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AGE AND GROWTH OF KING MACKEREL, *SCOMBEROMORUS CAVALLA*, FROM THE ATLANTIC COAST OF THE UNITED STATES[1]

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ABSTRACT

Whole sagittae from 683 and sectioned sagittae from 773 "adult" (age > 0 ; 437–1,310 mm FL), and lapilli from 29 larval (2–7 mm SL) and 69 young-of-the-year (79–320 mm FL) king mackerel, were examined. All fish were from waters off the Atlantic coast of the southeastern United States (Cape Canaveral, Florida to Cape Fear, North Carolina). Back-calculated lengths at ages and von Bertalanffy growth equations were calculated from both whole and sectioned sagittae. Ages determined from sectioned sagittae were significantly greater than ages determined from whole sagittae, and the magnitude of the difference increased with age (from sections). Rings on sectioned sagittae are considered to be true annual increments, forming during June–September. There was no clear pattern to ring formation on whole otoliths. The oldest fish examined was age 21. The daily nature of rings on lapilli of age 0 king mackerel was not validated, but if the marks are formed daily they suggest growth rates of approximately 0.47 mm/d for early larvae and 2.9 mm/d for fish 1–3 months of age.

The king mackerel, *Scomberomorus cavalla*, is a migratory pelagic scombrid occurring in coastal waters of the western Atlantic from Massachusetts to Brazil and throughout the Gulf of Mexico (Collette and Russo 1984). In the United States, this fish is highly sought by both commercial and recreational fishermen from North Carolina to Texas (Manooch 1979; Trent et al. 1983). Decreased abundance in part of its range has lead to the establishment of landings quotas and limits.[3] Tagging studies indicate that king mackerel from the Atlantic coast and those from the Gulf of Mexico form separate migratory groups, with some overlap and mixing in the waters of southern Florida.[4] Biological studies in each geographic area are essential due to the importance of the species, possible reproductive isolation of the groups, and the potential for group-specific life history traits. Considerable research effort has been directed toward king mackerel in the Gulf of Mexico, but fish from the Atlantic coast of the United States, especially north of Florida, have received little attention. Beaumariage (1973) utilized fish from both coasts of Florida, but the only sample he had from northeastern Florida was combined with the rest of his data. Similarly, Johnson et al. (1983) sampled fish from North Carolina and South Carolina, but they were pooled with larger samples from the Gulf of Mexico. A more recent study (Manooch et al. 1987) utilized only Gulf of Mexico fish. Thus, there are no previous studies of Atlantic group king mackerel on which to base management.

Despite evidence that otolith sections may give more accurate ages than whole otoliths in long-lived species (Beamish 1979), major studies of king mackerel age and growth have been based principally on data derived from whole otoliths (Beaumariage 1973; Johnson et al. 1983; Manooch et al. 1987). Adequate validation of the use of whole sagittae has apparently been achieved in at least one of these investigations (Manooch et al. 1987), but we encountered difficulties in the interpretation of whole otoliths while using similar methods in the present study. This report describes age and growth of king mackerel from the Atlantic coast of the southeast United States, compares results from whole and sectioned otoliths, and describes presumed daily growth of larval and young-of-the-year (YOY) king mackerel from the same geographic area.

METHODS

King mackerel were collected along the Atlantic coast of the southeastern United States (lat 29° to

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[3]South Atlantic Fishery Management Council, Charleston, SC. News release, 7 July 1987.

[4]Powers, J. E., and P. Eldridge. 1983. Assessment of Gulf of Mexico and south Atlantic king mackerel. Unpubl. manuscr., 24 p. Southeast Fisheries Center, National Marine Fisheries Service, NOAA, Miami, FL 33149.

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35°N) from May 1983 through January 1987. "Adult" (= age >0) fish were caught on hook and line in the recreational fishery, in the commercial fishery, and during research cruises aboard the RV *Oregon* and RV *Lady Lisa*. Most YOY kings were collected during research cruises aboard the RV *Lady Lisa* and RV *Carolina Pride* using trawls of various types, but some fish were taken with gill nets, seines, and from commercial shrimp trawling bycatch. Larvae were collected from the RV *Oregon* with bongo (505 μm mesh) and neuston (505 or 947 μm mesh) nets, and were preserved in 95% ethanol.

Nonlarval king mackerel were weighed and measured (total length [TL] and fork length [FL]), while larvae were measured to the nearest mm standard length (SL) using a dissecting microscope and ocular micrometer. Sagittae of adults were removed and stored dry, and gutted fish and gonads were weighed when possible. All otoliths were removed from larval and YOY fish. Larval otoliths were mounted on microscope slides, while otoliths from YOY fish were stored in 75% ethanol.

The lapillus was the best structure from which to count presumed daily rings for both larval and YOY king mackerel.[5] Larval lapilli were immersed in oil on a microscope slide and viewed with transmitted light at 623× on a microscope equipped with a video camera. Two readers made three counts for each of 29 larvae (2–7 mm SL), and the mean of the six counts, rounded to the nearest integer, was used to estimate the number of presumed daily rings. Lapilli from 69 YOY fish (79–320 mm FL) were prepared by a series of polishings on a smooth whetstone, on 600 grit sandpaper, and on glass with a fine liquid abrasive (AO Scientific Instruments Cat. No. 938C[6]). Polishing continued until rings in the central portion of the lapillus became visible, and readings were made in the same manner as those for larvae. Some lapilli were also read from photomicrographs taken with a scanning electron microscope (SEM) to determine differences in marginal increments (distance from the distal edge of the outer ring to the otolith margin) between fish caught at different times of day.

Whole sagittae from 683 adult fish were examined. Otoliths were placed in a dish of cedarwood oil and viewed, concave side up, under a dissecting microscope (12×) with reflected light. Measurements from the focus to the distal edge of each opaque ring, and from the distal edge of the last opaque ring to the otolith margin, were made with an ocular micrometer along an axis approximating the extension of the sulcus acousticus (Johnson et al. 1983). The marginal increment was zero when an opaque ring occurred at the otolith margin. Transverse sections (ca. 0.5 mm thick) of one sagitta from each of 773 fish, including otoliths also read whole, were made through the focus on a plane perpendicular to the long axis with a Buehler Isomet low speed saw. Sections were viewed at 50× in the same manner as whole sagittae. The focus was not always definite on sections, so measurements were standardized by defining the focus as the midpoint of a line connecting the two most distant points of the first ring. This convention closely agreed with actual focus locations for sections in which the focus was apparent. Because the axis of sagittal growth changed after the first year, sections were measured in two parts: 1) 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, and 2) from the first ring to the margin of the section, on a line perpendicular to the rings, along the recognizable major axis of sagittal growth after year 1. Additional sections were made of sagittae from 10 randomly chosen fish: one longitudinal section, and two sections at 45° perpendicular to each other. The purposes of these sections were to determine if there was evidence for splitting of rings and to ensure that the transverse section, described above, was the most legible preparation. All whole and sectioned sagittae were examined by two readers, and the age was excluded from analyses if the readers did not agree. Sex was determined by gross examination and was verified histologically in subsamples. Regressions of fork length on otolith radius were performed for sexes separately and combined. Back-calculated sizes at age were computed for males, females, and sexes combined by the Fraser-Lee method (Carlander 1982; Poole 1961). The SAS NLIN procedure (SAS Institute 1982) was used to fit von Bertalanffy equations to the weighted mean back-calculated lengths at age.

RESULTS

The astericus was not detected in any larvae, suggesting it forms at >7 mm SL. All larval lapilli had well-defined presumed daily rings that were easily

[5]Waltz, C. W. 1986. Evaluation of a technique for estimating age of young-of-the-year king (*Scomberomorus cavalla*) and Spanish (*S. maculatus*) mackerels. Unpubl. manuscr. South Carolina Wildlife and Marine Resources Department, Marine Resources Research Institute, P.O. Box 12559, Charleston, SC 29412.

[6]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

counted with good agreement between readers. The regression of mean ring count (R) on SL is $R = 0.11 + 1.56$ (SL); $n = 29$; $r^2 = 0.73$ (siginificant at $P < 0.001$). That r^2 is not higher is attributed to coarse length measurements (nearest mm). If the rings are daily, the regression of SL on R (SL $= 1.15 + 0.47(R)$) indicates a growth rate of 0.47 mm SL/d for early larvae (Fig. 1).

Presumed daily ring counts were obtained for 54 (78%) of 69 YOY king mackerel 79–320 mm FL. A strong correlation was found for the regression of mean ring count (R) on FL ($R = 2.0 + 0.32$(FL); $n = 54$; $r^2 = 0.92$, significant at $P < 0.001$). If these rings are actually daily, the regression of FL on R (FL $= 7.25 + 2.91(R)$) suggests that a growth rate of 2.9 mm/d occurs at 30–100 days of age (Fig. 2). Attempts to produce evidence for the daily nature of these rings by measuring diel variation in marginal increments using SEM were not successful, perhaps due to inadequate specimen preparation. Rings were normally visible on portions of the lapilli, but we could not consistently read increments near the margin.

Two readers agreed on annual ring counts for 77% of all whole sagittae and 70% for fish >850 mm FL, resulting in 15 age (= number of rings) classes. Examination of sections made in the four planes verified that sections perpendicular to the long axis of the sagitta were most legible, and no evidence for splitting of rings was found. Agreement on reading sections was greater than that for whole sagittae, with counts verified on 90% of all sections and 96% from fish >850 mm FL. The oldest fish aged from sections was age 21. Agreement between the two techniques was but 47% among fish on which both whole sagittae and sections were used, and the ages were significantly different (t test for paired observations: $P < 0.001$). Counts were very similar for the first three to five age classes, but sections from older fish commonly showed one or more rings not detected on whole sagittae and the difference increased with age. The two procedures differ at an earlier age for males than for females (Fig. 3).

The correlations of fish length with otolith radius were significant ($P < 0.001$ for all) for whole and sectioned sagittae of males, females, and sexes combined (Table 1). Plots of focus-ring measurements from sections for successive age groups through age 5 show that the distribution was unimodal for each increment, that distances to the rings varied little with age, and that overlap increased with age (Fig. 4). The pattern for whole sagittae was not quite as well defined (Fig. 5). Back-calculated lengths at ages from whole and sectioned otoliths agree well with observed lengths, especially among (younger) age groups with large sample sizes (Tables 2–7). Annual growth increments from whole and sectioned otoliths were generally higher for females than males, especially during the first few years of life. Lengths at age determined from whole otoliths were con-

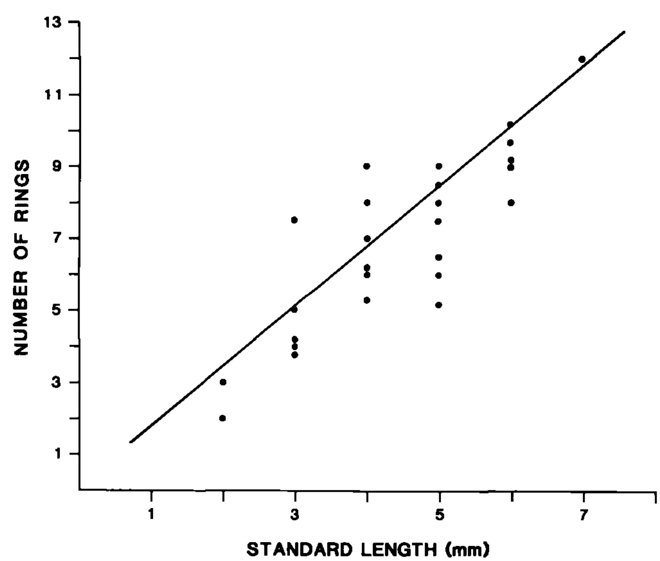

FIGURE 1.—Regression of number of presumed daily rings on standard length of larval king mackerel.

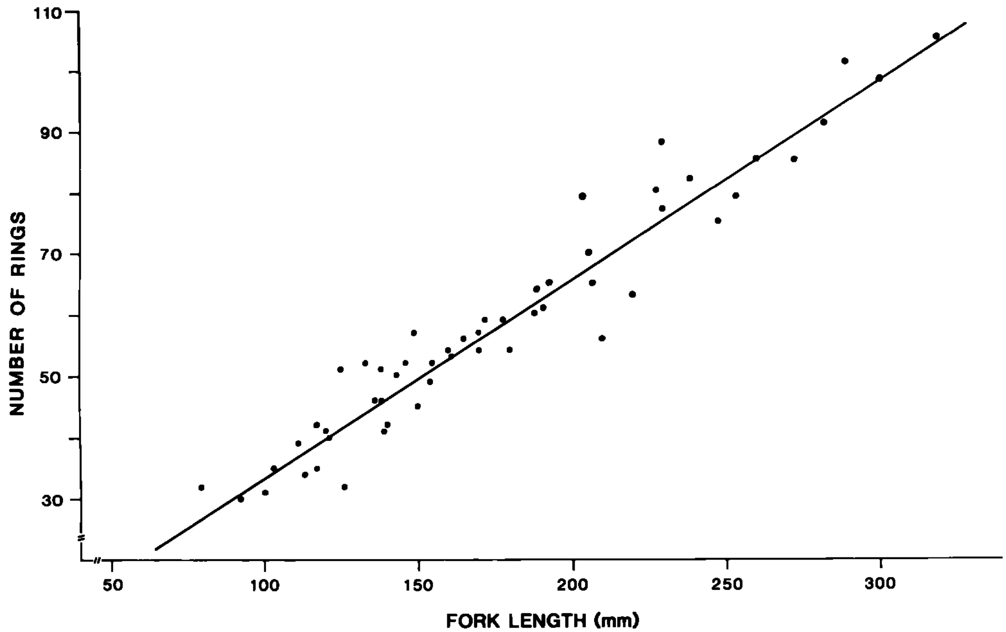

FIGURE 2.—Regression of number of presumed daily rings on fork length of young-of-the-year king mackerel.

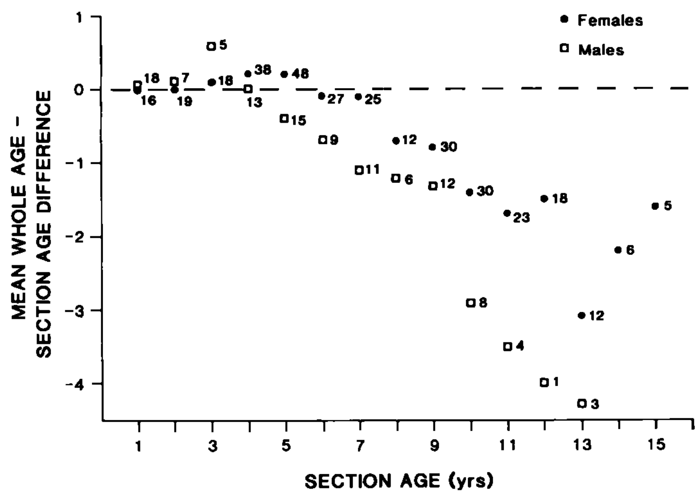

FIGURE 3.—Mean difference between whole and sectioned otolith ages for each sectioned age group, by sex. Sample size is indicated for each data point.

TABLE 1.—Least squares regression of fork length (FL, in mm) on otolith radius (OR, in ocular units) for sectioned and whole otoliths.

	Sectioned			Whole		
		N	r^2		n	r^2
male	$\log_{10}$ FL = 1.088 + 1.012 $\log_{10}$ OR	204	0.90	$\log_{10}$ FL = 1.242 + 0.918 $\log_{10}$ OR	172	0.80
female	$\log_{10}$ FL = 1.209 + 0.967 $\log_{10}$ OR	448	0.83	$\log_{10}$ FL = 1.116 + 1.002 $\log_{10}$ OR	409	0.77
combined	$\log_{10}$ FL = 1.350 + 0.884 $\log_{10}$ OR	704	0.80	$\log_{10}$ FL = 0.773 + 1.184 $\log_{10}$ OR	632	0.83

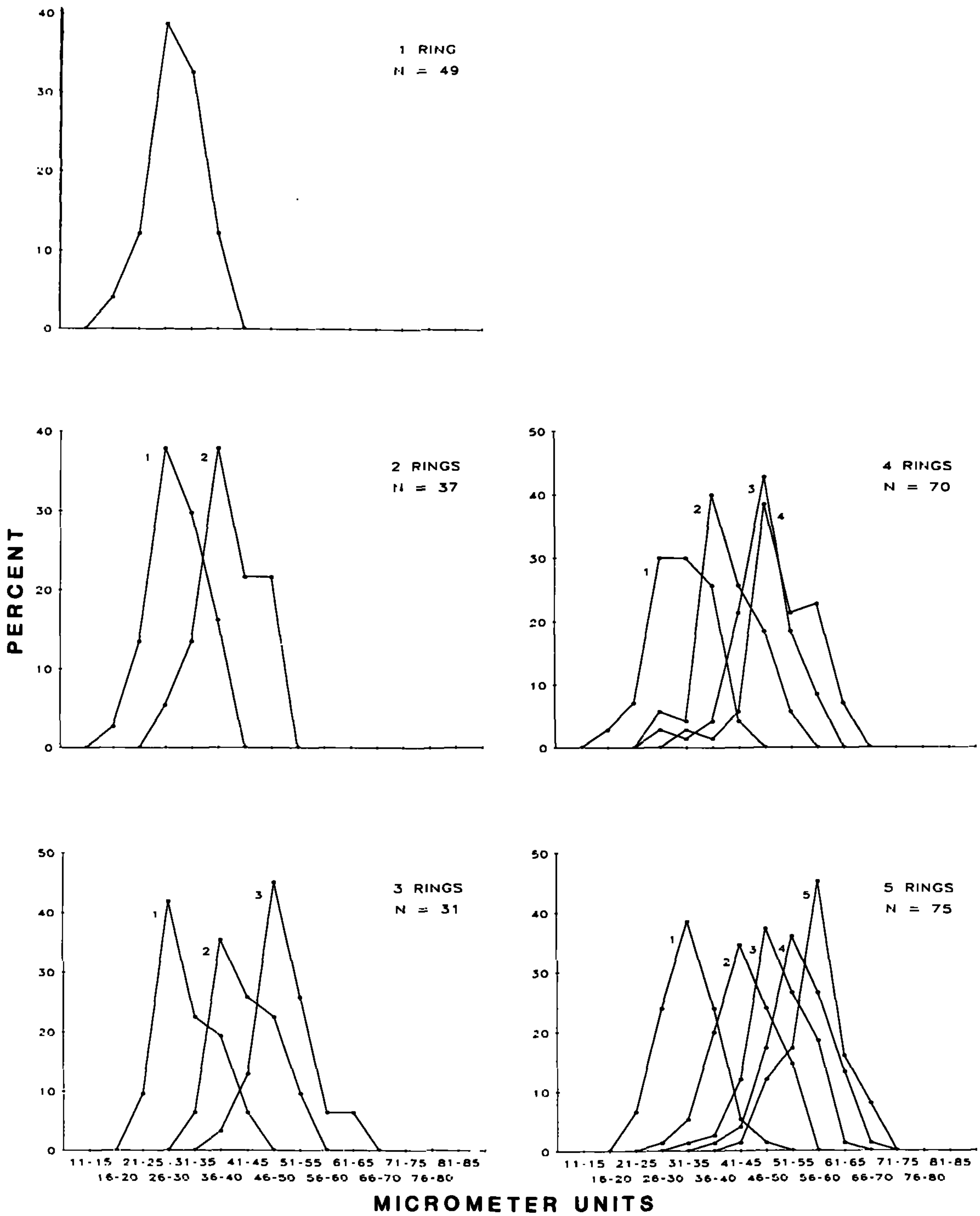

FIGURE 4.—Distributions of focus-ring distances from otolith sections for age groups one through five.

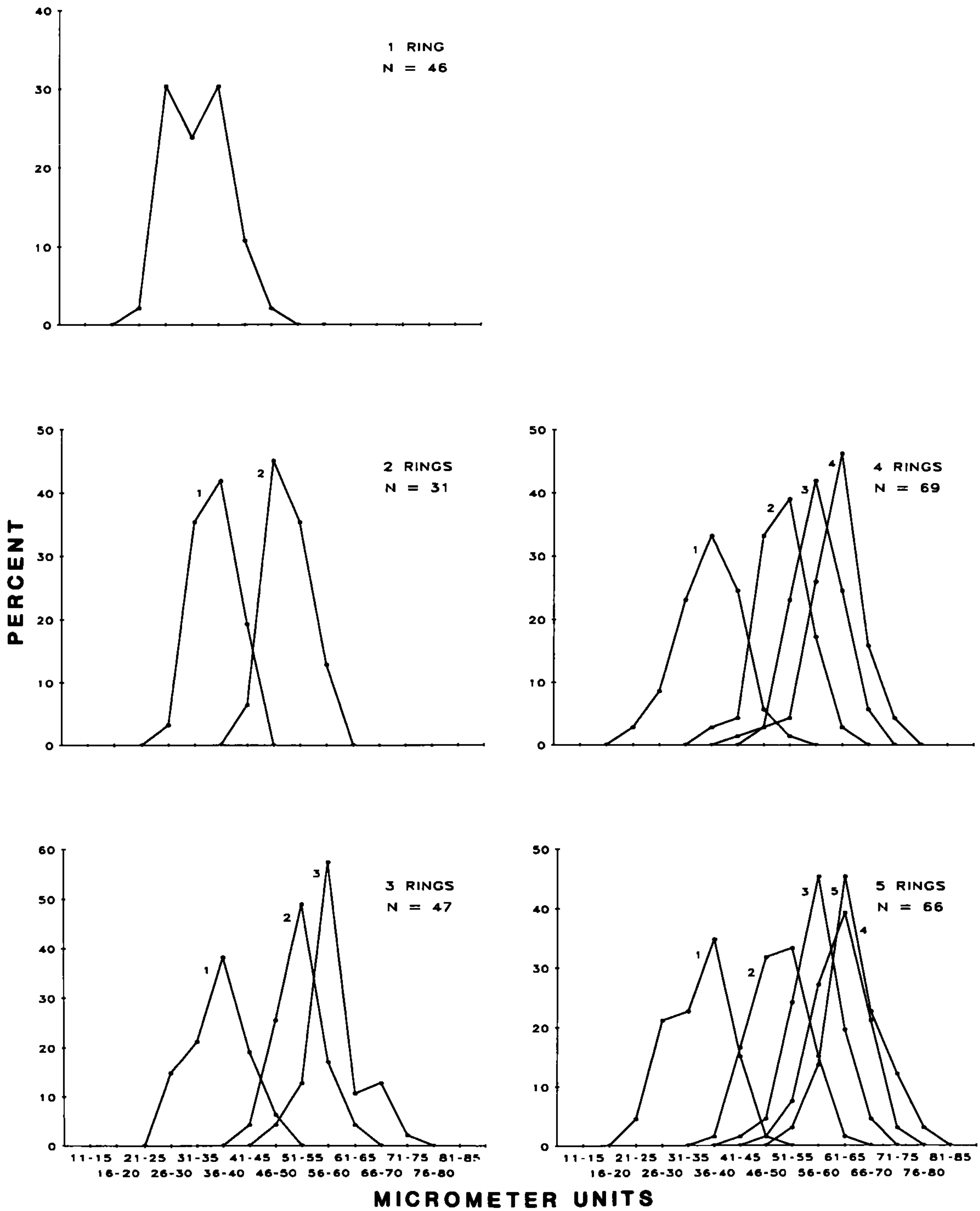

FIGURE 5.—Distributions of focus-ring distances from whole otoliths for age groups one through five.

TABLE 2.—Mean fork lengths (mm) at capture and mean back-calculated fork lengths at ages from sectioned otoliths of male king mackerel.

Age	No. of speci-mens	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
1	19	511	433															
2	7	716	479	649														
3	6	758	457	615	712													
4	16	791	465	601	690	754												
5	17	808	440	585	670	730	778											
6	14	825	441	580	652	712	759	805										
7	19	838	417	566	647	698	743	784	819									
8	11	884	455	600	666	716	757	792	826	862								
9	16	882	434	569	643	692	734	769	803	833	864							
10	13	882	404	546	612	670	709	744	773	805	836	867						
11	8	912	419	545	614	663	702	742	774	806	833	865	895					
12	10	909	387	532	597	641	681	718	748	780	810	838	863	892				
13	11	918	366	516	585	635	673	706	739	768	798	826	851	878	907			
14	7	954	375	505	581	630	673	706	742	773	805	833	857	884	911	938		
15	5	930	383	507	581	623	657	687	718	743	770	797	822	844	871	894	919	
16	3	948	383	475	547	607	646	677	709	737	758	787	815	839	864	892	912	937
	Total number		182	163	156	150	134	117	103	84	73	57	44	36	26	15	8	3
	Weighted mean		426	566	639	689	724	753	779	801	822	839	857	875	896	914	916	937
	Growth increment		426	140	72	50	34	29	25	22	20	17	17	18	21	17	2	20

sistently greater than from sections, except for age 1 females (Fig. 6). The von Bertalanffy growth constants (K) from whole and sectioned otoliths are greater for males (Table 8), while females attain greater maximum length. Estimates of asymptotic length (L_∞) from both otolith preparations are conservative for both sexes.

The distribution of monthly percentages of sectioned otoliths with zero marginal increment was unimodal and reasonably normal, indicating annual ring formation that peaks in August–September (Fig. 7). Few section margins were opaque during October–May, though sample sizes were smaller then. Similar treatment of marginal increment data from whole sagittae produced completely different results: opaque margins seem to occur irregularly from March through November. This suggests either that readings of whole otoliths were often in error despite agreement between observers, or that rings were not true annuli.

DISCUSSION

The daily nature of rings on lapilli of larval and YOY king mackerel was not validated, although correlations between otolith radius and fish length were very strong. If the marks are daily, they imply a moderately high average growth rate for early larvae followed by very rapid growth (2.9 mm/d) for fish 1–3 months of age. Future studies should concentrate on validation, possibly by chemical (tetracycline, calcein) labeling of otoliths or by describing diel variations in marginal increments.

Readability (percentage legible enough for observers to agree on age) of sectioned otoliths was greater than that of whole otoliths, especially among fish >850 mm FL. The two techniques agreed only 47% of the time, primarily for smaller individuals. Why Johnson et al. (1983) and Manooch et al. (1987) found much higher agreement (96% and 87%, respectively) between whole and sectioned otoliths is not clear. The opacity and appearance of sagittae may differ between Gulf of Mexico and Atlantic king mackerel (pers. commun., S. P. Naughton[7]), and could account for differences in agreement. Beamish (1979) noted that readability and reliability of whole otoliths differed between stocks of Pacific hake, *Merluccius productus*, supporting this hypothesis. He reported a 47% agreement between whole and sectioned otolith ages and concluded that ages from sections were more reliable, especially in older age groups and for certain geographic areas. He also found even greater deviations that we found between ages from whole and sectioned otoliths, but utilized all readings. If our procedures were liberalized in a like fashion, or if readings from a single observer were used, we feel that the deviations reported here would be much greater.

[7]S. P. Naughton, Southeast Fisheries Center Panama City Laboratory, National Marine Fisheries Service, NOAA, Panama City, FL 32407, pers. commun.

TABLE 3.—Mean fork lengths (mm) at capture and mean back-calculated fork lengths at ages from sectioned otoliths of female king mackerel.

Age	No. of speci-mens	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	21
1	16	548	462																				
2	24	719	503	668																			
3	19	820	519	681	775																		
4	43	832	494	635	727	794																	
5	51	878	500	650	739	804	856																
6	37	897	484	634	716	775	829	876															
7	30	937	487	632	718	778	831	876	919														
8	14	977	491	646	731	790	836	878	917	956													
9	39	990	477	616	709	768	815	857	896	937	975												
10	42	1,005	477	629	699	759	804	847	883	919	956	991											
11	32	1,052	482	630	710	765	812	855	893	929	964	998	1,034										
12	27	1,063	466	620	701	755	801	840	877	912	946	977	1,013	1,044									
13	17	1,035	482	610	674	724	767	801	837	870	902	931	961	990	1,022								
14	12	1,041	458	599	663	713	753	791	824	856	885	921	948	976	1,007	1,035							
15	9	1,145	500	643	718	772	818	858	899	931	962	993	1,022	1,050	1,077	1,105	1,134						
16	3	1,189	513	668	753	807	847	883	919	954	981	1,008	1,043	1,070	1,097	1,123	1,154	1,181					
17	2	1,216	504	629	708	766	811	850	889	928	960	992	1,018	1,056	1,088	1,120	1,152	1,177	1,203				
18	2	1,272	480	642	737	785	834	871	920	950	981	1,018	1,049	1,074	1,105	1,130	1,159	1,191	1,215	1,246			
19	2	1,075	416	551	626	663	704	740	766	791	812	843	869	889	916	936	962	983	1,003	1,034	1,054		
20	2	1,151	464	603	671	723	764	795	825	856	881	906	937	957	987	1,007	1,032	1,052	1,077	1,106	1,126	1,146	
21	1	1,220	421	602	686	727	768	796	823	865	892	920	947	974	988	1,015	1,043	1,070	1,084	1,111	1,138	1,165	1,192
Total number			424	408	384	365	322	271	234	204	190	151	109	77	50	33	21	12	9	7	5	3	1
Weighted mean			486	635	716	772	817	852	886	917	949	975	1,002	1,017	1,032	1,064	1,110	1,118	1,120	1,126	1,100	1,152	1,192
Growth increment			486	148	81	56	45	34	34	31	31	26	26	15	15	32	46	8	2	6	−26	52	40

TABLE 4.—Mean fork lengths (mm) at capture and mean back-calculated fork lengths at ages from sectioned otoliths of king mackerel, sexes combined.

			Mean back-calculated lengths at successive annuli																				
Age	No. of speci-mens	Mean length at capture	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	48	538	461																				
2	37	722	515	668																			
3	30	800	520	670	759																		
4	70	823	513	645	727	788																	
5	74	859	513	652	733	791	837																
6	61	871	500	635	708	763	810	851															
7	56	899	494	631	710	762	807	847	883														
8	28	938	508	650	722	773	814	850	884	918													
9	59	956	495	626	708	761	803	840	874	908	941												
10	59	976	492	636	703	758	798	836	868	900	932	963											
11	43	1,020	502	640	713	764	806	845	878	911	941	971	1,003										
12	39	1,018	479	625	697	746	788	823	855	887	916	944	974	1,002									
13	29	986	471	602	665	711	750	781	813	842	871	897	922	947	975								
14	20	1,007	464	597	662	709	747	781	812	840	868	898	922	947	974	998							
15	15	1,065	494	629	700	747	786	819	854	882	909	935	960	984	1,008	1,032	1,056						
16	6	1,068	490	610	684	738	775	806	837	867	889	914	943	966	989	1,013	1,037	1,060					
17	2	1,216	538	661	737	793	836	873	910	947	977	1,007	1,031	1,067	1,097	1,127	1,156	1,180	1,204				
18	2	1,272	516	676	767	813	860	896	942	970	1,000	1,035	1,064	1,087	1,117	1,139	1,167	1,196	1,219	1,248			
19	2	1,075	447	580	653	688	727	762	786	810	830	859	883	902	927	946	971	990	1,009	1,037	1,056		
20	2	1,151	497	633	699	748	788	817	846	875	899	923	951	970	998	1,017	1,041	1,059	1,082	1,110	1,128	1,146	
21	1	1,220	456	635	716	756	795	822	848	887	913	939	965	991	1,004	1,029	1,055	1,080	1,093	1,119	1,144	1,169	1,194
		Total number	683	635	598	568	498	424	363	307	279	220	161	118	79	50	30	15	9	7	5	3	1
		Weighted mean	497	638	712	763	802	833	864	892	920	943	964	975	989	1,020	1,060	1,086	1,124	1,130	1,102	1,154	1,194
		Growth increment	497	141	73	51	39	30	30	28	27	23	20	11	13	31	39	26	38	5	−27	51	40

TABLE 5.—Mean fork lengths (mm) at capture and mean back-calculated fork lengths at ages from whole otoliths of male king mackerel.

Age	No. of speci-mens	Mean length at capture	Mean back-calculated lengths at successive annuli								
			1	2	3	4	5	6	7	8	9
1	18	505	402								
2	8	689	511	670							
3	11	758	468	654	731						
4	20	794	488	655	726	772					
5	17	821	451	642	721	764	802				
6	5	827	420	629	688	737	772	805			
7	6	847	417	642	705	745	776	806	823		
8	0	—	—	—	—	—	—	—	—	—	
9	5	896	452	625	699	741	773	797	831	853	871
		Total number	90	72	64	53	33	16	11	5	5
		Weighted mean	453	649	719	760	788	803	827	853	871
		Growth increment	453	195	70	41	28	14	23	26	17

TABLE 6.—Mean fork lengths (mm) at capture and mean back-calculated fork lengths at ages from whole otoliths of female king mackerel.

Age	No. of speci-mens	Mean length at capture	Mean back-calculated lengths at successive annuli											
			1	2	3	4	5	6	7	8	9	10	11	12
1	18	552	440											
2	20	712	481	666										
3	26	810	502	696	780									
4	42	845	490	671	762	814								
5	46	882	474	670	759	820	862							
6	35	915	471	673	757	810	851	892						
7	21	949	453	651	746	802	845	887	921					
8	12	1,022	467	697	788	837	881	924	963	995				
9	8	1,035	475	669	785	842	885	918	954	986	1,018			
10	9	1,079	485	689	778	837	890	931	964	997	1,028	1,056		
11	1	1,138	350	654	785	814	873	917	976	1,020	1,064	1,093	1,123	
12	1	1,077	387	454	724	778	806	846	873	927	968	995	1,022	1,077
		Total number	239	221	201	175	133	87	52	31	19	11	2	1
		Weighted mean	475	673	764	817	861	901	943	992	1,022	1,054	1,073	1,077
		Growth increment	475	197	91	52	44	40	42	48	30	31	18	3

Van Oosten (1929) listed assumptions involved in the use of hard parts to determine age of fish: 1) the structures used are constant in number and identity throughout the life of the fish, 2) the ratio of structure size and fish size (length) remains constant with growth, and 3) marks (rings) are annual and form at about the same time each year. The first assumption is not in doubt for otoliths. Supporting the second assumption are the correlations between fish length and otolith radius, which were significant for whole and sectioned otoliths but stronger for the latter. It is in meeting the final assumption that the validity of ages from whole otoliths becomes doubtful. The distributions of focus-ring measurements were only slightly better for sectioned than for whole otoliths. However, the distribution of monthly percentages of whole otoliths with opaque margins was multimodal, indicating nonannual ring formation (or large and numerous reading errors), while that of sections was unimodal and fairly normal, indicating annual ring formation peaking in August–September. Manooch et al. (1987) found a peak in ring formation during February–May, but they also found ring formation in September for some fish taken off northwest Florida and suggested that this difference may be due to separate spawning groups within the Gulf of Mexico.

We consider rings in otolith sections valid annuli, but our evidence for validation is indirect, as in previous studies of king mackerel. As pointed out

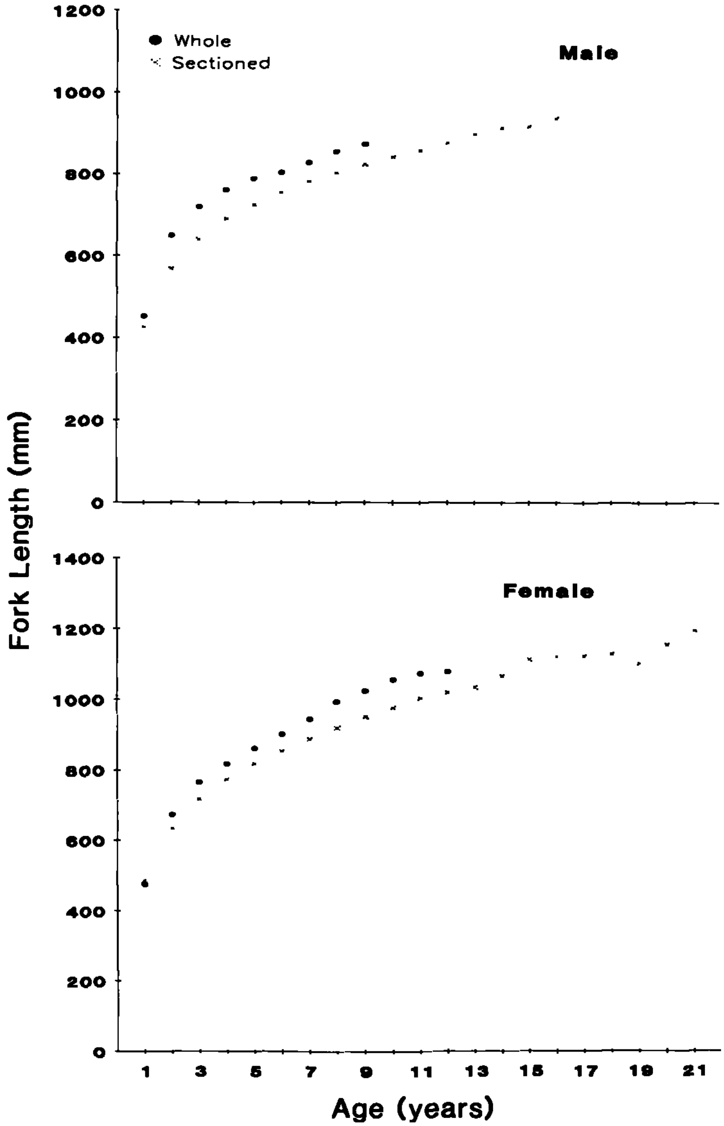

FIGURE 6.—Mean back-calculated lengths at age from whole and from sectioned otoliths for male and female king mackerel.

by Van Oosten (1929) and restated by Beamish and McFarlane (1983), procedures that produce direct evidence and validate ages of all age groups include mark-recapture techniques (which will involve chemical labeling if ages are to be determined from otoliths) and capture of known-age fish. The only previous study of king mackerel producing acceptable evidence for age validation (Manooch et al. 1987) generated very different life history characteristics from ours, including maximum ages of 11 and 14 for males and females, respectively, but was based on whole otoliths from Gulf of Mexico fish. Thus, whether the differing results are due to separate groups of king mackerel with different life history characteristics or to differences in techniques is not known. Regardless, we have demonstrated that dubious information from whole otoliths can appear valid, and suggest that sectioned sagittae be used to age king mackerel in future studies.

TABLE 7.—Mean fork lengths (mm) at capture and mean back-calculated fork lengths at ages from whole otoliths of king mackerel, sexes combined.

Age	No. of speci- mens	Mean length at capture	Mean back-calculated lengths at successive annuli 1	2	3	4	5	6	7	8	9	10	11	12
1	46	532	396											
2	30	706	453	662										
3	47	793	439	656	755									
4	69	827	437	635	734	792								
5	64	866	412	626	727	794	843							
6	44	898	410	629	721	780	827	872						
7	27	926	385	606	704	764	812	858	894					
8	13	1,014	404	644	749	803	853	902	947	983				
9	14	985	406	602	711	770	816	853	895	927	960			
10	9	1,079	421	636	734	800	861	907	945	983	1,019	1,052		
11	1	1,138	285	593	736	768	833	883	950	1,000	1,051	1,086	1,120	
12	1	1,077	322	390	675	735	765	811	841	903	950	981	1,013	1,077
	Total number		365	319	289	242	173	109	65	38	25	11	2	1
	Weighted mean		418	633	730	786	833	872	912	961	984	1,048	1,067	1,077
	Growth increment		418	215	96	56	46	39	39	48	23	63	18	9

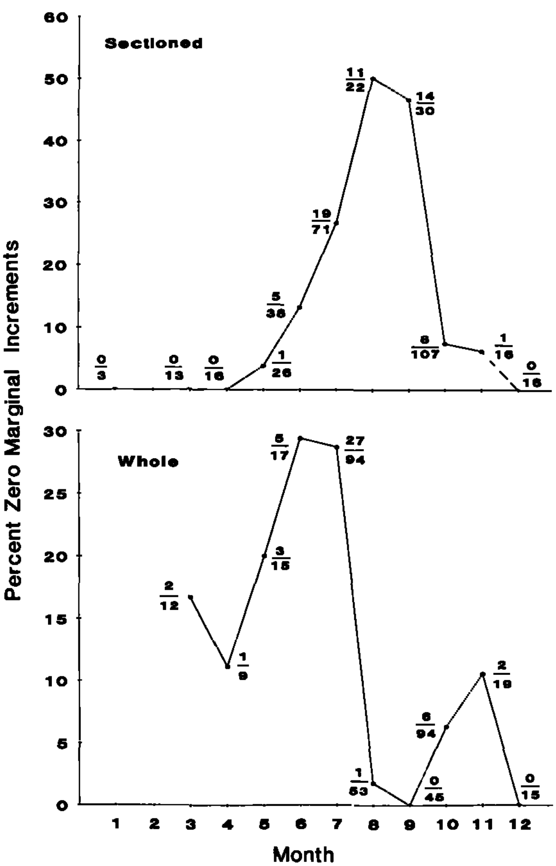

FIGURE 7.—Monthly percentages of zero marginal increments on whole and sectioned otoliths, with number of zero marginal increments over number in sample for each month.

TABLE 8.—von Bertalanffy growth parameters from whole and from sectioned otoliths of king mackerel.

Sex	Param- eter	Estimate	Asymptotic 95% confidence interval Lower	Upper
Sectioned otoliths				
Male	L_∞	942	905	979
	K	0.1915	0.1471	0.2358
	t_0	−2.5006	−3.4139	−1.5874
Female	L_∞	1,208	1,156	1,260
	K	0.1239	0.0978	0.1500
	t_0	−3.7445	−4.8442	−2.6448
Combined	L_∞	1,277	1,162	1,392
	K	0.0872	0.0572	0.1172
	t_0	−5.6836	−7.7409	−3.6262
Whole otoliths				
Male	L_∞	853	816	889
	K	0.5170	0.3334	0.7006
	t_0	−0.5266	−1.1493	−0.0960
Female	L_∞	1,122	1,051	1,192
	K	0.2278	0.1570	0.2987
	t_0	−1.6572	−2.5360	−0.7784
Combined	L_∞	1,127	1,027	1,227
	K	0.2128	0.1304	0.2951
	t_0	−1.4777	−2.5008	−0.4546

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