# Growth and Mortality of King Mackerel *Scomberomorus cavalla* Tagged in the Southeastern United States

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King mackerel *Scomberomorus cavalla* is a heavily exploited coastal pelagic scombrid that has received considerable attention from research and management concerns throughout the southeastern United States (Gulf of Mexico and South Atl. Fish. Manage. Counc. 1985). Age-length data from analyses of otoliths have recently been used to estimate growth and mortality of the Gulf of Mexico migratory ("stock") group (Manooch et al. 1987) and growth of the Atlantic group (Collins et al. 1988). Previous studies did not differentiate between Gulf and Atlantic groups (Beaumariage 1973, Johnson et al. 1983). Length-increment (tag return) data can also be used to estimate growth and mortality; however, the growth parameter values generated from these data may not be directly comparable with those developed using age-length information (Francis 1988). In this report, we present estimates of growth and mortality based on mark-recapture data for both the Gulf and Atlantic king mackerel groups.

**Table 1**
Number of king mackerel *Scomberomorus cavalla* tag releases off southeastern United States by year, 1975–79, and migratory group.

| | Location and month of release/Migratory group | | | |
|---|---|---|---|---|
| Year | Ft. Pierce, FL December–March/ Gulf of Mexico[1] | Florida Keys February, March/ Gulf of Mexico[2] | Jupiter, FL May, June/ Atlantic[3] | S. Carolina May, June/ Atlantic[4] |
| 1975 | 880 | – | 372 | – |
| 1976 | 1904 | 974 | 1318 | – |
| 1977 | 1666 | 844 | 588 | – |
| 1978 | 1966 | 776 | 396 | – |
| 1979 | – | – | – | 809 |
| Total | 6416 | 2594 | 2674 | 809 |

[1] For all years except 1975, the annual totals for the Ft. Pierce area include December releases of the previous year. Northern boundary of the release area was defined by 28°45′N lat. and the southern boundary by 27°07′N lat.
[2] Eastern boundary of the release area was defined by 81°10′W long., southern boundary by 24°10′N lat., western boundary by 83°30′W long., and northern boundary (Gulf of Mexico only) by 27°00′N lat.
[3] Northern boundary of the release area was defined by 27°07′N lat. and southern boundary by 26°19′N lat.
[4] Northern boundary of the release area was defined by 33°50.0N lat. and southern boundary by 32°03.0′N lat.

## Methods

King mackerel captured by hook-and-line were marked with internal anchor tags along the southeastern United States from South Carolina to the Florida Keys during 1975 to 1979 (Sutter et al. 1991). Tagged fish were assigned to the Gulf or Atlantic migratory groups (Table 1) based on location and date of release using current stock definitions (Powers and Eldridge 1983). King mackerel tag returns that did not show negative growth (based on reported length) were grouped into 30-day intervals based on time-at-large. The mean change in length between release and recapture and the mean time-at-large were determined for each 30-day period. Use of means within blocks eliminated the unequal weighting caused by the large number of fish returned less than one year after release, or by any periodicity in seasonal recaptures. These values were used to estimate the von Bertalanffy growth parameters $L_\infty$ (asymptotic size) and K (growth rate constant) using a non-linear solution (SAS 1985) of Fabens (1965) method. We did not have enough fish to partition our data further to describe growth parameters for male and female king mackerel.

Mortality estimates were made separately for Gulf of Mexico and Atlantic king mackerel groups.

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**Table 2**

Tag-recapture matrix for Gulf of Mexico and Atlantic migratory groups of king mackerel *Scomberomorus cavalla*. Year reported represents a 12-month time interval from time of release.

| Year released | No. released | Year reported 76/77 | 77/78 | 78/79 | 79/80 | 80/81 | 81/82 | 82/83 | 83/84 |
|---|---|---|---|---|---|---|---|---|---|
| **Gulf of Mexico group** | | | | | | | | | |
| 1976 | 2878 | 120 | 58 | 26 | 7 | 4 | 3 | — | — |
| 1977 | 2510 | | 108 | 62 | 22 | 12 | 3 | — | — |
| 1978 | 2742 | | | 104 | 66 | 25 | 12 | 8 | 2 |
| **Atlantic group** | | | | | | | | | |
| 1976 | 1318 | 34 | 15 | 7 | 6 | 2 | — | — | — |
| 1977 | 588 | | 25 | 16 | 12 | 8 | 3 | — | 1 |
| 1979 | 809 | | | | 12 | 14 | 7 | 6 | 1 |

Regression analysis techniques (Gulland 1969) were used to estimate the average annual survival rate for each tagging year by grouping returns into 12-month intervals beginning with month of release (December–March for the Gulf of Mexico group, and May–June for the Atlantic group) (Table 2). Fish recaptured within 30 days of release were not included in our analysis, which allowed tagged fish to recover from tagging and reduced the effect of short-term tagging mortality on our estimates of survival rate. Only the Gulf stock had sufficient numbers of recaptured fish to use the method of Brownie et al. (1985) to estimate annual survival.

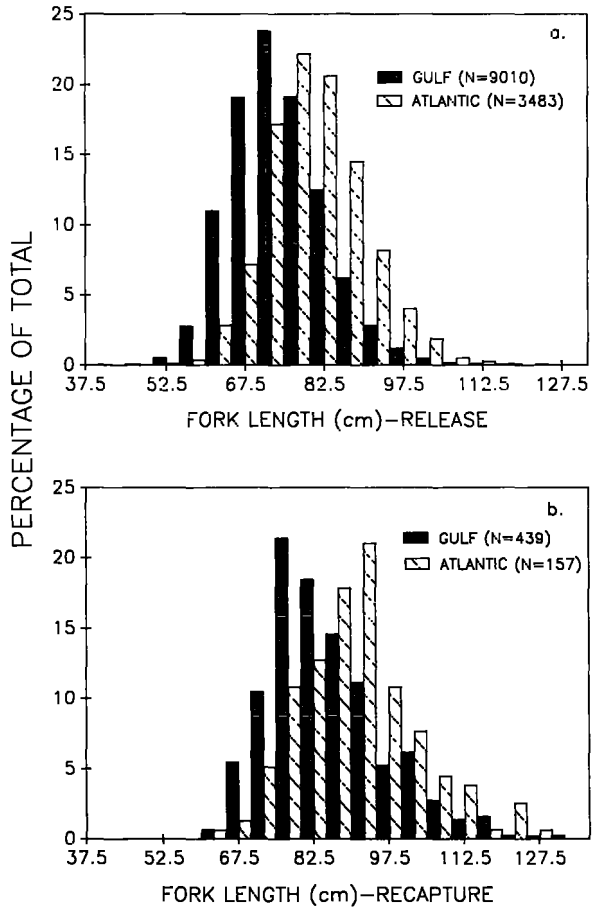


**Figure 1**

Length-frequencies of king mackerel *Scomberomorus cavalla* at release and recapture from Gulf of Mexico and Atlantic migratory groups. Fish were grouped by 50 mm FL intervals; mid-range values are used for each plot.

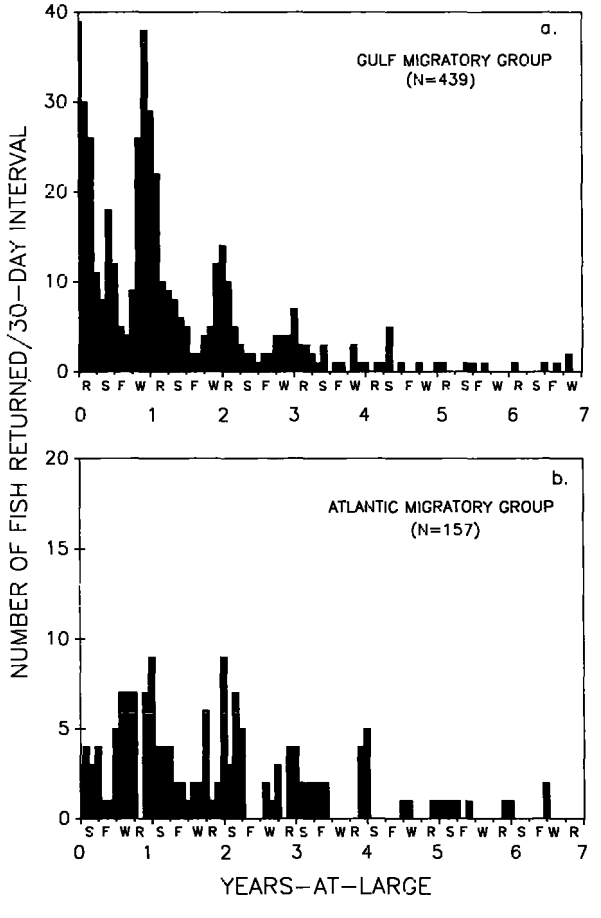


**Figure 2**

Recaptured king mackerel *Scomberomorus cavalla* utilized in the growth analysis, summarized by 30-day blocks from time of tagging, for the Gulf of Mexico (released during December–March) and Atlantic (released during May–June) migratory groups. Seasons for each year of recapture are: W = winter, R = spring, S = summer, and F = fall.

**Table 3**

Summary of theoretical growth parameters ($L_\infty$, K) and mortality estimates (Z), sexes combined, for Gulf of Mexico and Atlantic migratory groups of king mackerel *Scomberomorus cavalla*.

| Study | Migratory group | Interval | $L_\infty$ (cm) | K | Z |
|---|---|---|---|---|---|
| Present study | Gulf of Mexico | 1975–88[1] | 132.6 | 0.127 | 0.794 (1976–82[2])<br>0.877 (1977–82[2])<br>0.766 (1978–84[2]) |
| | Atlantic | 1975–85[1] | 152.0 | 0.070 | 0.658 (1976–82[2])<br>0.493 (1977–82[2])<br>0.582 (1979–84[2]) |
| Manooch et al. (1984) | Gulf of Mexico | 1980–85 | 147.8 | 0.115 | 0.54 (1980[3])<br>0.72 (1981[4])<br>0.50 (1984[5]) |
| Collins et al. (1988) | Atlantic | 1983–87 | 112.7[6]<br>127.7[7] | 0.213[6]<br>0.087[7] | Not available |

[1]Time from release to recapture used in calculating growth parameters.
[2]Years used in regression analysis of recaptured king mackerel.
[3]Year fish collected from recreational hook-and-line catches in northwest Florida.
[4]Year fish collected from gillnet catches in south Florida.
[5]Year fish collected from south Florida purse-seine catches.
[6]Whole otoliths.
[7]Sectioned otoliths.

## Results and discussion

### Growth analysis

A total of 9010 king mackerel from the Gulf of Mexico king mackerel migratory group were tagged; 794 were reported recaptured, and 439 fulfilled our criteria for inclusion in the growth analysis. The mean length-at-tagging was 74.5 cm FL (SD 8.92 cm, range 42.5–120.0 cm) (Fig. 1a), while the mean length-at-return was 85.2 cm FL (SD 11.61 cm, range 62.5–133.0 cm) (Fig. 1b). Maximum time-at-large was 10.48 years (3829 days), with a mean of 1.06 years (SD 1.24 yr). Fish were recaptured most frequently during the first year of freedom (51.5%), with seasonal increases in returns noted during winter and spring months (Fig. 2a). We recaptured Gulf of Mexico migratory group fish from Texas to southeast Florida through 1988, although 95.5% were taken before 1981.

The relationship between length-at-return minus length-at-tagging ($\Delta\ell$) vs. number of days-at-large ($\Delta t$) for Gulf of Mexico king mackerel was described by: $\Delta\ell = 3.722 + 0.012\ (\Delta t)$ ($r^2$ 0.503; df 1, 438; $P<0.01$). Mean values from a total of 63 30-day blocks were used to generate an estimate of $L_\infty = 132.6$ cm FL (95% CI 114.3–150.8 cm), and K = 0.127 (95% CI 0.068–0.186). Manooch et al. (1987) used whole otoliths to calculate an $L_\infty$ value of 147.8 cm (95% CI 131.6–164.0 cm) and K = 0.115 (95% CI 0.079–0.152) for Gulf of Mexico king mackerel captured during 1980–85 (the majority taken from Key West, northwest Florida, and Texas), combining both sexes (Table 3). Growth parameters determined from our tagging study overlap the spatial and temporal constraints of their age-length data.

A total of 3483 king mackerel were tagged from the Atlantic king mackerel migratory group. Recaptures were reported for 253 fish, of which 157 provided sufficient data for our growth analysis (Fig. 1b). Mean length-at-tagging was 81.0 cm FL (SD 9.17, range 50.0–122.5 cm), while the mean length-at-return was 91.0 cm FL (SD 11.65, range 64.8–127.0). The maximum time-at-large was 6.47 years (2361 days), with a mean of 1.56 years (SD 1.41 yr). Fewer returns were reported during the first year of freedom (31.2%) than were noted for the Gulf migratory group (Fig. 2b), and most returns occurred during the summer and fall. We recaptured Atlantic migratory-group king mackerel through 1985; however, 92.1% were taken before 1982, prior to commercial and recreational quota restrictions.

The relationship between growth ($\Delta\ell$) and time-at-large ($\Delta t$) for the Atlantic fish is: $\Delta\ell = 4.057 + 0.008\ (\Delta t)$ ($r^2$ 0.323; df 1, 156; $P<0.01$). The estimated asymptotic length for Atlantic king mackerel calculated from 52 30-day blocks was 152.0 cm FL (95% CI 87.3–216.8 cm), with an associated K = 0.070 (95% CI 0.005–0.146). Collins et al. (1988) used whole and sectioned otoliths from king mackerel in the Atlantic group to calculate estimates of $L_\infty = 112.7$ and 127.7 cm FL, and K = 0.213

and 0.087 (whole vs. sectioned, respectively) for fish collected from Cape Canaveral, Florida, to Cape Fear, North Carolina, during 1983–87 (Table 2). They concluded, however, that whole otoliths may have provided biased estimates, at least for Atlantic king mackerel. Although the spatial distribution of our tagging effort was similar to the geographical study area of Collins et al. (1988), their collections occurred during regulation of the king mackerel fishery.

Comparison of our growth estimates for Gulf and Atlantic king mackerel should be made with caution due to our limited sample size and our reliance on reported fish lengths. The Atlantic group appears to exhibit a larger maximum size ($L_\infty$) and a slower relative growth rate (K) than its Gulf of Mexico group counterparts (Table 2). This is supported by comparing the two regression equations of growth ($\Delta l$) vs. time-at-large ($\Delta t$). We found that the slope for the Gulf of Mexico group was significantly different (ANCOVA; F 7.344, df 1, 592; $P<0.01$) than that observed for the Atlantic king mackerel, indicating a faster growth rate over the size range that were tagged and recaptured.

Growth analyses using age-length data provide an estimate of asymptotic mean length-at-age, while mark-recapture data provide estimates of the maximum length achieved in the population (Francis 1988). Our $L_\infty$ estimate for the Gulf of Mexico migratory group (132.6 cm) was larger than that for any individual fish tagged or returned, except for one fish which was 133.0 cm FL; however, Trent et al. (1987) found fish as large as 158.0 cm FL in their work off Louisiana. These large fish were females taken from what may be a year-round resident population (Fable et al. 1987) which was not included in our tagging efforts. Fish from the Gulf of Mexico migratory group that were tagged in our study would therefore be considered part of the 'small' migratory fish described by Fable et al. (1987). Manooch et al. (1987) reported sampling fish up to 180.2 cm FL from the Gulf of Mexico; however, because they did not provide a length distribution, the frequency of fish larger than 132.6 cm FL in their samples could not be determined. All fish collected from both the Collins et al. (1988) and our study were smaller than the calculated $L_\infty$ values for the Atlantic migratory group.

### Annual survival rates

Between 1976 and 1984, estimates of survival rates were lower for the Gulf migratory group than those observed for the Atlantic migratory group of king mackerel (Table 3). Regression and maximum-likelihood techniques yielded similar estimates of survival rates for the Gulf group. Annual pooled estimates of survival rates of these fish were in the range 41.6–46.5% (Z 0.877–0.766/yr; Table 3). The simplest model of Brownie et al. (1985; Model 3, constant survival and recovery rates, independent of age) was the most applicable to our database for the Gulf group of king mackerel, yielding a pooled estimate of 42.290 (SE 1.60; Z 0.794/yr). Estimates of annual survival rates for the Atlantic migratory group were in the range 51.8–61.1% (Z 0.658–0.493/yr).

Previous estimates of annual survival rates generated from age-length data compare favorably with those calculated from our mark-recapture data. Manooch et al. (1987) calculated instantaneous total mortality estimates from age-length data for king mackerel from two locations in the Gulf of Mexico that overlapped with our study area (Table 3). Their estimates of annual survival rates were in the range 48.7–60.7% (Z 0.719–0.499/yr) for king mackerel (both sexes combined) in south Florida collected during 1981 (gillnet) and 1984 (purse seine). King mackerel collected from recreational hook-and-line catches in northwest Florida during 1980 yielded an annual survival rate estimate of 58.3% (combining sexes; Z 0.540/yr). A pooled estimate of annual survival rate for king mackerel collected during 1977–79 along both the Gulf and Atlantic coasts was 63.0% (Z 0.462/yr; Johnson et al. 1983).

Growth and mortality estimates generated from age-length and length-increment studies must account for behavioral characteristics germane to a migratory species. King mackerel have been shown to have at least two migratory patterns along the southeastern United States; however, there is a seasonal overlap of the two groups along southeast Florida that may be as high as 29.4–41.8% (Sutter et al. 1991). Resident populations of king mackerel may also exist in the northcentral Gulf of Mexico (Fable et al. 1987) and in southeast Florida waters (Sutter et al. 1991). These factors should be considered when designing future survey strategies to describe growth and mortality rates.

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