NOAA Technical Memorandum NMFS-SEFC-263

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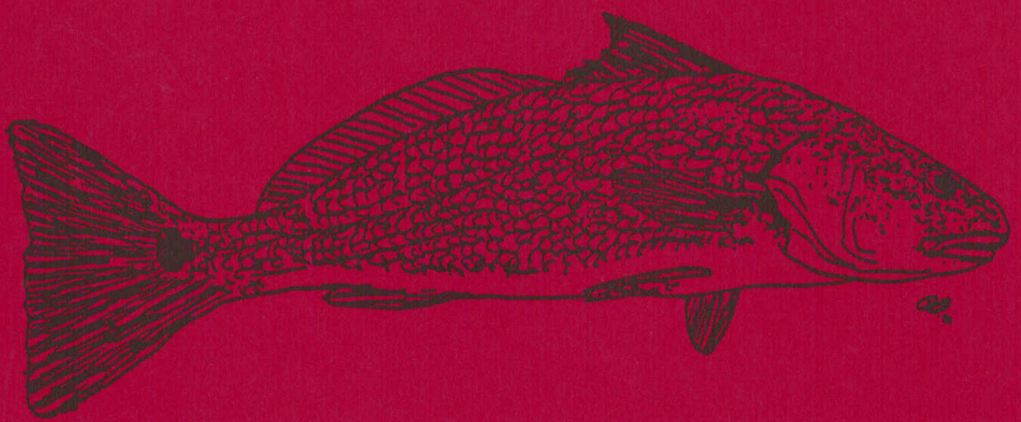

July 1990

U.S Department of Commerce
National Oceanic and Atmospheric Asministration
National Marine Fisheries Service
Southeast Fisheries Center
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EXECUTIVE SUMMARY

Commercial landings of red drum along the U.S. Atlantic coast are harvested as part of a mixed species fishery and catch statistics for the red drum have been collected since the 1930's (Pugliese 1989). Commercial landings show no particular temporal trends, averaging about 300,000 pounds. Recreation catch statistics have been collected annually only since 1979 (Mercer 1984). The recreational fishery has expanded from 679,000 pounds of red drum caught (270,000 fish) in 1980 to 1,670,000 pounds of red drum caught (593,000 fish) in 1988, with the highest recorded catch in 1985 (2,102,000 pounds or 1,110,000 fish). Both of these fisheries appear to be supported primarily by catches of sub-adult red drum (ages 0-5).

Population-level models used in this analysis are deterministic and these results should be viewed as best available estimates. Sparseness of commercial length frequency data, concerns over adequateness of recreational length frequency data, and minimal direct information on other biological aspects (e.g., natural mortality, migration, maturity, and fecundity) contribute to uncertainty in these results, due to additional assumptions required for application of these population-level models. To the extent that all assumptions made are reasonable and accurate, population-level models should provide useful information to assess the status of the stocks; however, as the assumptions are increasingly violated, results may continue to be useful, but should be viewed with a certain degree of skepticism.

Estimated rates of coastwide total instantaneous mortality are generally high, suggesting low subadult survival to the median age for female maturation. Because of these high rates of mortality, recruitment of sub-adults to the adult population may not be sufficient to support current levels of spawning stock biomass (or egg production). Coastwide total mortality rates for the adult stock (ages 6 and older) could not be estimated, but was assumed to equal M from Pauly's (1979) equation using K2 from the double von Bertalanffy growth function. A double rather than single von Bertalanffy function was used to describe growth of red drum along the U.S. Atlantic coast, growth rates for the Atlantic red drum were fairly consistent across areas and years. Age-length keys based on these growth data were developed for fishing years 1986 through 1988.

Estimates of age-specific fishing mortality from virtual population analysis (VPA) conducted on the sub-adult population indicate high levels on ages 1 through 3 and lower levels prior to full recruitment (age 0) and ages 4 and 5. The VPA applied to an alternate recreational data set (other than the MRFSS) indicated lower estimates of fishing mortality for ages 1-3 and higher estimates for ages 4-5. Population estimates under both scenarios range from 0.9 to 1.4 million recruits to age 1 for the Atlantic coast.

Estimated yield per recruit for the two scenarios are similar at current fishing conditions. Gains in yield per recruit appear greater from increasing minimum age at entry to the fishery than from reduction in overall fishing mortality. Gains from 68% to 85% may be obtained by raising the minimum age at entry to 2.0 years (approximately 21 inch fish), while maximum gains from decreasing fishing mortality range from 9% to 13%.

Under equilibrium conditions spawning stock ratios (either based on female biomass or on egg production) relative to F=0 were estimated to be substantially below the South Atlantic Fishery Management Council's goal of 20%. Greater escapement of sub-adult red drum will be necessary if this goal is to be met, and to prevent recruitment failure sometime in the future. If there has been no significant fishing on the adult population, there may be sufficient time to respond to overfishing of sub-adults because red drum are believed to live extremely long lives (up to 60 years). However, it is unlikely that the instantaneous fishing mortality rate (F) equals 0 for the adults (ages 6+), and F may be substantial, leading to optimistically high current spawning stock ratio estimates. There is currently insufficient data available to estimate fishing mortality on the adult red drum stock.

Potential benefits to the red drum stock from minimum and maximum size limits and from bag limits were assessed using the MRFSS data base. Although these data are somewhat limited as to the conclusions that can be drawn from them, some inferences can be made. Benefits obtained from minimum size limits would theoretically allow a greater escapement of females to the adult population to spawn at least once before becoming vulnerable to capture. Benefits obtained from maximum size limits would theoretically protect the adult spawning stock, caught primarily by the recreational fishery. In general, we do not recommend any expansion of fishing on the the red drum stock.

Modest gains to both yield per recruit and spawning stock ratio from bag limits are possible which could increase the numbers of survivors in the population (decrease mortality). Catch frequency distributions indicate that bag limits would not seriously restrict the catch of the average fisherman, although this may produce a shift in fishing mortality to older fish. However, there are difficulties in assessing the efficacy of bag limits once implemented without an independent sampling program free from effects of this management option.

INTRODUCTION

In recent years the red drum (Sciaenops ocellatus) has been placed among those of our nation's important recreational and commercial stocks which have been fished into a state of decline. The Gulf of Mexico stock was fished to excessively low levels which prompted emergency action by the Secretary of Commerce in 1986 and a moratorium was placed on the harvest of red drum occurring in U.S. Gulf of Mexico waters under federal jurisdiction. This event stimulated much needed investigations into the biology and ecology of red drum and also initiated the stock assessment requested by the Gulf of Mexico Fisheries Management Council (GMFMC) in 1986. Since 1986 three annual stock assessments have been conducted for red drum in the Gulf of Mexico (Goodyear 1989) which provided the basis for a Gulf Fisheries Management Plan (FMP) for red drum.

Biological and ecological information for red drum along the Atlantic coast are less extensive than in the Gulf of Mexico and knowledge of the status of the stock is fragmented. Preliminary population analyses were conducted in Florida and were included in a coastwide FMP for the Atlantic stock of red drum (Mercer 1984). Although the FMP has recently been reviewed (ASMFC Advisory Committee 1988), few substantial changes have been implemented due to a lack of an assessment of the entire Atlantic red drum stock. Included in that review however, were summaries of the various research and monitoring programs being conducted by the Atlantic coastal states. Data and results from some of these research activities on red drum have recently become available and can be used to reassess the status of the stock and present updated management options.

Unlike the U.S. Gulf of Mexico stock, no large directed commercial fishery exists for adult red drum in the Atlantic. However, a fairly intense recreational fishery that harvests primarily sexually-immature fish exists, and there is concern that these young Atlantic red drum are being overfished similar to the growth overfishing found to have occurred on the Gulf of Mexico's sub-adult population (Goodyear 1989). In response to these concerns and to develop a much needed updated FMP for the U.S. Atlantic red drum, the South Atlantic Fishery Management Council (SAFMC) requested the Southeast Fisheries Research Center to assess the current status of the U.S. Atlantic stock. This document presents the results of an Atlantic red drum stock assessment and is intended to provide a sound biological basis, using updated information, for the development of a Fishery Management Plan. This document also summarizes the most current information on the aspects of the biology of red drum and the status of the stock with the intent that it will serve as a framework for subsequent assessments.

DESCRIPTION OF THE FISHERY

Commercial landings for the east coast of Florida through North Carolina were obtained from the Southeast Fisheries Center's Economic and Statistics Office, and commercial landings for Virginia and north were obtained from the Northeast Fisheries Center. Commercial length-frequency information were obtained from the individual states (North Carolina Division of Marine Fisheries, South Carolina Marine Fisheries Division, and Georgia Department of Natural Resources). The commercial Trip Interview Program (TIP) data was also consulted for length-frequency data, but was extremely limited in what it contained. Recreational landings and length-frequency information were obtained from the Marine Recreational Fishery Statistic Survey (MRFSS). Additional biological sampling data was provided by Florida Department of Natural Resources and U.S. Fish and Wildlife Service.

There were a number of problems associated with the various data sets which required the use of several important assumptions to conduct the analysis. First, there was no length frequency information available from the commercial TIP data files with which catch in numbers at size could be estimated. Since the individual states conducted sampling programs with many of the gears which are currently used by the commercial fishery (North Carolina Marine Fisheries Division actually leased the commercial fisherman for many of their samples), we assumed that the catches of red drum from the corresponding gears were representative of the commercial catch. Further, concerns were raised over large red drum being under-represented in the MRFSS as would be indicated from a recreational tagging program conducted in North Carolina and South Carolina. Because such a bias in sampling the various size classes of fish in the population in relation to their abundance would most certainly affect the analysis, we conduct a concurrent analysis presented as an "alternate scenario" using length frequencies from the recreational tagging data. Under the "alternate scenario", as with the MRFSS data base, we assume of course that the sample of fish used to generate the length frequency was representative of the recreational fishery. Given the uncertainties of the data as to their representativeness, the samples of fish from the MRFSS and the alternate scenario upon which these analyses are based represent the extremes and probably the true condition lies some where in between.

Greater detail concerning the gears used and the assumptions made for this analysis will be discussed in their appropriate sections.

Recreational Fishery

In the early 1980's estimated catches of red drum from the recreational fishery were approximately equal to the catches from the commercial fishery. Beginning about 1983 recreational catches increased significantly over commercially harvested red drum and by 1984 dominated the total harvest for the entire Atlantic coast by 84 percent (Table 1). The recreational fishery for red drum appears to have expanded since 1979 when the Marine Recreational Fishery Statistic Survey (MRFSS) was first implemented (Figure 1). Estimated total annual catch in numbers (sum of types A and B1 defined in footnote to Table 1) increased from 270,000 fish in 1980 to approximately 600,000 in 1988 with a highest recorded catch of 1.1 million fish in 1985 corresponding to 2.1 million pounds (Figure 2). This peak catch in numbers of red drum compares to 2.3 million fish caught in the Gulf of Mexico for the same year. Estimated fishing effort for red drum has been steadily increasing during the 1980's with a concurrent downward trend in catch-per-unit effort (fish per trip) (Pugliese 1989). Mean weight of red drum in the catch for the Atlantic coast shows no clear temporal trends, averaging approximately 2.5 pounds over a nine year period and attaining a high of 4.5 pounds in 1986 (Figure 3).

Table 2 summarizes the estimated recreational catches of red drum by mode (boat vs. shore) and area of fishing (estuarine vs. ocean) by year along the Atlantic coast. Estimated catches of red drum by boat anglers (including rental, private and charter) were at least twice as great as estimated catches by shore based anglers for most years. For the later years of the survey, 1986-1988, the catches of red drum were dominated by boat anglers comprizing up to 93% of the total catch in 1986. Each year the greatest proportion of the red drum were caught in the estuarine environment (inshore), particularly for the later years when the catch was greater than about 80% of the total catch in weight.

The number of intercept survey interviews conducted in the southeastern U.S. Atlantic coastal region for the MRFSS has increased considerably since the early 1980's with a 223% increase from 1979 to 1988 (Pugliese 1989). Numbers of fish measured for length and weight from the intercepted fishing trips also became more numerous and were used to generate size frequency distributions representative of all fish harvested by recreational anglers. Figure 4 shows the length frequency distribution of the recreational catch of red drum from the Atlantic coast (annual length frequencies from the MRFSS are given in Appendix A). The mean size of fish caught by the recreational angler from 1979 to 1988 was between 350 and 420 mm in length. In all years, 90% of the red drum caught along the Atlantic coast were less than 525 mm which suggests that most of the recreational effort is directed towards the smaller sizes of red drum. Length frequencies of red drum by fishing mode and area fished are given in Figures 5 through

9. There is no apparent difference in the sizes of fish caught by mode of fishing or area fished which suggests that shore and boat anglers are fishing the same size classes of red drum or that the sizes of red drum available to capture by the different modes and areas of fishing are homogeneously mixed over the fishery. In either case, its apparent that the recreational fishery is concentrating its effort on red drum less than 525 mm.

To assess the potential affects of a fishery on a population it is neccessary to examine the age classes of fish which are vulnerable to the force of fishing. In constructing an age frequency distribution it was first neccessary to estimate the total catch at size of red drum from both the recreational and commercial fisheries. To estimate the recreational catch of red drum by size, the available annual length frequencies from the individual states were aggregated into 50 mm length intervals. Narrower length intervals were not used because of relatively rapid growth and inadequate age-length data for the sub-adults (described later). A period of one year, rather than finer time scale, was used due to limitations in the aged data sets. Annual length frequencies were normalized by state such that the frequencies associated with each length interval were converted to proportions or relative frequencies summing to one. The normalized length frequencies were then weighted by the total annual recreational catch for each state and the weighted normalized catch at length vector was multiplied by the total number of fish caught per year. This weighting procedure was used because the length samples in the MRFSS data were disproportionate to the catches of red drum by state.

The above normalizing procedure was similarly used to estimated the catch of red drum in numbers at length for the "alternate scenario" using length frequencies from the North Carolina, South Carolina, and Georgia recreational tagging programs. Figures 10 through 12 show the length frequencies from data collected in the various tagging programs (annual length frequencies by state are given in Appendix B). It should be noted from these figures that there are relatively more larger red drum caught than would be suggested by the MRFSS data. Although recreational fisherman were instructed to tag red drum of any size, it is possible, that anglers targeted the larger drum which could result in a bias towards the larger fish. Further justification for the use of the alternate scenario is the existence of a fishery for larger red drum at night and off the beaches of North Carolina for several months in the fall which is not sampled by the MRFSS (Ross, pers. comm). Coastwide length frequencies from 1986 to 1988 for the MRFSS and alternate scenarios are presented in Figures 13 through 18. It is clear from these figures that the alternate scenario includes catches of red drum greater than 825 mm in significant numbers. Finally, to construct the age frequency distribution of the catch of red drum by the recreational fishery (under both scenarios), the coastwide length frequencies were

converted to numbers at age by applying the annual age-length keys (the construction of which will be discussed later) to the appropriate years (Table 3).

The numbers of red drum caught per angler-trip from the MRFSS data base (1979-1988) are given in Figure 19 (with annual length frequencies given in Appendix C). These catch frequency distributions would imply that on the average an angler can expect to catch between one and four red drum per fishing trip. Further, the catch frequencies suggest that anglers are likely to catch less than 9 red drum per fishing trip as 90% of interviewed recreational fisherman caught less than 9 red drum. This frequency distribution is conditioned on at least one red drum being caught.

Commercial Fishery

Red drum landings in weight for the commercial fishery along the Atlantic coast between 1980 and 1988 have remained fairly constant about an approximate average of 300,000 pounds (Figure 20). Historic commercial data on red drum along the Atlantic coast indicate generally lower catches before 1971 (Pugliese 1989) with increasing landings paralleling an increase in the exvessel price between 1972 and 1980 (Mercer et al. 1987). More detailed information on historic commercial landing of red drum by gear and state can be found in Pugliese (1989; Appendix 2). In the early 1980's commercial landings of red drum were greatest in Florida with North Carolina second in catches. Since 1983, however, North Carolina has dominated the commercial catch of red drum along the Atlantic coast from about 60% of the total in 1983 and climbing steadily to 96% of the total in 1988 (Table 4). North Carolina's commercial fishery for red drum is a bycatch fishery.

Although a variety of commercial gears are in use for red drum along the Atlantic coast; we collapsed the gears into three primary categories which correspond to the bulk of the commercial landings. The gear categories for which we have lenth frequency data for use in this stock assessment are gillnets, pound nets, and hook-and-line. Most red drum caught in the Florida commercial fishery were from gillnets and hook and lines, while the greatest proportion of the commercial catch from North Carolina are from gillnets and pound nets.

Since lengths collected directly from the commercial landings were limited, it was necessary to use data collected from the sampling programs from the various states. In deriving representative length frequency distributions for the predominate gears used in the commercial fishery, data sets from a North Carolina, South Carolina, and Georgia were used. For the hook-and-line category, length frequencies were obtained from red drum caught in hook and line tagging programs in North Carolina, South

Carolina and Georgia. South Carolina and Georgia length frequencies were pooled to represent the area south of North Carolina, while North Carolina's length frequency represented that state and north. These two sets 1986-1988) of length frequencies were normalized to sum to one and combined by weighting with catch in numbers from each region (Figures 10-12). Gillnet length frequencies were available from North Carolina and Georgia, and the two sets of length frequencies (1986-1988) were also combined in the same manner described for lines (Figures 21 and 22). Length frequencies of pound nets were only available from North Carolina (1986-1988) and were used unadjusted (Figure 23). The North Carolina Division of Marine Fisheries leased the use and operation of gillnets and pound nets of commercial fisherman, and is assumed to provide an adequate representation of these commercial gears. Annual length frequencies for the commercial gears by state are presented in Appendix D.

To estimate the numbers of red drum at size in the commercial catch, the mean weight of red drum for each gear and year was determined by converting the mid-point of each length interval to its corresponding weight (weight-length relationship from MRFSS data for 1986-1988 discussed later), and then calculating a weighted mean with weightings based on the corresponding frequencies. The mean weight of fish in pounds from each gear was then divided into the total catch in pounds for that gear to estimate the numbers of red drum caught by gear from 1986 to 1988. Finally, the total catch in numbers for each gear was multiplied by the appropriate normalized length frequency. Figures 24 through 26 show the overall length frequency of red drum caught by all commercial gears along the Atlantic coast. Numbers of red drum caught by age were then estimated by applying the appropriate annual age-length key discussed later.

STOCK CHARACTERIZATION

Aspects of the biology of red drum can be found in the Source Document for the Atlantic Coast red drum Fishery Management Plan (Pugliese 1989). In this section, updated biological information not included in that document is reported along with aspects of red drum biology relevent to the stock assessment.

Distribution, Movement and Life History

The red drum is an estuarine-dependent species of fish which inhabits coastal and oceanic waters and ranges from southwest Florida to Mexico in the Gulf and from Florida to Massachusetts in the Atlantic (Simmons and Breuer 1962). Commercial landing were historically reported as far north as Massachusetts, however, none have been documented north of the Chesapeake Bay since 1950 (Yokel 1980). Management units of red drum include U.S. Atlantic and Gulf of Mexico stocks. The life histories of Gulf and Atlantic stocks of red drum appear to be very similar. The distribution of the adult and sub-adult red drum populations appear to be determined by habitat type, where sub-adult red drum inhabit the shallow coastal estuarine environments and move into the deeper oceanic environment during maturation. The adults are often found in large schools which move inshore and offshore seasonally, while sub-adults remain in the estuaries. Yokel (1966) reported that juvenile red drum exhibit a pronounced seasonal distribution pattern in the Chesapeake Bay and North Carolina, where they move into deeper estuarine waters. Also, sub-adult red drum have been found year round in the Pamlico sound and behind the barrier islands in North Carolina (Ross, pers. comm.). These data suggest that no clear distinction exists between the "inshore" and "offshore" stocks. Terms defining a particular life stage, therefore, will be restricted to "sub-adult" and "adult" stocks, implying no spatial reference, for the purposes of this assessment.

The sub-adult stage is characterized by high rates of growth (Pugliese 1989) and is dependent upon the estuarine habitat for food and refuge from predation. Data from the Chesepeake Bay indicate that juvenile red drum (20-90 mm) may be more restricted to shallow estuarine waters (Mansueti 1960) than larger sub-adults which may be found distributed around river mouths, bays and beaches (Daniel 1988). The movements of sub-adult red drum are thought to be generally restricted. A tagging study of one year old red drum (270-470 mm) in the Pamlico river in North Carolina indicates that there is no extensive movement and that most of the tagged fish remained in the general vicinity of capture (Ross and Stevens 1989). Some tagged fish did, however, move from the immediate vicinity of the estuary to the beaches and surf zones

near the barrier islands. Sub-adult red drum tagged in South Carolina (Wenner, pers. comm.) were shown to move, on the average, only four miles and similar studies in Georgia (Music and Pafford 1984) indicate comparable results with 88.6% of red drum (251-600 mm) tagged travelling a distance less than 25 km. The results of these tagging studies seem to indicate a consistent Atlantic-wide pattern that sub-adults remain in the same estuarine system from larval stage to their third or four year of life and probably do not join the spawning adult stock until sexual maturity. Early maturing sub-adults greater than age three probably move to deep holes or sloughs along the beaches while the fully mature adult stock winters offshore and will probably join the spawning stock the following year.

Adult red drum exhibit significantly slower growth rates and spend less time in estuaries than offshore (Yokel 1966). Large schools of adult red drum have been observed during aerial surveys and by menhaden spotter pilots offshore of North Carolina in April (Pugliese 1989). Red drum greater than 4 years of age (presumably adult) are found along the beaches and offshore waters of Georgia (Music and Pafford 1984). It is thought that adults migrate seasonally, moving inshore and in a northward direction in spring while moving offshore and southward in fall (Yokel 1966). Red drum tagged in Mosquito Lagoon on the east coast and Charlotte Harbor on the west coast of Florida (Murphy and Taylor 1986b) were reported to move south during winter and then back north during the subsequent summer and early fall. Movement patterns of adult red drum are less clear than sub-adults as most of the tagging studies to date have concentrated on younger fish and/or the recovery rates of larger fish are very low. In a recent Florida study, return rates for red drum greater than 650 mm were between 0 and 10% (Murphy and Taylor 1986a). Since 1984, South Carolina's Marine Resources Division has tagged 4961 red drum, most of which were sub-adult. Recovery rates of the 1983 year class (age 5+) were less than 5%. Recreational anglers, participating in North Carolina's tagging program, tagged a number red drum greater than 40 inches (80% > 40"), however, the recapture rates of these fish was very low. Only 11 fish were recaptured, and only 1 showed extensive northward movement (recaptured in Virginia approximately 120 miles from the site of tagging).

Age and Growth

Growth rates of sub-adult red drum (up to age 2) were the greatest among 11 different estuarine species of fish studied in Georgia (Music and Pafford 1984). These high rates are maintained until the onset of maturation (approximately 4 years of age) when there is a significant reduction in the growth rates, presumably because more energy is diverted into gonad production. The von Bertalanffy (1938) growth model has been used extensively to

describe the growth of many marine fishes. This is a three parameter exponential function and is written:

$$LENGTH = LMAX*(1-EXP(-K*(AGE-T0))).$$

Traditional von Bertalanffy growth kinetics, however, may be inadequate to describe the growth of a species which exhibits two very distinct life history stages and attempts at fitting a single curve over all ages of the red drum population in the Gulf was unsatisfactory (Goodyear 1989).

Condrey et al. (1988) proposed a method of fitting a continuous double von Bertalanffy growth curve to red drum in the Gulf using a non-linear iterative least squares approach. We examined the use of this method to describe the growth of the red drum population in the Atlantic and found much better results (reduced the mean squared error for the untransformed data) than with the single curve. Data sets of aged fish were available from Florida Department of Natural Resources, Georgia Department of Natural Resources, South Carolina Wildlife and Marine Resources Division, and North Carolina Division of Marine Fisheries, with the preponderence of fish collected from the 0 through 3 age classes. Scales were used for aging young red drum (ages 0 through 3), while otoliths were used primarily for aging older red drum. To avoid inordinately weighting the regression to the younger size classes we randomly selected 10 fish from each age class and each state and fit these points using PROC NLIN (SAS Institute Inc. 1987). Figure 27 compares the single and double von Bertalanffy fits to these data for 1988 pooled across all states. Its apparent from this figure that L_{max} for the single curve is quickly reached and levels off while the observed lengths still increase with increasing age. The double von Bertalanffy growth curve is able to fit the rapid growth at earlier ages while adequately describing the slower growth in later years and joins them into a continous curve at some transition age (Tx) defined as:

$$Tx = (K2*T2-K1*T1)/(K2-K1)$$

The data less than and greater than the transition age were fit by the appropriate equations using the statement:

```
IF AGE < Tx THEN
   LENGTH=LMAX*(1-EXP(-K1*(AGE-T1)))
ELSE
   LENGTH=LMAX*(1-EXP(-K2*(AGE-T2)))
```

where:

LMAX = The asymptotic length of the average fish in the population.

K1 = Growth rate for fish in the population less than the transition age.

K2 = Growth rate for fish in the population greater than the transition age.
T1 = Theoretical age at which length is 0 for fish less than transition age.
T2 = Theoretical age at which length is 0 for fish greater than transition age.

In this model the transition age (Tx) was computed to be approximately 5 years of age and corresponds to the expected size (approximately 800 mm) of red drum where males are fully mature and females are becoming mature (Murphy and Taylor 1986a). Condrey et al. (1988) reported a transition age of 3.5 for red drum (sexes combined) in the Gulf which is reported to generally coincide with the onset of sexual maturity and emmigration from the estuaries. Using a more comprehensive data set, which included a greater sample of young fish than that reported by Condrey et al. (1988), Goodyear (1989) reported transition ages for males and females of 8.35 years and 9.02 years, respectively, based on a modified double von Bertalanffy equation with two L_{max} parameters. Table 5 compares the double von Bertalanffy growth parameters for red drum in the Gulf of Mexico and the Atlantic. The growth coefficients corresponding to the sub-adult and adult stage of life for red drum in the Atlantic are slightly less than those reported for the Gulf, although the asymptotic lengths are smaller. Direct statistical comparison of L_{max} and K in these fits is confounded since the estimated parameters (L_{max} and K) are typically negatively correlated; i.e., large values of L_{max} are associated with smaller values of K.

We used data from South Carolina for which there were aged samples of males and female red drum and used Hotelling's T^2 multivariate test (Morrison 1967; Chap. 4.3) to examine the possibility of sex-specific growth rates. Contrary to the dimorphic growth observed in the Gulf of Mexico by Beckman et al. (1988), male and female red drum in the Atlantic were not found to exhibit differential growth rates [unable to reject the null hypothesis of no difference in growth, $F_c = 1.68 < 2.60 = F(3,977)$ for $\alpha = 0.05$], and thus an overall growth model was applied to the sexes combined. The double and single von Bertalanffy growth model was fit to the separate data sets from each state and where possible to different years to examine the growth of red drum over time and space. Growth of red drum from the various geographic regions was found to be fairly constant (Figure 28 and 29 for single and double von Bertalanffy curves, respectively) as no statistical differences were found in K and L_{max}. Apparent differences in asymptotic size of red drum probably reflect the inclusion of larger sizes of fish in the North Carolina data set (Table 6). Red drum growth was also compared over time, holding geographic region constant, using the South Carolina data set (Figure 30). The growth coefficient (K) and asymptotic size (L_{max}) was identical for 1986 and 1987 with a slightly lower and greater value of K and L_{max}, respectively, for 1988.

Age-length keys are used in the decomposition of catch in numbers by length category into catch in numbers at age. Using the observed data sets of aged fish from the North Carolina Division of Marine Fisheries, South Carolina Wildlife and Marine Resources Division, and Georgia Department of Natural Resources, age-length keys were developed directly for 1986, 1987, and 1988 (Table 3). The use of a single regional age-length key was intended to be applied to the MRFSS catch data which was itself developed to provide region estimates. Keys were developed annually, rather than to a finer temporal scale, because of the scarcity of older red drum (ages 3 through 5) in the aged data sets. The primary assumptions in using annual coastwide age-length keys concern a constancy in growth across geographic areas and relative uniformity in fishing mortality.

Catches of red drum by age for the recreational (MRFSS and alternate scenario) and the commercial fisheries from 1986 to 1988 were calculated by multiplying length-frequency distributions by age-length keys (Table 7). These data suggest that one and two year old fish are most vulnerable to both the recreational and commercial fisheries. For the recreational fishery 75% of the catch was composed of one year old fish and 95% were fish less than three years of age for each year. Under the alternate scenario a slightly larger fraction of the total catch appears in the ages greater than 3 where 60% of the catch of red drum is one year old and 84% are less than three years old. It appears that fish less than one year are not yet fully recruited into the recreational fishery but the numbers of those caught by anglers still remain high relative to ages 3 and greater. Attention should be drawn to the fact that the age frequencies are only through age 5 in 1987 and to age 6 for the other years and that the terminal ages are truncated to include older fish. As expected under the alternate scenario a fairly sizable number of larger red drum fell into the terminal age class. Thus, these data would suggest that the recreational fishery for red drum is primarily supported by the 0, 1, and 2 year classes or sub-adult fish. Its evident from Table 7, under the assumption that the length frequencies used were representative of the commercial catch, that the commercial fishery also heavily exploits juvenile red drum.

Length-Length/Length-Weight Relationships

In our analysis some of the length data were converted from total length to fork length. Also, fork lengths were converted to weight when calculating mean weight of fish by commercial gear and year, and for calculating spawning stock biomass. Few length-length and length-weight relationships of red drum in the Atlantic are reported in the literature. Murphy and Taylor (1986a) provide functional equations for conversion among fork length, standard

length, and total length from a sample of red drum (ranging from 225-1110 mm) which were captured in Florida waters. Data from South Carolina were also used to estimate the relationship of standard and total length of red drum. Table 8 gives the length-length conversion equations for red drum from all possible sources.

Predicted weights based on lengths of sub-adult red drum were not found to be significantly different between the Gulf and and Atlantic coasts of Florida (Murphy and Taylor 1986a). However, adult red drum on the Gulf coast were reported to be heavier than those on the Atlantic for the same length. Weight-length relations of Florida red drum were not found to be significantly different between the sexes. Only several other weight-length relationships for red drum in the Atlantic have been reported in the literature, from Georgia in 1984 and South Carolina in 1979. More recent relationships have been estimated using data provided by North Carolina, South Carolina, and Georgia. We also estimated the weight-length relationships of red drum sampled in the MRFSS for each year and years combined covered by this analysis (1986-1988). Table 9 gives a review of the published and the more recent unpublished weight-length relationships of red drum in the Atlantic.

Fecundity, Maturity and Sex Ratios

To date, no fecundity information on the Atlantic red drum are available, however a number of reports from the Gulf are and will be discussed here. Red drum are group synchronous, batch spawners in which females reproduce repeatedly over a protracted spawning season (Wallace and Selmon 1981). In general the spawning season for red drum is similar for both the Gulf and Atlantic begining in August and ending in October, although larvae and juvenile collections indicate that spawning along the Atlantic may begin as early as July and continue through December (Pugliese 1989). Holt et al. (1981) concluded that egg hatching and larval survival was most successful at salinities at 30 ppt and water temperatures above 30° C and may account for earlier spawning of higher latitudinal stocks. Recent studies of the reproductive biology of red drum in the Gulf of Mexico by Wilson et al. (1988) estimated an average batch fecundity of 2.64 million ova per spawn and a spawning frequency of 5.2 days (average over 1986-1988). They did not provide information concerning a relationship between length or weight and annual total egg deposition of individual females. The only other study to date which addresses this question in red drum was by Overstreet (1983) who found a linear relationship between the logarithm of the number of oocytes and standard length.

Various maturity schedules have been reported for red drum in the Gulf and more recently in the Atlantic. Based on the histological examination of red drum gonadal tissue, Wilson et al.

(1988) found that the proportion of individuals, from age 3 to 7, exhibiting late stage oocytes increased until age 7 when all females displayed vitellogenesis. Vitellogenesis is an indication of imminent spawn. Wilson et al. (1988) point out that no apparent relationship between sexual maturity and length or weight can be determined from their data. Murphy and Taylor (1986a) used a similar histological method of maturity determination on red drum from the Gulf and Atlantic coast of Florida. Results from this study indicated different maturity schedules for the Atlantic and Gulf stocks of red drum (no statistical test performed), a finding which is consistent with previous investigations suggesting the size or age at first maturity may vary over its geographical range (Pearson 1929; Gunter 1950; Miles 1951; Overstreet 1983; and Music and Pafford 1984). Murphy and Taylor (1986a) also report maturational differences between the sexes for both coasts. They found male and female red drum on the Gulf to mature at smaller sizes than on the Atlantic where the L_{100}, size at which 100 percent are mature, was 749 and 899 mm for the males and females, respectively. On the Atlantic, maturity is delayed in both male and female red drum until they reach 849 and 949 mm, respectively. However, very few fish were involved that exceeded 849 mm in fork length. Additional maturity information of red drum sampled in South Carolina was made available by C. Wenner using a histological method developed in their laboratory (Wenner et al. 1986). Ovarian tissues, which displayed cortical alveoli-vitellogenic stages of development and greater, were considered likely to spawn (Roumillat, pers. comm.). This method is consistent with the maturity criterion established by Murphy and Taylor (1986a). Although samples of larger fish are limited from both Florida and South Carolina, these data suggest that female red drum sampled in South Carolina were found to become fully mature (L_{100}) at an earlier age than those sampled on Florida's Atlantic coast. Figure 31 shows the proportion of females mature by age from Florida and South Carolina. We employ each maturity schedule separately (as a function of age) to investigate the consequence of these different schedules in the fecundity-based spawning stock ratio model presented later. It should be noted that maturational stages were determined for females only up to age three from South Carolina, and ages four and greater were assumed to be fully mature. This assumption was based on the relative proportionate increase in maturity between ages 2 and 3 where 14 and 69 percent, respectively, of the females sampled were found to be mature.

The proportion of females at age [2 (0.52), and 3+ (0.61)] were estimated from South Carolina data. These values were used in preference to the naive assumption of 0.50 because there is an apparent trend in the South Carolina data indicating increasing proportion of females with age. Sample sizes declined rapidly after age 3 resulting in widely varying estimates of proportion female for age 4 and greater.

NATURAL AND FISHING MORTALITY

Local Total Mortality (Z)

The total mortality from all causes on a fish population is probably most easily understood as the annual expectation of death of an individual fish which is expressed as the proportion of fish present at the beginning of the year and those that actually die during the year. The annual (or seasonal) mortality rate (A) is related to survival (S) where:

$$(1-A) = S = N_t/N_0 = e^{-zt}.$$

The proportion N_t/N_0 express the number alive at the end of the year (fishing season) to the number alive at the start of that year and can ultimately be expressed as the instantaneous rate e^{-z}. In assessments of fish populations, the instantaneous rate of total mortality (Z) is typically expressed on an annual basis and is equal to minus the natural logarithm of survival (S). The total instantaneous rate of mortality can be partitioned into a components due to natural deaths (M) and deaths through fishing (F) and expressed as:

$$Z = F + M.$$

Estimates of Z are most often obtained using a catch curve analysis where the natural logrithm of the catch is regressed against age for the ages beyond full recruitment (Ricker 1975). Bias can be introduced if fish are not sampled randomly from the population (i.e., sampled in relation to their actual abundance) or recruitment and mortality is not constant from year to year. Estimates of Z were obtained using catch curve analysis on red drum sampled from specific state-supplied data sets such as trammel nets in Georgia, stopnets in South Carolina, and from the MRFSS data set. The length frequencies of red drum captured in stop nets (Figure 32) and trammel nets (Figure 33) are given by year in Appendix E. The length frequency distribution from South Carolina's stopnet samples appear to capture mostly age 1 and 2 red drum, while Georgia's trammel nets are bimodal where each mode roughly corresponds to ages 1 and 2 red drum. These data would seem to indicate that larger (older) fish are either reduced in number due to high inshore mortality or unavailable to capture by the gear. Obviously, this may introduce a source of bias when estimating total mortality, in which case the instantaneuos rate of mortality is the sum of natural (M), fishing (F), and losses due to emmigration or reduced availability (E), i.e,

$$Z' = F + M + E.$$

Total rates of mortality from these data sets were considered to

estimate "local Z's" as the data were specific to the local estuaries in which fish were captured. However, its uncertain as to whether the rates of instantaneous total mortality derived from these data represent Z or Z'. Estimates of Z (or Z') from the Georgia and South Carolina data sets are given in Table 10 along with other estimates for Atlantic red drum from other sources. Rates of total mortality were also estimated from the catch curves from the MRFSS and alternate data and are considered to give coast-wide estimates of Z. Further, a coastwide estimate of Z was obtained using a cohort-based catch curve analysis which circumvented the use of equilibrium assumptions in the estimation procedure (1985 cohort). More details on the cohort-based estimates are given in the following section. Rates of the instantaneous total mortality range from a low of 0.81 to a high of 2.10. Estimates of Z from catch curve analysis tend to be on the high end of the range and may reflect losses due to emmigration or reduced availability as well as deaths (Z').

Fishing and Natural Mortality

The instantaneous rate of fishing mortality was estimated by several methods. The difference between Z and M, where natural mortality was estimated from Pauly's (1979) equation, would yield an estimate of the fishing mortality (F). Pauly's equation estimates M from the von Bertalanffy growth parameters (L_{max} and K) and the average annual water temperature. We estimated natural mortality for the subadults and the adults using K_1 and K_2, respectively, from the double von Bertalanffy growth model and average annual water temperatures recorded in South Carolina (Mathews and Shealy 1978). Estimates of the instantaneous rate of natural mortality for the subadults and adults were 0.44 and 0.13, respectively, and are given in Table 10 along with the corresponding estimates of F. The estimate of natural mortality for the subadults is certainly reasonable with respect to values from other sources, and a similar estimate for the adults was obtained from purse seine catches in the Gulf (Goodyear 1989).

Estimates of the instantaneous rate of fishing were also obtained using mark-recapture studies in Georgia and South Carolina. Red drum (mostly subadult) were marked throughout the fishing season with most recoveries occurring during the same fishing year which may suggest high exploitation rates on the sub-adults. Another possibility is a type C systematic error where marked fish are not allowed adequate time to mix with the general population and become differentially vulnerable. Ricker (1975, eqs. 4.13 and 4.14) prescribes of method for computing F and the exploitation rate (u) when marking of fish is done throughout the fishing season and most recoveries are obtained the year of marking and one following. It was neccessary to adjust the equation for tag loss and for non-reported marked fish. The effect of tag loss

is to overestimate natural mortality (M), when M is calculated from the difference of Z and F. Wenner (pers. comm.) estimates about 5% tag loss and mortality based on double tagging during the first 3 years of their study. Also, post-hooking mortality studies indicate 5 percent of red drum caught died subsequent to release (Pafford, pers. comm.). Matlock (1981) estimated a non-reporting rate of 72 percent for Texas anglers (for creel fish), however, we used a non-reporting rate of 50 percent which was consistent with Georgia (Woodward, pers. comm.). The equation used to estimate the instantaneous fishing mortality rate requires an estimate of total mortality (Z from both the MRFSS and alternate cohort-based catch curves). The average estimated fishing mortality rates for the first year after tagging of recreational caught red drum varied from 0.82 for the alternate scenario to 0.88 for the MRFSS scenario based on the first three ages (Table 10). Additional estimates of M are obtained from the difference of Z and F, but are considerably larger than those obtained from Pauly's (1979) equation (0.83 for the alternate scenario to 0.93 for the MRFSS scenario).

Estimates of Z were also obtained from trammel net catches in Mosquito Lagoon on the east coast of Florida for fished (Z = 1.69) and unfished (Z = 0.87 = M?) areas. It is probably questionable whether Z from the unfished area in the Mosquito Lagoon data set truly represents only natural mortality. Length frequencies for these two areas are presented in Figures 34 and 35. Tilmant et al. (1989) derived an estimate of Z for sub-adults equal to 1.87 from a VPA approach applied to data collected in Everglades National Park.

Whether red drum in the Atlantic emigrate from an estuarine habitat at the onset of maturity to join the spawning stock offshore as in the Gulf or whether fish of mature age simply become less vulnerable to the fishery is not clear. Nor is it clear at which age red drum begin to move offshore if they do emigrate or what the rates of emmigration might be. Because of these uncertainties, it is difficult to ascertain if declining numbers of red drum are truely due to deaths or if emmigration is also contributing.

Coastwide Total Mortality (Z)

To estimate total coastwide mortality, it is first necessary to obtain the catch curve (catch in numbers at age) representative of the entire Atlantic coast red drum fishery. We combine the different components of the Atlantic coast fishery for fishing years 1986 through 1988. As discussed earlier, two different scenarios are used to describe the recreational component. One scenario is based on the MRFSS data base and the other combines data from North Carolina, South Carolina and Georgia tagging length-frequency data for hook-and-line in proportion to their

recreational catches. Three commercial components (collapsed gear types: gillnets, pound nets, and hook-and-line) are also combined as described earlier. Catch in numbers at age by component and totalled for the two scenarios are presented in Table 7.

In this section total mortality is estimated in several ways. First, coastwide total mortality (Z) can be estimated by traditional catch curve analysis by regressing the natural logarithm of the catch curve against presumably fully recruited and available ages. We have applied this separately for fishing years 1986 through 1988 for ages 1-5 (Z ranges from 2.5 to 3.4 from MRFSS scenario and 1.6 to 1.9 for alternate scenario) and for ages 1-3 (Z ranges from 1.8 to 2.4 for MRFSS scenario and 1.6 for alternate scenario). The latter range through age 3 is intended to reduce the effect of potential decreasing availability of red drum for ages 4 and 5 due to movement offshore or other behavioral changes that might reduce their availability to the Atlantic coast fishery. The VPA is applied annually to capture some of the variability in resultant estimates of fishing mortality and population abundance estimates.

We also applied catch curve analysis to the 1985 cohort (i.e., those red drum spawned in 1985) that were age 1 in 1986, age 2 in 1987, and age 3 in 1988. Estimated Z for this approach ranged from 1.81 for the MRFSS scenario to 1.65 for the alternate scenario (Table 10). Estimating Z from the slope of the catch curve for a fishing year assumes equilibrium recruitment and mortality for the time period represented by the ages in the catch curve. This assumption is unnecessary when estimating Z from cohort data. We believe these estimates of Z are the best we have available for our coastwide or population-level analyses that follow. No data is available for directly estimating Z for older fish (age 6 and older).

Virtual Population Analysis

Application of virtual population analysis (VPA) to either the 1985 cohort or the 1986 through 1988 fishing years (with the same equilibrium assumptions required by catch curve analysis) can permit best available estimates of both age-specific population size and fishing mortality rates that cover the geographic range of our data (east coast of Florida to Maryland). We apply the VPA technique only to the sub-adult population (ages 0-5) and not to the adult population (ages greater than age 5) since no reliable data base is currently available indicating what the exploitation may be on these older fish. The VPA technique (Murphy 1965, Tomlinson 1970) requires independent estimates of natural mortality (on sub-adults) and a starting value of a particular age-specific fishing mortality rate.

Application of virtual population analysis requires adequate estimates of catch in numbers at age. This depends primarily on the adequacy of our length frequency distributions and age length keys. If in aggregate the length frequency distributions do not represent the length structure of the Atlantic coast red drum catch, then resultant estimates of population size and fishing mortality will be in error. Likewise, if our age-length key is inadequate, then resultant estimates of population size and fishing mortality will be biased. If natural mortality is overestimated, then age-specific fishing mortality will be underestimated or vice versa. Because of the limited number of ages and years in our assessment, a poor selection of a starting F will result in significant error carried through to estimates at earlier ages and/or years.

In our analyses we use Z based on the catch curve analysis applied to the 1985 cohort (MRFSS: Z=1.81, alternate: Z=1.65). We use M for subadults based on Pauly (1979) for one set of VPA runs (M = 0.44), and M calculated from the difference between Z and F estimated from the South Carolina tagging study (M for MRFSS = 1.81 - 0.88 = 0.93; and M for alternate = 1.65 - 0.82 = 0.83) for a second set of VPA runs. These sets of VPA runs are intended to represent the extremes in estimates of subadult natural mortality (M), although we feel that M on the order of 0.93 or even 0.83 are probably unreasonably high even for ages 1 through 5. A further set of VPA runs was made with low values of subadult M and F for the MRFSS and alternate scenarios (M = 0.44; and F = 0.88 and 0.82 for the two scenarios, respectively). Since red drum are not fully recruited until at least age 1, red drum in their first year of life (age 0) are assumed to be of 6 to 12 months of age so that half the natural mortality is applied for the half year in the virtual population analysis.

The VPA was run as a backward calculation from catches for ages 3 back through 0, and as a forward calculation from catches for ages 3 through 5. Since no catches of age 5 red drum were estimated in 1987 (hence the use of 5+ age group instead of 6+), F for age 5 is set to 0 for all VPA's for that year. If for some reason, our F is a poor choice for age 3, then some convergence is expected for our age-specific estimates for ages 0 through 2 (especially the earlier ages). No such convergence can be expected from the forward calculated VPA; in fact, divergence would be expected. In summarizing age-specific estimates for population sizes and fishing mortality rates and for use in later population analyses, estimates based on the 1985 cohort are given preference over estimates based on annual data (1986-1988). Hence, estimates for ages 1 through 3 are taken from VPA's applied to the 1985 cohort data, and estimates for ages 0 and 4-5 are taken from VPA's applied to 1986 through 1988 fishing year data.

For the MRFSS scenario (Table 11), estimated fishing mortality (F) for age 0 red drum ranged from 0.09 to 0.14 with a mean of 0.12

across the three sets of M and F. Similarly, F ranges from 0.91 to 1.42 with a mean of 1.23 for age 1; 0.83 to 1.31 with a mean of 1.09 for age 2; 0.88 to 1.37 with a mean of 1.04 for age 3; 0.07 to 0.15 with a mean of 0.11 for age 4; and 0.0 for age 5. It should be noted that for the 1986 VPA runs with MRFSS F for age 5 diverged to 10.0, while 0.0 was obtained for 1987 and 1988. Estimates of fishing mortality for ages 4 and 5 from the MRFSS scenario tend to support the idea that red drum aged 3 and older become less available to the fishery. Since the MRFSS scenario was intended to represent one extreme (few catches of old fish), mean F for age 5 was based on just 1987 and 1988 VPA runs. In general, higher estimates of F were obtained when M was low and vice versa, and intermediate estimates of F were obtained when both low values of M and F were used. However, for age 5, low M-high starting F produced the smallest estimate of F; while low M-low starting F produced the highest estimate of F. When comparing across years (1986-1988), no simple pattern emerges. Estimates of F from 1986 are highest for ages 0 through 2 and anomalously high for age 5, and lowest for age 4; while estimates of F from 1987 are lowest for age 1 and age 5, and estimates of F from 1988 are lowest for ages 0 and 2 and highest for age 4.

For the alternate scenario (Table 12), estimated fishing mortality (F) for age 0 red drum ranged from 0.13 to 0.21 with a mean of 0.18 across the three sets of M and F. Similarly, F ranges from 0.96 to 1.44 with a mean of 1.25 for age 1; 0.57 to 0.89 with a mean of 0.74 for age 2; 0.82 to 1.21 with a mean of 0.95 for age 3; 0.30 to 0.66 with a mean of 0.48 for age 4; and 0.09 to 0.31 with a mean of 0.23 for age 5. Again, estimates of fishing mortality for ages 4 and 5 from the alternate scenario tend to support the idea that these fish older than age 3 become less available to the fishery. Further, similar patterns in estimated F are obtained for the alternate scenario when comparing across M and F mixtures in the different VPA runs; that is, highest estimates of F were obtained for low M-high starting F. When compared across years (1986-1988), again no simple pattern emerges. Estimates of F from 1987 data are highest for ages 0 and 1 and lowest for ages 4 and 5; while estimates of F from 1986 are lowest for age 1 and highest for age 5, and estimates of F from 1988 are lowest for age 0 and highest for age 4.

Population estimates for MRFSS scenario (Table 13) start with about 1.5 million recruits to age 0.5 (ranging from 1.3 to 1.9 million), and continue with about 1.1 million age 1 red drum (0.9-1.4 million), 171 thousand age 2 (140-220 thousand), 31 thousand age 3 (24-38 thousand), 18 thousand age 4 (13-22 thousand), and 12 thousand age 5 (9-14 thousand). When applying a natural mortality rate of M = 0.13 (based on Pauly's equation using K2 from our double von Bertalanffy equation), we estimate a population size of age 6 and older (taken out to age 60) of about 61.2 thousand fish if the current level of fishing mortality were to remain for the next 50 to 60 years. This estimated population size compares to

estimates ranging from 3.7 to 15.1 thousand fish caught in this age category for years 1986 through 1988, indicating exploitation rates ranging from 6% to 25%.

Population estimates for alternate scenario (Table 13) start with about 1.4 million recruits to age 0.5 (ranging from 1.2 to 1.6 million), and continues with about 0.9 million age 1 red drum (0.8-1.2 million), 154 thousand age 2 (124-192 thousand), 40 thousand age 3 (32-47 thousand), 16 thousand age 4 (11-19 thousand), and 9 thousand age 5 (5-11 thousand). Again applying a natural mortality rate of M = 0.13, we estimate a population size of age 6 and older (taken out to age 60) of about 35.7 thousand fish if the current level of fishing mortality were to remain for the next 50 to 60 years. This estimated population size compares to estimates ranging from 43.5 to 133.3 thousand fish caught in this age category for years 1986 through 1988. Based on the assumption of equilibrium conditions, this translates into an apparent exploitation rate exceeding 100%. It is unlikely that the assumption of equilibrium conditions is valid for the adult population, because the recent high mortality on sub-adults would not yet have time to filter through to age-specific population sizes for these older ages (assuming high Z's concurrent with increased recreational catches during the early 1980's). This would seem to indicate that if as many older red drum are caught as the alternate scenario suggests, then current escapement is far from adequate to replenish the adult spawning stock. In summary, we are unable to estimate the true exploitation rate of the adult stock under either scenario, but recent exploitation rates on sub-adults may result in inadequate escapement to the adult stock.

POPULATION MODELS

Several population modelling approaches are now applied to the results of the virtual population analysis as applied to the sub-adult stock (ages 0-5). These include a Ricker yield per recruit analysis to address the question of growth overfishing, or whether greater yields can be obtained from the stock if fishing is delayed on younger fish so as to benefit from their growth in weight. Spawning stock ratios based on both female biomass and egg production are investigated in the light of the SAFMC goal of 20%. This approach is used to address the question of recruitment overfishing. In particular, it attempts to determine whether sufficient spawning stock is present to support the continuing viability of the coastwide stock. Potential benefits from minimum and maximum size limits and bag limits are reviewed based on the MRFSS data base.

Caveats and sources of error in estimating parameters of growth, mortality, and reproduction must be kept in mind during the application of yield per recruit analysis and estimating spawning stock ratio. To the extent that the above estimated parameters accurately reflect the underlying processes, the results of these population models are reasonable and produce useful information. But because of the sparseness of much of the data for which many assumptions had to be made to complete this assessment, one has to be careful about judgements derived from them. They are intended as best available estimates and are supportive of the results obtained from many of the individual states (e.g., North Carolina, South Carolina, and Georgia).

Yield Per Recruit Analysis

As stated above, yield per recruit analyis is used to investigate concerns about growth overfishing. The population structure changes in terms of the relative abundance of different age classes with increasing total mortality Z. As Z increases (primarily due to fishing mortality), the contribution of older fish to the stock declines in both numbers and biomass.

When following a cohort (those born in the same year) through time [$N_{t+1} = \exp(-Z_t)*N_t$], there is a decline in numbers at age (Figures 36 and 37 where Z formed from combined age-specific F in Tables 11 and 12), but a different pattern for cohort biomass at age occurs ($B_t = W_t*N_t$) (Figures 38 and 39). For an unfished population ($F_t = 0$ for all t), there is usually an increase in cohort biomass with age to some maximum, followed by a decline.

We examine the impact of current fishing levels (age-specific Z range from about 1.2 to 1.7) on the population structure (in

terms of numbers and biomass). Fishing mortality on subadult red drum apparently has been so great as to cause the age at maximum cohort biomass to occur at age 1 (age 0 was not included) (Figures 36 through 39).

The trade off between decreasing numbers and increasing biomass per average individual forms conceptually the basis for the yield per recruit analysis. In this assessment, we use the Ricker (1975; eq. 10.4) formulation for yield per recruit which allows for age-specific estimates of size and fishing mortality. This formulation was written in the SAS program language (SAS Institute Inc. 1987) so as to permit ease of graphing the results.

Some implicit assumptions in applying the Ricker yield per recruit model include (Vaughan et al. 1984): (1) Estimates of natural and fishing mortality are accurate representations for the time periods to which they are applied, (2) these mortality estimates are independent of population density, (3) the double von Bertalanffy growth function accurately describes individual growth during the exploited phase (sub-adult), (4) recruitment occurs instantaneously on the same date each year, and (5) there is no appreciable net migration. Furthermore, the population processes represented by the yield per recruit model are stochastic and the input parameters under the best of conditions are point estimates with some associated uncertainty. Typically, uncertainty exists in any set of input parameters; however, this uncertainty in input parameters is augmented by additional uncertainty due to the sparseness of our data base, which will result in greater uncertainty in the model predictions. Uncertainty arises from lack of precision (variability about a point estimate), lack of accuracy (or bias in a point estimate), and application of an inappropriate model. Restrepo and Fox (1988) note that "due to the nonlinearity in yield-per-recruit models, the input of apparently extreme parameter values does not necessarily result in extreme outcome ranges." They present a Monte Carlo-based method for incorporating parameter uncertainty into a Beverton and Holt formulation of yield per recruit. However, since the form that much of the uncertainty in our application of yield per recruit is itself unknown (especially with respect to potential bias), we attempt to use the most reasonable parameters estimates, and in some cases ranges of estimates, that are available in the model runs that follow.

Separate runs of the Ricker yield per recruit analysis were made for each of the scenarios (MRFSS and alternate) with combined mean age-specific F's (Tables 11 and 12, respectively, for ages 5 and younger), natural mortality of $M = 0.44$ for red drum ages 5 and younger, and $M = 0.13$ for red drum ages 6 and older. If M for subadults is high (true $M < 0.44$), then F for at least ages 1-3 is correspondingly low. Hence, yield per recruit would be underestimated. The converse is the case if M for subadults is low ($M > 0.44$), and yield per recruit is overestimated. Yield per recruit is not affected by errors in M for adults (ages 6 and

older), because F is set to 0 for these ages (no adequate data base exists for estimating the actual existing fishing mortality rate for this age group). If F for adults is greater than 0, then yield per recruit would be higher. Yield on a per recruit basis is calculated for different levels of age at entry and fishing mortality (Figure 40 and 41). Age at entry indicates the earliest age at which red drum are susceptible to the gear and are retained. Since fishing mortality is age-specific, yield per recruit is calculated on the basis of multiples of F (e.g., 1.0 times the F vector would indicate current conditions).

Contour plots for the two scenarios are presented for age at entry varying from 0 to 5 years of age and for multiple of F varying from 0.2 to 3.0. In both scenarios, maximum yield per recruit occurs at an age at entry of 3 years and at a multiple F of 3.0 (maximum used in plots). At recent estimated conditions (age at entry of 0 and F multiple of 1), yield per recruit estimates are on the order of about 460 to 470 g (MRFSS: 469 g, or 46% of maximum; alternate: 462 g, 44% of maximum). Contour plots for both scenarios (which indicate lines of equal proportion of maximum yield per recruit) suggest that greater yield is attainable either by decreasing fishing mortality to 50 or 60% of the current level or by increasing the age at entry of red drum (through for instance minimum size limits) to about age 2. In particular the MRFSS scenario suggests a gain in equilibrium yield per recruit of about 9% by decreasing the multiple F by 60% or a gain of about 68% by raising the age at entry to 2 years (doing both will lead to a gain of only about 44%). Similarly the alternative scenario suggests a gain in equilibrium yield per recruit of about 13% by decreasing the multiple F by 55% or a gain of about 82% by raising the age at entry to 2 years. A red drum just entering age 2 is approximately 530 mm or 21 inches long (total length).

Spawning Stock Ratios

In this analysis, spawning stock ratio is calculated in two ways. The first method follows that of Gabriel et al. (1984) which accumulates spawning stock or female biomass across all ages. We calculate female biomass (B_t) at age from the following equation:

$$B_t = N_t * S_t * W_t * M_t,$$

where N_t = cohort numbers at age t, S_t = proportion of females, W_t = mean weight females of age t, and M_t = proportion females mature at age t (maturity schedule). Since we did not find sexual dimorphism in growth the equations actually used for growth in length and weight were developed from both sexes combined.

The second method which computes the reproductive output with

age follows conceptually that of Goodyear (1989). However, we calculate egg production (E_t) at age from the following equation:

$$E_t = B_t * F(L_t),$$

where B_t = female biomass at age t, L_t = length of females at age t, and $F(\cdot)$ = egg production as a function of female length (Overstreet 1983). Egg production (or fecundity) at age shows a similar pattern to cohort biomass in that there is usually a peak at some intermediate age. Shifts in fecundity with increasing fishing mortality depend to a large extent on the timing of fishing compared to the onset of female maturity. When we use the South Carolina maturity schedule (Figure 31), fishing mortality (full on ages 1-3 and declining on ages 4 and 5) overlap the onset of maturity (ages 2-4), resulting in a shift in age of maximum egg production from age 4 to age 3 (both MRFSS and alternate scenario, Figures 42 and 43). With the Florida maturity schedule (Figure 31), there is very little effect on the relative contribution of different age classes because of the slight overlap in age between fishing mortality (full on ages 1-3 and declining on ages 4 and 5) and the Florida maturity schedule (increasing for ages 4 through 6) (see Figures 44 and 45). Be aware though that although there may be no shift in relative egg contribution, there will be an overall decline in egg production as Z is increased.

As with the yield per recruit analysis, natural mortality is assumed to be 0.44 for subadults and 0.13 for adults. If either of these are high, then so is estimated spawning stock ratio. The converse is true if our estimates of natural mortality are low. We also assume that F for adults is 0 (no estimates available). This assumption causes our estimates of spawning stock ratio to be high. In general we believe that the above assumptions err in the direction of overestimating spawning stock ratio.

The assumptions described in the yield per recruit section apply here as well. In addition, assumptions as to the validity of sex ratios, maturity schedules and fecundity estimates are needed. How uncertainty in the input parameters are expressed in the model output have not been described in the literature. Results of computer runs, which bracket some of the uncertainty in certain input parameters (e. g., maturity schedule and fishing mortality), are intended to partially address these questions.

In either method, population size in numbers are generated first under the assumption that F = 0 for all ages and in parallel using age specific estimates of F from the virtual population analyses (Tables 11 and 12). Contour plots for different values of age at entry (0 to 5) and multiple F (0.2 to 3.0) are presented separately for mean conditions of the MRFSS and alternate scenarios each with different maturity schedules (South Carolina and Florida). Little difference in estimated ratios is noted between the two methods (Figures 46-49 for biomass and Figures 50-53 for

fecundity), between the two scenarios, or even between the maturity schedules. In all cases estimates of spawning stock ratio for current (1986-1988) conditions range from 2% to 3% which is well below the South Atlantic Fishery Management Council's goal of 20%.

A limited set of simulations (without stochastic error) were made to compare time to attain 20% spawning stock ratio for different levels of reduced F. The purpose of these computer runs was to compare return times among different assumptions of reduced F, and not to obtain absolute estimates of return time. Separate computer runs were made based on the MRFSS and alternate scenarios, but both used the South Carolina maturity schedule. Although this is the more recent estimate, it would tend to decrease the estimated time to attaining the 20% goal, because spawning begins at a younger age (14% at age 2 instead of 25% at age 4 for the Florida maturity schedule). Because both indices of spawning stock ratio were similar, we used only that based on egg production in these simulations. Natural mortality for sub-adults was set at 0.44, and for adults at 0.13. Fishing mortality were from the mean values used in the above spawning stock ratio estimates. Starting population sizes for fished and unfished stocks were based on equilibrium conditions with a recruitment to age 0.5 of 1,000,000. Constant recruitment to age 0.5 was assumed for these simulations. When F was reduced by 90% (multiple F of 0.1) then 3 years were required to exceed the 20% goal; for 80% (multiple F of 0.2) then 4 years for MRFSS and 3 years for alternate scenario; and for 70% (multiple F of 0.3) then 5 years for MRFSS and 4 years for alternate. Since the population age structure was reduced to 12 years for the sake of these simulations, the significance of these results is only in how they compare either between the two scenarios or with increasing multiple F, and **not** in the absolute values presented. Reducing the population to 12 age classes will tend to increase the estimated spawning stock ratio, although this effect may be relatively small because only natural adult mortality (0.13) is applied to both the fished and unfished populations for ages 13 and older that are not included in these projections.

Potential Benefits from Management Options

An evaluation of several management options was requested by the SAFMC. Thus, an analysis was made of the MRFSS data base (1979-1988) to explore what proportion of the recreational catch would have been protected annually if a minimum size limit (12 to 20 inches) or a maximum size limit (25 to 32 inches) were institute (Table 14). Of course, most coastal Atlantic states have recently instituted a minimum size limit and a combination of bag limit combined with a maximum size (Pugliese 1989). Most of these size limits were instituted in 1986 and 1987. Between 1979 and 1985 a minimum size limit of 12 inches would have protected from 19% to 38% of the recreational catch (assuming the reliability of the

MRFSS data base and no release mortality), while a minimum size limit of 14 inches would have protected from 40% to 66% of the recreational catch. Gains in a 12 inch minimum size limit declined beginning from 10% in 1986 to 4% in 1988, presumably due to the states instituting minimum size limits. Note that 76% to 95% of the recreational catch was under 20 inches according to the MRFSS data base. Fairly substantial reductions in F on the youngest fish are potentially available, and an increase in yield to the fishery is likely. At the same time, this management approach can begin to reduce some of the excess fishing pressure that is apparently occurring on sub-adult red drum.

From a maximum size limit perspective 2% to 11% of the recreational catch exceeded 25 inches or approximately 2 years of age. Six year old red drum are approximately 38 inches long and are partially protected by the current 1 to 2 fish bag limit of fish caught over 32 inches that most South Atlantic states have in place. As indicated by the MRFSS data base, an actual maximum size limit of 32 inches would protect from 0.1% to 4% of the recreational catch. Data supplied by North Carolina (Ross, pers. comm.) indicate considerably greater gains likely from a maximum size limit than does the MRFSS data. Although maximum size limits show much less potential reduction in F than minimum size limits, they do protect those fish that have managed to survive to maturity.

Potential benefits from bag limits were also investigated using the MRFSS data base for years 1979-1988 (Table 15). First, the total number of fish caught by all anglers surveyed was calculated (N_2). Next, the total number of fish caught per angler is summed after setting any in excess of the bag limit to the bag limit value (N_1). The ratio of the latter to the former gives the proportion of red drum that would have been caught if the bag limit had been in place. One minus this ratio is the proportion of red drum potentially protected by the bag limit. How to relate the effect of a bag limit to reductions in fishing mortality is much less clear. The number of red drum caught per angler-trip is related to the population abundance at that time. As population abundance increases, the effectiveness of bag limits increase. However, as population abundance decreases, the effectiveness of bag limits decrease. The effectiveness of bag limits can not be assessed once in place without an independent data source that is unaffected by the bag limit. Furthermore, one cannot assume that the proportion protected by the bag limit can be simply multiplied by the age-specific estimated F's, because angler's are likely to retain the larger red drum while they catch and release (alive or dead) smaller red drum. Thus, most of any reduction in F is likely to occur for the younger ages and less on the older aged red drum.

RESEARCH NEEDS

The SAFMC intends that a stock assessment be conducted on the red drum population in the Atlantic annually for the next three years. If so, updated biological information and fishery data will be necessary to adequately build on the data and analyses presented. The purpose of this section is to summarize the data needed to strengthen the analyses presented in this document and to permit future analyses that current data do not allow.

Relevant biological information required for future stock assessment activities fall in the following categories: Movements/availability, maturity/fecundity, natural mortality, and recruitment. Research in the area of movements and availability should focus on the apparent disappearance of maturing (ages 3-5) red drum. Estimates of total mortality (Z) reported here and from other studies may be biased by such movements or reduced availability; and if so, need to be corrected. Furthermore, difficulties in conducting the virtual population analyses stemmed (on a single cohort and three fishing years) from having to run both backward and forward VPA's from age 3 (forward VPA's tend to diverge from true values) to estimate fishing mortality on ages 4 and 5. More tagging of ages 3-5 year old red drum may be needed with effort directed at recapturing fish from the sub-adult and adult populations to assess whether their disappearance is due to offshore emigration (and if so, then what are these rates) or reduced availability.

Two schedules of maturity were used in this assessment for which there were significant differences, thus more research is needed to reconcile these differences. The earlier (Florida: 1981-1983) schedule for females indicated the onset of maturity beginning with age 4 (25%) and complete maturity by age 6, while the more recent (South Carolina: 1985-1988; through age 3) indicated an earlier onset of maturity beginning with age 2 (14%) and presumed complete maturity by age 4 (no South Carolina samples were age 4 or greater). Greater sample sizes of older females (ages 4 and greater) are needed to increase precision for developing a more reliable maturity schedule for population-level analyses. Also, no relationship between annual egg production and female size (length or weight) was available for Atlantic red drum for this analysis, hence research in this area is needed.

In this report, estimates of natural mortality (M) for adults were obtained by indirect means (i.e., Pauly's equation was applied to the adult part of the double von Bertalanffy growth equation). More reliable estimates of natural mortality for the adult red drum population are needed, and might be obtained by better sampling of the adult population, since there is no "significant" directed fishery on the adult stock. Improved estimates of M for sub-adults can be obtained through continued tagging efforts and standardized

sampling. Again, separating Z from Z' for ages 3 through 5 will continue to be a problem.

Continued standardized sampling of sub-adults is also needed to develop long-term indices of recruitment. This is necessary to permit short-term warning of potential recruitment failure that otherwise could result in a collapse of the stock. When a collapse occurs, it may show up in the catch or other fishery statistics too late or take too long for a recovery to take place.

Improvements in catch, effort, and length frequency statistics from both the recreational and commercial fisheries are needed. Two scenarios for the recreational component were required because of potential bias in the sampling conducted with red drum fishermen. Concern was expressed that large fish were under-represented in the MRFSS sampling because fishermen seeking large red drum tended to fish through the night and not in the daylight hours when most sampling occurs (Ross, pers. comm.). Also, we had to restrict this assessment to fishing years 1986 through 1988 because of the lack of length frequency data from earlier years (primarily from the commercial fishery). Even the use of 1986 through 1988 data required extensive assumptions such as using gill net length frequencies from Georgia for the entire Atlantic coast for 1986, and pound net length frequencies from North Carolina for the "pound net" category that included some haul seine catches. If it is necessary for these assessments to be above reproach, then **all** significant sources of catches must have at least parallel length frequencies by gear and year. Further, greater sample sizes are needed to develop annual age-length keys. These data can also be used to improve estimates of growth equations for testing differences of growth among geographic areas, a major assumption in using a single coastwide age-length key for each year.

For a more complete VPA to be conducted (that is, by cohort), catches in age at numbers from more cohorts are needed. Only more years of adequate data will solve this problem. Preferably at least as many years as ages of interest are needed to conduct a reliable virtual population analysis so that reasonable confidence can be placed in the subsequent population and fishing mortality estimates.

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Table 1.

Red drum landings for recreational and commercial fisheries, 1980-1988. Recreational landings in numbers and weight. Commercial landings in weight. Total Atlantic landings also in weight.

YEAR	RECREATIONAL[a] NUMBERS A+B1	NUMBERS B2	WEIGHT A+B1 (1000 LBS)	COMMERCIAL WEIGHT (1000 LBS)	TOTAL WEIGHT (1000 LBS)
1980	269.8	147.0	679.2	439.9	1119.1
1981	186.1	14.3	627.1	353.1	980.2
1982	388.6	17.7	678.3	195.3	873.6
1983	635.0	73.0	1051.5	330.2	1381.7
1984	1068.6	64.0	2164.1	422.1	2586.2
1985	1109.7	437.4	2101.7	249.1	2350.8
1986	428.6	181.8	1741.4	341.9	2083.3
1987	738.0	763.7	1537.5	312.3	1849.8
1988	592.6	707.8	1670.2	228.7	1898.9

[a] Numbers in thousands and Weight in thousands of pounds.
Definitions of catch type (U.S. NMFS 1987):
A = catch available for identification,
B = catch not available for identification,
B1 = used for bait, filleted, discarded dead, etc.,
B2 = released alive.

Table 2.

Recreational catch in weight (1000 lbs.) by mode of fishing and area fished, 1980-1988.

YEAR	MODE[a] BEACH WGT	%	BOAT WGT	%
1980	340.3	50	338.9	50
1981	94.5	15	532.7	85
1982	164.0	24	514.3	76
1983	307.8	29	743.7	71
1984	792.7	37	1371.4	63
1985	1005.4	48	1096.3	52
1986	113.5	7	1627.9	93
1987	241.5	16	1296.0	84
1988	291.1	17	1379.1	83

	AREA[b] ESTUARINE WTG	%	OCEAN WTG	%
1980	250.7	37	161.2	24
1981	116.2	18	507.1	81
1982	257.5	38	226.1	33
1983	547.0	52	219.3	21
1984	1303.9	60	696.9	32
1985	1321.7	63	779.9	37
1986	1559.5	89	170.7	10
1987	1290.8	84	246.6	16
1988	1317.4	79	302.1	18

[a] Mode definition for beach includes piers, pilings, etc; boat includes private, charter, etc.

[b] Areas definition for estuarine are for inside waters; ocean covers from 0 miles on out; and a third unknown category makes up the difference.

Table 3.

Red drum age-length keys for 1986-1988.

LENGTH INTERVAL MIDPOINT	AGE 0	1	2	3	4	5	6+
			1986 (n = 1020)				
175	1.0	0.0	0.0	0.0	0.0	0.0	0.0
225	0.963	0.037	0.0	0.0	0.0	0.0	0.0
275	0.544	0.456	0.0	0.0	0.0	0.0	0.0
325	0.073	0.927	0.0	0.0	0.0	0.0	0.0
375	0.010	0.990	0.0	0.0	0.0	0.0	0.0
425	0.0	0.991	0.009	0.0	0.0	0.0	0.0
475	0.0	0.931	0.069	0.0	0.0	0.0	0.0
525	0.0	0.465	0.535	0.0	0.0	0.0	0.0
575	0.0	0.108	0.892	0.0	0.0	0.0	0.0
625	0.0	0.0	1.0	0.0	0.0	0.0	0.0
675	0.0	0.0	0.615	0.385	0.0	0.0	0.0
725	0.0	0.0	0.040	0.920	0.040	0.0	0.0
775	0.0	0.0	0.200	0.600	0.200	0.0	0.0
825	0.0	0.0	0.0	0.250	0.250	0.0	0.500
875	0.0	0.0	0.0	0.0	0.0	0.250	0.750
925	0.0	0.0	0.0	0.0	0.0	0.0	1.0
			1987 (n = 2044)[a]				
175	1.0	0.0	0.0	0.0	0.0	0.0	0.0
225	0.988	0.012	0.0	0.0	0.0	0.0	0.0
275	0.707	0.293	0.0	0.0	0.0	0.0	0.0
325	0.040	0.960	0.0	0.0	0.0	0.0	0.0
375	0.010	0.990	0.0	0.0	0.0	0.0	0.0
425	0.0	0.990	0.010	0.0	0.0	0.0	0.0
475	0.0	0.766	0.234	0.0	0.0	0.0	0.0
525	0.0	0.094	0.868	0.038	0.0	0.0	0.0
575	0.0	0.034	0.915	0.051	0.0	0.0	0.0
625	0.020	0.0	0.760	0.220	0.0	0.0	0.0
675	0.0	0.0	0.245	0.755	0.0	0.0	0.0
725	0.0	0.0	0.218	0.728	0.054	0.0	0.0
775	0.0	0.0	0.0	1.0	0.0	0.0	0.0
825	0.0	0.0	0.0	0.425	0.275	0.300	0.0
875	0.0	0.0	0.0	0.041	0.083	0.876	0.0
925	0.0	0.0	0.0	0.0	0.0	1.0	0.0

[a] No age 5 red drum in 1987 aged-fish sample, so 5-plus group used rather than 6-plus.

Table 3 (cont.).

Red drum age-length keys for 1986-1988.

LENGTH INTERVAL MIDPOINT	AGE 0	1	2	3	4	5	6+
			1988 (n = 942)				
175	1.0	0.0	0.0	0.0	0.0	0.0	0.0
225	1.0	0.0	0.0	0.0	0.0	0.0	0.0
275	0.955	0.034	0.011	0.0	0.0	0.0	0.0
325	0.219	0.781	0.0	0.0	0.0	0.0	0.0
375	0.009	0.986	0.005	0.0	0.0	0.0	0.0
425	0.033	0.967	0.0	0.0	0.0	0.0	0.0
475	0.121	0.697	0.182	0.0	0.0	0.0	0.0
525	0.032	0.677	0.290	0.0	0.0	0.0	0.0
575	0.0	0.400	0.600	0.0	0.0	0.0	0.0
625	0.0	0.108	0.757	0.135	0.0	0.0	0.0
675	0.0	0.015	0.470	0.515	0.0	0.0	0.0
725	0.0	0.0	0.410	0.557	0.033	0.0	0.0
775	0.0	0.0	0.111	0.861	0.028	0.0	0.0
825	0.0	0.0	0.0	0.600	0.300	0.0	0.100
875	0.0	0.0	0.0	0.083	0.167	0.083	0.667
925	0.0	0.0	0.0	0.0	0.053	0.0	0.947
975	0.0	0.0	0.0	0.0	0.0	0.0	1.0

Table 4.

Commercial catch (thousand pounds) of red drum by state and by gear, 1986-1988.

	YEAR		
STATE	1986	1987	1988
FL	75.1	43.0	0.4
GA	2.9	4.6	0.7
SC	12.4	14.7	0.0
NC	249.1	249.7	220.3
VA	1.3	0.4	1.1
MD	1.0	0.0	6.7
GEAR			
LINES	19.2	19.6	3.5
GILL	181.2	168.8	133.2
POUND	141.5	123.8	92.0

Table 5.

Comparison of Double Von Bertalanffy Growth Parameters for the Gulf and Atlantic

PARAMETER	ESTIMATE	
	GULF[a]	ATLANTIC[b]
L_{max}	987.3	1152.6
K_1	0.40	0.25
T_1	-0.02	-0.37
T_x	3.49	5.68
K_2	0.08	0.04
T_2	-13.60	-34.98

[a] Condrey et al. (1988)

[b] Based on subset of data (n = 393 of 4836).

Table 6.

Double and Single Von Bertalanffy Parameters for Red Drum by Year and State

STATE	DOUBLE PARAMETERS					
	L_{max}	K_1	K_2	T_1	T_2	T_x
FL	1037.0	0.30	0.14	-1.15	-7.5	4.7
GA	1148.1	0.24	0.03	-1.88	-44.6	3.9
SC	1041.9	0.29	0.07	-0.61	-18.1	5.7
NC	1168.2	0.26	0.07	-0.80	-15.9	4.7

STATE	SINGLE PARAMETERS			
	L_{max}	K_1	T_0	n
FL	1017.2	0.31	-1.14	523
GA	977.4	0.36	-1.51	102
SC	1046.8	0.28	-0.62	4044
NC	1052.7	0.35	-0.47	167

Table 7.

Catch in numbers at age for red drum, 1986-1988.

AGE	MRFSS	COMMERCIAL	TOTAL	ALTERNATE	COMMERCIAL	TOTAL
			1986			
0	28540	149545	178085	47481	149545	197026
1	323962	253378	577340	257428	253378	510806
2	56279	1161	57440	56595	1161	57756
3	4218	220	4438	20510	220	20730
4	0	32	32	3136	34	3168
5	691	8	699	673	8	681
6+	14907	193	15100	43323	193	43516
			1987			
0	49788	162066	211854	147381	162066	309447
1	578089	221952	800041	429170	221952	651122
2	84770	1483	86253	57729	1483	59212
3	21678	141	21819	24806	141	24947
4	331	7	338	1680	7	1687
5+	3335	317	3652	77297	317	77614
			1988			
0	60001	20021	80022	121702	20021	141723
1	458874	143502	602376	278606	143502	422108
2	52480	1854	54334	36830	1854	38684
3	15389	8	15397	18960	8	18968
4	943	1	944	2978	1	2979
5	0	0.2	0.2	404	0.2	404.2
6+	4923	70	4993	133270	70	133340

Table 8.

Length-Length Relationships for Red Drum as Reported in the Literature for the Atlantic

STATE	SIZE RANGE	N	RELATIONSHIP	r
GA[a]	16-40	5	TL= 0.47 + 1.25 SL	-
			SL= -0.29 + 0.80 TL	-
FL[b]	225-1110	1074	TL=-25.21 + 1.09 FL	0.999
			FL= 23.94 + 0.92 TL	0.999
	225-1110	1075	TL= 10.38 + 1.18 SL	0.998
			SL= -7.62 + 0.83 TL	0.998
	225-1110	1075	FL= 32.89 + 1.09 SL	0.998
			SL=-29.46 + 0.92 FL	0.998
SC[c]	6-980	1092	SL= -3.40 + 0.83 TL	0.999

[a] Jorgenson and Miller (1968)

[b] Murphy and Taylor (1986a)

[c] Wenner (pers. comm.)

Table 9.

Length-Weight Relationships for Red Drum as Reported for the South Atlantic

SOURCE	AREA	N	LOGa	b	r^2	CALCULATED WEIGHT (g)[a]
SC[1]	Marsh Empoundment	54	-1.29[b]	2.74[b]	-	186
GA[c2]	Estuaries	103	-4.22	2.72	-	111
FL[3]	Bays (Atl.)	484	-4.42	2.83	-	125
NC[d4]	-	59	-11.80	3.08	0.99	-
SC[d5]	-	1695	-13.71	3.37	0.99	-
MRFSS[d6]	-	1622	-12.06	3.13	0.92	-
1986[d]	-	1193	-14.02	3.44	0.99	-
1987[d]	-	1435	-13.05	3.28	0.99	-
1988[d]	-	738	-13.49	3.36	0.98	-
Overall[d]	-	3366	-13.67	3.38	0.99	-

[a] Weight was calculated using a 200 mm SL fish.
[b] Length in centimeters.
[c] Total Length-Weight.
[d] Fork length (mm) and weight in Kg.
[1] Theiling and Loyacano (1976)
[2] Music and Pafford (1984)
[3] Murphy and Taylor (1986a)
[4] Ross (1986-1988)
[5] Wenner (1986-1988)
[6] MRFSS (1986-1988)

TABLE 10.

Summary of estimates of mortality for red drum

STATE (AREA)	ESTIMATE Z	F	M	COMMENT
FL[1] (Mosquito Lagoon)	1.05[a]			FDNR trammel net (1987-1988)
	1.08[b]			
	1.05			
	(0.68-1.35)[c]			
	(0.87-1.69)[c5]			
FL[2] (Everglades National Park)	0.96[h]	0.40[e]	0.56[e]	Mark-recapture
	0.62[h]	0.34[f]	0.28[f]	
	0.81[h]	0.33[g]	0.48[g]	
FL[3] (Everglades and Florida Bay)	1.87	1.37	0.46	Average of 1984-1985 rates based on VPA
GA[4] (Estuaries)	0.92[c]	0.70	0.22	Mark-recapture
GA[5] (Estuaries)	(0.84-1.78)[c]			GDNR trammel nets (1984-1988)
	(0.97-1.89)[c]			GDNR recreational tagged fish (1986-1988)
SC[5] (Estuaries)	(1.72-2.83)[c]			SCDMF stop nets (1986-1987)
	(1.23-1.26)[c]			SCDMF recreational tagged fish (1986-1987)
South Atlantic[5]	1.65[c]	0.82[d]	0.83[h]	SCMFD tagging
	1.65[c]	1.12[h]	0.53[i]	Alternate
	1.65[c]	1.21[h]	0.44[j]	
	1.81[c]	0.88[d]	0.93[h]	MRFSS data base
	1.81[c]	1.28[h]	0.53[i]	
	1.81[c]	1.37[h]	0.44[j]	

TABLE 10 (cont.).

Estimation Methods:
[a] Heinke (1913)
[b] Robson and Chapman (1961)
[c] Cohort-Based Catch curve
[d] Ricker (1975) based on South Carolina tagging studies
[e] "Days at large"
[f] "Contour plot"
[g] Maximum likelihood
[h] Z = M + F
[i] Pauly's method (1979) on single von Bertalanffy for sub-adults.
[j] Pauly's method (1979) on K1 from double von Bertalanffy.

Sources:
[1] Murphy and Taylor (1986b)
[2] Rago and Goodyear (1986)
[3] Tillmant (1989)
[4] Pafford (pers. comm.)
[5] This analysis

Table 11.

Estimated age-specific fishing mortality of red drum for MRFSS scenario.

YEAR	M	Z	AGE 0	1	2	3	4	5
1986	0.44	1.81	0.18	1.88	1.96	1.37	0.03	a
	0.93	1.81	0.12	1.37	1.36	0.88	0.03	a
	0.44	1.32	0.18	1.85	1.75	0.88	0.02	a
1987	0.44	1.81	0.15	1.58	1.07	1.37	0.08	0.0
	0.93	1.81	0.09	1.00	0.66	0.88	0.06	0.0
	0.44	1.32	0.15	1.50	0.91	0.88	0.04	0.0
1988	0.44	1.81	0.08	1.69	1.00	1.37	0.34	0.0
	0.93	1.81	0.05	1.07	0.61	0.88	0.26	0.0
	0.44	1.32	0.08	1.60	0.85	0.88	0.15	0.0
Mean			**0.12**	**1.51**	**1.13**	**1.04**	**0.11**	**0.0**
1985	0.44	1.81	-	1.42	1.31	1.37	-	-
(cohort)	0.93	1.81	-	0.91	0.83	0.88	-	-
	0.44	1.32	-	1.36	1.13	0.88	-	-
Mean			**-**	**1.23**	**1.09**	**1.04**	**-**	**-**
Combined			**0.12**	**1.23**	**1.09**	**1.04**	**0.11**	**0.0**

[a] Divergence problems resulted in excessively large values of F.

Table 12.

Estimated age-specific fishing mortality of red drum for alternate scenario.

YEAR	M	Z	AGE 0	1	2	3	4	5
1986	0.44	1.65	0.20	1.42	0.82	1.21	0.83	0.58
	0.83	1.65	0.13	0.93	0.53	0.82	0.60	0.52
	0.44	1.26	0.19	1.33	0.70	0.82	0.37	0.16
1987	0.44	1.65	0.25	1.53	0.74	1.21	0.29	0.0
	0.83	1.65	0.16	1.00	0.47	0.82	0.22	0.0
	0.44	1.26	0.24	1.43	0.62	0.82	0.15	0.0
1988	0.44	1.65	0.18	1.46	0.66	1.21	0.87	0.35
	0.83	1.65	0.11	0.94	0.41	0.82	0.62	0.32
	0.44	1.26	0.17	1.36	0.56	0.82	0.38	0.10
Mean			**0.18**	**1.27**	**0.61**	**0.95**	**0.48**	**0.23**
1985	0.44	1.65	-	1.44	0.89	1.21	-	-
(cohort)	0.83	1.65	-	0.96	0.57	0.82	-	-
	0.44	1.26	-	1.36	0.76	0.82	-	-
Mean			**-**	**1.25**	**0.74**	**0.95**	**-**	**-**
Combined			**0.18**	**1.25**	**0.74**	**0.95**	**0.48**	**0.23**

Table 13.

Mean estimated age-specific population sizes (thousands) for both MRFSS and alternate scenarios.

YEAR	0	1	2	3	4	5	6+[b]
				MRFSS			
1986	1435.6	887.3	88.7	9.0	1.8	1.0	
1987	2194.3	1397.3	196.9	44.3	8.8	5.4	
1988	1507.1	1014.8	130.8	31.2	6.2	2.8	
1985 (cohort)	1496.4[a]	1066.5	170.5	31.2	18.0[a]	11.6[a]	61.2
				ALTERNATE			
1986	1483.6	925.8	154.3	43.7	9.7	3.3	
1987	1892.6	1133.0	172.8	52.6	11.7	6.1	
1988	1192.3	757.7	123.4	40.0	7.9	2.5	
1985 (cohort)	1357.4[a]	915.0	149.1	40.0	16.3[a]	8.5[a]	35.7

[a] Based on mean F from annual VPA's.
[b] Calculated based on adult M = 0.13.

Table 14.

Potential gains[a] from minimum and maximum size limit (TL) management options

FISHING YEAR	MINIMUM SIZE LIMIT (INCHES) 12	14	16	18	20
1979	31	51	65	77	83
1980	29	54	68	77	83
1981	19	40	61	68	76
1982	27	55	79	85	90
1983	21	48	78	87	89
1984	30	66	78	89	94
1985	38	66	81	91	95
1986	10	25	52	74	83
1987	6	35	75	83	88
1988	4	15	56	77	83

	MAXIMUM SIZE LIMIT (INCHES) 25	26	28	30	32
1979	8	7	4	1	6
1980	7	5	3	2	1
1981	11	11	6	3	1
1982	6	6	5	4	3
1983	5	4	2	b	b
1984	4	4	2	2	1
1985	2	1	b	b	b
1986	7	5	4	4	4
1987	4	2	1	1	1
1988	6	5	4	2	1

[a] Values in Table represent percent of fish that either fall below the minimum size limit or exceed the maximum.
[b] Value falls below 0.5%.

Table 15.

Potential gains for bag limit management options

BAG LIMIT	NO. CAUGHT WITH BAG LIMIT (N_1)	RATIO[a] ($1-N_1/N_2$)
1	1839	0.72
2	2760	0.58
3	3383	0.48
4	3849	0.41
5	4213	0.35
6	4508	0.31
7	4746	0.27
8	4945	0.24
9	5110	0.21
10	5255	0.19
11	5376	0.17
12	5486	0.16
13	5579	0.14
14	5668	0.13
15	5748	0.12

[a] The ratio represents the proportion of red drum caught that exceed the bag limit.
N_1 = Number caught within bag limit.
N_2 = 6,500 red drum caught without bag limit in MRFSS data base (1979-1988).

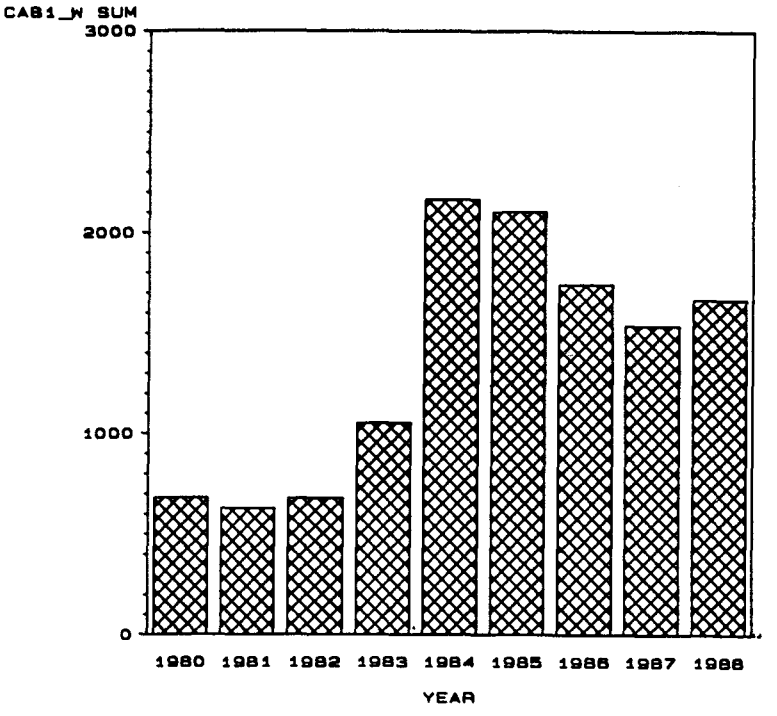


Fig. 1. Red drum landings in weight (1000 pounds) by the recreational fishery (Type A+B1, see footnote Table 1) for 1980-1988.

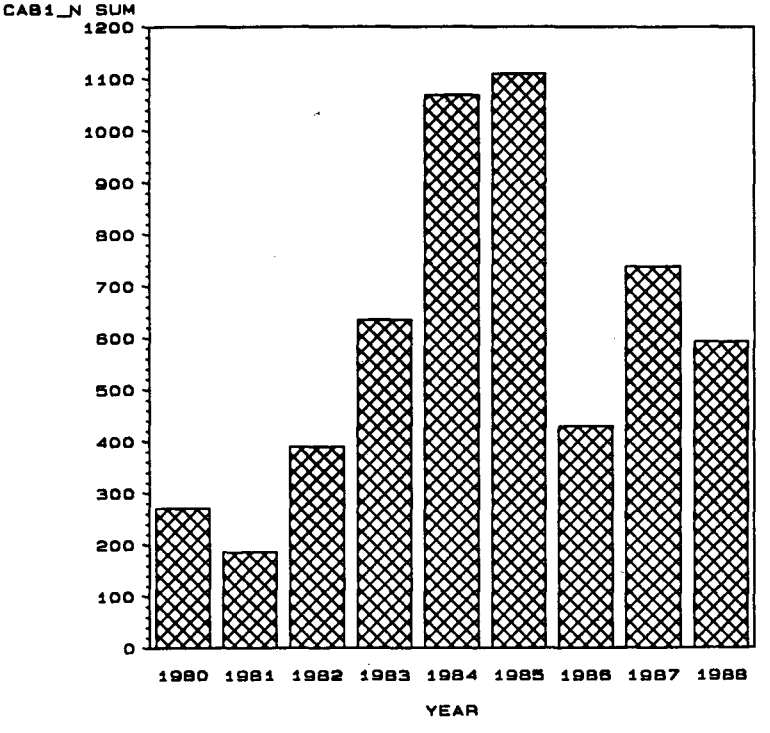


Fig. 2. Red drum landings in numbers (1000) by the recreational fishery (Type A+B1, see footnote Table 1) for 1980-1988.

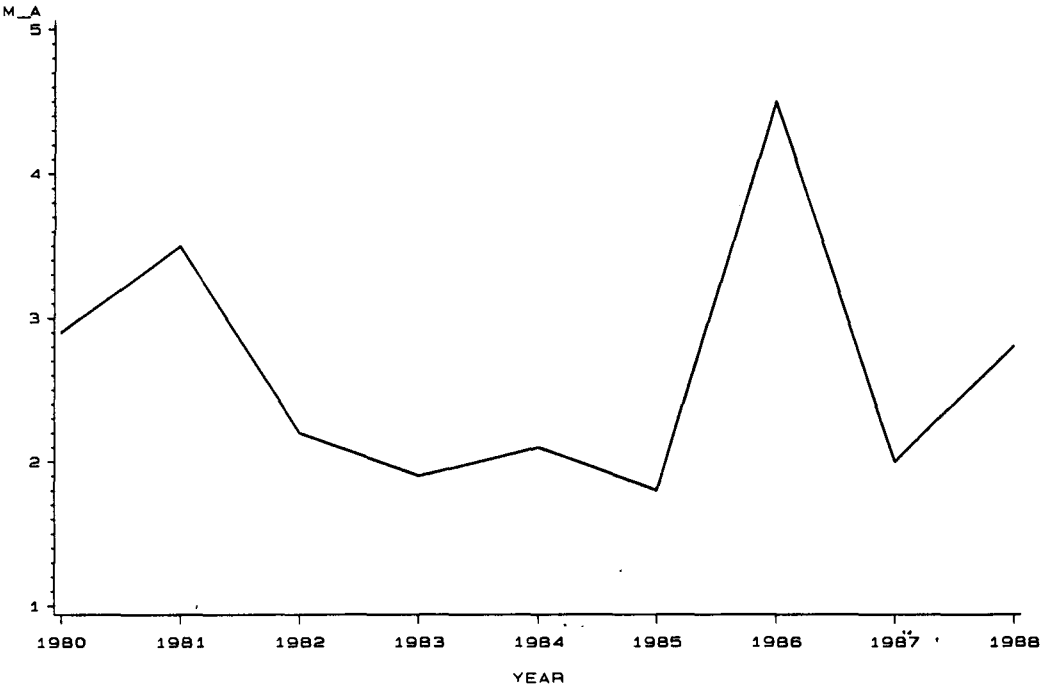


Fig. 3. Mean weight (pounds) of red drum in the recreational fishery (Type A, see footnote Table 1) for 1980-1981.

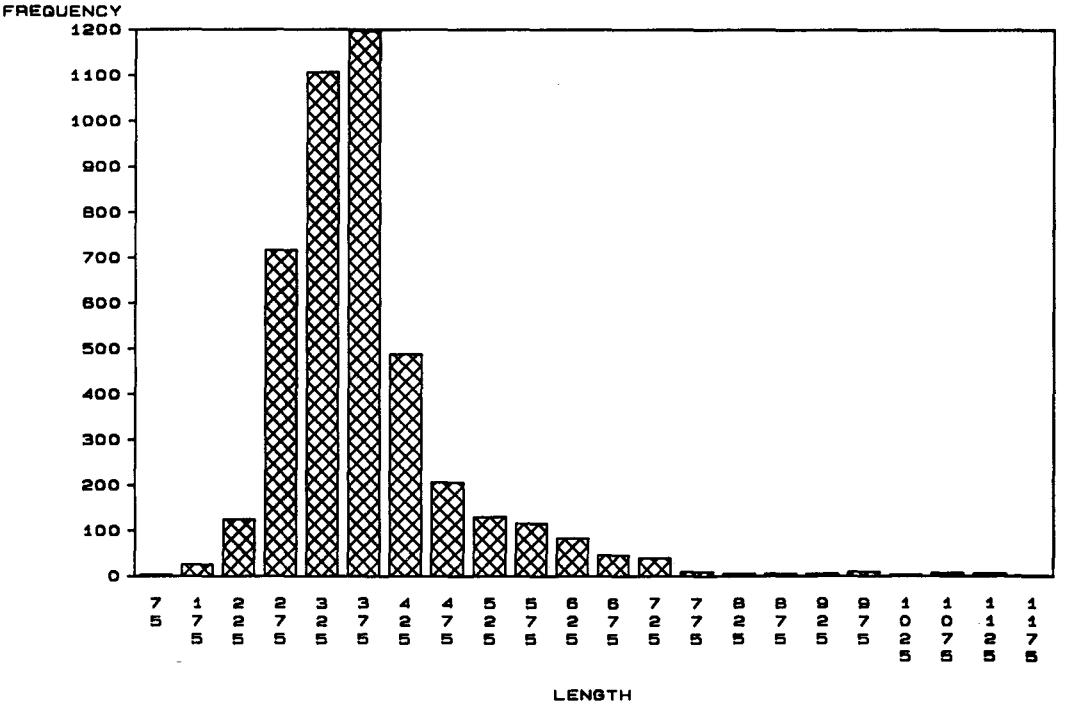


Fig. 4. Length frequencies of red drum from MRFSS sampling for period 1979-1988 (n=4329). Length intervals based on 50 mm width fork lengths.

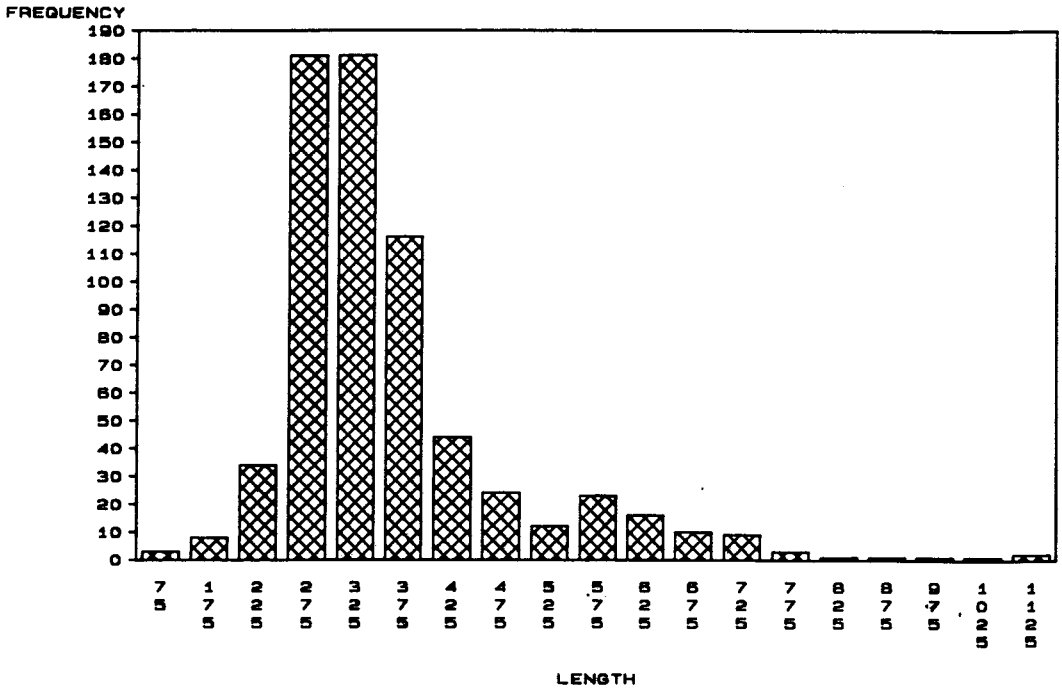


Fig. 5. Length frequencies of red drum by beach mode from MRFSS sampling for period 1979-1988 (n=670). Length intervals based on 50 mm width fork lengths.

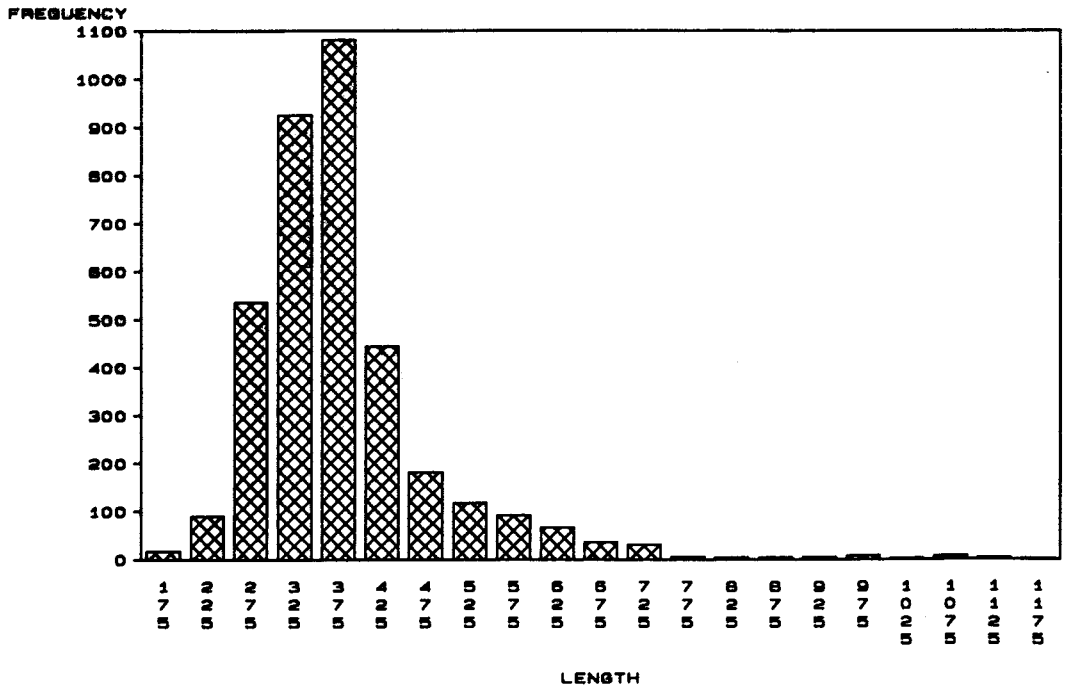


Fig. 6. Length frequencies of red drum by boat mode from MRFSS sampling for period 1979-1988 (n=3659). Length intervals based on 50 mm width fork lengths.

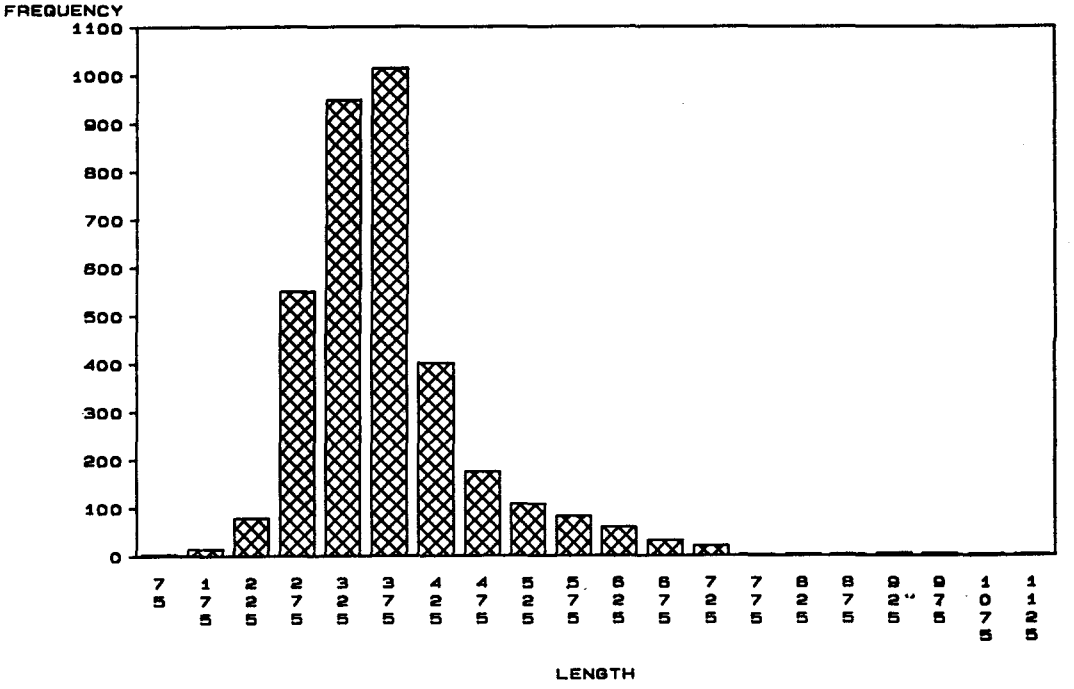


Fig. 7. Length frequencies of red drum by estuarine area from MRFSS sampling for period 1979-1988 (n=3504). Length intervals based on 50 mm width fork lengths.

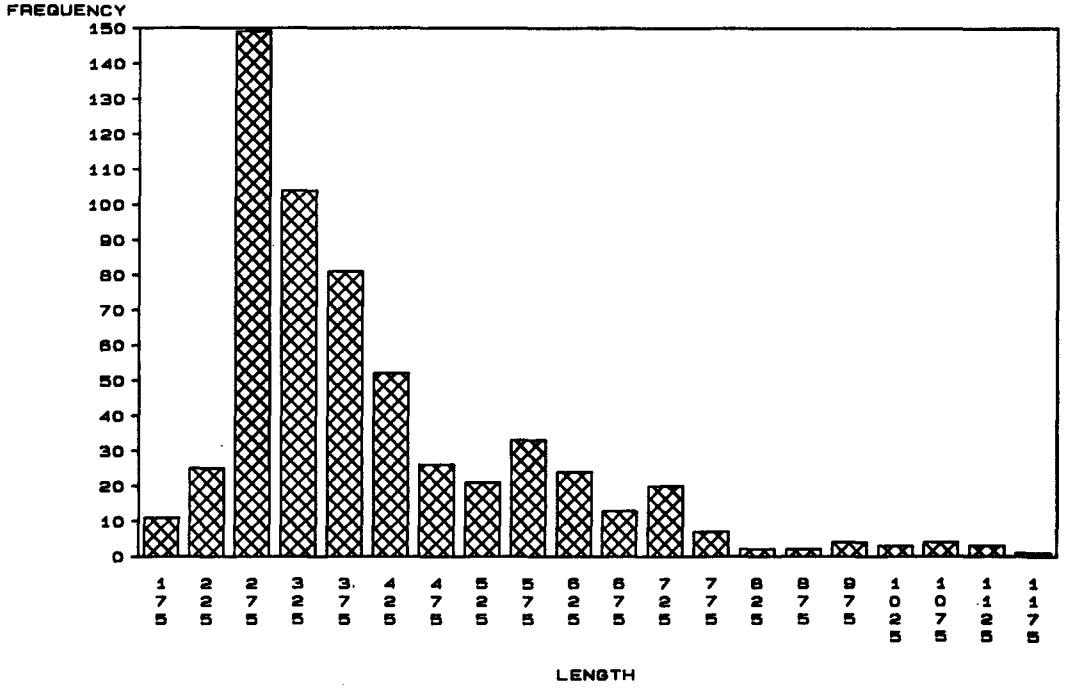


Fig. 8. Length frequencies of red drum by ocean area from MRFSS sampling for period 1979-1988 (n=585). Length intervals based on 50 mm width fork lengths.

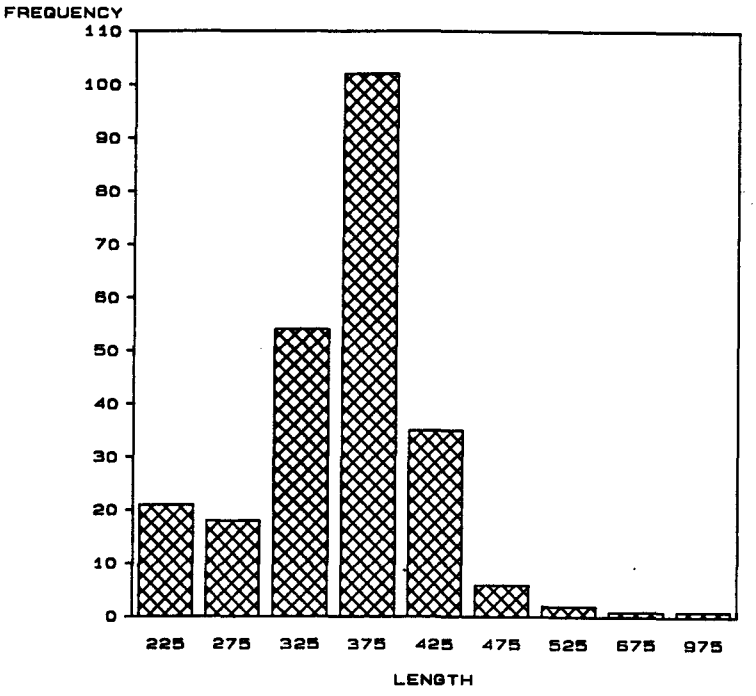


Fig. 9. Length frequencies of red drum by unknown area from MRFSS sampling for period 1979-1988 (n=240). Length intervals based on 50 mm width fork lengths.

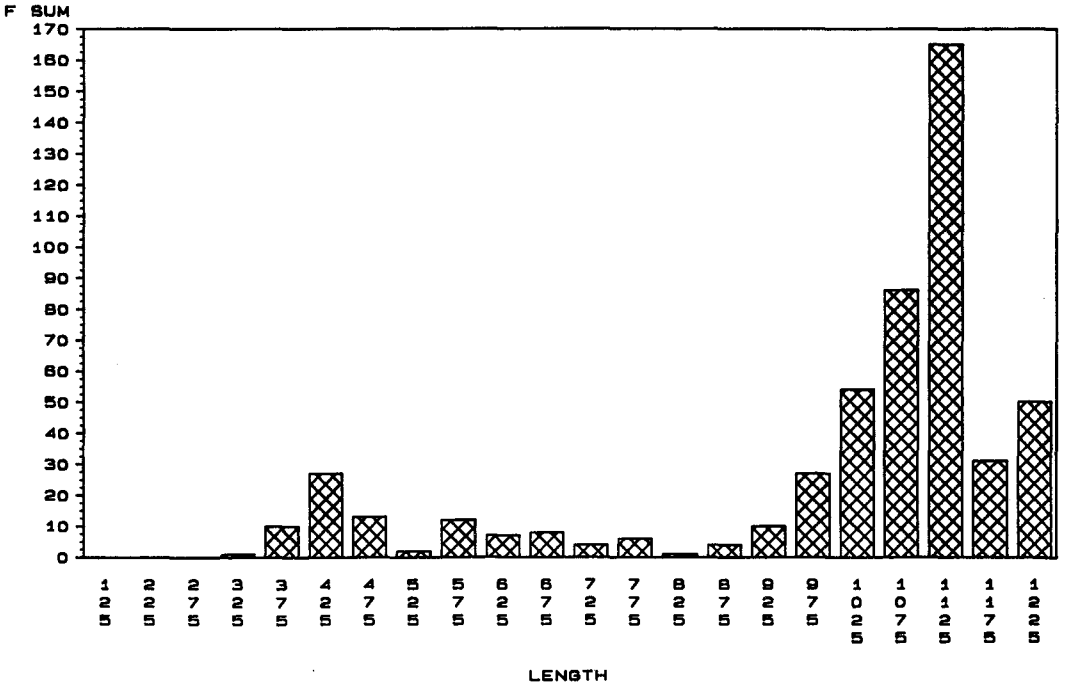


Fig. 10. Length frequencies of red drum by lines from North Carolina for period 1986-1988 (n=844). Length intervals based on 50 mm width fork lengths.

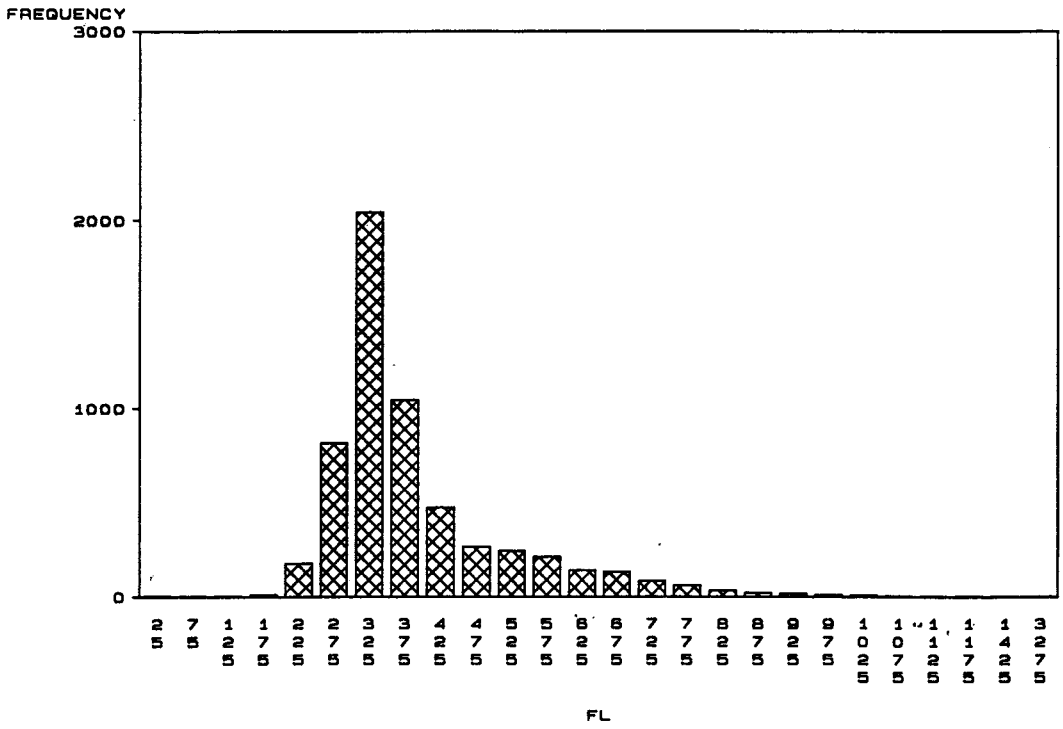


Fig. 11. Length frequencies of red drum by lines from South Carolina's tagging program for period 1986-1988 (n=5472). Length intervals based on 50 mm width fork lengths.

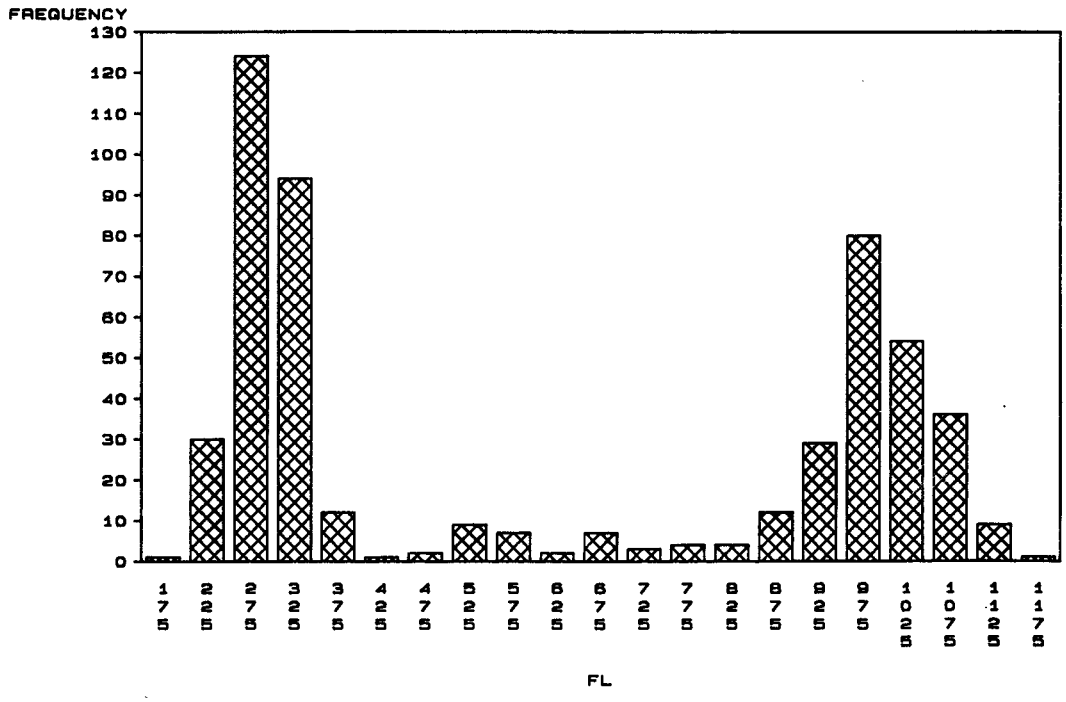


Fig. 12. Length frequencies of red drum by lines from Georgia's tagging program for period 1986-1988 (n=483). Length intervals based on 50 mm width fork lengths.

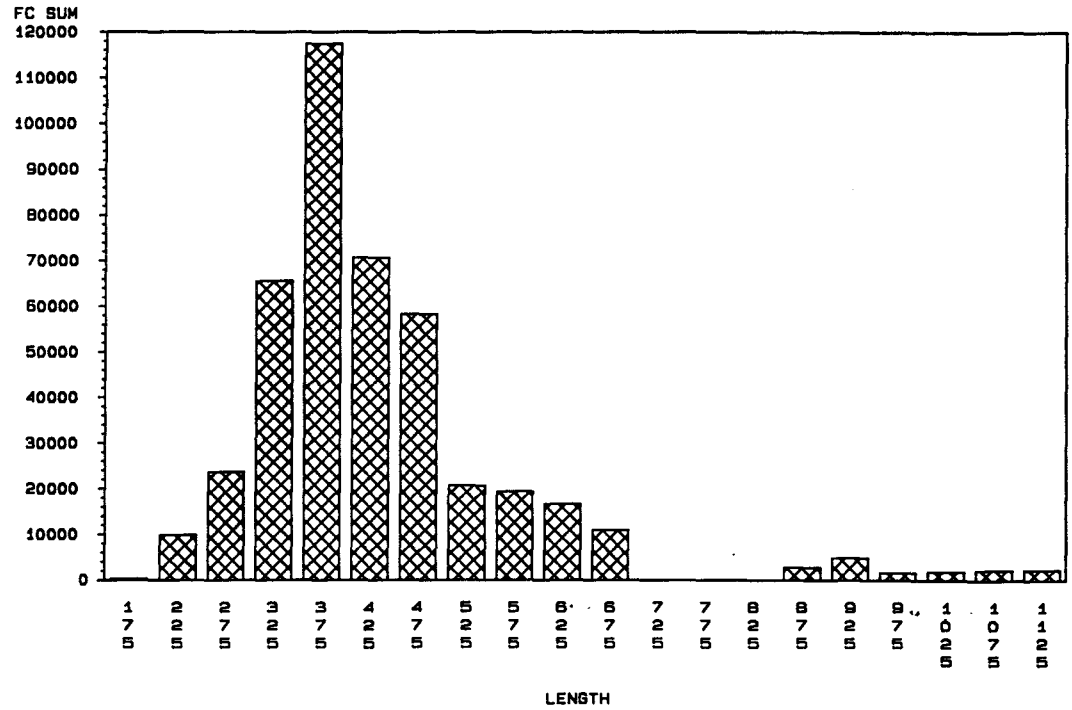


Fig. 13. Length frequencies of red drum for MRFSS recreational scenario for 1986. Length intervals based on 50 mm width fork lengths.

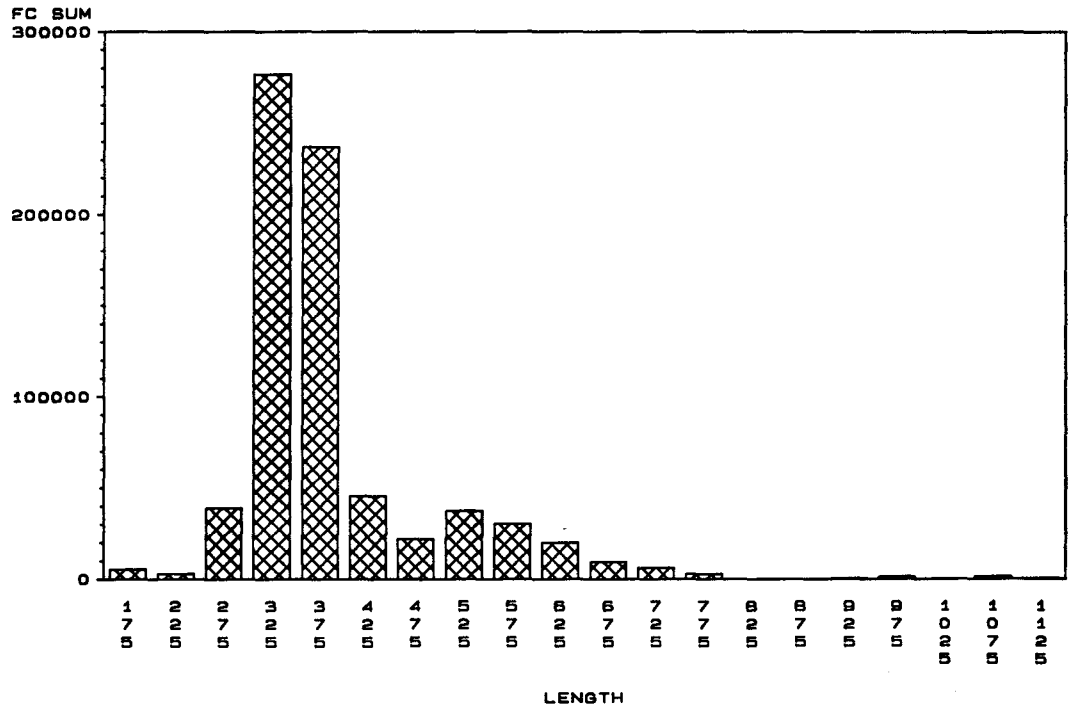


Fig. 14. Length frequencies of red drum for MRFSS recreational scenario for 1987. Length intervals based on 50 mm width fork lengths.

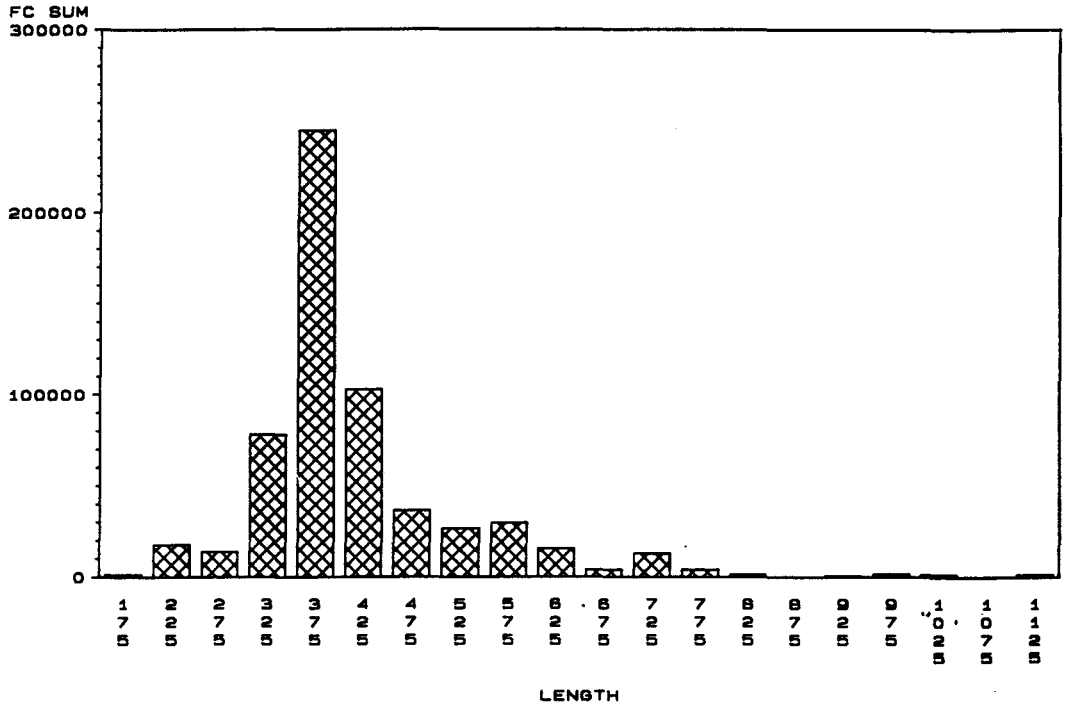


Fig. 15. Length frequencies of red drum for MRFSS recreational scenario for 1988. Length intervals based on 50 mm width fork lengths.

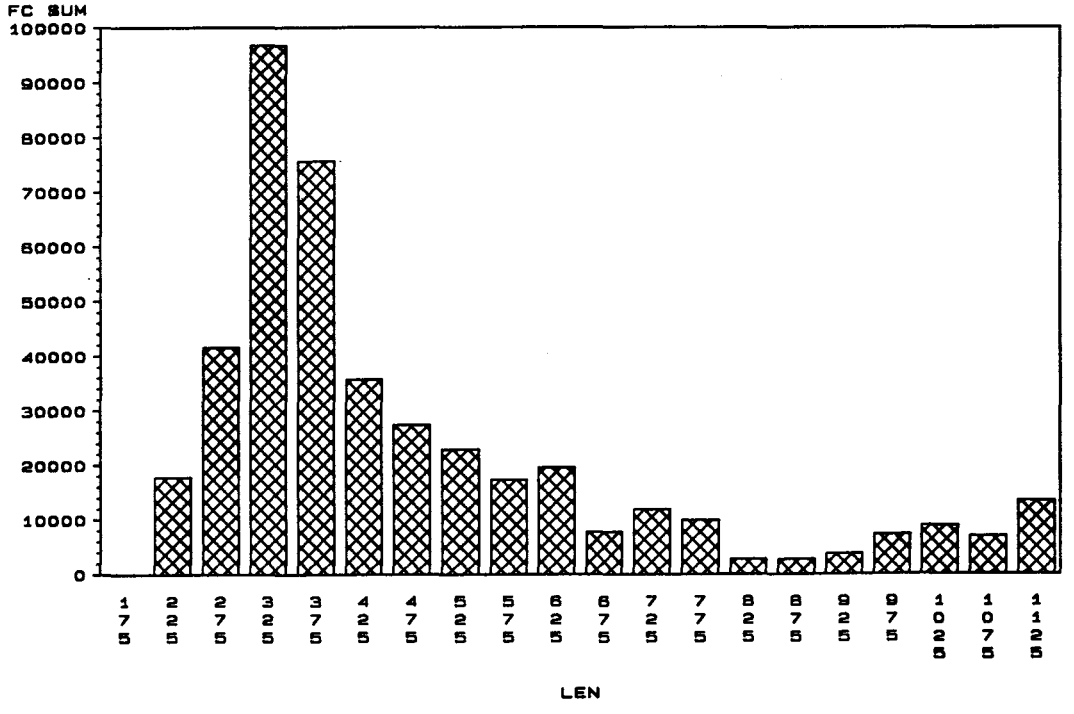


Fig. 16. Length frequencies of red drum for alternate recreational scenario for 1986. Length intervals based on 50 mm width fork lengths.

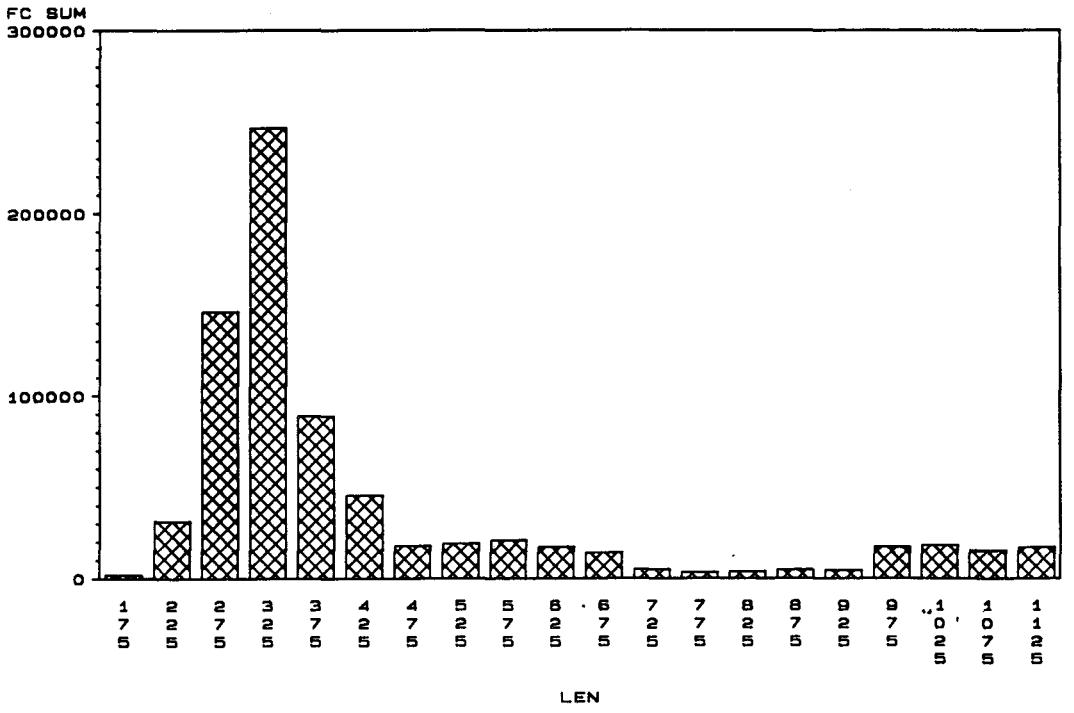


Fig. 17. Length frequencies of red drum for alternate recreational scenario for 1987. Length intervals based on 50 mm width fork lengths.

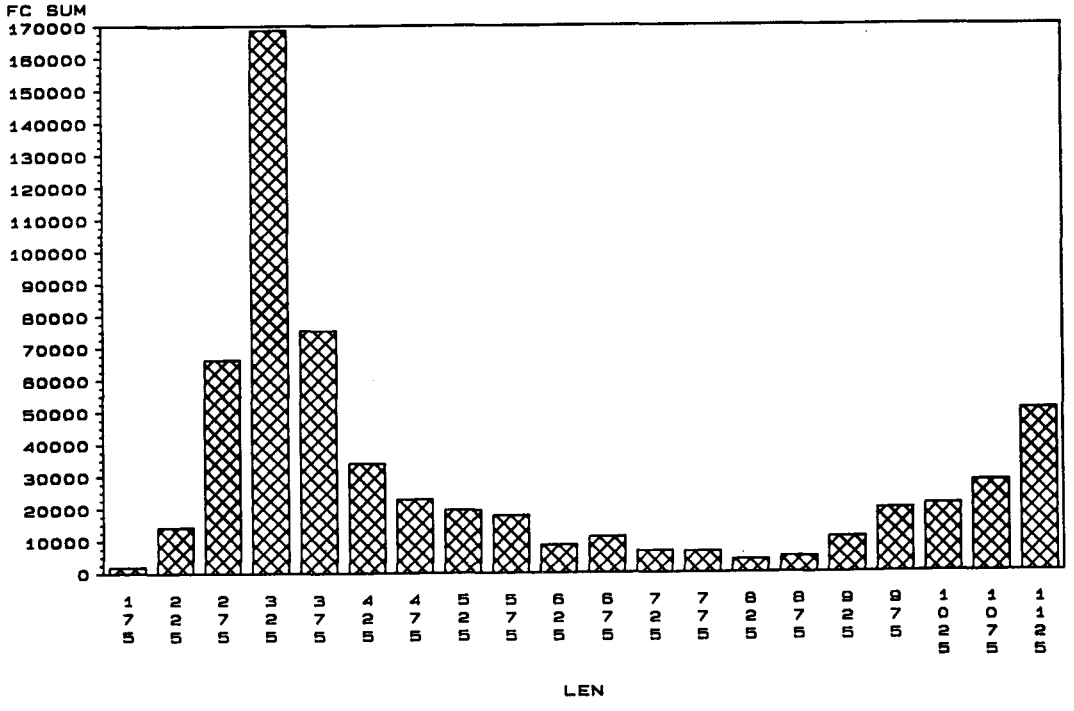


Fig. 18. Length frequencies of red drum for alternate recreational scenario for 1988. Length intervals based on 50 mm width fork lengths.

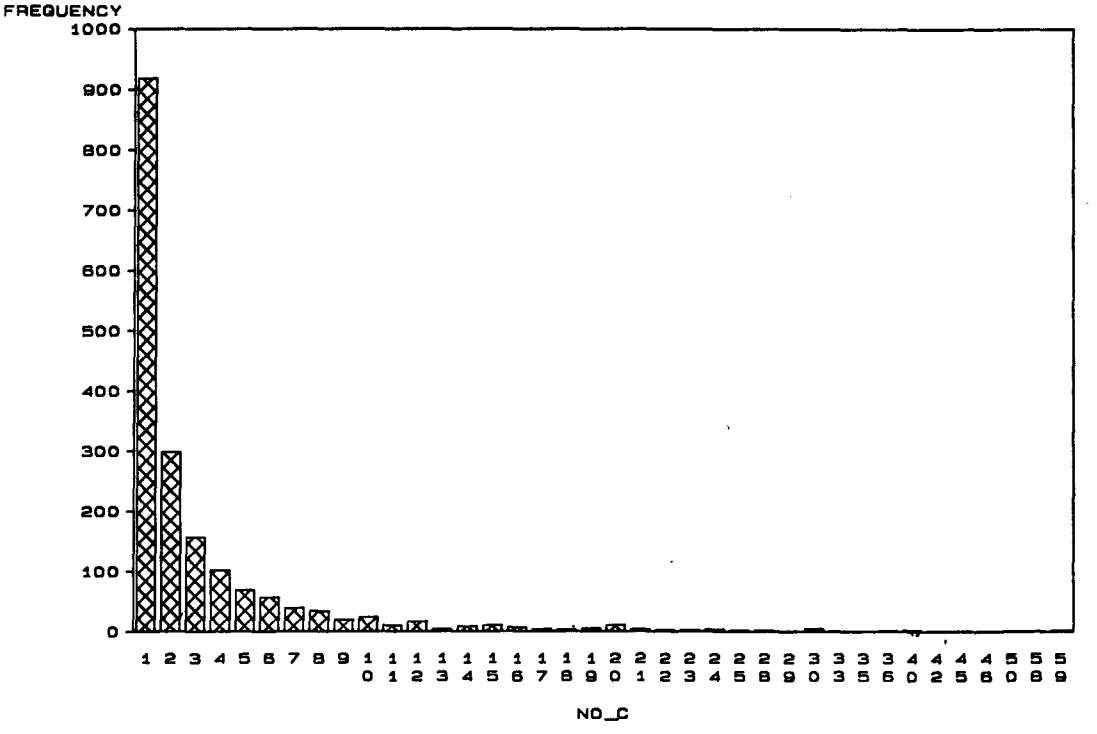


Fig. 19. Frequency distribution of number of red drum caught per angler-trip given at least one red drum caught for period 1979-1988 (n=1839).

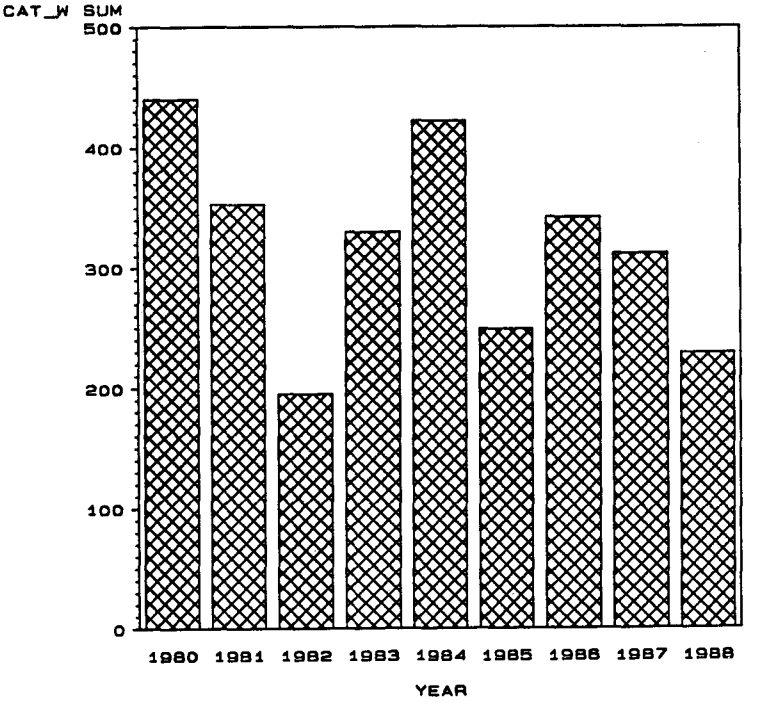


Fig. 20. Red drum landings in weight (1000 pounds) by the commercial fishery for 1980-1988.

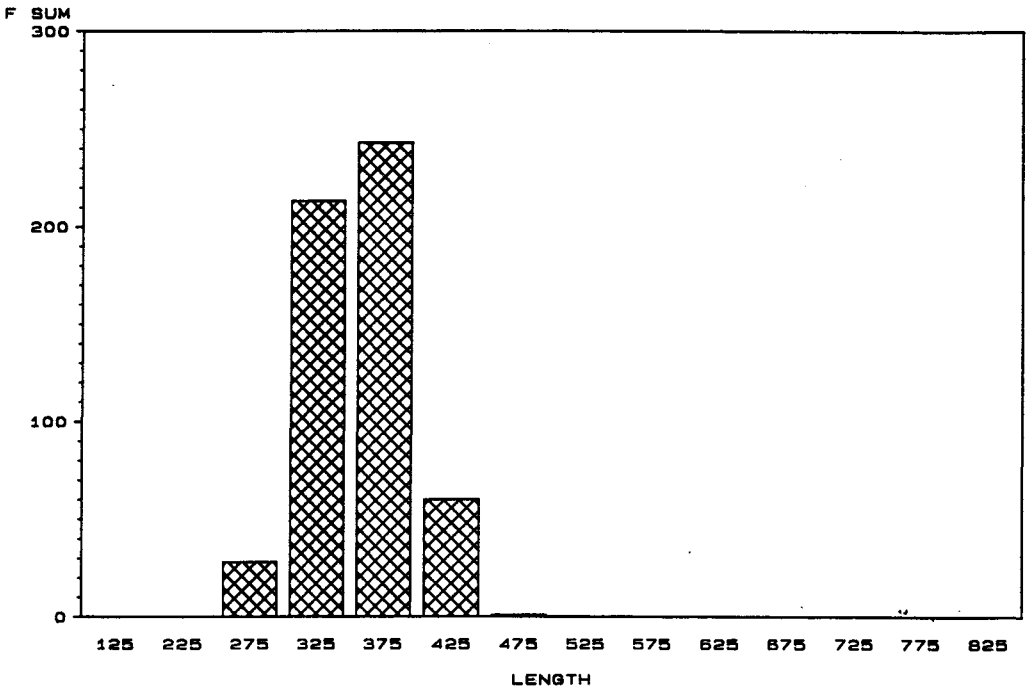


Fig. 21. Length frequencies of red drum by gillnets from North Carolina for period 1986-1988 (n=749). Length intervals based on 50 mm width fork lengths.

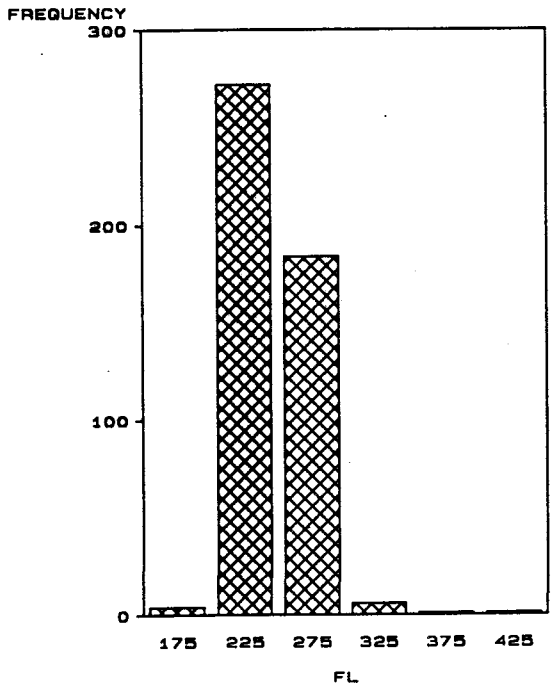


Fig. 22. Length frequencies of red drum by gillnets from Georgia for period 1986-1988 (n=354). Length intervals based on 50 mm width fork lengths.

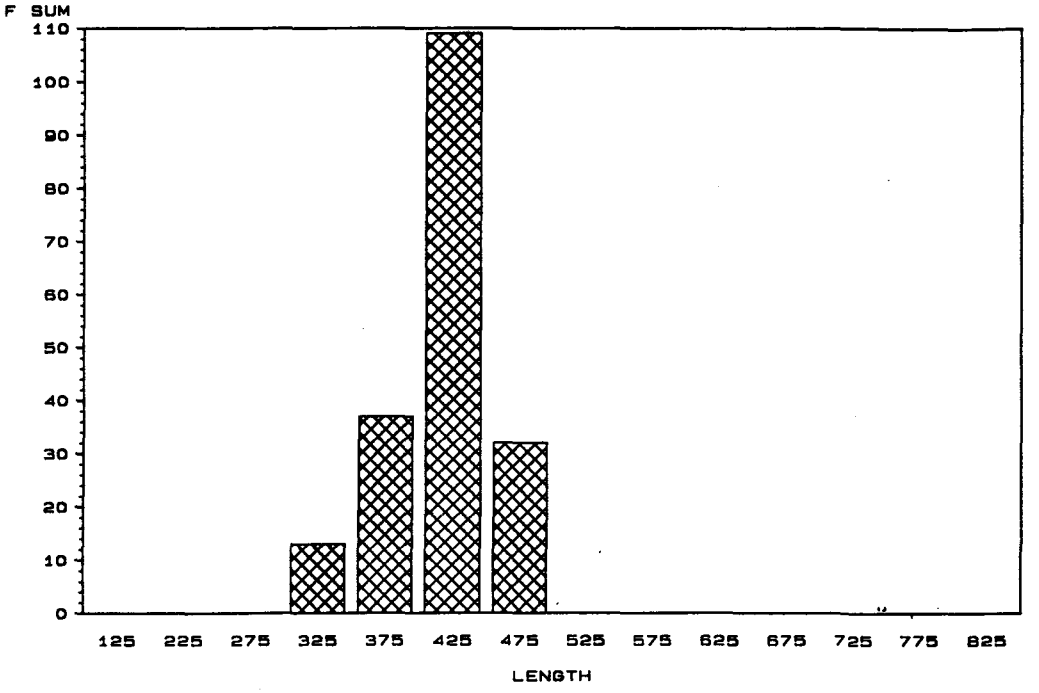


Fig. 23. Length frequencies of red drum by pound nets from North Carolina for period 1986-1988 (n=2051). Length intervals based on 50 mm width fork lengths.

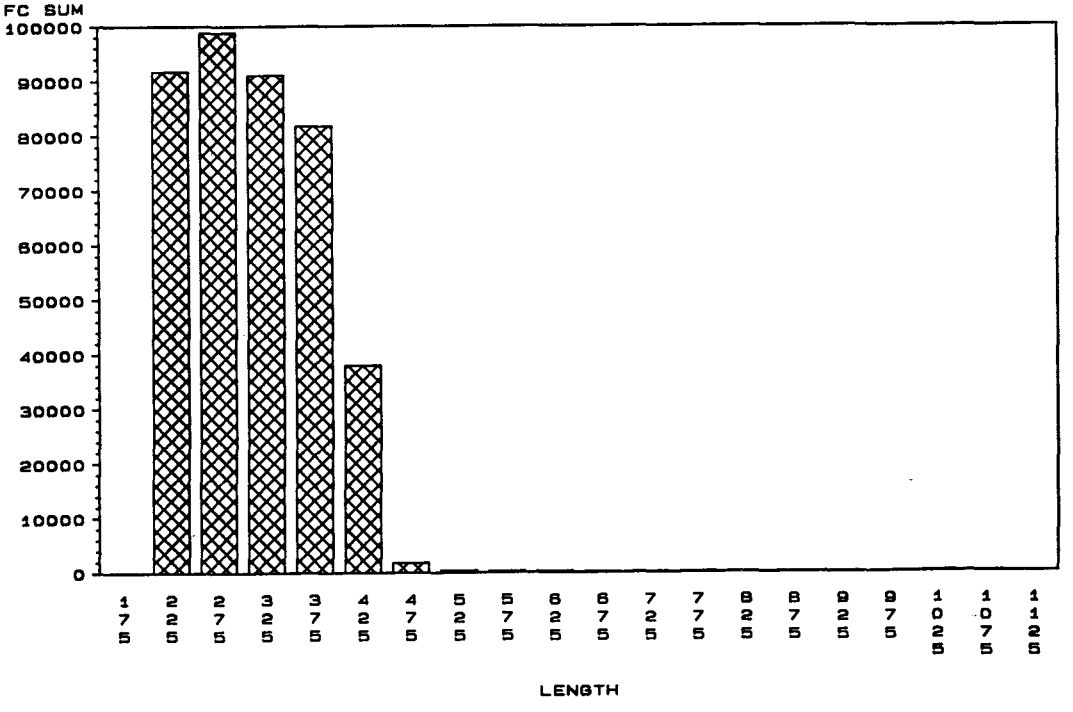


Fig. 24. Length frequencies of red drum for commercial fishery for 1986. Length intervals based on 50 mm width fork lengths.

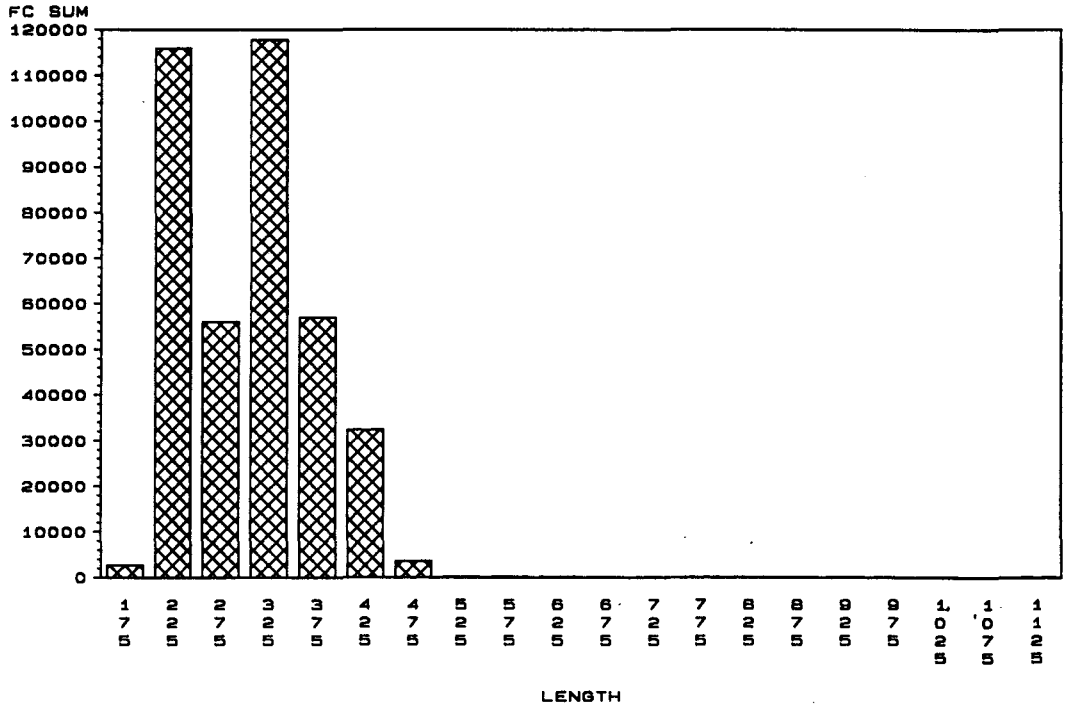


Fig. 25. Length frequencies of red drum for commercial fishery for 1987. Length intervals based on 50 mm width fork lengths.

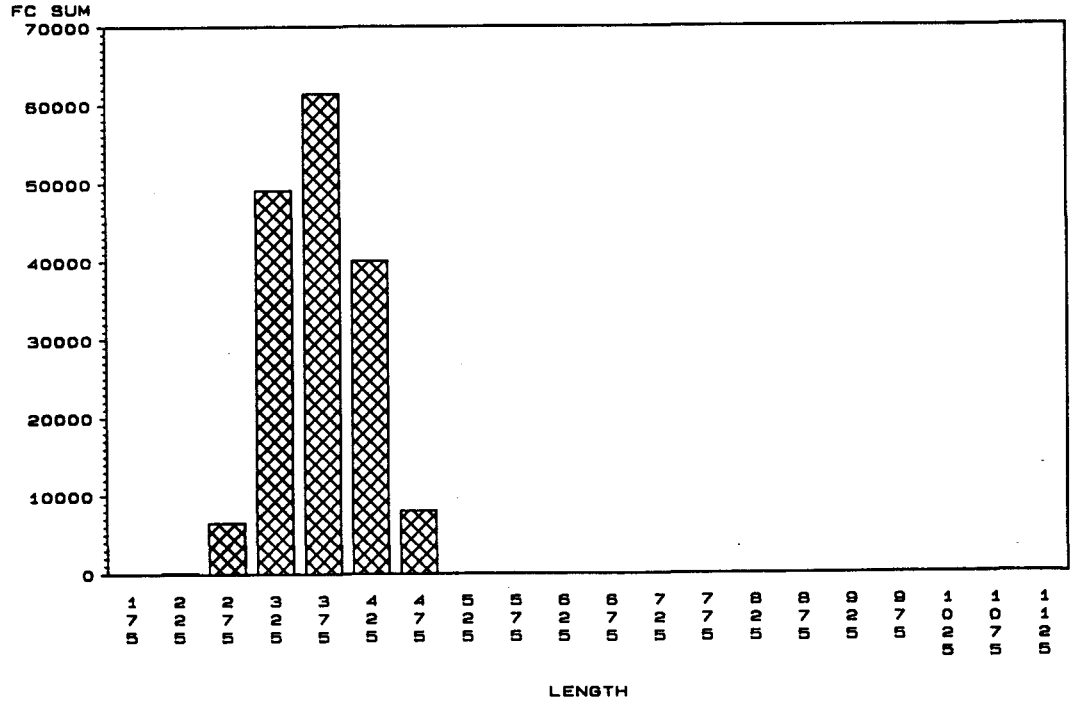


Fig. 26. Length frequencies of red drum for commercial fishery for 1988. Length intervals based on 50 mm width fork lengths.

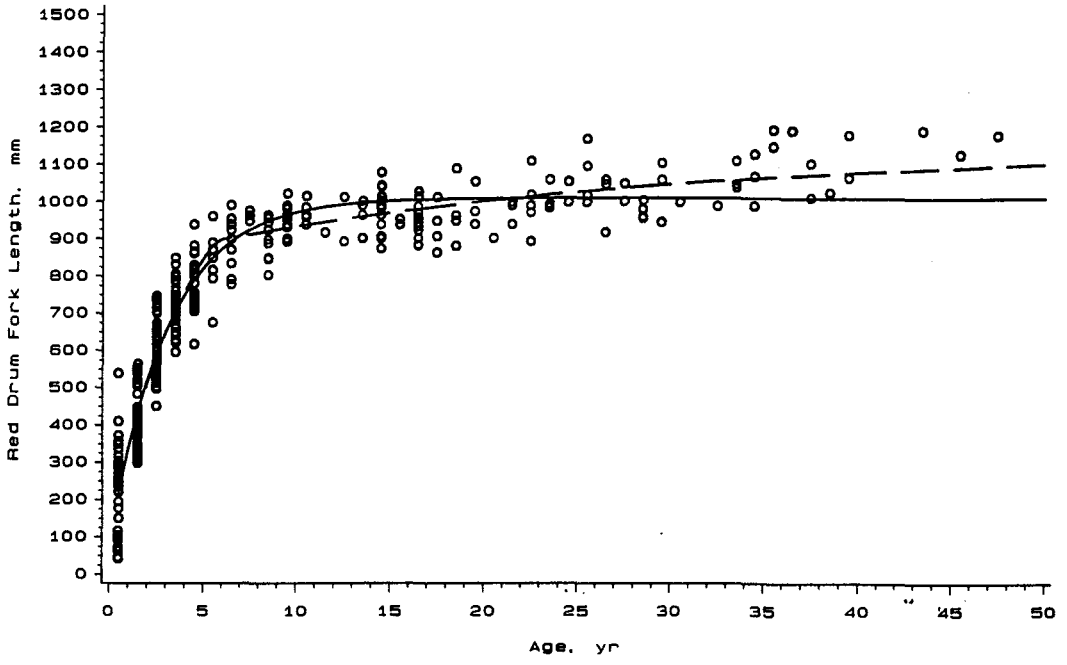


Fig. 27. Curve fits of single (solid) and double (dashes) von Bertalanffy growth equations superimposed on red drum data for Atlantic (circles). Data fit to random subset of entire Atlantic data (n=393), 1981-1988.

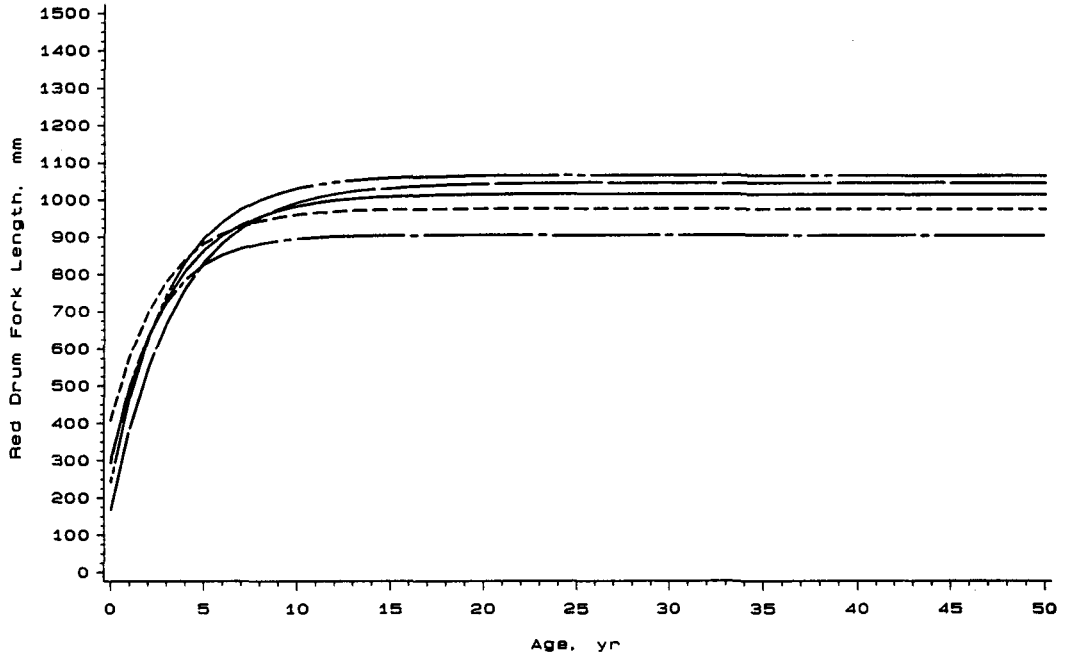


Fig. 28. Comparison of single von Bertalanffy growth equations for red drum from Florida (FL DNR, solid), Georgia (GA DNR, dashes), South Carolina (SCMRD, long dashes), South Carolina (Theiling and Loyacano 1976, dot-dashes), and North Carolina (NCDMF, dot-dot-dashes).

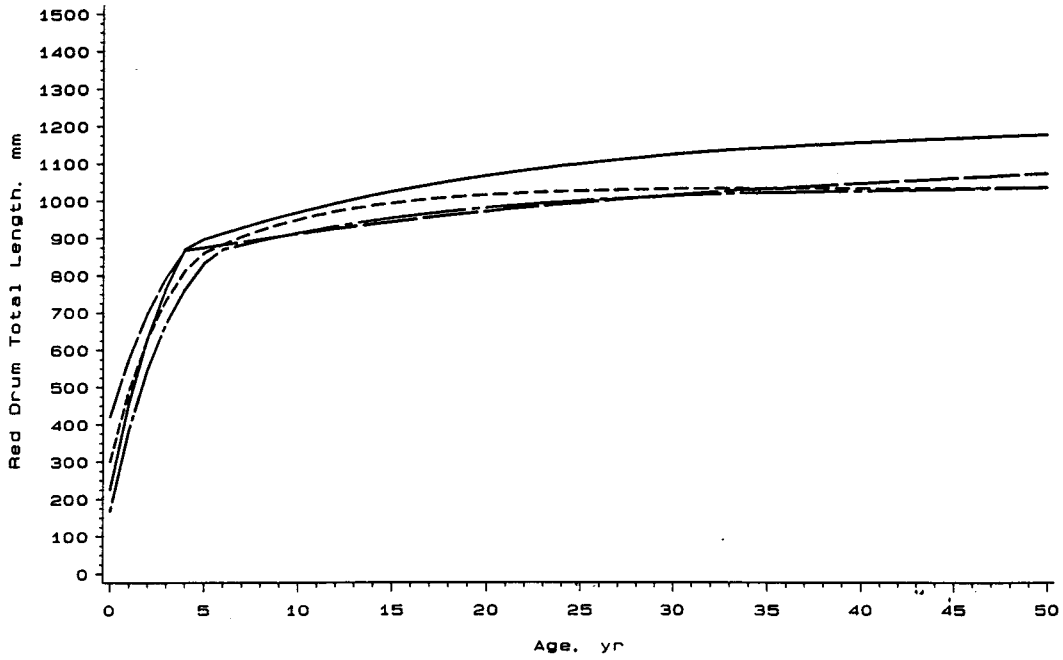


Fig. 29. Comparison of double von Bertalanffy growth equations for red drum from Florida (FL DNR, dot-dashes), Georgia (GA DNR, dot), South Carolina (SCMRD, dashes), and North Carolina (NCDMF, solid).

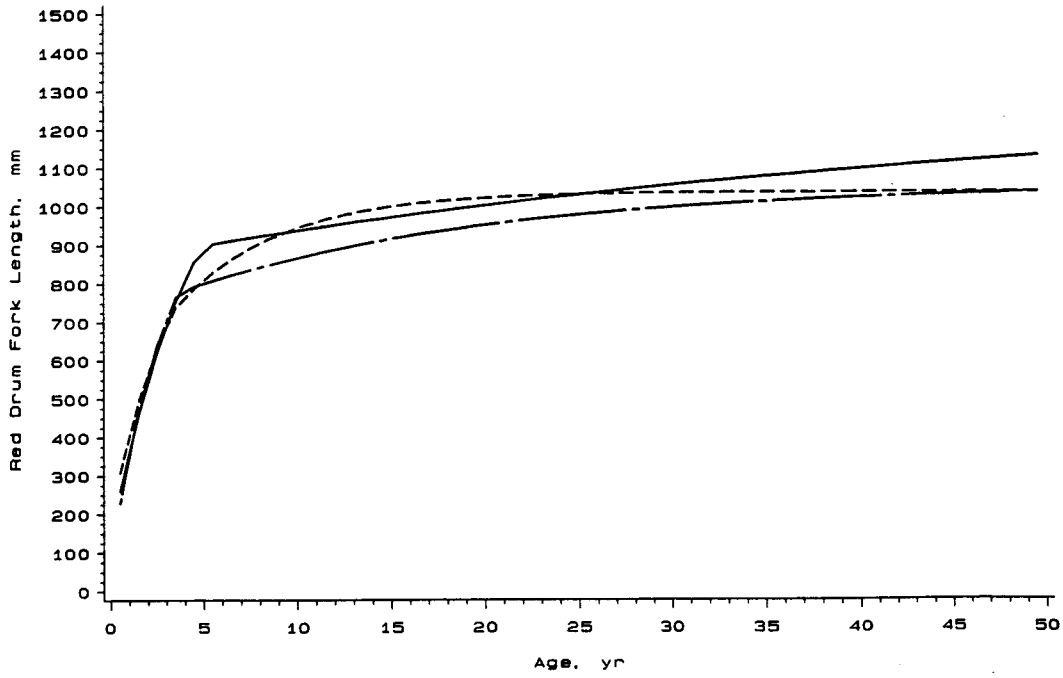


Fig. 30. Comparison of double von Bertalanffy growth equations for red drum from 1981-1983 (solid), 1986 (dashes), and 1988 (dot-dashes).

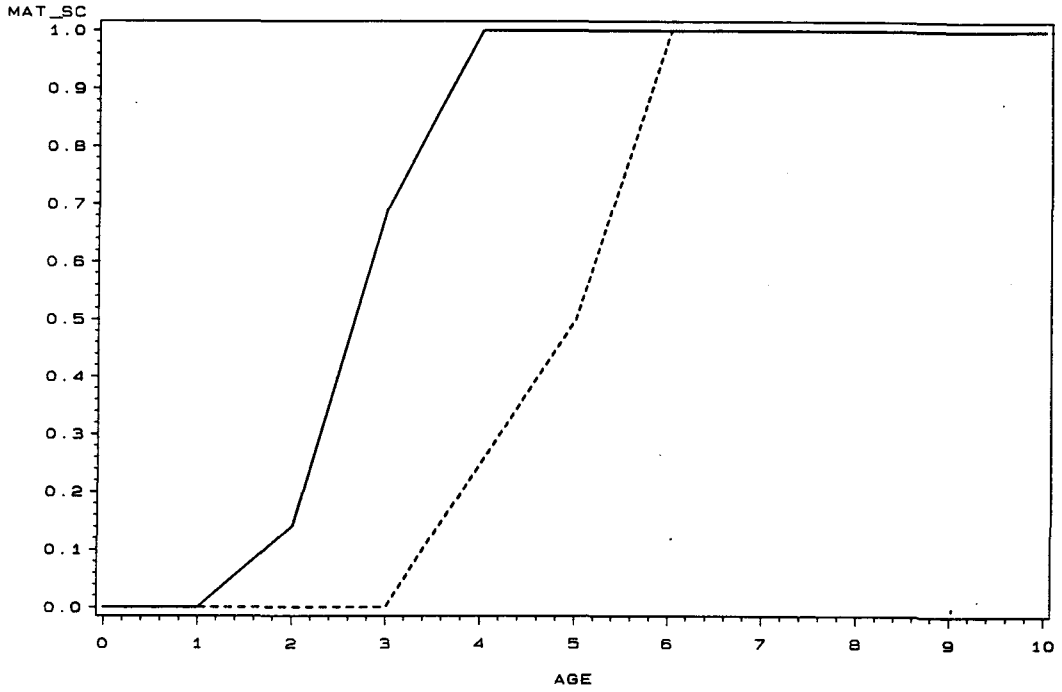


Fig. 31. Comparison of red drum maturity schedules based on data from Florida (FL DNR, n=238, dashes) and South Carolina (SCMRD, n=276, solid).

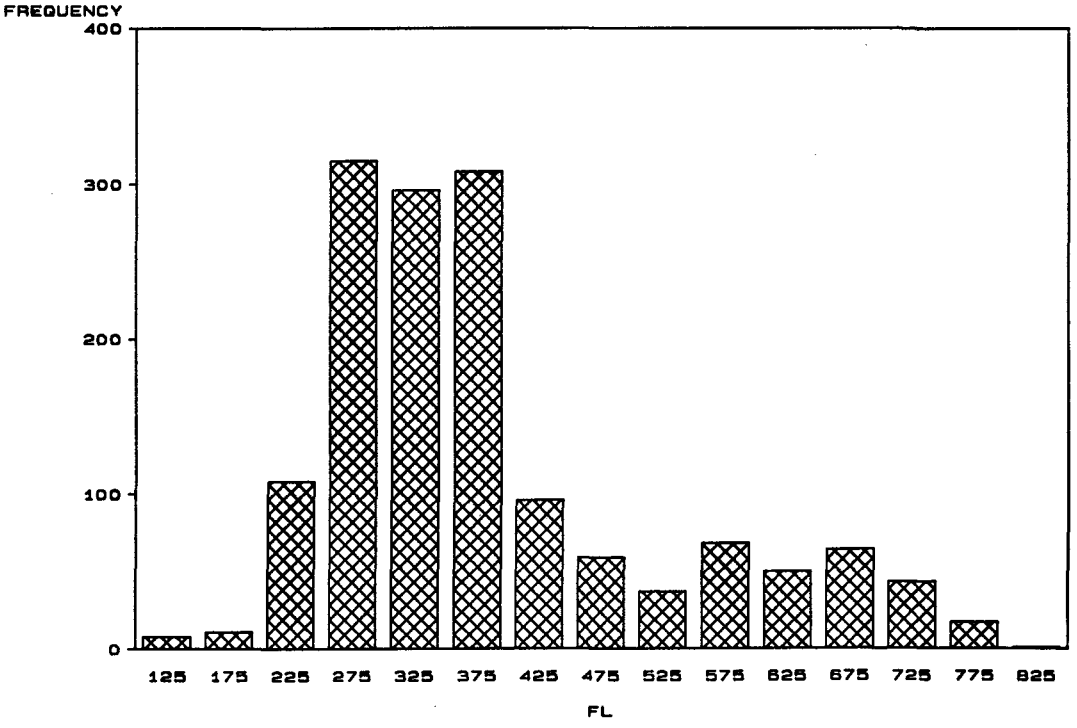


Fig. 32. Length frequencies of red drum from South Carolina stopnet samples for period 1985-1988 (n=1480). Length intervals based on 50 mm width fork lengths.

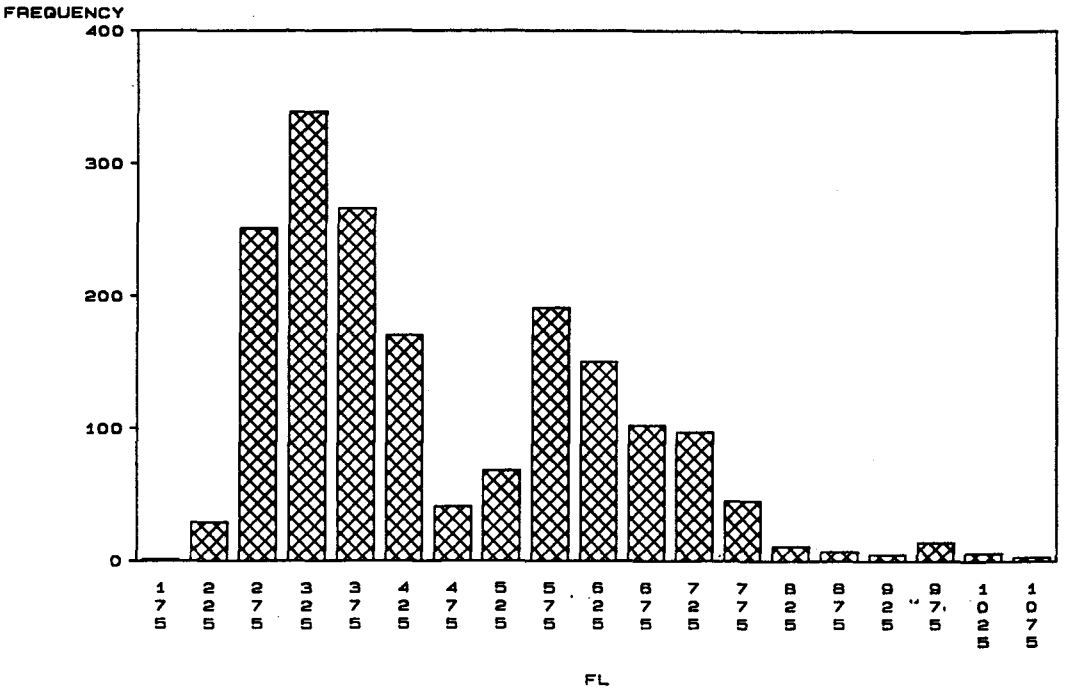


Fig. 33. Length frequencies of red drum from Georgia trammel net samples for period 1986-1988 (n=1673). Length intervals based on 50 mm width fork lengths.

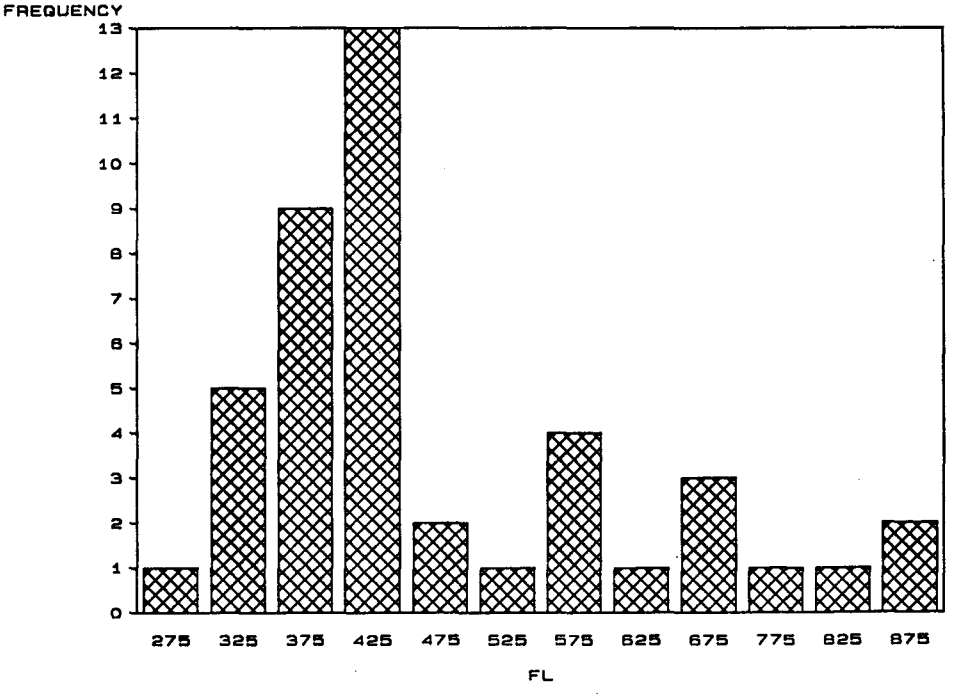


Fig. 34. Length frequencies of red drum from U.S. Fish and Wildlife samples from Mosquito Lagoon for period 1987-1988 (fished area, n=43). Length intervals based on 50 mm width fork lengths.

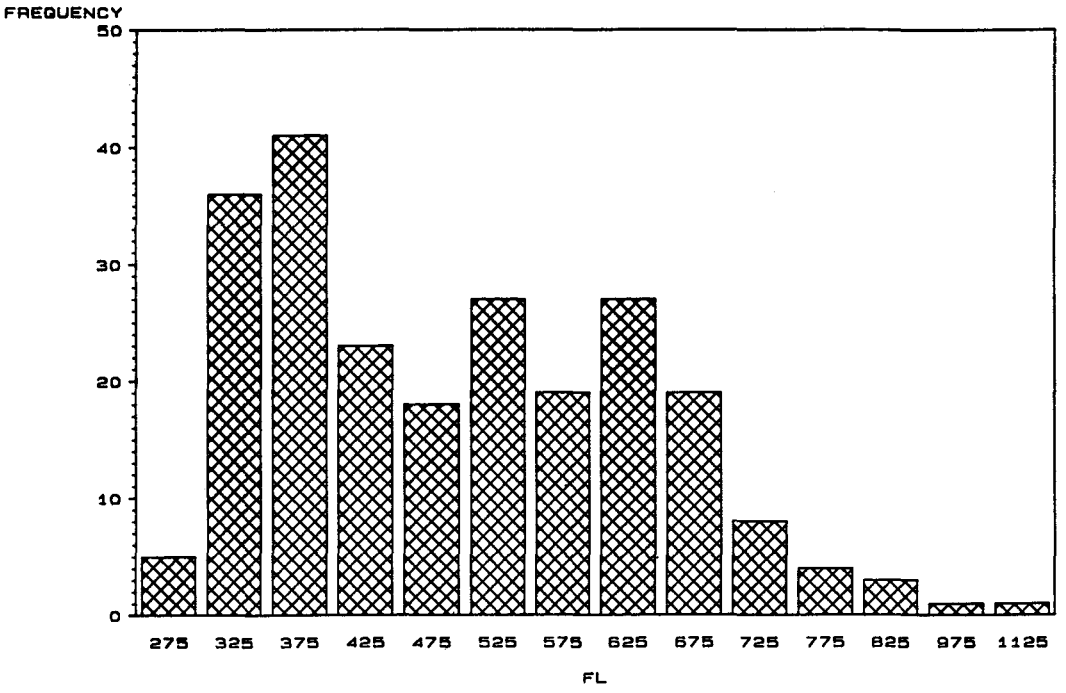


Fig. 35. Length frequencies of red drum from U.S. Fish and Wildlife samples from Mosquito Lagoon for period 1987-1988 (unfished area, n=232). Length intervals based on 50 mm width fork lengths.

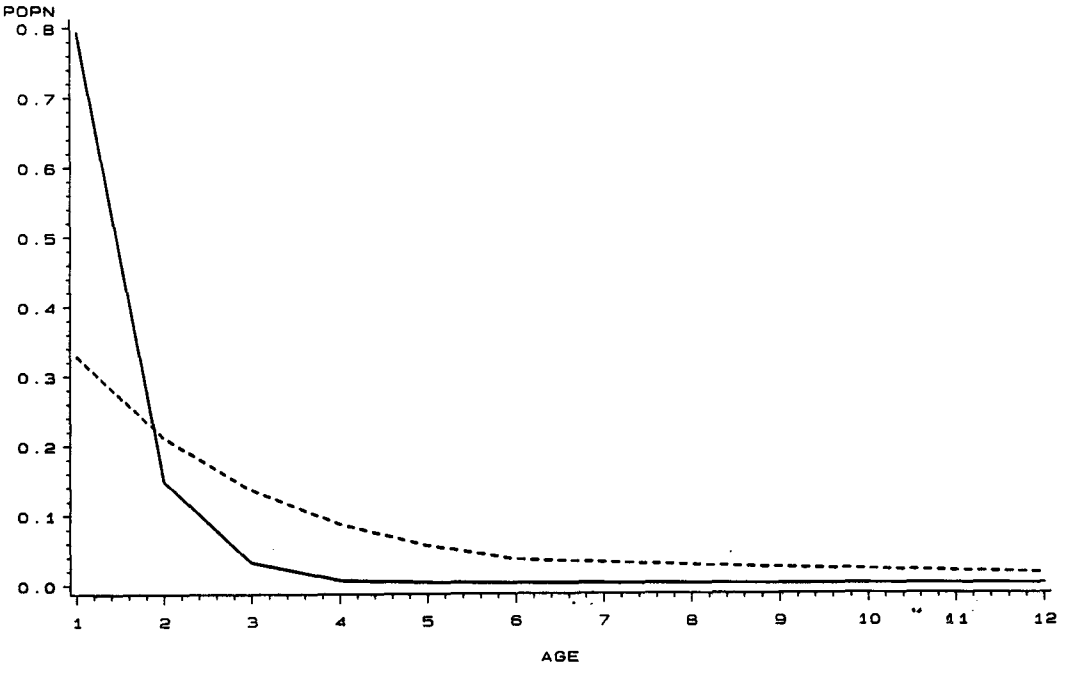


Fig. 36. Relative change in red drum population or cohort numbers with age based estimated age-specific F's from MRFSS scenario and natural mortality set at 0.44 (ages 1-5) and 0.13 (ages 6+). Comparison is made of cohort with F (solid line) and without F (F=0, dashed line).

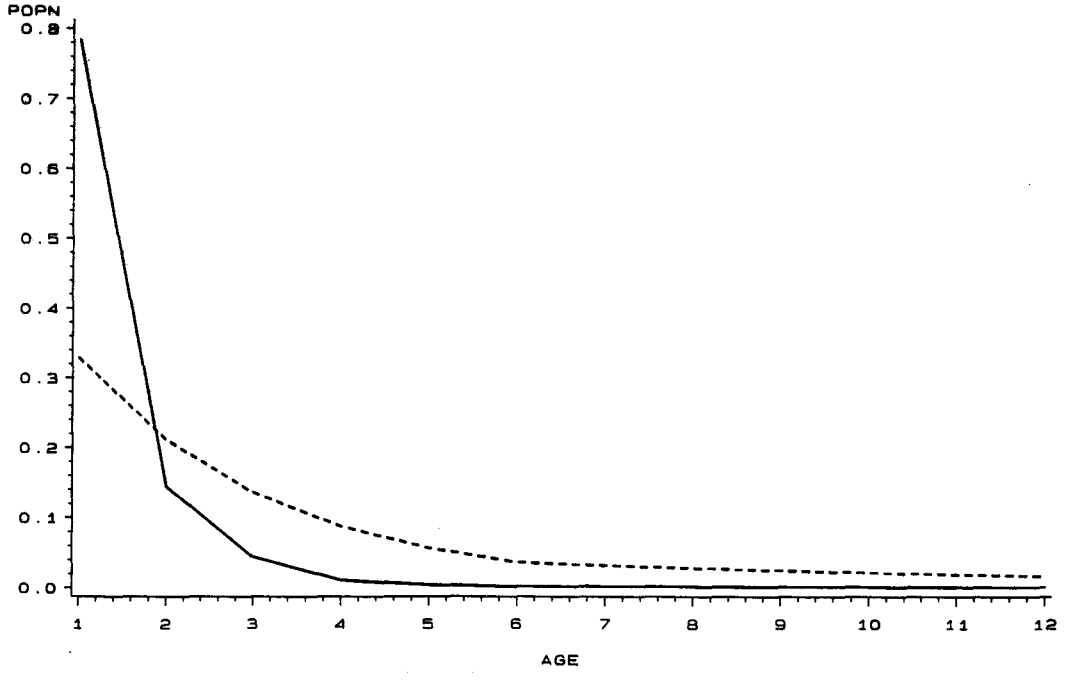


Fig. 37. Relative change in red drum population or cohort numbers with age based estimated age-specific F's from alternate scenario and natural mortality set at 0.44 (ages 1-5) and 0.13 (ages 6+). Comparison is made of cohort with F (solid line) and without F (F=0, dashed line).

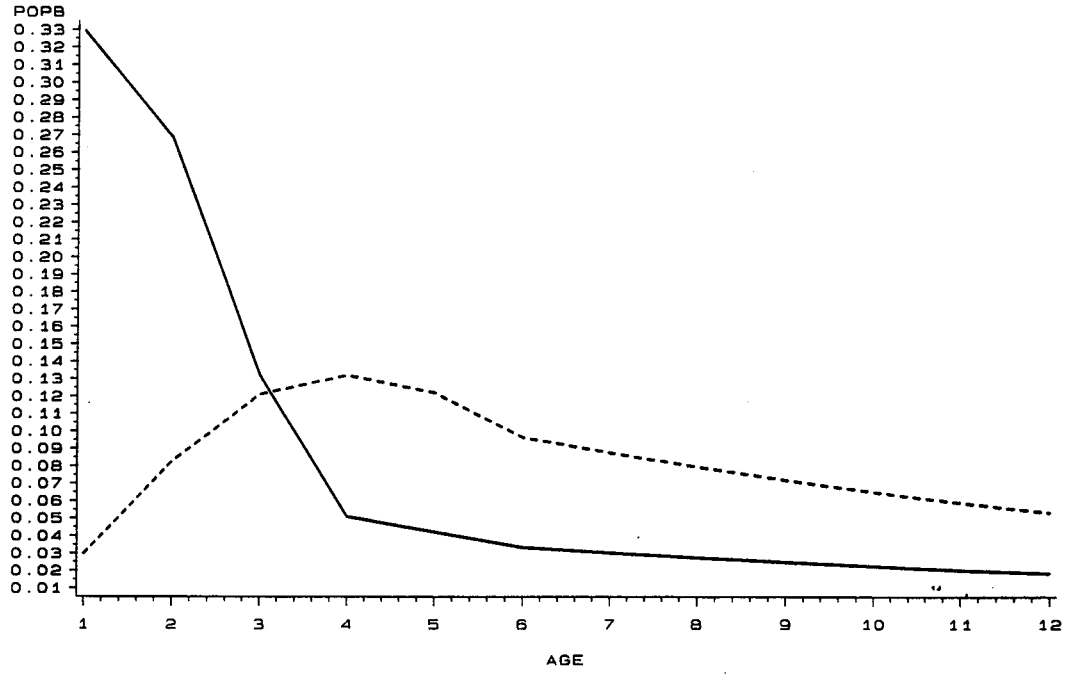


Fig. 38. Relative change in red drum population or cohort biomass with age based estimated age-specific F's from MRFSS scenario and natural mortality set at 0.44 (ages 1-5) and 0.13 (ages 6+). Comparison is made of cohort with F (solid line) and without F (F=0, dashed line).

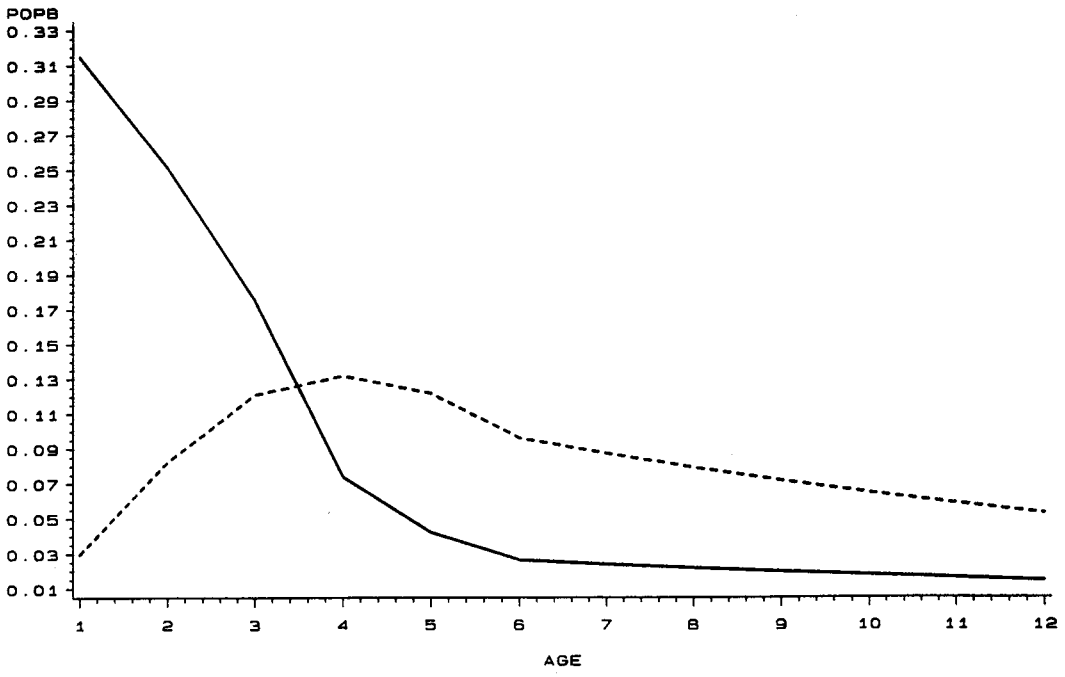


Fig. 39. Relative change in red drum population or cohort biomass with age based estimated age-specific F's from alternate scenario and natural mortality set at 0.44 (ages 1-5) and 0.13 (ages 6+). Comparison is made of cohort with F (solid line) and without F (F=0, dashed line).

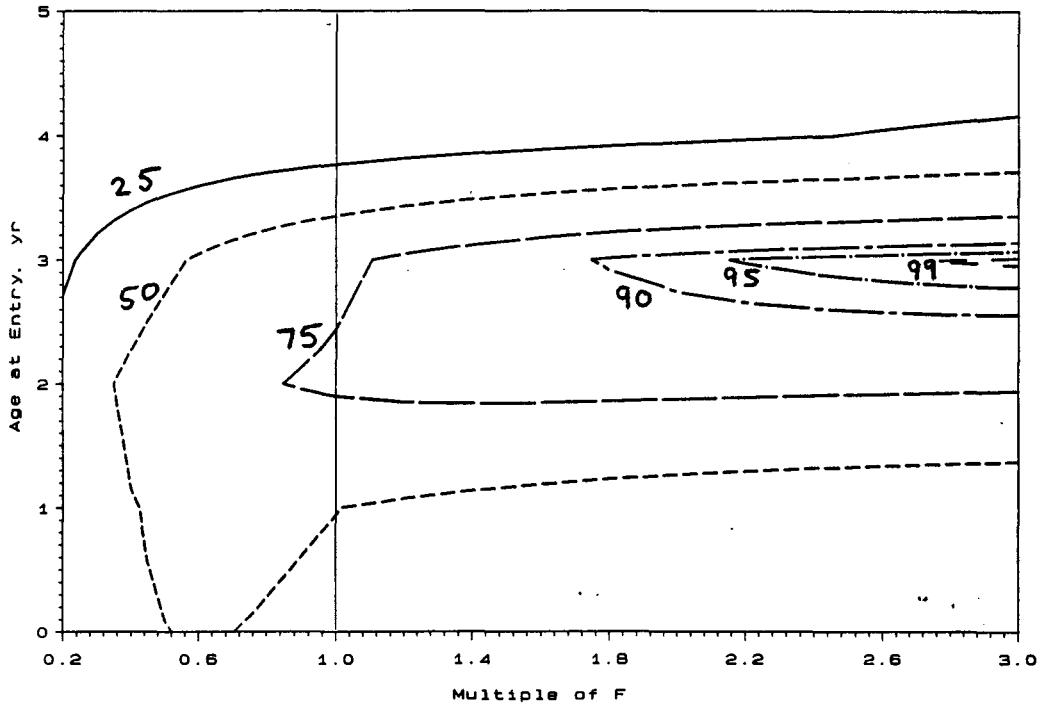


Fig. 40. Yield per recruit (g.) isopleths based on Ricker model using age-specific fishing mortality. Isopleths represent percent of maximum yield and vertical line at average fishing mortality from MRFSS scenario for 1986-1988.

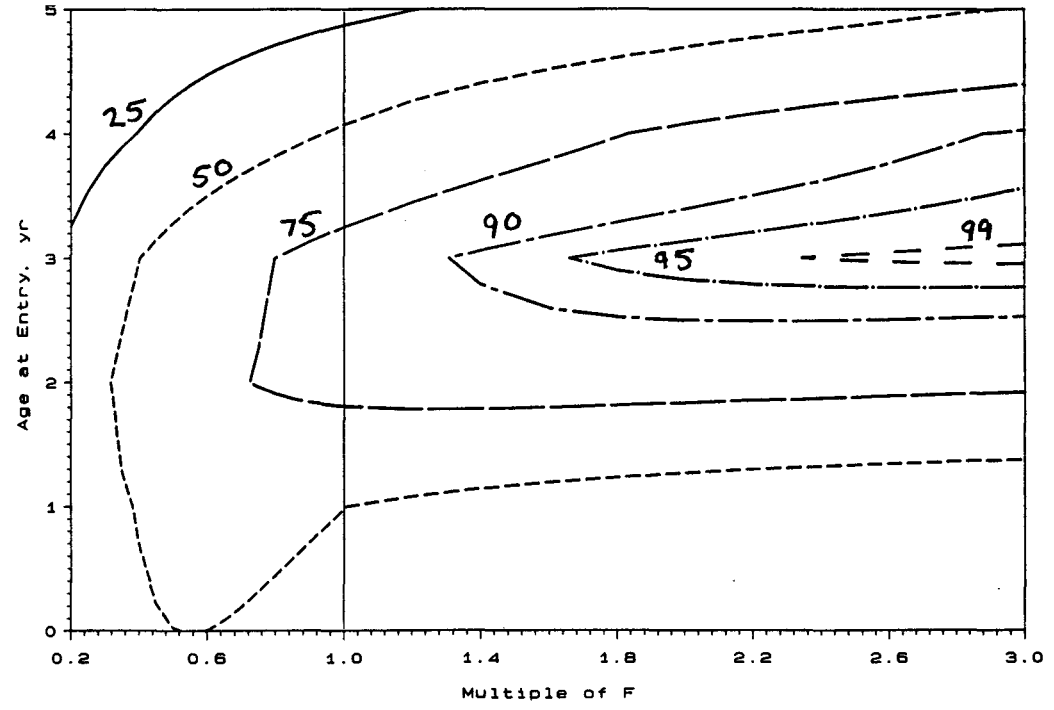


Fig. 41. Yield per recruit (g.) isopleths based on Ricker model using age-specific fishing mortality. Isopleths represent percent of maximum yield and vertical line at average fishing mortality from alternate scenario for 1986-1988.

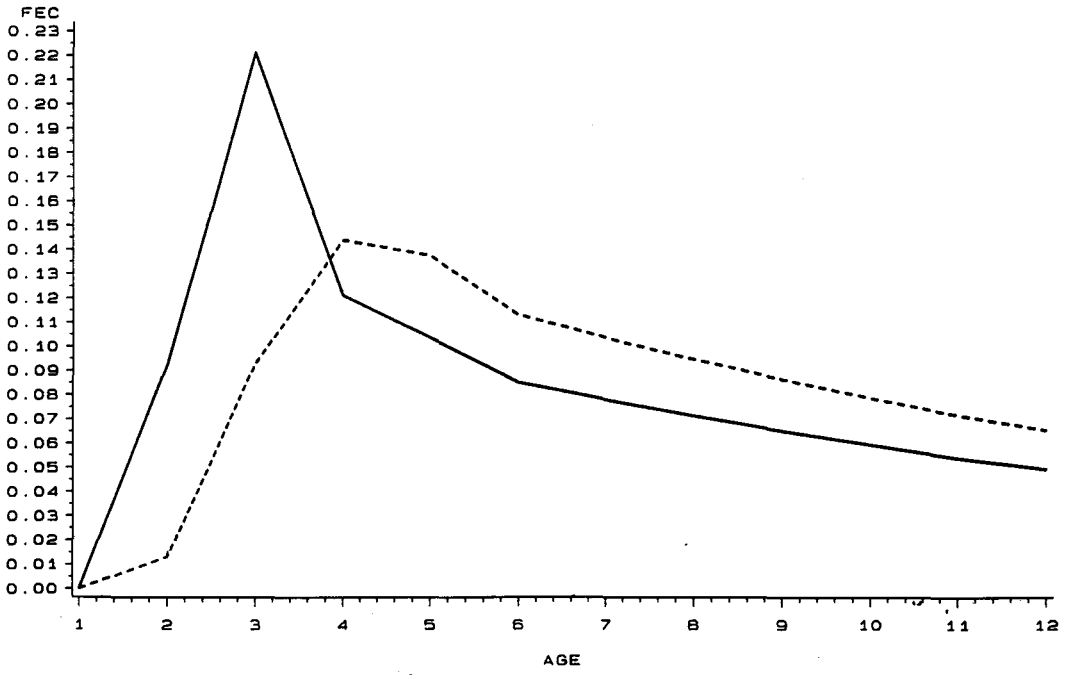


Fig. 42. Relative change in red drum population or cohort fecundity (South Carolina maturity schedule) with age based estimated age-specific F's from MRFSS scenario and natural mortality set at 0.44 (ages 1-5) and 0.13 (ages 6+). Comparison is made of cohort with F (solid line) and without F (F=0, dashed line).

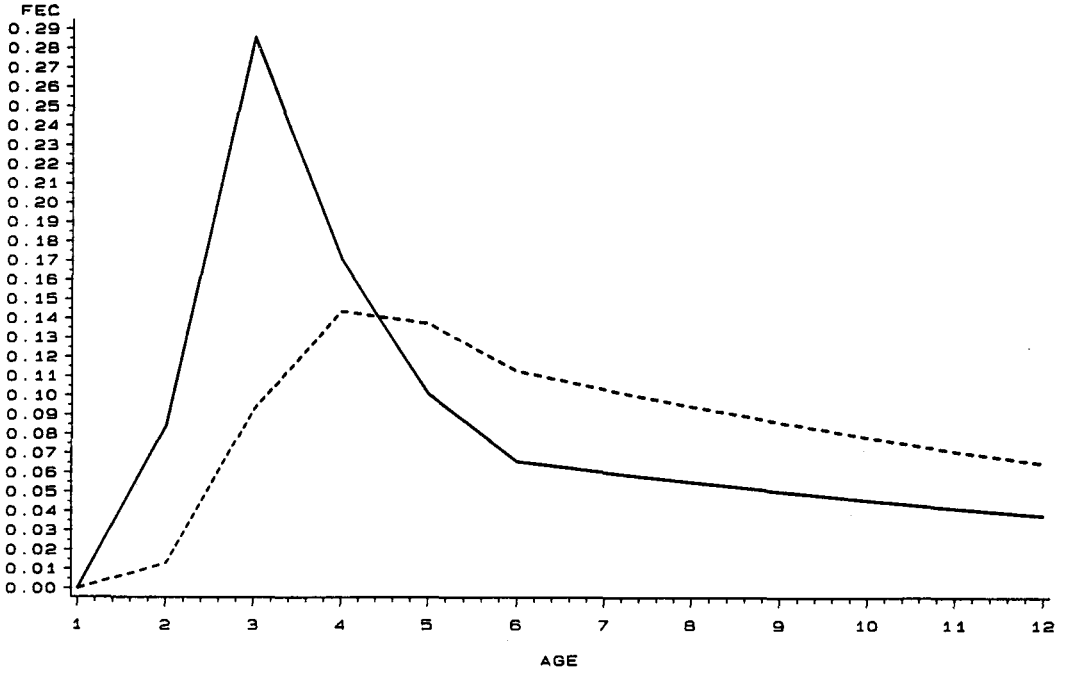


Fig. 43. Relative change in red drum population or cohort fecundity (South Carolina maturity schedule) with age based estimated age-specific F's from alternate scenario and natural mortality set at 0.44 (ages 1-5) and 0.13 (ages 6+). Comparison is made of cohort with F (solid line) and without F (F=0, dashed line).

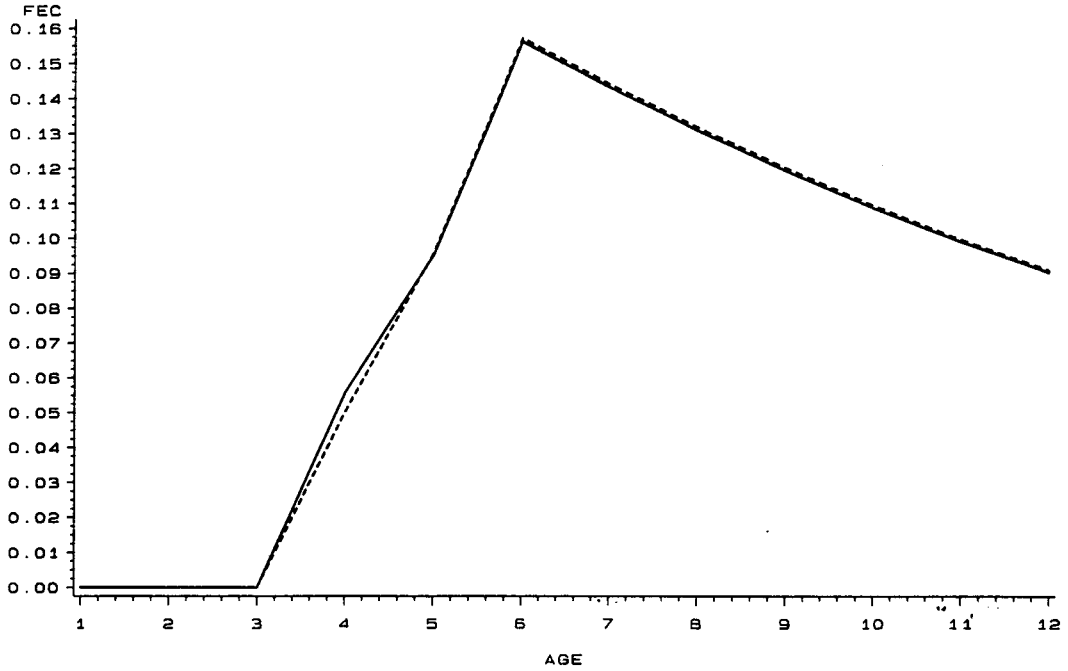


Fig. 44. Relative change in red drum population or cohort fecundity (Florida maturity schedule) with age based estimated age-specific F's from MRFSS scenario and natural mortality set at 0.44 (ages 1-5) and 0.13 (ages 6+). Comparison is made of cohort with F (solid line) and without F (F=0, dashed line).

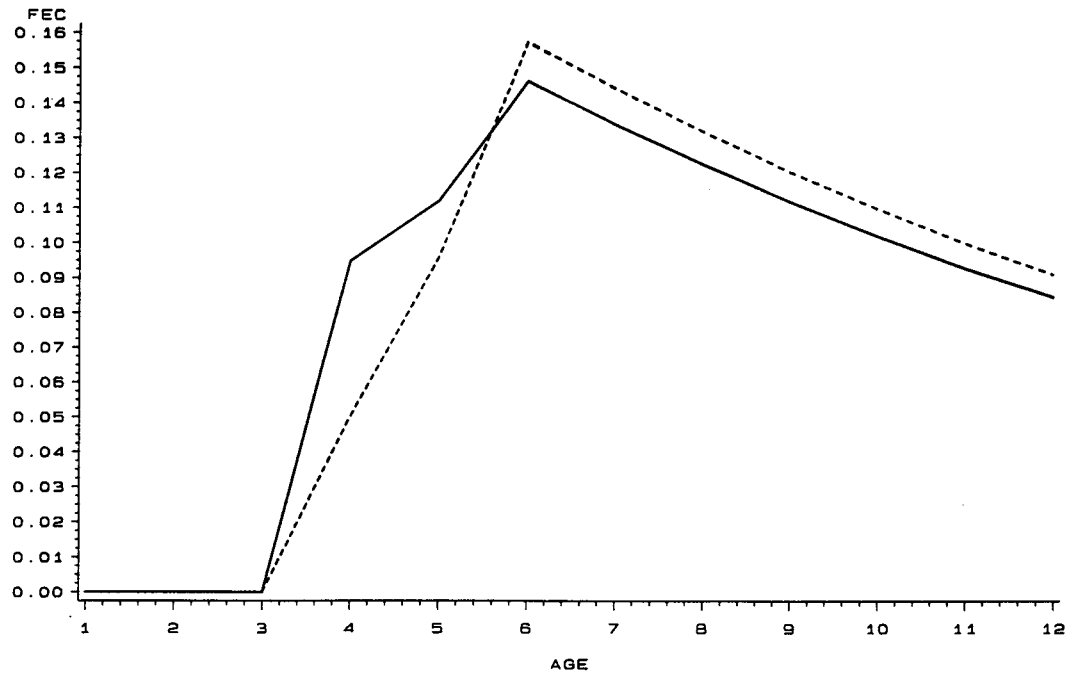


Fig. 45. Relative change in red drum population or cohort fecundity (Florida maturity schedule) with age based estimated age-specific F's from alternate scenario and natural mortality set at 0.44 (ages 1-5) and 0.13 (ages 6+). Comparison is made of cohort with F (solid line) and without F (F=0, dashed line).

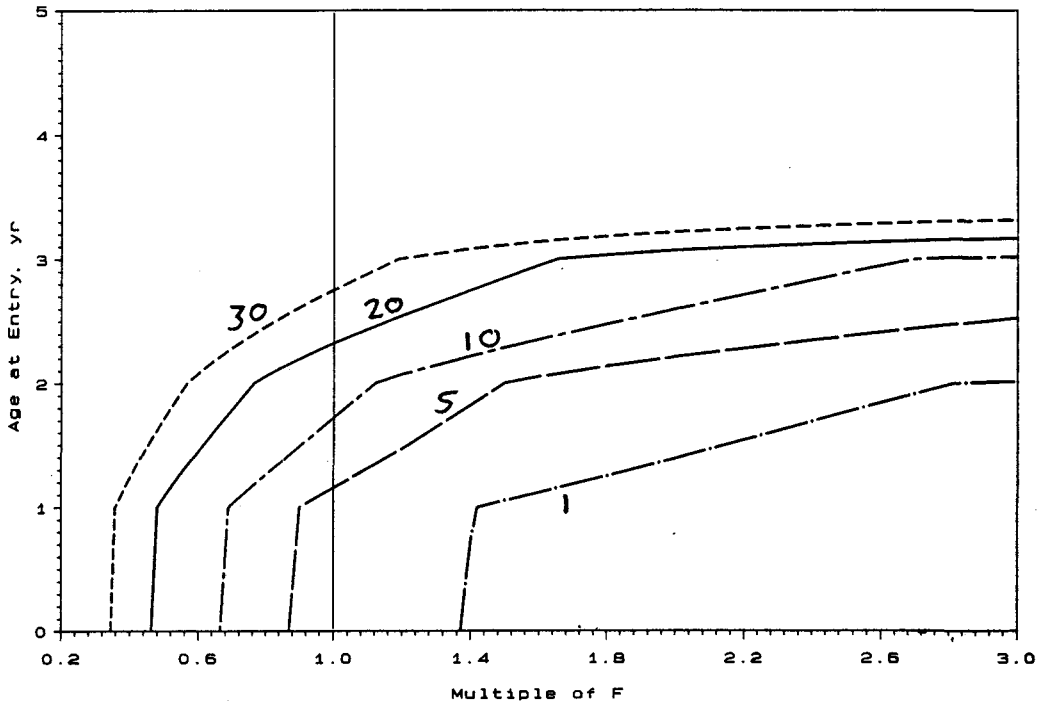


Fig. 46. Spawning stock ratio isopleth for red drum based on spawning stock biomass using South Carolina maturity schedule. Isopleths represent percent of spawning stock with F=0. Age-specific F's based on MRFSS scenario for 1986-1988. Natural mortality set to 0.44 (ages 1-5) and 0.13 (ages 6+).

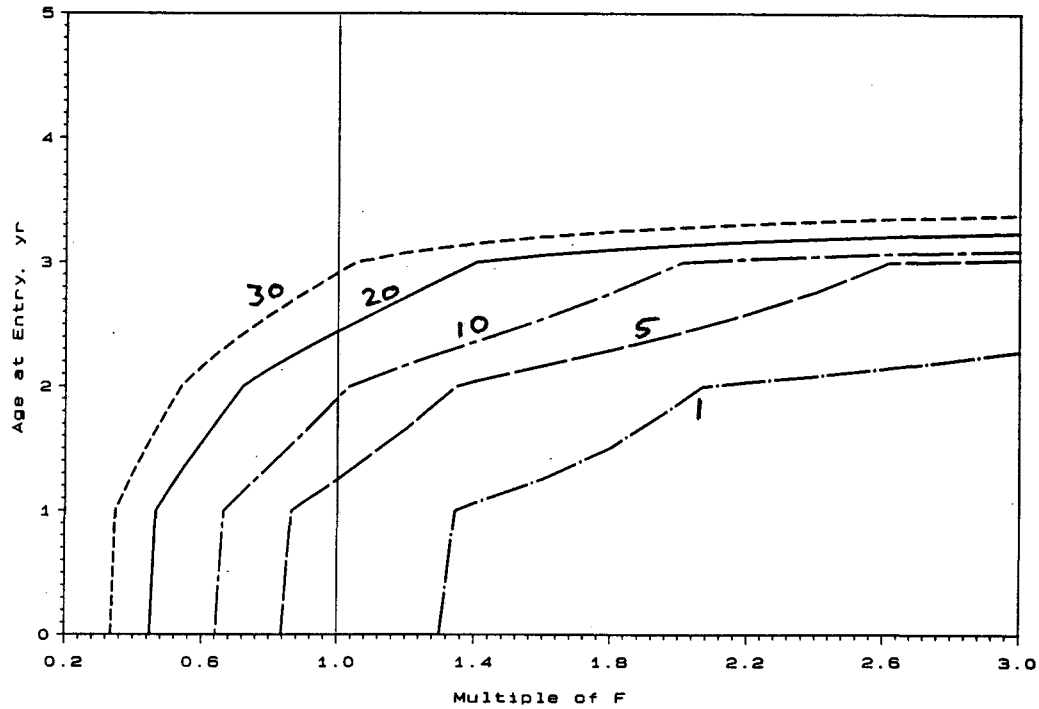


Fig. 47. Spawning stock ratio isopleth for red drum based on spawning stock biomass using Florida maturity schedule. Isopleths represent percent of spawning stock with F=0. Age-specific F's based on MRFSS scenario for 1986-1988. Natural mortality set to 0.44 (ages 1-5) and 0.13 (ages 6+).

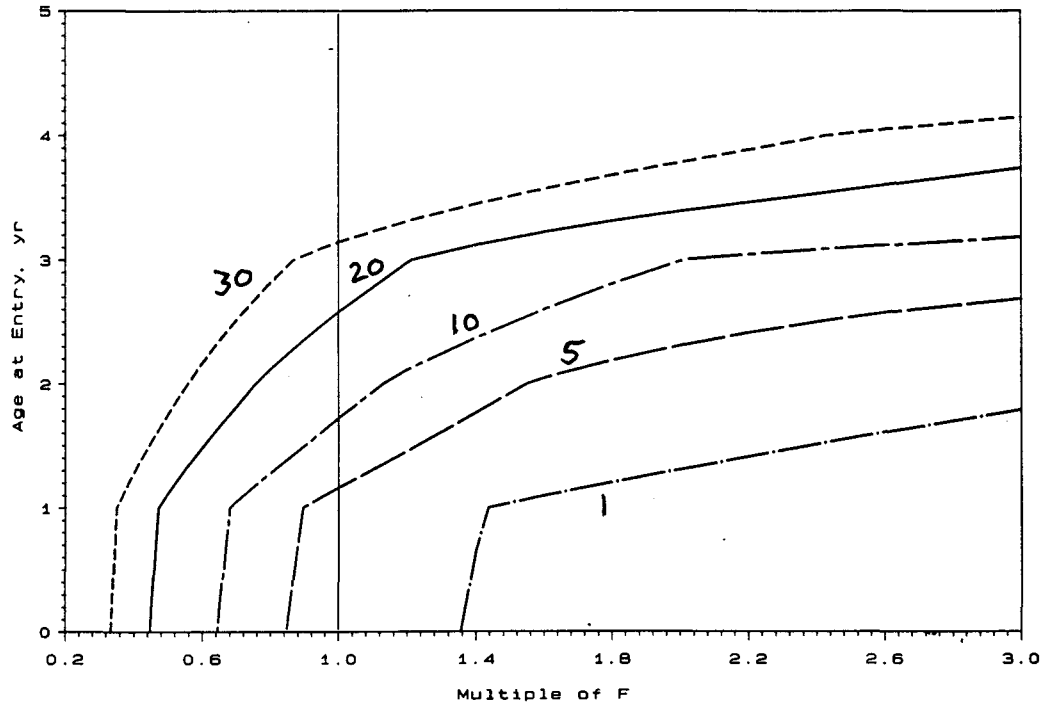


Fig. 48. Spawning stock ratio isopleth for red drum based on spawning stock biomass using South Carolina maturity schedule. Isopleths represent percent of spawning stock with F=0. Age-specific F's based on alternate scenario for 1986-1988. Natural mortality set to 0.44 (ages 1-5) and 0.13 (ages 6+).

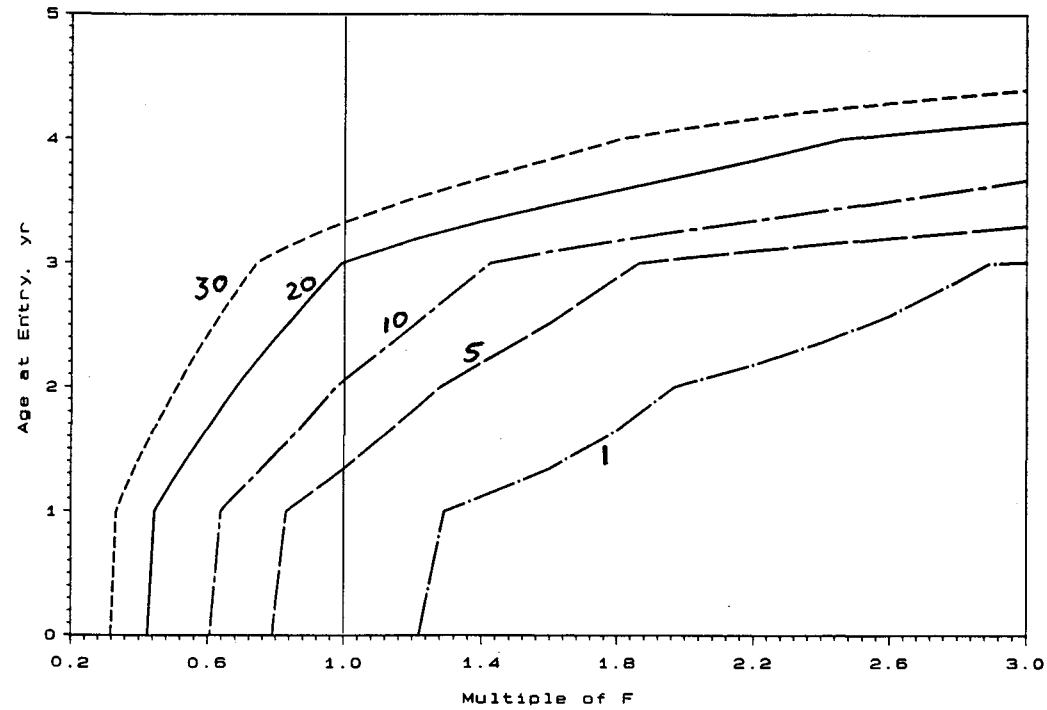


Fig. 49. Spawning stock ratio isopleth for red drum based on spawning stock biomass using Florida maturity schedule. Isopleths represent percent of spawning stock with F=0. Age-specific F's based on alternate scenario for 1986-1988. Natural mortality set to 0.44 (ages 1-5) and 0.13 (ages 6+).

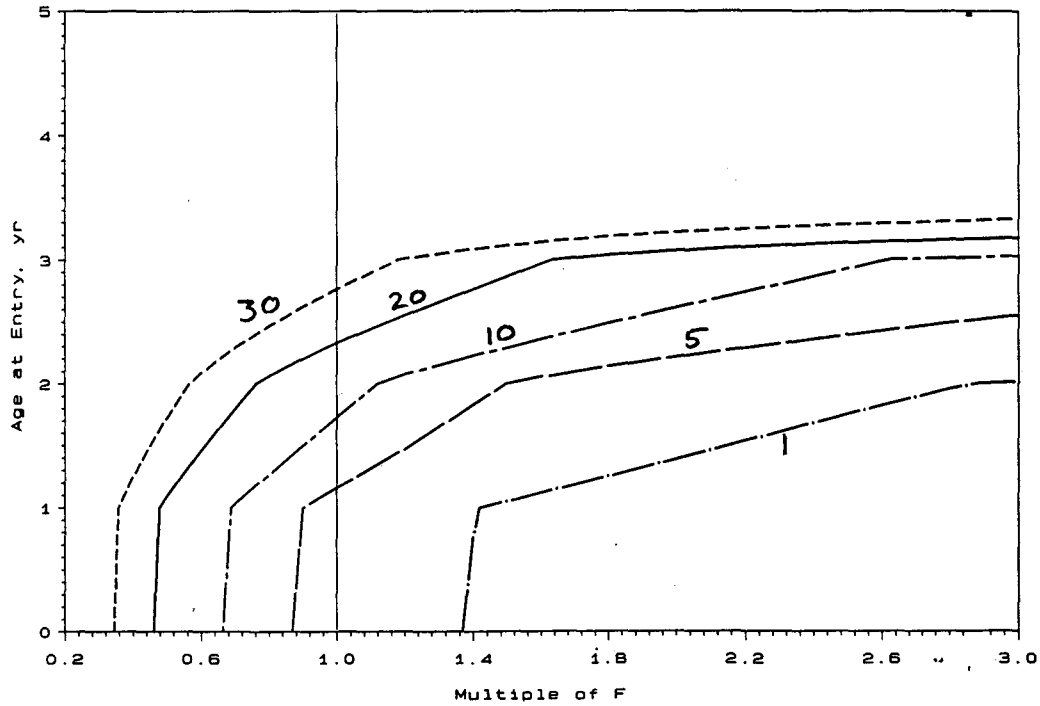


Fig. 50. Spawning stock ratio isopleth for red drum based on fecundity (Overstreet 1983) using South Carolina maturity schedule. Isopleths represent percent of spawning stock with F=0. Age-specific F's based on MRFSS scenario for 1986-1988. Natural mortality set to 0.44 (ages 1-5) and 0.13 (ages 6+).

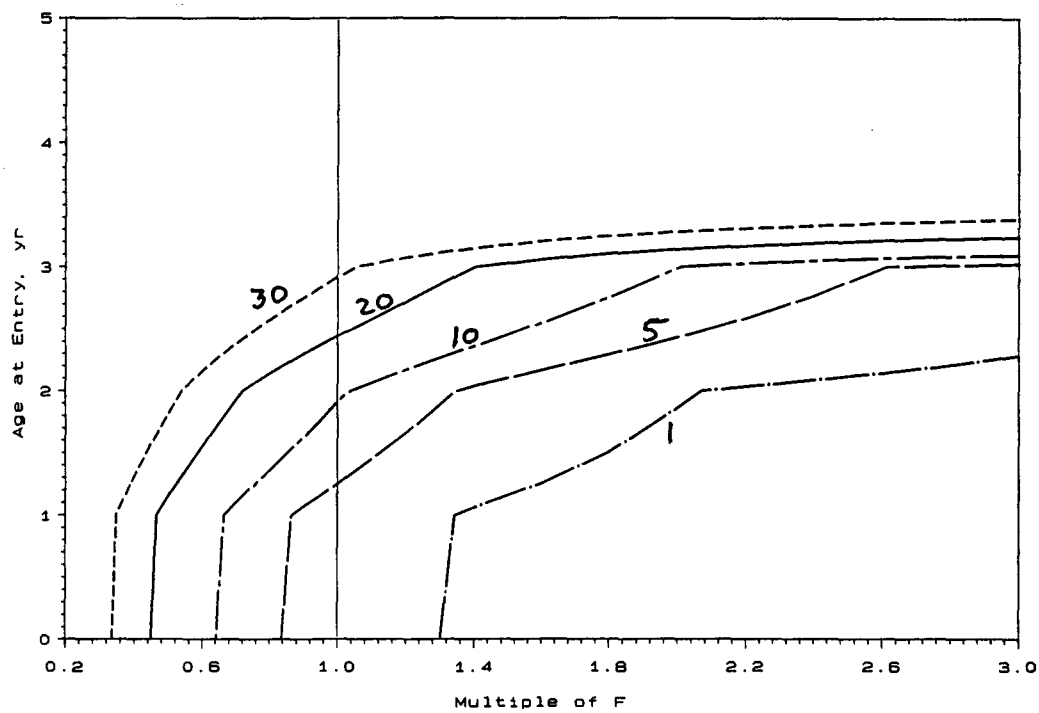


Fig. 51. Spawning stock ratio isopleth for red drum based on fecundity (Overstreet 1983) using Florida maturity schedule. Isopleths represent percent of spawning stock with F=0. Age-specific F's based on MRFSS scenario for 1986-1988. Natural mortality set to 0.44 (ages 1-5) and 0.13 (ages 6+).

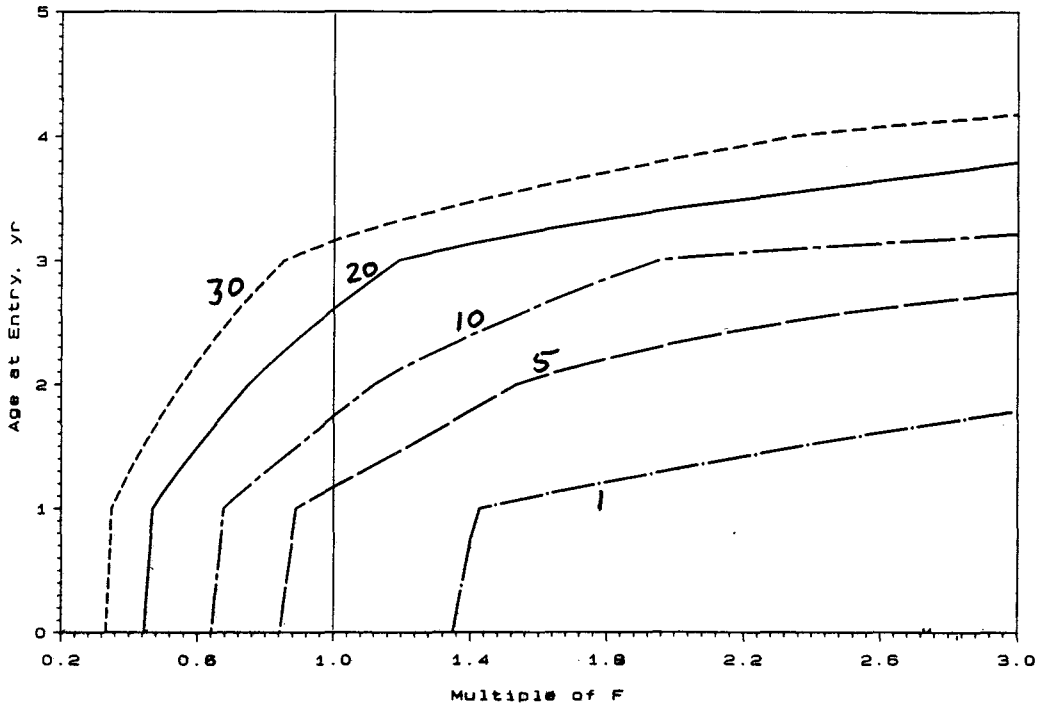


Fig. 52. Spawning stock ratio isopleth for red drum based on fecundity (Overstreet 1983) using South Carolina maturity schedule. Isopleths represent percent of spawning stock with F=0. Age-specific F's based on alternate scenario for 1986-1988. Natural mortality set to 0.44 (ages 1-5) and 0.13 (ages 6+).

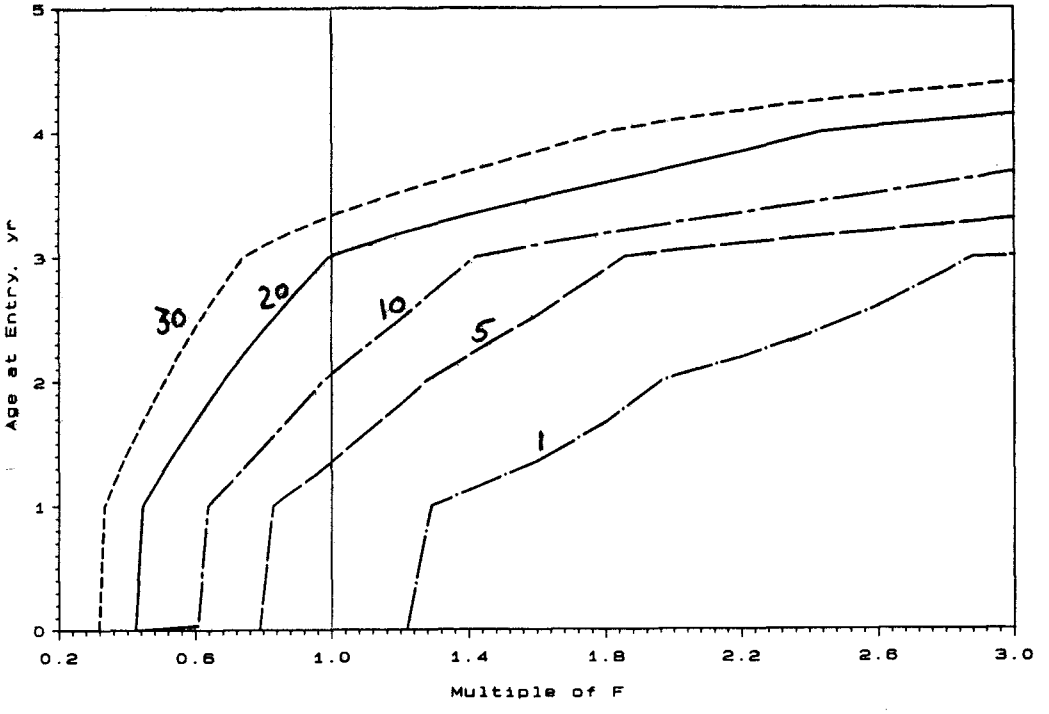


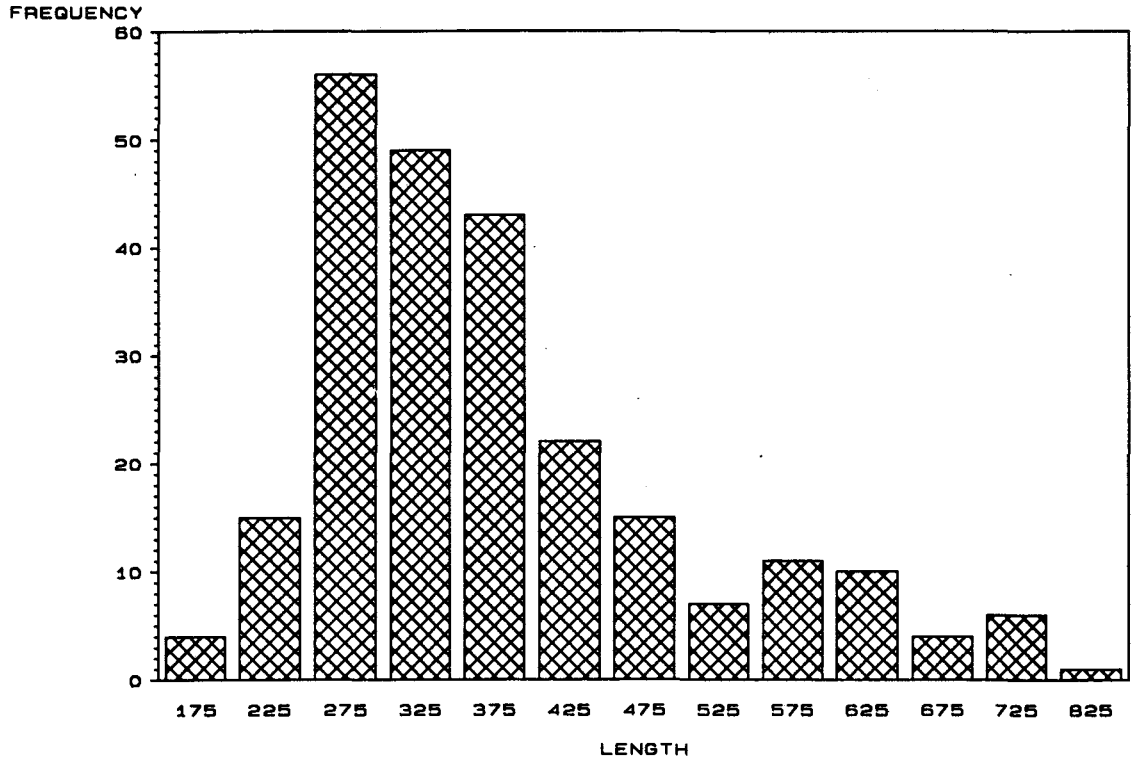
Fig. 53. Spawning stock ratio isopleth for red drum based on fecundity (Overstreet 1983) using Florida maturity schedule. Isopleths represent percent of spawning stock with F=0. Age-specific F's based on alternate scenario for 1986-1988. Natural mortality set to 0.44 (ages 1-5) and 0.13 (ages 6+).

APPENDIX A.

ANNUAL LENGTH FREQUENCIES OF MRFSS SAMPLING OF RED DRUM.

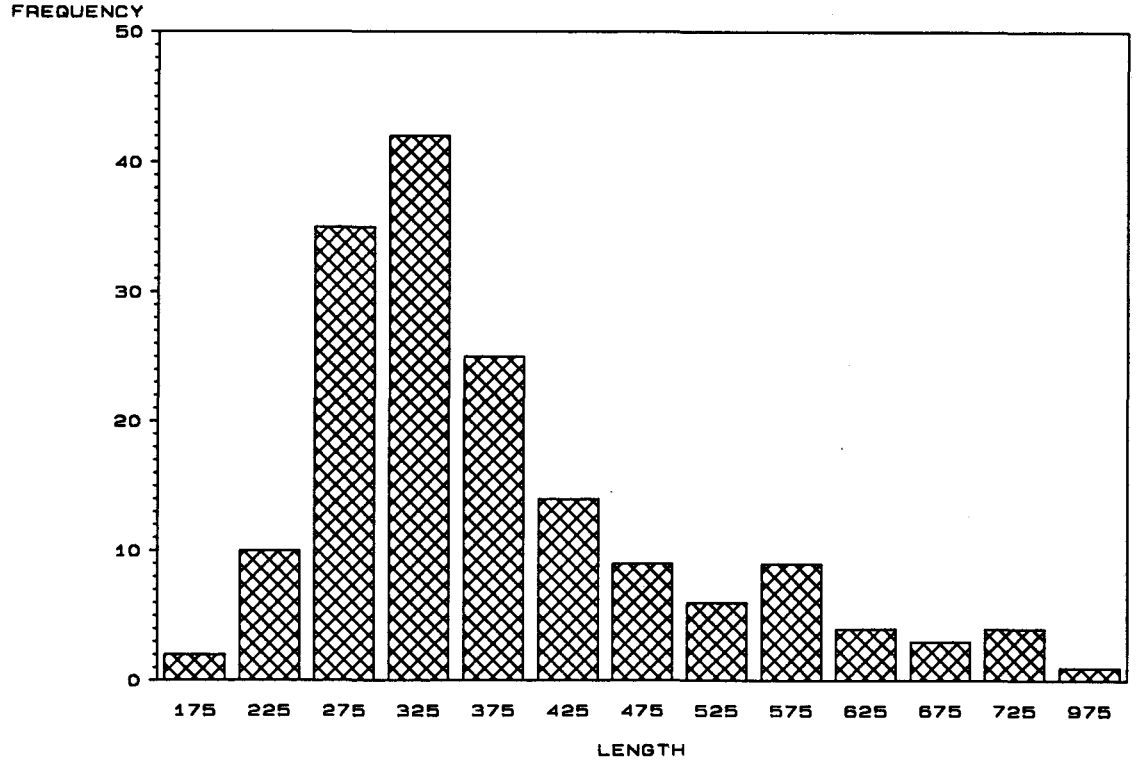
Annual Length Frequencies of MRFSS Sampling of Red Drum

YEAR=79



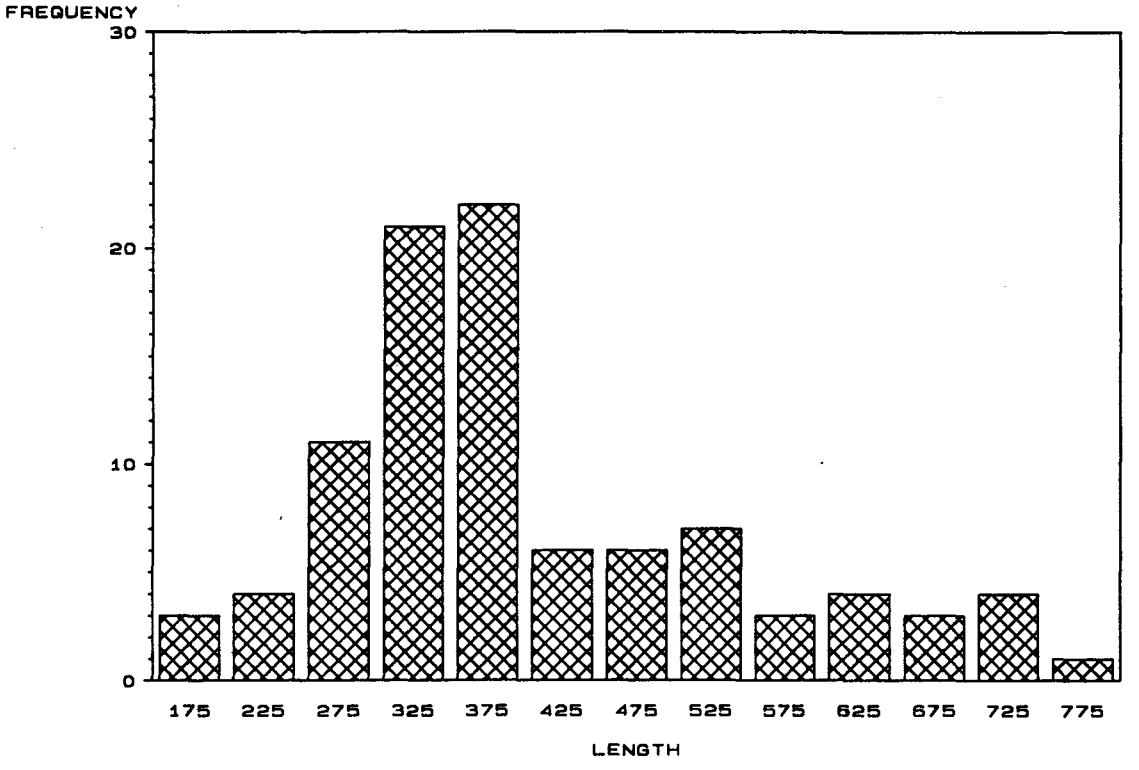
Annual Length Frequencies of MRFSS Sampling of Red Drum

YEAR=80



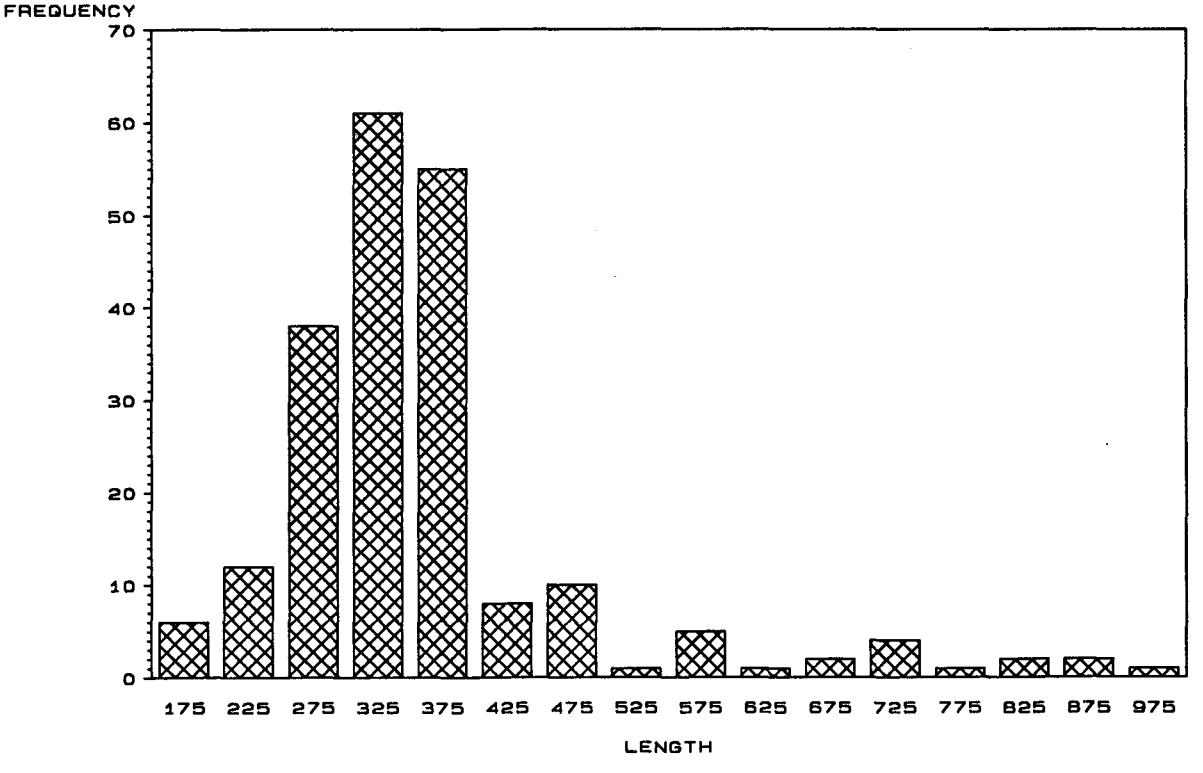
Annual Length Frequencies of MRFSS Sampling of Red Drum

YEAR=81



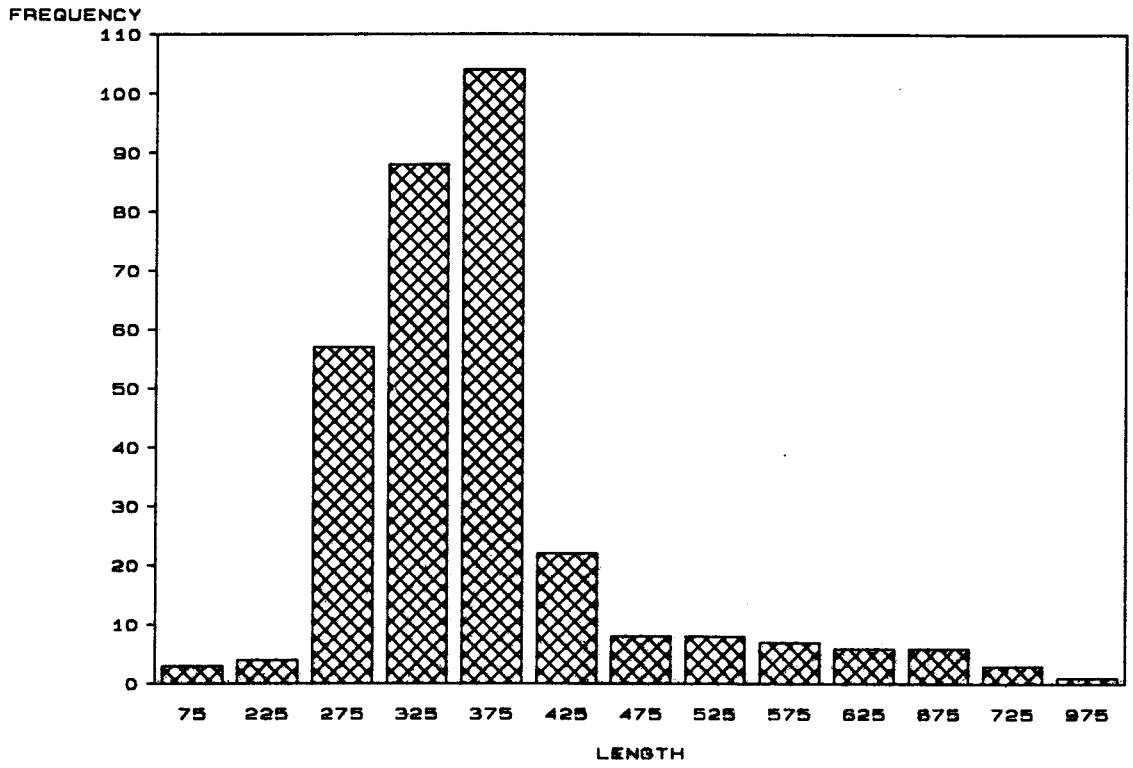
Annual Length Frequencies of MRFSS Sampling of Red Drum

YEAR=82



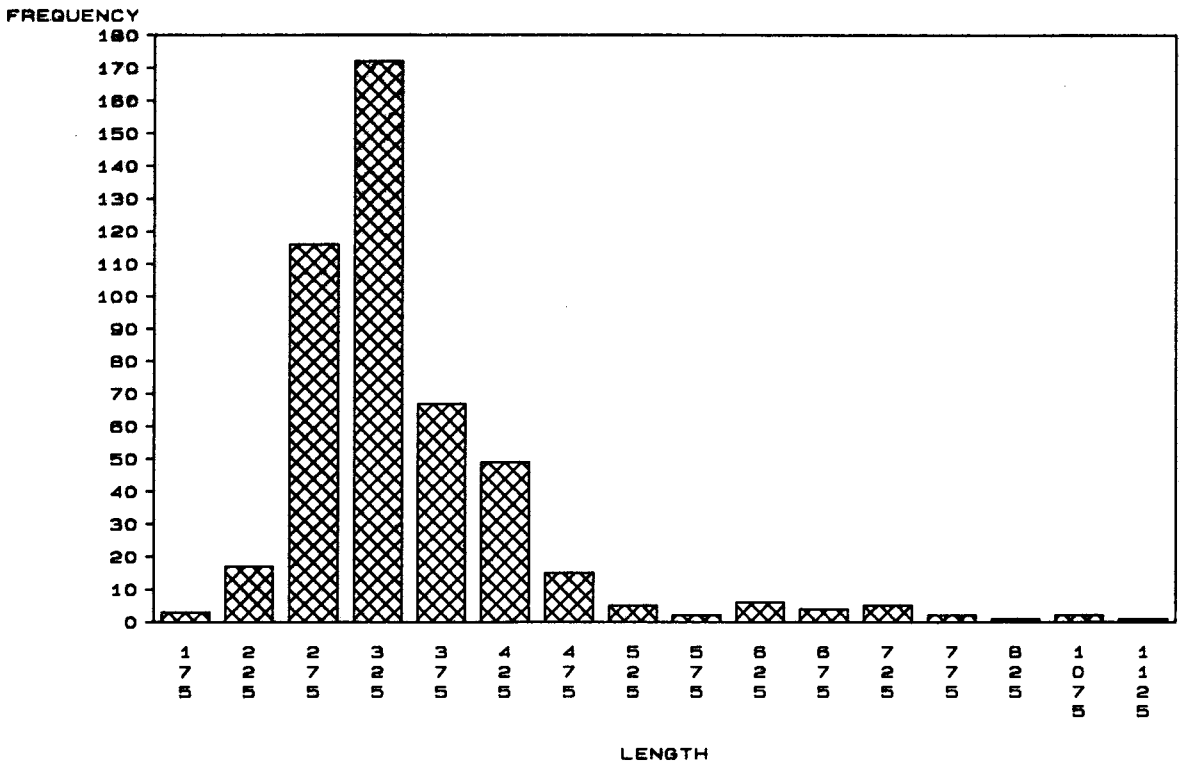
Annual Length Frequencies of MRFSS Sampling of Red Drum

YEAR=83



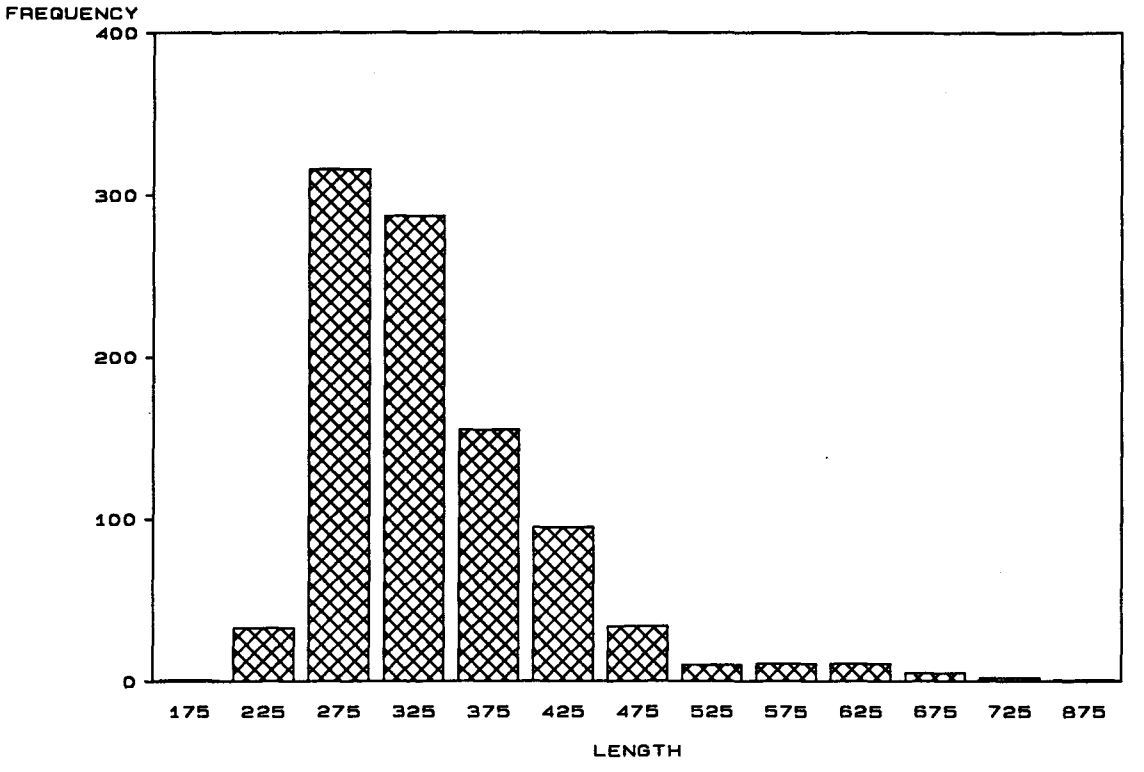
Annual Length Frequencies of MRFSS Sampling of Red Drum

YEAR=84



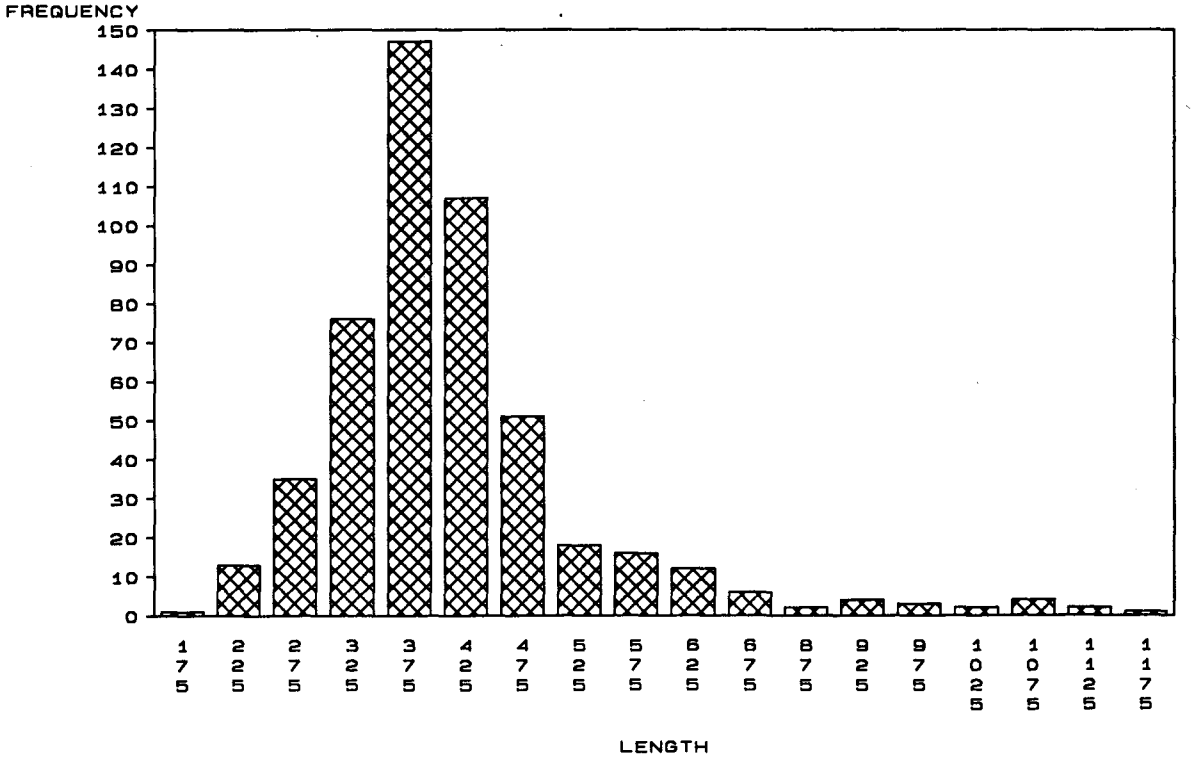
Annual Length Frequencies of MRFSS Sampling of Red Drum

YEAR=85



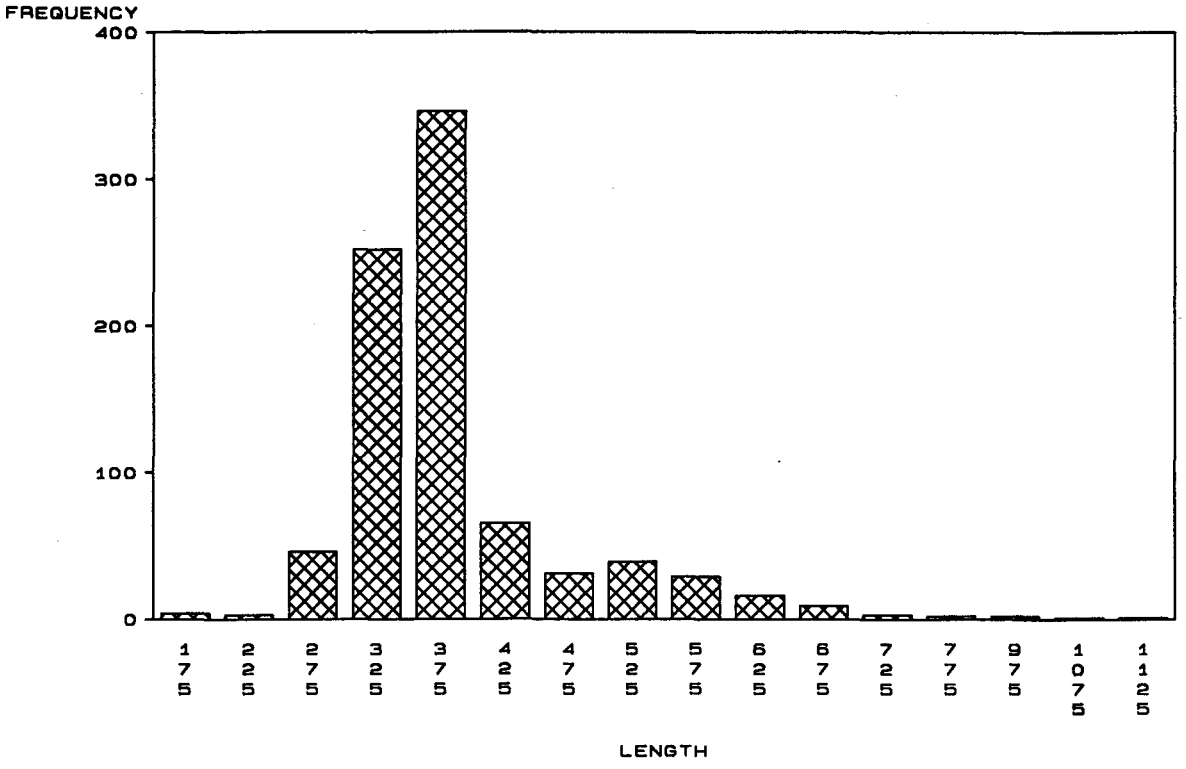
Annual Length Frequencies of MRFSS Sampling of Red Drum

YEAR=86



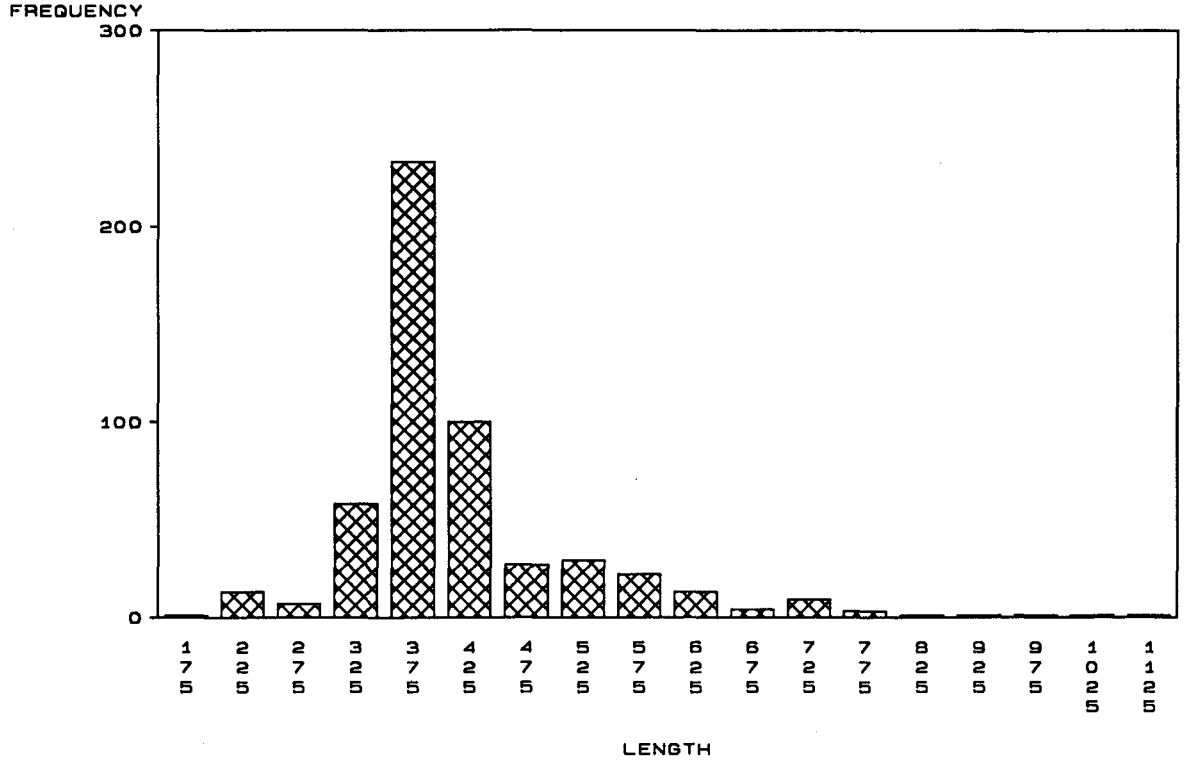
Annual Length Frequencies of MRFSS Sampling of Red Drum

YEAR=87



Annual Length Frequencies of MRFSS Sampling of Red Drum

YEAR=88

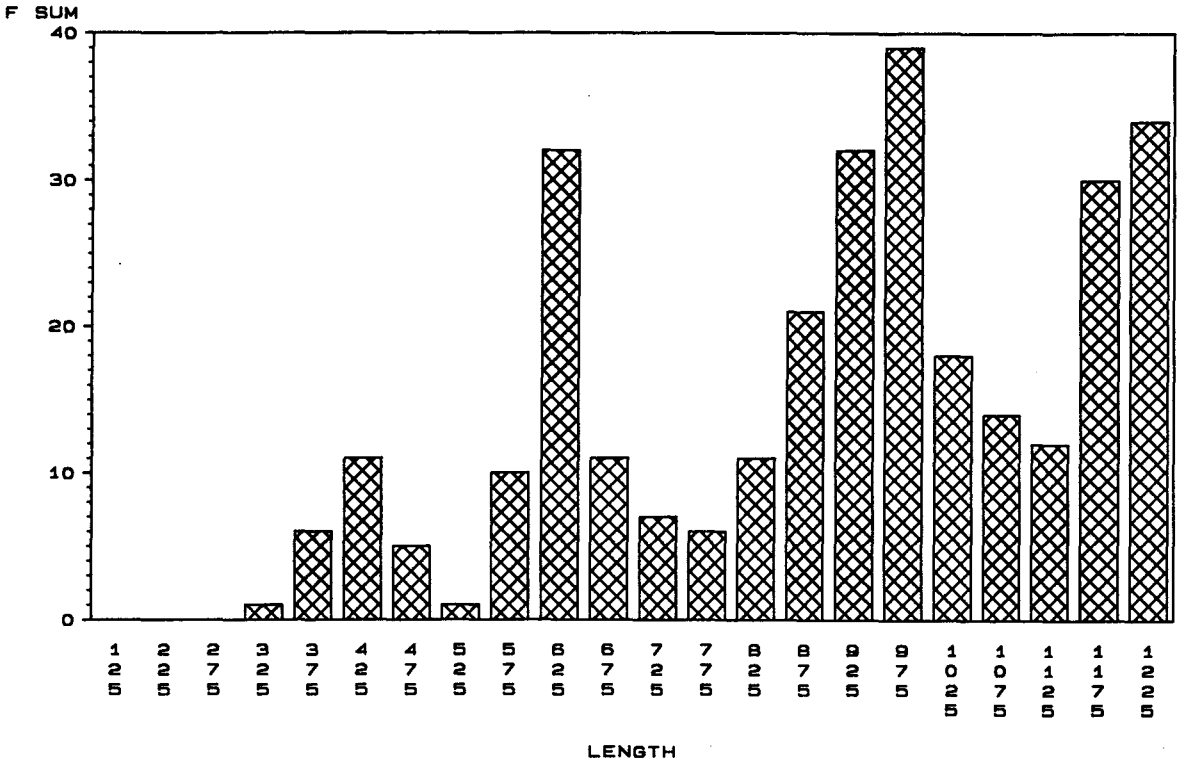


APPENDIX B.

ANNUAL LENGTH FREQUENCIES FOR RED DRUM TAGGED BY RECREATIONAL ANGLERS FROM NORTH CAROLINA, SOUTH CAROLINA AND GEORGIA.

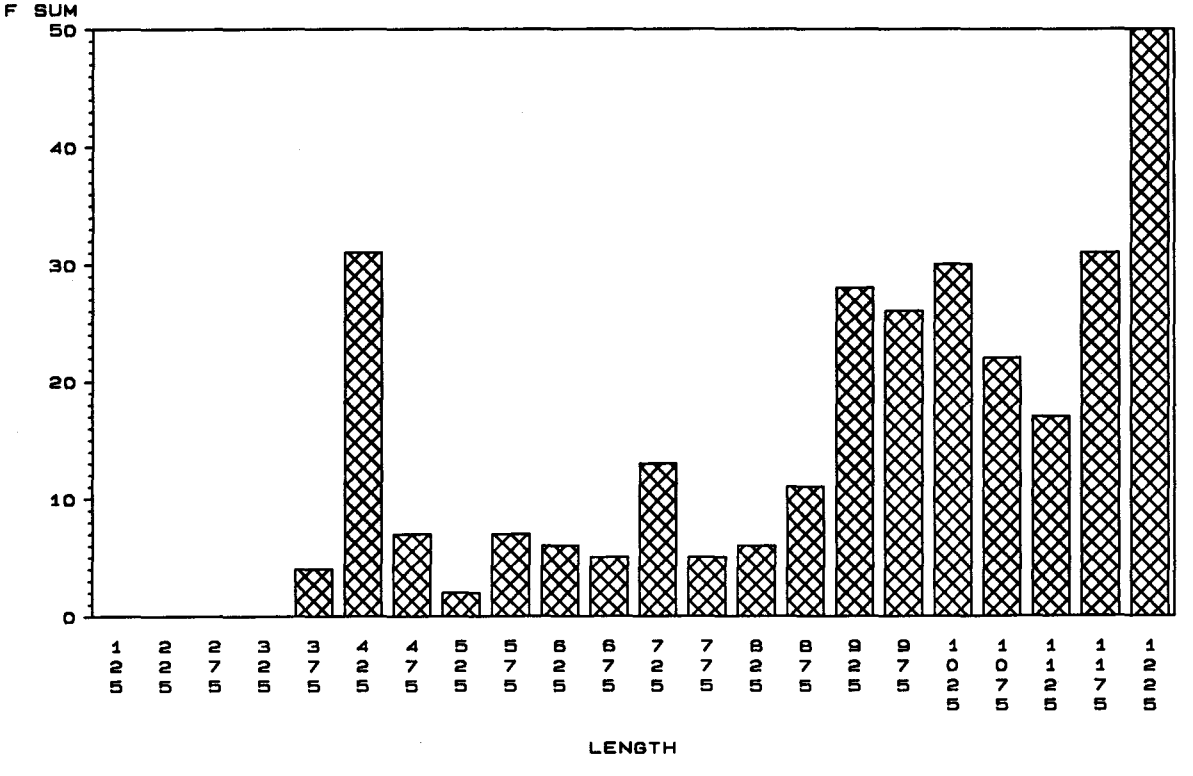
LENGTH FREQUENCIES FOR RED DRUM FROM NORTH CAROLINA

GEAR=lines YEAR=84



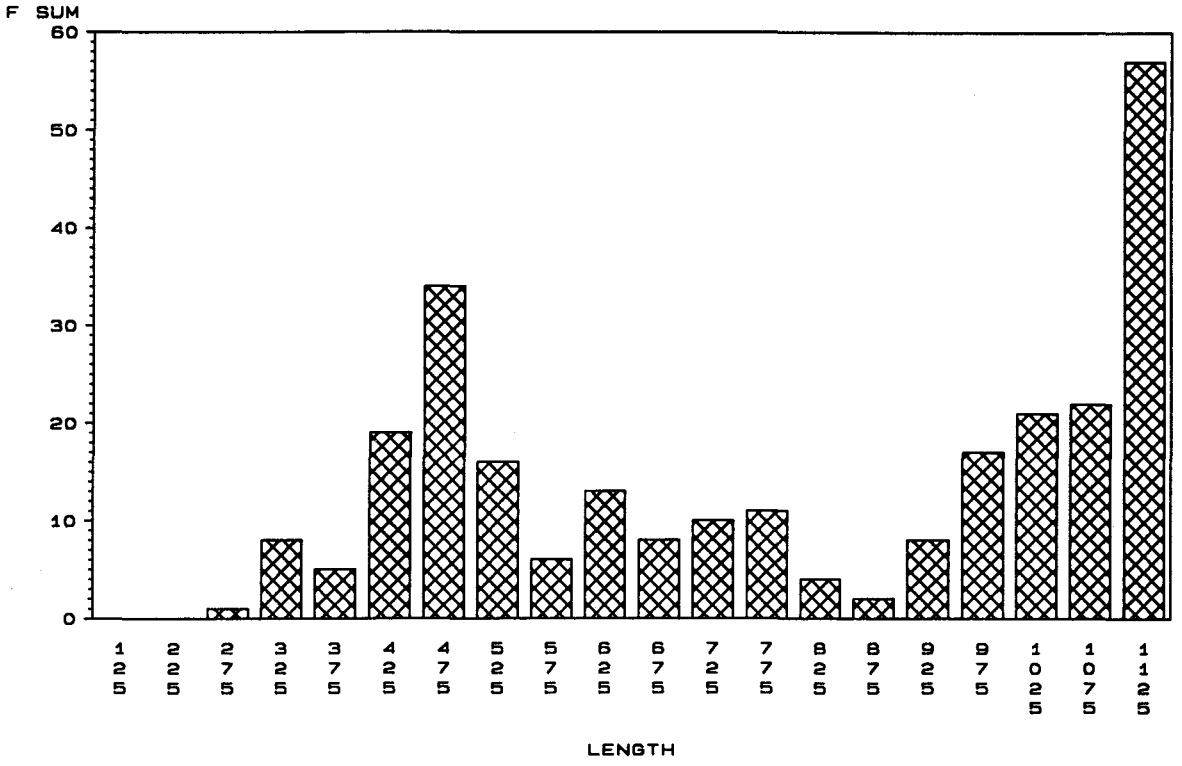
LENGTH FREQUENCIES FOR RED DRUM FROM NORTH CAROLINA

GEAR=lines YEAR=85



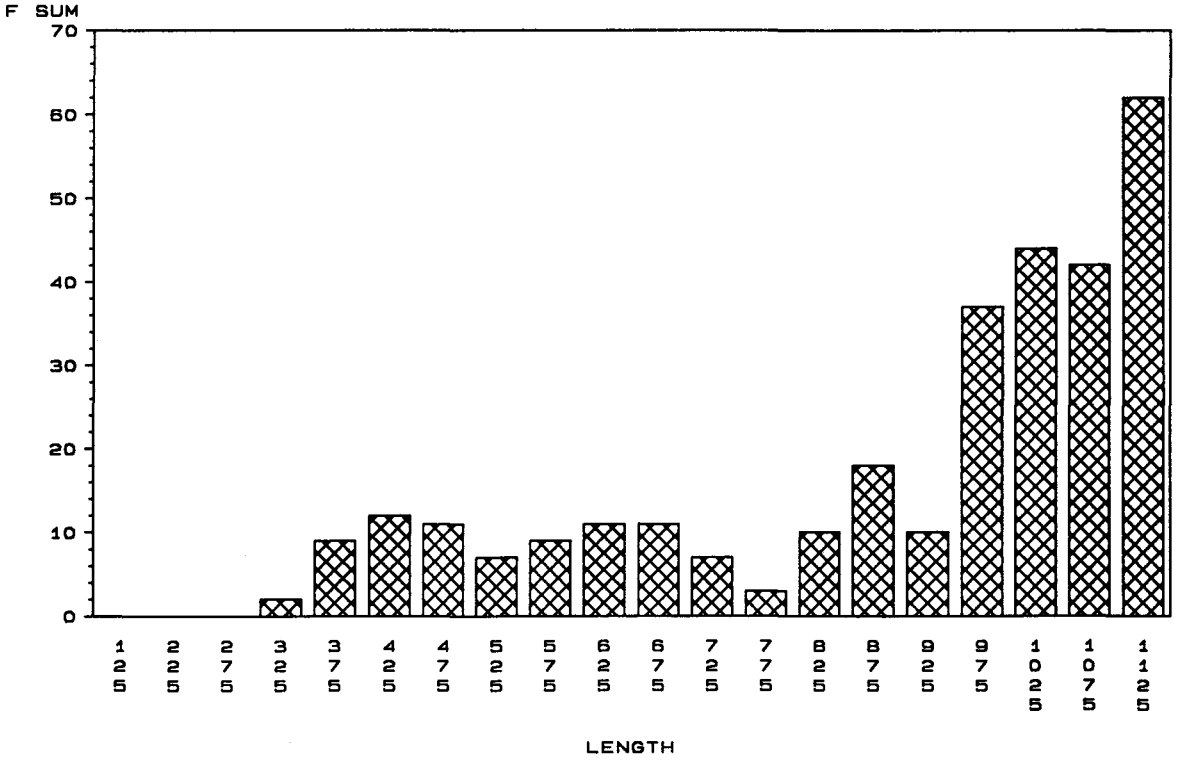
LENGTH FREQUENCIES FOR RED DRUM FROM NORTH CAROLINA

GEAR=lines YEAR=86



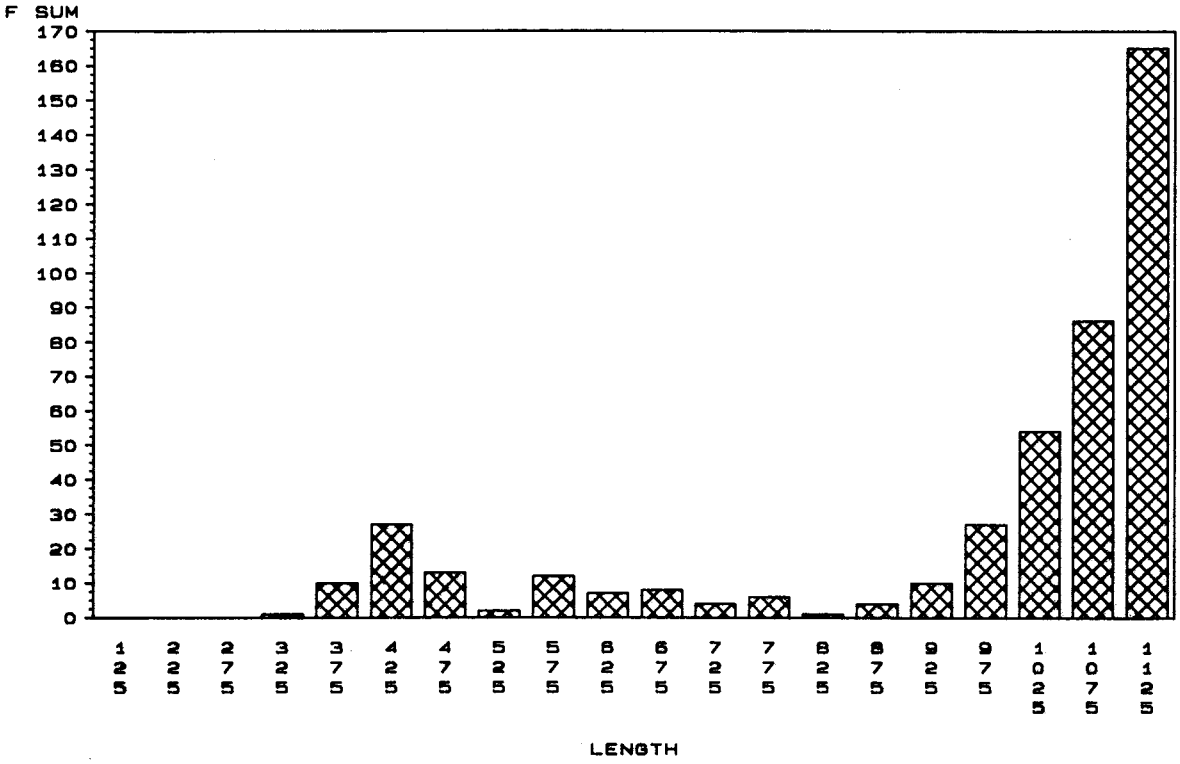
LENGTH FREQUENCIES FOR RED DRUM FROM NORTH CAROLINA

GEAR=lines YEAR=87

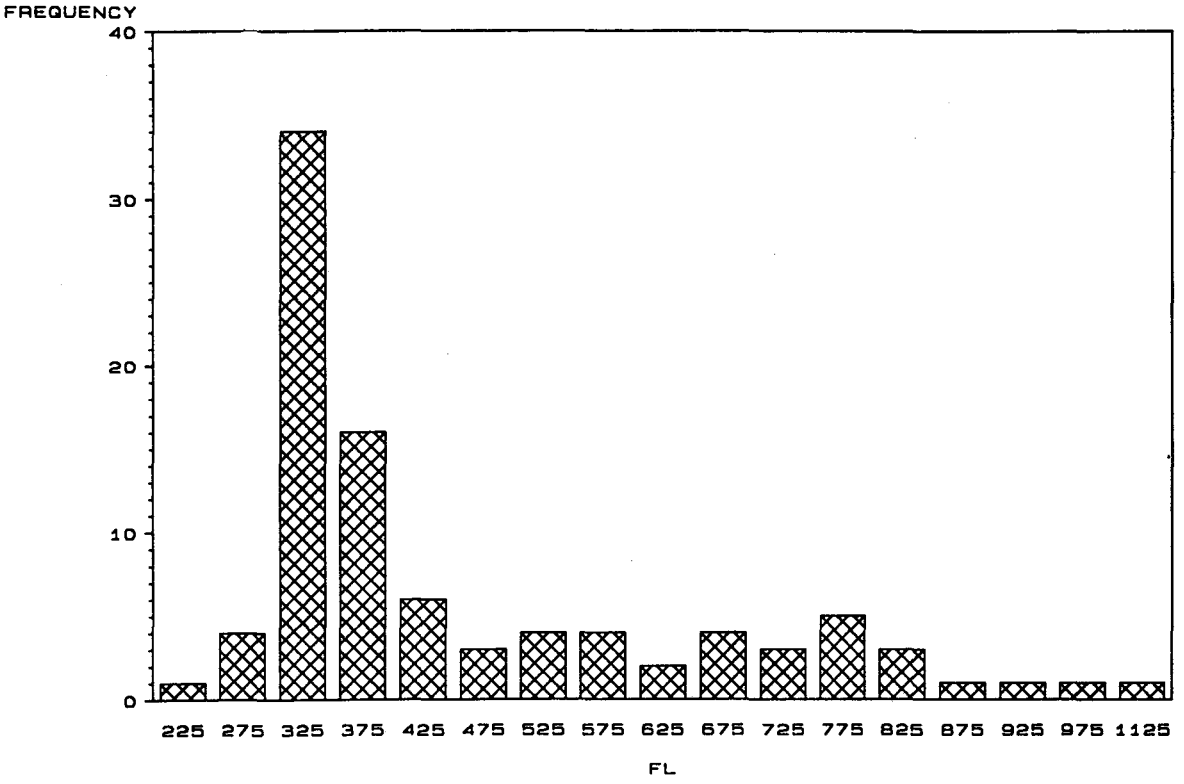


LENGTH FREQUENCIES FOR RED DRUM FROM NORTH CAROLINA

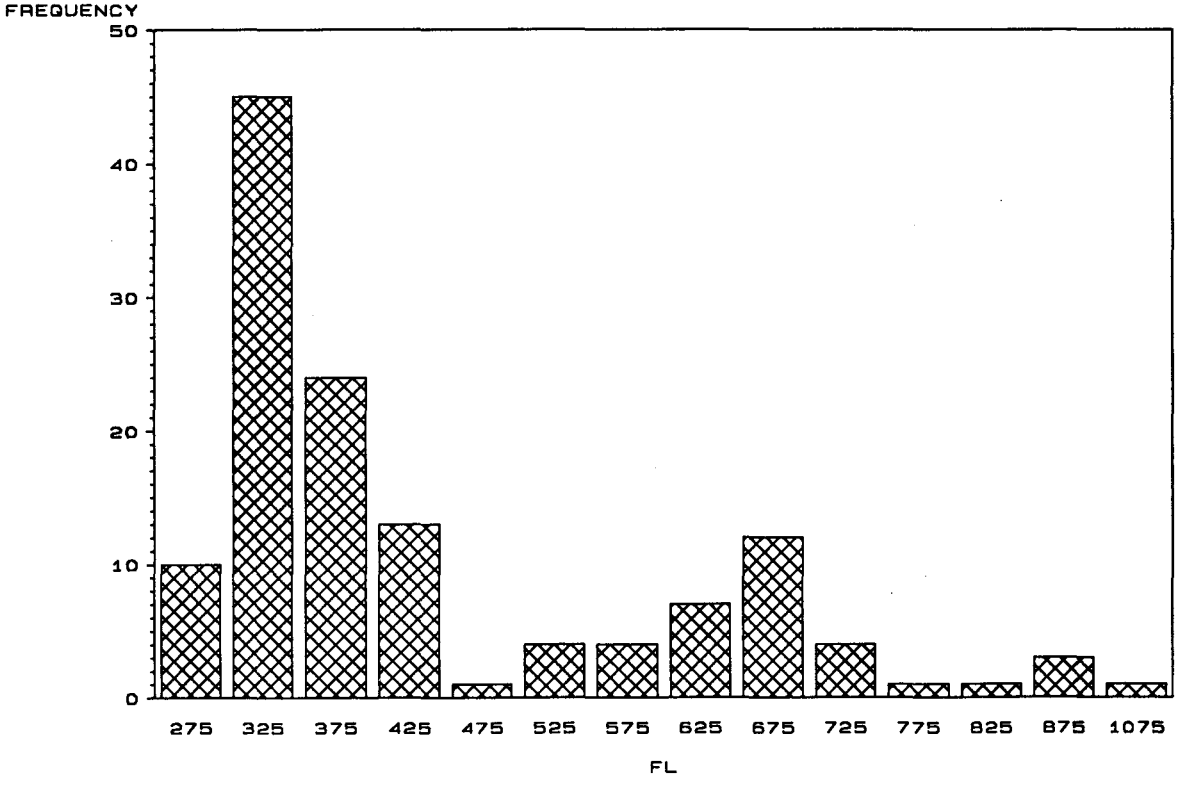
GEAR=lines YEAR=88



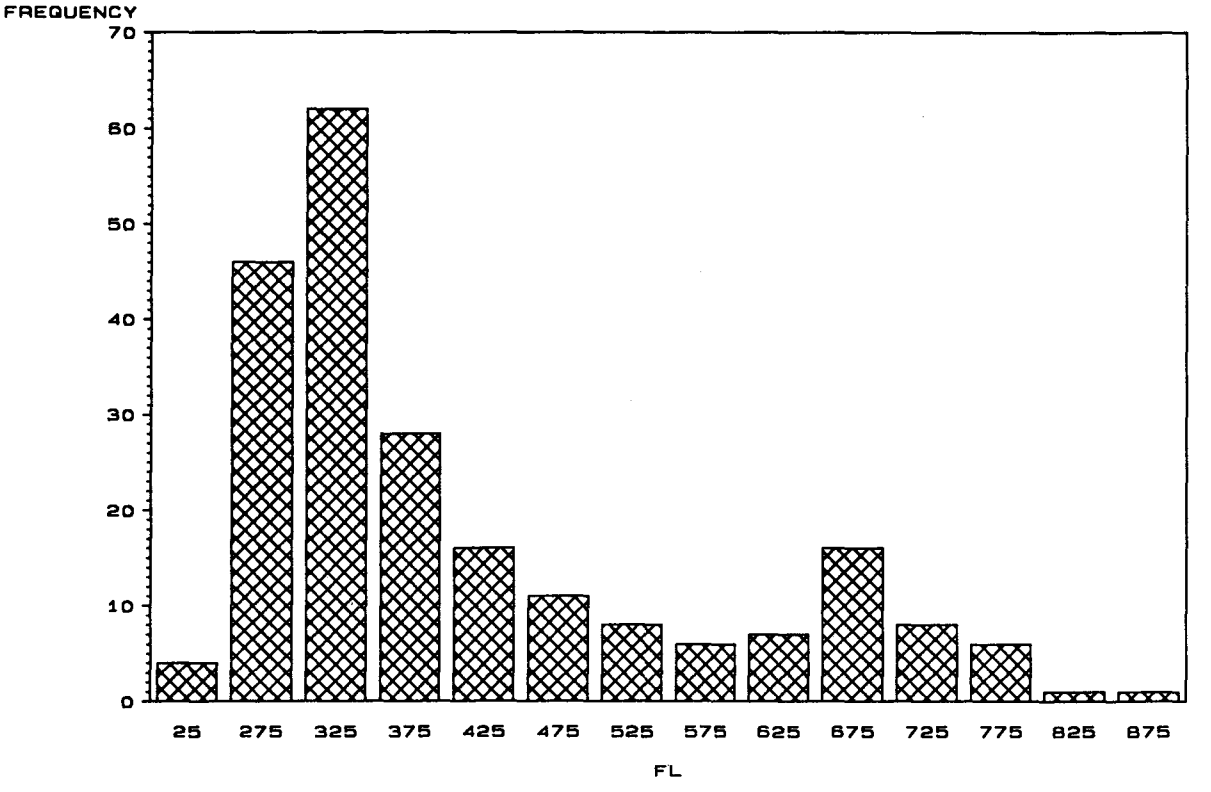
LENGTH FREQUENCIES FOR RED DRUM FROM SOUTH CAROLINA TAGGING PROGRAM
YEAR=1980



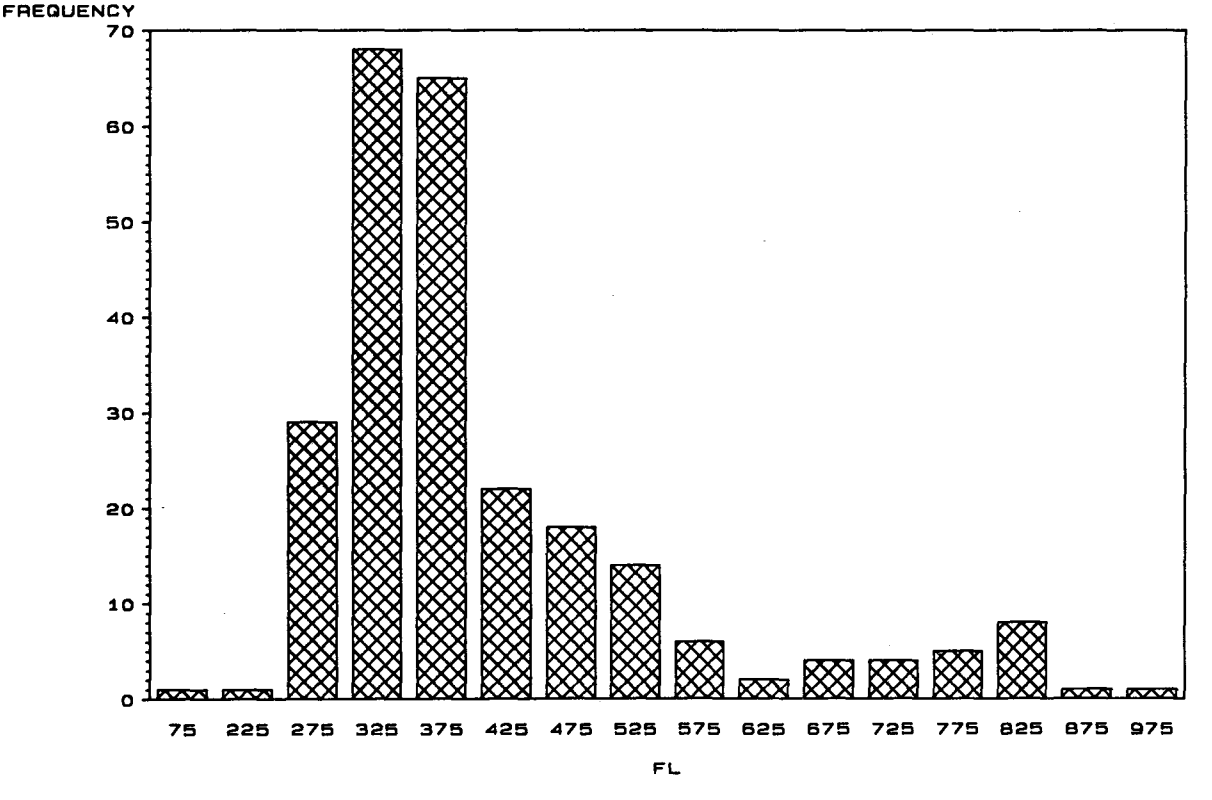
LENGTH FREQUENCIES FOR RED DRUM FROM SOUTH CAROLINA TAGGING PROGRAM
YEAR=1981



LENGTH FREQUENCIES FOR RED DRUM FROM SOUTH CAROLINA TAGGING PROGRAM
YEAR=1982

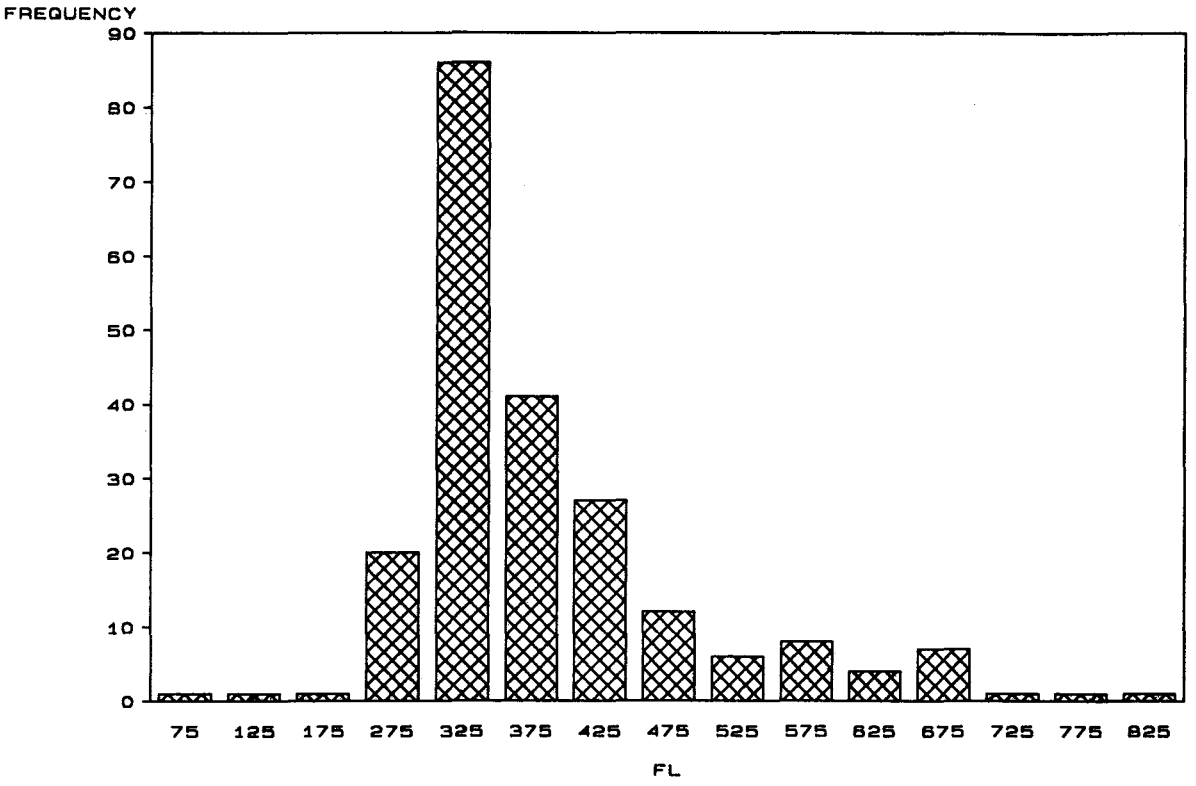


LENGTH FREQUENCIES FOR RED DRUM FROM SOUTH CAROLINA TAGGING PROGRAM
YEAR=1983



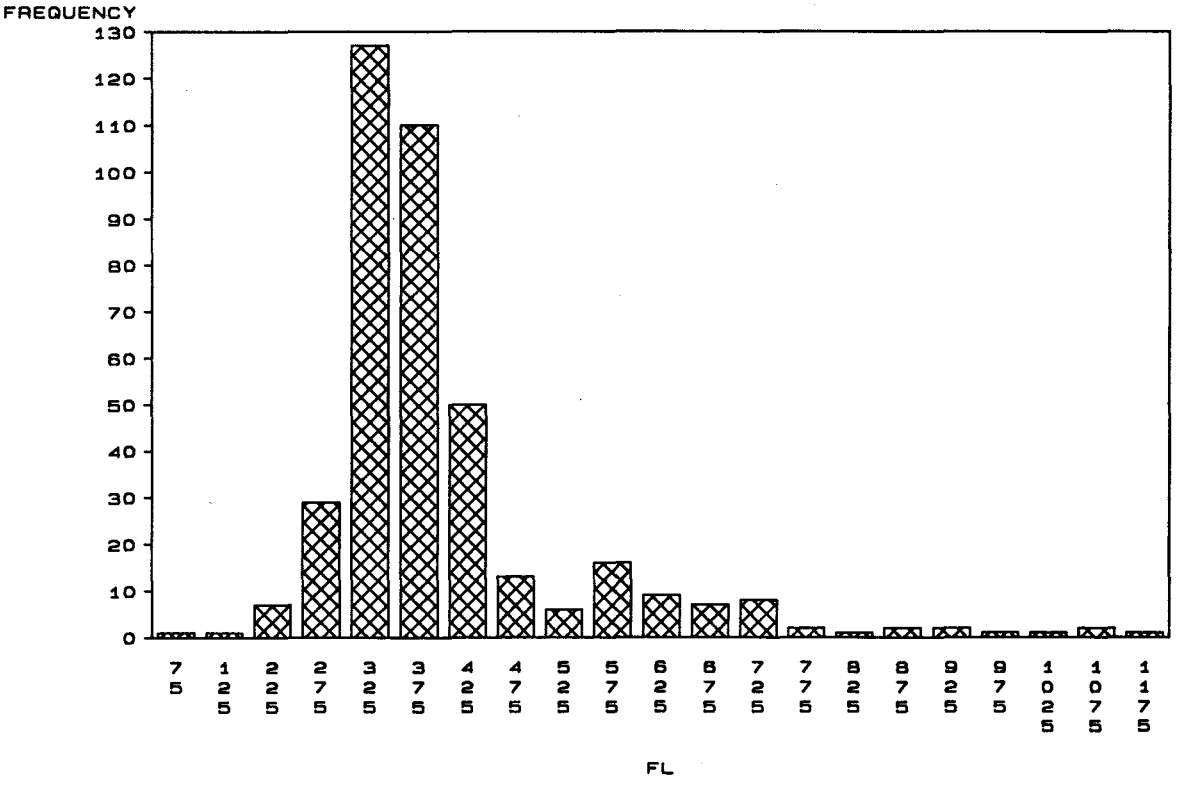
LENGTH FREQUENCIES FOR RED DRUM FROM SOUTH CAROLINA TAGGING PROGRAM

YEAR=1984



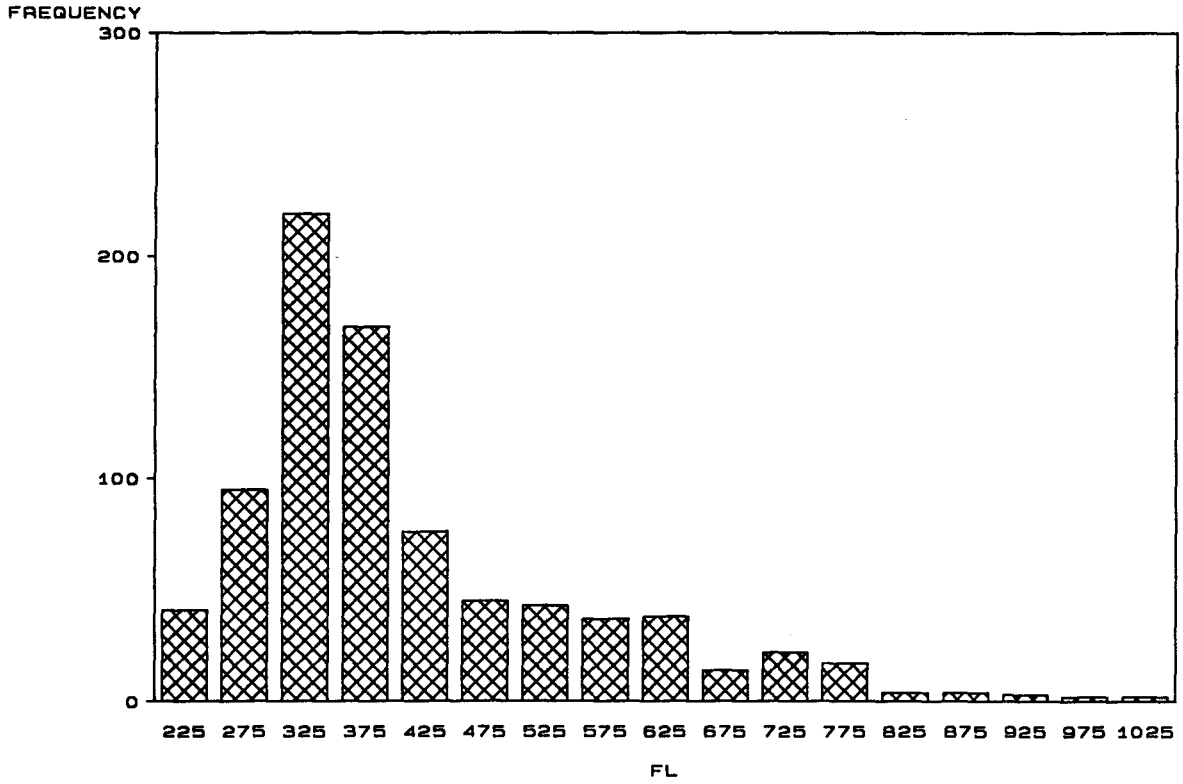
LENGTH FREQUENCIES FOR RED DRUM FROM SOUTH CAROLINA TAGGING PROGRAM

YEAR=1985



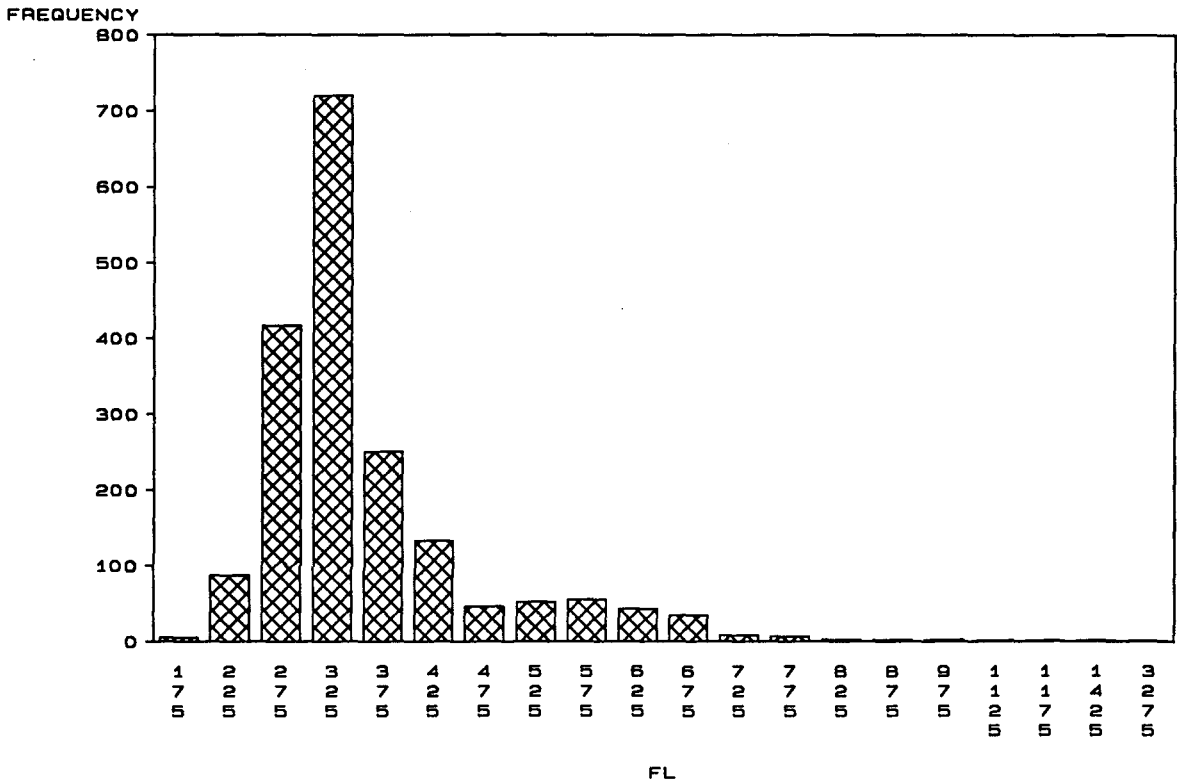
LENGTH FREQUENCIES FOR RED DRUM FROM SOUTH CAROLINA TAGGING PROGRAM

YEAR=1986



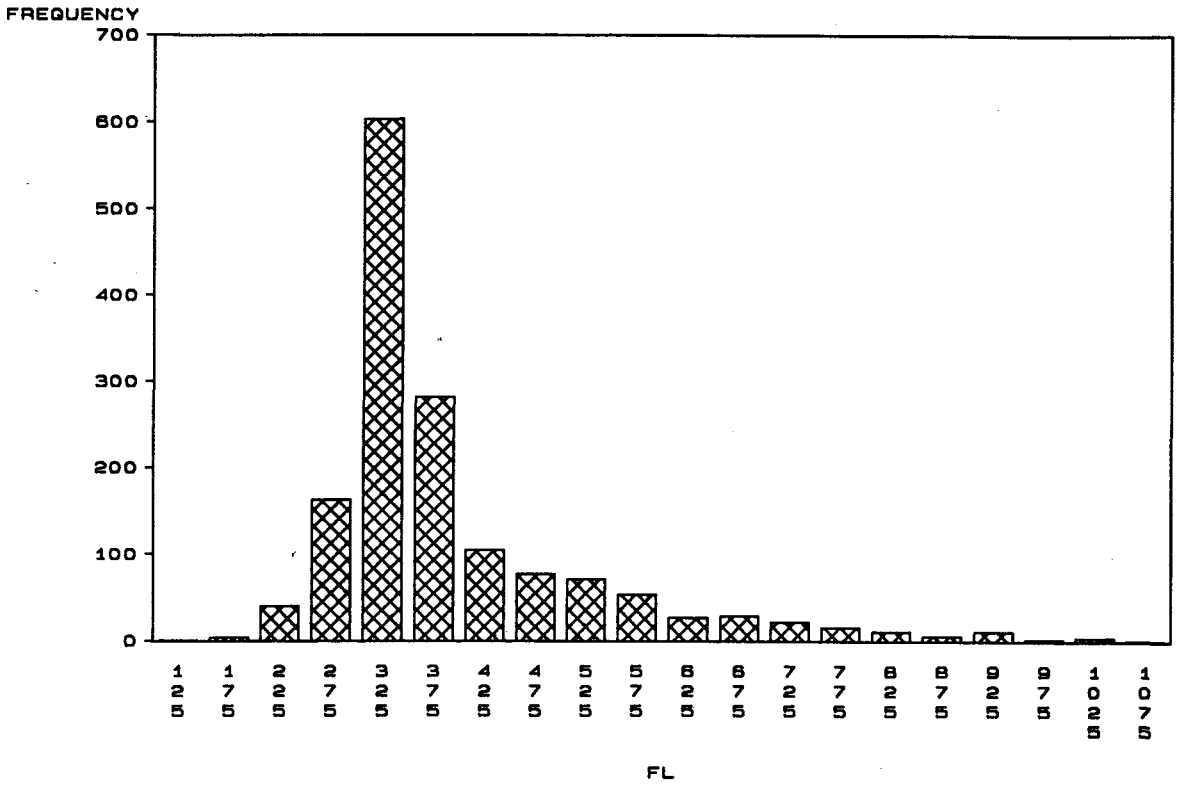
LENGTH FREQUENCIES FOR RED DRUM FROM SOUTH CAROLINA TAGGING PROGRAM

YEAR=1987



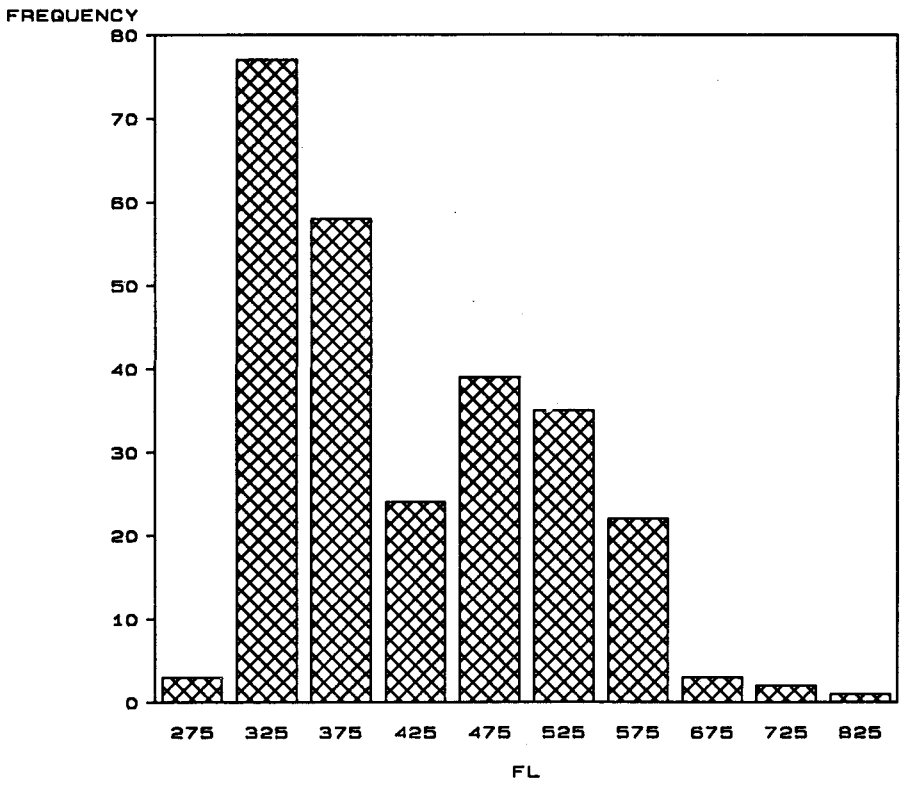
LENGTH FREQUENCIES FOR RED DRUM FROM SOUTH CAROLINA TAGGING PROGRAM

YEAR=1988



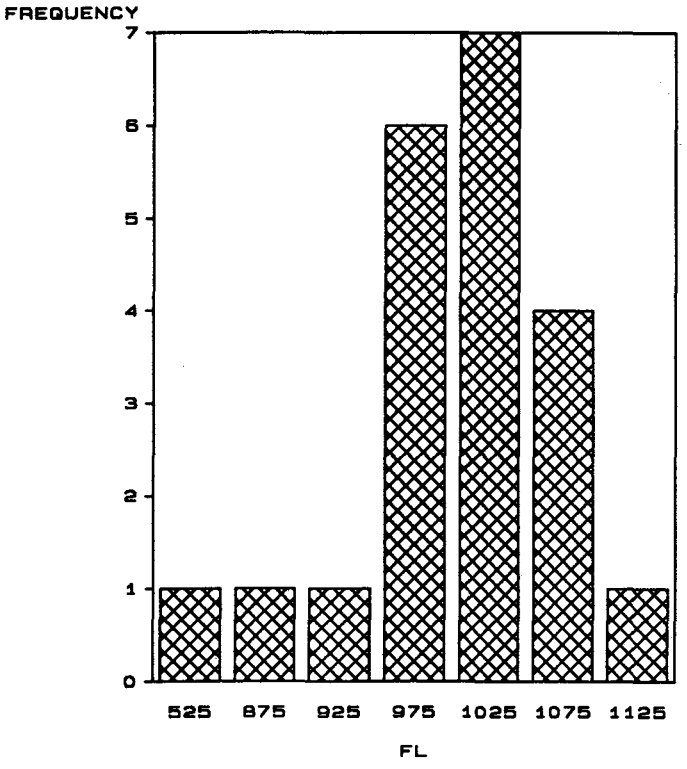
LENGTH FREQUENCIES FOR RED DRUM FROM SOUTH CAROLINA TAGGING PROGRAM

YEAR=1989



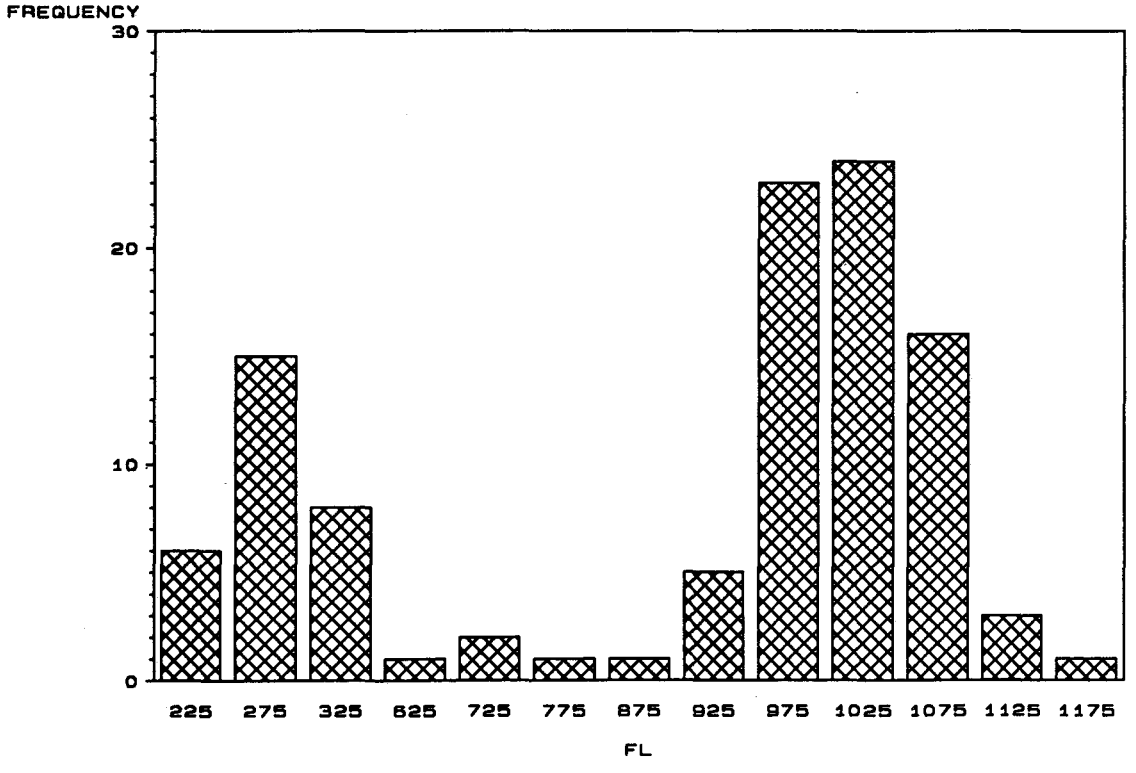
LENGTH FREQUENCIES FOR RED DRUM FROM GEORGIA

YEAR=86 GEAR=lines



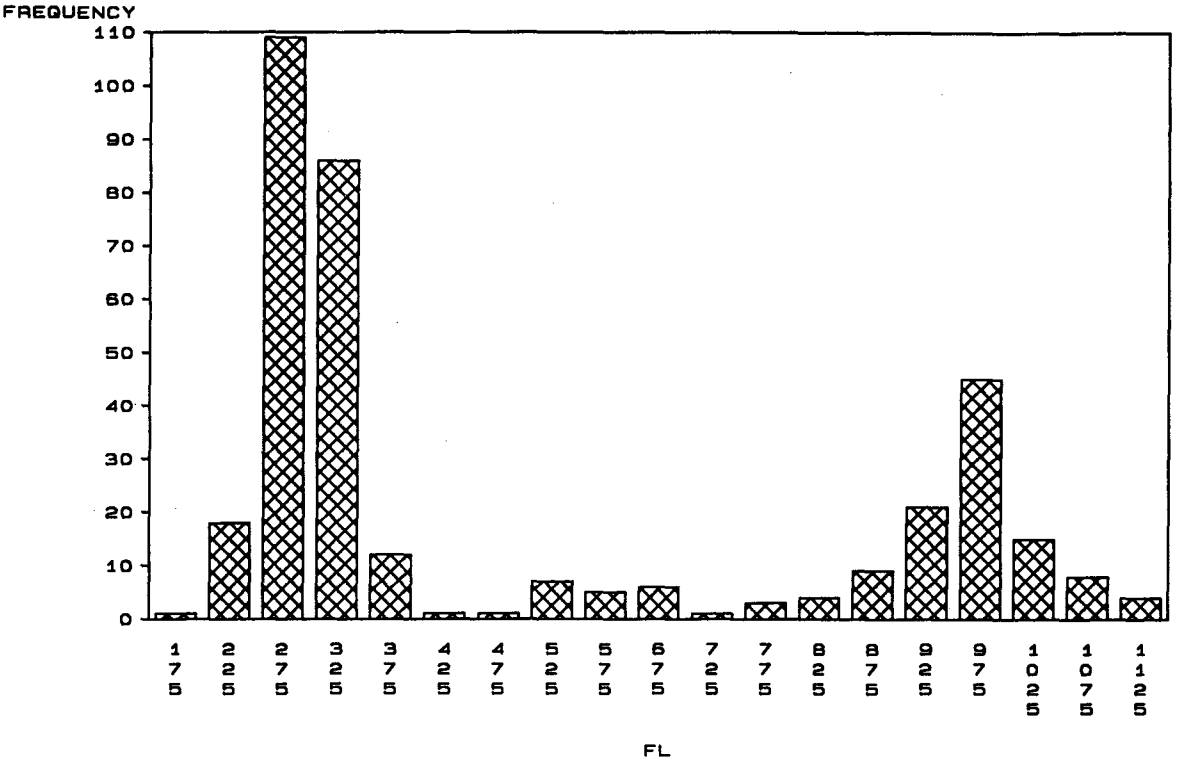
LENGTH FREQUENCIES FOR RED DRUM FROM GEORGIA

YEAR=87 GEAR=lines



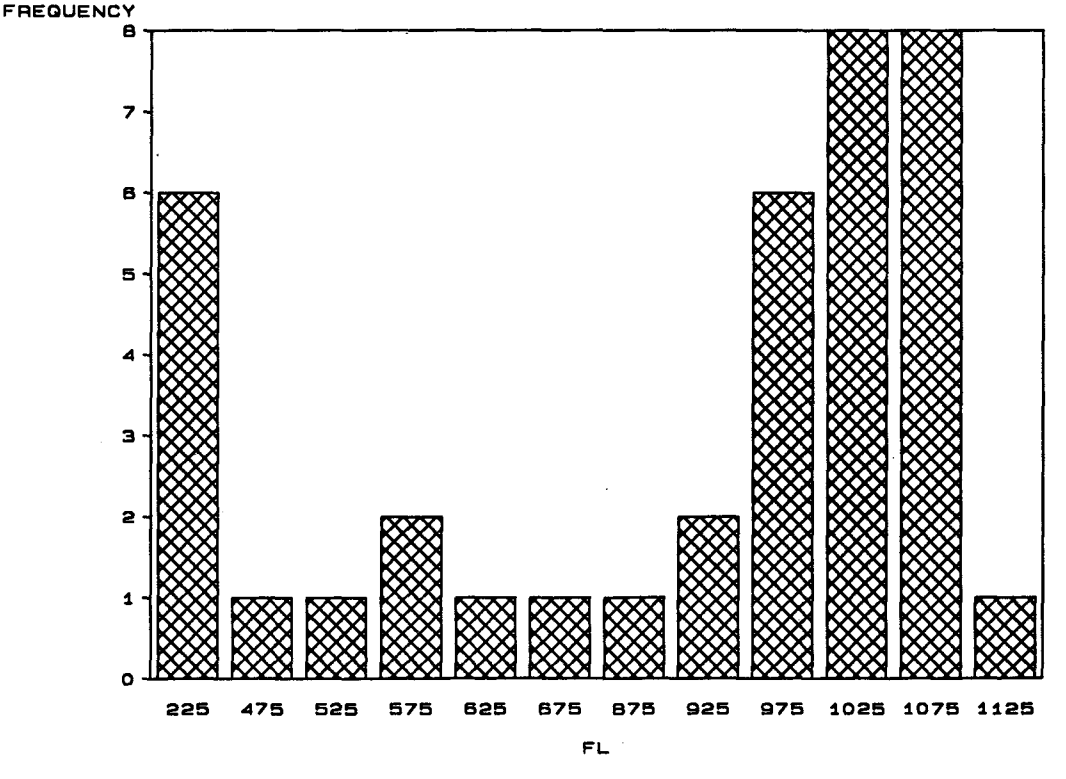
LENGTH FREQUENCIES FOR RED DRUM FROM GEORGIA

YEAR=88 GEAR=lines



LENGTH FREQUENCIES FOR RED DRUM FROM GEORGIA

YEAR=89 GEAR=lines

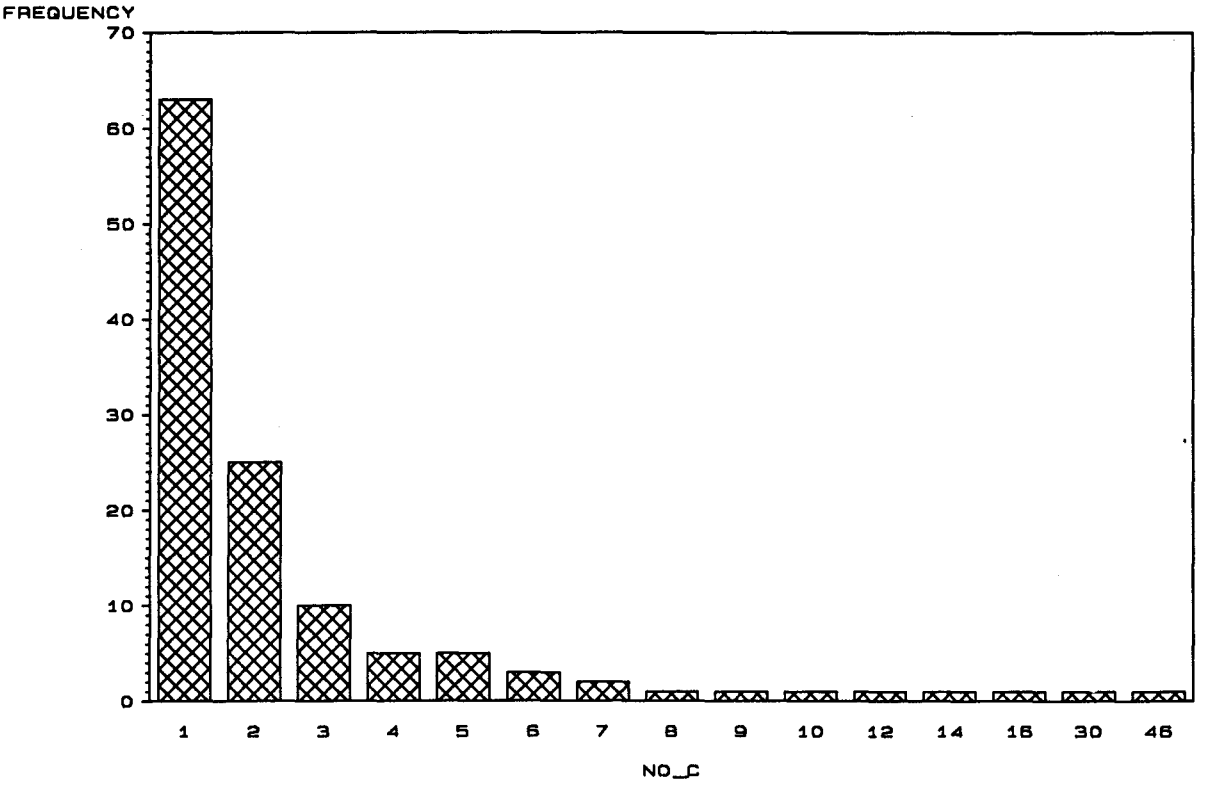


APPENDIX C.

ANNUAL FREQUENCY DISTRIBUTION OF NUMBER OF RED DRUM CAUGHT PER ANGLER-TRIP FROM MRFSS SAMPLING.

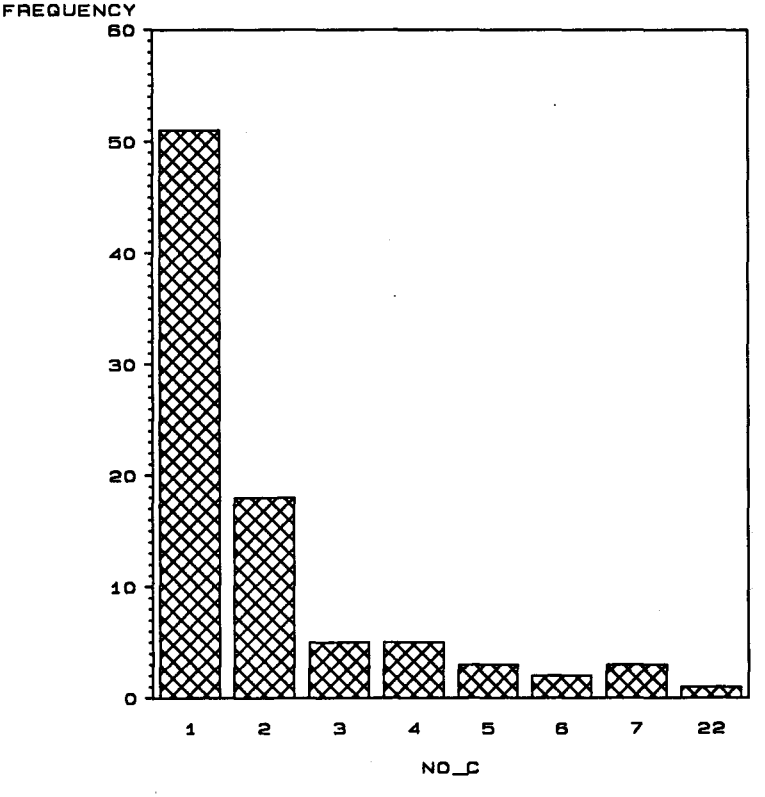
FREQUENCY DISTRIBUTION OF NUMBER CAUGHT FOR RED DRUM BY YEAR

YEAR=79



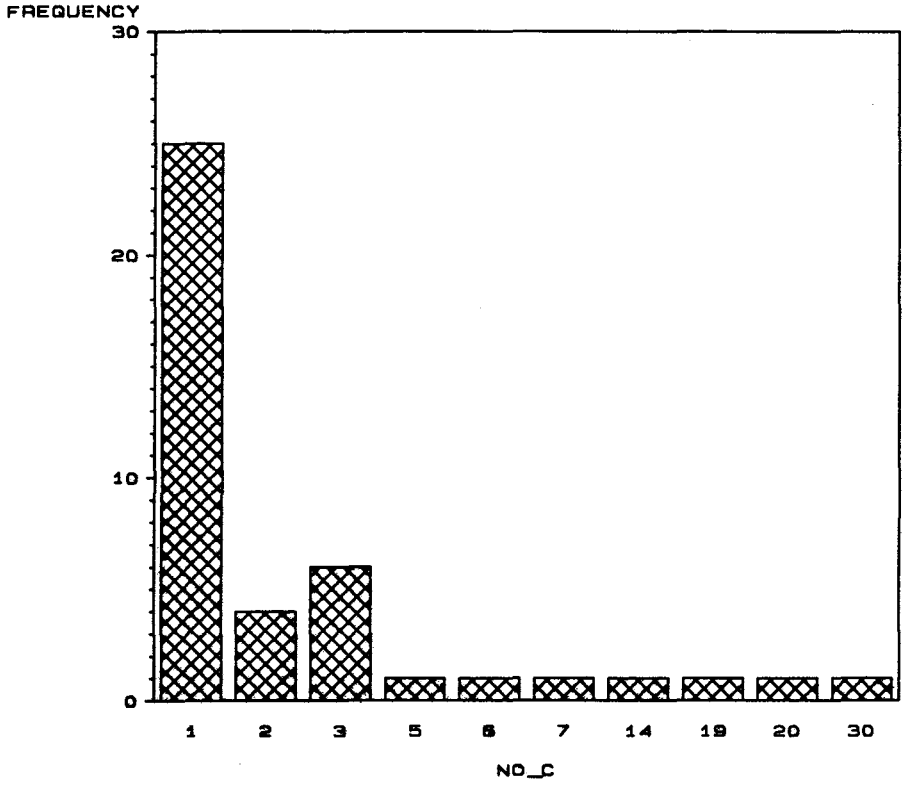
FREQUENCY DISTRIBUTION OF NUMBER CAUGHT FOR RED DRUM BY YEAR

YEAR=80



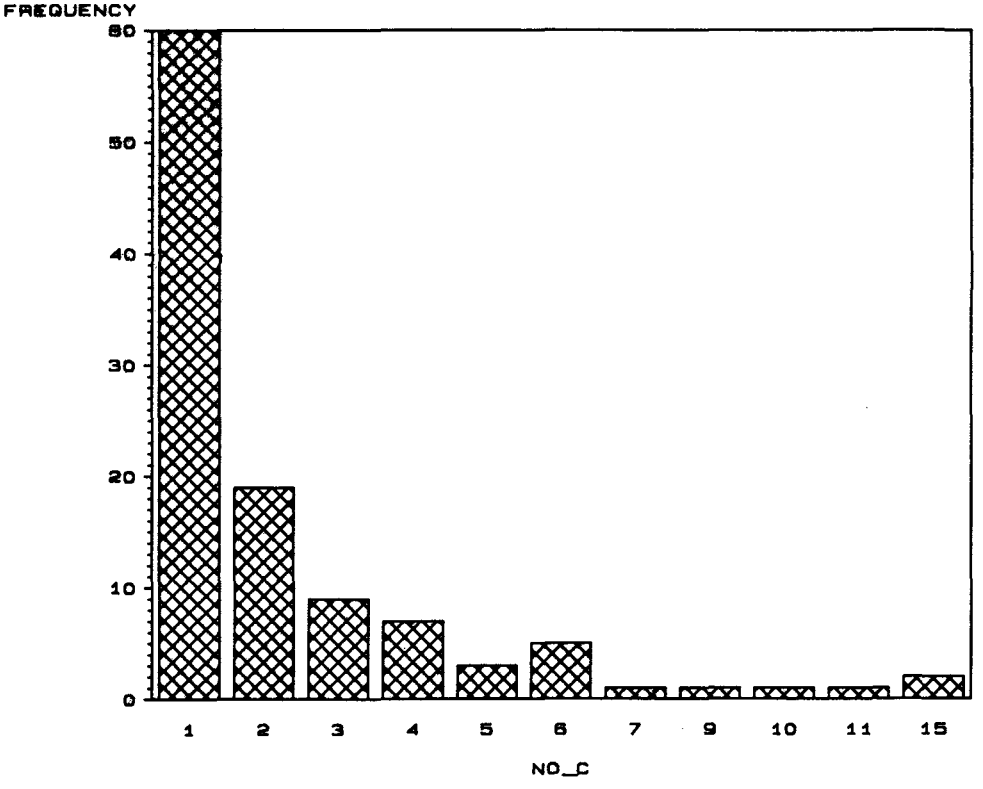
FREQUENCY DISTRIBUTION OF NUMBER CAUGHT FOR RED DRUM BY YEAR

YEAR=81



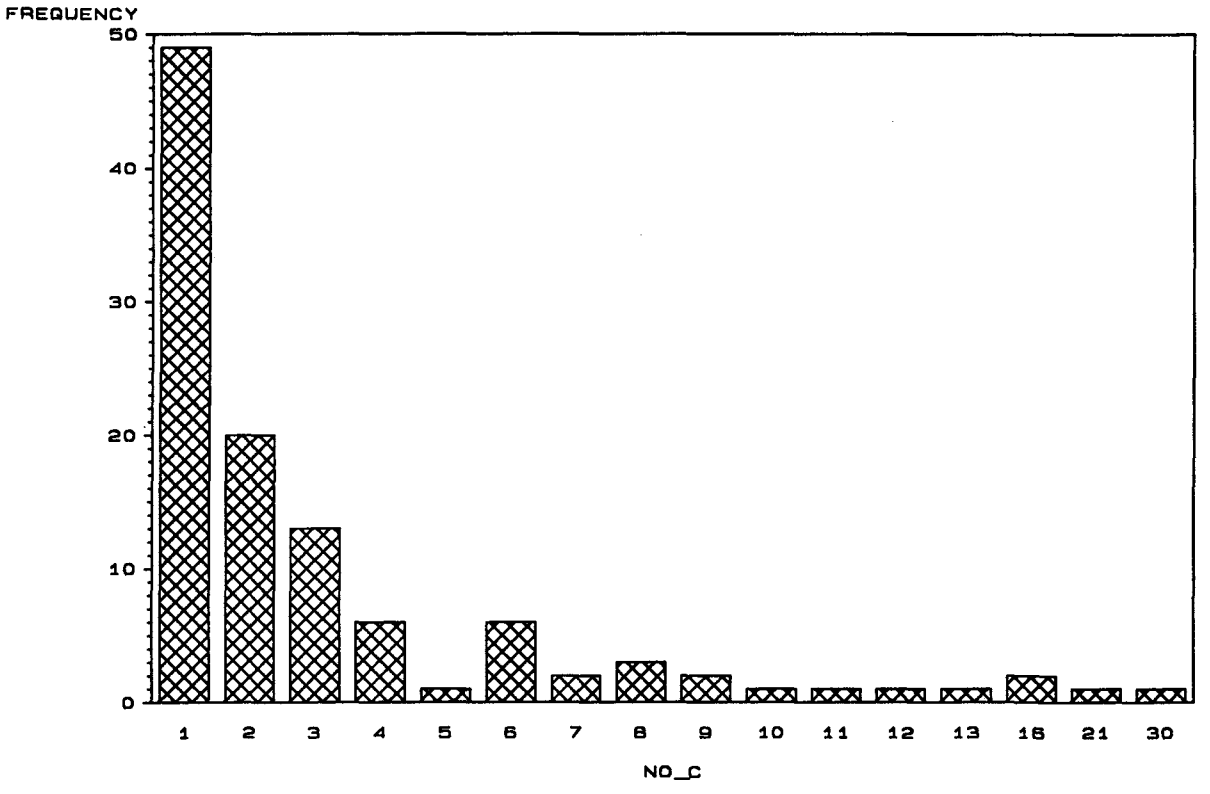
FREQUENCY DISTRIBUTION OF NUMBER CAUGHT FOR RED DRUM BY YEAR

YEAR=82



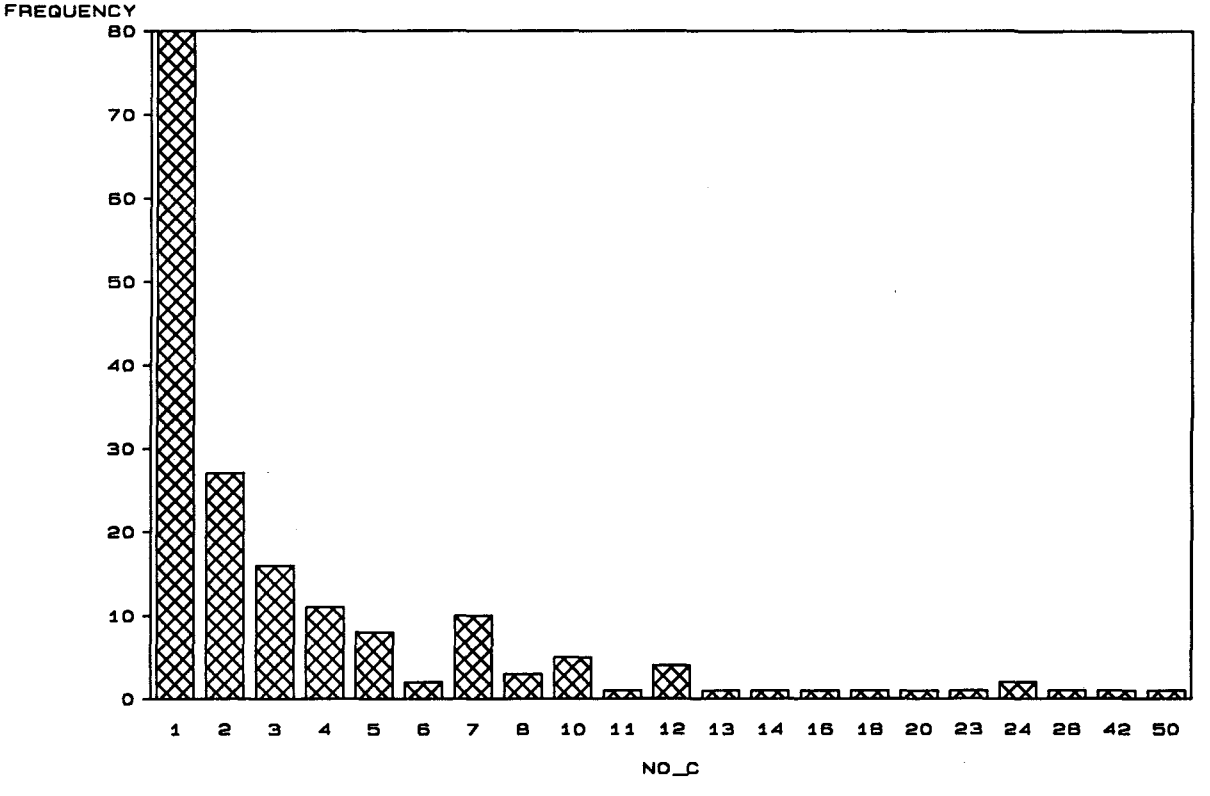
FREQUENCY DISTRIBUTION OF NUMBER CAUGHT FOR RED DRUM BY YEAR

YEAR=83



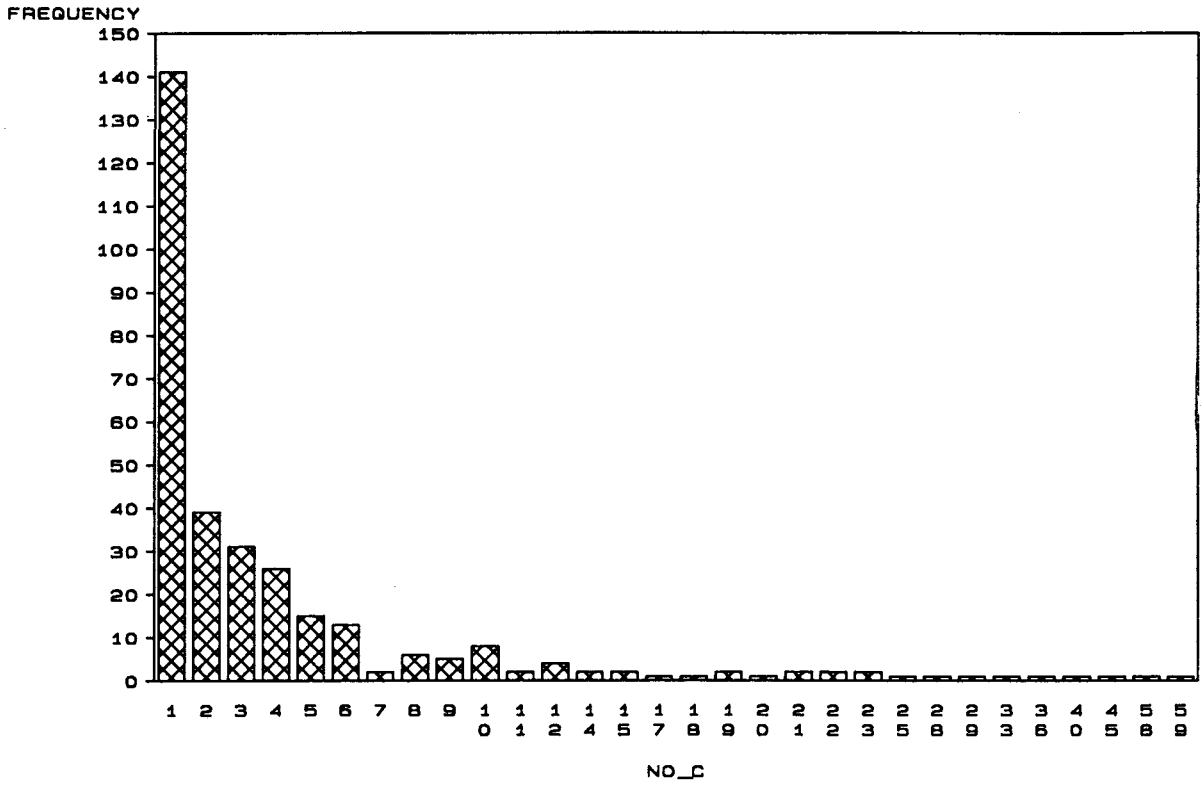
FREQUENCY DISTRIBUTION OF NUMBER CAUGHT FOR RED DRUM BY YEAR

YEAR=84



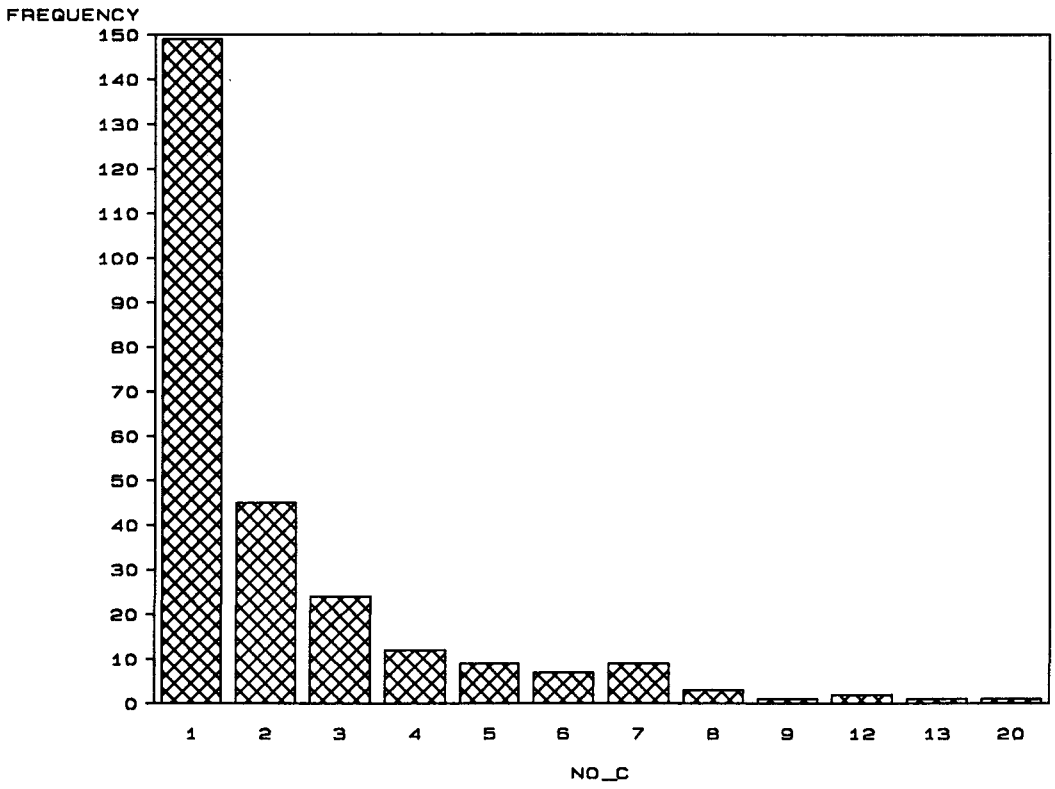
FREQUENCY DISTRIBUTION OF NUMBER CAUGHT FOR RED DRUM BY YEAR

YEAR=85



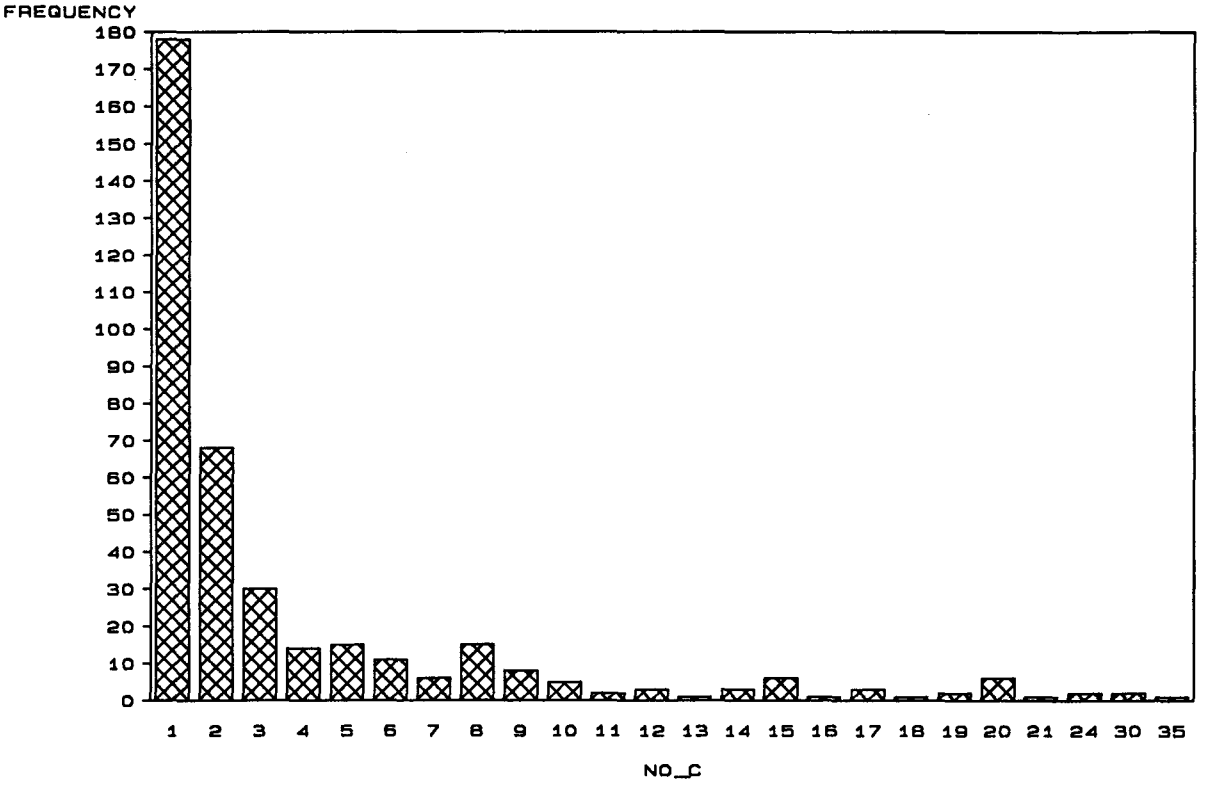
FREQUENCY DISTRIBUTION OF NUMBER CAUGHT FOR RED DRUM BY YEAR

YEAR=86



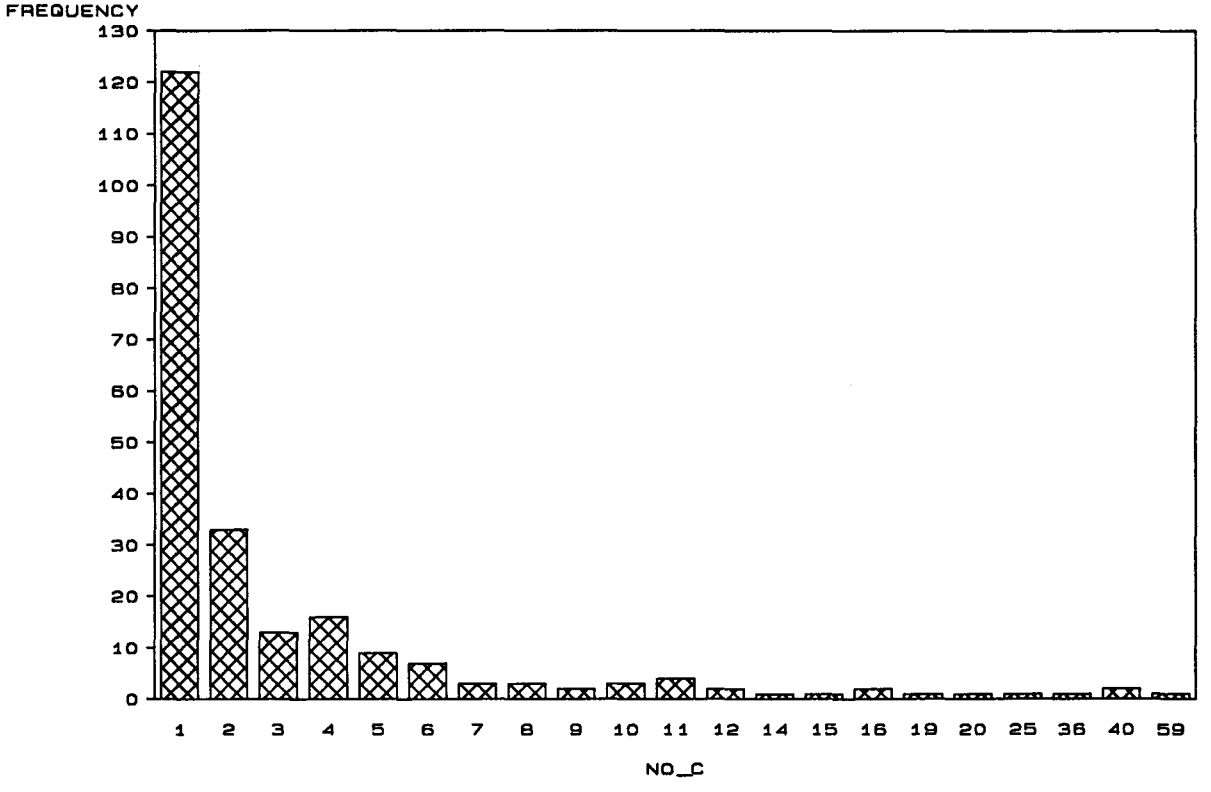
FREQUENCY DISTRIBUTION OF NUMBER CAUGHT FOR RED DRUM BY YEAR

YEAR=87



FREQUENCY DISTRIBUTION OF NUMBER CAUGHT FOR RED DRUM BY YEAR

YEAR=88

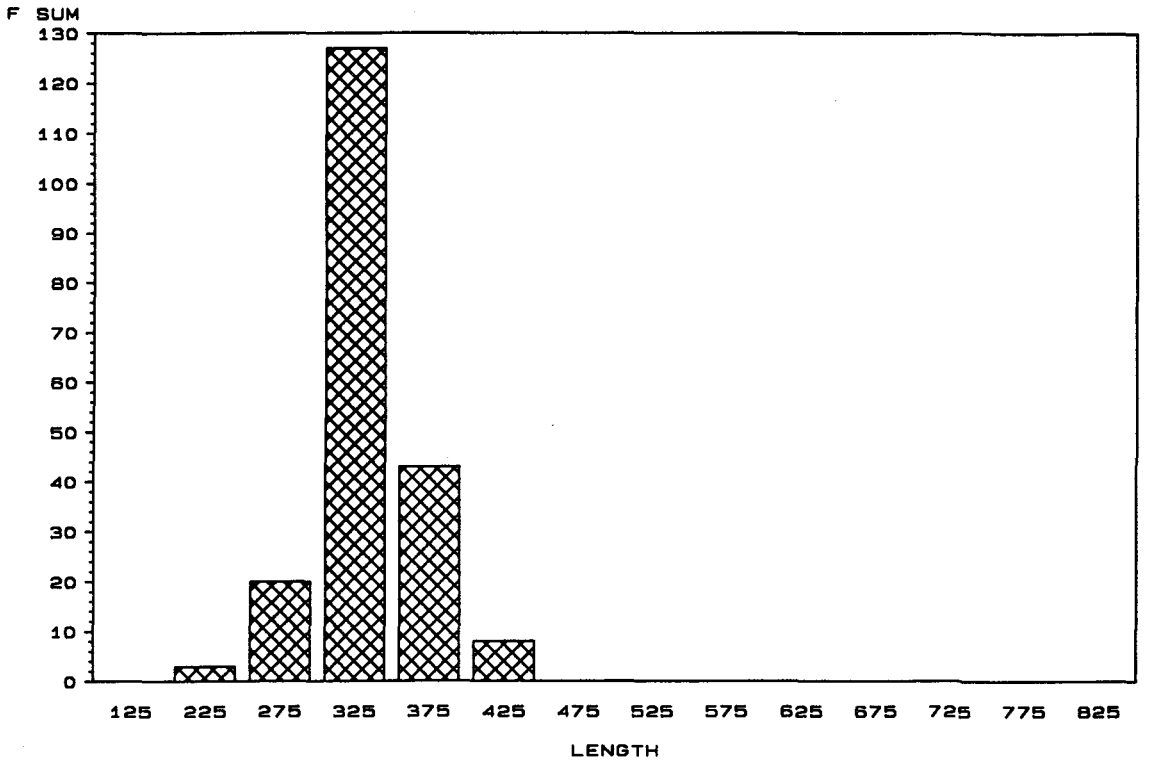


APPENDIX D.

ANNUAL LENGTH FREQUENCIES FOR RED DRUM OF GILLNET SAMPLES FROM NORTH CAROLINA AND GEORGIA, AND POUND NET SAMPLES FROM NORTH CAROLINA.

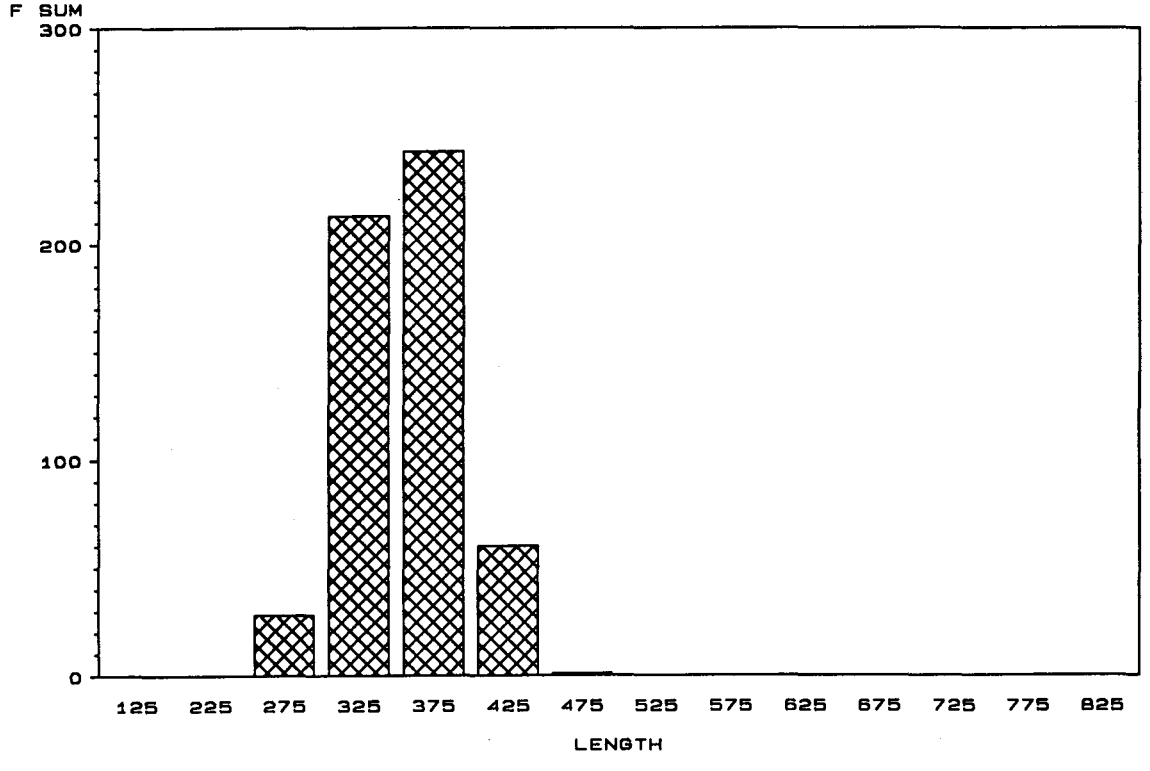
LENGTH FREQUENCIES FOR RED DRUM FROM NORTH CAROLINA

GEAR=gill YEAR=87



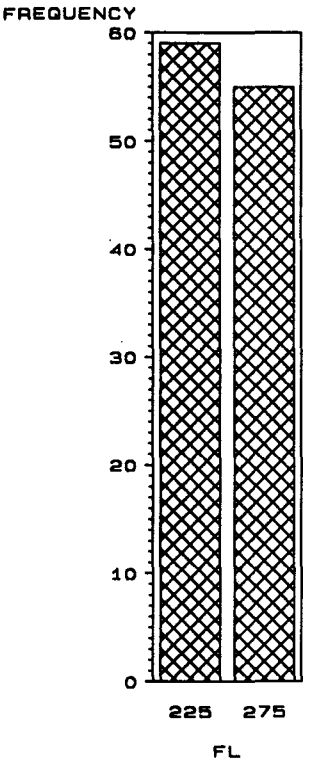
LENGTH FREQUENCIES FOR RED DRUM FROM NORTH CAROLINA

GEAR=gill YEAR=88



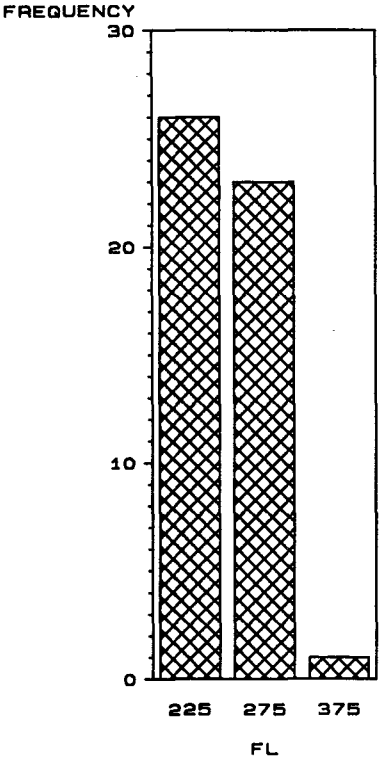
LENGTH FREQUENCIES FOR RED DRUM FROM GEORGIA

YEAR=85 GEAR=gill



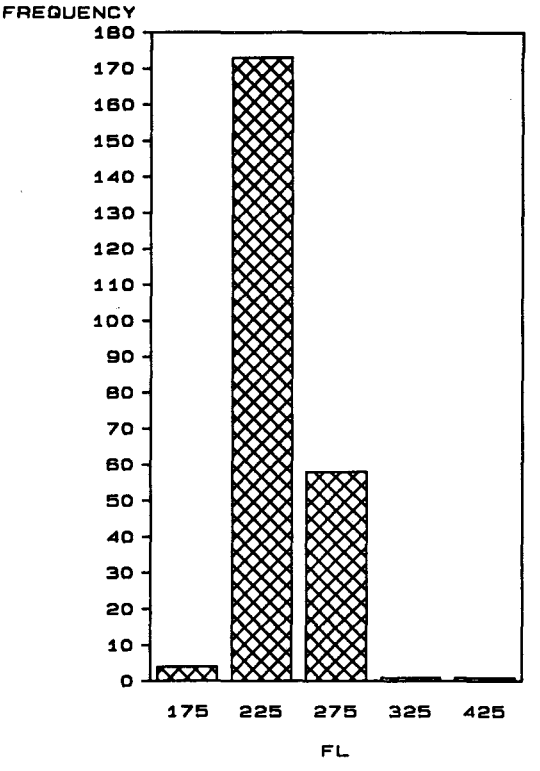
LENGTH FREQUENCIES FOR RED DRUM FROM GEORGIA

YEAR=86 GEAR=gill



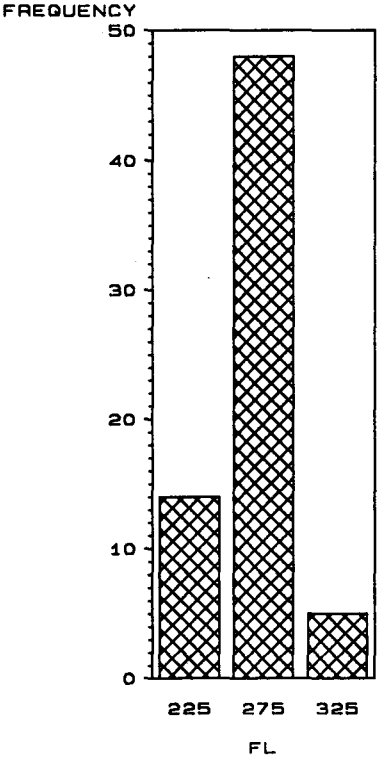
LENGTH FREQUENCIES FOR RED DRUM FROM GEORGIA

YEAR=87 GEAR=gill



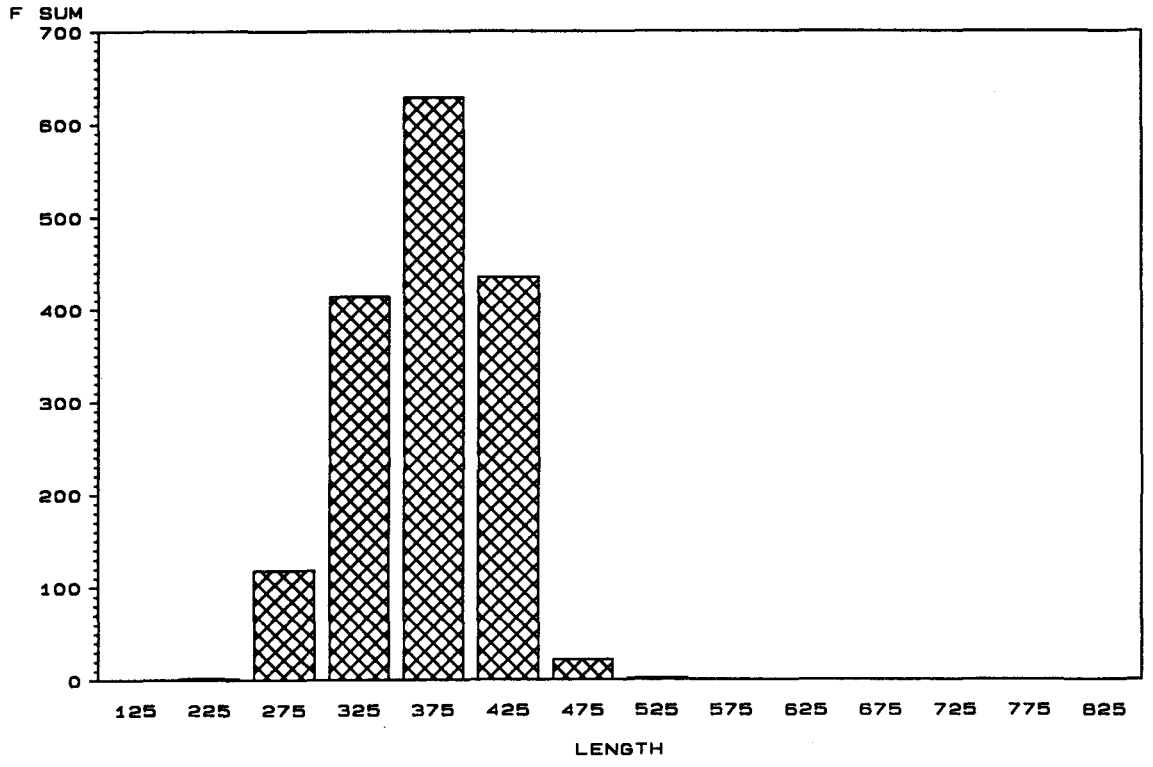
LENGTH FREQUENCIES FOR RED DRUM FROM GEORGIA

YEAR=88 GEAR=gill



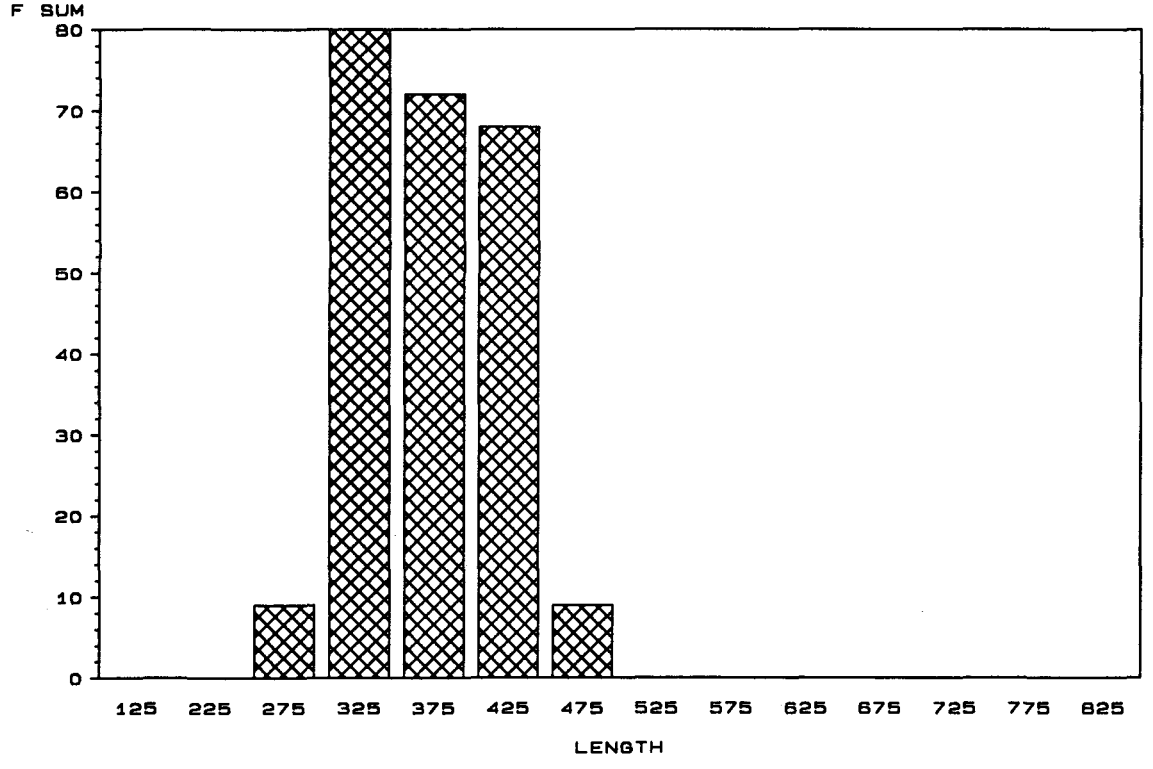
LENGTH FREQUENCIES FOR RED DRUM FROM NORTH CAROLINA

GEAR=pound YEAR=86



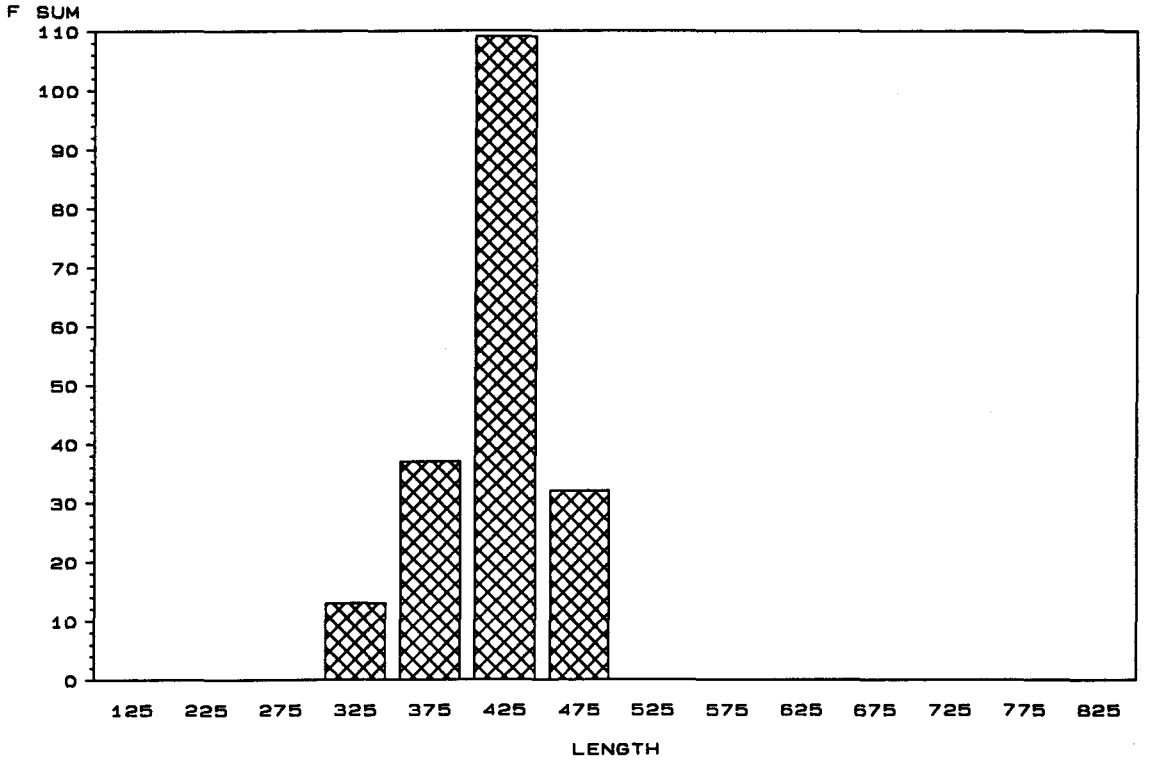
LENGTH FREQUENCIES FOR RED DRUM FROM NORTH CAROLINA

GEAR=pound YEAR=87



LENGTH FREQUENCIES FOR RED DRUM FROM NORTH CAROLINA

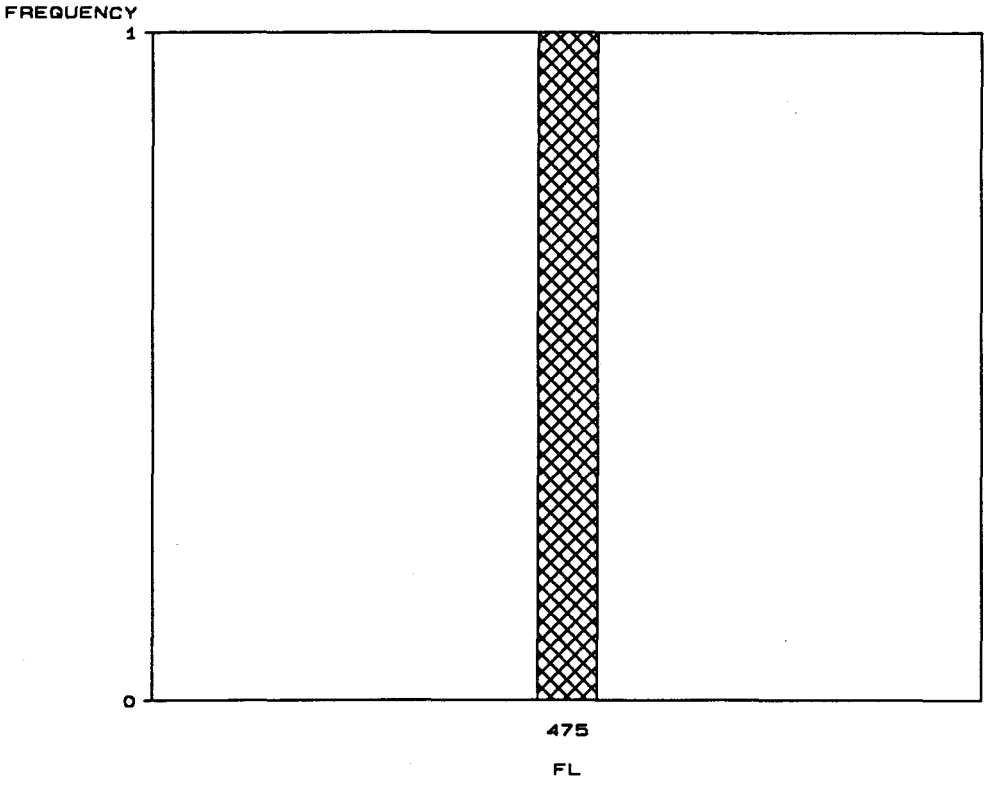
GEAR=pound YEAR=88



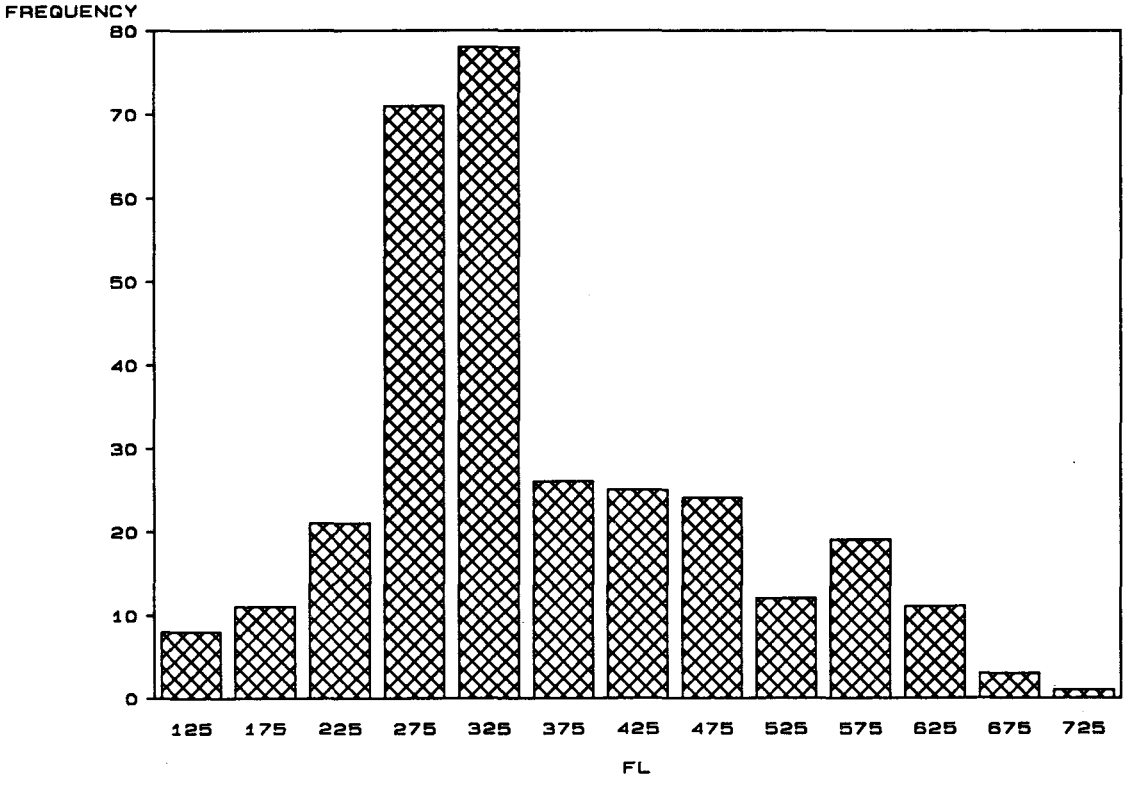
APPENDIX E.

ANNUAL LENGTH FREQUENCIES FOR RED DRUM FROM SOUTH CAROLINA STOPNET SAMPLES AND GEORGIA TRAMMEL NET SAMPLES.

LENGTH FREQUENCIES FOR RED DRUM FROM SOUTH CAROLINA STOP NET SAMPLES
YEAR=1985

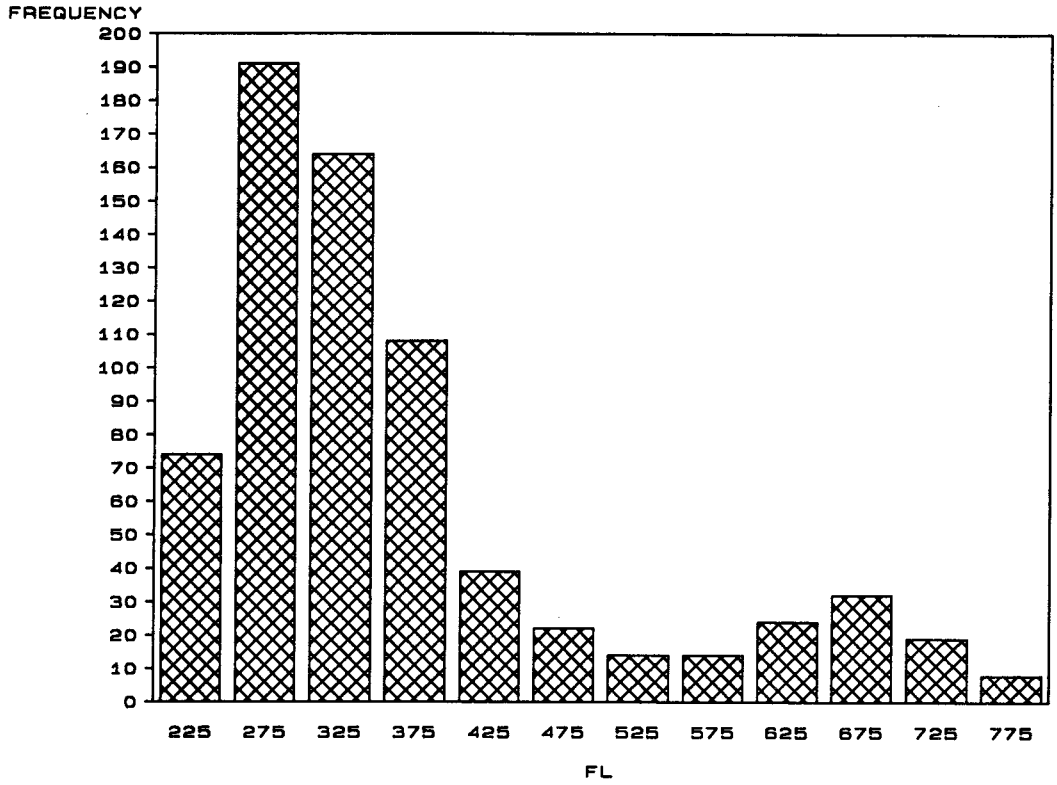


LENGTH FREQUENCIES FOR RED DRUM FROM SOUTH CAROLINA STOP NET SAMPLES
YEAR=1986



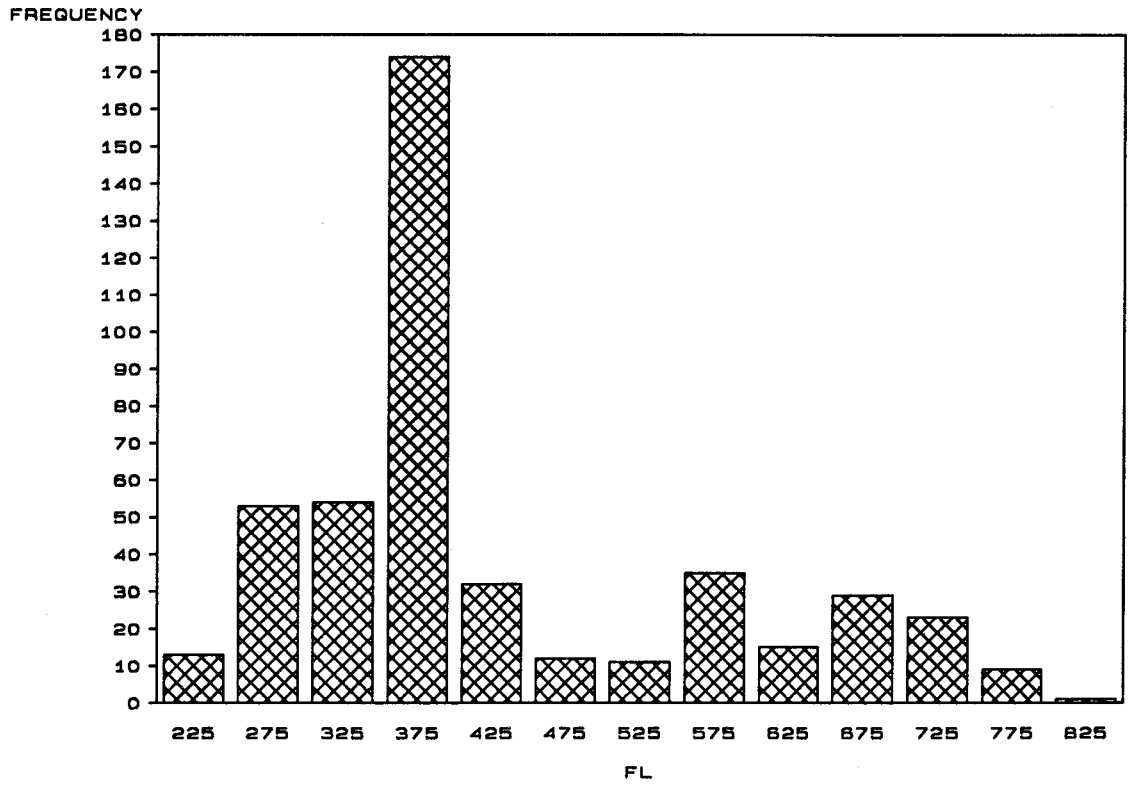
LENGTH FREQUENCIES FOR RED DRUM FROM SOUTH CAROLINA STOP NET SAMPLES

YEAR=1987



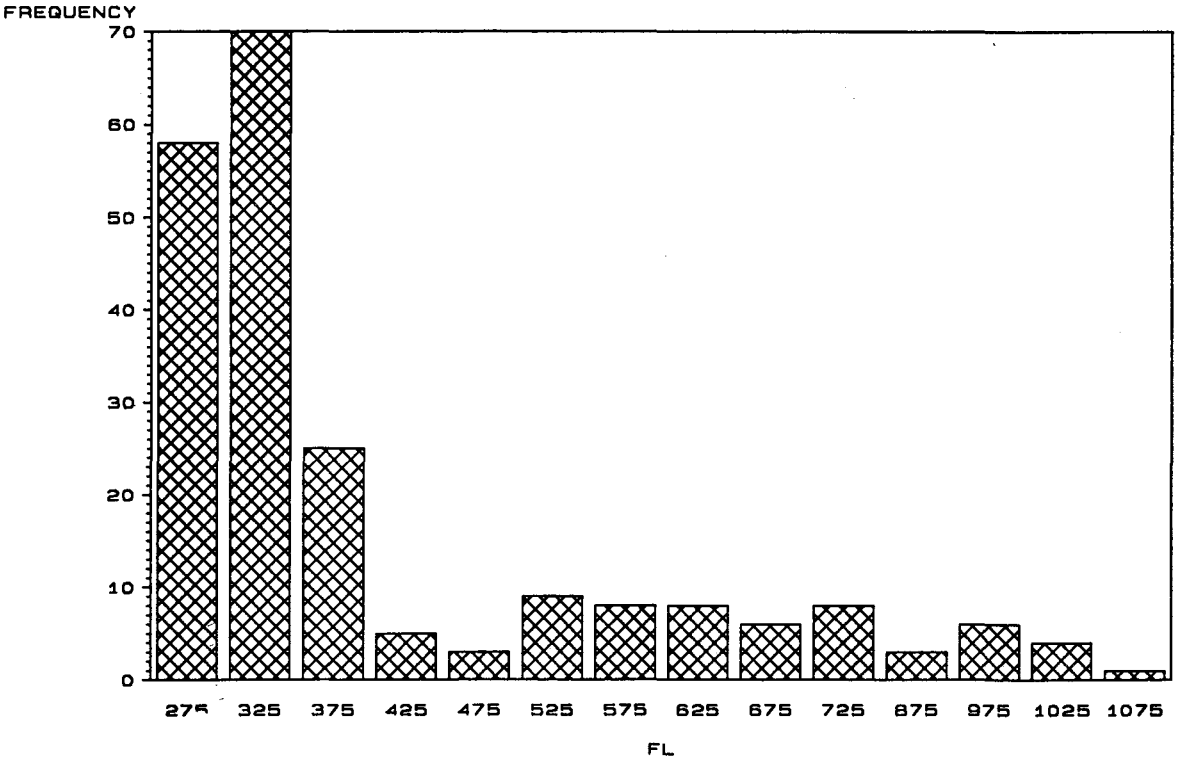
LENGTH FREQUENCIES FOR RED DRUM FROM SOUTH CAROLINA STOP NET SAMPLES

YEAR=1988



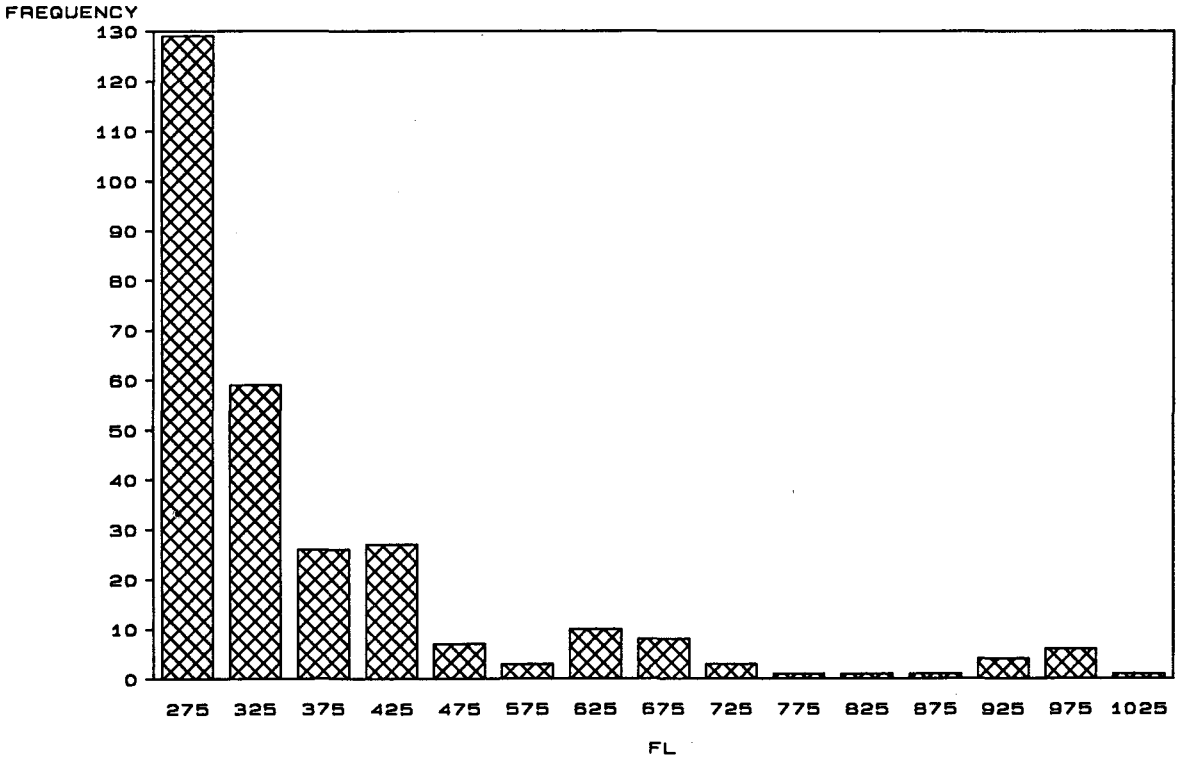
LENGTH FREQUENCIES FOR RED DRUM FROM GEORGIA

YEAR=84 GEAR=trammel



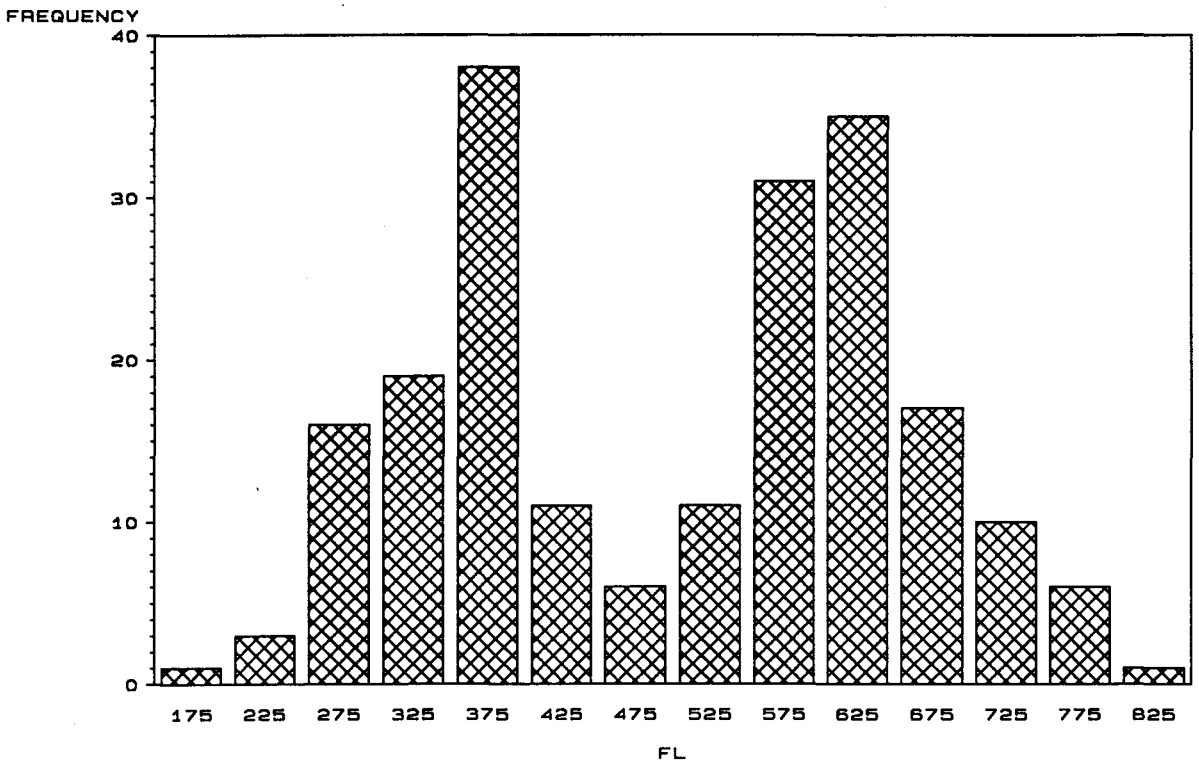
LENGTH FREQUENCIES FOR RED DRUM FROM GEORGIA

YEAR=85 GEAR=trammel



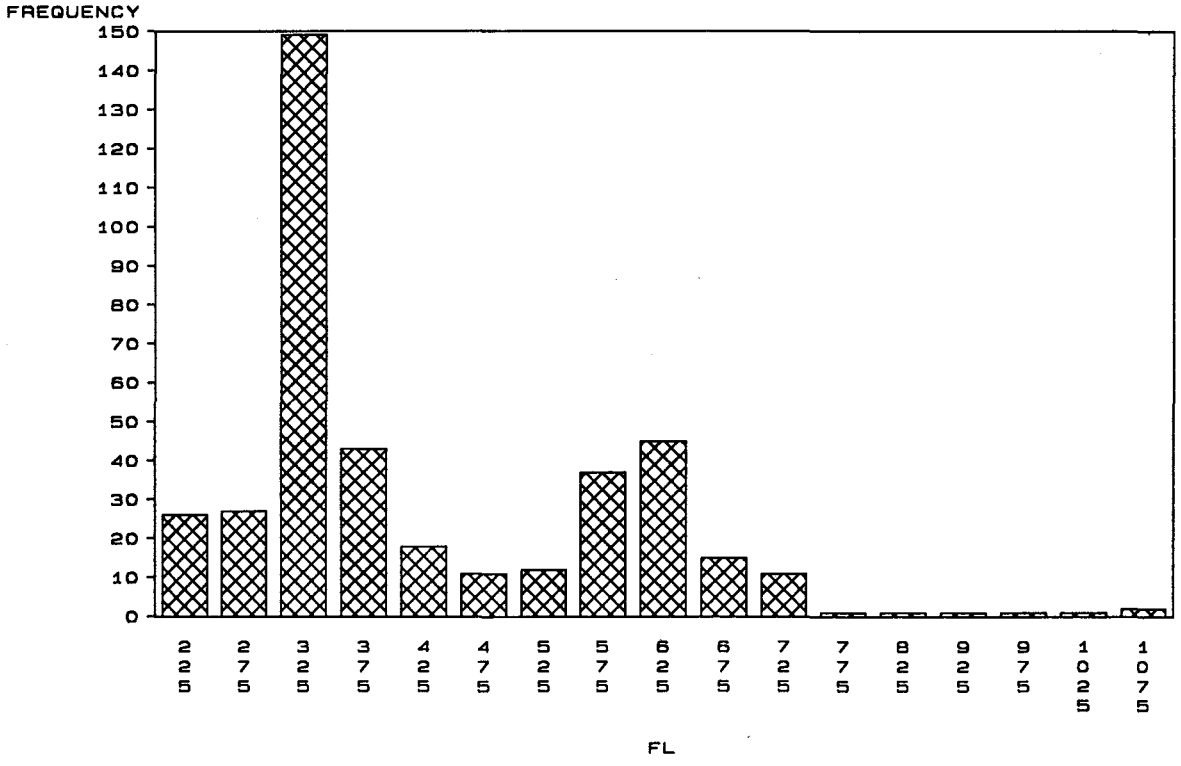
LENGTH FREQUENCIES FOR RED DRUM FROM GEORGIA

YEAR=86 GEAR=trammel



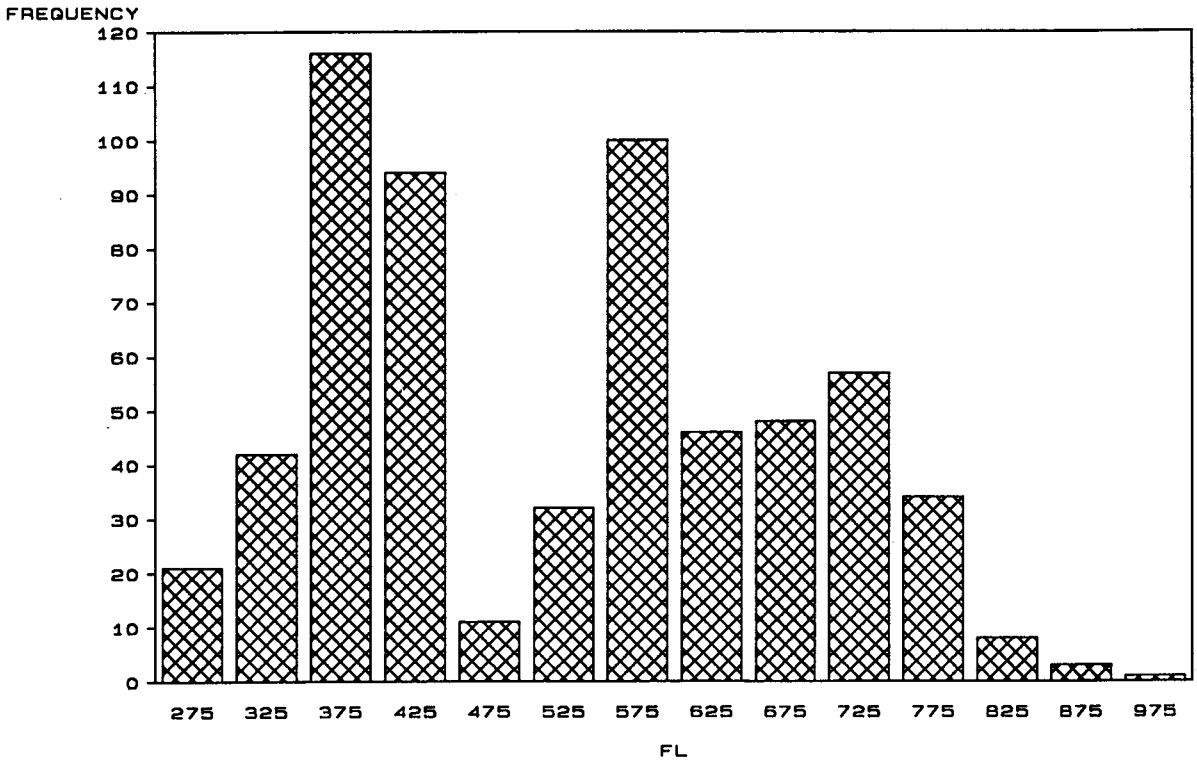
LENGTH FREQUENCIES FOR RED DRUM FROM GEORGIA

YEAR=87 GEAR=trammel



LENGTH FREQUENCIES FOR RED DRUM FROM GEORGIA

YEAR=88 GEAR=trammel



LENGTH FREQUENCIES FOR RED DRUM FROM GEORGIA

YEAR=89 GEAR=trammel