Some Morphometrics of Billfishes From the Eastern Pacific Ocean

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ABSTRACT

Length-weight and morphometric data collected over 4 yr (1967-70) from sport fisheries at three eastern Pacific locations are presented for striped marlin *(Tetrapturus audax)*, sailfish *(Istiophorus platypterus)*, and blue marlin *(Makaira nigricans)*. The data were gathered from San Diego, California (U.S.A.), Buena Vista, Baja California Sur (Mexico), and Mazatlán, Sinaloa (Mexico).

Regression of eye-fork length and covariance analysis were used to compare maximum body depth, depth at vent, pectoral fin length, dorsal fin height, maxillary length, snout to mandible and snout to posterior orbit lengths between sexes and areas for each species. Regression equations are given for converting fork length and mandible-fork length to eye-fork length. Based on these conversions our Pacific Ocean data on sailfish are compared with data from the Atlantic Ocean.

Length-weight regressions using both eye-fork length and fork length are given for each species by sex.

The eastern Pacific off Mexico and southern California is probably one of the world's most productive regions for billfishes. Specimens from this region, however, have too often been underrepresented in comparative studies on billfish morphology. It is the purpose of this paper to (1) present some basic data on morphometric and meristic characters of striped marlin *(Tetrapturus audax)*, blue marlin *(Makaira nigricans)*, and sailfish *(Istiophorus platypterus)* from the eastern North Pacific Ocean, and (2) discuss some sources of variation in morphometric characters.

SAMPLING

Source of Data

The data were gathered by the staff of the Tiburon Fisheries Laboratory during 1967 through 1970. The sole source of data was the sampling of sport landings at three locations. These locations were: (1) the San Diego Marlin Club at San Diego, California; (2) Rancho Buena Vista in the territory of Baja California Sur, Mexico; and (3) the Star Fleet at Mazatlán, Sinaloa, Mexico. Sampling at these locations each year was conducted primarily during the months when billfish catches were highest. The monthly distribution of samples is shown in Table 1.

The specimens examined were almost totally fish caught on one-day trips in small boats ranging from about 6 to 12 m in length. For this reason most of the samples at each location represent fishes caught in a radius of less than about 100 km from the landing site. All of the fish were kept fresh, unfrozen, and at San Diego and Buena Vista, usually moist. The billfish landed at Mazatlán tended to be in a more dried-out condition. This made full erection of the dorsal fin difficult. Many fish were, therefore, measured when the dorsal fin was only half erect, but we feel that this did not affect the results significantly. The effect of dryness on body measurements is unknown, but we feel that it was not significant. Body length measurements were made with a steel tape. Nearly all of the fish at San Diego and a few of the fish at Mazatlán were measured while hanging by the tail. Otherwise, measurements were made while fish were lying on their side on a flat surface with heads and tails raised to horizontal. We tested the effect of hanging on eye-fork lengths of 10 fish at San Diego by measuring each one while hanging

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FROM Shomura, R. S., and F. Williams (editors), Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972. Part 2. Review and contributed papers. NOAA Technical Report NMFS SSRF-675, 1974.

Table 1.—Number of blue marlin, sailfish, and striped marlin sampled in 1967-70 at Buena Vista, Mazatlán, and San Diego.

	Months											
	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Blue marlin												
Buena Vista												
Female												
1967	—	—	—	—	1	—	—	—	—	—	—	1
1969	—	—	—	—	2	7	—	—	—	5	—	14
1970	—	—	—	—	—	—	—	—	15	5	—	20
Total	—	—	—	—	3	7	—	—	15	10	—	35
Mazatlán												
Female												
1969	—	—	4	6	10	2	—	—	—	—	—	22
Sailfish												
Buena Vista												
Male												
1967	—	—	—	2	—	—	—	—	—	—	—	2
1968	—	—	—	—	3	—	—	—	—	—	—	3
1969	—	—	—	—	1	3	—	—	—	5	—	9
1970	—	—	—	—	—	—	—	—	8	6	—	14
Total	—	—	—	2	4	3	—	—	8	11	—	28
Female												
1967	—	—	—	2	4	—	—	—	—	—	—	6
1968	—	—	1	3	7	7	—	—	—	—	—	18
1969	—	—	—	10	1	9	—	—	—	—	6	26
1970	—	—	—	—	—	—	—	—	—	7	14	21
Total	—	—	1	15	12	16	—	—	—	7	20	71
Mazatlán												
Male												
1967	—	—	4	5	—	—	—	—	—	—	—	9
1968	—	—	7	44	15	—	—	—	—	—	2	68
1969	1	1	25	73	142	22	—	—	—	—	—	264
Total	1	1	36	122	157	22	—	—	—	—	2	341
Female												
1967	—	—	17	11	—	—	—	—	—	—	—	28
1968	—	—	14	64	26	—	—	—	—	—	3	107
1969	4	7	17	101	93	14	—	—	—	—	—	236
Total	4	7	48	176	119	14	—	—	—	—	3	371
Striped marlin												
Buena Vista												
Male												
1967	—	—	—	53	30	—	—	—	—	—	—	83
1968	—	—	49	64	74	34	—	—	—	—	—	221
1969	—	17	86	113	39	18	—	—	—	—	—	273
1970	—	—	—	—	—	—	—	—	6	33	1	40
Total	—	17	135	230	143	52	—	—	6	33	1	617
Female												
1967	—	—	—	46	19	—	—	—	—	—	—	65
1968	—	—	37	48	60	25	—	—	—	—	—	170
1969	—	22	51	54	42	29	—	—	—	9	—	207
1970	—	—	—	—	—	—	—	—	6	32	6	44
Total	—	22	88	148	121	54	—	—	6	41	6	486

Table 1.—Number of blue marlin, sailfish, and striped marlin sampled in 1967-70 at Buena Vista, Mazatlán, and San Diego.—Continued

	Months											
	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Mazatlan												
Male												
1967	—	—	21	7	—	—	—	—	—	—	—	28
1968	—	—	50	26	1	—	—	—	—	—	1	78
1969	13	42	30	30	5	1	—	—	—	—	—	121
1970	—	—	—	—	—	—	—	—	—	—	2	2
Total	13	42	101	63	6	1	—	—	—	—	3	229
Female												
1967	—	—	15	11	—	—	—	—	—	—	—	26
1968	—	—	31	18	—	—	—	—	—	—	4	53
1969	16	48	36	29	9	3	—	—	—	—	—	141
1970	—	—	—	—	—	—	—	—	—	—	6	6
Total	16	48	82	58	9	3	—	—	—	—	10	226
San Diego												
Male												
1967	—	—	—	—	—	—	22	50	—	—	—	72
1968	—	—	—	—	—	—	1	35	33	—	—	69
1970	—	—	—	—	—	—	—	6	—	—	—	6
Total	—	—	—	—	—	—	23	91	33	—	—	147
Female												
1967	—	—	—	—	—	—	35	126	—	—	—	161
1968	—	—	—	—	—	—	6	85	32	—	—	123
1970	—	—	—	—	—	—	3	26	2	—	—	31
Total	—	—	—	—	—	—	44	237	34	—	—	315

and then again after lying flat. The fish while hanging ranged from 1 mm shorter to 7 mm longer, the average being 3 mm longer than when lying flat. The mean difference was not significant.

Definitions of Counts and Measurements

The counts and measurements used in this study are defined below. Though the terminology is not identical, many of these are the same as those recommended by Rivas (1956).

Dorsal rays—number of rays in second dorsal fin.

Anal rays—number of rays in second anal fin.

Fork length—tip of snout to posterior margin of middle caudal rays.

Mandible-fork length—tip of mandible with mouth closed to posterior margin of middle caudal rays.

Eye-fork length—posterior margin of orbit to posterior margin of middle caudal rays.

Snout to mandible—tip of snout to tip of mandible with mouth closed.

Table 2.—Frequency of dorsal and anal fin ray counts for blue marlin, sailfish and striped marlin from the eastern Pacific.

	Number of rays						
	5	6	7	8	Total	$\bar{X}$	s
Dorsal fin rays							
Blue marlin	—	13	20	—	33	6.61	0.496
Sailfish	—	24	56	—	80	6.70	0.461
Striped marlin	10	223	14	—	247	6.02	0.312
Anal fin rays							
Blue marlin	—	5	27	1	33	6.88	0.415
Sailfish	1	29	48	1	79	6.62	0.538
Striped marlin	40	195	7	—	242	5.86	0.420

Snout to eye—tip of snout to anterior margin of orbit.

Length of maxillary—tip of mandible to posterior end of maxillary bone.

Maximum body depth—base of dorsal groove to edge of pelvic groove, in the transverse plane where this measurement is maximum (usually near base of pectorals).

Depth at vent—depth of body as described above except in the transverse plane through vent.

Length of pectoral fin—from base of first pectoral fin ray to tip of longest ray with fin folded against body.

Length of pelvic fin—from base of fin rays to tip when fin is held at slight angle from body.

Dorsal fin height—from base of first dorsal fin spine to tip of anterior lobe of first dorsal fin with fin held as nearly erect as possible (see previous section).

METHODS OF ANALYSIS

Meristic Characters

Counts of second dorsal and second anal fin rays were the only meristic characters used. It was quite evident early in the study that the number of fin rays did not vary significantly with fish size, at least for sizes of fish we examined, and that the number for a species varied within a narrow range of two to four rays (Table 2). The meristic characters were therefore eliminated from any further analyses.

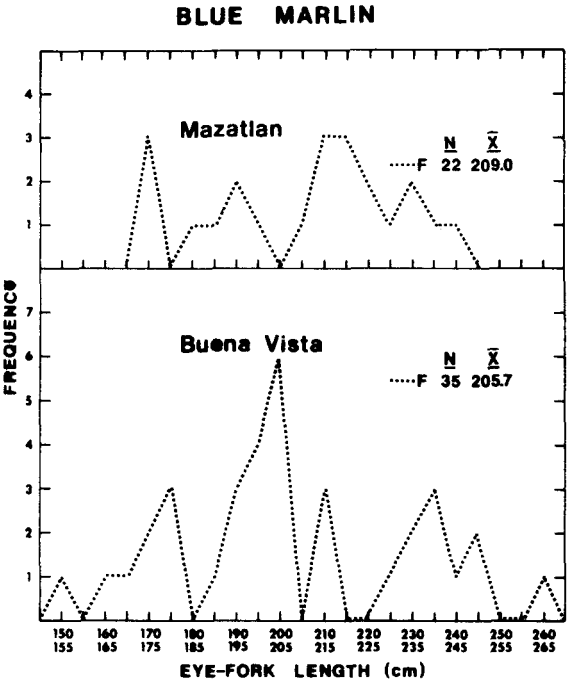

Figure 1.—Length frequency of blue marlin sampled in this study.

Morphometric Characters

Linear regression and analysis of covariance were the procedures used to analyze the data. Except for

Table 3.—Equations for converting fork and mandible-fork lengths to eye-fork length. Equations are based on $Y = a + bX$.

Relation	a	b	N	r	Range of X (cm)
Blue marlin					
Eye-fork length on fork length	−15.785	0.810	21	0.997	221.1-347.3
Eye-fork length on mandible-fork length	−5.105	0.893	22	0.979	194.0-297.6
Sailfish					
Eye-fork length on fork length	6.802	0.714	35	0.926	183.0-260.0
Eye-fork length on mandible-fork length	2.637	0.852	35	0.940	155.5-225.0
Fork length on eye-fork length	24.677	1.200	35	0.926	
Striped marlin					
Eye-fork length on fork length	−1.319	0.745	127	0.745	178.5-268.8
Eye-fork length on mandible-fork length	1.306	0.840	125	0.985	151.6-238.2

Table 4.—Coefficients of the weight-length relation for blue marlin, sailfish, and striped marlin from the eastern Pacific. (log weight = a + b (log length)).

Species	Measurement		a	b	Range of length (cm)	N	r
	Length (cm)	Weight					
Blue marlin							
Female	Eye-fork	kg	−5.690	3.318	154.0-265.1	57	0.948
	Eye-fork	lb	−5.347	3.318	154.0-265.1	57	0.948
	Snout-fork	kg	−7.543	3.905	221.1-347.3	20	0.954
	Snout-fork	lb	−7.199	3.905	221.1-347.3	20	0.954
Sailfish							
Male	Eye-fork	kg	−4.396	2.643	115.1-196.5	367	0.867
	Eye-fork	lb	−4.057	2.643	115.1-196.5	367	0.867
	Snout-fork	kg	−5.286	2.873	183.0-260.2	24	0.910
	Snout-fork	lb	−4.946	2.873	183.0-260.2	24	0.910
Female	Eye-fork	kg	−4.084	2.507	123.1-221.7	435	0.812
	Eye-fork	lb	−3.739	2.507	123.1-221.7	435	0.812
	Snout-fork	kg	−4.059	2.356	201.7-271.0	47	0.835
	Snout-fork	lb	−3.714	2.356	201.7-271.0	47	0.835
Combined sexes	Eye-fork	kg	−4.360	2.628	115.1-221.7	802	0.846
	Eye-fork	lb	−4.017	2.628	115.1-221.7	802	0.846
	Snout-fork	kg	−4.788	2.662	183.0-271.0	71	0.890
	Snout-fork	lb	−4.446	2.662	183.0-271.0	71	0.890
Striped marlin							
Male	Eye-fork	kg	−5.005	2.999	119.6-202.6	975	0.877
	Eye-fork	lb	−4.664	2.999	119.6-202.6	975	0.877
	Snout-fork	kg	−5.166	2.903	172.0-261.0	220	0.780
	Snout-fork	lb	−4.857	2.903	172.0-261.0	220	0.780
Female	Eye-fork	kg	−5.243	3.113	110.0-215.1	1,007	0.854
	Eye-fork	lb	−4.900	3.113	110.0-215.1	1,007	0.854
	Snout-fork	kg	−5.267	2.950	153.0-271.0	315	0.778
	Snout-fork	lb	−4.914	2.950	153.0-271.0	315	0.778
Combined sexes	Eye-fork	kg	−5.157	3.071	110.0-215.1	1,982	0.864
	Eye-fork	lb	−4.816	3.071	110.0-215.1	1,982	0.864
	Snout-fork	kg	−5.340	2.982	153.0-271.0	535	0.784
	Snout-fork	lb	−5.007	2.982	153.0-271.0	535	0.784

weight-length relations, transformations of the data were not necessary because plots of the data on eye-fork length indicated that they were reasonably linear. Equations for converting fork length and mandible-fork length are given in Table 3.

The equation used in the analyses, except that for weight, was $Y = a + bX$, where Y = morphometric character measured in centimeters, and a and b = constants that are determined by least-squares procedures. For weights, the equation $\log Y = a + b\log X$, where Y = weight, X = body length, and a and b = constants, was used. Weight-length relations based on weight in kilograms and pounds and body length as eye-fork length and snout-fork length are summarized in Table 4 for blue marlin, sailfish, and striped marlin. Statistical tests were performed to test the hypotheses that the intercept of the regression, a, is zero and that the slope of the regression, b, is zero for all regressions except those for weight-length.

All plots of the data were based on averages of 5-cm groupings of eye-fork length.

BLUE MARLIN

A total of 57 blue marlin was sampled at Buena Vista and Mazatlán. The average length was 206 cm at Buena Vista and 209 cm at Mazatlán (Fig. 1).

Table 5.—Regression of morphometric character on eye-fork length (cm) for blue marlin from the eastern Pacific. Weight-length relation is based on log transformed data ($\log Y = a + b\log X$); all other relations are based on untransformed data ($Y = a + bX$). Data are for females. (* = 5% significance level; ** = 1% significance level).

Character	a	b	Range x	Range Y	N
Buena Vista					
Weight (kg)	−5.960	3.433	154.0-265.1	40.9-244.9	35
Maximum body depth (cm)	−5.887	0.245**	154.0-239.8	32.2- 53.6	14
Length of pectoral fin (cm)	18.594**	0.163**	154.0-265.1	40.7- 62.0	35
Length of pelvic fin (cm)	37.244**	0.003	154.0-239.8	32.1- 45.3	14
Dorsal fin height (cm)	20.966**	0.084**	154.0-265.1	31.0- 49.4	34
Length of maxillary (cm)	15.236**	0.090**	154.0-265.1	25.9- 40.2	34
Number of dorsal fin rays	6.468**	0.001	154.0-265.1	6-7	33
Number of anal fin rays	5.286	0.008**	154.0-265.1	6-8	33
Mazatlán					
Weight (kg)	−4.972	3.011	171.4-242.2	46.7-171.5	22
Length of pelvic fin (cm)	57.859**	0.096*	171.4-242.2	30.1- 45.3	22
Dorsal fin height (cm)	7.560	0.150**	171.4-242.2	32.2- 45.9	22
Length of maxillary (cm)	4.014	0.140**	171.4-242.2	26.5- 40.2	21

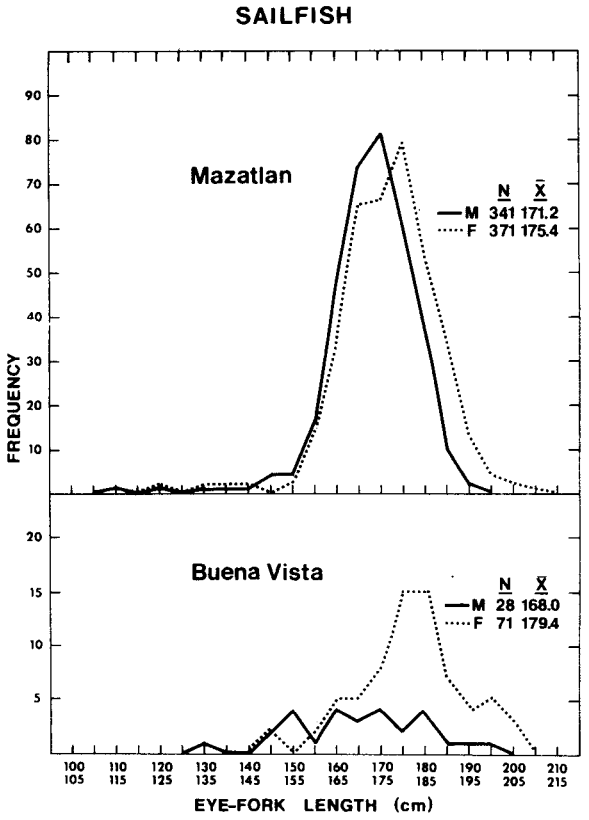

Figure 2.—Length frequency of sailfish sampled in this study.

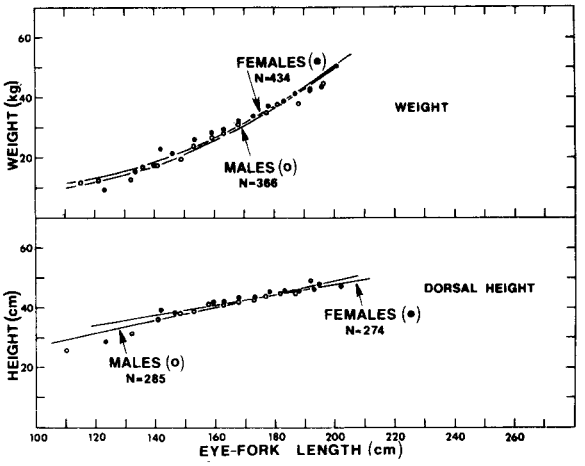

Figure 3.—Weight and dorsal height as a function of eye-fork length of sailfish from the eastern North Pacific.

Samples from both locations consisted of only females. We have no adequate explanation for this phenomenon; however, we note that in the central Pacific, which is west of our sampling area, more males than females are generally caught in the sport fishery (Strasburg, 1969). In the longline fishery sex ratios vary greatly both temporally and spatially (Kume and Joseph, 1969).

Regressions of each of the characters as a function of eye-fork length are shown in Table 5. Ex-

Table 6.—Results of analysis of covariance of morphometric character as a function of eye-fork length. The statistical test is whether the relation is significantly different among areas. (n.s. = not significant; * = 5% significance level; ** = 1% significance level).

Character	Blue marlin	Sailfish		Striped marlin	
	Female	Male	Female	Male	Female
Weight	n.s.	n.s.	n.s.	**	**
Maximum body depth	—	n.s.	*	**	**
Depth at vent	—	n.s.	n.s.	**	**
Length of pectoral fin	—	n.s.	n.s.	**	**
Length of pelvic fin	n.s.	n.s.	n.s.	n.s.	**
Snout to mandible length	—	n.s.	n.s.	**	**
Snout to eye length	—	—	*	*	**
Dorsal fin height	n.s.	n.s.	*	*	**
Length of maxillary	n.s.	n.s.	n.s.	n.s.	n.s.

cluding results for weight-length relations, results of the statistical test of $a = 0$ indicate that most of the a's are significantly different from zero. This suggests that growth of the body parts is allometric, or the parts do not grow as a constant proportion to body size, which is characteristic for most body parts of fishes (Martin. 1949).

Analysis of covariance was performed to test whether the regressions differed between sampling locations. No significant differences were found (Table 6). Samples from Buena Vista and Mazatlán were therefore pooled and the regressions were recalculated (Table 7).

SAILFISH

A total of 811 sailfish was sampled at Buena Vista and Mazatlán. Sampling at Buena Vista was in 1967-70 and at Mazatlán, only in 1967-69. More fish, however, were sampled at Mazatlán than at

Table 7.—Regression of morphometric character on eye-fork length (cm) for pooled (locations and sexes) samples of blue marlin and sailfish from the eastern Pacific. Weight-length relation is based on log transformed data ($\log Y = a + b \log X$); all other relations are based on untransformed data ($Y = a + bX$).

Character	a	b	Range of length	N
Blue marlin				
Weight (kg)	−5.690	3.318	154.0-265.1	57
Maximum body depth (cm)	−5.887	0.245	154.0-239.8	14
Length of pectoral fin (cm)	18.594	0.163	154.0-265.1	35
Length of pelvic fin (cm)	49.263	−0.056	154.0-242.2	36
Dorsal fin height (cm)	17.129	0.103	154.0-265.1	56
Length of maxillary (cm)	12.366	0.103	154.0-265.1	55
Sailfish				
Weight (kg)	−4.360	2.628	115.1-221.7	802
Maximum body depth (cm)	2.824	0.150	121.5-221.7	239
Depth at vent (cm)	10.160	0.073	121.5-221.7	239
Length of pectoral fin (cm)	0.703	0.211	121.5-221.7	279
Length of pelvic fin (cm)	12.171	0.274	115.1-203.0	529
Snout to mandible length (cm)	16.382	0.099	133.2-203.0	196
Snout to eye length (cm)	24.707	0.207	156.0-203.0	34
Dorsal fin height (cm)	8.292	0.202	115.1-203.0	559
Length of maxillary (cm)	9.910	0.110	115.1-203.0	553

Table 8.—Regression of morphometric character on eye-fork length (cm) for sailfish from the eastern Pacific. Weight-length relation is based on log transformed data (log $Y = a + b \log X$); all other relations are based on untransformed data ($Y = a + bX$). (* = 5% significance level; ** = 1% significance level).

Character	Male					Female				
			Range					Range		
	a	*b*	*X*	*Y*	*N*	*a*	*b*	*X*	*Y*	*N*
Buena Vista										
Weight (kg)	−4.825	2.829	133.4-196.5	13.4-47.5	28	−4.291	2.601	146.3-203.0	20.4-54.1	70
Maximum depth (cm)	2.163	0.156**	160.9-182.9	27.8-31.3	5	14.000**	0.092**	161.5-203.0	28.6-35.0	24
Depth at vent (cm)	−11.300	0.194	160.9-182.9	19.8-26.9	5	15.743**	0.043	161.5-203.0	20.3-26.4	24
Length of pectoral fin (cm)	7.181	0.174**	133.4-196.5	27.0-44.5	21	6.997	0.181**	146.3-203.0	29.8-47.4	49
Length of pelvic fin (cm)	17.612	0.248**	152.1-182.5	54.9-64.7	8	17.844	0.239**	147.2-203.0	52.0-70.0	24
Snout to mandible length (cm)	9.092	0.131**	160.9-182.9	30.5-33.3	5	4.060	0.167*	166.0-203.0	28.0-41.3	19
Snout to eye length (cm)	—	—	—	—	—	−72.145	0.692**	187.5-203.0	56.5-68.0	4
Dorsal fin height (cm)	10.713	0.178**	133.4-196.5	30.5-50.6	22	16.723**	0.151**	146.3-203.0	37.3-51.4	46
Length of maxillary (cm)	10.609**	0.103**	133.4-196.5	23.4-32.0	21	8.903**	0.116**	146.3-203.0	23.8-32.1	46
Number of dorsal fin rays	6.316**	0.002	133.4-196.5	6-7	22	−5.446**	0.008	146.3-193.4	6-7	35
Number of anal fin rays	5.190**	0.009	133.4-196.5	6-8	21	6.350**	0.001	146.3-193.4	6-7	35
Mazatlán										
Weight (kg)	−4.291	2.594	115.1-193.5	11.7-47.2	339	−4.020	2.479	123.1-221.7	9.9-50.6	365
Maximum depth (cm)	−0.443	0.168**	121.5-190.0	19.4-34.5	77	4.196	0.141**	133.2-221.4	20.4-39.1	133
Depth at vent (cm)	8.144**	0.086**	121.5-190.0	18.2-33.9	77	10.246**	0.073**	133.2-221.7	17.9-26.8	133
Length of pectoral fin (cm)	−8.092	0.259**	121.5-190.0	20.4-43.3	77	3.954	0.192**	133.2-221.7	26.8-45.9	132
Length of pelvic fin (cm)	11.830**	0.275**	115.1-193.5	37.9-67.7	263	12.156**	0.275**	123.1-195.8	44.9-71.6	234
Snout to mandible length (cm)	14.063	0.110*	135.6-190.0	21.4-41.2	63	22.401**	0.066*	133.2-194.1	25.4-41.1	109
Snout to eye length (cm)	27.064	0.180	167.3-184.4	49.5-64.3	8	17.135	0.260**	156.0-187.1	56.0-71.0	22
Dorsal fin height (cm)	5.539	0.217**	115.1-193.5	25.5-52.4	263	11.965**	0.184**	123.1-195.8	29.1-62.8	228
Length of maxillary (cm)	8.746**	0.116**	115.1-193.5	21.1-39.1	260	12.196**	0.097**	123.1-195.8	20.8-32.3	226
Number of dorsal fin rays	7.243*	0.003	149.2-181.6	6-7	12	3.175	0.019	142.1-191.4	6-7	11
Number of anal fin rays	4.083	0.015	149.2-181.6	6-7	12	4.110	0.014	142.1-191.4	5-7	11

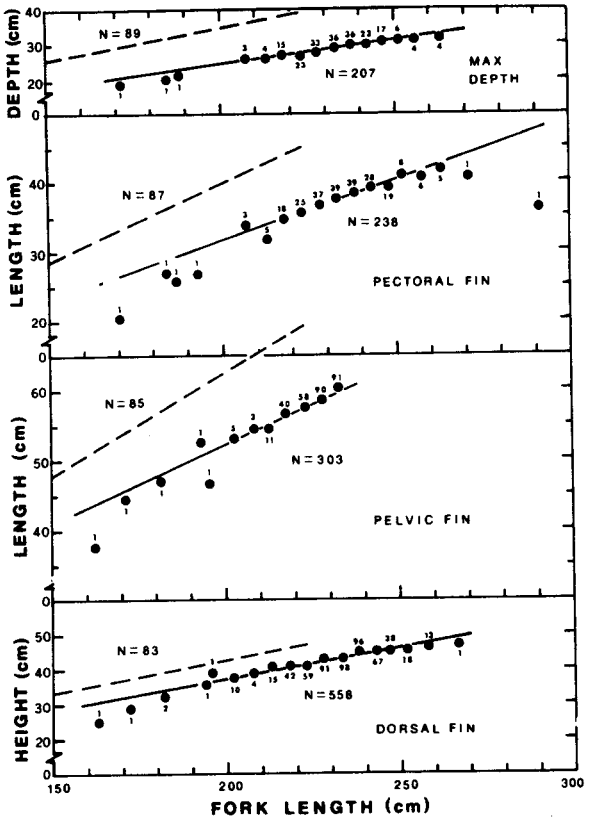

Figure 4.—Comparison of regressions of morphometric characters on fork length of sailfish from the Atlantic (dashed line) and the eastern North Pacific (solid line). Numbers indicate sample sizes for points.

Buena Vista (Table 1). At both sampling locations the sizes of sailfish were quite similar, although the females averaged 179 cm long and the males 168 cm long (Fig. 2). Between locations the size differences are statistically significant only for females.

Location and Sex Differences

Analysis of covariance was used to test whether for each sex the regressions (Table 8) were significantly different between locations (Table 6). Because there was no trend in the results, we assumed that there were no location differences and pooled the data from the two locations. We then used analysis of covariance to test whether there were differences between sexes. Only weight-length and dorsal fin height-length relations proved to be significantly different between sexes. Females were heavier for a given length than males, and females under about 160 cm long had a taller dorsal fin than males (Fig. 3). For fish larger than 160 cm long, the males had a taller dorsal fin. However, there is considerable overlap in the data for males and females, and probably the difference between sexes would disappear if a larger sample of fish were analyzed. Regressions based on the pooled data are shown in Table 7.

Comparison with Atlantic Sailfish

Morrow and Harbo (1969) analyzed meristic and morphometric measurements of sailfish from several locations in the Atlantic and Pacific Oceans. They found that the characters were similar for fish from both oceans and they therefore concluded that specimens from the two oceans belong to the same species. We used Morrow and Harbo's data from the Atlantic for comparison with our data, which provides a larger sample from the eastern Pacific

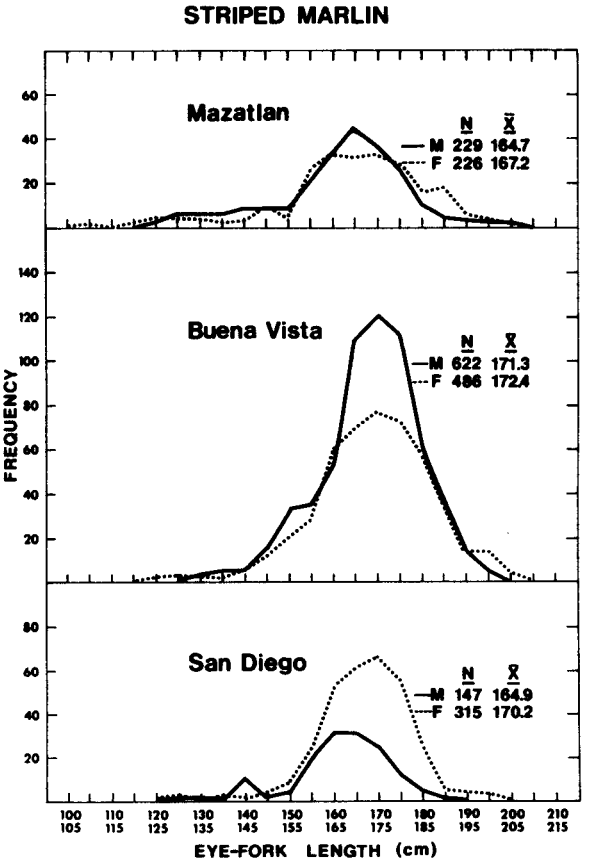

Figure 5.—Length frequency of striped marlin sampled in this study.

Table 9.—Regression of morphometric character on eye-fork length (cm) for striped marlin from the eastern Pacific. Weight-length relation is based on log transformed data ($\log Y = a + b \log X$); all other relations are based on untransformed data ($Y = a + bX$). (* = 5% significance level; ** = 1% significance level).

Character	Male					Female				
			Range					Range		
	a	*b*	*X*	*Y*	*N*	*a*	*b*	*X*	*Y*	*N*
Buena Vista										
Weight (kg)	−5.294	3.126	119.6-202.0	13.1-91.4	601	−5.420	3.183	125.0-215.1	16.9-101.3	472
Maximum depth (cm)	2.463*	0.178**	123.1-202.0	22.1-39.5	321	1.206	0.187**	125.0-215.1	22.9- 40.6	246
Depth at vent (cm)	−3.250*	0.173**	123.1-202.0	16.4-39.3	301	−1.618	0.165**	125.0-215.1	17.5- 37.8	232
Length of pectoral fin (cm)	2.557	0.242**	123.1-202.0	27.3-52.5	368	−2.124	0.273**	125.0-215.1	29.4- 59.0	303
Length of pelvic fin (cm)	41.864**	−0.041*	119.6-199.5	22.7-43.5	273	34.995**	0.006	126.9-201.4	7.5- 45.1	202
Snout to mandible length (cm)	13.376**	0.099**	123.1-202.0	15.6-41.0	280	14.324**	0.095**	125.0-215.1	22.0- 39.5	207
Snout to eye length (cm)	16.502**	0.260**	131.4-189.0	47.0-69.4	81	15.136**	0.267**	125.0-197.5	45.0- 73.0	64
Dorsal fin height (cm)	10.176**	0.171**	119.6-199.5	26.9-46.0	316	7.829	0.188	128.1-201.4	31.0- 47.2	246
Length of maxillary (cm)	5.369**	0.167**	119.6-199.5	22.9-41.3	311	5.054	0.170**	126.9-201.4	24.5- 46.2	248
Number of dorsal fin rays	6.527**	−0.003	131.0-195.2	5-7	101	5.438**	0.003	126.9-201.4	5-7	108
Number of anal fin rays	5.949	−0.001	131.0-195.2	5-7	91	5.228**	0.004	126.9-201.4	5-7	105
Mazatlán										
Weight (kg)	−5.183	3.064	120.4-202.6	15.8-73.5	227	−5.119	3.034	110.0-204.5	10.3- 86.5	222
Maximum depth (cm)	−5.508**	0.218**	124.0-200.0	20.1-36.3	104	−1.341	0.193**	116.8-204.5	22.4- 41.2	76
Depth at vent (cm)	−0.902	0.154**	124.0-200.0	16.0-29.0	104	0.588	0.144**	116.8-204.5	14.6- 32.3	76
Length of pectoral fin (cm)	−8.151**	0.302**	124.0-200.0	28.7-49.8	106	2.858	0.239**	116.8-204.5	24.0- 52.1	83
Length of pelvic fin (cm)	37.680**	0.010	120.4-202.6	21.5-44.1	118	30.045**	0.041	110.0-197.0	15.6- 45.2	136
Snout to mandible length (cm)	13.427**	0.095**	124.5-191.6	22.0-36.8	73	16.211**	0.079**	116.8-197.0	20.0- 35.2	51
Snout to eye length (cm)	7.285	0.306**	124.0-191.6	37.7-69.4	27	29.190**	0.179**	129.0-204.5	49.0- 68.0	24
Dorsal fin height (cm)	12.680**	0.155**	126.4-202.6	27.8-47.5	50	8.693*	0.180**	118.9-197.0	28.4- 48.4	61
Length of maxillary (cm)	7.467**	0.153**	120.4-202.6	22.4-38.0	107	8.380**	0.150**	118.9-197.0	25.1- 39.5	127
Number of dorsal fin rays	—	—	—	—	—	6	0	157.3-190.1	6	7
Number of anal fin rays	−1.244	0.040	170.7-180.2	5-6	3	6	0	157.3-190.1	6	7
San Diego										
Weight (kg)	−4.060	2.608	129.4-191.0	29.5-83.9	147	−4.574	2.843	127.0-203.3	22.2-103.4	313
Maximum depth (cm)	12.928**	0.120**	129.4-191.0	28.4-41.2	141	8.457**	0.153**	135.0-201.5	27.1- 46.9	284
Depth at vent (cm)	5.599**	0.129**	129.4-191.0	21.3-32.3	141	1.449	0.157**	135.0-201.5	21.0- 35.1	283
Length of pectoral fin (cm)	14.110**	0.164**	129.4-191.0	32.2-50.1	146	7.695**	0.209**	127.0-203.3	27.9- 53.2	315
Length of pelvic fin (cm)	—	—	—	—	—	—	—	—	—	—
Snout to mandible length (cm)	17.549**	0.075**	133.7-191.0	24.8-37.4	129	15.066**	0.095**	135.0-201.5	24.3- 39.8	267
Snout to eye length (cm)	27.478**	0.196**	133.7-182.7	50.4-68.1	66	19.784**	0.248**	135.0-192.5	50.6- 75.0	152
Dorsal fin height (cm)	1.095	0.207	158.2-183.0	33.6-41.0	5	2.771*	0.202**	127.0-203.3	27.5- 44.0	29
Length of maxillary (cm)	10.295	0.133	158.2-183.0	30.7-36.6	5	10.191**	0.144**	127.0-203.3	27.6- 40.1	28
Number of dorsal fin rays	—	—	—	—	—	6.272**	−0.002	127.0-203.3	5-7	31
Number of anal fin rays	8.775	−0.017	158.2-183.0	5-6	5	6.270**	−0.001	127.0-203.3	6-7	31

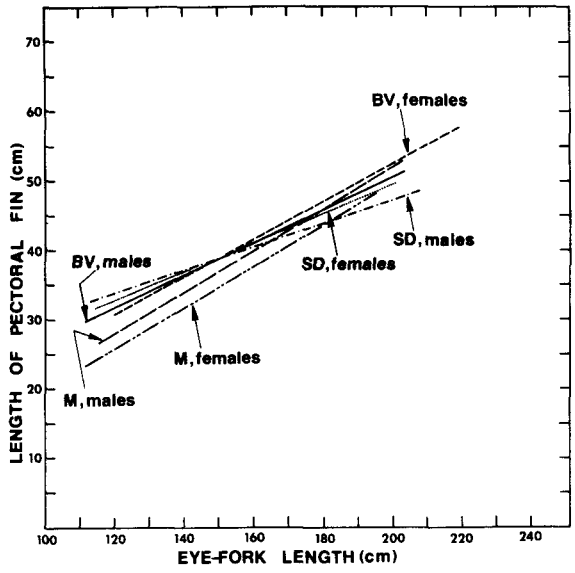

Figure 6.—Plotted regressions of pectoral fin length on eye-fork length of striped marlin by sex and locality. BV=Buena Vista, M=Mazatlán, SD=San Diego.

than was available to them (they had data on nine specimens from the coast of Peru). Body length for the Atlantic specimens was measured as fork length. In order to have the data comparable to our data, it was necessary to convert eye-fork length of our samples to fork length with the appropriate equation in Table 3.

Maximum body depth, length of pectoral fin, length of pelvic fin, and dorsal fin height were examined (Fig. 4). Analysis of covariance was not used to test for significant differences in these characters between Atlantic and eastern Pacific sailfish because of the complication of one set of data being based on converted lengths. However, we feel from visual inspection that there is sufficient separation between the regressions (especially the first three) to suggest that eastern Pacific sailfish differ significantly from Atlantic sailfish in morphometric measurements. More information based on a wide range of sizes of fish from the Atlantic and Pacific is needed for a more complete comparision.

STRIPED MARLIN

The eastern Pacific is apparently a center of high concentration of striped marlin. Considerable numbers of fish are annually caught by the commercial longline fleet and by sportsmen. In 1967-70 we sampled 2,020 specimens from the sport landings at Buena Vista, Mazatlán, and San Diego. Length frequencies of the samples are shown in Figure 5.

Location and Sex Differences

Regressions of each meristic and morphometric character as a function of eye-fork length are shown in Table 9. Analysis of covariance was performed on the data, sexes separate, to determine whether the regressions were significantly different among locations. The results (Table 6) indicated that the regressions were different. Analysis of covariance was also used to determine whether the relations were significantly different between sexes, within location. The results (Table 10) for this series of tests showed either no differences or inconsistency from one location to another, except for the relation of length of pectoral fin on eye-fork length. For this relation, significant differences between sexes were found at all three locations. The regressions are shown in Figure 6. On the basis of these results, except for pectoral fin length, it was assumed that there is no significant difference between sexes, but a significant difference among locations. The data were pooled accordingly and regressions recalculated (Table 11).

A plot of weight on eye-fork length for striped marlin from each location (Fig. 7) shows that for a given length, striped marlin from San Diego were heavier than fish from Buena Vista or Mazatlán.

Table 10.—Results of covariance analysis of morphometric character of striped marlin as a function of eye-fork length to test whether the relations are significantly different between sexes. (n.s. = not significant; * = 5% significance level; ** = 1% significance level).

Character	Buena Vista	Mazatlán	San Diego
Weight	n.s.	n.s.	n.s.
Maximum body depth	*	n.s.	**
Depth at vent	n.s.	n.s.	*
Length of pectoral fin	**	*	**
Length of pelvic fin	**	n.s.	—
Snout to mandible length	n.s.	n.s.	**
Snout to eye length	n.s.	n.s.	n.s.
Dorsal fin height	**	n.s.	n.s.
Length of maxillary	n.s.	n.s.	*

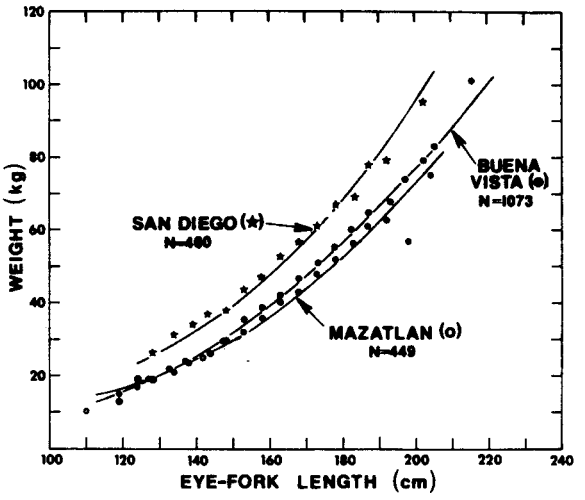

Figure 7.—Weight as a function of eye-fork length of striped marlin from the eastern North Pacific.

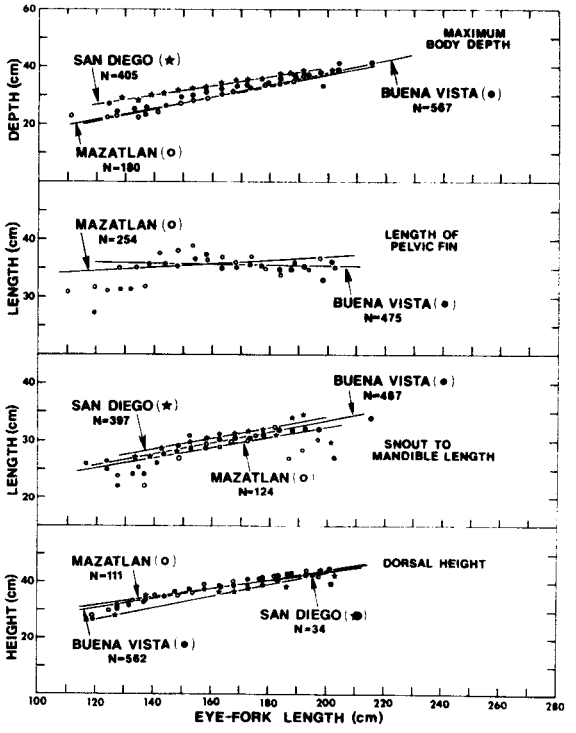

Figure 8.—Morphometric characters as a function of eye-fork length of striped marlin from the eastern North Pacific.

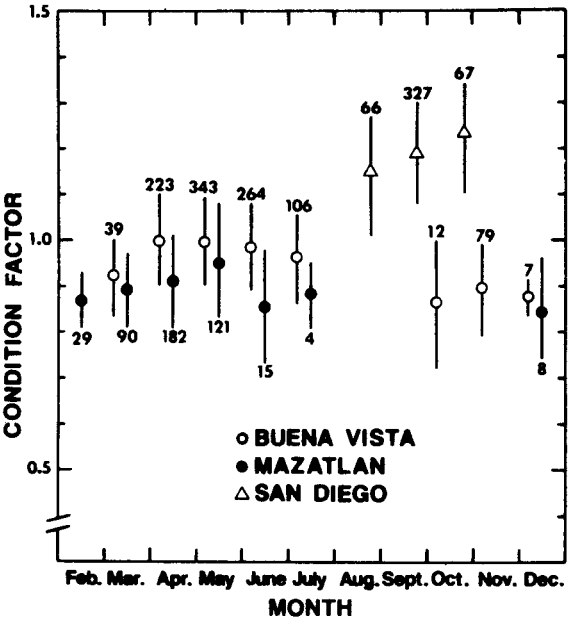

Figure 9.—Average condition factor by month for striped marlin from the eastern North Pacific. One standard deviation on each side of the mean and the sample size shown. Condition factor=$W \times 10^5/L^3$ where W=whole fish weight in kg and L=eye-fork length in cm.

This difference is also evident in the relation of maximum body depth on eye-fork length (Fig. 8); body depth is larger in San Diego fish. It was uncertain whether this difference was a seasonal phenomenon since San Diego samples were obtained only from August to October, months of the year when there were almost no samples from Buena Vista or Mazatlán (Table 1). Plots of condition factors by month for the three areas (Fig. 9), however, show that seasonal variation is unlikely to be the cause.

Some other relations are shown in Figure 8. They indicate that there is much overlap in the data. It thus appears that characters, other than perhaps weight, maximum body depth, and pectoral fin length, are not different enough to be useful as single diagnostic characters for separating striped marlin into location of capture.

Comparison with Other Studies

Kamimura and Honma (1958) examined five morphometric characters of striped marlin caught in the Pacific by the Japanese longline fleet. They dis-

Table 11.—Regression of morphometric character on eye-fork length (cm) for pooled (sexes) samples of striped marlin from the eastern Pacific. Weight-length relation is based on log transformed data ($\log Y = a + b \log X$); all other relations are based on untransformed data ($Y = a + bX$).

Character	a	b	Range of length (cm)	N
Buena Vista				
Weight (kg)	−5.356	3.154	119.6-215.1	1073
Maximum body depth (cm)	1.578	0.184	123.1-215.1	567
Depth at vent (cm)	−2.669	0.170	123.1-215.1	533
Length of pectoral fin (cm)	−0.333	0.261	123.1-215.1	671
Length of pelvic fin (cm)	38.797	−0.020	119.6-201.4	475
Snout to mandible length (cm)	13.656	0.098	123.1-215.1	487
Snout to eye length (cm)	15.750	0.264	125.0-197.5	145
Dorsal fin height (cm)	9.171	0.178	119.6-201.4	562
Length of maxillary (cm)	5.234	0.169	119.6-201.4	559
Mazatlán				
Weight (kg)	−5.143	3.045	110.0-204.5	449
Maximum body depth (cm)	−3.642	0.207	116.8-204.5	180
Depth at vent (cm)	−0.038	0.148	118.8-204.5	180
Length of pectoral fin (cm)	−3.225	0.274	116.8-204.5	189
Length of pelvic fin (cm)	33.018	0.021	110.0-202.6	254
Snout to mandible length (cm)	14.556	0.088	116.8-197.0	124
Snout to eye length (cm)	19.061	0.236	124.0-204.5	51
Dorsal fin height (cm)	10.526	0.169	118.9-202.6	111
Length of maxillary (cm)	7.840	0.152	118.9-202.6	234
San Diego				
Weight (kg)	−4.439	2.781	127.0-203.3	460
Maximum body depth (cm)	8.400	0.152	129.4-201.5	425
Depth at vent (cm)	2.245	0.152	129.4-201.5	424
Length of pectoral fin (cm)	8.262	0.204	127.0-203.3	461
Snout to mandible length (cm)	14.363	0.097	133.7-201.5	397
Snout to eye length (cm)	21.302	0.238	133.7-192.5	218
Dorsal fin height (cm)	2.534	0.203	127.0-203.3	34
Length of maxillary (cm)	10.017	0.144	127.0-203.3	33

covered that the length of the pectoral fin was significantly longer in fish caught in the South Pacific (lat. 18°-25°S) than in the North Pacific (lat. 30°-35°N). In Figure 10, we have superimposed Kamimura and Honma's equations on a band that represents the equations calculated from our data on pectoral fin lengths. The North Pacific sample is most similar to ours, which is from about lat. 20°-35°N. The South Pacific fish, on the other hand, have definitely longer pectoral fins than our samples, but only for fish less than about 210 cm long.

Data on length of pectoral fin for nine striped marlin (for which eye-fork length was available) reported by Royce (1957) from the central and eastern equatorial Pacific are also plotted in Figure 10. The plots indicate that either there is mixing in the central Pacific of the presumed South and North Pacific stocks of striped marlin or Kamimura and Honma's samples did not adequately reflect the degree of variability in length of pectoral fin of fish from the North and South Pacific.

SUMMARY AND CONCLUDING REMARKS

Morphometric data for 57 female blue marlin are presented; comparisons with fish from other areas were omitted due to the small sample size. For sailfish it appears that characters such as maximum

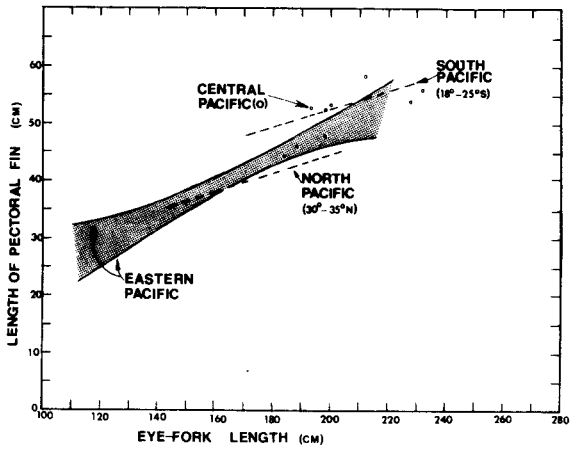

Figure 10.—Comparison of pectoral fin of striped marlin stocks in the Pacific Ocean. The shaded band represents the area in which our data for the relations of eastern Pacific fish fall. Data for South and North Pacific fish are from Kamimura and Honma (1958). Data for central Pacific fish are from Royce (1957).

body depth, length of pectoral fin, length of pelvic fin, and dorsal fin height are considerably shorter on the average in fish from the eastern Pacific than in fish of identical size from the Atlantic Ocean. For striped marlin, our results indicated that weight and maximum body depth can be used to separate striped marlin stocks within our study area. For example, a 180 cm long striped marlin landed off San Diego is, on the average, about 19% heavier and has a maximum body depth 3% greater than a striped marlin of identical size landed off Buena Vista or Mazatlán. Also, striped marlin from the northeastern Pacific (lat. 20°-35°N) and South Pacific (lat. 18°-25°S), apparently can be separated on the basis of length of pectoral fin.

We conclude, therefore, that there are morphometric characters that can be used to separate, with some degree of accuracy, sailfish and striped marlin stocks. We suggest, however, that more powerful techniques, such as multivariate analyses, be used in future attempts of stock identification of eastern Pacific billfishes.

ACKNOWLEDGMENT

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