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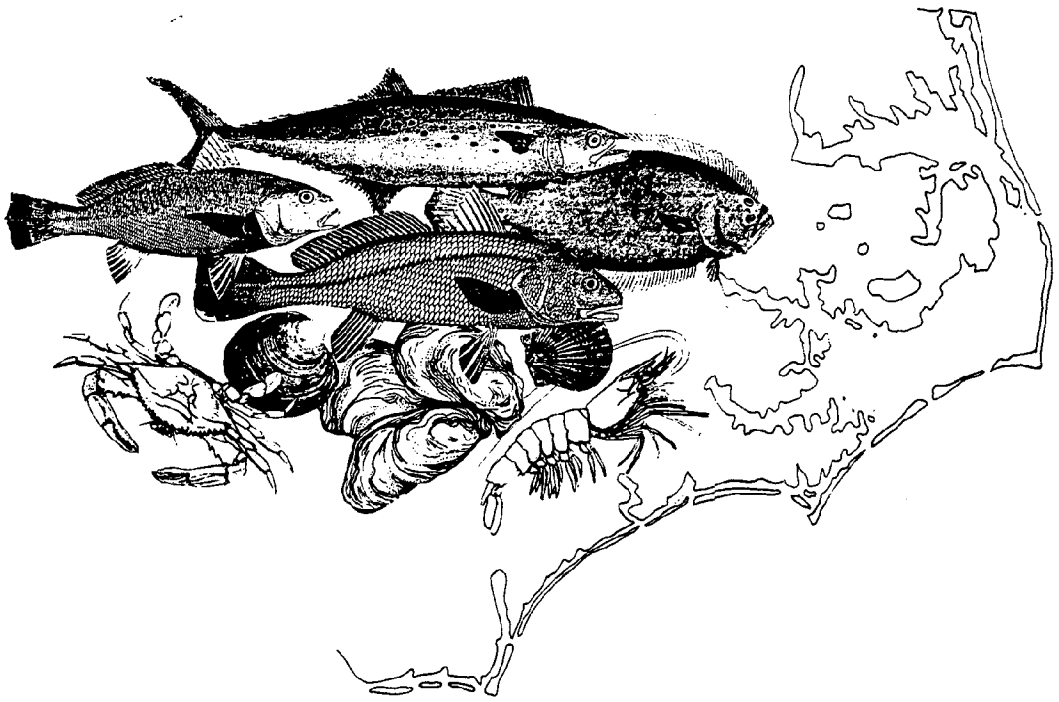
MARINE FISHERIES RESEARCH



North Carolina Department of Environment,
Health, and Natural Resources

Division of Marine Fisheries
Morehead City, NC 28557

April 1992

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MARINE FISHERIES RESEARCH

Division of Marine Fisheries
Morehead City, NC 28557

North Carolina Department of Environment,
Health, and Natural Resources

Completion Report
for
Project F-29

April 1992

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April 1992

STUDY 1

MIGRATION, AGE AND GROWTH, AND REPRODUCTIVE BIOLOGY OF KING MACKEREL (SCOMBEROMORUS CAVALLA) IN NORTH CAROLINA

By

Elizabeth B. Noble

Linda P. Mercer

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ABSTRACT

Declines in king mackerel (Scomberomorus cavalla) landings during the 1980s led to recreational-commercial conflicts and management efforts to resolve them. Migration, age and growth, and reproductive studies were conducted by the North Carolina Division of Marine Fisheries to provide king mackerel life history information to state and federal resource management agencies. From 1985 through 1990, 4,364 king mackerel were tagged and released off the central and northern coast of North Carolina. Sizes of fish tagged were significantly different ($p < .0001$) between areas tagged and seasons. Fall and summer separated out with high (746 mm FL) and low (563 mm FL) mean lengths, respectively. Largest fish (mean=769 mm FL) were tagged north of Cape Hatteras and smallest fish (mean=678 mm FL) were tagged south of Cape Lookout. The size of king mackerel did not influence distance or direction traveled nor probability of recapture. Seventy-four percent (n=63) of the king mackerel returns came from North Carolina, 18% (n=15) from Florida, 6% (n=5) from South Carolina, and 2% (n=2) from Virginia. Mean distance between release and recapture sites was 435 km (max=1,176 km) for fish tagged off the northern coast, and 146 km (max=1,117 km) for fish tagged off the central coast. Days at large ranged from eight days to almost five years (1,816 days). No correlation was found between days at large and distance between release and recapture site ($r=0.0696$). King mackerel were recaptured predominately (90%) by hook-and-line fisheries (65% recreational and 24% commercial). Thirty-nine percent were recaptured in the fall and 32% in the summer. Results provided evidence for a separate migratory group of king mackerel in North Carolina waters with some degree of mixing with more southern stocks.

Ages were determine for 521 king mackerel from whole otoliths and 896 king mackerel from sectioned otoliths. Females ranged in age from 1 to 26 years (460-1,520 mm FL) and males from 1 to 20 years (420-1,245 mm FL). Correlations of fish length with otolith radius were significant (<0.0001) for whole and sectioned otoliths from males, females, and sexes combined. Frequency distributions of distance from focus to each annulus for successive age groups were unimodal. Mean back-calculated lengths at age were greater for females than males in each age group. Growth increments were largest for the first three years, after which they gradually decreased. Asymptotic lengths for males from whole and sectioned otoliths were 770 mm FL and 1,153 mm FL; for females they were 897 mm FL and 1,370 mm FL, respectively. The von Bertalanffy growth constant was greatest for males from whole otoliths ($K=1.065$). Attempts to validate annual ring deposition (marginal increment analysis and mark-recapture studies) were inconclusive.

Gonads were examined macroscopically from males and females sampled at king mackerel tournaments June through October, 1988 and 1990. Very few fish <650 mm FL were present. Mature king mackerel dominated all samples with 100% of the males mature at 650 mm FL and 100% of the females mature at 800 mm FL. Results showed that king mackerel have a prolonged spawning season off North Carolina that peaks June through August. Overall sex ratio male to female for 13,064 king mackerel sampled at tournaments (1986-1990) was 1:2.

INTRODUCTION

The king mackerel (Scomberomorus cavalla) is a coastal migratory pelagic scombrid which ranges from Massachusetts to Brazil and throughout the Gulf of Mexico (Collette and Russo 1984). It is a highly sought sport fish from North Carolina to Texas, a primary target species of recreational charterboats and the focus of numerous saltwater angling tournaments (Manooch 1979, Trent et al. 1983). It is an important commercial species, as well, caught by hook and line and gill nets (Trent et al. 1983). Declines in king mackerel landings during the 1980s, especially in the Gulf of Mexico, led to recreational-commercial conflicts and management efforts to resolve them. A joint fishery management plan was developed by the Gulf of Mexico and South Atlantic Fishery Management councils (GMFMC and SAFMC 1982, 1985, 1987, 1989a,b, 1990). Two groups of king mackerel are recognized based on tagging studies, an Atlantic migratory and a Gulf of Mexico group, with some overlap and mixing along the southern Florida coast. Annual quotas are established for each group and allocated to the recreational and commercial fisheries based on historical catch rates.

King mackerel research efforts have largely been concentrated in Florida and the Gulf of Mexico under the Coastal Pelagics Program of the National Marine Fisheries Service (NMFS) and by state fisheries agencies and universities, principally in the Gulf of Mexico. Tagging studies (Williams and Godcharles 1984, Sutherland and Fable 1980, Sutter et al. 1991) have provided information on movements and migrations and provided the basis for the recognition of two migratory groups. Age and growth has been examined (Beaumariage 1973, Johnson et al. 1983, Manooch et al. 1987, Collins et al. 1989) and a historical database of length frequencies established (Trent et al. draft). Reproductive biology (Beaumariage 1973, Ivo 1974, Finucane et al. 1986), food habits (DeVane 1978, Naughton and Saloman 1981, Saloman and Naughton 1983), distribution and relative abundance by means of a charter boat catch and effort survey (Manooch and Laws 1979, Trent et al. 1983), and stock identification (May 1983, Williams and Godcharles 1984, Fable 1988, Johnson 1988, Sutter et al. 1991) have also been described.

This study was conducted for North Carolina waters from 1986 through 1990 to provide king mackerel life history information for the northern part of its

range to state and federal resource management agencies. With increased management efforts and more stringent regulations, these data were needed in king mackerel stock assessments. Research from 1986 to 1990 concentrated on migration, age and growth, and reproductive studies (Mercer et al. 1987, Reed et al. 1988, Monaghan et al. 1989, North Carolina Division of Marine Fisheries 1990). The primary objectives were:

1. identify and summarize available information for the South Atlantic;
2. analyze existing data on DMF Biological Database;
3. determine seasonal migration patterns off North Carolina;
4. determine exploitation patterns by season and gear;
5. validate an ageing procedure;
6. determine age composition of recreational catches;
7. determine the sex ratio by size, age and season;
8. determine size and age of maturity;
9. determine spawning season and peaks of spawning.

Objectives 1 and 2 were completed by Mercer et al. (1987) in the 1986 annual report and will not be included in this report.

MATERIAL AND METHODS

Migration

King mackerel for tagging were caught by charterboat and commercial fishermen under contract with North Carolina Division of Marine Fisheries (DMF), and by DMF and NMFS biologists using natural and artificial baits. Fish in good condition were placed ventral side up in a foam rubber-lined tagging box and measured to the nearest millimeter fork length (mm FL). All fish lengths in this report are fork lengths. An internal anchor tag (33 x 8 x 1 mm) with an 80 mm long streamer was inserted into the abdominal cavity through a small incision made in the left side of the ventral wall. Tagged fish were returned quickly to the water, usually within a half minute after de-hooking. Latitude, longitude, and condition of each release were recorded. Routine tagging was done using international orange tags while fish injected with tetracycline for age

validation were marked with blue tags. Fish were tagged in Onslow Bay, Raleigh Bay, and north of Cape Hatteras (Figure 1).

Each tag was uniquely and sequentially numbered with return instructions to receive a reward. All tags used from 1986 to 1989 had a NMFS Miami Laboratory return address as part of a cooperative tagging initiative and to reduce tag return bias from different tagging locations. In 1990, all tags had a DMF return address to encourage more tag returns. The tagging program was publicized through posters, newspaper articles, news releases, television and radio interviews, and talks to sport fishing clubs. A $10 reward was paid by NMFS for each return and each return was included in a drawing for a $1,000 prize also paid by NMFS at the end of each year. Along with returning tags, fishermen were asked to provide information on date and location of capture, length of fish, type of recapture gear, and whether they were fishing commercially or recreationally. Fishermen catching fish with blue tags were asked to save the fish for a $25 reward.

The molded nylon double-barb dart tag, designed by NMFS (Fable 1990), was tested in 1988 by comparing it to the internal anchor tag. Eighty-seven king mackerel were double tagged with one internal anchor tag and one double-barb dart tag. Methods were the same as for fish tagged with only the internal anchor tag.

Tag returns were analyzed for temporal and spatial relationships. The relationship between size and movement was examined using length at tagging of recaptured fish (length at recapture was not always accurate or available). Returns were also analyzed for which fishery and gear harvested king mackerel by season and area.

Age and Growth

King mackerel were collected along the North Carolina coast from September 1986 through December 1990 from the recreational and commercial hook-and-line fisheries and the commercial gill net fishery. Fish were measured to the nearest millimeter and sexed. Otoliths (sagittae) were removed and stored dry. Otoliths from male longer than 800 mm and female longer than 900 mm were sectioned.

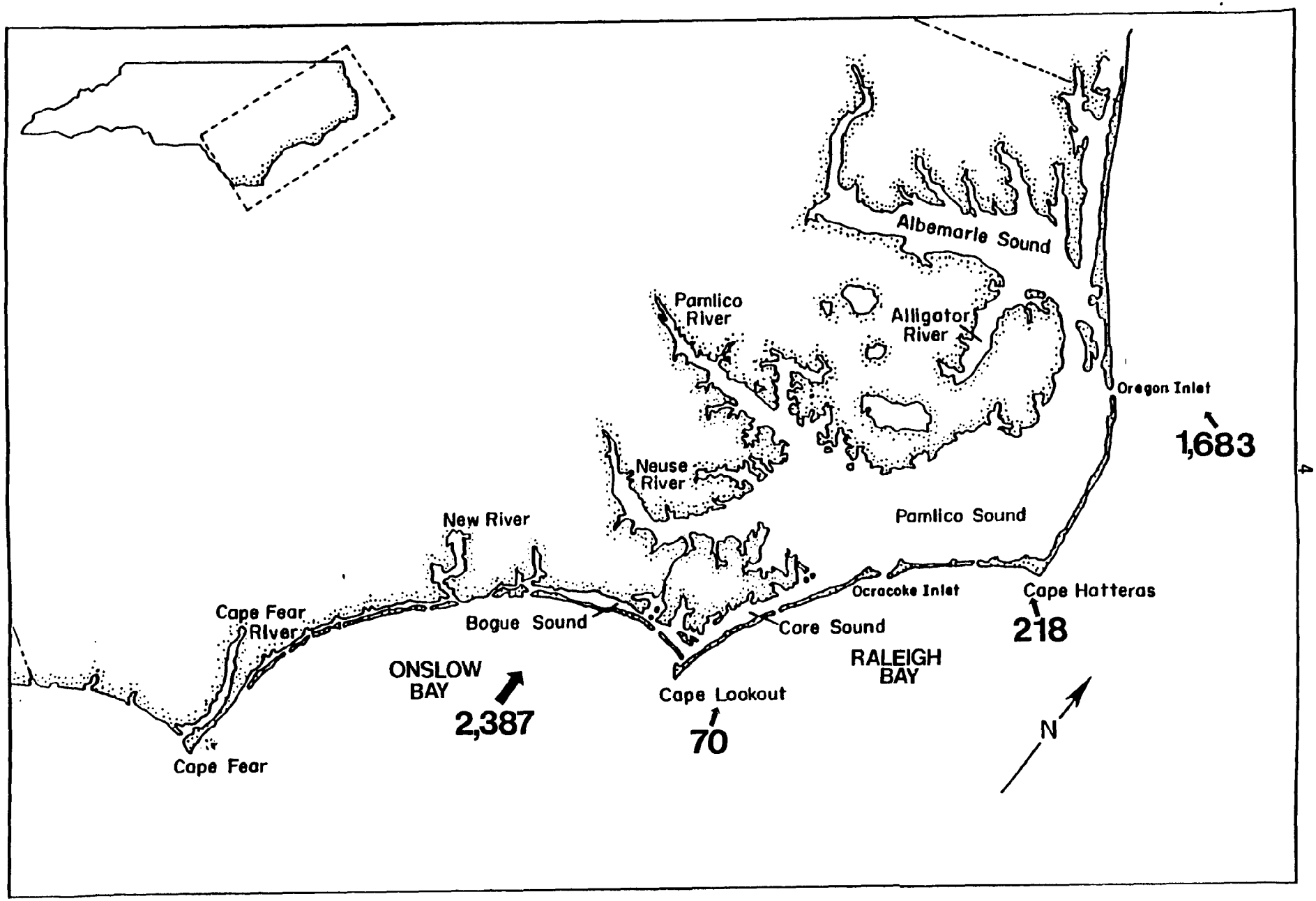
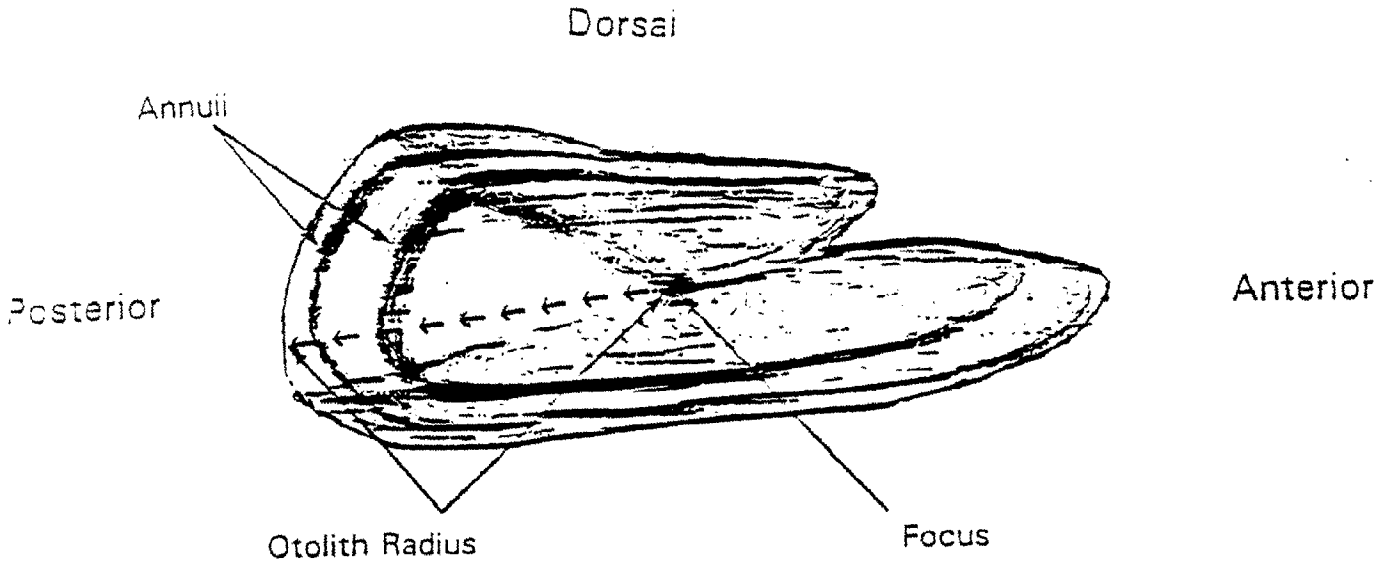


Figure 1. Primary tagging locations and numbers of king mackerel tagged off North Carolina, 1985-1990.

Whole otoliths were illuminated with reflected light and examined, concave side up, in a watch glass of glycerin under a dissecting microscope (37X). After Johnson et al. (1983) and Collins et al. (1989), opaque bands on the otolith were considered growth marks (annuli), and the translucent bands were treated as interspaces. Measurements were made from the focus to the distal edge of each opaque ring and to the otolith margin with a sonic digitizer on a video monitor along an axis approximating the extension of the sulcus acousticus (Johnson et al. 1983, Collins et al. 1989) (Figure 2). Annuli were only measured after they were completely deposited so that the marginal increment was never zero.

Transverse sections of either the left or right sagitta of each pair that were sectioned were made through the focus on a plane perpendicular to the long axis, with a Buehler Isomet low speed saw. Sections were mounted on slides, polished, and viewed under a dissecting microscope. Measurements were made with a sonic digitizer on images projected on a video monitor. The focus was not always definite on sections so measurements were standardized by defining the focus as the mid-point of a line connecting the two most distant points of the first ring (Collins et al. 1989). This method agreed with actual focus locations for sections in which the focus was apparent. Sections were measured in two parts because the axis of sagittal growth changed after the first year. Measurements of the distance to the first annulus were made at 92X from the focus to that point on the first ring, on the dorsal side of the sulcus acousticus, which minimized the length of the line without crossing the sulcus acousticus. Measurements from the first ring to the margin of the section were made at 204X on a line perpendicular to the rings, along the recognizable major axis of sagittal growth after year 1 (Figure 2). After Beaumariage (1973) and Johnson et al. (1983), otoliths were classified into age groups, based on the number of opaque nonmarginal marks.

The time of annulus formation was evaluated by plotting mean marginal increments by month. Least squares regressions of fork length on otolith radius were performed for sexes separately and combined to determine the relationship of the otolith to the size of the fish. Mean size at age were back-calculated for male, female, and sexes combined for both whole and sectioned otoliths by the direct proportion method (Lea 1910, Bagenal 1978) using DisBCAL89 microcomputer software packages (Missouri Department of Conservation 1989). Von Bertalanffy



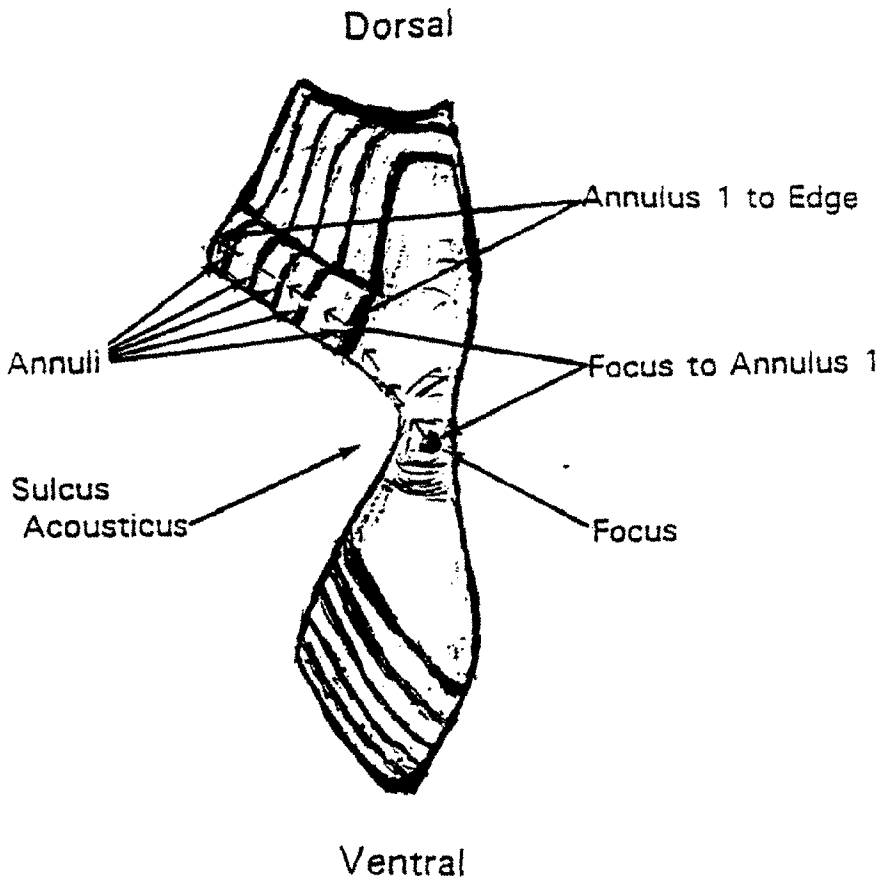


Figure 2. Diagram of a whole and sectioned king mackerel otolith. Dotted line shows path of measurement. Diagram is not to scale.

growth equations were fitted to back-calculated lengths at age using the Marquardt nonlinear iterative procedure (SAS Institute 1985).

Reproductive Biology

King mackerel were sampled for sex ratio by size, age and season at king mackerel tournaments June through October from 1986 through 1990. Sex, fork length to the nearest millimeter and weight in kilograms (kg) were recorded for each fish. A subsample of otoliths was taken from each tournament 1987 through 1990. The goal was to collect a minimum of three otolith pairs/50 mm size class/sex/month. Sex ratios were calculated for 50 mm size classes by season (summer: May-August, fall: September-November) and year. Ratios were also calculated for each age class (age 1-23 and 26).

Spawning season and spawning peaks were determined by visual inspection of gonads for both sexes acquired at tournaments June through October, 1988 and 1990. Macroscopic stages of gonad development were determined using a modification of Kesteven's (1960) classification (Table 1). Fork length to the nearest mm and weight were recorded for each fish. Seasonal maturation was determined by plotting percent frequency of each of the five stages across the months sampled.

RESULTS

Migration

A total of 4,364 king mackerel was tagged in North Carolina waters from 1985 through 1990. Overall, 86 (2.0%) king mackerel were recaptured (Table 2). Since no recapture information was available from one return, analyses were based on 85 fish. Annual return rates (1985-1990) ranged from 0.0% (1990) to 6.8% (1987). Individual release and recapture information is presented in Appendix A.

Sizes of king mackerel tagged varied among seasons (Figure 3) and among tagging areas (Figure 4). Mean lengths by season and by area were significantly different ($p < .0001$). Fall and summer separated out with high (746 mm) and low (563 mm) mean lengths, respectively, using Duncan's Multiple Range Test (Table 3). Spring (714 mm) and winter (707 mm) values were intermediate and are not clearly distinguishable from one another. South of Cape Lookout, larger fish

Table 1. Criteria used for macroscopic classification of maturity stages for king mackerel (after Kesteven 1960).

State	Females	Males
Immature	Ovaries very small, round transparent, colorless to gray. Eggs invisible to naked eye.	Testes small, ribbonlike in appearance, transparent, colorless to gray.
Maturing/resting	Ovaries opaque, gray-red with vascularization. Length about half the length of ventral cavity. Eggs visible to the eye as whitish granular.	Testes opaque, gray to white with vascularization. Occupy about half of ventral cavity.
Well developed	Ovaries reddish-yellow. Eggs clearly discernable, opaque. Occupy about two-thirds of ventral cavity.	Testes reddish-white. No milt grops appear under pressure. Occupy about two-thirds of ventral cavity.
Ripe (Spawning)	Ovaries fill ventral cavity. Eggs completely rounded, translucent.	Testes white, filling ventral cavity. Drops of milt fall with pressure.
Spent	Ovaries dark yellow to red, very flaccid and reduced in overall size, well vascularized.	Testes gray-red, blood vessels easily seen, flaccid and reduced in size.

Table 2. King mackerel tag returns by year tagged 1985-1990.

Year tagged	Number tagged	Year recaptured						Total	Return rate by year
		1985	1986	1987	1988	1989	1990		
1985	177	1	3	6	1	0	1	12	6.8%
1986	605		8	11	8	2	3	32	5.3%
1987	1,111			3	7	8	3	21	1.9%
1988	1,100				11	4	0	15	1.4%
1989	591					3	3	6	1.0%
1990	780						0	0	0.0%
Total	4,364	1	11	20	27	17	10	86	2.0%
Percent of total returns		1.2%	12.8%	23.2%	31.4%	19.8%	11.6%		

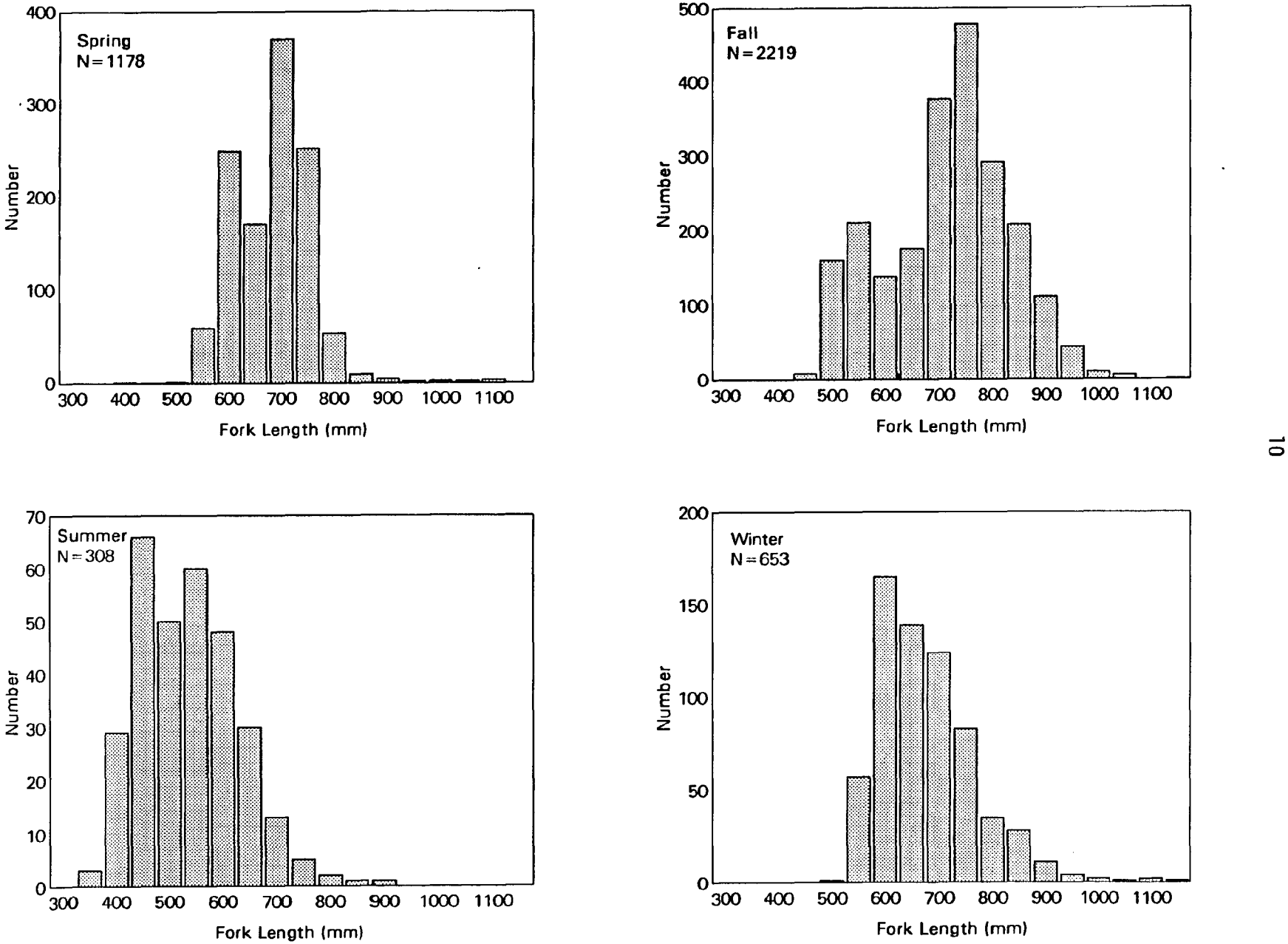


Figure 3. Length frequencies (FL, mm) of king mackerel tagged off North Carolina, 1985-1990, by season (Spring: April--May; Summer: June--August; Fall: September--November; Winter: December, March).

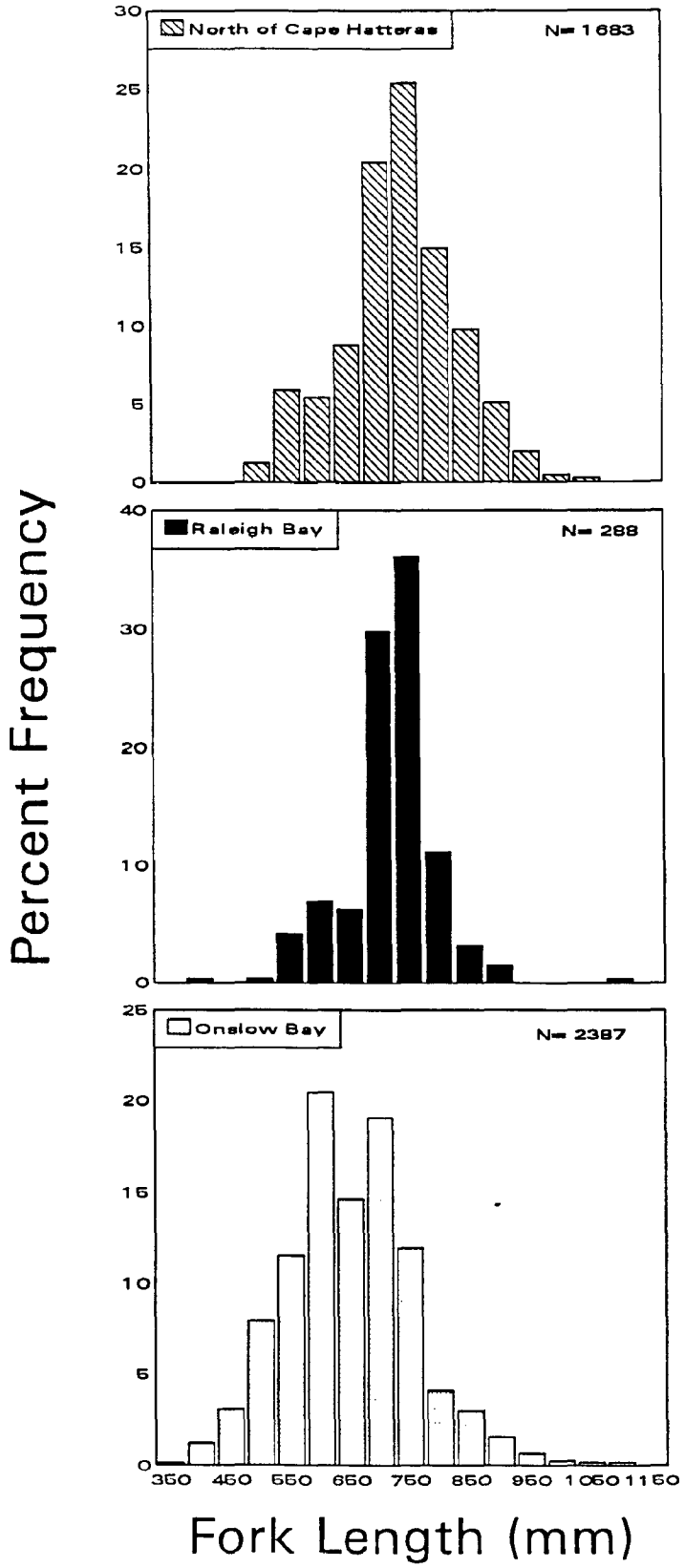


Figure 4. Length-frequency distribution of king mackerel tagged in Onslow Bay, Raleigh Bay, and north of Cape Hatteras, North Carolina, 1985-1990.

occurred in the winter and spring, intermediate-sized fish in fall, and smallest fish in the summer (Table 3). No seasonal differences were observed for fish tagged between Cape Hatteras and Cape Lookout, and all fish tagged north of Cape Hatteras were tagged in the fall.

Differences in mean lengths between areas were observed in all seasons. Largest fish were tagged north of Cape Hatteras and smallest fish were tagged south of Cape Lookout (Table 4). Seasonal differences existed between areas in fall and spring, with larger fish to the north in both cases (Figure 5).

Tagged king mackerel were recaptured during each season, but most were recaptured during the summer (32%) and fall (39%) when fishing effort was greatest (Table 5). Seventy-four percent (n=63) of the king mackerel returns came from North Carolina, 18% (n = 15) from Florida, 6% (n=5) from South Carolina, and 2% (n=2) from Virginia (Table 6). North Carolina and Florida returns occurred in all seasons, with North Carolina recaptures primarily in the fall and Florida recaptures primarily in spring and summer (Figure 6). Returns from Virginia and South Carolina were only in the summer.

A total of 1,683 king mackerel was tagged off the northern coast of North Carolina (Oregon Inlet area) in the fall. Forty-five (2.7%) were recaptured from Virginia to Florida (Tables 7 and 8). One fish was recaptured north of the tagging site (Virginia), ten were recaptured in the vicinity of the tagging site, 18 were recaptured south along the North Carolina coast, four in South Carolina waters, and 12 off the Florida coast (Figure 7). Distance between release and recapture sites ranged from 0 to 1,176 km and averaged 435 km. Average distance for fish recaptured >20 km from release site was 489 km.

A total of 2,387 king mackerel was tagged off the central North Carolina coast between Cape Lookout and Cape Fear. Forty fish (1.7%) were recaptured, including one from Virginia, 35 from North Carolina, one from South Carolina, and three from Florida. Distance between release and recapture site ranged from 0 to 1,117 km and averaged 146 km. Average distance traveled of fish recaptured >20 km from release site was 191 km.

Table 3. Comparison of mean lengths (mm) of tagged king mackerel by season (1985-1990) using Duncan's Multiple Range Test (means with the same letter are not significantly different).

Tagging area	Duncan grouping	Season*	N	Mean length	Length range
All	A	Fall	2,219	746	455-1,160
	B	Spring	1,178	714	440-1,140
	B	Winter	653	707	550-1,180
	C	Summer	308	563	388- 930
North of Cape Hatteras	A	Fall	1,683	769	515-1,160
Cape Hatteras to Cape Lookout	A	Spring	236	759	440- 950
	A	Fall	4	745	640- 873
	A	Winter	48	707	550-1,120
South of Cape Lookout	A	Winter	605	707	560-1,180
	A	Spring	942	702	550-1,140
	B	Fall	532	671	455-1,080
	C	Summer	308	563	388- 930
Total			2,387		

* Season: Fall (September-November), Winter (December-March), Spring (April-May), Summer (June-August).

Table 4. Comparison of mean lengths (mm) of tagged king mackerel by area (1985-1990) using Duncan's Multiple Range Test (means with the same letter are not significantly different).

Season*	Duncan grouping	Area	N	Mean length	Length range
All	A	North of Cape Hatteras	1,683	769	515-1,160
	B	Cape Hatteras to Cape Lookout	288	750	440-1,120
	C	South of Cape Lookout	2,387	678	388-1,180
Fall	A	North of Cape Hatteras	1,683	769	515-1,160
	A B	Cape Hatteras to Cape Lookout	4	745	640- 873
	B	South of Cape Lookout	532	671	455-1,080
Winter	A	Cape Hatteras to Cape Lookout	48	707	550-1,120
	A	South of Cape Lookout	605	707	560-1,180
Spring	A	Cape Hatteras to Cape Lookout	236	759	440- 950
	B	South of Cape Lookout	942	702	550-1,140
Summer	A	South of Cape Lookout	308	562	388- 930

* Season: Fall (September-November), Winter (December-March), Spring (April-May), Summer (June-August).

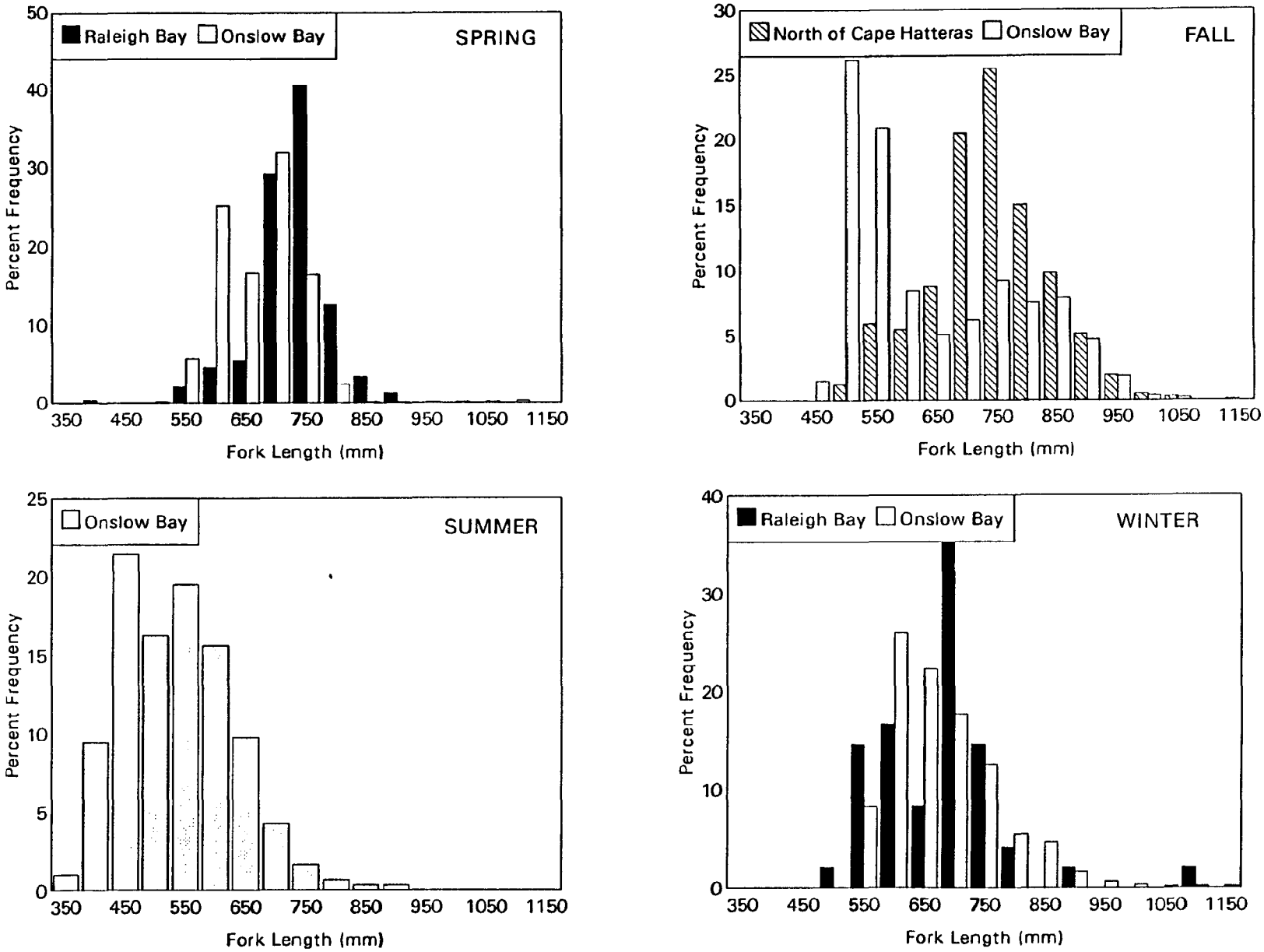


Figure 5. Seasonal length-frequency distribution of king mackerel tagged in Onslow Bay, Raleigh Bay, and north of Cape Hatteras, North Carolina, 1985-1990. Four fish tagged in the fall in Raleigh Bay are not shown. Seasons are Spring (April-May), Summer (June-August), Fall (September-November), Winter (December-March).

Table 5. King mackerel tag returns by season and year, 1985-1990. Seasons are winter (December, January, February, March), spring (April, May), summer (June, July, August), fall (September, October, November).

Season	1985	1986	1987	1988	1989*	1990	Total	Percentage by season
Spring	0	2	5	10	1	2	20	23.5%
Summer	0	3	5	8	7	4	27	31.8%
Fall	1	5	10	8	5	4	33	38.8%
Winter	0	1	0	1	3	0	5	5.9%
Total	1	11	20	27	16	10	85	100%

* Note: 1989 - 1 unknown recapture location and date.

Table 6. King mackerel recaptures by state and season, 1985-1990. Seasons are winter (December, January, February, March), spring (April, May), summer (June, July, August), fall (September, October, November).

Season	VA	NC	SC	FL	Total
Spring	0	13	0	7	20
Summer	2	15	5	5	27
Fall	0	31	0	2	33
Winter	0	4	0	1	5
Total	2	63	5	15	85
Percentage by state	2.4%	74.1%	5.9%	17.6%	100%

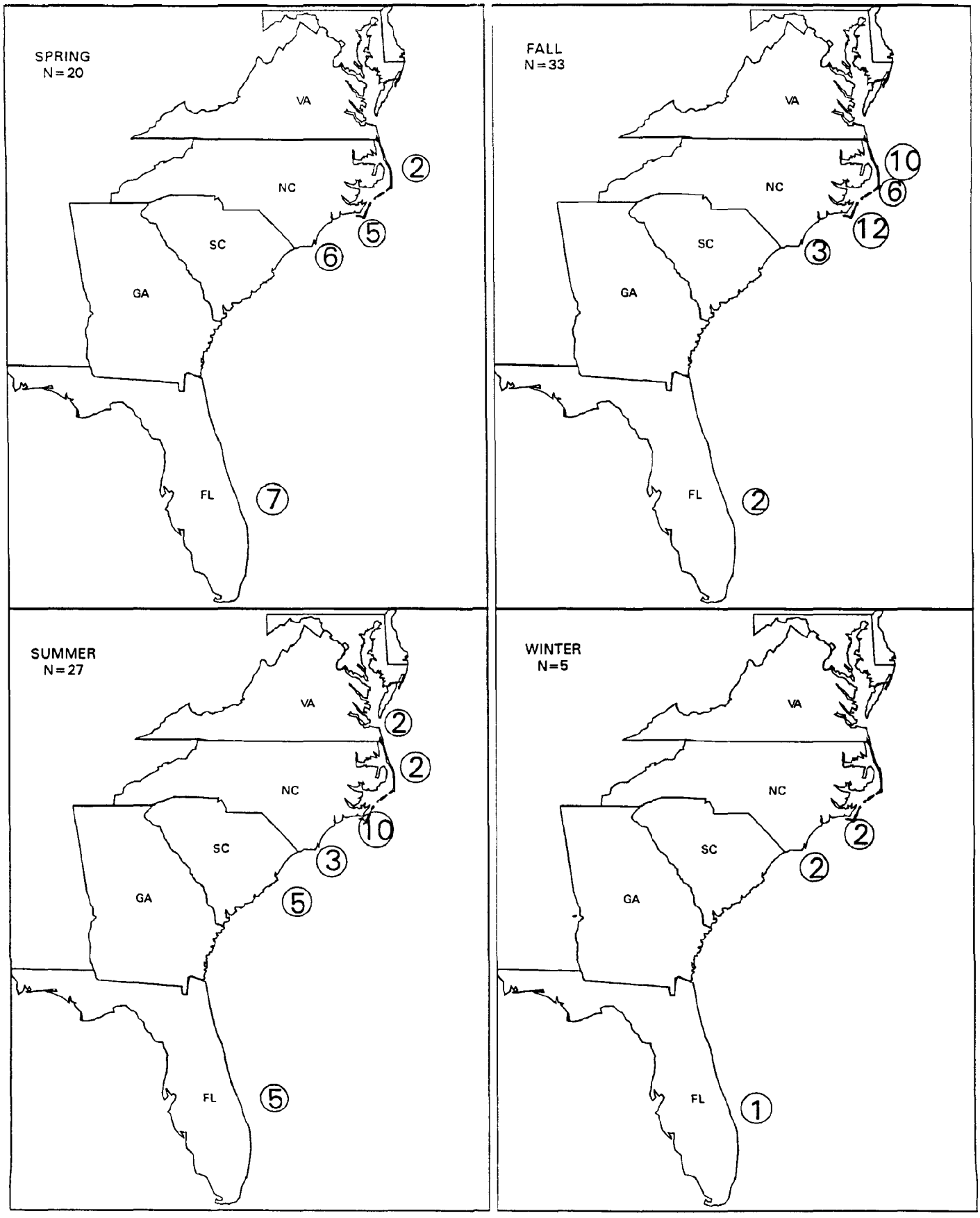


Figure 6. King mackerel recaptures by season of fish tagged off North Carolina, 1986-1990.

Table 7. King mackerel tag recaptures by area for fish released off North Carolina, 1985-1990.

	Number recaptured by area							
		NC						
Release area	VA	Oregon Inlet	Cape Hatteras	Cape Lookout	Cape Fear	SC	FL	Total
Oregon Inlet	1	10	7	5	6	4	12	45
Beaufort Inlet	1	2	1	24	8	1	3	40
Total	2	12	8	29	14	5	15	85

Table 8. King mackerel tag recaptures by season and area tagged for fish released off North Carolina, 1985-1990.

	Number recaptured by season							
		NC						
Recapture season/ Release area	VA	Oregon Inlet	Cape Hatteras	Cape Lookout	Cape Fear	SC	FL	Total
Spring								
Oregon Inlet			2	2	3		7	14
Beaufort Inlet				3	3			6
Summer								
Oregon Inlet	1	2		1	2	4	4	14
Beaufort Inlet	1			9	1	1	1	13
Fall								
Oregon Inlet		8	5	2			1	16
Beaufort Inlet		2	1	10	3		1	17
Winter								
Oregon Inlet					1			1
Beaufort Inlet				2	1		1	4

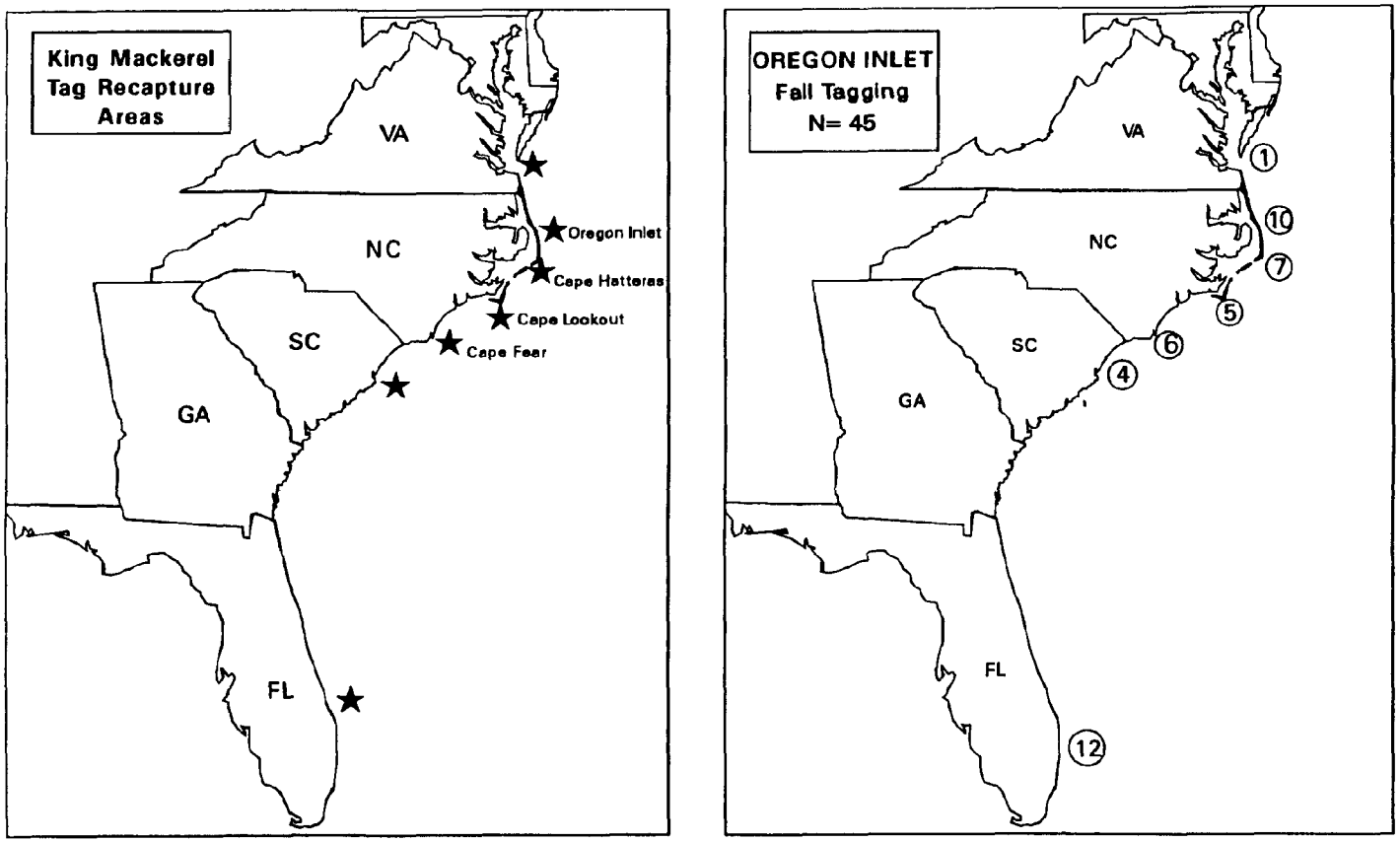


Figure 7. King mackerel tag recapture areas for fish tagged in North Carolina, 1985-1990. Also shown are those recaptures from fish tagged out of Oregon Inlet, North Carolina during October and November, 1985-1990.

King mackerel were tagged year-round off central North Carolina. Fish that were tagged in the spring, summer, and fall were recaptured off North Carolina and south to Florida (Figure 8). King mackerel tagged in the fall, however, were recaptured off North Carolina only.

Length frequencies and mean lengths of fish at time of release were compared for the 85 tag returns (Figure 9). No differences in mean lengths were apparent among recapture states or by season of recapture. Recaptured fish that had been tagged north of Cape Hatteras were predominantly larger at time of release than those tagged south of Cape Lookout. Recaptured fish tagged north of Cape Hatteras ranged from 660 mm to 1010 mm at release with a mean of 829 mm, while fish tagged south of Cape Lookout ranged from 500 mm to 1130 mm at release with a mean of 686 mm.

King mackerel were at large for eight days to almost five years (1,816 days) (Figure 10). Fifty-seven percent of the returns (n=48) were at large less than a year and 29% (n=25) were at large for 365-724 days (seven fish up to three years, four fish up to four years, and one fish up to five years). The fish at large for the longest period was recaptured out of Oregon Inlet, North Carolina, only 10 km from the release site.

Distance between release and recapture site ranged from 0 to 1,176 km (Figure 10). Fifty-five percent (n=47) of the returns were recaptured within 150 km of the release site. The fish that traveled the farthest was recaptured off Palm Beach, Florida. The fish that traveled the farthest and fastest was tagged out of Beaufort Inlet, North Carolina, and recaptured in 105 days off Pompano Beach, Florida. Fish recaptured in Florida had the greatest distance between release and recapture sites, but days at large ranged from 105 to 1,325 days. No correlation was found between days at large and distance between release and recapture site (r=0.0696).

King mackerel recaptures were predominately harvested by hook-and-line fisheries (65% recreational and 24% commercial) (Table 9). North Carolina's recreational hook-and-line fishery accounted for 73% of the recreational recaptures and 50% of the total recaptures (Table 10). North Carolina's hook-and-line commercial fishery accounted for 86% of the commercial fishery

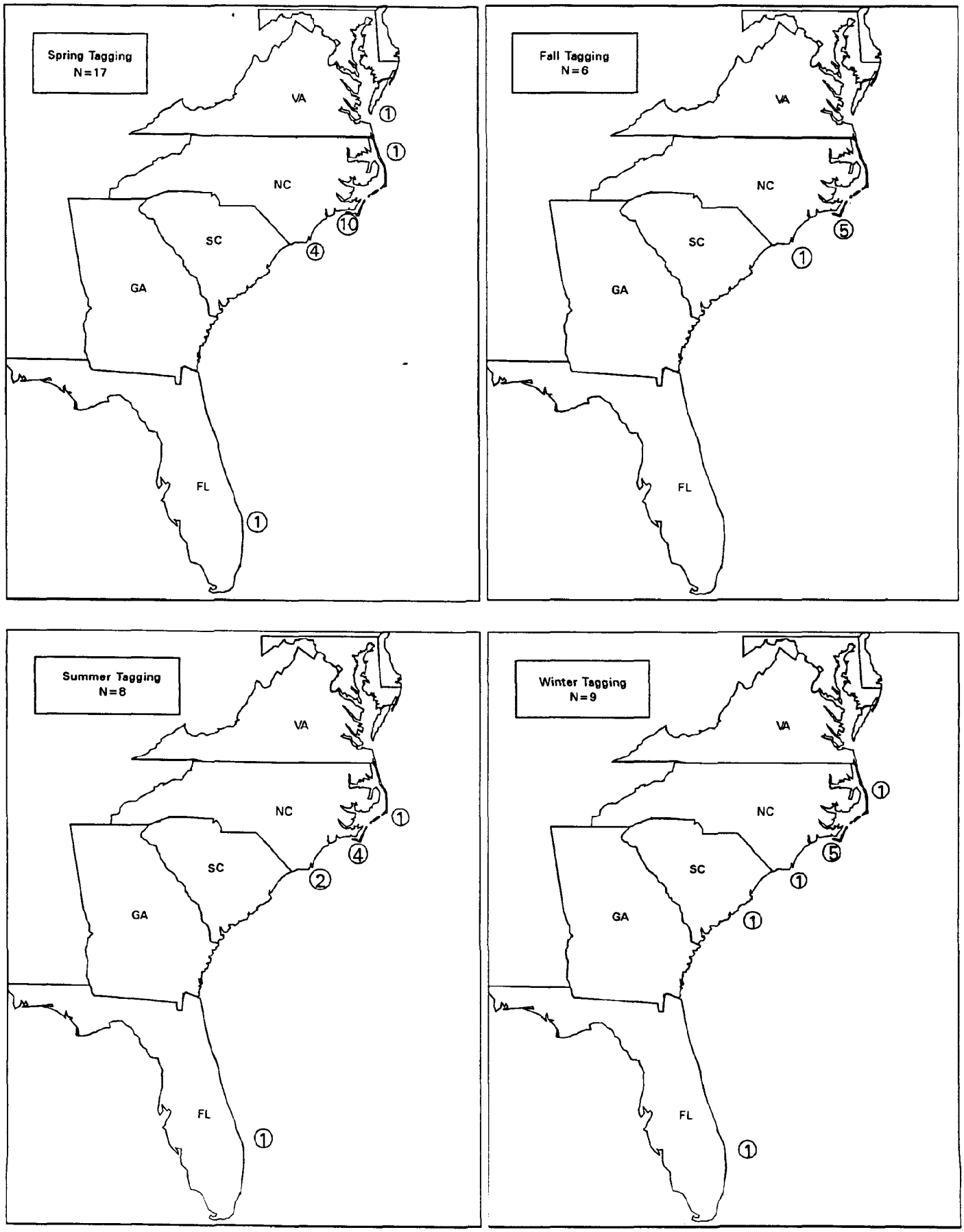


Figure 8. King mackerel recaptures (N=40) of fish tagged off central North Carolina by season tagged, 1985-1990.

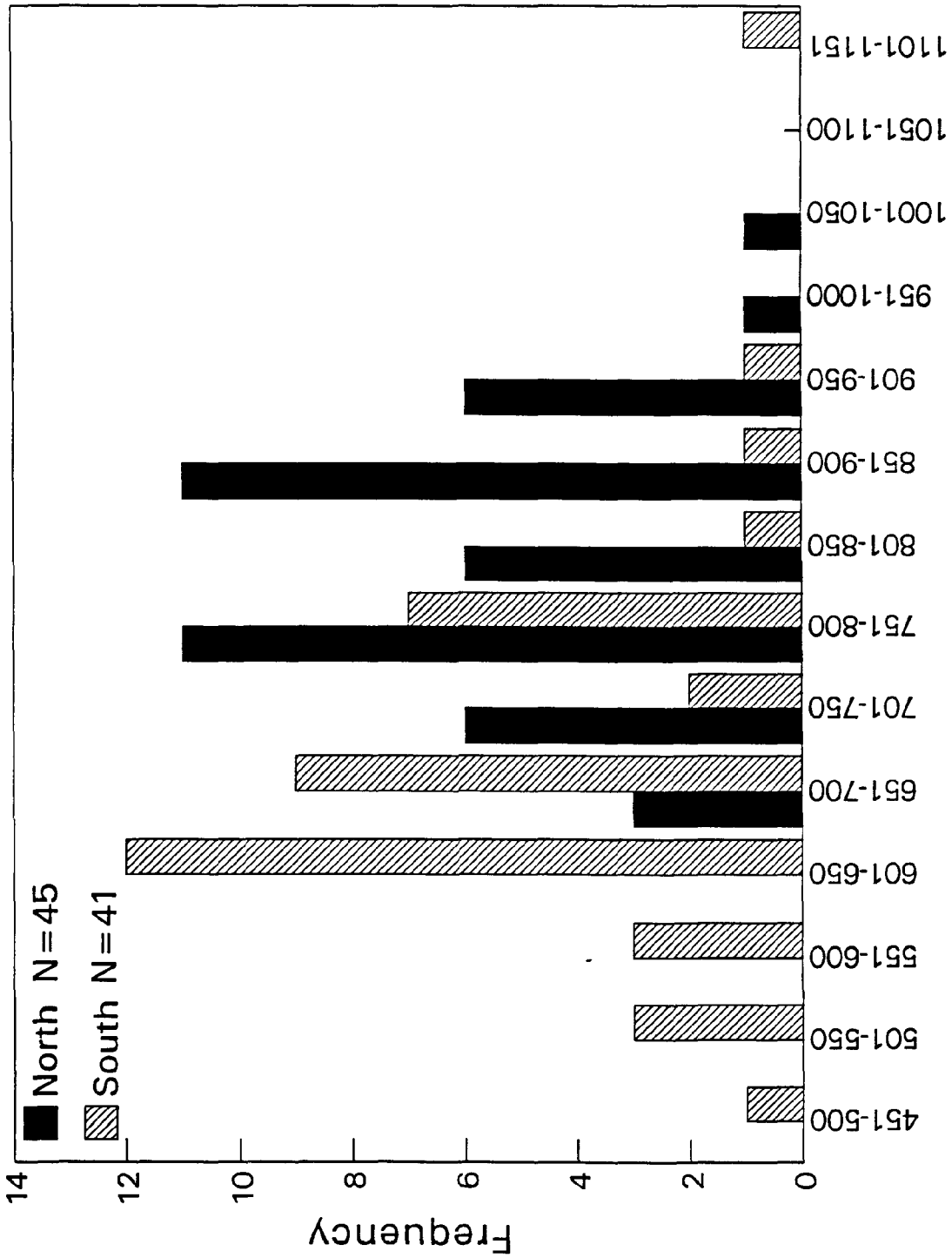


Figure 9. Fork lengths (mm) at release of king mackerel recaptures. Fish were tagged either south of Cape Lookout (south) or north of Cape Hatteras (north), North Carolina, between 1985 and 1990.

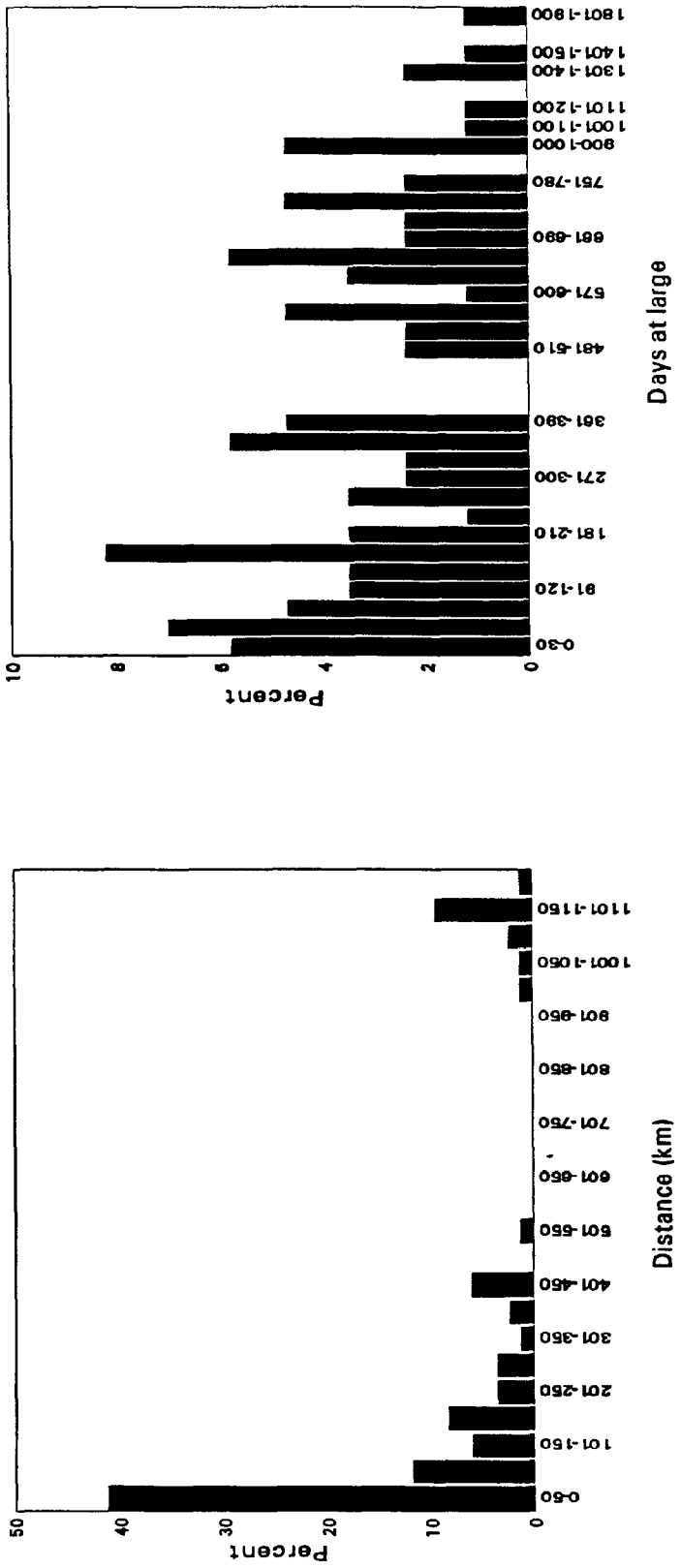


Figure 10. Distance between release and recapture sites and days at large for king mackerel tagged off North Carolina, 1985-1990.

Table 9. King mackerel recaptures by fishery and gear for fish tagged 1985-1990 in North Carolina.

	Recreational	Commercial					Unknown	
Year	Hook & line	Hook & line	Pound net	Drift gill net	Gill net	Purse seine		Total
1985		1						1
1986	7	4						11
1987	14	3			1		1	19
1988	18	8		1		1		28
1989	11	2			1		3	17
1990	6	3	1					10
Total	56	21	1	1	2	1	4	86

Table 10. King mackerel recaptures by state, season, fishery, and gear for fish tagged off North Carolina 1985-1990.

	NC	SC	FL	VA	Total	Percent
Recreational Fishery						
Hook and line						
Spring	12		6		18	22.0%
Summer	12	4	4		20	24.4%
Fall	15				15	18.3%
Winter	2		1		3	3.7%
Total	41	4	11		56	
Commercial Fishery						
Hook and line						
Spring			1		1	1.2%
Summer	2	1	1		4	4.9%
Fall	14				14	17.0%
Winter	2				2	2.4%
Total	18	1	2		21	
Other gear						
Spring					0	0%
Summer				[2][3,4]	2	2.4%
Fall	[2][1]		[1][2]		3	3.7%
Winter					0	0%
Total	2		1	2	5	
Overall total	61	5	14	2	82	100%

1. Gill net
2. Drift gill net
3. Pound net
4. Purse seine

Table 11. Least squares regression of fork length (mm FL) on otolith radius (mm OR) for sectioned and whole otoliths.

	Sectioned			Whole		
		N	r^2		N	r^2
Male	FL = 576.76 + 281.05 OR	283	0.38	FL = 0.83 + 156.61 OR	156	0.80
Female	FL = 510.19 + 455.27 OR	521	0.52	FL = 106.30 + 139.54 OR	325	0.68
Combined	FL = 446.80 + 469.60 OR	804	0.46	FL = -33.67 + 167.51 OR	481	0.80

recaptures and 22% of the total recaptures. Most recaptures from North Carolina recreational and commercial fisheries occurred in the fall.

Two fish double tagged the same day at the same location were recaptured. One was recaptured 116 days later (24 km from the release site) with the internal anchor tag in place and the dart tag missing. The second fish was recaptured 142 days later (16 km from the release site) with the dart tag in place and the internal anchor tag missing.

Age and Growth

The correlations of fish length with otolith radius were significant ($P < 0.0001$) for whole and sectioned otoliths of males, females, and sexes combined (Table 11). The least square regressions provided a better fit for whole otoliths than sectioned otoliths. Log transformations of the data did not improve the fit and are not reported.

Minimum values of mean marginal increments occurred from June through August for whole otoliths and August through October for sectioned otoliths (Figure 11); however sample sizes during November-April were insufficient to determine a clear trend during the winter. Examination of marginal increments on whole otoliths by sex resulted in lowest values in June for males and July for females (Figure 12). Lowest mean marginal increments from sectioned otoliths occurred in September and October for both males and females (Figure 12). Mean marginal increments for whole otoliths by age showed similar patterns (Figure 13). Excluding winter months, since sample size was insufficient, maximum values of mean marginal increments occurred in late fall and early spring.

Frequency distributions of the distance from the focus of the otolith to each annulus for successive age groups through age 4 for whole otoliths (Figure 14), and age 6 for sectioned otoliths were unimodal (Figure 15). Distances to the annuli varied little with age, indicating that ring formation was consistent for different age groups.

Ages were determined for 521 king mackerel from whole otoliths and 896 king mackerel from sectioned otoliths. Fish ranged in length from 351 to 1,520 mm (Figure 16). King mackerel of undetermined sex ranged from 351 to 550 mm (age

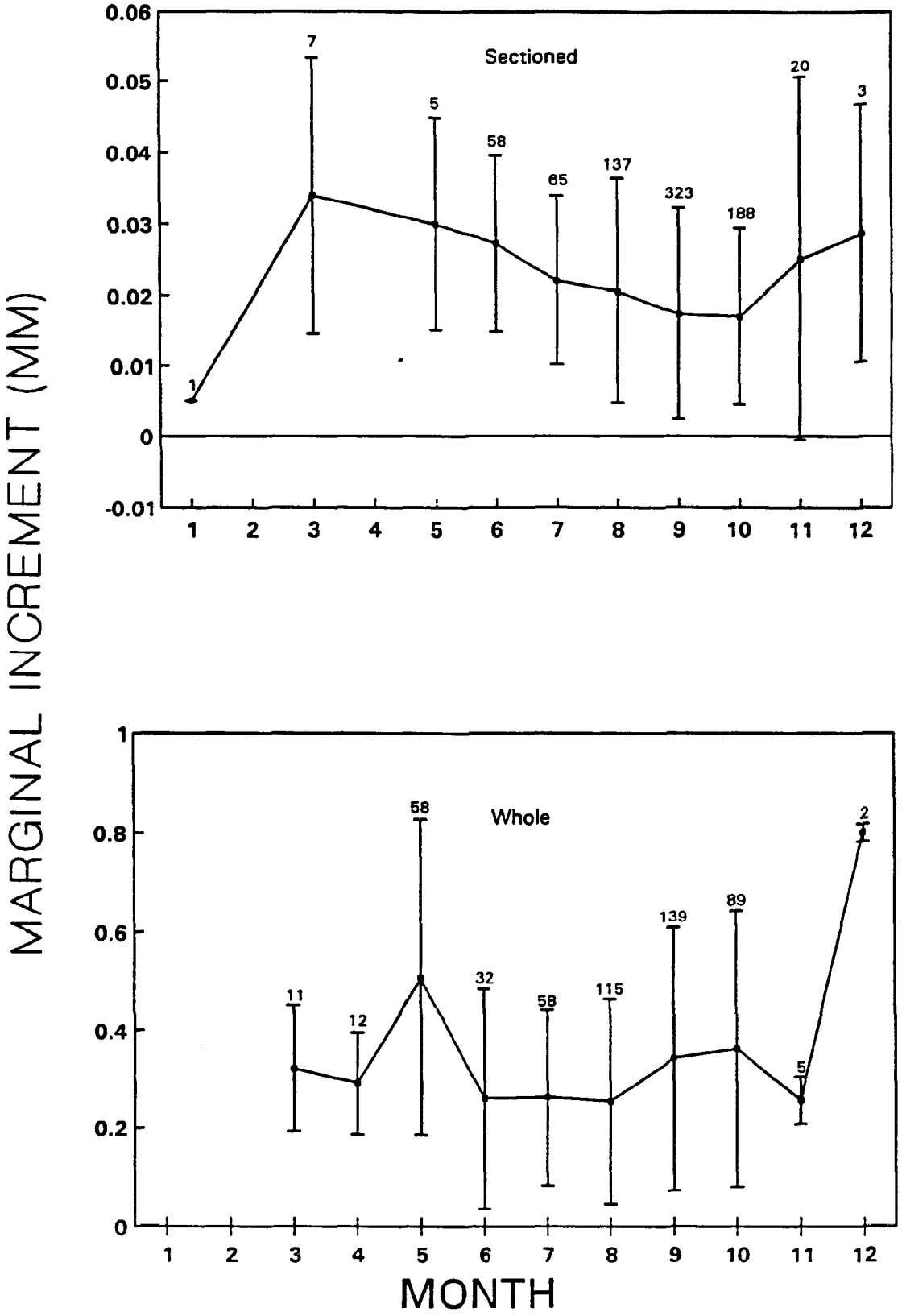


Figure 11. Monthly mean marginal increments on whole and sectioned otoliths of king mackerel. Vertical bars = +/- one standard deviation; number over each month's value = sample size.

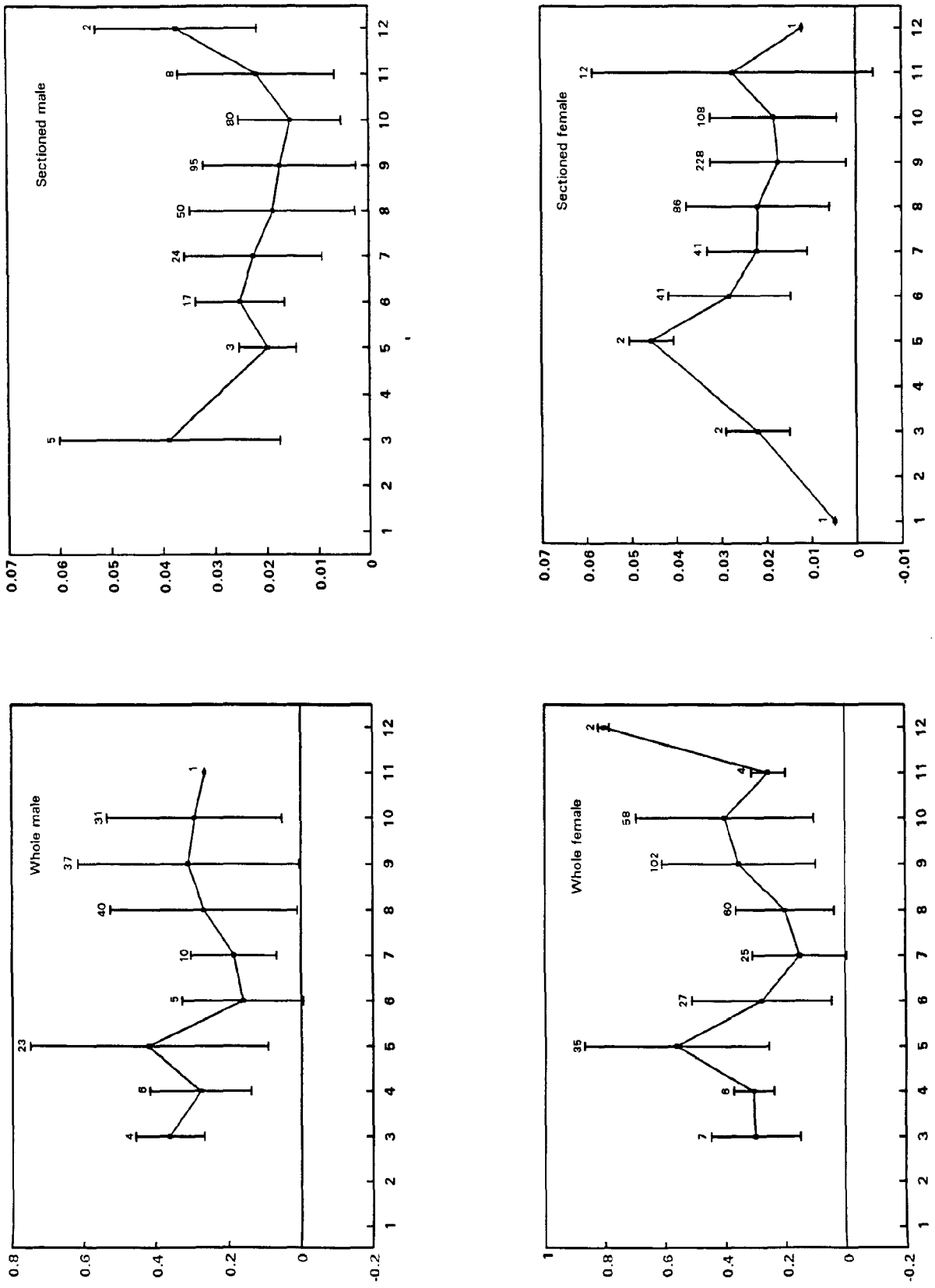


Figure 12. Monthly mean marginal increments on whole and sectioned otoliths of male and female king mackerel. Vertical bars = +/- one standard deviation; numbers over each month's value = sample size.

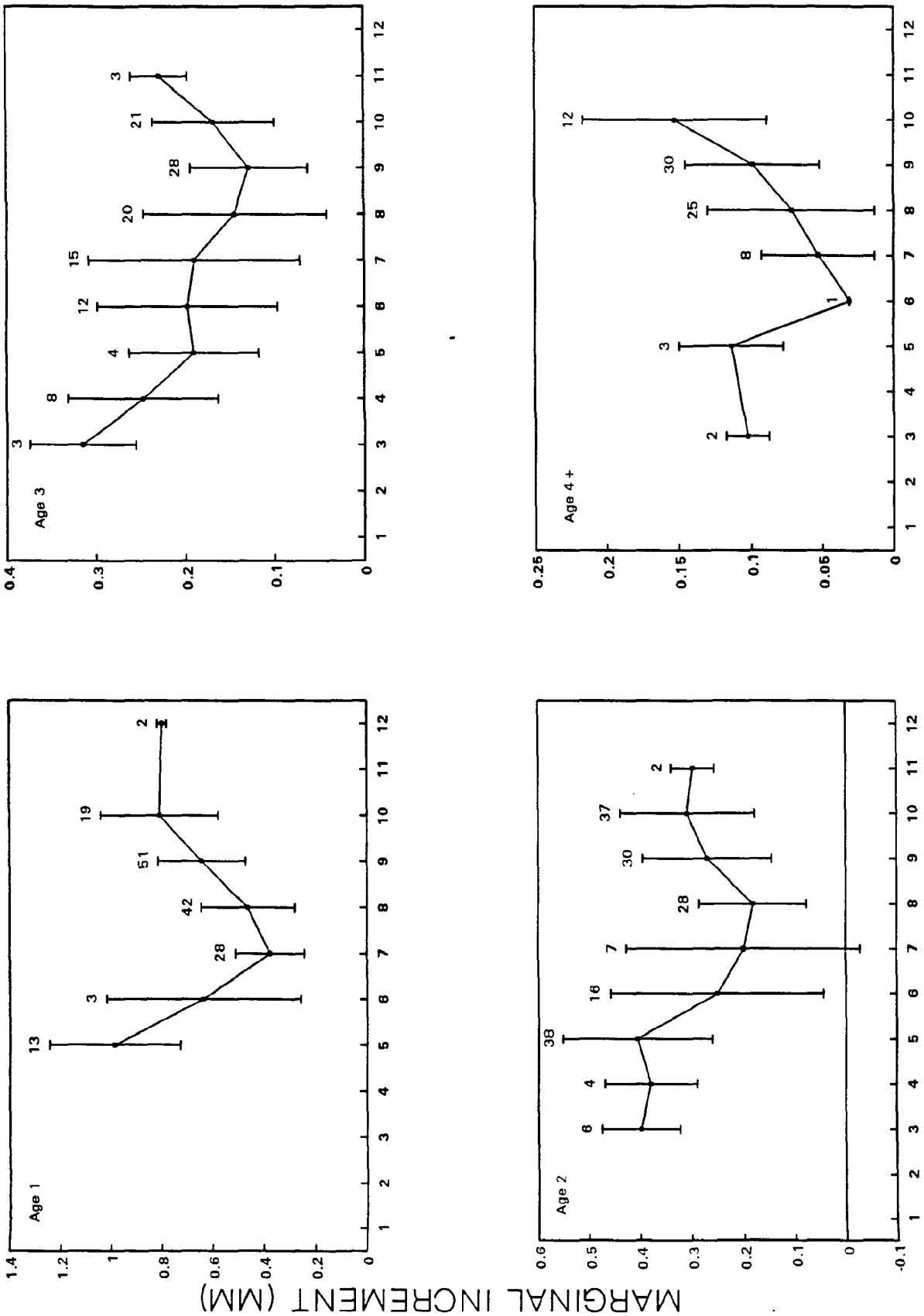


Figure 13. Monthly mean marginal increments on whole otoliths of king mackerel, by age. Vertical bars = +/- one standard deviation; numbers over each month's value = sample size; ages 4+ = fish aged four and older.

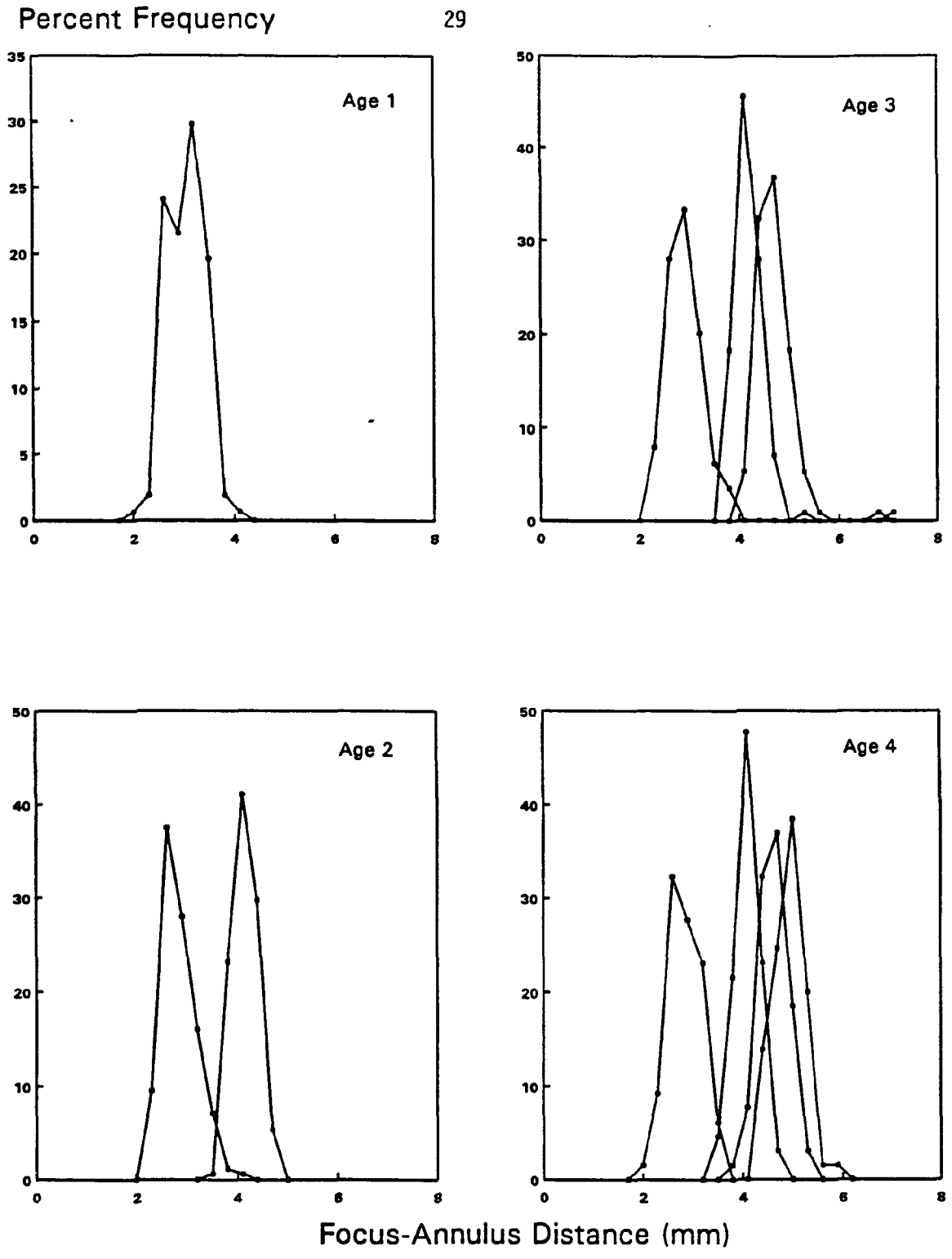


Figure 14. Frequency distributions of the distance from the focus of the otolith to each annulus on whole king mackerel otoliths from North Carolina, 1987-1990.

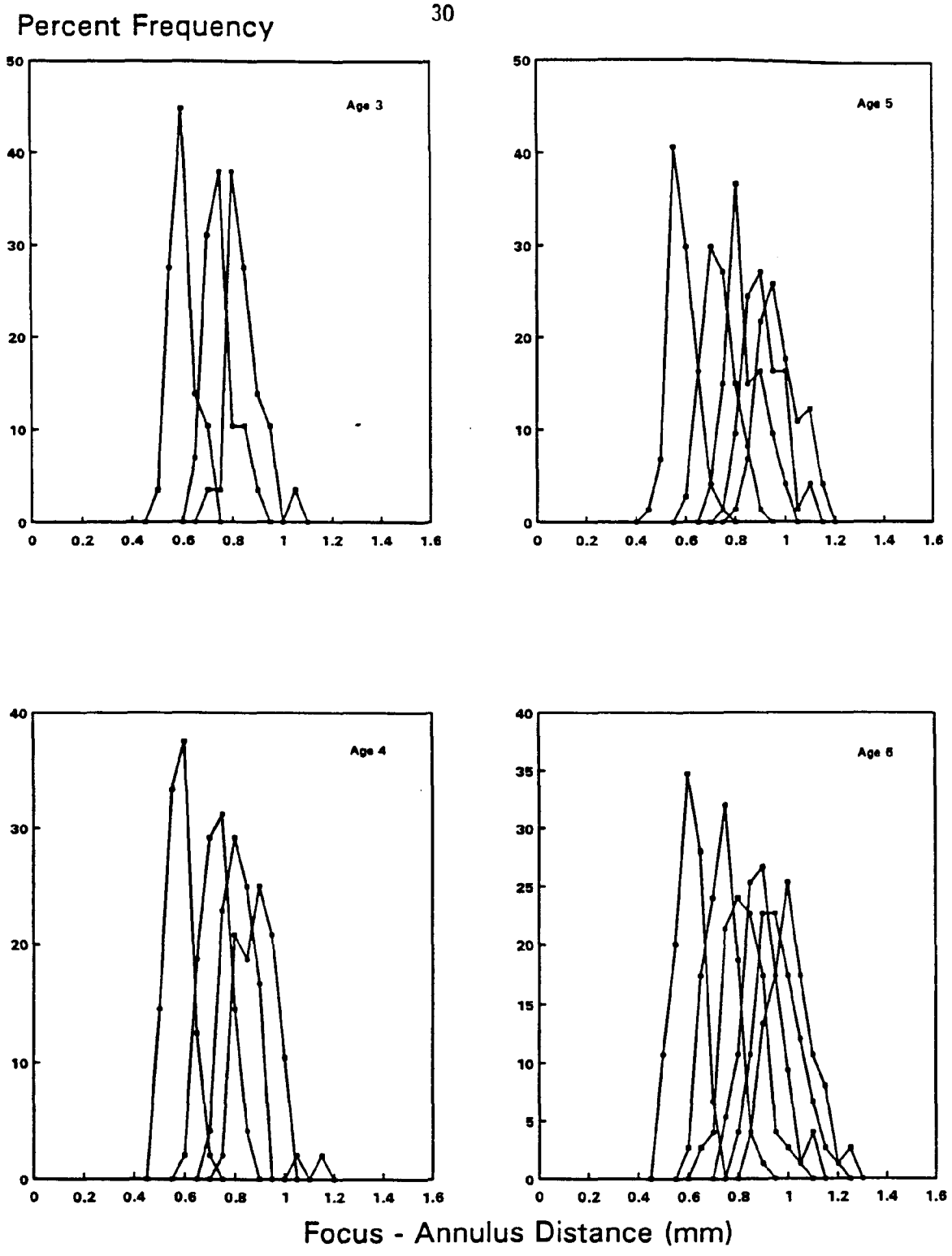


Figure 15. Frequency distribution of the distance from the focus of the otolith to each annulus on sectioned king mackerel otoliths from North Carolina, 1987-1990.

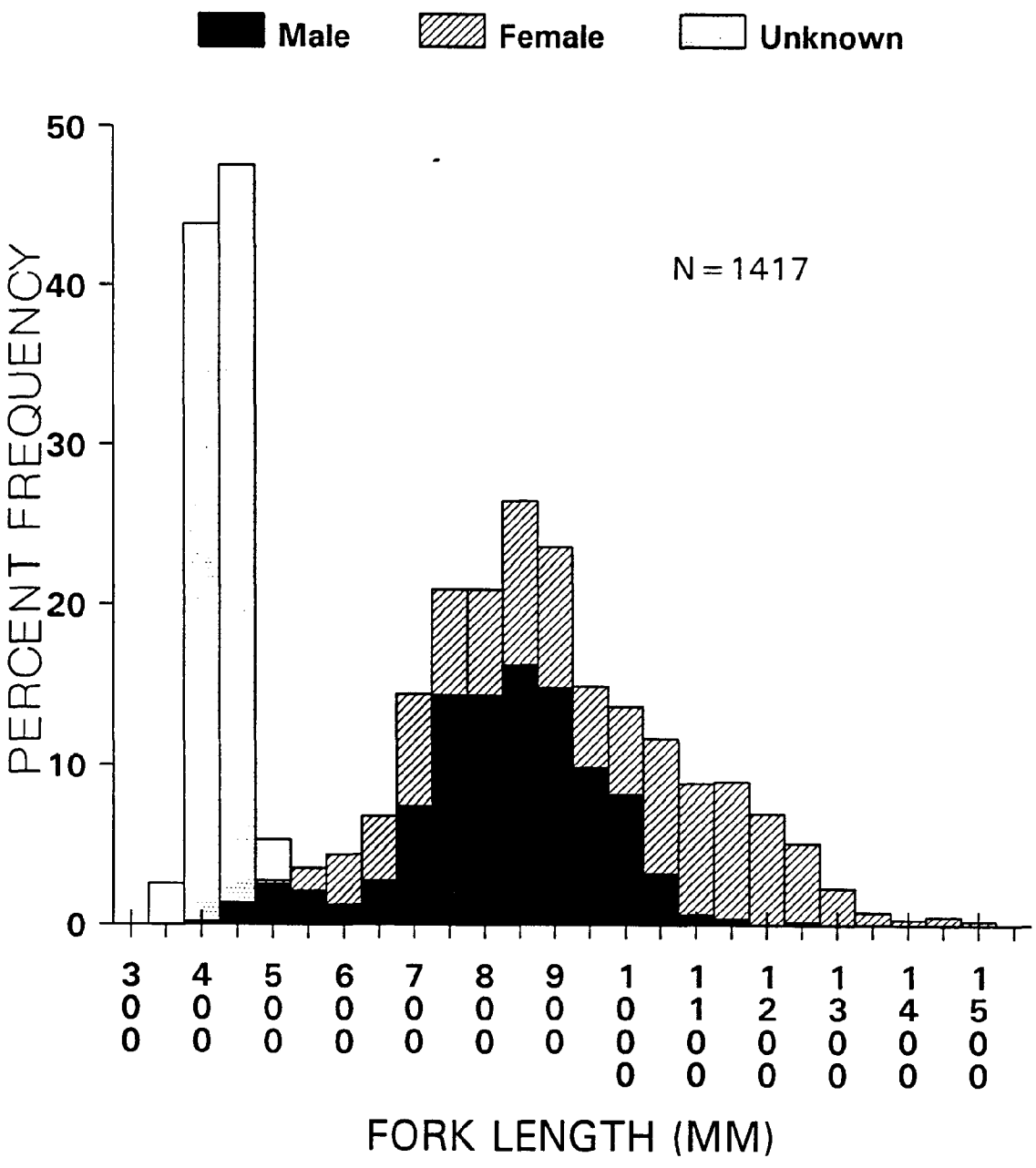


Figure 16. Length-frequency of king mackerel age samples, by sex, collected in North Carolina, 1987-1990.

1), females from 460 to 1,520 mm (age 1-26), and males 420 to 1,245 mm (age 1-20).

Two readers agreed on annual ring counts for 92% of double-read otoliths (n=221), including both whole and sectioned sagittae. Of those with different counts, 67% disagreed by one year. This discrepancy resulted from the NMFS Panama City Laboratory convention of adding one year at the established birth date (January 1) for age-length key purposes regardless of whether or not an annulus had formed. Comparisons of ring counts on whole and sectioned otoliths were not made. The direct proportion method of back-calculation (Lea 1910) rather than the regression method was used for both whole and sectioned otoliths because intercepts from the otolith radius and fish length regressions were either large or negative. Back-calculated lengths at age were determined for males and females separately because of the differences in mean observed size at age (Tables 12 and 13). Back-calculated lengths at age were not determined for fish greater than age 20 due to small sample size and ageing system logistics.

Fish aged from whole otoliths ranged from 372 to 905 mm (age 1-6). Fish aged from sectioned otoliths ranged from 590 to 1,520 mm (age 1 to 26). A clear progression of modes in length frequency distributions can be seen with increasing age (Figure 17). When data from annual age length keys (1987-1990) were compared to length frequency distributions of North Carolina's recreational catch (1987-1991) (Figure 18), a dominant 1986 year class could be followed through 1987, 1988, and 1989. In 1987, large numbers of age 1 fish (500-650 mm) were harvested. The remainder of the catch consisted primarily of age 2-13 males and age 2-9 females. Approximately seven percent of the fish harvested in 1987 were larger than 950 mm (age 14+ males and age 6+ females). Fewer age 1 fish were harvested in 1988 and 1989. Dominant age classes in 1988 were 2-5 for males and 2-3 for females. In 1989, age 3-7 males and age 2-4 females dominated the catch. In 1990, another strong year class was seen with greater than 50% of the catch age 1 fish (<600 mm). This year class was dominant in 1991 also. Mean back-calculated lengths at age from whole and sectioned otoliths were similar for females (Figure 19). Whole otoliths resulted in larger back-calculated lengths for age 2 to 4 males than sectioned otoliths. Mean back-calculated size at age was greater for females than males in each age group based on both whole and sectioned otoliths (Tables 14 and 15). Growth increments were largest for the

Table 12. Observed mean sizes for king mackerel from sectioned otoliths from North Carolina 1987-1990.

		SECTIONED			
Age	Sex	Mean fork length (mm)	SE	Minimum-Maximum	N
1	Male	540	-	-	1
2	Male	765	15.0	750- 780	2
3	Male	798	23.9	692- 990	11
	Female	886	19.4	795-1,125	19
	Combined	854	16.8	692-1,125	30
4	Male	802	6.2	745- 845	20
	Female	898	16.4	780-1,110	33
	Combined	862	12.3	745-1,110	53
5	Male	841	11.5	740-1,050	29
	Female	928	11.9	813-1,180	49
	Combined	896	9.8	740-1,180	78
6	Male	843	8.5	750-1,020	34
	Female	972	12.1	815-1,180	54
	Combined	922	10.4	750-1,180	88
7	Male	893	12.4	775-1,050	27
	Female	1,028	16.7	825-1,210	34
	Combined	968	13.8	775-1,210	61
8	Male	889	10.4	820-1,130	31
	Female	1,069	12.7	851-1,235	55
	Combined	1,004	12.9	820-1,235	86
9	Male	885	11.8	750-1,010	23
	Female	1,068	20.6	730-1,300	41
	Combined	1,002	17.7	730-1,300	64
10	Male	901	7.7	805-1,015	34
	Female	1,091	10.8	860-1,270	70
	Combined	1,029	11.7	805-1,270	104
11	Male	937	13.4	800-1,120	25
	Female	1,096	15.8	875-1,300	38
	Combined	1,033	14.7	800-1,300	63
12	Male	952	16.7	875-1,090	15
	Female	1,128	15.0	915-1,320	43
	Combined	1,083	15.7	875-1,320	58
13	Male	993	20.2	920-1,145	11
	Female	1,145	14.7	980-1,250	21
	Combined	1,093	17.5	920-1,250	32
14	Male	975	14.1	914-1,041	9
	Female	1,202	14.1	1,067-1,360	26
	Combined	1,144	20.3	914-1,360	35
15	Male	962	16.5	845-1,050	14
	Female	1,141	27.9	815-1,420	27
	Combined	1,080	23.3	815-1,420	41
16	Male	1,011	16.9	935-1,105	10
	Female	1,192	15.9	1,025-1,370	28
	Combined	1,145	18.1	935-1,370	38
17	Male	1,016	18.0	990-1,067	4
	Female	1,261	40.6	1,054-1,520	13
	Combined	1,204	40.4	990-1,520	17

Table 12. (Continued)

		SECTIONED			
Age	Sex	Mean fork length (mm)	SE	Minimum-Maximum	N
18	Male	1,005	50.3	800-1,245	7
	Female	1,264	30.2	1,117-1,440	11
	Combined	1,164	40.1	800-1,440	18
19	Male	1,030	-	-	1
	Female	1,241	29.5	1,055-1,350	9
	Combined	1,220	33.8	1,030-1,350	10
20	Male	980	20.0	960-1,000	2
	Female	1,288	22.2	1,220-1,360	5
	Combined	1,200	59.0	960-1,360	7
21	Female	1,233	88.0	1,030-1,445	4
22	Female	1,461	-	-	1
23	Female	1,382	76.6	1,245-1,510	3
26	Female	1,370	-	-	1

Table 13. Observed mean sizes of king mackerel from whole otoliths from North Carolina 1987-1990.

		Whole			
Age	Sex	Mean fork length (mm)	SE	Minimum-maximum	N
1	Unknown	432	7.1	372-660	38
	Male	533	9.9	420-660	37
	Female	618	5.8	460-756	83
	Combined	553	7.4	372-756	158
2	Male	700	4.6	620-775	51
	Female	727	4.0	615-860	117
	Combined	719	3.3	615-860	168
3	Male	754	3.6	685-800	48
	Female	806	5.9	710-902	66
	Combined	784	4.4	685-902	114
4	Male	773	4.5	720-800	19
	Female	842	4.6	765-895	46
	Combined	822	5.2	720-895	65
5	Male	800	-	-	2
	Female	869	7.7	838-905	10
	Combined	858	10.0	800-905	12
6	Female	883	6.5	865-895	4

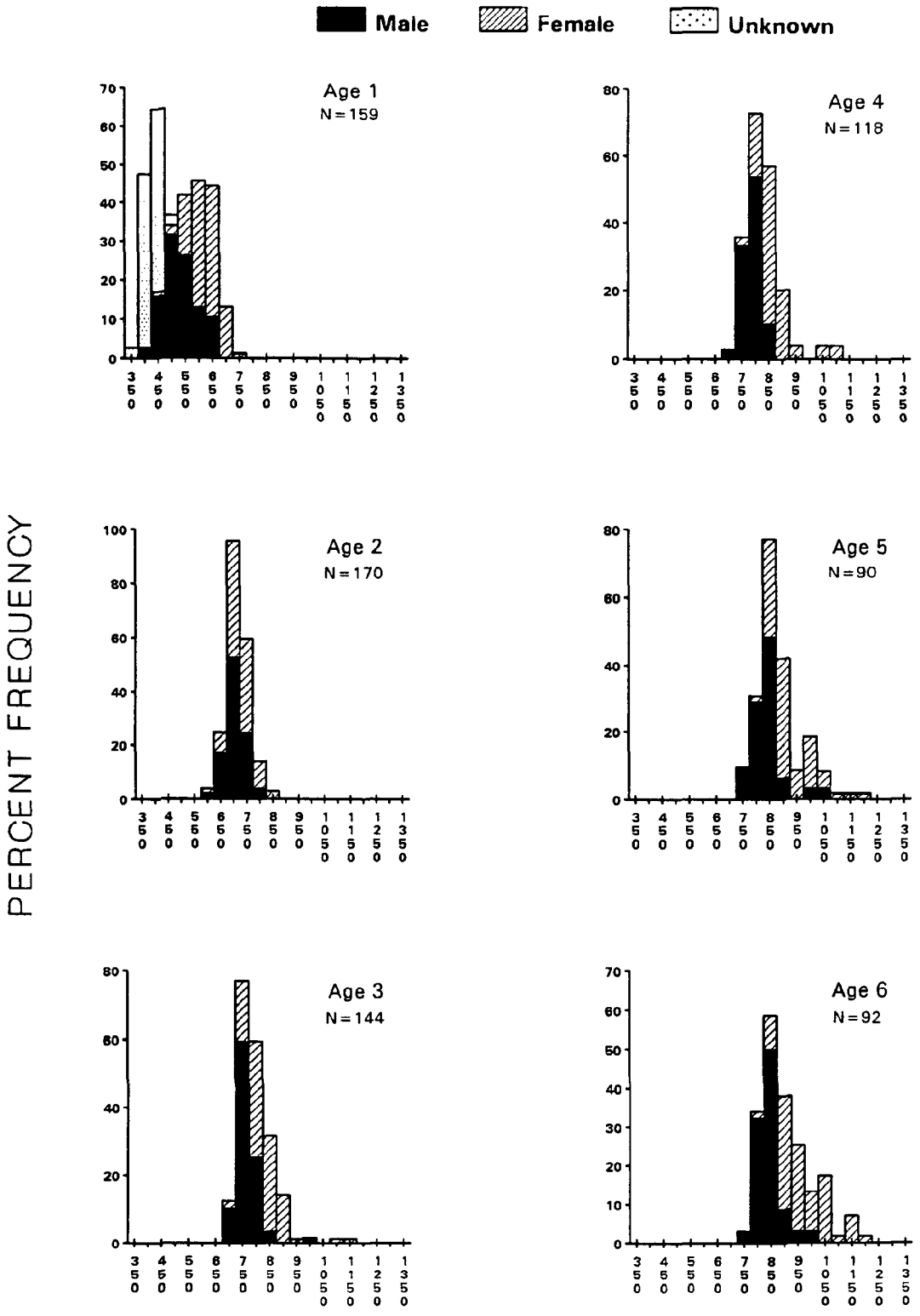


Figure 17. Length-frequencies of king mackerel by age and sex collected in North Carolina, 1987-1990. Ages 12+ = fish aged 12 and older.

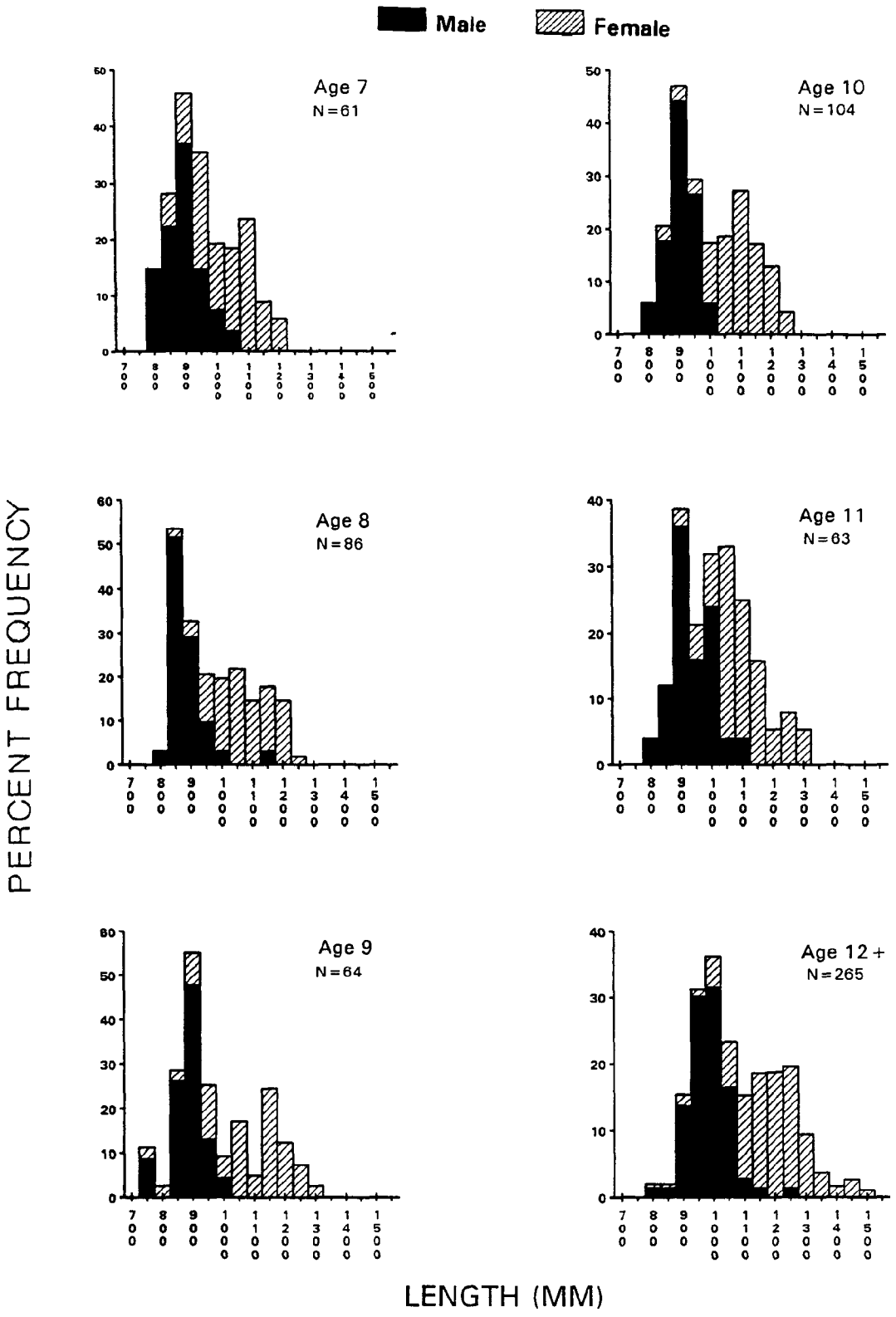


Figure 17. Continued.

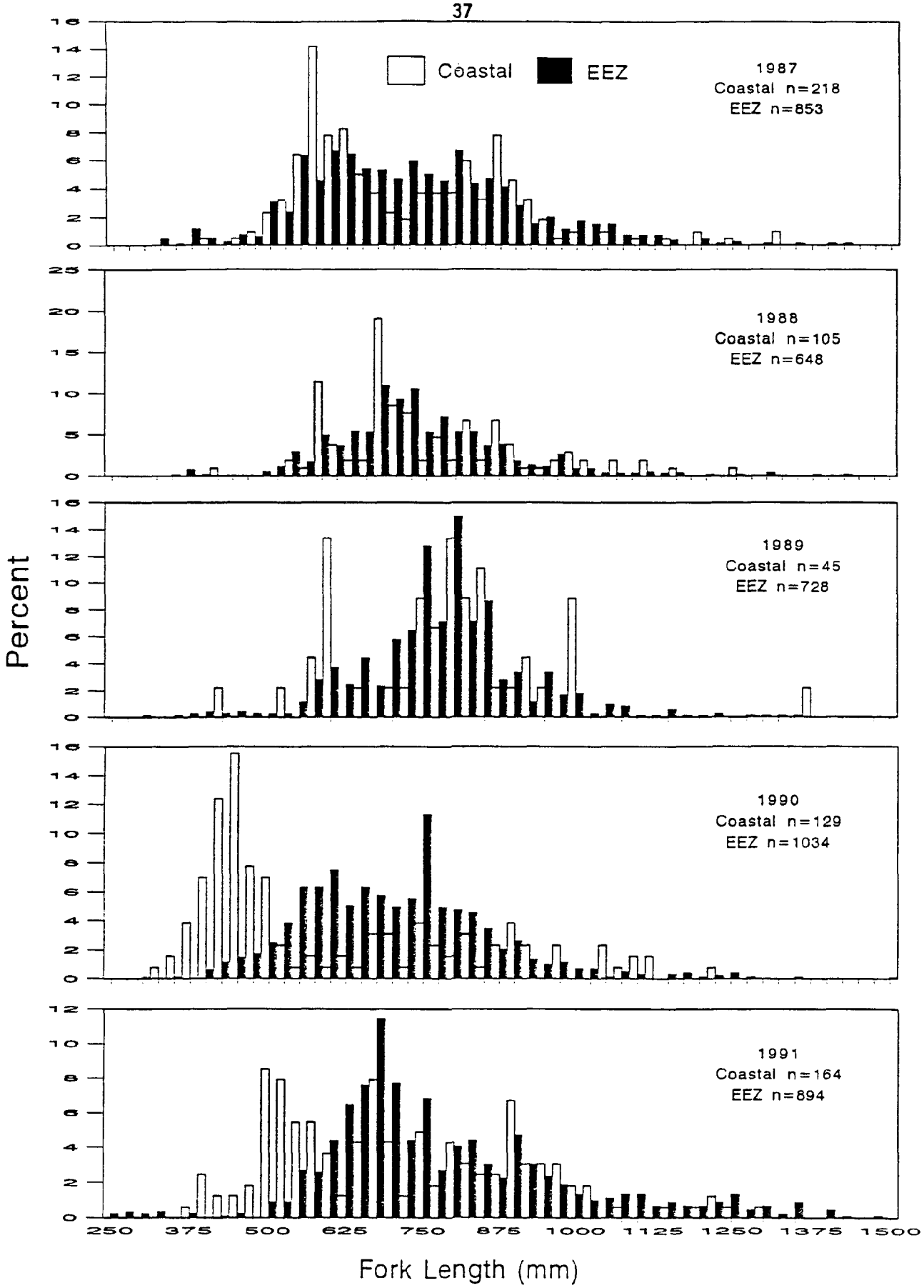


Figure 18. Length-frequency distributions of king mackerel sampled from the recreational catch in coastal waters and the Exclusive Economic Zone (EEZ) off North Carolina, 1987-1991 (from D. Mumford and P. Phalen, NC DMF personal communication).

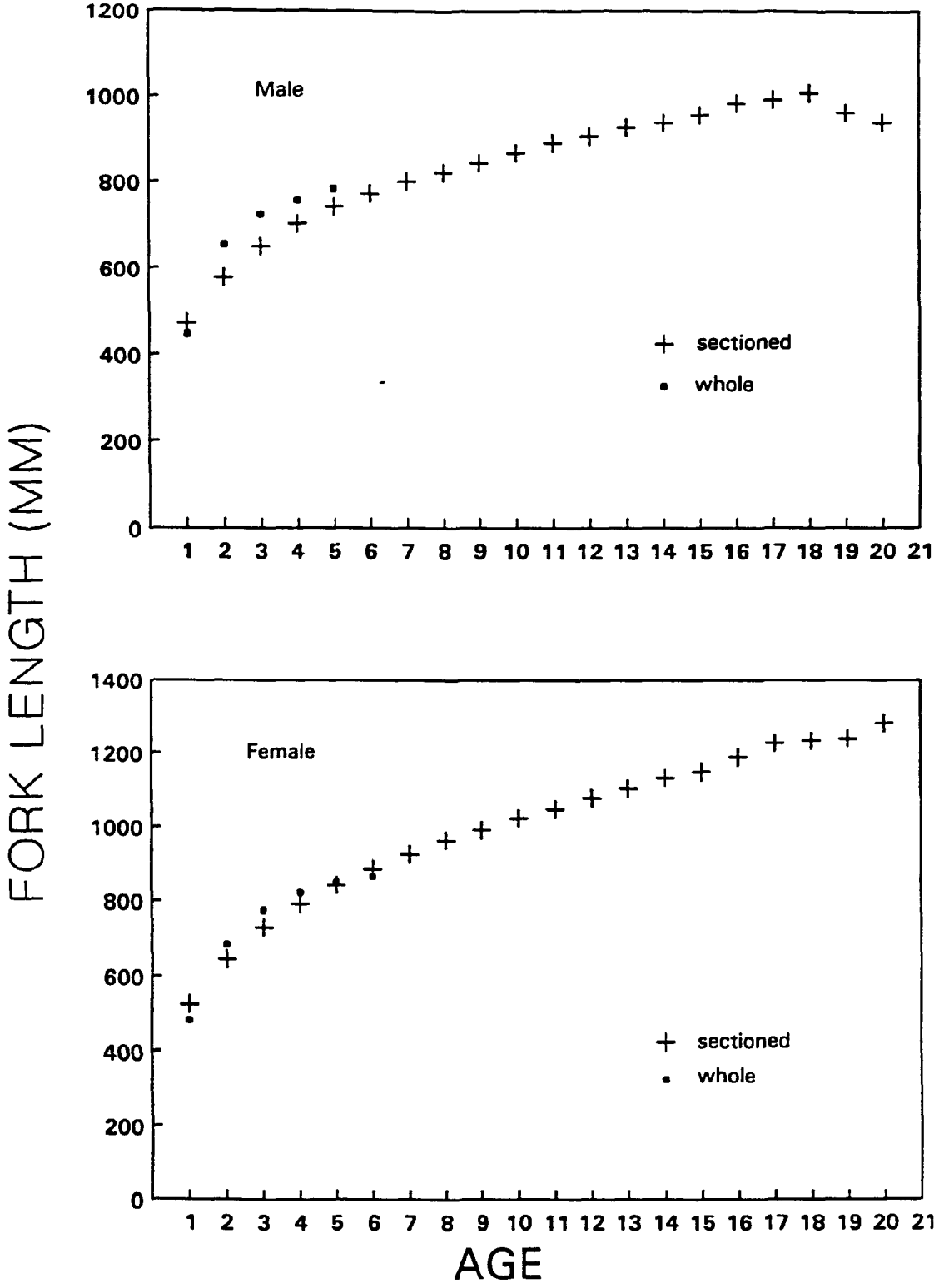


Figure 19. Mean back-calculated lengths at age from whole and sectioned otoliths for male and female king mackerel from North Carolina, 1987-1990.

Table 14. Mean lengths (mm FL) at capture and mean back-calculated lengths (mm FL) at ages from whole otoliths of males, females, and both sexes of king mackerel from North Carolina 1987-1990.

MALE

Age	N	Mean length at capture	Mean back-calculated lengths at successive annuli 1	2	3	4	5
1	37	533	439				
2	51	700	451	657			
3	48	754	456	658	729		
4	19	773	433	642	716	757	
5	2	800	407	607	685	739	783
	Total number		157	120	69	21	2
	Weighted mean		447	654	724	756	783
	Growth increment		447	205	72	42	43

FEMALE

Age	N	Mean length at capture	Mean back-calculated lengths at successive annuli 1	2	3	4	5	6
1	83	618	512					
2	117	727	465	677				
3	66	806	484	688	777			
4	46	842	480	686	775	826		
5	10	869	466	678	778	825	858	
6	4	883	475	766	739	788	834	867
	Total number		326	243	126	60	14	4
	Weighted mean		483	682	775	823	851	867
	Growth increment		483	209	89	51	36	33

SEXES COMBINED

Age	N	Mean length at capture	Mean back-calculated lengths at successive annuli 1	2	3	4	5	6
1	120	591	490					
2	168	719	461	671				
3	114	784	472	675	756			
4	65	822	466	673	758	806		
5	12	858	456	666	763	811	845	
6	4	883	475	655	739	788	834	867
	Total number		483	363	195	81	16	4
	Weighted mean		471	673	757	806	842	867
	Growth increment		471	207	83	48	37	33

Table 15. Mean lengths (mm FL) at capture and mean back-calculated lengths (mm FL) at ages from sectioned otoliths of males, females, and both sexes of king mackerel from North Carolina, 1987-1990.

MALE

Age	N	Mean length at capture	Mean back-calculated lengths at successive annuli																			
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0	0	0																			
2	2	765	594	741																		
3	11	798	546	672	756																	
4	19	800	504	631	712	774																
5	28	850	502	623	707	771	820															
6	30	842	490	604	683	741	788	827														
7	24	897	503	616	696	754	805	848	883													
8	27	874	490	588	663	720	765	806	844	876												
9	23	885	461	556	629	683	729	770	807	843	873											
10	31	900	443	545	615	671	715	757	794	828	861	889										
11	23	933	462	558	627	679	721	761	799	832	864	895	922									
12	13	944	440	534	600	656	701	738	774	809	841	873	904	932								
13	10	997	474	567	633	687	732	771	806	838	872	903	933	964	992							
14	8	980	437	527	599	649	692	728	766	801	830	860	888	914	940	965						
15	14	962	399	494	559	610	651	688	721	755	788	817	846	875	903	927	950					
16	9	1014	427	516	582	632	675	713	747	780	813	844	872	899	926	952	980	1004				
17	4	1016	375	481	550	604	646	686	721	755	785	816	844	870	900	930	960	988	1007			
18	6	1040	429	519	576	623	665	703	738	771	801	831	858	885	909	935	961	984	1008	1031		
19	1	1030	356	467	540	595	635	677	707	734	763	784	808	835	859	880	905	934	964	988	1013	
20	1	960	362	453	512	557	589	618	646	671	696	723	744	764	786	810	830	850	870	893	910	939
	Total number		284	284	282	271	252	224	194	170	143	120	89	66	53	43	35	21	12	80	24	1
	Weighted mean		472	577	650	702	742	772	800	822	844	868	890	906	927	937	956	984	992	1008	962	939
	Growth increment		105	105	74	56	45	40	36	34	32	30	28	28	27	26	26	24	22	23	21	28

Table 15. (Continued)

FEMALE

Age	N	Mean length at capture	Mean back-calculated lengths at successive annuli																			
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0	0	0																			
2	0	0	0	0																		
3	18	888	586	730	835																	
4	29	901	566	702	797	869																
5	46	928	543	677	773	846	903															
6	45	966	561	684	770	840	901	950														
7	34	1028	560	685	776	845	907	963	1011													
8	51	1066	545	669	756	827	888	944	996	1045												
9	33	1072	535	652	734	801	859	912	964	1012	1055											
10	63	1090	518	633	719	785	841	893	942	989	1035	1074										
11	36	1097	499	616	699	764	817	866	913	958	1001	1044	1083									
12	37	1126	509	622	701	762	814	861	905	950	994	1036	1076	1113								
13	18	1149	487	600	680	744	797	845	892	937	981	1022	1064	1104	1139							
14	26	1202	506	616	697	761	815	863	908	951	993	1035	1074	1113	1153	1190						
15	25	1141	461	570	644	705	754	800	840	882	920	957	992	1029	1065	1099	1131					
16	28	1192	481	585	664	724	776	821	862	904	943	982	1017	1052	1086	1120	1153	1183				
17	12	1277	480	591	1667	731	784	833	881	926	969	1010	1050	1089	1126	1163	1200	1236	1267			
18	10	1272	478	584	663	721	760	814	861	903	943	982	1021	1056	1092	1128	1165	1199	1232	1260		
19	9	1241	464	567	643	700	753	796	840	881	920	957	990	1022	1055	1086	1116	1147	1176	1204	1232	
20	3	1287	512	610	674	735	785	834	871	913	949	986	1018	1049	1082	1110	1143	1174	1205	1234	1262	1283
	Total number		523	523	523	505	476	430	385	351	300	267	204	168	131	113	87	62	34	22	12	3
	Weighted mean		525	644	729	792	843	887	927	964	993	1025	1049	1078	1104	1134	1150	1190	1227	1234	1240	1283
	Growth increment		525	119	85	66	56	50	47	45	43	40	38	37	36	35	33	32	31	28	28	21

Table 15. (Continued)

SEXES COMBINED

Age	N	Mean length at capture	Mean back-calculated lengths at successive annuli																		
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0	0	0																			
2	2	765	594	741																		
3	29	854	571	708	805																	
4	48	861	542	674	764	831																
5	74	894	528	657	748	817	872															
6	75	916	533	652	735	800	856	901														
7	58	974	537	657	743	807	865	915	958													
8	78	1004	526	641	724	790	846	896	944	987												
9	56	995	505	613	691	753	805	854	899	942	980											
10	94	1027	494	604	685	747	799	848	893	936	977	1013										
11	59	1033	485	593	671	730	780	825	868	909	948	986	1020									
12	50	1079	491	599	675	734	785	829	871	913	954	993	1032	1066								
13	28	1095	483	588	663	724	774	819	861	901	942	979	1017	1054	1086							
14	34	1150	490	595	674	735	786	831	874	916	955	993	1030	1066	1103	1137						
15	39	1077	439	543	614	671	717	760	797	836	873	906	940	974	1006	1037	1066					
16	37	1149	468	569	644	702	751	795	834	874	911	948	982	1015	1047	1079	1111	1139				
17	16	1211	454	564	638	699	749	796	841	883	923	961	999	1034	1069	1105	1140	1174	1202			
18	16	1185	460	560	630	684	731	773	815	854	890	925	960	992	1023	1056	1089	1119	1148	1174		
19	10	1220	453	557	632	689	741	784	827	866	904	940	971	1003	1036	1065	1095	1126	1155	1182	1210	
20	4	1205	475	571	634	691	736	780	815	853	886	921	950	977	1008	1035	1064	1093	1121	1149	1174	1196
	Total number		807	807	805	776	728	654	579	521	443	387	293	234	184	156	122	83	46	30	14	4
	Weighted mean		506	620	702	761	808	848	884	918	945	977	1000	1030	1053	1079	1094	1138	1166	1174	1200	1196
	Growth increment		506	114	81	63	52	47	43	42	39	37	35	34	33	32	31	30	29	27	27	23

first three years, after which they gradually decreased. Frequency distributions of the back-calculated size at age showed greater overlap between the sizes of males and females at age 1 than at older ages (Figures 20 and 21). The total length frequency distribution of the females was shifted to the right of that of the males at older ages.

Von Bertalanffy growth equations were generated for each sex and the combined data sets based on mean back-calculated lengths at age from whole and sectioned otoliths (Table 16). Females grew more rapidly and reached a larger theoretical size than males (Figure 22). Asymptotic lengths calculated from sectioned otoliths were larger than those from whole otoliths.

Age varied greatly within a single length group (Table 17). For example, at 901-950 mm males were ages 6 to 18 and females were ages 3 to 12. Age 1 males were all under 701 mm, age 2 males were all between 601 and 800 mm, and all but one age 3 male were between 651 and 850 mm. In contrast, females ranged from 451 to 800 mm at age 1, 601 to 900 mm at age 2, and except for two fish, 701 to 950 mm at age 3. Female king mackerel were 250-300 mm larger at age than males after age 3. Annual age-length keys are presented in Appendix B.

In addition to the standard age validation techniques utilized, a subsample of tagged king mackerel were injected with tetracycline which is known to result in a fluorochrome label on bony parts of fish. None of these fish have been returned.

Reproductive Biology

Females were more abundant than males in all size classes sampled, but this varied with season. The overall sex ratio male to female for the 13,064 king mackerel sampled at tournaments 1986-1990 was 1:2 (Table 18). Female king mackerel were dominant in all size classes. The proportion of females at lengths greater than 1,050 mm was 96% and 100% at lengths greater than 1,250 mm. The proportion of males to females was closest to 1:1 between 750 and 900 mm. The degree of dominance varied with size class and season (Table 19). During peak spawning, females dominated each size class, with the largest percentage of males 38% at 850-900 mm. During the fall, sex ratio more closely approached 1:1, with the proportion of males between 750 and 900 mm at 51%. The proportion of males

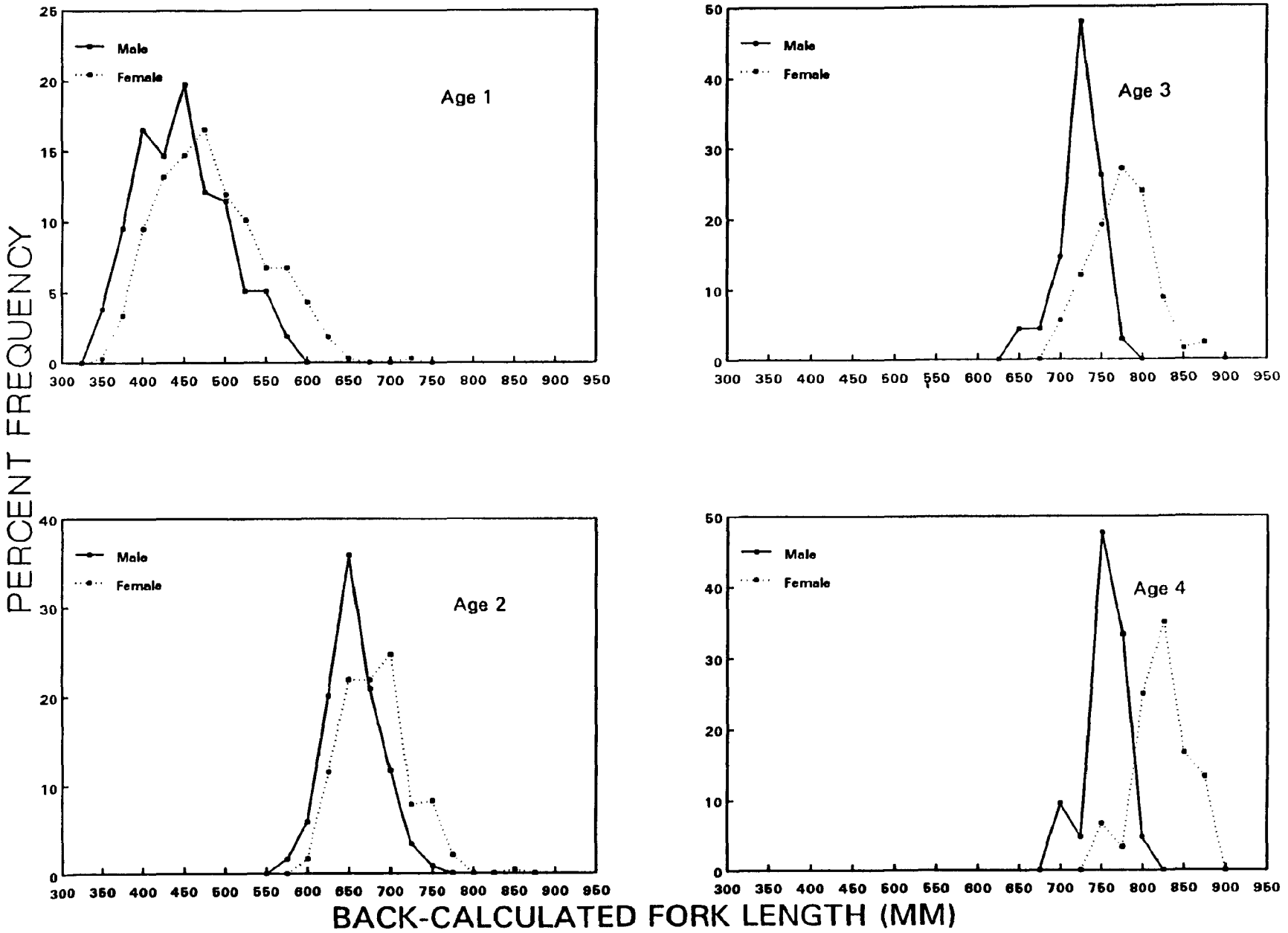


Figure 20. Frequency distributions of the back-calculated length (FL, mm) at ages 1-4 for male and female king mackerel from whole otoliths.

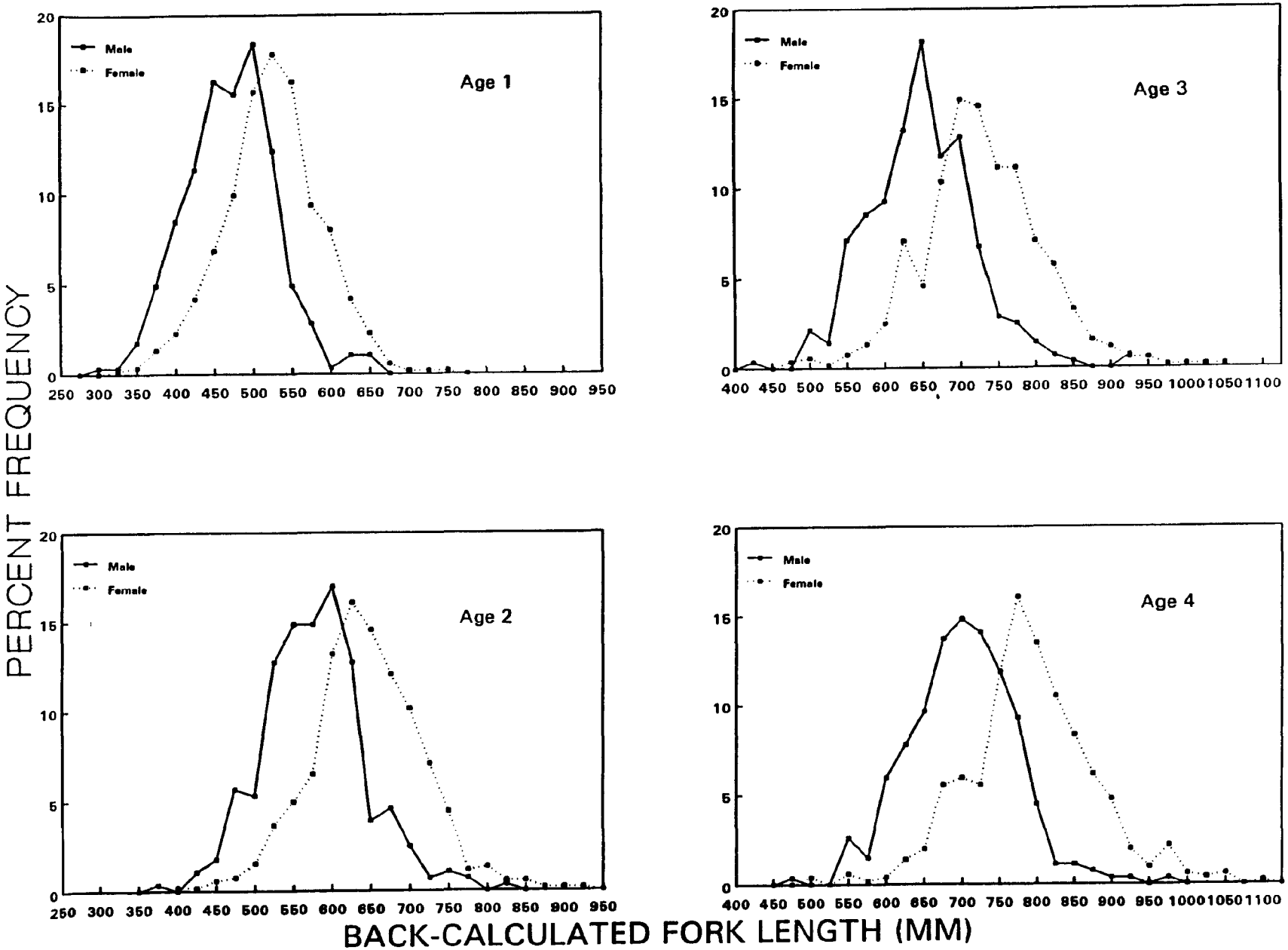


Figure 21. Frequency distributions of the back-calculated length (FL, mm) at ages 1-4 for male and female king mackerel from sectioned otoliths.

Table 16. Von Bertalanffy growth parameters of king mackerel from North Carolina, 1986-1990.

	L_∞ (mm FL)	K	t_0 (yr)
Whole			
Female	897	0.568	-0.49
Male	770	1.065	0.21
Combined	859	0.659	-0.29
Sectioned			
Female	1,370	0.087	-8.67
Male	1,153	0.065	-13.50
Combined	1,413	0.061	-10.72

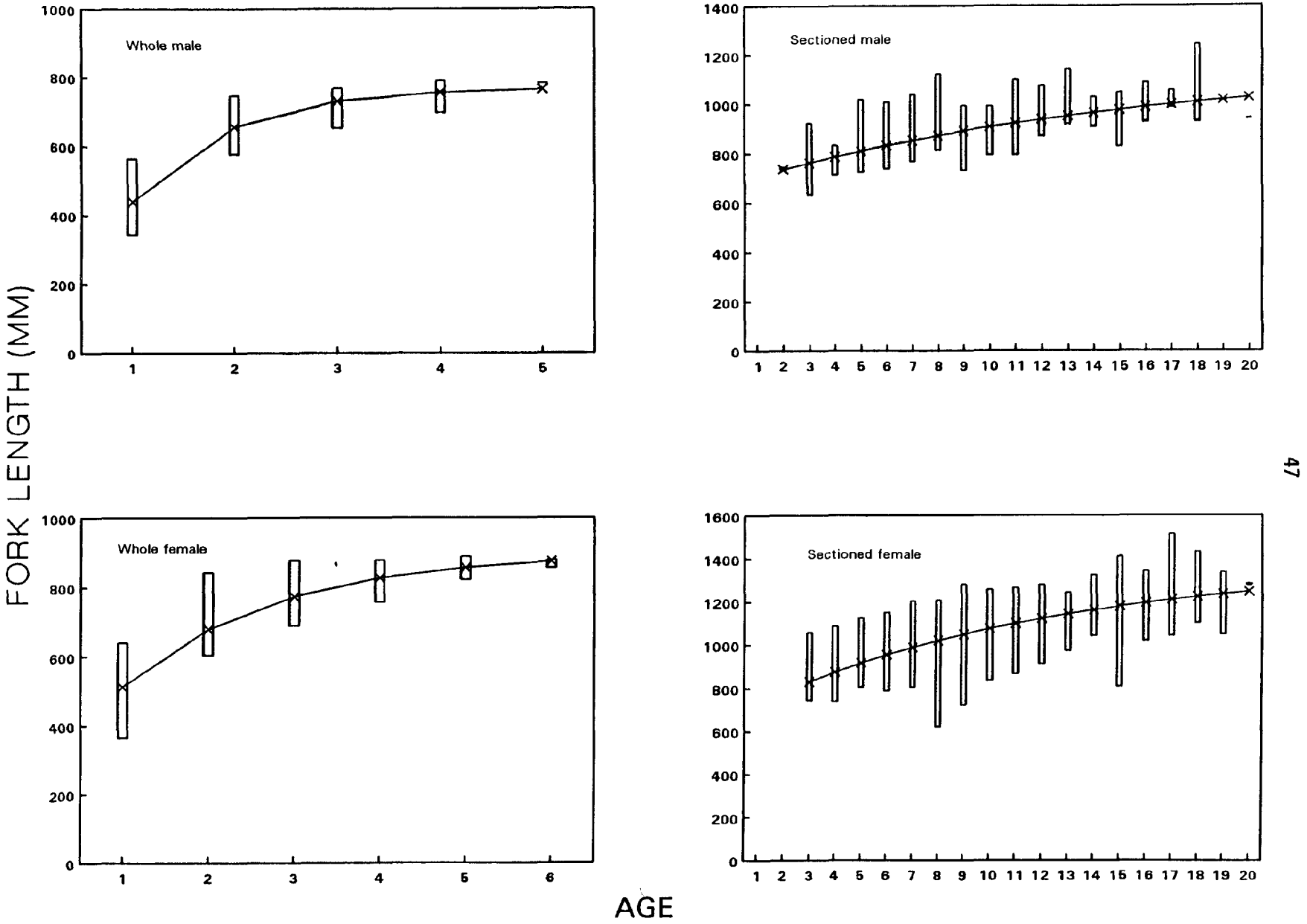


Figure 22. Von Bertalanffy growth curves for male and female king mackerel from whole and sectioned otoliths. Bars indicate the range in size at age.

Table 17. Length composition, in percent, of male and female king mackerel by age group in North Carolina, 1987-1990.

MALE

Length group (mm FL)	ANNULI 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	Total
401-450	100.0																										2
451-500	100.0																										12
501-550	100.0																										10
551-600	100.0																										8
601-650	55.6	44.4																									9
651-700	3.7	81.5	14.8																								27
701-750		46.2	40.4	5.8	3.8	1.9			1.9																		52
751-800		4.2	38.9	37.5	6.9	6.9	1.4		1.4		1.4							1.4									72
801-850			8.1	14.5	24.2	24.2	9.7	8.1	3.2	6.4					1.6												62
851-900					8.2	11.8	14.1	21.2	12.9	16.5	8.2	5.9			1.2												85
901-950						3.9	3.9	9.8	11.8	23.6	13.7	5.9	7.8	5.9	7.8	3.9		2.0									51
951-1000			2.6		2.6		10.3	5.1	2.6	7.7	17.9	7.7	5.1	7.7	10.3	5.1	5.1	5.1		5.1							39
1001-1050					3.3	3.3	6.7		3.3	3.3	6.7	10.0	13.3	10.0	13.3	13.3	3.3	6.7	3.3								30
1051-1100													33.3			33.3	33.3										3
1101-1150								25.0			25.0		25.0			25.0											4
1151-1200																											0
1201-1250																		100.0									1
Total																											467

FEMALE

Length group (mm FL)	ANNULI 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	Total
451-500	100.0																										3
501-550	100.0																										5
551-600	100.0																										23
601-650	87.9	12.1																									33
651-700	45.7	54.3																									46
701-750	1.4	83.3	13.9						1.4																		72
751-800	1.9	41.5	39.6	17.0																							53
801-850		5.3	34.0	39.4	12.8	3.2	1.1		2.1						2.1												94
851-900		1.2	18.3	24.4	26.8	18.3	3.7	1.2	1.2	2.5	1.2				1.2												82
901-950			9.1	10.9	16.4	21.8	7.3	10.9	9.1	5.5	3.6	3.6			1.8												55
951-1000					2.2	19.6	19.6	13.0	10.8	8.7	10.9	6.5	6.5	2.2													46
1001-1050				3.3	4.9	11.5	6.6	18.0	4.9	24.6	9.9	8.2	1.6		1.6	3.3					1.6						61
1051-1100			1.4	4.1	2.7	8.2	11.0	17.8	6.8	15.1	12.3	5.5	1.4	1.4	4.1	4.1	2.7		1.4								73
1101-1150			1.2	1.2	1.2	4.7	4.7	5.8	9.3	19.8	9.3	11.6	10.4	8.1	5.8	2.3	2.3	2.3									86
1151-1200					1.4	2.9	4.3	12.9	11.4	12.9	4.3	14.3	7.1	7.1	4.3	12.9		1.4	1.4		1.4						70
1201-1250							1.9	9.4	3.8	11.4	7.5	7.5	7.5	13.2	9.4	9.4	5.7	3.8	5.7	1.9			1.9				53
1251-1300									5.9	5.9	5.9	11.8		11.8	14.7	14.7	2.9	8.8	5.9	8.8	2.9						34
1301-1350												12.5		12.5		12.5	25.0	12.5	25.0								8
1351-1400														16.7		16.7		16.7		16.7			16.7			16.7	6
1401-1450															25.0		25.0	25.0			25.0						4
1451-1500																	50.0					50.0					2
1501-1550																	50.0						50.0				2
Total																											911

Table 18. Sex ratio of king mackerel by 50 mm length class sampled at king mackerel tournaments in North Carolina, 1986-1990.

Length class (mm FL)	Male (N=4,225) N	%	Female (N=8,839) N	%	Total N=13,064
51-100	2	67	1	33	3
101-150	0	0	3	100	3
151-200	0	0	0	0	0
201-250	0	0	1	100	1
251-300	0	0	3	100	3
301-350	0	0	0	0	0
351-400	1	100	0	0	1
401-450	0	0	0	0	0
451-500	7	32	15	68	22
501-550	50	46	58	54	108
551-600	45	30	105	70	150
601-650	33	22	119	78	152
651-700	91	31	204	69	295
701-750	297	37	514	63	811
751-800	579	44	729	56	1,308
801-850	827	45	1017	55	1,844
851-900	1103	47	1247	53	2,350
901-950	725	38	1174	62	1,899
951-1000	300	23	982	77	1,282
1001-1050	113	12	833	88	946
1051-1100	25	4	661	96	686
1101-1150	18	3	508	97	526
1151-1200	8	3	310	97	318
1201-1250	1	1	183	99	184
1251-1300	0	0	91	100	91
1301-1350	0	0	43	100	43
1351-1400	0	0	20	100	20
1401-1450	0	0	8	100	8
1451-1500	0	0	4	100	4
1501-1550	0	0	4	100	4
1851-1900	0	0	1	1000	4
2301-2350	0	0	1	1000	4
Ratio 1:2					

Table 19. Sex ratios of king mackerel by length class and season sampled from North Carolina king mackerel tournaments 1986-1990. [summer (May, June, July, August), fall (September, October, November)].

Length class (mm FL)	Summer (N=4,411)				Fall (N=8,653)			
	Male		Female		Male		Female	
	N	%	N	%	N	%	N	%
51-100	0	0	0	0	2	67	1	33
101-150	0	0	0	0	0	0	3	100
151-200	0	0	0	0	0	0	0	0
201-250	0	0	0	0	0	0	1	100
251-300	0	0	2	100	0	0	1	100
301-350	0	0	0	0	0	0	0	0
351-400	1	100	0	0	0	0	0	0
401-450	0	0	0	0	0	0	0	0
451-500	0	0	2	100	7	35	13	65
501-550	3	60	2	40	47	46	56	54
551-600	14	42	19	58	31	26	86	74
601-650	22	23	75	77	11	20	44	80
651-700	51	28	133	72	40	36	71	64
701-750	140	35	260	65	157	38	254	62
751-800	223	37	384	63	356	51	345	49
801-850	235	34	456	66	592	51	561	49
851-900	288	38	460	62	815	51	787	49
901-950	196	36	349	64	529	39	825	61
951-1000	78	22	277	78	222	24	705	76
101-1050	29	12	203	88	84	12	630	88
1051-1100	7	4	186	96	18	4	475	96
1101-1150	6	4	144	96	12	3	364	97
1151-1200	3	4	77	96	5	2	233	98
1201-1250	1	2	40	98	0	0	143	100
1251-1300	0	0	27	100	0	0	64	100
1301-1350	0	0	11	100	0	0	32	100
1351-1400	0	0	5	100	0	0	15	100
1401-1450	0	0	2	100	0	0	6	100
1451-1500	0	0	0	0	0	0	4	100
1501-1550	0	0	0	0	0	0	4	100
1851-1900	0	0	0	0	0	0	1	100
2301-2350	0	0	0	0	0	0	1	100
Total	1297		3114		2928		5725	
Seasonal ratio		1:2.4				1:2		

to females approximated 1:1 between age 5 and age 17 (Table 20). Fish younger than age 5 were predominately female, and fish 21 years and older were all female.

King mackerel have a prolonged spawning season off North Carolina that peaks June through August. Maturity stages of male and female king mackerel were determined for 2,157 fish from June through October, 1988 (Figure 23) and 3,094 fish from June through October, 1990 (Figure 24). In both 1988 and 1990, ripe males were found from June through September and most frequently occurred in June and July 1988 and in June and August 1990. Spent males occurred from June through October, but were most prevalent in September and October. Ripe females occurred June through September and were most prevalent June through August. Spent females occurred July through October and predominated in September and October.

Mature king mackerel dominated all samples (Tables 21 and 22). The smallest mature male observed was 451 mm. Fifty percent of the males were mature in the 501-550 mm size class and 100% were mature in fish > 650 mm. Spent males were first observed in the 701-750 mm size class. All male king mackerel age 2+ were mature (Table 23). No fish age 0 or 1 were sampled.

Virtually all females sampled were mature. The smallest mature female was 501 mm. Fifty percent of the females were mature in the 501-550 mm size class, and except for a few anomalies, 100% were mature in fish > 800 mm. Spent females were first observed in the 601-650 mm size class. All female king mackerel age 2+ were mature (Table 23). No fish age 0 or 1 were sampled.

DISCUSSION

Migration

Some movement of king mackerel occurs between North Carolina and Florida, but the majority of fish tagged in North Carolina waters were recaptured there. In the present study, 74% of the recaptures were in North Carolina and 18% were in Florida. Over 1,000 king mackerel were tagged off North Carolina by Fable (1987). Two were recaptured in Florida and the rest (12) recaptured in North Carolina. Williams and Godcharles (1984) tagged 108 fish off North Carolina. Seven of the eight recaptures occurred in North Carolina (May through December),

Table 20. Sex ratio of king mackerel by age sampled at king mackerel tournaments in North Carolina 1986-1990.

Age (years)	Male N=3,055 N	Male N=3,055 %	Female (N=3,712) N	Female (N=3,712) %	Total (N=6,767)
1	30	29	73	71	103
2	114	30	267	70	381
3	213	33	437	67	650
4	219	34	434	66	653
5	348	48	383	52	731
6	257	45	314	55	571
7	217	48	239	52	456
8	242	57	184	43	426
9	230	54	195	46	425
10	223	57	170	43	393
11	169	50	170	50	339
12	158	54	135	46	293
13	97	45	119	55	216
14	101	57	77	43	178
15	124	47	140	53	264
16	68	45	82	55	150
17	48	42	65	58	113
18	91	65	49	35	140
19	29	36	51	64	80
20	78	76	25	24	103
21	0	0	77	100	77
22	0	0	4	100	4
23	0	0	16	100	16
24	0	0	0	0	0
25	0	0	0	0	0
26	0	0	5	100	5

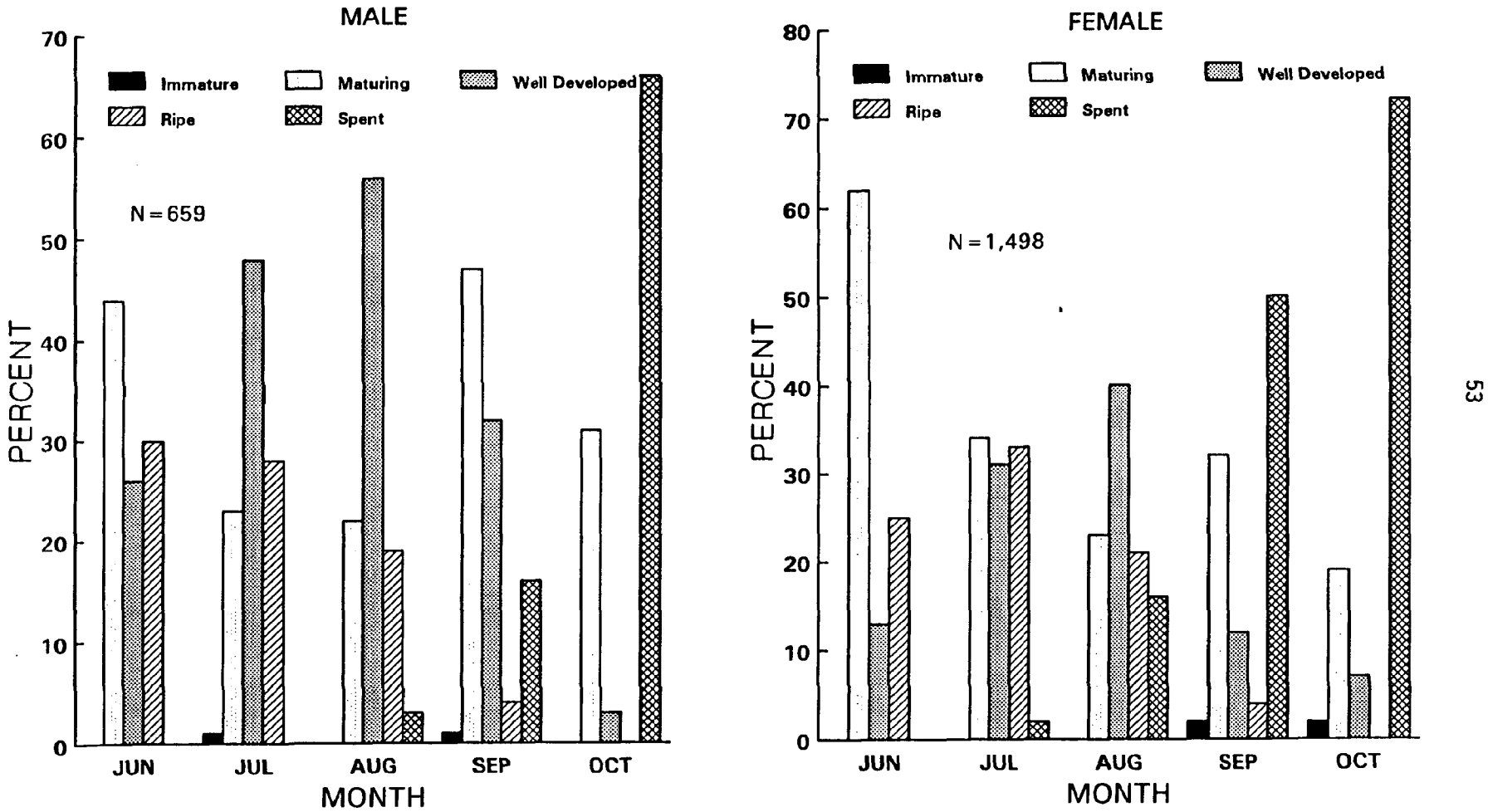


Figure 23. Reproductive stages of male and female king mackerel sample June through October 1988 at North Carolina king mackerel tournaments.

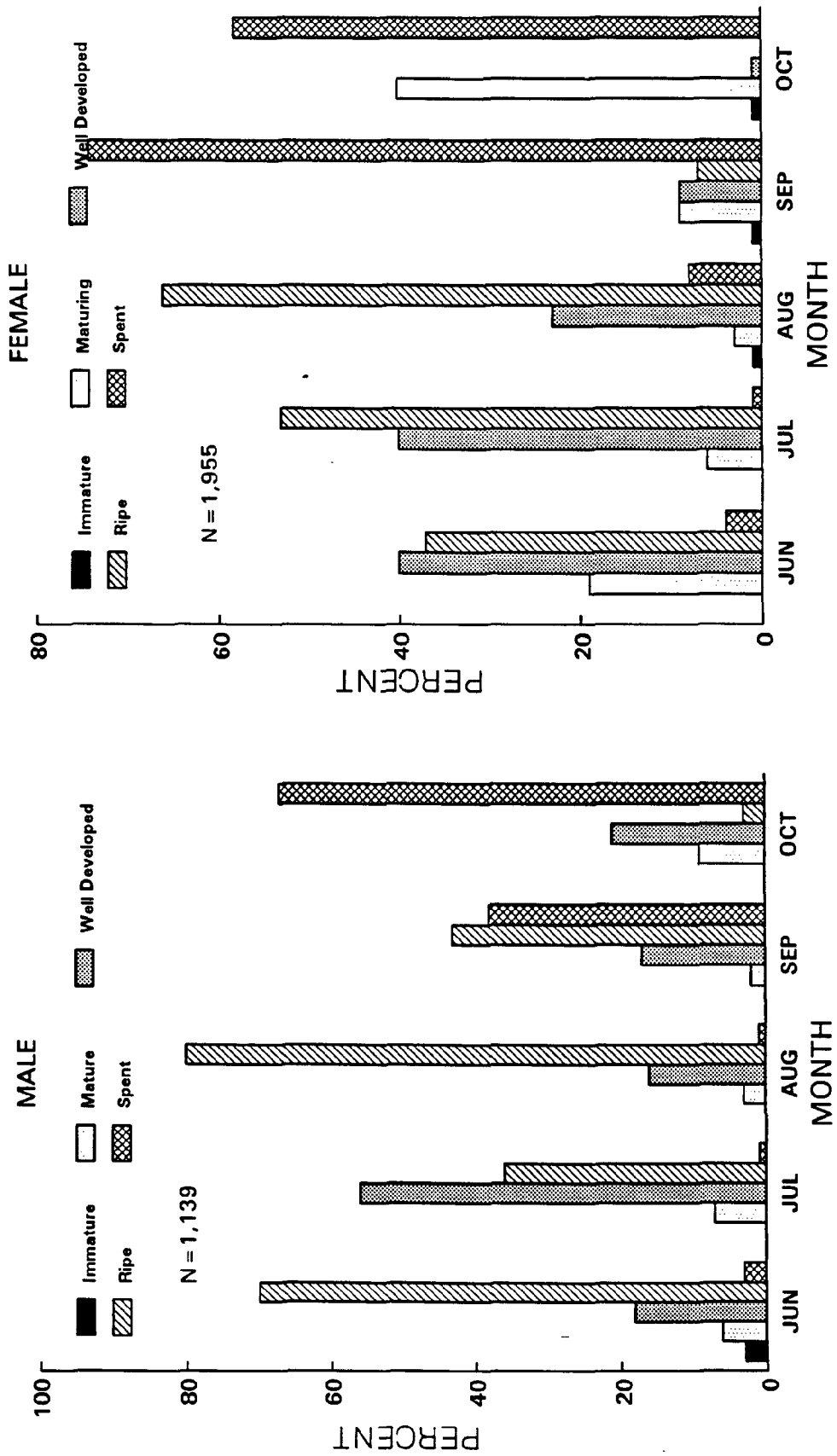


Figure 24. Reproductive stages of male and female king mackerel sampled June through October 1990 at North Carolina king mackerel tournaments.

Table 21. Percent maturity stages for male king mackerel by 50 mm size class. Greatest percentage of samples were in taken September and October, at the end of the spawning season.

Size class (mm, FL)	N	Percent maturity stage				
		Immature	Maturing	Well developed	Ripe	Spent
451-500	2	50.0	50.0			
501-550	12	25.0	75.0			
551-600	1	100.0				
601-650	4	25.0	50.0		25.0	
651-700	22		40.9	45.5	13.6	
701-750	91		12.1	27.5	38.5	22.0
751-800	283		8.5	20.1	46.3	25.1
801-850	340		12.1	26.2	36.2	25.6
851-900	482		18.7	24.3	27.0	30.1
901-950	333		23.1	29.4	20.1	27.3
951-1,000	136		16.2	23.5	26.5	33.8
1,001-1,050	65		27.6	20.0	26.2	26.2
1,051-1,100	10		20.0	40.0	30.0	10.0
1,151-1,200	5			40.0	20.0	0.0
1,101-1,150						
1,201-1,250	4		25.0	25.0	25.0	25.0

Table 22. Percent maturity stages for female king mackerel by 50 mm size class. Greatest percentage of samples were taken in September and October, at the end of the spawning season.

Size class (mm, FL)	N	Immature	Maturing	Well developed	Ripe	Spent
451-500	1	100.0				
501-550	15	26.7	73.3			
551-600	8	62.5	37.5			
601-650	18	5.6	50.0	27.8	5.6	11.1
651-700	50	2.0	38.0	26.0	26.0	8.0
701-750	193	2.1	40.4	20.7	13.5	23.3
751-800	258	1.2	26.4	17.1	25.2	30.2
801-850	487		21.6	17.9	27.9	32.7
851-900	546	0.4	21.1	16.7	24.7	37.2
901-950	467		22.1	16.3	15.4	46.3
951-1,000	414	0.2	19.3	13.5	15.0	51.9
1,001-1,050	313		19.8	11.8	13.1	55.3
1,051-1,100	279	0.4	16.1	17.2	15.8	50.5
1,101-1,150	174		14.4	14.4	21.3	50.0
1,151-1,200	104		3.9	18.3	23.1	54.8
1,201-1,250	63		12.7	7.9	20.6	58.7
1,251-1,300	30		3.3	20.0	16.7	60.0
1,301-1,350	11			9.1	9.1	81.8
1,351-1,400	7		14.3	14.3	14.3	57.1
1,401-1,450	3				33.3	66.7
1,451-1,500	2					100.0
1,501-1,550	1					100.0

Table 23. King mackerel age at maturity. No immature fish were sampled. No reproductive stages were sampled for males greater than age 14 and females greater than age 16.

	MALE				FEMALE			
Age	Maturing	Mature (ripe)	Running ripe	Spent	Maturing	Mature (ripe)	Running ripe	Spent
1								
2			1			1	2	1
3			1		1	1	1	1
4			2			1	1	1
5			1		1	1	1	
6					1	1	2	
7						1		
8					1	1	2	1
9								
10			1			2		1
11	1		1			1	1	
12						1		
13								
14			1			1		
15								
16								1
Total	1	0	8	0	4	12	10	6

and one occurred in Florida in May. Fable (1988) concluded that fish that were tagged off North Carolina were either recovered there or off the east coast of Florida in warm months.

Although the present study did not demonstrate reproductive isolation, results do provide evidence for a separate migratory group of king mackerel in North Carolina waters with some degree of mixing with more southern fish. Williams and Godcharles (1984) were able to distinguish a Gulf and an Atlantic stock of king mackerel from tagging in Florida. They concluded that north of Florida, especially off the Carolina coasts, the Atlantic stock probably occurred year-round. Williams and Godcharles (1984) thought it was likely that more stocks would be discovered through more extensive tagging in areas other than Florida and through other methods such as electrophoresis. Fable (1988) found tagging evidence of two stocks (migratory groups) of king mackerel in the Gulf of Mexico and one stock on the Atlantic Coast.

Previous tagging studies off South Carolina (William and Godcharles 1984) demonstrated that king mackerel movement was southward in summer and northward in fall, contrary to expectations based on seasonal temperatures. Williams and Godcharles (1984) also found that fish tagged in the summer off southeast Florida moved north and those tagged in the winter moved south and into the Gulf. Fish tagged off South Carolina were recaptured off Florida only during the warm months, and never during the winter months, even though fishing effort in eastern Florida is greatest during the winter. Sutter et al. (1991) also found Atlantic stock fish traveled south from South Carolina during the spring and summer and northward in the late summer and early fall. Results from the present study support these findings with 12 of the 15 Florida recaptures occurring in the spring and summer, and only three in the fall and winter.

The present study agreed with Sutter et al. (1991) in that size of king mackerel at release did not influence distance or direction traveled nor probability of recapture. Fish recaptured off Florida had the same size range as 71% of the fish recaptured off North Carolina. Length range when tagged of recaptured fish was between 450 and 1,150 mm, the same range as 99% of all tagged fish. Although Sutter et al. (1991) found that distance traveled was correlated with number of days at large, the present study found no correlation. Some of

the fish at large the longest were recaptured very near their release site. Days at large for fish which traveled the furthest (Florida) ranged from 105 to 1,325 days.

Results from the tag testing study were inconclusive. Only two double tagged fish were recaptured, one with only a dart tag and the other with only an internal anchor tag. Fable (1990) found internal anchor tags yielded a 8.1% return rate, whereas single-barb dart tags yielded only a 1.1% return rate. Double tagging by Fable (1990) found double-barb tags to be somewhat less effective than internal anchor tags. However, since dart tags can be inserted into fish still in the water, it is preferred for recreational angler taggers.

Age and Growth

Van Oosten (1929) established the following criteria that must be met before check marks on scales or bones can be considered annuli: (1) scales or bones must remain constant in number and identity throughout the life of the fish, (2) growth of the scale or bone must be proportional to the overall growth of the fish, (3) growth check marks must be formed at approximately the same time each year, and (4) back-calculated lengths should agree with empirical lengths of younger age groups. The number of otoliths remains constant in king mackerel, and thus fulfills the first criteria.

Previous age and growth studies on king mackerel have attempted to validate the use of otoliths (Beaumariage 1973, Johnson et al. 1983, Manooch et al. 1987, Collins et al. 1989, Sturm and Salter 1990). All of these studies except Collins et al. (1989) based their age determinations on whole otoliths. Johnson et al. (1983) found a 96% agreement and Manooch et al. (1987) found an 87% agreement between whole and sectioned otoliths and concluded that the use of whole otoliths was valid for ageing king mackerel. Comparisons by Collins et al. (1989), however, resulted in only a 47% agreement and the ages were significantly different. They suggested that the higher agreement found by Johnson et al. (1983) and Manooch et al. (1987) might be due to differences in the opacity and appearance of otoliths from Gulf of Mexico and Atlantic king mackerel. The present study used sectioned otoliths for larger fish based on Collins et al.'s (1989) conclusion that they gave a more accurate age than whole otoliths.

A stronger correlation between otolith radii and fish lengths was reported by previous investigators (Johnson et al. 1983, Manooch et al. 1987, Collins et al. 1989) than found in our study. These studies used least squares regressions of power curves, whereas the present study used a least squares linear regression. Unlike Collins et al. (1989), the present study found that correlations were stronger for whole otoliths (especially from males) than sectioned otoliths. The low correlations found in our study are troublesome and will be investigated further as more data are collected.

Marginal increment analysis indicated that annulus formation probably occurs in late spring or early summer, based on whole otoliths, and summer to early fall based on sectioned otoliths; however, otoliths were not collected in sufficient numbers during all months of the year. Collins et al. (1989) also reported a peak in annual ring-formation in August to September from sectioned otoliths. They found a multimodal distribution of the monthly percentages of whole otoliths with opaque margins suggesting non-annual ring formation or reading errors. Beaumariage (1973) examined whole otoliths of king mackerel from Florida and found most otolith margins opaque during April-June. Manooch et al. (1987), also using whole otoliths, found a peak in ring formation during February-May, but also found ring formation in September for some fish taken off northwest Florida, and suggested the difference may be due to separate spawning groups in the Gulf of Mexico. Thus, it appears that analyses of whole otoliths result in an earlier time of annulus formation than do sectioned otoliths. Although king mackerel were chemically marked in the tag and release portion of this study, none have been recaptured to date. Chemical marking should be continued in order to provide direct evidence of annual ring formation.

Back-calculated lengths at age differ between various studies and may be due to differences in back-calculation techniques (power curve, linear equation, direct proportion), use of whole or sectioned otoliths, geographical sampling range, or study time period. Mean back-calculated lengths derived from whole otoliths in the present study were most similar to those of Beaumariage (1973) and Collins et al. (1989) (Table 24). Females were larger than males at each age in all studies. Comparisons of back-calculated lengths at age derived from sectioned otoliths (Table 25) revealed slightly larger sizes at age for both males and females in the present study than reported by Collins et al. (1989).

Table 24. Mean back-calculated lengths (mm FL) at age for males, females, and sexes combined of king mackerel derived from whole otoliths.

	Male						Female						Combined	
Age	Beau-mariage (1973)	Johnson et al. (1983)	Manooch et al. (1987)	Collins et al. (1989)	Sturm and Salter (1990)	NCDMF	Beau-mariage (1973)	Johnson et al. (1983)	Manooch et al. (1987)	Collins et al. (1989)	Sturm and Salter (1990)	NCDMF	Collins et al. (1989)	NCDMF
1	457	414	415	453	437	447	491	434	425	475	418	483	418	471
2	643	613	614	649	576	654	703	652	635	673	586	682	633	673
3	705	689	698	719	660	724	793	747	738	764	680	775	730	757
4	752	734	756	760	709	746	857	807	799	817	768	823	786	806
5	795	777	812	788	793	783	928	854	866	861	851	851	833	842
6	822	809	863	803	859		986	899	929	901	931	867	872	867
7	839	851	903	827			1,033	939	988	943	1,001		912	
8			948	853					1,035	992	1,056		961	
9			989	871					1,094	1,022			984	
10			1,021						1,137	1,054			1,048	
11			1,045						1,174	1,073			1,067	
12									1,201	1,077			1,077	
13									1,235					
14									1,269					

Table 25. Mean back-calculated lengths (mm FL) at age derived from sectioned otoliths.

	Male		Female		Sexes combined	
Age	Collins et al. (1989)	NCDMF	Collins et al. (1989)	NCDMF	Collins et al. (1989)	NCDMF
1	426	472	486	525	497	506
2	566	577	635	644	638	620
3	639	650	716	729	712	702
4	689	702	772	792	763	761
5	724	742	817	843	802	808
6	753	772	852	887	833	848
7	779	800	886	927	864	884
8	801	822	917	964	892	918
9	822	844	949	993	920	945
10	839	868	975	1,025	943	977
11	857	890	1,002	1,049	964	1,000
12	875	906	1,017	1,078	975	1,030
13	896	927	1,032	1,104	989	1,053
14	914	937	1,064	1,134	1,020	1,079
15	916	956	1,110	1,150	1,060	1,094
16	937	984	1,118	1,190	1,086	1,138
17		992	1,120	1,227	1,124	1,166
18		1,008	1,126	1,234	1,130	1,174
19		962	1,100	1,240	1,102	1,200
20		939	1,152	1,282	1,154	1,196
21			1,192		1,194	

Lengths at ages greater than one derived from sectioned otoliths were generally less than those from whole otoliths.

Comparison of von Bertalanffy growth parameters revealed that L_∞ was larger for females than males in all studies (Table 26). As in the present study, Collins et al. (1989) derived larger values of L_∞ from sectioned otoliths than from whole otoliths. Values of K were larger based on whole otoliths from our study than all other areas, suggesting faster growth in the northern part of the range of king mackerel.

Older king mackerel were found in the present study than in previous studies. The oldest fish aged by Collins et al. (1989) who also used sectioned otoliths was an age 21 female (1,192 mm) compared with nine females ranging from 21 to 26 (1,030-1,510 mm) in the present study. Manooch et al. (1987) and Johnson et al. (1983) reported maximum age of 14, based on whole otoliths from Gulf of Mexico fish. Collins et al. (1989) suggested that these differing results might be due to separate groups of king mackerel with different life history characteristics or to differences in techniques.

The importance of age validation was thoroughly discussed by Beamish and McFarlane (1983). Errors in ageing can result in overestimates of mortality, incorrect growth rates, and large errors in estimates of stock production. Annual stock assessments of king mackerel have relied on the various age and growth studies reported herein, as well as age-length keys derived from the present study. None of these age and growth studies have successfully validated an ageing technique for king mackerel. Thus, there is a clear need to continue the present ageing study, not only to validate successfully our ageing technique, but also to provide data needed for annual stock assessments. This work should include validating the use of sectioned otoliths, determining time of annulus formation through marginal increment analysis, and documenting the formation of a single annual mark through our mark-recapture study.

Reproductive Biology

The present study found a greater proportion of female to male king mackerel. Sturm and Salter (1990), who had similar results, speculated that more females were hatched, mortality was higher in males, and/or males grew slower.

Table 26. Comparison of von Bertalanffy growth parameters from whole and sectioned otoliths of king mackerel.

		North Carolina	Southeastern United States			Gulf of Mexico	Trinidad
Parameters		NCDMF	Collins et al. (1989)	Beaumariage (1973)	Johnson et al. (1983) (excluding LA)	Manooch et al. (1987)	Sturm and Salter (1990)
Whole otoliths							
Male	L_∞	770	853	903	965	1,113	1,123
	K	1.065	0.517	0.350	0.280	0.208	0.180
	t_o	0.21	-0.53	-2.50	-1.17	-1.48	-1.79
Female	L_∞	897	1,122	1,243	1,067	1,417	1,401
	K	0.568	0.228	0.210	0.290	0.136	0.150
	t_o	-0.49	-1.66	-2.40	-0.97	-1.98	-1.52
Sectioned otoliths							
Male	$L\infty$	1,153	942				
	K	0.065	0.192				
	t_o	-13.50	-2.501				
Female	$L\infty$	1,370	1,208				
	K	0.087	0.124				
	t_o	-8.670	-3.745				

Behavioral differences or gear selectivity could also explain dominant female numbers. Slower growing males would recruit to the hook-and-line fishery later and thus would bias sex ratio towards the larger, faster growing females. All samples in the present study were collected at king mackerel tournaments. Targeting this fishery produced high numbers of samples and provided an opportunity to work closely with king mackerel recreational fishermen, however, a bias towards larger fish did exist. Most of the small fish were discarded, released, or kept for personal use. The hook-and-line fishery is directed towards large female fish. Even at the same sizes, females frequently outnumbered males. When dealing with larger fish, this is to be expected since females grow faster and live longer. Trent et al. (1983) also found females to dominate catches from Texas to North Carolina with the degree of dominance relative to fish size.

King mackerel in North Carolina spawn during a protracted season. Ripe males were found in all months sampled (June through October), and ripe females were found June through September. Finucane et al. (1986) demonstrated that the seasonal progression of mean gonadosomatic indices (GSI) and egg diameters (ES) in king mackerel indicated a prolonged spawning season (May through September) off the Carolinas. Finucane et al. (1986) also concluded that king mackerel exhibited serial spawning because multimodal ED distributions and highest coefficients of variation for GSIs occurred during the spawning months. Beaumariage (1973) concluded that multiple spawning was indicated by successive increases in vitellogenic oocyte size during the summer. He also correlated gonadal development with seasonal change in photoperiod suggesting extended spawning throughout the summer in Florida. Seasonal distribution of larval king mackerel in the south Atlantic support the occurrence of protracted spawning off North Carolina (Collins and Stender 1987, DeVries et al. 1990).

The peak spawning period for king mackerel off North Carolina occurs during June through August. Ripe males and females were found June through October, but the highest percentage were found June through August. Finucane et al. (1986) found the highest GSIs and EDs for female king mackerel off the Carolinas during July. Beaumariage (1973) found peak spawning in Florida occurred June through September. Marginal increment analyses from the present study suggested annulus formation for king mackerel in North Carolina occurring in late spring or early

summer based on whole otoliths and summer to early fall based on sectioned otoliths. This time frame correlates well with peak spawning period.

Length at maturation was difficult to determine because of a limited sample of small fish < 600 mm. In North Carolina waters during September and October, > 70% of the female king mackerel > 600 mm were gonadosomatically active (or spent) and > 50% of the 650+ mm fish were mature (well developed, ripe, or spent). Spent males were seen in only 700+ mm fish, but > 50% of the 650+ mm fish were mature (well developed, ripe, or spent). Finucane et al. (1986) found that 50% of the females off the Carolinas were mature at 650-699 mm, and that all females from all areas were mature at 850-899 mm. Beaumariage (1973) determined that fish this size may or may not actually spawn. Unfortunately, in the present study, distinctions between a fish that will spawn and one that is in an early developing stage were made macroscopically. Greater certainty that these fish would spawn could in the future be provided by histological examination of the gonads.

The few king mackerel sampled (for both age and maturity data) were $\geq$ 2 years old and mature. Beaumariage (1973) determined that males first spawned at age 3 and females first matured at age 4. Beaumariage (1973) also found precocious gonadogenic activity in immature males and females.

MANAGEMENT APPLICATIONS

Management of king mackerel in North Carolina is under state authority for coastal waters to three nautical miles (nmi) offshore and federal authority in the Exclusive Economic Zone (3-200 nmi). Catch quotas for the Atlantic migratory group are established annually by the South Atlantic Fishery Management Council and allocated to the recreational and commercial fisheries. Bag limits are also established annually by the councils for the EEZ and states are encouraged to adopt compatible rules. The recreational and commercial landings, acceptable biological catch (ABC), and total allowable catch (TAC) for 1986 to 1990 are shown below (Table 27).

Table 27. Atlantic king mackerel catch summary by weight in thousands of pounds, 1986-1990 fishing season (April-March). Acceptable biological catch (ABC) and total allowable catch (TAC) are also given.

	Recreational landings			Commercial landings				
	Mid and North Atlantic[2]	South Atlantic[3]	North Carolina	Mid and North Atlantic	South Atlantic	North Carolina	ABC	TAC
1986-1987[1]	100	5,138	-	4	2,823	1,040	6,900-15,400	9,680
1987-1988	58	3,740	1,748	16	3,430	1,394	6,900-15,400	9,680
1988-1989	184	4,526	1,729	15	3,065	804	5,500-10,700	7,000
1989-1990	94	3,094	1,171	10	2,619	858	6,900-15,400	9,000
1990-1991	39	3,435	1,274	*	2,521	1,232	6,500-15,700	8,300

1. Recreational statistics prior to 1987 may be higher than would be produced using current procedures.
2. Includes areas north of North Carolina.
3. Includes North Carolina and areas south of North Carolina.
* Not available.

The Director of the North Carolina Division of Marine Fisheries has proclamation authority to restrict the taking of king mackerel by specifying areas, seasons, quantity, means/methods, and size. Bag limits have been in place for state waters since 1989. There is also a daily landing limit of 3,500 pounds of Spanish or king mackerel, in the aggregate, per day.

Data from this project have been provided annually to the National Marine Fisheries Service Miami and Panama City laboratories from 1986 through 1990 for use in annual king mackerel stock assessments. These data include length, age, and sex data from both the commercial and recreational fisheries which harvest king mackerel. These data have been used to determine fishing mortality rates, abundance relative to an adequate spawning stock biomass, trends in recruitment, and acceptable biological catch on a regional basis (South Atlantic). The status of exploitation of king mackerel stocks is currently evaluated with age-based sequential models (Virtual Population Analysis) and future fish utilization levels (ABC) are estimated using fishing mortality rates and stock abundances obtained from these models. The models require accurate information on total catch and catch at age composition. Catch at age compositions are converted from numbers caught at size (length) by means of annual age-length keys.

The Division of Marine Fisheries has been represented on the Mackerel Stock Assessment Panel since 1988. The panel consists of scientists appointed by the

Gulf of Mexico and South Atlantic fishery management councils to review the annual stock assessments and make recommendations to the councils on stock divisions and levels of catch. Through its membership on this panel, the Division has realized the importance of basic life history data and long term databases describing the size, age, and sex composition of the catches. The North Carolina king mackerel database has been a valuable contribution to the regional stock assessment and management process. The reliability of the stock assessments has improved greatly since the inception of this project. The sparseness of the database prior to 1987 resulted in discrepancies in the assessments and uncertainty in the status of the stocks. This resulted in mistakenly categorizing the Atlantic migratory group of king mackerel as overfished in 1988 and a closure of the fishing season. The status of the Atlantic stock since that year has been considered healthy.

In addition to reviewing the condition of the stock, the panel addresses stock identity and distribution. Tagging and biochemical studies have suggested that the Gulf migratory group of king mackerel consists of eastern and western stocks which intermingle in the northern Gulf from Texas to northwest Florida. Tagging data are reviewed annually to determine whether alternate management boundaries are more appropriate than those currently used for the Atlantic and Gulf migratory groups. North Carolina tagging data are incorporated in these analyses.

MANAGEMENT RECOMMENDATIONS

1. Maintain the current limit of five fish/angler/day for the recreational fishery to protect the existing spawning stock biomass. Adjust this bag limit annually based on recommendations from the Mackerel Stock Assessment Panel, the South Atlantic Fishery Management Council, and also on pertinent data collected by DMF.

2. Whenever possible, enact state regulations consistent with federal regulations.

3. Maintain the daily landing limit of 3,500 lb of Spanish or king mackerel, in the aggregate, per day.

4. Advocate a king mackerel release category in DMF's North Carolina Saltwater Fishing Tournament. Presently, a citation is only given for a king mackerel ≥30 lb landed in the recreational fishery.

5. Support the minimum size limit of 28" FL enforced at most of North Carolina's king mackerel tournaments to encourage conservation ethics.

RESEARCH RECOMMENDATIONS

1. Increase tag and recapture efforts to better describe inter- and intra-seasonal movement patterns of king mackerel within and between North Carolina waters and other Atlantic Coast state waters. More king mackerel should be tagged during the spawning season, and efforts to tag north and south of Cape Hatteras should continue.

2. Initiate a king mackerel recreational angler tagging program to promote conservation ethics, to hopefully increase tag and recapture data, and to better educate the public about king mackerel life history.

3. Validate the use of sectioned otoliths for ageing king mackerel. This should include comparisons of ages from whole and sectioned otoliths. Continued marginal increment analysis is needed from samples collected during all months of the year from as wide a size range as possible.

4. Continue chemical marking of fish to aid in age validation.

5. Prepare annual age-length keys for use in stock assessments. Establish a birth date for king mackerel in North Carolina, and make appropriate adjustments when assigning ages for these keys.

6. Develop a more reliable maturity schedule of king mackerel off North Carolina to aid in population level analyses. Describe gonadogenic activity for all months from both the recreational and commercial fisheries from a wide range of length classes. Expand sampling of small king mackerel (<650 mm FL), and collect otoliths with gonad samples to more clearly define size and age at maturity.

7. Conduct histological examinations of a subsample of king mackerel gonadal tissue from both sexes in all stages of reproductive development in all months to better quantify macroscopic determinations and also spawning frequency of king mackerel off North Carolina.

8. Investigate the sex ratio present in North Carolina's commercial king mackerel fishery by season, age and length class. Combined with information already obtained from the recreational fishery, a clearer picture of sex ratio for king mackerel off North Carolina over a broader size/age range could be acquired.

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A cooperative agreement to further cooperative research on coastal pelagic resources was entered into in August 1986 by DMF and the National Marine Fisheries Service (NMFS), Southeast Fisheries Center. For the next several years, king mackerel were tagged and released out of Beaufort Inlet on the *NOAA R/V ONSLOW BAY* by DMF and NMFS staff. During the early years of the project, king mackerel tags had the NMFS Miami Laboratory address on them. All rewards for returned king mackerel tags were paid by NMFS. Data for all DMF king mackerel operations were supplied to NMFS, and NMFS provided all recapture information to DMF.

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APPENDIX A

APPENDIX A

King mackerel tag return information from 1983-1990 tagging in North Carolina.

Tag number	Release date	Release location	Fork length (mm)	Return date	Return location	Days at large	Distance from tag release site (km)
5573*	11-24-83	Atlantic Beach, NC	1015	07-03-84	24 mi S Masonboro Inlet, NC	222	177
6147*	12-07-84	Atlantic Beach, NC	1100	11-10-85	Cape Lookout, NC	338	32
D-1601	11-11-85	25 mi E Oregon Inlet, NC	740	11-27-85	Cape Hatteras, NC	16	121
D-1563	11-11-85	25 mi E Oregon Inlet, NC	660	05-06-86	2 mi E Masonboro Inlet, NC	176	531
8844	11-26-85	18 mi SE Oregon Inlet, NC	870	05-14-86	Jupiter, FL	169	1120
08357	06-02-86	8 mi W Beaufort sea buoy, NC	655	06-20-86	4 mi off Bogue Inlet, NC	18	23
08333	05-29-86	8 mi SE Bogue Inlet, NC	610	07-04-86	3 mi S Bogue Inlet, NC	36	11
08460	05-31-86	18 mi SE Bogue Inlet, NC	660	07-20-86	Off Jacksonville, NC	50	32
08270	05-30-86	8 mi S Bogue Inlet, NC	700	09-10-86	10 mi S Frying Pan Tower, NC	103	193
D-1603	11-11-85	25 mi E Oregon Inlet, NC	790	10-08-86	15 mi E Oregon Inlet, NC	331	16
08878	06-11-86	8 mi SW Beaufort, NC	657	10-10-86	New River Inlet, NC	121	43
19511	10-07-86	6 mi SE Beaufort Inlet, NC	855	10-29-86	2 mi E Beaufort Sea Buoy, NC	22	5
20152	10-30-86	18 mi off Oregon Inlet, NC	870	11-23-86	5 mi S Cape Lookout, NC	24	137
19612	10-29-86	Beaufort sea buoy, NC	800	12-12-86	9 mi W Cape Lookout, NC	44	32
20001	10-29-86	16 mi E Oregon Inlet, NC	710	05-06-87	Frying Pan Shoals, NC	189	370
D-1716	11-12-85	Wimble Shoals, NC	820	05-16-87	Palm Beach, FL	550	1115
08254	05-31-86	18 mi SE Bogue Inlet, NC	650	05-19-87	3 mi off Wrightsville Beach, NC	353	80
20129	10-30-86	18 mi off Oregon Inlet, NC	870	05-21-87	Palm Beach, FL	203	1176
D-1653	11-14-85	18 mi E Oregon Inlet, NC	810	05-24-87	Jupiter, FL	556	1150
08391	05-31-86	8 mi W Beaufort sea buoy	630	06-06-87	3 mi S Beaufort Bar, NC	371	19
08455	07-22-86	1 mi W Beaufort sea buoy, NC	500	06-14-87	Bogue Inlet, NC	327	48
08787	09-29-86	4 mi W Beaufort sea buoy, NC	540	07-11-87	5 mi outside Beaufort Inlet, NC	285	16
20009	10-29-86	16 mi SE Oregon Inlet, NC	920	07-11-87	10 mi SW Frying Pan Tower, NC	255	370
8893	11-26-85	18 mi SE Oregon Inlet, NC	930	08-30-87	Juno Beach, FL	642	1126

Appendix A. (Continued)

Tag number	Release date	Release location	Fork length (mm)	Return date	Return location	Days at large	Distance from tag release site (km)
D-1742	11-14-85	18 mi E Oregon Inlet, NC	890	09-12-87	Stuart, FL	668	1078
8966	11-12-85	15 mi SE Oregon Inlet, NC	870	09-24-87	Atlantic Beach, NC	692	219
19704	09-21-87	6 mi W Beaufort Inlet, NC	530	09-29-87	3 mi E Beaufort Inlet, NC	8	16
20509	06-01-87	8 mi W Beaufort Inlet, NC	580	09-30-87	Off Bear Inlet, NC	121	40
20136	10-30-86	24 mi SE Oregon Inlet, NC	940	10-22-87	15 mi E Cape Hatteras, NC	357	48
08719	06-11-86	6 mi SW Beaufort sea buoy, NC	610	10-30-87	7 mi E Hatteras Light, NC	506	167
20247	05-18-87	12 mi SW Beaufort Inlet, NC	810	10-31-87	Topsail Inlet, NC	166	72
20209	11-07-86	Avon Rocks, NC	980	11-01-87	15 mi E Cape Hatteras, NC	359	24
20140	10-30-86	24 mi SE Oregon Inlet, NC	760	11-04-87	Diamond Light, Hatteras, NC	370	45
D-1690	11-14-85	18 mi E Oregon Inlet, NC	940	11-23-87	3 mi S Diamond Shoals Light, NC	739	71
21020	11-04-87	35 mi SE Oregon Inlet, NC	810	01-21-88	35 mi off Wrightsville Beach, NC	78	282
20130	10-30-86	18 mi SE Oregon Inlet, NC	800	04-02-88	Jupiter Inlet, FL	520	1120
20217	11-07-86	25 mi off Oregon Inlet, NC	1010	05-06-88	20 mi off Hatteras, NC	545	40
22005	03-02-88	25 mi SE Cape Lookout, NC	650	05-13-88	6 mi W Beaufort Inlet, NC	72	72
21805	02-29-88	35 mi SE Bogue Inlet, NC	700	05-14-88	Beaufort Sea Buoy, NC	75	40
20012	10-29-86	16 mi SE Oregon Inlet, NC	940	05-17-88	8 mi SE Hatteras, NC	565	56
21774	02-29-88	35 mi SE Bogue Inlet, NC	760	05-19-88	30 mi S New River Inlet, NC	79	64
20002	10-29-86	16 mi SE Oregon Inlet, NC	780	05-21-88	Bogue Inlet Pier, NC	638	257
D-1667	11-14-85	18 mi E Oregon Inlet, NC	920	05-21-88	Jupiter, FL	919	1150
21311	11-04-87	35 mi SE Oregon Inlet, NC	740	05-22-88	12 mi E Cape Lookout, NC	166	193
08904	05-29-86	8 mi S Bogue Inlet, NC	650	05-29-88	Swansboro, NC	730	13
D-1564	11-11-85	25 mi E Oregon Inlet, NC	890	06-07-88	Oregon Inlet, NC	939	40
21027	11-04-87	35 mi E Oregon Inlet, NC	760	06-19-88	22 mi off Murrell's Inlet, SC	227	420

Appendix A. (Continued)

Tag number	Release date	Release location	Fork length (mm)	Return date	Return location	Days at large	Distance from tag release site (km)
19731	05-12-88	18 mi E/SE Bogue Inlet, NC	630	06-24-88	5 mi W/SW Beaufort Inlet, NC	43	13
19716	05-12-88	18 mi E/SE Bogue Inlet, NC	630	06-25-88	15 mi E New Inlet, NC	44	88
08332	05-29-86	8 mi SE Bogue Inlet, NC	640	06-30-88	Windmill Light, mouth of Rappahanock River, Chesapeake Bay, VA	762	402
21709	02-22-88	40 mi SE Cape Lookout, NC	700	08-12-88	Little River Inlet, SC	202	241
21009	11-04-87	35 mi SE Oregon Inlet, NC	750	08-21-88	40 mi S Cape Lookout, NC	291	193
21794	02-29-88	35 mi SE Bogue Inlet, NC	620	08-28-88	30 mi S Brown's Inlet, NC	180	56
08747	09-29-86	8 mi SW Beaufort Sea Buoy, NC	540	09-08-88	Off Morehead City, NC	710	19
21541	05-16-88	12 mi W Beaufort Inlet, NC	620	09-09-88	8 mi SE Atlantic Beach, NC	116	24
21032	11-04-87	35 mi E/SE Oregon Inlet, NC	790	09-25-88	21 mi E/SE Oregon Inlet, NC	326	23
E-01439	05-16-88	12 mi Beaufort Inlet, NC	630	10-05-88	8 mi E/SE Brown's Inlet, NC	142	16
20939	10-30-87	36 mi SE Oregon Inlet, NC	890	10-30-88	25 mi SE Oregon Inlet, NC	365	24
21704	02-22-88	40 mi SE Cape Lookout, NC	790	11-08-88	16 mi E Oregon Inlet, NC	260	161
20674	10-29-87	25 mi SE Oregon Inlet, NC	850	11-14-88	25 mi E/SE Oregon Inlet, NC	382	0
20185	11-06-86	Oregon Inlet, NC	870	11-15-88	10 mi E Oregon Inlet, NC	740	16
19583	10-03-86	12 mi W Beaufort Inlet, NC	790	-	-	-	-
21646	02-08-88	55 mi SE Beaufort Inlet, NC	920	01-26-89	Big Rock, NC	353	37
19625	06-02-87	1 mi SW Beaufort Inlet, NC	600	01-28-89	34 mi off Masonboro Inlet, NC	605	117
K27049	04-27-89	17 mi S Beaufort Inlet, NC	790	05-29-89	35 mi off Masonboro Inlet, NC	33	88
20789	10-30-87	36 mi SE Oregon Inlet, NC	870	07-07-89	29 mi off Murrell's Inlet, SC	613	422
21368	11-05-87	35 mi SE Oregon Inlet, NC	680	07-09-89	Topsail Beach, NC	612	299
20556	06-19-87	1 mi W Beaufort Inlet, NC	570	07-12-89	20 mi off Atlantic Beach, NC	754	0
24069	11-15-88	26 mi E/SE Oregon Inlet, NC	890	07-23-89	Murrell's Inlet, SC	250	444
20811	10-30-87	36 mi SE Oregon Inlet	750	08-01-89	Ft. Pierce, FL	641	1086

Appendix A. (Continued)

Tag number	Release date	Release location	Fork length (mm)	Return date	Return location	Days at large	Distance from tag release site (km)
K26802	04-18-89	23 mi S Beaufort Inlet, NC	750	08-01-89	Pompano Beach, FL	105	1117
20725	10-30-87	36 mi SE Oregon Inlet, NC	800	08-19-89	St. Lucie, FL	659	1118
8680	06-11-86	8 mi SW Beaufort Inlet, NC	700	09-02-89	Palm Beach, FL	1180	990
21871	03-02-88	14 buoy off Cape Lookout, NC	680	10-10-89	Brown's Inlet, NC	587	84
20720	10-29-87	26 mi SE Oregon Inlet, NC	790	10-14-89	2 mi SE Oregon Inlet, NC	652	45
K27091	04-27-89	19 mi S Beaufort Inlet, NC	750	10-15-89	30 mi S Oregon Inlet, NC	171	198
20639	10-29-87	35 mi SE Oregon Inlet, NC	790	11-01-89	35 mi SE Oregon Inlet, NC	732	0
21669	02-22-88	40 mi SE Cape Lookout, NC	680	12-19-89	Ft. Pierce, FL	665	1006
24129	11-12-89	32 mi SE Oregon Inlet, NC	850	04-28-90	40 mi off Wrightsville, NC	168	312
21221	11-04-87	35 mi S/SE Oregon Inlet, NC	760	05-04-90	Hobe Sound, FL	912	1107
21408	11-04-87	35 mi SE Oregon Inlet, NC	690	06-12-90	75 mi E North Inlet, SC	951	407
20075	10-29-86	25 mi S/SE Oregon Inlet, NC	840	06-15-90	Jupiter, FL	1325	1157
20197	11-06-86	25 mi S/SE Oregon Inlet, NC	900	07-05-90	Mouth York River, Chesapeake Bay, VA	1377	235
21243	11-04-87	35 mi SE Oregon Inlet, NC	770	08-12-90	Ocean Isle Beach, NC	1012	431
K27040	04-27-89	25 mi S Beaufort Inlet, NC	1130	09-14-90	12 mi SW Beaufort Inlet, NC	506	26
K26884	04-19-89	Cape Lookout 14 buoy, NC	770	09-25-90	E Cape Lookout, NC	525	23
19611	10-29-86	Beaufort Inlet, NC	760	10-05-90	10 mi S Cape Fear, NC	1437	167
8346	11-26-85	18 mi SE Oregon Inlet, NC	750	11-16-90	Avon Rocks, NC	1816	10

* King mackerel tagged by NMFS before 1985.

APPENDIX B

APPENDIX B

Length composition, in percent, of male and female king mackerel by age group in North Carolina, 1987.

Length group (mm FL)	MALE ANNULI 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
501-550	100.0																							7
551-600	100.0																							7
601-650																								0
651-700		100.0																						1
701-750		60.0	20.0	20.0																				5
751-800			57.1	28.6														14.3						7
801-850			18.2	27.2	18.2	18.2		18.2																11
851-900					9.1	9.1	22.7	22.7		22.7	4.6	9.1												22
901-950								25.0		25.0	12.5	12.5	25.0											8
951-1000											20.0		40.0			20.0	20.0							5
1001-1050																100.0								1
1051-1100								100.0																1
1101-1150													100.0											1
1151-1200																								0
1201-1250																		100.0						1
Total																								77

Length group (mm FL)	FEMALE ANNULI 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
451-500	100.0																							1
501-550	100.0																							2
551-600	100.0																							13
601-650	91.7	8.3																						13
651-700		100.0																						5
701-750		60.0	40.0																					5
751-800		50.0	50.0																					6
801-850		6.7	60.0	13.3		6.7	6.7		6.7															15
851-900			50.0	16.7	8.3	8.3	16.7																	12
901-950			5.6	16.6	5.6	27.8	5.6	16.6	11.1			11.1												18
951-1000						33.3	11.1	11.1	11.1	22.2			11.1											9
1001-1050					4.6	4.6	4.6	22.7	9.1	9.1	18.2	18.2	4.6			4.6								22
1051-1100						9.1	18.2	9.1		9.1	9.1	9.1				27.2	9.1							11
1101-1150									12.5	18.7	6.3	12.5	25.0	6.3	6.3		6.3	6.3						16
1151-1200										11.1		44.4	22.2	11.1							11.1			9
1201-1250											14.3	14.3		14.3	14.3		14.3			14.3			14.3	7
1251-1300														16.7	16.7	16.7	16.7			16.7	16.7			6
1301-1350												25.0				25.0	25.0	25.0						4
1351-1400																								0
1401-1450																	100.0							1
Total																								175

APPENDIX B

Length composition, in percent, of male and female king mackerel by age group in North Carolina, 1988.

Length group (mm FL)	MALE ANNULI 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total
601-650	75.0	25.0																		4
651-700		92.3	7.7																	13
701-750		81.8	18.2																	11
751-800			42.9	42.9	14.3															7
801-850					16.7	50.0		33.3												6
851-900						8.3		33.3	41.7	16.7										12
Total																				53

Length group (mm FL)	FEMALE ANNULI 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total
551-600	100.0																			1
601-650	85.7	14.3																		7
651-700	33.3	66.6																		15
701-750		84.0	16.0																	25
751-800		50.0	33.3	16.7																6
801-850		5.9	23.5	41.2	29.4															17
851-900			18.7	18.7	31.2	12.5		6.3	6.3		6.3									16
901-950						50.0									50.0					2
951-1000									100.0											1
1001-1050				50.0								50.0								2
1051-1100					11.1	11.1	22.2	33.3		11.1		11.1								9
1101-1150			3.7		3.7	3.7	7.4		11.1	11.1	7.4	14.8	14.8	14.8	3.7	3.7				27
1151-1200					6.3			12.5	6.3			18.7	12.5	12.5		25.0			6.3	16
1201-1250								17.6	5.9		5.9		17.6	29.4	5.9	11.8		5.9		17
1251-1300									20.0			20.0				40.0		20.0		5
1301-1350																			100.0	1
Total																				167

APPENDIX B

Length composition, in percent, of male and female king mackerel by age group in North Carolina, 1989.

Length group (mm FL)	MALE ANNULI 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
601-650	100.0																		1
651-700		87.5	12.5																8
701-750		37.5	37.5	25.0															8
751-800			41.7	41.7	16.6														12
801-850					16.7	33.3	33.3			16.7									6
851-900						6.7	6.7	20.0		26.6	20.0	13.3			6.7				15
901-950							6.3	6.3	6.3	31.2		6.3	6.3	18.7	12.5	6.3			16
951-1000							16.7		16.7	16.7					33.3		16.7		6
1001-1050												25.0	12.5	25.0	12.5	12.5	12.5		8
1051-1100																	100.0		1
1101-1150								100.0											1
Total																			82

Length group (mm FL)	FEMALE ANNULI 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
501-550	100.0																		2
551-600	100.0																		6
601-650	100.0																		5
651-700	50.0	50.0																	6
701-750		91.7	8.3																12
751-800	11.1	33.3	55.6																9
801-850		8.3	25.0	58.3	8.3														12
851-900			33.3	33.3		33.3													3
901-900			14.3		14.3	7.1	21.4	14.3	7.1	14.3	7.1								14
951-1000					14.3	28.6	28.6	14.3			14.3								7
1001-1050						33.3	11.1		11.1	44.4									9
1051-1100						11.8	11.8	11.8	11.8	17.6		5.9	5.9	5.9	11.8		5.9		17
1101-1150						8.3	8.3	8.3	8.3	16.7	8.3	25.0		8.3	8.3				12
1151-1200							8.3	16.7	16.7	16.7	8.3		8.3		16.7	8.3			12
1201-1250										42.8					28.6		28.6		7
1251-1300												16.7		33.3	16.7	16.7		16.7	6
1301-1350														100.0					1
Total																			140

APPENDIX B

Length composition, in percent, of male and female king mackerel by age group sampled in North Carolina, 1990.

Length group (mm FL)	MALE ANNULI 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	Total
401-450	100.0																										2
451-500	100.0																										12
501-550	100.0																										3
551-600	100.0																										1
601-650	25.0	75.0																									4
651-700	20.0	40.0	40.0																								5
701-750		32.1	53.6		7.1	3.6			3.6																		28
751-800		6.5	34.8	37.0	4.3	10.8	2.2		2.2		2.2																46
801-850			7.7	15.4	28.2	20.5	10.2	2.6	5.1	7.7					2.6												39
851-900					13.9	16.7	16.7	16.7	16.7	8.3	8.3	2.7															36
901-950						7.4	3.7	7.4	18.5	18.5	22.2	3.7	3.7		7.4	3.7		3.7									27
951-1000			3.6		3.6		10.7	7.1		7.1	21.4	10.7		10.7	7.1	3.6		7.1		7.1							28
1001-1050					4.8	4.8	9.5		4.8	4.8	9.5	4.8	14.2	4.8	14.2	9.5		9.5	4.8								21
1051-1100												100.0															1
1101-1150											50.0					50.0											2
Total																											255

Length group (mm FL)	FEMALE ANNULI 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	Total
451-500	100.0																										2
501-550	100.0																										1
551-600	100.0																										3
601-650	77.8	22.2																									9
651-700	65.0	35.0																									20
701-750	3.3	83.3	10.0						3.3																		30
751-800		40.6	34.4	25.0																							32
801-850		4.1	32.7	40.8	12.2	4.1			2.0						4.1												49
851-900		2.0	10.0	28.0	32.0	22.0	2.0			2.0					2.0												50
901-950			9.5	14.3	28.6	23.8		4.8	9.5	4.7	4.7																21
951-1000				3.5	27.6	13.8	10.3	10.3	6.9	10.3	6.9	10.3															29
1001-1050				3.7	7.4	11.1	7.4	22.2		29.7	7.4				3.7	3.7					3.7						27
1051-1100			2.8	8.3	2.8	5.6	5.6	19.4	8.3	16.6	22.2	2.8			2.8				2.8								36
1101-1150				3.2		6.5	3.2	12.9	6.5	29.1	12.9	3.2	3.2	3.2	6.5	3.2	3.2	3.2									31
1151-1200					3.0	3.0	6.1	15.2	15.2	18.1	6.1	9.1		6.1	3.0	12.1		3.0									33
1201-1250							4.6	9.1	4.6	13.6	9.1	13.6	4.6	4.6	4.6	13.6		4.6	13.6								22
1251-1300									5.9	11.8	11.8	11.8		5.9	17.6	5.9	17.6	5.9		5.9	11.8	11.8					17
1301-1350																	50.0		50.0								2
1351-1400														20.0		20.0		20.0					20.0			20.0	5
1401-1450															33.3			33.3			33.3						3
1451-1500																	100.0										1
1501-1550																	50.0						50.0				2
Total																											425

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