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AGE AND GROWTH OF BULLET TUNA *AUXIS ROCHEI* (RISSO,1810) IN TURKISH WATERS[1]*

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SUMMARY

In this investigation, the length-weight relationships of Auxis rochei *(Risso, 1810) commercially exploited in the Aegean and Mediterranean Seas from January 1994 to May 1996 were studied. The frequency distributions of 936 individuals were analysed according to years and sexes. The relationships between the parameters were determined by means of logarithmic regressions. The otolith readings and sections from the first fin ray of the first dorsal fin were used for age determination. The individuals ranged from 0. to V. age groups.Due to inadequate sample numbers (5), the specimens of the age groups 0. were not included.*

50.2% (311 individuals) of the 630 examined specimens (I. to V. age groups) were females and 49.8% (309 individuals) were males. As the gonad conditions of the these individuals could not be observed, the sexes of the 10 individuals mainly of the age group I were not determined.

The average fork lengths of the combined females and males in accordance with the age groups were 30.7 cm in the age group I; 34.43 cm in the age group II; 38.7 cm in the age group III; 41.1 cm in the age group IV and 42.39 cm in the age group V. The L value was 47.76 cm for combined females and males; L value was 42.26 cm for females; the L value for the males was 45.08 cm. The length-weight relationship was determined in accordance with Le Cren's (1951) allometric growth equation, namely: $W=0.0076\ L^{3.24291}$ *for combined females and males. The growth of* Auxis rochei *was found to be allometric. The spawning period of this species in the Aegean Sea and in the Mediterranean Sea was determined to be from March to September.*

RÉSUMÉ

*Le présent travail de recherche étudie la relation longueur-poids de l'*Auxis Rochei *(Risso, 1810) exploité de façon commerciale dans les mers Egée et Méditerranée entre janvier 1994 et mai 1996. La distribution des fréquences de 936 poissons a été analysée selon les années et les sexes. Le rapport entre les paramètres a été déterminé au moyen de régressions logarithmiques. La lecture des otolithes et de coupes du premier rayon de la première nageoire dorsale a servi à la détermination de l'âge. Les poissons allaient des groupes d'âge 0 à V. Le nombre inadéquat d'échantillons (5) n'a pas permis d'inclure les poissons du groupe d'âge 0.*

Sur les 630 poissons examinés (groupes d'âges I à V), 50,2% (311 poissons) étaient des femelles, et 49,8% (309 poissons) étaient des mâles. Comme il n'a pas été possible d'examiner l'état des gonades de ces poissons, on n'a pas déterminé le sexe des dis poisons qui provenaient surtout du groupe I.

La longueur moyenne à la fourche des femelles et mâles combinés selon les groupes d'âge était de 30,7 cm chez le groupe I, 34,43 cm chez le groupe II, 38,7 cm chez le groupe III, 41,1 cm chez le groupe IV et 42,39 cm chez le groupe V. La valeur de L était 47,76 cm pour mâles et femelles combinés; elle était de 42,26 cm pour les femelles et de 45,08 cm pour les mâles. La relation longueur-poids a été déterminée selon l'équation de croissance allométrique de Le

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*Cren (1951), à savoir W=0.0076 $L^{3,24291}$ pour mâles et femelles combinés. Il a été observé que la croissance de l'*Auxis Rochei *était allométrique. La période de frai de cette espèce dans les mers Egée et Méditerranée a été établie de mars à septembre.*

RESUMEN

En esta investigación, se estudiaron las relaciones entre longitud-peso del Auxis rochei *(Risso, 1810), comercialmente explotado en el Egeo y el Mediterráneo desde enero de 1994 hasta mayo de 1996. Las distribuciones de frecuencia de 936 individuos fueron analizadas según años y sexos Las relaciones entre los parámetros fueron determinadas por medio de regresiones logarítmicas. Para determinar la edad se utilizaron lecturas de otolitos y secciones de la primera raya de la primera aleta dorsal. Los individuos oscilaban entre grupos de edad de 0 a V. Debido a un número inadecuado de muestras (5), los especimenes de los grupos de edad 0 no fueron incluidos.*

El 50,2% (311 individuos) de los 630 especimenes examinados (grupos de edad I a V) eran hembras, y el 49,8% (309 individuos) eran machos. Dado que no se pudo observar el estado de las gónadas de estos individuos, el sexo de los 10 individuos, especialmente del grupo de edad I, no fue determinado.

Las longitudes a la horquilla medias de hembras y machos combinados de acuerdo con los grupos de edad fue de 30,7 cm en el grupo de edad I; 34,43 cm en el grupo de edad II; 38,7 cm, en el grupo de edad III; 41,1 cm en el grupo de edad IV; y 42,39 cm en el grupo de edad V. El valor de L fue de 47,76 cm para hembras y machos combinados; el valor de L fue de 42,26 cm para las hembras y 45,08 cm para los machos. La relación longitud-peso fue determinada según la ecuación de crecimiento alométrico de Le Cren (1951), W = 0,0076 $L^{3,24291}$ para hembras y machos combinados. Se descubrió que el crecimiento del Auxis rochei *es alométrico. Se determinó que el período de desove de esta especie en el Egeo y el Mediterráneo es desde marzo a septiembre.*

1. INTRODUCTION

The bullet tuna (*Auxis rochei* Risso, 1810) is the least studied but a rather numerous fish. In Turkey no data exists on this species. Bullet tunas together with other tuna species (Bluefin tuna, Atlantic little tuna, Albacore) are caught in the Turkish waters by purse - seiners. Bullet tunas are caught in the Gulf of Edremit, Ayvalýk, Ýzmir, Güllük, Fethiye, Antalya and Ýskenderun. In Turkey, the fisheries biology of the Bullet Tunas has not been studied.

The catch of *Auxis rochei* and of *Auxis thazard* in Turkey does not show any stability. The catch of this species was in 1991, 35.2 tons. In 1993 the catch increased to 323.8 tons. In the following years ýt decreased to 77.0 tons reached 316.3 tons. This was probably due to unreliable fishery statistics.

2. MATERIAL AND METHOD

From January through May in 1994 - 1996 the Bullet tuna samples were collected on board of the commercial tuna purse-seiners in the Aegean and the Mediterranean Seas. As there is no permanent fishing activity for bullet tunas; in November and December 1994-1996 no bullet tunas were landed.

During the research period 936 specimens were collected. The measurements of the fork lengths, and the total weights were made by using a calliper and a digital balance of accuracy to 0.01 g.

A calliper of 50 cm was used to determine the size of the fish. As the size of the bullet tunas differed from 28 to 44.5 cm, the calliper was divided into parts of 0.5 cm. and the calculations have

been conducted accordingly. By assessing the metric characters, the standard methods of FAO were applied.

Various parameters , arithmetical mean (S), variance (S^2), variance coefficient (CV), standard error (S_x),minimum and maximum values obtained were calculated. Log y= Log a + b. Log x logarithmic regression model which could easily be turned into $y=a.x^b$ was used for biometrics changes of *Auxis rochei.*

The otolith readings and sections from the first fin ray of the first dorsal fin were used for age determinations. The otoliths were examined in water in a petri dish by means of a stereoscopic microscope. To clarify the ring structure the burnt otolith surfaces were brushed with Xylol.

From the captured bullet tunas the first dorsal fin rays were removed. From each of the fin rays, two serial sections of 0.7 mm were cut using a low speed saw, mounted with a synthetic resin as described by Compean–Jimenez&Bard (1980) and González- Garcés and Fariña Perez (1983).

The measuring and reading of the spinal sections was carried out with a ocular micrometer. The back-calculated growth size of the fish and the diameter of the spines were calculated for 163 bullet tunas.

The Back Calculating equation: $\mathbf{FL_i = a + (FL - a) \bullet (A_i / A)}$

FL_i= fork length of the fish corresponding to age or ring i in cm,

a = ordinate in the origin of the equation FL fl a + bR,

FL = fork length of the fish in cm,

A_i = radius of the ring i (in 0.1 mm) calculated as the average value observed in ring i,

A = median radius of the spine for each size in 0.1 mm.,

To compute the parameters of the Von Bertalanffy growth equation (K, Von Bertalanffy growth constant, L∞, asymptotic maximum length and, age at time zero) July the 1.st was chosen as conventional birthday for the all individuals considered in the length-at-age key $\mathbf{L_t = L_\infty [1 - e^{-K(t - to)}]}$

The length–weight correlation of bullet tunas were calculated according to the different age groups and by Le Cren's (1951) allometric growth equation. The formula of this equation is $\mathbf{W= a. L^b}$

In order to calculate the ganodosomatic index value, the gonad weights of the monthly obtained samples, were determined with 0.01 g sensitivity. By the determination of the gender and the sexual maturity age of the fish , the macroscopic and microscopic structures and the positions of the gonads were observed. For the individuals with developed gonads LAEVESTU's (1965) scale was used.

3. RESULTS

3.1 The Length and Weight Frequency

During the study, biometrical measurements as 936 bullet tunas were made. Fork length (FL) and total weight (TW) distribution of bullet tunas was determined. The minimum measured length and the maximum measured length of bullet tunas were 28.5 cm and 44.5 cm respectively. The mean length was found to be 36.5 cm ± 0.1454 cm (±S). The most common repeated value of length was 36.5 cm with 9%. This FL interval was followed by 35-35.5 cm size interval with a percentage of 8.55%. The Bullet tunas in the size group of 28.5 cm and 44.5 cm Fl were least abundant. This interval comprised 1% of all measured, fish. The length frequency distribution of bullet tuna samples is shown in Fig.3.

It was determined that the average weight of the bullet tuna ranged from 350g to 1750g. The most frequent values of weight of bullet tunas were 650-699 g (16.1%) and 600-649 g (16%). The

Bullet tuna of 350g and 1750 g (0.11%) were least abundant. The average total weight being 875.51 ± 14.9294 g (±S) Fig. 4.

The analysis of length and weight of bullet tuna was performed in Excel and the arithmetical mean, standard deviation, variance, variance coefficient, standard error and maximum and minimum length and weight values of bullet tuna are presented in Table 1 and 2.

3.2 Length – Weight Relationship

The bullet tuna length – weight relationship from the Aegean and from the Mediterranean Sea were calculated on the basis of the data on length and weight obtained by measurements of 936 individuals sampled during 1994-1996.

The regression relation of the fork length and the weight parameters (length-weight) was calculated exponentially (Fig.3). The calculation of the confidence interval of "b" coefficient is necessary in determining the allometry of growth. The formula, b-Sx.t<...> b+Sx.t, used to calculate the confidence intervals are shown in Table 3.

From the regression line we interpreted a strong and positive relationship between the length and the weight of bullet tunas. This is clearly seen in the values of the correlation coefficient, being 0.9707. The length-weight correlation of *Auxis rochei* has been calculated by Le Cren formula; In the calculations; the sexes were separated. The condition quotation of the weight-length correlation a has been determined as 0.0076 and b value is 3.24; the condition quotation for the female individuals is 0.0018 and b is 4.26 and for the male individuals the quotation is 0.0076 and b is 3.24. The mathematical relationship between the bullet tuna length and the weight for total samples can be described by the following equation: Log W= Log 1.018 + 3.243 • Log LF

3.3 Age and Growth

During our research, the ages of 630 *Auxis rochei* from 936 specimens were examined on otoliths and the first rays of the dorsal fins. It was not possible to determine the age of the remaining 306 fish. Ages of these fish differed from 0. to IV. The number of the individuals of 0. age (only 5 fish) was not enough to form a group for age 0.

3.3.1 Age - Sex Composition

The sexes of Bullet tunas were determined. The number and the percentage of Bullet tunas according to the age classes are shown in Table 4.

From 630 fish whose age were determined, the sexes of 620 fish could be determined. The sexes of 10 individuals could not be determined. 311 individuals of the 620 samples of which the ages were determined, were females (50.2%) and 309 were males (49.8%). 630 *A.rochei* samples show that most of the individuals are in the second age group (45.7%) and followed by the age groups III. (24%), IV. (21%), V. (7.8%) and I. (1.59%). The age determination for the age group 0 was not possible.

3.3.2 Age - Length Composition

Table 5. Shows, the length distribution without separating the sexes of *Auxis rochei* in correlation with age. The average length of the group I. fish is 30.7cm; the length for the group II. is 34.43 cm and respectively 38.7 cm, 41.1 cm. and 42.38 cm.

The results of the comparison of the average length values determined by Back calculating and Bertalanffy formulas for each group, is given in Table 5. Between those values there is not a considerable difference. We could conclude that these values in this research are not so much

different from the real values. After figuring out by the Back calculating method and comparing through the Bertelanffy growth equation, the data about the individuals belonging to the group of fish, whose ages have been determined by the first ray of the dorsal fin; are given in Table 5.

The length at each age as derived from equation, as well as the annual increments. The growth curve, presented in Figure 4 and Table 5 shows that the most rapid rate of growth occurs during the first year of life. It slows down gradually.

The Von Bertalanffy equation describing the growth of bullet tuna in terms of fork length is as follows. The Von Bertalanffy equation used to calculate the length growth parameter of the Bullet tuna, and the values belonging to them are given in Table 6 As seen in the Table, the given length values are equal to annual growth of both male and female individuals, the theoretical length ($L\infty$) is also equal. The theoretical mean length at age and the annual growth figured out according to the above parameters of the Von Bertalanffy growth equation are listed in Table 6.

3.4 Reproduction

The total number of gonads collected during the research period was 936, of which were 448 females (52.2%) and 410 males (47.8%). The length of the females varied from 32.6 to 44.5 cm and the length of the males' was between 30-44.5cm. The male -female distribution in the 858 samples of which the genders are determined, is 1: 1.

As we could not get any material in November and December, we did not use data belonging to these months in the index values. Any gonad development in January could not be observed. The development of the gonads started after February.

In the Aegean and in the Mediterranean Seas, *Auxis rochei* reached the sexual maturity in the II. age group. The development of the gonads is almost the same for both genders. The gonads are mature after the month of March for most of the male or female individuals. At the end of October the gonads were in resting stages. The reproduction period of the gonads continued from March to September. As we did not have any samples of November and December, the reproduction period could not be determined.

4. DISCUSSION

Looking at the yearly production of aquatic products in Turkey, the catch figures of *Auxis rochei* is very low in Turkey. This fish is consumed mostly fresh. and sold as Bonito in Turkey. This research is the first on the growth and the age analysis of *Auxis rochei* in the Aegean and in the Mediterranean Sea, giving the most detailed biometric parameters of *Auxis rochei* in Turkey.

By analyzing the relations between the weight and the dimensional parameters, calculated from regression and correlation analyses, the growth was determined to be allometric. The correlation coefficient calculated for male and female was determined as 0.731 GRUDSTEV and KOROLEVICH (1985). The correlation coefficient was figured as 0.88 by RAMOS at al. (1985), and 0.91 by GRUDSTEV (1992). The found correlation coefficient is much closer to +1.

Le Cren's weight-length correlation, according to the results of our research and of the ones of other researchers. According RAMOS-ALOT (1985)(within 1986 Ramos at al.) the condition quotation (a) is higher in the Mediterranean Sea and in the coasts of Atlantic, showing that bullet tunas have possibly more food available in our seas.

The (b) coefficient determined by the statistical analysis, is close to the ideal fusiform value in male individuals and female-male composition according to their ages. In female individuals the b number is higher than the fusiform value. The research of SIVASUBRAMANIAM (1986) in Srilanka and LENARZ (1974) in Atlantic showed that the quotation in female male combination is higher than

4; ISHIDA (1971) (within 1981Uchida) in Shionomisaki Gulf in Japan , SILAS at al. (1985) in Cochin Coasts stated that the quotation is higher than 2.

Table 7. shows, the distribution of the length in correlation with the age , determined by other investigations. As there is not any available research on the length of the bullet tunas; It is not possible to make any comparisons for the bullet tunas in the Aegean Sea and in the Mediterranean Sea. In 1985, GRUDTSEV and KOROLEVCH, determined in the east of the equatorial Atlantic the growth of Bullet tunas. In 1992 determined GRUDTSEV in the Baltic Sea the growth of Bullet tunas in correlation with age, as being much more slower than in the Turkish waters. To the same conclusions came also in 1978 CHIAMPREECHA in Thailand Gulf (within 1994 Yesaki and Arce). According to DWIPONGO et al.(1986) in the Pacific and in the Indian Oceans; for the age group I; in Thailand Gulf the best growth rates were better than in Turkish waters. For the age groups II. and III.; the growth rates in our seas were slower than in other seas. It could be concluded that the warm environment and the nutrition of the fish and the fishing devices and methods may have affected the growth

The research of the GRUDSTEV and KOROLEVCH in Equatorial Atlantic in the year 1985, shows us that there was not a remarkable difference between the length and growth of the female and male individuals. In our own research, we have found that the lengths of two individuals of different sexes of the same age, are so much close to each other. Other investigations did not take into consideration the gender when analyzing the age- length correlation.

The results obtained by YESAKI in the year 1982 and by INGELES and PAUL (within 1994 Yesaki and Arce) in 1985 are very much close to those obtained by us. The values obtained by SILAS (1985) (within 1994 Yesaki and Arce)are much higher than our values. When compared to ours those obtained by SUPONGPAN and SAIKLIAN (1987) (within 1994 Yesaki and Arce) in the Thailand Gulf and the Baltic Sea are lower.

RODRIGUEZ-RODA and DICENT (1980), DICENT et al. (1983) the in Mediterranean coasts of Spain, MIYAKE (1982), PICCINETTI and PICCINETTI (1992) in The Northern Atlantic and in the Ligunian Sea , and COLLIGON (1954) in Gibraltar stated that the larva of bullet tuna are dispersed in the period between July and October. ANONYM (1989) determined that the spawning occurs when the gonad weight of *Auxis rochei* reaches 20% of its total weight generally in waters of 20 C^o or more along the coasts.

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Table 1. Parameters calculated from the length measurements of *A.rochei*.

Length	Years			Mean
	1994	1995	1996	
X	36.74	36.06	40.03	36.94
S	2.612	3.536	3.198	4.449
S^2	6.846	12.505	10.229	19.797
CV	0.005	0.009	0.024	0.004
Sx	0.124	0.185	0.279	0.145
Min. -Max.	30.2-43.9	28.1-44.1	29-44.	28.1-44.5

Table 2. Parameters calculated from the weight measurements of *A.rochei*.

Weight	Years			Mean
	1994	1995	1996	
X	791.31	828.28	1290.18	875.51
S	447.337	324.088	393.809	456.753
S^2	200107.4	105033.3	94520.6	208623.3
CV	1.0144	0.8903	2.3469	0.4879
Sx	21.3016	16.9899	26.8613	14.9294
Min.-Max.	516.1-1556.8	410.0-1597.0	393-4105.33	398.0-4105.3

Table 3. Regression and confidence intervals of allometric growth for biometrics parameters of *Auxis rochei* (r^2= 0.9423; p<0.005).

Sex	Variables	n	r	(a)	(b)	Confidence intervals(95%)
Total samples	TW-FL	936	0.971	0.0076	3.241	2.9881<....<3.4942
F	TW-FL	311	0.996	0.000156	4.298	3.7130<....<4.8842
M	TW-FL	309	0.965	0.000719	3.890	3.3536<....<4.4266

Table 4. The age composition and sex distribution of the bullet tunas.

AGE GROUPS	Female		Male		Female+Male	
	n	%	n	%	n	%
I	-	-	-	-	**10**	1.6
II	155	49.8	133	43.1	288	45.7
III	73	23.5	78	25.2	151	24.0
IV	63	20.2	69	22.4	132	21.0
V	20	6.5	29	9.3	49	7.8
Total	**311**	100.0	**309**	100.0	**630**	100.0

Table 5. The mean length in the each age group according to Von Bertalanffy and Back calculating values.

Age Group	n	Fork Lenght (cm)					
		Observed				Von Bertalanffy	Back Calculation
		Min.	Max.	Mean	Std. error	Mean	Mean
0						24.7	-
I	10	28.0	33.5	**30.7**	± 0.5686	30.6	30.6
II	288	29.5	39.5	**34.4**	± 0.1025	35.0	34.0
III	151	30.0	41.5	**38.7**	± 0.1613	38.5	36.8
IV	132	32.5	44.0	**41.1**	± 0.1200	41.1	39.6
V	49	39.0	44.5	**42.4**	± 0.1793	43.1	41.3

Table 6. Parameters of length growth estimated with Von Bertalanffy equation.

Sex	L∝	K	t_o	Equation
Female	45.26292	0.39722	-1.6044	$L=45.26292[1-e^{0.39722(t-(-1.0044)}]$
Male	45.08422	0.33988	-1.5984	$L=45.08422[1-e^{0.33988(t-(-1.5984)}]$
Total samples	47.76151	0.29235	-2.3649	$L=47.76151[1-e^{0.29235(t-(-2.3649)}]$

Table 7. Age – Length relationship of the Investigations

Authors	Area	Sex	Age Groups				
			I	II	III	IV	V
Chiampreecha 1978*	Thailand	+	21.0	27.0	35.0		
Klýnmuang 1978*	Thailand	+	26.0	38.0			
Yesaki 1982*	Thailand	+	26.0	37.0	43.0		
Ingles and Paul 1985*	Bohol	+	24.0	36.0	42.0		
Grudtsev and Korolevch 1985*	Western Atlantic	+	22.9	30.4	36.7	40.4	
Silas at al 1985*	India	+	29.0	42.0	50.0		
Dwipongo at al 1986*	West Jawa	+	24.0	36.0	42.0		
Dwipongo at al 1986*	West Jawa	+	33.0	45.0	49.0		
Joseph at al1986*	Sri Lanka	+	25.0	39.0	47.0		
Supongpan and Saiklian 1987*	Thailand Gulf	+	27.0	30.0	30.0		
Yesaki 1989*	Thailand Gulf	+	39.0	40.0			
Brucet and Nouen 1989	Indian Ocean	+	26.0	37.0	43.0		
1992 Grudtsev	Sahara	+	21.6	26.8	31.3	33.7	35.9
This Investigation	Aegean-Mediterranean	+	**30.7**	**34.4**	**38.7**	**41.1**	**42.4**

* within 1994 Yesaki and Arce

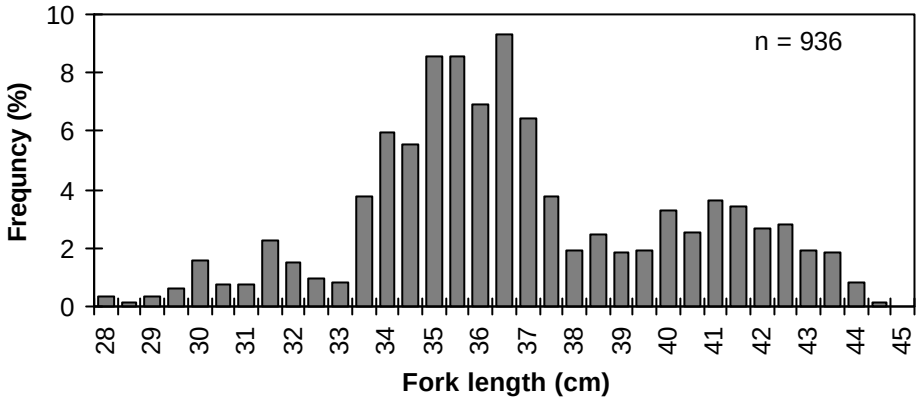

Fig.1.The length frequency distribution of *Auxis rochei* samples collected during the investigations

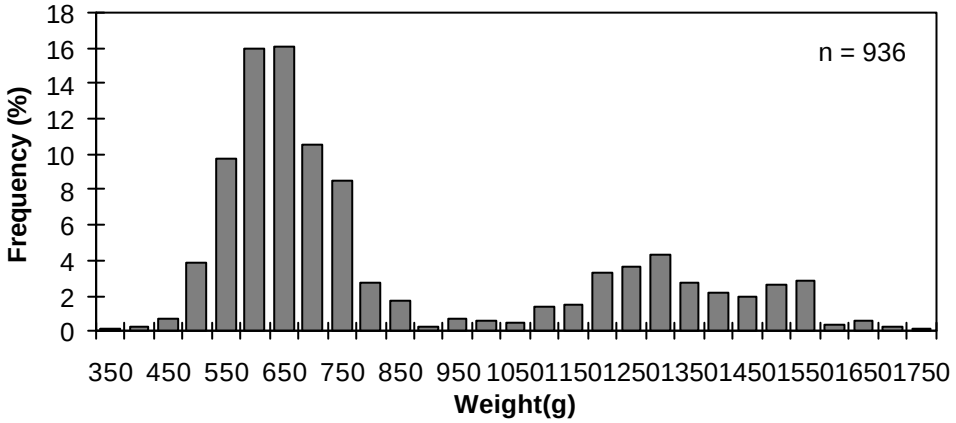

Fig. 2. The weight frequency distribution of *Auxis rochei* samples collected during the investigations.

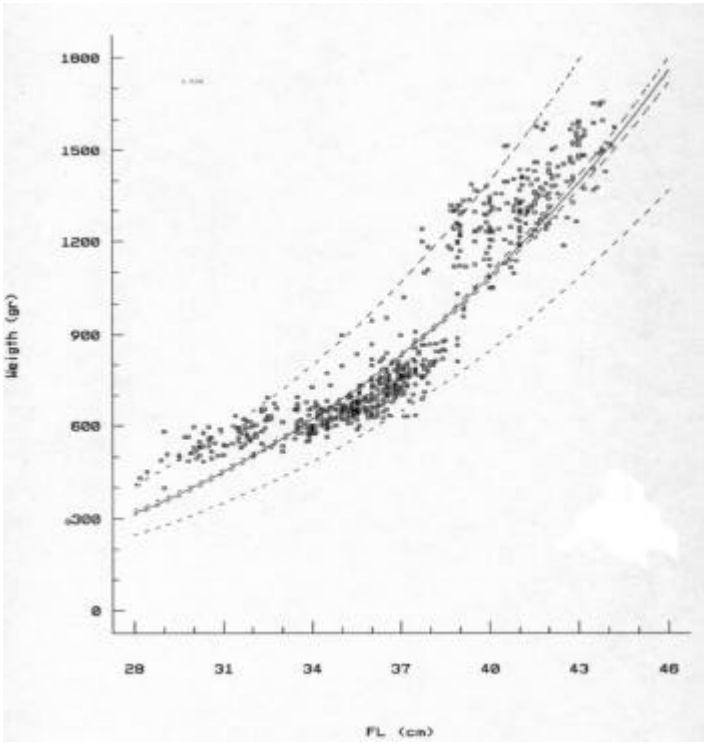

Figure 3. The regression between the length and weight measurement of *Auxis rochei*

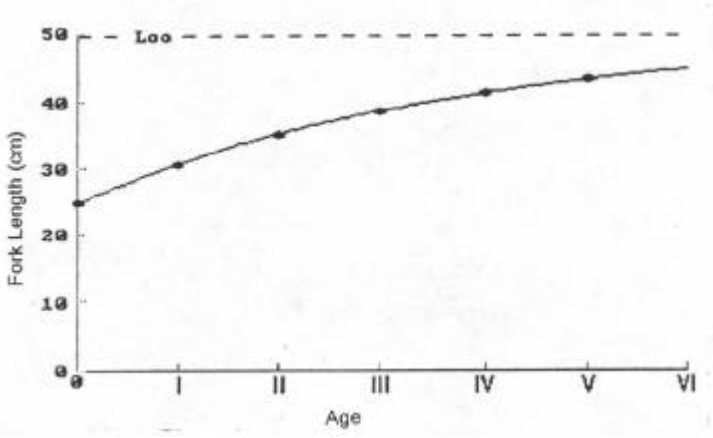

Figure 4. Growth of the bullet tuna according Von Bertalanffy.