LENGTH-WEIGHT RELATIONS FOR FIVE EASTERN TROPICAL ATLANTIC SCOMBRIDS

This paper presents an analysis of fork lengths and body weights of five species of scombrids measured from landings at several ports on the west coast of Africa during 1967 and 1968: yellowfin tuna, *Thunnus albacares*; skipjack tuna, *Katsuwonus pelamis*; bigeye tuna, *T. obesus*; little tunny, *Euthynnus alletteratus*; and frigate mackerel, *Auxis* sp. Sampling of landings took place between 26 September 1967 and 22 May 1968 at the ports of Dakar, Senegal; Freetown, Sierra Leone; Abidjan, Ivory Coast; Tema, Ghana; and Benguela, Angola. Samples were also taken from fish stored at a cannery in Mocamedes, Angola. Fish were captured by bait (pole-and-line) boats, purse seiners, and combinations of both. Only whole fish were used for this study, landed in fresh, iced, frozen, and indeterminate conditions. Fork lengths were usually measured to the nearest centimeter. Weight was usually measured to the nearest 0.1 kg. All nonmetric data were converted to centimeters and kilograms.

The allometric length-weight equation is used to describe the relation between length and weight:

$$W = aL^{b}e \qquad (1)$$

where W = weight in kilograms
L = length in centimeters
a and b = estimated parameters.
e = error term

Results

Estimates of a and b were made for each sample. A wide range in values of a and b occurred for the same species and, in some cases, for the identical sample category (category is defined as port, gear, and method of preservation of fish), that was at first alarming. However, examination of plots of the estimated curves revealed only minor differences among samples at sizes included in the samples. It was also noted that estimates of a are closely related to estimates of b (Figure 1), again indicating the fish at the same length weighed approximately the same.

Analyses of covariance were used to test the statistical significance of differences among length-weight relations within a sample category. F-tests for the significance of differences of the estimates of both parameters a and b[1] were made instead of F-tests for each parameter as is usually done, because I believe that the close relation between estimates of a and b demonstrates that no additional useful information would be obtained by making the separate tests. F-values for differences among samples within a category were almost always significant for all species with more than one sample. As mentioned previously, plots of the fitted lines showed only minor differences between samples for sizes found in both samples.

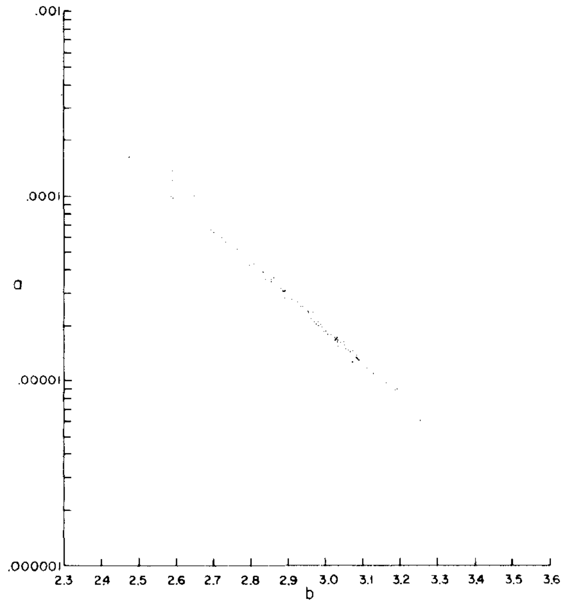

FIGURE 1.—Relation between estimates of a and b of the allometric length-weight relation from samples of Atlantic yellowfin tuna.

Analyses of covariance were also used to test whether differences among sample categories were present. Nested models were used because the significant differences among lines within sample categories indicated that samples rather than individual fish should be used to estimate the error term of the model. Only data for yellowfin and skipjack tunas were examined because there were insufficient data for the other species. Table 1 presents the analysis of covariance of differences among all sample categories for yellowfin tuna. The F-value for difference among sample categories is statistically significant at the

[1] H_0; $a_i = a_j$ and $b_i = b_j$ where a_i = value of a from ith sample, b_i = value of b from ith sample and $i \neq j$.

TABLE 1.—Analysis of covariance of length-weight relation of yellowfin tuna.

Source	Degrees of freedom	Sum of squares	Mean square	F-value
Categories	24	1.321851	0.0550771	3.4115*
Samples within categories	128	2.066484	0.0161444	6.7748*
Residual	3,485	8.304751	0.0023830	
Total	3,637	11.693086		

*Significant at 1% level.

TABLE 2.—Analysis of covariance of length-weight relation of skipjack tuna.

Source	Degrees of freedom	Sum of squares	Mean square	F-value
Categories	20	2.560355	0.128018	5.0189*
Sample within categories	84	2.142605	0.0255072	7.3030*
Residuals	2,448	8.550099	0.0034927	
Total	2,552	13.253059		

*Significant at 1% level.

1% level. The F-value for difference among samples within a category is greater than that among categories. Table 2 presents results for skipjack tuna. Again the F-value is statistically significant at the 1% level, and the F-value among samples within categories is greater than that among categories. The reasons for the differences are not known. Although there was considerable overlap of sizes of fish encountered among the samples, size composition of the samples did differ and may have contributed to the differences in the length-weight relations because Equation (1) may not perfectly describe the length-weight relation for fish of all sizes. Figure 2 illustrates the variability found in the length-weight relations of yellowfin tuna. The variability among the relations increases with size as Equation (1) assumes.

Statistics of length-weight relations from combined samples for each species are presented in Table 3.

Discussion

Length-weight relations for yellowfin tuna from the Pacific (Chatwin, 1959), from the Atlantic (Poinsard, 1969), and from the present study are illustrated in Figure 3. There is reasonably close agreement among the three curves at small sizes. The Pacific yellowfin tuna appear to be heavier at larger sizes than fish from the Atlantic, but Chatwin did not include fish larger than 115 cm in his work. Two relations are used in Poinsard's work. A relation between fork length and predorsal length and one between predorsal length and weight. Poinsard tried several functions to explain the relations. In the case of fork length and predorsal length he chose the following function:

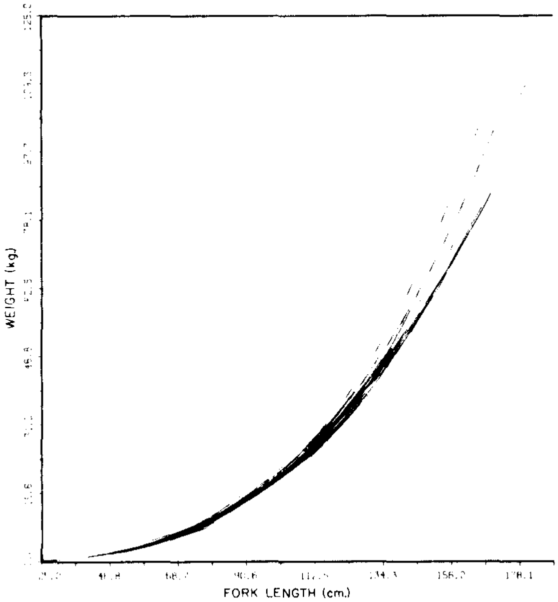

FIGURE 2.—Estimated length-weight relations for all sample categories of Atlantic yellowfin tuna.

$$LD_1 = -16.58774 + 4.66294 \sqrt{L} \qquad (2)$$

where LD_1 = predorsal length

He based his choice on the fact that Equation (2) resulted in the highest value of r (correlation coefficient) of the several functions he tried. The value of r when Equation (2) was used was 0.99402, but when a power relation similar to Equation (1) was used the value of r (0.99386) is only slightly less. Figure 3 is based on the square root relation between fork length and predorsal length as recommended by Poinsard. It is very difficult, however, to interpret differences between r values when different dependent variables are used: predorsal length in one case, log (predorsal length) in the other. Equation (2) seems a poor choice because it implies that $LD_1 \leq 0$ when $L \leq 12.65$. The estimated weights using Poinsard's logarithmic relation are illustrated in Figure 4—the two curves are very similar for all lengths. This similarity indicates that the results of Poinsard and of this study are accurate estimates of the average length-weight relationship of eastern tropical Atlantic yellowfin tuna.

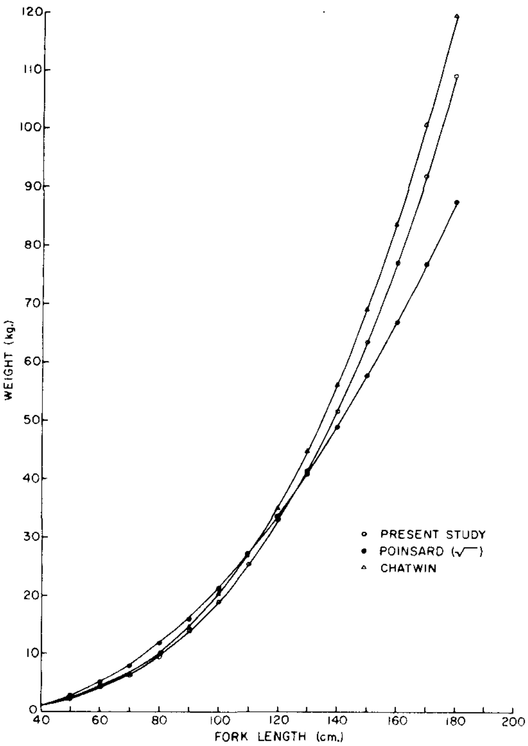

FIGURE 3.—Estimated length-weight relations for yellowfin tuna (Chatwin, 1959; Poinsard, 1969). Poinsard's relation based on square root relation between predorsal and fork length. Chatwin's study did not include fish longer than 115 cm.

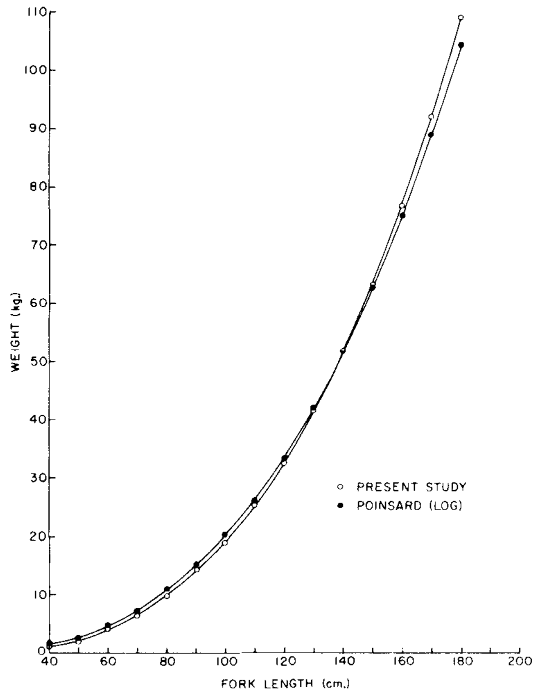

FIGURE 4.—Estimated length-weight relations for yellowfin tuna (Poinsard, 1969). Poinsard's relation based on logarithmic relation between predorsal and fork length.

Since it is desirable to utilize the function which was estimated directly from either predorsal or fork length data, the results of Poinsard should be used when predorsal lengths are measured and the results of the present study should be used when fork lengths are measured.

Beardsley[2] (pers. commun.) allowed me to examine length and weight measurements of more than 2,000 yellowfin tuna captured in the western Atlantic. These data are very similar to the data used in the present study.

Beardsley and Richards (1970) estimated the parameters of Equation (1) for skipjack tuna and little tunny captured off the coast of Florida. Their estimate of the equation for skipjack tuna is

$$W = 0.00007927L^{3.22750}$$

and for little tunny is

$$W = 0.0000181L^{3.02838}$$

These results are quite similar to the results of the present study. The range in fork length of skipjack tuna in their study was 38-78 cm and for little tunny 34-87 cm. Since these size ranges exceed the ranges encountered in this study their results should be used. Chatwin (1959) obtained similar results for skipjack tuna from the Pacific, and Batts (1972) for skipjack tuna from the western Atlantic.

The number of frigate mackerel used in this study is too small to produce very meaningful results. The results are presented here only to make them available to other workers.

Several authors including Pienaar and Thomson (1969) have questioned the validity of assumptions made about the error term in Equation (1). Also, the logarithmic transformation results in weight being slightly underestimated even if Equation (1) is correct. Results of simulations by Fox (1973)[3] indicate that b is unbiased and an unbiased estimate of a is given by

$$a' = a \exp \left(\tfrac{1}{2} (s^2_{W \cdot L})\right) \qquad (3)$$

[2]Southeast Fisheries Center, National Marine Fisheries Service, NOAA, Miami, FL 33149.

[3]Fox, W. W., Jr. 1973. Some simple biologically useful functions and multiplicative error regression models. Unpubl. manuscr. Southwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, La Jolla, CA 92037.

TABLE 3.—Statistics of length-weight relations for all data used in study.

Species	Number of fish	a	[1]b	Mean square error	Minimum fork length (cm)	Maximum fork length (cm)
Yellowfin tuna	3,689	0.000021804	2.96989	0.003265	40	170
Skipjack tuna	2,554	0.000005611	3.31497	0.005193	36	64
Bigeye tuna	190	0.000012494	3.12082	0.003405	41	132
Little tunny	753	0.000012000	3.08340	0.006935	41	57
Auxis sp.	50	0.000000280	4.13514	0.030871	30	45

[1]All estimates are significantly different than 0 at the 1% level.

where a' = unbiased estimate of a
$(s^2_{W \cdot L})$ = mean square error about the regression line.

The mean square errors for this study are low (Table 3). Thus the bias should be negligible. The results of this study were examined by comparing average weights of yellowfin used in the study against predicted weights. Differences were negligible as expected.

The significant differences found among samples and categories indicate that the variance of estimated numbers of fish caught, estimated from length frequency samples, could be reduced by a sophisticated sampling scheme which is stratified by category if not sample. Obviously it would be simpler to weigh fish from each sample rather than measure lengths, if one desired to stratify by sample. Logistics rule out this possibility. A formal cost-benefit analysis of the effort required to develop an adequate sampling scheme stratified by category probably would rule out this scheme. The significant differences among samples do point out the desirability of obtaining large numbers of samples rather than large sample sizes in further study of length-weight relations.

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ELECTRICAL THRESHOLD RESPONSE OF SOME GULF OF MEXICO FISHES

Threshold voltage is the minimum electrical potential to which an animal responds (Vibert, 1967). Usually threshold measurements are inexpensive and easy to obtain, and they provide guidelines for designing electrical fishing systems. Bary (1956) and Kessler (1965) showed that threshold voltage varied according to water temperature, size of animal, and width of the pulse. Earlier workers clearly demonstrated that threshold voltages are affected by the position of the animal in the electrical field. Klima (1968) documented experimentally the mathematical relationship between the angle of the animal in the