King Mackerel, *Scomberomorus cavalla*, Mark-Recapture Studies Off Florida's East Coast

H. CHARLES SCHAEFER and WILLIAM A. FABLE, JR.

Introduction

King mackerel, *Scomberomorus cavalla*, is a coastal, pelagic scombrid found off the U.S. Atlantic and Gulf of Mexico coasts. This species has historically contributed to commercial and recreational catches throughout its range in the southeastern United States. Commercial exploitation intensified there in the 1960's with the introduction of large power-assisted gillnet boats and spotter aircraft. By the late 1970's and early 1980's, increased demand for king mackerel had exceeded reproductive capacity causing stock reductions and declining recruitment (Godcharles[1]). King mackerel have been jointly managed by the South Atlantic and Gulf of Mexico Fishery Management Councils since the implementation of the Coastal Pelagic Fishery Management Plan (CPFMP) in 1983. The maximum sustainable yield (MSY) for the U.S. king mackerel resource is currently estimated at 26.2 million pounds (NMFS[2]).

The recreational fishery for king mackerel grew in importance as the commercial fishery thrived. Moe (1963) stated that in the early 1960's, king mackerel was the species most desired by anglers fishing from private boats, and was the staple catch of Florida's charterboat fleet. In 1990–91, king mackerel was one of the three most highly targeted species by recreational anglers along the southern U.S. Atlantic coast (NMFS, 1992). In recent years, estimated king mackerel recreational catches have exceeded reported commercial landings in both the Atlantic and Gulf of Mexico (Fig. 1).

In 1975, the Florida Department of Natural Resources (FDNR), now the Florida Department of Environmental Protection (FDEP), and the National Marine Fisheries Service (NMFS) Panama City Laboratory, began a cooperative mark-recapture study on king mackerel to determine movements in both the Gulf of Mexico and along the Atlantic coast. Subsequently, biologists from both agencies tagged king mackerel (17,042 releases, 1,171 returns) from 1975 through 1979 (Sutherland and Fable, 1980; Sutter et al., 1991; Williams and Godcharles[3]). Results from this study indicated that the species consisted of at least two migratory groups (stocks). Ranges of the two stocks basically coincided with the Gulf of Mexico and the Atlantic Ocean off the southeast U.S. coast, with some mixing of the stocks off southeastern Florida during winter months.

These conclusions were the primary basis for the division of the Gulf of Mexico (Gulf) and Atlantic king mackerel stocks, as defined by Amendment 1 to the CPFMP (Gulf of Mexico and South Atlantic Fishery Management Councils, 1985). Variable stock boundaries are used as part of the management strategy. The Gulf group is separated from the Atlantic group 1 April–31 October at the Collier/Monroe County line in southwest Florida and 1 November–31 March at the Flagler/Volusia County line in northeast Florida (Fig. 2). The area between the Collier/Monroe County line and the Flagler/Volusia County line in Florida is considered to be a mixing area for the Gulf and Atlantic migratory groups and is referred to within this text as the "mix-

H. Charles Schaefer is with the Statistics Office, Coastal Resources Division, Southeast Fisheries Science Center, National Marine Fisheries Service, NOAA, 19100 S.E. Federal Hwy., Tequesta, FL 33469. William A. Fable, Jr., is with the Panama City Laboratory, Southeast Fisheries Science Center, National Marine Fisheries Service, NOAA, 3500 Delwood Beach Road, Panama City, FL 32408.

ABSTRACT—King mackerel, Scomberomorus cavalla, *were tagged and released from eastern Florida between 1985 and 1993. Recapture trends from these studies indicate an increase in tag returns from areas north of the release sites, along with a decrease in recaptures from coastal waters in the Florida Keys and Gulf of Mexico, since earlier king mackerel tagging studies completed in the late 1970's. The data indicate that eastern Florida waters may maintain resident king mackerel. Cyclical tag return patterns were noted along eastern Florida and in North Carolina. The proportion of mixing of presently defined king mackerel stocks along eastern Florida may vary yearly. Comparison of king mackerel tags show internal anchor tags to have a higher percentage of return and lower percentage of tag loss than dorsal dart tags.*

[1] Godcharles, M. F. 1993. Synoptic history of Federal management of king and Spanish mackerel and other coastal migratory pelagic species in the Gulf of Mexico and South Atlantic. Southeast Regional Office, National Marine Fisheries Service, NOAA, St. Petersburg, Fla. Unpubl. rep., 8 p.

[2] NMFS. 1994. 1994 report of the mackerel stock assessment panel. Southeast Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Contrib. MIA-93/94-42, 27 p.

[3] Williams, R. O., and M. F. Godcharles. 1984. King mackerel tagging and stock assessment. Fla. Dep. Nat. Resour., Project 2-341-R, Completion rep. (unpubl.), 45 p.

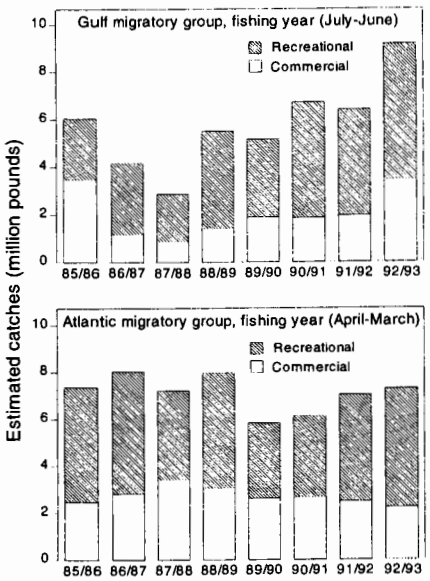

Figure 1.—Estimated catches of king mackerel from the Gulf and Atlantic stocks by fishing year (FY). Source: NMFS (1994).

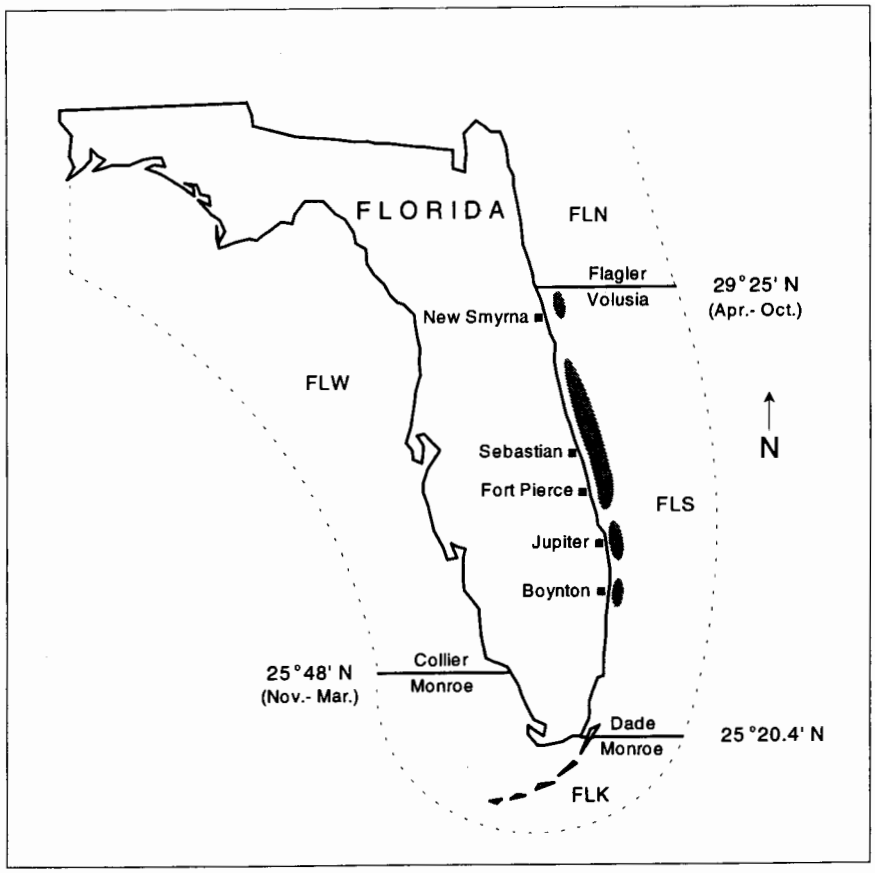

Figure 2.—NMFS tagging locations (shaded), variable Atlantic/Gulf stock boundaries, and subareas used to partition Florida tag returns.

ing zone." For management purposes, the commercial sector of the Gulf group is partitioned into the eastern (Florida) and western (Alabama to Texas) zones. Annual quota allocations and bag limits are enforced for each migratory group in accordance with the fishing year (FY). The Gulf group FY is defined as 1 July–30 June and the Atlantic group FY as 1 April-31 March.

In 1983, the NMFS began additional scientific mark-recapture work to further evaluate movement patterns of king mackerel within Gulf of Mexico and Atlantic waters. Since then, tagging studies have been conducted off Mexico, Texas, Louisiana, northwest and eastern Florida, and North Carolina. The primary objective of tagging along Florida's east coast was to better understand mixing patterns of king mackerel from the eastern Gulf group and the Atlantic group. This paper summarizes the current results of the NMFS mark-recapture work from 1985 through 1993 along eastern Florida.

Methods

For continuity, earlier king mackerel tagging studies (1975–79) by the state of Florida and NMFS are referred to as FDEP tagging. The tagging methods and techniques for procurement of fish follow the original procedures developed during the FDEP study. Although only internal anchor (IA) tags were used for the earlier FDEP tagging (Sutter et al., 1991), the NMFS has experimented with four different types of king mackerel tags from 1985 through 1993 (Fig. 3). Single red or orange plastic IA tags, similar to those used during the FDEP study, were used during 1985–88. Orange shrink-lock internal anchor (SLA) tags were tested along with IA tags during winter 1989–90 tagging. Yellow double-barb dorsal dart tags (DD92) were used in combination with IA and SLA tags during 1991–92 tagging. The following winter (1992–93), a new version of the dorsal dart tag (DD93) was tested along with IA tags. All tags included an identification number and return address or phone number printed on the streamer. IA and SLA tags also included the tag number printed on the disk portion.

During all of the tagging studies described, commercial handline fishermen were contracted to catch king mackerel for tagging. These fishermen were compensated for successfully tagged and released fish based on the total weight of marked releases during each trip, as calculated using a weight to length conversion table. Although this method of procurement proved costly, large numbers of relatively unharmed fish were usually available for tagging, and accurate information on releases could be obtained by NMFS personnel (Fable, 1990).

King mackerel were caught using commercial troll gear. Fish were immediately unhooked aboard the vessel and

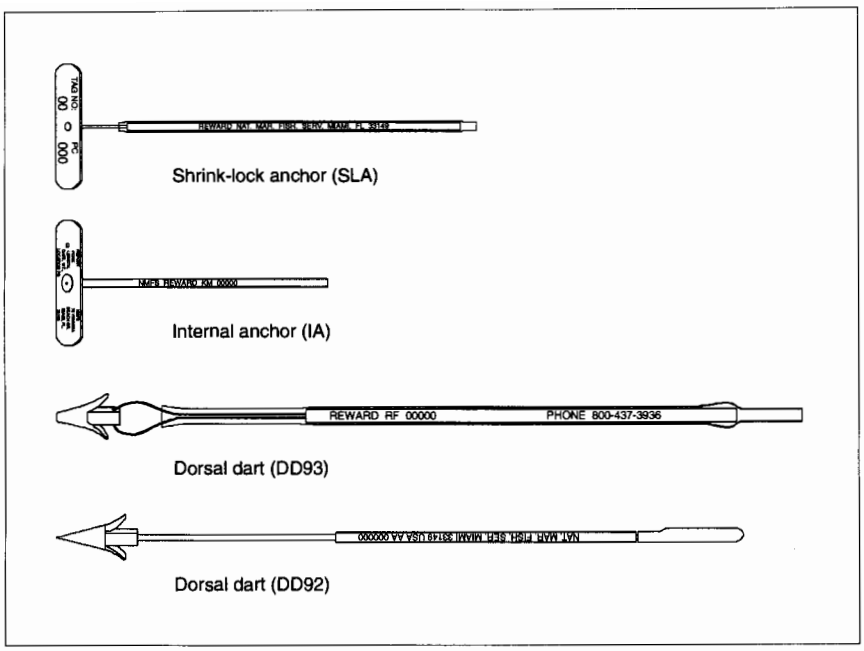

Figure 3.—Types of king mackerel tags used by NMFS during 1985–93.

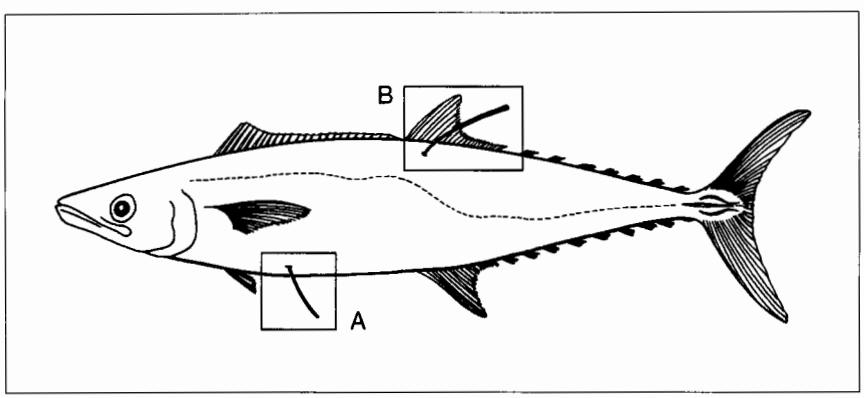

Figure 4.—Placement of internal anchor (IA and SLA) tags (A) and dorsal dart (DD92 and DD93) tags (B).

placed ventral side up in a V-shaped trough. Prior to 1991, IA tags were inserted with forceps into the abdominal cavity through a 6–10 mm slit made with a scalpel. During 1991–92 and 1992–93 tagging, IA and SLA tags were inserted using a stainless steel insertion tool designed by the NMFS Panama City Laboratory. With both methods, the disk portion of the tag remained inside the abdominal cavity, and the plastic streamer protruded externally (Fig. 4). Double-barbed dart tags were inserted beside the dorsal fin into the musculature using a short-handled insertion needle. Immediately after tagging and measurement, presumed healthy fish were released over the side of the boat. Information recorded for each released fish included tag numbers, fork length, month-day-year, latitude-longitude, and condition of fish. Release information was ultimately entered into a release and recapture database, currently managed by the NMFS Cooperative Gamefish Tagging Program, Miami.

Initially, to publicize the king mackerel tagging program and to reward anglers for returning tags, posters and news releases were circulated, and a $10 reward was offered for each returned tag. In 1986, to help increase the tag returns, an annual $1,000 drawing, sponsored by NMFS, was added to the reward program. In 1991, the individual reward was increased to $20 per fish.

Release and recapture data for the described studies (10,285 releases, 546 returns) were compiled from the NMFS Panama City Laboratory tagging records and the NMFS Cooperative Gamefish Tagging Program database. Six separate tagging experiments, conducted by the NMFS from 1985 through 1993, are described here. Table 1 lists the locations, dates, and release numbers during each experiment. No tagging was performed during winter 1990–91. The number of fish released during these studies (10,285) is comparable to the number released in eastern Florida during the 1970's FDEP study (10,120).

To describe movement patterns, releases were grouped into three spatial/temporal regions. Recaptures were grouped into the geographical location of recovery, taking into account the present management strategy. Returns from outside of Florida were partitioned into the state of recapture. Due to its expansive coast line and the high proportion of returns, Florida was divided into four subareas: Collier/Monroe County line to Alabama (FLW), Collier/Monroe County line to Dade/Monroe County line (FLK), Dade/Monroe County line to Flagler/Volusia County line (FLS), and Flagler/Volusia County line to Florida/Georgia border (FLN) (Fig. 2).

Recaptures were also grouped according to the ocean of recovery, using the Gulf of Mexico and Atlantic Ocean, as defined by the Supreme Court decision, United States v. Florida, October term 1975. No adjustments were made for possible factors affecting tag return rates. Temporal relationships were described by grouping recaptures by season and area of recapture in relation to time of freedom. Seasons are divided as 3-month periods: winter is defined

as December, January, and February; spring as March, April, and May; summer as June, July, and August; and fall as September, October, and November. One recapture from the 1987 tagging study, returned from a New York fish market, was not included for movement analysis.

Results

The mean fork length (FL) varied for each study with the largest fish tagged during the 1985–86 and 1987 studies (Table 1). Fish tagged during winter in southeast Florida (1988–93) averaged largest at the beginning of the winter for each study. Length frequency histograms, comparing percentages of releases to recaptures (5 cm grouping) show that a larger percentage of fish were released than were recaptured in smaller size groupings (<65 cm FL) (Fig. 5). This is most evident in the histogram developed from 1991–92 tagging.

The largest percentage of returns occurred within the first year following release for all studies with decreasing returns during each year thereafter (Table 2). The overall return rate from these studies is thus far 5.3%. Time at large varied from 0 to 2,261 days, averaging 360 days. Returns from the western zone of the Gulf of Mexico indicated the farthest distance traveled away from the point of release. All of the fish recaptured in Texas (3) were estimated to have traveled over 2,000 km. The most distant Atlantic recapture (1,430 km) was recovered from Virginia Beach, Va. Interestingly, 37.9% (207) of all recaptures were recovered within 50 km of tagging with 37.2% (77) of these at large for more than 1 year. Of the 248 fish recaptured more than 100 km away from the point of tagging, 63.3% were recovered from north of the tagging location. There was no observed relation between size and distance traveled. Due to spatial/temporal variations in tagging regions, recapture results of these studies are treated separately. Results from winter 1988–93 tagging in southeast Florida are treated both separately and combined, since tagging occurred within the same spatial/temporal area.

Table 1.—Summary of size distribution of king mackerel releases.

Tagging Study						
Years	Months	Location	No. tagged	Mean FL (mm)	S.E.	Size range FL (mm)
1985–86	Dec., Jan.	New Smyrna	891	872	10.9	540–1,180
1987	April, May	Jupiter	719	891	10.2	670–1,270
	April, May	Boynton	284	871	8.7	600–1,200
		Combined	1,003	885	9.7	600–1,270
1988–89	Dec.	Sebastian	599	879	7.9	525–1,450
	Jan.–March	Ft. Pierce	1,228	731	7.5	460–1,175
	March, April	Boynton	216	729	7.4	510–980
		Combined	2,043	774	6.1	460–1,450
1989–90	Dec.	Sebastian	288	744	6.6	540–1,160
	Jan.–March	Ft. Pierce	1,763	697	5.9	435–1,200
	April	Boynton	3	630	12.9	570–690
		Combined	2,054	703	6.0	435–1,200
1991–92	Dec., Jan., March	Sebastian	740	763	7.3	420–1,190
	Feb.	Ft. Pierce	638	672	8.0	480–1,120
	March	Jupiter	838	613	7.9	410–1,130
		Combined	2,216	680	6.2	410–1,190
1992–93	Dec., Jan.	Sebastian	296	854	6.9	560–1,370
	Feb., March	Jupiter	1,729	763	7.5	480–1,220
	March	Ft. Pierce	53	716	12.3	590–880
		Combined	2,078	775	7.1	480–1,370

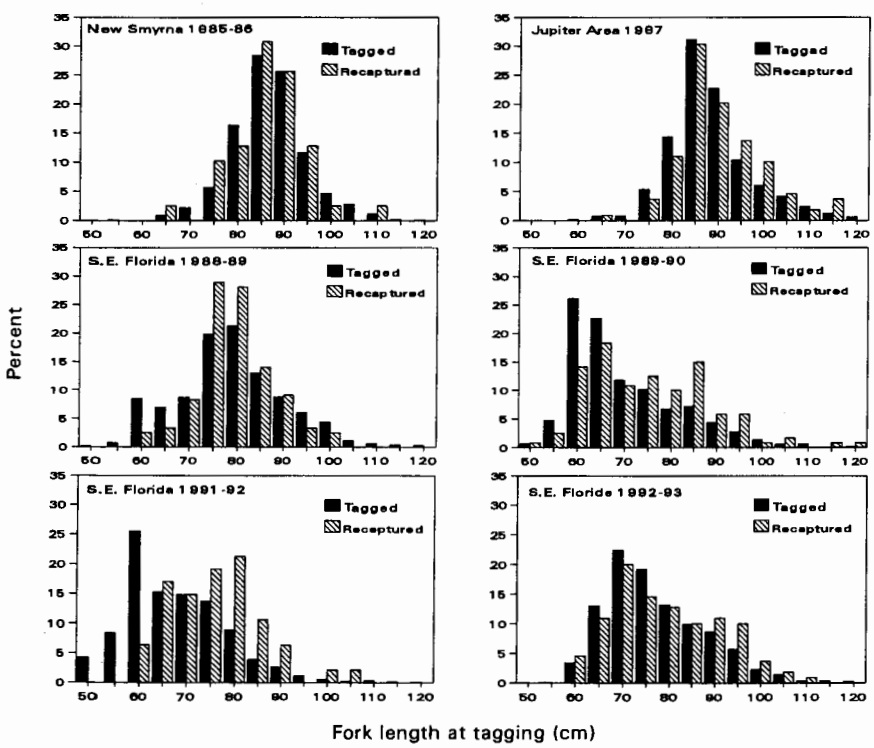

Figure 5.—Length frequency distribution of releases and returns from 1985-93 king mackerel tagging (5 cm groupings).

Table 2.—Number of receptures per 12-month period following release.

Tagging period	Days from release to recapture 0–365	366–730	731–1,095	1,096–1,460	1,461–1,825	1,826–2,190	2,191–2,555	Percent return
1985–86	18	12	6		3			4.0
1987	53	34	10	5	6	1		10.9
1988–89	87	20	7	5	1		1	5.9
1989–90	60	43	13	3	1			5.8
1991–92	35	8	4					2.1
1992–93	82	27	1					5.3
Totals	335	144	41	13	11	1	1	5.3

Winter Tagging 1985–86, New Smyrna Beach Area

Most of the recaptures (38) from fish tagged during winter in the New Smyrna Beach area (891 releases, 39 returns) were found along eastern Florida (Fig. 6, Table 3). One fish was recovered from the Gulf of Mexico off Louisiana in October 1987. All recoveries from north of the tagging area occurred summer through fall, while the majority of recoveries from south of the tagging area were concentrated during winter and spring months in southeast Florida. Results indicate that this group of fish may have been primarily residential (nonmigratory) off eastern Florida. The lack of tagging within this region during the FDEP study does not allow comparison of these results to those of 1970's tagging.

Spring Tagging 1987, Jupiter Area

Recaptures from April and May tagging in the Jupiter area (1,003 releases, 109 returns) ranged along the Atlantic coast from Virginia to the Florida Keys (Fig. 7). Outside of Florida, the majority of the recoveries (19) were from North Carolina in the fall. Only one tag was returned from the Gulf of Mexico—in the fall off Panama City, Fla. Temporal return patterns show the highest number of recaptures in southeast Florida during spring for four consecutive years following the tagging, as well as recurrent returns in North Carolina in the fall for more than four years following tagging (Table 4). Thirty percent of returns (33) from this study were fish at large for more than 1 year and recaptured within a 50 km radius of release. A comparison of these results to those of the FDEP study show a marked decrease in the number of Gulf of Mexico and Florida Keys returns along with an increase in southeast U.S. Atlantic coast returns (Table 6).

Winter Tagging 1988–93, Southeast Florida

From 1988–93 the NMFS tagged 8,391 king mackerel in the same region in southeast Florida during four winters (Table 1). Recaptures from 1988–89 tagging (2,043 releases, 121 returns) show extensive movements (Fig. 8). Atlantic Ocean returns ranged from North Carolina to the Florida Keys. Gulf of Mexico returns (7) ranged from western Florida to Texas, and occurred in late spring to early fall. Recaptures from north of the Flagler/Volusia border (15) occurred in the spring and summer months. Recaptures within southeastern Florida occurred during all months of the year, but were concentrated during the winter in the Cape Canaveral to Fort Pierce area and during May in the Jupiter to Palm Beach area. Fish tagged during mid-winter off Fort Pierce showed the most movement, accounting for five of the seven Gulf returns and all of the five Atlantic returns north of Florida.

Recaptures from 1989–90 tagging (Fig. 9) show fewer Gulf of Mexico returns (5) than from the previous study coupled with more returns from areas north of the Volusia/Flagler border (29) (Table 3). Fish tagged in mid-winter off Fort Pierce again showed the strongest tendency to move, providing all of the Gulf of Mexico returns and 11 returns from north of Florida. Returns from north of the tagging area were concentrated from spring through fall. Southeast Florida returns occurred year-round with the highest number during winter off the Cape Canaveral to Fort Pierce area.

Movement, as indicated by the distribution of tag returns from 1991–92

Table 3.—Distribution of king mackerel tag returns.

Recapture location	Tagging period 1985-1986	1987	1988-1989	1989-1990	1991-1992	1992-1993	All years
Virginia		1			1		2
N. Carolina		19	2	7	3	2	33
S. Carolina		2	2	6	1	2	13
Georgia		2	1	2		3	8
Florida[1]							
FLN[1]	11	5	10	14	3	13	56
FLS	27	74	94	84	38	88	405
FLK		4	5	2		2	13
FLW		1	4	4			9
Alabama					1		1
Louisiana	1		1				2
Texas			2	1			3
Unknown		1					1
Totals	39	109	121	120	47	110	546

[1] See Figure 1 and text for description of Florida subareas.

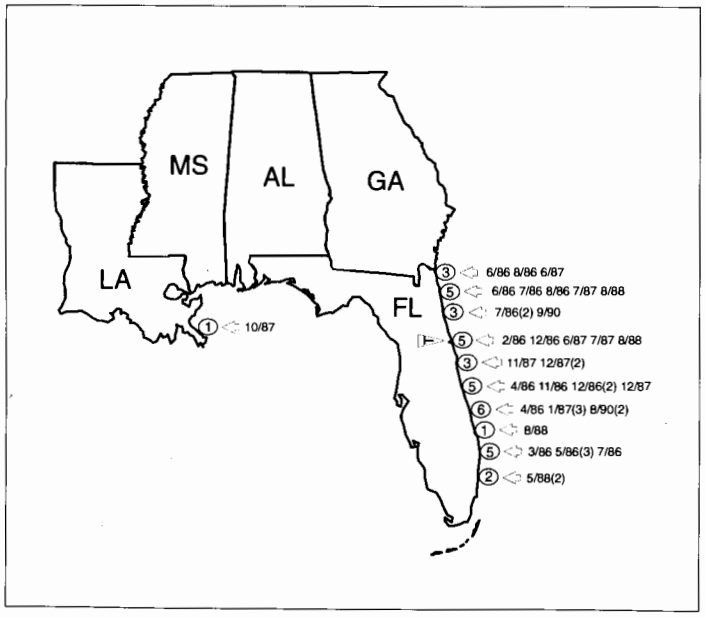

Figure 6.—Location and month/year of tag returns from 1985–86 tagging in the New Smyrna Beach, Fla., area.

tagging (2,216 releases, 47 returns), was restricted primarily to the Atlantic coast (Fig. 10, Table 3). Tag recoveries ranged along the Atlantic coast from Virginia to Miami, Fla. No tags were returned from the Florida Keys, but one tag was returned from the Gulf of Mexico off of Fort Morgan, Alabama. Recapture trends show northward movement in the spring and summer of 1992 and recurring recaptures in southeast Florida the following two winters.

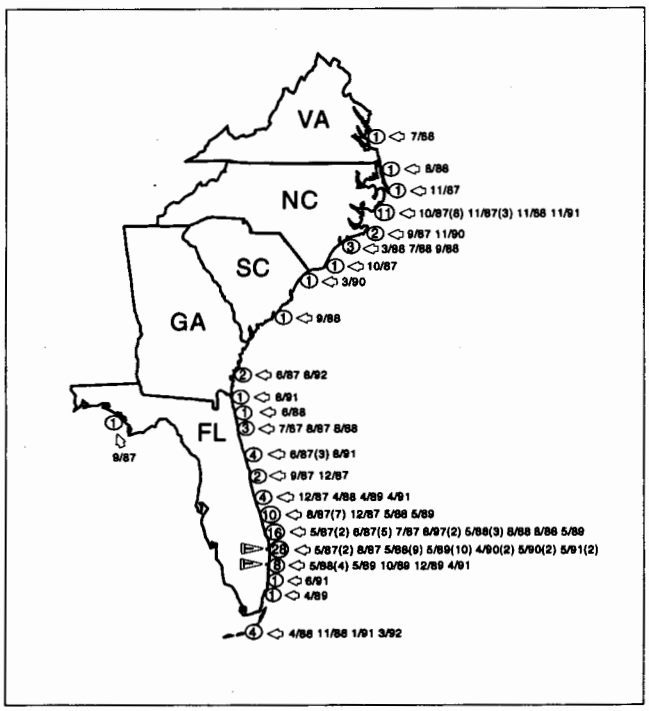

Figure 7.—Location and month/year of tag returns from 1987 tagging in the Jupiter, Fla., area.

Table 4.—Number of returns from Jupiter 1987 tagging by recapture location, days at large, and season of recapture.

Release to return (days)	Season of recovery[2]	Recapture location[1]							
		Florida							
		FLW	FLK	FLS	FLN	GA	SC	NC	VA
0–365	Winter			3					
	Spring		1	12				1	
	Summer			19	2	1			
	Fall	1		1				12	
366–730	Winter								
	Spring			22					
	Summer			2	2			2	1
	Fall		1				1	2	
731–1,095	Winter			1					
	Spring			7			1		
	Summer								
	Fall			1					
1,096–1,460	Winter		1						
	Spring			3					
	Summer								
	Fall							1	
>1,460	Winter								
	Spring		1	1					
	Summer			2	1	1			
	Fall							1	

[1] States outside of Florida are abbreviated; see Figure 1 and text for description of Florida subareas.
[2] Seasons are divided as 3-month periods (i.e. winter is Dec., Jan., Feb.).

Table 5.—Number of returns from 1988-93 tagging in southeast Florida by recapture location days at large and season of recapture.

Release to return (days)	Season of recovery[2]	Recapture location[1]										
					Florida							
		TX	LA	AL	FLW	FLK	FLS	FLN	GA	SC	NC	VA
0–365	Winter					1	51					
	Spring				2	3	121	4	1	1		
	Summer	1			3	1	20	21	3	3	4	1
	Fall		1				19	1		1	1	
366–730	Winter					2	15			1	1	
	Spring				1		25	3		3	1	
	Summer				2	1	17	9			2	
	Fall	1					8		1	2	3	
731–1,095	Winter						6					
	Spring					1	9					
	Summer	1		1			1	1			1	
	Fall						4					
1,096–1,460	Winter						1					
	Spring						4					
	Summer							1	1		1	
	Fall											
>1,460	Winter						2					
	Spring											
	Summer						1					
	Fall											

[1] States outside of Florida are abbreviated; see Figure 1 and text for description of Florida subarea.
[2] Seasons are divided as 3-month periods (i.e., winter is Dec., Jan., Feb.).

Recaptures from 1992–93 tagging (2,078 releases, 110 returns) are thus far confined to the Atlantic coast (Fig. 11). Seven fish were recovered north of Florida during spring through fall. Fish tagged later in the winter in Jupiter accounted for five of these seven returns and for the two returns from the Florida Keys. No fish have yet been recaptured in the Gulf of Mexico.

Combined results from winter tagging 1988–93 (8,391 tagged, 398 returns) show distinct differences from earlier FDEP tagging (Table 6). Williams and Godcharles[3] reported that migrating king mackerel tagged in the winter off southeast Florida moved principally into the Gulf of Mexico during the summer. More recent NMFS tagging indicates that only 3.3% (13) of all recaptures occurred north of the Collier/Monroe County line in the Gulf of Mexico, while 18.1% (72) were from north of the Volusia/Flagler County line in the Atlantic. Returns from within the Florida mixing zone (313) occurred nearly exclusively within the Atlantic Ocean. One fish was recaptured from Gulf of Mexico waters near Summerland Key. Thus, only 3.5% (14) of returns actually occurred within the Gulf of Mexico. There has been only one return as of yet from the Gulf of Mexico from the 1991–1993 tagging (4,294 releases, 157 returns) in southeast Florida.

Recaptures from southeast Florida occurred during all months of the year (Table 7). The number of recaptures occurring there from November through March (140) was actually smaller than those occurring from April through October (164). Seasonal grouping of returns from 1988–93 tagging show that although most tag recoveries during the winter and spring were in southeast Florida, by summer 49.5% of recoveries were from areas north of the Flagler/Volusia County line. Summer returns

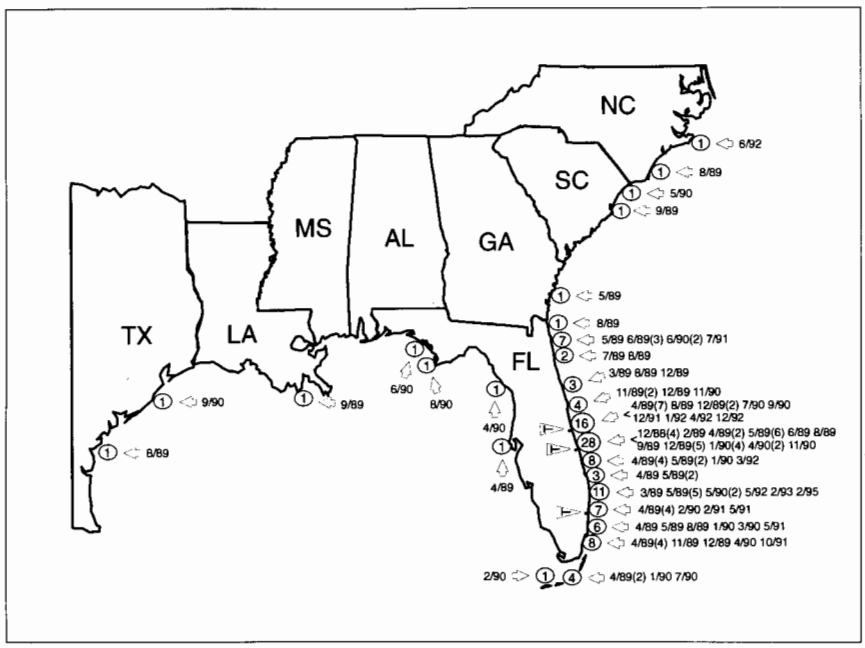

Figure 8.—Location and month/year of tag returns from 1988-89 southeast Florida tagging.

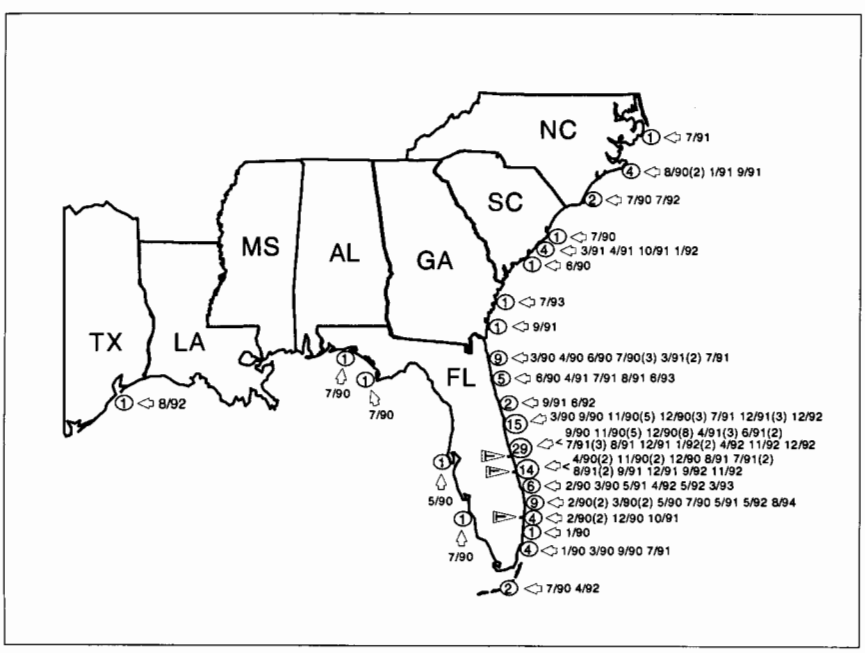

Figure 9.—Location and month/year of tag returns from 1989-90 southeast Florida tagging.

Table 6.—Comparison of NMFS tagging to earlier FDEP tagging showing the number of releases in parentheses.

	Jupiter area (May–June tagging)		S.E. Florida area (Dec.–April tagging)	
Recapture location	FDEP 1975–78 (2,674[1])	NMFS 1987 (1,003[1])	FDEP 1975–78 (6,500[1])	NMFS 1988–93 (8,391[1])
Virginia	2	1		1
N. Carolina	6	19	4	14
S. Carolina	5	2	1	11
Georgia	1	2	1	6
Florida[1]				
FLN	8	5	6	40
FLS	146	74	436	304
FLK	30	4	45	9
FLW	2	1	36	8
Alabama			4	1
Louisiana	1		3	1
Texas	5		16	3
Unknown	1	1	1	
Totals	207	109	553	398

[1] Number of releases.
[2] See Figure 1 and text for description of Florida subareas.

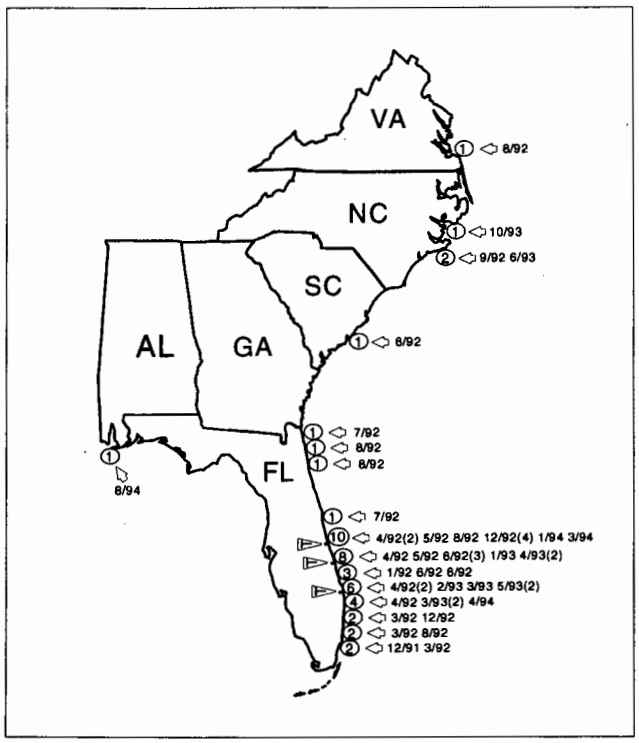

Figure 10.—Location and month/year of tag returns from 1991–92 southeast Florida tagging.

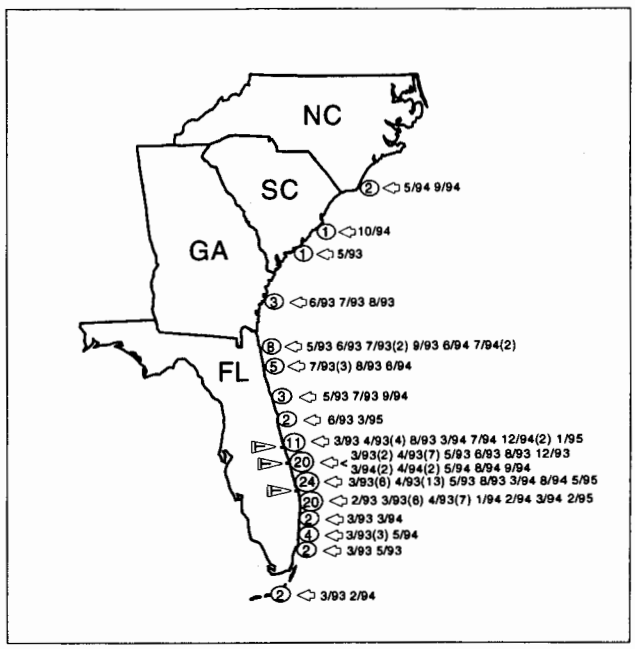

Figure 11.—Location and month/year of tag returns from 1992-93 southeast Florida tagging.

also included the highest number from the Gulf of Mexico (8) and from the Atlantic north of Florida (16). Fall returns, the lowest of any season, were concentrated along the Atlantic coast with the highest number of returns in southeast Florida. Temporal patterns show repeated returns in North Carolina in the summer and fall (Table 5). Recaptures from northeast Florida also showed a pattern of repeated returns in spring and summer.

Tag Comparisons

During the first three tagging studies (1985–86, 1987, 1988–89), all fish were single-tagged using IA tags (4.0–10.9% return). Results of 1989–90 tagging show that there were no appreciable differences in return rates (5.6–6.1%) from all of the four tag combinations of SLA and IA tags tested (Table 8). Tag loss was lower for SLA tags (16.0-22.5%) than IA tags (30.0%). During winter 1991-92 tagging, IA, SLA, and DD92 tags showed varying return rates per combination (0.5-5.3%). DD92 tags had a higher calculated tag loss (50.0-57.1%) than SLA (0%) or IA tags (10.7%). Tagging in 1992-93, which involved testing a new type of dorsal dart tag (DD93) along with IA tags also, showed varying rates of return per combination (0-7.1%). DD93 tags showed a much higher tag loss (54.4%) than IA tags (12.3%).

Early recaptures from 1992-93 tagging provided a clue to problems associated with the DD93 tag. Several double–tagged fish were recaptured with both tags intact, but with a large open wound slanting posteriorly from the DD93 tag (Fig. 12). We believe that vibrations of the streamer against the soft dorsal skin and tissue were progressively creating a larger hole surrounding the tag. Constant motion of the fish

Table 7.—Number of returns from 1988-93 tagging in southeast Florida by recapture location and season and month of recovery.

Recapture location	Winter			Spring			Summer			Fall		
	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.
Virginia									1			
N. Carolina		1				1	2	3	3	3	1	
S. Carolina		1		1	1	2	1	1	1	1	2	
Georgia						1	1	2	1	1		
Florida												
FLN[1]				3	2	2	12	15	5	1		
FLS	45	16	14	46	76	37	11	12	16	10	2	19
FLK		1	2	1	3			2				
FLW					2	1	1	3	1			
Louisiana										1		
Alabama									1			
Texas									2	1		
Totals	45	19	16	51	84	44	28	38	31	18	5	19

[1] See Figure 1 and text for description of Florida subareas.

and streamer of the DD93 tag would probably not allow such a wound to heal before the tag fell out. Supporting this theory, several other double-tagged fish were recaptured with the DD93 tag missing and a gaping wound where it had been inserted.

These experiments indicate a higher tag loss from both DD92 and DD93 tags than either SLA or IA tags. Double-tagged fish with one dorsal dart tag and one internal anchor tag also showed a lower percentage of return than those fish single- or double-tagged using only internal anchor tags, especially for smaller fish (<700 mm FL).

Discussion

The actual mechanisms of king mackerel migration are not well known. The highly pelagic nature of this species is evidenced by the range of recaptures from these studies (from Texas to Virginia). Recaptures from the Gulf of Mexico suggest that there has been at least limited migration from southeast Florida, beyond the Collier/Monroe County line, to both the eastern (9 returns) and western (6 returns) zones of the Gulf of Mexico. The percentage of cross mixing of king mackerel populations (i.e. fish that are spawned in the Atlantic Ocean and later travel to the Gulf of Mexico) has yet to be documented.

Important factors such as differential fishing mortality rates, variable tag reporting rates, fishery closures, and changes in fishing patterns have not been weighted for in this study. Differences in reporting rates of tagged fish most likely occur between different localities and among different resource users. The familiarity of fishermen in southeast Florida with the NMFS tagging program has undoubtedly contributed to the high return rate recorded there. Florida's east coast also supports intensive year-round king mackerel fishing, unlike certain areas in the Gulf of Mexico and north of Florida. The implementation of the CPFMP in 1983 did not affect the recoveries from earlier FDEP tagging, but has undoubtedly affected tag recoveries since the onset of recent NMFS tagging.

From 1987 through 1993 the commercial and recreational fisheries for Gulf migratory group king mackerel were closed for varying periods in the winter and spring, thereby eliminating tag recoveries which would have occurred both within south Florida and the Gulf of Mexico. Due to the complexity of interactions affecting tag returns and the relatively large area encompassed by these studies, no adjustments were attempted for these differences or their

Table 8.—Summary information on king mackerel releases by tag type showing percentage of tag loss in parentheses.

Tagging period	Tag combinations	Release No.	Release Mean FL(mm)	Return N	Return %	Tags not recovered
1985–86	1 IA	891	872	39	4.0	
1987	1 IA	1,003	885	109	10.9	
1988–89	1 IA	2,043	774	121	5.9	
1989–90	1 IA	33	636	2	6.1	
	1 SLA	510	697	31	6.1	
	1 IA + 1 SLA	675	698	40	5.9	12 IA(30.0%) 9 SLA(22.5%)
	2 SLA	836	714	47	5.6	15 SLA(16.0%)
1991–92	1 IA	287	673	2	0.1	
	1 SLA	188	690	10	5.3	
	1 DD92	197	616	1	0.5	
	1 SLA + 1 DD92	387	661	6	1.6	3 DD92(50.0%)
	1 IA + 1 DD92	1,157	698	28	2.4	3 IA(10.7%) 16 DD92(57.1%)
1992–93	1 IA	749	745	53	7.1	
	1 DD93	28	740			
	1 IA + 1 DD93	1,301	793	57	4.4	7 IA(12.3%) 31 DD93(54.4%)

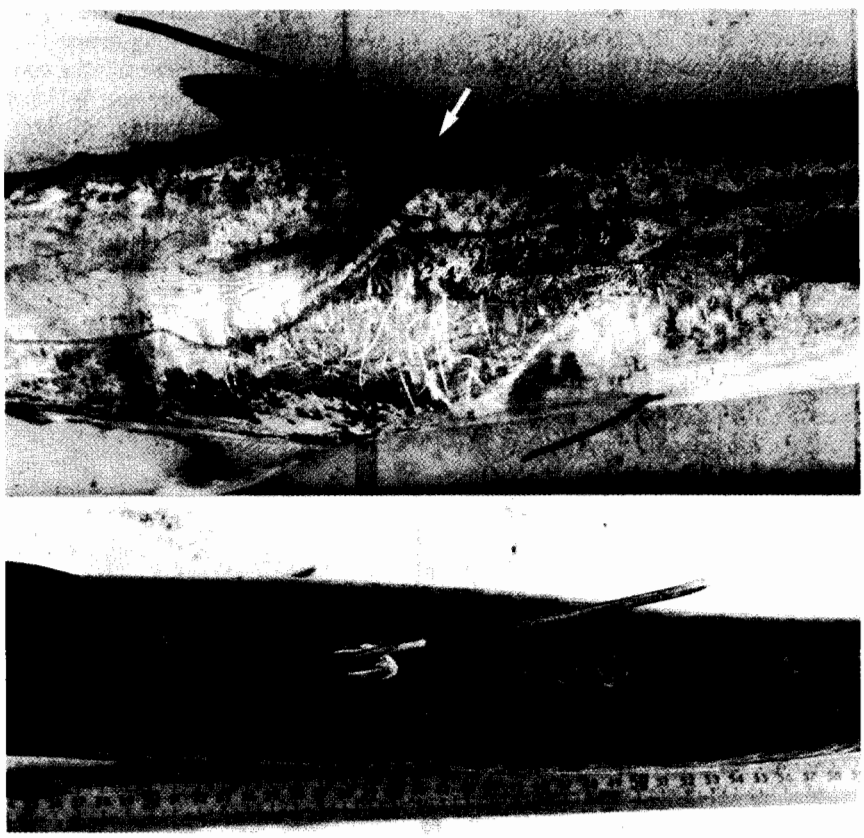

Figure 12.—King mackerel recaptured 60 days following tagging, showing a large wound surrounding the dorsal DD93 tag.

effects on results of this research. All results and conclusions within this text are based solely on the most current NMFS return data.

Sutter et al. (1991) estimated that seasonal overlap between the Gulf and Atlantic stocks off southeastern Florida in the late 1970's was 29.4-41.8%. These estimates were based upon the present management strategy, which classifies all king mackerel off southeast Florida in the winter (1 November–31 March) as eastern Gulf migratory group. Preliminary results of these NMFS studies continue to support the theory of separate Gulf of Mexico and Atlantic king mackerel stocks, but may indicate less mixing of these two groups along Florida's east coast than previously theorized.

Returns from the NMFS tagging studies along eastern Florida, which are likely to increase in the future (Table 2), suggest that only a small percentage of king mackerel tagged in the southern Atlantic from winter through early summer migrated into the Gulf of Mexico. This decrease in Gulf of Mexico recaptures, coupled with an increase in recaptures from north of southeast Florida, could be indicative of an alteration of migration patterns since completion of the FDEP tagging 15 years ago. It may be that as the Gulf group decreased in biomass in the early 1980's the number of fish migrating from the Gulf of Mexico to southeast Florida in the winter also decreased. This may have decreased the size of the winter population off southeast Florida, thereby causing the Atlantic stock to occupy a greater percentage of that population. Differential fishing mortality rates and changes in fishing patterns since the FDEP study may be other explanations for differences between the two studies. Environmental and biological parameters, such as water temperatures, storms, and the abundance of food may also influence annual migration patterns.

A brief overview of the entire NMFS Cooperative Gamefish Tagging Program king mackerel release and recapture database 1985-1993 (20,393 releases, 994 returns) indicates that only two fish from outside of these studies were released in the Atlantic and recaptured in the Gulf of Mexico, along with seventeen fish that were tagged in the Gulf of Mexico and recaptured in the Atlantic. This low transfer of tagged fish between these two areas, as indicated by recaptures, concurs with the results of these studies. Releases and recaptures within the Florida Keys region were sorted by latitude and longitude to establish Gulf of Mexico or Atlantic Ocean status.

When recaptures are grouped according to current stock boundaries (Fig. 13), the percentage of returns classified as Gulf group is inflated by the large number of winter returns from southeast Florida. If this area is actually no longer a major mixing area for stocks from the Gulf of Mexico and the Atlantic Ocean, as suggested by recent tagging, the majority of these returns may actually be Atlantic group fish. We thus decline to offer a percentage of stock mixing off southeastern Florida based on current variable stock boundaries.

Tagging results also indicate the possibility of a nonmigratory (resident) eastern Florida group, which moves seasonally along the Florida east coast. Winter tagging studies showed year-round recaptures within southeast Florida with a larger percentage occurring during summer months. Sutter et al. (1991) also noted indications of a resident population in southeast Florida during earlier FDEP tagging. Temporal patterns from 1987 and 1988–93 tagging show that the highest number of returns within southeast Florida occurred during the same season as tagging regardless of time at large, implying that there is a regrouping of some of the same fish each winter and spring in southeast Florida (Tables 4, 5).

In conclusion, long-distance migration of winter fish away from southeast Florida seems to start in early spring with a small percentage of fish moving into the Gulf of Mexico by summer and a larger percentage moving northward in the Atlantic, as far as Virginia, by summer and fall. Spring and early summer tagging in the Jupiter, Fla., area showed that long-distance migrating fish moved predominately northward

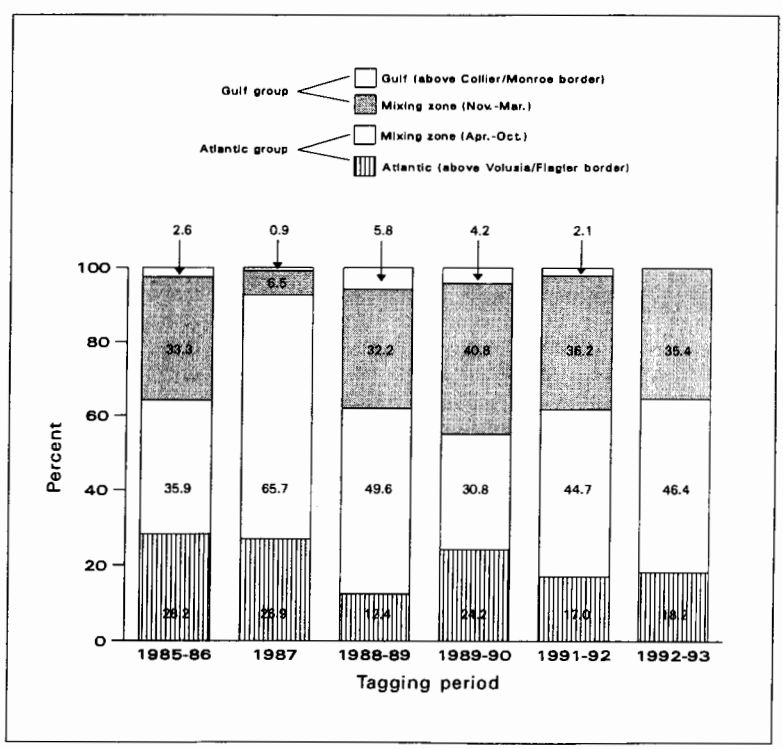

Figure 13.—Percentage of recaptures within present management zones.

during the first few months following tagging, reaching North Carolina by fall (Table 4). The large number of returns from North Carolina from both winter and spring tagging in southeastern Florida suggests that there may be substantial migration between these two areas.

Movement of king mackerel from North Carolina to southeast Florida has been documented by the North Carolina Division of Marine Fisheries. Noble et al.[4] reported that the state of North Carolina tagged and released king mackerel off the central and northern coast of North Carolina (4,364 releases, 86 returns) from 1985 through 1990. The majority of recaptures from south of North Carolina occurred in southeast Florida (15), all in an area from Fort Pierce to Pompano Beach. Seven of these Florida returns were from fish tagged in the early winter in North Carolina and recaptured in the Jupiter area in April and May.

Southeast Florida remains an active fishing area for king mackerel. Results of these studies indicate that the proportion of mixing of presently defined stocks during winter in this area may vary yearly. Mark-recapture work has helped to define migration patterns, but there are many variables affecting tag returns.

Recent electrophoretic variation research has identified limited genetic variation of king mackerel in U.S. waters. Fish samples taken from the western zone of the Gulf of Mexico showed genetic variation from fish samples taken in the Atlantic, but fish captured off western Florida in the Gulf of Mexico are thus far genetically indistinguishable from those found in the southeastern Atlantic (Johnson et al., 1994; NMFS[2]). Research to better define king mackerel populations is underway, and it includes mitochondria DNA analysis by Texas A&M University and a multivariate statistical procedure based upon otolith shape being tested by NMFS. The NMFS has continued mark-recapture of king mackerel in southeast Florida during the winters of 1993-94 (495 releases) and 1994-95 (952 releases). Results of this recent tagging are still preliminary, but do not yet include any recaptures from the Gulf of Mexico.

[4] Noble, E. B, L. P. Mercer, and R. W. Gregory. 1992. Migration, age and growth, and reproductive biology of king mackerel (*Scomberomorus cavalla*) in North Carolina. N.C. Div. Mar. Fish., Mar. Fish. Completion Rep. Proj. F-29, Study 1, 74 p.

Acknowledgments

We thank those directly related to the success of these studies, including contracted commercial fishermen and the many NMFS personnel who helped with fish tagging. We also thank all of those at the NMFS Southeast Fisheries Science Center in Miami who helped with this project, including N. Thompson, G. Davenport, and N. Parrack for editorial assistance, along with A. Martinez and J. Javech for help with several figures used, and the NMFS Cooperative Gamefish Tagging Program. Partial funding for this research was provided by grants from MARFIN.

Literature Cited

Fable, W. A., Jr. 1990. Summary of king mackerel tagging in the southeastern USA: mark-recapture techniques and factors influencing tag returns. Am. Fish. Soc. Symp. 7:161–167.

Gulf of Mexico and South Atlantic Fishery Management Councils. 1985. Final amendment 1, fishery management plan and environmental impact statement for coastal migratory pelagic resources (mackerels) in the Gulf of Mexico and South Atlantic region. Gulf Mex. Fish. Manage. Counc., Tampa, Fla., var. pagin.

Johnson, A. G., W. A. Fable, Jr., C. B. Grimes, and L. Trent. 1994. Evidence for distinct stocks of king mackerel, *Scomberomorus cavalla*, in the Gulf of Mexico. Fish. Bull. 92(1):91–101.

Moe, M. A., Jr. 1963. A survey of offshore fishing in Florida. Fla. State Board Conserv., Prof. Pap. Ser. 4, 117 p.

NMFS. 1992. Marine recreational fishery statistics survey, Atlantic and Gulf coasts, 1990–1991. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Curr. Fish. Stat. 9204, 275 p.

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. U.S. Dep. Commer., NOAA Tech. Memo NMFS-SEFC-12, 18 p.

Sutter, F. C., III, R. O. Williams, and M. F. Godcharles. 1991. Movement patterns and stock affinities of king mackerel in the southeastern United States. Fish. Bull. 89(2):315–324.