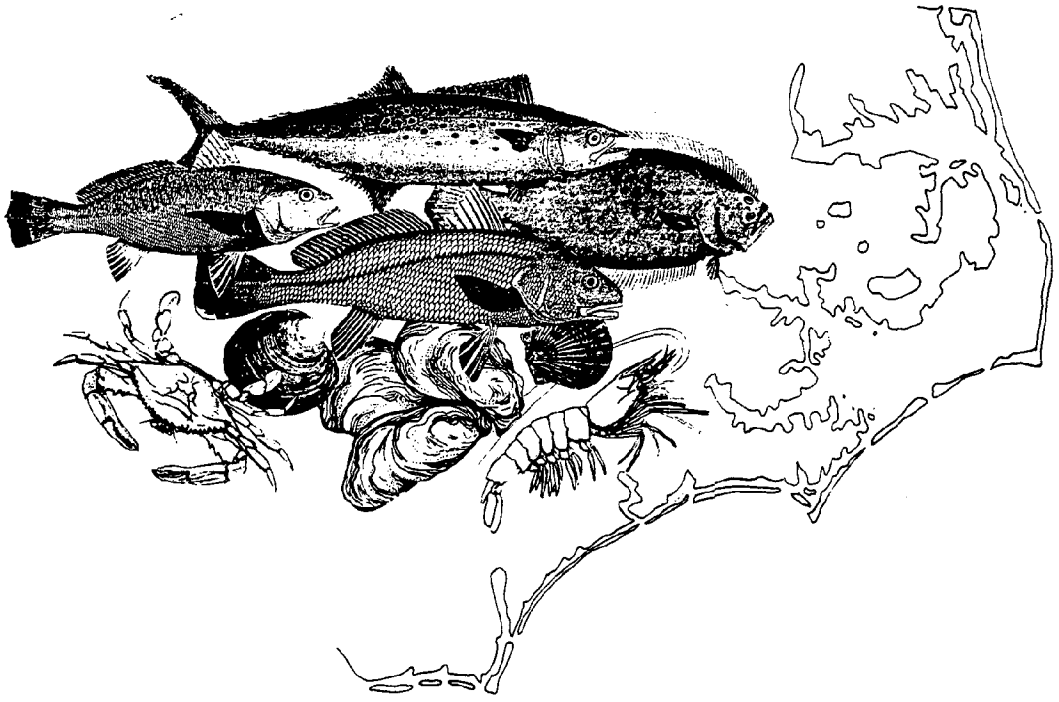
# MARINE FISHERIES RESEARCH



North Carolina Department of Environment,
Health, and Natural Resources

Division of Marine Fisheries
Morehead City, NC 28557

April 1992

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Health, and Natural Resources

Completion Report
for
Project F-29

April 1992

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# STUDY 1

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

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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.

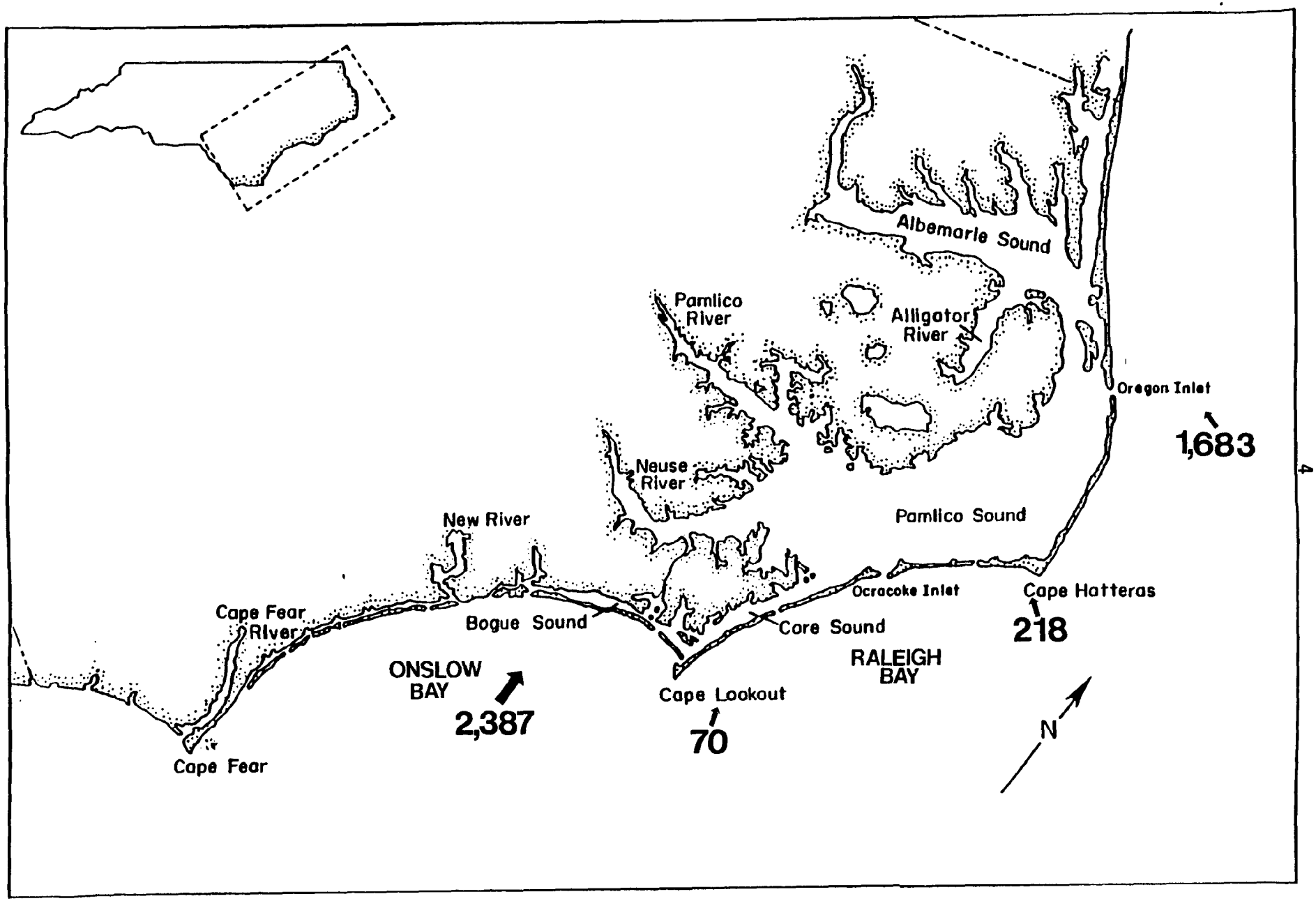
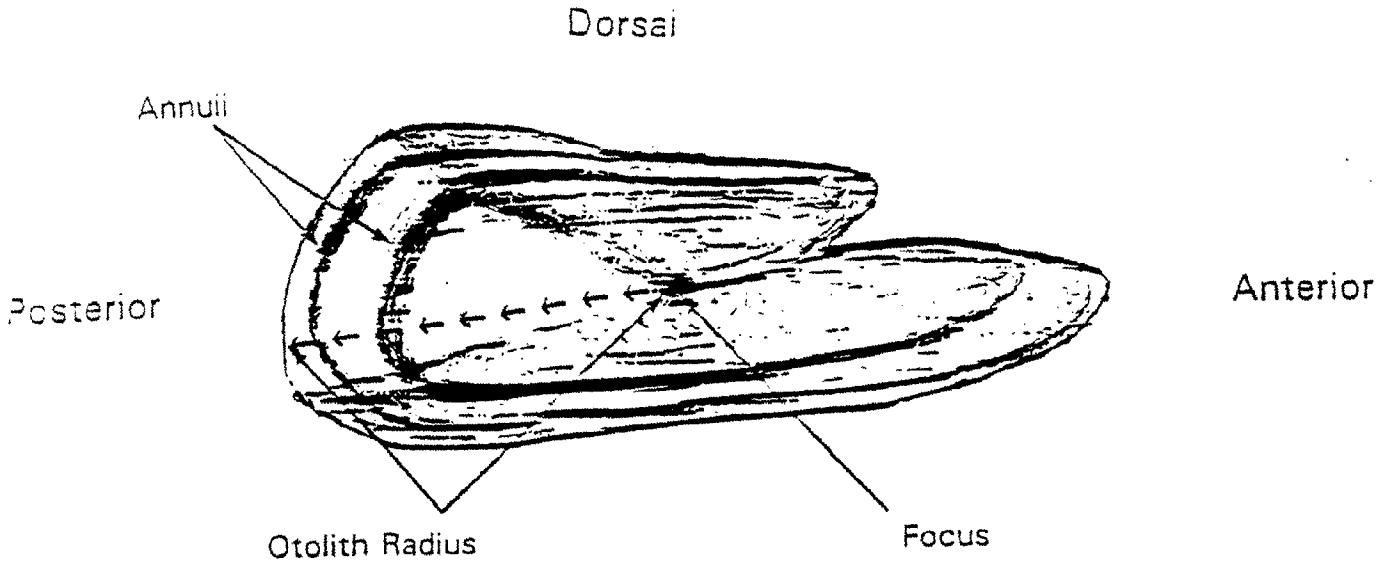



Figure 1. Primary tagging locations and numbers of king mackerel tagged off North Carolina, 1985-1990.

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



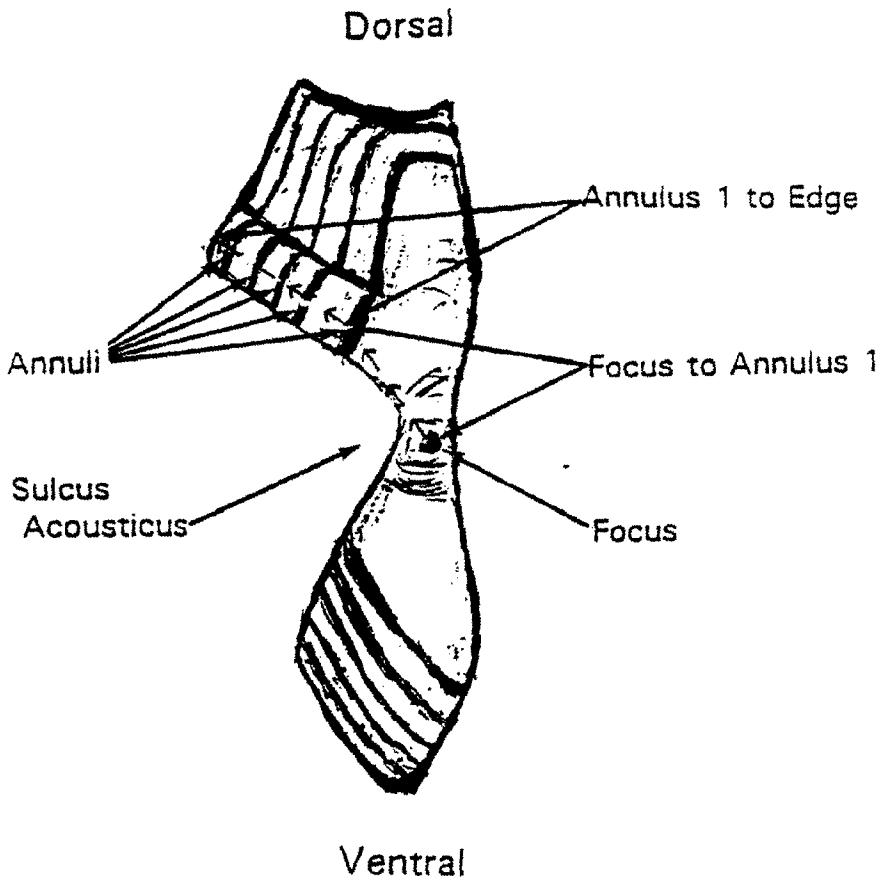




Figure 2. Diagram of a whole and sectioned king mackerel otolith. Dotted line shows path of measurement. Diagram is not to scale.

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% | | |

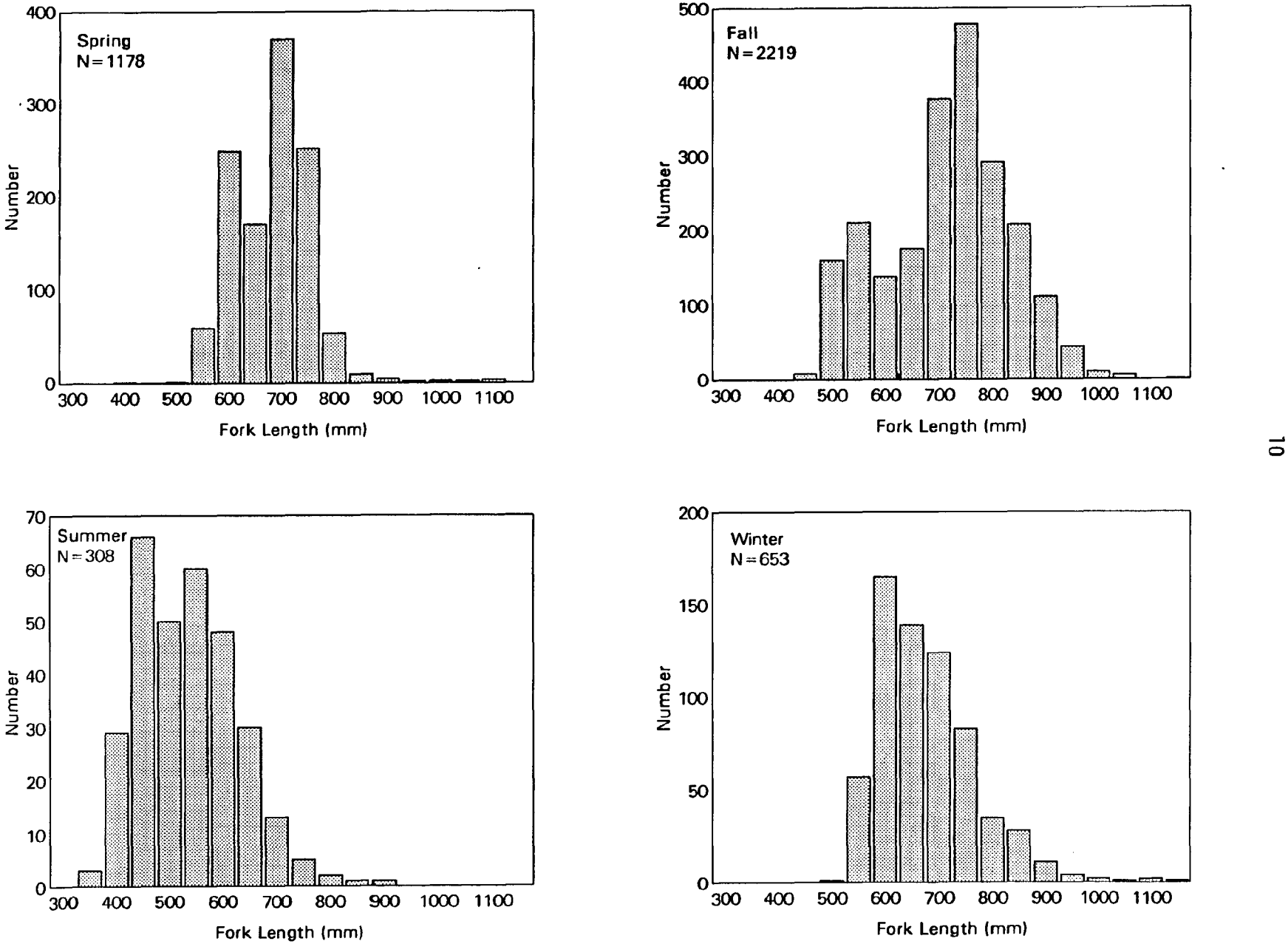



Figure 3. Length frequencies (FL, mm) of king mackerel tagged off North Carolina, 1985-1990, by season (Spring: April--May; Summer: June--August; Fall: September--November; Winter: December, March).

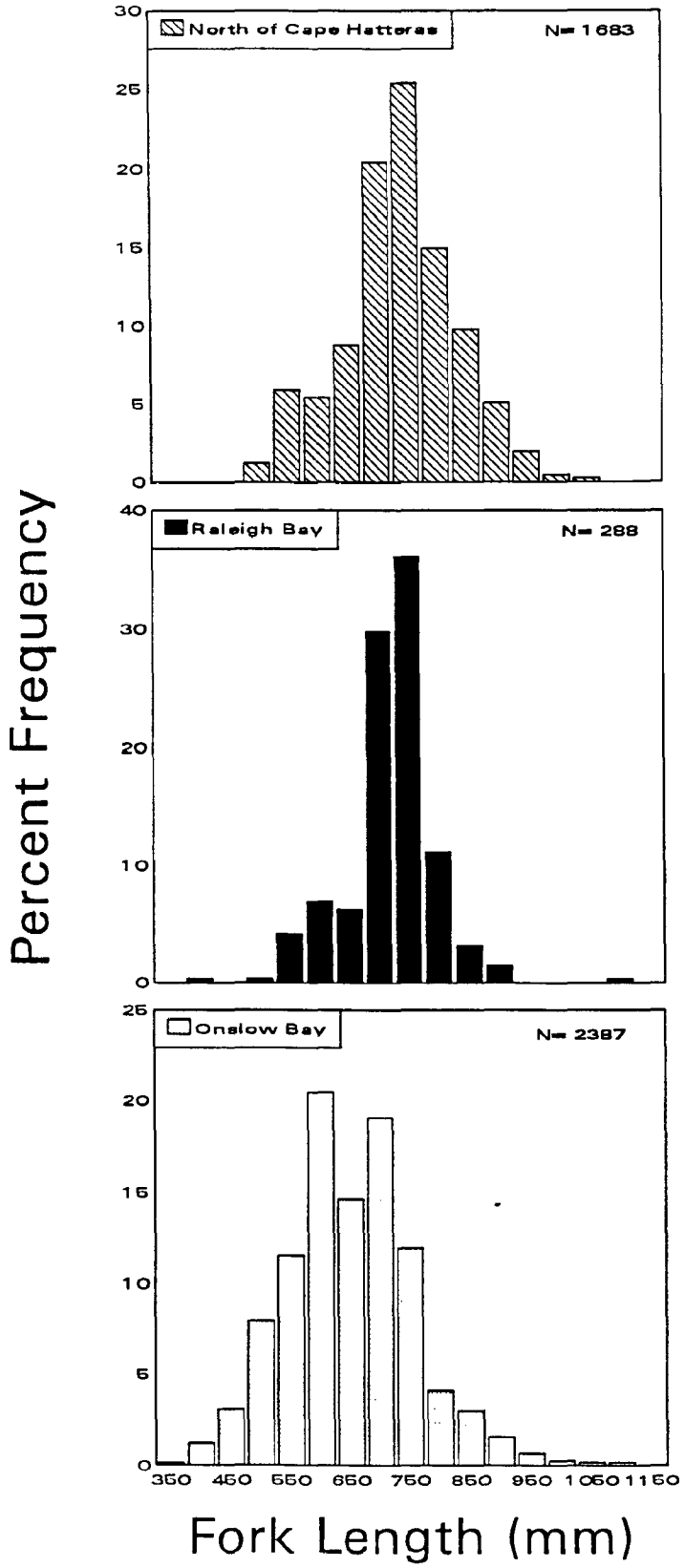



Figure 4. Length-frequency distribution of king mackerel tagged in Onslow Bay, Raleigh Bay, and north of Cape Hatteras, North Carolina, 1985-1990.

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).

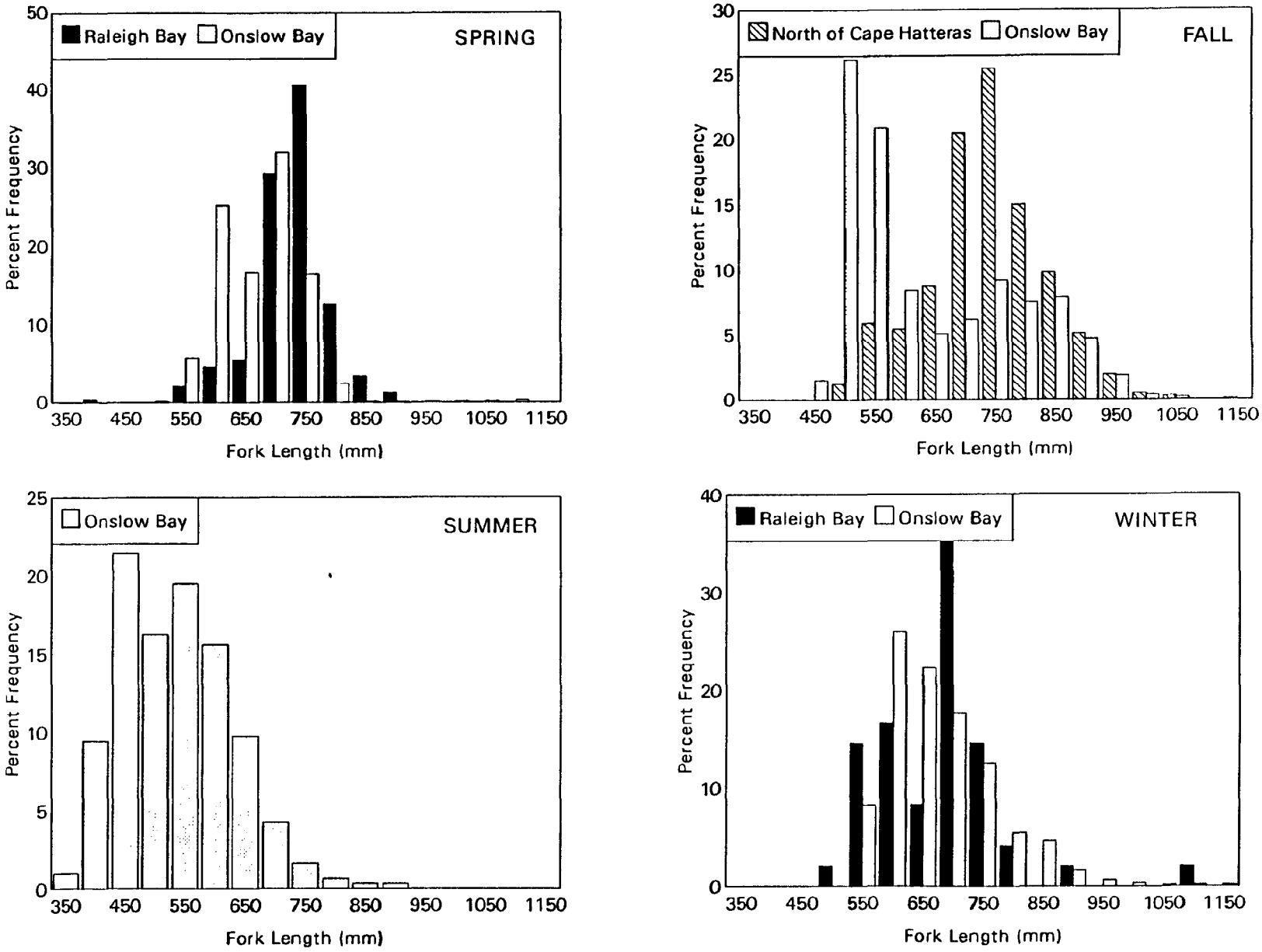



Figure 5. Seasonal length-frequency distribution of king mackerel tagged in Onslow Bay, Raleigh Bay, and north of Cape Hatteras, North Carolina, 1985-1990. Four fish tagged in the fall in Raleigh Bay are not shown. Seasons are Spring (April-May), Summer (June-August), Fall (September-November), Winter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

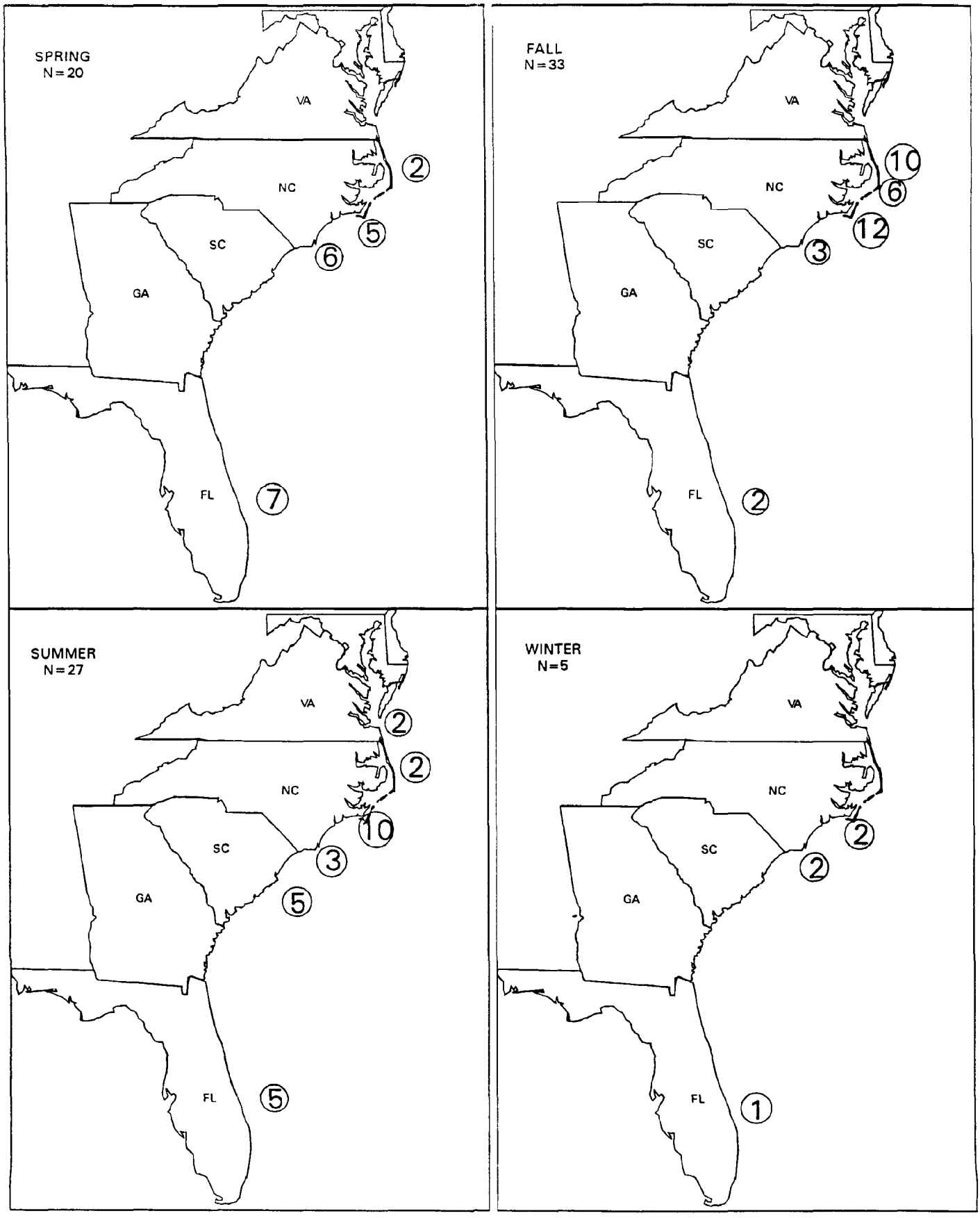



Figure 6. King mackerel recaptures by season of fish tagged off North Carolina, 1986-1990.

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 |

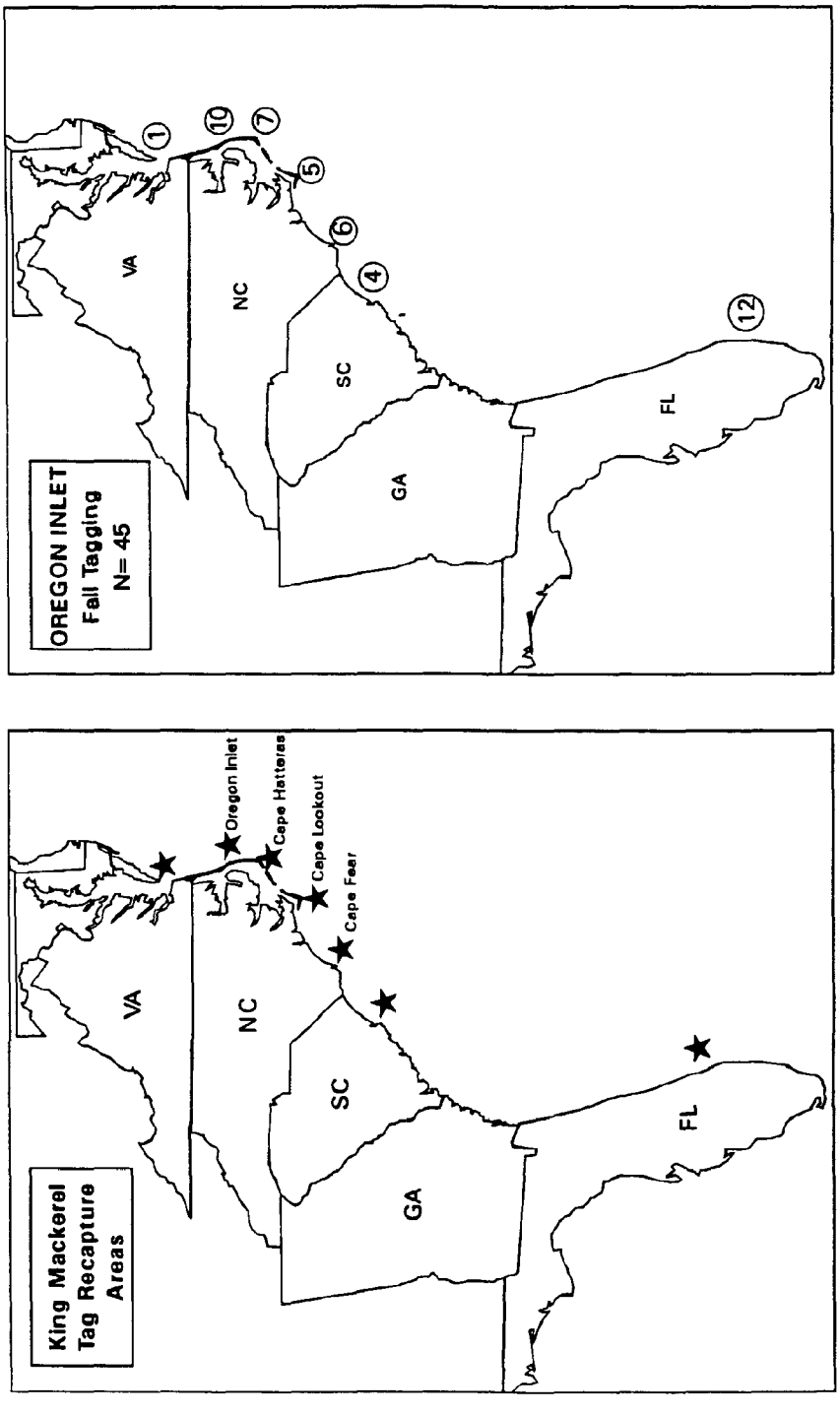



Figure 7. King mackerel tag recapture areas for fish tagged in North Carolina, 1985-1990. Also shown are those recaptures from fish tagged out of Oregon Inlet, North Carolina during October and November, 1985-1990.

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

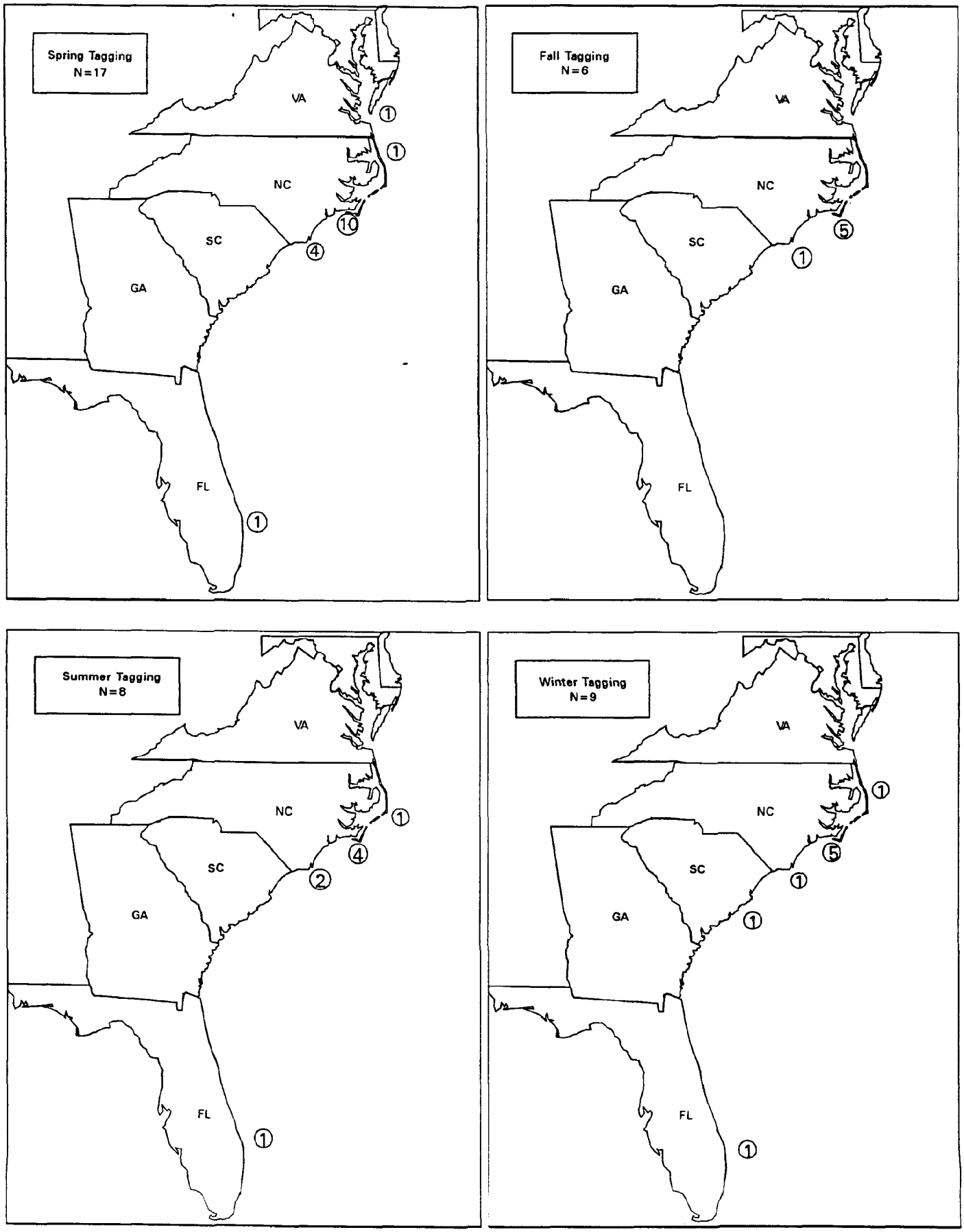



Figure 8. King mackerel recaptures (N=40) of fish tagged off central North Carolina by season tagged, 1985-1990.

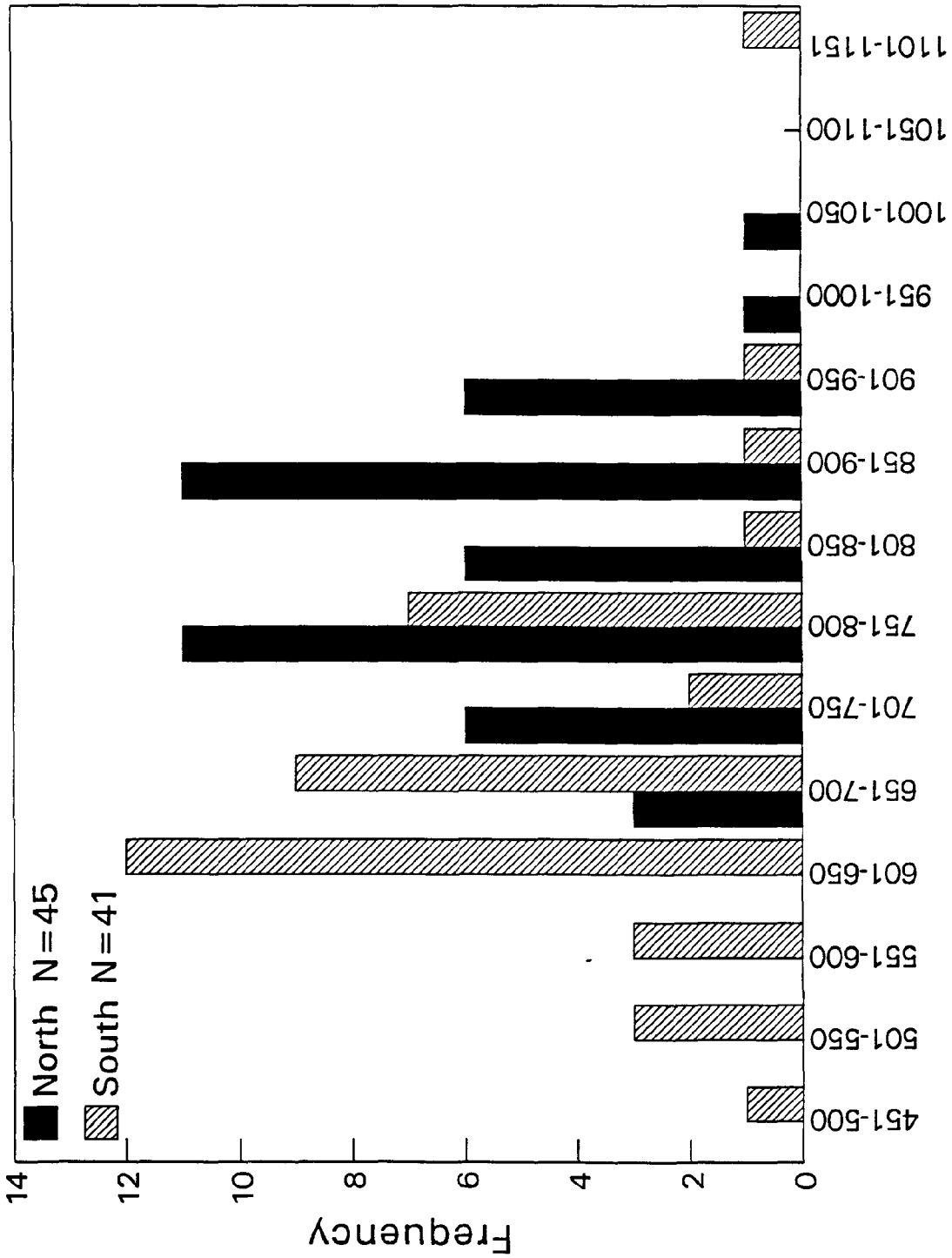



Figure 9. Fork lengths (mm) at release of king mackerel recaptures. Fish were tagged either south of Cape Lookout (south) or north of Cape Hatteras (north), North Carolina, between 1985 and 1990.

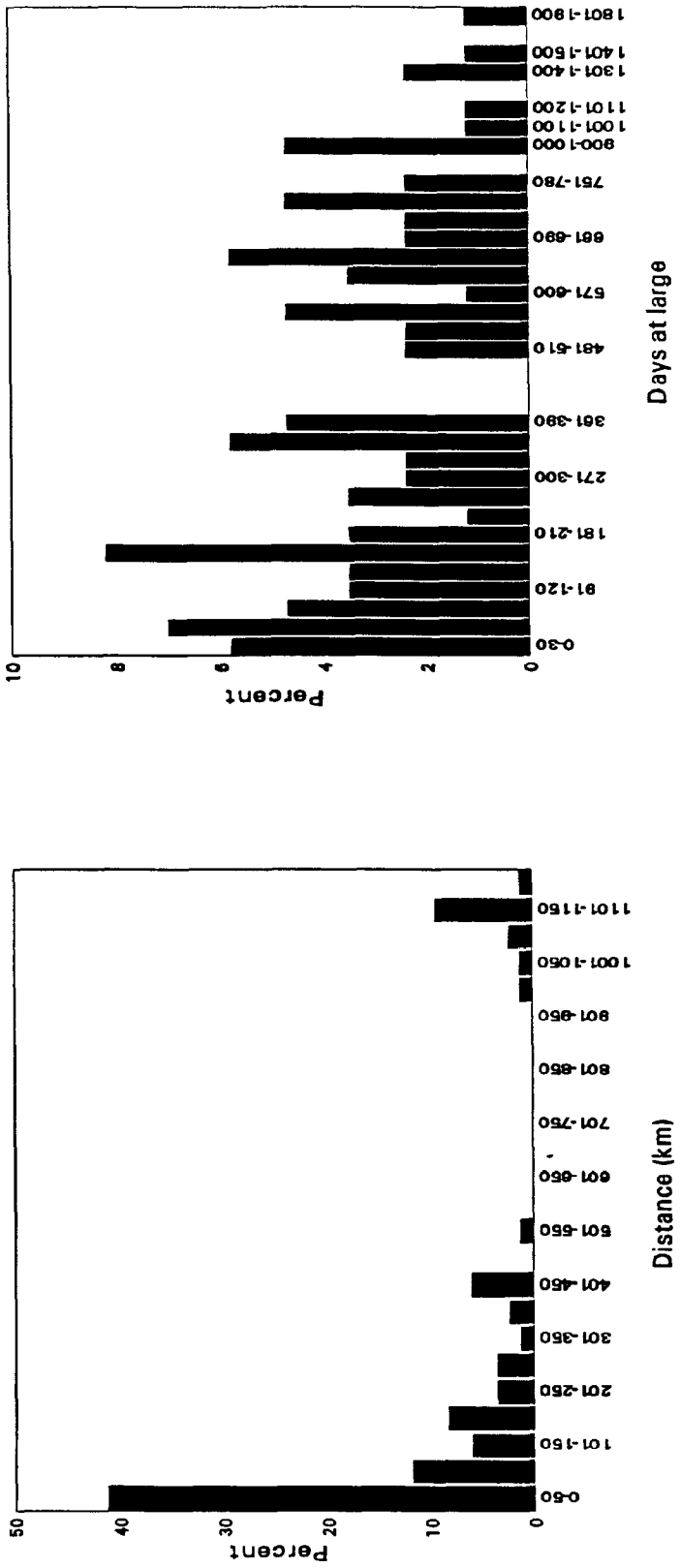



Figure 10. Distance between release and recapture sites and days at large for king mackerel tagged off North Carolina, 1985-1990.

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

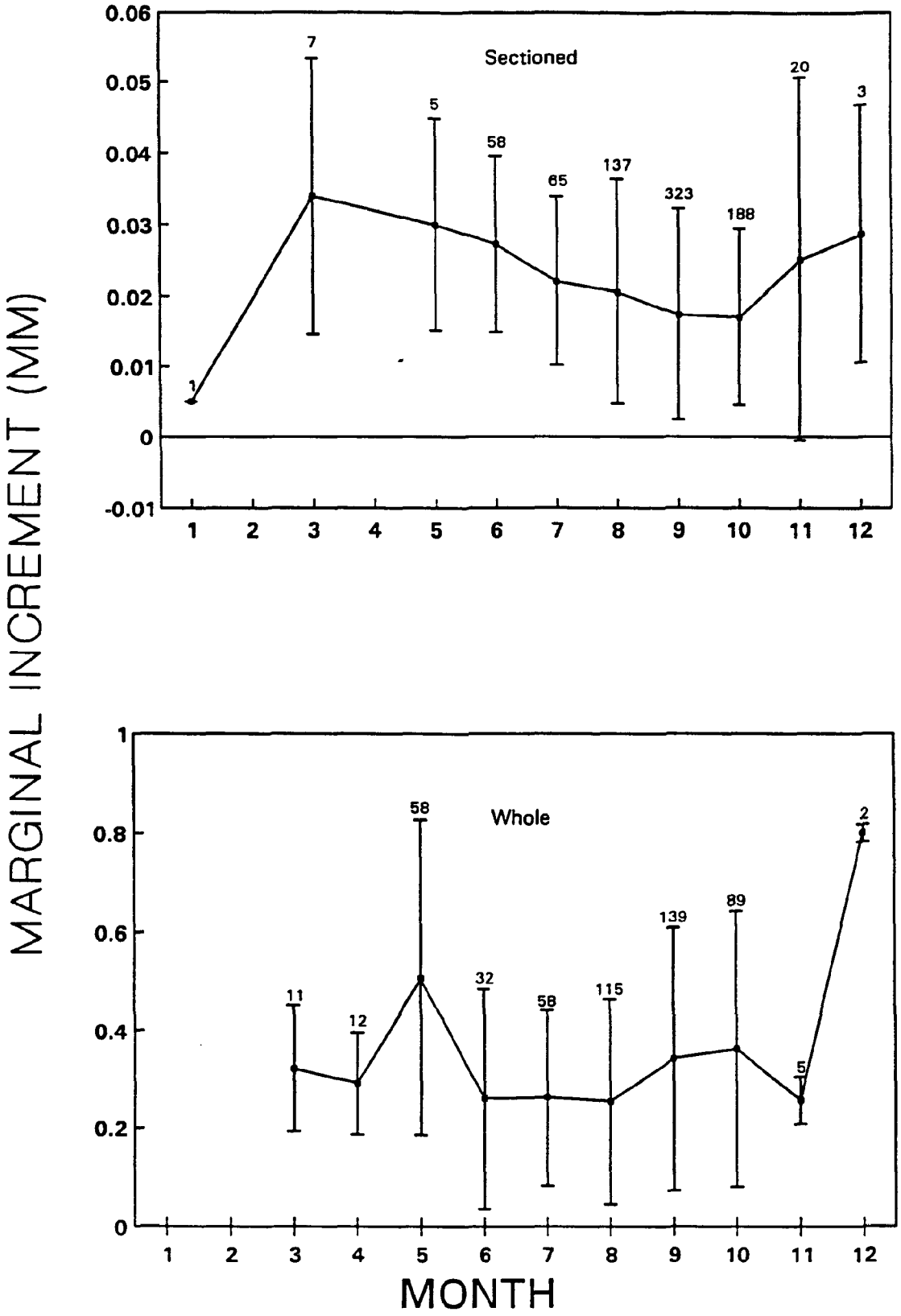



Figure 11. Monthly mean marginal increments on whole and sectioned otoliths of king mackerel. Vertical bars = +/- one standard deviation; number over each month's value = sample size.

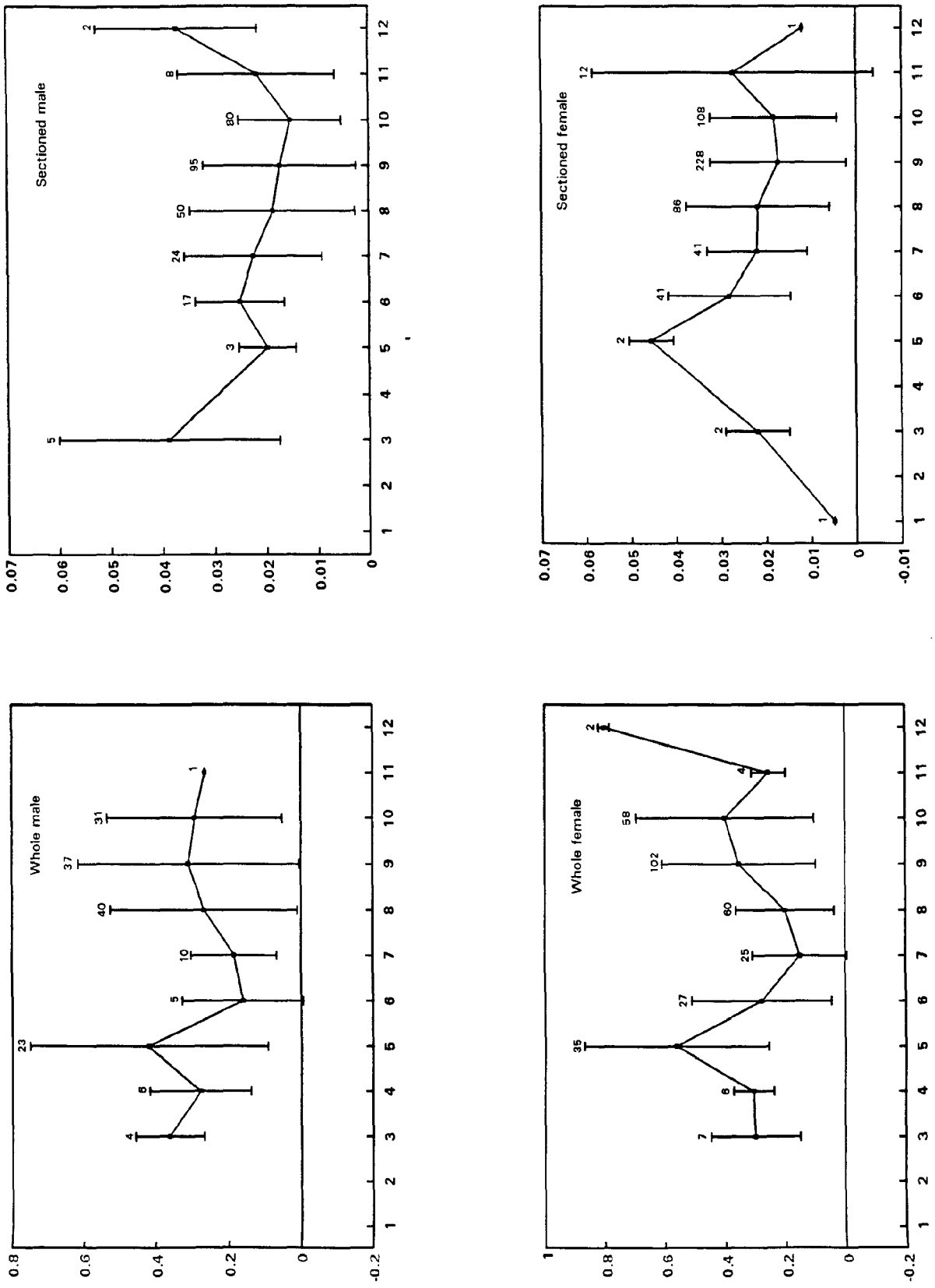



Figure 12. Monthly mean marginal increments on whole and sectioned otoliths of male and female king mackerel. Vertical bars = +/- one standard deviation; numbers over each month's value = sample size.

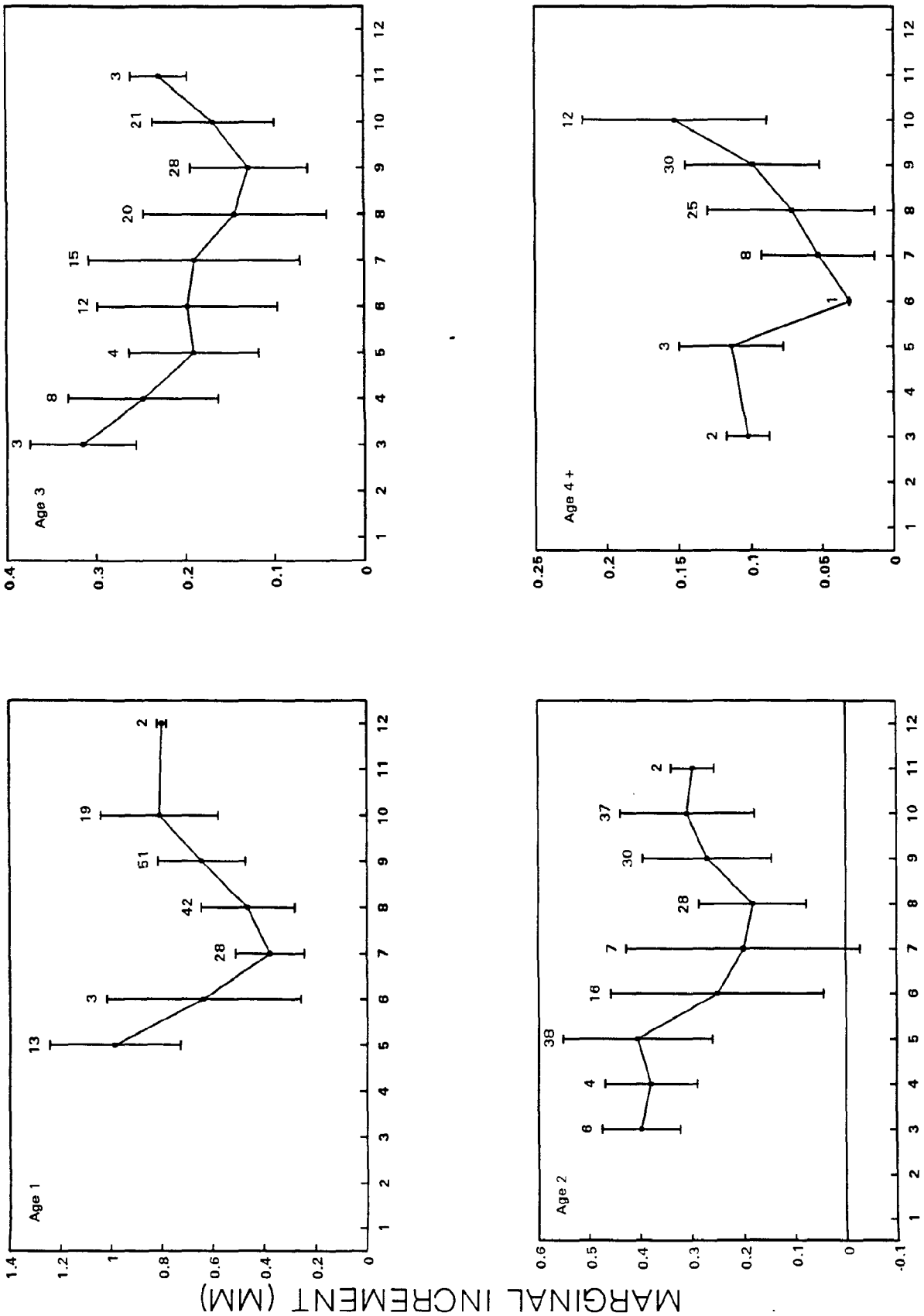



Figure 13. Monthly mean marginal increments on whole otoliths of king mackerel, by age. Vertical bars = +/- one standard deviation; numbers over each month's value = sample size; ages 4+ = fish aged four and older.

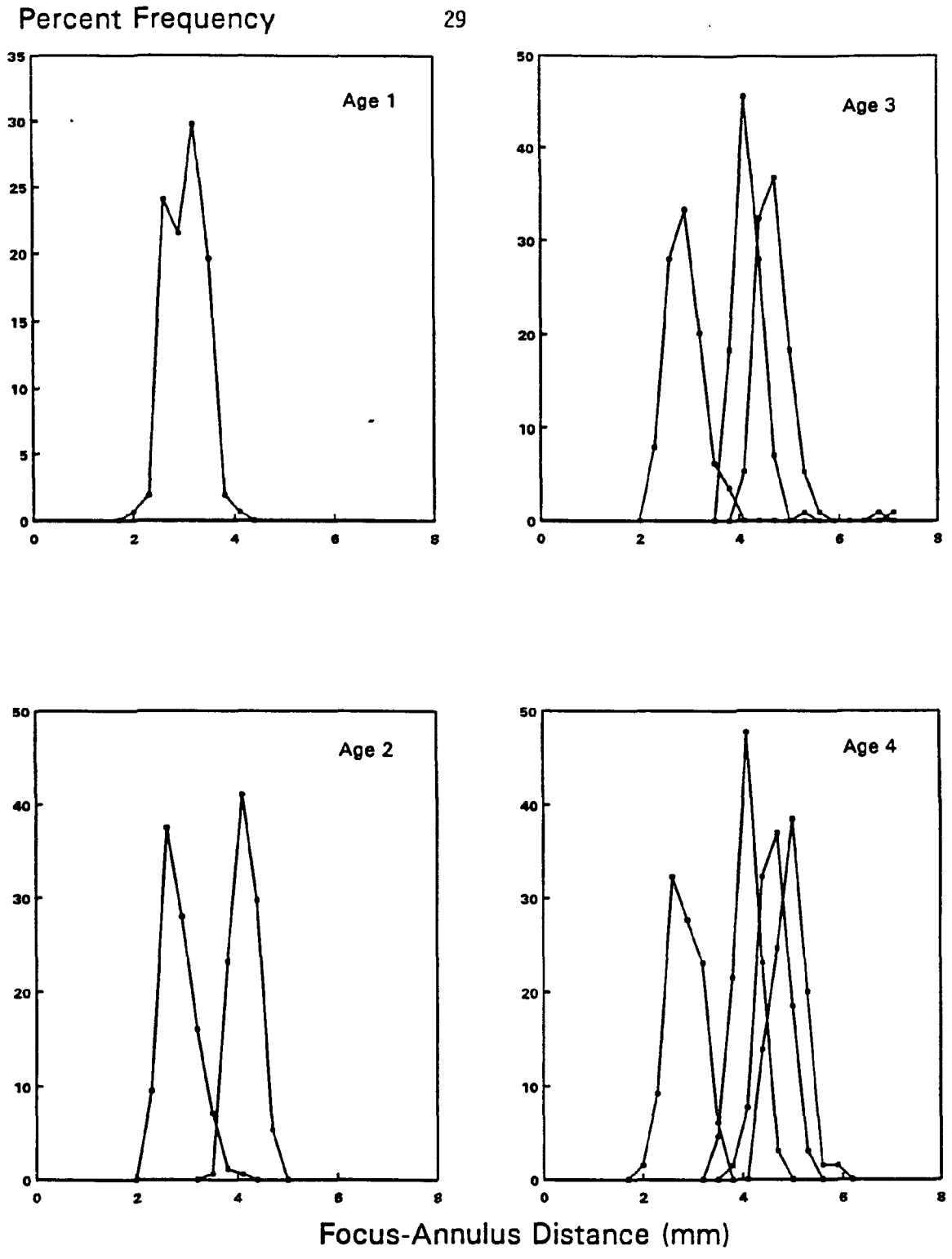



Figure 14. Frequency distributions of the distance from the focus of the otolith to each annulus on whole king mackerel otoliths from North Carolina, 1987-1990.

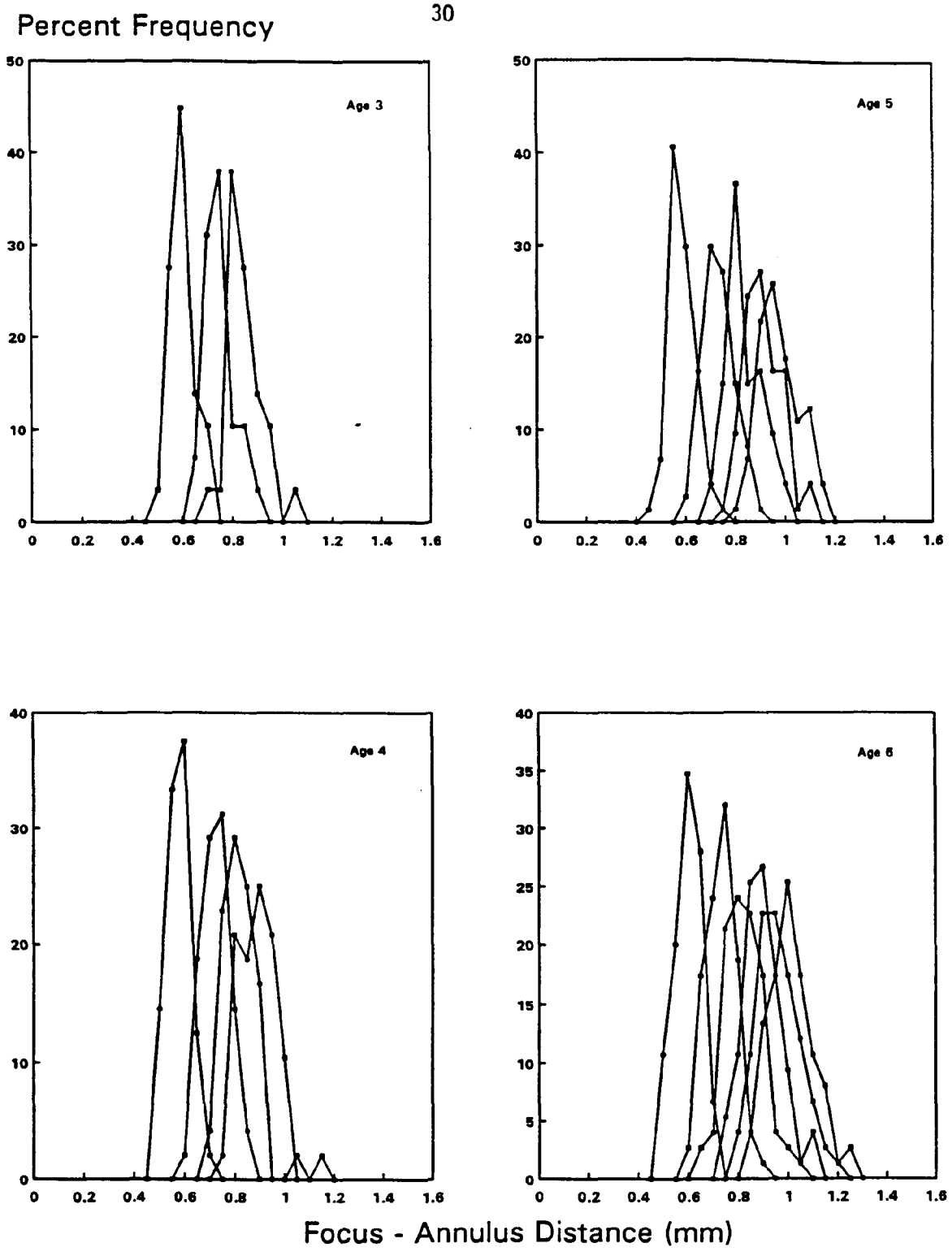



Figure 15. Frequency distribution of the distance from the focus of the otolith to each annulus on sectioned king mackerel otoliths from North Carolina, 1987-1990.

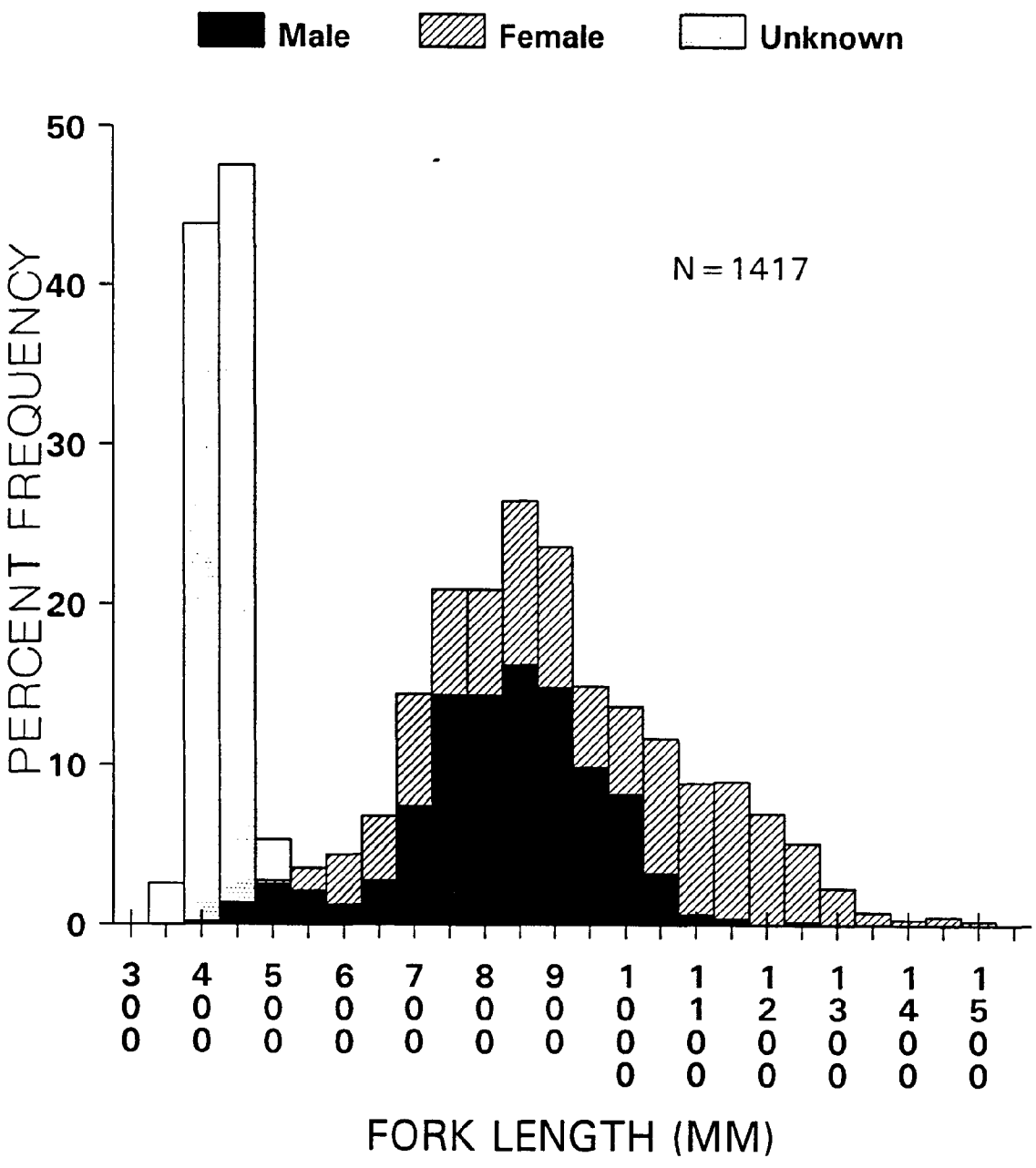



Figure 16. Length-frequency of king mackerel age samples, by sex, collected in North Carolina, 1987-1990.

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 |

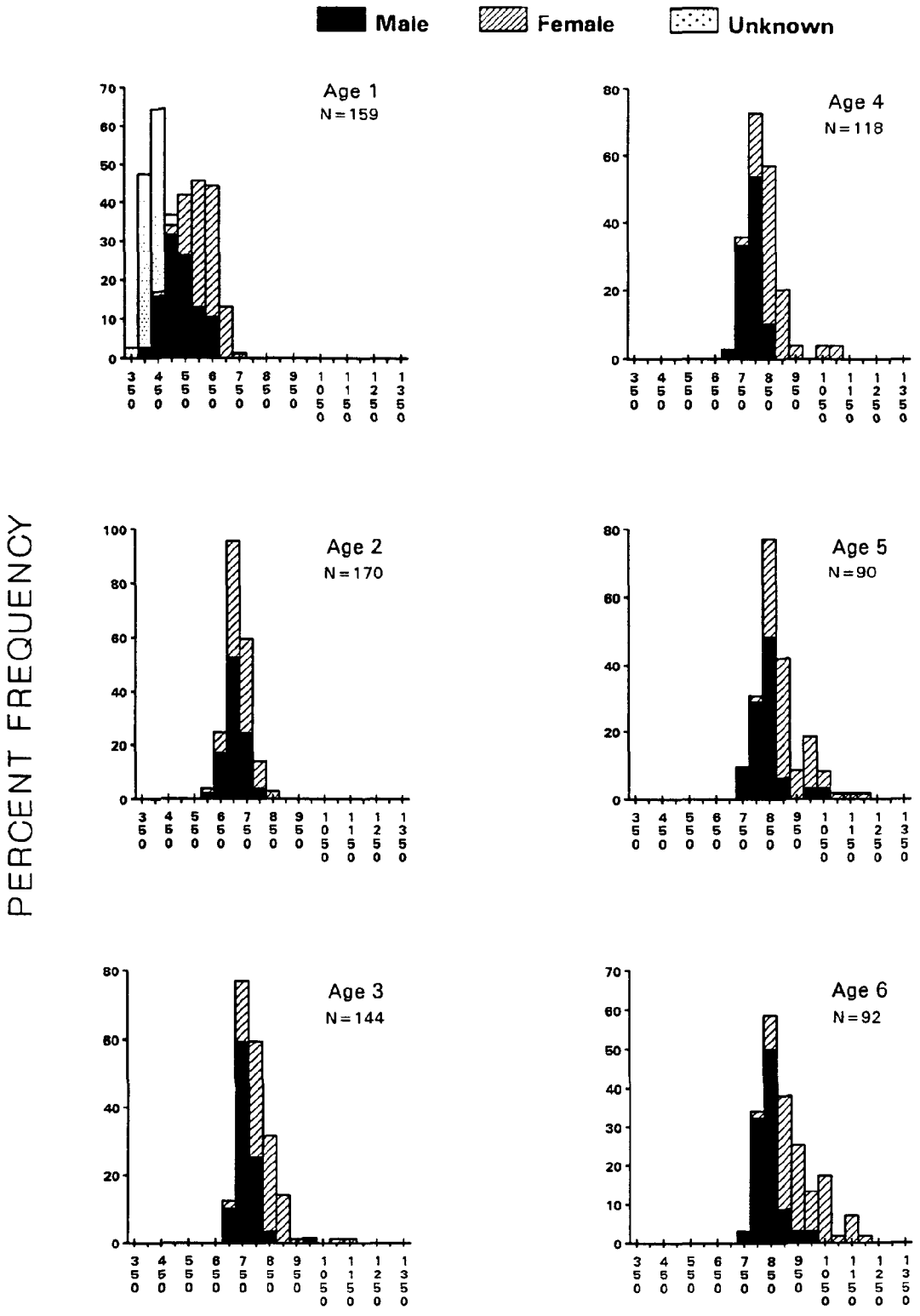



Figure 17. Length-frequencies of king mackerel by age and sex collected in North Carolina, 1987-1990. Ages 12+ = fish aged 12 and older.

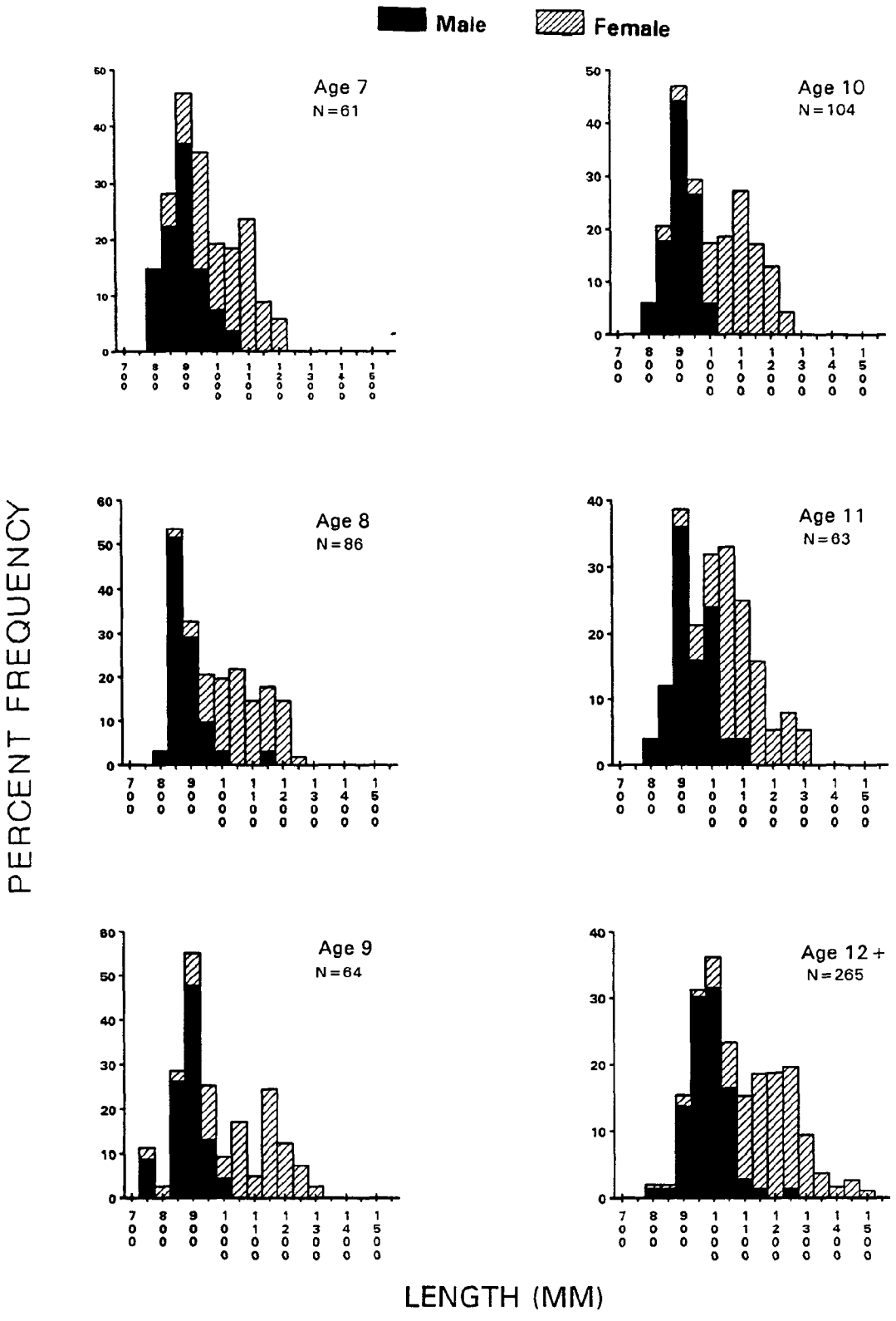



Figure 17. Continued.

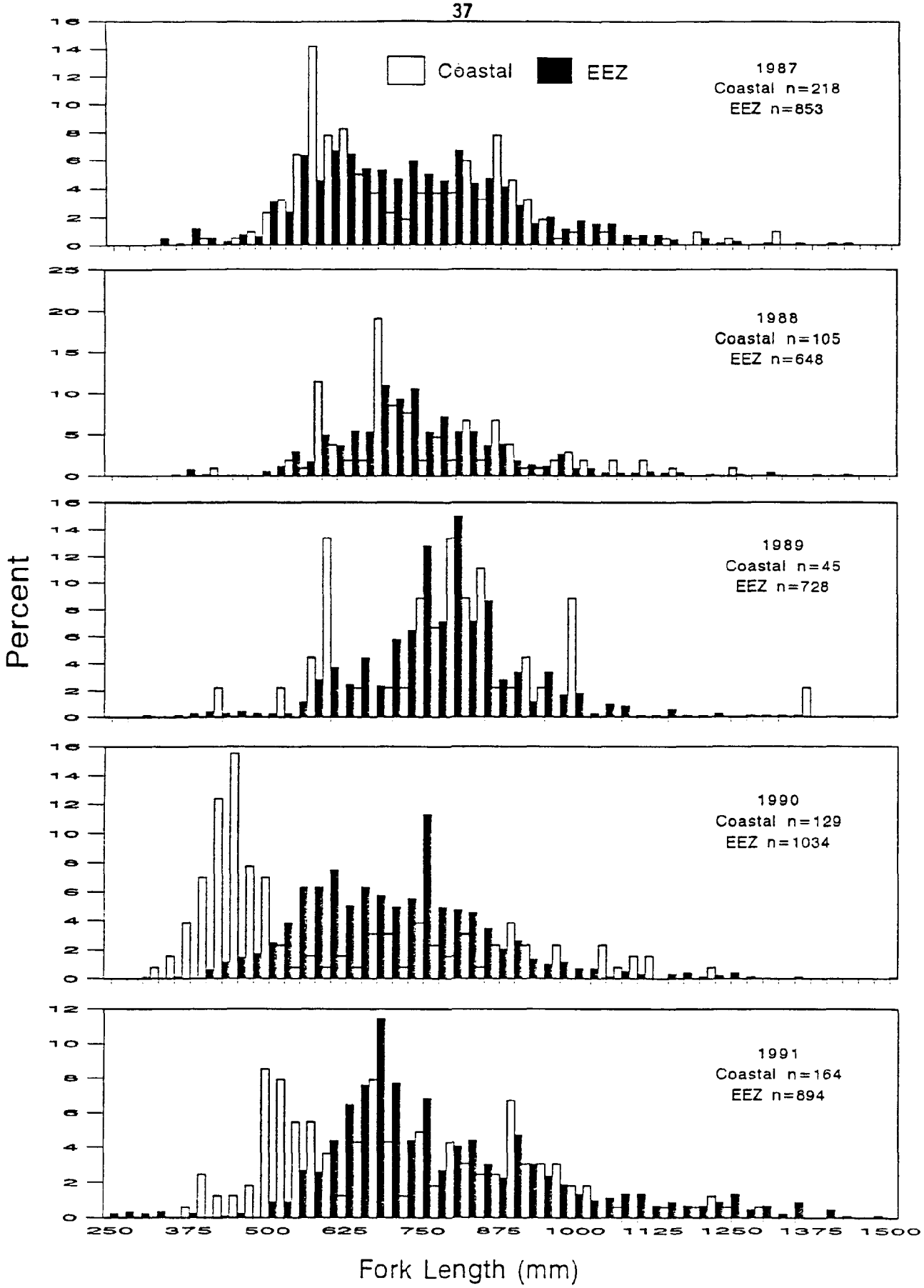



Figure 18. Length-frequency distributions of king mackerel sampled from the recreational catch in coastal waters and the Exclusive Economic Zone (EEZ) off North Carolina, 1987-1991 (from D. Mumford and P. Phalen, NC DMF personal communication).

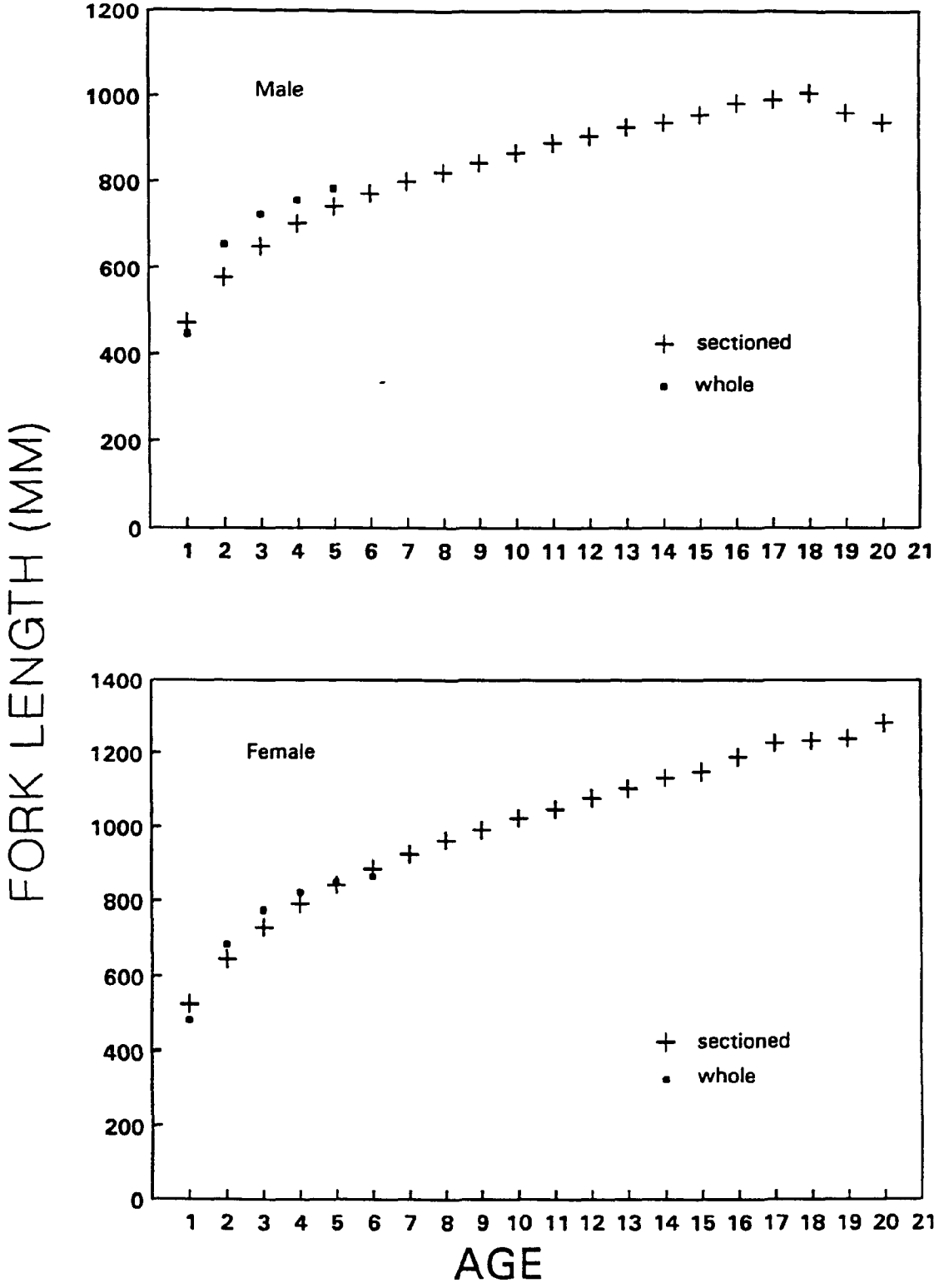



Figure 19. Mean back-calculated lengths at age from whole and sectioned otoliths for male and female king mackerel from North Carolina, 1987-1990.

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

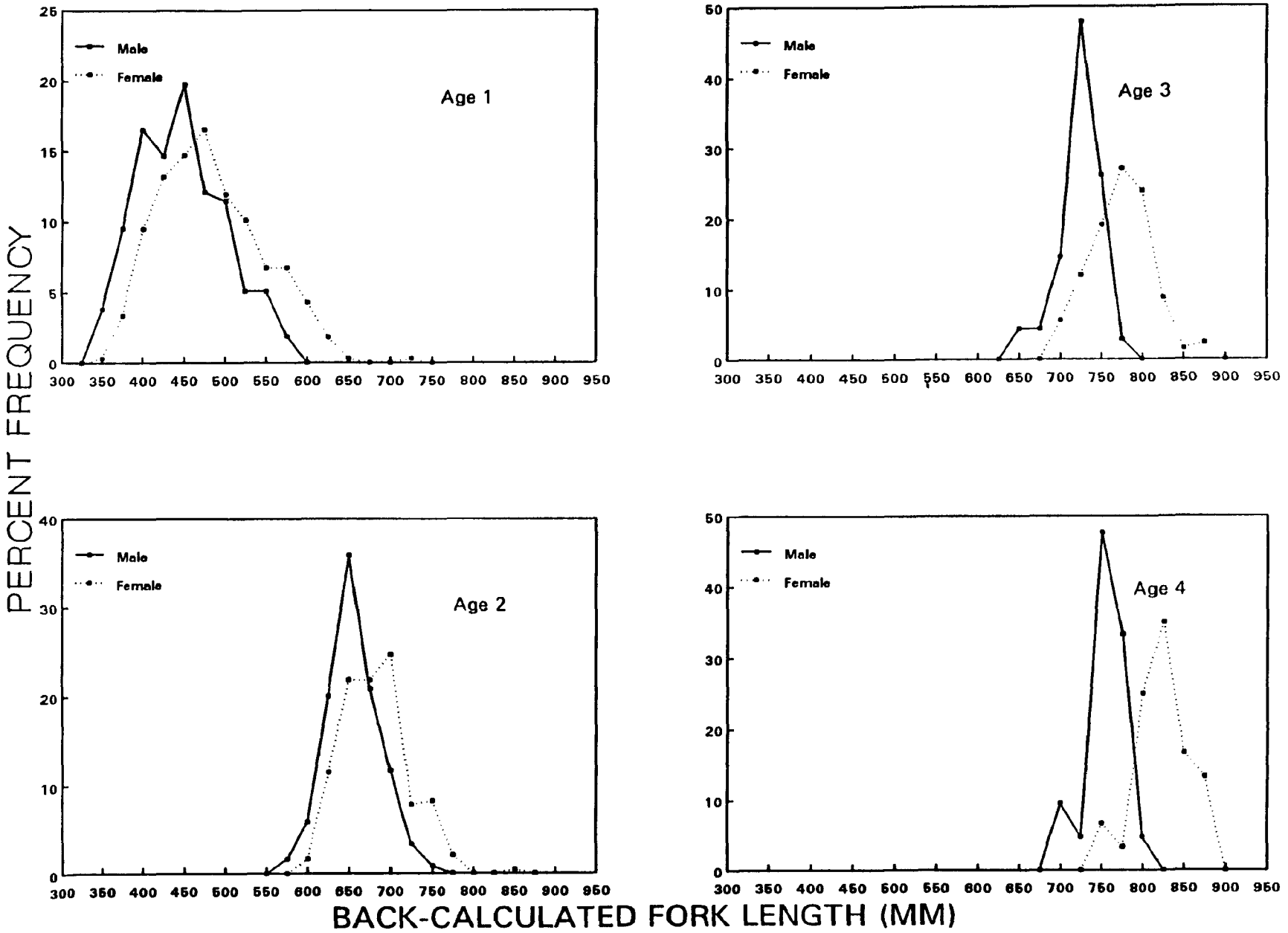



Figure 20. Frequency distributions of the back-calculated length (FL, mm) at ages 1-4 for male and female king mackerel from whole otoliths.

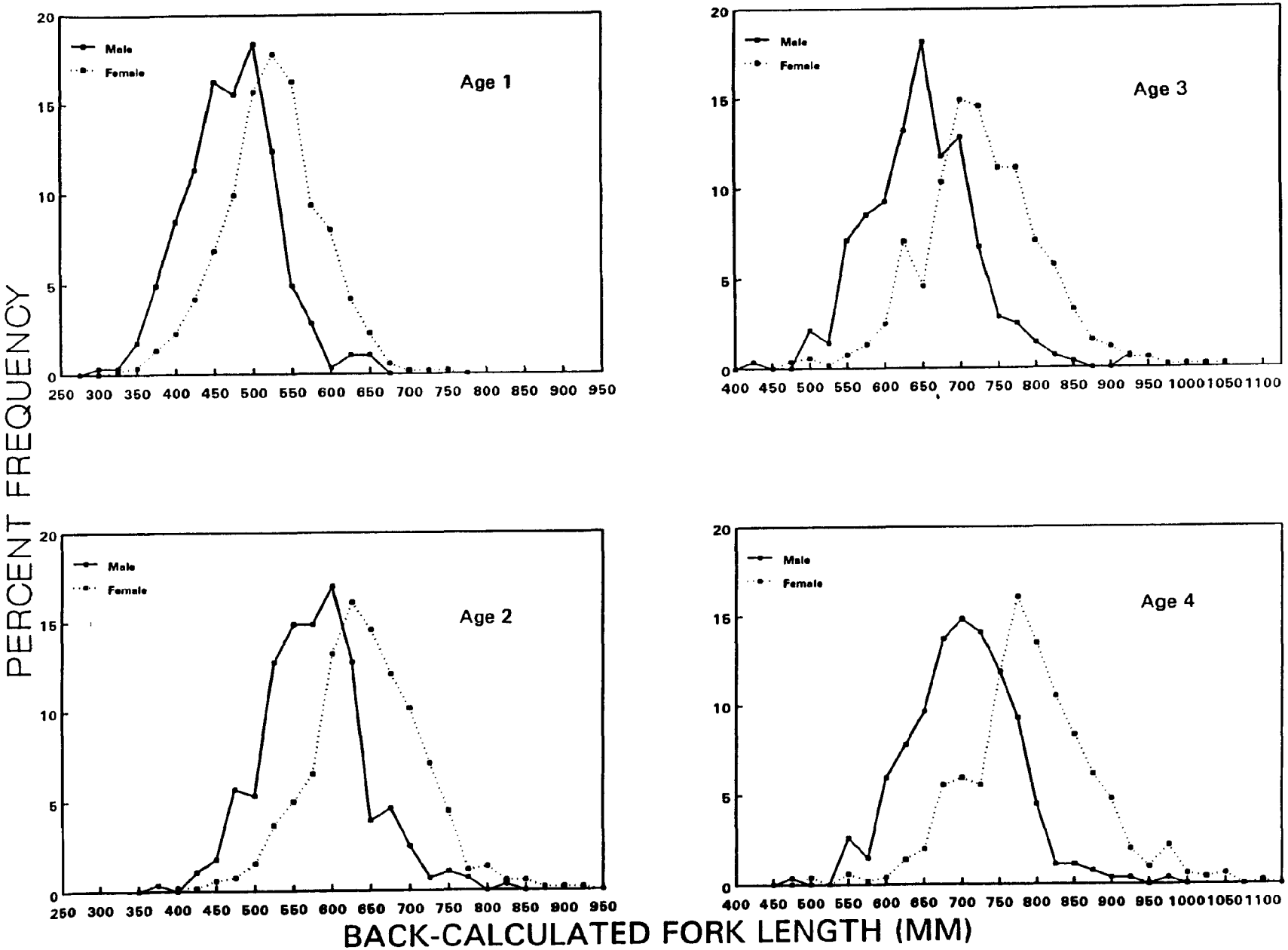



Figure 21. Frequency distributions of the back-calculated length (FL, mm) at ages 1-4 for male and female king mackerel from sectioned otoliths.

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

| | $L_\infty$ (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 |

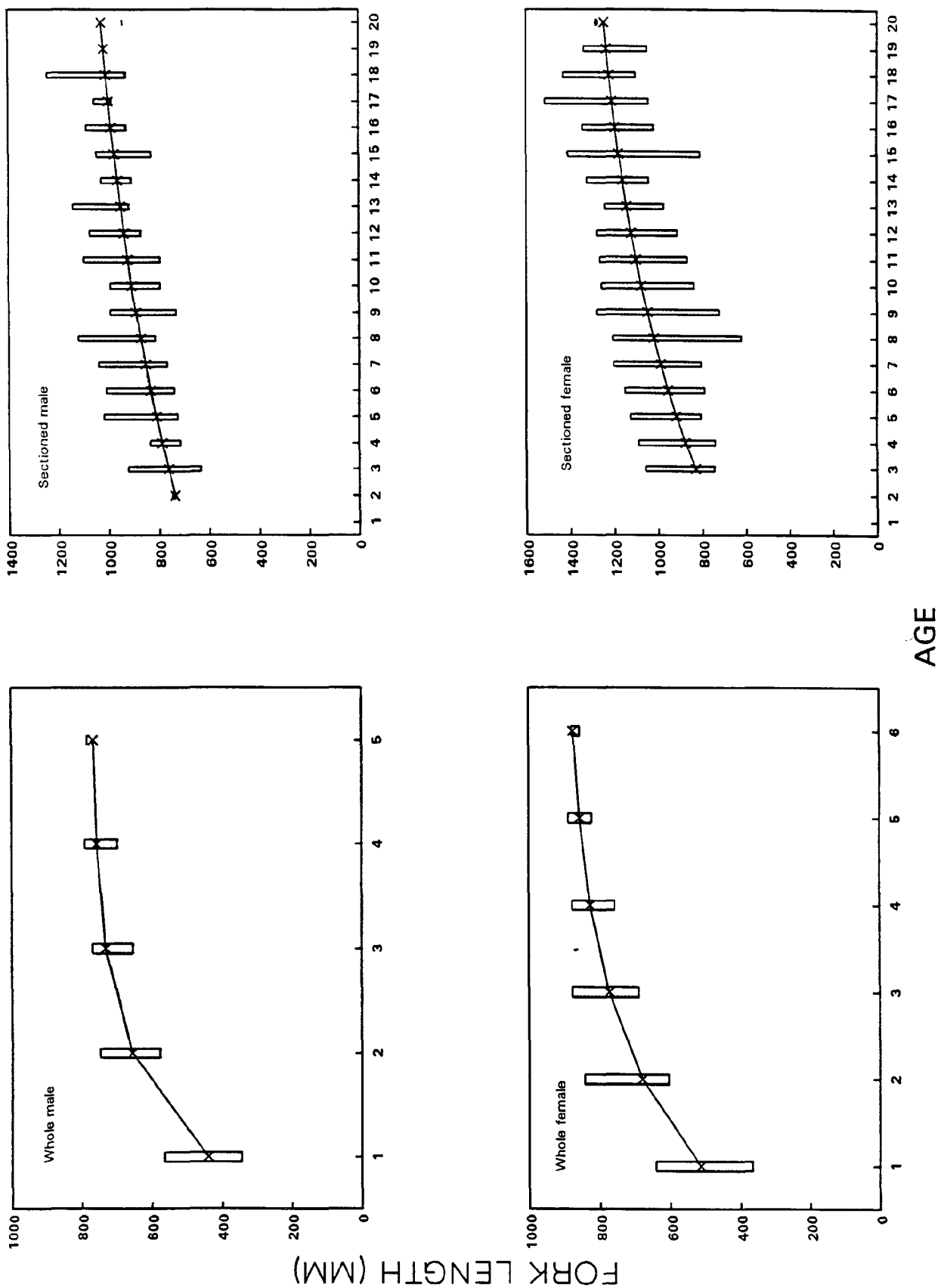



Figure 22. Von Bertalanffy growth curves for male and female king mackerel from whole and sectioned otoliths. Bars indicate the range in size at age.

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 |

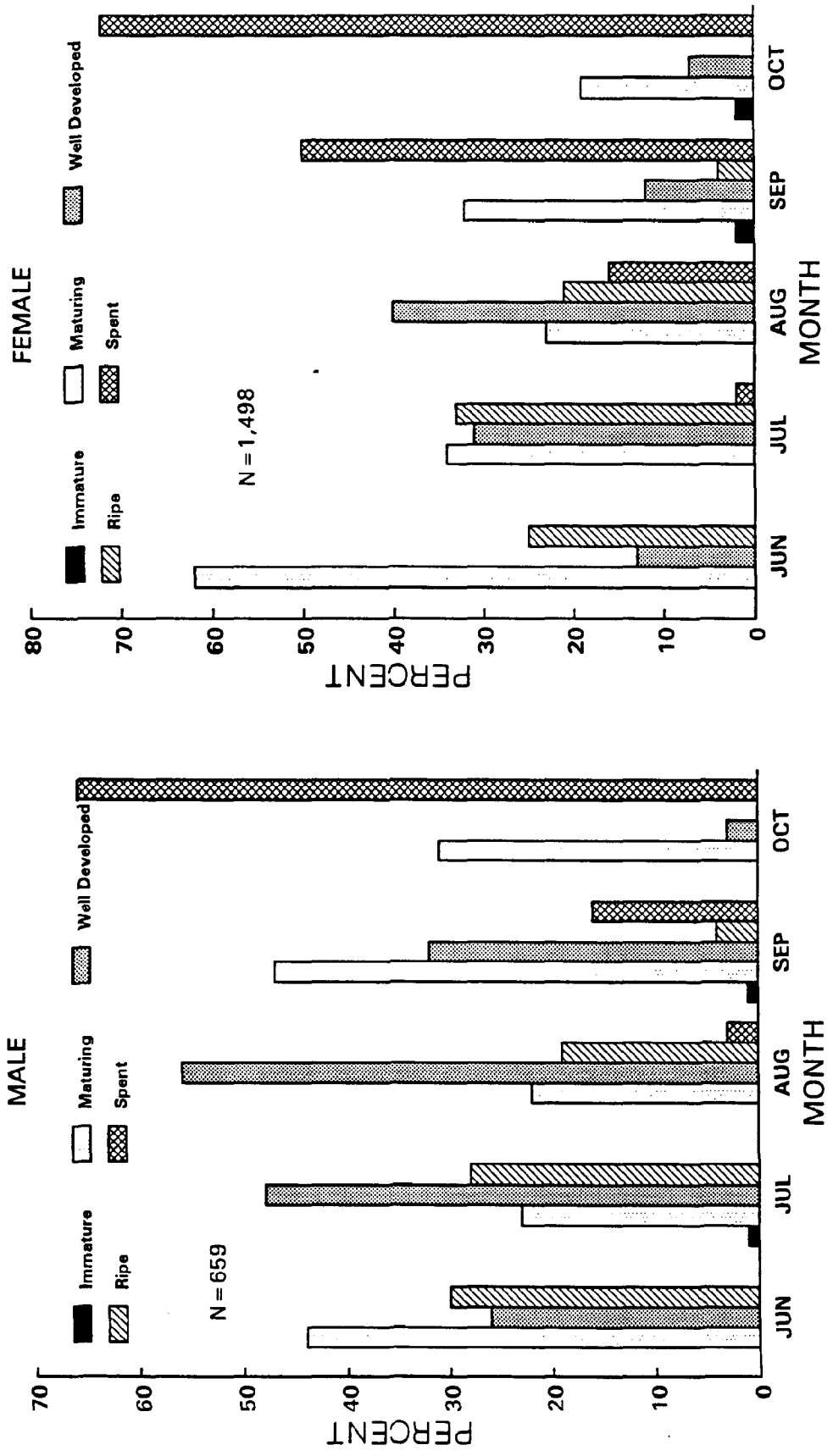



Figure 23. Reproductive stages of male and female king mackerel sample June through October 1988 at North Carolina king mackerel tournaments.

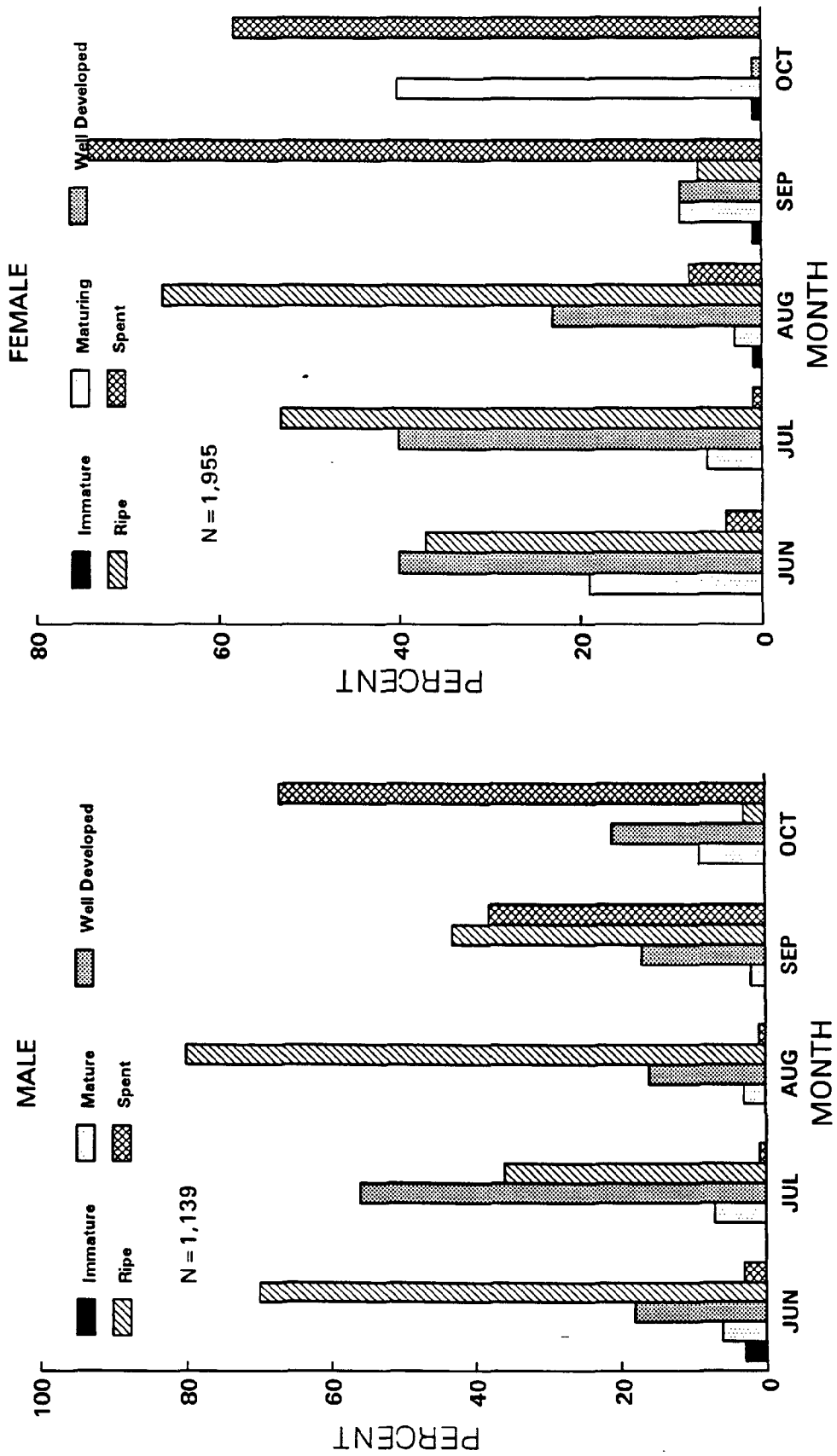



Figure 24. Reproductive stages of male and female king mackerel sampled June through October 1990 at North Carolina king mackerel tournaments.

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 $L_\infty$ was larger for females than males in all studies (Table 26). As in the present study, Collins et al. (1989) derived larger values of $L_\infty$ 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 | $L_\infty$ | 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 | $L_\infty$ | 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 |