SIZE, SEX RATIO, AND RECRUITMENT IN VARIOUS FISHERIES OF KING MACKEREL, *SCOMBEROMORUS CAVALLA*, IN THE SOUTHEASTERN UNITED STATES

LEE TRENT,[1] ROY O. WILLIAMS,[2] RONALD G. TAYLOR,[2]
CARL H. SALOMAN,[1] AND CHARLES H. MANOOCH III[3]

ABSTRACT

Data from over 54,000 king mackerel, *Scomberomorus cavalla*, were analyzed to evaluate spatial and temporal variations in size and sex composition in seven areas of the southeastern United States. Data were obtained from the recreational hook-and-line fishery of coastal states from Texas to North Carolina and from commercial hook-and-line and gill net fisheries of south Florida. Of the three types of gear, recreational hook and line appeared to be the least selective and gill net the most selective for particular sizes of king mackerel.

Size composition in each area varied considerably among months; patterns of size change were discernible in some areas. Sizes of king mackerel varied significantly among areas and years. Catches from south and northwest Florida contained high proportions of small fish (<700 mm FL); those from Texas and North Carolina contained mostly medium-sized fish (700-900 mm FL). Mean lengths of king mackerel were larger in 1978 than in 1977 in all areas except northwest Florida. In northwest Florida, modal fork lengths were 749 mm in 1968-69, 649 mm in 1977, and 549 mm in 1978. The majority of the smallest fish (400-600 mm FL) were recruited to the fisheries in Florida, but the range and areas of abundance of king mackerel smaller than this are not known. For purposes of evaluating effects of minimum size regulations, the king mackerel population was divided into groups (the Florida winter, immature, spawning, and Louisiana groups).

Females dominated catches in all size groups and in all areas and years, except for south Florida in 1978. Annual, or ranges of annual, estimates of percentage female by area were as follows: Texas, 60.8-62.2%; Louisiana, 91.9-92.2%; northwest Florida, 57.1-75.1%; south Florida, 40.2-75.4%; and North Carolina, 75.8%. Females predominated in 31 of 38 sample groups at lengths <900 mm FL, and in all sample groups at lengths >899 mm FL.

The king mackerel, *Scomberomorus cavalla*, is one of the most important species in the coastal pelagic fisheries of the southeastern United States. Despite its high commercial and recreational value (Deuel and Clark 1968; Wise and Thompson 1977), many details pertaining to king mackerel catches and population structure are not available. Information needs include the following: 1) Seasonal size compositions by geographic area, 2) sizes and sex ratios of king mackerel caught throughout the southeastern United States, and 3) the number of groups supporting the fisheries. To meet these needs we 1) summarized data from previous analyses (Trent et al. 1981) on seasonal changes in size and sex compositions of king mackerel catches, 2) determined size and sex compositions in catches by capture gear, area, and year, and 3) separated the stock(s) into four groups for the purpose of evaluating minimum size regulations in the fisheries.

This undertaking is complicated by the widespread nature of the species and by the diversity of various fisheries harvesting it. King mackerel occur from the Gulf of Maine to Brazil and are common in the Caribbean and Gulf of Mexico (Randall 1968). The number of populations or stocks is unknown. The stock(s) fished off the continental United States are probably not the same as those fished in the Caribbean because, of over 1,100 tag returns from over 14,000 king mackerel tagged in the southeastern United States, not a single return came from the Caribbean.[4] In U.S. waters north of North Carolina, king mackerel is not a target species, either commercially or recreationally. The fish are highly migratory and the recreational fishing effort for them in any given area is directly related to their availability. Recreational fishing effort is exerted along the Atlantic and northern Gulf of Mexico coasts during the warmer

[1]Southeast Fisheries Center Panama City Laboratory, National Marine Fisheries Service, NOAA, 3500 Delwood Beach Road, Panama City, FL 32407.
[2]Florida Department of Natural Resources, 100 Eighth Ave., SE, St. Petersburg, FL 33701.
[3]Southeast Fisheries Center Beaufort Laboratory, National Marine Fisheries Service, NOAA, Beaufort, NC 28516.

[4]R. O. Williams, Florida Department of Natural Resources, 100 Eighth Ave., SE, St. Petersburg, FL 33701, pers. commun., August 1982.

Manuscript accepted February 1983.
FISHERY BULLETIN: VOL. 81, NO. 4, 1983.

months and along the south Florida and Louisiana coasts year-round, especially during the winter. In contrast to recreational fisheries, the commercial king mackerel fisheries are conducted almost completely in Florida. In 1976, for example, 96.5% of the king mackerel caught commercially along the east coast of the United States was landed in Florida, while almost 100% of the fish landed commercially in the Gulf of Mexico was caught off Florida's west coast (Manooch 1979).

STUDY AREA AND METHODS

King mackerel were sampled from commercial and recreational landings at seven locations (Fig. 1). King mackerel were caught by 1) recreational hook and line in each area, 2) commercial gill net off south Florida, and 3) commercial hook and line off Mississippi (snapper boats), south Florida, and North Carolina.

Baits used by recreational fishermen to catch king mackerel vary among areas and could influence the sizes of king mackerel that are caught. The baits differ in size, and large king mackerel consume larger food items than do small king mackerel (Saloman and Naughton[5]). The most frequently used baits and their comparative sizes by area are Texas — Atlantic cutlassfish, *Trichiurus lepturus* (large); Louisiana — sand seatrout, *Cynoscion arenarius* and Atlantic croaker, *Micropogonias undulatus* (large); northwest Florida — ballyhoo, *Hemiramphus brasiliensis* (small); Georgia, North Carolina, and South Carolina — strips of cut bait and live fish of several species (small to large).

King mackerel that were sampled from commercial snapper boats were caught incidentally during the snapper fishing. Standard bottom rigs with three to six hooks were baited with pieces of fish or squid. The king mackerel were caught in an area east of the mouth of the Mississippi River, where water depths ranged from 50 to 130 m.

Most king mackerel landed by commercial fishermen in south Florida are caught by runaround gill nets or hook and line (Beaumariage 1973; Austin et al. 1978; Manooch 1979). The nets are from 360 to 640 m long, about 22 m (200 meshes) deep, with a stretched mesh of 12.1 cm. The nets are fished in water depths as great as 21 m. In the commercial hook-and-line fishery, spoons or feathered jigs, sometimes with strips of mullet or squid, are trolled behind boats (Harris 1974).

Length and sex data on king mackerel were obtained by personnel of the Florida Department of Natural Resources and by personnel of the National Marine Fisheries Service. Data were summarized by number of fish in relation to sex, location, capture gear, and time (Tables 1, 2).

Length measurements were taken from uncut, gutted, or filleted fish. Fork Length (FL) was measured from the tip of the snout (mouth closed) to the fork of the tail to the nearest millimeter or 0.1 in. Measurements, in inches were later converted to

[5]Saloman, C. H., and S. P. Naughton. 1982. Food habits of king mackerel in the southeastern United States. Unpubl. manuscr., 28 p. Southeast Fisheries Center Panama City Laboratory, National Marine Fisheries Service, NOAA, Panama City, FL 32407.

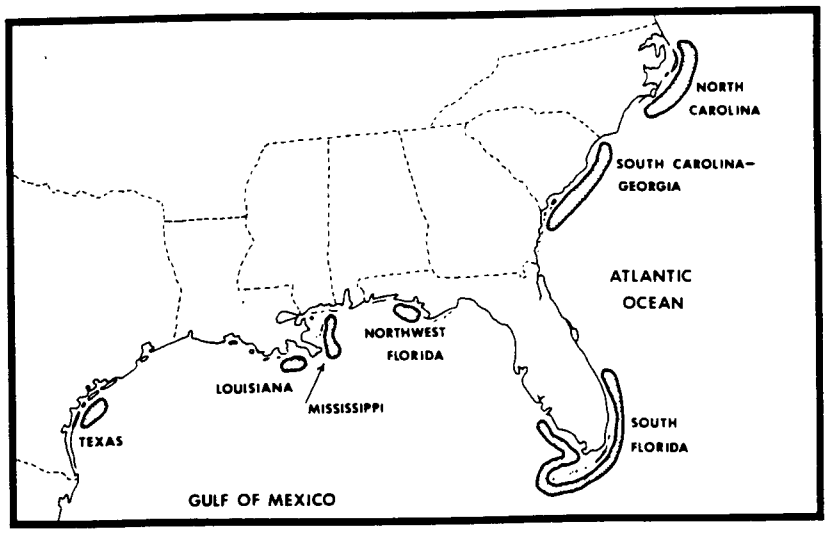

FIGURE 1.—Sampling locations in the southeastern United States.

TABLE 1.—Numbers of king mackerel by capture gear, year and month, and area (M = male, F = female, U = sex unknown). Data obtained by Florida Department of Natural Resources, St. Petersburg, Fla.

Year and month	Recreational hook and line		Commercial hook and line				Gill net		
	Northwest Florida		South Florida			North Carolina	South Florida		
	M	F	M	F	U	U	M	F	U
1968									
Jan.			135	316			361	473	
Feb.			182	457			792	816	
Mar.			283	667			460	578	
Apr.	22	36	28	19			5	13	
May	18	20	40	24					
June	17	55	26	33					
July	11	86							
Aug.	14	46	22	38					
Sept.	21	39	27	29					
Oct.	17	22	19	23	2				
Nov.				4			2	3	
Dec.			445	671					
1969									
Jan.			709	1,102					
Feb.			15	43					
Mar.			10	31			8	12	
Apr.	4	16					10	12	
May	17	15							
June	6	8							
July	1	32	26	34					
Aug.	5	24	11	19					
Sept.	3	27							
Oct.	1	8							
Nov.	12	18	14	44					
Dec.			6	9					
1975									
Jan.					534				
Feb.					1,343				
Mar.					117				
Apr.					35				
May					373				
June					121				
Aug.					203				
Oct.					3				
Dec.					244				
1976									
Jan.					304				
Feb.					1,796				313
Mar.					2,907				
Apr.					36				
May					1,226				
June					180				
Aug.					166				
Oct.					61				
Dec.					2,266				
1977									
Jan.					1,193				2,777
Feb.					4,106				1,062
Mar.									306
May					335				
June					246				
Aug.					227				
Dec.					708				
1978									
Jan.					2,475				
Feb.					1,107				
Mar.					2,931				
Apr.					1,305				
May					378				
June					20				
Sept.						72			
Oct.						36			
1979									
May						809			
Total	169	452	1,998	3,563	26,948	917	1,638	1,907	4,458

TABLE 2.—Numbers of king mackerel by capture gear, year and month, and area (M= male, F= female, U= sex unknown). Data obtained by the National Marine Fisheries Service, Panama City, Fla.

Year and month	Recreational hook and line																		Commercial hook and line			Commercial snapper hook and line		
	Texas			Louisiana			Mississippi		Northwest Florida			South Florida	South Carolina-Georgia			North Carolina			South Florida			Mississippi		
	M	F	U	M	F	U	M	F	M	F	U	U	M	F	U	M	F	U	M	F	U	M	F	U
1977																								
Feb.				1	24																			
May																		45						
June	5	18	20	2	16	40			9	26	6							28						40
July	17	21	106			32			49	352	48					2	4	11						
Aug.	9	9	251			19	1	7	4	255	59													
Sept.				8	59				260	673														
Oct.				10	135	6			180	94	23													
Dec.				3	38																			
1978																								
Jan.				3	36																			
Feb.					8																			
Mar.				4	64																			
Apr.					3																			
May	23	99		1	4				1	5						13	41	4						
June	95	281	13	7	61		2	12	5	23						2	19	24				20	29	19
July	193	254	75	13	86	1			177	456	7					2	13	4				4	11	15
Aug.	234	262	1	5	81				301	259			3		7	3	16	2				15	28	31
Sept.					24	1			417	472			2	1	127	5	48	91	205	138	1	4	1	2
Oct.				4	75				203	255	16		156	248	6	103	256	82						
Nov.					34												10	6						
Dec.					7																			
1979																								
Jan.												371							209	346	12			
Feb.												482												
Mar.												1,052							33	85				
Total	576	944	466	61	755	99	3	19	1,606	2,870	159	1,905	161	249	140	130	407	297	447	569	13	43	69	107

millimeters. Length data were grouped into 100 mm intervals and categorized by month, location, year, and gear type.

Seasonal differences in size were analyzed in great detail in an earlier version of this paper by examining length-frequency distributions by month within gear type, area, and year. This detailed evaluation (20 figures, 10 tables, and 7 appendix tables) is available upon request from the Florida Department of Natural Resources (footnote 3).

Chi-square tests were used to compare homogeneity of frequency distributions in relation to month and gear type and to compare observed sex ratios to a hypothetical 1:1 ratio (Simpson et al. 1960).

SEASONAL DIFFERENCES IN SIZE AND SEX RATIO

Within each area along the northern Gulf of Mexico, changes in mean and modal lengths between months of king mackerel were generally similar (Tables 3, 4; Fig. 2). Mean sizes along northwest Florida were high in spring and fall and low during July or August of each year, except in 1969. Mean sizes were also generally lowest during the warmer months in Louisiana and although the data were meager, seasonal changes in size in Texas appeared similar to those in northwest Florida.

In south Florida, seasonal size changes, as evidenced by commercial hook-and-line data, were only weakly discernible. During most years, mean lengths tended to be highest during warmer months. When monthly means from different years were averaged over 3-mo periods, the lengths were as follows: April-June, 808 mm; July-September, 816 mm; October-December, 769 mm; and January-March, 758 mm.

Seasonal size changes along the south Atlantic coast above Cape Canaveral, Fla., could not be defined with any certainty because of the paucity of data. In North Carolina, mean lengths of recreationally caught fish increased from May (682 mm) to June (735 mm) 1977, decreased from May (809 mm) to June (789 mm) 1978 and increased from September (844 mm) to October (856 mm) 1978. Fish caught by commercial hook and line also increased from September (804 mm) to October (836 mm) 1978 in North Carolina. In the South Carolina-Georgia area the recreationally caught fish decreased from September (895 mm) to October (811 mm) 1978.

Females dominated catches from all areas in most months and years (Tables 3, 4, 5). In Louisiana, annual estimates of percent females were 91.9 in 1977 and 92.9 in 1978. In other parts of the northern gulf and along North Carolina, South Carolina, and Georgia, the annual estimates of percent female

TABLE 3.—Mean length (mm, $\bar{x}$), modal length (mm, ML), and percent female (%F) of king mackerel samples by area, gear type, and month during 1968-69 and 1975-76.

Year and month	Recreational hook and line			Commercial hook and line			Gill net		
	Northwest Florida			South Florida			South Florida		
	$\bar{x}$	ML	%F	$\bar{x}$	ML	%F	$\bar{x}$	ML	%F
1968									
Jan.				754	749	70.1	818	749	56.7
Feb.				746	749	71.5	757	749	50.7
Mar.				759	749	87.9	806	749	55.7
Apr.	757	749	62.1	901	900	40.4			
May	729	749	52.6	832	849	38.1			
June	743	749	76.4	792	749	55.9			
July	660	549	88.7						
Aug.	715	749	76.7	835	749	63.3			
Sept.	695	649	65.0	811	749	51.8			
Oct.	724	700	56.4	722	649	54.8			
Dec.				732	649	60.1			
1969									
Jan.				771	749	60.8			
Feb.				802	749	74.1			
Mar.				777	749	75.6			
May	747	749	46.9						
July	798	849	97.0	842	849	56.7			
Aug.	595	549	82.8	850	849	63.3			
Sept.	703	749	90.0	900	849	75.9			
Nov.	790	749	60.0						
1975									
Jan.				780	749				
Feb.				732	749				
Mar.				689	649				
Apr.				763	749				
May				774	749				
June				767	749				
Aug.				782	749				
Dec.				704	749				
1976									
Jan.				735	749				
Feb.				770	749		750	749	
Mar.				712	749				
Apr.				807	849				
May				800	749				
June				768	749				
Aug.				776	749				
Oct.				783	749				
Dec.				757	749				

ranged from 57.1 to 75.8. Only in south Florida did the sex ratio favor males; during 1978 the annual estimate based on commercial hook-and-line data was 40.2% females. Sex data were available from all seven areas in 1978; percent female ranged from 40.2 in south Florida to 92.9 in Louisiana (Table 5).

The degree of dominance by female king mackerel varied in relation to size of fish and type of capture gear (Table 5). Females were dominant in all size classes ≥900 mm FL and were dominant in 31 of 38 sample groups at lengths <900 mm FL.

COMPARISONS AMONG GEAR TYPES

An understanding of the variations in fishing techniques with a particular gear, and of the selective characteristics of each gear, is needed to interpret our data properly in making comparisons of size composition among years and geographic areas. The baits used by recreational fishermen in various areas

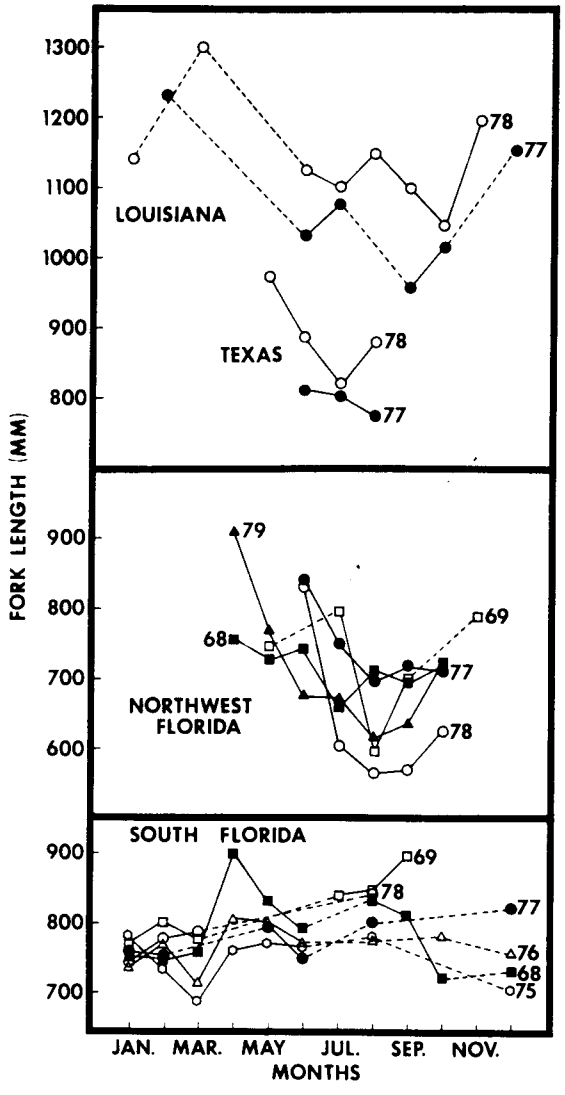

FIGURE 2.—Monthly mean fork lengths of king mackerel, *Scomberomorus cavalla*, caught by recreational hook and line by year and area.

are described above. Since data are not available for evaluating variations in recreational fishing techniques and their selectivity for particular sizes of fish, we assumed that the various baits and methods were not sufficiently selective to bias our analyses to this point. We did, however, have data to evaluate size selection among recreational hook and line, commercial hook and line, and gill nets.

Time, area, and sample size were used as criteria to select data for comparison. A minimum of 25 fish was required from the same geographic area during the same month from each of two compared gear types.

TABLE 4.—Mean length ($\bar{x}$), modal length (ML), and percent female (% F) of king mackerel samples by area, gear type, and month during 1977-79.

Year and month	Recreational hook and line																		Commercial hook and line								Gill net	
	Texas			Louisiana			Northwest Florida			South Florida		South Carolina-Georgia			North Carolina			Mississippi			South Florida			North Carolina		South Florida	
	$\bar{x}$	ML	%F	$\bar{x}$	ML	%F	$\bar{x}$	ML	%F	$\bar{x}$	ML	$\bar{x}$	ML	%F	$\bar{x}$	ML	%F	$\bar{x}$	ML	%F	$\bar{x}$	ML	%F	$\bar{x}$	ML	$\bar{x}$	ML
1977																												
Jan.																					754	749				803	749
Feb.				1,233	1,149	96.0															750	749				803	749
Mar.																										903	749
Apr.																										772	749
May															682	649					797	749					
June	812	849	78.3	1,032	1,049	88.9	844	849	74.3						735	749					751	749					
July	804	749	55.3	1,077	1,049		753	749	87.8																		
Aug.	774	749	50.0				697	649	98.4												802	749					
Sept.				958	949	88.1	720	649	72.1																		
Oct.				1,016	949	93.1	713	749	34.3																		
Dec.				1,152	1,000	92.7															825	849					
1978																											
Jan.				1,141	1,149	92.3															742	749					
Feb.																					779	749					
Mar.				1,299	1,249	94.1															789	749					
Apr.																										772	749
May	973	949	81.1												809	849	75.9				842	849					
June	888	849	74.7	1,126	1,049	89.7	831	849	82.1						789	749	90.5	899	849	59.2							
July	821	849	56.8	1,104	1,049	86.9	606	549	72.0									962	849	73.3							
Aug.	881	849	52.8	1,154	1,100	94.2	568	549	42.2									945	849	65.1							
Sept.				1,101	1,049	100.0	570	549	53.1			895		849	844	849	90.6							804	849		
Oct.				1,047	1,049	94.9	628	549	55.7			811	849	61.4	856	849	71.3							836	849		
Nov.				1,196	1,049	100.0																					
1979																											
Jan.										861	949										740	649	62.3				
Feb.										743	649																
Mar.										729	749										775	749	72.0				
Apr.							908	849																			
May							772	749																867	849		
June							679	649																			
July							675	649																			
Aug.							619	649																			
Sept.							639	649																			
Oct.							725	649																			

TABLE 5.—Percentage composition of female king mackerel by area, type of gear, year, and size class. Ratios in parentheses were determined from samples of <10 fish.

Fork length interval (mm)	Texas		Louisiana		Mississippi	Northwest Florida				South Florida						South Carolina-Georgia	North Carolina
	Recreational hook and line		Recreational hook and line		Commercial snapper	Recreational hook and line				Commercial hook and line			Gill net			Recreational hook and line	Recreational hook and line
	1977	1978	1977	1978	1978	1968	1969	1977	1978	1968	1969	1978	1979	1968		1978	1978
300- 499						(75.0)	(100.0)	(100.0)	33.3*	(100.0)	(100.0)		(100.0)				
500- 699	(57.1)	41.8	(100.0)		(0.0)	68.0*	70.7*	73.3*	57.0*	52.7	35.6*	(37.5)	58.2*	24.3*		57.8	61.9
700- 899	56.9	52.3	85.4*	80.0*	58.5	73.5*	72.2*	72.0*	72.7*	69.4*	65.0*	34.9*	63.4*	56.3*		54.6	68.2*
900-1,099	(100.0)	78.3*	90.2*	86.5*	61.0	85.0*	100.0*	88.6*	96.5*	78.5*	84.4*	67.9*	94.3*	70.7*		82.4*	94.0*
1,100-1,299		94.7*	98.1*	97.9*	100.0*	(100.0)	100.0*	(87.5)	100.0*	100.0*	93.3*	(100.0)	(100.0)	100.0*		100.0*	100.0*
1,300-1,499		(100.0)	100.0*	98.9*		(100.0)								(100.0)		(100.0)	
1,500-1,699			(100.0)	(100.0)													
300-1,699	60.8*	62.2*	91.9*	92.9*	63.5*	71.7*	75.1*	73.6*	57.1*	65.4*	61.8*	40.2*	64.0*	53.7*		61.5*	75.8*

*Significantly different (probability=0.05, chi-square test) from a 1:1 ratio.

All data meeting the above criteria were from fish caught off south Florida and North Carolina (Tables 1, 2) and are summarized in Table 6.

All comparisons of south Florida frequency distributions (recreational hook and line to commercial hook and line, and commercial hook and line to gill net) showed significant differences between size compostions; no significant differences were found in comparisons of compositions from North Carolina. The summary data (Table 6) from the south Florida samples showed the following: 1) Mean lengths were greater from gill nets than from commercial hook and line in 5 of 6 cases, 2) standard deviations about the mean were similar between gill nets and commercial hook and line, and 3) frequency distributions were slightly skewed to the right in 15 of 16 cases.

Although no significant differences were found between the size-frequency distributions of the recreational and commercial hook-and-line catches in North Carolina (Table 6), the summary data showed the mean size to be larger, and the standard deviation about the mean to be smaller, in the recreational catches.

The frequency distributions, from which data in Table 6 were computed, were converted to percent frequency and averaged within gear type and year. These distributions, summary statistics, and results of chi-square comparisons are shown in Figure 3 and Table 7. All comparisons between gear types were significantly different. Mean lengths and standard deviations were greater for the fish caught by gill nets than by commercial hook and line during 1968 and 1977; the opposite was true for 1976. Mean lengths of fish caught by recreational hook and line were greater than those caught by commercial hook and line in 1979 (south Florida) and by commercial hook and line 1978 (North Carolina).

The available data (above) were not adequate to evaluate selectivity and did not reflect the wide variations in mean and modal lengths that occurred among months in the catches. When individual monthly modes are viewed, we see that modal lengths varied from 649 to 849 mm FL in distributions from commercial hook and line but were always 749 mm FL in the gill net catches (Tables 3, 4). Modal lengths from recreational hook-and-line catches showed even more variation and ranged from 549 to 1,249 mm FL.

Although selectivity of the gears could not be properly quantified, we concluded, based on fluctuations (or lack of) in the modal lengths, that among the three gear types the gill net is the most selective and the recreational hook and line is the least selective toward sizes of king mackerel.

TABLE 6.—Monthly summary statistics (mean, standard deviation of mean, and skewness) of king mackerel length data used to compare size composition among gear and results of chi-square comparisons among length frequency distributions.

Area	Year and month	Recreational hook and line				Commercial hook and line				Gill net				Recreational vs. commercial hook and line		Commercial hook and line vs. gill net	
		N	$\bar{x}$	$s_{\bar{x}}$	Y_i	N	$\bar{x}$	$s_{\bar{x}}$	Y_i	N	$\bar{x}$	$s_{\bar{x}}$	Y_i	df	χ^2	df	χ^2
South Florida	1968																
	Jan.					451	754	3.7	1.4	834	819	3.7	1.0			5	149.5*
	Feb.					639	746	3.5	1.4	1,608	758	1.7	0.3			5	91.0*
	Mar.					950	759	2.8	0.6	1,038	807	3.2	0.7			6	124.1*
	1976																
	Feb.					1,796	771	2.5	0.8	313	751	3.0	0.1			5	136.6*
	1977																
	Jan.					1,194	755	2.2	0.1	2,777	804	2.0	0.7			6	246.8*
	Feb.					4,106	751	1.5	0.4	1,062	804	2.4	0.7			6	311.9*
	1979																
	Jan.	371	861	7.8	−0.3	567	742	4.7	0.5					6	211.3*		
	Mar.	1,052	729	4.9	0.3	118	775	7.9	0.1					6	54.0*		
North Carolina	1978																
	Sept.	144	844	10.1	−0.7	72	804	14.1	−0.5					5	6.9		
	Oct.	441	856	4.4	0.8	36	836	17.0	0.9					5	8.5		

*Probability ≤0.05.

TABLE 7.—Annual summary statistics (mean, standard deviation of mean, and skewness) of king mackerel length data used to compare size composition among gear and results of chi-square comparisons among length frequency distributions.

Area	Year and month	Recreational hook and line				Commercial hook and line				Gill net				Recreational vs. commercial hook and line		Commercial hook and line vs. gill net	
		N	$\bar{x}$	$s_{\bar{x}}$	Y_i	N	$\bar{x}$	$s_{\bar{x}}$	Y_i	N	$\bar{x}$	$s_{\bar{x}}$	Y_i	df	χ^2	df	χ^2
South Florida	1968					2,032	752	4.9	1.1	3,480	794	6.0	1.0			5	11.3*
	1976					1,796	770	10.7	0.8	313	750	5.3	0.1			5	64.3*
	1977					5,300	752	6.1	0.3	3,839	803	6.6	0.7			6	15.3*
	1979	1,423	795	10.9	−0.1	685	757	7.1	0.2					6	24.0*		
North Carolina	1978	585	850	7.6	−0.3	108	769	8.2	0.1					6	33.0*		

*Probability ≤0.05.

SIZE COMPARISONS AMONG YEARS AND AREAS

The following categories were used to compare size compositions between years: 1) Northwest Florida, recreational hook and line: 1968, 1969, 1977, and 1978; 2) south Florida, commercial hook and line: 1968, 1969, 1977, and 1978; and 3) Texas, Louisiana, and North Carolina, recreational hook and line: 1977 and 1978. Monthly data were combined by summing frequencies within length intervals and plotted to yield figures of annual size composition for each category (Figs. 4, 5).

Size composition varied considerably in northwest Florida between 1968 and 1978 (Fig. 4). Modal lengths decreased from 749 mm in 1968 and 1969 to 649 mm in 1977 and 549 mm in 1978. The mean length was over 115 mm, smaller in 1978 than during any of the other three years. During 1978, few fish >700 mm FL were caught, but a large percentage of the fish during each of the other three years was >700 mm FL.

In south Florida, no large differences in size composition among years were apparent. Modal lengths in the commercial hook-and-line data remained constant among years, while mean lengths ranged between 752 and 778 mm. Percents of fish above 700 mm FL were high and did not vary greatly among the four years. Size composition could have varied considerably in the population, however, and may not have been reflected in the catches owing to gear selectivity.

In Texas, Louisiana, and North Carolina differences in size composition between 1977 and 1978 were opposite that observed in northwest Florida (Fig. 5). From 1977 to 1978, modal and mean lengths increased in Texas (749-849 and 785-872, respectively), Louisiana (949-1,049 and 1,050 - 1,145), and North Carolina (649-849 and 718-850).

Recreational hook-and-line data from 1977 and 1978 were used to compare size composition between the following areas: Texas, Louisiana, northwest Florida, and North Carolina (Fig. 5). South Florida data were compared also but were collected in January-March 1979. The comparisons produced the following results: 1) Texas and North Carolina size compositions were more similar than any other areas; 2) Louisiana catches were composed of much

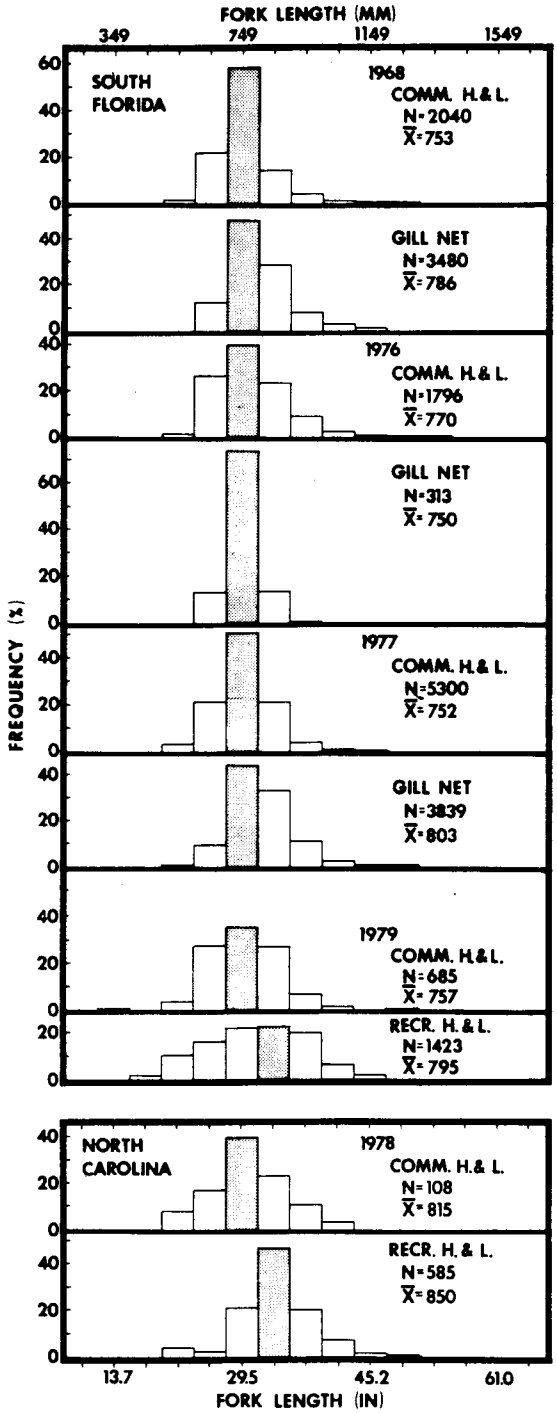

FIGURE 3.—Length-frequency distributions of king mackerel, *Scomberomorus cavalla*, by capture gear, area, and year.

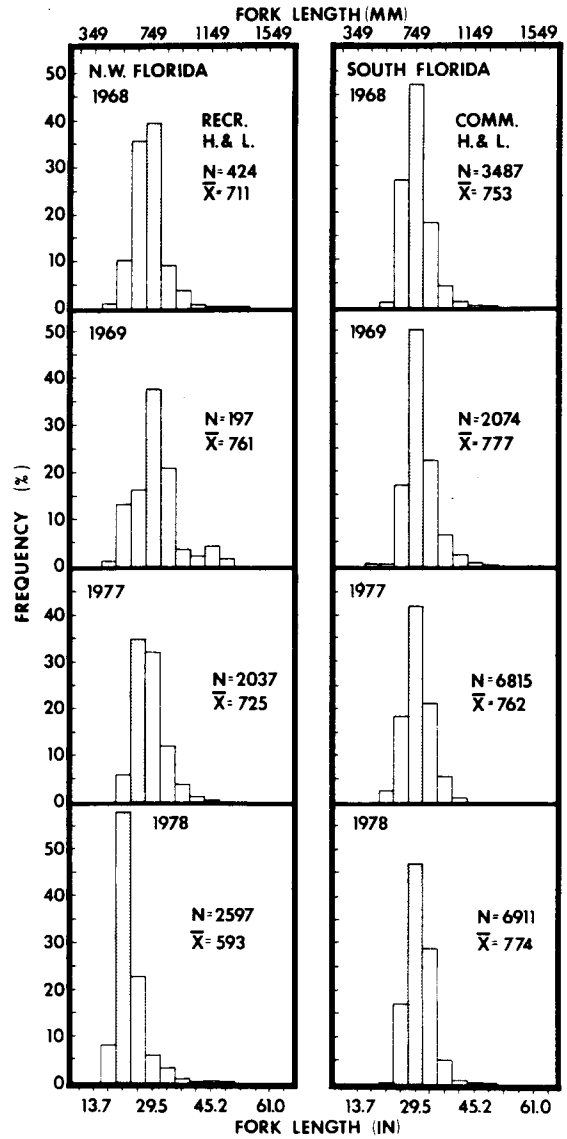

FIGURE 4.—Yearly length-frequency distributions of king mackerel, *Scomberomorus cavalla*, caught by recreational hook and line in northwest Florida and commercial hook and line in south Florida.

larger fish than were catches from any other area in either year; 3) northwest Florida catches, although similar to Texas and North Carolina catches in 1977, were composed of much smaller fish in 1978; 4) south Florida catches, like northwest Florida catches, contained fish in the 300-400 mm FL range as well as sizes representative of the Texas and North Carolina catches (fish in the 500-1,000 mm FL range).

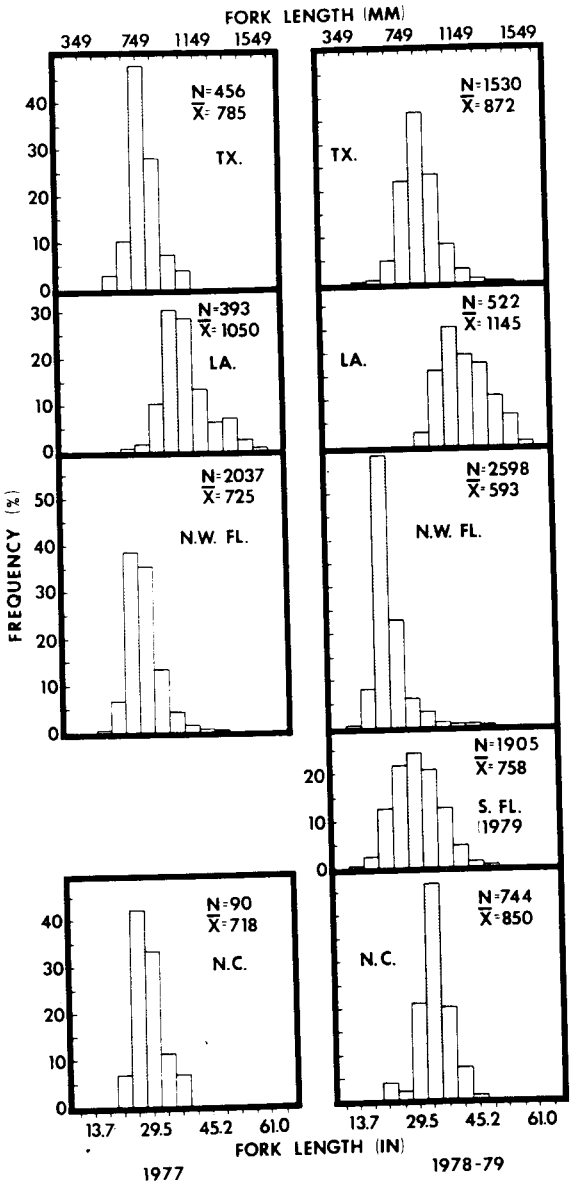

FIGURE 5.—Geographic variations in length-frequency distributions of king mackerel, *Scomberomorus cavalla*, caught by recreational hook and line during 1977-78 (and 1979 for south Florida).

SIZE AT RECRUITMENT AND EVALUATION OF MINIMUM SIZE LIMITS

Recruitment has been defined as 1) the addition of new fish to the vulnerable population by growth from among smaller categoreis (Ricker 1975; Royce 1972) and 2) a movement of fish onto the fishing grounds (Beverton and Holt 1957). For reasons discussed below, the latter definition appears most useful in evaluating recruitment of king mackerel.

King mackerel <400 mm (15.7 in) FL were reportedly not caught in appreciable numbers in any of the sampling areas in this study (Table 8). We suspect that small king mackerel did not occur in our collections for reasons related to fish distribution, gear selectivity, or both. Small king mackerel may occur offshore beyond the areas where recreational and commercial gill net fishermen normally fish for small coastal pelagic species such as bluefish, *Pomatomus saltatrix*, and Spanish mackerel, *Scomberomorus maculatus*, because few king mackerel are landed by these fishermen (Fable and Trent[6]). Whether small king mackerel intermingle to a great extent with large king mackerel offshore is unknown. Methods used by fishermen to catch king mackerel in the offshore areas (large hooks, large baits, and large mesh sizes) are selective towards fish >400 mm FL.

The size of king mackerel at recruitment into recreational fisheries varied among areas and among years within some areas (Table 8). In 1978, king mackerel were most available or susceptible to capture at lengths between 600 and 899 mm FL in all areas except Louisiana and northwest Florida. Most king mackerel from Louisiana were between 900 and 1,099 mm FL, while most from northwest Florida were between 500 and 599 mm FL. More king mackerel were reported at smaller sizes in Florida than in other areas.

King mackerel were fully vulnerable to the commercial hook-and-line and gill net fishermen at lengths between 700 and 799 mm FL during every year, except 1969 in gill nets (Table 8). In 1969, full recruitment to the gill net fishery occurred between 800 and 899 mm FL.

The management measure of adopting minimum size limits was considered by State and Federal agencies responsible for managing king mackerel. This measure would, however, drastically affect some areas because of the nonhomogeneous distribution of the king mackerel stock(s). To illustrate, the data in Table 8 were used to estimate the percentage of king mackerel that would have been illegal to retain had particular minimum size limits been in effect. For example, a minimum size of 599 mm FL (23.6 in) would have had a great impact upon recreational fishermen in northwest Florida during 1978, because about 66% of the fish caught would have been below

[6]Fable, W. A., and L. Trent. 1982. The percentages of king mackerel and cero caught in the Spanish mackerel gill-net fishery. Unpubl. manuscr., 13 p. Southeast Fisheries Center Panama City Laboratory, National Marine Fisheries Service, NOAA, Panama City, FL 32407.

TABLE 8.—Percentage of king mackerel caught within fork length intervals (mm) by gear, area, and year.[1]

	Recreational hook and line							Commercial hook and line						Gill net				
Area and year	<400	400-499	500-599	600-699	700-799	800-899	>899	<499	500-599	600-699	700-799	800-899	>899	<599	600-699	700-799	800-899	>899
Texas																		
1977	0.0	0.0	2.8	10.1	48.0	28.0	10.9											
1978	0.0	0.1	0.4	4.7	22.1	36.8	35.9											
Louisiana																		
1977	0.0	0.0	0.0	0.5	1.5	10.1	87.9											
1978	0.0	0.0	0.0	0.0	0.0	2.9	97.1											
Northwest Florida																		
1968	0.0	0.9	10.1	35.6	39.4	9.0	5.0											
1969	0.0	1.0	13.2	16.2	37.6	20.8	11.2											
1977	0.1	0.1	6.6	38.5	35.2	13.3	5.9											
1978	0.1	8.1	58.2	22.8	6.1	3.1	1.7											
South Florida																		
1968								0.1	1.0	27.0	47.7	18.0	6.2	0.1	13.1	50.2	26.6	10.0
1969								0.0	0.3	17.2	50.3	22.5	9.7	0.0	0.5	30.9	38.1	21.5
1975								0.0	2.1	19.6	52.2	21.4	4.6					
1976								0.1	1.5	28.2	44.3	19.5	6.3	0.0	12.8	73.5	13.4	0.3
1977								0.0	2.8	20.2	46.2	23.4	7.4	0.1	10.7	41.4	30.4	17.4
1978								0.0	0.3	17.2	47.2	29.0	6.3	0.0	6.4	65.1	27.9	0.7
1979	0.3	2.2	12.4	21.6	24.4	20.7	18.2	0.1	5.0	30.5	33.6	23.1	7.5					
South Carolina-Georgia																		
1978	0.0	0.0	9.3	4.2	22.6	36.5	27.5											
North Carolina																		
1977	0.0	0.0	6.7	42.2	33.3	11.1	6.7											
1978	0.0	0.0	1.6	4.2	22.8	46.2	25.2	0.0	6.5	5.6	26.8	44.4	16.6					

[1]Percent of fish caught by commercial snapper fishermen from Mississippi by length group in 1978 were: <699 mm, 1.1; 700-799, 16.2; 800-899, 30.2; >899, 52.5.

the legal size. A minimum size of 699 mm FL (27.5 in) would have made significant portions (over 40%) of the 1977 recreational catch in northwest Florida and in North Carolina illegal. This minimum size of 699 mm FL would have made 17-36% of the commercial hook-and-line catch and 7-14% of the gill net catch illegal, depending on the year.

DISCUSSION

The seasonal distribution of adult king mackerel in the coastal zone of the southeastern United States can be inferred from catch data. These fish are caught in abundance along the south Atlantic coast (north Florida to North Carolina) in the spring and fall, along the northeast and northwest segments of the Gulf of Mexico in late spring, summer, and fall, and off the south Florida and Louisiana coasts year-round. Size and sex composition data indicate, however, that fish found in these areas and times do not belong to a homogeneous king mackerel population (assuming that we are dealing with only one) and should not be considered as such for management purposes. To evaluate the impact of proposed minimum size regulation and possibly to provide a framework for managing minimum size, we have partitioned the U.S. portion of the North American king mackerel population into four groups: 1) Florida winter group; 2) the immmature group; 3) the spawning group; and 4) Louisiana group. These groups are not known to be stocks or genetic groups, but rather they represent groups that can be identified in time, space, or sexual maturity states.

Florida Winter Group

This group occurs along the east and west coasts of the southern half of Florida, including the Florida Keys during colder months (December-March), and is thought to be sexually inactive during this period (Beaumariage 1973; Finucane et al.[7]). The group includes all sizes of king mackerel known to exist in the exploited populations. The abundance of medium-sized king mackerel each winter is well documented; several years of commercial hook-and-line and gill net data show that about 90% of the king mackerel landed by commercial fishermen in south Florida are between 600 and 899 mm FL. Large king mackerel (1,000-1,500 mm FL) caught by recreational fishermen from the south Florida area have been reported by Beardsley and Richards (1970). A 90-lb (about 1,800 mm FL) king mackerel was caught in south Florida in February 1976 (Anonymous 1976). The Florida winter group becomes reorganized, through movement and migration during spring, summer, and fall, into the more northerly immature and spawning groups.

The Immature Group

Members of this group include the small (300-600 mm FL) king mackerel from the Florida winter group

[7]Finucane, J. H., L. A. Collins, H. A. Brusher, and C. H. Saloman. 1983. Reproduction of king mackerel from the Gulf of Mexico and south Atlantic. Unpubl. manuscr., 15 p. Southeast Fish. Center Panama City Laboratory, National Marine Fisheries Service, NOAA, FL 32407.

and are, for the most part, sexually inactive (Beaumariage 1973, Finucane et al. footnote 7). Immature fish form a large proportion of the Florida winter catch but are proportionately less abundant along the North Carolina, South Carolina, and Texas coasts. For example, percent compositions of king mackerel between 300 and 600 mm FL in the recreational catches by area and year were as follows:

Location	*Year*	*%*
South Florida	1979	14.9
South Carolina-Georgia	1978	9.3
North Carolina	1977	6.7
	1978	1.6
Northwest Florida	1968	11.0
	1969	14.2
	1977	6.8
	1978	66.4
Texas	1977	2.8
	1978	0.5

King mackerel <600 mm FL were not observed from Louisiana. Members of the immature group are caught in abundance in areas other than south Florida only during summer months. They are proportionately abundant in the catches in July-August in northwest Florida, in August in Texas, and in September in North Carolina.

The Spawning Group

Members of this group include the sexually mature individuals (usually >600 mm FL) of the Florida winter groups and, during warmer months, are distributed throughout the coastal zone of the southeastern United States and along the northeast U.S. coast. In the Gulf of Mexico, most members of this group residing in south Florida during winter apparently migrate north earlier or faster than do members of the immature group (Trent et al. 1981). Early departure of the larger king mackerel is reflected, for example, in the recreational landings in south Florida during 1979; mean fork lengths decreased from 861 mm in January to 729 mm in March. King mackerel occurring in the early months of each fishing season in northwest Florida and Texas are usually the largest. Members of this group that migrate northward along the Atlantic coast in the spring did not reveal the same seasonal size pattern as did those in the Gulf of Mexico. The largest individuals did not arrive in North Carolina until June of each year and were preceded by smaller fish.

Louisiana Group

This group is characterized by large fish, most of which are female. Of all fish examined only 12.1% in 1977 and 2.9% in 1978 were <900 mm FL (about 12 lb) and 92.5% of all fish were females. Although king mackerel of both sexes were caught during all seasons, monthly estimates of the proportion of females were never <80%. The highest proportions of males occurred from May through September. Exceptionally large fish (>1,399 mm FL) were caught in highest proportions from November through March. Fish <800 mm FL were caught only during June, September, and October.

The range and migration patterns of the Louisiana group are not known. Most of the king mackerel observed from Louisiana were caught adjacent to oil rigs in water depths of 10-20 fathoms about 12-18 mi southeast of Grand Isle. This area is fished heavily by recreational fishermen, because it is within practical range of two ports (Grand Isle and Empire) that produce most of the fishing effort for king mackerel in Louisiana and because king mackerel fishing is known to be good in the area. The oil rigs, however, are numerous at depths from 10 to 50 fathoms from the Mississippi Delta (long. 89°30′) westward to areas off the Texas-Louisiana border (long. 93°50′), an east-west distance of about 250 mi. Members of the Louisiana group probably occur throughout the oil field but, evidently, do not participate in extensive north-south migrations as do smaller king mackerel. The presence of large king mackerel off the Louisiana coast in winter (Table 4) suggests that environmental factors are favorable for them there throughout the year. Munro (1943) stated that minimum temperatures of 20°C limit the distribution of members of the genus *Scomberomorus*. Large king mackerel were caught in abundance off the Louisiana coast during the winters of 1977 and 1978, two of the coldest winters on record (Ingham 1979). In 1978, surface water temperatures and their deviations from the 1948-67 mean (°C) in the one-degree square (long. 89°-90° and lat. 28°-29°) just south of the area where king mackerel were caught averaged 19.4°C (−1.3) in January, 18.7°C (−1.8) in February, and 18.6°C (−2.4) in March. Data collected during January-March 1976 indicated that bottom temperatures are about 1°-2°C higher than surface temperatures where depths are between 10 and 20 fathoms off Louisiana (Ragan et al. 1978); thus a habitat in which temperatures were 20°C or greater could have been available to king mackerel in 1978.

Atlantic croaker; longspine porgy, *Stenotomus ca-*

pirinus; silver seatrout, *Cynoscion nothus*; and other fish species acceptable as food by king mackerel are especially abundant during winter months in 10-30 fathom depths off Louisiana and east Texas (Moore et al. 1970). Food studies of large king mackerel from Louisiana indicate that sciaenids (seatrouts and Atlantic croaker) are the dominant species of prey during the winter and spring months (Saloman and Naughton footnote 5).

Sex Ratio

We could not explain why the sex ratio favored females. The ratios we observed may be real in that more females than males are produced at spawning or that mortality rates are higher for males than females at sizes (<400 mm FL) smaller than those we observed.

ACKNOWLEDGMENTS

Sincere appreciation is extended to the commercial and recreational fishermen and members of sportfishing organizations who contributed samples, time, and information for this paper and to those who critically reviewed the manuscript. We are especially indebted to Raymond Groom, Jinx Martin, Dickie Myers, Joan Browder, Ann Langes, Mike Parrack, John Merriner, personnel of the Louisiana Wildlife and Fisheries Commission, and the anonymous reviewers of the *Fisheries Bulletin*.

LITERATURE CITED

ANONYMOUS.
1976. International Marine Angler. Newsl. Int. Game Fish Assoc., Vol. 38, No. 3. Fort Lauderdale, Fla.

AUSTIN, C. B., J. A. BROWDER, R. D. BRUGGER, AND J. C. DAVIS.
1978. Mackerel workshop report. Univ. Miami Sea Grant Publ. No. 14, 156 p.

BEARDSLEY, G. L., JR., AND W. J. RICHARDS.
1970. Size, seasonal abundance, and length-weight relation of some scombrid fishes from southeast Florida. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 595, 6 p.

BEAUMARIAGE, D. S.
1973. Age, growth and reproduction of king mackerel, *Scomberomorus cavalla* in Florida. Fla. Mar. Res. Publ. 1, 45 p.

BEVERTON, R. J. H., AND S. J. HOLT.
1957. On the dynamics of exploited fish populations. Fish. Invest. Minist. Agric. Fish. Food. (G.B.), (Ser. II) 19, 533 p.

DEUEL, D. G., AND J. R. CLARK.
1968. The 1965 salt-water angling survey. U.S. Fish Wildl. Serv., Resour. Publ. 67, 51 p.

HARRIS, A. R.
1974. Commercial kingfishing off Florida requires special gear, techniques. Nat. Fisherman, July 1974, p. 16-26.

INGHAM, M. C.
1979. Marine environmental conditions off the Atlantic and Gulf coasts of the United States, January 1977-March 1978. Mar. Fish. Rev. 41(5-6):35-47.

MANOOCH, C. S., III.
1979. Recreational and commercial fisheries for king mackerel, *Scomberomorus cavalla*, in the South Atlantic Bight and Gulf of Mexico, U.S.A. *In* E. L. Nakamura and H. R. Bullis, Jr. (editors), Proceedings: Colloquium on the Spanish and king mackerel resources of the Gulf of Mexico, p. 33-41. Gulf States Mar. Fish. Comm., March 1979, No. 4.

MOORE, D., H. A. BRUSHER, AND W. L. TRENT.
1970. Relative abundance, seasonal distribution, and species composition of demersal fishes off Louisiana and Texas, 1962-64. Publ. Inst. Mar. Sci. Univ. Tex. 15:45-70.

MUNRO, I. S. R.
1943. Revision of Australian species of *Scomberomorus*. Mem. Queensl. Mus. 12(1):65-95.

RAGAN, J. G., A. H. HARRIS, AND J. H. GREEN.
1978. Temperature, salinity and oxygen measurements of surface and bottom waters on the continental shelf off Louisiana during portions of 1975 and 1976. Professional papers series (Biology) No. 3, 29 p. Nicholls State Univ., Thibodaux, La.

RANDALL, J. E.
1968. Caribbean reef fishes. T.F.H. Publ., Inc., Jersey City, 318 p.

RICKER, W. E.
1975. Computation and interpretation of biological statistics of fish populations. Fish. Res. Board Can., Bull. 191, 382 p.

ROYCE, W. F.
1972. Introduction to the Fishery Sciences. Acad. Press, N.Y., 351 p.

SIMPSON, G. G., A. ROE, AND R. C. LEWONTIN.
1960. Quantitative zoology. Revised ed. Harcourt, Brace, and Co., N.Y., 440 p.

TRENT, W. L., R. W. WILLIAMS, R. G. TAYLOR, C. H. SALOMAN, AND C. S. MANOOCH III.
1981. Size and sex ratio of king mackerel, *Scomberomorus cavalla*, in the southeastern United States. U.S. Dep. Commer., NOAA Tech. Memo. NMFS SEFC-62, 59 p.

WISE, J. P., AND B. G. THOMPSON.
1977. Fishery statistics of the United States, 1974. U.S. Natl. Mar. Fish. Serv. Stat. 68, 424 p.