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LENGTH AND WEIGHT PARAMETERS OF WESTERN ATLANTIC BLUEFIN TUNA (THUNNUS THYNNUS)

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SUMMARY

Atlantic bluefin tuna (Thunnus thynnus) were collected during 1974 through 1977 from the east coast of the United States, from Florida to Maine, and from the Bahamas. Geometric mean regressions were calculated from straight fork length-round weight, round weight-dressed weight and straight fork length-curved fork length for each sex by month. On the average, males were larger than female bluefin tuna.

RESUME

Des thons rouges de l'Atlantique (*Thunnus thynnus*) ont été prélevés de 1974 à 1977 sur la côte est des Etats-Unis, du Maine à la Floride, et aux Bahamas. Des régressions de la moyenne géométrique ont été calculées par sexe et par mois à partir de: longueur fourche projetée/poids vif, poids vif/poids du poissons manipulé et longueur fourche projetée/longueur fourche suivant la courbure du poisson. Dans l'ensemble les mâles se sont avérés plus grands que les femelles.

RESUMEN

Se recogió atún rojo del Atlántico (Thunnus thynnus) durante 1974 a 1977, en la costa Este de los Estados Unidos, desde Florida a Maine y también en las Bahamas. Se calcularon las medias geométricas de regresiones, partiendo de las correlaciones longitud horquilla-peso en vivo, peso en vivo-peso manipulado, longitud horquilla - longitud horquilla curvada, para cada sexo por mes. Por regla general, los machos eran más grandes que las hembras.

INTRODUCTION

The Atlantic bluefin tuna, Thunnus thynnus, is seasonally distributed over most of the North Atlantic Ocean from Newfoundland to Brazil and from Norway to the Canary Islands (Gibbs and Collette, 1967). There has been a great reduction in the Atlantic-wide catch (including Mediterranean) from 38,500 metric tons in 1964 to 12,500 metric tons in 1973 (Miyake et al., 1974). Because of this, a number of studies have been made and are being continued in order to understand the reason for this decline (Parks, 1977; Shingu and Hisada, 1977).

Length-weight, length-to-length and weight-to-weight relationships are necessary in population analyses for converting one measurement to another. In this paper we present the relationships of the following: round weight-straight fork length, round weight-dressed weight, and straight fork length-curved fork length.

During our review of bluefin tuna literature, we found a lack of information on size relationships. Mather and Schuck (1960) used a length-weight curve based on 778 bluefin from Cape Cod to estimate length. They did not indicate, however, when these fish were collected. They did not give a regression formula for the length-weight relationship, but they did present a straight length-curved length relationship based on 185 measurements of both sexes fitted by inspection. Rodriquez-Roda (1964, 1971) collected 793 bluefin tuna and then determined the length-weight relationship. Of these, 467 bluefin (pre-spawning) were entering the Mediterranean during May and June and 326 bluefin (post-spawning) were leaving the Mediterranean during July and August 1956, 1958, 1959, and 1961. Butler (1971) determined the length-weight relationship by the standard least squares regression method for 237 giant bluefin tuna caught during July through September 1966 from Conception Bay, Newfoundland. His length-weight relationship was based on both sexes combined. Mather et al. (1974) presented regression equations for converting from weight to length for bluefin from Newfoundland, Libya, and the Bahamas from data supplied by the Fisheries Research Board of Canada, the International Council for the Exploration of the Sea, and the Woods Hole Oceanographic Institution. They also presented an equation for converting dressed weight to round weight. The method of determining the equations, the sample sizes, and time period sampled were not presented. Coan (1976) gave a length, weight, and age conversion table for bluefin of both sexes. He converted length to weight based on a length-weight regression given in Sakagawa and Coan (1974), who had in turn, obtained this regression from Frank J. Mather, Woods Hole Oceanographic Institution. Unfortunately, there was no mention of sample size, location or date.

METHODS

Bluefin tuna length and weight measurements were collected during 1974 through 1977 from various landing points and processing plants along the east coast of the United States from Florida to Maine, and from the Bahamas. These fish had been caught by purse seine, rod and reel, hand-line, and harpoon. Straight fork length (cm) was measured by caliper, and curved fork length (cm) was measured along the body contour by tape. Round weight (total weight of fish when caught) and dressed weight (head, viscera, and tail removed) were recorded in pounds and later converted to kilograms.

Ricker (1973) showed that the geometric mean (GM) regression can be used for a majority of biological situations as a reasonable and consistent estimate of the functional slope because most of the variability is natural.

Ricker's GM regression was calculated for the logarithmic transformations of the length-weight relationship for 956 males and 716 females from May through October. The GM regression was also calculated for the relationship between round weight and dressed weight for 435 males and 250 females taken from July through September, and for the straight fork length to curved fork length relationship for 374 males and 232 females taken from July through October.

The general equation for the GM regression as given by Ricker is: $Y = u + vX$, with variables X and Y, and u is the Y-axis intercept, where $u = \bar{Y} - v\bar{X}$, v is the slope, and $v = [\Sigma y^2/\Sigma x^2]$, where $y_i = Y_i - \bar{Y}$ and $x_i = X_i - \bar{X}$. The limits on all Σ are $i = 1, \ldots, n$.

The standard error of the slope was computed for each regression equation using the following equation from Ricker (1973):

$S_v = [S^2_{yx} / \Sigma x^2]^{\frac{1}{2}}$, where S_v is the standard error of the slope, S^2_{yx} is the mean square or variance of the observations from the regression line in the vertical direction.

RESULTS AND DISCUSSION

The average size of males for each month for which samples were available was consistently greater than the average size of females (Table 1), which agrees with Rivas (1976). A recent study (Baglin, 1979) has shown the opposite to be true for white marlin from the western North Atlantic. The difference in average size of bluefin may be due to faster growth of males or higher mortality of females and should be considered in future growth studies of bluefin tuna.

Based on the classification system of Rivas (1979), fish sampled for each month, except June, mainly consisted of giant bluefin tuna (greater than 180 cm straight fork length and 130 kg round weight). Based on previous growth work by Mather and Schuck (1960), these fish are probably age 9 and older. Fish sampled during June consisted of 37 small bluefin tuna (less than 130 cm straight fork length or less than 45 kg round weight) most likely age 4 or younger, 48 medium bluefin tuna (130 to 180 cm straight fork length and 45 to 130 kg round weight) probably ages 5 through 8, and 7 giant bluefin tuna.

The GM regressions for straight fork length-round weight (log transformations), round weight-dressed weight, and straight fork length-curved fork length are presented by month and sex in Table 2, and the data points for July through September are plotted with regression lines in Figures 1, 2, 3. The data points show that the GM regression model fits the data reasonably well for the size ranges studied. Extrapolation beyond the size range of observations may yield erroneous predictions. The slope in the straight fork length-round weight relationship is greater for each month for the females, and there was great variation between months (Table 2). There was no consistent trend in the value of the slope for the other two relationships.

Since analysis of covariance is based on the least squares regression and the assumptions underlying this type of regression (Snedecor and Cochran, 1967), we were unable to perform this test using the GM regressions. However, some inferences can be drawn from examination of the data presented in Figures 1, 2, 3. For a given length, males were heavier than females during July. During August and September, females at the upper end of the size range were heavier for a given length, while males were heavier for a given length at the lower end of the size range (Figure 1). There appears to be little difference in the round weight-dressed weight relationship for each sex during the summer months (Figure 2). The relationship between straight fork length and curved fork length also does not appear to vary by month or sex (Figure 3).

The use of logarithmic transformations may lead to bias in data estimates (Pienaar and Thomson, 1969; Beauchamp and Olson, 1973; Lenarz, 1974). However, since the mean square errors for the round weight-straight fork length logarithmic transformations are low (Table 2), the bias in these data estimates was found to be minimal (1 percent or less).

Previous publications have not included standard errors or confidence limits or statistics necessary for their estimation. Therefore, comparisons with our data could not be made. In order to compare results from our study with studies by other authors, weighted averages for both sexes (from July through September) of 254 cm straight fork length, 316 kg round weight, 257 kg dressed weight, and 271 cm curved fork length, which we calculated, were substituted into the appropriate equations.

The following authors have presented equations for estimated weight from length. The estimated weight in kilograms for a 254 cm bluefin in 294 (Butler, 1971), 306 (Sakagawa and Coan, 1974), and 311 and 287 for pre-spawning and post-spawning fish (Rodriguez-Roda, 1964, 1971). Our estimates ranged from 303 to 329 kg for males and 288 to 332 kg for females. Therefore, the estimates based on these previous studies fall at the lower end of the range of values that we found.

Mather et al. (1974) estimated length from weight. Using their equations, a 316 kg bluefin from Newfoundland is 253 cm and one from the Bahamas is 265 cm. There appears to be a typographical error in the equations these authors gave for bluefin from Libya. Our estimates of straight fork length range from 250 to 258 cm for males and 250 to 262 cm for females. Therefore, their estimate for Newfoundland bluefin falls within our range of values. Their estimated length for the Bahamas is slightly greater than the largest estimated length which we calculated for a 316 kg fish.

A direct comparison between the relationship found for round weight and dressed weight can be made here with Mather et al. (1974). The estimated round weight from a 257 kg dressed weight fish using the Mather et al. (1974) equation is 326 kg. We found a range in estimating round weight for bluefin of 257 kg, with the head, guts, and tail removed, to be from 319 to 329 kg for males and 320 to 326 kg for females. Therefore, using their equation, the estimate falls at the upper end of the range of our values.

The estimated straight fork length in centimeters for a 271 cm curved fork length bluefin is 260 (Mather and Schuck, 1960). Our estimates ranged from 256 to 261 cm for males and 252 to 260 cm for females. Therefore, using their equation, the estimate falls at the upper end of the range of values we found, using the equation derived from our data.

This study shows there are some differences in the length and weight relationships, which should be taken into account when estimates are made. Sex and time of capture may affect the length and weight relationships of bluefin tuna. These factors should be considered when size estimates are to be made.

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ADDENDUM

Since our work was completed, another paper has appeared which considered aspects of length and weight parameters - M.L. Parrack and P.L. Phares. 1979. Aspects of the growth of Atlantic bluefin tuna determined from mark recapture. International Commission for Conservation of Atlantic Tunas. Collective Volume of Scientific Papers 8 (SCRS-1978):356-366.

LITERATURE CITED

Baglin, R.E., Jr. 1979. Sex composition, length-weight relationship, and reproduction of the white marlin, Tetrapturus albidus, in the western north Atlantic Ocean. Fish. Bull., U.S. 76:919-926.

Beauchamp, J.J., and J.S. Olson. 1973. Corrections for bias in regression estimates after logarithmic transformation. Ecology 54(4): 1403-1407.

Butler, M. 1971. Biological investigation on aspects of the life history of the bluefin tuna 1970-1971. Newfoundland and Labrador Tourist Development Office St. Johns, NFLD. 169 pp.

Coan, A. 1976. Length, weight and age conversion tables for Atlantic tunas. International Commission for the Conservation of Atlantic Tunas. Collective Vol. Sci. Pap. 5 (SCRS-1975):64-66.

Gibbs, R.H., Jr., and B.B. Collette. 1967. Comparative anatomy and systematics of the tunas, genus Thunnus. U.S. Fish Wildl. Serv., Fish Bull. 66(1):65-130.

Lenarz, W.H. 1974. Length-weight relations for five eastern tropical Atlantic scombrids. Fish. Bull., U.S. 72:848-851.

Mather, F.J. III, and H.A. Schuck. 1960. Growth of bluefin tuna of the western North Atlantic, U.S. Fish and Wildl. Serv., Fish Bull. 61(179):39-52.

Mather, F.J., J.M. Mason, and A.C. Jones. 1974. Distribution, fisheries and life history data relevant to identification of Atlantic bluefin tuna stocks. International Commission for the Conservation of Atlantic Tunas. Collective Vol. Sci. Pap. 2 (SCRS-1973):234-258.

Miyake, M.P., A.A. DeBoisset, S. Manning (compilers). 1974. International Commission for the Conservation of Atlantic Tunas. Stat. Bull., Vol. 5. Unnumbered pages.

Parks, W.W. 1977. Cohort and equilibrium yield-per-recruit analyses for the Atlantic bluefin tuna fisheries system accounting two system configurations and two natural mortality models. International Commission for the Conservation of Atlantic Tunas. Collective Vol. Sci. Pap. 6(SCRS-1976):385-401.

Pienaar L.V. and J.A. Thomson. 1969. Allometric weight-length regression model. J. Fish. Res. Board Can. 26:123-131.

Ricker, W.E. 1973. Linear regressions in fishery research. J. Fish. Res. Board Can. 30:409-434.

Rivas, L.R. 1976. Variation in sex ratio, size differences between sexes, change in size and age composition in western North Atlantic giant bluefin tuna (Thunnus thynnus). International Commission for the Conservation of Atlantic Tunas. Collective Vol. Sci. Pap. 5(SCRS-1975):297-301.

Rivas, L.R. 1979. Proposed terminology for size groups of the north Atlantic bluefin tuna Thunnus thynnus. International Commission for the Conservation of Atlantic Tunas. Collective Vol. Sci. Pap. 8 (SCRS-1978):441-446.

Rodriguez-Roda, J. 1964. Biología del Atún, Thunnus thynnus (L.), de la costa sudatlantica de España Invest. Pesq. 25:33-146.

Rodriguez-Roda, J. 1971. Investigations of tuna (Thunnus thynnus) in Spain, In: Report for biennial period 1970-71, Part II. p. 110-113. International Commission for the Conservation of Atlantic Tunas.

Sakagawa, G.T. and A.L. Coan. 1974. A review of some aspects of the bluefin tuna Thunnus thynnus thynnus fisheries of the Atlantic Ocean. International Commission for the conservation of Atlantic Tunas. Collective Vol. Sci. Pap. 2(SCRS-1973):259-313.

Shingu, C. and K. Hisada. 1977. A review of the Japanese Atlantic longline fishery for bluefin tuna and the consideration of the present status of the stocks. International Commission for the Conservation of Atlantic Tunas. Collective Vol. Sci. Pap. 6(SCRS-1976):366-384.

Snedecor, G.W., and W.G. Cochran. 1967. Statistical methods. The Iowa State Univ. Press, Ames, Iowa. 593 pp.

Table 1. Regression statistics for $\log_{10}$ round weight (Y) - $\log_{10}$ straight fork length (X), round weight (Y) - dressed weight (X), and straight fork length (Y) - curved fork length (X) of western Atlantic bluefin tuna arranged by month and sex.

			X Variable		Y Variable				
Month	Sex	Number	$\bar{X}$	Range	$\bar{Y}$	Range	Σx^2	Σy^2	Σxy
			Log_{10} Round Weight (kg) - Log_{10} Straight Fork Length (cm)						
May	M	11	2.40290	2.35-2.45	2.47586	2.33-2.61	0.009589	0.086213	0.026884
	F	18	2.38846	2.34-2.42	2.42449	2.29-2.51	0.006472	0.059004	0.016904
June	M	47	2.16243	1.88-2.43	1.77932	0.95-2.57	0.923085	7.750190	2.667680
	F	45	2.14145	2.00-2.40	1.69770	1.26-2.44	0.292153	2.481660	0.842531
July	M	270	2.41717	2.33-2.47	2.51465	2.31-2.64	0.131426	0.913775	0.259607
	F	173	2.40268	2.34-2.46	2.45371	2.20-2.58	0.074311	0.580540	0.134541
Aug.	M	351	2.41601	2.30-2.47	2.52444	2.22-2.66	0.176307	1.273320	0.351716
	F	197	2.40203	2.33-2.45	2.48524	2.24-2.61	0.069948	0.612912	0.143785
Sept.	M	260	2.39598	2.30-2.47	2.49144	2.20-2.65	0.217477	1.796580	0.539930
	F	269	2.38661	2.27-2.46	2.46685	2.13-2.63	0.179302	1.568010	0.451339
Oct.	M	17	2.40201	2.32-2.44	2.51456	2.31-2.60	0.013892	0.152024	0.033966
	F	14	2.37857	2.29-2.41	2.46059	2.10-2.57	0.014270	0.205530	0.053480
			Round Weight (kg) - Dressed Weight (kg)						
July	M	127	260	170-352	326	209-440	156,556	271,772	194,718
	F	72	230	180-302	291	225-381	40,222	62,966	46,475
Aug.	M	217	268	164-354	343	216-432	247,359	393,910	281,164
	F	123	246	179-302	315	232-404	88,491	141,996	102,635
Sept.	M	91	268	129-352	333	163-433	132,510	229,401	167,550
	F	55	246	136-313	305	170-411	56,568	100,267	71,994
			Straight Fork Length (cm) - Curved Fork Length (cm)						
July	M	146	275	223-309	263	214-292	24,052	22,338	19,266
	F	98	266	226-288	254	216-277	17,351	15,034	14,403
Aug.	M	176	276	231-305	264	210-289	29,750	29,110	24,867
	F	98	267	246-300	256	234-282	10,662	9,333	8,414
Sept.	M	38	271	219-297	261	210-285	10,569	10,137	10,077
	F	23	265	226-285	255	216-274	3,962	4,033	3,960
Oct.	M	14	269	220-291	255	211-278	3,388	2,849	3,016
	F	13	252	201-274	240	193-257	5,167	3,775	4,299

Table 2. Geometric mean regression equations, mean square error, and standard error of the slope for the relationships between round weight (Y) and straight fork length (X), round weight (Y) and dressed weight (X) and straight fork length (Y) and curved fork length (X) for western Atlantic bluefin tuna by month and sex.

Month	Sex	Geometric mean regression equation	Mean square error	Standard error of slope
		$\log_{10}$ Round Weight (kg) - $\log_{10}$ Straight Fork Length (cm)		
May				
	M	log Y = -4.7290 + 2.9984 log X	0.001204	0.354413
	F	log Y = -4.7872 + 3.0194 log X	0.000928	0.378746
June				
	M	log Y = -4.4865 + 2.8976 log X	0.000904	0.031303
	F	log Y = -4.5436 + 2.9145 log X	0.001207	0.064280
July				
	M	log Y = -3.8590 + 2.6368 log X	0.001496	0.106693
	F	log Y = -4.2619 + 2.7950 log X	0.001970	0.162836
Aug				
	M	log Y = -3.9684 + 2.6874 log X	0.001638	0.096387
	F	log Y = -4.6251 + 2.9601 log X	0.001627	0.152530
Sept				
	M	log Y = -4.3951 + 2.8742 log X	0.001767	0.090158
	F	log Y = -4.5908 + 2.9572 log X	0.001617	0.094978
Oct				
	M	log Y = -5.4315 + 3.3081 log X	0.004598	0.575339
	F	log Y = -6.5664 + 3.7951 log X	0.000425	0.172638
		Round Weight (kg) - Dressed Weight (kg)		
July				
	M	Y = -15.7721 + 1.3176 X	236.726	0.038884
	F	Y = 2.5246 + 1.2512 X	132.346	0.057362
Aug				
	M	Y = 4.7280 + 1.2619 X	345.674	0.037381
	F	Y = 2.6043 + 1.2667 X	189.729	0.046303
Sept				
	M	Y = -19.3282 + 1.3157 X	197.130	0.038569
	F	Y = -22.5036 + 1.3314 X	163.004	0.053679

Table 2. (con't.)

Month	Sex	Geometric mean regression equation	Mean square error	Standard error of slope
		Straight Fork Length (cm) - Curved Fork Length (cm)		
July				
	M	Y = -2.6949 + 0.9637 X	47.9623	0.044654
	F	Y = 5.9914 + 0.9308 X	32.0687	0.042990
Aug				
	M	Y = -9.0715 + 0.9892 X	47.8487	0.040103
	F	Y = 5.6874 + 0.9356 X	28.0594	0.051299
Sept				
	M	Y = -4.4196 + 0.9793 X	14.7228	0.037321
	F	Y = -12.8862 + 1.0089 X	3.5113	0.029769
Oct				
	M	Y = 7.9580 + 0.9170 X	13.6974	0.063583
	F	Y = 23.8264 + 0.8547 X	17.9918	0.059007

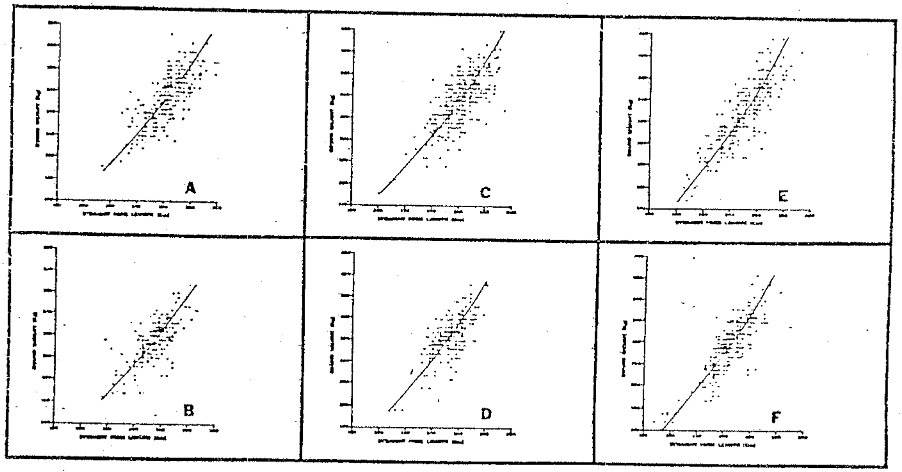

Figure 1 - Relationship between round weight and straight fork length for western Atlantic bluefin tuna, 1974-77: A.- July males; B.- July females; C.- August males; D.- August females; E.- September males; and F.- September females.

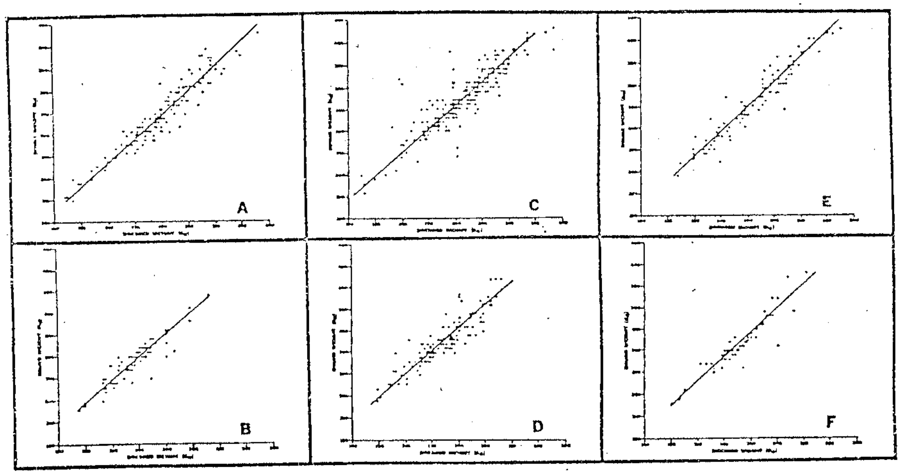

Figure 2 - Relationship between round weight and dressed weight for western Atlantic bluefin tuna, 1974-1977: A.- July males; B.- July females; C.- August males; D.- August females; E.- September males; and F.- September females.

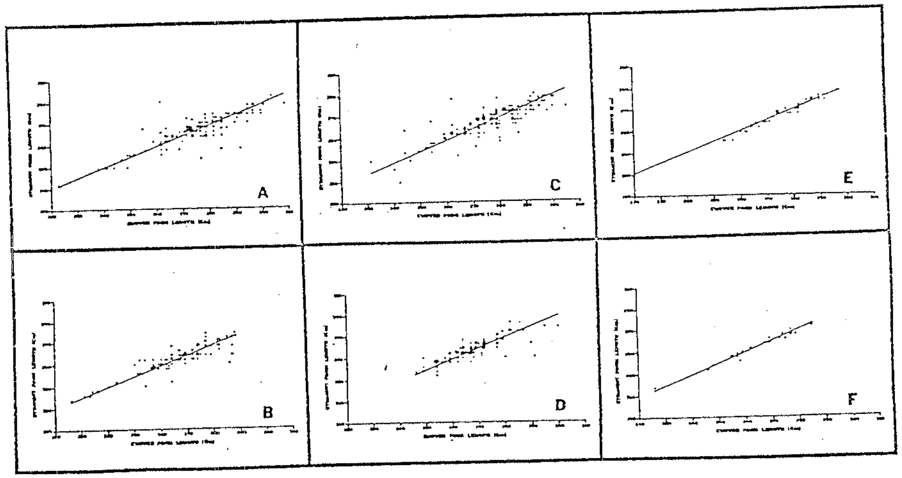

Figure 3 - Relationship between straight fork length and curved fork length for western Atlantic bluefin tuna, 1974-1977: A.- July males; B.- July females; C.- August males; D.- August females; E.- September males; and F.- September females.