SEDAR 5 DW-6

A Literature Review of the Growth of King mackerel in the Southeastern United States

by

Nancie J. Cummings[1], Doug A. Devries[2] and Chris Palmer[2]

U.S. Department of Commerce
National Oceanic and Atmospheric Administration (NOAA)
National Marine Fisheries Service (NMFS)
Southeast Fisheries Science Center (SFSC)

Sustainable Fisheries Division (SFD)
[1]75 Virginia Beach Drive
Miami, Florida 33149

[2]Panama City Laboratory
3500 Delwood Beach Road
Panama City, Florida 32408

December 2003

Sustainable Fisheries Division Contribution No. SFD 2003-00

and

Mackerel SEDAR Data Workshop Report No. DW-6

Final Draft

Introduction and Background

King mackerel, *Scomberomorus cavalla*, have been intensely exploited by both recreational fishermen from North Carolina through Texas since the mid 1950's (Manooch 1979, Beaumariage 1970, Moe 1963) and by commercial trolling fishermen along Florida's southeast coast since the early 1960's. Since 1983 this species has been managed by a joint fishery management plan of the Gulf of Mexico and South Atlantic Fishery Management Councils (GM & SAFMC 1982). The current management plan assumes two stocks, an Atlantic migratory group and a Gulf of Mexico migratory group, although scientific information, from genetic studies and from mark - recapture experiments, suggests the existence of two groups in the Gulf of Mexico- an east and a west (see Devries and Grimes 1997). The Gulf migratory group has been considered overfished throughout much of its management history (Mackerel Stock Assessment Panel 1994).

In 2003 the Councils initiated the Southeast Data, Assessment, and Review (SEDAR) process under coordination and management with the National Marine Fisheries Service Southeast Fisheries Science Center (NMFS, SEFSC) and the Interstate Commissions. In the SEDAR Data Workshop phase, a review of all the available fishery and life history data is conducted for the species under review. King mackerel was selected by the SEDAR steering Committee as a priority species for the SEDAR process for CY 2003 and 2004 (Merriner 2003). The purpose of this report is to provide a literature review of the growth of king mackerel in the southeastern United States. This information is important to upcoming stock assessments of U.S. king mackerel stocks and in carrying out the mission of the SEDAR King mackerel Data Workshop. Included in the review are historical published and non-published information regarding weight to length transformations, length to length relationships, length to age conversion formulae. Sexual dimorphism is discussed and aspects of the variability of growth temporally and spatially are included. This report does not include information on the growth of larval king mackerel.

Individual Length to Weight Transformations

Summarized weight to length transformations for U.S. king mackerel stocks are presented in Table 1. Accurate formulae for transformation individual samples from length to weight are required to convert samples of landings in weight (usually pounds) to samples of numbers caught. These studies span the time period from 1968 through about 1983. The data sets from which the conversions were developed included samples obtained off Florida, the Carolinas, Louisiana, and Texas. Observations from commercial and recreational fisheries were used to describe the weight to length relationship. The majority of the studies developed separate formulae for males and females; statistical tests of differences between sexes were presented only for the south Florida study of Beaumariage (1973). Comparison of regression coefficients ($t_{(0.05)}$=3.235 suggested females were heavier than males of a similar length. One study (Waltz 1986) also provided conversion formulae for converting individual observations of gutted weights to whole weight. The Waltz (1986) study provides the most current weight to length transformations formulae for Atlantic king mackerel. The Campbell et. al. (1988) study included fish collected from recreational catches between 1978 and 1983 off Galveston, Aransas, and the lower Laguna Madre Bay system off Texas. The Johnson et al. (1983) study represents the largest spatial coverage in the Gulf of Mexico king mackerel; samples were collected during 1977 and 1978.

Length to Length Transformations

Table 2 summarizes the available length to length transformation for king mackerel in the southeastern U.S. These formulae included samples from 1968-1983, covering the Carolinas through Cape Canaveral (Florida), south Florida, southeast Louisiana, and the bay systems of Texas. The Waltz (1986) study is the most current for all areas combined.

Length to Age Transformations

Methodologies

Several investigators have described growth in king mackerel from otolith observations (Beaumariage 1983, Johnson et al. 1983, Manooch 1987, Collins et al. 1988, and Nobel et al. 1992). Von Bertalanffy growth parameters were derived in most of these studies using estimates of back calculated sizes at age (usually means or weighted means) generated from whole otolith readings. The early studies of Johnson et al. (1983) and Manooch et al (1987) as well as Nobel et al. (1992) reported high percent agreement in age readings made from both sectioned and whole otoliths however, later researchers clearly documented difficulties in using whole otoliths for age determinations of king mackerel (Waltz 1986, Collins et al. 1988). In particular, comparison between methods in age readings made from the same otolith resulted in disparities in both the enumeration of the number of rings (i.e., annuli) as well as in the determination of the timing of mark formation as defined by the percentage of opaque margins (see Collins et al. 1988, Cummings 1985). The study of Collins et al. (1988) further showed that the disparities were especially large for individuals >85 cm Fl. Apparently use of whole otoliths produces significant underestimation of ages as also shown by DeVries and Grimes (1990). More recent investigators of king mackerel growth have utilized sectioned otoliths for age determinations of larger (>80cm FL males and >90 cm FL females) king mackerel (Devries 1992).

Beamish and McFarlane (1983) reviewed important requirements for establishing age from hardparts. These included 1) establishing a positive relationship between body size and a selected hardparts, 2) identifying a periodicity in annuli deposition and 3) consistent location in annuli on the hardpart. Nearly all of the king mackerel growth studies have validated otolith ages indirectly evaluating the percentage decrease in the marginal increment by month, the average marginal increment by month, the frequency distribution of marginal increment by month, and other indirect methods including examining the progression in body size (mean lengths) for a given number of rings. In addition visual inspection of plots of the percentage of observations with opaque margins has been used to support annulus deposition. Only two studies have attempted to validate annuli deposition directly. Johnson and Fable (1986) reported preliminary information on age validation from oxytetracycline (OTC) marked fishes (n=4) off Panama City, Florida. Of 216 fish tagged and injected with OTC 13 fishes were recaptured and 4 returned for examination for the OTC mark. Two of the four returns were at liberty more than one year and both deposited one opaque mark on their annuli thus supporting mark formation. These individuals were both small fish, less than four years of age. Nobel et. al. (1992) also used OTC marking however returns of those experiments have not yet been reported.

Johnson and Fable(1986) further used the results of their OTC experiments to evaluate growth. They compared predicted length (at mark formation) from the equations of Beaumariage (1973) and Johnson et al. (1983) with empirical length at mark (from otolith increment analysis). These authors reported that the latter two theoretical models under-estimated size. The differences between the equation estimates and the observations of Johnson and Fable may have been due to differences in how the otoliths were handled; the equations were based on whole otoliths.

Two additional studies have modeled growth from tagging data (Sutter et al.1991, Cummings 1985.

Variability in growth spatially, temporally and by sex

Beaumariage (1973) reported that growth rates were not different between coasts for either sex for fish sampled off Florida's east and west coast. Johnson et al. (1983) noted that females from Louisiana grew faster than females from other areas of the Gulf and from the Atlantic. DeVries and Grimes (1997) examined the variability in growth temporally, regionally and by sex from fish collected between 1977 and 1992. These authors obtained and re-aged the samples of Johnson et al. (1983), who collected fish from 1977-1978. DeVries and Grimes reported statistical differences in growth between sexes in each region during both time periods not totally un-expected since earlier researchers (Beaumariage 1973, Waltz 1986) have noted sexual dimorphism in king mackerel growth. In addition the DeVries and Grimes (1997) report suggested 1) large variability in age-at-size in all regions again for both sexes, 2) slightly higher maximum ages in the Atlantic than in the eastern or western gulf during the second period (1986-1992), and highest growth in the eastern Gulf of Mexico migratory group (for the 1986-1992 samples), intermediate growth in the western gulf and the lowest in the Atlantic for both sexes. DeVries and Grimes (1997) finding of large variability in size at age across regions could be related to variability in recruitment size across regions. Interestingly, DeVries and Grimes (1997) reported similar maximum ages by sex unlike earlier growth investigators (females:26 (Atlantic), 24 (Gulf of Mexico) and males: 24 (Atlantic) and 23 (Gulf of Mexico). Both Beaumariage (1973) and Collins et al. (1988) reported higher maximum age for females. Beaumariage's lower estimates of longevity could also be explained by the use of whole otoliths for age determinations. Maximum age was slightly smaller in the 1977-1978 samples however this could also be due to an artifact of sampling. Plots of fitted Von Bertalanffy curves by region were examined to ascertain differences in growth rates over time. These plots suggest slight differences regionally however further and more complete statistical examination of the data are needed to determine to the degree estimates of the growth parameters overlap by region, sex and year (cohort group).

Useful Literature Citations for king mackerel growth

Beamish, R.J. and G.A. McFarlane. 1983. The forgotten requirement for age validation in fisheries biology. Trans. Am. Fish. Soc. 112:735-743.

Beardsley, G.L. and W.J. Richards. 1970. Size, seasonal abundance, and length to weight relationship of some scombrid fishes from southeast Florida. U.S. Fish. and Wildl. Serv., Spec. Sci. Rept. No 595, 6pp.

Beaumariage, Dale S. 1973. Age, growth, and reproduction of king mackerel, *Scomberomorus cavalla*, in Florida. Fl. Mar. Res. Publ., No. 1, 44 pp.

Beaumariage, Dale. S. 1970. Current status of biological investigations of Florida's mackerel fisheries. Proc. Gulf Caribb. Fish. Inst., 22nd Annual Meeting, 1969:79-86.

Campbell, R.Page, Karen L. Meador, and David a. McKee. 1988. Weight-length and length-length relationships of king mackerel off Texas. TPWD Manag. Data Ser. No. 138,11 p.

Collins, Mark R., David J. Schmidt, C. Wayne Waltz, and James L. Pickney. 1988. Age and growth of king mackerel, *Scomberomorus cavalla*, from the Atlantic coast of the United States. Fish. Bull. 87:49-61.

Collins, Mark R. and Charles A. Wenner. Occurrence of young-of-the-year king, *Scomberomorus cavalla*, and Spanish, *S. maculatus*, in commercial-type shrimp trawls along the Atlantic coast of the southeast United States. Fish. Bull. 86(2):394-397.

DeVries, Doug A. and Churchill B. Grimes. 1997. Spatial and temporal variation in age composition and growth of king mackerel *Scomberomorus cavalla*, 1977-1992. Fish. Bull. 95:694-708.

Fischer, Myron. 1980. Size distribution, length-weight relationship, sex ratios, and seasonal occurrence of king mackerel (*Scomberomorus cavalla)* off the southeast Louisiana coast. Louisiana Dept. Wildl. Fish. Contrib. Mar. Res. Lab., Tech. Bull. No. 31, 1978. 20 pp.

Gulf of Mexico and South Atlantic Fishery Management Councils plan/final environmental impact statement/regulatory impact review/draft regulations for the coastal pelagic resources (mackerels) in the Gulf of Mexico and South Atlantic region. Tampa, Fla. (GMFC), and Charleston, S.C. (SAFMC).

Johnson, A.G., W.A. Fable Jr., M.L. Williams, and L.E. Barger. 1983. Age, growth, and mortality of king mackerel, *Scomberomorus cavalla*, from the southeastern United States. Fish. Bull. 81(1):97-106.

Johnson Allyn G. and William A. Fable. 1986. Evidence for age validation in otoliths of king mackerel. Unpublished manuscript, NMFS, SEFSC Panama City Laboratory, 6 pp.

Manooch, C.S., S.P. Naughton, C.G. Grimes, and L. Trent. 1987. Age and growth of king mackerel from the U.S. Gulf of Mexico. Mar. Fish. Rev. 49(2):102-108.

Merriner, John. Draft SEDAR Steering committee Meeting. Summary notes from January 24, 2003 discussions. 2 pp. 2 attachments (1: Draft agenda for SEDAR Process, 2: SEDAR: an Overview and its Proposed Relationship to existing GMFMC assessment activities).

Waltz, Wayne. 1986. Data report on preliminary attempts to assess and monitor size, age, and reproductive status of king mackerel in the South Atlantic Bight. Rpt. Prepared in partial fulfillment of Contract No. 6-35147, sponsored by NMFS, MARMAP Program Office, and the South Carolina Division Marine Resources, 56 pp.

Weymouth, F.W. and H.C. McMillin. 1931. Relative growth and mortality of the Pacific razor clam (*Siliqua patula*, Dixon) and their bearing on the commercial fishery. U.S. Bur. Fish. Vol 46. Doc. No. 1099: 543-567. [as cited in Beaumariage 1973).

Table 1. Summary of weight to length and weight to weight transformations for king mackerel in the southeastern United States.

Study	Geographical Location	Study Period	Fishery	Sex	n	Size Range Length Weight.	a	b	Notes
Beardsley and Richards (1970) Units : FL (cm), Wt (kgs) Length recorded to 1mm Wt recorded to 0.1 pound	Miami, Florida	1968 and 1969	commercial (troll, gnet, purse seine) and recreational tournament samples	Combined	197	58.5-150 1.47-32.09	$2.701 * 10^{-6}$	3.2300	
Beaumariage (1973) Units: SL (mm), Wt (grams)	South Florida (east and west coast)	1968 and 1969	recreational and commercial (troll, purse seine, gnet	Males Females Combined	237 293 530	465-1,030 Sl 879-9.752 g 390-1,590 SL 454-37,195 g 390-1,590 SL 454-37,195 g	$1.330 * 10^{-5}$ $3.907 * 10^{-6}$	2.9372 3.1256	
Fischer (1980) Units: FL (mm), Wt(pounds) and converted to grams for estimation	Southeastern Louisiana	December 1 1977 to November 30 1978	Recreational	Males Females	38 500	Not provided 11-27 Not provided 8-67	$1.922 * 10^{-7}$ $1.002 * 10^{-6}$	3.533 3.291	Size range (wgt) interpolated from Figure 16 of Fischer
Johnson et al. (1983) Units: FL (mm), Wt (grams)	N. and S. Carolina, Tx, La, Fl	June 1977-August 1979	recreational hook and line, few small individuals from shrimp trawls (cape Canaveral)	Males Females Combined	701 2023 2821	428-1,355 Not provided 351-1,554 Not provided 351-1,554 Not provided	$0.8064 * 10^{-5}$ $0.8801 * 10^{-5}$ $0.8464 * 10^{-5}$	2.9928 2.9827 2.9881	n=20 (or max if <20) per 50mm length interval used in regression
Campbell et al. (1988). Units: TL(mm),Wt(grams) and Wt converted to grams for estimation Relation fit was: log Wt=log a + b Log TL	Galveston Bay, Matagorda/San Antonio Bay, Aransas/Corpus Christi Bay and lower Laguna Madre Bay	1978-1983	recreational creel surveys	Males Females Combined	231 386 1331	595-1170 Not Provided 614-1440 Not Provided 573-1675 Not Provided	-5.641 -5.428 -5.495	3.114 3.045 3.070	
Campbell et al. (1988). Units: TL(mm), Wt(grams) and Wt converted to grams for estimation Relation fit was: log Wt=log a + b Log FL	Galveston Bay, Matagorda/San Antonio Bay, Aransas/Corpus Christi Bay and lower Laguna Madre Bay	1978-1983	recreational creel surveys	Males Females Combined	199 308 754	515-1050 Not Provided 500-1323 Not Provided 500-1350 Not Provided	-5.322 -4.910 -4.879	3.059 2.921 2.911	
Waltz (1986) Units: Fork length mm WT : grams Relation fit was: log(WT)=b(log (FL mm) -a	Cape Fear - Cape Canaveral Fl	May 1983 - Dec. 1985	commercial hook line, recreational tournaments, research cruises (otter trawls, try nets, seam trawl, gillnets, seines) commercial shrimp trawls	Males Females Combined	418 174 912	Not Provided	4.69 4.65 4.80	2.85 2.85 2.89	
Waltz (1986) Units: Total length mm WT : grams Relation fit was: log(WT)=b(log (TLL mm) -a	Cape Fear - Cape Canaveral Fl	May 1983 - Dec. 1985	commercial hook line, recreational tournaments, research cruises (otter trawls, try nets, seam trawl, gillnets, seines) commercial shrimp trawls	Males Females Combined	164 393 873	Not Provided	5.05 5.33 5.08	2.93 3.03 2.93	
Waltz (1986) Units: Wt 9grams) Relation fit was: log (whole WT)=b(log(Gutted Wt)) - a	Cape Fear - Cape Canaveral Fl	May 1983 - Dec. 1985	commercial hook line, recreational tournaments, research cruises (otter trawls, try nets, seam trawl, gillnets, seines) commercial shrimp trawls	combined	15	Not Provided	169.21	1.11	1.Relation fit: log(whole WT)= b(log(Gutted Wt)) - a

Table 2 Length to Length transformations for king mackerel in the southeastern U.S.

Study	Geographical Location	Sample Size by sex	Length to Length Relation	Length Range
Beaurmariage (1973)	Southeast Florida	combined 100	FL(mm) = 1.0960*FL(mm) - 17.143	550-1,045 mm SL, n=100 randomly selected
Campbell et al. (1988)	Texas	males 202 females 310 combined 812	TL(mm) = 1.090 * FL(mm) + 27.768 TL(mm) = 1.071 * FL(mm) + 47.034 TL(mm) = 1.067 * FL(mm) + 48.968	FL 600-1050 FL 500-1323 FL 500-1445
Campbell et al. (1988)	Texas	males 110 females 188 combined 651	TL(mm) = 1.182 * SL(mm) + 11.790 TL(mm) = 1.096 * SL(mm) + 85.641 TL(mm) = 1.167 * SL(mm) + 23.799	SL 485-1000 SL 476-1090 SL 476-1410
Campbell et al. (1988)	Texas	males 110 females 185 combined 455	FL(mm) = 1.069 * SL(mm) - 3.029 FL(mm) = 1.021 * SL(mm) + 38.880 FL(mm) = 1.038 * SL(mm) + 22.833	FL 485-1000 FL 476-1090 FL 476-1410
Fischer (1980)	Southeast Louisiana	combined 129	TL(mm) = 1.0131*FL(mm) + 51.5 FL(mm) = 0.9700*TL(mm) - 50.63	Not provided
Waltz (1986)	Cape Fear - Cape Canaveral	males 169 females 401 combined 904	TL(mm) = 1.08* FL(mm) + 29.44 TL(mm) = 1.13* FL(mm) + 69.31 TL(mm) = 1.10* FL(mm) + 9.81	Not provided
Waltz (1986)	Cape Fear - Cape Canaveral	males 169 females 401 combined 904	FL(mm) = 0.92* TL(mm) - 20.68 FL(mm) = 0.91* TL(mm) - 13.08 FL(mm) = 0.91* TL(mm) - 6.22	Not provided

Table 3. Sex ratios reviewed for king mackerel in the southeastern U.S..

Study	Geographical Location	n	Sex Ratio (M:F)
Fischer (1980)	Southeast Louisiana recreational charterboat and private vessel fishery. Rod and reel gear only.	558	0.074 : 0.926 (Jan-March) 0.031 : 0.969 (April-June) 0.104 : 0.896 (July-Sept.) 0.034 : 0.966 (Oct.-Dec) 0.073 : 0.927 (all months)

Table 4. Information on annuli formation timing and periodicity for king mackerel in the southeastern U.S.

Study	Timing	Comments
Beaumariage- Florida samples. 1968-1968	Plots suggested annuli deposited February through November. Minimum depositon in May as shown by % marginal increment growth vs month	1. Modeled relative (percentage) increment growth vs month after Weymouth and McMillin (1931) with clams. 2. Beaumariage suggested annuli formation is a peak of gonad activity (just prior to spawning)
Johnson et al Tx, La, Carolinas, Florida. 1977-1979	Johnson noted marking occurred (i.e, opaque margin present on otolith) in eleven of twelve months with the peak in May	1. Used whole otoliths. Performed comparison readings of whole vs section ages (n=133 otoliths, ages 0-14+) and reported 96.5% agreement. 2.Evaluated marking by comparing frequency of opaque margins vs month.
Manooch et al. 1984 Gulf of Mexico Key West to Yucatan Pennisula, Mx. 1980-1985	February through May and also September for fish taken off northwest Florida. Manooch suggested this difference could be due to separate spawning groups within the Gulf of Mexico	1. Measured distance from last ring to otolith margin (i.e., mi) for ages 1-3. 2. Plotted mi's by month suggested marking from Februry through May. 3. Used whole otoliths in final tests. Performed comparison readings of whole vs section ages on 24 individuals. Reported 87% agreement.
Cummings 1985 - Re-analysis of Johnson et al. 1985 (whole otoliths readings from 1977-1979)	1st mark (band one) - possibly late spring Other bands deemed inconclusive to determine mark formation timing from.	1. Plotted marginal increments (mi) vs month by sex and age group (0, 1,2,3,4,5,6+). Mark time was inconclusive from these data. 2. Scatter plot of mi vs week showed no trend in change in mi vs time (week)
Collins et al. 1987 Cape Fear (NC)- Cape Canaveral Florida. Sampled May 1983 - January 1987	August - September	1.Plotted percentage mi's for whole and sections 2. Plotted percentage zero mi vs month for sectioned and whole ages. Whole age distribution was unimodal suggesting non-annular ring formation or age error readings.
Noble et al. 1992, North Carolina September 1986- December 1990, recreational and commercial hook and lines and commercial gillnets	Minimum mi (June-August) whole otoliths Minimum mi (August-October) sectioned otoliths.	1. Plotted mean mi by month and by month and sex 2. Sample sizes deemed insufficient (across winter months) to yield conclusive information on timing.

Table 5. Information on sexual dimorphism of king mackerel in the southeastern U.S.

Study	Location	Relationship Examined	Test Statistic	Decision
Beaumariage 1973	Florida	Log_{10}=a Log_{10}(SL)-b; tested regression coefficients	$t_{0.05}=3.235$	Sex specific weight to length conversions justified.
Cummings (1985) re-analysis of Johnson et al. (1980) otolith data	Tx, La., N.& S. Carolina, Florida	Body Size (Fl- mm) vs Otolith size (OT)	$F_{2,1730} = 59.32$ Pr(no sex difference) = 0.000	Sex specific relations needed when modeling individual increments (e.g., computing Back calculated length at age)
Cummings (1985) re-analysis of Johnson et al. (1980) otolith data	Tx, La, N. & S. Carolina, Florida	Form of Body Size vs Otolith size relation (i.e., linear (y=a+bx) vs curvalinear ($y=a + bx + cx^2$)	$F_{1,439} = 5.88$ males, Pr(curvature)=0.9843 $F_{1,1289} = 0.0016$ males, Pr(curvature)=0.0808	Curvalinear relation needed for males.

Table 6. Age to Length Conversions for king mackerel in the southeastern U.S.

Study	Geographical Region	Sex	Sample Size	Estimate of K	Estimate of Linfinity	T zero	Size Range	Notes
Beaumariage 1973 1968-1969 samples	South Florida	Males Female	140 225	0.35 0.21	903 mm FL 1,243 mm FL	-2.50 -2.4	635- 864 657-1,068	1. whole otolith samples 2. Ford Walford estimates 3. Annuli validated via plots of marginal increment deposition by month. 4.Modeled BCL's at whole age; only 10% of the observatons used within each Otolith radious group thus significantly reducing the sample size from n=1,888 otoliths (combined sexes)
Johnson et al. 1980 1977-1979 samples	Tx. La, Fl, S.& N. Carolina excl. Louisiana Louisiana	Males Females Females	376 792 281	0.28 0.29 0.14	965 mm FL 1,067 mm FL 1,529 mm FL	-1.17 -0.97 -2.08	570- 970 605-1,062 635-1,420	1.whole otoliths used in estimates 2. Least squares estimates 3. Used mean BCL's at whole age 4. Annuli validated via plots of marginal incremetn deposition by month,ring.
Williams and Godcharles 1984	Florida	Combined	467	0.1575	1,266 FL(mm)	NA	58 cm - 116 cm release size 65 cm 137 cm recaputer size	1. Mark recapture samples 2. Least squares estimates 3. Modeled lapsed size vs time
Cummings 1985	Gulf of Mexico and Atlantic	combined	818	0.1419	1,248 mm FL	NA	55cm - 116 cm release size 62 cm 137 cm recapture size	1.Mark recapture samples 2. Marquardt estimation method 3. Modeled lapsed size vs time 4. Considered age readings from whole otoliths as non-annular.
Manooch et al. 1987 1980-1985 samples	Key West, Fl to Yucatan Pen., Mx	Males females Both	88 122 210	0.208 0.136 0.1154	1,113 mm FL 1,417 mm FL 1,478 mm FL	-1.480 -0.9754 -2.3599	Not Provided Not Provided Not Provided	1. Used whole otoliths for estimates 2. Used mean BCL's at whole age

Collins et al. (1988) Sectioned Ages. 1983-1987	Atlantic: Cape Fear - Canaveral Fl	Males Females Combined	182 424 683	0.1915 0.1239 0.0872	942 mm TL 1,208 mm TL 1,277 mm TL	-2.5006 -3.7445 -5.6836	511-948 mean mm TL 548-1220 mean mm TL 538-1220 mean mm TL	1. Hard part samples 2. Non linear fit to weighted back-calculated lengths at age 3. BCL's estimated using sex specific body size- otolith size relations
Collins et al. (1988) Whole Ages. 1983-1987.	Atlantic: Cape Fear - Canaveral Fl	Males Females Combined	90 239 365	0.5170 0.2278 0.2128	853 mm TL 1,122 mm TL 1,127 mm TL	-0.5266 -1.6572 -1.4777	505 - 896 mean mm TL 552 - 1,077 mean mm TL 532 - 1,077 mean mm TL	1. Hard part samples 2. Non linear fit to weighted back-calculated lengths at age 3. BCL's estimated using sex specific body size- otolith size relations
Sutter et al. (1991). 1975-1988.	GM 1975-1988 Atlantic	combined combined	439 157	0.127 0.070	1,326 mm FL 1,520 mm FL	NA NA	42.5-120 cm FL release 62.5-133 cm FL recapture 55,0-122,5 cm FL release 64.8-127.0 cm FL recapture	1.Mark recapture samples 2.Modeled mean change in length (by 30 day periods) 3.Non-linear solution
Nobel et al. (1992) Sectioned Ages. 1985-1990.	North Carolina 1985-1990	Males Females Combined	284 523 807	0.065 0.087 0.061	1,153 mm FL 1,370 mm FL 1,413 mm FL	-13.50 -8.67 -10.72	692-1,245 mm FL 795-1,520 mm FL 692-1,520 mm FL	1. K and T zero estimates are suspect
Nobel et al. (1992) Whole Ages. 1985-1990.	North Carolina 1985-1990	Males Females Combined	127 326 373	1.065 0.568 0.659	770 mm FL 897 mm FL 859 mm FL	-0.21 -0.49 -0.29	420-895 mm FL 460-905 mm FL 372-905 mm FL	1. K and L infinity estimates are out of range with literature point estimates
DeVries and Grimes (1997)	Atlantic 1986-1992	Males Females	2083 3407	.262 .145	96.4 cm FL 126.7 cm FL	-1.98 -3.15	Not Provided Not Provided	Estimates of T zero are suspect Estimates of T zero are suspect
DeVries and Grimes (1997)	Eastern Gulf 1986-1992	Males Females	1330 2796	.247 .172	102.6 cm FL 137.8 cm FL	-1.84 -1.83	Not Provided Not Provided	Estimates of T zero are suspect Estimates of T zero are suspect
DeVries and Grimes (1997)	Western Gulf 1986-1992	Males Females	995 1662	.203 .150	102.8 cm FL 134.1 cm FL	-2.74 -2.69	Not Provided Not Provided	Estimates of T zero are suspect Estimates of T zero are suspect
DeVries and Grimes (1997)	Atlantic 1977-1978	Males Females	128 323	.211 .124	95.9 cm FL 122.7 cm FL	-3.14 -4.54	Not Provided Not Provided	Estimates of T zero are suspect Estimates of T zero are suspect
DeVries and Grimes (1997)	Eastern Gulf 1977-1978	Males Females	343 1011	.269 .160	99.0cm FL 137.1cm FL	-1.63 -2.12	Not Provided Not Provided	Estimates of T zero are suspect Estimates of T zero are suspect

DeVries and Grimes (1997)	Western Gulf 1977-1978	Males Females	40 188	.094 .127	116.0 cm FL 151.5 cm FL	-6.78 -2.78	Not Provided Not Provided	Estimates of K and Tzero are suspect

NA = Not applicable.

BCL= Backcalculated length at age estimated from marginal increment analysis and body size : otolith size relation.

Table 7. Information on occurrence of young king mackerel in the southeastern U.S.

Source of Information	Location	Size	Season	Notes
Beaumariage (1973)	Florida	Troll fishery age II or III Gillnet fishery (south west)- III	winter winter	Beaumariage noted larger sized fish in gillnet schools
Wayne Waltz (personal communication)	South Carolina	13-17 cm age zero fish	July and August	modal length observed in shrimp trawls
Collins and Wenner 1987, sampled 1980-1982 and 1985-1986. Sampling depths were 3-18 n 1980-1981 and 3-9 m all subsequent years. Trawl was gear.	Cape Hatteras,NC -Cape Canaveral, FL)	8 cm FL - 48 cm size range of individuals sampled.	July-Oct., one fish in Dec.	Modal lenght est. to be about 14 cm from Fig. 2 of the manuscript.n=481 individuals.
Grimes et al. (1990) Gulf of Mexico from review of studies conducted from 1983-1986 using neuston & bongo gear.	Gulf of Mexico	<= 50 mm SL larval and small juvenile >= 59 m SL	Narch-October Jan.-Nov.	1.Authors noted Peak in juvenile occurrence in July and October