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LENGTH-WEIGHT RELATIONS FOR BIGEYE TUNA CAPTURED IN THE EASTERN ATLANTIC OCEAN

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SUMMARY

Parameters of the allometric length-weight relations were estimated for bigeye tuna (*Thunnus obesus*) captured in the eastern Atlantic Ocean. Data were stratified by area, gear and season of capture and by sex. Data were for captures between 30°N and 20°S latitudes and between 30°W longitude and the coast of Africa; data were from all quarters of the year. Data were from 1957 to 1979 with data from 1971 to 1974 comprising 75% of the total. Data were for captures by surface and longline gear.

Analyses of covariance were used to test for differences in length-weight relations related to area, gear, season and sex. Results are tentative due to the lack of data for many strata.

Results were mixed for difference related to area. For those strata for which data are available, there were no significant differences in length-weight relations related to gear of capture. Results showed significant differences related to season capture. Results were mixed for differences related to sex. For some strata differences were significant, for some they were not significant.

RESUME

On a estimé les paramètres de la relation allométrique poids-longueur pour le thon obèse (*Thunnus obesus*) capturé dans l'Atlantique oriental. Les données ont été stratifiées par zone, engin et saison de capture et par sexe. L'information concerne des prises effectuées entre 30ºN et 20ºS de latitude et entre 30ºW de longitude et la côte africaine; elle porte sur tous les trimestres de l'année. Les données couvrent les années 1957 à 1979, celles pour 1971 à 1974 représentant 75% du total. Il s'agit de prises effectuées par des engins de surface et de palangre.

Les analyses de la covariance ont servi à déceler les différences que présente la relation poids-longueur selon la zone, l'engin, la saison et le sexe. Les résultats sont provisoires du fait du manque de données pour de nombreuses strates.

Les résultats sont ambigus pour ce qui est des différences suivant les secteurs. En ce qui concerne les strates pour lesquelles on dispose de données, la relation poids-longueur ne présente pas de différence sensible selon l'engin utilisé pour la capture. Les résultats varient sensiblement suivant la saison. Ils sont peu clairs pour ce qui est des différences liées au sexe. Les différences sont accusées dans certaines strates, et peu marquées dans certaines autres.

RESUMEN

Se calcularon los parámetros de la relación alométrica talla/peso para el patudo *(Thunnus obesus)* capturado en el Atlántico Este. Se estratificaron datos por zona, arte, temporada de captura y sexo. Se confeccionaron: datos sobre capturas efectuadas entre las latitudes 30°N y 20°S, y entre la longitud 30°W y la costa africana; datos sobre todos los trimestre del año; datos desde 1957 a 1979, con datos obtenidos desde 1971 a 1974, comprendiendo el 75% del total; datos sobre capturas por artes de superficie y palangre.

Se utilizaron análisis de covarianzas para comprobar las diferencias en la relación talla-peso en cuanto a la zona, arte, temporada y sexo. Los resultados deben considerarse provisionales, debido a la insuficiencia de datos en varios de los estratos tratados.

Se combinaron los resultados obtenidos, con el fin de salvar las diferencias existentes en relación con la zona. En aquellos estratos para los cuales se disponía de datos, no surgieron discrepancias importantes en la relación talla-peso, en cuanto al arte de pesca. Los resultados arrojaron diferencias notables respecto a la temporada de captura. En cuanto al sexo, se combinaron los resultados obtenidos. En algunos estratos, las diferencias fueron significativas; en otros, no lo fueron tanto.

INTRODUCTION

The relationship between fork lengths and body weights of bigeye tuna, Thunnus obesus, captured in the eastern Atlantic Ocean, was examined. Data were from catches made between 1957 and 1979 by surface (pole-and-line, some purse seine and a small amount of transshipped pole-and-line) and longline gear.

Data were stratified into categories (area, gear and season (quarter) of capture and sex). The allometric length-weight relation was fit to data in each strata:

$W = aL^{b}e$ where

W = whole weight in kilograms (1)

L = fork length in centimeters

a and b = estimated parameters, and

e = error term.

The log transformation of the relation was fitted to log transformed data using least-squares linear regression. Analyses of covariance were used to test for differences in the fitted relations related to sex, season, gear and area of capture.

METHODS AND MATERIALS

Lengths and weights of 3,240 bigeye tuna were recorded. Data were for fish captured between 30° N and 20° S latitudes and between 25° W longitude and the coast of Africa. Data were for captures during the period 1957-1979; data from 1971-1974 comprised 75% of the total. Data represented captures from all quarters of the year.

Data were stratified by four areas (Figure 1). The separation of areas 3 and 4 was motivated by the hypothesis of ICCAT scientists working on this species that there may be a north-south separation of bigeye tuna stocks in the vicinity of the equator (ICCAT, 1981). Whereas the opinion of that group was that the separation was probably at 5° N latitude, inspection of the evidence in ICCAT (1981) suggests 5° S latitude as more likely and the more southern separation was used in this study.

The data were collected by a number of different agencies to different degrees of completeness (Figure 2). Area of capture was available to at least large blocks for all observations and to actual latitude and longitude for many observations. Gear of capture was available for all observations. Data for northern and north central areas (areas 1 and 2) were for captures by surface gear only. Data for the south central area (area 3) were for captures by both surface and longline gear; those for the southern area (area 4) were for longline captures only.

Quarter of capture was available for observations in areas 3 and 4; quarter was not available for observations in areas 1 and 2. The sex of measured fish was available for bigeye tuna taken by longline gear (some of observations in area 3; all observations in area 4). Sex was not available for fish taken by surface gear (observations in areas 1 and 2; some of the observations in area 3).

The precision of the measurements varied, however all lengths were at least to the nearest cm, all weights at least to the nearest kg. Certain of the lengths were recorded as predorsal fork length. These were converted to fork length using relations derived from analysis of data collected by Champagnat and Pianet (1974)[1].

The transformed length-weight relation

$$\ln W = \ln a + b \ln L + \ln e \qquad (2)$$

was fit to log transformed data for each data stratum (e.g., area, gear and season of capture and sex) by least-squares linear regression. Analyses of covariance were performed to test for differences in fitted log-length log-weight relations related to sex or to quarter, gear or area of capture, for each comparison, data were stratified to eliminate possible confounding of effects (e.g., to test for differences related to sex in area 4, for gear 2 in quarter 1, the relation for area 4, gear 2 quarter 1, male was compared to the relation for area 4, gear 2, quarter 1, female).

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[1] For predorsal fork length (LD) less than 21 cm, total fork length FL = 2.685 x LD + 7.168. For LD between 21 and 50 cm, FL = 3.737 x LD - 15.98.

A certain number of outlying observations in each data subset were judged to be errors in recording and were eliminated. Following discussions in Chatwin (1959) and in Draper and Smith (1966) candidate observations for elimination were those whose residuals were three standard deviations from the mean of the residuals from the line fitted to the data subset. The decision to keep or eliminate an observation was made by comparison with the relation fit to the entire data set. This procedure resulted in the elimination of an average of 3% of the observations.[2]

RESULTS

Differences Related to Sex

Data to test for differences in length-weight relations related to sex were available only for bigeye tuna taken by longline gear in south central and southern areas (areas 3 and 4; Figure 2).

Results of analyses were mixed. For bigeye tuna taken in area 3, by longline, in the first quarter, length-weight relations for males and females were significantly different (comparison 1; Table 1). However, relations for fish taken in this area and by this gear in the fourth quarter were not significantly different (comparison 2). The situation was similar in area 4. Length-weight relations for males and females taken in the first quarter were significantly different while relations for those taken in the third and fourth quarters were not (comparisons 3, 4 and 5).

[2]FORTRAN computer programs to create subfiles of the main data file as well as programs to identify outlying data points and analysis of covariance and linear regression programs tailored to this study were written by the principal author.

For comparison 1, fitted length-weight relations for the two sexes differed significantly in both regression coefficient and adjusted mean (Table 1). Ranges of lengths of fish measured were essentially the same and sample sizes were adequate (Table 2). However, the fit of the relation was poor for males and not significant for females (relation 7; Table 3). This suggests that the data are not a representative sample of lengths and weights of females in this stratum. To a lesser extent the data for males are also non-representative. The validity of the discovered difference in relations is therefore questionable.

For comparison 3, fitted relations differed significantly in regression coefficient but not in adjusted mean (Table 1). Ranges of lengths were comparable and sample sizes were adequate (Table 2). In addition, relations fit the data well suggesting that the data are representative of the populations (relations 8 and 9; Table 3). The differences are therefore real.

Of the five strata for which data were available significant differences in fitted relations could be convincingly shown for only one comparison. For another, the data appeared unrepresentative, therefore inadequate to prove or disprove significant difference. Thus the results are inconclusive; sex-specific length-weight relations for bigeye tuna taken in eastern Atlantic longline fisheries may or may not, in general, be significantly different. Due to a lack of data (only 5 of the 17 area-gear-season strata had sex of measured fish recorded (Figure 2)) no conclusions can be drawn concerning the significance of sex-specific relations for fish taken by surface gear or in areas 1 and 2.

Differences Related to Season of Capture

Data to test for differences in length-weight relations for Atlantic bigeye tuna related to season of capture were available only for south central and southern areas (areas 3 and 4; Figure 2).

For these strata, results indicated that relations are significantly different for bigeye tuna taken in different quarters (comparisons 6-10; Table 4).

Differences in fitted length-weight relations for fish taken in the four quarters differed only in regression coefficient in the four comparisons involving bigeye tuna captured by longline (comparisons 7-10; Table 4). Ranges of fish measured were substantially the same and sample sizes adequate (Table 2). The great disparity in sample sizes for compared strata in comparisons 9 and 10, while a concern, probably does not bias the results. For comparisons 9 and 10 the fit of the relations to the data was good (relations 8-12; Table 3). There is no reason to suspect that the data do not adequately represent the populations. The differences therefore are real. For comparisons 7 and 8 some of the relations did not fit the data and suggested differences are not shown (relation 7).

Differences in fitted relations for bigeye tuna taken in the four quarters for the single surface fishery stratum differed in both regression coefficient and adjusted mean (comparison 6). Ranges of lengths of fish measured were comparable and sample sizes were adequate (Table 2). However sex of measured fish was not recorded and the effects of season of capture and sex on possible differences in the length-weight relation were confounded. Notwithstanding the very significant F-value for this comparison, this compounding makes it impossible to state for certain that the season effect in surface fisheries is significant.

Results were mixed. For two comparisons of fitted length-weight relations for bigeye tuna taken by longline gear in areas 3 and 4, differences related to season of capture were significant. For two comparisons the data were insufficient to show difference. The significance of season-related differences for fish taken in surface fisheries while suggested is not shown.

Differences Related to Gear of Capture

Only data for the south central area (area 3) included catches of bigeye tuna by both surface and longline gears (Figure 2). The two gears overlapped temporally only in the first and fourth quarters. Results of earlier comparisons indicated a significant difference in length-weight relations related to sex for bigeye tuna taken by longline gear in the first quarter. Sex data were not available for fish taken by surface gear in the first quarter. Since it was not possible to avoid confounding the effects of sex and gear of capture, the test for differences related to gear in the first quarter was not performed. Results of comparisons indicated no significant difference due to sex for bigeye tuna taken by longline gear in the fourth quarter.

Results indicated significant differences for fish taken by surface gears due to either of the confounded effects of sex or season. To get a preliminary idea of possible differences in length-weight relation due to gear of capture it was assumed that the significant effects of sex and season were due to season and not sex.

Results indicated no significant difference in length-weight relations due to gear of capture (Table 5). The lack of data makes the result for strata compared inconclusive. The result cannot be generalized to other strata.

Differences Related to Area of Capture

Complete data (i.e. area, gear, quarter and sex) was available only for bigeye tuna taken by longline gear in south central and southern areas (areas 3 and 4). Previous comparisons indicated significant differences due to season for fish taken in both areas; tests for area differences accounted for quarter of capture. Results indicated significant differences due to sex for fish taken in the first quarter; tests for area - differences accounted for sex. Results indicated no significant differences due to sex in the fourth quarter in either area , and tests for area differences did not account sex.

Results of analyses were mixed. Length-weight relations for bigeye tuna taken on longline and in the first quarter were significantly different between areas 3 and 4 (comparisons 12 and 13; Table 6). Relations were not significantly different between areas 3 and 4 for the longline, fourth quarter case (comparison 14).

For comparisons 12 and 13, differences in fitted relations were due to signficant differences in regression coefficient; adjusted means were not significantly different. Ranges of fish measured were essentially the same and sample sizes were adequate (Table 2). However, area-3 relations did not fit the data well, suggesting the data did not adequately represent lengths and weights of fish in these strata. The discovered statistical differences are therefore questionable.

It was not possible to test for differences in the length-weight relation due to area of capture for areas 1, 2, and 3. Only surface gear is common to these areas. There was a significant difference in relations due to either season of capture or sex in area 3. Neither season nor sex data was available for observations in areas 1 and 2 and analysis was not possible.

Differences in fitted length-weight relations related to area of capture, while suggested for bigeye tuna taken by longline in quarter 1, cannot be conclusively shown with the data available. No information is available to test for possible differences for fish taken by surface fisheries.

Statistics of length-weight relations for the appropriate strata and for all strata pooled are listed in Table 3. The relations are plotted in Figure 3. Relations 1 and 2 for bigeye tuna taken by surface gear in areas 1 and 2 and included. Neither sex nor season of capture data was available for these fish and these relations are tentative.

Except for relation 7, which is of questionable relaibility due to low sample size and high variance, the curves for the specific strata are similar to both pooled data curves over the range of most observations (87% of all observations were of fish between 80 and 170 cm fork length). So except for very large fish, one of the pooled relations would probably serve sufficiently well for all strata. The pooled curves for which outlying, and presumably erroneous, observations were deleted appears more representative of the set of individual curves than does the pooled curve for which no observations were deleted and may be the preferred relation. Evidence that the deletions were probably justified is the 95% reduction in mean square error resulting from the deletion of the 1.6% of the observations comprised of the outliers. If deletion is considered inappropriate, the pooled, non-deleted relation is preferred.

DISCUSSION

Fitted length-weight relations for bigeye tuna taken in eastern Atlantic fisheries from three previous studies and the two pooled-data relations of this study are illustrated in Figure 4. Statistics of the relations are listed in Table 7. Over the range of common lengths there is good agreement between the pooled, non-deleted relation of this study and Chur and Krasovskaya's (1980) two southern-area relations (relations 1, 7 and 8; Figure 4). There is also good agreement between this study's pooled-deleted relation, the Lenarz (1974) and Chur and Krasovskaya's northern area relations (relations 2, 3, 5 and 6; Figure 4). The relation of ICCAT (1981) falls midway between these two groups (relation 4).

Data to which three of Chur and Krasovskaya's relations were fit were for three areas in the Gulf of Guinea (relations 6, 7 and 8; Figure 4). The authors suggest that data from the area corresponding to relation 6 may be representative of lengths and weights of bigeye tuna taken north of the equator. Actually this area straddles the equator and overlaps the next area to the south. This more southerly area in turn overlaps the yet more southerly area. Differences in fitted length-weight relations noted by the authors as suggesting different stocks are of the same magnitude as differences between pooled, non-deleted and pooled-deleted relations of this study and may be more indicative of natural variability.

Pooled-deleted and pooled, non-deleted relations of this study are in close agreement with relations fitted in previous studies. They are in close agreement with stratum-specific relations fitted in this study. Until there are sufficient data to conclusively demonstrate significantly different area-, gear-, season- or sex-specific relations, these pooled relations can be assumed representative of the relation between length and weight of bigeye tuna taken in the eastern tropical Atlantic ocean.

The decision to use either the pooled-deleted or the pooled, non-deleted relation is subjective. As noted, the pooled-deleted relation appears consistent with slightly more of the relations of this and other studies suggesting that it may be the preferred relation. However, the evidence is inconclusive, and on balance the decision is perhaps better made on the basis of whether data deletion is appropriate.

The length-weight relation was fitted by least-squares regression of logarithmically transformed data. The validity of this procedure has been questioned by many researchers including Pienaar and Thomson (1969) and Ricker (1973). Beauchamp and Olson (1973) note that, in general, logarithmic transformation results in biased estimates. In particular, Lenarz (1974) notes that the length-weight relation fit by this procedure underestimates arithmetic mean weight. Both Beauchamp and Olson and Lenarz provide techniques to test the degree of bias. Applying the Lenarz procedure shows the average bias in parameters a estimated in this study to be 0.4%. Parameters b are unbiased. Thus the bias caused by the procedure is negligible.

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Table 1. Results of comparisons (analyses of covariance) to test for differences related to sex of measured fish in fitted length-weight relations for Atlantic bigeye tuna.

Comparison	Source (Area, Gear, Quarter)	Degrees of freedom	Sum of squares	Mean square	F-value
1	3 Longline 1				
	Inequality of slopes	1	4,849.948	4,849.948	12.980**[a]
	Residual	62	23,166.300	373.650	
	Inequality of adj. means	1	3,130.792	3,130.792	7.040**
	Residual	63	28,016.248	444.702	
2	3 Longline 4				
	Inequality of slopes	1	1.682	1.682	0.043
	Residual	89	3,504.178	39.373	
	Inequality of adj. means	1	45.284	45.284	1.162
	Residual	90	3,505.860	38.954	
3	4 Longline 1				
	Inequality of slopes	1	307.873	307.873	10.188**
	Residual	61	1,843.298	30.218	
	Inequality of adj. means	1	1.742	1.742	0.050
	Residual	62	2,151.171	34.696	
4	4 Longline 3				
	Inequality of slopes	1	53.300	53.300	1.261
	Residual	767	32,424.326	42.274	
	Inequality of adj. means	1	63.854	63.854	1.510
	Residual	768	32,477.626	42.289	
5	4 Longline 4				
	Inequality of slopes	1	20.023	20.023	0.547
	Residual	1,381	50,590.886	36.634	
	Inequality of adj: means	1	0.209	0.209	0.006
	Residual	1,382	50,610.909	36.622	

[a] The conventional indication of statistical significance is used: * = probability of F this high by chance is between 0.01 and 0.05; ** = probability is less than 0.01 (Snedecor and Cochran, 1967).

Table 2. Sample sizes and ranges of fork lengths of measured fish for data sets used in comparisons of fitted length-weight relations for Atlantic bigeye tuna.

Comparison	Area	Gear	Season	Sex	Sample size	Fork length range (cm)
1	3	Longline	1	M	34	101 -198
				F	32	92.5-198
2	3	Longline	4	M	46	75.2-165
				F	47	75.2-165
3	4	Longline	1	M	39	102 -175
				F	26	87.5-172
4	4	Longline	3	M	429	70 -187
				F	342	73 -177
5	4	Longline	4	M	758	67 -188
				F	627	81 -174
6	3	Surface	1	-[a]	23	59 - 85
			2	-[a]	78	43 -164
			3	-[a]	120	37 -101
			4	-[a]	45	38 -170
7	3	Longline	1	M	34	101 -198
			4		46	87.5-179
8	3	Longline	1	F	32	92.5-198
			4		47	75.2-165
9	4	Longline	1	M	39	102 -175
			3		429	70 -187
10	4	Longline	1	F	26	87.5-172
			3		342	73 -177
			4		627	81 -174
11	3	Surface	1	-[b]	23	59 - 85
		Longline			63	92.5-198
12	3	Longline	1	M	34	101 -198
	4				39	102 -175
13	3	Longline	1	F	32	92.5-198
	4				26	87.5-172
14	3	Longline	4	-	93	72.5-179
	4				1406	67 -188

[a] Data on sex of fish measured not available.

[b] Differences due to sex not significant so sex not accounted.

Table 3. Statistics of fitted length-weight relations for Atlantic bigeye tuna for significant strata and the pooled observations cases.

Relation	Area	Gear	Quarter	Sex	Number of fish	a[a]	b[a]	Mean square error[b]	Range of fork lengths cm
1	1	Surface	Combined[c]	Combined[d]	124	0.00004711	2.8277	0.0060	98 -210
2	2	Surface	Combined[c]	Combined[d]	47	0.00001694	3.0518	0.0008	44 - 82
3	3	Surface	1	Combined[d]	23	0.00002937	2.9351	0.0015	59 - 85
4	3	Surface	2	Combined[d]	78	0.00003213	2.9017	0.0022	43 -164
5	3	Surface	3	Combined[d]	120	0.00003703	2.8623	0.0074	37 -101
6	3	Surface	4	Combined[d]	45	0.00002162	2.9967	0.0040	36 -170
7	3	Longline	1	Male	34	0.002896	2.0137	0.0556	101 -198
	3	Longline	1	Female	32	Regression not significant			
8	4	Longline	1	Male	39	0.00004603	2.8288	0.0055	102 -175
9	4	Longline	1	Female	26	0.00002106	3.0078	0.0055	87.5-172
10	4	Longline	3	Combined[e]	771	0.00001667	3.0493	0.0035	70 -187
11	3,4 Combined[f]	Longline	4	Combined[e]	1,385	0.00001713	3.0480	0.0032	67 -188
12	Combined	Combined	Combined	Combined	3,240	0.00006684	2.7520	0.1509	37 -211.5
13[g]	Combined	Combined	Combined	Combined	3,186	0.00002396	2.9774	0.0076	37 -210

[a]Estimates are significant at the 0.001 level.

[b]Mean square deviation from regression of ln weight on ln length.

[c]No season of capture data available.

[d]No sex data available.

[e]Relations for separate sexes are not significantly different.

[f]Relations for separate areas are not significantly different.

[g]Curve 13 uses the same data set as curve 12 with outliers removed.

Table 4. Results of comparisons (analyses of covariance) to test for differences related to season of capture in fitted length-weight relations for Atlantic bigeye tuna.

Comparison	Area Gear Sex / Source	Degrees of freedom	Sum of squares	Mean square	F-value
6	3 Surface --[a]				
	Inequality of slopes	3	5,136.267	1,712.089	298.456**
	Residual	258	1,480.011	5.736	
	Inequality of adj. means	3	670.600	222.533	8.818**
	Residual	261	6,616.278	25.350	
7	3 Longline male				
	Inequality of slopes	1	1,104.556	1,104.556	11.690**
	Residual	76	7,181.341	94.491	
	Inequality of adj. means	1	6.604	6.604	0.061
	Residual	77	8,285.897	107.609	
8	3 Longline female				
	Inequality of slopes	1	9,499.709	9,499.709	36.558**
	Residual	75	19,489.137	259.855	
	Inequality of adj. means	1	556.342	556.342	1.459
	Residual	76	28,988.846	381.432	
9	4 Longline male				
	Inequality of slopes	2	2,219.373	1,109.687	26.894**
	Residual	1,220	50,388.452	41.261	
	Inequality of adj. means	2	64.566	32.283	0.751
	Residual	1,222	52,557.825	43.010	
10	4 Longline female				
	Inequality of slopes	2	808.289	404.145	17.253**
	Residual	989	23,166.773	23.424	
	Inequality of adj. means	2	1.745	0.873	0.036
	Residual	991	23,975.063	24.193	

[a]Data on sex not available.

Table 5. Results of comparisons (analyses of covariance) to test for differences related to gear of capture in fitted length-weight relations for Atlantic bigeye tuna.

Comparison	Source (Area / Quarter / Sex)	Degrees of freedom	Sum of squares	Mean square	F-value
11	3 / 1 / --[a]				
	Inequality of slopes	1	297.940	297.907	3.957
	Residual	82	6,173.278	75.284	
	Inequality of adj. means	1	230.375	230.375	2.954
	Residual	83	6,471.182	77.966	

[a]Sex data unavailable for surface gear.

Table 6. Results of comparisons (analyses of covariance) to test for differences related to area of capture in fitted length-weight relations for Atlantic bigeye tuna.

Comparison	Source (Gear / Quarter / Sex)	Degrees of freedom	Sum of squares	Mean square	F-value
12	Longline / 1 / male				
	Inequality of slopes	1	1,580.687	1,580.687	14.784**
	Residual	69	7,377.284	106.917	
	Inequality of adj. means	1	19.181	19.181	0.150
	Residual	70	8,957.970	127.971	
13	Longline / 1 / female	1			
	Inequality of slopes	1	8,561.548	8,561.548	26.220**
	Residual	54	17,632.314	326.524	
	Inequality of adj. means	1	318.220	318.220	0.668
	Residual	55	26,193.862	476.252	
14	Longline / 4 / --[a]				
	Inequality of slopes	1	172.551	172.551	5.619
	Residual	1,495	45,911.877	30.710	
	Inequality of adj. means	1	48.708	48.708	1.581
	Residual	1,496	46,084.428	30.805	

[a]Differences due to sex are not significant for bugeye tuna caught by longline in the fourth quarter in areas 3 and 4.

Table 7. Statistics of fitted length-weight relations for bigeye tuna taken in eastern Atlantic fisheries as reported in various studies. Relations are shown in Figure 4.

Relation	Reference	Number of fish	a	b	mean square error	Range of fork lengths (cm)
1	Present study (pooled, non-deleted)	3240	0.00006684	2.7500	0.1509	37-211.5
2	Present study (pooled - deleted)	3186	0.00002396	2.9774	0.0076	37-210
3	Lenarz (1972)	190	0.00001249	3.1208	0.0034	41-132
4	ICCAT (1981)	----[a]	0.0000215	2.984	----[a]	----[a]
5	Chur and Krasovskaya (area 1)	489	0.00002261	2.9885	----[a]	98-147
6	Chur and Krasovskaya (area 2)	729	0.00001812	3.0386	----[a]	93-162
7	Chur and Krasovskaya (area 3)	132	0.00001879	2.9912	----[a]	148-182
8	Chur and Krasovskaya (area 4)	413	0.00001603	3.0242	----[a]	133-167

[a] Information not available

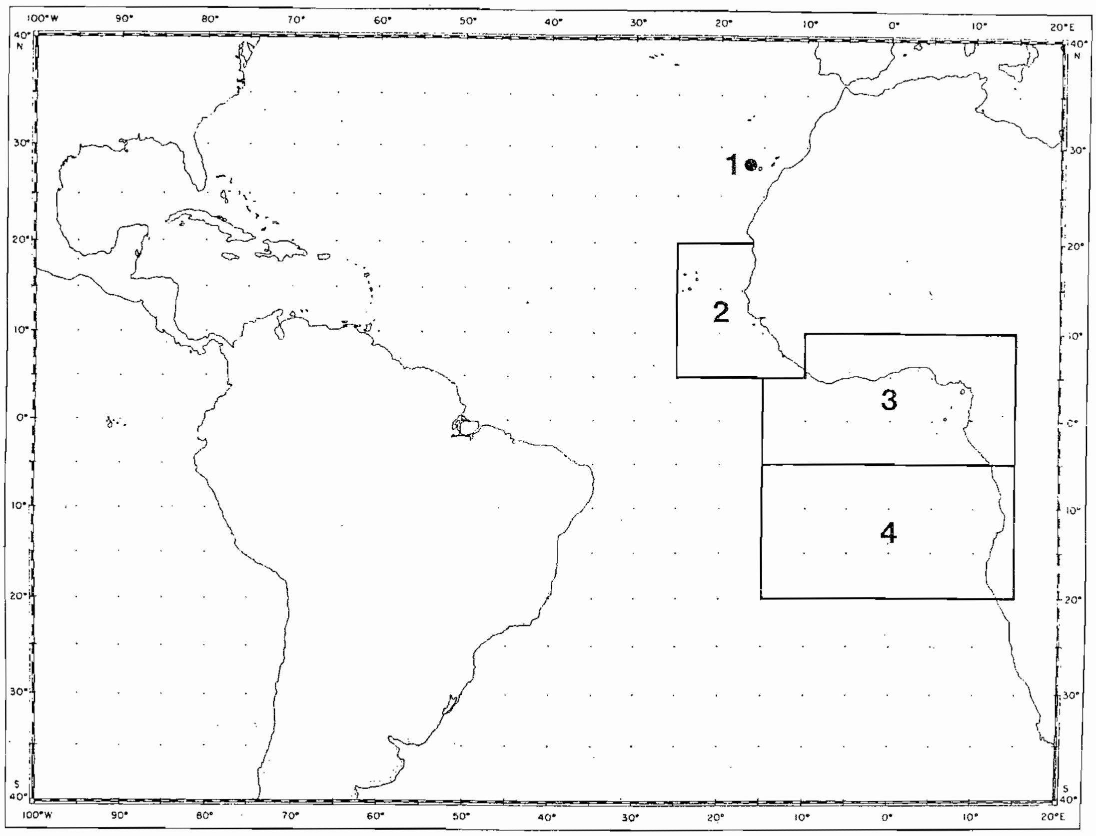

Figure 1. Eastern Atlantic Ocean areas for which length-weight relations for bigeye tuna were fitted.

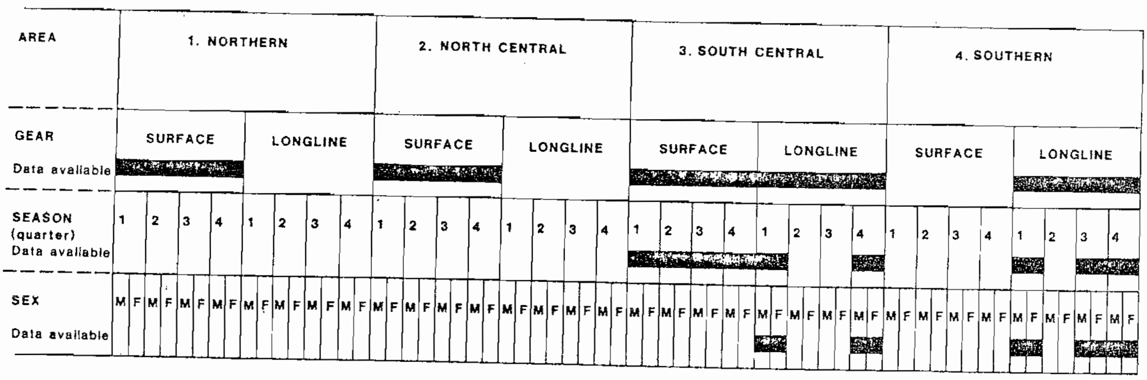

Figure 2. Completeness of sample length-weight data for Atlantic bigeye tuna. A solid bar under a stratum indicates data is available.

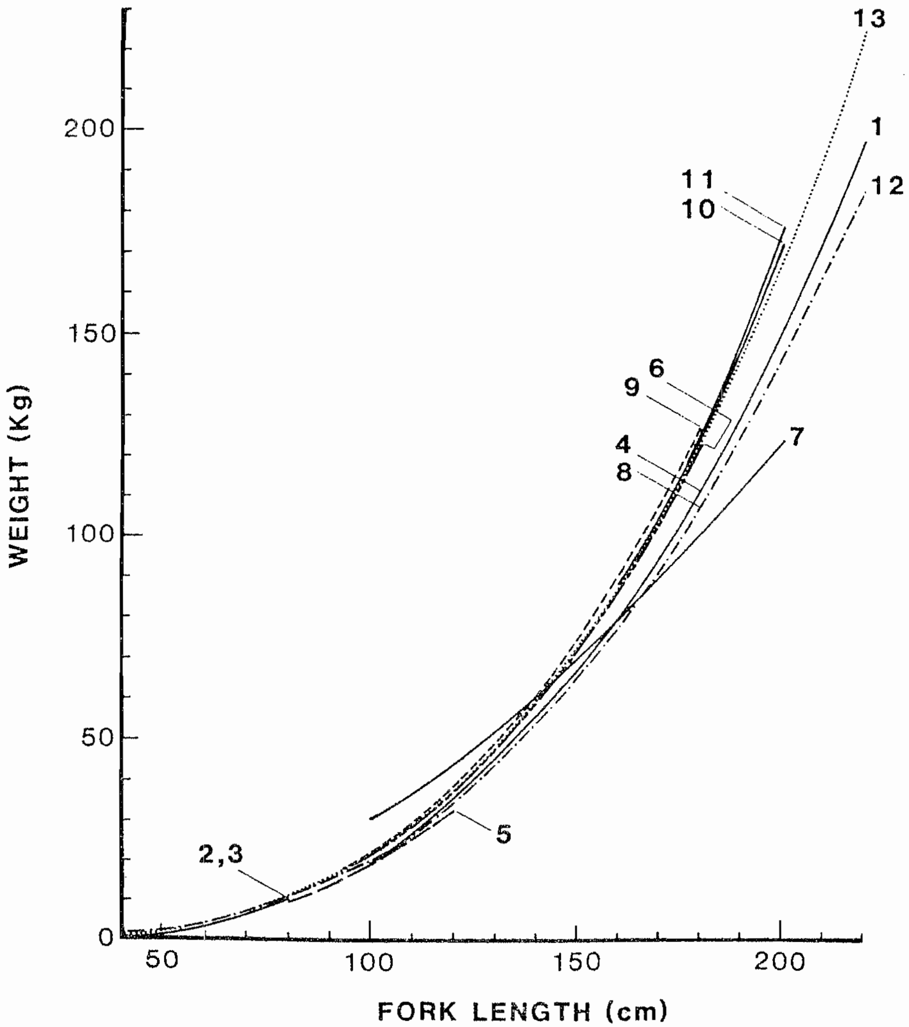

Figure 3. Fitted length-weight relations for Atlantic bigeye tuna. Numbers refer to statistics of the relations in Table 3. Ranges of length data is indicated by lengths of curves.

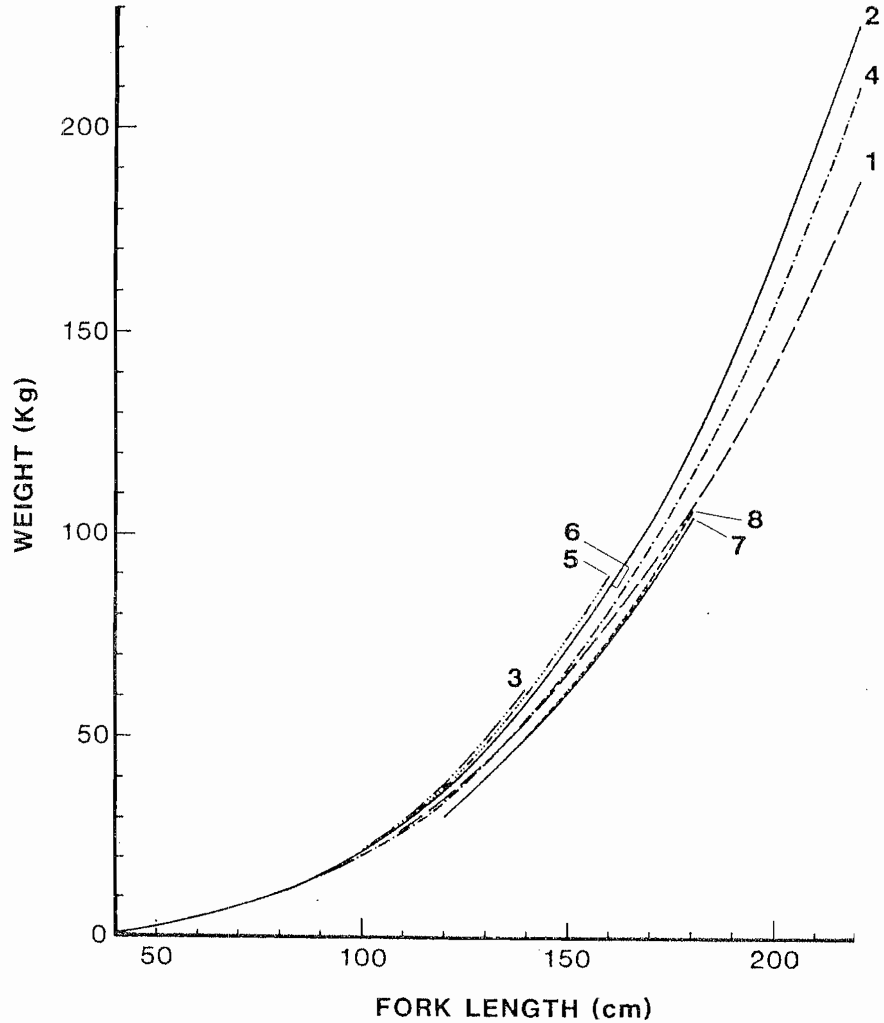

Figure 4. Fitted length-weight relations for Atlantic bigeye tuna (Lenarz, 1972; Chur and Krasovskaya, 1980; ICCAT, 1981). Numbers refer to statistics of relations in Table 7. Ranges of lengths data is indicated by lengths of curves.