	.18057	9.3395	1.9207	4.6377	1.6001	18.23
	.15	.58466	.17981	8.8194	1.6549	4.1345	1.3428	15.30
	.20	.62564	.17533	8.0023	1.2684	3.3532	.9718	11.07
	.25	.65370	.16973	7.4432	1.0297	2.8287	.7459	8.50
	.30	.67435	.16423	7.0323	.8698	2.4512	.5967	6.80
	.35	.69033	.15916	6.7145	.7561	2.1657	.4923	5.61
	.40	.70318	.15459	6.4593	.6714	1.9418	.4158	4.74
	.45	.71381	.15049	6.2483	.6060	1.7611	.3578	4.08
	.50	.72281	.14681	6.0696	.5540	1.6119	.3124	3.56
	.55	.73058	.14349	5.9156	.5117	1.4864	.2762	3.15
	.60	.73739	.14047	5.7808	.4765	1.3793	.2467	2.81
	.65	.74343	.13772	5.6612	.4467	1.2868	.2222	2.53
	.70	.74885	.13520	5.5540	.4212	1.2058	.2016	2.30
	.75	.75376	.13288	5.4570	.3991	1.1345	.1841	2.10
	.80	.75823	.13072	5.3685	.3797	1.0710	.1690	1.93
	.85	.76234	.12871	5.2872	.3625	1.0141	.1559	1.78
	.90	.76614	.12683	5.2122	.3471	.9628	.1444	1.65
	.95	.76967	.12506	5.1425	.3333	.9163	.1343	1.53
	1.00	.77296	.12340	5.0775	.3208	.8740	.1253	1.43

Table 7. Commercial landings (mt), NEFSC autumn survey biomass index (kg/tow), and index of exploitation for Gulf of Maine redfish.

Year	Commercial landings (mt)	Biomass Index	Exploitation Ratio
1963	10046	24.1	0.4168
1964	8313	54.6	0.1523
1965	8057	13.1	0.6150
1966	8569	29.1	0.2945
1967	10864	24.3	0.4471
1968	6777	40.4	0.1677
1969	12455	23.5	0.5300
1970	16741	32.9	0.5088
1971	20034	23.4	0.8562
1972	19095	24.6	0.7762
1973	17360	17.0	1.0212
1974	10471	24.2	0.4327
1975	10572	39.9	0.2650
1976	10696	15.3	0.6991
1977	13223	17.3	0.7643
1978	14083	20.7	0.6803
1979	14755	16.0	0.9222
1980	10183	12.6	0.8082
1981	7915	12.2	0.6488
1982	6903	3.4	2.0303
1983	5328	4.1	1.2995
1984	4793	3.9	1.2290
1985	4282	5.7	0.7512
1986	2929	8.0	0.3661
1987	1894	5.5	0.3444
1988	1177	6.3	0.1868
1989	637	6.8	0.0937
1990	601	12.2	0.0493
1991	525	8.4	0.0625
1992	849	8.1	0.1049
1993	800	11.2	0.0714
1994	440	5.9	0.0741
1995	440	4.7	0.0946
1996	322	30.6	0.0105
1997	251	18.9	0.0133
1998	320	31.7	0.0101
1999	353	22.9	0.0154
2000	319	26.2	0.0122

Table 8. Spawning biomass (thousand mt), fully-recruited fishing mortality, recruitment (millions of age-1 fish), and population biomass (thousand mt) estimates for Gulf of Maine redfish during the period 1963-2000 from the age-structured dynamics model.

Year	Spawning Biomass	Fishing Mortality	Recruitment	Population Biomass
1963	111.7	0.09	48.3	136.5
1964	112.9	0.08	98.1	137.7
1965	115.7	0.08	76.9	141.1
1966	120.2	0.07	33.8	147.0
1967	122.8	0.09	7.8	150.8
1968	126.0	0.05	4.3	150.8
1969	131.0	0.09	2.6	153.7
1970	130.2	0.11	2.8	148.3
1971	124.7	0.14	4.2	139.6
1972	114.0	0.15	249.2	128.6
1973	101.3	0.16	6.5	116.2
1974	91.0	0.11	2.5	110.6
1975	85.1	0.12	1.9	109.9
1976	82.9	0.14	1.7	108.8
1977	81.9	0.18	1.6	101.9
1978	76.4	0.21	2.2	89.7
1979	68.1	0.29	52.8	79.9
1980	54.4	0.24	2.5	63.1
1981	44.3	0.25	2.8	53.3
1982	35.8	0.28	10.2	45.1
1983	30.4	0.20	21.2	38.2
1984	27.9	0.17	8.7	34.2
1985	25.3	0.17	20.0	31.0
1986	24.3	0.12	11.2	29.7
1987	23.7	0.08	5.1	29.2
1988	24.1	0.05	4.4	29.2
1989	25.5	0.03	29.0	30.2
1990	27.9	0.02	51.4	32.6
1991	29.4	0.02	8.7	34.5
1992	30.6	0.03	35.7	37.8
1993	32.5	0.03	327.5	44.3
1994	35.9	0.01	73.3	51.6
1995	40.3	0.01	35.0	66.1
1996	47.7	0.01	22.4	81.6
1997	62.7	<0.01	24.9	99.2
1998	81.9	<0.01	32.2	111.2
1999	100.5	<0.01	34.5	120.5
2000	119.6	<0.01	29.2	134.6

Table 9. Estimates of relative biomass and fishing mortality for redfish from ASPIC with 80% confidence intervals (CI).

Year	Bt/Bmsy	Lower 80% CI	Upper 80% CI	Ft/Fmsy	Lower 80% CI	Upper 80% CI
1963	31%	29%	34%	157%	157%	158%
1964	32%	29%	34%	127%	127%	129%
1965	33%	30%	35%	119%	118%	120%
1966	34%	32%	37%	121%	120%	124%
1967	36%	34%	38%	150%	147%	155%
1968	36%	34%	38%	90%	87%	94%
1969	39%	37%	40%	160%	153%	169%
1970	39%	38%	40%	221%	210%	235%
1971	37%	36%	37%	286%	271%	304%
1972	33%	32%	34%	305%	290%	324%
1973	29%	28%	30%	314%	299%	332%
1974	26%	25%	27%	204%	195%	216%
1975	25%	24%	26%	212%	201%	226%
1976	24%	24%	25%	223%	210%	239%
1977	23%	23%	24%	296%	278%	319%
1978	21%	21%	21%	360%	337%	388%
1979	18%	18%	18%	463%	435%	496%
1980	14%	14%	14%	397%	378%	423%
1981	12%	11%	12%	367%	351%	388%
1982	10%	10%	10%	376%	361%	394%
1983	8%	8%	9%	335%	321%	351%
1984	7%	7%	8%	342%	324%	359%
1985	6%	6%	7%	349%	323%	375%
1986	6%	5%	7%	264%	238%	291%
1987	5%	5%	6%	175%	154%	198%
1988	5%	5%	7%	103%	90%	118%
1989	6%	5%	7%	50%	44%	58%
1990	7%	6%	8%	42%	36%	48%
1991	8%	6%	9%	32%	27%	36%
1992	9%	7%	10%	45%	38%	52%
1993	10%	9%	12%	37%	31%	43%
1994	11%	10%	13%	18%	15%	21%
1995	13%	11%	16%	15%	13%	18%
1996	15%	13%	18%	10%	8%	12%
1997	18%	15%	21%	6%	5%	8%
1998	21%	18%	25%	7%	6%	9%
1999	24%	21%	29%	7%	5%	8%
2000	28%	24%	34%	5%	4%	7%
2001	33%	27%	40%			

Table 10. Results from alternative ASPIC analyses as compared to the accepted run, "REDFISH3" (B1R: B_{1934}/B_{MSY}; IQR: interquartile range; Q: catchability).

run options	REDFISH3	REDFISHX	REDFISH2		REDFISHT	
CPUE	included	excluded	excluded		included	
B1R	fixed	fixed	estimated	sensitivity	fixed	
time series	1934-2000	1934-2000	1934-2000	to B1R	1934-1999	sensitivity
results				and CPUE		to time series
B1R	2	2	1.647	17.7%	2	0.0%
IQR	0%	0%	25%			
MSY	20.18	20.19	20.77	2.9%	16.12	20.1%
IQR	8%	12%	13%			
r	0.1776	0.1779	0.1766	0.7%	0.118	33.6%
IQR	16%	23%	25%			
qCPUE	0.0489				0.03623	25.9%
IQR	17%					
qFall	0.3811	0.3772	0.3776	1.0%	0.2942	22.8%
IQR	15%	22%	23%			
qSpring	0.3577	0.3569	0.3569	0.2%	0.2758	22.9%
IQR	17%	24%	24%			
Bmsy	227.2	227.1	227.1	0.0%	273.3	20.3%
IQR	8%	11%	11%			
Fmsy	0.0888	0.08893	0.08893	0.1%	0.05898	33.6%
IQR	16%	23%	23%			
B2001/Bmsy	0.3289	0.3363	0.3363	2.2%		
IQR	21%	25%	25%			
F2000/Fmsy	0.05496	0.05011	0.05011	8.8%		
IQR	16%	33%	33%			
B1996/Bmsy	0.1539				0.1193	22.5%
IQR	17%					
F1995/Fmsy	0.152				0.24	57.9%
IQR	19%					
% bootstrap convergence	100	100	0.79			
random seed sensitivity	<0.01%	<0.01%	25%			

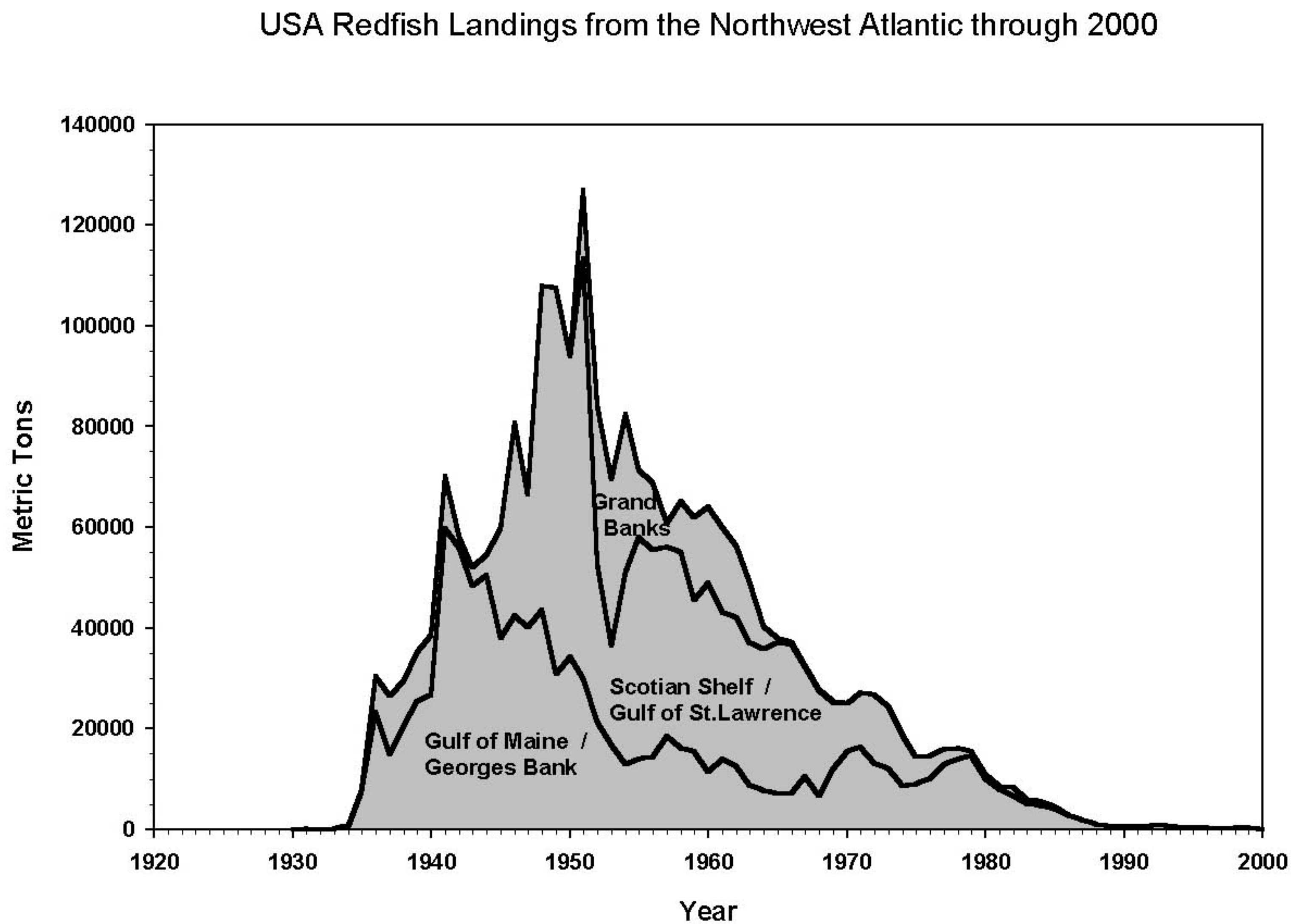
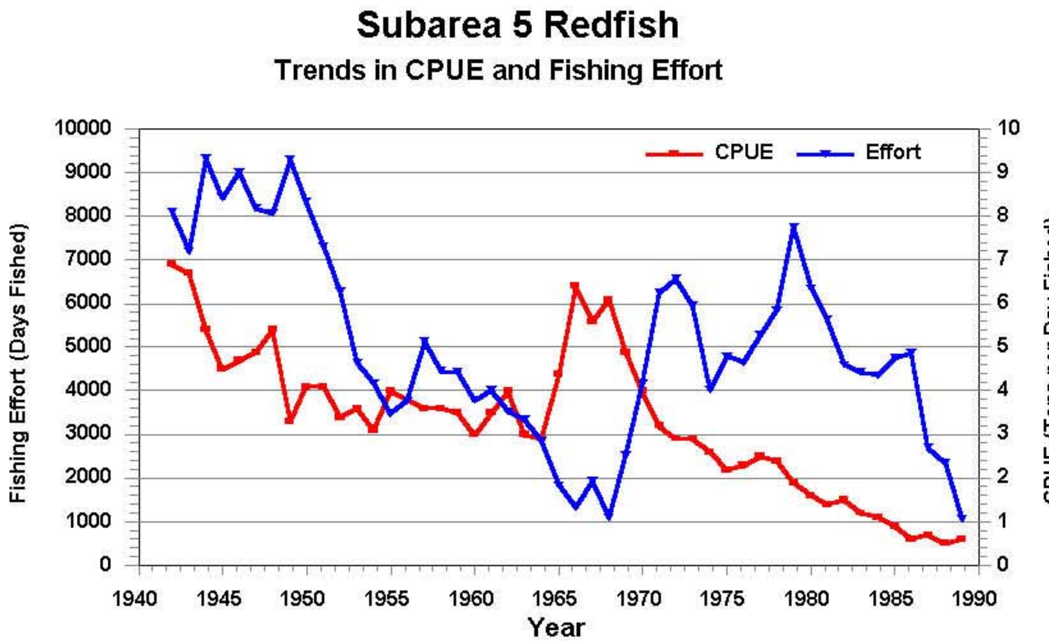


Figure 1. USA landings (metric tons, live weight) of redfish from NAFO Subarea 3 (Grand Banks and Flemish Cap), Subarea 4 (Gulf of St. Lawrence and Scotian Shelf), and Subarea 5 (Gulf of Maine and Georges Bank).



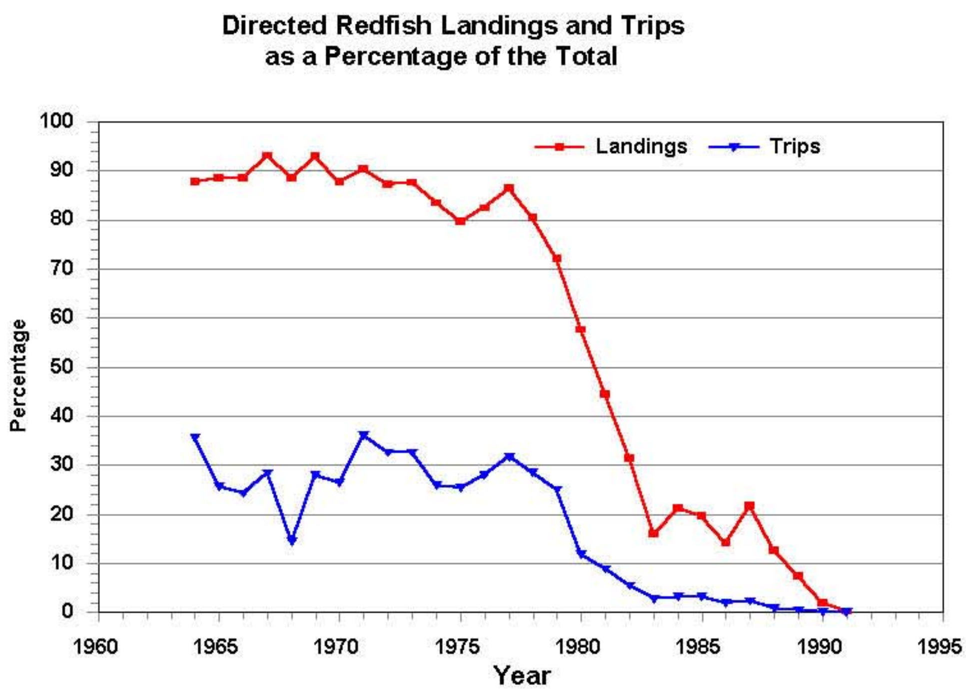


Figure 2. (a) Trends in CPUE and Effort and
(b) Percentage of directed Redfish Trips (> 50% redfish)

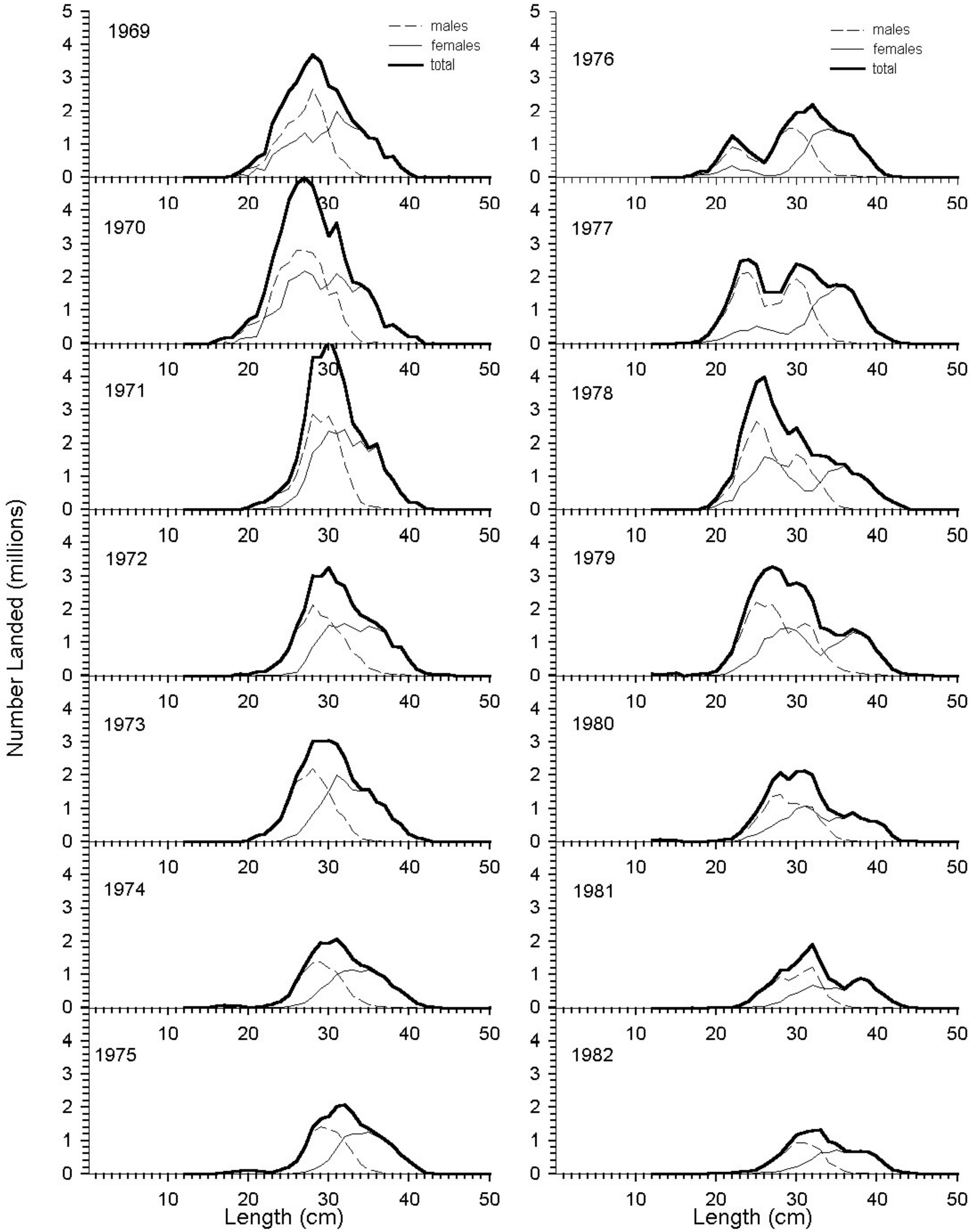


Figure 3. Length composition of redfish in the commercial landings.

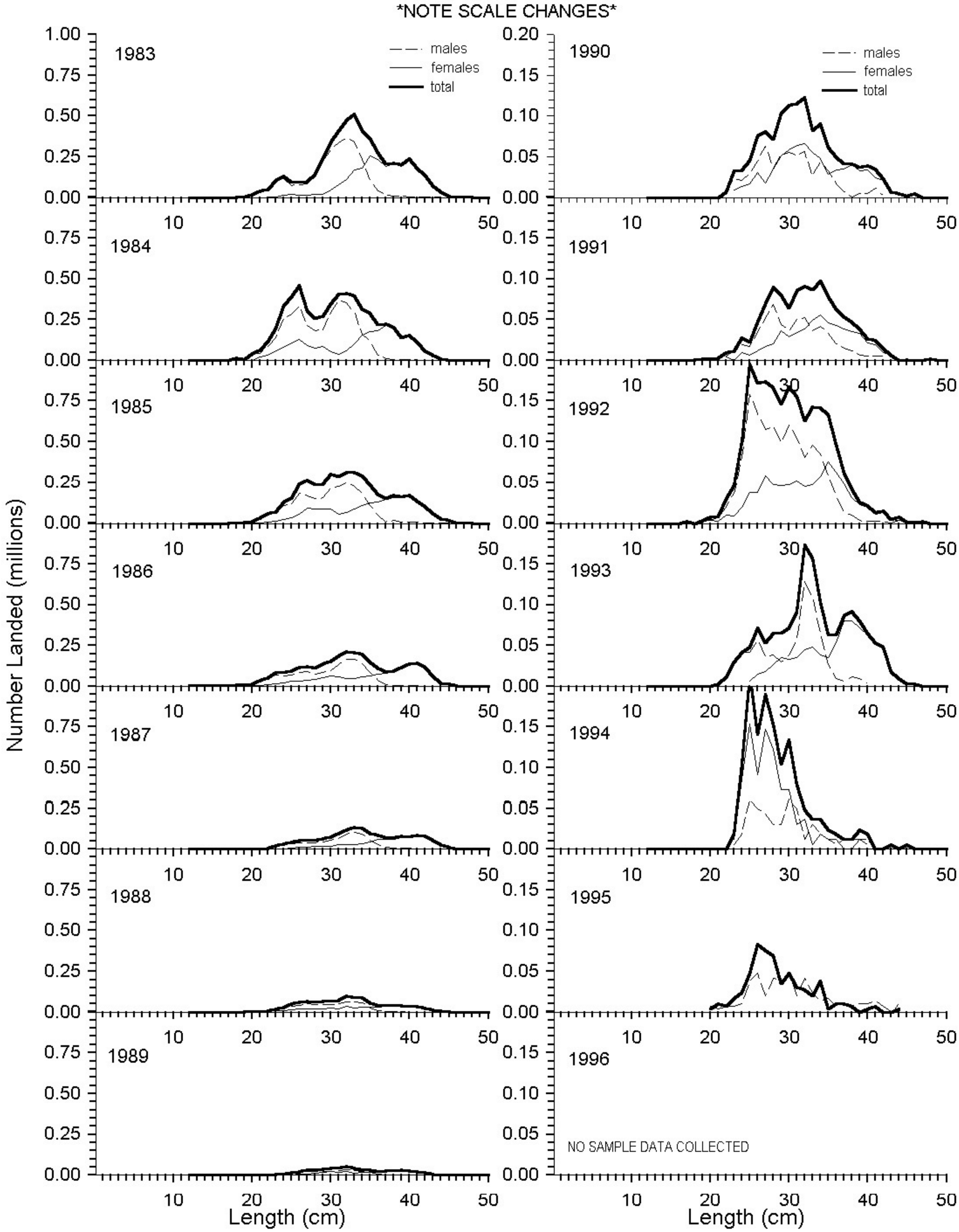


Figure 3 (Continued).

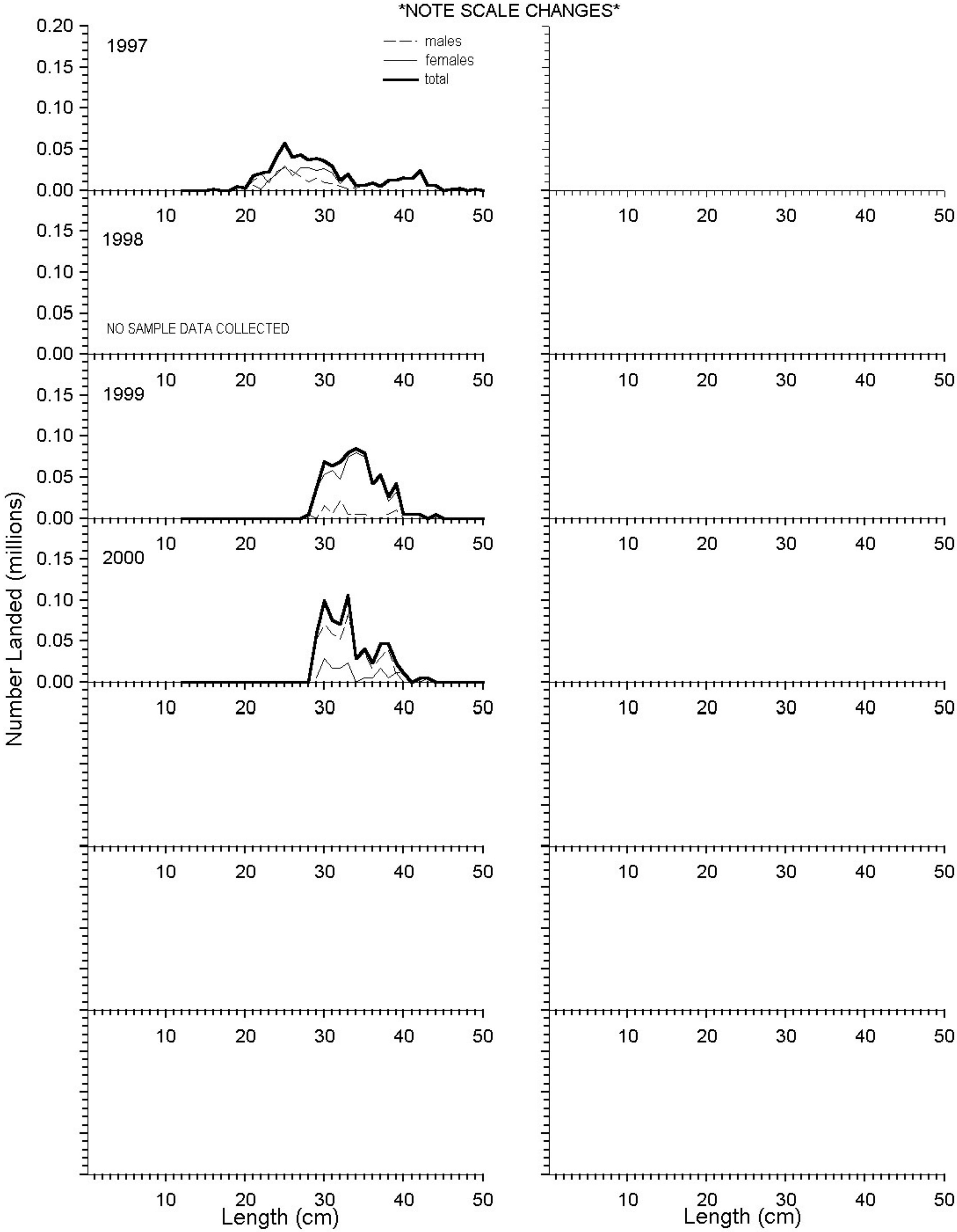


Figure 3 (Continued).

SA 5 Redfish
Trends in Mean Length in the Commercial Landings
1942 - 2000

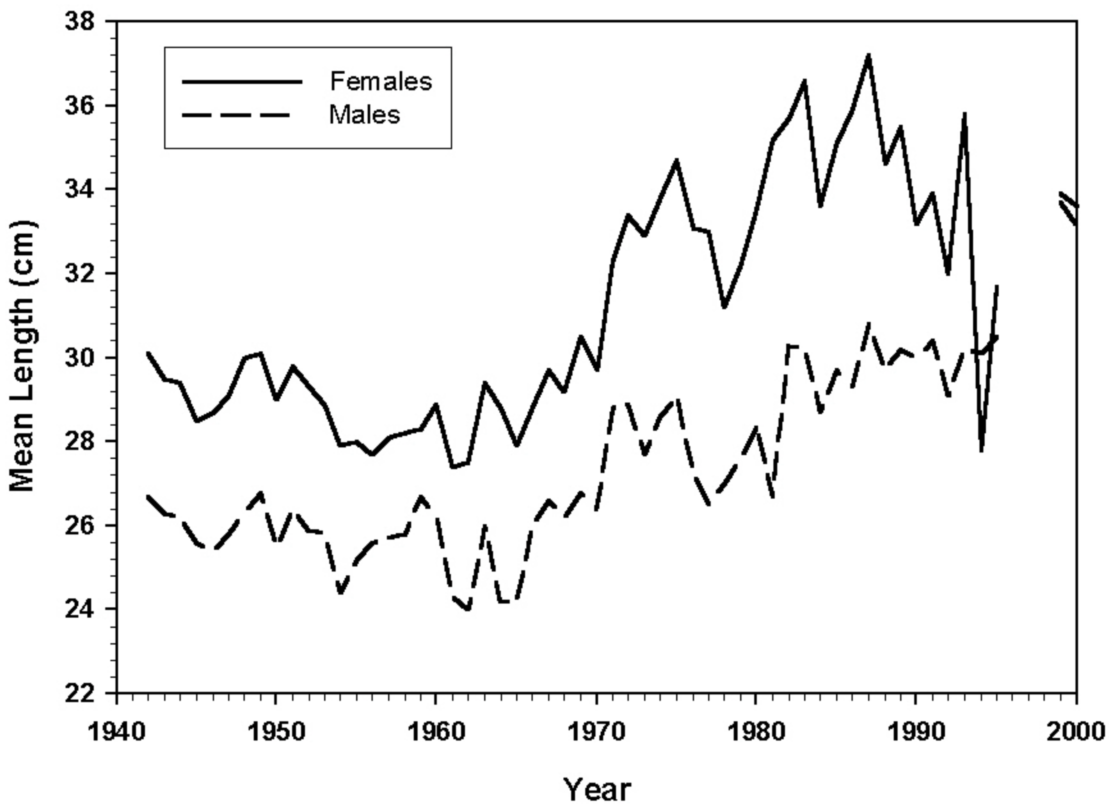


Figure 4. Trends in mean length (cm) of redfish in the commercial landings.

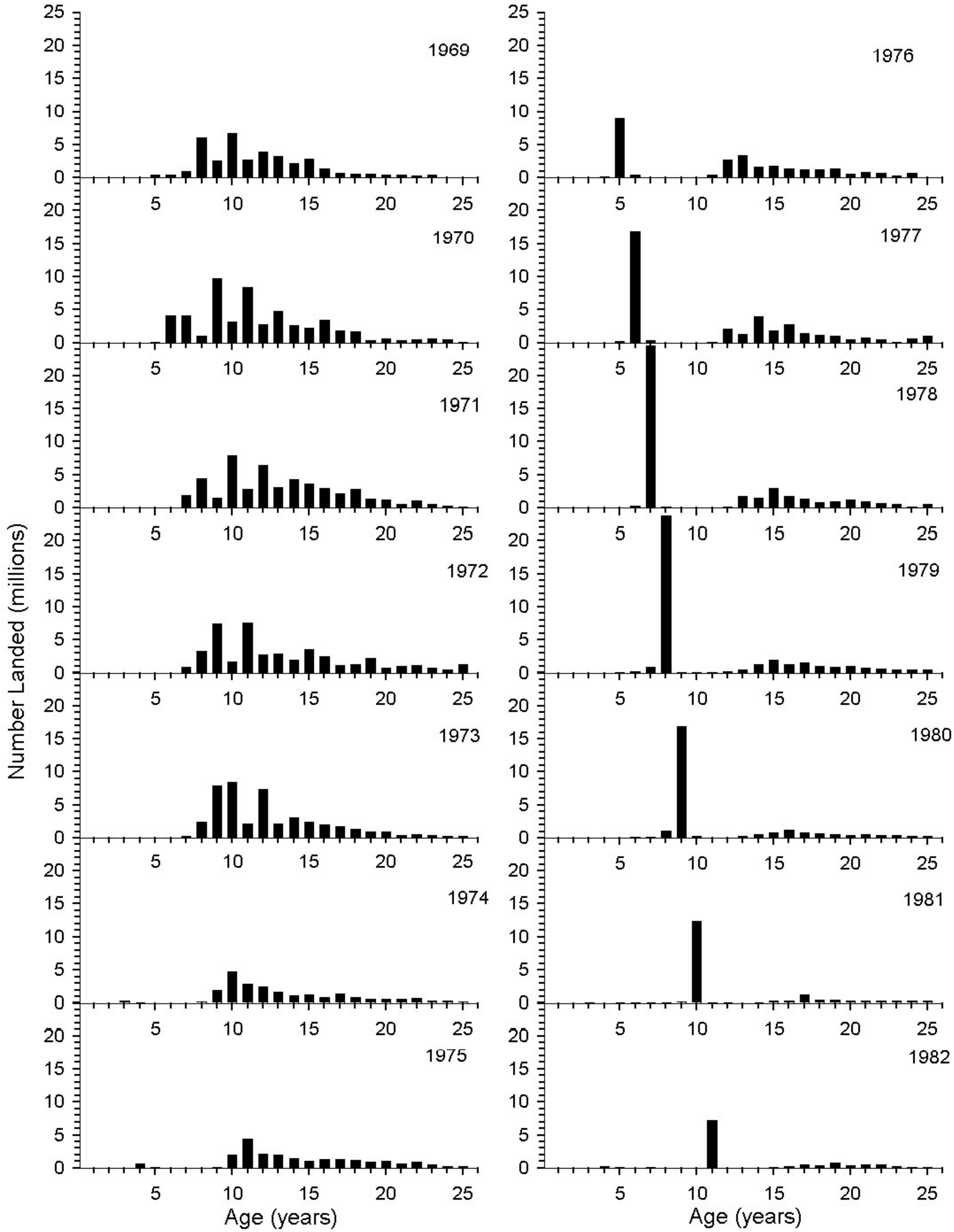


Figure 5. Age composition of redfish in commercial landings.

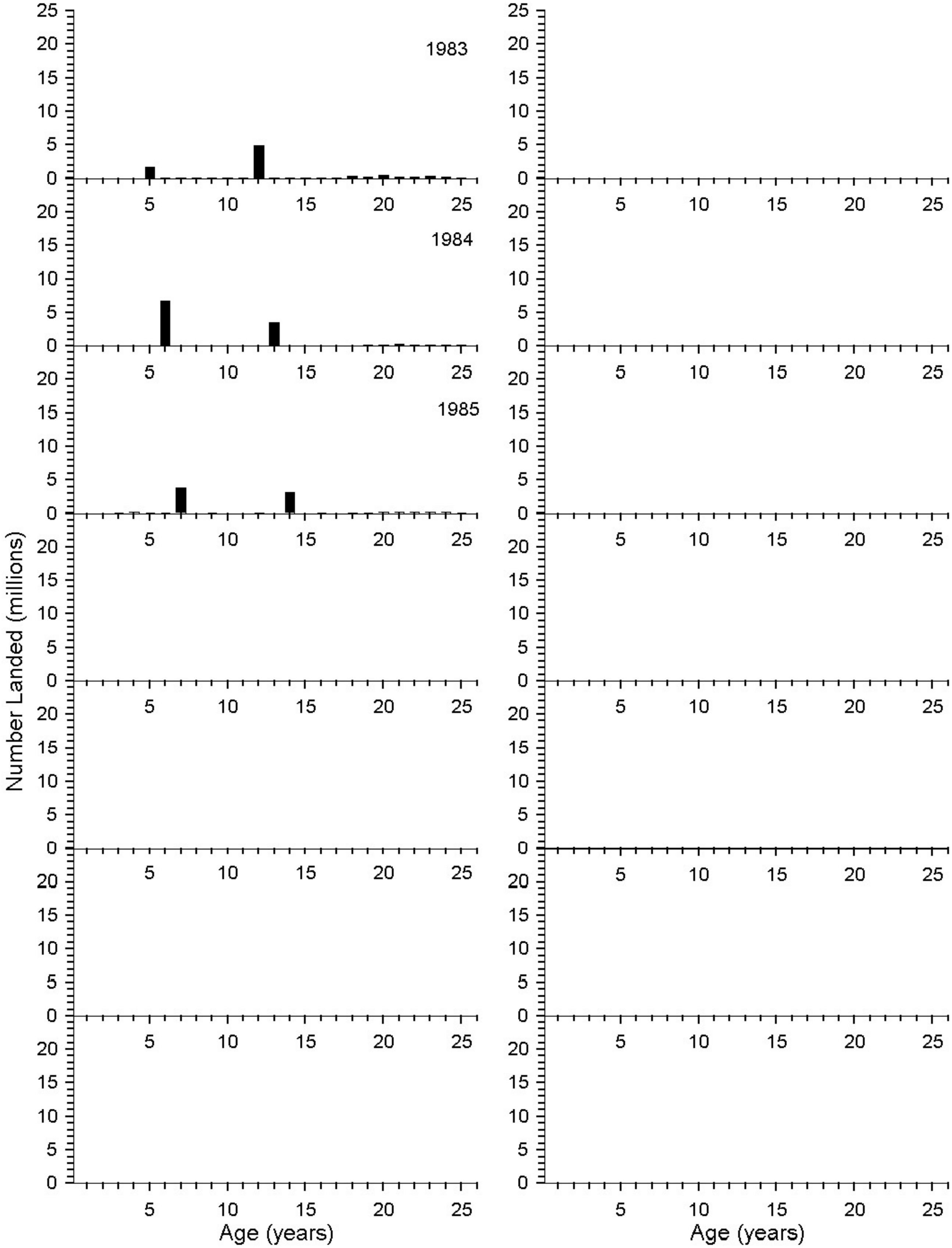


Figure 5 (Continued).

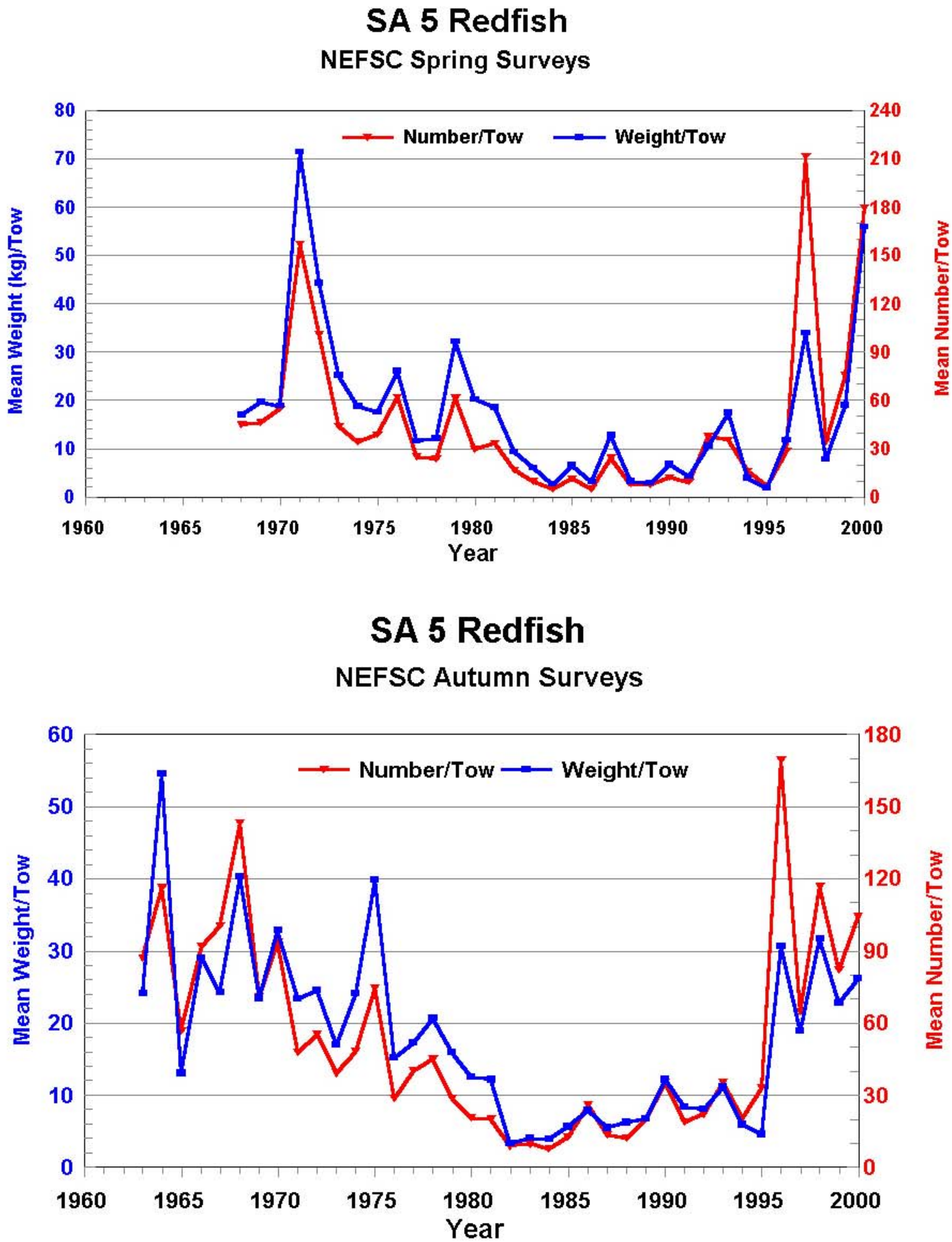
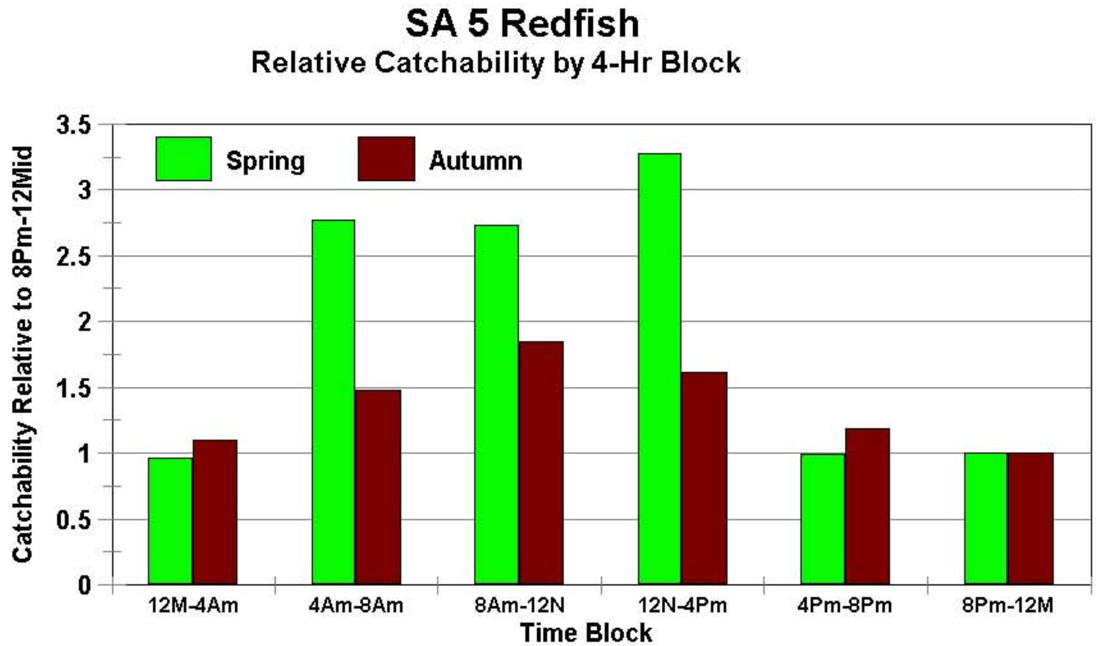


Figure 6. (a) Stratified mean number and weight (kg) per tow of redfish in NEFSC spring surveys, (b) Stratifeid mean number and weight (kg) per tow of redfish in NEFSC autumn surveys.



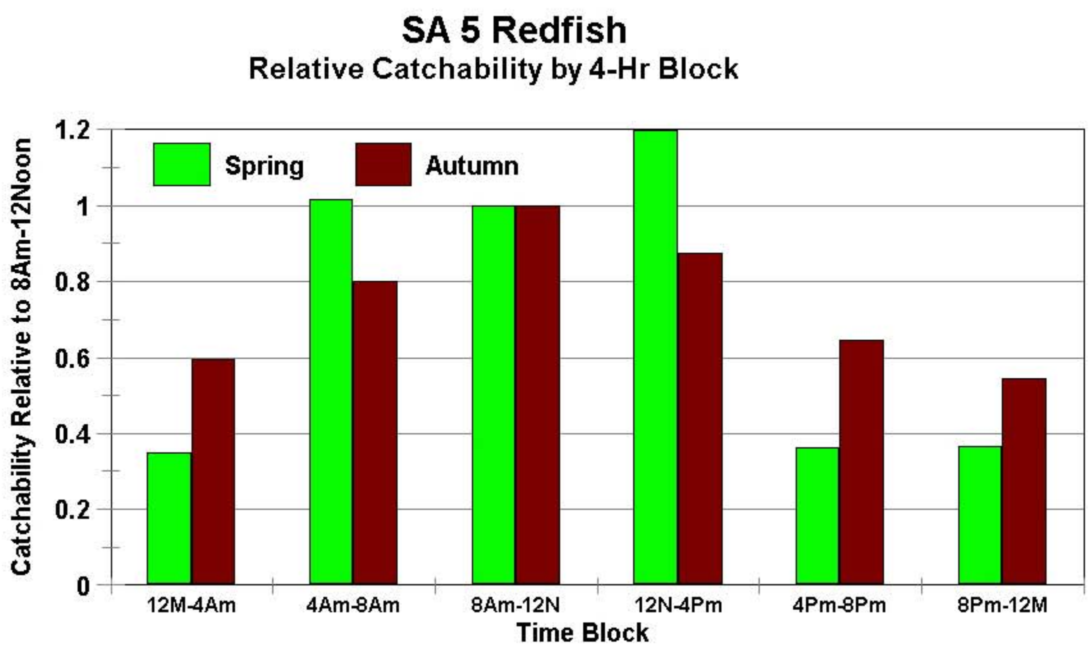
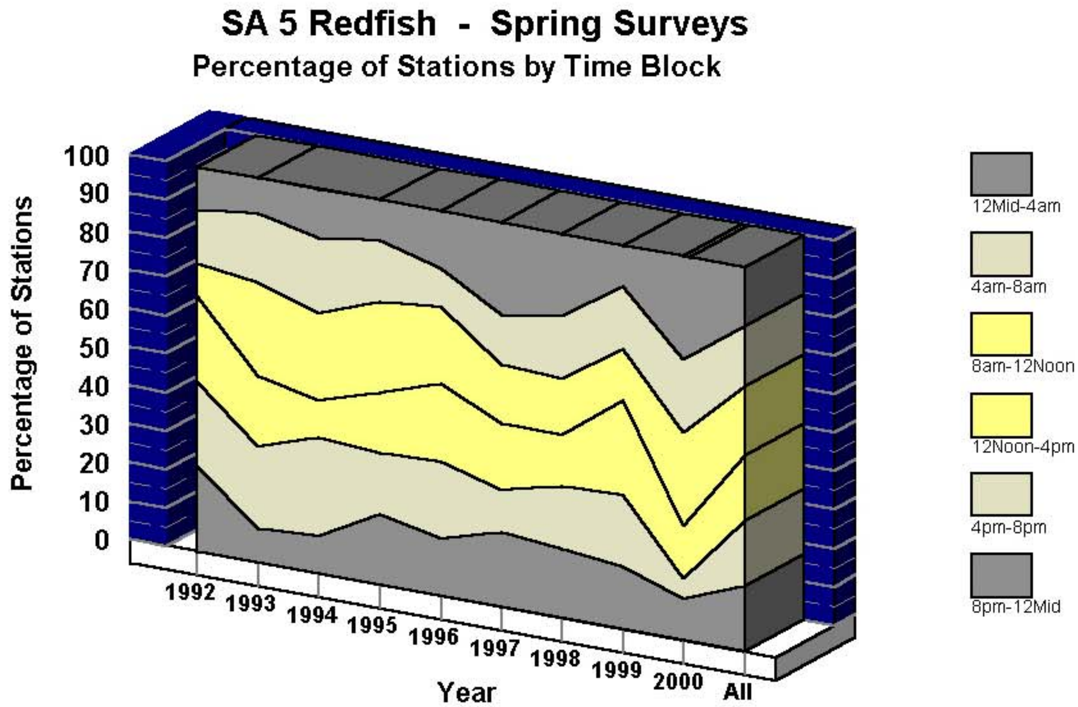


Figure 7. Relative catchability of redfish in NEFSC spring and autumn bottom trawl surveys.



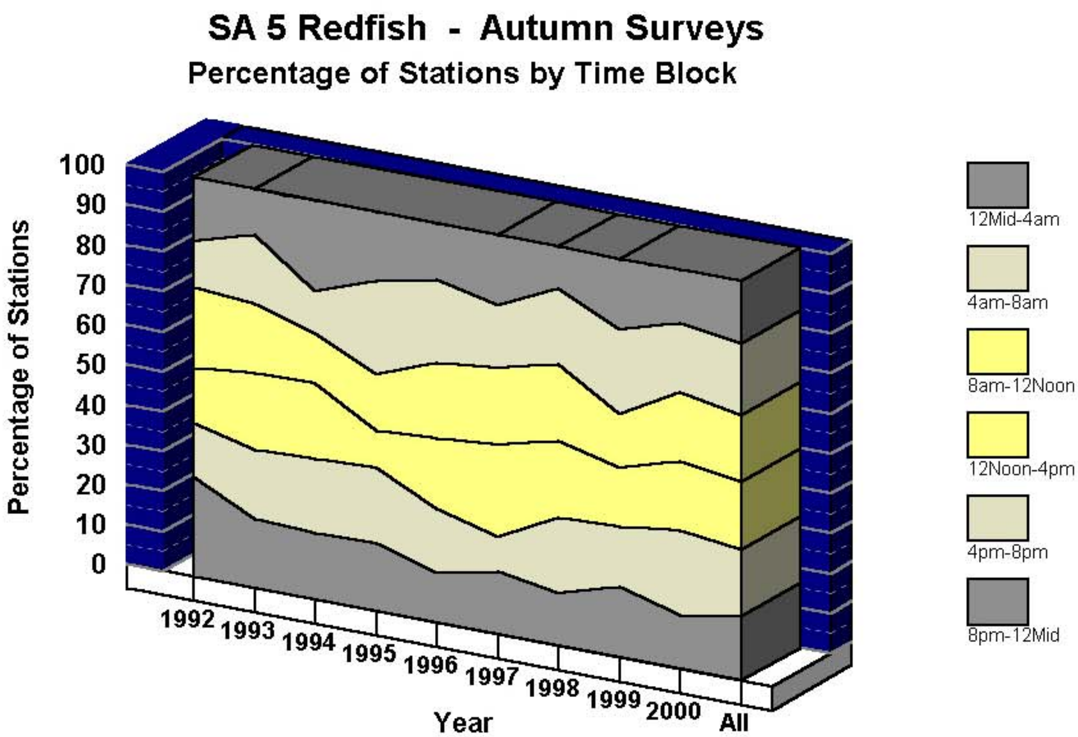


Figure 8. (a) Station coverage percentages by 4-hour time block, NEFSC spring surveys.
(b) Station coverage percentages by 4-hour time block; NEFSC autumn surveys.

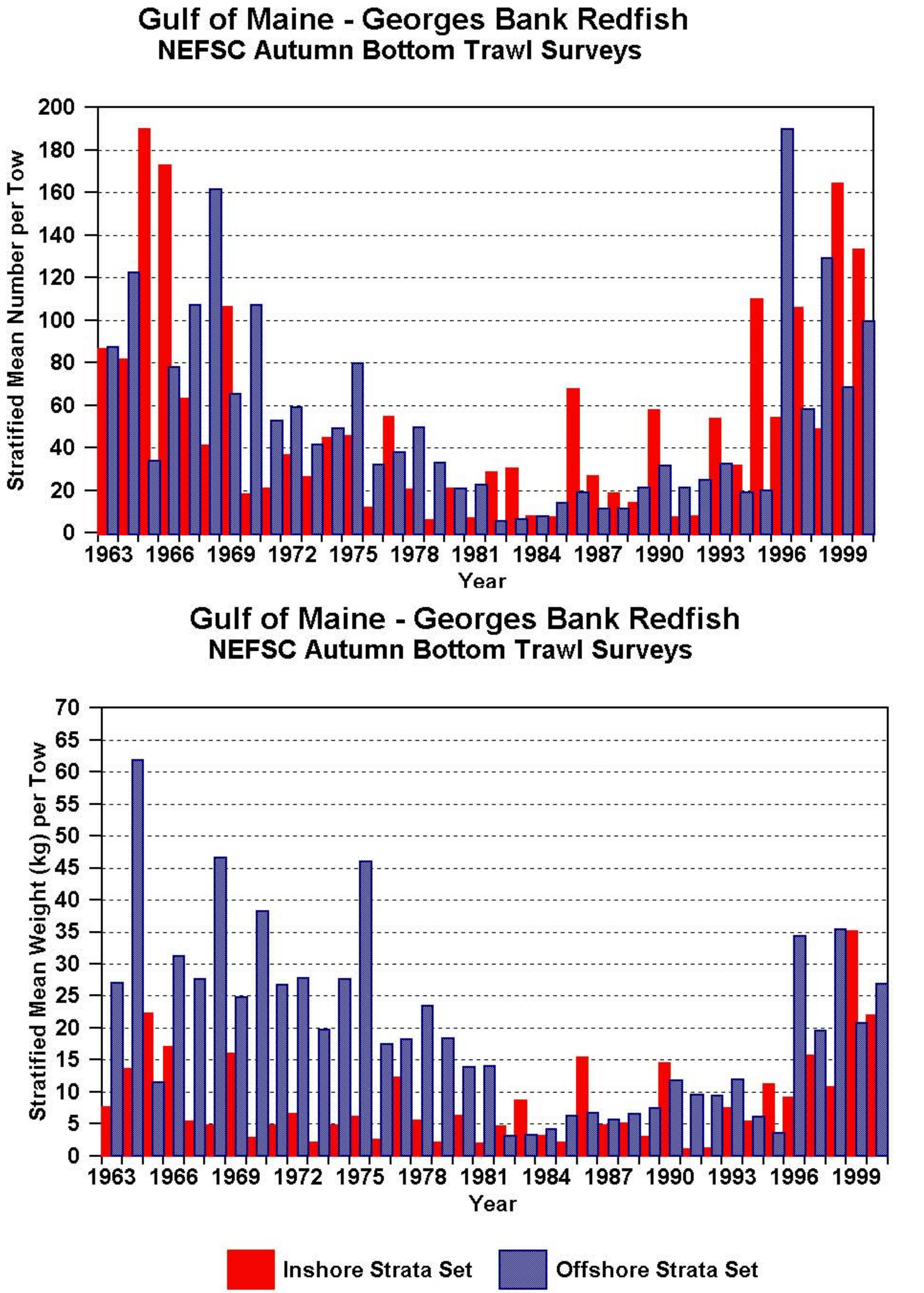
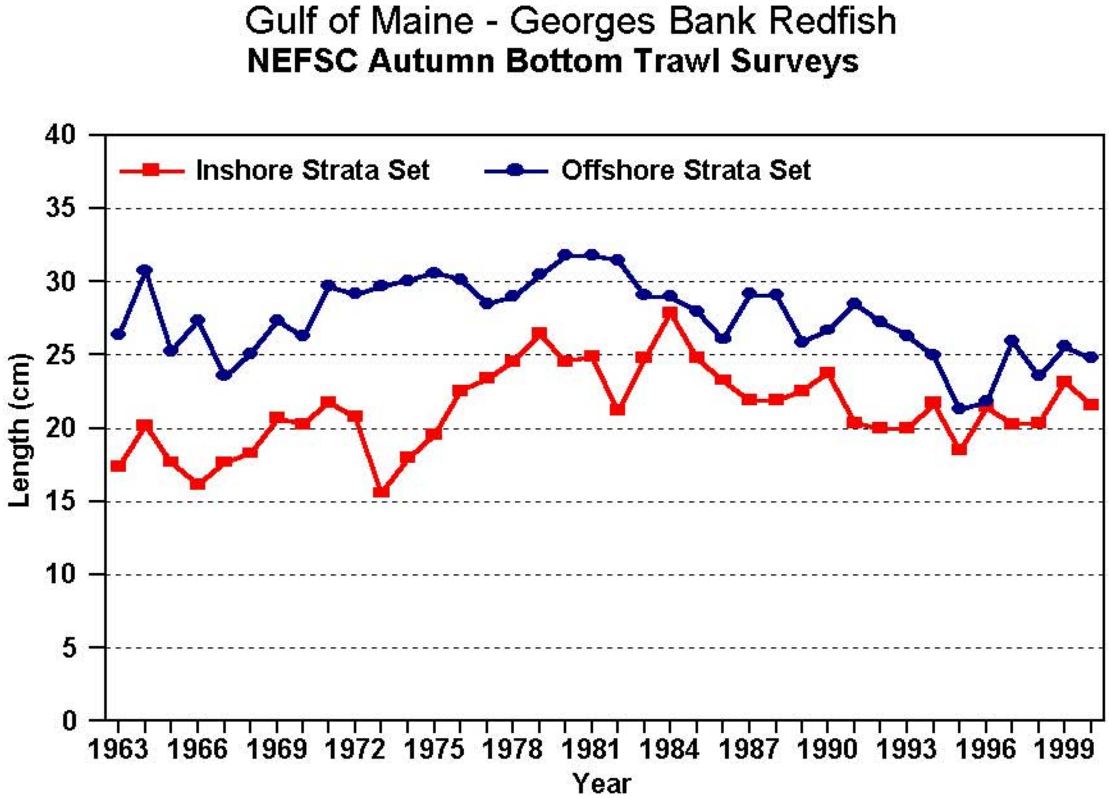


Figure 9. (a) Density indices (number per tow) for redfish in NEFSC autumn inshore and offshore strata sets.
(b) Density indices (weight per tow) for redfish in NEFSC autumn inshore and offshore strata sets.



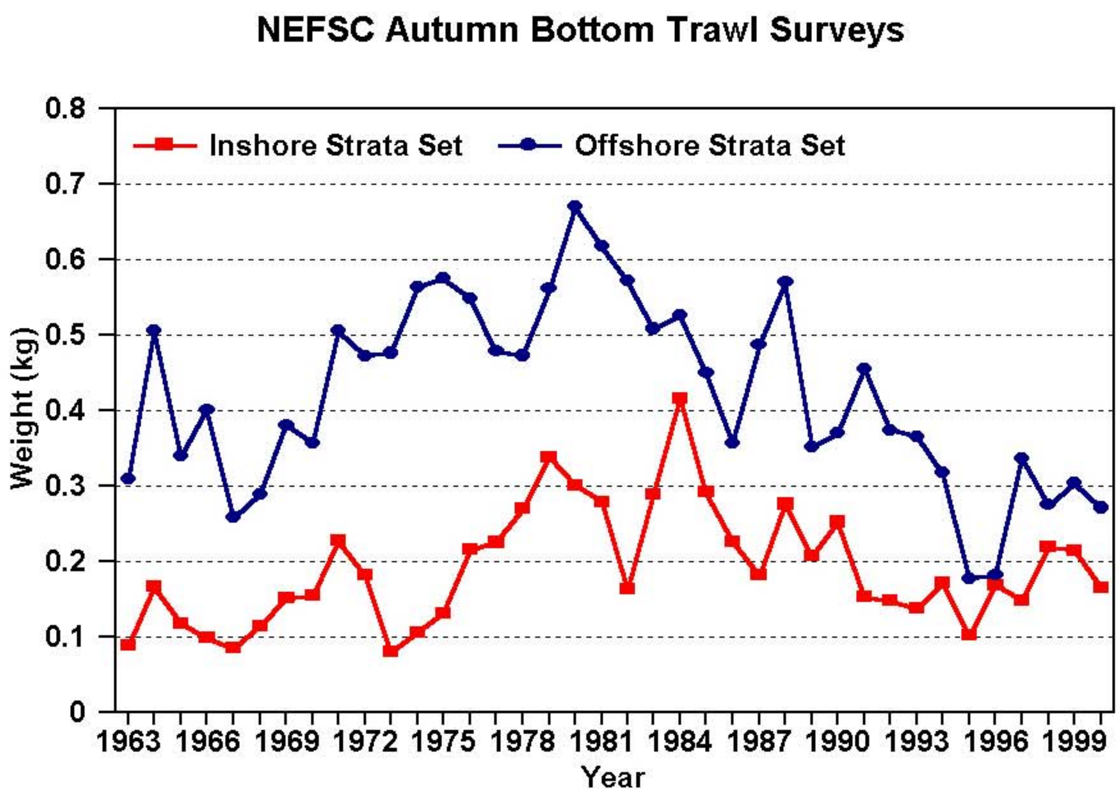
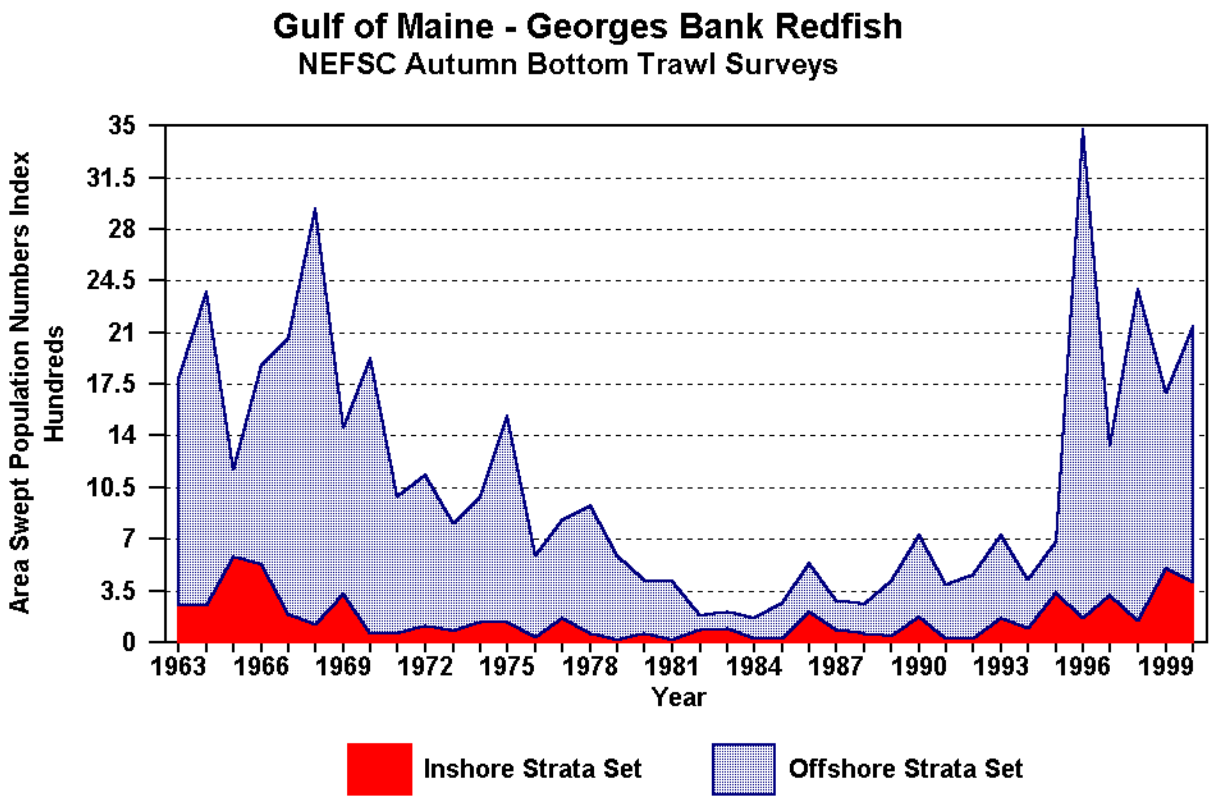


Figure 10. (a) Mean length (cm) of redfish in NEFSC autumn survey inshore and offshore strata sets.
(b) Mean weight (kg) of redfish in NEFSC autumn survey inshore and offshore strata sets.



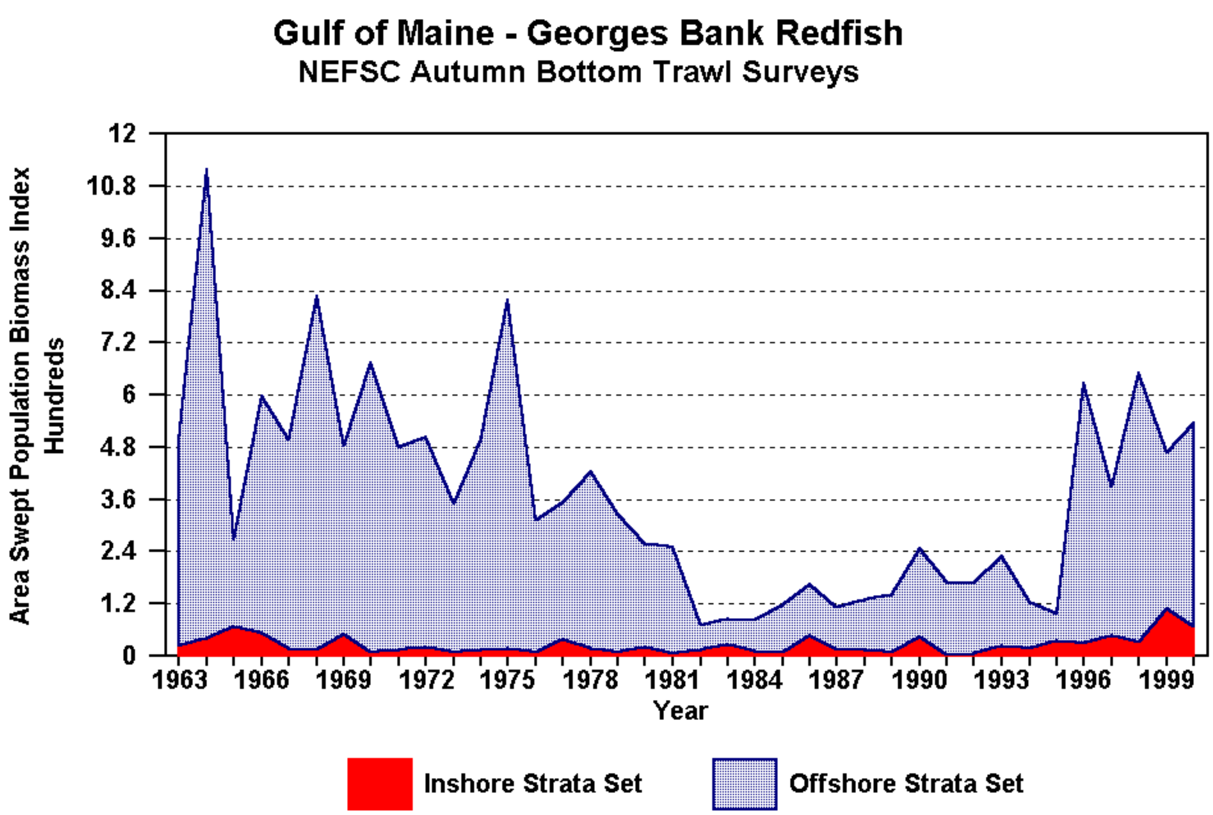


Figure 11. (a) Index of area swept abundance of redfish in NEFSC autumn inshore and offshore strata sets.
(b) Index of swept area biomass of redfish in NEFSC autumn inshore and offshore strata sets.

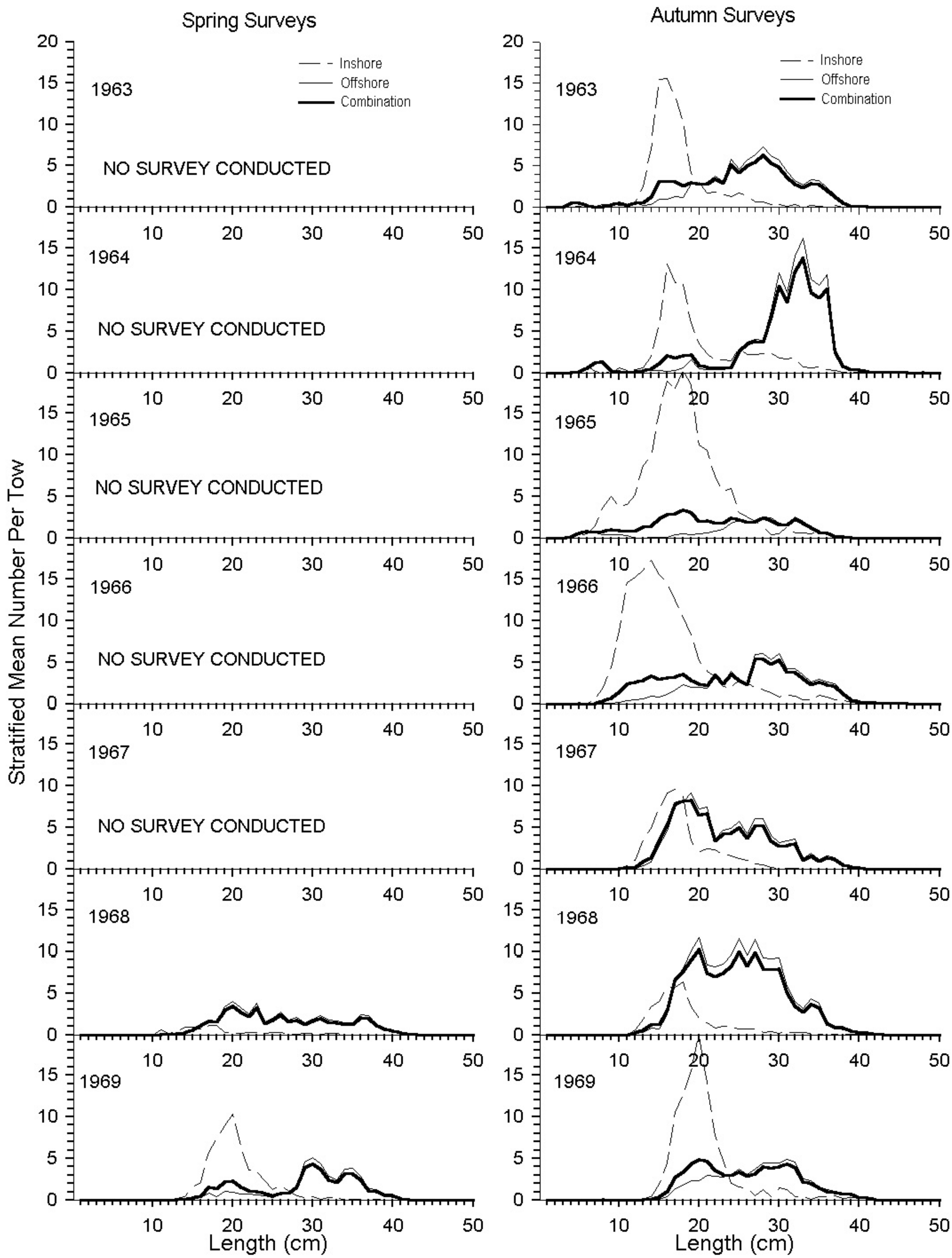


Figure 12. Length composition of redfish in NEFSC spring and autumn surveys.

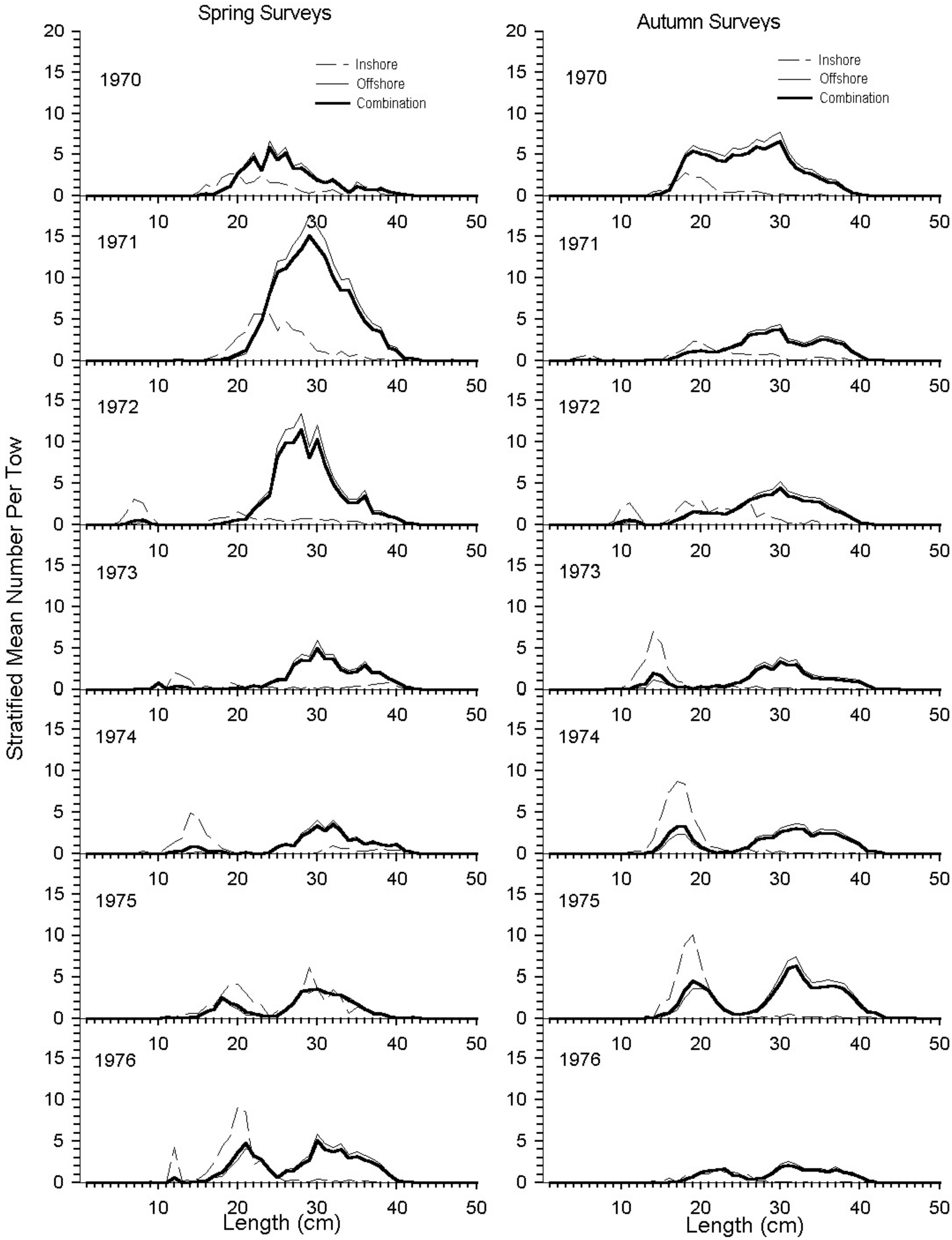


Figure 12 (Continued).

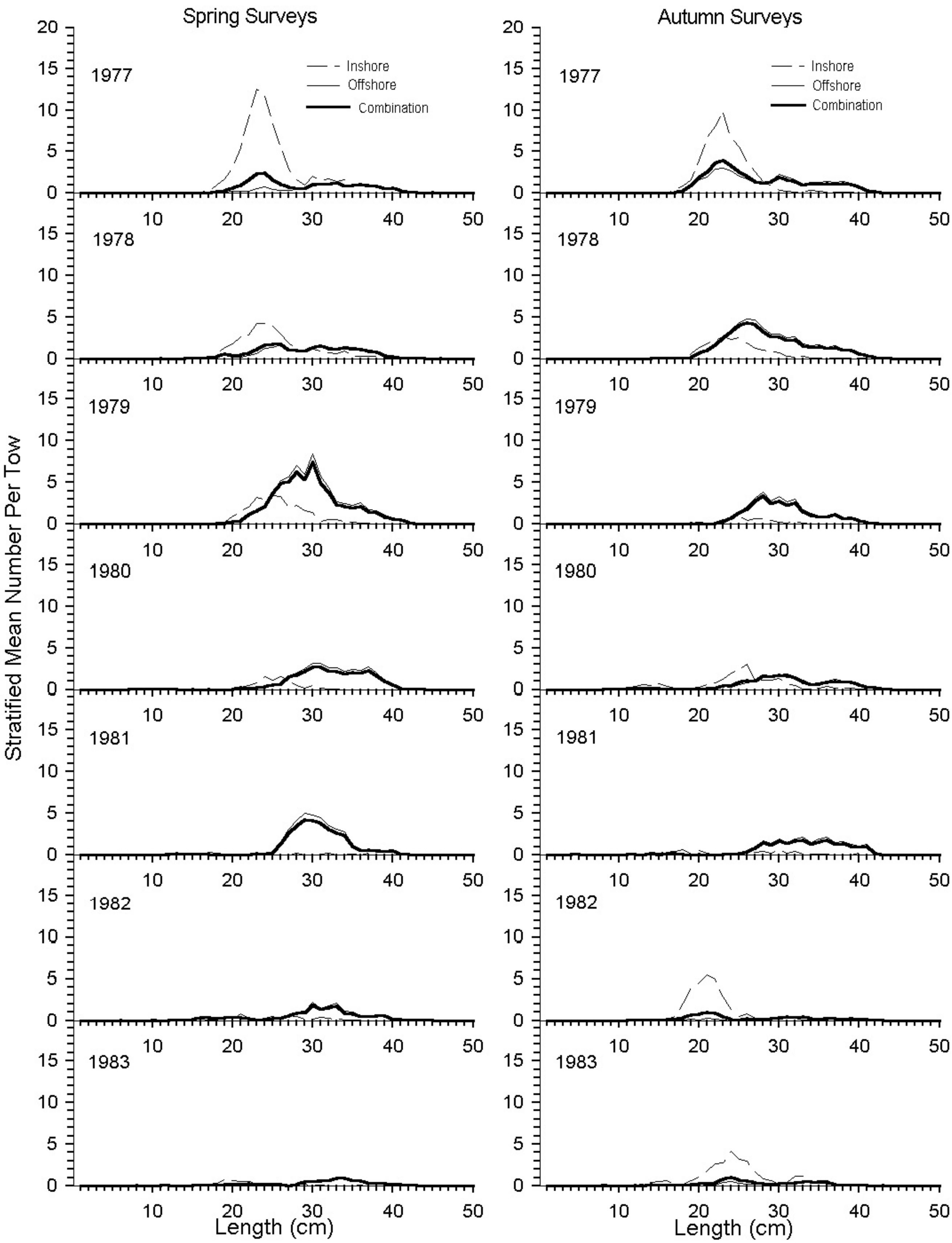


Figure 12 (Continued).

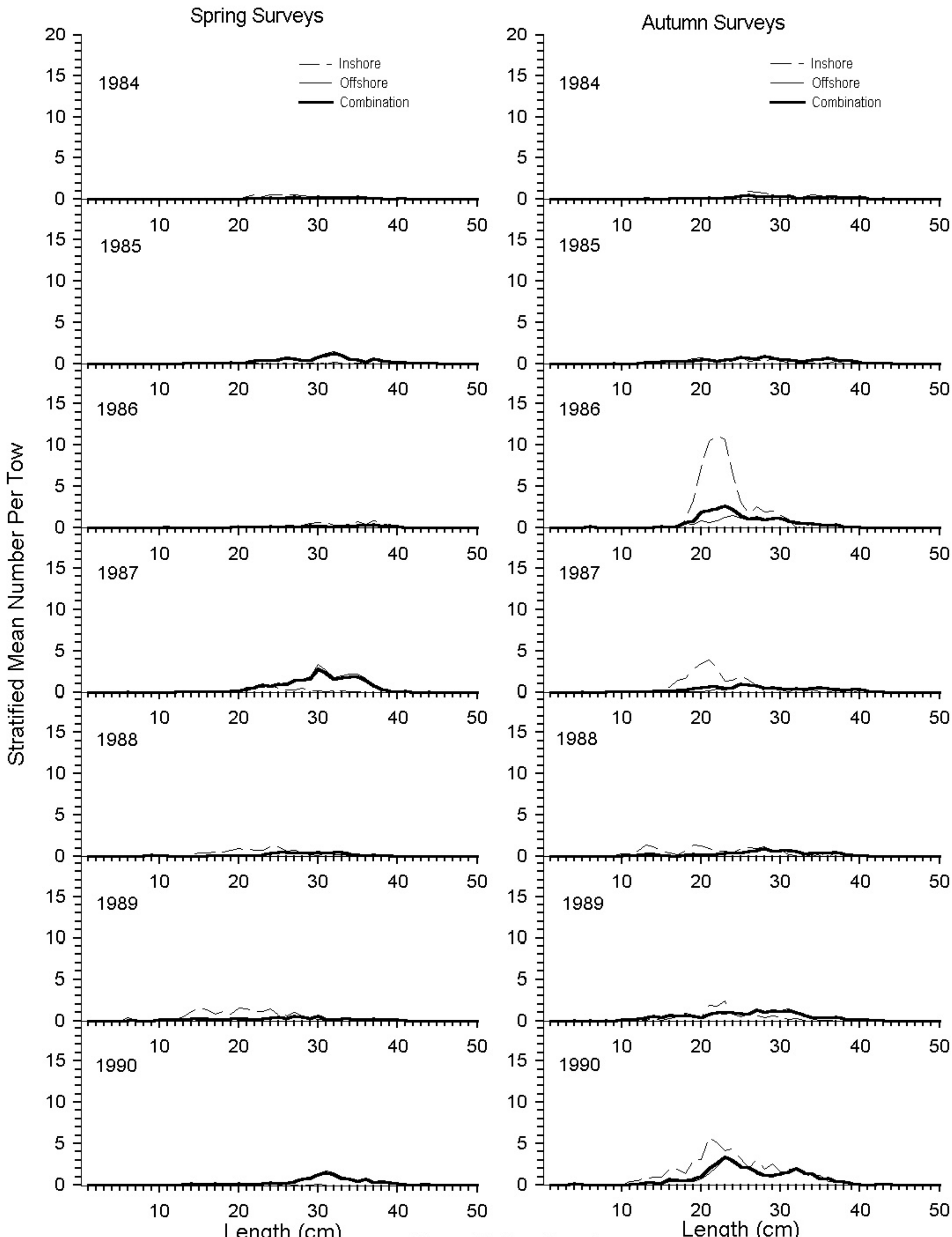


Figure 12 (Continued).

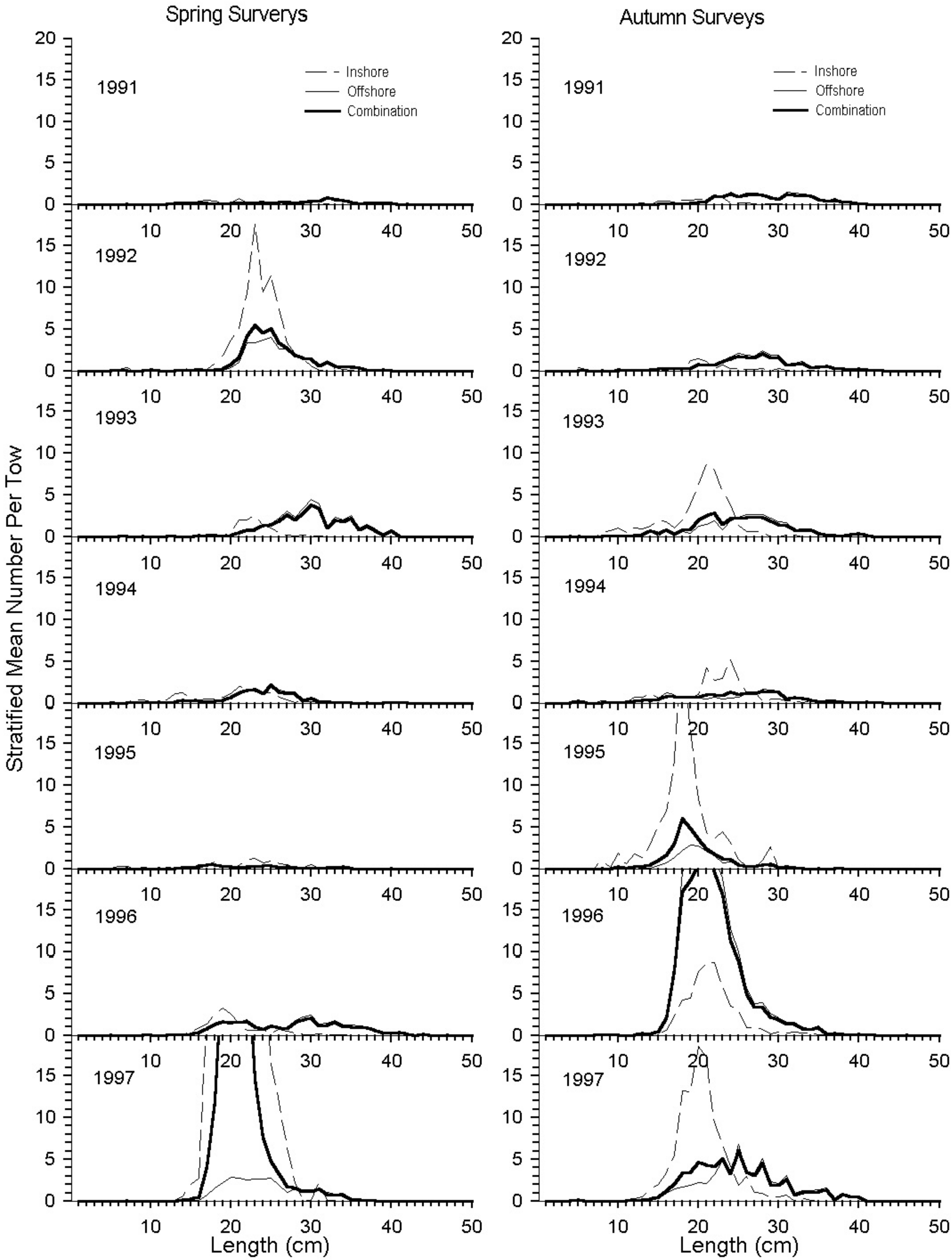


Figure 12 (Continued).

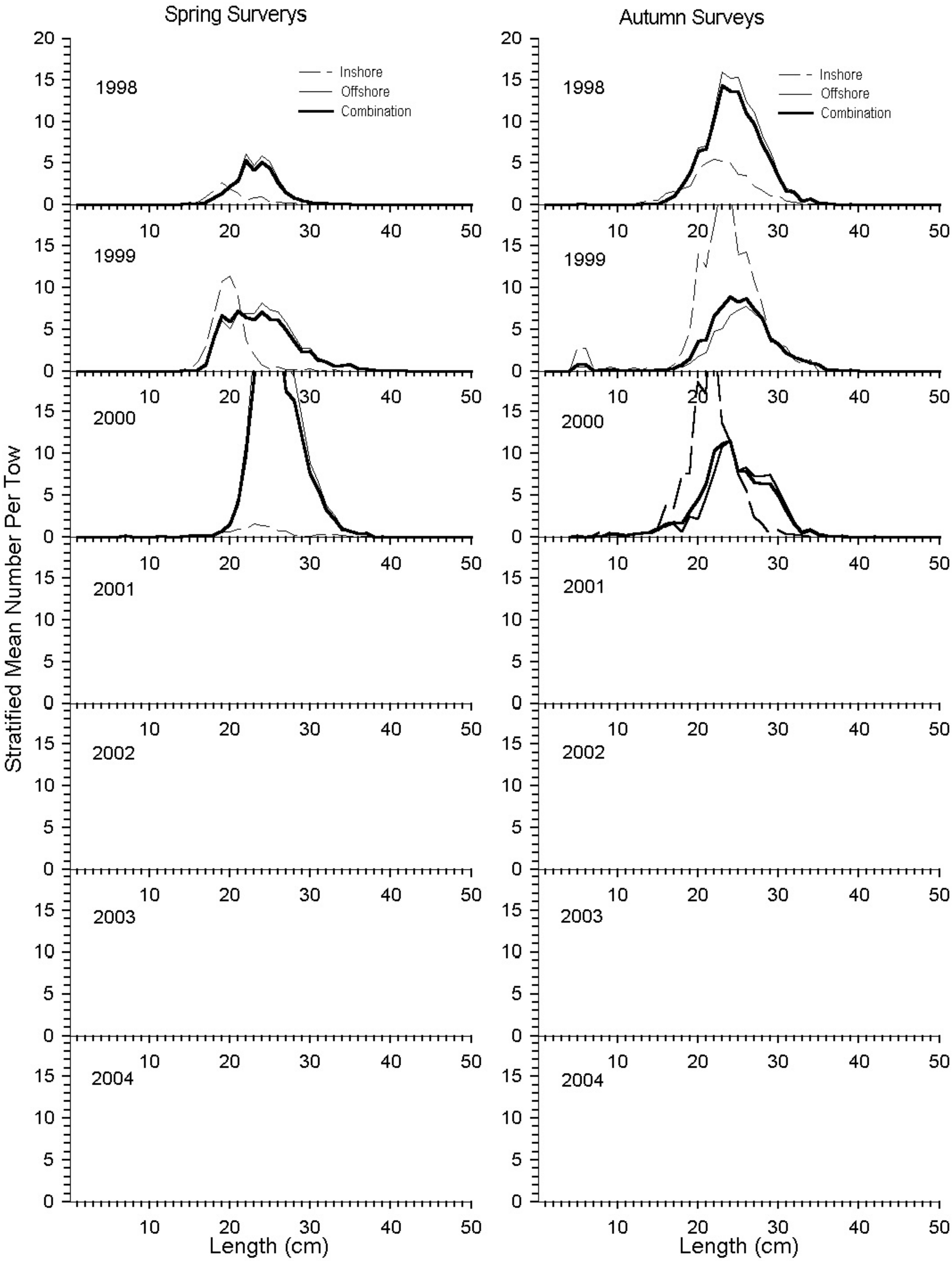


Figure 12 (Continued).

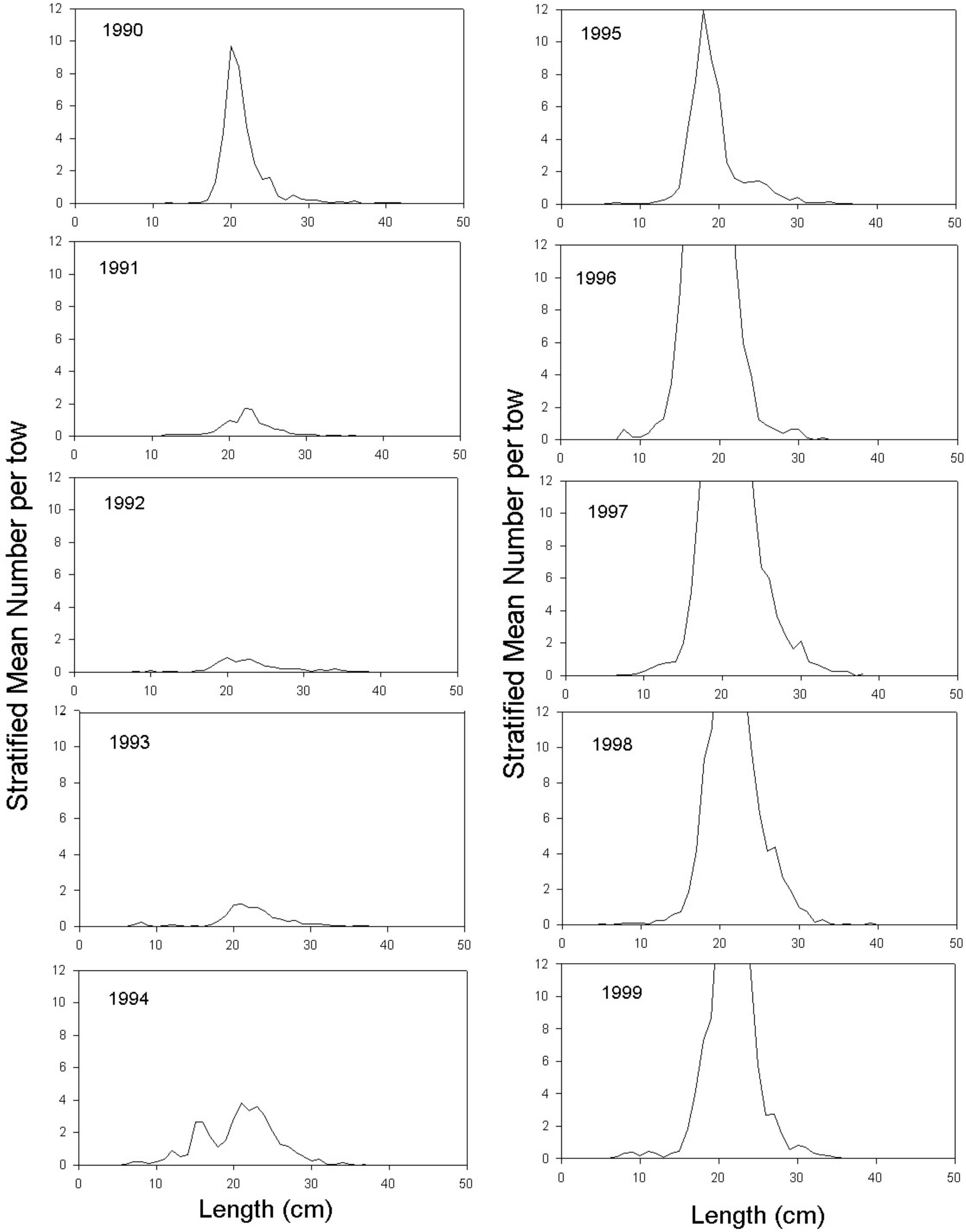


Figure 12a. Length composition of redfish from NEFSC shrimp surveys.

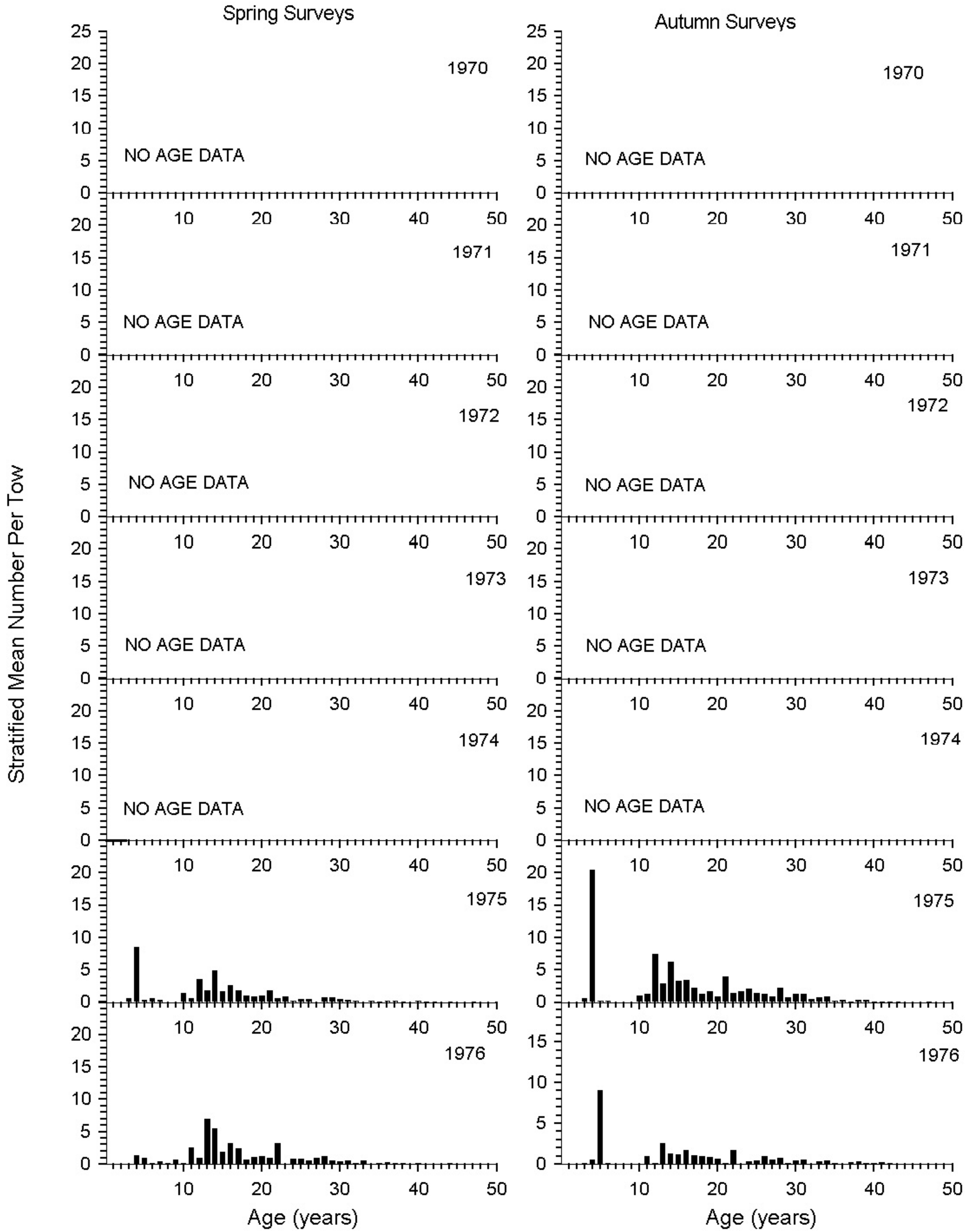


Figure 13. Age composition of redfish in NEFSC spring and autumn surveys.

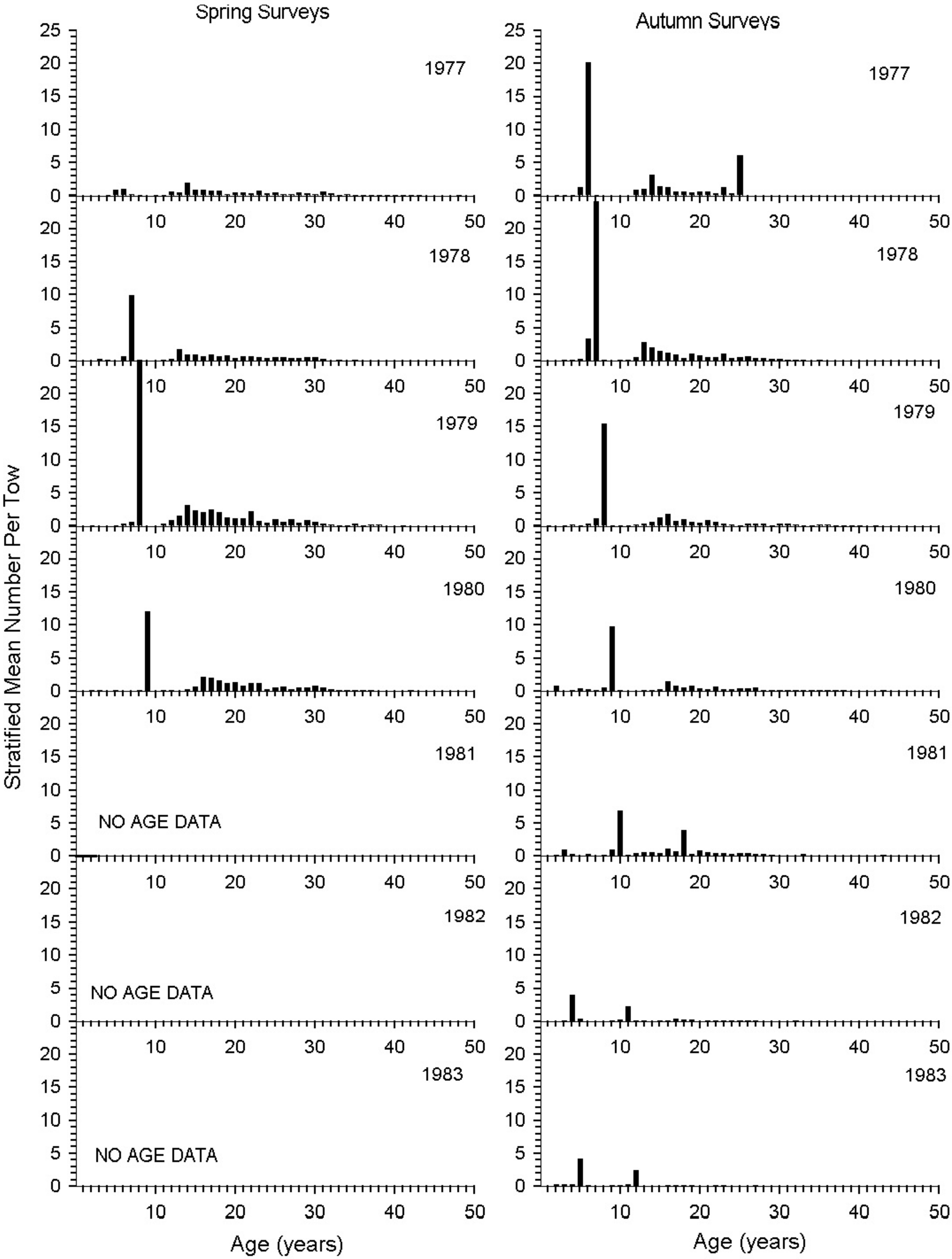


Figure 13 (Continued).

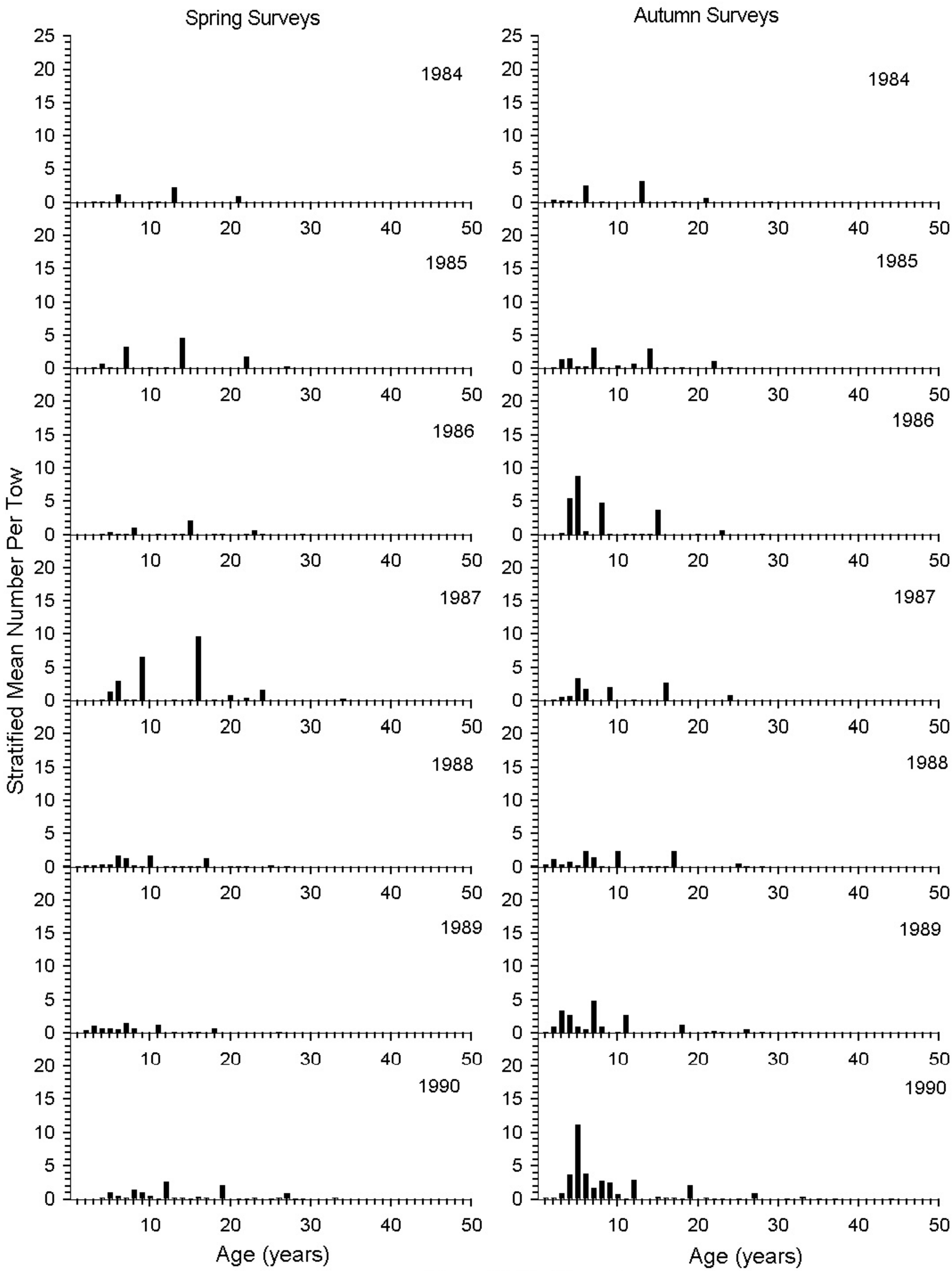


Figure 13 (Continued).

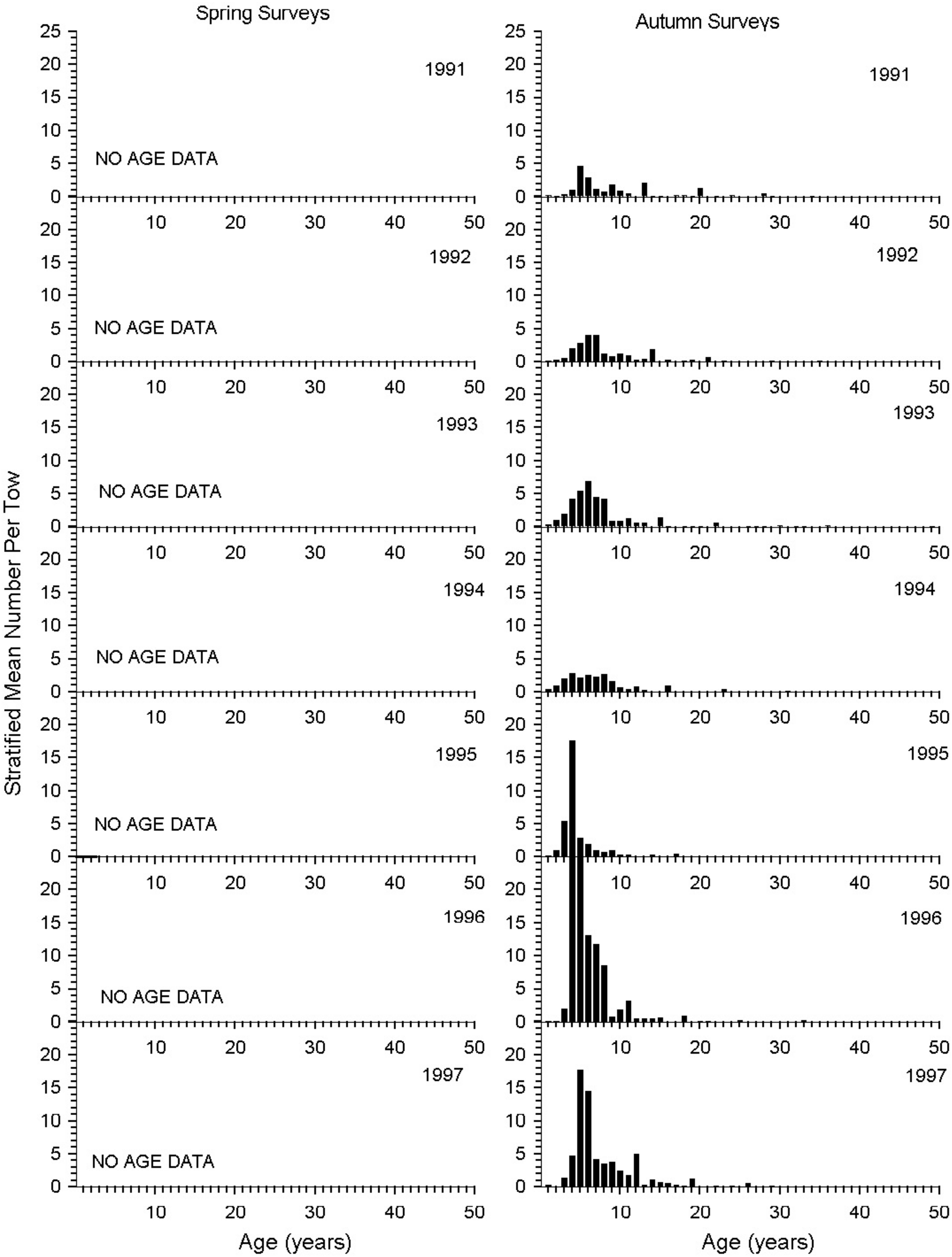


Figure 13 (Continued).

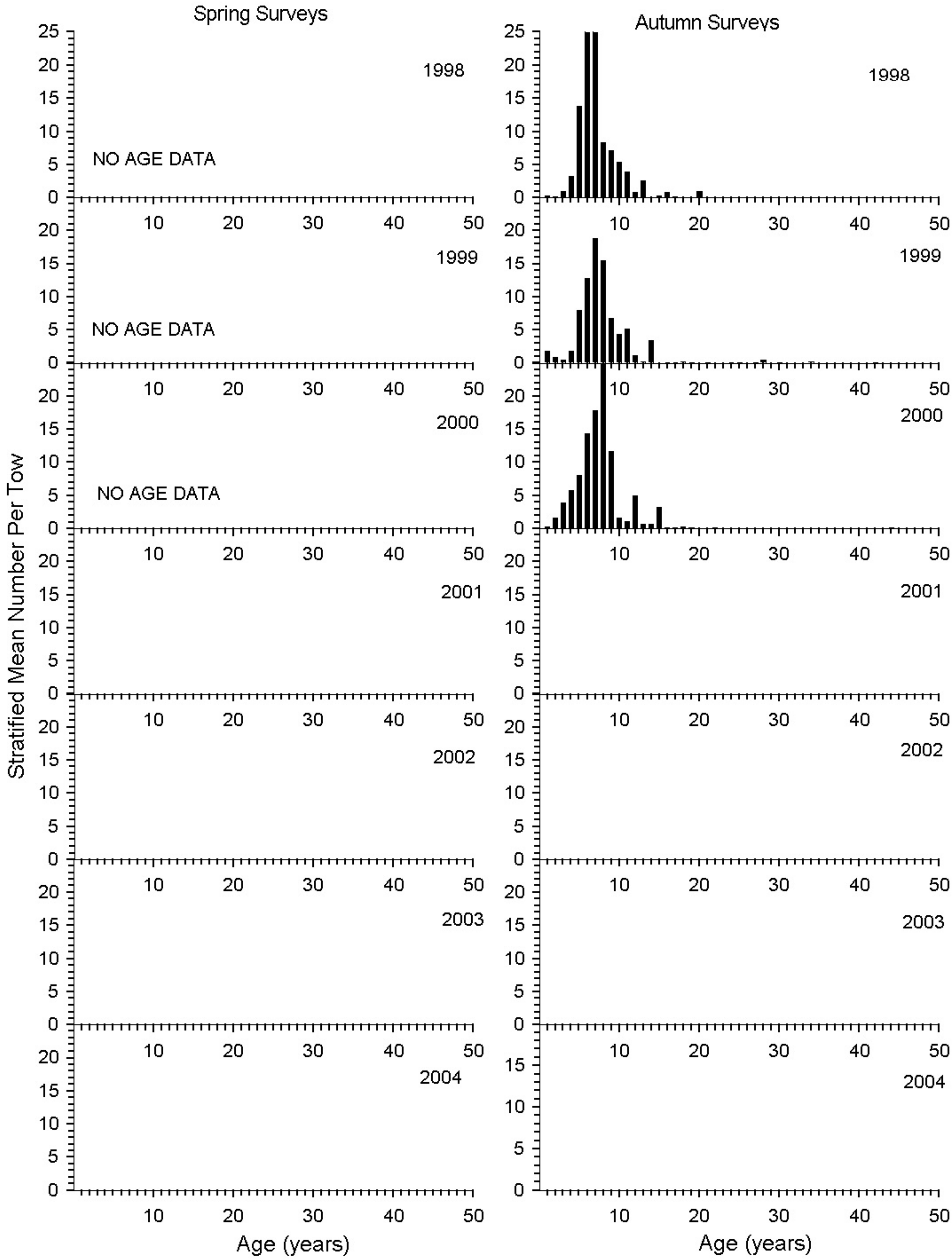


Figure 13 (Continued).

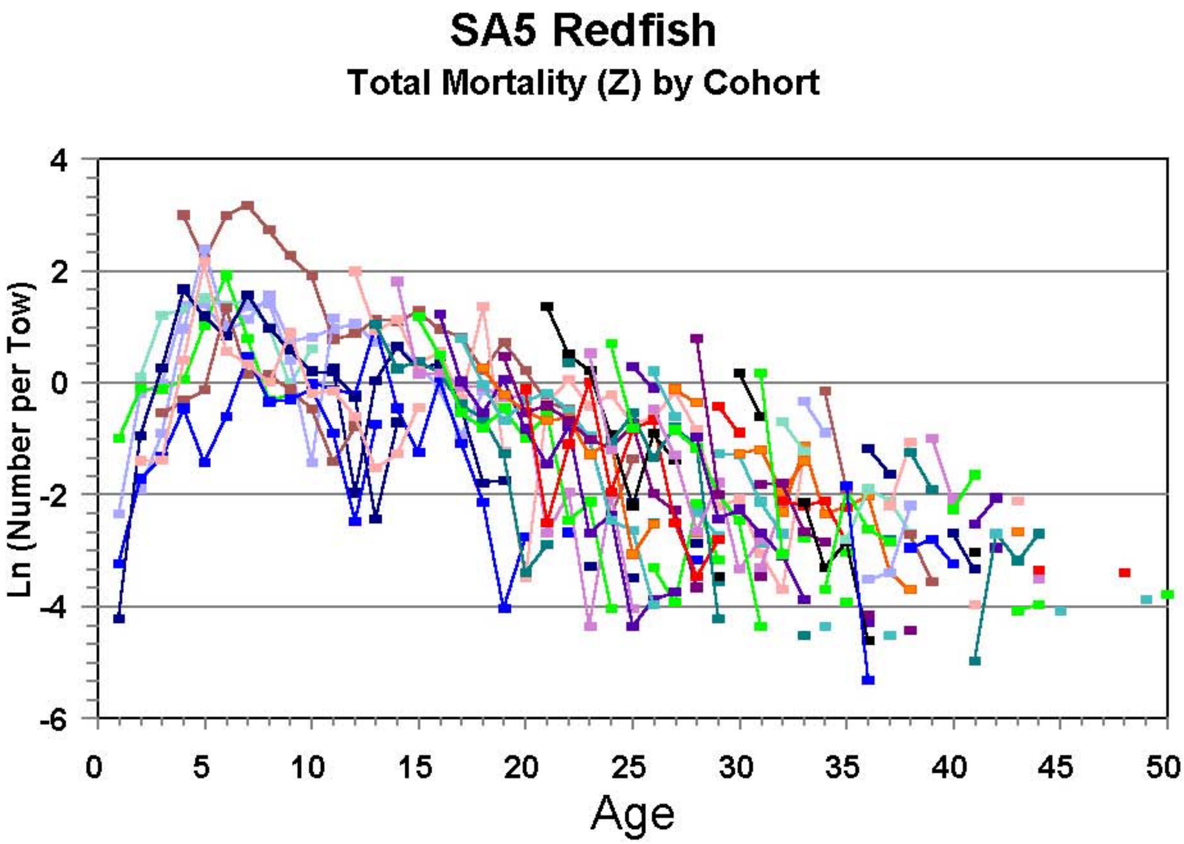


Figure 14. Catch curves based on redfish cohorts from 1925-1995.

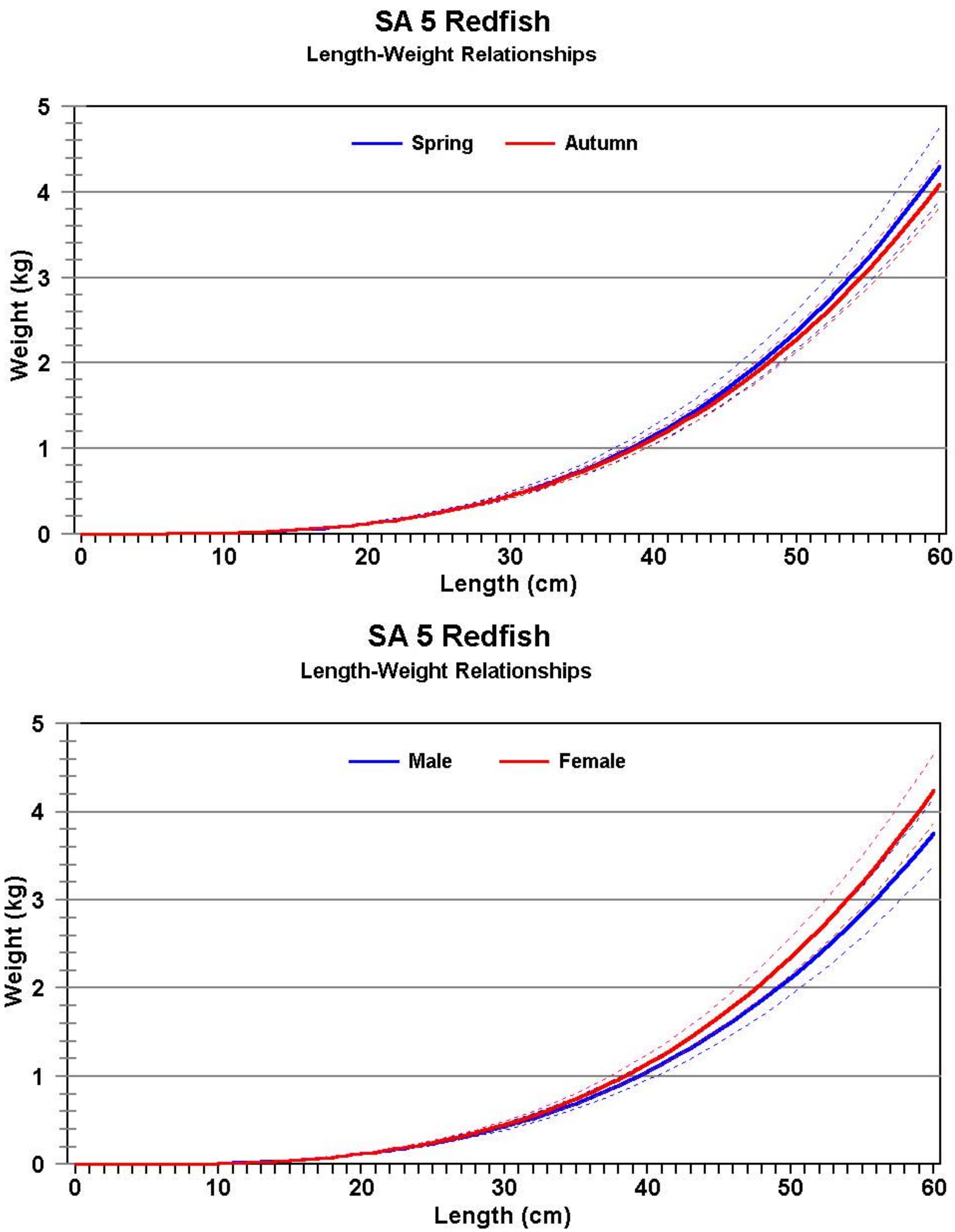
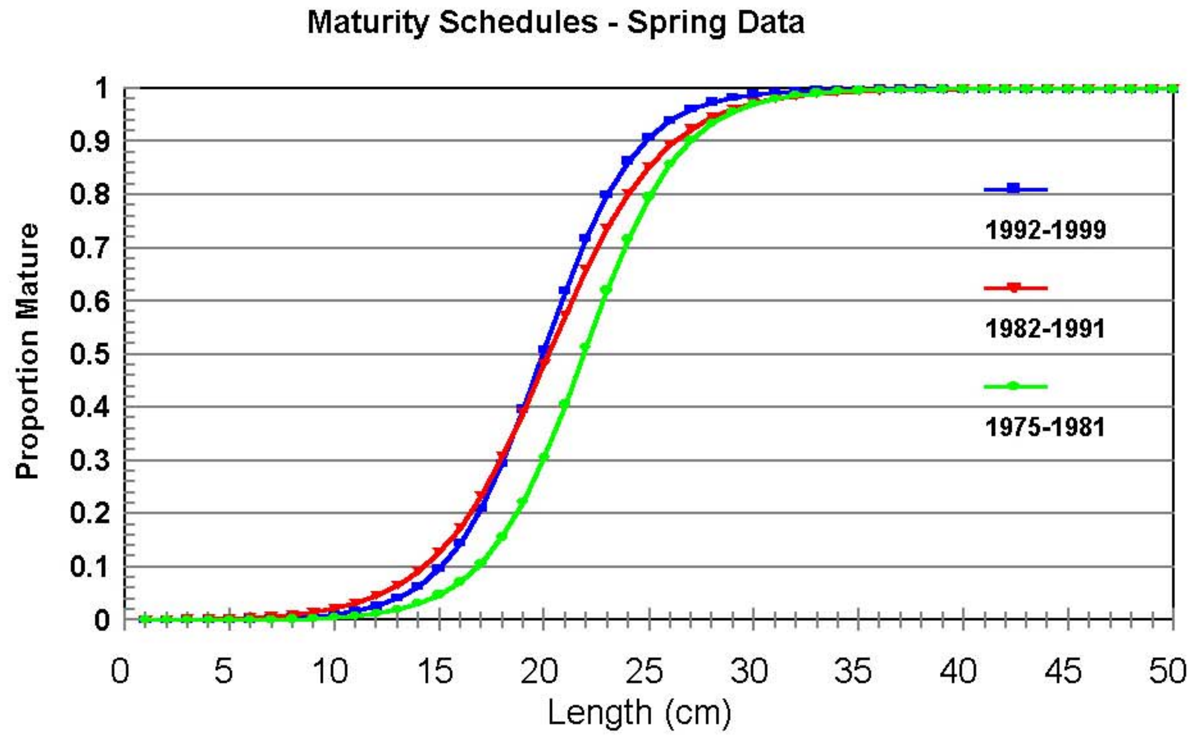


Figure 15. Length-weight relationships for redfish (a) by season and (by) by sex from NEFSC spring and autumn bottom trawl surveys, 1992-2000.

SA 5 Redfish



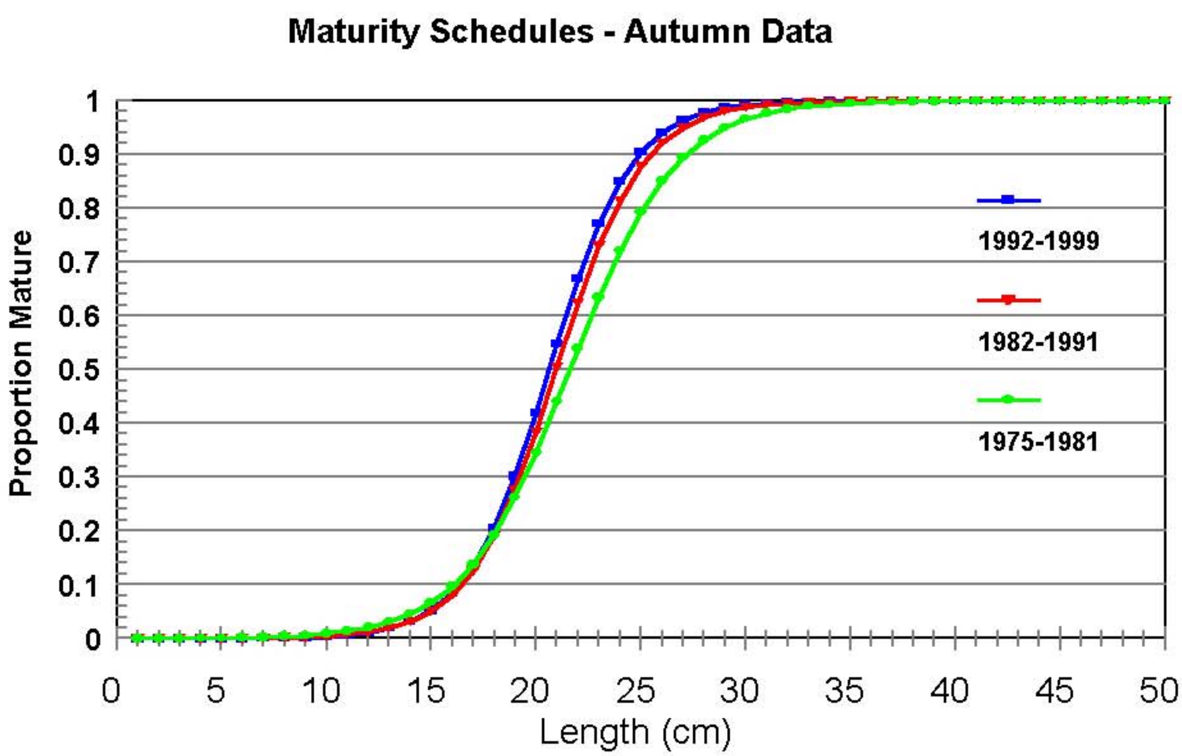


Figure 16. Maturity at length results for redfish (sexes combined) for three time periods from NEFSC (a) spring and (b) autumn bottom trawl surveys, 1975-1999.

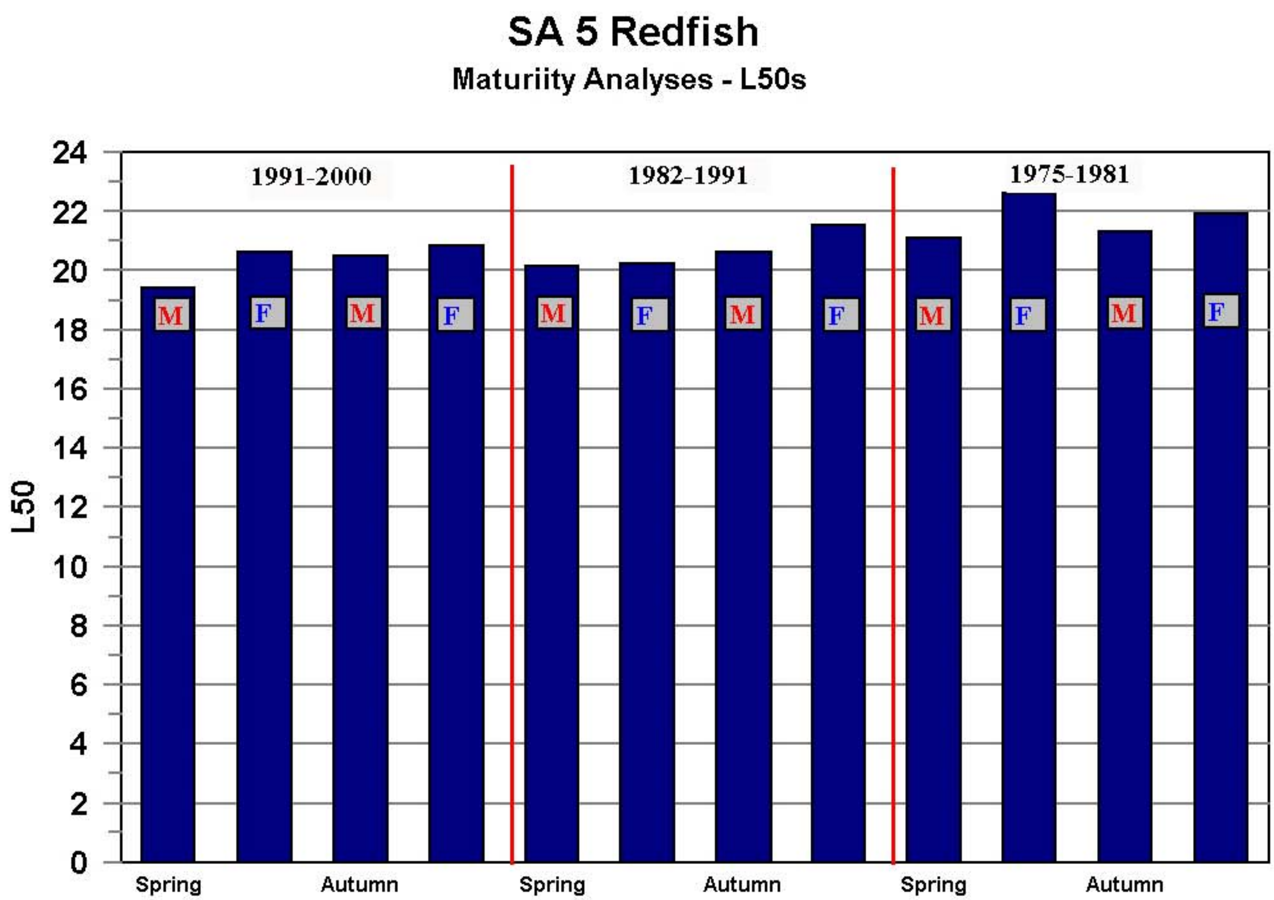


Figure 17. Median length at maturity (L50) by sex for redfish for three time periods from NEFSC spring and autumn bottom trawl surveys.

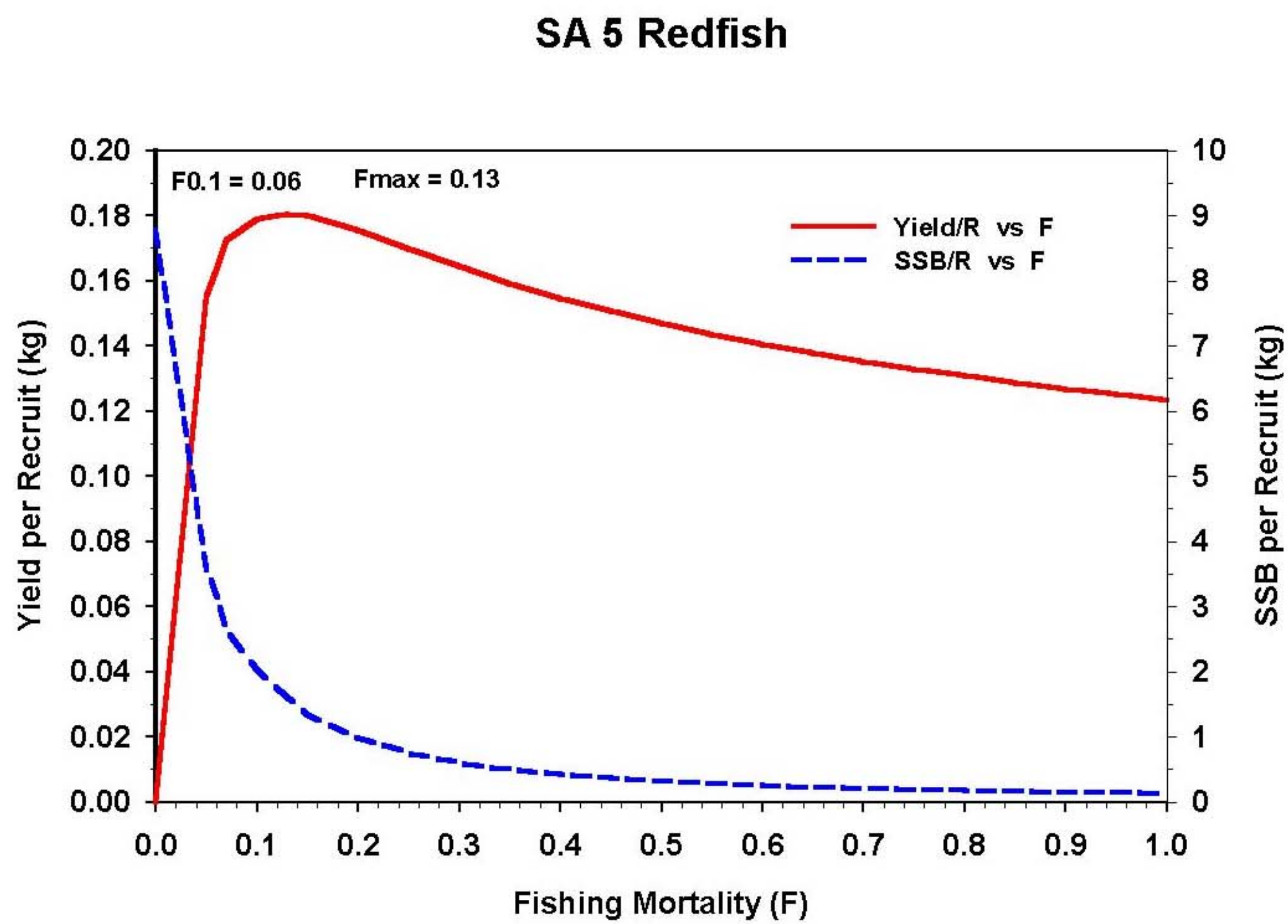
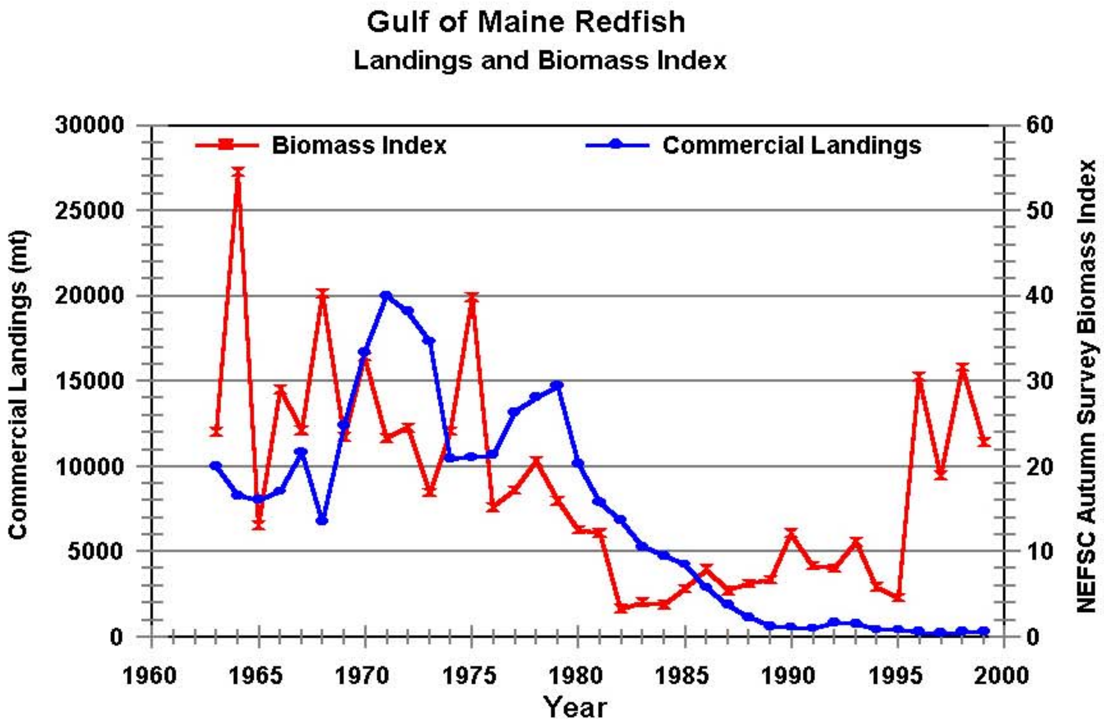


Figure 18. Yield and spawning stock biomass per recruit (kg) for redfish in the Gulf of Maine - Georges Bank region.



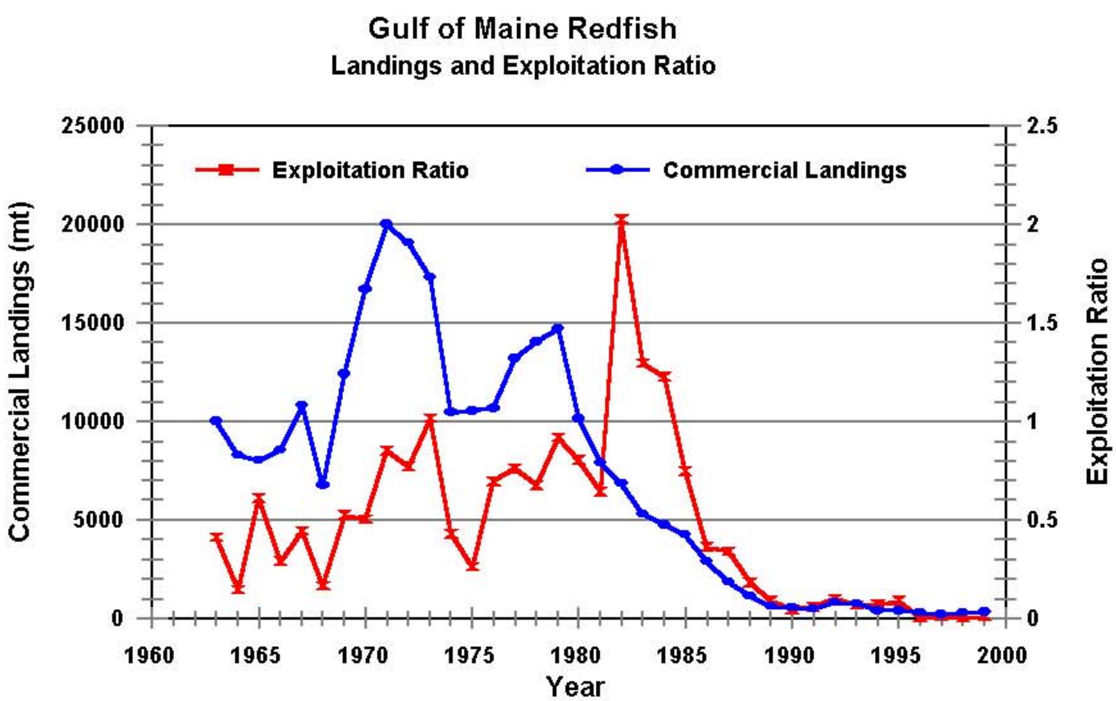
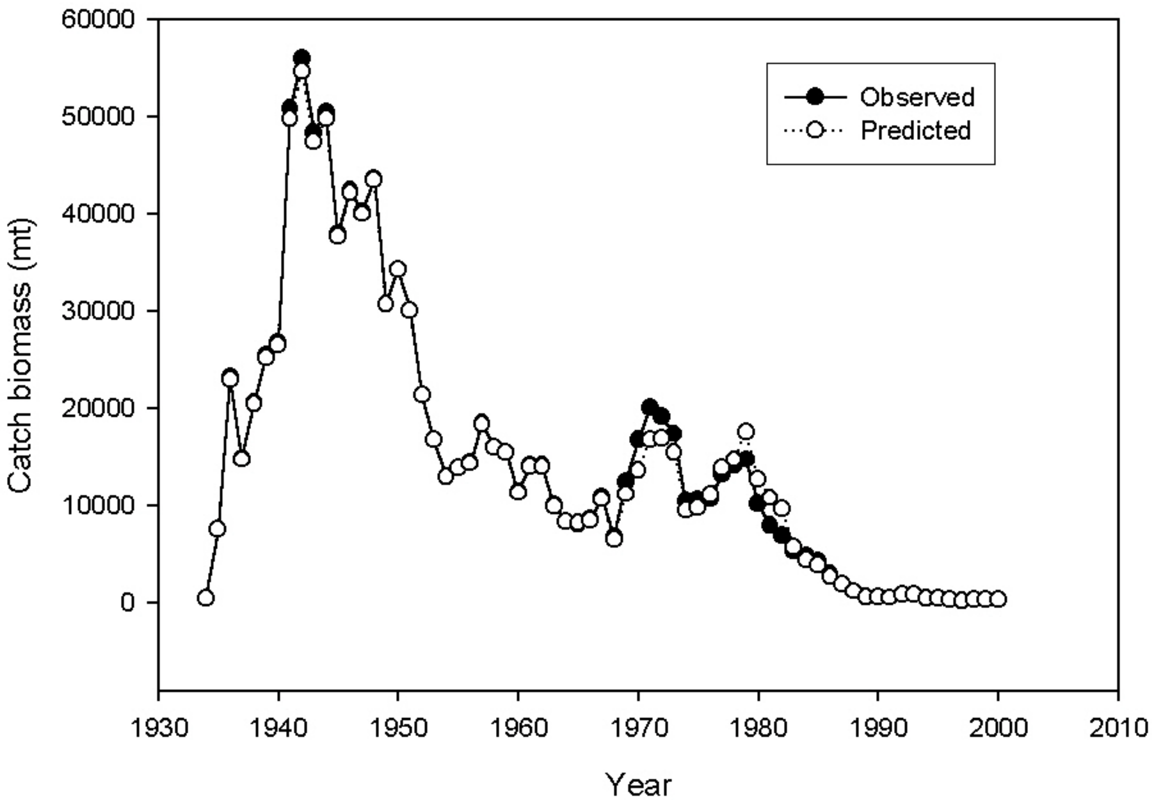


Figure 19. Exploitation index for Gulf of Maine-Georges Bank Redfish expressed as the ratio of NEFSC autumn biomass index to total fisheey removals, 1963-2000.

Figure 20. Redfish catch biomass residuals (mt), 1934-2000
including 1999-2000 autumnm survey age data.



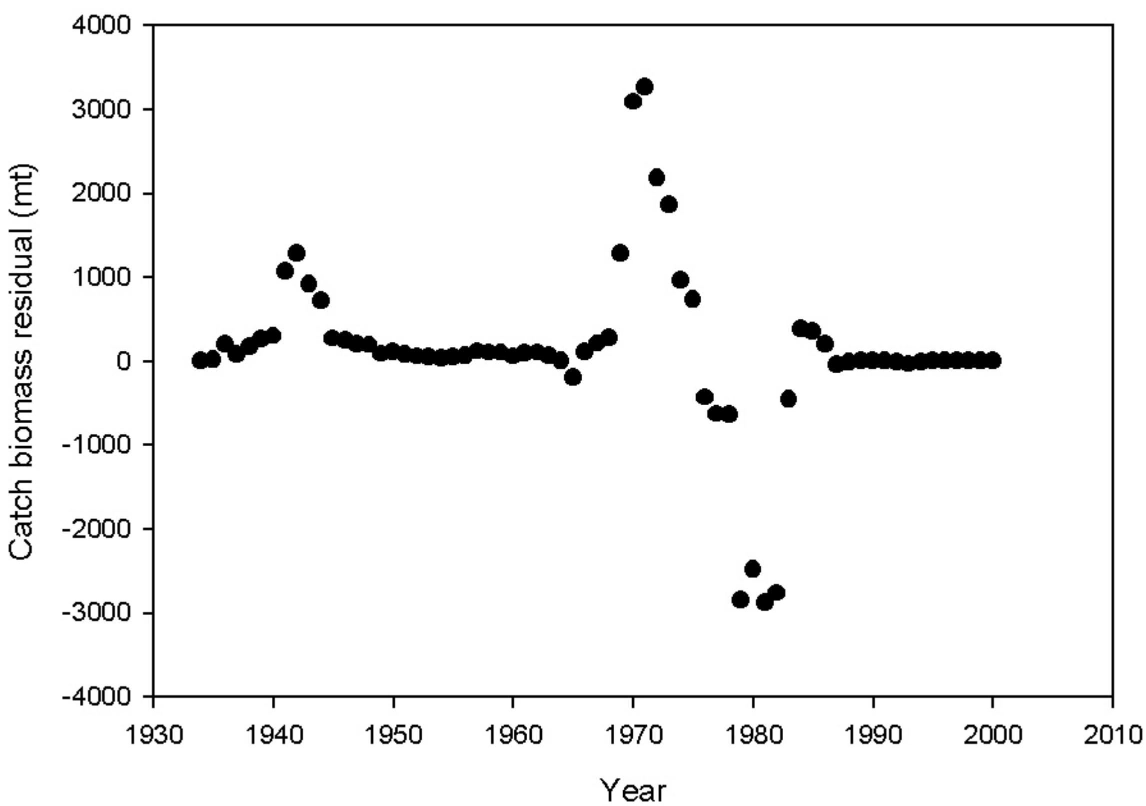


Figure 21. NEFSC autumn survey redfish biomass index residuals, 1963-2000 including 1999-2000 autumn survey age data

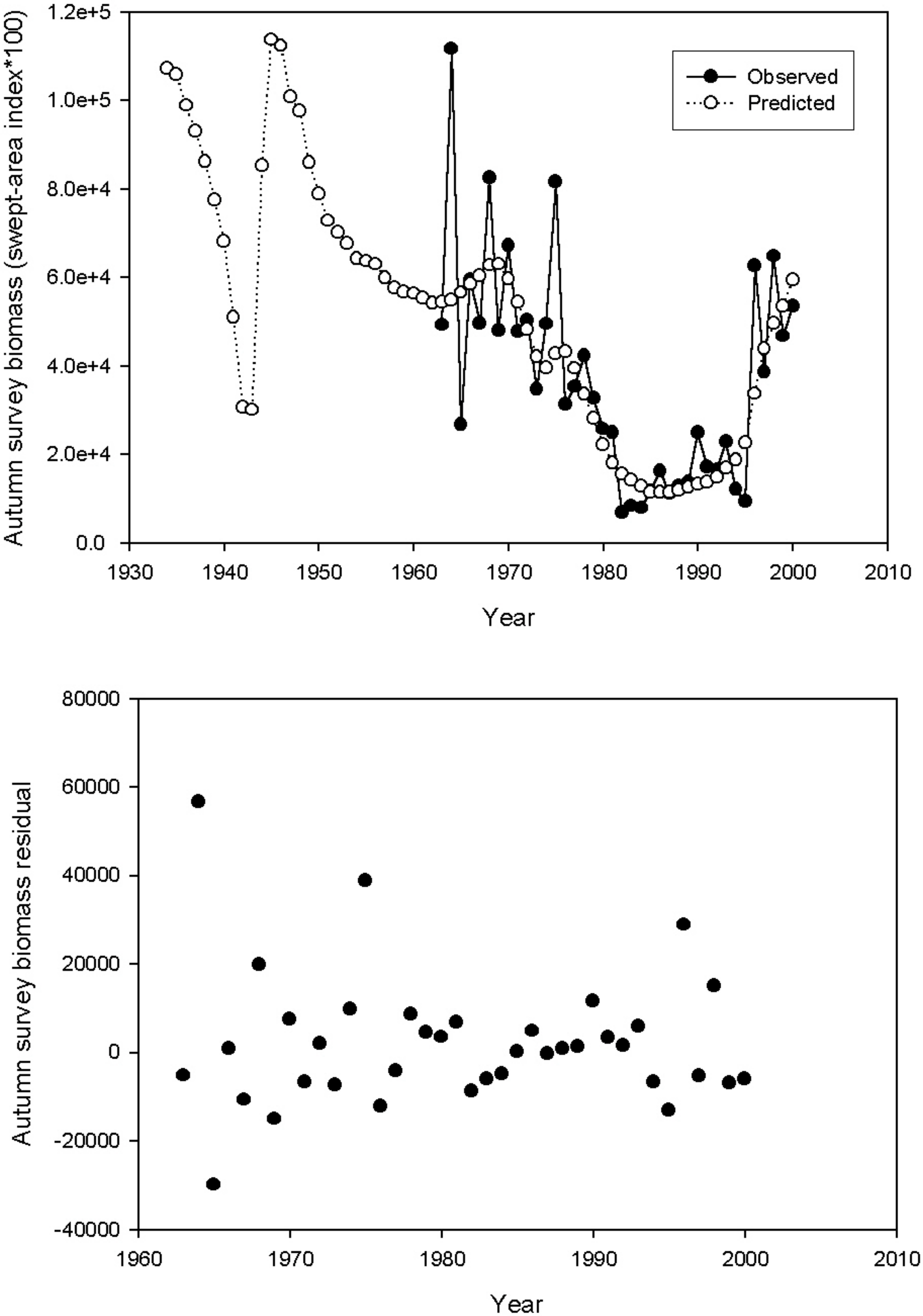
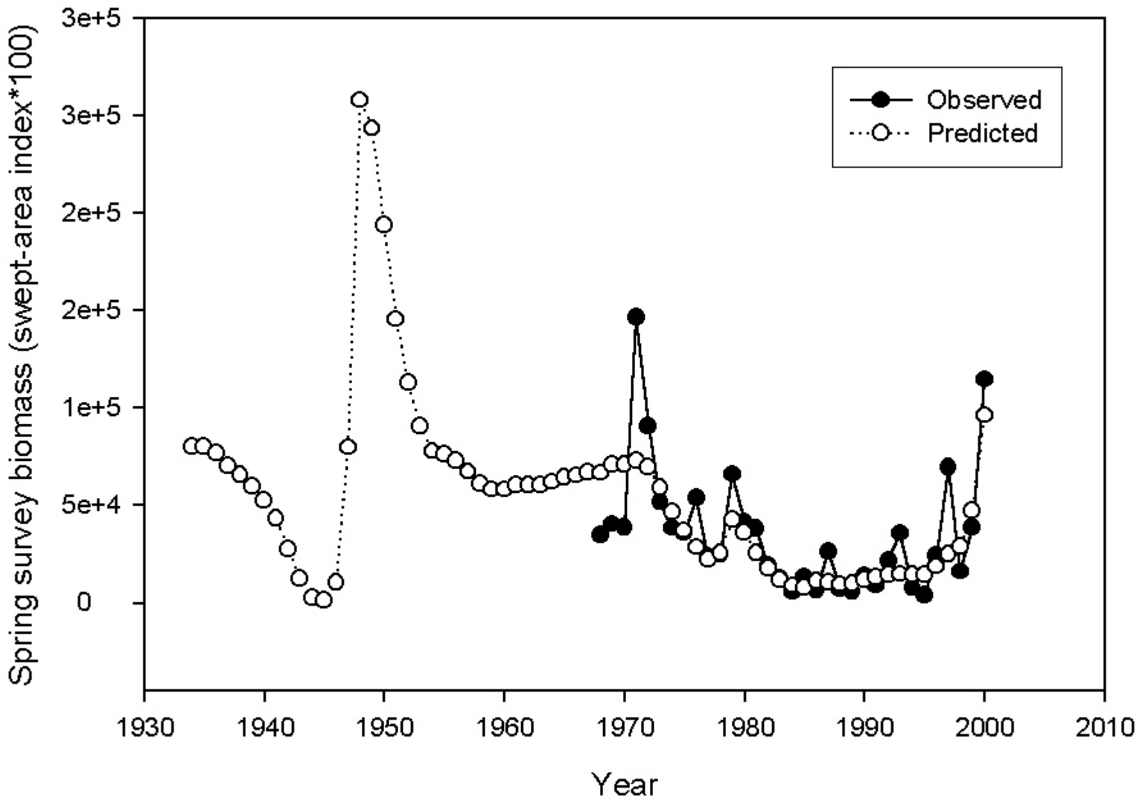


Figure 22. NEFSC spring survey redfish biomass index residuals, 1968-2000 including 1999-2000 autumn survey age data



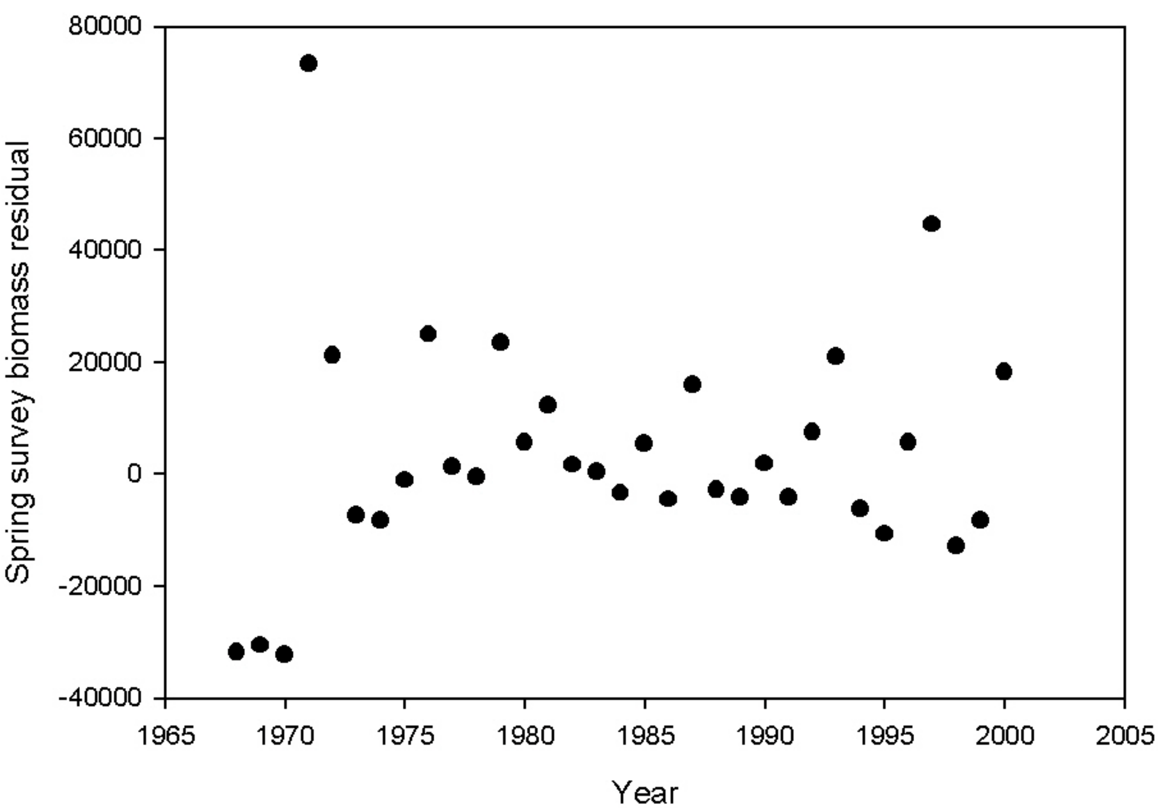
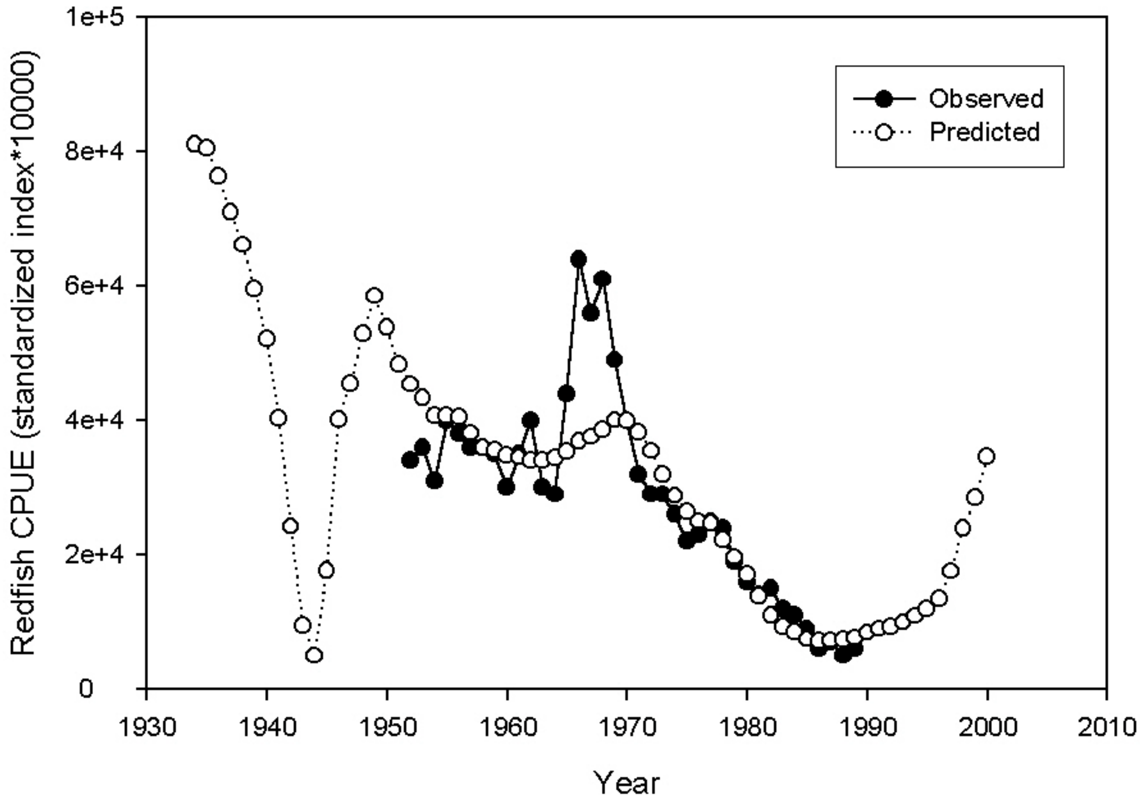


Figure 23. Standardized redfish CPUE index residuals, 1952-1989 including 1999-2000 autumn survey age data



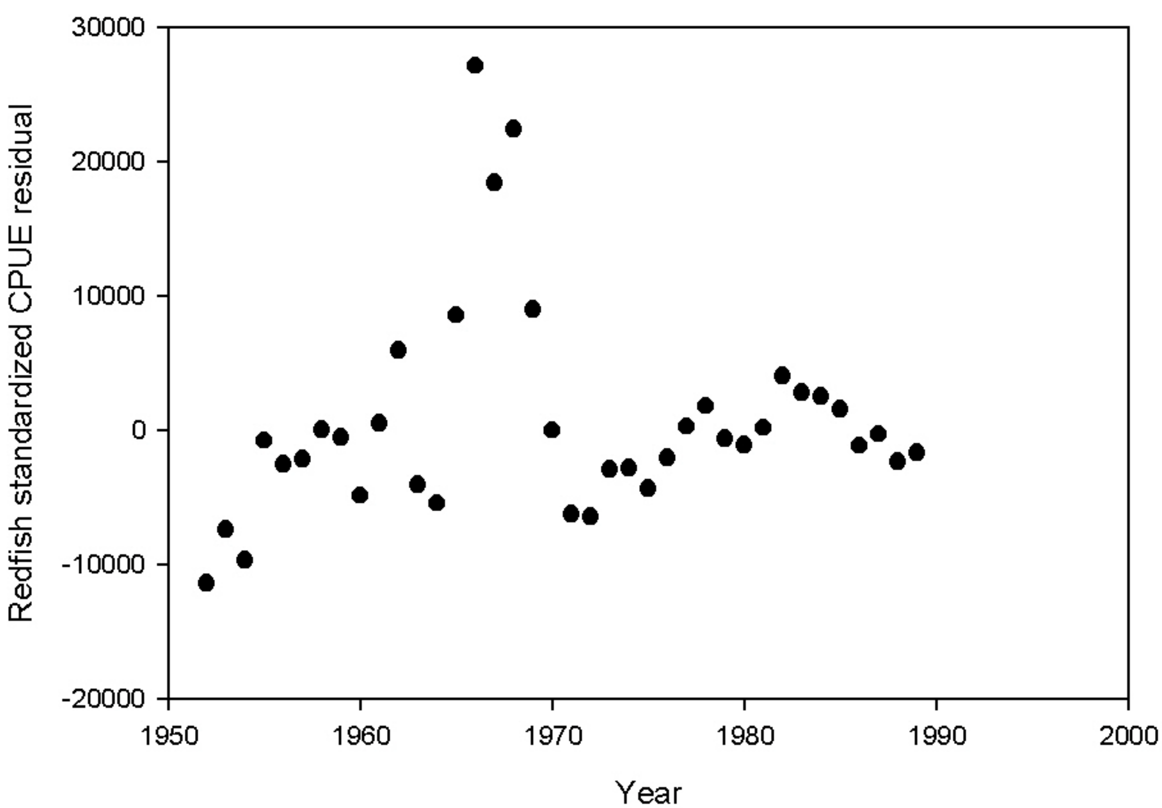


Figure 24. Redfish fishery age composition residuals, 1969-1985 including 1999-2000 autumn survey age data

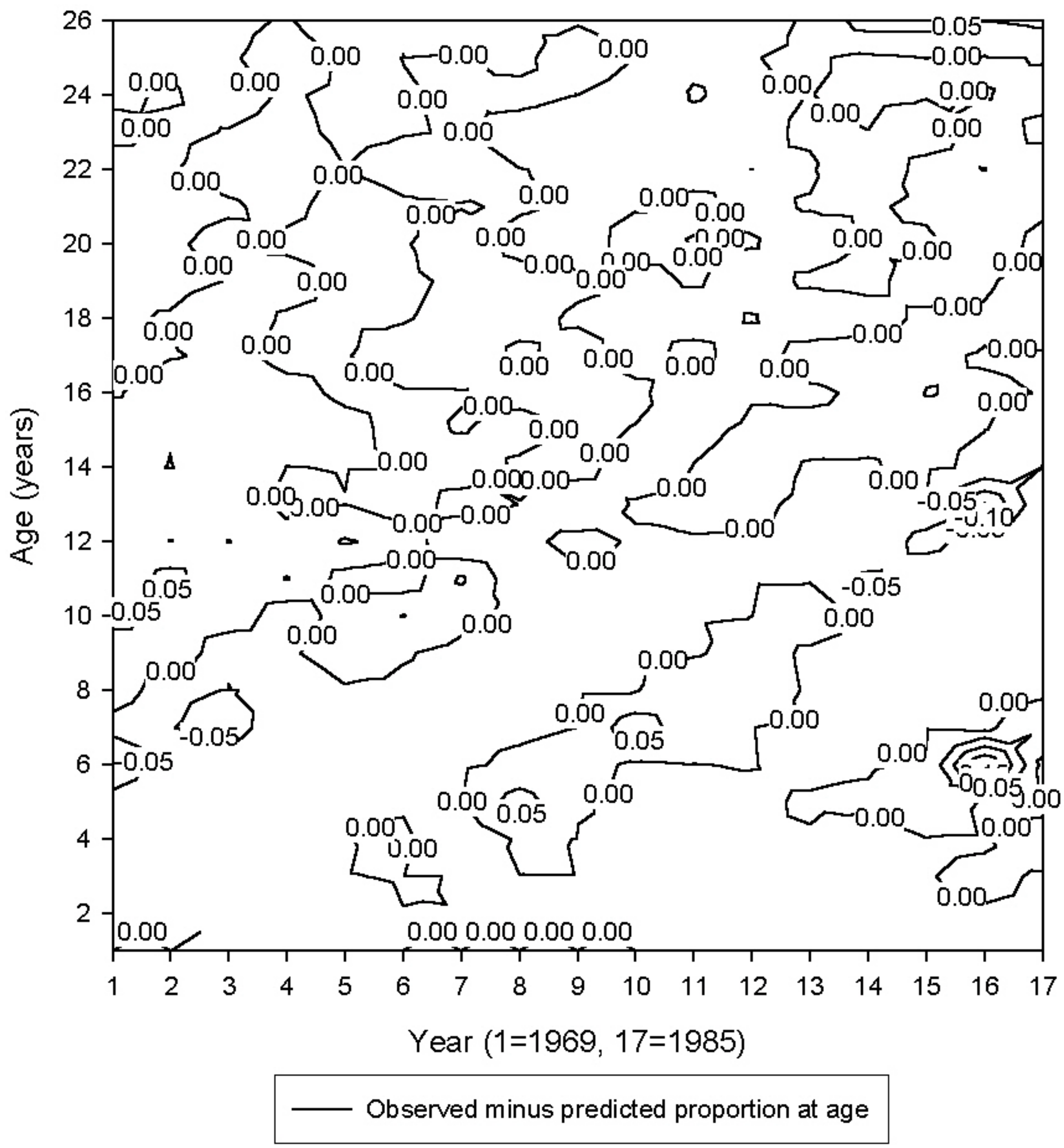


Figure 25. Redfish autumn survey age composition residuals, 1975-2000 including 1999-2000 autumn survey age data

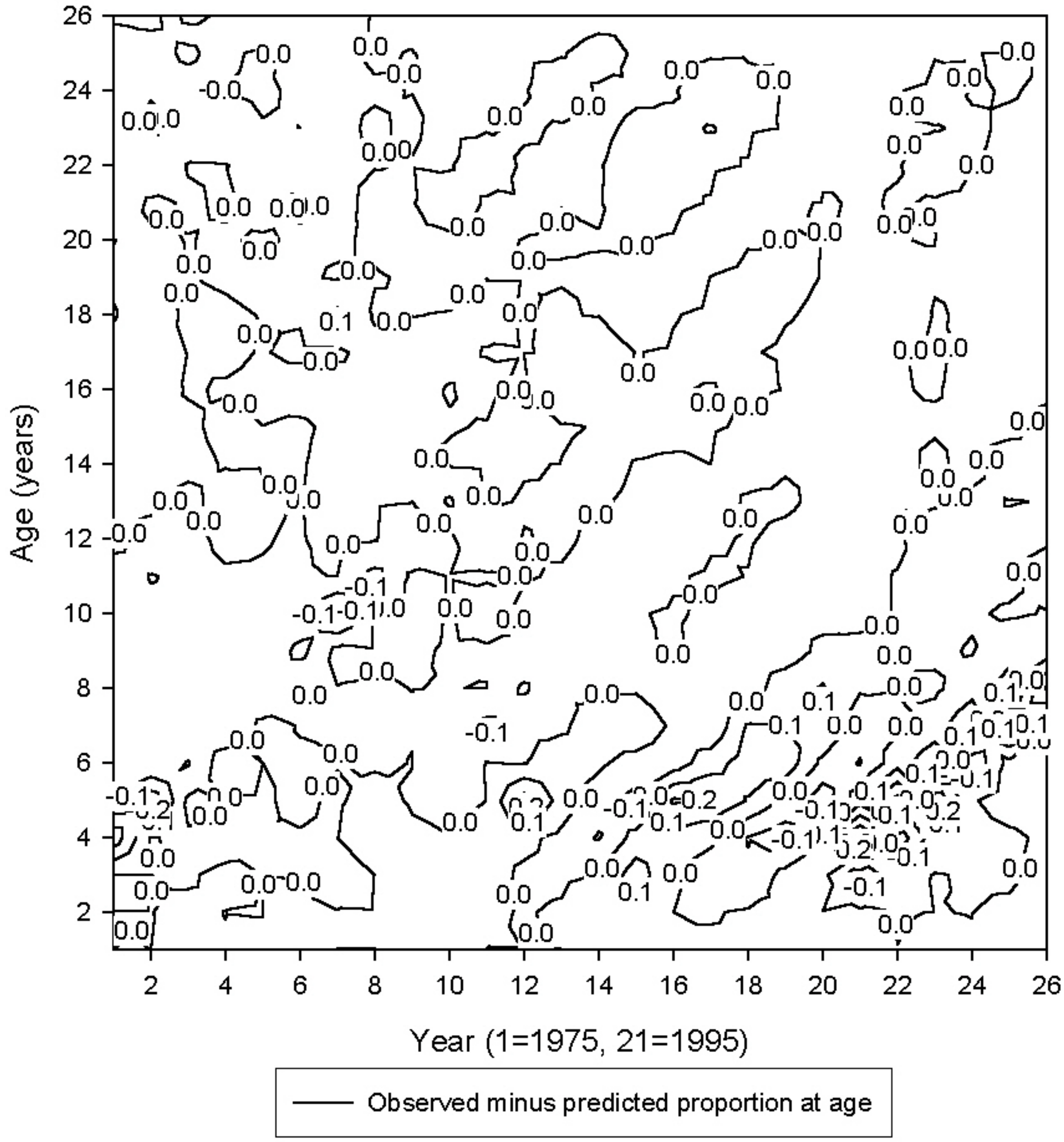


Figure 26. Redfish spring survey age composition residuals, 1975-1990 including 1999-2000 autumn survey age data

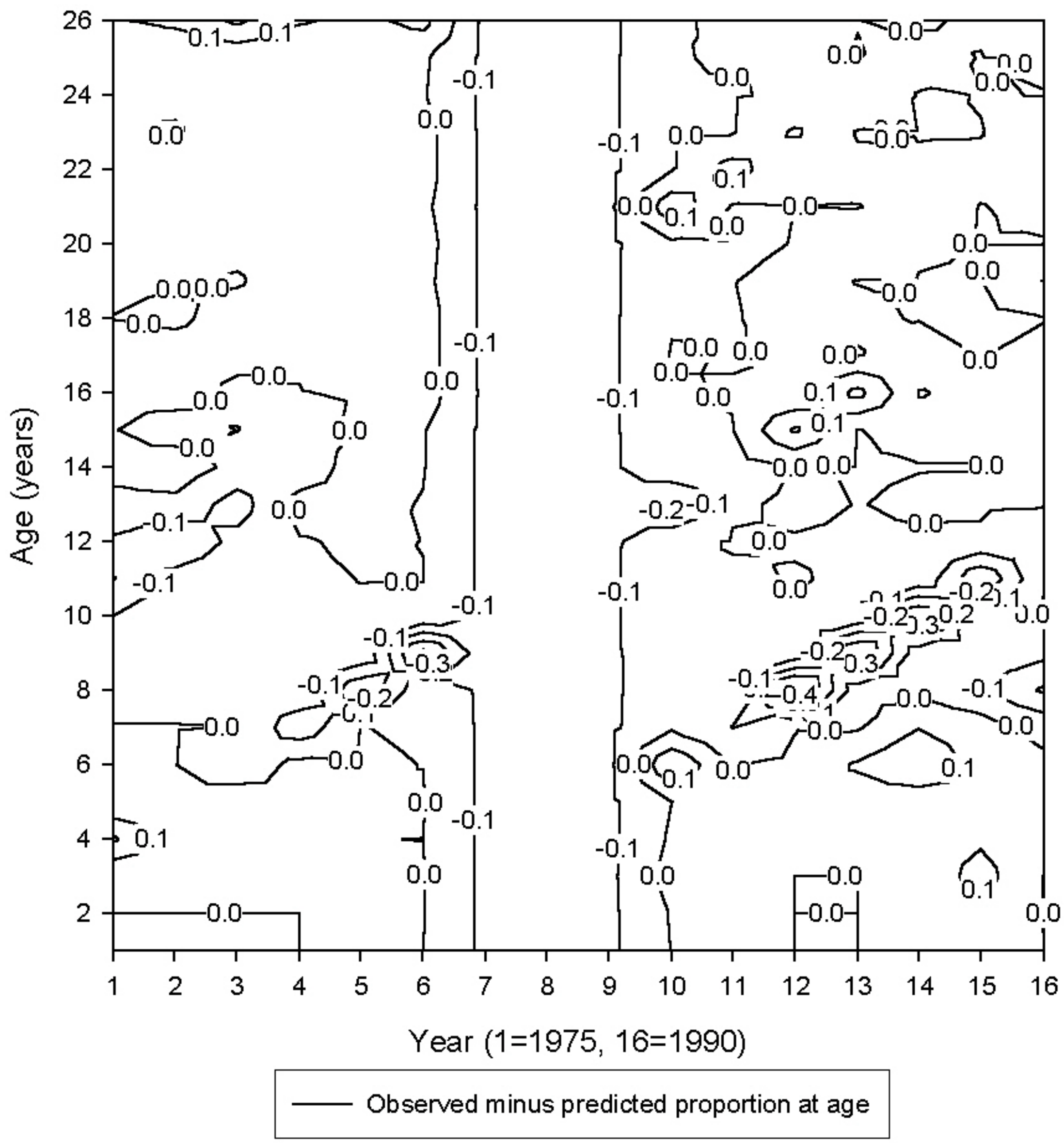


Figure 27. Redfish fishery and survey selectivity at age including 1999-2000 autumn survey age data

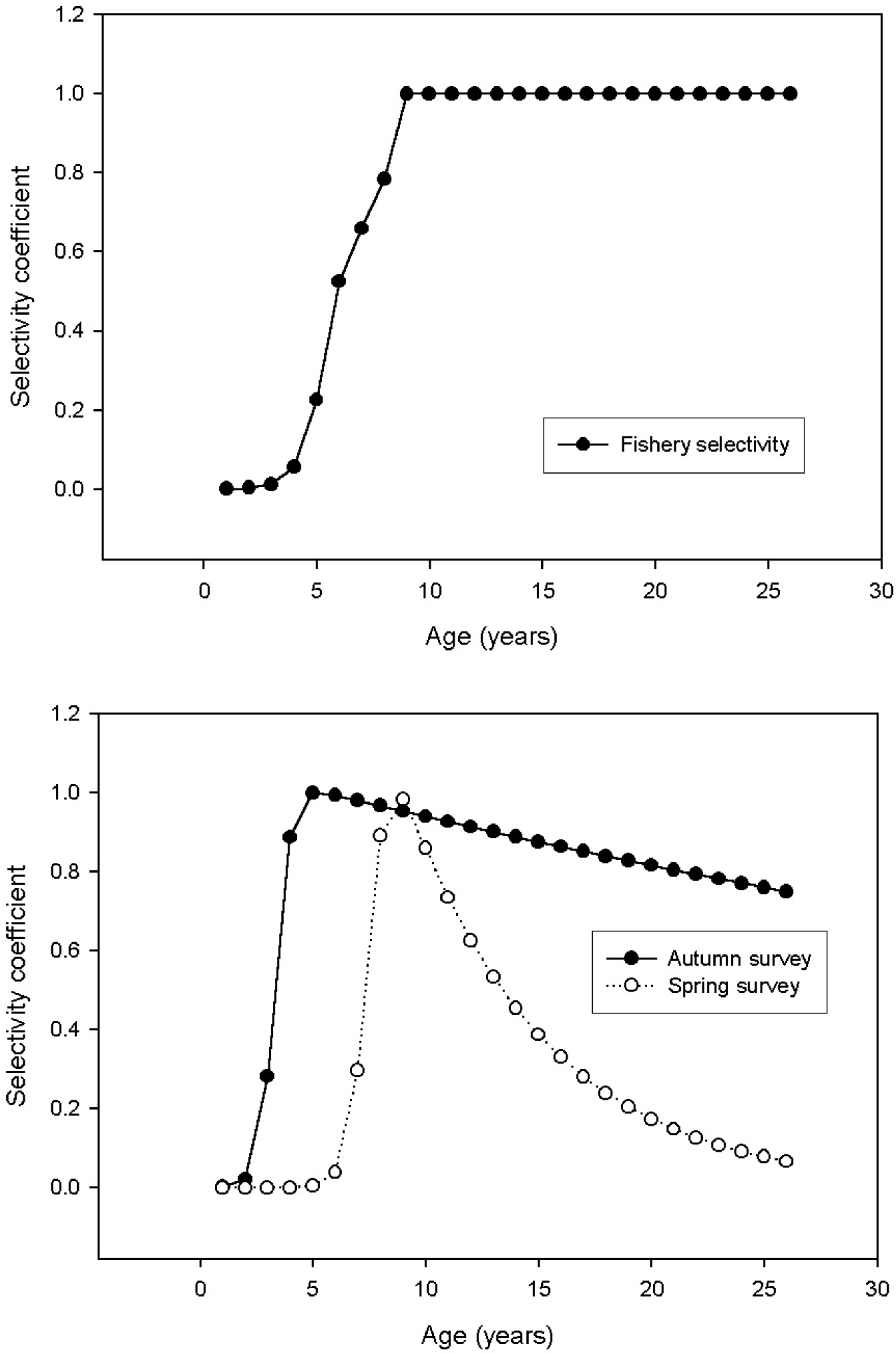
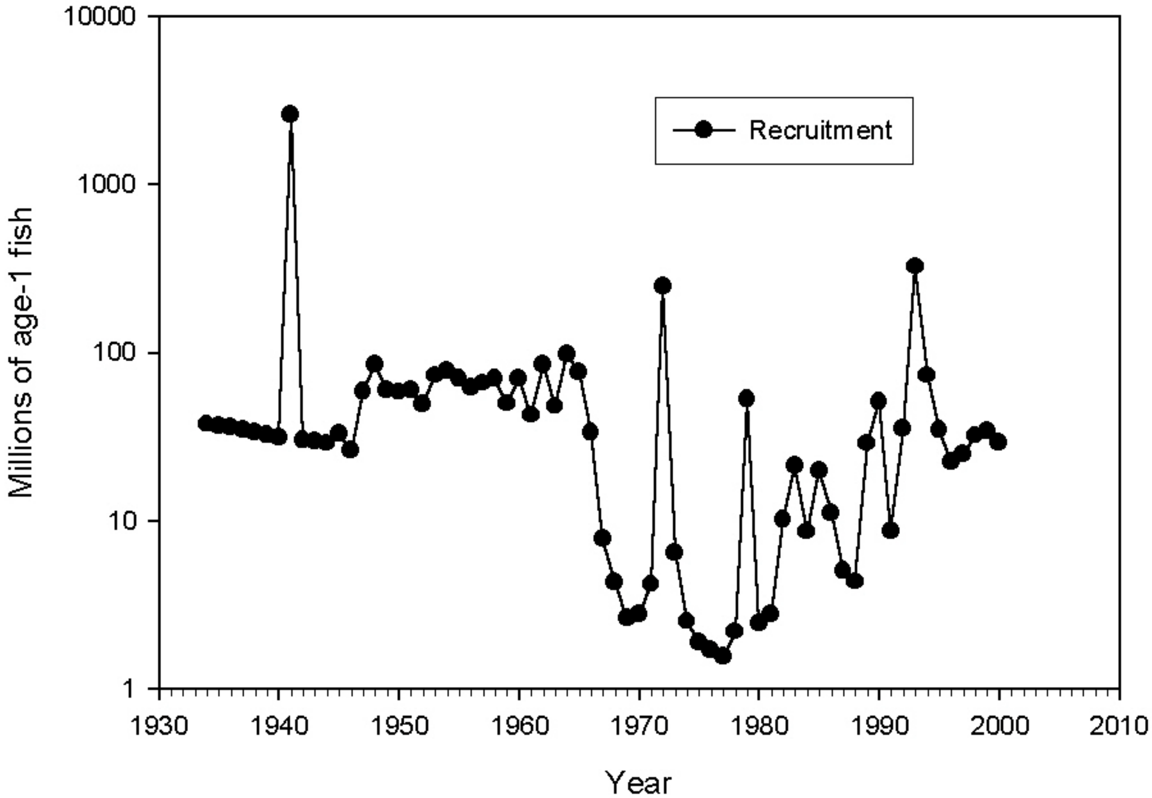


Figure 28. Redfish recruitment, 1934-2000 including 1999-2000 autumn survey age data



Redfish recruitment, 1963-2000
including 1999-2000 autumn survey age data

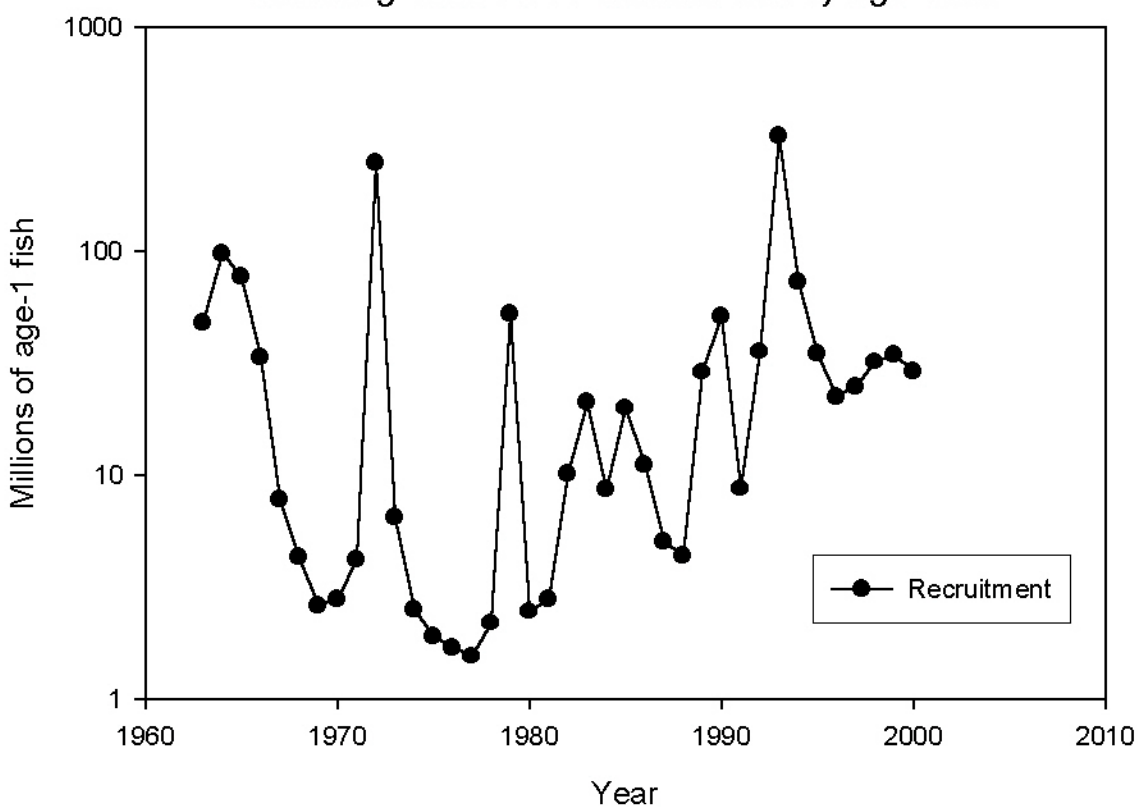
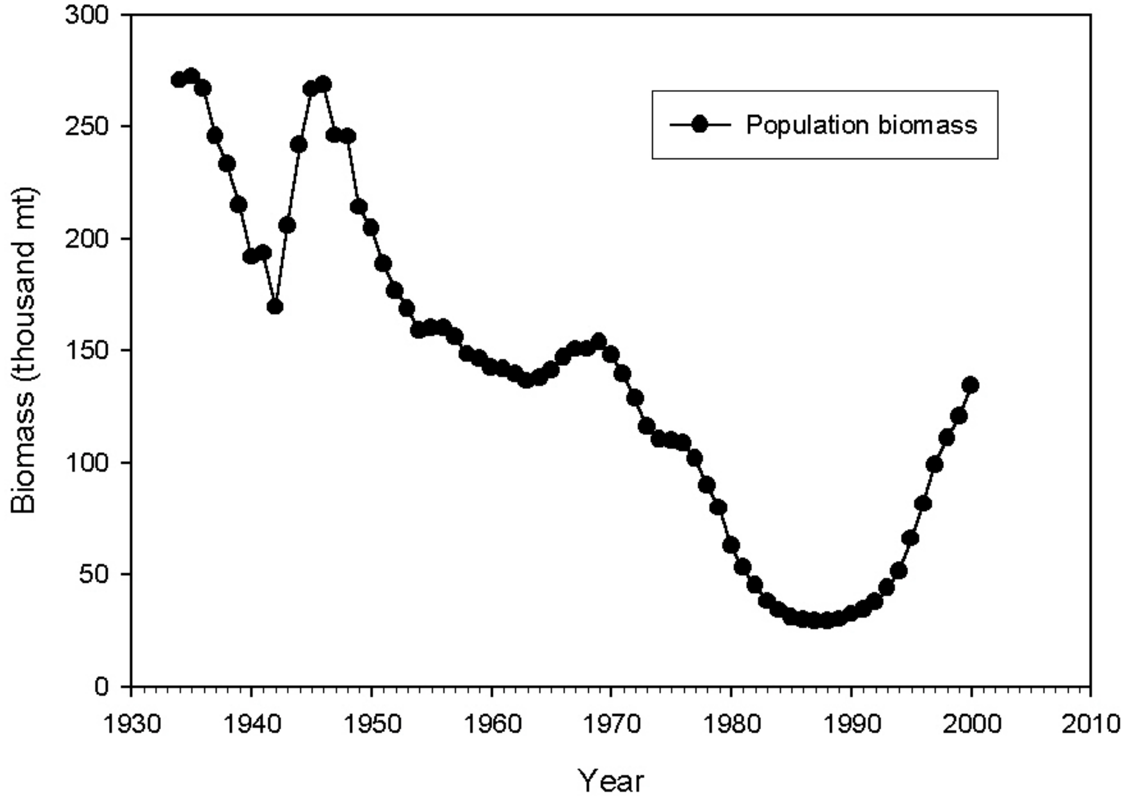


Figure 29. Redfish population biomass (thousand mt), 1934-2000 including 1999-2000 autumn survey age data



Redfish population biomass (thousand mt), 1963-2000 including 1999-2000 autumn survey age data

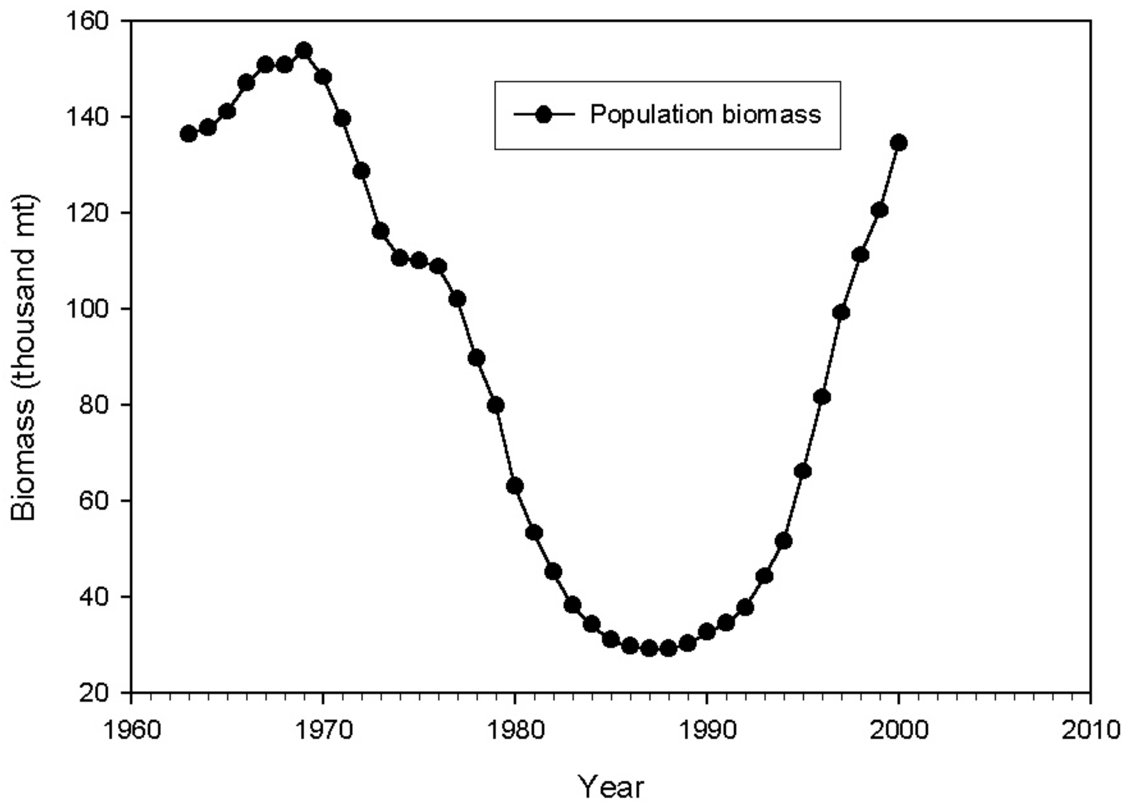
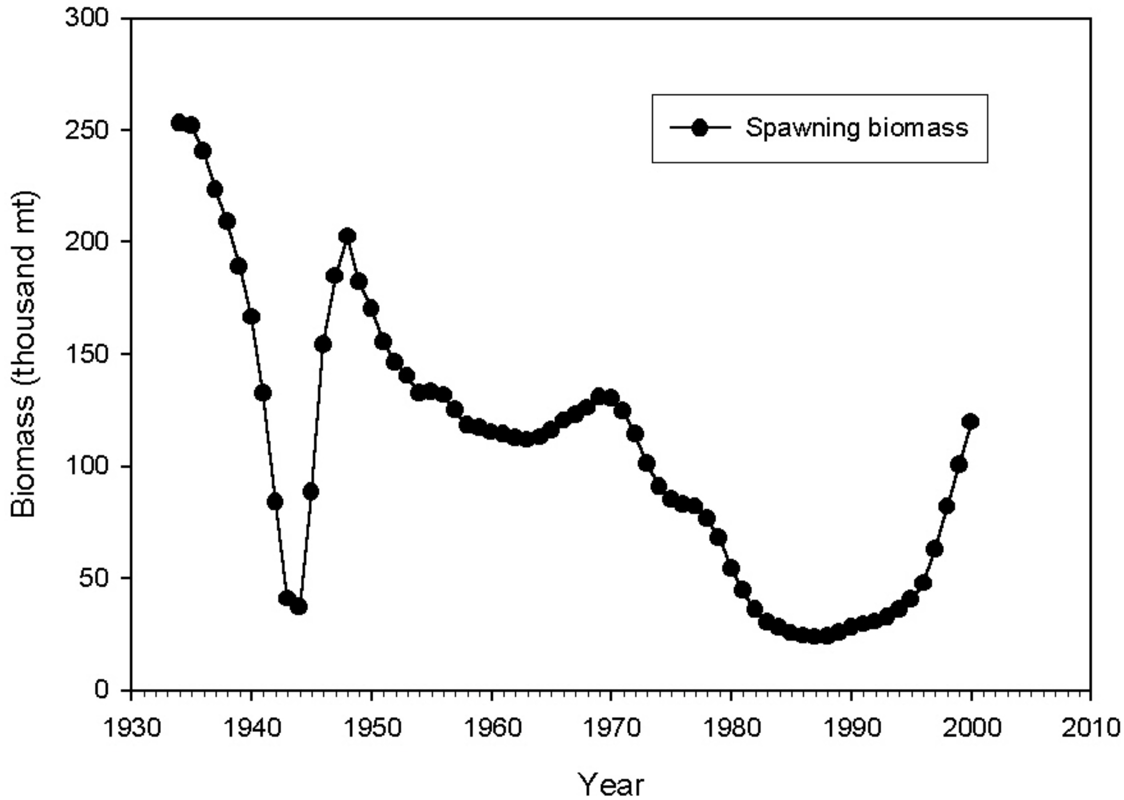


Figure 30. Redfish spawning biomass (thousand mt), 1934-2000 including 1999-2000 autumn survey age data



Redfish spawning biomass (thousand mt), 1963-2000 including 1999-2000 autumn survey age data

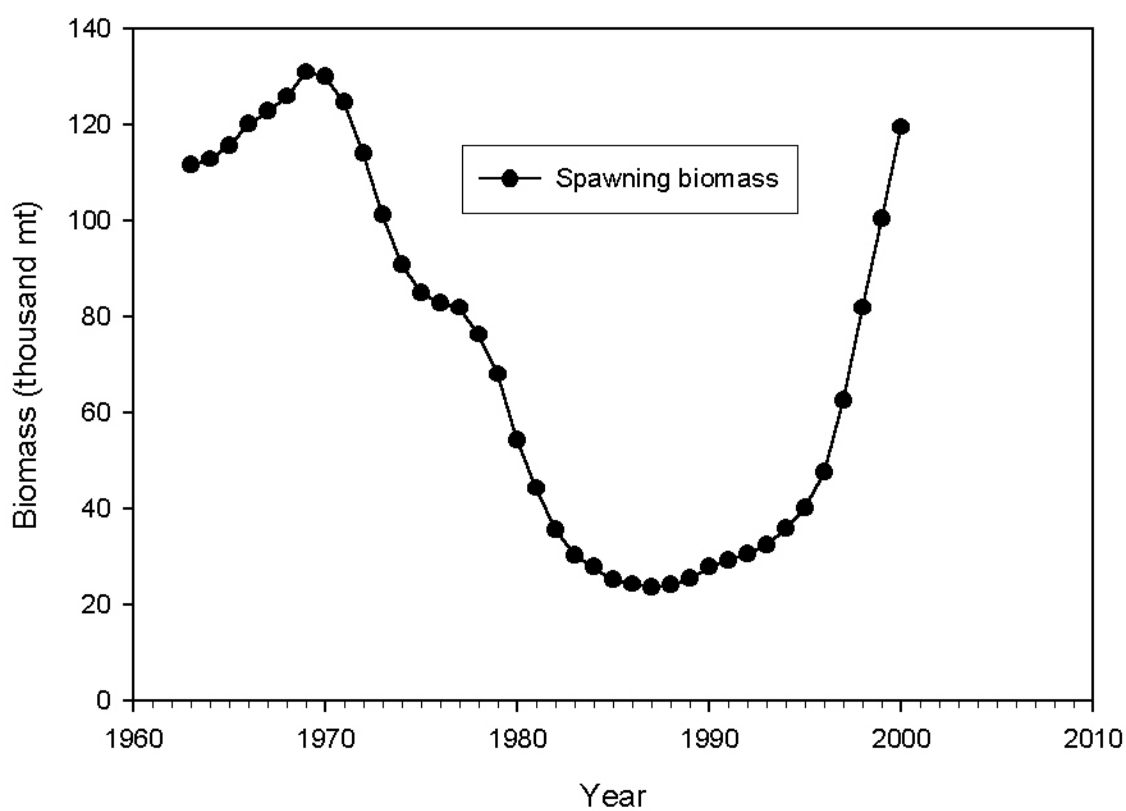
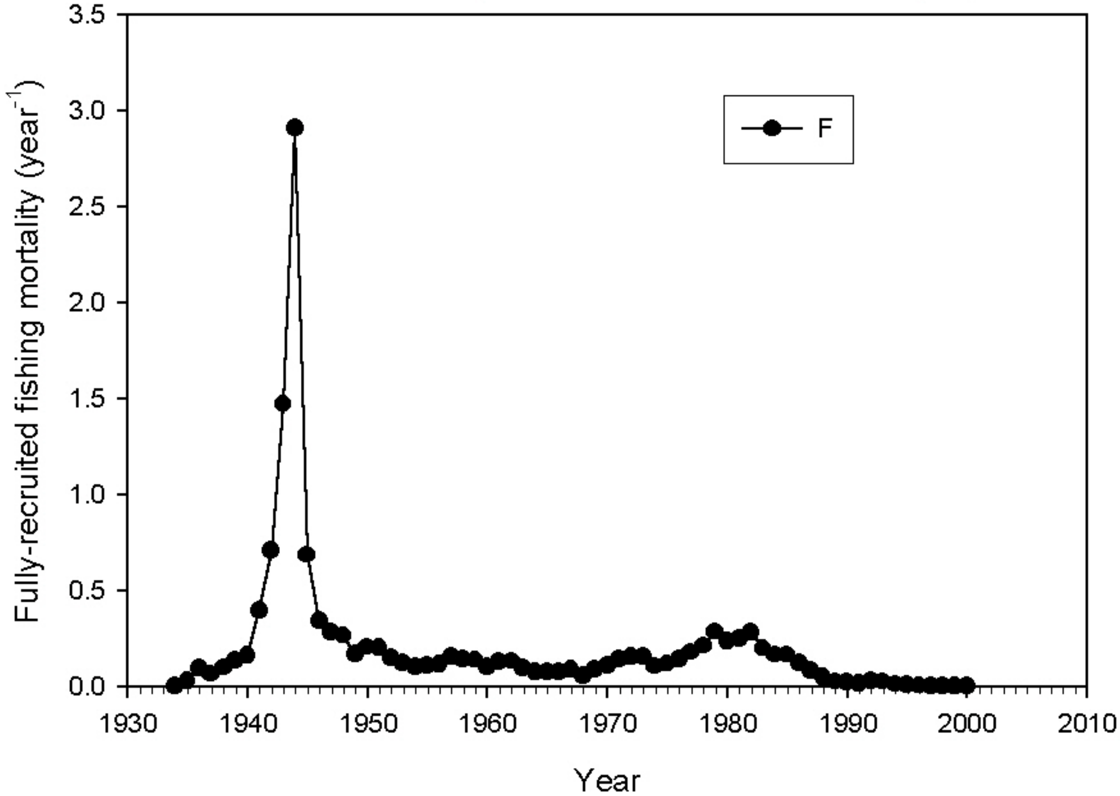


Figure 31. Redfish fishing mortality (F), 1934-2000 including 1999-2000 autumn survey age data



Redfish fishing mortality (F), 1963-2000 including 1999-2000 autumn survey age data

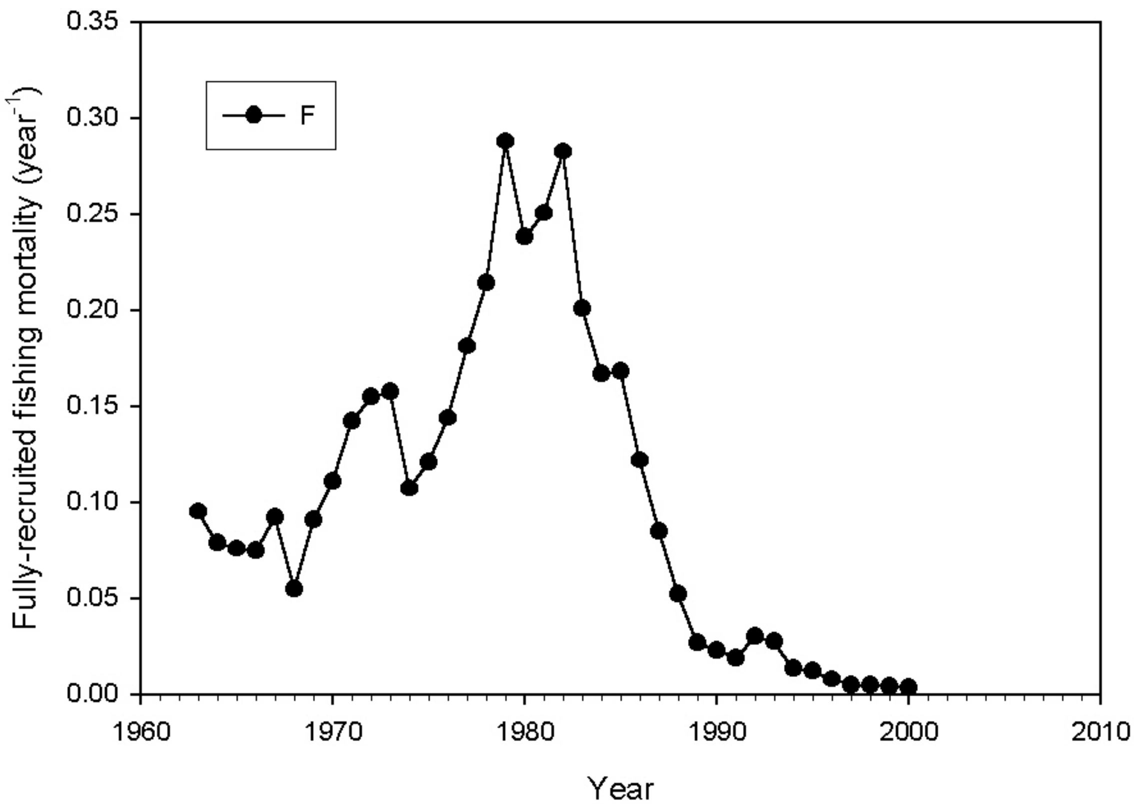


Figure 32. Redfish stock-recruitment data, 1963-2000 including 1999-2000 autumn survey age data

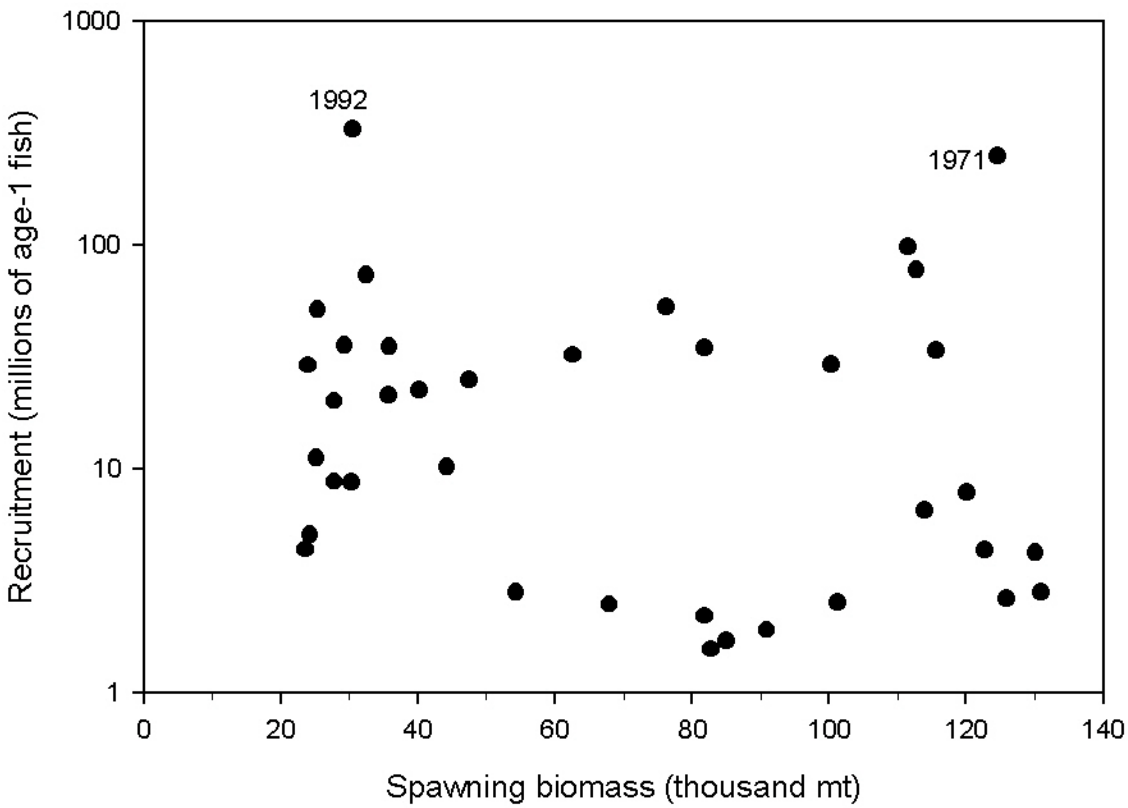
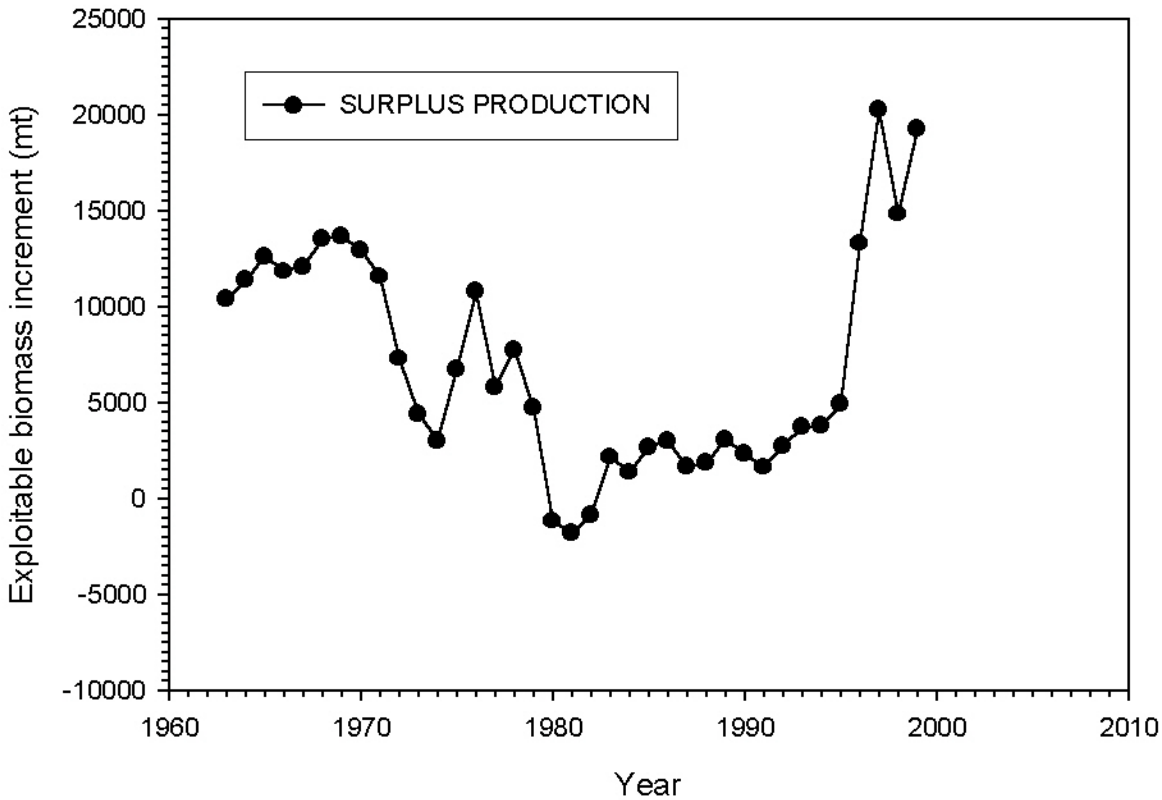


Figure 33. Redfish surplus production, 1963-1999
including 1999-2000 autumn survey age data



Redfish surplus production trajectory, 1934-1999
including 1999-2000 autumn survey age data

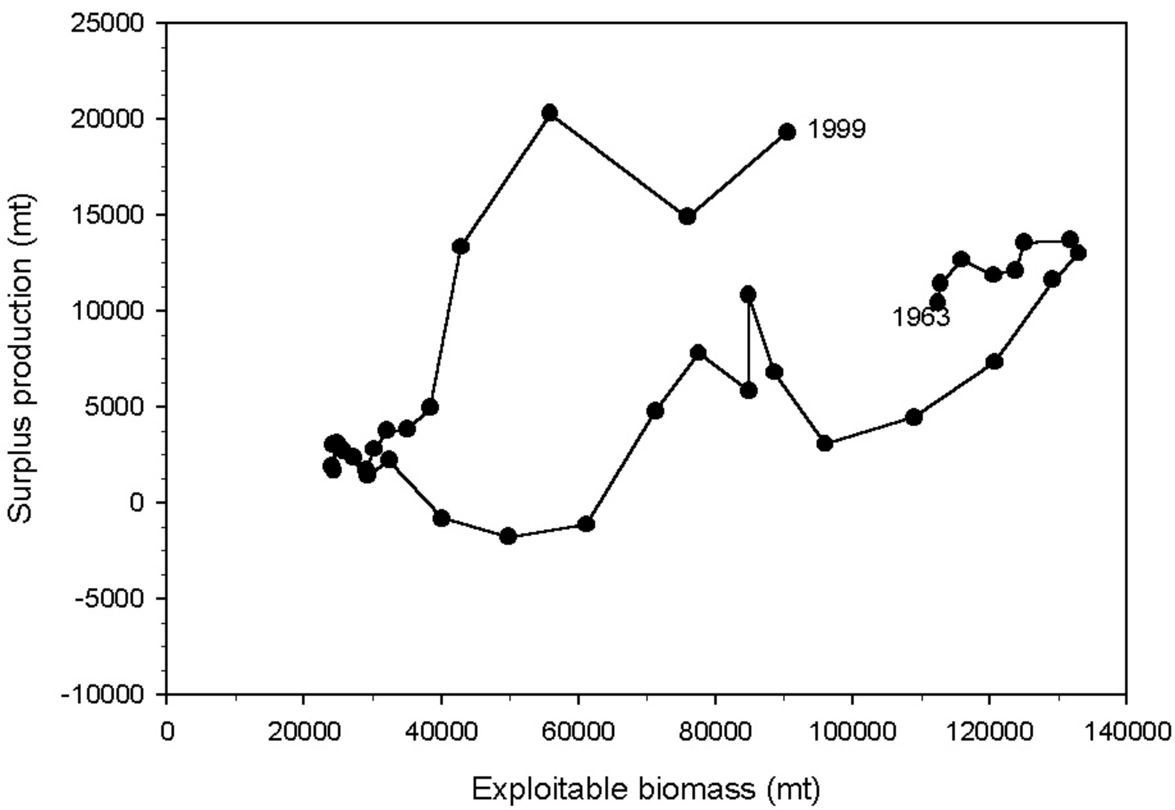
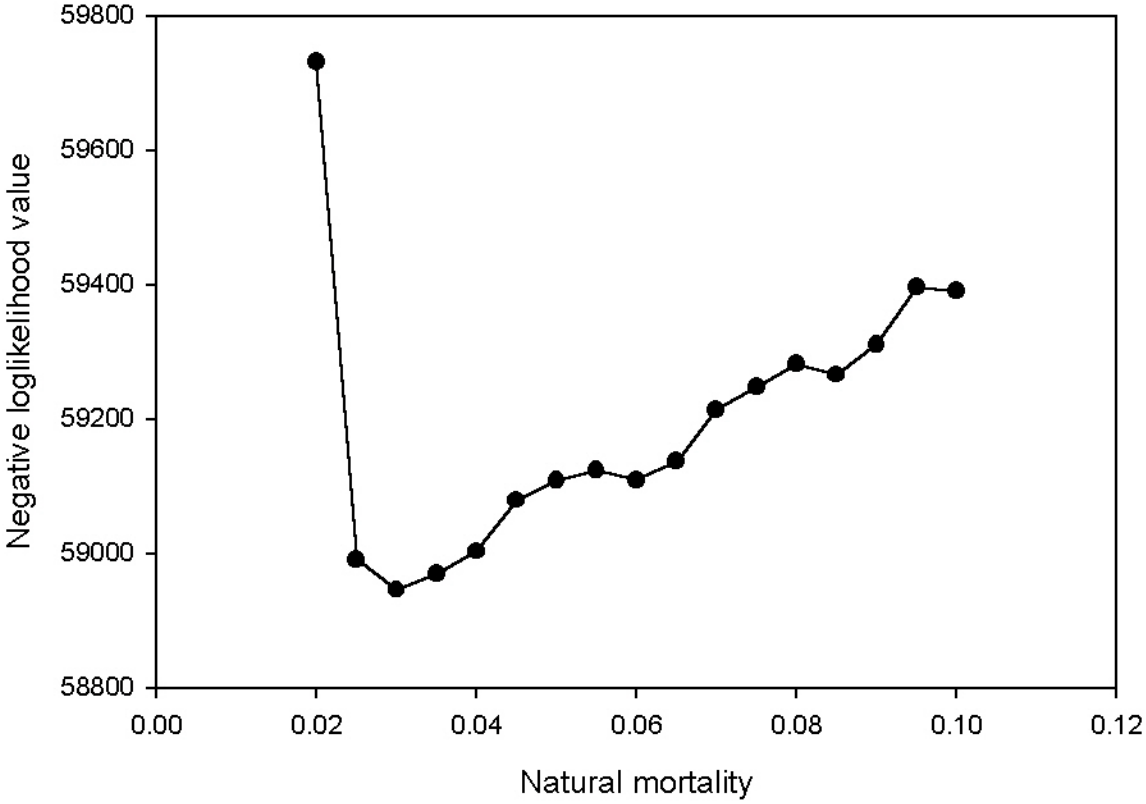


Figure 34. Redfish likelihood profile for natural mortality



Redfish population biomass as a function of natural mortality, 1934-2000

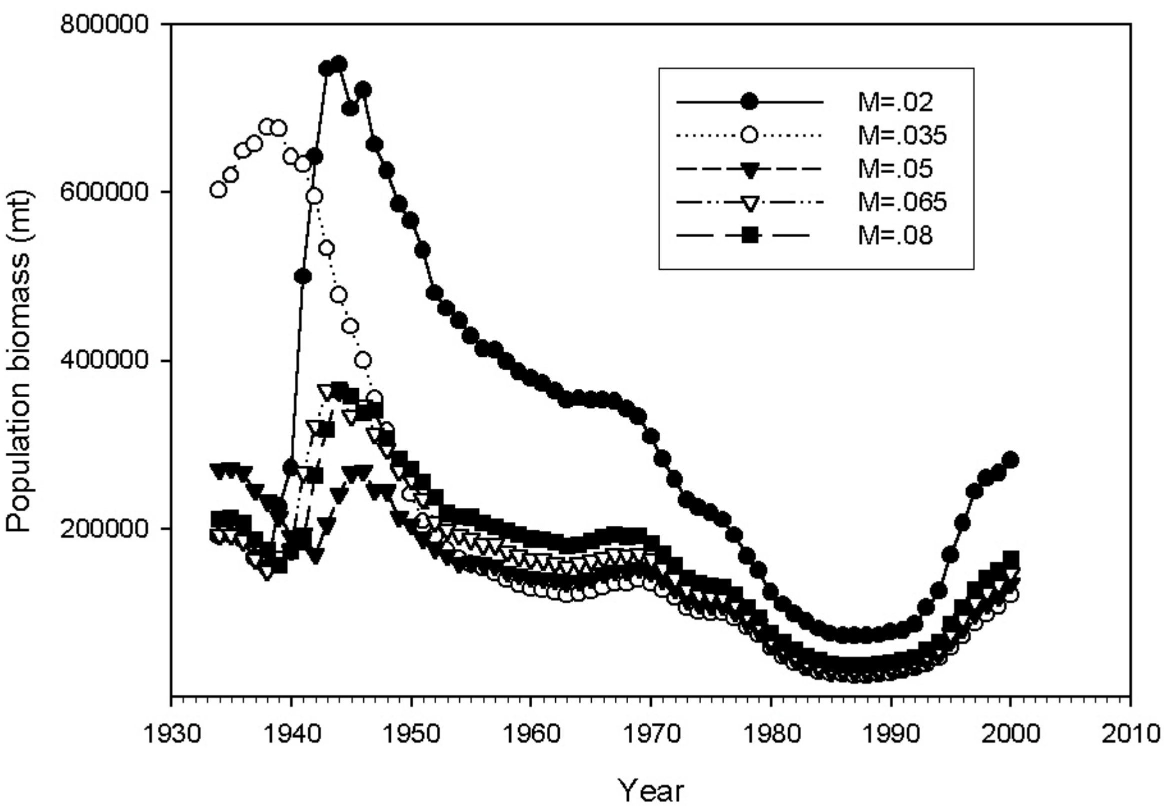
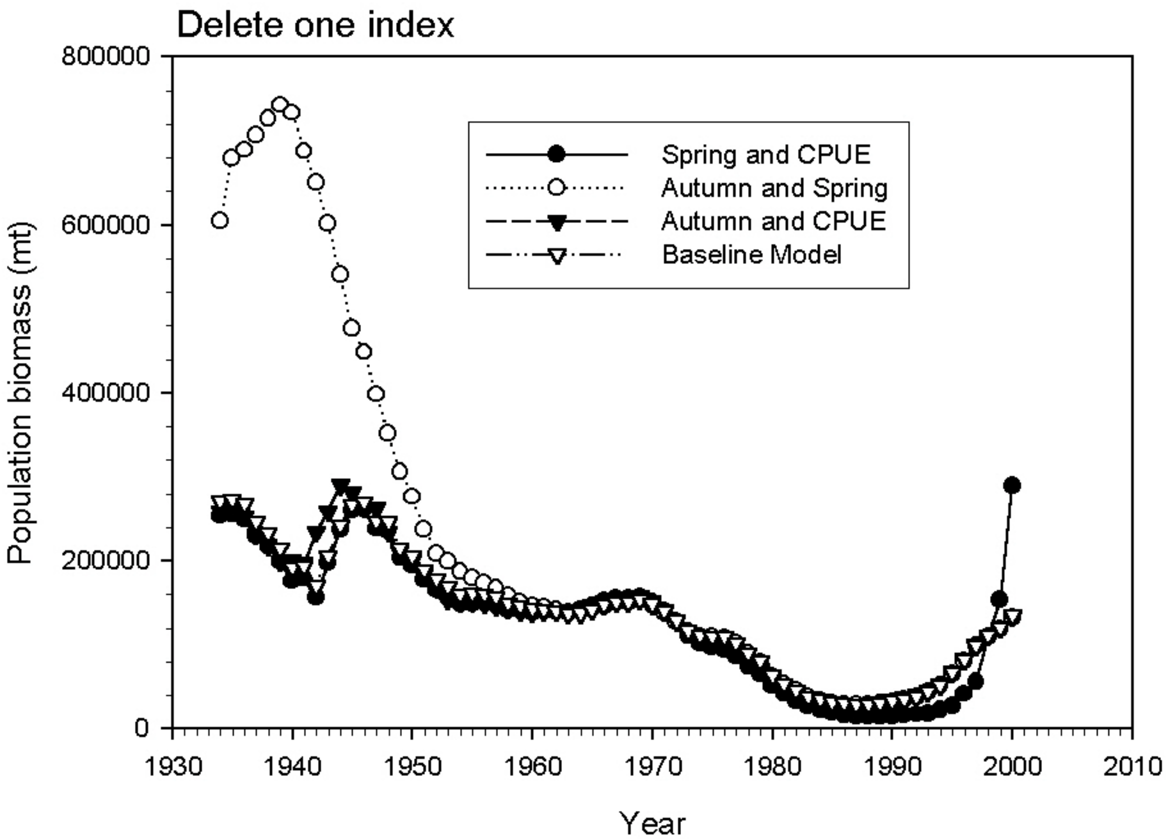
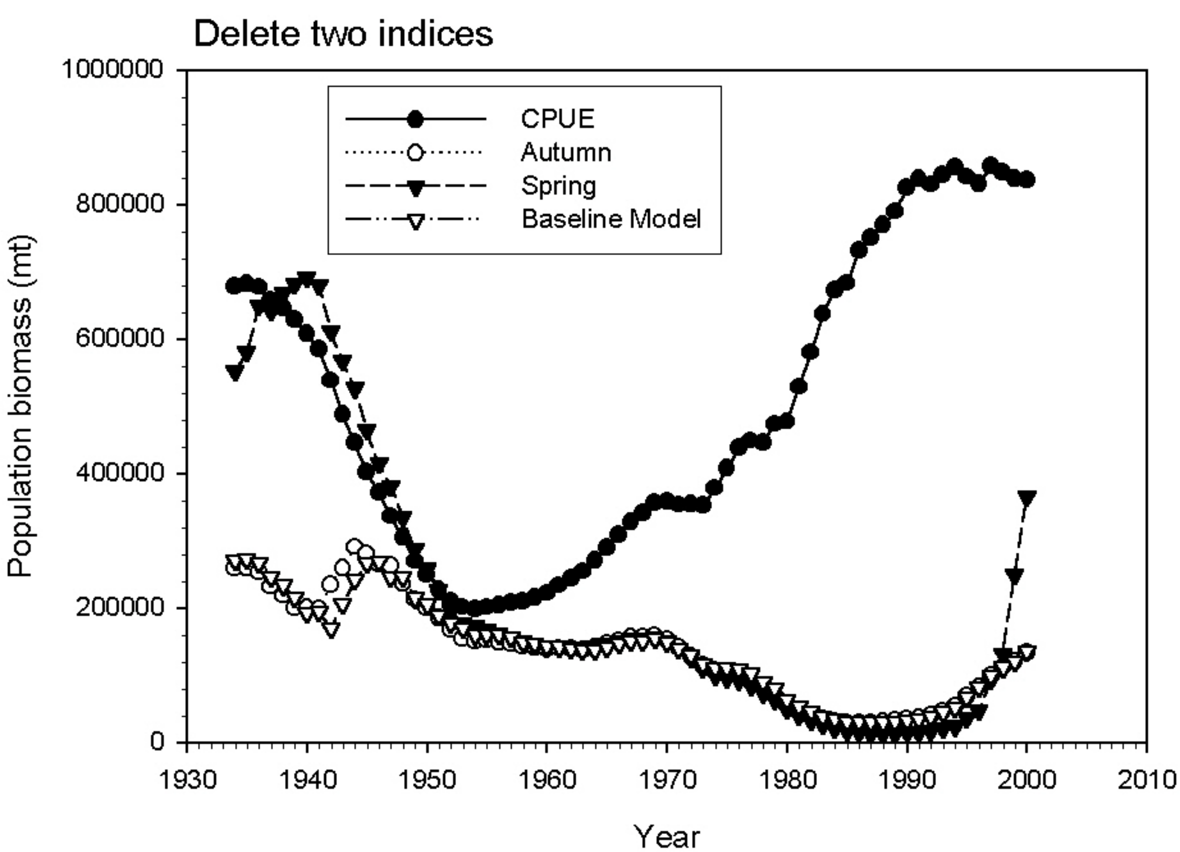


Figure 35. Redfish abundance index sensitivity analyses





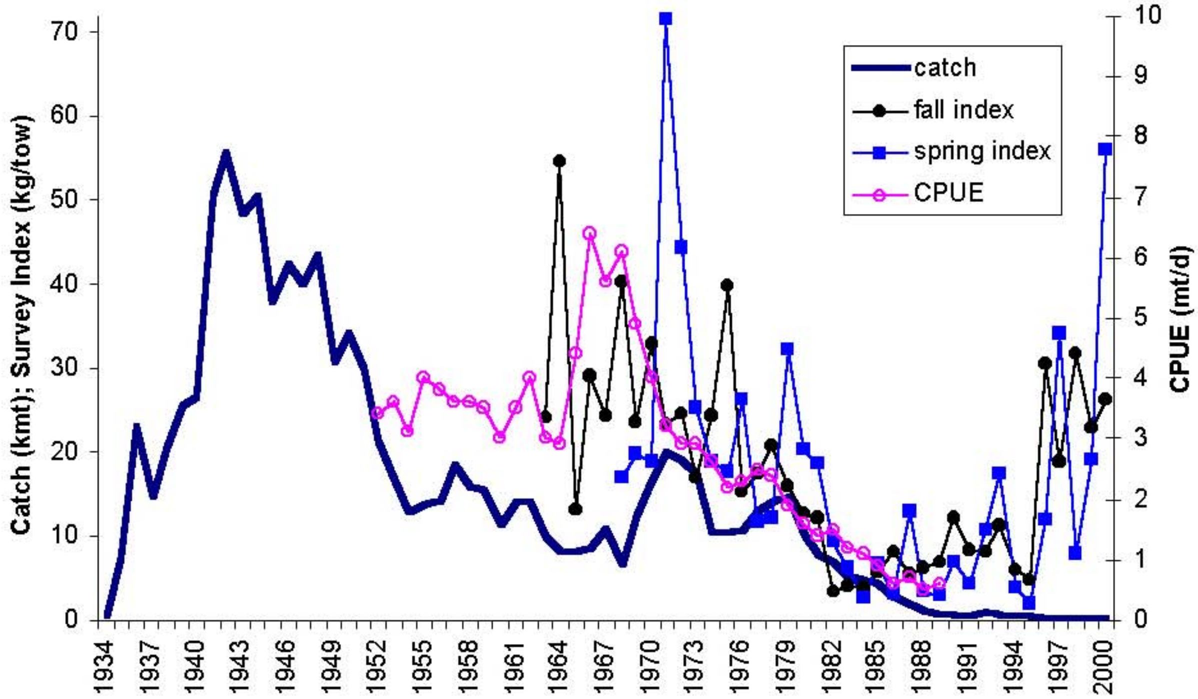


Figure 36. Input data for biomass dynamics analysis.

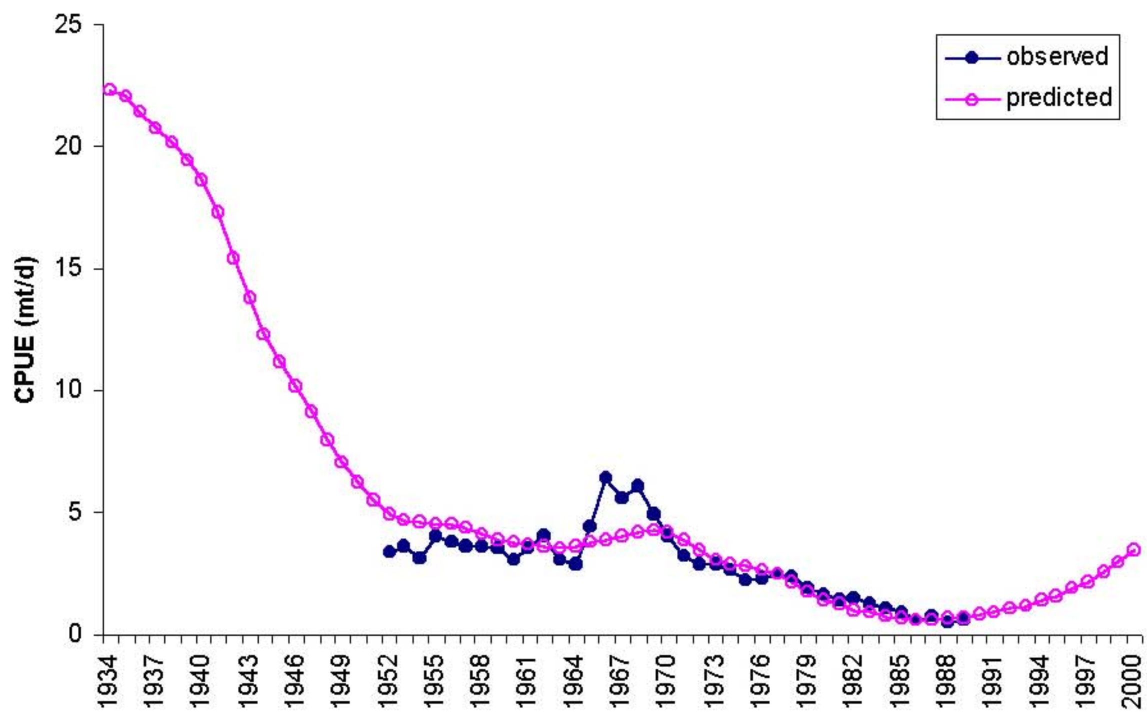


Figure 37. Observed and predicted CPUE from ASPIC.

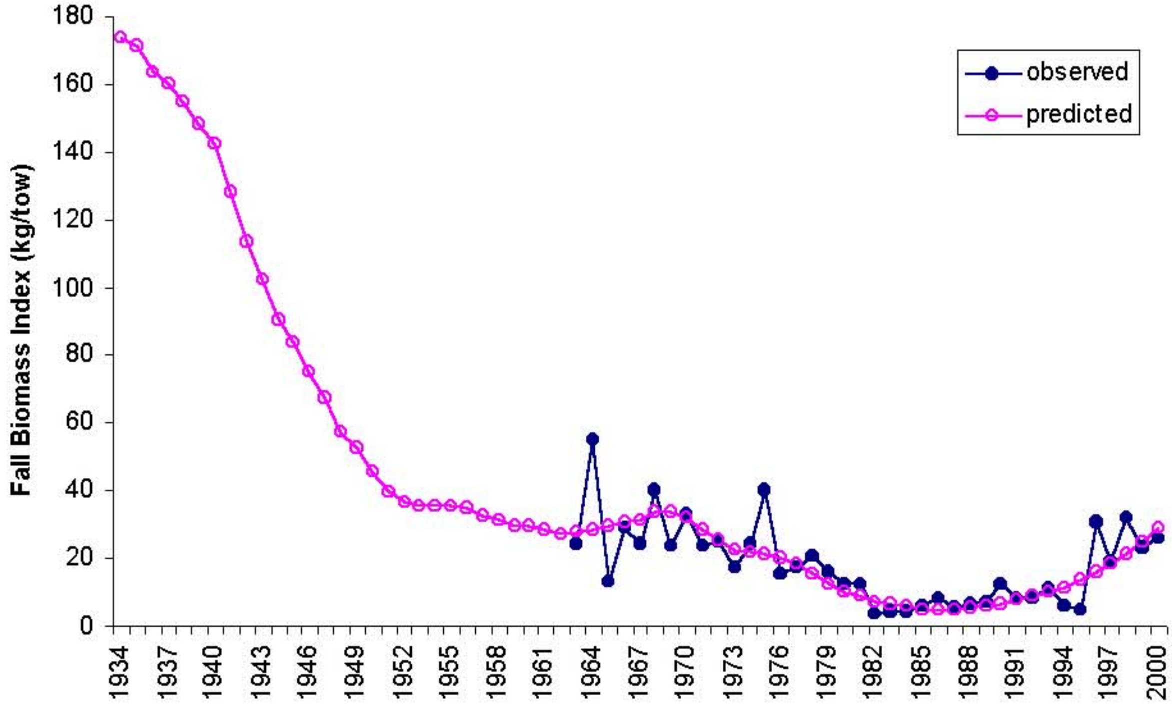


Figure 38. Observerd and predicted autumn survey biomass index from ASPIC.

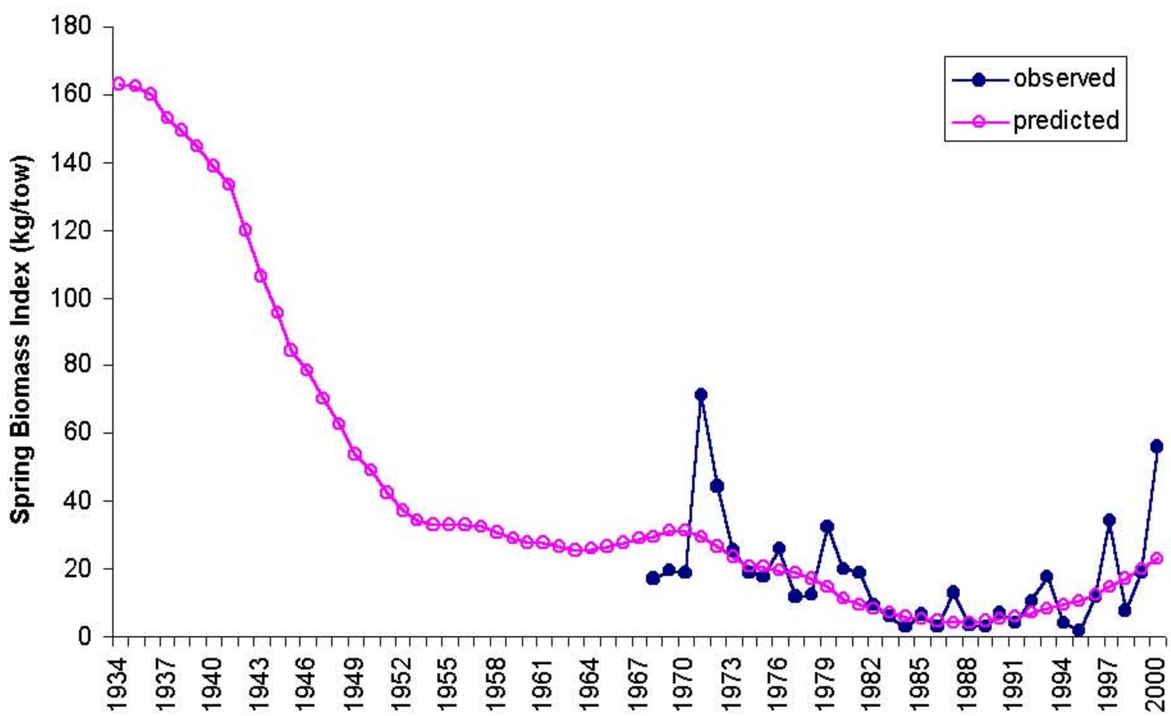


Figure 39. Observed and predicted spring survey biomass index from ASPIC.

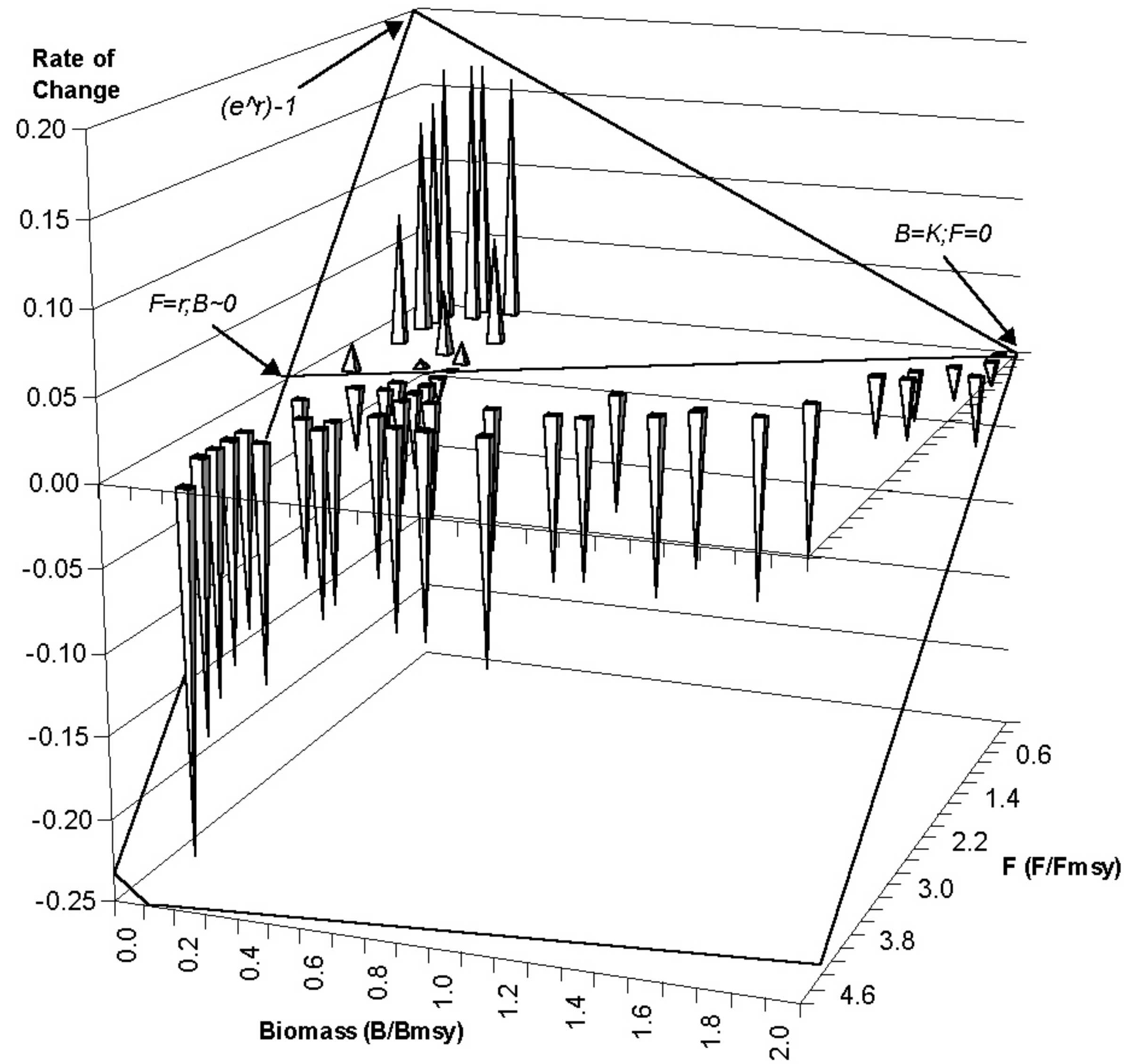


Figure 40. Observed rate of change, expressed as a planar function of biomass and fishing mortality, for estimation of biomass dynamics parameters (dashed line indicates equilibrium conditions.

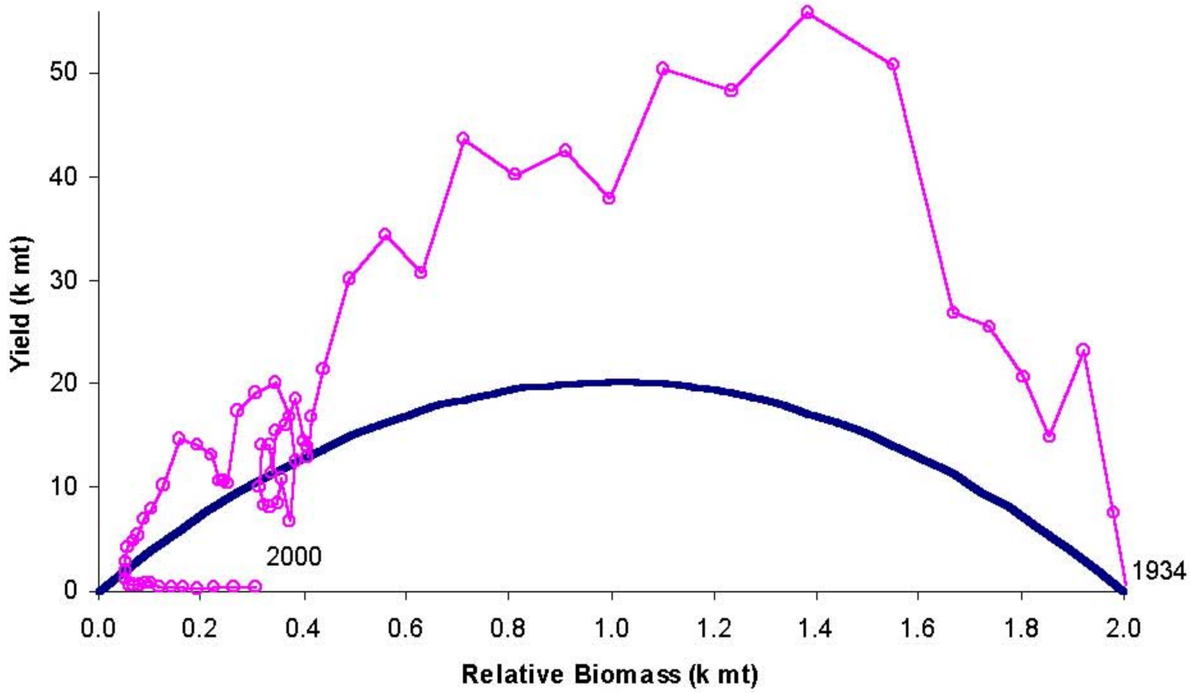


Figure 41. Biomass dynamics of Subarea 5 Redfish from ASPIC.

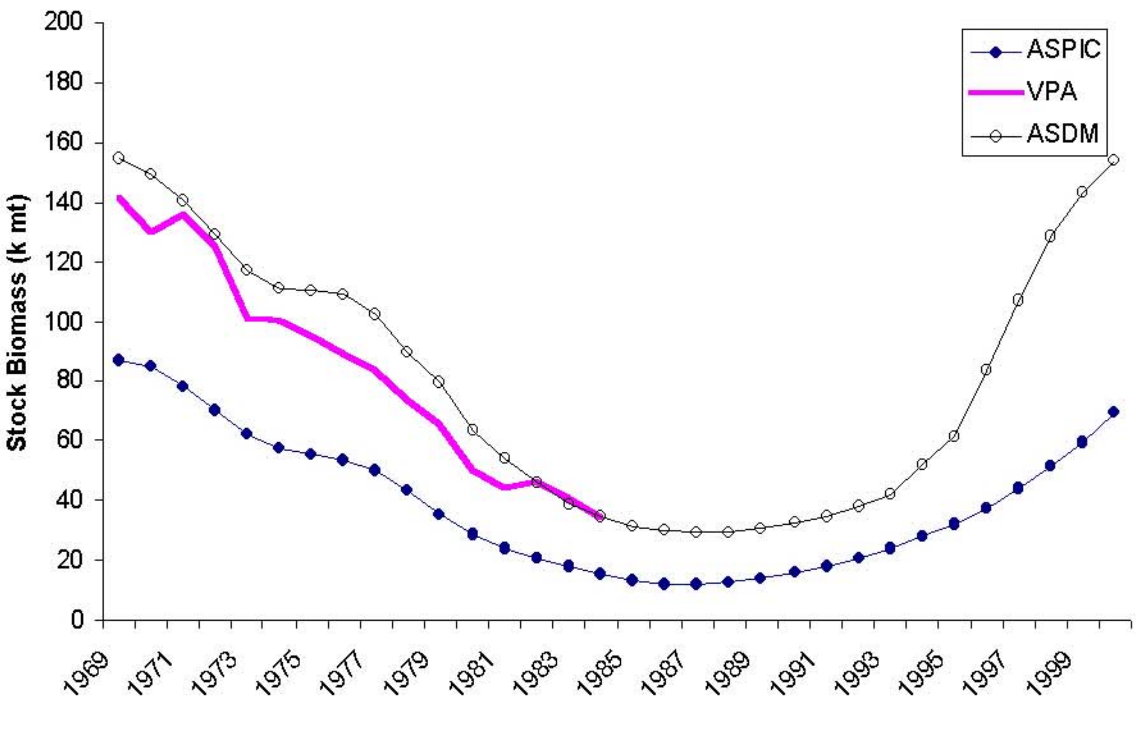


Figure 42. Comparison of biomass estimates from ASPIC, VPA (NEFSC 1986), and the age-structured dynamic model.

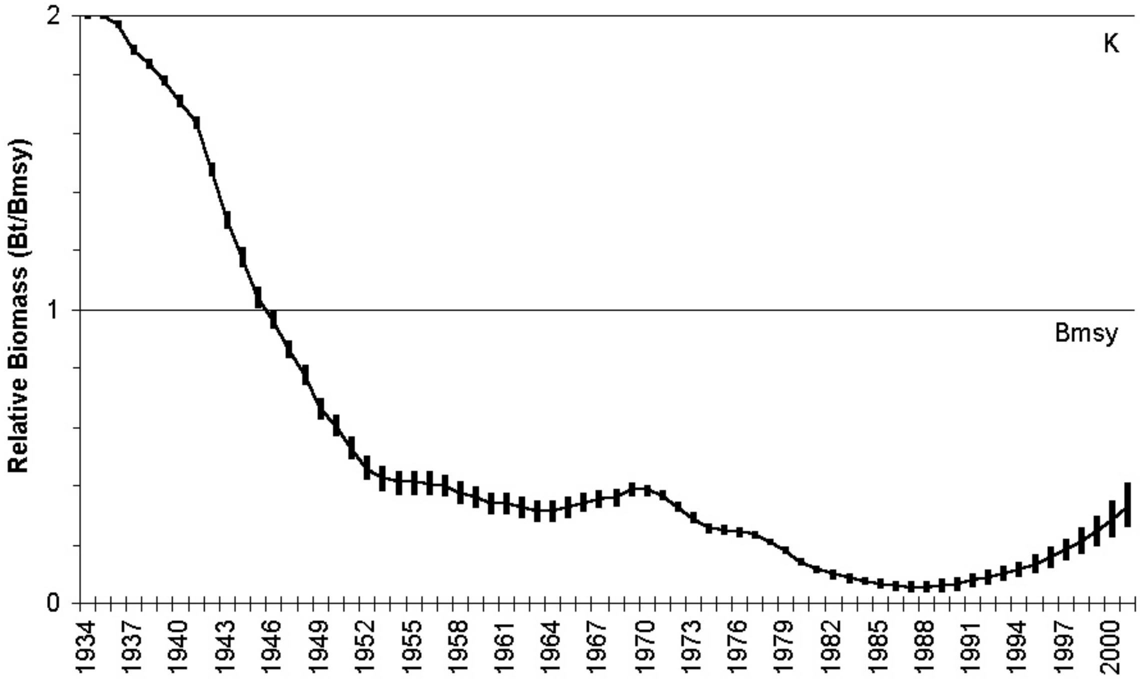


Figure 43. Estimates of relative biomass and 80% confidence limits from ASPIC.

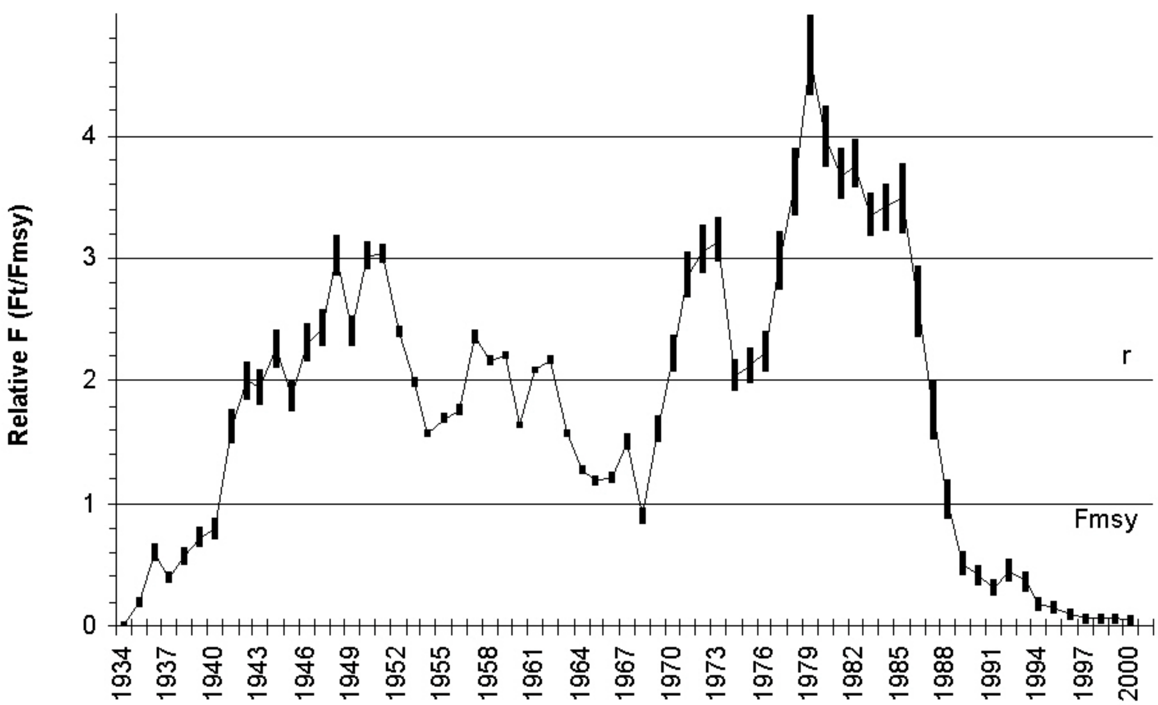


Figure 44. Estimates of relative fishing mortality and 80% confidence limits from ASPIC.

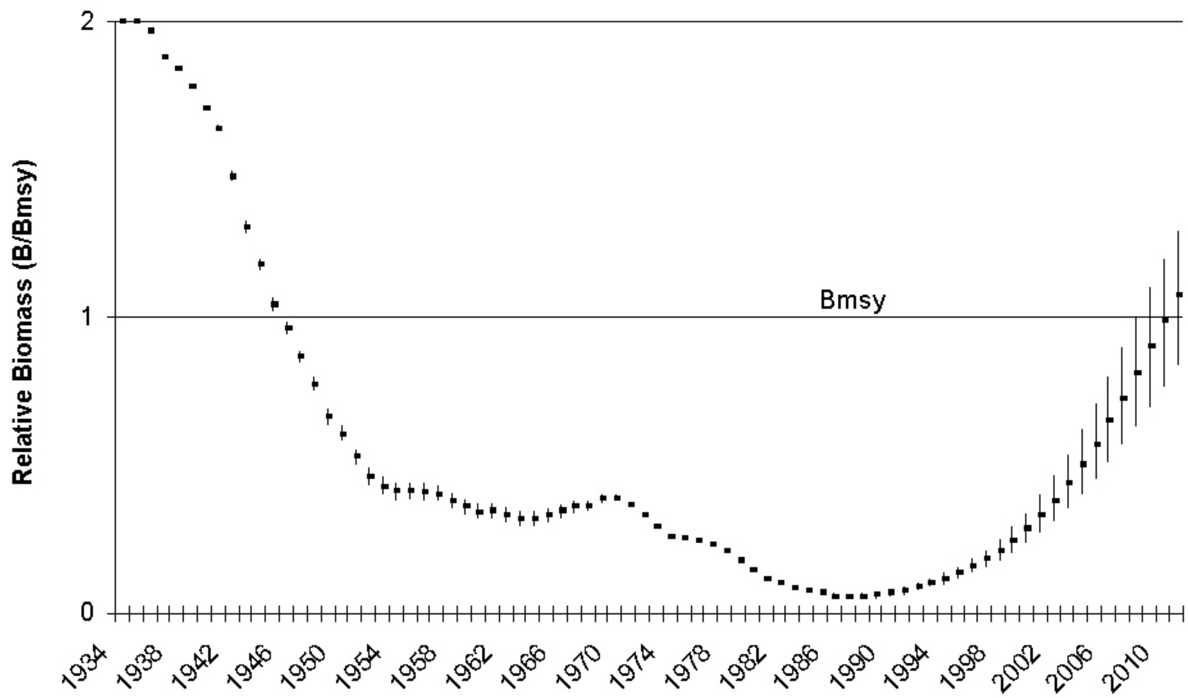


Figure 45. Ten-year projections of redfish biomass assuming no fishing mortality from 2001-2010.

Appendix 1. Redfish age-structured model

Part A. AD model builder code for the baseline redfish model

```
  //REDFISH AGE-STRUCTURED MODEL
  //JON BRODZIAK NEFSC APRIL 2001
  //MODIFIED TO INCORPORATE NDWG COMMENTS MAY 2001
  //COMMENT LINES BEGIN WITH "//"
DATA_SECTION
  //READ DATA FROM INPUT FILE "RED.DAT"
  init_int styr
  init_int endyr
  init_int nages
  init_int nselages_fish
  init_vector catch_bio(styr,endyr)
  init_int nobs_cpue
  init_ivector yrs_cpue(1,nobs_cpue)
  init_number zfrac_cpue
  init_vector obs_cpue(1,nobs_cpue)
  init_int nobs_fish
  init_ivector yrs_fish(1,nobs_fish)
  init_int nsamples_fish
  init_matrix obs_p_fish(1,nobs_fish,1,nages)
  init_int nobs_srv1
  init_ivector yrs_srv1(1,nobs_srv1)
  init_number zfrac_srv1
  init_vector obs_srv1(1,nobs_srv1)
  init_int nsamples_srv1
  init_matrix obs_p_srv1(1,nobs_srv1,1,nages)
  init_int nobs_srv2
  init_ivector yrs_srv2(1,nobs_srv2)
  init_number zfrac_srv2
  init_vector obs_srv2(1,nobs_srv2)
  init_int nsamples_srv2
  init_matrix obs_p_srv2(1,nobs_srv2,1,nages)
  init_vector wt(1,nages)
  init_number zfrac_spawn
  init_vector maturity(1,nages)
  init_number lambda_recruitment
  init_number lambda_fishery_cpue
  init_number lambda_fishery_age
  init_number lambda_srv1_age
  init_number lambda_biomass_index_srv1
  init_number lambda_srv2_age
  init_number lambda_biomass_index_srv2
  init_number lambda_catch_biomass
  init_number lambda_fishery_sel
  init_number lambda_f_penalty

  int styr_rec

 LOCAL_CALCS
 //COMPUTE YEAR OF FIRST RECRUITMENT DEVIATION TO BE ESTIMATED
  styr_rec=styr-nages+2;
 END_CALCS


INITIALIZATION_SECTION
  //PROVIDE INITIAL PARAMETER VALUES
  //NATURAL MORTALITY (NOT ESTIMATED)
```

```
  M 0.05

  //LOG(MEAN RECRUITMENT) IN THOUSANDS OF FISH
  mean_log_rec 11.5

  //LOG(MEAN ANNUAL FISHING MORTALITY)
  log_avg_fmort -2.5

  //CPUE INDEX PARAMETERS
  q_cpue 1.
  exp_cpue 0.8

  //AUTUMN SURVEY INDEX PARAMETERS
  q1 1.
  log_gamma_srv1 -2.
  log_beta_srv1 0.
  log_a50_srv1 1.5

  //SPRING SURVEY INDEX PARAMETERS
  q2 1.
  exp_srv2 1.
  log_gamma_srv2 -2.
  log_beta_srv2 0.
  log_a50_srv2 1.5

PARAMETER_SECTION
  //DECLARE MODEL PARAMETERS AND VARIABLES
  init_bounded_number M(.02,.25,-1)
  init_number mean_log_rec(1)
  init_bounded_dev_vector rec_dev(styr_rec,endyr,-15,15,3)

  init_bounded_number q_cpue(.01,100.,7)
  init_bounded_number exp_cpue(.25,4.,7)

  init_bounded_number q1(.02,50.,8)
  init_bounded_number log_gamma_srv1(-50.,0.999,4)
  init_bounded_number log_beta_srv1(-50.,10.,4)
  init_bounded_number log_a50_srv1(0.,3.,4)

  init_bounded_number q2(.02,50.,8)
  init_bounded_number exp_srv2(.25,4.,8)
  init_bounded_number log_gamma_srv2(-50.,0.999,4)
  init_bounded_number log_beta_srv2(-50.,10.,4)
  init_bounded_number log_a50_srv2(0.,3.,4)

  init_number log_avg_fmort(2)
  init_bounded_dev_vector fmort_dev(styr,endyr,-15,15,2)

  init_vector log_selcoffs_fish(1,nselages_fish,4)

  vector log_sel_fish(1,nages)
  vector sel(1,nages)
  vector sel_srv1(1,nages)
  vector sel_srv2(1,nages)
  number avgsel_fish

  vector rec_years(styr_rec,endyr)
  vector years(styr,endyr)
```

```
  vector ages(1,nages)

  vector totn_srv1(styr,endyr)
  vector totn_srv2(styr,endyr)
  vector popnbiom(styr,endyr)
  sdreport_vector spawnbiom(styr,endyr)
  sdreport_vector recruitment(styr,endyr)
  vector explbiom(styr,endyr)
  vector surplus_production(styr,endyr-1)
  vector pred_cpue(styr,endyr)
  vector pred_srv1(styr,endyr)
  vector pred_srv2(styr,endyr)
  matrix pred_p_fish(styr,endyr,1,nages)
  matrix pred_p_srv1(styr,endyr,1,nages)
  matrix pred_p_srv2(styr,endyr,1,nages)
  vector pred_catch(styr,endyr)

  vector natage_cpue(1,nages)
  vector natage_srv1(1,nages)
  vector natage_srv2(1,nages)
  vector natage_spawn(1,nages)
  matrix natage(styr,endyr,1,nages)
  matrix catage(styr,endyr,1,nages)
  matrix Z(styr,endyr,1,nages)
  matrix F(styr,endyr,1,nages)
  matrix S(styr,endyr,1,nages)
  number beta_srv1
  number gamma_srv1
  number a50_srv1
  number beta_srv2
  number gamma_srv2
  number a50_srv2
  number survival

  vector offset(1,3)
  number rec_like
  number catch_like
  vector age_like(1,3)
  vector sel_like(1,3)
  number fpen
  number cpue_like
  number srv1_like
  number srv2_like

  objective_function_value f

  sdreport_number endbiom
  sdreport_number depletion_popnbiom
  sdreport_number endspawn
  sdreport_number depspawn
  sdreport_number deppopnbiom63
  sdreport_number depspawn63
  sdreport_vector endN(1,nages)
  likeprof_number endF


RUNTIME_SECTION
  convergence_criteria 1e-6;
```

```
PRELIMINARY_CALCS_SECTION

  //SET TIME HORIZON:years
  for (int i=styr; i<=endyr; i++)
    {
    years(i)=i;
    }

  //SET RECRUITMENT TIME HORIZON:rec_years
  for (i=styr_rec; i<=endyr; i++)
    {
    rec_years(i)=i;
    }

  //SET AGE CLASSES:ages
  for (i=1; i<=nages; i++)
    {
    ages(i)=i;
    }

  //RESCALE FISHERY CPUE INDEX
  obs_cpue*=10000;

  //RESCALE SURVEY1 INDEX
  obs_srv1*=100;

  //RESCALE SURVEY2 INDEX
  obs_srv2*=100;

  //CHECK INPUT DATA
  cout << "START YEAR: "<<styr<< endl;
  cout << "END YEAR: "<<endyr<< endl;
  cout << "AGE CLASSES: "<<nages<<endl;
  cout << "FISHERY SELECTED AGES: "<<nselages_fish<<endl;
  cout << "CATCH BIOMASS" << endl;
  cout << catch_bio << endl;
  cout << "FISHERY YEARS"<<endl;
  cout << yrs_fish<< endl;
  cout << "FISHERY CPUE YEARS"<<endl;
  cout << yrs_cpue<< endl;
  cout << "FRACTION OF Z BEFORE CPUE"<<endl;
  cout << zfrac_cpue<< endl;
  cout << "FISHERY CPUE INDEX"<<endl;
  cout << obs_cpue<< endl;
  cout << "SURVEY1 YEARS"<<endl;
  cout << yrs_srv1<< endl;
  cout << "FRACTION OF Z BEFORE SURVEY1"<<endl;
  cout << zfrac_srv1<< endl;
  cout << "SURVEY1 INDEX"<<endl;
  cout << obs_srv1<< endl;
  cout << "SURVEY2 YEARS"<<endl;
  cout << yrs_srv2<< endl;
  cout << "FRACTION OF Z BEFORE SURVEY2"<<endl;
  cout << zfrac_srv2<< endl;
  cout << "SURVEY2 INDEX"<<endl;
  cout << obs_srv2<< endl;
  cout << "FISHERY AGE COMPOSITION"<<endl;
```

```
cout << obs_p_fish<< endl;
cout << "SURVEY1 AGE COMPOSITION"<<endl;
cout << obs_p_srv1<< endl;
cout << "SURVEY2 AGE COMPOSITION"<<endl;
cout << obs_p_srv2<< endl;
cout << "WEIGHT AT AGE"<<endl;
cout << wt<< endl;
cout << "FRACTION OF Z BEFORE SPAWNING"<<endl;
cout << zfrac_spawn<< endl;
cout << "MATURITY AT AGE"<<endl;
cout << maturity<< endl;
cout << "LAMBDA RECRUITMENT: " << lambda_recruitment <<endl;
cout << "LAMBDA FISHERY CPUE: " <<lambda_fishery_cpue <<endl;
cout << "LAMBDA FISHERY AGE: " <<lambda_fishery_age <<endl;
cout << "LAMBDA SURVEY1 AGE: " <<lambda_srv1_age <<endl;
cout << "LAMBDA SURVEY1 INDEX: " <<lambda_biomass_index_srv1 <<endl;
cout << "LAMBDA SURVEY2 AGE: " <<lambda_srv2_age <<endl;
cout << "LAMBDA SURVEY2 INDEX: " <<lambda_biomass_index_srv2 <<endl;
cout << "LAMBDA CATCH BIOMASS: " <<lambda_catch_biomass <<endl;
cout << "LAMBDA FISHERY SELECTIVITY: " <<lambda_fishery_sel <<endl;
cout << "LAMBDA F PENALTY: " <<lambda_f_penalty <<endl;

//COMPUTE OFFSET FOR FISHERY AGE MULTINOMIAL
    for (i=1; i <= nobs_fish; i++)
      {
      //CHECK FOR FISHERY AGE DATA IN YEAR i, -99 = MISSING DATA
      if (obs_p_fish(i,1) >= 0.0)
        obs_p_fish(i)=obs_p_fish(i)/sum(obs_p_fish(i));
      for (int j=1; j<=nages; j++)
        {
          if (obs_p_fish(i,j)>0.0)
            {
            offset(1)-=nsamples_srv1*obs_p_fish(i,j)*log(obs_p_fish(i,j));
            }
        }
      }
cout << "FISHERY PROPORTION AT AGE DATA" << endl;
cout << obs_p_fish << endl;

//COMPUTE OFFSET FOR AUTUMN SURVEY AGE MULTINOMIAL
    for (i=1; i <= nobs_srv1; i++)
      {
      //CHECK FOR SURVEY1 AGE DATA IN YEAR i, -99 = MISSING DATA
      if (obs_p_srv1(i,1) >= 0.0)
        obs_p_srv1(i)=obs_p_srv1(i)/sum(obs_p_srv1(i));
      for (int j=1; j<=nages; j++)
        {
          if (obs_p_srv1(i,j)>0.0)
            {
            offset(2)-=nsamples_srv1*obs_p_srv1(i,j)*log(obs_p_srv1(i,j));
            }
        }
      }
cout << "SURVEY1 PROPORTION AT AGE DATA" << endl;
cout << obs_p_srv1 << endl;

//COMPUTE OFFSET FOR SPRING SURVEY AGE MULTINOMIAL
    for (i=1; i <= nobs_srv2; i++)
```

```
        {
        //CHECK FOR SURVEY2 AGE DATA IN YEAR i, -99 = MISSING DATA
        if (obs_p_srv2(i,1) >= 0.0)
          obs_p_srv2(i)=obs_p_srv2(i)/sum(obs_p_srv2(i));
        for (int j=1; j<=nages; j++)
          {
            if (obs_p_srv2(i,j)>0.0)
              {
              offset(3)-=nsamples_srv2*obs_p_srv2(i,j)*log(obs_p_srv2(i,j));
              }
          }
        }
  cout << "SURVEY2 PROPORTION AT AGE DATA" << endl;
  cout << obs_p_srv2 << endl;

TOP_OF_MAIN_SECTION
  //ALLOCATE SPACE IN READ-WRITE MEMORY
  arrmblsize=2000000;
  gradient_structure::set_GRADSTACK_BUFFER_SIZE(2000000);
  gradient_structure::set_CMPDIF_BUFFER_SIZE(60000000);

PROCEDURE_SECTION
  //DO THE FUNCTION CALLS IN SEQUENCE
  get_selectivity();
  get_mortality();
  survival=mfexp(-1.0* M);
  get_numbers_at_age();
  get_catch_at_age();
  evaluate_the_objective_function();

FUNCTION get_selectivity
  //FISHERY SELECTIVITY ESTIMATION FOR AGES 1 TO NSELAGES_FISH
  //SET AVERAGE TO 1 AND THEN RESCALE SO MAX VALUE=1
  for (int j=1;j<=nselages_fish;j++)
    {
    log_sel_fish(j)=log_selcoffs_fish(j);
    }
  for (j=nselages_fish+1;j<=nages;j++)
    {
    log_sel_fish(j)=log_sel_fish(j-1);
    }
  avgsel_fish=log(mean(mfexp(log_selcoffs_fish)));
  log_sel_fish-=log(mean(exp(log_sel_fish)));
  sel=mfexp(log_sel_fish);
  sel/=max(sel);
  //cout<<"FISHERY SELECTIVITY"<<endl;
  //cout<<sel<<endl;
  //cout<<"MAXIMUM VALUE: "<<max(sel)<<endl;

  //AUTUMN SURVEY1 SELECTIVITY ESTIMATION VIA THOMPSON MODEL
  beta_srv1=mfexp(log_beta_srv1);
  gamma_srv1=mfexp(log_gamma_srv1);
  a50_srv1=mfexp(log_a50_srv1);
  for (j=1; j<=nages; j++)
    {
    sel_srv1(j)=(1./(1.-gamma_srv1))*pow((1.-gamma_srv1)/gamma_srv1,
                gamma_srv1)*(exp(beta_srv1*gamma_srv1*(a50_srv1-
                double(j)))/(1+exp(beta_srv1*(a50_srv1-double(j)))));
```

```
    }
  //sel_srv1/=max(sel_srv1);
  //cout<<"SURVEY1 SELECTIVITY"<<endl;
  //cout<<sel_srv1<<endl;
  //cout<<"MAXIMUM VALUE: "<<max(sel_srv1)<<endl;

  //SPRING SURVEY2 SELECTIVITY ESTIMATION VIA THOMPSON MODEL
  beta_srv2=mfexp(log_beta_srv2);
  gamma_srv2=mfexp(log_gamma_srv2);
  a50_srv2=mfexp(log_a50_srv2);
  for (j=1; j<=nages; j++)
    {
    sel_srv2(j)=(1./(1.-gamma_srv2))*pow((1.-gamma_srv2)/gamma_srv2,
                gamma_srv2)*(exp(beta_srv2*gamma_srv2*(a50_srv2-
                double(j)))/(1+exp(beta_srv2*(a50_srv2-double(j)))));
    }
  //sel_srv2/=max(sel_srv2);
  //cout<<"SURVEY2 SELECTIVITY"<<endl;
  //cout<<sel_srv2<<endl;
  //cout<<"MAXIMUM VALUE: "<<max(sel_srv2)<<endl;

  //cout << "END OF GET SELECTIVITY" << endl;


FUNCTION get_mortality
  //COMPUTE TOTAL MORTALITY BY YEAR AND AGE
  //COMPUTE FISHING MORTALITY MATRIX
  for (int i=styr;i<=endyr;i++)
    {
    for (int j=1;j<=nages;j++)
       {
        F(i,j)=sel(j)*mfexp(log_avg_fmort + fmort_dev(i));
       }
    }

  //COMPUTE TOTAL MORTALITY MATRIX
    Z=F+M;

  //COMPUTE SURVIVAL MATRIX
    S=mfexp(-1.0*Z);

  //cout << "END OF GET MORTALITY" << endl;

FUNCTION get_numbers_at_age
  //COMPUTE NUMBERS AT AGE MATRIX
  int itmp;

  //COMPUTE NUMBERS AT AGE IN INITIAL YEAR
  for (int j=1;j<nages;j++)
    {
      itmp=styr+1-j;
      natage(styr,j)=mfexp(mean_log_rec-M*double(j-1)+rec_dev(itmp));
    }
    natage(styr,nages)=mfexp(mean_log_rec-M*(nages-1))/
                       (1. - survival);

  //COMPUTE RECRUITMENT IN SUBSEQUENT YEARS
  for (int i=styr+1;i<=endyr;i++)
```

```
  {
    natage(i,1)=mfexp(mean_log_rec+rec_dev(i));
  }

//COMPUTE NUMBERS AT AGES 2 TO PLUS-GROUP VIA FORWARD PROJECTION
for (i=styr;i< endyr;i++)
  {
     for (j=2;j<=nages;j++)
       {
       natage(i+1)(j)=natage(i)(j-1)*S(i)(j-1);
       }
     natage(i+1,nages)+=natage(i,nages)*S(i,nages);
  }

//COMPUTE VARIABLES DERIVED FROM NUMBERS AT AGE MATRIX
for (i=styr;i<=endyr;i++)
  {

  //COMPUTE PREDICTED AUTUMN SURVEY1 INDEX AND AGE COMPOSITION
   natage_srv1=elem_prod(natage(i),mfexp(-zfrac_srv1*Z(i)));
   totn_srv1(i)=(natage_srv1*sel_srv1);
   pred_srv1(i)=q1*(natage_srv1*elem_prod(sel_srv1,wt));
   pred_p_srv1(i)=elem_prod(sel_srv1,natage_srv1)/totn_srv1(i);

   //COMPUTE PREDICTED SPRING SURVEY2 INDEX AND AGE COMPOSITION
   natage_srv2=elem_prod(natage(i),mfexp(-zfrac_srv2*Z(i)));
   totn_srv2(i)=(natage_srv2*sel_srv2);
   pred_srv2(i)=q2*pow((natage_srv2*elem_prod(sel_srv2,wt)),exp_srv2);
   pred_p_srv2(i)=elem_prod(sel_srv2,natage_srv2)/totn_srv2(i);

   //COMPUTE POPULATION AND SPAWNING AND EXPLOITABLE BIOMASS
   popnbiom(i)=natage(i)*wt;
   natage_spawn=elem_prod(natage(i),mfexp(-zfrac_spawn*Z(i)));
   spawnbiom(i)=natage_spawn*elem_prod(maturity,wt);
   explbiom(i)=natage(i)*elem_prod(sel,wt);

   //COMPUTE PREDICTED CPUE INDEX
   natage_cpue=elem_prod(natage(i),mfexp(-zfrac_cpue*Z(i)));
   pred_cpue(i)=q_cpue*pow(natage_cpue*elem_prod(sel,wt),exp_cpue);

   //COMPUTE RECRUITMENT
   recruitment(i)=mfexp(mean_log_rec+rec_dev(i));

  }

  //COMPUTE ANNUAL SURPLUS PRODUCTION
  for (i=styr;i<endyr;i++)
    {
    surplus_production(i)=explbiom(i+1)-explbiom(i)+catch_bio(i);
    }

  //COMPUTE DEPLETION RATIOS FOR POPULATION AND SPAWNING BIOMASS
  depletion_popnbiom=popnbiom(endyr)/popnbiom(styr);
  depspawn=spawnbiom(endyr)/spawnbiom(styr);
  deppopnbiom63=popnbiom(endyr)/popnbiom(1963);
  depspawn63=spawnbiom(endyr)/spawnbiom(1963);

  //COMPUTE POPULATION AND SPAWNING BIOMASS IN ENDING YEAR
```

```
    endbiom=popnbiom(endyr);
    endspawn=spawnbiom(endyr);

    //COMPUTE F AND NUMBERS AT AGE IN ENDING YEAR
    endF=mfexp(log_avg_fmort+fmort_dev(endyr));
    endN=natage(endyr);

  //cout << "END OF GET NUMBERS AT AGE" << endl;

FUNCTION get_catch_at_age
  //COMPUTE CATCH NUMBERS BY YEAR AND AGE
  for (int i=styr; i<=endyr; i++)
  {
    pred_catch(i)=0.;

    //APPLY THE CATCH EQUATION
    for (int j = 1 ; j<= nages; j++)
      {
      catage(i,j) = natage(i,j)*F(i,j)*(1.-S(i,j))/Z(i,j);

      //COMPUTE PREDICTED CATCH BIOMASS
      pred_catch(i)+=catage(i,j)*wt(j);
      }

      //COMPUTE PREDICTED FISHERY AGE COMPOSITION
      pred_p_fish(i)=catage(i)/sum(catage(i));
    }
  //cout << "END OF GET CATCH AT AGE" << endl;


FUNCTION evaluate_the_objective_function
  //COMPUTE THE MODEL LIKELIHOOD (f)
  f=.0;

  //DO THIS WHEN RECRUITMENT DEVIATIONS ARE ESTIMATED (PHASE>2)
  if (active(rec_dev))
    {
    age_like=0.;
    int ii;

    //COMPUTE RECRUITMENT LIKELIHOOD COMPONENT
    rec_like=norm2(rec_dev);
    f+=lambda_recruitment*rec_like;

    //COMPUTE AGE COMPOSITION LIKELIHOODS
    //FISHERY COMPONENT
    for (int i=1; i <= nobs_fish; i++)
      {
      ii=yrs_fish(i);
      for (int j=1; j<=nages; j++)
        {
        if (obs_p_fish(i,1) >= 0.0)
          age_like(1)-
=nsamples_fish*obs_p_fish(i,j)*log(pred_p_fish(ii,j)+1.e-13);
       //cout << "FISHERY AGE: "<<age_like(1) << " " << i << " "<<j<< endl;
        }
      }
      age_like(1)-=offset(1);
```

```
      age_like(1)*=lambda_fishery_age;

    //AUTUMN SURVEY1 COMPONENT
    for (i=1; i <= nobs_srv1; i++)
      {
      ii=yrs_srv1(i);
      for (int j=1; j<=nages; j++)
        {
        if (obs_p_srv1(i,1) >= 0.0)
          age_like(2)-
=nsamples_srv1*obs_p_srv1(i,j)*log(pred_p_srv1(ii,j)+1.e-13);
       //cout << "SURVEY1 AGE: " << age_like(2) << " " << i << " "<<j<< endl;
        }
      }
      age_like(2)-=offset(2);
      age_like(2)*=lambda_srv1_age;

    //SPRING SURVEY2 COMPONENT
    for (i=1; i <= nobs_srv2; i++)
      {
      ii=yrs_srv2(i);
      for (int j=1; j<=nages; j++)
        {
        if (obs_p_srv2(i,1) >= 0.0)
          age_like(3)-
=nsamples_srv2*obs_p_srv2(i,j)*log(pred_p_srv2(ii,j)+1.e-13);
       //cout << "SURVEY2 AGE: " << age_like(3) << " " << i << " "<<j<< endl;
        }
      }
      age_like(3)-=offset(3);
      age_like(3)*=lambda_srv2_age;

      f+=sum(age_like);
    }

  //COMPUTE CPUE INDEX LIKELIHOOD (LOGNORMAL)
  cpue_like=norm2(log(obs_cpue+0.001)-log(pred_cpue(yrs_cpue)+0.001));
  f+=lambda_fishery_cpue*cpue_like;

  //COMPUTE AUTUMN SURVEY INDEX LIKELIHOOD (LOGNORMAL)
  srv1_like=norm2(log(obs_srv1+0.001)-log(pred_srv1(yrs_srv1)+0.001));
  f+=lambda_biomass_index_srv1*srv1_like;

  //COMPUTE SPRING SURVEY INDEX LIKELIHOOD (LOGNORMAL)
  srv2_like=norm2(log(obs_srv2+0.001)-log(pred_srv2(yrs_srv2)+0.001));
  f+=lambda_biomass_index_srv2*srv2_like;

  //COMPUTE CATCH BIOMASS LIKELIHOOD
  catch_like=norm2(log(catch_bio+0.000001)-log(pred_catch+0.000001));
  f+=lambda_catch_biomass*catch_like;

  //COMPUTE SELECTIVITY LIKELIHOODS
  //FISHERY COMPONENT
  sel_like(1)=norm2(first_difference(first_difference(log_sel_fish)));
  f+=lambda_fishery_sel*square(avgsel_fish);

  //SURVEY COMPONENTS (PLACEHOLDERS FOR FUTURE USE)
  sel_like(2)=0.;
```

```
  sel_like(3)=0.;

  f+=lambda_fishery_sel*sel_like(1);

  //COMPUTE F PENALTY LIKELIHOOD CONSTRAINT
  //HIGH PENALTY IF ESTIMATION PHASE < 3
  //LOW PENALTY IF ESTIMATION PHASE >= 3
  if (current_phase()<3)
    {
     fpen=10.*norm2(mfexp(fmort_dev+log_avg_fmort)-.1);
    }
  else
    {
     fpen=0.001*norm2(mfexp(fmort_dev+log_avg_fmort)-.1);
    }
  if (active(fmort_dev))
    {
     fpen+=norm2(fmort_dev);
    }
  f+=lambda_f_penalty*fpen;


REPORT_SECTION
  //OUTPUT RESULTS TO FILE "RED.REP"

  report << "Redfish Age-structured Model RED" << endl;

  report << "Estimated Numbers (000s) of Fish at Age (year,age)" << endl;
  report << natage << endl;
  report << "Estimated Fishing Mortality (year,age)" << endl;
  report << F << endl;

  report << "Observed Fishery CPUE (year)" << endl;
  report << yrs_cpue << endl;
  report << obs_cpue << endl;
  report << "Predicted Fishery CPUE (year)" << endl;
  report << pred_cpue << endl;
  report << "Residuals for Fishery CPUE (year)" << endl;
  report << obs_cpue - pred_cpue(yrs_cpue) << endl;

  report << "Observed Survey1 Biomass Index (year)" << endl;
  report << yrs_srv1 << endl;
  report << obs_srv1 << endl;
  report << "Predicted Survey1 Biomass Index (year)" << endl;
  report << pred_srv1 << endl;
  report << "Residuals for Survey1 Biomass Index (year)" << endl;
  report << obs_srv1 - pred_srv1(yrs_srv1) << endl;

  report << "Observed Survey2 Biomass Index (year)" << endl;
  report << obs_srv2 << endl;
  report << "Predicted Survey2 Biomass Index (year)" << endl;
  report << pred_srv2 << endl;
  report << "Residuals for Survey2 Biomass Index (year)" << endl;
  report << obs_srv2 - pred_srv2(yrs_srv2) << endl;

  report << "Observed Fishery Proportion at Age (year,age)" << endl;
  report << obs_p_fish << endl;
  report << "Predicted Fishery Proportion at Age (year,age)" << endl;
```

```
  report << pred_p_fish << endl;

  report << "Observed Survey1 Proportion at Age (year,age)" << endl;
  report << obs_p_srv1<< endl;
  report << "Predicted Survey1 Proportion at Age (year,age)" << endl;
  report << pred_p_srv1<< endl;

  report << "Observed Survey2 Proportion at Age (year,age)" << endl;
  report << obs_p_srv2<< endl;
  report << "Predicted Survey2 Proportion at Age (year,age)" << endl;
  report << pred_p_srv2<< endl;

  report << "Population Biomass (mt) by Year"<< endl;
  report << years << endl;
  report << popnbiom << endl;
  report << "Population Biomass in 2000" << endl;
  report << endbiom << endl;
  report << "Depletion ratio in 2000 for population biomass" << endl;
  report << depletion_popnbiom << endl;
  report << "Depletion ratio in 2000 relative to 1963 population biomass" <<
endl;
  report << deppopnbiom63 << endl;

  report << "Spawning Biomass (mt) by Year" << endl;
  report << years << endl;
  report << spawnbiom << endl;
  report << "Spawning Biomass in 2000" << endl;
  report << endspawn << endl;
  report << "Depletion ratio in 2000 for spawning biomass" << endl;
  report << depspawn << endl;
  report << "Depletion ratio in 2000 relative to 1963 spawning biomass" <<
endl;
  report << depspawn63 << endl;

  report << "Exploitable Biomass (mt) by Year"<< endl;
  report << years << endl;
  report << explbiom << endl;

  report << "Population numbers at age (thousands) in 2000" << endl;
  report << ages << endl;
  report << endN << endl;

  report << "Recruitment (thousands of age-1 recruits) by Year" << endl;
  report << rec_years << endl;
  report << mfexp(mean_log_rec+rec_dev) << endl;

  report << "Observed Catch Biomass (mt) by Year" << endl;
  report << years << endl;
  report << catch_bio << endl;
  report << "Predicted Catch Biomass (mt) by Year" << endl;
  report << pred_catch << endl;
  report << "Residuals for Catch Biomass (year)" << endl;
  report << catch_bio - pred_catch << endl;

  report << "Annual Surplus Production (mt)" << endl;
  report << years << endl;
  report << surplus_production << endl;
```

```
  report << "Estimated Average Annual Fishing Mortality by Year" << endl;
  report << years << endl;
  report << mfexp(log_avg_fmort+fmort_dev) << endl;
  report << "Fishing Mortality in 2000" << endl;
  report << endF << endl;

  report << "Fishery Selectivity by Age" << endl;
  report << ages << endl;
  report << sel << endl;

  report << "Survey1 Selectivity by Age" << endl;
  report << ages << endl;
  report << sel_srv1 << endl;

  report << "Survey2 Selectivity by Age" << endl;
  report << ages << endl;
  report << sel_srv2 << endl;

  report << "OBJECTIVE FUNCTION VALUE: " << f << endl;

  report << "LIKELIHOOD EMPHASIS FACTORS" << endl;
  report<< "RECRUITMENT::FISHERY AGE::SURVEY1 AGE::SURVEY2 AGE::F
PENALTY"<<endl;
  report << lambda_recruitment<<"  "<< lambda_fishery_age<< "
"<<lambda_srv1_age<< " "<<lambda_srv2_age<< " "<<lambda_f_penalty<<endl;
  report<< "FISHERY SELECTIVITY::CATCH BIOMASS::CPUE::SURVEY1 INDEX::SURVEY2
INDEX"<<endl;
  report << lambda_fishery_sel<<" "<<lambda_catch_biomass<<"
"<<lambda_fishery_cpue<<" "<<lambda_biomass_index_srv1<<"
"<<lambda_biomass_index_srv1<<endl;

  report << "LIKELIHOOD COMPONENTS" << endl;
  report<< "RECRUITMENT::FISHERY AGE::SURVEY1 AGE::SURVEY2 AGE::F
PENALTY"<<endl;
  report << rec_like<<"  "<< age_like<< " "<<fpen<<endl;
  report<< "FISHERY SELECTIVITY::CATCH BIOMASS::CPUE::SURVEY1 INDEX::SURVEY2
INDEX"<<endl;
  report << sel_like(1)+square(avgsel_fish)<<" "<<catch_like<<"
"<<cpue_like<<" "<<srv1_like<<" "<<srv2_like<<endl;

  //END OF MODEL
```

Part B. AD model builder input data file for the baseline redfish model

```
#Styr endyr
1934 2000
# Number of age classes
26
# Number of age classes for selectivity estimation
9
# Catch biomass:1934 to 2000, n=67
519     7549    23162   14823   20640   25406   26762   50796   55892   48348
50439   37912   42423   40160   43631   30743   34307   30077   21377   16791
12988   13914   14388   18490   16047   15521   11375   14101   14134   10046
8313    8057    8569    10864   6777    12455   16741   20034   19095   17360
10471   10572   10696   13223   14083   14755   10183   7915    6903    5328
4793    4282    2929    1894    1177    637     601     525     849     800
440     440     322     251     320     353     319
```

```
# Number of years of fishery CPUE data
38
# Years of fishery CPUE data
1952 1953 1954 1955 1956 1957 1958 1959 1960 1961 1962 1963 1964 1965 1966
1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981
1982 1983 1984 1985 1986 1987 1988 1989
# Fraction of Z Prior to CPUE (fraction of year)
0.50
# Untransformed CPUE biomass index
3.4     3.6     3.1     4.0      3.8     3.6     3.6     3.5     3.0
3.5     4.0      3.0      2.9     4.4     6.4     5.6     6.1     4.9
4.0      3.2     2.9     2.9     2.6     2.2     2.3     2.5     2.4     1.9
  1.6     1.4     1.5     1.2     1.1     0.9     0.6     0.7     0.5     0.6

# Number years of fishery age data
17
# Years of age fishery data
1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983
1984 1985
# Number of age samples in fishery (nsamples_fish)
200
# Fishery age composition data 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
20 21 22 23 24 25 26+
0 0 0.0000  0.0006  0.0111  0.0115  0.0265  0.1594  0.0660  0.1765  0.0699
0.1045  0.0864  0.0584  0.0741  0.0354  0.0197  0.0138  0.0159  0.0112  0.0119
0.0091  0.0123  0.0010  0.0026  0.0223
0 0 0.0000  0.0000  0.0027  0.0741  0.0740  0.0194  0.1772  0.0589  0.1526
0.0500  0.0859  0.0488  0.0421  0.0638  0.0325  0.0300  0.0072  0.0121  0.0067
0.0097  0.0105  0.0089  0.0012  0.0319
0 0 0.0000  0.0000  0.0000  0.0014  0.0376  0.0859  0.0298  0.1533  0.0536
0.1261  0.0599  0.0827  0.0713  0.0561  0.0428  0.0536  0.0261  0.0225  0.0109
0.0203  0.0108  0.0055  0.0027  0.0473
0 0 0.0000  0.0000  0.0000  0.0000  0.0196  0.0692  0.1554  0.0360  0.1592
0.0584  0.0606  0.0419  0.0742  0.0514  0.0253  0.0268  0.0471  0.0154  0.0212
0.0246  0.0151  0.0113  0.0269  0.0604
0 0 0.0000  0.0000  0.0000  0.0000  0.0050  0.0523  0.1685  0.1781  0.0467
0.1558  0.0441  0.0658  0.0504  0.0430  0.0382  0.0293  0.0183  0.0198  0.0087
0.0125  0.0090  0.0063  0.0061  0.0420
0 0 0.0122  0.0042  0.0000  0.0007  0.0003  0.0069  0.0748  0.1874  0.1168
0.0966  0.0678  0.0442  0.0517  0.0371  0.0577  0.0361  0.0254  0.0262  0.0234
0.0290  0.0108  0.0113  0.0099  0.0696
0 0 0.0002  0.0294  0.0030  0.0005  0.0000  0.0013  0.0052  0.0822  0.1844
0.0911  0.0817  0.0610  0.0427  0.0569  0.0575  0.0522  0.0400  0.0472  0.0257
0.0375  0.0208  0.0124  0.0126  0.0542
0 0 0.0000  0.0065  0.2986  0.0146  0.0000  0.0000  0.0007  0.0016  0.0156
0.0902  0.1125  0.0567  0.0575  0.0463  0.0411  0.0389  0.0475  0.0203  0.0256
0.0227  0.0108  0.0224  0.0031  0.0670
0 0 0.0000  0.0000  0.0061  0.4335  0.0081  0.0000  0.0000  0.0000  0.0021
0.0551  0.0327  0.1039  0.0472  0.0711  0.0379  0.0308  0.0275  0.0119  0.0183
0.0140  0.0030  0.0148  0.0262  0.0558
0 0 0.0000  0.0000  0.0000  0.0064  0.5767  0.0050  0.0000  0.0008  0.0008
0.0043  0.0396  0.0348  0.0692  0.0410  0.0307  0.0203  0.0211  0.0301  0.0210
0.0172  0.0117  0.0045  0.0124  0.0521
0 0 0.0000  0.0000  0.0006  0.0051  0.0211  0.5911  0.0038  0.0029  0.0012
0.0042  0.0135  0.0306  0.0491  0.0324  0.0394  0.0245  0.0210  0.0251  0.0199
0.0148  0.0133  0.0134  0.0106  0.0624
```

```
0 0 0.0000  0.0000  0.0000  0.0049  0.0065  0.0412  0.6266  0.0077  0.0016
0.0017  0.0080  0.0182  0.0308  0.0453  0.0319  0.0246  0.0209  0.0168  0.0175
0.0137  0.0129  0.0109  0.0098  0.0485
0 0 0.0012  0.0000  0.0039  0.0020  0.0029  0.0024  0.0114  0.6313  0.0043
0.0011  0.0000  0.0022  0.0162  0.0186  0.0650  0.0258  0.0272  0.0202  0.0162
0.0194  0.0156  0.0166  0.0178  0.0785
0 0 0.0002  0.0190  0.0086  0.0042  0.0064  0.0021  0.0000  0.0011  0.5091
0.0039  0.0022  0.0015  0.0090  0.0130  0.0408  0.0317  0.0588  0.0227  0.0351
0.0339  0.0211  0.0094  0.0073  0.1590
0 0 0.0000  0.0010  0.1464  0.0138  0.0040  0.0037  0.0075  0.0043  0.0122
0.4302  0.0050  0.0092  0.0056  0.0036  0.0074  0.0277  0.0234  0.0478  0.0147
0.0194  0.0272  0.0169  0.0114  0.1576
0 0 0.0033  0.0008  0.0037  0.4813  0.0000  0.0014  0.0029  0.0000  0.0025
0.0011  0.2575  0.0000  0.0032  0.0035  0.0025  0.0066  0.0151  0.0120  0.0234
0.0155  0.0104  0.0113  0.0117  0.1303
0 0 0.0026  0.0143  0.0032  0.0030  0.3734  0.0000  0.0027  0.0011  0.0013
0.0039  0.0012  0.3131  0.0000  0.0024  0.0011  0.0099  0.0113  0.0254  0.0225
0.0183  0.0193  0.0139  0.0105  0.1456
# Number of Years: Survey1
38
# Survey1 years
1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977
1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992
1993 1994 1995 1996 1997 1998 1999 2000
# Fraction of Z Prior to Survey1 (fraction of year)
0.75
# Survey1 biomass index
493.1101        1117.1706       268.0391        595.4151        497.2023
826.6244        480.8335        673.1669        478.7874        503.3406
347.837 495.1562        816.3939        313.0533        353.9753
423.5427        327.376 257.8086        249.6242        69.5674 83.8901
79.7979 116.6277        163.688 112.5355        128.9043        139.1348
249.6242        171.8724        165.611334      229.122278      121.517879
95.205033       626.781813      387.53134       649.02292       467.820304
 536.078
# Number of age samples in survey1 (nsamples_srv1)
100
# Survey1 age composition data
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
```

```
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
0.0000      0.0001      0.0085      0.2724      0.0023      0.0025      0.0000
      0.0000      0.0000      0.0135      0.0173      0.0996      0.0382
      0.0829      0.0436      0.0461      0.0298      0.0176      0.0216
      0.0120      0.0529      0.0195      0.0231      0.0271      0.0181
      0.1514
0.0000      0.0000      0.0020      0.0168      0.3159      0.0048      0.0000
      0.0000      0.0000      0.0000      0.0311      0.0049      0.0880
      0.0449      0.0415      0.0576      0.0358      0.0341      0.0285
      0.0206      0.0029      0.0586      0.0000      0.0106      0.0155
      0.1859
0.0000      0.0020      0.0007      0.0006      0.0319      0.5005      0.0014
      0.0000      0.0000      0.0000      0.0000      0.0201      0.0259
      0.0774      0.0366      0.0301      0.0146      0.0147      0.0127
      0.0151      0.0166      0.0083      0.0314      0.0087      0.1509
      0.0000
0.0003      0.0001      0.0041      0.0020      0.0069      0.0732      0.5333
      0.0032      0.0000      0.0015      0.0023      0.0126      0.0616
      0.0434      0.0318      0.0269      0.0207      0.0100      0.0237
      0.0160      0.0113      0.0114      0.0227      0.0088      0.0131
      0.0589
0.0033      0.0000      0.0022      0.0069      0.0022      0.0095      0.0387
      0.5368      0.0012      0.0013      0.0012      0.0062      0.0123
      0.0222      0.0453      0.0614      0.0238      0.0323      0.0223
      0.0155      0.0290      0.0187      0.0128      0.0050      0.0039
      0.0860
0.0014      0.0403      0.0019      0.0049      0.0208      0.0145      0.0078
      0.0222      0.4781      0.0026      0.0000      0.0000      0.0026
      0.0020      0.0142      0.0691      0.0365      0.0258      0.0382
      0.0184      0.0115      0.0303      0.0137      0.0153      0.0213
      0.1066
0.0000      0.0062      0.0431      0.0123      0.0015      0.0124      0.0042
      0.0074      0.0416      0.2958      0.0084      0.0183      0.0231
      0.0239      0.0187      0.0468      0.0282      0.1701      0.0123
      0.0339      0.0252      0.0198      0.0166      0.0153      0.0208
      0.0940
0.0000      0.0033      0.0064      0.4456      0.0451      0.0000      0.0000
      0.0020      0.0133      0.0183      0.2467      0.0105      0.0089
      0.0039      0.0066      0.0166      0.0378      0.0188      0.0331
      0.0038      0.0077      0.0096      0.0077      0.0096      0.0052
      0.0394
```

0.0015 0.0250 0.0308 0.0343 0.4121 0.0163 0.0052
0.0076 0.0120 0.0238 0.0250 0.2443 0.0058
0.0055 0.0073 0.0121 0.0141 0.0120 0.0177
0.0031 0.0056 0.0142 0.0121 0.0095 0.0072
0.0360
0.0052 0.0509 0.0330 0.0274 0.0035 0.3223 0.0043
0.0070 0.0027 0.0035 0.0039 0.0000 0.4073
0.0000 0.0039 0.0000 0.0099 0.0041 0.0023
0.0000 0.0897 0.0000 0.0017 0.0023 0.0017
0.0137
0.0000 0.0140 0.1024 0.1178 0.0277 0.0242 0.2419
0.0139 0.0000 0.0303 0.0000 0.0541 0.0033
0.2339 0.0015 0.0109 0.0000 0.0111 0.0022
0.0049 0.0043 0.0830 0.0000 0.0106 0.0000
0.0080
0.0000 0.0000 0.0108 0.2161 0.3510 0.0197 0.0000
0.1921 0.0034 0.0004 0.0057 0.0025 0.0057
0.0047 0.1472 0.0000 0.0008 0.0000 0.0010
0.0027 0.0000 0.0000 0.0268 0.0000 0.0007
0.0087
0.0000 0.0119 0.0461 0.0502 0.2591 0.1388 0.0057
0.0061 0.1637 0.0000 0.0027 0.0066 0.0037
0.0037 0.0023 0.2074 0.0036 0.0037 0.0000
0.0021 0.0016 0.0055 0.0030 0.0634 0.0000
0.0092
0.0299 0.0904 0.0334 0.0595 0.0198 0.1900 0.1144
0.0063 0.0000 0.1856 0.0000 0.0000 0.0051
0.0102 0.0041 0.0092 0.1856 0.0000 0.0000
0.0012 0.0000 0.0000 0.0000 0.0000 0.0392
0.0160
0.0031 0.0450 0.1682 0.1314 0.0440 0.0274 0.2423
0.0503 0.0000 0.0063 0.1317 0.0000 0.0000
0.0018 0.0092 0.0027 0.0028 0.0630 0.0000
0.0018 0.0076 0.0110 0.0064 0.0000 0.0015
0.0423
0.0063 0.0070 0.0253 0.1055 0.3132 0.1092 0.0454
0.0759 0.0695 0.0223 0.0014 0.0819 0.0000
0.0000 0.0090 0.0048 0.0070 0.0015 0.0587
0.0000 0.0073 0.0010 0.0035 0.0000 0.0034
0.0409
0.0106 0.0059 0.0184 0.0558 0.2403 0.1495 0.0614
0.0379 0.0965 0.0432 0.0240 0.0000 0.1097
0.0051 0.0059 0.0000 0.0121 0.0101 0.0037
0.0666 0.0000 0.0051 0.0000 0.0089 0.0000
0.0294
0.0089 0.0100 0.0256 0.0881 0.1258 0.1779 0.1768
0.0519 0.0335 0.0557 0.0392 0.0143 0.0168
0.0861 0.0000 0.0112 0.0027 0.0081 0.0099
0.0000 0.0317 0.0000 0.0041 0.0025 0.0000
0.0190
0.0101 0.0294 0.0531 0.1174 0.1520 0.1935 0.1263
0.1162 0.0252 0.0255 0.0345 0.0156 0.0177
0.0000 0.0407 0.0018 0.0000 0.0019 0.0030
0.0014 0.0000 0.0175 0.0000 0.0000 0.0000
0.0173
0.0184 0.0466 0.0949 0.1340 0.1052 0.1212 0.1074
0.1308 0.0725 0.0306 0.0198 0.0374 0.0106
0.0016 0.0000 0.0427 0.0000 0.0000 0.0009

```
      0.0008      0.0015      0.0000      0.0176      0.0000      0.0000
      0.0056
0.0061      0.0299      0.1631      0.5279      0.0875      0.0570      0.0280
      0.0221      0.0298      0.0073      0.0074      0.0026      0.0027
      0.0086      0.0000      0.0000      0.0120      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0028      0.0000
      0.0051
0.0003      0.0006      0.0114      0.3269      0.4075      0.0770      0.0695
      0.0504      0.0048      0.0110      0.0189      0.0027      0.0028
      0.0029      0.0038      0.0000      0.0000      0.0052      0.0000
      0.0003      0.0007      0.0000      0.0000      0.0000      0.0015
      0.0017
0.0051      0.0015      0.0216      0.0725      0.2734      0.2226      0.0642
      0.0540      0.0576      0.0373      0.0276      0.0760      0.0047
      0.0177      0.0111      0.0091      0.0050      0.0021      0.0185
      0.0009      0.0000      0.0025      0.0001      0.0024      0.0000
      0.0126
0.0022      0.0007      0.0079      0.0274      0.1177      0.3412      0.2411
      0.0717      0.0602      0.0458      0.0337      0.0074      0.0215
      0.0000      0.0029      0.0069      0.0015      0.0000      0.0000
      0.0078      0.0000      0.0004      0.0006      0.0000      0.0000
      0.0014
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
# Number of Years: Survey2
33
# Survey2 years
1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997
1998 1999 2000
# Fraction of Z Prior to Survey2 (fraction of year)
0.25
# Survey2 biomass index
347.837 403.0817        386.7129        1465.0076       908.4684
517.6633        384.6668        360.1136        536.0782        237.3476
249.6242        660.8903        415.3583        380.5746        192.3334
124.8121        55.2447 135.0426        65.4752 263.9469        67.5213
59.3369 139.1348        87.9823 218.31887       358.0675        80.20712
39.28512        243.28129       696.49244       160.41424       389.16822
1146.02
# Number of age samples in survey2 (nsamples_srv2)
100
# Survey2 age composition data
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
```

```
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
0.0000      0.0000      0.0151      0.2174      0.0080      0.0161      0.0080
      0.0000      0.0000      0.0342      0.0140      0.0899      0.0445
      0.1262      0.0413      0.0682      0.0453      0.0242      0.0215
      0.0267      0.0469      0.0149      0.0207      0.0032      0.0107
      0.1031
0.0000      0.0000      0.0010      0.0329      0.0229      0.0034      0.0105
      0.0021      0.0150      0.0033      0.0622      0.0218      0.1676
      0.1320      0.0464      0.0759      0.0594      0.0162      0.0253
      0.0285      0.0218      0.0780      0.0004      0.0183      0.0176
      0.1375
0.0000      0.0000      0.0008      0.0027      0.0548      0.0717      0.0147
      0.0019      0.0000      0.0023      0.0037      0.0368      0.0309
      0.1327      0.0604      0.0622      0.0463      0.0513      0.0162
      0.0278      0.0281      0.0189      0.0520      0.0223      0.0289
      0.2324
0.0000      0.0000      0.0089      0.0026      0.0005      0.0267      0.4146
      0.0031      0.0016      0.0000      0.0029      0.0110      0.0740
      0.0373      0.0412      0.0253      0.0396      0.0268      0.0328
      0.0170      0.0299      0.0278      0.0203      0.0150      0.0200
      0.1208
0.0000      0.0004      0.0001      0.0002      0.0015      0.0055      0.0093
      0.5378      0.0000      0.0000      0.0051      0.0136      0.0244
      0.0503      0.0375      0.0327      0.0402      0.0343      0.0202
      0.0182      0.0187      0.0354      0.0121      0.0068      0.0167
      0.0790
0.0000      0.0034      0.0026      0.0000      0.0036      0.0000      0.0000
      0.0050      0.4086      0.0000      0.0057      0.0024      0.0000
      0.0091      0.0200      0.0731      0.0650      0.0528      0.0389
      0.0424      0.0259      0.0397      0.0386      0.0108      0.0163
      0.1363
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
0.0000      0.0066      0.0344      0.0129      0.0000      0.2546      0.0029
      0.0000      0.0033      0.0123      0.0100      0.0000      0.4611
      0.0000      0.0000      0.0000      0.0055      0.0000      0.0029
      0.0000      0.1862      0.0000      0.0000      0.0000      0.0000
      0.0074
0.0000      0.0040      0.0178      0.0608      0.0133      0.0000      0.2764
      0.0000      0.0000      0.0124      0.0000      0.0165      0.0055
```

```
      0.3921      0.0039      0.0039      0.0000      0.0000      0.0017
      0.0000      0.0026      0.1531      0.0000      0.0000      0.0077
      0.0283
0.0000      0.0000      0.0000      0.0111      0.0747      0.0177      0.0091
      0.2037      0.0054      0.0050      0.0123      0.0016      0.0179
      0.0105      0.4224      0.0036      0.0036      0.0111      0.0089
      0.0020      0.0034      0.0081      0.1187      0.0131      0.0056
      0.0306
0.0000      0.0000      0.0000      0.0048      0.0549      0.1204      0.0057
      0.0041      0.2703      0.0000      0.0000      0.0000      0.0035
      0.0000      0.0055      0.3953      0.0000      0.0059      0.0000
      0.0320      0.0000      0.0172      0.0000      0.0695      0.0000
      0.0110
0.0070      0.0243      0.0273      0.0413      0.0416      0.2168      0.1646
      0.0215      0.0054      0.2054      0.0000      0.0039      0.0110
      0.0029      0.0132      0.0039      0.1589      0.0000      0.0000
      0.0029      0.0099      0.0029      0.0015      0.0000      0.0303
      0.0035
0.0000      0.0431      0.1388      0.0859      0.0805      0.0645      0.1898
      0.0807      0.0061      0.0048      0.1558      0.0000      0.0151
      0.0030      0.0124      0.0101      0.0026      0.0780      0.0000
      0.0000      0.0000      0.0041      0.0000      0.0024      0.0000
      0.0225
0.0000      0.0000      0.0000      0.0141      0.0815      0.0375      0.0197
      0.1127      0.0850      0.0419      0.0105      0.2091      0.0149
      0.0151      0.0052      0.0262      0.0195      0.0000      0.1692
      0.0000      0.0035      0.0035      0.0166      0.0000      0.0031
      0.1111
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
-99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99   -99
      -99
```

```
# Weight at age 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
25 26+
0.010 0.020 0.059 0.099 0.145 0.178 0.201 0.250 0.272 0.310 0.348 0.391 0.423
      0.429 0.463 0.495 0.503 0.508 0.548 0.558 0.565 0.581 0.595 0.583 0.582
      0.637
# Fraction of Z Prior to Survey2 (fraction of year)
0.4
# Maturity at age 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
24 25 26+
0.01 0.02 0.05 0.15 0.36 0.64 0.85 0.95 0.98 0.99 1.0 1.0 1.0 1.0 1.0 1.0 1.0
1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
# Likelihood emphasis: recruitment
10.0
# Likelihood emphasis: fishery CPUE
10.0
# Likelihood emphasis: fishery age composition
10.0
# Likelihood emphasis: survey1 age composition
1.0
# Likelihood emphasis: survey1 biomass index
1000.0
# Likelihood emphasis: survey2 age composition
1.0
# Likelihood emphasis: survey2 biomass index
1000.0
# Likelihood emphasis: catch biomass
1000.0
# Likelihood emphasis: fishery selectivity
100.0
# Likelihood emphasis: F penalty
1.0
```

Part C. Parameter estimates for the baseline redfish model

```
# Number of parameters = 180  Objective function value = 59085.6
Maximum gradient component = 0.00504383
# M:
0.0500000
# mean_log_rec:
10.2724
# rec_dev:
 0.268855 0.283947 0.297777 0.314857 0.333105 0.350796 0.369690
0.387451 0.403300 0.420083 0.440757 0.464639 0.483848 0.501822
0.518171 0.529029 0.535958 0.539225 0.537752 0.532906 0.520225
0.503848 0.483875 0.453279 0.422725 0.390453 0.356663 0.322604
0.280342 0.241802 0.186877 0.131817 4.41036 0.0730586 0.0447724
0.177915 -0.0599116 0.739315 1.09719 0.752359 0.721279 0.740825
0.551414 0.940173 0.999282 0.893913 0.763189 0.821884 0.879004
0.537755 0.876231 0.361673 1.04706 0.460299 1.21943 1.01003 0.181569
-1.29956 -1.88507 -2.37217 -2.33104 -1.95963 2.15325 -1.45054 -2.39424
-2.67683 -2.80352 -2.92961 -2.59663 0.631947 -2.41794 -2.27252 -1.19573
-0.457794 -1.17594 -0.363761 -0.730176 -1.73081 -2.09661 -1.11887 1.03656
-1.13811 -0.138773 0.959950 2.88905 -0.408892 -0.419690 -0.318368 -0.106372
0.0321912 0.0377070
# q_cpue:
0.237518
# exp_cpue:
1.02686
```

```
# q1:
0.433081
# log_gamma_srv1:
-26.4739
# log_beta_srv1:
1.64018
# log_a50_srv1:
0.899916
# q2:
0.269453
# exp_srv2:
1.13955
# log_gamma_srv2:
-2.69852
# log_beta_srv2:
0.912254
# log_a50_srv2:
1.98356
# log_avg_fmort:
-2.38105
# fmort_dev:
 -3.88561 -1.21407 -0.0593014 -0.444405 -0.0599694 0.228452
0.384928 1.20714 1.65149 2.02563 3.06284 3.32126 2.21159
1.37306 1.35777 0.864387 0.860784 0.831010 0.560203 0.335825
0.0938184 0.201353 0.233430 0.509311 0.422418 0.430442
0.116242 0.336893 0.356479 0.0151891 -0.185709 -0.216506
-0.211847 -0.00849619 -0.530360 -0.0220489 0.178860 0.427356
0.510032 0.529555 0.142097 0.261029 0.446245 0.694902 0.847007
1.11955 0.920498 0.976525 1.09685 0.764003 0.579625 0.573149
0.239577 -0.122847 -0.604619 -1.26892 -1.41317 -1.60553
-1.13971 -1.22792 -1.93687 -2.06806 -2.47179 -2.90879 -2.98155 -3.21671 -
3.49401
# log_selcoffs_fish:
 -6.66942 -5.04366 -3.42745 -1.87496 -0.472954 0.367989 0.593606 0.763784
1.02302
```

Part D. Standard deviation estimates for the baseline redfish model

index	name	value	std dev
1	mean_log_rec	1.0272e+01	1.4742e-02
2	rec_dev	2.6885e-01	2.5312e-01
3	rec_dev	2.8395e-01	2.5553e-01
4	rec_dev	2.9778e-01	2.5780e-01
5	rec_dev	3.1486e-01	2.6068e-01
6	rec_dev	3.3311e-01	2.6385e-01
7	rec_dev	3.5080e-01	2.6704e-01
8	rec_dev	3.6969e-01	2.7056e-01
9	rec_dev	3.8745e-01	2.7398e-01
10	rec_dev	4.0330e-01	2.7715e-01
11	rec_dev	4.2008e-01	2.8061e-01
12	rec_dev	4.4076e-01	2.8501e-01
13	rec_dev	4.6464e-01	2.9037e-01
14	rec_dev	4.8385e-01	2.9493e-01
15	rec_dev	5.0182e-01	2.9938e-01
16	rec_dev	5.1817e-01	3.0359e-01
17	rec_dev	5.2903e-01	3.0653e-01
18	rec_dev	5.3596e-01	3.0848e-01
19	rec_dev	5.3922e-01	3.0947e-01

20	rec_dev	5.3775e-01	3.0917e-01
21	rec_dev	5.3291e-01	3.0793e-01
22	rec_dev	5.2023e-01	3.0461e-01
23	rec_dev	5.0385e-01	3.0039e-01
24	rec_dev	4.8387e-01	2.9546e-01
25	rec_dev	4.5328e-01	2.8833e-01
26	rec_dev	4.2273e-01	2.8159e-01
27	rec_dev	3.9045e-01	2.7488e-01
28	rec_dev	3.5666e-01	2.6832e-01
29	rec_dev	3.2260e-01	2.6212e-01
30	rec_dev	2.8034e-01	2.5509e-01
31	rec_dev	2.4180e-01	2.4898e-01
32	rec_dev	1.8688e-01	2.4111e-01
33	rec_dev	1.3182e-01	2.3387e-01
34	rec_dev	4.4104e+00	5.4561e-02
35	rec_dev	7.3059e-02	2.2667e-01
36	rec_dev	4.4772e-02	2.2340e-01
37	rec_dev	1.7792e-01	2.1008e-01
38	rec_dev	-5.9912e-02	1.9343e-01
39	rec_dev	7.3932e-01	1.3464e-01
40	rec_dev	1.0972e+00	9.6926e-02
41	rec_dev	7.5236e-01	9.6297e-02
42	rec_dev	7.2128e-01	8.2512e-02
43	rec_dev	7.4083e-01	7.0654e-02
44	rec_dev	5.5141e-01	6.7518e-02
45	rec_dev	9.4017e-01	5.0120e-02
46	rec_dev	9.9928e-01	4.3512e-02
47	rec_dev	8.9391e-01	4.0973e-02
48	rec_dev	7.6319e-01	3.9513e-02
49	rec_dev	8.2188e-01	3.5459e-02
50	rec_dev	8.7900e-01	3.1787e-02
51	rec_dev	5.3776e-01	3.3825e-02
52	rec_dev	8.7623e-01	2.8416e-02
53	rec_dev	3.6167e-01	3.2249e-02
54	rec_dev	1.0471e+00	2.5424e-02
55	rec_dev	4.6030e-01	3.0990e-02
56	rec_dev	1.2194e+00	2.4601e-02
57	rec_dev	1.0100e+00	2.5843e-02
58	rec_dev	1.8157e-01	3.3159e-02
59	rec_dev	-1.2996e+00	6.0605e-02
60	rec_dev	-1.8851e+00	7.8658e-02
61	rec_dev	-2.3722e+00	9.6087e-02
62	rec_dev	-2.3310e+00	8.9168e-02
63	rec_dev	-1.9596e+00	7.3734e-02
64	rec_dev	2.1533e+00	1.8505e-02
65	rec_dev	-1.4505e+00	5.7869e-02
66	rec_dev	-2.3942e+00	8.3351e-02
67	rec_dev	-2.6768e+00	8.8403e-02
68	rec_dev	-2.8035e+00	8.8833e-02
69	rec_dev	-2.9296e+00	9.1506e-02
70	rec_dev	-2.5966e+00	8.7627e-02
71	rec_dev	6.3195e-01	2.3502e-02
72	rec_dev	-2.4179e+00	9.9245e-02
73	rec_dev	-2.2725e+00	9.6637e-02
74	rec_dev	-1.1957e+00	6.3151e-02
75	rec_dev	-4.5779e-01	5.3984e-02
76	rec_dev	-1.1759e+00	9.8257e-02
77	rec_dev	-3.6376e-01	6.7866e-02

78	rec_dev	-7.3018e-01	7.3664e-02
79	rec_dev	-1.7308e+00	7.5533e-02
80	rec_dev	-2.0966e+00	8.7799e-02
81	rec_dev	-1.1189e+00	1.0655e-01
82	rec_dev	1.0366e+00	3.4310e-02
83	rec_dev	-1.1381e+00	1.0369e-01
84	rec_dev	-1.3877e-01	7.4339e-02
85	rec_dev	9.5995e-01	9.3736e-02
86	rec_dev	2.8891e+00	3.7045e-02
87	rec_dev	-4.0889e-01	1.6864e-01
88	rec_dev	-4.1969e-01	1.8040e-01
89	rec_dev	-3.1837e-01	1.8829e-01
90	rec_dev	-1.0637e-01	2.0653e-01
91	rec_dev	3.2191e-02	2.2190e-01
92	rec_dev	3.7707e-02	2.2252e-01
93	q_cpue	2.3752e-01	1.6228e-01
94	exp_cpue	1.0269e+00	6.0747e-02
95	q1	4.3308e-01	3.8020e-03
96	log_gamma_srv1	-2.6474e+01	7.3724e+03
97	log_beta_srv1	1.6402e+00	6.7084e-02
98	log_a50_srv1	8.9992e-01	1.3036e-02
99	q2	2.6945e-01	2.7187e-02
100	exp_srv2	1.1396e+00	9.2428e-03
101	log_gamma_srv2	-2.6985e+00	3.2973e-02
102	log_beta_srv2	9.1225e-01	1.9160e-02
103	log_a50_srv2	1.9836e+00	2.8834e-03
104	log_avg_fmort	-2.3811e+00	1.5254e-02
105	fmort_dev	-3.8856e+00	3.3472e-02
106	fmort_dev	-1.2141e+00	3.2644e-02
107	fmort_dev	-5.9301e-02	3.2353e-02
108	fmort_dev	-4.4440e-01	3.2756e-02
109	fmort_dev	-5.9969e-02	3.2975e-02
110	fmort_dev	2.2845e-01	3.3947e-02
111	fmort_dev	3.8493e-01	3.5892e-02
112	fmort_dev	1.2071e+00	4.0939e-02
113	fmort_dev	1.6515e+00	5.6966e-02
114	fmort_dev	2.0256e+00	9.8459e-02
115	fmort_dev	3.0628e+00	2.9377e-01
116	fmort_dev	3.3213e+00	1.7008e-01
117	fmort_dev	2.2116e+00	3.6096e-02
118	fmort_dev	1.3731e+00	3.3732e-02
119	fmort_dev	1.3578e+00	3.3118e-02
120	fmort_dev	8.6439e-01	3.4271e-02
121	fmort_dev	8.6078e-01	3.0787e-02
122	fmort_dev	8.3101e-01	3.1657e-02
123	fmort_dev	5.6020e-01	3.2059e-02
124	fmort_dev	3.3583e-01	3.1773e-02
125	fmort_dev	9.3818e-02	3.1120e-02
126	fmort_dev	2.0135e-01	2.9817e-02
127	fmort_dev	2.3343e-01	2.9208e-02
128	fmort_dev	5.0931e-01	2.8586e-02
129	fmort_dev	4.2242e-01	2.8156e-02
130	fmort_dev	4.3044e-01	2.7689e-02
131	fmort_dev	1.1624e-01	2.7701e-02
132	fmort_dev	3.3689e-01	2.7228e-02
133	fmort_dev	3.5648e-01	2.6979e-02
134	fmort_dev	1.5189e-02	2.7083e-02
135	fmort_dev	-1.8571e-01	2.7187e-02

136	fmort_dev	-2.1651e-01	2.7359e-02
137	fmort_dev	-2.1185e-01	2.7017e-02
138	fmort_dev	-8.4962e-03	2.6881e-02
139	fmort_dev	-5.3036e-01	2.6847e-02
140	fmort_dev	-2.2049e-02	2.6148e-02
141	fmort_dev	1.7886e-01	2.5395e-02
142	fmort_dev	4.2736e-01	2.5391e-02
143	fmort_dev	5.1003e-01	2.5633e-02
144	fmort_dev	5.2955e-01	2.5675e-02
145	fmort_dev	1.4210e-01	2.6245e-02
146	fmort_dev	2.6103e-01	2.6446e-02
147	fmort_dev	4.4625e-01	2.7437e-02
148	fmort_dev	6.9490e-01	2.7582e-02
149	fmort_dev	8.4701e-01	2.7505e-02
150	fmort_dev	1.1196e+00	2.7876e-02
151	fmort_dev	9.2050e-01	2.7643e-02
152	fmort_dev	9.7652e-01	2.8618e-02
153	fmort_dev	1.0969e+00	2.8678e-02
154	fmort_dev	7.6400e-01	2.7683e-02
155	fmort_dev	5.7962e-01	2.6796e-02
156	fmort_dev	5.7315e-01	2.7042e-02
157	fmort_dev	2.3958e-01	2.7547e-02
158	fmort_dev	-1.2285e-01	2.8522e-02
159	fmort_dev	-6.0462e-01	2.8535e-02
160	fmort_dev	-1.2689e+00	2.8231e-02
161	fmort_dev	-1.4132e+00	2.8137e-02
162	fmort_dev	-1.6055e+00	2.8094e-02
163	fmort_dev	-1.1397e+00	2.8292e-02
164	fmort_dev	-1.2279e+00	2.8619e-02
165	fmort_dev	-1.9369e+00	2.8233e-02
166	fmort_dev	-2.0681e+00	2.7947e-02
167	fmort_dev	-2.4718e+00	2.7878e-02
168	fmort_dev	-2.9088e+00	2.8105e-02
169	fmort_dev	-2.9815e+00	2.8336e-02
170	fmort_dev	-3.2167e+00	2.9394e-02
171	fmort_dev	-3.4940e+00	2.9754e-02
172	log_selcoffs_fish	-6.6694e+00	2.4589e-01
173	log_selcoffs_fish	-5.0437e+00	1.6381e-01
174	log_selcoffs_fish	-3.4274e+00	1.0990e-01
175	log_selcoffs_fish	-1.8750e+00	8.4252e-02
176	log_selcoffs_fish	-4.7295e-01	7.5597e-02
177	log_selcoffs_fish	3.6799e-01	7.3073e-02
178	log_selcoffs_fish	5.9361e-01	7.2418e-02
179	log_selcoffs_fish	7.6378e-01	7.2433e-02
180	log_selcoffs_fish	1.0230e+00	7.1379e-02
181	spawnbiom	2.8053e+05	8.5828e+03
182	spawnbiom	2.8114e+05	8.4823e+03
183	spawnbiom	2.7111e+05	8.3532e+03
184	spawnbiom	2.5543e+05	8.2028e+03
185	spawnbiom	2.4206e+05	8.0555e+03
186	spawnbiom	2.2341e+05	7.9104e+03
187	spawnbiom	2.0157e+05	7.7750e+03
188	spawnbiom	1.6865e+05	7.6787e+03
189	spawnbiom	1.2073e+05	7.6117e+03
190	spawnbiom	7.4178e+04	7.6393e+03
191	spawnbiom	3.2350e+04	8.7278e+03
192	spawnbiom	3.3190e+04	2.5613e+03
193	spawnbiom	8.1265e+04	1.1524e+03

194	spawnbiom	1.3825e+05	1.8652e+03
195	spawnbiom	1.6172e+05	2.4202e+03
196	spawnbiom	1.7576e+05	2.9492e+03
197	spawnbiom	1.5986e+05	2.8738e+03
198	spawnbiom	1.4673e+05	2.8268e+03
199	spawnbiom	1.3834e+05	2.6914e+03
200	spawnbiom	1.3641e+05	2.5455e+03
201	spawnbiom	1.3534e+05	2.3289e+03
202	spawnbiom	1.3040e+05	1.9940e+03
203	spawnbiom	1.2983e+05	1.8638e+03
204	spawnbiom	1.2707e+05	1.7234e+03
205	spawnbiom	1.2058e+05	1.5079e+03
206	spawnbiom	1.1609e+05	1.3274e+03
207	spawnbiom	1.1684e+05	1.2649e+03
208	spawnbiom	1.1607e+05	1.1550e+03
209	spawnbiom	1.1371e+05	1.0555e+03
210	spawnbiom	1.1320e+05	9.9770e+02
211	spawnbiom	1.1534e+05	9.6451e+02
212	spawnbiom	1.1759e+05	9.3257e+02
213	spawnbiom	1.2009e+05	9.2347e+02
214	spawnbiom	1.2401e+05	9.4346e+02
215	spawnbiom	1.2685e+05	9.5168e+02
216	spawnbiom	1.3167e+05	9.6523e+02
217	spawnbiom	1.3076e+05	9.5698e+02
218	spawnbiom	1.2528e+05	9.2349e+02
219	spawnbiom	1.1463e+05	8.6531e+02
220	spawnbiom	1.0187e+05	7.9818e+02
221	spawnbiom	9.1548e+04	7.5488e+02
222	spawnbiom	8.5609e+04	7.2825e+02
223	spawnbiom	8.3358e+04	7.1061e+02
224	spawnbiom	8.2181e+04	6.9399e+02
225	spawnbiom	7.6385e+04	6.5534e+02
226	spawnbiom	6.8200e+04	5.8212e+02
227	spawnbiom	5.4823e+04	4.9362e+02
228	spawnbiom	4.4925e+04	4.3336e+02
229	spawnbiom	3.6442e+04	3.8463e+02
230	spawnbiom	3.1076e+04	3.6143e+02
231	spawnbiom	2.8623e+04	3.4623e+02
232	spawnbiom	2.6007e+04	3.2754e+02
233	spawnbiom	2.5054e+04	3.2578e+02
234	spawnbiom	2.4335e+04	3.2461e+02
235	spawnbiom	2.4590e+04	3.2475e+02
236	spawnbiom	2.5853e+04	3.2959e+02
237	spawnbiom	2.8238e+04	3.4553e+02
238	spawnbiom	2.9766e+04	3.5285e+02
239	spawnbiom	3.0834e+04	3.5993e+02
240	spawnbiom	3.2526e+04	3.7373e+02
241	spawnbiom	3.5815e+04	3.9726e+02
242	spawnbiom	4.0296e+04	4.3298e+02
243	spawnbiom	4.6209e+04	4.8447e+02
244	spawnbiom	5.8759e+04	5.9829e+02
245	spawnbiom	7.9244e+04	8.1151e+02
246	spawnbiom	1.0785e+05	1.2686e+03
247	spawnbiom	1.3267e+05	1.7057e+03
248	recruitment	4.4138e+04	1.2467e+04
249	recruitment	4.2737e+04	1.1793e+04
250	recruitment	4.1317e+04	1.1137e+04
251	recruitment	3.9933e+04	1.0524e+04

252	recruitment	3.8281e+04	9.8293e+03
253	recruitment	3.6833e+04	9.2378e+03
254	recruitment	3.4865e+04	8.4857e+03
255	recruitment	3.2997e+04	7.8054e+03
256	recruitment	2.3803e+06	1.0019e+05
257	recruitment	3.1114e+04	7.1394e+03
258	recruitment	3.0246e+04	6.8400e+03
259	recruitment	3.4554e+04	7.3462e+03
260	recruitment	2.7240e+04	5.3286e+03
261	recruitment	6.0577e+04	8.2185e+03
262	recruitment	8.6643e+04	8.3992e+03
263	recruitment	6.1373e+04	5.9079e+03
264	recruitment	5.9494e+04	4.8803e+03
265	recruitment	6.0669e+04	4.2304e+03
266	recruitment	5.0200e+04	3.3368e+03
267	recruitment	7.4053e+04	3.5614e+03
268	recruitment	7.8562e+04	3.2172e+03
269	recruitment	7.0705e+04	2.6999e+03
270	recruitment	6.2041e+04	2.2709e+03
271	recruitment	6.5791e+04	2.1101e+03
272	recruitment	6.9659e+04	1.9413e+03
273	recruitment	4.9519e+04	1.4994e+03
274	recruitment	6.9466e+04	1.6632e+03
275	recruitment	4.1524e+04	1.1866e+03
276	recruitment	8.2407e+04	1.6718e+03
277	recruitment	4.5828e+04	1.2396e+03
278	recruitment	9.7908e+04	1.8514e+03
279	recruitment	7.9411e+04	1.6247e+03
280	recruitment	3.4680e+04	1.0199e+03
281	recruitment	7.8856e+03	4.6736e+02
282	recruitment	4.3909e+03	3.4280e+02
283	recruitment	2.6978e+03	2.5913e+02
284	recruitment	2.8111e+03	2.5013e+02
285	recruitment	4.0754e+03	2.9790e+02
286	recruitment	2.4910e+05	2.5040e+03
287	recruitment	6.7806e+03	3.8303e+02
288	recruitment	2.6389e+03	2.1908e+02
289	recruitment	1.9893e+03	1.7550e+02
290	recruitment	1.7526e+03	1.5540e+02
291	recruitment	1.5450e+03	1.4127e+02
292	recruitment	2.1554e+03	1.8837e+02
293	recruitment	5.4410e+04	9.2557e+02
294	recruitment	2.5771e+03	2.5569e+02
295	recruitment	2.9805e+03	2.8754e+02
296	recruitment	8.7484e+03	5.4045e+02
297	recruitment	1.8298e+04	9.4363e+02
298	recruitment	8.9233e+03	8.7210e+02
299	recruitment	2.0102e+04	1.3199e+03
300	recruitment	1.3935e+04	1.0057e+03
301	recruitment	5.1233e+03	3.8348e+02
302	recruitment	3.5537e+03	3.1177e+02
303	recruitment	9.4473e+03	1.0097e+03
304	recruitment	8.1546e+04	2.4053e+03
305	recruitment	9.2673e+03	9.6254e+02
306	recruitment	2.5174e+04	1.8575e+03
307	recruitment	7.5532e+04	7.0835e+03
308	recruitment	5.1991e+05	1.6788e+04
309	recruitment	1.9215e+04	3.2723e+03

310	recruitment	1.9009e+04	3.4646e+03
311	recruitment	2.1036e+04	4.0031e+03
312	recruitment	2.6004e+04	5.4313e+03
313	recruitment	2.9868e+04	6.7058e+03
314	recruitment	3.0033e+04	6.7617e+03
315	endbiom	1.5392e+05	2.0941e+03
316	depletion_popnbiom	5.1047e-01	1.5690e-02
317	endspawn	1.3267e+05	1.7057e+03
318	depspawn	4.7294e-01	1.5553e-02
319	deppopnbiom63	1.1171e+00	1.4645e-02
320	depspawn63	1.1720e+00	1.5310e-02
321	endN	3.0033e+04	6.7617e+03
322	endN	2.8411e+04	6.3787e+03
323	endN	2.3529e+04	4.9144e+03
324	endN	1.8105e+04	3.4453e+03
325	endN	1.5559e+04	2.8358e+03
326	endN	1.4947e+04	2.5455e+03
327	endN	3.8386e+05	1.2401e+04
328	endN	5.2877e+04	4.9593e+03
329	endN	1.6688e+04	1.2315e+03
330	endN	5.8013e+03	6.0261e+02
331	endN	4.8079e+04	1.4226e+03
332	endN	5.2266e+03	5.5882e+02
333	endN	1.8349e+03	1.6108e+02
334	endN	2.4639e+03	1.8462e+02
335	endN	6.2406e+03	4.5097e+02
336	endN	8.3395e+03	5.4927e+02
337	endN	3.4063e+03	3.3332e+02
338	endN	6.3448e+03	3.2869e+02
339	endN	2.6956e+03	1.6712e+02
340	endN	7.9452e+02	7.6755e+01
341	endN	5.7673e+02	5.7362e+01
342	endN	9.9533e+03	1.9368e+02
343	endN	3.1103e+02	2.7441e+01
344	endN	1.7020e+02	1.5716e+01
345	endN	1.4672e+02	1.3172e+01
346	endN	1.1422e+04	2.5474e+02
347	endF	2.8086e-03	7.7356e-05

Appendix 2.

Biomass Dynamics Analysis of Subarea 5 Redfish (ASPIC - REDFISH3)

```
Redfish SAW33 (biomass and yield in kmt)                                                                  Page 1
                                                                                            14 May 2001 at 09:38.44
ASPIC -- A Surplus-Production Model Including Covariates (Ver. 3.74)                                      BOT Mode

Author: Michael H. Prager
        National Marine Fisheries Service                                                      ASPIC User's Manual
        Southwest Fisheries Science Center                                                     is available gratis
        3150 Paradise Drive                                                                        from the author
        Tiburon, California 94920  USA

CONTROL PARAMETERS USED (FROM INPUT FILE)
--------------------------------------------------------------------------------------------------------------------
Number of years analyzed:                      67            Number of bootstrap trials:                      1000
Number of data series:                          3            Lower bound on MSY:                         6.667E-01
Objective function computed:            in effort            Upper bound on MSY:                         1.000E+02
Relative conv. criterion (simplex):     1.000E-08            Lower bound on r:                           1.000E-02
Relative conv. criterion (restart):     3.000E-08            Upper bound on r:                           1.000E+01
Relative conv. criterion (effort):      1.000E-04            Random number seed:                           4952310
Maximum F allowed in fitting:               5.000            Monte Carlo search trials:                      50000

PROGRAM STATUS INFORMATION (NON-BOOTSTRAPPED ANALYSIS)                                                       code  0
--------------------------------------------------------------------------------------------------------------------
Normal convergence.

CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)
--------------------------------------------------------------------------------------------------------------------
                                      |
 1  Std. CPUE                         |   1.000
                                      |      38
                                      |
 2  Fall Survey                       |   0.633   1.000
                                      |      27      38
                                      |
 3  Spring Survey                     |   0.421   0.431   1.000
                                      |      22      33      33
                                      --------------------------------------------------
                                              1       2       3

GOODNESS-OF-FIT AND WEIGHTING FOR NON-BOOTSTRAPPED ANALYSIS
--------------------------------------------------------------------------------------------------------------------
                                                   Weighted             Weighted      Current    Suggested    R-squared
Loss component number and title                         SSE      N           MSE       weight       weight      in CPUE

Loss(-1)  SSE in yield                            0.000E+00
Loss( 0)  Penalty for B1R > 2                     0.000E+00      1           N/A    1.000E+00          N/A
Loss( 1)  Std. CPUE                               1.911E+00     38     5.307E-02    1.000E+00    2.025E+00        0.707
Loss( 2)  Fall Survey                             6.249E+00     38     1.736E-01    1.000E+00    6.192E-01        0.585
Loss( 3)  Spring Survey                           1.290E+01     33     4.162E-01    1.000E+00    2.582E-01        0.371
TOTAL OBJECTIVE FUNCTION:                     2.10613812E+01

Number of restarts required for convergence:             16
Est. B-ratio coverage index (0 worst, 2 best):       1.9474               < These two measures are defined in Prager
Est. B-ratio nearness index (0 worst, 1 best):       1.0000               <     et al. (1996), Trans. A.F.S. 125:729

MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)
--------------------------------------------------------------------------------------------------------------------
Parameter                                          Estimate     Starting guess    Estimated   User guess

B1R       Starting biomass ratio, year 1934       2.000E+00          2.000E+00            0            1
MSY       Maximum sustainable yield               2.026E+01          2.000E+01            1            1
r         Intrinsic rate of increase              1.789E-01          2.000E-01            1            1
........  Catchability coefficients by fishery:
q( 1)     Std. CPUE                               4.922E-02          4.000E-01            1            1
q( 2)     Fall Survey                             3.842E-01          4.000E-01            1            1
q( 3)     Spring Survey                           3.593E-01          4.000E-02            1            1

MANAGEMENT PARAMETER ESTIMATES (NON-BOOTSTRAPPED)
--------------------------------------------------------------------------------------------------------------------
Parameter                                          Estimate            Formula        Related quantity

MSY       Maximum sustainable yield               2.026E+01               Kr/4
K         Maximum stock biomass                   4.528E+02
Bmsy      Stock biomass at MSY                    2.264E+02                K/2
Fmsy      Fishing mortality at MSY                8.946E-02                r/2

F(0.1)    Management benchmark                    8.051E-02          0.9*Fmsy
Y(0.1)    Equilibrium yield at F(0.1)             2.005E+01          0.99*MSY

B-ratio   Ratio of B(2001) to Bmsy                3.292E-01
F-ratio   Ratio of F(2000) to Fmsy                5.143E-02
F01-mult  Ratio of F(0.1) to F(2000)              1.750E+01
Y-ratio   Proportion of MSY avail in 2001         5.500E-01        2*Br-Br^2     Ye(2001) = 1.114E+01

........  Fishing effort at MSY in units of each fishery:
fmsy( 1)  Std. CPUE                               1.817E+00         r/2q( 1)       f(0.1) = 1.636E+00
```

ESTIMATED POPULATION TRAJECTORY (NON-BOOTSTRAPPED)

Obs	Year or ID	Estimated total F mort	Estimated starting biomass	Estimated average biomass	Observed total yield	Model total yield	Estimated surplus production	Ratio of F mort to Fmsy	Ratio of biomass to Bmsy
1	1934	0.001	4.528E+02	4.535E+02	5.190E-01	5.190E-01	4.475E-02	1.279E-02	2.000E+00
2	1935	0.017	4.524E+02	4.488E+02	7.549E+00	7.549E+00	7.086E-01	1.880E-01	1.998E+00
3	1936	0.053	4.455E+02	4.351E+02	2.316E+01	2.316E+01	3.037E+00	5.951E-01	1.968E+00
4	1937	0.035	4.254E+02	4.205E+02	1.482E+01	1.482E+01	5.367E+00	3.940E-01	1.879E+00
5	1938	0.050	4.159E+02	4.089E+02	2.064E+01	2.064E+01	7.086E+00	5.642E-01	1.837E+00
6	1939	0.064	4.024E+02	3.940E+02	2.541E+01	2.541E+01	9.152E+00	7.208E-01	1.777E+00
7	1940	0.071	3.861E+02	3.781E+02	2.676E+01	2.676E+01	1.116E+01	7.912E-01	1.705E+00
8	1941	0.145	3.705E+02	3.514E+02	5.080E+01	5.080E+01	1.404E+01	1.616E+00	1.636E+00
9	1942	0.178	3.338E+02	3.136E+02	5.589E+01	5.589E+01	1.720E+01	1.992E+00	1.474E+00
10	1943	0.173	2.951E+02	2.799E+02	4.835E+01	4.835E+01	1.910E+01	1.931E+00	1.303E+00
11	1944	0.202	2.658E+02	2.501E+02	5.044E+01	5.044E+01	2.000E+01	2.255E+00	1.174E+00
12	1945	0.168	2.354E+02	2.263E+02	3.791E+01	3.791E+01	2.025E+01	1.873E+00	1.040E+00
13	1946	0.206	2.177E+02	2.062E+02	4.242E+01	4.242E+01	2.008E+01	2.300E+00	9.616E-01
14	1947	0.217	1.954E+02	1.848E+02	4.016E+01	4.016E+01	1.956E+01	2.430E+00	8.629E-01
15	1948	0.270	1.748E+02	1.618E+02	4.363E+01	4.363E+01	1.859E+01	3.014E+00	7.719E-01
16	1949	0.215	1.497E+02	1.430E+02	3.074E+01	3.074E+01	1.750E+01	2.404E+00	6.613E-01
17	1950	0.270	1.365E+02	1.272E+02	3.431E+01	3.431E+01	1.636E+01	3.014E+00	6.028E-01
18	1951	0.272	1.185E+02	1.108E+02	3.008E+01	3.008E+01	1.496E+01	3.035E+00	5.236E-01
19	1952	0.215	1.034E+02	9.962E+01	2.138E+01	2.138E+01	1.390E+01	2.399E+00	4.568E-01
20	1953	0.178	9.596E+01	9.422E+01	1.679E+01	1.679E+01	1.335E+01	1.992E+00	4.238E-01
21	1954	0.140	9.252E+01	9.261E+01	1.299E+01	1.299E+01	1.318E+01	1.568E+00	4.086E-01
22	1955	0.151	9.271E+01	9.233E+01	1.391E+01	1.391E+01	1.315E+01	1.685E+00	4.095E-01
23	1956	0.158	9.195E+01	9.127E+01	1.439E+01	1.439E+01	1.304E+01	1.762E+00	4.061E-01
24	1957	0.211	9.060E+01	8.762E+01	1.849E+01	1.849E+01	1.264E+01	2.359E+00	4.001E-01
25	1958	0.194	8.475E+01	8.275E+01	1.605E+01	1.605E+01	1.210E+01	2.168E+00	3.743E-01
26	1959	0.197	8.080E+01	7.884E+01	1.552E+01	1.552E+01	1.165E+01	2.201E+00	3.569E-01
27	1960	0.148	7.693E+01	7.696E+01	1.138E+01	1.138E+01	1.143E+01	1.652E+00	3.398E-01
28	1961	0.187	7.699E+01	7.555E+01	1.410E+01	1.410E+01	1.126E+01	2.086E+00	3.400E-01
29	1962	0.195	7.415E+01	7.251E+01	1.413E+01	1.413E+01	1.090E+01	2.179E+00	3.275E-01
30	1963	0.141	7.091E+01	7.126E+01	1.005E+01	1.005E+01	1.074E+01	1.576E+00	3.132E-01
31	1964	0.114	7.161E+01	7.292E+01	8.313E+00	8.313E+00	1.095E+01	1.274E+00	3.162E-01
32	1965	0.106	7.424E+01	7.586E+01	8.057E+00	8.057E+00	1.130E+01	1.187E+00	3.279E-01
33	1966	0.108	7.748E+01	7.903E+01	8.569E+00	8.569E+00	1.167E+01	1.212E+00	3.422E-01
34	1967	0.134	8.058E+01	8.111E+01	1.086E+01	1.086E+01	1.191E+01	1.497E+00	3.559E-01
35	1968	0.080	8.163E+01	8.437E+01	6.777E+00	6.777E+00	1.228E+01	8.979E-01	3.605E-01
36	1969	0.143	8.714E+01	8.721E+01	1.246E+01	1.246E+01	1.260E+01	1.596E+00	3.848E-01
37	1970	0.197	8.728E+01	8.506E+01	1.674E+01	1.674E+01	1.236E+01	2.200E+00	3.855E-01
38	1971	0.255	8.290E+01	7.859E+01	2.003E+01	2.003E+01	1.162E+01	2.849E+00	3.661E-01
39	1972	0.272	7.449E+01	7.013E+01	1.909E+01	1.909E+01	1.060E+01	3.043E+00	3.290E-01
40	1973	0.280	6.599E+01	6.200E+01	1.736E+01	1.736E+01	9.573E+00	3.130E+00	2.915E-01
41	1974	0.182	5.821E+01	5.745E+01	1.047E+01	1.047E+01	8.975E+00	2.037E+00	2.571E-01
42	1975	0.189	5.671E+01	5.579E+01	1.057E+01	1.057E+01	8.752E+00	2.118E+00	2.505E-01
43	1976	0.199	5.489E+01	5.377E+01	1.070E+01	1.070E+01	8.478E+00	2.224E+00	2.424E-01
44	1977	0.265	5.267E+01	4.998E+01	1.322E+01	1.322E+01	7.955E+00	2.957E+00	2.326E-01
45	1978	0.322	4.740E+01	4.380E+01	1.408E+01	1.408E+01	7.077E+00	3.594E+00	2.094E-01
46	1979	0.412	4.040E+01	3.577E+01	1.476E+01	1.476E+01	5.892E+00	4.611E+00	1.784E-01
47	1980	0.354	3.153E+01	2.876E+01	1.018E+01	1.018E+01	4.819E+00	3.957E+00	1.393E-01
48	1981	0.327	2.617E+01	2.421E+01	7.915E+00	7.915E+00	4.100E+00	3.655E+00	1.156E-01
49	1982	0.335	2.236E+01	2.061E+01	6.903E+00	6.903E+00	3.520E+00	3.743E+00	9.873E-02
50	1983	0.299	1.897E+01	1.781E+01	5.328E+00	5.328E+00	3.062E+00	3.343E+00	8.379E-02
51	1984	0.307	1.671E+01	1.564E+01	4.793E+00	4.793E+00	2.701E+00	3.427E+00	7.378E-02
52	1985	0.314	1.461E+01	1.363E+01	4.282E+00	4.282E+00	2.366E+00	3.511E+00	6.454E-02
53	1986	0.238	1.270E+01	1.230E+01	2.929E+00	2.929E+00	2.141E+00	2.662E+00	5.608E-02
54	1987	0.158	1.191E+01	1.201E+01	1.894E+00	1.894E+00	2.091E+00	1.763E+00	5.260E-02
55	1988	0.093	1.211E+01	1.261E+01	1.177E+00	1.177E+00	2.193E+00	1.044E+00	5.347E-02
56	1989	0.046	1.312E+01	1.400E+01	6.370E-01	6.370E-01	2.427E+00	5.086E-01	5.795E-02
57	1990	0.038	1.491E+01	1.597E+01	6.010E-01	6.010E-01	2.756E+00	4.208E-01	6.586E-02
58	1991	0.029	1.707E+01	1.835E+01	5.250E-01	5.250E-01	3.150E+00	3.198E-01	7.538E-02
59	1992	0.040	1.969E+01	2.103E+01	8.490E-01	8.490E-01	3.588E+00	4.512E-01	8.697E-02
60	1993	0.033	2.243E+01	2.403E+01	8.000E-01	8.000E-01	4.071E+00	3.721E-01	9.907E-02
61	1994	0.016	2.570E+01	2.776E+01	4.400E-01	4.400E-01	4.663E+00	1.771E-01	1.135E-01
62	1995	0.014	2.993E+01	3.233E+01	4.400E-01	4.400E-01	5.371E+00	1.521E-01	1.322E-01
63	1996	0.009	3.486E+01	3.772E+01	3.220E-01	3.220E-01	6.186E+00	9.542E-02	1.539E-01
64	1997	0.006	4.072E+01	4.407E+01	2.510E-01	2.510E-01	7.117E+00	6.366E-02	1.798E-01
65	1998	0.006	4.759E+01	5.142E+01	3.200E-01	3.200E-01	8.153E+00	6.957E-02	2.102E-01
66	1999	0.006	5.542E+01	5.979E+01	3.530E-01	3.530E-01	9.283E+00	6.599E-02	2.448E-01
67	2000	0.005	6.435E+01	6.934E+01	3.190E-01	3.190E-01	1.050E+01	5.143E-02	2.842E-01
68	2001		7.453E+01						3.292E-01

RESULTS FOR DATA SERIES # 1 (NON-BOOTSTRAPPED) Std. CPUE

Data type CC: CPUE-catch series Series weight: 1.000

Obs	Year	Observed CPUE	Estimated CPUE	Estim F	Observed yield	Model yield	Resid in log scale	Resid in yield
1	1934	*	2.232E+01	0.0011	5.190E-01	5.190E-01	0.00000	0.000E+00
2	1935	*	2.209E+01	0.0168	7.549E+00	7.549E+00	0.00000	0.000E+00
3	1936	*	2.142E+01	0.0532	2.316E+01	2.316E+01	0.00000	0.000E+00
4	1937	*	2.070E+01	0.0352	1.482E+01	1.482E+01	0.00000	0.000E+00
5	1938	*	2.013E+01	0.0505	2.064E+01	2.064E+01	0.00000	0.000E+00
6	1939	*	1.939E+01	0.0645	2.541E+01	2.541E+01	0.00000	0.000E+00
7	1940	*	1.861E+01	0.0708	2.676E+01	2.676E+01	0.00000	0.000E+00
8	1941	*	1.730E+01	0.1445	5.080E+01	5.080E+01	0.00000	0.000E+00
9	1942	*	1.544E+01	0.1782	5.589E+01	5.589E+01	0.00000	0.000E+00
10	1943	*	1.378E+01	0.1727	4.835E+01	4.835E+01	0.00000	0.000E+00
11	1944	*	1.231E+01	0.2017	5.044E+01	5.044E+01	0.00000	0.000E+00
12	1945	*	1.114E+01	0.1675	3.791E+01	3.791E+01	0.00000	0.000E+00
13	1946	*	1.015E+01	0.2057	4.242E+01	4.242E+01	0.00000	0.000E+00
14	1947	*	9.095E+00	0.2173	4.016E+01	4.016E+01	0.00000	0.000E+00
15	1948	*	7.964E+00	0.2696	4.363E+01	4.363E+01	0.00000	0.000E+00
16	1949	*	7.036E+00	0.2151	3.074E+01	3.074E+01	0.00000	0.000E+00
17	1950	*	6.263E+00	0.2696	3.431E+01	3.431E+01	0.00000	0.000E+00
18	1951	*	5.452E+00	0.2715	3.008E+01	3.008E+01	0.00000	0.000E+00
19	1952	3.400E+00	4.904E+00	0.2146	2.138E+01	2.138E+01	0.36620	0.000E+00
20	1953	3.600E+00	4.637E+00	0.1782	1.679E+01	1.679E+01	0.25323	0.000E+00
21	1954	3.100E+00	4.559E+00	0.1402	1.299E+01	1.299E+01	0.38560	0.000E+00
22	1955	4.000E+00	4.544E+00	0.1507	1.391E+01	1.391E+01	0.12760	0.000E+00
23	1956	3.800E+00	4.492E+00	0.1576	1.439E+01	1.439E+01	0.16735	0.000E+00
24	1957	3.600E+00	4.313E+00	0.2110	1.849E+01	1.849E+01	0.18069	0.000E+00
25	1958	3.600E+00	4.073E+00	0.1939	1.605E+01	1.605E+01	0.12346	0.000E+00
26	1959	3.500E+00	3.881E+00	0.1969	1.552E+01	1.552E+01	0.10325	0.000E+00
27	1960	3.000E+00	3.788E+00	0.1478	1.138E+01	1.138E+01	0.23323	0.000E+00
28	1961	3.500E+00	3.719E+00	0.1866	1.410E+01	1.410E+01	0.06062	0.000E+00
29	1962	4.000E+00	3.569E+00	0.1949	1.413E+01	1.413E+01	-0.11402	0.000E+00
30	1963	3.000E+00	3.507E+00	0.1410	1.005E+01	1.005E+01	0.15628	0.000E+00
31	1964	2.900E+00	3.589E+00	0.1140	8.313E+00	8.313E+00	0.21324	0.000E+00
32	1965	4.400E+00	3.734E+00	0.1062	8.057E+00	8.057E+00	-0.16419	0.000E+00
33	1966	6.400E+00	3.890E+00	0.1084	8.569E+00	8.569E+00	-0.49789	0.000E+00
34	1967	5.600E+00	3.992E+00	0.1339	1.086E+01	1.086E+01	-0.33839	0.000E+00
35	1968	6.100E+00	4.153E+00	0.0803	6.777E+00	6.777E+00	-0.38449	0.000E+00
36	1969	4.900E+00	4.293E+00	0.1428	1.246E+01	1.246E+01	-0.13234	0.000E+00
37	1970	4.000E+00	4.187E+00	0.1968	1.674E+01	1.674E+01	0.04564	0.000E+00
38	1971	3.200E+00	3.869E+00	0.2549	2.003E+01	2.003E+01	0.18974	0.000E+00
39	1972	2.900E+00	3.452E+00	0.2723	1.909E+01	1.909E+01	0.17427	0.000E+00
40	1973	2.900E+00	3.052E+00	0.2800	1.736E+01	1.736E+01	0.05103	0.000E+00
41	1974	2.600E+00	2.828E+00	0.1823	1.047E+01	1.047E+01	0.08401	0.000E+00
42	1975	2.200E+00	2.746E+00	0.1895	1.057E+01	1.057E+01	0.22174	0.000E+00
43	1976	2.300E+00	2.647E+00	0.1989	1.070E+01	1.070E+01	0.14037	0.000E+00
44	1977	2.500E+00	2.460E+00	0.2646	1.322E+01	1.322E+01	-0.01604	0.000E+00
45	1978	2.400E+00	2.156E+00	0.3216	1.408E+01	1.408E+01	-0.10732	0.000E+00
46	1979	1.900E+00	1.761E+00	0.4125	1.476E+01	1.476E+01	-0.07610	0.000E+00
47	1980	1.600E+00	1.416E+00	0.3540	1.018E+01	1.018E+01	-0.12230	0.000E+00
48	1981	1.400E+00	1.192E+00	0.3269	7.915E+00	7.915E+00	-0.16115	0.000E+00
49	1982	1.500E+00	1.015E+00	0.3349	6.903E+00	6.903E+00	-0.39087	0.000E+00
50	1983	1.200E+00	8.768E-01	0.2991	5.328E+00	5.328E+00	-0.31378	0.000E+00
51	1984	1.100E+00	7.696E-01	0.3065	4.793E+00	4.793E+00	-0.35720	0.000E+00
52	1985	9.000E-01	6.710E-01	0.3141	4.282E+00	4.282E+00	-0.29364	0.000E+00
53	1986	6.000E-01	6.053E-01	0.2382	2.929E+00	2.929E+00	0.00887	0.000E+00
54	1987	7.000E-01	5.910E-01	0.1577	1.894E+00	1.894E+00	-0.16923	0.000E+00
55	1988	5.000E-01	6.206E-01	0.0934	1.177E+00	1.177E+00	0.21604	0.000E+00
56	1989	6.000E-01	6.891E-01	0.0455	6.370E-01	6.370E-01	0.13840	0.000E+00
57	1990	*	7.859E-01	0.0376	6.010E-01	6.010E-01	0.00000	0.000E+00
58	1991	*	9.032E-01	0.0286	5.250E-01	5.250E-01	0.00000	0.000E+00
59	1992	*	1.035E+00	0.0404	8.490E-01	8.490E-01	0.00000	0.000E+00
60	1993	*	1.183E+00	0.0333	8.000E-01	8.000E-01	0.00000	0.000E+00
61	1994	*	1.367E+00	0.0158	4.400E-01	4.400E-01	0.00000	0.000E+00
62	1995	*	1.592E+00	0.0136	4.400E-01	4.400E-01	0.00000	0.000E+00
63	1996	*	1.857E+00	0.0085	3.220E-01	3.220E-01	0.00000	0.000E+00
64	1997	*	2.169E+00	0.0057	2.510E-01	2.510E-01	0.00000	0.000E+00
65	1998	*	2.531E+00	0.0062	3.200E-01	3.200E-01	0.00000	0.000E+00
66	1999	*	2.943E+00	0.0059	3.530E-01	3.530E-01	0.00000	0.000E+00
67	2000	*	3.413E+00	0.0046	3.190E-01	3.190E-01	0.00000	0.000E+00

* Asterisk indicates missing value(s).

Redfish SAW33 (biomass and yield in kmt)   Page 4

```
UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 1
                   -1       -0.75     -0.5      -0.25       0       0.25      0.5       0.75       1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual   ------------------------------------------------------------------------------------
1934     0.0000                                             |
1935     0.0000                                             |
1936     0.0000                                             |
1937     0.0000                                             |
1938     0.0000                                             |
1939     0.0000                                             |
1940     0.0000                                             |
1941     0.0000                                             |
1942     0.0000                                             |
1943     0.0000                                             |
1944     0.0000                                             |
1945     0.0000                                             |
1946     0.0000                                             |
1947     0.0000                                             |
1948     0.0000                                             |
1949     0.0000                                             |
1950     0.0000                                             |
1951     0.0000                                             |
1952     0.3662                                             |===============
1953     0.2532                                             |==========
1954     0.3856                                             |===============
1955     0.1276                                             |=====
1956     0.1674                                             |=======
1957     0.1807                                             |=======
1958     0.1235                                             |=====
1959     0.1032                                             |====
1960     0.2332                                             |=========
1961     0.0606                                             |==
1962    -0.1140                                        =====|
1963     0.1563                                             |======
1964     0.2132                                             |=========
1965    -0.1642                                      =======|
1966    -0.4979                         ====================|
1967    -0.3384                               ==============|
1968    -0.3845                              ===============|
1969    -0.1323                                        =====|
1970     0.0456                                             |==
1971     0.1897                                             |========
1972     0.1743                                             |=======
1973     0.0510                                             |==
1974     0.0840                                             |===
1975     0.2217                                             |=========
1976     0.1404                                             |======
1977    -0.0160                                            =|
1978    -0.1073                                         ====|
1979    -0.0761                                          ===|
1980    -0.1223                                        =====|
1981    -0.1611                                       ======|
1982    -0.3909                             ================|
1983    -0.3138                                =============|
1984    -0.3572                               ==============|
1985    -0.2936                                 ============|
1986     0.0089                                             |
1987    -0.1692                                      =======|
1988     0.2160                                             |=========
1989     0.1384                                             |======
1990     0.0000                                             |
1991     0.0000                                             |
1992     0.0000                                             |
1993     0.0000                                             |
1994     0.0000                                             |
1995     0.0000                                             |
1996     0.0000                                             |
1997     0.0000                                             |
1998     0.0000                                             |
1999     0.0000                                             |
2000     0.0000                                             |
                  ------------------------------------------------------------------------------------
```

RESULTS FOR DATA SERIES # 2 (NON-BOOTSTRAPPED) Fall Survey

Data type I2: End-of-year biomass index Series weight: 1.000

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Resid in index
1	1934	0.000E+00	0.000E+00	0.0	*	1.738E+02	0.00000	0.0
2	1935	0.000E+00	0.000E+00	0.0	*	1.712E+02	0.00000	0.0
3	1936	0.000E+00	0.000E+00	0.0	*	1.634E+02	0.00000	0.0
4	1937	0.000E+00	0.000E+00	0.0	*	1.598E+02	0.00000	0.0
5	1938	0.000E+00	0.000E+00	0.0	*	1.546E+02	0.00000	0.0
6	1939	0.000E+00	0.000E+00	0.0	*	1.484E+02	0.00000	0.0
7	1940	0.000E+00	0.000E+00	0.0	*	1.424E+02	0.00000	0.0
8	1941	0.000E+00	0.000E+00	0.0	*	1.282E+02	0.00000	0.0
9	1942	0.000E+00	0.000E+00	0.0	*	1.134E+02	0.00000	0.0
10	1943	0.000E+00	0.000E+00	0.0	*	1.021E+02	0.00000	0.0
11	1944	0.000E+00	0.000E+00	0.0	*	9.044E+01	0.00000	0.0
12	1945	0.000E+00	0.000E+00	0.0	*	8.366E+01	0.00000	0.0
13	1946	0.000E+00	0.000E+00	0.0	*	7.507E+01	0.00000	0.0
14	1947	0.000E+00	0.000E+00	0.0	*	6.715E+01	0.00000	0.0
15	1948	0.000E+00	0.000E+00	0.0	*	5.753E+01	0.00000	0.0
16	1949	0.000E+00	0.000E+00	0.0	*	5.244E+01	0.00000	0.0
17	1950	0.000E+00	0.000E+00	0.0	*	4.555E+01	0.00000	0.0
18	1951	0.000E+00	0.000E+00	0.0	*	3.974E+01	0.00000	0.0
19	1952	0.000E+00	0.000E+00	0.0	*	3.687E+01	0.00000	0.0
20	1953	0.000E+00	0.000E+00	0.0	*	3.555E+01	0.00000	0.0
21	1954	0.000E+00	0.000E+00	0.0	*	3.562E+01	0.00000	0.0
22	1955	0.000E+00	0.000E+00	0.0	*	3.533E+01	0.00000	0.0
23	1956	0.000E+00	0.000E+00	0.0	*	3.481E+01	0.00000	0.0
24	1957	0.000E+00	0.000E+00	0.0	*	3.256E+01	0.00000	0.0
25	1958	0.000E+00	0.000E+00	0.0	*	3.104E+01	0.00000	0.0
26	1959	0.000E+00	0.000E+00	0.0	*	2.956E+01	0.00000	0.0
27	1960	0.000E+00	0.000E+00	0.0	*	2.958E+01	0.00000	0.0
28	1961	0.000E+00	0.000E+00	0.0	*	2.849E+01	0.00000	0.0
29	1962	0.000E+00	0.000E+00	0.0	*	2.724E+01	0.00000	0.0
30	1963	1.000E+00	1.000E+00	0.0	2.410E+01	2.751E+01	-0.13240	-3.412E+00
31	1964	1.000E+00	1.000E+00	0.0	5.460E+01	2.852E+01	0.64931	2.608E+01
32	1965	1.000E+00	1.000E+00	0.0	1.310E+01	2.977E+01	-0.82085	-1.667E+01
33	1966	1.000E+00	1.000E+00	0.0	2.910E+01	3.096E+01	-0.06199	-1.861E+00
34	1967	1.000E+00	1.000E+00	0.0	2.430E+01	3.136E+01	-0.25518	-7.064E+00
35	1968	1.000E+00	1.000E+00	0.0	4.040E+01	3.348E+01	0.18791	6.921E+00
36	1969	1.000E+00	1.000E+00	0.0	2.350E+01	3.353E+01	-0.35557	-1.003E+01
37	1970	1.000E+00	1.000E+00	0.0	3.290E+01	3.185E+01	0.03240	1.049E+00
38	1971	1.000E+00	1.000E+00	0.0	2.340E+01	2.862E+01	-0.20130	-5.218E+00
39	1972	1.000E+00	1.000E+00	0.0	2.460E+01	2.536E+01	-0.03023	-7.551E-01
40	1973	1.000E+00	1.000E+00	0.0	1.700E+01	2.236E+01	-0.27420	-5.363E+00
41	1974	1.000E+00	1.000E+00	0.0	2.420E+01	2.179E+01	0.10498	2.412E+00
42	1975	1.000E+00	1.000E+00	0.0	3.990E+01	2.109E+01	0.63761	1.881E+01
43	1976	1.000E+00	1.000E+00	0.0	1.530E+01	2.024E+01	-0.27967	-4.937E+00
44	1977	1.000E+00	1.000E+00	0.0	1.730E+01	1.821E+01	-0.05143	-9.131E-01
45	1978	1.000E+00	1.000E+00	0.0	2.070E+01	1.552E+01	0.28793	5.179E+00
46	1979	1.000E+00	1.000E+00	0.0	1.600E+01	1.212E+01	0.27806	3.884E+00
47	1980	1.000E+00	1.000E+00	0.0	1.260E+01	1.005E+01	0.22563	2.545E+00
48	1981	1.000E+00	1.000E+00	0.0	1.220E+01	8.589E+00	0.35095	3.611E+00
49	1982	1.000E+00	1.000E+00	0.0	3.400E+00	7.289E+00	-0.76263	-3.889E+00
50	1983	1.000E+00	1.000E+00	0.0	4.100E+00	6.419E+00	-0.44821	-2.319E+00
51	1984	1.000E+00	1.000E+00	0.0	3.900E+00	5.615E+00	-0.36441	-1.715E+00
52	1985	1.000E+00	1.000E+00	0.0	5.700E+00	4.878E+00	0.15565	8.216E-01
53	1986	1.000E+00	1.000E+00	0.0	8.000E+00	4.575E+00	0.55873	3.425E+00
54	1987	1.000E+00	1.000E+00	0.0	5.500E+00	4.651E+00	0.16759	8.487E-01
55	1988	1.000E+00	1.000E+00	0.0	6.300E+00	5.042E+00	0.22281	1.258E+00
56	1989	1.000E+00	1.000E+00	0.0	6.800E+00	5.729E+00	0.17129	1.071E+00
57	1990	1.000E+00	1.000E+00	0.0	1.220E+01	6.557E+00	0.62083	5.643E+00
58	1991	1.000E+00	1.000E+00	0.0	8.400E+00	7.566E+00	0.10457	8.340E-01
59	1992	1.000E+00	1.000E+00	0.0	8.094E+00	8.619E+00	-0.06279	-5.245E-01
60	1993	1.000E+00	1.000E+00	0.0	1.120E+01	9.875E+00	0.12568	1.323E+00
61	1994	1.000E+00	1.000E+00	0.0	5.939E+00	1.150E+01	-0.66061	-5.559E+00
62	1995	1.000E+00	1.000E+00	0.0	4.653E+00	1.339E+01	-1.05718	-8.739E+00
63	1996	1.000E+00	1.000E+00	0.0	3.063E+01	1.565E+01	0.67190	1.499E+01
64	1997	1.000E+00	1.000E+00	0.0	1.894E+01	1.828E+01	0.03529	6.567E-01
65	1998	1.000E+00	1.000E+00	0.0	3.172E+01	2.129E+01	0.39857	1.043E+01
66	1999	1.000E+00	1.000E+00	0.0	2.286E+01	2.472E+01	-0.07820	-1.860E+00
67	2000	1.000E+00	1.000E+00	0.0	2.620E+01	2.864E+01	-0.08893	-2.437E+00

* Asterisk indicates missing value(s).

```
UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 2
                   -2       -1.5       -1       -0.5        0        0.5        1        1.5        2
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    ------------------------------------------------------------------------------------
1934     0.0000                                             |
1935     0.0000                                             |
1936     0.0000                                             |
1937     0.0000                                             |
1938     0.0000                                             |
1939     0.0000                                             |
1940     0.0000                                             |
1941     0.0000                                             |
1942     0.0000                                             |
1943     0.0000                                             |
1944     0.0000                                             |
1945     0.0000                                             |
1946     0.0000                                             |
1947     0.0000                                             |
1948     0.0000                                             |
1949     0.0000                                             |
1950     0.0000                                             |
1951     0.0000                                             |
1952     0.0000                                             |
1953     0.0000                                             |
1954     0.0000                                             |
1955     0.0000                                             |
1956     0.0000                                             |
1957     0.0000                                             |
1958     0.0000                                             |
1959     0.0000                                             |
1960     0.0000                                             |
1961     0.0000                                             |
1962     0.0000                                             |
1963    -0.1324                                          ===|
1964     0.6493                                             |=============
1965    -0.8208                             ================|
1966    -0.0620                                            =|
1967    -0.2552                                        =====|
1968     0.1879                                             |====
1969    -0.3556                                      =======|
1970     0.0324                                             |=
1971    -0.2013                                         ====|
1972    -0.0302                                            =|
1973    -0.2742                                        =====|
1974     0.1050                                             |==
1975     0.6376                                             |=============
1976    -0.2797                                       ======|
1977    -0.0514                                            =|
1978     0.2879                                             |======
1979     0.2781                                             |======
1980     0.2256                                             |=====
1981     0.3510                                             |=======
1982    -0.7626                              ===============|
1983    -0.4482                                    =========|
1984    -0.3644                                      =======|
1985     0.1557                                             |===
1986     0.5587                                             |===========
1987     0.1676                                             |===
1988     0.2228                                             |====
1989     0.1713                                             |===
1990     0.6208                                             |============
1991     0.1046                                             |==
1992    -0.0628                                            =|
1993     0.1257                                             |===
1994    -0.6606                                =============|
1995    -1.0572                        =====================|
1996     0.6719                                             |=============
1997     0.0353                                             |=
1998     0.3986                                             |========
1999    -0.0782                                           ==|
2000    -0.0889                                           ==|
                   ------------------------------------------------------------------------------------
```

RESULTS FOR DATA SERIES # 3 (NON-BOOTSTRAPPED) Spring Survey

Data type I0: Start-of-year biomass index Series weight: 1.000

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Resid in index
1	1934	0.000E+00	0.000E+00	0.0	*	1.627E+02	0.00000	0.0
2	1935	0.000E+00	0.000E+00	0.0	*	1.625E+02	0.00000	0.0
3	1936	0.000E+00	0.000E+00	0.0	*	1.601E+02	0.00000	0.0
4	1937	0.000E+00	0.000E+00	0.0	*	1.528E+02	0.00000	0.0
5	1938	0.000E+00	0.000E+00	0.0	*	1.494E+02	0.00000	0.0
6	1939	0.000E+00	0.000E+00	0.0	*	1.446E+02	0.00000	0.0
7	1940	0.000E+00	0.000E+00	0.0	*	1.387E+02	0.00000	0.0
8	1941	0.000E+00	0.000E+00	0.0	*	1.331E+02	0.00000	0.0
9	1942	0.000E+00	0.000E+00	0.0	*	1.199E+02	0.00000	0.0
10	1943	0.000E+00	0.000E+00	0.0	*	1.060E+02	0.00000	0.0
11	1944	0.000E+00	0.000E+00	0.0	*	9.551E+01	0.00000	0.0
12	1945	0.000E+00	0.000E+00	0.0	*	8.457E+01	0.00000	0.0
13	1946	0.000E+00	0.000E+00	0.0	*	7.823E+01	0.00000	0.0
14	1947	0.000E+00	0.000E+00	0.0	*	7.020E+01	0.00000	0.0
15	1948	0.000E+00	0.000E+00	0.0	*	6.280E+01	0.00000	0.0
16	1949	0.000E+00	0.000E+00	0.0	*	5.380E+01	0.00000	0.0
17	1950	0.000E+00	0.000E+00	0.0	*	4.904E+01	0.00000	0.0
18	1951	0.000E+00	0.000E+00	0.0	*	4.259E+01	0.00000	0.0
19	1952	0.000E+00	0.000E+00	0.0	*	3.716E+01	0.00000	0.0
20	1953	0.000E+00	0.000E+00	0.0	*	3.448E+01	0.00000	0.0
21	1954	0.000E+00	0.000E+00	0.0	*	3.324E+01	0.00000	0.0
22	1955	0.000E+00	0.000E+00	0.0	*	3.331E+01	0.00000	0.0
23	1956	0.000E+00	0.000E+00	0.0	*	3.303E+01	0.00000	0.0
24	1957	0.000E+00	0.000E+00	0.0	*	3.255E+01	0.00000	0.0
25	1958	0.000E+00	0.000E+00	0.0	*	3.045E+01	0.00000	0.0
26	1959	0.000E+00	0.000E+00	0.0	*	2.903E+01	0.00000	0.0
27	1960	0.000E+00	0.000E+00	0.0	*	2.764E+01	0.00000	0.0
28	1961	0.000E+00	0.000E+00	0.0	*	2.766E+01	0.00000	0.0
29	1962	0.000E+00	0.000E+00	0.0	*	2.664E+01	0.00000	0.0
30	1963	0.000E+00	0.000E+00	0.0	*	2.548E+01	0.00000	0.0
31	1964	0.000E+00	0.000E+00	0.0	*	2.573E+01	0.00000	0.0
32	1965	0.000E+00	0.000E+00	0.0	*	2.667E+01	0.00000	0.0
33	1966	0.000E+00	0.000E+00	0.0	*	2.784E+01	0.00000	0.0
34	1967	0.000E+00	0.000E+00	0.0	*	2.895E+01	0.00000	0.0
35	1968	1.000E+00	1.000E+00	0.0	1.700E+01	2.933E+01	-0.54536	-1.233E+01
36	1969	1.000E+00	1.000E+00	0.0	1.970E+01	3.131E+01	-0.46322	-1.161E+01
37	1970	1.000E+00	1.000E+00	0.0	1.890E+01	3.136E+01	-0.50632	-1.246E+01
38	1971	1.000E+00	1.000E+00	0.0	7.160E+01	2.978E+01	0.87711	4.182E+01
39	1972	1.000E+00	1.000E+00	0.0	4.440E+01	2.676E+01	0.50629	1.764E+01
40	1973	1.000E+00	1.000E+00	0.0	2.530E+01	2.371E+01	0.06491	1.590E+00
41	1974	1.000E+00	1.000E+00	0.0	1.880E+01	2.091E+01	-0.10647	-2.112E+00
42	1975	1.000E+00	1.000E+00	0.0	1.760E+01	2.037E+01	-0.14639	-2.775E+00
43	1976	1.000E+00	1.000E+00	0.0	2.620E+01	1.972E+01	0.28408	6.479E+00
44	1977	1.000E+00	1.000E+00	0.0	1.160E+01	1.892E+01	-0.48943	-7.324E+00
45	1978	1.000E+00	1.000E+00	0.0	1.220E+01	1.703E+01	-0.33362	-4.831E+00
46	1979	1.000E+00	1.000E+00	0.0	3.230E+01	1.451E+01	0.79995	1.779E+01
47	1980	1.000E+00	1.000E+00	0.0	2.030E+01	1.133E+01	0.58318	8.970E+00
48	1981	1.000E+00	1.000E+00	0.0	1.860E+01	9.403E+00	0.68218	9.197E+00
49	1982	1.000E+00	1.000E+00	0.0	9.400E+00	8.032E+00	0.15731	1.368E+00
50	1983	1.000E+00	1.000E+00	0.0	6.100E+00	6.816E+00	-0.11103	-7.163E-01
51	1984	1.000E+00	1.000E+00	0.0	2.700E+00	6.002E+00	-0.79886	-3.302E+00
52	1985	1.000E+00	1.000E+00	0.0	6.600E+00	5.250E+00	0.22877	1.350E+00
53	1986	1.000E+00	1.000E+00	0.0	3.200E+00	4.562E+00	-0.35457	-1.362E+00
54	1987	1.000E+00	1.000E+00	0.0	1.290E+01	4.279E+00	1.10360	8.621E+00
55	1988	1.000E+00	1.000E+00	0.0	3.300E+00	4.350E+00	-0.27615	-1.050E+00
56	1989	1.000E+00	1.000E+00	0.0	2.900E+00	4.715E+00	-0.48594	-1.815E+00
57	1990	1.000E+00	1.000E+00	0.0	6.800E+00	5.358E+00	0.23838	1.442E+00
58	1991	1.000E+00	1.000E+00	0.0	4.300E+00	6.132E+00	-0.35490	-1.832E+00
59	1992	1.000E+00	1.000E+00	0.0	1.070E+01	7.075E+00	0.41367	3.625E+00
60	1993	1.000E+00	1.000E+00	0.0	1.750E+01	8.059E+00	0.77538	9.441E+00
61	1994	1.000E+00	1.000E+00	0.0	3.900E+00	9.235E+00	-0.86199	-5.335E+00
62	1995	1.000E+00	1.000E+00	0.0	1.900E+00	1.075E+01	-1.73322	-8.852E+00
63	1996	1.000E+00	1.000E+00	0.0	1.190E+01	1.252E+01	-0.05107	-6.235E-01
64	1997	1.000E+00	1.000E+00	0.0	3.404E+01	1.463E+01	0.84445	1.941E+01
65	1998	1.000E+00	1.000E+00	0.0	7.840E+00	1.710E+01	-0.77966	-9.257E+00
66	1999	1.000E+00	1.000E+00	0.0	1.902E+01	1.991E+01	-0.04580	-8.913E-01
67	2000	1.000E+00	1.000E+00	0.0	5.601E+01	2.312E+01	0.88485	3.289E+01

* Asterisk indicates missing value(s).

```
UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 3
                   -2       -1.5       -1       -0.5        0        0.5        1        1.5        2
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    ------------------------------------------------------------------------------------
1934     0.0000                                             |
1935     0.0000                                             |
1936     0.0000                                             |
1937     0.0000                                             |
1938     0.0000                                             |
1939     0.0000                                             |
1940     0.0000                                             |
1941     0.0000                                             |
1942     0.0000                                             |
1943     0.0000                                             |
1944     0.0000                                             |
1945     0.0000                                             |
1946     0.0000                                             |
1947     0.0000                                             |
1948     0.0000                                             |
1949     0.0000                                             |
1950     0.0000                                             |
1951     0.0000                                             |
1952     0.0000                                             |
1953     0.0000                                             |
1954     0.0000                                             |
1955     0.0000                                             |
1956     0.0000                                             |
1957     0.0000                                             |
1958     0.0000                                             |
1959     0.0000                                             |
1960     0.0000                                             |
1961     0.0000                                             |
1962     0.0000                                             |
1963     0.0000                                             |
1964     0.0000                                             |
1965     0.0000                                             |
1966     0.0000                                             |
1967     0.0000                                             |
1968    -0.5454                                  ===========|
1969    -0.4632                                    =========|
1970    -0.5063                                   ==========|
1971     0.8771                                             |==================
1972     0.5063                                             |==========
1973     0.0649                                             |=
1974    -0.1065                                           ==|
1975    -0.1464                                          ===|
1976     0.2841                                             |======
1977    -0.4894                                   ==========|
1978    -0.3336                                      =======|
1979     0.7999                                             |================
1980     0.5832                                             |============
1981     0.6822                                             |==============
1982     0.1573                                             |===
1983    -0.1110                                           ==|
1984    -0.7989                             ================|
1985     0.2288                                             |=====
1986    -0.3546                                      =======|
1987     1.1036                                             |======================
1988    -0.2761                                       ======|
1989    -0.4859                                   ==========|
1990     0.2384                                             |=====
1991    -0.3549                                      =======|
1992     0.4137                                             |========
1993     0.7754                                             |================
1994    -0.8620                            =================|
1995    -1.7332                    =========================|
1996    -0.0511                                            =|
1997     0.8444                                             |=================
1998    -0.7797                             ================|
1999    -0.0458                                            =|
2000     0.8848                                             |==================
                   ------------------------------------------------------------------------------------
```

RESULTS OF BOOTSTRAPPED ANALYSIS

Param name	Bias-corrected estimate	Ordinary estimate	Relative bias	Approx 80% lower CL	Approx 80% upper CL	Approx 50% lower CL	Approx 50% upper CL	Inter-quartile range	Relative IQ range
B1ratio	2.000E+00	2.000E+00	0.00%	2.000E+00	2.000E+00	2.000E+00	2.000E+00	5.931E-09	0.000
K	4.544E+02	4.528E+02	-0.35%	4.229E+02	4.888E+02	4.370E+02	4.718E+02	3.472E+01	0.076
r	1.776E-01	1.789E-01	0.74%	1.520E-01	2.058E-01	1.641E-01	1.926E-01	2.849E-02	0.160
q(1)	4.890E-02	4.922E-02	0.66%	4.142E-02	5.687E-02	4.486E-02	5.313E-02	8.264E-03	0.169
q(2)	3.811E-01	3.842E-01	0.81%	3.260E-01	4.428E-01	3.526E-01	4.108E-01	5.813E-02	0.153
q(3)	3.577E-01	3.593E-01	0.44%	3.041E-01	4.166E-01	3.293E-01	3.899E-01	6.058E-02	0.169
MSY	2.018E+01	2.026E+01	0.39%	1.857E+01	2.176E+01	1.935E+01	2.104E+01	1.689E+00	0.084
Ye(2001)	1.109E+01	1.114E+01	0.49%	8.774E+00	1.353E+01	9.804E+00	1.228E+01	2.472E+00	0.223
Bmsy	2.272E+02	2.264E+02	-0.35%	2.115E+02	2.444E+02	2.185E+02	2.359E+02	1.736E+01	0.076
Fmsy	8.880E-02	8.946E-02	0.74%	7.600E-02	1.029E-01	8.204E-02	9.629E-02	1.425E-02	0.160
fmsy(1)	1.814E+00	1.817E+00	0.22%	1.641E+00	1.990E+00	1.721E+00	1.904E+00	1.833E-01	0.101
fmsy(2)	2.341E-01	2.328E-01	-0.53%	2.070E-01	2.659E-01	2.203E-01	2.500E-01	2.962E-02	0.127
fmsy(3)	2.493E-01	2.490E-01	-0.12%	2.184E-01	2.851E-01	2.315E-01	2.675E-01	3.594E-02	0.144
F(0.1)	7.992E-02	8.051E-02	0.67%	6.840E-02	9.263E-02	7.384E-02	8.666E-02	1.282E-02	0.160
Y(0.1)	1.998E+01	2.005E+01	0.38%	1.839E+01	2.155E+01	1.916E+01	2.083E+01	1.672E+00	0.084
B-ratio	3.289E-01	3.292E-01	0.09%	2.708E-01	3.985E-01	2.978E-01	3.652E-01	6.747E-02	0.205
F-ratio	5.167E-02	5.143E-02	-0.47%	4.062E-02	6.640E-02	4.562E-02	5.895E-02	1.333E-02	0.258
Y-ratio	5.496E-01	5.500E-01	0.07%	4.683E-01	6.382E-01	5.069E-01	5.971E-01	9.021E-02	0.164
f0.1(1)	1.632E+00	1.636E+00	0.19%	* * * * *	0.101				
f0.1(2)	2.107E-01	2.095E-01	-0.48%	* * * * *	0.127				
f0.1(3)	2.244E-01	2.241E-01	-0.11%	* * * * *	0.144				
q2/q1	7.748E+00	7.806E+00	0.75%	6.742E+00	8.899E+00	7.203E+00	8.324E+00	1.121E+00	0.145
q3/q1	7.292E+00	7.299E+00	0.10%	6.299E+00	8.445E+00	6.733E+00	7.904E+00	1.170E+00	0.160

NOTES ON BOOTSTRAPPED ESTIMATES:

- The bootstrapped results shown were computed from 1000 trials.
- These results are conditional on the constraints placed upon MSY and r in the input file (ASPIC.INP).
- All bootstrapped intervals are approximate. The statistical literature recommends using at least 1000 trials for accurate 95% intervals. The 80% intervals used by ASPIC should require fewer trials for equivalent accuracy. Using at least 500 trials is recommended.
- The bias corrections used here are based on medians. This is an accepted statistical procedure, but may estimate nonzero bias for unbiased, skewed estimators.

Trials replaced for lack of convergence:	0
Trials replaced for MSY out-of-bounds:	0
Trials replaced for r out-of-bounds:	0
Residual-adjustment factor:	1.0238

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

STANDARD MAIL A

Publications and Reports of the Northeast Fisheries Science Center

The mission of NOAA's National Marine Fisheries Service (NMFS) is "stewardship of living marine resources for the benefit of the nation through their science-based conservation and management and promotion of the health of their environment." As the research arm of the NMFS's Northeast Region, the Northeast Fisheries Science Center (NEFSC) supports the NMFS mission by "planning, developing, and managing multidisciplinary programs of basic and applied research to: 1) better understand the living marine resources (including marine mammals) of the Northwest Atlantic, and the environmental quality essential for their existence and continued productivity; and 2) describe and provide to management, industry, and the public, options for the utilization and conservation of living marine resources and maintenance of environmental quality which are consistent with national and regional goals and needs, and with international commitments." Results of NEFSC research are largely reported in primary scientific media (*e.g.*, anonymously-peer-reviewed scientific journals). However, to assist itself in providing data, information, and advice to its constituents, the NEFSC occasionally releases its results in its own media. Those media are in four categories:

NOAA Technical Memorandum NMFS-NE -- This series is issued irregularly. The series typically includes: data reports of long-term or large area studies; synthesis reports for major resources or habitats; annual reports of assessment or monitoring programs; documentary reports of oceanographic conditions or phenomena; manuals describing field and lab techniques; literature surveys of major resource or habitat topics; findings of task forces or working groups; summary reports of scientific or technical workshops; and indexed and/or annotated bibliographies. All issues receive internal scientific review and most issues receive technical and copy editing.

Northeast Fisheries Science Center Reference Document -- This series is issued irregularly. The series typically includes: data reports on field and lab observations or experiments; progress reports on continuing experiments, monitoring, and assessments; background papers for scientific or technical workshops; and simple bibliographies. Issues receive internal scientific review, but no technical or copy editing.

Fishermen's Report -- This information report is a quick-turnaround report on the distribution and relative abundance of commercial fisheries resources as derived from each of the NEFSC's periodic research vessel surveys of the Northeast's continental shelf. There is no scientific review, nor any technical or copy editing, of this report.

The Shark Tagger -- This newsletter is an annual summary of tagging and recapture data on large pelagic sharks as derived from the NMFS's Cooperative Shark Tagging Program; it also presents information on the biology (movement, growth, reproduction, etc.) of these sharks as subsequently derived from the tagging and recapture data. There is internal scientific review, but no technical or copy editing, of this newsletter.

OBTAINING A COPY: To obtain a copy of a *NOAA Technical Memorandum NMFS-NE* or a *Northeast Fisheries Science Center Reference Document*, or to subscribe to the *Fishermen's Report* or the *The Shark Tagger*, either contact the NEFSC Editorial Office (166 Water St., Woods Hole, MA 02543-1026; 508-495-2228) or consult the NEFSC webpage on "Reports and Publications" (*http://www.nefsc.nmfs.gov/nefsc/publications/*).