SEDAR 16-RD-04

Spatial and temporal variation in age composition and growth of king mackerel *Scomberomorus cavalla* from the southeastern U.S., 1986-1989; implications for stock structure and recruitment variability

Douglas A. DeVries

and

Churchill B. Grimes

National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Science Center
Panama City Laboratory
3500 Delwood Beach Road
Panama City, FL 32408

ABSTRACT

Otoliths of 5,145 king mackerel from North Carolina to Yucatan, Mexico were collected during 1986-89. Concurrently, lengths on 84,738 individuals were collected. Ages were determined using whole and sectioned sagittae. The oldest fish aged were a 24-year-old female and a 23-year-old male. Growth, as measured by observed mean size at age, showed little annual variation within sexes and regions (Atlantic, east Gulf, and west Gulf). Females grew faster and larger than males in all regions. Gulf females were significantly larger than Atlantic females at all ages except age one. Overall age composition was quite similar between sexes in all regions in the recreational fishery. Both sexes began recruiting to the recreational fishery by age one and were fully recruited by age three. The age structure in the recreational fishery was slightly truncated in the Atlantic and very truncated in the eastern Gulf. Age composition varied each year within regions and fisheries, but a common feature was the persistence of unique, dominant or weak year classes in each region. The existence of clearly recognizable, different strong or poor cohorts in each region strongly suggests that there is independent recruitment in each and therefore that they contain distinct stocks.

INTRODUCTION

King mackerel *Scomberomorus cavalla* are economically valuable and highly sought after by U.S. recreational and commercial fishermen from North Carolina to Texas (Manooch 1979). Their popularity led to overfishing of some populations and the implementation of a joint fishery management plan in 1983 by the Gulf of Mexico and South Atlantic Fishery Management Councils (1983)[1/]. The species is managed as two stocks, an Atlantic migratory group and Gulf migratory group, although the councils recognize there are actually two groups in the Gulf (Gulf of Mexico and South Atlantic Fishery Management Councils 1989)[2/]. However, the paucity of data from the large Mexican fishery precludes managing the two Gulf groups separately. Because tag return data (Sutter et al. 1991) collected during 1975-1978 indicated considerable seasonal movement between the Gulf and Atlantic Ocean, the boundary between the Gulf and Atlantic stocks was defined as the Volusia/Flagler County line off northeast

---

1/ Gulf of Mexico and South Atlantic Fishery Management Councils. 1983. Fishery management plan, final environmental impact statement, regulatory impact review, final regulations for coastal migratory pelagic resources (mackerels) in the Gulf of Mexico and South Atlantic region. Gulf of Mexico Fishery Management Council, Tampa, FL and South Atlantic Fishery Management Council, Charleston, SC.

2/ Gulf of Mexico and South Atlantic Fishery Management Councils. 1990. Amendment Number 5 to the fishery management plan for the coastal migratory pelagic resources (mackerels). Gulf of Mexico Fishery Management Council, Tampa, FL and South Atlantic Fishery Management Council, Charleston, SC.

Florida during November-March and the Monroe/Collier County line off southwest Florida during April-October.

Several studies have examined spatial, temporal, and gear related variation in life history and fishery parameters of king mackerel. The parameters have included mean back-calculated sizes, (Beaumariage 1973, Johnson et al. 1983), mortality or survival rates (Beaumariage 1973, Manooch et al. 1987), von Bertalanffy growth rates (Johnson et al. 1983, Manooch et al. 1987), and size, age, and sex composition of the catch (Beaumariage 1973, Johnson et al. 1983, Trent et al. 1983, Trent et al. 1987).

The usefulness of this information for current stock assessments is limited for several reasons. Much of the work was based on data collected 10 to 20 years ago when exploitation was much lower and population size, at least in the eastern Gulf of Mexico, was higher, i.e., 1968-1969 (Beaumariage 1973), 1968-1979 (Trent et al. 1983), and 1977-1978 (Johnson et al. 1983). Also, all of the studies involving ageing were based on examination of whole otoliths, which Collins et al. (1989) found to result in considerable underageing of older, larger fish when compared to using sectioned otoliths. In addition, current stock boundaries did not exist then; therefore, none of these studies partitioned their data accordingly. Also, some were quite limited geographically (Beaumariage 1973, Trent et al. 1987).

The primary objective of this study was to examine variation in growth and age composition in relation to space, time, sex, and fishing gear. Data from the recreational, tournament, commercial hook and line, and gill net fisheries during 1986-1989 were used to determine if they supported the current hypothesis on stock structure of king mackerel.

METHODS

Sagittal otoliths of king mackerel were quota-sampled (20 fish per year, region, sex, and 10-cm-size interval) from North Carolina through Yucatan, Mexico during 1986-1989 via a cooperative network of U. S. and Mexican samplers. Heads were shipped to our laboratory where otoliths were removed and stored dry. Quotas were often exceeded for abundant size intervals and not reached for the smallest and largest intervals. Regions reflected, more or less, those that were inferred by current stock hypotheses (Grimes et al. 1987, Johnson et al. Ms), i.e., Atlantic: North Carolina to about Miami, FL; Eastern Gulf: Florida Keys through Mississippi, and, during April-October, Louisiana; and Western Gulf: Mexico and Texas and, during November-March, Louisiana. All Louisiana samples in this study were collected during April-October, so all were classified as eastern Gulf. We made no attempt to adjust seasonally the Atlantic-eastern Gulf boundary as the current fishery management plan does. Only 134 (2.6%) of all aged fish were collected off east and southeast Florida during November-March, the months when the east Gulf and Atlantic stocks are thought to mix in that area.

The largest portion of length frequency data was collected by the same samplers collecting otoliths. They attempted to collect randomly at least 200 fork lengths, and sex whenever possible, each month from each type of gear during the fishing season. Other significant sources of length data included NMFS's Trip Interview Program (Zweifel 1988)[3/] (commercial data) and Marine Recreational Fishery Statistics Survey (Department of Commerce 1980), various state fishery agencies, and a headboat survey conducted by the NMFS Beaufort Laboratory in Beaufort, NC.

Length data from four major gear types were analyzed. Recreational hook and line (hereafter referred to as recreational) included data from head boats, charterboats, private boats, piers, shorelines, jetties, and tagging studies. Tournament-caught fish were considered separately, because the data usually did not accurately represent the size distribution available to recreational gear, but was biased towards large fish. Commercial hook and line (hereafter referred to simply as commercial) included commercial trolling, longline, and bottom

---

3/ Zweifel, J.R. 1988. Operations manual for the trip interview program in the State/Federal Cooperative Statistics Program. Unpubl. manuscr., 65 p. Southeast Fisheries Center, National Marine Fisheries Service, NOAA, Miami, FL 33149.

line gear. Gill net included both run-around and drift gill nets.

Otoliths were sectioned using a Beuhler Isomet low-speed saw. Three dorsoventral, transverse sections about 0.7 mm thick were made about the focus. Sections were examined under transmitted light at 50 or 125X using a compound microscope. Whole otoliths were placed in a black-bottomed dish containing glycerin and examined with a dissecting microscope at 12-25X using reflected light from two fiber optic lights. Annuli of whole otoliths were identified using the criteria of Johnson et al. (1983), while Waltz's (1986)[4/] criteria were used for sections. Waltz identified annuli as narrow opaque bands extending from each side of the sulcus acousticus. In almost every instance the dorsal half of the section was read because it was much clearer than the ventral.

Otoliths were read whole for males <80-cm FL and females <90-cm FL except for 1987 fish, in which case all fish <90-cm FL were aged with whole otoliths. All otoliths collected during 1986-1988 were read independently by two readers. If disagreement occurred on the first reading, a second reading was made; if disagreement occurred again, the otolith was excluded

---

4/ Waltz, W. 1986. Data report on preliminary attempts to assess and monitor size, age, and reproductive status of king mackerel in the south Atlantic Bight. S.C. Wildl. Mar. Res. Dep. MARMAP Rep. for contract number 6-35147.

from the analysis. Otoliths collected in 1989 were read by the senior author alone.

Ages of fish collected from mid-July through March were assigned solely on the basis of number of visible annuli. One year was added to the age of fish collected during April through mid-July if the marginal increment was estimated to be >80% of the previous annual increment. This adjustment was necessary, because the annulus typically forms then (Beaumariage 1973, Johnson et al. 1983) but is often difficult to distinguish until later in the summer. All ages reported herein are in years.

Unsexed length frequency data were sexed using sex ratios generated from sexed length data collected in the same year, region, and 5-cm-size interval. If no sexed data were available in a size interval, the ratio from the nearest interval with data was used, except that a 1:1 ratio was applied to fish <77.5 cm, while all ≥137.5 cm were assumed to be females. This procedure was based on the findings of Trent et al. (1983) and our data.

Length-frequency data were aged using proportions at age (age-length keys) calculated from age data collected from the same year, region, sex and 5-cm-size interval. In cases where there were length data but no matching age data, which typically involved the smallest and largest size intervals, age data in the closest size interval were used.

RESULTS

We aged 5,145 king mackerel: 705 from 1986, 1,435 from 1987, 1,537 from 1988, and 1,468 from 1989 (Table 1). Lengths were collected on 84,738 individuals: 21,757 in 1986, 30,882 in 1987, 16,007 in 1988, and 16,092 in 1989.

Longevity

The oldest king mackerel was a 24-year-old female, 144-cm FL, caught off Galveston, Texas in 1989. The oldest male, collected off North Carolina in 1988, was age 23 and 114.0-cm FL. Maximum ages of males during 1986-1989 were 17, 19, 23, and 20, respectively, in the Atlantic Ocean; 17, 18, 22, and 19 in the eastern Gulf; and 12, 18, 16, and 15 in the western Gulf. Maximum ages of females those same years were 18, 18, 20, and 20 in the Atlantic; 19, 21, 21, and 21 in the eastern Gulf; and 19, 18, 17, and 24 in the western Gulf.

Growth

Variation Among Years Within Regions and Sexes

Growth, as measured by observed mean size at age, showed little annual variation within sexes and regions during 1986-1989 (Figure 1). Significant differences (ANOVA, $P \leq .05$) in mean size at age among years occurred in only 19 out of 104 age, sex, and region combinations with at least two years of data (Table 2). Six of those 19 combinations with significant differences were age 1 or 2, when: 1) growth is fastest and size is most variable, so that mean size was most sensitive to sampling dates, and 2) sample sizes were typically largest, so that small differences which might not be biologically meaningful were statistically detectable. Ten of those 19 significant differences occurred in Atlantic fish, 3 in eastern Gulf fish, and 6 in western Gulf fish. The lack of significant annual differences in mean sizes at age within regions validates our pooling those data for growth comparisons among regions.

Variation Between Sexes Within Regions

Female king mackerel grew faster and larger than males in all regions. The differences between mean observed sizes at age were highly significant (T-test, $P \leq 0.001$)between sexes for almost all age classes in all regions for pooled 1986-1989 data (Figure 2). Sizes were not significantly different between sexes only in age 1 and 20 Atlantic and age 16 east Gulf fish. Although statistically significant, the differences at ages one and two were quite small, averaging 1.5, 2.6, and 6.0 cm in the Atlantic, east Gulf, and west Gulf. For older fish, however, the difference was much greater. Pooling mean observed sizes-at-age for all ages above age 5, females averaged 17.0, 23.6, and 18.8 cm larger than males in the Atlantic, east Gulf, and west Gulf.

Variation Among Regions Within Sexes

Female king mackerel from the Gulf of Mexico, except for age 1 fish from the west Gulf, were significantly larger (T-test, $P \leq .01$ in all but one case) than Atlantic females at all ages (Figure 3, Table 3). East Gulf females were significantly larger ($P \leq .03$) than west Gulf females at ages 4-9 and 12-14, while the latter were larger at age 2. At all other ages there were no significant differences. For all ages above 6, the mean of all mean observed sizes-at-age for east Gulf females averaged 15.6 cm larger than Atlantic and 6.0 cm larger than west Gulf females. West Gulf females older than age 6 averaged 9.7 cm larger than Atlantic females.

In most cases (24 of 33 age-region combinations), Gulf male king mackerel were significantly larger than Atlantic males of the same age. Within the Gulf, there were no significant differences in mean size at age between east and west Gulf fish except at ages 1, 3, and 4, when east Gulf fish were larger (Figure 3, Table 3). East Gulf males ages 2-12 and 14-16 and west Gulf males ages 2, 6-12, and 14-15 were significantly larger ($P \leq 0.02$) than Atlantic males. There were no significant differences in mean size at age between Atlantic and east Gulf males, ages 1, 13, and 17 and west Gulf males ages 4, 5, 13, and 18. Atlantic males were never significantly larger than east Gulf males, and only at ages 1 and 3 were they larger than west

Gulf males. East and west Gulf males above age 6 averaged 8.9 and 7.4 cm larger than Atlantic males.

Age Composition

Variation Between Sexes

Overall age composition was quite similar between sexes in all regions in the recreational fishery during 1986-1989 (Figure 4). We examined only the recreational fishery, because we assumed it was the least size-selective fishery. Both sexes began recruiting to the fishery at age 1 in all regions. In Atlantic samples 2-year-olds dominated both sexes; 55.5% of females and 49.6% of males were 1 or 2 years old. Both sexes were fully recruited by age 3. Although skewed towards young ages, fish through age 11 represented at least 1% of both distributions. East Gulf distributions were very truncated; 70.1% of the females and 54.0% of the males were 1 or 2 years old. Females were fully recruited by age 3, males by age 2, although in reality most females are recruited by age 2 as well. The oldest females making up at least 1% of the total distribution were age 7, compared to age 9 for males. In the western Gulf, modal age was 3 to 4 for both sexes, with females to age 11 and males to age 10 comprising at least 1% of the total distribution.

Variation Among Regions

Overall age composition for 1986-1989 within the recreational, tournament, and commercial fisheries varied considerably among regions (Figure 5). In the recreational fishery, the age distribution was slightly truncated in the Atlantic and very truncated in the east Gulf, with age 2 fish dominating the former and age 1 and 2 the latter. In contrast, modal age was 3 to 4 in the west Gulf.

The age distribution of tournament samples in the Atlantic had a mode at age 4, but fish as old as 17 years composed at least 1% of the total. The east Gulf had a strong mode at age 2 and the distribution was much more truncated than the other two regions. The west Gulf samples, like the Atlantic, had a modal age of 4, with fish up to age 16 constituting at least 1% of the distribution.

In commercial samples, Atlantic fish were dominated by 2-year olds; the east Gulf distribution was slightly bimodal with peaks at ages 2 and 5, while in the west Gulf the modal age was 3.

Variation Among Gears

Age composition within regions varied considerably among recreational, commercial, and tournament fisheries (Figure 5). In the Atlantic, both the recreational and commercial fisheries were dominated by 2-year olds, although age composition in the former was more truncated than in the latter. The oldest age class comprising at least 1% of the total recreational distribution was 11, compared to 14 for the commercial fishery. In contrast, age distribution of tournament samples was much broader, with a mode at age 4 and fish as old as 17 making up at least 1% of that distribution.

In the east Gulf, the recreational age distribution was very truncated, with a strong mode at ages 1 and 2 and no ages older than 8 comprising >1% of the total. Age distribution of east Gulf tournament samples was slightly truncated, with a mode at age 2 and fish to age 11 present in significant amounts (>1% of total distribution). In commercial samples, the distribution was bimodal, with peaks at age 2 and 5, and much broader than that of either the recreational or tournament fisheries, with fish to age 15 comprising at least 1%.

West Gulf samples showed the least variation among fisheries. Modal ages in the recreational, tournament, and commercial fisheries were 3-4, 4, and 3, respectively. As in the Atlantic, age distribution was broadest in the tournament samples, where fish to age 16 comprised >1% of the total, compared to age 10 for commercial and age 11 for recreational samples.

Variation Among Years Within Regions and Fisheries

Age composition varied each year within regions and fisheries, sometimes considerably, but a common feature was the persistence of unique, dominant or conspicuously absent year classes in each region.

Recreational fishery - Age distributions in the recreational fishery were truncated in the Atlantic and eastern Gulf, and showed a slight increase in modal age in the Atlantic and a decrease in the western Gulf. A strong 1979 cohort in the Atlantic, a strong 1982 cohort in the eastern Gulf, and a weak 1980 cohort in the western Gulf were apparent in the distributions (Figure 6).

In the Atlantic, the age distribution was slightly truncated compared to the western Gulf, and the modal age increased from 2 during 1986-1988 to 3 in 1989. A strong secondary mode equating to the 1979 cohort tracked from age 7 to 10 during 1986-89. The increase in modal age in 1989, along with a large increase in the proportion of age 3 fish in 1988 and, to a lesser extent, age 4 fish in 1989, hints at the possibility that the 1985 year class was also quite strong.

The age distribution in the eastern Gulf was greatly truncated all four years; modal age increased from 1 in 1986 to 2 in 1987, where it remained until 1989, when it returned to 1. An apparently strong 1982 year class was readily visible as a secondary mode which progressed from age 4 to 7 during 1986-1989.

Age distribution in the western Gulf was broadest of the three regions and became more truncated each year. Modal age dropped from 5 in 1986 to 4 in 1987 to 2-3 in 1988 before increasing to 3 in 1989. The scarcity of 6-year olds in 1986 and 7-year olds in 1987 suggests that the 1980 year class was poor.

Tournament fishery - The most notable feature of age distribution in the tournament data was the even more obvious presence of the same strong and weak year classes seen in the recreational data (Figure 7). In the Atlantic, the 1979 cohort was again very conspicuous; it was the modal age class in 1986 and comprised very strong secondary modes during 1987-1989. As in the recreational data, there is some indication that the 1985 year class was quite strong, as it dominated the 1988 samples and was only slightly less abundant than the modal ages in 1987 and 1989. In the eastern Gulf, the strong 1982 cohort observed in the recreational data was again prominent, at least after 1986, despite small sample sizes. The weak 1980 cohort seen in the recreational data of the west Gulf was even more obvious in the tournament data, as it was conspicuously weak in all four years. The inherent bias towards large individuals in tournament data, as well as small sample sizes from the entire Gulf, precludes making any generalizations about annual variations in the overall regional age distributions.

<u>Commercial fishery-</u> As in the recreational and tournament data, age composition from the commercial fishery was characterized by the presence of a strong 1979 cohort in the Atlantic; a strong 1982 year class in the eastern Gulf, at least through 1988; and a poor 1980 group in the western Gulf through 1987 (Figure 8). Modal ages in the Atlantic increased from age 2 in 1986 and 1987 to age 2-3 in 1988 to age 3 in 1989. The strong secondary mode at ages 7-10, the 1979 cohort, noted each year in the recreational and tournament fisheries, was again obvious in this fishery. The predominance of 2-year olds in 1987 and the high proportions of 3- and 4-year olds in 1988 and 1989 provide further evidence of the possibly strong 1985 year class suggested in the recreational and tournament data.

In the east Gulf, the dominant ages through 1988 were those which comprised the secondary modes in the recreational and tournament fisheries, i.e., 4, 5, and 6, confirming the dominance of the 1982 cohort in that region. Age-2 fish comprised the secondary modes in the commercial fishery through 1988. In 1989 the distribution was extremely truncated and totally dominated by age-1 fish.

In the west Gulf, modal ages declined from age 5 in 1986 to 2 by 1988, then increased to 3 in 1989. Along with the decline in modal ages was the same progressive truncation of the age distribution noted in the recreational data. The poor 1980 year class so obvious in the tournament data was noticeable in the commercial data only in 1986, and to some extent, 1987.

Gill-net fishery - Age distribution of catches from gill nets was quite different from that of the other three fisheries, and only in the Atlantic was there evidence of the strong or weak year classes noted in those other fisheries.

In the Atlantic, modal age fell from 4 in 1986 and 1987 to 3 in 1988 and 1989, which is opposite the pattern seen in the recreational and commercial data, where modal age rose from 2 to 3 during the study. The strong 1979 cohort so conspicuous in the other fisheries was also very evident in the gill-net data, at least after 1986.

In the east Gulf, large proportions of fish ages 1-4 were present in 1986. In 1987, the distribution was greatly truncated and totally dominated by 2-year olds. No 1988 or 1989 data were collected.

Age distributions of gill-netted fish from the west Gulf were very truncated each year with few fish older than age 4 and with modes dropping from age 2 in 1986 and 1987 to age 1 in 1988 and 1989.

DISCUSSION

Longevity

The 24-year-old female and 23-year-old male that we found are the oldest king mackerel reported to date. Our finding of males almost as old as our oldest female differs from all previous studies, which, except Beaumariage (1973), found that typically females lived longer than males. Collins et al. (1989), using sectioned otoliths, found a 21-year-old female and males to age 16. Other studies, using whole otoliths, reported maximum ages for males and females of 12 and 12 (Beaumariage 1973), 9 and 14 (Johnson et al. 1983), 11 and 14 (Manooch et al. 1987), and 7 and 10 (Sturm and Salter 1990).

Growth

The very-limited annual variation we observed in mean size at age within sexes and regions suggests there were no density-dependent responses in growth during our study, unlike results reported for haddock Melanogrammus aeglefinus (Jones 1983) and silver hake Merluccius bilinearis (Ross and Almeida 1986). Perhaps the reasonably stable exploitation rates and absence of recently-recruited dominant year classes in the fisheries (except possibly the 1985 Atlantic cohort) simply did not produce any large enough changes in population density to elicit such a response.

A comparison of our observed mean sizes at age for east Gulf fish to Beaumariage's (1973) fish collected in 1968 and 1969 off southwest, southeast, and northeast Florida show no obvious patterns, although we could not test for statistical differences, because his raw data were unavailable. Back-calculated lengths at age from Johnson et al. (1983) and Manooch et al. (1987) were usually smaller than our observed lengths at age; these results were not unexpected, given that back-calculated lengths are usually less than observed lengths at age.

Our finding that females grew faster and larger than males agrees with all previous studies. Beaumariage (1973) and Sturm and Salter (1990) reported females grew more rapidly than males after or by age 2, and Johnson et al. (1983) noted that females were larger than males at all ages. Mean back-calculated sizes at age of Atlantic females above age 5 (Collins et al. 1989), averaged 13.9 cm larger than males, which is fairly close to the 17.0 cm we calculated for that region.

The significant differences in observed sizes at age, and hence growth, between Gulf and Atlantic king mackerel, especially females, may be further evidence that they are different stocks. Also these differences may reflect their recent history of exploitation, i.e., higher growth rates in the eastern Gulf could be a density dependent response to the higher rate of exploitation there. The fact that east Gulf females were significantly larger than those in the west Gulf at ages 4-9 and 12-14 can be similarly interpreted, i.e., it supports the concept of eastern and western stocks in the Gulf (Grimes et al. 1987, Johnson et al. Ms), or it may reflect higher exploitation in the eastern Gulf. While not indicative of genetic discontinuity, these three groups of fish apparently experience sufficient differences in environmental and fishery conditions to have identifiable and consistent differences in growth.

Contrary to our finding of regional differences in growth within sexes, Beaumariage (1973) reported that growth rates did not differ for either sex between the Gulf and Atlantic coasts of Florida. There are at least three possible explanations for this. First, density dependent growth responses to differing exploitation rates may not have been occurring 20 years ago, whereas they may be now. Second, many of Beaumariage's samples were collected off southeast Florida during winter and thus may have been Gulf fish, based on mark-recapture studies that have shown that Gulf and Atlantic fish both migrate to south Florida in winter (Sutter et al. 1991, Sutherland and Fable 1980). Third, Beaumariage used whole otoliths for ageing, so many of the larger individuals may have been underaged, which would have inflated his length at age estimates for older fish.

Johnson et al. (1983) did find regional differences in growth, but not the same as we found. They reported that female king mackerel from Louisiana grew faster than females from other areas of the Gulf and from the Atlantic. However, their mean observed sizes for Louisiana fish ages 4-8, the ages with adequate sample sizes (n = 16-78) and the ages which according to our results could have been accurately aged with whole otoliths, were only 0.9-4.9 cm larger than ours for eastern Gulf fish. Above age 8, their estimates were increasingly larger than ours, most likely because their use of whole otoliths resulted in underageing these larger fish.

Age Composition

The similarity in age composition between sexes in king mackerel in the Atlantic suggests that they experience similar mortality rates. The age distributions of both eastern and western Gulf females were slightly more truncated than that of the males, indicating the females have slightly higher mortality rates. This is probably explained by the fact that Gulf females are exposed to fishing longer than males because their faster growth rates result in earlier recruitment to the fishery. The mean observed sizes of eastern and western Gulf females were 3.2 and 4.5 cm larger than males at age 2 and 4.7 and 7.7 cm larger at age 3. In contrast Atlantic females were only 1.6 and 3.9 cm larger than males at ages 2 and 3. Manooch et al. (1987) reported that total mortality was always higher for males than females from south Florida, northwest Florida, and Texas. Probable underageing of older fish owing to their use of whole otoliths could explain these contradictory findings.

Most of the regional variation in the overall recreational age distributions probably reflects their individual exploitation histories. The very truncated recreational age composition in the east Gulf is characteristic of a heavily fished population, which the Gulf of Mexico and South Atlantic Fishery Management Councils (1989)[2/] reported to be the case for that group. The broader, much less truncated age distribution and higher modal age (3-4 versus 1-2) in the west Gulf suggests that this group has experienced a lower fishing rate than the Atlantic or east Gulf. These regional differences could also be, at least in part, the results of differences in growth and/or recruitment. The biased nature of tournament data weakens any conclusions drawn from it, but the fact that the age distribution in the east Gulf was the most truncated of the three regions is consistent with the pattern seen in the recreational fishery.

The broader age distribution and older modal age in commercial samples from the east Gulf than in samples from the Atlantic or west Gulf contradicts our findings in the recreational and tournament fisheries. This inconsistency reflects the presence of large proportions of 4-and 5-year olds from the dominant 1982 year class in the east Gulf, the more size-selective nature of commercial king mackerel fisheries, and the fact that many (68%) of the east Gulf samples were collected in Louisiana, where large fish have historically been caught. Trent et al. (1987) reported that "mean lengths of king mackerel caught in commercial hook-and-line fisheries in the southeastern United States were generally larger in Louisiana than other areas except South Carolina or Georgia".

Variation in age composition among gears within regions reflects gear selectivity more than any other factor. Recreational fisheries are the least selective, while tournament fisheries select for larger, older individuals. Selectivity in commercial fisheries is influenced by market demands, which may vary seasonally and regionally. The great differences noted among fisheries of the east Gulf reflect the fact that a large proportion of the commercial data came from Louisiana, as noted above.

The age structures of most of the king mackerel fisheries in the western Gulf became increasingly truncated and the age of full recruitment declined during 1986-1989. Both of these changes were undoubtedly the result of fishing, which removed larger and older fish. The Gulf of Mexico and South Atlantic Fishery Management Councils (1989)[2/] concluded that "it is likely that the abundance of these (west Gulf) fish has declined in the last decade, and that controls on the U.S. rate of fishing should be maintained". It seems unlikely the decline in age of full recruitment represents an actual decrease in size of recruitment to the gear, as size selectivity of both recreational and commercial gear is quite stable and the decline appeared in both fisheries simultaneously. The age structure of east Gulf fish showed no evidence of increasing truncation, probably because it was already truncated by heavy exploitation prior to 1986. In the Atlantic, the absence of increasing truncation probably reflects the relatively stable and moderate level of exploitation occurring there. The Gulf of Mexico and South Atlantic Fishery Management Councils (1989)[2/] noted that the Atlantic stock was not overfished and the fishing mortality rate is below the level which will produce maximum yield.

The data showing annual variation in age composition within regions support the concept that three distinct stocks of king mackerel exist, one each in the east Gulf, west Gulf, and Atlantic. Different strong or poor year classes are clearly recognizable in each region, strongly suggesting that there is independent recruitment in each. These dominant and poor cohorts were conspicuous as secondary modes or obvious gaps in the age distribution in each region each of the four years, and in all the fisheries in the Atlantic and all but the gill-net fishery in the Gulf. It is important to underscore that these data provide good evidence that the Atlantic and east Gulf contain distinct stocks. Starch gel electrophoretic data were used to identify discrete east and west Gulf stocks (Grimes et al. 1987, Johnson et al. Ms) but the Atlantic was not distinguishable from the east Gulf. However, the limited recapture data from fish tagged during the spawning season (Sutter et al. 1991, Johnson et al., Ms) showed little or no mixing between Atlantic and east Gulf fish, so the two regions are considered to contain distinct stocks.

The fact that we detected and tracked different strong and poor year classes in each region indicates that the design and sampling level of our program to collect length and age data on king mackerel are adequate to at least detect major trends in the fisheries, and also provides additional validation, at least for king mackerel 4-10 years old, of our ageing technique. In addition, the annual variability in age structure underscores the need to conduct frequent stock assessments. The passage of dominant or poor cohorts through the fishery could significantly impact the proportions of each age within a size interval in an age-length key and the distribution about the mean sizes at age in a growth curve. The density dependent effect of a reduced growth rate which sometimes characterizes dominant year classes (Jones 1983, Ross and Almeida 1986) could also affect the accuracy of an assessment using growth curves from previous years to age the fish.

ACKNOWLEDGMENTS

We would like to thank the Instituto Nacional de la Pesca for the cooperation of their personnel at the fishery laboratories in Yucalpeten, Campeche, Alvarado, and Tampico in obtaining samples and data from the Mexican fisheries. K. Burns and her colleagues at the Mote Marine Laboratory were especially helpful both in field sampling in Mexico and in ensuring the shipment of samples and data to us. J.J. Isely provided valuable insight and data processing assistance with the length frequency data sets. Special thanks are also due the North Carolina Division of Marine Fisheries, and in particular L. Mercer, L. Nobles, and R. Gregory, for providing us with large numbers of processed otoliths.

LITERATURE CITED

Beaumariage, D.S. 1973. Age, growth and reproduction of king mackerel, Scomberomorus cavalla, in Florida. Fla. Mar. Res. Publ. 1:45 p.

Collins, M.R., D.J. Schmidt, C.W. Waltz, and J. L. Pickney. 1989. Age and growth of king mackerel, Scomberomorus cavalla, from the Atlantic coast of the United States. Fishery Bulletin, U.S. 87:49-61.

Department of Commerce. 1980. Marine recreational fishery statistics survey, Atlantic and Gulf coasts, 1979. U.S. Dept. Commerce, NOAA, National Marine Fisheries Service, Current Fishery Statistics Number 8063.

Grimes, C.B., A. G. Johnson, and W.A. Fable, Jr. 1987. Delineation of king mackerel, Scomberomorus cavalla, stocks along the U.S. east coast and in the Gulf of Mexico (ABSTRACT). NOAA Tech. Mem. NMFS-SEFC-199.

Johnson, A.G., W.A. Fable, Jr., M.L. Williams, and L.E. Barger. 1983. Age, growth and mortality of king mackerel, Scomberomorus cavalla, from the southeastern United States. Fish. Bull., U.S. 81(1):97-106.

Johnson, A.G., W.A. Fable, Jr., C.B. Grimes, L. Trent and J.V. Perez. Ms. Evidence for distinct stocks of king mackerel Scomberomorus cavalla in the Gulf of Mexico. Submitted for publication. Fish. Bull., U.S.

Jones, R. 1983. An investigation of North Sea haddock (Melanogrammus aeglefinus) length-at-age data, with particular reference to the effects on growth of the outstanding year classes of 1962 and 1967. Journal du Conseil, Conseil International pour l'Exploration de la Mer 4:50-62.

Manooch, C.S., III. 1979. Recreational and commercial fisheries for king mackerel, Scomberomorus cavalla, in the South Atlantic Bight and Gulf of Mexico, U.S.A. In: E.L. Nakamura and H.R. Bullis, Jr. (editors), Proceedings of the mackerel colloquium, p. 33-41. Gulf States Mar. Fish. Comm., Brownsville, TX.

Manooch, C.S., III, S.P. Naughton, C.B. Grimes, and W.L. Trent. 1987. Age and growth of king mackerel, Scomberomorus cavalla, from the U.S. Gulf of Mexico. Mar. Fish. Rev. 49(2):102-108.

Ross, M.R., and F.P. Almeida. 1986. Density-dependent growth of silver hakes. Transactions of the American Fisheries Society 115:548-554.

Sturm, M.G.deL., and P. Salter. 1990. Age, growth, and reproduction of the king mackerel, Scomberomorus cavalla (Cuvier), in Trinidad waters. Fish. Bull., U.S. 88:361-370.

Sutherland, D.F., and W.A. Fable, Jr. 1980. Results of a king mackerel (Scomberomorus cavalla) and Atlantic Spanish mackerel (Scomberomorus maculatus) migration study, 1975-79. NOAA Tech. Memo., NMFS-SEFC-12. 18 pp.

Sutter, F.C., R.O. Williams, and M.F. Godcharles. 1991. Movement patterns and stock affinities of king mackerel in the southeastern United States. Fish. Bull., U.S. 89:315-324.

Trent, L., W.A. Fable, Jr., S.J. Russell, G.W. Bane, and B.J. Palko. 1987. Variations in size and sex ratio of king mackerel, Scomberomorus cavalla, off Louisiana, 1977-85. Mar. Fish. Rev. 49(2):91-97.

Trent, L., R.O. Williams, R.G. Taylor, C.H. Saloman, and C.S. Manooch, III. 1983. Size, sex ratio, and recruitment in various fisheries of king mackerel, Scomberomorus cavalla, in the southeastern United States. Fish. Bull., U.S. 81:709-721.

Table 1. Sample sizes of king mackerel ageing and length frequency data by year, sex, and region. F = Female, M = Male, U = Unknown.

			Region		
Data	Year	Sex	Atlantic Ocean	Eastern Gulf	Western Gulf
Ageing	1986	F	204	163	48
		M	176	66	48
	1987	F	345	382	203
		M	233	141	131
	1988	F	258	299	433
		M	200	124	223
	1989	F	497	278	152
		M	336	142	63
Length frequency	1986	F	3,758	2,308	1,129
		M	2,750	2,061	854
		U	5,908	1,643	1,404
	1987	F	7,820	1,806	1,667
		M	5,488	832	895
		U	6,242	3,567	2,856
	1988	F	2,644	577	1,331
		M	2,568	271	776
		U	3,547	1,210	3,204
	1989	F	3,464	791	890
		M	2,793	366	384
		U	2,677	301	4,423

Table 2. Results of ANOVA to test hypothesis that there was no difference in mean size at age among years by sex and region for king mackerel collected in 1986-1989. Underlined values indicate significant differences.

	Atlantic Ocean				Eastern Gulf				Western Gulf			
	Females		Males		Females		Males		Females		Males	
Age	Pr>F	n	Pr>F	n	Pr>F	n	Pr>F	n	Pr>F	n	Pr>F	n
0	.395	5										
1	.000	136	.477	120	.000	265	.003	95	.043	46	.786	25
2	.031	224	.000	174	.933	228	.622	95	.499	133	.200	52
3	.013	176	.490	134	.804	93	.398	50	.292	164	.560	65
4	.399	149	.081	93	.592	88	.229	49	.126	143	.131	73
5	.552	87	.001	55	.323	90	.146	28	.011	88	.707	53
6	.936	59	.392	48	.973	58	.117	44	.340	51	.288	45
7	.079	66	.281	33	.179	53	.074	41	.397	34	.648	42
8	.726	57	.299	38	.216	37	.611	15	.336	22	.576	32
9	.627	60	.005	29	.114	35	.428	12	.320	28	.622	21
10	.029	61	.127	65	.087	30	.512	8	.048	29	.617	21
11	.628	35	.772	23	.084	18	.120	12	.448	31	.855	8
12	.035	39	.055	29	.724	19	.629	4	.640	16	.023	8
13	.084	26	.968	17	.380	17	.396	3	.957	13	.050	4
14	.251	31	.496	21	.793	28			.288	10	.515	5
15	.097	32	.216	19	.446	19	.581	5	.043	9	.064	7
16	.560	23	.051	19	.148	10			.618	10		
17	.013	19	.256	15	.478	9			.514	6		
18	.080	11	.685	7	.023	13						
19	.767	6			.868	3						
20												
21					.308	4						

Table 3. Sample sizes for observed mean sizes at age data of king mackerel collected during 1986-89 and results of T-tests to test hypothesis that there was no difference in mean size at age between regions within sexes. AO = Atlantic Ocean. EG = East Gulf. WG = West Gulf.

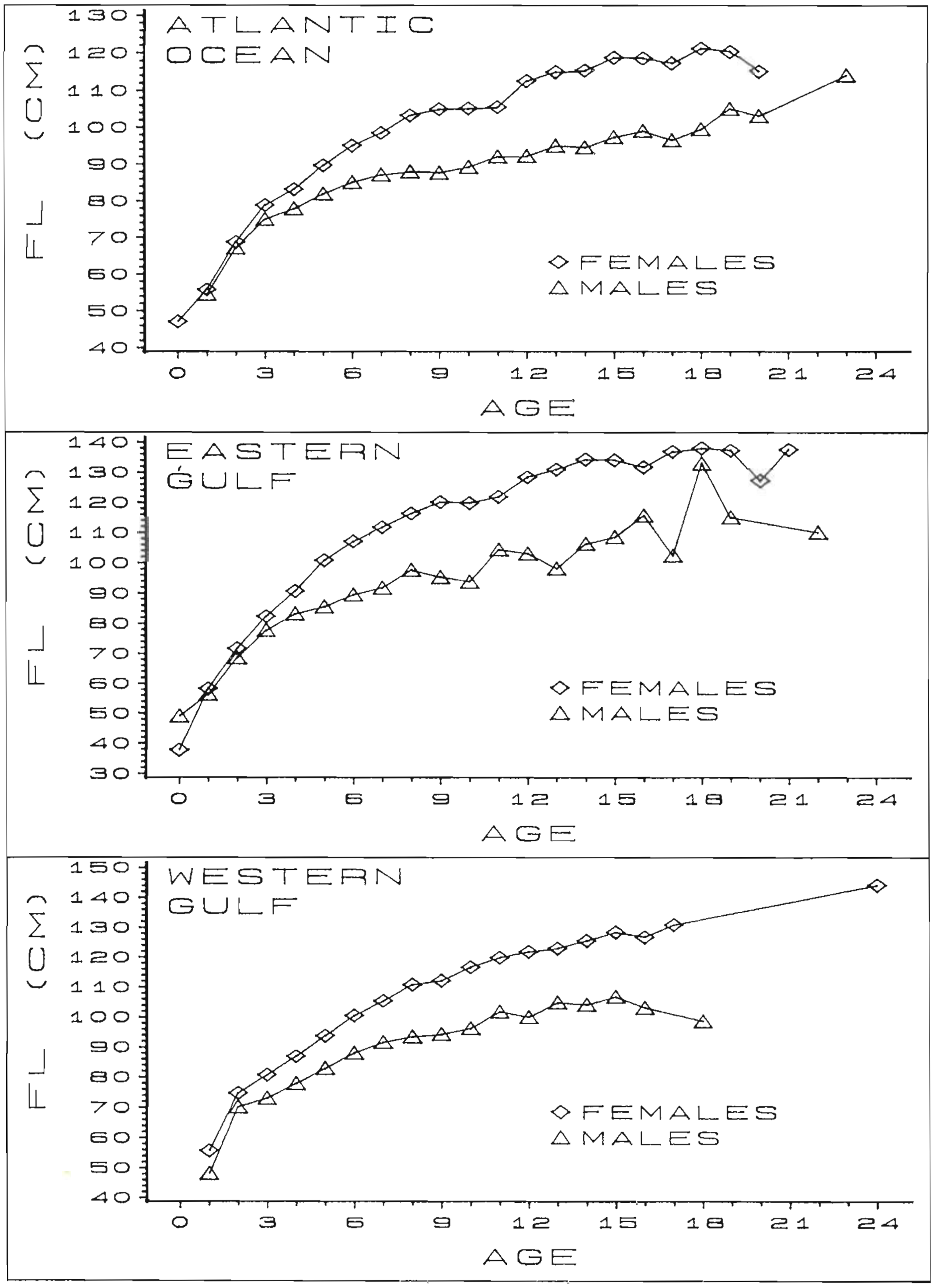
SAMPLE SIZE

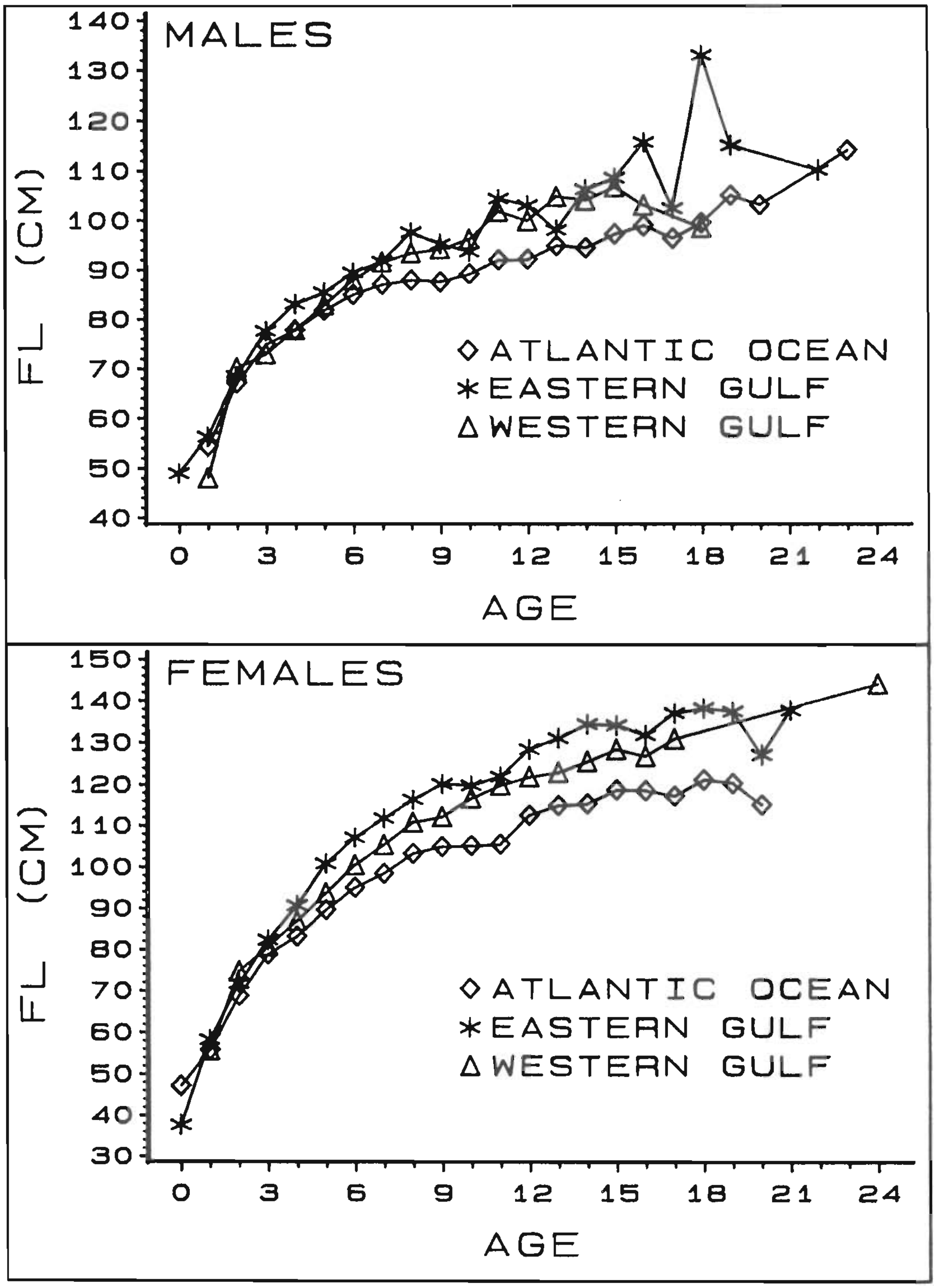
Age	Females			Males		
	AO	EG	WG	AO	EG	WG
0	5	3			1	
1	137	265	46	120	95	25
2	224	228	133	174	95	52
3	176	93	164	134	50	65
4	149	89	143	93	49	73
5	86	90	88	55	28	53
6	59	58	51	48	44	45
7	66	53	34	33	41	42
8	57	37	22	28	15	32
9	60	35	28	29	12	21
10	61	30	29	65	8	21
11	35	18	31	23	12	8
12	39	19	16	29	4	8
13	26	17	13	17	3	4
14	31	28	10	21	2	5
15	32	19	9	19	5	7
16	23	10	10	19	3	2
17	19	9	6	15	3	
18	11	13		7	1	2
19	6	3		3	1	
20	2	1		2		
21		4				
22					1	
23				1		
24			1			

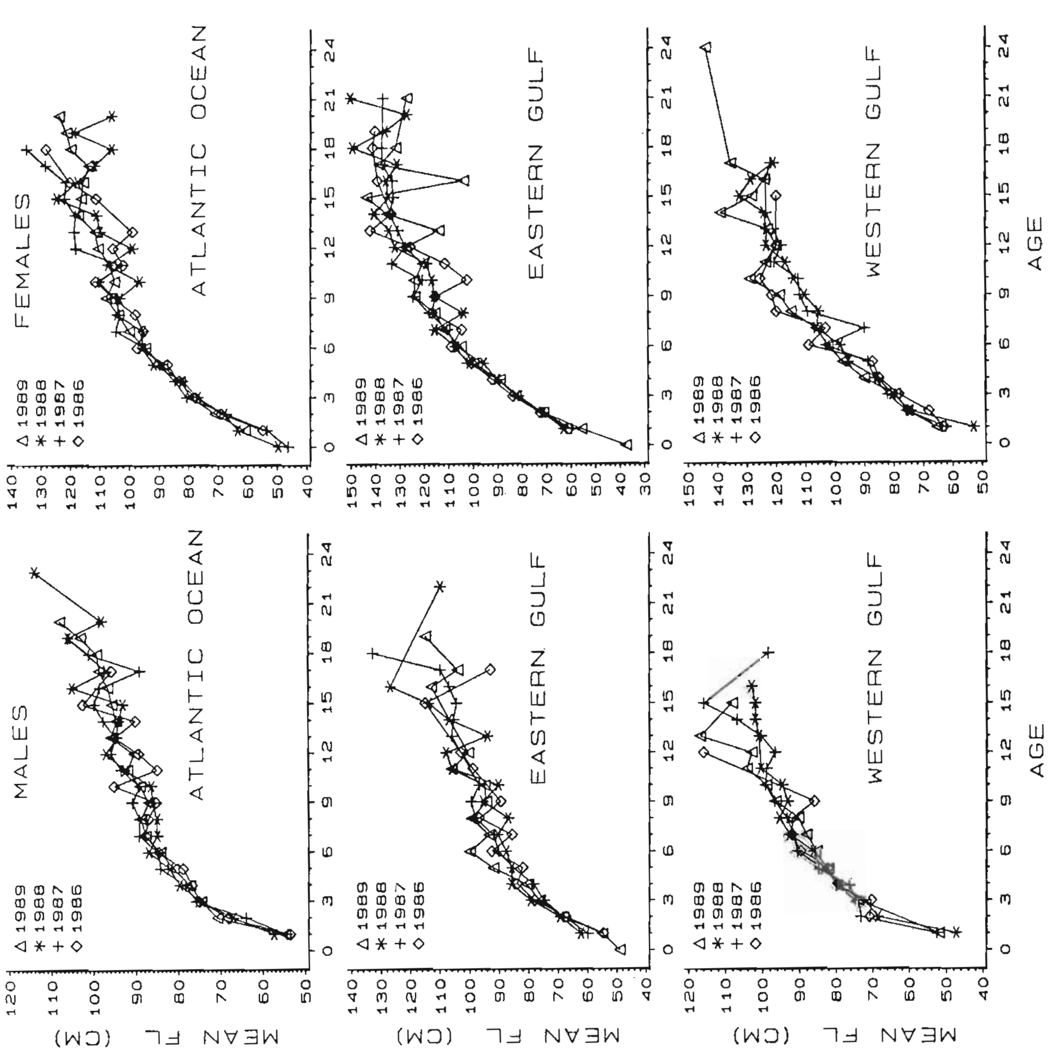
T-test for Differences Among Regions
Probability>ITI

Age	Females			Males		
	EG-AO	EG-WG	AO-WG	EG-AO	EG-WG	AO-WG
0	.0035					
1	.0012	.1247	.9227	.0715	.0038	.0220
2	.0001	.0006	.0001	.0227	.1657	.0101
3	.0001	.0703	.0045	.0147	.0003	.0166
4	.0001	.0017	.0001	.0001	.0001	.9589
5	.0001	.0000	.0040	.0066	.0615	.2934
6	.0000	.0018	.0052	.0002	.3261	.0191
7	.0000	.0082	.0016	.0002	.9139	.0049
8	.0000	.0348	.0032	.0004	.0716	.0004
9	.0000	.0018	.0032	.0015	.7269	.0017
10	.0000	.3046	.0000	.0212	.4896	.0031
11	.0000	.5426	.0000	.0000	.4232	.0028
12	.0000	.0115	.0004	.0004	.4814	
13	.0000	.0344	.0149	.5942	.3403	
14	.0000	.0094	.0111	.0006	.6863	
15	.0000	.0624	.0014	.0014	.6699	
16	.0012	.3020	.0091	.0005		
17	.0001	.2810	.0171	.1530		
18	.0024					
19	.0389					

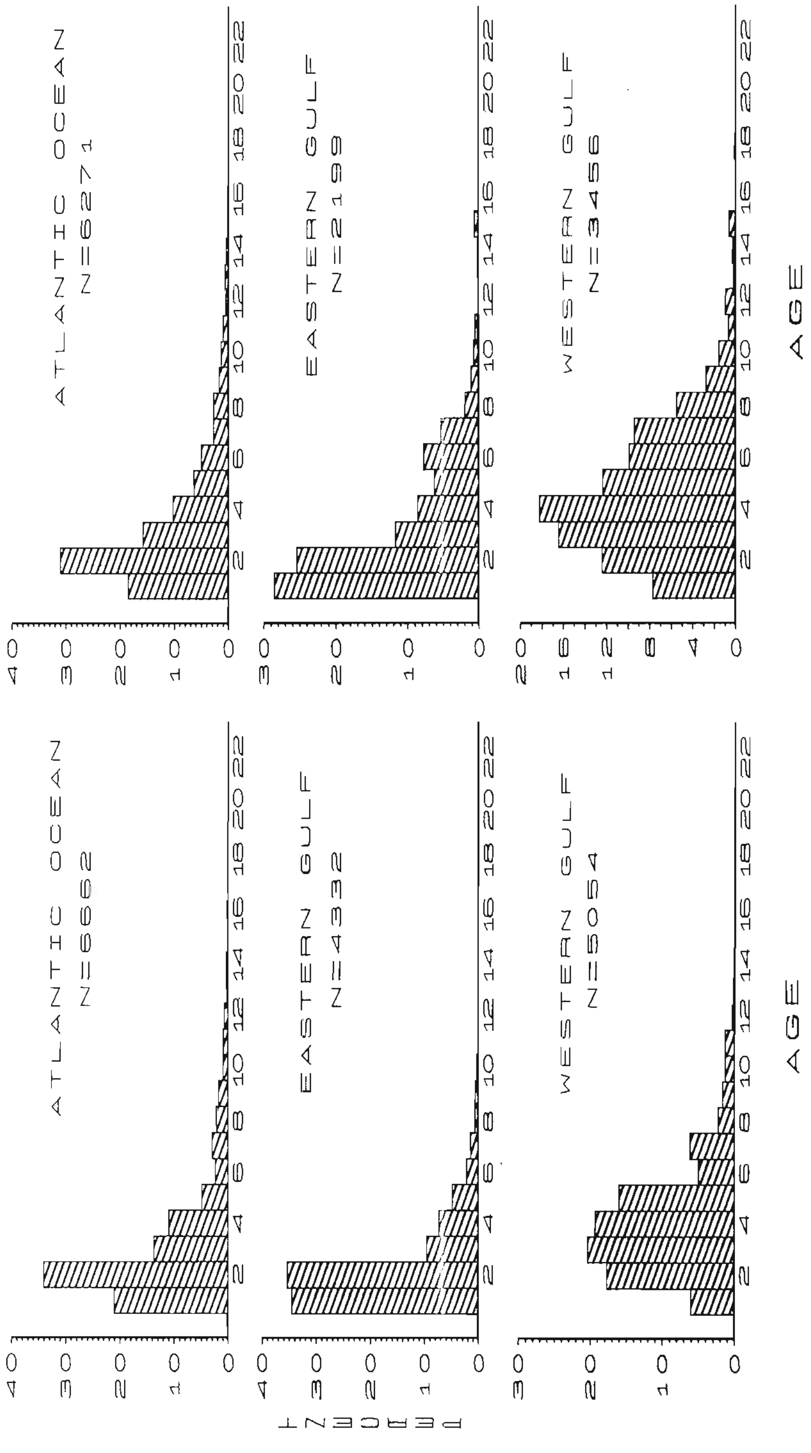
LIST OF FIGURES

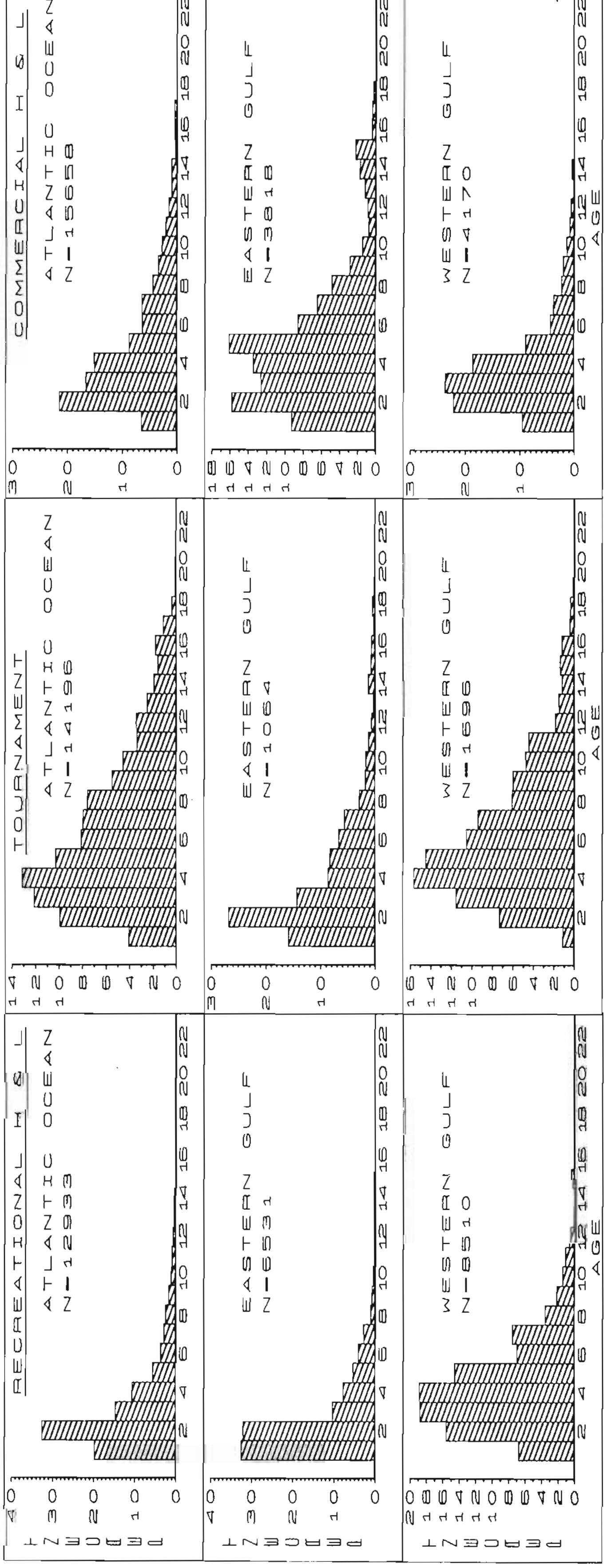

ATLANTIC OCEAN
FL (CM)
AGE
◇ FEMALES
△ MALES
EASTERN GULF
FL (CM)
AGE
◇ FEMALES
△ MALES
WESTERN GULF
FL (CM)
AGE
◇ FEMALES
△ MALES

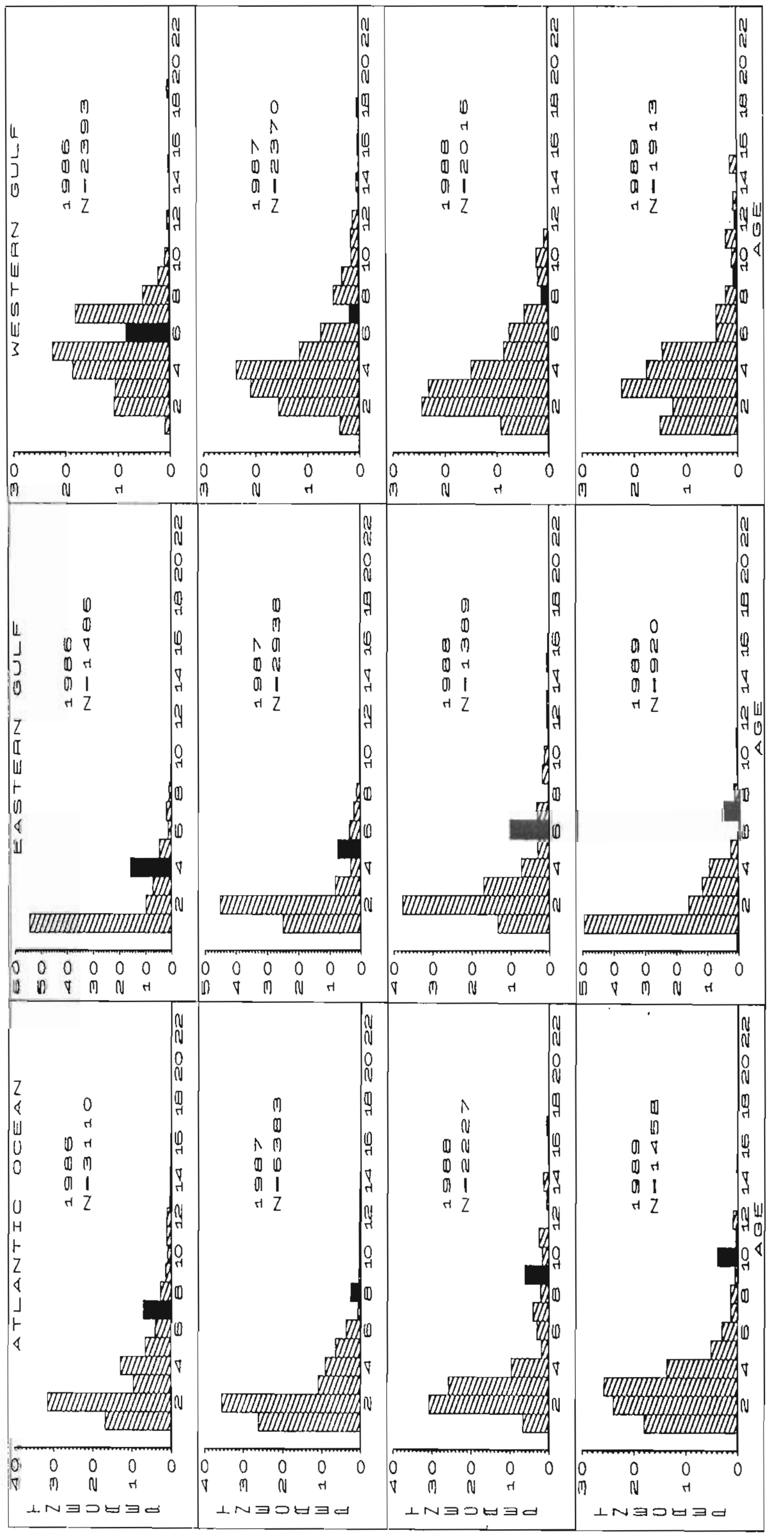

MALES
FL (CM)
140
130
120
110
100
90
80
70
60
50
40
0
3
6
9
12
15
18
21
24
AGE
◇ ATLANTIC OCEAN
✳ EASTERN GULF
△ WESTERN GULF
FEMALES
FL (CM)
150
140
130
120
110
100
90
80
70
60
50
40
30
0
3
6
9
12
15
18
21
24
AGE
◇ ATLANTIC OCEAN
✳ EASTERN GULF
△ WESTERN GULF



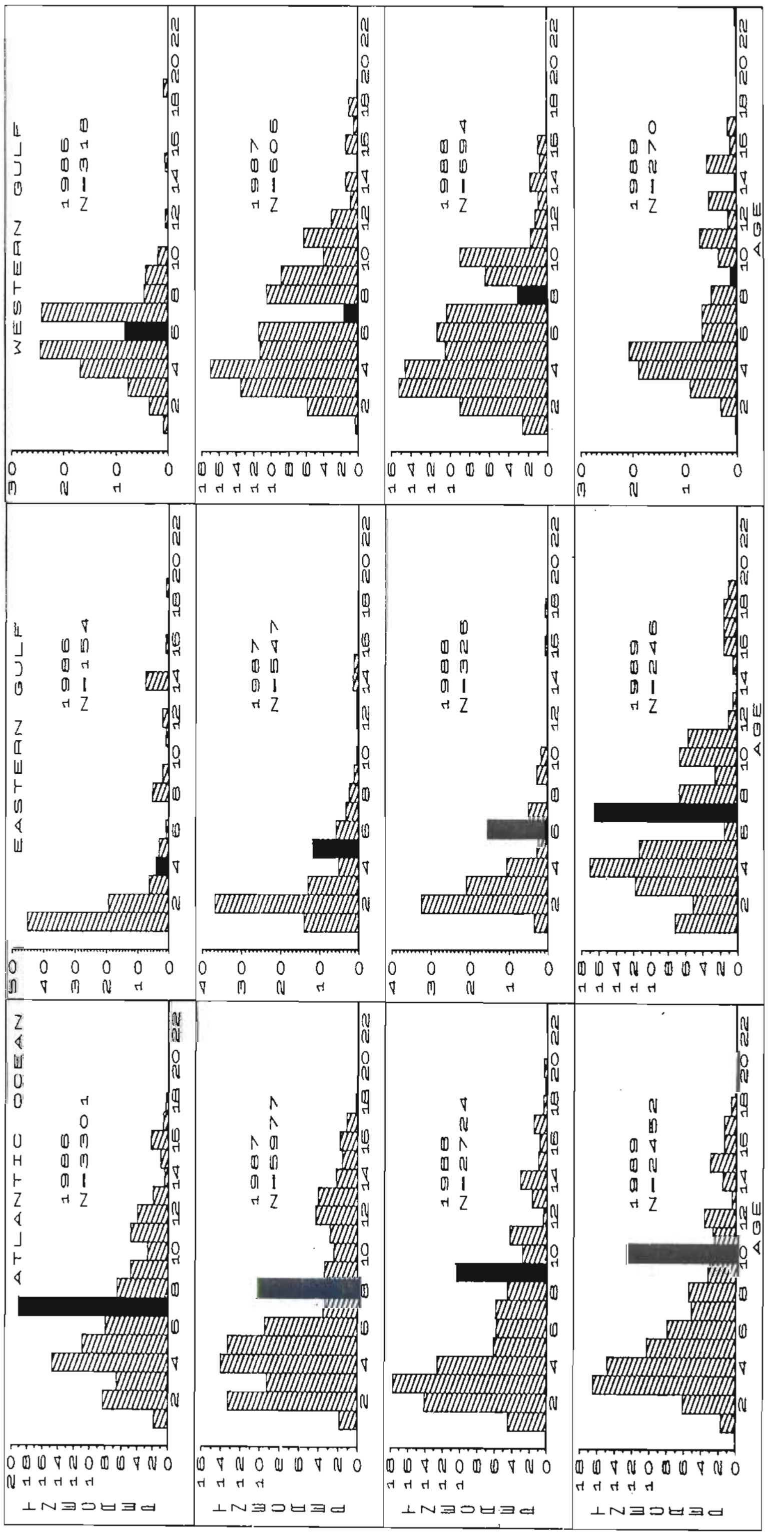
MALES
FEMALES
△ 1989
✱ 1988
+ 1987
◇ 1986
ATLANTIC OCEAN
EASTERN GULF
WESTERN GULF
MEAN FL (CM)
AGE

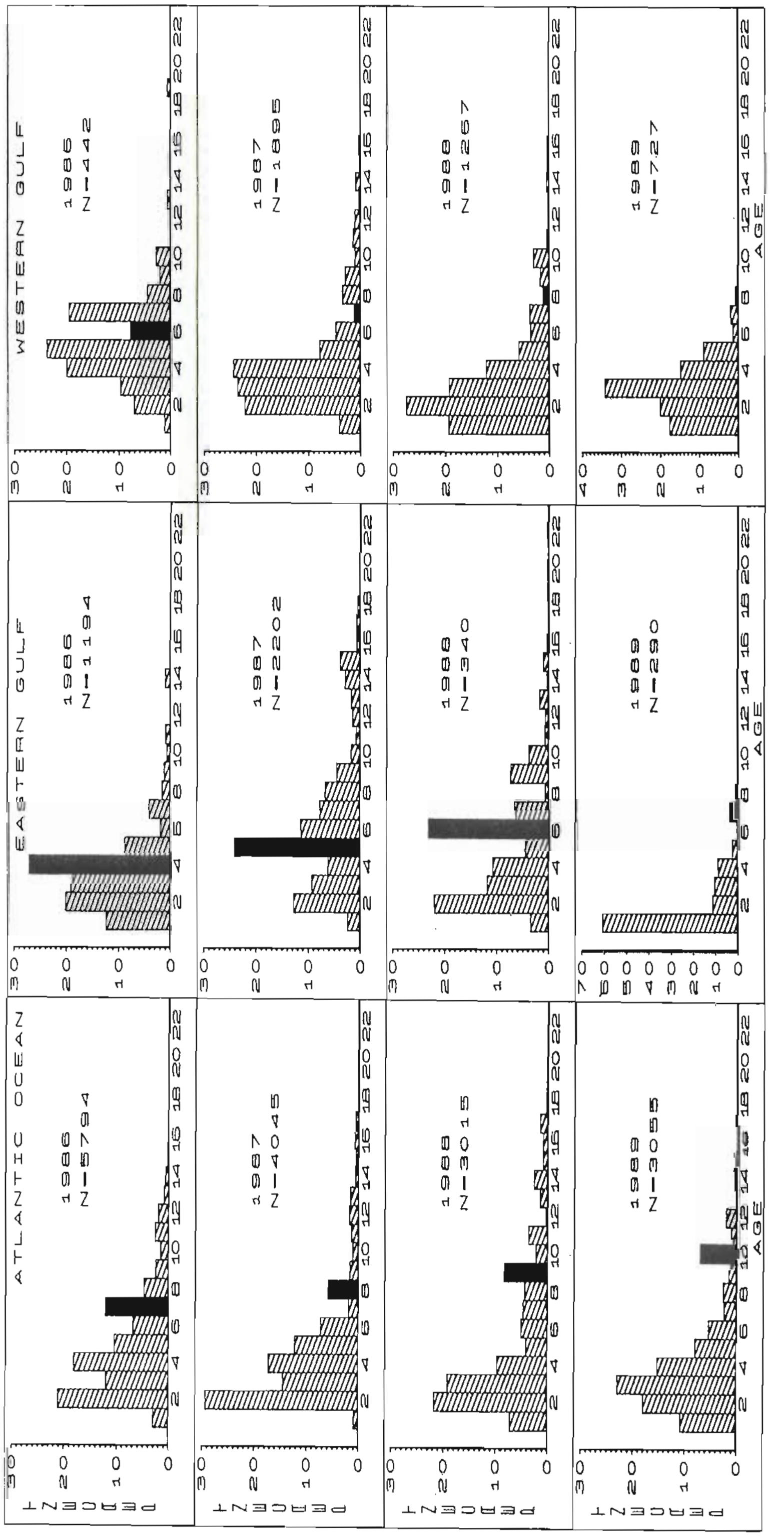

MALES
ATLANTIC OCEAN
N=6271
EASTERN GULF
N=2199
WESTERN GULF
N=3456
AGE
FEMALES
ATLANTIC OCEAN
N=6662
EASTERN GULF
N=4332
WESTERN GULF
N=5054
AGE
PERCENT

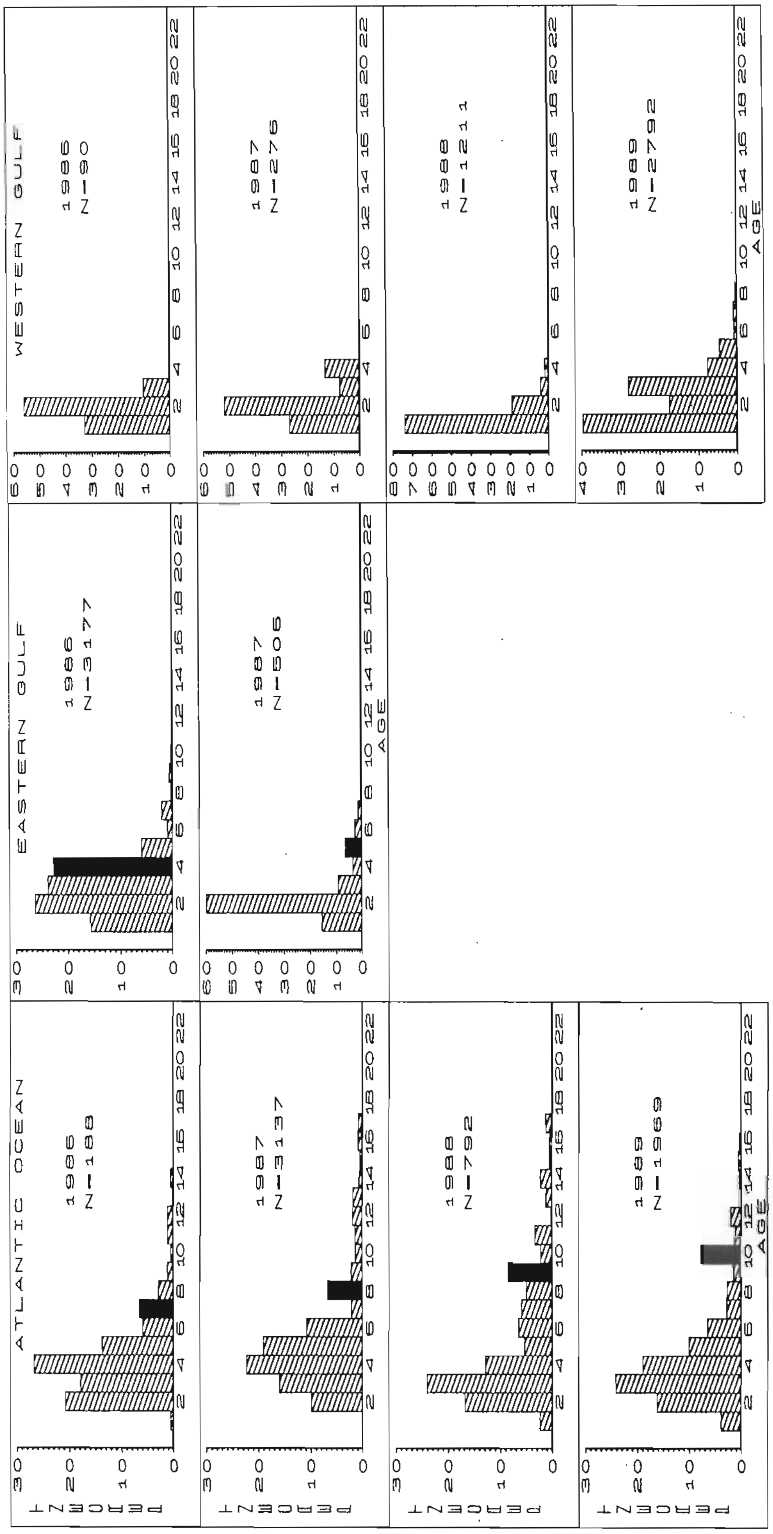

RECREATIONAL H & L
ATLANTIC OCEAN
N=12933
EASTERN GULF
N=6531
WESTERN GULF
N=8510
TOURNAMENT
ATLANTIC OCEAN
N=14196
EASTERN GULF
N=1064
WESTERN GULF
N=1696
COMMERCIAL H & L
ATLANTIC OCEAN
N=15658
EASTERN GULF
N=3818
WESTERN GULF
N=4170
PERCENT
AGE



ATLANTIC OCEAN
EASTERN GULF
WESTERN GULF
1986 N=3110
1987 N=6383
1988 N=2227
1989 N=1458
1986 N=1486
1987 N=2938
1988 N=1389
1989 N=920
1986 N=2393
1987 N=2370
1988 N=2015
1989 N=1913
PERCENT
AGE


ATLANTIC OCEAN
EASTERN GULF
WESTERN GULF
PERCENT
AGE


WESTERN GULF
1986
N=442
1987
N=1895
1988
N=1267
1989
N=727
EASTERN GULF
1986
N=1194
1987
N=2202
1988
N=340
1989
N=290
ATLANTIC OCEAN
1986
N=5794
1987
N=4045
1988
N=3015
1989
N=3055
PERCENT
AGE


ATLANTIC OCEAN
1986
N=188
1987
N=3137
1988
N=792
1989
N=1969
EASTERN GULF
1986
N=3177
1987
N=506
WESTERN GULF
1986
N=90
1987
N=276
1988
N=1211
1989
N=2792
PERCENT
AGE