A Review of the Stock Structure

of King Mackerel

off the Southeastern U.S.

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Introduction

King mackerel *Scomberomorus cavalla* are jointly managed by the Gulf of Mexico and South Atlantic Fishery Management Councils under the Coastal Pelagics Management Plan, first implemented in February, 1983 (Anon., 1983). Under the original plan, the species was managed as a single stock from North Carolina to Texas. In 1985, Amendment One of the plan (Anon., 1985) recognized the existence of separate stocks, or "migratory groups," in the Atlantic and Gulf of Mexico based primarily on analyses of tag return data collected by the Florida Department of Environmental Protection (FDEP) during 1975–79 (Williams and Godcharles, 1984; Sutter et al., 1991), as well as seasonal patterns of length-frequency, CPUE, and commercial landings data. With the implementation of Amendment One, because the FDEP study suggested that more than half the fish along the Florida east coast in winter were from the Gulf migratory group, all king mackerel caught south of the Volusia–Flagler County border off northeast Florida during Nov-Mar are allocated to the Gulf group quota. During the rest of the year, the Monroe–Collier County border off southwest Florida is used as the dividing line between Gulf and Atlantic groups. This area between the Volusia–Flagler and Monroe–Collier County borders is commonly known as the mixing zone. Because there are very large commercial fisheries for king mackerel off Florida's east coast during Nov-Mar, allocating all those catches to only one group (Gulf) has a major impact on the stock assessments. For example, Legault (1998) calculated that assigning all fish from the mixing area to the Atlantic group would increase the 1998/99 allowable biological catch (ABC) for that group, assuming an $F_{30\%\,SPR}$ management strategy, between about 400 and 2000 mt, depending on the level of bycatch used; under this scenario, he projected that the Gulf ABC would decrease approximately 550 mt. Estimates of fishing mortality remained about the same for both groups when all mixing area fish were assigned to the Atlantic group (Legault, 1998).

Given the impact of the current allocation scheme, it is critical that king mackerel stocks in the southeastern U.S. be accurately delineated, and their mixing rates accurately estimated. It is reasonable to question whether the vast majority of the fish in the mixing zone off east Florida during the winter are Gulf group. The FDEP tagging study never suggested that all the fish originated from the Gulf, just that a significant proportion may have. Exploitation histories of the two putative stocks have been quite different, and exploitation rates have certainly changed since the FDEP tagging study in the 1970's. The Gulf group has been considered overfished for more than a decade, while that is not the case for Atlantic king mackerel. Even if the stocks were unexploited, recruitment variation alone would likely result in dynamic mixing rates. There have been many attempts over the last few decades to discern the stock structure of king mackerel in the southeastern U.S. using a number of techniques. The objective of this paper is to review the history of those attempts, with a special emphasis on the mixing rate problem off Florida's east coast.

Mark and Recapture

Mark and recapture studies have provided the foundation upon which most of the current ideas on king mackerel stock structure in the southeastern U.S. have been built. The earliest significant studies were the concurrent projects of FDEP and the National Marine Fisheries Service (NMFS) during 1975-1979 (Sutherland and Fable 1980; Williams and Godcharles, 1984; Fable 1990; Sutter et al., 1991). Over 14,000 fish were tagged by FDEP, primarily off east Florida and the Florida Keys, but also off South Carolina, Texas, and Veracruz; over 2,900 were tagged by NMFS, primarily off northwest Florida, but also off Texas and North Carolina. Return rates for those studies were 8.1 and 1.1 % , respectively, and the large difference between them was attributed to the use of different types of tags (Williams and Godcharles, 1984; Sutter et al., 1991; Fable 1990). The seasonal and geographic distribution of the recaptures of these two studies are shown on pages 9-18. In the FDEP study, the greatest number of fish were tagged between Cape Canaveral and Jupiter during Dec-Mar (n=6500); of 548 returns, 59 (10.8%) were caught in the Gulf of Mexico from SW Florida to Veracruz Mexico (n=1), including 15 in Texas. If the Florida Keys are included, 87 (15.9%) came from the Gulf. The remaining 462 (84.3%) were caught in the Atlantic Ocean from SE Florida to North Carolina, although only 6 came from north of Florida. Sutter et al. (1991) estimated an overlap of the two stocks off SE Florida of as much as 29.4 - 41.8 % based on a discriminant analysis. Williams and Godcharles (1984) concluded that "at least two stocks, or migratory groups, can be identified: a Gulf group and an Atlantic group. The ranges of the two groups coincide with the geographic boundaries of the Gulf of Mexico and the South Atlantic. However, the Gulf group extends its winter range into southeast Florida. It thus overlaps the range of the South Atlantic group, especially between Cape Canaveral and the Florida Keys". Sutherland and Fable (1980) concluded from their study that "some fish inhabiting the northern Gulf from Panama City to southern Texas in the summer months ranged into Atlantic waters from the Keys north to Ft. Pierce in the winter months" but that "most of the Gulf fish, however, appear to over winter on Florida's west coast from the Keys north to Naples".

The next major tagging study in the Gulf of Mexico occurred during 1983-1989 (Fable et al. 1987; Fable et al., 1992?). In this study 1656 king mackerel were tagged off northwest Florida during May-Oct; 2,398 off Grand Isle, Louisiana year round; 615 off Texas during May-Sep; 2,077 off Tamaulipas (103) and Veracruz (1,974), Mexico during Mar-May; and 164 off the Yucatan peninsula of Mexico during Jan-Apr. The geographic and seasonal distribution of the recaptures in this study are shown on pages 19-24. Fable et al. (1992?) stated that their results demonstrated that movements from the northern and NW Gulf to Mexican waters may be common, and that movements in the reverse direction were not unusual. They also concluded that tagging data, along with some unpublished electrophoretic data, provided "convincing evidence for a migratory group in the western Gulf of Mexico which seasonally moves between U.S. waters in the northern Gulf and Mexican waters in the southern Gulf". Fable et al. (1987) found that king mackerel tagged off Louisiana during the winter were larger fish (>85 cm FL) that tended to remain in the NW Gulf, while those tagged during summer did the same if large, but if small (<80 cm FL), migrated to south Florida or Mexico. They concluded that there was a resident population of larger fish in the NW Gulf year round, and that these fish may move to Mexico, and during summer, mix with smaller king mackerel migrating from Mexico and south Florida.

Burns (1994) reported the results of a tagging study conducted in Mexican waters of the Gulf of Mexico during 1986-1994. Results of the 1986-89 releases were also reported in (Fable et al., 1992?). In this study 103 fish were tagged off Tamaulipas, 2,700 off Veracruz, 70 off Campeche, 196 off Yucatan, and 10 off Quintana Roo. The spatial distribution of the recaptures in this study are shown on pages 25-26.

The most recent NMFS mark-recapture study was conducted off east Florida in the mixing zone during 1985-1993; 10,285 fish were tagged and 546 were recaptured (Schaefer and Fable, 1994). The spatial and temporal distribution of those tag returns are shown on pages 27-28. Schaefer and Fable (1994) found continued evidence of limited migration from southeast Florida to both the eastern (9 recaptures) and western (6 recaptures) Gulf and concluded the results continued to support the two stock hypothesis. They also noted that the data suggested less mixing of those stocks off east Florida than previously theorized. Only 3.3% (13) of all recaptures of the 8,391 fish tagged in winter off east Florida occurred north of the Collier/Monroe County line in the Gulf, compared to 18.1% (72)caught north of the Volusia/Flagler County line in the Atlantic. Only 14 of the 313 returns (3.5%) from the mixing zone actually occurred in the Gulf. The authors also reported that of the 994 returns in the NMFS Cooperative Gamefish Tagging Program during 1985-93 (20,393 releases), only two king mackerel released in the Atlantic were recaptured in the Gulf and 17 fish tagged in the Gulf were caught in the Atlantic. Schaefer and Fable (1994) also found that their winter tagged fish were recaptured year-round off southeast Florida , more in summer than winter; they noted this suggests the possibility of a resident eastern Florida group which moves seasonally along that coast.

Genetics

Genetic population structure of king mackerel in the U.S. was first investigated by May (1983). He used electrophoresis to screen 48 enzymes in fish collected from Texas to South Carolina, but found only two loci which were more than minimally polymorphic - Pgm-3 and Pep-GL-2. Only the latter had significant differences in allele frequency among locations. May concluded that king mackerel are less heterozygous than most species of fish, but that the Pep-GL-2 locus was a good Mendelian trait, and their was compelling evidence that there was not a single interbreeding population.

Johnson et al. (1994) conducted the first large scale electrophoretic study of king mackerel population structure, examining tissue from 8,976 fish collected during 1985-1990 from North Carolina to Yucatan. Fifty loci were screened with the same results as May (1983) - only PEPA-2 (= Pep-GL-2 in May's report) showed consistent variation among locations. Johnson et al. (1994) concluded that their data suggested two stocks occurred in the Gulf of Mexico, an eastern and a western which mixed in the northern Gulf during the summer. Their data did not show any differences between eastern Gulf and Atlantic Ocean fish.

Gold et al. (1997) were next to examine the genetics of king mackerel. They surveyed 678 individuals collected from North Carolina to Yucatan during 1992-93 for variation in mtDNA and the dipeptidase locus PEPA-2 used by Johnson et al. (1994). Their findings on geographic variation in the PEPA-2 locus were similar to those of Johnson et al. (1994), but contrary to that earlier study, Gold et al. (1997) found that the variation was not independent of sex or age. The mtDNA evidence was consistent with separate Atlantic and Gulf stocks, suggesting weak genetic differences between eastern Gulf and Atlantic fish, but did not show any differences between fish from the western Gulf and those in the eastern Gulf or Atlantic Ocean.

More recently Broughton et al. (2002) were the first to look at variation in microsatellite allele distribution in king mackerel, examining samples from eight locations between North Carolina and Veracruz, Mexico, including the same fish used in the study of Gold et al. (1997). Boughton et al. (2002) concluded that "none of the current hypotheses of geographic population structure in king mackerel were supported by the microsatellite data". They found no evidence of a cline in microsatellite variation either within or between the Gulf and the Atlantic, and noted that their findings were consistent with previous studies suggesting meaningful gene flow in U.S. waters.

The most recent genetic study again examined microsatellite variation to look at stock structure around peninsular Florida (Gold et al. 2002). This study assayed 1006 fish from 20 locations around Florida collected during 1996-98 and concluded the microsatellite data were consistent "with the hypothesis that two, weakly differentiated "genetic" subpopulations of king mackerel exist in waters off Florida and that considerable, perhaps extensive, mixing occurs between them." They also found that samples from the Florida Keys could not be unequivocally assigned to either of the "genetic" stocks because there were almost equal proportions of each in every collection tested; for this reason they concluded that the microsatellite findings were not consistent with the current spatial and temporal boundaries used in managing and assessing king mackerel in the U.S.

Otolith Studies

Another technique employed in the quest to better understand king mackerel stock structure was otolith shape analyis. Johnson (1996) used stepwise discriminant analysis of various combinations of distances between a series of 20 points (truss system) equally spaced at 18 degree intervals around the margin of the otolith in an attempt to distinguish fish from North Carolina, northwest Florida, and Yucatan; and obtained classification success rates of 66.7-70.0 and 57.7-77.5% for two different suites of truss variables. DeVries et al.(2002) were next to use shape analysis to try to separate king mackerel stocks. The impetus for their study, besides Johnson's (1996) promising results, was the discovery that there were significant, persistent differences in growth rates and size at age between fish from the eastern Gulf and the Atlantic Ocean (DeVries and Grimes 1997) and the hope that those growth differences might be reflected in the shape and size of the fishes' sagittae. Using a set of shape variables (area, perimeter, and 10 Fourier harmonics) selected with a stepwise discriminant procedure, the authors used a maximum likelihood method to estimate the stock composition of 463 fish taken in the winter fishery off east Florida in 1996-97. The variable suite used correctly classified 71.1% of Atlantic and 77.5% of Gulf fish of known origin in an independent test data set. They estimated that the percentage of Atlantic stock was 99.8% with the remaining 0.2% from the Gulf. The standard error of the estimates was 3.4% using a bootstrap technique with 500 replications.

Using the same technique and variable suite from the 1996 training data, and a sample of 280 fish, DeVries (2001) estimated the composition of the 1999-2000 winter fishery to be 100% Atlantic fish, with a standard error of 3.9%, and a 90% empirical confidence interval of 89.1-100.0%. To determine the temporal stability of these estimates, DeVries and Mangum (2002) estimated the composition of the 2000-2001 winter fishery using a variable suite of shape data derived from samples of known origin collected during summer of 2000. Using the six variable suites with the highest classification success rates, they estimated that Atlantic stock fish composed 40 to 67 % of the 2000-2001 winter fishery; the variable suite with the highest classification success rate of both stocks yielded an estimate of 64% with a 95% confidence interval of 40-76%. DeVries and Mangum (2002) also examined the sensitivity of these estimates to the training data and variable suite used. Using the variable suite derived from the 2000 training data, they re-estimated the composition of the 1999-2000 winter fishery to be 59% Atlantic fish, considerably less than the initial estimate of 100% derived from the 1996 training data. Because of these findings, they recommended that the 99-00 estimate not be used and that further work be conducted on temporal stability and sensitivity of the estimates to the training data and variable suite used.

CPUE patterns, growth, recruitment, spawning season, and stable isotope differences

Johnson et al. (1994) suggested that the findings by Trent et al. (1987) of simultaneous migrations northward along both eastern and western coasts of the Gulf of Mexico during spring and early summer, as indicated by charterboat CPUE data, supported their hypothesis of two Gulf stocks. Trent et al. (1987) also found that king mackerel were caught off Louisiana year-round, especially large fish, which they said supported the idea that a portion of the population in that area do not migrate and that the abundance of those residents peaks during colder months.

Grimes et al. (1990) back-calculated spawning dates of 240 juvenile king mackerel 45-300 mm FL collected in Mexico and found that spawning occurred from at least January to September. They noted that this extended spawning season is clearly different from the May to October season found in U.S. Gulf waters, and probably indicated that a separate spawning group occurred in Mexican waters.

DeVries and Grimes (1997) examined spatial and temporal variation in age and growth of king mackerel collected from North Carolina to Yucatan during 1986-1992 (n=12,180) and during 1977-1978 (n=2,033). They found significant, persistent, consistent differences in growth among fish from the western Gulf, eastern Gulf, and Atlantic Ocean during 1986-92 and between east Gulf and Atlantic Ocean fish during 1977-78. Growth was highest in the eastern Gulf, lowest in the Atlantic, and intermediate in the western Gulf. Plots of annual growth curves by region for males and females are shown on page 29. DeVries and Grimes (1997) concluded that these findings supported a three stock hypothesis for king mackerel in the U.S.

DeVries and Grimes (unpubl. MS) examined annual patterns in age composition in various king mackerel fisheries in the western Gulf, eastern Gulf, and Atlantic Ocean during 1986-89. They found different strong or poor year classes in each region in almost every fishery, which they said strongly suggested independent recruitment in those regions and supported the concept of three distinct stocks in the U.S. Annual age distributions by fishery and region are shown on pages 30 and 31, with black bars indicating probable strong or weak year class.

Roelke and Cifuentes (1997) used still another technique, stable isotope analysis, to determine stock structure of king mackerel in U.S. waters. They measured stable carbon and nitrogen isotopes on the dorsal fin spines of 65 fish collected at sites from Yucatan to Ft. Pierce, FL They found that fish from Mississippi, Louisiana, and Texas were enriched with isotopic N and depleted of isotopic C, in contrast to those from Florida and Mexico (only differed in N). Roelke and Cifuentes (1997) concluded that their findings indicated the presence of at least two distinct groups of king mackerel in the Gulf of Mexico, and possibly a third group in the northwest Gulf.

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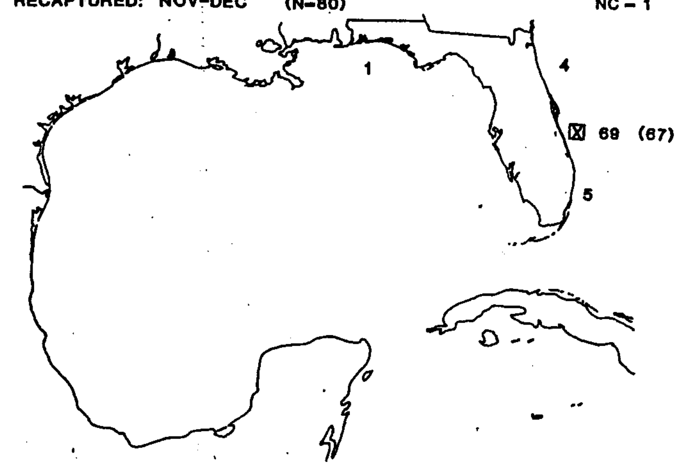


Figure 1. Tag recoveries during November-December (all years) for fish tagged between Cape Canaveral and Jupiter during the winter fishing seasons (December-March) of 1975, 1976, 1977, and 1978. The 'X' shows the tagging area. Numbers shown are numbers of recoveries in each area; the number in parentheses adjacent to 'X' shows the number of recoveries from the tagging area with a one season lag, i.e., not including the season when tagged. Total number tagged = 6500.

Williams and Godcharles, 1984

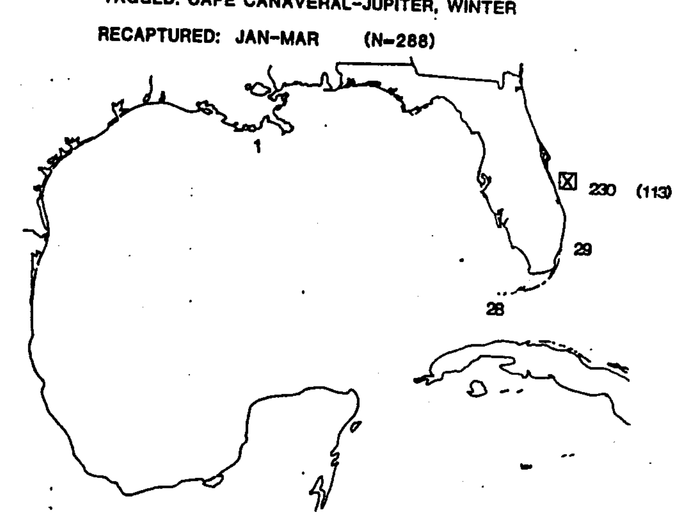


Figure 2. Tag recoveries during January-March (all years) for fish tagged between Cape Canaveral and Jupiter during the winter fishing seasons (December-March) of 1975, 1976, 1977, and 1978. The 'X' shows the tagging area. Numbers shown are numbers of recoveries in each area; the number in parentheses adjacent to 'X' shows number of recoveries from the tagging area with a one season lag, i.e., not including the season when tagged. Total number tagged = 6500.

Williams and Godcharles, 1984

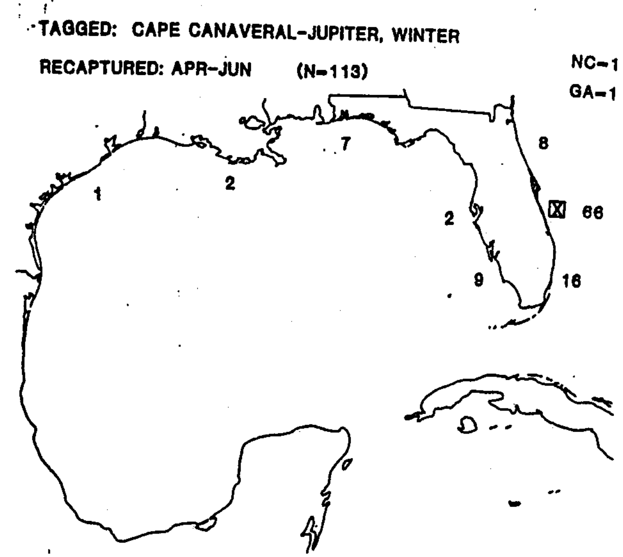


Figure 3. Tag recoveries during April-June (all years) for fish tagged between Cape Canaveral and Jupiter during the winter fishing seasons (December-March) of 1975, 1976, 1977, and 1978. Total number tagged = 6500.

Williams and Godcharles, 1984

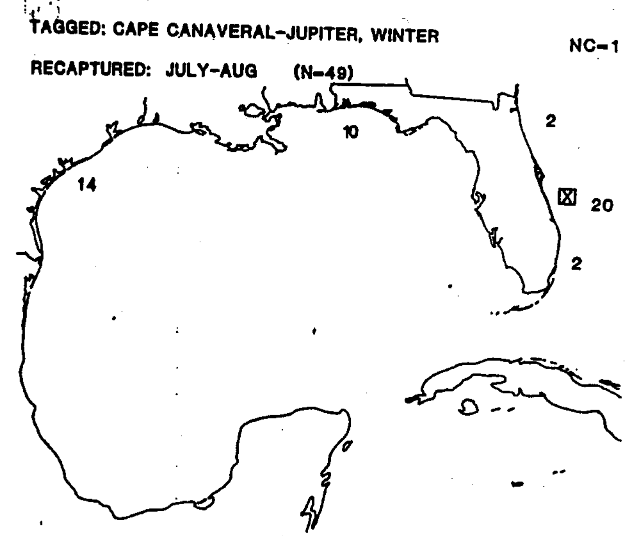


Figure 4. Tag recoveries during July-August (all years) for fish tagged between Cape Canaveral and Jupiter during the winter fishing seasons (December-March) of 1975, 1976, 1977, and 1978. Total number tagged = 6500.

Williams and Godcharles, 1984

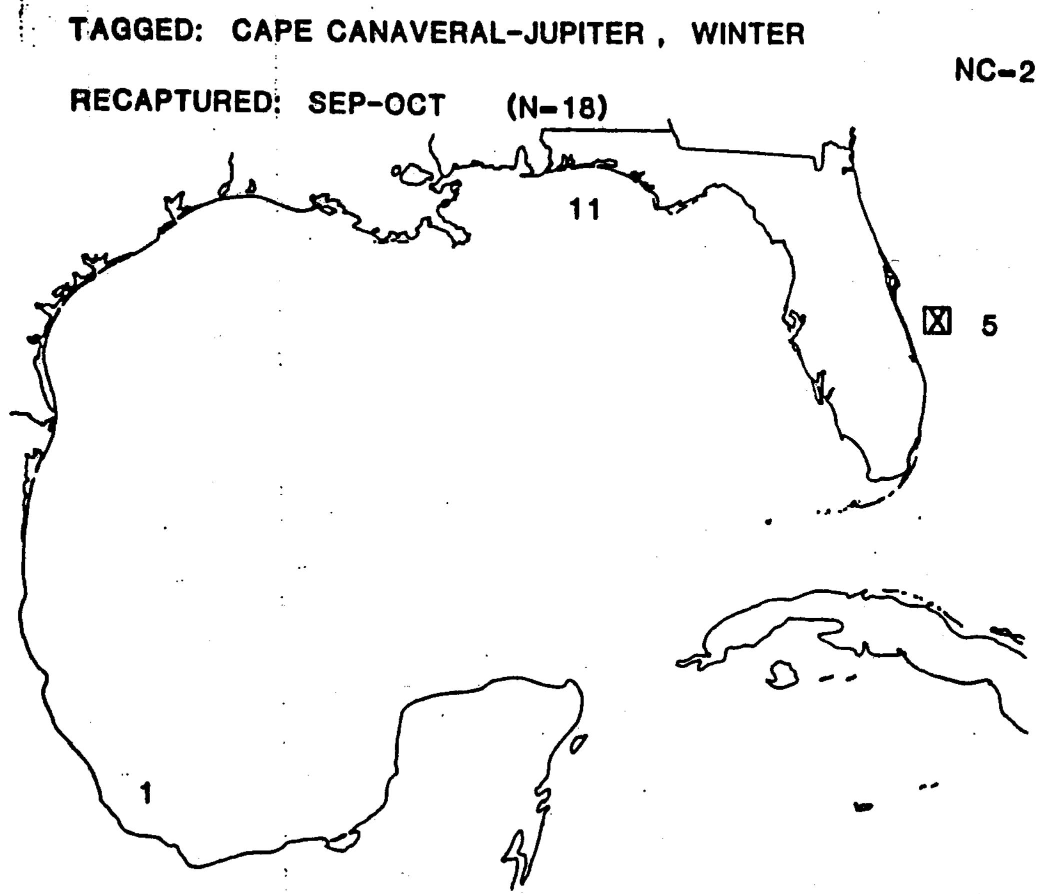


Figure 5. Tag recoveries during September-October (all years) for fish tagged between Cape Canaveral and Jupiter during the winter fishing seasons (December-March) of 1975, 1976, 1977, and 1978. Total number tagged = 6500.

Williams and Godcharles, 1984

11

RECAPTURED: JAN-MAR (N-167)(65)

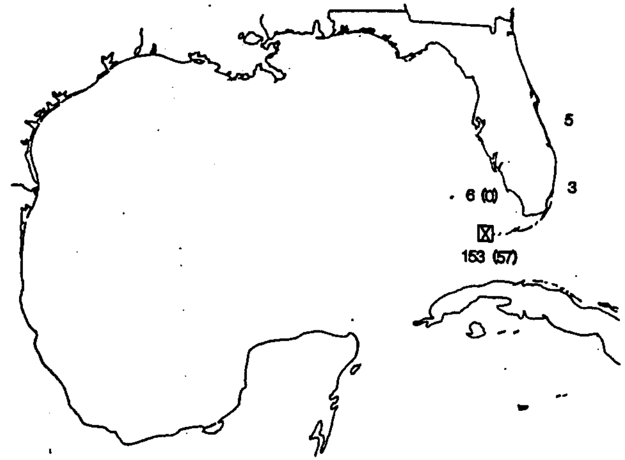


Figure 6. Tag recoveries during January-March (all years) for fish tagged off Key West and Naples during the winter fishing seasons (February-March) of 1976, 1977, and 1978. The 'X' shows the tagging area. Numbers shown are numbers of recoveries in each area; the number in parentheses adjacent to 'X' shows number of recoveries from the tagging area with a one season lag, i.e., not including the season when tagged. Total number tagged = 2594.

Williams and Godcharles, 1984

RECAPTURED: APR-JUN (N-20)

Figure 7. Tag recoveries during April-June (all years) for fish tagged off Key West and Naples during the winter fishing seasons (February-March) of 1976, 1977, and 1978. Total number tagged = 2594.

Williams and Godcharles, 1984

TAGGED: KEY WEST-NAPLES

RECAPTURED: JUL-SEP (N-46)

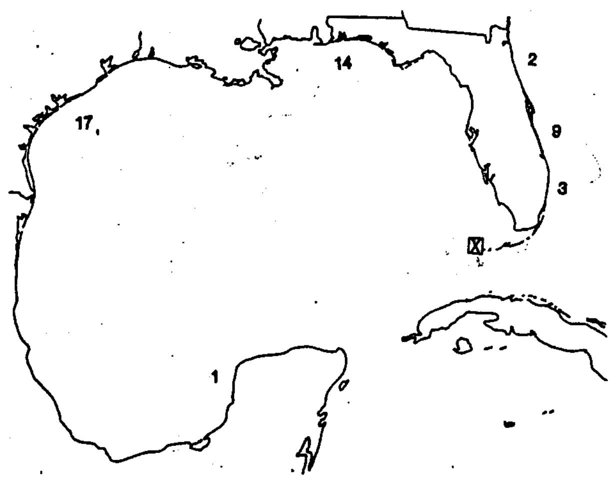


Figure 8. Tag recoveries during July-September (all years) for fish tagged off Key West and Naples during the winter fishing seasons (February-March) of 1976, 1977, and 1978. Total number tagged = 2594.

Williams and Godcharles, 1984

TAGGED: KEY WEST-NAPLES

RECAPTURED: OCT-DEC (N-18)

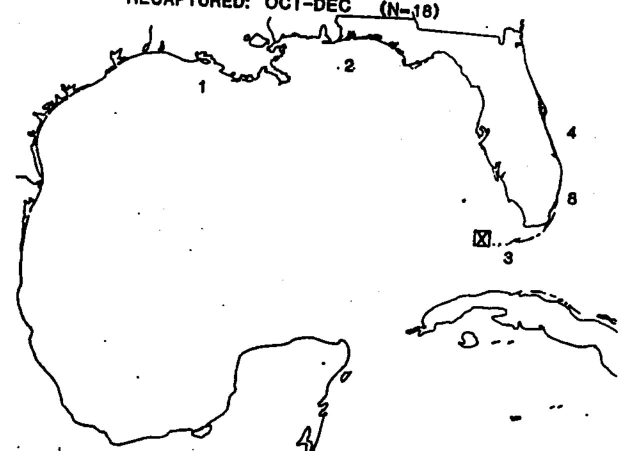


Figure 9. Tag recoveries during October-September (all years) for fish tagged off Key West and Naples during the winter fishing seasons (February-March) of 1976, 1977, and 1978. Total number tagged = 2594.

Williams and Godcharles, 1984

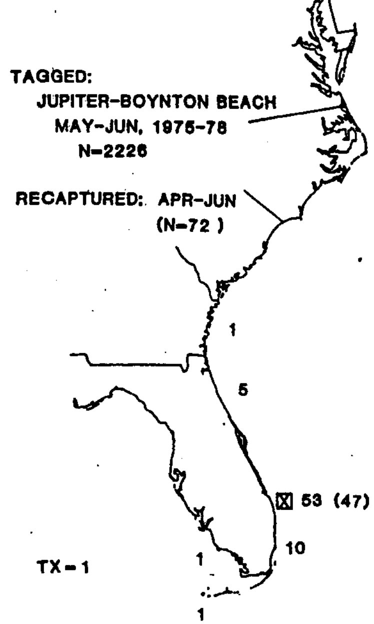


Figure 11. Tag recoveries during April-June (all years) for fish tagged between Jupiter and Boynton Beach during spring fishing seasons (May-June) of 1975, 1976, 1977, and 1978. The 'X' shows the tagging location. The '(47)' shows numbers of recoveries from the tagging area with a one season lag. Total number tagged = 2226.

Williams and Godcharles, 1984

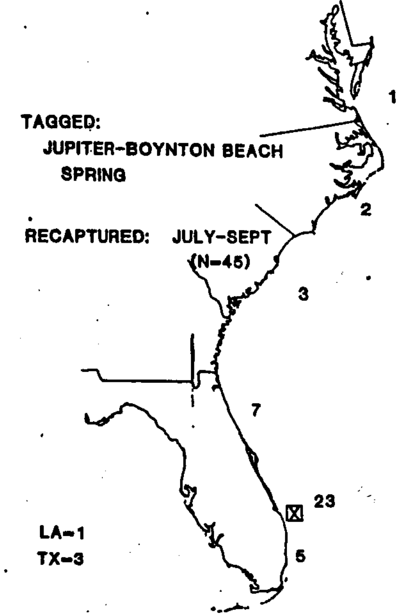


Figure 12. Tag recoveries during July-September (all years) for fish tagged between Jupiter and Boynton Beach during spring fishing seasons (May-June) of 1975, 1976, 1977 and 1978. Total number tagged = 2226.

Williams and Godcharles, 1984

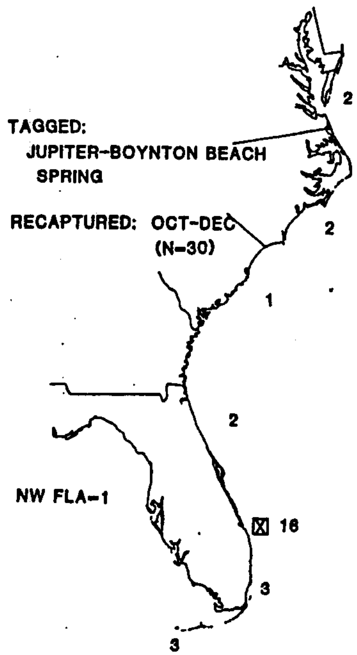


Figure 13. Tag recoveries during October-December (all years) for fish tagged between Jupiter and Boynton Beach during spring fishing seasons (May-June) of 1975, 1976, 1977, and 1978.

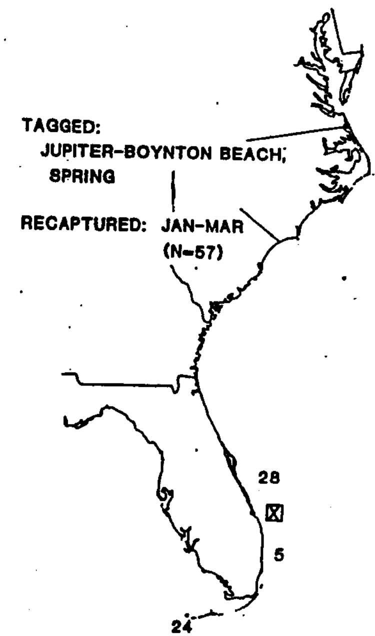


Figure 14. Tag recoveries during January-March (all years) for fish tagged between Jupiter and Boynton Beach during spring fishing seasons (May-June) of 1975, 1976, 1977, and 197

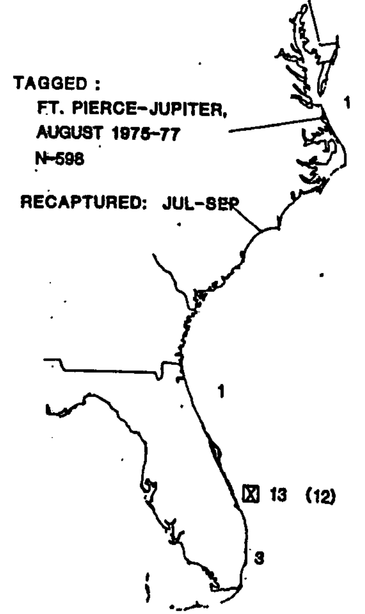


Figure 16. Tag recoveries during July-September (all years) for fish tagged between Ft. Pierce and Jupiter during August 1975, 1976, and 1977. The 'X' shows the tagging area, and numbers are numbers of recoveries in each area. The '(12)' shows numbers of recoveries from the tagging area with a one year lag. Total number tagged = 598.

Williams and Godcharles, 1984

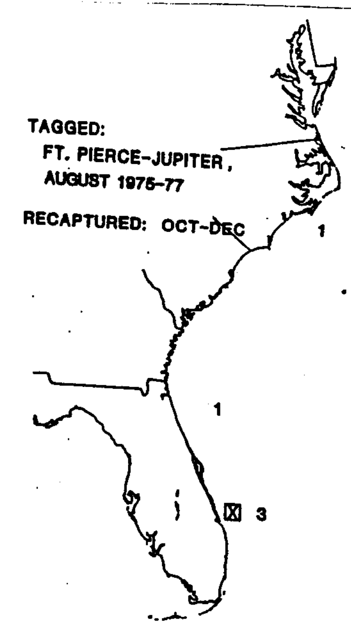
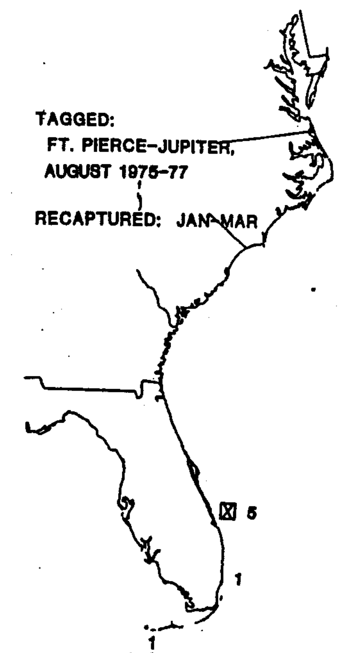


Figure 17. Tag recoveries during October-December (all years) for fish tagged between Ft. Pie and Jupiter during August 1975, 1976, and 1977. Total number tagged = 598.

Williams and Godcharles, 1984



Fi 18. Tag recoveries during January-March (all years) for fish tagged between Ft. Pierce an

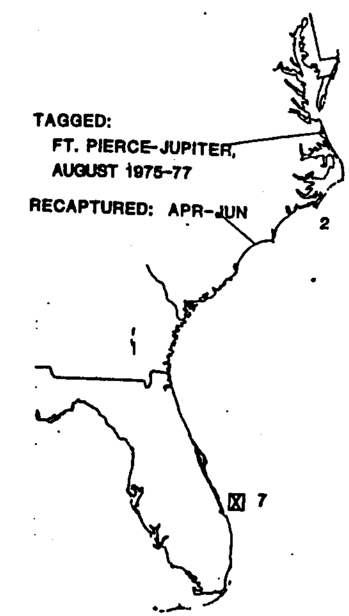


Figure 19. Tag recoveries during April-June (all years) for fish tagged be Ft. Pierce and

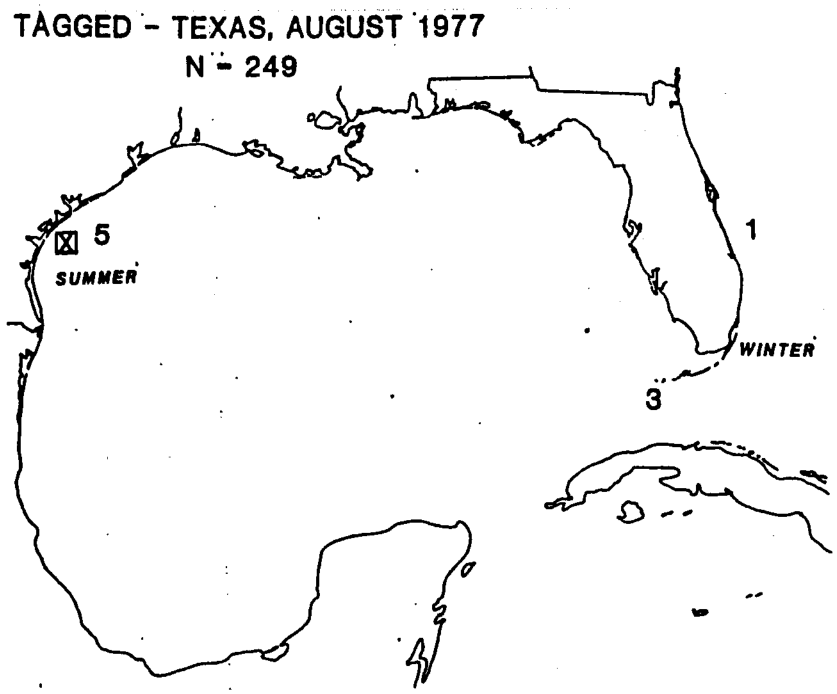


Figure 10. Tag recoveries during all months and all years for fish tagged off Port Aransas, Texas in August 1977. The 'X' shows tagging location. All recaptures were from the western Gulf during warm months and off south Florida during winter months. Total number tagged = 249.

Williams and Godcharles, 1984

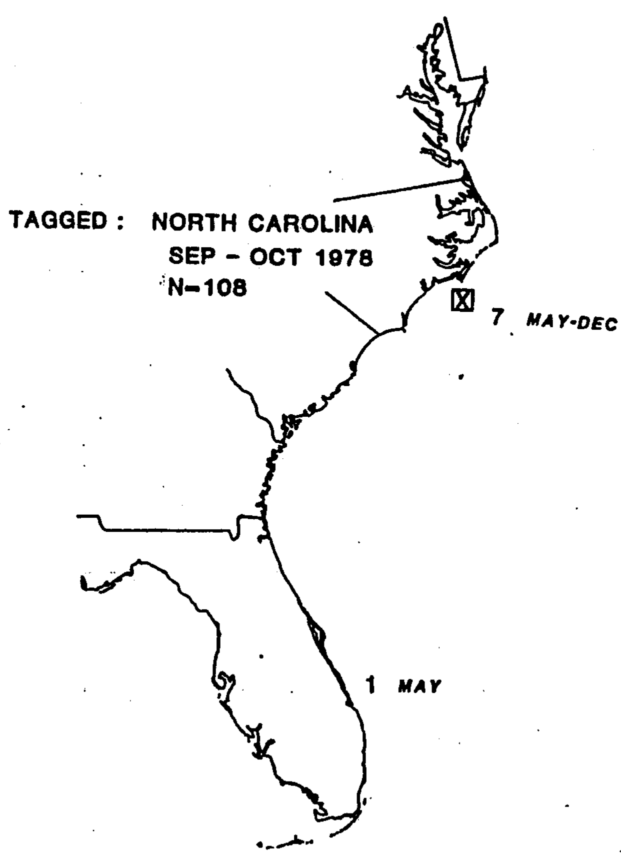


Figure 24. Tag recoveries during all months and all years for fish tagged off Beaufort, North Carolina during September-October 1978. The 'X' shows tagging locations, and numbers shown are numbers of recaptures. Total number tagged = 108.

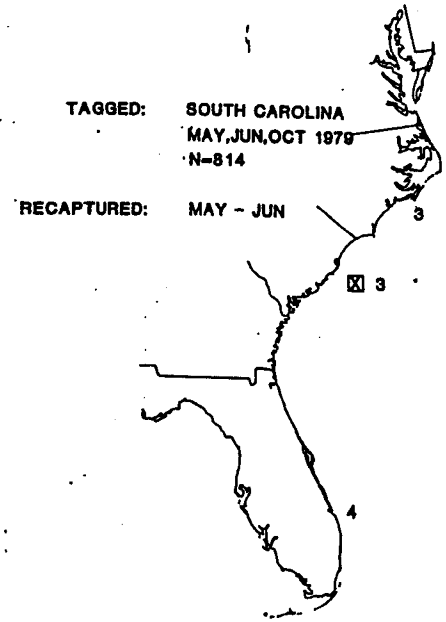


Figure 20. Tag recoveries during May-June (all years) for fish tagged off Murrells Inlet, South Carolina during May, June, and October 1979. The 'X' shows the tagging location, and numbers are numbers of recoveries within each area. Total number tagged = 814.

Williams and ~~Godcharles~~ Godcharles, 1984

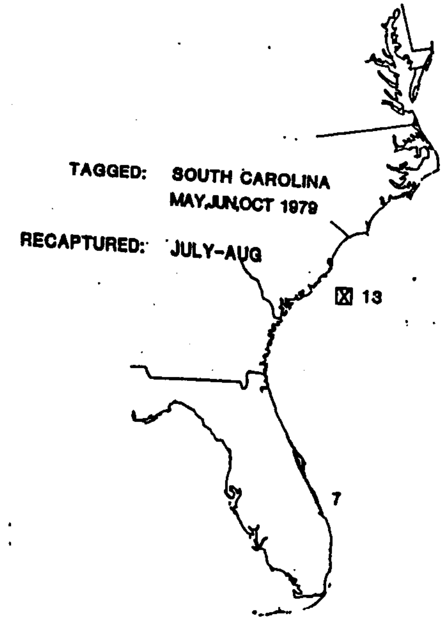
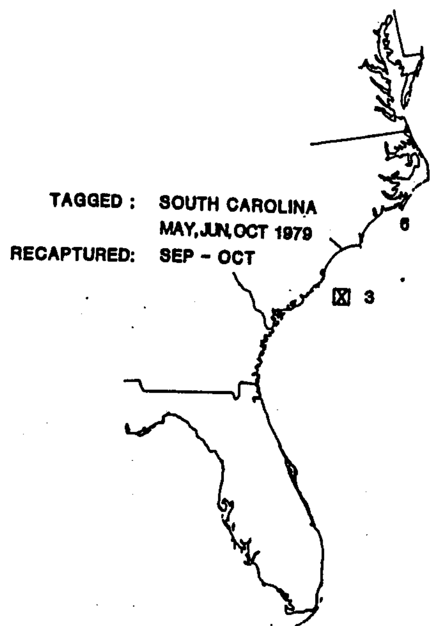
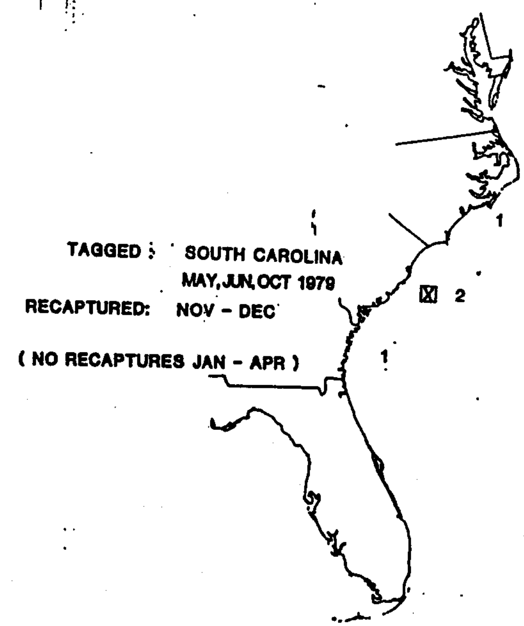


Figure 21. Tag recoveries during July-August (all years) for fish tagged off Murrells Inlet, Sout Carolina during May, June, and October 1979. Total number tagged = 814.

Williams and Godcharles, 1984





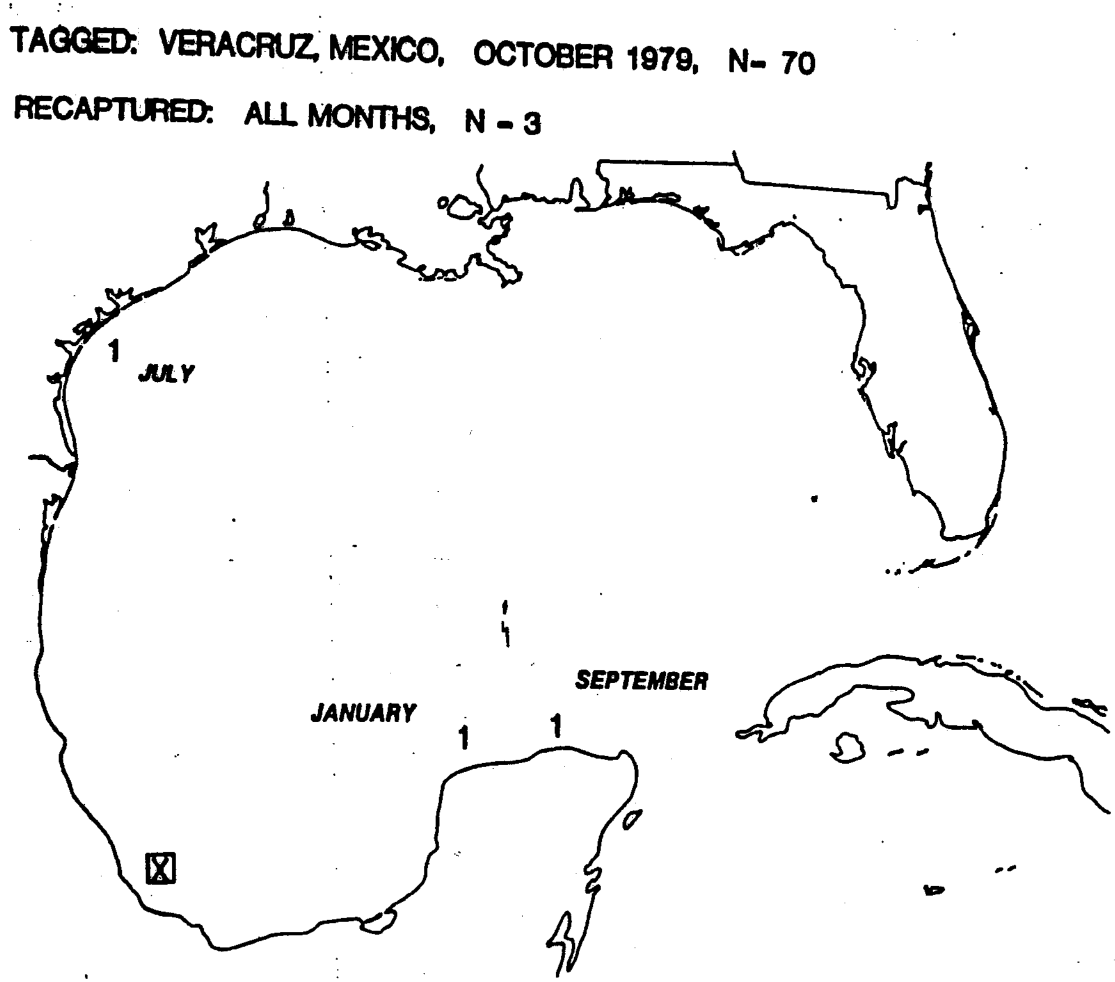


Figure 25. Tag recoveries during all months and all years for fish tagged off Veracruz, Mexico during October 1979. The 'X' shows tagging location, and numbers shown are numbers of recaptures. Total number tagged = 70.

Williams and Godcharles, 1984

Sutherland and Fable, 1980

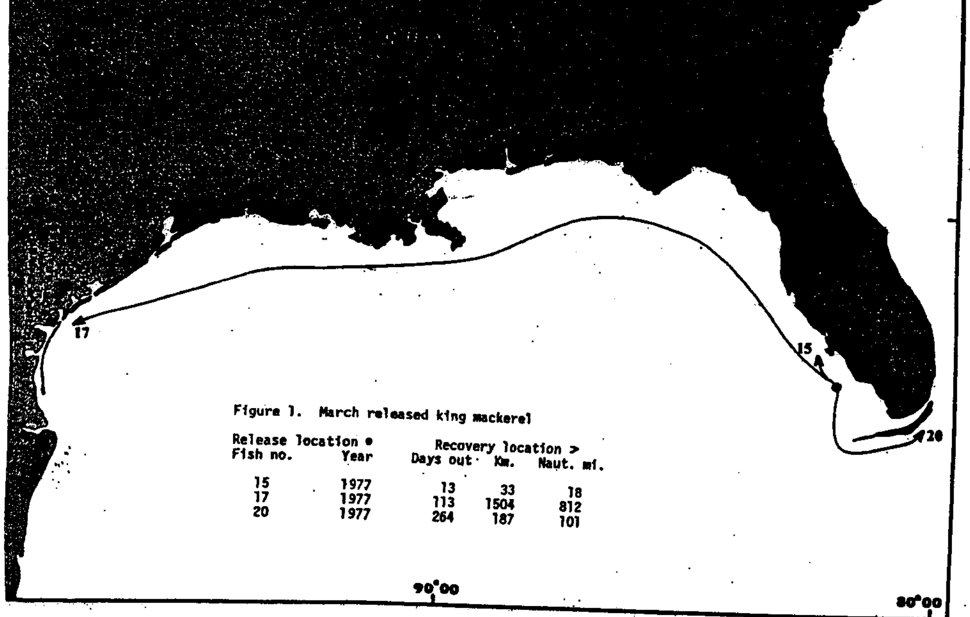


Figure 1. March released king mackerel

Release location ● Fish no.	Year	Recovery location > Days out	Km.	Naut. mi.
15	1977	13	33	18
17	1977	113	1504	812
20	1977	264	187	101

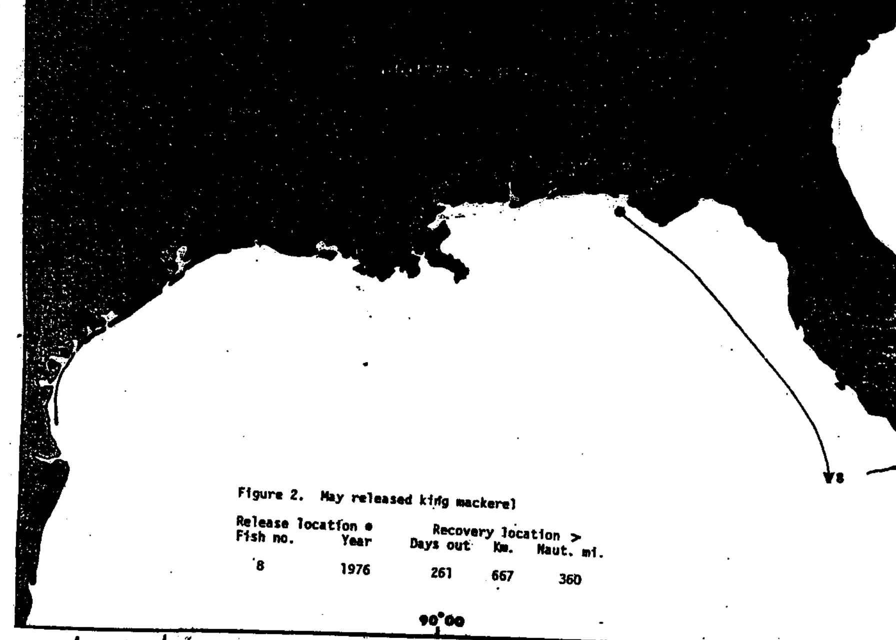


Figure 2. May released king mackerel

Release location ● Fish no.	Year	Recovery location > Days out	Km.	Naut. mi.
8	1976	261	667	360

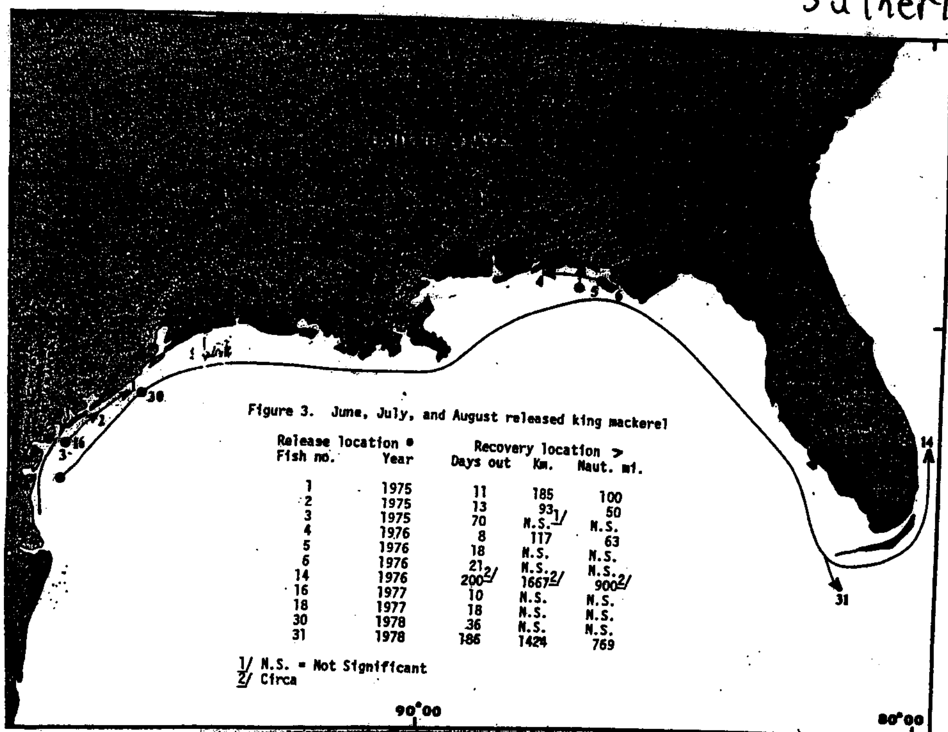


Figure 3. June, July, and August released king mackerel

Release location ● Fish no.	Year	Recovery location > Days out	Km.	Naut. mi.
1	1975	11	185	100
2	1975	13	93	50
3	1975	70	N.S.1/	N.S.
4	1976	8	117	63
5	1976	18	N.S.	N.S.
6	1976	21	N.S.	N.S.
14	1976	200 2/	1667 2/	900 2/
16	1977	10	N.S.	N.S.
18	1977	18	N.S.	N.S.
30	1978	36	N.S.	N.S.
31	1978	186	1424	769

1/ N.S. = Not Significant
2/ Circa

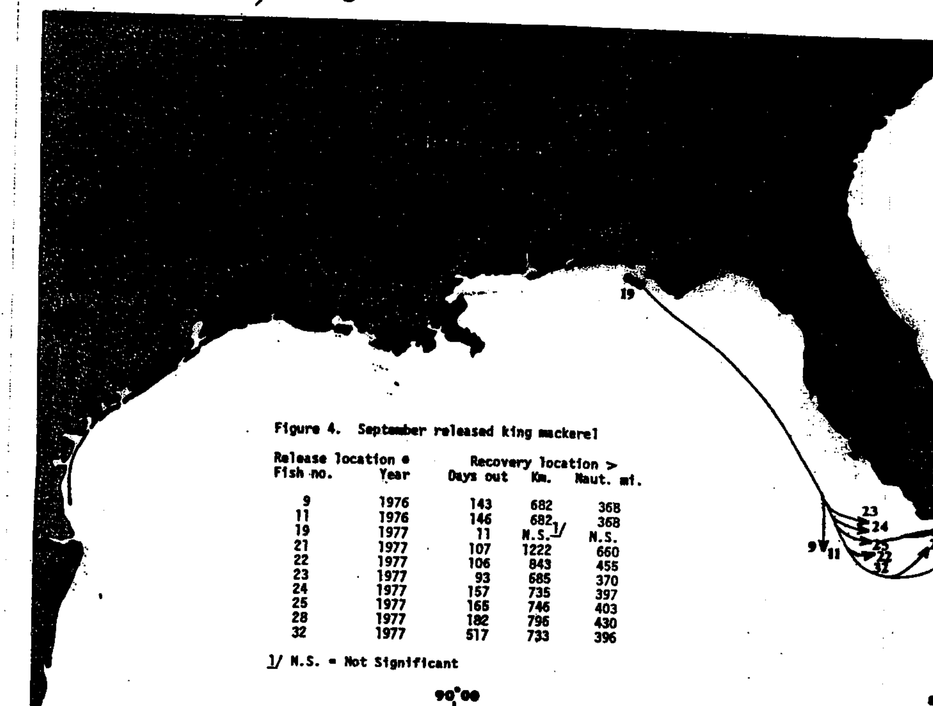


Figure 4. September released king mackerel

Release location ● Fish no.	Year	Recovery location > Days out	Km.	Naut. mi.
9	1976	143	682	368
11	1976	146	682	368
19	1977	11	N.S.1/	N.S.
21	1977	107	1222	660
22	1977	106	843	455
23	1977	93	685	370
24	1977	157	735	397
25	1977	166	746	403
28	1977	182	796	430
32	1977	517	733	396

1/ N.S. = Not Significant

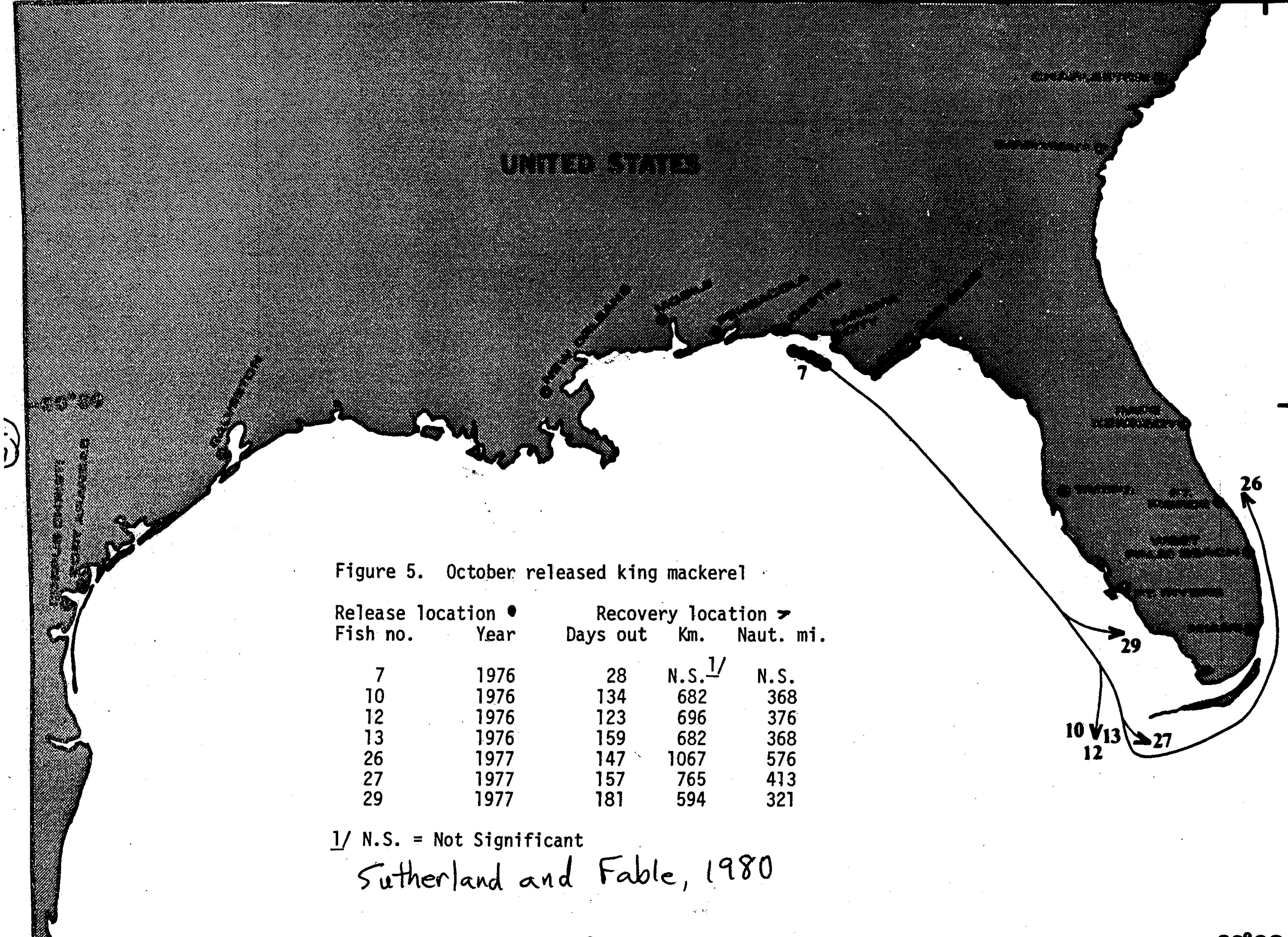


Figure 5. October released king mackerel

Release location ● Fish no.	Year	Recovery location ➤ Days out	Km.	Naut. mi.
7	1976	28	N.S.[1/]	N.S.
10	1976	134	682	368
12	1976	123	696	376
13	1976	159	682	368
26	1977	147	1067	576
27	1977	157	765	413
29	1977	181	594	321

1/ N.S. = Not Significant

Sutherland and Fable, 1980

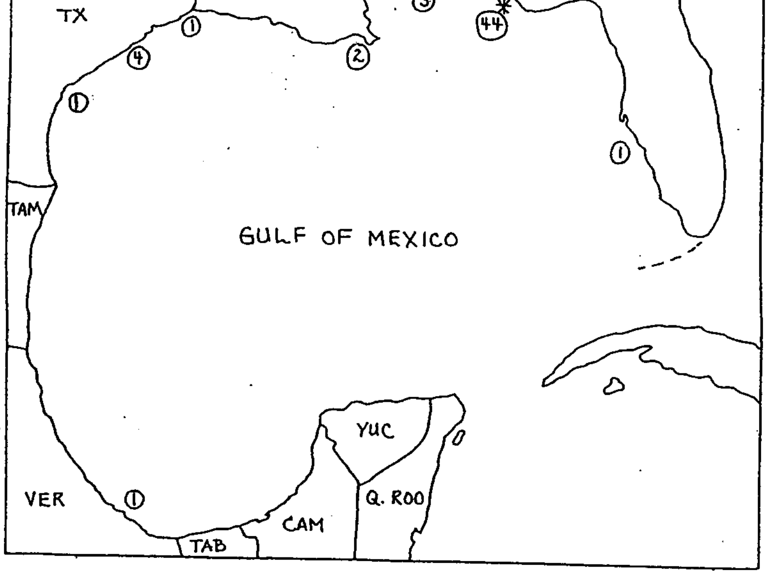


Figure 3. Locations and numbers of tagged king mackerel recovered in June through August from tagging off northwest Florida. Asterisk indicates tagging area, circled numbers indicate location and number of tag recoveries (57).

Fable et al, (1992?)

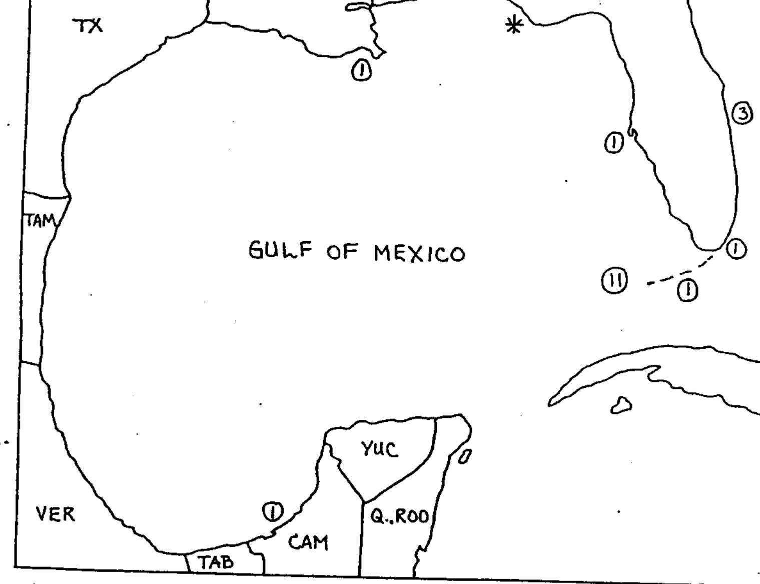


Figure 4. Locations and numbers of tagged king mackerel recovered in December through February from tagging off northwest Florida. Asterisk indicates tagging area, circled numbers indicate location and number of tag recoveries (19).

Fable et al, (1992?)

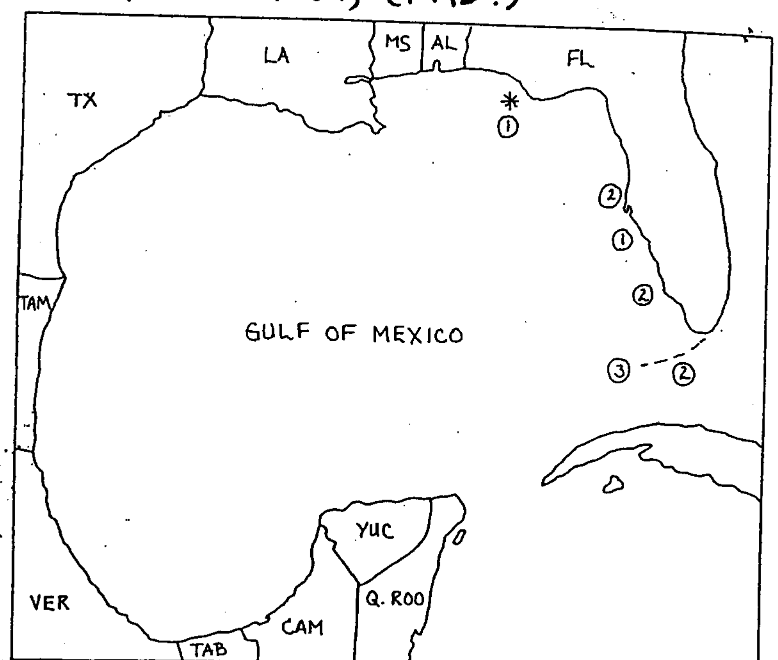


Figure 5. Locations and numbers of tagged king mackerel recovered in March through May from tagging off northwest Florida. Asterisk indicates tagging area, circled numbers indicate location and number of tag recoveries (11).

Fable et al, (1992?)

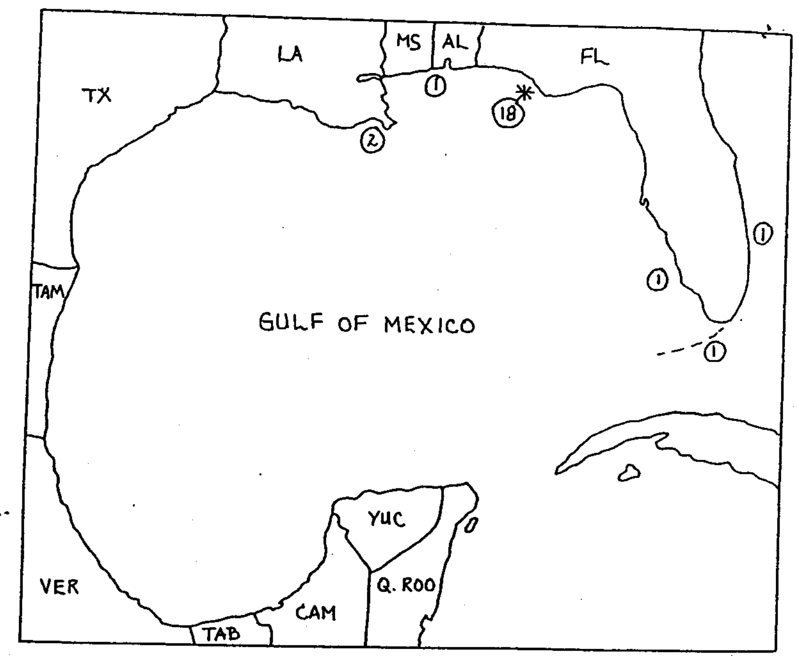


Figure 6. Locations and numbers of tagged king mackerel recovered in September through November from tagging off northwest Florida. Asterisk indicates tagging area, circled numbers indicate location and number of tag recovereis (24).

Fable et al, (1992?)

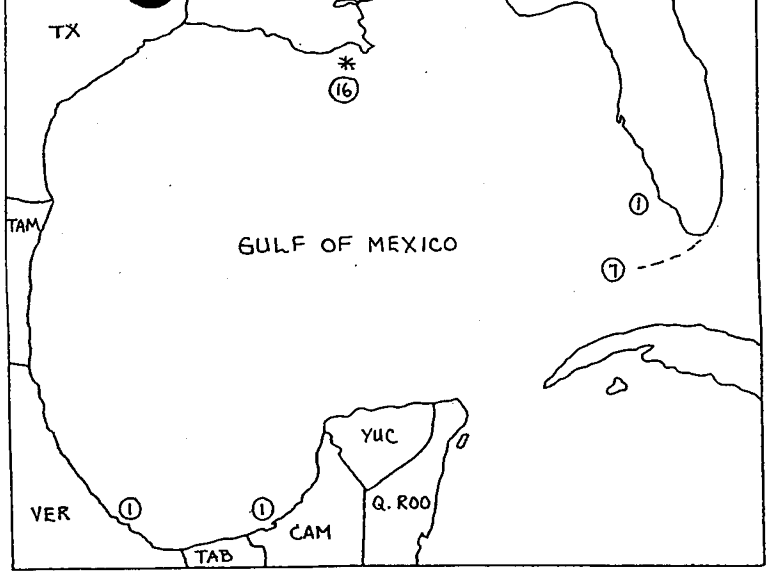


Figure 9. Locations and numbers of tagged king mackerel recovered in December through February from tagging off Louisiana. Asterisk indicates tagging area, circled numbers indicate location and number of tag recoveries (26).

Fable et al, (1992?)

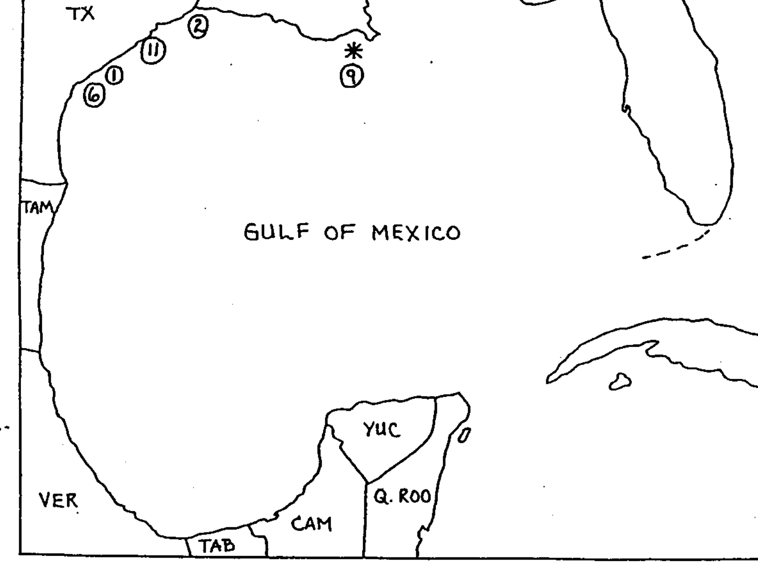


Figure 10. Locations and numbers of tagged king mackerel recovered in June through August from tagging off Louisiana. Asterisk indicates tagging area, circled numbers indicate location and number of tag recoveries (29).

Fable et al, (1992?)

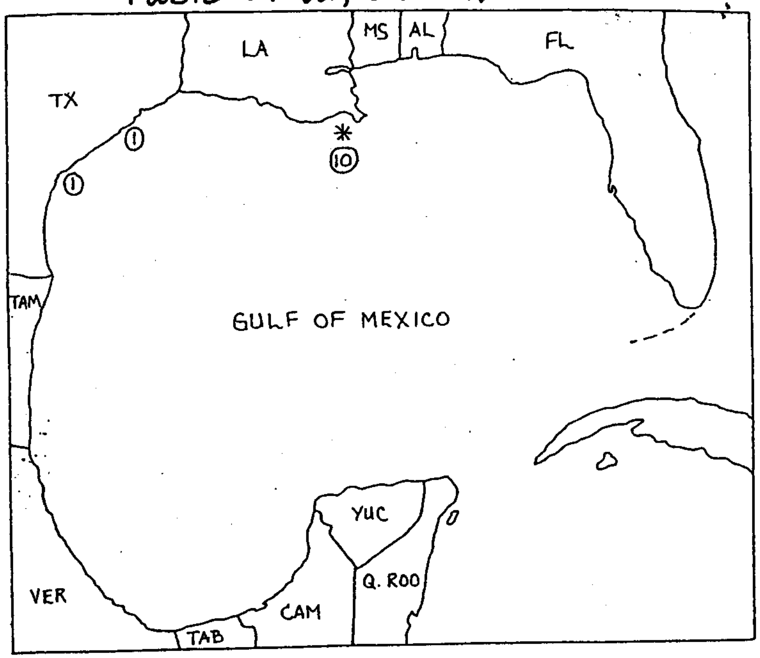


Figure 11. Locations and numbers of tagged king mackerel recovered in September through November from tagging off Louisiana. Asterisk indicates tagging area, circled numbers indicate location and number of tag recoveries (12).

Fable et al, (1992?)

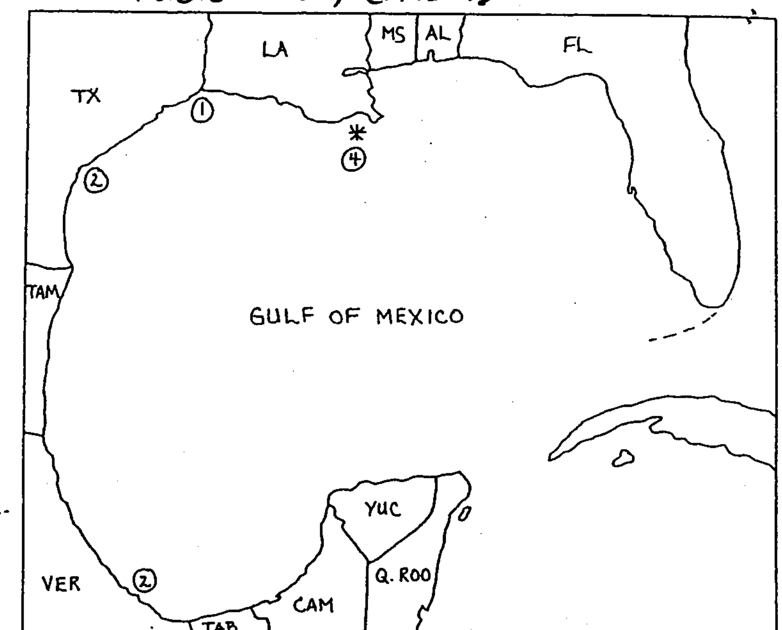


Figure 12. Locations and numbers of tagged king mackerel recovered in March through May from tagging off Louisiana. Asterisk indicates tagging area, circled numbers indicate location and number of tag recoveries (9).

Fable et al, (1992?)

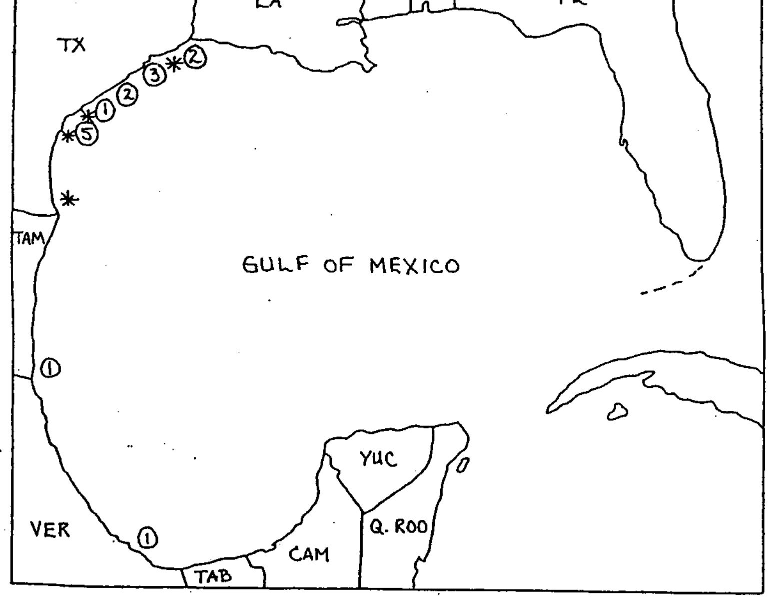


Figure 14. Locations and numbers of tagged king mackerel recovered in June through August from tagging off Texas. Asterisks indicate tagging areas, circled numbers indicate location and number of tag recoveries (15).

Fable et al, (1992?)

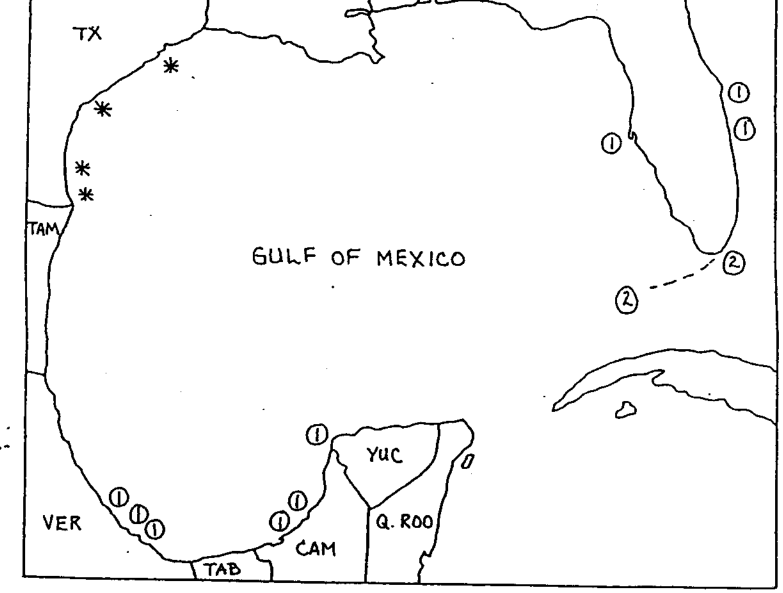


Figure 15. Locations and numbers of tagged king mackerel recovered in December through February from tagging off Texas. Asterisks indicate tagging areas, circled numbers indicate location and numbers of tag recoveries (13).

Fable et al, (1992?)

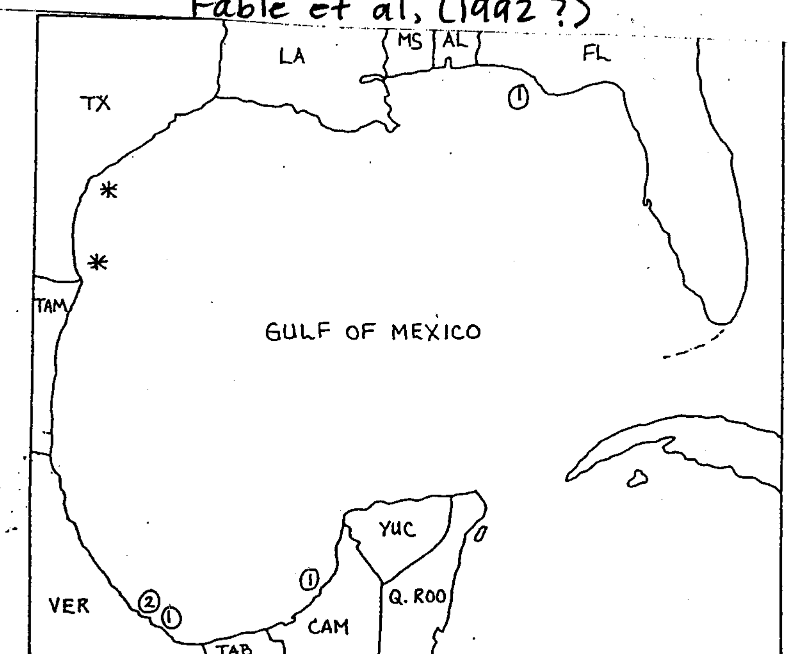


Figure 16. Locations and numbers of tagged king mackerel recovered in March through May from tagging off Texas. Asterisks indicate tagging areas, circled numbers indicate location and number of tag recoveries (5).

Fable et al, (1992?)

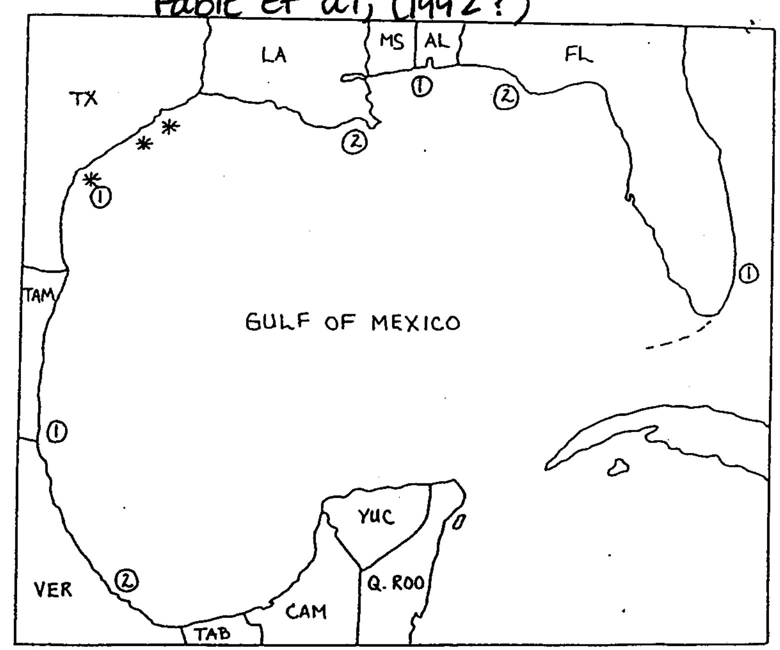


Figure 17. Locations and numbers of tagged king mackerel recovered in September through November from tagging off Texas. Asterisks indicate tagging areas, circled numbers indicate location and number of tag recoveries (10).

Fable et al, (1992?)

(21)

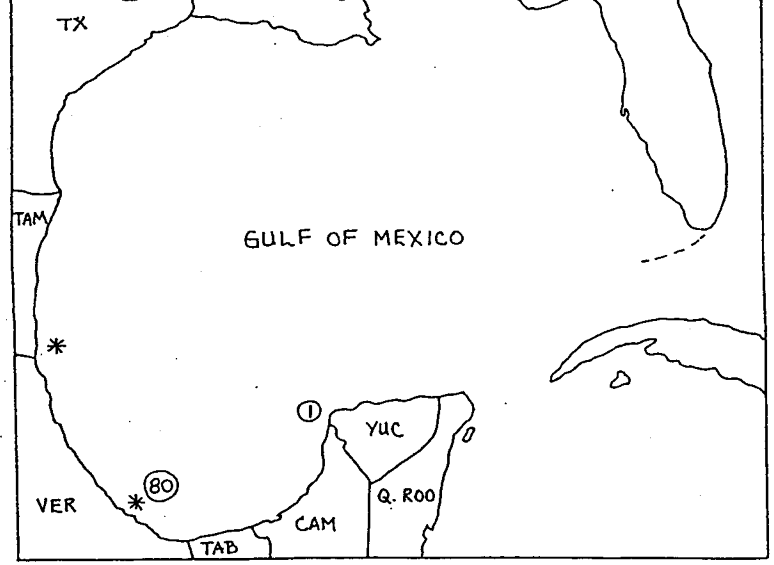


Figure 19. Locations and numbers of tagged king mackerel recovered in March through May from tagging off Tamaulipas and Veracruz. Asterisks indicate tagging areas, circled numbers indicate location and number of tag recoveries (81).

Fable et al, (1992?)

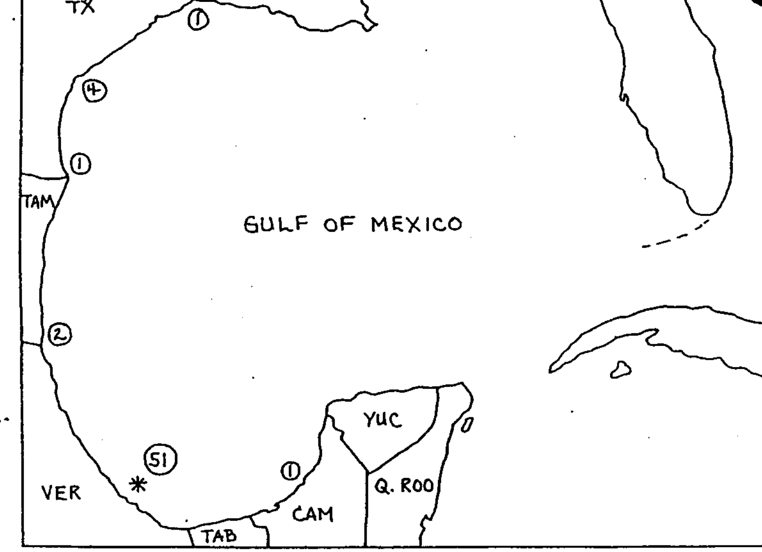


Figure 20. Locations and numbers of tagged king mackerel recovered in June through August from tagging off Tamaulipas and Veracruz. Asterisk indicates tagging area, circled numbers indicate location and number of tag recoveries (60).

Fable et al, (1992?)

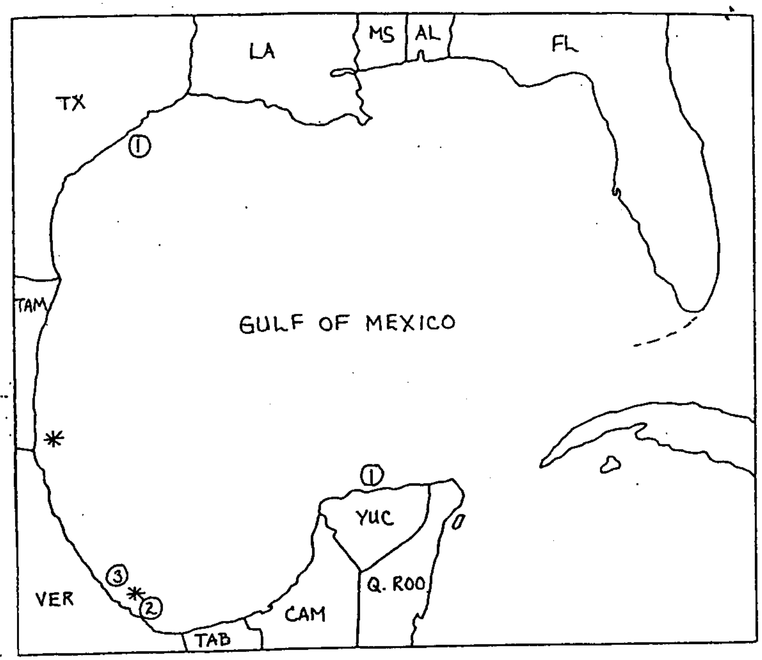


Figure 21. Locations and numbers of tagged king mackerel recovered in September through November from tagging off Tamaulipes and Veracruz. Asterisks indicate tagging areas, circled numbers indicate location and number of tag recoveries (7).

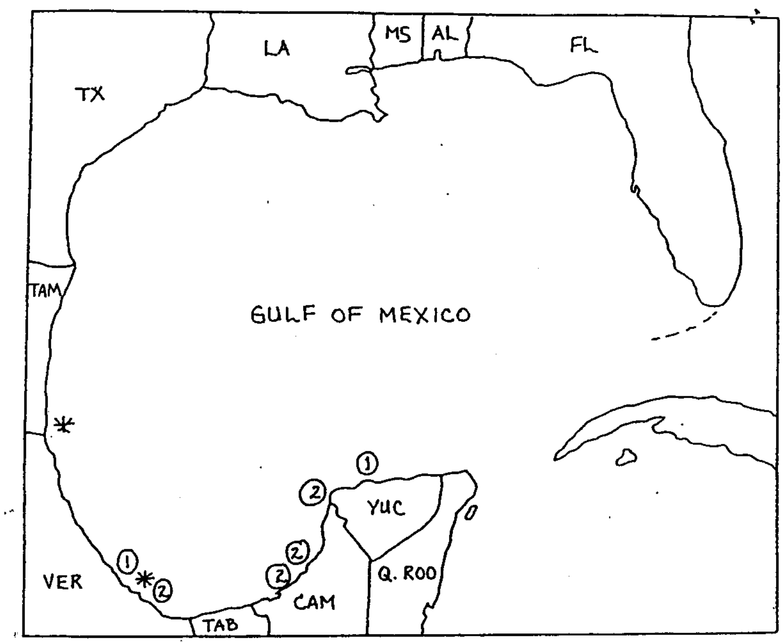


Figure 22. Locations and numbers of tagged king mackerel recovered in December through February from tagging off Tamaulipas and Veracruz. Asterisks indicate tagging areas, circled numbers indicate location and number of tag recoveries (10).

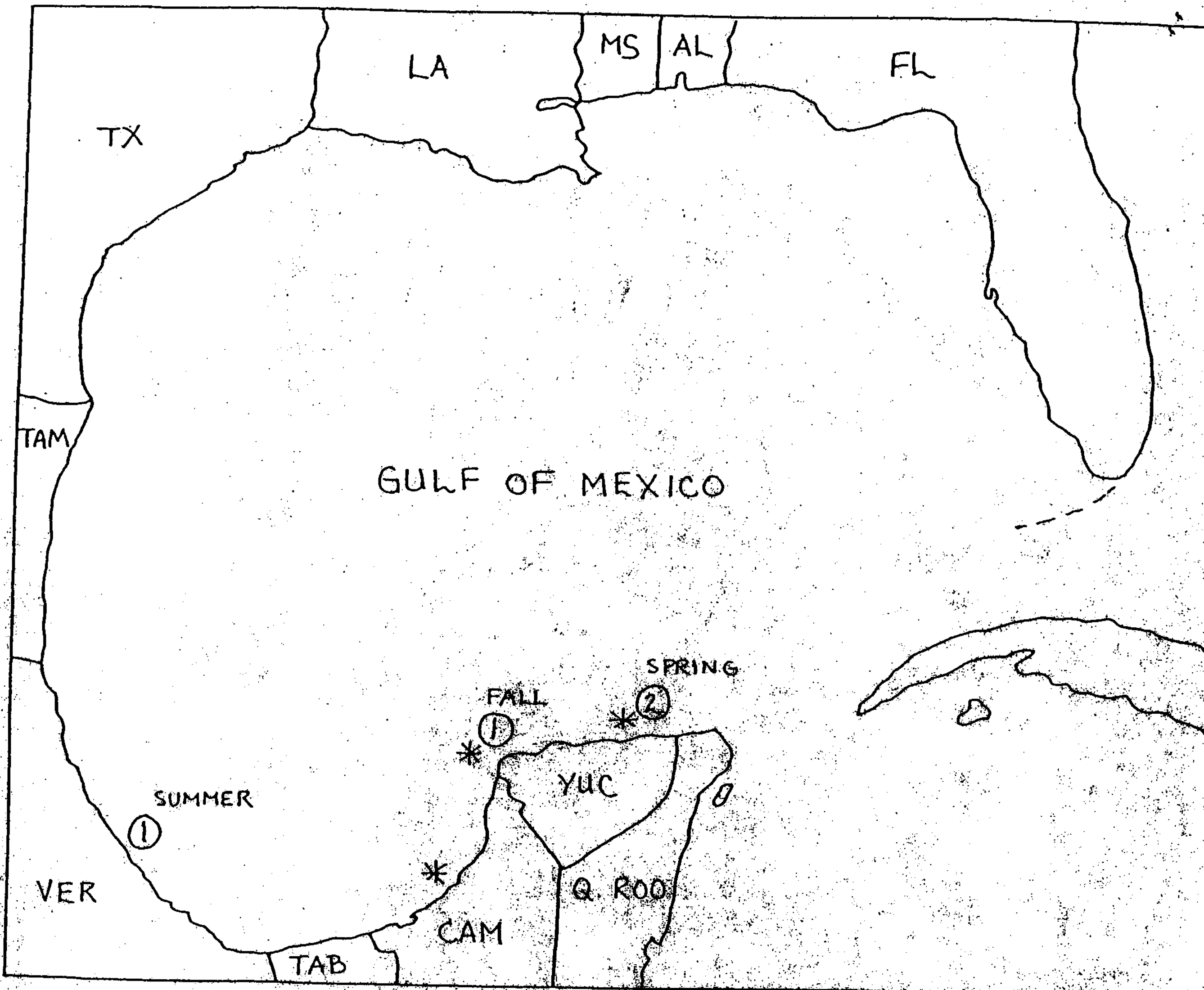
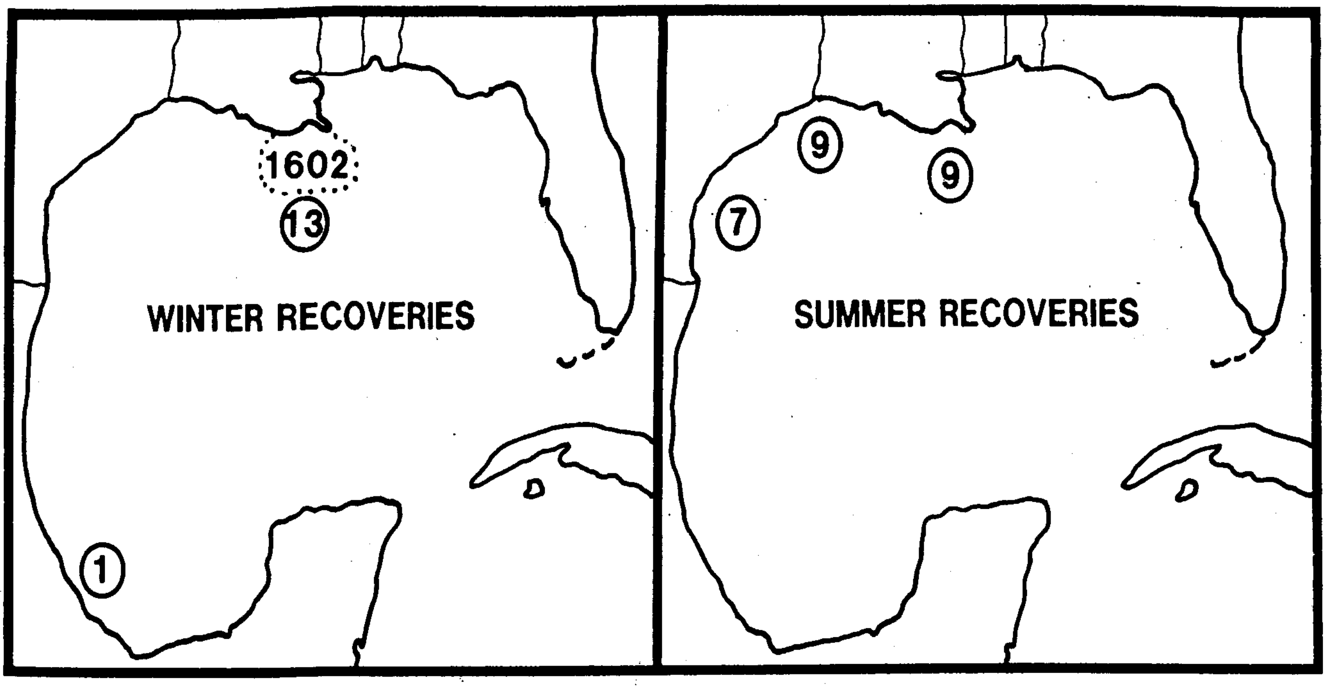
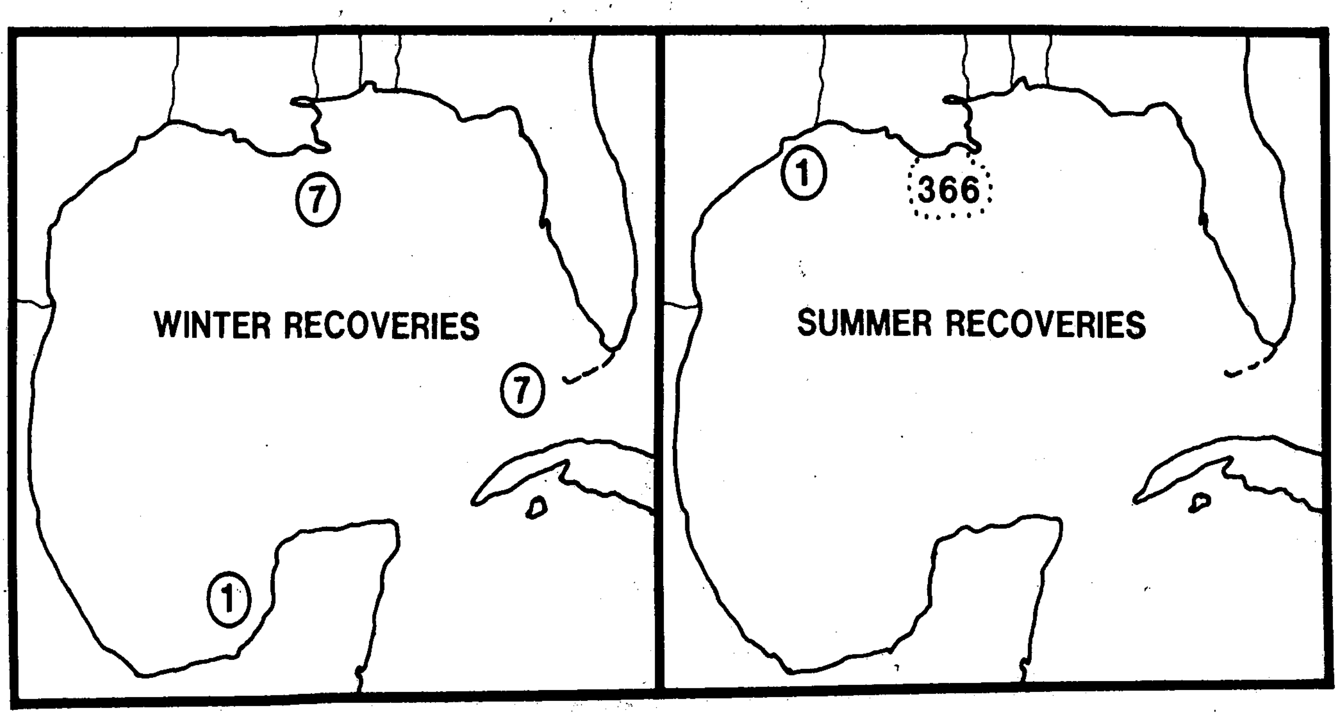


Figure 24. Locations, seasons, and numbers of tagged king mackerel recovered from tagging off Campeche and Yucatan. Asterisks indicate tagging areas, circled numbers and adjacent season notations indicate location, number and season of tag recoveries (4).

Fable et al, (1992?)



WINTER TAGGING



SUMMER TAGGING

Figure 3.—Numbers of tagged king mackerel (in dots) and recovered king mackerel (in circles) by time period.

Fable et al., 1987

Figure 5. Number of mackerel tagged off Mexican Gulf Coast states (1986-1994).
Figure 6. Important tag returns from Texas to Mexico (1986-1994).
Figure 7. Significant long distance tag returns from Louisiana to Mexico (1986-1994).
Figure 8. Significant tag returns from Florida to Mexico (1986-1994).
Burns, 1994

Fig. 5

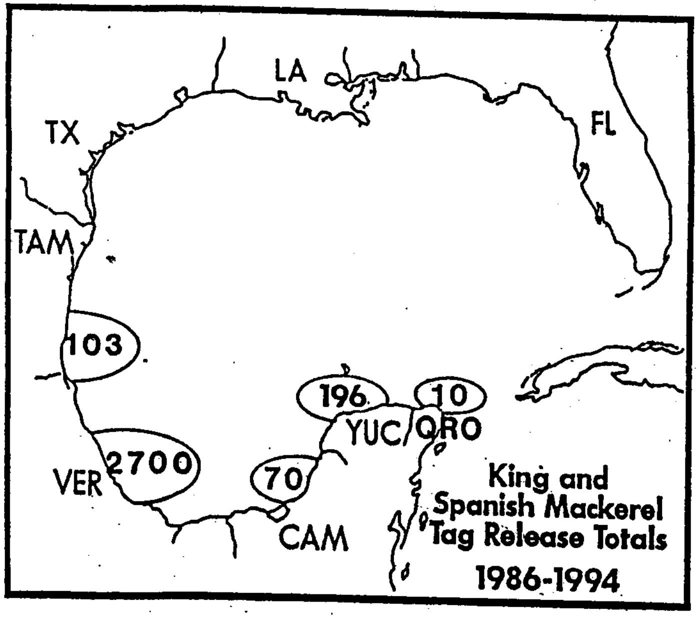


Fig. 6

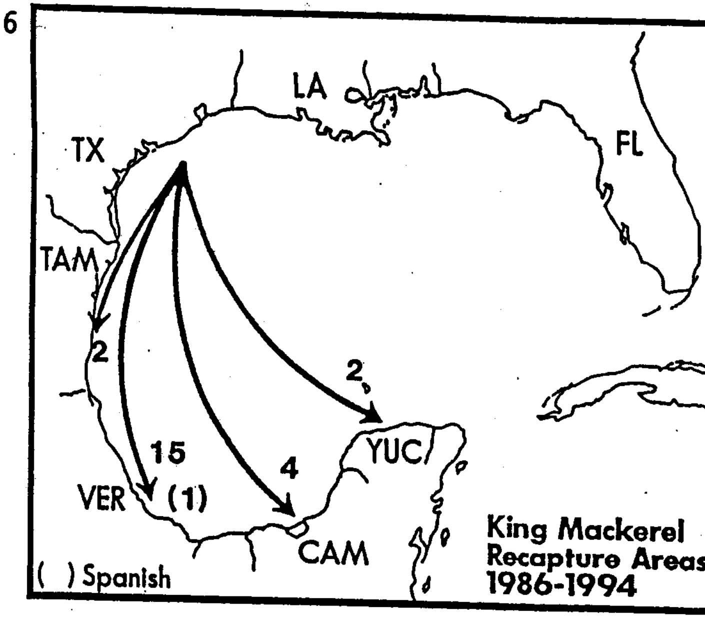


Fig. 7

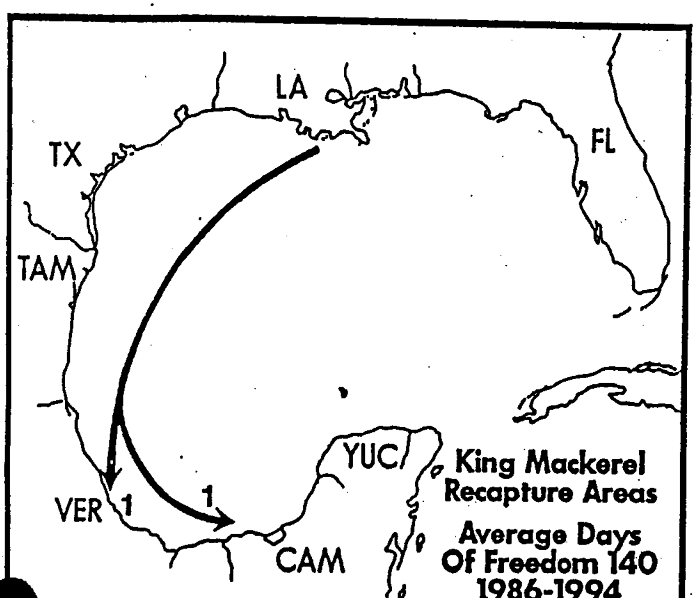


Fig. 8

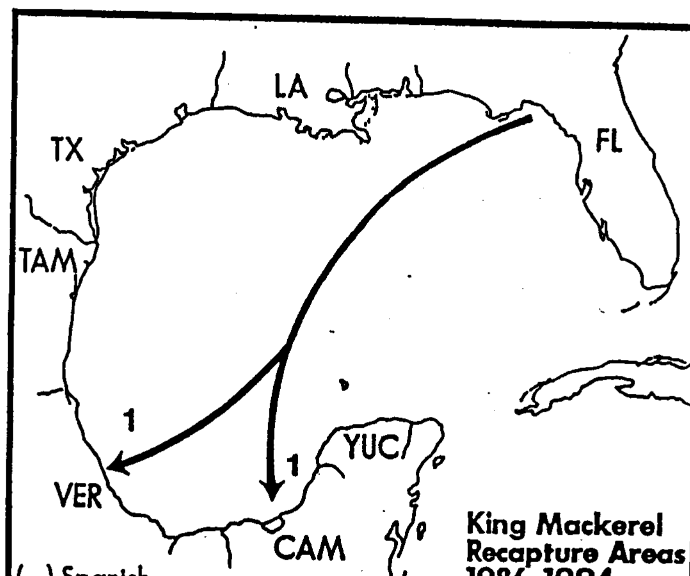


Figure 9. Significant tag returns within Mexico and from Veracruz, Mexico to the U.S. (1986-1994).
Figure 10. Important long distance tag returns from Tamaulipas to other Mexican states (1986-1994).
Figure 11. Significant long distance tag returns from Campeche to other Mexican states (1986-1994).
Figure 12. Important tag returns from Yucatán to Veracruz (1986-1994).
Burns, 1994

Fig. 9

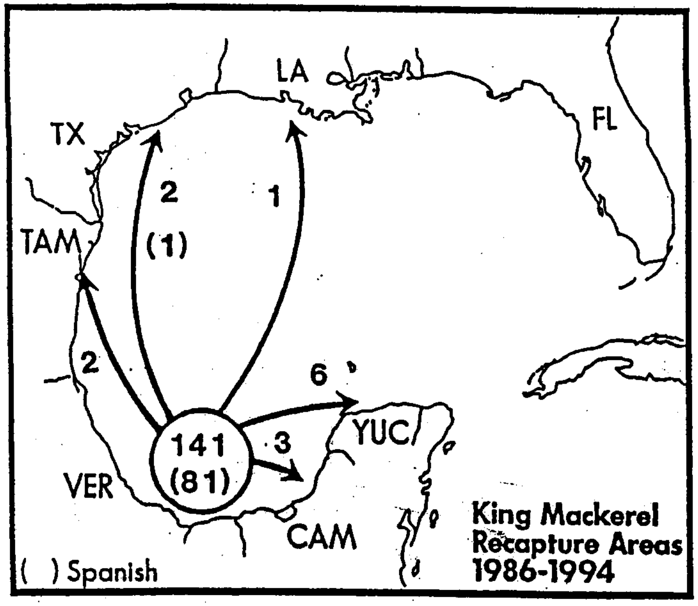


Fig. 10

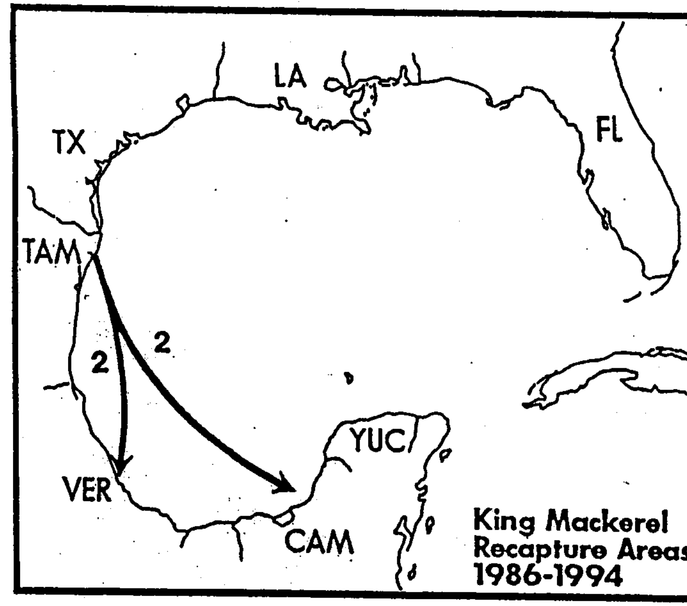


Fig. 11

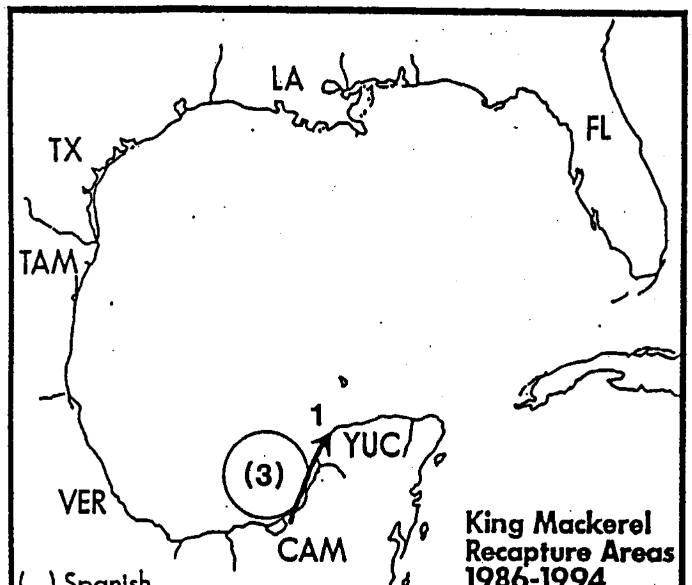
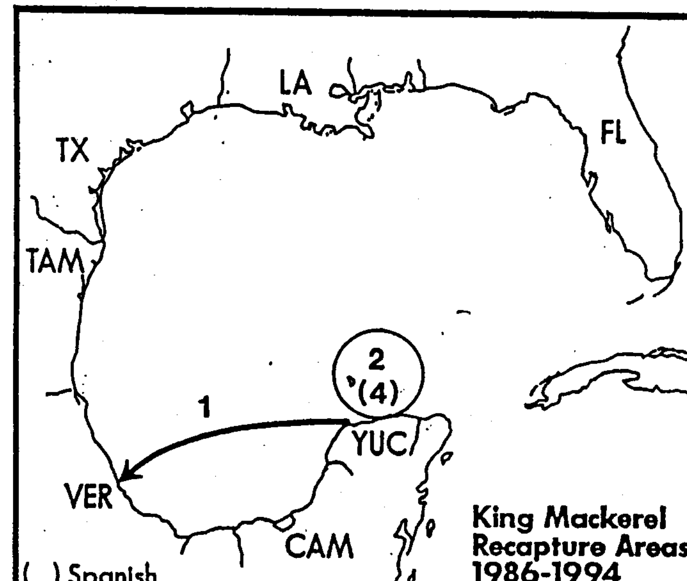
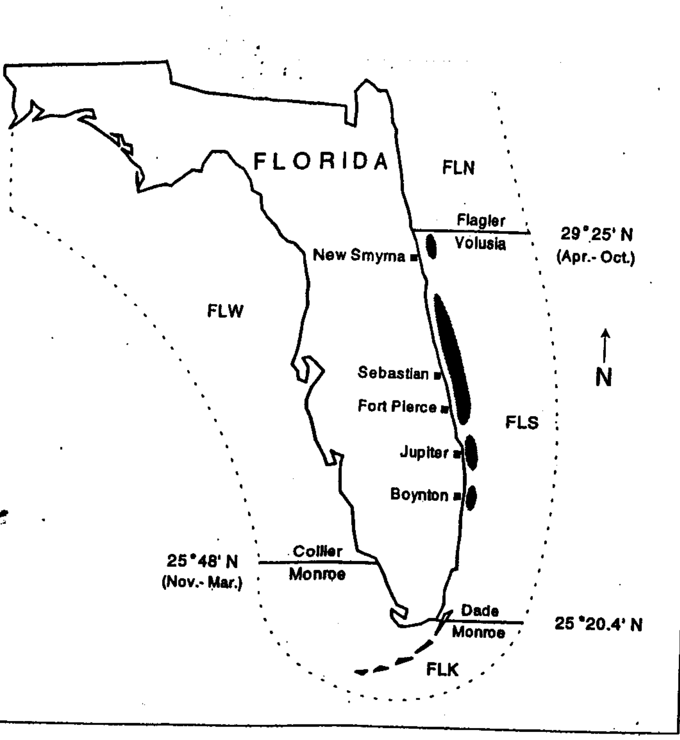


Fig. 12





ure 2.—NMFS tagging locations (shaded), variable Atlantic/Gulf stock boundaries, and reas used to partition Florida tag returns.

Schaeffer and Fable, 1994

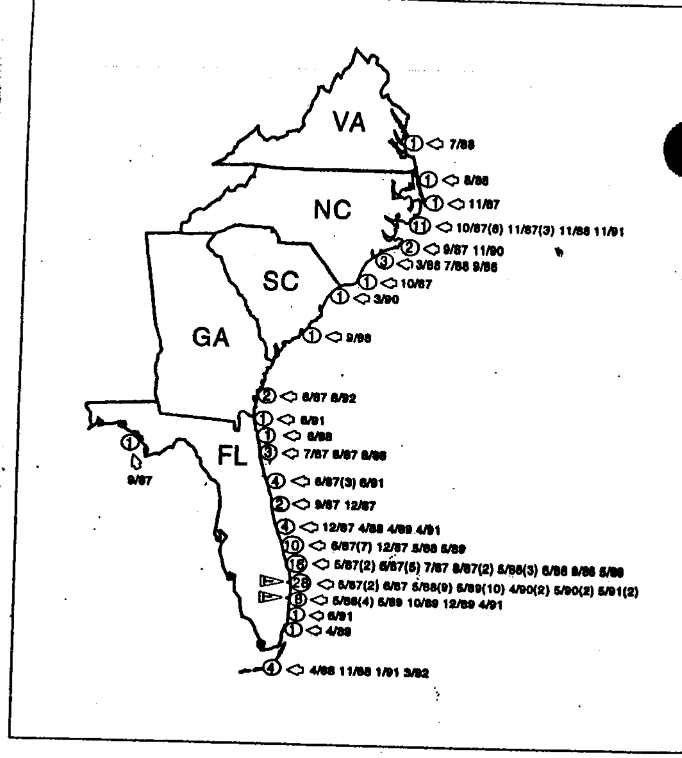


Figure 7.—Location and month/year of tag returns from 1987 tagging in the Jupiter, Fla., area.

Schaeffer and Fable, 1994

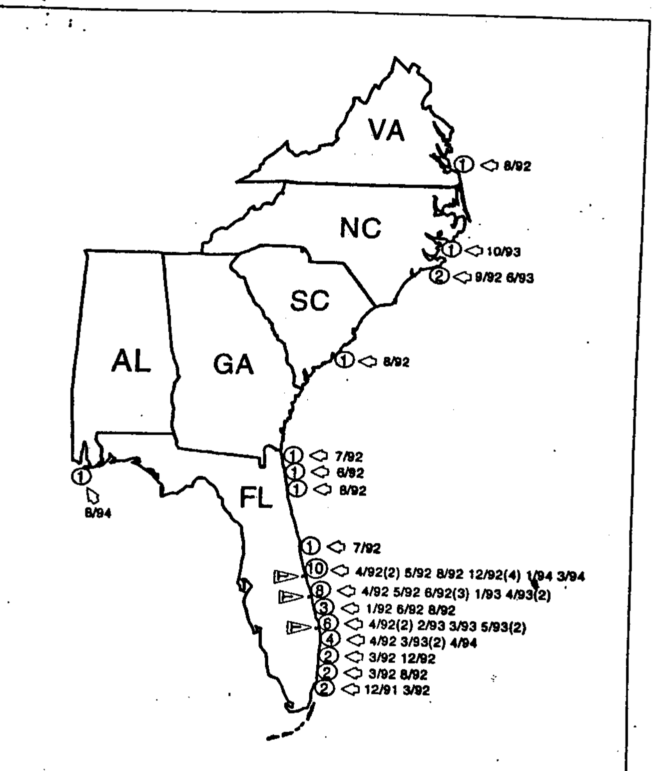


Figure 10.—Location and month/year of tag returns from 1991–92 southeast Florida tagging.

Schaeffer and Fable, 1994

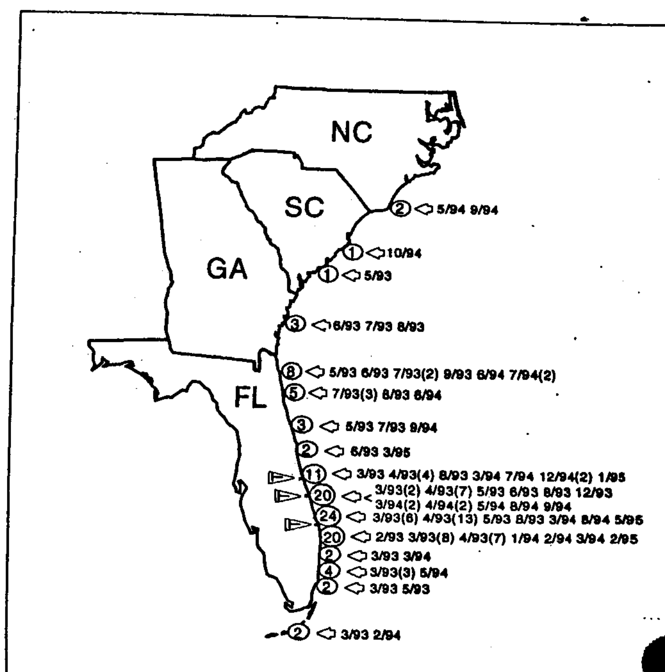


Figure 11.—Location and month/year of tag returns from 1992–93 southeast Florida tagging.

Schaeffer and Fable, 1994

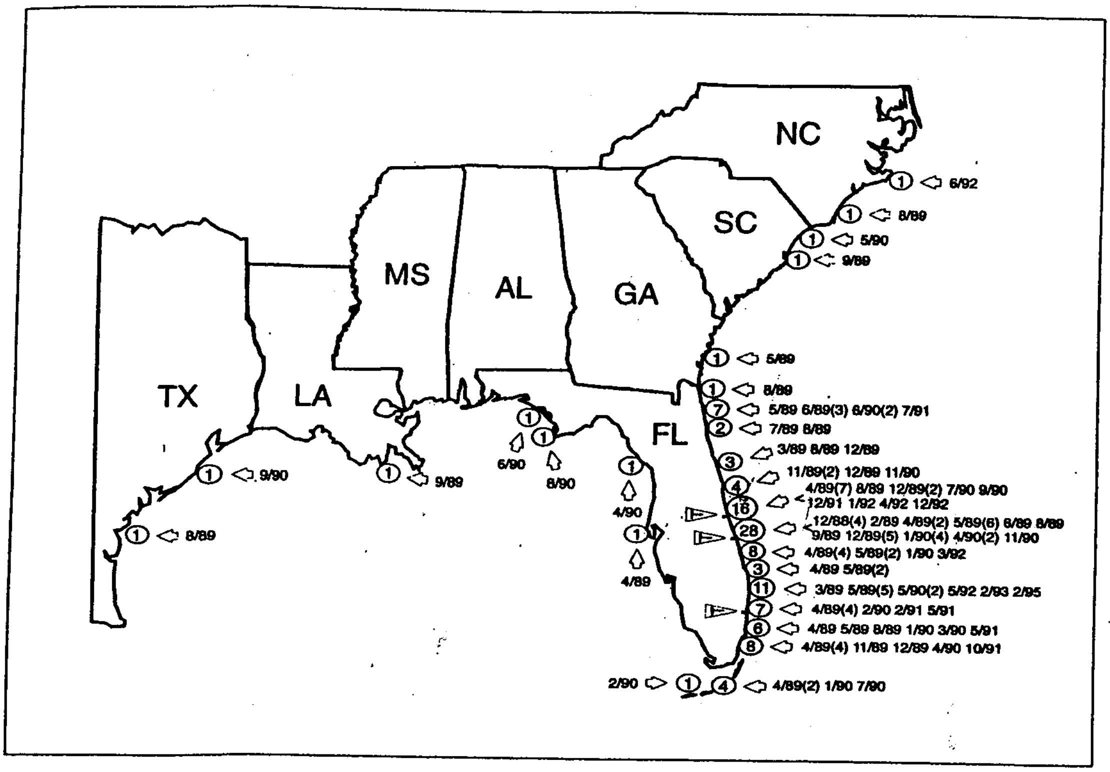


Figure 8.—Location and month/year of tag returns from 1988-89 southeast Florida tagging.

Schaefer and Fable, 1994

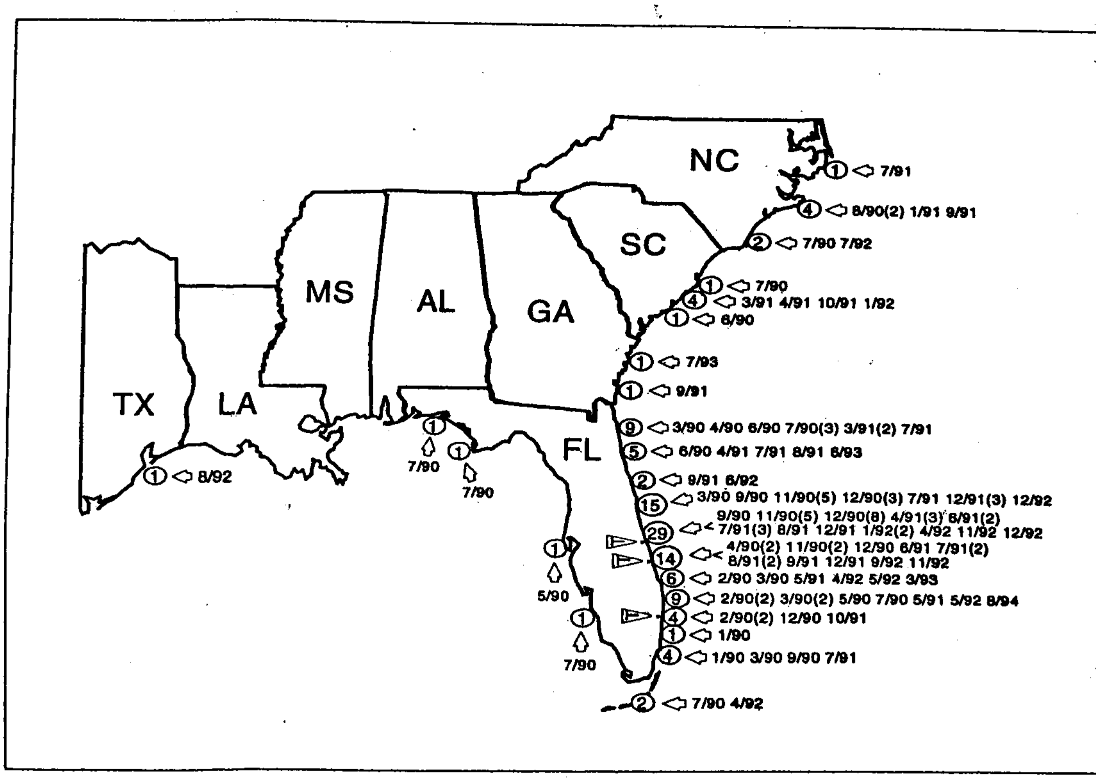


Figure 9.—Location and month/year of tag returns from 1989-90 southeast Florida tagging.

Schaefer and Fable, 1994

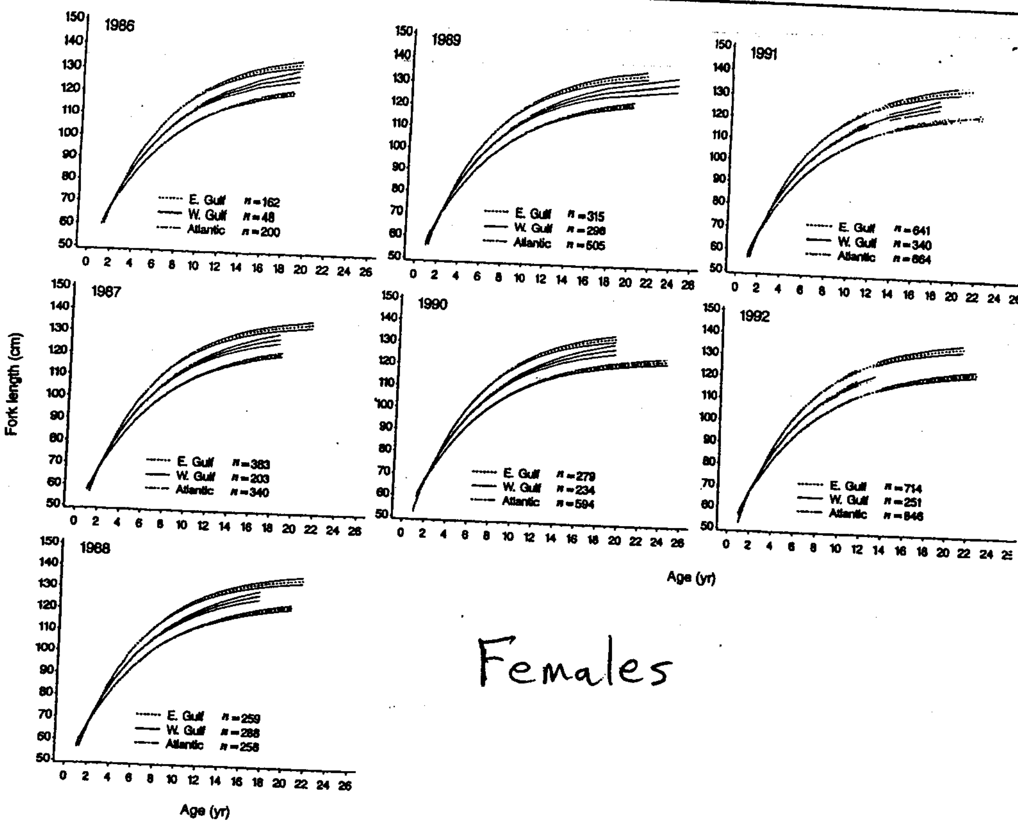


Figure 4

Annual von Bertalanffy growth curves and 95% confidence limits by region for female king mackerel collected 1986–92. Growth curves were calculated by using individual quarterly observed sizes-at-age.

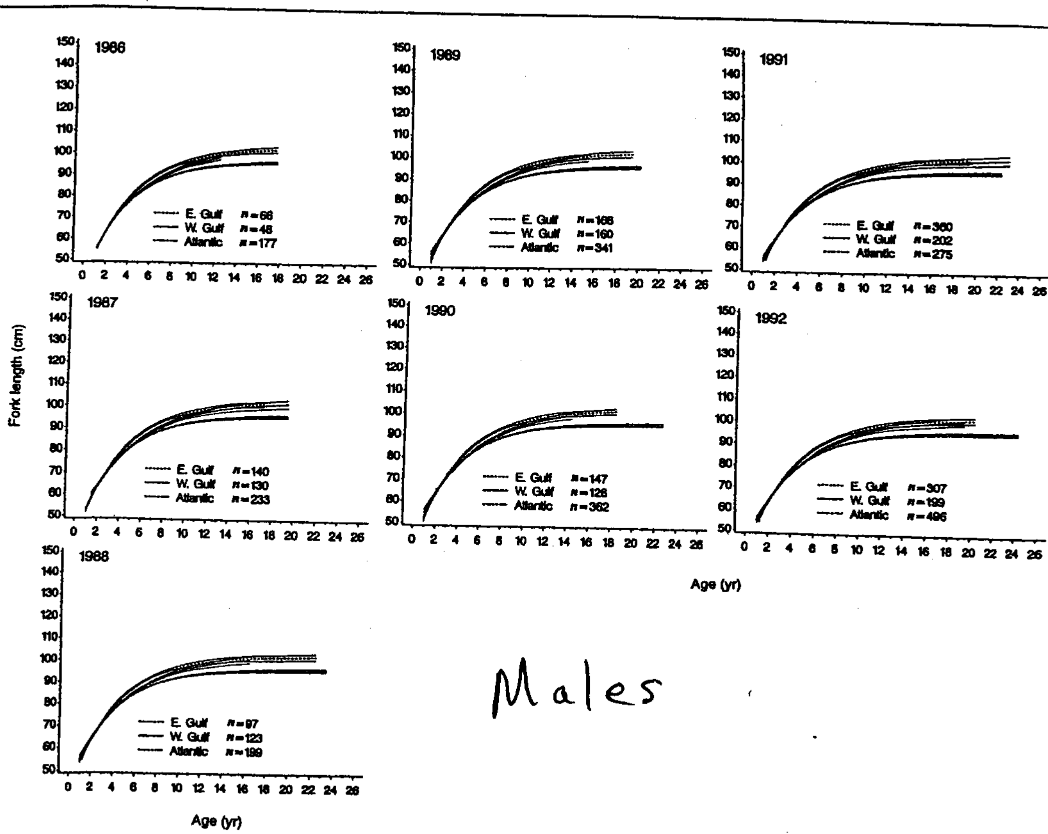
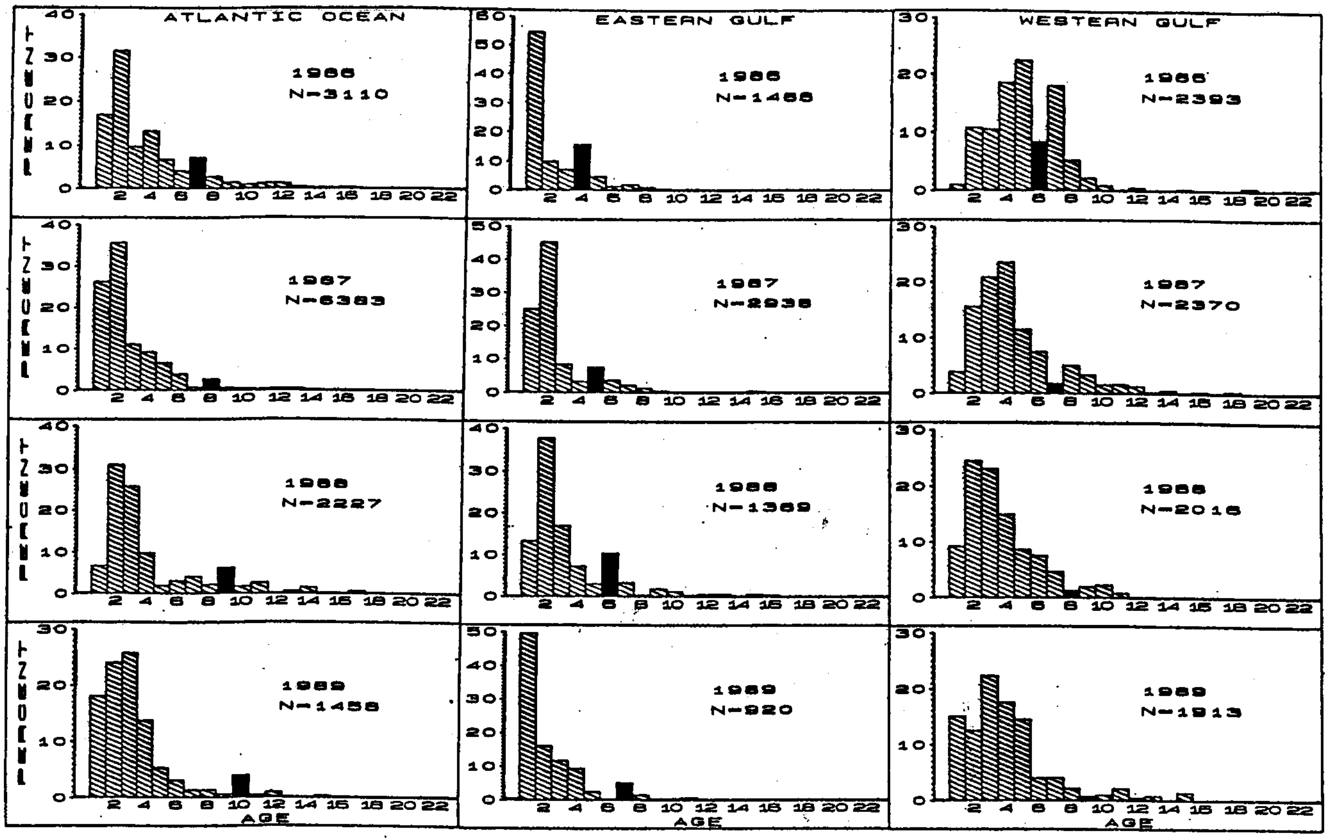


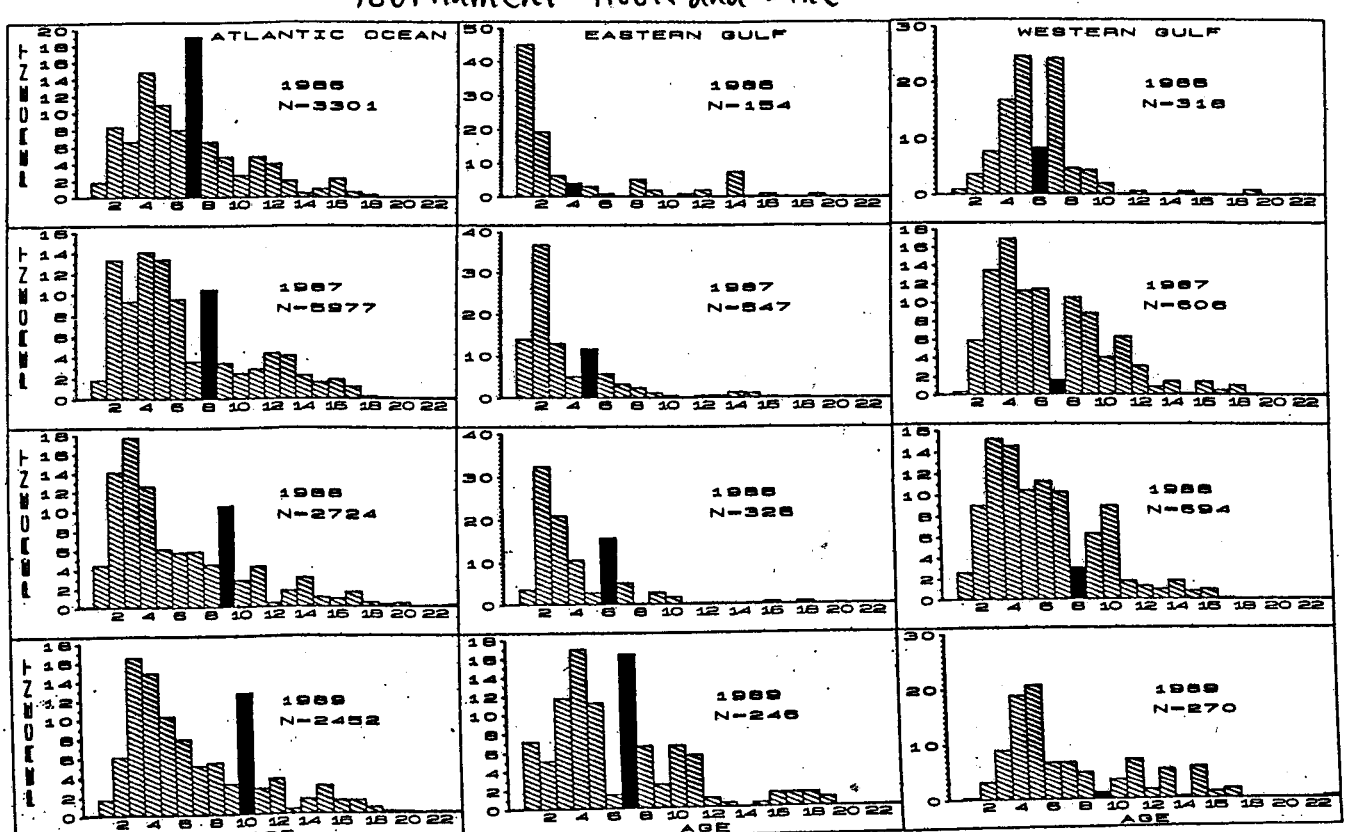
Figure 5

Annual von Bertalanffy growth curves and 95% confidence limits by region for male king mackerel collected 1986–92. Growth curves were calculated by using individual quarterly observed sizes-at-age.

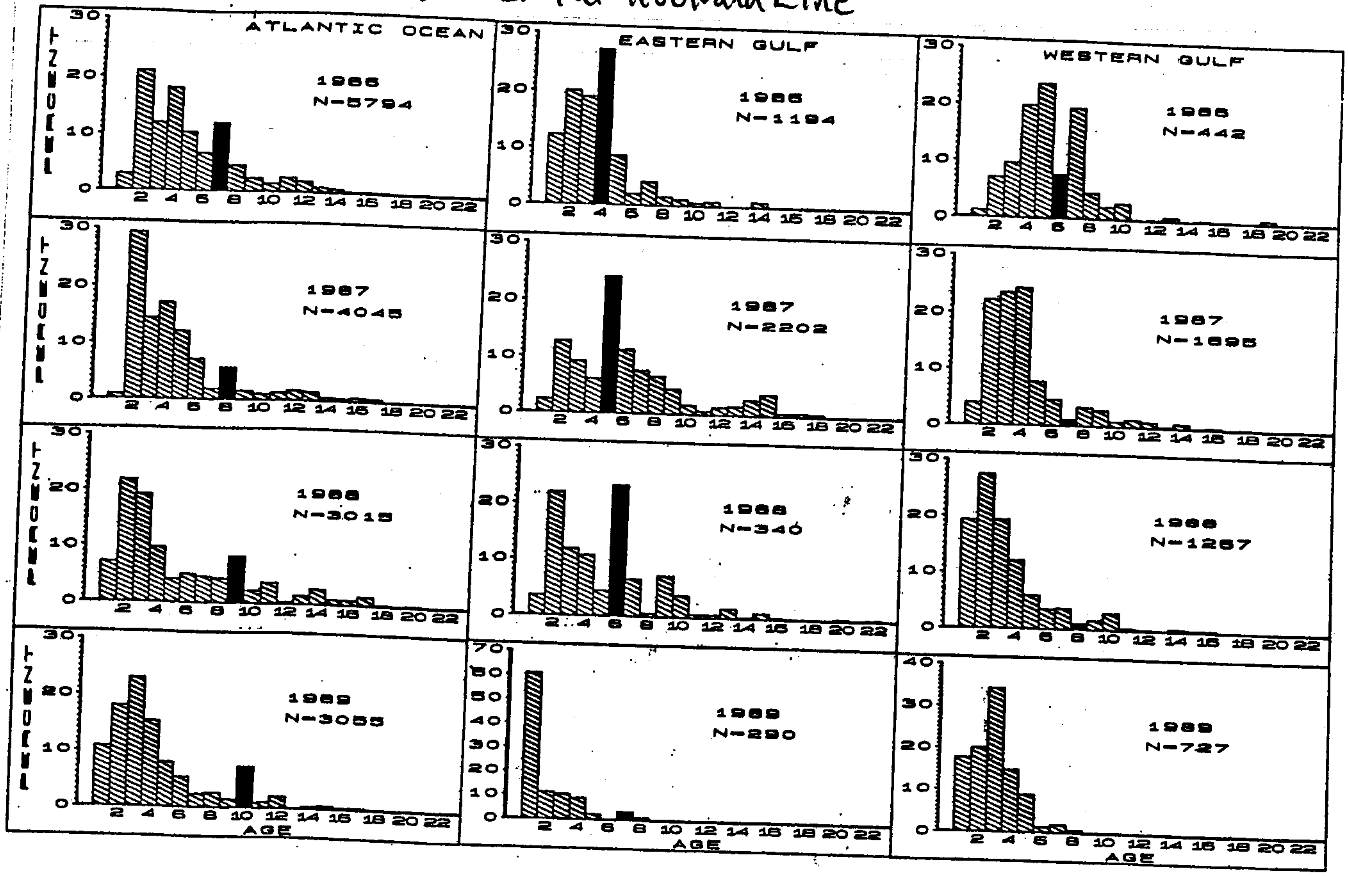
Recreational Hook and Line



Tournament Hook and Line



Commercial Hook and Line



Commercial Gill Net