

AGE AND GROWTH OF SWORDFISH (*XIPHIAS GLADIUS* L., 1758) IN THE EASTERN MEDITERRANEAN SEA.*

T. Zahit ALIÇLI** İsyk K. ORAY**

SUMMARY

Swordfish (*Xiphias gladius* L., 1758) is widely distributed in tropical and temperate seas including the Mediterranean Sea. In this investigation, age and growth of swordfish were studied. Round weight and LJFL of fish were measured and fins were collected. A total of 794 specimens were measured from Turkish commercial longline and drift net vessels; minimum and maximum length of sampled species were 52,5 and 219 cm respectively.

Anal fin spine sections were used to determine the age composition of 213 specimens. Readable spines were found between 0+ and X. age classes. The mean calculated lengths at estimated age were determined for both sexes. These data were used to fit the Von Bertalanffy growth model and parameters were estimated as: $L = 252.196$, $k = 0.133$ and $t_0 = -2.432$.

The length-whole weight relationship was determined in accordance with Le Cren's (1951) allometric growth equation, and parameters were estimated as; $a = 1.345 \times 10^{-6}$ and $n = 3.4474$. The relationship between JFL and anal fin spine radius for 213 samples was: $LJFL = 50.81 + 13.52 * S$ ($r = 0.96$)

RÉSUMÉ

L'espadon (*Xiphias gladius* L., 1758) est amplement réparti dans les mers tropicales et tempérées, dont la Méditerranée. Le présent document examine l'âge et la croissance de l'espadon. On a mesuré le poids vif et la longueur maxillaire inférieur-fourche (LJFL), et des nageoires ont été prélevées. Au total, on a mesuré 794 spécimens capturés par des palangriers commerciaux turcs et par des bateaux pêchant au filet dérivant; la longueur minimale et maximale des espèces échantillonnées a été respectivement de 52,5 cm et 219 cm.

Les rayons épineux de la nageoire anale ont été utilisées pour déterminer la composition démographique de 213 spécimens. On a découvert des épines lisibles dans des classes d'âge entre 0+ et X. La moyenne du calcul des tailles à l'âge estimé a été déterminée pour les deux sexes. Ces données ont servi à ajuster le modèle de croissance Von Bertalanffy, et des paramètres ont été estimés comme suit: $L_4=252,196$, $k=0,133$ et $t_0=-2,432$.

Le rapport taille-poids complet a été déterminé conformément à l'équation de croissance allométrique de Le Cren (1951), et des paramètres ont été estimés comme suit: $a=1,345 \times 10^{-6}$ et $n=3,4474$. Le rapport entre la longueur JFL et le rayon épineux de la nageoire anale pour 213 échantillons était comme suit: $LFJL = 50,81 + 13,52 * S$ ($r = 0,96$).

RESUMEN

El pez espada (*Xiphias gladius* L. 1758) se distribuye ampliamente en los mares tropicales y templado, incluyendo el Mediterráneo. El presente documento investiga la edad y el crecimiento del pez espada. Se ha medido el peso vivo y la LJFL de los peces y se han recogido aletas. Se midió un total de 794 especímenes capturados por palangreros y barcos de redes de enmalle a la deriva comerciales de Turquía; la mínima y máxima longitud de los peces muestreados era de 52,5 y 219cm respectivamente.

* This work was supported by the Research Fund of the University of İstanbul. Project number B-628/17072000

** University of Istanbul, Faculty of Aquatic Product. Department of Fish Catching Technology Ordu cad.No: 200 34470 Laleli - İstanbul / TURKEY.

Se utilizaron secciones de la espina de la aleta anal para determinar la composición por edades de 213 especímenes. Se descubrieron radios leíbles entre las clases de edad 0+ y X. Se determinaron las longitudes medias calculadas a la edad estimada para ambos sexos. Estos datos se utilizaron para ajustar el modelo de crecimiento Von Bertalanffy y los parámetros se estimaron en: $L_{\infty} = 252,196$, $k = 0,133$, y $t_0 = -2,432$.

*La relación longitud-peso total ha sido determinada conforme a la ecuación de crecimiento alométrico de Le Cren (1951), y los parámetros se estimaron de la siguiente forma: $a = 1,345 \times 10^{-6}$ y $n = 3,4474$. La relación entre JFL y los radios de la espina de la aleta anal para 213 muestras fue: $LJFL = 50,81 + 13,52 * S$ ($r = 0,96$).*

1. INTRODUCTION

In the Turkish waters, swordfish are caught in mainly Northern (Gökçeada Island and Gulf of Edremit) and Southern parts of the Aegean Sea and the Mediterranean Sea (Gulf of Antalya) using drift-net, longline and harpoons. The annual catch of swordfish are affected by weather conditions and number of the fishermen. In 1999, total landing of this species, around 113 MT.

Many investigations on this species were done in the Mediterranean Sea and in the other seas.

Different age determination methods were being used by the researchers. Porter and Smith (1992) stated that the anal fin spines, otoliths and vertebra were the most important hard parts for the age determination. In fact, these hard parts have been used in aging until today.

The scales could not be used for the age determination as only juvenile swordfish have scales (Nakamura, 1985). Until recently, size at age or growth estimates have been based on modal analysis of size distribution by Yabe et al. 1959, Kume and Joseph 1969, Beckett 1974, Ovchinnikov et al. 1980 (Berkeley and Houde, 1983).

Artüz (1964) examined the dorsal fin spines for the age determination for swordfish in the Marmara Sea and found the age rings. The work of Artüz encouraged using of the fin spines for age determination. Berkeley and Houde (1983), than Megalofonou and De Metrio (1989), Chalabi and Ifrene (1992), Ehrhard (1995) used the anal fin spine method for the age determination.

Wilson and Dean (1983) examined the use of sagitta for the age determination, Megalofonou et al. (1995) investigated growth using otoliths finding that the otoliths were easily broken and quite small.

The use of vertebra is the new method for the aging of swordfish. Hunt stated that 14. and 15. vertebra are useful for the age determination (Porter and Smith, 1991).

De Metrio et al. (1988), Cavallaro et al. (1991), Megalofonou et al. (1995), Chalabi (1993), Chalabi et al. (1993,1995), Mejuto and De la Serna (1993), Orsi Relini et al.(1993,1995,1996), Sion (1993), De la Serna et al.(1993) and Hattour (1996) investigated the biology of swordfish in the Mediterranean Sea.

The most detailed investigations on the biology of the swordfish were done by Demir et al. (1956), Artüz (1964) and Demir (1970) in the Marmara Sea and Black Sea. Devedjian (1926), Demir et al. (1956), Gökođlu and Oray (1992) and Alýçlý and Oray (1996) investigated the fishery of this species in Turkish waters.

The aim of this work, to find the biological parameters of the swordfish in Turkish waters.

2. MATERIALS AND METHOD

Swordfish were sampled by means of commercial long lines and drift net vessels between May 1993 – September 1996 in the Aegean and in the Mediterranean Seas.

Total 794 samples were collected during the research period. Collection of samples were affected through weather conditions and traditional fishing techniques.

The measurement of fork lengths were made using a caliper and total weight were measured. And Anal fins were collected for age determination. In the age determination Berkeley and Houde's (1983) method was used. Excised fins were labeled, placed in plastic bag and frozen. Later, fins were thawed and individual elements were separated and the skin and the tissues were cleaned. The second spine has the smallest matrix and the largest diameter and this was used. The spine was sectioned according to Berkeley and Houde (1983). The distances from the focus to the edge of the sections and from the focus to each growth band were recorded. The relationship between spine radius and LJFL was determined using standard linear regression procedures. This relationship and the distances from the focus to successive growth bands were used to calculate back the length at presumed age from the relationship in figure 1.

$$L_n - C = \frac{S_n}{S} (L - C)$$

Where; L = LJFL at time of capture,
 L_n = LJFL when band n was formed,
 C = intercept on length axis from regression of length on spine radius,
 S_n = distance from spine focus to band n,
 S = spine radius

The mean back calculated lengths at estimated ages were determined for both sexes and were fitted to the Von Bertalanffy growth model.

The length –weight correlatoion of swordfish was calculated according to different age groups and by Le Cren's (1951) allometric growth equation. The formula of this equation is $W = a.L^b$.

3. RESULTS

3.1. The Length and Weight Frequency

During the study, 794 specimens were measured from commercial longline and drift net vessels. Distribution of fork length (FL) were determined using a caliper . The minimum and maximum measured length of swordfish were 52.5 cm and 219 cm respectively. The most abundant size groups were between 100 – 125 cm. The length frequency of swordfish samples is shown in figure 2.

Round weight of 794 specimens were measured using commercial balance. The minimum and maximum measured weight were 1,5 kg and 133 kg respectively.

3.2. The Length – Weight Relationship

794 specimens were used for the length – weight relationship. The regression analysis were done for each year and for the total samples (table 1).

3.3. Age and Growth

In the age determination, 213 samples were found suitable for age determination. Some spine sections were eliminated immediately as unreadable.

The readable spines were found to be between the 0. and X. age classes. The most abundant specimens were in the II. Age class, the less in X. age class. The total values of I., II., II., age classes in the samples was 56,34 %.

The mean calculated lengths at estimated age were determined for both sexes. These data were used to fit in the Von Bertalanffy growth model. The equations, parameter estimates, back calculated lengths predicted by the Von Bertalanffy model are presented.

$$L = 252.196 [1 - e^{-0.133(t-(-2.432))}]$$

$$L = 252.196$$

$$k = 0.133 \text{ and } t_0 = -2.432$$

3.3.1. Age – length Composition

The minimum, maximum and mean length distributions of swordfish according to age composition is shown in table 2.

Table 3 shows the mean length, back calculated length and Von Bertalanffy length values.

3.3.2. Age – Weight Composition

The whole weights of 213 specimens varied between 1,5 – 133 kg. Table 4 shows distribution of min., max. and mean whole weight and values of Le Cren according to age classes.

4. Fish Size – Anal Fin Spine Radius Relationship

The relationship between LJFL and anal fin spine radius for 213 samples is:

$$\mathbf{LJFL = 50.81 + 13.52 S \quad (r = 0,96)}$$

Where; LJFL = Lower jaw fork length (cm)
S = anal fin spine radius (mm)
r = correlation coefficient.

4. DISCUSSION

Swordfish is the one of important commercial species in the Mediterranean Sea. Despite of its highly commercial value, biological studies have not been carried out in Turkish waters until recently.

Between May 1993 – September 1996, 794 samples were investigated. Length distributions of 794 species were 52,5 cm. and 219 cm. In the Mediterranean Sea these values showed changes depending on areas and years. For example, the length distribution in the Gulf of Taranto was 64-205cm in 1985, 71,5-207 cm in 1986 (De Metrio and Megalofonou, 1987); in Greece 71,5-207cm (Megalofonou et al. 1991); in the lengths varied between 65-172 cm in Algeria (Chalabi and Ifrene, 1992); in the eastern Mediterranean sea it was 90-206cm, in the South Adriatic Sea 56-195 cm., in the Thyraean Sea 56-195cm., in Chania Island in Greece 49-218 cm and 56-214 cm, in Kalimnos Island 56-214 cm. (De Metrio, 1993). In the North Mediterranean Sea the length distributions were between 62,5-205cm (Tsimenides and Tserpes, 1995). In the Tunisian waters it was 63-276 cm. (Hattour, 1996) and in the Ligurian sea 75-185 cm. was determined. In the Mediterranean Sea except in 1996, swordfish generally didn't reach 220 cm fork length. But in Atlantic Ocean; Lee (1992) and Ehrhardt (1995) found 280cm and 225 cm respectively. We can easily say that, the swordfish in the Atlantic Ocean gets bigger than the swordfish in the Mediterranean Sea. If we consider our length distribution data of swordfish we see that these fish are generally under the 120 cm. fork length. De Metrio (1993) has also stated that swordfish are caught in the Italian and Greek Seas with less than 120 cm. fork length.

So far, different methods have been used for the age determination of swordfish in the world. In our research anal fin spine sectioning method was used. The ages of a total 213 samples were assessed using anal spines. The minimum and maximum of estimated ages were obtained as 0+ and 10 years.

Age groups of II., III., and I. were the most numerous in the sample. In the Mediterranean research minimum and maximum estimated ages values were between 0+ and 9 years old. Age groups 0+, I. and II. were the most numerous in 1532 samples (De Metrio, 1993).

Although in this study 794 samples were collected only, 213 of them were used for age determinations. The minimum and maximum length of the sampled species were between 52,5cm and 219 cm. In the aged samples this values were between 62,5 cm and 219 cm.

The results stated that mostly three years old swordfish were caught in the Mediterranean Sea. Only 5 samples belong to the age group 0+, as we think that many juvenile specimens are caught in Turkish waters, the estimated ratio of 0+ age group (2,35 %) is not a reflection of true values.

To determine the growth parameters of swordfish, the back calculated average lengths of individuals assigned to each groups were used to fit the Von Bertalanffy growth model. The parameters were estimated for

both sexes as: $L = 252,196$, $k = 0,133$, $t_i = -2432$. In the investigations carried out in the Mediterranean Sea, these values were changed depending on areas and years. Estimated L values were changed in the whole of the Mediterranean sea as : 243.8 (De Metrio and Megalofonou, 1989), 237. 109 in the Gulf of Taranto (Sion, 1993), 238.582 in Aegean Sea (Tserpes and Tsimenides) and 237.1 in the Mediterranean sea (both in Italian and Greek Seas). If we consider L values in the Mediterranean Sea, we could conclude swordfish generally cannot exceed 250 cm fork length.

The length-whole weight relationship for both sexes was calculated using 794 specimens. And Le Cren (1951) parameters estimated as $a = 1.345 \times 10^{-6}$ and $n = 3.4474$. However the comperation of the results weren't done. Because, in the Mediterranean sea generally dressed weights were used.

The relationship of spine radius-fork length was found as:

$$LJFL = 50.81 + 13,52S \quad (r = 0.96)$$

Due to careful sectioning of each spine at the condyle base helped us to obtain the significant linear relationship ($r = 0.96$).

As a result of investigations ýt was found that the Turkish fishermen generally catch swordfish under 125 cm fork length. The Age groups II., III., I. were most numerous in the samples. These values will affect the population in the near future as decrease in fish sizes in the Atlantic Ocean.

REFERENCES

ALIÇLI, T.Z. ORAY,I.K. (1996) : Second report on the investigation of swordfish *Xiphias gladius* caught in the Turkish waters. ICCAT Col. Vol. Sci. Pap. Vol.XLV (1), 141-144.

ARTÜZ, M.I. (1964) : Contribution to the knowledge of the biology of the swordfish (*Xiphias gladius* L.) in the sea of Marmara. FAO, G.F.C.M., Proceedings and Technical Papers. No.4, 459-471

BERKELEY,S., HOUDE, E.D. (1983) : Age determination of broadbill swordfish, *Xiphias gladius*, from the straits of Florida using anal fin spine sections. U.S. Dep. Commers., NOAA Tech. Rep. NMFS 8: 137-143.

CAVALLARO,G., CEFALI, A., POTOSCHI, A. (1991): Aspetti biologici di *Xiphias gladius* L. Dei Mar Meridionali Italiani. GFCM-ICCAT. Report of the GFCM-ICCAT Expert Consultation on Evaluation of Stocks of large pelagic fishes in the Mediterranean area. FAO Fisheries Report no. 449, 126-143.

CHALABI, A. (1993): Approche de la croissance de l'Espadon *Xiphias gladius* en Baies de Beni-saf et de bou Ismail.ICCAT Col. Vol. Sci. Pap. Vol XL (1), 158-161.

CHALABI, A., CHERRAK, I., HAMIDA, S., SAIL, M. (1995): La croissance de l' Espadon peche pres des cotes Algeriennes. ICCAT Col. Vol. Sci. Pap. Vol XLIV (1), 305-308.

CHALABI, A., DIB, H., OURDANI, A., RAHMOUN, S. M. (1993): Approche de la croissance de l' Espadon *Xiphias gladius* en Mediterranee Algerienne. ICCAT Col. Vol. Sci. Pap. Vol XL (1), 157.

CHALABI, A., IFRENE, F. (1992): Determination del'age de L'Espadon *Xiphias gladius* a partir de l' observation du second rayon epineux de la nagoire anale. Rapp. Comm. Int. Mer. Medit., 33, 289

DE LA SERNA., J.M., ALOT, E., GODOY, D. (1993): Analisis preliminar del sex-ratio por clase de talla del pez espada *Xiphias gladius* capturado con palangre de superficie en el Mediterraneo occidentale. ICCAT Col. Vol. Sci. Pap. Vol XL (1), 141-148.

DE METRIO,G. (1993): Swordfish research in the Mediterranean sea. Ý.Ü. Su Ürünleri Fakültesi su Ürünleri dergisi. Cilt7, sayý :1-2, 129-146.

DE METRIO, G., MEGALOFONO, P. (1987): Catch, size distribution, growth and sex ratio of swordfish *Xiphias gladius* in the gulf of Taranto. Tech. Consul. Adriatic and Ionian Sea, FAO-C.G.P.M., Fishery Report no. 394, 91-102.

DE METRIO, G., MEGALOFONOU, P., TSELAS, S., TSIMENIDES, N. (1988): Fishery and biology of the swordfish *Xiphias gladius*, L., 1758 in Greek waters. FAO Fishery report no. 494, 139-145.

DE METRIO, G., MEGALOFONOU, P. (1989): Stima delle catture e di alcuni parametri di popolazione del pesce spada *Xiphias gladius* in alcuni distretti del Mediterraneo Orientale. Nova Thalassia vol. 10. suppl. 1, 425-435.

DEMÝR, N. (1970): Contribution to the knowledge of the swordfish *Xiphias gladius* L. C.I.E.S.M. Monaco. Journees Etud. Planctonol, 155-157.

DEVEDJIAN, K. (1926): Peche et pecheries en Turquie. 4-10.

EHRHARDT, N.M. (1995): On the age and growth of swordfish in the northwest Atlantic ocean. ICCAT, Coll. Vol. Sci. Pap. Vol. XXIV (2), 84-88.

GÖKOĐLU, M., ORAY, L.K. (1992) : Antalya körfezi'nde kılıç balığı avcılığında kullanılan paraketalar ile kılıç balığı avcılığının yapıları ve av yapan teknelerin özellikleri üzerine bir araştırma. Su Ürünleri Avlama ve İşleme Teknolojisi Seminer Tebliğleri. 48-51.

HATTOUR, A. (1996): La peche de l'espadon *Xiphias gladius* en Tunisie : Analyse preliminaire de la relation taille-poids. ICCAT, Coll. Vol. Sci. Pap. Vol. XLV (1), 145-151.

LEE, D. (1992): Update of the 1990 and 1991 data available on Atlantic swordfish sex ratio at size collected from the U.S. fishery. ICCAT, Coll. Vol. Sci. Pap. Vol. XXXIX (2), 579-592.

LE CREN, E.D. (1951): The length-weight relationship and seasonal cycle in gonad weight and condition in the perche (*Perca fluviatilis*) J.Anim. Ecol. 20, 201-219.

MEGALOFONOU, P., DEAN, J.M., DE METRIO, G., WILSON, C., BERKELEY, S. (1995): Age and growth of juvenile swordfish, *Xiphias gladius* Linnaeus, from the Mediterranean Sea. Jor. Exp. Marine Bio. And Ecology. 188 (1995) 79-88.

MEGALOFONOU, P., DE METRIO, G. (1989): Stima dell' accrescimento di *Xiphias gladius* L. Del Mar Egeo mediante lo studio dei raggi spiniformi della pinna anale. Nova thalassia vol. 10. Suppl. 1, 437-446

MEGALOFONOU, P., DE METRIO, G., LENTI, M.C. (1987): Catch, size distribution, age and some population of swordfish, *Xiphias gladius*, in the Greek Seas. GFCM-ICCAT Expert Consultation on evaluation of stocks of large pelagic fishes in the Mediterranean area. FAO fisheries Report No. 449, 224-244.

MEJUTO, J., DE LA SERNA, J.M. (1993): A preliminary analysis to obtain a size weight relationship for the Mediterranean swordfish *Xiphias gladius*. ICCAT Coll. Vol. Sci. Pap. Vol. XL(1), 113-115.

NAKAMURA, I. (1985): Billfishes of the World. FAO Fisheries Synopsis No. 125, Vol. 5. pp 65.

ORSI RELINI L., GARIBALDI, F., CIMA, C., PALANDRI, G. (1995): Feeding of the swordfish, the bluefin and other pelagic nekton in the western Ligurian sea. ICCAT Col. Vol. Sci. Pap. Vol. XLIV (1), 283-286.

ORSI RELINI L., GARIBALDI, F., PALANDRI, G. (1996): A tentative VPA for the Mediterranean swordfish. GFCM-ICCAT/95/7.

ORSI RELINI L., GARIBALDI, F., PALANDRI, G. (1993): Notes about the structure of the fished stock of swordfish from the Ligurian Sea. ICCAT, Coll. Vol. Sci. Pap. Vol. XL (1), 400-403.

PORTER, J.M., SMITH, S.C. (1991): Literature review of differential growth and mortality in Atlantic swordfish, *Xiphias gladius*. ICCAT Coll. Vol. Sci. Pap. Vol. XXXV(2), 445-448.

SION, L. (1993): Biologia e pesce del pesce spada *Xiphias gladius* L. 1758 nell' Adriatico meridionale e nel golfo di Taranto. Università degli studi di Bari. Facoltà di Medicina Veterinaria. Scuola di Specializzazione in Biochimica Marina. Tesi di specializzazione in biologia marina pp, 17.

TSREPES, G.,TSIMENIDES, N. (1995): Determination of age and growth of swordfish, *Xiphias gladius*, 1758, in the Eastern Mediterranean using anal-fin spines. Fishery bulletin 93, 594-602.

WILSON, C.A., DEAN, J.M. (1983): the potential use of sagittae for estimating age of atlantic swordfish, *Xiphias gladius*. Proceedings of the International workshop on age determination of oceanic pelagic fishes:tunas,Billfishes, and Sharks. NOAA Tech. Rep. NMFS 8, 151-156.

Table 1. The results of regression analysis depending on years

Years	a	N	R²	r
1993	5.10 ^{-0.7}	3.6742	0.938	0.9685
1994	2.10 ^{-0.6}	3.3864	0.9485	0.9739
1995	1.10 ^{-0.6}	3.5119	0.9717	0.9858
1996	2.10 ^{-0.7}	3.8359	0.9785	0.9892
TOTAL	6.10 ^{-0.7}	3.617	0.9659	0.9828

Table 2. The Min., Max., Mean and Std. Error of FL values according to age.

Age groups	n	Min. FL (cm)	Max. FL (cm)	Mean FL (cm)	Std. Error
0	5	60	75	67.0	0.1715
I	21	70	115	84.05	3.4952
II	94	100	130	117.55	0.7124
III	22	120	145	132.5	1.1746
IV	20	135	155	144.5	1.3523
V	13	145	165	156.54	1.7343
VI	12	150	175	162.5	2.1759
VII	11	165	180	173.18	1.3936
VIII	8	175	190	183.75	1.8298
IX	5	190	200	196.0	1.8708
X	2	210	215	212.5	2.5

Table 3. The Back calculation, Von Bertalanffy and Observed FL values according to age class.

Age groups	n	Min. FL (cm)	Max. FL (cm)	Mean FL (cm)	Std. Error
0	5	60	75	67.0	0.1715
I	21	70	115	84.05	3.4952
II	94	100	130	117.55	0.7124
III	22	120	145	132.5	1.1746
IV	20	135	155	144.5	1.3523
V	13	145	165	156.54	1.7343
VI	12	150	175	162.5	2.1759
VII	11	165	180	173.18	1.3936
VIII	8	175	190	183.75	1.8298
IX	5	190	200	196.0	1.8708
X	2	210	215	212.5	2.5

Table 4. W_{\min} , W_{\max} , W_{mean} and Le Cren values according to age classes.

Age Groups	W_{\min} (kg)	W_{\max} (kg)	W_{mean} (kg)	$W = a \times L^n$ (kg)
0	1.5	4.5	2.4	2.902
I	2	16.5	6.57	6.278
II	10	37.0	21.56	19.67
III	20	49.0	31.48	29.56
IV	20	57.0	43.32	39.71
V	35	67.0	55.31	52.15
VI	43	100.0	67.58	59.22
VII	52	107.0	75.45	73.55
VIII	66	120.0	93.87	89.99
IX	72	125.0	105.0	112.1
X	72	133.0	110.40	147.6

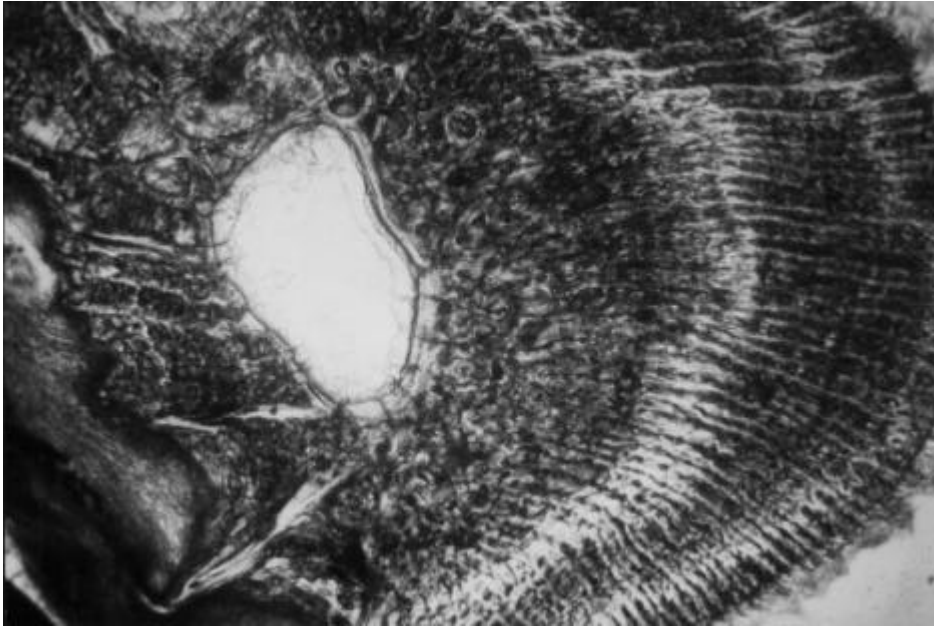


Figure 1. Cross-section of anal fin (about 1mm thickness).

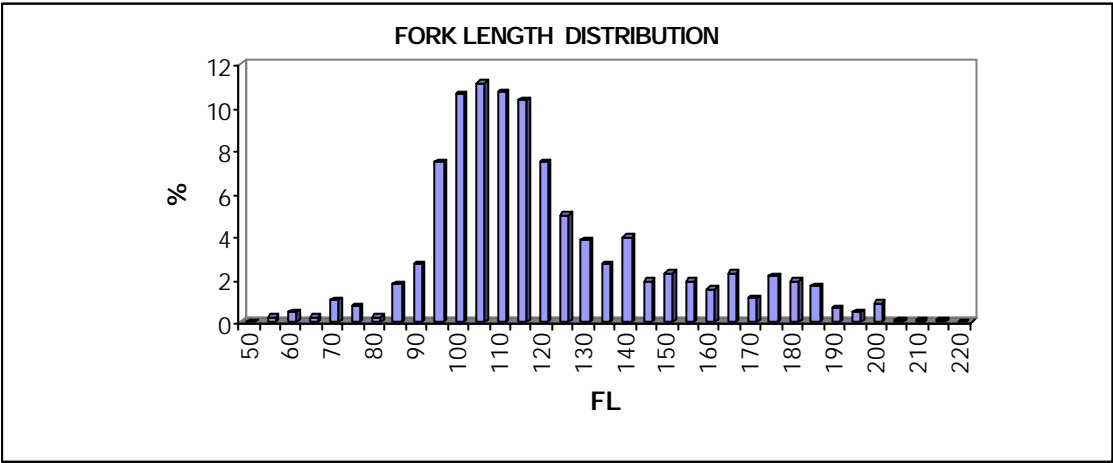


Figure 2. The length frequency distribution of Swordfish *Xiphias gladius*.